ACTA UNIVERSITATIS SZEGEDIENSIS

PARS CLIMATOLOGICA SCIENCIARUM NATURALIUM

CURAT: G. KOPPÁNY

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SZEGED (HUNGARIA)

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PREPARATIONS FOR THE MEASUREMENTS OF GAS-HYDRATE CRYSTAL CLOUDS IN THE OUTER SOLAR SYSTEM

by

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Előkészületek gázhidrát kristály felhők mérésére a külső naprendszerben.
A tanulmányban a szerző 1. a naprendszer kémiájára, 2. a gázhidrát összetevők kristályformáira és 3. a jégkristály felhőkön mutatkozó légköri „haló" jelenségekre alapozott kísérlet elvégzését ajánlja a külső naprendszer típusú kristályfelhők (KN-t-KF) megfigyelésére. Tekintettel a Pluto-Charon kettős bolygó-rendszer igen tömör jellegére (kis méretek), az ilyen KN-t-KF jelenléte a rendszer L4 és L5 Lagrange pont-jai közelében várható. Ezért e kettős bolygórendszer Lagrange KN-t-KF-jének a Pluto Fast Flyby Mission alkalmával való megfigyelésére egy kísérlet tervezésének és összeállításának intenciója lett eljuttatva a NASA NRA 93-OSSA 5 részlegéhez. Ehhez a kísérlethez az előkészületek elvégezhetők az Antarktiszon (amint az felvázoltatott az Antarktiszi Metoriokról tartott 18. Szimpoziumon [Tokyo, 1993]), hasonlóképpen ajánlottak az előkészületek Föld körüli pályán az ürrepülőgéppel és más, külső bolygókhoz (mint például a Cassini) tartó űrobjektumok révén is.

On the basis of. 1. Solar System chemistry, 2. crystal forms of gas-hydrate compounds, and 3. the atmospheric „halo" phenomenon in ice-crystal clouds, an experiment to observe Outer Solar System type Crystal Clouds (OSS-t-CC) has been proposed in this paper by the autor. Considering the very compact (small-scale) nature of the Pluto-Charon double-planet system such OSS-t-CC may be expected in the vicinity of the Lagrangian points L4 and L5 of this system. Therefore an intention to plan and construct such an experiment for observation of the Lagrangian-point OSS-t-CC in this double-planet system by the Pluto Fast Flyby Mission has been sent to the NASA call of NRA 93-OSSA 5. Preparations to this experiment can be carried out in Antartica (as summarized on the 18th Symposium on Antaractic Meteorites, Tokyo, 1993.), on Earth orbit by Space Shuttle and other space probe missions to the outer planets, (i.e. Cassini) have also proposed.

INTRODUCTION

There are different, indepent pictures about the Solar System. They were developed by using disciplinary „filters" of concepts. Such disciplinary filters sometimes may be characterized by cardinal concepts. For the Solar System we mention three of them.

The first was: the *mass-point*. Considering the celestial bodies to be mass-points, and using the law of motion and law of gravitation by Newton to describe their movements, the mechanical view of the Solar System has been formed (in the 17th century). Another cardinal concept is the *chemical composition of materials*. By this concept a material map with different mineral belts around the Sun in gradually increasing distance could has been sketched (in the middle of our century). The third concept is the *size-frequency of the mineral-rock-planetary-body sequence* (or with other words: the crystal-rock cloud) in the Solar System. In this picture the number of bodies are summed up in every size-intervals (size-regions) to give the size-frequency-distribution, and this distribution is the function of time. This function also describes changes and evolutionary processes in the Solar System, because it appears on the cratered surfaces of planetary bodies as a result of their collisions by with this crystal-rock cloud. These three independet overviews of the Solar System are summarized in **Table I.**

Table I

The „parameter distinguished" column show those regions where reductions over the „regardless of" column were carried out in model-building.

Three kinds of multiple-particle system-approaches in the Solar System Evolution Models

Authors	Multised considered	Parameter distinguished	Regardless of	Phenomena which preserved the events
Kepler Newton	orbiting mass-points	orbital elements	a. chemic. comps. b. size-frequency	remnant orbits of celestial bodies in the Solar System
Larimer Levis-Barshay Grossman	orbiting minerals	chemical composition	a. orbital element b. size-frequency	composition of minerals in smaller and larger bodies of the Solar System
Hartmann Wilhelms Wood Chapman	orbiting bodies and „particles"	spectrum of size-frequency of „particles"	a. orbital element b. chemic. compos.	crater statistics of surface layers of different age from planetary bodies

OUTER SOLAR SYSTEM TYPE CRYSTAL CLOUDS

In the 60ies and the 70ies a more and more detailed model was published by different experts about the chemical structure of the Solar System. (*Barshay* and *Lewis*, 1975, *Grossman*, 1972, etc.) On the basis of these models one can see what kind of minerals may be expected (because of its equilibrium with the surrounding solar-system conditions during its origin) in different distances from the Sun. The equilibrium and the implicated chemical composition at a given solar distance were calculated in these models from the estimated temperature, pressure at that place and from solar element abundances. A more crude chemically changing belt „map" departing from the Sun has also been suspected from the average density of planets changing with solar distances. According to the chemical equilibrium models the minerals of crystal clouds in the Outer Solar System may have been mainly H_2O, NH_3, CH_4 and their gas-hydrate compounds. They are the candidates for OSS-t-CC.

A „SCATTERING" PHENOMENON IN CRYSTAL CLOUDS

The bright halo (or ring) surrounding Sun or Moon is a well know atmospheric phenomenon, although it occurs only occasionally. This halo is produced by the refraction of the light of a „central" light source in tiny (10—100 mikrometer sized) water-ice crystal particles floating in the atmosphere. From the multitude of floating particles those sum up the bright halo which are well oriented in order to refract the light of the source into the eyes of the observer. We may show the rising up of the phenomenon from the refraction geometry of crystal particles (local picture) and from the arrangement and orientation of particles — randomly dispersed — in the crystal cloud (global picture). The origin of the phenomenon is essentially similar to that of the rainbow, but at rainbow there is backscattering (inner reflection backwards) of the light in rain drops, so the light source is in backward when we observe the rainbow's arc. *(Fig. 1.c.)*

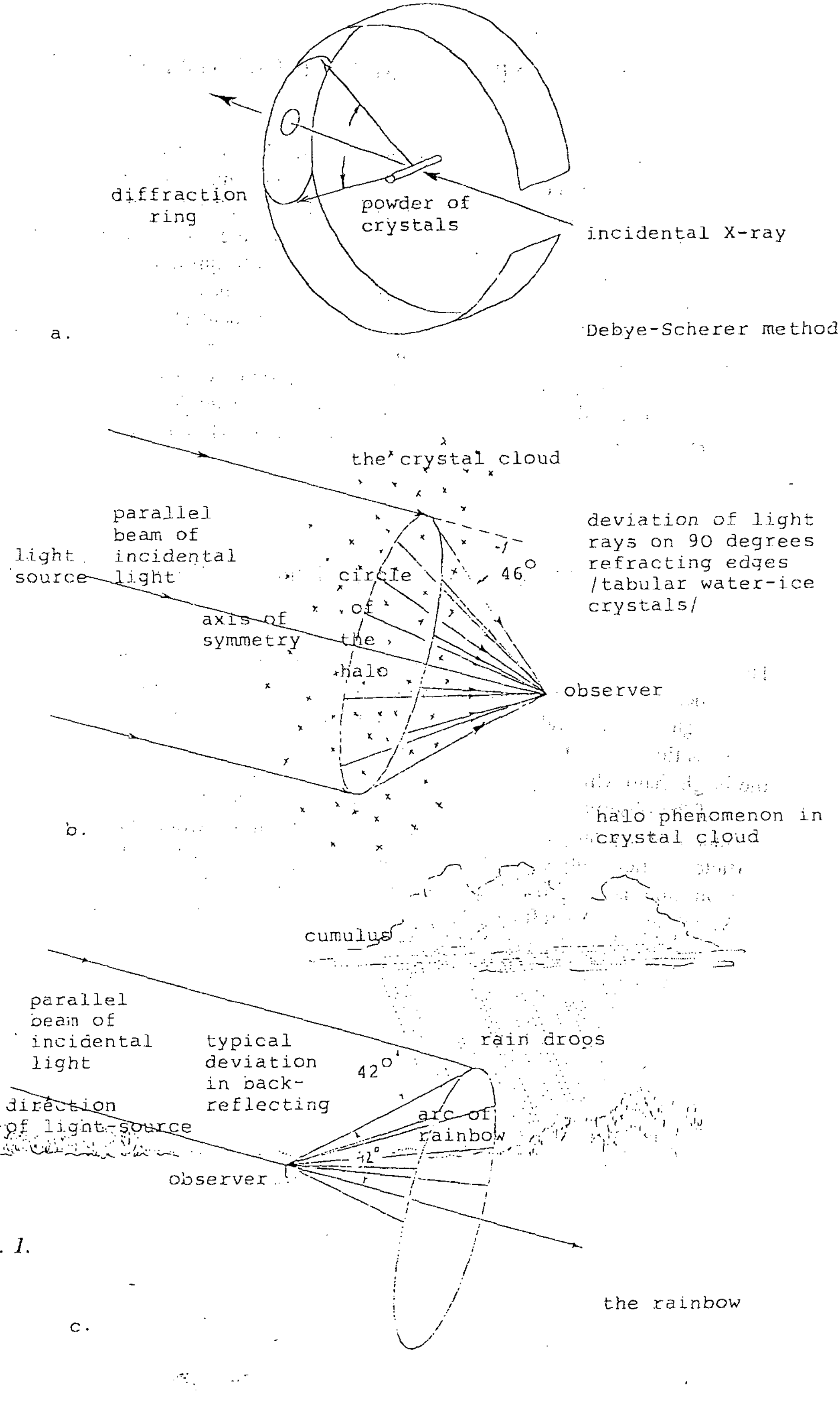
diffraction ring
powder of crystals
incidental X-ray
a.
Debye-Scherer method
the crystal cloud
parallel beam of incidental light
light source
circle of the halo
axis of symmetry
46°
deviation of light rays on 90 degrees refracting edges /tabular water-ice crystals/
observer
b.
halo phenomenon in crystal cloud
cumulus
parallel beam of incidental light
typical deviation in back-reflecting
42°
rain drops
direction of light-source
arc of rainbow
observer
the rainbow
c.

