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**ACTA UNIVERSITATIS SZEGEDIENSIS**

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PARS CLIMATOLOGICA SCIENCIARUM NATURALIUM

CURAT: G. KOPPÁNY

**ACTA CLIMATOLOGICA**

**TOMUS XXX.**

**SZEGED (HUNGARIA)**

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**DR. GYÖRGY KOPPÁNY**

Technical editor

**LAJOS CSIKÁSZ**  
**DR. JÁNOS UNGER**

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## PREFACE

Acta Climatologica of this year is the 30th and also a jubilee volume. The publication of the periodical has been closely linked with the academic activity of the Departments of Geography and Climatology of the University of Szeged. We have to pay our attention to the evolution of these departments and also to the history of the periodical.

The Department of Geography of the University of Szeged was established in 1921 when certain sections/departments of the University of Kolozsvár were removed to our city/Szeged. The physical geography of atmosphere was among the first courses held by famous climatologists like Gábor Schilling, Károly Kogutowitz, Alfréd Hille. Richárd Wagner, the establisher of the present Department of Climatology, participated in presenting lectures in connection with climatology as early as in the 1930's. From 1930, he conducted the practice "Geographical instrumental and mapping techniques". Even as a young scientist, he devoted care to giving a forum of the students' and the academic-researchers' results. This was first realized by publishing the "Geographical seminars", the periodical which, however, existed only for 2 years. After the World War 2, the education of climatology was involved in the activities of the Department of Geography led by Gyula Prinz. In 1952, climatology split off from the Department of Geography, with the name of Department of Geography 2. Then, from September of 1953, the Department of Climatology made the climatological research and education independent from geography. Richárd Wagner, the head of the new department conducted the high-standard microclimatological research at the department. The first results of these research can be found still in the Acta Geographica, in the articles of Wagner, R.; Kiss, Á.; Andó, M.. The first volume of Acta Climatologica was published in 1959.

The volume presented 5 studies which demonstrated the results of the microclimatological research of the Department of Climatology. Among these, there are the issues of microclimatological research carried out on the sand-surfaces of the Great Plain, on different floras and in 3 factories of Szeged. Up to Wagner's death in 1972, 8 high-level volumes came out edited by him in which Wagner, R.; Horváth, I.; Kiss, Á.; Boros, J.; Juhász, J.; Bárány-Kevei, I. published their studies. Several famous Hungarian climatologists including Béll, B. and Takács, J. as well as foreign authors also published studies in the Acta. The volumes of the Acta Climatologica were often referred to abroad, too, and its studies were cited quite frequently.

The Tomus XII. (Volume 9) was edited by the new head of the department, György Péczely, in 1973. There was a change in the profile of the research, and though there were still some studies issued on microclimatology, macroclimate research was beginning to be dominant. Besides Péczely's high-standard publications, numerous home researchers also represented themselves in these volumes. There were studies by young researchers like Makra, L.; Pelle, L. on the anomaly of temperature and precipitation on the Great Plain and on the distribution of air pressure fields. After Péczely's death in 1985, one volume was edited by Jakucs, L. in which Péczely's colleagues, and the future head of department, György Koppány, published articles. The volumes which were edited by Péczely, Gy. mark an important and

high-level period in the life of the periodical, which include many issues that attracted attention abroad, too.

From 1989, 4 volumes were edited by György Koppány. The department and the periodical as well observed the traditional macroclimatological profile. Besides the editor, who published more articles on regional climatology, former authors: Kiss, Á.; Makra, L. also issued their experiments. Unger, J.'s studies on urban climate and some other correspondents Bartholy, J.; Mika, J.; Bérczy, Sz. also appeared in these volumes. In the latest volume, two Transylvanian studies were published. In one of them, Urdea, P. and Sarbovan, C. present the morphoclimatical outline of the Romanian Carpathians. The other was made by Pálffy, E. who studied the formation of inversion of temperature in the Csik (Ciuc) Basin.

This short summary cannot undertake to show the professional profile of the periodical in its entirety. The few data and subject indication give merely a short introduction to the achievements of the scientific workshop which issues the 30th volume of the Acta. The volumes of Acta Climatologica which have been published so far, represent the research work and the results of the Department of Climatology of the University of Szeged. The further assignment of the preface can only be to commend the new, jubilee volume to the readers' kind attention and at same time, to thank the authors' and editors' for the assistance to produce and maintain the high-standard scientific periodical.

The national and international research on macroclimate will play a more and more significant role in the prediction and evaluation of the effects of global change of environment. But the local change of environment and the change of life standard require the research of mezo- and micro-regions' climate. Acta Climatologica is willing to present the results of the above mentioned research. I wish the editor board the best to continuing their successful research and to publishing the high-standard periodical.

Szeged, May 1996

*Dr. Ilona Bárány-Kevei*  
Head of Department of Climatology

## THE WATER-AMMONIA SYMMETRY OF AMINO ACIDS: CONSTRAINTS ON PALEOATMOSPHERES

Sz. BÉRCZI<sup>1</sup> and B. LUKÁCS<sup>2</sup>

<sup>1</sup> *Dean's Office, Department of Astronomy, L. Eötvös University, Rákóczi út 5, 1088  
Budapest, Hungary*

<sup>2</sup> *Central Research Institute for Physics RMKI, P.O.Box 49, 1525 Budapest, Hungary*

**Összefoglalás** - Mindenfajta földi életet három alapvető és közös vonás jellemez: fehérjék alkotják a testet, nukleinsavak hordozzák az információt és víz az oldószer. A fehérjékre, mint a legősibb anyagokra tekintve tudjuk, hogy aminosavakból épülnek fel. Az aminosavak lényeges jellemzője az, hogy a vízre ill. az ammóniára (mint oldószerre) vonatkoztatva számos tulajdonságuk szimmetriát mutat. Ez azt jelenti, hogy ha a vizet ammóniára cseréljük, akkor a fehérjeépítés lényeges vonásai (pl. peptidkötés, fehérjefélepítés) nem változnak meg. Ebből a szimmetriatulajdonságból, ill. abból a tényből, hogy a keletkezéskor az aminosavak környezetében ammóniának is jelen kellett lennie, von le következtetéseket a cikkünk az ősi földi légkörre vonatkozólag.

**Abstract** - In formation of terrestrial life amino acids played a key role. There is a basic symmetry in amino acids if the solvent liquid is exchanged "behind them" from water to ammonia. This chemical symmetry of solvents behind a characteristic building-block type compound set can give strong constraints when we intend to reconstruct primordial terrestrial atmosphere. Our paper discusses some consequences of the water-ammonia symmetry of amino acids onto the initial conditions of the primordial terrestrial planetary atmospheres.

### 1. INTRODUCTION

The only type of life of which we know anything definite is the life on Earth; all forms of terrestrial life have common building blocks, solvents and processes in their very fundamentals. Terrestrial life is characterized by at least 3 fundamental properties:

- 1) The body is built up from *proteins*.
- 2) Genetic information is carried by *nucleic acids*.
- 3) The general solvent is *water*.

Proteins and nucleic acids are macromolecules built up modularly from moderate molecules of limited variety. (It is still an open question if two separate types of macromolecules are really needed, or the fact is merely a historic accident.) Terrestrial life is the action of giant carbon chains in water solvent.

Of the mentioned subsystems of macromolecule families the building blocks of the proteins, the amino acids seem to be the most ancient (Chaps. 2 and 4). Therefore we focus on tracing their origin in connection with atmospheres.

Amino acids form an elementary set of units as building blocks in cellular level terrestrial life. Considering the primordial liquids as solvents where these units could have been developed, the ambivalent characteristics of amino acids might be explained. There are two such liquids: *water* and *ammonia*. Both of them are good solvents but they use up different radicals of amino acids in forming their chemical characteristics in their reactions in the liquids. So amino acids are "Janus-faced" chemicals which have counterpart radicals for both "water-world" and "ammonia-world".

The ambivalency of amino acids in respect of water-world and ammonia-world may represent a kind of symmetry. This symmetry is expressed by the amino acid molecules, when liquid solvent is exchanged from water to ammonia or vice versa "around them". The characteristic radicals of amino acid molecules are carboxyl, hydroxyl, amine and amide ones, too. Therefore they can interact both with water and ammonia in a similar way in many reactions (Chapter 3). Terrestrial life, however, is not W-A symmetric, using W radical at the positive ends and A ones at negative ends and never inversely.

From the ambivalency of amino acids it can be suggested that in the place of their origin both water and ammonia was present. In our previous paper we discussed these regions on a Solar System horizon (*Bérczi and Lukács, 1995*). In this paper we focus our attention to the constraints which arise onto the composition and origin of the primordial terrestrial atmosphere from the Janus-faced chemical character of amino acids.

## 2. EXPERIMENTS AND PREDICTIONS IN SEARCH OF MAIN COMPONENTS OF ANCIENT TERRESTRIAL ATMOSPHERE - CHEMISTRY, GEOLOGY, PLANETOLOGY

The present atmosphere of Earth is clearly the product of billion years of biologic activity, as shown by the free oxygen, impossible without continuous oxygen source (*Koppány, 1996*). The palaeoatmosphere is a matter of speculation. *Miller (1953)* was able to produce amino acids in an artificial reducing atmosphere with  $H_2O$ ,  $CO_2$ ,  $NH_3$  and  $H_2$ . While  $H_2$  and  $H_2O$  do not need explanation, and  $CO_2$  is present at Venus and Mars,  $NH_3$  seems to belong to the outer Solar System, and so its original presence is often questioned. Two important definite observations indeed do not confirm the simple schemes.

The situation can be summarized as follows. Abiotic synthesis, and especially that of amino acids, is a very easy and natural process in the presence of  $NH_3$  in a reducing atmosphere. On the other hand, there is no evidence for  $NH_3$  in the palaeoatmosphere, and primordial  $NH_3$  is not expected from Solar System condensation. In this paper we summarize

both scenarios (with and without  $\text{NH}_3$ ); the final conclusion will be an alternative. Now first let us see the relevant experiences and planetologic theories.

The *Miller* (1953) experiment used  $\text{H}_2\text{O}$ ,  $\text{H}_2$ ,  $\text{CO}_2$ ,  $\text{NH}_3$ , substantial temperature, UV radiation and electric discharges. As told above and will be seen below, presence of  $\text{NH}_3$  in the palaeoatmosphere is doubtful; all other components and circumstances were characteristic in those times. In such syntheses many organic compounds appeared, in descending order of quantities the first 5 were (*Brooks and Shaw*, 1973)

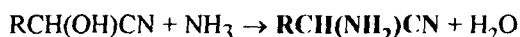
Formic acid > Glycine > Glycolic acid > Alanine > Lactic acid.

Let us remember this sequence. Miller's explanation is that the reaction to amino acids goes in 4 steps:

1) From the simple molecules first an aldehyde **RCHO** is formed. Parallely **HCN** is formed too.

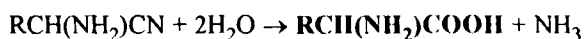
2) RCHO and HCN forms **RCH(OH)CN**.

3) That compound is *aminated* by  $\text{NH}_3$ , i.e. the hydroxyle radical is substituted by an  $\text{NH}_2$ :



Since both  $\text{NH}_3$  and  $\text{H}_2\text{O}$  are present, this reaction does not change the main components of the reaction qualitatively.

4) The amino nitrile takes again  $\text{H}_2\text{O}$  and gives back  $\text{NH}_3$  into the solution:



So the final result is an amino acid; we can see that the reactions are quite natural in the simultaneous presence of  $\text{NH}_3$  and  $\text{H}_2\text{O}$ . No doubt, by complicated catalysers the synthesis may be successful from other sources of nitrogen too, but, as we shall see below, the only possible abundant primordial N source could be  $\text{NH}_3$  anyway. We also can see that there is a possibility for bifurcation in the reaction chain. If the amination in Step 3 does not happen, then the final result is not amino acid, but oxiacid, **RCH(OH)COOH**. Indeed, oxiacids are also among the endproducts of the Miller-type syntheses, but with *lower* abundances. Glycolic acid is the oxi-analagon of glycine, and lactic acid is that of alanine.

So primordial  $\text{NH}_3$  is welcome for abiotic amino acid synthesis. But let us see observations. *Szalay* (1975) extracted gases from precambrian sediments. He found  $\text{H}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{N}_2$ ,  $\text{CO}_2$  and  $\text{CH}_4$ , but not  $\text{NH}_3$ . And *Brooks and Shaw* (1973) emphasize that no geologic traces of the often assumed "primordial bouillon" of sugars, amino acids, nucleic acid building stones &c. Then the remainders should be found at least as carbon layers with high nitrogen abundance. However the earliest layers seem to be poor in nitrogen; e.g. the amino acid concentration of such sediments seem to be not higher than  $10^{-9}$  (*Schöpf, Kwenvolden and Barghoorn*, 1968). This low concentration comes from the Fig Tree layer where the oldest fossil microorganisms were identified (3.7-3.0 Gy old). From this reason *Brooks and Shaw* (1973) prefer an extraterrestrial origin of terrestrial life and their scenario is that a

microorganism survived a space travel on a meteorite, found an ammonia-free atmosphere and their descendants converted the reducing atmosphere into oxidative. This is a viable solution if there was life somewhere else in the Solar System. However, up to now there has not been found any evidence for such extraterrestrial life. Then it is not uninteresting to see what are the possibilities of appearance of ammonia in the terrestrial palaeoatmosphere.

The Lewis-Barshay model summarizes the most probable precipitates from the Solar Nebula. The original presolar nebula was more or less chemically homogeneous but temperature was dropping outward. When chemical reactions started such compounds precipitated which were in solid state at the specific temperature and pressure. Therefore refractories condensed inside as well as outside but volatiles did it only outside. In the particular calculation only such minerals were incorporated which had well-known geochemical and geological importance according to the state of arts at that time. During the last one and a half decade space probes, mainly the two Voyager missions revealed the satellites in the outer Solar System. So a new emphasis appeared when considering crystalline materials in the solar system. This new emphasis focuses attention to the icy materials, outer cool regions, smaller (cometary, asteroidal, fragmented) bodies in the Solar System.

Now let us see the possible nitrogen sources. N is fairly abundant on Earth; it dominates the present atmosphere, and it is necessary for amino acids. However, N-bearing minerals are rare on Earth, so the original calculations included only  $\text{NH}_3$ . According to the Barshay-Lewis model (1976) ammonia could have condensed somewhere outwards from Saturn. Gas evaporation from the bulk of Earth may have seriously contributed to the palaeoatmosphere, but the present Earth lithosphere seems to be very poor in ammonia.

In this new perspective the importance of the volatile-metamorphized minerals increased, because of studies on surface geological structures and reflected spectra of asteroids and outer satellites at Jupiter, Saturn, Uranus and Neptune. There the rocky components of satellites may be the hydrated silicates according to the equilibrium condensation model of Lewis and Barshay. But other important constituents of these partly rocky, partly icy bodies may also be relevant, if we pay attention to the other important volatile component,  $\text{NH}_3$ . Besides water  $\text{H}_2\text{O}$ , ammonia,  $\text{NH}_3$  can also build into silicates. So ammonium silicates are alternative candidates as precipitation products in this part of the Solar System. Being N almost as abundant as O and C in the cosmic set of chemical elements, the "ammonized"-variants of known terrestrial silicates may also be represented considerably among volatile-metamorphized silicates.

For clarity we must distinguish two kinds of minerals affected by ammonia. The first kind is ammonium silicate, the  $\text{NH}_4$  radical acts as a pseudo-alkali ion (similar to rubidium), so in the presence of  $\text{NH}_3$  and excess H ammonium can substitute potassium or sodium in their compounds. There are different known members of this group of ammonium-silicates: the ammonium feldspar BUDDINGTONITE (Erd *et al.*, 1964), the ammonium muscovite TOBELITE (Vedder, 1964; Hiyashi *et al.*, 1982), the AMMONIOLEUCITE (Hori *et al.*,

1986), the AMMONIUM-ILLITE (Juster *et al.*, 1987), and AMMONIUM PHLOGOPITE (Bos *et al.*, 1987).

The other kind of ammonia-altered minerals is still practically unknown outside of laboratories, and even in laboratories such *silicates* are rare. They are called ammins or ammoniates: salts with crystallic ammonia instead of crystallic water. Hundreds of ammin salts are known, e.g.  $\text{FeSO}_4 \cdot 6\text{NH}_3$ , but for our purposes data of ammoniated *silicates* would be needed, e.g. the ammoniated analogon of serpentine. We note that generally one expects lower temperatures for an ammoniate analogon than for the hydrated crystal. Such ammoniates (i.e. crystals with structural ammonia) may have contributed to the composition of primordial Earth, and then lost the ammonia when the bulk of the planet was being heated up.

If the possibility of ammoniates is ruled out in later studies (no serious theoretical predictions exist now for the ammonia content in the inner Solar System) but there will be evidence for the atmospheric presence of ammonia in the far past, then a possible source would be extraterrestrial origin, e.g. a collision with an ammonia-rich planetesimal during the formation of Earth. A planetesimal of cca. radius of 1000 km from beyond Uranus could have filled up the terrestrial palaeoatmosphere to 1 atm partial pressure. Of course, there remains the problem that no geologic remnant of this ammonia is found. (Gradual delivery of ices - with ammonia content - by comets might also be considered.)

Other N sources are improbable. Molecular  $\text{N}_2$  condensed somewhere at Pluto. For oxides and cyan one can only guess the conditions for condensation, because they have not been incorporated into LB schemes. However, first, the H surplus is overwhelming, so one expects mainly molecules with H, not with O and C. Second, by comparing freezing points, crude estimations for the condensation distances can be made. Observe that  $\text{H}_2\text{O}$  starts to condensate at Jupiter. Now, at 1 atm freezing points are as follows:

Molecule	Freezing point, °C at 1 atm
NO	-163
$\text{N}_2\text{O}_4$	-10
$\text{C}_2\text{N}_2$	-34
HCN	-15
$\text{NH}_3$	-33

One can see that no possible N source condensed much more inside than ammonia, and, as told, their quantity was probably much less.

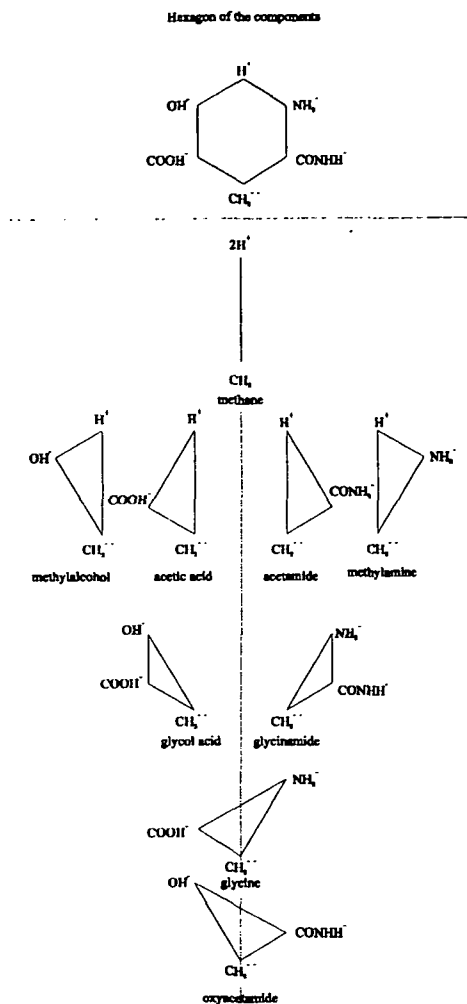


Fig. 1 The simplest organic acids and bases in the water-ammonia mirror. The simplest amino acid, glycine, (together with most amino acids) is "just on the mirror" although is not mirror symmetric. Glycinamid is "in the ammonia world", but has some minor role in terrestrial (aquatic?) biochemistry. Its mirror image, glycolic acid, is completely aquatic, but has no role in terrestrial biology, it is simply a rare by-product.

Now, one may derive the present N from ammonia, ammonium silicates and ammoniated silicates; the final result will be anyway  $\text{NH}_3$ . Namely, inside proto-Earth,  $\text{NH}_3$  was driven out of the silicates. So, according to planetology terrestrial proto-atmosphere must have contained  $\text{NH}_3$ , otherwise we would not have had  $\text{N}_2$  now. However,  $\text{NH}_3$  dissociates quite easily, so it is possible that this primordial  $\text{NH}_3$  was short-living.

### 3. THE BEGINNING OF ORGANIC CHEMISTRY

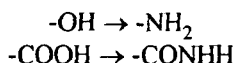
Our goals are: to guess if biochemistry is possible in A-chemistry (A for ammonia as solvent), and to see how natural is it in the presence of substantial  $\text{NH}_3$  in W-chemistry (W for water as solvent). Let us see first the connection of biochemistry with A- and W-solvents. Some parts of biochemistry are immensely complicated. However, as it will be demonstrated, biochemistry originates quite from the basement of organic chemistry. These initial steps are simple and can be easily understood. Afterwards we may relegate the task to selection, survival of fittest, enzyme effects, and so on.

For a methodical introduction to organic chemistry it is usual to start from methane, or more generally, from the paraffine series  $\text{C}_n\text{H}_{2n+2}$ , and to enumerate the other simple and fundamental compounds as derivatives, substituting H atoms. Not everything fits smoothly into this "classification", but one can go far enough in this way.

Now, at each step we shall give the

"mirror" formulae for the hypothetical organic A-chemistry. It is necessary to state that the ammonia-based organic chemistry is still in a not too evolved status, and our detailed knowledge about it is even less so. However, all the mirror molecules we will mention do exist and are chemically well-known. Reaction velocities, equilibrium ratios &c. in  $-40^{\circ}\text{C}$  liquid  $\text{NH}_3$  are another matter.

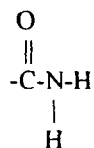
Our rules to get the mirror molecules will be simple enough. Only the basis and organic acid radicals will be changed as



We will call these simultaneous operations in this paper the WA mirror reflection (see *Fig. 1*). The idea is the analogy with the "C-reflection" of particle physics, where some quantum numbers as electric charge, baryon charge etc. are changed to their opposite, while some other data (e.g. mass) are unchanged to get antiparticles from particles and vice versa. The first rule is obvious and has been mentioned in the previous Chapter. The second needs some explanation. An organic acid in terrestrial aquaeous chemistry has generally not the simple  $-\text{H}$  radical of anorganic chemistry but the carboxyl radical  $-\text{COOH}$ , since the paraffine chains are rather apolar, and so an H ion is not expected to dissociate from a paraffine carbon atom. Now this group has the approximate structure



with the easily dissociable  $-\text{H}$ . It is definitely outside of the scope of the present paper to discuss why just this complicated radical is an effective H donor in carbon sequences; it obviously has its proper quantum many body reasons, and we definitely will not try to recalculate the problem in liquid ammonia. However, the most natural mirror molecule is  $-\text{CONHH}$  or



Later we will mention examples that such molecules exist indeed. We leave the second O atom unchanged; anyway oxygen is abundant everywhere. The quantum mechanical and chemical analogies between the O atom and the NH imino radical are often mentioned in chemistry.

In this paper we choose such a presentation in which the mirror symmetry between W and A-chemistries is explicit. However, note that the nomenclature of organic chemistry has been established in W-chemistry. Therefore in names the analogons are not the aquo and

amino molecules but rather C and N atoms, or methane and ammonia. So some names do not fit into the scheme, which must be kept in mind.

We note that some molecules are known in which oxygen is completely substituted with the imino radicals. Sometimes we will just mention these analogons.

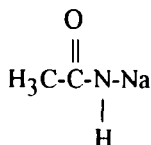
Now let us start with methane. It does not contain either O or N, therefore it is independent of the solvent; and neither water nor ammonia solve it efficiently. Further members of the paraffine sequence would do similarly; however, for simplicity we remain at the first member.

We may form an (aquatic) organic basis from methane by substituting one H with an -OH. It is an alcohol, the first member is the methylalcohol, CH<sub>3</sub>OH. Alcohols do not dissociate too much in water, so their basical nature is not too explicit. However, they perform neutralisation with acids.

The ammonic analogon is CH<sub>3</sub>NH<sub>2</sub>. It is a well-known molecule called methylamine, which appears in plants (*Mercurialis perennis* & *annua*) and in the juice of processed herring. With aquatic acids it produces some organic salts soluble in water. (For compound properties see e.g. *Römpp* (1958) and *Bailar* (1973).)

By substituting one -H of a paraffine with a carboxyl radical organic (aquatic) acids are obtained. The 1<sup>st</sup> member is the acetic acid, CH<sub>3</sub>COOH. However, now there exists a 0<sup>th</sup> member as well, HCOOH, the formic acid. The mirror molecules are, respectively: CH<sub>3</sub>CONHH, acetamide, and HCONHH, formamide. These compounds are artificial industrial products. (If O is completely substituted, one gets acetamidin, CH<sub>3</sub>C(NH)(NHH), which exists too.)

Now one could try neutralisation reaction of an organic acid and an anorganic basis. In water a simple reaction is sodium hydroxide + acetic acid, giving sodium acetate. With the mirror basis and acid we end in sodium acetamide, CH<sub>3</sub>CONHNa. The molecule may be represented by



Sodium salts of this type were indeed observed when a carbonic acidic amid reacted with sodium amide in aether; that they are unstable in water via hydrolysis is irrelevant in A-chemistry.

As for an organic acid and an organic basis (i.e. alcohol), that reaction is again a neutralisation; only it is slow in W-chemistry and generally needs a small amount of anorganic acid for stimulation. The reason seems to be the low dissociation rate of alcohols. Since methylamide possesses the same -NH<sub>2</sub> radical as sodium amide does, by any chance the reaction follows the same pattern.

#### 4. THE BEGINNING OF BIOCHEMISTRY

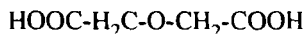
Organic acids and alcohols are improper as building stones of larger, versatile molecules. For that we would need a molecule which is an organic acid on one end and basis or alcohol on the other. Such molecules could repeat themselves in neutralisation steps. With solvent loss at the touching ends the product is a longer molecule again with an acid radical on one end and a basic one at the other; and then the new molecule can enter the process in the same way. In addition, the only by-product is the solvent itself. Therefore the solution will be more diluted but the environment does not change qualitatively. In this case the end-products do not inhibit the reaction. The scheme will be shown immediately.

Now, such an amphoteric molecule can be obtained by doing both substitution steps mentioned above. So take a paraffine and substitute one H with one radical, and another with another. In W-chemistry the 0<sup>th</sup> and 1<sup>st</sup> members of these oxyacids would be



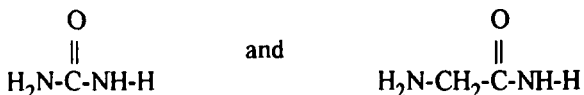
formic and acetic oxyacids. The first molecule does not exist according to the established fact that two -OH radicals cannot be carried by the same C atom. The explanation is of quantum many-body origin and we will not go into details. But a remark is needed. Generally, the -O-H of the carboxil group is not considered to be a hydroxil radical and is not working as one such; the carboxil group has the tendency to lose -H, not -OH. However, the hypothetic formic oxyacid would be so mirror symmetric that there would not be any way (other than spontaneous symmetry breaking) to distinguish the two ends. Therefore in this special case even if the empirical rule did not hold against two hydroxiles, the molecule would not be an acid. The said molecule is sometimes called formaldehyde hydrate, and its polymer is known by the name of poly-oxymethylene hydrate. It seems that this 0<sup>th</sup> oxyacid can exist in aqueous solution, at least transiently.

Without doubt acetic oxyacid (alias glykolic acid) does exist, and can be found in some grapes. But generally it is not a building stone of the terrestrial life, probably, because it has no tendency to duplicate into a double oxyacid; rather one of its duplication reaction results in the twin molecule diglykolacid:



with one molecule H<sub>2</sub>O lost. So it seems that, from some quantum mechanical reasons, it would be hard to build up versatile macromolecules from oxyacid modules, in spite of their amphoteric nature.

The mirror molecules of 0<sup>th</sup> and 1<sup>st</sup> oxyacids in A-chemistry are, according to the rules,



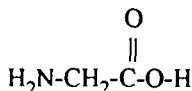
The first molecule again would be symmetric and therefore would not be amphoteric; however it is the carbamide, a key molecule of higher terrestrial animal metabolism. This shows, at the same time, that some caution is needed when sketching the mirror chemistry; contrary to the W-chemistry, two amino radicals may attach to the same C atom. (If O is completely eliminated, instead of carbamide we get guanidine, again a completely stable molecule.)

The second A-molecule is called glycine, and it is a rare but important building stone of terrestrial biology: glycine has been found in the hormone-type peptides oxytocin and vasopressin. We return to the problem of the -CONH radical at the end of this Chapter.

Now, oxyacids do not work properly as building blocks of W-macromolecules; and of course the terrestrial biology cannot have been built on their A-mirror molecules, being the solvent water. But maybe something in between is still possible.

And it is definitely so. There are two possible hybrid WA amphoters originating from methane. Either the hydroxyl of the acetic oxyacid can be substituted by an amino radical, or its carboxyl is substituted by the "A-carboxyl". For practical reasons we turn to the first possibility and shortly comment the second at the end of the Chapter.

The corresponding WA hybrid is the molecule



called acetic aminooxyacid, or by shorter name, glycine. And it definitely exists, and is one of the 20 standard amino acids which build up the proteins. The 0th member of this series, H<sub>2</sub>N-COOH is called amino formic acid, or carbamic acid. It is unstable in W-chemistry, but some of its derivatives are familiar, as e.g. polyurethanes. Its potassium salt is found in the urine of horses.

