# MANTRA 2004 Sixth Quarterly Meeting


# Minutes & Proceedings

November 10, 2004
Department of Physics
University of Toronto

# MANTRA 2004 Sixth Quarterly Meeting
# Attendees

David Barton, Meteorological Service of Canada
Jonathan Davies, Meteorological Service of Canada
Jim Drummond, University of Toronto
Annemarie Fraser, University of Toronto
Pierre Fogel, Denver University
Florence Goutail, Service d'Aeronomie (Telephone)
Tobias Kerzenmacher, University of Toronto
Tom McElroy, Meteorological Service of Canada
Stella Melo, University of Toronto
Clive Midwinter, University of Toronto
Caroline Nowlan, University of Toronto
Brendan Quine, University of Toronto
Kimberley Strong, University of Toronto (Part)
Dale Summerfeldt, Scientific Instruments Ltd. (Telephone)
Lana Tobiash, University of Toronto (Part)
Matthew Toohey, University of Toronto
Jennifer Walker, University of Toronto
Kaley Walker, University of Waterloo
David Wardle, Meteorological Service of Canada
Ron Wilkinson, Canadian Space Agency
Debra Wunch, University of Toronto
Aaron Ullberg, Meteorological Service of Canada

# Agenda

**Time:** 9:00 AM – 5:00 PM
**Date:** Wednesday, November 10, 2004
**Place:** Room 713, Department of Physics, University of Toronto, 60 St. George Street

Objectives:

- Brief summary of ground-based or flight performance – data obtained, what worked, what didn't work
- Lessons learned – what should be changed for future flights
- Plans and anticipated schedule for data analysis/publications
- Is all the campaign data archived on the internal web site?

## Agenda

9:00 Coffee, welcome…
9:20 Review of agenda ***(Melo)***
9:30 MANTRA 2004 – field campaign ***(Melo)***

### Instruments

09:40 Service d'Aéronomie SAOZ (main flight, BrO, ground-based) ***(Goutail – 33 -1 64 4 7 42 89)***
10:00 MSC SunPhotoSpectrometers: SPS-B1, SPS-B2 ***(McElroy)***
10:10 MSC emission radiometers ***(Toohey)***
10:20 U of Denver Fourier transform spectrometer ***(Fogal)***
10:30 MSC Fourier transform spectrometer ***(Wunch)***
10:40 U of Waterloo PARIS ***(K. Walker)***
10:50 MSC OH spectrometer ***(Tarasick/Wardle)***
11:00 MAESTRO-B ***(Kerzenmacher/Midwinter)***
11:15 MSC airglow infrared radiometer – AIR ***(Quine/Tarasick)***
11:30 MSC ozonesondes, aerosol sondes ***(Davies)***
12:00 Lunch
13:30 Ground-based campaign - summary ***(Fraser)***
13:40 GB U of T Spectrometer ***(Fraser)***
13:50 GB York U AOTF spectrophotometer ***(Solheim)***
14:00 GB MAESTRO ***(McElroy/Kerzenmacher)***
14:10 GB SPS ***(McElroy)***
14:20 GB Brewer ***(Barton)***
14:30 Pointing system ***(Drummond/Sommerfeldt)***

### Payload and Launch Issues

14:40 SIL payload support and flight systems (power, telemetry, GPS, etc.) ***(Sommerfeldt)***
15:00 Payload control/failure assessment ***(Ostwald/Sommerfeldt)***
**15:20 BREAK**
15:30 Summary of lessons learned ***(Melo/All)***
15:45 Future of MANTRA mission ***(All)***
16:45 Future plans: schedule, satellite validation, papers, conferences ***(Melo/All)***
16:55 Assignment of any action items ***(Melo)***
17:00 End of meeting!

# MANTRA 2004 Sixth Quarterly Meeting – Minutes

## Introduction and Welcome

Dr. Melo provided a comprehensive introduction and review of the MANTRA 2004 main activities and review meeting as off January. The field campaign was briefly reviewed and plans for publications were discussed. Overpass for Odin, Envisat, and SCISAT-1 satellites were shown and possibilities for satellite validation activities were discussed (presentation appended).

## Instruments

1. **Service d'Aéronomie SAOZ (main flight, BrO, ground-based)** ***(Goutail)*** Florence Goutail reported by telephone from PARIS. Dr. Goutail reviewed the measurements obtained by the three SAOZ instruments in Vanscoy. SAOZ ground-based operated throughout the whole campaign and a series of about 43 days of measurements (O3, NO2) is already available for analysis. SAOZ BrO was successfully launched on August 24 in a small balloon and sunset profiles for BrO, O3, Temperature, and NO2 were obtained. Dr. Goutail reported on the measured profiles showing preliminary inter-comparisons with satellite data. The measurements acquired with the SAOZ instruments are of high quality and are now being used for satellite validation (presentation appended).
2. **MSC SunPhotoSpectrometers: SPS-B1, SPS-B2, SPS-G, and MAESTRO-G** ***(McElroy)*** Dr. McElroy revised the methodology to be used to extract NO2 column densities and vertical profiles from the solar spectra measurements made by the SPSs and MAESTRO instruments. Preliminary results for MAESTRO ground-based measurements were presented and compared with SAOZ ground and U of T ground-based measurements. The value of the inter-comparison of the ground-based instruments made at Vanscoy was discussed emphasizing the importance of having SAOZ ground-based, an NDSC certified instrument, as part of this year campaign. Plans for data processing/analysis were discussed. Dr. McElroy stressed that although SPSs and MAESTRO balloon instruments acquired some useful data, we need human resources to work in the data processing/analysis since Dr. H. Wu (RA) left the project (presentation appended).
3. **MSC emission radiometers (Toohey)** Toohey reported that no anomalies were seen in the two radiometers data during the second flight. Although some data were acquired during the first flight, the quality of the data is poor. Toohey reported that anomalous encoder position values have corrupted the collected scans (more later) for both instruments. Analysis indicated that the problem would be solved with better sealing the radiometers and by filling with LN2 done closer to launch time. The two instruments were refurbished and these recommendations were implemented but could not be tested since the second flight terminated prematurely. Toohey discussed then the analysis of previous campaign data and reported on the activities on modeling of the gondola azimuth dynamics. A paper reporting the results is planned (presentation appended).

4. **U of Denver Fourier transform spectrometer *(Fogal)*.** Denver FTS was refurbished and prepared for 2004 campaign on site. This happened as a consequence of the delay in receiving the NASA found for this activity. Nevertheless, the instrument was ready for the first flight. Lots of condensation in the mirrors and instrument optics occurred during the first flight. The instrument acquired sun spectra till the balloon reached an altitude of about 16.5 km. Then the scan mechanism ceased working. Since about that time the gondola command capability was lost, nothing could be done and no further data were acquired till the gondola was back to the ground. The failure was assessed (see presentation appended) and the instrument was partially refurbished for the second flight. However, since the launch was at night time, no spectrum was acquired. However, the instrument acquired useful ground-data that can be processed to produce total column of N2O, CH4, CFC-11, CFC-12, HNO3, and H2O. Those data can be used to support the ground-based campaign in the satellite validation activity.
5. **MSC Fourier transform spectrometer *(Wunch)*** MSC FTS recorded two spectra during the first flight during the sunset. It also acquired ground-based data during 9 days. Data are of very good quality. From the balloon data, mixing ratios of CO2, O3, CH4, N2O can be obtained (along the observational path). Not possible produce vertical profile though. From the ground-based data, total columns of HCl, O3, N2O, CH4, H2O, N2, CO, HDO, OCS. Retrievals begun to be done using SFIT2 to retrieve HCl, O3 and N2O. Plans for the MINI_MANTRA campaign (inter-comparison among the MANTRA FTSs with Toronto Observatory FTS operating co-located) to be held in Toronto next January. Possible improvements in the instruments were discussed as well as the plan for processing and analysis of the acquired data (presentation appended).
6. **U of Waterloo ACE-FTS clone *(Walker)*** Issues with PARIS instrument in the field were discussed and the adopted solutions were presented. The instrument did not acquired data during any of the flights. There is one day of ground-based measurements that may be useful. Plans for improvements on the instrument were presented and discussed (presentation appended).
7. **MSC OH spectrometer *(Wardle)*** Revision on 2002 data was presented. For 2004, this instrument was one of the few that acquired useful data. The flight performance of the instrument was shown and plans for data processing was presented and discussed. Three papers communicating the results for all the MANTRA campaigns are planned (presentation appended).
8. **MAESTRO-B *(Midwinter)*** MAESTRO performance was discussed. The instrument consists of two channels: UV and visible. For the first flight only the visible channel performed as planned. The UV channel presented serious RFI problems (from the pointing system) making the signal to noise ratio just marginal. This problem could be solved if command was available. However, a better isolation of the instrument should be implemented. Data were acquired while pointing of the gondola was available. No usable data was acquired after lost of pointing. It is then possible retrieve ascend profiles of O2, O3, H2O, and NO2. Due to the excellent performance of this instrument by the ground, plans are in place now for building a dedicated ground-based MAESTRO.

9. **AIR *(Quine)*** The MANTRA 2004 gondola contained two AIR instruments. None of the instruments acquired measurements since we lost command. Unfortunately both AIR instruments were launched in manual mode, requiring command to initiate measurements. The plan is freeze the hardware and focus on calibration activities for future missions.
10. **MSC ozonesondes and aerosol sondes *(Davies)*** During this MANTRA campaign 21 ozonesondes were launched. 18 of them performed very well producing high quality ozone profiles. For this campaign the WMO SOP rather than MSC standard was adopted. Therefore, we have now a nice time series of WMO 'standard' ozonesondes with co-incident total ozone measurement (Brewer) allowing determination of upper atmosphere residual. This material is planned to be used in the next WMO SOP report. The sonde operated perfectly in the first flight. The new implemented boom was successfully holding the sonde in clear air and the supplemental heater kept the instrument within temperature limits avoiding problems we had in previous campaign. The second flight terminated prematurely
11. **Ground-based Campaign *(Fraser)*** This MANTRA campaign gave special emphasis on ground-based measurements. They not only complement but extend in time the measurements. While the balloon provides the characterization of the atmosphere in one day – the day the balloon is launched – the ground-based instruments provide characterization of the atmosphere during the whole campaign. The limitation is that it does not provide details of the vertical profiles of the constituents. However, for some species like NO2, useful information about the vertical distribution can be extracted after applying retrieval techniques. The ground-based profiles can then be validated against the high vertical resolution balloon profile for the day it is available. Another importance of the ground-based part of the campaign this year was the opportunity to operate the Canadian instruments side by side with a NDSC certified spectrometer – SAOZ. Data processing is in place and for SAOZ the O3 and NO2 Slant Column densities, as well as vertical column densities are available. For the other instruments, the retrieval of those quantities is in process with some days already available for inter-comparisons. A summary of the campaign was presented by Annemarie Fraser that also discussed plans for scientific publications communicating the results (presentation appended).
12. **U of Toronto zenith-sky grating spectrometer *(Fraser)*** This instrument is part of the MANTRA campaigns since 1998. Annemarie Fraser revised the data products and reported on problems we had with this instrument this year. Despite of those problems a large dataset was acquired and the analysis is now in process (presentation appended).
13. **Ground-based York U AOTF spectrophotometer *(Solheim)*** Brian Solheim was not able to attend this meeting. However he has provided the information that the instrument operated well during the campaign and the data process has already started.
14. **Brewer instrument *(D. Barton)*** David Barton reported on the work he is developing as part of his graduate study (Master) which consists in develop and test a procedure for retrieve NO2 concentrations from the Brewer measurements.

The data acquired during MANTRA campaign has been processed in a preliminary version and is now being compared with data from other instruments (presentation appended).

15. **Pointing System *(Drummond)*** Jim Drummond revised the activities related to the development of the pointing system emphasising the importance of the hanging tests made in Toronto. The data with the flight performance was shown clearly demonstrating that the pointing system performed very well before it turned itself off due to overheating of the hardware in the first flight. The technology was transferred to SIL. Suggestions for improvements were presented and discussed (presentation appended).
16. **Payload and Launch issues (SIL)** SIL reported on the assessment of the two flight failures they have been performed. SIL participation was via teleconference and slides were not provided. However, SIL will provide detail reports on the results from those assessments. The causes of the failures in the first flight were identified and the implementations were done in order to assure that this problem is solved. Overall, the risks were reduced to a level SIL feels confident the same problems will not happen again. Nevertheless a revision of the thermal design of the pointing system was suggested. The causes of the premature termination of the second flight are still undetermined. Possibilities were discussed but SIL still do not have a conclusive explanation. A detail report will be delivered to the MANTRA PI by November 17.

The future of the MANTRA project was discussed. The question of whether the team wants to continue with the project was put by Jim Drummond and the answer was yes, the team seems very optimist in proceed. However, Rom Wilkinson made clear the need of strong recommendations on improvements that could significantly raise the level of confidence on the success of future missions. The team need a solid “go forward” plan. A new proposal may be submitted by January.

The meeting ended at about 5:00 pm.


# MANTRA 2004

*Post-flight Meeting*

*Department of Physics, U of T*

*Nov 10 2004*

# Objectives

- Summary of ground-based and flight performance
  - Data obtained
  - What worked?
  - What did not work?
- Lessons learned
- Plans and anticipated schedule for data analyses/publications
- Archives
- Next MANTRA?

# Agenda

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9:30 MANTRA 2004 – field campaign ***(Melo)***

**Instruments**

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***12:00 LUNCH***

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15:45 Future of MANTRA mission ***(All)***
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16:55 Assignment of any action items ***(Melo)***

***17:00 End of meeting!***

# MANTRA 2004 - Schedule

January: begin preparation (more intense) of the 2004 campaign

*3rd Quarterly Meeting: Jan 29, U of T – Requirements review*

*4th Quarterly Meeting: April 7, York – Critical design review*

*5th Quarterly Meeting: July 27, U of T – Flight readiness review*

**Tests at U of T:**

- Hanging test at high bay: 10-14 May – Gondola and PS at U of T
- Vacuum testing of instruments: May-June
- Mechanical and Electrical integration: week of July 16

**Ship instruments to Vanscoy: July 29**

**Field Campaign starts: August 3**

Ground-based instruments start: August 5

Ozonesonde launch starts: August 9

**1st SAOZ BrO flight: August 24, sunset (successful!)**

**1st Big Balloon launched on September 01 at 8:30 am** *(lost control, PS off 5:00pm, flight terminated by 8:40 pm)*

**2nd SAOZ BrO flight: September 12 at 5:00 pm *(attempt)***

**2nd Big Balloon launched on September 14 at 2:15 am** *(5 minutes flight)*

**End of field campaign: September 15.**

# The MANTRA 2004 Project

-The original proposal (Second Small Payloads Program) called for a launch of the balloon in August 2003.

- Because of the timing of the SciSat launch and the scope of work for the balloon flight, the campaign was delayed for a year to 2004.

-To make use of the lengthened schedule, the work of the project was partly spread over two years:

- The delay in getting the contract from Public Works constrained the work possible in FY2003/04 (initial budget to CSA 12 March 2003, contract received 8 January 2004).

- Some work started in the FY 2003/04 with the remainder, including the launch, planned for FY2004/05.

- The work in FY2003/04 included the early preparation of the instruments and the pointing system.

# MANTRA 2002/2004 Scientific Objectives

(1) To fly a comprehensive suite of instruments in order to measure the vertical profiles of the key stratospheric species that control the mid-latitude ozone budget, particularly species in the NOy, Cly, Bry, and HOx chemical families, along with dynamical tracers and aerosols.

(2) To combine these measurements with those obtained from similar northern mid-latitude campaigns of the past 20 years, in order to quantify changes in the chemical balance of the stratosphere.

(3) To perform an intercomparison of multiple measurements of the same trace species made by different instruments, in order to resolve previously observed discrepancies and to assess the instruments' performance.

(4) To use the 2002 balloon-borne measurements for validation and ground-truth for the Odin satellite mission, and the 2004 measurements for validation and ground-truth for the SCISAT-1 mission.

# MANTRA 2004 – Planned Measurements

(1) - On ascent: ozonesondes, aerosol sondes, emission radiometers, SAOZ-BrO (separate flight);

(2) - Solar occultation: SPS-B1, SPS-B2, MAESTRO-B, SAOZ, all FTSs;

(3) - Limb scanning: SPS-B1, SPS-B2, MAESTRO-B;

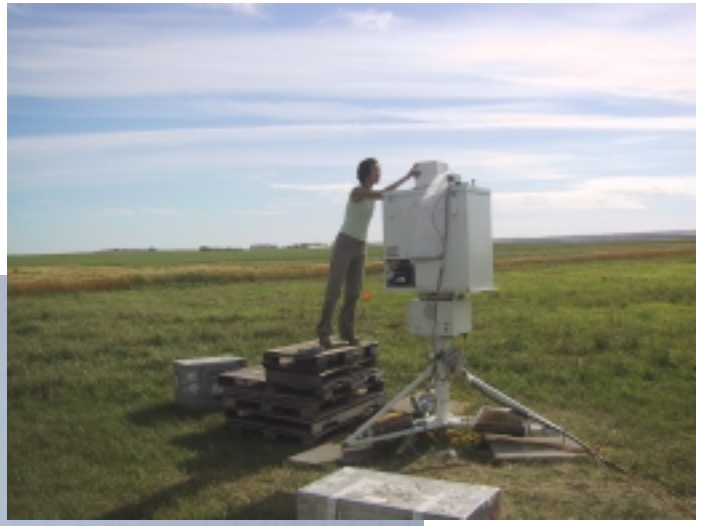
(4) - Other modes: SPS-B2 also records radiances (its primary measurement), OH looks at scattering through the day (needs pointing knowledge), AIR measures daytime $O_2$ emissions (needs pointing knowledge). SAOZ NO2 does not requires pointing.

(5) - Ground-based measurements

# Balloon-Borne Instruments for MANTRA 2004

| **PRIMARY BALLOON-BORNE INSTRUMENTS** | **SECONDARY BALLOON-BORNE INSTRUMENTS** |
|---|---|
| • MSC emission radiometer<br>• MSC SPS-B1<br>• MAESTRO-B<br>• U of Denver FTS<br>• Service d'Aéronomie SAOZ<br>• MSC ozonesonde<br>• aerosol sonde | • second radiometer<br>• MSC FTS<br>• PARIS<br>• MSC SPS-B2<br>• MSC OH spectrometer<br>• AIR |

SAOZ BrO – Separate flight
Ground-based instruments



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# SAOZ'S / Mantra 2004

**Florence Goutail**
**Service d'Aeronomie / CNRS, France**

## Outline

- Objectives
- Ground-based Measurements
- SAOZ-BrO flight
- SAOZ on Main balloon


# SAOZ's MANTRA

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## OBJECTIVES

- **Ground-based SAOZ** — **One month monitoring**

  (270 -620 nm, 1nm resolution)
  Columns: O3, NO2, Colour index (clouds)

- **UV-enhanced SAOZ-BrO** — **Small balloon**

  (350-420 nm, 0.2 nm resolution)

  Profiles: BrO, $NO_2$, $O_3$, (OClO, CH2O)
  + GPS + PTU sensor + Argos

- **Standard balloon-borne SAOZ-N** — **Main Balloon**

  (270 -620 nm, 1nm resolution)
  Profiles: O3, NO2, O4, O2, Trop. H2O, extinction.
  + GPS + PTU sensor + Argos

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# Ground-based Measurements

- **Operations**
  - Measurements between Aug 5, 2004 PM and Sept. 15 AM
  - Problems with shutter → days missing: Aug 13 (PM), 14, 15, 16 (AM)
- **Results**
  - O3, NO2 Slant columns
  - Converted → Vertical columns
    - using AMF at mid latitude (from SAOZ balloon)
    - selection: 86 - 91 SZA
    - residual in reference spectrum (one for the whole campaign)
- **Satellite validation:** in progress
- **Funny "cloud" on August 28, 2004.**
  - Evolution of color index (ratio 550nm/450nm) during sunset



# SAOZ's MANTRA

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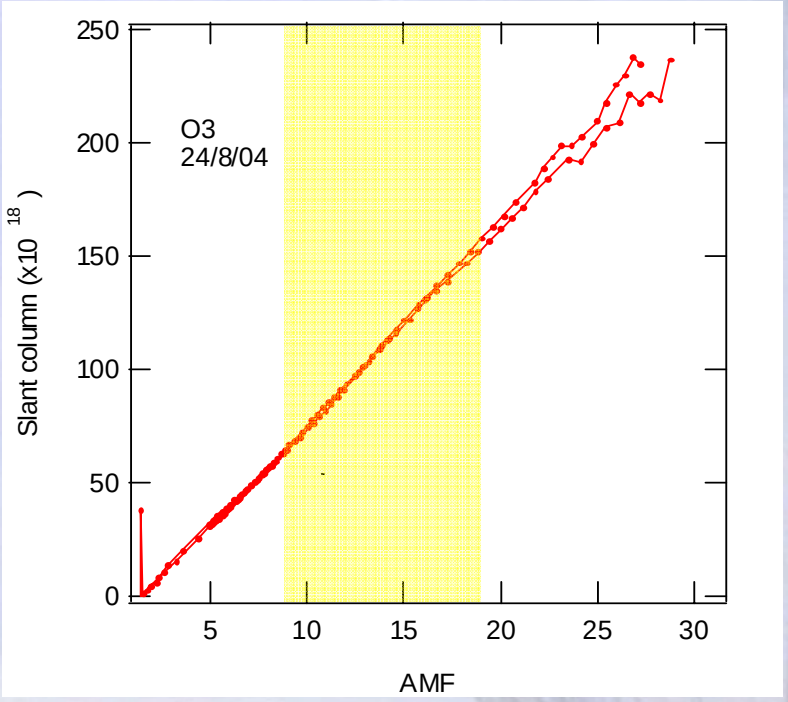
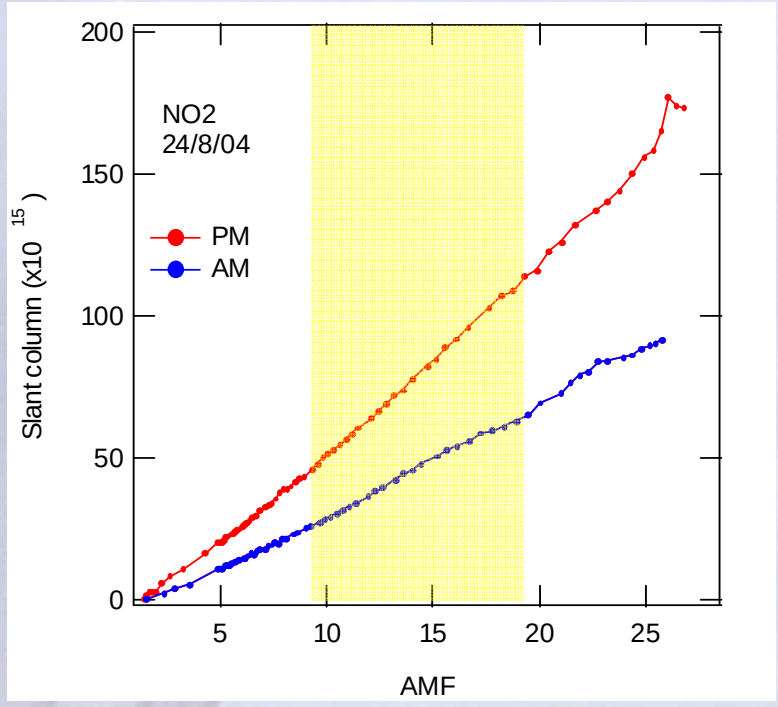
## Ground-based Measurements




- AMF between 9 – 19 (86-91SZA)
- Residual (O3: 9e18 NO2:1.1 e16)

# SAOZ's MANTRA

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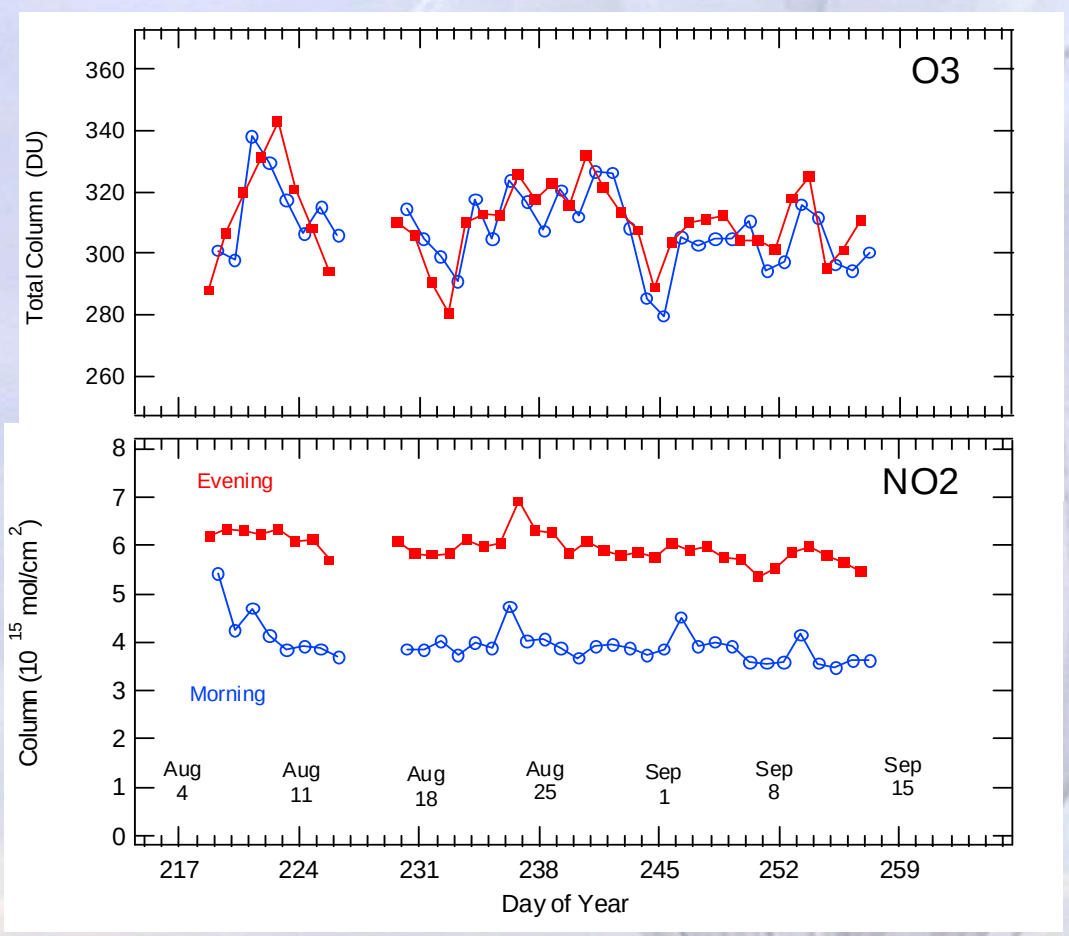
## SAOZ O3 and NO2 columns




-Ozone variable between 280 and 340 DU

-NO2 very stable:
5.96 e15 in the evening
3.96 e15 in the morning



# SAOZ's MANTRA

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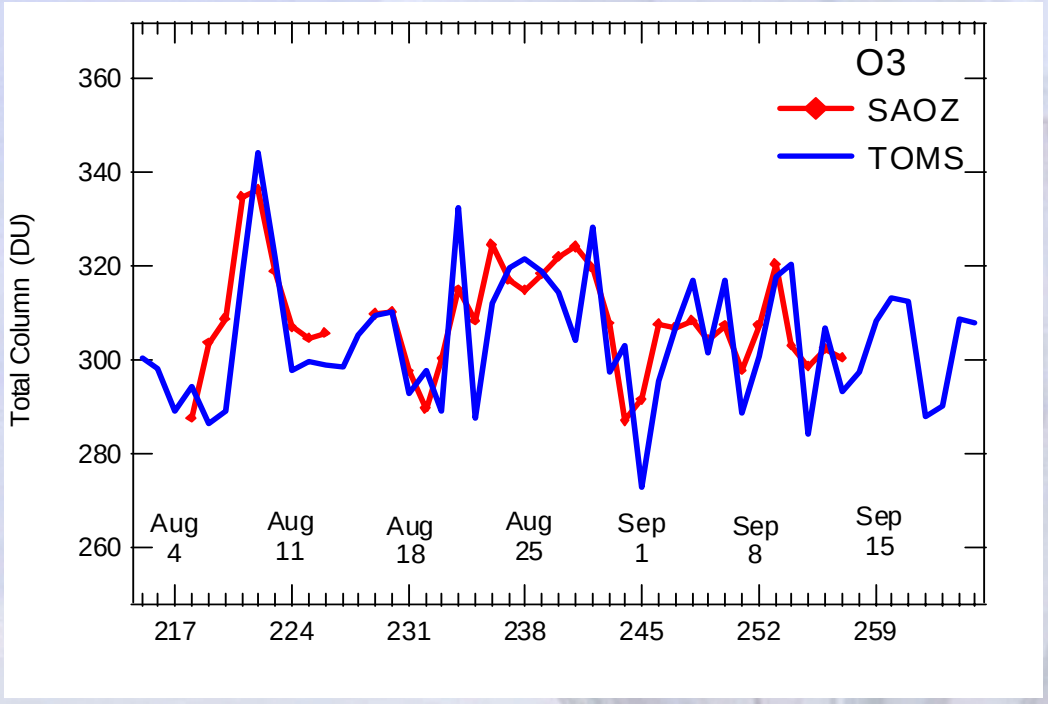
## Satellite validation: TOMS




-Very good agreement

Ratio= 1.011 ± 0.058



# SAOZ's MANTRA

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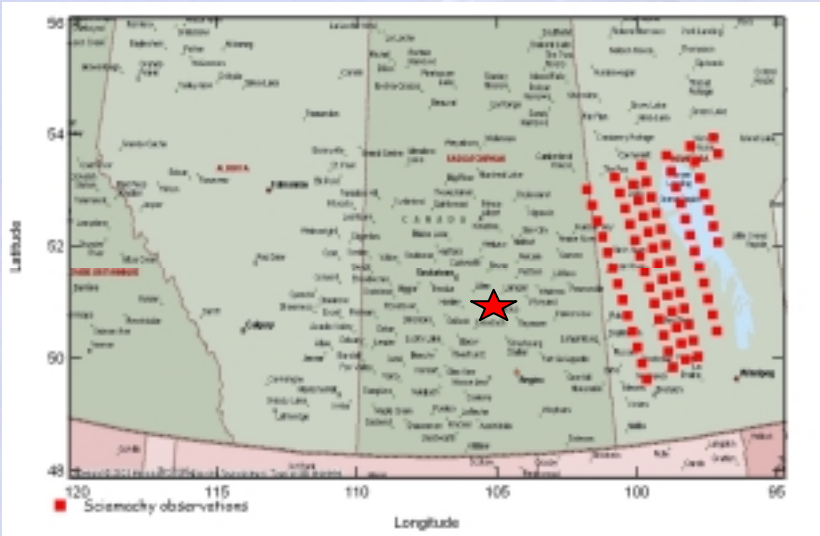
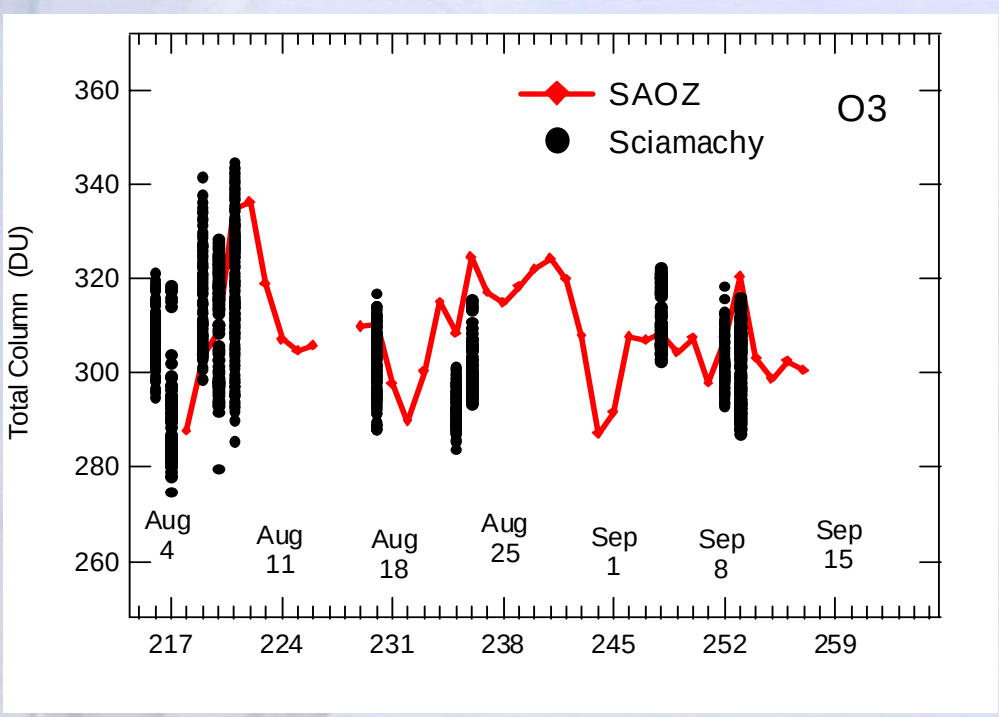
## Satellite validation: Sciamachy




-Sciamachy overpass close to SAOZ morning observations
-Large variablility in Sciamachy ozone columns: ± 20 dobson



# SAOZ's MANTRA

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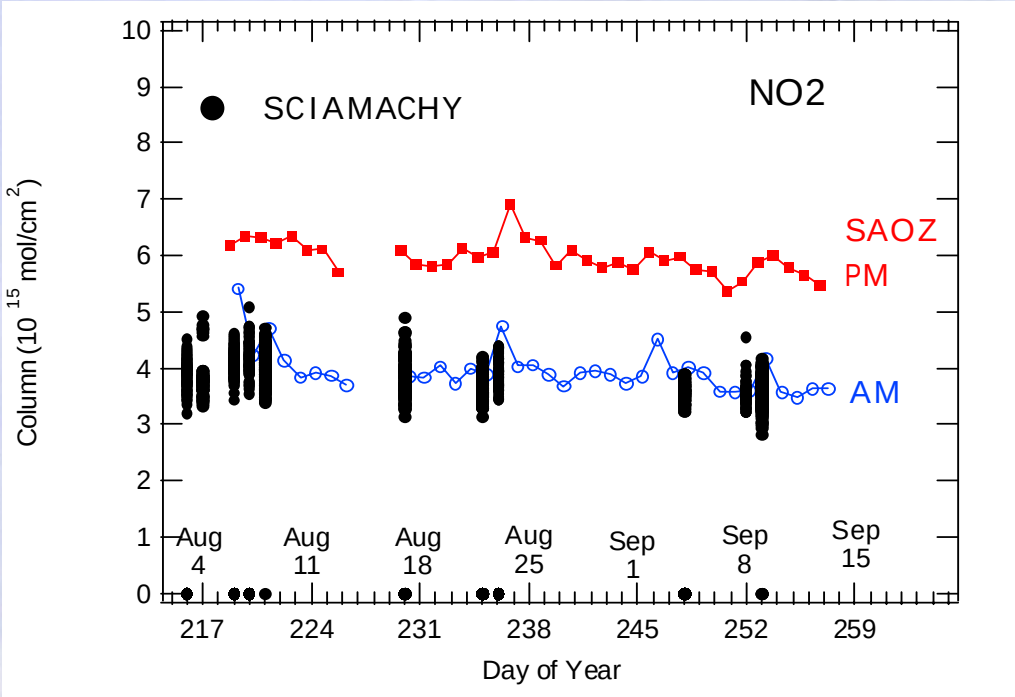
## Satellite validation: Sciamachy




-Sciamachy overpass:
-In the morning (SZA:50°)

-Good agreement with SAOZ AM values

SCIA: 3.848 ± 0.335

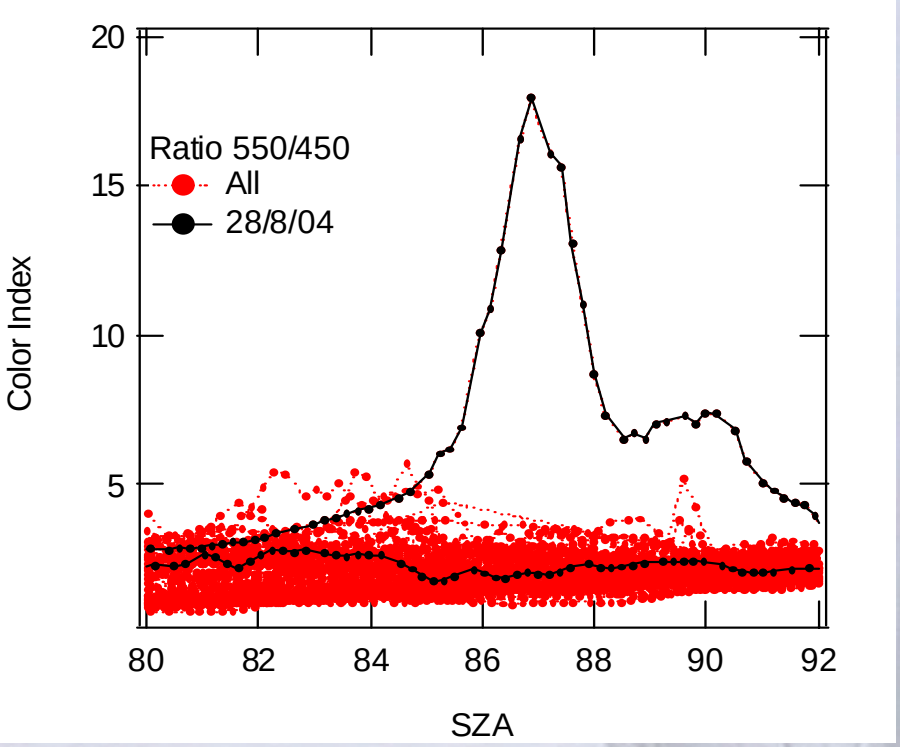
SAOZ: 3.958 ± 0.383

Ratio: 1.028

More work to be done: compare with GOME overpass



# Color Index 550nm/450nm




- Funny sky on Aug 28. → no volcano, no fire, what is the reason?

