INSTITUTE OF INNOVATIVE PROFESSIONS
(KYRGYZSTAN)

REPORT

on project «Technical support for equipping Issyk-Kul OMD station, Kyrgyzstan with modern measuring equipment for monitoring the ozone layer in the atmosphere of the mountainous region of Central Asia»

2023

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This descriptive report on the activities carried out within the framework of the project **"Technical support for equipping Issyk-Kul OMD station, Kyrgyzstan with modern measuring equipment for monitoring the ozone layer in the atmosphere of the mountainous region of Central Asia"** was developed in accordance with paragraph 3.3 of Article 3 Letter of Agreement between the World Meteorological Organization and the Institute of Innovative Professions (Agreement) and Second Amendment to the Letter of Agreement (Amendment 2) to the Agreement, which changed the timing of the project and the activities contained.

Introduction

Unlike the vast majority of stations in the world network located in the oceanic and coastal regions of the planet, the Issyk-Kul OMD station is located in the inland, poorly explored mountainous part of Central Asia (see figure 1). The uniqueness of the station's location is determined by the fact, that in this inland mountain ecosystems of Central Asia (Himalayas, Tien Shan, Pamir-Alai, Tibetan Plateau), generating powerful orographic waves, have a significant impact on the turbulence of the troposphere-stratosphere and high-altitude jet streams, that play a special role in the spatial and temporal variability of ozone and other climatically active small impurities in the atmosphere. In addition, this region is called the third pole of the planet because the mountain glaciers of this region significantly affect the climatic parameters of the atmosphere, similar to the glaciations of the north and south poles.

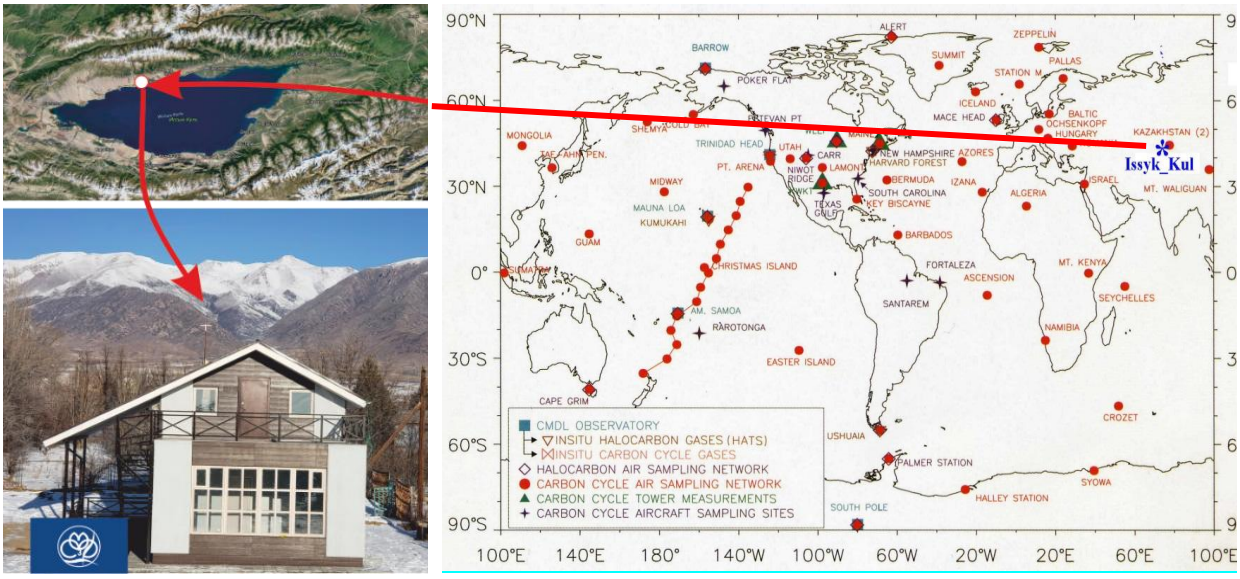


Figure 1. Location of the Issyk-Kul OMD station in relation to other stations of the Global Atmosphere Watch (GAW) network

An analysis of experimental data previously obtained at the Issyk-Kul OMD station (1980 - 2022) showed the presence of particularities in the variability of total ozone (TO), greenhouse

gases, aerosols and UV radiation intensity levels for the mountainous region of Central Asia in comparison with other regions of the planet, which require further thorough research using modern high-precision measuring equipment.

In recent years, in the conditions of the Issyk-Kul OMD station, high-precision field measurements were difficult due to the outdated and poor technical condition of the equipment used to measure TO for more than 40 years, which often failed and required a lot of time to repair it due to lack of spare parts. Interruptions in TO monitoring significantly reduced the value and reliability of the time series of experimental data for its use in order to identify patterns of TO changes and develop predictive models of the stratosphere.

In connection with the above, there was an urgent need to replace the spectrophotometric scanning device (SPSD), developed at the Kyrgyz State University, with a modern high-precision spectrophotometer. The need for a replacement has also increased due to the fact that the final documents of the 10th Meeting of Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer (ORM) included a proposal on the importance of supporting experimental research in the mountainous regions of Central Asia and the Himalayas, which was also included in the anniversary (30th) of the Montreal Protocol.

In order to increase the value and reliability of the experimental data obtained in the mountainous regions of Central Asia, the Institute of Innovative Professions (IIP) began to prepare a new scientific station Issyk-Kul OMD (OMD - Ozone Monitoring Development) near the old station on a land plot of 0.5 hectares. To equip the new station with modern high-precision measuring instruments, we prepared and submitted the project proposal in 2017 to the competition of the UN Secretariat for the Environment Program (UNEP Secretariat) “Technical support, information exchange for atmospheric monitoring at the shore of high mountain Issyk-Kul Lake (42.60 N, 77.00 E, 1650 m.a.s.l.)". The UNEP Secretariat supported our project proposal and submitted it to the Advisory Committee of the Vienna Convention Trust Fund on Scientific Research and Systematic Observations (the Committee). Based on the results of the competitive selection, the Committee decided to submit our project for consideration to the Scientific Advisory Group of the World Meteorological Organization (WMO), which, at its meeting held in Geneva, decided to provide the IIP, Kyrgyzstan, with a Brewer MkIV (# 083) spectrophotometer donated by the Government of Canada to WMO.

Thus, as a result of the preparatory work carried out over 3 years (2017-2019), on January 22, 2020, an Agreement on the roles and responsibilities of the parties was signed by IIP and WMO within the framework of the project **“Technical support for equipping Issyk-Kul OMD station, Kyrgyzstan with modern measuring equipment for monitoring the ozone layer in the atmosphere of the mountainous region of Central Asia”.**

Unfortunately, due to the outbreak of the COVID19 pandemic at the end of 2019, the Agreement was amended twice in the form of an Amendment to the Agreement - the first on February 2, 2021, the second on September 5, 2021.

