

# **Report of Ongoing and Planned Ozone Research and Monitoring Activities in the Czech Republic**

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## **1. OBSERVATIONAL ACTIVITIES**

Systematic monitoring of atmospheric ozone and UV solar radiation is performed in the Czech Republic (CR) by the Czech Hydrometeorological Institute (CHMI). The observations contribute to the regular and complex monitoring of the atmosphere and climate in CR and to international activities and projects, mainly to the GAW Programme. All the observations are performed and regularly audited under the rules of the ISO-9001 standards and the data are deposited in the central climate data base of CHMI.

### **1.1 Column measurements of ozone**

Routine daily observations of total ozone (TOZ) have been performed with the Dobson and Brewer (single and double) spectrophotometers operated at the Solar and Ozone Observatory (SOO-HK) of the Czech Hydrometeorological Institute (CHMI) in Hradec Kralove since 1961. In 2010 the SOO-HK reached 50-year period of regular observations of and thus belongs to the GAW stations with the longest continuous data series of TOZ worldwide.

In February 2010 the double MKIII Brewer spectrophotometer B199 was installed at the Marambio Base - Argentina, Antarctica. The activity is part of the project supported by the Ministry of the Environment of the Czech Republic - SPIII 9/23/07 that is realized under the bilateral governmental agreement between CR and Argentina on cooperation in the environmental research in Antarctica. The instrument is controlled and all the primary data and calibration metadata are saved from SOO-HK operationally via the satellite telecommunication system. The TOZ data are currently evaluated and used for the scientific purposes. The data are supposed to be deposited into the WOUDC in 2011.

### **1.2 Profile measurements of ozone**

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 sondes monitored by the VAISALA DigiCORA facility 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.150 m are submitted to the WOUDC and NDACC data bases, as well.

Vertical distribution of ozone is also measured by the Umkehr inverse technique with the Brewer spectrophotometers at the SOO-HK and at Marambio. The observations are processed by the NOAA/NASA UMK-2004 algorithm. Currently the Umkehr profiles are being compared with the simultaneous ozone sonde observations from UAD Prague to evaluate differences in the particular pressure levels.

## **1.3 UV measurements**

### **1.3.1 Broadband measurements**

The UV-Biometers are operated at 4 CHMI stations (Hradec Králové, Košetice, Kuchařovice and Labská Bouda) that are located in typical climate and geographical regions (lowlands, rural land and mountains). The 10-minute erythemal irradiances (EUV) are collected in the near-real-time at SOO-HK. The actual TOZ and UV-Index values are presented to the public at the Portal of CHMI:

### **1.3.2 Narrowband filter instruments**

Narrowband filter instruments are not operated in the Czech Republic presently.

### **1.3.3 Spectroradiometers**

Spectral measurements of UV solar radiation (298-325 nm) are performed with single (MKIV) and double (MKIII) Brewer spectrophotometers at SOO-HK and at the Marambio station. The high-quality and evaluated scans are submitted also to the European UV Data Base (EUVD) at FMI, Helsinki. The Brewer MKIII operated at SOO-HK is used as the national reference for calibration of the operational UV-Biometers.

## **1.4 Calibration activities**

All ozone and UV instruments operated by CHMI are regularly calibrated towards the international etalons and operated according to proper SOPs. In this way their long-term calibration stability can be checked and evaluated. Because of years of experience in the GAW calibration campaigns the experts from SOO-HK frequently perform on-request calibrations of ozone spectrophotometers at individual stations or they assist to the GAW intercomparisons of the instruments. These activities are mainly anchored in the bilateral cooperation of SOO-HK with the GAW Regional Dobson Calibration Centre - Europe (RDCC-E), the Meteorological Observatory, Hohenpeissenberg, Germany – see Projects and Collaborations.

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

The recent analyses of the Dobson and Brewer observations of TOZ from SOO-HK show that both data series should be analyzed separately. While the Dobson record represents mostly a historical memory of the condition of the ozone layer including very important pre-ozone hole period, the Brewer observations have become the dominant source of the current and future information on TOZ in the recent decades. Because of the well known annual differences between Dobson and Brewer observations a simple combination of both data series could introduce unreal signal on the recovery of ozone, mostly in the winter-spring period. Therefore, the trend analyses of TOZ during the last 50 years should go from the assimilated Dobson/Brewer data set. The method of assimilation is now being tested at SOO-HK and will be published in a peer-review paper.

