Instrumental and Methodological Developments in UV Research

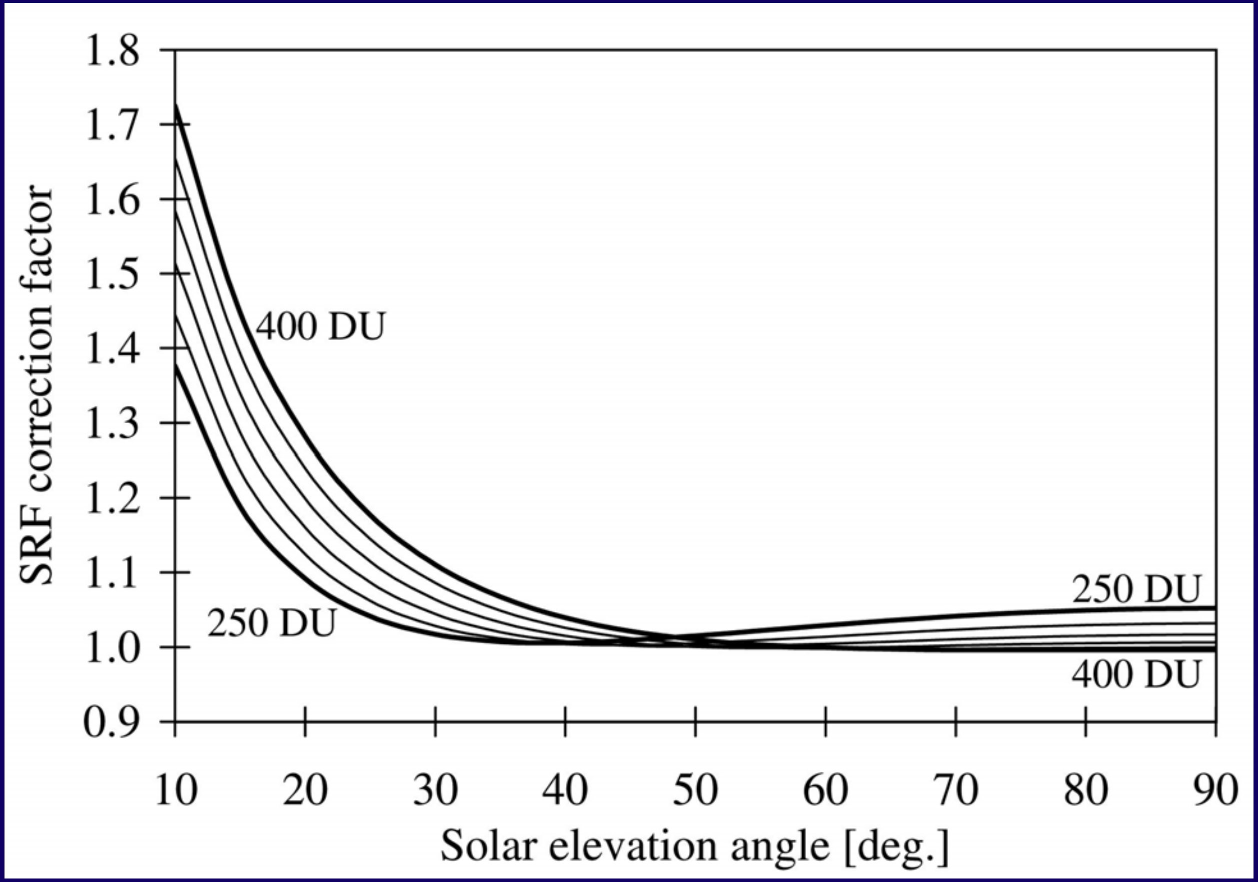
Germar Bernhard
Biospherical Instruments Inc, San Diego, CA

- Instrumental Developments
- Intercomparisons
- Correction Methods
- Methods for Interpreting UV Data

Single-Channel Broadband Radiometers

From: COST/LAP/WMO intercomparison, Thessaloniki, Greece, in 1999

Single-Channel Broadband Radiometers

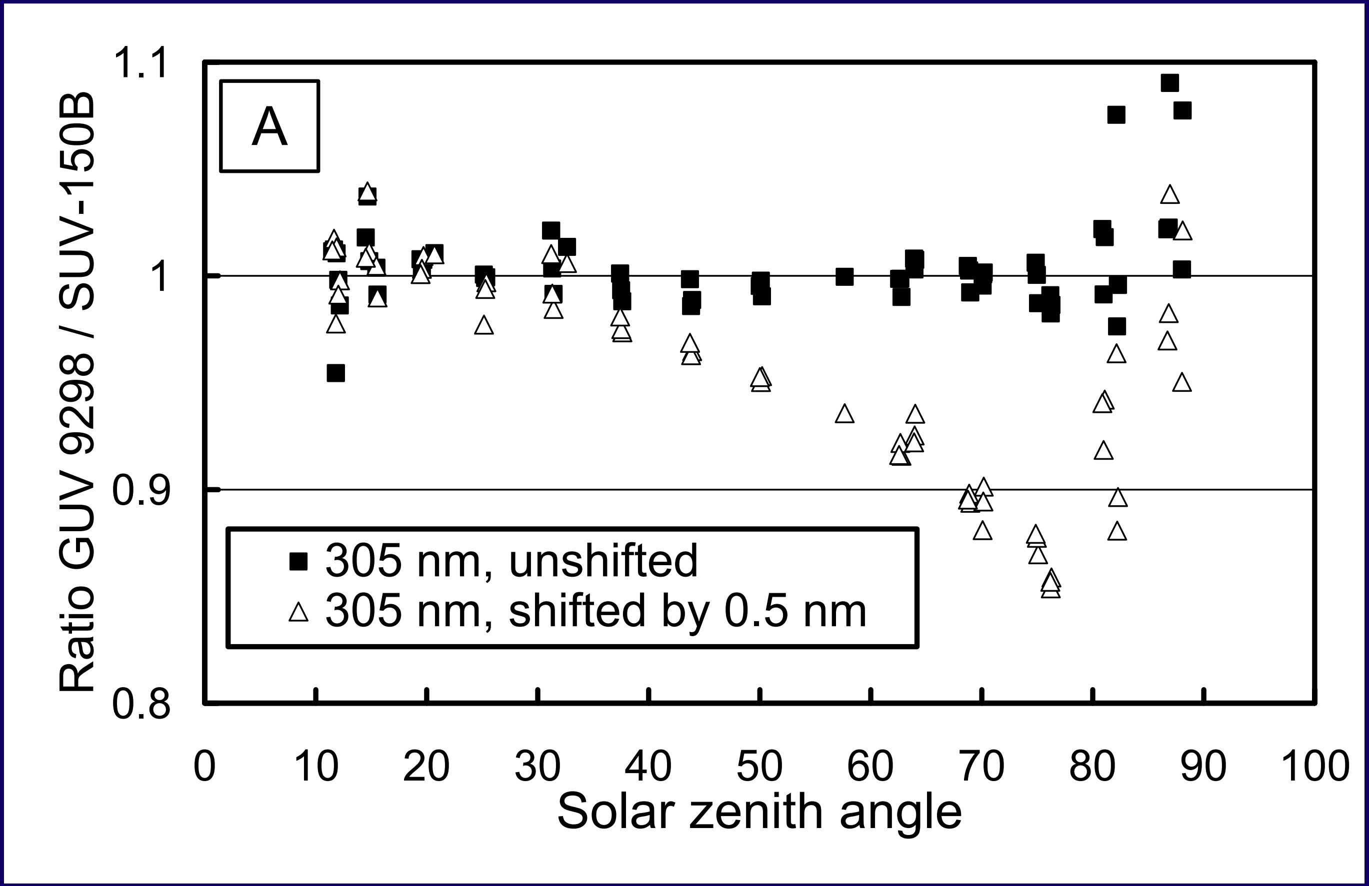


From: Leszczynski K., K. Jokela, L. Ylianttila, R. Visuri, and M. Blumthaler, Report of the WMO/STUK intercomparison of erythemally weighted solar UV radiometers, WMO-GAW report No.112, 1995.

Multichannel Filter Instruments

FARIN intercomparison, Oslo, Norway, 2005

Multichannel Filter Instruments



From: G. Bernhard, C.R. Booth, and J.C. Ehramjian, Real-time UV and column ozone from multi-channel UV radiometers deployed in the National Science Foundation's UV monitoring network, Optical Engineering, 44(4), 041011-1 - 041011-12, 2005.

Multichannel Filter Instruments

Calibrations methods:

Raw data → 1st guess Erythemal Irradiance → Erythemal Irradiance
↑ Comparison with Spectroradiometer; ↑ Correction for SZA, Ozone

Raw data → Spectral Irradiance → Erythemal Irradiance
↑ Comparison with Spectroradiometer; ↑ Inversion

Raw data → "Response weighted irradiance" → Erythemal Irradiance
↑ Spectral Response Functions; ↑ Inversion

Raw data → Direct irradiance → Global irradiance → Erythemal Irradiance
↑ Langley Plots; ↑ Inversion

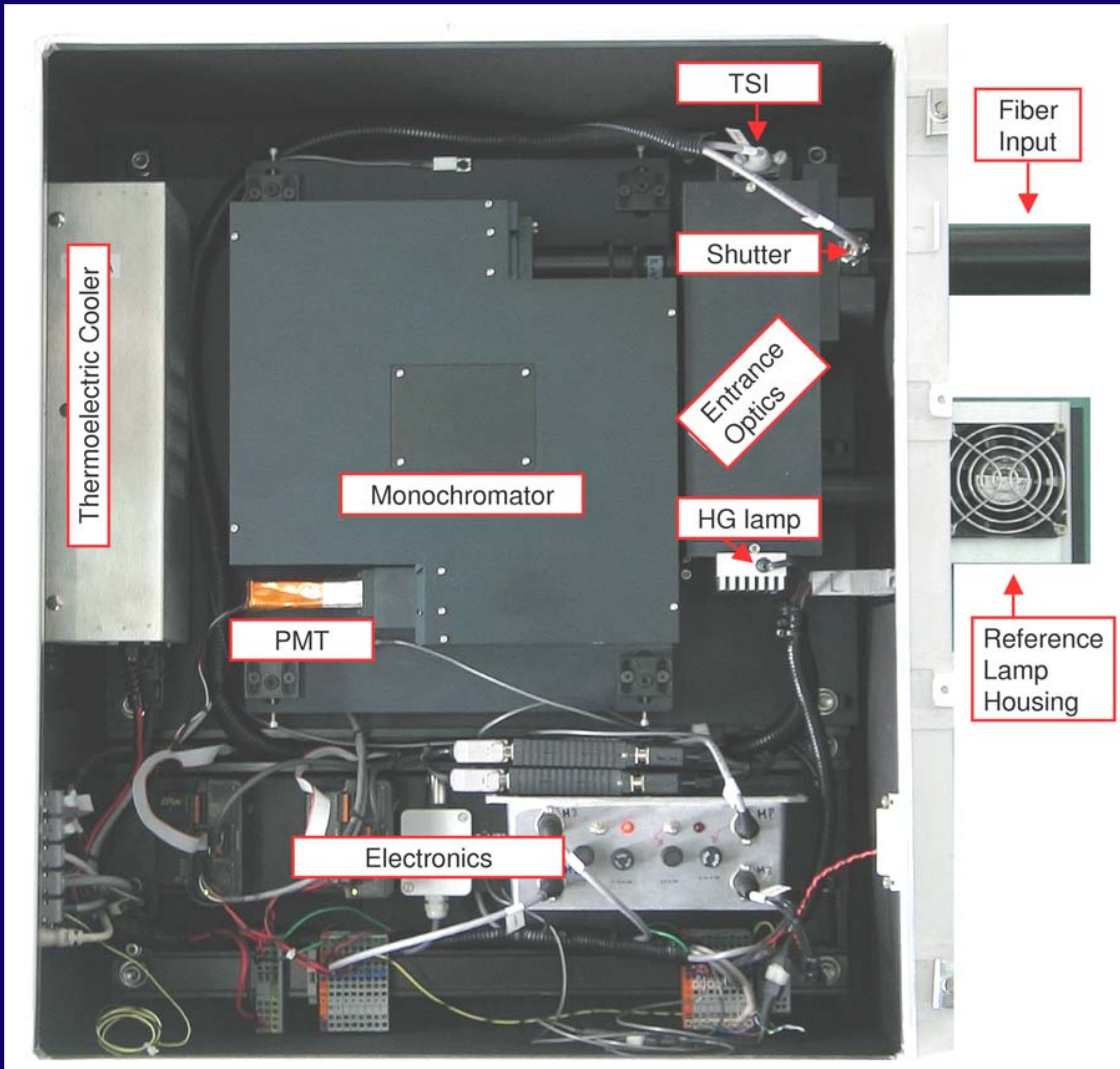
Raw data → Reconstructed Spectrum → Erythemal Irradiance
↑ Inversion; ↑ Weighting

