

## BELARUS

A number of significant amendments to the Law of the Belarus Republic for Ozone Layer Protection, adopted in 2001, were introduced by the National Assembly of Belarus in October 2004. Ozone monitoring was determined as a part of National Environmental Monitoring System (NEMS). A plan for the development of the Atmosphere Ozone Monitoring subsystem up to 2010 has been prepared. Decision of Belarus Government N 949 dated the July, 14 2003 pronounced the Ministry of Education responsible for ozone monitoring in Belarus.

### OBSERVATIONAL ACTIVITIES

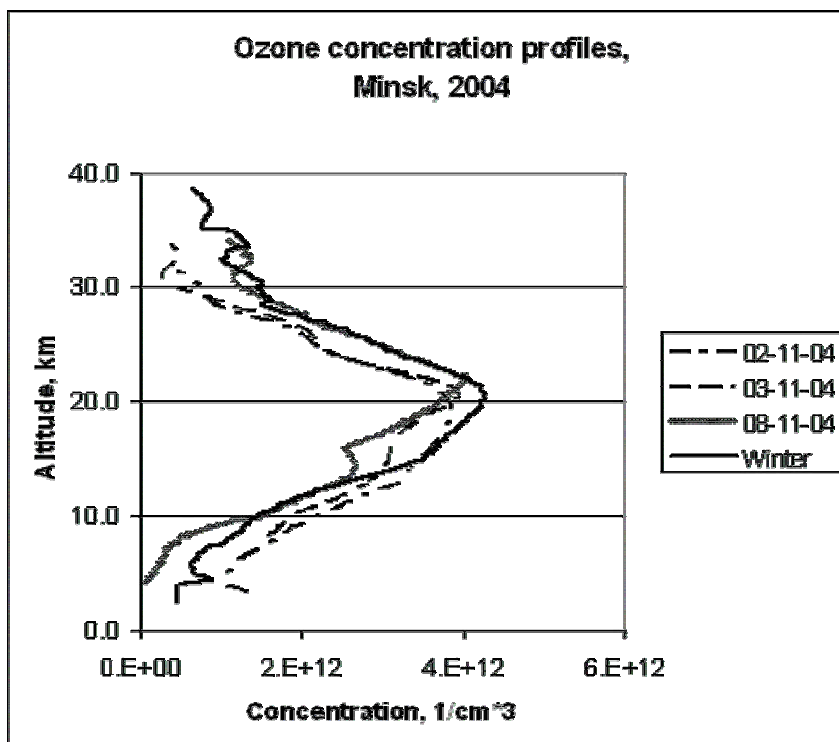
In accordance with decisions of the Sixth Meeting of the Conference of the Parties to the Vienna Convention, Belarus has continued to construct instruments and develop monitoring, calibration and archiving of stratospheric and tropospheric ozone, aerosols, and surface UV radiation data.

#### Column measurements of ozone

Total ozone measurements are carried out at an Ozonometric station (WOUDC identification N 354) located in Minsk at the National Ozone Monitoring Research & Education Center (NOMREC). The Station coordinates are (53.833N, 27.469E). The daily measurements are implemented with the ultraviolet multi-wavelength spectrometer-ozonometer PION. The total ozone amounts are also retrieved via intensity ratios of pairs of wavelengths using Stamnes tables from the observation of horizontal UV irradiance measured with spectroradiometer PION-UV. The both instruments constructed at the Belarus State University.

#### Profile measurements of ozone and aerosols

Profile monitoring of ozone concentrations and stratospheric aerosol executes by means of Dial lidar with working wavelength 308 and 355 nm up to 35-40 km. Routine measurements are carrying out three times per month on average at the Institute of Physics of National Academy of Sciences (IPNAS), Minsk (see Figure 1).



**Figure 1: Ozone concentration profiles during negative ozone anomalies in 2004, winter period. Solid line - Middle profile for winter period.**

## UV measurements

Regular measurements of irradiance in the spectral range 285-450 nm are carried out at the Ozonometric station (NOMREC, Minsk) with the portable UV spectroradiometer PION-UV since September 2001. The automated instrument PION-UV registers more than a hundred global/diffuse UV spectra per day. Simultaneously controlling programme calculates UV-index and daily doses of biological effects.

## Calibration activities

Spectrometer-ozonometer PION was inter-compared with a WMO regional standard (Dobson N 108 spectrometer) in St.-Petersburg (Russia, August 2001). NOMREC consistently develops and successfully introduces in practice a concept of self-calibration of the net ozonometers. This means carrying out all available calibration procedures mainly on the base of results of measurements and testing made during operation cycle of the instrument and excluding any laboratory testing and inter-comparisons. Now following procedures are available:

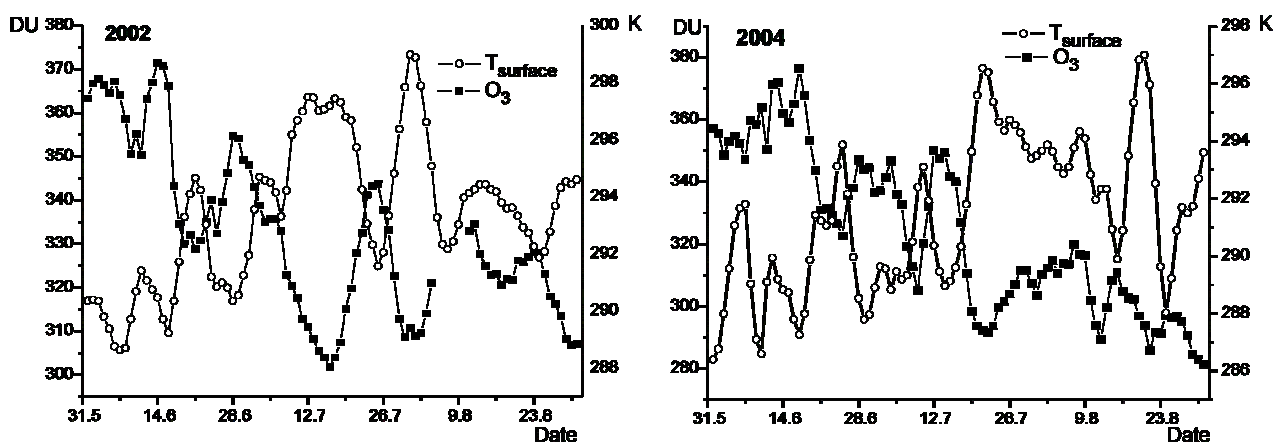
- testing and correction of the extraterrestrial parameters for total ozone calculation by analysis of the diurnal total ozone trends;
- testing and correction of the wavelength setting;
- Langley absolute calibration of the spectrometer.

Calibration testing of the current instrument's parameters is performed in NOMREC using special calibration bench with band-lamp certified by Russian National Standard Agency in spectral range 285 – 1200 nm.

## RESULTS FROM OBSERVATIONS AND ANALYSIS

The annual average total ozone value above Belarus in 2004 was lowest for all period of ground-based observations (1997-2004). In the second half of 2004 from middle of July till December the total ozone deficit above Belarus territory was about 5%. In the first half of 2005 the total ozone deficit above Belarus has increased up to 7%. Occurrence of the «mini-hole» has been observed in unusual for Belarus period of time – beginning of September and the end of May.

The analysis of surface air temperature and total ozone data has shown that the daily total ozone and surface air temperature values are correlated (for summer in Belarus, see Figure 2). This interconnection has been taken into account in the UV index forecast technique.



*Figure 2: Daily values of surface air temperature and total ozone (smoothed by 4 point moving average).*

## **THEORY, MODELLING, AND OTHER RESEARCH**

An improved multi-wave variant of algorithm on vertical ozone profile retrieval from Umkehr measurements has been developed to update the ozonometer PION controlling programme.

A theoretical method to improve the technique of “direct-sun” Aerosol Optical Depth measuring in the UV spectral range has been proposed.

The Langley-procedure accuracy for “direct-sun” UV devices has been estimated and a method to avoid the clouds disturbance has been implemented.

Epidemic studies carried out in collaboration of NOMREC and Belarus Sanitary & Hygiene Research Institute (BSHRI) have demonstrated that the incidence of skin cancer in Belarus has been increasing rapidly over the last 10 years. Incidence of melanoma in 1993 was 3,0 per 100000 and increased to 4,56 in 2002, incidence basal cell carcinoma (BCC) increased from 19,96 to 35,57, and squamous cell carcinoma of skin (SCC) from 4,29 to 8,45.

## **DISSEMINATION OF RESULTS**

### **Data reporting**

The total ozone data are submitted to the World (Canada) and CIS (Russia) data centers. UV monitoring was carried out from September 2001 with the PION-UV spectroradiometer. But some calibration problems prevented us to put our surface UV spectra at WMO’s disposal. In 2005 year the spectroradiometer PION-UV was recalibrated using the new Russian National UV Source Standard. Now results obtained are recalculating and soon NOMREC will be ready to send data to WOUDC and other centers regularly (in real time mode if necessary).

### **Information to the public**

Short-term UV index forecast (both for cases of clear sky and with forecasted cloudiness taken into account) are daily submitted to Belarus Telegraph Agency and to national daily newspaper “Zvyazda” (about 50 000 numbers daily).

Also these values are presented at NOMREC Internet site <http://www.nomrec.bsu.by>.

## **PROJECTS AND COLLABORATION**

There are 6 federally funded national projects on ozone, UV radiation and tropospheric ozone. These projects are coordinated by NOMREC. Main topics are:

- Ozone mini-holes dynamics and climate parameters.
- Stratospheric and surface ozone interaction.
- DOAS instruments development.
- Stratospheric ozone and aerosols lidars.
- UV radiation level and human health.

Ozone and aerosols investigations are carried out in collaboration with Lidar Station of IPNAS. Lidar investigations of ozone layer are implemented in the frame of CIS-LiNet (lidar network in CIS countries) activity.

## **FUTURE PLANS**

Five new UV irradiance monitoring stations will be put into operation next 5 years.

New zenith observation instrument is developed for nitrogen dioxide total amount and profile retrieval in NDSC standard. It will be put into operation on NOMREC Ozonometric station aiming to be included into NDSC.

Developed theoretical models, software, and optical tool kit allow us to participate in international projects on validation of satellite spectral measurements and ozone/aerosol retrieval algorithms.

Planned activity on the atmospheric aerosol investigation includes theoretical modeling and realization of Sun-Aureole UV experiments aiming the aerosol micro-characteristics retrieval.

