5.7. Summit, Greenland (02/18/17 – 08/09/17)

This section describes quality control of "Volume 27" solar data that were recorded by the SUV-150B spectroradiometer at Summit Station between 02/18/17 and 08/09/17. On-site support by Research Associates from CH2M HILL Polar Field Services (PFS) with funding from the NSF ensured that the system was regularly calibrated and serviced during the reporting period (e.g., cleaning of irradiance collector). However, there was no financial support to maintain the system otherwise. In July 2017, the NSF requested to remove the system from Summit Station. The system was demobilized starting the day after the last day with solar measurements (8/9/17), and returned to BSI. There are currently no plans to re-establish UV measurements at Summit Station.

The system was affected by several problems (see list below), which could only be partially addressed due to the funding situation. Despite of these challenges, solar spectra of good quality could be produced from the SUV-150B's measurements, and 12,406 scans were published.

- The system control computer failed on 01/24/17. Attempts to repair the computer (including replacing motherboard and memory, and switching to a secondary hard drive) were not successful. A new computer was assembled at BSI and shipped to Summit. Measurements with the new computer commenced on 2/18/17. Unfortunately, the hard drive of the old computer was unreadable and data collected in 2017 prior to 2/18/17 were lost.
- The monochromator of the SUV-150B lost its wavelength position on 3/9/17, 6/15/17, 7/12/17, and 7/17/17, and had to be "re-homed". Data from these days are therefore incomplete.
- On 3/13/16, the electronics interfacing the computer with the power supply of the system's wavelength standard (mercury pen ray lamp) failed and could not be repaired. Scans of the mercury lamp were not performed from this day onward. Because the system uses encoders to set the position of the monochromator's gratings, day-to-day fluctuations of the wavelength registration remained small and deviations from the ideal wavelength scale could be corrected by means of a Fraunhofer line correlation method (Section 5.7.3). The wavelength accuracy of published Version 2 data is therefore only marginally affected by this problem.
- Three standards of spectral irradiance are typically used to calibrate the system throughout any given year. The use of three lamps ensures that a drifting standard is promptly detected. At the start of the reporting period, only two lamps where available because the third lamp (200W030) failed at the end of 2015. One of the remaining two lamps (200W027) became unstable on 4/27/16, and calibrations of solar data after this date, including all calibrations of Volume 27, were exclusively based on the other remaining lamp (200W038). After the system had been returned to BSI, the scale of spectral irradiance of lamp 200W038 was compared with other standards available at BSI. It was found that the scale of spectral irradiance of lamp 200W038 was in excellent agreement with the scales of these other lamps (Section 5.7.1). The uncertainty of solar measurements at Summit referenced to lamp 200W038 during the Volume 26 and 27 periods is therefore not increased despite the fact that all calibrations are based on a single lamp.
- Periodic changes in responsivity of the SUV-150B spectroradiometer observed during the last years continued in 2017. These changes are caused by variations in collector efficiency and PMT sensitivity. These chances are now well understood and were corrected during data processing. Residual variations in published data were assessed by comparing SUV-150B data with measurements of the GUV-511 multi-filter radiometer and results of radiative transfer calculations, and are smaller than ±2.5%.
- The collectors of the SUV-150B and GUV-511 radiometers were shaded by nearby obstacles during some scans. Affected scans were flagged in the Version 2 dataset but were not removed from the Version 0 dataset.
- The sensitivity of the 305 nm channel of the GUV-511 radiometer that is co-located with the SUV-150B instrument decreased by about 25% during 2016 and by additional 10% during the reporting period. These large drifts are likely caused by damage to the instrument that occurred in the summer of 2015 when the cable connecting the GUV-511 radiometer to its control unit was severed. Because of this

large change in sensitivity, no data of the GUV-511 instrument were published. However, measurements of the instrument's remaining four channel were essential for assessing the stability of the SUV-150B system.

The Eppley pyranometer that is co-located with the SUV-150B and GUV-511 radiometers has the serial number 33120F3 and had been calibrated by Eppley Laboratories on 4/15/2013; the calibration constant is 8.44×10^{-5} V/(W m^{-2}). There was no problem with this instrument.

