National Report of Belgium

for the 8th WMO/UNEP Ozone Research Managers Meeting

Geneva, 2-4 May 2011

1. OBSERVATIONAL ACTIVITIES

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

1.1.1 The Royal Meteorological Institute (RMI)

The RMI performs Daily Ozone column measurements with two automated Brewer spectrophotometers. One (nr 16) is a single monochromator, in use since 1983 and the other one (nr 178) is a double monochromator installed in 2001. Both instruments are operational in Uccle (Belgium).

Measurements with a Dobson spectrophotometer (nr 40) which started in 1971, continued until end of May 2009. As RMI has two Brewer instruments and a long overlap period with the Dobson instrument, the Dobson measurements were stopped. In agreement with WMO-GAW the instrument is now loaned to the University of Kiev (Ukraine) and is operational there.

The observations mentioned above take place at Uccle (50°48'N, 4°21'E, 100 m asl, complementary NDACC station (see http://www.ndacc.org) and station 053 in the WOUDC list).

In addition RMI started in January 2011 observations at the Belgian Antarctic station Princess Elisabeth with Brewer instrument 100, which was put at our disposal by KNMI in the Netherlands. The new Antarctic station is located at 71 deg south, 23 deg East, 1397m asl. It obtained nr 499 in the WOUDC list, and will be operational during the manned periods in the austral summer.

1.1.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

BIRA-IASB performs **ground-based** monitoring of the total column of ozone and interacting species (halogens, NOy, BrO, HCFC, CFC…) for budget, processes and long-term trend studies, at:

- the International Scientific Station of the Jungfraujoch, Switzerland (46.5ºN, 8.0ºE, 3580 m asl): FTIR and SAOZ instruments. SAOZ measures O_3 and NO_2 columns in the UV-Vis spectral range, since 1990. The time series of FTIR data starts in the early eighties. The FTIR observations at Jungfraujoch are lead by ULg. In the second half of 2010, an additional MAXDOAS Instrument has been installed at the Jungfraujoch and provides stratospheric profiles of BrO, NO_2 and ozone as well as tropospheric abundances of NO_2, H_2O, O_3, H_2CO and aerosols.
- Harestua, Norway (60°N, 11°E): UV-VIS DOAS instruments, since 1994 (O_3, NO_2, OClO, BrO)
- the Observatoire de Haute Provence (OHP), France (44°N, 8°E): UV-VIS DOAS instrument (O_3, NO_2, BrO columns), since summer 1998. The UV-VIS DOAS instrument has been upgraded with an off-axis capability (MAXDOAS) in 2000 and since then provides also tropospheric abundances of NO_2 and H_2CO.
- Ile de la Réunion (22°S, 55°E): FTIR observations (total column abundances and vertical distributions of O_3, halogenated and nitrogenated source and reservoir gases, and more) starting in summer 2002. Initially FTIR observations were made on a campaign basis, in Sept-Oct. 2002, August to November 2004, and May to November 2007. Since May 2009, the instrument is operated on a continuous basis. During the first FTIR campaign in 2002, simultaneous measurements at sea level and at high altitude (2200 m asl) were performed, allowing to infer columns in the boundary layer/low troposphere, via a differential approach. From August 2004 to July 2005, a UV-Vis MAXDOAS instrument (O_3, NO_2, BrO, H_2CO columns and tropospheric abundances) was operated at the same site as the FTIR instrument.
- Ile de la Réunion (22°S, 55°E): in September 2010, BIRA-IASB has installed a new more performant FTIR instrument for high-precision measurements of greenhouse gases (CO_2 and CH_4). The instrument will become operational in summer 2011. As the evolution of the stratospheric ozone layer is influenced by climate changes, these measurements are relevant indirectly for understanding ozone in the future.

BIRA-IASB is involved in several **satellite** missions measuring the total column of ozone and interacting species (halogens, NOy, BrO, HCFC, CFC…) for budget, process and long-term trend studies, by:

- Global Ozone Monitoring Experiment (GOME), measuring aboard ESA's ERS-2 platform since 1995 the column of O_3, NO_2, BrO and OClO. BIRA-IASB is a co-proposer of the instrument, plays a key role in scientific developments and geophysical validation of the operational GOME Data Processor for total ozone and NO_2 run at DLR (Germany) on behalf of ESA *(Lambert et al. 1999, 2000; Spurr et al. 2004; Van Roozendael et al. 2007; Balis et al. 2007; Loyola et al. 2009; Lerot et al. 2010)*. OIP in Belgium has built the GOME Polarization Devices (PMDs).
- Scanning Imaging Absorption spectrometer for Atmospheric Chartography (SCIAMACHY), a tri-national contribution to ESA's Envisat by Belgium, Germany and The Netherlands, measuring since 2002 O_3, NO_2, BrO, OClO columns. BIRA-IASB is a Co-PI of the instrument, has followed the technical development of the instrument, is involved in the development of retrieval algorithms, plays a coordinating role in the geophysical validation of SCIAMACHY data. OIP in Belgium has built the SCIAMACHY Polarization Devices (PMDs).
- Ozone Monitoring Instrument (OMI) measuring aboard NASA's EOS-Aura platform since 2004 the column of O_3, NO_2, BrO and OClO. BIRA-IASB has been active in the development and validation of ozone, NO_2 and BrO data products from OMI.
- Global Ozone Monitoring Experiment-2 (EUMETSAT GOME-2 aboard MetOp-A), measuring aboard EUMETSAT METOP platform since 2006 the column of O_3, NO_2, BrO, SO_2, OClO, etc. BIRA-IASB plays a key role in scientific developments and geophysical validation of the operational GOME-2 Data Processor for total ozone, NO_2, BrO, H_2CO and SO_2 run at DLR (Germany) as part of the O3M-SAF *(Loyola et al. 2011; Lerot et al. 2010b)*.
- IASI, Infrared Atmospheric Sounding Interferometer, on board METOP. BIRA-IASB is developing an N_2O product. N_2O releases NO_x in the stratosphere, which is an Ozone Depleting Substance (ODS), the steady growth of N_2O makes it a threat to the stratospheric ozone layer in the future. In addition, BIRA-IASB is developing a methane product from IASI.

