

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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INVESTIGATION OF TOTAL OZONE AMOUNT AND DEVELOPMENT OF ITS RESEARCH METHODS

SUMMARY OF DOCTORAL DISSERTATION

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Introduction

Formulation of the problem. The total ozone amount in the atmosphere is determined only under conditions of clear sky and low nebulosity. Therefore, it is impossible to carry out the continuous (daily) data record of total ozone amount due to the weather conditions. There is little scientific information on total ozone amount studies in Lithuania made, there are no comprehensive and methodologically sound studies on short-term changes in total ozone amount over the territory of Lithuania.

Artificial Earth Satellites are also used for the monitoring of total ozone amount. These satellite measurements can be used as additional information for the assessment of thickness of the ozone layer, and especially for the determination of strong depletions and prognosis, but there is no system that combines all the available information. Moreover, for the assessment of detailed changes, the assessment of thickness of the ozone layer once per day is insufficient. Measurement data of foreign countries are not used in Lithuania since the results of the total ozone amount measured are not adapted for the assessment.

One of the pending issues in the world is prevention and control of depletion of the ozone layer and protection of existing biodiversity on the Earth from harmful exposure of ultraviolet radiation. This requires a detailed analysis of changes in the ozone layer which can be done only after having improved methods and equipment used through the creation of continuous measurement system for the monitoring of changes in total ozone amount.

The topicality of the thesis. Issues related to the changes in the ozone layer and the origin of the ozone holes become important and relevant globally. Amount of ozone molecules in the atmosphere is relatively very low. The depletion of the ozone layer by 1 % is proportional to approximately 2 % of the ultraviolet radiation (UV) of 280–320 nm wavelength increase in intensity at the Earth's surface.

Therefore, more than ever, the attention must be paid to the researches of the ozone layer and development of research methods in today's environmental issues. It should be noted that to achieve these goals it is relevant to identify and assess the dynamics of changes in total ozone amount, to improve research methods and instruments.

In order to fully ascertain the reasons for the decrease and increase in total ozone amount, it is important to have continuous data on its overground changes. There is little scientific literature on short-term (e.g. day, hour) changes in total ozone amount. In addition, there are no possibilities to accurately measure its amount in the atmosphere every day. Therefore, taking

into account the following, it is relevant to find other ways of determination of total ozone amount and expansion of determination possibilities.

The object of the research. The object of the research is the total ozone amount and methods for its determination.

The aim of the work – to assess the changes in total ozone amount and to improve the research methodology through the expansion of the possibilities for determination of total ozone amount.

The tasks of the work

1. To create an improved measurement method using ozonometer Microtops II and to expand possibilities for the determination of total ozone amount.
2. To carry out studies on short-term changes in total ozone amount under different meteorological conditions and to assess fluctuations of changes in the latitudes of Lithuania.
3. To examine on-going changes in total ozone amount in Lithuania and neighbouring countries, to assess data use options of other countries for the determination of total ozone amount over the territory of Lithuania.
4. To develop mathematical model for the assessment of total ozone amount, using results on measurements of total ozone amount carried out by the neighbouring countries.

Methodology of research. Researches on total ozone amount were carried out using an improved method of measurement with an automated measurement system. In order to theoretically determine the total ozone amount in Lithuania and to assess its changes, measurement results received from the neighbouring countries surrounding Lithuania and Artificial Earth Satellite have been applied.

Scientific novelty. Both improved methods and developed equipment significantly expand possibilities for the researches of total ozone amount. Complex researches related to the determination of total ozone amount have been carried out, and short-term and long-term changes in total ozone amount over Lithuania have been studied and assessed.

Integrated method for the determination of total ozone amount using measurement results received in Lithuania and from its surrounding countries, Artificial Earth Satellites and automated measurement system has been developed.

Practical value. Designed automated measurement system can be applied for the determination of total ozone amount and assessment of changes in practice, continuous monitoring of the ozone layer and in particular identification of the holes formed in the ozone layer in real-time and prediction. Using the developed methodology, timely determinations of intense ultraviolet radiation episodes can be carried out and timely warning about their dangerous levels can be made as well.

There is the presentation of expansion possibilities for the measurements of total ozone amount. The thesis covers examination of changes in total ozone amount over Lithuania and neighbouring countries in 1993–2008, and their relationship is given. Summarized research results show that fluctuations sequence of total ozone amount can be seen and their change processes can be predicted as well. Practical implication of proposed work methodology is the possibility to assess the changes in total ozone amount over the territory of Lithuania, using measurement results accumulated by its neighbouring countries.

Thesis statements

1. The exact total ozone amount over the territory of Lithuania can be determined from the measurement results on total ozone amount carried out by the neighbouring countries surrounding Lithuania by using the method of least quadrates (optimal interpolation). The accuracy of the method in 95% of the cases is not less than 8% deviation from the true values of total ozone amount.
2. The continuous measurements with automated system give the ability to measure more than 1 % deviation from the true total ozone amount values.
3. When accumulations (clouds) of water droplets or ice crystals block the optical measurement path, total ozone amount and its changes may be measured by using solar tracking device.

The scope of the scientific work. The thesis consists of an introduction, five main chapters, general conclusions and recommendations, list of references and list of the author's publications. The total scope of the thesis is 126 pages, 36 numbered formulas, 69 pictures, 9 tables. 86 sources of literature were cited in the thesis. The results of the thesis are published in 6 publications. The results were presented in 5 national conferences.

Chapter 1 is intended for the review of literature. The chapter presents review of the total ozone amount, the factors affecting its changes, causes of the depletion of the ozone layer and origins of the ozone holes. In chapter 2 method and device for measuring total ozone amount are described. It presents improved method for the determination of total ozone amount using an

automated measurement system. Chapter 3 describes experimental results on the determination of total ozone amount using an automated measurement system and expansion of measurement possibilities. It provides short-term experimental studies using an integrated monitoring system. Chapter 4 describes long-term changes in total ozone amount over Lithuania and neighbouring countries. It deals with the possibilities for determination of total ozone amount in Lithuania, using measurement results of other countries. Chapter 5 describes additional device created for the studies of the changes in total ozone amount – automated measuring system and its equipment.