5.7.1. Irradiance Calibration

The on-site irradiance standards used during the reporting period were the lamps 200W027 and 200W038. As mentioned above, lamp 200W027 became unstable on 4/27/16, and calibrations of solar data after this date were exclusively based on lamp 200W038.

Lamp 200W038 was originally calibrated against lamps 200W028 and 200W022 in April 2008. At this time, the calibration of lamp 200W038 was consistent to that of lamp 200W017, which was the travelling standard at this time. Lamp 200W038 was again compared with lamp 200W017 on 7/23/2015; the scales of spectral irradiance of both lamps agreed to within ±1%.

After the system was returned to San Diego, the scales of spectral irradiance of lamps 200W027 and 200W038 were compared with the scales of several lamps (200W050, 200W051, and 200W056) that have been calibrated against BSI's primary NIST standard F-616, which is a 1000 W FEL lamp. The scale of lamp 200W038 agreed almost ideally with the scales of the three San Diego standards, while the scale of (unstable) lamp 200W027 was 4% off (Figure 5.7.1). These results confirm that the scale of irradiance of lamp 200W038, which was the only standard used to calibrated solar data from Summit of the reporting period, is still accurate despite the fact that the lamp had been calibrated nine years ago.

Of note, the scale of spectral irradiance of the previous travelling standard 200W017 was checked in March 2015 against a lamp that had been calibrated against the NIST standard F-616. The scales of spectral irradiance of both lamps agreed to within ±1%, giving confidence in the long-term stability of the scale of irradiance applied to solar data.

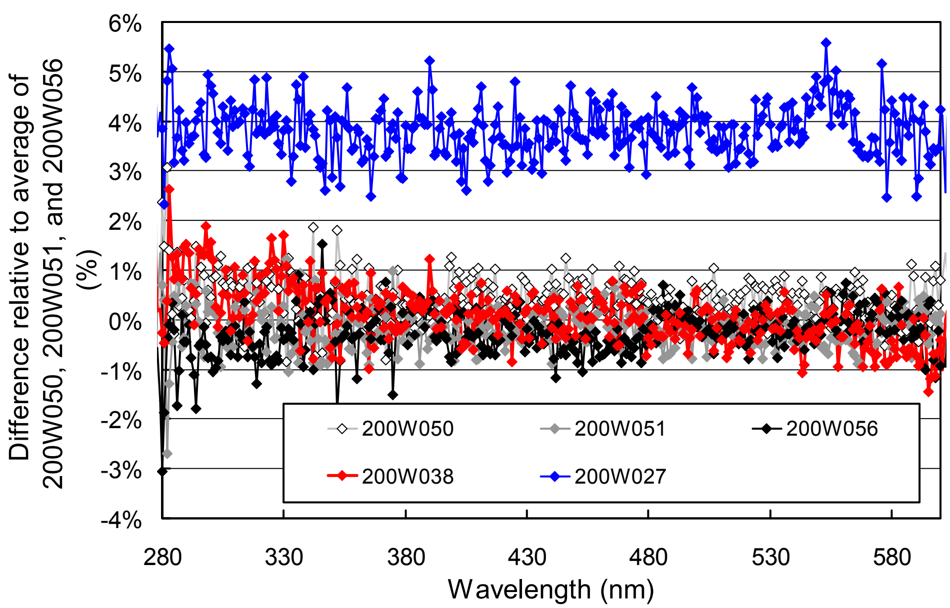

Figure 5.7.1. *Comparison of San Diego standards 200W050, 200W051, and 200W056 with Summit standards 200W027 and 200W038. Data are referenced to the average of the three San Diego lamps.*

5.7.2. Instrument Stability

The temporal stability of the spectroradiometer is monitored with bi-weekly calibrations utilizing the on-site standards; daily response scans of the internal irradiance reference lamp; and by comparison with the co-located GUV-511 radiometer and results from a radiative transfer model.