UV index mapping and differential forecast will be introduced in 2006.

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# BELGIUM<sup>1</sup>

## OBSERVATIONAL ACTIVITIES

The main research institutes that are currently involved in ozone/UV and ozone related observations include: the Royal Meteorological Institute (KMI-IRM), the Belgian Institute for Space Aeronomy (BIRA-IASB) and the Université de Liège (ULg) - Institute of Astrophysics and Geophysics. The Université Libre de Bruxelles (ULB, Laboratoire de Chimie Physique Moléculaire) is providing the laboratory support for analysing spectra.

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

#### *The Royal Meteorological Institute (KMI-IRM)*

Continuation of regular ozone column measurements with two automated Brewer spectrophotometers (Nrs 16, 178) and one Dobson instrument (Nr 40) is a single monochromator, in use since 1983 and the other one (Nr 178) is a double monochromator installed in 2001. All these instruments are operated at Uccle (50.8°N, 43.5°E, 100 m asl), a complementary NDSC station and station 053 in the WOUDC list.

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

#### *University of Liège (ULg)*

Continuation of infrared solar observations at the International Scientific Station of the Jungfraujoch (ISSJ - Primary Alpine NDSC Station in the Swiss Alps 46.5°N, 8.0°E, 3580 m asl)<sup>2</sup> using wide-band pass, very high spectral resolution Fourier transform Infra-Red (FTIR) instruments, which allow measuring multiple species, simultaneously. Geophysical parameters consist in total- and more recently- in distinct partial tropospheric and stratospheric column abundances above the site. Table 1 lists the atmospheric gases which have been studied routinely at the Jungfraujoch.

**Table 1: Molecules currently studied in FTIR solar spectra recorded at the Jungfraujoch**<sup>3</sup>

Reference gas:	N <sub>2</sub>
Minor constituents:	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub> , CO, O <sub>3</sub>
Trace constituents:	
	Halogenated species: <i>HCl</i> , <i>ClONO<sub>2</sub></i> , <i>HF</i> , <i>COF<sub>2</sub></i> , CCl <sub>2</sub> F <sub>2</sub> , CHClF <sub>2</sub> , CCl <sub>3</sub> F, CCl <sub>4</sub> , SF <sub>6</sub>
	Nitrogenated species: <i>NO</i> , <i>NO<sub>2</sub></i> , <i>HNO<sub>3</sub></i>
	Others: C <sub>2</sub> H <sub>6</sub> , C <sub>2</sub> H <sub>2</sub> , HCN, OCS, H <sub>2</sub> CO <sub>2</sub> , H <sub>2</sub> CO (multi-month avg.,)

#### *The Royal Meteorological Institute (KMI-IRM)*

The vertical distribution of ozone continues to be measured three times per week by means of balloon soundings with ECC ozone sensors, since 1997; Brewer-Mast sensors were used during the 1969-1997 period.

<sup>1</sup> no input was received from the Université Libre de Bruxelles (Dr M. Carleer) nor from the University of Antwerp (Dr Deckmyn)

<sup>2</sup> <http://www.ndsc.ws>

<sup>3</sup> Species typed in *italic* are primarily present in the stratosphere, while the others are tropospheric source gases.

### ***The Belgian Institute for Space Aeronomy (BIRA-IASB)***

Monitoring of O<sub>3</sub> and interacting species (halogens, NO<sub>y</sub>, BrO, HCFC, CFC...) for budget and long-term trend studies, continues to be performed at:

- the International Scientific Station of the Jungfraujoch, Switzerland: FTIR and SAOZ instruments. SAOZ measures O<sub>3</sub> and NO<sub>2</sub> columns in the UV-Vis spectral range, since 1990. They complement the FTIR time series produced by ULg summarised in 1.2.1. An additional MAXDOAS Instrument will be installed at the Jungfraujoch in late 2005.
- Harestua, Norway, 60°N, 11°E: UV-VIS DOAS instruments, since 1994 (O<sub>3</sub>, NO<sub>2</sub>, OCIO, BrO)
- the Observatoire de Haute Provence (OHP), France, 44°N, 8°E: UV-VIS DOAS instrument (O<sub>3</sub>, NO<sub>2</sub>, 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 O<sub>3</sub>, NO<sub>2</sub>, BrO, and H<sub>2</sub>CO.
- at Ile de la Réunion (22°S, 55°E): UV-Vis MAXDOAS instrument (O<sub>3</sub>, NO<sub>2</sub>, BrO, H<sub>2</sub>CO columns and tropospheric abundances), starting in summer 2002. Campaigns with a mobile Fourier-transform infrared (FTIR) instrument have been conducted in Sept-Oct. 2002, and August to November 2004. Permanent FTIR measurements at Ile de la Réunion are planned, starting in 2008. During the first FTIR campaign at the Ile de La Réunion, 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.

### **UV measurements - spectroradiometers**

#### ***The Royal Meteorological Institute (KMI-IRM) -The Belgian Institute for Space Aeronomy (BIRA-IASB)***

- 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)

### **Calibration activities**

#### ***The Royal Meteorological Institute (KMI-IRM)***

- The Dobson instrument was last calibrated at the Regional Calibration Centre of WMO in Hohenpeißenberg in 2000. Since then the monthly calibration tests with standard and mercury lamps showed that the instrument remains stable.
- The Brewer instruments were compared with the travelling reference instrument in 2003. The results of this calibration 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 level was checked with 1000W lamps in 2003 during the calibration visit. 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). This showed that the calibration based on the monthly tests with 50W lamps was within the expected errors.

## **The Belgian Institute for Space Aeronomy (BIRA-IASB)**

The observations are all contributing to the NDSC and are being certified in this framework. Only for the measurements at the Ile de La Réunion, the NDSC qualification has not yet been solicited. But the quality of the spectral data has been verified by performing daily HBr cell measurements for controlling the instrument's alignment, as recommended by the NDSC IRWG (Infrared Working Group).

The MAXDOAS instruments have participated to several calibration campaigns, e.g., in Andoya in winter 2003, in the EC project FORMAT, and recently (summer 2005) in the Dandelions campaign in Cabauw (NL).

## **University of Liège (ULg)**

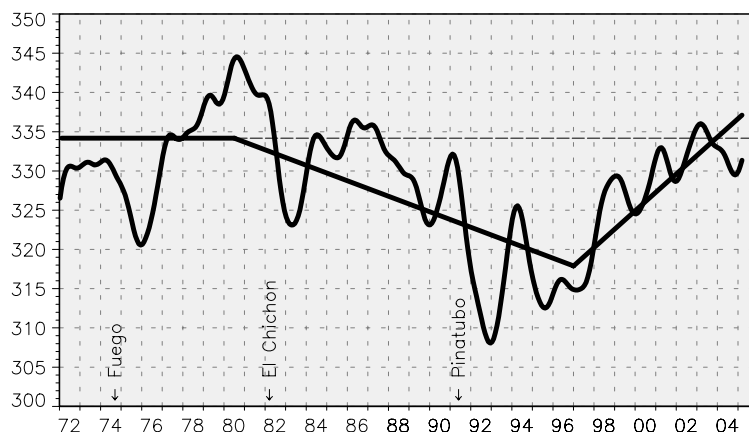
Calibration of the Jungfraujoch FTIRs is performed according to recommendations in related NDSC protocols. This is done regularly by using sealed cells containing known amounts of either HBr or N<sub>2</sub>O gases, which allow characterising the instrumental line shape. In addition, atmospheric gases whose vertical distributions and concentrations are well known (i.e., N<sub>2</sub> and CO<sub>2</sub>) are used to check the overall instrumental performances and their long-term stability

## **RESULTS FROM OBSERVATIONS AND ANALYSIS**

### **The Royal Meteorological Institute (KMI-IRM)**

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 from Dobson and Brewer instruments (1990-now). The ozone column decreased by 3% per decade in the period 1980-1997, with a likely sign of recovery afterwards, although the period is too short to draw firm conclusions. According to the Uccle soundings, the decrease occurred 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.



**Figure 1: running annual mean of total ozone 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.**

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

Based on monitoring, from aboard satellites, of stratospheric aerosol loading on a quasi-global scale. the spatio-temporal distribution between 12- and 35-km altitude has shown that aerosols are among the most varying constituents in the lower stratosphere, capable of exerting negligible to acute regional-scale effects on climate. In particular, major volcanic eruptions, like that of Mount Pinatubo (Philippines) in June 1991, enhance aerosol abundance significantly, worldwide. Belgian scientists were able to show that the aerosol increase following this event caused temporary depletion of stratospheric ozone above Uccle and of nitrogen dioxide over the Jungfraujoch. This is one example demonstrating the importance of simultaneous long-term monitoring of the particulate and gaseous composition of the stratosphere. Other important results are:

- Updated trends of stratospheric bromine
- Time series of O<sub>3</sub>, NO<sub>2</sub> and BrO at the NDSC stations operated by BIRA-IASB (at Jungfraujoch since 1990; at Harestua since 1994; at OHP since 1998)
- Time series of OCIO abundances in Harestua, including model simulations.
- Global maps of BrO, SO<sub>2</sub>, NO<sub>2</sub> from GOME and SCIAMACHY
- BASCOE 4D Var assimilation analyses
- Climatology of stratospheric aerosol; time series of vertical distributions of aerosol optical properties based on SAGE II data
- campaign data at Ile de La Réunion : vertical distributions of a large number of species measured by FTIR: O<sub>3</sub>, HCl, HF, CO, N<sub>2</sub>O, HNO<sub>3</sub>, ...; O<sub>3</sub>, NO<sub>2</sub>, SO<sub>2</sub>, BrO distributions in the troposphere from MAXDOAS
- NO<sub>2</sub> vertical profile climatology

## University of Liège (ULg)

- Consistent monitoring, since the mid-1980s, of the vertical column abundances above the Jungfraujoch, of HCl and ClONO<sub>2</sub>, which are the main inorganic Cl<sub>y</sub> reservoirs in the stratosphere. Their sum shows that the rate of increase of Cl<sub>y</sub> has progressively slowed down during the early-1990s, and stabilised in 1996-1997, in response to the amended production regulations on O<sub>3</sub>-depleting substances by the Montreal Protocol. Since, the Cl<sub>y</sub> loading has shown a slow but statistically significant decrease ( $-0.7 \pm 0.2$  %) over the 1998-2004 period, which is commensurate with the organic chlorine decrease in the troposphere.
- Monitoring of the evolution of anthropogenic chlorine-bearing source gases such as CFC-11, CFC-12, HCFC-22 and CCl<sub>4</sub> demonstrates the efficiency of the amended Montreal Protocol upon regulated versus unregulated ozone-depleting compounds.
- The O<sub>3</sub> column monitored from 1984 to 2004 shows that it has decreased by ( $4.5 \pm 0.5$  %) during that 20-year period, with significant temporary perturbations that resulted from inter-annual variability and from the strong Mt. Pinatubo volcanic eruption in 1991.
- The most abundant NO<sub>y</sub> compounds (HNO<sub>3</sub>, NO<sub>2</sub>, NO, ClONO<sub>2</sub>) show no statistically significant change in their total stratospheric loading. However, NO<sub>2</sub> reveals a rate of increase of ( $0.5 \pm 0.2$  %)/yr which is consistent with similar investigations performed at the NDSC southern mid-latitude station of Lauder (N-Z).
- The continued rise, although having slightly slowed down during the past years, of the inorganic fluorine concentration in the stratosphere, contrary to the decrease of chlorine.
- Measured rates of increase of the major radiatively active gases that are to be controlled under the Kyoto Protocol;<sup>4</sup>

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<sup>4</sup> <http://sunset.astro.ulg.ac.be/girpas/>.

