POLAND

In Poland, ozone and UV monitoring and related research activities are conducted by the Institute of Meteorology and Water Management- National Research Institute (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, and National Science Centre.

OBSERVATIONAL ACTIVITIES

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

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IGFPAS has been involved in the long-term monitoring of the ozone layer for over 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 the 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).

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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

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The ozone content in selected layers in the stratosphere over Belsk have been calculated using the Umkehr measurements by the Dobson spectrophotometer (since 1963) and the Brewer spectrophotometers (the Brewer No.64 since 1992 and Brewer No.207 since 2010). 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.

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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

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Broadband UV Biometers model SL 501 vers. 3 have been used for UV measurements at three IMWM stations: 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 northeastern 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.

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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 IMMW 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

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The UV Biometers model SL 501 have been regularly calibrated at PMOD/WRC in Davos. The next calibration of the instrument is planned in 2014. A method of calibration of the Biometers OPTIX UVEM-6C which does not disturb the continuity of measurements on the IMMW network has recently been elaborated.

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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 2010, and the next calibration is planned in June 2014. 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 Belsk observatory) in 2012, the Hradec Kralove Observatory (Czech Hydrometeorological Institute) in 2013, and the next calibration is planned at Belsk in 2014. During the Brewer intercomparison campaigns both the total ozone and UV spectra were calibrated. Since 2010 the output of the Belsk's broad band UV meters is compared against the Belsk's Brewer No.207 (double monochromator).

RESULTS FROM OBSERVATIONS AND ANALYSIS

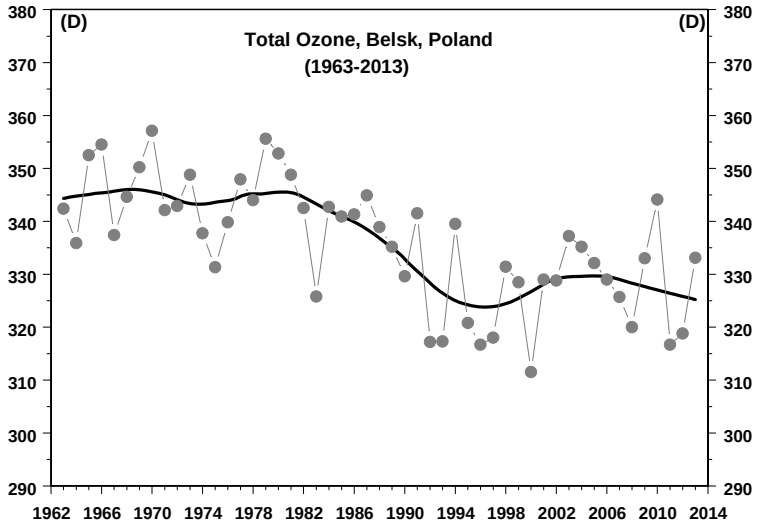

Figure 1. Annual means (1963-2013) of total ozone at Belsk, Poland, from the Dobson spectrophotometer measurements.

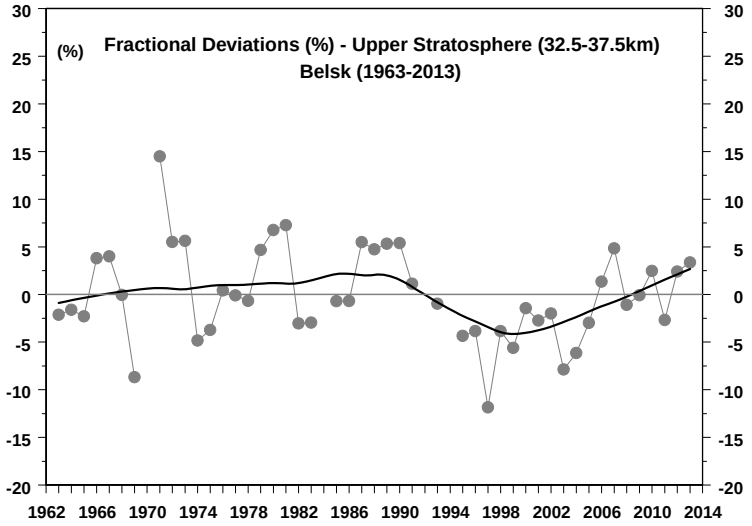

Figure 2. Fractional deviations of the annual mean ozone content in the upper stratosphere (32.5km - 37.5km) from the long-term (1963-2013) annual mean in percent of the long-term mean, from the Umkehr observations carried out at Belsk

