5.3. Amundsen-Scott South Pole Station (1/17/03–1/20/04)

The 2003-2004 season at Amundsen-Scott South Pole Station is defined as the period between the site visits 1/11/03–1/19/03 and 1/20/04–1/30/04. The season opening and closing calibrations were performed on 1/17/03 and 1/20/04, respectively. Volume 13 solar data comprise the period 1/17/03–1/20/04. About 92% of the scheduled scans are part of the data set; 3.3% are missing because of technical problems.

Except of the issues described in the following, the system performed well:

- **Ice build-up underneath the collector**
  Ice build-up was observed underneath the collector between July and 9/19/03 despite a new collector heater that was installed during the site visit in January 2003. Solar data were not affected as the collector was cleaned before solar scans commenced after Polar Night.

- **Malfunctioning of shutter**
  The instrument's shutter malfunctioned during several scans on 11/24/03, 12/5/03, 12/6/03,12/9/03, and between 12/13/03 and 12/16/03. Affected scans were excluded from the data set. The shutter was replaced by a spare on 12/16/03.

The Eppley PSP and TUVR instruments installed at South Pole were replaced by identical instruments during the site visits in 2003 and 2004. The instruments that were installed during the Volume 13 period had been calibrated by Eppley Laboratory Inc. in April 2002. PSP data measured after the site visit in 2003 exhibit a variation with the solar azimuth angle in the order of ±4%, which was likely caused by tilt of the internal PSP detector with respect to the PSP body, which is used as reference for leveling. The problem was corrected on 2/7/03 by applying intentionally a leveling offset. Data collected after this time agree well with data from previous years. TUVR data from 2003 are within the range of previous years too. However, the uncertainty of TUVR data is comparatively large and we therefore advise data users to treat TUVR data as "uncalibrated," and use them only for referential purposes only.

5.3.1. Irradiance Calibration

The site irradiance standards for the 2003/04 South Pole season were the lamps 200W006, 200W021, and M-666. Lamp M-764 was used as the traveling standard at the beginning and end of the season. The lamp has been re-calibrated by Optronic Laboratories in March 2001.

Lamps 200W006 and 200W021 have irradiance calibrations of Optronic Laboratories from November 1996 and September 1998, respectively. Lamp M-666 was calibrated with lamps 200W006 and 200W021 using season closing scans of Volume 9 and opening scans of Volume 10. See Section 4.2.1.5. for further explanation on the method of transfer. Due to the good stability of all three lamps, calibration functions used for Volume 13 were identical to functions implemented for Volumes 9 -12.

Figure 5.3.1 shows a comparison of 200W006, 200W021, and M-666 with M-764 at the start of the season (1/17/03). The figure indicates that lamps 200W006 and 200W021 agree with M-764 to within ±1%. There is a difference of 1-2% between lamps M-666 and M-764. A comparison of the three site standards performed on 9/10/03 indicated agreement on the ±0.5% level. Figure 5.3.2 shows the comparison of the site standards with M-764 at the end of season. At this time, all lamps agreed to within ±1.5%.

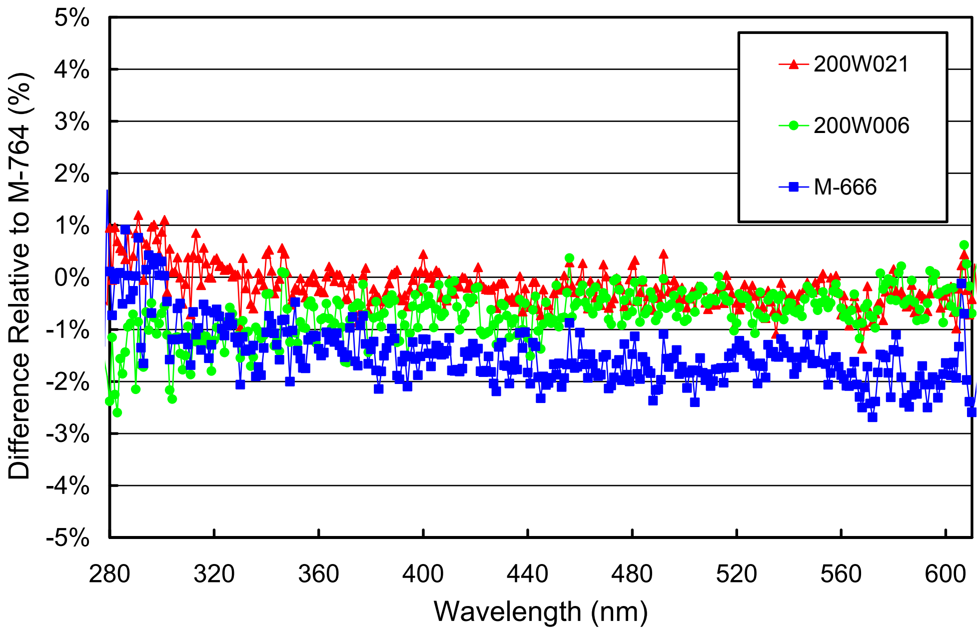

Figure 5.3.1. *Comparison of South Pole lamps 200W006, 200W021, and M-666 with the BSI traveling standard M-764 at the start of the season on 1/17/03.*

