THE MANTRA 2002 BALLOON FLIGHT FROM VANSCOY, CANADA

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ABSTRACT

The MANTRA series of high-altitude balloon flights is being undertaken to investigate changes in the concentrations of mid-latitude stratospheric ozone, and of nitrogen and chlorine compounds that play a role in ozone chemistry. Three balloons have been launched since August 1998, all from Vanscoy, Saskatchewan. Each carried a payload of instruments to measure vertical concentration profiles of stratospheric trace gases, and made observations from a float altitude of about 35 km for one day. Several of these instruments were flown 15-20 years ago, thus providing a link to historical data predating the onset of mid-latitude ozone loss. The third of these balloons was launched on September 3, 2002, and measurements were made by 11 instruments. In addition, four ground-based spectrometers were deployed at Vanscoy approximately two weeks prior to this flight, and a total of 15 independent ozonesonde flights were made. This paper provides an overview of the MANTRA 2002 balloon campaign, and briefly describes each of the instruments, the data acquired, and the status of data analysis. We expect to retrieve vertical profiles of O_3, NO, NO_2, HNO_3, N_2O, OH, H_2O, CH_4, CO_2, aerosol extinction, pressure and temperature from O_2 (as well as from sondes), and total columns of O_3, NO_2, SO_2, and possibly BrO. Data analysis is complete for some instruments and ongoing for others. These data will be used to contribute to the validation of the SCIAMACHY, MIPAS, and GOMOS instruments on ENVISAT through the Category 1 CAL/VAL project #1335.

1 INTRODUCTION

MANTRA (Middle Atmosphere Nitrogen TRend Assessment) is a balloon program to study the mid-latitude stratosphere. Three high-altitude balloon flights have been undertaken to date, all launched from Vanscoy, Saskatchewan (52°N, 107°W). The first two balloons were launched on August 24, 1998 and August 29, 2000. This paper describes the most recent balloon flight, which took place on September 3, 2002.

The primary objective of the MANTRA program is to fly a comprehensive suite of instruments in order to measure vertical concentration profiles of the key stratospheric species that control the mid-latitude ozone budget, particularly species in the NO_y, Cl_y, Br_y, and HO_x chemical families, along with dynamical tracers and aerosols. These measurements are being combined with those obtained from similar northern mid-latitude campaigns of the past 20 years, particularly the Stratoprobe flights (e.g., [1,2,3]) of the Atmospheric Environment Service (now the Meteorological Service of Canada – MSC) in order to quantify changes in the chemical balance of the stratosphere. In addition, multiple measurements of the same trace species made by different instruments are being compared, with several of the earlier Stratoprobe instruments included in the payloads to provide a link to the earlier data. The 2002 measurements are also intended to contribute to validation and ground-truthing for the OSIRIS and SMR instruments on the Odin satellite, and SCIAMACHY, MIPAS, and GOMOS on ENVISAT.

2 THE MANTRA 2002 PAYLOAD

The primary balloon payload included a pointing control system, two emission radiometers, two SunPhotoSpectrometers (SPSs), two infrared Fourier transform spectrometers (FTSs), a SAOZ spectrometer, MAESTRO-B, an OH spectrometer, and two ozonesondes (ECC and UV). Fig. 1 shows the layout of these instruments on the gondola, and Table 1 lists the full payload. Two aerosol backscatter sondes were flown separately, and a total of 15 independent ozone profiles were collected during the campaign using ECC sondes.

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Ground-based measurements were made by four instruments: a Brewer spectrophotometer, a grating spectrometer, an acousto-optical tunable filter spectrometer, and SPS-G.

During the flight, the following data were collected: sonde and radiometer measurements on ascent; SAOZ sunrise occultation measurements; daytime measurements with SPS-B2 and the OH spectrometer; daytime SPS-B1 and MAESTRO-B limb scans; a high sun spectrum with the MSC FTS; sunset data with the OH spectrometer, SPS-B1, SPS-B2 in direct sun mode, MAESTRO-B, the DU FTS, and SAOZ. Due to the azimuth top mount seizing up on ascent, the only sunrise data were obtained by SAOZ. Despite a number of problems during the flight, it was generally successful, with some observations made by all the instruments.

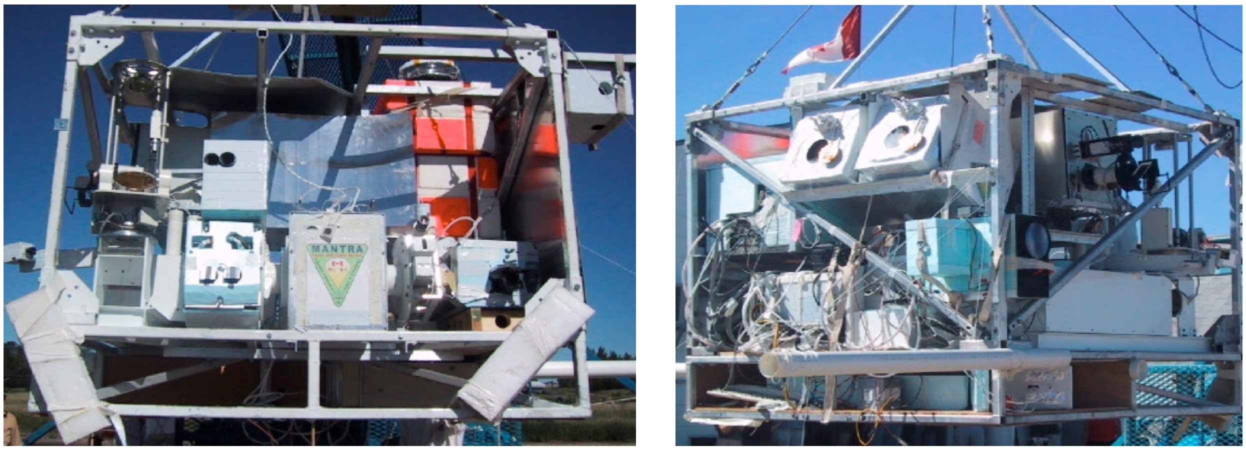

Fig. 1. The MANTRA 2002 gondola. (a) Sun-pointing side, showing (from left to right) the University of Denver FTS, SPS-B1 and MAESTRO-B mounted on the pointing control system, the MSC FTS, the Service d'Aéronomie SAOZ, and SPS-B2 suspended from the right-hand side. (b) Anti-sun-pointing side, showing the two emission radiometers, the OH spectrometer, a sonde package, and the University of Denver FTS.

