Network for the Detection of Atmospheric Composition Change

Newsletter

Volume 3, January 2008

The NDACC Newsletter is published by the NDACC Steering Committee. This is the third issue. The plan is to make one issue per year. The next issue is planned for the spring of 2009.

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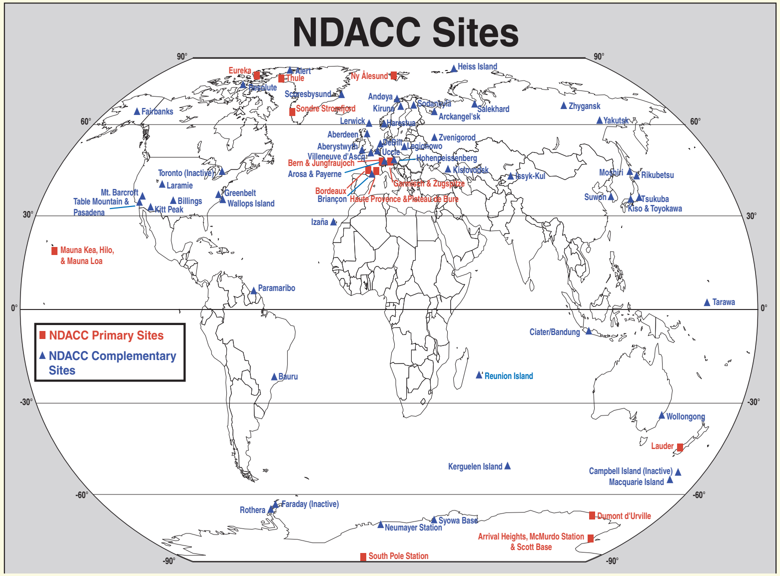


Cover photo: Lidar observations at the Table Mountain Observatory, California. Photo: Stuart McDermid.

Contents

NDSC becomes NDACC

The international Network for the Detection of Stratospheric Change (NDSC) was formed to provide a consistent standardized set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed research stations. Officially formalized and operational since 1991, the NDSC was set up during the late 1980s in response to the need to document and understand worldwide stratospheric perturbations resulting from increased anthropogenic emissions into the atmosphere of long-lived halogenated source gases with strong ozone-depleting and global-warming potentials.

The initial objective of the NDSC was to monitor, from pole to pole, the temporal evolution of the stratosphere, including its protective ozone layer, and to understand the causes (i.e., natural versus anthropogenic, chemical versus dynamical) of the observed changes and their impacts on the troposphere and at the ground. This dual goal of long-term global measurement and understanding has led to the implementation of a ground-based network of "primary" and "complementary" NDSC stations equipped with a suite of remote-sensing instruments, allowing the quasi-simultaneous study of a large number of chemical compounds and physical parameters.

Because of its worldwide dimension, the NDSC has been recognized as a major component of the international atmospheric research effort. As such, it has been endorsed by national and international scientific agencies, including the United Nations Environmental Programme (UNEP) and the International Ozone Commission (IOC) of the International Association of Meteorology and Atmospheric Physics (IAMAP). It also has been recognized by the World Meteorological Organization (WMO) as a major contributor to its Global Atmosphere Watch (GAW) Programme.

While the NDSC remains committed to monitoring changes in the stratosphere, with an emphasis on the long-term evolution of the ozone layer (its decay, likely stabilization, and expected recovery), its priorities and measurement capabilities have broadened considerably to encompass:

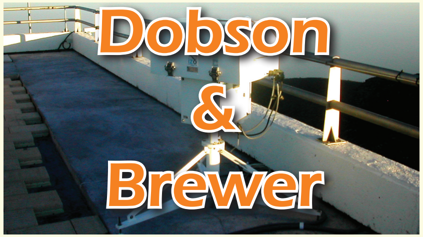
- detecting trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere,
- establishing links between climate change and atmospheric composition,
- calibrating and validating space-based measurements of the atmosphere,
- supporting process-focused scientific field campaigns, and
- testing and improving theoretical models of the atmosphere.

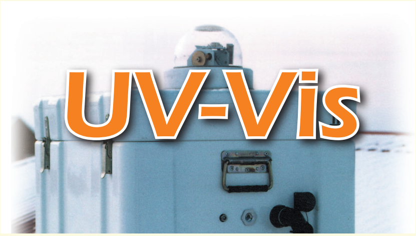
Many members of the atmospheric science community have noted that this expanded emphasis is not adequately reflected in the name of the Network and, in fact, that the word “Stratospheric” has led to a mistaken impression that the focus of NDSC activities is that of a “solved problem” (i.e., stratospheric ozone depletion). Hence, to better reflect the free tropospheric and stratospheric coverage of Network measurement, analysis, and modeling activities, as well as to convey the linkage to climate change, the Steering Committee voted to change the name of the network to the Network for the Detection of Atmospheric Composition Change (NDACC). The web site has been changed to:
http://www.ndacc.org.

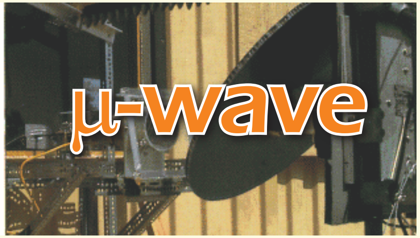
A new logo for the network has been made by Stuart McDermid, NASA Jet Propulsion Laboratory. It decorates the front page of this newsletter.

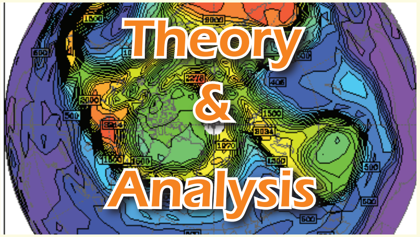
Working Group news

The NDACC consists of 9 working groups representing the various techniques that are used in the network: Spectral UV, Dobson and Brewer, Ozone and Aerosol sondes, FT-IR, UV-visible, Lidars, Microwave, Satellites, and Theory and Analysis. In this section we bring news from the various working groups. The text on each image is clickable.









Comparison of Ultraviolet Spectroradiometers in Antarctica

Richard McKenzie [1], Germar Bernhard [2], and Gunther Seckmeyer [3]

[1] *NIWA, Lauder, Central Otago, New Zealand*
[2] *Biospherical Instruments Inc., San Diego, CA, USA*
[3] *University of Hannover, Germany*

The UV group of NDACC met in Hannover in June 2006. One of the invited attendees was Germar Bernhard from Biospherical Instruments (BSI). This group is responsible for the U.S. National Science Foundation's (NSF) Ultraviolet Spectral Irradiance Monitoring Network (UVSIMN), which was established in 1987 for monitoring ultraviolet (UV) radiation at high latitudes [Booth et al., 1994]. These data sets are some of the most valuable resources of spectral UV irradiance in existence. Consequently, we decided to organize an in situ intercomparison between the NSF instrument at Arrival Heights and one of NIWA's NDACC-instruments to see whether the data complied with the criteria required for acceptance by NDACC [McKenzie et al., 1997]. The NSF instrument at Arrival Heights is similar to those at other NSF sites with the exception of the newer system at Summit, Greenland, which was successfully intercompared with an NDACC instrument in 2003 [Wuttke et al., 2006], as was reported in a previous Newsletter.

The campaign took place over the Austral summer of 2006-2007. Results from the campaign and instrument characterizations showed that the NSF data meet the NDACC criteria in most respects, including overall calibration accuracy and absolute stability. The cosine response error in the raw data was slightly larger than that required by the NDACC specification. However, for the observing conditions during the campaign, which were typical for high-latitude sites (e.g., no cumulus clouds), the data processing algorithms adequately corrected for these errors. There were two remaining areas where data did not quite meet the NDACC specifications: the wavelength precision was slightly poorer than required, and the threshold for minimum irradiance detectable was larger. These relatively minor deficiencies can be accommodated by including a statement in the UV metadata.

Measurements of this instrument were on average 5-7% lower than NIWA data (see **Figures 1** and **2**). This deviation is within the expected uncertainty of high quality spectroradiometers [Bernhard and Seckmeyer, 1999]. In addition, several factors that may cause these differences have been analysed. Several of these factors have systematic components, which happened to all act in the same direction. The sum of

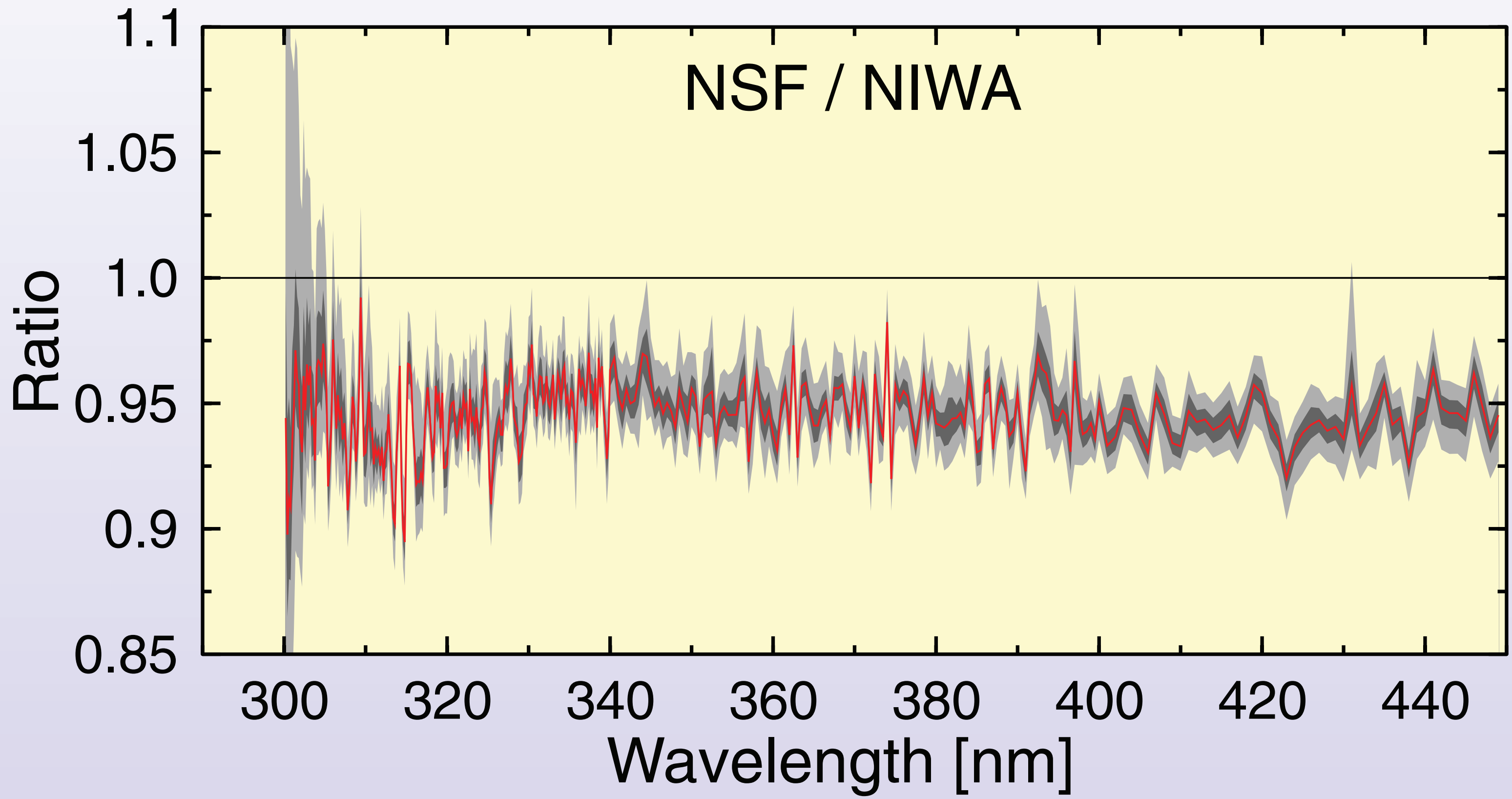


Figure 1. Ratio of clear sky spectra measured by NSF and NIWA. Red line is the median, calculated on a wavelength-by-wavelength basis, of all 1133 ratio-spectra recorded between November 2006 and January 2007. Dark gray shading indicate the 50%-percentile and light gray shading the 90%-percentile of ratio-spectra. Ratios within the 90%-percentile fall within a range of ±3% about the median for wavelengths larger than 315 nm, demonstrating good stability of both instruments in the UV-A and visible. At 305 nm, the spread of the range is ±5%. All spectra were normalized to a nominal bandwidth of 1 nm FWHM and corrected for timing differences of up to 3.6 minutes prior to calculating the ratio.

these factors was 5.2%, which can therefore explain all of the observed difference. The reasons were attributed as follows:

Bias	
Difference irradiance scales NSF – NIWA	1.3±0.3%
Diffuser geometry NIWA instrument	1.4±0.6%
Drift of NSF calibration standards	1.0±1.0%
Diffuser temperature dependence	0±1.4%
Photomultiplier high-voltage dependence NSF instrument#	1.5±1.0%
Sum	5.2±2.1%$

The biases are given as a range representing the maximum differences.
Bias is largest at small solar zenith angles.

$ The range of ±2.1% was calculated by the root of sum of squares of the individual components.

The campaign also highlighted a number of concerns with the NIWA instrument and data analysis procedures, including a wavelength offset error of 0.04 nm. These issues are being addressed as a result of the campaign.

Full results from the campaign are available in the work by Bernhard et al. [2008].

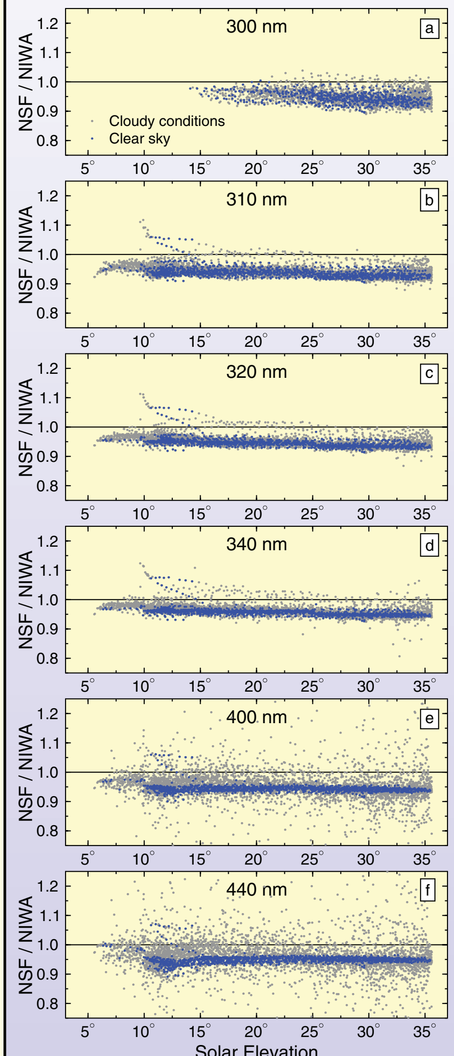


Figure 2. Ratio of measurements by NSF and NIWA as a function of solar elevation for several wavelengths. Blue (gray) dots indicate clear sky (cloudy sky) conditions. (a) 300 nm. (b) 310 nm. (c) 320 nm. (d) 340 nm. (e) 400 nm. (f) 440 nm. Ratios for clear and cloudy conditions deviate by less than 1% on average. The larger scatter in the cloudy-sky subset at 400 and 440 nm is mostly caused by timing differences of the two instruments of up to 3.6 minutes at those wavelengths. Scans were synchronized to within ±5 seconds up to wavelength 340 nm.

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Sky radiance in Hannover, Germany and Antarctica

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[1]Institute of Meteorology and Climatology, Leibniz University Hannover, Germany
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Abstract. Spectral sky radiance is a fundamental measurement quantity for the characterization of the atmospheric radiation field. We present results of spectral sky radiance measurements from Hannover (52.23°N, 9.42°E), Germany and the German Antarctic station Neumayer (70.65°S, 8.25°W).

The spectral sky radiance is a function of incident and azimuth angle, and it is not uniformly distributed over the sky. A distinct minimum can be found for all wavelengths opposite of the Sun whereas a maximum is to be found around the Sun. For wavelengths shorter than 500 nm the distribution of sky radiance is much more homogeneous and concentrates only around the Sun. For longer wavelengths the distribution of sky radiance becomes more inhomogeneous and concentrates additionally around the Sun also close to the horizon. The reason for the homogenous distribution of sky radiance for short wavelengths (**Figure 1**) is Rayleigh scattering

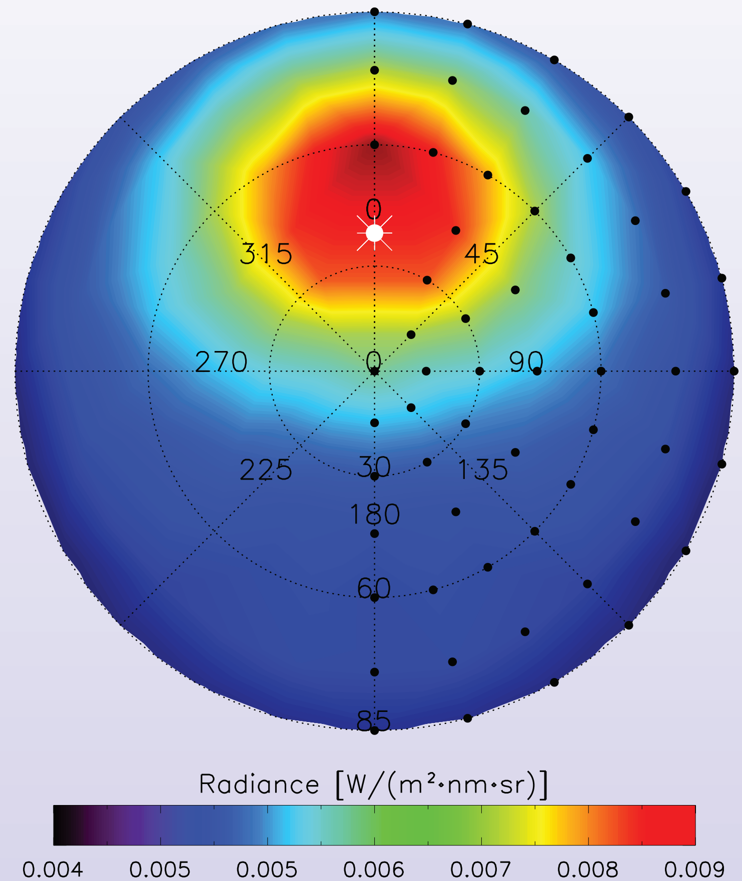

Figure 1. Spectral sky radiance measured at 305 nm in Hannover, Germany (52.23°N, 9.42°E) at 60 m above sea level on 2nd May, 2007 for a SZA of 39°. The radiance is mainly concentrated in the region around the sun.

since it is most effective for short wavelengths (Lenoble, 1993). The 500 nm radiance map (**Figure 2**) is inhomogeneous and shows horizon brightening in the direction of the Sun.

Measurements of spectral sky radiance from different directions are presented in **Figure 3**. Since sky radiance is scattered radiation, the actual values depend on the atmospheric constituents. The combination of extraterrestrial solar spectrum and Rayleigh scattering result in almost wavelength independent spectral sky radiance between 330 and 450 nm. Above 450 nm the spectral sky radiance decreases with increasing wavelength.

By comparing spectral sky radiance in Antarctica, where the spectral albedo (Wuttke et al., 2006) can reach values above 0.99, with low albedo situations we conclude that a snow covered surface can enhance horizon brightening compared to a low surface albedo by 40% for low sun (SZA=86°) and by 80% for high sun (SZA=48°). Furthermore, an overcast spectrum exceeds the cloud free spectrum by up to a factor of 100 due to radiation trapping between the high albedo surface and the clouds (**Figure 4**).

Results of model calculations for Antarctic conditions show fair agreement in the UV and in the visible, but shows significant deviations in the infrared.

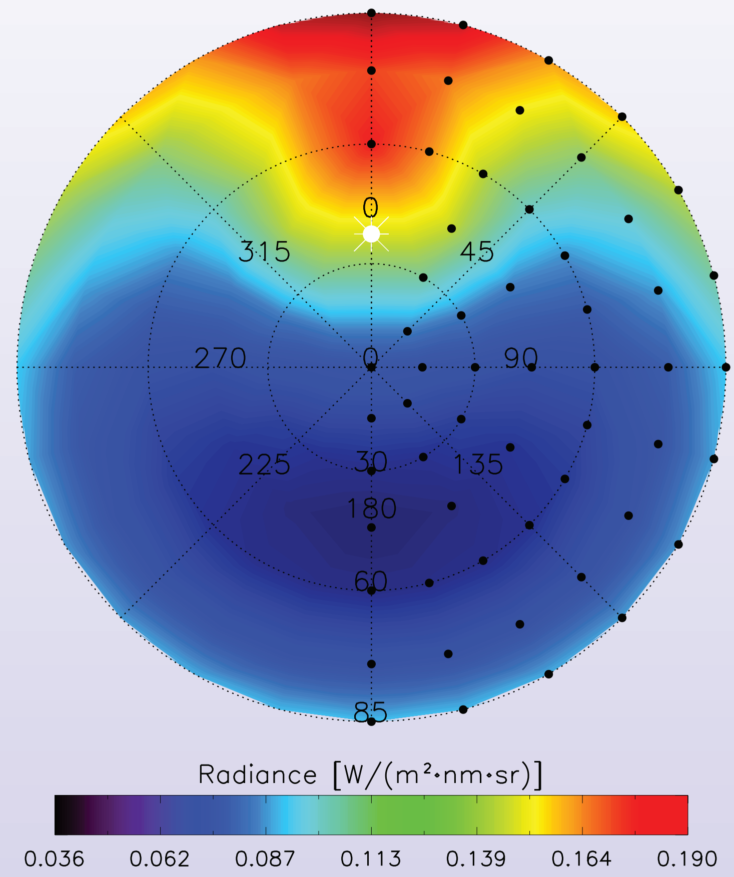

***Figure 2.** Spectral sky radiance measured at 500 nm in Hannover, Germany on 2nd May, 2007 for a SZA of 38°. The radiance is mainly concentrated towards the horizon and a slight enhancement of radiance at the horizon can be seen opposite of the Sun.*

References

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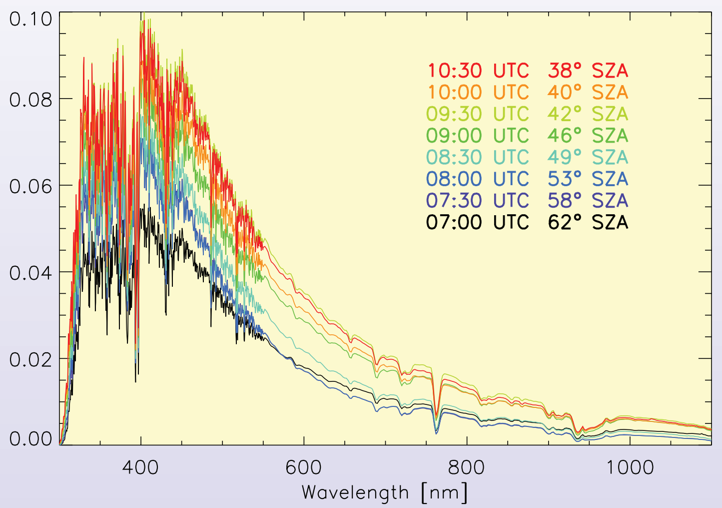

***Figure 3.** Spectral sky radiance measured between 290-1100 nm in Hannover, Germany on 2nd May, 2007. Each spectrum starts with an increase of sky radiance up to 330 nm followed by a constant part up to 450 nm. Then, each spectrum decreases to the maximum measured wavelength of 1100 nm following the Rayleigh scattering scheme.*

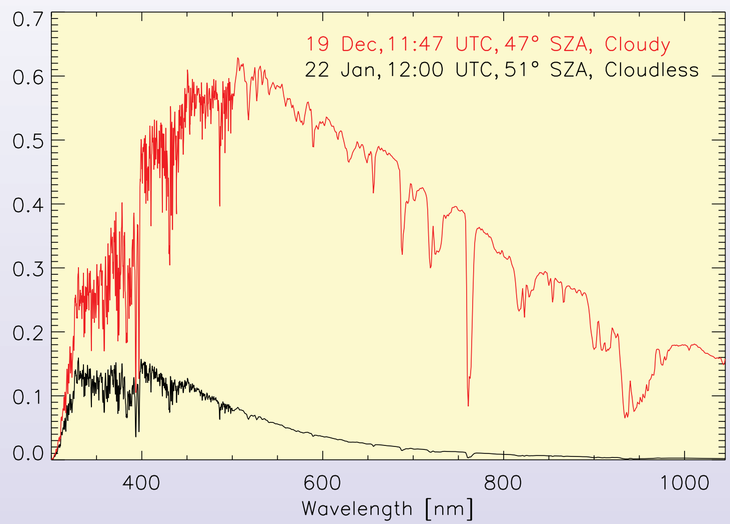

***Figure 4.** Cloudless (22 Jan., 2004, black curve) and cloudy (19 Dec, 2003, red curve) zenith radiance in Antarctica (70.65° S, 8.25° W). The maximum spectral radiance is shifted from the UV to VIS for cloudless and overcast sky, respectively.*

Dobson and Brewer Working Group

Intercomparison of Dobson spectrophotometers at Hohen-peissenberg in 2007, Germany. Photo: Ulf Köhler.

Quality Assurance and Quality Control (QA/QC) in the Dobson and Brewer Networks

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[2] Environment Canada - Toronto

Introduction

The Dobson and Brewer QA/QC programmes continue to work toward improving the quantity of high-quality data available for ozone trend analysis and satellite comparison. The Dobson calibration network has been operational for more than two decades and the main goal in recent activities is to stabilize the function of the existing parts and to establish new facilities in Regional Dobson Calibration Centres (RDCC‘s) in the WMO RA I (Africa) and II (South America). The scheme below (**Figure 1**) shows the current structure of the Dobson calibration network with one World Dobson Calibration Center (WDCC at NOAA, Boulder) and five RDCC’s, with all centres connected via travelling secondary standard Dobson No. 065.