## **THEORY, MODELLING, AND OTHER RESEARCH**

### **The Royal Meteorological Institute (KMI-IRM)**

The Brewer data have been analysed for aerosol information in the UV. These data are available now (Cheymol and De Backer, 2003).

### **The Belgian Institute for Space Aeronomy (BIRA-IASB)**

#### ***Modelling***

- Complete 3D modelling of the stratosphere, including transport, chemistry, aerosol micro-physics and a heterogeneous chemistry module
- Chemical 4D variational data assimilation, in particular of O<sub>3</sub>
- 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 improve emissions estimates (e.g., for CO)

#### ***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.

#### ***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

#### ***Retrieval algorithm developments***

- 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<sub>2</sub>, O<sub>3</sub>, HNO<sub>3</sub>, HCl, ... For the FTIR data this approach has been optimised for some target species (incl. O<sub>3</sub>) in the EC project UFTIR coordinated by BIRA-IASB.

#### ***Satellite data retrievals***

- Development, validation and implementation of satellite data retrieval algorithms (e.g., for GOME and SCIAMACHY total O<sub>3</sub>, NO<sub>2</sub>, BrO, SO<sub>2</sub>...; e.g. for aerosol and trace gases from GOMOS); data processing and dissemination
- Development of retrieval algorithms for IASI/Metop for aerosol and gases.

#### ***Satellite data validation and characterisation***

- Continued contributions to the validation of ESA satellite data for O<sub>3</sub>, NO<sub>y</sub>, CH<sub>4</sub>, CO, N<sub>2</sub>O... (GOME, SCIAMACHY, GOMOS, MIPAS, ACE/SciSat ...) using independent

ground-based data, mostly NDSC 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 from successive satellite sensors (e.g., for O<sub>3</sub> 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 NO<sub>2</sub>.

### **University of Liège (ULg)**

Most of the research activities reported in the previous Ozone Research Managers Report (2002) are continuing<sup>5</sup>

#### ***Satellite data validation and characterisation***

- Further exploitation of the ATMOS data (Atmospheric Trace MOlecule Spectroscopy, spanning the 1985-1994 period) as references for subsequent trend studies (e.g., the SciSat-ACE project (see below)) of over two dozen constituents present in the free troposphere and the stratosphere.<sup>6</sup>

## **DISSEMINATION OF RESULTS**

### **Data reporting**

#### ***The Royal Meteorological Institute (KMI-IRM)***

The ozone data (columns and profiles) are regularly deposited in the WOUDC of WMO. Uccle is also a complementary station for ozone in the NDSC. 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.

#### ***The Belgian Institute for Space Aeronomy (BIRA-IASB)***

- Data concerning the chemical species are submitted to NADIR/NILU and NDSC/NOAA databases, as well as to the Envisat Cal/val database at NILU. UV-B data are in the SUVDAMA (EC) database.
- Satellite data are disseminated via dedicated services and Web pages, e.g., <http://www.temis.nl>; <http://www.oma.be/GOME/index.html>; <http://www.oma.be/DAEDALUS>, <http://www.gse-promote.org/>
- Spectroscopic laboratory data are submitted to international databases like HITRAN, GEISA, and via the institute Web page <http://www.oma.be/BIRA-IASB/Scientific/Data/CrossSections/CrossSections.html>
- Project Web pages (see 'Projects and collaboration')

### **University of Liège (ULg)**

- Series of NDSC-relevant molecules (e.g., HCl, ClONO<sub>2</sub>, HF, COF<sub>2</sub>, HNO<sub>3</sub>, NO<sub>2</sub>, NO, O<sub>3</sub>, CFC-12, HCFC-22) measured from 1989 to present, are being archived routinely at the NOAA Data Host Facility (Washington, DC, USA), with the ozone data mirrored to the WOUDC archive in

<sup>5</sup> <http://sunset.astro.ulg.ac.be/girpas/>.

<sup>6</sup> <http://remus.jpl.nasa.gov/atmosversion3/atmosversion3.html>.

Toronto. Pre-1989 data are available upon requests sent to the ULg scientists listed at the end of this report. Specific databases produced in support of European campaigns or for the validation of space-based sensors of the atmosphere are generally archived at NILU<sup>7</sup> (Norway).

## Information to the public

### **The Royal Meteorological Institute (KMI-IRM)**

- Daily UV forecasts are produced and disseminated with the weather forecasts. They are also available at the internet ([www.meteo.be](http://www.meteo.be)).
- Ozone and UV data of Uccle were also used in yearly reports on the environment (MIRAT-2003, 2004, Polders et al, 2003, 2004).

### **The Belgian Institute for Space Aeronomy (BIRA-IASB)**

- via participations to expositions, via Web pages<sup>8</sup>
- BASCOE provides daily global O<sub>3</sub> forecasts via the Web<sup>9</sup>.

### **Belgian Federal Public Planning Service Science Policy (BELSPO)**

The Belgian Public Planning Service Science Policy recently published an Assessment and Integration Report on Belgian Global Change research 1990 – 2002. It just one of the initiatives taken towards improved integration of research results into information relevant to policymaking<sup>10</sup>.

Final Reports of relevant research projects within the Scientific Support Plan for a Sustainable Development Policy can be ordered or downloaded from the BELSPO website<sup>11</sup>.

## Relevant scientific papers

### **The Royal Meteorological Institute (KMI-IRM)**

Peer reviewed:

Coheur, Pierre-François, C. Clerbaux, M. Carleer, S. Fally, D. Hurtmans, R. Colin, C. Hermans, A.C. Vandaele, B. Barret, M. De Mazière and **H. De Backer**, Retrieval of atmospheric water vapor columns from FT visible solar absorption spectra, Evaluation of spectroscopic databases, *Journal of Quantitative Spectroscopy & Radiative Transfer*, 82, 133-150, 2003.

Cheyamol, Anne and H. De Backer, Retrieval of the aerosol optical depth in the UV-B at Uccle from Brewer ozone measurements over a long time period 1984-2002, *J. Geophys. Res.*, 108(D24), 4800, doi:10.1029/2003JD003758, 2003.

Lait, L., P. Newman, M. Schoeberl, T. McGee, L. Twigg, E. Browell, M. Fenn, W. Grant, C. Butler, R. Bevilacqua, J. Davies, H. De Backer, S. Andersen, E. Kyrö, R. Kivi, P. von der Gathen, H. Claude, A. Benesova, P. Skrivankova, V. Dorokhov, I. Zaitcev, G. Braathen, M. Gil, Z. Litynska, D. Moore and M. Gerding, Non-Coincident inter-instrument comparisons of ozone measurements using quasi-conservative coordinates, *Atmospheric Chemistry and Physics*, Vol. 4, pp 2345-2352, 2004. <http://www.copernicus.org/EGU/acp/acp/4/2345/acp-4-2345.pdf>

<sup>7</sup> <http://www.nilu.no/>

<sup>8</sup> <http://www.aeronomie.be/>; <http://www.oma.be/ESACII/Home.html>; <http://www.temis.nl/>, etc.

<sup>9</sup> <http://www.bascoe.oma.be>

<sup>10</sup> <http://www.belspo.be/belspo/home/publ/index>

<sup>11</sup> <http://www.belspo.be/belspo/fedra/prog.asp?l=nl&COD=EV>

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Delcloo, Andy and H. De Backer, *Modelling planetary boundary layer ozone, using meteorological parameters at Uccle and Payerne*, *Atmospheric environment*, Volume 39, Issue 28, Pages 5067-5077, doi:10.1016/j.atmosenv.2005.05.013, 2005.

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Other RMI publications related to the ozone research are available from:

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### **The Belgian Institute for Space Aeronomy (BIRA-IASB)**

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Other BIRA-IASB publications related to the ozone research are available from:

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## **University of Liège (ULg)**

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Other ULg publications related to the ozone research are available from:

<http://sunset.astro.ulg.ac.be/girpas/>

## **PROJECTS AND COLLABORATION**

### **Participation in other national and international collaborations projects**

#### ***The Royal Meteorological Institute (KMI-IRM)***

- Belgian programme Scientific Support for Sustainable Development: ESAC-II: Experimental Studies of Atmospheric Changes II (2001-2005)
- COST action 726 on Long term changes and climatology of UV radiation over Europe (2004-2009).
- Action 1 of 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.