# SAOZ-BrO Flight

- **Operations**
  - Balloon released on Aug 24, 2004 PM
  - Nominal flight
- **Results**
  - O3, NO2, BrO Slant columns
  - Converted → Profile (onion peeling)
- **Satellite validation:**
  - in progress

# SAOZ's MANTRA

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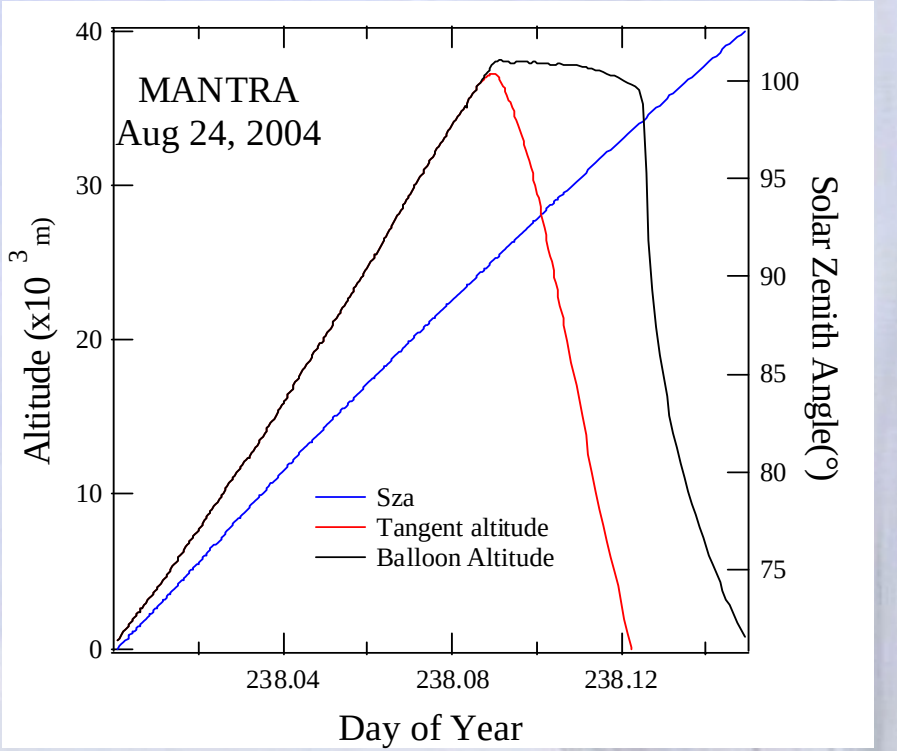
## SAOZ-BrO Flight




**Balloon released Aug 25 at 00:02 UT**
00:02 UT (18:02 local time)

**20 km altitude**
01:11 UT (19:11 loc) SZA =82

**Sunset start** (alt 36200)
02:03 UT (20:03 loc) SZA =90

**Float : 38100m**
02:10 UT (20:10 loc) SZA =91

**Tangent point 20 km**
02:33 UT (20:33 loc) SZA = 94.3

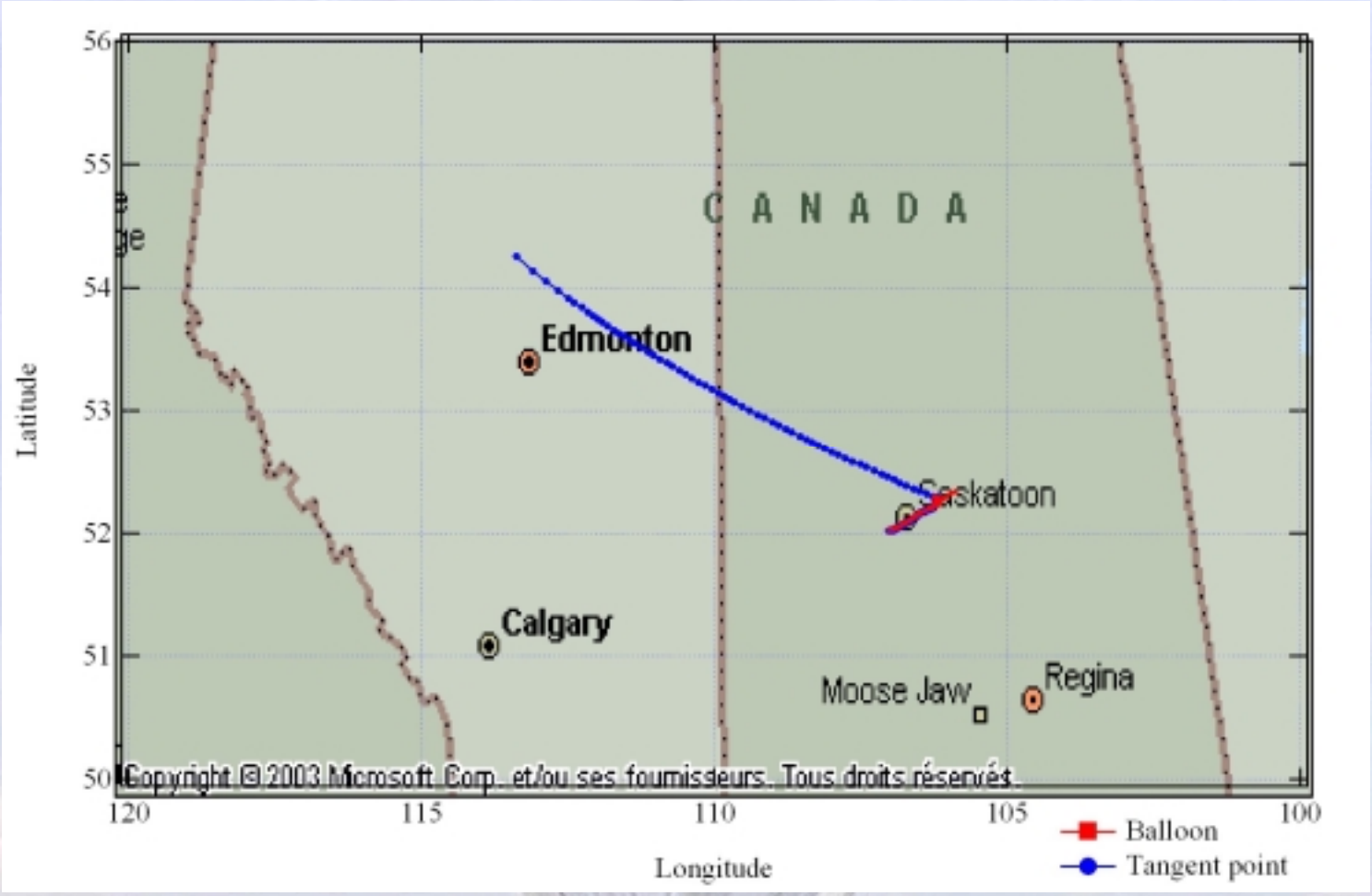
**End occultation**
02:35 UT SZA = 94.6

**Cut down**
02:59 UT SZA = 98

**Landing**
03:34 UT



# SAOZ - BrO


56
55
54
53
52
51
50
Latitude
C A N A D A
Edmonton
Saskatoon
Calgary
Moose Jaw
Regina
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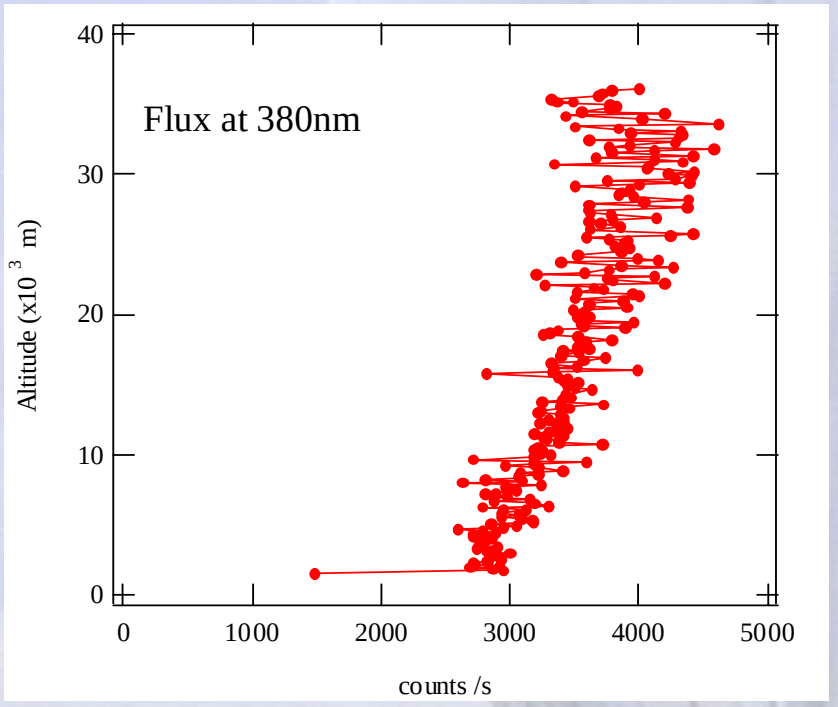
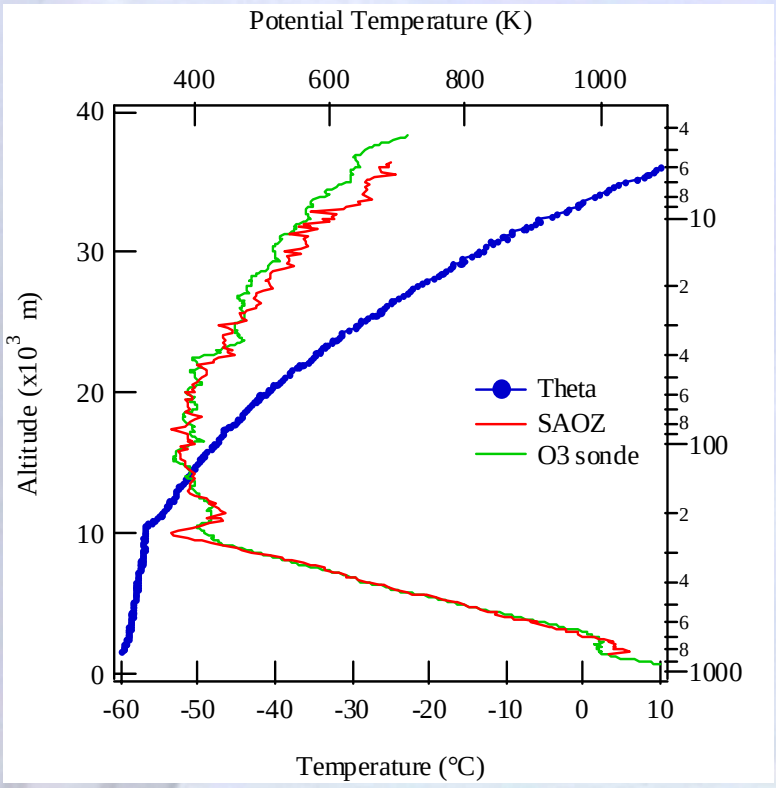
120
115
110
105
100
Longitude
Balloon
Tangent point



# SAOZ – BrO: Flight conditions



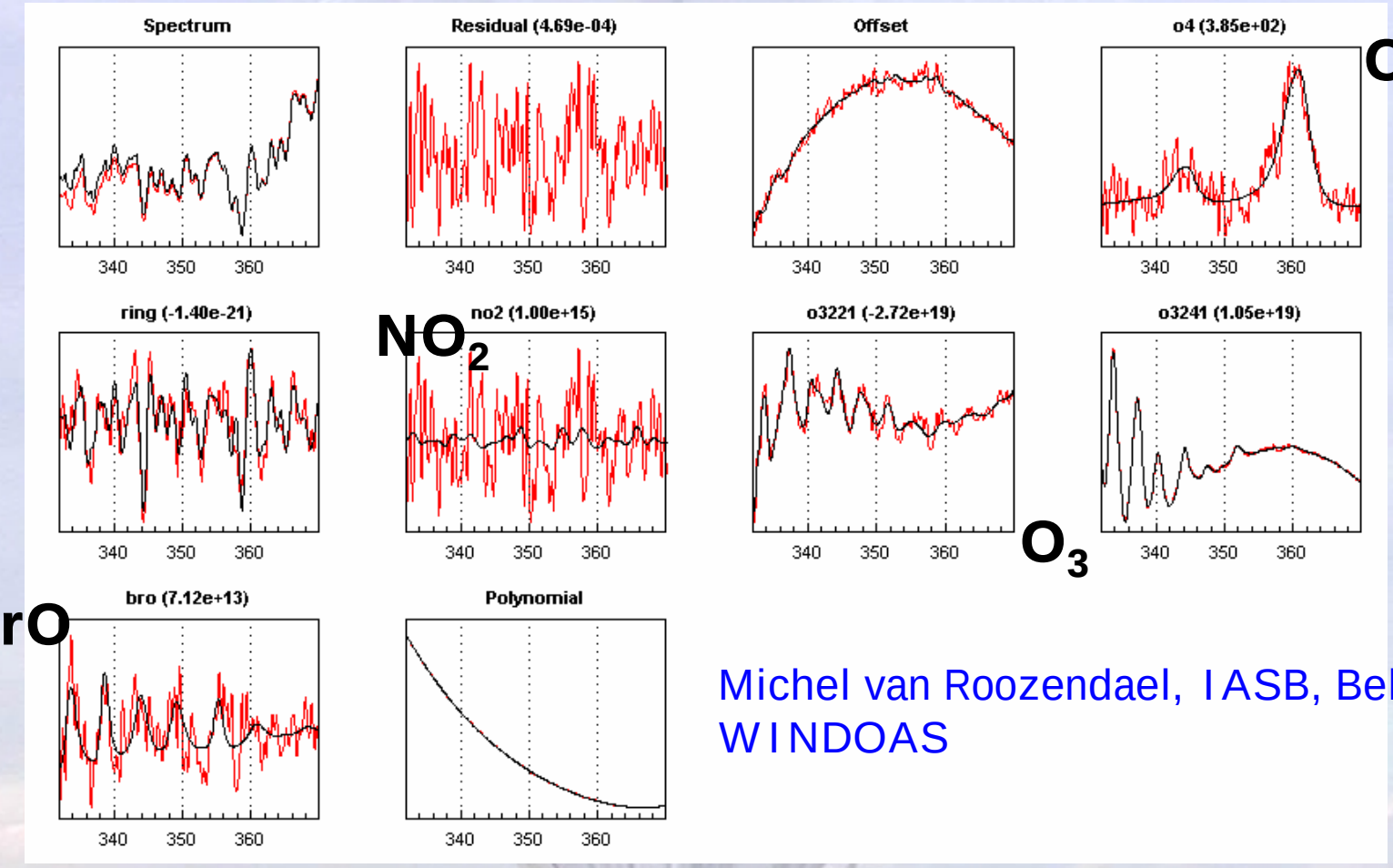

No clouds above 1.5 km

Tropopause at 10500 m : -53.3°C

# SAOZ's MANTRA

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

## SAOZ – BrO: Fit during ascent 81SZA

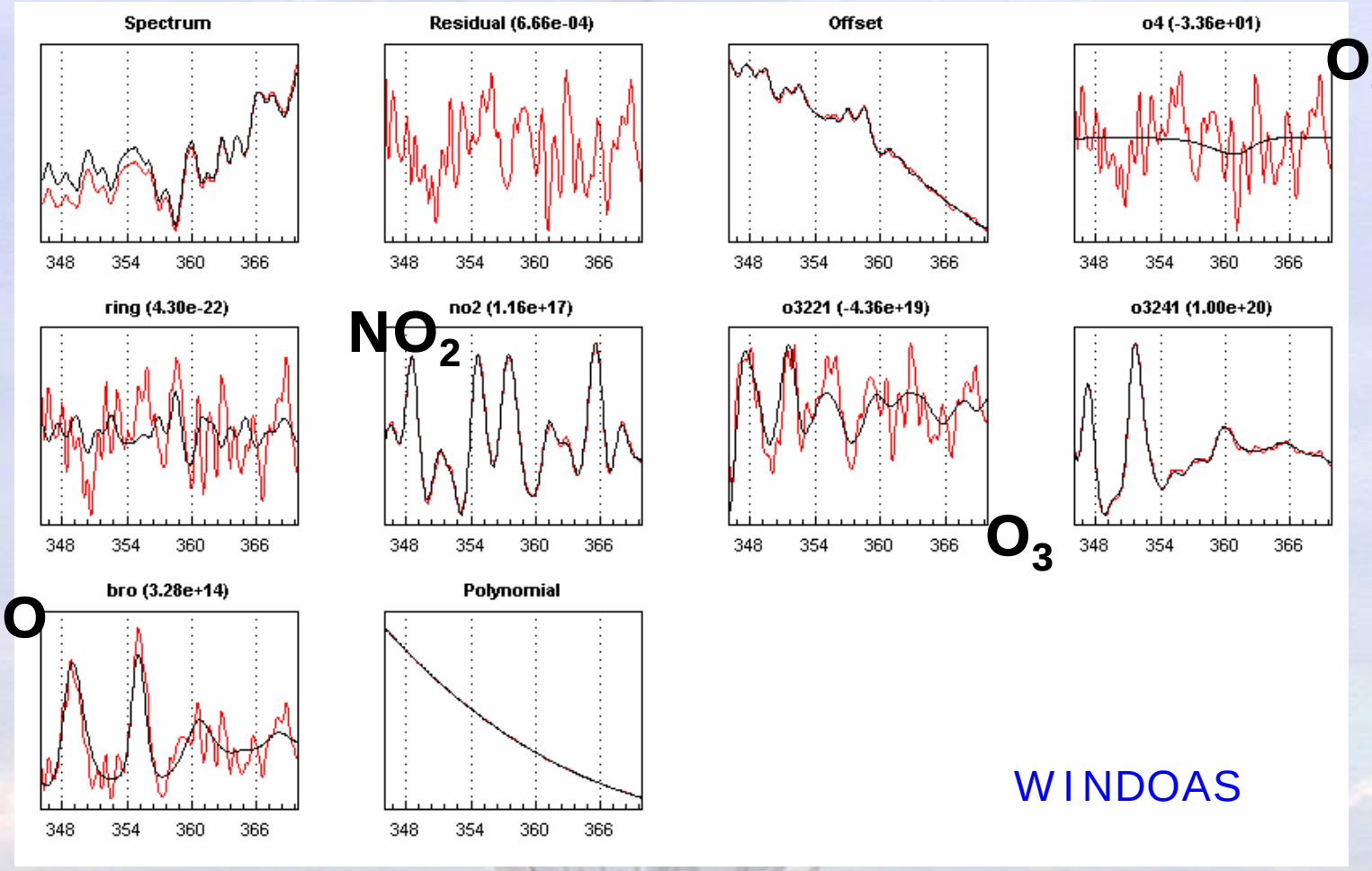



Michel van Roozendael, IASB, Belgium
WINDOAS

# SAOZ's MANTRA

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

## SAOZ – BrO: Fit during sunset 93SZA



# SAOZ's MANTRA

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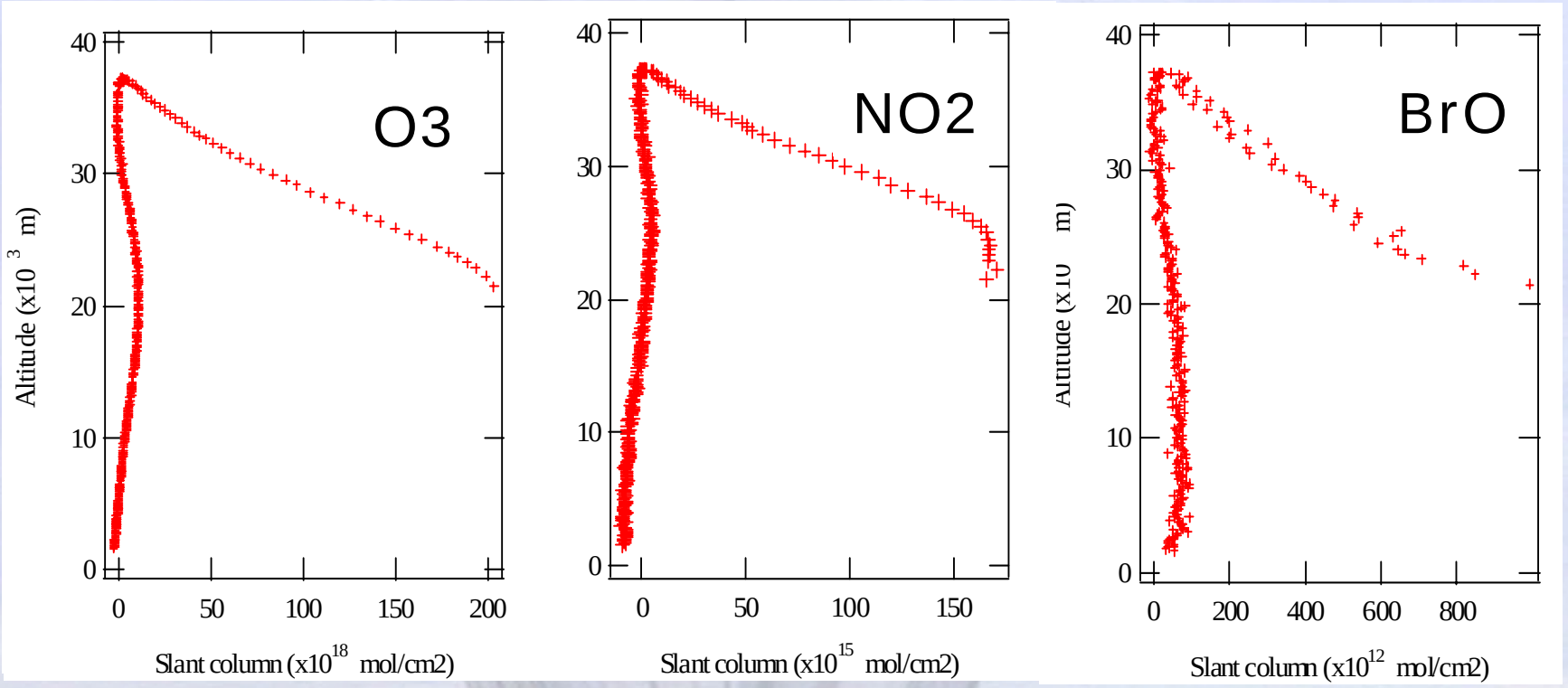
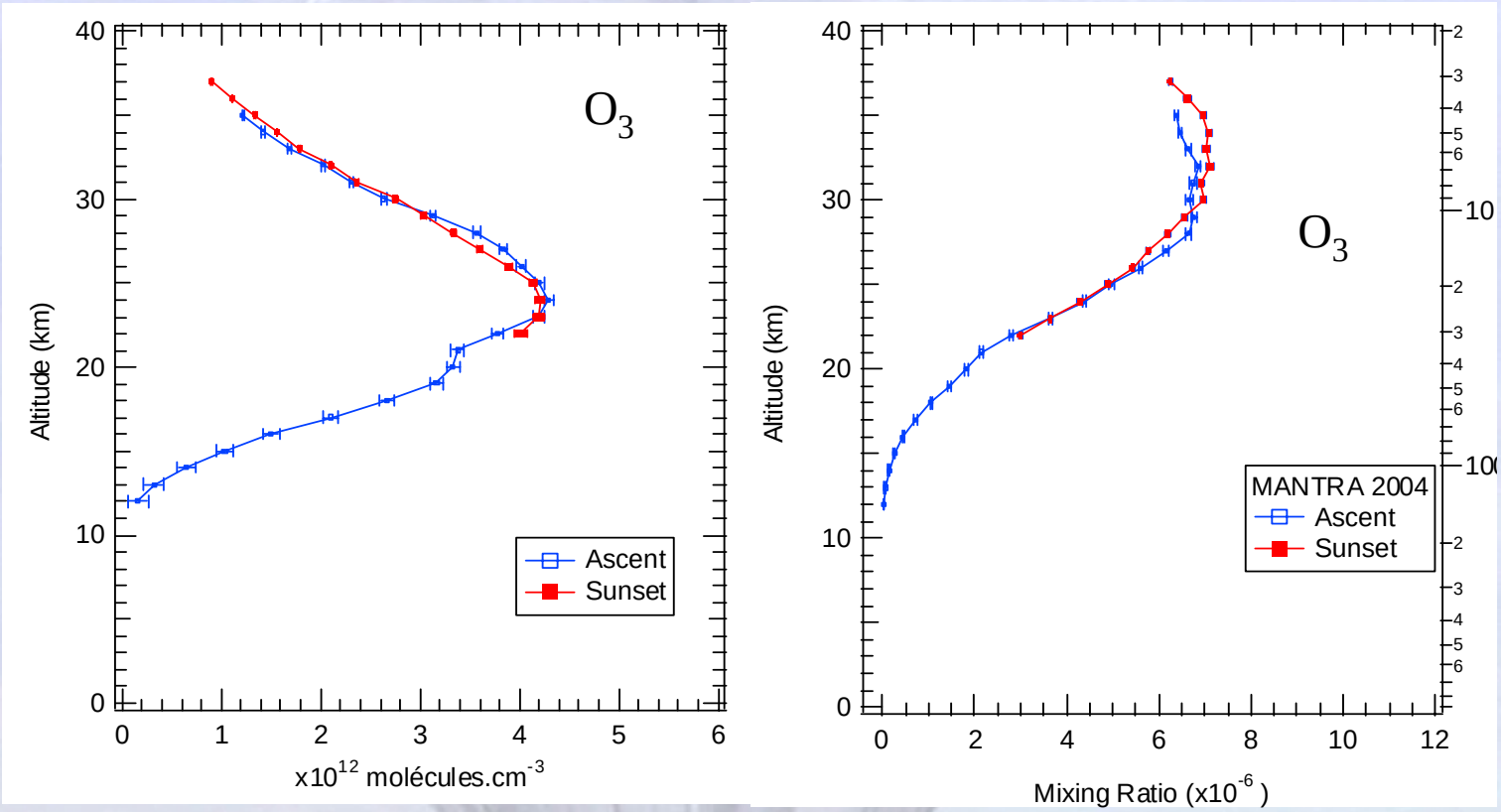
## SAOZ Species




Slant columns during ascent and sunset



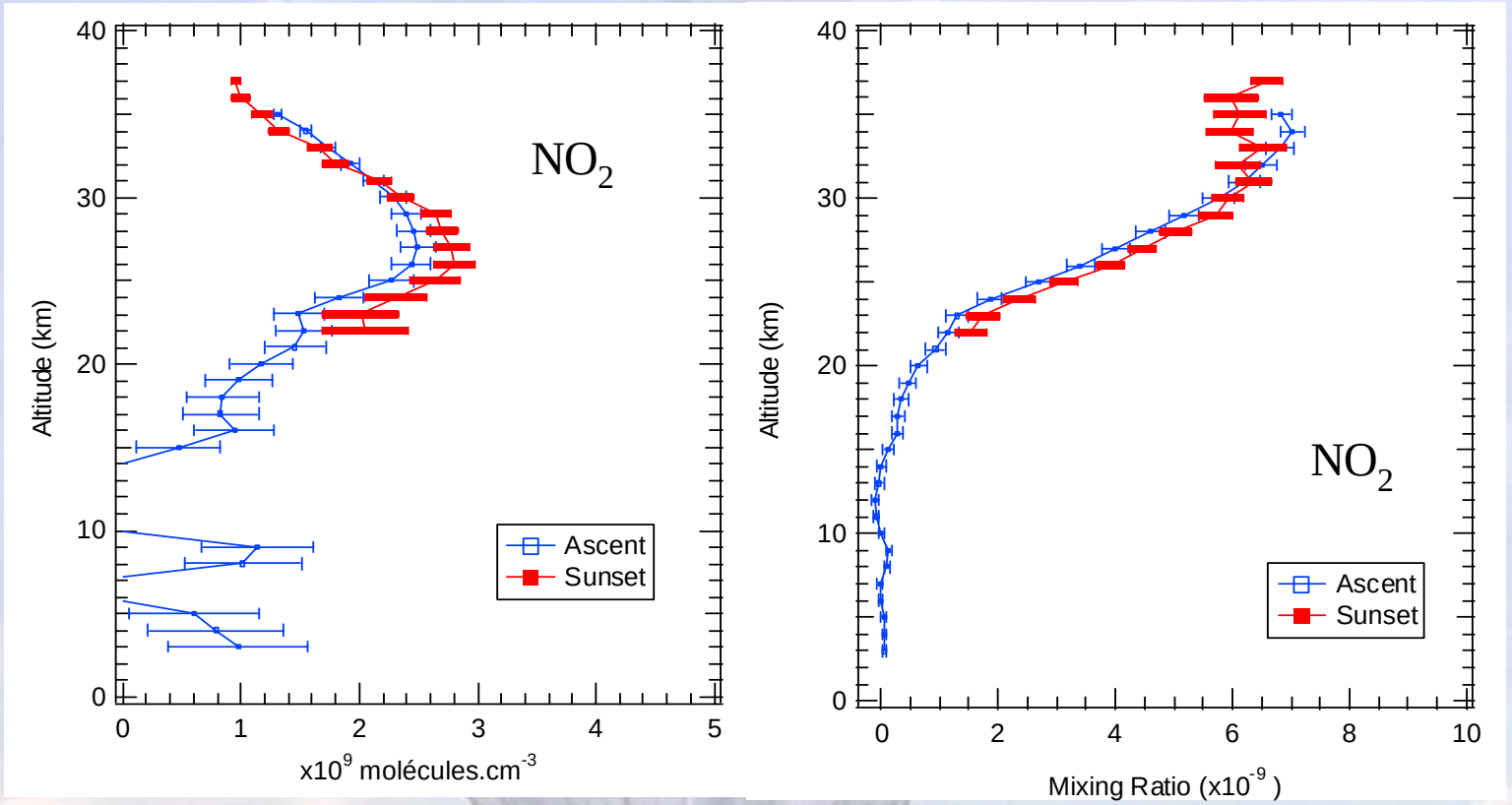
# SAOZ Profiles : O3




- Residual in reference spectrum: 1.6e19.
- Still preliminary: Arbitrary adjustment for 03: x 1.4 … cross sections to be checked



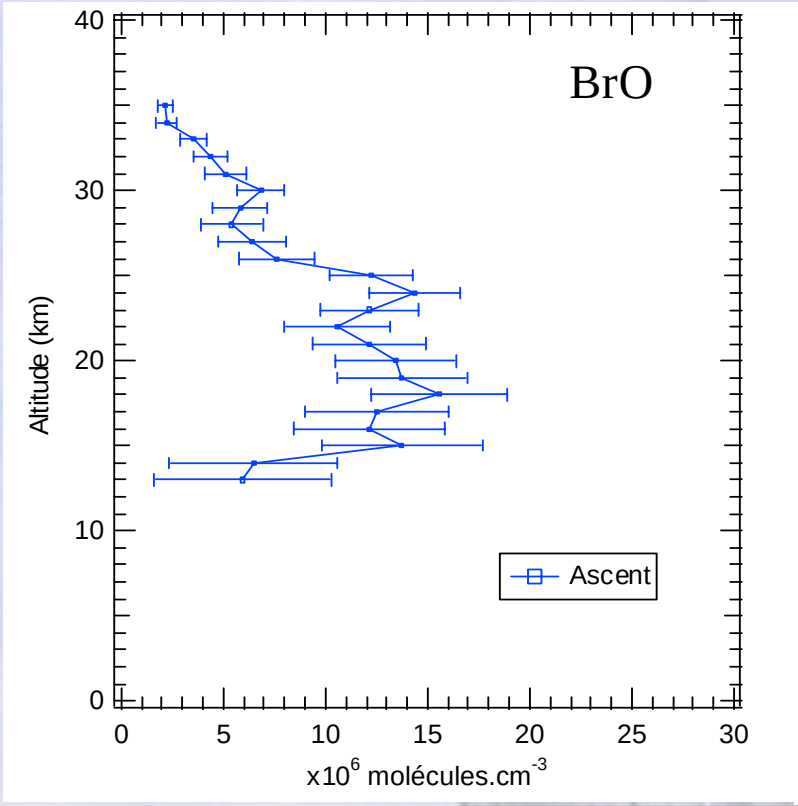
# SAOZ Profiles : NO2

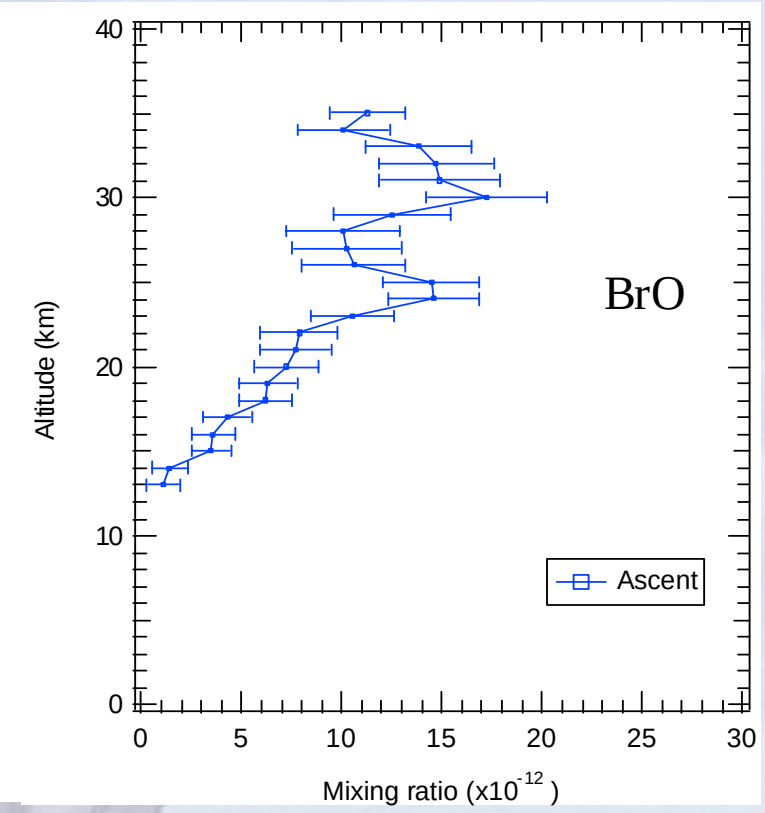



Residual in reference spectrum: 2.15 e16



# SAOZ Profiles : BrO




Residual in reference spectrum: 4 e13

# SAOZ's MANTRA

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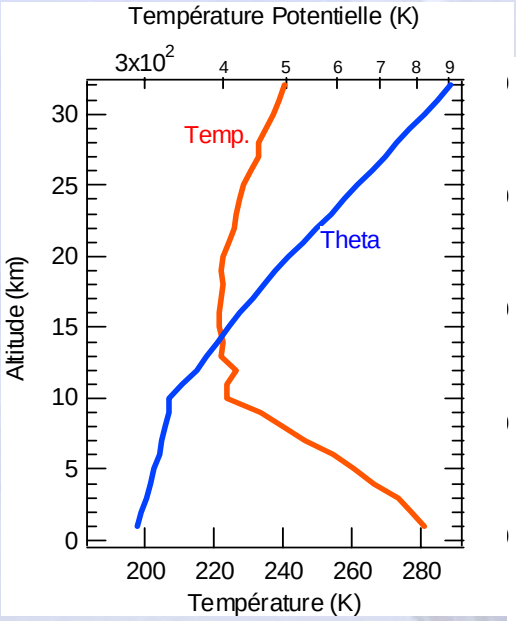
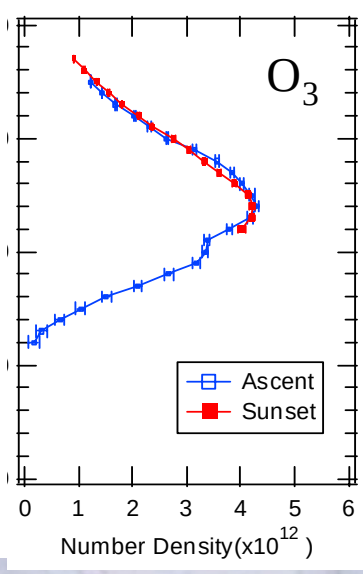
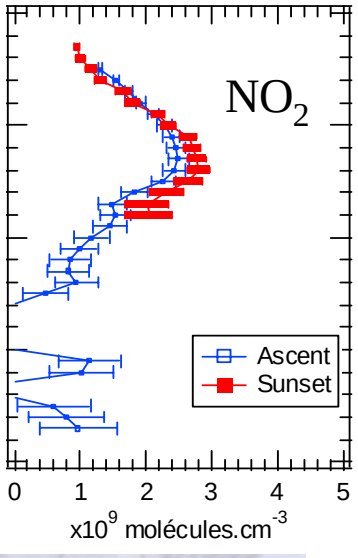
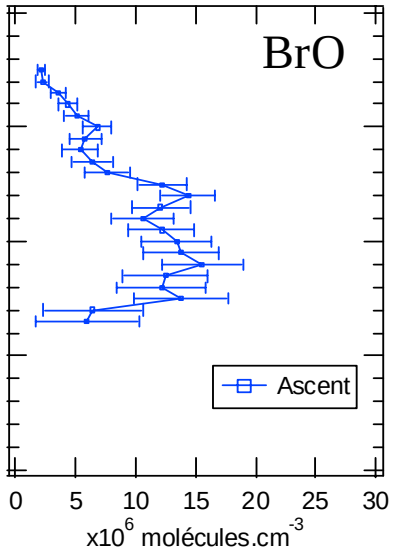
## SAOZ Profiles



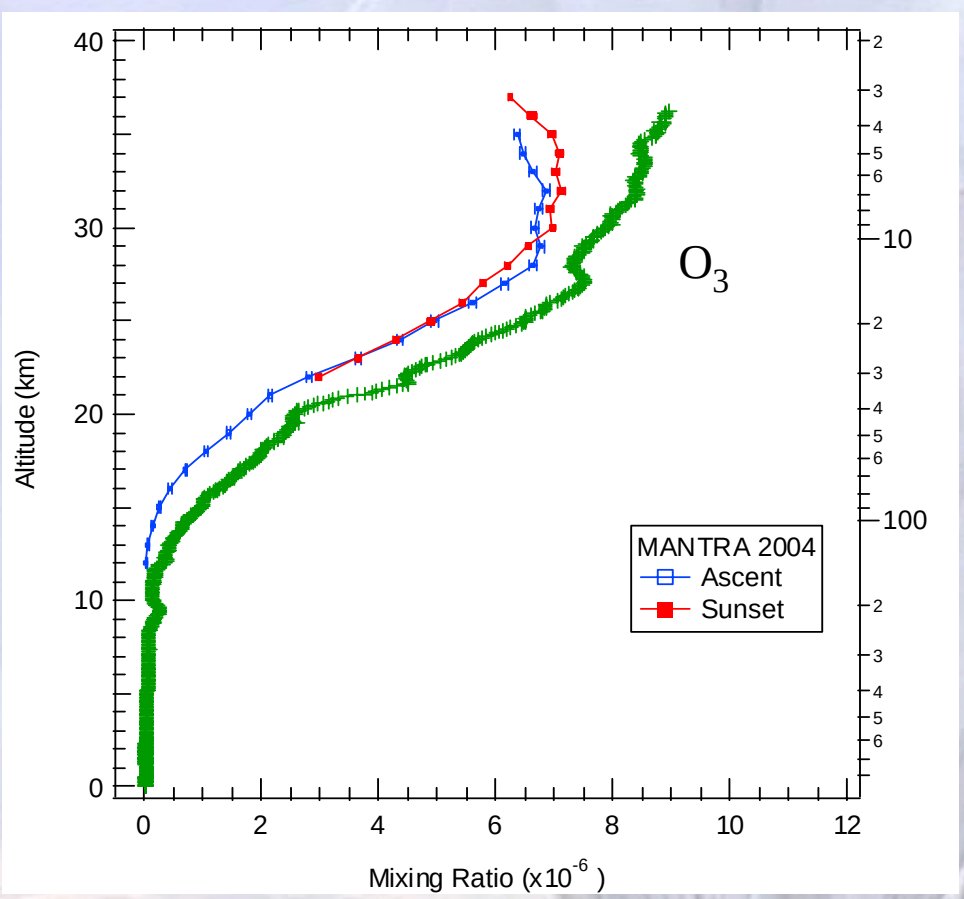




-BrO below NO2 maximum



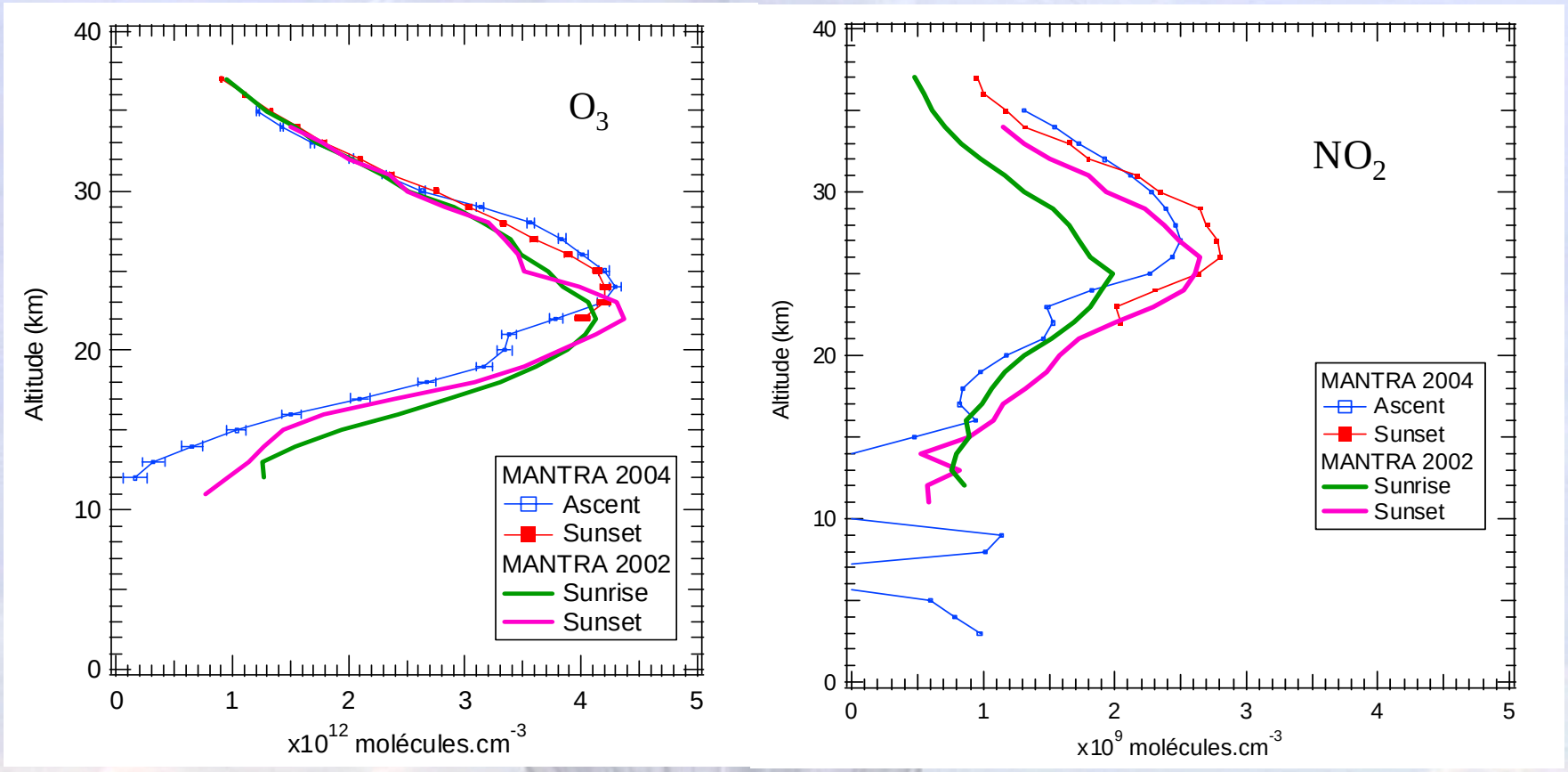
# Comparison with O3 sonde




Sonde: 20% larger compared to SAOZ



# Comparison with Mantra 2002




Good agreement with Mantra 2002 sunset



# Comparison with Satellites

**No coïncidences:(too far north)**

- Haloe
- Sage II
- POAM III

**Coïncidences with**

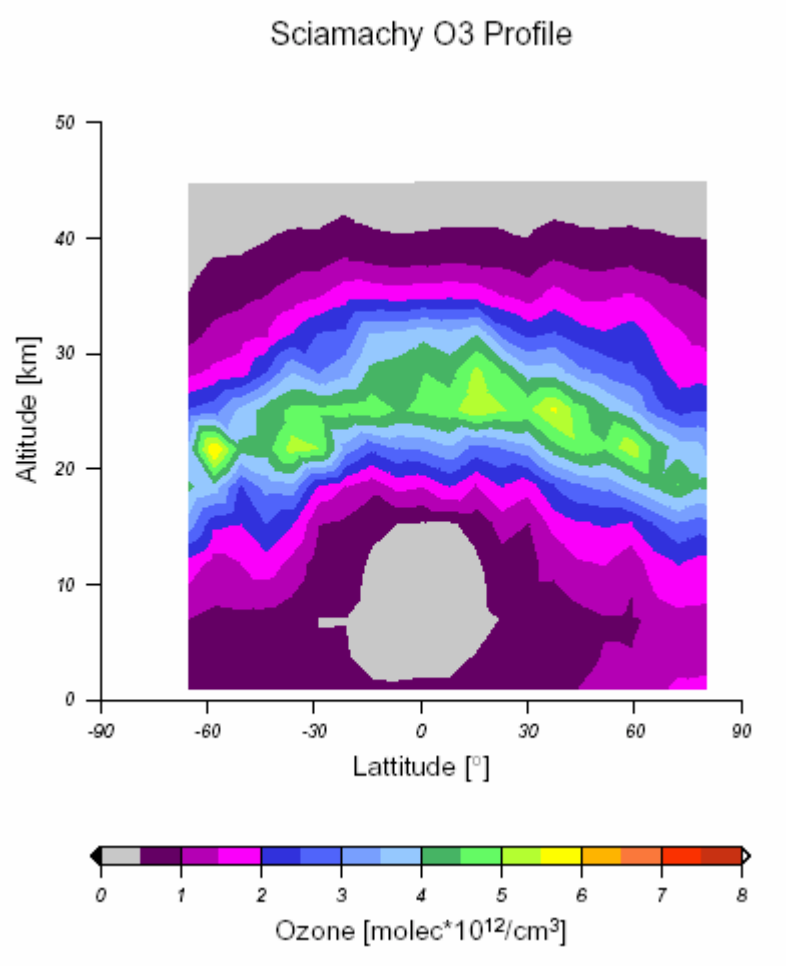
- ENVISAT/Sciamachy (orbit 12992 and 12991)
- ENVISAT/Mipas (?)
- ENVISAT/GOMOS
- ODIN/Osiris
- ODIN/SMR
- Sage III (?)

