5.3. Amundsen-Scott South Pole Station (1/21/05–1/14/06)

The 2005-2006 season at Amundsen-Scott South Pole Station is defined as the period between the site visits 1/18/05–1/21/05 and 1/14/06–1/18/06. The season opening and closing calibrations were performed on 1/21/05 and 1/14/06, respectively. Volume 15 solar data comprise the period 1/21/05–1/14/06. A total of 16904 scans are part of the published South Pole Volume 15 dataset. Less than 1% of all possible scans are missing because of technical problems.

The SUV-100 spectroradiometer performed well during the reporting period, but there were some problems with the suite of auxiliary radiometers:

- **Variation of Eppley PSP data with azimuth position of the Sun**
  The signal of the Eppley PSP pyranometer (S/N 27198F3) exhibited a pronounced variation with the azimuth position of the Sun. This variation was likely caused by misalignment of the internal sensor of the instrument and the external reference plane used for leveling. We tried to mitigate the problem by deliberately misleveling the instrument. This proved to be difficult and some attempts worsened the asymmetry in solar data. Table 5.3.1 gives an overview of the diurnal variation in solar clear-sky data for different periods. Measurements during overcast conditions are not affected by the problem. Instantaneous measurements during clear sky period should not be used and diurnal averages calculated from data measured before 11/25/05 should be used with caution. The instrument was exchanged with a newly calibrated instrument (S/N 33690F3) during the site visit in 2006.

  Table 5.3.1: Diurnal Variations in Eppley PSP Data.

Period	Diurnal variation
01/20/05 – 02/18/05	±7% - ±10%
02/19/05 – 02/28/05	±40%
03/01/05 – 03/30/05	±12%
09/15/05 – 11/18/05	±10%
11/19/05 – 11/24/05	±18%
11/25/05 – 12/02/05	±5%
12/03/05 – 01/14/06	<±2%

- **Sensitivity change of Eppley TUVR radiometer**
  For matching solar zenith angles, calibrated data of the TUVR radiometer (S/N 27305) from the period January – March 2005 are 15-30% lower than data collected during September 2005 – January 2006. Since TUVR data are not sensitive to changes in total ozone, this difference cannot be explained with ozone depletion during the austral spring. Measurements from December 2005 are consistent with measurements performed during December 2003 and 2004. The TUVR radiometer was calibrated by Eppley Laboratories in April 2002 and the calibration factor was implemented for the entire Volume 15 period without modification. We advise data users to treat TUVR data as uncalibrated and use them only for the evaluation of short-term variations of UVA irradiance.

- **Sensitivity change of GUV-541 radiometer**
  The sensitivity of the 320 nm channel of the GUV-541 radiometer changed by 13% over the course of the year. GUV data was segregated into three periods and different calibration factors were applied for each period. Drifts in published GUV data are smaller than 3%.

- **Time errors**
  The GPS receiver that is used to update the computer time was not correctly read between 9/16/05 and 11/5/05. As the computer clock was going fast, the time stamp of all measurements became

too large over time. The time error was largest on 11/6/05 when the clock was fast by 122 seconds, shortly before it was reset. The GPS was also not read between 11/8/05 and 12/2/05. The reset on 12/2/05 was 66 seconds.

– Due to a problem with the instrument's high resolution analog-to-digital converter, no ancillary data (PSP, TUVR, system temperatures, etc.) are available for the period 1/29/05 – 1/31/05.

5.3.1. Irradiance Calibration

The site irradiance standards for the 2005/06 South Pole season were the lamps 200W006, 200W021, and M-666. Lamp M-764 was used as the traveling standard at the beginning and lamp 200W017 at the end of the season. Both lamps have been calibrated by Optronic Laboratories in March 2001.

Shortly before the site visit, the calibrations of lamps M-764 and 200W017 were compared against our long-term standards M-763 and 200W022. The latter two lamps have also been calibrated by Optronic Laboratories in March 2001, but have been rarely used since. The calibration of the traveling standard 200W017 agreed with M-763 and 200W022 to within ±1%. This confirms that the original calibration of lamp 200W017 from March 2001 was still valid as of January 2006. The calibration of lamp M-764 was systematically different from the calibrations of the other three lamps by 2-3%. Further analysis revealed that this lamp has drifted by approximately 2% during the last two years.

Lamp 200W021 has an irradiance calibration from Optronic Laboratories that was established in September 1998. Lamp 200W006 was originally calibrated by Optronic Laboratories in November 1996. The lamp was dropped during the site visit in 2004 and recalibrated against M-764 using data from 1/28/04. The lamp proved to be stable during the 2004/05 and 2005/06 seasons despite the mechanical stress that it had suffered. 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 details on the method of transfer.