Table 1. The MANTRA 2002 balloon-borne and ground-based instruments.

PRIMARY BALLOON-BORNE INSTRUMENTS	**SECONDARY BALLOON-BORNE INSTRUMENTS**	**GROUND-BASED INSTRUMENTS**
• MSC emission radiometer • MSC SunPhotoSpectrometer (SPS-B1) • University of Denver FTS • Service d'Aéronomie SAOZ • MSC ozonesonde • aerosol sonde (two independent flights)	• second MSC emission radiometer • MSC SPS-B2 • MAESTRO-B • MSC FTS • MSC OH spectrometer • MSC UV ozonesonde	• MSC Brewer spectrophotometer • University of Toronto grating spectrometer • York University AOTF spectrometer • MSC SPS-G

3 THE MANTRA 2002 FLIGHT

The field campaign at Vanscoy began with ozonesonde and ground-based Brewer measurements on August 13 and continued until September 4. Initial mechanical and electrical integration of the instruments onto the gondola was done in Toronto. Final instrument preparation and calibration, and payload integration took place at Vanscoy. Scientific Instrumentation Limited of Saskatoon was responsible for preparation of the gondola and support systems (command interface package, telemetry, power distribution system, and battery packs). All instruments and telemetry were integrated on the gondola for all-up checks, electrical tests including external and battery power tests, radio frequency interference tests, and balancing. A launch dry run was performed on the night of August 22.

Plots of daily forecast balloon trajectories and surface and stratospheric winds were produced using information from ECMWF objective analyses (up to 1 hPa) and wind data from the regular Vanscoy ozonesonde launches. This information was used to help in identifying turnaround and in flight planning. In addition, surface wind forecasts were obtained regularly from Environment Canada and were also used in ozonesonde and primary launch planning.

The 11.8-mcf balloon was launched at 2:02 AM local time (08:02 UTC) on Tuesday, September 3, 2002 under calm surface wind conditions. The total mass of the gondola with instruments was approximately 660 kg. Table 2 summarizes the main flight activities and measurements during the balloon flight. The balloon reached its maximum altitude of 37.8 km at 4:45 AM local time. It remained at a float altitude of 36-37 km through the morning, until it began a slow descent near midday as helium was repeatedly released to bring the balloon down to an altitude of lower winds and to thereby ensure that it remained within telemetry range through sunset. Fig. 2 shows the altitude profile and the latitude-longitude position for the balloon. These plots were constructed from the SAOZ GPS data, and agree with the payload GPS data recorded with the onboard datalogger.

Just after sunset, at 8:20 PM local time (02:20 UTC on September 4), the terminate command was sent and separation of the gondola and parachute from the balloon occurred without incident. The gondola landed soon afterwards, at ~9 PM local time at 52.276°N latitude, 100.208°W longitude, near Duck Bay on Lake Winnipegosis. The payload was recovered the following day and returned to Vanscoy on September 5, with all instruments intact.

Table 2. Primary activities during the MANTRA 2002 balloon flight.

LOCAL TIME (UTC – 6 hrs)	**MANTRA 2002 FLIGHT ACTIVITIES**
2:02 AM, Sept. 3	launch; ozonesonde and radiometer measurements on ascent
3:30 AM	aerosol backscatter sonde launch, measured on ascent
4:45 AM	gondola stabilized at 37.8 km
~6 AM (sunrise)	SAOZ sunrise occultation measurements; azimuth top mount seized up so no other sunrise data
7:40 AM	began limb-scanning with SPS-B1 and MAESTRO-B
~10 AM	azimuth top mount began rotating, regained pointing control of gondola
10:30 AM	began opening the balloon valve to descend to an altitude of lower winds (went from ~38 to ~34 km)
daytime	SPS-B2 measurements all day; good spectra with OH spectrometer; SPS-B1 and MAESTRO-B limb scans; high sun spectrum with MSC FTS; tuned pointing system
5:30 PM	reacquired solar pointing with the pointing system but lost it at 6:20 PM due to large torque required
7:35-7:55 PM (sunset)	reacquired the sun and took sunset data (-2° to -5°) with OH spectrometer, SPS-B1, SPS-B2 in direct sun mode, MAESTRO-B, DU FTS, MSC FTS, and SAOZ
8:20 PM	sent signal to cut down payload; landed near Duck Bay on Lake Winnipegosis

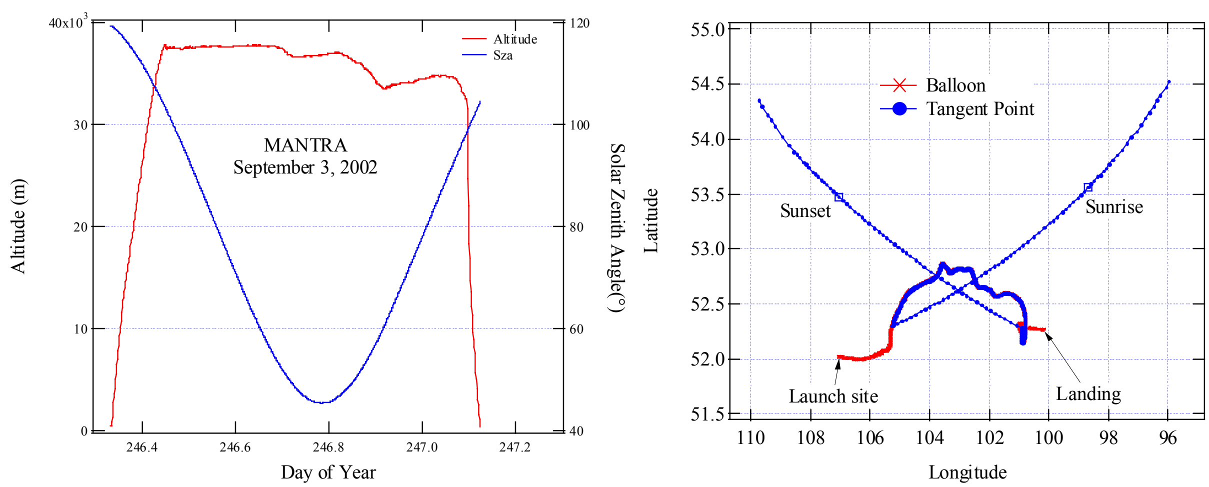

Fig. 2. (a) Altitude of the balloon (red) and solar zenith angle (blue) obtained from the SAOZ GPS. (b) Position of the balloon (red) and of the tangent point (red) obtained from the SAOZ GPS. (F. Goutail).