1. Brewer MkIV (# 083) spectrophotometer platform

In connection with the above, as well as in accordance with the recommendations and decisions adopted in the final documents of the 10th ORM (Geneva, 2017) and the 11th Meeting of the Parties to the Vienna Convention (Montreal, 2017) on the priority of resuming and expanding experimental observations and research in mountainous regions of Central Asia and the Himalayas, IIP created a scientific station Issyk Kul OMD, which meets the modern requirements in the field of research on ozone layer and climate variability. For this, the IIP purchased a land plot (0.5 ha), built a modern laboratory building and houses for employees (Figure 2).



Figure 2. The platform and rooms for storing spare parts and related equipment for Brewer Mk IV (# 083)

As a result of participation in the competition announced by WMO, the IIP received support from WMO and the Vienna Convention Fund for the **project "Technical support for equipping Issyk-Kul OMD station, Kyrgyzstan with modern measuring equipment for monitoring the ozone layer in the atmosphere of the mountainous region of Central Asia"** (09.05.2019). As part of the Agreement (2020) between the IIP and WMO, a Brewer MkIV (# 083) spectrophotometer was delivered and put into operation at the Issyk-Kul OMD station.

For the Brewer MkIV (# 083) to work in automatic continuous mode, it was necessary:

- to ensure uninterrupted, stable power supply to the Brewer Mk IV (# 083) in the face of a shortage of electricity due to the congestion of the local transformer substation. For this, a separate power line was laid and a separate, own transformer substation was installed (Figure 3) after obtaining special permits from local authorities.

- to provide a reliable Internet connection. For this, a fiber optic cable (800 m) was laid, which was connected to the optical network of the local provider "ElCat" and the appropriate terminal equipment was installed to connect the Brewer MkIV (# 083) .

- to purchase a computer with UPS in accordance with paragraph (b) of Article 1.2 of the Agreement (Figure 4) to control the Brewer MkIV (# 083) , collect and process data and transmit to the World Data Center for Ozone and UV Radiation.



Figure 3. Transformer substation for uninterrupted power supply



Figure 4. Computer for management of Brewer Mk IV (# 083) with Uninterruptible Power Supply (UPS)

2. Provision of financial and technical conditions for the shipment of Brewer MkIV (# 083) and additional equipment from Canada to the Issyk-Kul OMD station

In accordance with paragraph (c) of Article 1.2 of the Agreement and Amendment 2 to the Agreement, financial and technical conditions were provided for the shipment of the Brewer MkIV (# 083) spectrophotometer and additional equipment from Canada (Toronto, Ontario) to the Issyk-Kul OMD station and organized customs clearance of import and export. The shipment from Toronto was at the beginning of March 2021. The delay in sending the cargo was due to the pandemic. All customs procedures were completed in mid-April 2021. Delivery of cargo from Bishkek to the station Issyk-Kul (village Baet, Issyk-Kul region, Kyrgyzstan) was carried out by road. Despite the long journey, the Brewer MkIV (# 083) spectrophotometer arrived at the Issyk-Kul OMD station in very good condition, which indicates the excellent work of the ECCC staff in preparing the cargo for shipment.

3. Working with an external expert to commission the Brewer MkIV (# 083) spectrophotometer and train Issyk-Kul OMD station personnel

In accordance with paragraph (f) of Article 1.2 of Agreement and Amendment 2 to the Agreement, the IIP entered into an Agreement (dated December 9, 2021) with an external expert from International Ozone Services Inc. Toronto Canada (IOS, Savastiouk V.) for funding and logistics for the installation, configuration of the Brewer MkIV (# 083) spectrophotometer, data acquisition and communication, regular calibration of the instrument, and staff training.

Due to the uncertainty of the timing due to pandemic, in agreement with WMO (Geneva) and an external expert from IOS, installation, configuration, commissioning of the Brewer Mk IV (# 083) spectrophotometer and training of station personnel with the participation of an external expert were carried out remotely (online) from 12 to 23 November 2021. Three specialists participated in these works on behalf of the IIP - a physicist, an IT engineer and an electronics engineer, who were trained to work with the Brewer MkIV (# 083).

The “Brewer IOS” operating software version 4.22 was installed on the local Brewer MkIV (# 083) control computer. In order to control the operation of the device in the measurement mode by operators, the software "O3Brewer" and "UvBrewer" was installed. The “ReporPro” software was installed to monitor the performance of the device by regular internal tests.

After completion of the installation, configuration, commissioning of the Brewer MkIV (# 083) spectrophotometer and training of personnel, an external expert presented a report on the work performed in accordance with the Contract concluded by him with the IIP.

After bringing the Brewer MkIV (# 083) into working condition, as it was being used, the IIP specialists repeatedly asked for advice and technical assistance from the external IOS expert, who always provided them promptly, efficiently and in the required volume.

4. Measurements with Brewer MkIV (# 083) spectrophotometer

Systematic continuous field measurements with the Brewer MkIV (# 083) spectrophotometer at the Issyk-Kul OMD station began on November 12, 2021. Figures 5-18 present the results of daily average TO and UV radiation, as well as world maps of ozone, which are compiled from satellite and reliable ground-based measurements, including our Issyk-Kul OMD station.

Figure 5 shows the average daily TO values measured by the Brewer MkIV spectrophotometer (serial no. 91-083) at the Issyk-Kul OMD station.