#### ***The Belgian Institute for Space Aeronomy (BIRA-IASB)***

- Belgian programme Scientific Support for Sustainable Development: ESAC-II: Experimental Studies of Atmospheric Changes II (2001-2005) (as coordinator)<sup>12</sup>
- IPCC Climate and WMO Stratospheric Ozone assessments

<sup>12</sup> <http://www.oma.be/ESACII/Home.html>

- 6th Framework Programme of the European Commission: GMES-GATO (finished Jan 31, 2005) GEMS, Evergreen<sup>13</sup>, NOVAC, UFTIR<sup>14</sup>, STAR<sup>15</sup> SCOUT-O3, ACCENT (and its subproject AT2)...
- 'Chemistry and climate related studies using the IASI remote sensor' for preparing the scientific research aspects of the IASI mission onboard METOP-1 (launch nominally 2005).
- ESA GSE project PROMOTE
- ESA study 'Capacity'<sup>16</sup>
- Envisat Atmospheric Chemistry Validation Team, and SCIAVALIG

### ***University of Liège (ULg)***

- IPCC Climate and WMO Stratospheric Ozone assessments

### **Representation in international organisations**

#### ***The Royal Meteorological Institute (KMI-IRM)***

- COST 726
- Brewer and Dobson scientific advisory groups of WMO
- Advisory group for the Regional Brewer Calibration Centre for region VI (Europe)
- EUMETSAT
- Ozone-SAF
- NDSC

#### ***The Belgian Institute for Space Aeronomy (BIRA-IASB)***

- WMO: UV-SAG (GAW)
- SPARC/WCRP
- NDSC (GAW/WMO) (co-chairmanship of UV-VIs, IR and Satellite Working Groups)
- CEOS
- SAG of GOME and GOME-2, GOMOS, SCIAMACHY, OMI
- Atmospheric Science Panel (European Commission)
- ESA council
- Member of the Science Team of the Canadian ACE/SciSAT mission
- Member of EOS-Aura OMI International Science Team

### ***University of Liège (ULg)***

- Atmospheric Science Panel (European Commission)
- NDSC-Steering Committee,
- IOC
- GMES-GATO coordinating group.
- Science Team of the Canadian SciSat-ACE project.
- International Foundation of the 'Hochalpine Forschungsstationen Jungfrauoch und Gornergrat, Switzerland.

<sup>13</sup> (<http://www.knmi.nl/evergreen>)

<sup>14</sup> <http://www.nilu.no/uftir>

<sup>15</sup> <http://www.knmi.nl/samenw/star>

<sup>16</sup> <http://www.knmi.nl/capacity/>

## **Other collaborations**

### ***The Royal Meteorological Institute (KMI-IRM)***

- with the Alfred Wegner Institute in Bremen for the Match Campaigns since the beginning of the 1990's.
- with the Forschung Zentrum Jülich in Germany, and other National institutes performing ozone soundings for the setting up standard operating procedure for ozone soundings for WMO.

## **FUTURE PLANS**

### ***The Royal Meteorological Institute (KMI-IRM)***

It is envisaged to stop the Dobson measurements and make an agreement with the University of Ile de La Réunion to loan the instrument to use it there to complete the NDSC capacities of that station

### ***The Belgian Institute for Space Aeronomy (BIRA-IASB)***

- Continuation of long-term NDSC observations at abovementioned stations
- Permanent FTIR and MAXDOAS measurements at Ile de La Réunion from 2008 onwards (nominally)
- Acquisition of a mini-MAXDOAS instrument for mobile measurements
- Acquisition of a CIMEL sun photometer, to be integrated in the Photons-Aeronet network
- Volcano monitoring with MAXDOAS instruments (EC project NOVAC)
- Participation in satellite experiments with ESA, Canada, EUMETSAT

### ***Belgian Federal Public Planning Service Science Policy (BELSPO)***

Within the programme 'Science for a sustainable development (SSD)' a first call for proposals was launched. One of the priorities relates to the interaction between atmospheric composition and climate change. The evaluation procedure is ongoing; projects are to start in December 2005.

Recurrent measurements at NDSC stations are mainly funded with multi-annual research budget. BELSPO is considering a more sustainable solution in cooperation with the federal scientific research institutes.

Belgium will open in 2007 a new scientific station in Antarctica

## **NEEDS AND RECOMMENDATIONS**

- Needs to secure the financial support to continue long-term monitoring activities (including calibration of instruments, necessary equipment for ozone soundings) instruments and associated software upgrades,...) and data archiving and dissemination services.

## CO-ORDINATES OF BELGIAN INSTITUTES AND LEADING SCIENTISTS INVOLVED IN O<sub>3</sub> RELATED RESEARCH AND OBSERVATIONS

University of Liège  
Institute of Astrophysics and Geophysics  
Dr E. MAHIEU (Data analysis, interpretation and archiving)  
Prof. (Emeritus) R. ZANDER (Data analysis and interpretation)  
Ph. DEMOULIN (Data analysis and observations)  
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Belgian Institute for Space Aeronomy  
Dr M. DE MAZIÈRE (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 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 D. FONTEYN (Stratospheric modelling, 4D VAR data assimilation)  
Dr J.-F. MULLER (Global tropospheric ozone modelling, inverse source/sink modelling)  
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## **BOLIVIA**

### **OBSERVATIONAL ACTIVITIES**

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

In Bolivia, there is only one station measuring the ozone layer. This station is run by the Atmospheric Physics Laboratory (LFA) at the Physical Research Institute (IIF) of the University of San Andres (UMSA), at La Paz.

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

There is ozone column profile data from Umhker measurements for three years, based on the Brewer data and using a standard atmospheric model.

#### **UV measurements**

##### ***Broadband measurements***

From December 1995, when the laboratory started measurements, until May 1997, we were using a Solar Light 501 Biometer. Since July 1998, there are two YES broadband radiometers. One of the YES is kept fixed at the LAF, and the second is used for the field campaigns.

##### ***Spectroradiometers***

The LFA has a special agreement with the Brazilian National Institute for Space Research (INPE) which allows the LFA to run the Brewer #110 at La Paz since 1996. There is a nearly continuous data series of the ozone layer depth from July 1996 to July 2004, when the equipment breakdown and was shipped back to Brazil for repair. It is scheduled to be returned next September.

#### **Calibration activities**

One of the YES broadband radiometers was recalibrated at Innsbruck, Austria in 2002. Two intercomparison campaigns were held at the LFA. The first as an extension of the Argentinean calibration of the National network in year 2000, and the second during the Second Latin American Congress on Ultraviolet Radiation, with equipments from several countries.

### **RESULTS FROM OBSERVATIONS AND ANALYSIS**

Several reports were written and published locally on the ozone layer trends measured at the LFA station in the outskirts of La Paz (16.5° S, 68.0 °W, 3200 m asl). Also there are studies comparing satellite-based data (from NASA's TOMS) and our ground station, with a nearly perfect fit. The main result from the analysis was the discovery of a small depletion of the ozone layer over the Bolivian high plateau (Altiplano) in relation to other locations at the same latitude. This effect was first attributed to the high altitude of the measuring station; as it misses the first three kilometers of the atmosphere, but more refined calculations show that the "altitude effect" is not enough to account for the difference, which has values around 15 DU.

One of the main findings was the discovery that the ozone layer at La Paz shows no large change when we compared the profiles obtained during two ozone-sounding campaigns, one in 1963, and the second in 1998. Therefore, one can postulate that the ozone layer over the Bolivian Altiplano has remained unchanged for the last 40 years.

The main work of the LFA is on the solar Ultraviolet Radiation monitoring. Due a combination of several factors like, latitude, altitude, clear sky and open horizons; the Bolivian Altiplano receives very high UV doses, sometimes tagged as the highest in the world, with values above  $8 \text{ kJ m}^{-2} \text{ yr}^{-1}$ . The average UV Index at La Paz is 11, corresponding to  $0.275 \text{ W m}^{-2}$ . Also, there is a seasonal dependence of the UV values, with the higher values on summer and lower at winter months. The climate favors our case in the sense that when the solar zenithal angles is minimum (even zero twice a year) usually correspond to the rainy season, and the cloud cover filters out a lot of the solar UVR. But, in the case of drought (as when ENSO appears) November becomes with clear skys and the UVI values jump out of the scale. We reported an exceptional value of (extrapolated) UVI = 23 for one day.

## **THEORY, MODELLING, AND OTHER RESEARCH**

Aiming to get a better spatial coverage of the UVR in Bolivia, the LFA uses both the STAR model, and data from TOMS. The first is used to get an approximation of the UV irradiance in selected locations, to be contrasted with field-campaign data. These campaigns are carried out only for short periods, usually 3-5 days in each location.

In terms of modeling, there is a couple of works aimed to explain the “ozone anomaly” over the Bolivian Altiplano. Both works use TOMS and local data, and are based on the assumption that the ozone layer over the region is thinner due an effect of the gravity waves. The main hypothesis is that the air coming from the lowlands is trapped between the double chain of mountains, and the bouncing cause perturbations that in the end, erode the ozone layer. This is a permanent situation, contrasting to the seasonal “ozone hole” over Antarctica.

Another line of research is on the effects of the UV radiation over technological materials, on cultivable plants, on plankton and the food chain, and on the human health. On the first case, the LFA research focused on the effects of the high level of solar UVR in the Altiplano on the corrosion process of base metals exposed to the open environment. The main finding (yet to be confirmed) is a depletion of the corrosion rate of copper. A second line of research in this area is on the UVR effects on polymers, specially textile fibers (nylon and rayon), plastic sheets for greenhouses (Agrofilm™) and plastic bottles (PET). In the first case, we found that the damaging effects on the fibers depends more on the coloring treatment of the yarn than on the amount of UV absorbed by the fiber. In the second study, we found that the Agrofilm™ loses most of its good properties after being irradiated with 1 MJ of UVB. The films becomes almost opaque to the visible light, but allows a lot more (60%) of the UV radiation to come through. The changes on the heat transmission properties are still under study, as the behavior of the PET bottles.

In the case of the cultivars, the LFA team worked with one of the most popular Andean cereals, the quinoa grain (*Chenopodium quinoa*, Wild.). We choose this plant by several reasons: it is a strong component of the Altiplano's people, being the main protein source; it grows in the Southern Altiplano, which a region with very high UV levels, but at the same time is one of the poorest regions of the country, due its extreme aridity. We were exploring the relation of the UV exposure of the plant, and the protein and saponine content of the grain. Those substances are in competition inside the grain, the more saponine the plant develop, the less protein it has, and viceversa. A high content of saponine is bad news for the use of the grain as food, but is good for its industrial use. The main result of the study is that the high UV levels cause a delayed growing and maturation times, shifting the phenic stages. We could not get conclusive results on the saponine production as function of the UV irradiance due the lack of equipment (a spectrometer) and some other logistical problems.