4 INSTRUMENTS AND ANTICIPATED MEASUREMENTS

4.1 Pointing Control System

MANTRA 2002 provided the second flight opportunity for a new pointing control system that combines solar occultation and limb-scanning capabilities. The system hardware comprised a flight computer, elevation and azimuth actuators, gyroscope, magnetometer, encoder, tilt sensor, sun sensors, temperature and pressure sensors and serial communications channels for command and control. The pointing system design was modified from the MANTRA 2000 configuration [4] to include a reaction wheel for fine azimuth control and revised software.

The pointing system, in common with other instrumentation, was operational during launch. Pointing control was tested during ascent at 8:21 UTC, and a temporary pointing lock was acquired at 8:22 UTC before returning the system to no-control mode for the remainder of the ascent. The top mount and reaction wheel actuators performed nominally. Pointing control was activated at 11:04 UTC, but the gondola system no longer responded correctly to either the top mount or the reaction wheel azimuth control actuators. The anomaly was consistent with a diagnosis that the top mount rotational pivot had seized or frozen due to the cold temperatures experienced during ascent through the tropopause. Several attempts were made to loosen the top joint pivot but consistent with the fault diagnosis, the reaction wheel, running at maximum torque, was only able to turn the gondola around 20° in either direction before reaching wheel saturation, and the operation of the top mount had no control effect. With a seized top mount pivot, it was not possible to acquire sun pointing for sunrise.

At 16:28 UTC, after several hours of sunlight, the azimuth pivot resumed operation, and full pointing control was returned. SPS-B1 and MAESTRO-B gains were tested and then adjusted by pointing-system command, and an extensive period of limb scanning was initiated with both instruments acquiring limb-scanning-data sets under pointing system control and synchronized with the elevation pointing. After this period, some adjustments were made to the pointing-system-control parameters by ground command, and the sun-pointing mode was tested. Sunset was acquired at an elevation angle of ~2° until sunset at ~5°. The system was deactivated at 01:56 UTC.

Our analyses indicate that the magnetometer with its modified mount, the tilt sensor, encoder, flight computer, new automated scheduler, serial communications channels and 2-axis gyro systems performed well. The reaction wheel performed well but was probably underpowered for the control of a gondola of this size and under the flight conditions experienced. The azimuth top mount froze during ascent but otherwise performed nominally during the rest of the flight. Overall, the system demonstrated pointing performance of 0.1° in elevation and 1° in azimuth during limb scanning and solar occultation scanning.

4.2 Service d'Aéronomie SAOZ Spectrometer

The SAOZ (Systeme d'Analyse et d'Observations Zenithales) instrument is a UV-visible diode array spectrometer that looks at the absorption of the sunlight by the atmosphere during sunrise or sunset from the float altitude. The SAOZ-N version was flown on MANTRA 2002 [5,6,7]. It is a commercial flat field, 360 grooves/mm, holographic grating spectrometer equipped with a 1024-diode linear array detector and an entrance slit of 50 µm. In this arrangement, measurements can be performed between 290 and 640 nm, with an average 0.8 nm resolution. SAOZ-N has been flown more than 100 times since September 1991.

The SAOZ instrument performed nominally during the MANTRA 2002 flight. Spectra were transmitted in real time via telemetry and were also recorded in the on-board memory (1900 spectra = 3 MB) during the lifetime of the SAOZ flight battery (30 hours). SAOZ GPS altitude, longitude and latitude are available for the whole flight, as are pressure and temperature from the Vaisala PTU sonde (but only the ascent profile obtained during the night should be used as during the daytime the temperature is erroneous).

Due to the geometry of the optical head, SAOZ useful data are restricted to SZA>80°. Solar occultation spectra of very high quality were recorded during sunrise and sunset. The tangent altitude for each individual spectrum has been calculated taking into account the latitude, longitude, altitude of the instrument, the solar zenith angle of the sun and the refraction of the atmosphere. Slant columns of O_3, O_2, and O_4 have been derived and show the same variations during sunrise and sunset. NO_2 has been analyzed and the slant columns of NO_2 present a large diurnal variation, with less NO_2 during sunrise than during sunset, as expected. The order of magnitude of the H_2O slant columns during sunrise seems correct. During sunset, it seems that outgassing from the balloon or from the gondola itself is masking the stratospheric content of H_2O. Vertical profiles of concentration have been retrieved using the onion peeling method. The resulting O_3 and NO_2 vertical profiles are shown in Fig. 3. Vertical profiles of O_4 and O_2 are also available, and H_2O vertical profiles are being assessed.