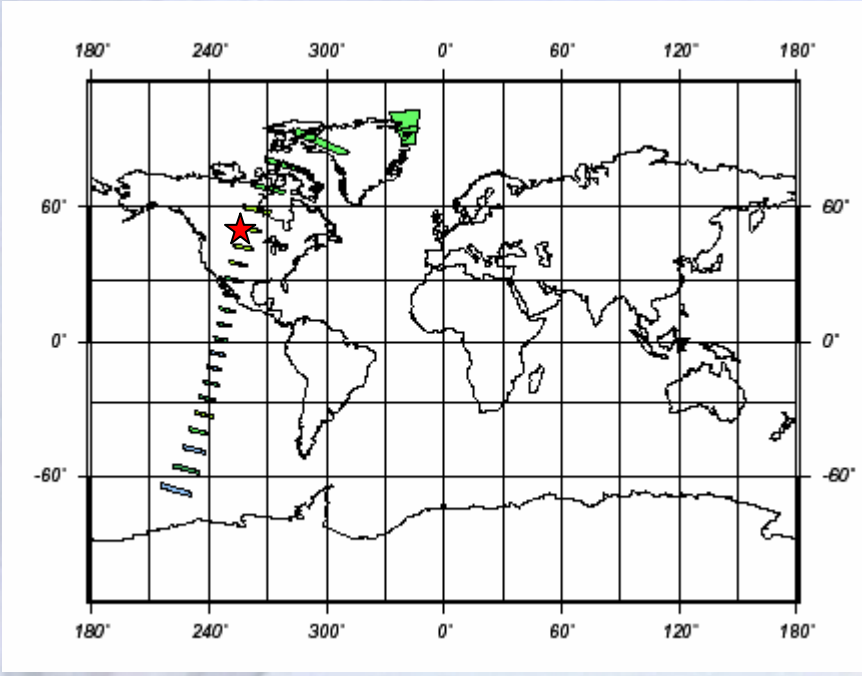


# SAOZ's MANTRA

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

## SCIAMACHY



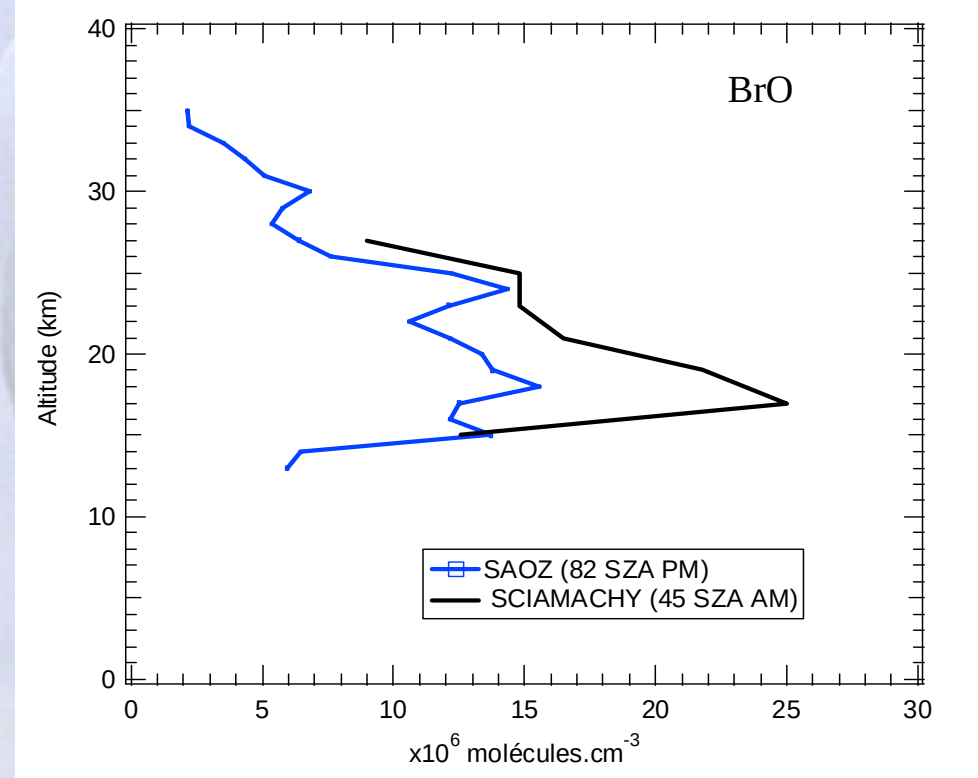




**Orbit: 12992**
**Only O3 available on Bremen web site**

**BrO profile received from C. Sioris**



# Comparison with Sciamachy



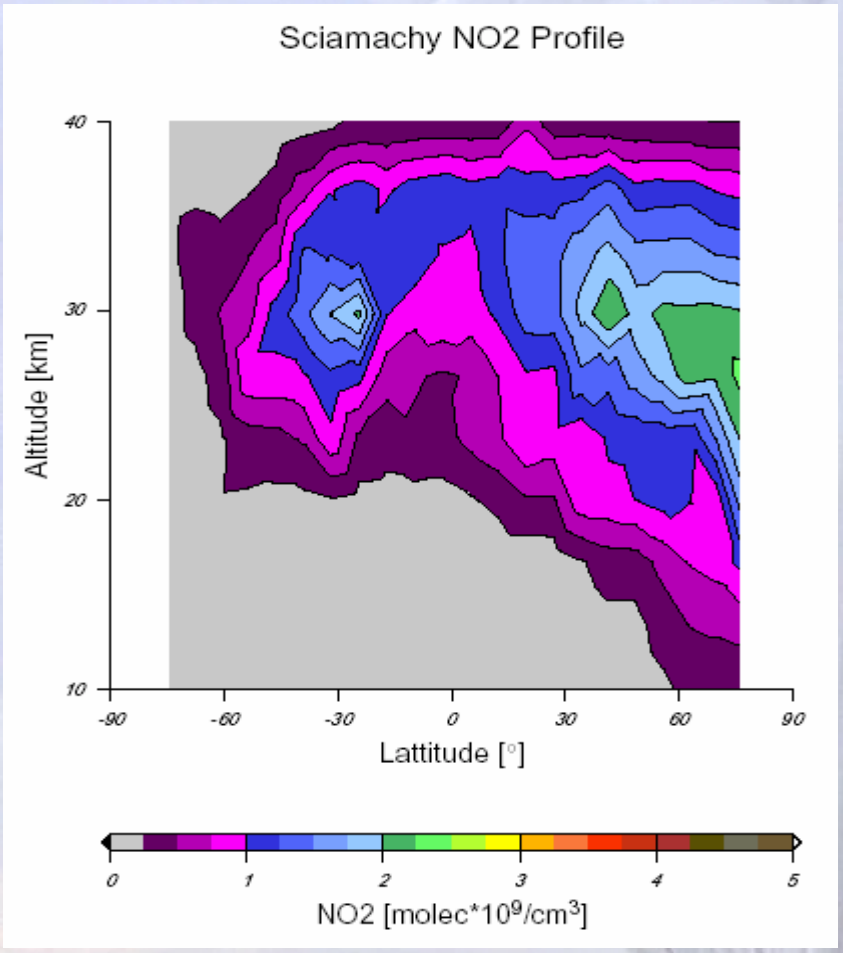

C. Sioris

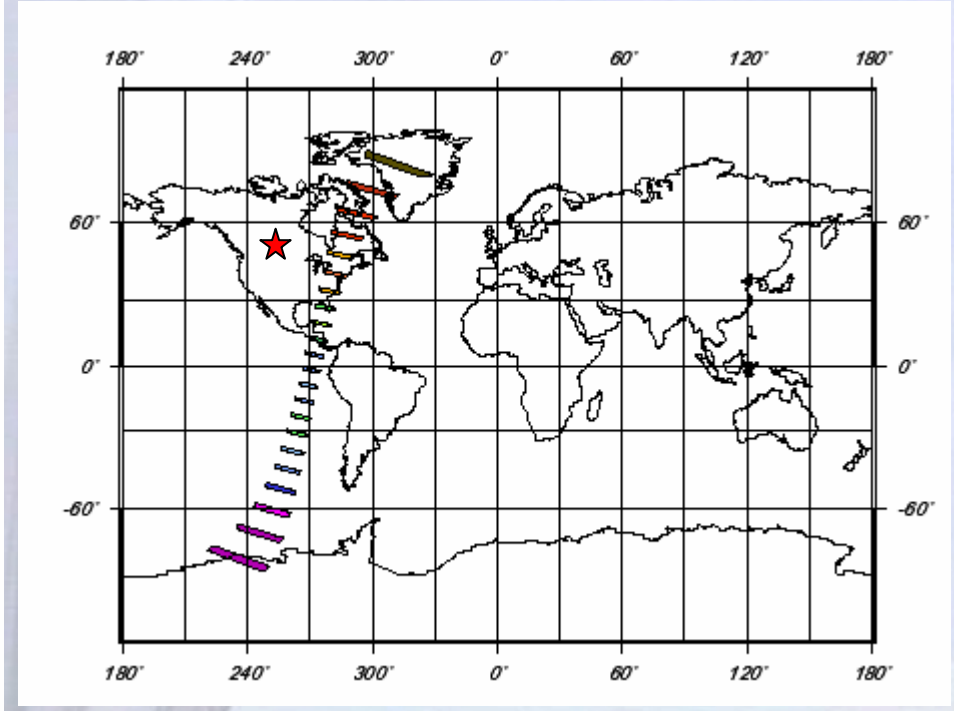
Orbit: 12992 24-Aug-2004 SZA=45 AM (at TH=20 km, lat=52°N, lon=98.8 °W )
Work to be done: convert to time of SAOZ observations + NO2 profiles

# SAOZ's MANTRA

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

# SCIAMACHY



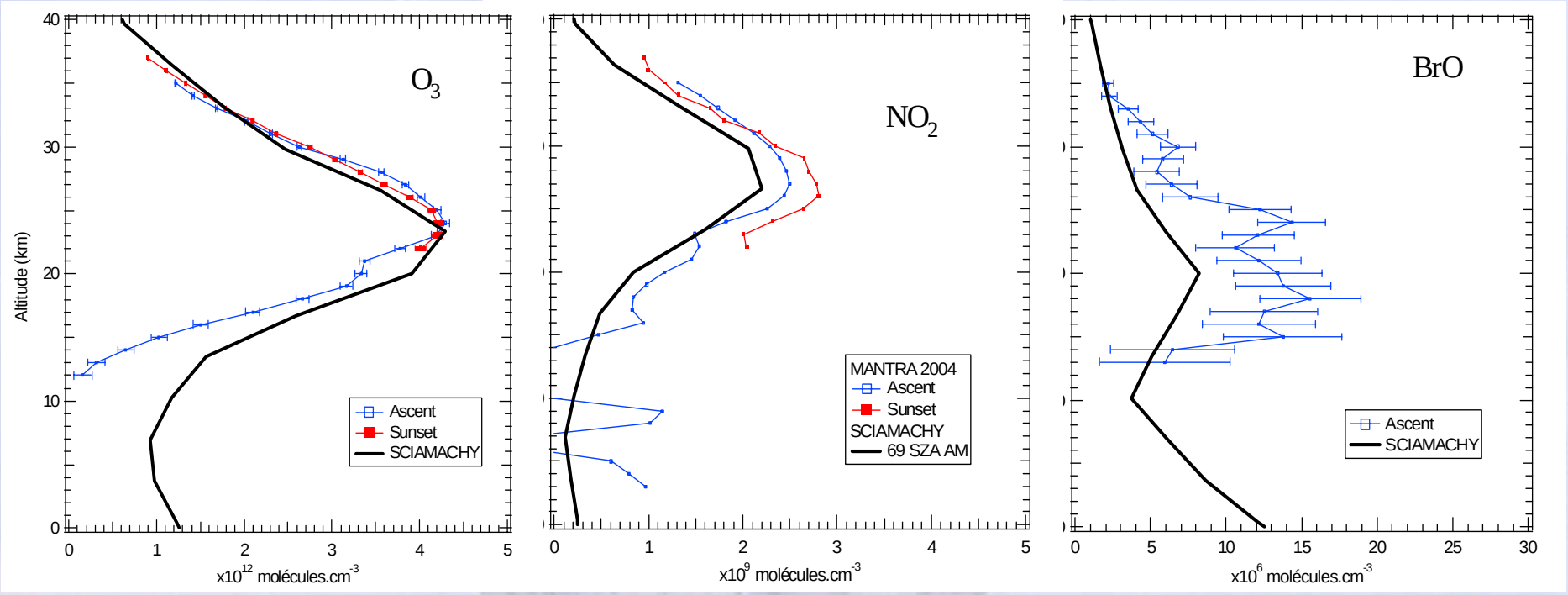

**Orbit: 12991 Scan: 609_03 24-Aug-2004**
**15:32 UT 56N 70W SZA:69.68**

O3, NO2, BrO available

# SAOZ's MANTRA

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

## Comparison with Sciamachy




SCIAVALID=Bremen

Orbit: 12991 Scan: 609_03 24-Aug-2004 15:32:29 56N 70W SZA:69.68
Bremen processing (Rozanov et al.) work to be done: convert to SAOZ observation time

# SAOZ on main Flight – first one

- **Operations**
  - Balloon released on Sept 1, 2004 at 14:30 UT (08:30 loc)
- **Results**
  - SAOZ stopped acquiring spectra at 13:48 UT
  - No results

**Failure Analysis**

- Reason unknown (Instrument and batteries OK after recovery)
- Intensive tests in the lab: failure not reproduced

**Further work:**

- Working on wireless telemetry transmission between SAOZ and main payload in case of a future Mantra 200X

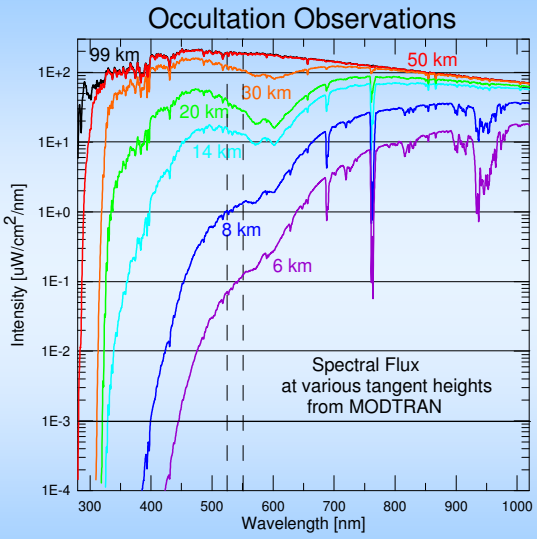
# SAOZ on main Flight – second one

- **Operations**
  - Balloon released on Sept 14, 2004 at 08:16 UT (02:16 loc)
  - BUT stopped after reaching 2000 m at 08:19 UT
- **Results**
  - SAOZ working nominally
  - Strange noise in SAOZ box
- **Noise Analysis**
  - Screw blocking the rotating disc (for dark current) had moved



# Conclusion

- Ground-based SAOZ
  - One and a half month of O3 and NO2 columns
  - Ready for comparison with others
  - Ready to get low resolution vertical profiles
- SAOZ balloon
  - O3, NO2 and BrO profiles
  - Satellite comparison



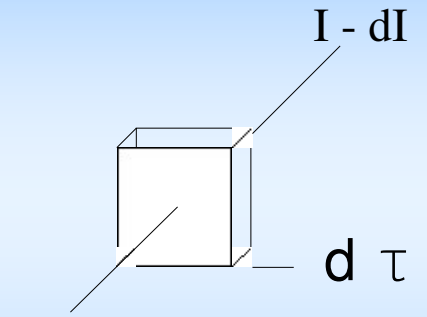

# MANTRA $NO_2$ Observations

C.T. McElroy

## Topics for Today

- Introduction
- Differential Spectroscopy
- SunPhotoSpectrometer
- MAESTRO Measurements
- Relationship with Satellite Measurements

# Beer-Lambert Law




$$dI = I * d\tau$$

Intensity $I(\lambda)$, is given by:

$$I(\lambda) = I^{o}(\lambda) \exp[ -\tau(\lambda)]$$

Where

$\tau(\lambda)$ is the optical depth at $\lambda$

# Optical Depth

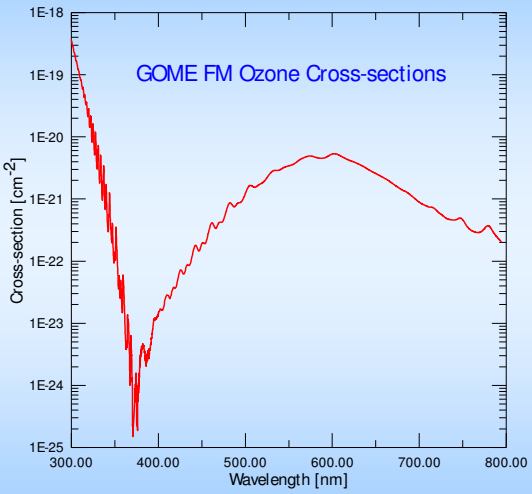
$$\tau_{total}(\lambda) = \tau_c(\lambda) + \tau_a(\lambda)$$

$$\tau_c(\lambda) = \sum_{c=0}^{N_c-1} \sigma_c(\lambda) X_c$$

$\sigma_c(\lambda)$ is the molecular cross-section for constituent c at wavelength $\lambda$

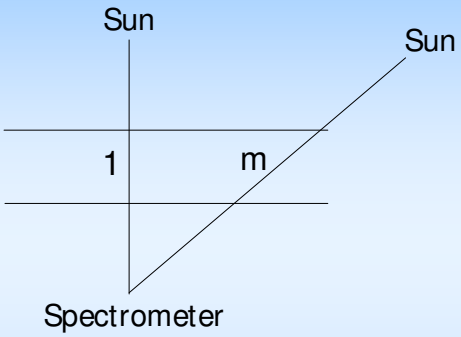
$X_c$ is the surface density of constituent c in the column

# Ozone Cross-sections




# Differential Measurements – original DOAS

(E.g.: Dobson or Brewer)




$I(\lambda_s) = I^o(\lambda_s) \exp[ -\tau(\lambda_s) ]$

$I(\lambda_l) = I^o(\lambda_l) \exp[ - \tau(\lambda_l) ]$

$\log[ I(\lambda_s) / I(\lambda_l) ] =$

$\log[ I(\lambda_s^o) / I(\lambda_l^o) ] - [ \sigma(\lambda_s) - \sigma(\lambda_l) ] \times m$

or $F = F^o - \Delta \sigma \times m$

$X = (F^o - F) / (\Delta \sigma\, m)$ $\quad m = 1.0 / \cos(SZA)$

## The Brewer Triad

## Fitting

- Ozone
- $NO_2$
- $NO_3$
- $O_4$
- $O_2$
- $H_2O$

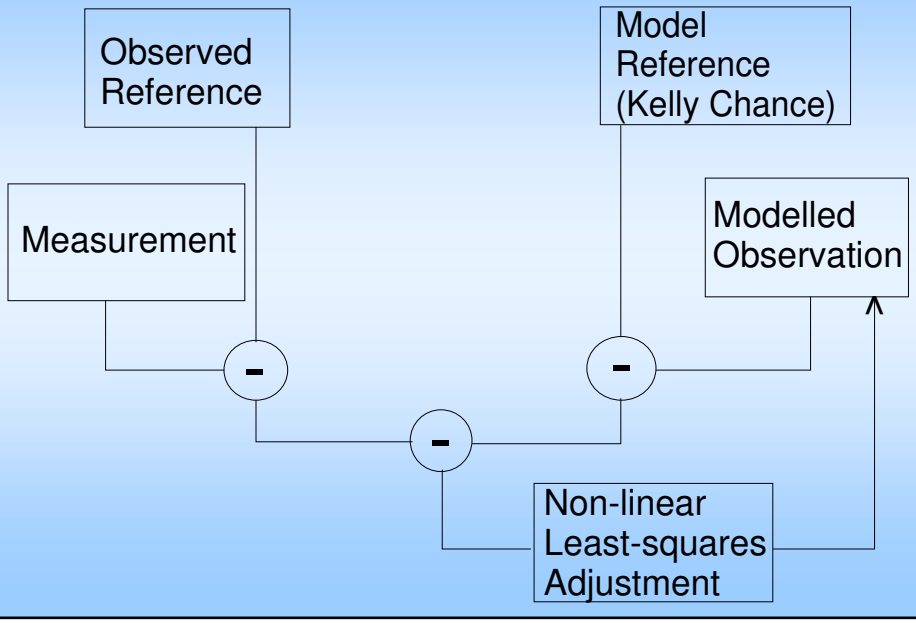
- Etalon shift
- Rayleigh
- Offset
- Linear
- Shift
- Stretch

## Serious Issues…

- Slit Function
- Sensitivity, Etalonning & Pixel-to-pixel Gain
- Dynamic Range, Dark count & Noise Level
- Stray Light, Linearity & Thermal drift (analog)
- Resolution, Free Spectral Range
- Wavelength Assignment
- Cross-section wavelength assignment

*… for twilight measurements*

## Fitting Code



# ‘Effective’ Optical Depth

$\tau_{lt} = \tau_{lt}\,( X_{ct}, a_{it}, \text{shift}, \text{stretch})$

| | |
|---|---|
| l | pixel number (wavelength) |
| t | solar angle number ($\theta_t$) |
| i | index to 3 polynomial coefficients |

| | |
|---|---|
| $X_{ct}$ | column density of constituent c at solar angle $\theta_t$ |
| $\theta_t$ | solar zenith angle |
| $a_{it}$ | polynomial coefficients |

# Retrieval

$$\chi^2 = (\tau^m_{lt} - \tau^d_{lt})\, \sigma^{-1}_{lqt}\, (\tau^m_{qt} - \tau^d_{qt})$$

Is minimized for:

$$\frac{\partial \chi^2}{\partial w} = 2\,(\tau^m_{lt} - \tau^d_{lt})\, \sigma^{-1}_{lq}\, \frac{\partial \tau^m_{qt}}{\partial w}$$

where w represents any one of the elements of $X_{ct}$, $a_{it}$, shift or stretch. Superscript m denotes modeled values.

If the differential can be calculated - the minimization can be done. If it is done analytically – it is fast.

## For the Twilight Sky

$$\tau^{m}_{lt} = -\left[ \log( I_{lt}) - \log( I_{lt}^{ref}) \right]$$

Where:

$I_{lt}$ – is the observed intensity at $\lambda_l$ and $\theta_t$

$I_{lt}^{ref}$ - is the reference spectrum

## A Simple Model…

We assume that the apparent optical depth can be written as:

$$\tau^{m}_{lt} = \sum_{Nc} X_{ct}\, \sigma_{cl} + \sum_{3} a_{it}\, P_{il}$$

$X_{ct}$ – column density of constituent c at $\theta_t$

$\sigma_{cl}$ – cross-section for $X_c$

$a_{it}$ – polynomial coefficient

$P_{il}$ – polynomial term as function of pixel number l (at $\lambda_l$)

## Differentials 1:

From:

$$\tau^m_{lt} = \Sigma\, X_{ct}\, \sigma_{cl} + \Sigma\, a_{it}\, P_{il}$$

$$\frac{\partial \tau^m_{qt}}{\partial X_{ct}} = \sigma_{cq}^{Nc} \quad \text{and} \quad \frac{\partial \tau^m_{qr}}{\partial a_{it}} = P_{iq}^{3}$$

## Differentials 2: Shift and Stretch

$$\frac{\partial \tau^m_{qt}}{\partial \text{Shift}} = \frac{\partial \tau^m_{qt}}{\partial \lambda} \frac{\partial \lambda}{\partial \text{Shift}}.$$

$$\frac{\partial \tau^m_{qt}}{\partial \text{Stretch}}. = \frac{\partial \tau^m_{qt}}{\partial \lambda} \frac{\partial \lambda}{\partial \text{Stretch}}.$$

## The values:

$\partial T^{m}_{qt}$ is mostly from the reference spectrum

$\partial\lambda$ it is calculated using the interpolation formula

Shift: $= \lambda' + \text{shift}; \quad \frac{\partial \lambda}{\partial \text{Shift}} = 1.0$

## Stretch

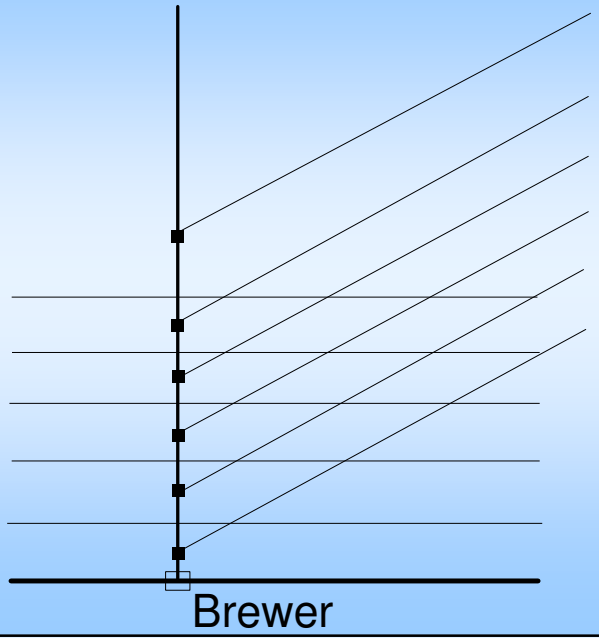
$$\lambda = \lambda' + \text{stretch} * (\lambda' - \lambda_m)$$

$\lambda_m$ - mean wavelength of spectrum

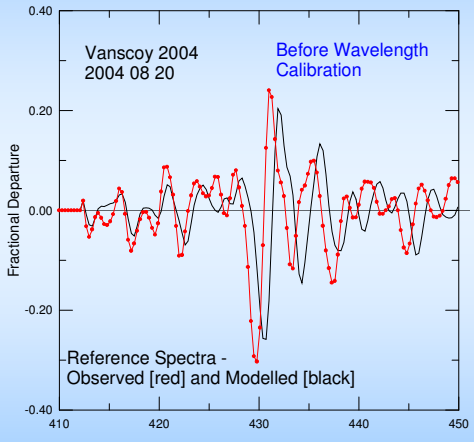
$$\frac{\partial \lambda}{\partial \text{Stretch}} = (\lambda' - \lambda_m)$$

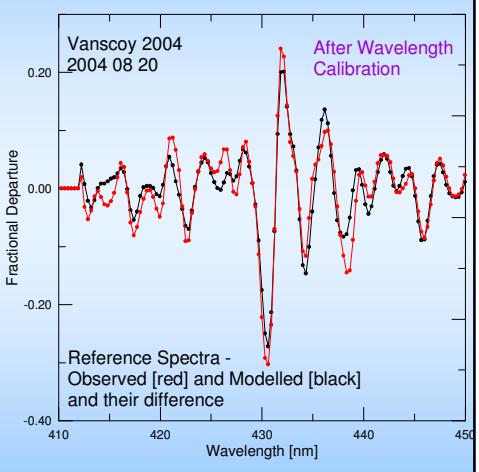
Higher powers can be handled the same way and involve terms in $(\lambda' - \lambda_m)^N$

# From Whence the Reference??



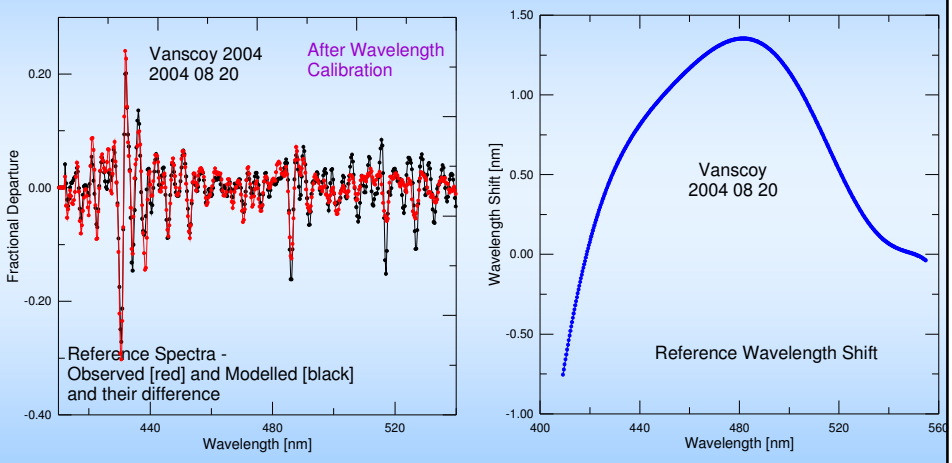

# Wavelength Calibration…



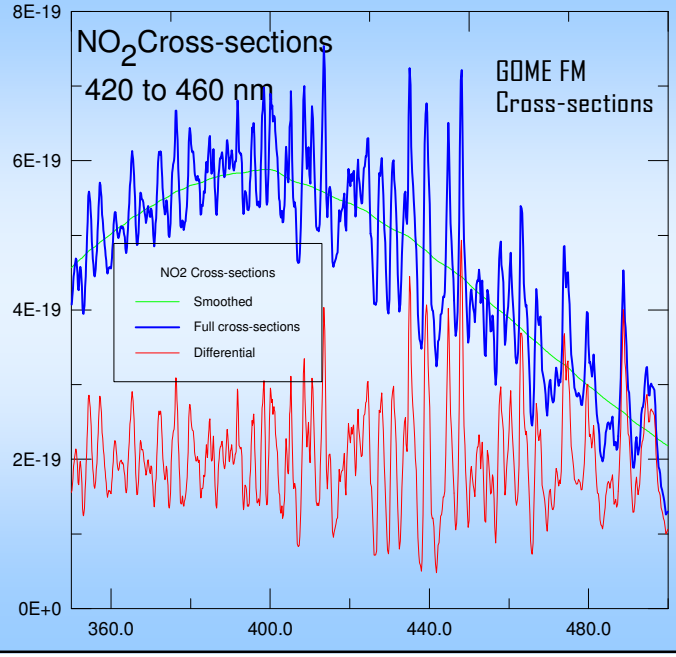




…matching to the ATLAS1 reference.

# The Correction




# Differential Cross-sections

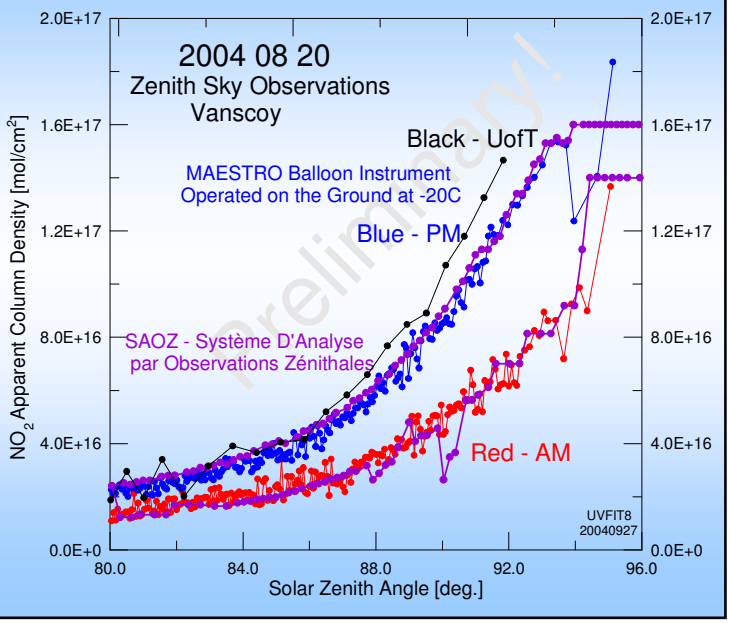


# Why??

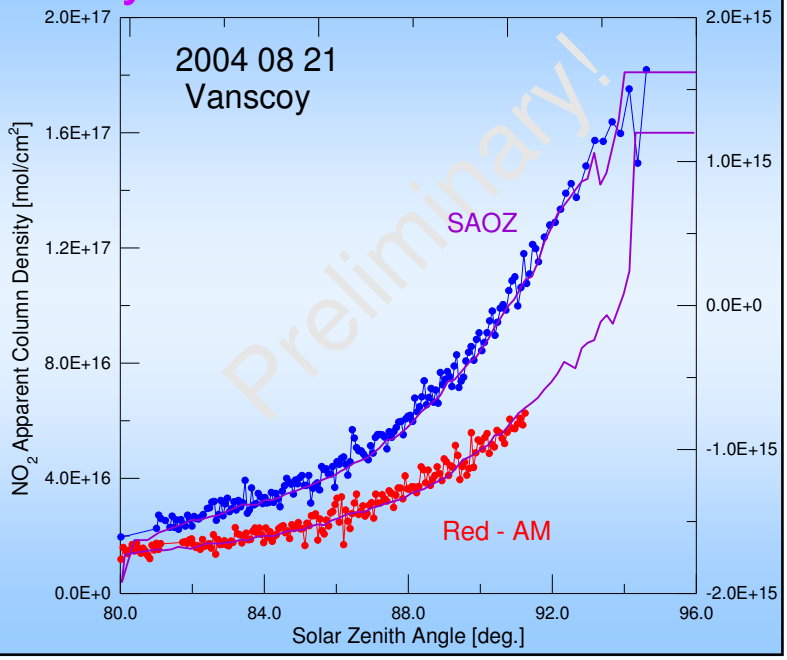
- Dedicated science folks..
- Masochists
- Saskatoon Holiday…
- Avoiding Toronto
- Free food
- Stratospheric Chemistry
- Satellite Validation

# MAESTRO-G!

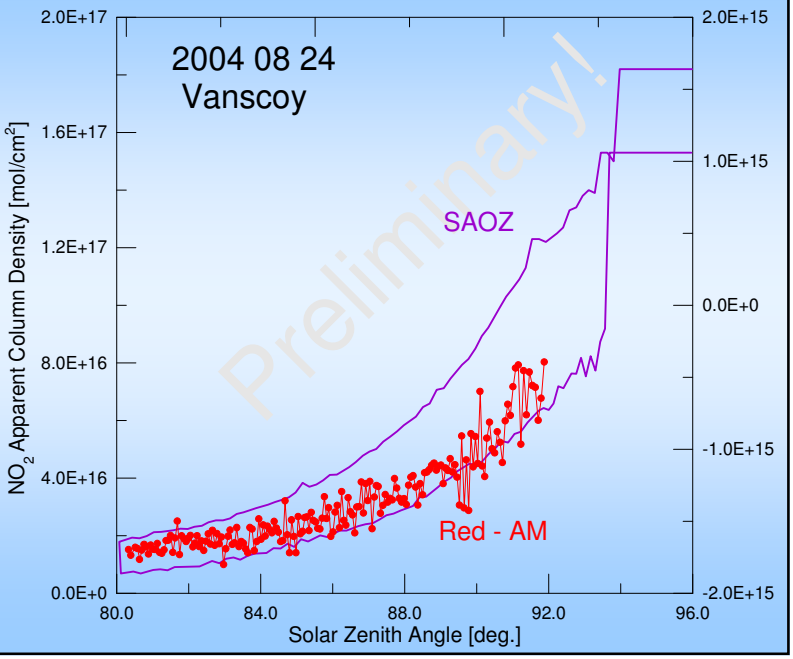
MAESTRO was operated in a freezer mounted on a solar tracker. the low temperature reduces the dark current from the detector.



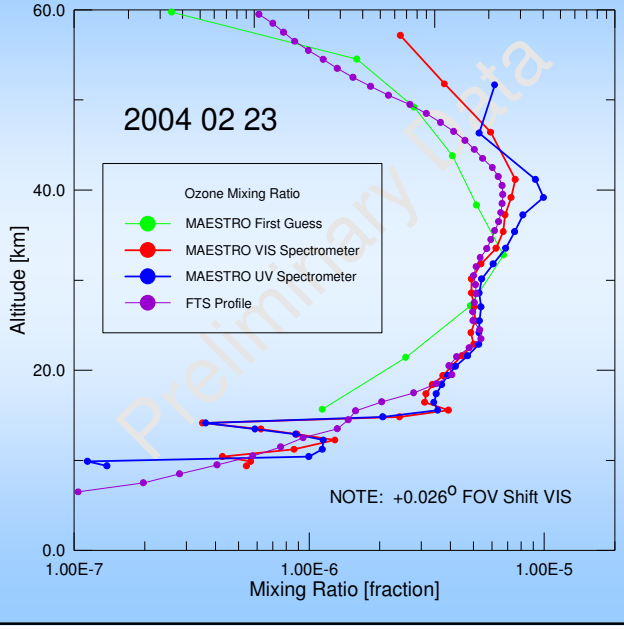
# Another day…



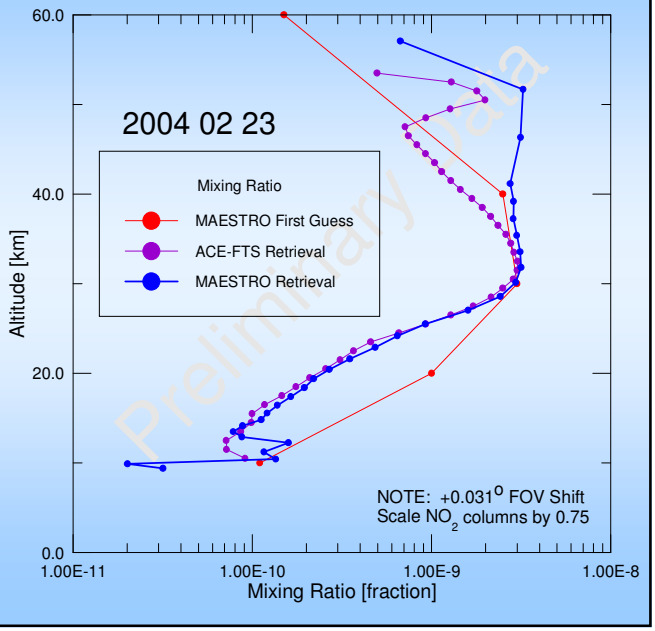

# And another…

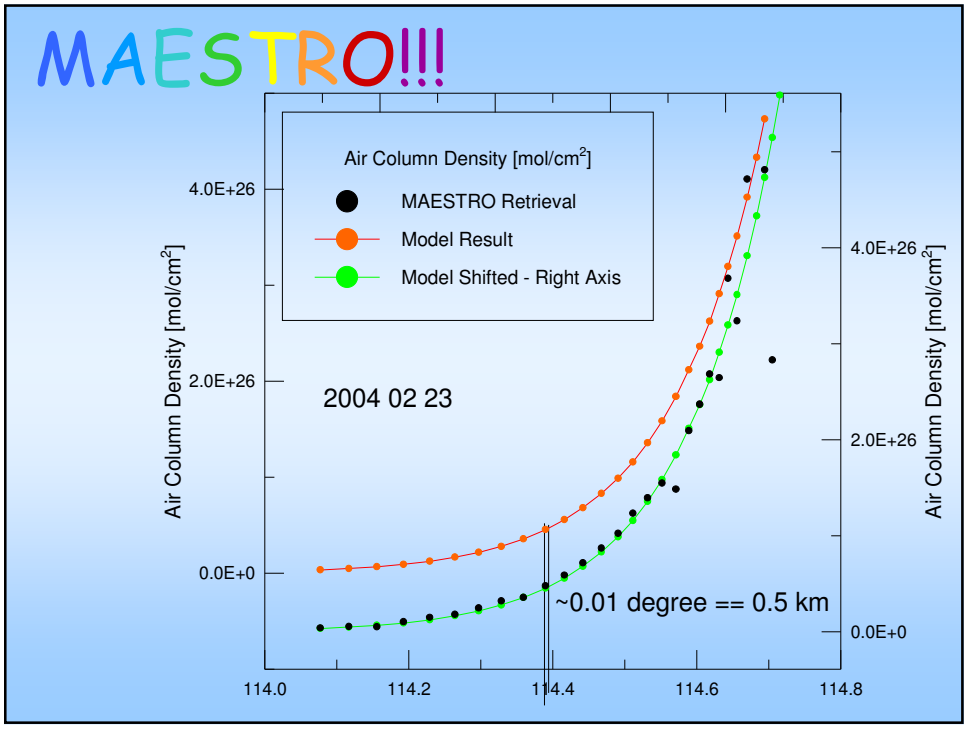


# MAESTRO!




# MAESTRO!!




MAESTRO!!!
Air Column Density [mol/cm$^2$]
MAESTRO Retrieval
Model Result
Model Shifted - Right Axis
2004 02 23
~0.01 degree == 0.5 km
Air Column Density [mol/cm$^2$]
4.0E+26
2.0E+26
0.0E+0
114.0
114.2
114.4
114.6
114.8


"Sometimes science can
Be a 'hare-y' business…"
The End

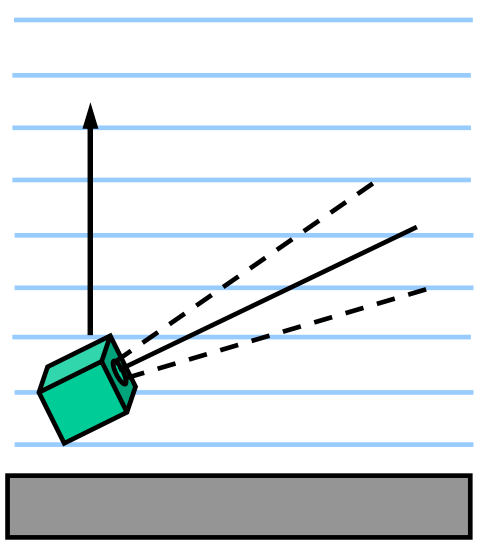
# MANTRA Q6 Meeting/Post-flight Review

Emission Radiometers

November 10, 2004

Matthew Toohey

# The Emission Radiometer

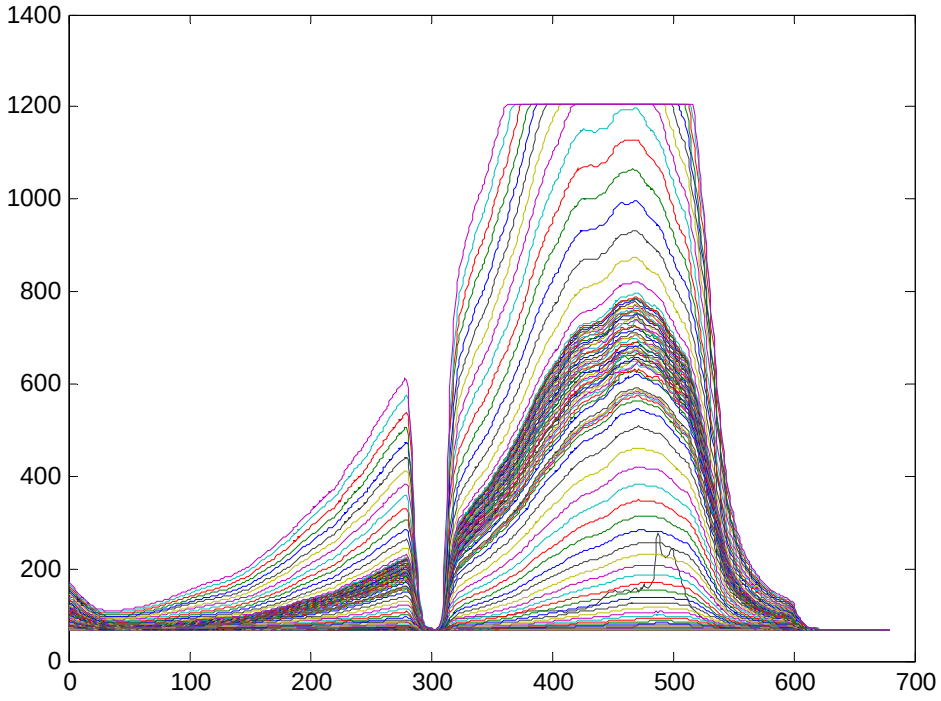


- Emission Radiometer instrument developed in early 1970's
  (*e.g. Evans et al., Atmosphere, 14:172-179, 1976*).
- Measures atmospheric thermal IR emission during balloon ascent until cryogen is exhausted.
- Circular variable filter 4-14 µm: crude spectral resolution by modern standards (20 $cm^{-1}$).
- In-flight radiance calibrations performed using blackbody flap.
- Primary measurement goal: $HNO_3$
- Also measures emission from $O_3$,
  CFC-12, CFC-11, $N_2O$, $CH_4$, $CO_2$, $H_2O$.
- Modern data collected during MANTRA 1998, 2000, 2002 (and 2004).
- Possibility exists to reanalyse data from 1989, 1990, 1991.