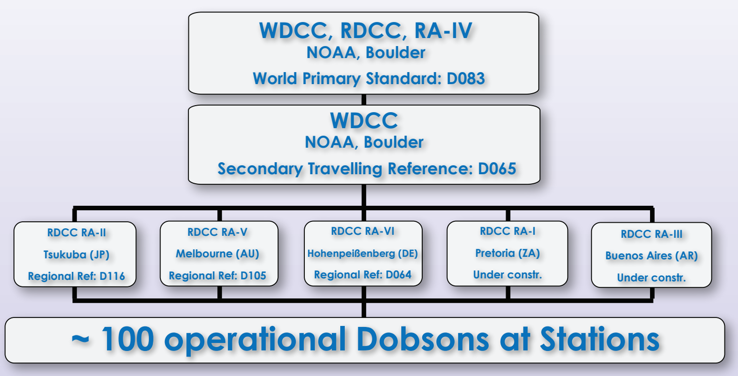


Figure 1. Structure of the calibration system for the global WMO-GAW Dobson network.

The primary reference for Brewer Ozone Spectrophotometers is essentially a Langley plot carried out with data from any well-characterized Brewer. Because the instrument has internal characterization tests (e.g. slit function, dispersion and stray light), the long-term reference for ozone measurements is de-coupled from the measurements made by any one particular instrument. However, it isn’t practical, and it is sometimes dangerous, to send individual instruments to a site which has observing conditions suitable for the determination of the extraterrestrial constant. For this reason, a triad of calibrated instruments is maintained at Toronto and a reference calibration provided by that group of instruments is transported to individual stations via a travelling standard instrument (most frequently the Environment Canada single Brewer #017). Most Brewers calibrated each year are calibrated against instrument #017 by International Ozone Services of Toronto, Canada.

However, there are a large number of Brewers in Europe and it has become apparent that the addition of a European calibration centre would be advantageous for providing reference data for European, Asian and African instruments. The Spanish government has funded a significant contribution to the global observing system by providing three double Brewers to the Izaña Observatory which acts as a regional standard for Brewer calibration.

Results of Recent Activities

Dobson Network

Seven International WMO Dobson Intercomparisons have been organized during the past two years by the various DCC's. **Table 1** gives a summary of these events.

Table 1: Summary of Dobson calibration events

Year	Location	WMO RA	# of Dobsons
2006	Melbourne	V	5
2006	Tsukuba	II	5
2006	Hohenpeissenberg	VI	6
2006	Arosa (by Hohenpeissenberg)	VI	3
2006	Buenos Aires	III	10
2007	Hohenpeissenberg	VI	5
2007	El Arenosillo (by Hohenpeissenberg)	VI	5

This number of calibrated instruments – 39 in two years – matches with the requirement of the WMO, that each operational Dobson should be calibrated within a four to five years cycle. Nine of these instruments are in operation at Primary or Complementary NDACC stations. In addition the operational regional standard Dobsons were undergone the regular calibrations (D064 in 2006, D105 in 2006, D116 in 2007) towards the world standards, to guarantee, that the calibration level of all Dobsons in the network can be traced back to the calibration of the primary standard instrument D083.

Figure 2 (next page), updated from the last report (2006), illustrates the success of this work maintaining a high level of data quality in the global Dobson network.

The refurbishment programme of the RDCC-E at Hohenpeissenberg was continued. Four Dobsons got the new electronic (US-type MOHp-modified), two of these at Hohenpeissenberg (D050 from Iceland in 2007, D103 from Antarctica in 2006). The refurbishment of the D051 and D101 were conducted by Swiss technicians themselves, who were trained in 2005 during the D062-upgrading at MOHp.

A special mission was the visit of the Observatoire de Haute Provence (OHP) by Bob Evans (WDCC) and Ulf Köhler/Bert Dömling (RDCC-E) in April 2007. It had turned out that the D085 of the NDACC primary station OHP and its auxiliary electronics for semi-automation was damaged by water impact. The hatch of the Dobson dome was unfortunately not automatically closed during a severe thunder shower. An overhaul of the instrument in the workshop of MOHp and subsequent calibration was necessary, to bring it back to normal operation.

Two standard instruments (D064 from MOHp, D065 from NOAA – Boulder) successfully participated in the SAUNA-campaign at Sodankylä (Finland) in spring 2006, where different total ozone instruments (Dobson, Brewer, SAOZ and DOAS) were intercompared for the purpose of improving satellite validation especially under difficult conditions (low sun and high ozone).

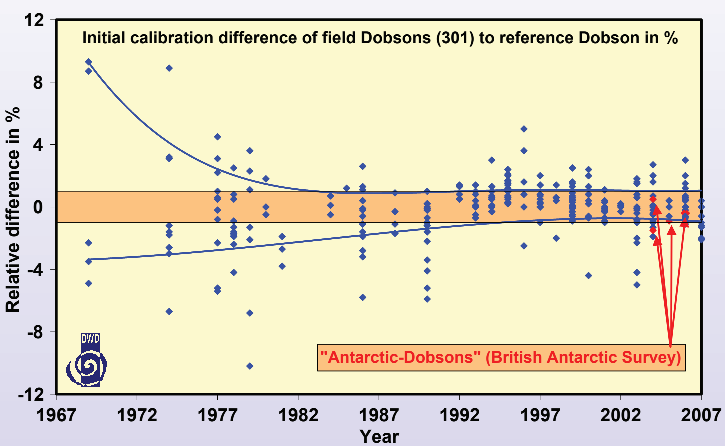


Figure 2. Relative difference of the calibrated Dobsons to the reference instruments during the Initial Calibrations (Status Quo at the beginning of an intercomparison)

The relocation of vacant Dobsons was pursued. In 2006 re-location of the instrument D049 from the University Bordeaux to the new station Lannemezan in Pyrenées (France) was assisted by the specialist from SOO-HK Hradec Kralove. Actual candidate for a relocation is the Belgium Dobson No. 040 (proposed new location La Reunion, NDACC-CS). Contacts and a kind of negotiations between the involved parties (Royal Meteorological Institute of Belgium R.M.I.B., AREP-WMO, l'Observatoire de physique de l'atmosphère de La Réunion OPAR, DAHC, RDCC-E) are already started). The future of the Dobson No. 008 from the PS Ny-Ålesund and of the other two Norwegian instruments (No. 14 Tromsø and No. 54 Oslo) is still unknown, potential instruments for relocation is Dobson No. 110 (Budapest, Hungary; interested country Croatia). The overhaul of the Italian D046 is not started yet, as it will consume a lot of time and success is not guaranteed.

Under activities on the capacity building two Dobson observers from the new GAW/KMD Nairobi station were trained at SOO-HK in 2006 (see **Figure 3** and **Photo 1**). The Dobson observations from this station have been re-evaluated and data submitted to WOUDC by experts of CHMI. Similar assistance on data re-evaluation was given by SOO-HK also to the Bangkok station after participation of the Czech specialists at the Dobson IC, Tsukuba 2006.

Brewer Network

During 2007 a total of 44 Brewers from 18 countries were repaired and/or calibrated. 12 countries were visited by International Ozone Services. Regular calibration visits continue to show benefits both from improving the performance of the hardware and software but also as a result of the instrument calibrations and staff training that takes place. Keep-

Photo 1. Training of Dobson operators from Kenyan Meteorological Department, Nairobi at SOO-HK, Hradec Kralove, Czech Republic.

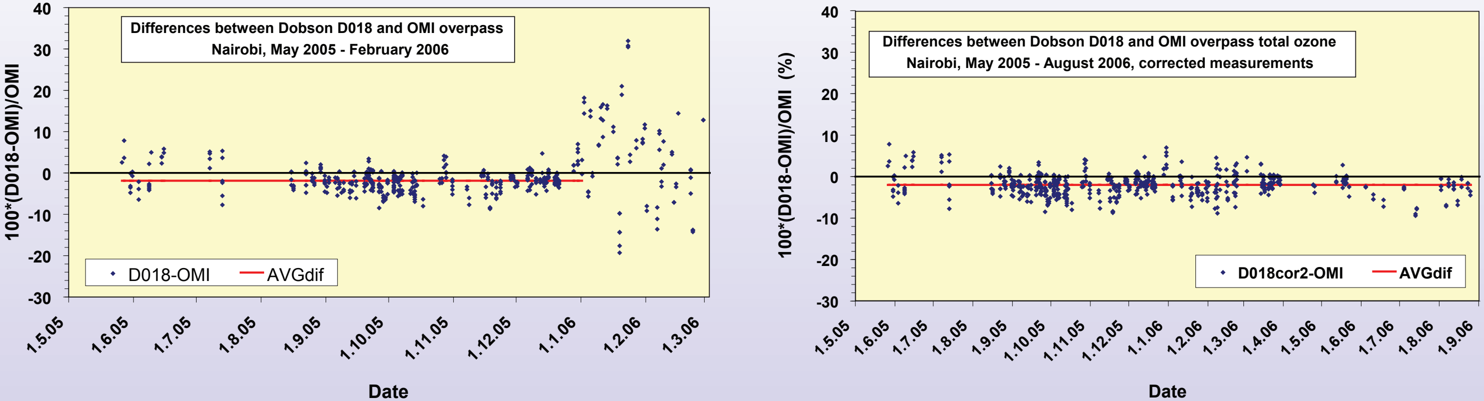


Figure 3. Re-evaluation of the Dobson observations from the new station in Nairobi, SOO-HK 2006

ing humidity out of the Brewer instruments is still the single most important issue and with a new type of rubber seal, this problem is finally being brought under control. Instrument levelling/sighting is another aspect that can easily jeopardize observations. An increase in the amount of hands-on training available at Brewer workshops is being tried as a way to remedy this problem.

Countries that brought their Brewers to one of the following calibration places I the last year include: Slovakia (to Czech Republic), Poland (to Czech Republic), Hungary (to Czech Republic), Morocco (to Spain/EIA), Portugal (to Spain/EIA) and Uruguay (to Spain/Izaña).

Table 2 provides details about calibrations performed in the following countries: Czech Republic, Denmark, Finland, Germany, Greece, H.K., Hungary, Italy, Morocco, Norway, Poland, Portugal, Slovakia, Spain,

Table 2: Brewer calibrations performed since the autumn of 2006.

Location	Country	Instruments	Month in 2007	Julian days
Houston	USA	#154	February	057-059
Hong Kong	H.K.	#115	March	079-082
Taipei	Taiwan	#023, #061, #129	March	083-091
University of Rome	Italy	#067	April	104-106
Aosta	Italy	#066	April	109-113
Hohenpeissenberg	Germany	#010	May	122-124
Lindenberg	Germany	#030, #078, #118	May	125-131
Hradec Kralove	Czech Republic	#064, #097, #098, #152, #184	May	133-138
Jokioinen	Finland	#107	May	141-143
Sodankylä	Finland	#037	May	144-147
Alomar	Norway	#104	May	149-151
Oslo	Norway	#042	June	154-156
Thessaloniki	Greece	#005, #086	June	170-173
Athens	Greece	#001	June	174-178
Arosa	Switzerland	#040, #072, #156	July	201-208
Copenhagen	Denmark	#053, #082	August	225-230
Izaña	Spain	#155, #157, #183, #033, #185	August	240-245
El Arenosillo	Spain	#051, #070, #117, #150, #151, #165, #166, #172, #075, #102, #186	September	246-254

Switzerland, Taiwan, Uruguay and USA.

Brewer User's Workshops

Normally, Environment Canada and WMO host a workshop for Brewer users every other year. However, 2007 was the 20th anniversary of the signing of the Montreal Protocol to Protect the Ozone layer. As part of the world-wide celebration it was decided to host two workshops in 2007, one in Europe and one in Asia. The European workshop was held in Northwich, England at the beginning of June. It was hosted by John Rimmer at Manchester University and drew approximately 50 attendees. It was a very successful meeting and included both tutorial sessions on Brewer operations and a 'hands-on' day to aid operators in identifying technical issues in the operation of their instruments. The second workshop, the first in Asia since the Japanese workshop in 2000, was hosted by Jhoon Kim at Yonsei University in Seoul, South Korea at the end of October. Approximately 25 people attended the meeting.

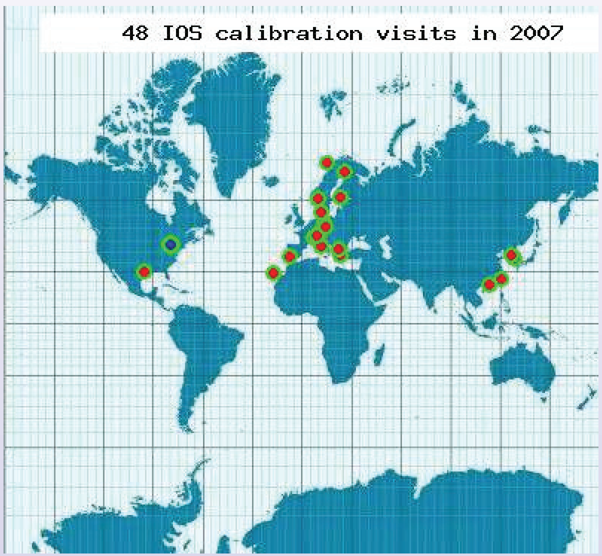


Figure 4. A map of countries visited for calibrations in 2007. On the map it says 45 countries because Toronto is always included in this web plot (IOS web site http://www.IO3.ca *).*

Instrument Intercomparison and Data Re-evaluation

A major intercomparison of Brewers was hosted in Spain at the El Arenosillo Observatory. A total of 16 Brewers were compared. Instruments on site included #185 double Brewer form Izaña, a Spanish reference instrument and single Brewer #017, the Canadian travelling standard instrument and #145 a double from Toronto with an independent calibration history from Mauna Loa Observatory. On one day, using previous calibration constants, 15 of the instruments (not including #185) provided lamp-corrected data with a full range of 6 DU, less than 0.4% rms. Some instruments had not been calibrated for 4 years.

This exercise underlined the fact that Brewer data are highly correctable for known changes in calibration. Indeed, in most cases simply making a standard lamp correction, as is done operationally for the Dobson, removes drift in the data record to a very high accuracy (<0.4%). The data set from Hong Kong is a good example. The re-analysis of these data has been published as a journal paper [Lam et al., 2006].

Figure 5 shows the standard lamp record for Brewer #115. The large drift in the standard lamp ratios (3 units on the R6 scale is approximately one Dobson Unit) was cause by improper sealing of the instrument. Humidity caused drift to occur in the order-sorting filter in the PM housing resulting in instability in the lamp ratios and in the ozone and SO_2 calibrations. The drift was finally stopped in December 2003 with the replacement of the faulty seals and drifting filter. However, using the standard lamp record, the authors constructed a proxy calibration history based on the intercomparison points and the information on drift contained in the standard lamp record. The resulting calibration 'history' (**Figure 6**) was used to re-analyze the data. The resulting corrected total ozone time series is shown in **Figure 7**.

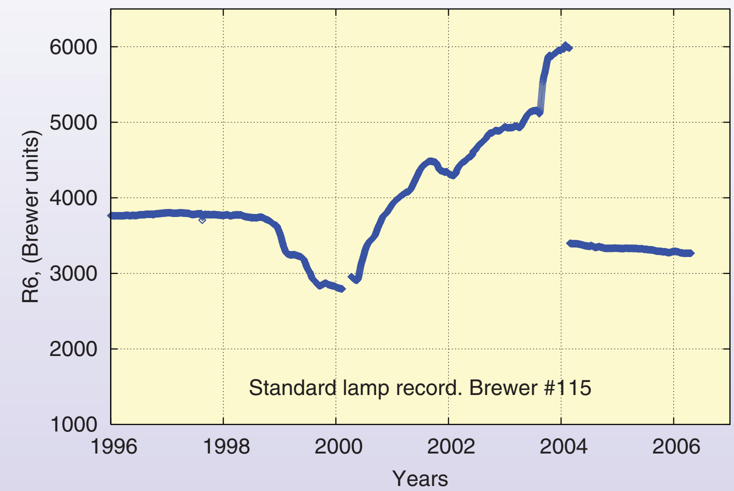


Figure 5. Standard lamp record for Brewer instrument #115. R6 (ordinate) changes along with the instrument response to ozone. 3 units is approximately 1 Dobson Unit.

WMO Ozone SAG Technical Panel

In a bold new initiative, the WMO Ozone Scientific Advisory Group struck a technical panel to evaluate and report on Brewer and Dobson station data quality based on a comparison of satellite and ground-based data. Gordon Labow of NASA Goddard and Vitali Fioletov of Environment Canada were both asked to prepare an analysis that used satellite data as a method of assessing the long-term consistency of ground-based data records and to compare results from stations located near each other. This analysis has lead to a report to each station suggesting steps

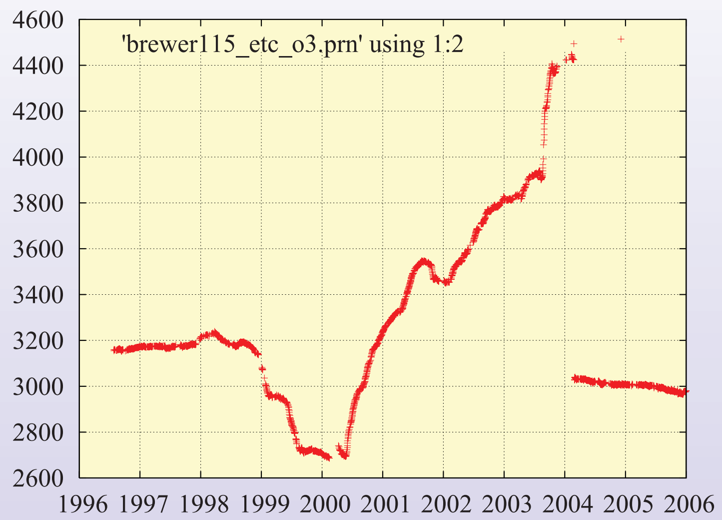


Figure 6. A re-constructed calibration history for Brewer #115 based on the intercomparison data and the standard lamp record.

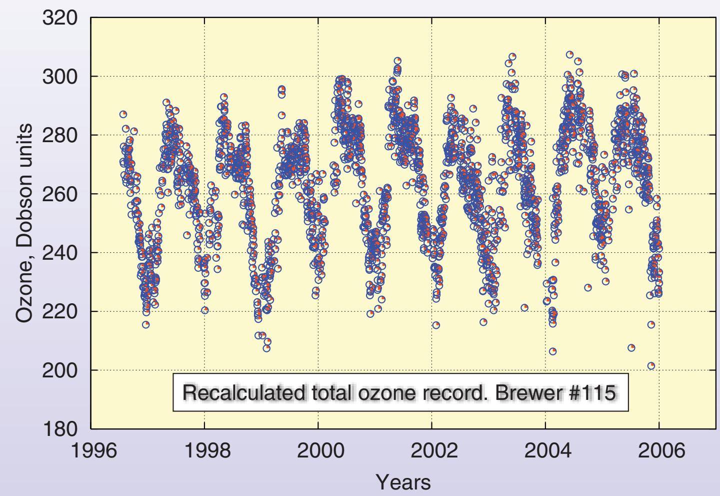


Figure 7. The corrected ozone record for Hong Kong.

to take to produce an improved, reprocessed data set. Letters were sent out in October informing all stations of the results of the analysis and a short report on the performance of the global network was prepared for WMO. The findings indicated that of Brewer and Dobson stations that have long-term records with suitable for long-term trend studies, approximately half of the instruments of each type are producing data of adequate quality. Re-analysis should improve these numbers with a larger improvement expected in the number of Brewer data sets.

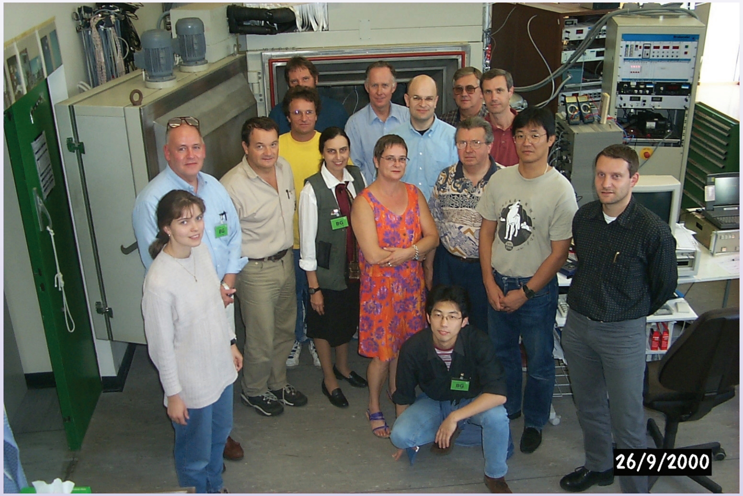
References

Lam, K.S., V. Savastiouk, W.Y. Fung, T.K. Chan, and K. Lamb (2007), Recalculation of 11-year total ozone of Brewer spectrophotometer 115, J. Geophys. Res., 112, D15104, doi:10.1029/2006JD008178)

Aerosol and Ozonesonde Working Group report

1. Standard operating procedures for ozonesondes

Herman Smit, Forschungszentrum Jülich, is nearing completion of the second draft of a World Meteorological Organization (WMO) document on Standard Operating Procedures (SOPs) for ozonesondes. This document, which will contain recommendations regarding instrument preparation, preliminary and preflight, data processing, data formatting, and explanations of the rationale behind the procedures, is planned to be made available to the ozonesonde community in January 2008. The SOPs in their basic form, as formulated by Advisory panel on SOPs for ozonesondes (ASOPOS) in September 2004 has been approved by WMO/ Global Atmospheric Watch (GAW)-Scientific Advisory Group in April 2007. The version to be made available in early 2008 will be open for comment from the community for several months. After that time the comments received will



Participants to the second JOSIE 2000 campaign.

The JOSIE simulation chamber.

be addressed by the document prior to its publication and dissemination by the WMO/GAW program.

The recommendations in the SOPs are supported by several papers published, or in press, related to standard operating procedures for ozonesondes. The first of these Smit et al. [2007] presents the results of three laboratory tests comparing SPC-6A and ENSCI-Z ozonesondes in the environmental simulation facility at the Research Centre Jülich within the framework of the Jülich Ozone Sonde Intercomparison Experiment (**JOSIE**).

1.1 Laboratory comparisons of ozonesonde performance (JOSIE)

The experiments have shown that above 20 km the ENSCI-Z sonde tends to measure 5–10% more ozone than the SPC-6A sonde, while below 20 km the differences are 5% or less. There is also a significant difference when sondes of the same type are operated with different cathode sensing solutions. For both ECC manufacturer the use of 1.0% KI and full buffer gives 5% larger ozone values compared with the use of 0.5% KI and half buffer, and as much as 10% larger values compared with 2.0% KI and no buffer. Thus changing the sensing solution type or

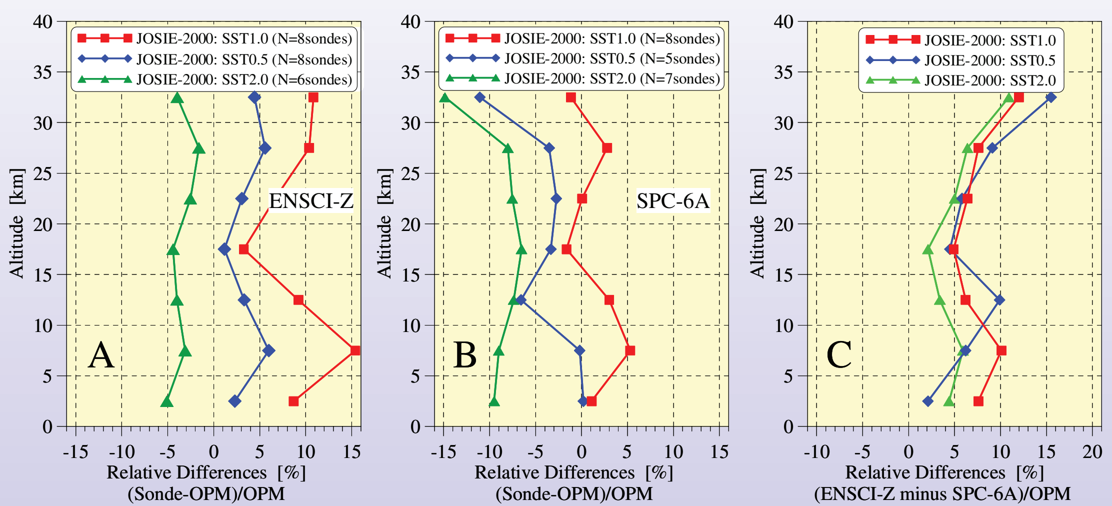


Figure 1. JOSIE: Differences of ENSCI-Z (A) and SPC-6A sondes (B) relative to UV-photometer (OPM) and relative differences between both sonde types (C) for use of SST1.0, SST0.5 and SST2.0 during JOSIE 2000. All sondes were prepared according to Komhyr [1986]. All data were processed with pump correction from Komhyr [1986], pressure dependent background correction and no total ozone normalisation. Data are averaged over 5 km altitude bins.

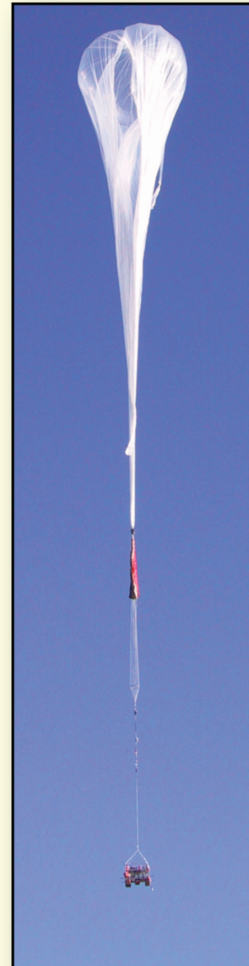
electrochemical concentration cell (ECC) sonde type can easily introduce a change of ±5% or more in long term records. Standardization of operating procedures for ECC-sondes yields a precision better than ±(3–5)% and an accuracy of about ±(5–10)% up to 30 km altitude. **Figure 1**, from Smit et al., 2007 summaries the results from the three JOSIE experiments. For this figure SST0.5 = 0.5% KI, SST1.0= 1.0% KI and SST2.0= 2.0% KI. These solution strengths and the two different sonde types are compared with the reference photometer.