The comparison of lamps M-666 and 200W021 with the traveling standard 200W017 during the site visit revealed that lamps M-666 and 200W021 have drifted by about 2% since their original calibrations. These drifts are similar in magnitude than that of the traveling standard M-764. New calibrations were established for these lamps by transferring the calibration of 200W017 using scans performed during the 2006 site visit. Both "closing" scans of the Volume 15 season and "opening" scans of the Volume 16 were used. The calibration of solar data from the 2005/06 period are based on the new calibration functions of lamps M-666 and 200W021 as well as the 2004 calibration of lamp 200W006.

Figure 5.3.1 shows a comparison of lamps 200W006, 200W021, M-666, and M-764 at the start of the season (1/21/05). The figure indicates that lamps 200W006, 200W021, M-666 agreed with each other to within ±0.7%. The calibration of the traveling standard M-764 is systematically low by 1.5-2.5%. This bias is consistent with the discrepancy seen in the comparison of lamp M-764 and the two long-term standards M-763 and 200W022.

Figure 5.3.2 shows a comparison of lamps 200W006, 200W021, and M-666 with the traveling standard 200W017 performed at the end of the season (1/14/06). The site standards agreed with lamp 200W017 to within ±0.7%.

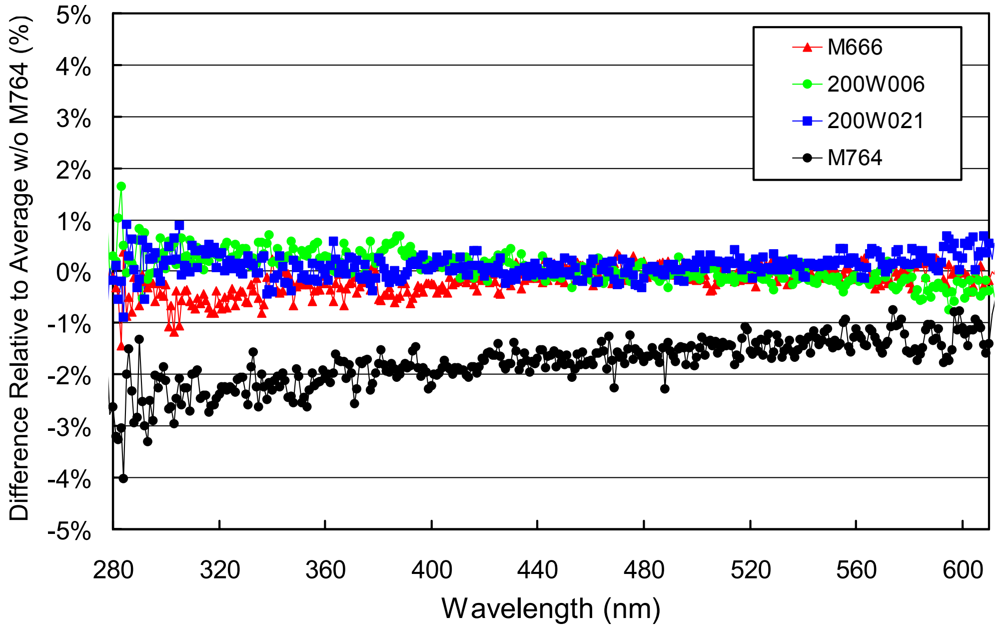

Figure 5.3.1. *Comparison of South Pole lamps 200W006, 200W021, and M-666 and the BSI traveling standard M-764 at the start of the season (1/21/05). The calibration functions of lamps M-666 and 200W021 are based on comparisons with the traveling standard 200W017, which were performed in January 2006.*

