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# IDŐJÁRÁS

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## EDITORIAL

*„Időjárás" (***Weather** *in English) is one of the oldest journals publishing papers in meteorology. Its first aim was to make known to Hungarian scientific community and public what was happening in the country and around the world in this field. For this reason, papers were published in the Hungarian language, in some cases even the proper Hungarian expressions for certain technical terms were introduced on the pages of this journal.*

*After the second world war, it became even clearer than before that meteorology was an international science. Consequently, papers were also published in foreign languages prepared partly by foreign experts. The problem was that articles appeared mostly in Russian and German, and only relatively few in English. This was caused by the political situation at that time and also by the language knowledge of the older generation of meteorologists in this part of Europe. An important change was made in 1980 when it was decided to publish papers only in English and Hungarian. This was very necessary since in the meantime English became the leading international language in natural sciences including meteorology. On the other hand, a new generation was grown up for whom it was evident to speak and write in English.*

*Now, we want to make a further step in the direction of internationalism. Since the beginning of this year, all the papers will be published in English, although we will preserve the traditional Hungarian name of the journal. It is hoped that in this way we will create a really international quarterly forum promoting the east-west information exchange and facilitating the approach of eastern-central Europe to the western world.*

*It goes without saying that good manuscripts prepared in English are needed to realize this purpose. For this reason, all meteorologists and atmospheric scientists in East and West are encouraged to submit their papers to this old but renewed journal.*

*E. Mészáros Editor-in-Chief*

IDŐJÁRÁS

**Quarterly Journal of the Hungarian Meteorological Service,**
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# Development and application of a method for direct measurement of $SO_2$ fluxes

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*(Manuscript received on 21 October 1991)*

A simple method for direct measurements of $SO_2$ fluxes onto a surrogate surface has been developed. While employing a filter technique for the sampling itself, a chemiluminescence method was applied for the $SO_2$ analysis. Laboratory tests on the reliability of the sampling technique by means of a calibration chamber are reported. Some measurements of vertical $SO_2$ concentration and deposition profiles within forest areas are presented in order to demonstrate the applicability of the filter sampling technique developed. Deposition velocities ranging from 0.15 to 0.86 cm/s have been derived. The deposition velocity is not constant with height but depends on the ambient $SO_2$ concentration, which is strongly influenced by characteristics of turbulence and transport within forest areas.

*Key-words:* sulfur dioxide, dry deposition, forest pollution.

## *1. Introduction*

The exchange of pollutants between the atmospheric boundary layer and any surface (vegetation, soil, water, materials) is controlled by transport mechanisms within the atmosphere as well as by adsorption and desorption processes at the surface (*Garland*, 1978). The dry deposition of trace constituents has to be considered as a very important cleansing mechanism for the atmosphere. Close to industrial sources the contribution of dry deposition to the total sulfur deposition rate is estimated up to 80 per cent (*Kuttler*, 1982).

### *1.1. Definition of the deposition velocity*

The pollutant flux generally is described as being proportional to the referring concentration gradient. Assuming this gradient is directed vertically and the concentration of a pollutant disappears at any surface (*Flothmann*, 1982):

$$F \sim c\,(z) - c\,(z_0, \text{ whereby } c\,(z_0) = 0$$

leads to the simple relationship:

$$F \sim c\,(z)$$

respectively:

$$F = v_d \; c\,(z)$$

$c\,(z)$ = concentration of the pollutant at a given height $z$ [$\mu g/m^3$]
$F$ = pollutant flux [$\mu g/m^2$ s]
$v_d$ = constant of proportionality, defined as deposition velocity [cm/s]

The deposition velocity depends on the effectiveness of the pollutant transfer, which is governed by the stability of the atmosphere and windspeed, as well as on the physical and chemical properties of the particular surface. Analogous to Ohm's law, a pollutant flux can be treated as counteracted by various transport resistances arranged in series (*Roth,* 1975):

$$r = r_t + r_l + r_s$$

$r_t$ = turbulent transport resistance [s/cm]
$r_l$ = diffusive transport resistance [s/cm]
$r_s$ = surface resistance, determined by the special properties of the surface (e. g. pH, moisture conditions . . .)

The sum of $r_t$ and $r_l$ is defined as atmospheric resistance $r_a$. *Fig. 1* shows a scheme of the various transport resistances according to *Fowler* (1980).

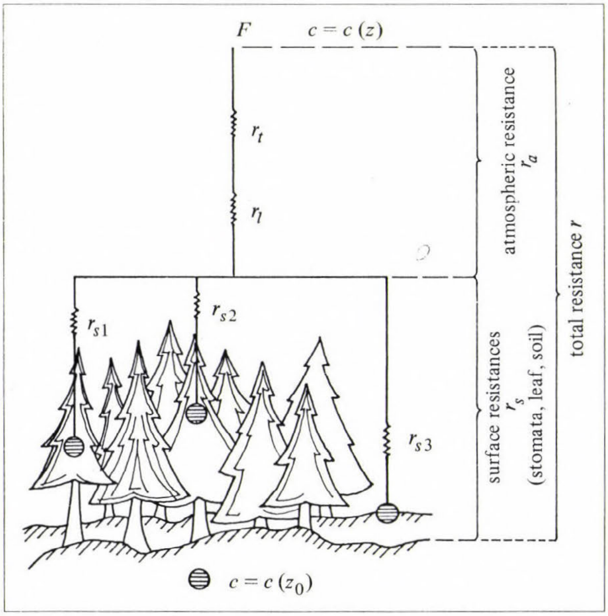

*Fig. 1:*
Scheme of transport resistances (*Fowler,* 1980).
$F$ = pollutant flux,
$c\,(z)$ = concentration of the pollutant at a given height $z$,
$c\,(z_0)$ = concentration of the pollutant at any surface

The deposition velocity can be explained as the reciprocal of the overall transport resistance:

$$v_d\,(z) = (1/r) = (1/(r_a + r_s)) = (F/c\,(z)).$$

## 2. *Measuring method*

The measuring method for $SO_2$ applied in this investigation is based on the technique developed by *West* and *Gaeke* (1956). A 0.1 M sodium-tetrachloromercurate solution

(TCM – $Na_2[HgCl_4]$) is used as absorber for $SO_2$. After absorption the $SO_2$ is converted into sulfite and fixed in a stable, nonvolatile disulfitomercurate complex. According to *WEST* and *GAEKE* TCM is assumed to be a perfect sink for $SO_2$. For the sampling procedure the „DELBAG Microsorban-98" filter material (47 mm dia.) seved as an appropriate surrogate surface.

The TCM impregnated filters were kept in customized filterholders allowing deposition fluxes to both sides of the filters and exposed for a defined period of time. Impregnation and analysis of the filters were performed using a chemiluminescence technique first introduced by *Stauff* and *Jaeschke* (1975) and by *Jaeschke* and *Stauff* (1978).

## 2.1. *Analytical Method*

The chemiluminescence technique is shortly summarized in this section.

The disulfitomercurate complex formed during the $SO_2$ sampling is generally stable. However, treating this complex with an acidic potassium permanganate solution (pH 2.5), dissociation occurs along with a chemiluminescence phenomenon indicating the oxidation of the free bisulfite ion to sulfate. The light yield of this process is proportional to the complexed $SO_2$ sample on the filter.

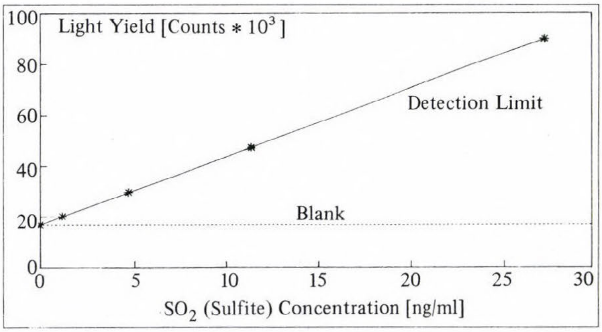

*Fig. 2:* Typical calibration curve for the chemiluminescence technique. The average signal of blank samples is 17 918 counts (impulses). The detection limit, defined as blank counts plus 3σ standard deviation of the noise, is 22 428 counts, corresponding to 1.2 ng $SO_2$ (sulfite)/ml

To calibrate the chemiluminescence effect a standard sulfite solution is used diluted with TCM for stability purposes. A set of standards in the range 2–80 ng complexed $SO_2$ (sulfite)/ml is achieved by further dilution of the primary standard with 0.1 M TCM. Prior to any measurements the calibration of the chemiluminescence instrument took place (*Fig. 2*).

## 2.2. *Filter sampling*

In order to avoid contamination sealed filter holders were kept in an airtight box during transportation to any field site. *Fig. 3* shows exposed filter holders.

## 3. *Laboratory experiments*

Prior to any field experiments the applicability of the sampling method had to be verified. Therefore, various laboratory tests were undertaken using a calibration chamber to provide controlled and definite conditions (*Fig. 4*).

Ambient air, purified by means of an activated charcoal filter, was used to flush a vertical oriented glass tube (20 cm dia.) at a mean mass flow of about 100 l/min. Within the calibration chamber this carrier gas was homogenously mixed with controlled rates of 99.975 % pure $SO_2$. By using a flexible tension ring the filter holders containing the impregnated filters were exposed into the laminary $SO_2$ flow inside the glass tube. To adjust for different relative humidities any given fraction, up to the total amount of the purified airstream, was allowed to bypass through a set of four thermostated bubblers. $SO_2$ concentration, temperature and relative humidity within the glass tube were recorded continuously. Concerning the $SO_2$ deposition, the results of these investigations gave information on:

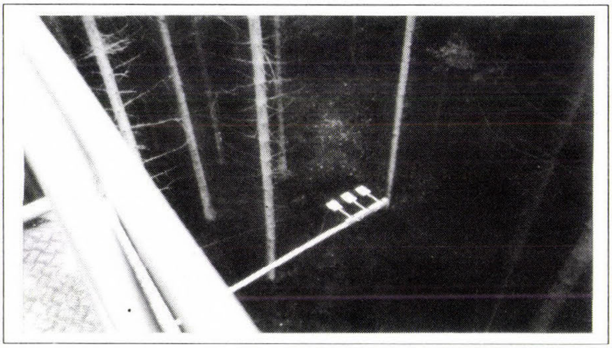

*Fig. 3:*
Exposed filter holders. The measurements preferably took place at different heights on specially equiped measuring

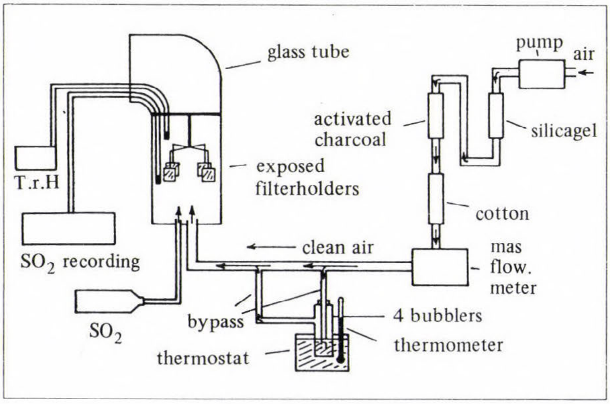

*Fig. 4:*
Scheme of the calibration chamber

- the reproducibility of the sampling method;
- the dependence on the actual $SO_2$ concentration;
- the influence of temperature and relative humidity;
- the suitable exposure periods during field experiments.

With the exception of $SO_2$ concentration dependence, all results were normalized to a standard $SO_2$ concentration of 50 $\mu g/m^3$ to exclude the influence of different $SO_2$ concentration values during individual measurements.

By simultaneous exposition of four filters under identical conditions the reproducibility of the measurements has been examined (*Table 1*).

*Table 1: Reproducibility (T = 24.7 °C, rH = 51 %, t = 50 min)*

| **Filter ≠** | **Deposition rate [μg/m$^2$ s]** | **Deposition velocity (cm/s]** |
|---|---|---|
| 1 | 0.16 | 0.15 |
| 2 | 0.18 | 0.17 |
| 3 | 0.18 | 0.17 |
| 4 | 0.17 | 0.16 |

An average deposition rate of 0.17 ± 0.01 μg/m$^2$ s (± 5,6 % deviation) has been obtained, leading to a mean deposition velocity of 0.16 ± 0.01 cm/s (±5.9 % deviation). By repeating this experiment on different days, without changing the parameter settings, a maximum standard deviation of 23 per cent was obtained. Therefore one can expect the reproducibility to be better than at least 75 per cent.