Sondes on the gondola ready for launch during the BESOS campaign.

1.2 Atmospheric comparison of ozonesonde performance (BESOS)

The second paper related to comparisons of the performance of ozonesondes made similar comparisons but during a balloon borne atmospheric measurement (BESOS) which compared 18 ozonesondes with an ozone photometer, and with ozone column measurements from Dobson and Brewer spectrophotometers in April 2004 [Deshler et al., 2008].

The core experiment consisted of 12 ECC ozonesondes, 6 from Science Pump Corporation (SP) and 6 from ENSCI Corporation (ES), prepared with cathode solution concentrations of 0.5% KI (half buffer) and 1.0% KI (full buffer). Auxiliary ozonesondes consisted of 2 electrochemical concentration cell sondes with 2.0% KI (no buffer), two reconditioned sondes, and two Japanese-KC96 sondes. Precision of each group of similarly prepared



Balloon ascent early in the morning of 13 April 2004.

ozonesondes was < 2-3%. The 6 ozonesondes prepared according to the manufacturer's recommendations (SP, 1.0% KI, ES 0.5% KI) overestimated the photometer measurements by 5-10% in the stratosphere, but provided ozone columns in good agreement with the ground-based spectrophotometer measurements. This is consistent with the difference (~5%) in ozone photometer and column measurements observed during the experiment. Using cathode cell concentrations of 1.0% KI for ES sondes caused over estimates of the photometer by 10-15% and of ozone column by 5-10%. In contrast 0.5% KI in SP sondes led to good agreement with the photometer, but underestimates the ozone column. The

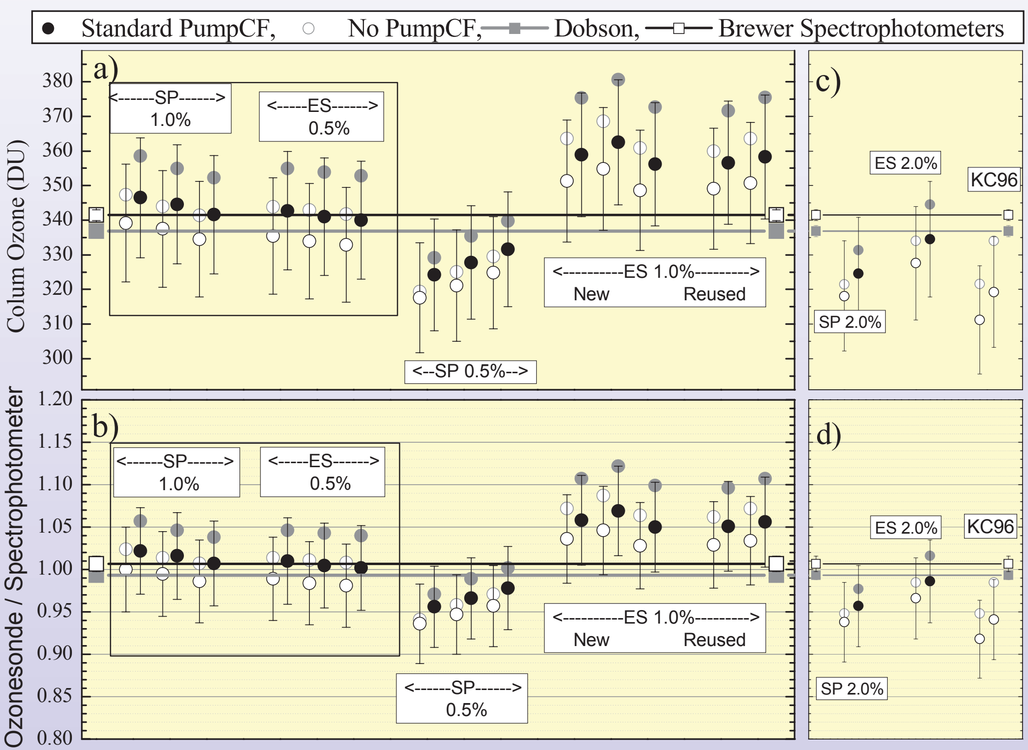


Figure 2. *a) Integrated ozone from the 12 core ozonesondes (3 SP1.0, 3 ES0.5, 3 SP0.5, and 3 ES1.0), two reused ES1.0 ozonesondes, circles with error bars, and from Dobson and Brewer spectrophotometers located at the launch site, lines with boxes and error bars. The ozonesonde measurements are extrapolated using both the SBUV climatology (40 DU for April at 41°N) black circles filled and open [McPeters et al., 1997], and at constant ozone mixing ratio above the last ozone measurement, gray circles filled and open, without error bars. Results with and without the standard pump efficiency correction [Komhyr, 1986] for measurements at low air pressures are shown. The error bars indicate a precision of 5%. The standard deviation of the seven Dobson and Brewer spectrophotometer measurements completed during the balloon flight do not exceed the symbol sizes. b) As in a) but ratios of integrated total ozone from the ozonesondes to the average of the Dobson and Brewer measurements. c) and d) Same as a) and b) for the other 4 auxiliary ozonesondes flown (1 SP2.0, 1 ES2.0, 2 KC96). Results from the manufacturer's recommendations for solution strength are enclosed in the box in a) and b).*

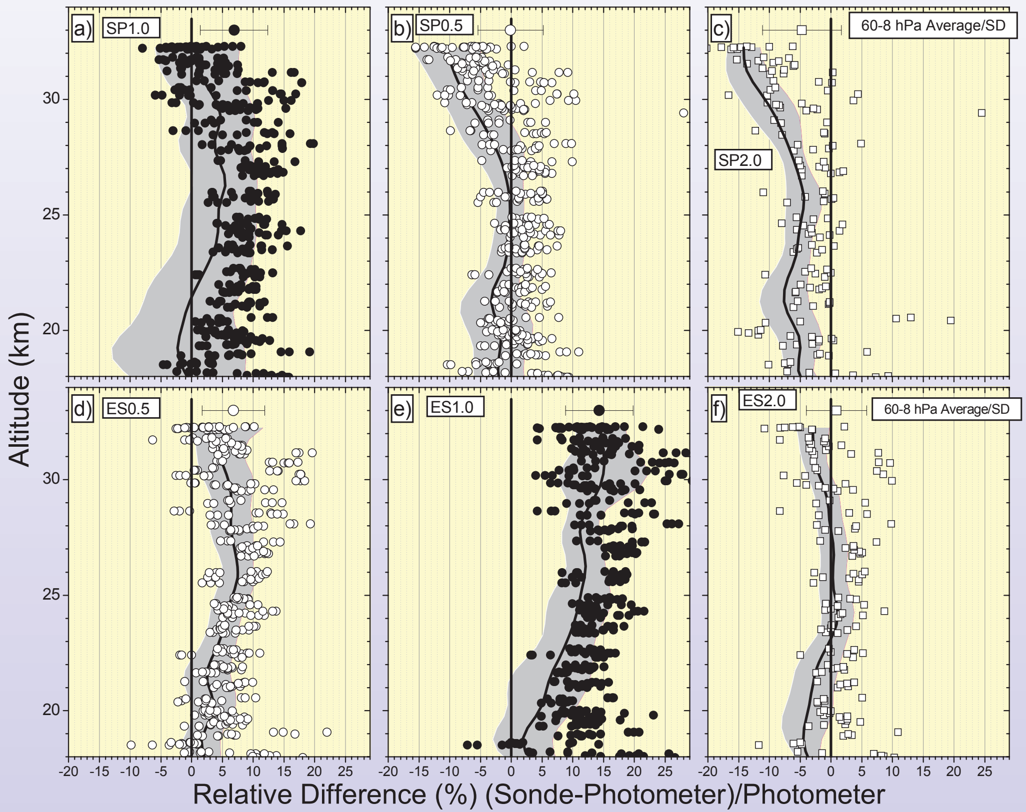


Figure 3. *Relative differences (ozonesonde-photometer)/photometer as a per cent for balloon-borne and laboratory [Smit et al., 2007, Figure 7] measurements at air pressures of less than 70 hPa for: a) SP1.0, b) SP0.5, c)SP2.0, d)ES0.5, e) ES1.0, and f) ES2.0. The number of balloon-borne photometer measurements at higher pressures was too few to warrant a comparison with the laboratory measurements. The laboratory results represent the mean (solid line) and standard deviation (shaded area) of approximately 8 individual measurements for each sonde type and solution strength (JOSIE 2000). The balloon measurements for panels a), b), d), and e) are the measurements from the three core sondes flown at 0.5KI (open circles) and 1.0KI (closed circles). The balloon measurements in panels c) and f) are the result of the single SP/ES sondes flown at 2.0KI (open boxes). The single data point at 36 km in each panel indicates the mean and standard deviation for the set of balloon-borne comparisons shown in that panel. For this comparison the JOSIE results are processed in the same way as the balloon measurements.*

KC96 sondes underestimated the photometer measurements by about 5-15% at air pressures above 30 hPa. Agreement was within 5% at lower pressures. **Figure 2**, from Deshler et al., summarises the comparisons with column measurements, while **Figure 3** summarises the comparisons above 20 km where the in situ ozone photometer worked well. In both these figures SP1.0, ES0.5 indicate 1.0% KI in Science Pump and 0.5% KI in ENSCI ozonesondes, etc. The results of the balloon experiment are also compared with the JOSIE experiments in **Figure 3** (from Deshler et al. [2008]).

1.3 Comparisons of ozonesonde performance through dual flights

To complement the previous laboratory and field results, individual programs of dual flights have been carried out by individual groups. In late November 2006 a group meeting took place in Payerne, Switzerland, to share the results of these dual flight experiments. This first overview of these results has shown that the different stations produce consistent results, and that these results agree with the BESOS data presented above. The final analysis is ongoing and the results should be published in 2008. The different institutions represented at that meeting, and the location of the dual flights, are listed in the first of the following tables, while the different flight configurations that have been tested are described in the second table.

Table 1: Stations that carry out dual flights and that were represented at the November 2006 meeting in Payerne.

Institution	Station Location	Latitude, Longitude	Station Altitude (m)	PI
Finnish Meteorological Institute (FMI)	Sodankylä, Finland	67.4°N, 26.6°E	179	R. Kivi
Environment Canada (EC)	Saskatchewan, Canada	52.0°N, 107.0°W	510	J. Davis
University of Wyoming (UWY)	McMurdo, Antarctica	77.8°S, 166.7°E	10	J. Mercer
Federal Office of Meteorology and Climatology, MeteoSwiss (MCH)	Payerne, Switzerland	46.8°N, 7.0°E	491	R. Stübi
Goddard Space Flight Centre (NASA)	Virginia, USA	37.9°N, 75.5°W	12	F. Schmidlin

Table 2: Different flight configurations that have been tested

	Ens-1% vs. Ens-0.5%	SPC-1% vs. SPC-0.5%	Ens-1% reused vs. Ens-0.5%	SPC-1% vs. Ens-0.5%	SPC-1% reused vs. Ens-0.5% resused	SPC-1% vs. Ens-1%	SPC-1% resused vs. Ens-1% resused	SPC-0.5% vs. Ens-0.5%	SPC-2%u vs. SPC-1%	Ens-2%u vs. Ens-1%	Ens-0.5% vs. Ens-0.5% resused
NASA		22				17			2		
FMI	4		4	10	8	11	11	1			
AES		5							5		
UWY	19									7	
MCH	34			30							30
Total	57	27	4	40	8	28	11	1	7	7	30
										Total	**220**

1.4 Technical issue: Change of meteorological sondes

Sounding stations from the NDACC network and elsewhere are facing the problem of the discontinued production of the Vaisala RS80, a standard at many stations for a long time. In spite of stockpiles of RS80 sondes, stations are now running out of these sondes and are obliged to upgrade to a new system for meteorological variables. A number of options are available including the Vaisala RS92, the French MODEM, or the Swiss Meteolabor. Below is a list of stations which have selected these various options as well as links to information for these systems.

In Uccle, the RS80 has been replaced by the RS90 / RS92 and the DIGICORA III system.

(http://www.meteo.be/meteo/view/fr/66980-Recents.html?view=1144298).

In Canada all operational sites are using RS92 and Vaisala receiving stations for the ozone soundings.

In Réunion Island, the RS80 has been replaced by the French sondes system called MODEM (http://www.meteomodem.com/sceneindex_content.html). The MODEM system has also been selected by MeteoFrance for their aerological soundings.

The different stations under the ESRL (Earth System Research Laboratory, Global Monitoring Division) responsibility are still measuring for a few years with RS80 thanks to a large stock of sondes.

For the Nairobi station of the SHADOZ network, the options are still open but the product from the Swiss company Meteolabor (http://www.meteolabor.ch/e/english.htm) is considered as a possible alternative to the Vaisala system.

2 Scientific Activities

2.1 Ozonesonde observations during the Sodankylä Total Column Ozone Intercomparison and Validation Campaign (SAUNA)

The Sodankylä Total Ozone Intercomparison and Validation Campaign (SAUNA) was conducted in March -April 2006 in Sodankylä, Finland (67.4°N, 26.6°E) to validate the performance of ground-based and satellite borne ozone sensors at high latitudes. Among other measurements a total of 33 balloon borne ozonesonde observations were made in the time period of 22 March - 14 April 2006 timed to the ozone measurements on board the NASA Aura satellite. The sounding system used was the new version of the DigiCora ground station and the Metgraph software by Vaisala allowing the use of the digital RS92-SGP radiosondes. The ozonesondes reached average altitudes of 7 hPa, which allows reliable total column estimation. The total ozone from sondes was compared to the total ozone measurements based on five Brewer spectrophotometers operated in Sodankylä during the campaign and the OMI instrument on board the Aura satellite. The campaign period in spring 2006 was characterized by large short-term ozone variability, and strong horizontal gradients in ozone. During the ozonesonde measurements the lowest (highest) ozone columns were 416 (501) DU with an average of 459 ± 24 DU. Yet the total ozone from the sondes agreed extremely well with the best total ozone estimate using five Brewer spectrophotometers (average difference -0.8 ± 1.5%). The difference using the OMI measurements was similar, 1.0 ± 2.0 %. In addition profile comparisons with ozone LIDAR and a series of dual ozonesonde flights were completed. In each dual sonde payload an EN-SCI ozonesonde was flown using 0.5% KI sensing solution and a SPC ozonesonde using 1% KI

Launching ozonesondes from Sodankylä during SAUNA using a rubber balloon.

Launching ozonesondes from Sodankylä during SAUNA using a polyethylene balloon.

solution. These flights showed an average agreement better than 2% in the stratosphere.

2.2 ORACLE – O3

From June to October 2007 the second Antarctic Match campaign was conducted as part of the International Polar Year project (ORACLE-O3). Almost 300 ozonesondes were launched. This experiment involved NDACC stations at Neumayer, Dumont d'Urville, McMurdo, and South Pole, in addition to Belgrano, Davis, Syowa, Halley Bay, and Dome C. A very preliminary result of the campaign is shown in **Figure 4**, which shows the ozone loss rate per day within the polar vortex between 450 and 500 K potential temperature (around 20 km). Notice the increase in ozone loss when the sun returns and the decrease after about day 260 when no ozone is left. In addition there is zero ozone loss (in this height region) during most of October, which shows very nicely the insensitivity of the method to mixing.

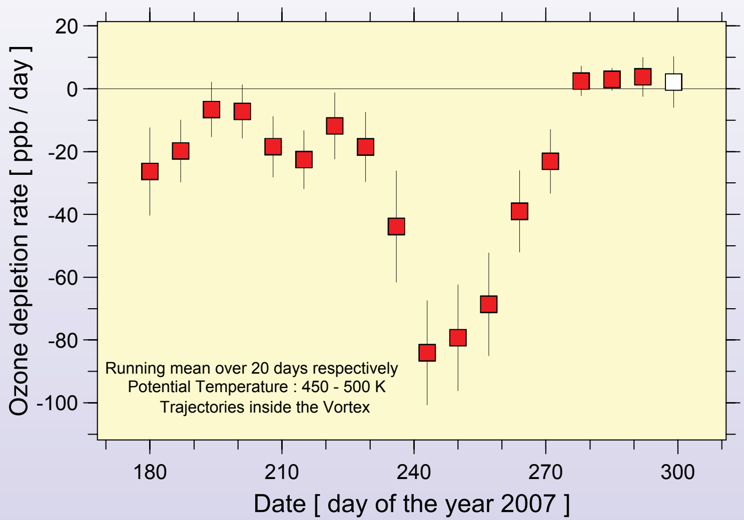


Figure 4. Ozone loss rate over Antarctic, June – November 2007, derived from the second Antarctic Match campaign.

2.3 Ozonesonde times series from stations

The NDACC network is based on long term regular operation of measuring systems. The various ozonesonde stations attached to NDACC are producing longer and longer times series of the ozone content in the atmosphere from the station altitude up to about 30 km. In the figures below, long term series are illustrated for two stations:

a) Results from the last 20 years series from Neumayer/Forster Antarctic station are summarized **Figures 5** and **6**. Further information can be found under the link: http://www.awi.de/en/infrastructure/stations/neumayer_station/observatories/meteorological_observatory/upper_air_soundings/ozone_soundings/,

b) The 40 years from Payerne mid-latitude station are summarized in **Figures 7** and **8**. Further information can be found under the following link:

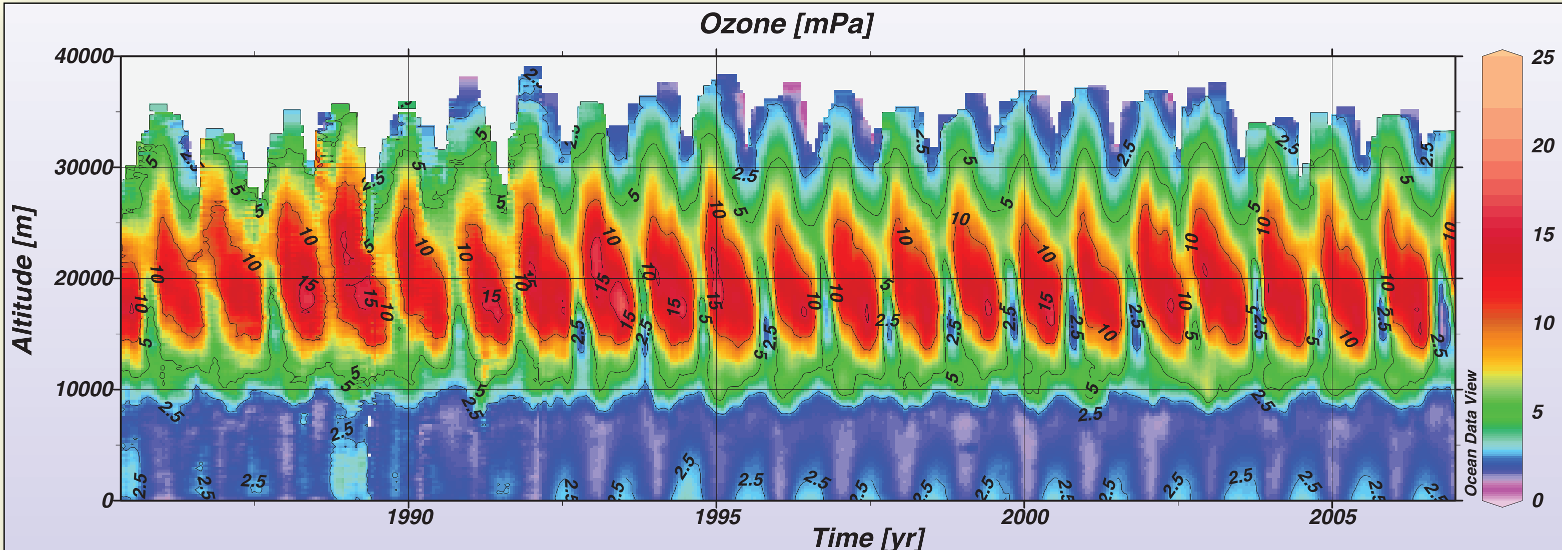


Figure 5. 2D plot of the ozone time series from the Neumayer sounding station located in Antarctica.

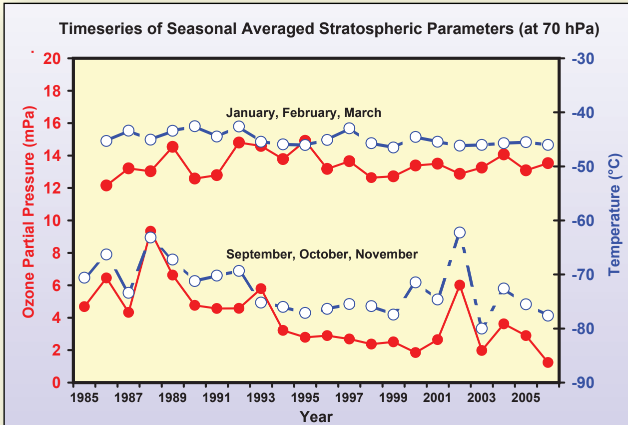


Figure 6. Seasonal ozone time series on the 70 hPa pressure level (~ 18 km) for ozone and temperature for the Neumayer station.

http://www.meteoswiss.admin.ch/web/en/weather/ozone_layer.html. The Payerne station is under the responsibility of MeteoSwiss since 1968. A first two years of sounding has taken place in the Zürich area between 1966 and 1968. The Brewer-Mast sonde was used until September 2002 when it was replaced by the ECC (ENSCI-0.5% KI solution).

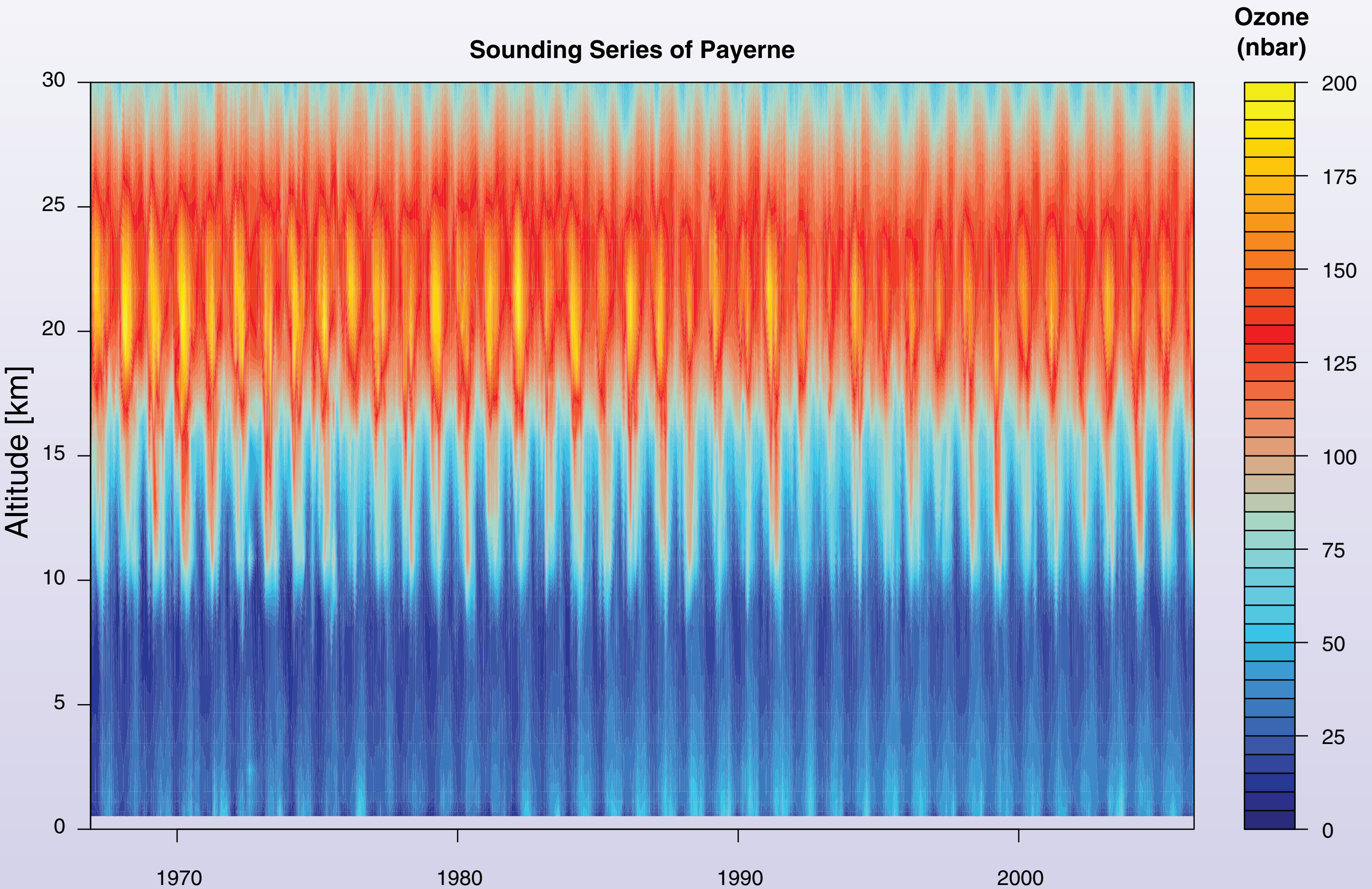


Figure 7. 2D plot of the ozone time series from the Payerne sounding station located in the Swiss Plateau.

