UKRAINE
National Report for the 12th WMO/UNEP Ozone Research Managers Meeting

1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone and other gases/variables relevant to ozone loss

Historically, in Ukraine, column measurements of ozone were carrying out by ozonometric stations (measurements stopped in 2019) subordinated to the national hydrometeorological service and two scientific stations, including the regional WMO station Kyiv-Goloseyev (498 KGV) and the Antarctic Vernadsky Research Base.

The ozone network was established in 1973 by launching measurements in Feoodosiia (Karadag) and Kyiv (Boryspil). Lviv and Odesa started ozone column measurements in 1974; Kyiv (at the Ukrainian Hydrometeorological Institute – UHMI) and Boguslav in 1989. Kyiv (UHMI) and Bohuslav were scientific stations. All these stations used M-83/M-124 filter ozonometers for column ozone observations. In 1996, calibration of filter ozonometers was stopped, previously provided at the A.I. Voeykov Main Geophysical Observatory (MGO). In 1996, the Ukrainian Hydrometeorological Service started searching for new ways to support the national network and calibration activity. Within the framework of collaboration with WMO under the project ENV/1/3/1, it was sent an inquiry for the Brewer spectrophotometer (renewed request in 2003). However, this way did not find further development. In 2011–2012, the main center for technical services of the Ukrainian Hydrometeorological Center started modernizing filter ozonometers. In 2014, a working group was created to coordinate the work of the Ukrainian ozonometric network and identify its main issues. This group provided its activity until 2019. Because of the outdated filter ozonometers that stopped working properly, column ozone measurements at the national network were interrupted, and the working group stopped activity until the renovation of network measurements. Since 2019, no column ozone measurements are available at the Ukrainian ozonometric network operated by the national Hydrometeorological Service.

Regional WMO station Kyiv-Goloseyev (498 KGV) was established in 2010, being operated by Taras Shevchenko National University of Kyiv (TShNUK) and located at the Main Astronomical Observatory (MAO). Column ozone measurements are provided by the Dobson spectrophotometer D040 (Beck). The station is supported by the staff of TShNUK and MAO. Another regional WMO station Faraday-Vernadsky (FAD) is operated at the Ukrainian Akademik Vernadsky Research Base, Galindez Island (former British Antarctic Survey base Faraday), since 1956. Column ozone measurements are provided by Dobson spectrophotometer D031/ D123.

The problems with ozone observations in Ukraine resulted in active use of satellite measurements. Since 1990th, ozone monitoring in Ukraine continuously maintained by using GOME, GOME-2, TOMS, OMI, TROPOMI and other satellite instruments.

1.2 Profile measurements of ozone and other gases/variables relevant to ozone loss

The Umkehr vertical ozone profiles are measured using Dobson spectrophotometers D040 and D123 at the KGV Dobson station (Ukraine) and over Vernadsky FAD station in Antarctica, respectively (*Andrienko et al., 2021*). The Umkehr observations are pre-processed using the UMK92 algorithm. The latest research activities include the consideration of the UMK04 algorithm.

1.3 UV measurements

UV observations were conducted in Kyiv (UHMI) till 2000, and Karadag till 2014, retrieved from M-124 measurements. Apart from these, UV is estimated using the methodology developed at UHMI that requires ozone total column data (ground-based or satellite) as input (e.g., *Dvoretska et al., 2019; Savenets et al., 2020*). This methodology includes an empirical model that quantifies the spectral density of UV-B radiation (at a wavelength of 300–315 nm with a step of 0.5 nm) based on Beer-Lambert law, considering the Forbes effect (*Beliavskiy et al., 1999*). The input parameters are solar angle, total ozone, and cloudiness. The spectral density is recalculated to UVI for better public understanding.

1.4 Calibration activities

Till 1996, the calibration of M-83/M-124 filter ozonometers was conducted at the MGO every two years. Since that time, the calibration of filter ozonometers used on the Ukrainian network has stopped. Consequently, reporting to WOUDC stopped in 1998. After the attempt at outdated filter ozonometers modernization in 2012, a seminar was organized in 2014 to discuss the coordination work for the Ukrainian ozonometric network, including calibration procedures. Despite the calibration against the Dobson spectrophotometer D040 and testing, filter ozonometers stopped working properly, and observations were terminated.

