POLAND

In Poland, ozone and UV monitoring and related research activities are conducted by the Institute of Meteorology and Water Management (IMWM), and Institute of Geophysics of the Polish Academy of Sciences (IGFPAS). The ozone and UV-B monitoring and research, carried on in both Institutes, are supported by: Chief Inspectorate for Environmental Protection; National Fund for Environmental Protection and Water Management; Ministry of the Environment.

OBSERVATIONAL ACTIVITIES

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

Institute of Geophysics of the Polish Academy of Sciences

IGFPAS has been involved in the long-term monitoring of the ozone layer for almost 50 years. Measurements of the total ozone content and ozone vertical profile by the Umkehr method at Belsk (51°50'N, 20°47'E) by means of the Dobson spectrophotometer No.84 started in 1963, long before the depletion of the ozone layer became great challenge for research community and the policy makers. In 1991 a Brewer spectrophotometer No.64 (single monochromator) with a UV-B monitor was installed .The Brewer spectrophotometer No. 207 (double monochromator) has been put into operation in 2010. The column ozone and ozone content in the Umkehr layers are measured simultaneously by 3 instruments that helps to determine precision of the ozone observations by each spectrophotometer. The surface ozone measurements with Monitor Labs, ML8810 meter started in 1991 (replaced by ML9811 in 2004) and since 1992 NOx measurements have been performed with Monitor Labs ML8841 meter (replaced by API200AV in 2004).

The extended duration of the measurements and the high quality of the ozone data were essential for trend detection. Because the high quality of the ozone data is crucial subject in the analysis of the ozone variability the quality control and quality assurance of the ozone measurements is the major concern of the ozone research group. The Belsk ozone data were revaluated in 1983 and 1987 on a reading-by-reading basis, taking into account the calibration history of the instrument. The performance of the Belsk's ozone instruments has been compared several times with the ground-based reference instruments (during international intercomparisons campaigns) and the satellite spectrophotometers (TOMS, OMI).

Institute of Meteorology and Water Management

Surface ozone measurements with Monitor Labs. ML9810 are performed at 3 stations: Leba (54.75N, 17.53E) on the Baltic Coast, Jarczew (51.81N, 21.98E) located in the central Poland, Sniezka (50.73N, 15.73E) in Sudety Mountains.

Profile measurements of ozone

Institute of Geophysics of the Polish Academy of Sciences

The ozone content in selected layers in the stratosphere over Belsk (51°50' N, 20°47'E) have been calculated using the Umkehr measurements by the Dobson spectrophotometer (since 1963) and the Brewer spectrophotometers (the Brewer No.64 since 1992 and the Brewer No.207 since 2010). The ozone profiles are derived by UMK92 algorithm applied to the Dobson data. UMK04 algorithm is used both for to the Dobson and Brewer Umkehr data. The Belsk ozone profiles have been used in the validation of ozone profiles derived by Microwave Limb Sounder on board of the Aura satellite.

Institute of Meteorology and Water Management

The ozone soundings have been performed at Legionowo (52.40N, 20.97E) upper-air station since 1979. Up to May 1993 the OSE ozone sensor with the METEORIT/MARZ radio

sounding system was used. Later on the ECC ozone sensor and DigiCora/RS80/92 radio sounding system of Vaisala is in use. The ozone soundings are launched regularly on each Wednesday. Additional ozone soundings were performed for the purpose of the MATCH campaign (statistical evaluation of ozone chemical destruction in Polar Vortex). The Legionowo ozone profiles were also used in the validation procedures of ozone profiles derived from satellite projects: MIPAS, SCIAMACHY and OMI.
Legionowo is a complimentary station of the global NDACC/NDSC ozone sounding network. Ozone sounding data from Legionowo are submitted to the NDACC database.
Since 1993, on the base of the NOAA/TOVS/ATOVS satellite data, total ozone maps over Poland and surroundings have operationally been performed at the Satellite Remote Sensing Center of IMWM in Krakow.