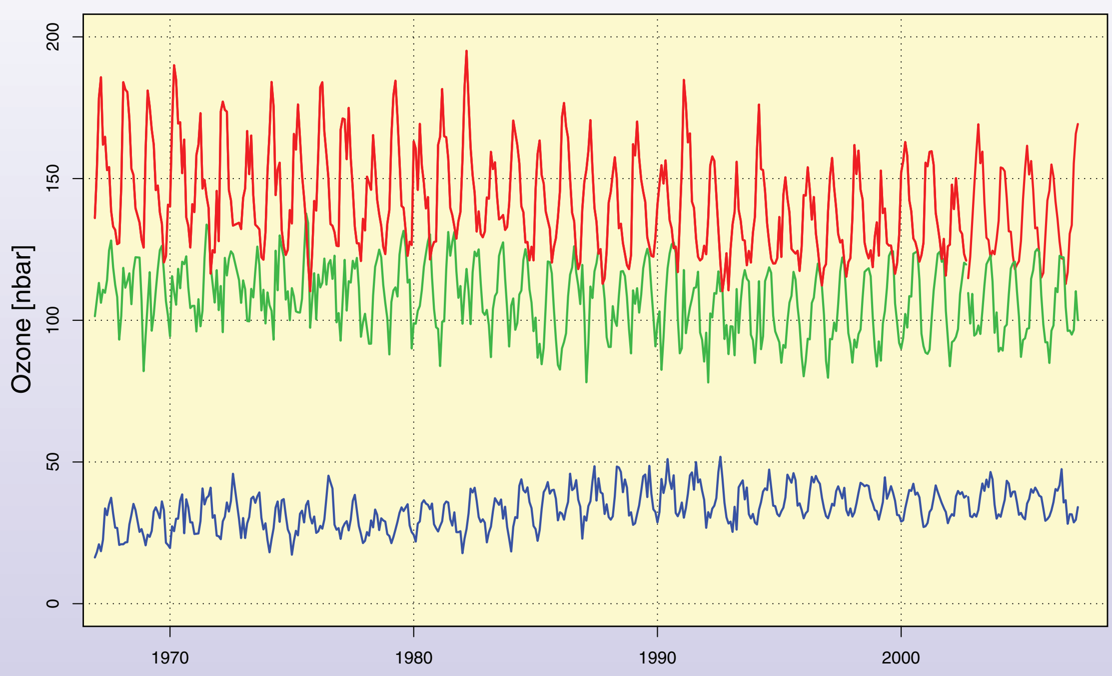


Figure 8. ***Ozone time series for altitude level 3 km (blue), 22 km (red) and 27 km (green) for the Payerne station.***

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FT-IR Working Group

The annual infrared working group meeting in May 2007 assembled more than 40 scientists.

Report from the 2006 IRWG Annual Meeting

Jim Hannigan, Martine De Mazière, Peter Woods, co-chairs IRWG

The NDACC-IRWG met for its annual meeting in Tsukuba, Japan on 8-10 March 2006. The meeting is hosted at a different NDACC site each year which allows the IR community to better understand the uniqueness of each site, to share the effort in hosting the meeting and affords the opportunity to participate in the meeting to local students and young scientists. We were very pleased to have our first meeting in Japan on the occasion of the 10th anniversary of ground-based solar absorption FTS measurements at the NDACC complimentary site in Moshiri, Japan. The meeting of 40 attendees was graciously hosted by Hideaki Nakajima (NIES).

Presentations covered a wide range of topics from data archiving to instrument and analysis validation, from improvements in data processing and diagnostic techniques to new data products. Since validated, long-term trends in atmospheric composition is a primary mission of NDACC we had several discussions on continuing calibration methods and improvements to the calibration analysis. This is especially important in light of the difficulty in side-by-side instrument intercomparisons. Revision of the certification/validation procedure was discussed and is on-going. We identified a need to address the issue of instrument upgrade or replacement and the possibility of a change of a site's management from one PI to another.

As the network focus evolves from stratospheric change to atmospheric composition, high-resolution solar absorption FTS spectra can be re-analyzed to retrieve information targeted to alternate altitude regimes. Two presentations illustrated the extension of trace gas profile retrieval techniques to high altitudes. One focused on stratospheric – lower mesospheric CO and the other on mesospheric - thermospheric NO. Also presented were retrievals and analysis of tropospheric H_2O and HDO. It was shown that profile information content was improved by constraining the isotopic ratios while retrieving both species simultaneously. Further details are given in a separate article in this issue. Also in a separate article, the use of IRWG associated instrumentation in satellite validation programs is discussed. Several presentations employing satellite data and comparisons and FTS retrievals were made including those of the NIR FTS Total Carbon Column Observing Network (TCCON). The ground-based network is separate from the IRWG but we maintain a close relationship as there are many overlapping concerns, techniques and sites so that interaction is of mutual benefit to all.

This meeting continues to be of great interest to the NDACC-IR community. We look forward to the 2007 meeting to be held in May on Tenerife Is.

Ground-based remote sensing of H_2O and HDO profiles

Matthias Schneider, Frank Hase and Thomas Blumenstock

Institut für Klimaforschung, Forschungszentrum Karlsruhe.

Water vapour is the dominant greenhouse gas in the atmosphere, and in particular its concentration and evolution in the upper troposphere and lower stratosphere are of great scientific importance. It can be measured in-situ by sondes, or remote sensed by microwave and more recently by Lidar instruments. Applying an innovative retrieval approach allows the measurement also by FTIR instruments. Advantages of this technique are: (i) FTIR measurements are performed for more than 20 years within the NDACC and (ii) the additional quantification of water vapour isotopologues (the isotope ratio gives valuable information about transport processes). The innovative approach consists in the transformation of the inversion problem on a logarithmic scale (Hase et al., 2004; Schneider et al., 2006 a) and in constraining the different isotopologues against each other, which results in an optimal estimation method for ratio profiles (Schneider et al., 2006 b). The innovative retrieval is applied to spectra measured at the Izaña observatory since 1999 with a Bruker IFS 120M spectrometer and since 2005 with a Bruker IFS 125HR spectrometer. These measurements form part of the NDACC. The FTIR results are validated by a comparison to sondes and interpreted by isentropic trajectories.

The comparison of FTIR and sonde measurements confirms the estimated precision (error relative to typical variability of water vapour amount) of 22% for the lower and middle troposphere and of 48% for the upper troposphere. This is depicted in **Figure 1** for

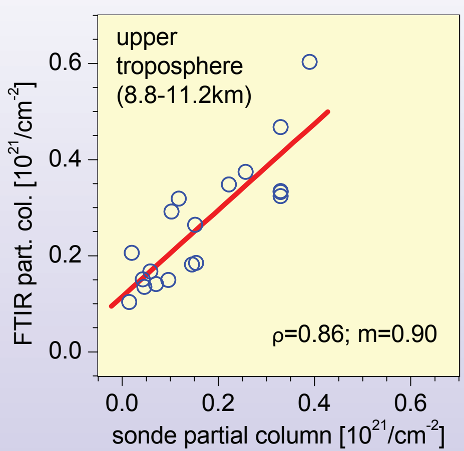

Figure 1. Correlations between partial column amounts measured by the sonde and by the FTIR instrument in the upper troposphere (8.8-11.2km). Correlation coefficient ρ and regression line slope m are given in the panel.

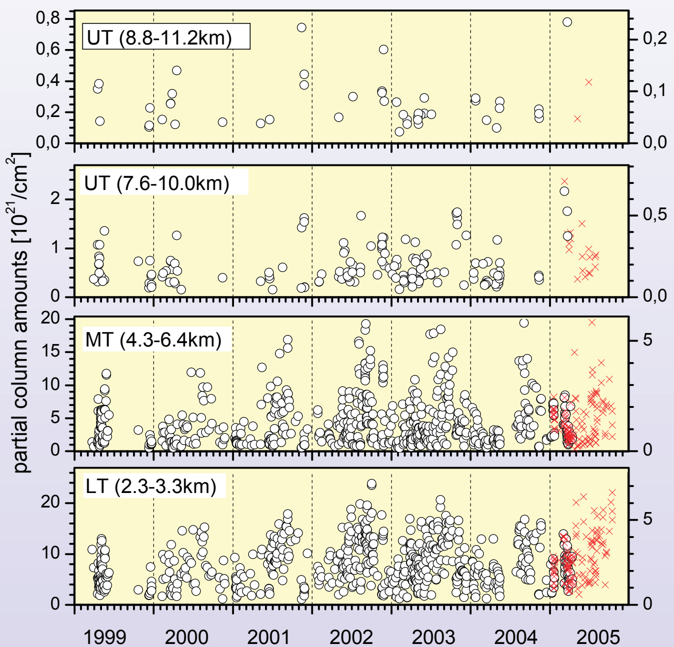

Figure 2. Time series of water vapour above Izaña determined from FTIR measurements. Water vapour amounts above 8km are only detectable for weakly- or non-saturated absorption lines. Black circles: measurement of spectrometer Bruker IFS 120M; red crosses: measurements of Bruker IFS 125HR.

the upper troposphere (8.8-11.2km). **Figure 2** shows a time series from 1999 to the end of 2005 of the water vapour amounts detected above Izaña by the FTIR measurements.

The small natural variability of the HDO/H_2O ratio requires a very high precision of the retrieved data: for a known H_2O concentration the remaining variability of HDO is only 7% compared to the absolute variability of HDO of 100%. Only an optimal estimation of the ratio profile provides for the necessary precision to detect middle/upper tropospheric HDO/H_2O ratios. We estimate that, applying the innovative approach, lower and middle/upper tropospheric ratios are detectable with a precision of 15% and 50%, respectively. The detection is feasible even for moderately saturated H_2O lines. Only for very large atmospheric water vapour content the HDO absorptions are masked by H_2O absorption wings and the ratio is not detectable. Thus, our method also allows the detection of the middle tropospheric ratio at stations situated at lower altitudes. **Figure 3** shows the evolution of the HDO/H_2O ratio at Izaña from January 2005 to March 2006. The ratio is expressed in form of a δD value, which is the relative difference of the actual ratio to a standard ratio in per mil. The annual cycle of δD in the lower troposphere is correlated to the sea surface temperature. It peaks in the end of summer and has lowest values in winter. The middle tropospheric values provide information about the origin of the detected airmass. If it originates from a region with a statically instable troposphere like the tropics, the value is relatively high.

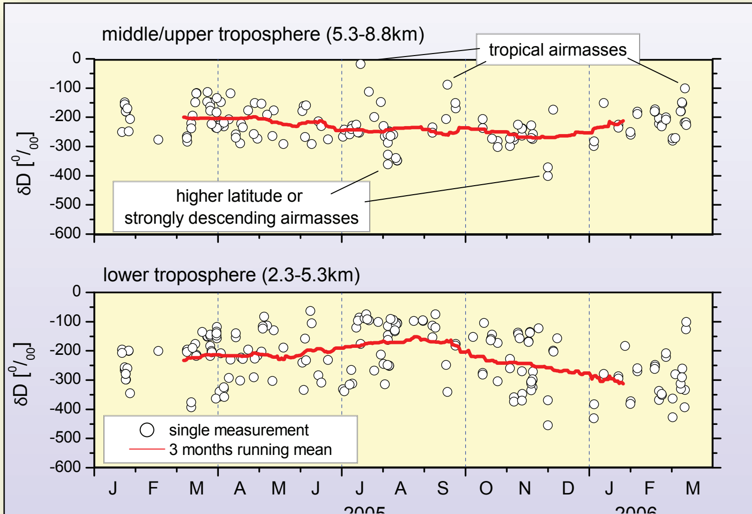

Figure 3. 15-months record of δD above Izaña.

This innovative approach allows for the first time a continuous monitoring of the middle/upper tropospheric δD.

Important remaining errors in the H_2O and δD products are caused by an unsufficient understanding of the spectroscopic line shapes. We expect that this situation will improve within the next years, which will further improve the quality of the FTIR products.

Furthermore, it can be applied for the retrieval of strongly correlated trace gases, like CH_4 and N_2O. In this case the method should improve the precision and accuracy of both trace gas profiles. The results of our study strongly recommend the application of this approach whenever strongly correlated trace gases are the objective. It could be adapted to a wide range of retrieval codes, including satellite codes, for the inversion of limb sounder as well as nadir spectra.

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Trend of stratospheric BrO over Harestua, Southern Norway (60°N, 11°E)

F. Hendrick and M. Van Roozendael, IASB-BIRA, Belgium

A trend analysis of stratospheric BrO has been performed using ground-based zenith-sky UV-visible observations of BrO at the NDACC station of Harestua (60°N, 11°E) from 1995 to 2006. To fit the time-series of stratospheric BrO vertical column densities obtained by applying a profiling technique to the DOAS observations (Hendrick et al., 2007), a statistical model with a linear trend and seasonal components of the form of polyharmonic functions has been used. The inclusion of such functions in the model enables the strong NO_2-related seasonality of stratospheric BrO to be fitted. For the 1995-2001 period, the polyharmonic fit gives a positive trend of 2.5 ± 0.3 % per year, while a negative trend of –0.7 ± 0.3 % per year is found between 2001 and 2006 (see **Figure 1**). The calculation of the ratios between the trend values and their standard deviations shows that, assuming a t-Student distribution, the trends are statistically significant for both periods. Given a mean age of air of 4.3 ± 1 years over Harestua, the decline of BrO in the stratosphere from 2002 is consistent with the decline of long-lived bromine source gases (mainly methyl bromide) observed from the second half of 1998 (WMO, 2007) as a result of the Montreal protocol. A similar trend study using the 1995-2005 time-series of stratospheric BrO vertical columns at the NDACC station of Lauder (45°S, 170°E) is currently under progress.

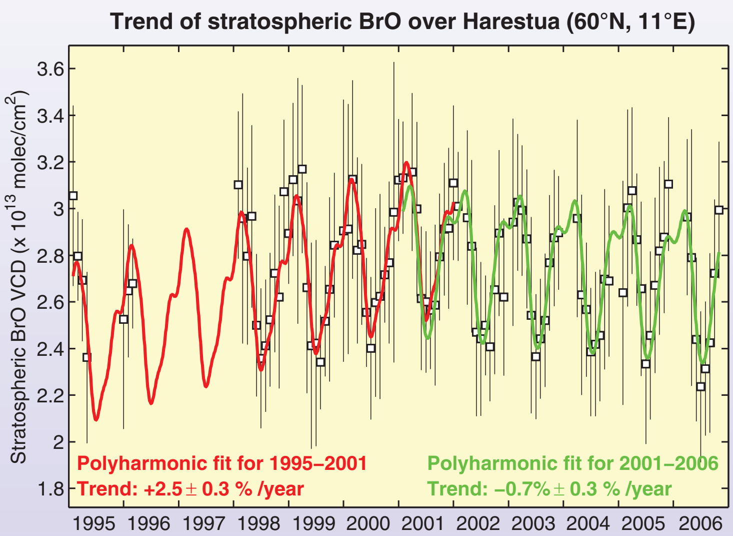

Figure 1. 1995-2006 time-series of ground-based DOAS BrO vertical column densities (VCDs) and results of the polyharmonic fit for the 1995-2001 and 2001-2006 periods (F. Hendrick and M. Van Roozendael, IASB-BIRA).

Campaign to observe bromine explosion and ozone depletion events in McMurdo Sound (78°S), Antarctica

Karin Kreher, NIWA, New Zealand

To study bromine explosion and ozone depletion events on the sea-ice at McMurdo Sound during the 2006 and 2007 IPY (International Polar Year) spring season, we have deployed a MAX-DOAS spectrometer and in-situ ozone monitor on a portable platform which also contains a camera to monitor the field of view, and an electronic meteorological station (**Photo 1**). Six 12V batteries are charged by a 400W photovoltaic array, a wind generator (2007 season only) and a 2kVA petrol generator to power the instrumentation. The semi-automated instruments need to be visited every 3 days to charge batteries and download data. These observations have been complemented with tethered helikite (balloon kite) flights to measure temperature and ozone profiles using a Vaisala RS80 radiosonde and 2Z ozonesonde, and surface snow samples for mercury analysis.

The data collected during the two campaigns is complemented by long-term observations of BrO and surface ozone made since 1995 and 1997, respectively, at the NDACC observatory Arrival Heights (77.8°S, 166.7°E) located on Hut Point Peninsula of Ross Island, Antarctica. During the first 6 weeks of the 2007 field campaign, the NIWA instrument has been set-up near Inaccessible Island on first year sea ice, looking to the northwest in the direction of more new sea ice and open leads. The NIWA and Canterbury PhD student Tim Hay was joined by a PhD student from the University of Heidelberg (Selami Yilmaz) with a second MAX-DOAS and in-situ ozone instrument. For the second 6 week period, both instruments are flown further north to Cape Bird where Katja Riedel is joining Tim to look after the observations while Selami is returning to Germany. The results of both campaigns will be published shortly.

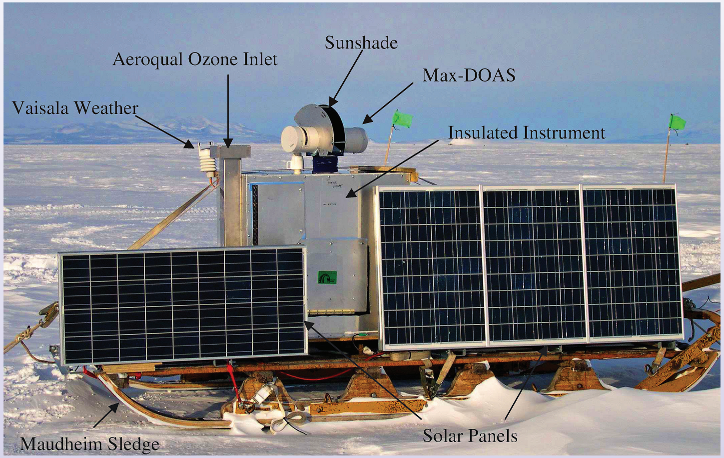

Photo 1. NIWA instrument platform and solar array on the Maudheim sledge on the sea ice.

DANDELIONS campaigns in 2005 and 2006

Folkard Wittrock, IUP Bremen, Germany

Tropospheric NO_2 profiles have been derived from MAX-DOAS observations during the Dutch Aerosol and Nitrogen Dioxide Experiments for vaLIdation of OMI and SCIAMACHY (DANDELIONS). For days with good weather conditions these profiles have been compared to measurements from the novel RIVM NO_2 lidar instrument and to in situ observations close to the ground and on top of a 200 m mast. All measurements were performed during two periods at the Cabauw Experimental Site for Atmospheric Research (CESAR, 51.97°N, 4.93°E, 0.7 m below mean sea level) which ran from May 8 - July 14, 2005, and September 1 - September 30, 2006, respectively (**Figure 1**).

As already pointed out in the last NDACC newsletter an important step in passive UV/vis remote sensing was the development from ground-based zenith sky observations to multi-axis (MAX)-DOAS measurements. This has enabled us to better validate findings from satellite observations and study the behaviour of important trace gases in the troposphere on a local scale. Recently, an automated optimal estimation based profile retrieval algorithm (BREAM) was developed for the MAX-DOAS measurements. The method first determines appropriate aerosol settings using measurements of the O_4 columns and then inverts the profile of the absorber of interest from the trace gas slant columns. DANDELIONS has provided an unique opportunity to validate the retrieval by comparison with independent measurements.

More general information on DANDELIONS can be found at http://www.knmi.nl/omi/research/validation/dandelions/

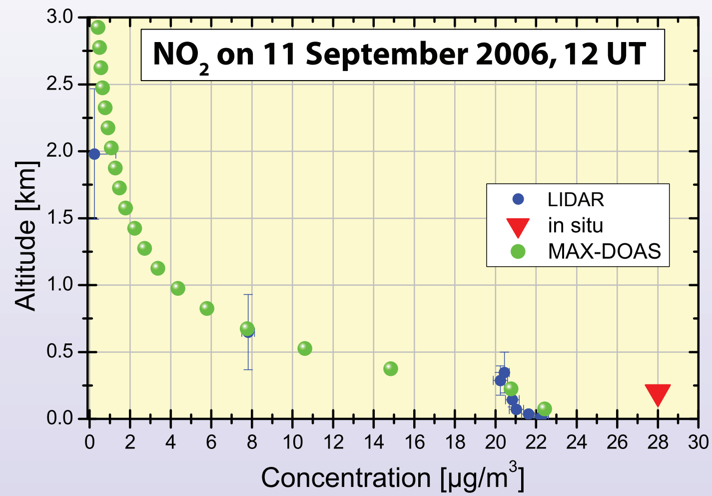

Figure 1. Comparison of the NO_2 profile on September 11, 2006 above Cabauw, The Netherlands. Green: MAX-DOAS, IUP Bremen, Germany, blue: LIDAR, RIVM, Bilthoven, The Netherlands, red: in situ (on top of the 200m mast), KNMI, De Bilt, The Netherlands.

New MAX-DOAS station within the Bremian DOAS network for atmospheric measurements (BREDOM): Heraklion, Crete (35°N, 25°E)

Folkard Wittrock, IUP Bremen, Germany

The MAX-DOAS instrument has been installed in summer 2007 on the roof of the Department of Chemistry, University of Crete (photo). The main purpose of this station is to fill a gap in the latitudinal coverage of BREDOM between mid-latitudes and the equatorial regions. In addition, it should provide valuable information on the seasonal variation of tropospheric trace gases namely formaldehyde and glyoxal in the Mediterranean (**Figure 1**).

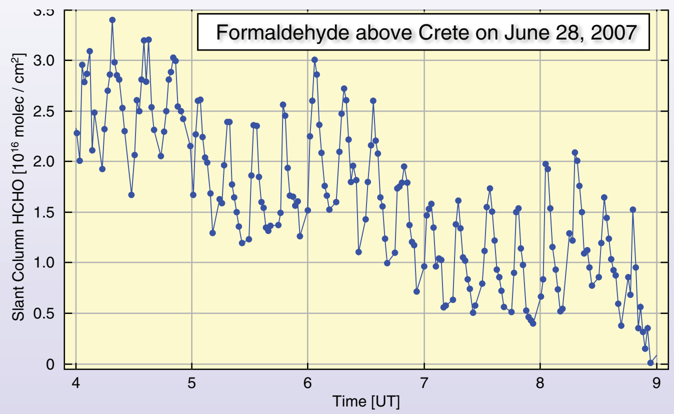

Figure 1. HCHO slant columns show clearly elevated levels due to a biomass burning plume observed over the Finokalia station. This was the first of a series of disastrous forest fires on Greek mainland in summer 2007.

Finokalia station, located about 70 km east of Heraklion, Greece. Photo: Folkard Wittrock, IUP Bremen

NO_2 satellite - Ground based intercomparisons from Tenerife (Northern subtropics)

Manuel Gil, INTA, Spain

The NO_2 long term record obtained at Izaña Observatory (Tenerife island, 28˚N, 16˚W) has been used for comparisons with Bremen evaluation (v2.0) of GOME and SCIAMACHY instruments on board of ERS-2 and ENVISAT platforms, respectively. Results show an excellent agreement for SCIAMACHY data while GOME displays too low values in summer due to a spectral interference pattern induced by the diffuser plate of GOME. Mean differences between ground-based and satellite NO_2 column data are of +1.1% for SCIAMACHY and –9.6% for GOME. This comparison is part of the material to be published soon (Gil et al., in press ACPD) on the NO_2 climatology at the Northern Subtropical regions.

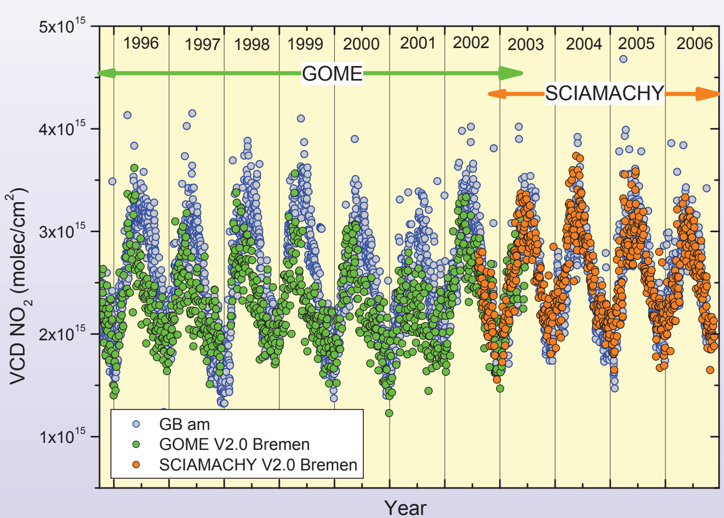

Figure 1. 1994-2006 time-series of ground-based DOAS NO_2 vertical column densities (VCDs) comparison with GOME and SCIAMACHY NO_2 VCDs.

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The Envisat Quality Assessment with Lidar (EQUAL) project

Yasjka Meijer and Daan Swart,
National Institute for Public Health and Environment (RIVM), Bilthoven, The Netherlands

Lidar observations from thirteen systems worldwide check the data quality of ozone and temperature profiles from GOMOS, MIPAS and SCIAMACHY on Envisat.

In March 2002 the European Space Agency (ESA) launched the polar-orbiting environmental satellite Envisat. It incorporates three instruments measuring the lower and middle atmosphere, which make use of a variety of measurement techniques. The Global Ozone Monitoring by Occultation of Stars (GOMOS)[1] instrument is a medium-resolution stellar occultation spectrometer operating in the ultraviolet–visible–near infrared (UV-VIS-NIR) spectral range. The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS)[2] instrument is a Fourier transform spectrometer detecting the Earth's limb emission in the mid-infrared. The Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY)[3] instrument is an UV-VIS-NIR spectrometer allowing observations in nadir, limb emission and solar occultation mode. An overview of the different

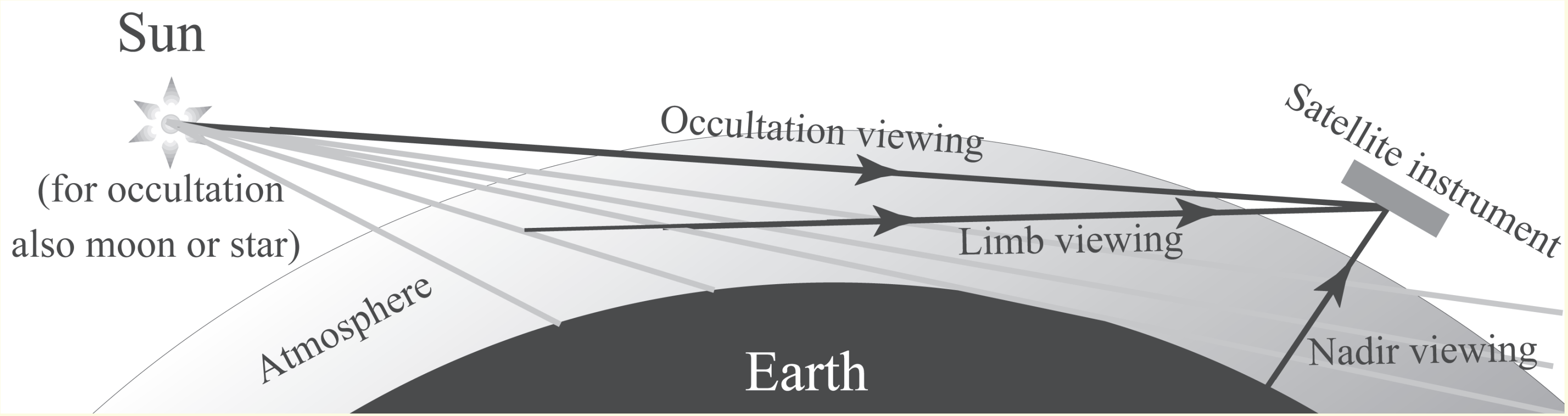

Figure 1. Schematic illustration that shows the different viewing geometries used for detecting ozone and temperature in the atmosphere from space.

viewing geometries used by these instruments is shown in **Figure 1**.