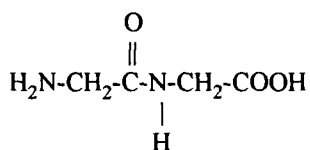
Although glycine is formally not an amphoteric compound in any solvent, it forms "twin ions" in most aquatic environments. Between the pH's 2.34 and 9.60 its usual ionisation type is



and, at least formally, two such glycine twin ions can form a double molecule by water loss. The new molecule will be



which exists and is called glycylglycine. Its slightly more detailed structure can be written as



and the link between the C and N is called the peptide link, the characteristic way of binding together polypeptides and proteins. Here remember that this link automatically appeared above, in Chap. 3, in a simple neutralisation reaction of A-chemistry. The chain can be repeated without any limit because the two ends of glycylglycine are the same as of glycine. For all of the present knowledge, this is the way of building terrestrial proteins. The building process is not too simple and needs catalyser enzymes in W-chemistry.

At this point we stop and recapitulate that the first 5 products of Miller-type synthesis are, in descending order, formic acid > glycine > glycolic acid > alanine > lactic acid. Lactic acid is the W counterpart of the WA alanine. So the yield is decreasing with molecular weight (which is natural), and WA molecules are more abundant than W ones (which is interesting and important).

There is a process called *spontaneous amination* (Bailar, 1973). Having solved molecules with hydroxile radicals in water contaminated by ammonia, in a substantial part of molecules -OH is substituted with -NH<sub>2</sub> without any catalyser. We have seen this reaction in Sect. 2 as a step of the Miller synthesis. Therefore in the presence of ammonia the occurrence of *amino acids* is inevitable indeed.

Now some comments on the existence of "A-carboxyl" and the possibility of the "inverse WA hybriide".

- 1) As we have seen, organic acid amides do indeed neutralize with alkali amides even in some terrestrial situations. Therefore they behave as acids, i.e. the terminal H indeed dissociate from (CO)NHH.
- 2) The more complicated amino acids may have extra hydroxile, carboxyle or amino radicals on some branches. Two such examples are asparagine acid and glutamine acid, having two -COOH radicals; only one is participating in the peptide link when forming proteins. Now, both of them have their near relatives, asparagine and glutamine, with the only difference of possessing -CONHH instead of the second carboxyle. No surprise that this arm does not form peptide link; from this peptide link could form with NH<sub>3</sub> loss, not the most natural one in W-chemistry.
- 3) As for the possibility of an inverse hybriide, oxyacidamides, having -CONHH for "acidic" and -OH for "basic" end, they are not used, to our knowledge, in terrestrial life. However two analogous compounds do appear. The 1st member of a simpler series, oxyamides, is methanolamide, HO-CH<sub>2</sub>-NHH. It is not used in terrestrial life. However the 2nd member, ethanolamide, is called also cholamine, and it appears in some biological phosphatides. Another analogy is oxytocine (see Fig. 2). It is not exactly a polypeptide, since it is cyclic at

the amino end. However the -OH radical of tyrosine is free, and the other end is free, with glycinamide in the beginning, i.e. a -CONHH radical.

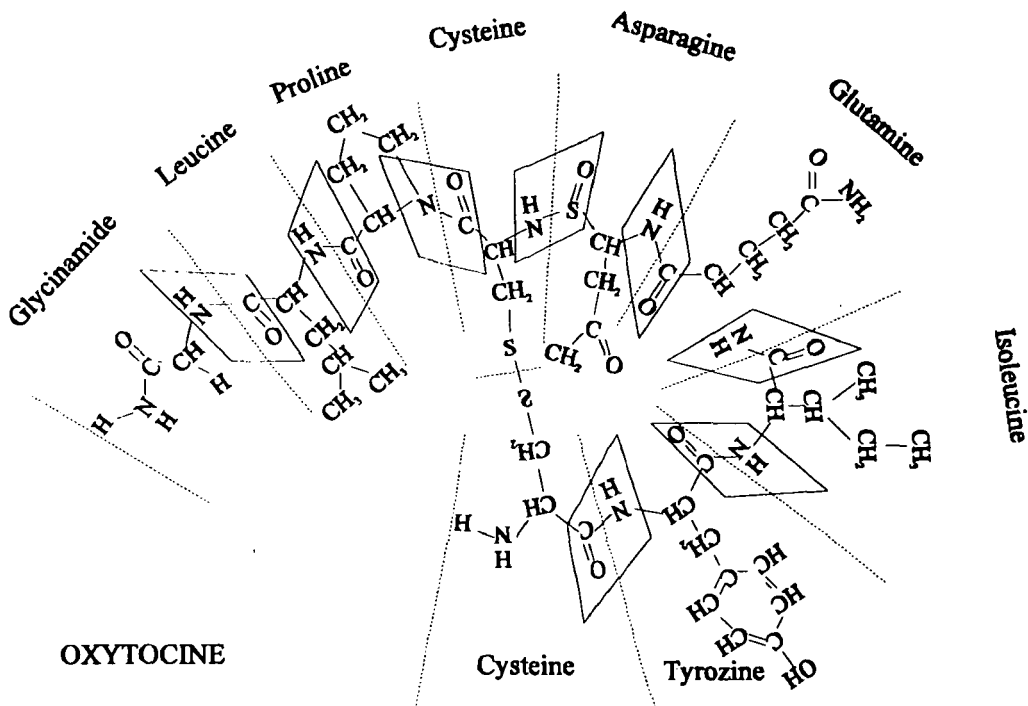


Fig. 2 The structure of oxytocine, a hormone-like polypeptide of terrestrial biochemistry. It utilizes glycinamid, an "ammonia-world amphoteric" compound, and, except for the cyclic form of its end, models an "ammonia protein" in small.

The practical absence of biological oxyacidamides in terrestrial life does not need too much explanation. Amino acids and oxyacidamides would be alternative solutions for the same problem. One in itself can do the work, and mutual presence would originate in compounds which would be not amphoters but double acids or double "amino bases". In some sense the elimination of one of them helps and is a spontaneous symmetry breaking.

We close this Chapter by returning to Fig. 1, showing the "mirror symmetry" between some simple organic molecules of W- and A-chemistry. The scheme displays the acids and bases (alcohols) derivated from methane.

The hexagon above the horizontal line is not a compound but the set of building stones. The vertical dashed line separates the W- and A-worlds. Observe the mirror symmetry of the structure.

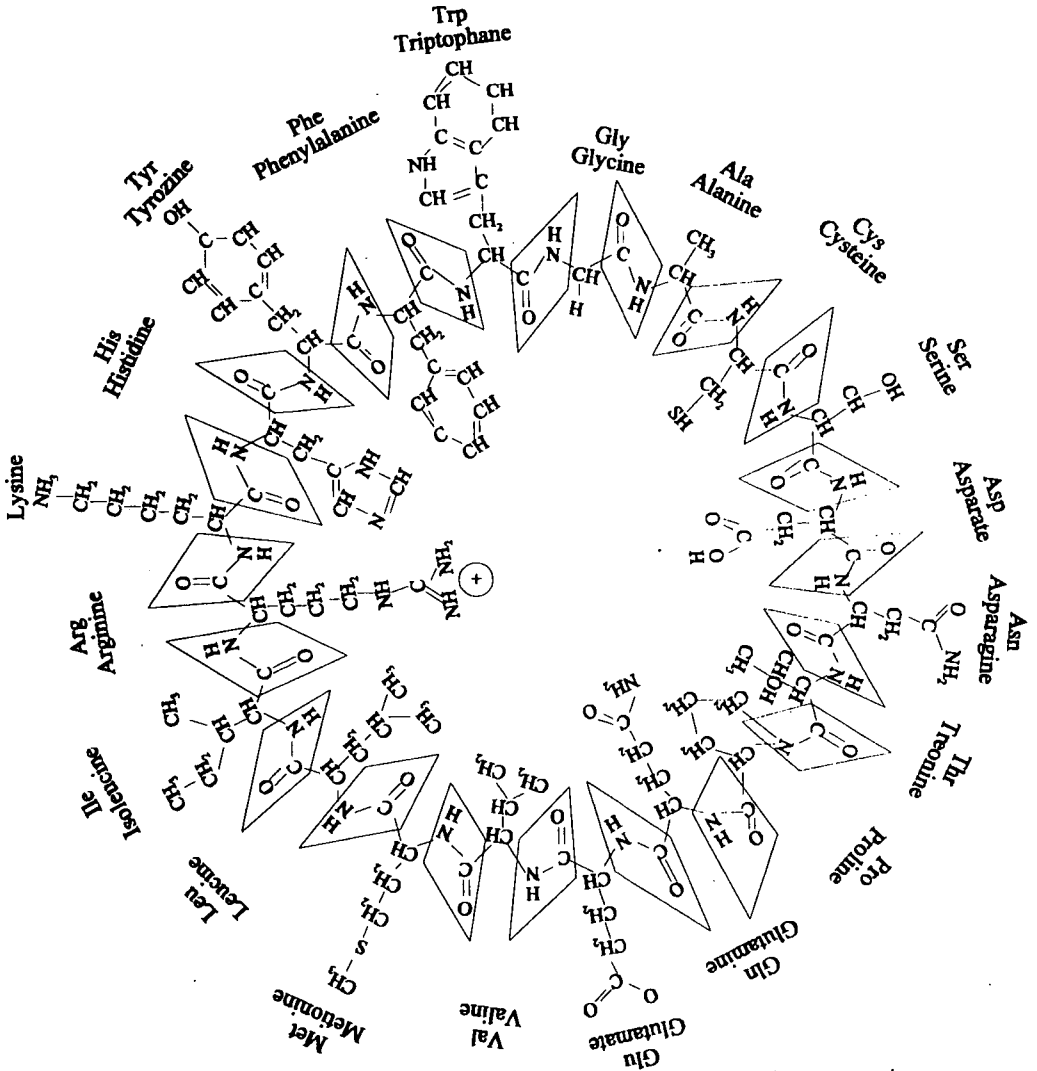


Fig. 3 The 20 canonical terrestrial amino acids in a so far cyclic peptide chain. Glycinamid is not among them.

Methane (Row 1) is a vertical line on the dividing line. It is common in both worlds. All the other compounds considered here are triangles.

Row 2 contains bases or alcohols (outside), and organic acids (inside). Row 3 gives the amphoteres ("oxyacids"). Finally, Rows 4 and 5 are the logically possible amphoteric WA hybrides. They are not mirror symmetric in themselves, but the reflection carries one hybride to another. They are "on the dividing line", with equal areas in both worlds. The upper such hybride is just glycine, the simplest existing terrestrial amino acid.

In this scheme glycine is one of the simplest organic compounds. Therefore not too much explanation is needed for its formation and for amino acids, the building stones of proteins, if water, ammonia and simple carbon compounds are simultaneously present, with some energy transfers.

Even the more complicated amino acids are "half way between W and A worlds". Namely, some of them contain extra basic or acidic radicals above the one pair of  $-NH_2$  and  $-COOH$ . In the 20 usual amino acids of terrestrial living organisms (Fig. 3) there are 8 such extra radicals, and of them 4 are of the W-chemistry ( $-COOH$  and  $-OH$ ), while 4 are of the A one ( $-CONHH$ ,  $-CNHNH$  and  $-NH_2$ ).

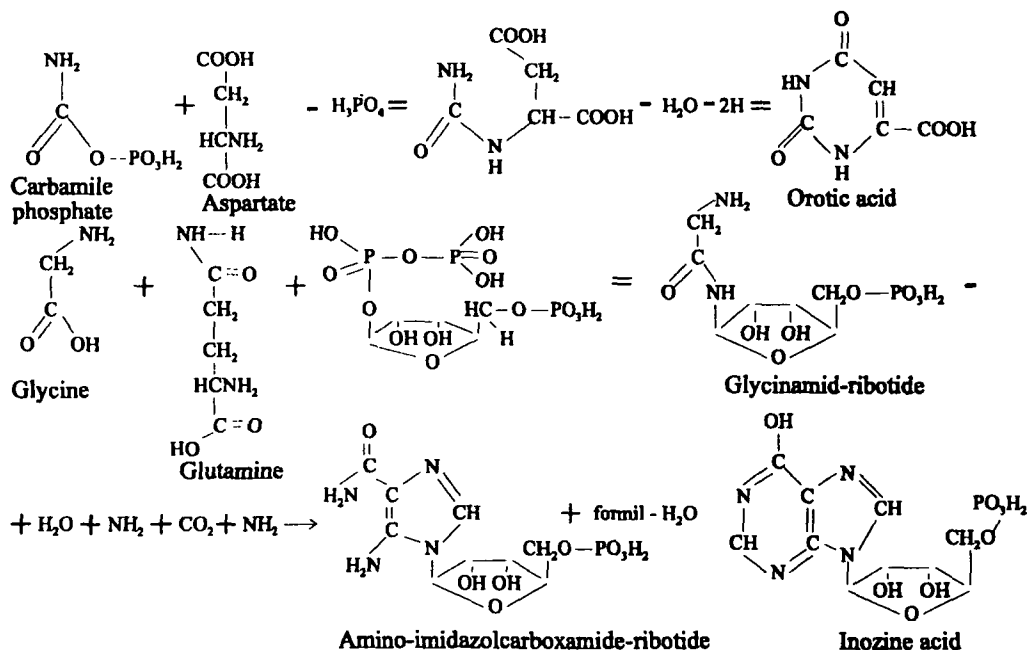


Fig. 4 The scheme of uracil acid synthesis (after Csányi, 1976). Uracil acid is one of the 4 building stones of RNA, the non-peptide fundament of life. Observe that the initial steps of synthesis use amino acids and other aminated compounds, and one peptide link can be seen even in the final product

We close this Chapter with a very brief note of nucleic acids. Terrestrial life uses them for genetic information. They seem very different from proteins; their building stones, the nucleotides, have a  $-PO(OH)OH$  radical for acid and an  $-OH$  for basis. However in the beginnings there was some connection between the building stones of amino acids and nucleotides. The details are complicated and we mention only one example for demonstration. Uridil acid, UMP, one of the four building stones of RNA, starts to be biosynthesized from carbamile phosphate and aspartate. (For a scheme of the synthesis see *Fig. 4.*) The second is a canonical amino acid, while the first is synthetised from ATP, carbon dioxide and ammonia. Indeed, in the basis of UMP one peptide link can be seen.

## 5. THE ESSENTIALS OF PROTEIN STRUCTURE

The structure of proteins is very complicated, not always known in details, and important for enzyme functions. However, it seems that there are 4 major factors determining the spatial form of the protein. (*Dickerson and Geis, 1969*) These factors will be listed here in decreasing order of occurrence and strength. So the terms primary &c. in this Chapter are not to be confused with the usual biochemical terms. (The items can be seen on *Fig. 3.*)

- 1) *The peptide link.* It builds up the polypeptide chain of the protein; all the chain-forming links are peptide links with the slight modification at the N of proline, which does not bear H. The peptide link is not a straight line, so there appears a zigzag in the chain, and a tendency to spiral up. In terrestrial biochemistry in each amino acid only one  $-COOH$  can form the link, so there is no branching in the chain. This link is covalent and as strong as any usual valence link.
- 2) *The S bridges.* The  $-SH$  radicals in two cysteines can bound. So if 2 such amino acids get near, then an S-S bridge links the two parts of the chain. This link is covalent and as strong as any usual valence link.
- 3) *The H bridges.* For quantum mechanical reasons an H in valence link with an O or N atom can make a weak ( $E \sim 0.03$  eV) link with another O or N atom too (*Pimentel and McLellan, 1960; Biczó et al., 1966*). This is just the situation if by zigzag or spiralling two peptide links get near (with the exception of the N of proline.); then H bridges can alter the spatial structure. This link is weak and can break down well below the decay point of the chain.
- 4) *Electrostatic interactions.* Some radicals, e.g.  $-COOH$ ,  $-OH$  and  $-SH$  may dissociate, and then the free charges establish attraction or repulsion. This link is not too strong; its strength depends on the solvent, via dissociation rates and dielectric constants, and of course on the nature of the radicals too.

According to the above statements, one expects a polypeptide chain if the constituents and the solvent are appropriate for peptide link; there is a good chance that the chain and its

primary strength will be practically the same in W- and A-chemistry. Since the S-bridges are covalent, there again the strength may be similar. As for H-bridges the fundamental quantum mechanical effect behind is independent of any solvent, and the solvent is expected to cause only minor disturbing effects at most. Finally, as it was told above, the strength of electrostatic interactions of ions is clearly solvent-dependent.

Therefore, even if the fundamental protein chain can be produced in A-chemistry, then the primary, secondary and tertiary structures will be similar to that in W-chemistry, but the quaternary interactions will be different in degrees, so some denaturalizable structures will be different. In addition, in terrestrial proteins the H-bridges mainly form at the peptidic links; the H coupled to N bridges between the N and the O, with double coupling to the C. So the structure is the same in both chemistries if the peptide link is the same. But, if that O is eliminated too, and exchanged with NH, then the new H would disturb the H of the bridge. I.e. if O were completely eliminated from the mirror images of amino acids, then the tertiary structure and so the spatial form of mirror peptides might be completely different from the terrestrial ones. (For terrestrial amino acids and peptide bridges see *Fig. 3*, and for the alteration of the peptide link see the link at the proline which is amino acid only by courtesy.)

## 6. ON THE POSSIBILITY OF A-PROTEINS

Protein formation in ammonia solvent is a matter of many details, some still unknown. What will be done here is pure guesswork.

However, let us do it. One may try first with the W amino acids as building blocks. In principle two glycines might bind with ammonia loss, resulting in



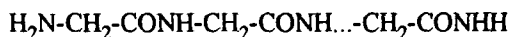
which is an analogon of glycylglycine, but the link is definitely not the peptide link. This molecule is not familiar in W-chemistry; it may or may not be stable in different environment, and H bridges will be absent because of the lack of H in the link. However, let us not spend too much time on hypothetical molecules.

Then let us try with glycinamide. There is no reason to doubt that two glycinamides can react with ammonia loss resulting in



The reaction is a simple neutralisation process of A-chemistry. Such processes between other but analogous molecules have been observed even in terrestrial situations. We do not know this molecule, but it is the twin of glycinamide, it is again a regular A-amphoter, and it contains the correct peptide link.

What is more, consider the molecules analogous to amino acids, but interchanging -COOH's and -CONHH's. The peptide binding energy will be practically independent of the solvent; the dissociation rates of H in -COOH and -CONHH will differ, but it influences only reaction rates. So di-, tri- and polypeptides seems possible from the mirror molecules too. Now consider the hypothetical polypeptide built up from many glycinamides and nothing else. Its form is



This molecule is exactly the same as the terrestrial poly-glycine, except for the last 3 atoms of the extreme right end. So the bulk properties of this (useless) protein will only infinitesimally differ from those of its W-counterpart, by which the possibility of such chains is demonstrated. (For the existence of peptide chains with a -CONHH end remember the terrestrial oxytocine.)

So amino acid amines (meaning those with a -CONHH "acidic" end) seem to be able to form very similar polypeptides (and so A-proteins) in A-chemistry to those of W-chemistry. Low temperature will not disturb stability, and ammonolysis does not seem for us strong enough to break up the chains (this can be experimentally investigated using W-proteins in liquid ammonia). In addition, A-chemistry is possible on terrestrial room temperature above cca. 10 atm pressure, not impossible on extraterrestrial planets.

To close this Chapter observe that glycinamide is the natural amphoter of A-chemistry (while glycine is not in W-chemistry; there glykolic acid = acetic oxyacid would be natural; see Fig. 1, where glycinamide is purely in A-world). In addition, in A-chemistry the peptide link can arise even in simple neutralisation reactions. So: may it be possible that biological macromolecules could build up more easily in A-chemistry than in W-chemistry?

## 7. LIFE WITHOUT NITROGEN?

Our life definitely uses N. However, let us see briefly if N is really necessary. The answer consists of two halves.

First, the 5 most abundant atoms in the Universe are:

H	valence 1
He	valence 0
O	valence 2
C	valence 4
N	valence 3

He is irrelevant; the other 4 have all different valence numbers, so all possible roles in chain formation are represented. Omitting N, valence number 3 would be absent, so the possible chain structures would be highly reduced. P is much rarer, so could not substitute effectively N.

Second, as it was told above, oxyacids are formally analogous to amino acids, but they cannot act as bases of a biochemistry, because in aqueous chemistry they do not tend to form larger amphoteric molecules but rather geminate up as double acids. No doubt, the explanation is quantum mechanical, but irrelevant here.

Consequently, primordial N sources ( $\text{NH}_3$  or  $\text{NH}_3^-$  and  $\text{NH}_4^-$ -bearing silicates) are necessary for life. If a planet is formed at a too hot part of the prestellar nebula, there will be serious problems with life on it.

## 8. DISCUSSION

Life needs long carbon chains built up from small modules of great number but moderate variety. If so, then the modules must have some amphoteric or ambivalent nature, one "polarity" on one end, the opposite on the other; then the long chain can build up by simple reactions, and, if it is needed, the chain can be continued without limit.

On Earth, the amphoteric modules are simple molecules of two types. Terrestrial life has a duality of performance and information; the first is done by proteins, the second by nucleic acids. We do not know if this duality is inevitable. The proteins are built up from amino acids which are acids on one end in water chemistry and bases on the other end in ammonia chemistry. (If our chemical naming reference system were to be based on ammonia instead of water, then we would call amino acids carboxile bases.) Therefore the protein-building reaction is almost neutralisation, which would be the simplest chemical reaction. The true amphoters of water chemistry are practically without use in terrestrial life. However, the protein-building reaction, the peptide linking, would be a true neutralization process in ammonia chemistry. The nucleic acids build up from nucleotides. The binding reaction is a simple neutralisation of water chemistry, although the acidic end of the modules is not the carboxyl radical of organic chemistry but the analogon with phosphor instead of carbon. However, the synthesis of the nucleotides needs amino acids and ammonia too.

Therefore it seems that even in aqueous environment the emergence of life would need or would be speeded up by substantial amount of ammonia. Ammonia seems not too abundant in the internal part of the aqueous belt because of the high temperature of the ancient solar nebula. So for life in water solvent chances seem best near to the outer boundary of the belt where liquid water can exist on planets in the Solar System, in the vicinity of Earth and Mars.

As for ammonia solvent, it seems that the natural building stones are amino acid amides (amino acids with  $-\text{CONHH}$  instead of  $-\text{COOH}$ ). The simplest of them, glycinamide, does have a role, albeit minor, in terrestrial biochemistry. The ammonia neutralisation reaction of these molecules would result in a peptide link, and the peptide chain would be identical with the terrestrial protein, except one radical at the very end.

It is obvious from the whole presentation that here we did not restrict ourselves to atmospheres, but to the whole volatile sphere of planets, containing the gaseous and liquid spheres plus all volatiles bound in lithosphere. The reason is that during planetary evolution volatiles take part in circulation, so all these molecules can interchange roles. Planets are open thermodynamic systems with the only restrictions that the energy flux going through is roughly stationary, prescribed by solar distance, solar luminosity and albedo (of which the latter two can, however, moderately change) and that there is practically no incoming matter after the era of great bombardments (cca. 600 My after Solar System formation).

Applying all these to the Solar System, Venus is almost in the water belt, but in her present status the high greenhouse effect evaporated water. For primordial life we note that Venus must always have been poor in ammonia.

For Earth there is a problem. Earth is and seems to have always been in the water belt. However, at 1 AU not too much ammonia must have been in the solar nebula. To be sure, ammonium silicates have been suggested for ammonia source (*Eugster and Munoz, 1966*), and they could have taken part in the formation process of proto-Earth (albeit in this temperature zone even ammonium silicates seems to have been rare), or Earth may have got an impact of an ammoniated planetesimal from the outer system. Then the most appealing story about terrestrial proto-life would go as follows. First ammonia appears in water as a solved gas, aminates oxyacids and then appear amino acids. They build up proto-proteins. Slightly later from similar compounds nucleotides start to be formed; but these processes, thermal decay and some other processes are eating up ammonia, so in nucleic acids the amino radical is no more operative, only a relict; RNA and DNA build up by usual W acid-basis neutralisation. The only problem is that the earliest known deposits are N-poor, even in the neighbourhood of the first known fossil procariotes. This controversy needs an explanation, not available yet.

Neither water nor ammonia is liquid on present Mars. Some 2 Gys ago Mars had some liquid because riverbeds can be seen. Then Mars may have had either liquid ammonia with abundant water ice, partly solved, or liquid water, with abundant gaseous ammonia, partly solved; Mars may have got substantial amounts of both hydrated and ammoniated and ammonium silicates. We only note that *King et al. (1993)* found ammonium saponite on Ceres by spectroscopy. Therefore there is a chance that ancient Mars generated life, either W or A.

Outwards from Mars liquid water is impossible; liquid ammonia is improbable in the outer system.

Now, let us see what conclusion is possible from the data above for the ammonia content of the primordial atmosphere of Earth.

Planetology tells that in the beginning  $\text{NH}_3$  must have been present in the atmosphere, because  $\text{NH}_3$  or  $\text{NH}_4$ -containing silicates seem to be the most effective condensates carrying N into the proto-Earth; other sources are improbable or very minor ones.

However  $\text{NH}_3$  might have dissociated very early. So we have 2 possible scenarios. Atmospheric  $\text{NH}_3$  either still existed at the emergence of life, or not. If not, the atmosphere

may have contained NO, NO<sub>2</sub>, N<sub>2</sub>O<sub>4</sub> and N<sub>2</sub>, maybe with smaller amount of C<sub>2</sub>N<sub>2</sub> and derivatives. (NH<sub>3</sub> dissociates to N and H, but NO and relatives are created in the *present*, oxidizing atmosphere by lightnings.)

Now, let us assume first that NH<sub>3</sub> was abundant at the emergence of life. Then abiotic synthesis of amino acids, proteins and nucleic acids was very easy, see the Miller experiment and later improvements. We have seen that the simpler amino acids are indeed simple and abundant organic compounds and their appearance is inevitable in the presence of NH<sub>3</sub>.

However, then the very early minerals would have had N content, in two ways. NH<sub>3</sub> can be built into silicates either as crystalline ammonia or as ammonium ion substituting alkalis, and these silicates are fairly stable at temperatures permitting life. Now, Szalay (1975) did not find NH<sub>3</sub> in Precambrian gas inclusions, but those samples, although Precambrian, did not go back to the beginning of life. However Shöpf *et al.* (1968) did not find N either in layers of ~3.4 Gy age, with microfossils (of course, outside the organic matter). Then there is an alternative. Either life on Earth is much earlier than 3.4-3.7 Gy, or not.

If it is much earlier, then it may have appeared from the "primordial bouillon", waters containing very abundant amino acids. Then the layers synchronous with primordial life do contain N abundantly, but these layers are not yet unearthed. This bouillon, then, came into existence under the heavy influence of atmospheric NH<sub>3</sub>, still present.

If life on Earth is not much earlier than the Fig Tree and Onverwacht layers, then the absence of N in the minerals is an evidence against substantial atmospheric ammonia concentration at the emergence of terrestrial life. What is more, then it is an evidence that in that time the atmosphere contained only *molecular N*. Namely, nitrogenic oxides react with H<sub>2</sub>O and form nitric acids. These acids attack and alter minerals. Only molecular N is inert enough not to enter minerals even for aeons, as it can be seen in the present atmosphere. In addition, since no trace of primordial bouillon is seen (Brooks and Shaw, 1973), then there was no slow and long accumulation of amino acids.

So, if no microfossils were to be found later older than ~3.4 Gy, then spontaneous terrestrial abiotic amino acid synthesis would be ruled out. Then one should turn to the scenario preferred by Brooks and Shaw (1973): the transport of extraterrestrial, evolved microorganisms to Earth, where they utilized the atmospheric N (which was already pure N<sub>2</sub> according to the lack of N in minerals).

Indeed, some C chondrites do contain biomolecules, quite similar to the terrestrial ones. For example, Brooks and Shaw (1969) found a component in the Orgueil and Murray meteorites (C1) which was undistinguishable from terrestrial sporopollenine, a biocompound of terrestrial plants.

Now, there remains the question, *where* did then happen the primordial abiotic synthesis of amino acids? For moderately short meteoritic travel only the Solar System is worth discussing. Now, the only major planet whence meteorites can come and where primordial H<sub>2</sub>O and NH<sub>3</sub> were present according to the Lewis-Barshay scheme is Mars.

As it was told earlier, in the condensation of Mars, which planet is farther out than Earth, hydrated, ammoniated and ammonium silicates must have played more substantial role than in the formation of Earth. Now Mars is without liquid water and atmospheric ammonia, but we know that some 2-2.5 Gy rivers existed on the planet. So the early atmosphere may have been good for abiotic amino and nucleic acid synthesis.

Martian meteorites, although rare, are well known. A group of meteorites, called SNC (shergottite, nakhlite and chassignite) meteorites, are identified as Martian ones (*McSween and Stolper, 1980*). SNC's are mafic and ultramafic rocks, and do not go far beyond 1.3 Gy age. However if an impact can dislodge Martian rocks now and can send them to Earth, then it was possible 3.5 Gy ago as well.

So until one does not find substantial N in layers with early microfossils, the NH<sub>3</sub> content of atmosphere at the time of emergence of life and the terrestrial abiotic amino acid synthesis is not proven. Alternatively, manned Martian expeditions may settle the question by checking the N content of early *Martian* layers. But, according to planetology, in the primordial atmosphere NH<sub>3</sub> must have been present at least in the beginning.

### **Acknowledgements**

The authors would like to thank Prof. J. Ladik for illuminating discussions about H bridges in proteins and DNA. One of the authors (B. L.) acknowledges that the idea of the symmetry between W and A chemistries was suggested to him by an article of V. A. Firsoff in *Discovery* in cca. 1960.