*Fig. 5* shows the $SO_2$ deposition rate versus the $SO_2$ concentration. All individual results of the several measurements have been plotted. The correlation coefficient from the linear regression is 0.96. Despite some scatter in the data, the linear relationship between $SO_2$ deposition and actual concentration could be verified.

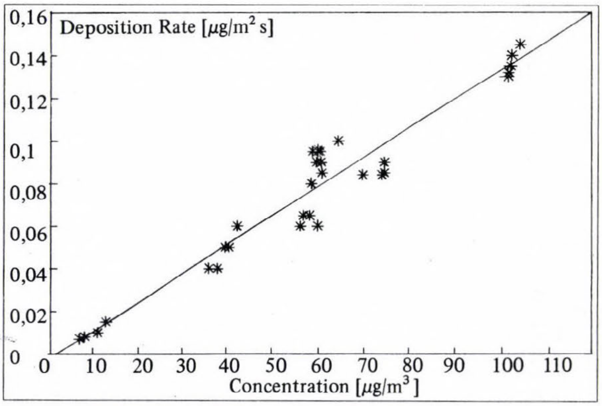

*Fig. 5:*
$SO_2$ deposition rate as function of $SO_2$ concentration. All individual results have been plotted

The relative humidity was varied over the range 33–94 % (T = 22.7°, t = 10–135 min). With regard to a correlation coefficient of 0.82 a significant dependence on the relative

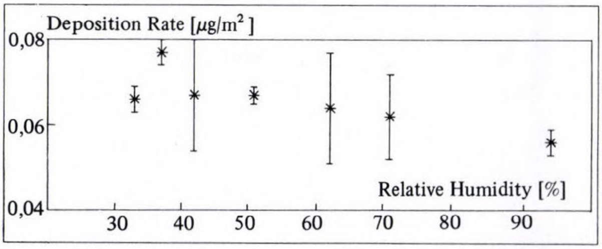

*Fig. 6:*
Influence of the relative humidity on the deposition rate in the range 33–94 %.
*T* = 22.7°C, *t* = 10–135 min.
The concentration has been normalized to 50 μg/m$^3$

humidity was not found (*Fig. 6*). In high relative humidity, however, the impregnated filters are prevented from untimely drying.

No temperature dependence within the range 19–27°C was observed. Due to technical restrictions it was not possible to extend the investigation towards lower temperatures. Applying a linear regression, a correlation coefficient of 0.7 was derived. Therefore, a significant dependence on temperature, within the temperature range investigated, may be discounted (*Fig. 7*).

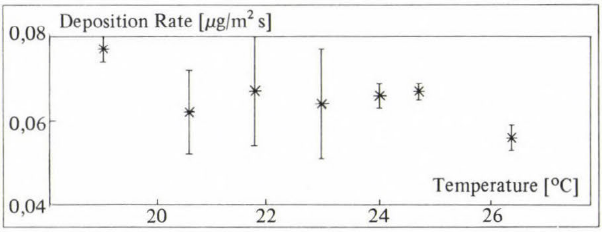

*Fig. 7:*
Influence of temperature on the deposition rate in the range 19–27°C. The concentration has been normalized to 50 $\mu g/m^3$

Further data analysis was concerned with the relationship between $SO_2$ deposition and the exposure period. An additional generalization was achieved by defining five time classes (20, 40, 60, 80, 100 minutes) and combining data from different experiments falling within these classes. *Fig. 8* clearly shows a strong linear dependency of $SO_2$ deposition on exposure time as represented by a correlation coefficient of 0.99. The linearity over the total time scale also shows that the efficiency of the impregnated filters to absorb $SO_2$ remains unchanged at least up to 100 minutes.

However, during field experiments the exposure time is not recommended to exceed an average period of about 50–90 minutes to fulfill analytical demands at low atmospheric $SO_2$ concentrations and to prevent the filters from drying.

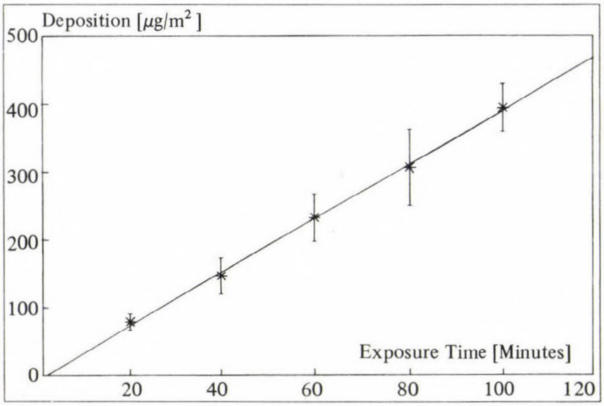

*Fig. 8:*
Deposition at different time classes (20, 40, 60, 80, 100 minutes). The concentration has been normalized to 50 $\mu g/m^3$

Summarizing these results, the presented filter sampling method was applicable for field measurements.

### 4. *Field measurements*

Due to limitations of space, only a selection of field results are presented here. For detailed and complete information refer to *Fähnrich* (1990). All measurements took place at specially equiped measuring towers within forest areas at three different sites in the Federal Republic of Germany.

Tower a. (*Billtalhöhe/Königstein*) is located 20 km NW of Frankfurt/Main (520 m asl, height of the tower = 30 m, maintained by the *Hessische Landesanstalt für Umwelt*, spruce stand). Tower b. (*Göttinger Forst*) is located 5 km E of Göttingen (424 m asl, height of the tower = 43 m, maintained by the *Institut für Bioklimatologie* of the University of Göttingen, beech stand). Tower c. (*Nationalpark Bayerischer Wald*) is located 7 km NE of the small town Spiegelau and about 150 km NE of Munich (840 m asl, height of the tower = 52 m, maintained by the *Lehrstuhl für Bioklimatologie und Angewandte Meteorologie* of the University of Munich, spruce stand).

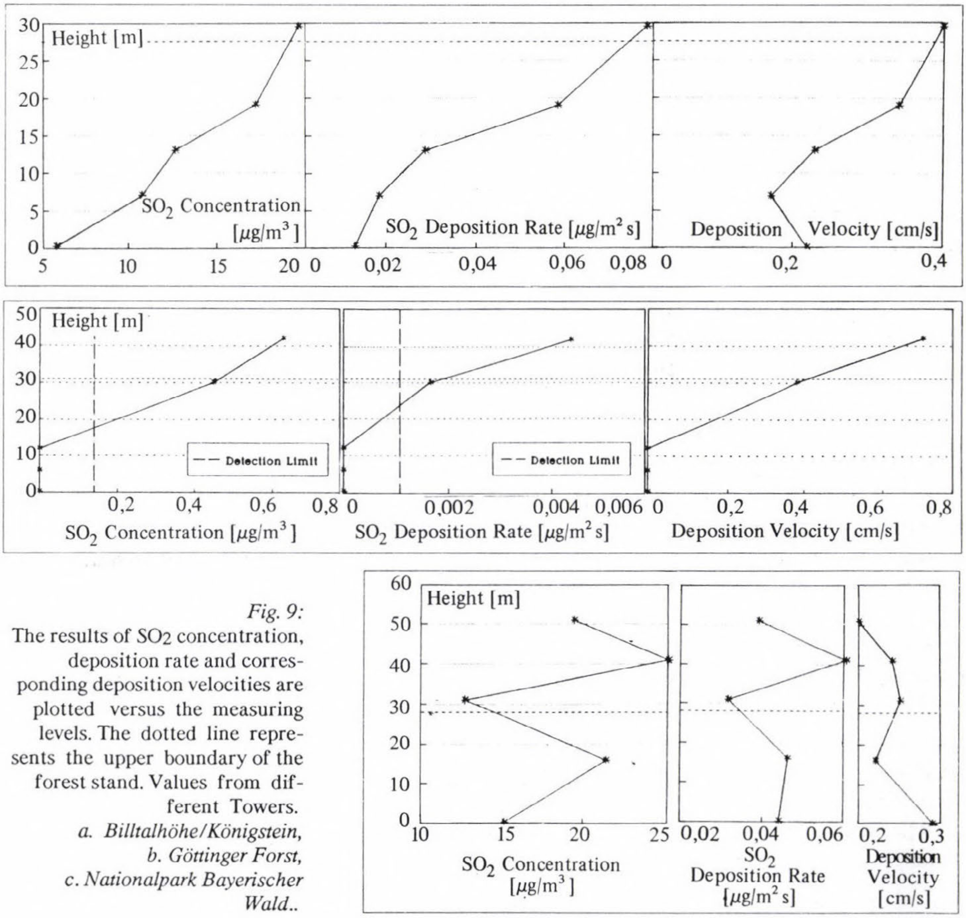

*Fig. 9:*
The results of SO2 concentration, deposition rate and corresponding deposition velocities are plotted versus the measuring levels. The dotted line represents the upper boundary of the forest stand. Values from different Towers.
*a. Billtalhöhe/Königstein,*
*b. Göttinger Forst,*
*c. Nationalpark Bayerischer Wald..*

Individual measurements of $SO_2$ deposition were performed at several levels of the measuring towers. During the deposition measurements samples to determine the actual $SO_2$ concentration in the respective levels were taken by means of an automated air sampling system. Details about this system are published elsewere (*Haunold* et al., 1986). Since this sampling procedure is also based on fixation of $SO_2$ by TCM and since furthermore, both kinds of samples were analyzed in the same way by the chemiluminescence technique, a very unique and comparable set of data is provided. Due to the reproducibility found during calibration chamber tests, the number of exposed filters was limited to two at each measuring level.

### 4.1. *Results of the field measurements*

The results of the measurements of $SO_2$ concentration and deposition rate and the calculated deposition velocities are plotted versus the several measuring levels in *Fig. 9 a., b., c.* The dotted lines represent the upper boundary of the forest stands.

Results of measurements which took place at the site *Billtalhöhe/Königstein* are illustrated in *Fig. 9. a.* Both $SO_2$ concentration and deposition rate show an increase with height. The mean rising rate of the concentration is 0.48 $\mu g/m^3$ per meter and 2.5 $ng/m^2$ s per meter for the deposition rate. The corresponding deposition velocities are lowest directly below the canopy. The higher values close to the ground and within the foliage region indicate a lower transport resistance.

The results of the measuring site *Göttinger Forst* are given in *Fig. 9. b.* Unstable weather conditions in combination with frequent rainfall led to a strong turbulent exchange of air masses which caused extremely low $SO_2$ concentrations, partly below the detection limit defined by the analytical procedure. The vertical profile of $SO_2$ concentration shows a strong decrease towards the soil surface, especially within the region below the canopy. High wind speeds up to 4.4 m/s above the forest stand led to an increase of the deposition velocity. Accordingly, only in the upper two measuring levels deposition rates could be estimated.

*Fig. 9 c.* represents the results of the site *Nationalpark Bayerischer Wald.* The vertical profiles of both $SO_2$ concentration and deposition rate show rather untypical behaviour without clearly directed gradients. Rather stable atmospheric conditions were dominant during this day. Due to the good correspondence between the profiles of concentration and deposition rate, the deposition velocity appeared to be constant, showing a slight decrease with height.

### 4.2. *Discussion of the the results*

The results found during field measurements indicate the strong influence of a forest stand formed by single plants. Very little reliable data are presently available on the characteristics of the plants as $SO_2$ sources and sinks. The interaction of gases with forest ecosystems, especially the input and output of gases during photosynthesis and respiration of the plants, needs further investigation.

The effectiveness of plants to act as a sink for $SO_2$ is also guided by the exchange of the gas through the stomata and cuticula of the plants (*Schaub* and *Knacker,* 1982). *Rennenberg* et al. (1990) reported about $H_2S$ and even $SO_2$ emission from spruce trees under solar radiation. The lack of knowledge concerning the aerodynamical conditions within forest stands creates an additional problem and is a major restriction for a more detailed interpretation of the data.

The deposition velocity corresponds with the ratio of deposition rate and concentration at a given time and place. Higher values for the deposition velocity at constant ambient

$SO_2$ concentration indicate higher fluxes. It is obvious that forest stands are complex systems, without idealized behaviour of $SO_2$ concentration and deposition rates.