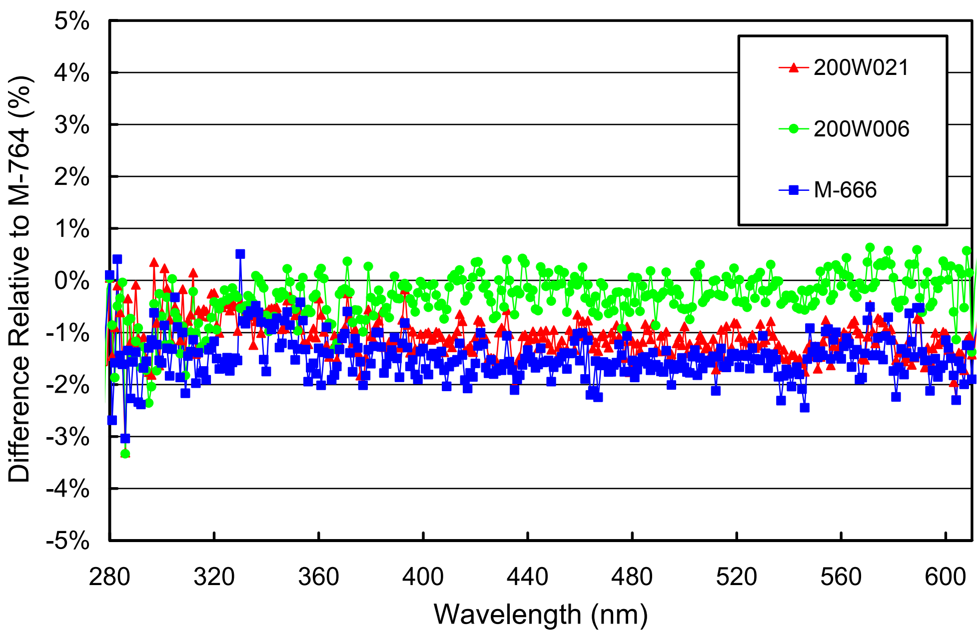

Figure 5.3.2. *Comparison of South Pole lamps 200W006, 200W021,M-666 with the BSI traveling standard M-764 at the end of the season on 1/20/04 and 1/21/04.*

5.3.2. Instrument Stability

The stability of the spectroradiometer over time is primarily monitored with bi-weekly calibrations utilizing site irradiance standards, and daily response scans of the internal irradiance reference lamp. The stability of the internal lamp is monitored with the TSI sensor, which is independent from possible monochromator and PMT drifts.

Figure 5.3.3 shows the changes in TSI readings and PMT currents at 300 and 400 nm, derived from the daily scans of the internal lamp during the South Pole 2003/04 season. The TSI measurements indicate that the internal lamp became brighter by about 3% during the year. The PMT currents at 300 and 400 nm are tracking the signal of the TSI until October before they increase by approximately 2% relative to the TSI, indicating a change of system responsivity. The replacement of the shutter introduced a step-change of about 2% on 12/16/03. Solar data are not affected as response scans are used to adjust the instrument's calibration accordingly.

A total of four different calibrations were applied to the solar measurements of Volume 13. The first calibration was applied between the start of the season and the commencement of Polar Night. The second calibration included the period between Polar Night and 10/28/03. Calibration Periods 3 and 4 include the intervals 10/29/03–12/16/03 and 12/17/03–1/21/04, respectively. The break point between the last two calibration periods coincides with the time of shutter replacement. Figure 5.3.4 shows ratios of the calibration functions applied during Periods 2-4, relative to the function of Period 1.