Internal to the instrument's fore optics is a filtered photo diode, called TSI, with a peak sensitivity in the UV. It is used to track changes in the light intensity of the internal reference lamp. By monitoring the TSI while measuring the current of the system's photomultiplier tube (PMT) detector, changes in the lamp's output can be decoupled from drifts in monochromator throughput or PMT sensitivity. Figure 5.7.2 shows changes in TSI readings and PMT currents at 320 and 400 nm, derived from response scans performed between 2/14/06 and 8/9/17. TSI measurements changed by about 10% between 2/14/06 and 6/20/09. The lamp failed and the end of August 2009 and was replaced. Data recorded after this time were scaled downward by a constant factor to better compare with previous measurements. The relative change of the second lamp's intensity as recorded by the TSI between 9/2/09 and 8/9/17 is similar to that of the original lamp, except of two brief periods (7/15/13 – 9/29/13 and 11/4/15 – 4/29/16). TSI measurements were virtually constant in 2017, indicating that the response lamp was stable during the reporting period.

The trend of PMT currents agrees with that of the TSI measurements but there is a sinusoidal variation with a periodicity of one year superimposed on the general trend. The highest PMT sensitivity is observed in mid-February of every year, while the lowest sensitivity is observed in August. We attribute this periodicity to a long-term memory of the PMT to the radiation levels it has "seen" during the months prior to the measurement. During the period of winter darkness, the PMT becomes more sensitive, and during the summer months its sensitivity decreases. As the variation is very predictable, it can be well corrected when solar data are processed.

To account for the combined changes of the throughput of the system's entrance optics and PMT-sensitivity, the reporting period was broken into five sub-periods and a different irradiance spectrum was applied to the internal lamp in each period. A summary of the calibration periods is provided in Table 5.7.1. Ratios of irradiance spectra applied in Periods P1 – P3 relative to the spectrum applied in Period P2 are shown in Figure 5.7.3.

The quality of calibrated solar measurements of the SUV-150B was further assessed by comparison with data of the GUV-511 radiometer. Figure 5.7.4 shows the ratio of measurements of the GUV's 340 nm channel to measurements of the SUV-150B. The latter have been weighted with the spectral response function of the GUV's channel prior to forming the ratio. Measurements of the two instruments generally agree to within about ±5%, with the exception of several outliers (The standard deviation of the ratio with outliers removed is 2%.). Most outliers occur between June and August and are related to obstacles in the field of view of either the GUV or the SUV that shade the direct Sun. Because the two instruments are located approximately one meter apart, they are shaded at slightly different times, leading to variations in the ratio. Affected data were flagged in the Version 2 dataset of the SUV-150B. Figure 5.7.4 also indicates a ~4% step in the GUV/SUV ratio between Periods P2 and P3. The reason for this step is unknown. However, there is no step of similar magnitude in the ratio of SUV measurements and the results of the Version 2 radiative transfer model, suggesting that the step is not caused by an unexplained shift in the SUV calibrations.

Table 5.7.1. Calibration periods for Summit Volumes 27.

Period name	Period range	Number of absolute scans
P1	02/15/17 – 02/28/17	1
P1B	03/01/17 – 04/02/17	1
P2	04/03/17 – 05/18/17	2
P2B	05/19/17 – 05/30/17	0 (average of Periods P2 and P3)
P3	05/31/17 – 08/10/17	3