The simulation of deposition rates by means of simplified models is not applicable to forest stands. The preconditions (neutral stratification, logarithmic wind profile, soil as definite sink) are not given. The results of the field investigations show that a forest stand, in its entirety, acts as a sink for $SO_2$, to be classified in smaller subdivisions within the stand such as the foliage area or the soil area.

In general, the profiles of measured $SO_2$ concentration and deposition rate are very similar. Assuming the TCM impregnated filters are a perfect sink for $SO_2$, thus ensuring a constant absorption surface ($r_s = 0$), the deposition rate mainly depends on the ambient $SO_2$ concentration and on the atmospheric resistance. Due to the negligable surface resistance of the filters, a maximum rate of $SO_2$ absorption is reached. This is in contrast to natural surfaces, whose surface resistance will cause less absorption. The application of an identical absorption surface, however, provides a better chance to investigate atmospheric transport mechanisms.

A definite relationship between measured deposition rates and certain weather conditions has not been found. The turbulent exchange within forest stands is reduced compared to regions above the stand, so that very often the obtained concentration and deposition values refer to stagnant air masses. However, the results indicate that higher wind speeds cause higher fluxes and proportionally higher deposition velocities. Clearly directed and strictly proportional gradients of $SO_2$ concentration and deposition rate were not found. Due to this, the corresponding deposition velocities turned out not to be constant with height.

### *4.3. Comparison with other methods*

Presently, no results of comparable measurements within forest areas are available. Measurements by means of common methods like eddy correlation or gradient method mostly are used only in one respectively two different levels above the surface. Unlike the filter technique described, these methods do not provide a direct measurements of the $SO_2$ flux.

Apart from that, theoretical gradient models concerning turbulent conditions within forest stands do not exist. So far, a comparison of the filter technique with other methods must be judged as rather limited. In spite of this, the comparison of the measured deposition rates reported here shows a good accordance with results of other techniques (*Table 2*).

*Table 2: Comparison of the measured deposition rates with results of other authors*

| **Deposition rate** [$\mu g/m^2$ s] | **Surface** | **Method** | **Author (year)** |
|---|---|---|---|
| 0.110 | oak/hickory | eddy correlation | *Meyers/Baldocchi* (1988) |
| 0.102 | spruce, 1986 | flux calculation | *Grosch* (1990) |
| 0.112 | spruce, 1987 | | |
| 0.012–1.92 | spruce | lab./wind tunnel | *Dollard* (1980) |
| 0.045–2.22 | pince | | |
| 0.011–0.26 | birch | | |
| -0.17–0.20 | spruce/fir | eddy correlation | *McMillen* et al. (1987) |
| 0.042<br>(min 0.0017,<br>max 0.155) | impregnated filters | filter technique | *Fähnrich* (1990) |

The deposition rates obtained by *Meyers/Baldocchi* and *Grosch* are not calculated for the whole leaf area but for 1 $m^2$ surface area.

## 5. Conclusion

According to the laboratory investigations, the developed filter sampling technique for direct $SO_2$ flux measurements showed the following advantages:

- reproducibility >75 per cent;
- lew detection limit;
- no significant influence of temperature and relative humidity on the sampling method;
- short exposure periods.

The method has been successfully established for field measurements within forest areas. The $SO_2$ concentration and deposition profiles in the forest stands - especially within the crown regions - showed a rather unsteady behaviour indicating the influence of aerodynamical conditions within forest areas. There is no strong indication for anticipating an strict increase of $SO_2$ concentration and deposition rate with height. Therefore, the corresponding deposition velocities were not constant with height.

A strong dependence of the deposition rate on certain weather conditions could not be found. However, high wind speed effected high deposition velocities.

The obtained deposition rates of $SO_2$ are comparable with results of other techniques. Summarizing the results it can be stated that deposition rate and deposition velocity are strongly influenced by aerodynamical conditions within forest areas.

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# IDŐJÁRÁS

**Quarterly Journal of the Hungarian Meteorological Service,**
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# Energy production, economy and greenhouse gas emissions in Hungary⁽¹⁾

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*(Manuscript received on 14 October 1991; revised form on 22 January 1992)*

The aim of this paper is to present the carbon dioxide, nitrous oxide and methane source strengths in Hungary. All the possible anthropogenic and biogenic sources are considered. The carbon dioxide cycle in the air over the country is also calculated. It is found that the quarter of the total carbon dioxide flux into the air (~ 100 $\mathrm{TgCyr^{-1}}$) is due to energy production, while another quarter is liberated by the vegetation. The half of the carbon dioxide quantity is released by the soils. The sum of methane emissions is around 1 $\mathrm{TgCyr^{-1}}$. It is dominated by human activities like natural gas production and solid waste treatment. On the other hand, the emission of nitrous oxide (18 $\mathrm{GgNyr^{-1}} = 0.018\ \mathrm{TgNyr^{-1}}$) is controlled by the release due to fertilizer use. In the paper the possibilities of the reduction of carbon dioxide, methane and nitrous oxide emissions are discussed.

*Key words:* Economy and air pollution, greenhouse gases, Hungary

## *1. Introduction*

The composition of the atmosphere plays an important part in the control of climate on the Earth. This is caused by the fact that the transfer of short-wave solar and long-wave terrestrial radiations in the air is affected by atmospheric constituents. On the other hand, the composition is controlled by the material flows in nature, called the biogeochemical cycles. During geological times a natural equilibrium has been developed between atmospheric sources and sinks of different components leading to a constant composition.

This natural equilibrium is now jeopardized by human activities releasing a large amount of materials (pollutants) into the atmosphere. Fortunately, man is not able to modify the atmospheric concentration of main constituents (oxygen and nitrogen) owing to their huge quantities. However, the levels of so-called trace substances, giving less than 0.04 % of

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(1) Some parts of this paper are published as a chapter in the book entitled *Global Climate Change: Implications, Challenges and Mitigation Measures (Pennsylvania Academy of Sciences, Pennsylvania, U. S. A.)*

the volume of the dry air, can considerably be increased. The modification of the amount of gases (carbon dioxide, methane, nitrous oxides etc.) absorbing the thermal radiation emitted by the Earth's surface is dangerous in particular. The residence time of these greenhouse gases is relatively long (10–100 years) compared to the characteristic mixing time of the atmosphere. Consequently, they are well-mixed in the entire atmosphere causing world-wide problems like global warming.

This does not mean, however, that anthropogenic warming is solely a global issue. For solving this international problem all nations have to determine their greenhouse gas release and should study the possibilities of its mitigation measures. Moreover, the impacts of global warming in its area and to make all the feasible steps to avoid or reduce harmful effects.

The aim of this paper is to discuss the greenhouse gas emission (carbon dioxide, methane and nitrous oxide) for a small country, Hungary. Since greenhouse gas emissions are in close relation with energy production as well as with agricultural and industrial activities of a certain area, the economy of the country is also discussed in some detail. Finally, possibilities are proposed to reduce the emissions of the greenhouse gases discussed.

## *2. Carbon dioxide emission and budget*

### *2.1. Biogenic sources*

Carbon dioxide is the most important nutrient for plants, 90 % of their dry matter come from $CO_2$ fixed by photosynthesis (*Fung* et al., 1987). A part of carbon dioxide fixed is emitted by the plants by respiration. The release by respiration can be estimated on the basis of net primary production of the vegetation of different kinds (*Bolin* et al., 1977). If we assume that the total quantity of carbon assimilated is shared equally by net assimilation and respiration and consider the area of Hungary covered by different plants and forests, for the Hungarian $CO_2$ emission (expressed in C) by respiration of the vegetation a figure of 27.6 $Tgyr^{-1}$ is obtained. 70 % of this emission are due to the agriculture, that is related to human activities.

The respiration of man and animals also results in carbon dioxide emission. This emission can be determined by measurements of the $CO_2$ quantity exhaled by humans and different animals. The results of such measurements show that for mammals the $CO_2$ produced is proportional to the weight of the body. Taking into account the results of *Freeman* (1973) as well as the number of people and animals in Hungary we calculated a value of 2.4 $TgCyr^{-1}$ for this emission. The major part of this $CO_2$ source is caused by the respiration of man (28 %) and pigs (33 %). This latter is due to the importance of pigs in Hungarian animal husbandry (their number is 8.7 million).

Soil also provides an important biological carbon dioxide source. This source consists of three parts: microbiologial activity in soil, root respiration and decomposition of organic matter on the surface. In the literature empirical relationships can be found for estimation the strength of this complex source. These relationships are given for different vegetation types (*Fung* et al., 1987), including cultivated areas (*Hampicke*, 1980). Considering this information and the area of the vegetation cover of different types, the calculation results in a $CO_2$ emission between 38.6 and 47.7 $TgCyr^{-1}$. The uncertainty comes from the fact that a rather wide range of emission rate for agricultural soils (10–150 $gCm^{-2}yr^{-1}$) is given in the literature (e. g. *Hampicke*, 1980). On the basis of our calculations forests control the emission of $CO_2$ (73–90 %).

## 2.2. *Energy production and industry*

As it is well-known the combustion of fossil fuels is the most important world-wide anthropogenic carbon dioxide source. This emission depends on the quantity and carbon content of the fossil fuels used as well as on the fraction of carbon which can be oxidized (*Rotty,* 1987). For this reason the emission factors published in the literature are slightly different.

The first column of *Table 1* gives the energy produced in Hungary in 1987 by burning fossil fuels of different types. It should be noted that the sum of the values tabulated does not give the total energy use of the country. This is due to the fact that 110 PJ was produced in 1987 by a nuclear power plant, while an important quantity of electricity (106 PJ) was imported from the Soviet Union. The second column of the table shows the $CO_2$ emissions published by *Lévai* and *Mészáros,* 1989. It can be concluded that an important part of the total emission is caused by the use of solid fossil fuels (44 %). Taking into account the number of the population a value of 2.24 $tCyr^{-1}$ per capita can be calculated for Hungary. This is about two times more than the world average, but not too large compared to the values for developed countries (*Rotty,* 1987).

*Table 1:*
*Hungarian energy structure and carbon dioxide emissions*
*(Lévai and Mészáros, 1989)*

| **Fossil fuel** | **Energy (PJ)** | **Emission ($TgCyr^{-1}$)** |
|---|---|---|
| Solid | 359 | 10.5 |
| Liquid | 391 | 8.0 |
| Gaseous | 389 | 5.4 |
| Total | 1139 | 23.9 |

The Hungarian $CO_2$ emission per energy unit (17.5 MtC/EJ) is rather similar to the global mean value. Also, the Hungarian energy demand per capita (127 $GJyr^{-1}$) is acceptable considering the values for other countries. The problem is caused by the unefficient use of the energy produced. This is illustrated by the very high $CO_2$ emission per capita during the production of a value of one U. S. dollar. This figure is around 1000 $gCyr^{-1}$,which is considerably higher than the corresponding values for developed countries.

Finally, it is to be noted that cement industry and treatment of waste materials also emit carbon dioxide into the atmosphere. Calculations show, however, that for Hungary the strength of these sources can be neglected compared to the release during energy production (0.6 and 0.1 $TgCyr^{-1}$).

## 2.3. *Atmospheric budget*

As it was mentioned vegetation is a net carbon dioxide sink. Like $CO_2$ quantity released during respiration, the net sink can be determined on the basis of the mass of dry matter formed in plants (*Bolin* et al., 1977). Considering the appropriate data a value of 55.0 $TgCyr^{-1}$ is calculated for the country. A negligible sink is provided by the removal of $CO_2$ from the air by precipitation fall. Therefore this term (0.03 $TgCyr^{-1}$) is not considered in the following discussuion.

*Table 2* summarizes the results of our study. One should say, however, that the figures given can be considered with some caution. While the error of the $CO_2$ emission by fossil fuel burning is not greater than ± 15 %, the uncertainty of other terms reaches probably ± 50 %. In spite of this problem it can be accepted on the basis of values tabulated, that atmospheric carbon dioxide budget is positive over Hungary: about two times more carbon is released than removed. This means that even if the energy production were entirely stopped, biogenic sources would produce more carbon dioxide than the quantity removed by the vegetation. Unfortunately, it is not possible to determine the role of man in the unbalance of biological sources. Agricultural activities produce an important amount of carbon dioxide at present, but we do not know the biogenic emission of this area before the beginning of intensive agriculture. Considering the fact, however, that an important part of the territory of the country was covered by forests about thousand years ago (the present forested area is only 17 %), one can speculate that deforestation has played some part in the development of the present situation.