Solar and lunar occultation viewing instruments, like SCIAMACHY (and earlier SAGE), provide a high vertical resolution but with a limited global coverage. Nadir-viewing spectrometers, like SCIAMACHY (and earlier SBUV and GOME) provide data with good global coverage but with a much lower vertical resolution. Spectrometers viewing the scattered sunlight or emissions in the atmospheric limb, like MIPAS and SCIAMACHY, do provide both qualities but these observations are very sensitive to instrument calibration and pointing of the satellite platform. GOMOS exploits the stellar occultation principle, in which stars are observed above and subsequently through the atmosphere providing spectra with ozone absorption features. Specific advantages of this principle are its self-calibrating property, well-known pointing information, high vertical resolution and good global coverage due to the multitude of available stars.

Like data of any new satellite instrument, Envisat data demand a thorough quality assessment, which requires correlative measurements from a large data set with known quality. The Envisat Quality Assessment with Lidar (EQUAL) project exploits the high quality of NDACC lidar data. This ESA funded project has been set up to support the long-term validation of Envisat's three atmospheric chemistry instruments. The project started in 2004 and involves eleven, and since 2006 thirteen, lidar stations around the world measuring ozone and temperature profiles (see **Table 1**, **Figure 2** and **Photo 1**. All stations, except one,

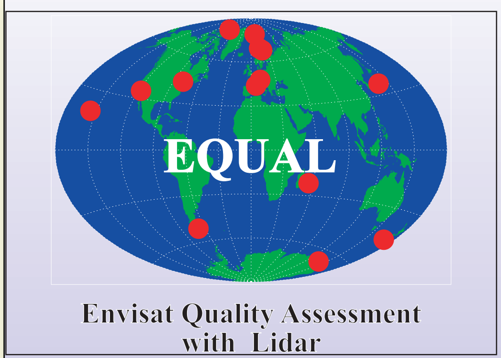

Figure 2. This logo of the EQUAL project shows all locations worldwide of the involved lidar stations.

Photo 1. Laser beams probe the night sky above Lauder, New Zealand. Photo is taken using a 60 seconds exposure time during full moon.

have a Differential Absorption Lidar (DIAL) system for ozone profile retrieval. From data of most of these systems also temperature profiles can be obtained, but sometimes temperature profiles are measured using backscatter lidar systems. Apart from Esrange (Sweden), which is not part of NDACC, and Rio Gallegos (Argentina) that has recently applied, all stations are part of NDACC.

The main focus will be on the quality of the operational ESA products, in which the data quality is monitored during satellite's lifetime (health of instruments and processing chain), and new data releases (processor upgrades) are validated. Currently the assessment focuses on the ozone profiles of GOMOS (IPF version 5.0), and ozone and temperature profiles of MIPAS (IPF version 4.61/4.62). SCIAMCHY ozone profile validation awaits a new processor release (expected in mid 2006). The retrieval of the High Resolution Temperature Product (HRTP) from GOMOS data is still too preliminary for a thorough assessment. Over the period 2002–2006 more than 4,000 lidar profiles are available for correlative studies. This vast amount of lidar data covering several latitudinal regions allows the analysis for possible dependencies of these data on several geophysical (e.g., latitude) and observational (e.g., star characteristics) parameters.

As an example we show here the validation results of the GOMOS ozone profiles, which show excellent agreement with lidar (**Figure 3**). The complete assessment confirms that the data quality is independent on star characteristics, interannual effects, and latitude region, with only a slight (5%) negative bias in Polar regions. MIPAS ozone and temperature profiles both show good agreement with lidar profiles.

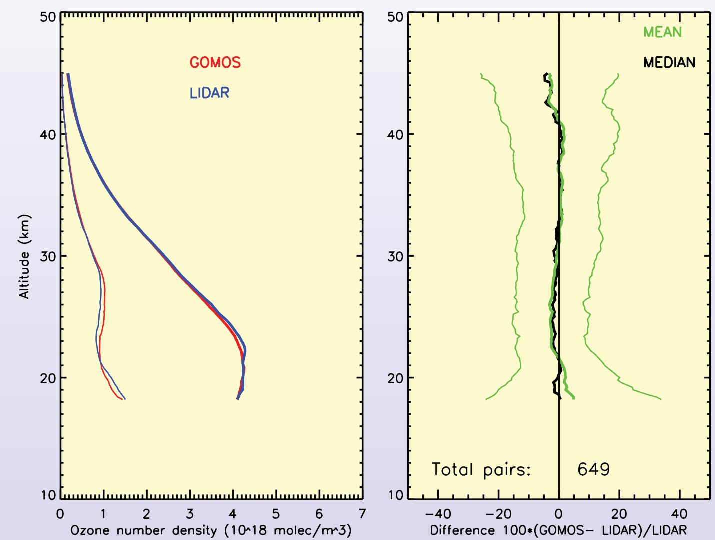

Figure 3. GOMOS ozone profiles (measured in a dark atmospheric limb) are compared to collocated high-quality lidar measurements. Left panel shows mean ozone profiles. Right panel shows their relative differences.

Temperature profiles have a mean bias compared to lidar which is smaller than 2 K between 18 and 65 km altitude.

The prospect of the Envisat mission lasting until 2010 offers potential to use Envisat data for a wide variety of research purposes. This not only includes studies for ozone monitoring but also potential use in models for numerical weather forecasts. Envisat data are freely available for scientific users; please inquire at ESA's Earth Observation Helpdesk (eohelp@esa.int) or visit their web portal (http://eopi.esa.int/). The EQUAL project will continue to provide up to date quality assessment studies.

Acknowledgements

The authors are grateful for the contributions and support of ESA, and the GOMOS and EQUAL teams.

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Table 1: Overview of lidar stations; location and measured parameters.

Station	Lat.	Lon.	Parameter
Eureka (N)	80.05	-86.42	Ozone, temperature
Ny Ålesund (N)	78.92	11.93	Ozone, temperature
Alomar (N)	69.30	16.00	Ozone, temperature
Esrange	67.88	21.10	Temperature
Hohenpeissenberg (N)	47.80	11.02	Ozone, temperature
Obs. Haute Provence (N)	43.94	5.71	Ozone, temperature
Tsukuba (N)	36.05	140.13	Ozone, temperature
Table Mountain (N)	34.40	-117.70	Ozone, temperature
Mauna Loa (N)	19.54	-155.58	Ozone, temperature
La Reunion (N)	-21.80	55.50	Ozone, temperature
Lauder (N)	-45.04	169.68	Ozone, temperature
Rio Gallegos	-51.55	-69.14	Ozone
Dumont d'Urville (N)	-66.67	140.01	Ozone, temperature

Note: (N) indicates stations that are part of NDACC

Observation of Polar Stratospheric Clouds down to the Mediterranean coast

P. Keckhut

Service d'Aéronomie, CNRS, Verrières-le-Buisson, France

A Polar Stratospheric Cloud (PSC) was detected for the first time in January 2006 over Southern Europe after 25 years of systematic lidar observations above Observatory of Haute-Provence (**Figure 1**). This cloud was observed while the polar vortex was highly distorted during the initial phase of a major stratospheric warming. Very cold stratospheric temperatures (>190 K) centred over the Northern-Western Europe were reported, extending down to the South of France where lidar observations were performed. MIPAS has also reported on the same days PSCs at latitudes of 40–60°N, at longitudes of 10°W on the 18th and 0° on the 19th, respectively (**Figure 2**). CTM (Chemical Transport Model) investigations show that this event led to a significant direct ozone destruction (35 ppb/day), as chlorine activated air masses were moved to sunlight regions allowing ozone destruction (**Figure 3**). However, the overall effect of such events on stratospheric ozone is more complex. Indeed, a strong distortion of the polar vortex like the one observed is usually associated with strong planetary wave activity. This enhanced wave activity favours the occurrence of major or sudden stratospheric warmings that weaken the vortex, enhance

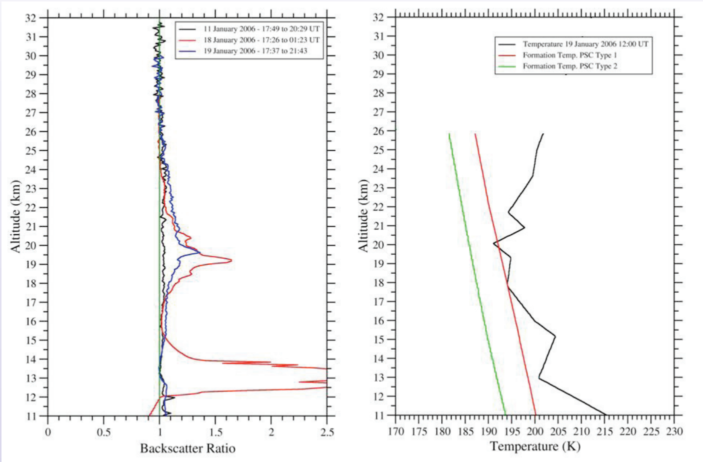

Figure 1. Left panel: Backscatter ratio measured by lidar on 11, 18 and 19 January 2006. Right panel: Temperature profile above OHP on 19 January 2006 at 12 UT. The existence temperatures for PSCs of type I and II are shown in red and green, respectively.

polar temperatures and ultimately reduce the potential for PSC formation later on. While ozone is expected to recover this century, is this extremely unusual event of a mid-latitude PSC a precursor sign of the climate feedback on stratospheric ozone budget or a simple anecdotal phenomena, part of the natural variability? In fact, in this case-study, the cold stratospheric temperatures were the result of a particular dynamical situation, i.e. the initial phase of a major stratospheric warming. During this initial phase of warming, very strong wave activity increases the baroclinic circulation in the Arctic stratosphere. Adiabatic

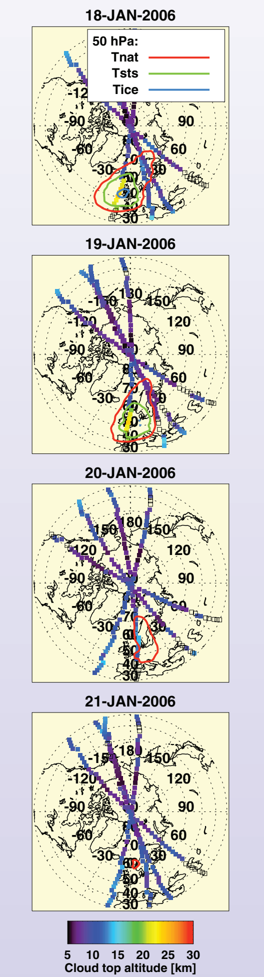

Figure 2. Cloud top height measured by MIPAS on 18-21 January 2006. Isotherms for the formation of NAT, STS and ice are shown in red, green and blue, respectively.

expansion of air that is lifted on one side of the polar vortex induces the development of an extremely cold region at the edge of the polar vortex, while temperatures warm up on the other side of the vortex, where air sinks. Dissipation of the wave then results in a strong poleward and downward motion of air over the whole Arctic, connected with strong warming everywhere. The outcome is a weak and warm vortex. The occurrence of such major stratospheric warming usually reduces or even terminates the conditions favourable for the Arctic polar vortex, limiting the overall amount of ozone that is destroyed during the Arctic winter. This type of event decreases the chance of a long lasting ozone depletion during the rest of the winter. This PSC cloud led to a sporadic ozone loss over mid-latitude populated area early in the winter, but most probably minor implications on the ozone recovery.

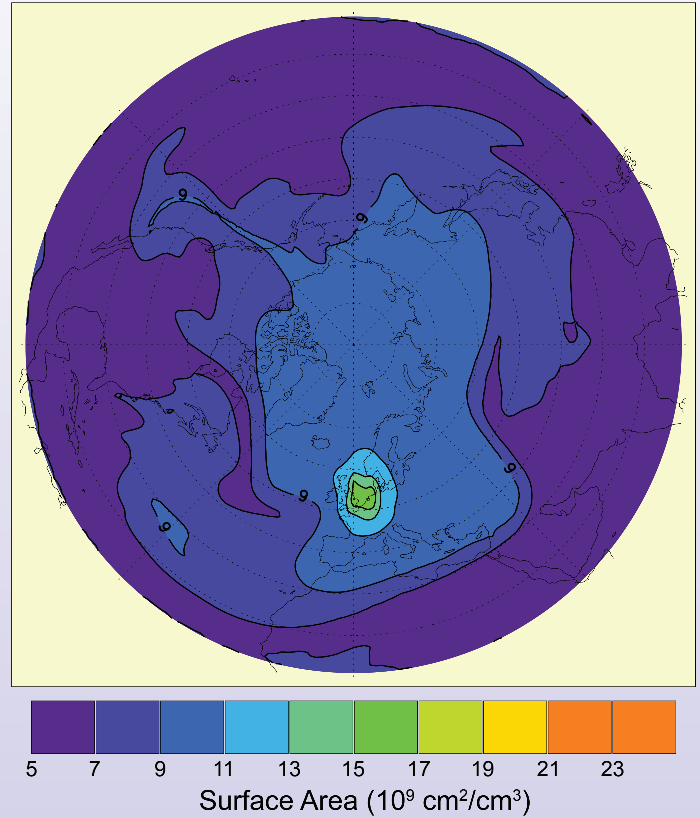

Figure 3. PSC surface area calculated using the MImosa-CHIM model.

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NDACC Lidar Working Group meeting at Bilthoven, The Netherlands, June 2007

S. Godin-Beekmann

Service d'Aéronomie, Centre National de la Recherche Scientifique.

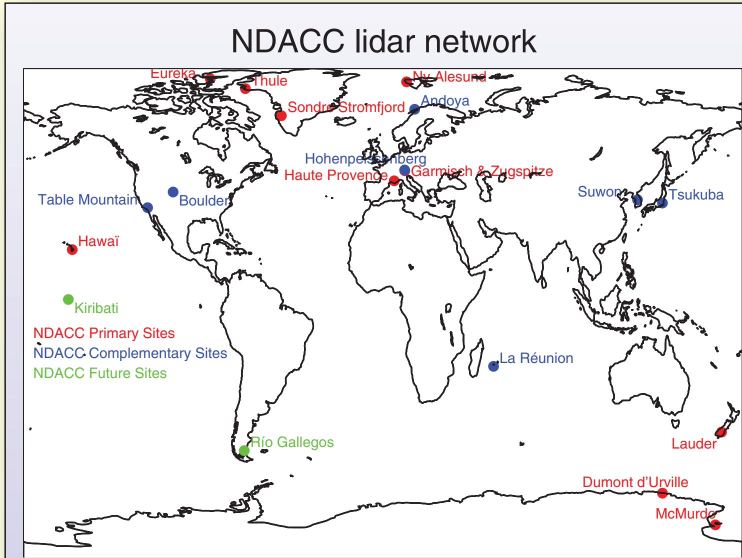

Figure 1. The NDACC lidar stations

The NDACC Lidar Working Group met in Bilthoven, the Netherlands, on June 12 – 15, 2007. The meeting was hosted by Yasjka Meijer and Daan Swart of RIVM. The NDACC lidar measurements include ozone, temperature and aerosol vertical distributions. The possibility to measure water vapour in the upper troposphere - low stratosphere is under investigation and several inter-comparison campaigns have already taken place to sort this issue.

During the meeting, the PI of the various lidar instruments and stations (**Figure 1**) reported on recent instrumental changes and scientific results. Several invited talks were also presented on new scientific issues in relation to NDACC observations or on initiatives for collaborative observations. A study on stratospheric aerosol enhancement due to forest fires based on TOMS aerosol index and other measurements was presented by M. Fromm (NRL, USA). J. Bösenberg (Max Planck Institut für Meteorologie, Hamburg) talked about the GALION project, which consists in a network of aerosol lidar networks at global scale. P. Keckhut (CNRS, France) presented the CAWSES campaign, which aims at coordinating measurements for atmospheric tide studies. T. Leblanc (JPL, USA) showed results from the 1st MOHAVE campaign organised in California in order to compared water vapour measurements from lidar and various types of sondes. Several presentations were dedicated to satellite missions and validation campaigns. OMI ozone profile measurements were presented by P. Veefkind (KNMI, the Netherlands), an update on the status of the ENVISAT mission was given by R. Koopman and an overview of the future ESA EarthCare mission was made by D. Donovan (KNMI).

During the meeting, a visit to the CABAUW experimental site for Atmospheric Research (CESAR), located nearby RIVM was organised.

The next NDACC LWG meeting scheduled in 2009, will be organised by K. Strawbridge (Environment Canada) in Toronto (Canada).

The participants at the NDACC lidar working group meeting in Bilthoven, June 2007.

Zimmerwald observatory located at 46.88°N, 7.47°E and 905.5 masl.

News from the microwave community of NDACC

Niklaus Kämpfer, University of Berne

The middle atmospheric water vapour radiometer, MIAWARA, operated by the University of Bern has got a new home at the Zimmerwald observatory near Bern. In fall 2006 a new observatory has been inaugurated dedicated to remote sensing of the atmosphere with a special weight on water vapour research (photo on previous page). Several instruments are operated from this location that give information on the total amount of water vapour (microwave radiometers, sun photometer, GPS receiver) and about the profile of water in the troposphere and in the stratosphere and mesosphere. The key instrument is the NDACC radiometer MIAWARA. MIAWARA is operated remotely from Bern and provides water vapour profiles on a regular basis with a time resolution of a few hours. Data are delivered to the NDACC data base and also to the data base of the EC-project GEOMON on a near real time basis (**Figure 1**).

In addition to the water vapour radiometer the microwave instruments for ozone operated at the University of Bern and also by MeteoSwiss in Payerne continue to operate on a regular basis. There exists now a homogenized data set of ozone profiles (**Figure 2**) since 1994 with an outstanding time resolution of 1 hour.

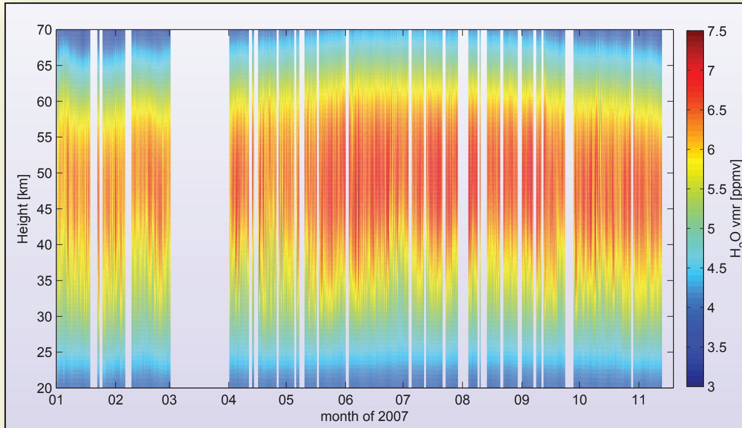

Figure 1. Time series of water vapour profiles in 2007. Data gap in March is due to a instrumental upgrade.

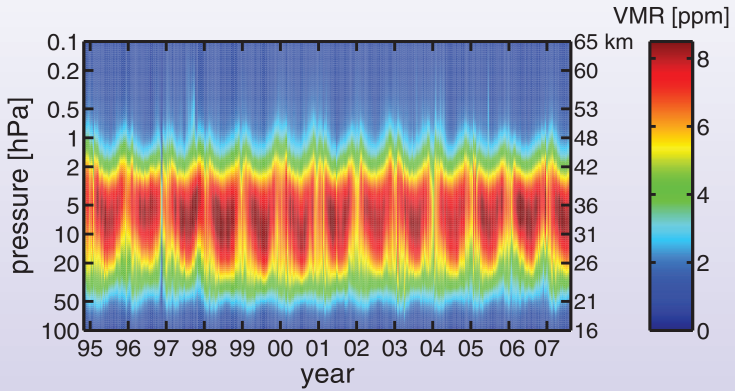

Figure 2. Homogenized data set of ozone since 1994.

This high temporal resolution allowed investigating tidal structures in the middle atmosphere. Using data from the three NDACC microwave instruments in Switzerland plus data from the NDACC lidar in Haute Provence it was possible to study diurnal and semidiurnal tidal structures in temperature, ozone and water vapour.

Long-term measurement of middle atmospheric water vapour measurement from the ground

Gerald Nedoluha, Naval Research Lab

The Water Vapour Mm-wave Spectrometer (WVMS) instruments have been providing measurements of water vapour from NDACC sites since the early 1990s. In 1996 such an instrument was installed at Mauna Loa, HI, and has been measuring nearly continuously. This instrument, along with the WVMS instrument at Lauder, New Zealand, as well as the HALOE and POAM instruments, provided a useful dataset for the study of long-term changes in middle atmospheric water vapour. In late 2005/early 2006, however, both the HALOE and POAM instruments ceased to provide measurements. These two solar occultation instruments had provided water vapour measurements which showed good agreement in their measurements of changes in water vapour, including a sharp drop in water vapour which occurred in 2001 in the lower stratosphere. This was shown to be correlated with a decrease in tropical tropopause temperature [Randel et al., 2004, 2006].

Luckily, AURA MLS was launched in August 2004, so in this case it was possible to compare coincident satellite water vapour data and thus in principle a satellite trend record could be maintained. Nevertheless, a longer period of coincidences is useful for ensuring that no trend is introduced between datasets, and this extended period can be provided by the WVMS measurements. In **Figure 1** we show this comparison

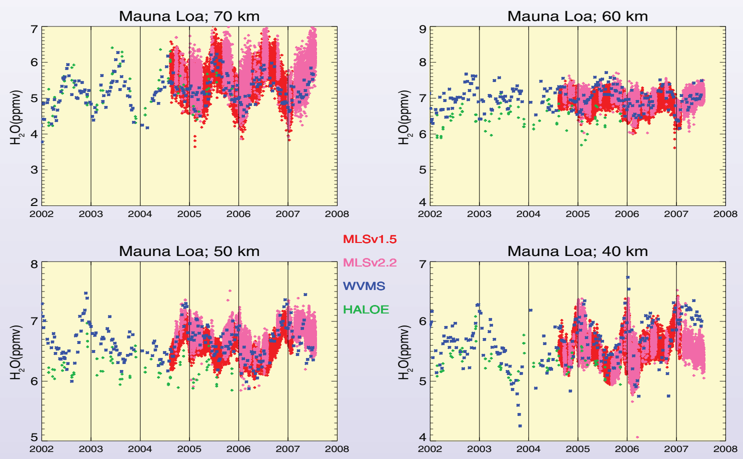

Figure 1. Water vapour measurements from WVMS at Mauna Loa, and coincident measurements from MLS and HALOE. In this as in the subsequent figure the satellite data is convolved with the WVMS averaging kernels in order to reflect the coarser vertical resolution of the microwave measurements.

for HALOE, MLS, and WVMS measurements coincident with Mauna Loa at 50 km. The WVMS and MLS measurements are clearly in very good agreement (and both slightly higher than HALOE). While the MLS time series is still too short to provide any significant trend information, the similarity in the seasonal cycles between the MLS and WVMS measurements is very encouraging. In addition, the instruments show good agreement in the interannual variation, which shows less water vapour in January-February 2006 as compared to January-February 2005, a difference which is presumably related to the QBO.

In **Figure 2** we show the 10-year comparison between coincident WVMS measurements at Mauna Loa, Hawaii and the HALOE measurements at 50 and 60 km. Mauna Loa is an ideal site for the monitoring of long-term trends both because the high altitude (3.4 km) reduces the amount of tropospheric water vapour which absorbs the signal of the stratospheric/mesospheric water vapour which we are trying to observe, and because the low latitude reduces the seasonal variation, and thus simplifies the identification of long-term trends [Nedoluha et al., 2003]. The relative values of the WVMS and HALOE water vapour measurements remain quite stable, and the relative trend at the altitudes shown is everywhere below the 2σ level. This stability between the two instruments gives confidence that the WVMS instrument can maintain a stable long-term measurement, and, provided that the MLS instrument operates for many years, it will provide a good check on any trends measured by MLS. Perhaps more importantly, should there come a gap in the satellite water vapour data record it will be able to provide a bridge between such records.

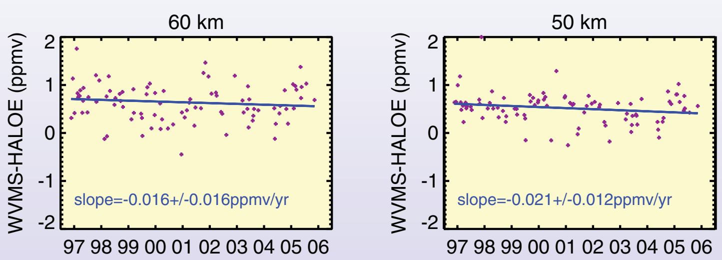

Figure 2. Comparison of WVMS water vapour measurements from Mauna Loa and coincident HALOE measurements from 1996 through 2005.