# Mission Overview

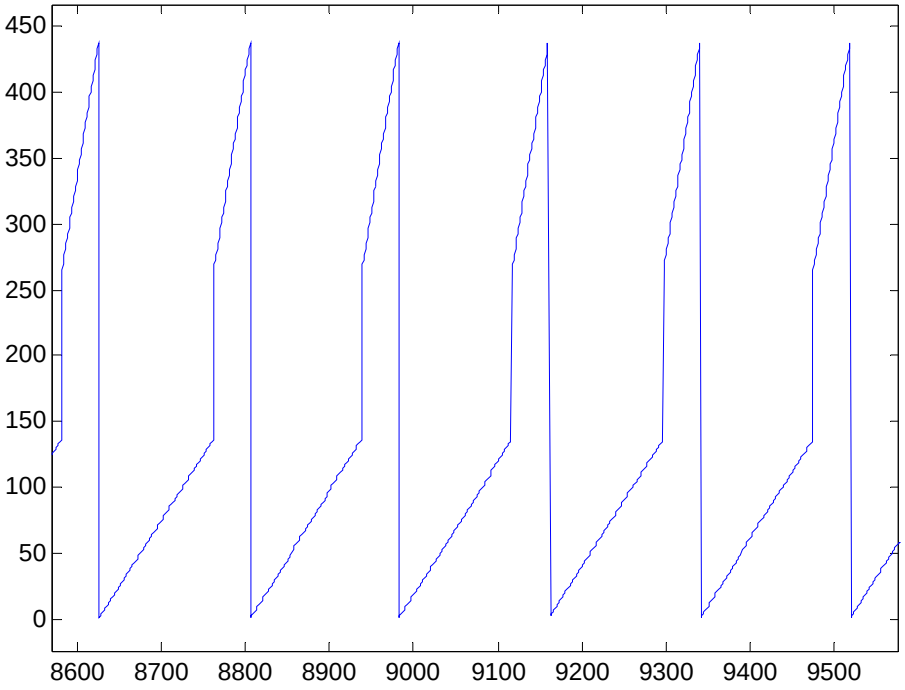
- Prior to campaign: Detector and preamp replaced in MX-36. Tested and shipped to Vanscoy in working condition.
- Bench Blackbody tests on Aug 7 and 8 confirmed flight readiness.
- Sept 1 flight: anomalous encoder position values have corrupted the collected scans (more later) for both instruments.
- Sept 14 flight: no anomalous observations regarding flight failure.

# The way things should be

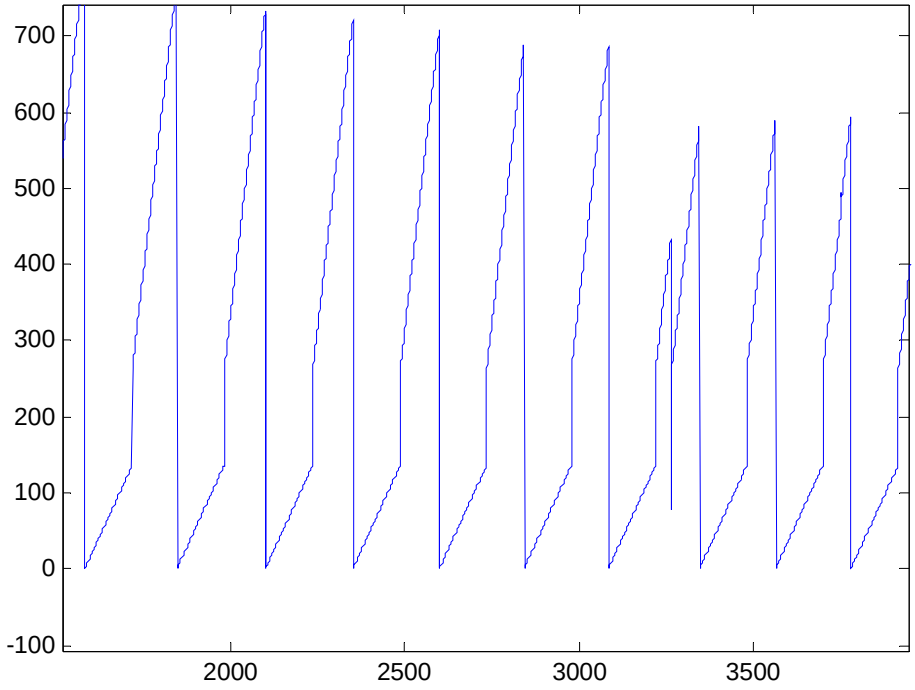



MX36 Bench Blackbody test, Aug 7

# Flight encoder records

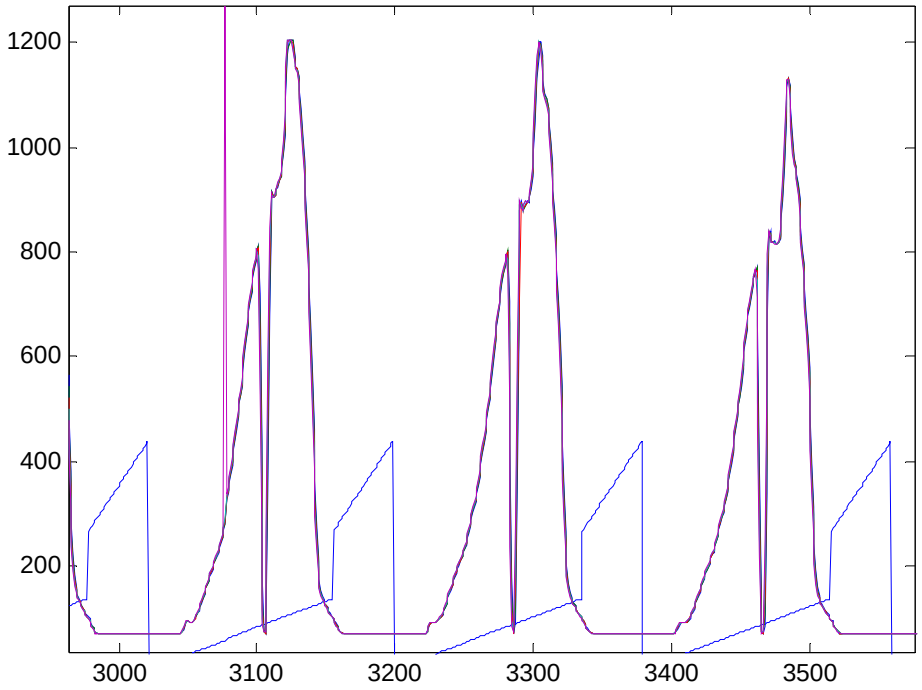



MANTRA 2000

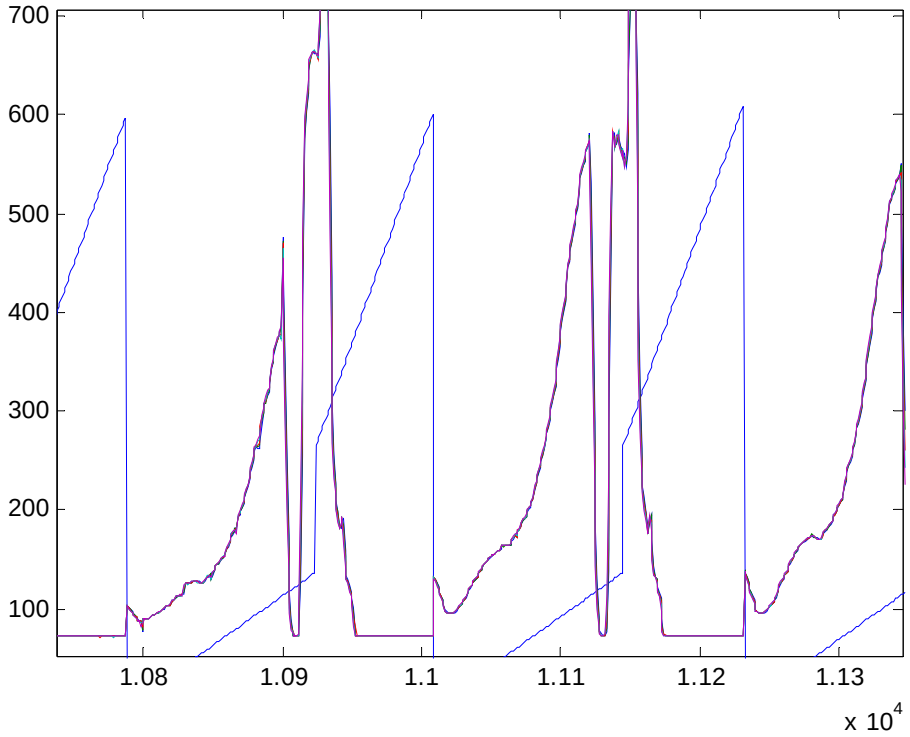



MANTRA 2004

# Encoder values and radiance scans

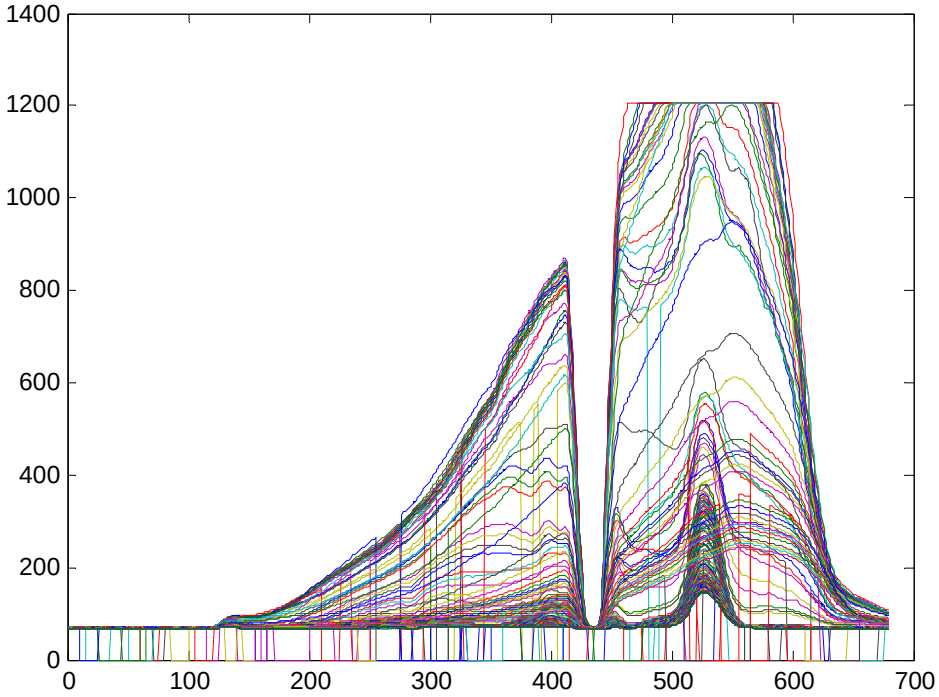



MANTRA 2000

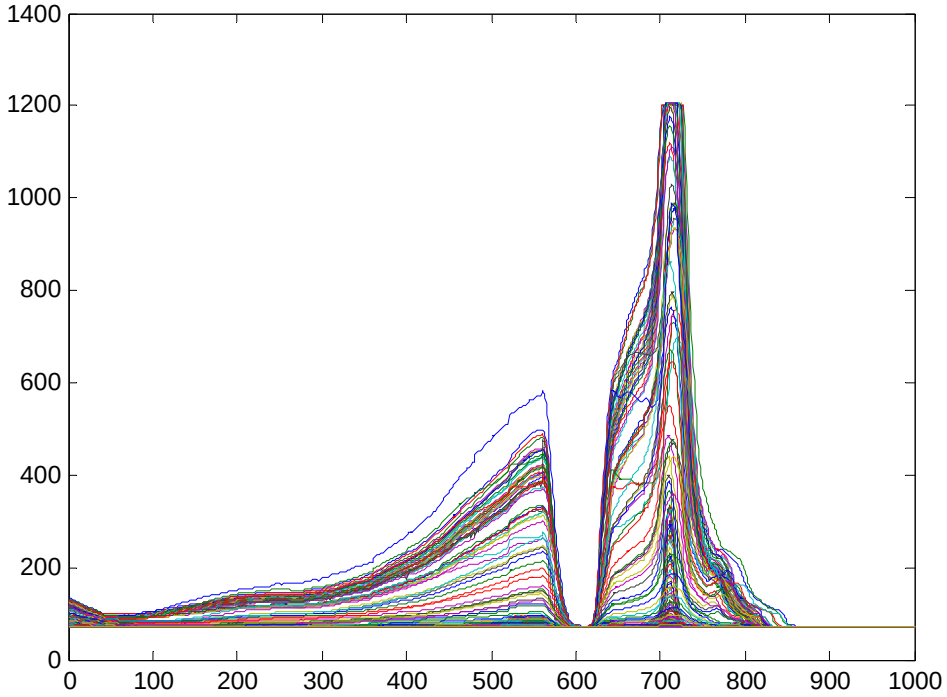



MANTRA 2004

# “cleaned scans”

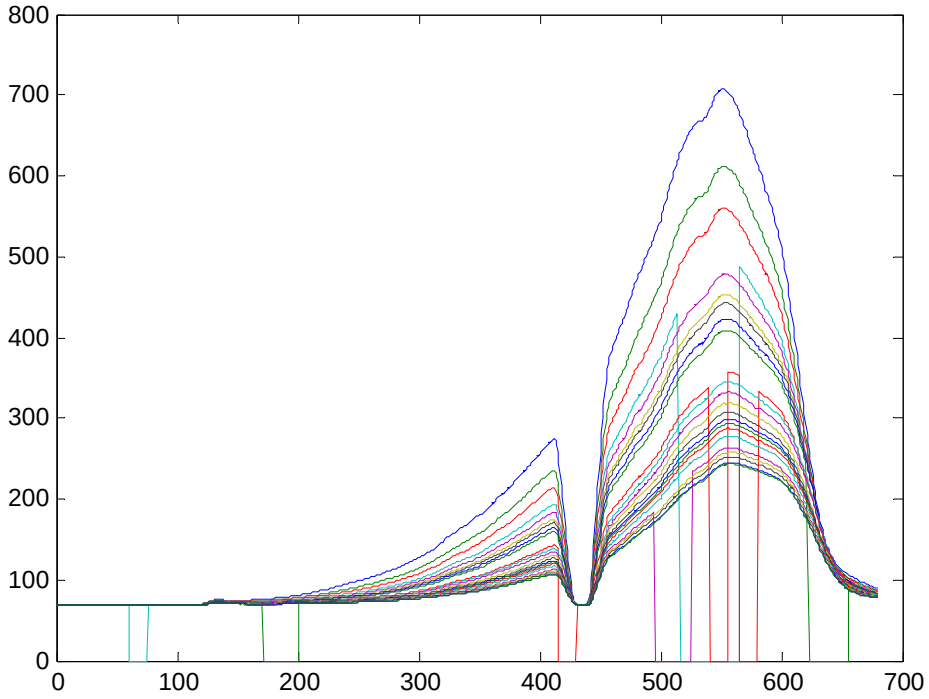



MANTRA 2000

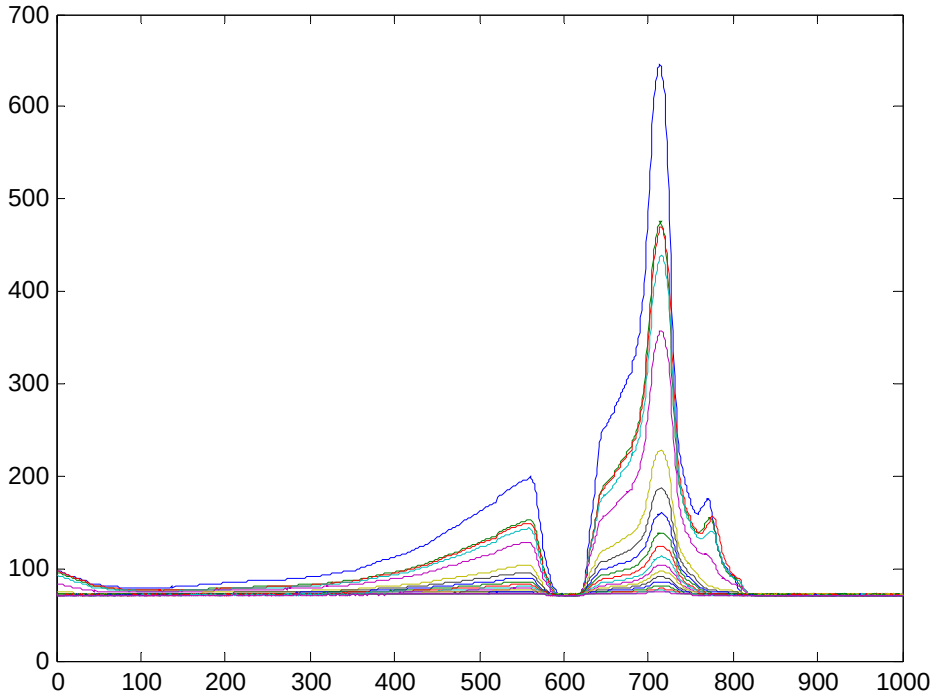



MANTRA 2004

# In-flight black-body scans




MANTRA 2000




MANTRA 2004

# “I only want to fit in”

- Major issues with 2004 analysis:
  - Encoder/wavenumber mapping will be very uncertain
  - Faster filter rotation rate in HNO3 emission feature region leads to even poorer resolution
  - Poor signal to noise due to faster than typical cryogen boil off

# What happened?

- Hypothesis:
  - Radiometers sat in very humid conditions at LN2 temperatures for hours before launch.
  - Ice buildup on encoder wheel resulted in poor wheel rotation and encoder reading
- Experiment
  - If radiometers were better sealed, and filled with LN2 closer to launch time, the observed anomalies should be minimized:
  - Launch 2: success! Sort of…

# Greener pastures?

- 98 reanalysis:
  - Currently improving the analysis code to take another look at 98 data.
  - Implementing systematic frequency scaling
  - Experimenting with a weighted least-means-squares minimization technique, that finds best fit for HNO3 and O3 peak
  - Two-stage retrieval technique can basically reproduce Ben's original results. We can also now produce averaging kernels and other retrieval diagnostics.

# Greener pastures 2

- Gondola azimuth dynamics modelling
  - Model created, could use a critical review (another set of eyes) and comparison with experiment
  - Very initial tests show flight gondola oscillated with a fast natural period of ~13 s
  - Model flight train displays natural fast oscillation with period ~20 s, but simpler earlier models had periods as small 5s
  - Is this worth pursuing as a paper?

THE ROYAL SOCIETY

# The dynamic response of a ballooning yarn: theory and experiment

BY J. D. CLARK[1], W. B. FRASER[1], R. SHARMA[2] AND C. D. RAHN[2]

[1]*School of Mathematics and Statistics, The University of Sydney, NSW 2006, Australia*

[2]*Department of Mechanical Engineering, Clemson University, Clemson, SC 29634-0921, USA*

*Received 18 August 1997; accepted 27 January 1998*

Rotating yarn loops, which are called *yarn balloons* in the textile industry, play an important role in establishing yarn tension in textile yarn-manufacturing processes such as ring spinning and two-for-one twisting. Recent theoretical work has brought the computational simulation of these processes to a high degree of refinement.

In this paper, a simple experimental system, consisting of a loop of yarn rotating about a fixed axis, without twist insertion, is described. This system exhibits a rich variety of bifurcation behaviours as the length of yarn in the loop is varied.

# University of Denver
# Fourier Transform Spectrometer

## MANTRA 2004 ReCap

Pierre Fogal
John Olson
Ron Blatherwick
Frank Murcray

11 November 2004

# Accomplishments

- Went from a stand-still to a flight ready instrument package in approximately 7 weeks
    - This included:
        1. Incorporating a new detector
        2. Assembling and testing flight computer hardware
        3. Building custom Linux kernel with real-time capabilities
        4. Writing kernel module to sample DSP output in a deterministic manner
        5. Writing flight code in 'C'
        6. Testing all the above
        7. Developing ground-station software (big THANKS! to Akira)
        8. All the usual pre-flight instrument preparation issues

- Item #8 usually occupies most if not all of the pre-flight field time

- On arrival at Vanscoy, items 2 and 3 were complete

# Flight #1 Results

- **Flight #1:**
  - Launched after sunrise
  - A lot of condensation reported
  - acquired sun at about 14000 feet (about 4250 m)
  - recorded scans to about 54000 feet (about 16500 m)
  - scan mechanism ceased working
  - at about that time command capability was lost
  - no further data acquired until gondola returned to ground

- After recovery we determined that the scan mechanism itself had not failed, but that the encoder responsible for determining scan length had developed a fault
- We couldn't identify which component or components was directly responsible, so the encoder was replaced with a 555 based circuit and we resumed operation
- Scan mechanism was damaged on landing. We decided not to attempt a field repair as a quick (less than 1 week) re-flight was anticipated.

# Flight #2

- Spent a great deal of time attempting to align instrument in compensation of scan mechanism problems
- That was carried out successfully, and the DU FTS was working nearly as well as for flight #1
- Pre-dawn launch, Sun was never acquired

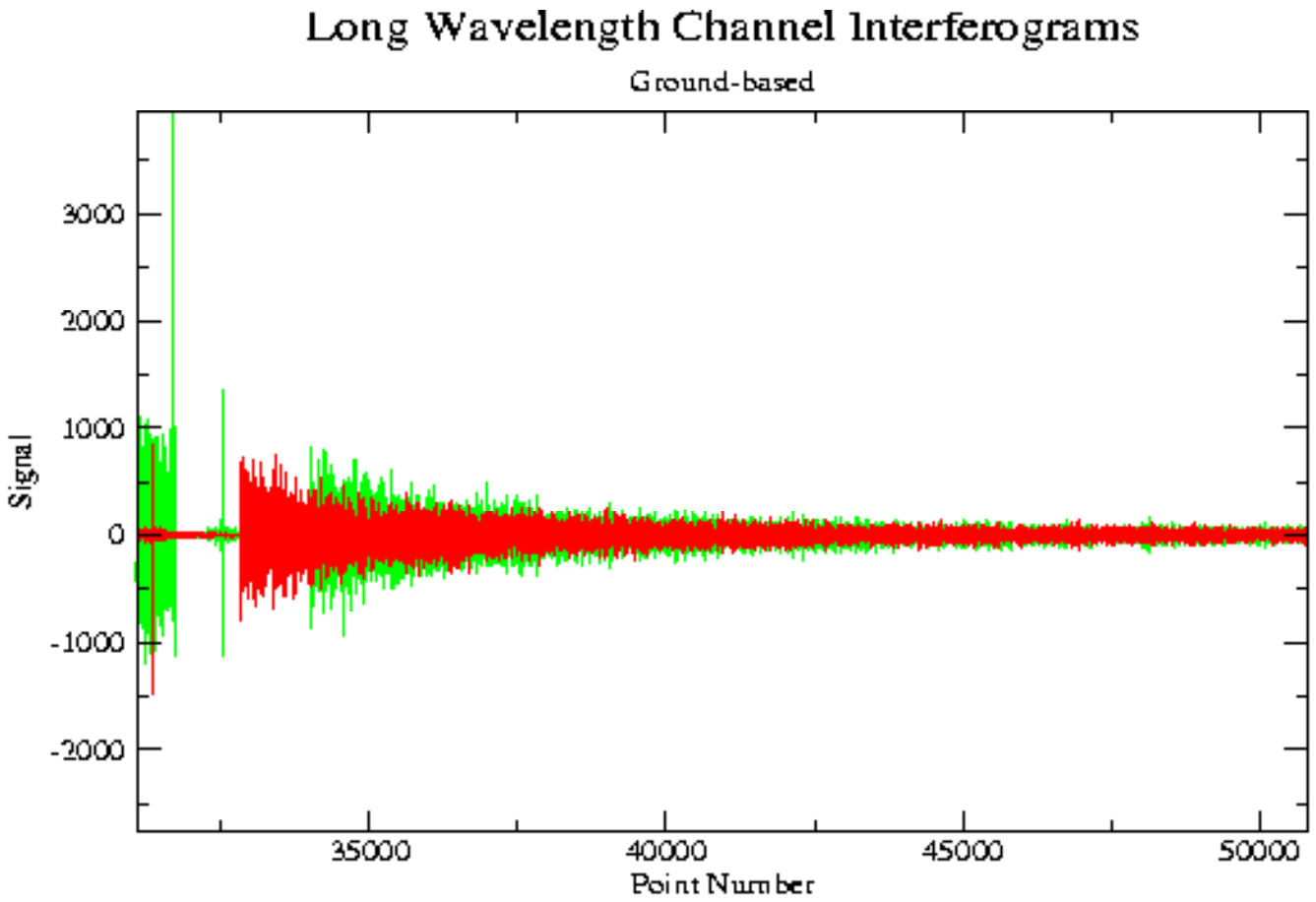
# Acquired Spectra --- Ground-based

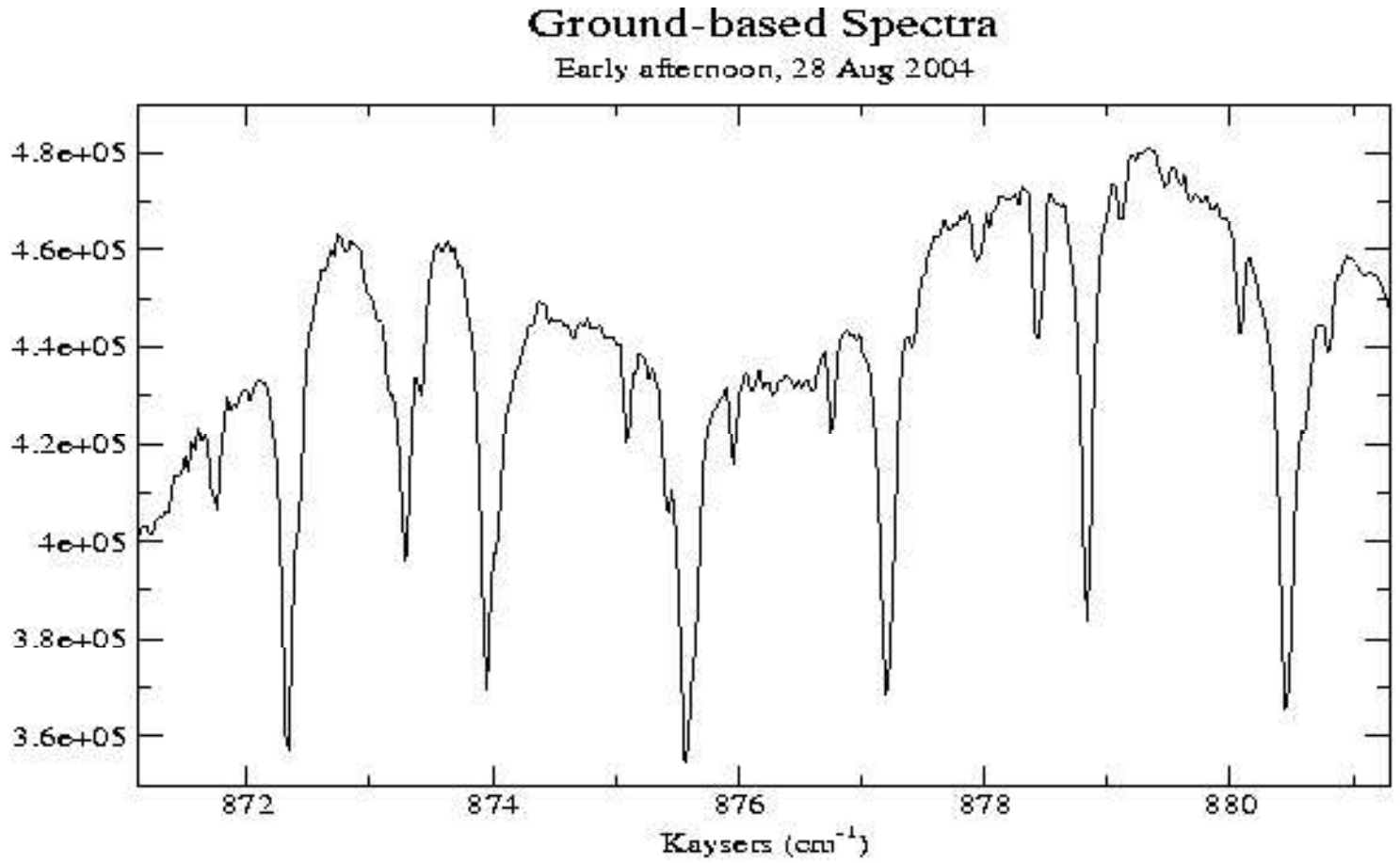
- A number of ground-based spectra were acquired before the flight #1 and between the two flights

- These could yield column amounts for:
    - CFC-11, 12
    - $N_2O$
    - $CH_4$
    - $O_3$
    - $HNO_3$
    - $H_2O$

- Some (very) limited profile information *might* be extracted

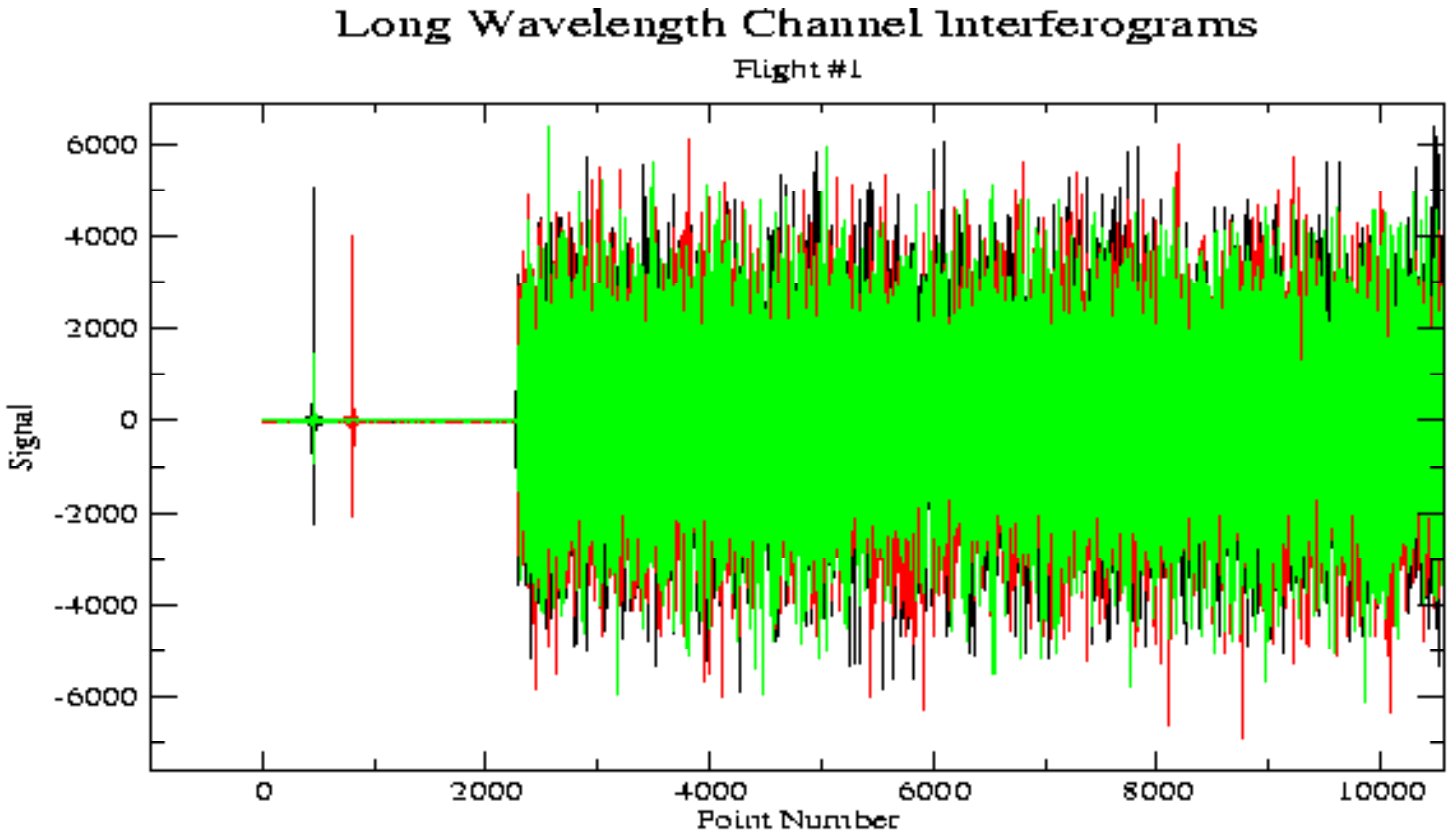
# Ground-based Interferograms

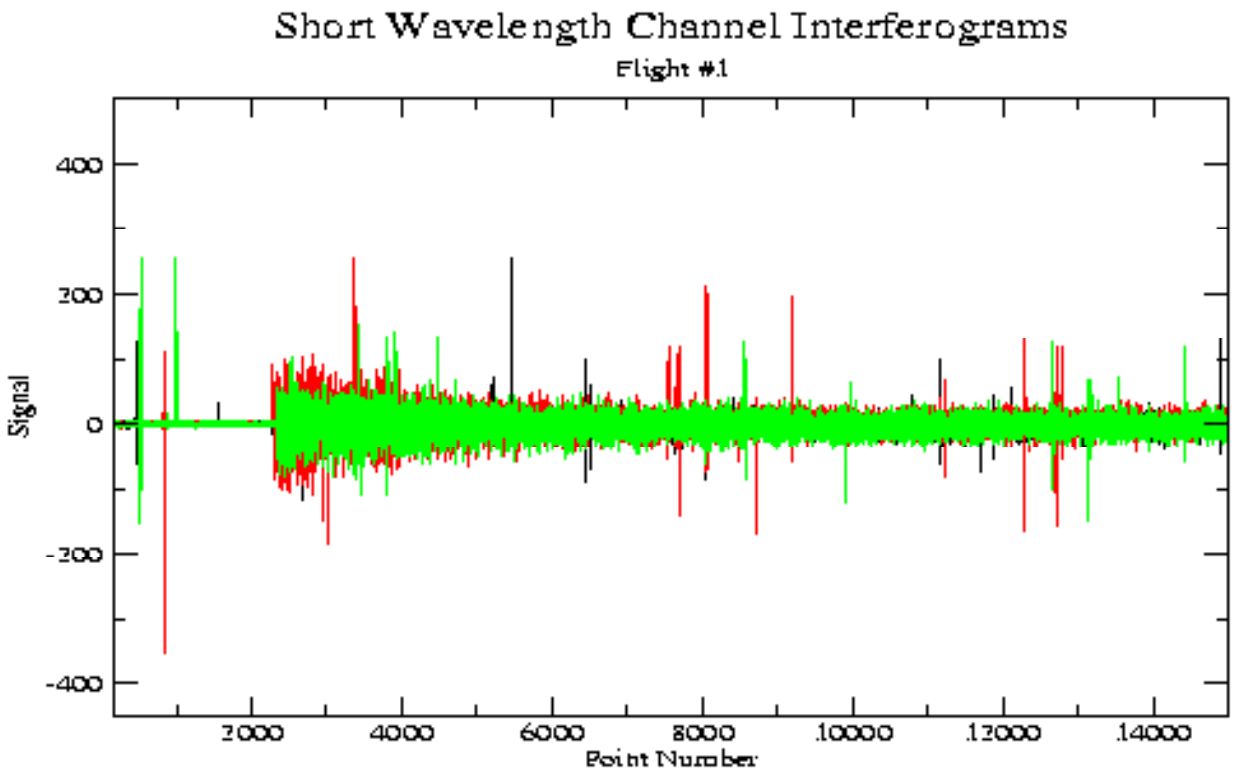



Ground-based Spectra
Early afternoon, 28 Aug 2004
4.8e+05
4.6e+05
4.4e+05
4.2e+05
4e+05
3.8e+05
3.6e+05
872
874
876
878
880
Kaysers (cm-1)

# Acquired Spectra --- Flight #1

- Interferograms do not present as expected
- A large number of noise spikes present, likely from the transponder
- Probably degraded due to presence of a water-ice mixture on external optics




Short Wavelength Channel Interferograms
Flight #1
Signal
400
200
0
-200
-400
2000
4000
6000
8000
10000
12000
14000
Point Number

# Concluding Remarks

- An unfortunate confluence of events prevented the acquisition of a transition
- Ground-based data may still yield some science, in support of ground-based campaign measurements and any subsequent modelling of those measurements
- FTS, new data acquisition system, and new software actually did work rather well

# MSC FTS on MANTRA 2004

MANTRA 2004
6th Quarterly Meeting
November 10th, 2004
Debra Wunch

# Outline

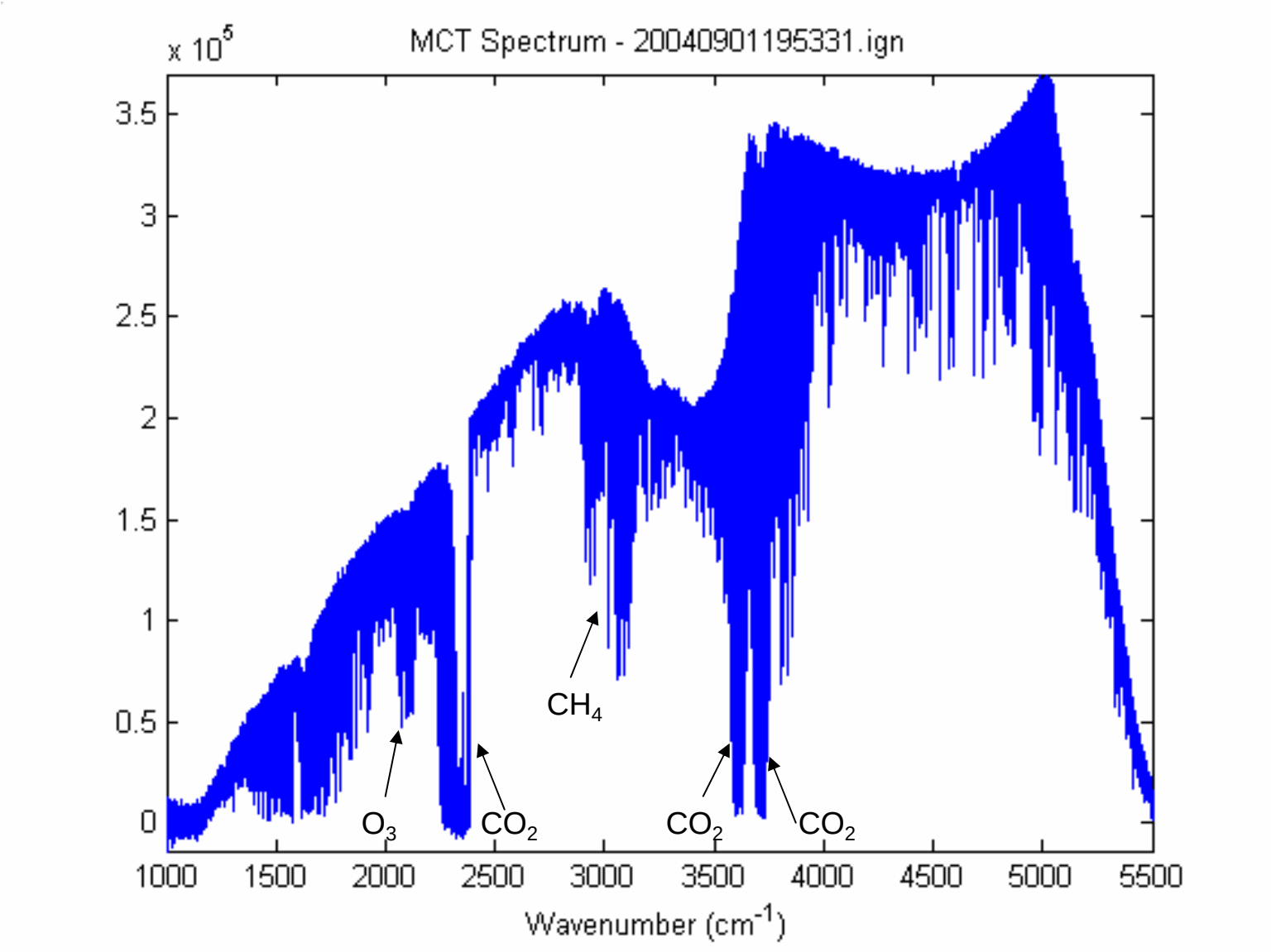
- Data from MANTRA 2004
  - Balloon-based results
  - Ground-based results
- Continuing work
- Future work

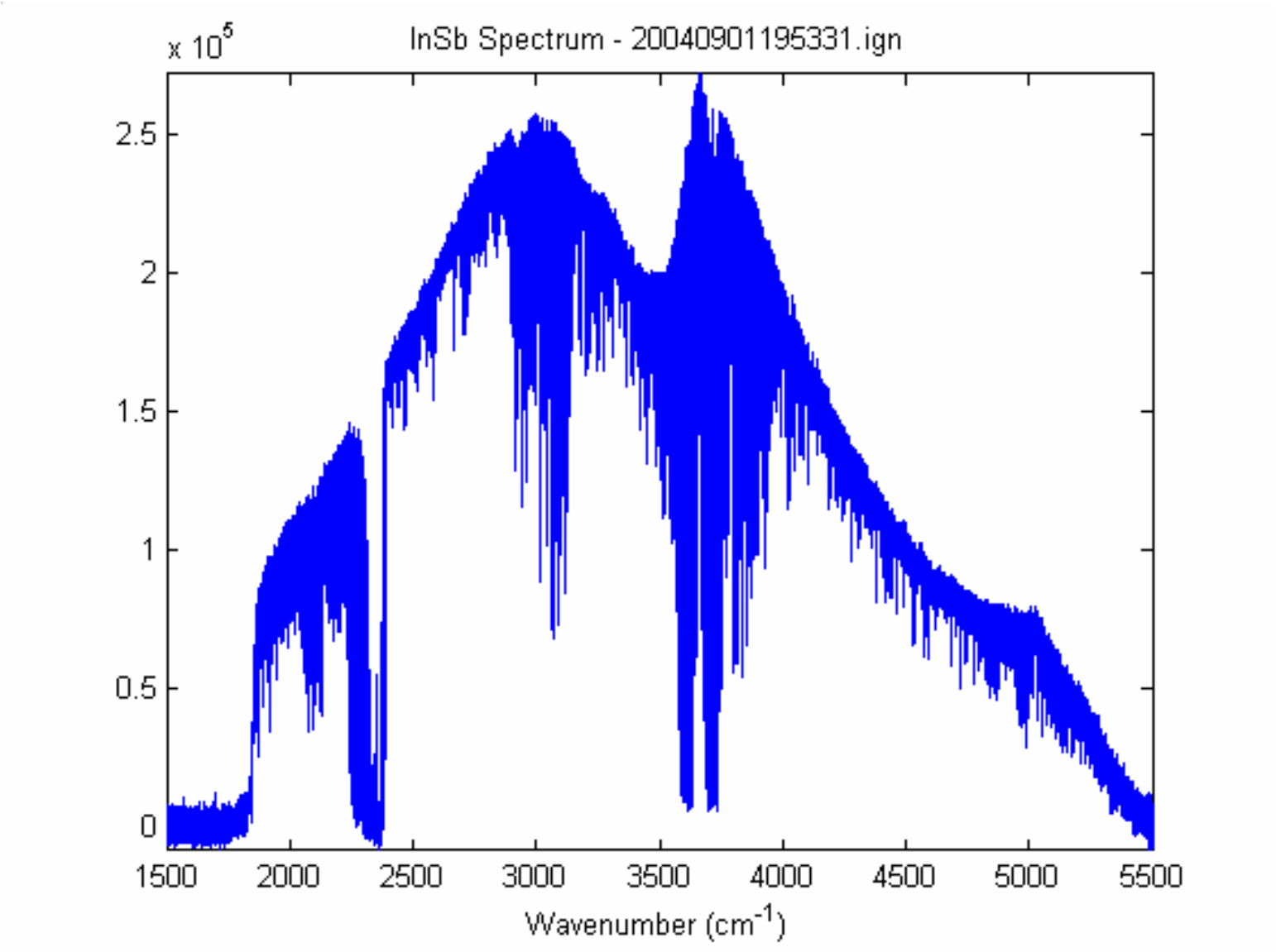
# Data from MANTRA 2004

- Two spectra (on each detector) during sunset on the first MANTRA 2004 flight
  - Acquired during rotation of payload at sunset
- Good quality ground-based data
  - Data acquired during almost every clear-sky opportunity
  - August $10^{th}$-$12^{th}$, $19^{th}$, $24^{th}$, $27^{th}$, $28^{th}$, September $3^{rd}$, $7^{th}$, $14^{th}$.