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### **APPENDIX: ON THE PROPERTIES OF SOME KEY COMPOUNDS**

Here we give some important properties of the simplest molecules used in the text when comparing W- and A-chemistries. The main reason is to demonstrate that the simple fundamental molecules of A-chemistry (both anorganic and organic) are not at all exotic, missing or self-contradictory. Densities, colours and odours are meant at room temperature and pressure.

#### *The Paraffine series*

**CH<sub>4</sub>**: Methane. Colour: -. Odour: -. Freezing & Boiling Points, K: 89 & 109. Density, g/cm<sup>3</sup>: - (Gas). Characteristic Reaction: With free oxygen detonates, giving CO<sub>2</sub> and water. Interesting Property: Apolar. Appears: Marshes, decaying organic matter.

*Alcohols W & A*

**H<sub>3</sub>OH**: Methylalcohol. C: -. O: alcoholic. Fr. & B.: 179 & 338. D: 0.81. Ch. R.: Neutralization with organic acids resulting in esthers. I. P.: Affecting neural systems of higher animals. A: Aromatic oils, some grapes, spontaneous fermentation.

**CH<sub>3</sub>NH<sub>2</sub>**: Methylamine. C: -. O: Fishy. Fr. & B.: 194 & 267. D: - (Gas). Ch. R.: With W-acids gives salts solvable in water. I. P.: -. A: Maratiales perennis & annua; in juice of processed herring.

*Organic acids, W & C*

**HCOOH**: Acidum formicum. C: -. O: acrid. Fr. & B.: 282 & 374. D: 1.22. Ch. R.: Thermal decay to CO and H<sub>2</sub>O. I. P.: -. A: Ants, bee poison.

**HCONHH**: Formamide. C: -. O: -. Fr. & B.: 275 & 470. D: 1.15. Ch. R.: Good solvent. I. P.: Very viscous. A: Artificial.

**CH<sub>3</sub>COOH**: Acetic acid. C: -. O: acrid. Fr. & B.: 290 & 391. D: 1.06. Ch. R.: Neutralization. CH<sub>3</sub>COOH+NaOH = CH<sub>3</sub>COONa+H<sub>2</sub>O. I. P.: -. A: Wines, &c. spontaneously formed.

**CH<sub>3</sub>CONHH**: Acetamide. C: White. O: -. Fr. & B.: 355 & 595. D: 1.16. Ch. R.: Forms from ammonium acetate. I. P.: -. A: Artificial.

*Anorganic bases W & A*

**NaOH**: Sodium hydroxyde. C: white. O: -. Fr. & B.: 591 & 1663. D: 2.13. Ch. R.: Very strong basis, neutralization, e.g. NaOH + HCl = NaCl + HOH. I. P.: Very hygroscopic. A: Artificial.

**NaNH<sub>2</sub>**: Sodium amide. C: -. O: ?. Fr. & B.: 481 & decay. D: 1.39. Ch. R.: NaNH<sub>2</sub> + HOH = NaOH + NH<sub>3</sub>. I. P.: Reacts with water. A: Artificial.

*Organic salts W & A*

**CH<sub>3</sub>COONa**: Sodium acetate. C: -. O: -. Fr. & B.: 592 & decay. D: 1.39. Ch. R.: Forms in neutralization of acetic acid with sodium hydroxyde. At low temperatures accepts 3 molecules of crystalline water. I. P.: High specific heat. A: Artificial.

**CH<sub>3</sub>CONHNa**: Sodium acetamide. C: ?. O: ?. Fr. & B.: ? & ?. D: ?. Ch. R.: Forms in reaction of acetamide and sodium amide, in other solvent, but not in water. I. P.: Unstable in the presence of water. A: Artificial.

Observe the high analogy between the reaction of sodium hydroxyde with HCl and that of sodium amide and HOH (water). The reaction is observed in terrestrial environment without any solvent if water vapour is ejected on solid sodium amide. In ammonia the sodium amide happens to be a weak basis because of its low solubility. This shows that the analogies are sometimes only qualitative; in water sodium hydroxyde is very soluble.

As for sodium acet-amide, the instability in water is no argument against analogy. Water has the tendency to react vehemently with available sodium.

There is a well-known tendency in the paraffine series that both the freezing and the boiling points are increasing with the chain length. The same is true for simple (W) alcohols. Now, Fig. 5 displays the respective temperatures for the A-alcohols too, according to the available data. (Some points are interpolations.) The tendency is clear: the boiling points of A-alcohols are lower than those of the W-alcohols. So, at least for boiling points, some compounds of the A-chemistry follow the solvent into the cooler temperature regions.

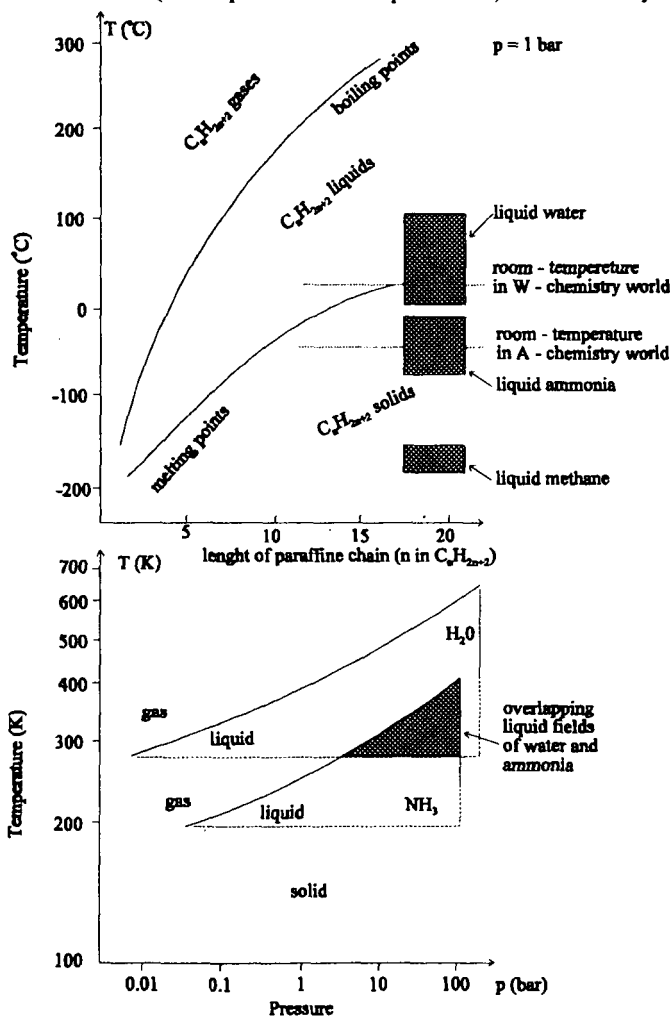


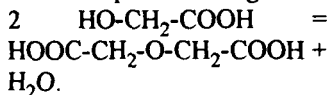
Fig. 5a Boiling and freezing points of paraffine chains and of their alcohol derivatives in the two solvents

of the W-alcohols. So, at least for boiling points, some compounds of the A-chemistry follow the solvent into the cooler temperature regions.

Here we compare the compounds shown schematically in Rows 3 and 4 of Fig. 1. They all can be derived from the first member of the paraffines, i.e. from methane, by replacing one H with an organic acid radical, and another with an organic basis one. So all these 3 molecules are amongst the simplest possible molecules of organic chemistry. According to their structures, all of them have some amphoteric properties.

*WW amphoter:* HO-CH<sub>2</sub>-COOH, glykolic acid or acetic oxyacid.

Freezes at 351 K; decays before boiling. Appears: in some grapes. With itself it gives dimers as anhydrides, but the product is not amphoteric.. E.g.:



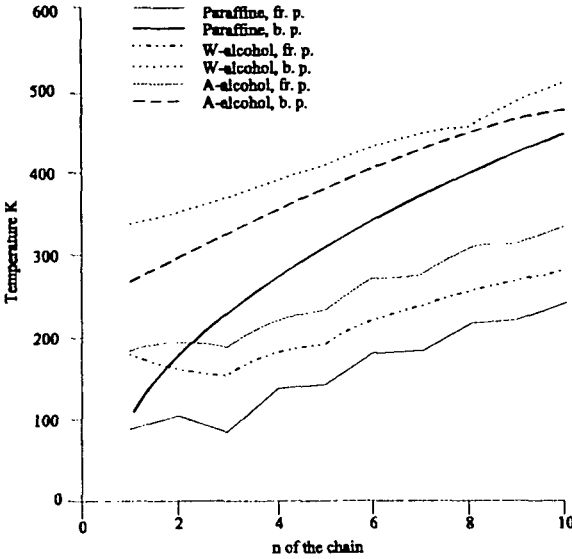


Fig. 5b A very schematic T-p diagram of paraffine chains and the two solvents.

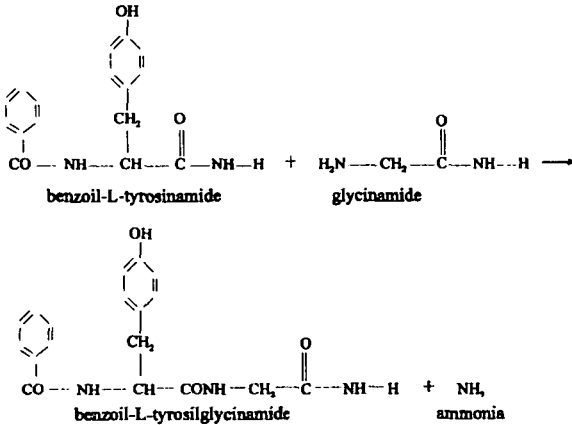


Fig. 6 A peptidisation reaction of terrestrial biochemistry using glycinamid in the presence of chimotripsine katalyser. The link is formed by ammonia loss. The reaction is an analogy of possible peptidisation in ammonia solvent (After Csányi, 1976 and Straub, 1958).

AW amphoter:  $\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$ , glycine or amino acetic acid.

Freezes at 505 K; decays before boiling. Appears: in proteins or glues. With itself, at least in the presence of some enzymes, gives an amphoteric dimer, glyciLglycine, which is a dipeptide:  $2 \text{H}_2\text{N}-\text{CH}_2-\text{COOH} = \text{H}_2\text{N}-\text{CH}_2-\text{CONH}-\text{CH}_2-\text{COOH} + \text{H}_2\text{O}$ . Here CONH stands for the peptide link. GlyciLglycine is a colourless crystall; liquefies at 530 K, then decays. Solvable in hot water, weakly in alcohol.

AA amphoter:  $\text{H}_2\text{N}-\text{CH}_2-\text{CONHH}$ , glycinamide.

Freezing point is unknown for us. Appears: in the hormones oxytocine and vasopressine, at the C end of the chain instead of glycine. In the presence of the enzyme chimotripsine reacts in peptidisation: say bensoil-L-tyrosinamide + glycinamide = bensoil-L-tyrosilglycin-amide +  $\text{NH}_3$  (Fig. 6). Now, this process would be just an elementary neutralisation process in ammonia: an A-acid radical reacts with an A-basis radical, with ammonia loss. This reaction could build up A-analogons of proteins.

The WA amphoteric compound,  $\text{HO}-\text{CH}_2-\text{CONHH}$ , glycolic acidamide, is not used anywhere in terrestrial life. The possible reason is that in the simultaneous presence of WA and AW hybrides the module

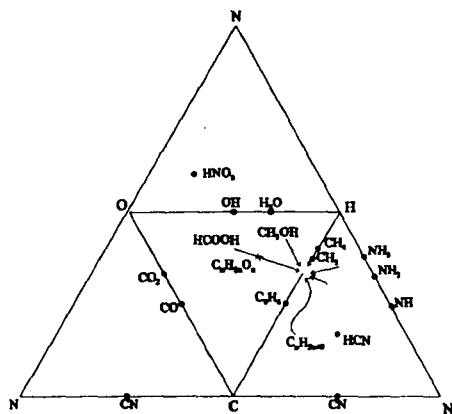


Fig. 7 The roles of the 4 major elements of terrestrial biochemistry. The correct picture is obtained if the figure is cut and glued into a tetrahedron with N at the top. More details in the text.

building of long chains would be disturbed.

Fig. 7 tries to compare the role of 4 main elements of biochemistry, H, C, N and O. The Figure is a tetrahedron, bent into the plane of the paper. Restoring the tetrahedron, C, H and O are at the 3 points of the triangle of the basis and N is at the top point. Some simple molecules of life are on the basis plane, but not all. Two very important gases of terrestrial metabolism, oxygen and carbon dioxide, are there, the terrestrial solvent, water, too, and hydrocarbons (up to this point all on the edges) together with sugars (in the interior of the basis triangle). But the summed formula of glycine, the simplest amino acid, is  $C_2H_5O_2N$ . This molecule is, of course, nearer to the O peak than to the N one; but for glycynamid the relationship is opposite.

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## MUTUAL EVOLUTION OF TERRESTRIAL ATMOSPHERE AND BIOSPHERE

Gy. KOPPÁNY

*József Attila University, Department of Climatology, P.O.Box 653,  
6701 Szeged, Hungary*

**Összefoglalás** - A földi légkör jelenlegi összetétele merőben eltér a Naprendszer többi bolygójának légkörétől. A Föld kialakulásakor megjelent az őslégkör, amelynek összetétele kissé hasonló volt az óriás bolygók ismert légköréhez. Ezt mintegy 4 milliárd éve fölváltotta a redukáló másodlagos légkör, amelyben túlsúlyban voltak az üvegház hatású gázok. A felszín fölmelegedésével megjelent a cseppfolyós víz és az óceán, az utóbbi otthont adott az első élőlényeknek. A fotoszintézis révén megjelent a légkörben az  $O_2$ , majd ezt követően az ózon. Ettől kezdve a légkör és a szárazföldi és tengeri élővilág kölcsönhatásban fejlődött a jelenkorig. A légkör  $CO_2$  változása több tényezőtől függ, ezek mérsékelhetik az emberi tevékenység hatását.

**Summary** - The present composition of terrestrial atmosphere differs remarkably from atmospheres of other planets in our Solar system. At the beginning of the history of Earth the primordial atmosphere was more or less similar to those in giant planets. This atmosphere was soon replaced by secondary one containing predominantly greenhouse gases but no oxygen. After rise of temperature liquid water appeared on the surface and formed oceans. The latter gave home to the first living creatures, and by means of photosynthesis the oxygen appeared in the atmosphere, and after that the ozone. Hence the atmosphere and biosphere have developed mutually up to the present time. The change in atmospheric  $CO_2$  depends upon a great number of factors, so they can moderate the effect caused by human activity.

**Key words:** atmosphere both primordial and secondary, photosynthesis, atmospheric oxygen, carbon-dioxide, biosphere, paleoclimatic variations of temperature.

### THE PRESENT TERRESTRIAL ATMOSPHERE

The mass of the planet earth is as much as  $6 \cdot 10^{24}$  kg, the mass of terrestrial atmosphere is about  $5.2 \cdot 10^{18}$  kg, i.e. the latter is less than one ppm of the former. The mass and volume ratios of main atmospheric gases are as follows (*Table 1*):

Atmospheric gases	Mass	Vol. ratios
N <sub>2</sub>	4.00·10 <sup>18</sup> kg	78.00% volume
O <sub>2</sub>	10 <sup>18</sup> kg	20.90 % "
Ar	4.80·10 <sup>16</sup> kg	0.93 % "
H <sub>2</sub> O (water vapour)	1.30·10 <sup>16</sup> kg	0.25
CO <sub>2</sub>	1.80·10 <sup>15</sup> kg	350 ppmv
CH <sub>4</sub>	1.04·10 <sup>13</sup> kg	2 ppmv
O <sub>3</sub>	3.36·10 <sup>12</sup> kg	650 ppbv

Table 1 The main atmospheric gases and their mass and volume ratios

Besides the atmosphere contains several other gases in very small ratios, like Ne, Kr, Xe, NO<sub>x</sub>-s, CO, CFC-s and microsized solid and liquid particles, the so called aerosol.

The most abundant components of terrestrial atmosphere, the nitrogen and oxygen, take nearly 99 % of the atmosphere. Thus the Earth's atmosphere differs significantly from the atmospheres of the other planets in our solar system. In the atmospheres of the giant planets, like Jupiter, Saturn and Uran, there are abundance of hydrogen and helium, which are not able to escape, because of great gravity force of these planets and very low temperature.

However the atmospheres of Venus and Mars, nearest planets to the Earth, differ from terrestrial atmosphere, too. They contain much more carbon dioxide, but much less nitrogen and oxygen, e.g. the atmosphere of Venus consists of CO<sub>2</sub> in 98.8 %, of N<sub>2</sub> in 1.01 % and practically no oxygen, according to our present knowledge. So the atmosphere of inner planets consists predominantly of CO<sub>2</sub>, while those of giant planets consist of H<sub>2</sub> and He and besides NH<sub>3</sub> and CH<sub>4</sub>. Consequently the question arises: in what way did the terrestrial atmosphere develop producing so very peculiar composition?

#### PRIMORDIAL ATMOSPHERE, SECONDARY ATMOSPHERE (REDUCING, WITHOUT OXYGEN) APPEARANCE OF OXYGEN

The protoplanet Earth consisted of interstellar dust, solid materials and gases in a dispersal system. The gravitation force assembled heavier particles to the centre, while the gases started gradually forming an outer cover. This primordial atmosphere consisted of H<sub>2</sub>, He, CH<sub>4</sub>, H<sub>2</sub>O, NH<sub>3</sub> and H<sub>2</sub>S. It is supposed that mass of the earth was at this time manifold of

the present mass. Nevertheless its gravity force was small and its temperature high, so H<sub>2</sub> and He escaped to the space. The water vapour largely condensed, the other gases were undergone chemical reactions with lithosphere and infiltrated into that. It is plausible that the dissipation of the primordial atmosphere existed for 200-300 million years, and the Earth became a planet without atmosphere at least for an unknown period.

Afterwards gases escaped gradually through the rocks partly through volcanic activity, partly through several chemical reactions. Thus started the longlasted formation of secondary atmosphere consisting mainly of H<sub>2</sub>O and CO<sub>2</sub>, but there were smaller quantities of N<sub>2</sub>, H<sub>2</sub> and S<sub>2</sub> present as well. Due to greenhouse effect of CO<sub>2</sub> and H<sub>2</sub>O the global surface temperature rose from about -18, -10°C up to 0°C and above freezing-point, so liquid water appeared on the Earth's surface and gathered into oceans. About 3-4 billion years ago the atmosphere contained no free oxygen, therefore it has been called reducing atmosphere.

A great number of researchers have been engaged in questions relating to changing solar radiation, density and composition of the terrestrial atmosphere, as well as regulation of global surface temperature (*Budyko*, 1982; *Budyko, Ronov and Yanshin*, 1987; *Lamb*, 1988; *Rambler, Margulis and Fester*, 1989; *Lovelock and Margulis*, 1974; *Frakes et. al.*, 1992; *Mészáros and Pálvölgyi*, 1990; *Koppány*, 1993, 1996). In early phase of the evolution of terrestrial atmosphere, about 4 billion years ago, the solar luminosity was less by at least 30 % compared with the present value. The luminosity of the sun has increased gradually during the last 4 billion years. Meanwhile two very important events must have taken place: 1. Appearance of liquid water on the Earth's surface, in other words, the temperature had to exceed the freezing-point, 2. At some depth in water, organic systems appeared and began to transform the chemical composition of the atmosphere: e.g. release of O<sub>2</sub>.

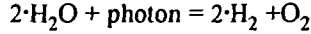
The first event may be explained by greenhouse effect of sufficiently dense atmosphere, or less planetary albedo, or by both. The reduction of atmospheric carbon-dioxide is partly the consequence of photosynthesis carried out by organic materials in deep water. The total photosynthetic reaction may be written in a simplified form as:



This process is accompanied by a release of O<sub>2</sub>. The other consumer of the atmospheric CO<sub>2</sub> is the ocean itself.

However before the oxygen appeared in the atmosphere, there was not ozone and so the lethal UV radiation could reach the ground preventing the formation of living material on it. Only a water-layer at least with 10 m depth can absorb the lethal UV radiation. Hence the first living creatures could form and exist in oceans.

On the other hand the comparatively high abundance of O<sub>2</sub> in the atmosphere is also the consequence of photosynthesis. For a long time it was assumed that the free oxygen is the product of photodissociation of water vapour. It may be written in form:



The very light  $\text{H}_2$  has escaped and the amount of  $\text{O}_2$  increased according to this theory. But nowadays the wellknown Urey-effect has been entirely accepted which establishes that as soon as the ratio of atmospheric  $\text{O}_2$  reaches 0.001 PAL (Present Atmospheric Level), the photodissociation will stop, because the  $\text{O}_2$  absorbs that band of UV radiation which is responsible for the photodissociation. The changes of mass of the atmospheric  $\text{O}_2$  during the last 560 million years (Phanerozoic) can be estimated by equation:

$$\frac{dM(\text{O})}{dt} = A(\text{O}) - B(\text{O}),$$

where  $A(\text{O})$  is the income,  $B(\text{O})$  the loss of  $\text{O}_2$  mass. The income is product of photosynthesis, the loss is the consequence of consumption of  $\text{O}_2$  by organic materials (oxydation). The difference between them in a def. period is considered proportional with organic carbon, accumulated in sediments on the whole Earth. In this relation the  $\text{O}_2$  income is as follows:

$$A(\text{O}) = a(\text{O}) \cdot C_o,$$

where  $a(\text{O})$  is the ratio between masses of  $\text{O}_2$  molecule and C atom, i.e.  $(32:12 = 2.67)$ ,  $C_o$  stands for organic carbon accumulated in sediments during a relevant interval.

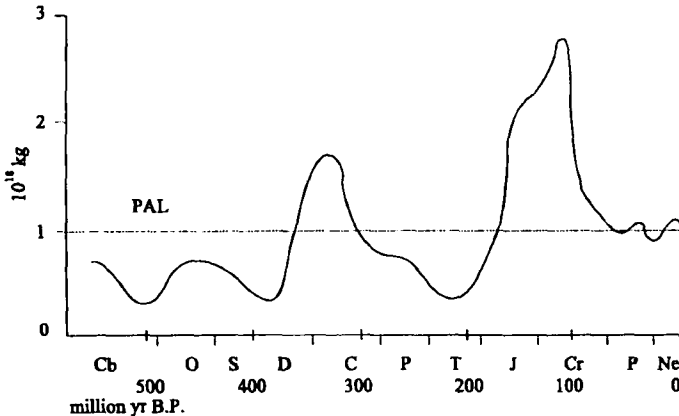
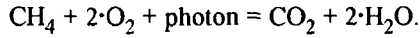


Fig. 1 Changes in oxygen mass in the Phanerozoic (after Budyko, Ronov and Yanshin, 1987)

Fig.1 presents the  $\text{O}_2$  accumulation in the atmosphere with assumption of active contribution of the biosphere. The abundance of atmospheric  $\text{N}_2$  must be the product of the biosphere as well. The simultaneous presence of  $\text{CH}_4$  and  $\text{O}_2$  in the atmosphere could not be explained without contribution of the biosphere. Namely due to the effect of the solar radiation the methane and oxygen will be converted to carbon-dioxide and water vapour:



Hence the atmospheric  $\text{CH}_4$  reproduced continuously by the biosphere may control the  $\text{O}_2$  amount in the atmosphere.

The ratio of atmospheric  $\text{O}_2$  is crucial for the living materials. If the ratio of  $\text{O}_2$  is below 15 %, there is very low chance to get fire. On the other hand, if the ratio exceeds 25 or 30 %, the danger of spontaneous fire is extremely high (Lovelock, 1991).

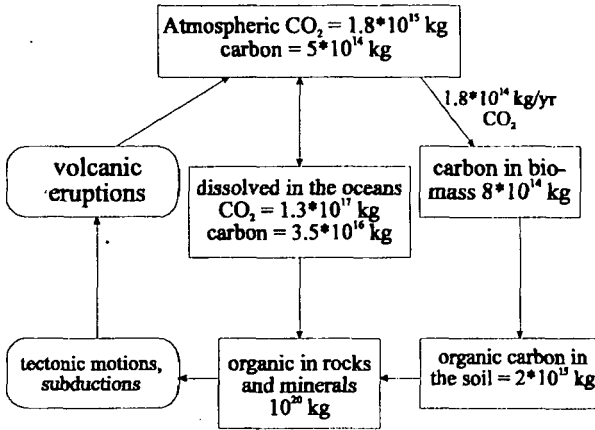


Fig. 2 The great cycle of terrestrial carbon and carbon-dioxide, respectively. The mass and migration rate relate to the present conditions.

The optimum  $\text{O}_2$  density, which was most favourable for its conversion into  $\text{O}_3$ , is about 0.001 of present density at sea level. At the time of the first appearance of atmospheric  $\text{O}_2$ , this optimum density was near the ground, but by increasing amount of  $\text{O}_2$  the altitude of optimum density has risen in hundreds of million years up to the present layer at 20-40 km above the ground. Thus ozonosphere has risen gradually from the ground to the stratosphere. This ozone layer has protected the living creatures on the surface against the lethal UV radiation.

The appearance of  $\text{O}_2$  in the atmosphere might have been a great challenge for anaerob living creatures being existed before and accustomed to an environment without oxygen. At the same time the circumstances changed favourably for aerob species of plants and animals on the continents and sea surface. This change took place in the last 560 million years, i.e. in Phanerozoic.

### VARIATIONS OF ATMOSPHERIC $\text{CO}_2$ IN PHANEROZOIC

The atmospheric gases are in continuous interrelation with the hydrosphere, lithosphere and biosphere. It is valid in case of  $\text{CO}_2$ . Below about  $300^\circ\text{C}$  the  $\text{CO}_2$  can be absorbed by lithosphere in form of carbonates. Besides the hydrosphere and biosphere are also consumer of this gas.

Fig. 2 gives a very simple picture of great cycle of terrestrial CO<sub>2</sub> in earth-atmosphere system. Due to changing tectonic motions and volcanic activity the reduction and release of CO<sub>2</sub> could not maintain stable equilibrium in the atmosphere. This fact is reflected in remarkable variations of atmospheric CO<sub>2</sub> in Phanerozoic accompanied with variations of global surface temperature.

A rough relation was found between the doubling atmospheric CO<sub>2</sub> and rise in global temperature. Partly theoretical, partly experimental investigations lead to the approximative relation, as follows:

if CO<sub>2</sub> past : CO<sub>2</sub> present = k > 1,

and  $\log k : \log 2 = b > 0$ , here b is the number of doubling in CO<sub>2</sub>, then

$\Delta T (T \text{ past} - T \text{ present}) = b \cdot 2.5$ .

One can test this relation using data given in Fig. 3. For example in Carboniferous: k = 7.22, b = 3.67 and  $\Delta T = 9.2\text{K}$ , according to estimation presented in Fig. 3  $\Delta T = 11\text{K}$ . In Ordovician: k = 7.5, b = 2.85,  $\Delta T = 7.13$ , that presented in Fig 3  $\Delta T = 7.5\text{K}$ . In Permian: k = 11.11, b = 3.47,  $\Delta T = 8.6$ , that presented in Fig. 3  $\Delta T = 7.5\text{K}$ . In Jurassic: k = 10, b = 3.32,  $\Delta T = 8.3\text{K}$ , presented in Fig.3  $\Delta T = 10.5\text{K}$ . For the sake of simple comparisons (Tab. 2):

	Calculation	Assessment
Ordovician, middle	7.13 K	7.5 K
Carboniferous, lower	9.2 K	11.0 K
Permian, lower	8.6 K	7.5 K
Jurassic, upper	8.3 K	10.5 K

Tab. 2 Explanation see in text

Mutual evolution of terrestrial atmosphere and biosphere

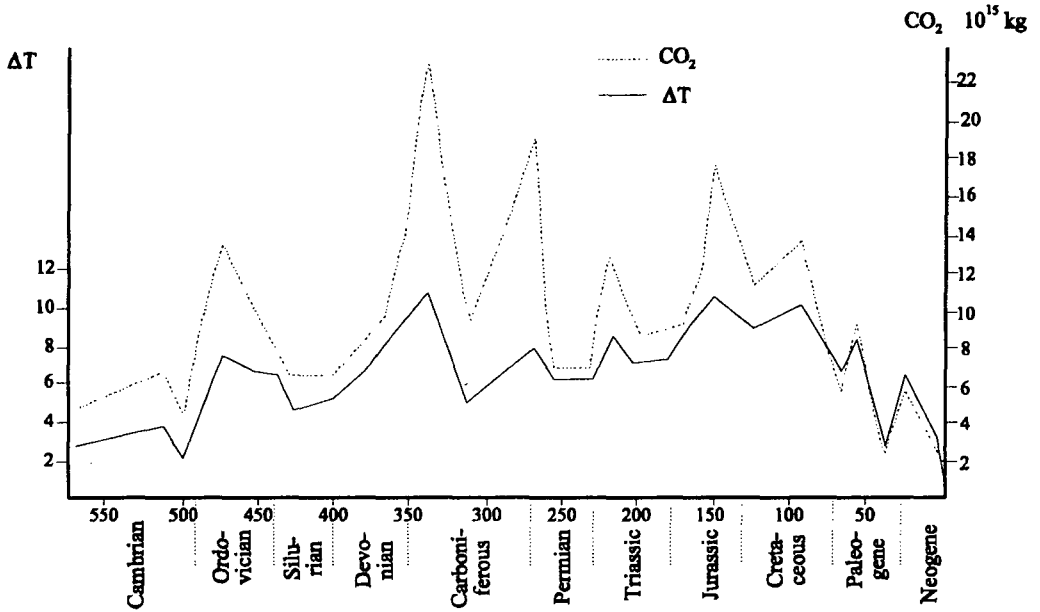


Fig. 3 Changes in mass of atmospheric CO<sub>2</sub> and global surface temperature in the Phanerozoic. ΔT denotes the departure from present value. (Making use of data given by Budyko et al., 1987.)

