Assessment of Monthly Total Ozone Values Allocation Changes in the Atmosphere in Account of Superficial Temperatures Variations of Significant Regions of the Atlantic Ocean

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Abstract:
Accounting of the average monthly superficial temperatures changes of regions of the Atlantic ocean, which considerably influence allocation of the monthly values of the general ozone content above Poland, allows to imply effective modeling and forecasting of these variations with the forecast for some years. Errors in forecasting allocations of TOC changes over Poland are maximal in June and increase while increasing forecasting. Nevertheless, at values of forecast of more than 2 years their levels by module don't exceed absolute error of measurements of this characteristic with the help of the most exact of the existing devices - Dobson spectrophotometer.

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INTRODUCTION

Changeability of the total ozone contents (TOC) allocation in the atmosphere influences changes of the ultra-violet radiation streams, which take part in creating tropospheric and ground ozone, and also on development of all species of land plants, animals and microorganisms, which worsen human health.

Therefore improvement of its changeability above the planets regions monitoring techniques is a problem of physical geography, meteorology and ecology.

Nowadays, since January,1979, researches of changeability and allocation of daily and monthly TOC values are carried out by means of the system of global monitoring. In this measuring system TOCs of various regions of the planet, which are not in the area of a pole night, are made by spectrophotometers TOMS and OMI. Thus received information goes to the Global monitoring centre of ultra-violet radiation and ozone (Toronto), where it is placed on free access to the Internet. Possibilities of these machines and techniques of data processing provide data in permission of 25 Dobson points (e.D.), with spatial permission 1°x1° [1]. As this information arrives a few months later, it's problematic to use it for protecting population and economy from this factor.

In some parts of the planet TOC changeability monitoring is carried out by means of land devices, the most absolute of which is Dobson spectrophotometer, with measuring error 7.5, e.D., that allows to study the process peculiarities in more detail. Nevertheless, developing alternative monitoring techniques of this process for their population is of greatest interest. One of them is Poland.

It is established, that to the number of major factors, which cause TOC allocation changes in the terrestrial atmosphere, relates variability of substances streams, which take part in ozone destruction, which arrive to its various segments [2]. All these substances of technogenic or natural origin are formed at terrestrial surface and can be delivered to stratosphere, where is mainly contained destructed by them ozone, by air streams. Within troposphere their transfer is carried out by streams, which arise at various convectional and synoptic processes [3]. The point is, the question how exactly they are transferred to stratosphere is not completely studied yet. According to H.P.Pogosyan, advection of tropospheric air through gaps of tropopause, located above subtropical jet currents plays the main role in this process [4]. But the specified mechanism does not explain how exactly further substances, which got to the lower stratosphere, distribution occurs in its steadily stratified average and top layers, where ozone destruction occurs.

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E.A. Zhadin has offered and proved the hypothesis about the nature of the process. In his opinion, essential role in it is carried out by planetary and gravitational waves, which arise as a result of various interactions of atmosphere and spreading surface [5]. The mentioned waves may arise at interaction of jet currents with orographical and barical uniformities and at movement of cyclones and anticyclones [6,7]. For such waves are nonlinear and long, while spreading in stratosphere their wave profile transforms and on some distance from the source it “breaks” [8]. Turbulent air streams arise. They transfer the air, which got to stratosphere, to any heights.

Important role in creating barical heterogeneities, which take part in generation of similar waves, plays impact on atmosphere of heat streams and water vapor, which come from the surface of World ocean. Therefore can exist connection between superficial temperatures changes of some water areas and TOC above many regions of the world.

The adequacy of such perceptions is confirmed by many researchers [9] that allows to avoid the possibility of using the results of measurements of the surface temperature of the different areas of the World ocean during the monitoring of variations of the total ozone over many regions of the planet.

The biggest and the warmest part of the World ocean - the Atlantic ocean, what allows to suppose possibility of regions existing in it, superficial temperatures changes of which influence condition of ozonosphere over Poland.

Existence of significant statistical connections between TOC changes in most atmosphere segments with variations of superficial temperatures of many Atlantic ocean regions, on coinciding periods of time, was established. With the temporary shift between these processes their statistical connections on the average weaken the more, the bigger is its size [10].

Observations of changes of superficial temperatures of most Atlantic ocean regions have been made for >100 years already, and their results as temporary ranks of average monthly anomalies values of these characteristics, made average on the area of trapeze, sides of which are parallels and meridians, differing for 5°, are given in the Internet [11].