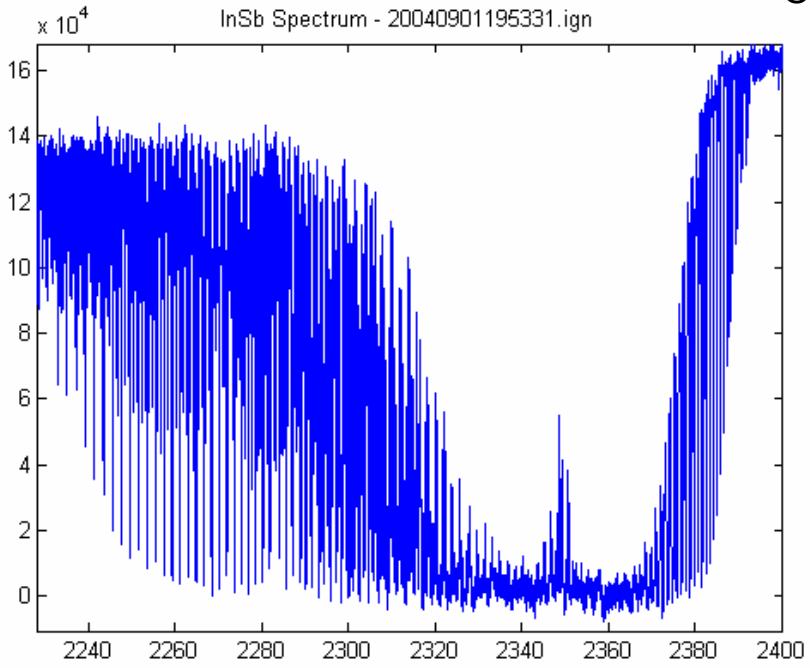
# Balloon-based Results

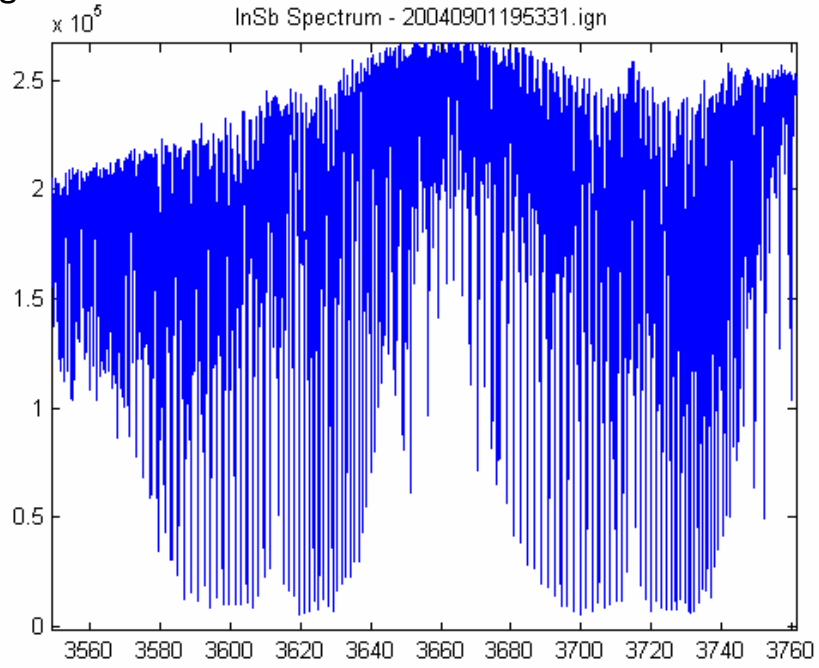
- Signal-to-noise ratio ~100-130:1
  - maximum signal over rms noise in a region outside the spectral range
    - there are no completely saturated bands
  - lower SNR attributed to rotation of payload – tracker at ends of its field of view
- Can resolve $CO_2$, $O_3$, $CH_4$, $N_2O$
- No vertical profile retrievals possible

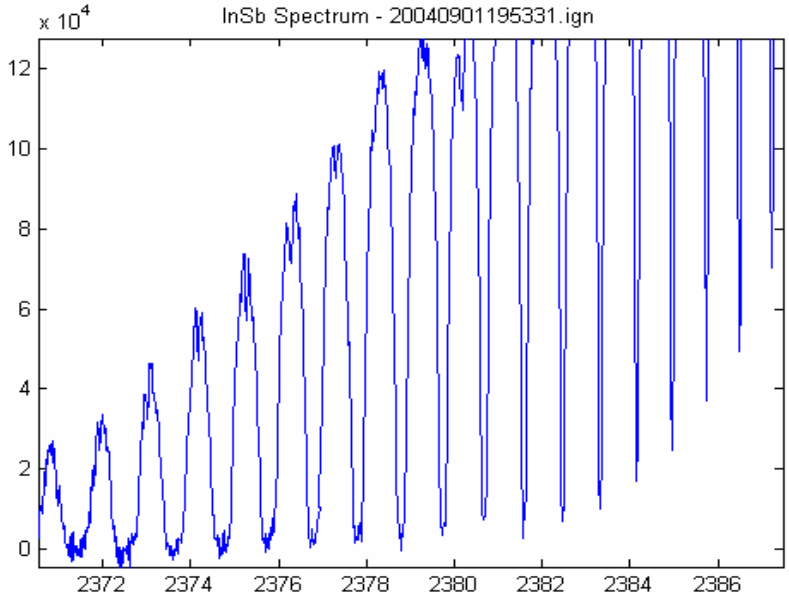

MCT Spectrum - 20040901195331.ign
x 10^5
3.5
3
2.5
2
1.5
1
0.5
0
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Wavenumber (cm^-1)
O3
CO2
CH4
CO2
CO2

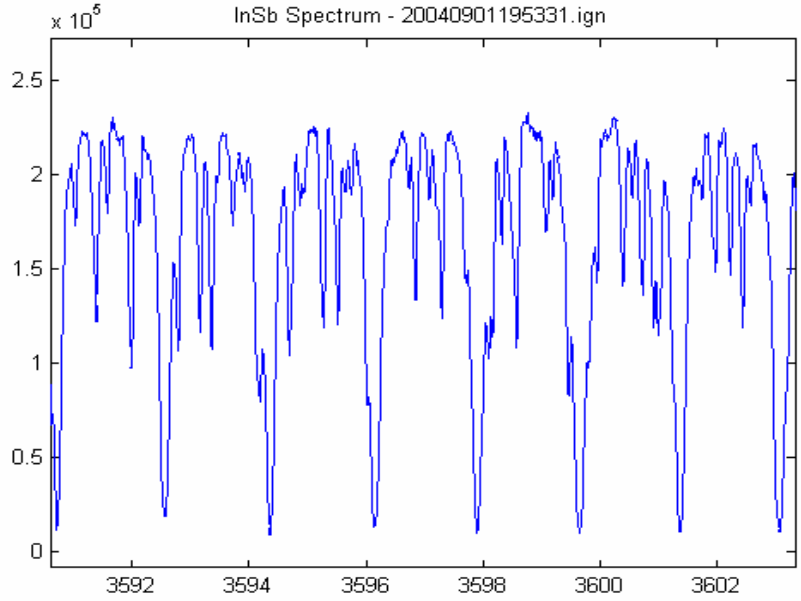

InSb Spectrum - 20040901195331.ign
x 10^5
2.5
2
1.5
1
0.5
0
1500
2000
2500
3000
3500
4000
4500
5000
5500
Wavenumber (cm^-1)

# $CO_2$ Bands

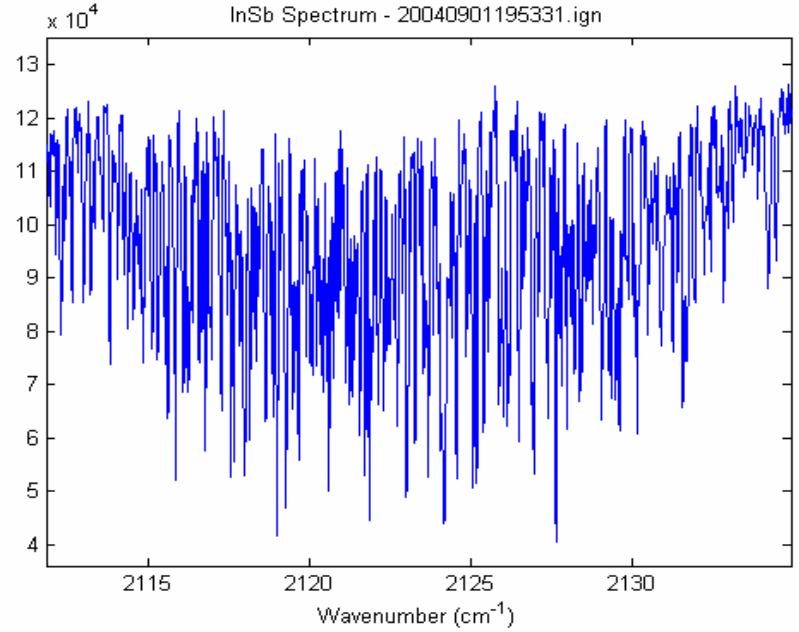

x 10^4
InSb Spectrum - 20040901195331.ign
16
14
12
10
8
6
4
2
0
2240
2260
2280
2300
2320
2340
2360
2380
2400


x 10^5
InSb Spectrum - 20040901195331.ign
2.5
2
1.5
1
0.5
0
3560
3580
3600
3620
3640
3660
3680
3700
3720
3740
3760

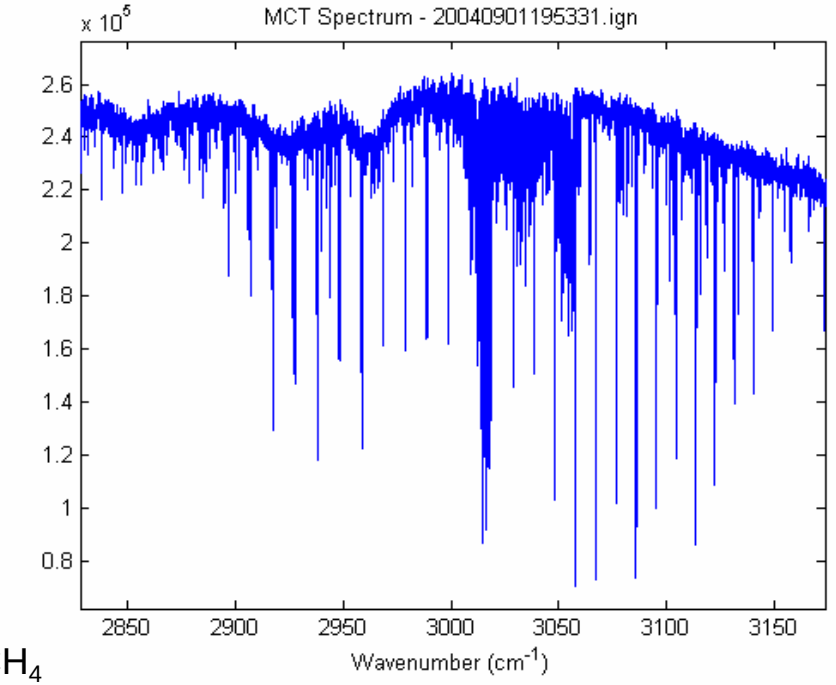

x 10^4
InSb Spectrum - 20040901195331.ign
12
10
8
6
4
2
0
2372
2374
2376
2378
2380
2382
2384
2386

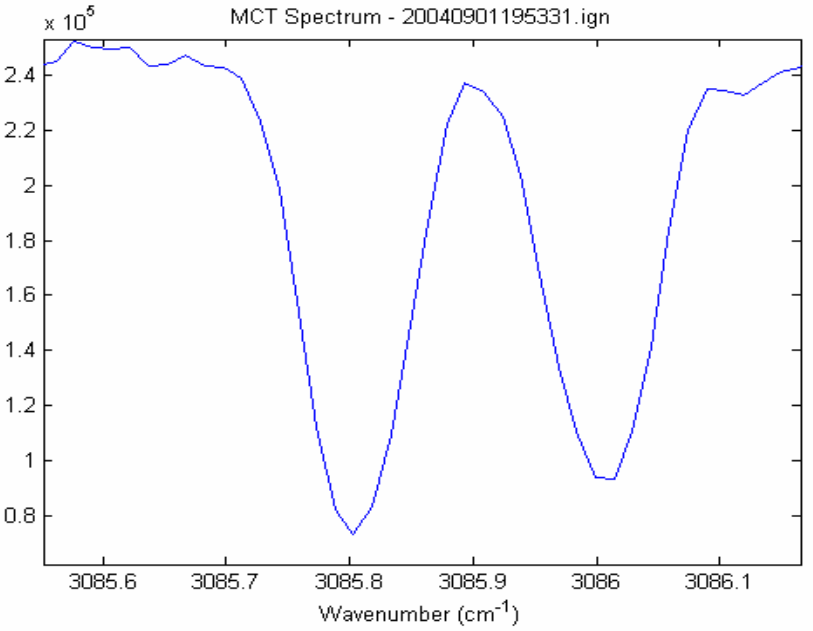

x 10^5
InSb Spectrum - 20040901195331.ign
2.5
2
1.5
1
0.5
0
3592
3594
3596
3598
3600
3602

$O_3$


x 10^4
InSb Spectrum - 20040901195331.ign
13
12
11
10
9
8
7
6
5
4
2115
2120
2125
2130
Wavenumber (cm^-1)

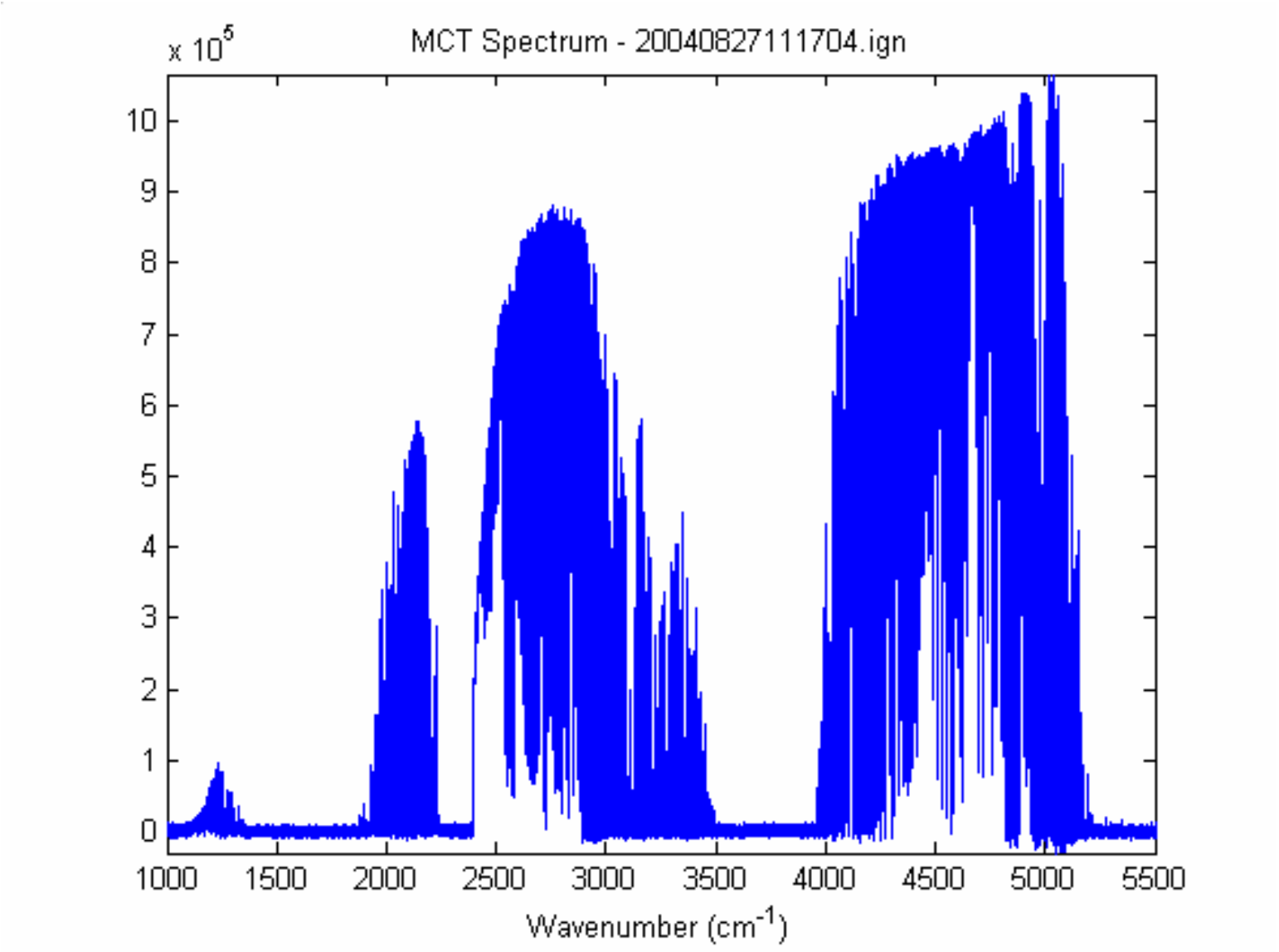
$CH_4$

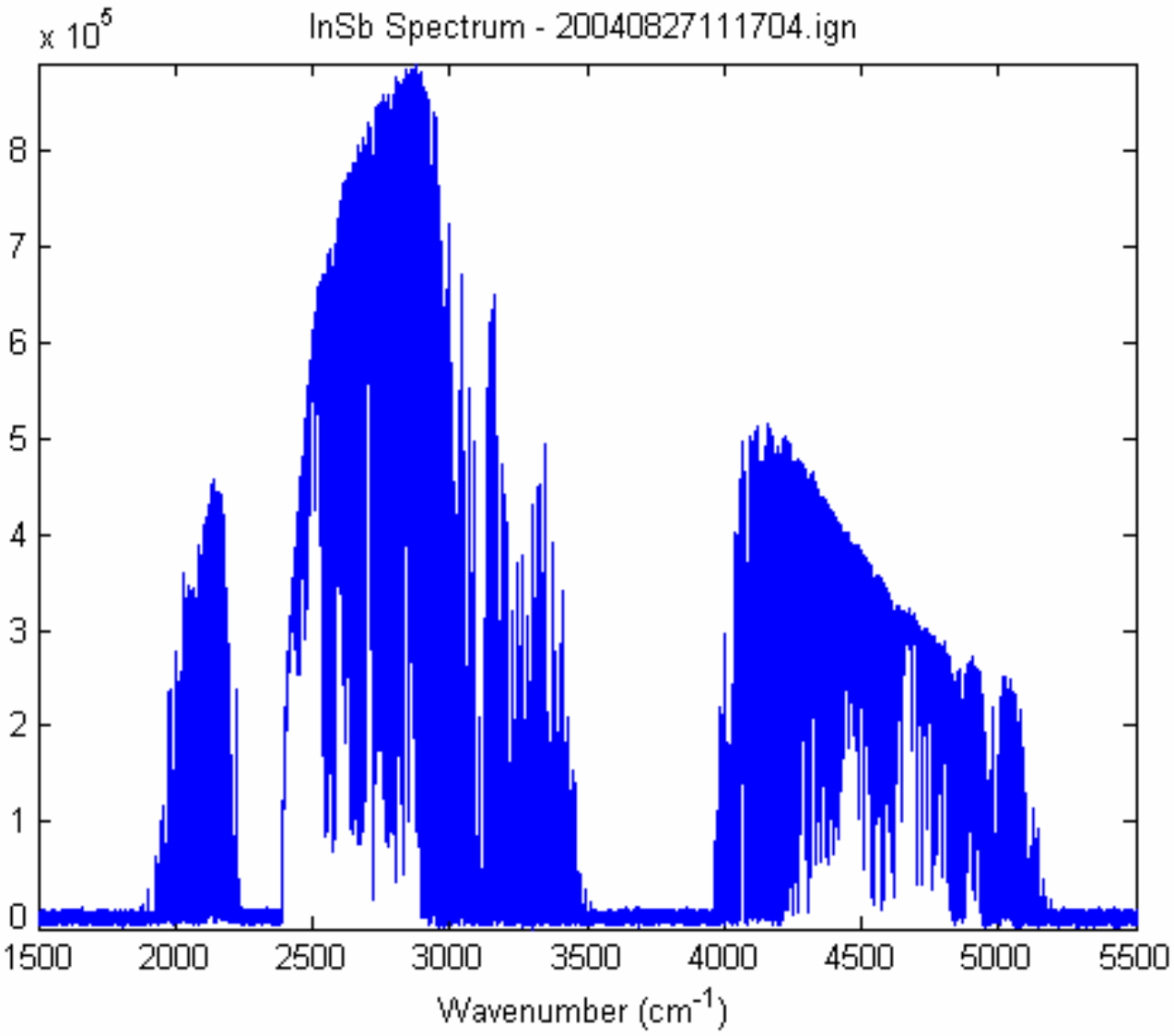

x 10^5
MCT Spectrum - 20040901195331.ign
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
2850
2900
2950
3000
3050
3100
3150
Wavenumber (cm^-1)

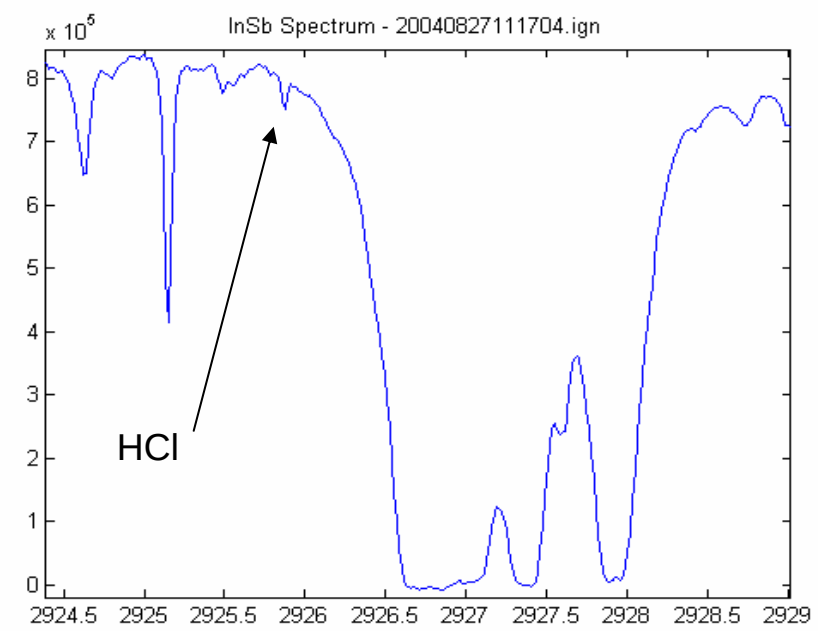

x 10^5
MCT Spectrum - 20040901195331.ign
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
3085.6
3085.7
3085.8
3085.9
3086
3086.1
Wavenumber (cm^-1)

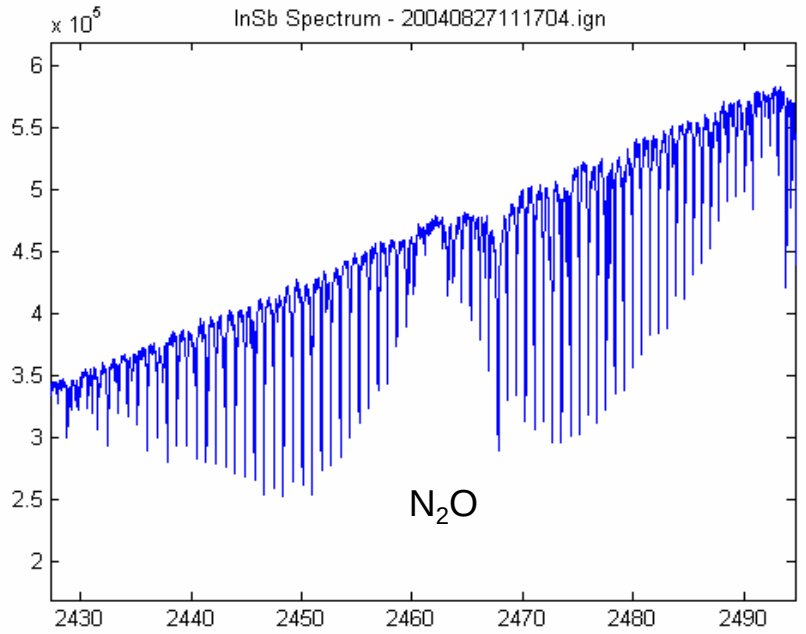
# Ground-Based Results

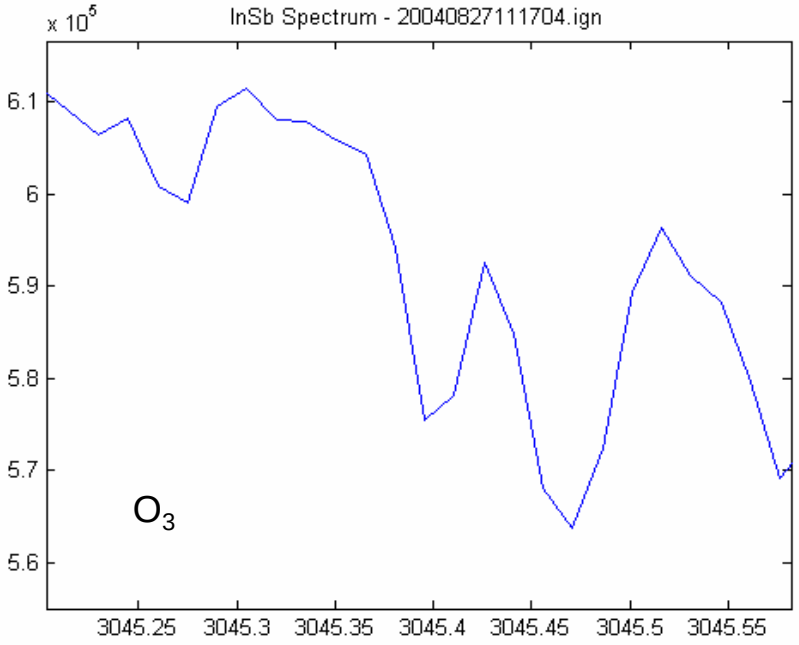
- Signal-to-noise ratio of ~350-390:1
  - maximum signal over rms noise in a saturated band
- Can see features from HCl, $O_3$, $N_2O$, $CH_4$, $H_2O$, $N_2$, CO, HDO, OCS
- Retrievals begun using SFIT2 on HCl, $O_3$ and $N_2O$
  - Will be able to retrieve column amounts for HCl and $O_3$
  - Possibly two independent vertical pieces of information for $N_2O$

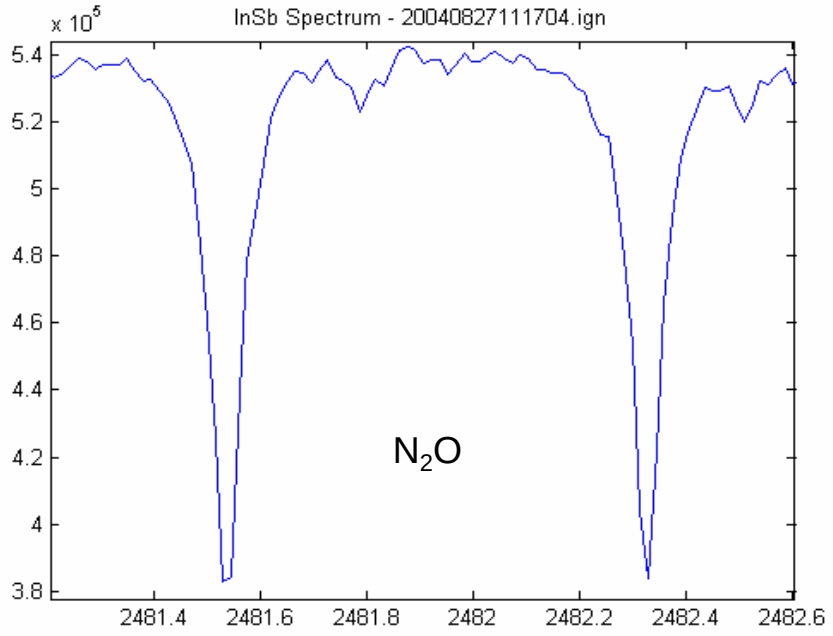

MCT Spectrum - 20040827111704.ign
x 10^5
10
9
8
7
6
5
4
3
2
1
0
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Wavenumber (cm^-1)


x 10^5
InSb Spectrum - 20040827111704.ign
8
7
6
5
4
3
2
1
0
1500
2000
2500
3000
3500
4000
4500
5000
5500
Wavenumber (cm^-1)


x 10^5
InSb Spectrum - 20040827111704.ign
HCl


x 10^5
InSb Spectrum - 20040827111704.ign
N2O

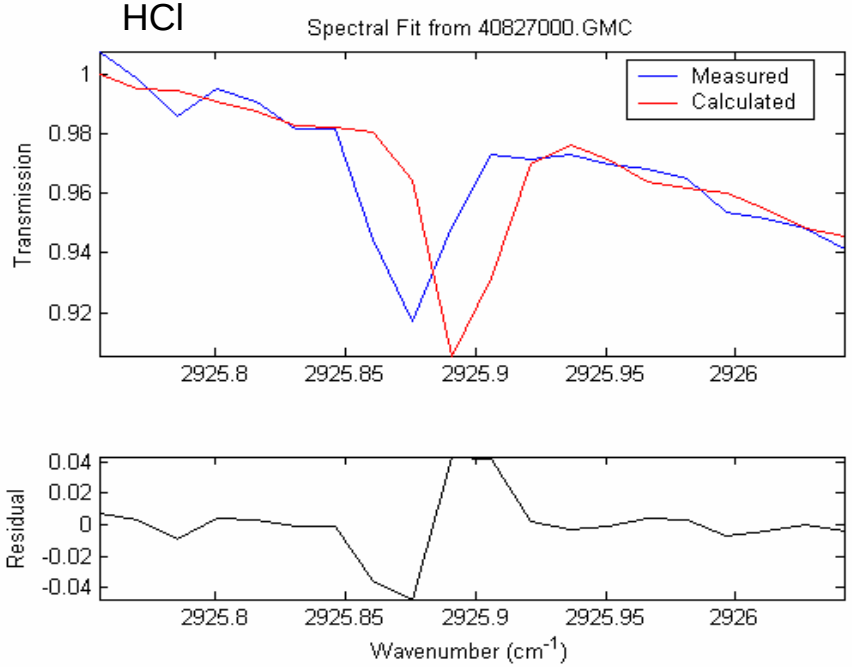

x 10^5
InSb Spectrum - 20040827111704.ign
O3


x 10^5
InSb Spectrum - 20040827111704.ign
N2O

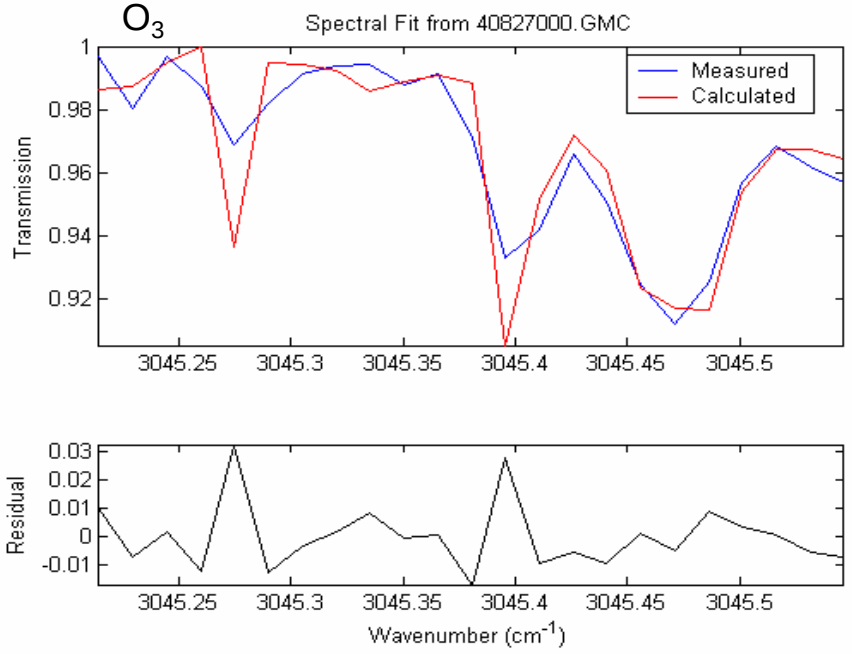
# Continuing Work

- Optimising micro-window selection for ground-based and balloon-based data
- Continued improvement of ground-based retrievals with SFIT2

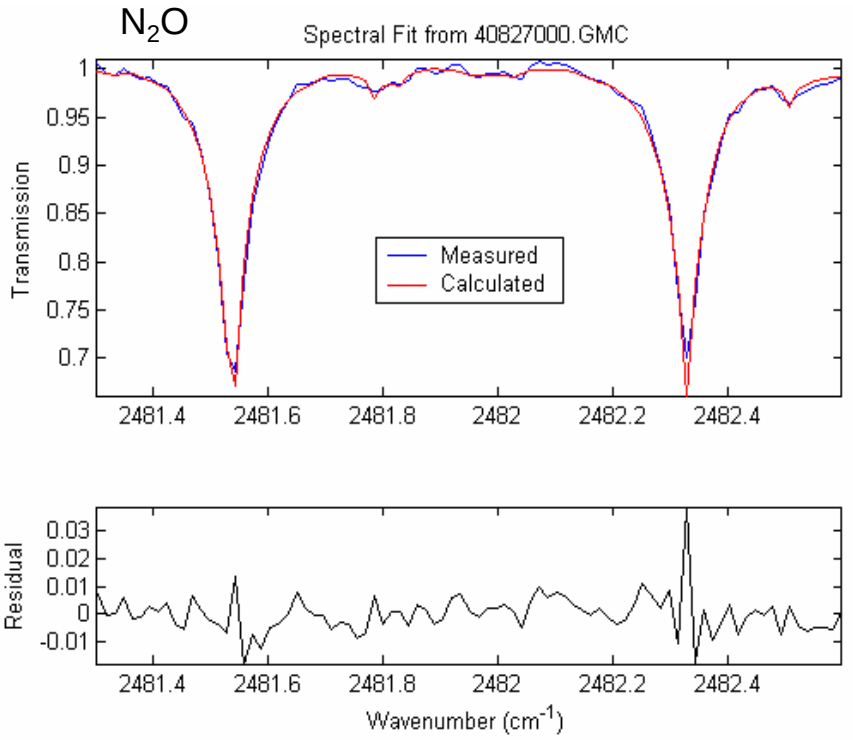
HCl


Spectral Fit from 40827000.GMC
Measured
Calculated
Transmission
1
0.98
0.96
0.94
0.92
2925.8
2925.85
2925.9
2925.95
2926
Residual
0.04
0.02
0
-0.02
-0.04
Wavenumber (cm-1)

$O_3$


Spectral Fit from 40827000.GMC
Measured
Calculated
Transmission
1
0.98
0.96
0.94
0.92
3045.25
3045.3
3045.35
3045.4
3045.45
3045.5
Residual
0.03
0.02
0.01
0
-0.01
Wavenumber (cm-1)

$N_2O$


Spectral Fit from 40827000.GMC
Measured
Calculated
Transmission
1
0.95
0.9
0.85
0.8
0.75
0.7
2481.4
2481.6
2481.8
2482
2482.2
2482.4
Residual
0.03
0.02
0.01
0
-0.01
Wavenumber (cm-1)

# Future Work

- Slant columns for balloon-based data
- Developing method for balloon-based retrievals
- Update MSC FTS to measure $ClONO_2$, fundamental $HNO_3$?
  - Need to know well before next MANTRA campaign
- Mini-MANTRA 2005
  - To be held in January in Toronto
  - Comparison between Toronto Atmospheric Observatory DA8 (TAO), PARIS and MSC FTS


# MANTRA 2004
# 6th Quarterly Meeting
# - PARIS -
# Post-Flight Report

Kaley Walker

University of Waterloo

November 10, 2004

“… autumn’s here – it makes you sad
about the crummy summer we had…”