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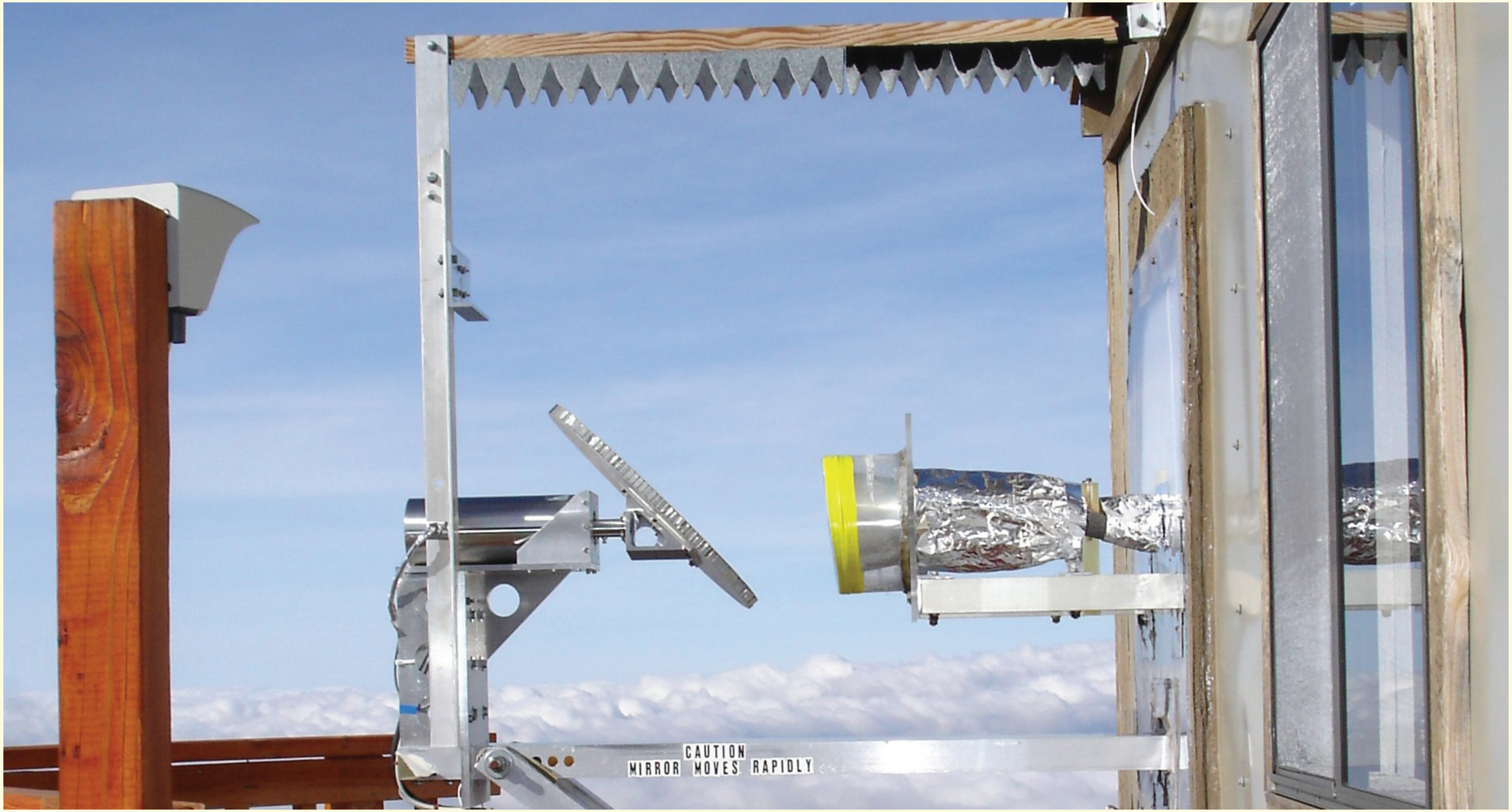
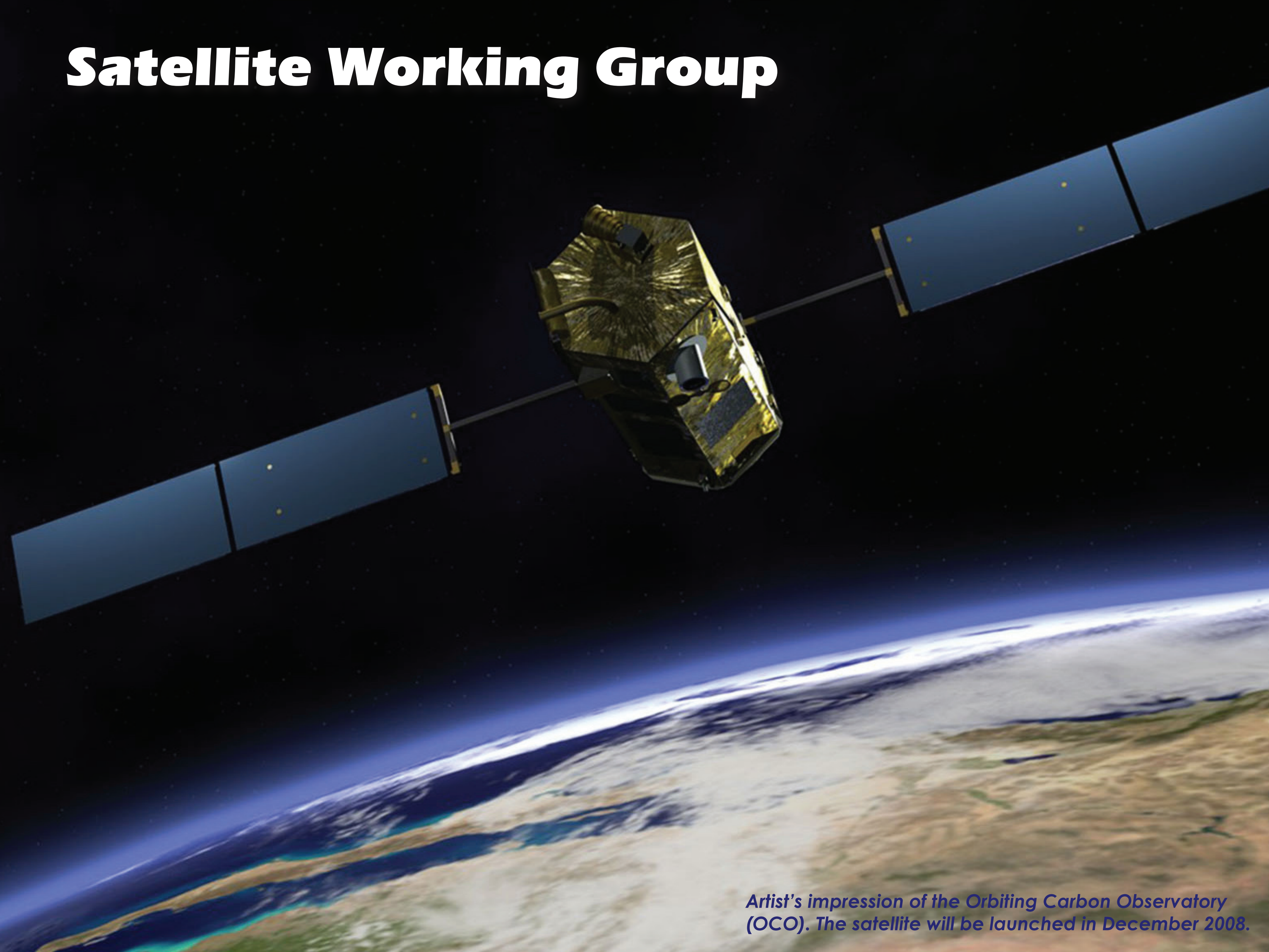


The WVMS instrument at Mauna Loa, Hawaii.

Satellite Working Group



Artist's impression of the Orbiting Carbon Observatory (OCO). The satellite will be launched in December 2008.

The Orbiting Carbon Observatory Mission

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Carbon dioxide (CO_2) is the primary man-made greenhouse gas and the primary atmospheric component of the global carbon cycle. Precise measurements of CO_2 made since the late 1950's indicate that atmospheric CO_2 has increased from ~310 to over 380 parts per million (ppm) over this period. Comparisons of these data with estimates of CO_2 emission rates from fossil fuel combustion, biomass burning, and other human activities indicate that only about half of the CO_2 that has been emitted into the atmosphere has remained there. The rest has apparently been absorbed by surface "sinks" in the land biosphere or oceans. Existing CO_2 measurements also show that the atmospheric CO_2 buildup varies dramatically from year to year in response to smoothly increasing emission rates. The existing CO_2 monitoring network does not have the spatial resolution, coverage, or sampling rates needed to identify the natural CO_2 sinks or the processes that control how their efficiency variations over time.

The NASA Orbiting Carbon Observatory (OCO) is currently scheduled for launch in December 2008. OCO will make space-based measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize the geographic distribution of CO_2 sources and sinks and quantify their variability over year. During its 2-year nominal mission, OCO will fly in the Earth Observing System Afternoon Constellation (EOS A-Train). This circular, 705 km-altitude, near-polar, sun synchronous orbit provides global coverage of the sunlit hemisphere with a 1:26 PM nodal crossing time and 16-day ground-track repeat cycle. The observatory carries a single instrument that measures the absorption of reflected sunlight by CO_2 and molecular oxygen (O_2) at near infrared wavelengths. High spectral resolution ($\lambda/\Delta\lambda$>20,000) measurements within the CO_2 bands near 1.61 and 2.06 μm yield CO_2 column abundance estimates that are most sensitive near the surface. High resolution ($\lambda/\Delta\lambda$>17,000) measurements within the 0.765-μm O_2 A-band spectra yield clear-sky surface pressure estimates with accuracies near 1 mbar and constrain cloud and aerosol profiles to reduce pathlength uncertainties associated with multiple scattering. Boresighted measurements of the CO_2 and O_2 spectra will be analyzed to retrieve spatial variations in the column-averaged CO_2 dry air mole fraction, X_{CO2}. Surface sources and sinks must be inferred from small spatial variations in X_{CO2}, since this quantity varies by only ~2% from pole to pole. A sensitive, stable instrument and a comprehensive ground-based validation network are being implemented to provide X_{CO2} measurements with random errors and systematic biases no larger than 0.3-0.5% on regional scales. These measurements are expected to improve our understanding of the nature and processes that regulate atmospheric CO_2 enabling more reliable forecasts of CO_2 buildup and its impact on climate change.

The NASA OCO mission is part of a global CO_2 monitoring network that includes the NOAA ESRL Flask and tower networks, Aircraft, and the ground-based up-looking Fourier Transform Spectrometers in the Total Column Carbon Observing Network (TCCON). The OCO mission will also fly at the same time as the Japanese GOSAT mission, providing opportunities for coordinated observations and in-flight cross calibration activities.

GOSAT Greenhouse Gases Observing Satellite

Improving the global mapping of greenhouse gas sources and sinks

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As part of the international efforts to promote greenhouse-gases observation for better understanding the carbon cycle among the atmosphere, the terrestrial biosphere, and oceans, the Ministry of the Environment of Japan (MOE), the National Institute for Environmental Studies (NIES), and the Japan Aerospace Exploration Agency (JAXA) will launch the Greenhouse Gases Observing Satellite (GOSAT) in 2008 for global monitoring of CO_2 and CH_4 from space. Objectives of the GOSAT mission are to assess distribution of carbon flux (sources and sinks) on a sub-continental scale, to characterize geographical distribution and its variation of CO_2 and CH_4, and to provide scientific basis to climate change policies.

A Fourier transform spectrometer (TANSO-FTS) on board the satellite is designed to measure the spectra of both solar radiation scattered by Earth's surface and radiation emitted by the Earth's surface and the atmosphere. The spectrometer spans the whole spectral range from near-infrared (NIR) to thermal infrared (TIR), which is filtered into 4 spectral bands for detection: 6-14 µm thermal band, 2.0 µm CO_2 and water vapour band, 1.6 µm CO_2 and CH_4 band, and 0.76 µm O_2 A-band. A set of two detectors is associated to each of the NIR bands in order to measure polarization components separately. The absorption bands in 1.6 µm and 2.0 µm regions provide very good sensitivity to column amount of CO_2 and CH_4 from the ground to the lower stratosphere. Over oceans, the sensor is pointed towards sun-glint to improve sensitivity and spatial coverage. GOSAT sensors include a cloud/aerosol imager (CAI) in addition to the TANSO-FTS. GOSAT will be put into a sun-synchronous orbit (666 km in altitude and 3 days of recurrent time) with 13:00 of equator crossing time (descending).

Data acquired by GOSAT sensors will be collected at JAXA's Tsukuba Space Center facilities. Level 1 data of FTS (spectra) and CAI will be generated by JAXA and transferred to NIES Data Handling Facility for further processing. Cloud coverage and aerosol information (CAI Level 2 data) will be estimated from calibrated CAI Level 1 data. The FTS data identified with "low cloud coverage" by CAI will be processed to generate column amount of CO_2 and CH_4 (FTS Level 2 data). Level 3 data contains global map of the column amount averaged in time and space, and Level 4 data provides global distribution of sources/sinks.

Validation of the GOSAT products is planned to start three months after launch. A ground-based high resolution FTS will be utilized together with a lidar (laser radar) and a sky-radiometer at a couple of stations for extensive validation data acquisition. In-situ measurements and/or sampling of CO_2 and CH_4 aboard commercial aircraft will be also employed. FTIR measurements at the NDACC stations would provide valuable datasets for the GOSAT validation. NIES team as well as research teams selected through Research Announcement (RA) activity will conduct the validation process. The RA to solicit research teams interested in participating in algorithm development, validation and scientific use of GOSAT data should follow soon.

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[2] Earth Observation Portal (eoPortal), GOSAT (Greenhouse gases Observing Satellite) URL: http://directory.eoportal.org/pres_GOSAT-GreenhousegasesObservingSatellite.html

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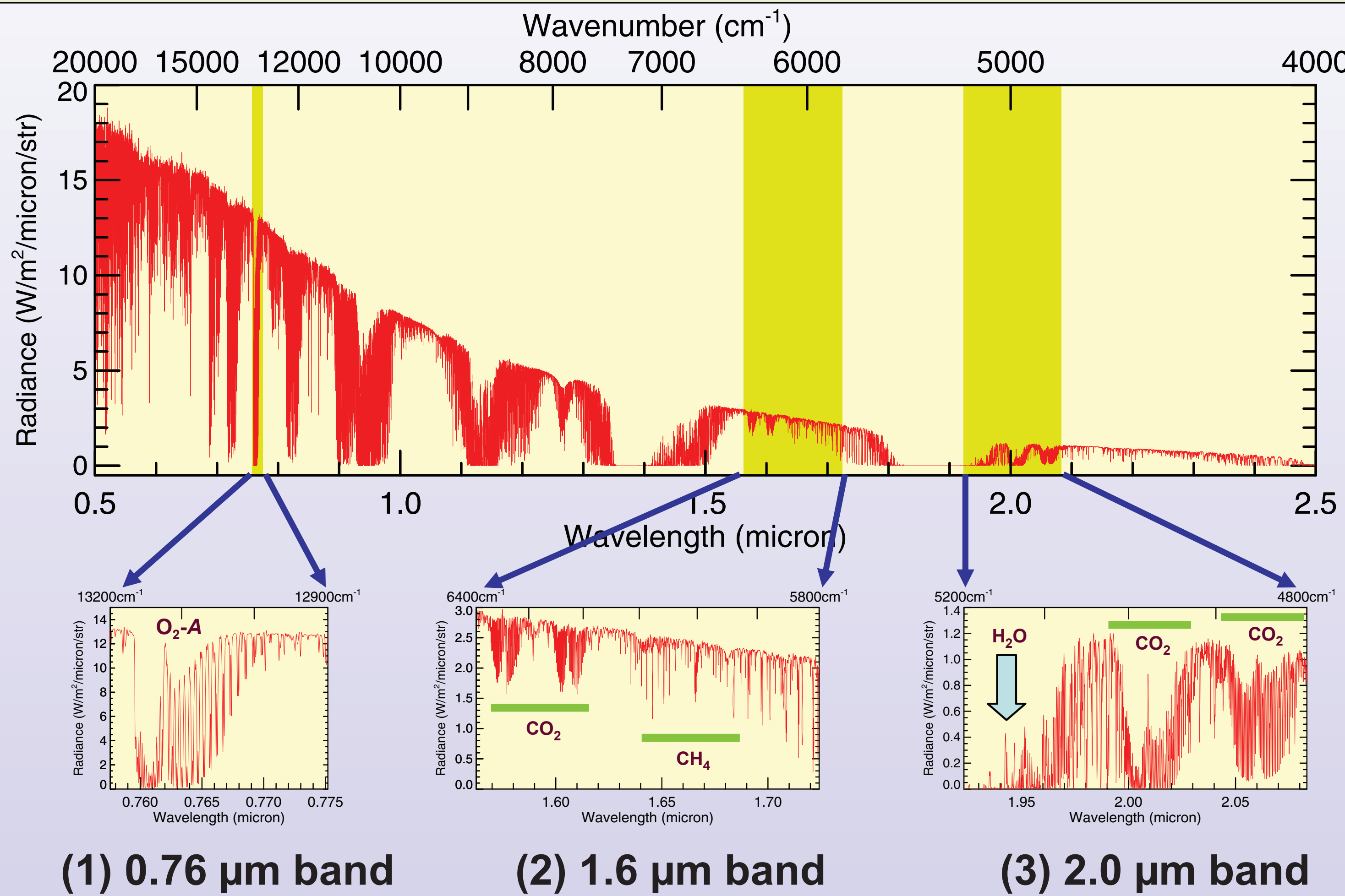

Figure 1. Near-infrared spectra simulated from spectroscopic data of atmospheric constituents and solar spectrum in full near-infrared spectra range (upper), and expanded three bands (lower).

Three-Dimensional Modelling of Long-Term Trends in NO_2: Issues With ERA-40 Analyses

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A principal motivation for NDACC is provide continuous, high quality data sets of trace atmospheric constituents which can be used to detect long-term trends. A prime example of such data is the ground-based observations of column NO_2 made at Lauder, New Zealand using a UV/visible spectrometer. These observations have been performed since December 1980 and show a number of significant long-term variations (see Liley et al., 2000 and **Figure 1**). On top of the clear diurnal and annual variations, this data set shows long-term changes in NO_2. Relatively low NO_2 was observed around 1992, following the eruption of Mt. Pinatubo, followed by an increase. However, in addition to these aerosol-induced variations there is also an expected increase in NO_2 from the increasing atmospheric burden of N_2O. There have been suggestions that this upward trend in NO_2 is larger than models predict (e.g. WMO, 2003; 2007).

It is important to investigate whether global chemical-dynamical models, used for assessment studies, are able to reproduce observed variations such as these. Here we compare these NO_2 observations with multi-decadal simulations of the SLIMCAT off-line 3-D

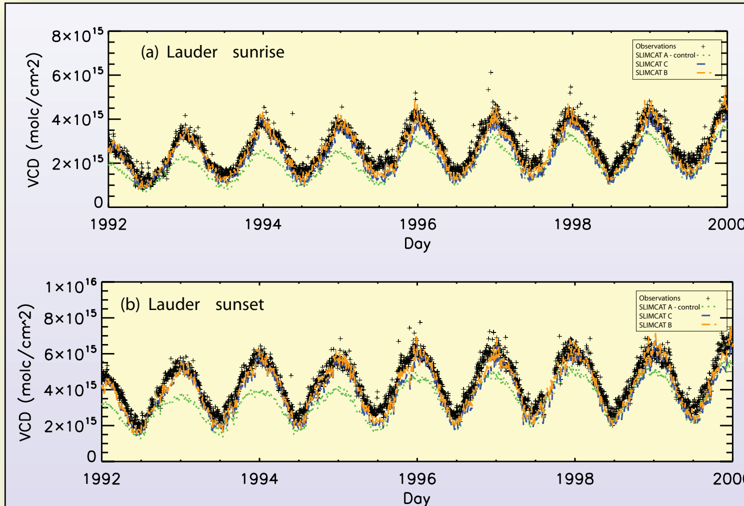

Figure 1. Observed vertical column of NO_2 (+ marks) at Lauder (45°S, 170°E) at 90° for (a) sunrise and (b) sunset from 1992 to 2000. Also shown are results from three SLIMCAT 3D model simulations: The basic model run A (green line), run B (orange line) with assimilation of HALOE CH_4 and O_3, and run C (blue line) with assimilation of CH_4 only.

stratosphere-troposphere chemical transport model (Chipperfield 1999, 2006). The model was forced using 6-hourly European Centre for Medium-Range Weather Forecasts (ECMWF) analyses including, from 1977 to 2001, the ERA-40 reanalyses. Time-dependent monthly fields of liquid sulphate aerosol for 1979 - 1999 were taken from WMO (2003). After 1999 the aerosol was kept constant at the 1999 values. The time-dependent surface mixing ratios of source gases were also taken from WMO (2003).

The model was run from 1977-2004 in a series of three experiments. Run A was the basic model while the two further runs included assimilation of chemical data using the method described in Chipperfield et al. (2003). Run B assimilated HALOE observations of CH_4 and O_3 from 1991 on. These data are available on ~15 sunrise/sunset profiles per day at latitudes which vary over the course of a couple of months. In the assimilation scheme the assimilated CH_4 is used as a strong constraint on the other model long-lived tracers (e.g. N_2O, NO_y) which are scaled to preserve the model tracer-tracer correlations. In this way the assimilation of a long-lived tracer can correct for transport-induced model errors in all long-lived species. Run C was the same as run B but without assimilation of O_3.

Figure 1 also shows the modelled sunrise and sunset column NO_2 at Lauder. The comparison of the basic model run A with the observations is quite poor especially in the early 1990s. The model captures the annual cycle but significantly underestimates the magnitude of the summertime maximum. Column NO_2 in A does increase during this period and by 1999/2000 the agreement is much better. Evidently this modelled NO_2 trend in run A is therefore too large.

Both of the model runs which include chemical data assimilation show much better agreement throughout the whole period shown. The improvement is especially marked in the early 1990s and the modelled summertime maximum is now in good agreement with the observations. Moreover, the modelled NO_2 trend over this period agrees with the observations. Note the improvement in modelled NO_2 in runs B and C is due to improvements in the modelled distribution of NO_y via it's correlation with the long-lived tracer CH_4. The chemical partitioning of NO_y, and indeed the production of NO_y from N_2O is still determined by the model chemistry. Therefore, the NO_2 comparison is still testing many aspects of the model.

An important result from **Figure 1** is the implications for the cause of the modelled NO_2 trend. Given the poor agreement of run A it would have been tempting to question whether the modelled aerosol trend or processes, for example, were realistic. However, runs B and C use the same aerosol values and parameterisations and can largely reproduce the observations. Overall the results point to the cause of the poor agreement in run A being principally due to the transport-related errors in the forcing ERA-40 winds. Similar results are obtained by Gil et al. (2007) using column NO_2 observations at Tenerife. The ever increasing NDACC database provides many more such opportunities for the testing of global chemical models, especially over long timescales.

Acknowledgements

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Comparisons of stratospheric temperature trends derived from NDACC lidars with satellite measurements

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Introduction

The largest temperature changes in the atmosphere over the past several decades have occurred in the stratosphere. Observations show cooling rates of ~0.5 – 2 K/decade, increasing in magnitude from the lower to the upper stratosphere (Ramaswamy et al., 2001), and this cooling is primarily attributable to increases in atmospheric CO_2 and decreases in stratospheric ozone (Shine et al., 2003). Monitoring stratospheric temperature change is key for understanding stratospheric ozone variability and trends (WMO, 2006), and careful analysis of simulated trends is a standard diagnostic for evaluating stratospheric model performance (e.g. Eyring et al., 2006). Regular measurements of stratospheric temperatures by Rayleigh lidar are obtained by several stations within the NDACC network, and stations with long time series provide a valuable data source for monitoring and comparison to satellite observations (which are the primary data source for temperatures above ~30 km). In this article we present some comparisons of temperature variability and trends in the stratosphere between NDACC lidar observations and satellite data.

Lidar and satellite temperature measurements.

Relatively long time series of stratospheric temperatures have been obtained from lidar measurements at a number of NDACC stations, and we focus on three stations with the longest data records (**Table 1**). The Rayleigh lidar technique uses the backscattering of a pulsed laser beam to derive the vertical profile of atmospheric density, from which the temperature profile is deduced (Hauchecorne and Chanin, 1980). This technique provides an absolute temperature measurement over ~30-75 km, which does not require adjustment or external calibration. Validation studies suggest that individual profiles can be derived

Table 1. Lidar stations used for temperature trend analysis

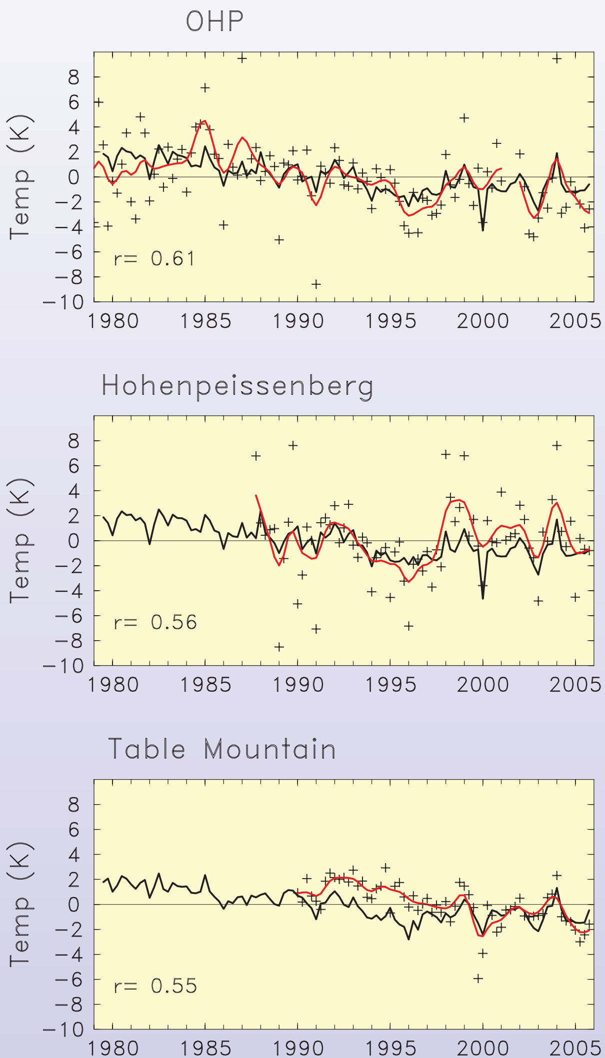
Station	Lat/Lon	Start date	Reference
Hohenpeissenberg	47.8 °N/11.0 °E	1987	Werner et al., 1983 Steinbrecht et al., 1997
Obs. de Haute Provence	43.9 °N/5.7 °E	1979	Keckhut et al., 1993
Table Mountain Facility	34.0 °N/117.7°W	1988	McDermid et al., 1990 Leblanc et al., 1998

with an accuracy of better than 1 K in the range 35-65 km. Temperature measurements are typically available 5-20 nights per month at each station (dependent on clear sky). The longest record of lidar temperature data is from the Observatory of Haute-Provence (OHP) in southern France, beginning in 1979, and temperature trends derived from these OHP data have been discussed in Keckhut et al (2001) and Ramaswamy et al (2001). We also include measurements from Hohenpeissenberg, Germany (beginning in 1987) and Table Mountain, California (beginning in 1988).

