ATMOSPHERIC OZONE REMOTE SENSING AND THE VALORIZATION OF THE WEB-SITES CONTAINING SUCH SPECIFIC INFORMATION

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Abstract. *The research of the atmospheric (especially stratospheric) ozone is achieved by the World System for Ozone Observing (SMOO$_3$), a part of the World Weather Organization. In the field of space observation there are involved several programs, such as TOMS-EP, UARS, ERS, ENVISAT, METOP and METEOR, AURA. The TOMS, GOME, OMI and SCIAMACHY spectrometers, embarked on some of the mentioned satellites, allow the measurement of the UV radiation and of the ozone concentration, together with the monitoring of the horizontal and vertical facilitates the possibility of obtaining specific graphic and cartographic representations: the graph of the altitudinal O_3 distribution and maps of the O_3 distribution at global scale or above each hemisphere, in the Arctic, the Antarctic and in other regions of the world and in particular places. The real-time data, databases and related documents (tables, graphs and maps) are available on the web-sites of the specialized agencies/institutions, being available to various users, both scientists and practitioners. The paper presents the thematic content of some specialized web-sites and exemplifies the possibilities to use it through an application concerning the ozone concentration in the atmospheric column corresponding to the Romanian territory.*

Keywords: ozone, UV radiation, remote sensing, SCIAMACHY, website, databases

1. Introduction

One of the major risks endangering our environment is the destruction of the stratospheric ozone layer. It is a global process, intensified during the last decennia by the amplification of the CFC substances emission in the atmosphere. It has been demonstrated that the most active gas destroying the O_3 molecule is chlorine.

The ozone is an extremely rare gas in the Earth's atmosphere, yet very important for our environment. There are, in average, about three molecules of ozone to ten millions molecules of air. It can be found everywhere in the troposphere, but its concentration is higher in the stratosphere, between 25-40 km, where a characteristic layer is present. Constituted under the action of the UV rays, this layer has a role of protective screen exactly for the respective radiations, which, at very high rates, become damaging for organisms.

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The ozone is important for Terra from an energetic and a climatic viewpoint as well. It is considered that the lowering of the stratospheric ozone concentration contributes to the acceleration of the atmospheric warming process.

The destruction of the stratospheric ozone layer consists in the reduction of the O_3 concentration and, implicitly, in the rarefaction of the respective layer, a process amplified up to the appearance of the so-called “holes” in the Earth’s polar zones. The research undertaken so far has shown that the process of destruction of the ozone layer records variations in time, both intra-annual (seasonal) and inter-annual, and also in space (especially latitudinal). The most significant losses occur during the spring of the respective hemisphere, when the “holes” above Antarctica and the Arctic region become larger. Their dimensions fluctuate from one year to the next. So, the satellite measurements concerning the ozone layer in the stratosphere of Antarctica indicate the following differences for the period 2006-2008: 29 millions km^2 in 2006, 25 millions km^2 in 2007 and 27 millions km^2 in 2008 (EARSeL, Newsletter, December 2008, No. 76).

The most significant variations in space are the latitudinal ones. As we have already shown, the greatest losses occur in the stratosphere from the poles, with the appearance of the “ozone holes” above the Arctic region and over Antarctica (more extended). At the same time, we have in view the pollution with O3 of the tropospheric air, a much more accentuated process in the northern hemisphere, whose emissions are higher because of its urbanization and industrialization.

The monitoring of the stratospheric / tropospheric ozone, and of all the chemical and physical atmospheric constituents is achieved in a corroborated way, from terrestrial stations, by means of spectrophotomeric surveys / measurements using survey balloons (aerological balloons) and from specialized spatial platforms (satellites), where emission / absorption spectrometers have been installed. At the same time, these instruments are used to measure as well the ultraviolet (UV) radiation. We can say that today, the concentration of O_3 and the quantity of UV rays are continually under control, which allows the people worldwide to adopt concerted measures on a global scale.

Satellite remote sensing has a special contribution to the investigation of the tropospheric and stratospheric ozone in many ways: measuring the concentration, the spatial distribution in the planetary atmosphere (vertically and horizontally) and the distribution in time (daily, monthly, annual, and multiannual), the consequences on the environment (climate, vegetation, fauna) and especially on the human organism. These measurements and representations implicitly highlight the situation of the tropospheric air pollution with ozone.

