5.3. Amundsen-Scott South Pole Station (1/18/02–1/11/03)

The 2002-2003 season at Amundsen-Scott South Pole Station is defined as the period between the site visits 1/12/02 - 1/18/02 and 1/11/03 - 1/19/03. The season opening and closing calibrations were performed on 1/18/02 and 1/12/03, respectively. Volume 12 solar data comprise the period 1/18/02–1/11/03. The system control computer was replaced by a new computer during Polar Night. About 93% of the scheduled scans are part of the data set; 2.1% are missing because of technical problems. Except of the issues described in the following, the system performed well:

– **Ice build-up underneath the collector**
  After Polar Night, moisture started to freeze underneath the instrument's irradiance collector. The collector was inspected and cleaned on 10/9/02. Calibrations performed on 9/5/02 and on 10/9/02 after cleaning of the collector were stable to within 1%. The calibration from 9/27/02 indicates that the collector throughput was reduced by approximately 3-5%, but this calibration does not allow to defer the temporal change of the throughput between 9/5/02 and 10/9/02. We therefore applied the calibration from 9/27/02 to the period 9/15/02 (first day after Polar Night) through 10/9/02, and estimate that the measurement uncertainty for this period is increased by about 5%.

  A similar problem occurred in November and December 2000, and in October 2001. We believe that the problem is caused by the modification of the instrument's collector during the site visit in January 2000. The upgrade involved installing a field-of-view limiting aperture made of PTFE underneath the cosine diffuser. This significantly improved the instrument's angular response (see the introduction to this section) but may have decreased the heat flow from the roof box to the collector. In response to the problem, we replaced the aperture that with one made of aluminum (which has a better thermal conductivity than PTFE) during the 2002 site visit. Since the problem returned in October 2002, we installed a heater during the site visit in 2003.

– **Malfunctioning of shutter**
  The instrument's shutter that is installed between the collector and relay lens (see Section 2) ceased to function on 12/28/02. The shutter was replaced by a spare on 12/31/02.

– **Monochromator misalignment**
  The monochromator that was installed during the previous season (2001-2002) was somewhat misaligned (see Volume 11 Operations Report). It was therefore planned to replace the monochromator with a refurbished spare during the site visit in 2002. Prior to shipment, the alignment of this monochromator was checked and found to be in good condition. When the system was powered up with the new monochromator it was found that external (i.e. through-the-collector) wavelength scans had an excessive bandwidth of larger than 1.5 nm in the UVB (the normal bandwidth is 1 nm), and that the bandshape was highly wavelength dependent. In order to solve the problem, the previously installed monochromator was realigned, serviced, and reinstalled. After realignment, the bandwidth of external wavelength scans was 1.1 nm, which is only slightly larger than the target value. Published solar spectra have a somewhat larger bandwidth than usual, but this does virtually not affect the accuracy of published dose rates.

– **Difference in solar measurements compared to previous volumes**
  Volume 11 and Volume 12 clear-sky data in the visible (400-600 nm) agree to within ±1%, except for the period 11/12/02 – 11/16/02 when Volume 12 data is low by 3%. Volume 11 and Volume 12 data in the visible are about 1-4% lower than Volume 10 data. Part of the discrepancy is likely due to ice build-up during November and December 2000. (see Volume 10 Operations Report). In the UV-A, Volume 12 data appear to be 2-3% lower than Volume 11 data and 2-5% lower than Volume 10 data. All datasets were double-checked , yet the reason of this difference could not be conclusively identified. It is likely a combination of various factors such as drifts of calibration standards, the different acceptance angles of the monochromators used during the

three seasons, and a possible change in the instrument's angular response. For example, model calculations indicate that the replacement of the collector's PTFE aperture by one made of aluminum could have degraded the instrument's cosine response (see the introduction to this chapter), and could have lead to reduced measurements in 2002. Due to the low solar elevations prevailing at the South Pole, a small change in the cosine-response can have significant effects on solar data. As the instrument's angular response was not measured during the site visits in 2002 and 2003, it is not possible to verify this hypothesis.