Fig. 1.

THE LOCAL AND THE GLOBAL PICTURE

The local picture: Here we show typical paths of the light when it refracts during crossing through water-ice crystals. In this respect there are two characteristical and frequently occurring forms of such crystals: the needle (or pencil) like and the tabular prismatic ones. *(Fig. 2.)* The typical path of refracting light during the passing through these crystal forms depends on the refracting angle at the prismatic edge of the crystal (and also depends on the refraction coefficient of water-ice). The refracting phenomenon can be characterized by the deviation angle, which is the angle between the direction of entrancing light and the direction of departing light stepping out from the crystal. Because of its molecular structure, the characteristical crystal form of water-ice is the hexagonal prims. This form may have been developed into two different prismatic edge/hexagonal diameter ratio. If this ratio is large, the form of hexagonal prisms is pencil like, elongated. If this ratio is small, the form of the hexagonal prisms is plate-like, tabular (*Grennler,* 1980).

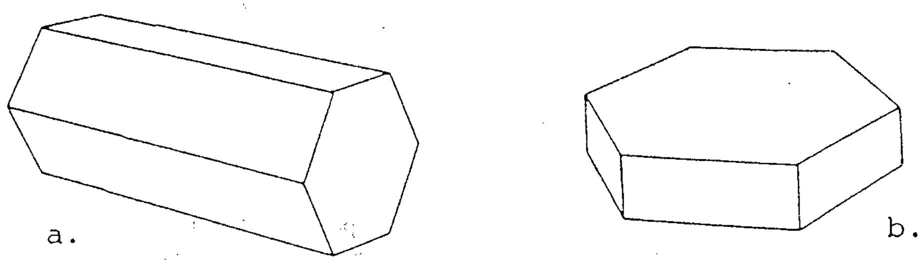

Fig. 2. The two most frequently occurring water-ice crystal-form: a. elongated, pencil-like hexagonal prims, b. tabular prism.

The two different hexagonal forms has different dominating refracting angle. For the pencil-like, elongated form the prismatic edge is 60 degrees; this can be seen when we complete its hexagonal cross-section to a regular triangle *(Fig. 2.a.)* For the tabular crystal form the dominating refracting angle can be found at the closing faces (pedions) of the prims. This angle between the pedion and any of the prismatic faces is 90 degrees.

The deviation of the passing and so rafracting light through a pencil-like water-ice crystal (with 60° refracting angle) is min. 22 degrees. This deviation for the tabular case, (when refracting angle is 90°) is min. 46 degrees. The deviation angles are more if the incidental direction is not perpendicular to the prismatic edges (or their parallel lines cut through the incidental point of the light ray) (*Greenler,* 1980).

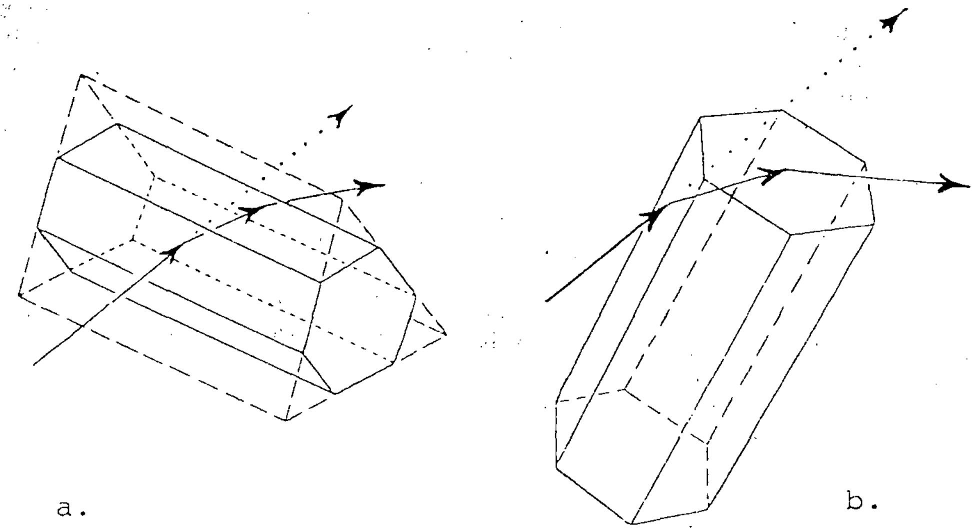

Fig. 3. Deviation of the refracted light-ray passing through
a. the elongated hexagonal prism, givin 22 deviation, and,
b. the tabular hexagonal case at pedion-prismface refraction, giving 46° deviation.

The probability of the dominating deviation of the refracting ray on a randomly oriented crystal depends on the form of the crystal. For an elongated crystal there are larger surfaces on the crystal to meet with light rays on the prismatic faces. Therefore the dominating light ray passing is through the pencil, almost perpendicularly to the 60° refracting edges. For tabular crystals there are larger surfaces on the crystal to meet with light rays on their pedions. Those rays which suffer refraction step out from the crystal at the prismatic faces. Therefore the dominating light ray passing, which produces refraction in tabular crystals, is that with 90° refracting edge. *(Fig. 2.b.)*

In summary we may conclude, that for crystal clouds consisting of mainly elongated, pencil-like water-ice crystals, the most probable deviation for its crystal components is the 22 degrees one. Similarly, for crystal clouds consisting of mainly platelike, tabular water-ice crystals, the most probable deviation for its crystal components is the 46 degrees one. The global picture will show how sum up local deviations (local refractions) to give the halo phenomenon.

Global picture: Let us imagine, that the crystal cloud consists of homogeneously dispersed ice crystals with similar measure and characteristical form (as earlier discussed) in the atmosphere. In the global picture the light source-observer axis is the main selector for the phenomenon to produce. Of the light rays running parallel with this axis the suitable orientation (in space) and the suitable position (in the cloud) of some crystals select those rays which have refracted (and so deviated) path advancing into the ocular of the observer. On the other hand, of the randomly oriented crystal particles the source-observer axis, the parallel beam of light rays and the (local) refraction rules (shown earlier) select those ones which can contribute to form the halo phenomenon. Therefore the selection is a mutual and simultaneous coincidence of both the local and the global rules and effects of refraction and observational geometric arrangement. Although the actors, i.e. the particles, which produce the effect, change from instance to instance, (because of the rotation) the global phenomenon remains. *(Fig. 1.b.)* In this respect the phenomenon is very similar to the X-ray diffraction method of Debye-Scherer for crystal-powder materials. There, such mutuality between X-rays with a given wavelength and well oriented (of the randomly dispersed) crystals produce interference rings (according to the rules of interference of waves on a lettice, given for example as Bragg-conditions). *(Fig. 1.c.)*

THE „GIGANTIC LENS IN FRAGMENTS" MODEL FOR HALO

All the geometric arrangement of the global picture preserves the cylindrical symmetry of the source-observer axis. For observer halo forming light rays arrives along a mantle of a cone. The vertex of this cone is at the observer. The basic circle (a large circular refracting ring region) is the halo itself, in the cloud. In this region well oriented crystals (form instance to instance) refract the parallel light of the source along the mantle of the cone into the direction of the observer. We may summarize this mutual working of suitable crystals so, that they work as if they were a „gigantic lens in fragments" in the cloud. Because of local rotation the components of this gigantic lens always change. But the particles are similar and they have great number enough to sum up the phenomenon continuously.

The contributing particles form only the edge region of the lens. But the cloud may serve as a „set of opportunity" for not only one type of halo formation. If the form of the ice crystals is not dominated by neither the pencil-like nor the tabular shapes, then both of the two most probable halos can appear. In this double-halo formation light rays and refracting rules select the instantaneous representatives for both halos from the same crystal cloud.

The chemical crystallization (and local chemical equilibrium) models (*Barshay, Lewis,* 1975, *Grossman,* 1972) deduced the composition of minerals in the Outer Solar System. There the principal components of crystalline material - which can form clouds - are ices. These ices are the crystalline precipitates of highly volatile (mainly atmospheric) compounds in terrestrial and Inner Solar System conditions: CH_4, HN_3 and H_2O. In chemistry they are called gas-hydrates. These minerals have a common crystal-form characteristic: they all have crystal structure in the regular (cubic) system. (*Berecz, Balla-Achs,* 1980) Therefore investigators may expect such cubic crystals as the main components of OSS-t-CC. Because of the dominating refracting angle for cubic crystals is the 90°, in the estimation and experiment planning we can use up the experiences shown earlier in the case of tabular water-ice crystals (*Bérczi,* 1993).