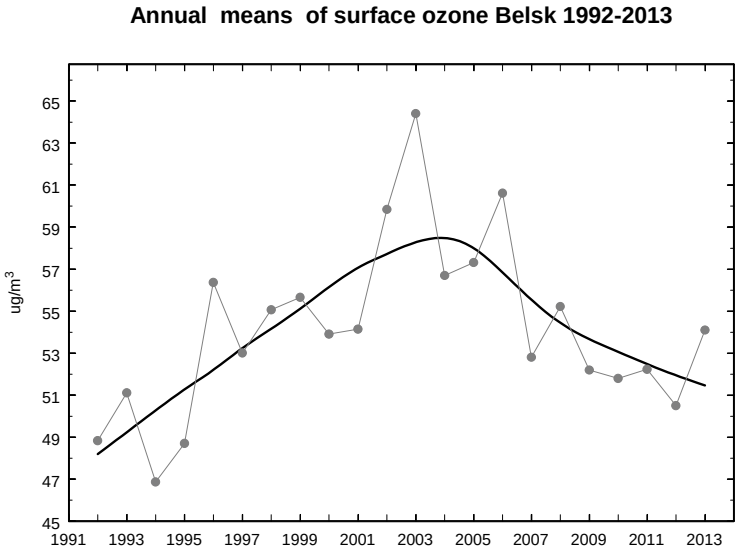

Figure 3. Annual means (1992-2013) of surface ozone concentration at Belsk, Poland.

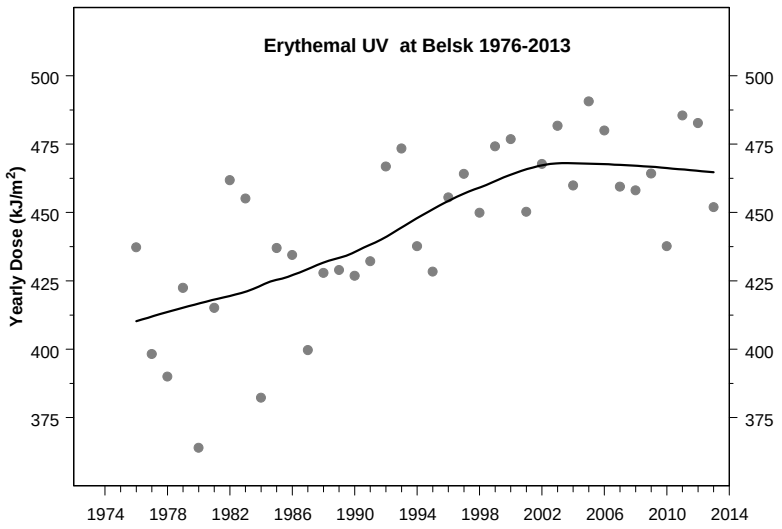

Figure 4. Annual means of the erythemaly weighted doses (1976-2013) at Belsk, Poland.

RESEARCH

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Long term changes in ozone profile at Legionowo, Poland, have been studied. Significant downward trends of ozone concentration in winter and spring months in the lower stratosphere have been found during the period of acceleration of ozone depletion processes on global scale (1979-1993). In recent years (1998-2012) signs of ozone recovery in the middle stratosphere have 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.

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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.