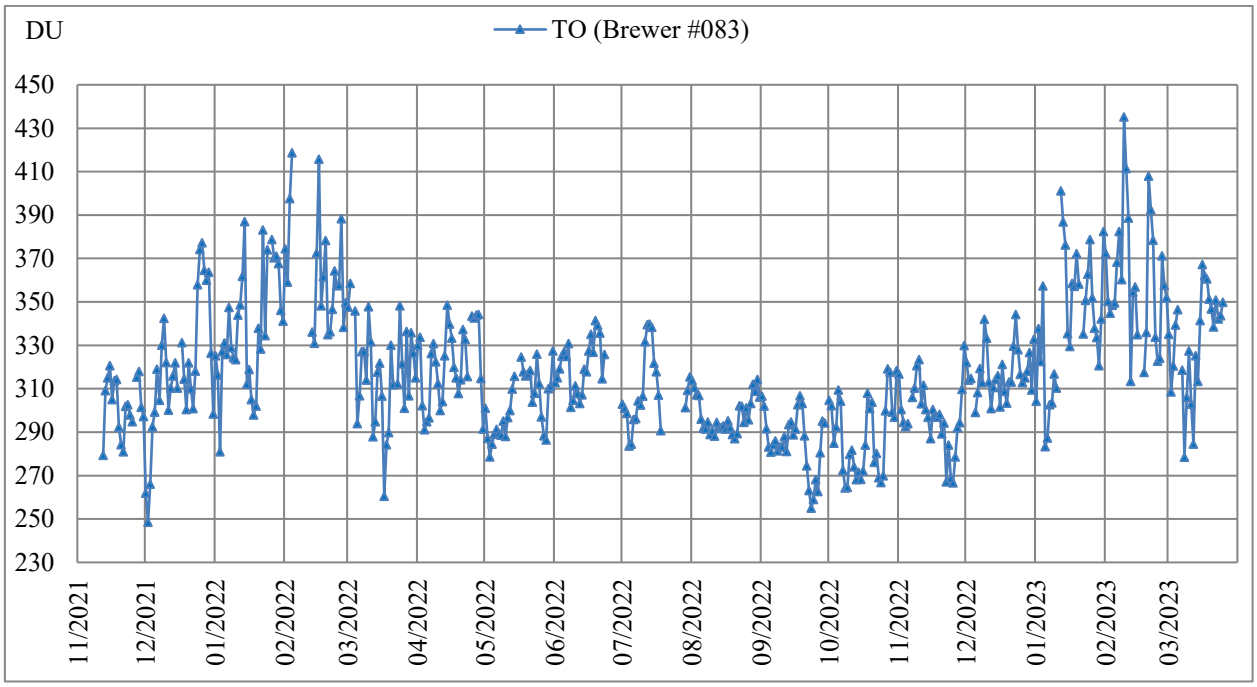


Figure 5. Average daily TO values measured by the Brewer MkIV (# 083) spectrophotometer at the Issyk-Kul OMD station

Figure 6 shows the deviations of the mean daily TO values obtained from satellite measurements (blue bars) from ground-based data measured with a Brewer MkIV (# 083) spectrophotometer. The red dotted line is the total mean deviation.

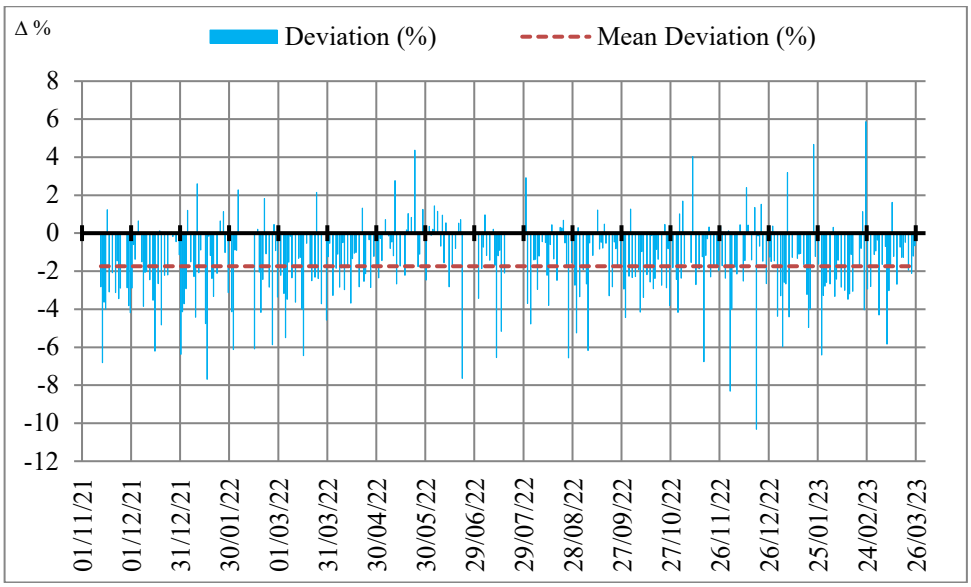


Figure 6. Deviations of satellite (omi, https://avdc.gsfc.nasa.gov) daily mean TO values (blue bars) from ground-based measurements obtained with a Brewer MkIV (# 083) spectrophotometer. The red dotted line is the average deviation (1.74%).

Comparative statistical analysis of the data (Figure 7) obtained with OMI [https://avdc.gsfc.nasa.gov] and the Brewer MkIV (# 083) spectrophotometer made it possible to correctly fill in data gaps in both ground-based and satellite measurements. Figure 8 shows a continuous homogeneous TO time series, on the basis of which a spectral analysis was carried out to identify significant harmonics and their parameters in TO fluctuations in the atmosphere over the mountainous region of Central Asia (Table 1).

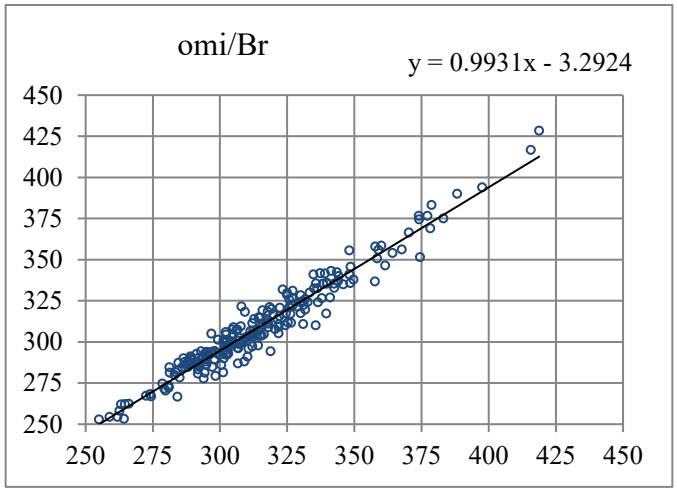


Figure 7. Comparative statistical analysis of TO data received at the Issyk-Kul OMD (Br) station and the satellite ones (omi, https://avdc.gsfc.nasa.gov).