On the basis of the refracting rules for cubic crystals (now regardless of refraction coefficients) the two different type of refracting paths in such crystals don't give different deviations. *(Fig. 4.)* Therefore both ray paths contribute in forming a 46 degrees type halo (as first estimation) for OSS-t-CC.

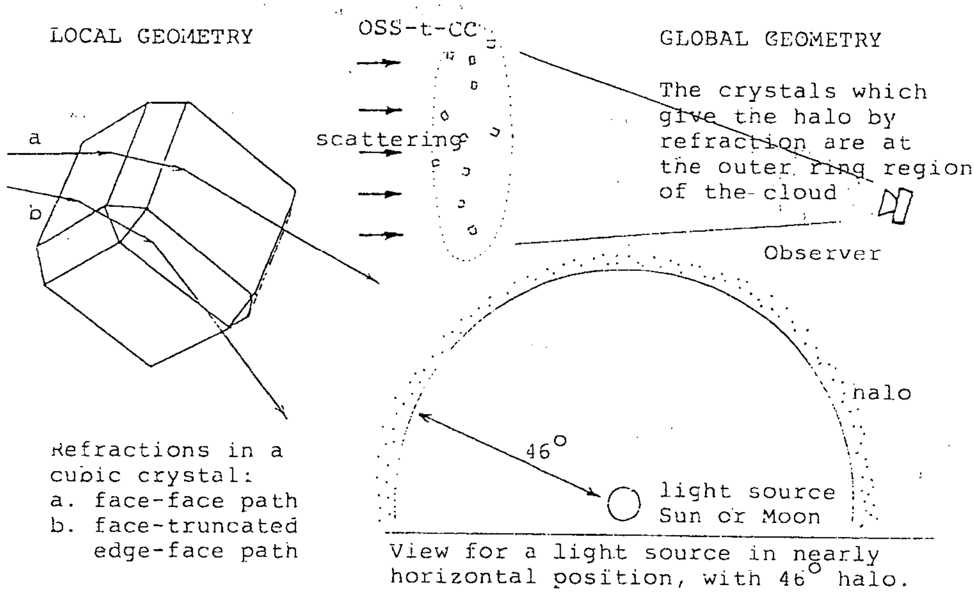

Fig. 4. Local and global geometry of the halo formation in an OSS-t-CC. Cubic cristal refractions show the two main types of path which contribute to the 46° halo formation.

PROPOSED MEASUREMENTS FOR THE PLUTO FAST FLYBY MISSION, NASA

NASA plans to launch a space probe towards the Pluto at the beginning of the next millenium. The name of this mission is Pluto Fast Flyby. On the basis of the given estimations the author has proposed the following experiment for this mission. (*Bérczi,* 1993a)

The Pluto (c.a. 4000 km in diameter) and its moon, the Charon (c.a. 2000 km in diameter) forms a close double planet system. (Pluto-Charon-System= PCS.) From the celestial three body problem it is known that in the vicinity of two larger, almost circularly rotating bodies there are semistable regions, where a third mass system may exist for a longer time. These points are the Lagrangian Points. In our case especially the L_4 and L_5 points are interesting in focus, because in such points many satellites are known. Most of them are in the case of Sun-Jupiter system, where the Troian asteroids can be found, but the *Kordilewsky* moons of the Earth-Moon system are also detected by Apollo astronauts (photographed), and Voyagers also found such type of satellites in the vicinity of Saturn, of the Saturn-Titan system.

My hypothesis was that tiny crystals of gas-hydrates may have been accumulated in the vicinity of the L_4 and L_5 points of the Pluto-Charon-System (PCS). We call these clouds Lagrangian Point Crystal Clouds (LPCC). In the proposed experiment the Pluto-Charon-LPCC system is the object for observations, because Pluto or Charon may be the light source behind the LPCC.

Orbit planning may make it possible for the Pluto Fast Flyby probe *to see through the LPCC* in the direction of both Pluto and Charon. On the basis of the earlier given estimations the width (the Diameter) of the suspected halo around the light source (Pluto or Charon) should be a 46 degrees type one. But other components may also be important to study. If the LPCC is dense enough to produce halo during seeing through it, than from the position of halo rings the nature and composition of LPCC in the Pluto-Charon System can be determined. The method later, if successful, can be used for other double-planet system, too, although it has less probability, because of the extraordinary compactness of the PCS, which may be an important condition in the experiment of the Pluto Fast Flyby Mission on LPCC. *(Fig. 5.)*

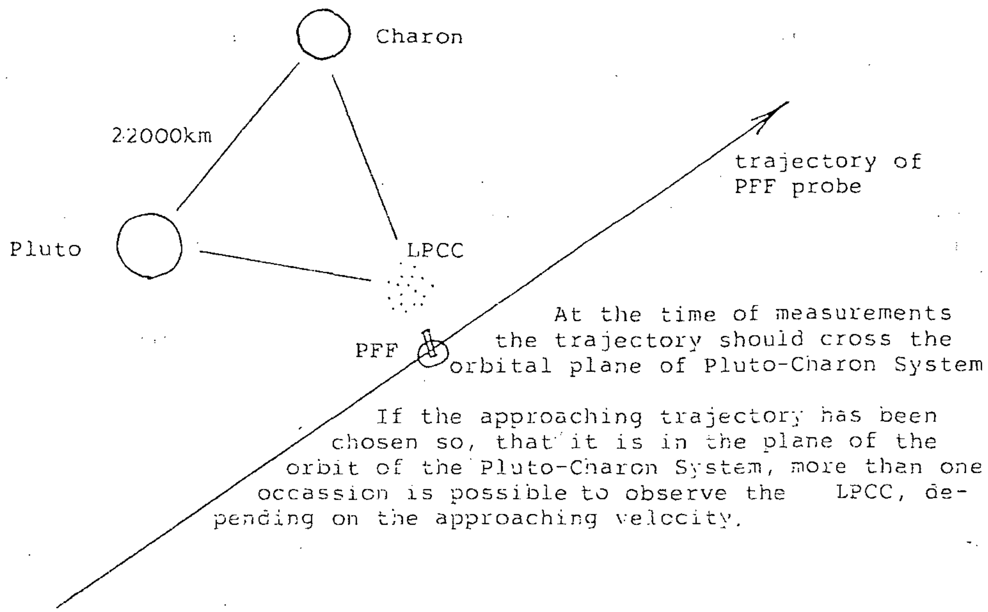

Fig. 5. A simple sketch about the spatial arrangement and real distance rations for the observation of Lagrangian Point Crystal Cloud in the Pluto-Charon System (the proposal). The sketch shows the LPCC in the triangular Lagrangian Point and the experimental arrangement of trajectory and orientation of the Pluto Fast Flyby probe to Charon.

PREPARATIONS...

There are three different places where preparations to such halo-type measurements can be carried out. The first one is a desert-like region, where different transparent „salts" may be the refracting minerals. This experiment can be accomplished in Hungary, too. The other place is Antartctica, where in the colt atmospheric conditions low temperature ices may be the refracting minerals. (*Bérczi,* 1993b) The thired place is the Space Shuttle where space-cold real ice candidate crystals may be the actors. For all these experiments the most suitable light source is our Moon.

SUMMARY

An Outher Solar System type Crystal Cloud (OSS-t-CC) measuring experiment and its conceptional background has been discussed. In this experiment knowledge from different disciplines was built together. The most important basis came from climatology: the phenomenon of halo around a light source in terrestrial atmosphere. Outer Solar System type components were taken from solar system chemistry models: a characteristical refracting rule was shown on the basis of regular system crystal structure and form of gas-hydrates. Finally the idea, where to look for this OSS-t-CC was triggered by the NRA 93-OSSA-5 call for experiments by NASA which turned my attention to the close binary-planet system of Pluto and Charon. For Pluto-Charon system the close binarity suggested that in Lagrangian Points Crystal Clouds may be dense enough to exhibit the proposed halo phenomenon. Although the principles and concepts abouth the experiment has been built together, further discussoins are necessary to reveal the probability of measurability of the OSS-t-CC in the Pluto Charon System. But proposals for more simple experimental preparations in terrestrial conditions were also given, which may confirm or reject the type of experiment which should be a new method in identification of OSS-t-CC in other places.

