

## **Czech Republic**

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

**Geneva, 24-26 April 2024**

In the Czech Republic (CR), ozone and UV monitoring activities are mostly carried out at the facilities of the Czech Hydrometeorological Institute (CHMI). Scientists from CHMI and Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague (IAP-CAS) are involved in investigation of the relation between ozone and the processes in the upper atmosphere.

#### **1. OBSERVATIONAL ACTIVITIES**

Long-term monitoring of the ozone layer started in CR more than six decades ago, in 1961, as a contribution to the initiative of the International Geophysical Year and later to the GAW Programme of WMO. In 1994, measurements of UV spectral and erythemal radiation have been implemented at the Solar and Ozone Observatory in Hradec Kralove (SOO-HK) to couple the monitoring of both important environmental parameters. Currently these activities became more integrated into the projects and in-situ infrastructure of the European Union. Significant attention is paid to the scientific presentation of the outputs and to the public information.

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

Uninterrupted daily observations of total ozone column (TOC) by the Dobson D#074 (since 1961), Brewer MK-IV B#098 (since 1994) and MK-III B#184 (since 2004) spectrophotometers have been performed at SOO-HK in Hradec Kralove. The TOC measurements are regularly deposited into the World Ozone and UV Data Center (WOUDC) in Toronto as free available data sets and to the Total Ozone Mapping Center operated by Environment Canada for the daily mapping of the TOC geographical distribution.

The results of AC-SAF for Central Europe were made available for the public at the CHMI web portal.

Between 2010 and 2020, the Brewer MK-III spectrophotometer B#199 of CHMI has been in operation at the station Marambio Base in Antarctic Peninsula, under the bilateral cooperation of CR and Argentina. All available functions of the Brewer spectrophotometer were implemented in the measurement schedule (TOC, UV, Umkehr). This international project was supported by the Ministry of the Environment of the Czech Republic and the State Environmental Fund of the Czech Republic as a contribution of CR to the monitoring of the ozone layer in the polar regions. This project was finished in early 2020.

Since 2021, Brewer MK-III spectrophotometer B#199 is located at the roof of the building of Icelandic MetOffice (IMO) in Reykjavik, Iceland. All available functions of the Brewer spectrophotometer are implemented in the measurement schedule (TOC, UV, Umkehr). The operation is supported by the Czech Ministry of Environment within the framework of the project Long-term Concept of Research Organization Development (Dlouhodobá koncepce rozvoje výzkumné organizace) as a contribution of CR to the monitoring of the ozone layer in the Northern sub-polar regions. The TOC measurements are regularly deposited into the World Ozone and UV Data Center (WOUDC) in Toronto as free available data sets and to

the Total Ozone Mapping Center operated by Environment Canada for the daily mapping of the TOC geographical distribution.

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

Since 1978 the balloon-borne ozone profiles monitoring programme using the electrochemical ozone sondes has been performed at the Upper Air Department (UAD) of CHMI in Prague. Currently the ECC 6A ozone sensors connected with VAISALA RS41 radiosondes monitored by the VAISALA MW 41 ground sounding system are launched three times a week from January to April. The vertical profiles of ozone from the ground to about 30 km, with a vertical resolution of approx.30 m are submitted to the WOUDC and NDACC data bases, as well.

Regular daily measurements of the vertical distribution of ozone to about 50 km by the Umkehr inverse technique are performed at SOO-HK by the Brewer spectrophotometers. A special software package was developed by the experts from SOO-HK and NOAA Boulder that is used for operation of the instruments and data processing.

Umkehr measurements continued at the Marambio Base, Antarctica, with the help of B#199 (MkIII) till the end of the supporting project in January 2020. Since 2021, Umkehr measurements are performed by B#199 (MkIII) at Reykjavik, Iceland.

## **1.3. UV measurements**

### **1.3.1. Broadband measurements**

UV-Biometers are operating at four CHMI stations (Hradec Králové, Košetice, Kuchařovice and Luční bouda). They are located in four typical climatic and geographical regions of CR. 10-minute erythemal irradiances (EUV) are collected in the near-real-time at SOO-HK, archived in the CHMI CLIDATA database and presented at the web Portal of CHMI together with the actual TOC in Hradec Kralove and UV-Index values forecasts.