Multichannel Filter Instruments

New developments

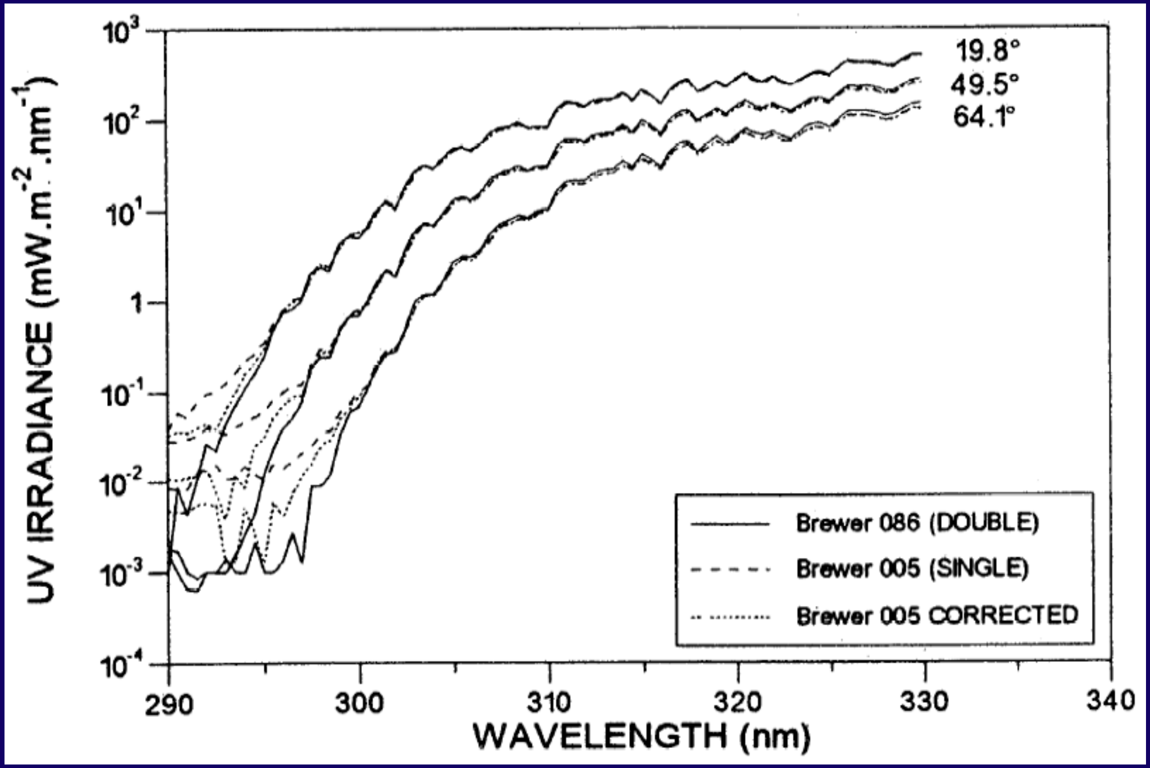
- Miniaturization
- New geometries
- Larger dynamic range
- High sampling rates (>15 Hz)
- Improved data reduction procedures

Spectroradiometers



SUB-150 Spectroradiometer at Summit, Greenland

Stray Light Correction



From: Bais, A. F., C. S. Zerefos, C. T. McElroy, Solar UVB measurements with the double- and single-monochromator Brewer Ozone Spectrophotometers, *Geophys. Res. Lett.*, *23*(8), 833-836, 10.1029/96GL00842, 1996.

Correction is done by "<u>subtracting the mean apparent irradiance measured between 290 and 292.5 nm from the whole spectrum</u>."

Stray Light Correction

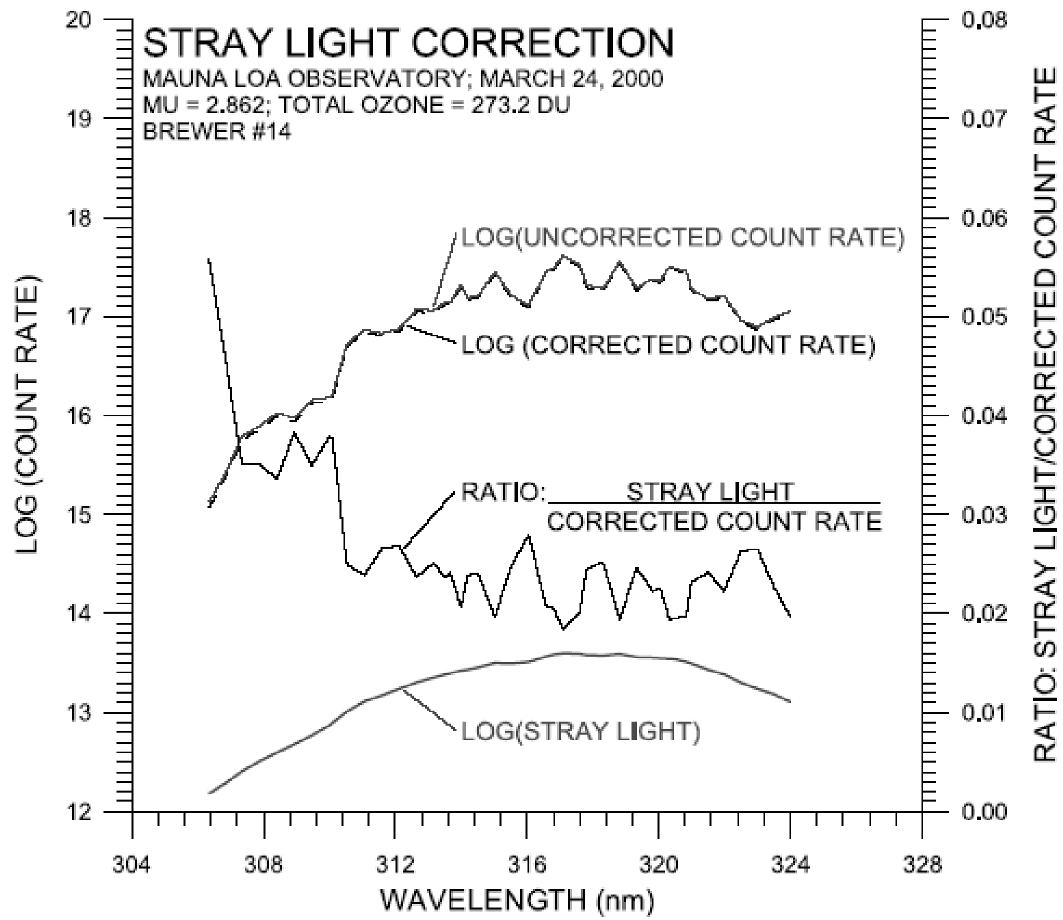
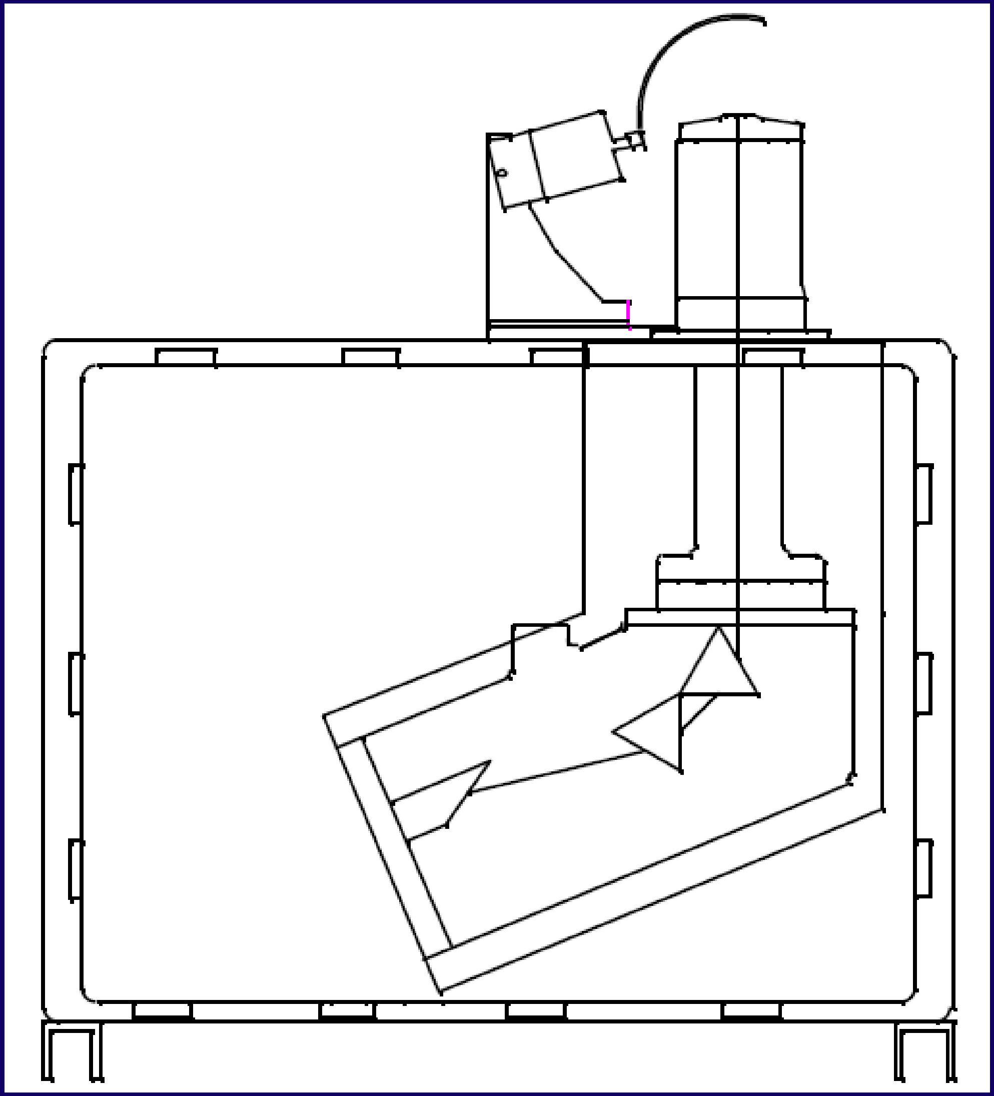


Figure 3. Example of stray light correction for a spectrum measured by Brewer instrument 14. The relative contribution of stray light as a function of wavelength is also shown.