The work on GOME/SCIAMACHY/OMI/GOME-2 is a response to the requirement resulting from the 7th ORM Meeting in 2008 (*WMO TD No. 51*): Continuation of the solar backscatter UV observations must be ensured as they constitute a key baseline set of measurements…

1.1.3 Université Libre de Bruxelles (ULB)

- The Atmospheric Spectroscopy group (Service de Chimie Quantique et Photophysique) at ULB is heavily involved in the IASI/MetOp satellite mission, being directly involved in its Science Working Group (ISSWG-2), under auspice of CNES and EUMETSAT. IASI is a sounder that measures the thermal infrared radiation of the Earth/atmosphere in nadir geometry, at fairly high spatial (12 km diameter circular pixel on-ground) and spectral (0.5 cm^{-1}) resolutions (*Clerbaux et al 2009*). IASI is part of the EPS system, and is scheduled to operate up to 2020 at least. The first IASI instrument onboard the European MetOp-A was launched platform in late 2006 and declared operational in July 2007. As compared to UV sounders but also precursor infrared sounders (IMG and TES), IASI has the advantage of high spatial and temporal sampling, providing global measurements twice daily, once in the morning and once in the evening. The measurements at night are especially of added value for monitoring the composition of the stratosphere in the polar night, prior to the appearance of the ozone hole. Also the small pixel allows capturing fine concentration variations in and out the polar vortex. The ULB group has set-up, in collaboration with the French LATMOS, a near-real time processing chain for IASI. Of particular relevance here are
    - Ozone total columns distributions, which are retrieved global twice a day, in near-real time. The product has already undergone partial validation against ground-based measurements and GOME-2 *(Boynard et al. 2009, Keim et al., 2009, Antón et al., 2011)*.
    - Nitric acid total columns distributions, which have an important role in regulating the ozone hole, and a sensitive species to monitor its development *(Wespes et al. 2009)*
    - Methane total columns (*Razavi et al. 2009*)

- In addition a series of column measurements for tropospheric species, strongly involved in the ozone budget by being ozone precursors, are provided. These include CO (*George et al. 2009*) and volatile organic compounds (*Razavi et al. 2011*).

- In addition to IASI, the ULB has also derived total column measurements of HNO_3 and O_3 from IMG instrument, for the year 1997 (*Clerbaux et al. 2003, Coheur et al. 2005, Wespes et al. 2007*).

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

1.2.1 The Royal Meteorological Institute (RMI)

The vertical distribution of ozone at Uccle is measured three times per week by the means of balloon soundings with ECC ozone sensors, since 1997. Ozone profile data in the period 1969-1997 were obtained with Brewer-Mast sensors

1.2.2 University of Liège (ULg)

Fourier Transform Infrared (FTIR) spectrometers are operated on a regular basis since the mid-1980s at the Jungfraujoch station (an NDACC site in the Swiss Alps, 46.5ºN, 8.0ºE, 3580 m asl, see http://www.ndacc.org) to record high-resolution IR solar absorption spectra. Analysis of these observations with dedicated algorithms allows studying and characterizing the state and evolution of the stratosphere and troposphere at northern mid-latitudes. Geophysical parameters consist in total and partial column abundances above the site, including related uncertainty evaluations. Table 1 provides the current list of atmospheric gases routinely studied at the Jungfraujoch. Ozone is among the target gases as well as halogenated or nitrogenated species (sources and reservoirs) involved in ozone depletion. In addition, numerous greenhouse gases are also monitored.

Table 1. Molecules currently studied in FTIR solar spectra recorded at the Jungfraujoch [1]

Reference gas:	N_2
Minor constituents:	CO_2, N_2O, CH_4, CO, *O_3*
Trace constituents:	
Halogenated species:	*HCl*, *$ClONO_2$*, *HF*, *COF_2*,
	CCl_2F_2, $CHClF_2$, CCl_3F, CCl_4, CF_4, SF_6
Nitrogenated species:	*NO*, *NO_2*, *HNO_3*
Others:	H_2O, C_2H_6, C_2H_2, C_2H_4, HCN, OCS, H_2CO, H_2CO_2,
	Isotopologues of CO, CH_4, H_2O, *O_3*

1.2.3 The Belgian Institute for Space Aeronomy (BIRA-IASB)

BIRA-IASB performs **ground-based** monitoring of the vertical distribution of ozone and interacting species (halogens, NOy, BrO, HCFC, CFC…) for budget, processes and long-term trend studies, at:

- the International Scientific Station of the Jungfraujoch, Switzerland (46.5ºN, 8.0ºE, 3580 m asl): the time series of FTIR data starts in the early eighties. The FTIR observations at Jungfraujoch are lead by ULg.
- Harestua, Norway (60°N, 11°E): UV-VIS DOAS instruments, since 1994, from which profiles of stratospheric NO_2 and BrO are retrieved.

[1] Species typed *in italic* are primarily present in the stratosphere, while the others are tropospheric source gases.

- the Observatoire de Haute Provence (OHP), France (44°N, 8°E): UV-VIS DOAS instrument since summer 1998, from which profiles of stratospheric NO_2 and BrO are retrieved.
- Ile de la Réunion (22°S, 55°E): From the FTIR observations, at high spectral resolution, one can derive some limited information about the vertical distribution of the observed species. In particular, for Ozone, one can derive 5 independent partial columns between the ground and the upper stratosphere.

BIRA-IASB is involved in several **satellite** missions measuring the vertical distribution of ozone and interacting species (halogens, NOy, BrO, HCFC, CFC…) for budget, process and long-term trend studies, by:

- Scanning Imaging Absorption spectrometer for Atmospheric Chartography (SCIAMACHY), a tri-national contribution to ESA's Envisat by Belgium, Germany and The Netherlands, measuring since 2002 O_3, NO_2, BrO and OClO columns. BIRA-IASB is a Co-PI of the instrument, has followed the technical development of the instrument, is involved in the development of retrieval algorithms, plays a coordinating role in the geophysical validation of SCIAMACHY data. OPI in Belgium has built the SCIAMACHY Polarization Devices (PMDs).
- Envisat GOMOS (launched in 2002). BIRA-IASB is a co-proposer of the instrument and has been active in the development and validation of ozone, temperature and nitrogen dioxide data products.
- Envisat MIPAS (launched in 2002). BIRA-IASB has been active in the geophysical validation of ozone, temperature, NO_y, HCFC and CFC data products.
- SCISAT-1 ACE-FTS (launched in 2003). Belgium has provided the imagers. BIRA-IASB has been active in the development and validation of ozone, NO_y, HCl, HCFC and CFC data products.
- National development of ALTIUS, a limb viewing satellite instrument responding to the requirements resulting from the 7th ORM Meeting in 2008 (*WMO TD No. 51*): "Satellite observations of high vertical resolution profiles using limb viewing for O_3 and key molecules are required in order to more accurately understand the changes in O_3 as CFCs decline and climate change occurs."

1.2.4 Université Libre de Bruxelles (ULB)

Contribution to **satellite** missions:

- The Atmospheric Spectroscopy group (Service de Chimie Quantique et Photophysique) at ULB is at the forefront of the chemistry-related activities around the IASI/MetOp satellite mission. The researchers take active part in the IASI Sounder Science Working Group (ISSWG-2), under auspice of CNES and EUMETSAT. In addition to providing information on total columns (see above), IASI has also profiling capabilities at least equal if not superior to most instrument currently in operation. With the FORLI processing chain set-up at ULB, the following products are available in near-real-time
    - Ozone vertical profiles, which are retrieved in 40 layers of 1km thickness starting from the ground, with 3-4 independent pieces of information. Stratospheric and tropospheric contributions are well decorrelated. The maximum sensitivity of IASI to the ozone profile is in the upper troposphere and the lower stratosphere (UTLS), and thus of high relevance for monitoring the vertical structure of the ozone hole.
    - Nitric acid vertical profiles. The vertical information is almost inexistent but the retrieval of vertical profiles improves on the columns measurements by accounting for changes in tropopause height. Vertical profiles are available in NRT.
    - In addition, vertical profiles of methane are retrieved locally or for restricted periods of time. The sensitivity is highest in the UTLS.
- The ULB researchers are involved SCISAT-1 ACE-FTS Science Team. They have contributed to several studies, including on quantifying the stratospheric chlorine budget.