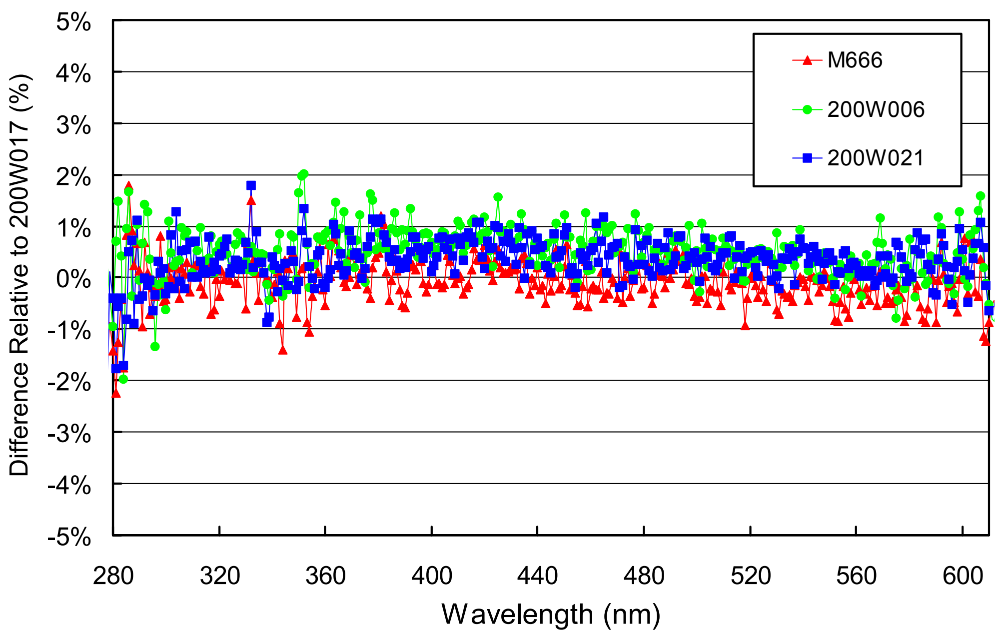

Figure 5.3.2. *Comparison of South Pole lamps 200W006, 200W021, and M-666 with the BSI traveling standard 200W017 at the end of the season (1/14/06).*

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 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 2005/06 season. The TSI measurements indicate that the internal lamp became dimmer by about 1.5% during the year. This amount of drift is typical. The PMT currents at 300 and 400 nm vary by less than ±2%, indicating good stability of the instrument.

Four different calibration functions were applied to the solar measurements of Volume 15. An overview of the calibration periods is given in Table 5.3.2. Figure 5.3.4 shows ratios of the calibration functions applied during Periods P1B – P3, relative to the function of Period P1A. Calibrations applied before start of Polar Night (Periods P1A and P1B) are consistent to within 2%. At the end of Polar Night, when temperatures were very low, moisture was freezing underneath the instrument's collector. This led to a reduction in throughput. The detector was cleaned on 9/17/05. For the very first two days of data measured after Polar Night, the collector was still frosted and a different calibration was applied for these days (Period P2). Between 9/17/05 and 1/14/06 (Period P3), the instrument's responsivity was very stable and only one calibration function was applied. This calibration agreed to within 4% with the calibration of Period P1A.

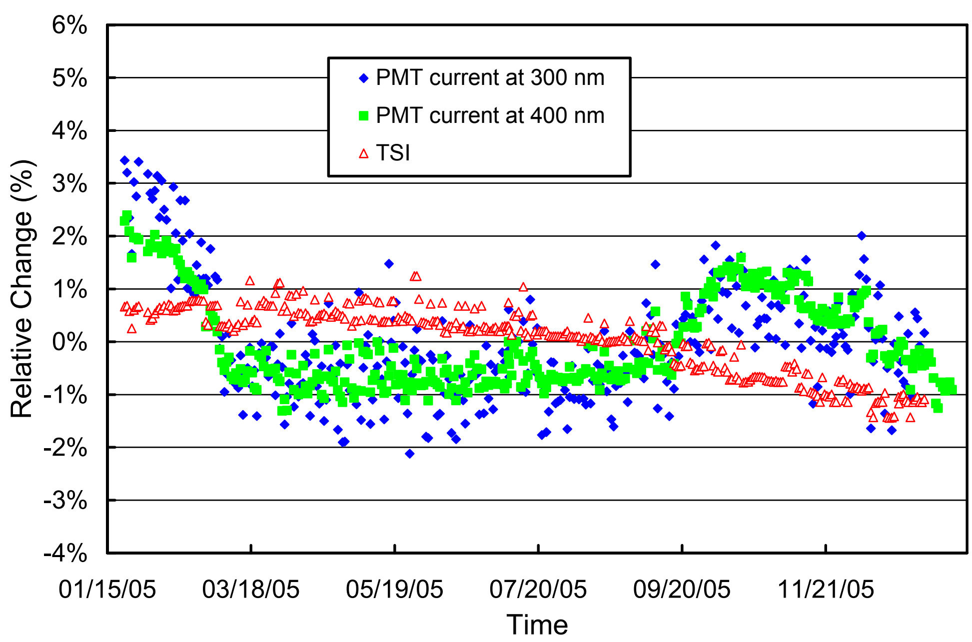

Figure 5.3.3. *Time-series of PMT current at 300 and 400 nm, and TSI signal during measurements of the internal irradiance standard performed during the South Pole 2005/06 season. The data are normalized to the average of the whole period.*