*Table 2: Atmospheric carbon dioxide budget over Hungary*

| | **Sources ($TgCyr^{-1}$)** | **Sinks ($TgCyr^{-1}$)** |
|---|---|---|
| Vegetation | 27.6 | 55.0 |
| Man and animals | 2.4 | |
| Soils | 38.6 - 47.7 | |
| Energy | 23.9 | |
| | 92.5 - 101.6 | 55.0 |

### *3. Methane emission in Hungary*

In the case of methane it is again very difficult to differentiate natural and anthropogenic sources. This means that even a large part of biological methane release is due to human activities.

Animal husbandry is one of these biological sources, which modifies considerably the emission of this gas. If we know the quantity of feedstuff consumed by ruminants their methane production can be calculated. In *Table 3* the input data necessary for this calculation as well as the results obtained are tabulated. It follows from this information, that sources in Hungary owing to ruminants emit into the air a $CH_4$–C quantity of 0.125 Tg per year. In spite of the fact that the Hungarian live-stock farming in this category of animals is dominated by sheeps, an important fraction of methane emission is caused by cows.

*Table 3: Estimation of methane production from entertic fermentation of ruminants*

| **Ruminants** | **Feed uptake (dry matter kg)(1)** | **$CH_4$ prod.($gCH_4$/day per capita)(2)** | **Number of animals $10^3$** | **$CH_4$ yield ($MgCyr^{-1}$)** |
|---|---|---|---|---|
| Calves | 2.8 | 64 | 214 | 3.8 |
| Heifers | 8.3 | 173 | 395 | 18.7 |
| Cows | 10.6 | 219 | 219 | 45.4 |
| Beef cattles | 13.0 | 266 | 266 | 26.3 |
| Sheep | 1.7 | 43 | 2337 | 27.5 |
| Deer | 3.0 | 68 | 55 | 1.1 |
| Fallow deer | 2.0 | 49 | 14 | 0.2 |
| Roe deer | 1.0 | 29 | 227 | 1.8 |
| Moufflon | 1.0 | 29 | 9 | 0.1 |
| **Total** | | | | 124.9 |

(1) Kakuk and Schmidt, 1987 (2) Baintner, 1957

Under anaerobic conditions methane is also formed in soils mostly in marshy areas. Concerning human activities the most important global methane source of this kind is provided by paddy fields. The strength of this release depends on many factors as discussed by several authors (*Ehhalt,* 1985; *Holzapfel–Pschorn* and *Seiler,* 1986). These factors include the content of organic matter and temperature of soils as well as the physiological activity of the vegetation. Mathane emission can also be observed in the case of fresh waters, medows, forests and different cultivated lands. Calculations made on the basis of the information on emission factors available (*Ehhalt,* 1985; *Holzapfel–Pschorn* and *Seiler,* 1986) and of the areas of appropriate surfaces in Hungary show that the total methane emission from soils is between 0.05 and 0.1 $TgCyr^{-1}$.

The uncertainty of these figures makes it evident that the error of such calculations is at least a factor of 2. Due to the structure of the agriculture the emission from paddy fields is not too important in this country: it is less than about 0.02 $Tgyr^{-1}$ expressed in carbon. On the other hand, a rather large amount of $CH_4$ is released into the air by reeds, lakes, fish-ponds and water catchments. The upper limit of this emission is around 0.05 $TgCyr^{1}$.

Methane molecules are also released into the air from solid and liquid waste materials. In 1986 the total quantity of solid wastes in Hungary was equal to 18.5 $10^6$ $m^3$. According to *Bingemer* and *Crutzen* (1987) under anaerob circumstances about 80 % of the organic matter is transformed and results biogas, the 50 % of which is $CH_4$. Such conditions are created if the solid wastes are deposited in landfills or in open dumps. Taking into account this information and the composition of the waste quantity given above, a yearly methane formation of 0.189 TCg can be calculated. It can be assumed, however, that only a fraction (a value of 0.7 of this mass) (*Jager* and *Peters,* 1985) is released to the air, a $CH_4$-C emission of 0.132 $Tgyr^{-1}$ is obtained for this source strength.

For liquid waste materials similar calculations were carried out. In these calculations were carried out. In these calculations the organic dry matter content (0.3 $kgm^{-3}$) and biodegradability of 3 % of the wastes were taken into account. The results indicate that this methane source strength has an order of $10^{-3}$ $TgCyr^{-1}$, which can be neglected compared to the magnitude of other terms.

The main component of natural gas used for energy production is methane. Due to this fact during the mining and distribution of natural gases some methane quantity is released into the air. According to the literature (CONCAWE, 1986) and information given by the Hungarian Trust of Gas Industry methane release during mining is equal to 2 %. Since 86 % of natural gas exploited in Hungary (7.1 $10^9$ $m^3$) is $CH_4$ the loss in this way can easily be calculated. In Hungary an important part of natural gas (4.8 $10^9$ $m^3$ containing 90 % of $CH_4$) is imported from the Soviet Union in pipe- line systems. At the joining points of pipe-lines mainly in the case of low pressure system supplying houses about 3 % of the gas is lost (CONCAWE, 1986). This figure can also be applied for the transport of natural gas mined in Hungary. Taking into account all these values we calculate a total $CH_4$–C release of 0.234 $Tgyr^{-1}$.

Coal and lignite mining also provides a methane source since coals contain a certain amount of this gas. This amount is 5 $m^3$ per tons of coal on an avergage (*Ehhalt,* 1985), 50–100 % of this methane comes to the air during coal mining. For methane content of lignites we estimated the same value of 5 $m^3$/tons and assumed that 25–75 % of this methane is escaped into the air. The total quantities of coal and lignite exploited yearly in Hungary are 15.3 Mt and 7.0 Mt, repectively. This results in a $CH_4$ emission between 0.025 and 0.055 $TgCyr^{-1}$.

Considering the results discussed one can conclude that the total methane emission in Hungary is around 1 $TgCyr^{-1}$. About a quarter of this emission is due to natural gas production and distribution (see *Table 4*). It can also be stated that about 100 times more carbon dioxide-carbon is released into the air than carbon in methane form. This means that mitigation measures must be centered first of all on $CO_2$ emission. This conclusion is even valid if we take into account that for the same concentration increase methane is a more efficient greenhouse gas than carbon dioxide.

*Table 4:*
*Details of Hungarian methane emission*

| Source type | Emission ($TgCyr^{-1}$) |
|---|---|
| Entertic fermentation of animals | 0.125 |
| Soils, water surfaces, marches etc. | 0.054 – 0.093 |
| Soild wastes | 0.132 |
| Natural gas production and distribution | 0.234 |
| Coal and lignite mining | 0.025 – 0.055 |
| **Total** | 0.570 – 1.209 |

For the determination of atmospheric methane budget the sinks of this gas should be estimated. It is well known that methane does not have significant direct sinks, althought $CH_4$ uptake of some types of soils might be important. Methane is primarily removed by oxidation (OH radicals) in the troposphere. In the statosphere $CH_4$ is also oxydized by OH radicals and excited oxygen atoms and they play non-negligible role in the removal of chlorine containing hydrocarbons. Determination the yield of these processes is so uncertain, mainly for a small country like Hungary, that we did not undertake doing it.

## *4. Sources of nitrous oxide*

Nitrous oxide is the most abundant nitrogen compound in the atmosphere. This greenhouse gas is formed in the soils by nitrification and denitrification. The most direct way of $N_2O$ formation is the reduction of nitrate ions by hydrogen in gaseous and ionic form. However, nitrifying microorganisms also produce nitrous oxides during nitrification of ammonium and hydroxylamine, both coming from the decomposition of organic materials (*Brenner* and *Blackmer*, 1981). The emission from different soils treated with N-fertilizers in the form of ammonium sulfate or urea was significant in particular (*Breitenbeck* et al., 1980).

The release of $N_2O$ from the soils not treated with fertilizers can be estimated on the basis of data of *Fenger* et al. (1990) giving the $N_2O$ emissions for unit area of different soils. Using this procedure a value of 2.9 Gg of annual nitrogen emission is calculated for forests and grasslands in Hungary. On the other hand, in 1986 91.2 kg/ha N-fertilizers was used in the country. Taking into account the relationship between $N_2O$ emission and the quantity of different N- fertilizers used (*Fenger* et al., 1990) the calculation results in a 12 $GgNyr^{-1}$ overall emission from Hungarian agricultural lands.

A certain amount of $N_2O$ is also emitted from combustion sources during fossil fuel burning. Applying statistical information on the quality and quantity of different fossil fuels used in Hungary in 1986 as well as the emission factors proposed by *Fenger* et al. (1990) 1.4 $GgNyr^{-1}$ and 1.7 $GgNyr^{-1}$ are obtained for stationary and mobile sources, respectively.

The $N_2O$–N emissions from different Hungarian sources are summarized in *Table 5*. It can be seen that combustion sources emit only 17 % of the total emission.

However, if the $N_2O$–N quantity released from fertilizers is taken into account the anthropogenic fraction reaches 84 % of the total. This result must be considered with caution due to the uncertainties involved in the calculations. This is true in particular for soil emissions.

*Table 5:*
*Total Hungarian $N_2O$ emission in 1986 from different sources (expressed in $GgNyr^{-1}$)*

| **Source type** | **Emission** |
|---|---|
| Biological sources | |
| N-fertilized soils (agriculture) | 11.9 |
| Other soils | 2.9 |
| Combustion sources | |
| Stationary combustion | 1.4 |
| Mobile sources | 1.7 |
| **Total** | 17.9 |

### *5. Possibilities of the reduction of man-made emissions*

On the basis of the above discussion it is obvious that the main possibility of the reduction of the $CO_2$ emission in Hungary is the *energy saving* and *conservation.* Considering the value produced by the national economy the energy demand and consequently the quantity of carbon dioxide emitted are too high. There is no intention here to discuss in detail the possible ways of rational energy use. It is clear, however, that the transformation of the total economic system is needed. For this, however, an important capital investment and a good economic policy are necessary.

The $CO_2$ release into the atmosphere can also be reduced by the *diversification of energy sources.* This can be obtained by the application of sources with lower or zero specific emission like nuclear and hydroelectric power plants, electric energy import as well as geothermal and solar energy use. According to our experts (*Lévai* and *Mészáros,* 1989) it would be possible in 2010 to assure 80 % of the electric energy consumption of the country by nuclear energy. However, it is very probable that a large part of the population would be against this solution, not only because of the protection of the atmosphere but also because of the problems due to the storage of radioactive waste materials.

According to our calculations in the future among traditional fuels natural gas is preferred to coal: at the same energy production about 60 % of $CO_2$ are emitted into the atmosphere with using natural gas than in the case of coal (for further details see *Lévai* and *Mészáros,* 1989).

Possibility of the reduction of methane is unfortunately limited. It is well known that the largest changes of global and national $CH_4$ production are of anthropogenic origin. The increasing agricultural (raising cattles, growing rice etc.) and industrial activities represent the major sources of atmospheric methane. Thus, it is difficult to control or even reduce their strength. As it can be seen in *Table 4* natural gas production and distribution are the most important sources; mainly during the distribution a large amount of methane is released, which can be probably reduced by modernizing the pipi-line network. Another significant amount of methane is released by the wastes, its strength could be decreased by more reasonable utilization of wastes (municipal and agricultural) for biogas production in closed system.

Since nitrous oxide emissions are dominated by the application of nitrogen containing fertilizers, it is obvious that its release can be mitigated by a more rational and economic fertilizer use. It is necessary to find a compromise between ecological needs and agricultural production.

## *6. Conclusions*

The Hungarian carbon dioxide emission due to the energy production can be reduced first of all by energy saving and conservation. On the other hand the release of methane can be mitigated by the production of biogas from waste materials and by modernization of pipe-line network of natural gas. For the decrease of nitrous oxide emission the rational use of fertilizers is obviously needed.

Since the water management, agriculture and forestry of this country are climate dependent, Hungary is very much interested in the climatic changes due to the increasing concentration of greenhouse gases, and it supports all international efforts aiming to reduce their unfavourable effects.