Variability of solar UV radiation over Belsk since 1976 up to now, 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 (2011) could be summarized as follow:

- Developing a novel trend model to disclose the temporal variability of the long-term component of the ozone variability and to discuss effectiveness of the Montreal Protocol (MP) 1987 and its subsequent Amendments regulations to save the ozone layer. The model has been used for the trend detection in the global satellite and Belsk's ozone data. (Krzyścin, 2012a, Krzyścin et al., 2013)
- Calculation of the vertical profile of ozone from the Umkehr observations using neural network approach. The ozone pattern in the troposphere and lower stratosphere could be calculated with higher accuracy than that by the standard inverse Umkehr retrieval (Jarosławski, 2013)
- Finding evidences of slowing down the recovery rate of the Belsk's total ozone (see Figure 1) since ~ 2005 especially in the summer total ozone data due to unknown yet dynamical process (Krzyścin et al., 2013)
- The pattern of the upper stratospheric ozone changes over Belsk with the trend overturning about 1996 corroborates the success of the Montreal Protocol and its further Amendments regulations to save the ozone layer (see Figure 2)
- Modelling biomedical aspects of solar and artificial (due to fluorescent tubes) UV radiation. The UV level at Belsk has stabilized since the beginning XXI century at level ~10% higher than that in the mid 1970s (see Figure 4). Scenarios for getting the appropriate vitamin D level due to solar radiations and basis for anti-psoriatic heliotherapy in Poland have been prepared (Lesiak et al., 2011; Krzyścin et al., 2011; Krzyścin et al., 2012b; Krzyścin et al., 2012d)
- Finding the impact of Eyjafjallajokull volcano ash on surface UV at Belsk. Eruption of Eyjafjallajokull volcano on 13-14 April 2010 created an ash cloud moving towards densely populated areas in Europe. Since 16 April thin aerosol clouds, linked to the volcanic eruption, were found below 5 km at Belsk. The optical thickness of the cloud (at 500 nm) varied only slightly in the range of a few hundredths that had no impact on surface UV there. (Pietruczuk et al., 2011).
- Developing a multiple regression model to attribute the Arctic total ozone variability to various chemical and dynamical ozone forcing factors. The total area with extremely depleted total ozone over the Arctic reached the maximum at the end of March 2011, equal to $\sim 11 \times 10^6$ km^2. The model reproduces the ozone loss in early 2011 and the overall picture of the ozone long-term changes since 1979. The extreme ozone decline in 2011 could be attributed to the long-lasting period with low stratospheric temperature (<195 K), weaker than the normal Brewer-Dobson circulation, and the Arctic Oscillation in a strong positive phase. (Krzyścin, 2012c)

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).

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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 measurements 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

Zenobia Litynska, Alois Schmalwieser, Alkiviadis Bais, Karell Ettler,Julian Grobner, Peter Kopke, Janusz Krzyscin, Peter Den Outer, Jean Verdebout, Gaetano Zipoli and Julita Biszczuk-Jakubowska. (2012) COST Action 726 – Final Report European Commnities Luxembourg; Publications Office of the European Union ISBN 978-92-898-0053-2 doi:10.2831/12318

Biszczuk-Jakubowska J., Curylo A., Kois B. and Zablocki G., Solar UV radiation system at IMGW-PIB, Proceedings of Electrotechnical Institute, vol. 255'12, ISSN-0032-6216, pp. 251-258, 2012

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Junk, J., Feister, U., Helbig, A., Goergen, K., Rozanov, E., Krzyścin, J. W., Hoffmann, L., (2012) The benefit of modeled ozone data for the reconstruction of a 99-year UV radiation time series, Journal of Geophysical Research-Atmospheres, 117, D16102,doi.10.1029/2012JD017659.

Jarosławski, J., (2013), Improvement of the Umkehr ozone profile by the neural network method: analysis of the Belsk (51.80°N, 20.80°E) Umkehr data, International Journal of Remote Sensing, 34, 15, 5541-5550, doi: 10.1080/01431161.2013.793463

Krzyścin, J. W., Jarosławski, J., Sobolewski, P. S., (2011) A mathematical model for seasonal variability of vitamin D due to solar radiation, Journal of Photochemistry and Photobiology B-Biology, 105,1, 106-112, doi.10.1016/j.jphotobiol.2011.07.008

Krzyścin, J., (2012a) Onset of the total ozone increase based on statistical analyses of global ground-based data for the period 1964-2008, International Journal of Climatology, 32, 2, 240-246. doi.10.1002/joc.2264