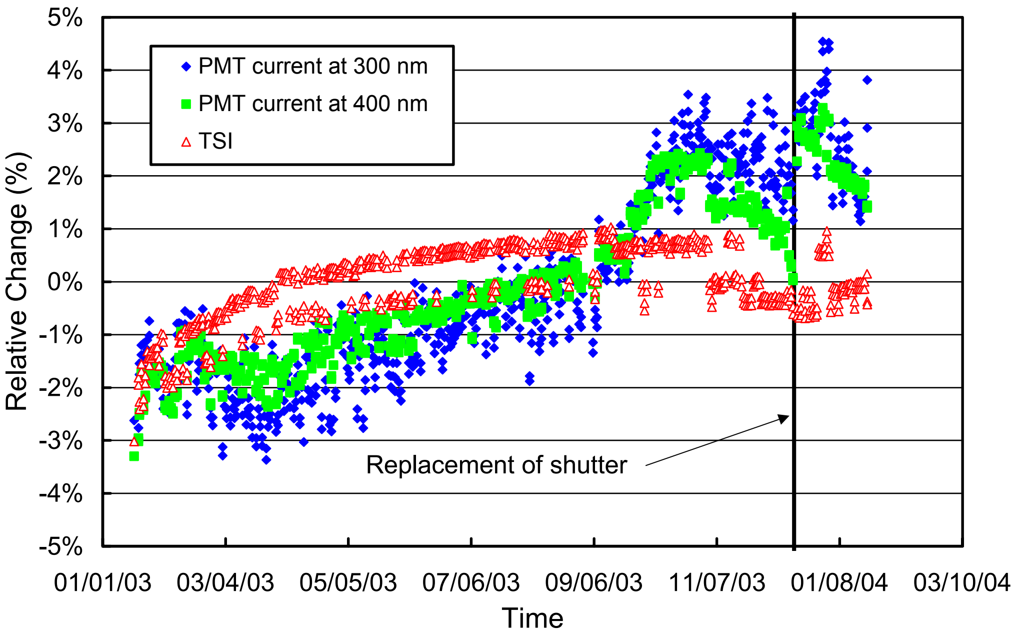

Figure 5.3.3. *Time-series of PMT current at 300 and 400 nm, and TSI signal during measurements of the internal irradiance standard performed during the South Pole 2003/04 season. The data are normalized to the average of the whole period.*

Figure 5.3.5 presents the ratios of the standard deviation and average spectra, calculated from the individual spectra of each period. This ratio is useful for estimating the variability of the calibrations in each period. The variability is typically less than 1% for wavelengths above 300 nm in all periods, indicating good stability.

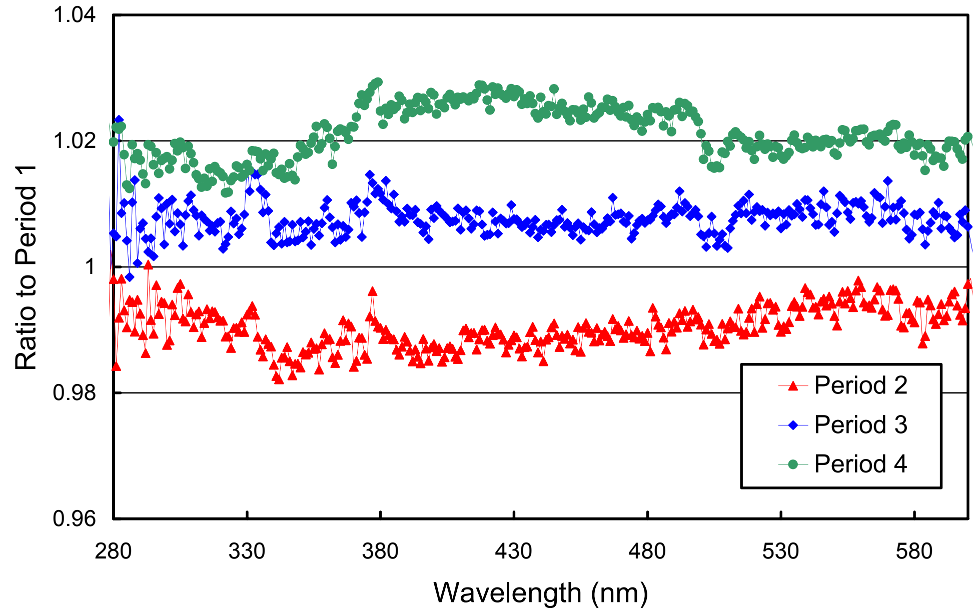

Figure 5.3.4. *Ratios of irradiance assigned to the internal lamp relative to Period 1.*