The Eppley PSP and TUVR instruments installed at South Pole were replaced by identical instruments during the site visits in 2002 and 2003. The instruments that were installed during the Volume 12 period had been calibrated by Eppley Laboratory Inc. in November 2001. PSP data from 2002 agree well with data from previous years. TUVR data from 2002 are approximately 15% higher than historic data. Based on our experience from other sites, we believe that this discrepancy is caused by the poor calibration reproducibility provided by Eppley Laboratory Inc. We therefore advise data users to treat TUVR data as "uncalibrated," and use them only for referential purposes.

5.3.1. Irradiance Calibration

The site irradiance standards for the 2002/03 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 was 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 explanations on the method of transfer. For Volume 12, the same calibration functions were used as for Volume 9 and 10.

Figure 5.3.1 shows a comparison of 200W006, 200W021, and M-666 with M-764 at the start of the season (1/18/02). The figure indicates that lamps 200W021 and M-666 agree with M-764 to within ±1%. There is a difference of 2-2.5% between lamp 200W006 and M-764. This difference was only observed during the "season opening" calibrations. An intercomparison of the three site standards performed on 3/27/02 and 9/5/02 showed agreement on the ±0.5% level. Figure 5.3.2 shows a comparison of the site standards with M-764 at the end of season. All lamps agree to within ±1%.

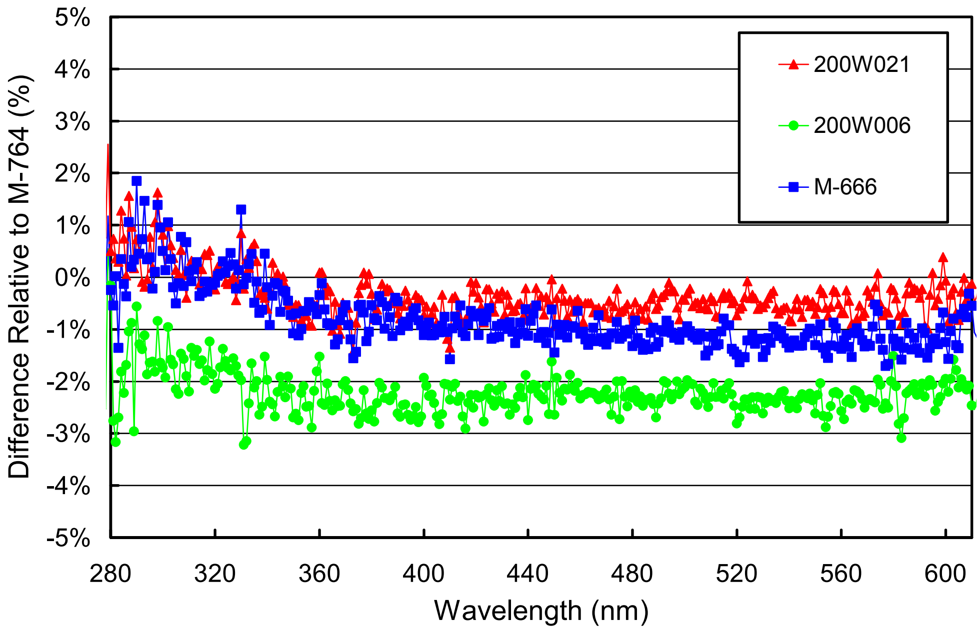

Figure 5.3.1. *Comparison of South Pole lamps 200W006, 200W021, and M-666 with the BSI traveling standard M-764 at the start of the season on 1/18/02.*