UV measurements

Broadband measurements

Institute of Meteorology and Water Management

Broadband UV Biometers model SL 501 vers. 3 have been used for UV measurements at three IMWM stations in Poland: Leba (54.75N, 17.53E), on the Baltic Coast, Legionowo (52.40N, 20.97E), in central Poland, Zakopane 857m, in Tatra Mountains (49.30N, 19.97E). Since 2006, broadband OPTIX UVEM-6C have been used for nowcasting purposes at six IMWM stations in Poland: Leba (54.75N, 17.53E), Mikolajki (53.78N, 21.58E), in the north-eastern Poland, Legionowo (52.40N, 20.97E), Katowice (50.23N, 19.03E) in the southern Poland, Zakopane 857m, in Tatra Mountains (49.30N, 19.97E), Mount Kasprowy Wierch 1988m (49.23N, 19.98E), in Tatra Mountains.

Institute of Geophysics of the Polish Academy of Sciences

Systematic measurements of ground level ultraviolet solar radiation (UV-B) with the Robertson- Berger meter were carried out at Belsk station in the period May 1975 – December 1993. In 1992 UV Biometer SL501A (replaced by the same type of the instrument in 1996) , and in 2005 Kipp and Zonen UVS-AE-T broadband radiometer were installed. The instruments have been operated continuously up to now. The UV monitoring has been conducted at the Polish Polar Station at Hornsund, Svalbard (77°00'N, 15°33') in the period 1996-1997 by UV Biometer SL501A and since spring 2006 up to now by Kipp and Zonen UVS-AE-T.

Narrowband filter instruments

Two NILU-UV spectral filter instruments, installed at IMWM station Legionowo, measure the UV-B, UV-A, total ozone and cloud transmission.

Spectroradiometers

Spectral distribution of UV radiation has also been monitored with the Brewer spectrophotometers at Belsk since 1992 (Brewer No.64) and in addition since 2010 (Brewer No.207). The spectra with 0.5 nm resolution for the range 290-325 nm and 286-363 nm have been calculated by the Brewer (No.64) and Brewer (No.207), respectively. Several spectra per hour are usually obtained for the solar zenith angles less than 85^0.

Calibration activities

Institute of Meteorology and Water Management

The recent calibration of the reference UV Biometer model SL 501 took place in 2008 at PMOD/WRC – EUVC in Davos. The next calibration of the instrument is planned in 2011.
The NILU-UV spectral filter instruments are regularly calibrated at NRPA, Norway.

Institute of Geophysics of the Polish Academy of Sciences

The Dobson and Brewer spectrophotometers have been regularly calibrated. The recent calibrations of the Dobson instrument took place at the Hohenpeissenberg Observatory of DWD in 2009 and in 2010. The intercomparisons were carried out against the European substandard Dobson No.64. The Brewer spectrophotometer No.64 was calibrated against the reference instrument Brewer No.17 maintained by the International Ozone Corporation (Canada) at the Arosa observatory (Swiss Meteorological Institute) in 2008 and 2010 and at the Hradec Kralove Observatory (Czech Hydrometeorological Institute) in 2009. During the Brewer intercomparison campaigns both the total ozone and UV spectra were calibrated.
The Belsk's broad band UV meters were calibrated in 2008 and 2009 in Innsbruck (CMS Company, Kirchbichl, Austria). Since 2010 the output of the broadband meters is compared against the Belsk's Brewer No.207 (double monochromator).

RESULTS FROM OBSERVATIONS AND ANALYSIS

Figure 1.

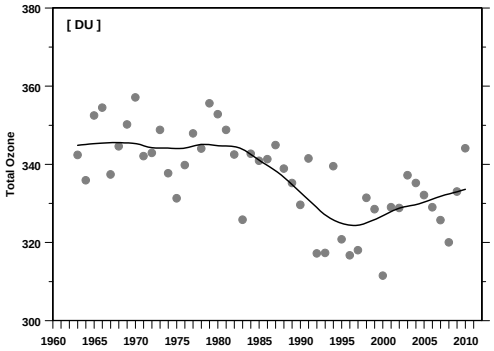

Figure 1. Annual means (1963-2010) of total ozone at Belsk, Poland.