Hawksley Workman, 2003

# PARIS Flight Issues

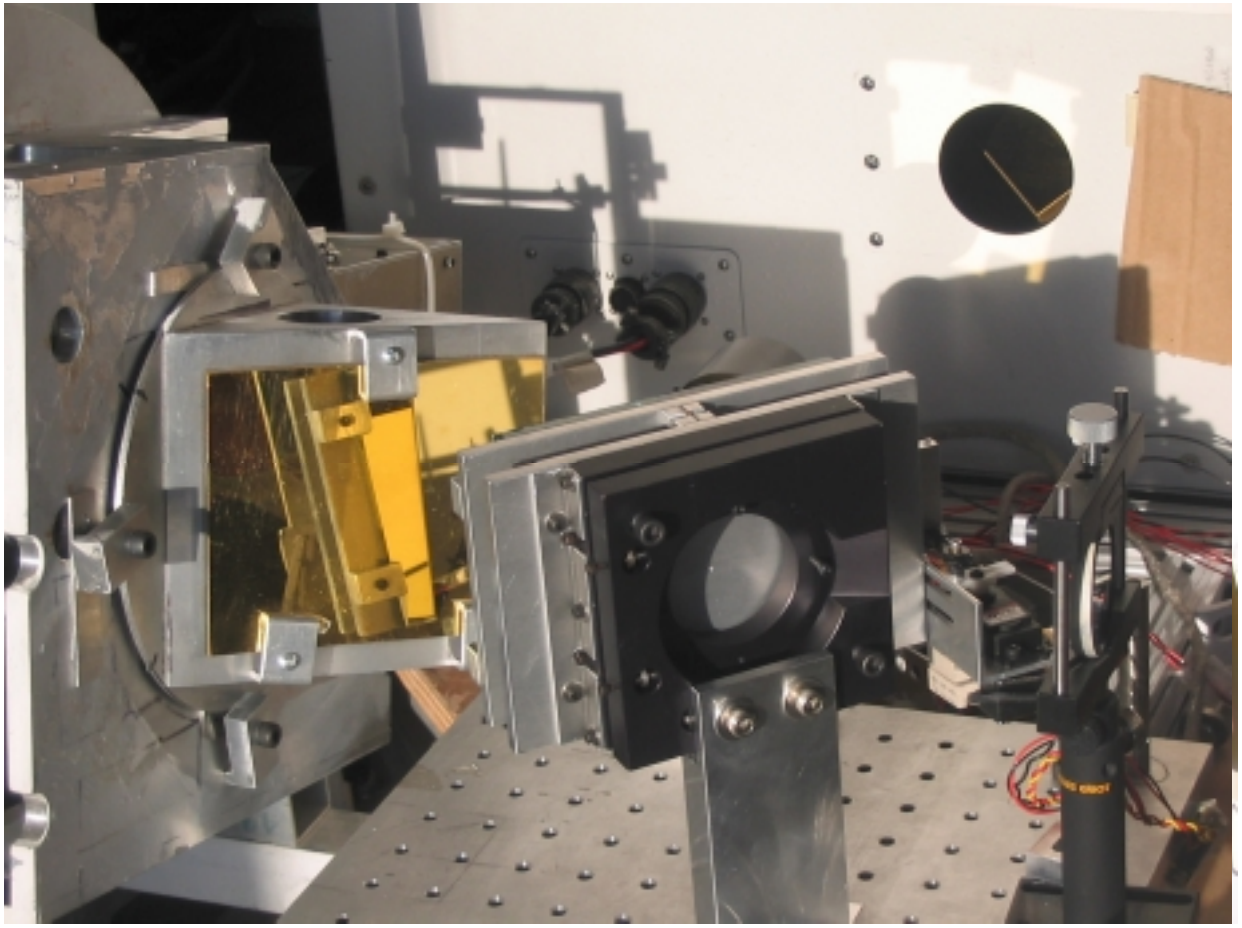
- Suntracker
  - Bomem suntracker was not able to fly because it caused perturbations in MSC-FTS and DU FTS measurements
  - Had to use plan C – beam from pointing system
- PARIS commanding
  - Did not get any usable data from flight 1 because of commanding problem
- Shared data downlink
  - Shared link relies on having uplink available to initiate transfer – system not entirely autonomous

# Suntracker Plan C

Using a mirror on the pointing system to feed PARIS:

- "Very good" pointing needed
  - PARIS FOV is 3.32 mrad (1/3 of Sun diameter) so need tracker with better than 0.15° pointing accuracy
  - Pointing system was estimated to be good to 0.5°
  - Azimuth tracker (AzTraX) built by Clive and Ann-Flore to provide better pointing in azimuth
- Alignment procedure had to be developed
  - More complex because need pointing system (and Sun)

# AxTraX Sunrise Alignment on Aug. 27



# Suntracker Alignment

- Very frustrating process to align PARIS and AzTraX
  - Laser alignment relied on knowing pointing direction of pointing system sun sensors – reference mirror
  - Test with Sun and pointing system – hanging or using leveling frame to adjust azimuth
  - Clouds proved to be large problem for sufficiently good pointing by pointing system

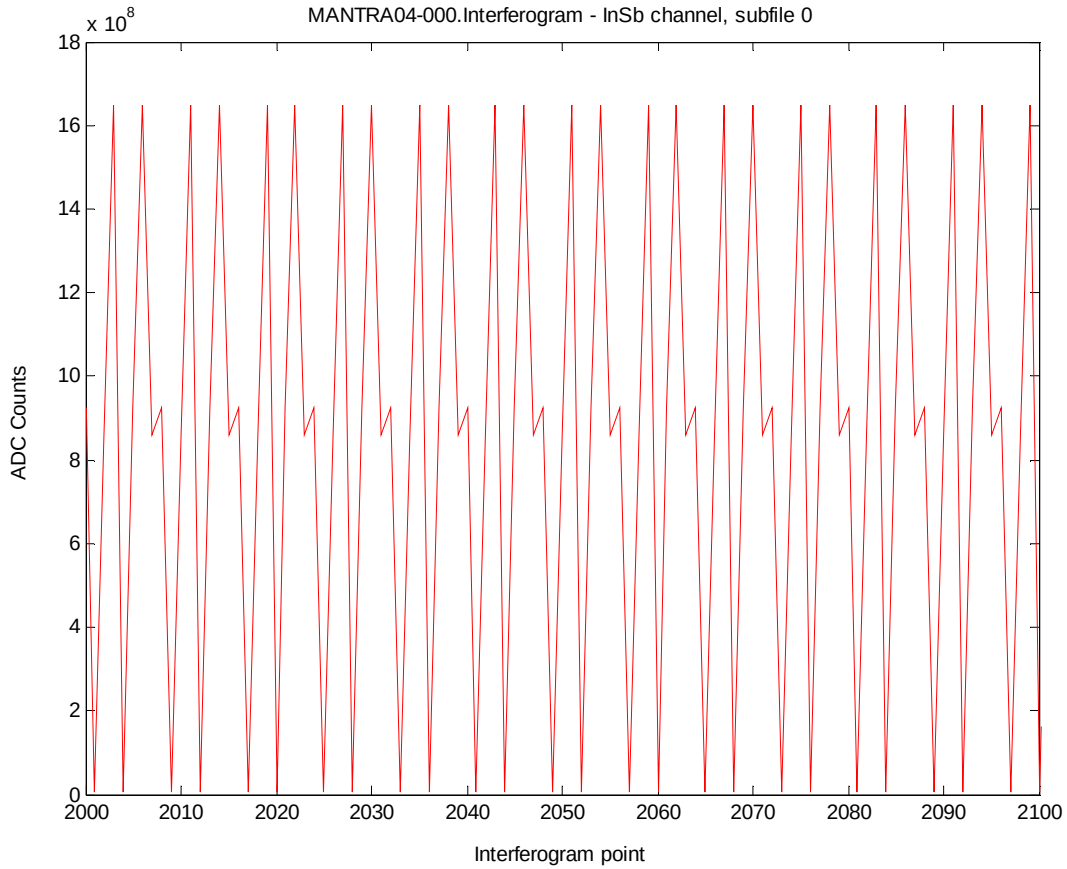
# PARIS Solar Alignment for Flights

- First flight – very poor alignment
  - Adjusted mirror on Aug 28 – then there was not enough Sun before launch to verify alignment (tried on Aug 31)
- Second flight – much improved alignment
  - Laser alignment was redone and tweaked at sunrise
  - Verified throughout day (40° -10° solar elevation)
  - Unfortunately didn’t get a chance to use it…

# Commanding Problem

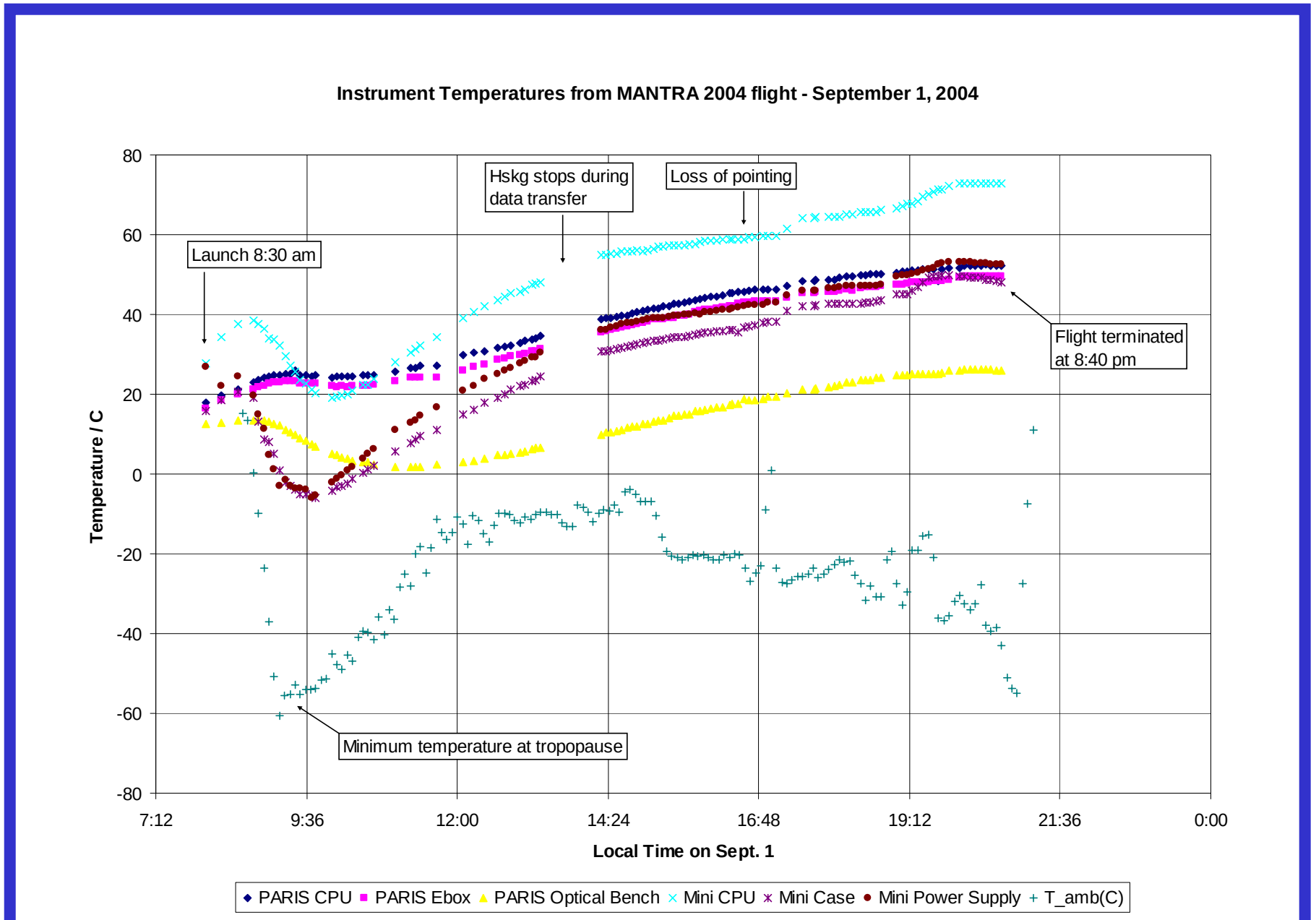
- Bomem “Undocumented Feature” identified during flight 1
  - Have to set MPD after turning on interferometer!
  - Cannot consolidate all of the commands in one part of the batch file and then turn interferometer on / off
- Batch file was not adequately tested before hand
  - Tested commands were sent but did not take any spectra because there was not enough clear sky
- Could not fix in flight because of loss of commanding…

# IGM without MPD set at right time…



# What data did PARIS get?

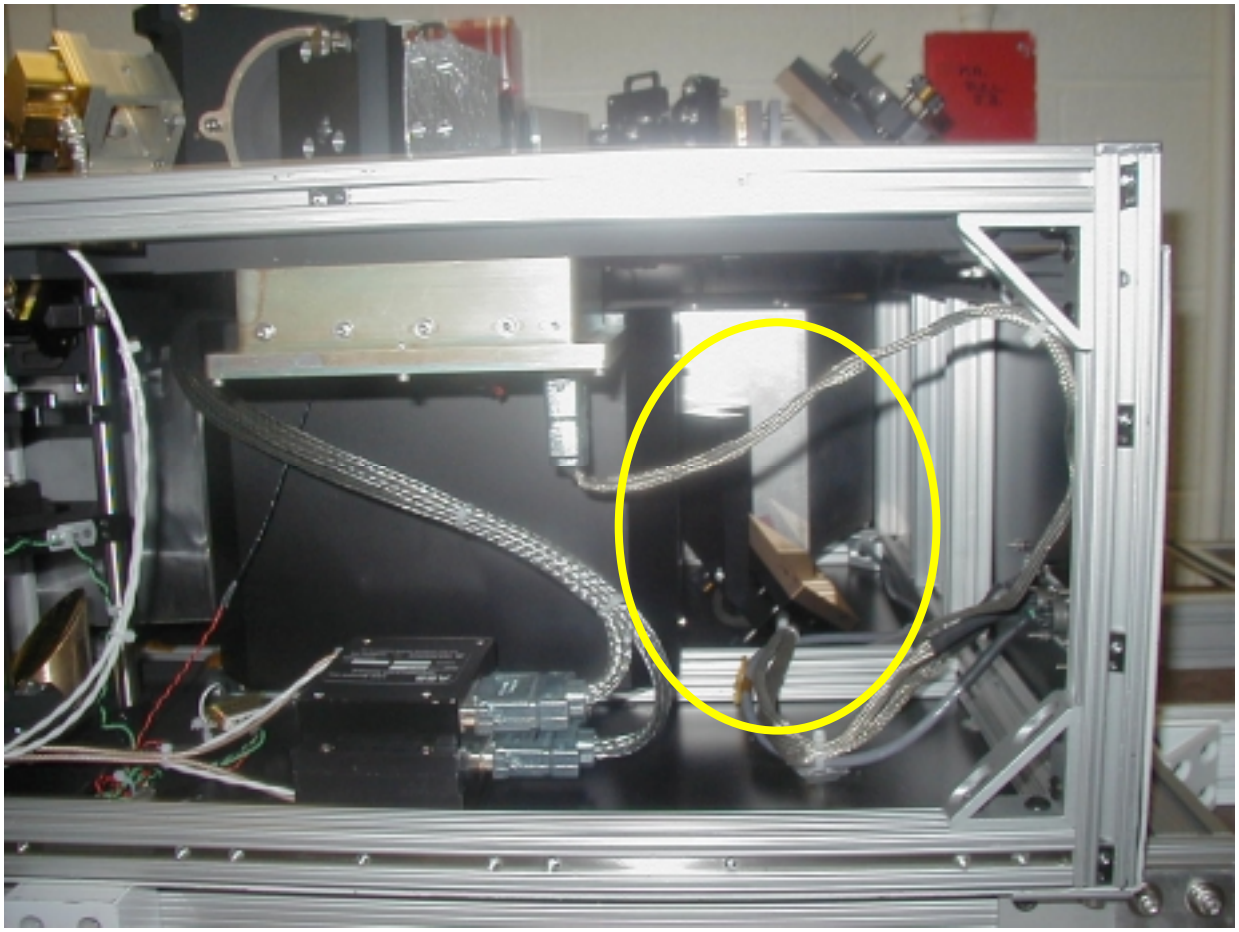
- One day of suntracker tests with the Bomem tracker
  - August 13 (only day that PARIS was off the gondola)
- Perhaps some interferograms taken during the AzTraX testing in September?
  - Lots of noise bursts because the gondola was on the leveling frame and had to be moved to track in azimuth
  - Will be difficult to analyse
- Engineering data on thermal performance
  - PARIS survived being on for 12 hours !
  - On-board computer needs better heat sinks


Instrument Temperatures from MANTRA 2004 flight - September 1, 2004
Launch 8:30 am
Hskg stops during data transfer
Loss of pointing
Flight terminated at 8:40 pm
Minimum temperature at tropopause
Temperature / C
80
60
40
20
0
-20
-40
-60
-80
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Local Time on Sept. 1
PARIS CPU
PARIS Ebox
PARIS Optical Bench
Mini CPU
Mini Case
Mini Power Supply
T_amb(C)

# What needs to be fixed?

- ***"STAND ALONE" SUNTRACKER !***
  - Not reliant on pointing system
  - Instrument can be taken on and off the gondola to make solar measurements whenever weather permits
- More robust data downlink – to be automated
- Minor command and control software updates
- Yet another Bomem visit is planned
  - Solve vibration sensitivity of PARIS
  - Realign instrument and train UW team in how to do alignment in the field

# Why PARIS needs realignment…



Periscope mirror should not be resting on the floor of instrument…

# The OH spectrometer data from the Mantra 2004 flight

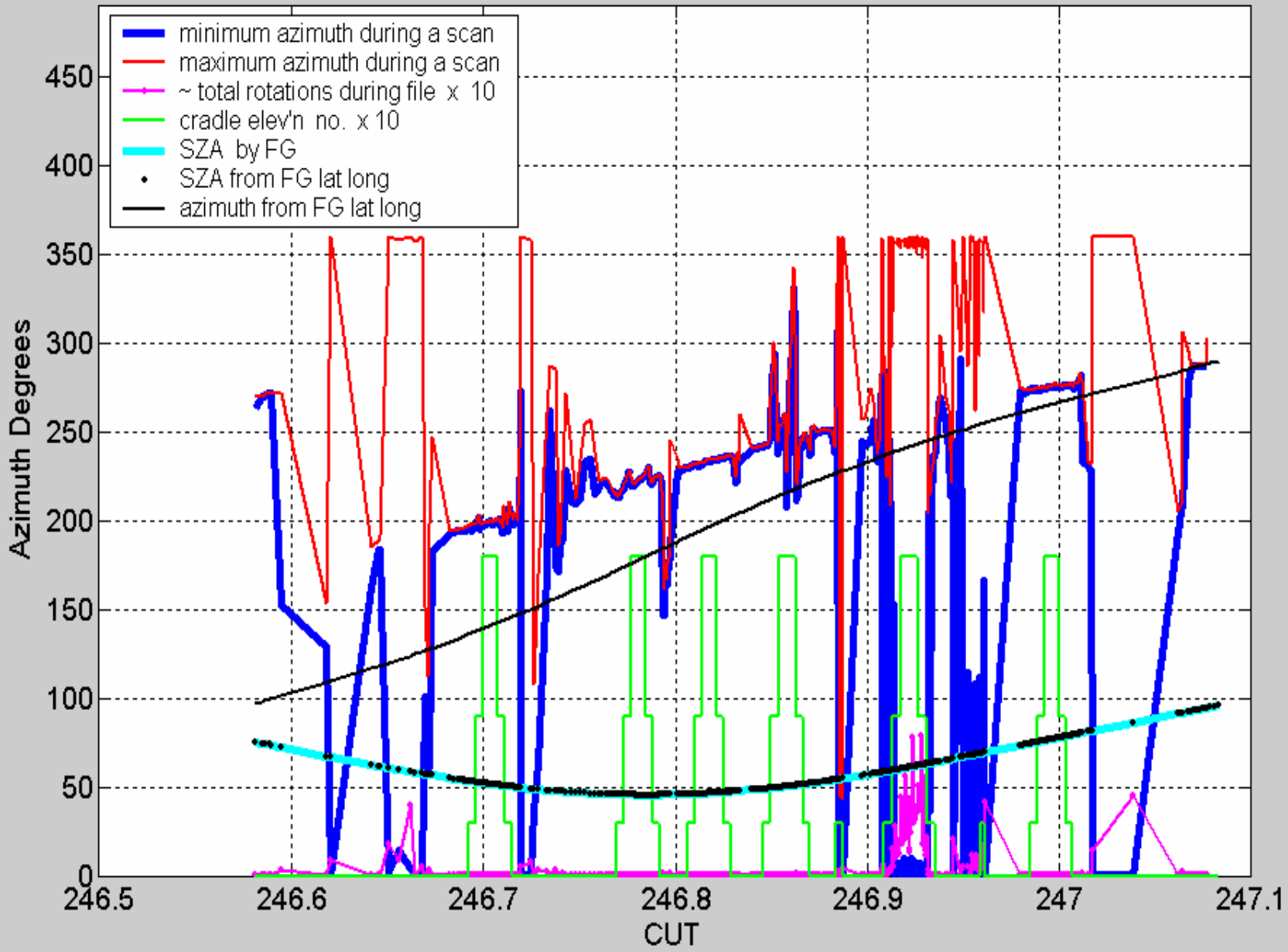
Spectrometer measures in the range 294-320 nm with ~0.08 nm fwhi resolution.

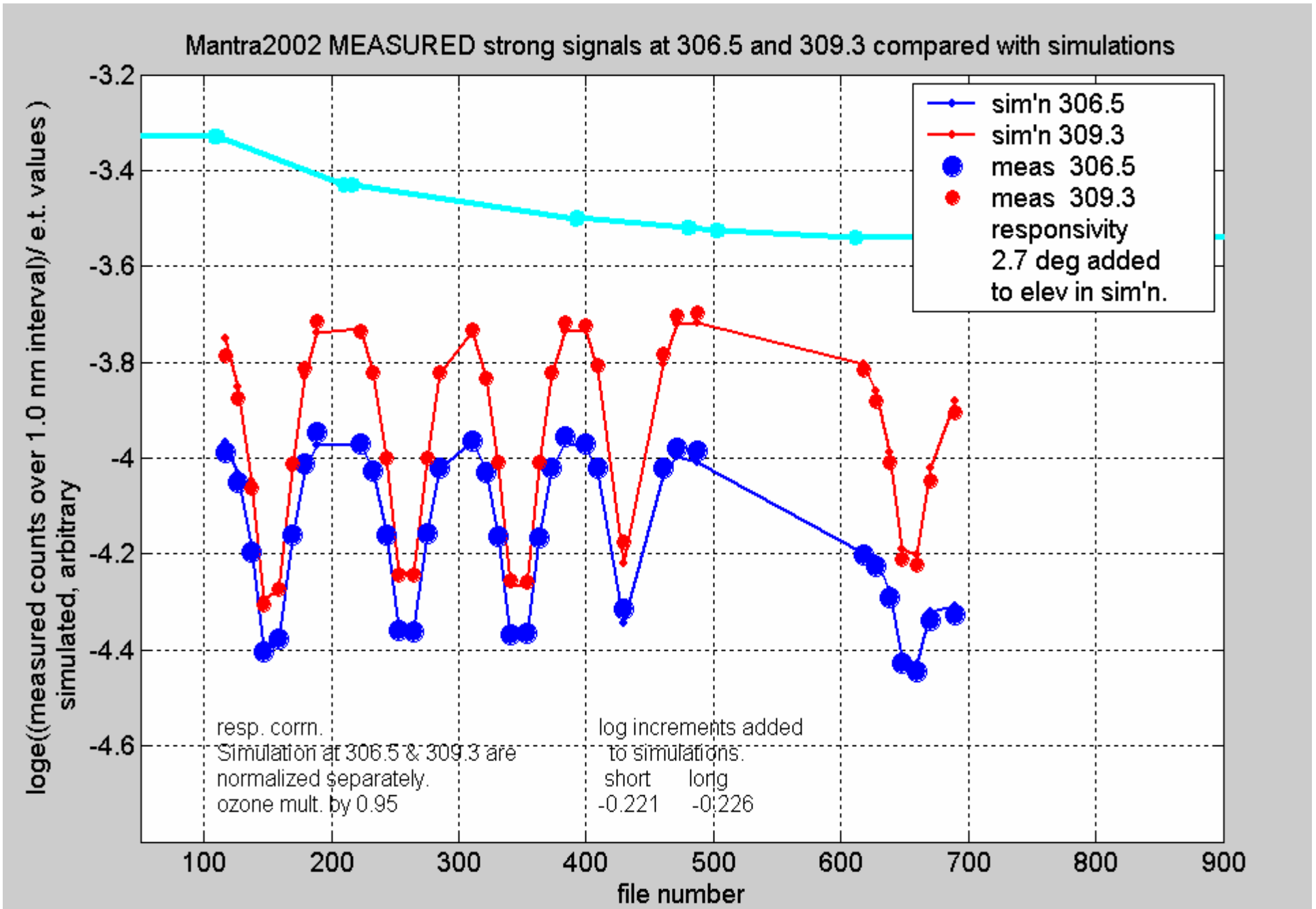
Makes spectral scans of:

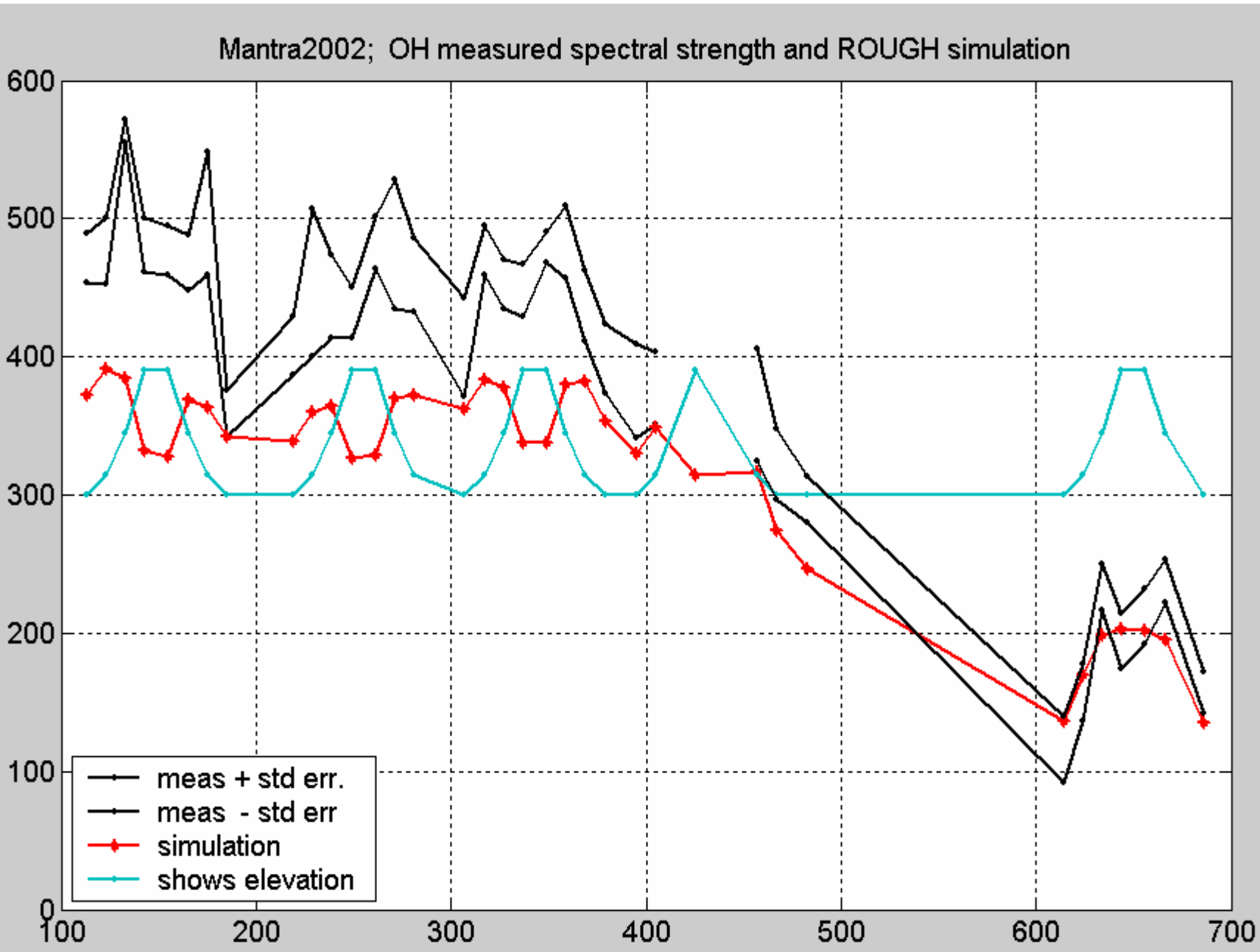
sunlight scattered by a diffuser (can use to measure ozone)

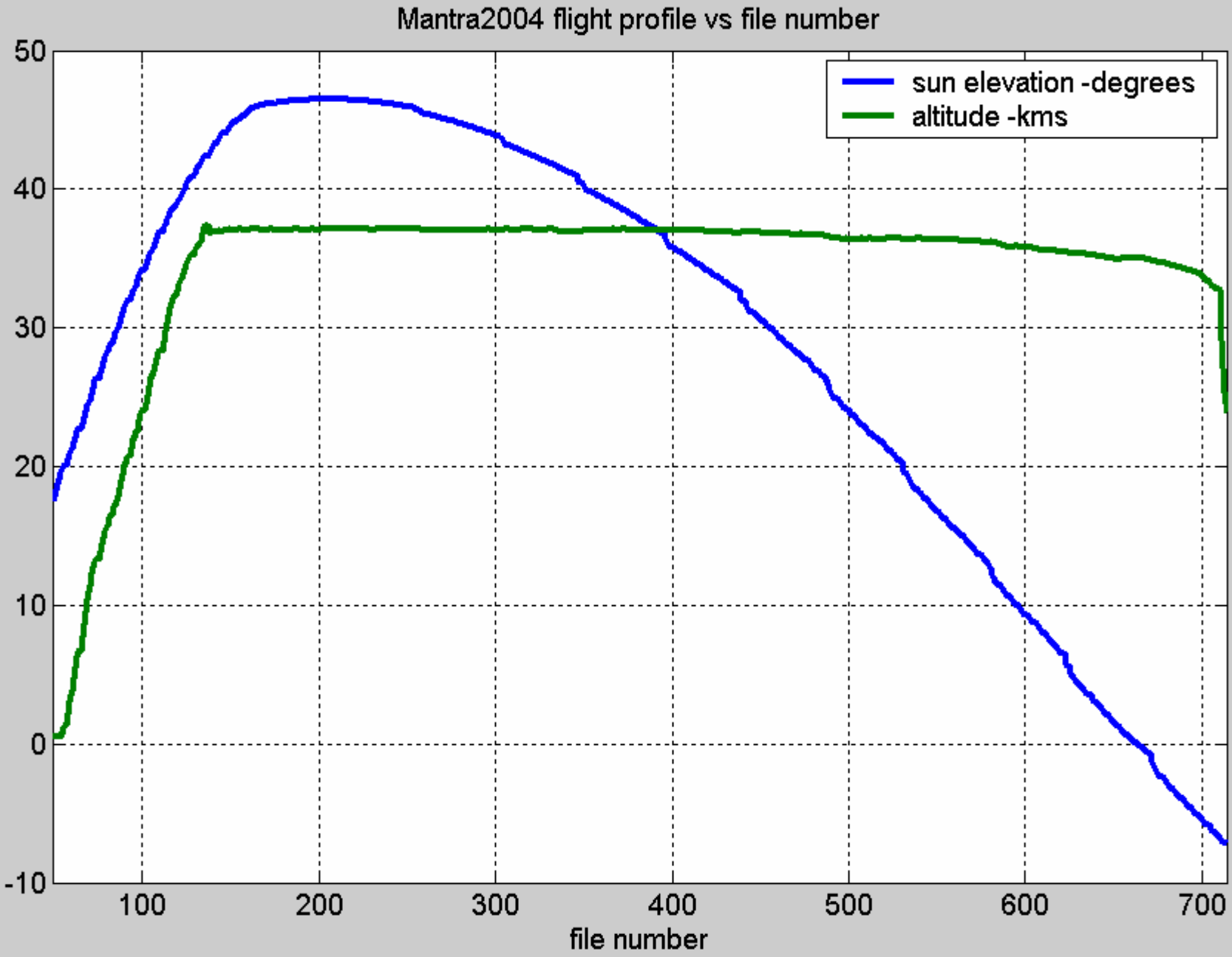
the limb 90 degrees from the sun
at four elevations (~2.5, 3.5, 5.5 & 8.5 degrees)
at two polarization settings (STRONG and WEAK)
( OH radiation is measured in the WEAK spectra).

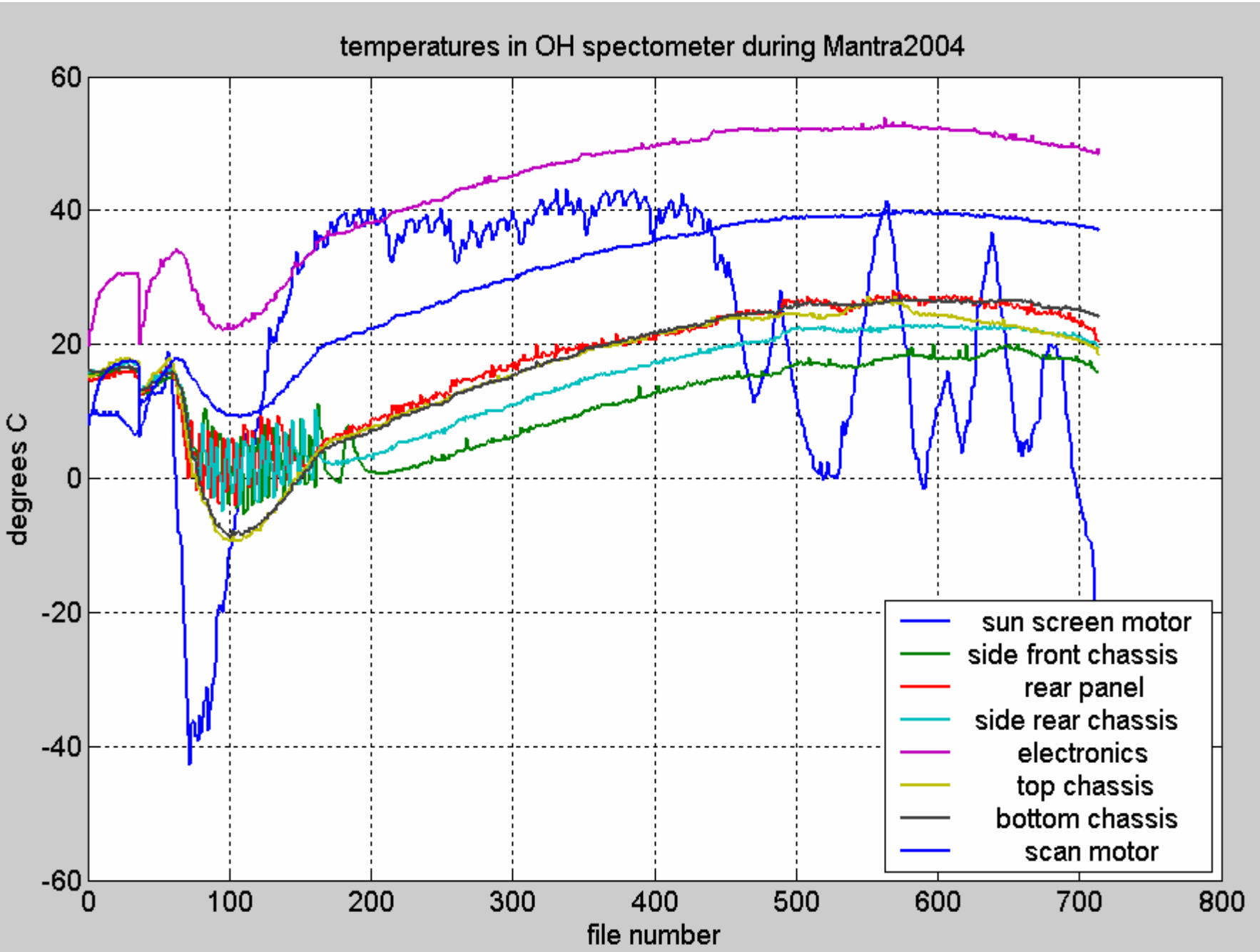
also radiation from a mercury lamp to calibrate wavelength


Mantra 2002 Azimuth Record and OH spectrometer operation
minimum azimuth during a scan
maximum azimuth during a scan
~ total rotations during file x 10
cradle elev'n no. x 10
SZA by FG
SZA from FG lat long
azimuth from FG lat long
Azimuth Degrees
0
50
100
150
200
250
300
350
400
450
246.5
246.6
246.7
246.8
246.9
247
247.1
CUT

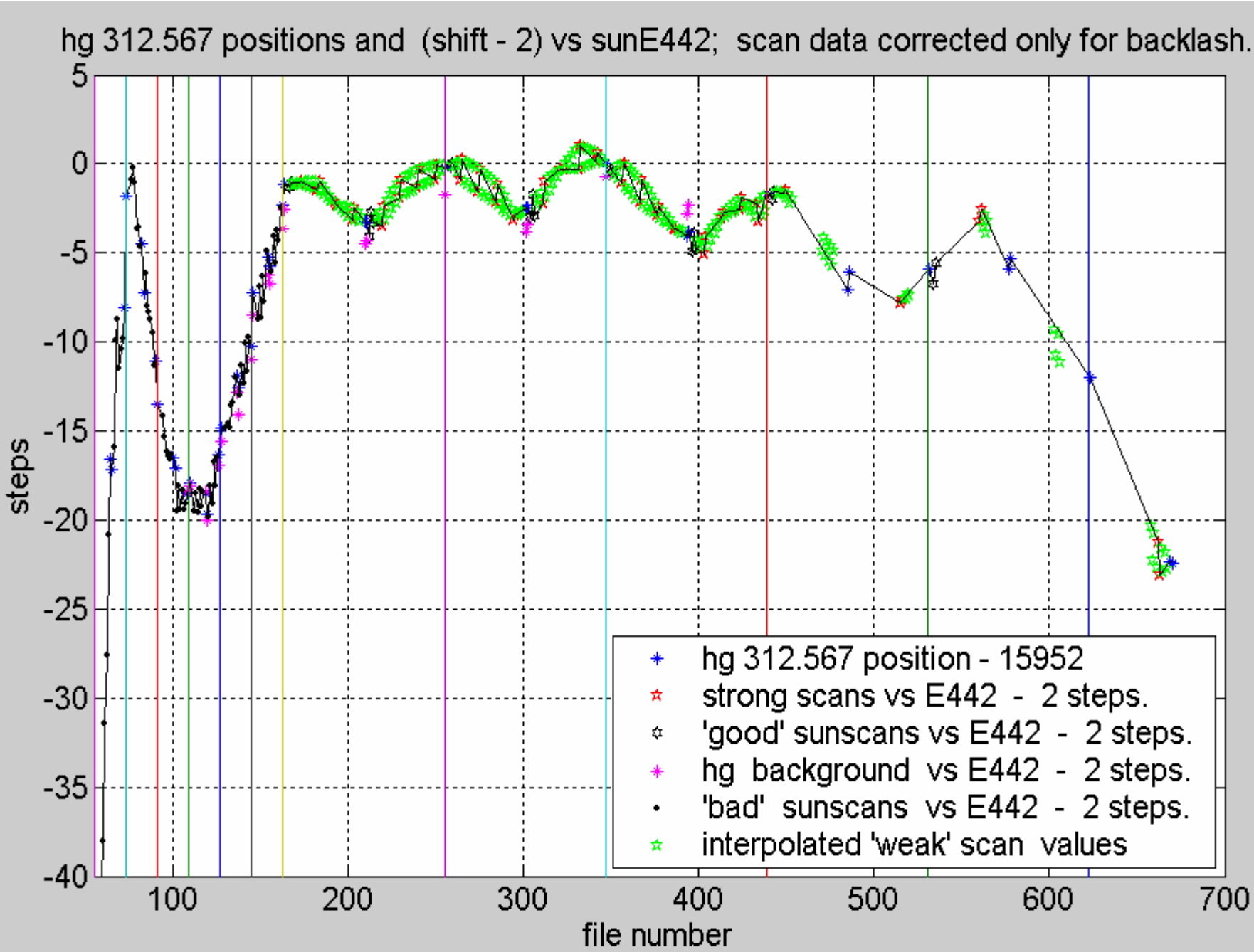

Mantra2002 MEASURED strong signals at 306.5 and 309.3 compared with simulations
loge((measured counts over 1.0 nm interval)/ e.t. values )
simulated, arbitrary
-3.2
-3.4
-3.6
-3.8
-4
-4.2
-4.4
-4.6
100
200
300
400
500
600
700
800
900
file number
sim'n 306.5
sim'n 309.3
meas 306.5
meas 309.3
responsivity
2.7 deg added
to elev in sim'n.
resp. corrn.
Simulation at 306.5 & 309.3 are
normalized separately.
ozone mult. by 0.95
log increments added
to simulations.
short long
-0.221 -0.226

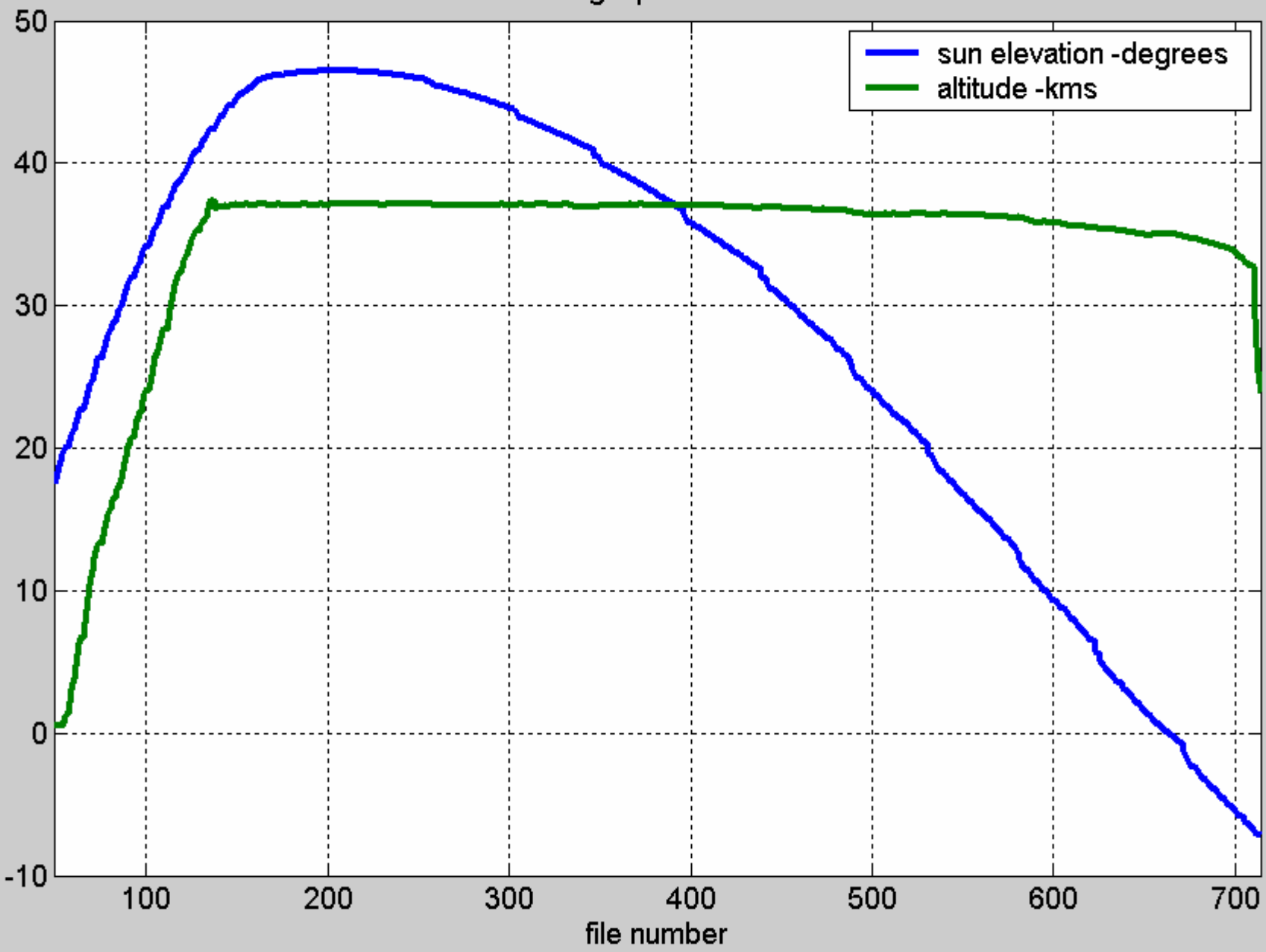

Mantra2002; OH measured spectral strength and ROUGH simulation
600
500
400
300
200
100
0
100
200
300
400
500
600
700
meas + std err.
meas - std err
simulation
shows elevation