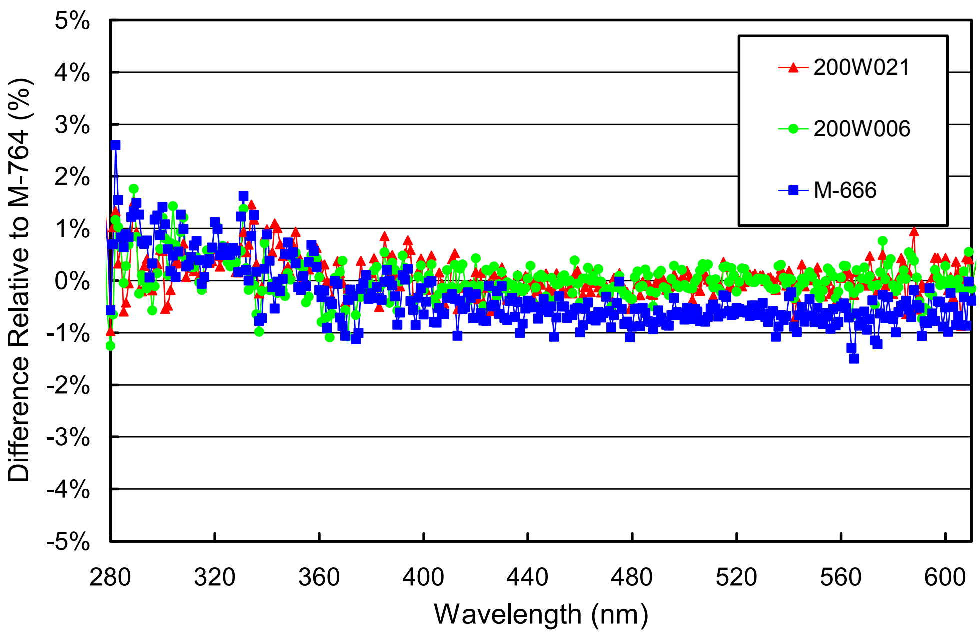

Figure 5.3.2. *Comparison of South Pole lamps 200W006, 200W021,M-666 with the BSI traveling standard M-764 at the end of the season on 1/11/03 and 1/12/03.*

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. 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 response scans of the South Pole 2002/03 season. The TSI measurements show that the internal lamp became brighter by about 4% during the year. The PMT currents at 300 and 400 nm are well tracking the signal of the TSI, suggesting that monochromator and PMT were stable to within ±1% during the entire season. The only exception is a short period between mid-September to mid-October, when PMT currents were increased by 1-2%. Most of the drift seen in Figure 5.3.3 is caused by the aging of the reference lamp, and was adjusted by changing the instrument's calibration accordingly.

A total of five different calibrations was applied to the solar measurements of Volume 12. 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 10/9/02. The number of calibrations during end of September and the first week in October was not sufficient to defer the temporal change of the throughput between 9/5/02 and 10/9/02 due to the ice build-up. The calibration uncertainty of the period between Polar Night and 10/9/02 is therefore increased by about 5%. Calibration Period 4 ends on 12/28/02, when the shutter was replaced. The calibration applied to the period after the shutter replacement is surprisingly consistent with the calibration of Period 4, despite the fact that the instrument had to be partly dismantled for service. Figure 5.3.4 shows the ratios of the calibration functions applied during the different periods to the calibration of Period 1.