Figure 2

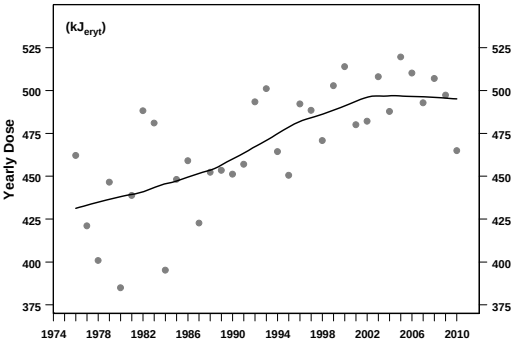

Figure 2. Annual means of the erythemaly weighted doses (1976-2010) at Belsk, Poland.

Figure 3

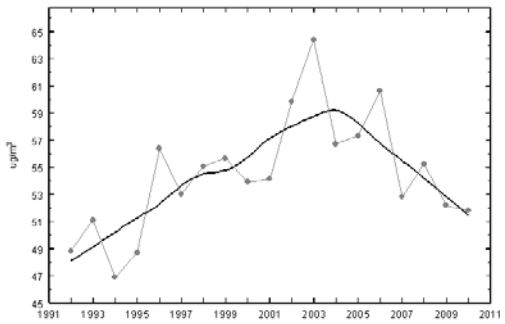

Figure 3. Annual means (1992-2010) of surface ozone concentration at Belsk, Poland.

RESEARCH

Institute of Meteorology and Water Management

Ozone and UV research activities are carried on in the Centre of Aerology in Legionowo in cooperation with the Satellite Remote Sensing Center in Krakow.

- Long term changes in ozone profile at Legionowo, Poland have been studied. A definition of the ozone tropopause was proposed to study the variability in the stratospheric ozone columns. A significant ozone increase in the middle stratosphere has been detected. The observed differences in stratospheric ozone destruction from year to year are the result of changing meteorological conditions in the NH stratosphere.
- Legionowo is often located at the edge of the polar vortex and since 1995 participates in MATCH campaigns (statistical evaluation of ozone chemical destruction in Polar Vortex). Episodes of serious ozone deficiencies, observed during the displacements of the cold polar vortex in the winter/spring seasons have been observed.

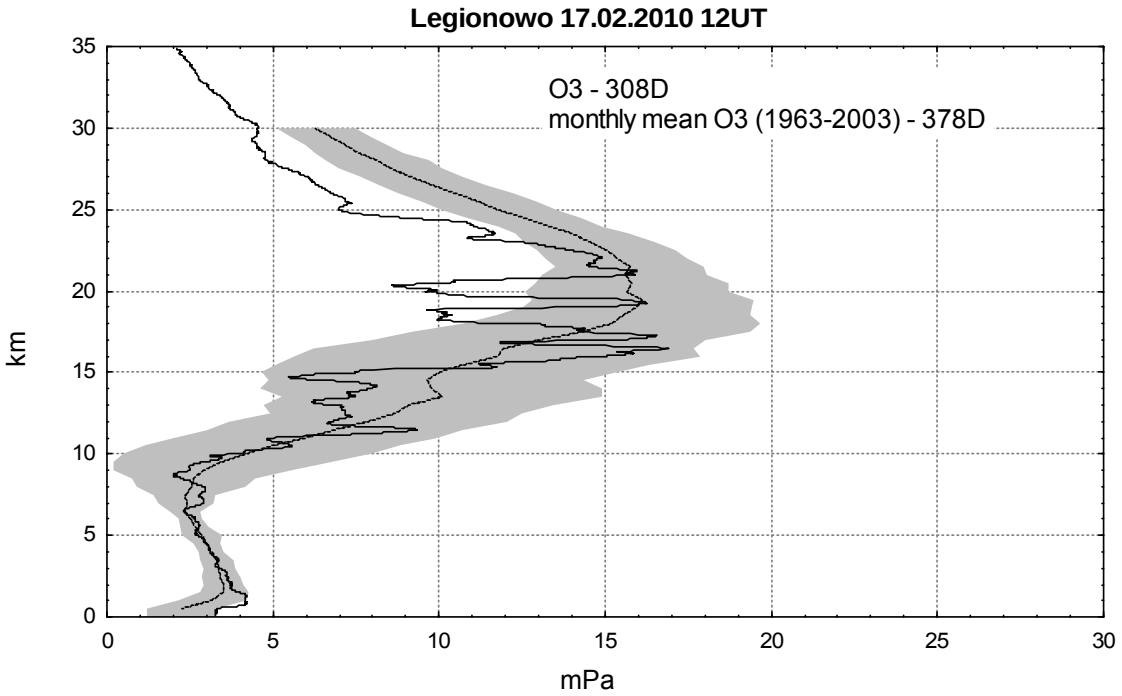

Figure 4. Example of ozone depletion recently observed at Legionowo.