### **1.3.2. Narrowband measurements**

Since January 2013, the narrowband spectral measurements of the solar radiation have been carried out at SOO-HK using the 10-channel SPUV-10 filter sun photometer (Yankee Env. Systems, Inc, USA). The instrument measures direct sun irradiances at 10 selected wavelengths from UV to IR parts of the solar spectrum (316.6, 331.7, 367.3, 413.4, 495.8, 613.4, 672.0, 869.4, 938.3 and 1023.6 nm). This enables the calculation of atmospheric parameters related to ozone (AOD, NO<sub>x</sub>, vertically integrated water vapor amount, SO<sub>2</sub>).

In 2020, POM-02 Sky Radiometer (PREDE) was installed at SOO HK. The instrument measures direct sun irradiances and their azimuthal distribution (at the Sun elevation) at 11 wavelengths from UV to IR parts of the solar spectrum (315, 340, 380, 400, 500, 675, 870, 940, 1020, 1627 and 2200 nm). This improved our ability of calculation of atmospheric parameters related to aerosols and ozone. POM-02 was included to the international SkyNet network and SOO-HK became a member of COST Harmonia project (COST Action 21119).

### **1.3.3. Spectrophotometers**

Spectral measurements of UV solar radiation are performed with both Brewer spectrophotometers at SOO-HK (B#098 MK-IV 290-325 nm, B#184 MK-III 290-363 nm). The measurement with B#199 MK-III at Marambio Base was finished in January 2020, spectral UV measurements with this instrument continue since 2021 at Reykjavik (Iceland). The high-quality and evaluated scans from B098 and B184 are submitted also to the European UV

Data Base (EUVDB) at FMI, Helsinki. The Brewer MK-III operated at SOO-HK is used as the national reference for calibration of the operational UV-Biometers.

#### **1.4. Measurements of substances controlled under the Montreal Protocol**

There is no measurement of these substances in the CR.

#### **1.5. Calibration activities**

The Dobson D#074 instrument is regularly compared towards the regional standard D064 at the Regional Dobson Calibration Center – Europe (RDCC-E), Hohenpeissenberg. The spectrophotometer is maintained as the secondary reference for Europe. D074 was repaired at Hohenpeissenberg observatory in 2019 (new electronic, mirrors, photomultiplier) and calibrated against D064.

The Brewers at SOO Hradec Kralove (B#098 and B#184) are regularly calibrated every two years by the travel reference B#017 that represents the calibration scale of the World Triad maintained by EC, Canada. The last calibration was carried out at SOO-HK in 2023.

Brewer B#199, operating at Reykjavik, Iceland, is serviced every year and in 2021 and 2023 it was calibrated with the help of the travel reference B#017.

Calibration of all spectrophotometers and UV-Biometers may be now performed even by the UV calibration unit (dark box, precise power supply and sets of the PTB standard lamps) that is available at SOO-HK. In the future, the calibration activities are to expand, in cooperation with the Czech Metrological Institute within the framework of the European Metrology Research Programme EMRP that is currently underway.

The ozonesondes are properly calibrated in the pre-launch preparation procedures defined by the SOPs. Ozone tester Model TSC-1 Ozonizer from the Science Pump Corporation is being used at UAD-PR since 2012.

## **2. RESULTS FROM OBSERVATIONS AND ANALYSIS**

Analyses of observed data were mostly focused on the data obtained in 2010-2020 at Marambio and 2021-2023 in Reykjavik (both with Brewer#199). Several studies were published, concerning both TOC, UV and Umkehr measurements (see part 4.3.)

## **3. THEORY, MODELLING AND OTHER OZONE RELATED RESEARCH**

The IAP CAS activities were limited and focused on problems related to long-term trends in the stratosphere.

Kozubek et al. (2021) analyzed climatology and long-term trends in stratospheric temperature and winds at several levels between 100 and 1 hPa based on ERA5. They found a two-cell structure in temperature in the Northern Hemisphere. The biggest difference was found between 2000–2010 and 1990–2000 for temperature averages and 2010–2020 and 2000–2010 for temperature trend at 1, 5 and 10 hPa. Negative differences occur between 2000–2010 and 1990–2000, and positive differences occur between 1980–1990 and 1990–2000 or 2000–2010 and 2010–2020 for average winds. The possible reason for the behaviour of climatology is the irregular occurrence of major SSWs in the stratosphere.

Krizan et al. (2021) studied discontinuities in ozone concentration data from reanalysis MERRA-2, ERA-5 and JRA-55 with the help of the Pettitt, the Buishand, and the Standard Normal Homogeneity tests above the 500 hPa level. The share of discontinuities in individual grid points varies from 30% to 70% and they are strongly layer dependent. The share of

discontinuities is the lowest for JRA-55. Differences between reanalysis were found to be larger than differences between homogeneity tests within one reanalysis.