- The ULB have PI contribution for TANSO-FTS GOSAT.
- The ULB have demonstrated the potential to retrieve vertical information from nadir infrared radiances by analysing the measurements of the IMG/ADEOS instrument. First vertical profiles of CO, O_3 and HNO_3 were provided (*Barret et al. 2005, Coheur et al 2005, Wespes et al 2007*)

1.3 UV measurements

1.3.1 Broadband measurements

Nihil

1.3.2 Narrowband filter instruments

Nihil

1.3.3 Spectroradiometers

1.3.3.1 The Royal Meteorological Institute (RMI)

UV spectral irradiance measurements at Uccle: both Brewer spectrophotometers are also used to monitor the UV-B radiation intensities. They perform several scans per day (number depending on the time the sun is above the horizon).

Since January 2011, also the Brewer in Antarctica performs UV spectral measurements during its operational period the austral summer.

1.3.3.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

BIRA-IASB exploits a UV-monitoring network in Belgium (see http://www.aeronomie.be/uv/globaluv/index.php

1.4 Calibration activities

1.4.1 The Royal Meteorological Institute (RMI)

Before the transfer to Ukraine, the Dobson instrument nr 40 was refurbished and calibrated at the Regional Calibration Centre of WMO in Hohenpeißenberg in 2009-2010. It turned out that the instrument has been very stable since the last calibration. Therefore no reprocessing of the data set at Uccle was necessary.

The Brewer instruments 016 and 178 were compared with the travelling reference instrument nr 017 in 2006 and 2008. In 2010 the instruments were calibrated in Uccle together with Brewer #100 (before it was sent to Antarctica) against Brewer reference instrument 158. The results of these calibrations were taken into account for the new ozone observations and also the older data were recalculated.

The ozone sondes are carefully prepared and a correction procedure is applied to minimise the inhomogeneity that could have been introduced at the change of the sonde type in 1997.

The UV-B calibration of the Brewer instruments was checked with 1000W lamps in 2006, 2008 and 2010 during the calibration visits. In 2004 the special comparative observations were performed with a travelling reference UV instrument of the Joint Research Centre (JRC in Ispra) in the frame of the Qasume project (*Gröbner et al, 2004*). All the 1000W calibrations were consistent with the calibrations based on the monthly tests with 50W lamps within the expected errors.

1.4.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

The ground-based FTIR and MAXDOAS observations are all contributing to the NDACC and are being certified in this framework.

The MAXDOAS instruments have participated to several calibration campaigns, e.g., the recent CINDI campaign in Cabau (NL) in summer 2009 *(Roscoe et al., 2010)*.

The calibration of the FTIR instrument at La Réunion is verified on a daily basis by doing HBr cell measurements. We also participate in the data processing standardisation procedures that are ongoing in the frame of the NDACC Infrared Working Group.

BIRA-IASB coordinates cal/val activities for GOME, GOMOS, MIPAS, SCIAMACHY, ACE-FTS, OMI and GOME-2. BIRA-IASB contributes to the international development of a global data quality strategy for the GEOSS, an effort led by CEOS WGCV in response to GEO Tasks DA-06-02 and DA-09-01. It is involved in the group establishing the Quality Assurance framework for Earth Observation (QA4EO, http://qa4eo.org). At European level it is active in the system engineering for the GMES Atmospheric Service (GAS) and ensures coordination and harmonisation of the data quality strategy for the GMES pioneering project PROMOTE and the EC FP7 projects establishing the GMES atmospheric core service (MACC), the GMES air quality service (PASODOBLE) and the GMES volcanic observatory (EVOSS).

1.4.3. University of Liège (ULg)

Calibration of the Jungfraujoch FTIRs is performed according to NDACC recommendations, in order to characterize the instrument performance and stability. This is done by regularly recording HBr cell measurements. Also, N_2 (whose vertical distribution and concentration are well known) absorption features are further used to check the instrumental consistency, in particular for time periods for which regular cell measurements are unavailable.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

2.1. The Royal Meteorological Institute (RMI)

Research evolution of total atmospheric ozone and its distribution versus altitude at northern mid-latitudes, in particular above Belgium revealed a mean temporal decrease in ‘good’ ozone in the stratosphere and an increase in ‘bad’ ozone in the troposphere. With the help of model calculations it was shown that both changes are primarily of anthropogenic origin. Further observations in Uccle (Brussels) showed that observed levels of harmful UV-B irradiance at ground level anti-correlate with levels of stratospheric ozone. Initiatives have been taken to warn the general public about health risks resulting from excessive exposure to the sun in summertime.

The figure below shows the time evolution of the ozone column over Uccle based on the combined data of the Dobson (1971-1989) and the Brewer Instruments (1990-now). The ozone column decreased with 3% per decade in the period 1980-1997 and then there is possible sign of recovery afterwards, although the period is too short to draw firm conclusions. The ozone soundings have shown us that the decrease occurs in the lower stratosphere, especially during winter and early spring. In the troposphere, on the contrary, the ozone concentrations tend to increase due to photochemical reactions in polluted air.

The first ozone measurements at the Antarctic Station princess Elisabeth (January and February 2011) are reported to the WOUDC.

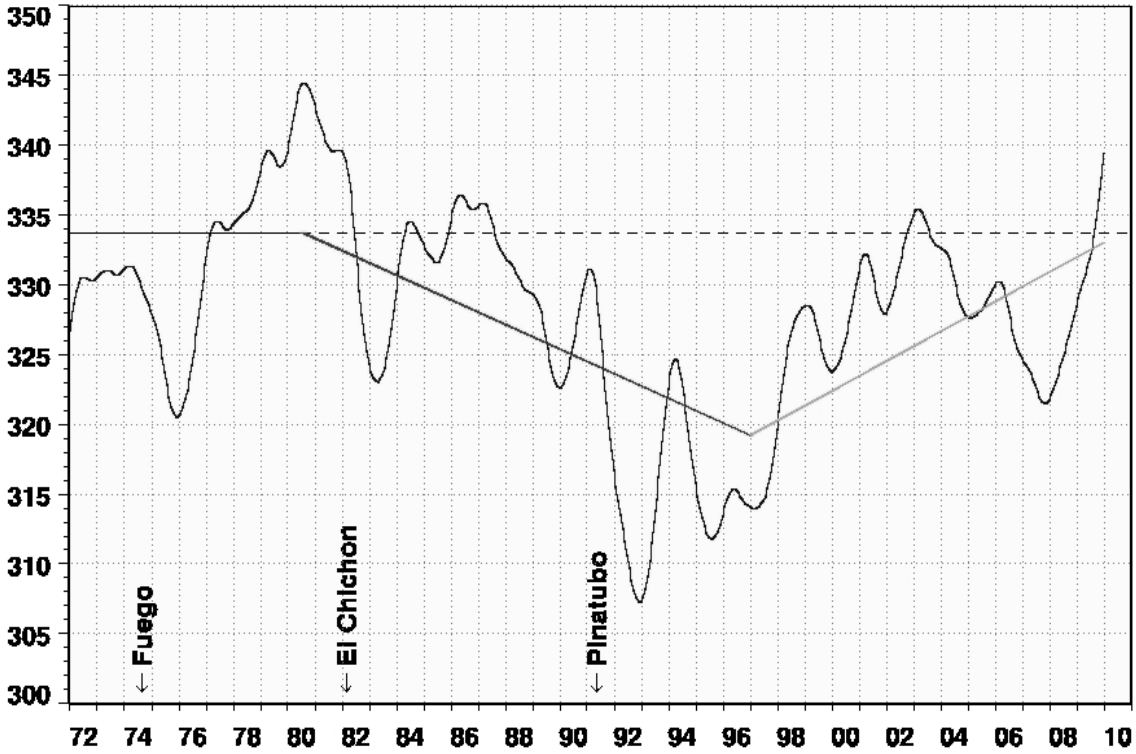

Figure 1: running annual mean of total ozone (in Dobson Units) from Dobson and Brewer spectrophotometers at Uccle, together with a stepwise regression. The times of major volcanic eruptions, affecting the ozone layer are also indicated.