Satellite observations of stratospheric temperature are obtained from the series of Stratospheric Sounding Unit (SSU) instruments on board operational NOAA satellites spanning 1979-2005. These data include measurements from several individual SSU channels that correspond to stratospheric layers approximately 15 km thick (Nash, 1988); we focus here on results from SSU channels 26 (spanning ~27-44 km) and 27 (~35-52 km). The time series of SSU data include measurements from ten individual satellite instruments, and the time series have been adjusted using the overlap between individual instruments to account for instrument calibration changes and satellite orbit effects (WMO, 2006). The SSU time series are also adjusted to account for the influence of increasing CO_2 on the SSU weighting functions, as described in Shine et al (2007). The SSU data are available as zonal means on a 10 degree latitude grid, with monthly average sampling.

Results

The comparisons here are based on daily lidar observations binned into monthly samples, which are deseasonalized to form monthly anomalies, and then combined to generate three-month seasonal means (this is done in order to reduce the large variability of monthly means at the individual stations). For the time series comparisons to individual SSU channels, the lidar temperature anomalies are vertically integrated using the corresponding SSU weighting function. The resulting lidar data are compared to corresponding seasonal averages of (zonal mean) SSU data, interpolated to the latitude of the individual lidar stations. In comparing these data it should be kept in mind that there are substantial sampling differences between the two sets of measurements, including the localized lidar observations versus zonal mean SSU data, and limited temporal sampling of the lidars versus true monthly means of SSU. Time series of lidar and SSU channel 27 temperature anomalies are shown in **Figure 1** for the three lidar stations. The lidar data exhibit significantly more variability than SSU for all the comparisons, but this is reasonable considering the different sampling. There is significant correlation between the lidar and SSU seasonal temperature anomalies at each location (correlations of ~0.5-0.6), and also some reasonable agreement for the low-frequency interannual variations (represented by the red lines for the lidar data). The vertical profile of temperature trends derived from the lidar data and SSU



data are shown in **Figure 2**, based on calculations using a standard linear regression model. Trends from the OHP record for 1979-2005 are shown in **Figure 2a**, showing statistically significant cooling of ~1.5 K/decade over altitudes ~35-55 km. There is quite reasonable agreement with the SSU trends for this period. **Figure 2b** shows a corresponding comparison of trends for the shorter period 1988-2005, including results from all three lidar stations. Substantially different trends are derived from the three separate stations, although the statistical uncertainty is relatively large for this shorter record (especially for Hohenpeissenberg, where there are typically less than 10 lidar observations per month). It is unclear if these differences among the lidar station trends are associated with sampling uncertainties at the individual stations, or to spatially localized structure of the actual trends (or some combination of the two factors). The zonal average SSU trends cluster near the middle of the lidar trends in **Figure 2b**, and the statistical uncertainties overlap most

Figure 1. Time series of seasonal temperature anomalies from lidar measurements at OHP (top), Hohenpeissenberg (middle) and Table Mountain (bottom), compared with zonal mean SSU channel 27 data. In each panel the plus signs indicate the individual lidar seasonal anomalies, the red line is a smooth fit through the lidar data (using a running Gaussian smoother with halfwidth of 3 months), and the black line is the zonal mean SSU data interpolated to the lidar station latitude. The correlation between the lidar and SSU seasonal anomalies is indicated in each panel.

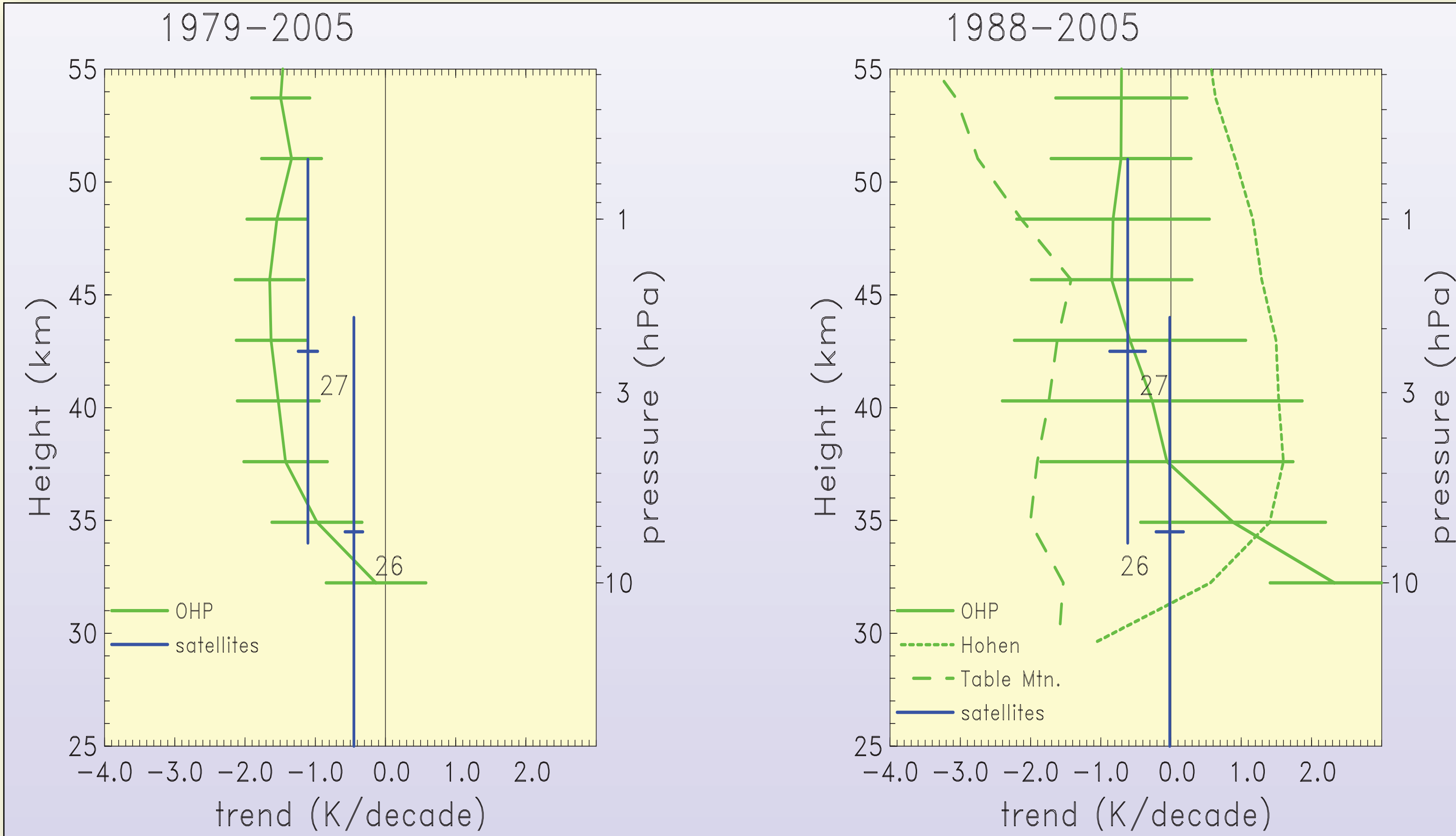


Figure 2. Vertical profile of trends derived from lidar measurements compared to zonal average SSU results. Left panel (a) shows trends for 1979-2005 from OHP data, and right panel shows results for 1988-2005, including results from OHP, Hohenpeissenberg and Table Mountain lidars. The heavy lines denote SSU trends, and the vertical bars denote the approximate altitude range of the SSU weighting function. Error bars denote the two sigma statistical trend uncertainties (for clarity, included only for the OHP results in (b)).

of the lidar results. However, given the large statistical uncertainties for this shorter record, together with the space-time sampling differences between the lidar and SSU data sets, it is difficult to constrain uncertainties in either data set by these comparisons.

Outlook

Lidar measurements provide a valuable record of stratospheric temperature variability and trends, and provide the only complement to long-term satellite observations above 30 km. While there are relatively few stations with multi-decadal records available at present (and these only in NH midlatitudes), regular measurements continue at several additional NDACC stations across the globe. It will be important to maintain and enhance these observations to provide climate-quality data sets for ongoing assessments of stratospheric (and mesospheric) changes.

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The WAVES campaigns

Aura/Aqua satellite validation activities at the Howard University Research Campus in Beltsville, MD

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Intensive Aura/Aqua satellite validation field campaigns have been hosted during the past two summers at the Howard University Research Campus in Beltsville, MD. The WAVES (Water Vapor Variability – Satellite/Sondes) campaigns were staged from July 7 to August 10, 2006 and July 14 to August 8, 2007. The Beltsville, MD site is a 110-acre forested facility located in a mixed suburban, light industrial area on the periphery of Washington, DC. As such it offers a wide range of meteorological and air quality conditions ranging from hot and polluted in the summer to cold and pristine in the winter. This makes the Beltsville location of particular interest to satellite validation by permitting retrieval studies under varying atmospheric conditions. During the WAVES campaigns, measurements of various sensors have been coordinated during more than 50 A-Train overpasses. The measurement systems involved included Vaisala RS-92 radiosonde, ENSCI ozonesonde, Cryogenic Frostpoint Hygrometer, Raman and backscatter lidars. The episodic measurements from these systems were supported by the large number of sensors permanently sited at the Howard University facility including a 31-m instrumented tower, various broad-band and spectral radiometers, microwave radiometer, GPS, whole sky imager, Doppler C-band radar, research level air quality monitoring including a complete set of gas filters (w/56 organic species) and particulate measurements (PM2.5 and 10), wind profiler and RASS (Radio Acoustic Sounding System) system. These supportive instruments permit studies of surface latent heat and carbon dioxide fluxes, boundary layer height and evolution, cloud optical and physical properties, aerosols, gas concentrations, and precipitation.

Using WAVES data, numerous research topics in addition to validation of satellite ozone, water vapor and temperature retrievals have been targeted including comparison of operational characteristics of Raman water vapor lidars, calibration studies of Vaisala RS-92 radiosondes, case studies of mesoscale meteorological events including pollution outbreak periods and warm and cold frontal passages. WAVES campaigns have also brought together researchers from several U.S government agencies, universities and foreign institutions and thus has offered unique training opportunities for students in the atmospheric sciences. Undergraduate and graduate students from both the U.S and several foreign countries have participated in ozonesonde preparation and launch, lidar data acquisition and analysis and in performing daily regional forecasts using the Weather Research and Forecasting (WRF) model. WAVES data have been used in 5 papers submitted to the Aura validation special issue of the Journal of Geophysical Research.

One of the core activities of the WAVES efforts has been to extend the research in radiosonde and Raman lidar corrections that was initiated during the AWEX-G field campaign in 2003. Of particular interest to the satellite overpass coordinated radiosonde measurements provided by WAVES is the empirical correction of Vaisala RS-92 radiosonde relative humidity data by comparison with Cryogenic Frostpoint Hygrometer instruments launched on the

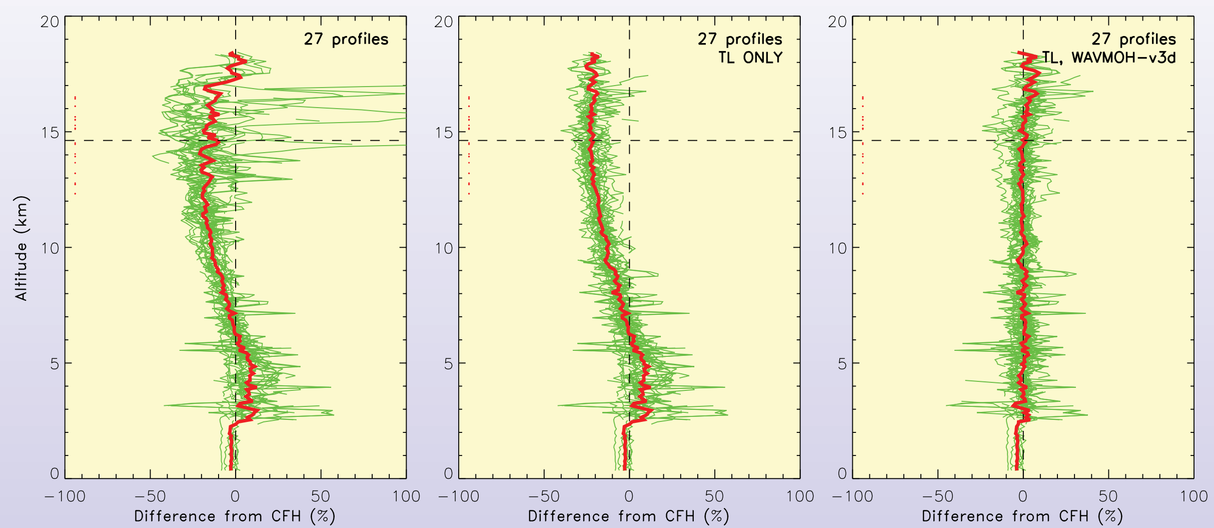

Figure 1. Left: percentage difference in relative humidity measurements of uncorrected Vaisala RS-92 and CFH. Middle: Same comparison after correction for the increasing response time of the Vaisala sensor with altitude. Right: Same comparison after application of the empirical correction to RS-92 data.

same balloon. An example of that correction is shown in **Figure 1**.

The left panel of **Figure 1** shows the percentage difference between the original Vaisala RS-92 measurements and those of the CFH. A moist bias in the middle troposphere and a distinct dry bias that increases with altitude in the upper troposphere is observed in the Vaisala sensor. The middle panel shows the same comparison after correction for the increase in response time of the relative humidity sensor due to the decreasing temperatures at higher altitudes. A dry bias in the UT is still observed however the variability in the comparisons with CFH is greatly reduced in the upper troposphere and lower stratosphere. The right-most panel shows the comparison of the RS-92 with the CFH after application of the empirical correction to the RS-92 measurements. In the mean, the two measurements agree within less than ±10% to well above the tropopause, the mean height of which is indicated by the dashed horizontal line at an altitude of approximately 15 km.

The total column water measurements from several systems including CFH and RS-92 were compared for total column water vapor amounts from the WAVES_2006 campaign. That comparison is shown in **Figure 2**. The reference instrument for this figure is a 2-channel Radiometrics microwave radiometer, the instrument that has become the "gold standard" for total column water measurements within the Department of Energy's Atmospheric Radiation Measurements (ARM) program. The instruments that are compared with the MWR for total column water amounts are the Suominet GPS, the TES instrument on Aura, the AIRS instrument on Aqua, the CFH, the RS-92 with empirical correction (ECNT) and the RS-

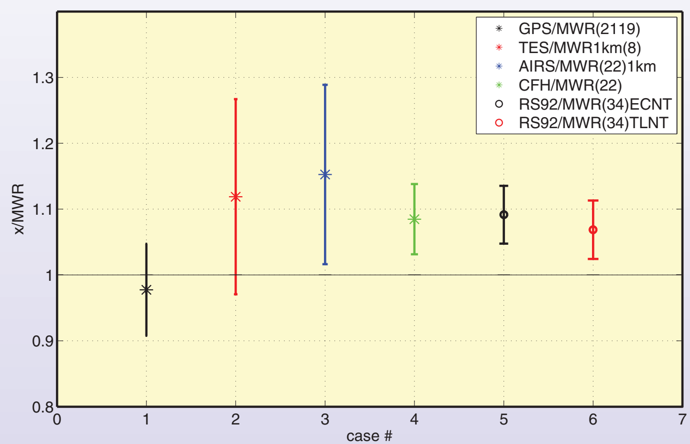

Figure 2. Comparison of precipitable water amounts measured by microwave radiometer, GPS, the TES instrument on Aura, the AIRS instrument on Aqua, Cryogenic Frostpoint Hygrometer and Vaisala RS-92.

92 with time lag correction only (TLNT). The range of PW calibrations covers almost 20% with the GPS retrievals being on average ~ 3% dry of the MWR and the AIRS retrievals being ~ 15% wet. This large range in PW measurements exceeds the claimed accuracy of all the individual measurement systems and indicates the need for further work in this area.

It is interesting to note from **Figure 2** that the CFH and corrected RS-92 are in good agreement with each other (as expected) and are significantly moist of the MWR. They are also moister than the RS-92 measurements that have only received a timelag correction. This result prompted a re-analysis of the CFH and RS-92 data using Raman water vapor lidar and other measurements to help study the problem. The conclusion was that under the moist, polluted conditions of WAVES_2006 – conditions under which the CFH has not previously been tested - the CFH was measuring artificially moist in the boundary layer. This moistness of the CFH results caused the empirical correction derived for Vaisala RS-92 from WAVES-2006 to also be significantly moist. A complete re-analysis of CFH/RS-92 dual sensor launches from WAVES and MOHAVE, lidar data from WAVES and data acquired by the ARM program is currently in process in order to derive a new empirical correction to the RS-92 data that does not rely on the CFH under the moistest of conditions. This new correction will be one of the major achievements of the WAVES_2007 campaign. Additional work that is under way using WAVES_2007 data includes assessment of TES water vapor retrievals using airborne Raman water vapor lidar measurements from the Raman Airborne Spectroscopic Lidar (RASL). Multi-instrument Raman water vapor lidar comparisons using RASL, the Howard University Raman Lidar, the GSFC Aerosol Temperature Raman lidar and the UMBC Raman lidar called ALEX (Atmospheric Lidar Experiment) are also being performed as is analysis of mesoscale meteorological case studies including a low level jet event on August 3, 2007.

We are currently making plans for a WAVES_2008 activity to begin in February, 2008. It will focus on clear, night time winter-time water vapor measurements using radiosonde and Raman lidar coordinated with A-train satellite overpasses. The WAVES_2008 experiment will provide satellite validation data in a distinctly different season than the previous WAVES experiments thus extending the set of conditions under which satellite retrievals can be tested from Beltsville, MD. We also expect that under these conditions we will be able to study the UT/LS water vapor measurement capability of Raman lidar.

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3. M. Shephard et. al., Comparison of Tropospheric Emission Spectrometer (TES) Water Vapor Retrievals with In Situ Measurements

4. R. Herman et. al, Validation of Tropospheric Emission Spectrometer Temperature Retrievals with Aircraft and Sondes

5. H. Vömel et. al., Validation of Aura/MLS Water Vapor by Balloon Borne Cryogenic Frostpoint Hygrometer Measurements

6. R. Nassar et. al., Validation of Tropospheric Emission Spectrometer (TES) Nadir Ozone Profiles Using Ozonesonde Measurements

7. B. Nardi et. al., Initial Validation of Ozone Measurements from the High Resolution Dynamic Limb Sounder (HIRDLS

A report on the NDACC Database Facility

Jeannette Wild and Roger Lin, NOAA, NCEP

Data acquisitions have returned to approximately 80,000 files per month (**Figure 1**) after being out of service for a time in 2006. You can find the NDACC public dataset and its description via its web site at http://www.ndacc.org, or directly via anonymous ftp at ftp://ftp.cpc.ncep.noaa.gov/ndacc.

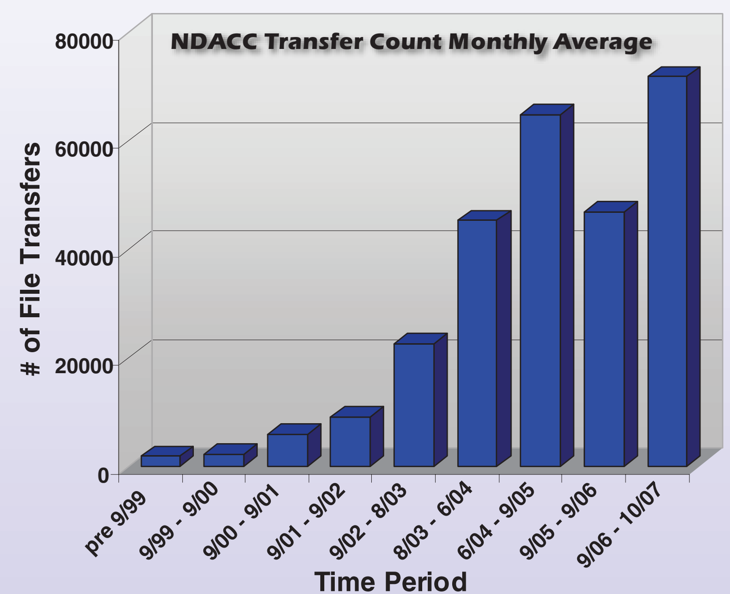


Figure 1. Number of files transferred per month from the NDACC Data Host Facility.

Relevant projects

This section brings information on ongoing and new projects that are relevant to NDACC. These can be both national and international projects.

GEOmon

Sophie Godin-Beekmann[1] and Martine de Mazière[2]

[1] Service d'Aéronomie, Centre National de la Recherche Scientifique
[2] Belgian Institute for Space Aeronomy

GEOmon is an Integrated Project of the 6th European Framework programme, with duration of four years (2007-2011). Its overall goal is to sustain and analyse European ground-based observations of the atmospheric composition in synergy with satellite measurements, in order to quantify and understand the ongoing changes.

GEOmon is a first step to build a future integrated pan-European Atmospheric Observing System dealing with systematic observations of atmospheric composition in relation with:

- Greenhouse Gases
- Air Pollution
- Atmospheric Particles
- Stratospheric Ozone

The project aims at optimising the European strategy for environmental monitoring in the field of atmospheric composition observations. It will support data gathering at existing networks, develop new methodologies to use these data for satellite validation, and evaluate long term changes.

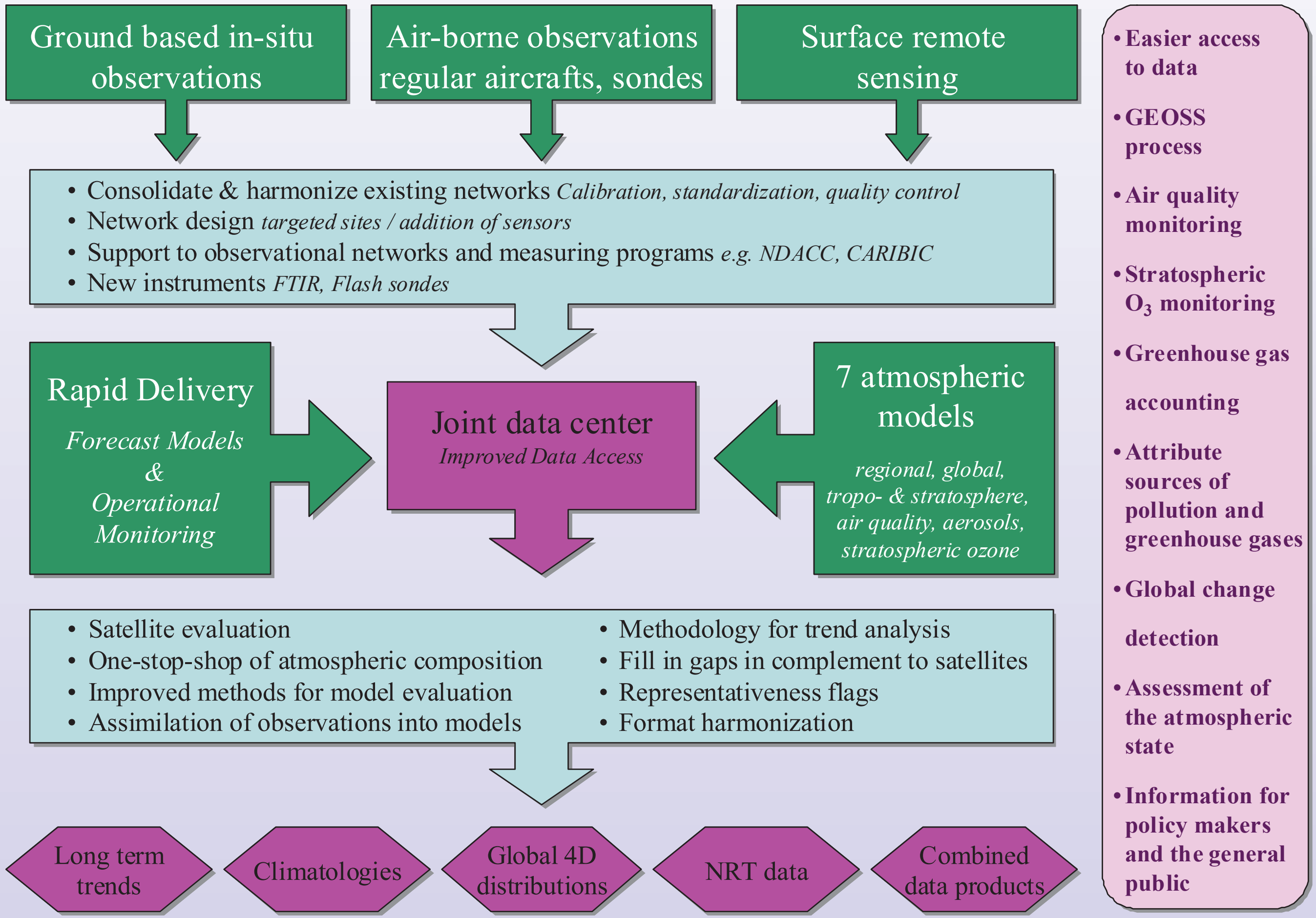
It is a European contribution to the Global Earth Observation System of Systems (GEOSS)

Almost all European NDACC stations are contributing to GEOmon.

The main atmospheric parameters monitored within GEOmon are two major greenhouse gases (CO_2, CH_4), reactive gases in the troposphere (e.g. ozone, CO, NO_2 and formaldehyde), atmospheric particles and atmospheric compounds involved in stratospheric ozone chemical depletion and the link with climate (e.g. ozone, NO_2, water vapour, BrO, Cl_y, F_y, stratospheric temperature and Polar Stratospheric Clouds).