The question, where exactly are located the regions, which influence TOC allocation variations over this or that World ocean region the most, including Poland (which we will call significant further), is not sufficiently studied. It does not allow to use connections between the mentioned processes when modeling and forecasting TOC changes over such regions.

Considering stated above, the object of this research-average monthly TOC allocation changes over Poland, and of superficial temperatures of various Atlantic ocean regions.

The object of research was possibility of average monthly TOC allocation changes in the atmosphere monitoring implementation, including superficial temperatures variations of the Atlantic ocean significant regions on the example of Poland.

Purpose of work- identifying the Atlantic ocean significant regions, and assessment of modeling accuracy and TOC allocation variations forecasting over Poland.

For achieving the set purpose are solved next problems:
1. Identification of the Atlantic ocean regions, where interannual changes of their average monthly temperatures in coinciding in time months significantly influence TOC variations over most regions of Poland.
2. Identification of interannual TOC changes predictive models over the territory of Poland.
3. Developing TOC allocation changes forecasts over the territory of Poland with various forecasts in tome, and assessment of their adequacy.

Methodology and actual material:

One of the most universal mathematical modeling methods of casual processes modeling is method of multiple regression [12]. This method is also applied for their forecasting if the factors, considered as arguments of the predictive model, are reasonably connected with the studied process. Proving existence of casual connections between such natural process as TOC changes over Poland and other natural processes is really hard, in many cases impossible. It is much easier to establish existence of statistical connection between them.

Implementing in the multiple-regress process model as arguments of factors, connected with it statistically, does not guarantee its applicability in the forecasting tasks. But, possibility of its applicability is the higher, the stronger are statistical connections, considered while modeling. Therefore application of this method while developing forecasting techniques of studied process was recognized admissible.

The mentioned technique includes two stages.

On the first stage with use of correlation analysis method is solved the first task: among all the Atlantic ocean areas, limited by cells of the coordinate grid with step 5°, are searched those, where interannual changes of their superficial temperatures are significantly statically connected with this or that atmosphere segment over the territory of Ukraine in the size of 1°x1°. Thus, connections to which corresponds the value of pair correlation, exceeding level of 99% level, set by the Student criteria, accounting to all the numbers of freedom degrees of corresponding temporary ranks were admitted significant.
Further among the revealed areas are set those, where temperature changes are significantly connected with TOC variations on coinciding periods of time not less than in 75% of similar atmosphere segments. Namely they were taken further as significant ones.

Identification of interannual changes of monthly TOC, which correspond to each atmosphere segment over Poland, in this or that month is made on the second stage. Linear equation of multiple regression is used as predictive model, which looks like: 

\[ Y(t) = c_0 + c_1 x_1(t) + c_2 x_2(t) + \ldots + c_N x_N(t) \]  

(1)

here \( c_i \) – constants, which are chosen so that the sum of deviation squares \( z(t) = Y(t) - y(t) \) for all the moments of period of time \( t \), when monitoring was made, was minimal; 

\( y(t) \) – is a temporary rank for each forecasting process over the period of 1979-2008y., and \( Y(t) \) – its model; 

\( x_i(t) \) – state in a moment of time \( t \) of some process, which is significantly statically connected with \( y(t) \).

As model arguments (1) of temporary ranks of average monthly superficial temperatures of significant World ocean regions are used in some, coinciding in time \( y(t) \) month, for the period of 1979-2008.

Forecasting was made for 2009 and 2010y., for there are results of satellite TOC monitoring for these years over Poland, what allows to make their comparison.

It was supposed, that the number of models arguments (1) is equal to the number of significant areas \( N \), and temporary rank of each of them contains \( M \) members (\( M = 2N \)). Then model coefficients (1) are counted as components (\( N+1 \)) of measuring vector \( C \), which is decision of vector-matrix equation:

\[ B = A \cdot C \]  