1. The total ozone amount and their changes in the atmosphere

Systematic measurement of total ozone amount has been started relatively recently. The salient depletion of the ozone layer is observable above the Antarctic. However, the recent trends of depletion are more visible above the middle latitudes, too. Approximately 99% of UV solar radiation (UV C, and the greater part of the UV B sector) is absorbed by stratospheric ozone. This is a natural protective function created by the nature to protect us from harmful effect of ultraviolet rays. Main advantage of overground devices is a more accurate determination of total ozone amount values. However, most of them are morally outdated and bulky, require high financial cost. In addition, it is not possible to use them every day due to the weather conditions. Measurement results using Artificial Earth Satellite have large errors, and their maintenance requires high financial cost.

2. Methods and tools for the researches of total ozone amount

For the TOA measurements, portable ozonometer Microtops II has been chosen. It is used to measure total ozone amount in the atmosphere from the Earth surface by precisely directing it to the sun. This device has a high-quality stable filters that register sunlight wavelengths of 305 nm, 312 nm and 320 nm. Ozonometer programme calculates the total ozone amount using the Lambert-Beer's law:

$$I = I_0 e^{-\alpha \mu \Omega - m \beta P / P_0}, \quad (1)$$

where: I_0 – intensity of a specific light ray wavelength before passing through the atmosphere; I – intensity of the light rays which passed the atmosphere; μ – the ratio between the actual and vertical distance that light rays pass through the ozone layer; Ω – total ozone amount, DU; α – ozone absorption coefficient for a given wavelength, P – atmospheric pressure, mB, P_0 – standard atmospheric pressure, mB; m – air mass which is expressed in the ratio of

actual and vertical ray distance travelled throughout the atmosphere to the detector, β – dispersion coefficient of light rays.

The main difference between this measurement method and analogous methods is that not one pair of light wave signals, but two pairs are evaluated during the measurement, and the calculation is done using the formula:

$$\Omega(DU) = \frac{1000 \left[L_{12} - \ln\left(\frac{I_1}{I_2}\right) - L_{23} - \ln\left(\frac{I_2}{I_3}\right) - (\beta_{12} - \beta_{23}) \cdot m \frac{P}{P_0} \right]}{(\alpha_{12} - \alpha_{23}) \cdot \mu}, \quad (2)$$

where: I_1, I_2, I_3 – intensity of a specific light ray wavelength before passing through the atmosphere, mV; α_{12} – light absorption coefficients of 305 nm and 312 nm wavelength difference between the respective channels (the ozonometer) α_{23} – absorption coefficients, difference of light wavelengths of 312 nm and 320 nm in the respective channels (determined in ozonometer); β_{12} – dissemination coefficients for the light wavelengths of 305 nm and 312 nm in the respective channels (determined in ozonometer); β_{23} – dissemination coefficients for the light wavelengths of 312 nm and 320 nm in the respective channels.

Automated measurement system has been developed for the facilitation of researches, consisting of solar tracking device, auto-switch and algorithm for transfer of measuring and processing of data (Fig. 1). Operating principle of the developed solar tracking device is based on spherical surface used by the astronomers in practice, and ozonometer is constantly directed to the sun regardless of weather conditions.

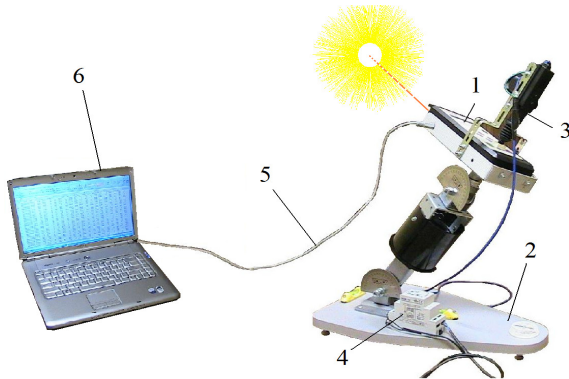


Fig. 1. Automated measurement system: 1 – Ozonometer Microtops II; 2 – Solar tracking device; 3 – auto-switch; 4 – measurement frequency controller; 5 – RS232 connector, 6 – computer

Using the TOA data received from Artificial Earth Satellites along with other results of overground measurement and experimental researches, TOA surveillance system is formed by which complex assessments of changes within TOA taking place in the atmosphere are assessed.

3. Experimental researches of total ozone amount

In cases when clouds obscure the sun, there is no possibility to direct the ozonometer using the desired accuracy, and to measure the total ozone amount at the same time. In addition, due to the human factor, it is impossible to assess the possible measurement errors when holding the ozonometer in hands. Researches have been carried out and possibilities of the use of total ozone amount measurement method, using an automated measurement system during sunny days have been examined. The characteristic results of 15 July 2011 of one of such short-term researches are shown in Fig. 2.