Evaluation of the assimilated TOZ data set from SOO-HK shows that in the winter-spring season the amount of ozone is rising up towards the pre-ozone hole values during the recent 15 years. This can be attributed to the reduction of emissions of ODS due to the Montreal Protocol. But in the summer months the ozone layer remains significantly depleted, Fig 1. This could be explained by persistent changes in stratospheric circulation and dynamics at least over Central Europe. Further research on this phenomenon is underway in CHMI.

Changes of vertical distribution of ozone over Central Europe during the past three decades are evident also from ozone sonde observations taken at UAD of CHMI in Praha. While the most significant decrease of ozone concentrations appears in mid and lower stratosphere

(~10% at 22 km) comparing prior and post Pinatubo periods (1978-1991 and 1992-2009) in troposphere the amount of ozone has increased by about 50%, Fig. 2.

To expand information about vertical ozone profiles an extensive programme of the Brewer Umkehr observations was implemented at SOO-HK in 2005. The pilot comparison of 77 simultaneous Umkehr and ozone sonde profiles from the winter-spring months, 2005- 2009 show that the new UMK-2004 algorithm gives a good fit of the shape of profiles including location of the maximum of ozone concentration. The best fit (less than 2% difference) of concentrations has been found in the Layers 2 (~13 km) and 4 (~23 km). Higher but still acceptable differences (~8%) are at the Layers 3 and 5, Fig 3.

The newly established ozone and UV observations performed with the Brewer instrument at the Marambio station in Antarctica are focused on three main goals – implementation of regular measurements of total ozone and UV-spectral radiation with on-line transmission of data to SOO-HK, the use of measurements of Umkehr vertical profiles of ozone for the operational assessment of the state of the ozone layer including validation of satellite measurements and the use of spectral measurements of UV radiation for operational evaluation of the field UV-index in the Antarctic. The ground Brewer observations of TOZ from Marambio of 2010-2011 have been compared with the overpass OMI-DOAS satellite measurements from the summer periods of 2010-2011. The preliminary results show a fairly good agreement between both data sets, Fig 4. This is a good message which confirms quality of ground and satellite observation systems in this very important location.

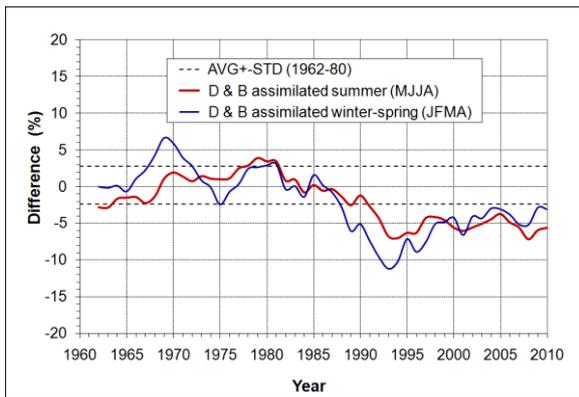


Fig 1: Differences between seasonal averages of assimilated total ozone, Hradec Králové of 1962-2010 towards 1962-1980

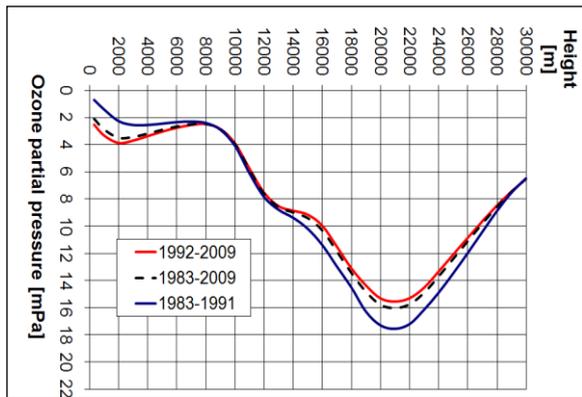


Fig 2: Comparison of average ECC sonde ozone profiles of different periods, UAD Praha 1983-2009