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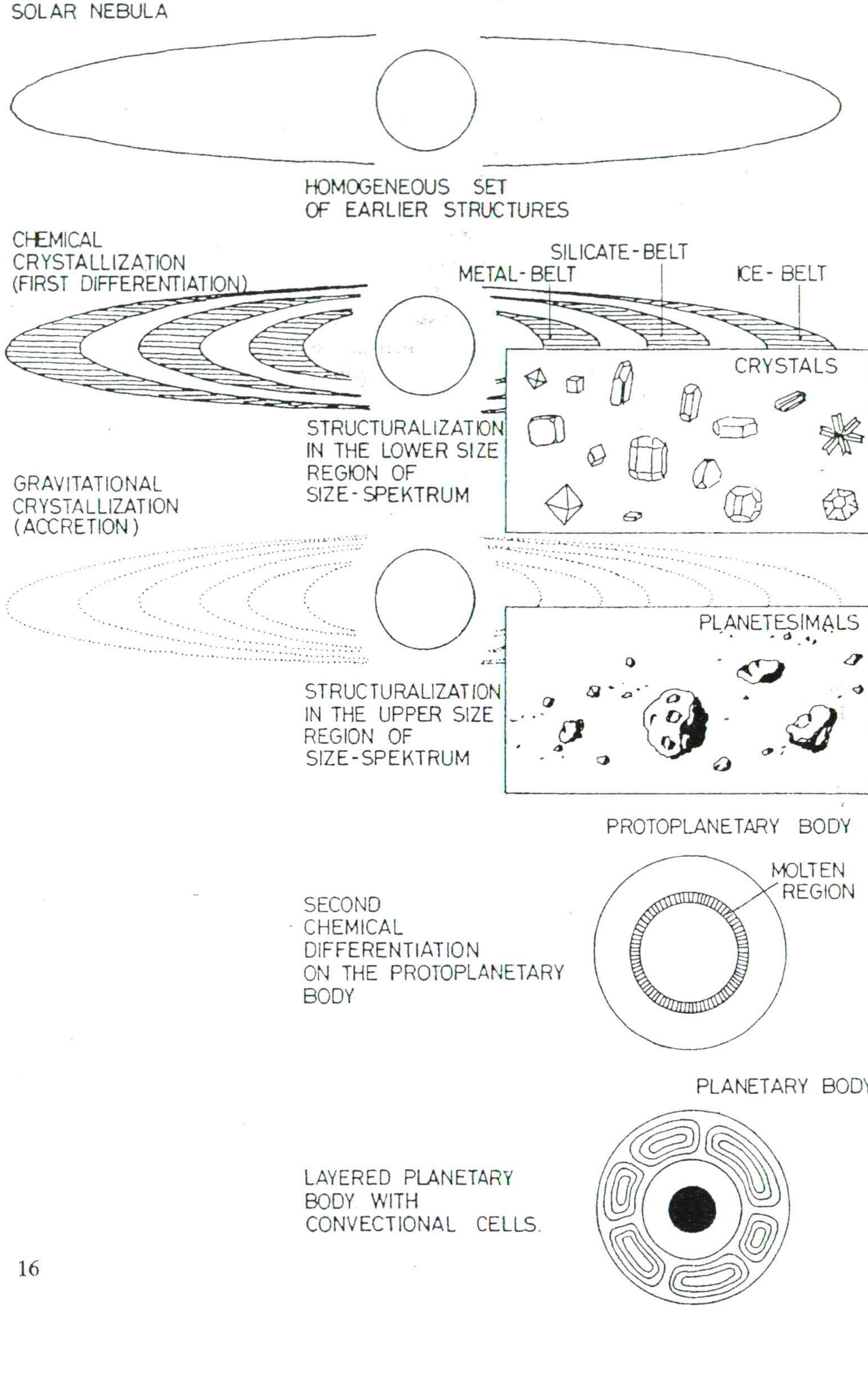
SOLAR NEBULA
HOMOGENEOUS SET
OF EARLIER STRUCTURES
CHEMICAL
CRYSTALLIZATION
(FIRST DIFFERENTIATION)
SILICATE-BELT
METAL-BELT
ICE-BELT
CRYSTALS
STRUCTURALIZATION
IN THE LOWER SIZE
REGION OF
SIZE-SPEKTRUM
GRAVITATIONAL
CRYSTALLIZATION
(ACCRETION)
PLANETESIMALS
STRUCTURALIZATION
IN THE UPPER SIZE
REGION OF
SIZE-SPEKTRUM
PROTOPLANETARY BODY
MOLTEN
REGION
SECOND
CHEMICAL
DIFFERENTIATION
ON THE PROTOPLANETARY
BODY
PLANETARY BODY
LAYERED PLANETARY
BODY WITH
CONVECTIONAL CELLS.

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VARIOUS TYPES OF CHANGES IN CLIMATIC SERIES OF BUDAPEST AND SZEGED, COMPARISON WITH REMOTE CLIMATIC STATIONS

by
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Különböző típusú éghajlatingadozások a budapesti és szegedi adatsorokban összehasonlítás távoli klímaállomásokkal.

A viszonylag hoszabb éghajlati adatsorokban a rövidebb-hosszabb változások különböző formái jelenhetnek meg *(1. ábra)*. Budapest 150 éves, Szeged 137 éves csapadéksorozatában kimutatható egy emelkedő trend 1940-ig, majd 1941 után egy meredek süllyedő trend gyors nívóváltással. Másrészt 1841-től illetve 1854-től 1990-ig csökkenő változékonyság a jellemző. Hasonló emelkedő, majd süllyedő trend található Kiev és Barnaul csapadéksorozatában. Ezzel ellentétes változások jelentkeztek Kelet-USA illetve Kelet-Ausztrália területén. Budapest 200 éves hőmérsékleti sorozatában az 1880-as évekig süllyedő, innen emelkedő trend mutatkozik, ez utóbbi összehasonlítható a globális átlaghőmérséklet rendelkezésre álló sorozatával *(4. ábra)*.

In climatic series of relatively long period may appear shorter or longer changes of different forms *(Fig. 1.)*. In the 150 year long precipitation series of Budapest and 137 year long series of that in Szeged it was found an increasing trend until 1940, thereafter a sharp decrease with rapid change of level. On the other hand since 1841 in Budapest and since 1854 in Szeged up to 1990 decreasing variability could be pointed out. Similar uptrend, the sinking was found in series of annual sum of precipitation of Kiyev and Barnaul. In the same time contrary trends appeared in the regions of East U.S.A. and East Australia, respectively. In 200 year long temperature series of Budapest a cooling trend is presented up to 1880-s, after that a warming tendency was found. The latter is comparable with the available data of global mean temperature *(Fig. 4.)*.

For the sake of correct definition of climate change or variation and distinguishing between their terms, such designations, appeared in the literature like fluctuation, oscillation, variation, trend etc. With negligation of determing the temperal scales, orders of magnitude and time units of the changes, we restrict our investigation to the forms of changes. On the basis of the forms of changes, six main types may be distinguished (*Pfister*, 1988):

1. periodic change (in its ideal form this type is mostly theoretical one),
2. quasiperiodic change,
3. rapid change of level with sharp trend
4. slow trend (rising or sinking),
5. stationary trend,
6. increasing or decreasing variability *(Fig. 1.)*.

The basic aim of this investigation to present some kind of change forms mentioned above, on Hungarian climatic series. It is evident that more comprehensive analysis would be needed to prove the existence of types at all, and what forms are not existing in the available climatic series. However our goal has been to provide only a few samples of climate changes in series of annual sums of precipitation and annual mean temperatures. This paper does not include analysis of monthly or seasonal data.

In recent decades a growing demand of hydrologists was experienced on investigation of precipitation data observed during the period of recent decades. This interest has been arosed by gradual sinking of underground water-level, the more and more frequent droughts which may be explained either with decrease of annual precipitation or with human activity (exhausting of ground water reservoirs). For this reason, the series of annual precipitations were investigated frist of all. In Hungary longest continues series of precipitation possesses Budapest where the observation began in 1841, so there were available a 150 year long series (1841—1990). A similar long series of precipitation data is found in Szeged, started in 1854, though two short breaks occured before 1871, thus only 120 year long continous series are available from 1871 to 1990 (*Hajósy, Kakas* and *Kéri*, 1975, *Réthly*, 1947, Monthly Reports of the Hungarian Meteorological Service — Havijelentések, 1971—1990).

It has been made use of so called rank analysis, i.e. the annual sums of precipitation were orderd from smaller to greater values regardless their cronology. This method is widespread in meteorological researches, because it provides comfortable and informative aid for data survey. It is worthy to mention that in 150 year long period the driest year in Budapest was 1857, with rank number one and only 326 mm annual sum of precipitation, while in the wettest year, 1937, with rank number 150, the annual sum of precipitation was as much as 989 mm. The ratio of annual precipitation in the year of rank one and that in the year of rank 150 is approximately 1:3. In Szeged the driest year was also 1857 with 267 mm annual sum, but the most precipitation, 979 mm was measured in 1855. The ratio between these extremes is as much as 1:3,66. Merely these simple ratios may rather well characterize the variability of precipilation in climate of Hungary.