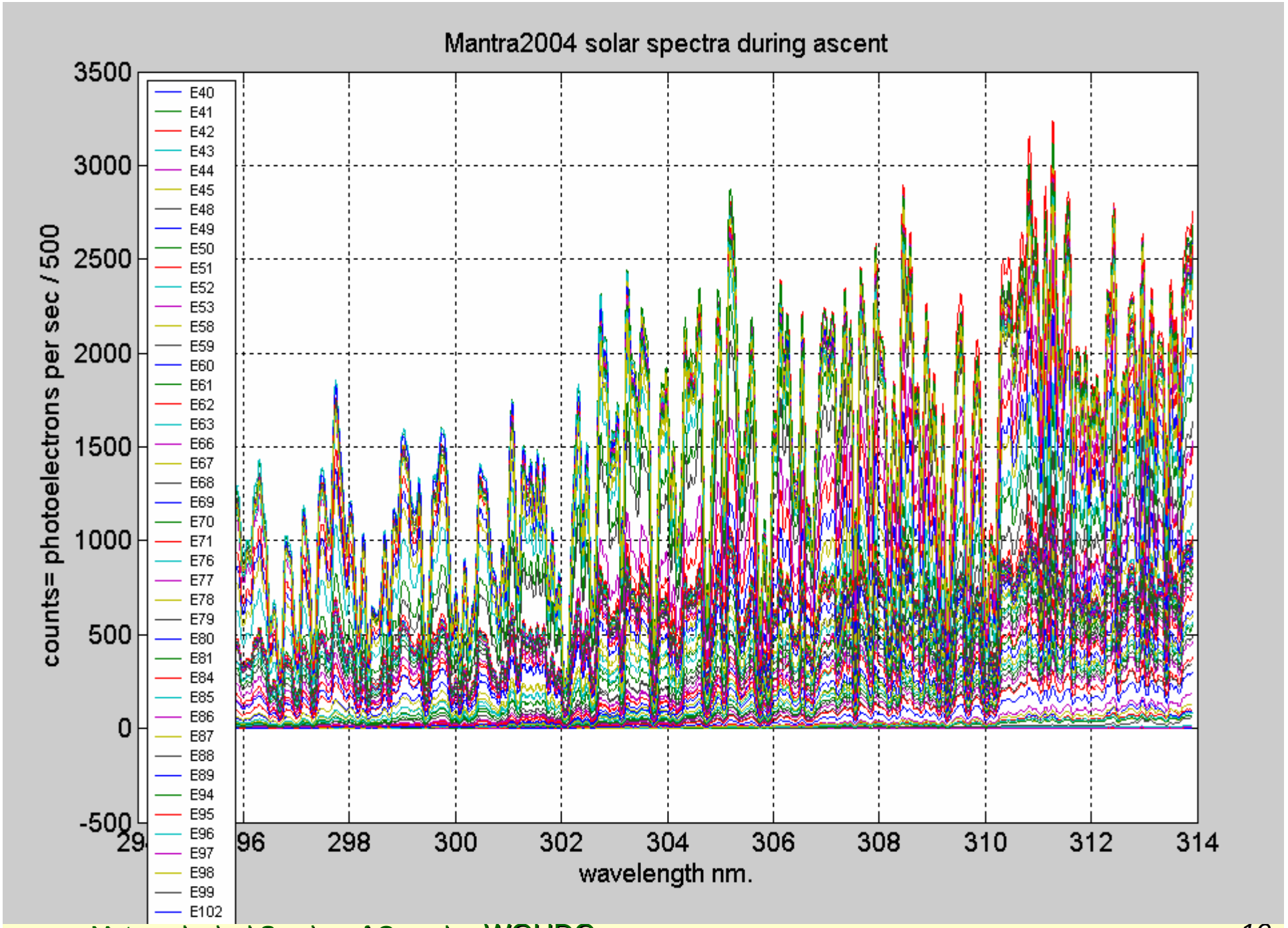

Mantra2004 flight profile vs file number
sun elevation -degrees
altitude -kms
50
40
30
20
10
0
-10
100
200
300
400
500
600
700
file number


temperatures in OH spectometer during Mantra2004
degrees C
file number
60
40
20
0
-20
-40
-60
0
100
200
300
400
500
600
700
800
sun screen motor
side front chassis
rear panel
side rear chassis
electronics
top chassis
bottom chassis
scan motor


hg 312.567 positions and (shift - 2) vs sunE442; scan data corrected only for backlash.
steps
file number
5
0
-5
-10
-15
-20
-25
-30
-35
-40
100
200
300
400
500
600
700
hg 312.567 position - 15952
strong scans vs E442 - 2 steps.
'good' sunscans vs E442 - 2 steps.
hg background vs E442 - 2 steps.
'bad' sunscans vs E442 - 2 steps.


hg 312.567 positions and (shift - 2) vs sunE442; scan data corrected only for backlash.
steps
file number
5
0
-5
-10
-15
-20
-25
-30
-35
-40
100
200
300
400
500
600
700
hg 312.567 position - 15952
strong scans vs E442 - 2 steps.
'good' sunscans vs E442 - 2 steps.
hg background vs E442 - 2 steps.
'bad' sunscans vs E442 - 2 steps.
interpolated 'weak' scan values


Mantra2004 flight profile vs file number
sun elevation -degrees
altitude -kms
50
40
30
20
10
0
-10
100
200
300
400
500
600
700
file number


Mantra2004 solar spectra during ascent
counts= photoelectrons per sec / 500
wavelength nm.
3500
3000
2500
2000
1500
1000
500
0
-500
296
298
300
302
304
306
308
310
312
314
E40
E41
E42
E43
E44
E45
E48
E49
E50
E51
E52
E53
E58
E59
E60
E61
E62
E63
E66
E67
E68
E69
E70
E71
E76
E77
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E81
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E85
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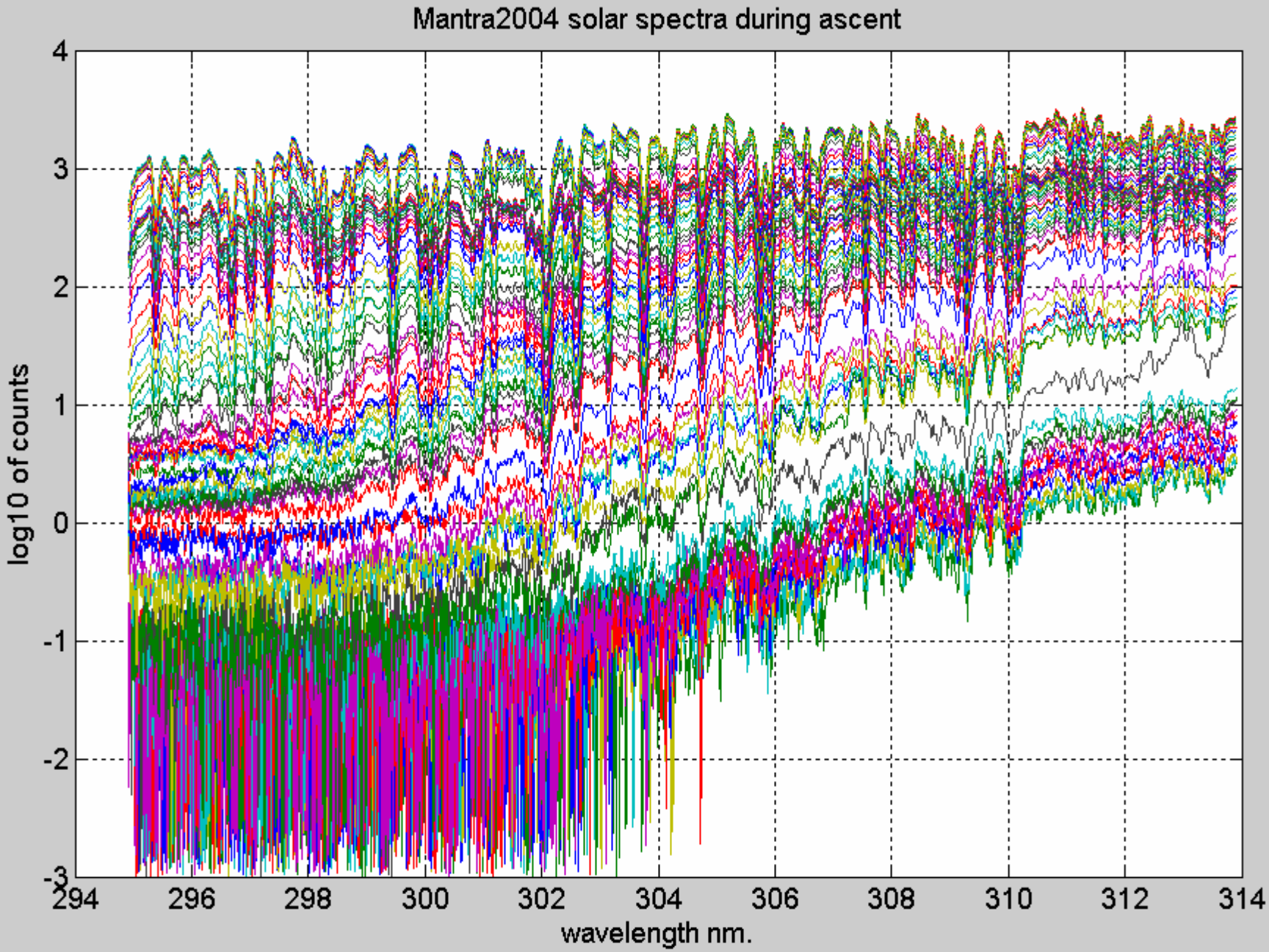
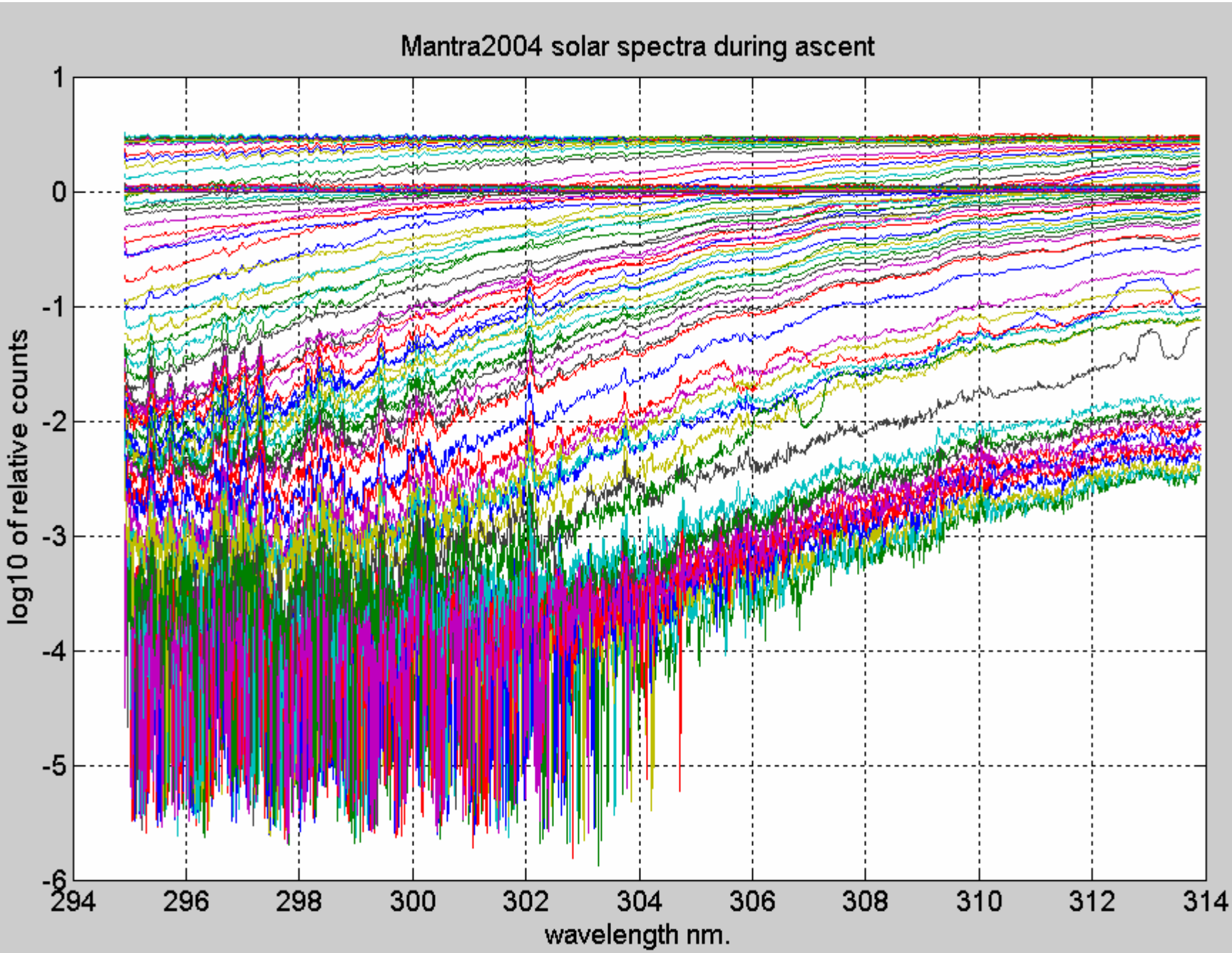
E88
E89
E94
E95
E96
E97
E98
E99
E102


Mantra2004 solar spectra during ascent
log10 of counts
wavelength nm.
4
3
2
1
0
-1
-2
-3
294
296
298
300
302
304
306
308
310
312
314


Mantra2004 solar spectra during ascent
log10 of relative counts
wavelength nm.
1
0
-1
-2
-3
-4
-5
-6
294
296
298
300
302
304
306
308
310
312
314

# Useful measurements

OH:

THREE full up-down sequences at 37 Km & sun elev'n
30 - 40 degrees, i.e. 24 sets of 4weak 2sun 4weak.

One measurement at viewing elevation 2.5 degrees
with very low sun elevation

Some isolated measurements in between

Direct sun ozone:

~70 spectra during ascent; called 'bad' spectra because the diffuser screen was not pointed correctly.

and
~ 10 'good' spectra at float altitude, mostly at high sun.

# publication

Mantra2002 float ozone.

OH radiation measurement from M2002-2004

simulation of OH radiation measurements

# MAESTRO-B

Tobias Kerzenmacher

&

Clive Midwinter

# Reminder

- Two grating spectrometers
- UV
  - 280 – 560 nm @ resolution ~ 1.5 nm
- Vis
  - 520 – 1020 nm @ resolution ~ 2.5 nm
- Direct sun and limb scanning
- $O_3$, $NO_2$, $O_2$, $H_2O$ profiles
- Used as ground and flight instrument

# Preflight

- Vacuum tested
- Radiometric calibration
- Dispersion

# Flight 20040901

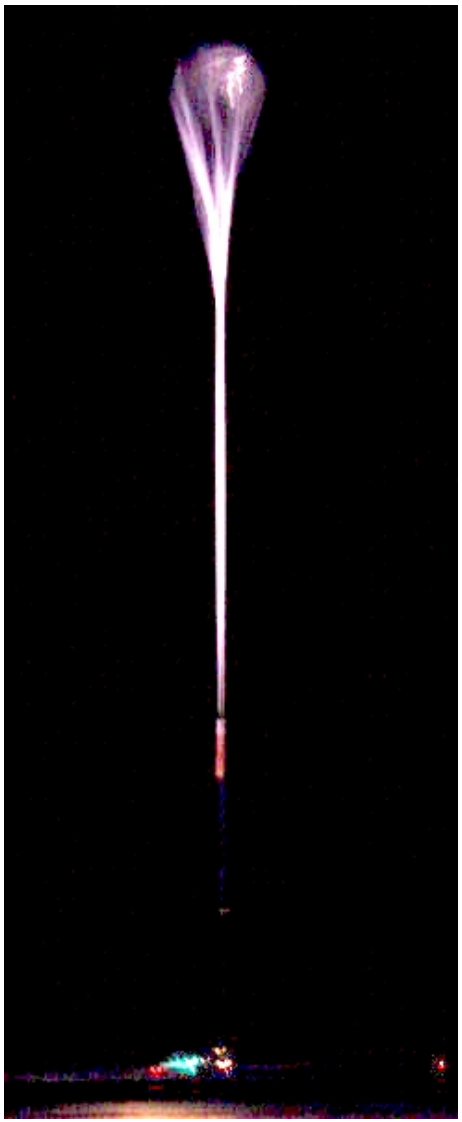
- Launch 14:36:00 /SZA 91 25:56:00
- Visible channel
  - Good signal
    - Lock on sun 14:49:25
    - Loss of pointing 22:26:52
- Occasional passage of sun as gondola slowly rotates
- No usable data after loss of pointing

# Flight 20040901

- Launch 14:36:00 /SZA 91 25:56:00
- UV channel
  - Signal
    - Lock on sun 14:49:25
    - Instrument hangs 16:46:38
  - Serious RFI problems
    - S/N marginal
  - Required commanding to reset UV channel

# Future

- Analyze data
  - Ascent profiles
    - $O_2$, $O_3$, $H_2O$, some $NO_2$
- Build a dedicated ground instrument
- RFI caused by pointing system
  - Try to isolate it better
- Otherwise ready to go



YORK UNIVERSITÉ UNIVERSITY redefine THE POSSIBLE.

# MANTRA 2004

## Q6 Workshop

November 2004

Ben Quine, Mike Ilnicki

# AIR: Airglow Infrared Radiometer

YORK UNIVERSITÉ UNIVERSITY redefine THE POSSIBLE.

- It is an airglow camera, designed to make continuous measurements of the intensities of the $O_2(^1\Delta)$ and $O_2(^1\Sigma)$ dayglow emissions produced by the photodissociation of ozone above 40 km.
- Primary observing mode is daytime, but twilight and nightime observations are also useful. Calibration is via a blackbody source, before flight.
- Uses 16-pixel photodiode array (sensitivity visible to about 1.8m), a filter wheel with four filters centred at 1.27m, 1.27m, 1.58m, and 762nm, and a camera lens.
- Collaborators in crime: David Tarasick and Ben Quine

# AIR: Science

YORK UNIVERSITÉ UNIVERSITY redefine THE POSSIBLE.

- $O_2(^1\Delta)$ and $O_2(^1\Sigma)$ emissions are measured along several lines of sight over a range of about 11° in the vertical
- Data used to infer profile over 45-90km altitude range
- $O_2(^1\Delta)$ dayglow is produced primarily by
  - $O_3 + h\nu(\lambda = 210\text{-}310\ nm) \rightarrow O_2(^1\Delta) + O(^1D)$
- Can be used to infer ozone above 45 km (SME, SABER, TIMED)
- But… $O_2(^1\Delta)$ also produced by
  - $O(^1D) + O_2 \rightarrow O(^3P) + O_2(^1\Sigma)$ (below 65 km)
  - $O_2 + h\nu(\lambda = 762\ nm) \rightarrow O_2(^1\Sigma)$ (65 - 100 km)
  - $O_2(^1\Sigma) + M \rightarrow O_2(^1\Delta)$
- Contributions from these reactions as yet not well characterized.
- Opportunity to measure both species at same time and compare results with balloon instruments measuring ozone.

# AIR: The Instrument

YORK UNIVERSITÉ UNIVERSITY redefine THE POSSIBLE.

- The instrument is a small 15 cm cube, plus lens
- Mass ~3 kg
- Power (~10 w?)
- Low data rate
- No special requirements except pointing knowledge.
- Preferred direction 90° away from sun.

# AIR: 2004 Tasks

YORK UNIVERSITÉ UNIVERSITY redefine THE POSSIBLE.

- Develop management computer - done
- Install new lens system compatible with geometry - done
- Add polariser to remove some of Rayleigh scattering - done
- Filter (re-)characterization - done
- Calibration, packaging, vacuum testing - done

# AIR: What we got

YORK UNIVERSITÉ UNIVERSITY redefine THE POSSIBLE.

- Instrument only collects good data above 30km when correctly oriented.
- Flight 1
  - Neither instrument was in automated data collection mode at time of comms uplink failure.
  - No data collected.
- Flight 2
  - Instruments operational but mission terminated at 2km.

# An instrument of opportunity

YORK UNIVERSITÉ UNIVERSITY redefine THE POSSIBLE.

- We deployed grating spectrometer 300nm-800nm (2000 spectral intervals) as part of ground based campaign.
- Zenith sky geometry with 20$^{o}$ field.
- Measurements collected every 30 sec (50ms measurement averaged 300 times per collection).
- Collected five days of very good data.
- Data now in MATLAB ☺ looks nice (at first glance).
- DVB hopes to use it in brewer analysis.

# Summary

- We have two calibrated AIR instruments prepared for balloon flight.
- Should like an opportunity to fly them again.
- Propose no further hardware or software modifications – freeze hardware.
- Focus on calibration of instruments before flight in future missions.
- Will continue to develop GB spectrometer. Needs a name!

# *MANTRA "quarterly" meeting November 2004*

MSC ozonesondes and Backscatter sondes

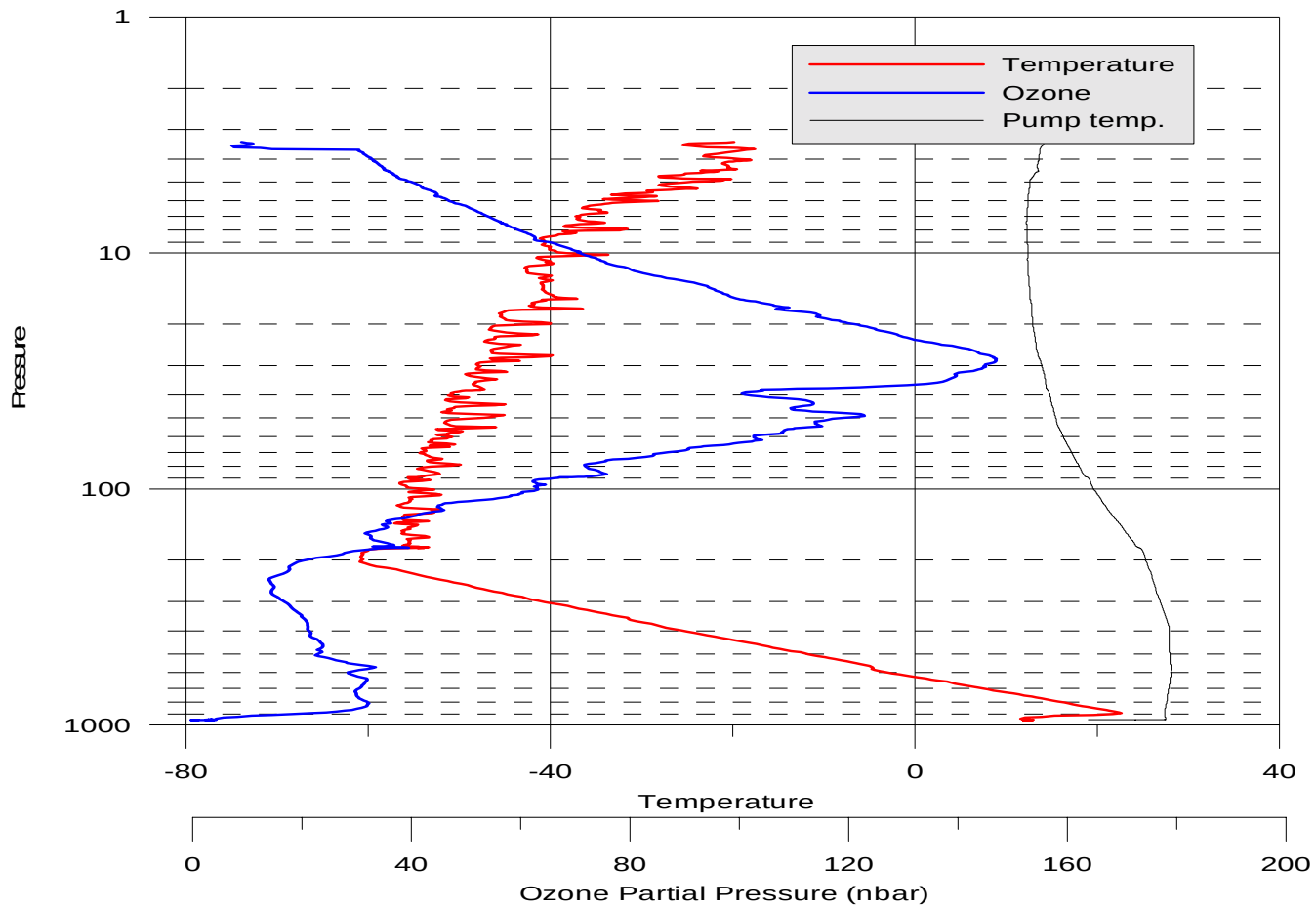
# Ozonesondes – Free fliers

- Record number of balloons for MANTRA
- 21 Launches not including main payload
- 18 good profiles
- ECC sondes w/ standard PTU and GPS
- WMO SOP rather than MSC standard
- Backscatter sondes not flown

# Ozonesonde – Main Payload

- First flight went perfect!
- Ozone and PTU data very similar to free flyers
- Boom was successfully holding the sonde in clear air
- Supplemental heater kept the instrument within temperature limits
- GPS data OK for entire flight
- Second flight…

# September 1st ozone profile



# Future Work

- Correct pressure measurement using GPS altitude – this will only be noticeable above about 10 hPa
- Nice time series of WMO ‘standard’ ozonesondes with co-incident total ozone measurement and residual?
- Might use this in WMO SOP report

# MANTRA 2004 Ground-Based Campaign

MANTRA Sixth Quarterly Meeting

November 10, 2004

Annemarie Fraser

(with input from lots of others)

# Campaign Overview

- ☆Five ground-based instruments operating for the duration of the campaign
- ☆Data from August 4 – September 15 (43 days!)
- ☆There is also some data taken on the ground from some of the flight instruments (If this refers to you, please let me know what you are willing to share!)

# Ground-Based Instruments

| Instrument | Date Operating | Species Retrieved |
|---|---|---|
| Brewer | Aug.3 – Sept. 15 | Ozone, $NO_2$, $SO_2$ |
| SPS-G | Aug. 6 – Sept. 15 | Ozone, $NO_2$ |
| MAESTRO | Aug. 20, 21, 24 | Ozone, $NO_2$, BrO, $NO_3$ |
| SAOZ | Aug. 5 – Aug. 13,<br>Aug. 16 – Sept. 15 | Ozone, $NO_2$, $O_4$, Colour Index |
| AOTF | Aug. 10 – Aug. 21,<br>Aug. 25 – Aug. 28 | Ozone, $NO_2$ |
| UV-VIS DOAS | Aug. 6- Sept. 15 | Ozone, $NO_2$ |

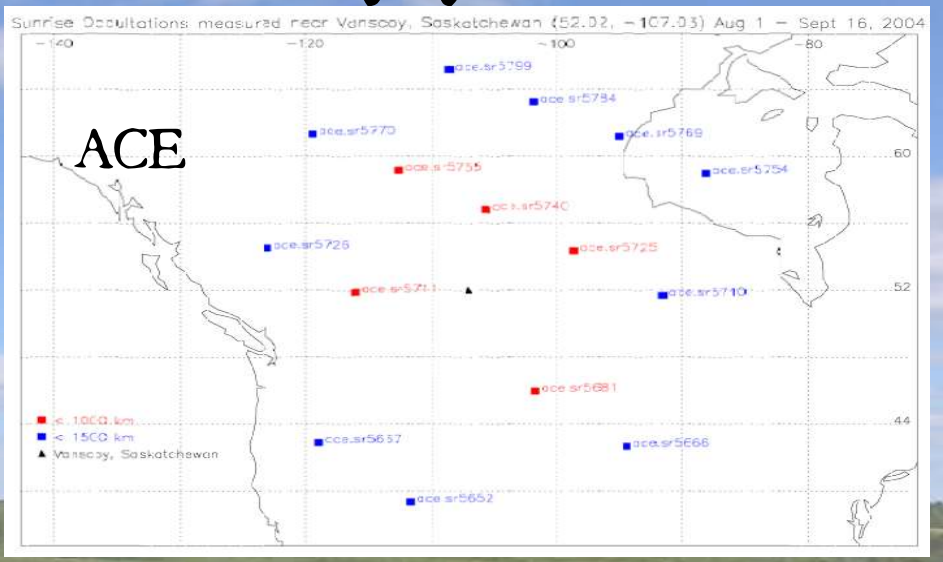
# Where to go now...

- Instrument intercomparison
  - Where possible, trade codes – are differences introduced by software?
  - Retrieval parameters – are they the same?
    - eg. cross-sections used
    - For DOAS, calibration techniques, reference spectrum used, range of SZA to include....
  - Planning a short paper in GRL to be submitted soon (Do you want in? Let me know.)

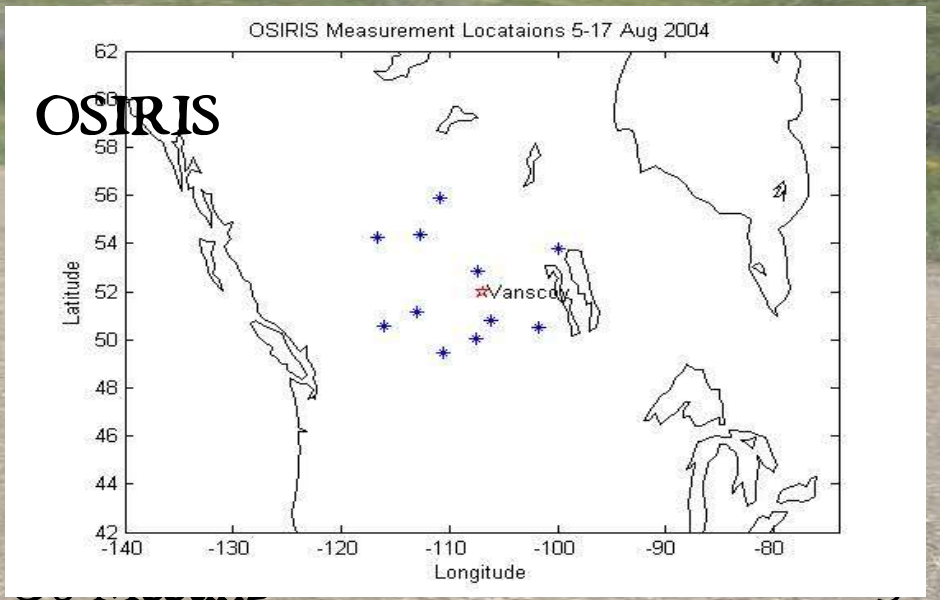
# Where to go now… (2)

- ☆Satellite comparisons
  - ☆SCISAT – Aug. 30 – Sept. 9
  - ☆ENVISAT – Aug. 14 – Aug. 22
  - ☆ OSIRIS, GOMOS, MIPAS, etc…!
  - ☆Both profiles and column amounts

ACE




OSIRIS



# Where to go now... (3)

- Model comparisons
  - CMAM (GCM), MEZON (CTM), SLIMCAT, etc...
  - Investigate:
    - Diurnal variations
    - Grid spacing
    - etc...

# Summary

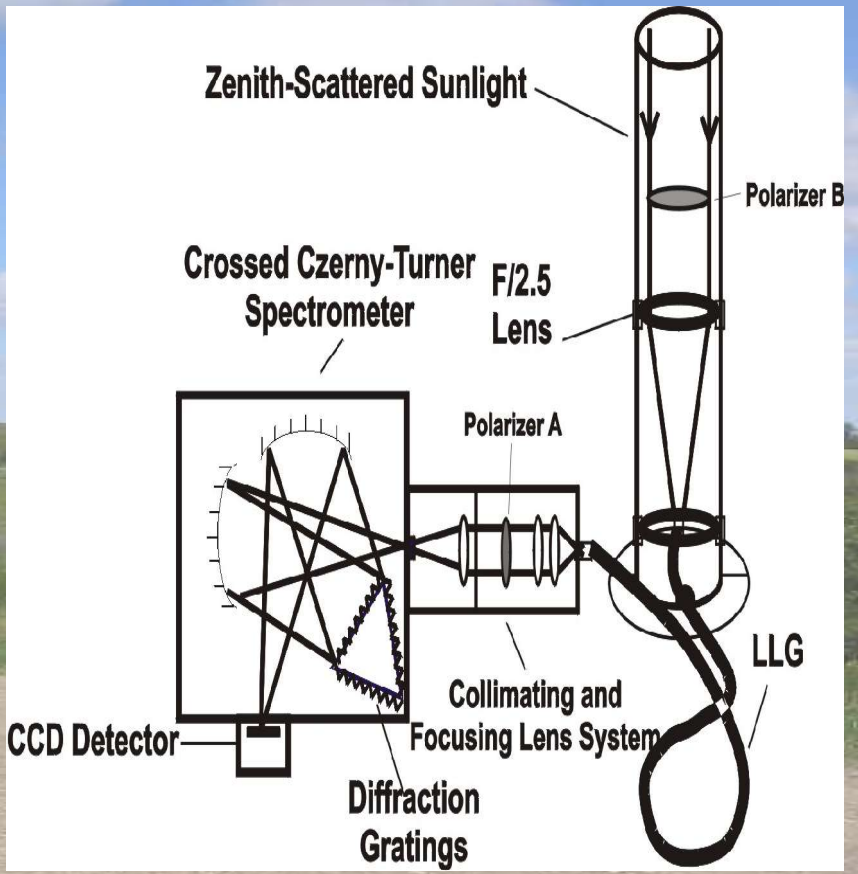
- ☆The ground-based campaign was a success, and there is a lot of science that can/will be done with the 43 days of measurements we have.

# U(T) Ground-Based UV-VIS Spectrometer

MANTRA Sixth Quarterly Meeting
November 10, 2004
Annemarie Fraser

# The Instrument

- ☆ UV-Vis diffraction grating spectrometer
- ☆ 3 gratings give 3 varying wavelength regions and resolutions
- ☆ $LN_2$ cooled CCD detector
- ☆ Collects zenith-scattered solar spectra
- ☆ 9 previous campaigns



# Data Products

- Using the DOAS technique, can retrieve vertical columns of ozone and $NO_2$
- Using an optimal estimation method can retrieve profiles of $NO_2$
- When coupled to a telescope, can retrieve $NO_3$ using direct light from stars, planets or the Moon
  - 2 nights of lunar data from MANTRA – August 26 and September 1

# The Tale of the Loaner CCD

- ☆In July, the instrument was installed on the roof, but the CCD could only record saturated spectra
- ☆After discussions with the technicians at JY, it was decided that the CCD could not be repaired in time for the campaign
- ☆They were able to lend us a CCD, chosen on its compatibility with our hardware and software (which arrived the day before we shipped to Vanscoy.)