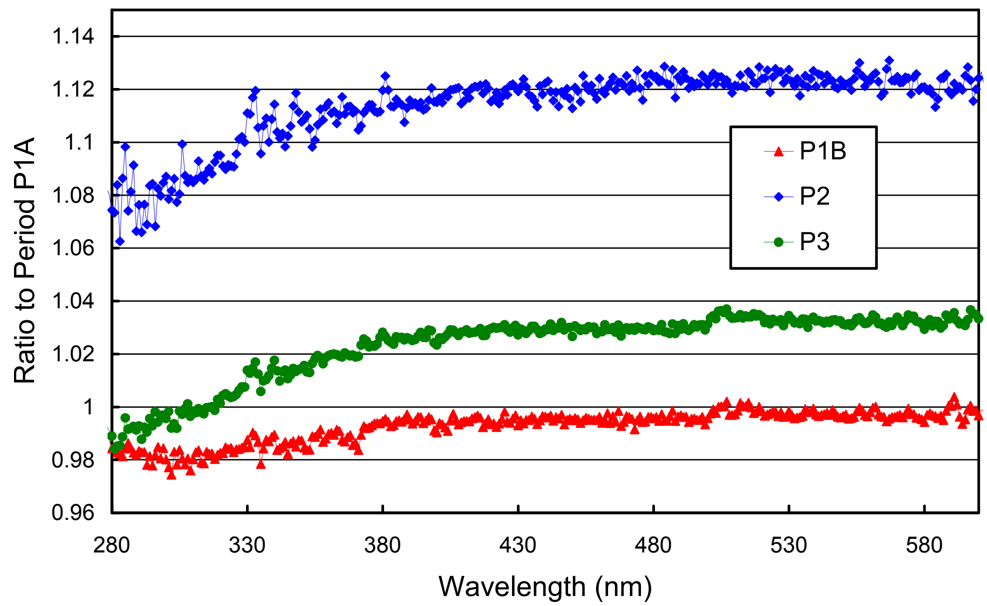

Figure 5.3.4. *Ratios of irradiance assigned to the internal lamp relative to Period P1A.*

Figure 5.3.5 presents the relative standard deviation calculated from the individual calibration scans of each period. These data are useful for estimating the variability of calibrations in each period. The variability is typically less than 1% for wavelengths above 300 nm in all periods, indicating very good stability.

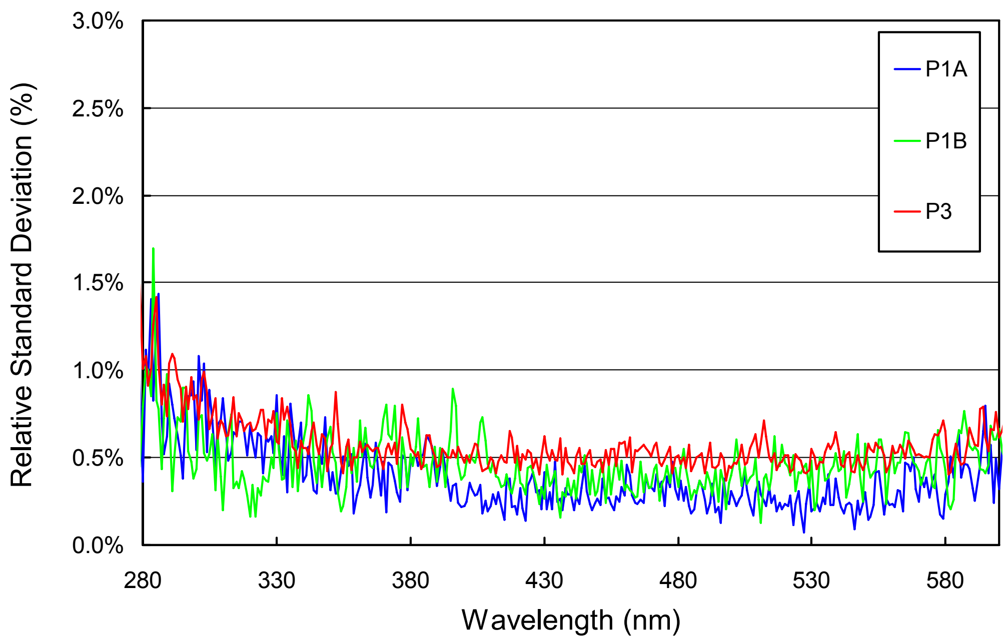

Figure 5.3.5. *Relative standard deviation calculated from the absolute calibration scans measured during the South Pole 2005/06 season.*

Table 5.3.2: Calibration periods for South Pole Volume 15 data.