In addition to providing access to validated datasets of key atmospheric parameters, one of the main outcomes of GEOmon is the *quantification of long term changes* in these parameters over Europe. Such long term change information will be accessible to the public at large and policy makers through diagnostics to be published on the GEOmon web site.

GEOmon is coordinated by the CEA (Commissariat à l'Energie Atomique, France) and involves 37 scientific institutions from the European Union, Norway, Switzerland and Russia.



Key elements of the European Commission-funded project GEOmon

This section brings information on recent and up-coming meetings that are relevant to NDACC. Scientific highlights presented at Steering Committee meetings will be conveyed through the NDACC Newsletter.

The 2005 Steering Committee meeting

The 2005 meeting of he NDACC Steering Committee took place in Puerto de la Cruz, Tenerife, Spain from 8-11 November 2005. A comprehensive presentation of the activities at the Izaña station on Tenerife is given in the next section.

Participants at the 16th NDACC Steering Committee meeting in November 2005.

The 2006 Steering Committee meeting

The 2006 meeting of he NDACC Steering Committee took place at the site of Observatoire de Haute Provence (OHP) in Southern France from 26-28 September 2006. A description of the activities at OHP is given in the next section.

Participants at the 17th NDACC Steering Committee meeting in September 2006.

The 2007 Steering Committee meeting

The 2007 meeting of he NDACC Steering Committee took place in Waikoloa, Hawaii, from 3-5 December 2007. A description of the activities at the Mauna Loa Observatory will be given in the next issue of the newsletter.

Participants at the 18th NDACC Steering Committee meeting in December 2007.

Overview of meetings

NDACC Steering Committee meetings	Place	Date
2005 Steering Committee meeting	Puerto de la Cruz, Tenerife, Spain	8-10 Nov. 2005
2006 Steering Committee meeting	Obs. de Haute Provence, France	26-28 Sep. 2006
2007 Steering Committee meeting	Kona/Mauna Loa, Hawaii	3-5 Dec. 2007
2008 Steering Committee meeting	Jakobshavn, Greenland	25-30 Sep. 2008
2009 Steering Committee meeting	Geneva, Switzerland	Autumn 2009

NDACC Working group meetings		
FT-IR working group	Queentstown, New Zealand	Nov. 2004
FT-IR working group	Tenerife, Spain	1-3 May 2007
FT-IR working group	Pasadena, California	May 2008
Lidar working group	Hohenpeissenberg, Germany	26 -30 Sep. 2005
Lidar working group	Bilthoven, The Netherlands	12-15 Jun. 2007
Microwave working group	Kos, Greece	May 2004
Dobson & Brewer WG: Brewer workshop	Delft, The Netherlands	31 May - 3 Jun. 2005
UV-Vis working group	Madrid, Spain	6-8 Jun. 2005
UV-Vis working group	Cambridge, UK	29-30 Nov. 2007
Other meetings relevant to NDACC		
Workshop on IGACO-O3/UV	Anavyssos, Greece	15-17 May 2006
Workshop on IGACO-O3/UV	Dübendorf, Switzerland	12-14 Mar. 2007
Workshop on GCOS Reference Upper Air Network (GRUAN)	Lindenberg, Germany	26-28 Feb. 2008
1st NDACC Water Vapour Workshop	Berne, Switzerland	5-7 Jul. 2006
2nd NDACC Water Vapour Workshop	Berne, Switzerland	11-14 Feb. 2008
GAW/NDACC/IGACO Ozone theme meeting	Geneva, Switzerland	21-23 Apr. 2008
7th Meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer	Geneva, Switzer-land	18-21 May 2008
Quadrennial Ozone Symposium	Tromsø, Norway	29 Jun - 5 July 2008
SPARC General Assembly	Bologna, Italy	31 Aug.-5 Sep. 2008
IGAC 10th International Conference	Annecy, France	7 - 12 Sep. 2008

Station Highlights

The Izaña Observatory on the Island of Tenerife. The station is located at 2360 m.a.s.l.

Izaña Observatory in NDACC

Emilio Cuevas, Instituto Nacional de Meteorologia

The site

The Izaña Observatory (IZO) (photo on previous page) is located on the island of Tenerife (The Canary Islands) at 28°18'N, 16°29'W, 2360 m a.s.l. on the top of a mountain plateau (**Figure 1**). Its position in the Atlantic Ocean and above a stable inversion layer (between 1200 and 1800 m a.s.l.), typical of subtropical regions, provides clean air and clear sky for most of the year, offering excellent conditions for atmospheric observations by remote sensing techniques.

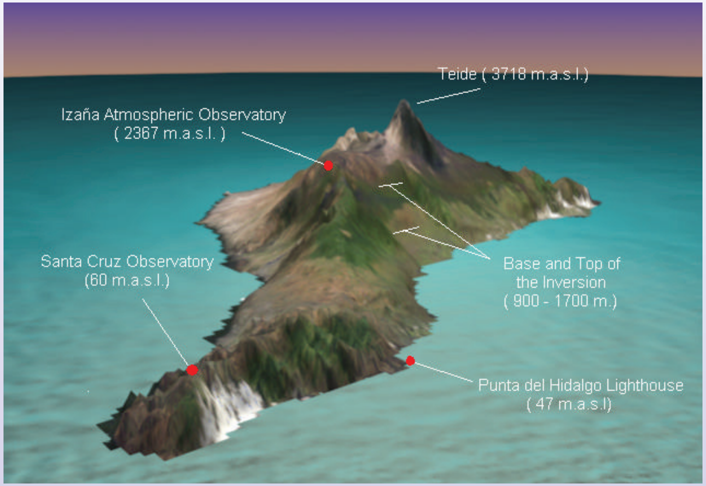


Figure 1. View from the North. Location of the Izaña Observatory (IZO) on Tenerife (the Canary Islands).

IZO is managed by the "Instituto Nacional de Meteorología" (INM, Spain) through a service named "Observatorio Atmosférico de Izaña" (OAI). IZO is complemented by a sea-level station in Santa Cruz de Tenerife (SCO; 34 km northeast of IZO). This double-station facility allows us to perform atmospheric monitoring simultaneously under free troposphere and marine boundary layer conditions.

IZO is a World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) station of global importance. Therefore, it makes in-situ measurements of many atmospheric components (O_3, CO_2, CO, CH_4, N_2O, NO_x, SO_2 and SF_6). Due to its location in the subtropics, IZO is a privileged site to monitor and study the tropical-to-mid latitude stratospheric transport and stratosphere-troposphere exchange processes. IZO is a good site to investigate the influence of Saharan dust and its role in radiative forcing. IZO is equipped with different in-situ analysers for physical and chemical aerosol characterization and sunphotometers, which are part of the AERONET (AErosol RObotic NETwork of the Goddard Space Flight Center - NASA) and the GAW network. In addition, IZO is the absolute solar calibration site for PHOTONS (PHOtométrie pour le Traitement Opérationnel de Normalisation Satellitaire).

NDACC activities include Brewer, ozone sonde, UV/Vis, and FTIR. These instruments were accepted by the NDSC/NDACC network in March 2001. UV-B measure-

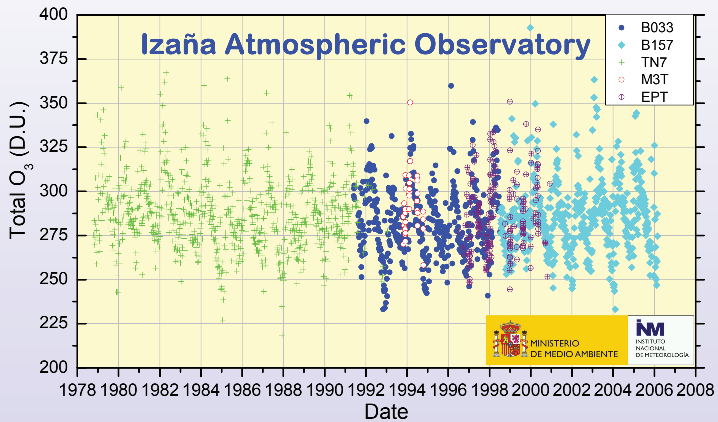


Figure 2. The total column ozone series at Izaña Observatory since 1978. Notice that assimilated TOMS series has been added to the ground-based ozone series.

ments have been made since 1992. An NDACC application is in preparation and in addition, there is an aerosol Micro-Pulse LIDAR at SCO. In total, there is an almost complete set of NDACC instruments at the IZO-SCO facility. Groups operating other instruments, such as microwave radiometer or LIDAR instruments, are very welcome.

Brewer total column ozone activity

Total column ozone measurements (**Figure 2**) started at IZO with the single monochromator Brewer 033 (B033) in May 1991. This instrument was replaced in 1998 by the double monochromator Brewer 157 (B157). IZO has hosted several total ozone and spectral UV intercomparisons since 1993 (e.g. Cuevas et al., 1994).

In November 2003, the WMO/GAW Regional Brewer Calibration Centre for Europe (www.rbcc-e.org) was established at Izaña Observatory. It consists of three double Mark-III Brewer spectrophotometers (the IZO triad): a Regional Primary Reference (B157), a Regional Secondary Reference (B185) and a Regional Travelling Reference (B183) (the triad is shown in **Photo 1**). The establishment of the IZO triad allows the implementation of a self-sufficient European Brewer calibration system

Photo 1. The double monochromator Brewer Spectrophotometer triad over the observation tower roof at the Izaña Observatory with other instruments.

that works as independent GAW infrastructure. This is an essential step for the creation of a coordinated European Brewer network that is needed for both present and future consistency of quality of ground total ozone observations and for validation of satellite instruments. The IZO triad is regularly sun calibrated by means of the Langley method and by external lamps and linked to the world reference MSC (Meteorological Service of Canada) triad with yearly calibrations towards the Canadian travelling reference B017 (agreement within 1%). This annual comparison at IZO could be considered as a quality assurance method for the world MSC triad reference. Further intercomparison campaigns with other ground and satellite based instruments are performed regularly (e.g. Gil et al. 2000; Cuevas et al. 2004; Schneider et al., 2005a; Bojkov et al., 2006). The function of the Regional Brewer Calibration Centre also allows development and testing of new measurement techniques for the Brewer network like zenith, polarimetric, UV or aerosol optical depth measurements. A dark room and an electronic workshop are available at IZO for accurate fittings and indoor calibration and maintenance of the triad instruments.

A fourth Brewer (Mark-II single B033) is located at SCO. It complements total ozone measurements performed at IZO adding information from the lower 2km.

Ozone sonde activity

The ozone sonde program started in November 1992 (Cuevas et al., 1993) applying ECC-type (Scientific Pump 6A) ozonesondes and RS80-type Väisalä radiosondes. The sondes are launched from the Santa Cruz station (**Photo 2**), normally on Wednesdays on a routine basis. However, every year intensive ozonesonde campaigns are carried out significantly increasing the total number of ozonesondes per year. Most of the good soundings fly up to 32 km in altitude. ECC sondes are ground checked with an ozone calibrator. A constant mixing ratio above burst level is assumed for the determination of residual ozone. The integrated column obtained in those ozonesondes reaching a burst level of at least 18 hPa is ratioed with the same column amount measured at the same time by

Photo 2. Preparation of ozone sonde launching at the Santa Cruz Meteorological Center.

the B033 at SCO (52 m a.s.l.). The correction factor is normally within the range of 0.95-1.05.

The ozone sonde data series has been used to validate ozone vertical profiles derived from Brewer Umkehr observations and the corresponding inversion algorithms (Godin et al., 1999; Redondas et al., 2000). They are also used for satellite validation (Parrondo et al., 2000) and for investigating the troposphere-stratosphere exchange around the subtropical jet (Kowol-Santen et al., 1999; Timmis et al., 1999; Cuevas, 2000). The ozone sonde program has contributed to characterizing the layered structure of the subtropical troposphere over the North Atlantic (Oltmans et al, 1996), to validating modelled stratospheric intrusions in the subtropical region (Kentarchos et al., 2000), to reconstructing 3D ozone fields with assimilated data (Randall et al., 2002) and for the validation of vertical ozone profiles obtained with other techniques (Schneider et al., 2005a).

Photo 3. Izaña Observatory terrace during a moderate Saharan event. The tripod in the foreground holds the UV-spectrometer optics and stepper motor for off-axis measurements. In the back the housing of the scanning spectrometer located outdoor.

Photo 4. INTA PDA UV/Vis spectrometers are hosted in a laboratory located on the top floor of Izaña tower. Sunlight from the optical devices located on the terrace reach the instruments by means of a quartz fiber-bundle. Spectrometers are thermally regulated to minimize spectral shift and stretch.

UV-Vis activity

Routine observations of NO_2 at IZO started in March 1993. At that time a scanning spectrometer operating at zenith during twilight was installed within the framework of a cooperation agreement between INTA and INM. The instrument is still in use at present. In December 1998, a new visible spectrograph based on PDA technology was

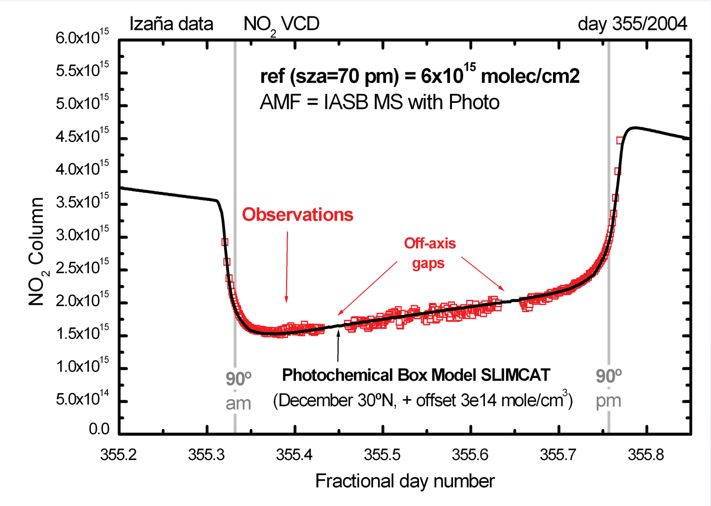


Figure 3. Continuous measurements throughout the day under very low aerosol conditions can be used for testing the NO_2 photochemistry. The NO_2 column over Izaña for the 2004 winter solstice measured by the UV/Vis spectrometer is shown in red squares. The black line represents the altitude integrated output of a photochemical box model.

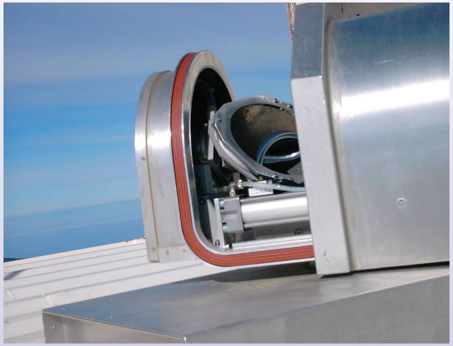


Photo 5. FTIR Solar tracker on the roof of the new container

installed extending the observations in time and spectral range to include ozone. Finally, in January 2002, an UV spectrograph was incorporated for BrO and HCHO measurements (**Photos 3** and **4**). This later instrument has the capability of measuring at any zenithal angle, including the horizon (see van Roozendael, 2005) to enhance the contribution of the tropospheric layers to the signal and derive a stratospheric/tropospheric ratio. The Observatory is located high above the marine boundary layer in an unpolluted atmosphere providing an excellent site for measuring stratospheric species. Under non Saharan conditions, the very low optical depth (AOD<0.02) allows the extension of observations to low solar zenith angles useful to study the diurnal evolution of photochemically active species such as NO_2 (see **Figure 3**).

The spectrometers have participated in Haute-Provence-1996 and Andoya-2003 Uv-Vis blind NDACC intercomparison exercises (Roscoe et al, 1999, Vandaele et al, 2005). Data has been used for characterization of NO_2 and O_3 during solar eclipses (Gil et al. 2000), the study of fast and sharp enhancements of the NO_2 column associated to upwind thunderstorms (Gil et al., 2004) and for in satellite instrument validation (Lambert, 2004). Long-term NO_2 data was re-evaluated within the EU-QUILT project and a manuscript is currently under preparation.

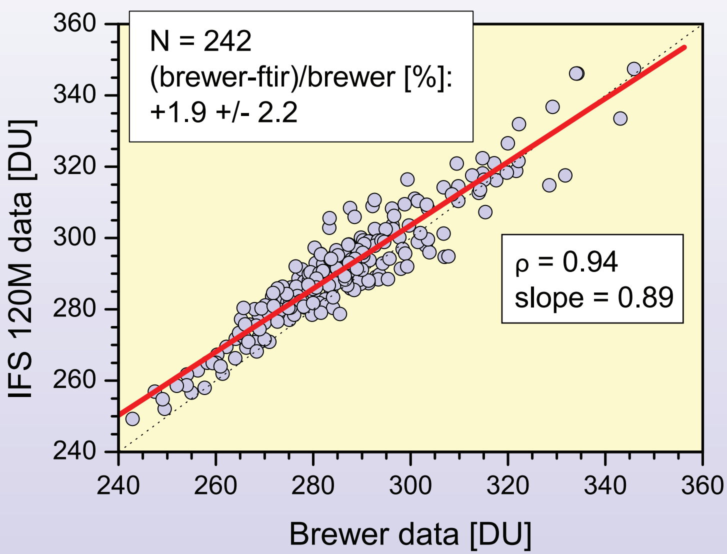


Figure 4. Comparison of O_3 total column amount measurements from Brewer and FTIR instrument.

FTIR activity

In 1999 the FTIR measurements at IZO began with a Bruker IFS 120M spectrometer and have been performed since 2005 applying a Bruker IFS 125HR spectrometer. **Photo 5** shows the solar tracker mounted on the roof of the new container. Great importance is given to assuring the quality of the retrieved products. Therefore the instrumental performance is continuously monitored by cell measurements (Hase et al., 1999), and the retrieved data are compared to other measurements. O_3 profiles and column amounts are compared continuously to ECC-sondes and Brewer measurements (Schneider et al., 2005a). **Figure 4** depicts the comparison to Brewer measurements from 1999 to 2003. H_2O profiles are compared to meteorological radiosondes, which are launched twice a day close to the Observatory (Schneider et al., 2006a; Schneider et al., 2006b). Since 1999, two intercomparisons with other FTIR instruments have been performed. The first in 1999 against measurements performed on board the Polarstern (Schneider, 2002), and the second between a Bruker IFS120M and an IFS125HR operated simultaneously at IZO from January to April 2005. The retrieved products have a wide range of applications. They are used for satellite and model validations (see example of **Figure 5**) and trend examinations (e.g. Yurganov et al., 2005; Schneider et al., 2005b; De Mazière et al., 2006; Dils et al, 2006) and to test improvements in spectroscopic parameters (Goldman et al., 2006).

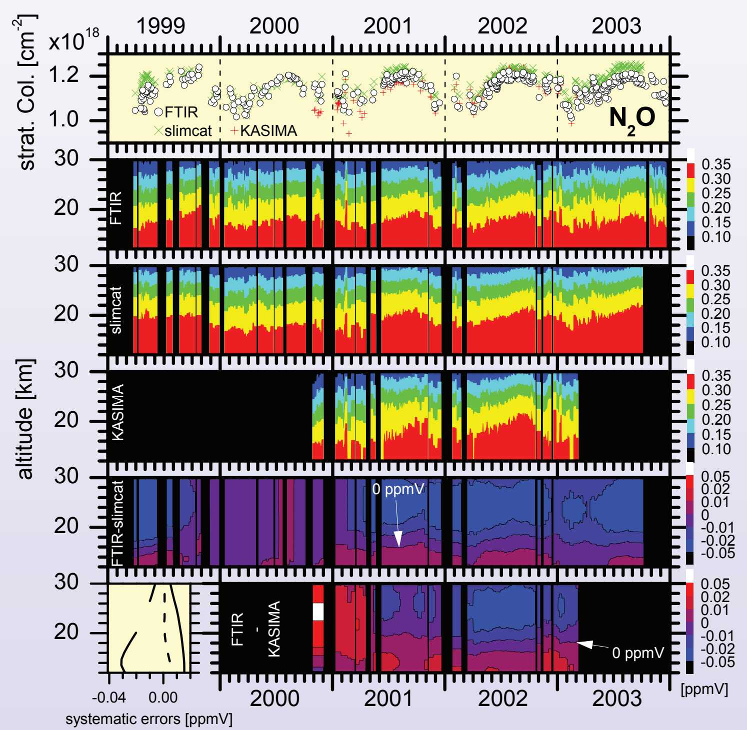


Figure 5. Comparison of measured and modelled N_2O time series. Upper panel: stratospheric column amounts above 12.4km; black circles: FTIR; green crosses: SLIMCAT model; red crosses: KASIMA model. Second to fourth panel: mixing ratio profiles of FTIR, SLIMCAT, and KASIMA. Lower panels: Difference between FTIR and SLIMCAT and between FTIR and KASIMA. Left hand side of lowest panel: systematic errors for the difference between FTIR and models. For further details see Schneider 2005b.

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Observatoire de Haute Provence

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The Observatoire de Haute-Provence (OHP) (44°N, 6°E) is part the Marseille-Provence Astronomical Observatory (OAMP) federation. It is located near the town of Forcalquier on a plateau at 650 meter altitude in the southern French pre-Alps. First dedicated to astronomical observations, the Observatory accommodated geophysical observations from the beginning of the 1970s. A geophysical station devoted to the long term monitoring of the atmosphere was established in 1980. It was one of the first stations to be part of the Network of the Detection of Stratospheric Changes (former designation of NDACC) in 1991.

Aerial photo of the Observatoire de Haute Provence

The first astronomical observations were made at OHP in 1943 and the Observatory was open to foreign astronomers in 1949. The main facilities include telescopes of 1.93, 1.52 and 1.20 meter diameter. The first planet outside the solar system was discovered in 1995 at OHP by M. Mayor and D. Queloz of the University of Geneva using the radial velocity technique. Presently, the detection of exo-planets is a main research activity at OHP, based on high resolution cross-dispersed spectrometer implemented on the 1.93 m telescope.

First geophysical observations began at OHP in the 1970s, in particular with the pioneering work on lidar by Gérard Mégie. The first lidar system implemented on the site used the resonance-fluorescence technique for the measurement of the sodium layer in the mesosphere. Subsequently other lidar systems for measuring atmospheric parameters such as the temperature and ozone vertical distributions were set up at OHP. Initially based on dye lasers as active radiation source, the lidar instruments became more reliable with the development of commercial solid state or gas lasers. Temperature and ozone lidar time series started in 1980 and 1985 respectively and they are the longest worldwide. During the same period, various instruments for the monitoring of the atmospheric composition were also implemented on the site. A Dobson spectrometer, part of the automated Dobson network and providing measurements of ozone total content and ozone vertical distribution using the Umkehr technique was installed in 1983. Ozone soundings started in 1984 using first Brewer-Mast and then ECC sondes from 1991. A UV-Visible spectrometer for the measurement of ozone and nitrogen dioxide total contents was implemented in 1992. Most recent instruments implemented at OHP include a CIMEL sun photometer as part of the AERONET program for the measurement of the aerosol optical depth, a Max-DOAS UV-Visible spectrometer measuring BrO, a high resolution spectro-radiometer for the measurement of UV radiation, and surface ozone and CO analysers. Tropospheric aerosols lidar measurements are performed as part of the EARLINET network. New lidar techniques continue to be tested and implemented, e.g. Doppler wind, high resolution backscatter and water vapour Raman lidars.

The OHP site is particularly well suited for lidar observations, with in average 170 clear-sky and 50 partially cloudy nights per year. OHP is part of the NDACC Alpine station, which includes the Jungfraujoch, Bern and Payerne stations in Switzerland, Garmisch-Partenkirchen, Zugspitze and Hohenpeissenberg in Germany and Lannemezan in France. The institutions participating to the NDACC monitoring programme at OHP are the CNRS, ADEME and CNES (France), NOAA (USA) and IASB-BIRA (Belgium). Long term measurements at OHP have been extensively used for the validation of satellite observations, in particular the UARS, Envisat and AURA platforms. Lidar and UV-Visible measurements are currently part of the long term Envisat validation programme. Several NDACC intercomparison were organised at OHP for lidar (1992 and 1997) and UV-Visible measurements (1996). The next inter-comparison campaign involving the NASA-GSFC mobile lidar instrument is scheduled for 2008.

The international Network for the Detection of Atmospheric Composition Change (NDACC) was formed to provide a consistent, standardised set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed sites.

The principal goals of the network are:

- To study the temporal and spatial variability of atmospheric composition and structure in order to provide early detection and subsequent long-term monitoring of changes in the physical and chemical state of the stratosphere and upper troposphere; in particular to provide the means to discern and understand the causes of such changes.
- To establish the links between changes in stratospheric ozone, UV radiation at the ground, tropospheric chemistry, and climate.
- To provide independent calibration and validation of space-based sensors of the atmosphere and to make complementary measurements.
- To support field campaigns focusing on specific processes occurring at various latitudes and seasons.
- To produce verified data sets for testing and improving multidimensional models of both the stratosphere and the troposphere.

The primary instruments and measurements of NDACC are:

- Ozone lidar (vertical profiles of ozone from the tropopause to at least 40 km altitude; in some cases tropospheric ozone will also be measured)
- Temperature lidar (vertical profiles of temperature from about 30 to 80 km)
- Aerosol lidar (vertical profiles of aerosol optical depth in the lower stratosphere)
- Water vapour lidar (vertical profiles of water vapour in the lower stratosphere)
- Ozone microwave (vertical profiles of stratospheric ozone from 20 to 70 km)
- H_2O microwave (vertical profiles water vapour from about 20 to 80 km)
- ClO microwave (vertical profiles of ClO from about 25 to 45 km, depending on latitude)
- Ultraviolet/Visible spectrograph (column abundance of ozone, NO, and, at some latitudes, OClO and BrO)
- Fourier Transform Infrared spectrometer (column abundances of a broad range of species including ozone, HCl, NO, NO_2, $ClONO_2$, and HNO_3)
- Ozone and aerosol sondes (vertical profiles of ozone concentration and aerosol backscatter ratio)
- UV spectroradiometers (absolutely calibrated measurements of UV radiance and irradiance)

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