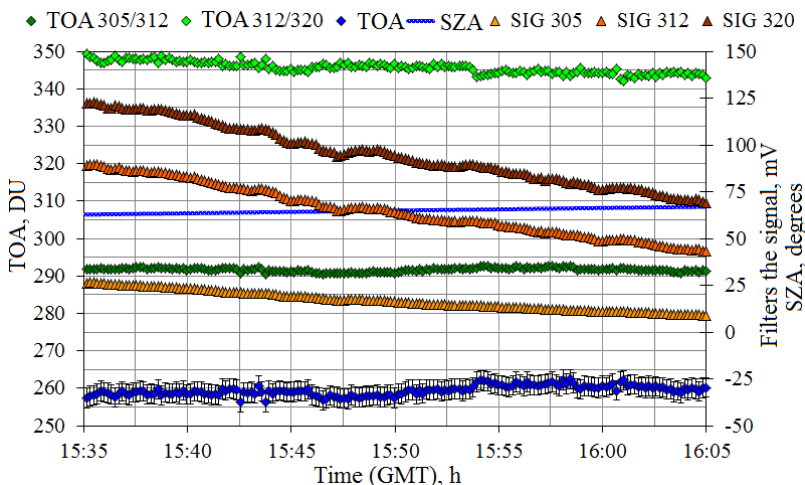


Fig. 2. The results of measurements on sunny days using an automated measurement system

During the assessment of the experimental results, it was found that the developed automated measurement system adapted to the ozonometer Microtops II allows carrying out continuous researches of total ozone amount on sunny days. Therefore the opportunity to direct the ozonometer to the sun for up to 3 days has been made, and during the slight corrections of movable bracket angle every three days – to perform continuous measurements. Also, the possibilities to carry out the measurements of total ozone amount at a

frequency the range of which can be from 10 seconds to several hours, to analyze the measurement results received and to assess the reliability of total ozone amount data have been made as well.

In order to examine the possibilities for the expansion of improved distance measurement method, experimental studies on cloudy days were carried out. The results show that under these conditions ozonometer can record the intensity of solar radiation emission and calculates the TOA. However, the result values calculated with the ozonometer are different compared to the results obtained in the absence of clouds. This is illustrated in Fig. 3 by the results of 10 July 2011 obtained after the studies when the optical measurement path is briefly obscured by the clouds.

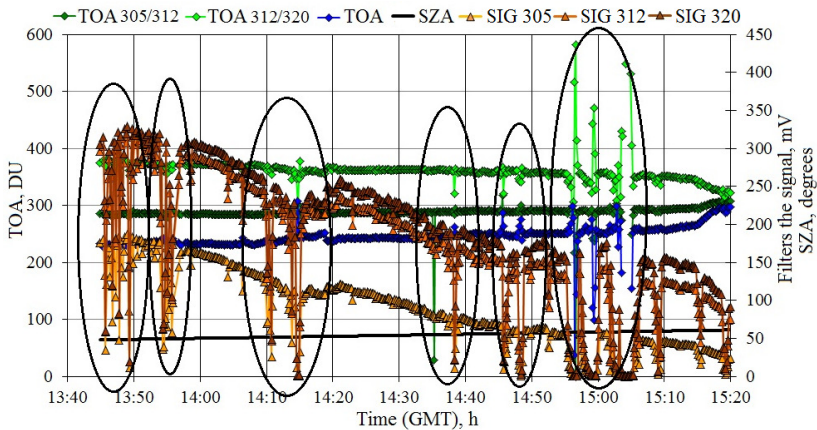


Fig. 3. Measurement results of total ozone amount on cloudy days using an automated measurement system

Research results show that the use of ozonometer with solar tracking device enables measurements of total ozone amount when the solar ray is invisible in the ozonometer sight. This enables the performance of measurements when the optical measurement path is obscured by clouds. This also extends the possibility to receive more data of total ozone amount under adverse weather conditions, and at the same time to assess changes in total ozone amount and influence of clouds on the research results.

When measuring the total ozone amount under cloudless conditions and slight nebulosity, the accuracy of ozonometer Microtops II set by the manufacturer does not exceed 2%. Given the total ozone amount of 300 DV, measurement error can be up to 6 DV. But, due to the atmospheric pollution, the measurement accuracy may be lower. A number of measurements carried

out during the experimental researches shows that the accuracy on clear days can be up to 1% or less. When measuring with the automated measurement system and calculating the average daily value – the measurement accuracy increases more. This allows the accurate determination of the total ozone amount and assessment of short-term changes.

When measuring short-term changes in total ozone amount, it was found that there are short-term fluctuations and the ozone layer during the day may change. Compared with long-term changes in total ozone amount (per year they can change over 200 DV or more), short-term changes are significantly lower, fluctuations of total ozone amount during October and March are the highest (up to 40 DV), in April–August – the lowest (up to 10 DV). This is to be related to the carries of air mass – the so-called Brewer-Dobson circulation – happening in the atmosphere, because the carries of air mass and thus of the stratospheric ozone increase during the cold season. Because of this, the cases showing strong depletion of the ozone layer increase as well. Therefore, it is appropriate to perform continuous measurements during the cold period. Using an automated measurement system helped to determine the changes in the values of total ozone amount measurements and values of ozonometer signals every ten seconds when signals close to the minimum values (Fig. 4).

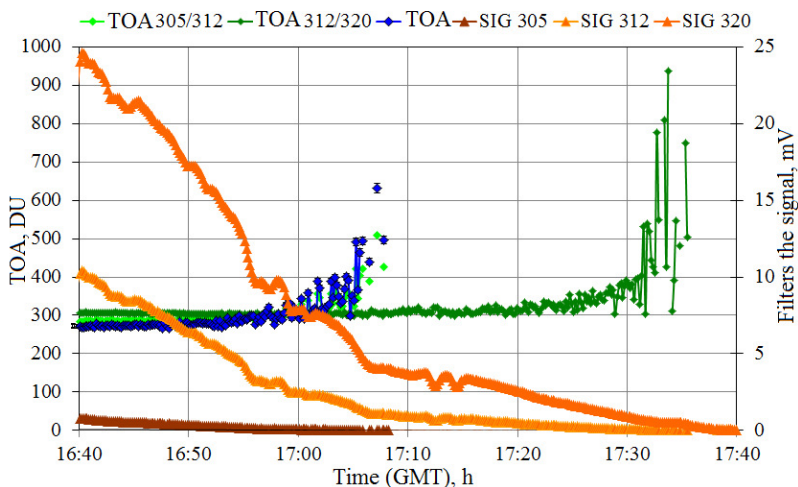


Fig. 4. Variations of results of total ozone amount due to the light absorption effect

In such cases, the device cannot measure the total ozone amount to an accuracy defined by the manufacturer (up to 2%). When SZK is increasing, the change of total ozone amount values is becoming greater. When assessing the

dispersal of these results every minute, it was found that the change in total ozone amount results within 11 minutes can increase by more than 9 times.