2.2 University of Liège (ULg)

The Jungfraujoch FTIR observational data set from ULg now covers more than 25 years. It is the longest available worldwide and hence is particularly appropriate for trend determination investigations. We summarize here below a selection of relevant and recent results.

- Since the mid-1980s, ULg has maintained the consistent monitoring of the vertical column abundances of HCl and $ClONO_2$, which are the main inorganic Cl_y reservoirs in the stratosphere. Their sum shows that the rate of increase of Cl_y has progressively slowed down during the early-1990s, and stabilised in 1996-1997, in response to the amended production regulations on O_3-depleting substances by the Montreal Protocol. Since then, the Cl_y loading has shown a slow but statistically significant decrease (-0.93 ± 0.14 %/yr; 2σ) over the 1996-2009 time period, which is commensurate with the organic chlorine decrease in the troposphere when accounting for a mixing time of about 4 years.
- The check of the evolution of anthropogenic chlorine-bearing source gases such as CFC-11, CFC-12 and CCl_4 demonstrates the efficiency of the amended Montreal Protocol. Significant rates of decrease are determined for these three first source gases. In contrast, HCFC-22 whose (partial) regulation started later on is still on the rise (+4.22 ± 0.07 %/yr. over 2001-2010; 2σ).
- Recent trend values computed over the 1995-2010 time interval indicate a small but significant (at 2-σ) recovery of stratospheric ozone. This is true for the three stratospheric partial column time series accessible to the FTIR technique (altitude ranges from 10.6 to 17.8 km, 17.8 to 27.4 and 27.4 to 42.4 km). Trend derived from the total column data set amounts to (+0.12 ± 0.06) %/yr.
- A slowing down in the accumulation of the inorganic fluorine concentration in the stratosphere has been detected and characterized. At present, the observed evolution –in particular the

partitioning among the two major reservoirs, HF and COF_2– is not well simulated by model calculations.

- Measured rates of increase of the major radiatively active gases that are to be controlled under the Kyoto Protocol are: for CO_2, an average of 0.49 %/year over the 1984-2010 period; for CH_4, a series of contrasted changes, with in particular a trend of 0.36 %/yr in 1995-1999, 0%/yr in 2000-2004 and a re-increase since then (0.28 %/yr in 2005-2009); for N_2O, an average of 0.28%/year from 1984 to 2009; for SF_6, a substantial increase of still more than 6 %/yr over the last decade.

2.3 Université Libre de Bruxelles (ULB)

In the last years The ULB has been heavily involved in the monitoring of global ozone distributions using IASI, both in terms of columns and vertical profiles. Time series are available from 2008 onwards. The ozone products – columns and profiles – have first been analyzed and compared to other available means, showing good overall agreement, although some biases with UV measurement techniques remain (*Anton et al. 2011, Boynard et al. 2009, Keim et al. 2009*).

The O_3 have been supported by measurements of nitric acid, and the temporal evolution of both species in and outside vortex during Antarctic winter and spring have been carefully analyzed for the first time (*Wespes at al., 2009*). The results show HNO_3 to be a sensitive probe for the chemistry of the stratosphere. The ability of IASI to probe the polar stratosphere during night, combined to its excellent spatial resolution and sampling were shown to be of added value for future research.

The first trends of the Antarctic ozone hole have been obtained and the ability of IASI to capture the vertical structure of the ozone hole has been looked at (*Scannell et al., 2011*).

The ULB has contributed to quantifying the chlorine budget in the stratosphere in 2004 and through this to the WMO Scientific assessment on stratospheric ozone.

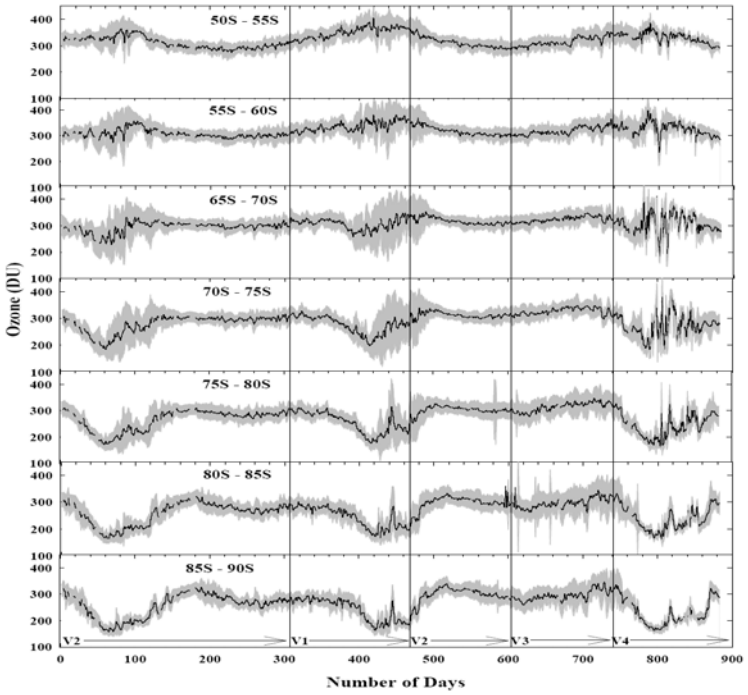

Figure 2: Time evolution of the total ozone concentration (in DU) measured by IASI on a daily basis at 5 degree latitude increments from 50°S to 90°S. The daily trend is shown as the black line; the shaded grey represents the standard deviation about the average. From (*Scannell et al., 2011*)

3. THEORY, MODELLING, AND OTHER RESEARCH

3.1. The Royal Meteorological Institute (RMI)

The Brewer data have been analysed for aerosol information in the UV. These AOD data at 320 nm are available now (*Cheymol and De Backer, 2003*). Special measurements with Brewer 178 (and

later also with Brewer 100 in Antarctica) were started to measure also the AOD at 340 nm (De Bock et al, 2010).

RMI is also partner in the BACCHUS project. The aim of the RMI contribution is to run the Canadian regional model for Chemical composition (including ozone) over Europe.