The studies on plankton and UV were two fold. One side was carried out in the Titikaka lake, which is the highest navigable lake in the world (3860 m asl). Among the results of the campaigns we found that the phytoplankton has adapted it self to the very high solar UV levels producing a series of “sun screening” compounds, mainly of the mycosporine-acid type. The zooplankton did not produce this substance, but takes it from the phytoplankton and bioaccumulates it. The second stage was carried out several years later, in the First Bolivian

Scientific Expedition to Antarctica, merged to the Peruvian “XV Antar” when a similar study was taken, including the next step of the food chain: the krill. The result is also positive: the krill has the same UV-protecting substances as the zooplankton eaten by the crustacean, also keeping it by bioaccumulation.

Besides these activities, the LFA is also engaged in other research activities like air quality, air pollution monitoring, measurements of carbon dioxide and smoke from forest burning, climate change and their impacts on the ecosystems, etc.

## **DISSEMINATION OF RESULTS**

### **Data reporting**

The UV and ozone layer thickness values obtained with the Brewer are reported monthly to the INPE headquarters in Brazil for validation and later dissemination. This is done according the working agreement between our institutions. A copy of the data, in a booklet format is kept at the LFA and a second copy is given to the IIF library.

The UV data taken with other equipment (like the YES broadband radiometers) is available on request, and if the requester has not any commercial purpose, the LFA release the data for free.

### **Information to the public**

The LFA is in charge to broadcast the UV Index on behalf of the Bolivian Ministry for Health. The UV Index is calculated from the measurements with several instruments at the LFA, and it is extrapolated for other cities in the country, or even neighboring countries (e.g Peru & Paraguay). As the weather forecast system in Bolivia is not very well developed (mainly due the complex topography of the country) the UV forecast is released as a table, with columns for three weather conditions: clear sky, cloudy, overcast; and rows for three skin types: I or Nordic, III or Mediterranean and V or dark. The forecast is released each day before noon, with the values for the next day, and it is transmitted to the media via fax and e-mail. Actually, the LFA is working with 2 national newspapers, 10 TV stations and 15 radio stations.

Also, as the LFA has been named as “National Institution of Reference” by the Pan American Health Organization (PAHO) and recognized as such by the Bolivian Ministry for Health, it has the task to monitor the UV levels in order to point out to the Ministry when to declare an “UV alert” which work in a similar way as the “epidemiological alerts”.

The LFA had published two books, the first one were the Proceedings of an International Seminar on Ultraviolet Radiation and the Ozone Layer, (R.Forno & M.Andrade, eds.1997) and the second book and a compendium of the activities around UVR in Bolivia during the LFA life (“La Radiación Ultravioleta en Bolivia”, F.Zaratti & R. Forno, eds. 2002) A Third volume is in press, with the activities during the PAHO-sponsored Technical Cooperation among Countries Programme between Peru and Bolivia (“TCC Peru – Bolivia, Activities Report”, D.Daza & E.R.Palenque, eds., 2005).

### **Relevant scientific papers**

Among other publications, the next is a short list of the main results from the research activity at the LFA during the years 1996- 2004:

*Blacutt, L.A. & Palenque, E.R. “Efectos de la RUV sobre Materiales Tecnológicos. Metales Base”. Informe de Labores 1998, IIF – UMSA.*

*Blacutt, L.A., Limachi, O. & Palenque, E.R. “Efectos de la RUV sobre Materiales Tecnológicos. Parte III: Fibras textiles”. Informe de Labores 2003, IIF – UMSA.*

- Ghezzi, F. et al. "Análisis de correlación entre actividad solar y columna de ozono a latitudes tropicales" *Revista Boliviana de Física*, Vol.8, p.16 (2002).
- Helbling, E.W. et al. "Mycosporine-like amino acids protect the copepod *Boeckella titicacae* (Harding) against high levels of solar UVR". *Journal of Plankton Research*, Vol.24, p.225 (2002)
- Palenque, E.R et al. "Efectos de la radiación ultravioleta sobre el desarrollo de la quinua (*Chenopodium quinoa*, Willd.). *Revista Boliviana de Física*, Vol.3, p.120 (1998).
- Torres, R. & Blacutt, L.A. "Magnitud de las componentes UVA y UVB de la radiación solar en Cota –cota" *Proceeding of the "Simposio Nacional de Cambios Globales"*, La Paz, 2000.
- Zaratti et al. "Longitudinal and latitudinal variations of the total ozone over the Central Andes" *Il Nuovo Cimento*, Vol.22C, N2, p.1456 (1999)
- Zaratti, F. et al "Seis años de medidas de ozono y radiación ultravioleta en La Paz, Bolivia" *Revista Boliviana de Física*, Vol.9, p.48 (2003).
- Zaratti, F. et al."Erythemally weighted UV-B variations at two high altitude locations" *Journal Geophysical Research*, Vol. 108, D9, p.4263 (2003)

## PROJECTS AND COLLABORATION

The LFA is a Collaborating Center for UV Radiation issues of the World Health Organization, since last year. This nomination comes as result of the successful experience of the LFA measuring and broadcasting the UV Index and carrying out the UVI campaign each year. This activity has been named as "National Institution of Reference" by the Pan American Health Organization (PAHO) who sponsors a large share of the campaigns. In addition, the LFA was nominated as "Collaborating Center" by the WHO, for all the issues concerning UV radiation for the Andean Countries. These nominations represent a broader collaboration and, at the same time, more duties for the LFA for the research and dissemination on UV and its effects

Besides the nominations by the PAHO and the WHO, the LFA has a special agreement with the Faculty of Medicine at the UMSA, for provide the UV data needed by the epidemiological studies and by the postgraduate school on Public Health.

On the technical side, the LFA has several agreements with a lot of international partners. The first of them was with the Brazilian INPE which allows the LFA to run the Brewer station at La Paz. This collaboration includes the LFA as a member of the South American Network for Ozone layer Monitoring, with station deployed in Brazil, Bolivia, Chile and Antarctica. The collaboration includes not only the exchange of data but also training and joint research.

The LFA started a expansion of the number of Bolivian sites for UVR monitoring, and next September, we will be installing a station in the city of Tarija, in agreement with the local university (Universidad Autónoma Juan Misael Saracho). It is foreseen a future expansion towards the cities of Cochabamba and Santa Cruz for the next year, depending on the funding side.

Related to the radiation aspects (including the UV bands) the LFA has an agreement with the Meteorological Institute of the University of Munich, Germany on both the theory of the radiative process and the measurements, linked also with the diurnal circulation on the Altiplano.

With the Space Physics Laboratory (SPL) at the Vikram Sarabhai Space Centre (VSCC) of the Indian Space Research Organization (INSO) is an agreement for the monitoring of the atmospheric aerosols and its relation on the radiative transfer properties. This includes studies on the near-UV band and the tropospheric ozone, linked to the generation of urban smog.

With the European Space Agency (ESA) the LFA has an agreement to carry out research on the vertical distribution of aerosols, including stratospheric clouds. For this, the ESA gave the LFA an alexandrite LIDAR which will be starting operations very soon, we estimate at mid-September.

## FUTURE PLANS

The LFA had presented a proposal for research to the WHO, one project for a network of UV-monitoring stations distributed among localities in Peru and Bolivia; a second project for a system devoted to ensure the quality of the sun glasses commercialized in the Andean countries; and a third project aimed to refine the Parrish classification of skin types covering the range of the Native American people, specially for the inhabitants of the Andean region. The projects were accepted by the PAHO/WHO Office at La Paz, and redirected to PAHO's central office in Washington, later the documents should be transferred to the WHO's Headquarters.

Besides the route taken by the aforementioned projects, the LFA is opening a new station for solar UVR in the city of Tarija, in the Southern part of Bolivia. Due the recent natural gas boom in the region, there is a lot migration towards the city of Tarija and its surroundings, and as it can be considered also as "high altitude city" (2700 m asl) we considered worthy to start measurements there.

Another project in the planning stage is a new "Technical Cooperation among Countries" (TCC), sponsored by the PAHO, this time would be between Bolivia and Ecuador. This TCC is some like the second chapter of the previous TCC between Peru and Bolivia, where the LFA "exported" the know-how of the UVI campaigns.

The ESA's alexandrite LIDAR will be operating since next September, and we hope to get the first validated results on clouds and tropopause height for the end of the year.

In addition, the LFA is now engaging itself in the development of some small, portable and cheap system for working as dosimeters. These equipments can be based on diodes acting as sensors, or based on the fluorescence of some special materials. This research is at its first stage, just started few months ago.

## NEEDS AND RECOMMENDATIONS

Among the several needs of the LFA is the lack of some equipment, as a set of standard UV lamps for calibration, or spectrometers, one for working at the LFA, and other portables, for a better monitoring during the field campaigns. Maybe the most useful equipment for the LFA activities at the moment will be a Microtops (Solar Light Co.) to be used both at fixed locations or during the field campaigns.

On a different side, we need to carry out some atmospheric sounding, in order to get a real temperature profile over our station at La Paz. The profile will be used both for refining the Umhker measurements and the LIDAR data retrieve.

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# BRAZIL

## OBSERVATIONAL ACTIVITIES

The Ozone Laboratory of the National Institute for Space Research (INPE), was created in 1985 and the coordinator is Dr Voker W.J.H.Kirchhoff. In the present it is formed by 4 Ph.D.s, 2 engineers, 5 technicians and a few graduate students in special MSc and PhD programmes. Our major activity is to make observations of the ozone layer using a network of ground based spectrophotometers, of the Dobson and the Brewer types. We presently operate 2 Dobson stations and 6 Brewer observation sites: Natal and Cachoeira Paulista are Dobson sites; Natal, Cuiabá ( now , São José dos Campos), Cachoeira Paulista, Santa Maria ( 1992 to 2002), La Paz, and Punta Arenas ( 1991 to 2000) are Brewer sites. In addition, ozone concentrations are also measured by the ECC sounding technique on balloons. A long term measurement programme at Natal has been operational since 1978. Special field campaigns have also been made at other sites, especially in Amazonia, to study biomass burning effects. More recently, instruments to measure the UV-B radiation have been added to the network.