From: Kerr J. B., New methodology for deriving total ozone and other atmospheric variables from Brewer spectrophotometer direct sun spectra, J. Geophys. Res., 107 (D23), 4731, doi:10.1029/2001JD001227, 2002.

Correction based on information gained from scanning the 325 nm line of the helium cadmium laser.

UV-Rotating Shadowband Spectroradiometer (UV-RSS)



Published Applications:
Global, direct and diffuse irradiance, aerosol retrievals, determination of extraterrestrial solar spectrum, column water vapor, photon pathlength, cloud optical depth

From: Yankee Environmental Systems Inc., product description

UV-Rotating Shadowband Spectroradiometer (UV-RSS)

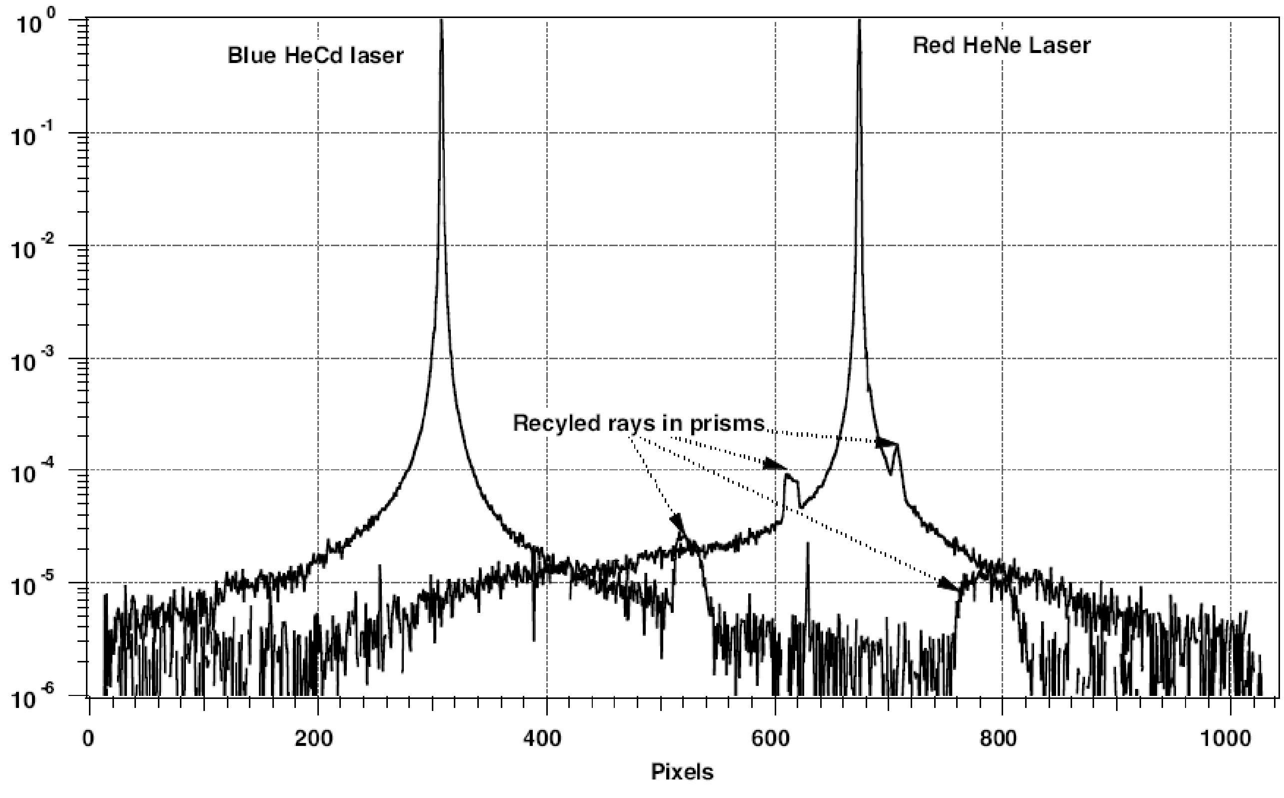
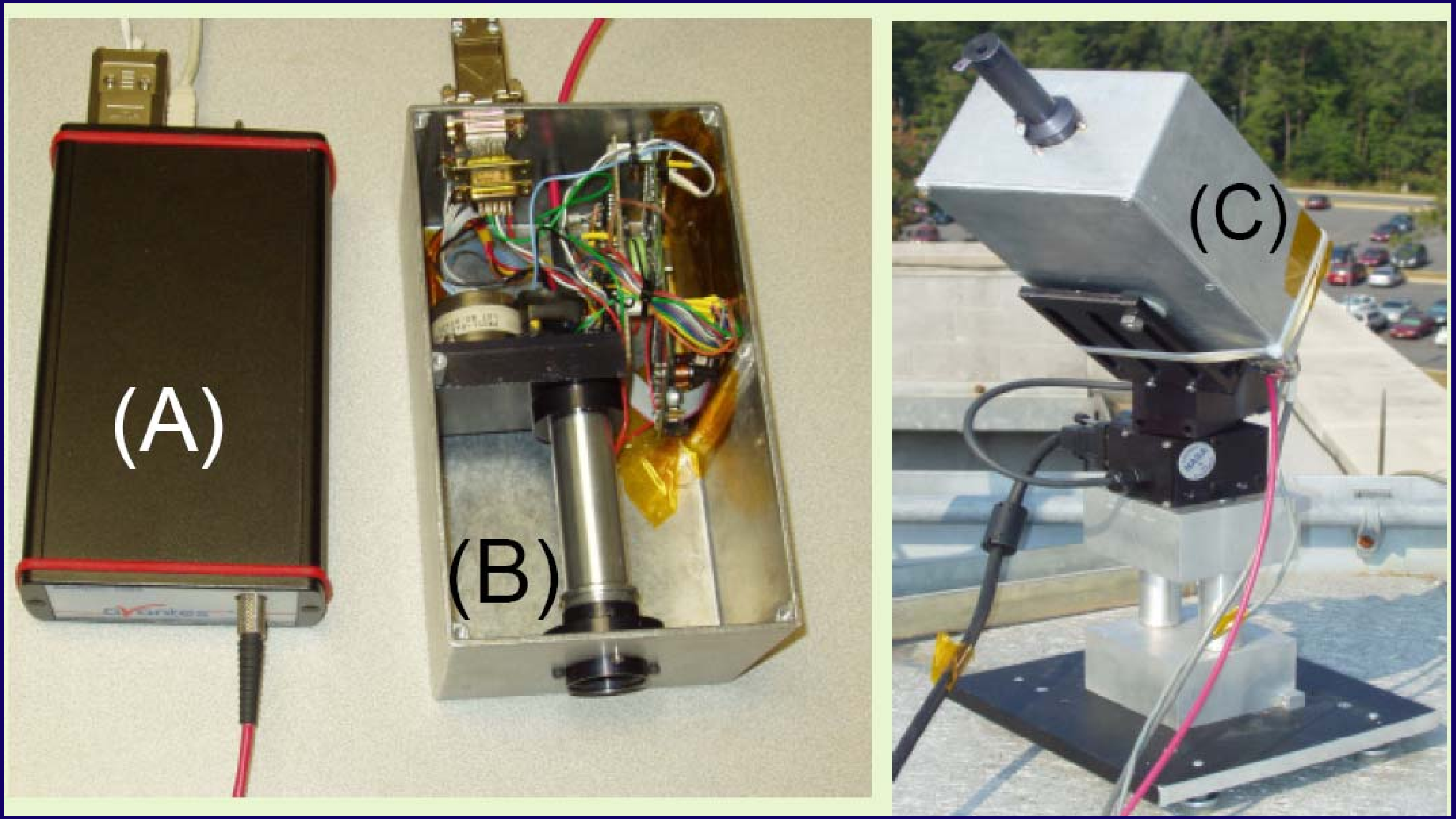


Figure 17: Slit scattering function.

From: P. W. Kiedron, L. Harrison, J. J. Michalsky, J. Joseph J. A. Schlemmer, J. L. Berndt, Data and signal processing of rotating shadowband spectroradiometer (RSS) data Proc. SPIE Vol. 4815, p. 58-72, 2002 .

PAN-1 CMOS spectrometer



From: J. Herman, A. Cede, N. Abuhassan, and M.Tzortziou, DS-DOAS: An Accurate Direct-Sun Method for Measuring NO2 Total Column Content Using a Brewer Monochromator and a Small Spectrometer, Poster presented at Aura Science and Validation Team Meeting NCAR Center Green Facility, Boulder, CO, September 11-15, 2006

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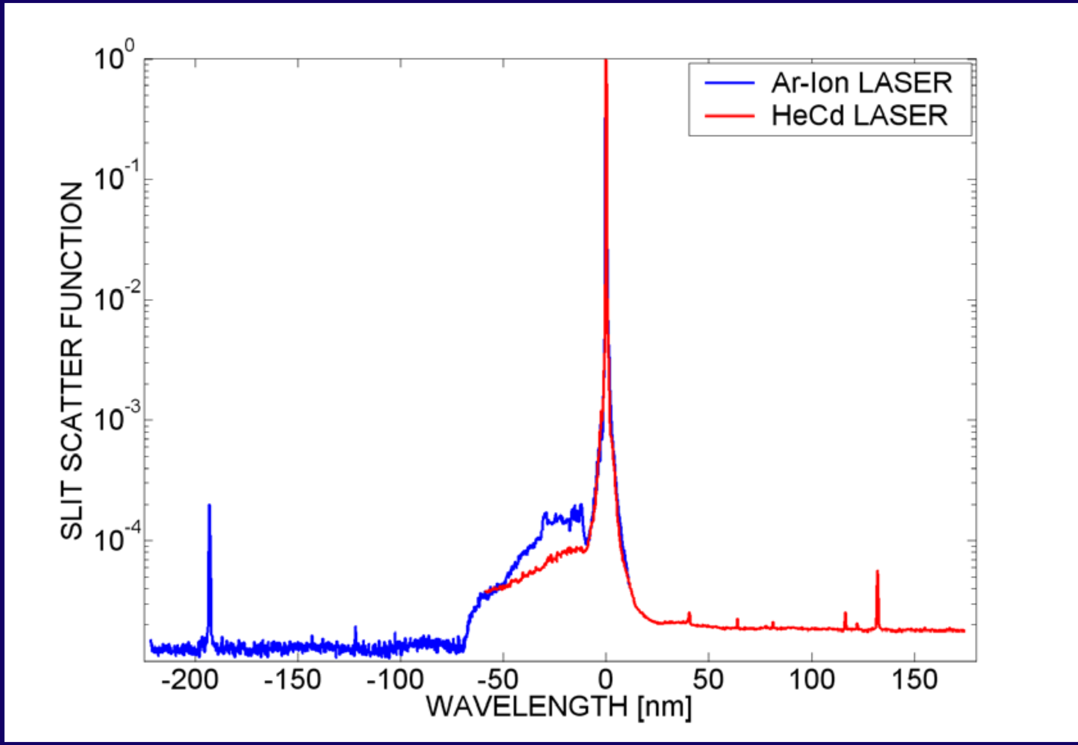