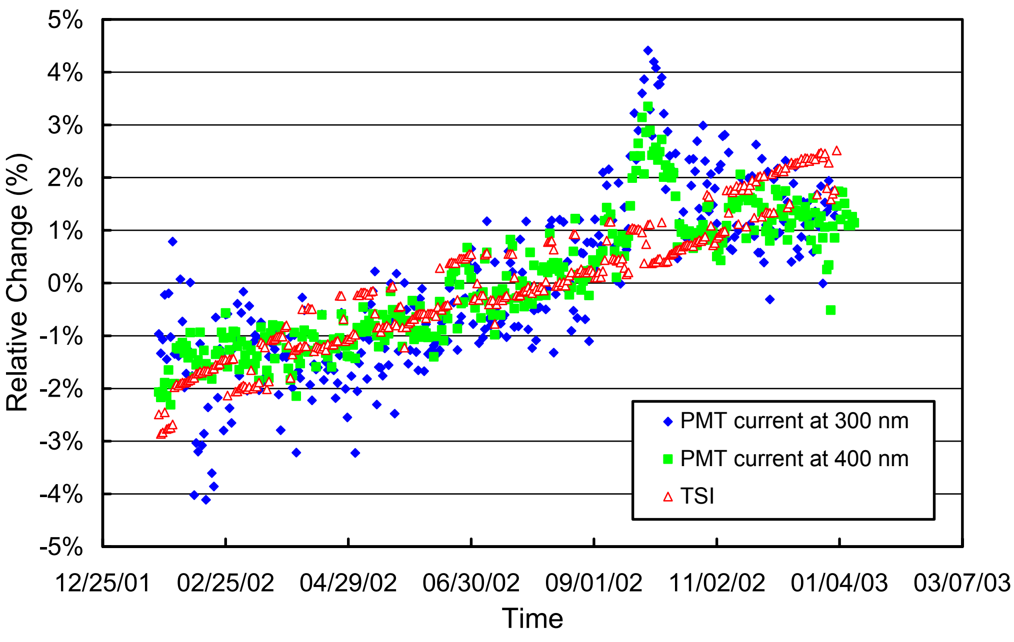

Figure 5.3.3. *Time-series of PMT current at 300 and 400 nm, and TSI signal during measurements of the internal irradiance standard performed during the South Pole 2002/03 season. The data are normalized to the average of the whole period.*

Figure 5.3.5 presents the ratios of the standard deviations 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 exceptionally good stability of the instrument.

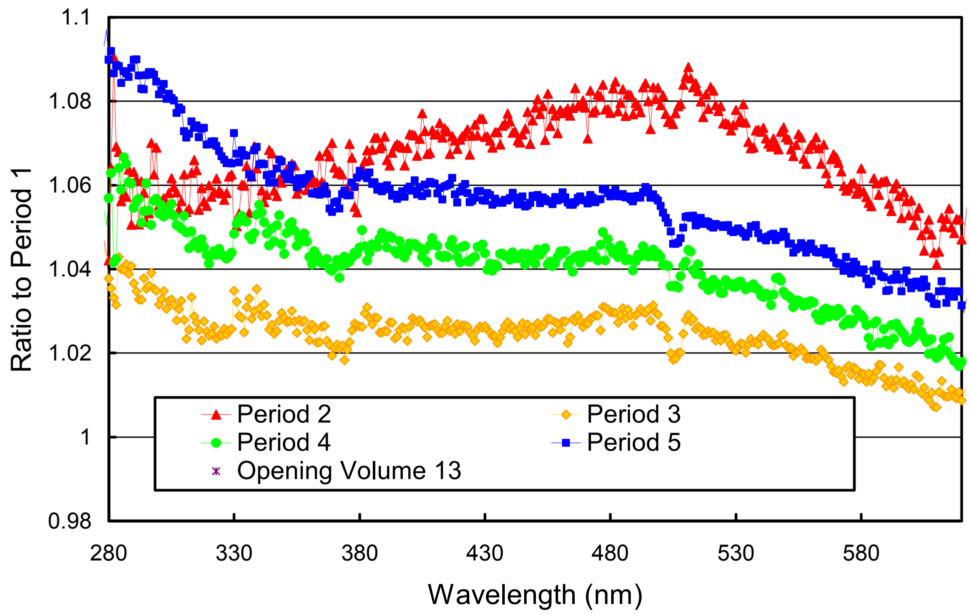

Figure 5.3.4. *Ratios of irradiance assigned to the internal lamp relative to Period 1.*