Period name	Period range	Number of Absolute scans	Remarks
P1A	01/20/2005 - 01/31/2005	6	
P1B	02/01/2005 - 04/01/2005	6	Before Polar Night
P2	09/15/2005 - 09/16/2005	1	After Polar Night, collector frosted
P3	09/17/2005 - 01/14/2006	17	

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, 403 scans were evaluated. The change in offset was smaller than ±0.025 nm for 90% of the scans and smaller than ±0.055 nm for 98% of the scans. The shifts between 7 scan-pairs 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 Version 2 Fraunhofer-line correlation method (*Bernhard et al*., 2004). The resulting correction function is shown in Figure 5.3.7. 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 properties of the monochromator installed. The accuracy of solar data is not compromised, since the correction is well defined.

After the data had been wavelength corrected using the shift-function described above, the wavelength accuracy was tested again with the Version 2 Fraunhofer-line correlation method. The results are shown in Figure 5.3.8 for four UV wavelengths. The standard deviation of the residual shifts is 0.036 nm. 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 (*Bernhard et al*., 2004).

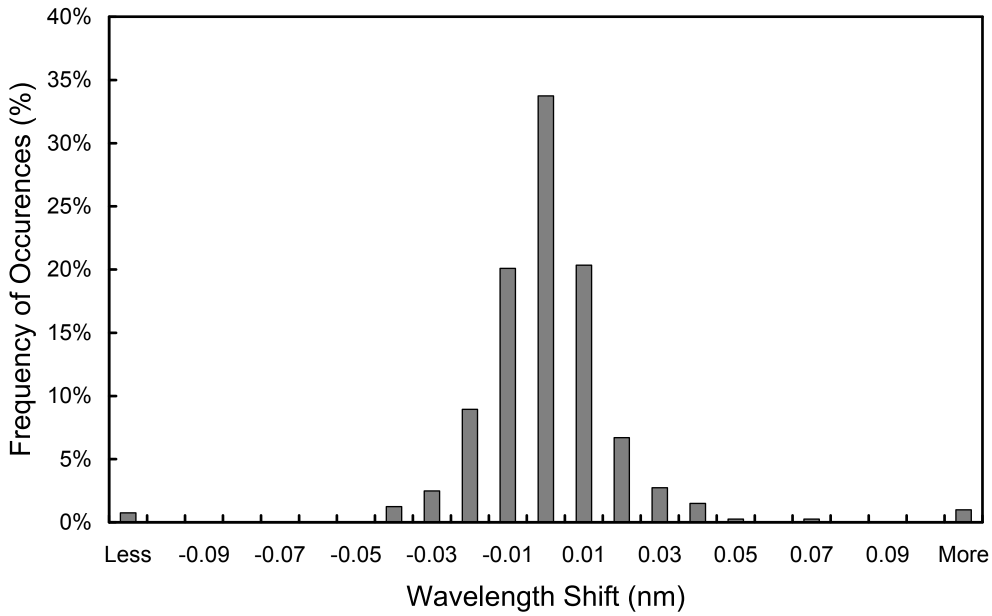

Figure 5.3.6. F*requency distribution of the difference of the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. The 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts beyond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