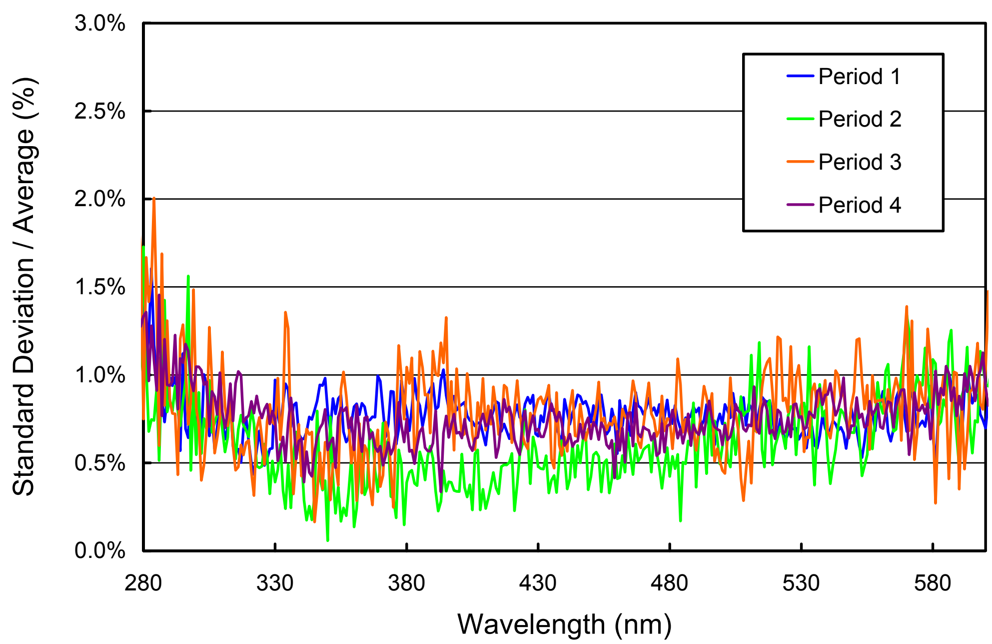

Figure 5.3.5. *Ratio of standard deviation and average calculated from the absolute calibration scans measured during the South Pole 2003/04 season.*

5.3.3. Wavelength Calibration

Wavelength stability of the system was monitored with the internal mercury lamp. Information from the daily wavelength scans was used to homogenize the data set by correcting day-to-day fluctuations in the wavelength offset. After this step, there may still be a deviation from the correct wavelength scale, but this bias should be similar for all days. Figure 5.3.6 shows the difference of the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 405 scans were evaluated. The change in offset was smaller than ±0.025 nm for 97% of the scans and smaller than ±0.055 nm for 99.5% of the scans. The shifts of 2 scans was larger than ±0.1 nm due to operator intervention; the wavelength calibration was adjusted accordingly.

After the data was corrected for day-to-day wavelength fluctuations, the wavelength-dependent bias between this homogenized data set and the correct wavelength scale was determined with the Fraunhofer-correlation method, as described in Section 4.2.2.2. The resulting correction function is shown in Figure 5.3.7. The corrections exceed 1 nm for wavelengths larger than 500 nm. The magnitude of the correction is considerably larger than typical and is caused by the monochromator installed. As this correction is well defined, accuracy of solar data is not compromised.

After the data has been wavelength corrected using the shift-function described above, the wavelength accuracy was tested again with the Fraunhofer method. The results are shown in Figure 5.3.8 for four UV wavelengths. The residual shifts are typically smaller than ±0.04 nm. The somewhat larger scatter shortly before and after Polar Night is caused by low light levels, which affect the precision of the correlation algorithm. The actual wavelength uncertainty of the instrument may be slightly larger as indicated in Figure 5.3.8 due to wavelength fluctuations during a given day (Figure 5.3.8 shows only one point per day), and possible systematic errors of the Fraunhofer-correlation method (Section 4.2.2.2).