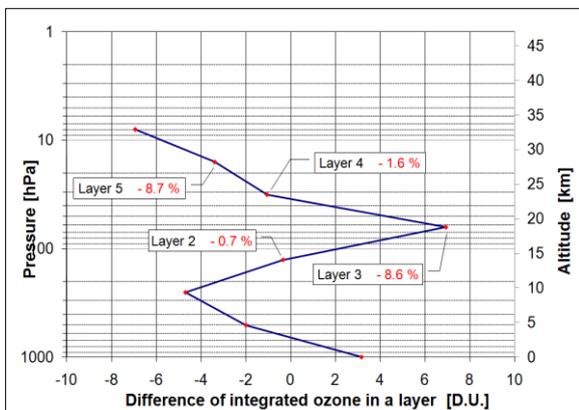


Fig 3: Differences between the ECC sonde and Umkehr ozone profiles from Hradec Králové and Praha

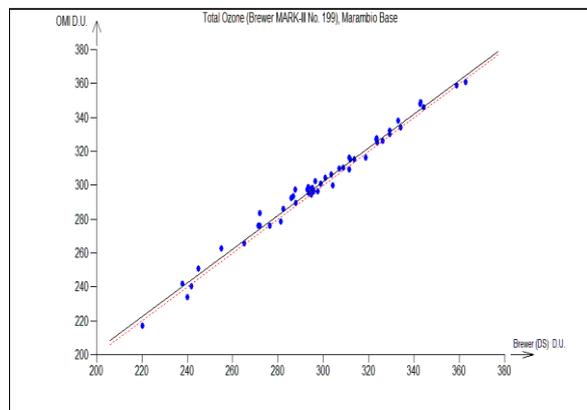


Fig 4: Correlation between OMI and Brewer (direct sun) measurements at Marambio, (November 2010–February 2011)

### 3. THEORY, MODELLING, AND OTHER RESEARCH

Evaluation of the long-term changes of the ozone layer over CR during the last 50 years is the most actual research project for 2010-2012. The realization requires development, tests and application of specific models and techniques that are tied with the geographic and climate condition of the country. But some of them have possibility for a wider application outside the region. So far the Dobson-to-Brewer TOZ assimilation model has been developed and tested at SOO-HK using the multi-regression transfer function with ozone effective temperature (TOef) and slant-path ozone as the proxies. The TOef values derived from the ozone sonde observations at UAD Praha were correlated with the stratospheric temperatures. Finally temperature at the 20 hPa standard level (T20) has been taken as the most representative parameter of the TOef. Comparison of the assimilated Dobson and measured Brewer daily averages of TOZ confirm the accuracy of the model well below 1%.

A special technique has been developed for reconstruction of the T20 data set representative for the area of CR of the period 1961-2010. The method assimilates T20 values measured by meteorological sondes at UAD Praha and approximation of T20 values from the ERA-40 and ERA-INTERIM data bases for the days with low-quality or missing measurements.

In the next steps the long-term changes of the assimilated daily averages of TOZ from SOO-HK will be investigated mainly with the aim to the circulation patterns and stratospheric dynamics. The extreme-values theory and the neural-network models will be used to evaluate influence and fingerprints of the main contributors (ENSO, NAO, ODS, QBO, polar vortex and volcano).

### 4. DISSEMINATION OF RESULTS

#### 4.1 Data reporting

The CHMMI facilities continue deposition of the ozone observations mainly to the WOUDC Toronto and the high quality UV spectral irradiances into the European UV Data Base (EUVDB) at FMI, Helsinki. The daily representative values of TOZ are submitted to the World Ozone Mapping Centre of the Environment Canada daily via the GTS/VIS telecommunication system using the CREX-BUFFER codes. The ozone sonde observations are submitted to WOUDC via the NDSC data base and to the partners in the MATCH campaigns.