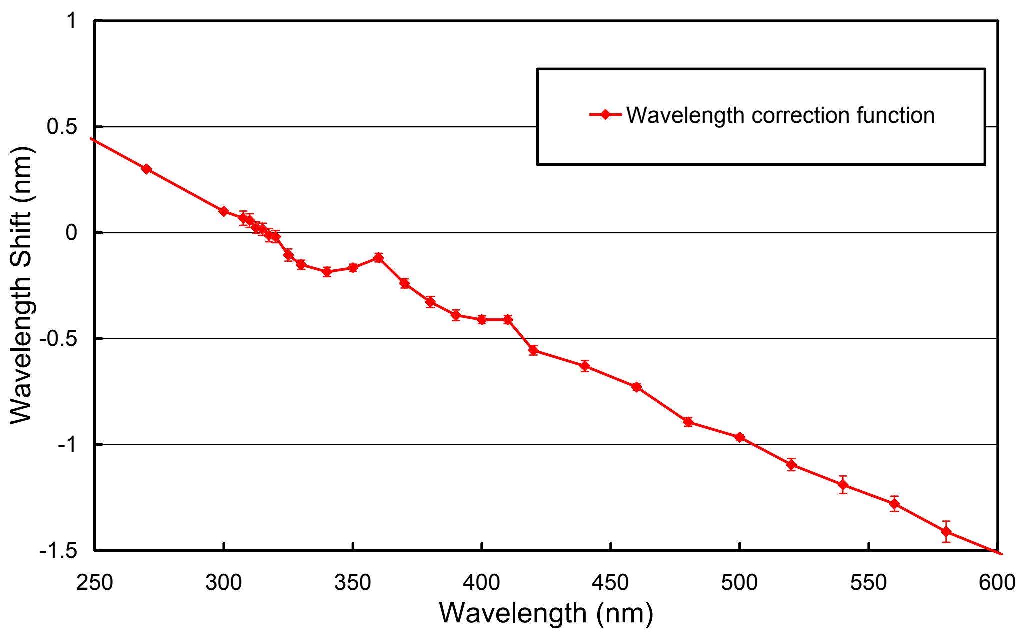

Figure 5.3.7. *Monochromator non-linearity functions for the South Pole 2005/06 season.*

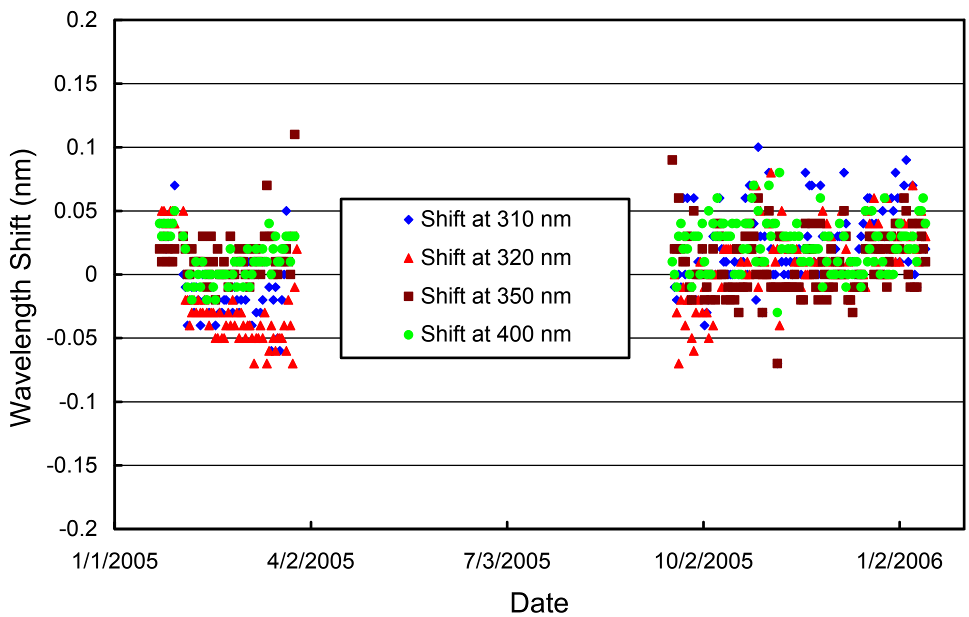

Figure 5.3.8. *Wavelength accuracy check of the final data at four wavelengths by means of Fraunhofer correlation. The noontime measurement has been evaluated for each day of the season. No data exist during Polar Night.*

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 scans of the internal and external mercury lamp at 296.728 nm collected during both site visits. External scans have a bandwidth of about 1.06 nm FWHM and internal scans of 0.72 nm FWHM. The center wavelengths are shifted by about 0.11 nm. The reason for this discrepancy is explained in Section 4. External scans have the same light path as solar measurements and therefore represent the monochromator's bandpass relevant for solar scans. Figure 5.3.9 indicates that scans performed during the sites visits in 2005 and 2006 are very consistent.