The research on the stratospheric ozone is systematically achieved by the WMO ozone observing system in which are involved a network of terrestrial stations and a series if satellite Earth observation programs (TOMS, UARS, ERS, ENVISAT, ADEOS, AURA).

In this work is presented the thematic content of certain specialized sites and the way how their content can be used by means of an application concerning the ozone concentration in the atmospheric column corresponding to the territory of Romania.

2. Satellites used for ozone remote sensing

The remote sensing satellites used to carry out the ozone measurements evolve on a quasipolar (heliosynchronic) orbit. They have been launched as part of some special Earth observation programs, managed by several of the most significant space agencies: NIMBUS (launched by *NASA*[1] in 1978), UARS (*NASA*, 1991), TOMS (*NASA*, 1996), ERS-2 (*ESA*[2], 1995), ENVISAT (*ESA*, 2002), METOP (*ESA*, 2006), ADEOS (*NASDA*[3], 1996), METEOR-3 (Russia, 1998), AURA (*NASA, 2004).*

Given the quantity and quality of the information acquired and analyzed so far by the scientific community, we can consider that these missions have revolutionized many domains in the sphere of sciences and practical applications.

• **UARS** (Upper Atmospheric Research Satellite):

- *NASA* orbital observatory achieved as part of the *NASA*'s Mission to Planet Earth program (which today is called Earth Science)
- it is the first satellite meant for the study of global atmospheric changes: composition, temperature and dynamics of the upper atmosphere (stratosphere, mesosphere), energy inputs.
- it was launched in 1991 on an orbit at an altitude of 600 km

• **TOMS-EP** (Total Ozone Mapping Spectrometer – Earth Planet):

- *NASA* satellite evolving as part of the Mission to Planet Earth program (Earth Science)
- it was launched in December 1996
- the altitude of its orbit is: 720 km
- it takes a day to surround the Earth
- it continues the measurements made by Nimbus – 7 and Meteor – 3, being equipped with the same instruments
- it provides a daily map of the O_3 layer

[1] *NASA* – National Aeronautics and Space Administration
[2] *ESA* – European Space Agency
[3] *NASDA* – National Space Development Agency of Japan

• **ERS-2** (European Remote Sensing Satellite):

- it is a European program (*ESA*) meant for the observation of the Earth and of its environment using quasipolar orbit satellites
- it was launched in 1995, and the height of its orbit is: 800 km
- it is one of the best equipped satellites of its kind (especially with radar sensors and spectrometers)
- one of its objectives is to measure the atmospheric ozone (GOME spectrometer)
- the revisit interval is: 3 days

• **ENVISAT** (Environmental Satellite):

- it is the most complex European program (*ESA*) for environmental monitoring, continuing the observations made by ERS-1 and ERS-2
- the ENVISAT satellite was set into orbit in March 2002, at an 800 km altitude
- onboard are installed 9 high precision sensors in order to make measurements concerning the atmosphere, the oceans, the land and the ice.
- its mission is that of global Earth monitoring as part of the World Climate Research Program (WCRP).
- it represents the contribution of Europe (*ESA*) to supervising and understanding the environmental problems on a global scale; it provides useful data for explaining climate change and general environmental change mechanisms.
- repetition cycle: 35 days

• **METOP** (Meteorological Operational Satellite):

- European meteorological program that uses the polar orbit, while METEOSAT makes use of equatorial orbits
- the altitude of the orbit is around 840 km
- revisit interval: 14 times a day
- onboard are installed instruments for the measurement of the ozone level

• **METEOR-3**

- third generation satellites as part of the former USSR meteorological program

. this Russian satellite was launched in 1998, on a 1200 km altitude polar orbit

- endowed with a spectrometer made in America (TOMS), by virtue of a common program concerning the atmospheric ozone measurement.

• **ADEOS** (Advanced Earth Observing System)

- Japanese environmental satellite meant for atmospheric and oceanic investigations

- launched by *NASA* in 1996 (since 1997 it has been out of order)
- orbital altitude: 800 km
- revisit interval: 4 days

• **AURA**

- multinational scientific research satellite, launched as part of the EOS (Earth Observing System) missions in 2004; managed by *NASA.*

- orbital altitude: 705 km

- meant for measurements concerning the atmospheric pollutants (CH4, SO2, S2O, NO2, CO, CFC etc.), and especially concerning the ozone.