(2)

where \( C = N + 1 \) - measuring vector

\[ B = \left\{ \sum_{i=1}^{M} y_i \right\} \]

\[ B = \left\{ \sum_{i=1}^{M} y_i x_{i,1} \right\} \]

\[ B = \left\{ \sum_{i=1}^{M} y_i x_{i,1} x_{i,2} \right\} \]

\[ A = \left( \begin{array}{cccc} M & \sum_{i=1}^{M} x_{i,1} & \sum_{i=1}^{M} x_{i,2} & \ldots & \sum_{i=1}^{M} x_{i,N} \\ \sum_{i=1}^{M} x_{i,1} & \sum_{i=1}^{M} x_{i,1} x_{i,1} & \sum_{i=1}^{M} x_{i,2} x_{i,1} & \ldots & \sum_{i=1}^{M} x_{i,N} x_{i,1} \\ \sum_{i=1}^{M} x_{i,2} & \sum_{i=1}^{M} x_{i,1} x_{i,2} & \sum_{i=1}^{M} x_{i,2} x_{i,2} & \ldots & \sum_{i=1}^{M} x_{i,N} x_{i,2} \\ \sum_{i=1}^{M} x_{i,N} & \sum_{i=1}^{M} x_{i,1} x_{i,N} & \sum_{i=1}^{M} x_{i,2} x_{i,N} & \ldots & \sum_{i=1}^{M} x_{i,N} x_{i,N} \end{array} \right\} \]

The mention decision has the view: 

\[ C = A^{-1} \cdot B \]  

(3)

here \( A^{-1} \) is a matrix, which is reverse in relation to \( A \). The second task consisted in finding corresponding vector \( C \) for each considered region of Poland. The forecasting was carried out by substitution to a ratio (1) members of temporary ranks of its arguments, which correspond to 2009 and 2010y. Values of TOC are calculated for each month and each region of Poland. For each of them forecast rejections from the actual values are estimated.

As the actual material are used temporary ranks of the monthly values of superficial temperatures anomalies of all the regions of the Atlantic ocean, which correspond to the squares of coordinate grid in the size of
5°x5°, taken from [11]. Were concerned regions where temporary ranks during 1979-2010 do not contain admissions. Also were applied temporary ranks of the average monthly TOC values over each square 1°x1° of terrestrial surface, centre of which is located between parallels 55°N and 49°N, and also between meridians 14°E and 24°E, received from [1]. The considered atmosphere segment completely covers the whole territory of Poland with the adjacent regions of Germany, Ukraine and Belarus.

**Main part:**

With the use of the stated technique significant regions of the Atlantic ocean, which correspond to all the months of the year, had been revealed. The smallest number of such regions - 15, correspond to June. Coordinates of the significant revealed regions of the Atlantic ocean are specified in the Table 1. From the Table 1 it is clear that in the Atlantic ocean significant regions are located in Bering, Okhotsk, Yellow and Philippine seas, in the region of California.

**Table 1**: Coordinates of the regions centers of the Atlantic ocean, which are significant in modeling TOC changes above Poland in June.

<table>
<thead>
<tr>
<th>#</th>
<th>latitude (°)</th>
<th>longitude (°)</th>
<th>#</th>
<th>latitude (°)</th>
<th>longitude (°)</th>
<th>#</th>
<th>latitude (°)</th>
<th>longitude (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57.5N</td>
<td>17.5E</td>
<td>6</td>
<td>52.5N</td>
<td>17.5E</td>
<td>11</td>
<td>37.5N</td>
<td>17.5E</td>
</tr>
<tr>
<td>2</td>
<td>57.5N</td>
<td>22.5E</td>
<td>7</td>
<td>42.5N</td>
<td>12.5E</td>
<td>12</td>
<td>37.5N</td>
<td>22.5E</td>
</tr>
<tr>
<td>3</td>
<td>52.5N</td>
<td>2.5E</td>
<td>8</td>
<td>42.5N</td>
<td>17.5E</td>
<td>13</td>
<td>32.5N</td>
<td>7.5E</td>
</tr>
<tr>
<td>4</td>
<td>52.5N</td>
<td>7.5E</td>
<td>9</td>
<td>37.5N</td>
<td>7.5E</td>
<td>14</td>
<td>32.5N</td>
<td>22.5E</td>
</tr>
<tr>
<td>5</td>
<td>52.5N</td>
<td>12.5E</td>
<td>10</td>
<td>37.5N</td>
<td>12.5E</td>
<td>15</td>
<td>27.5N</td>
<td>-12.5W</td>
</tr>
</tbody>
</table>

Current, in the zones of Interpassat contrecurrent and Southern passat current, and on the Northern and Southern peripheries of the Western winds current.

While solving the second task for each month the TOC change models (1) are identified in all the considered segments of atmosphere.

By means of these models are calculated TOC values for various parts of Poland, forecasted for June 2009 and 2010. These forecasts, as well as the essential values of TOC over various regions of Poland in June 2009 are given in the table 2.