## 4. DISSEMINATION OF RESULTS

### 4.1. Data reporting

The CHMI facilities continue the deposition of the ozone observations mainly to the WOUDC Toronto and the high quality UV spectral irradiances into the European UV Data Base (EUVDDB) at FMI, Helsinki. The daily representative values of TOC are submitted to the World Ozone Mapping Centre of the Environment Canada via the GTS/VIS telecommunication system using the CREX-BUFFER codes.

Ozone sonde observations are regularly submitted to the WOUDC, Toronto and also to other partner institutions and projects - e.g. NDSC data base, GAW cooperating stations in Central Europe, MATCH campaigns and satellite validating teams (e.g. currently are ozonesonde data used to validate The Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGEIII/ISS) products).

### 4.2. Information to the public

For a long time, the actual values of total ozone and the UV-Index at the territory of CR and their comparison with the long-term averages have been presented daily in mass media and at the CHMI web portal. In this way, the public has the access to the actual information related to the condition of the ozone layer and harmful UV irradiances at our territory.

From 2015 to February 2020, the actual data of total ozone from the Marambio station were presented at the CHMI web portal. Data of total ozone for Reykjavik are presented at CHMI web portal since 2021. Moreover, daily forecasts of UV-index for the Czech republic (for high UVI values accompanied by recommendations for public) are presented in mobile application ČHMÚ+ for Android and iOS.

The results of AC-SAF for Central Europe were also made available for the public at the CHMI web portal. Actual ozone profiles are presented at the CHMI web site.

### 4.3. Relevant scientific papers

- Kozubek M., Laštovička J., Zajicek R.: Climatology and long-term trends in the stratospheric temperature and wind using ERA5, *Remote Sens.*, 13:4923, <https://doi.org/10.3390/rs13234923>, 2021.
- Krizan P., Kozubek M., Lastovicka J., Lan R.: Share of discontinuities in the ozone concentration data from three reanalyses, *Atmosphere*, 12:1508, <https://doi.org/10.3390/atmos12111508>, 2021.
- Čížková, K., Láska, K., Metelka, L., and Staněk, M., 2021. Comparison of results of total ozone measurement by Brewer and Dobson spectrophotometers in Antarctica. *Meteorologické zprávy*, 74, 69–75, ISSN: 0026-1173.
- Čížková, K., Láska, K., Metelka, L., and Staněk, M., 2023. Assessment of spectral UV radiation at Marambio Base, Antarctic Peninsula. *Atmos. Chem. Phys.*, 23, 4617–4636, DOI: 10.5194/acp-23-4617-2023.
- Čížková, K., Láska, K., Metelka, L., and Staněk, M., 2021. Preliminary results of spectral UV radiation modeling using Artificial Neural Networks. *Students in Polar and Alpine*

Research Conference 2021, Brno.

- Čížková, K., Láška, K., Metelka, L., and Staněk, M., 2021. Modelling spectral UV radiation at Marambio Base, Antarctic Peninsula Region, using Artificial Neural Networks. Quadrennial Ozone Symposium 2021, Seoul (online).
- Čížková, K., Láška, K., Metelka, L., and Staněk, M., 2022. Monitoring of spectral UV radiation at Marambio Base, Antarctic Peninsula Region. European Conference on Solar UV Monitoring 2022, Vienna.
- Čížková, K., Láška, K., Metelka, L., and Staněk, M., 2023. Ozone layer monitoring in Reykjavik, Iceland. Nordic Ozone Group Meeting, Vindeln.
- Tichopád, D., Láška, K., Čížková, K., Petkov, B.: Springtime evolution of stratospheric ozone and circulation patterns over Svalbard Archipelago in 2019 and 2020. Submitted to Czech Polar Reports
- Čížková, K., Láška, K., Tichopád, D., Metelka, L., Staněk, M., Sigurdsson A.: Effect of volcanic sulfur dioxide on solar UV irradiance during the 2023 Fagradalsfjall eruption in Reykjavík, Iceland. Submitted to Meteorologische Zeitschrift.