3. Instruments for measuring the ozone concentration and for ozone layer mapping

The instruments used for measuring the O_3 concentration are absorption spectrometers. In fact, the spectrometers measure the atmospheric transparency to solar radiation in the UV domain, and these measurements help calculate the total ozone quantity contained in an atmospheric column. It is known that the ozone is formed under the UV rays' action. The measurements and the calculations concern the stratospheric and the tropospheric ozone and the total ozone column.
Remote sensing satellites are equipped, each one differently, with the following types of spectrometers:

• **GOME** (*Global Ozone Monitoring Experiment*):

- it is a sophisticated absorption spectrometer that can be found onboard the European Satellites ERS-2 and METOP,

- it measures the contents of gases and aerosols (including pollutants) in the troposphere and in the stratosphere; the horizontal resolution of its recordings is 40 km, and the vertical resolution is 1 km,

-it records the solar radiation transmitted through the Earth atmosphere (including the UV radiation),

-the total ozone column derives from the GOME radiance data, using the Differential Optical Absorption Spectroscopy (DOAS) concept,

- on the basis of the concept of spectral analysis, daily ozone distribution maps have been achieved (a global map, a global model, with an accuracy of the modeled data of about 2%),

-at the same time, vertical profiles of the stratospheric and tropospheric ozone are obtained (the total ozone column)

-the purpose is to elaborate more precise models concerning the ozone loss and to formulate more accurate predictions concerning the tendency of our atmosphere in the future.

• **SCIAMACHY** (*Scanning Imaging Absorption Spectrometer for Atmospheric Cartography – UV/VIS/IR*):

- absorption spectrometer for measuring and mapping the ozone, NO_2, SO_2 and aerosols content in the Earth's atmosphere
- it is embarked onboard the ENVISAT environment observing satellite.

• **TOMS** (Total Ozone Mapping Spectrometer):
- American spectrometer
- meant for sulfur dioxide and ozone measurement and mapping
- this type of spectrometer is installed onboard the American satellite TOMS-EP, onboard the Russian satellite METEOR-3 and onboard the Japanese satellite ADEOS.

• **OMI** (Ozone Monitoring Instrument)
- spectrometer onboard the AURA satellite
- its measurements allow for the obtaining of the vertical profiles for ozone and different pollutants

4. Web-sites with information on the atmospheric ozone and their valorization

4.1. Web-sites with information on O_3

- www.osei.noaa.gov:

- *osei* = Operational Significant Event Imagery
- *noaa* = National Oceanic and Atmospheric Administration

- www.esa.int:

- *esa* = European Space Agency

- www.wmo.int

- *wmp* = World Meteorological Organization

- www.sma.ch:

- *sma* = Switzerland Meteorological Agency

- http://www.temis.nl:

- *temis* = Tropospheric Emission Monitoring Internet Service

4.2. The content of the web-sites used

The informational content concerning the ozone and UV rays is posted on sites as cartographic representations (maps, Globe models) and graphs (latitudinal and vertical profiles) of their distribution, and also as online measurements (values), in real or near-real time, or as archived data for certain observation intervals for any point of the terrestrial atmosphere.

Bellow, we present the main themes and documents available on the consulted sites:

a) *Near-real time global ozone field* (images and data)

Based on the measurements achieved by different instruments (SCIAMACHY, GOME-2, TOMS and OMI) it is possible to find the O_3 repartition on the Globe for daily, monthly, yearly and multi-yearly intervals.

Recent Ozone Maps: for the entire Globe, for the hemispheres, in the Arctic region and in Antarctica (fig. 1).

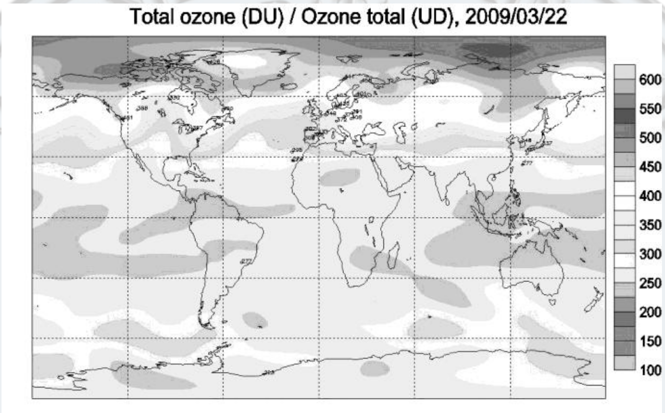
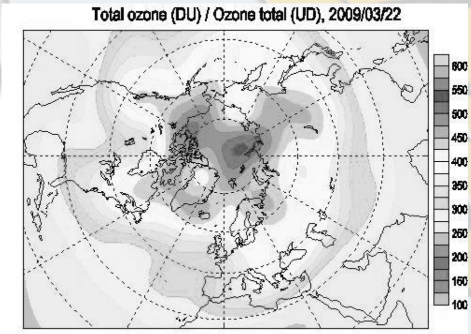