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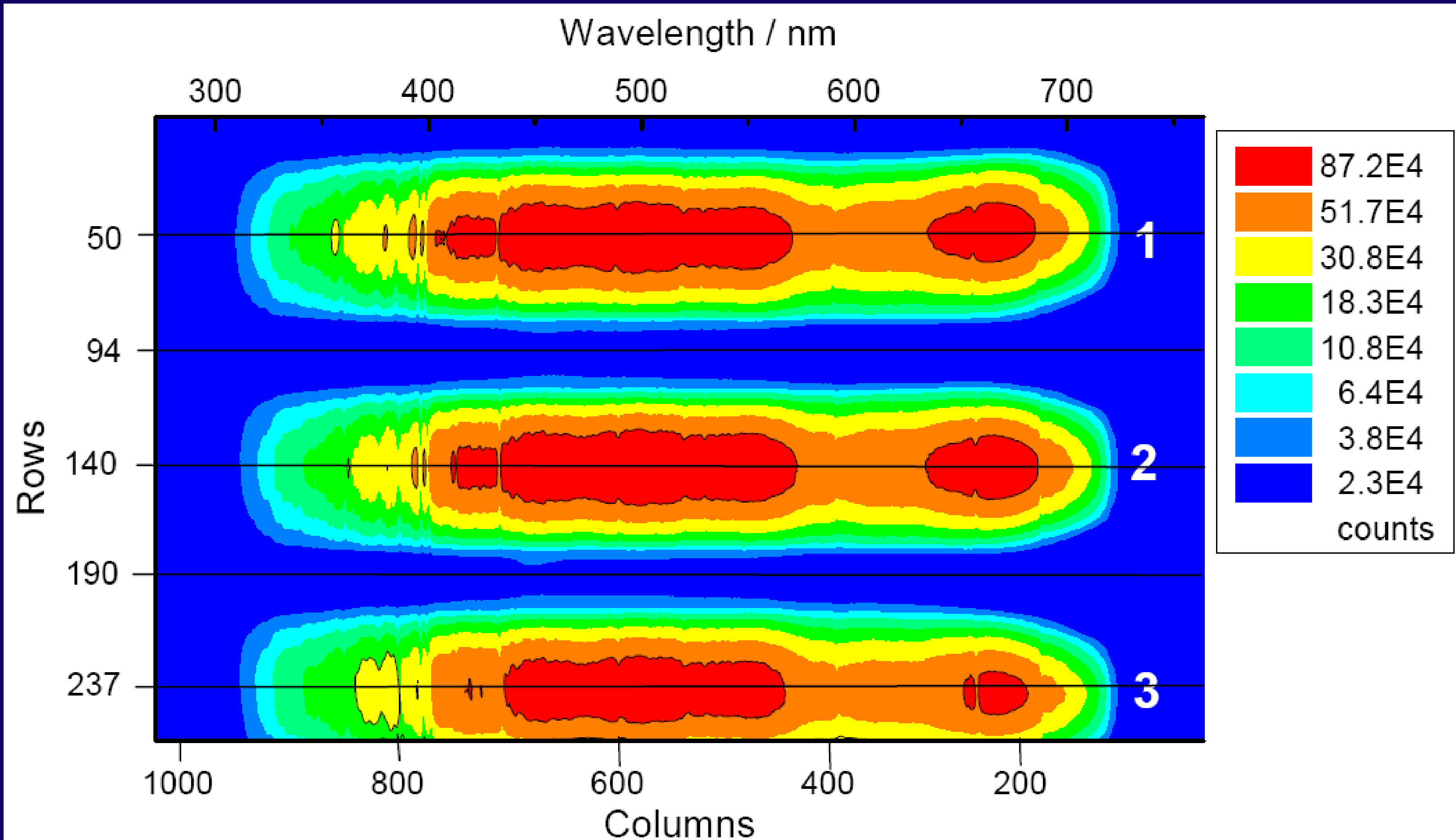
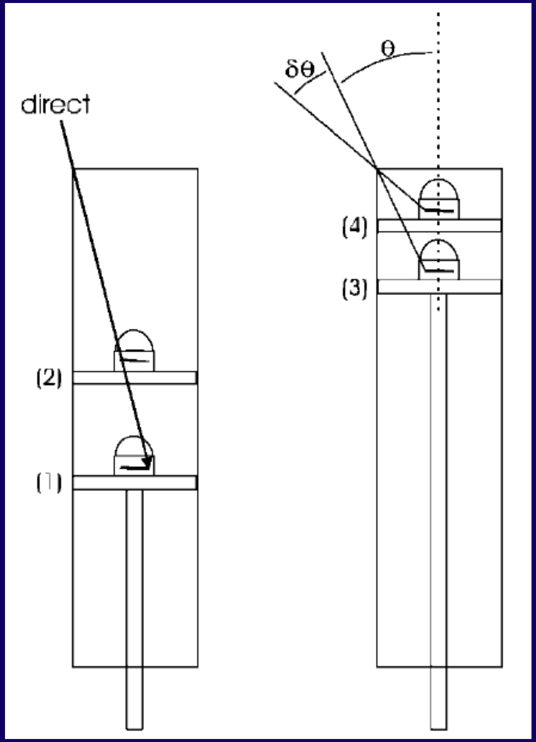
CCD-based Spectrograph



From: E. Eckstein, D. Perner, Ch. Brühl, and T. Trautmann, A new actinic flux 4pi-spectroradiometer: instrument design and application to clear sky and broken cloud conditions, *Atmos. Chem. Phys.*, *3*, 1965-1979, 2003.

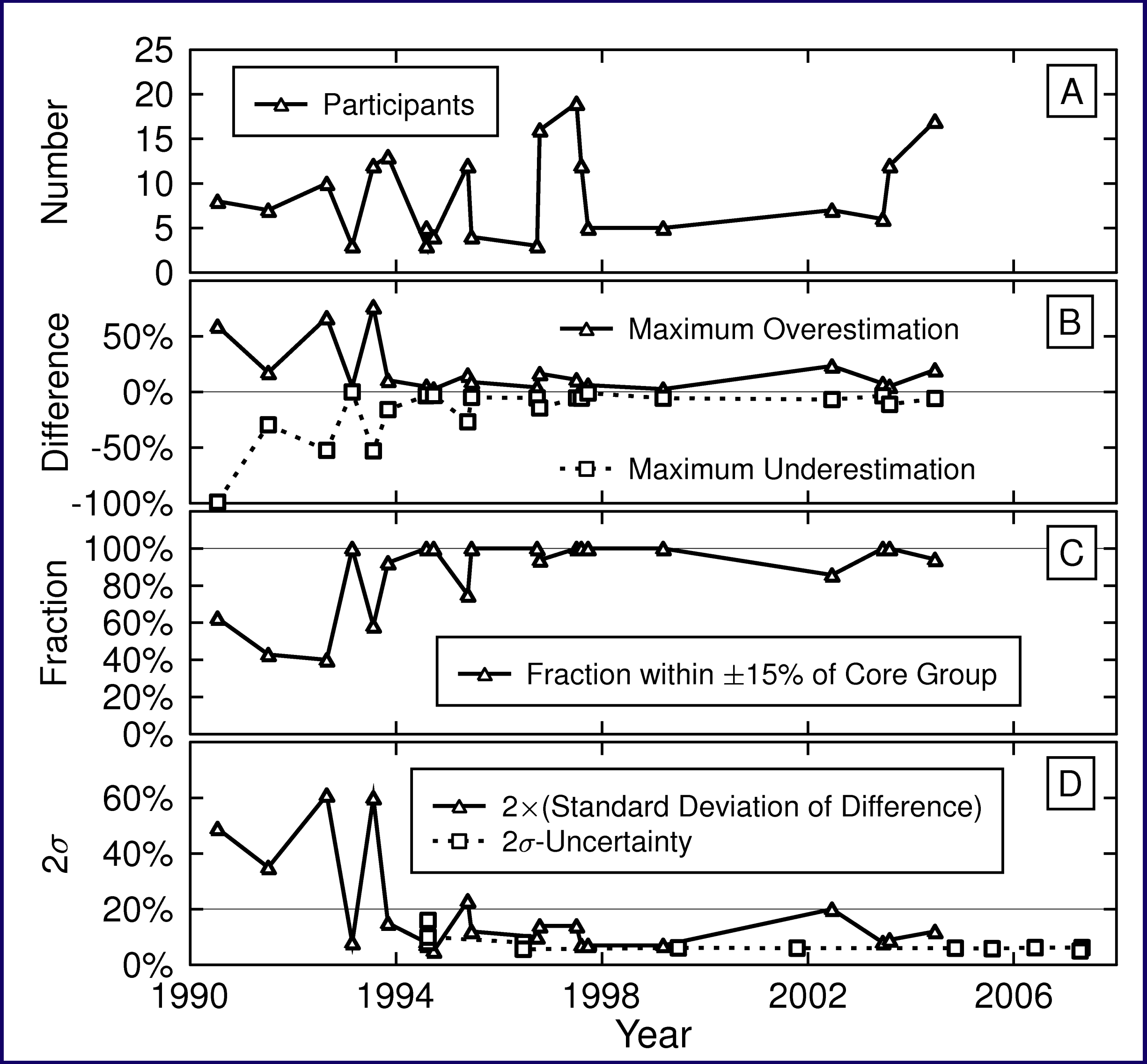
New “front ends”

- Development of input optics with small cosine error
- Actinic flux
- Radiation on inclined surfaces
- Sky scanners (also including polarization)
- “Variable Sky Platform” ⟶



From: K. P. Kuchinke and Kurt S. Fienberg, Using shaded filter instruments for measurements of sky radiance: retrieval of the apparent sky-view factor from ultraviolet radiation measurements, *Appl. Opt.*, *45*(27), 2006.