Krzyścin, J.W., Jarosławski, J., Rajewska-Wiech, B., Sobolewski, P. S., Narbutt, J., Lesiak, A., Pawlaczyk, M., (2012b) Effectiveness of heliotherapy for psoriasis clearance in low and mid-latitudinal regions: A theoretical approach, Journal of Photochemistry and Photobiology B-Biology , 15,35-41,doi:10.1016/j.jphotobiol.2012.06.008

Krzyścin, J.W., (2012c) Extreme ozone loss over the Northern Hemisphere high latitudes in the early 2011, Tellus Series B- Chemical and Physical Meteorology, 64, 17347, doi.10.3402/tellusb.v64i0.17347

Krzyścin, J. W., Jarosławski, J., Rajewska-Wiech, B., Sobolewski, P. S., Narbutt, J.; Lesiak, A.; Pawlaczyk, M.; Janouch, M., (2012d) Space-based estimation of the solar UV-B doses for psoriasis heliotherapy in Poland using OMI data for the period 2005-2011, Journal of Photochemistry and Photobiology B- Biology , 117, 240-246, doi.10.1016/j.jphotobiol.2012.10.007

Krzyścin, J.W., Rajewska-Wiech, B., Jarosławski, J., (2013) The long-term variability of atmospheric ozone from the 50-yr observations carried out at Belsk (51.84 degrees N, 20.78 degrees E), Poland, Tellus Series B- Chemical and Physical Meteorology, 65, 21779,doi.10.3402/tellusb.v65i0.21779

Lesiak, A., Narbutt, J., Pawlaczyk, M., Sysa-Jedrzejowska, A., Krzyścin, J., (2011) Vitamin D serum level changes in psoriatic patients treated with narrowband ultraviolet B phototherapy are related to the season of the irradiation, Photodermatology Photoimmunology & Photomedicine, 27, 6, 304-310, doi. 10.1111/j.1600-0781.2011.00617.x

Pietruczuk, A.; Krzyścin, J.W., Jarosławski, J. Podgórski, J., Sobolewski, P., and Wink, J.,(2010) Eyjafjallajokull volcano ash observed over Belsk (52 degrees N, 21 degrees E), Poland, in April 2010, International Journal of Remote Sensing, 31,15, 3981-3986. PII 926840392 doi.10.1080/01431161.2010.498030

Rieder, H., Jancso, L., Di Rocco, S., Staehelin, J., Maeder, J.A., Peter, T. Ribatet, M., Davison, A.C. De Backer, H., Koehler, U., Krzyścin, J., Vanicek, K., (2011) Extreme events in total ozone over the Northern mid-latitudes: an analysis based on long-term data sets from five European ground-based stations, Tellus Series B- Chemical and Physical Meteorology, 63,5, 860-874, doi. 10.1111/j.1600-0889.2011.00575.x.

PROJECTS AND COLLABORATION

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- 2011-2014 National Science Centre (Poland) grant No. 2011/01/B/ST10/06892 " Effect of the Montreal Protocol (1987) on atmospheric ozone"
- 2013-2015 National Science Centre (Poland) grant No. 2012/05/B/ST10/00495 " Modelling of ground level solar UV radiation for assessment of antipsoriatic heliotherapy in Poland"
- 2013-2017 Earth System Science and Environmental Management COST Action ES1207, A EUropean BREWer NETwork - EUBREWNET

FUTURE PLANS

Continuation of the current monitoring and research:

- continuation of the ozone (column, profile and surface) and UV observations at Belsk Observatory
- trend analyses of updated time series of the ground-based and satellite ozone and biologically weighted solar UV
- searching for pro-healthy scenarios of out-door activities taking into account erythema risk
- elaboration of the atlas containing spatial and temporal distribution of UV radiation over Poland using the reconstructed data. (IMWM)

NEEDS AND RECOMMENDATIONS

IMWM and IGF PAS recommend closer international collaboration on interactions between the ozone and climate changes to determine the ozone recovery date and evolution of policy instruments to reduce greenhouse gases.