**Table 2**: Essential and forecasting TOC values over the regions of Poland in June, 2009.

<table>
<thead>
<tr>
<th>Fact</th>
<th>14°E</th>
<th>16°E</th>
<th>18°E</th>
<th>20°E</th>
<th>22°E</th>
<th>24°E</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°N</td>
<td>355.3</td>
<td>354.7</td>
<td>354.6</td>
<td>353.7</td>
<td>354.7</td>
<td>355.2</td>
</tr>
<tr>
<td>53°N</td>
<td>350.9</td>
<td>350.9</td>
<td>351.7</td>
<td>351.5</td>
<td>351.6</td>
<td>352.1</td>
</tr>
<tr>
<td>51°N</td>
<td>348.8</td>
<td>348.9</td>
<td>350.2</td>
<td>349.8</td>
<td>350.5</td>
<td>349.8</td>
</tr>
<tr>
<td>49°N</td>
<td>349.9</td>
<td>350.0</td>
<td>350.9</td>
<td>350.8</td>
<td>350.2</td>
<td>349.7</td>
</tr>
</tbody>
</table>

**Table 2**: Essential and forecasting TOC values over the regions of Poland in June, 2009. Outlook |

<table>
<thead>
<tr>
<th>Fact</th>
<th>14°E</th>
<th>16°E</th>
<th>18°E</th>
<th>20°E</th>
<th>22°E</th>
<th>24°E</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°N</td>
<td>352.6</td>
<td>351.8</td>
<td>348.8</td>
<td>346.8</td>
<td>345.9</td>
<td>346.0</td>
</tr>
<tr>
<td>53°N</td>
<td>352.5</td>
<td>352.2</td>
<td>350.6</td>
<td>350.0</td>
<td>340.0</td>
<td>348.5</td>
</tr>
<tr>
<td>51°N</td>
<td>350.9</td>
<td>349.5</td>
<td>350.0</td>
<td>351.8</td>
<td>350.6</td>
<td>350.7</td>
</tr>
<tr>
<td>49°N</td>
<td>350.9</td>
<td>350.6</td>
<td>350.9</td>
<td>352.3</td>
<td>351.9</td>
<td>351.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Forecast error</th>
<th>14°E</th>
<th>16°E</th>
<th>18°E</th>
<th>20°E</th>
<th>22°E</th>
<th>24°E</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°N</td>
<td>2.7</td>
<td>2.9</td>
<td>5.8</td>
<td>5.8</td>
<td>6.8</td>
<td>8.9</td>
</tr>
<tr>
<td>53°N</td>
<td>-1.6</td>
<td>-1.3</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>51°N</td>
<td>-0.1</td>
<td>-0.5</td>
<td>0.2</td>
<td>-2.0</td>
<td>-0.1</td>
<td>-0.9</td>
</tr>
<tr>
<td>49°N</td>
<td>-1.1</td>
<td>-0.3</td>
<td>-0.1</td>
<td>-1.4</td>
<td>-1.7</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

From the table 2 it is clear that the greatest forecast error values (9.1 e.D.) correspond to the region of Poland with the centre coordinates 55°N, 24°E. Average forecast error value over the whole Polish territory with anticipation in a year makes 1.44 e.D., which is less than the TOC error measurement, provided by the Dobson spectrophotometer.

Similar comparisons for 2010 have shown, that at forecast of 2 years average value of a forecast error equals 4.6 e.D. If the forecast for 2010 is made with taking the changes of model (1) in the period of 1980-2009 (i.e. with the forecast for one year) into account, average value of its mistake will be =2.64 e.D. In other months the number of significant regions of the Atlantic ocean is bigger, and the mistakes of TOC forecasts over Poland are less.

**Conclusions:**

1. There are areas in the Atlantic ocean, where interannual changes of their superficial temperatures significantly influence variations of TOC over Poland, which correspond in time. It confirms adequacy of hypothesis on the wave nature of the allocation mechanism in the stratosphere of substances, which destroy ozone.
2. Errors in forecasting allocations of TOC changes over Poland are maximal in June and increase while increasing forecasting. Nevertheless, at values of forecast of more than 2 years their levels by module don't exceed absolute error of measurements of this characteristic with the help of the most exact of the existing
devices - Dobson spectrophotometer. It confirms efficiency of implying herein described technique when forecasting the considered process.

REFERENCES