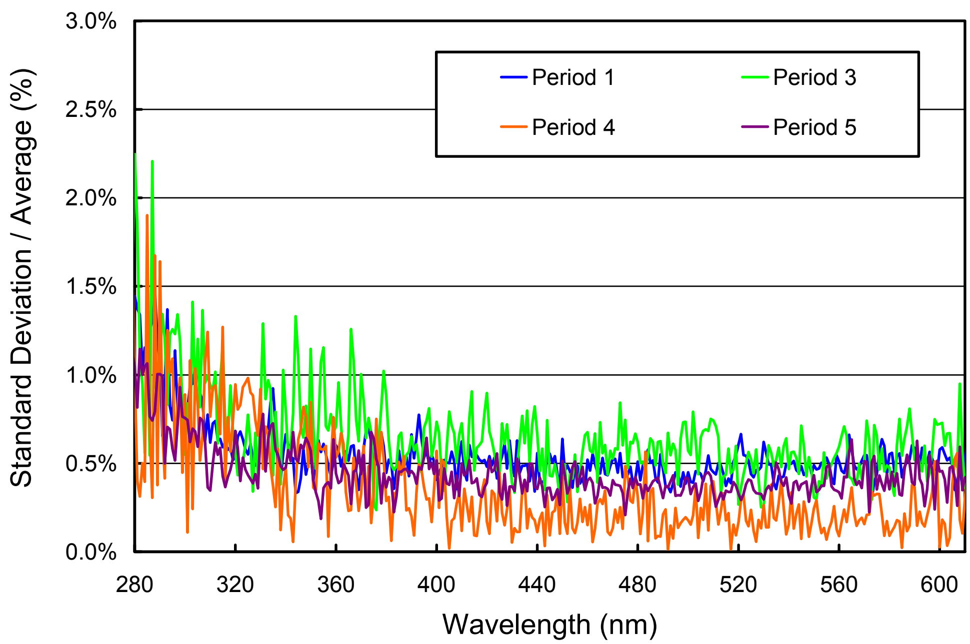

Figure 5.3.5. *Ratio of standard deviation and average calculated from the absolute calibration scans measured during the South Pole 2002/03 season.*

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 ideally be the same for all days. Figure 5.3.6 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 381 scans were evaluated. The change in offset was smaller than ±0.055 nm for 97% of the scans. The shifts of 4 scans was larger than ±0.1 nm, and these shifts were mostly caused by operator intervention; the wavelength calibration was adjusted accordingly. Our analysis of the wavelength precision further indicates that the scan-to-scan reproducibility was somewhat better before 9/1/02 than thereafter (see also Figure 5.3.8). The reason for the deterioration is unclear, but it is most like related to the monochromator drive. The monochromator temperature stabilization cannot be the cause as the temperature was stable to within ±0.1 °C.

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 functions are shown in Figure 5.3.7. Three functions were established, one for the period 1/16/02 – 6/21/02 (for data measured before Polar Night), one for the period 6/22/02 – 12/30/02, and one for the period 12/31/02 – 1/13/03. The start of the third period coincides with the start of solar measurements after the replacement of the instrument's shutter. The corrections exceed 1 nm for wavelengths larger than 500 nm. The magnitude of the correction is considerably larger than typical, but does not affect data accuracy.

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 before Polar Night, and smaller than ±0.08 nm thereafter. As pointed out above, we attribute the increased variability in the second part of the season to the mechanics of the monochromator drive. 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 (see Section 4.2.2.2).

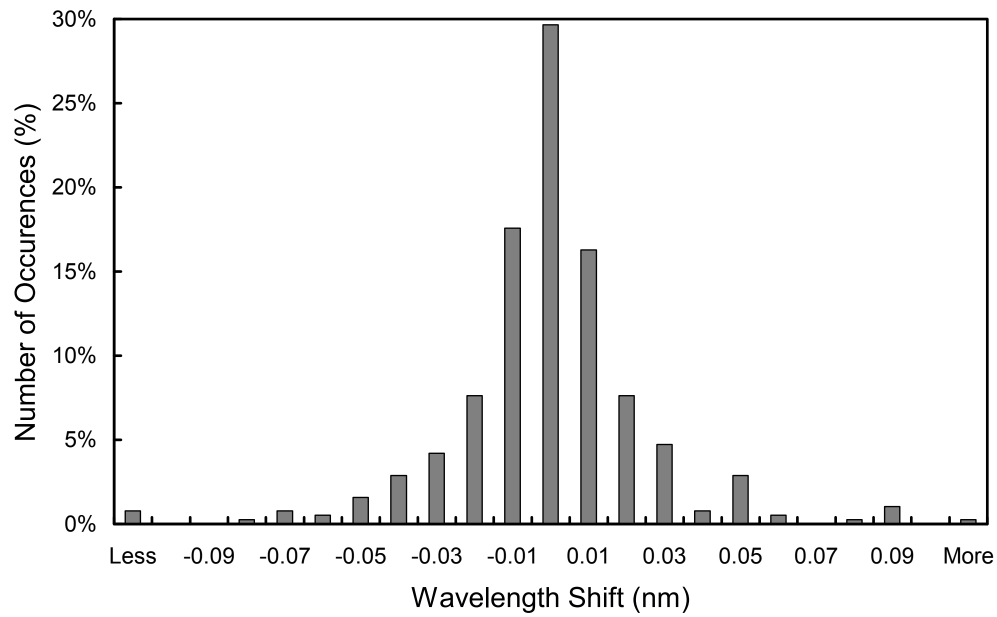

Figure 5.3.6. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. The 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means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