Fig.1a.



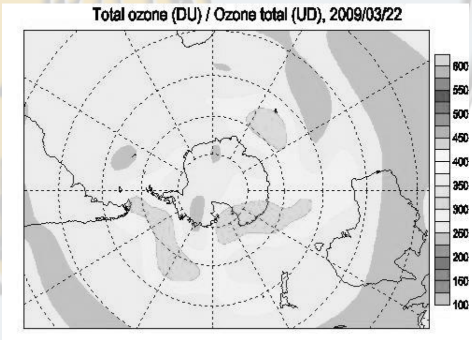


Fig. 1b. **Fig.1c.**

b) *Near-real time total ozone column*

c) *Global ozone field forecasts*, document achieved on the basis of SCIAMACHY recordings (fig. 2)

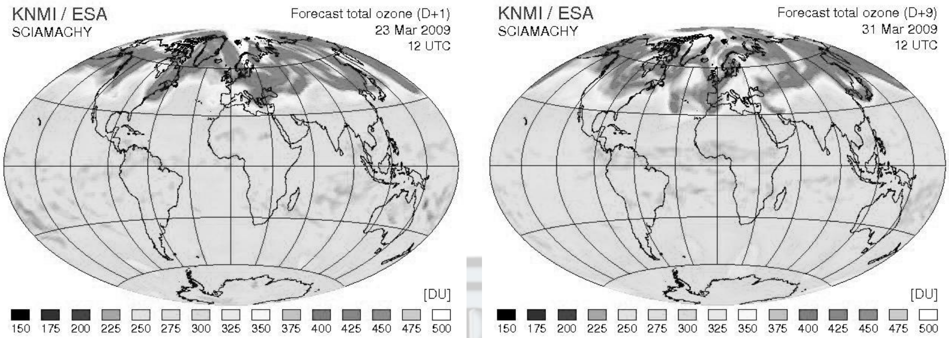


Fig. 2

d) UV radiation monitoring from SCIAMACHY
- on the Globe
- Europe
- Romania
- any place determined using geographic coordinates (fig. 3)

UV radiation monitoring products		
product	*near-real time delivery*	*archives*
UV index	Forecasts for today + 8-days ahead	UV index archives (SCIAMACHY Jul 2002 - present)
	Forecasts at your location	UV index archives (GOME Aug 1995 - May 2003)
UV daily doses - erythema - DNA-damage - Vitamin-D	Yesterday's analysis	UV dose archives (SCIAMACHY Jul 2002 - present)
		UV dose archives (GOME Aug 1995 - May 2003)
Timeseries (selected locations)	time series until yesterday	UV station data (SCIAMACHY Jul 2002 - present)
		UV station data (GOME Aug 1995 - May 2003)

Fig. 3

e) *Clear Sky UV index and ozone at a location from SCIAMACHY* (fig. 4)
- important towns from allover the world
- Romanian towns

f) *Archives* ((table 1, table 2):
- TOMS (Total Ozone Mapping Spectrometer Inventory Page)

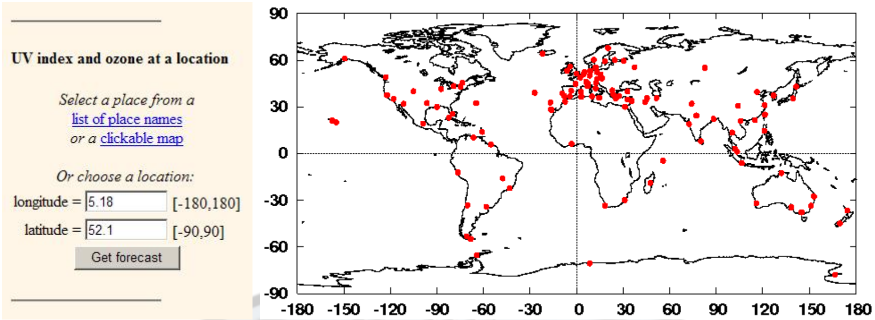


Fig. 4

(http://www.osei.noaa.gov/TOMS)
- OMI: images (2004-2009); data (2004-2009)
- SCIAMACHY: data and images (2002-2009)
- GOME: Near real time images (1998-2009)