Of course there may be discrepancies both in calculation method and paleoclimatological assessment, but in the warmest periods of Phanerozoic the temperature data obtained in different ways are close to each other.

Similar comparisons can be made for cooler periods in Phanerozoic (Tab. 3):

	Calculation	Assessment
Cambrian, lower	3.7 K	3.0 K
Silurian	1.84 K	2.0 K
Oligocene	4.6 K	4.5 K

Tab. 3 Explanation see in text

### VARIATIONS OF ATMOSPHERIC CO<sub>2</sub> IN RECENT YEARS

The amount of atmospheric CO<sub>2</sub> has been rising since the beginning of industrialization, i.e. since the end of 19th century from 280 ppmv to 360 ppmv. It is unlikely that an increase of CO<sub>2</sub> by 28 % within about 100 years occurred any time in Phanerozoic. The human activity, namely the growth in motorization, industrialization, consumption of fossil fuels and depleting forest must be responsible for rapid changes in atmosphere.

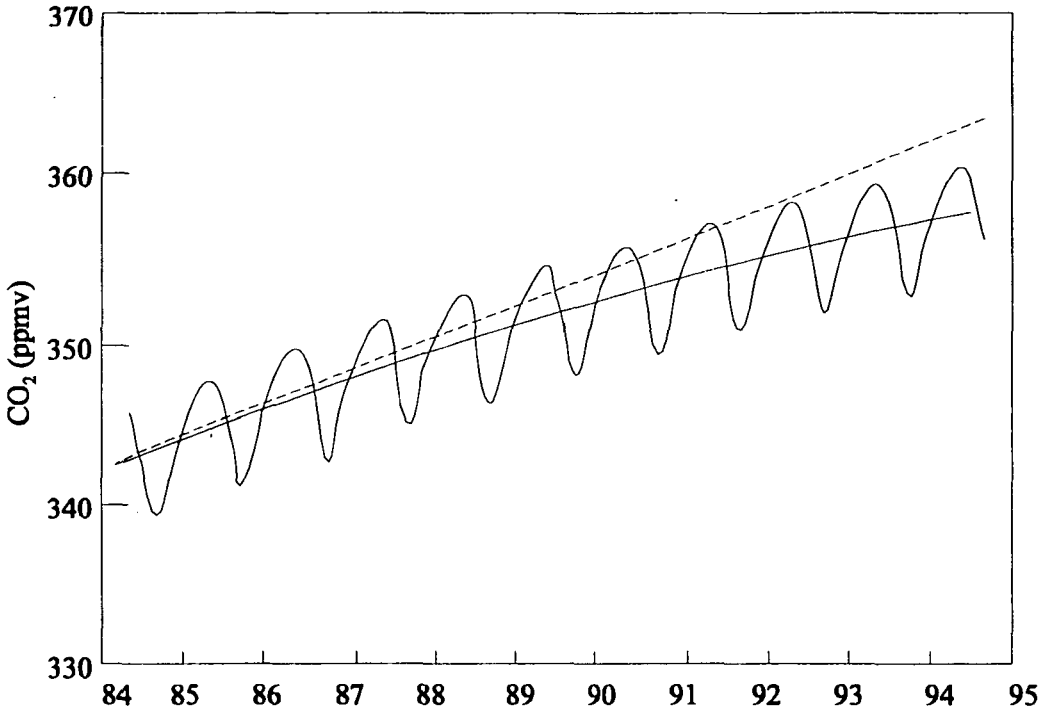
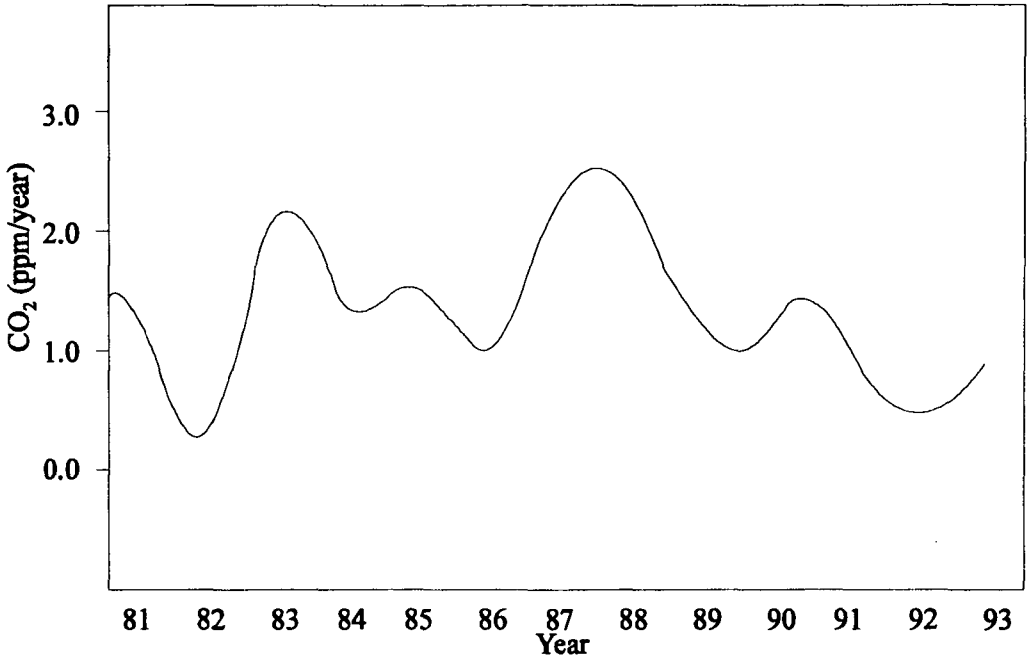


Fig. 4 Observations of CO<sub>2</sub> at the Izaña observatory. Trends: extrapolated with invariable rate (plotted), and actual (solid) (after *European Climate Support Network*, 1995)

What will happen to the climate if this change continues invariantly in the coming centuries? It was mentioned above in a previous chapter that the CO<sub>2</sub> cycle can not maintain stable equilibrium in atmospheric CO<sub>2</sub> (Fig. 2). This statement is supported by the fact that the rate of increase in atmospheric CO<sub>2</sub> has become slower in the recent decade, 1985-94 (Fig. 4), as it has been pointed out by *European Climate Support Network* (1995). The variable growth



*Fig. 5 A slow down in the growth rate of carbon dioxide levels in period 1981-93 (after The Global Climate System Review, 1995)*

rate of atmospheric CO<sub>2</sub> is illustrated in *Fig. 5* published in *The Global Climate System Review* by WMO (1995). Consequently, the future of our atmosphere and global climate is rather doubtful in light of complicated interactions of a great number of factors which are active in earth-atmosphere system including the biosphere and human behaviour.

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**SOME BIOCLIMATIC INDICATORS OF KOLOZSVÁR (CLUJ-NAPOCA),  
ROMANIA**

R. GÉCZI<sup>1</sup>, G. DORMÁNY<sup>1</sup> and J. UNGER<sup>2</sup>

<sup>1</sup>*Department of Physical Geography, József Attila University, P.O.Box 653, 6701 Szeged,  
Hungary*

<sup>2</sup>*Department of Climatology, József Attila University, P.O.Box 653, 6701 Szeged, Hungary*

**Összefoglalás** - Cikkünkben a Kolozsvár (Cluj-Napoca) hivatalos állomásáról és másik három jellemző pontjáról rendelkezésre álló egy évszázados, illetve rövidebb kolozsvári éghajlati adatsorokat felhasználva, különböző bioklimatikus mérőszámok - a pulmonáris, a termális komfort és a termohigrometrikus indexek - értékelésére vállalkozunk.

**Summary** - This paper investigates some bioclimatical indicators (pulmonary, thermal comfort and thermohygro-metrical indices) given by a hundred-year and shorter climatological data series which are measured at the official station and another three characteristic parts of Kolozsvár (Cluj-Napoca).

**Keywords:** bioclimatical indicators, urban climate, spatial differences, annual and diurnal courses

INTRODUCTION

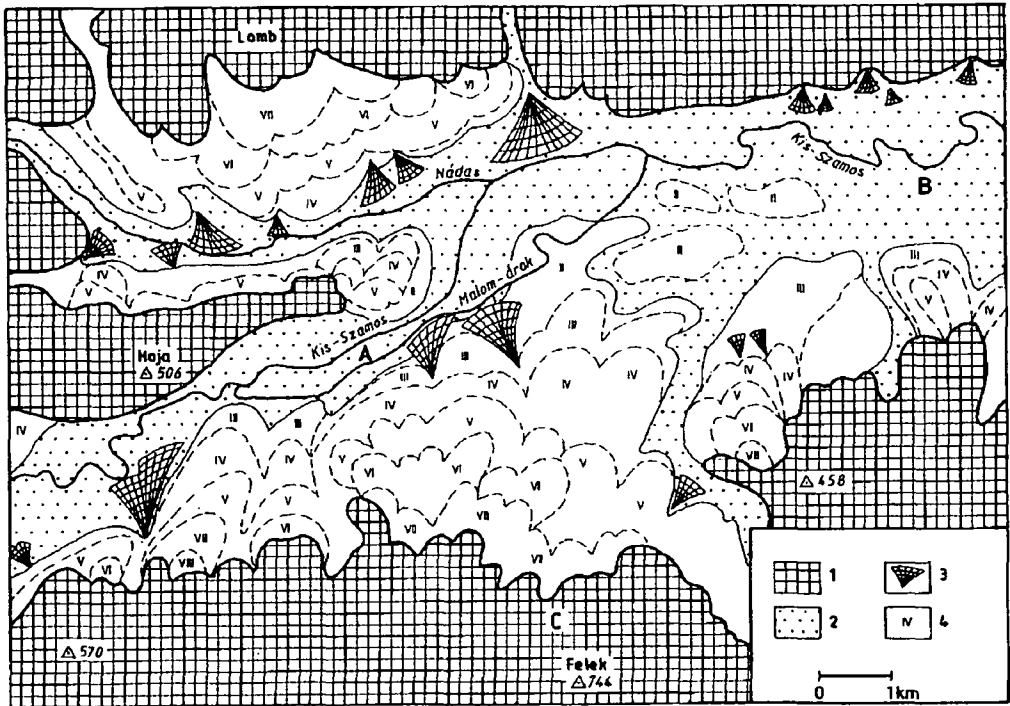
Our environment is a very dynamical system, its components are in close relation. These components can be classified in three groups as natural, social and artificial ones. The base is built up by the natural environment whereupon the other two components are lying. Considering this problem the urban climate is the most relevant example. The urban areas are characterized by a transformed climate, which is being formed under the influence of built-up territories, effect of specific upwarming and emission of pollutants.

The question is how this artificial modification of the natural environment influences the bioclimatological comfort sensation of human individuals. What are the advantageous and the disadvantageous effects of the modified climate on the population living in urban areas and how long do these effects take in the different parts of the built-up areas?

## THE INVESTIGATED AREA AND DATA

Kolozsvár (Cluj-Napoca) is situated in the middle north-west part of Romania, in the valley of the Kis-Szamos River (Someşul Mic), between 300 and 700 m above the sea level (46°47'N, 23°35'E). From geographical point of view the city is situated at the junction of three topographically different areas: the mountains of Erdélyi-Szigethegység (Apuseni Mountains), the hillocks of Erdélyi-Mezőség (Câmpia Transilvaniei) and the hills of Szamos Plain (Podişul Someşan). The city's territory reaches 4068 ha and its population is 340000 in 1996. The surface of the city extends on three height levels, which are as follows:

- the tide land of Kis-Szamos River (Someşul Mic) and its affluent Nádas Rivulet,
- the neighbouring hills (Felek, Lomb and Hoja),
- the river terraces (*Fig. 1*).



*Fig. 1* Geomorphological map of Kolozsvár (Cluj-Napoca) and its surroundings: 1. hills, 2. tide land, 3. alluvial cones, 4. river terraces (I-VIII - number of terraces) as well as the meteorological station network: A. Centre, B. Airport, C. Felek Hill (*modified after Belozero, 1972*)

The climatological parameters which determine the comfort sensation of the human body are temperature, humidity, air movement and radiation. In an investigated region the following measures could be accepted as simple bioclimatical indicators, for example:

- variations of average daily temperature,
- the numbers of summer, winter, heat days and the number of days with frost,
- the daily variation of relative humidity,
- the insolation.

However, the above enumerated indicators are not relevant enough, in the present study an attempt is made to analyse the joint effects of the climatological elements using complex bioclimatical indices like the pulmonary stress index, thermal comfort index and the thermohygro-metrical index in the city centre and surroundings of Kolozsvár (Cluj-Napoca).

We are using averages of data series concerning the main climatological parameters being at disposal like vapour pressure, relative humidity and temperature. These parameters were measured at the official station of Kolozsvár (Kolozsvár Station), which changed its place during the time. Nowadays it has been on the Fellegvár (Cetățuia) Hill near the city centre. Despite the moving of the observation site the series are homogeneous between 1880 and 1992. There is a gap between 1972 and 1982, thus the available data series are 102 years long. A part of our data was received from the microclimatological examinations made by *Belozarov* (1972) in the 1960's and 1970's. We have to emphasize that our results are preliminary ones because we did not take into consideration the urban development of the city during the last more than hundred years. This type of investigation will be the next aim of the following study.

Concerning the sites of the other three stations, which are lying in the represented areas of Kolozsvár as follows (*Fig. 1*):

- the first station (A) was placed on a square in the city centre, which is a very densely built-up area at 346 m a. s. l.;
- the second one (B) was situated 7 km to the east of the town centre at the airport at 334 m a. s. l.;
- the third station (C) was set up on the north part of Felek Hill, sheltered against the major air circulation, 7 km to the south from the centre at 702 m a. s. l. It is situated in an orchard area between the city and Felek village.

## METHODS, RESULTS AND DISCUSSION

Among the important bioclimatical indicators there is the *pulmonary stress index*, which represents the real quantity of moisture getting in touch with the pulmonary mucous of the human body. Normal water vapour content of blood plasma is 31.3 hPa. In reality normal

lung function produces evaporation to a vapour pressure of 19.7 to 23.8 hPa so that the true balance situation occurs at a vapour pressure of 7.5 to 11.6 hPa. For values above or below this it was deduced that the greater is the difference, the greater is the stress placed on the pulmonary interface. The pulmonary stress index values can be ranged in 7 class types between +2 (0 - 4 hPa) and -4 (26.6 - 31.2 hPa) (Beşancenot, 1974). The first value indicates the *dehydrating* state, the second one the *hydrating* state. The index gives the limit value for the normal function of the lung. Between the hydrating and dehydrating values, the *balanced* state (index 0) corresponds to the values of water vapour pressure from 7.5 hPa to 11.6 hPa. The value of 7.5 hPa represents the limit of tendency to dehydration or blood condensation. Otherwise the value of 11.6 hPa represents the limit of tendency to hydration or dilution of the plasma.

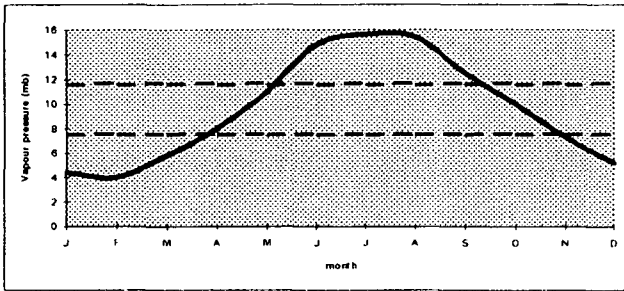


Fig. 2 The annual variation of the pulmonary stress index in Kolozsvár (Cluj-Napoca) (1880-1971) (dotted lines are the thresholds for normal function of lung)

*dehydrating* (+1) index values with a minimum of 4.0 hPa in January. Three months are *balanced* (April, May and October) and the rest of the year, the summer months belong to the *hydrating* (-1) stage with a maximum of 15.6 hPa in July. The monthly means increase steeply from the beginning of the year till July and then decrease till December. So only the three less extreme pulmonary stress index class type occur in this town (-1, 0 and +1). The annual average index is *balanced* with a value of 9.6 hPa.

The second complex bioclimatical indicator applied in this study is the so called *thermal comfort index*, which is based on an approach of the effective temperature according to the *Missenard formula*:

$$ET = t - 0.4(t - 10) \left( \frac{1 - f}{100} \right)$$

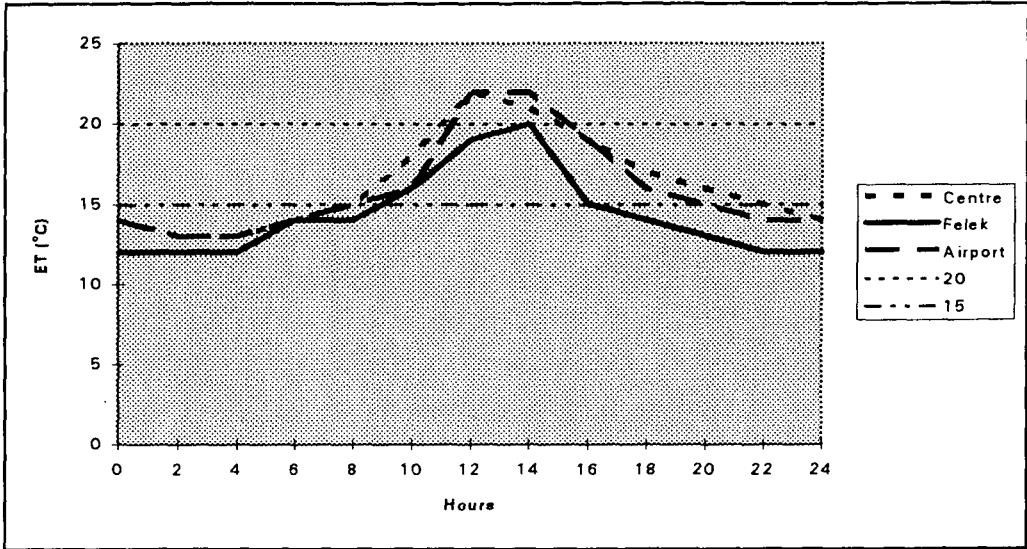


Fig. 3 Diurnal variation of thermal comfort index given by Missenard formula in the centre, at the airport and on the Felek Hill in Kolozsvár (Cluj-Napoca) (summer 1964) (the lines are the thresholds for the adequate thermal comfort)

This is a relation given by temperature in °C ( $t$ ) and relative humidity in % ( $f$ ), and  $ET$  represents the temperature effectively felt by the human body under different climatic conditions (Missenard, 1947). The adequate temperature for the human body varies between 15° and 20°  $ET$  for a sedentary standard man with light clothes. In this case the organism neither gains nor loses energy. If the temperature increases above the upper threshold or decreases under the lower one it would produce metabolic changes in order to maintain the body's internal temperature constant.

Substituting the two-hourly means of temperature and relative humidity and comparing the numbers of thermal comfort hours at the three stations in the summer months of 1964, we can find 12 hours at the centre, 8 hours on the Felek Hill and 10 hours at the airport which belong to the narrow interval of thermal comfort. The daily variation of this index is changing from one station to other (Fig. 3).

The average index values of the airport stations (B) in the representative months of the three warm seasons (April, July and October) in the periods 1964-1971 and 1983-1988 show that 6 thermal comfort hours can be found in the afternoon and 4 in the morning in the hottest month of the year, in July. Very pleasant afternoons can be exhibited in April with 6 comfort hours but this comfort period occurs four hours earlier than in July (Fig. 4). In

October there are only 4 hours which belong to the comfort type and they occur also in the afternoons. There are not comfortable hours mornings in the transition seasons.

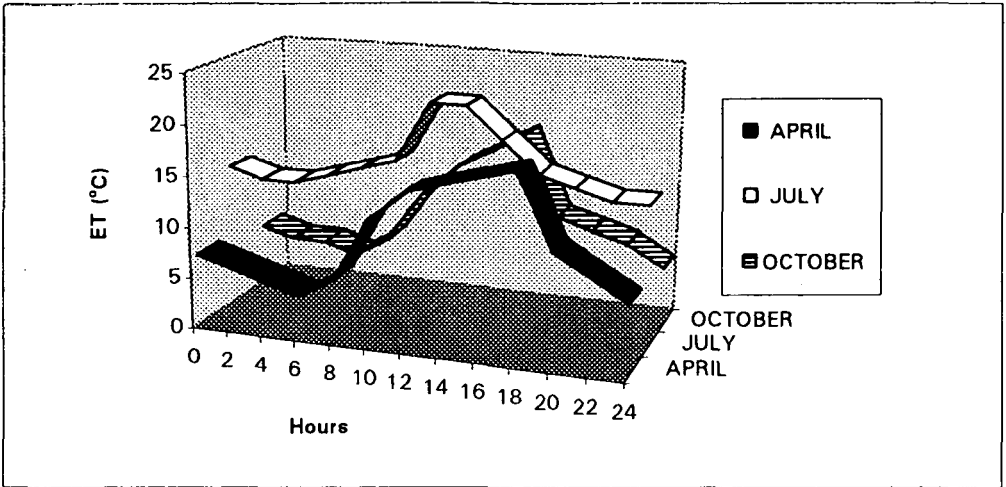


Fig. 4 Diurnal variation of the thermal comfort index in April, July and October at the airport station (B) in Kolozsvár (Cluj-Napoca) (1964-1971, 1983-1988)

Another bioclimatical indicator which was applied in our investigation, and also estimates the effective temperature is the *thermohygro-metrical index*. It is writing according to the *Thom's* empirical formula:

$$THI = t - (0.55 - 0.0055f)(t - 58).$$

where  $t$  is the air temperature in °C,  $f$  is the relative humidity in % and  $THI$  is given in °C (Unger, 1995). The optimal values of  $THI$  are between 15° and 20°. The  $THI$  was used originally to determine the discomfort due to heat stress, therefore *Beçancenot* (1978) evaluated it over a much wider range of conditions with 10 class types from *hyperglacial* (below -40°) to *torrid* (above +30°).

Using the monthly means of temperature and relative humidity of the Kolozsvár Station in the periods 1880-1971 and 1983-1988 the monthly average index values show that only the values in April and October belong to the narrow *comfort* type. The winter months belong to the *cold* interval between -1.7° and 12.9°, and the summer months to the *hot* class type (20° - 26.4°). Just in July the average  $THI$  value emerges into the *very hot* interval between 26.6° and 29.9° (Table 1).

Some bioclimatic indicators of Kolozsvár (Cluj-Napoca), Romania

	J	F	M	A	M	J	J	A	S	O	N	D
THI (°C)	0.6	3.7	11.6	18.5	22.7	24.6	26.7	25.4	21.4	15.3	8.5	2.2

Table 1 The annual variation of the thermohygrometrical index in Kolozsvár (Cluj-Napoca) (1880-1971, 1983-1988)

Considering the daily variations of the *THI* values of the three stations in a hot summer month, in July 1964, the following general features emerge (Fig. 5):

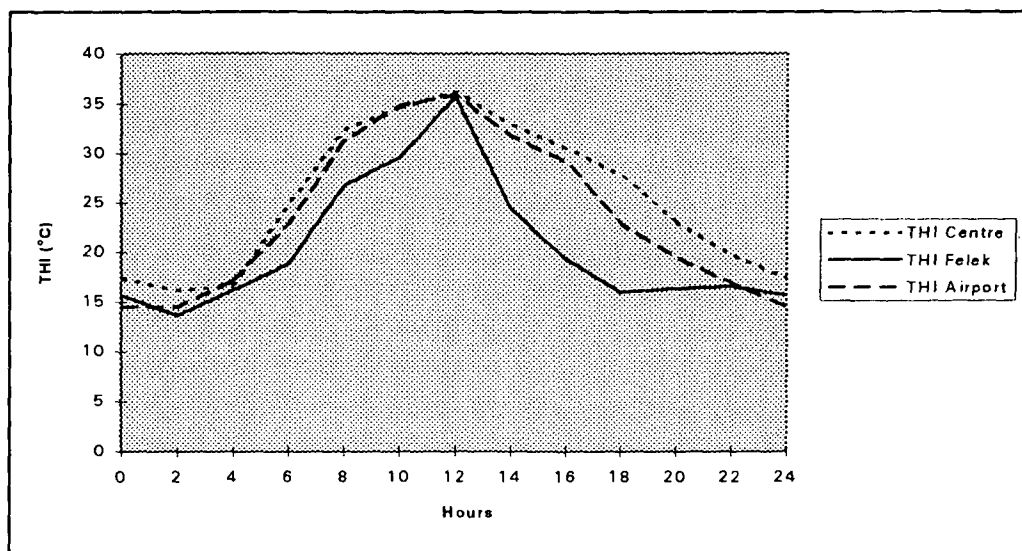


Fig. 5 The daily variation of the thermohygrometric index in the centre, at the airport and on the Felek Hill in Kolozsvár (Cluj-Napoca) in July 1964

- In the centre the most pleasant period occurs at night, between midnight and 6 AM (6 hours). During the day the *THI* values reach the *hot* and the *very hot* type and even the *torrid* one between 10 AM and 6 PM (max. 36.2°)
- Outside the centre on the Felek Hill the adequate period starts already at 6 PM and lasts till 8 AM. It takes 12 hours because the *THI* value sinks under 15° at 4 AM ( 13.6° - *cool* type). In the daytime there is a steep increase and a steep decrease and the highest value occurs at 2 PM (35.7° - *torrid* type).
- At the airport station the situation is similar to the one in the centre but the *comfortable* period is a little bit postponed (from 10 PM till 6 AM).

## CONCLUSIONS

According to the annual courses of the pulmonary stress index values, the vapour pressure conditions in Kolozsvár (Cluj-Napoca) do not cause a very loading situation, but the period which really advantageous lasts only three months and the rest of the year can be featured as slightly hydrating or slightly dehydrating ones. Only two months are comfortable by the annual courses of thermohygommetrical index, the rests are colder or warmer, which means a very disadvantageous effect during this long period.

The diurnal courses of bioclimatical indices shows spatial differences of the inside and outside urban climates. In the centre, an artificial innercity climate prevails in opposition with the one in the surrounding area. On the north part of Felek Hill the bioclimatic indices indicate a climate with north exposure slope characters. This is the most likely territory of the area which is featured by stimulating bioclimate: the temperature are quite moderate with the longest thermal comfort period during the summertime. The situations in the centre and at the airport are very similar. It can be explained with the huge amount of concrete at the airport, which thus has similar thermal properties as the densely built-up city centre.

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## LIGHT TRAPPING OF HARMFUL INSECTS IN PÉCZELY'S MACROSYNOPTIC WEATHER SITUATIONS

Cs. KÁROSSY<sup>1</sup>, L. NOWINSZKY<sup>2</sup>, J. PUSKÁS<sup>1</sup> and L. MAKRA<sup>3</sup>

<sup>1</sup> Department of Geography, Berzsényi Dániel Teachers' Training College, P.O. Box 170, 9701 Szombathely, Hungary

<sup>2</sup> Department of Technology, Berzsényi Dániel Teachers' Training College, P.O. Box 170, 9701 Szombathely, Hungary

<sup>3</sup> Department of Climatology, József Attila University, P.O. Box 653, 6701 Szeged, Hungary

**Összefoglalás** - Vizsgálatainkhoz az országos fénycsapda hálózat anyagából a Budapest környékén üzemelő 6 fénycsapda adataiból a felkiáltójeles bagolylepke (*Scotia exclamationis* L.) gyűjtési eredményeit dolgoztuk fel az ugyanerre a térségre megállapított Péczely-féle makroszinoptikus időjárási helyzetekkel összefüggésben. A fogási eredményeket a helyzetek változásával összefüggésben is vizsgáltuk. Először valamennyi változás hatását megvizsgáltuk, így azonban a viszonylag kevés megfigyelési adat miatt csak néhány esetben kaptunk szignifikáns eredményt. A továbbiakban ezért a 13 helyzetet a rájuk jellemző áramlási rendszerek alapján 6 típusba vontuk össze.

**Summary** - We used the collecting results of the heart-and-dart moth (*Scotia exclamationis* L.) for our examination. We got the data of 6 light-traps from the national light-trap network operating in the surrounding of Budapest. We examined this data connected with the Péczely's type macrosynoptic weather situations determined for the same territory. We also examined the catching results connected with the changes of macrosynoptic weather situations. First we examined the effects of all changes but we got significant results only sometimes, because of the relatively small number of observing data. That is why we later made 6 types from the 13 situations on the basis of their typical streaming system.

**Key-words:** insects, light trapping, Péczely's macrosynoptic situations

### INTRODUCTION

Insect flight activity - and similarly, the effectiveness of their light-trap collection - are considerably modified by weather, together with a number of abiotic factors. So, it is understandable why researchers all over the world are engaged in revealing the effects of weather elements. In Hungary, for more than 3 decades a uniform, Jermy-type light-trap network has been in operation, which so far has already provided an unvaluable mass of information both for entomological basic research and plant protection prognostication. Unfortunately, a decisive majority of the catch results provided by the light-trap network can't

be examined in connection with the particular weather elements as most observation sights are situated far from meteorological stations, and those operating the traps did not take any meteorological measurements. Therefore, we revealed the connection between weather and effectiveness of collecting with a light-trap by using a different method. For the purposes of our investigations we found those *Péczely's* macrosynoptic weather situations suitable which express complex weather conditions simultaneously existing and pertaining to the whole area of the Carpathian Basin. The macrosynoptic typifying which can be considered as pertaining to the area of the Carpathian Basin was elaborated by *Péczely* (1957, 1983). The daily macrosynoptic weather situations which were determined on the basis of the baric field at ground level were classified into 13 types by him. Since 1983, typifying has been continued, and the daily code numbers are published by *Károssy* (1987, 1994).