3.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

3.2.1 Modelling

- Complete 3D modelling of the stratosphere, including transport, chemistry, aerosol microphysics and a heterogeneous chemistry module
- Chemical 4D variational data assimilation, in particular of O_3
- 1D box model for process studies, and for interpretation of UV-Vis DOAS observations
- Studies based on 3D model IMAGES for the troposphere and UT/LS boundary region
- Development of inverse tropospheric modelling methods, to identify emissions (e.g., for CO)

3.2.2 Laboratory experiments

- Spectroscopic studies in support of remote sensing experiments (optical spectroscopy, ion chemistry for mass spectrometry applications…)
- Spectroscopic studies in support of investigations concerning global warming issues
- Radiometric calibration for UV monitoring instruments
- Studies of reaction pathways and kinetics of atmospheric species, using mass spectrometry.

3.2.3 Instrument developments

- MAXDOAS instruments and associated data analysis algorithms; The MAXDOAS technique has the capability of determining vertical distributions in the troposphere and low stratosphere.
- BARCOS: a system for remote-control and automatic operation of a Bruker FTIR spectrometer for monitoring the atmospheric composition (*Neefs et al., Rev. Sci. Instr., 2007*)
- Optimisation of the FTIR observations for achieving higher-quality measurements.

3.2.4 Retrieval algorithm developments

- Development of inversion algorithms (using the Optimal Estimation Method) for ground-based DOAS and FTIR remote sensing spectral data, for the retrieval of vertical distributions of the absorbing atmospheric constituents

Recently developed algorithms have implemented the Optimal Estimation Method, and therefore allow the retrieval of vertical profile information from the ground-based DOAS and FTIR spectra, at low vertical resolution (worse than 5 km), for e.g., NO_2, O_3, HNO_3, HCl, ... For the FTIR data this approach has been optimised for some target species in the EC project UFTIR coordinated by BIRA-IASB. Recently Tikhonov regularisation and Information Operator Approach have been implemented as alternative inversion algorithms for FTIR measurements; in some cases, these approaches improve the robustness of the retrievals.

3.2.5 Satellite data retrievals

- Development, validation and implementation of satellite data retrieval algorithms (e.g., for GOME, SCIAMACHY and GOME-2 total O_3, NO_2, BrO, SO_2….; e.g., aerosol and trace gases from GOMOS); data processing and dissemination

- Development of retrieval algorithms for IASI/Metop for aerosol and gases.

3.2.6 Satellite data validation and characterisation

- Continued contributions to the validation of satellite data for O_3, NO_y, CH_4, CO, N_2O… (GOME, SCIAMACHY, GOMOS, MIPAS, ACE/SciSat …) using independent ground-based data, mostly NDACC affiliated. This activity will be continued for OMI, GOME-2, IASI, …
- Characterisation of the 4D information content of various satellite data, on the purpose of (1) integrating time series form successive satellite sensors (e.g., for O_3 total column and profile), remote sensing and in situ data from various platforms (ground, balloon, aircraft, satellite,..) and, (2), developing observation operators for correct integration/comparison of satellite data with models.
- Development of climatologies of some stratospheric species like BrO and NO_2

3.2.7 Trend studies

- BIRA-IASB studied trends of stratospheric BrO at several NDACC stations and verified the consistency with the observed trends from SCIAMACHY. BrO is decreasing since 2001 at a rate of about -1%/year *(Hendrick et al., 2008 and 2009)*
- BIRA-IASB studies trends of O_3 above Europe in various layers in the atmosphere, based on FTIR observations *(Vigouroux, C. et al., 2008)*. An updated trend analysis up to end of 2009 will be published in the upcoming WMO Scientific Assessment of Ozone Depletion: 2010.
- BIRA-IASB has contributed with HCl and HF measurements at La Réunion to a study of the inorganic chlorine and fluorine trends on a global scale, involving all NDACC Infrared Working Group members. This study has been led by the Karlsruhe Institute of Technology (KIT), in the frame of the EU project GEOmon. It compares observed trends with model simulations, and will be published in the course of 2011. Its major findings are also included in the WMO Scientific Assessment of Ozone Depletion 2010.
- In support to the SPARC/IO3C/WMO-IGACO initiative on long-term trend studies of the vertical distribution of ozone, BIRA-IASB investigates the multi-mission consistency and potential drifts of about ten satellite ozone profilers having provided, all together, ozone profile data records from 1984 to 2010. The study is based on the integrated use of GAW-contributing (WOUDC, NDACC, SHADOZ) ground-based network data as a reference.

3.3 University of Liège (ULg)

Most of the research activities reported in the previous Ozone Research Managers Report (2002, 2005) are continuing.

3.3.1 Satellite data validation and characterisation

ULg has been involved in numerous satellite validation studies over recent years (e.g. SCIAMACHY, MIPAS, and MOPITT). In particular, ULg has been strongly involved in the calibration/validation of ACE data products (O_3, N_2O…), leading the validation for HCl, HF, CCl_2F_2 and CCl_3F.

3.3.2 Instrument developments

Since more than two years, a remote control system has been in control of the Jungfraujoch Bruker instrument, allowing to complement the observations performed locally and to maximize the observation time. The system is perfectly working despite the challenging harsh meteorological

conditions encountered at the Jungfraujoch; it has already undergone numerous evolutions to improve reliability and determination of the instrument status.

In parallel, we have been developing a new acquisition system that, along with total integration inside the remote control system, will provide improved signal to noise ratio and instrument throughput as well as the capacity to implement new digital processing methods, leading to enhanced spectrum quality, improved line shape and therefore better vertical distribution determinations.

3.3.3 Trend studies

Numerous relevant long-term trend studies have been performed over the period under review here, on the basis of Jungfraujoch ground-based data (see e.g. section 2.2) or using satellite products (inorganic chlorine and fluorine, organic chlorine and fluorine, source gases relevant to ozone (N_2O, CH_4)…

3.4 Université Libre de Bruxelles (ULB)

3.4.1 Laboratory experiments

The "Service de Chimie Quantique et Photophysique" has a worldwide established expertise in the measurement of accurate absorption line parameters (positions, intensities and widths) for atmospheric trace gases in the infrared (far-, mid- and near-) and visible ranges, using high-resolution Fourier transform spectroscopy. Analysis of spectra is carried out using software written in the laboratory. As highlighted by the list of relevant scientific publications, species as diverse as C_2H_2, C_2H_4, C_2H_6, HCOOH, $^{13}C^{16}O_2$, N_2O, OCS and several isotopologues of water vapor have been studied since 2005. Most of these activities support investigations of the terrestrial atmosphere. In particular, we showed that absorption line intensities available for HCOOH in HITRAN before 2008 were a factor of about 2 too low (*Perrin and Vander Auwera, 2007, and Zander et al, 2010*).