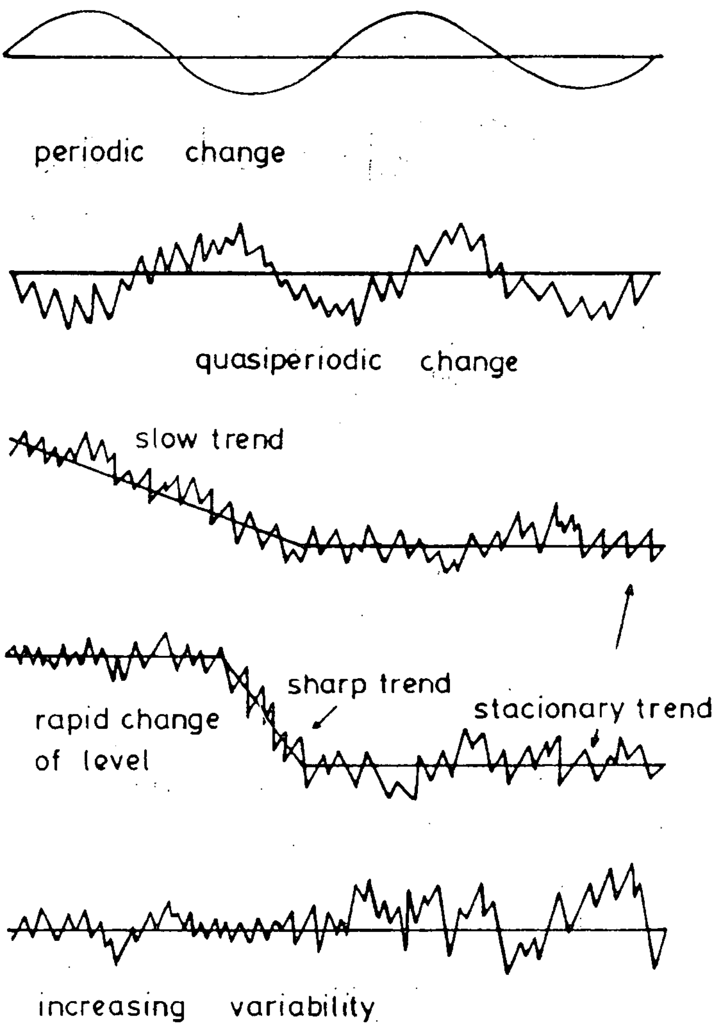

Fig. 1. Six types of climatic variations (after *Pfister*, 1988)

The series of annual sum of precipitation of Budapest were devided into three equally long periods: 1841—90, 1891—1940, and 1941—90, respectively. Each period is 50 year long. On the basis of rank number, 1—150, the data may be devided into terciles moereover even into deciles. In latter case it seemed sufficient only the lowest and highest deciles to be presented. The results are summerized in **Table I**. In the lowest three rows of the **Table I** the 50 year averages, the standard deviations, and the ratios of standard deviation/average, i.e. the relative standard deviations in per cent are given.

Table I
Statistical characteristics of annual precipitation of Budapest

	1841—90	1891—1940	1941—90	Total
Lower tercile (1—50)	16	12	22	50
Middle tercile (51—100)	17	17	16	50
Higher tercile (101—150)	17	21	12	50
Total	50	50	50	150
Lower decile (1—15)	6	2	7	15
Higher decile (136—150)	6	6	3	15
	Most variable	Wettest	Driest	
P (mm) std (mm) std/P %	617 130 21	639 110 17.2	574 107 18.6	

It can be clearly seen that in the first 50 year period between 1841 and 1890, the occurances of very dry and very wet years were practically equal, therefore this period is considered the *most variable.* For the second period, 1891—1940, the surplus of very wet years is characteristic, while the very dry years occured rarely. This period was *the wettest* comparing to others. The last 50 years (1941—90) possessed surplus of very dry years and deficit of wet years. This period was consequently the *driest one.*

From 1891—1940 to 1941—90 *in 50 year average precipitation* about 10% *decrease* occured which is *significant difference* at 1% significance level according to t-test. The standard deviation of annual sums *decreased* during the recent 150 years, but this decrease is a little less, than needed to 5% significance level.

The annual precipitation series of Szeged, as a control station were also discussed taking into consideration both the continuos 120 year series and the partly discontinuos 137 year period. The results are presented in **Table II**. It can be established that the 50 year period of 1891—90 was abundant in wet years, like in Budapest, while in period of 1941—90 in contrary, the surplus of very dry years followed. Just like in Budapest, also in Szeged a rapid sinking of level occured between 1930-s and 1940-s. The average precipitation of period 1891—1940 was 577 mm in Szeged, while in the next 50 year average took only 502 mm, the decrease amounted 13% from one period to the next. The *difference is significant* at 1% level. The standard deviation of annual sums was calculated for the discontinuos period, 1854—90, too, given in paranthesis in **Table II**.

Table II
Statistical characteristics of annual precipitation of Budapest

	1871—90	1891—1940	1941—90	Total
Lower tercile (1—40)	4	11	25	40
Middle tercile (41—80)	10	15	15	40
Higher tercile (81—120)	6	24	10	40
Total	20	50	50	120
Lower decile (1—12)	1	5	6	12
Higher decile (109—120)	1	9	2	12
	Most variable	Wettest	Driest	
P (mm) std (1854—90) std/P %	547 (525) 77 (133) 14 (25)	577 116 20.2	502 86 17	

According to F-test the *decrease of standard deviation is significant at 1% level.*

According to the analysis of decadal data it was pointed out that *rapid sinking of level* took place from the 1930-s to 1940-s, as it is shown in *Fig. 2.*, and above in *Fig. 3.* The former present the graph of variation of decadal precipitation in Budapest. The latter serves for comparison of long term variation of decadal precipitation in several remote climatic stations (after *H.H.Lamb,* 1977), including the graphs of Budapest and Szeged. It can be established the rough similarity at stations: Budapest, Szeged, Kiyev, Barnaul, the last with a lag of about ten years. Apparent contrasted trends exhibit the series of East U.S.A. and East Australia, namely relative wet periods were observed in these regions before 1890 or 1900, and after 1940 or 1950, while the same time in Budapest, Szeged, Kiyev and Barnaul were relative dry epochs, and reverse was the case in the first half of the 20-th century.

It is well know that in the 200 year long temperature series of Budapest (1781—1980) there appeared a sinking trend till the end of 19-th century, then it was followed by a rising tendency (*Fig. 4.*, above). The latter was interrupted by a transitory cooling by the 1960-s. Howerer a remarkable similarity can be found between the variations of smoothed global mean temperature (*Fig. 4.*, below) after *Lockwood,* 1986, *Barry* and *Chorley,* 1982, available since 1880. In general there is a rather good relationship between the length of averaging meteorological data and the size of area represented by the average.

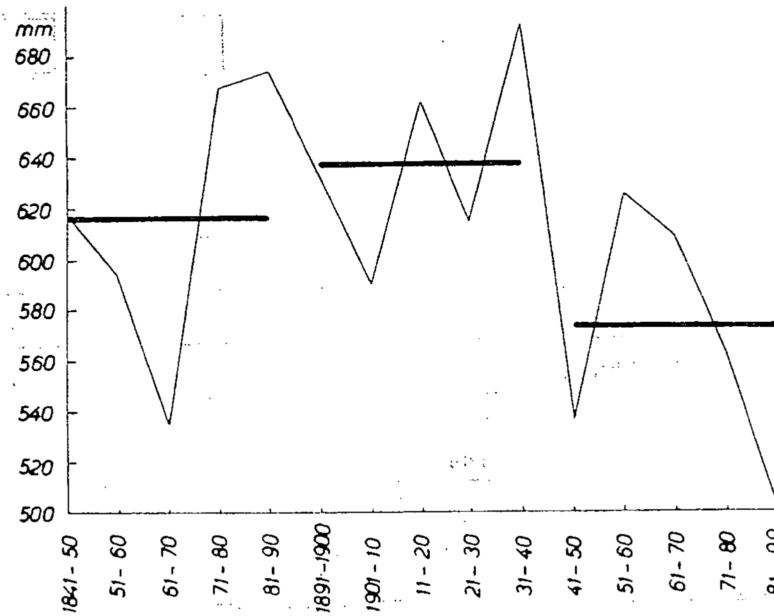

Fig. 2. Variation of decadal precipitation of Budapest during the period of 1841—1990 (thin line), and the 50 year averages: 1841—90, 1891—1940, 1941—90 (thick line)

In a previous paper (*Koppány,* 1992) it was pointed out that in 16 European and 2 North-American climatic stations, possessing more then 200 year long series of temperature data, exhibited more or less significant cooling in the second half of the 19-th century, mostly in 1880-s. Before that cooling in several stations remarkable warming was observed, some of them exceeding the maxima of 1930-s or 1940-s. The 9 year running mean of the temperature of these stations exhibited their maxima during the 18-th century or early 19-th century. After all it may be suggested that in several remote regions of the world after a relative warm period of the 18-th century (or the first half of the 19-th century) a sinking trend took place ended in 1880-s in long term temperature series.