Results of 21 Intercomparisons



Deterioration of Calibration Standards

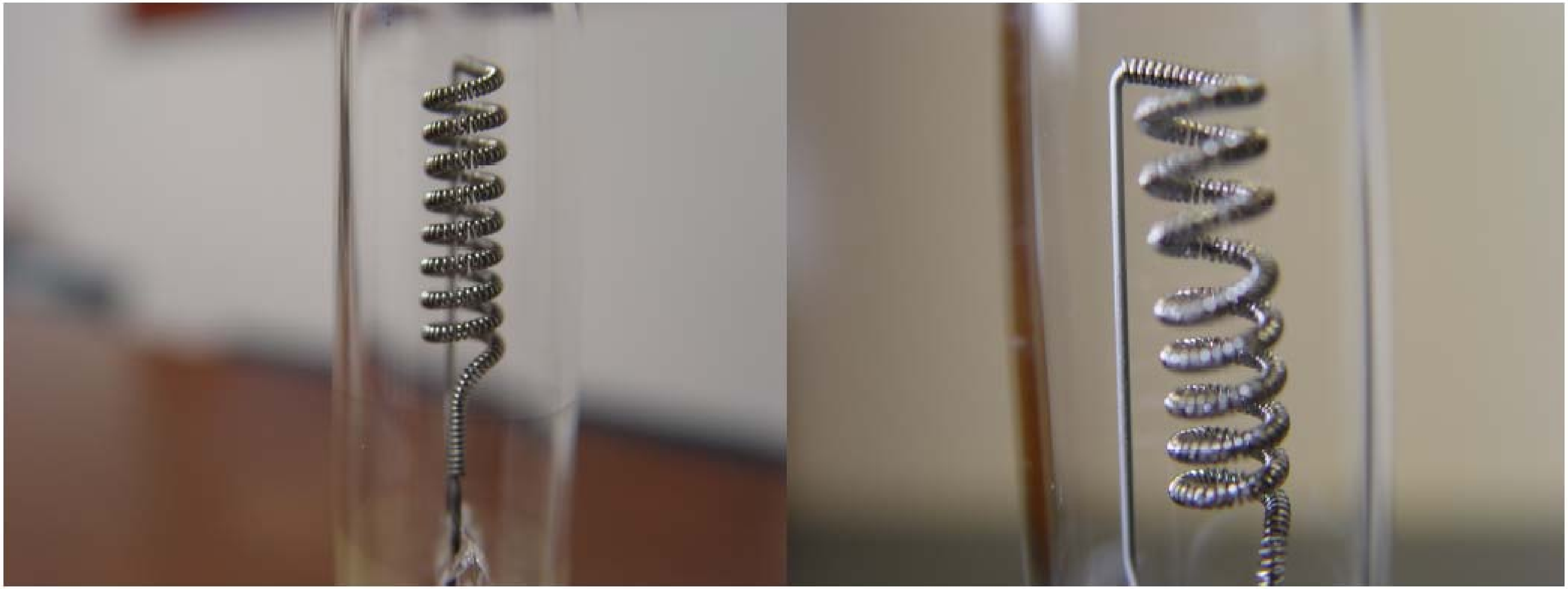


Figure 2a. *Normal evenly spaced coiled-coil filament* **Figure 2b.** *Abnormal warped tungsten filament*

From: P. Disterhoft, Stability characteristecs of 1000 watt FEL-type QTH lamps during the seasoning and screening process, *Proc. of SPIE*., 5886, G1-G12, 2005.

Need for lower uncertainty

- Calculation of extraterrestrial spectrum via Langley plots
- Satellite validation
- Model validation
- Process studies
- Simultaneous retrieval of albedo and cloud optical depth

Simultaneous Retrieval of Albedo and Cloud OD

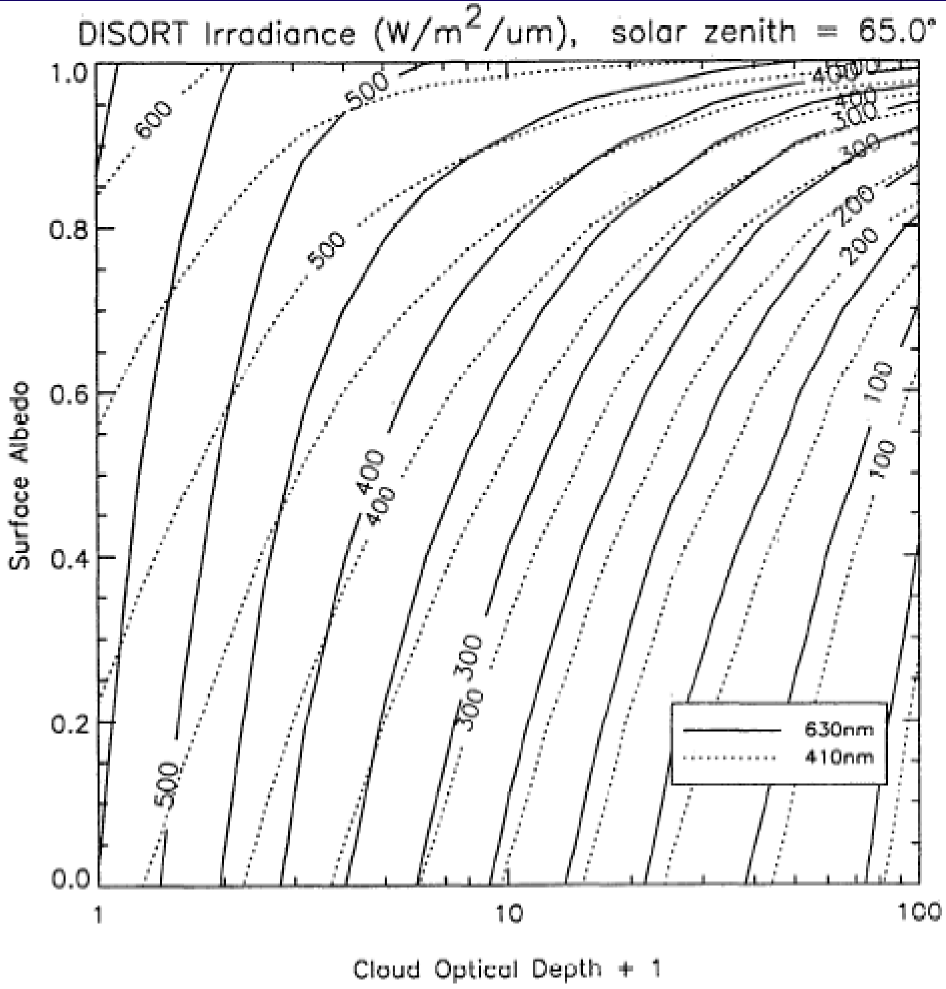


Figure 2. DISORT model calculations of downwelling surface irradiance of the 630-nm (solid) and 410-nm (dashed) bands for a solar zenith angle of 65°.

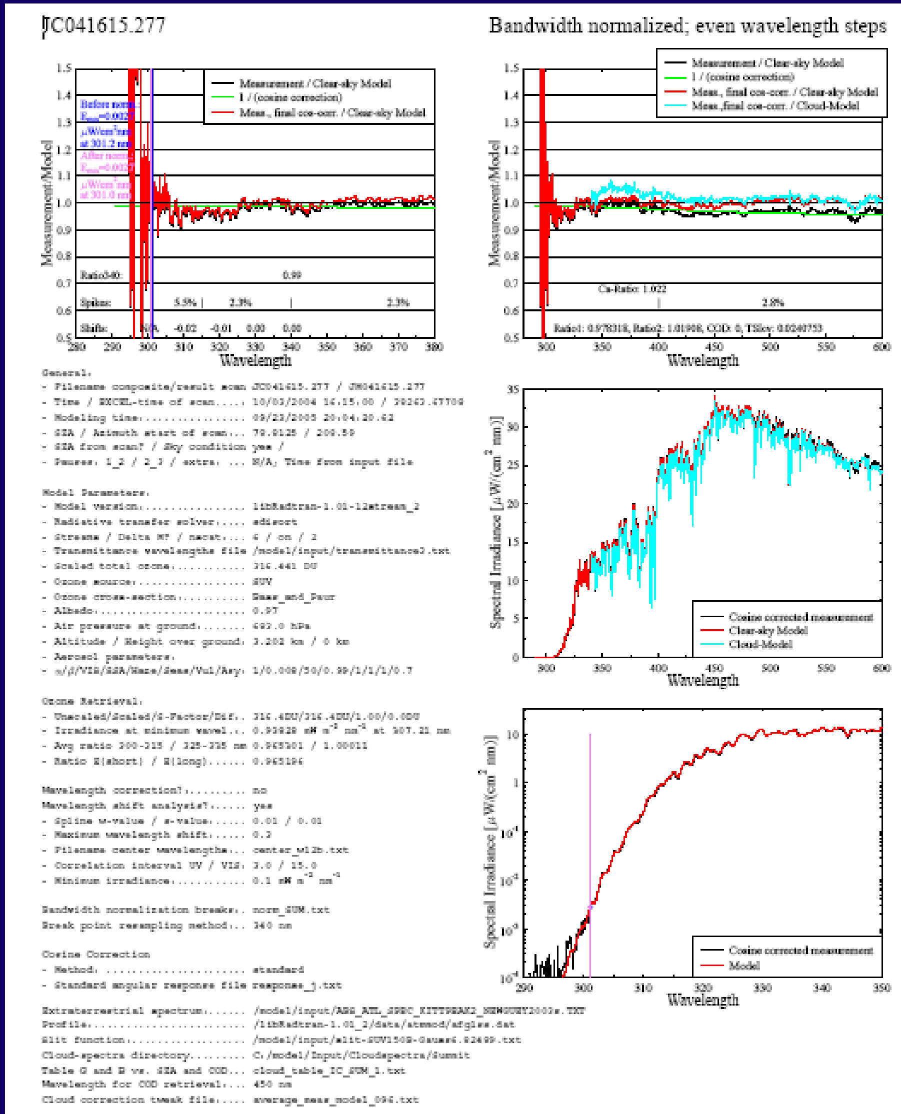
"This high sensitivity of optical thickness to calibration error is rather disturbing, considering the fact that it is extremely difficult to calibrate instruments to better than ±5%."

From: P. Ricchiazzi, C. Gautier, and D. Lubin, Cloud scattering optical depth and local surface albedo in the Antarctic: Simultaneous retrieval using ground-based radiometry, *J. Geophys. Res.*, *100*(D10), 21,091-21,104, 1995

Correction and Analysis Methods

Correction	SHICrivm	NSF Version 2
Cosine error correction		✓
Azimuth error correction		✓
Wavelength shift determination	✓	✓
Wavelength shift correction	✓	✓
Model spectra for clear skies	(✓)	✓
Model spectra for cloudy skies		✓
Normalization to standard bandpass	✓	✓
Detection of anomalies, spikes	✓	✓
Calculation of “start” wavelength	✓	✓
Calculation of transmission, cloud OD	✓	✓
Calculation of effective UV	✓	✓
GUI	✓	

NSF Version 2 Reports


JC041615.277

Bandwidth normalized; even wavelength steps

General:
- Filename composite/result scan JC041615.277 / JM041615.277
- Time / EXCEL-time of scan..... 10/03/2004 16:15:00 / 38263.67708
- Modeling time................. 09/23/2005 20:04:20.62
- SZA / Azimuth start of scan... 79.8125 / 209.59
- SZA from scan? / Sky condition yes /
- Pauses: 1_2 / 2_3 / extra: ... N/A; Time from input file

Model Parameters:
- Model version................. libRadtran-1.01-12stream_2
- Radiative transfer solver..... sdisort
- Streams / Delta M? / nscat.... 6 / on / 2
- Transmittance wavelengths file /model/input/transmittance2.txt
- Scaled total ozone............ 216.441 DU
- Ozone source.................. SUV
- Ozone cross-section........... Bass_and_Paur
- Albedo........................ 0.97
- Air pressure at ground........ 692.0 hPa
- Altitude / Height over ground: 3.202 km / 0 km
- Aerosol parameters:
- α/β/VIS/SSA/Haze/Seas/Vul/Asy: 1/0.008/50/0.99/1/1/1/0.7