Short-term researches carried out on cloudy days show that individual measurement results of total ozone amount may not be reliable (error greater than 2%) due to the properties of water crystalline collections in the atmosphere to absorb and diffuse solar light waves. Using an automated measurement system, these misleading results can be eliminated (Fig. 5).

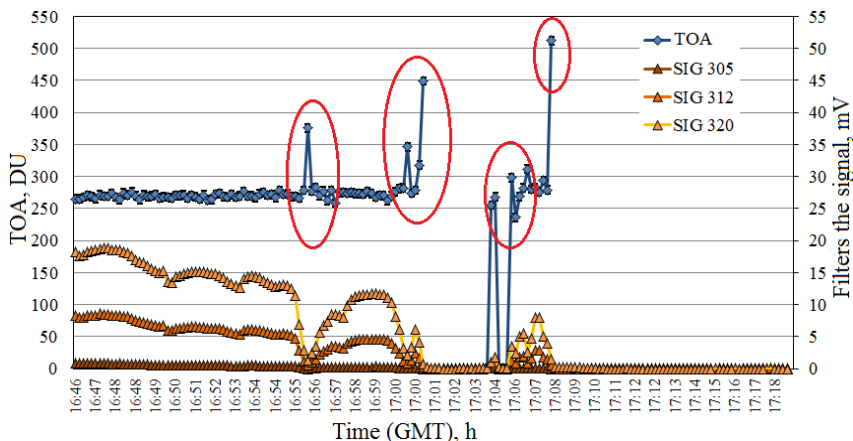


Fig. 5. Unreliable results of total ozone amount determined on cloudy days (marked by ellipses)

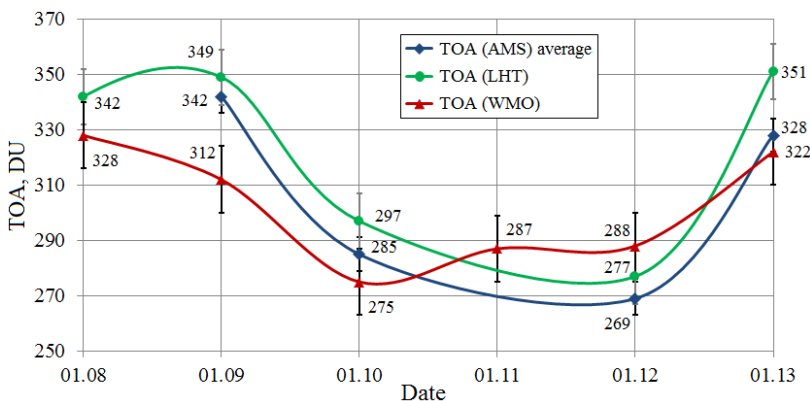


Fig. 6. Results of total ozone amount measurements on 8–13 January, 2012

It has been determined that using an integrated system for the monitoring of total ozone amount, it is possible to timely identify and monitor changes in the total ozone amount and formation of ozone holes in cases when direct overground measurements are not carried out.

During the experiment, the changes in total ozone amount when the ozone hole was moving nearby Lithuania were carried out using an integrated system for the monitoring of total ozone amount. Results of changes in total ozone amount determined on 8–13 January 2012 are presented in Fig. 6.

This system enables timely and accurate monitoring of changes in total ozone amount in real time; it also enables to carry out the records of both long-term and short-term changes in total ozone amount, and at the same time to assess the impact of UV radiation on the environment.

4. Researches on the expansion possibilities for the determination of total ozone amount using the data received from Lithuania and neighbouring countries

For the assessment of long-term changes in the TOA over Lithuania, TOA data of 1993–2008 from the Lithuanian Hydrometeorological Service and fifteen meteorological stations of neighbouring country were used. It was found that TOA changes happening over Lithuania have clear seasonal process, and it is different TOA dispersion during individual months: in June–August, the lowest TOA fluctuations, in October–April – the highest TOA fluctuations are observed.

Researches show that seasonal TOA fluctuations over the territories of neighbouring countries have a similar trend of variation like over Lithuania: the highest TOA values are determined in winter–spring, the lowest – in summer–autumn. The highest fluctuations are observed in January–April, the lowest – in June–August. Long-term trends have different variation trends, although their discrepancy is not high and significant.

After having processed TOA data available from all sixteen cities, and having compared the measurement results of the same day and average values of months, it was found that the variation trends of measurement data carried out in Kaunas coincide with the annual variation trends of pending neighbouring countries. The largest part of 201 linear correlation coefficients is of a strong correlation – higher than 0.9; 43 coefficients are between 0.8 and 0.9 (strong correlation), 10 coefficients are between 0.7 to 0.8 (strong correlation) and only 2 coefficients are lower than 0.7 (average correlation).

When examining the dispersion of changes, it was determined that dispersal of the data throughout the year is seasonally variable: in February–March it is over 70 DV (maximum 73.9 DV), in June to September is lower

than 35 DV (minimum 2.7 DV). During the year, the data dispersion varies more than 2 times: in March – 30, 9 DV, in August – 14.8 DV. Fig. 7 graphically shows their distribution during the year.