- UV reconstruction model, elaborated within COST 726 Action 'Long term and variability UV radiation over Europe', was used for reconstruction of UV for Poland. The reconstruction algorithm was adopted for the period of 1985-2008 for 21 stations. Spatial and temporal analyses of monthly mean UVI values over area of Poland were performed. The monthly mean all sky UV index values in Poland decrease with increasing latitude. Deviation from latitudinal pattern of monthly mean UVI distribution has been observed in summer. The UVI isopleths direction changes to more longitudinal one with the maximum values in South Eastern Poland. This effect is especially seen in the multiyear monthly mean UVI map for July.
- Seasonal analysis of temporal variability in the years 1985-2008 shows an increase in monthly mean UVI calculated for all stations and cloud free conditions. When all sky UVI values are considered, the positive tendency was obtained for all seasons except for winter, when no

change can be seen. The increase in monthly mean UVI values is especially pronounced in spring and summer.

- Temporal variability of monthly mean UVI depends on the geographical localization as it can be seen in the analysis performed for maritime and mountainous stations. Nevertheless, for both stations the increase in monthly mean UVI has been obtained for spring and summer, what is especially significant for UV radiation biological effects.
- Biologically effective UV radiation (UVBE) for 3 stations of IMWM: Leba, Warsaw and Zakopane was analyzed. Analyses were performed on the basis of reconstructed data series: 17-years (1985-2001) for Leba and 24-years (1985-2008) for Warsaw and Zakopane. In Poland, there are hazards connected with excesses or deficiencies of UV radiation. Biologically effective UV radiation during the summer months may be harmful for human health without any protection. In winter time the UV radiation is not sufficient for natural synthesis of vitamin D3 by humans.

Institute of Geophysics of the Polish Academy of Sciences

The ozone time series (from the observations taken at Belsk and from the global ozone data bases) are examined by statistical models developed in IGFPAS to determine factors responsible for the ozone changes. The ozone variability and quantification of the impact of human activities on the ozone layer is essential because of the coupling of the ozone layer and the global climate system. The changes in the ozone layer are examined in connection with changes in the dynamic factors characterizing the atmospheric circulation in the stratosphere. Various studies have been carried out in the Institute focusing on the role played by the dynamical factors of the ozone variability. Natural dynamical processes in the Earth's atmosphere could perturb the recovery of the ozone layer. To get more comprehensive view of ozone long-term changes over Europe the trends have been calculated using the reconstructed daily total ozone data since January, 1, 1950 for the area 30-80^{o}N and 25^{o}W-35^{o}E. Variability of solar UV radiation over Belsk since 1976 up to now, i.e. based on the world longest series of the erythemal observations, has been analyzed after homogenization of the whole series of the broadband UV measurements. Recent studies on the atmospheric aerosols properties (from sunphotometric measurements at Belsk and Hornsund) are triggered by our previous findings (Krzyścin and Puchalski, 1998, J.Geophys.Res.,vol.103, No. D13, PP. 16,175-16,181, doi:10.1029/98JD00899, Jarosławski and Krzyścin, 2005, J.Geophys.Res.,110, D16201, 9 PP., doi:10.1029/2005JD005951) suggesting that the variability of the aerosol optical characteristics in summer induces changes in the surface UV radiations comparable to those due to total ozone variability.
The research achievements since the previous Report (2008) could be summarized as follow:

- introducing the wavelet multi-resolution decomposition in calculation of the trend pattern in UV time series. (Borkowski, 2008)
- developing the methodology to reconstruct the total ozone time series for the periods without the ozone observations based on the meteorological data from the global 3-D reanalyses (NCAR/NOAA) database. (Krzyścin, 2008)
- building of the European total ozone data base comprising the grided (1 deg x 1 deg) daily total ozone data over the region (30-80^{o}N, 25^{o}W-35^{o}E) since January 1, 1950. The statistically significant negative trends are found almost over the whole Europe only in the period 1985–1994. Negative trends up to −3% per decade appeared over small areas in earlier periods when the anthropogenic forcing on the ozone layer was weak . The statistically significant positive trends are found only during warm seasons 1995–2004 over Svalbard archipelago. The reduction of ozone level in 2004 relative to that before the satellite era is not dramatic, i.e., up to ~5% and ~3.5% in the cold and warm subperiod, respectively. Present ozone level is still depleted over many popular resorts in southern Europe and northern Africa. For high latitude regions the statistically significant trend overturning could be inferred in last decade (1995–2004) (Krzyścin and Borkowski, 2008).

- support of high quality of the ozone profiles by the Microwave Limb Sounder (MLS) on board of the Aura satellite since 2004 by comparison with the ground-based data from Umkehr observations at Belsk (Krzyścin et al., 2008).
- finding that the UV radiation measured on a surface vertical to ground (usual position of human face and hands, i.e., parts of body being always irradiated by harmful UV radiations) could be effectively recalculated from the output of instrument placed horizontally (standard configuration of the UV measuring instruments at meteorological stations). The conversion constant (~0.5) is universal and allows to have a first guess of the real irradiation of human body by solar UV.(Sobolewski et al., 2008)
- homogenization of the Umkehr observations at Belsk (52°N, 21°E) for the period 1963 to 2007, taking into account step changes in the R-N tables and re-evaluated total ozone values. The negative trend in total ozone (ąbout 3.5% per decade), found for the period 1980 to 1995, is due to the ozone depletion in the lower- and mid-stratosphere (up to 23.5 km). Afterwards, the trends in total ozone and in lower and mid-stratospheric ozone are not statistically significant. In the upper stratosphere (> 37 km) the trends in the period 1996 to 2007 are positive and of about 3-5% per decade. The occurrence of the positive trend after 1995 is in line with the Montreal Protocol regulations on ozone-depleting substances. (Krzyścin and Rajewska, 2009a)
- building a novel trend models capable of detecting signs of the ozone recovery and finding that ozone over Belsk, in central Europe, and in midlatitudinal Europe reaches at least first stage of recovery as defined by the World Meteorological Organization, i.e., a statistically significant reduction in the rate of decline. Substantial seasonal dependent long-term ozone oscillations by the dynamical drivers are revealed causing estimation of the ozone recovery time even more uncertain. (Krzyścin and Rajewska, 2009b)
- homogenization of the Belsk's UV data obtained by various broadband UV meters since 1975 and calculation of the UV trends (yearly, seasonal, and monthly) in the erythemaly weighted solar radiation for the period 1976-2008 and quantification sources of these trends (ozone, cloudiness). The UV climatology was established and the UV variability was determined. Positive UV trends were found for the period of 1976-2008 in the annual mean (5.6±0.9% per decade), in the seasonal mean for the warm subperiod of the year (April-October, 5.5±1.0% per decade), and in monthly means (~2-9% per decade). A satisfactory agreement between the trend extracted from the homogenized ground-based data and that found in satellite UV data for Belsk (1979-2008) supports the reliability of satellite trend analyses over wider areas during snowless periods. (Krzyścin et al., 2011)
- determination of optical properties of aerosol in the UV range over Belsk (Pietruczuk and Jarosławski, 2008; Jarosławski and Pietruczuk, 2010) and over the Polish Arctic station – Hornsund (Rozwadowska and Sobolewski, 2010) from the sunphotometric measurements and finding factors influencing the aerosol variability there.

DISSEMINATION OF RESULTS

Data reporting

The ozone data taken at Belsk are regularly submitted to the World Ozone and Ultraviolet Radiation Data Centre in Toronto. The mean daily values of total ozone are also submitted operationally to the Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Greece.

The ozone sounding data from Legionowo are submitted to the World Ozone and Ultraviolet Radiation Data Centre in Toronto regularly on monthly schedule, and operationally to the Data Base at NILU (Norway).

.

Information to the public

- Since 2006, an operational monitoring of UV Index from the IMWM network has been published on IMWM web pages.
- Since 2000, the UV Index forecast for Poland has been available from May to September on IMWM web pages.