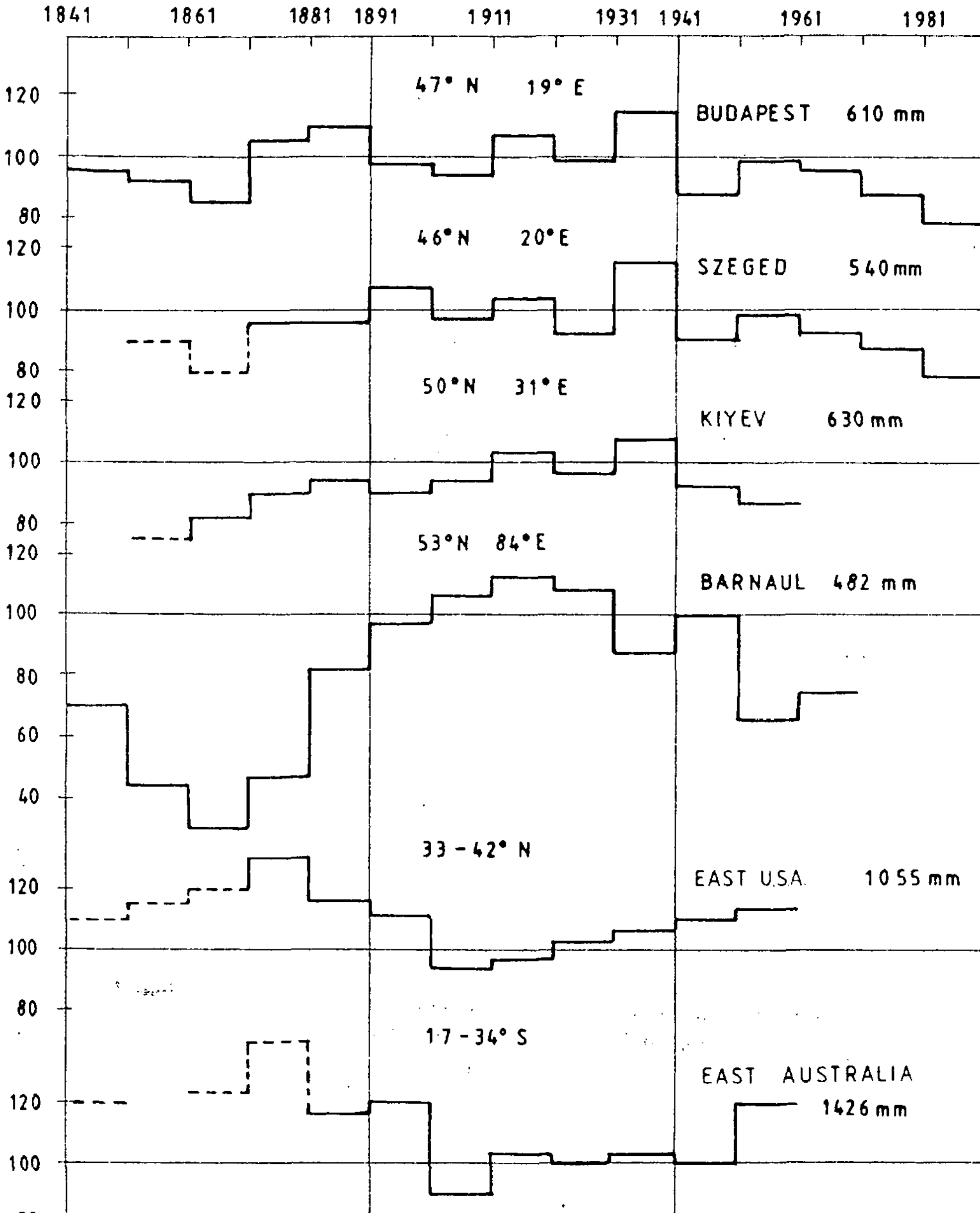

Fig. 3. Series of decadal precipitation of Budapest and Szeged, furthermore that of some remote climatic stations (the latter after *H.H. Lamb*, 1977)

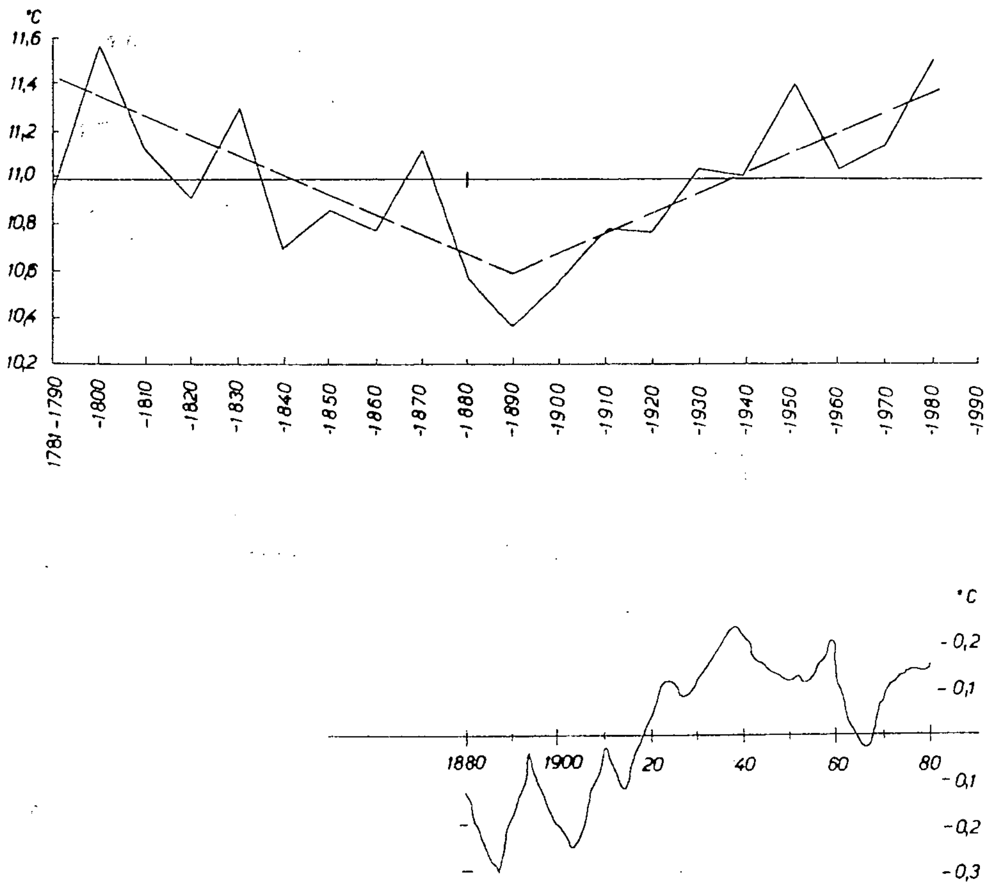

Fig. 4. Long term variation of decadal temperature of Budapest during the period of 1781—1980 (above), and variation of 5 year smoothed global mean temperature since 1880

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THE TENDENCIES OF THE MEDITERRANEAN CLIMATIC CHARACTER IN HUNGARY

by
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A mediterrán klímajelleg tendenciái Magyarországon.
Magyarország két helyén a csapadék éves összegei járásának jellemzésére egy alkalmas, úgynevezett Mediterrán Indexet *(MI)* használunk. Szeged és Budapest 120 éves adatsorainak vizsgálata azt mutatja, hogy a csapadék járásának jellege csaknem azonos a két helyen a vizsgált időszakban. Az első évek *MI* értékeinek enyhe emelkedési tendenciája a mediterrán jelleg erősödésére, míg az utolsó 75—110 év (az évek többsége) enyhe csökkenő tendenciája a kontinentális jelleg erősödésére utal.

We use a suitable, so called Mediterranean Index *(MI)* for characterization of variation of yearly precipitation amounts at two places in Hungary. The investigation of 120-year data series of Szeged and Budapest shows that the character of precipitation variation of the two places have almost identical course during the investigated term. The mildly increasing tendency of the first few years in *MI* values shows the dominance of the Mediterranean character, while the mildly decreasing tendency of the last 75—110 years (the majority of the years) shows the dominance of the continental character.

INTRODUCTION, METHOD AND OBJECTIVE

This short study is a further part of a paper on the Mediterranean climatic character in the annual distribution of precipitation in Europe and Hungary (*Koppány* and *Unger*, 1992). As mentioned in the former paper, Hungary is situated on the border of continental and Mediterranean climatic regions. The authors used the so called Mediterranean Index *(MI)*, which is a quantitative value for characterization of Mediterranean character of precipitation (precipitation maximum is in autumn). Theirs formula is the next:

$$MI = (P_{10+11} - P_{5+6}) (100/P_{year}),$$

where P_{10+11} is the amount of precipitation in October and November, P_{5+6} is the amount of precipitation of May and June, P_{year} is the annual amount of precipitation in mm. The greater is the *MI* value the stronger is the Mediterranean character.

As in certain parts of Hungary, *MI* shows a slight continental character (*Koppány and Unger*, 1992), we supposed that regarding a long series of the years, the continental and Mediterranean effects appear alternately. Therefore, we have investigated the precipitation series of two climatological stations which are in possession of at least 120 years' pluviometry, namely the data series of Budapest and Szeged between 1870 and 1989 *(Fig. 1.)*. Questions are raised: How close the connection between the precipitation variation of the two stations is? Can significant tendency be pointed out in the index value series during the 120 years or during some subperiods?