Dobson spectrophotometers (D040 at KGV station and D123 at FAD station) remain the only calibrated instruments. In particular, spectrophotometer D040 was intercalibrated in the SOO Hradec Kralove against D074 in April 2010.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

The analyses of ozone distribution and variability were conducted as for Ukraine (e.g. *Dvoretska et al., 2021; Grytsai & Milinevsky, 2013*) and northern hemisphere (e.g. *Evtushevsky et al., 2014*), so also for Antarctica region (e.g. *Andrienko et al., 2021; Grytsai et al., 2022*). In 1990th – early 2000th results of ozone and UV observations were published annually as a chapter in the national reports on environmental conditions by the Ministry of Environmental Protection. Over the last decades, monitoring results was presented in interim and final reports of the governmental projects and in scientific papers (e.g., *Dvoretska et al., 2011; Dvoretska et al., 2019; Savenets et al., 2020*). The updated ozone climate normals were calculated for the period of 1991–2020 based on the TOMS/OMI data (*Dvoretska et al., 2021*). Typically, total ozone varies from 285 to 375 D.u. The maximum total column is observed from March 19 to 30, depending on the region. Total ozone decreased over Ukraine compared to the previous climate period, with the highest changes of 8 D.u. in winter. However, no increase in UV levels was observed. Figure 1 shows total ozone content (TROPOMI) and estimated levels of UVI in 2023 for Kyiv (northern part of Ukraine) and Odesa (southern part of Ukraine).

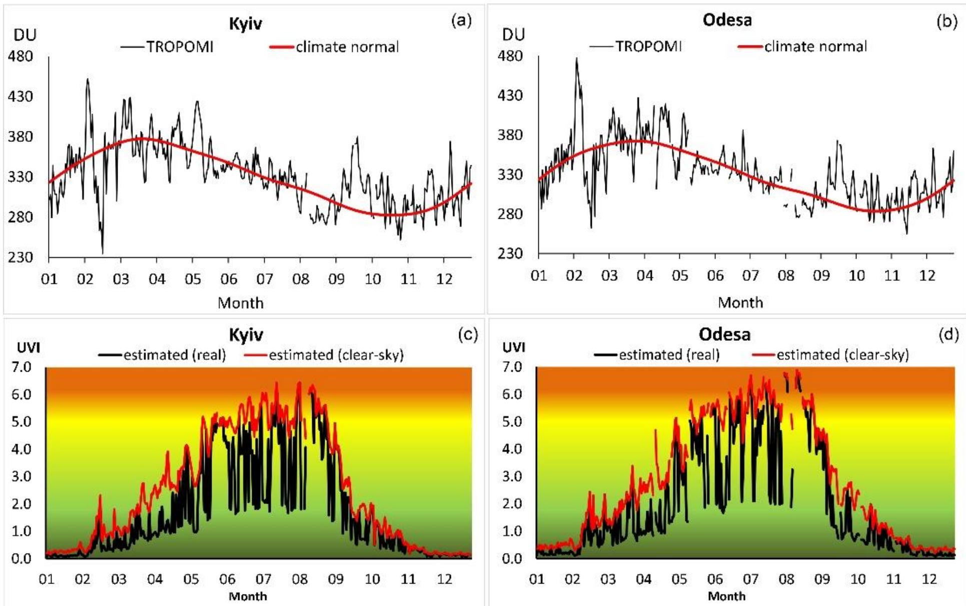

Figure 1. Annual variability of TROPOMI total ozone content (a, b) and estimated UVI (c, d) in 2023 over Kyiv, located on the north (a, c), and Odesa, located on the south of Ukraine (b, d)

The Umkehr observations with Dobson spectrophotometer indicated that the maximum ozone concentration locates in the altitudes of 15–25 km with an average height of 19.8±1.4 km (*Andrienko et al., 2021*). The maximum ozone partial content is of 60–80 DU/layer. Long-term changes of total ozone correspond to its decrease from the 1970s to the 1990s, but the rate of decline slowed down at the beginning of the 21st century (*Mogylchak & Milinevsky, 2017*).