$$X(t)=\sum A \cos(\omega t+ \boldsymbol{\varphi})+ \bar{X} \qquad (1)$$

- where values of A, φ given in Table 1, $\bar{X}$=317,2 DU

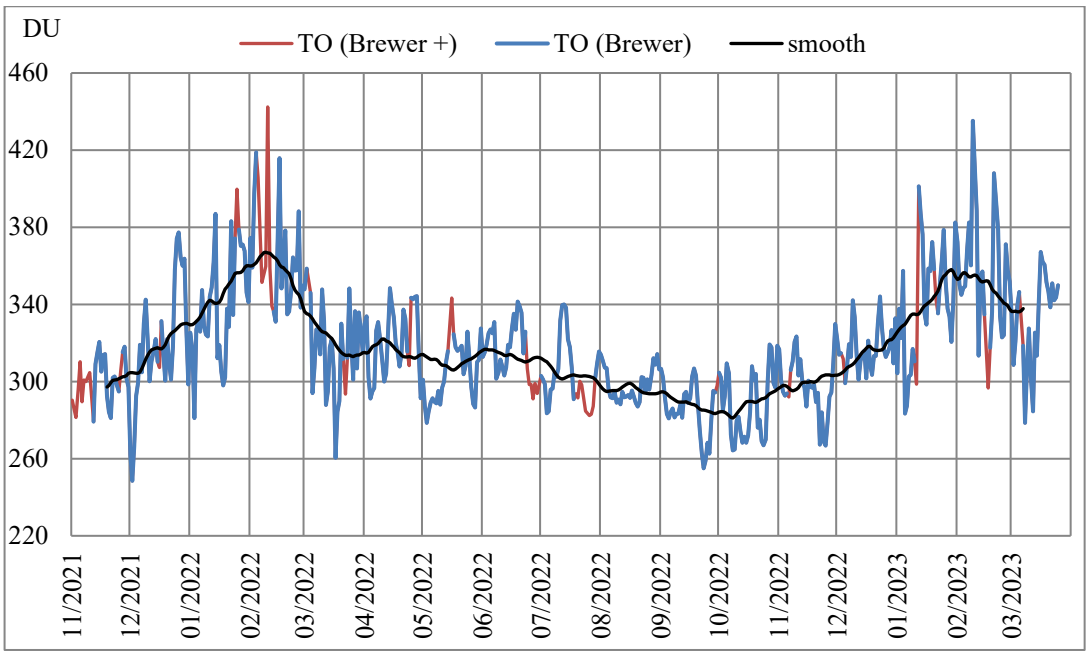


Figure 8. Average daily TO values obtained at the Issyk-Kul OMD station using the Brewer Mk (TO), with filled gaps in TO measurements (TO +) and smoothed over 36 days (smooth)

Table 1. Parameters of short-period harmonics of TO oscillations according to experimental measurement data

#	T (day)	A (DU)	φ
1	27,9	5,18	3
2	26,3	5,01	1
3	20,6	6,83	3
4	17,6	5,28	1
5	15,8	4,68	1
6	15,3	4,24	3
7	10,3	5,50	3
8	9,3	4,12	1
9	7,0	4,67	0
10	6,5	5,12	2

Figures 9-15 present global ozone distribution maps that demonstrate the features of the ozone layer change over Central Asia and confirm the facts of the appearance of ozone miniholes over this region, previously established in our experiments, during the years of significant depletion of the ozone layer over the Arctic. The observed phenomena are most likely related to the influence of the powerful mountain ecosystems of Central Asia on the thermodynamic processes of the tropoposphere and stratosphere.

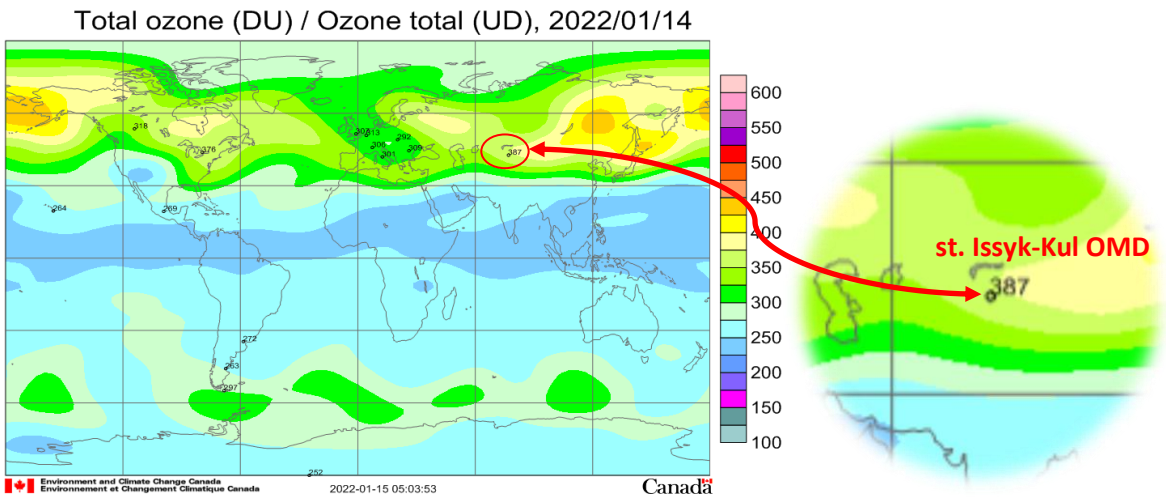


Figure 9. TO value (387 DU) for January 14, 2022 according to the Issyk-Kul OMD station on the map of the ECCC Global Monitoring and Ozone Mapping Service [https://exp-studies.tor.ec.gc.ca/e/ozone/ozoneworld.htm]

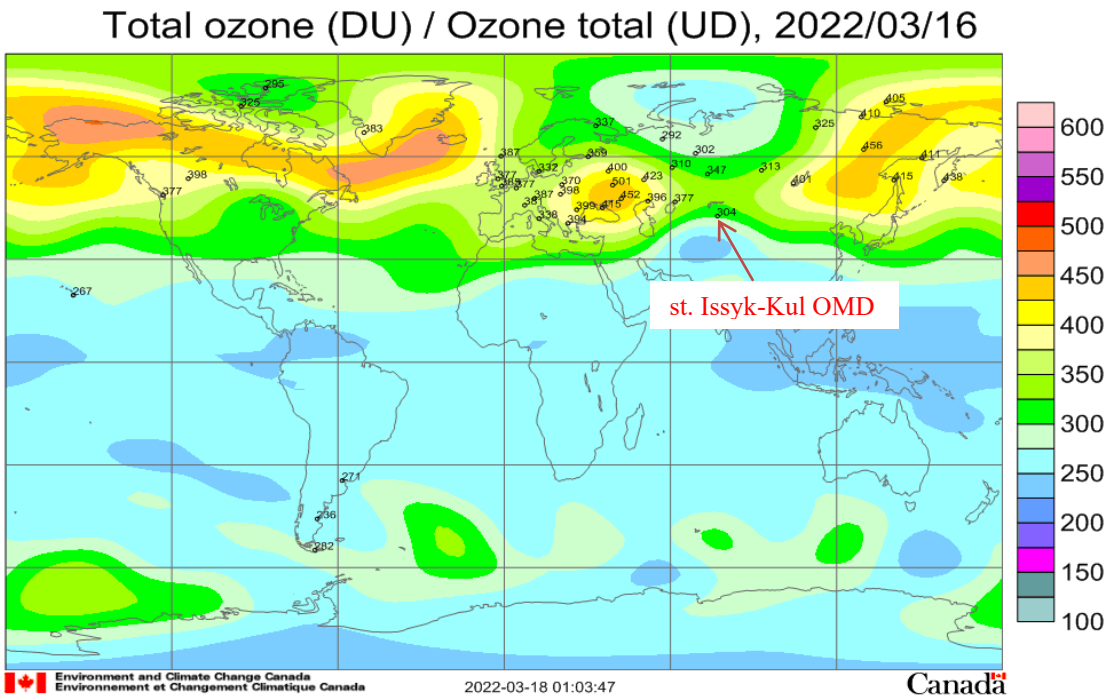


Figure 10. Global map of TO distribution over the mountainous region of Central Asia relative to other regions of the planet. (306.5 DU, as of March 16, 2022 according to the Issyk-Kul OMD station)
[ECCC: https://exp-studies.tor.ec.gc.ca/e/ozone/ozoneworld.htm]