The data interpretation period for each type is 24 hours belonging to a calendar day. The one and single criterion for coding is the definition of the type which pertains for a longer period of time during a day, so the type-shift may as well differ  $\pm 12$  hours from the time of the change of the calendar date. The progression of the changes in time as well as the tendency of particular types to endure and the empiric frequency of the occurrence of situations replacing each other differ significantly.

Following *Péczely's* work (1957, 1983) in the field of typifying macrosynoptic weather situations, his collaborators elaborated on the particular weather situations with regard to some weather elements and included a detailed data-base. In the following, with the continuity of the typifying ensured, the examinations of the element-sets relating to the macrosynoptic situations were also performed.

In the last few years the examination of the connection between the flying activity of harmful insects and the various macrosynoptic weather situations has become an important and determining trend in the above mentioned research. During this research we examined the effectiveness of trapping in connection with the macrosynoptic weather situations pertaining to the trapping time of harmful insects flying at dawn or in the first part of the night. We extended our investigations to the cockchafer (*Melolontha melolontha* L.) which swarms in spring, to the winter moth (*Operophtera brumata* L.) which flies late in autumn, and to two species of moths which are although insignificant from an economical point of view, are easy to trap in autumn, winter and spring, too, the common chesnut (*Conistra vaccinii* L.) and the satellite moth (*Eupsilia transversa* Hfn.) (*Nowinszky and Károssy*, 1986, 1988; *Károssy and Nowinszky*, 1987a; *Károssy et al.*, 1990a; *Nowinszky [ed.]*, 1994).

When investigating species which are active all night, we employed a different method since macrosynoptic situations pertain to one calendar day only; so in those cases when one macrosynoptic type pertained to the date of the evening and another to that of the dawn, we had to examine the formation of the flying activity during the periods when the changes occurred.

In the beginning we analysed the effect of any possible situation-shifts on the flight activity of the turnip moth (*Scotia segetum* Schiff.) and the fall webworm moth (*Hyphantria cunea* Drury), both of which fly in the summer months (Károssy and Nowinszky, 1987b; Nowinszky and Károssy, 1988; Károssy et al., 1990a), although certain changes occurred rarely. This method provided a lot of information; however, it was difficult to survey, and too intricate to use for plant protection prognosis. Therefore, in the following, we applied a simpler and more easily manageable method, which in any case, is just as valuable for prognostication purposes.

We contracted the 13 macrosynoptic situations typified by Péczely on the basis of their characteristic wind patterns into 6 types. The changes of these types form 36 transitional types, so far uncharacterised even from climatological points of view. We examine the effectiveness of light trapping the turnip moth (*Scotia segetum* Schiff.), the fall webworm moth (*Hyphantria cunea* Drury) and the gypsy moth (*Lymantria dispar* L.) in relation to these 36 types (Károssy et al., 1990b; Károssy et al., 1992; Nowinszky [ed.], 1994; Nowinszky et al., 1995).

In our present study we tried to correct our examination with the processing of collecting data coming from this territory and Péczely's macrosynoptic weather types working out for the surroundings of Budapest. We couldn't find such publications neither in Hungarian nor in international special literature to examine the success of light trapping connected with macrosynoptic weather situations except our publications.

## MATERIAL AND METHODS

We used for our examinations the collecting results of the heart-and-dart moth (*Scotia exclamationis* L.) from the collecting data provided by the 6 light-trap stations operating around Budapest. We chose this species because the swarming of heart-and-dart moth (*Scotia exclamationis* L.) is twice a year, and this pest can be caught in great number regularly between May and September. We used the data coming from the collecting stations mentioned below: Budakeszi (1962-1970), Budatétény (1960-1967), Budapest-Rókushegy (1959-1967), Nagytétény (1959-1976), Martonvásár (1960-1961) and Érd (1977-1979). We had 3461 observing data and 7239 specimen coming from 1762 nights. We mean on observing data the catching result at one night at one observing station independently from the number of the caught individuals.

The code numbers and moments of changes of Péczely's macrosynoptic weather situations - valid for surrounding of Budapest - were determined by Imre Örményi Ph. D. biometeorologist. He gave this data for us, we thank for his selfless help. A short characterization of the 13 macrosynoptic weather situations is given in the following:

## **Meridional, northerly oriented situations**

### *mCc (1) Cold front from the meridional situations*

A situation with meridional direction and northern stream. Hungary belongs to the rear cold front current system of the cyclone which stays east or north-east of it over the Balticum or the Ukraine. This situation causes changeable, windy and wet weather in the Carpathian Basin. In summer a version without a cold front may also arise when a termic depression effect from South-West Asia spreads over South-East Europe. In summer, this situation is favourable for forming local showers, thunderstorms, in winter snowstorms. In summer the temperature is above the average, in winter it is below the average, in spring the deviation is not significant. Cloudiness surpasses the average level, visibility is good, in winter the tendency for fog is smaller. Air pollution is usually insignificant. Typically, the northerly and the north-westerly winds are strong while the westerly and south-westerly winds are strong beyond the Tisza river. There is more precipitation in the eastern half of the country. Atmospheric temperature layers are stable, the lower layers are warmer. The daily temperature fluctuation is small and aperiodic.

### *AB (2) Anticyclone over the British Isles*

This is a meridionally directed situation with northerly current. Partly because of the Azori anticyclone moving to the north, partly because of the anticyclones moving from the arctic basins to the south, high-pressure air masses develop over the British Isles or the North Sea. Its appearance in the Carpathian Basin is usually connected to the passing of a cold front, and results in intensive north-, north-westerly air currents in our region. When the above mentioned situation stabilizes in summer, the baric gradient is a lot lower over Central Europe; on such occasions dry, prolonged warm weather evolves in the Carpathian Basin. It is a misty situation in autumn, winter and spring as well. During the greater part of the year it is characterized by colder air masses of arctic origin and average cloudiness with higher degrees of cloudiness in summer. There is a strong tendency for fog in winter. There is a north-westerly, westerly wind; over the Tisza river it is westerly, south-westerly, and relatively strong. The temperature-stratification of the air is stable.

### *CMc (3) Cold front arising from a Mediterranean cyclone*

A situation with meridional direction and northern current. It is the current-system of the back-side of the cyclone. The situation emerges by way of a Mediterranean cyclone moving towards the Balcan peninsula or the region of the Black Sea, so the Carpathian Basin falls in the rear, cold front current system of the cyclone. The movement of air is in a northern, north-west direction. Its speed - mainly in the Transdanubia - may even reach storm intensity. Especially in summer, precipitation may increase, in different amounts at various locations. Snow showers are frequent in winter, storms in spring. Cloudiness is definitely extensive especially in the summer half of the year. Air pollution is low, the tendency for fog is also low

in winter. The temperature is lower in spring and autumn, and higher in winter than on the days preceding this weather situation. The daily fluctuation of the temperature is aperiodic.

### **Meridional situations with a southern direction**

#### *mCw (4) Warm front arising from a meridional cyclone*

This is a situation of meridional direction with flow toward the south; it is the frontal current system of the cyclone. The current over the Carpathian Basin is directed by a cyclone with its centre either in the region of North-Western Europe or in Western Europe. Hungary's territory is under the effect of the cyclone's warm front or falls into its warm sector. In autumn it is cooler, in winter and spring milder than the average temperature of the given season. Cloudiness is more extensive mainly in spring and autumn. Prolonged, slow rains and snowfalls are equally frequent from autumn to spring. Visibility is bad, the frequency of fog is high in winter. In summer it is characterized by sultriness and high degree of air pollution. The southern air current brings considerable precipitation especially in the winter half of the year.

#### *Ae (5) Anticyclone located east of the Carpathian Basin*

A meridional situation with southern current. A dry, southerly or south-westerly air current dominates in an anticyclone located east of Hungary with its center over the Ukraine. The weather fronts range from west of the Carpathian Basin. This situation is characterized by dry, warm, bright weather in summer, and in winter, after snowy days by bitter cold, frequent rime and fog. In autumn and spring, temperature fluctuation is large with a strong rise in temperature. In the cold season the range of the Eastern Carpathians often modifies the direction of the isobars, and in this way the cold, surface level air masses invade the territory of the country passing round the Southern Carpathians (Kossava effect). It is characterized by a temperature surpassing the average prevalent during the greater part of the year. Cloudiness, mainly in summer, is smaller and dry, droughty weather is frequent at this time. In accordance with the weak, southerly current, the amount of precipitation is small, visibility is bad and air pollution is considerable. The air shows inverse temperature stratification.

#### *CMw (6) Warm front arising from a Mediterranean cyclone*

This situation has a meridional direction and southerly current. The cyclone's frontal system of current asserts itself in Hungary. The system is defined by a cyclone which arises over the central part of the Mediterranean Sea and moves toward the Adriatic region. Its warm front passes over the Carpathian Basin causing substantial rains in the winter and spring months as well as snowfalls in winter. In summer its temperature is lower than the national average temperature. Visibility is low, cloudiness is strong and the fluctuation of the temperature is aperiodic.

### **Zonal situations with western direction**

#### *zC (7) Zonal cyclone*

There is a zonal, westerly flow. While it prevails the European stretch of the frontal zone ranges near the 50° latitude. The air flow is westerly. Northern Europe is affected by fast moving cyclones. The weather is windy and changeable. The temperature, characteristically, is cool in autumn, mild in winter, and in summer it is colder than the average for that season. In spring the fluctuation in temperature is low. Cloudiness is strong, especially in the spring and autumn months. The yield of precipitation is larger at the beginning of autumn and in winter. The lower air strata are warmer. Colder, arctic air strata flow in the higher layers.

#### *Aw (8) Anticyclone located west of the Carpathian Basin*

It has zonal current with a western direction. When the Azori anticyclone travels north (mainly in summer), its protrusion advances as far as the Central-European region. Its formation usually takes place in connection with a cold front which passes through and results in an intense westerly or north-westerly current in the Carpathian Basin. It is characterized by pleasant, warm and bright weather which, however, is misty in autumn and spring, and mild, misty and foggy in winter. In winter it is colder than the temperature typical for that season. Its cloudiness is average, yet it is overcast in summer. Visibility is good, air pollution is low. The lower stratum of air is usually warmer than the one over it, in which there is a cold air current.

#### *As (9) Anticyclone located south of the Carpathian Basin*

This situation has a zonal, western current. The northern fringe of the anticyclone situated over the basin of the Mediterranean Sea protrudes into the Carpathian Basin. The northern edge of the frontal zone moves upward, so the cyclone moves along a more northern trajectory, and their frontal system does not affect Hungary. During the greater part of the year this situation-type is warmer than the average and is characterized by a lower degree of cloudiness. In winter, autumn and spring the bright, warm days are followed by mild nights. In winter cloudiness is somewhat stronger, and the frequency of fog is higher. In summer it brings about sultry weather. The air flow is weak, and precipitation is low. The lower stratum of air is colder than the upper, however the opposite may also occur.

### **Zonal situation with eastern direction**

#### *An (10) Anticyclone located north of the Carpathian Basin*

This situation has an eastern, zonal current. The anticyclone stays north of Hungary over the Balticum or Poland, and forms a high-pressure ridge from the British Isles as far as Eastern Europe. In summer it is warmer than the temperature typical for that season. It causes a strong fall in temperature in autumn and in spring, but after the cold night a rise in temperature follows about midday. It is characterized by clean air and northern winds. In winter it is connected with the invasion of very cold air masses. On such occasions it is easy to

observe how the Carpathian ranges modify the movement of ground level cold air masses and their passage through mountain passes. Many times characteristic, embracing izobars develop along the Carpathians, and the cold invasion from either side sometimes may result in an occlusion front inside the Basin. The weather is windy and foggy even in winter with average cloudiness, and a sky which is a bit more overcast in the spring and autumn months. Sometimes air pollution is high. The air-flow is typically of north-eastern direction. The stratification of air characterized by warmer, lower and colder higher strata.

*AF (11) Anticyclone located over the Skandinavian peninsula*

This situation has a zonal eastern air-flow. The characteristic orientation of the longitudinal axis of the anticyclone which stays in the Fenno-Skandinavian region has a north-easterly direction. This weather situation brings about a northern or north-eastern flow in Hungary. During its existence, the weather, especially in autumn, winter and spring is bright and clear, but the air is very cold. It is characterized by northerly winds, wide fluctuation in temperature, average cloudiness, and little precipitation. The Icemen (the three chilly days in May) are usually connected to this macrosynoptic type.

**Central anticyclone**

*A (12) Anticyclone located over the Carpathian Basin*

The whole region of Central Europe is dominated by a centrally situated anticyclone which rises above the Carpathian Basin. It can be of smaller size, even just a few hundred kilometres in diameter, but it can also be a so called intermediate anticyclone, which moves fast separating other cyclone systems. In most cases, however, it remains for a longer period over the Carpathian Basin. Its duration gets prolonged in winter by a cold air-cushion stuck on the bottom of the Basin (inversion). Its prolonged existence ensures undisturbed radiant weather. In winter it is accompanied by a strong fall in the temperature, and considerable inversions of temperature, and in summer by a great rise in temperature, heat waves and thunderstorms. One frequent feature is an air-flow in diverse directions which originates from the centre. During the greater part of the year it can be characterized by a temperature of radiation effect - i. e. warm during the day and in summer, cold during the night and in winter. The weather is warm and pleasant either in spring or in autumn, while it is foggy, frosty and rimy in winter. Temperature fluctuation is great. Cloudiness is slight. It is a bit more overcast in winter, and brighter in summer. Precipitation is small, showing large regional variability. Visibility is bad. There is a high frequency of fog, and air pollution may be strong. The air is usually dry. The wind has no uniform or characteristic direction.

## **Central cyclone**

### *C (13) Cyclone located above the Carpathian Basin*

The centre of the cyclone is located over the Carpathian Basin. In the great majority of cases, Mediterranean cyclones, which pass over Hungary, are from this type. There may, however, be cases when a cyclone develops having local, orographic causes along a front that has grown stagnant. A sharp contrast in temperature evolves in Hungary. The north-western parts of the country fall in the rear flow system of the cyclone, so the temperature is much lower there than in the eastern part of the country, which fall into the frontal flow system. In the western, north-western and south-western regions of the country, because of what was said above, the frequency of fronts is higher than in the rest of the country. When this type is present, in winter the temperature is higher, in summer it is lower than during the preceding days. In autumn this type is characterized by cold, windy, overcast and rainy weather, and in winter by stormy weather. In spring it is characterized by rainy weather. In all three seasons temperature fluctuation is small. Cloudiness is greater in summer, smaller in winter. Visibility is bad, and air pollution is low. A strong field of flow is characteristic, although its direction is not homogeneous. Precipitation is markedly large.

In the previous chapter we have already stated that the number of the individuals trapped at different observation sites and times can't be compared to each other even in the case of identical species, as each trap works in different environment, and the environmental factors constantly vary according to time as well. To solve the problem, from the catch data we calculated relative catch (RC) values for observation sites, species and generations. RC is the quotient of the number of individuals caught during the sampling interval (1 night or 1 hour), and the mean values of the number of individuals of one generation counted for the sample interval. In this way, in the case of expected mean number of individuals, the value of relative catch is 1.

In the course of processing we made a comparison between the values of relative catches and *Péczely's* code number, if the same macrosynoptic weather situation was during whole night. After it, we made catches in all the 13 macrosynoptic weather situations. We controlled the difference of catches in each weather situation type with variance analysis, and we calculated also significance level compared to the expectable values of relative catches. We also had an examination to make a comparison between the catching results and the changes of macrosynoptic weather situations. First the effects of all changes were examined, but we got significant results in few cases, because of the relatively small number of observing data. That is why we contracted the 13 *Péczely's* macrosynoptic groups into 6 types on the basis of their characteristic flow systems:

Meridional types with northern direction: mCc (1), AB (2) and CMc (3),  
Meridional types with southern direction: mCw (4), Ae (5) and CMw (6),  
Zonal types with western direction: zC (7), Aw (8) and As (9),

Zonal types with eastern direction: An (10) and AF (11),  
 Central anticyclone: A (12),  
 Central cyclone: C (13).

The changes of these types form 36 transitional types which have not been satisfactorily characterized even from a climatic point of view.

When one of the *Péczeley* type macrosynoptic situations changed during the night, we averaged the values of relative catches into 36 transitional types. We determined the significance level of changes in these cases also in the above-mentioned way.

## RESULTS

Our results are shown in *Table 1, 2 and 3.*

<i>Péczeley's</i> types	<i>Péczeley's</i> codes	Number of observing data	Relative catches	Significance level %
mCc	(1)	337	0.795	99.0 %
AB	(2)	122	0.761	95.0 %
CMc	(3)	76	0.792	90.0 %
mCw	(4)	179	1.245	99.0 %
Ae	(5)	220	1.070	
CMw	(6)	72	1.437	95.0 %
zC	(7)	44	0.598	95.0 %
Aw	(8)	404	0.895	90.0 %
As	(9)	104	0.671	95.0 %
An	(10)	269	1.381	99.9 %
AF	(11)	112	0.957	
A	(12)	89	1.246	95.0 %
C	(13)	416	1.060	

*Table 1* Relative catch of heart-and-dart moth (*Scotia exclamantis* L.) from the material of light-trap stations in the surrounding of Budapest, in the whole night unchanged *Péczeley's* macrosynoptic weather situations determined for this territory *Péczeley's* types

Former situations	Following situations	Relative catches	Number of observed data	Significance level %
mCc (1)	Aw (8)	0.588	71	99 %
CMw (6)	C (13)	1.525	34	99 %
Aw (8)	As (9)	1.454	24	95 %
Aw (8)	A (12)	1.761	37	99 %
As (9)	Aw (8)	1.754	24	95 %
An (10)	C (13)	1.616	13	95 %
C (13)	mCc (1)	0.640	62	99 %
C (13)	CMc (3)	0.469	19	95 %
C (13)	Ac (5)	0.491	22	95 %
C (13)	Aw (8)	0.435	41	99 %

Table 2 Relative catch of heart-and-dart moth (*Scotia exclamatoris* L.) from the material of light-trap stations in the surrounding of Budapest, in the *Péczezy's* macrosynoptic weather situations changing during the night

Former and following situations	Meridional northern	Meridional southern	Zonal western	Zonal eastern	Central anticyclone	Central cyclone
<b>Meridional northern</b>	<b>0.665</b> (30)	<b>1.441</b> (21)	<b>0.603</b> (101)	<b>1.290</b> (52)	<b>0.594</b> (20)	<i>0.855</i> (21)
<b>Meridional southern</b>	0.920 (42)	<i>0.842</i> (52)	<b>1.202</b> (43)	1.802 (42)	0.998 (16)	<b>1.183</b> (101)
<b>Zonal western</b>	1.027 (29)	1.075 (56)	<b>1.364</b> (84)	1.111 (62)	<b>1.668</b> (42)	<b>0.585</b> (22)
<b>Zonal eastern</b>	0.910 (4)	0.960 (65)	0.991 (25)	<b>1.212</b> (17)	<b>1.237</b> (13)	<b>1.720</b> (19)
<b>Central anticyclone</b>	0.564 (5)	<i>1.136</i> (27)	0.869 (15)	0.514 (8)	-	<b>1.050</b> (13)
<b>Central cyclone</b>	<b>0.617</b> (93)	<b>0.577</b> (38)	<b>0.673</b> (56)	1.032 (33)	1.088 (10)	-

Table 3 Relative catch of heart-and-dart moth (*Scotia exclamatoris* L.) from the material of light-trap stations in the surrounding of Budapest, in the *Péczezy's* macrosynoptic weather situations contracted according to the direction of streaming

Notes: If the difference are in relative catches 0.165 and 0.125, significance levels are 99 % or 95 % in contracted situations. We used bold numbers if difference of relative catch is significant at 99 % level, and italic ones, if the level is 95 %.

## CONCLUSIONS

The meridional northern directed situations are the most unfavourable ones from the point of view of collecting among unchanged macrosynoptic situations during the whole night, but the meridional southern and zonal western directed ones are favourable. The An (10) and A (12) are the only favourable from anticyclonic situations, but neither Ae (5) and AF (11) situations nor central cyclon (13) has significant influence on catching. It is interesting, if we examine without contractions the changing situations during the night and the difference of catchings are significant, the catching is favourable in all cases if C (13) changes for anything else, the collecting is unfavourable. Similar phenomena can also be found connected with Aw (8) situation, but here is favourable, if this situation changes. If we make a contraction according to the air current direction among the changing situations during the night, because of the relatively small number of observing data, we got the same above mentioned results for the most part. Those effects of changes are favourable from the point of view of catching success as was exoected, where the air current direction changes are significant (from meridional northern situations to zonal eastern ones and from zonal western situations to zonal eastern ones). We got the same results connected with other species in our earlier examinations (Károssy *et al.*, 1992; Nowinszky [ed.], 1994), but of course the difference of catching results belonging to each types were smaller, because at that time we used types valid for the whole country.

Our method offers a possibility of investigating the insect's life-phenomena in connection with weather also in those cases where the measuring of certain elements for some reasons come up against difficulties. The collecting data of the national light-trap network, which is invaluable for science, has also become employable to insect ecological and etological investigations. On the basis of our work it is also proved that *Péczely's* macrosynoptic situations are reliable not only from the points of view of climatological typization, but also with regard to agrometeorological research. We think it essential to elaborate a similar typization for other geographical regions and other harmful species of insects as well.

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## SOME WEATHER EVENTS FROM THE 14TH CENTURY

A. KISS

*Department of Climatology, József Attila University,  
P.O.Box. 653, 6701 Szeged, Hungary*

**Összefoglalás** - A dolgozat célja annak bemutatása, hogy milyen típusú, időjárási eseményekre utaló 14. századi források találhatóak Magyarországon. Mivel az egykorú hazai krónikák és évkönyvek szinte teljesen hiányoznak, ezért a korabeli oklevelekben található információk szolgáltathatnak adatokat.

**Summary** - This paper discusses the different kinds of allusions to weather events which can be found in various 14th century written sources in Hungary: e.g. data referring to the floods of different rivers, water levels, precipitation etc. In lack of narrative sources (annals, chronicles etc.) Hungarian references to other events are restricted to different charters. Until recently in Hungary no comprehensive attempts have been made to collect and analyse such data from the 14th century charters, yet.

**Key words:** climate history, compillations, weather sources, charters, 14th century, floods of rivers, Hungarian Kingdom

### INTRODUCTION

In great part of Europe there are a lot of reliable narrative sources which make it possible to produce continuous climatic data-bases concerning to the Middle Ages (especially for the Late Middle Ages).

In contrast to this, in Hungary there is a very small number of narrative sources which have any reference to meteorological events. Most of the climatic information from the 14th century appear in the contemporaneous charters, which do not contain long-term data (for a month or the whole year) as the documents produced in the western part of Europe.

### LATER COMPILLATIONS

In Europe several historical climatic compillations were published as early as in the 18th century. Some of them are not reliable because of misdating and other mistakes.

The most important Hungarian collection is: *A. Réthly: "Weather events and natural disasters in Hungary"* published in two volumes (1966). The first volume contains data from the Middle Ages.

Based on the comparison and analysis of sources from the entire 14th century it can be concluded that the reliability of the records used by *Réthly* (works of German authors, mainly Hennig, Weikinn, and Hungarians) is rather doubtful (*Lamb, 1982; Rácz, 1989*). Because the works of references are not indicated in most cases (e. g. the information published in *Vasárnapi Újság*) it is difficult to verify the data. A typical example of this problem is the invasion of locusts, which devastated the country and great parts of Europe in 1338. *Réthly* - using the reference books - dated this invasion of locusts not only for 1338, but also for the years of 1336, 1337, 1340-1341, 1340-1342.

The original Hungarian, Bohemian, Bavarian and Austrian sources prove the fact that the data - except for the year of 1338 - are incorrect and in this period there was only one invasion in the Carpathian Basin (*Mályusz, 1966*). For this reason the reference works of *Réthly's* compilation for the 14th century need a comprehensive textual analysis before application.

#### METEOROLOGICAL DATA IN THE CONTEMPORANEOUS CHARTERS FOR THE PERIOD OF 1338-1358

The 1310s and the 1340s were the most unfavourable years of the century. There is a small number of documents from the turbulent years of the 1310s, but from the 1340s and 1350s more documents have survived. (It is possible to point out what sort of information can be found in these charters.)

From about 9000 records of this period I could investigate 4000 which have been published in repertoires. I have also examined the summaries (*regesta*) of the charters kept in the Hungarian National Archive and the citations of the *Lexicon Latinitatis Medii Aevi Hungariae*. Among the documents of the 21 years' interval 16 charters have been found which contain data for meteorological events (*Table 1*).

The examined documents from approximately 4000 the half of the charters that are accessible, so the chartered data-base is incomplete and needs further elaboration.

The charter-based research is complicated on the one hand by the unlucky situation that until recently in the summaries of charters information that could be useful from the aspect of climate-history has been ignored and therefore omitted, and on the other hand that a considerable number of documents from the Late Middle Ages have not been published. Following from this we must use the original documents or their later transcriptions, which significantly delays research.

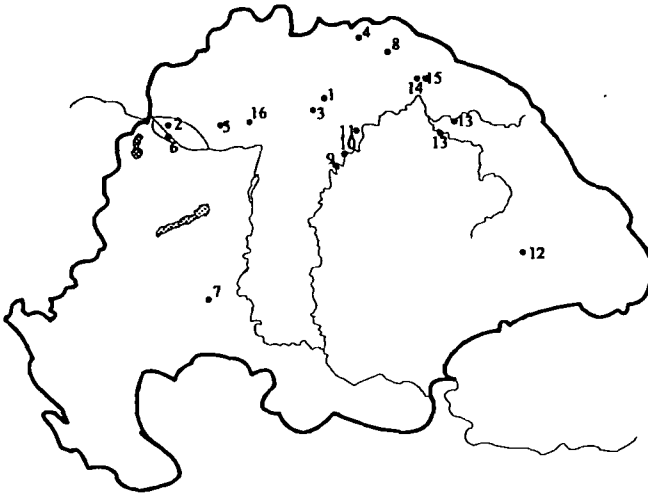
*Some weather events from the 14th century*

number of charters	county	place	year	month, day	event	floods of rivers
1.	Gömör	Csoltó, Leklene	1339	31 August	flood	Halbokapataka (Sajó)
2.	Pozsony	Páka	1340	25 July	very wet field	near the Danube
3.	Gömör	Harmacz	1341	8 November	flood	tributary of Rima
4.	Sáros	Tarkó, Lucska, Haruncsár	1342	between 21 July and 16 August	severe frost, cold weather	-
5.	Bars	Besenyő	1342	25 April	flood	Zsitva
6.	Pozsony	Zámoly	1342	1 July or winter (?)	hard times, deep snow	-
7.	Baranya	Vaiszló, Hirics, Luszok	1342	15 September	flood	Dráva
8.	Zemplén	Maráza	1342	11 November	flood	Toplu and Ondava
9.	Heves	Kömlő	1343	15 May	flood and hard times	Tisza
10.	Heves	Poroszló	1346	20 April	great flood	Tisza (Egervize)
11.	Borsod	Ónod, Hidvég	1347	23 February	extreme flood	Sajó
12.	Küküllő	Dombó	1348	19 October	flood	Kis-Küküllő
13.	Szatmár, Bereg	Badaló, Kér	1349	13 January and the following days	flood	Tisza
14.	Ungvár	Sislóc	1356	7 December	great flood	Ung
15.	Ungvár	Daróc	1357	1 May	great flood	Ung
16.	Hont	Tarcsány	1358	20 January	frozen soil	-

*Table 1* The data of the records from the period of 1338 - 1358

Among the chosen charters - because the aim of the research was to collect information relating to the Hungarian Kingdom in the 1340s and 1350s - data concerning foreign or previous events (before 1338) are not included.

## THE TYPE OF THE ORIGINAL DOCUMENTS



The geographical distribution of the data in the Hungarian Kingdom  
*Fig. 1*  
country (*Fig. 1*).

The majority of surviving medieval charters deals with juristical cases. Because of the high cost of the production of the document besides the obligatory formulae - which can often be omitted - they usually restrict themselves to concrete information regarding the given case. Therefore, they refer to meteorological or climatic events only if these events relate to the given case. The geographical distribution of the charters is uneven: most of them refer to the northern, northeastern regions of the

Descriptions of events influencing the legal procedures are most frequent in the so-called charters of reambulation (*litterae reambulatoriae*), and a significant part of these is in connection with rivers and unusual meteorological events, playing an important role in the life of the population.

Data concerning of floods (from the whole 21 years' period) can be grouped according to seasons:

- 1, Winter: from the 3 winter-floods (in the charters 11, 13, 14) 2 were extreme floods ( charters 11, 13)
- 2, Spring: 2 great floods (charters 10, 15)
- 3, Summer: only 1 flood was noticed for the last day of summer of 14. charter
- 4, Autumn: it is interesting that all of the four cases (charters 3, 7, 8,12) were mentioned as normal floods.

But it is important to note that the flooding rivers are rather small ones (except the rivers Tisza and Dráva).

The data of floods are important in case of large rivers, because the floods of these show the growing precipitation of greater areas (or melting). In most of these cases river Tisza (charters 9, 10 and 13) or one of the tributaries are mentioned.

The temporal distribution of the charters is remarkable:

*Some weather events from the 14th century*

From the 1340s - when there was disadvantageous weather in Europe (Lamb, 1982, etc.) - I could find 10 data. Four of these especially refer to the year 1342, which was the most unfavourable and wettest one of the decade (Alexandre, 1987; Brazdil and Kotyza, 1995).

For the fifties - in spite of the growing number of charters - only 3 pieces of information were found.