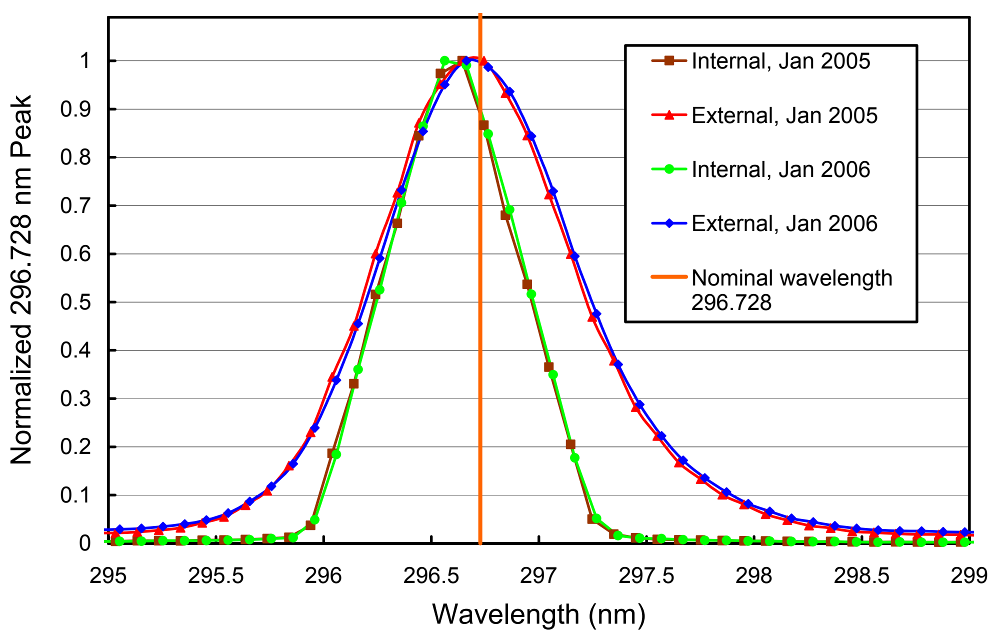

Figure 5.3.9. *The 296.73 mercury line as registered by the PMT from external and internal sources.*

5.3.4. Missing Data

A total of 16904 scans are part of the published South Pole Volume 15 dataset. These are about 94% of the maximum possible number of data scans. Of the missing scans, 184, 410, and 336 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. Less than 1% of all possible scans were missed due to technical problems: a total of 128 scans were lost between 1/29/05 and 1/31/05, when the scan frequency was reduced from four scans per hour to two scans per hour due to a lock-up of the system's high resolution analog to digital converter (HRAD). This device samples the instrument's ancillary sensors but not the PMT current. Due to this problem, no Eppley PSP, TUVR and system parameter readings are available for the period. On 2/1/05, there was a planned power outage to connect the ARO building to a new power generator. The SUV-100 system was powered down, which led to a loss of 19 scans. 48 additional scans were excluded from the data set that were affected by shading from the air sampling stack installed at the ARO building.

5.3.5. GUV Data

The GUV-541 radiometer, which is installed next to the SUV-100, was calibrated against final SUV-100 measurements following the procedure outlined in Section 4.3.1. The calibration of the instrument's 320 nm channel drifted by 13% over the course of the year. To corrected for this change, GUV data was segregated into three periods and different calibration factors were applied for each period. Drifts in published GUV data are smaller than 3%.

From the calibrated measurements, data products were calculated (Section 4.3.2). Figure 5.3.10. shows a comparison of GUV-541 and SUV-100 erythemal irradiance based on final Volume 15 data. For solar zenith angles smaller than 80°, measurements of the two instruments agree to within ±2% (±1σ), except for times when an air sampling stack installed at the ARO building cast a shadow on the GUV-541 radiometer but not on the SUV-100.[+] We advise data users to use SUV-100 rather than GUV-511 data whenever possible, in particular for low-Sun conditions.

Figure 5.3.11 shows a comparison of total ozone measurements from the GUV-541 radiometer and the Ozone Monitoring Instrument (OMI) installed on NASA's AURA satellite. GUV-541 ozone values were calculated as described in Section 4.3.3. In the austral spring, the two datasets agree well for SZAs smaller than 80°. There is a bias of about 5% for the second half of February 2005. A similar bias is also observed when comparing total ozone data calculated from Version 2 SUV-100 measurements with OMI data. The reason of this bias is still unresolved. For SZA larger than 80°, GUV-541 data become unreliable and should not be used.

[+] SUV-100 data affected by shading from the air sampling stack have been excluded from the published data set. GUV-541 data concurrent with shaded SUV-100 measurements have also been excluded. Since the SUV-100 collector is located approximately 2 meters away from the GUV-541 radiometer, both instruments are not shaded during exactly the same time and some data affected by the stack are still part of the GUV-541 data set.