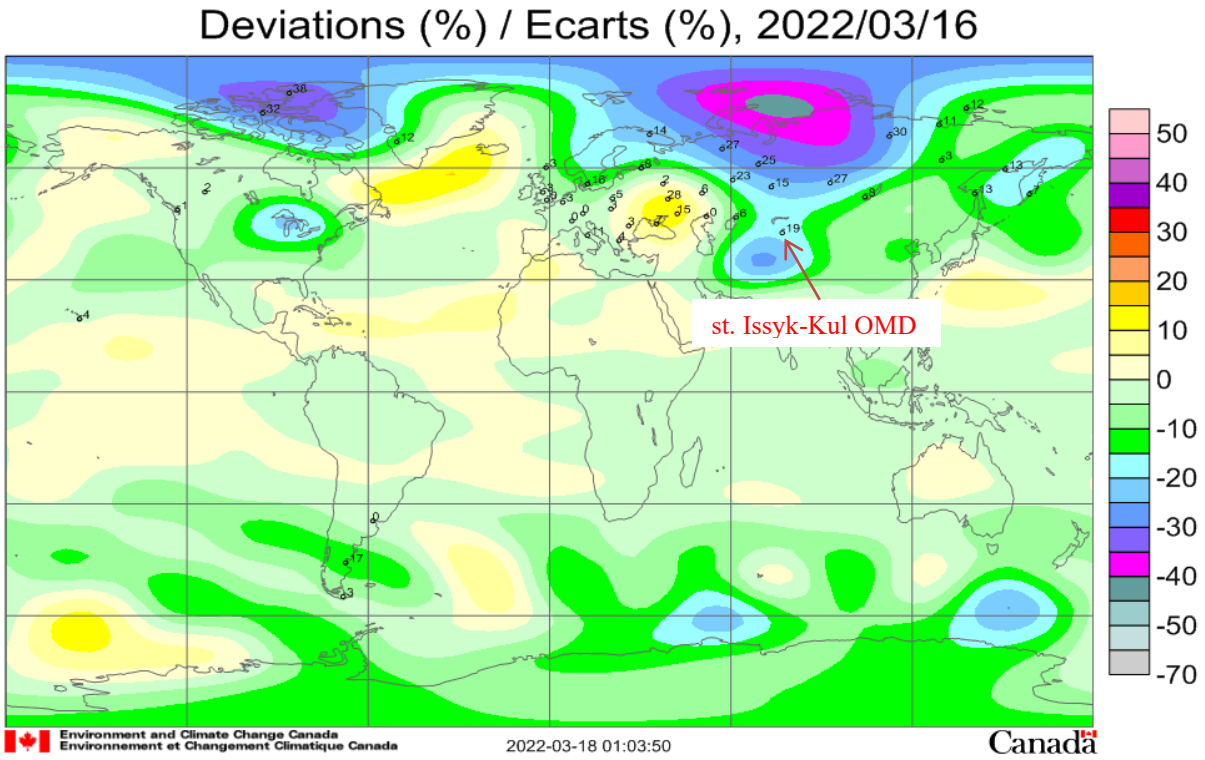


Figure 11. Global map of TO deviation from the norm (1978-1988), (as of March 16, 2022, Δ = - 19% according to the Issyk-Kul OMD station data). [ECCC: https://exp-studies.tor.ec.gc.ca/e/ozone/ozoneworld.htm]

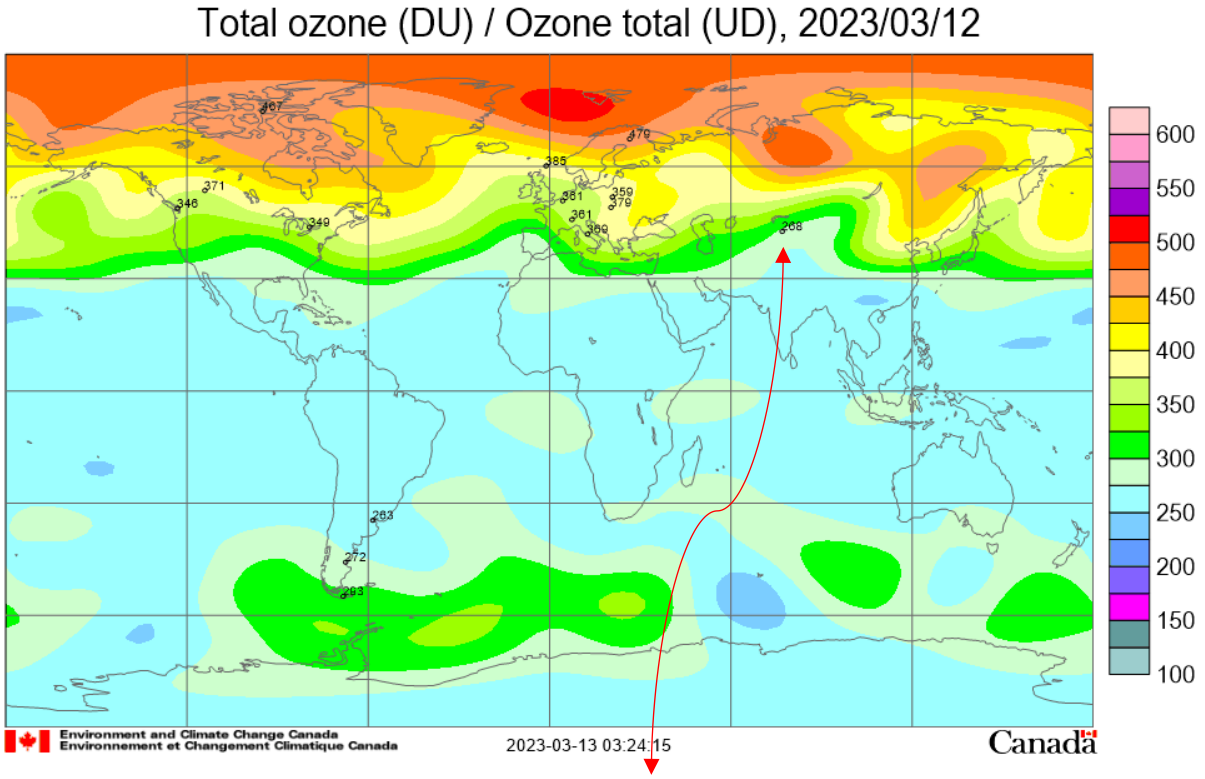


Figure 12. TO (268 DU) from the "Issyk-Kul OMD" station.
[ECCC: https://exp-studies.tor.ec.gc.ca/e/ozone/ozoneworld.htm].