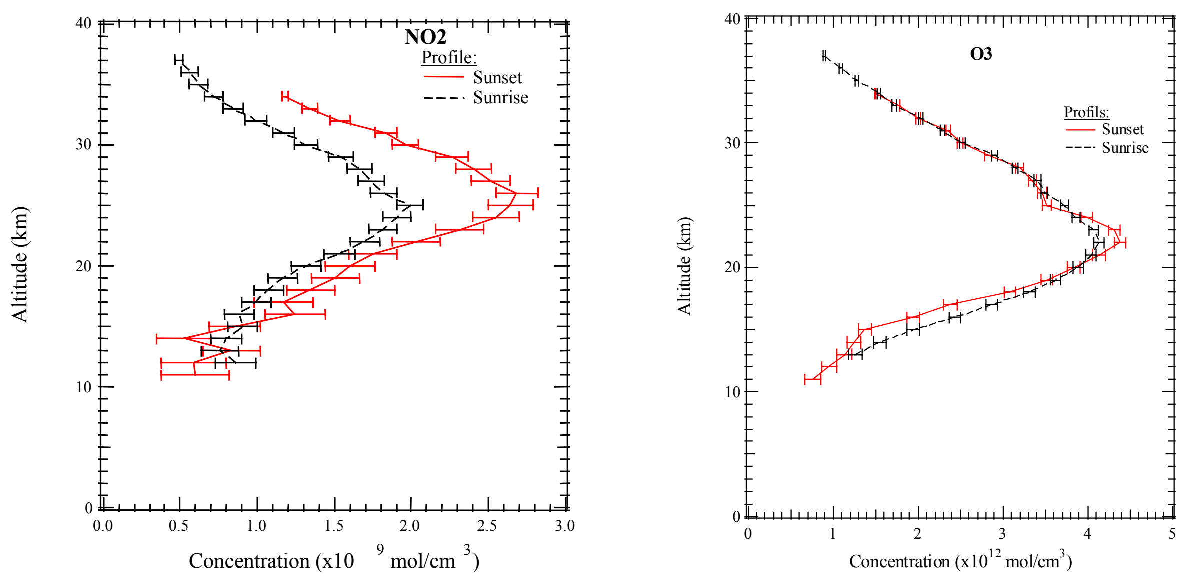

Fig. 3. Vertical concentration profiles retrieved from SAOZ solar occultation spectra: (a) NO_2, (b) O_3. (F. Goutail)

4.3 MSC SunPhotoSpectrometers SPS-B1 and SPS-B2 and the MAESTRO-B Instrument

The MSC SunPhotoSpectrometer (SPS) has flown on STS-52, and aboard the ER-2 nearly 100 times as part of the NASA Upper Atmospheric Research and High Speed Research Programs [8,9]. In addition, the SPS was flown on both the MANTRA 1998 and 2000 balloon flights. It is based on a photodiode array detector, situated at the focus of an f/2 holographic diffraction grating. Spectra are recorded from 300-785 nm at 0.5 nm steps, with a spectral resolution varying from 1.2 to 4 nm (FWHM). Data can be collected in solar occultation mode and limb-scan mode, and are analyzed using spectral fitting to determine vertical profiles of O_3, NO_2, and aerosol. The SPS can also be used to make absolute radiometric measurements in order to obtain J-values for the photolysis of O_3 and the photodissociation of NO_2 [10], which are needed to properly partition the odd-nitrogen family in photochemical model simulations.

The SPS-B1 instrument was mounted on the pointing system and worked well during the flight with no problems arising. Limb scans (down-up from 37 km) were recorded between 13:38 and 15:14 UTC. High sun measurements were recorded during for the rest of the day whenever the pointing system was locked on the sun. Solar occultation measurements from a float altitude of ~34 km were taken during sunset from 01:25 to 01:52 UTC on September 4, at tangent heights from 16 to 30 km. Slant columns of O_3 (Chappuis band), NO_2, and H_2O have been retrieved, and preliminary O_3 and NO_2 vertical profiles have been obtained from the sunset spectra (see Fig. 4a). Data analysis is continuing to retrieve O_3 in the UV and to analyze the limb-scan spectra.

SPS-B2 (for J-values) was suspended on one side of gondola and worked well throughout the flight. It was set up in solar occultation mode at the start of the flight (beginning at 7:45 UTC), then was changed to J-values mode at 12:35 UTC. It collected data in this mode through three ports (zenith, limb and nadir) until 0:00 UTC on September 4. Finally, it was switched back to solar occultation mode and collected direct sun spectra through a fourth port during sunset until the end of the flight. Post-flight radiometric calibrations have been performed, and preliminary O_3 profiles and J-values for O^1D and NO_2 have been retrieved (see Fig. 4).

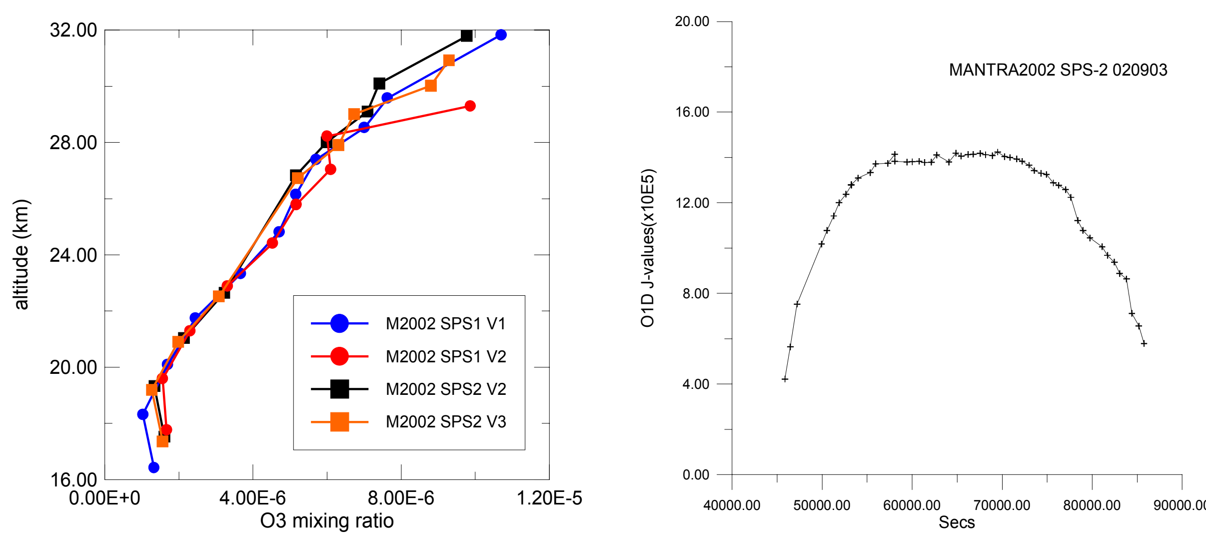

Fig. 4. (a) O_3 vertical profiles retrieved using SPS-B1 and SPS-B2. V1 refers to an integration time of 3 ms, V2 to 10 ms, and V3 to 30 ms. (b) J-values for O^1D obtained from SPS-B2. (C. Nowlan, H. Wu, C.T. McElroy)

The SPS is the forerunner of the MAESTRO (Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation) instrument, which will be launched on SCISAT-1 in 2003 as part of the ACE satellite mission. It is a new dual spectrometer with two channels: covering 285-550 nm and 525-1030 nm at ~1 nm resolution. The balloon version, MAESTRO-B, had its first flight during the MANTRA 2002 campaign and took the first atmospheric spectra recorded by a MAESTRO spectrometer. Both the UV and visible channels were working prior to and during launch. A complete down-up limb scan was recorded by both channels between 13:38 and 15:14 UTC, and high sun spectra were collected during the afternoon while the pointing system was locked on the sun (see Fig. 5). Solar occultation measurements were taken during sunset. MAESTRO data has never been previously analyzed, and preprocessing and retrieval algorithms are being developed in parallel with development of analysis tools for the MAESTRO satellite instrument.