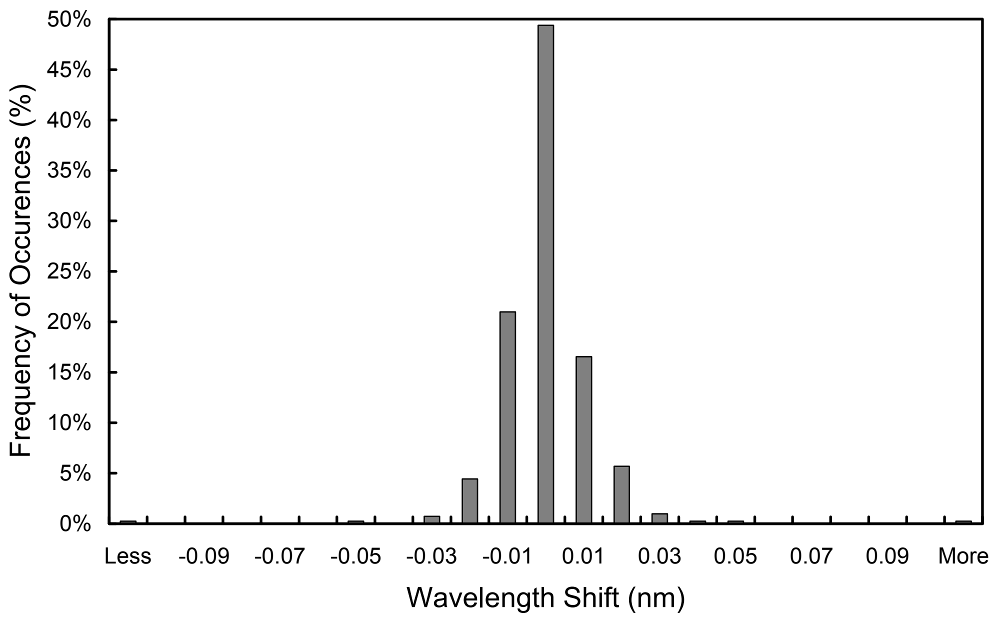

Figure 5.3.6. F*requency distribution of the difference of the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. The 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than – 0.105 nm; "more" means shifts larger than 0.105 nm.*

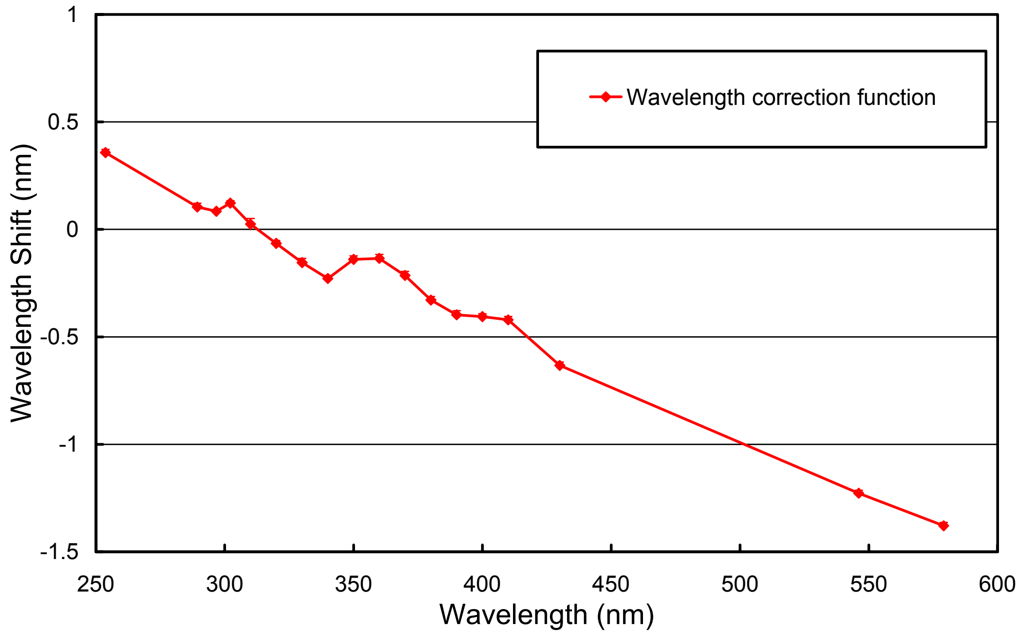

Figure 5.3.7. *Monochromator non-linearity functions for the South Pole 2003/04 season.*