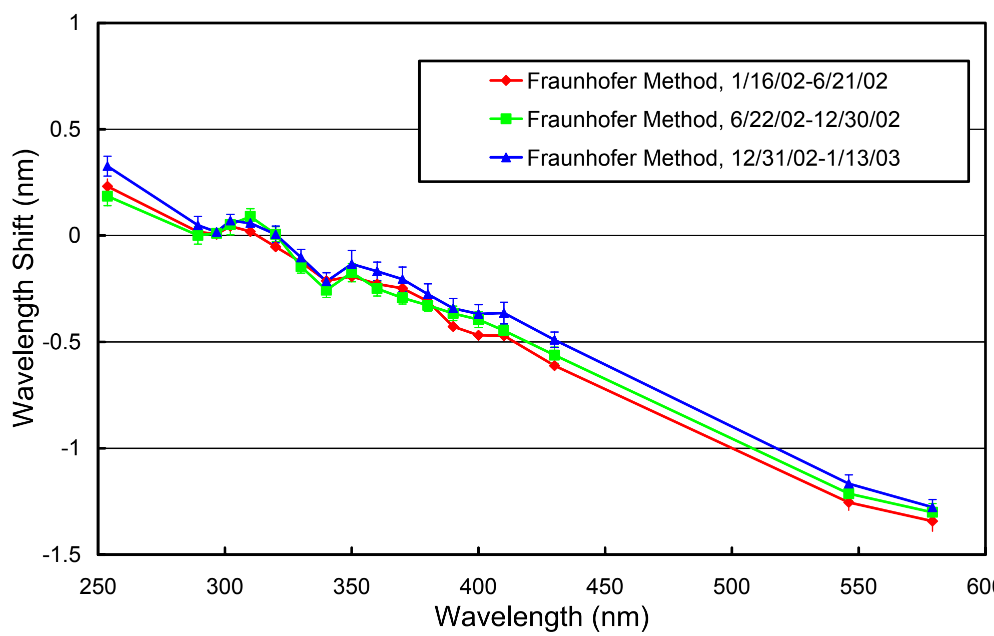

Figure 5.3.7. *Monochromator non-linearity functions for the South Pole 2002/03 season. The error bars show the 1σ standard deviation of the wavelength shifts.*

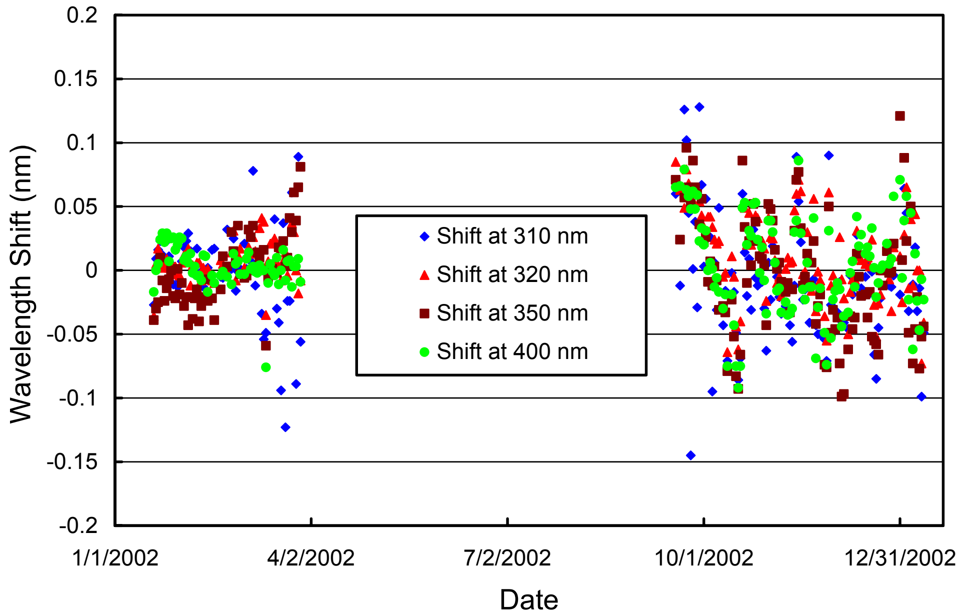

Figure 5.3.8. *Wavelength accuracy check of the final data at four wavelengths by means of Fraunhofer correlation. The noontime measurement has been evaluated for each day of the season. No data exist during polar night.*