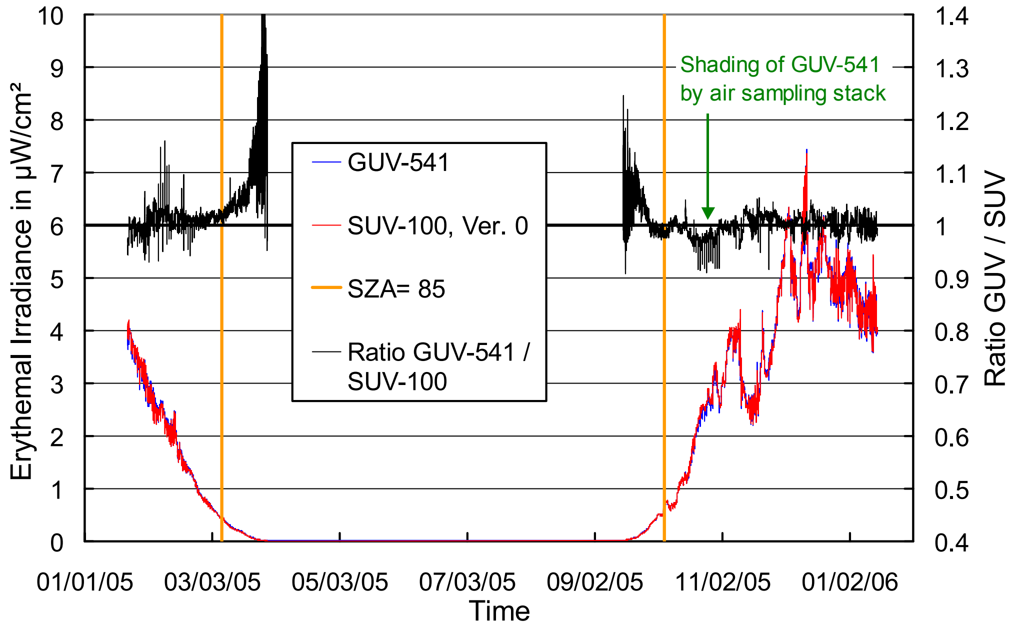

Figure 5.3.10. *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-541 radiometer. SUV-100 measurements are based on "Version 0" (cosine-error uncorrected) data.*

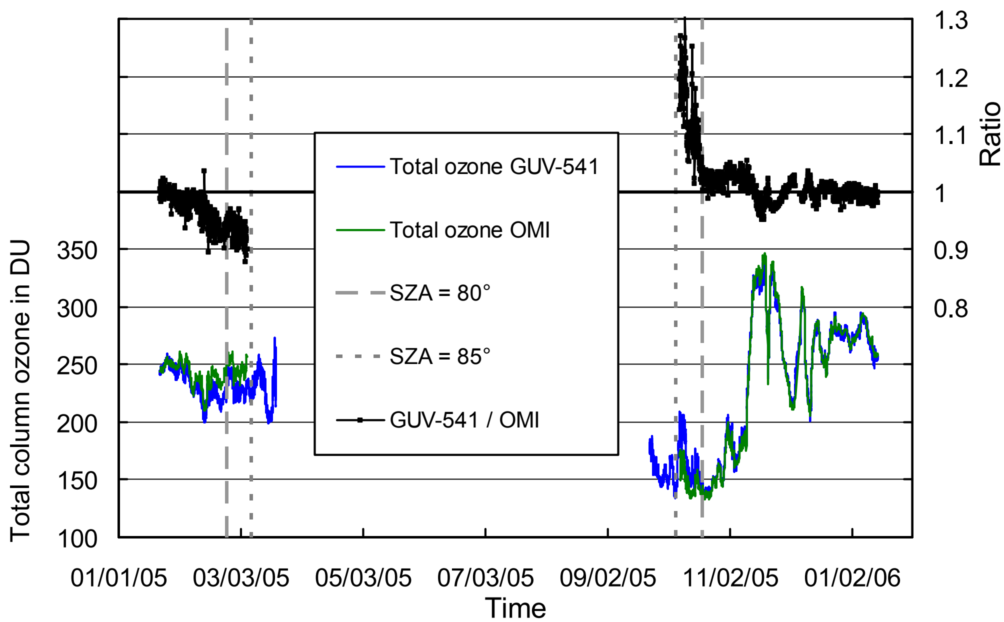

Figure 5.3.11. *Comparison of total column ozone measurements from GUV-541 and OMI. GUV-541 measurements are plotted in 15 minute intervals. For calculating the ratio of both data sets, only GUV-541 measurements concurrent with OMI overpass data were evaluated.*