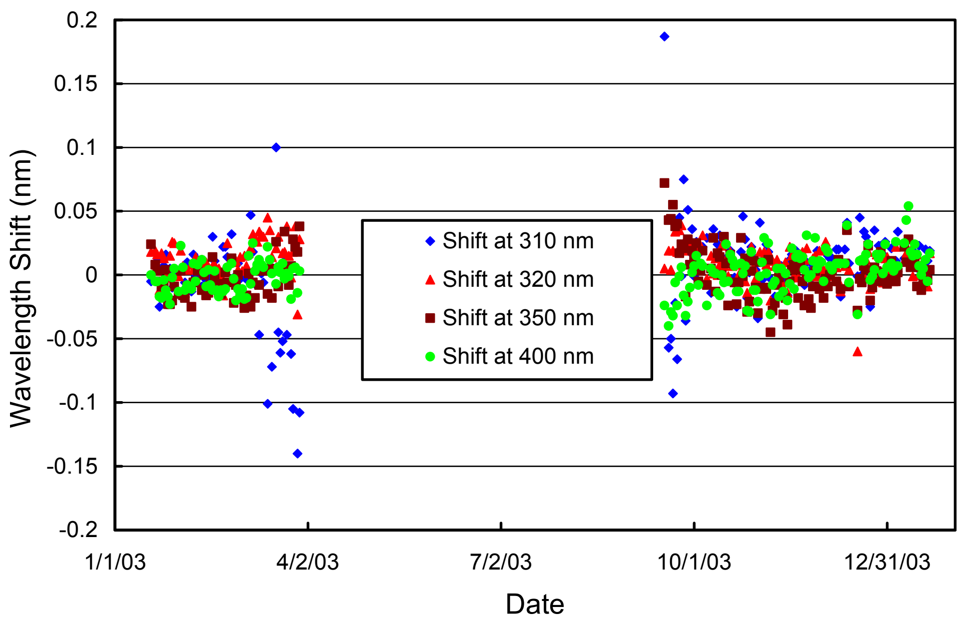

Figure 5.3.8. *Wavelength accuracy check of the final data at four wavelengths by means of Fraunhofer correlation. The noontime measurement has been evaluated for each day of the season. No data exist during Polar Night.*

Although data from the external mercury scans do not have a direct influence on data products, they are an important part of instrument characterization. Figure 5.3.9 illustrates the difference between internal and external mercury scans collected during both site visits. External scans have a bandwidth of about 1.04 nm FWHM and internal scans of 0.75 nm FWHM. The reason for this discrepancy is explained in Section 4. Since external scans have the same light path as solar measurements, they represent the monochromator bandpass relevant for solar scans more realistically. Figure 5.3.9 indicates that scans performed during the sites visits in 2003 and 2004 are very consistent.

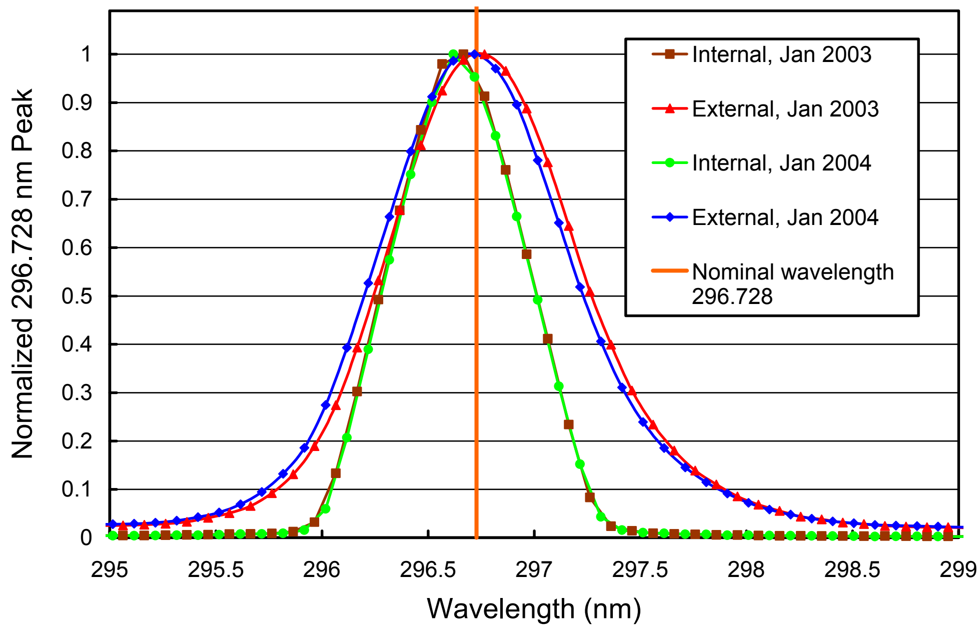

Figure 5.3.9. *The 296.73 mercury line as registered by the PMT from external and internal sources.*

5.3.4. Missing Data

A total of 17351 scans are part of the published South Pole Volume 13 dataset. These are about 92% of all scans scheduled. Of the missing scans, 76, 428, and 367 were superseded by absolute, wavelength, and response scans, respectively. Since South Pole Station has 24 hours of sunlight per day during the summer season, a loss of solar data cannot be avoided. Because of technical problems, 3.3% of the scheduled scans are missing: a total of 365 scans were lost between 11/24/03 and 12/16/03 due to problems with the instrument's shutter and its replacement. In particular 12/5/03, and the period 12/13/03 – 12/16/03 are affected. The digital multimeter that is used to control the lamp current was not accessible between 12/31/03 and 1/1/04, leading to a loss of 194 scans. 35 scans were superseded in January 2004 on second days at 00:30 and 10:15 UT by reading of the GPS receiver. 21 scans were lost throughout the year for various or unknown reasons. In addition, 79 scans were excluded from the data set as they were recorded at times when the instrument's collector was shaded by an air sampling stack. These scans were measured between 05:30 and 06:15 UT.