Ozone Retrieval:
- Unscaled/Scaled/S-Factor/Dif.. 216.4DU/216.4DU/1.00/0.0DU
- Irradiance at minimum wavel... 0.93928 mW m⁻² nm⁻¹ at 307.21 nm
- Avg ratio 300-315 / 325-335 nm 0.965301 / 1.00011
- Ratio E(short) / E(long)...... 0.965196

Wavelength correction?......... no
Wavelength shift analysis?...... yes
- Spline w-value / s-value...... 0.01 / 0.01
- Maximum wavelength shift...... 0.3
- Filename center wavelengths... center_s12b.txt
- Correlation interval UV / VIS: 3.0 / 15.0
- Minimum irradiance............ 0.1 mW m⁻² nm⁻¹

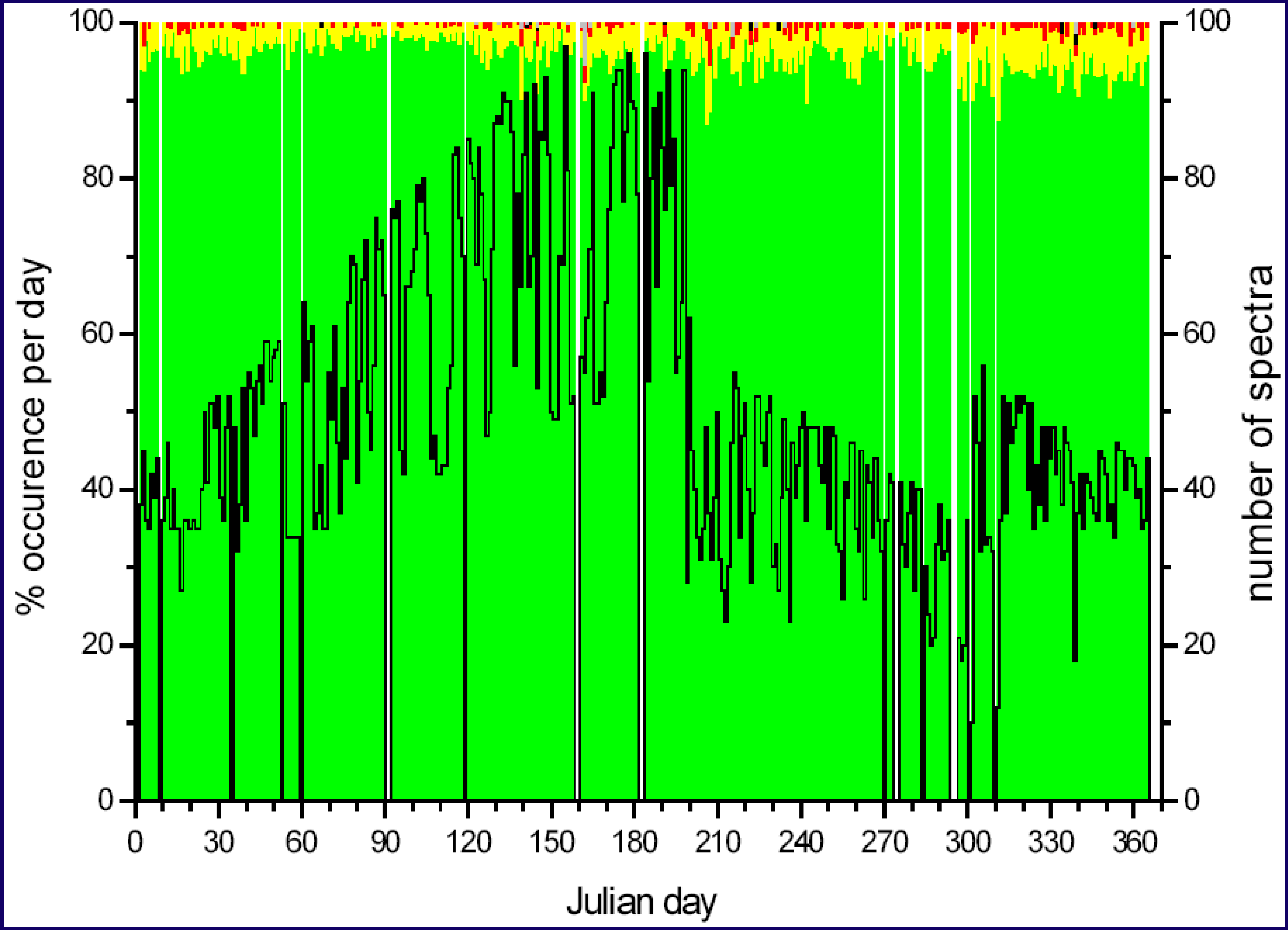
Bandwidth normalization breaks:. norm_SUM.txt
Break point resampling method... 340 nm

Cosine Correction
- Method: .... standard
- Standard angular response file response_j.txt

Extraterrestrial spectrum....... /model/input/ASS_ATL_SREC_KITTPEAK2_NEWSUSY2002s.TXT
Profile......................... /libRadtran-1.01_2/data/atmmod/afglss.dat
Slit function................... /model/input/slit-SUV150B-Gauss6.82499.txt
Cloud-spectra directory......... C:/model/Input/Cloudspectra/Summit
Table G and R vs. SZA and COD... cloud_table_IC_SUM_1.txt
Wavelength for COD retrieval.... 450 nm
Cloud correction tweak file..... average_meas_model_096.txt

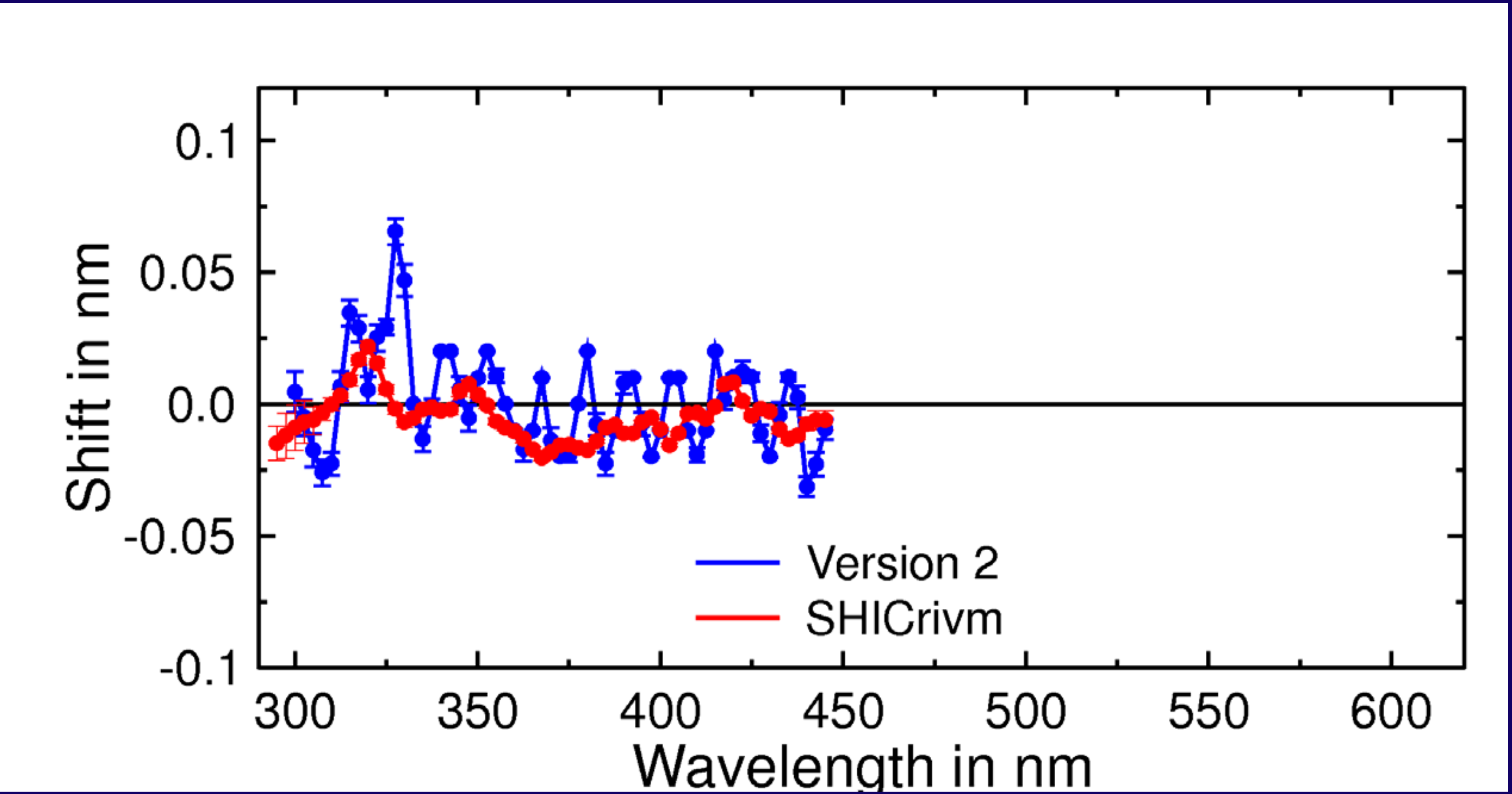
From: NSF Version 2 Network Data, Volume 15, Summit

SHICrivm Flagging



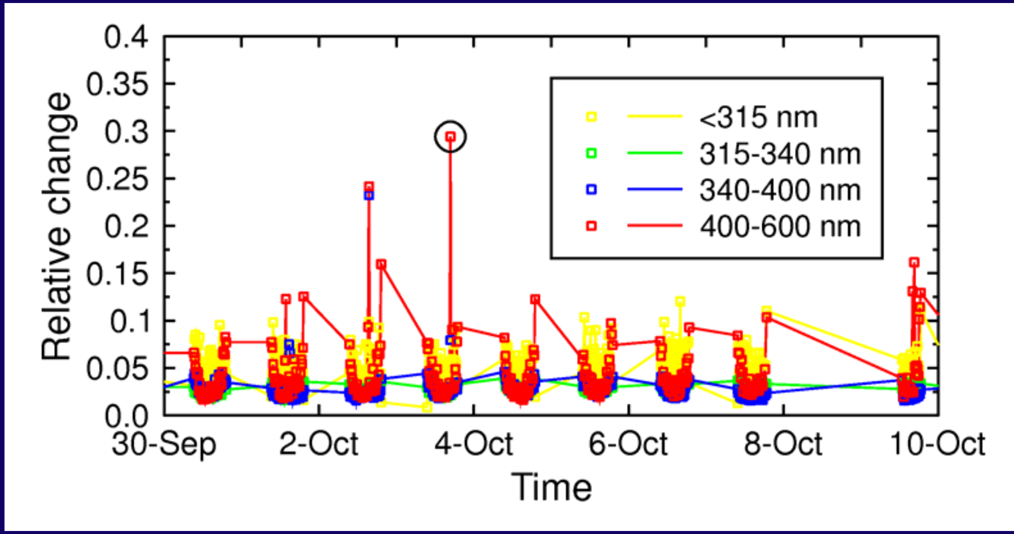
From: http://www.muk.uni-hannover.de/~martin/database.html