- An information system of solar UV radiation for outdoor workers was developed in the frame of project 'Determination of UV radiation on Polish territory for the purposes of risk assessment'. (IMWM)
- since 2001, the daily means of total ozone from the Dobson measurements at Belsk and UV Index from the SL501A measurementse are displayed in almost real time on web pages http://ozon.igf.edu.pl and http://uvb.igf.edu.pl, respectively. (IGF PAS)

Relevant scientific papers

Institute of Meteorology and Water Management

Biszczuk J.,. Antarctic ozone hole – signature in UV measurements on the H. Arctowski Polish Antarctic Station during the period 2003-2007, Weather extremes in Poland – observations, measurements, forecasting, ISBN 978-83-61102-00-7, pp. 41-46, 2008
Biszczuk J., Litynska Z., Curyło A., UV radiation influence on human Heath – action spectra: erythemal, prewitamin D3, SCUP-H, Proceedings of Electrotechnical Institute, vol. 234, ISSN-0032-6216, pp. 205-216, 2008
Koepke P., H. De Backer, A. Bais, A. Curylo et al.: Modelling solar UV radiation in the past: Comparison of algorithms and input data: COST Office, ISBN 978-92-898-0043-3, 2008;
Curyło A., Litynska Z., Krzyscin J., Bogdanska B.: "UV reconstruction algorithm and diurnal cycle variability", Proceedings of the International Radiation Symposium (IRC/IAMAS), Foz do Iguaçu, Brazil, 3 - 8 August 2008, pp. 615-618, 2009
Lapeta B., Walawender J., Curylo A., Biszczuk J., Litynska Z., Krzyscin J. and Bogdanska B.: "Climatology of UV biologically effective radiation in Poland", Proceedings of the International Radiation Symposium (IRC/IAMAS), Foz do Iguaçu, Brazil, 3 - 8 August 2008, pp. 623-626, 2009
Biszczuk-Jakubowska Julita, Measurements of personal UV doses at different human activities, Geologica Balcanica 39. 1-2, XIX Congress of the Carpathian Balkan Geological Association, Saloniki, Grecja, 23-26.09.2010, Sofia, Bulgarian Academy of Sciences, pp. 47,2010
Biszczuk-Jakubowska J., Curylo A., Solar UV radiation and human health, Proceedings of Electrotechnical Institute, vol. 244'10, ISSN-0032-6216, pp. 93-106, 2010
Curylo A., Kois B., Cloud observations and surface solar radiation measurements, Proceedings of Electrotechnical Institute, vol. 244'10, ISSN-0032-6216, pp. 69-78, 2010
Biszczuk-Jakubowska J., Curylo A., Litynska Z., Bogdanska B., Hazards resulting from UV radiation excess or deficiency over Poland, Risk factor in environmental hazards, ISBN 978-83-61102-33-5, pp. 34-49, 2010

Institute of Geophysics of the Polish Academy of Sciences

Borkowski, J., (2008). Modelling of UV radiation variations at different time scales, Annales Geophysicae 26 (3), 441-446.
Krzyścin, J. W., (2008). Statistical reconstruction of daily total ozone over Europe 1950 to 2004, Journal of Geophysical Research, 113, D07112, doi:10.1029/2007JD008881.
Krzyścin, J.W., Borkowski, J., (2008) Variability of the total ozone trend over Europe for the period 1950-2004 derived from reconstructed data, Atmospheric Chemistry and Physics, 8, 2847-2857.
Krzyścin, J. W., J. Jarosławski, B. Rajewska-Więch, P. S. Sobolewski, and L. Froidevaux (2008), Comparison of ozone profiles by the Umkehr measurements taken at Belsk (52°N, 21°E) with the Aura Microwave Limb Sounder overpasses: 2004–2006, Journal of Geophysical Research, 113, D15S09, doi:10.1029/2007JD008586.
Sobolewski, P., Krzyścin, J. W., Jaroslawski, J., and Stebel, K. (2008): Measurements of UV radiation on rotating vertical plane at the ALOMAR Observatory (69° N, 16° E), Norway, June 2007, Atmos. Chem. Phys., 8, 3033-3043, doi:10.5194/acp-8-3033.
Krzyścin, J.W., and B. Rajewska-Więch, (2009a),Trends in the ozone vertical distribution from the Umkehr observations at Belsk, 1963-2007, International Journal of Remote Sensing, vol.30, 3917-3926, 2009.
Krzyścin, J.W., and B. Rajewska-Więch, (2009b). Ozone recovery as seen in perspective of the Dobson spectrophotometer measurements at Belsk (52N, 21E) in the period 1963-2008, Atmospheric Environment 43, 6369-6375.
Krzyścin, J.W., Sobolewski, P., Jarosławski, J., Podgórski, J., Rajewska-Więch, B (2011). Erythemal UV observations at Belsk, Poland: Data Homogenisation, Climatology, and Trends, Acta Geophysica, 59, 1, 155-182.