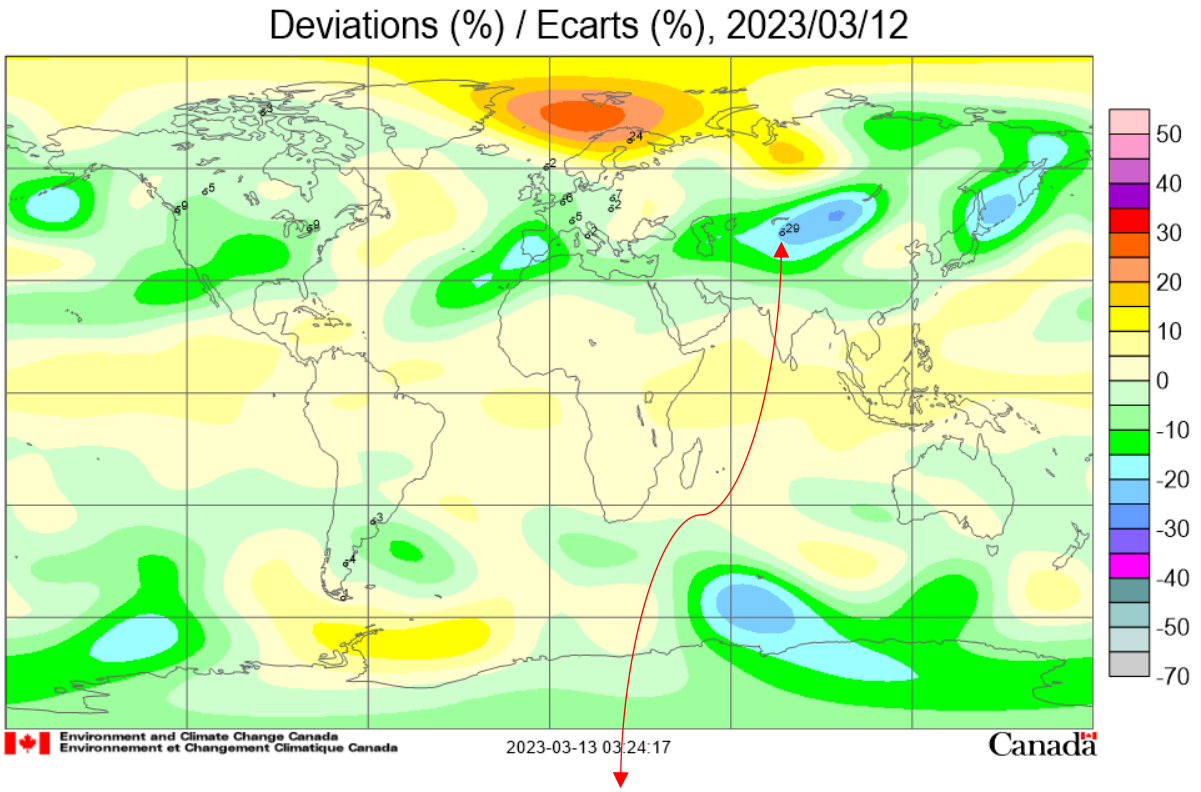


Figure 13. ΔTO (-29 %) for the "Issyk-Kul OMD" station.
[ECCC: https://exp-studies.tor.ec.gc.ca/e/ozone/ozoneworld.htm].

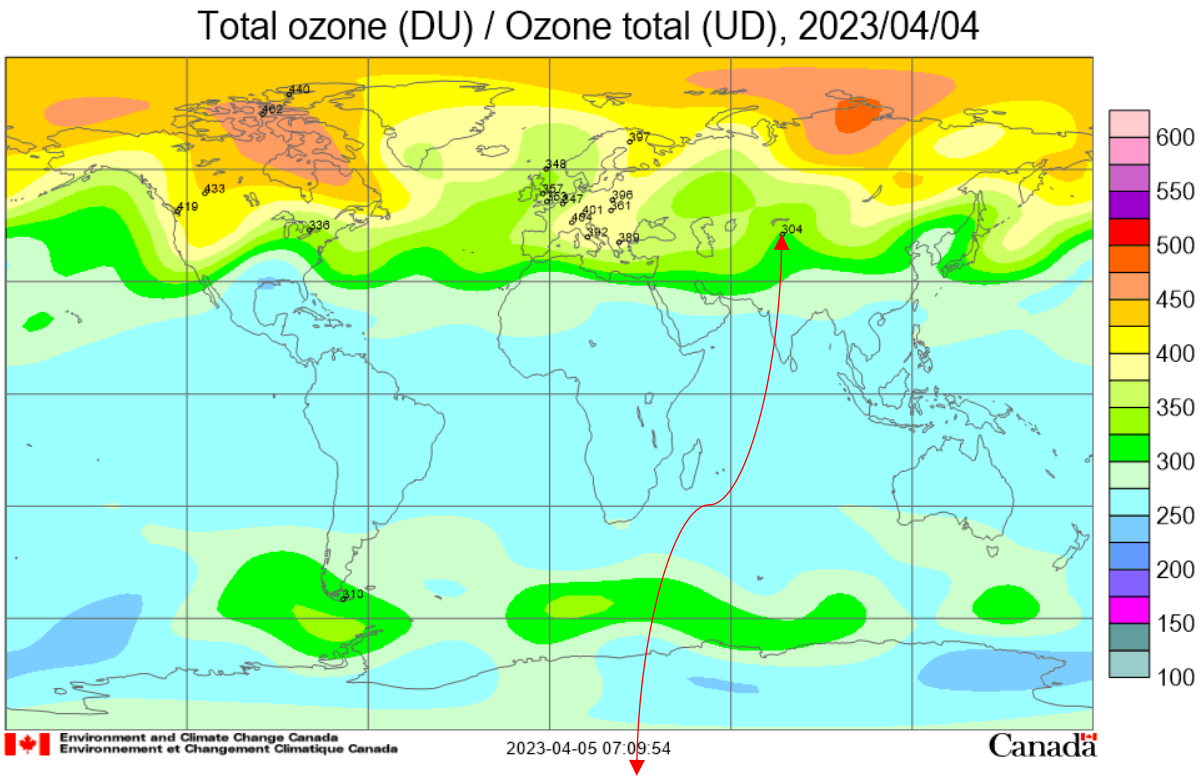


Figure 14. TO (304 DU) from the "Issyk-Kul OMD" station.
[ECCC: https://exp-studies.tor.ec.gc.ca/e/ozone/ozoneworld.htm].