5.3.5. GUV Data

The 2003/2004 period was the first season when a multichannel filter instrument of type GUV-541 was installed next to the SUV-100 spectroradiometer. The GUV-541 instrument provides measurements in five approximately 10 nm wide UV bands centered at 305, 313, 320, 340, and 380 nm. From data recorded at these wavelength, total column ozone, spectral integrals, and dose rates for a large number of action spectra is calculated and made available in near real-time via the website http://www.biospherical.com/nsf/login/update.asp. Details about calibration and calculation of data products are at http://www.biospherical.com/nsf/presentations/SPIE_paper_5156-23_Bernhard.pdf . In addition to providing data via the Internet, the radiometer is also used to quality control SUV-100 measurements. For example, fluctuations in the ratio of measurements of the two instruments may indicate a problem with either of the two data sets, prompting for further examination.

After the 2003/2004 season was finished, final GUV data were produced. Figure 5.3.10. shows a comparison of GUV-541 and SUV-100 erythemal irradiance based on final data. Both data sets agree to within ±5% for solar zenith angles up to 85°. The temperature stabilization of the GUV-541 was turned off between 12/15/03 and 12/20/03, leading to a 5% error in erythemal measurements of the GUV-541. These data were excluded from the published data set.

The agreement for some data products (e.g. DNA damaging variation) may be worse that that for erythema due to principal limitations in calculating dose-rates from the five GUV-541 channels when the Sun is low and when the data product in question is heavily weighted toward wavelengths below 310 nm. We therefore advise data users to use SUV-100 rather than GUV-541 data when possible, in particular for low-Sun conditions.

Note that a new data set of SUV-100 data, named "Version 2" has been prepared (see http://www.biospherical.com/nsf/Version2/Version2.asp). Version 2 data are corrected for the cosine error of the SUV-100 spectroradiometer. Version 2 erythemal data are approximately 6% higher than the Version 0 data that are discussed in this report. GUV measurements were calibrated both against Version 0 and Version 2 SUV-100 data, and both data sets were published. Preliminary GUV data made available via the website http://www.biospherical.com/nsf/login/update.asp are based on the calibration with the cosine corrected SUV-100 data set, and are therefore approximately 6% higher than the data plotted in Figure 5.3.10.

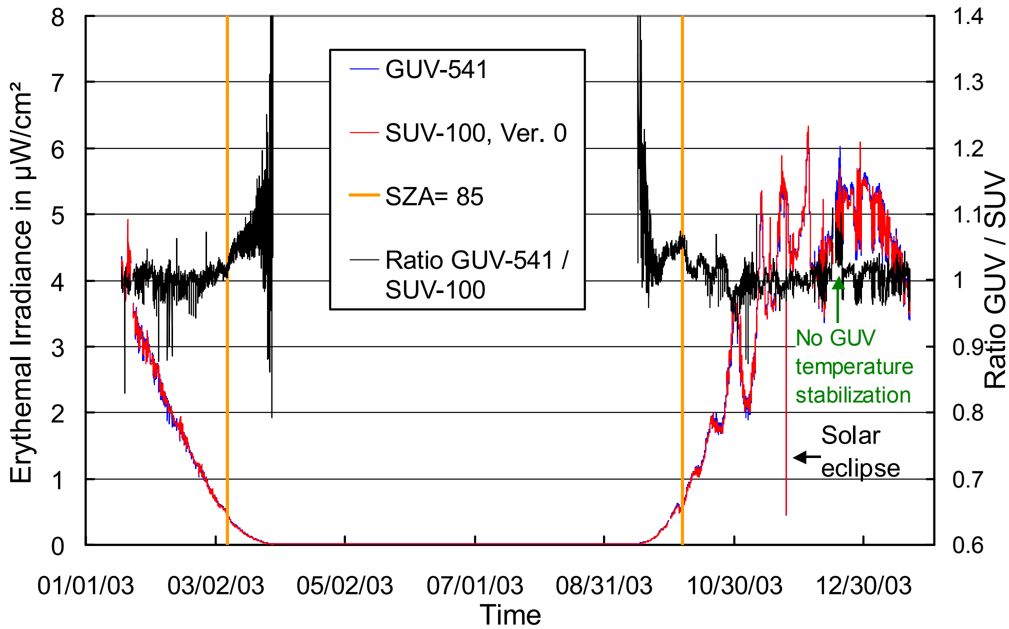

Figure 5.3.10. Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-541 radiometer. All data is based on "Version 0" data, see text.