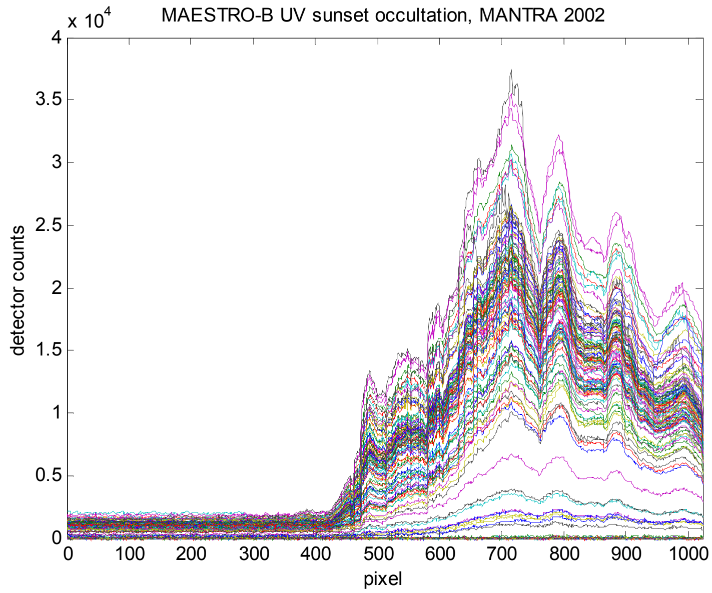

Fig. 5. Spectra recorded with the UV channel of MAESTRO-B, from 285-550 nm. (C.T. McElroy, C. Nowlan)

4.4 The University of Denver Fourier Transform Spectrometer

The University of Denver infrared Fourier Transform Spectrometer (FTS) is a Bomem DA2 that has flown many times as part of various balloon missions in the United States starting in 1977 [11,12,13]. This FTS has an unapodized FWHM resolution of about 0.01 cm^{-1} and is equipped with two infrared detectors. During the MANTRA 2002 flight, it was used to record sunset solar occultation spectra using a HgCdTe detector operating from 1483 to 2154 cm^{-1}.

Some high sun spectra were acquired at about 21:30 UTC. Sunset data acquisition began at 00:10 UTC on September 4 (SZA = 76°). During sunset the FTS operated well, recording data when the azimuth pointing was good enough to allow the FTS sun-seeker to acquire the sun. Data acquisition continued until about 01:58 UTC (SZA = 93.7°). A preliminary review of the spectra shows that we have spectral data of reasonable quality from high sun through sunset (see Fig. 6). We expect to retrieve vertical profiles of O_3, NO, NO_2, N_2O, HNO_3, H_2O, CH_4, and CO_2, and possibly HCN, O_2, CO, and OCS from the working short-wavelength channel. We can also retrieve CFC-11 and CFC-12 profiles at lower vertical resolution from ground-based FTS spectra taken in the last week of August.

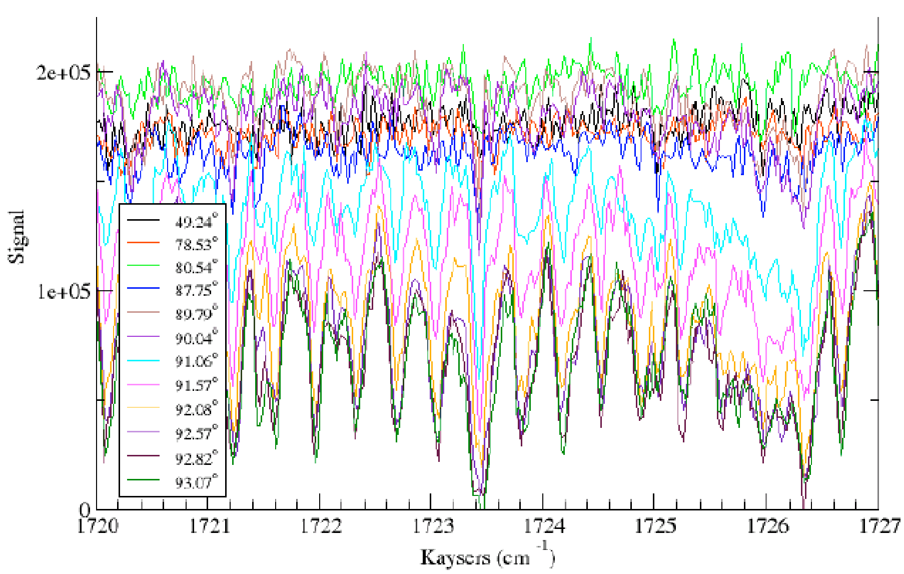

Fig. 6. Sunset solar occultation spectra acquired with the University of Denver Fourier transform infrared spectrometer in a region showing HNO_3 absorption lines. (P. Fogal, J. Olson, F. Murcray)

4.5 The MSC Fourier Transform Spectrometer

The MSC Fourier transform spectrometer is a Bomem DA2 unit which operates in the spectral ranges 1840-1990 cm^{-1} and 2870-2980 cm^{-1} using HgCdTe and InSb detectors simultaneously with a dichroic beamsplitter. It has a spectral resolution of 0.01 cm^{-1} (unapodized) and is optimised to measure HCl, NO, NO_2, and N_2O. MANTRA 2002 represented the first test flight of this instrument, which was extensively refurbished prior to the campaign. Both the refurbished power supply and detector assembly worked well throughout the flight, and were a significant improvement both in stability and robustness from the original configuration. An on-board status monitor of voltages and temperatures showed that the instrument hardware also worked properly during the flight. One interferogram was obtained on the MCT channel at 16:40 UTC when the sun was high. However, a malfunction of the on-board commercial data acquisition software shortly before sunset resulted in no solar occultation data being recorded. However, this was a very useful test flight of the instrument, and a great deal was learned for future flights, particularly with regard to requirements for the software and the alignment of the instrument with the pointing control system.