3.4.2 Retrieval algorithm developments

Building on their expertise in fundamental spectroscopy, the group has acquired a leading position for the atmospheric radiative transfer modelling in the thermal infrared and also for the development of atmospheric trace gases retrieval methods. It owns and maintains sophisticated algorithms, for research and operational applications in atmospheric chemistry and physics. They include

- The *Atmosphit* line-by-line radiative transfer model, which allows simulation of spectra recorded under various geometries and/or with different instruments. Accurate and versatile, it has been used in most studies prior to IASI launch, and for IASI local analyses. Recently the group has started modelling the radiative transfer for atmospheric aerosols, with an advanced doubling-adding method to account for multiple scattering. The module was coupled to *Atmosphit*, allowing simultaneous retrieval of gas and aerosol properties (Clarisse et al. 2010a, 2010b).
- The *FORLI* series of software specific to IASI. These rely on fast radiative transfer calculations using look-up-table (LUT) approaches. The LUT compile absorbance spectra, pre-calculated on a given spectral range and on well-defined temperature/pressure/humidity grids. *FORLI* versions are currently in place for O_3, HNO_3 of particular for stratospheric sounding, and in addition NH_3 and CO. The *FORLI* series allow NRT processing of the huge IASI data flow to provide global distribution of concentrations twice daily.
- Radiance indexing schemes for IASI, which are used to track a reactive species, among which SO_2, CH_3OH, HCOOH, and aerosols, including volcanic ash

3.4.3 Satellite data retrievals

- Development, upgrade and maintenance of a NRT IASI processing chain. Processing starts with the receiving of the calibrated L1C radiances from Eumetcast, which are transformed in suitable format and quality-flagged using available ancillary information (e.g. cloud coverage). The retrievals are performed on a cluster of PCs, which currently has 190 CPU's and 24TB of storage capabilities. Retrieved products from *FORLI* include O_3, HNO_3, CO and NH_3 profiles on the global scale (cloud-free data).
- Local retrievals of trace gases and aerosols using the line-by-line *Atmosphit* software.

3.4.4 Satellite data validation and characterisation

- Contribution to the validation activities of IASI and ACE-FTS chemistry products, in particular CO and O_3 but also (ongoing) NH_3, HNO_3, CH_3OH.
- Continued cross-comparisons between satellites, in particular CO and O_3

3.4.5 Trend studies

- First time series from IASI have been obtained for polar ozone (*Scannel et al. 2011*). Seasonnal and interannual variabilities of the HNO_3/O_3 ratio have been analyzed (*Wespes at al. 2009*). Trends of CO are monitored.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

4.1.1. The Royal Meteorological Institute (RMI)

The ozone data (columns and profiles) are regularly deposited in the WOUDC of WMO. Uccle is also affiliated to NDACC. Therefore the data are also made available in that network. In near real time the data are also distributed via NILU, where the data can be used for campaigns (e.g. Match campaigns to determine ozone losses in the polar and sub polar winter atmosphere, see *Streibel et al, 2005*). The data are also stored and used in databases for the validation of satellite data (ENVISAT and EUMETSAT). Total ozone values are exchanged daily with the WMO ozone mapping centres in Canada and Greece for the production of daily ozone maps.

4.1.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

Data are submitted on a regular basis to the NDACC database hosted at NOAA.

Major results are included in the WMO Scientific Assessment of Ozone Depletion: 2010.

4.1.3 University of Liège (ULg)

Time series of NDACC-relevant molecules (e.g., HCl, $ClONO_2$, HF, COF_2, HNO_3, NO_2, NO, O_3, CFC-12, HCFC-22) from 1989 onwards are being archived routinely at the NOAA Data Host Facility (Washington, DC, USA), with the ozone data mirrored to the WOUDC archive in Toronto. Pre-1989 data are available upon request. Transition to hdf file archives is in progress.

In addition, important results deduced from Jungfraujoch observations have been included in successive editions of the scientific assessment of ozone depletion (UNEP/WMO), with ULg scientists involved as co-author or contributors in all recent volumes.

4.1.4 Université Libre de Bruxelles (ULB)

IASI CO distributions of profiles are distributed in NRT to ECMWF in the frame of GMES atmosphere service MACC (http://www.gmes-atmosphere.eu/). The data are also archived at the

French ETHER datacenter (http://ether.ipsl.jussieu.fr) and available upon request. O_3 distributions have been distributed for preliminary validation to a series of research groups. They are now similarly available upon request. Future operational dissemination of the IASI CO, O_3, HNO_3 and SO_2 products from IASI will occur within the O3SAF, in the 2012-2015 timeframe (data to processed at EUMETSAT-CAF and disseminated through EUMETCAST system).

Spectroscopic information obtained by the "Service de Chimie Quantique et Photophysique" is disseminated through various channels:

- the HITRAN (HIgh-resolution TRANsmission molecular absorption, http://www.cfa.harvard.edu/HITRAN/) and GEISA (Gestion et Etude des Informations Spectroscopiques Atmosphériques, http://ether.ipsl.jussieu.fr) databases. The laboratory is a significant contributor to these databases.
- as supplementary data of publications, maintained by the editors of journals.
- the web site of the laboratory (http://www.ulb.ac.be/cpm/).
- laboratory data obtained for water vapour and its isotopologues are included in the MARVEL database (International Union of Pure and Applied Chemistry IUPAC project; http://chaos.chem.elte.hu/marvel/).

4.2 Information to the public

4.2.1. The Royal Meteorological Institute (RMI)

Daily UV forecasts are produced and disseminated with the weather forecasts. They are also available at the internet (www.meteo.be).

Ozone and UV data of Uccle were also used in yearly reports on the environment (successive MIRA reports).

4.2.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

See http://www.aeronomie.be/uv/globaluv/index.php

4.3 Relevant scientific papers

4.3.1 The Royal Meteorological Institute (RMI)

Papers since 2005 (after those included in the previous report) are mentioned. Authors affiliated to RMI are in bold.

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5. PROJECTS AND COLLABORATION

5.1 Participation in national and international other collaborations projects

5.1.1 The Royal Meteorological Institute (RMI)

- Belgian federal research programme Scientific Support for Sustainable Development: AGACC and AGACC-II: Advanced exploitation of ground based measurements for atmospheric chemistry and climate applications (http://www.oma.be/AGACC/Home.html) (2006-2010 and 2011-2014)
- COST action 726 on Long term changes and climatology of UV radiation over Europe (2004-2009).
- COST Action ES0604 on Water Vapor and climate (WAVACS)
- Action 1 Belgian federal science policy (2005-2006): Aerosol optical thickness deduced from ground solar radiation measurements.
- 6th Framework Programme of the European Commission: GEMS - Aerosol subproject (2005-2009)
- Satellite validation projects of ESA and Eumetsat.
- Prodex Project Bacchus (2010-2013)
- Belgian federal science policy: Belatmos project for monitoring of atmospheric composition at the Belgian Antarctic Base (2008-2012)
- Solar Terrestrial centre of Excellence (recurrent support of the ozone research programme)
- Participation in the validation team of the Ozone monitoring SAF of EUMETSAT

5.1.2. The Belgian Institute for Space Aeronomy (BIRA-IASB)

- Belgian federal research programme Scientific Support for Sustainable Development: Projects AGACC and AGACC-II: Advanced exploitation of Ground-based measurements for Atmospheric Chemistry and Climate applications (as coordinator) (http://www.oma.be/AGACC/Home.html) (2006-2010; 2011- March 2015).
- IPCC assessments, WMO Stratospheric Ozone assessments and SPARC Vertical Ozone Trend assessments
- 6th Framework Programme of the European Commission: GEOmon, ACCENT (and its subproject AT2)
- 7th Framework Programme of the European Commission MACC, PASODOBLE, SHIVA
- 'Chemistry and climate related studies using the IASI remote sensor' for preparing the scientific research aspects of the IASI mission onboard METOP-1
- ESA GMES Service Element project PROMOTE (http://www.gse-promote.org)
- ESA CHEOPS-GOME, CHEOPS-SCIA, Multi-TASTE, CEOS Campaigns
- ESA Climate Change Initiative Ozone_cci (http://www.esa-ozone-cci.org/)
- ESA study 'Capacity' (http://www.knmi.nl/capacity/) and CAMELOT
- ESA's Envisat Atmospheric Chemistry Validation Team, ESA's Quality Working Groups
- Involved in a dozen science and processing teams of satellite missions, e.g. SCIAMACHY SSAG, SCIAVALIG, and SADDU
- Atmospheric Composition, Chemistry and Climate (A3C), PRODEX contract (2011-2013).