Pietruczuk, A., and Jarosławski, J (2008). An alternative method for aerosol optical thickness retrieval in the UV range, A. Pietruczuk i J. Jarosławski, Journal of Atmospheric and Solar-Terrestrial Physics, 70, 973-979.
Jarosławski, J., and Pietruczuk A., (2010), On the origin of seasonal variation of aerosol optical thickness in the UV range over Belsk, Poland, Acta Geophysica, 58,6, 1134-1146
Rozwadowska, A., Sobolewski, P. (2010) , Variability in aerosol optical properties at Hornsund, Spitsbergen, Oceanologia, 2010, No. 52 (4), s. 599-620.
Rieder, H,E., Holawe, F., Simic, S., Blumthaler, M., Krzyścin, JW, Wagner, J.E., Schmalwieser, A,W., and Weihs, P. (2008) Reconstruction of erythemal UV-doses for two stations in Austria: a comparison between alpine and urban regions: Atmospheric Chemistry and Physics, 8, 6309-6323,
Rajewska-Więch B., Krzyścin J., (2010), Changes in total column ozone at Belsk in perspective of ozone changes over Europe 1963-2008 (in Polish), Przegląd Geofizyczny, Z. 1-2, s. 49-59

PROJECTS AND COLLABORATION

• Institute of Meteorology and Water Management have participated in projects:
- 2004-2009: COST 726 Action 'Long term and variability UV radiation over Europe'
- 2008-2010: 'Determination of UV radiation on Polish territory for the purposes of risk assessment', coordinated by Central Institute for Labour Protection - National Research Institute, funded by National Center for Research and Development.

• Institute of Geophysics of the Polish Academy of Sciences
- 2004-2009 COST 726 Action 'Long term and variability UV radiation over Europe'
- 2006-2008 Ministry of Science and Higher Education grant No. N307 005 31/0495 – "Variability of the biologically active solar UV radiation in the mid- and high–latitudes in different time scales"
- 2007-2008 ALOMAR eARI (contract number RITA-CT -2003-506208) under the European Community's 6th Framework Programme – "Reconstruction of the biologically active UV-radiation reaching the Earth surface using results of standard meteorological measurements and output of the broadband meters"

FUTURE PLANS

Continuation of the current monitoring and research and:
- An e-atlas containing spatial and temporal distribution of UV radiation over Poland will be prepared using the reconstructed data. (IMWM)
- gaining a more robust picture of the ozone global changes examining output of all available trend models used in recent few years (IGF PAS)
- quantification of the impact **the Montreal Protocol** on the levels of ozone by a novel trend model that searches for a residual trend component that remains in the ozone series after subtracting the ozone signal related to long-term changes in the concentration of the ozone depleting substances in the stratosphere (IGF PAS)
- construction a retrieval algorithm applicable to the Umkehr profiles for the Dobson and Brewer spectrophotometers that allows statistical analyses of the aggregated time series comprising the Dobson and Brewer ozone profiles (IGF PAS)

NEEDS AND RECOMMENDATIONS

IMWM and IGF PAS recommend closer international collaboration on UV radiation to find a proper balance between the risk (carcinogen effects) and the benefit (synthesis of vitamin D in skin) of the solar exposure.
Ozone dial lidar would make possible the extension of the IGF PAS monitoring of the troposphere and lower stratosphere ozone with a special emphasis on the ozone changes in the tropopause region.