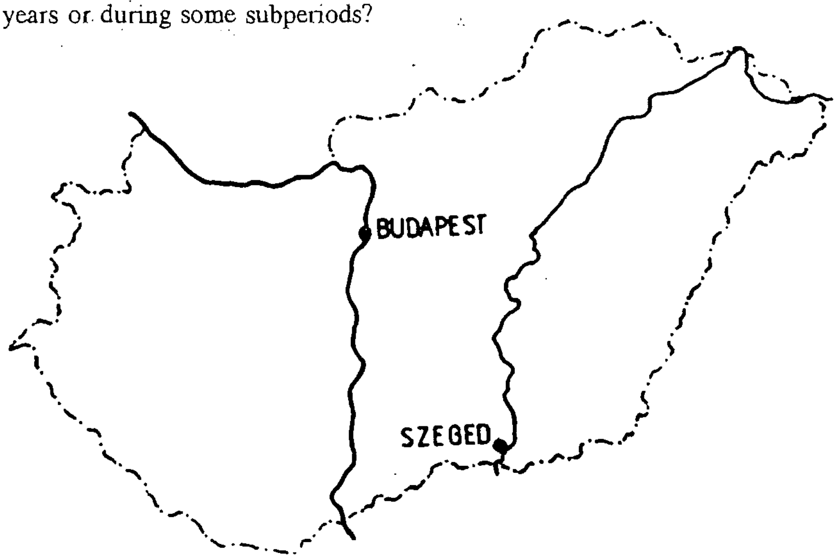

Fig. 1. The situations of the investigated stations in Hungary

RESULTS

We surveyed the 120-year (1870—1989) precipitation series of Budapest and Szeged. The *MI* values were counted up station by station and year by year so as to investigate the closeness of the connection between the characters of the precipitation variations of the two stations by the correlation coefficient. The coefficient was found:

$$r = 0.58,$$

which even at a 1% significance-level relates to a very close connection with an identical sign (the critical value, in case of 120 pairs of value, is $p^{1\%} = 0.23$).

Thus, in the 120-year precipitation series of the two stations, the years having either a Mediterranean or a continental character, as well as the order of magnitude of the indices alternated in a rather identical manner.

Our investigation extended to every possible interval between 2 and 120 years to point out the incidental tendencies. A lot of longer or shorter significant trends related to different intervals could be pointed out on several significance-level (0.1%, 1% and 5%). Interesting to mention that in case of Szeged much more significant trends could be received than in case of Budapest. All of them are impossibile to list, thus only the most tipical trends relating to intervals coming one after the other and their parameters are presented (**Table I**).

It can be seen from the **Table I** that in case of Szeged the tendency was increasing in the first few years, that means the Mediterranean character became stronger, while the tendency was mildly decreasing in the further much longer phase, that means the continental character dominance grew. In the decomposition of the intervals, where the first few years are not considered, in each intervals the tendency was increasing, however to a different degree. The longest significant trend was related to the last 113 years and its tendency was also decreasing.

In case of Budapest, the two decompositions are hardly different (only 1 year), so their parameters are almost the same. However, the fact established in case of *MI* values of Szeged are also relavant in the case of Budapest.

Table I

Statistical characteristics of *MI* values at Szeged and Budapest (1870—1989)

intervals (years)	trend coefficient *(MI)*	mean *(MI)*	standard deviation *(MI)*	correlation coefficient	sign. level (%)
	Szeged				
1—15 *(1870—1884)*	1.51	−6.19	12.87	0.526	5
16—45 *(1885—1914)*	−0.51	−8.99	12.11	0.367	5
46—120 *(1915—1989)*	−0.18	−6.34	13.12	0.294	1
2—17 *(1870—1886)*	1.40	−6.37	12.67	0.528	5
18—45 *(1887—1914)*	−0.57	−9.25	12.36	0.378	5
46—120 *(1915—1989)*	−0.18	−6.34	13.16	0.294	1
9—47 *(1878—1916)*	−0.42	−6.47	11.91	0.399	5
48—120 *(1917—1989)*	−0.18	−6.54	13.18	0.282	5
8—120 *(1877—1989)*	−0.06	−6.55	12.64	0.164	5
	Budapest				
9—45 *(1878—1914)*	−0.30	−5.4	10.51	0.311	5
46—120 *(1915—1989)*	−0.13	−4.15	13.28	0.207	5
9—46 *(1878—1915)*	−0.28	−5.75	10.37	0.301	5
47—120 *(1916—1989)*	−0.13	−4.12	13.37	0.215	5

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THE URBAN INFLUENCE ON THE DIURNAL AND ANNUAL PATTERNS OF ABSOLUTE HUMIDITY IN SZEGED, HUNGARY

by

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A város hatása az abszolút nedvesség napi és évi menetére Szegeden.
3 éven keresztül napi négyszeri vízgőznyomás mérések értékeinek felhasználásával vizsgáltuk a város és környéke közötti abszolút nedvesség-különbségek napi és éves járását Szegeden. A város egész évben nedvesebbnek bizonyult környezeténél. A nedvesség városi többlete a város és környéke eltérő energiamérlegével és a rendelkezésre álló nedvesség eltérő forrásaival magyarázható. Szoros kapcsolat létezik egyrészt a város és környéke abszolút nedvesség-különbsége, másrészt az éjszakai hősziget intenzitása, az ariditási index járása, valamint a Tisza vízhőmérsékletének járása között.

Measurements of vapour pressure taken four times daily over a 3-year period were used to investigate diurnal and annual patterns of urban-rural absolute humidity differences in Szeged. The city was found to be more humid than its surroundings during the whole year. Variation of urban humidity surplus can be explained by reference to urban and rural energy balances and sources of moisture. Good relationships exist between urban-rural absolute humidity differences and partly nocturnal heat island intensity, partly the variation of aridity index, partly the variation of the water temperature of the River Tisza.

INTRODUCTION

The urban area is an important place where atmosphere should be studied and understood in greater detail. This atmosphere is modifided by the artificial surface of the city, the anthropogenic heat emission and the air pollution in gaseous and aerosol phases. This process of urbanization has been investigated at an ever increasing rate throughout the world. Although in recent years the observational studies of various climatic elements are still of great importance, greater attention has been paid to investigation of the urban boundary and canopy layers.

The urban heat island is now well documented from many cities, but there are very few studies about the urban influence on atmospheric humidity.

Only a very small fraction of the water existing on the earth is in the air. However, humidity plays several important roles among the meteorological processes which are taking place within the atmosphere. It is an agent for transferring energy from one place to the other on the earth's surface and humidity, together with clouds, affects the transmission of radiation both to and from the surface. Humidity is also an important input for determining the state of human physiological comfort.

Very few studies have made effective comparison of urban-rural vapour pressure values. Efforts have concentrated on relative humidity characteristics. Relative humidity values may be useful in human comfort studies, but they are not of great value in climate process work, especially since they are highly controlled by temperature values. However, for certain purposes such as studies of radiative fluxes and of the role of water vapour in air pollutant reactions, absolute humidities and their differences are needed.

In this light, this paper concerns itself with the characteristics of some aspects of atmospheric vapour content in the city.

In Leicester (England) and in Chapel Hill (N.C., United States) surface traverse measurements have been made (*Chandler,* 1967; *Kopec,* 1973). The cities have been found to be moist at night and dry by day relative to the surroundings. In Edmonton (Canada) and in London (England) the urban absolute humidities were lower by day but higher at night than those in the country in the warm season. In winter the absolute humidity was higher in the city at all hours (*Hage,* 1975; *Lee,* 1991). In a tropical city, in Ibadan (Nigeria), the absolute humidity was higher in the city during the wet season and lower during the dry season (*Adebayo,* 1991).

THE INVESTIGATED AREA, DATA AND METHODS

Szeged is situated in the south-east and flat (69 m above sea level) territory of Hungary, free from orographical effects. The number of inhabitants of the city was up to 175 000 in the investigated term, in 1978.

Most regions of Hungary are in climatic region *Cf* by Köppen (temperate warm climate with comparatively equal precipitation distribution) or in climatic region *D.1* by Trewartha (continental climate with a long warm season). A better climatic partitioning can be made by using the mean temperature of vegetation season (t_v) and the $H=E/LC$ aridity index (where E is the net radiation, L is the evaporation heat and C is the amount of precipitation). So Szeged is in the warm-dry climatic region which is characterized with $t_v > 17.5$ °C and $H > 1.15$ (*Péczely,* 1979).

In Szeged a 10-meteorological-station network was established where observations were taken between 1978 and 1980. With possibilities taken into consideration, the stations represented several types of built-up areas of the city *(Fig. 1.)*.

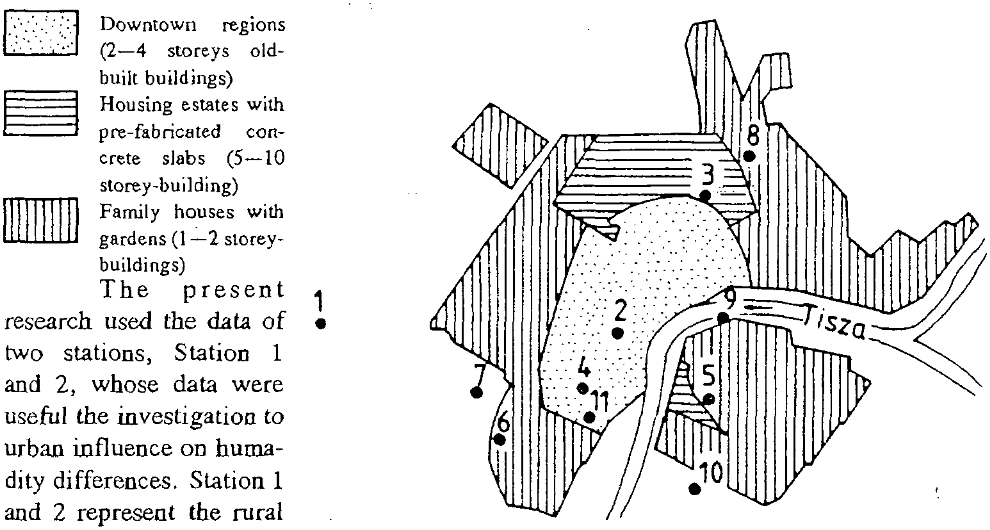

Fig. 1. The morphological types of Szeged and the urban meteorological station network (St.1 — Aerological Observatory, St.2 — Restaurant of Napsugár)

The present research used the data of two stations, Station 1 and 2, whose data were useful the investigation to urban influence on humadity differences. Station 1 and 2 represent the rural place and the inner city, respectively. Station 2 was set up at the city centre influenced freshly by climate modification effects of the town, at a paved square bounded by multi-storey buildings.