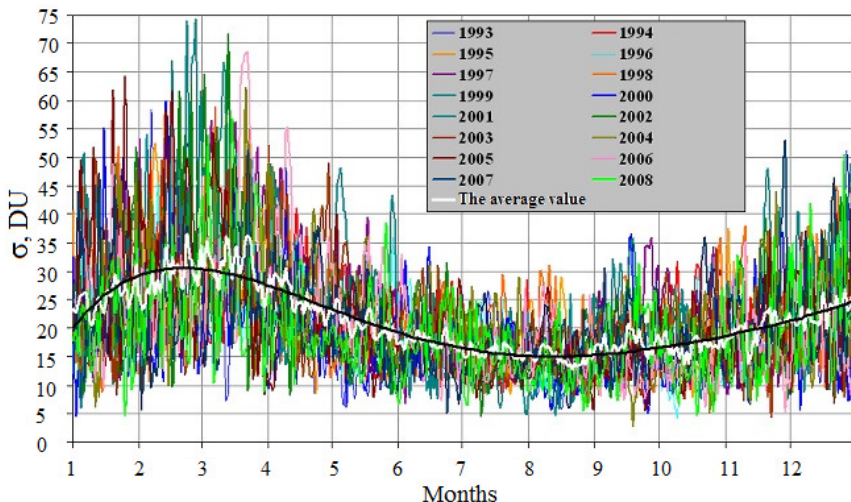


Fig. 7. Standard deviation σ of total ozone amount of Lithuania and the neighbouring countries during 1993–2008 period

Using TOA data from sixteen stations, the possibility to determine TOA over Lithuania using the data received from other countries has been expanded. This was carried out by means of interpolation through the assignment of the ozone layer to the surface of a small series using the method of least quadrates. Optimal trend or a linear function has to minimize the quadratic deviations from the trend as far as possible. The best two-dimensional surface option of first series (plane) has been got defined by the regression of least quadrates.

Considering the results obtained and having assessed the TOA changes in trends in Lithuania and neighbouring countries as well as using the data from neighbouring countries, the changes of which most coincide with TOA changes happening within Lithuanian latitudes, in 95% of cases, sufficiently accurate TOA values with a relative error of 8% are calculated.

Using the network of stations described in this chapter, the computational model of TOA detection over Lithuania, using the data of neighbouring countries which calculates the TOA by means interpolation using the method of least quadrates through the assignment of the ozone layer to the surface of a small series. Linear correlation coefficient of simulation results and measurement data is close to 0.9. High value of correlation coefficient indicates

good equivalence of simulation and measurement results. The obtained results are quite reliable, and the discrepancy can be influenced by a number of factors: high (more than 10%), inaccuracy of measuring devices, measurements were performed under adverse weather conditions, etc.

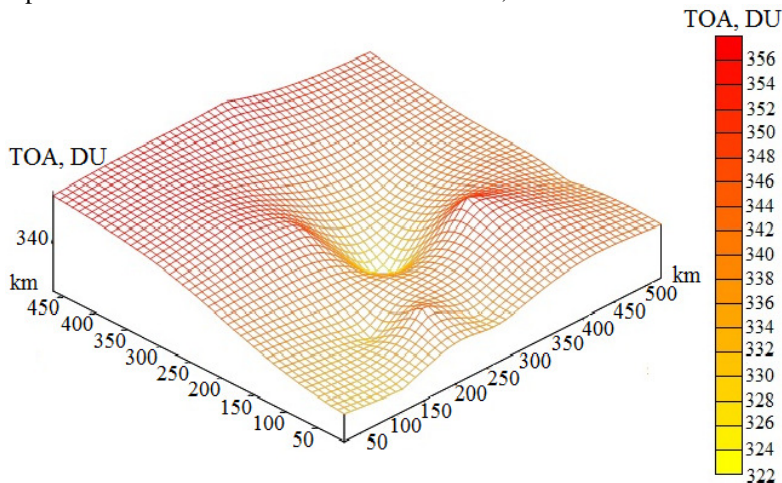


Fig. 8. Three-dimensional TOA change results over Lithuania and neighbouring countries

As an alternative, interpolation models for TOA measurements can be developed by a computer programme. Interpolation methods allow creation of horizontal (flat) and three-dimensional representation maps, having initial TOA measurement data. Using the data of network stations analyzed in Chapter , horizontal (flat) and three-dimensional images the change of ozone layer over Lithuania and neighbouring countries are modelled (Fig. 8).

5. The engineering solutions

For the facilitation of TOA measurements, developed additional equipment is used – an automated measurement system. This system consists of solar tracking device auto-switch, algorithm for data transfer to the PC and its processing.

The main mechanism of this designed system is a solar tracking device. It has an ozonometer which is directed to the Sun attached (Fig. 9). The operation principle of this device is based on the spherical surface used by the astronomers in practice. The device itself has a watch-mechanism that rotates at a 360 degrees angle in 24 hours.

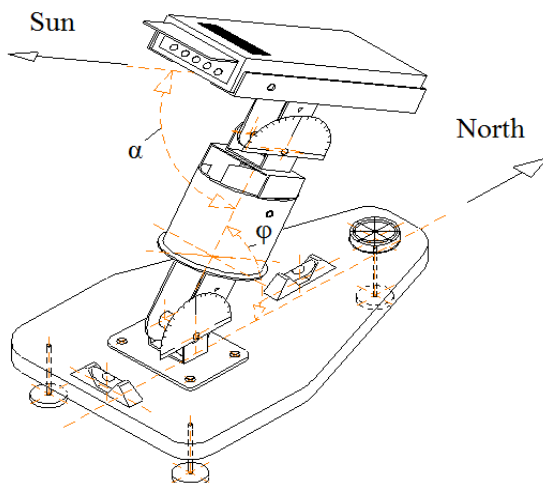


Fig. 9. Solar tracking device with ozonometer Microtops II

For the facilitation of experimental researches, the designed auto-switch is used, which automatically activates the ozonometer Microtops II at selected frequency. Auto-switch is attached to the solar tracking device. Additionally, power supply and measurement frequency regulator are used for its operation.