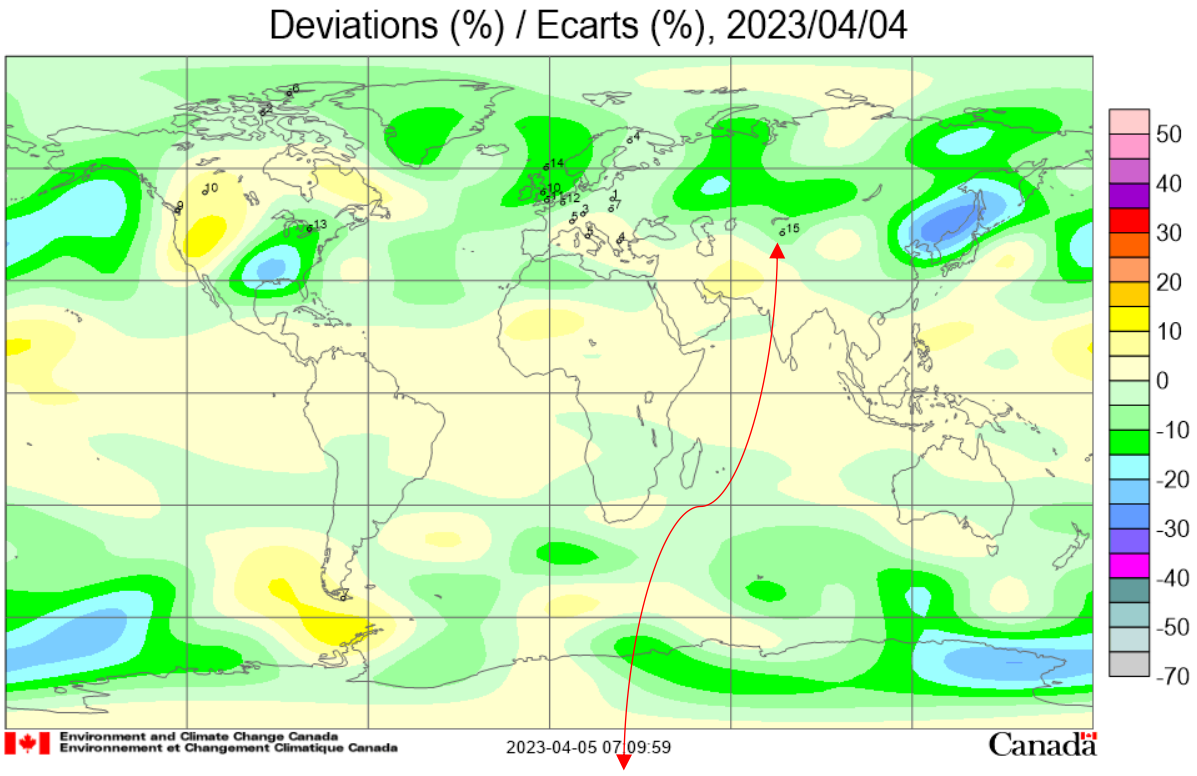


Figure 15. ΔTO (-15 %) for the "Issyk-Kul OMD" station.
[ECCC: https://exp-studies.tor.ec.gc.ca/e/ozone/ozoneworld.htm].

The Brewer MkIV (# 083) spectrophotometer, along with ozone, allows to measure the intensity of UV radiation in the range from 286.5 to 363 nm and visible radiation in the solar spectrum (from 430 to 450 nm).

Figures 16-18 show the daily integral values of UV radiation.

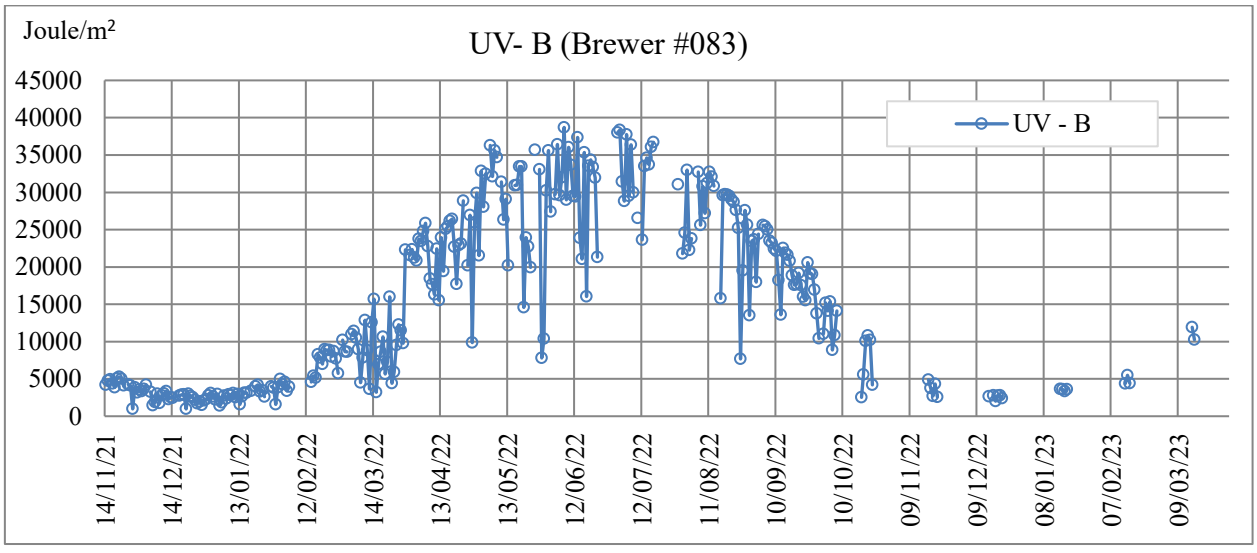


Figure 16. Daily raw cumulative levels of UV-B radiation measured with a Brewer MkIV (# 083) spectrophotometer.

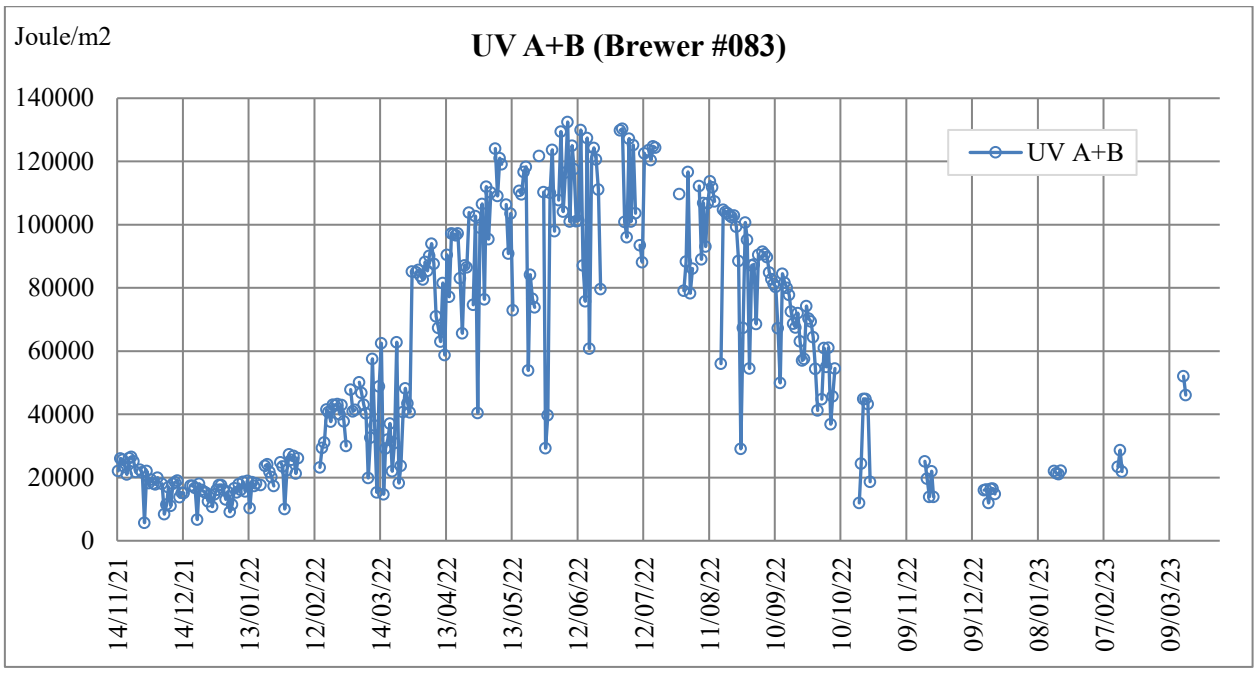


Figure 17. Daily raw integrated levels of UV-A+B radiation measured with a Brewer MkIV (# 083) spectrophotometer.