4.6 The MSC Emission Radiometer

The MSC emission radiometer is based on the balloon emission radiometer of Pick and Houghton [14], which was later modified by Evans *et al.* [15], and further improved in the early 1980s. The instrument measures thermal emission in the range 715-1250 cm^{-1} at a resolution of 20 cm^{-1}, using a circular variable filter to provide spectral information. It is usually pointed at a 20 to 40° elevation angle to increase the atmospheric slant path and makes measurements during balloon ascent.

One of the two MSC radiometers included on the MANTRA 2002 payload (MX36) produced a complete data set on ascent (237 full scans from launch to initial float altitude) with a high signal-to-noise ratio. In-flight blackbody calibration scans were recorded, and the temperature of the detectors was seen to be within the ideal range for the extent of the ascent. Raw data plots appear good, with just a few telemetry drop-outs. Vertical profiles of HNO_3, O_3, CFC-11, CFC-12, CH_4, and N_2O will be retrieved from the raw radiance data using a forward estimation technique that uses a line-by-line forward model and a non-linear least-squares minimum search algorithm.

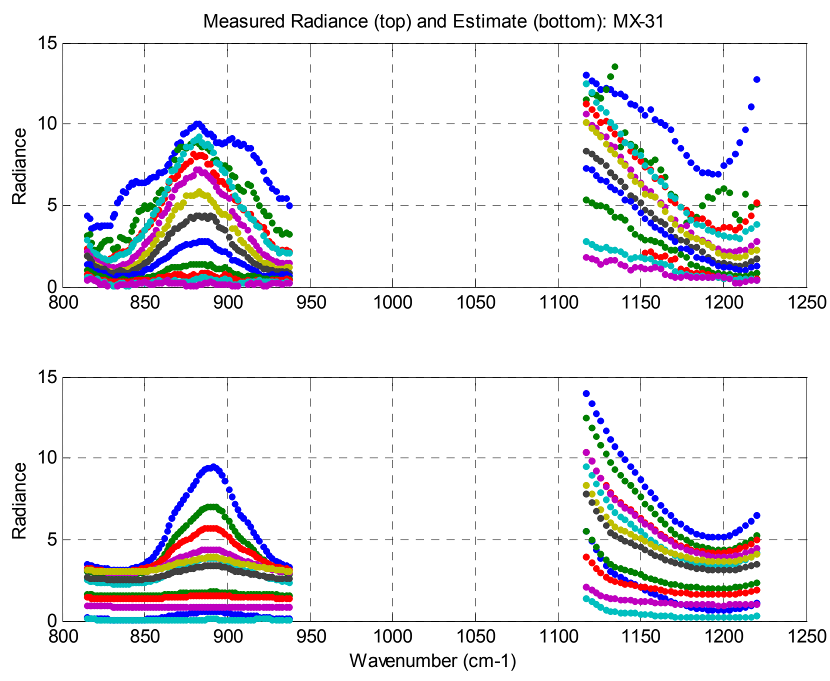

Fig. 7. Measured and modelled radiances for the MSC emission radiometer. The radiances in the region of a saturated O_3 band have been omitted – this region is not included in the retrieval. (M. Toohey, B. Quine, D. Wunch)

4.7 The MSC OH Spectrometer

The MSC high-resolution scattering spectrometer was originally flown on Stratoprobe payloads in July 1975 from Yorkton, SK and in September 1976 from Palestine, TX [16]. It was also refurbished and flown during

MANTRA 1998. The OH resonance scattering technique has been used since 1975 by others [17], but without the use of polarization. This instrument measures polarized spectra of the sky at right angles to the sun and at about 10° above the horizon. It observes the direct solar beam (as reference), and strong and weak polarizations at 90° to sun to detect resonant scattering from OH. The spectral range of the instrument is 305 to 311 nm, and a resolution of 0.08 nm was achieved during the campaign. During the flight, the OH spectrometer acquired two full up-down scans, each consisting of 80 spectral scans, as well as partial sunset data. The data appear to be good, and the strong (Rayleigh) and weak polarization scans are easily distinguished by eye. Work is underway to retrieve vertical profiles of OH from these spectra.

4.8 MSC Ozonesondes and Aerosol Sondes

A total of 19 ozone profiles (15 independent balloon ascents) were successfully collected between August 15 and September 5 using ECC sondes. These included one on the main payload (mounted at the end of a 1.5-m plastic boom to minimize contamination of the sampled air by the gondola), two attached to the backscatter sondes and two dual sondes. These ozone profiles are shown in Fig. 8. Each separate ozone launch included a complete suite of PTU measurements and a GPS receiver was used to calculate upper air winds. Most of the ozonesondes flown during the campaign were recovered, refurbished and re-flown. A UV ozonesonde was flown on the main payload and sampled air through a Teflon filter next to the ozonesonde at the end of the boom. It worked well during the flight and reproduced features seen in ozonesonde ozone profile.

Two aerosol backscatter sondes, obtained from the University of Wyoming, were also flown. These instruments use a photodiode to measure backscattered light from a xenon flashlamp at 490 and 940 nm on ascent during darkness and are used to derive vertical profiles of aerosol backscatter [18,19]. The first was launched immediately after the main payload and operated normally through the flight. The second backscatter was launched a few days later and again worked properly. These data are being processed at the University of Wyoming.