For transfer of measured data from the ozonometer Microtops II to the PC, algorithm for data transfer to PC and its processing is used.

Main technical characteristics of the designed automated measurement system are as follows: TOK determination accuracy $\leq 1\%$, measurement frequency – up to 360 pcs./hr., operation period – 120 hours, the data transfer to the computer – every 2 hours (when measuring every 10 s), preparation for the use – 20 min., mobile.

General conclusions

1. Improved method for the determination total ozone amount with an automated measurement system has been prepared, which allows the measurements to be carried out under adverse optical, when UV radiation is reduced to 45 % conditions, resulting, in significantly more data received, which makes it possible to assess its changes and impact of clouds on the research results.
2. Researches on short-term changes in total ozone amount in different weather conditions have been carried out, and changes in fluctuations over the territory of Lithuania have been assessed. It was found that short-term

- changes in total ozone amount are higher up to 30 % during the cold (autumn-spring) period of the year than during the warm period (spring-summer).
3. Changes in total ozone amount happening in Lithuania and neighbouring countries have been examined, and it has been found that the correlation of changes in total ozone amount over Lithuania and neighbouring countries is strong. Using the measurement data from neighbouring countries, it is possible to determine the total ozone amount over the territory of Lithuania using methods of optimal interpolation in 95% cases with an accuracy of 8% error.
 4. Calculation model for the determination of total ozone amount over Lithuania has been designed which enables to assess the changes in total ozone amount over the territory of Lithuania, where it is impossible to perform direct measurements. It was found that linear correlation of total ozone amount results calculated under the module and measured is strong; coefficient of linear correlation is close to 0.9.
 5. After the measurements with the automated measurement system at 10 seconds period and calculation of average daily value it was determined that the measurement accuracy increases, the error is of 1% or less.
 6. Using an automated measurement system with a solar-tracking device, it is possible to measure the total ozone amount and its changes when collections (clouds) of water droplets or ice crystals obscure the measuring optical path.
 7. The integrated system for monitoring of total ozone amount enables the early identification of the approximation of the ozone layer “holes”, makes it possible to determine the changes in total ozone amount in real time, and thus to predict the potential impact of ultraviolet radiation on the environment.
 8. Solar tracking device was tested. This device consistently monitors the movement of the Sun in the sky dome, i.e. directs the ozonometer after the sun regardless of the nebulosity with accuracy of 0.3°.

Recommendations

1. In order to receive more reliable results on the total ozone amount on cloudy days, it is recommended to carry out continuous measurements of total ozone amount using the method proposed in this work with an automated measurement system.
2. The assessment of changes in total ozone amount, it is appropriate to use the results received during the continuous monitoring system in integrated

- manner, as well as measurement data carried out by local overground measurement stations and Artificial Earth Satellites.
3. It is recommended to use the developed computational model for the determination of total ozone amount over the territory of Lithuania which is proposed in this work using the data of neighbouring countries, when it is impossible to carry out direct measurements of total ozone amount in Lithuania.
 4. For the monitoring of strong depletion of the ozone layer thickness and detailed monitoring of holes and prevention of UV-induced adverse effect, it is recommended to use the methods and equipment proposed in this work.

List of published works on the topic of the dissertation In the reviewed scientific periodical publications

Tretjakovas, S.; Girgždys, A.; Masilevičius R. 2012. The total ozone amount changes over Lithuania and neighbouring countries, *Journal of Environmental Engineering and Landscape Management* 20(3): 147–154 (ISI Web of Science) IF = 1,508

Chadyšienė, R.; Tretjakovas, S.; Girgždys, A. 2009. Relationship of the total ozone amount, UV radiation intensity and cases of melanoma and skin cancer, *Health science: public health, medicine, nursing* 19(5): 2638–2642. (IndexCopernicus) ISSN 1392-6373.

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BENDRO OZONO KIEKIO TYRIMAI IR MATAVIMO METODŲ TOBULINIMAS

Problemos formulavimas. Bendras ozono kiekis atmosferoje nustatomas tik giedro dangaus ir mažo debesuotumo sąlygomis. Todėl dėl meteorologinių sąlygų atlikti nenutrūkstanti (kasdieninė) bendro ozono kiekio duomenų registravimą nėra galimybių. Rasta mažai mokslinės informacijos apie Lietuvoje atliktus bendro ozono kiekio tyrimus ir metodiškai pagrįstus tyrimus apie trumpalaikius bendro ozono kiekio pokyčius virš Lietuvos teritorijos.

Bendro ozono kiekio stebėsenai naudojami ir dirbtiniai Žemės palydovai. Šiuos satelitinių matavimų duomenis galima būtų naudoti kaip papildomą informaciją ozono sluoksnio storio įvertinimui, ypač ryškių suplonėjimų nustatymui ir prognozavimui, bet nėra sistemos, apjungiančios visą gaunamą informaciją. Be to, detaliam pokyčių vertinimui, ozono sluoksnio storio nustatymas vieną kartą paroje yra nepakankamas. Lietuvoje užsienio valstybių matavimų duomenys nenaudojami, nes išmatuoti bendro ozono kiekio rezultatai nepritaikyti vertinimui.

Viena iš pasaulyje sprendžiamų problemų – sustabdyti ir kontroliuoti ozono sluoksnio plonėjimą bei apsaugoti Žemėje egzistuojančią biologinę įvairovę nuo ultravioletinės spinduliuotės žalingo poveikio. Reikalinga detali ozono sluoksnio pokyčių analizė, kuri gali būti atlikta tik patobulinus naudojamus metodus bei įrangą, sukuriant nepertraukiamo matavimo sistemą bendro ozono kiekio pokyčių stebėjimui.