#### 4.2 Information to the public

The actual values of total ozone and the UV-Index in the territory of CR and their comparison with the long-term averages are presented daily in mass media and at the Portal of CHMII: <http://portal.chmi.cz/files/portal/docs/meteo/ozon/o3uvb.htm> [http://portal.chmi.cz/files/portal/docs/meteo/ozon/UV\\_online.html](http://portal.chmi.cz/files/portal/docs/meteo/ozon/UV_online.html). In this way the public have the full access to the fresh pieces of information related to the condition of the ozone layer and harmful UV irradiances. Actual data of total ozone from the Marambio station are presented at the web page of the project.

#### 4.3 Relevant scientific papers

- Motl M., Kalvova J., Skrivankova P. (2008): *Connection between pressure in tropopause level and amount of ozone above the Czech Republic, Meteorological Bulletin, In Press (in Czech)*.
- Harris N.R.P., S.B. Andersen, D. Brunner, S. Dhomse, S. Godin-Beekman, P. Hadjinicolaou, G. Hansen, I. Isaksen, A. Jrrar, A. Karpetchko, R. Kivi, B. Knudsen, P. Krizan, E. Kyrö, J. Laštovička, J. Maeder, L. Metelka, Y. Orsolini, J. A. Pyle, M. Rex, J. Staehelin, K. Vanicek, M. Weber, I. Wohltmann, P. Zanis and C. Zerefos (2008). *Ozone trends at northern mid- and high latitudes – a European perspective. Annales Geophysicae, 26, 1207-1220*

- V. E. Fioletov, K. Vanicek et al (2008), *The performance of the ground-based total ozone network assessed using satellite data*. *JGR – Atmospheres*, Vol.113, D143 13, doi:10.1029/2008JD009809, 2008
- Feister, U., Junk, J., Woldt, M., Bais, A., Helbig, A., Janouch, M., Josefsson, W., Kazantzidis, A., Lindfors, A., den Outer, P. N., and Slaper, H.: *Long-term solar UV radiation reconstructed by ANN modelling with emphasis on spatial characteristics of input data*, *Atmos. Chem. Phys.*, 8, 3107-3118, doi:10.5194/acp-8-3107-2008, 2008.
- Arola, A., S. Kazadzis, A. Lindfors, N. Krotkov, J. Kujanpää, J. Tamminen, A. Bais, A. di Sarra, J. M. Villaplana, C. Brogniez, A. M. Siani, M. Janouch, P. Weihs, T. Koskela, N. Kouremeti, D. Meloni, V. Buchard, F. Auriol, I. Ialongo, M. Stanek, S. Simic, A. Webb, A. Smedley, and S. Kinne, 2009 *A new approach to correct for absorbing aerosols in OMI UV Geophys. Res. Lett.* 36, L22805.
- den Outer, P. N., H. Slaper, J. Kaurola, A. Lindfors, A. Kazantzidis, A. F. Bais, U. Feister, J. Junk, M. Janouch, and W. Josefsson (2010), *Reconstructing of erythemal ultraviolet radiation levels in Europe for the past 4 decades*, *J. Geophys. Res.*, 115, D10102.
- J. Lastovicka, P. Krizan, M. Kozubek (2010): *Long-term trends in the middle atmosphere dynamics at northern middle latitudes - one regime or two different regimes?* *Atmos. Chem. Phys. Discuss.*, 10, 2633-2668, 2010, [www.atmos-chem-phys-discuss.net/10/2633/2010/J](http://www.atmos-chem-phys-discuss.net/10/2633/2010/J).

## 5. PROJECTS AND COLLABORATION

Currently the experts from Czech institutions participate in the following research and development projects, international programmes and co-operations.