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IDŐJÁRÁS

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# Statistical mechanics of inviscid truncated models of two-dimensional incompressible flows

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In two-dimensional turbulence of the inviscid fluids the enstrophy is a conserved quantity in addition to energy if the wavenumber-space is continuous and isotropic. Accordingly, the absolute equilibria of the system can be described by two-parameter canonical distribution. This picture is valid in a spectrally truncated case, if the truncated Jacobian conserves the above mentioned quantities and satisfies the Liouville's theory of statistical physics.

In this paper the existence of the equilibrium solution is examined for the finite difference approximations to the vorticity equations. It is clear that the structure of aliased interactions has an important role.

The „temperature" parameters of equilibria in a spectrally truncated case is principally depending on the shape of the wavenumber-space. The „temperature" of the equilibria is one of the possible index-numbers describing the stability of the model. The accuracy of theoretical considerations has been verified by a simple finite difference model.

*Key-words:* two-dimensional turbulence, temperature of equilibrium, effects of phase errors and aliased interactions, canonical distribution.

## *1. Introduction*

One of the fruitful lines of studying turbulence is the analysis of the power spectra of the kinetic energy. This problem has a long history of use in theoretical investigation of turbulence since the pioneering work of *Kolmogorov* (1941) and the newest research based on fractal geometry (*Jensen* et al., 1991; *Benzi* et al., 1990). It is well known that Kolmogorov's theory gives a qualitatively correct description of the main mechanism acting in the three dimensional turbulence at high Reynolds number, if the fluid is incompressible. In this case there is a cascade transfer of energy toward small scales where the dissipation is due to molecular friction.

The situation is quite different in two dimensions as firstly demonstrated by *Fjörtoft* (1953). It has been shown (*Kraichnan*, 1967) that the two-dimensional turbulence has two formal inertial ranges, $E(k) \sim \varepsilon^{2/3}k^{-5/3}$ and $E(k) \sim \eta^{2/3}k^{-3}$, where $\varepsilon$ is the rate of cascade of kinetic energy per unit mass, $\eta$ is the rate of cascade of enstrophy (enstrophy is the one-half squared vorticity) per unit mass. Some observational studies (*Kao* and *Wendell,* 1970; *Morel* and *Necco,* 1973) indicate that in the wavenumber range higher than $k = 10$, the energy spectrum approximately follows the power law of minus third.

The above described theory is valid if the turbulence is isotropic and homogeneous, thus the numerical integration of the model equations has an important role in the theoretical investigation of energy spectra. The dynamics of the three dimensional flow is governed by the existence of a single quadratic invariant: the total kinetic energy of the flow. A numerical truncated model flow evolves toward an equipartition of energy among all degrees of freedom. Hence, this flow has an $E(k) \sim k$ equilibrium spectrum if the turbulence is isotropic.

In contrast to three-dimensional flow, there are two inviscid constants of motion in the two-dimensional case. Namely, in addition to kinetic energy, enstrophy is an inviscid constant of motion. *Kraichnan* (1967) pointed out that according to the two-dimensional Navier-Stokes equation, the interaction of each triad of wavenumbers individually conserves both energy and squared vorticity.

Therefore, the truncated models conserve their total kinetic energy and enstrophy too, thus they have two-parameter equilibrium kinetic energy and enstrophy spectra (*Salmon* et al., 1976; *Kraichnan,* 1967, 1975) if the governing equation of the model satisfies the Liouville's theorem of statistical physics. In this generalized case the equilibrium distribu-tion can be described by the microcanonial distribution. Under the assumption that the system exhibits suitable ergodic properties, the expected energy spectra can be computed by long-term numerical experiments (*Basdevant* and *Sadourney,* 1975). When there is no significant excitation in the regions of wavenumber space where the modes are not dense, the canonical distribution can give a fairly accurate approximation to the spectrum (*Salmon* et al., 1976; *Kraichnan,* 1975) which is given by

$$E(k_i) = \frac{1}{2}(\alpha + \beta k_i^2)^{-1} \tag{1}$$

where a and b are the solutions of

$$\frac{1}{2}\sum_i (\alpha + \beta k_i^2)^{-1} = E_0 \tag{2}$$

and

$$\frac{1}{2}\sum_i k_i^2 (\alpha + \beta k_i^2)^{-1} = Z_0 \tag{3}$$

where $E_0$ and $Z_0$ are the initial total energy and enstrophy. In this way the equilibrum can be computed from the initial conditions. *Salmon* et al., (1976) have shown that there exists an unique solution of the above system of equations if $k^2{}_0 \leq k^2{}_1 \leq k^2{}_{\max}$, where $k_0$ denotes the lowest (non-directional) wavenumber, $k_{\max}$ the upper cutoff or „grid" wavenumber used in the computational model, and $k^2{}_1 = Z_0/E_0$.

*Bennet* and *Haidvogel* (1983) studied the power spectra of the kinetic energy of slow-decaying two-dimensional turbulence in a low-resolution pseudospectral numerical model. The initial equilibrium energy spectra were determined by (1) for a given $E_0$ and $Z_0$. *Bennett* and *Middleton* (1983) solved the system of (2) and (3) for a finite difference approximation to the barotropic vorticity equation. However, a simplification was introduced in both cases, namely $dk = 1$ (where $dk = k_{i+1} - k_i$ if $k_0 \leq k_i \leq k_{max}$. Apparently this method could not take the current shape of the truncated wavenumber space into consideration.

The main purposes here are to discuss in detail the canonical distribution of truncated models of two-dimensional incompressible flows, and the solution of (2) and (3) without the above mentioned simplification.

## 2. *The existence of the equilibrium solution*

The vorticity equation of two-dimensional flows is

$$\partial\omega/\partial t = J(\omega, \psi) \tag{4}$$

where $J$ is the Jacobian and the streamfunction $\psi$ is related to the vorticity $\omega$ by

$$\Delta\psi = \omega. \tag{5}$$

This system of equations can be written in truncated spectral form if all fields are assumed to be periodic in each direction. Let $\Psi(k, t)$ be the Fourier series of $\Psi(x, t)$, thus the governing equation (*Basdevant* and *Sadourney,* 1975) becomes

$$\frac{\partial}{\partial t}\Psi(k, t) + \sum_{p+q=k} \frac{P^2}{K^2} a(p, q)\, \Psi(p, t)\, \Psi(q, t) = 0. \tag{6}$$

In this equation $a(p, q)$ is depending on the choice of the truncated Jacobian, $P$ and $K$ are pseudo-wavenumbers. It has been shown (*Basdevant* and *Sadourney,* 1975) that (6) satisfies the Liouville's theorem if

$$a(p, q) = 0 \qquad \text{when } p = 0 \qquad \text{or} \qquad q = 0.$$

If a finite difference approximation is applied to the system of (4) and (5), (6) becomes

$$\frac{\partial}{\partial t}\Psi(p, q) = \sum_{r=-1}^{1} \sum_{s=-1}^{1} \sum_{a+c=p+rN} \sum_{b+d=q+sM} k^2{}_{ab} k^{-2}{}_{cd} A_{abcd}\, \Psi(a, b)\, \Psi(c, d), \tag{7}$$

where $\Psi(p, q)$ is the double discrete Fourier transform of the discretized streamfunction, $N$ and $M$ are the numbers os gridpoints in $x$ and $y$ direction respectively. The pseudo- wavenumber $k(p, q)$ and the function $A_{abcd}$ are depending on the choice of the approximation to the Laplacian and Jacobian. The summations over the integers $r$ and $s$ with values $-1$ and $1$ express the effect of the aliased interactions (*Orszag,* 1971). It is clear that (7) satisfies the Liouville's theorem if

$$A_{abcd} = 0 \text{ when } a = p, b = q \text{ or } c = p, d = q.$$

In addition, the finite difference Jacobian obviously has to conserve the total energy and enstrophy. If a numerical method satisfies the above conditions, the examination of the statistical mechanical properties of the model is possible.

### 3. *The „temperature" of equlibria*

The canonical distribution is related to a thermal equilibrium ensemble with $\alpha$ playing the role of inverse temperature and $\beta$ acting as a thermodynamic potential for enstrophy (*Kraichnan,* 1975). The „temperature" of the equlibrium solution is negative if one of the above parameters is below zero. *Fox* and *Ország* (1973) pointed out that the only qualitative difference between positive and negative temperature equilibria is the possible existence of a maximum of $E(k)$ within the interval $k_{min} \leq k < k_1$, if the wavenumber space is continuous.

The situation is quite different in a discretized case because the shape of the equilibrium spectra is strongly depending on the pseudo-wavenumber space.

Equations (2) and (3) exhibit three regimes of equilibria, distinguished by the value of $k^2{}_1$. In the energy-equipartition state $\beta = 0$ thus

$$k^2{}_1 = k^2{}_b = (NM)^{-1} \sum_{i}^{NM} k^2{}_i \tag{8}$$

while in the enstrophy-equipartition state $\alpha = 0$

$$k^2{}_1 = k^2{}_a = NM \sum_{i}^{NM} k^{-2}{}_i \tag{9}$$

The regimes are then

$$k^2{}_0 < k^2{}_1 < k^2{}_a \qquad \beta > 0, \ -\beta k^2{}_0 < \alpha < 0; \tag{10}$$

$$k^2{}_a < k^2{}_1 < k^2{}_b \qquad \alpha > 0, \quad \beta > 0; \tag{11}$$

$$k^2{}_b < k^2{}_1 < k_{max} \qquad \alpha > 0, \ -\alpha < \beta k^2{}_{max} < 0. \tag{12}$$

It follows that the „temperature" of equilibrium is depending not only on $k_0$, $k_1$ and $k_{max}$ (which is valid if the $k$ space is continouos) but on the choice of the pseudo-wavenumbers too, according to the truncated Laplacian. As a main result, if a finite difference method is applied, the effects of phase errors influence the „temperature" of the equilibrium solution.

### 4. *Numerical method for the computation of $\alpha$ and $\beta$*

The system of (2) and (3) can not be solved by a classical Newton's method, because there are some problems with the accurate choie of initial values for the iteration. It means that an „individual" method has to be applied. The equations (2) and (3) are partial derivatives of

$$f(\alpha, \beta) = \frac{1}{2} \sum_i \ln(\alpha + \beta k^2{}_i) \tag{13}$$

thus the numerical solution of system of equations can be attributed to the finding the extremum of the

$$P(\alpha, \beta) = f(\alpha, \beta) - E_0\alpha - Z_0\beta \tag{14}$$

potential function. This is a resolvable problem for the **BASF-Hitachi** computer of the Hungarian Meteorological Service. The only difficulty is to choose the interval including the extremum. However, by taking (10), (11) and (12) into account, a computationally efficient method could be designed. If the solution is in a negative temperature regime, the values of $\alpha$ nad $\beta$ must be computed more precisely, else in the wavenumber region, which contains the predominant part of the energy, the spectrum becomes reasonably deformed. This is indeed a strong constraint in the case of negative $\alpha$.

## *5. Numerical experiments*

The applied numerical model was suggested by *Bennett* and *Middleton* (1983). They have pointed out that (7) satisfies the Liouville's theorem if the Jacobian is approximated by the Arakawa's nine-point scheme. Therefore, the equlibrum spectra can be estimated by the canonical distribution.

All fields were assumed to be periodic in both $x$ and $y$ directions with periods of $D = 11\,200$ km. The spatial derivatives were approximated by centred finite differences on the grid, where $N = M = 32$. In this way $h = DN^{-1}$ and $(x_m, y_i) = (mh, 1h)$, $-N/2 \le m$, $1 < N/2$. According to the second-order five- point scheme approximated to the Laplacian in equation (5), the pseudo-wavenumber is

$$k(p, q) = 2N\,[\sin^2(\pi p/N) + \sin^2(\pi q/N)]^{1/2}. \tag{15}$$

The number of modes in wavenumber bands of unit width for both (15) and the $k(p, q) = (p^2 + q^2)^{1/2}$ space (which is valid in a pseudospectral case) is shown in *Fig. 1*. In this figure, the straight line has a slope of $2\pi$, according to the isotropic continous wavenumer space.