Darbo aktualumas. Ozono sluoksnio pokyčiai ir ozono skylių atsiradimo klausimai tapo svarbūs ir aktualūs pasauliniu mastu. Ozono molekulių kiekis atmosferoje santykinai yra labai mažas. Ozono sluoksnio sumažėjimas 1 % yra proporcingas maždaug 2% ultravioletinės 280–320 nm ilgio bangų spinduliuotės (UVB) intensyvumo padidėjimui ties Žemės paviršiumi.

Todėl šiuolaikinėje aplinkosaugoje daugiau dėmesio nei iki šiol, turi būti skiriama ozono sluoksnio tyrimams ir tyrimų metodų tobulinimui. Pažymėtina, kad siekiant šių tikslų aktualu nustatyti bei įvertinti bendro ozono kiekio pokyčių dinamika, tobulinti tyrimų metodus bei priemonę.

Siekiant išsamiai išsiaiškinti bendro ozono kiekio mažėjimo ir padidėjimo priežastis, svarbu turėti nenutrūkstamus antžeminius jo pokyčių duomenis. Mažai yra mokslinės literatūros apie trumpalaikius (pvz. dienos, valandos) bendro ozono kiekio pokyčius. Nėra nagrinėti bendro ozono kiekio trumpalaikiai pokyčiai ir virš Lietuvos teritorijos. Be to, nėra galimybių kasdien tiksliai išmatuoti jo kiekį atmosferoje. Tad, atsižvelgiant į tai, aktualu surasti kitus būdus bendram ozono kiekiui nustatyti ir nustatymo galimybės praplėsti.

Tyrimų objektas. Darbo tyrimo objektas – bendras ozono kiekis ir jo nustatymo metodai.

Darbo tikslas. Darbo tikslas – įvertinti bendro ozono kiekio pokyčius ir patobulinti tyrimų metodiką, praplečiančią bendro ozono kiekio nustatymo galimybes.

Darbo uždaviniai

1. Sukurti patobulintą matavimo metodą naudojant ozonometrą Microtops II ir praplėsti bendro ozono kiekio nustatymo galimybes.
2. Atlikti trumpalaikių bendro ozono kiekio pokyčių tyrimus esant skirtingomis meteorologinėmis sąlygomis ir įvertinti pokyčių fluktuacijas Lietuvos platumose.
3. Išnagrinėti Lietuvoje ir kaimyninėse šalyse vykstančius bendro ozono kiekio pokyčius, įvertinti kitų šalių duomenų panaudojimo galimybes bendro ozono kiekio nustatymui virš Lietuvos teritorijos.

4. Sukurti bendro ozono kiekio įvertinimo matematinį modelį, naudojant kaimyninių šalių atliktų matavimų bendro ozono kiekio rezultatus.

Tyrimų metodika. Bendro ozono kiekio tyrimai atlikti naudojant patobulintą matavimo metodą su automatizuota matavimo sistema. Siekiant teoriškai nustatyti bendro ozono kiekį Lietuvoje ir įvertinti jo pokyčius, taikomi Lietuvą supančių kaimyninių šalių ir dirbtinų Žemės palydovų matavimų rezultatai.

Darbo mokslinis naujumas. Patobulinti metodai ir sukurta įranga ženkliai praplečia bendro ozono kiekio tyrimų galimybes. Atlikti kompleksiniai bendro ozono kiekio nustatymo tyrimai, ištirti ir įvertinti trumpalaikiai ir ilgalaikiai bendro ozono kiekio pokyčiai virš Lietuvos.

Sukurtas kompleksinis bendro ozono kiekio nustatymo metodas naudojant Lietuvos ir ją supančių šalių, Žemės dirbtinių palydovų bei automatizuota matavimo sistema gautus matavimo rezultatus.

Darbo rezultatų praktinė reikšmė. Sukurta automatizuota matavimo sistema gali būti taikoma bendro ozono kiekio nustatymui ir pokyčių vertinimui praktikoje, nepertraukiamam ozono sluoksnio stebėjimui, o ypač susidarančių ozono sluoksnio skylių atpažinimui realiu laiku ir prognozei. Naudojant sukurta metodika gali būti atliekami savalaikiai intensyvesnės ultravioletinės spinduliuotės epizodų nustatymai ir savalaikiai perspėta apie pavojingus jos lygius.

Pateikiamas bendro ozono kiekio matavimų galimybių praplėtimas. Disertacijoje išnagrinėti 1993–2008 metų bendro ozono kiekio pokyčiai virš Lietuvos ir kaimyninių šalių, pateikiamas jų ryšys. Iš apibendrintų tyrimo rezultatų galima vertinti bendro ozono kiekio fluktuacijų seką, prognozuoti jų pokyčių eigą. Siūlomos darbo metodikos praktinė reikšmė – galimybė įvertinti bendro ozono kiekio pokyčius virš Lietuvos teritorijos, panaudojant kaimyninių šalių sukauptus matavimų rezultatus.

Ginamieji teiginiai

1. Tikslų bendro ozono kiekį virš Lietuvos teritorijos galima nustatyti iš Lietuvą supančių kaimyninių šalių atliktų bendro ozono kiekio matavimų rezultatų, panaudojant mažiausiųjų kvadratų (optimalios interpoliacijos) metodą. Metodo tikslumas 95 % atvejų nemažesnis nei 8 % nuokrypis nuo tikrosios bendro ozono kiekio vertės.
2. Vykdamas nenutrūkstamus matavimus sukurta automatizuota matavimo sistema galima išmatuoti bendro ozono kiekio vertę ne didesniu negu 1 % nuokrypiu nuo tikrosios vertės.

3. Vandens lašelių ar ledo kristalų sancaupoms (debesims) užstojus matavimo optinį kelią galima išmatuoti bendro ozono kiekį ir jo pokyčius, naudojant Saulės sekimo prietaisą.