- Long-term Changes of the Ozone Layer over the Territory of the Czech Republic. Research project supported by the Czech Grant Agency No.P209/10/0058, 2010-2012. Assimilation of the Dobson and Brewer total ozone data series of 1961-2010. Investigation of contributions of ODS and stratospheric dynamics to changes of the ozone layer during the last 50 years. CHMI, SOO-HK.
- Contribution of CR to detection of the stage of the Ozone Layer and UV Radiation in Antarctic. Research project SPIII 9/23/07 funded by the Ministry for Environment of CR. 2010-2014. Measurements of total ozone, Umkehr ozone profiles and solar UV spectra by the Brewer spectrophotometer at the Marambio station. Co-operation of CHMI with the Argentine Antarctic Institute and the Argentine National Weather Service, <http://www.antarktida-ozon.cz/>
- MATCH: International ozone sonde campaigns for the quantification of polar chemical ozone loss since 1998. Participation in yearly campaigns by alert ozone sonde flights. Multinational funding. CHMI, UAD
- Changes in trends of total ozone in China and Europe, Joint project of the Department of Amt. Physics of the Czech Academy of Sciences and the Chinese Academy of Science. KONTAKT, 2010-2012.
- NDACC: "The Network for the Detection of Atmospheric Composition Change". Monitoring of the vertical distribution of ozone by balloon flights. CHMI, UAD.
- WMO-GAW-VIAGOS. Pilot project: Improvement of Dissemination of Ozone (total column, profiles and surface) and Aerosol observations through the WIS" Preparation of the Guidance for Reporting Total Ozone Data in Near Real Time by experts from CHMI. SOO-HK.
- WMO-GAW-RDCCE: 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, Dobson web information site, re-location of instruments, training of operators, software for the GAW Dobson network.

- WMO-GAW-SAG Ozone: “The Scientific Advisory Group for Ozone”, Participation of Czech experts since 2002. CHMI, SOO-HK.

The most recent campaigns co-organized by the Czech experts:

- Sub-regional calibration of the Brewer spectrophotometers from Central Europe (CR, Hungary, Poland, Slovakia) towards the travel reference of the IOS, Hradec Kralove, 2009
- Calibration of Dobson spectrophotometers and training of operators for two newly established stations Kampala (Uganda) and Kiev (Ukraine) at SOO-HK. Joint action contributed by the experts from WDCC (Boulder, CO) and RDCC-E, 2010
- Dobson Data Quality Workshop. The UNEP/WMO action initiated by the 7-ORMM. Update of the knowledge on operation of Dobson instruments, instructions of Dobson data managers on methods of the data quality control, evaluation of data series and collection of the primary (0-level) data and metadata from stations into the WOUDC. Hradec Kralove, 2011, [www.dobsonworkshop.cz](http://www.dobsonworkshop.cz)

## 6. FUTURE PLANS

- The ozone and UV monitoring programme performed by CHMI including the international data transfer will continue in its current structure and scope.
- The quality of total ozone and UV radiation observations taken with the Brewer instrument at the Marambio station will be evaluated and compared with the satellite overpass measurements. Then the data of TOZ will be deposited into the WOUDC.
- The research project on assimilation and analyses of 50-year total ozone data series is to be completed as specified above in 2012 and results published in peer-reviewed papers.
- SOO-HK will continue assistance to the ozone segment of the GAW programme mainly through the activities and actions organized by the Regional Dobson Calibration Centre-Europe and by participation in the SAG-Ozone.

## 7. RECOMMENDATIONS addressed to the 8-th ORMM

- Though several new stations have been established by re-location of the Dobson instruments in developing countries and in the former USSR territory in the recent years a significant gap in the ground network still persists mainly in central Asia. The capacity building should be focused primarily on this region
- To reach the highest possible quality of processing the ozone observations and to implement a wider data exchange via the GTS/VIS the unified software tools developed by the GAW central facilities and approved by the SAG-Ozone should be primarily used at the stations.
- The Dobson Data Quality Workshop held in 2011 has encouraged the Dobson station managers to pay more attention to routine assessment of quality total ozone observations and to evaluate the historical records. Such meetings of the experts with station representatives should be organized regularly under the auspices and assistance of the UNEP MP Secretariat and the WMO SAG-Ozone.
- The process of collection historical primary (0-level) data and calibration metadata from the Dobson stations in the WOUDC data base that started at the above Workshop should be continued. The stations that did not participate at the action should be invited to join this very important activity as the Dobson records are bearers of the historical knowledge about condition of the ozone layer of the pre-ozone hole period. The primary data sets are highly important for a complex re-processing of the reference data series if new sets of ozone cross section are to be implemented in the future, among others.