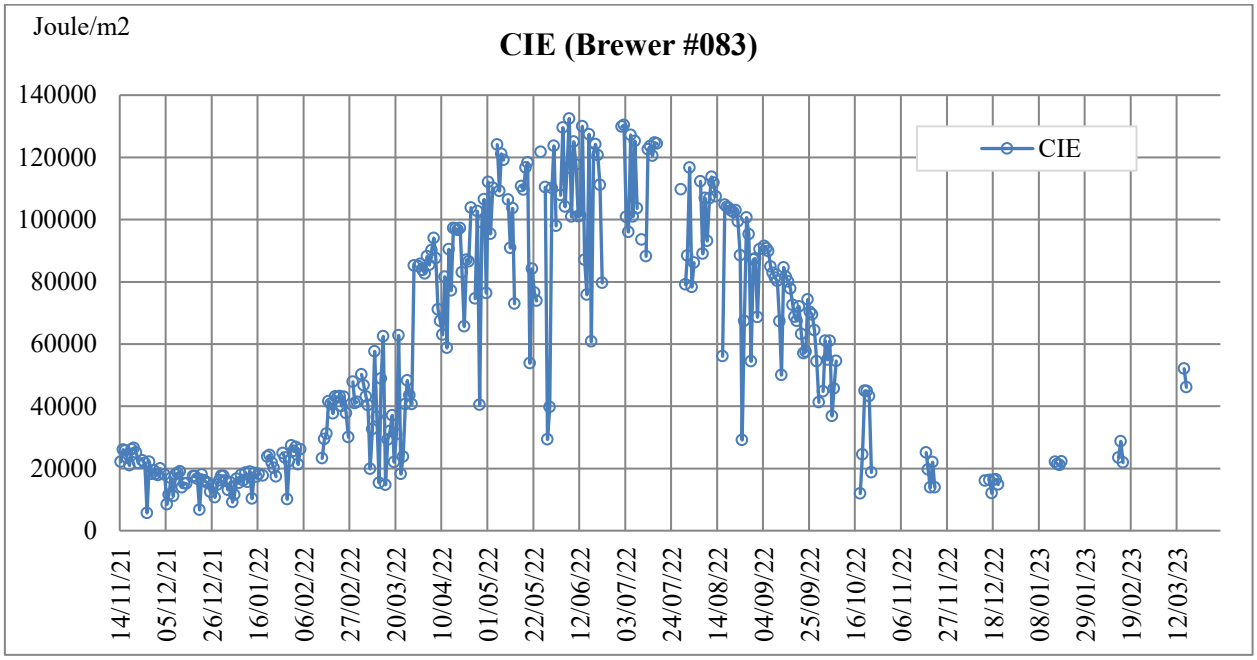


Figure 18. Daily raw integrated levels of UV-CIE radiation measured with a Brewer MkIV (# 083) spectrophotometer.

During the operation of the device, there have been interruptions in monitoring due to the following facts:

1) Failure of the mercury lamp of the spectrophotometer, which was replaced with a new one sent by an external expert from IOS (Canada).

2) Failure of the power supply of the spectrophotometer, which was replaced with a new analogue purchased locally.

3) Failure of the general power supply stabilizer of the equipment, which was replaced with a new uninterruptible power supply (UPS) purchased locally.

In general, we think that the Brewer MkIV spectrophotometer (S/N BR91-083) installed at the Issyk-Kul OMD station works well and reliably.

5. Financial report

In accordance with paragraph 3.1 of Article 3 of the Agreement and Amendment 2 to the Agreement, a detailed income and expenditure report (financial report) on fulfilled work in accordance with paragraph 1.2 of Article 1 of the Agreement and Amendment 2 to the Agreement was sent to WMO on January 7 2022.

6. Submission of data on ozone and ultraviolet Radiation to the World Center

The Brewer Mk IV (# 083) spectrophotometer installed at the Issyk-Kul OMD station has been continuously operating since November 2021. Near real-time TO measurements are reported to Environment and Climate Change Canada (ECCC) (https://exp-studies.tor.ec.gc.ca) and used in satellite data validation processes for global ozone mapping in Earth's atmosphere (Figures 9-15).

Submission of data on ozone and ultraviolet radiation to the World Data Center for Ozone and Ultraviolet Radiation in Toronto, Canada (https://www.woudc.org/home.php) will be carried out after official registration of the scientific station Issyk-Kul OMD. To register the Issyk-Kul OMD station, a package of necessary documents was prepared and sent to the WMO (03/16/2022).

Conclusions

As a result of the work performed in accordance with the Agreement, the following goals were achieved:

1. A new platform for TO monitoring was prepared at the Issyk-Kul OMD scientific station, located in the inland region of the Central Asian mountain ecosystem

2. At the scientific station, a modern high-precision spectrophotometer Brewer MkIV (# 083) was installed and put into operation.

3. Continuous monitoring of TO and UV radiation in the mountainous region of Central Asia was resumed, this increased the reliability and value of the time series of experimental data for its use in studies of the patterns of TO and the development of predictive models of the stratosphere.

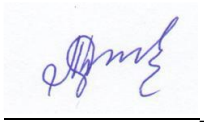
4. Local staff of scientific station were trained in the operation of the Brewer MkIV

spectrophotometer (#083) by an external expert.

Thus, the introduction of the Brewer MkIV (# 083) spectrophotometer at the Issyk-Kul OMD station provides reliable, continuous data on TO and UV radiation, which make it possible to study the characteristics of the ozone layer and climate response to the variability of anthropogenic and helio-geophysical factors in the region of powerful mountain ecosystems Central Asia.

In conclusion, we express our gratitude to everyone who provided invaluable assistance in organizing the transfer of the Brewer MkIV (# 083) spectrophotometer to Kyrgyzstan, its technical preparation and preparation for transportation, as well as the installation, configuration and training of the personnel of the Issyk-Kul OMD station.

Scientific supervisor of the project



Orozaliev M.D.