**Table 1: The Brazilian Network Instrumentation.**

SITE	LAT. (SOUTH)	LONG. (WEST)	DOBSON NUMBER	GUV NUMBER	BREWER NUMBER	PERIOD and TYPE
NATAL BRAZIL	5.84°	35.21°	093 since 1978	9285 - since 1997	110 073	1994-1996 MARK IV 1996 - today MARK IV
CUIABÁ BRAZIL	15.3°	56.1°	-	-	056 081	1991-1997 MARK II 2002-today MARK IV
LA PAZ, BOLÍVIA	16.54°	68.06°	-	-	110	1996-2004 MARK IV
CACHOEIRA PAULISTA BRAZIL	22.68°	45.00°	114 since 1976	9255 - since 1997	124	1997 MARK IV
SAO JOSE DOS CAMPOS BRAZIL	23,2°	45,86°	-	-	056	2000 - today MARK II
SANTA MARIA BRAZIL	29.26°	53.48°	-	-	081 056	1992-1998 MARKIV 2000-2002 MARK II
PUNTA ARENAS CHILE	53.20°	70.90°	-	-	068	1992-2000 MARKIV
BRAZILIAN ANTARCTIC STATION	62.1°	58.4°	-	9285 - since 1996	068	SPRING 2001 2003 2004 2005

### Calibration activities

Five Brewer spectrophotometers were calibrated by International Ozone Services Inc. (IOS) in 2004: São José dos Campos (B#056), Cachoeira Paulista (B#124), Cuiabá(B#081), La Paz(B#110) and Natal (B#073).

The Ozone Laboratory participated in international calibration in 1994, in Spain, where the Natal Dobson ( 093) was shipped with our expert. In 1997 expert Bob Evans, from NOAA, checked the Natal Dobson, on a visit to Natal, but did no adjustments; the Buenos Aires WMO Intercomparison, in December 2001 and 2003, has shown that the Natal Dobson (093) did not need any corrections, even doing some work on it, such as electronic repairs/improvements, optics cleaning, and wedge calibrations. The C.Paulista Dobson (114) and a correction was adjusted in 5%.

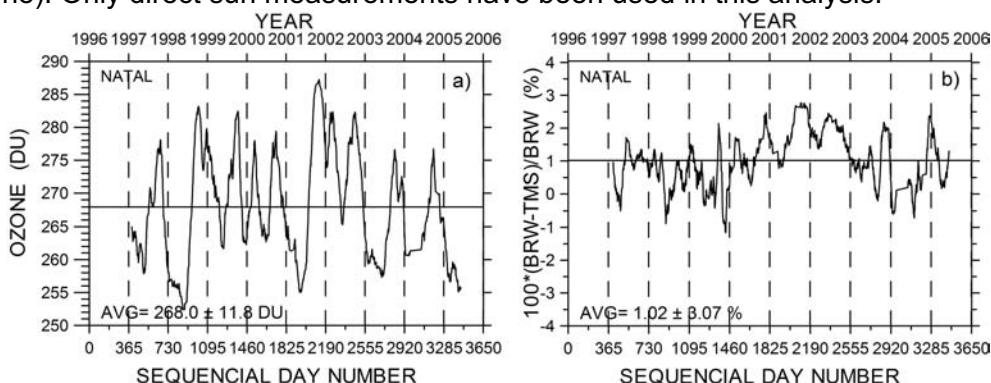
Three GUV was calibrated in 2001, in Sao Jose dos Campos, Brazil, using standard instrument of Biospherical Instruments Inc.. The GUV 9285, is operating in Natal, the GUV 9255, in Cachoeira Paulista and the GUV 9285, in Brazilian Antarctic Station.

## RESULTS FROM OBSERVATIONS AND ANALYSIS

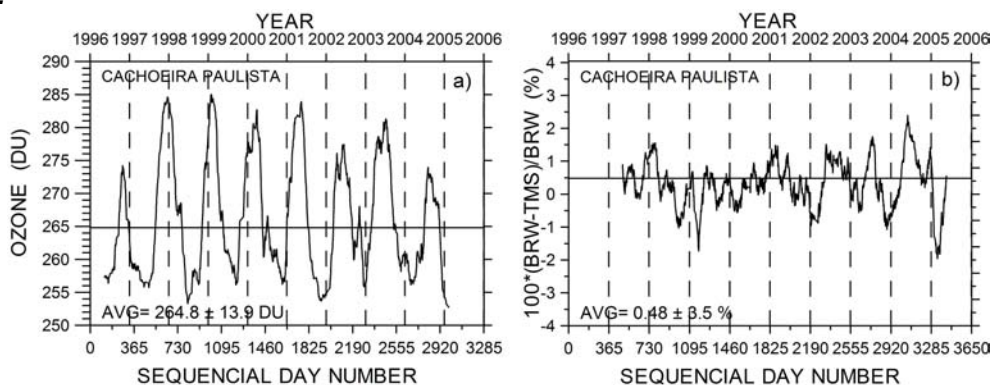
### Total column ozone observations

#### *Brewer and Dobson spectrophotometers*

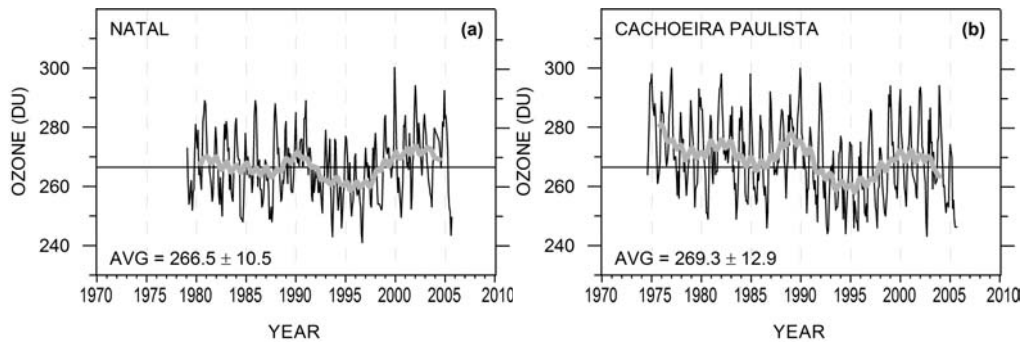
Ground based total column ozone has been measured continuously at low latitude sites, using Brewer spectrophotometers. In addition, two of these sites also operate Dobson spectrophotometers to obtain total ozone. The tropical Brewer-Dobson sites are Natal (6° S, 35° W) and Cachoeira Paulista (23° S, 38° W). The new Brewer spectrophotometer ozone data set for Natal and Cachoeira Paulista is presented it is compared with the TOMS version 8 (V8), from 1997 to 2005 (June). Only direct sun measurements have been used in this analysis.



**Figure 1:** The figure shows a new 8 years data set of the Brewer, obtained at Natal (a). The data are presented as running means of 31 days and this data varies between minima of 250 and 290 DU, and shows large year to year variability. The fig.1b shows the difference parameter Brewer – Toms (version 8).



**Figure 2:** The figure shows a new 8 years data set of the Brewer, obtained at Cachoeira Paulista (a). The data are presented as running means of 31 days and this data varies between minima of 250 and 290 DU, and shows large year to year variability. The fig.2b shows the difference parameter Brewer – Toms (version 8).



**Figure 3: The figure shows a new 26 years data set of the Dobson, obtained at Natal (a) and C.Paulista (b). The data are presented as mensal average (black line) and running means of 15 days (grey line) and this data varies between minima of 240 and 300 DU, and shows large year to year variability. The average is 266.5 DU and the standard deviation is 10.5 at Natal and 269.3 DU at Cachoeira Paulista and the standard deviation is 12.9.**

The Tables 2 and 3 give further statistical details of the data sets. The total column ozone data are compared with the Total Ozone Mapping Spectrometer, Toms data, versions 7 and 8. The data set of 6 years (1997 – 2003 ) is discussed.

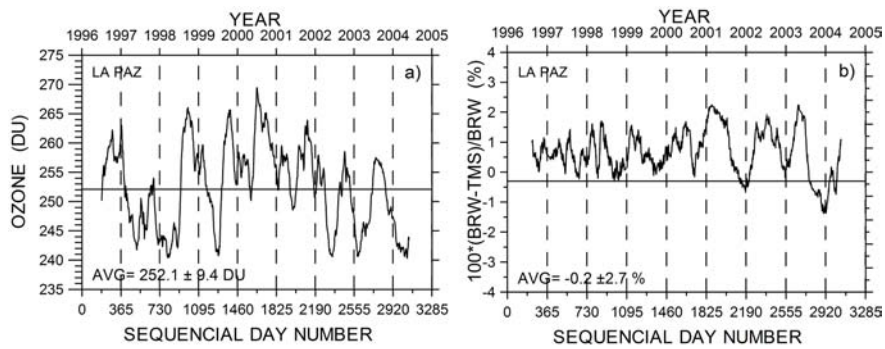
**Table 2: Monthly Average O<sub>3</sub> Data Statistics (Du).**

STATION NAME	INSTR.	AVERAGE	SIGMA	MIN.	MAX.	# DATA POINTS
NATAL	BRW	268.9	9.6	250.0	290.4	75
	DOB	268.7	10.1	252.3	289.4	66
	TMS7	268.4	8.7	253.2	286.4	76
	TMS8	263.5	8.9	245.8	282.3	77
C.PAULISTA	BRW	265.4	12.3	240.4	289.9	72
	DOB	267.6	12.5	245.6	293.5	71
	TMS7	268.0	11.1	243.9	290.5	77
	TMS8	264.4	12.9	234.5	292.8	77

**Table 3. Monthly Averages of the difference parameters: data statistics for  $100*(BRW-DOB)/BRW$ ,  $100*(BRW-TMS)/BRW$  and  $100*(DOB-TMS)/DOB$ , in %.**

STATION NAME	DIFFER.	AVERAGE	SIGMA	MIN.	MAX.	# DATA POINTS
NATAL	BRW-DOB	0.2	1.2	-2.4	3.1	55
	BRW-TMS7	0.0	2.1	-4.3	7.9	74
	BRW-TMS8	0.32	1.4	-4.56	3.13	77
C.PAULISTA	BRW-DOB	-1.0	1.6	-4.5	4.5	63
	BRW-TMS7	-1.0	1.5	-5.4	3.7	73
	BRW-TMS8	1.1	3.6	-11.9	8.0	74
	DOB-TMS7	-0.1	1.9	-7.6	3.9	68
	DOB-TMS8	3.18	4.5	-18.1	12.6	74

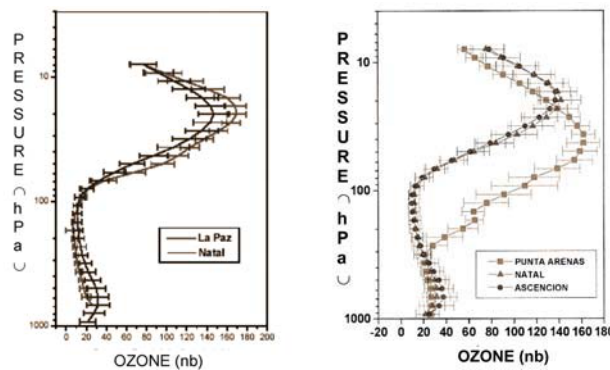
A new set of ground based total column ozone data is described for the period 1996 to 2004 (May) at the high altitude (3.400 m) site La Paz (16,5° S, 68° W). This station operates a Brewer spectrophotometer. These are compared with the Total Ozone Mapping Spectrometer, Toms, satellite data (version 8).