**METEOROLOGICAL INFORMATION FOR 1342**

From the 21 years' period, 1342 was the only year, from which some conclusions can be drawn:

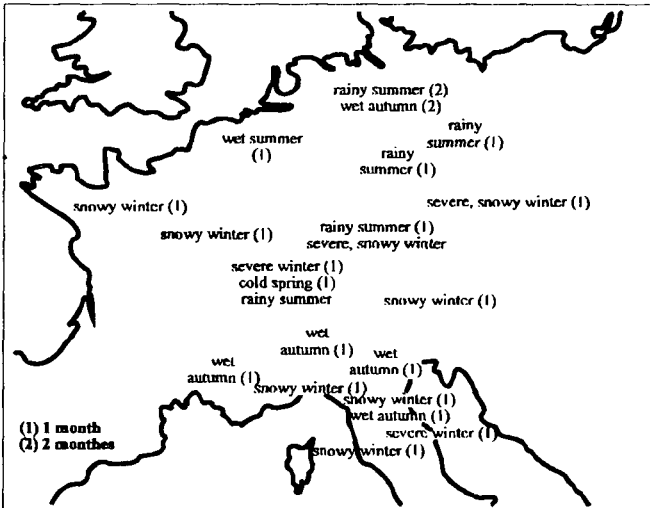


Fig. 2 The weather in parts of Europe - 1342 (data based on Alexandre, 1987)

The second one is more likely because the winter of 1342 was hard and snowy in the central parts of Europe (e.g. Czech Lands, Carinthia and Styria) (Fig. 2).

c) Autumn: 15 September 1342. flood in county Baranya near the river Dráva (charter 7)

In comparison, in the 20th century the probable periods of floods are as follows:

- at the beginning of spring
- at the beginning of summer
- and in autumn.

a) Spring: 25 April, 1342 (charter 5) flood in county Bars, at the upper course of river Zsitva. In consequence of the character of the terrain it was a typical spring flood caused by a bigger rainfall (or a later melting).

b) Summer: 1 July, 1342 (this is the most likely date of the charter 6) hard times, great snow. Two explanations are possible:

1. either an extreme event, which was different from the recent regional climatic conditions,
2. or the misdating of the charter.

The event relating to the settlements nearby river Dráva (and not far from the Danube) in charter 7 might indicate that the flood of this river was the consequence of the higher water level of the Danube.

d) Autumn 11 November 1342 flood between the rivers Toplu and Ondava in county Zemplén. This flood in autumn perhaps shows some influence from the Mediterranean.

These four data are not enough to draw any conclusions nevertheless if we also consider the flood of 1343 (charter 9) on the upper course of river Tisza (this flood can characterize the catchment area of the river at that time), it is not surprising that in 1343 in another source a reference can be read to the high prices in the Szepes area (*Schmauk*, 1889), because - with the exception of the charter 6 - all of these charters are concerned with the high water level of many rivers in the Carpathian Basin.

#### OTHER TYPE OF DATA IN THE CHARTERS FROM THE 14TH CENTURY

Meteorological information - in some exceptional cases - can be obtained from the (narratio) "narrative" part of royal donation charters, where - in contrast to the western European practises - sometimes it rather expects on the merits of the donated person.

A charter from 1322 represents a good example, when László Szécsi took the risk of his life to save Charles I. from the broken ice of the river Bodrog (in Zemplén county):

"... Ceterum cum vice quadam *super glacies fluvii Budrug* consolationis causa cum quibusdam nostris fidelibus graderemur et *ipsa glacies pre gravitate nobiscum* existentium in plures partes *rupta extitisset*, prenominate magister Ladislaus, ne in tam formidabili mortis orrende duritie exponere haud pavescens, nos de discrimine fracturarum glaciei viriliter erexit ..."

(... And another case, when with our followers we went to find consolation on the ice of river Bodrog, the ice was broken because of our followers' weight, the above-mentioned master Ladislaus, so that our person was not threatened in the fearful moment of death, was not afraid of exposing himself to the terrible cruelty of death, and he bravely lifted us up from among the broken pieces of ice ...) (*Györffy*, 1964, DL 99892).

#### LONG-TERM RESEARCH ON CLIMATE-SENSITIVE REGIONS

This method demands the complete investigation of smaller regions that were sensitive to environmental (especially hydrological and climatic) changes. This means the research of the whole medieval data-base and the establishment of the exact environmental

conditions (and changes) with the help of the results of other sciences (e.g. archeology, natural sciences etc.)

There have already been some investigations of charters on this subject on different areas (Fügedi, 1992; Györffy, 1994), that supports the theory of growing mean precipitation for the 14th century, but complete research was made only on lake Balaton (Fig. 3).

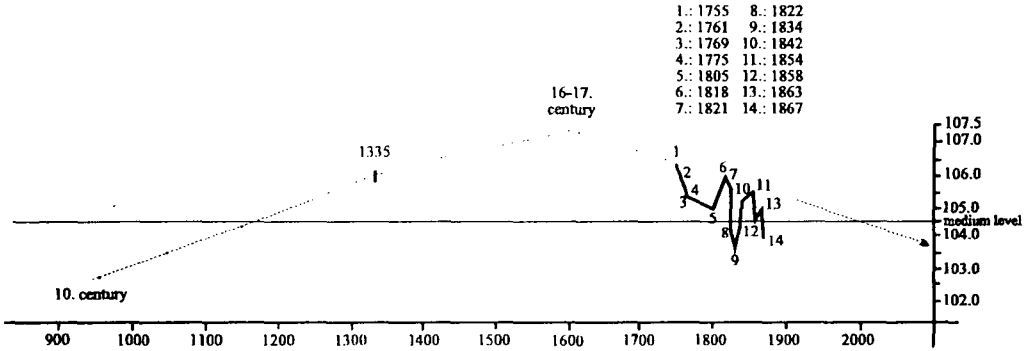


Fig. 3. The water level of lake Balaton in the 2nd millennium A.D. (after Sági, 1973)

## CONCLUSION

While other European regions are rich in contemporaneous sources, Hungarian investigations can lean only on few written Hungarian documents, and have to make use of the results of other sciences and the foreign narrative sources which have some allusions to the Hungarian conditions. The findings show that it is worth continuing this research based on written sources, and that is just the beginning of a long-term examination of climate history in the medieval Hungarian Kingdom.

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- |  |                                      |
|--|--------------------------------------|
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*Andrea Kiss*

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

Gy. KOPPÁNY and A. KISS

*József Attila University, Department of Climatology, P.O. Box 653  
6701 Szeged, Hungary*

**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-chlorine hence of hygroscopic quality, while the continental nuclei are predominately 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 Atlantic 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, moreover 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 :

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

here  $SD$  stands 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.

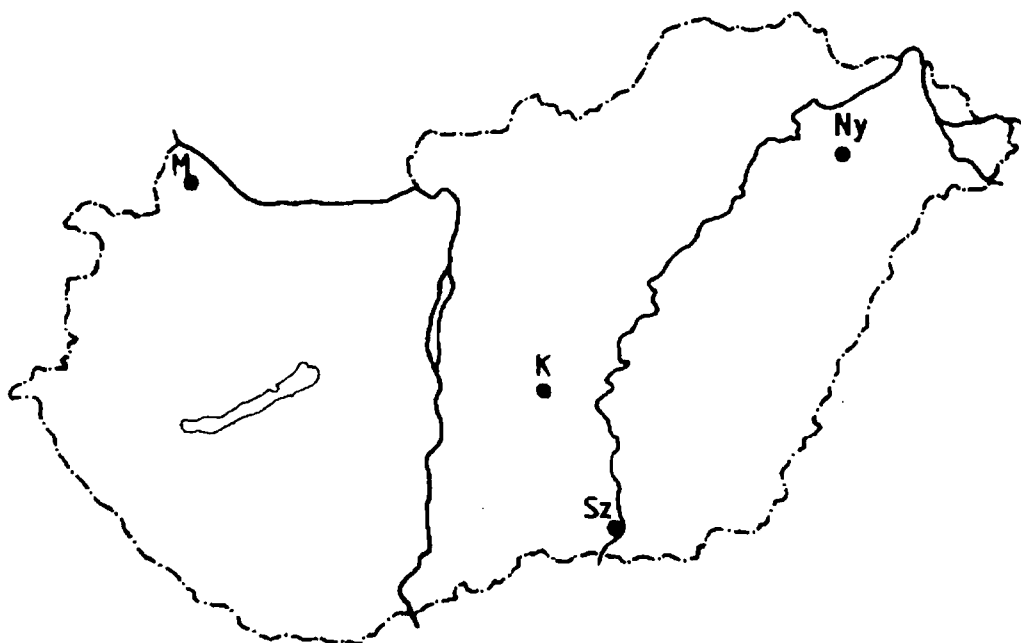


Fig. 1 Climatic stations in Hungary mentioned in Table 1 (M = Mosonmagyaróvár, K = Kecskemét, Ny = Nyíregyháza, Sz = Szeged)

	J	F	M	A	M	J	J	A	S	O	N	D	Y
<b>Precipitation (mm)</b>	32	34	38	49	61	68	51	48	47	52	52	41	573
<b>Clouds (deca)</b>	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
<b>REC Szeged</b>	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
<b>REC Mosonmagyaróvár</b>	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
<b>REC Kecskemét</b>	4.8	5.9	7.3	10.4	14	14.3	14.3	14.4	13.7	11.7	9.8	6.5	120
<b>REC Nyíregyháza</b>	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 *Péczeley* (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:

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

*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 occur 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 plausible decrease in mixing ratio of sodium-chlorine may occur as well causing less vigorous growing of water droplets in clouds, consequently less rainfall will drop.

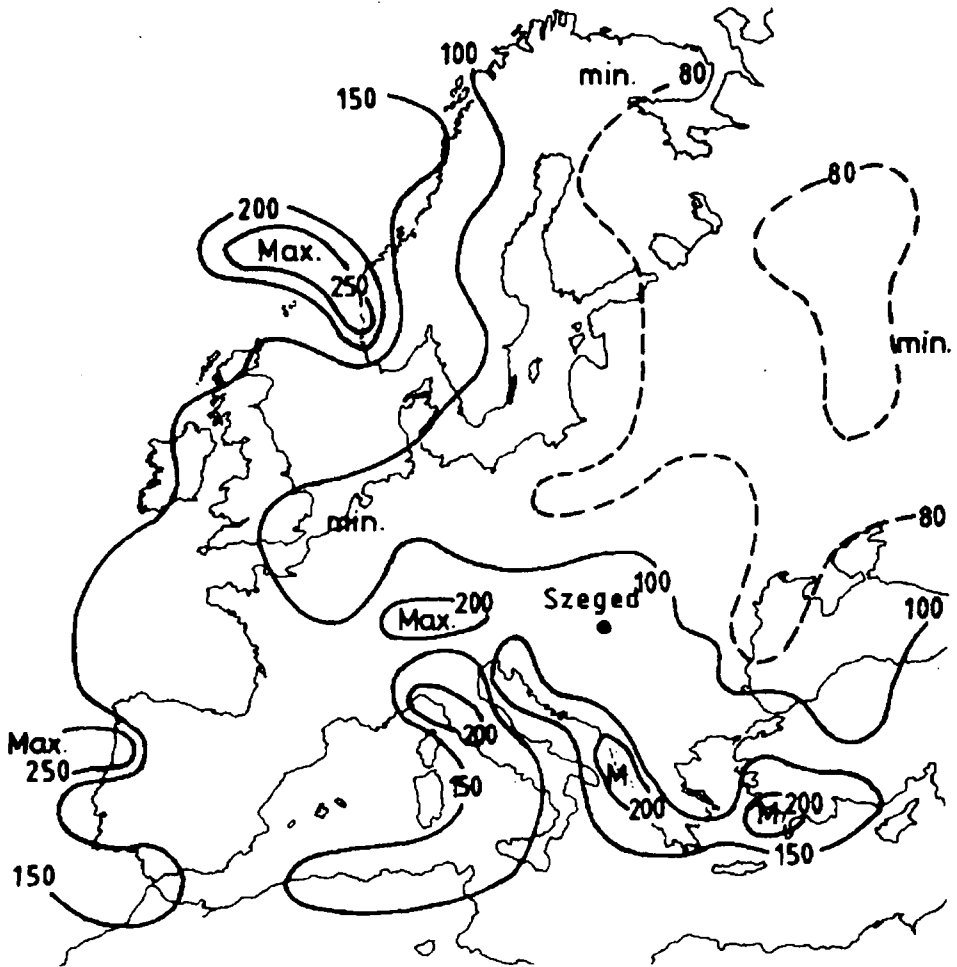


Fig. 2 Macroscale distribution of rain effectivity of cloudiness over Europe and its closest surroundings

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:

	<b>0-20 W</b>	<b>0-10 E</b>	<b>10-20 E</b>	<b>20-30 E</b>	<b>30-60 E</b>
<b><i>REC</i></b>	145	130	136	104	90
<b>( number)</b>	(22)	(25)	(33)	(33)	(12)
	<b>60-70 N</b>	<b>50-60 N</b>	<b>40-50 N</b>	<b>30-40 N</b>	
<b><i>REC</i></b>	130	103	126	138	
<b>( number)</b>	(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 characteristics 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	<b>4.8</b>	<b>11.0</b>
Standard deviation, mm	5.05	11.06
Clouds in decas	<b>8.44</b>	<b>7.8</b>
Standard deviation, decas	1.95	2.39
<i>REC</i> 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 significant 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 chlorine nuclei per total amount of condensation nuclei. The mixed ratio of chlorine must have important role in the growth of water droplets and forming rainfall.

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*György Koppány and Andrea Kiss*

## STRONG WIND OCCURENCES IN EGYPT DURING 1994

A. A. Kh. NAGWA<sup>1</sup>, Gy. KOPPÁNY<sup>2</sup> and L. MAKRA<sup>2</sup>

<sup>1</sup>*Educational College of Girls, Art Section, Department of  
Geography, Riyadh, Saudi Arabia*

<sup>2</sup>*Department of Climatology, József Attila University,  
6701 Szeged, P.O.B. 653., Hungary*

**Összefoglalás** - A szerzők az 1994. évi, naponként kétszeri mérésadatok alapján megvizsgálják három egyiptomi állomáson a legalább 14 csomó erősségű szelek előfordulását. Megállapítják ezek évszakos és napszakos fellépését, a szélirányok gyakoriságát erős szelek esetén. Külön elemzik a délies szeleket kísérő légköri paramétereket, így a hőmérsékletet, relatív nedvességet, felhőzetet és a tengerszinti légnyomást.

**Summary** - The authors investigate the occurrences of strong winds of at least 14 knots wind speed, using twice-a-day records at three Egyptian stations from 1994. The frequencies of strong winds are established both in seasonal and diurnal variations as well as wind directions. Special attention was paid to weather phenomena during wind blowing from south quadrant, analysing the synchronous values of temperature, relative humidity, cloud and sea level pressure.

**Key words:** climate of Egypt, strong wind, khamsin, wind direction, sand storm

### INTRODUCTION

Strong wind is defined in this paper as wind speed of at least 14 knots (about 7 m/s). It is likely that such wind speeds are often accompanied by gusts of 15 m/s velocity or more. In Sahara and its vicinity strong winds indicate either sand storms or atmospheric fronts. Sand storm or in Arabic: "*khamsin*", is one of the most unpleasant and harmful phenomena in North African desert. It is well known in Egypt and Sudan, in the latter country it is called: "*ghibli*".

The purpose of this paper is to give a survey on occurrences of strong winds observed in three Egyptian stations and to select some case studies to be scrutinized. The meteorological stations involved into this paper are as follows:

- |                 |          |         |         |
|-----------------|----------|---------|---------|
| 1. Mersa Matruh | (62 306) | 31°21'N | 27°13'E |
| 2. Alexandria   | (62 318) | 31°12'N | 29°57'E |
| 3. Cairo        | (62 366) | 30°08'N | 31°34'E |

In parentheses: the synoptic code numbers of the stations.

## DATA BASE

Regular daily weather records were used in this investigation, namely from three Egyptian stations mentioned above. Measurements were made twice a day, at 00 and 12 GMT, respectively. The weather records include relative humidity, sea level pressure, air temperature, wind direction and velocity in knots and clouds in octas. These data have been available for the complete year of 1994.

It was found that strong winds (at least 14 knots) occurred most frequently in some months, namely from January to May as well as in November and December. From June to October strong winds are infrequent or entirely missing. Thus days with strong wind were selected from relevant months only. Five to sixteen records per month have been chosen including cases when strong wind happened twice a day, both at 00 and 12 GMT.

The main features of climatic background in North Africa are given in books, like *Climates of Africa*, edited by *J.F. Griffiths* (World Survey of Climatology, Volume 10, 1972) - *Tropical Meteorology, Compendium of Meteorology*, prepared by *T. N. Krishnamurti* (1979) - *Climate of the Earth* (in Hungarian) by *G. Péczely* (1984) - *Climatological Normals for the Period 1931-1960* by WMO (1982).

## SOME CHARACTERISTICS OF THE CLIMATE IN EGYPT

There are essentially four sub-regions that one should consider when describing the weather systems over tropical Africa:

1. West Africa,
2. The deserts,
3. Somalia and East Africa, and
4. Central Africa.

The area of Egypt is mostly covered with desert except the northernmost part, close to the Mediterranean Sea. The annual amount of rain varies between 20 and 190 mm in the region affected by the sea, where the rainy season begins in October and finishes by March or April. To the south of 30°N latitude practically no significant rainfall occurs in Egypt.

The annual mean temperature ranges between 19 and 26°C, the seasonal variation of monthly mean temperature is as much as 13-18°C, with maximum in July or August and minimum in January. The absolute maximum of temperature measured in Egypt has been nearly +50°C, while as absolute minimum -4°C was recorded.

In winter the Mediterranean depressions affect Lower Egypt directly, causing surface winds to become variable, both in speed and direction. Since the tracks of depressions are north of the coastline the prevailing directions are south and southwesterly in front of the depressions and west or northwesterly in the rear. The subtropical high pressure cell covers the

western desert of Egypt during this season. The prevailing winds are, therefore, northerlies.

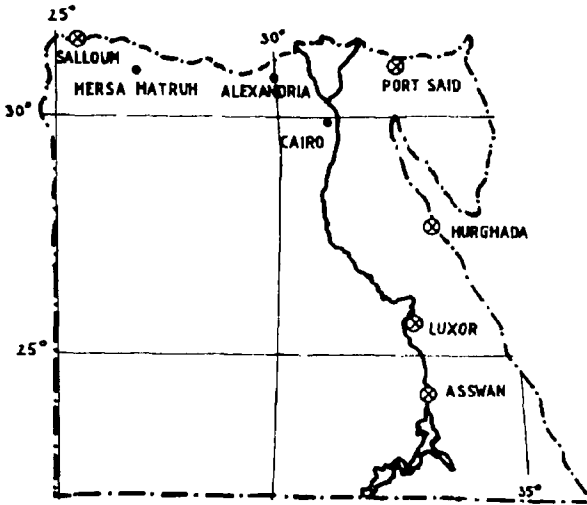


Fig. 1 Meteorological stations in Egypt in this investigation

of wind speed are the highest on the western side of the Mediterranean coast. The value decreases from about 20 km/h in the extreme west, Sallouh ( $31^{\circ}32'N$ ,  $25^{\circ}11'E$ ) to about 8 km/h in the extreme east, Port Said ( $31^{\circ}17'N$ ,  $32^{\circ}14'E$ ).

In the Mediterranean coastal areas the mean monthly values of relative humidity increase eastwards, but they decrease rapidly southwards. For example the mean annual value is 69 % at Alexandria and 29 % at Aswan.

Winter and early spring are the seasons of strong and gale winds in Lower Egypt usually blowing from the western quadrant. Stronger winds become more frequent in the spring months over Lower Egypt because of the passage of the centre of "khamsin" depressions at the south of the Mediterranean coast line.

In summer steady northerly winds prevail over all of Egypt. Gales do not occur during this season, except on the Red Sea. In this area the strong northwesterly winds are the products of the local topography and centres of low pressure that appear over the northern Red Sea.

The mean annual values

## ANALYSIS AND RESULTS

Out of the twice-a-day weather records (00 and 12 GMT) there were selected cases with comparatively strong wind, at least 14 knots, regardless the wind directions. Data were available from Mersa Matruh, Alexandria and Cairo (Fig. 1). In months from January to May and November, December 44 to 81 records were chosen depending on the stations (Table 1).

	Mersa Matruh		Alexandria		Cairo	
	n	%	n	%	n	%
<b>NW-NE</b>	30	37	18	27	3	7
<b>SW-NW</b>	34	42	26	40	13	30
<b>SE-SW</b>	13	16	16	25	20	45
<b>NE-SE</b>	4	5	5	8	8	18
<b>total</b>	81	100	65	100	44	100

Legend: n - number of occurrence, % - relative frequency

Table 1 Frequency of wind directions

In Table 1 the number or relative frequency of strong winds are presented regarding the four quadrants of wind directions. It is remarkable that at the westernmost Mersa Matruh the westerlies are predominant with 42 %, while easterlies are rare but eastwards, at Alexandria and farther at Cairo the south quadrant becomes gradually prevailing, meanwhile the frequency of northwinds decreases from 37 % at Mersa Matruh to 7 % at Cairo. (The maximum frequencies are marked by italics in Table 1.) It means that from the western part of Lower Egypt to its eastern area the wind turns from west, northwest to south, southeast.

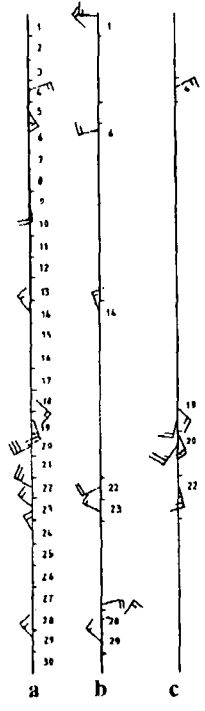
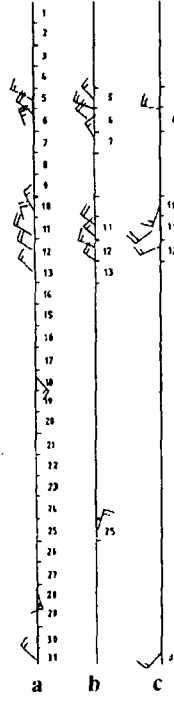
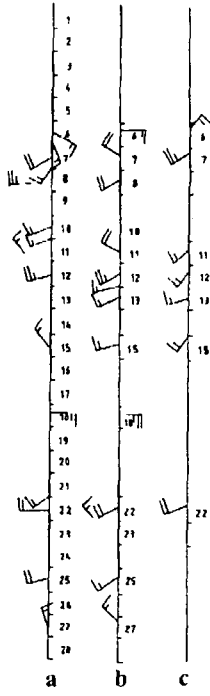
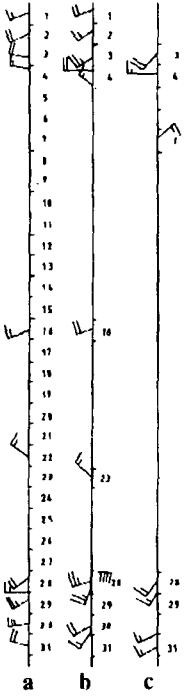
The individual cases of strong winds occur most frequently in Mersa Matruh and rather rarely in Cairo (Fig. 2-8). It seems evident that wind directions of south quadrant are linked with transport of air masses with low relative humidity arriving from the Sahara. So it is expected that strong southerlies are accompanied with dry and hot air. Data given in Table 2 prove partly our expectation.

Strong wind occurrences in Egypt during 1994

**a: Mersa Matruh**

**b: Alexandria**

**c: Cairo**



*Fig. 2*  
Chronological occurrences of strong wind in January, 1994

*Fig. 3*  
The same as in *Fig. 2* but in February, 1994

*Fig. 4*  
The same as in *Fig. 2* but in March, 1994

*Fig. 5*  
The same as in *Fig. 2* but in April, 1994

**a: Mersa Matruh**

**b: Alexandria**

**c: Cairo**

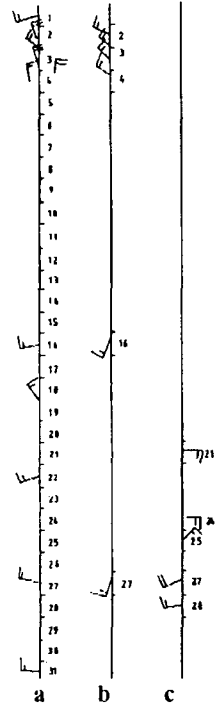
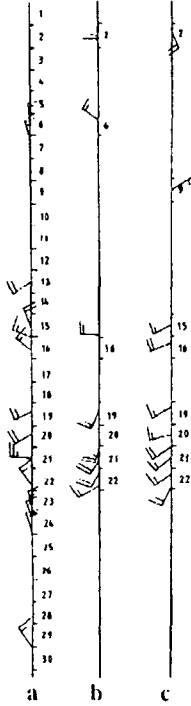
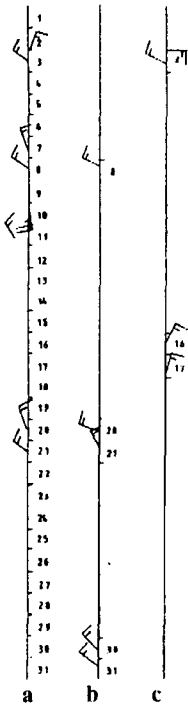


Fig. 6

The same as in Fig. 2  
but in May, 1994

Fig. 7

The same as in Fig. 2  
but in November, 1994

Fig. 8

The same as in Fig. 2  
but in December, 1994

*Strong wind occurrences in Egypt during 1994*

Date	relative humidity, %	temperature °C	sea level pressure, mb	clouds octas
<b>February: Mersa Matruh</b>				
6.	53	17.8	1019.6	0
7.	30!	15.0	1015.0	0
8.	33!	17.4	1016.4	0
<b>March: Mersa Matruh</b>				
18.	77	15.0	1014.4	8
28.	22!	27.9	1014.1	7
<b>Cairo</b>				
10.	38!	19.7	1009.8	4
11.	78	12.6	1007.8	7
12.	57	16.4	1014.3	6
31.	32!	19.7	1014.8	5
<b>April: Mersa Matruh</b>				
5.	21!	30.1!	1007.6	2
9.	24!	27.4!	1015.4	0
18.	13!	36.3!	1007.7	4
19.	11!	39.2!	1000.3	4
20.	10!	39.7!	1003.3	0
<b>Cairo</b>				
19.	13!	30.6!	1006.8	0
19.	5!!!	39.6!!!	1005.9	7
20.	6!!!	40.2!!!	1005.6	6
22.	11!	31.7!	1009.4	7
<b>May: Mersa Matruh</b>				
10.	28!	31.7!	1008.4	6
<b>November: Alexandria</b>				
19.	53	22.7	1011.2	0
21.	61	17.6	1008.8	4
22.	61	18.6	1011.0	7
<b>December: Alexandria</b>				
16.	50.	19.8	1017.0	4
27.	62	18.6	1008.0	3

*Table 2 Cases with strong southerly wind in 1994*

The unusually low values of relative humidity and high temperature, respectively, are indicated with simple or triple exclamation marks. Such weather phenomenon occurred almost exclusively in spring months. It can be also established that extreme high temperature values were recorded in cases with rather low sea level pressure and vica versa.

The temporal distribution of strong wind occurrences is unequal between days and nights. Strong winds appear more frequently at noon than at midnight, as it can be established from data as follows (Table 3):

	Mersa Matruh		Alexandria		Cairo	
at 12	63	(78%)	44	(68%)	37	(84%)
at 00	18	(22%)	21	(32%)	7	(16%)
total	81	(100%)	65	(100%)	44	(100%)

Table 3 Strong wind occurrences

It can also be seen in Table 2 that there is not strong correlation between amounts of clouds and the synchronous relative humidities. It is hoped that with more availability of weather records made in North Africa we shall be able to carry out more detailed analysis of that kind of peculiar weather phenomenon as sand storms, especially "khamsin" and "ghibli".

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## SOME ASPECTS OF THE WIND IN THE NORTHERN AREA OF THE DEPRESSION OF TRANSYLVANIA

V. SOROCOVSCHI and F. MOLDOVAN

*Department of Geography, Babeş-Bolyai University,  
5-7, Clinicilor Street, 3400 Cluj-Napoca, Romania*

**Összefoglalás** - A jelen tanulmány az Erdélyi Medence északi részén előforduló talajmenti és magaslati szél egyes vonásait mutatja be. A szél paramétereinek az elemzése 5 meteorológiai állomás (Torda, Kolozsvár, Dézs, Beszterce és Marosvásárhely) és a Kolozsvári Aerológiai Állomás által szolgáltatott, 1961 és 1980 között feljegyzett adatok alapján történt. A szél irányának és sebességének az évi, évszaki és havi középértékeit a talajszinten és az 5 standard izobár szinten számítottuk ki. A felszín morfológiai sajátosságai és ennek a Kárpátok vonulatához viszonyított elhelyezkedése meghatározza a talajmenti szél paramétereinek regionális jellemzőit. A Kárpátok vonulatának a légmozgásra gyakorolt hatása körülbelül 3000 m magasságig érződik, főként a nyugati széljárás jellemző.