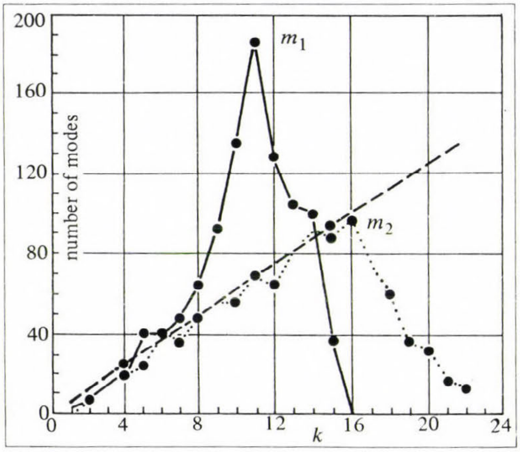

*Fig. 1:*
Number of modes in the wavenumber bands of unit width for finite difference modes (solid line) and the truncated spectral modes (dotted line). Straight line shows the number of modes in the isotropic continuous case.

The values of $k_o$, $k_a$, $k_b$ and $k_{max}$ were determined for the second-order five-point scheme and the pseudo-spectral representation with some different $N$ (*Table 1*). It is clear that $k_o$, $k_a$, $k_b$ and $k_{max}$ are lower in the finite difference approximation compared to the pseudospectral case. The wavenumbers separating the wavenumber ranges are increasing functions of $N$. The main difference between the two representations is the lower „grid" (or upper cutoff) wavenumber in case of the finite difference approximation. Summing up, the applied finite difference method leads to a narrower negative $\beta$ range.

*Table 1:*
*Comparison of the equilibrium regimes concerning the different representations*

(The first value belongs to the finite difference representation, the second value belongs to the truncated spectral representation)

| N | $k_0$ | | $k_a$ | | $k_b$ | | $k_{max}$ | |
|---|---|---|---|---|---|---|---|---|
| 16 | 00.0 | 1.4 | 3.6 | 3.9 | 5.1 | 6.5 | 7.2 | 11.3 |
| 32 | 00.0 | 1.4 | 6.6 | 7.0 | 10.2 | 13.1 | 14.4 | 22.6 |
| 64 | 00.0 | 1.4 | 12.1 | 12.8 | 20.4 | 26.1 | 28.8 | 45.3 |
| 128 | 00.0 | 1.4 | 22.5 | 23.6 | 40.7 | 52.2 | 57.6 | 90.5 |

*Table 2* contains the parameters of the experiments. The initial geopotential field (Experiment 1) was defined by

*Table 2:*
*Parameters of the experiments*

| **Experiment** | **Resolution** | **Time steps** |
|---|---|---|
| 1 | 32 x 32 | 0 |
| 2 | 64 x 64 | 0 |
| 3 | 32 x 32 | 75 |
| 4 | 32 x 32 | 150 |

| **Experiment** | $E_0$ | $Z_0$ | $\alpha$ | $\beta$ | $k_1$ |
|---|---|---|---|---|---|
| 1 | 210.4859 | 6454.62 | -0.02748 | 0.04052 | 5.5 |
| 2 | 290.027 | 34785.30 | -0.06478 | 0.11826 | 10.9 |
| 3 | 845.378 | 88559.80 | 0.62640 | -0.00020 | 10.2 |
| 4 | 845.378 | 88559.80 | 0.62640 | -0.00020 | 10.2 |

$$\Phi_{m,l} = 5500 - 300\,[\sin^2(2m\Pi/15) + \sin^2(2l\Pi/15)] \text{ if } -8 \le m,l \le 7 \qquad (16)$$

$$\Phi_{m,l} = 5500 \text{ if } -16 \le m,l \le -9 \text{ or } 8 \le m,l \le 15$$

It must be emphasized that this geopotential field is not an example of the real atmosphere; the purpose of our experiments is to demonstrate the extent to which the appearence of energy spectra depends upon the temperature of equilibria. It can be easily shown that (16) determines an equilibrium state. Therefore it is possible to discuss the errors of the expected equilibrum spectra computed by (1), (2) and (3).

The band-summed equilibrium spectra and the the spectra defined by canonical distribution are shown is *Fig. 2*, while the band-averaged specta are demonstrated in *Fig. 3*. For the computation, all fields were transformed to a $2\pi$ x $2\pi$ domain, thus in the figures the values of energy have to be multiplied by $(D/2\pi)^2$ to obtain the results in *kJ* units. It can be seen that according to the theoretical considerations the canonical distribution gives a more accurate estimation of the equilibrium spectra, except in a wavenumber range where the modes are not dense.

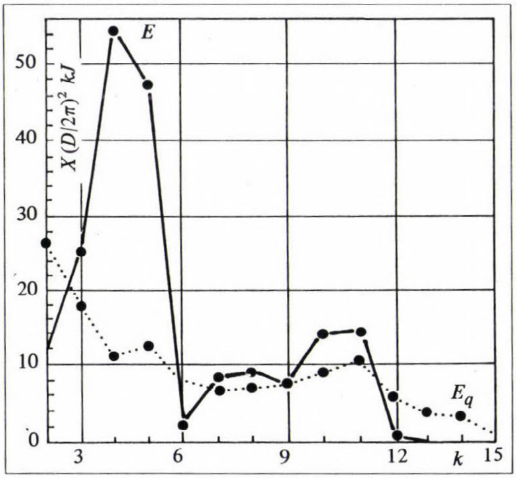

*Fig. 2:*
Band-summed energy spectra of the model (solid line) and the band-summed equlibrium energy spectra based on the canonical distribution (dotted line) in the Experiment 1.

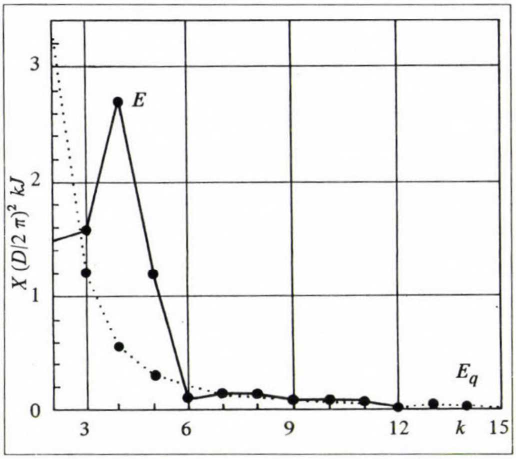

*Fig. 3:*
Band-averaged energy spectra of the model (solid line) and the band- averaged equilibrium energy spectra based on the canonical distribution (dotted line) in Experiment 1.

Transforming the (16) geopotential field to a $N = 64$ x $64$ grid, the total energy, enstrophy and $k_1$ are increasing, while the negative $\alpha$ involves the weakest decreasing. However, the increasing resolution does not change dramatically the temperature of equilibria.

For the time-depending experiments (Experiment 3 and 4) the initial field was created by the perturbation of (16) with a Gaussian white noise, when the expected value was 80. The initial band-summed energy spectra and the equilibrium spectra of the form (1) are shown in *Fig. 4*. It can be seen that the region of lower wavenumbers has an energy surplus in proportion to the equilibrium spectra, while in the higher wavenumbers there is a deficit of energy.

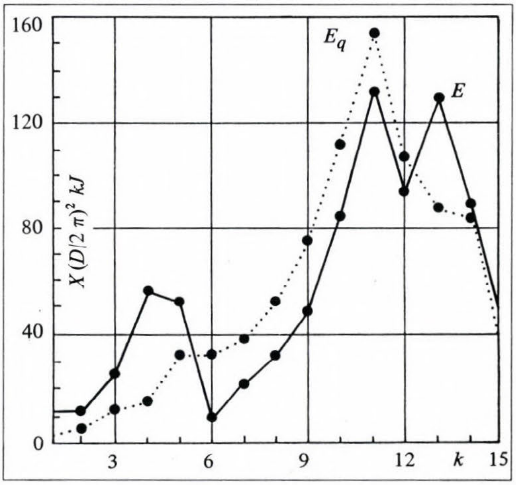

*Fig. 4:*
Initial band-summed energy spectrum in Experiment 3 and Experiment 4. (Lines mean the same as in Fig. 3.)

As a result of the perturbation, the equilibrium temperature belongs to the negative β regime. In Experiment 3 and 4 the time integration of equation (4) completed by leap-frog scheme and Euler forward scheme in the first time step. A time step of $\Delta t = 5$ minutes was used according to the Courant-Friedrichs-Lewy condition, while in the first step $\Delta t = 2.5$ minutes was applied in order to decrease the errors of the Euler's scheme.

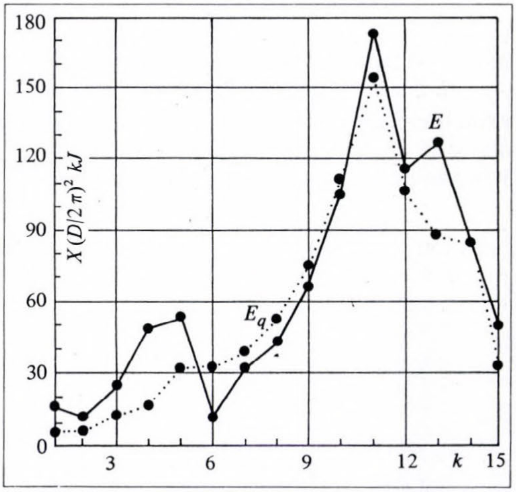

*Fig. 5:*
Band-summed energy spectrum after 75 time steps in Experiment 3. (Lines mean the same as in Fig. 3.)

*Figs 5* and *6* show the energy spectra after 75 and 150 time steps, respectively. It is evident that the energy spectrum is in the neighbourhood of the equilibria in the region of higher wavenumbers, while in the lower wavenumbers the spectra advanced to the equlibrium spectra. Meanwhile, the integration was stable, and the total energy and enstrophy did not increase significantly. In consequence of the increasing energy of higher wavenumbers, the model became less and less stable and the energy surplus was distributed proportionally to the number of modes after 150 time steps. This means that the negative β states, which are very stable in respect of the enstrophy, are significantly unstable in the numerical modelling.

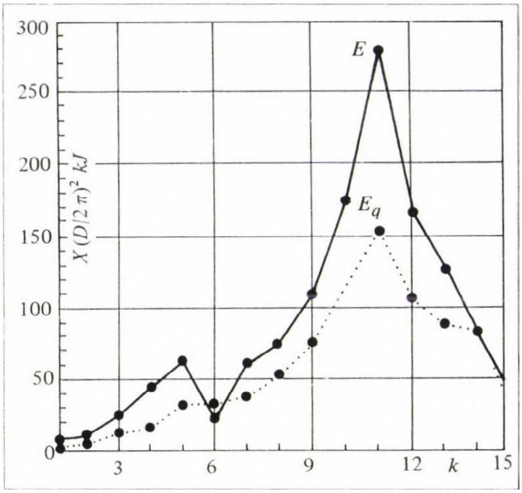

*Fig. 6:*
Band-summed energy spectrum after 150 time steps in Experiment 4.
(Lines mean the same as in Fig. 3.)

## *6. Concluding remarks*

The numerical method developed in Section 4 is suitable for the accurate computation of the equilibrium solution. In this way, the initial conditions of the equilibrum experiments can be designed with the knowledge of $E_0$ and $Z_0$, following the procedure of *Bennett* and *Haidvogel* (1983). One of the possible continuations of this work is to repeat the experiments of *Bennett* and *Haidvogel* (1983), and *Bennett* and *Middleton* (1983) using the above mentioned more accurate method. Nevertheless, it seems to be more interesting to use it in a more up-to-date high-resolution (at least $515^2$) turbulence model.

The theory of two-dimensional equlibrium flows can be extended to shallow-water equation where the enstrophy is subjected to the constraint of the absolute potential-enstrophy. Some numerical experiments with a finite difference approximation to a shallow-water model will be shown in a subsequent paper.

## *List of symbols*

| | |
|---|---|
| $k$ | – nondirectional wavenumber; |
| $\varepsilon$ | – rate of cascade of kinetic energy per unit mass; |
| $\eta$ | – rate of cascade of enstrophy per unit mass; |
| $E_0$ | – initial total energy; |
| $Z_0$ | – initial total enstrophy; |
| $\alpha$, $\beta$ | – parameters of the equilibrium solution; |

$\psi$ – stramfunction;

$\omega$ – two-dimensional vorticity;

$\Psi$ – Fourier series and Fourier transform of $\psi$;

$k_0$ – $k_{\min}$;

$x_m, y_i$ – gridpoints;

$N, M$ – numbers of gridpoints in each direction;

$\Phi$ – geopotential field;

$D$ – extension of the model-area in both direction.