5.1.3 University of Liège (ULg)

- Atmospheric Composition, Chemistry and Climate (A3C), PRODEX contract.
- Projet ESA-Multi-TASTE (Technical assistance to Multi-mission Validation by Sounders, Spectrometers and Radiometers)
- Contract FNRS FRFC (Observations and study of the variability and evolution of the free atmosphere from the Jungfraujoch International Scientific Station)
- Project: GAW-CH (FTIR measurements at the Jungfraujoch 2010-2013)
- Project: EC- GEOMON (Global Earth Observation and Monitoring)

5.1.4. Université Libre de Bruxelles (ULB)

- Belgian federal research programme Scientific Support for Sustainable Development: Projects AGACC and AGACC-II: Advanced exploitation of Ground-based measurements for Atmospheric Chemistry and Climate applications (http://www.oma.be/AGACC/Home.html) (2006 – 2010; December 2010 – March 2015).
- Atmospheric Composition, Chemistry and Climate (A3C), PRODEX contract (2011-2013).
- ESA CAMELOT study for preparation of Sentinel4 and Sentinel5
- FRS-FNRS "Mandat d'Impulsion Scientifique", 2007-2010.
- 6th Framework Programme of the European Commission: Quantitative Spectroscopy for Atmospheric and Astrophysical Research (QUASAAR, 2005-2009).
- Fonds de la Recherche Fondamentale Collective (FNRS, Belgium): Measurements of CO_2 pressure broadening parameters for molecular trace constituents of the Venus atmosphere (2008-2011).

- Programme Hubert Curien (Belgium-France collaboration): Precise modeling of the low energy infrared spectrum of ethylene for applications to planetary atmospheres (2009-2010).
- Fonds de la Recherche Fondamentale Collective (FNRS, Belgium): Diode laser and Fourier transform spectroscopy: Contribution of the Belgian groups to the "Laboratoire Européen Associé (LEA)" HiRes (2009-2012).

5.2 Representation in international organisations

5.2.1 The Royal Meteorological Institute (RMI)

- EUMETSAT Scientific and Technical Group, Policy Advisory Committee and Council
- Domain Committee ESSEM van COST (http://w3.cost.esf.org/index.php?id=269).
- Brewer sub-committee of WMO-GAW
- EUMETSAT Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (Steering Group member)

5.2.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

- International Ozone Commission (IO3C) of the IAMAS-IUGG
- WMO GAW NDACC Steering Committee (co-chairman of UV-VIs, IR and Satellite Working Groups)
- WMO GAW UV-SAG
- SPARC/WCRP
- Committee on Earth Observation Satellites (CEOS)
- SAG of GOME and GOME-2, GOMOS, SCIAMACHY, OMI
- Atmospheric Science Panel (European Commission)
- ESA Council, EUMETSAT Council
- International Committee on Space Research (COSPAR)
- Member of the Science Team of the Canadian ACE/SciSAT mission, of the EOS-Aura OMI International Science Team…
- EUMETSAT Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring

5.2.3 University of Liège (ULg)

- ACE science team
- ISSJG (International Scientific Station Jungfraujoch and Gornergrat) Astronomic Commission
- NDACC steering committee
- NDAC-Infrared working group
- PI contribution to Task Group 3 of ACCENT-TROPOSAT 2 (strategies for the validation of tropospheric products from satellites)

5.2.4 Université Libre de Bruxelles (ULB)

- Member of the Scientific committee of the "IASI Conference" series
- Member of the IASI Sounder Science Working Group–II
- Member of the ACE Science Team

- Member of ACCENT and coordinator of AT2 activities (2009-)
- International Advisory Committee of the HITRAN (HIgh-resolution TRANsmission molecular absorption, http://www.cfa.harvard.edu/HITRAN/) database.

6. FUTURE PLANS

6.1 The Royal Meteorological Institute (RMI)

- Continuation of the observations at Uccle (ozone column, ozone profile, Spectral UVB, aerosol) and at the Antarctic station (Ozone column, Spectral UVB and aerosol).
- Installation of a Ceilometer LIDAR in Uccle to monitor the aerosol backscatter in the troposphere.
- Analysis of the data obtained at the Belgian Antarctic station.
- Participation in the validation and quality assurance of satellite observations (O_3MSAF CDOP-2 of EUMETSAT and Ozone CCI of ESA).
- A thorough re-evaluation of ozone trends from the balloon ozone profile measurements, using several statistical techniques, is planned in the near future.

6.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

There are firm plans to install a MAXDOAS instrument and a CIMEL instrument in Bujumbura, Africa, in 2012, for the measurement of ozone-related species, pollutants and aerosol optical depth.

6.3 University of Liège (ULg)

The ULg group has accumulated a solid experience in the high resolution FTIR spectroscopy under high altitude harsh climatic conditions, including remote control operation. Based on this experience, in agreement with our long term development plans and fully in accordance the recommendations in the 7th Ozone Research Managers Meeting, ULg has initiated the necessary contacts, authorization requests and technical preparation to apply a funding proposal to install a remote controlled FTIR facility on the Atacama plateau (about 5100m alt), probably on the ESO APEX or ALMA premises. This location is ideal to characterize the composition of tropical air masses above South America, being a very dry site, free of air and electromagnetic pollution and providing abundant clear sky conditions. The local topology of the site is also ideal for satellite data validation and calibration of an otherwise FTIR uncovered area. It is also accessible for heavy equipment transportation. Of course, our plans include the continuation of the NDACC observations at the Jungfraujoch station and the application of the new acquisition system to all of our instruments

6.4 Université Libre de Bruxelles (ULB)

The ULB group will maintain its research activities around laboratory rotation-vibration spectroscopy and atmospheric remote sensing. On the remote sensing side, IASI-related activities will be strengthened. The NRT FORLI processing chain will be upgraded and is planned to be implemented shortly at the EUMETSAT CAF (Central Application Facility) for wider dissemination of the L2 products to the community. This should be done within the O3M-SAF. Dedicated researches in relation to polar stratospheric chemistry are ongoing. ACE-FTS measurements will be exploited whenever relevant. On the medium term, the group will also be involved in MTG.

6.5 Princess Elisabeth Research Station

At the occasion of the International Polar Year 2007, the Belgian government decided to build a new scientific summer station at Utsteinen, East Antarctica and committed the International Polar Foundation to design and build this new base.