**Figure 4:** Shows a new 8 years data set of the Brewer, obtained at La Paz. The data are presented as running means of 31 days and this data varies between minima of 235 and 270 DU. The average and the standard deviation are  $252.1 \pm 9.4$  DU (a). The fig. 4b shows the difference parameter Brewer – Toms, version 8. The average difference is slightly negative before 2000 and close to zero after that, with higher deviations.

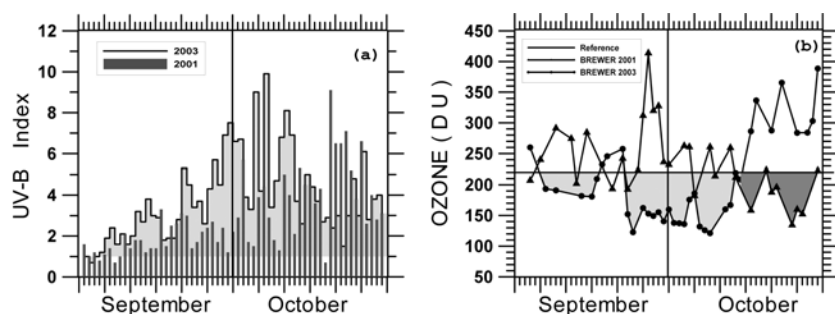
### Ozonesondes

Since 1978, weekly ozonesondes were launched in Natal, Brazil, and campaigns were made in Punta Arenas, Chile (1995, 1997 and 2001), in La Paz, Bolivia (2000) and Brazilian Antarctic Station (1992, 1999, 2003 and 2004).

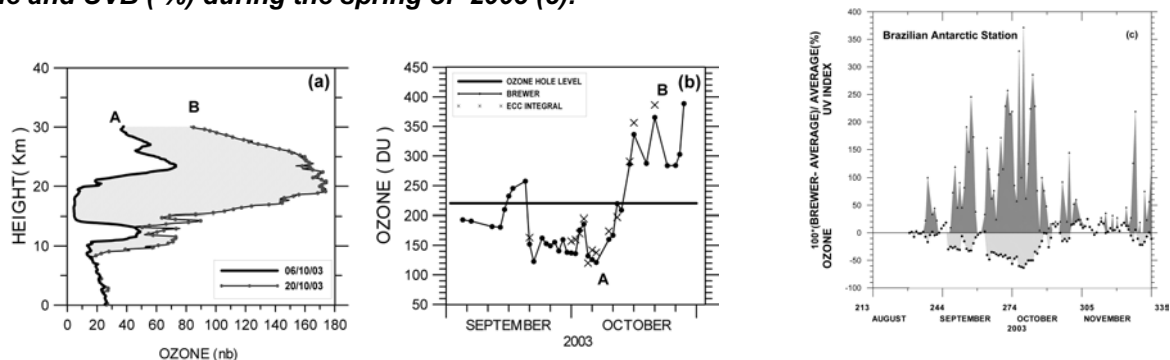


**Figure 5:** Average ozone profile characterizing the normal profile of ozone concentration, expressed as partial pressure, at Natal, Brazil, Punta Arenas, Chile and compared with ozone profile at Ascension Island. (F. Guarniere, Ph.D. Thesis, INPE 2001).

Results are described from an intense field campaign, at the Brazilian Antarctic Station Comandante Ferraz, on King George Island ( $62.1^\circ$  S;  $58.4^\circ$  W) during the Spring of 2003. Ozone was measured using a ground based Brewer spectrophotometer, filter photometers, and the vertical profile was obtained on several days using balloon-borne ECC ozonesondes. In terms of the UV-B index, higher values were seen during 2003: on two occasions the Index passed the level of 9; which is larger than values observed on any previous campaign at the site.



**Figure 6: Shows the comparison between the UV-B index (a) and total ozone (b) for September and October, 2001 and 2003. Higher values were seen during 2003 when the ozone hole appeared earlier and the minimum of ozone was present during several consecutive days. The anti correlation for ozone and UVB (%) during the spring of 2003 (c).**



**Figure 7: shows a composite of the vertical profile of the severe ozone hole of October 6, plus a "normal" profile shown for comparison, obtained on October 20. The second panel shows the ozone integrals measured by a Brewer spectrophotometer, plus the ozone integrals from vertical soundings, shown with x sign. The UV-B index observed on this day was 9.9 and the ozone was 121 DU measured with the Brewer spectrophotometer.**

## DISSEMINATION OF RESULTS

### Data Reporting

The Brewer data have been submitted for the WOUDC, since 2004 and the Dobson data since 1978.

### Information to the public

The UV forecasts is in web site [www.dge.inpe.br/ozonio](http://www.dge.inpe.br/ozonio)

### Relevant scientific papers

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- Rosen, J.M., R.M. Morales, N.T. Kjome, V.W.J.H. Kirchhoff, and F.R. da Silva, Equatorial aerosol-ozone structure and variations as observed by balloon-borne backscattersondes since 1995 at Natal, Brazil (6°S), **J.Geophys.Res.**, 109, D03201, doi: 10.1029/2003JD003715, 2004.

## PROJECTS AND COLLABORATION

Project in the Brazilian Antarctic Programme : The ozone and UVB radiation over Brazilian Antarctic Station and Punta Arenas, Chile.

Collaboration with the project SHADOZ ( Southern Hemisphere Additional Ozonesondes ).

Collaboration with the San Andres University, La Paz, Bolivia

Collaboration with the Magallanes University, Punta Arenas, Chile

## FUTURE PLANS

Participation in the Internacional Polar Year (YPI) and International Heliophysical Year (IHY).

## NEEDS AND RECOMMENDATIONS

It is very important the support for the annual calibrations and maintenance of the Brewer.

Financial support for trips techniques and participation in Ozone and UV Meetings, Congresses and Symposium.

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# **BULGARIA**

## **OBSERVATIONAL ACTIVITIES**

One of the goal, outlined in the Recommendations of the last meeting of the Ozone Research Managers is the systematic measurements, which provide the basis for understanding the ozone regime, its trends and validation the effects of the measures requested by the Montreal Protocol.

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

In Bulgaria, the first total ozone measurements were initiated to the early 1960s, under the supervision of Prof. Dr R. D. Bojkov. Germany carried them out using Dobson spectrophotometer # 64 provided for about 5 years. After a few years interruption Russian filter ozonometers started to be used in the Bulgarian National Institute of Meteorology and Hydrology. In 1998 with the financial support from WMO two Russians ozonometers M-124 were renovated and calibrated at Main Geophysical Observatory – St. Petersburg. The measurements at only one station (NIMH-Sofia) could be maintain (but experiencing technical problems because of the device age).

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

In the period 1983-1992, balloon ozone soundings were released once a week at the NIMH-Sofia. For that purpose were used ozonesondes OSE – manufactured in the former German Democratic Republic. The activities were interrupted largely due to financial difficulties resulting from transition to market economy. From May- 2001 a Vaisala DigiCORA III –a PC based radiosounding system for measuring pressure, temperature and humidity has replaced the Russian radiosounding system. The present financial status doesn't allow us to expand the measurements of the ozone vertical profiles with the above-mentioned Vaisala system, because of the expensive additional equipment (ozone sensors, special balloons, etc.).

### **UV measurements**

At the present moment we are not provide a modern spectral UV-radiation monitoring. Such kind of regular measurements are very desirable to be developed in our country, but again there is a shortage of funds.

**Note :** The NIMH experiences financial difficulties to buy modern equipment for measuring Ozone, ozone profiles, UV solar radiation, NO<sub>x</sub> profiles.

## **RESULTS FROM OBSERVATIONS AND ANALYSIS**

The comparison between the monthly variations of the total ozone over Sofia for 2003 and 2004 is presented at the next Figure 1.

The monthly variations of the total ozone over Sofia for 2004, compared with those ones over Potsdam and Rome are presented at the further Figure 2.

All data are being sent every month to the WMO World Ozone and UV Data Center operated by the Canadian AES in Toronto.