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# Problems in potato irrigation using the scheduler plant stress monitor

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Invetigation on irrigation scheduling based on infrared thermometry and soil moisture measurements were carried out at Keszthely, Hungary, during the 1989 growing season. The microclimate of irrigated plots changed during the growing season and became more sensitive to plant diseases. Decreased leaf area and early defoliation of irrigated potatoes resulted in lowered final yields. This negative effect drew our attention to the importance of plant protection when using the „Scheduler" Plant Stress Monitor in irrigation timing. There were no significant differences between the „Scheduler" and conventional irrigation systems, but the „Scheduler" method used less water.

*Key-words:* irrigation, soil moisture, potato.

## *1. Introduction*

Scheduling irrigation using surface temperature measurements is based upon the assumption that when water becomes limiting, transpiration reduces and temperature increases. However, real water status of plants depends on other environmental factors such as air temperature, vapour pressure and wind speed. The basis of using infrared thermometry in irrigaton scheduling was developed by *Fuchs* and *Tanner* (1966), *Idso* et al. (1981) and *Jackson* et al. (1981). As a result of wide range investigations in plant physiology and meteorology the „scheduler" system was developed by Standard Oil Engineered Materials Company, these modern technologies in agriculture and computer science take the guesswork out of irrigation. The monitor automatically measures crop and air temperatures, global radiation and humidity, then the 64 K microprocessor analysing the data detects plant stress long before it is apparent to the eye. After field sampling, the data are transferred to an IBM PC/AT computer.

As *Stark* and *Wright* (1985) reported, foliage temperature measurements cannot be used effectively in schedule irrigation for potatoes, because of the high sensitivity of plants to environmental factors. Our purpose was to verify the validity of the „Scheduler" under Hungarian climatic conditions in irrigated potato trials. Potato is a suitable crop for such investigations since it is relatively sensitive to water stress.

## 2. *Theoretical consideration*

The ability of substances to reflect, absorb and transmit radiation varies considerably, thus providing a method of extracting informatión about substances (*Jackson* et al., 1980). The infra-thermometer recieves reflected radiation from the canopy in a direction within the field of view of the instrument. The amount of reflected radiation, which depends on surface temperature, can be expressed using the Stefan-Boltzmann law. The different type of the plant water stress indices are calculated from various environmental factors which influence the plant- water relationship. One of the most popular indices is the CWSI, the Crop Water Stress Index (*Jackson,* 1982) and this is used in construction of the „Scheduler Plant Stress Monitor".

## 3. *Material and methods*

Investigation was carried out with potatoes at the Potato Research Institute of Pannon University of Keszthely, during the 1989 growing season. The soil of experimental field is a Ramann type brown forest soil.

### *Agronomic procedures*

Before ploughing (in September 1988) 50 kg $ha^{-1}$ phosphorus, and 250 kg $h^{-1}$ potassioum fertilizers, and at planting, 175 kg $ha^{-1}$ nitrogen fertilizer were applied. The potato cultivar Desiree was planted with a plant density of 50 000 $ha^{-1}$ on the 7th April, and immidiately hilled. The control of weeds was carried out by spraying Patoran Special before emergence, later on Sencor was used. Diseases were controlled by weekly spraying of pesticides and fungicides, but twice weekly when it was necessary.

### *Irrigation*

A NADIR drop irrigation system was used, dropping elements were spaced every 50 cm. The plastic tubes were placed directly on the rows before emergence. Three different water treatments were used:

- natural rainfall only;
- irrigation using the „Scheduler" insturctions;
- irrigation by measuring the soil moisture.

### *Scheduler description*

The „Scheduler" Plant Stress Monitor determines the most important meteorological elemets that effect the transpiration. It works quickly, it takes four samples every second. In our experiment we took 30–40 samples in each of the treatments and the measurements were replicated three times. The instrument sees an oval shaped area. The size of this area depends on how far the target is from the user and how far the instrument is above the canopy. In our case the sampled area was 1000 $cm^2$.

To get correct results the „Scheduler" must be aimed at sunlit leaves. The insolation must be stable, between 11.00 and 15.00 hours. Another contributing factor is the wind speed. Wind speed was determined at 1 m above the plant stand. Measurements were taken daily, except for cloudy and rainy days.

The field moisture capacity and the wilting point of the soil are important factors in irrigation. When soil moisture fell near the wilting point, the amount of water required to bring the soil moisture to 60–65 percent of field capacity was added by irrigation. Soil samples were taken from the root zone of plants of a border row twice weekly, and the soil moisture was determined gravimetrically.

Phenological observations and leaf-area measurements using LI–3000 type leaf-area-meter were performed during the growing season. At the end of the vegetative period the yield of plots (25 $m^2$) was determined.

## *4. Results and discussion*

The weather in 1989 growing season was rainy and humid. The average air temperature during the measuring period was very close to the climatic normal. The amount of raifall was 18.5 percent higher than that of the earlier 15 year mean. The summer – except June – was wet, the rate of precipitation was 74.5 percent of the averages.

As there was no significant difference between the results concerning microclimate and plant morphology of the two differently irrigated treatments, only the results received with irrigation by „Scheduler" instructions are given.

The microclimate of plants may be affected by irrigation. The measured air temperature – 1 m above the canopy – as a result of higher water supply was lower in irrigated plants compared to the air temperature during control treatment (*Fig. 1.a*). The difference in air temperature between the two different water level treatments was not always high, but it could effect the intensity of physiological processes, mainly transpiration and photosynthesis.

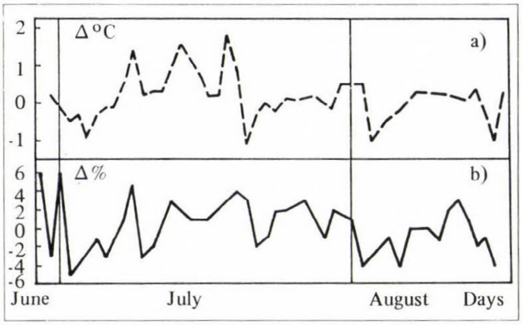

*Fig. 1:*
Difference in air temperature
*(a)* and relative humidity
*(b)* between irrigated and non-irrigated treatments

In July, the irrigation increased the relative humidity of the air (*Fig. 1.b*). In August, when the leaf-area-index (LAI) of irrigated plots decreased rapidly due to plant diseases the difference in relative humidity of the two different water levels ceased. Although the quantity of change in elements of microclimate was not high, they may effect physiological processes and the appearance of different plant diseases.

The seasonal variations of the water stress indices measured and of those corrected by wind speed were also investigated (*Fig. 2*). The influence of wind speed on the measured index was determined studying the relationship between wind speed and stress index by regression analysis. The relationship between the two elements was linear ($y = 1.11x + 0.27$; $r = 0.99$).

The whole research period was divided into two parts. In the first part of the measuring period – until the end of July – both the irrigated and non-irrigated plant stands were healthy. From the beginning of August in irrigated treatments we had problems with plant diseases, and for this reason the stress index values for August were studied separately.

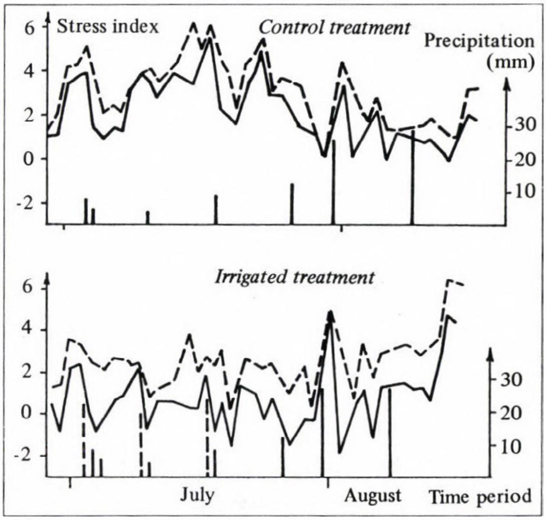

*Fig. 2:*
Measured (continuous line) and corrected (broken line) stress indices during 1989 growing season. The broken vertical lines are the amounts of irrigation water

Wind speed measured at higher levels above the canopy resulted in a larger difference in corrected stress indices. The influence of convective cooling on the index of control plants was lower than that of the irrigated treatment.

In July the difference in corrected stress index between control and irrigated plots was 1.15. The irrigated canopy had 11.5 percent higher transpiration rate than the non-irrigated control.

In the second half of investigation the change in microclimate of irrigated potatoes resulted in the appearance of different plant diseases, and this caused changes in physiological processes and the timing of phenological phases (*Table 1*).

*Table 1:*
*Phenological phases (days from planting) of potato in control and irrigated conditions*

| **Treatment** | **Planting date** | **Emergence** | **Flowering** | **Maturation** | **Harvesting** |
|---|---|---|---|---|---|
| Control | 07.04 | 29 | 66 | 165 | 183 |
| Irrigated | 07.04 | 29 | 68 | 147 | 174 |

Different plant diseases decreased the length of the vegetative period of irrigated potato through defoliation. The longer the time period of vegetation, the higher the possibility of producing more photosynthates. Larger leaf areas increase the difference in dry matter production (*Fig. 3*). In spite of the usual plant protection, Colorado beetles attacked irrigated potatoes on 1st August. Irrigation resulted in a special leaf texture, that favoured the spreading of Colorado beetles. The insect damage caused a 12.5 percent decrease in LAI and increased the possibility of attack of plant diseases. At the same time the change in LAI of control plants was zero. Unfortunately, the weather conditions in August (high air humidity) were good for other microbes, mainly for the Early blight fungus. *Caligari* and *Nachmias* (1988) also reported that potatoes with normal disease control cannot be protected from infection of Early blight.

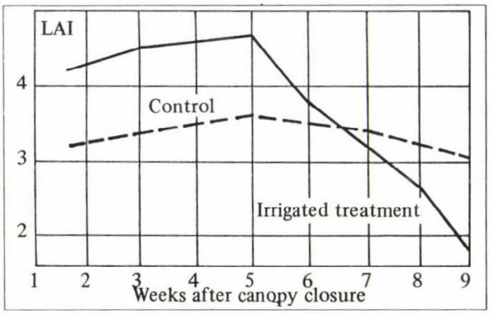

*Fig. 3:*
The leaf-area-indes (LAI) values during 1989 after canopy closure

The best parameter for predicting the appearance of plant disease is the change in plant temperature and crop-air temperature difference (*Fig. 4*). In August the difference in crop and air temperature of irrigated potatoes increased drastically. The same was observed for stress indices. As a result of insect damage the LAI of irrigated potatoes decreased. The stress indices were 4.2 and 2.0 for irrigated and control plants, respectively (10 August – 16 August).

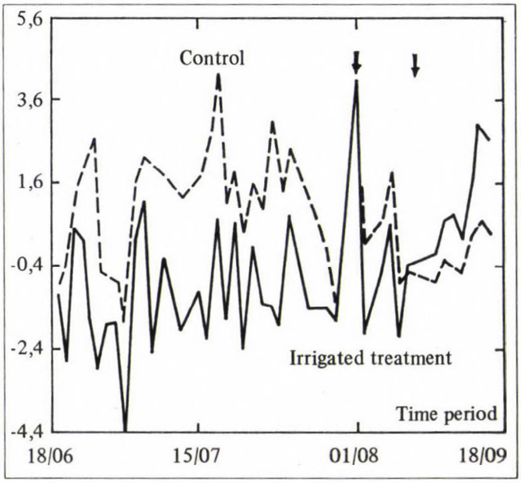

*Fig. 4:*
Seasonal variation of plant-air temperature difference

Change in the microclimate of irrigated potatoes made the attack of plant diseases possible. Decreased assimilatory surface and length of flowering and maturity time resulted in lowered yields. No significant difference in yield was observed between irrigation methods used in spite of the fact that amount of irrigation water was different in the two treatments.

Potatoes irrigated by „Scheduler" instructions used up 48.8 percent less water than the plants irrigated with monitoring the soil moisture in the field.

On the basis of these investigations we can conclude that under Hungarian climatic conditions changes in microclimate are important in plant protection of irrigated potato crop.