3. THEORY, MODELLING, AND OTHER OZONE RELATED RESEARCH

The total ozone prediction methodology was developed in UHMI based on the regression dependencies on wind, air temperature and air moisture parameters at different altitudes (*Dvoretska & Sydorenko, 2012*). The error of total ozone forecast does not exceed 5%, being slightly higher compared to the observed values. Consequently, it is used for operational forecasting, including the prediction of UVI. *Dvoretska et al. (2021)* showed that the average values of higher/lower total ozone content over Ukraine do not always align with the characteristics of latitudinal distribution. This discrepancy occurs due to more frequent air advection with atypical total ozone levels for the Ukrainian territory, primarily from January to March. Changes in total ozone are mainly associated with shifts in the meridional wind to negative values, which influence the frequency of air advection from the north. The Umkehr observations showed that a that the lower ozone content occurs in summer and autumn months in the range of 60–75 DU/layer, while higher ozone profiles are in winter and spring (*Andrienko et al., 2021*). The study of ozone distribution in the northern hemisphere reveals a 2- to 3-month lead of annual cycle in eastern Asia (120–150° E) in comparison with that in eastern Atlantic (0–30° W) (*Evtushevsky et al., 2014*). Efforts are made to study the role of planetary (Rossby) waves and sudden stratospheric warming for ozone distribution (*Grytsai et al., 2022; Shi et al., 2022; Zhang et al., 2022*).

4. DISSEMINATION OF RESULTS

4.1 Data reporting

Ozone data measured by Dobson spectrophotometers are regularly submitted to WOUDC. Until 1998, total ozone data measured by filter ozonometers from all stations were also submitted to WOUDC. At the national level, total ozone data measured by M-83/M-124 filter ozonometers were submitted daily to the Ukrainian Hydrometeorological Center (UHMC) and monthly to the Central Geophysical Observatory (CGO) until 2019. In the 1990s and early 2000s, results of ozone and UV observations were annually published as a chapter in the national reports on environmental conditions by the Ministry of Environmental Protection. Results of daily total ozone monitoring derived from satellite data and estimated UV Index are included in the corresponding reports of the national government orders.

4.2 Information to the public

Information about total ozone content from the satellite missions and estimated UVI levels, as well as their forecast, is available to the public upon request. The results of analysis and research are regularly published in national and international peer-reviewed journals.

4.3 Relevant scientific papers

Andrienko Y., Milinevsky G., & Danylevsky V. (2021). Vertical ozone profiles in the atmosphere over the Antarctic Peninsula and Kyiv by Umkehr observations. Ukrainian Antarctic Journal, 2, 35-47. https://doi.org/10.33275/1727-7485.2.2021.676

Beliavskiy A.V., Grishchenko V.F., & Kruchenitskiy G.M. (1999). Empirical model to estimate solar ultraviolet irradiance based on the observations performed during the Second Ukrainian Antarctic Expedition. Scientific papers of UkrNDGMI, 247, 30-35 [In Rus.]

Dvoretska I.V., Banakh R.I. & Savenets M.V. (2011). UVI climate normals over the territory of Ukraine. Physical geography and geomorphology, 63, 164-168 [In Ukr.]

Dvoretska I.V. (2012). Features of total ozone dynamics in the modern period. Scientific papers of UkrNDGMI, 262, 251-271 [In Ukr.]

Dvoretska I.V. & Sydorenko A.V. (2012). Forecast of the total ozone content over the territory of Ukraine. Scientific papers of UkrNDGMI, 261, 106-116 [In Ukr.]

Dvoretska I. V., Savenets M. V., Umanets A. P., & Komisar, K. M. (2019). Examination of the ozone layer condition and level of ultraviolet irradiation within the territory of Ukraine in 2018. Ukrainian Hydrometeorological Journal, 23, 34-41. https://doi.org/10.31481/uhmj.23.2019.04 [In Ukr.]

Dvoretska I. V., Savenets M. V., & Umanets A. P. (2021). Updated total ozone climate normals over the territory of Ukraine. Ukrainian Hydrometeorological Journal, 28, 5-15. https://doi.org/10.31481/uhmj.28.2021.01 [In Ukr.]

Evtushevsky O., Grytsai A. & Milinevsky G. (2014) On the regional distinctions in annual cycle of total ozone in the northern midlatitudes. Remote Sensing Letters, 5:3, 205-212, https://doi.org/10.1080/2150704X.2014.894653

Grytsai A. & Milinevsky G. (2013) SCIAMACHY/Envisat, OMI/Aura, and ground-based total ozone measurements over Kyiv-Goloseyev station. International Journal of Remote Sensing, 34:15, 5611-5622, https://doi.org/10.1080/01431161.2013.794988

Grytsai A.V. & Milinevsky G.P. (2014). Analysis of the discrepancy between ground-based and satellite total ozone content measurements at Kyiv-Goloseyev station. Kosm. nauka tehnol., 20(1), 03-13. https://doi.org/10.15407/knit2014.01.003 [In Ukr.]