Darbo struktūra. Disertaciją sudaro įvadas, penki skyriai, bendrosios išvados ir rekomendacijos, literatūros sąrašas, autoriaus publikacijų sąrašas. Darbo apimtis yra 126 puslapiai, tekste panaudotos 36 numeruotos formulės, 69 paveiksiai ir 9 lentelės. Rašant disertaciją panaudoti 86 literatūros šaltiniai.

Pirmas skyrius skirtas literatūros analizei. Apžvelgiama informacija apie bendro ozono kiekį, jo pokyčius lemiančius veiksnus, ozono sluoksnio plonėjimo ir ozono skylių atsiradimo priežastis. Antrame skyriuje aprašomi tyrimams naudoti bendro ozono kiekio matavimo ir įvertinimo metodai. Pateikiamas patobulintas bendro ozono kiekio nustatymo metodas naudojant automatizuotą matavimo sistemą. Trečiame skyriuje pateikiami bendro ozono kiekio nustatymo eksperimentinių tyrimų rezultatai naudojant automatizuotą matavimo sistemą ir matavimų galimybių praplėtimas. Ketvirtame skyriuje aprašyti ilgalaikiai bendro ozono kiekio pokyčiai virš Lietuvos ir kaimyninių šalių teritorijų. Sprendžiamos bendro ozono kiekio nustatymo galimybės Lietuvoje, naudojant kitų šalių matavimų rezultatus. Penktame skyriuje aprašomas bendro ozono kiekio pokyčių tyrimams sukurtas papildomas įrenginys – automatizuota matavimo sistema ir jos įranga.

Bendrosios išvados

1. Parengtas patobulintas bendro ozono kiekio nustatymo metodas su automatizuota matavimo sistema, kuris leidžia atlikti matavimus esant optiškai nepalankioms meteorologinėms sąlygoms, kai UV spinduliuotė sumažėja iki 45 %, ir gaunama ženkliai daugiau duomenų, o tai leidžia vertinti jo pokyčius ir debesų įtaką tyrimų rezultatams.
2. Atlikti trumpalaikiai bendro ozono kiekio pokyčių tyrimai esant skirtingoms meteorologinėms sąlygoms ir įvertinti jo pokyčiai virš Lietuvos teritorijos. Nustatyta, kad trumpalaikiai bendro ozono kiekio pokyčiai šaltuoju (rudens–pavasario) metų periodu daugiau nei 30% didesni, negu šiltuoju (pavasario–vasaros) periodu.
3. Išnagrinėti Lietuvoje ir kaimyninėse šalyse vykstantys bendro ozono kiekio pokyčiai ir nustatyta, kad virš Lietuvos ir kaimyninių šalių bendro ozono kiekio pokyčių koreliacija yra stipri. Naudojant kaimyninių šalių matavimų duomenis yra galimybė 95 % atvejų tikslumu su 8 % paklaida nustatyti bendrą ozono kiekį virš Lietuvos teritorijos naudojant optimalios interpoliacijos metodus.
4. Sukurtas bendro ozono kiekio nustatymo virš Lietuvos teritorijos skaičiavimo modelis, leidžiantis įvertinti bendro ozono kiekio pokyčius

virš Lietuvos teritorijos, kai nėra galimybės atlikti tiesioginių matavimų. Nustatyta, kad pagal modulį suskaičiuotų ir išmatuotų bendro ozono kiekio rezultatų tiesinė koreliacija yra stipri, tiesinės koreliacijos koeficientas artimas 0,9.

5. Atlikus matavimus su automatizuota matavimo sistema esant 10 sekundžių periodui ir apskaičiavus vidutinę dienos reikšmę nustatyta, kad matavimų tikslumas padidėja, paklaida siekia 1 % ir mažiau.
6. Naudojant sukurtą automatizuotą matavimo sistemą su Saulės sekimo prietaisu galima išmatuoti bendrą ozono kiekį ir jo pokyčius kai vandens lašelių ar ledo kristalų sankaupos (debesys) užstoja matavimo optinį kelią.
7. Sudaryta kompleksinio bendro ozono kiekio stebėjimo sistema sudaro galimybę iš anksto nustatyti ozono sluoksnio „skylių“ priartėjimą, leidžia tiksliau nustatyti bendro ozono kiekio pokyčius realiaame laike, o tuo pačiu prognozuoti ultravioletinės spinduliuotės galimą įtaką aplinkai.
8. Išbandžius sukurtą Saulės sekimo prietaisą, nustatyta, kad šis įrenginys nukreipia ozonometrą Microtops II į Saulę ir seka ją nepriklausomai nuo debesuotumo 0,3° tikslumu.

Rekomendacijos

1. Siekiant patikimesnių bendro ozono kiekio rezultatų debesuotomis dienomis rekomenduotina vykdyti nenutrūkstamus bendro ozono kiekio matavimus naudojant darbe siūlomą metodą su automatizuota matavimo sistema.
2. Bendro ozono kiekio pokyčių vertinimui tikslinga kompleksiškai naudoti nenutrūkstamų matavimų sistemos rezultatus, vietinių antžeminių matavimo stočių ir Žemės dirbtinių palydovų atliktų matavimų duomenis.
3. Rekomenduotina naudoti sukurtą ir darbe pasiūlytą bendro ozono kiekio nustatymo virš Lietuvos teritorijos skaičiavimo modelį, naudojant kaimyninių šalių duomenis, kai Lietuvoje nėra galimybės atlikti tiesioginių bendro ozono kiekio matavimų.

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INVESTIGATION OF TOTAL OZONE AMOUNT ANT DEVELOPMENT OF ITS
RESEARCH METHODS

Summary of Doctoral Dissertation

Technological Sciences, Environmental Engineering (04T)

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BENDRO OZONO KIEKIO TYRIMAI IR MATAVIMO METODŲ TOBULINIMAS

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