*Acknowledgement*

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# Variation of sun-shine duration in Bulgaria

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Variability of the annual and monthly sun-shine duration for 21 meteorological stations in Bulgaria were analysed. Varying sun-shine duration tendencies were found using an integral difference curve method. Trend analysis was carried out using visual estimation of smoothed time curve and fitted 8-order polynomial. To identify the trend character of the climatic data the Spearman rank correlation test was used.

*Key-words: sun radiation, climate change, Bulgaria.*

## *1. Introduction*

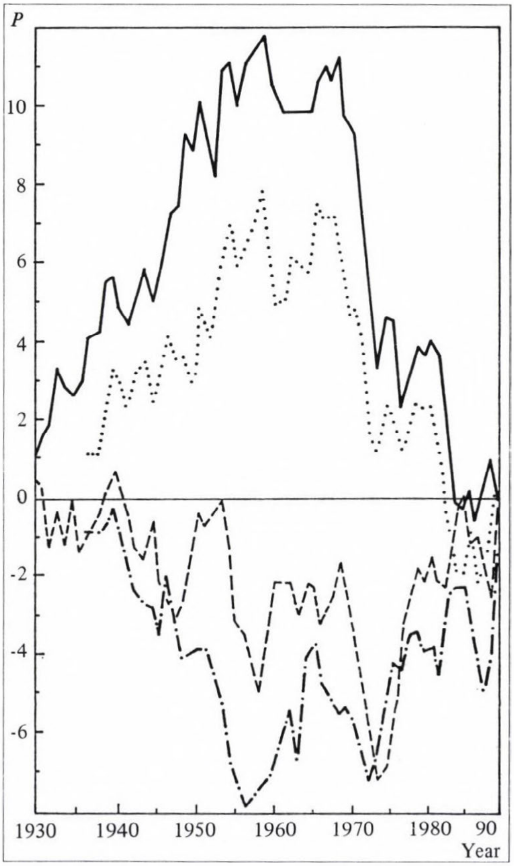
Industrialization exerts an increasing influence on the natural course of climatic changes. Fears of unfavorable change in climate, caused by human activity has led to many climate change studies. The temporal and spatial changes of the sun-shine duration due to either the natural processes in the atmosphere or human activity are one of the characteristic features of climate change.

Variation in sun-shine duration data, were analysed for 21 climatic stations in Bulgaria. Three stations were located on mountain peaks – Musala (2925 m), Cherni vrah (2286 m) Murgash (1687 m). The period studied was from 1938 to 1990. The records of sun-shine duration for the months of January, April, July and October as well as annual values were analysed.

## *2. Analysis and Results*

The variations of both the annual and monthly sun-shine duration from year to year are so large that any trends could be obscured. To dampen the high-frequency interannual variation and to identify the trends in the monthly and annual records, both graphical and statistical approaches were used.

To define the occurrence of high or low sun-shine duration more clearly, the method of the integral difference curves was used (*Battalow,* 1968; *Drozdov* and *Grigorieva,* 1971). The same method has been used before by *Lingova* and *Ivancheva* (1983) to study the variation of sun-shine duration up to 1975. In present analysis the emphasis was placed on the existence of trends in subsequent years.



$P$ is computed as follows:

$$P = \frac{\sum_i (K_i - 1)}{C_v}$$

where $K_i = \frac{Q_i}{Q}$ and $C_v = \frac{\bar{Q}}{\sigma}$

$Q_i$ – sun-shine duration for i-th year,
$Q$ – mean sun-shine duration,
$\sigma$ – mean square deviation

*Fig. 1:*
Integral difference curves of sun-shine duration

During recent years the sun-shine duration record has shown a tendency towards increase in January (*Fig. 1*). It is worth noting that the highest value of sun-shine duration occurred in 1989 at nearly all the stations. Since 1967 sun-shine duration in October has shown an increase, too. As for July a clearly expressed decrease in sun-shine duration can be observed since 1965 (*Fig. 1*). For April a decreasing tendency was found for some of the stations, while for others short periods of decreasing and increasing alternated. The annual sun-shine duration has shown an increase since 1970 for most of the stations, while in isolated stations showed a decrease (*Fig. 2*).

The time-series of sun-shine duration was smoothed by overlapping the 9-year weighted mean. The series were fitted with an 8-order polynomial. (*Fig. 3*). These methods eliminated random and short-term fluctuations. These series showed a generally oscillatory character with increases and decreases during the shorter-term period. The most pronounced feature of this curves is the significant above-average July and annual sun-shine duration about 1950. The other outstanding feature is the significant below-average sun-shine duration in July about 1970 and in January about 1954. Note the similarity between the various sun-shine duration records at different stations in particular months. However, the magnitudes of the trends are smaller than the interannual variations of the sun-shine duration records.

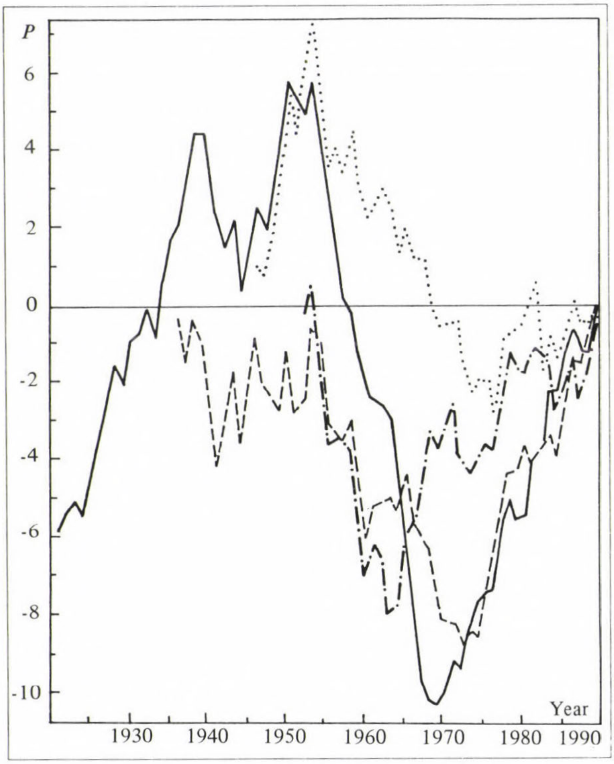


*Fig. 2:*
Integral difference curves of annual sun-shine duration

Because the visual examination of the smoothed curves is very subjective, an objective statistical method was used to further investigated the trends in sun-shine duration.

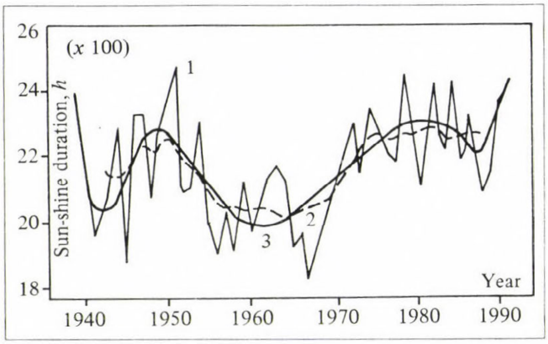


*Fig. 3:*
The time series of sun-shine duration at Obr. Chiflik
1: original series;
2: the 9-year weighted moving average;
3: the fitted 8-order polynomial

The presence of some form of trend in climatological data may be examined by the Spearman rank statistics $r$ (*WMO,* 1966; 1990) which is computed as follows:

$$r = 1 - \frac{6 \sum\limits_{i=1} d^{-}_{i}}{N(N^2 - 1)},$$

where $d_i = m_i - i$, $m_i$ is a rank of the $i$-th member in the series and $N$ is the size of a sample.

Using this statistics, the trend analysis for each station and month is applied for the period 1938–1990. In general the trends are positive in January and negative in July. Also trends in annual sun-shine duration differ between stations.

The value of $r$ was tested for significance by solving for $t$ in the equation

$$t = r\sqrt{\frac{N-2}{i-r}}$$

and compared with the two-tailed 95 % probability points of „Student's" $t$ with $(N - 2)$ degrees of freedom. Since most of the computed $t$ lies within these limits, the presence of trend in these data in the last 50 years can not be substantiated.

### *3. Conculusion*

There is a great variability in the course of sun-shine duration for the different months and that is why a common trend cannot be observed. The trends in the series was an oscillatory. In winter sun-shine duration increases and in summer it decreases in the last years. This trend, however, is not significant at most of the stations. It also agrees with the evaluation of the temperature conditions of the recent years in Bulgaria (*Koleva* and *Iotova*, 1990).

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# LITERATURE

RAMBLER, M. B., MARGULIS, L. and FESTER, R. (Editors): **Global Ecology. Towards a Science of the Biosphere.** Academic Press, Inc. London, 1989. 12 + 204 pages, 30 figures, 17 tables

Including the editors, 18 authors contributed in writing this comprehensive book, among others **J. E.** Lovelock and L. Margulis prominent representatives of Gaia hypothesis.

One of the greatest scientific challenges of our age is to understand the fundamental nature of the system that supports life on our planet. In this system biological, chemical and physical processes interact in such manner that the biosphere has existed since millions of years while its development, transformation has taken place, morever it has contributed actively to the transformation of its enviroment.

The book provides review of this complicated chain of various mechanisms in six chapters. The title of the first chapter is „Gaia and geognosy". The term geognosy denotes a new science, which considers the Earth not only as a planet, but along with its hydrosphere and biosphere it exhibits a combined system. One of the simpliest model of this system is the „daisy world", with white and black flowers controlling the planetary temperature, is also presented in this chapter.

The further chapters give analysis of various types of ecosystems, the cycles of transport of chemical elements within the Earth-atmosphere system, the photochemistry of biogenic gazes, the methods of remote sensing, and the human responsibility in influencing the composition of the atmosphere. Finally two appendixes are added to the book: the first provides a dictionary of therminology, the second presents the goal and function of GERO (Global Environmental Research Organization).

*G. Koppány*

# CHRONICLE

## Formation of the Commission on Environmental Science of the Hungarian Academy of Sciences

In the last years it has become evident that human activities modify the different media of our environment: atmosphere, hydrosphere, pedosphere etc. Since environmental conditions have made the development of human economy and society possible, man jeopardizes in this way his own future. To avoid problems we have to learn that natural resources are not illimited and we must live in harmony with nature. In other words we have to create the conditons of the so-called sustainable development which preserves the environment for future generations.

It goes without saying that, among other things, scientific research is needed to elaborate the strategy of sustainable development. We have to know in more detail environmental processes we are modifying and possible effects of modifications. Briefly, the study of the interaction of man and his environment is an obvious research purpose. It is evident that research can not be done solely by one branch of classical sciences. Considering the classification of sciences, environmental science is interdisciplinary in nature. The cooperation of many scientific fields is needed to fill the requirements.

By recognizing the importance of the subject, the General Assembly of the Hungarian Academy of Sciences held in 1991 made a resolution to form a Commission on Environmental Science under the auspice of its Presidium. It was also decided that membership of the Commission should consist of scientists delegated by different departments of the Academy due to the complexity of the problem.

During its first meeting on September 26, 1991 the Commission discussed its terms of references. It was concluded that the aim of the Commission is to coordinate and evaluate basic research being carried out in Hungary by environmental scientists. Members agreed that for obtaining this aim the continuous survey of results received by the scientific community all over the world is necessary. Members accepted to propose for assent to the Presidium the following points as basic purposes of the Commission:

a) Discussion and evaluation of Hungarian scientific conceptions in environmental science;

b) Selection of new research areas and methodologies;

c) Discussion of scientific research carried out in different institutions;

d) Elaboration of propositions for environmental education at different levels; working out the general concepts of the education;

e) Survey of the state of environment in the country; elaboration of the scientific bases of environmental protection;

f) Evaluation of non-governmental international relations;

g) Promotion of the publication of environmental issues including the information of the public;

h) Coordination of the work of environmental committees of the departments of the Academy.

It was emphasized by the members that it would be useful to look for contact with other similar commissions abroad taking into account the international character of environmental science. The importance of such world-wide projects as the International Geosphere-Biosphere Programme was stressed in particular.

*E. Mészáros*

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## Volume 26A Number 1 1992

**Technical Note**

**Discussion**

# Volume 26A Number 2 1992

**Short Communication**

**Discussion**

# Volume 26A Number 3 1992

**Short Communication**

**Discussion**

# NOTES TO THE AUTHORS

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