Grytsai A.V. & Milinevsky G.P. (2018). Total ozone content over Kyiv-Goloseyev station by ground-based and satellite measurements in 2010-2015. Space Science and Technology, 24(3), 40-54.

Grytsai A., Milinevsky G., Andrienko Y., Klekociuk A., Rapoport Y., & Ivaniha O. (2022). Antarctic planetary wave spectrum under different polar vortex conditions in 2019 and 2020 based on total ozone column data. Ukrainian Antarctic Journal, 20(1(24), 31-43. https://doi.org/10.33275/1727-7485.1.2022.687

Gvozdovskyy I., Orlova T., Salkova E., Terenetskaya I. & Milinevsky G. (2005) Ozone and solar UV-B radiation: monitoring of the vitamin D synthetic capacity of sunlight in Kiev and Antarctica. International Journal of Remote Sensing, 26(16), 3555-3559. https://doi.org/10.1080/01431160500076863

Lozitsky V., Grytsai A., Klekociuk A. & Milinevsky G. (2011) Influence of planetary waves on total ozone column distribution in northern and southern high latitudes. International Journal of Remote Sensing, 32(11), 3179-3186. https://doi.org/10.1080/01431161.2010.541519

Mogylchak V.Y. & Milinevsky G.P. (2017). Variations of total ozone in the atmosphere over the territory of Ukraine. Space Sci. & Technol., 23 (2), 41-47. https://doi.org/10.15407/knit2017.02.041

Savenets M.V. (2014). Transition from the nomogram to the analytical calculation of the total ozone content measured by the M-124 instrument. Scientific papers of UkrNDGMI, 266, 94-98. [In Ukr.]

Savenets M. V., Dvoretska I. V., Umanets A. P., & Grechana N. V. (2020). Ozone layer state and level of ultraviolet irradiance over the territory of Ukraine in 2019. Ukrainian Hydrometeorological Journal, 25, 53-62. https://doi.org/10.31481/uhmj.25.2020.05 [In Ukr.]

Shi Y., Evtushevsky O., Milinevsky G., Grytsai A., Klekociuk A., Ivaniha O., & Andrienko Y. (2022). The data processing and analysis methods for stratospheric ozone and planetary wave study. Ukrainian Antarctic Journal, 20(2(25), 164-187. https://doi.org/10.33275/1727-7485.2.2022.698

Zhang C., Evtushevsky O., Milinevsky G., Klekociuk A., Andrienko Y., Shulga V., Han W. & Shi Y. (2022). The Annual Cycle in Mid-Latitude Stratospheric and Mesospheric Ozone Associated with Quasi-Stationary Wave Structure by the MLS Data 2011–2020. Remote Sensing, 14, 2309. https://doi.org/10.3390/rs14102309

Zhang C., Grytsai A., Evtushevsky O., Milinevsky G., Andrienko Y., Shulga V., Klekociuk A., Rapoport Y., & Han W. (2022) Rossby Waves in Total Ozone over the Arctic in 2000–2021. Remote Sens., 14, 2192. https://doi.org/10.3390/rs14092192

5. PROJECTS, COLLABORATION, TWINNING AND CAPACITY BUILDING

Research related to ozone and UV is carried out within the national projects funded by the State Emergency Service of Ukraine and the National Academy of Sciences of Ukraine (e.g., Reg. No. 0121U109319, 0115U002801, etc.), Taras Shevchenko National University of Kyiv (e.g., 11BF051-01), and the State Institution National Antarctic Scientific Center of the Ministry of Education and Science of Ukraine (e.g., No. 4293). International collaboration included projects within the framework of the WMO GAW Programme, the Australian Antarctic Program, and others.

6. IMPLEMENTATION OF THE RECOMMENDATIONS OF THE 11th OZONE RESEARCH MANAGERS MEETING

NA

7. FUTURE PLANS

The main task is the resumption of the Ukrainian ozone observational network equipped with new instruments, with the consequent renewal of reporting by the national hydrometeorological service. Searching the ways and financial support to re-establish the network. Updating the plans, standards, regulations, and requirements during the process of ozone network resumption.

8. NEEDS AND RECOMMENDATIONS

Financial support to restore the ozone network and deepen international collaboration and consultancy at different stages of the resumption procedure.