**Summary** - The study presents some aspects of the ground level and altitudinal wind in the northern area of the Depression of Transylvania. The analysis of the wind parameters is based on the data provided by 5 meteorological stations (Turda, Cluj-Napoca, Dej, Bistrița and Târgu-Mureș) and the Cluj-Napoca Aerological Observatory, covering the interval between 1961-1980. The annual, seasonal and monthly average values of the direction and speed of the wind at ground level and at the five standard isobaric levels have been calculated. The regional differences of the wind parameters at ground level are affected by the morphologic peculiarities of the area and by its position in the vicinity of the Carpathian bow. In the altitude the influence of the Carpathians upon the circulation of the air is felt as high as 3000 m. Above this level the western circulation is predominant.

**Key-words:** direction and speed of the wind, morphology of the relief, Carpathian bow, standard isobaric levels

### INTRODUCTION

The studied region includes the hilly area on the northern part of the Mureș, between Deda and the affluence of the Arieș, limited by the Apuseni Mountains and the Eastern Carpathians (*Fig. 1*). The transition towards the two adjacent mountain regions is made gradually through some hills and submontane and intra-hill depressions.

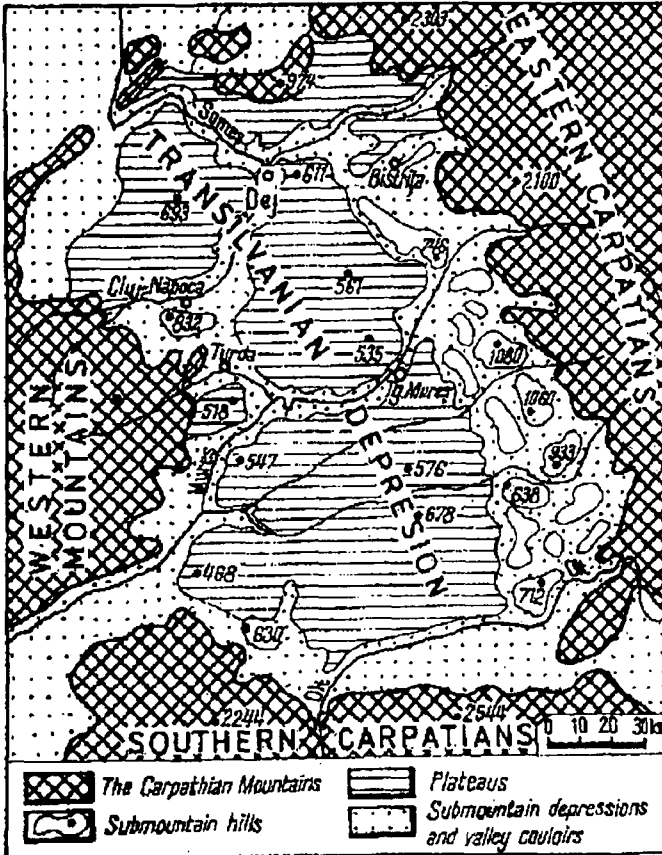


Fig. 1 Location of meteorological stations in the studied region

Depression of Transsylvania, which generate the shelter peculiarities of the wind system different from those of the periferic regions.

Due to the barrier made up by the Eastern Carpathians the masses of air from the eastern part of the continent reach the territory of the depression only if they are considerably developed in altitude. From the south, the flow of atmospheric currents along the Olt Valley occurs rather infrequently. Neither do the masses of air penetrate into the depression along the Mureş Valley very often.

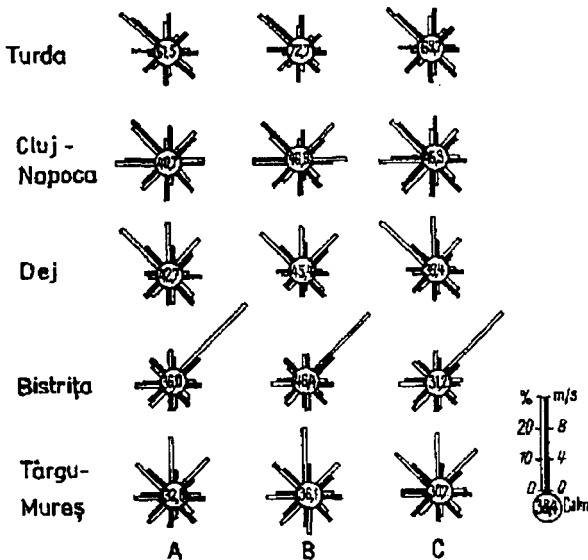
As we ascend in altitude, the wind system is less influenced by the morphologic peculiarities of the relief or by the position of the territory related to the Carpathian bow.

The different features of the wind in this region are determined by the elevation and the position of the relief related to the direction of the western masses of air, their movement being favoured at certain levels by the occurrence of some channels, cols and wide valleys. Thus, above the ground level the movement of air currents is directed by some wide cols between isolated ridges which in the north-west make the connection between the Apuseni Mountains and the Eastern Carpathians (Fig. 1).

At higher levels, between 600 and 1000 m, the penetration of the masses of air is facilitated by the lower elevation of the peaks in the Apuseni Mountains. Massiveness and the higher elevation in the central part of the Apuseni Mountains make it more difficult for the masses of air to penetrate into the

The study of the wind system in the northern part of the Depression of Transsylvania was carried out through the detailed analysis of the parameters describing the direction and intensity of the wind, including their variations in time and space. Consequently, we analysed and interpreted the data recorded between 1961-1980, resulting from five meteorological stations (Turda, Cluj-Napoca, Dej, Bistrița and Târgu-Mureș) and from the only aerological observatory in the Depression of Transsylvania (Cluj-Napoca), which is representative for the whole studied region.

THE GROUND LEVEL WIND



The direction of the wind. Taking into account its position within the Carpathian relief, the studied region is under the influence of the predominantly western circulation. On this background there occur, however, some local changes in the direction of the wind, imposed by the peculiarities of the subjacent surface and especially by the general configuration of the relief. Moreover, on the margins of the region the situation is complicated by a breeze-like circulation from the mountains. Observing the annual frequency of the directions of the wind, we can notice that on the western margin the westerlies represents

Fig. 2 The annual (A) and seasonal (B-winter; C-summer) frequency (%) and the mean speed (m/s) of the wind at 10 m a.g.l.

31.2 % of the total at Cluj-Napoca and 19.5 % at Turda (Fig. 2A). The percentage of the different directions depends on the position and the configuration of the relief of the area where the meteorological stations are situated (Fig. 1). In the Depression of Turda the most frequent is the north-western direction (Turda 15.7 %), while in the valley of the Somesul Mic is the western (Cluj-Napoca 12.1 %). On the eastern margin a transfer of the mountain-origin masses of air is quite noticeable. This phenomenon is emphasized by the predominance of the

north-eastern wind (Bistrița 29.8 %). The same phenomenon was noticed at the Odorheiu-Secuiesc meteorological station situated in the same eastern part of the depression, but outside the studied region.

Within the plateau, the predominant direction of the wind is rather varying, depending on the orientation of the major valleys. Thus, along the valley of the Mureș between Târgu-Mureș and Ludus, the circulation is directed to the west and east. All the other directions show diminished frequency (under 10 %). The same influence of the configuration of the relief upon the channelling of the masses of air can be mentioned in the case of the Mureș Valley upstream Târgu-Mureș, and of the Somes Valley in the vicinity of Dej, where almost all the circulation is directed from the north quadrant (Târgu-Mureș 41 %, Dej 40.1 %).

The seasonal frequency of the direction of the wind, except for a few cases, shows the same features as in the case of the annual frequency. That is to say, in winter when the circulation is marked by the presence of the Euroasian continental anticyclone, a slight increase of the frequency in the occurrence of the north-eastern wind can be noticed. The phenomenon is more visible on the eastern edge where the frequency of the north-eastern wind is over 12% (Fig. 2B).

We should mention that during this season the north-eastern direction shows a higher percentage in February. Also, a relatively high frequency occurs in the case of the western winds during winter. The explanation most probably lies in the intensified cyclonic activity from the northern basin of the Atlantic Ocean.

In spring, like in winter, the predominant directions are those from the north-east, in the northern and eastern parts of the region and from the west in the rest of the region. Beginning in March or April, following the strengthening of the Azoric anticyclonic dorsal towards the east and south-east of the continent. The frequency of the western and north-western directions increases, mainly in the western part of the region, going as high as over 20 %. The increased frequency of these directions can be felt in the appreciable growth in the quantity of rainfall compared to the preceding season. The late spring frosts and low temperatures, which are rather frequent on the eastern margin especially in the first part of the season can be explained by the invasion of cold air, by the north-eastern winds that have a remarkable frequency (34.4 % at Bistrița).

In summer the western wind prevails with a high frequency of the western and north-western directions, the percentage of which ranges between 13 and 16 % on the eastern edge and 20 to 30 % in the rest of the territory (Fig. 2C).

In autumn, once the Azoric anticyclone has reduced its activity, the western circulation diminishes and the northern and north-eastern winds are intensified reaching frequencies almost as high as in winter.

*The calm intervals.* The influence of the peculiarities of the relief is well mirrored in the frequency of the calm intervals. Thus, in the region which is sheltered from the prevailing

western circulation, the calm intervals were recorded with a very high percentage (Turda 61.5 %), while in the proximity of the Eastern Carpathians the currents of air from the mountain region considerably diminish the annual frequency of the calm (Bistrița 36 %). The great ventilation along the valleys causes lower values of the calm (Târgu-Mureș 32.2 %, Cluj-Napoca 40.7 %). During the year, the frequency of the calm intervals displays a major maximum value in October, not very much different from the value recorded in December (Fig. 3).

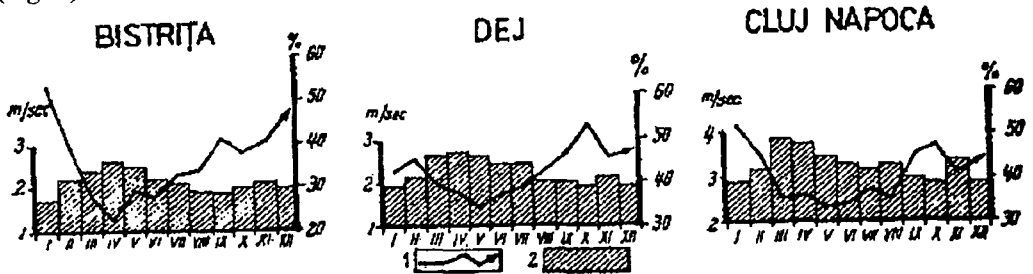


Fig. 3 Monthly variations of the mean wind speed (1) (m/s) and calm intervals (2) (%) at 10 m a.g.l.

On the eastern margin of the region the major maximum value is usually recorded in December and January. The main minimum value occurs in April, sometimes even earlier (March) in the western part of the region and somewhat later (April, May) in the northern and eastern parts.

*The speed of the wind.* This is a varying parameter depending on the general atmospheric circulation and on the local surface of the relief (sheltered region or exposed to the wind). The mean annual speed in the studied region ranges between 2.0 and 3.6 m/s. On the margins of the area the descent of the currents from the mountains causes the intensity of the wind to be somewhat higher than in the plateau (Bistrița 3.6 m/s, Cluj-Napoca 3.2 m/s, Târgu-Mureș 2.4 m/s). Generally, the highest mean annual speed is recorded on the predominant directions (Fig. 2).

The speed of the wind shows monthly and seasonal variations, resulting in an intensified spring period and a reduced late summer and early autumn period. In winter the speed of the wind is diminished, in general under 3 m/s. However, higher speeds do occur on the prevailing directions. That is to say, the speed of the north-western wind exceeds 5 m/s at Cluj-Napoca and Turda (Fig. 2B). In spring, once the cyclonic circulation has intensified its activity, the mean speed of the wind goes up considerably, in most of the cases the recorded values were 1 m/s higher than in winter. Consequently, all the directions show high speeds, a fact that is not encountered in the other seasons. In summer the mean speeds drop with 0.5-1 m/s related to the previous season, often being under 3 m/s. In autumn the mean values go up at the beginning with October in the east of the region and in November in the rest of the area.

In comparison with the other seasons, in autumn the mean speeds of the wind are more reduced (Fig. 3).

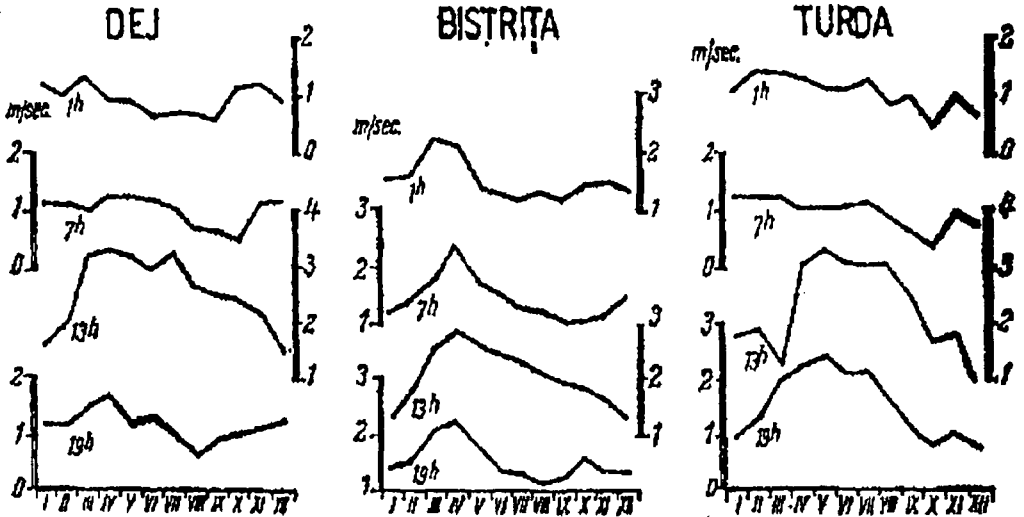


Fig. 4 The evolution of the wind speed recorded at the four climatological observation hours

The daily oscillations of the mean speed of the wind display a maximum value recorded around noon when the isolation is strong, the thermal convection is developed and the coefficient of turbulence is high, and there is a minimum during the night, toward morning when the stationary thermal stratification of the air is predominant and the temperatures are the lowest. The daily evolution of the wind speed along the year is characterised by two intervals of intensified activity: in spring, in March and April, and in autumn in November; however, this is less intense and more visible on the western margin of the region (Fig. 4).

In spring, which is the most agitated season, the mean speed reaches 3-4 m/s around noon, while in autumn the recorded values are 1-2 m/s lower. The daily annual minimum value occurs during summer nights, when the speed of the wind exceeds 1 m/s on the margins of the area, but stays under this value in the plateau.

From the analysis of the mean wind speeds, calculated for 5 categories, we could draw the conclusion that during the year the highest frequency (50-70 %) is for the very weak currents (under 1 m/s), while the lowest (under 3 %) is for a speed range between 11 and 15 m/s (Fig. 5). Wind speeds of more than 15 m/s are of a reduced frequency (under 0.5 %) or are non-existent.

*Some aspects of the wind in the northern area of the depression of Transsylvania*

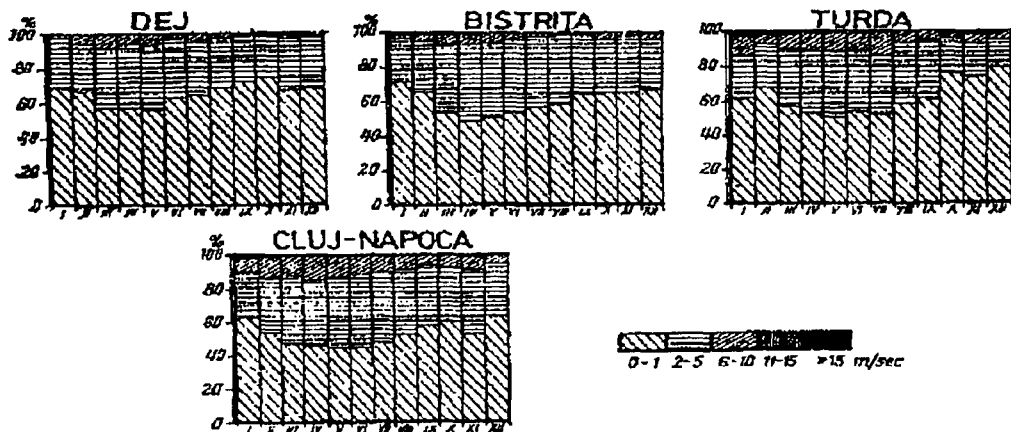


Fig. 5 Frequency (%) of the mean wind speeds

### THE ALTITUDIAL WIND

Its characteristics are based on data obtained from the radiosondes recorded at the Cluj-Napoca Aerological Observatory. They were determined at the standard isobaric levels: 950 hPa (540 mgp medium height), 850 hPa (1480 mgp), 700 hPa (3040 mgp), 500 hPa (5620 mgp) and 100 hPa (16250 mgp), at 00 UTC.

The first thing to be remarked is that at all the mentioned levels the maximum frequency was on the western direction. The 850 hPa level was an exception, as in this case the north-western direction was predominant (*Fig. 6*). The phenomenon was more and more obvious as the elevation grows, due to the fact that as we ascend, the influence of the earth's surface decreases diminishing the effect determined by the configuration of the relief.

Secondly, we should mention the variation in frequency of the south-western direction at different isobaric levels. Thus, due to the barrier effect of the Apuseni Mountains, the frequency of the wind blowing from the south-west was reduced (15-16 %) at lower levels. Beginning with the 700 hPa level, the percentage of the south-western wind increases considerably until it reaches values that are specific to the western direction (21-27 %). In concordance with the altitudinal intensification of the zonal hemispheric vortex, the percentage of the western wind increases from 58.3 % at 950 hPa to 77.3 % at 100 hPa.

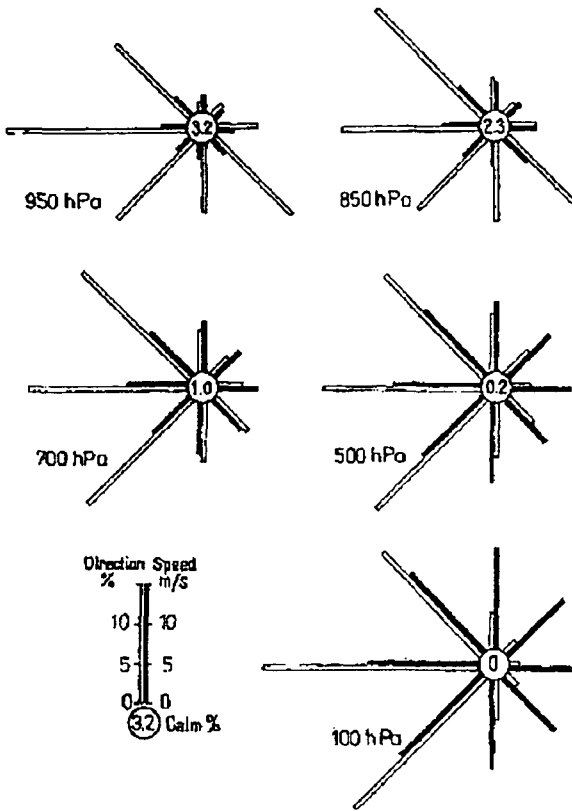


Fig. 6 The annual frequency (%) and mean speed (m/s) of the altitudinal wind, at 00 UTC hours, as recorded by the Cluj-Napoca Aerological Observatory radiosondes

the wind speed occur on the north-western direction (5.4 m/s at 950 hPa, 6.9 m/s at 850 hPa, 9.5 m/s at 700 hPa), while at the 100 hPa level they were recorded on the south-western (16.6 m/s) and western (16.3 m/s) directions. The lowest speeds are specific to the eastern winds (Fig. 6).

With regards to the monthly variations of the mean speed of the altitudinal wind, the highest values were recorded in winter, and the lowest in late

Following the monthly variation of the frequency of the wind, we can notice that it has an irregular feature at all the isobaric levels. However, in the case of western directions the frequency is higher in the latter half of the year, while eastern winds occur more frequently in the former half (Fig. 7).

As for the mean speeds of the altitudinal wind, we have noticed that the highest values occur in the case of the predominant directions. Including the 500 hPa level, the highest values of

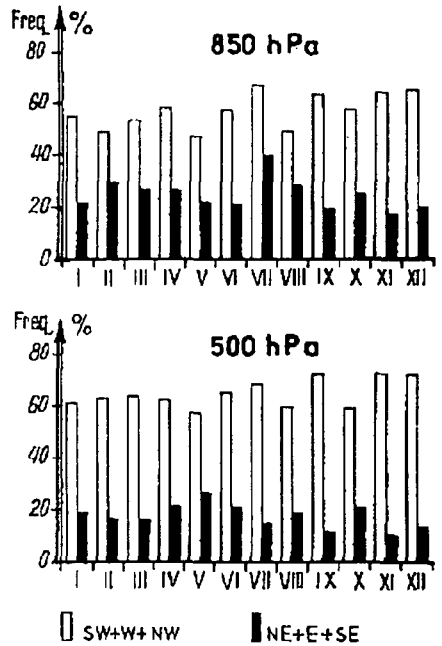


Fig. 7 The monthly variation of the altitudinal wind frequency (%) for the western and eastern quadrants

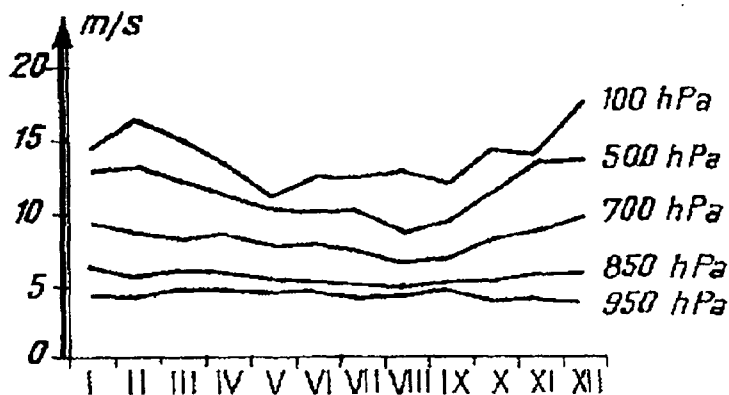


Fig. 8 The monthly variation of the mean speed (m/s) of the altitudinal wind

summer (Fig. 8).

The annual amplitude of the mean speeds increases with the altitude, from 0.9 m/s at 950 hPa to 6.5 m/s at 100 hPa. The frequency of the calm intervals is insignificant in the altitude: 3.2% at 950 hPa, 1.0% at 700 hPa, while at the 500 hPa level it is virtually absent.

## CONCLUSIONS

The geographic position and the morphologic features of the studied region are essential factors that determine the spatial variations of the wind parameters.

The influence of the Carpathian bow upon the circulation of the air can be felt as high as roughly 3000 m. Above this level the predominant circulation is from the west.

The fragmentation of the Carpathian bow in the north-west of the studied region facilitates the penetration of oceanic masses of air at low levels (under 1000 m), which are mainly directed towards the eastern margin of the region.

The regional peculiarities of the wind system are reflected in the diversified landscape of the area.

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## THE MAIN RESULTS OF THE NEARLY 30-YEAR-OLD URBAN CLIMATOLOGICAL RESEARCH IN SZEGED, HUNGARY

J. UNGER

*Department of Climatology, József Attila University  
P.O.Box 653, 6701 Szeged, Hungary*

**Összefoglalás** - A dolgozat egy közepes méretű magyar városban, Szegeden folyó városklímakutatás legfontosabb eredményeit tekinti át, amely közel 30 éves múltra vezethető vissza. Az áttekintés az 1967 és 1995 közötti korszakot elemzi és ismerteti minden olyan fellelhető munkát (cikket, disszertációt és kéziratot), amely Szeged városklímájával foglalkozik. A sokéves dokumentáció azért is értékes, mert általa a vidéki városaink közül itt nyerhetjük a legrészletesebb, legátfogóbb képet egy nagyobb város klímamódosító hatásairól.

**Summary** - This paper describes the most important results of urban climatological investigations, which goes back to the 1960s, in a medium-sized Hungarian town, Szeged. The overview analyses the period between 1967 and 1995 and it contains every retraceable work (papers, theses and manuscripts) which dealt with the urban climate of Szeged. So many years of documentation is also valuable as it gives the most detailed and most extensive picture among the Hungarian country towns of the climate modification effects of a bigger town.

**Key words:** urban climate, Szeged, Hungary, chronological overview

### INTRODUCTION

The establishment of towns strongly alters the original natural surface. It modifies the materials, the structure and the energy-balance. There are other anthropogenic modifying factors such as the artificial heat release and the air polluted by different gases and aerosols. The joint effects of these factors determine a peculiar local climate in towns. It is the so called *urban climate*.

The main feature of an urban climate is that almost every meteorological element in the town shows some alteration compared to the ones in the surroundings free of anthropogenic effects. The magnitudes of the modifying effect of a town on the different elements depend on the mezo-climate of the wider area, on the geographical and orographical

circumstances, on the features of industry, on the structure and surface of the built-up area, as well as on the population of the town.

The climate modifying effect of the town is disadvantageous from the aspects of human bioclimatology and sometimes it is very loading although its health damage depends mainly on air pollution. The disadvantageous effects can be decreased by appropriate planning methods and for this reason we have to know the local climate of the town.

The big towns in Hungary can be put in three orographical region types: juncture of mountains and plain, valley, and plain.

In the case of the first two types the artificial modifying effects are disturbed by the varied orographical conditions thus their recognition is difficult. To demonstrate the undisturbed urban climate, a town situated on a plain is the most suitable. The detailed climatological measurements of this town can give us a basis for drawing general urban climatological conclusions. Besides laying the foundation of future plans of urbanization scientifically this fact has also given reason to investigate the urban climate of the town, Szeged.

## STUDY AREA

Szeged is situated in the south-east of Hungary at 79 m above sea level on a plain (46°15'N, 20°09'E) and altitude differences inside the town are only a few metres. In 1980, Szeged had 175 000 inhabitants and its built-up area was approximately 46 km<sup>2</sup>. The town is a long way from large water bodies except the River Tisza intersecting the town. The area has a continental climate with a long warm season. The main average meteorological parameters of Szeged region are as follows:

- mean annual temperature is 11.2°C.
- mean January and July temperatures are -1.2°C and 22.4°C respectively,
- mean annual precipitation is 573 mm,
- mean annual sunshine duration is 2102 hours (*Péczely*, 1979).

The ground of the town structure is a boulevard-avenue street system rested on the River Tisza (*Fig. 1*). Its advantage is that the town structure is easy to survey, but its disadvantage is that the traffic concentrates towards the town centre which increases air pollution. The industrial area is located mainly in the north-western part of the town. Thus the prevailing westerly and northerly winds transport the pollution originating from this area towards the central parts of the town which is also helped by the supposed inhaling effect of the Tisza valley channel.

During the last decades the structure of the built-up areas has been significantly modified by the construction of huge housing estates with pre-fabricated concrete slabs on the

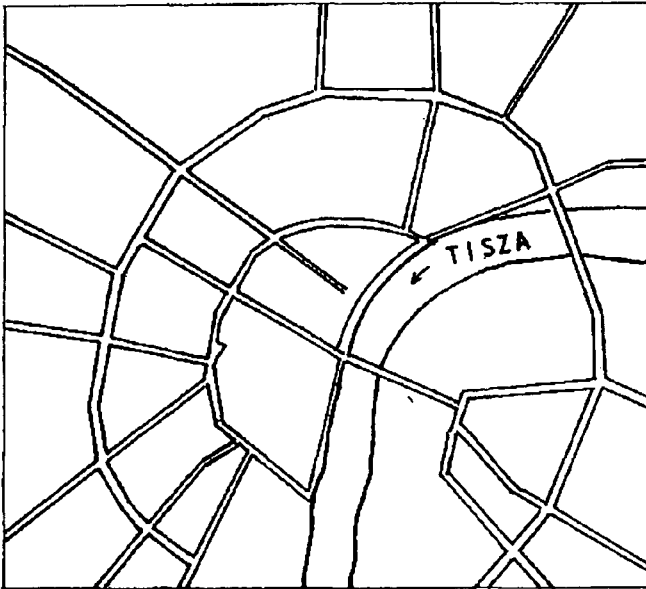


Fig. 1 Urban structure scheme of Szeged

northern and eastern outskirts. They mean particular structure proportions because there is a belt with detached houses with lots of gardens and green areas between the town centre with densely packed 2-4-storey buildings and the tall, concrete, not too densely built 5-10-storey buildings of the new housing estates. This area with tall buildings used to be a gradual transition built-up area between the town centre and the open spaces.

In the next part of the paper the main results of the investigations related to the urban climatology of Szeged will be exhibited in chronological order. The results and establishments can

be found in published papers, in manuscripts of theses and doctoral theses as well as in other manuscripts.