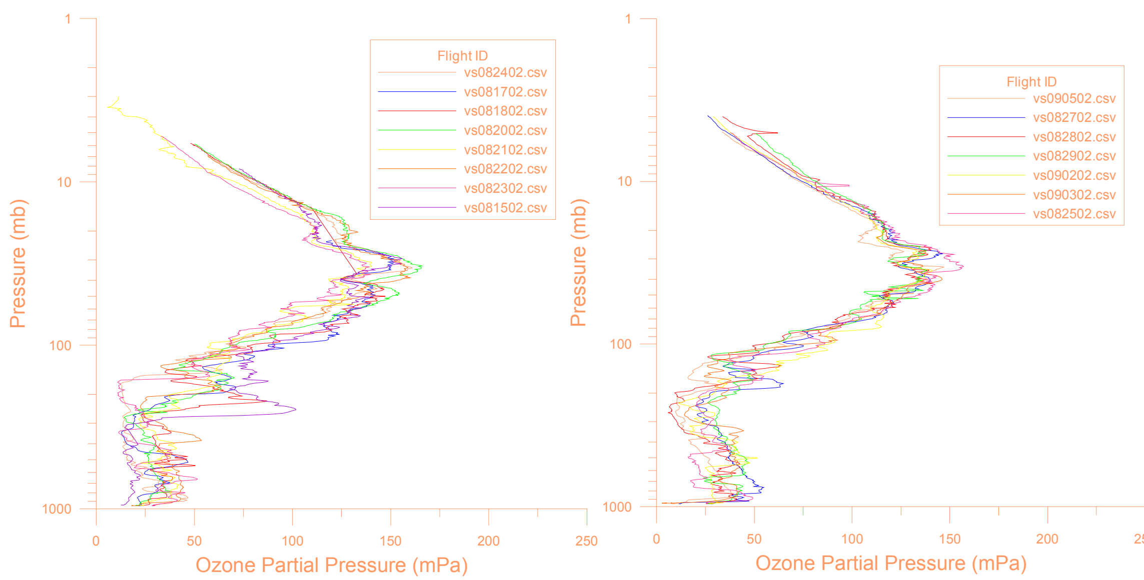

Fig. 8. Ozone profiles measured during the MANTRA 2002 campaign. (J. Davies)

4.9 Ground-Based Instruments

Four ground-based spectrometers were deployed on site at Vanscoy for approximately two weeks prior to the main balloon launch. These were used to make background atmospheric measurements to characterize the local atmospheric conditions. MSC Brewer Spectrophotometer #007 [20] made continuous measurements between August 13 and September 4, including direct sun and zenith sky total column O_3 and SO_2, Umkehr profile data, and UV irradiance (UV index).

The University of Toronto ground-based UV-visible spectrometer [21,22] acquired zenith-sky spectra from August 18 to September 4. The data were obtained with a 100-µm slit width and the 600g/mm grating. The resulting spectral resolution was 0.6-1.24 nm FWHM (0.75 nm in the middle of the CCD chip) based on spectral lamp lineshape measurements made in Vanscoy. Twilight spectra (330-570 nm) were recorded daily at solar zenith angles from 80° to about 95° during both sunrise and sunset. A nightly bias was derived for more accurate pre-processing of spectra. Preliminary O_3 and NO_2 vertical columns and NO_2 vertical profiles have been retrieved. The spectra were analysed using differential optical absorption spectroscopy (DOAS), with a common reference spectrum recorded at local noon (SZA= 40°) on August 21. The analysis bandwidth was 450-545 nm for O_3 and 405-450 nm for NO_2.

The York University Acousto-Optic Tuneable Filter (AOTF) instrument was first flown on the MANTRA 1998 balloon, and was subsequently operated on the ground during the MANTRA 2000 and 2002 campaigns. It uses a MgF_2 acousto-optic filter to scan the spectrum from 250 to 400 nm, with a wavelength-dependent resolution varying from 0.07 nm at 250 nm to 0.21 nm at 400 nm. The detector is a photomultiplier tube with very low dark count. The AOTF instrument made zenith-sky observations between August 19 and 30, obtaining six morning twilight, eight noon reference, and nine evening twilight observations. Preliminary O_3 and BrO slant column densities have been retrieved using DOAS; NO_2 and OClO columns are below the noise level in the spectral region used.

A ground-based version of the SunPhotoSpectrometer (SPS-G) was mounted on a sun tracker and collected spectra (285-785 nm) from August 21-30 and on September 3. During sunrise and sunset, it recorded scattered sunlight through a zenith-sky-viewing port for solar zenith angles from 80^o to 95^o. In the daytime, it tracked the sun through a direct-solar-viewing port. These spectra are being analyzed to retrieve O_3 and NO_2 vertical columns.

5 ANTICIPATED MEASUREMENTS AND ENVISAT VALIDATION

Table 3 below summarizes the measurements expected from the MANTRA 2002 balloon campaign, along with their anticipated accuracies. We intend to use these data to contribute to the validation of the three atmospheric chemistry instruments on ENVISAT, and ESA has accepted the MANTRA 2002 Category 1 CAL/VAL proposal for this purpose (#1335). For SCIAMACHY, we anticipate contributing to the validation of O_3, NO_2, CH_4, H_2O, and aerosol backscatter. Fig. 9 shows the SCIAMACHY overpasses near Vanscoy for September 3 and 4. For MIPAS, in addition to O_3, NO_2, CH_4, and H_2O, we are measuring N_2O, HNO_3, and temperature profiles. For GOMOS, we have O_3, NO_2, H_2O, O_2, and temperature. In addition, we are measuring a number of other constituents that can be used in correlative studies, including profiles of OH, J-values for O^1D and NO_2, and total columns of O_3, NO_2, BrO, and SO_2.

Table 3. Measurements made or anticipated from the MANTRA 2002 balloon campaign, along with conservative estimates of their expected accuracies. * refers to ranges and accuracies obtained with the emission radiometers during the MANTRA 1998 flight. DOAS = University of Toronto zenith-sky grating spectrometer, GB = ground-based, OD = optical depth, DU = Dobson units, tbd = to be determined.