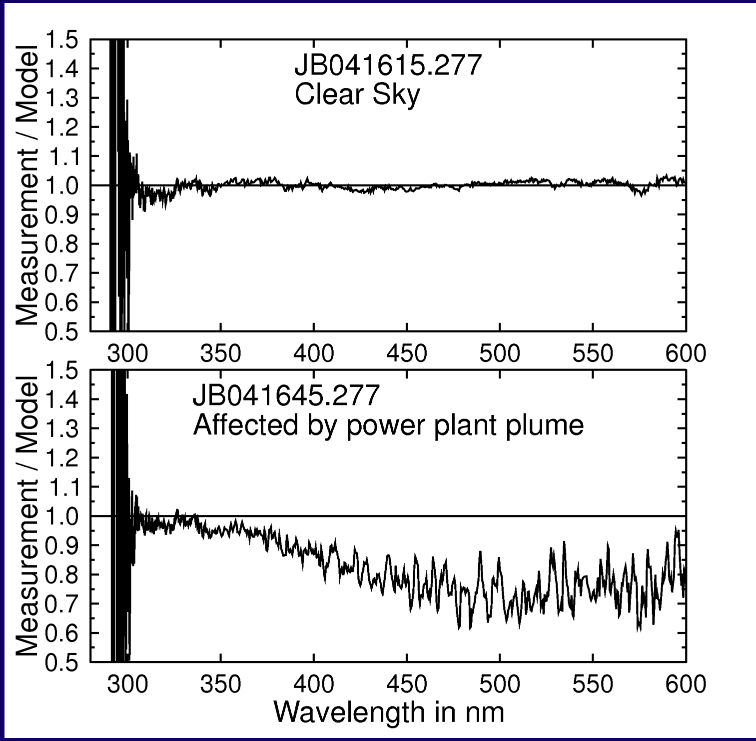
Comparison of Wavelength-Shift Programs



From: G. Bernhard, R. L. McKenzie, M. Kotkamp, S. Wood, C. R. Booth, J. C. Ehramjian, and Paul Johnston, First Comparison of Ultraviolet Spectroradiometers in Antarctica, paper in preparation.

Detection of distorted spectra





From: NSF Version 2 Network Data, Volume 15, Summit

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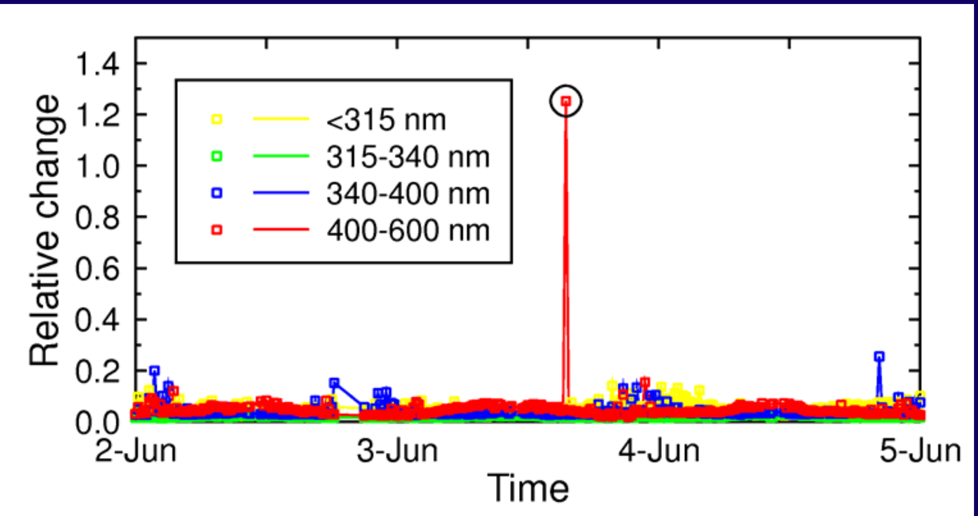
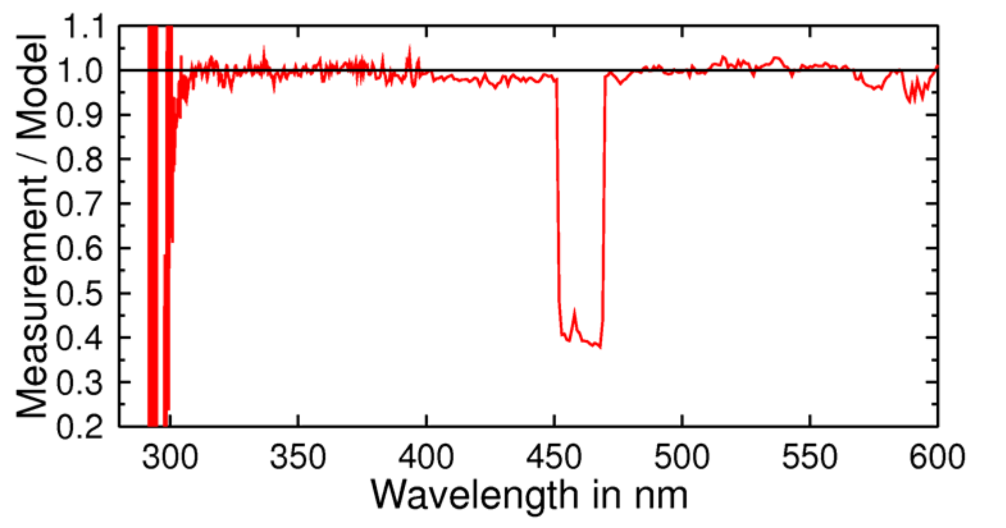
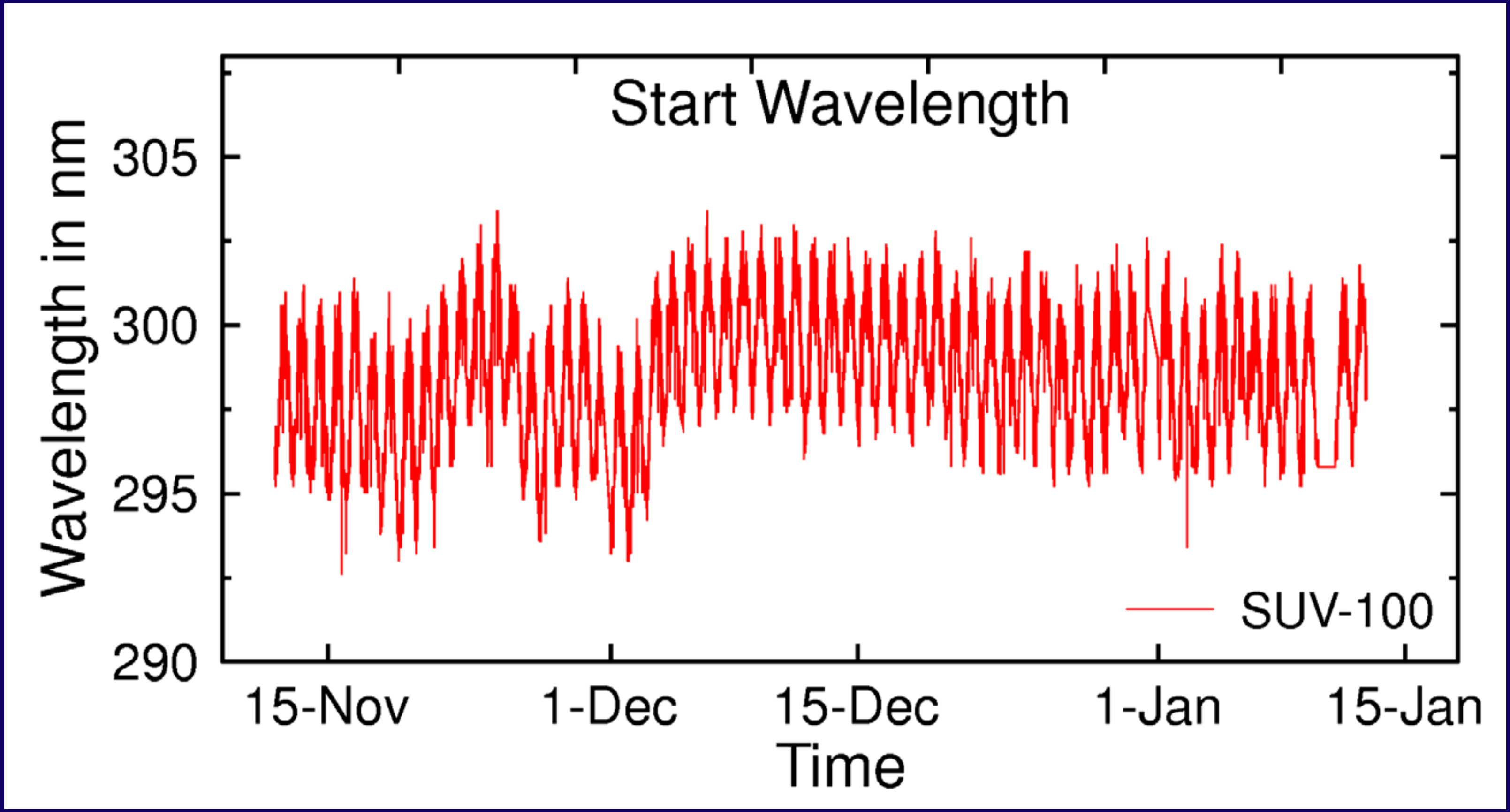