## 5. PROJECTS, COLLABORATION, TWINNING AND CAPACITY BUILDING

In cooperation with RDCC-E Hohenpeissenberg, the training of Dobson operators from Kenya took place in Hradec Kralove in June 2018. Four operators from the Kenya Meteorological Department (KMD) Nairobi were trained in the operation of both Dobson and Brewer spectrophotometers at the SOO-HK to improve their routine procedures of measurement, testing and reporting. The action was recommended by the SAG-Ozone and organized under the umbrella of the Global Atmosphere Watch Programme (GAW) of the WMO as the activity of the Regional Dobson Calibration Centre – Europe on the capacity building.

Currently the experts from Czech institutions participate in the following research and development projects that are focused both on scientific topics, analyses of observations and cooperation on maintenance of the international ozone monitoring systems.

- Preparatory work towards a homogenization of ozone sonde time series from UAD has been started according GAW Report No. 268 (Ozonesonde Measurement Principles and Best Operational Practices; ASOPOS 2.0; August 2021).
- NDACC: “The Network for the Detection of Atmospheric Composition Change”. Contribution to ozone monitoring infrastructure. CHMI-UAD.
- SAGEIII/ISS: Using in-situ ozonesonde data to validate the SAGE III/ISS products. Coordination with the SAGE III/ISS Validation Event Prediction Locator when planning measurement events. CHMI-UAD.
- MATCH: International ozonesonde campaigns for the quantification of polar chemical ozone loss since 1998. Participation in yearly campaigns by alert ozonesonde flights. Multinational funding. CHMI, UAD-PR. Continued.
- COST-ES1207 „A EUROpean BREWer NETwork – EUBREWNET“: Research and development project implemented by the European Union (2013-2017). The creation of a joint infrastructure for the operation of the Brewer spectrophotometers in Europe is the main goal of the project. Experts from CHMI-SOO-HK are involved mostly in creation and implementation of the operational software and calibration procedures of the instruments. Data submission continued.
- COST Harmonia project 21119 (International network for harmonisation of atmospheric aerosol retrievals from ground based photometers), WG I. Czech participation supported by the project CAAARGO (Czech Activities in Atmospheric Aerosol Retrievals from Ground

Observation)

- WMO/GAW/RDCC-E: “The Regional Dobson Calibration Centre – Europe”. Bilateral cooperation between the German Weather Service, Meteorological Observatory Hohenpeissenberg, and the CHMI, SOO-HK on activities of RDCC-E, since 1999. Calibration campaigns, re-location of instruments, training of operators, and software for the GAW Dobson network. Continued.
- Sub-regional calibration campaigns of the Brewer spectrophotometers from Central Europe (CR, Hungary, Poland, Slovakia) towards the travel reference of the IOS. Continued.

## **6. IMPLEMENTATION OF THE RECOMMENDATIONS OF THE 11<sup>th</sup> OZONE RESEARCH MANAGERS MEETING**

In the recent years, the organizations in the Czech Republic were active in a number of areas in accordance with the recommendations of the 11.ORMM, namely:

- Studies of factors affecting UV radiation: cooperation with Faculty of Science, Masaryk University, Brno (diploma and doctoral theses focused on this topic were entered and are being processed).
- Analyses of ozone and UV measurements at Marambio, Antarctica, mainly by students of Faculty of Science, Masaryk University, Brno (diploma and doctoral theses).
- Systematic observations: continuation in high-quality TOC and UV measurements in both Czech republic (SOO Hradec Kralove, UAD Prague) and Reykjavik (Iceland MetOffice – since 2021).
- Continuation of measurements of vertical ozone profiles at UAD Prague.
- Active work on ATMOZ project in cooperation with CMI (Czech Metrological Institute).
- Research: activities of IAP-CAS on stratospheric long-term trends.
- Preparatory work towards a homogenization of ozone sonde time series from UAD

## **7. FUTURE PLANS**

For upcoming years we plan

- to continue all the activities related to running projects and cooperations (see chapter 5), including RDCC-E and RBCC-E activities.
- to continue all running ozone and UV measurements (D#074, B#098, B#184, B#199, 4 UV-Biometers, ozonesondes)
- to take active part in the implementation of new ozone absorption coefficients (Serdyuchenko) in Europe
- continuously modernize the instruments for ozone and UV measurements
- to continue our activities in international projects and cooperation (RDCC-E, RBCC-E, EuBrewNet, Harmonia, Icelandic MetOffice)

## **8. NEEDS AND RECOMMENDATIONS**

- Continue and successfully complete the started process of homogenization of ozone sonde time series from UAD according GAW Report No. 268 (Ozonesonde Measurement Principles and Best Operational Practices; ASOPOS 2.0; August 2021).