TRACE GAS	INSTRUMENT	TECHNIQUE	EXPECTED ALTITUDE RANGE (km) AND RESOLUTION	EXPECTED ACCURACY (%)
O_3 profile	ozonesondes (15)	in situ chemical	typically 0-40 at 0.01 mPa	10
	SAOZ	sunrise and sunset solar occultation	11-37 at 1 km	10
	FTS	sunset solar occultation	10-35 at 2-5 km	10
	radiometer	emission on ascent	10-35 at 2 km	11-100*
	SPS-B1, SPS-B2	sunset solar occultation & daytime limb scanning	16-32 at 2-4 km	10
	MAESTRO-B	sunset solar occultation & limb scanning	tbd	tbd
O_2 profile	SAOZ	sunrise and sunset solar occultation	11-37 at 1 km	tbd
	SPS-B1	sunset solar occultation & daytime limb scanning	16-32 at 2-4 km	tbd
	FTS	sunset solar occultation	10-35 at 5 km	tbd
O_4 profile	SAOZ	sunrise and sunset solar occultation	11-37 at 1 km	tbd
NO profile	FTS	sunset solar occultation	10-35 at 5 km	15
NO_2 profile	SAOZ	sunrise and sunset solar occultation	11-37 at 1 km	10
	SPS-B1, SPS-B2	sunset solar occultation & daytime limb scanning	16-32 at 2-4 km	10
	FTS	sunset solar occultation	10-35 at 2-5 km	15
	MAESTRO-B	sunset solar occultation & limb scanning	tbd	tbd
	GB DOAS	ground-based zenith sky	10-35 at 5-7 km	tbd
HNO_3 profile	FTS	sunset solar occultation	10-35 at 2-5 km	10
	radiometer	emission on ascent	10-30 at 2 km	13-100*
CFC-11 profile	GB FTS (pre-flight)	solar occultation	tbd	tbd
	radiometer	emission on ascent	10-30 at 2 km	15-100*
CFC-12 profile	GB FTS (pre-flight)	solar occultation	tbd	tbd
	radiometer	emission on ascent	10-25 at 2 km	13-100*

OH profile	OH spectrometer	scattered sunlight	30-50 km at 5 km	15
H_2O profile	FTS	sunset solar occultation	10-35 at 2-5 km	tbd
	SAOZ	sunrise and sunset solar occultation	10-35 at 1 km	50?
N_2O profile	FTS	sunset solar occultation	10-35 at 2-5 km	10
	radiometer	emission on ascent	10-30 at 2 km	12-100*
CH_4 profile	FTS	sunset solar occultation	10-35 at 2-5 km	10
	radiometer	emission on ascent	10-30 at 2 km	12-100*
CO_2 profile	FTS	sunset solar occultation	10-35 at 2-5 km	tbd
HCN, CO, OCS	FTS (possibly)	sunset solar occultation	tbd	tbd
J-values	SPS-B2	absolute radiometry (O^1D and NO_2)		tbd
aerosol	SPS-B1	sunset solar occultation & limb scanning		
	aerosol sonde (2)	backscatter	0-40 at 1 km	0.002 OD
	Brewer	GB direct sun	column OD	
pressure	radiosondes	Vaisala RS 80	0-40 km at 0.1 mb	0.5 mb
temperature	radiosondes	Vaisala RS 80	0-40 km at 0.1 °C	0.2-0.4 °C
wind	radiosondes	GPS	0-40 km	
O_3 column	GB Brewer	GB direct sun	column	1
	GB DOAS	GB zenith sky	column	5
	GB SPS-G	GB direct sun & zenith sky	column	5
	GB AOTF	GB zenith sky	column	10-15
NO_2 column	GB DOAS	GB zenith sky	column	10-12
	GB SPS-G	GB direct sun & zenith sky	column	10-12
BrO column	GB DOAS, AOTF	GB zenith sky	column / upper limit	15-35
SO_2 column	GB Brewer	GB direct sun	column	0.2-0.6 DU

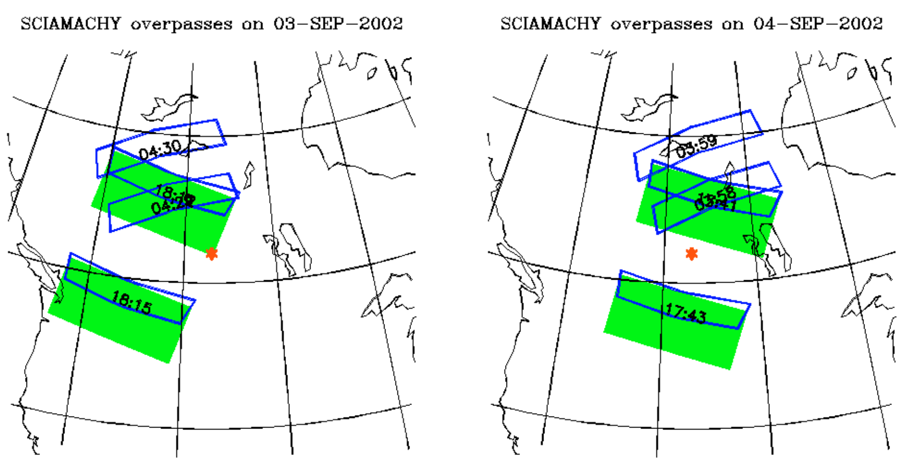

Fig. 9. SCIAMACHY overpasses for Vanscoy (red star) for September 3 and 4. Times are UTC, so the useful overpasses correspond to near noon local time. These overpasses correspond to ENVISAT orbits 2672 and 2686. (SCIAMACHY Operations Support Team, DLR-IMF & IUP-IFE)

6 SUMMARY

The MANTRA 2002 balloon campaign took place in Vanscoy, Saskatchewan, Canada (52°N, 107°W) between August 13 and September 4. The primary balloon was launched at 08:02 UTC on September 3 and the flight continued until 02:20 UTC on September 4. Measurements were made by 11 instruments during the flight, with data acquired on ascent, at sunrise, during the day, and at sunset. In addition, four ground-based spectrometers made measurements for approximately two weeks prior to this flight, an additional aerosol backscatter sonde was launched, and a total of 15 independent ozonesonde flights were made. We expect to retrieve vertical profiles of O_3, NO, NO_2, HNO_3, N_2O, OH, H_2O, CH_4, CO_2, aerosol extinction, pressure and temperature from O_2 (as well as from sondes), and total columns of O_3, NO_2, SO_2, and possibly BrO. Data analysis is complete for some instruments and ongoing for others. These data will be used to contribute to the validation of the SCIAMACHY, MIPAS, and GOMOS instruments on ENVISAT through the Category 1 CAL/VAL project #1335.

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