A Brewer ozone spectrophotometer was installed mid-January 2011and was able to measure until 14 February 2011. It measured the total column amount of ozone and the UV radiation in the UV-A and UV-B bands. It was successfully set up for the first time. It was mounted on the northern roof of the station. It needs sun and regular maintenance for operation and was therefore de-installed at the end of the season. First analyses of the data show that it made very good and interesting measurements of total ozone and the UV index at Utsteinen.

7. NEEDS AND RECOMMENDATIONS

Needs to secure financial support for laboratory spectroscopic activities supporting investigations of the terrestrial atmosphere.

8. HOW RECOMMENDATIONS OF THE 7TH MEETING OF THE OZONE RESEARCH MANAGERS OF THE PARTIES TO THE VIENNA CONVENTION FOR THE PROTECTION OF THE OZONE LAYER (GENEVA, 18 - 21 MAY 2008) FROM P. 27-32) ARE TAKEN INTO ACCOUNT

8.1 Research Needs

8.1.1 The Royal Meteorological Institute (RMI)

In response to “Further research is needed on the response of ground-level UV to changes in ozone and other atmospheric parameters in response to changes in ODSs, air quality, and climate-forcings.” (p 27, *WMO TD No. 51*):

- RMI participated in the COST action 726 which prepared a UV reconstructed data set (starting from 1950) over Europe.
- At RMI a study on the different contributions to the variations in UV intensities reaching the ground was made (see *De Backer, 2009*)

In response to “Coupled chemistry-climate models (CCMs) are becoming more mature, but it is clear that more effort must be devoted to model development and validation, including through international programmes” (p 27, *WMO TD No. 51*):

- At RMI a coupling between the chemical transport model CHIMERE and the numerical weather prediction model (Alladin) was performed.
- Within the BACCHUS project RMI works on the adaptation of the Canadian coupled transport/chemical GEMBACH model to Europe.

8.2 Systematic Observations

8.2.1 The Royal Meteorological Institute (RMI)

In response to “Balloon sonde networks provide critical observations which give vital high resolution vertical profiles of ozone and water vapour that are needed for multiple scientific activities in ozone research and therefore need to be maintained and increased.” ” (p 27, *WMO TD No. 51*):

- The observing program of total ozone (with two Brewers at Uccle) and ozone profiles (3 times a week ozone soundings) at Uccle is continued.
- A Brewer instrument was installed in Antarctica
- The water vapour profiles from the radio sondes at Uccle (RMI) were corrected for known errors with algorithms found in literature.

- To maintain the data quality the Brewer instruments were calibrated several times at RMI**.**

8.2.2. The Belgian Institute for Space Aeronomy (BIRA-IASB)

- The work on GOME/SCIAMACHY/OMI/GOME-2 mentioned under 1.1.2 is a response to the requirement resulting from the 7th ORM Meeting in 2008 (p.30 *WMO TD No. 51*): Continuation of the solar backscatter UV observations must be ensured as they constitute a key baseline set of measurements
- National development of ALTIUS, a limb viewing satellite instrument responding to the requirements resulting from the 7th ORM Meeting in 2008 (p 30, *WMO TD No. 51*): "Satellite observations of high vertical resolution profiles using limb viewing for O_3 and key molecules are required in order to more accurately understand the changes in O_3 as CFCs decline and climate change occurs."

8.2.3 University of Liège (ULg)

In accordance with the specific recommendation "*Priority to be given to the tropics, Central Asia, and southern mid-latitudes for filling data gaps in geographic coverage. We should consider the redistribution of observation sites from areas highly populated with instruments to those areas that are poorly populated. This requires infrastructure support in these areas*." (p. 29 *WMO TD No. 51*), ULg has initiated the necessary contacts, authorization requests and technical preparation to apply a funding proposal to install a remote controlled FTIR facility on the Atacama plateau (about 5100m alt), probably on the ESO APEX or ALMA premises.

8.3 Spectroscopic standards

8.3.1 Université Libre de Bruxelles (ULB)

In response to "Data archives should include documentation of the spectroscopic parameters used for the analysis of the data" (p. 30, *WMO TD No. 51*):

- The HITRAN and GEISA databases provided spectroscopic information documented in a standardized way.
- One of the tasks of the "International Advisory Committee" of the HITRAN database is to assess the quality of spectroscopic information reported in the literature, and to evaluate its possible inclusion into the database.

8.4 Data Archiving

8.4.1 The Royal Meteorological Institute (RMI)

In response to "Urge all data centres to develop procedures for the prompt submission of their ozone, UV, and ancillary ozone- and climate-related data to the World Ozone and Ultraviolet Data Centre (WOUDC). Data archiving must include detailed metadata that describe the quality of the measurement and the instrument history. "(p 29, *WMO TD No. 51*):

- Besides the local archiving of the data at RMI the data are also stored in WOUDC and NDACC databases.

8.5 Capacity Building

8.5.1 The Royal Meteorological Institute (RMI)

In response to"Unused Dobson instruments are a more economical way to expand these networks and to introduce observations into new sites or programmes." (p 29*, WMO TD No. 51*): and "Support and encourage regional and bilateral cooperation and collaboration (twinning) among developed and developing countries and to extend global expertise in ozone and UV measurements and research. Several twinning collaborations are already on-going through in-kind contributions. Successful existing twinning collaborations should be identified and expanded with additional funds:

- The unused Dobson instrument is loaned to Ukraine.

- The instrument was refurbished with the support of the regional Dobson Calibration centre in Germany and the operators were trained through collaboration with the Czech Hydro Meteorological Institute.

9. CO-ORDINATES OF BELGIAN INSTITUTES AND LEADING SCIENTISTS INVOLVED IN O_3 RELATED RESEARCH AND OBSERVATIONS

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Dr. Alexander Mangold (Measurements on the Princess Elisabeth Station Antarctica)

Dr. Roeland Van Malderen (Analysis of ozone time series)

Dr. ir. Andy Delcloo (Validation of satellite ozone data, Member of project team of O3M SAF of EUMETSAT)

Ms. Veerle De Bock (Retrieval of aerosol optical parameters from Brewer observations)

Dr. Joris Van Bever (Modelling of chemical composition of the atmosphere within Bacchus)

Dr. Steven Dewitte (Head of department, member of Council of EUMETSAT)

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Dr. M. De Mazière (Satellite and ground-based remote sensing measurements of the composition of the atmosphere, especially with infrared spectrometric techniques, implementation and testing of retrieval algorithms to invert observations into geophysical data, remote-sensing instrument developments, data validation)

Dr. J.-C. Lambert (Member of the International Ozone Commission, satellite and ground-based remote sensing of the composition of the atmosphere, synergistic exploitation of atmospheric composition data, data quality strategy, multi-mission satellite validation)

Dr. M. Van Roozendael (Satellite and ground-based remote sensing measurements of the composition of the atmosphere, implementation and testing of retrieval algorithms to invert observations into geophysical data, remote-sensing instrument developments, data validation)

Dr. Q. Errera (stratospheric modeling, chemical data assimilation, reanalysis of long-term data records)

Dr. S. Chabrillat (stratospheric modeling, chemical data assimilation, chemical weather)

Dr. J.-F. Muller (Global tropospheric ozone modelling, inverse source/sink modelling)

Dr. D. Gillotay (Ground- and space-based measurements of solar radiation: UV-B)

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