4.3. Ozone distribution over the territory of Romania on February 22, 2009

The data concerning the O_3 concentration and UV radiation in the Earth's atmosphere are obtained by means of the SCIAMACHY spectrometer, being available online on the site: www.esa.int. We took over the data concerning 28 towns from allover Romania on 22.02, 10.03 and 23.03.2009, by automatic rendering immediately after we introduced of the geographic coordinates (longitude and latitude). They were transcribed in a table (table 3) and, at the same time, on the Romanian map, which made it possible to achieve the O_3 distribution map for the respective data (fig. 5, fig. 6, fig.7).

Table 3. *Clear Sky UV index and ozone at different locations from Romania by SCIAMACHY* (22.02, 10.03, 23.03.2009)

No.	Locality	Longitude/Latitude	UV Index			Ozone column (DU) [1)]		
			22.02	10.03	23.03	22.02	10.03	23.03
1	Calafat	22°55’/44°00’	1.9	2.9	3.4	422.4	374.3	401.1
2	Turnu Măgurele	24°52’/43°43’	1.9	3.1	3.4	412.9	365.2	407.5
3	Giurgiu	26°00’/43°52’	1.9	3.1	3.3	403.7	364.2	414.0
4	Călăraşi	27°22’/44°14’	1.0	3.0	3.1	430.3	367.2	420.5
5	Mangalia	28°35’/43°53’	2.0	3.0	3.3	395.0	371.2	414.2
6	Moldova Nouă	21°40’/44°42’	1.7	2.8	3.3	423.6	379.7	398.3
7	Drobeta Turnu Severin	22°40’/44°40’	1.7	2.8	3.3	424.1	375.2	401.2
8	Craiova	23°45’/44°20’	1.8	2.9	3.3	421.5	369.2	404.5

9	Bucureşti	26°05'/44°25'	1.8	3.0	3.1	404.5	362.6	418.2
10	Constanţa	28°35'/44°13'	1.9	2.9	3.1	394.3	369.7	422.4
11	Timişoara	21°15'/45°45'	1.6	2.6	3.2	423.4	382.0	495.4
12	Hunedoara	22°54'/45°44'	1.7	2.8	3.3	422.8	375.0	400.9
13	Sibiu	24°10'/45°46'	1.7	2.9	3.2	417.4	364.9	407.9
14	Braşov	25°40'/45°35'	1.8	2.9	3.1	407.6	362.0	416.4
15	Focşani	27°12'/45°42'	1.7	2.8	2.9	398.0	367.1	428.8
16	Galaţi	28°00'/45°30'	1.8	2.8	2.9	395.8	366.4	432.7
17	Tulcea	28°48'/45°10'	1.8	2.8	2.9	394.6	366.2	432.0
18	Sulina	28°45'/45°10'	1.8	2.8	2.9	394.7	366.2	432.0
19	Oradea	21°55'/47°05'	1.4	2.4	3.0	425.2	386.0	390.8
20	Cluj-Napoca	23°42'/46°48'	1.6	2.6	3.1	420.7	373.7	399.9
21	Târgu-Mureş	24°35'/46°35'	1.6	2.7	3.0	415.2	368.5	405.1
22	Piatra Neamţ	26°20'/46°56'	1.6	2.7	3.0	400.3	364.2	414.0
23	Iaşi	27°38'/47°15'	1.6	2.6	2.8	393.8	361.9	417.7
24	Satu Mare	22°53'/47°48'	1.4	2.4	3.0	427.5	385.5	392.3
25	Baia Mare	23°38'/47°48'	1.4	2.4	3.0	426.2	381.7	395.3
26	Vatra Dornei	25°20'/47°18'	1.6	2.6	3.0	411.2	367.4	402.6
27	Suceava	26°15'/47°45'	1.6	2.6	2.9	411.2	364.7	407.2
28	Botoşani	26°42'/47°43'	1.5	2.6	2.9	402.3	364.7	409.2