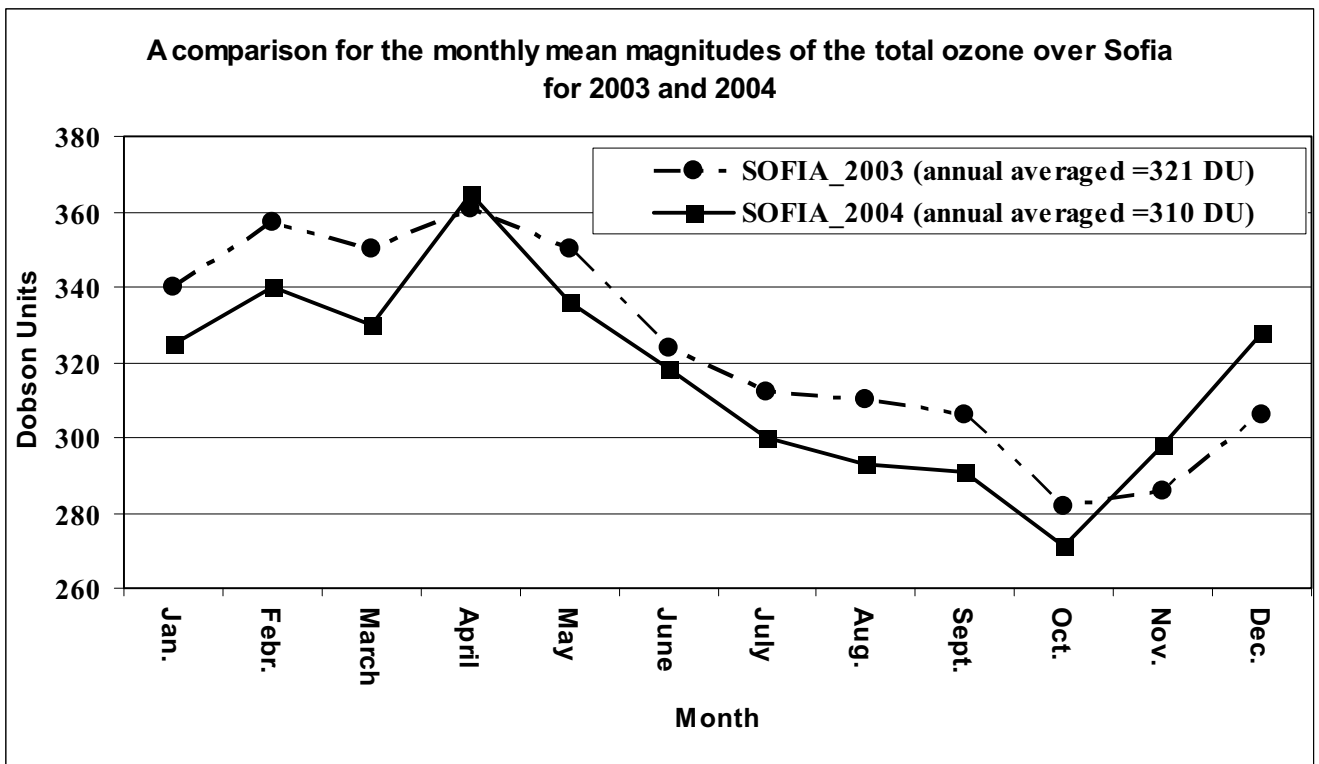


Figure 1

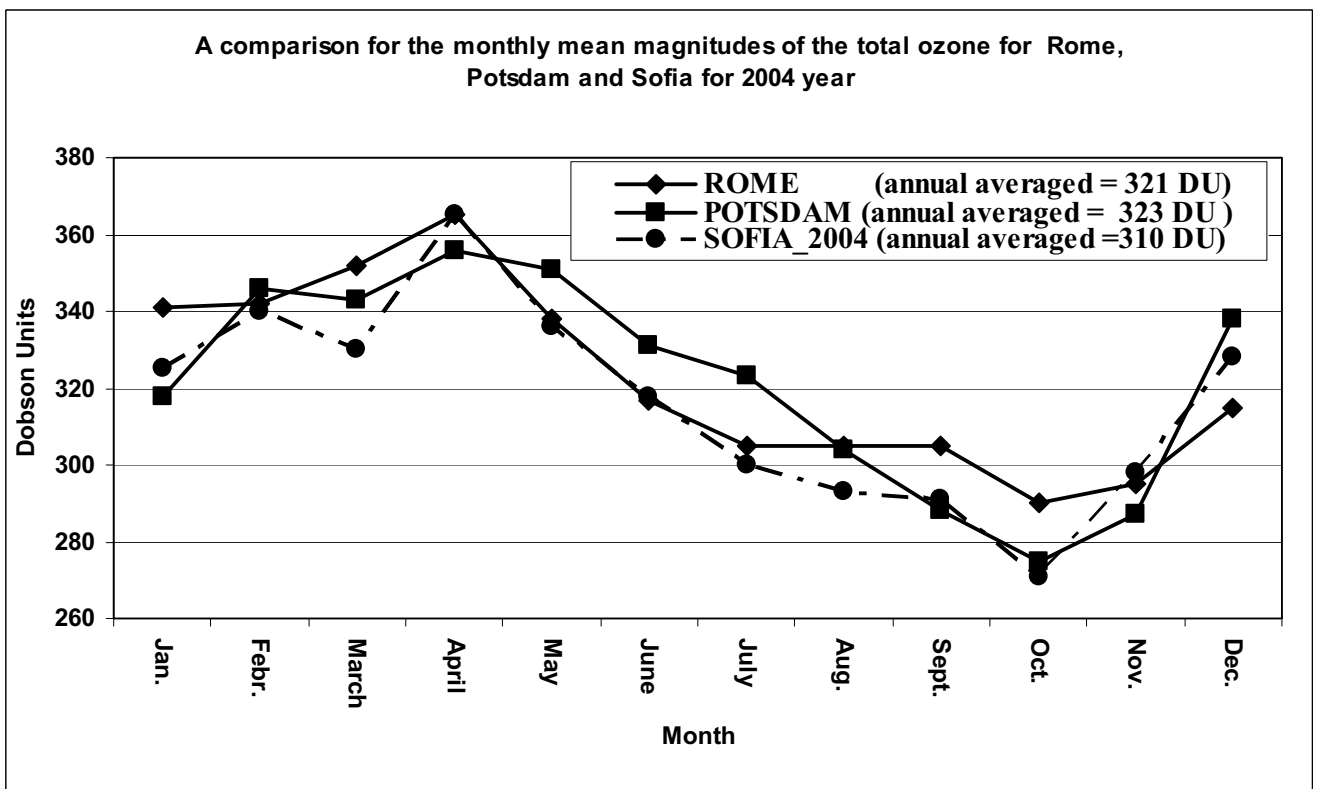


Figure 2

## Surface ozone

Another important topic is the surface ozone. Initial investigations of the surface ozone in Bulgaria began ten years ago. The following goals were pursued: to evaluate the surface ozone state in Sofia ; to ascertain the diurnal and seasonal ozone variations, ; to investigate ozone behaviour with respect to meteorological conditions.

*Site description.* The measurements were performed in Sofia, located in the western part of Bulgaria (42° 49' N, 23° 23' E, 530 m. a.s.l.). The observation site is about 7 km to southeast of Sofia center and possesses a ground cover of fairly well vegetation. At 100 m distance from the site the road of considerable car traffic runs. The ozone recorder was installed at height of about 10 m above the ground level.

*Instrument.* The ozone detector used in the investigations is chemiluminescent analyzer, model 3-02P1, OPTEC Inc. The measuring principle of the sensor is arisen in ozone presence chemiluminescence of an organic dye, adsorbed on the solid state composition. The ozone analyzer has the following characteristics: response time is no more than 1 s, the sensitivity is 2 µg/m<sup>3</sup>. Periodically, the analyzer was calibrated by using an external O<sub>3</sub> generator. The measurements were performed mostly at the daylight hours and less regularly in twenty-four hour period. The analysis of the diurnal ozone variations is carried out by using the hourly values of the ozone concentrations determined as 15-min average.

*Diurnal variations.* The pattern of diurnal variations of the surface ozone concentrations is strongly influenced by meteorological conditions. The pronounced O<sub>3</sub> maximum in the daytime, which is explained in terms of vertical mixing process and photochemical ozone production, occurred on clear windless afternoons.

The ozone data show a maximum in summer months , roughly three-four times higher that in winter months. During the fine windy weather the dilution of the atmospheric pollutants takes place. So the decreased ozone concentrations are detected and ozone level is approximately constant throughout the day. However, in the cases when vertical exchange is limited (autumn-winter period, nocturnal inversions) the wind enhances the vertical mixing and increases the ozone content near the ground. The cloudiness strongly decreases the ozone concentrations near the ground but when it is foggy the ozone content is very low, often zero.

So, the ozone concentrations sensitively reflect meteorological conditions at which measurements are performed. It is very like that more realistic information about temporal and spatial ozone variations may be obtained if ozone data received at similar meteorological situations are analyzed. The surface ozone behavior clearly shows a seasonal variation with a summer maximum.

The variations are indicated by monthly mean, obtained by averaging clear and overcastted days mean concentrations. The minimal, 20-35 µg/m<sup>3</sup> ozone concentrations were detected during winter period, the maximal, 60-100 µg/m<sup>3</sup> ozone content near the ground was observed in summer months.

Only in windless days diurnal cycle of ozone concentrations displays pronounced maximum in the early afternoon (12:00-14:00 Local Time). The forcing of the wind with increased speed and the cloudiness decreases ozone pollution. Average summertime daylight means at site vary from 100 to 50 µg/m<sup>3</sup>, depending on meteorological circumstances.

The peak concentrations during photochemical episodes rarely exceeded 130 µg/m<sup>3</sup> and are observed a several times during summer season.

It is considered that episodes with high surface ozone concentrations in southern Europe show local character and are associated with local primary pollutant emissions, but in western Europe summer smog is due to long-range transport of ozone and its precursors and so has transboundary character.

*Summary:* The experimental data from Sofia site and from other sites of Balkan peninsula (with the exception of Athens), for which information is available show that summer ozone concentrations (peak and average) have more lower values in comparison with those, measured in western and central Europe.

In general, the ozone pollution doesn't exceed the EU threshold values. The result is consistent with the model calculations, which show that in spite of the efficiency of the photochemical ozone production (the number O<sub>3</sub> molecules per NO<sub>x</sub> molecule) is higher in southern Europe than in western Europe, the chemical ozone formation per unit area is more intensive in the western part of the Continent due to the high precursors concentrations.

## DISSEMINATION OF RESULTS

### Data reporting

All data are being sent every month to the WMO World Ozone and UV Data Center operated by the Canadian AES in Toronto.

### Information to the public (e.g. UV forecasts)

In case of inquiry we provide roughly information on a base of distributed Large-Scale UV Index forecasts by Germany.

### Relevant scientific papers

1. **St. Kolev** and V. Grigorieva, *Surface and Total Ozone Over Bulgaria*, 2005, Kluwer Academic Publishers, NATO publishing unit, in press.
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## PROJECTS AND COLLABORATION

National project, Peculiarities in the ozon variations and a study of the proceessess which determine them. ; Project № H3 1406, 2004-2007,funded by the Bulgarian Ministry of Education and Science.

**FUTURE PLANS** (e.g. new stations, upcoming projects, instrument development)

NIMH would like to establish a regular station for ozone and UV solar radiation measurements. The very appropriate site is Ahtopol (42°05' 02,8" ; 27°57'08,2" ) . It is the former Bulgarian-Russian rocket station for middle atmosphere soundings and it is situated at the Bulgarian south Black sea coast.

**NEEDS AND RECOMMENDATIONS**

NIMH needs modern equipments for measuring total ozone and ozone profile, UV solar radiation , NOx profiles.

**AN OFFER:** The Bulgarian NIMH proposes, the former Bulgarian-Russian rocket station for middle atmosphere soundings at Ahtopol (42°05' 02,8" ; 27°57'08,2"), for a place of a permanent international site for measuring total ozone and ozone profile, UV solar radiation , NOx profiles, etc. Please, the interested potential participants to sent a letter of intent to the Bulgarian NIMH.

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