Although data from the external mercury scans do not have a direct influence on the 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. As mentioned before, the monochromator installed during 2002 could not be perfectly aligned. External scans have a bandwidth of about 1.1 nm FWHM instead of the more typical bandwidth of 1.0 nm. Internal scans on the other hand have a bandwidth of 0.61 nm. The typical bandwidth is 0.75 nm. Since external scans have the same light path as solar measurements, they more realistically represent the monochromator bandpass relevant for solar scans. Figure 5.3.9 indicates that scans performed during the sites visits in 2002 and 2003 are very consistent.

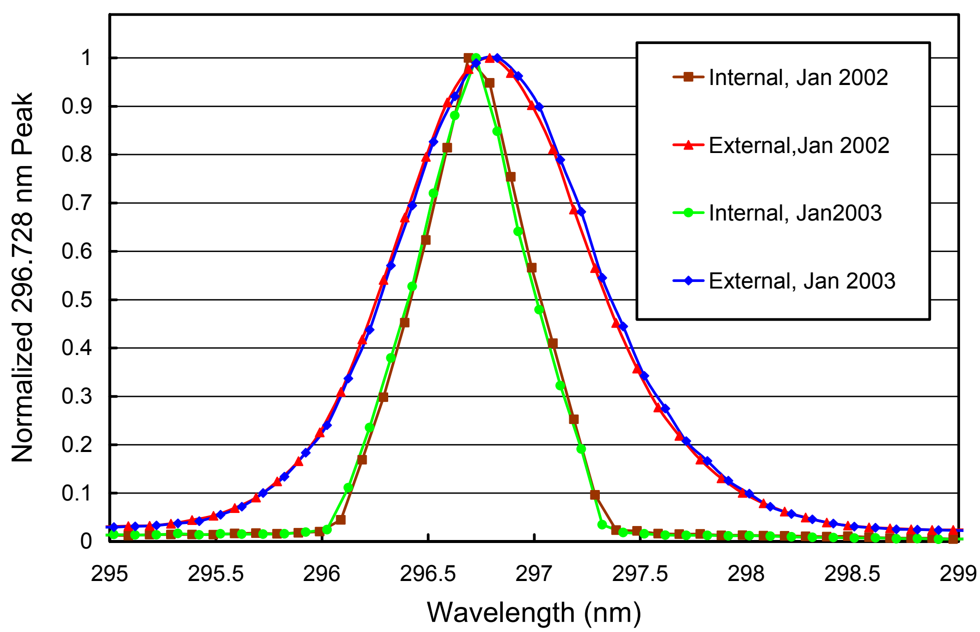

Figure 5.3.9. *The 296.73 mercury line as registered by the PMT from external and internal sources.*

5.3.4. Missing Data

A total of 16740 scans are part of the published South Pole Volume 12 dataset. These are about 93% of all scans scheduled. Of the missing scans, 116, 416, and 297 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 2.1% of the scheduled scans are missing. A total of 98 scans was lost on 2/17/02 and 2/18/02 when the system time was incorrectly set by the GPS receiver. Reading of the GPS receiver superceded 27 scans between October 17 and 29. Malfunction and replacement of the shutter lead to the loss of 205 scans between 12/28/02 and 12/31/02. A total of 110 solar scans that were affected by shading of a mast of the ARO building were removed from the data set. Mostly scans recorded between 5:15 and 6:30 UT are affected. The sensitivity of the system was set too high between 10/10/02 and 10/13/02, leading to a loss of 30 scans. Finally, a total of 19 scans measured on 3/27/02 and 10/9/02 was excluded from the published data set as they were affected by calibration problems.