# Battle of the CCDs

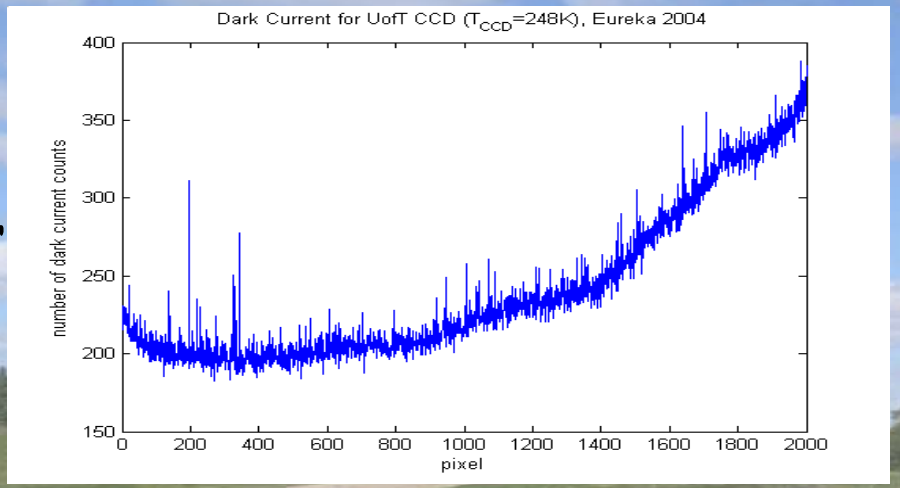
| Property | UofT CCD | Loaner CCD |
|---|---|---|
| Size | 2000x800 pixels<br>30 x 12 mm | 1024x128 pixels<br>26.6 x 3.3 mm |
| Cooling | Thermo-electric, 250 K | Liquid nitrogen, 140 K |
| Illumination | Back | Front |
| Peak quantum efficiency | 250 nm | 700 nm |
| QE for 300-600nm | Approx. 60% | Approx. 10% |

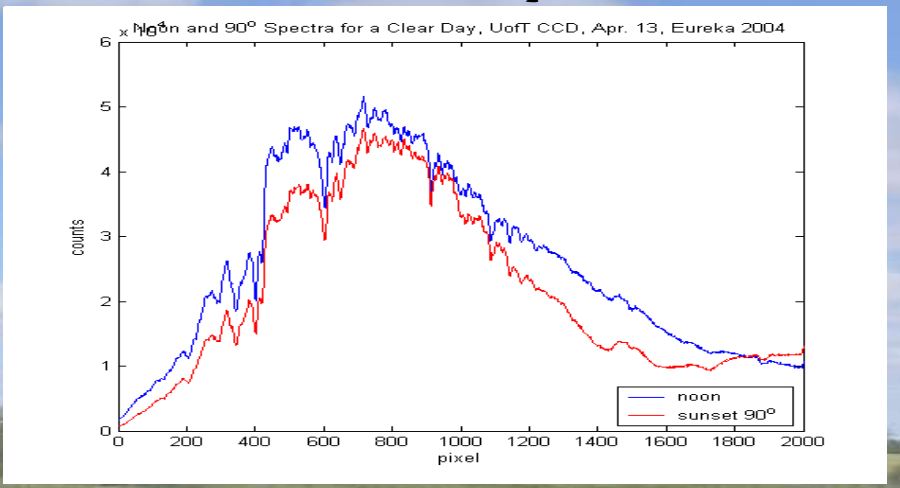
# Battle of the CCDs (2)

## Dark current

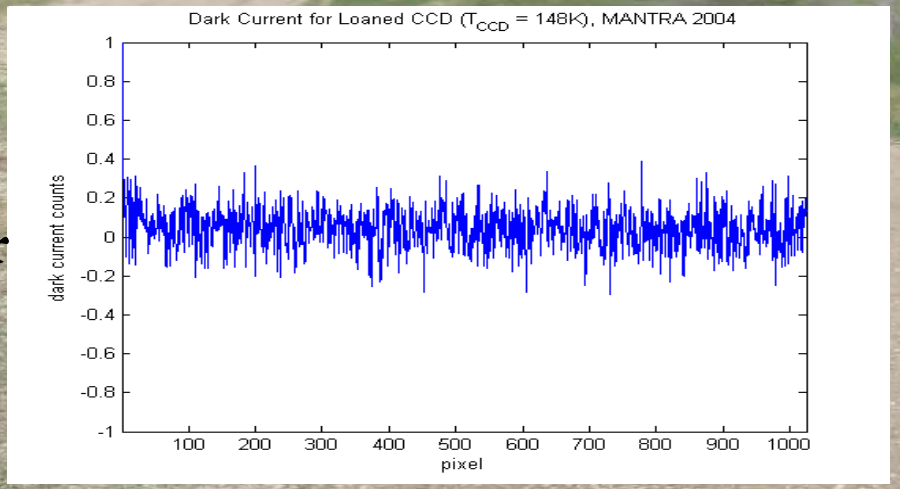
## Zenith-Sky Spectra

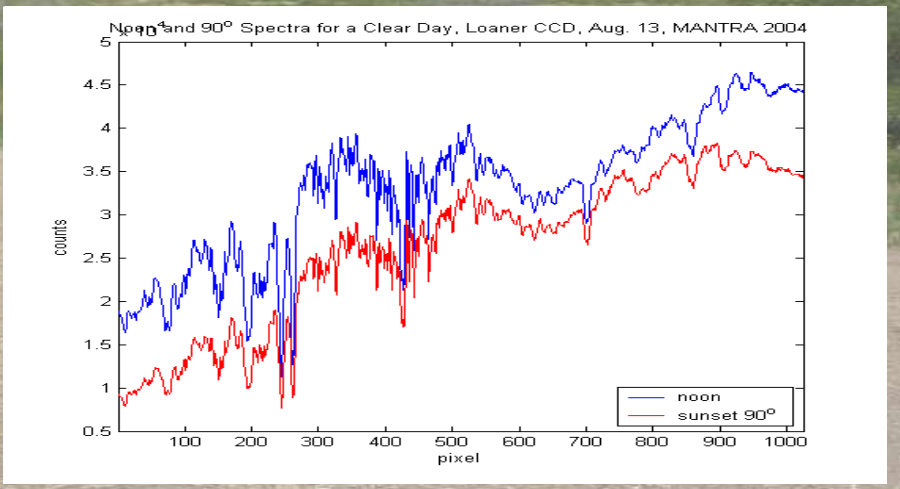
UofT



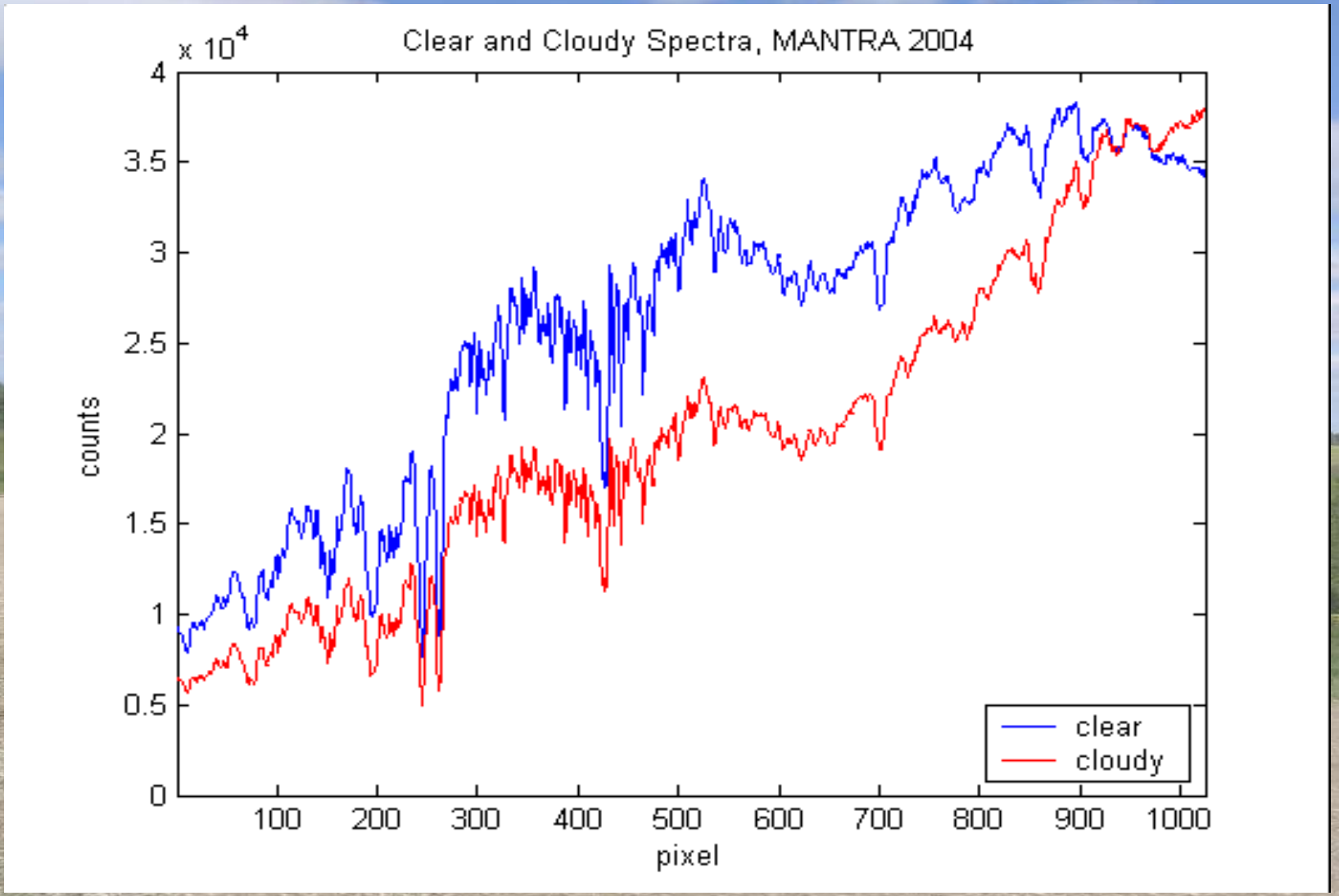




loaner



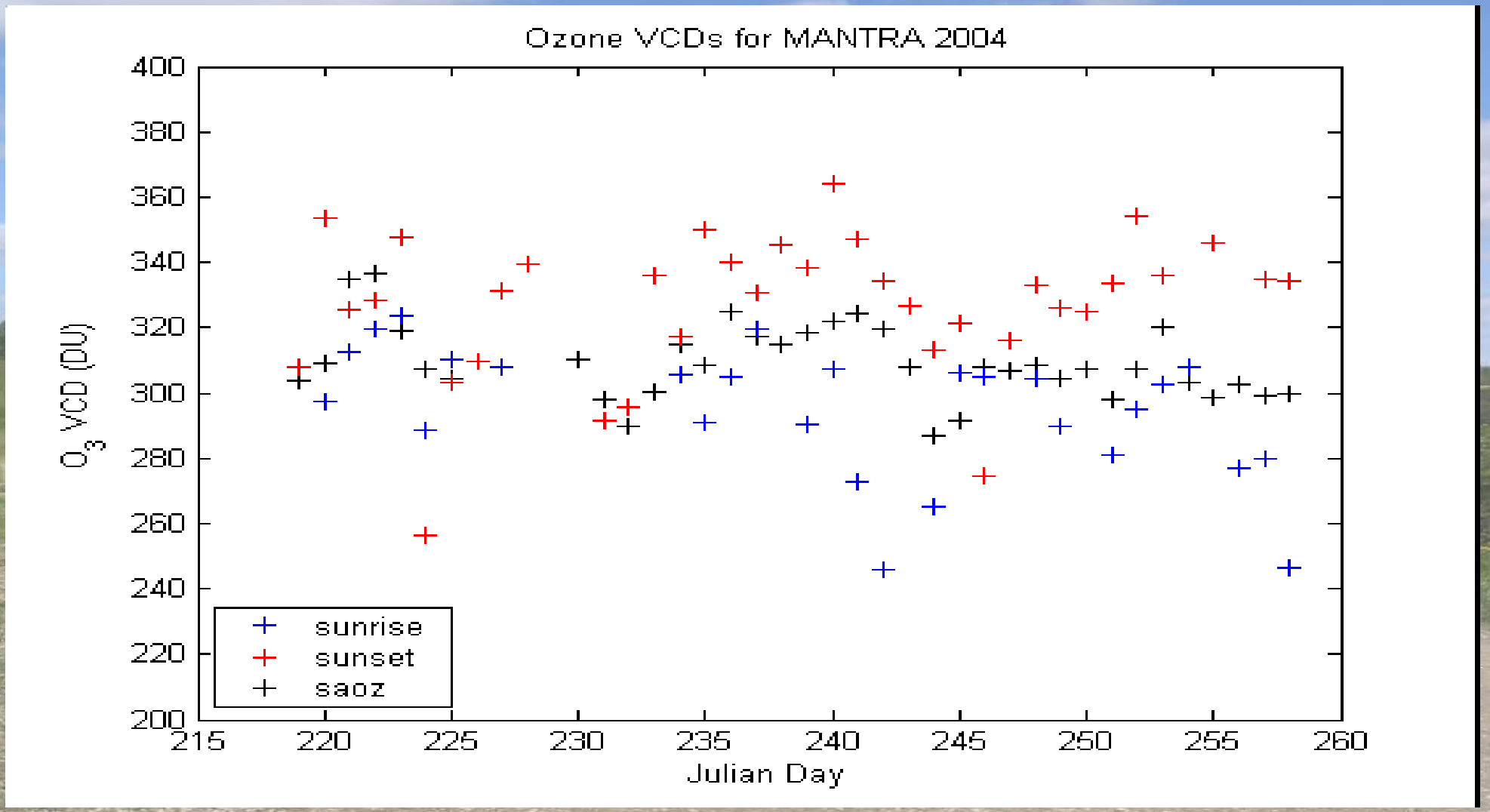
# Battle of the CCDs (3)



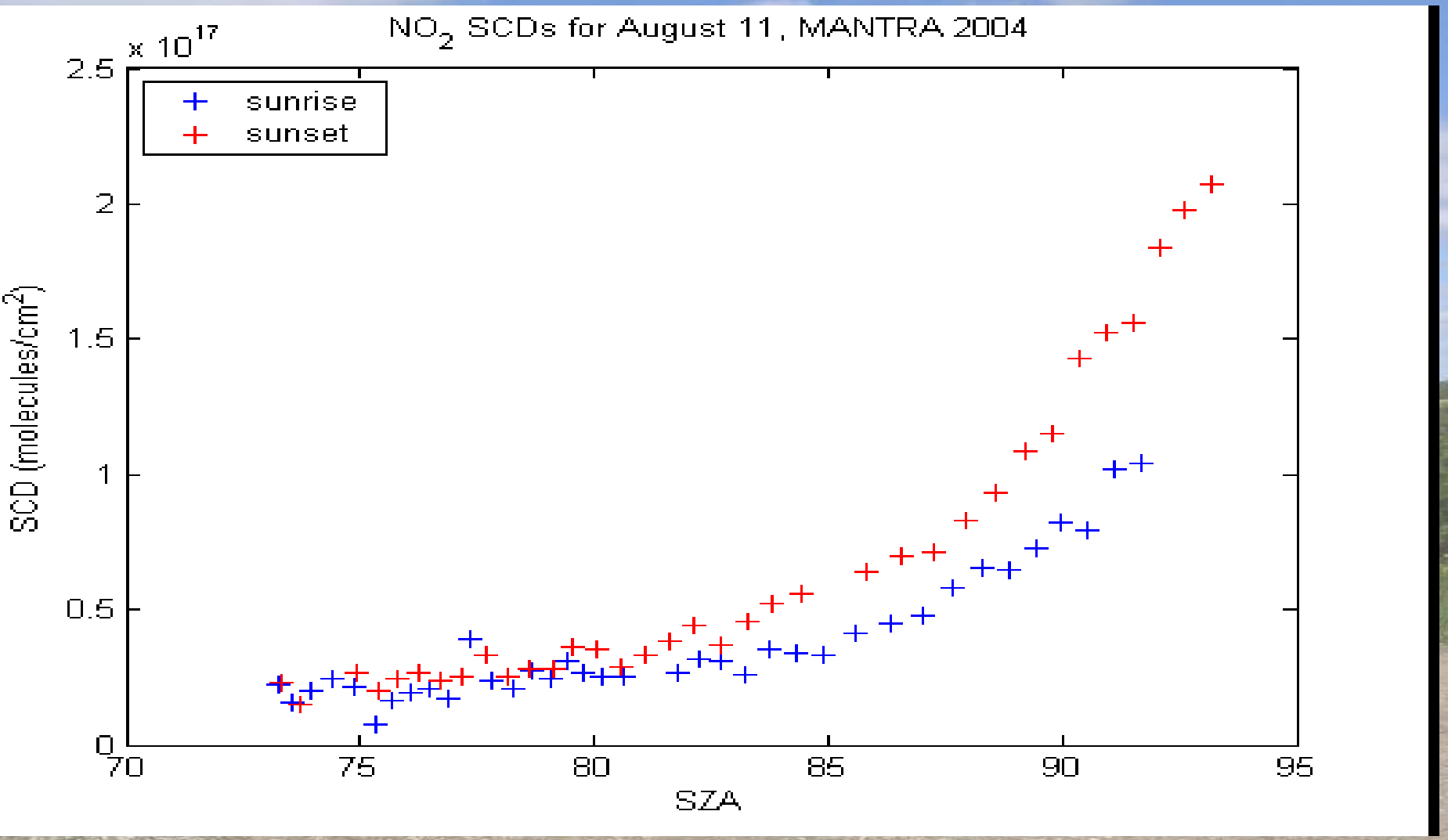
# Data Analysis So Far

- Out in the field, Jennifer and I did some preliminary analysis of ozone and $NO_2$ for some days
- Since then, I have done a more complete analysis for the whole campaign for column ozone amounts
- $NO_2$ is next on the list, but some days have been done
- Profiles of $NO_2$ will also be retrieved

# Preliminary Ozone Results

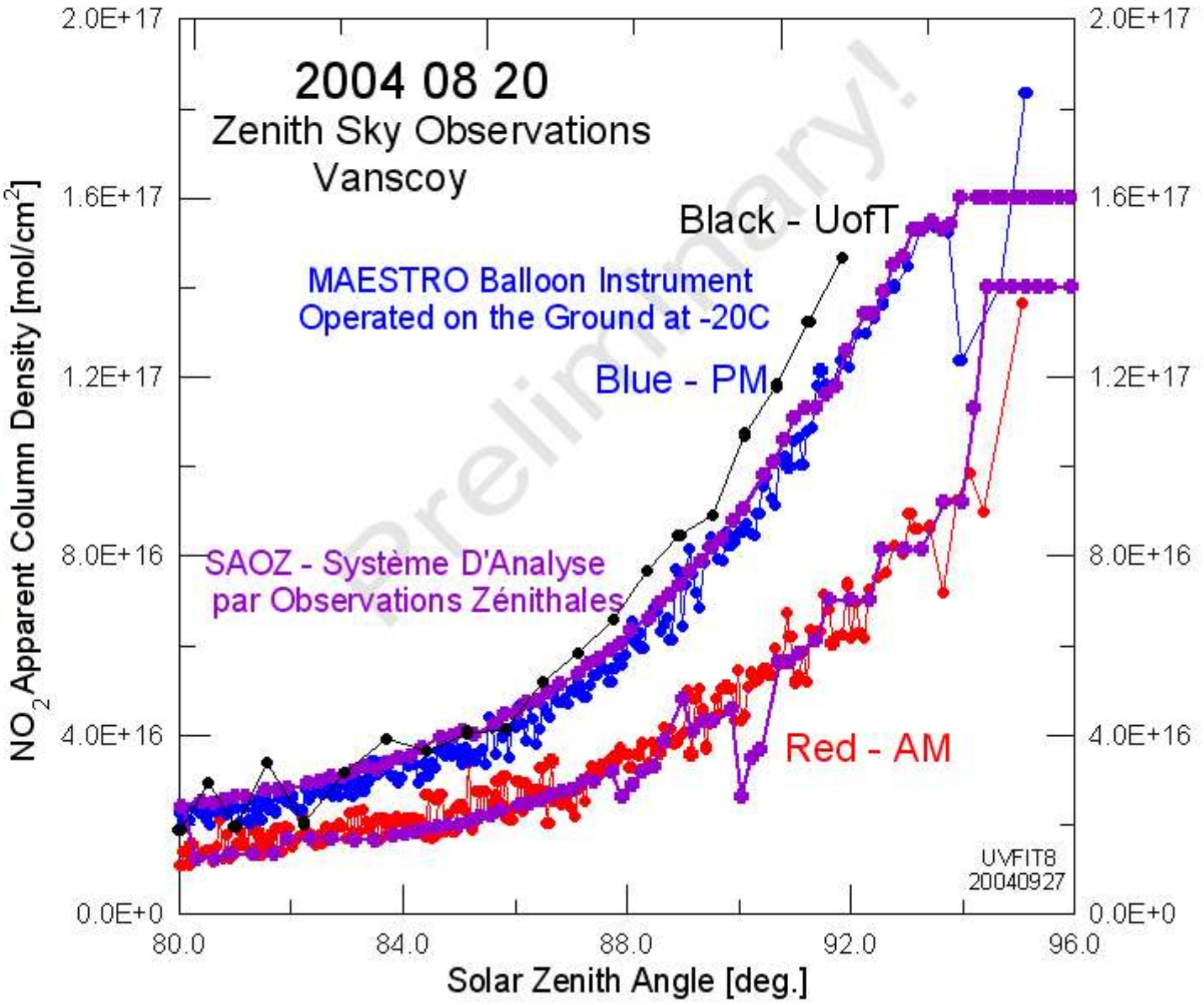


# Preliminary $NO_2$



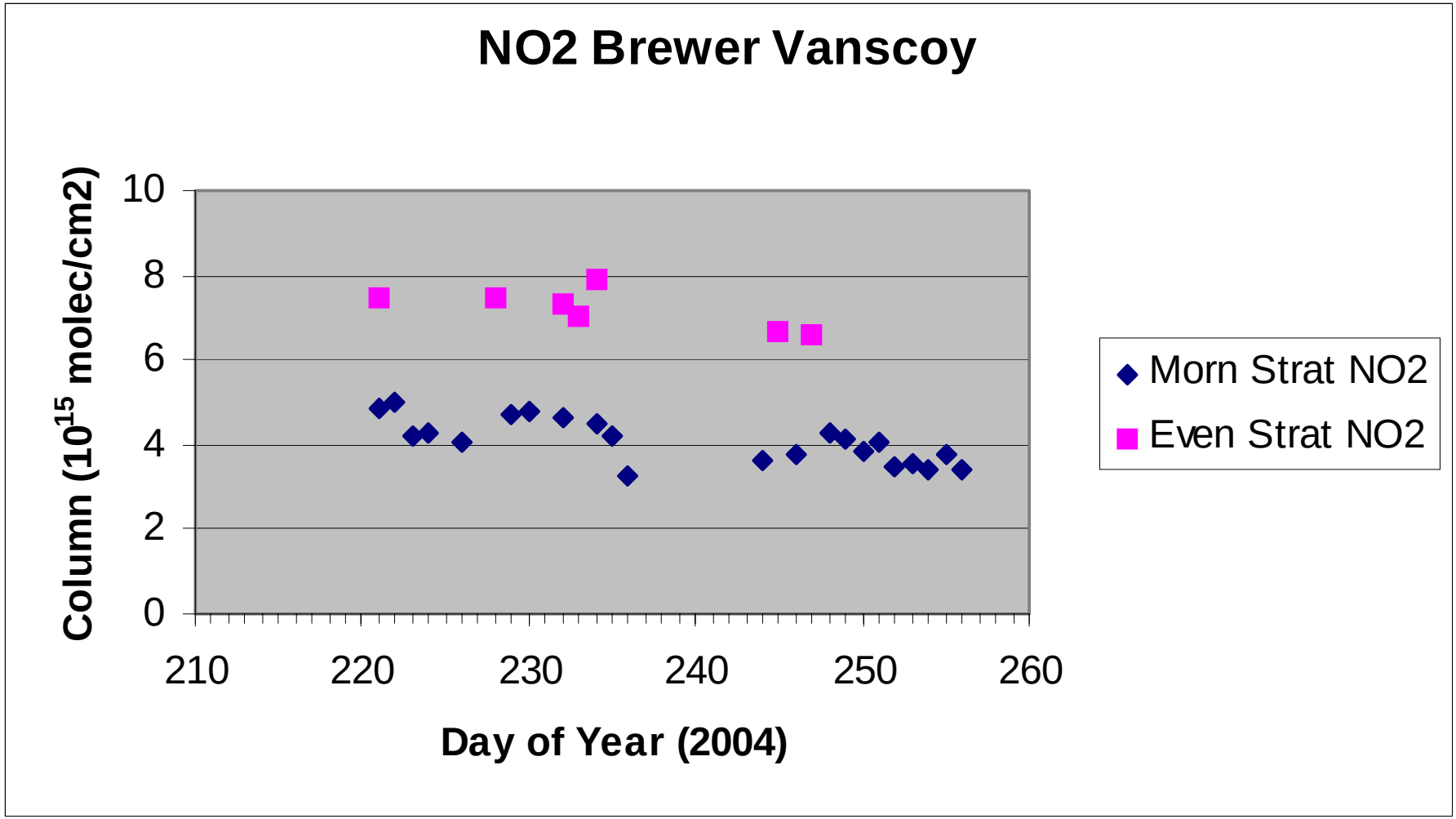
# MAESTRO!

MAESTRO was operated in a freezer mounted on a solar tracker. the low temperature reduces the dark current from the detector.

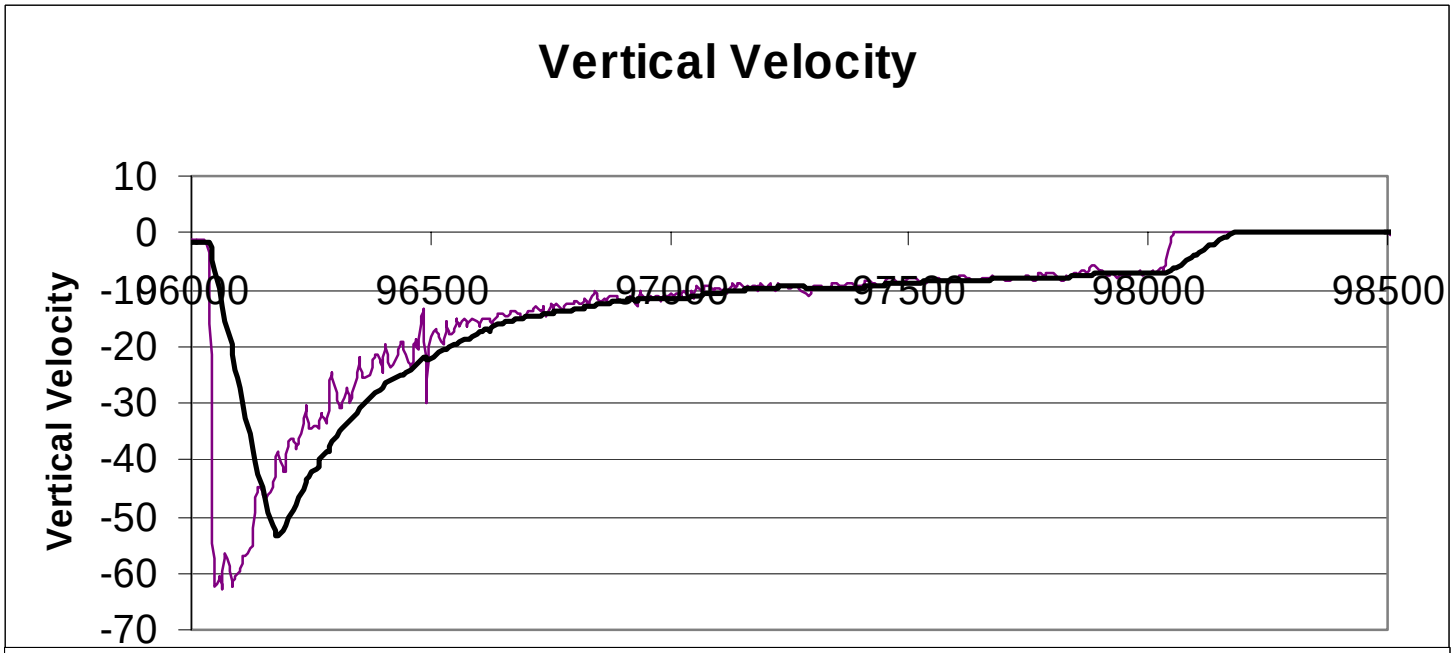


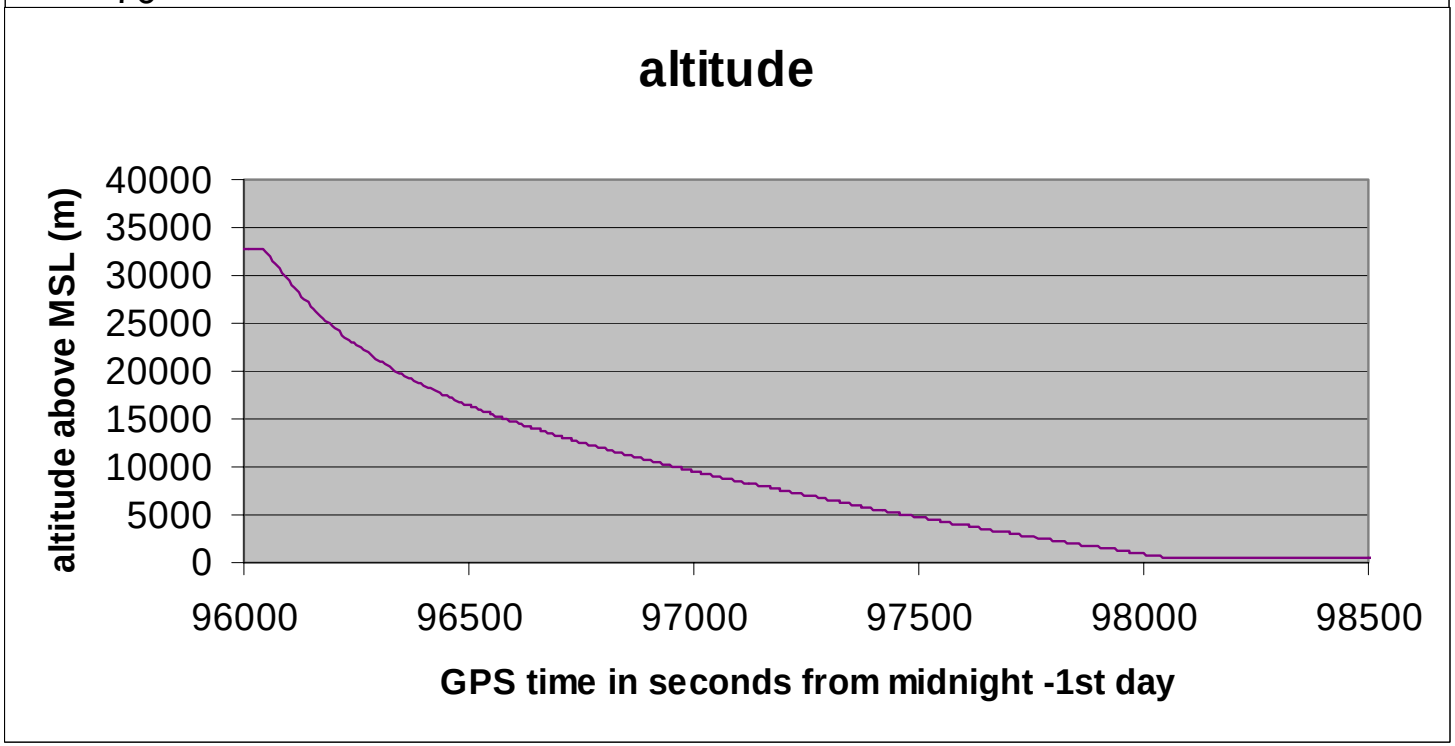
# What's Next?

- ☆We've been using an old AMF file, we need to calculate a new one using the ozone sondes launched during the campaign
- ☆Analyse more days for $NO_2$
  - ☆investigate differences with SAOZ and MAESTRO
- ☆Instrument intercomparison – for the GRL paper


NO2 Brewer Vanscoy
Column ($10^{15}$ molec/cm2)
10
8
6
4
2
0
210
220
230
240
250
260
Day of Year (2004)
Morn Strat NO2
Even Strat NO2

| Date | B file | Zenith | Sky | Direct | Sun | NJ file | NZ file | SAOZ | MAESTRO | SPS-G |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N2 Sum | N2 | N2 Sum | N2 | | | S2004*.EFM | du* & dv* | 2004*.dat |
| 08/08/2004 | | | | | | | | 08080000 | | |
| 09/08/2004 | | | | | | | | 08090000 | | |
| 10/08/2004 | B22304.007 | | | | | | | 08100000 | | 52 files |
| 11/08/2004 | B22404.007 | | | | | | | 08110000 | | 43 files |
| 12/08/2004 | B22504.007 | | | | | | | 08120000 | | 17 files |
| 13/08/2004 | B22604.007 | | | | | | | 08130000 | | 23 files |
| 14/08/2004 | B22704.007 | | | | | | | | | 33 files |
| 15/08/2004 | B22804.007 | 12 | 84 | 4 | 20 | | | | | 29 files |
| 16/08/2004 | B22904.007 | 25 | 175 | 8 | 40 | | | 08161007 | 040816.dat | 59 files |
| 17/08/2004 | B23004.007 | 22 | 154 | 8 | 40 | | | 08170000 | 040817.dat | 216 files |
| 18/08/2004 | B23104.007 | 11 | 77 | 4 | 20 | | | 08180000 | 040818.dat | 310 files |
| 19/08/2004 | B23204.007 | 24 | 168 | 8 | 40 | | | 08190000 | 040819.dat | 276 files |
| 20/08/2004 | B23304.007 | 23 | 161 | 7 | 35 | NJ23304.007 | | 08200000 | 040820.dat | 286 files |
| 21/08/2004 | | | | | | NJ23404.007 | | 08210000 | 040821.dat | 156 files |
| 22/08/2004 | B23504.007 | 26 | 182 | 8 | 40 | NJ23504.007 | | 08220000 | 040822.dat | 97 files |
| 23/08/2004 | B23604.007 | 20 | 140 | 5 | 25 | NJ23604.007 | NZ23604.007 | 08230000 | 040823.dat | 96 files |
| 24/08/2004 | B23704.007 | 11 | 77 | 4 | 20 | NJ23704.007 | NZ23704.007 | 08240000 | 040824.dat | 92 files |
| 25/08/2004 | B23804.007 | 10 | 70 | 6 | 30 | NJ23804.007 | NZ23804.007 | 08250000 | | 85 files |
| 26/08/2004 | B23904.007 | 14 | 98 | 11 | 55 | NJ23904.007 | NZ23904.007 | 08260000 | | 82 files |
| 27/08/2004 | B24004.007 | 13 | 91 | 10 | 50 | NJ24004.007 | NZ24004.007 | 08270000 | | 36 files |
| 28/08/2004 | B24104.007 | 15 | 105 | 12 | 60 | NJ24104.007 | NZ24104.007 | 08280000 | | 73 files |
| 29/08/2004 | B24204.007 | 14 | 98 | 11 | 56 | | | 08290000 | | 91 files |
| 30/08/2004 | B24304.007 | 17 | 119 | 9 | 45 | | | 08300000 | | 90 files |
| 31/08/2004 | B24404.007 | 24 | 168 | 9 | 45 | | | 08310000 | | 93 files |


Vertical Velocity
Vertical Velocity
10
0
-10
-20
-30
-40
-50
-60
-70
96000
96500
97000
97500
98000
98500


altitude
altitude above MSL (m)
40000
35000
30000
25000
20000
15000
10000
5000
0
96000
96500
97000
97500
98000
98500
GPS time in seconds from midnight -1st day

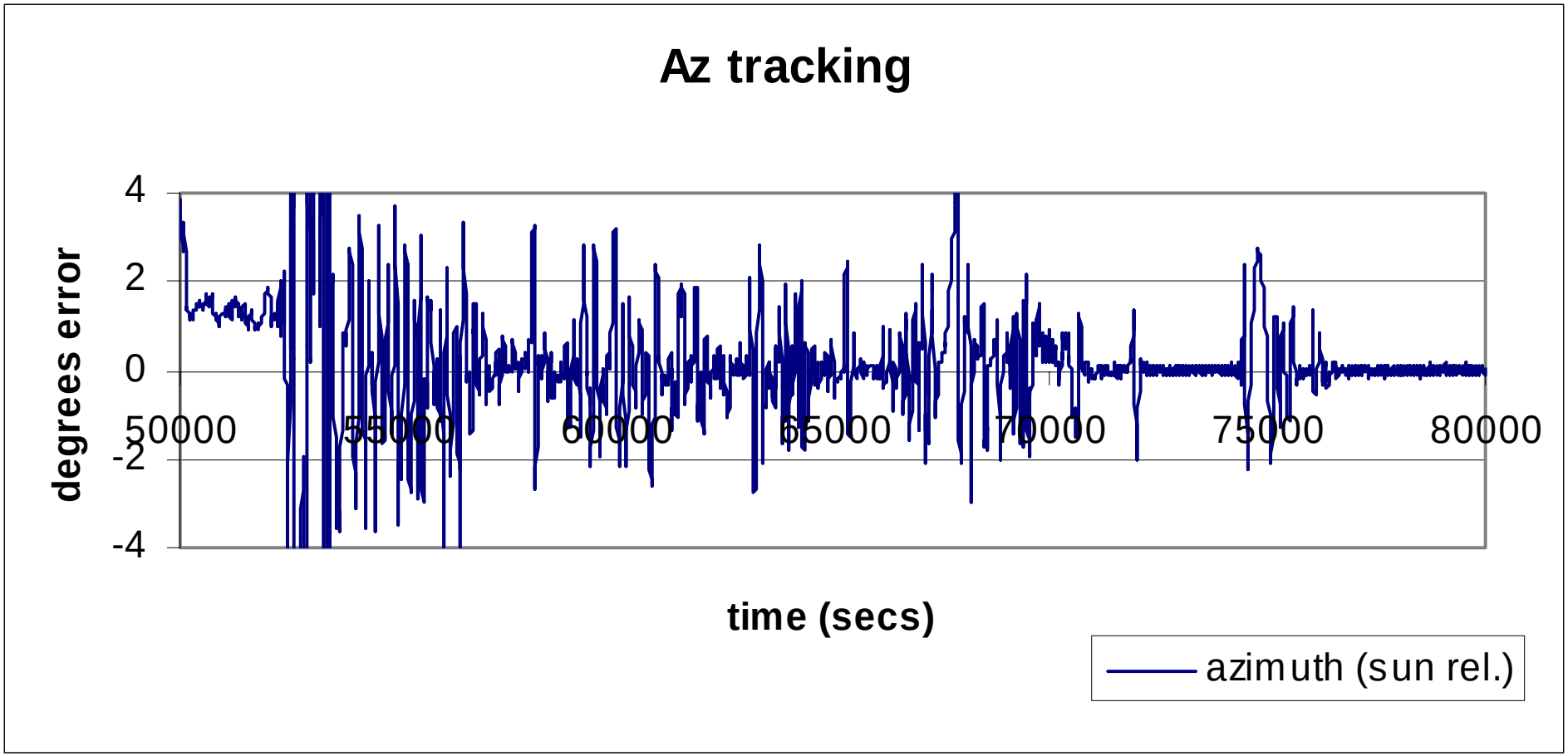
# Pointing System

Jim Drummond

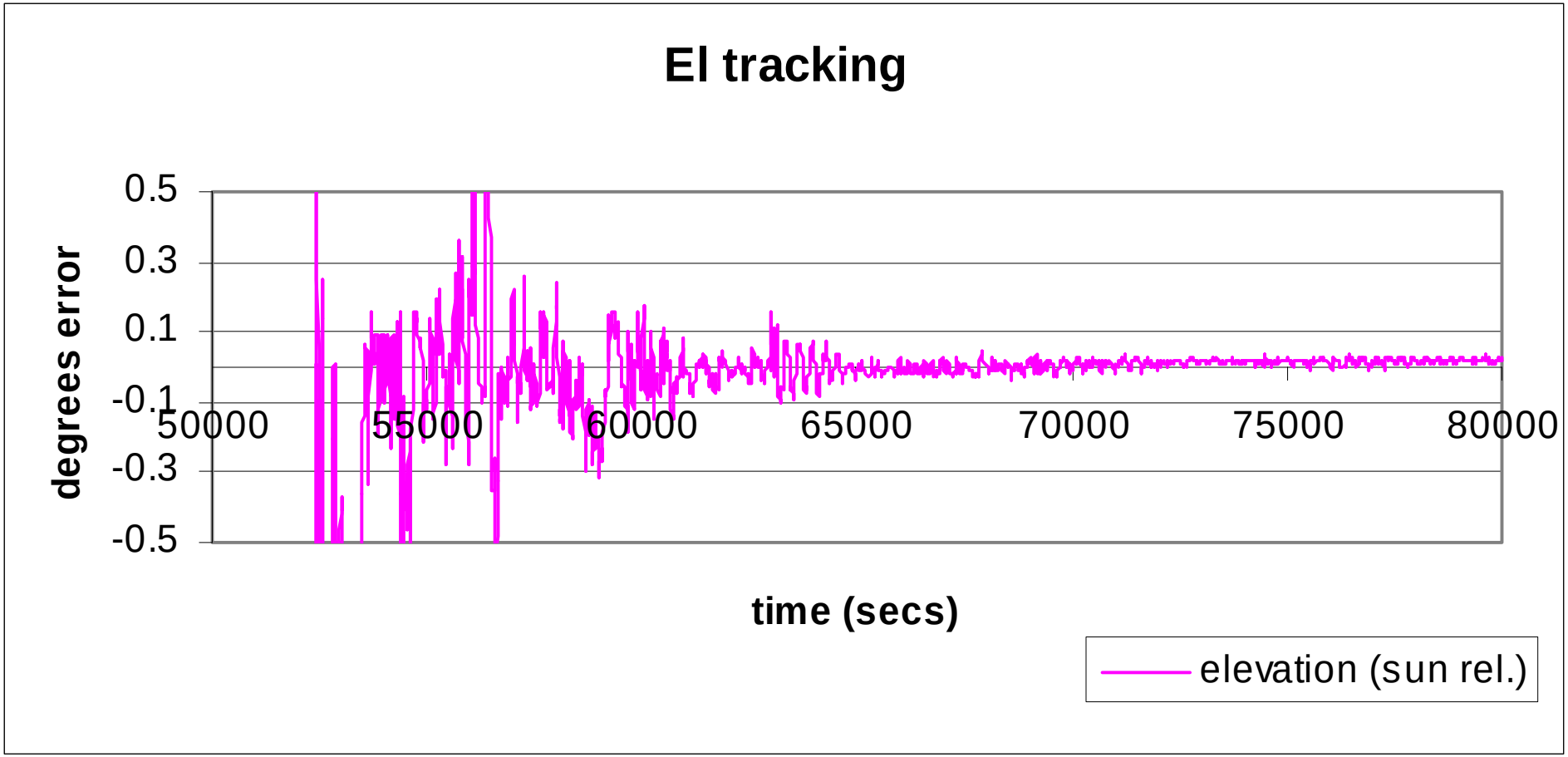
# Pre-Flight Comments

- Hanging tests were very useful for tuning performance
  - Four was probably too large a number
- There was conflict between payload and instruments for calibration and alignment
- Software still needs some work to be “user-friendly”

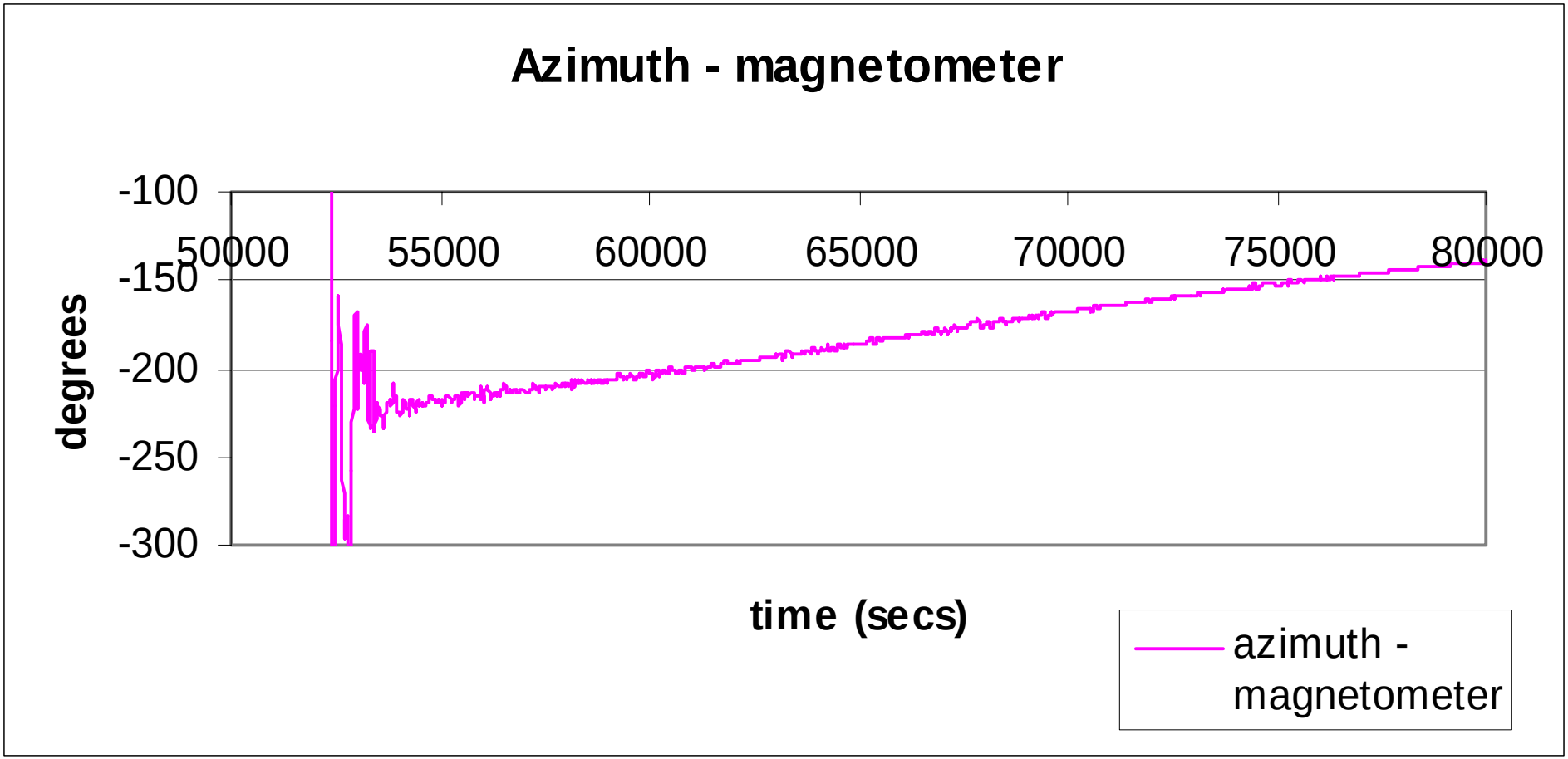
# Azimuth


Az tracking
degrees error
4
2
0
-2
-4
50000
55000
60000
65000
70000
75000
80000
time (secs)
azimuth (sun rel.)

# Elevation


El tracking
degrees error
0.5
0.3
0.1
-0.1
-0.3
-0.5
50000
55000
60000
65000
70000
75000
80000
time (secs)
elevation (sun rel.)

# Magnetometer



# Performance Points

- Azimuth was within 4 degrees (3 sigma) for flight
- Elevation was within 0.1 degrees (3 sigma) for flight
- Some tuning at altitude would have been beneficial
- Not enough temperature sensors
- Need better sun shielding

# Thoughts

- Instruments need their own “delta trackers” for alignment and calibration
  - Limited azimuth, full elevation
  - Unties the instruments from the payload
- Need better way of loading
  - Limbscan sequences
  - Schedules
- Needs some more tuning