[1)] **DU** – *Dobson Unit* – A Dobson unit is a unit of measurement rendering the concentration (density) of the ozone layer in a column situated over a certain location

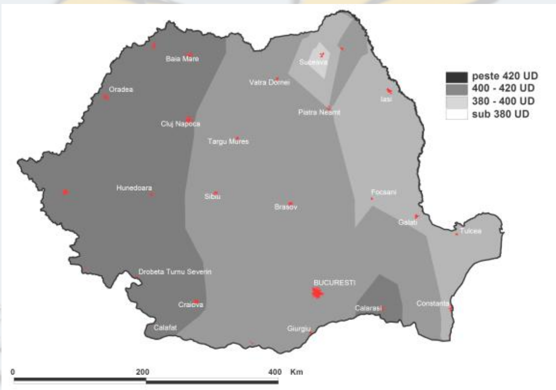


Fig. 5. The ozone concentration distribution map (DU) in the atmospheric column of Romania On February 22, 2009

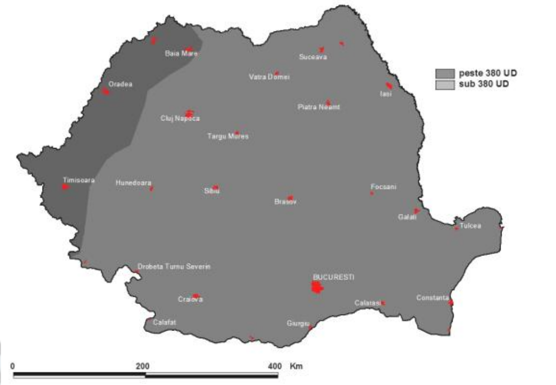


Fig. 6. The ozone concentration distribution map (DU) in the atmospheric column of Romania On March 10, 2009

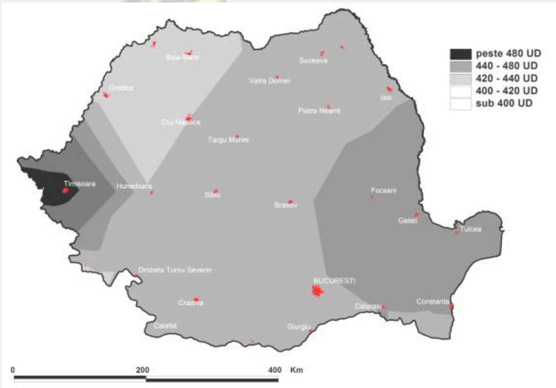


Fig. 7. The ozone concentration distribution map (DU) in the atmospheric column of Romania on March 23, 2009

The values of the ozone concentration in the atmospheric column situated over the territory of Romania are correlated to those from the European region in which our country is situated (400 – 550 DU) for the interval under analysis.
On 22.02.2009 the values range between 364.7 - 430.3 DU (with an average of 397.2 DU), on 10.03.2009, between 361.9 – 386.0 (average: 373.9), and on 23.03.2009 between 393.3 - 495.4 (average: 444.3).

The ozone concentration evolved as follows during the 22.02 – 23.03.2009 interval: a decrease during the second decade of the month of February and the first decade of the month of March, which corresponds to the period of overall decrease of the O_3 concentration in the entire northern hemisphere (especially in the polar area) and an increase beginning with the second decade of the month of March.

It is interesting to notice that on February 22 the highest values (over 420 DU) were recorded in the western area of the country, while the lowest values (under 380 DU) were registered in the east and south-east of Romania (the Danube Delta and the Romanian coast of the Black Sea) and on March 23, the highest values (over 480 DU) were recorded in the western extremity of the country, the average values in the south-east (420 – 440 DU) and the minimal values (under 400 DU) in the west – north-west of Romania.

The temporal and spatial variations of the ozone concentration are closely related to those of the UV radiation index, a value representing the atmospheric transparency to this type of rays of the electromagnetic spectrum. This index is related to the duration of Sun brilliance, to nebulosity and also to the atmospheric properties on the day and at the place where the measurement took place. Among the atmospheric features, the most significant role goes to transparency, determined, in its turn, by the content of water vapors and pollutants (especially aerosols and CFCs), substances responsible for the O_3 molecule decomposition in the stratosphere.

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