The vapour pressure measurements were taken four times a day (at 01, 07, 13 and 19 hours, Central European Time) from 1978 to 1980. Both stations had a thermometer shelter with an Assman-type psychrometer.

The monthly mean vapour pressure values were determined for both stations at different observation times and the differences of means were counted. On the basis of these differences the annual variation of the absolute humidity surplus can be drawn at the given observation times and their connection with the maximum urban heat island intensity (*Unger,* 1992), with the monthly values of the aridity index (*Dobosi,* 1973; *Péczely,* 1984) and with the monthly mean water temperature values of the river Tisza can be examined.

RESULTS AND CONCLUSIONS

Let's consider the monthly means of absolute humidity differences in the different times between Station 1 and 2 (**Table I**):

Table I

The monthly mean vapour pressure surplus of the town
(Station 2 — Station 1) (1978—1980)

(mb)	J	F	M	A	M	J	J	A	S	O	N	D
01h	1.0	0.7	1.4	2.0	2.3	2.6	3.0	3.4	2.9	2.4	0.8	1.4
07h	0.9	0.7	1.5	1.6	1.7	2.9	3.0	3.6	2.0	2.2	0.8	1.0
13h	1.2	0.8	2.3	2.2	2.5	3.9	4.2	4.8	3.1	2.3	2.2	1.1
19h	1.0	0.9	1.9	2.1	3.5	4.6	5.0	5.6	3.0	2.8	0.8	0.7

By means of these data, the diagram of the absolute humidity surplus can be drawn at all observation times *(Fig. 2.)*.

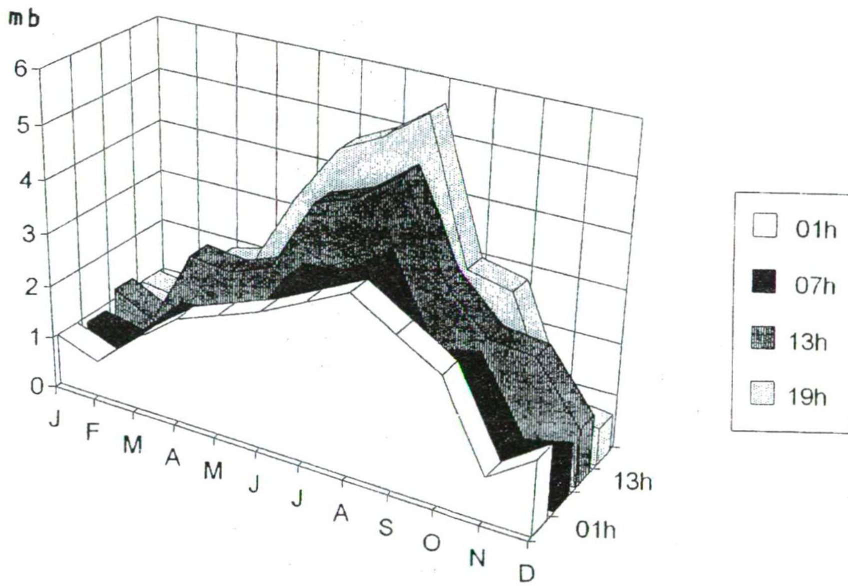

Fig. 2. The annual variation of absolute humidity surplus of the town (1978—1980)

The *Fig.* 2. shows clearly that the town has an absolute humidity surplus during the whole year and this surplus is increasing continuously from January-February to August and then it is decreasing till November-December at each observational time.

The maximum of August is increasing from 01 to 19 hours (from 3.4 to 5.6 mb). The *minimum* values are in February and December (0.7 and 0.8 mb). Thus the annual variation of urban absolute humidity surplus in Szeged is only partly similar to the results of the other cities mentioned above, so this phenomenon has to be explained. To this explaination further climatological values have to be taken into consideration.

Table II

The annual variation of the maximum heat island intensity (at 01), the water temperature of the river Tisza at Szeged (1978—1980), the aridity index, the monthly mean energy-balance, temperature and precipitation in Szeged (1900—1950)

	max T_{u-r} (°C)	*water* (°C)	H	E_s (MJm^{-2})	T (°C)	P (mm)
J	1.3	0.6	0.1	7.8	−1.2	32
F	1.6	1.8	0.2	14.0	0.6	34
M	2.9	5.1	0.9	88.1	6.3	38
A	3.5	10.4	1.5	178.1	11.4	49
M	3.6	15.2	1.8	278.6	16.8	61
J	3.7	21.4	1.9	322.9	20.0	68
J	4.0	20.9	2.3	292.8	22.3	51
A	4.5	22.1	2.0	242.3	21.4	48
S	4.8	18.4	1.2	142.9	17.5	47
O	3.8	13.8	0.5	68.7	11.9	52
N	1.9	7.0	−0.1	−11.3	5.9	52
D	1.6	3.1	−0.2	−16.8	1.4	41

By means of these data, diagrams can be drawn *(Fig. 3.)*.

The phenomenon mentioned above can be explained by comparison of *Fig.* 2. and *Fig. 3.*

The examination of annual variation of the aridity index in the Szeged region showed that the „humidity-hunger" of air is increasing till July continuously and it is also very great in August, since the precipitation is much less than the heat-energy being at the disposal of evaporation. This state is valid for Station 1 being free of urban influence which is far (5.0 km) from the evaporative surface of the River Tisza.

In the case of Station 2 the evaporative surface of the Tisza also gives the humidity (the distance between them is 0.6 km). The water of the river is the warmest and also the „humidity-hunger" of air is the greatest in summer months (June-August), so the water surface can give the most moisture to the air of its direct surroundings in this time. This time coincides with the maximum urban humidity surplus well.

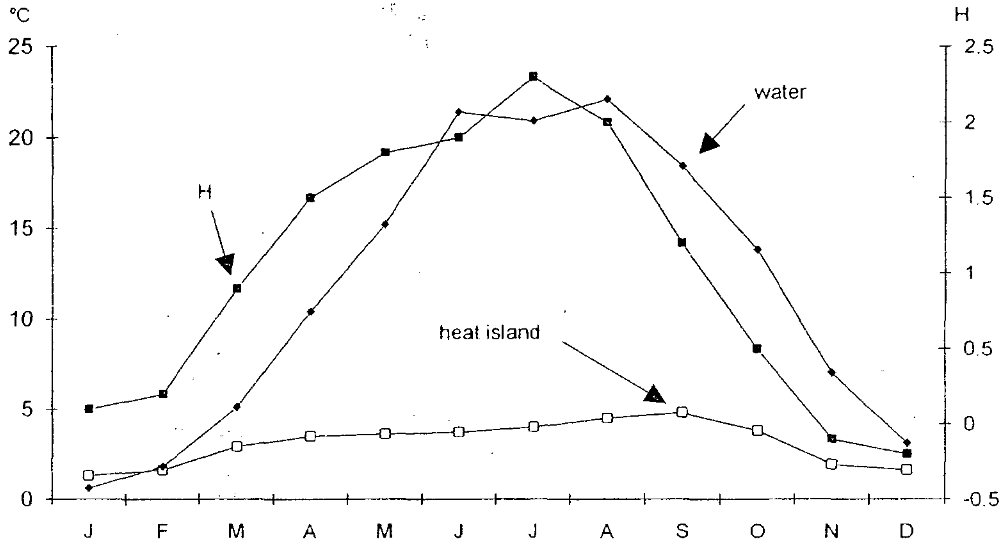

Fig. 3. The annual variation of the maximum heat island intensity, the water temperature of the river Tisza at Szeged (1978—1980) and the aridity index in Szeged (1900—1950)

Thus, the greater is the aridity index (it depends on the air temperature especially) and the higher is the water temperature of Tisza (with a bit of a lag because of the heat inertia) the greater is the urban-rural vapour pressure difference during the year.

The water vapour from traffic gas combustion also contributes to the existence of urban-rural humidity differences, because the urban station is situated on a very busy place of traffic. On the other hand the displacement of air is slow among the narrow streets of the inner city, so the vapour content of air is trapped there better than in the well aspirated surroundings.

At the end of summer the evapotranspiration of the rural natural surface is very weak because of the harvest and the almost complete desiccation of agricultural and natural vegetation. However in the city the parks and the gardens are irrigated mainly in the summer months. It guarantees the life of vegetation, so it gurantees the evapotranspiration. These facts also contribute to the summer maximum of urban-rural humidity difference.

In summary, this analyse study of 3 years of vapour pressure data from rural and urban climatological stations and other climatological data from Szeged area showed that the urban absolute humidity surplus with summer maximum can be explained by the climatological characteristics of the region of Szeged (aridity index), by the evaporative surfaces available (River Tisza, irrigated parks and gardens) and by the influence of the urban traffic.

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