From: NSF Version 2 Network Data, Volume 10, Barrow

Determination start wavelength



From: NSF Version 2 Network Data, Volume 16, McMurdo

Methods for Interpreting UV Data

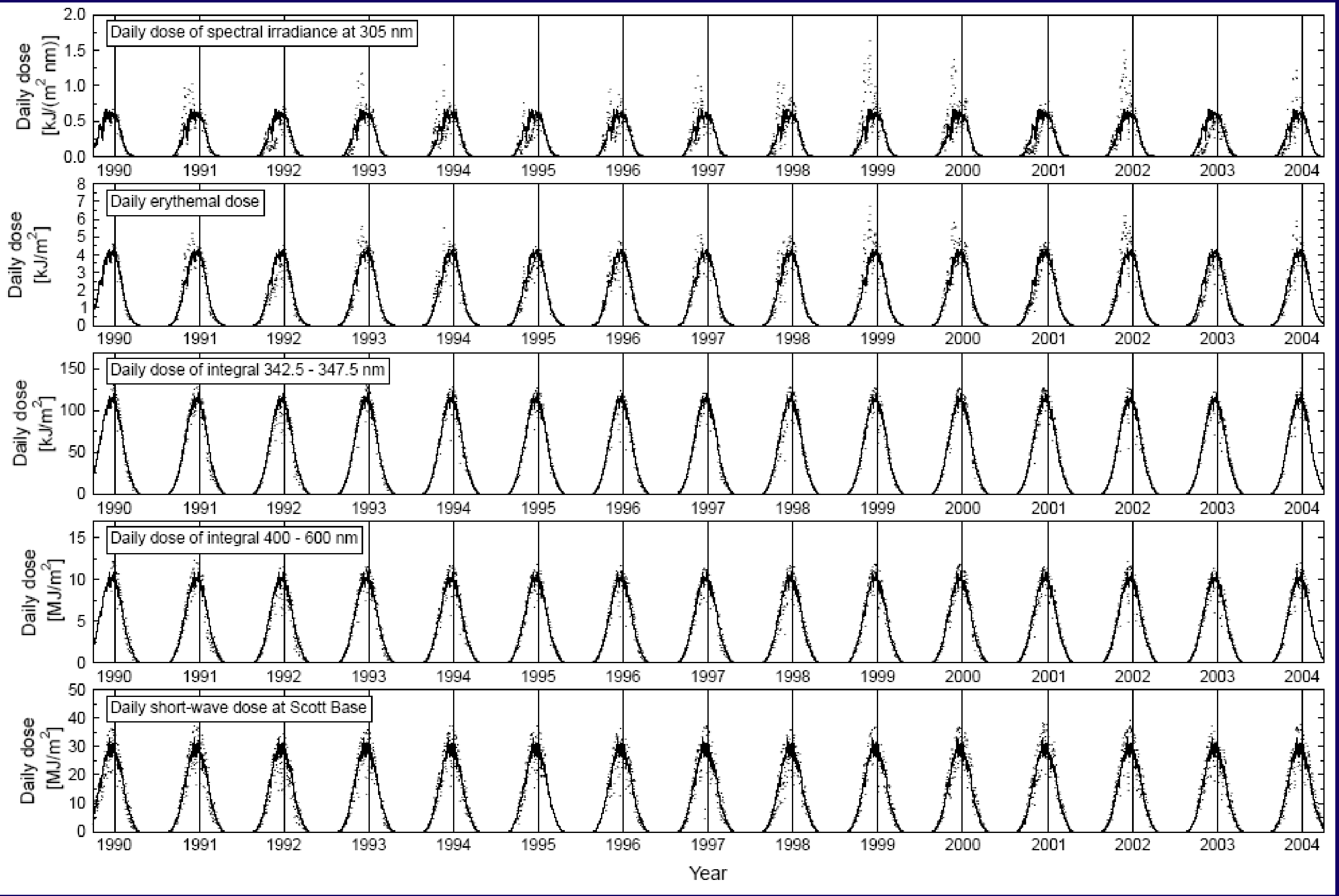
- Statistical methods
  - ➔ Climatological information, geographical differences, trends

- Process studies
  - ➔ Correlation with factors affecting UV
  - ➔ Reconstruction / forecast

- Process studies based on radiative transfer modeling
  - ➔ Model provides reference spectra
  - ➔ Parameters not accessible by measurements

- Retrieval of data products
  - ➔ Total ozone, aerosol OD, effective albedo, actinic flux, effective ozone temperature

UV Climatology at McMurdo, Antarctica



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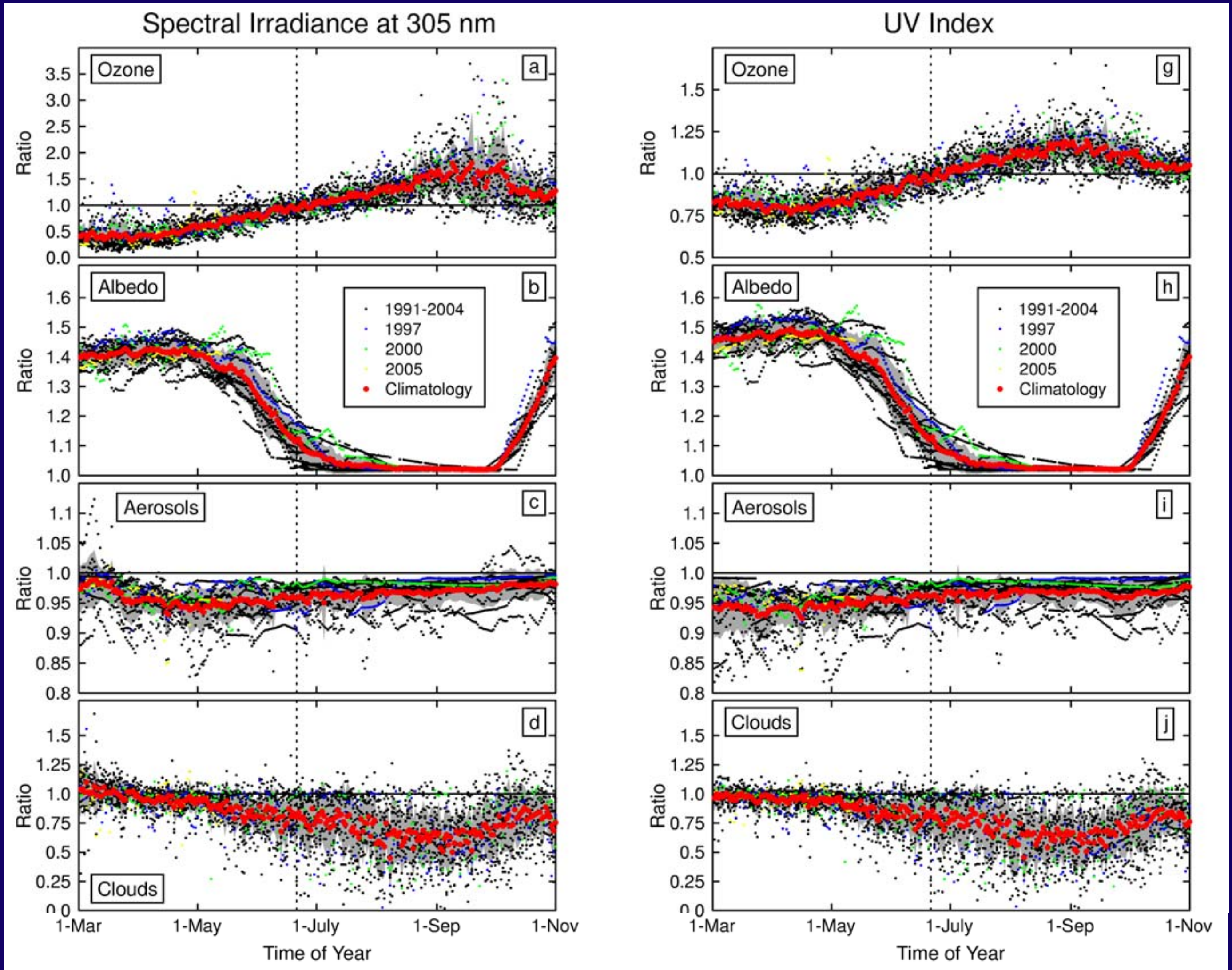
Process Studies with Models



From: Bernhard,G., C.R.Booth, J.C.Ehramjian, R.Stone,and E.G.Dutton(2007), Ultraviolet and visible radiation at Barrow, Alaska: Climatology and influencing factors on the basis of version 2 NSF network data, J.Geophys.Res., 112, D09101.

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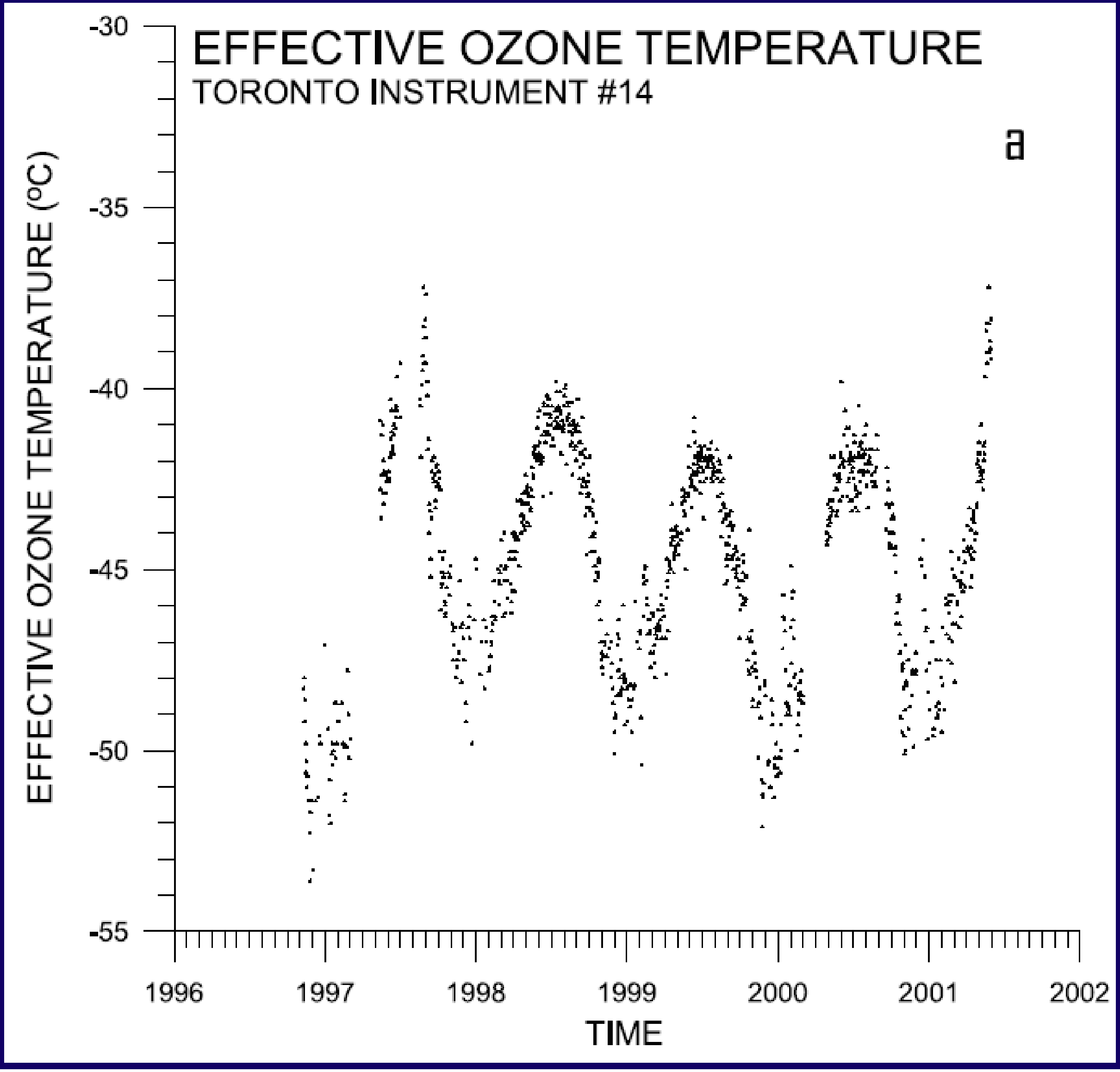
Retrieval of Effective Ozone Temperature from Brewer



From: Kerr, J. B., New methodology for deriving total ozone and other atmospheric variables from Brewer spectrophotometer direct sun spectra, *J. Geophys. Res.*, *107*(D23), 4731, doi:10.1029/2001JD001227, 2002.

Conclusions

- UV instruments have matured over the last 20 years
- Current developments focus on "front end" geometries, spectrographs, and improved accuracy
- Need for reducing uncertainties further
- Methods for assessing and improving the quality of measurements are now operational
- Methods for data interpretation are continuously advanced (reconstruction, forecasting, model integration, retrievals of secondary data products)

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