Figure 5.3.11 shows a comparison of total ozone measurements from the GUV-541 and SUV-100 radiometers, and NASA/TOMS Earth Probe satellite (Version 7). GUV-541 ozone values were calculated as described in http://www.biospherical.com/nsf/presentations/SPIE_paper_5156-23_Bernhard.pdf. SUV-100 data were retrieved with the algorithm described in "G. Bernhard, C.R. Booth, and R.D. McPeters, Calculation of total column ozone from global UV spectra at high latitudes *J. Geophys. Res., 108*(D17), 4532, doi:10.1029/2003JD003450, 2003." This data set is also part of Version 2. Figure 5.3.11 indicates that TOMS and SUV-100 data are in excellent agreement between January and March 2003. In the austral spring (September – November), TOMS measures high by approximately 3-8%. This bias is attributable to TOMS, and will be corrected in the soon-to-be-released TOMS Version 8 data set. GUV-541 data agree to within 5% with SUV-100 data during the austral spring for solar zenith angles smaller than 80°. For very large solar zenith angles, GUV-541 data become unreliable and should not be used. (For this reason, only ozone values for SZA smaller than 83° are displayed on the web page http://www.biospherical.com/nsf/login/update.asp). Between January and March, the difference between GUV-541 and SUV-100 data ranges between 4 and 10%. The larger difference in the first half of the season may be attributable to the fact that the look-up table used for GUV-541 ozone determination was calculated with an ozone profile for medium ozone depletion, as it is typical for November and December. This profile is clearly not appropriate for the January-March period, explaining part of the discrepancies. In contrast, SUV-100 data were calculated with ozone profiles measured by NOAA/CMDL with balloon sondes, which were launched close in time with the ozone calculation. Hence, we regard the SUV-100 data as the most accurate all data set.

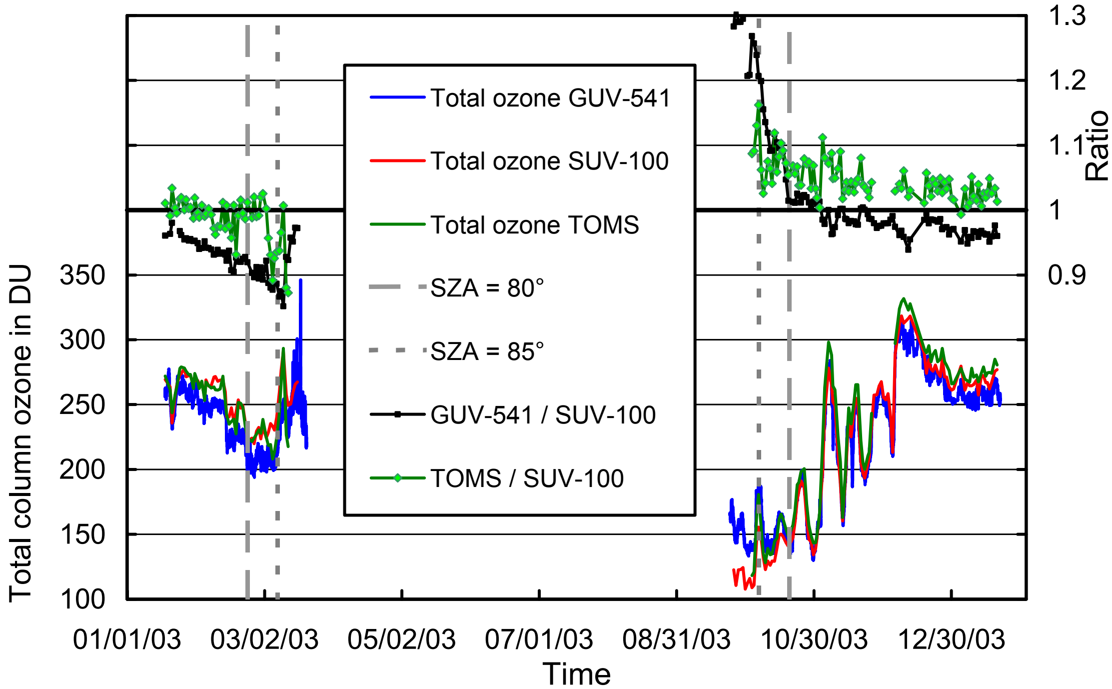

Figure 5.3.11. Comparison of total column ozone measurements from GUV-541, SUV-100, and NASA/TOMS Earth Probe satellite. GUV-541 measurements are provided every minute. Only SUV-100 measurements coincident with the TOMS overpass data were evaluated.