#### CHRONOLOGICAL OVERVIEW OF THE URBAN CLIMATE INVESTIGATIONS IN SZEGED

The first work was a doctoral thesis (Jantos, 1967) which investigated the temperature differences between two stations situated in the town centre and near the town respectively using 15-year data series (1951-65). The urban station was above the Department of Climatology on the top of the University Building and the rural station was to west of the town at the airfield. The mean urban-rural differences were highest at 07h in July (1.5°C), at 14h in September (0.9°C) and at 21h in August (2.3°C). In other months the greatest differences also appeared at 21h and the smallest ones - sometimes negative values - at 14h. At the monthly mean temperatures the highest differences were in the summer months (>1°C). At the extreme temperatures the monthly mean minimum temperature difference exceeded 2°C in July and the

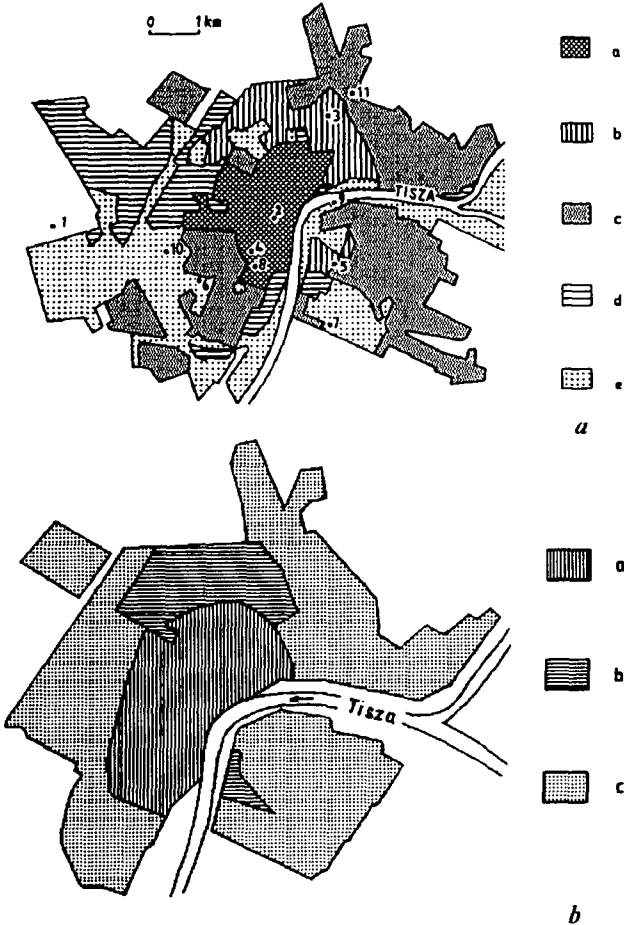


Fig. 2 a. Urban climatological station network of Szeged and its main built-up types. b. The simpler built-up structure draw of the town used earlier /a - town centre (2-4-storey buildings), b - housing estates with pre-fabricated concrete blocks (5-10-storey buildings), c - detached houses with gardens, d - industrial areas, e - green areas/

difference of monthly absolute minimum was even greater. The urban-rural temperature differential is reflected in differences in the number of meteorologically rigorous (very cold) days (urban 9; and 11.5) and in the number of heat days (very hot) (urban 26; and 22).

The Department of Climatology initiated a plan to measure the local climate features of two new housing estates with tall concrete blocks ('Tarján' and 'Odessza') during a month, from May to June, 1973 (Péczely *et al.*, 1975). These data were compared to the ones of the station at the airfield. The information material was incomplete so all that can be established is that the greatest temperature excess appeared at night. During the day the temperature of the housing estate with a lot of trees ('Odessza') was lower with 1.5°C on average than that of the other one. The advantageous effect of the urban afforestation was verified because it decreased the heat load of the human body even in the warmest time of the day.

Five years later a doctoral thesis (Sindely, 1978)

used 5-year temperature and humidity data sets (1967-1971) and revealed that the annual average minimum temperature at the urban station was 1.6°C higher than the annual average at the rural site. The differences of maximum temperatures were smaller and they equalized during the year. The greatest differences of temperature excess appeared at 01h in summer and

at 07h in winter with the means of 1.4°C and 1°C, respectively. The relative humidity differences showed that the town was drier than its surroundings in winter, in early spring and at the end of summer. Finally, the author found only insignificant vapour pressure differences.

In 1977 a network of meteorological observation stations was established in the town and data were collected between July 1977 and May 1981. Thus, there are three years whose data sets were complete. Air temperature, humidity (3 or 4 times a day), maximum and minimum temperature and precipitation were measured. The stations more or less represented the different built-up areas of the town (Fig. 2). The 11 different observation sites and their features were as follows:

- The station, which is free from urban climate modification effects (Station 1 = Aerological Observatory of Hungarian Meteorological Service), is situated at a distance of 4.4 km to the west of the town centre. The surrounding area is a cultivated land and it is considered to be a good example of the rural area. The station has been working till now.
- Station 2 was located in the town centre in a paved square bounded by multi-storey buildings.
- Station 3 was set up in a new housing estate with 5-10 storey buildings built from pre-fabricated concrete slabs.
- Station 4 was beside the 3-storey University building and in this way it represented the climate of streets with more-storey buildings built from traditional materials.
- Station 5 was located in the grovy garden of the Children's Hospital bounded by busy streets.
- Station 6 was in the suburb to the south-west of the town centre.
- Station 7 was set up at the south edge of the town in the University Botanical Garden.
- Station 8 was between the town centre and the suburb with detached houses and gardens.
- Station 9 on the river bank represented the modification effects of Tisza.
- Station 10 was situated in a site with small lakes and natural vegetation.
- Station 11 was in the suburb to the north-east of the town centre.

The following thesis (Vámos, 1979) investigated 10-year temperature and humidity series of the station at the airfield and the station on the top of the University Building (1962-1971). The urban heating effect was the most significant in summer and in autumn. The monthly mean temperature excess were highest in August (0.86°C) and in October (0.89°C). The monthly mean minimum temperature excess was the greatest also in August (1.58°C). Such characteristic picture did not take form in the case of maximum temperatures. The relative humidity differences were the greatest in September (-6.4 %) and in October (-7.0 %), which were in negative accordance with the differences in the heat excess. The vapour pressure differences were negligible. The further part of the thesis used the monthly mean minimum and maximum temperatures of eight stations of the station network in 1978 were used because the network had already serviced data at that time. Station 1 was the rural station (and this application will be used in each of the works mentioned later). The spatial distribution of the monthly mean minimum temperatures showed that the pattern of excess

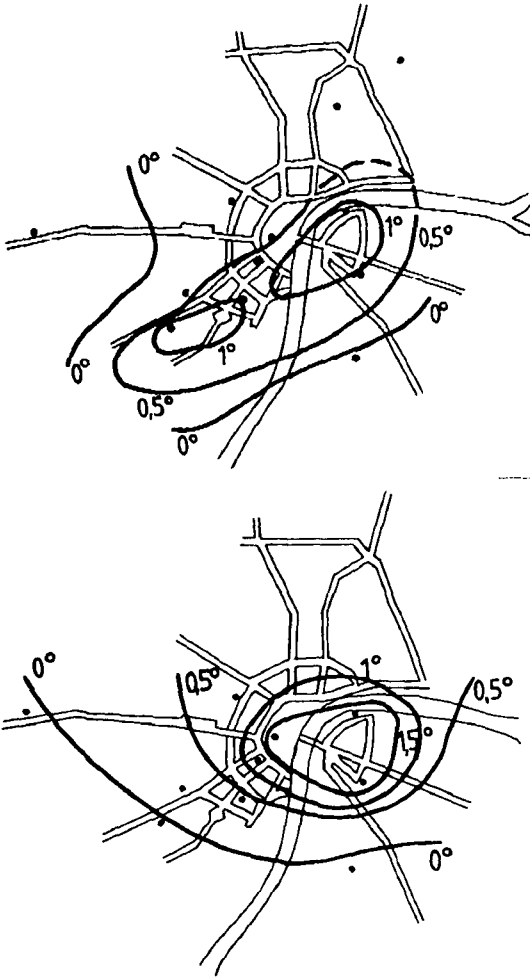


Fig. 3 Isotherms of mean minimum temperature differences in winter (Januar, Februar and December, 1978) and in summer (June-August, 1978) (after Vámos, 1978)

the exception of Station 3 which is located in the town centre.

Pelle (1983) discussed the establishments of Károssy and Gyarmati after a short overview of the urban climate of Szeged. Then the author examined the influence of a strong

expressed itself more strongly in summer, the isolines became denser towards the centre. In winter the isolines showed smaller differences (Fig. 3).

Next year a paper used longer data series of the station network than the previous one (Károssy and Gyarmati, 1980). The minimum and maximum temperature values of the cloudless and calm days between 1977 and 1979 were examined. There were 123 days in this period which were all connected with anticyclonic weather types. The authors grouped the temperature values by seasons and drew isolines of urban-rural differences. The patterns were better defined in winter in both cases. At that time the minimum differences exceeded 3°C and the maximum ones exceeded 2°C in the town centre (Fig. 4).

The next thesis (Gyarmati, 1981) partly contained the results of the previous paper and partly deduced further establishments from the data series of the station network (1979-1980). The examination of minimum and maximum temperature differences of days with advection grouped by seasons exhibited that the mean differences are smaller than 1°C every season. Thus the ventilation of the town in the days with advection was unambiguous. The relative humidity values observed at 13h at the rural and three urban stations showed that the mean urban values were higher than the rural ones in each season, with

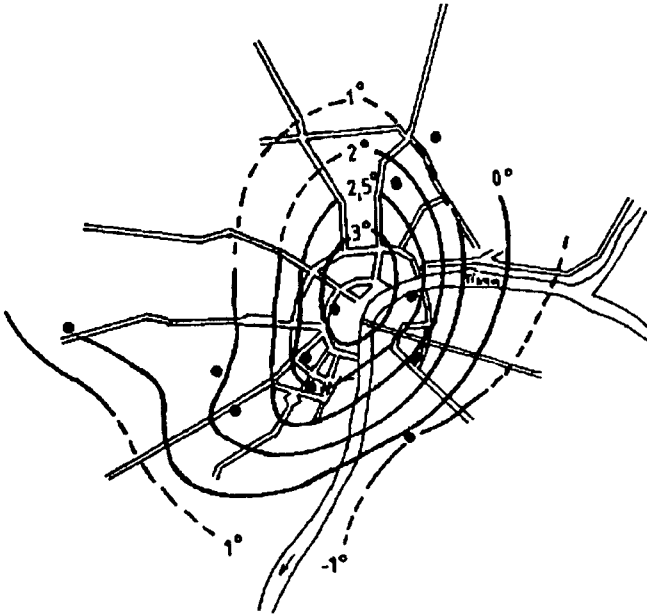


Fig. 4 Isotherms of daily mean minimum temperature difference in winter (after Károssy and Gyarmati, 1980)

cold front of 19 February, 1978 on the urban-rural difference of minimum temperature in the next 3 days. The isolines of the differences were drawn for each day (Fig. 5). On the 19th February the differences were normal, on the 20th it increased (in the centre the excess was 8.3°C!), then they gradually decreased on the 21st and 22nd. That is the town took over the energy from its surroundings with delay, which was advantageous from human bioclimatological aspect. So it can be stated that highly remarkable temperature differences can develop in certain macrosynoptical types between the town and its surroundings.

Another paper at that time (Zsiga, 1983) determined the built-up types in the town (Fig. 6). The area of big town type is the largest among the cities in the south-eastern part of the Great Hungarian Plain. It can be divided into parts: shopping, administrative, university and residential districts. It is difficult to separate the area of big and small town types because there are a lot of multi-storey houses in the latter area. This type also occupies a large territory. The surface of concrete housing estate type is similar to the previous one. Its location is not near but a long way from the town centre, it is in the former half-agricultural belt. The suburb type has the largest area. Its parts can be distinguished as a part of inside and as a part of outside the town circle dam. The author found good relationship between the built-up types and the distribution of differences of winter minimum and maximum temperatures (Fig. 6).

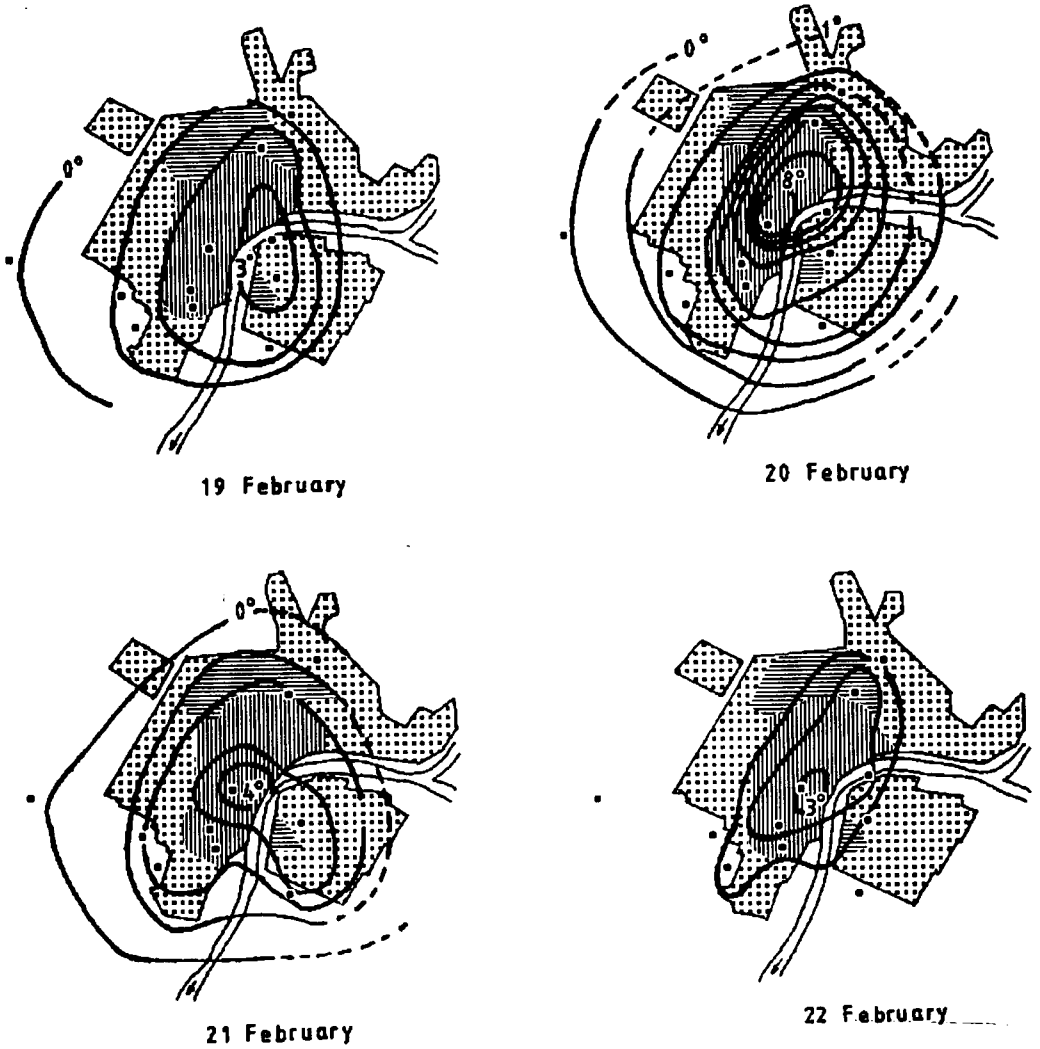


Fig. 5 Isotherms of daily minimum temperature difference in the days after a cold front 19-22 February, 1978) (after Pelle, 1983)

His paper five years later (Zsiga, 1988) dealt with the modifying effect of the town on the wind-directions. The frequencies of wind-directions measured on the top of the University

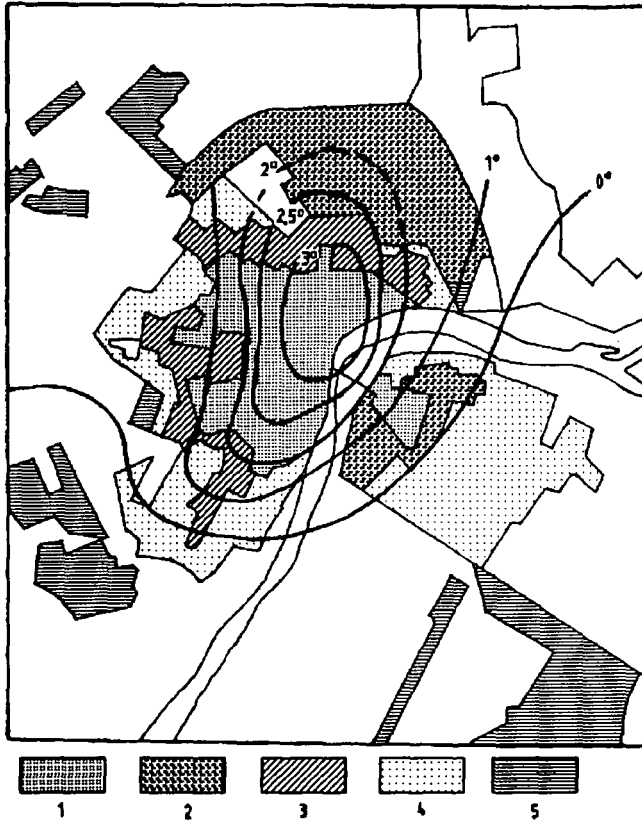


Fig. 6 The isotherms of daily mean minimum temperature difference in winter and morphological map of Szeged: 1 - big town type, 2 - concrete housing estate type, 3 - small town type, 4 - suburb type, 5 - village type (after Zsiga, 1983)

Building between 1931 and 1940 represented the urban conditions, while the frequencies measured at the airfield between 1971-1980 represented the rural conditions. The mean monthly, seasonal and yearly data showed that the wind-directions of north-west and south-east prevailed in the centre while northerly and southerly ones prevailed in the surroundings. That is the prevailing wind-directions in the town formed as a function of built-up conditions.

By the early years of the 1980s an enormous quantity of climatological data of the urban station network was accumulated. Only a small part of this data set was elaborated till the early years of the 1990s thus, it was necessary to make further analyses with more aspects. The work continued in 1992 with the investigation of the temperature means of days without advection between 1978 and 1980 (Unger,

1992a). 278 such days were found and the spatial distribution of the seasonal mean differences showed that the town centre was warmer than the rural areas from 1.5°C to 2°C every season, in autumn the difference even exceeded 2.5°C (Fig. 7).

That year Unger (1992b) examined the relationship between the urban morphological types and the urban heat excess from 1978 to 1980. The monthly mean temperature differences of 6 stations (1, 2, 3, 4, 5 and 6) representing different built-up areas (Fig. 2) reflected built-up

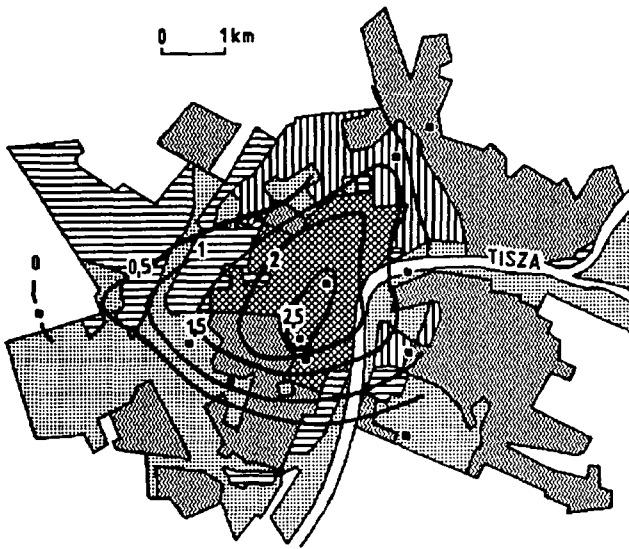


Fig. 7 Spatial distribution of the mean daily temperature difference in autumn (1978-80)

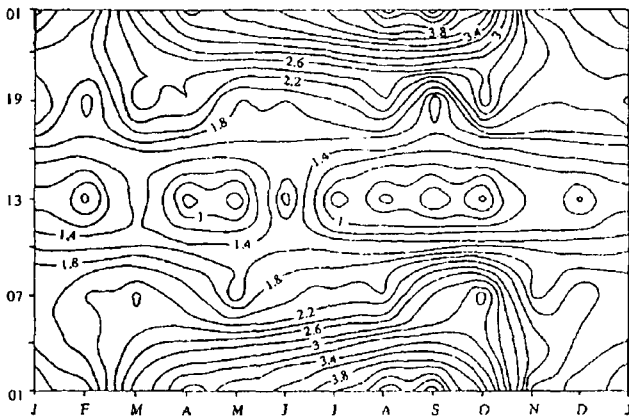


Fig. 8 Isopleths of the temperature excess of Station 2 (1978-80)

densities. Values differed by months and by observation times. The temperature increasing effect of the town was the most obvious in the town centre (Station 2). The largest difference was manifested at 1h in early autumn (Fig. 8). The ranking of built-up types as a function of decreasing heat excess were as follows: Station 3 (housing estate with tall concrete buildings), Station 4 (loosely built inner area), Station 5 (area between housing estate with tall concrete buildings and outskirts), and finally, Station 6 (outskirts).

A paper one year later (Unger, 1993) investigated the urban influence on vapour pressure. The daily and annual variation of urban-rural differences were exhibited using the vapour pressure values of urban (2) and rural (1) stations, which were observed four times a day between 1978 and 1980. The town was more humid than its surroundings during the whole year (Fig. 9). This urban humidity excess was explained by the different energy-balances, the different evaporative surfaces available and the influence of the urban traffic. Close relationships existed between the humidity difference and partly the nocturnal heat island intensity, partly the aridity index, partly the water temperature of the River Tisza.

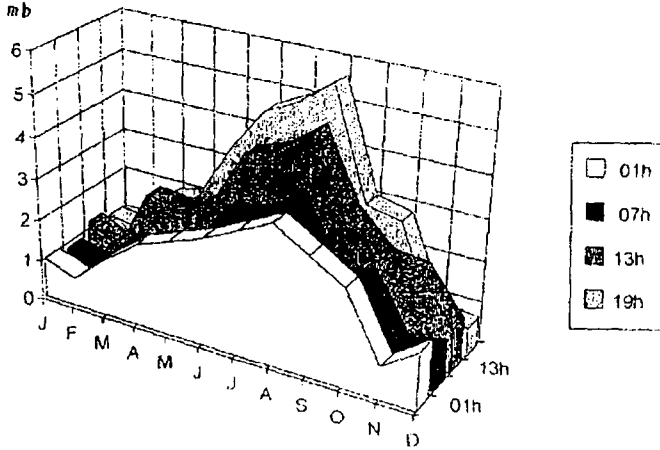


Fig. 9 The annual variation of water pressure excess at different observation times (1978-1980)

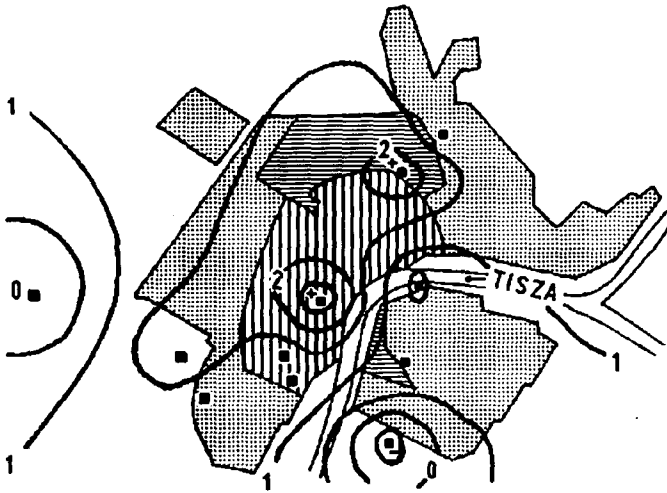


Fig. 10 Spatial structure of the urban heat island in September (1978-1980) (°C)

Unger and Csáki (1994) described the urban effect of Szeged on daily minimum temperature values in 1980. The characteristics of the heat island were examined by revealing relationships between the heat island intensity (temperature difference between rural and town centre sites) and cloudiness, wind speed at 01h and weather types. For strong development of heat island the anticyclonic weather types, little or no cloud and less than 2 m/s wind speed were favourable. The monthly mean urban-rural differences of minimum temperatures at the stations of the network between 1978 and 1980 clearly showed that the temperature excess increased towards the centre with a secondary warm pocket in the housing estate with tall concrete buildings, and was greatest in August, in September (see Fig. 10) and October.

The next paper (Unger and Ondok, 1995) examined the influence of different built-up areas on the spatial distribution of the number of summer, winter and frost days, as well as of the dates of the last and first frost and the length of the frost-free

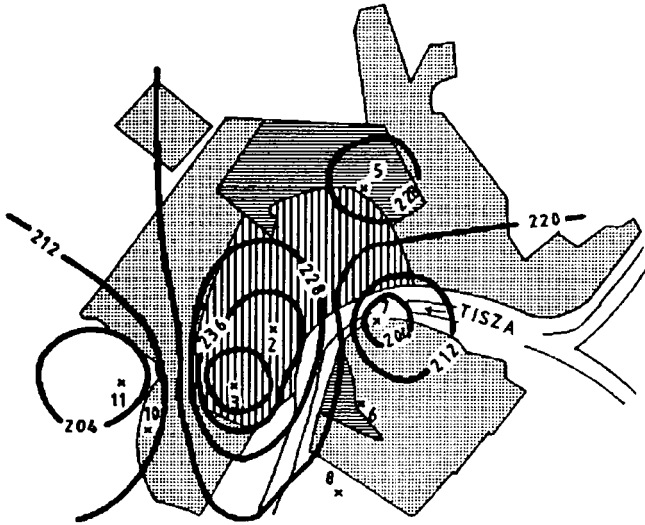


Fig. 11 Spatial distribution of the number of summer days (1978-1980)

period. The investigation was based on the data series of the urban station network during a three-year period mentioned above. The distribution patterns largely depended on the density and the building materials of the built-up areas, and the influence of large water bodies were rather significant because they tempered the extremes (Fig. 11).

Unger (1995a) analysed the influence of the medium-sized town on the bioclimatic comfort of individuals which is mainly determined by air temperature and humidity values. With the help of a suitable measure, the

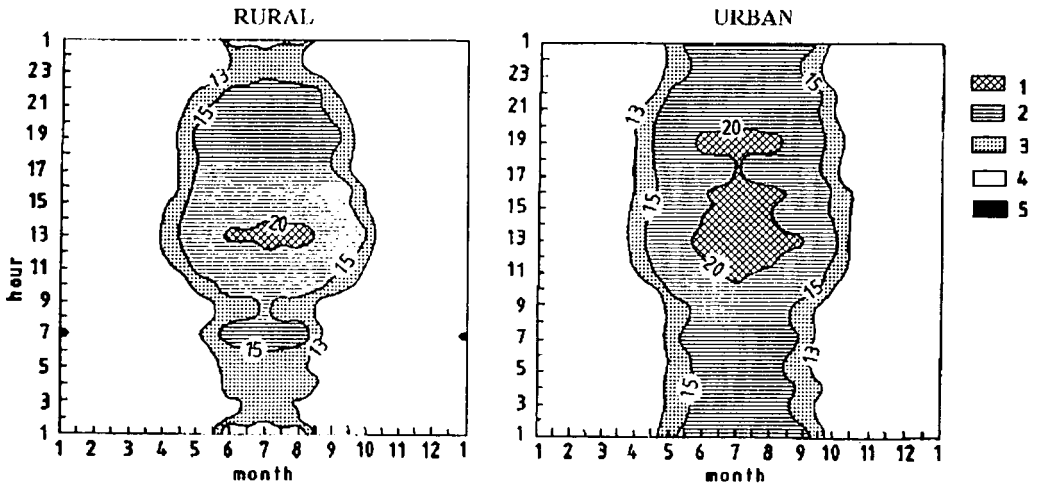


Fig. 12 Isoleths of mean rural and urban  $T_{III}$  (types: 1 - hot, 2 - cool, 3 - cool, 4 - cold, 5 - very cold)

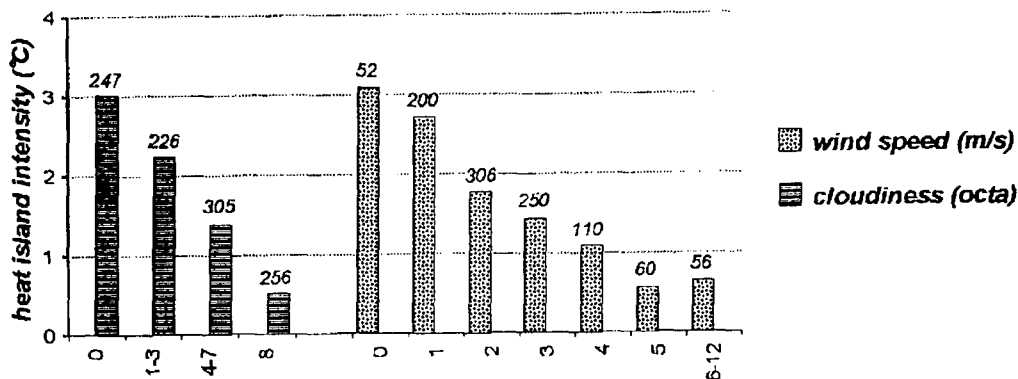


Fig. 13 Average heat island intensity as a function of cloud amount and of wind speed and the numbers of the days by categories (italics numbers) (1978-1980)

thermohygrometric index of Thom (*THI*) and its class types, the author demonstrated the differences of the annual and diurnal variation of human bioclimatic characteristics of the urban and rural environments (Fig. 12). The main features of the differences were as follows: considering a whole year as 100 %, in the urban and rural areas 6 and 1 % of the time were in the 'hot' *THI* type, 30 and 20 % were in the (most important) 'comfortable' type, 10 and 12 % were in the 'cool' type while 54 and 66 % were in the 'cold' type, respectively. Consequently, the town modified the main climatological elements inside the general climate of its region so that staying in the city was comfortable for longer than at rural places.

So far the last paper (Unger, 1995b) dealt with the effect of the town on minimum temperatures between 1978 and 1980. The characteristics of the urban heat island effect were examined by revealing of the relationships between heat island intensity and macrosynoptical types, cloudiness, wind speed as well as the combination of cloud amount and wind speed. As the results showed anticyclonic weather situations, little or no cloud coverage, and calm or slight wind were favourable for a strong development of the heat island effect (Fig. 13). In the case of extreme heat islands the domination of anticyclonic weather types was almost absolute.

This is the state of urban climate research in Szeged in January 1996. Work on further important aspects will be continued, partly in the direction of carrying out several new observations.

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