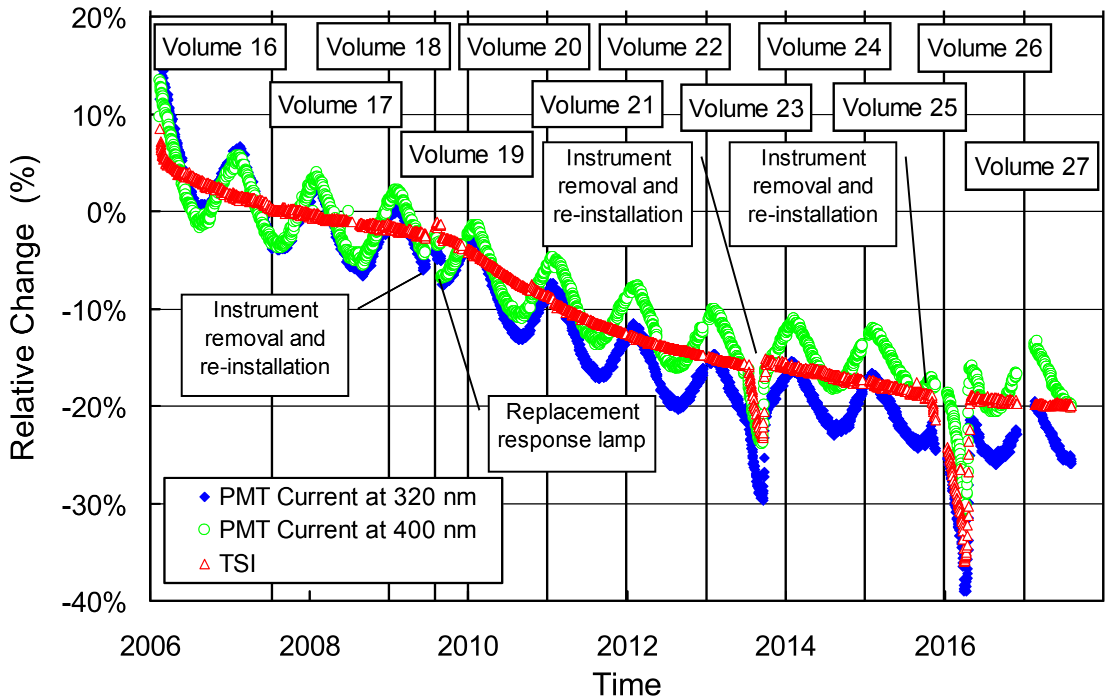

Figure 5.7.2. *Time-series of TSI signal and PMT currents at 320 and 400 nm during measurements of the internal reference lamp performed at Summit between 2/15/06 and 11/28/16. Data from 9/2/10 (date of response lamp replacement) onward were scaled downward to fit into the existing pattern. Data are normalized to the period 2/14/06 - 6/20/09.*

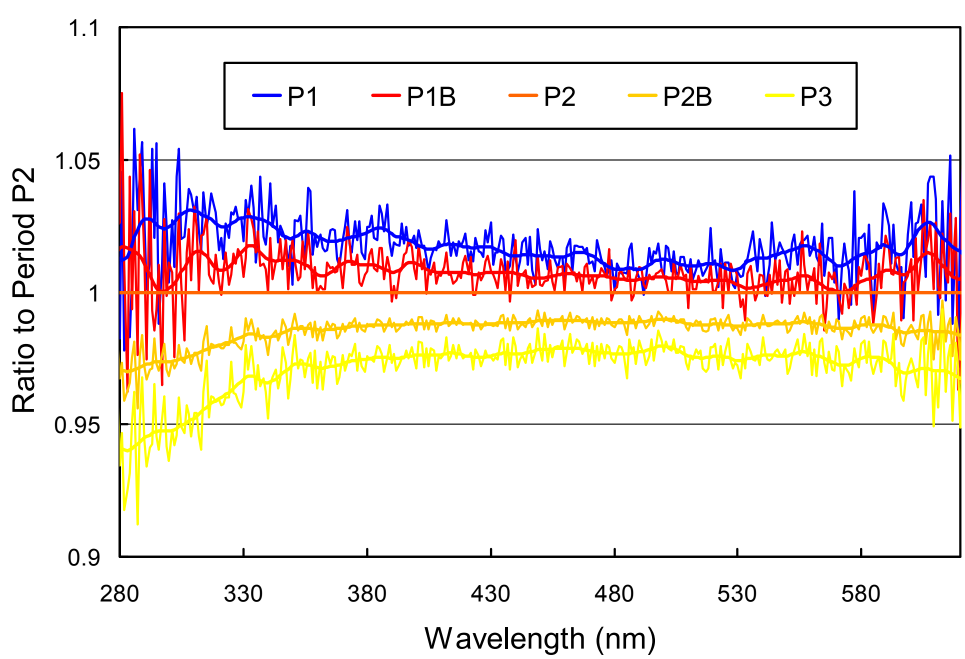

Figure 5.7.3. *Ratios of irradiance assigned to the internal reference lamp in Periods P1 – P3, referenced to the irradiance of Period P2. Thin lines indicates ratios calculated from the processed lamp spectra. Thick lines are a spline fit to the data. The splined dataset was used for the calibration of solar spectra.*

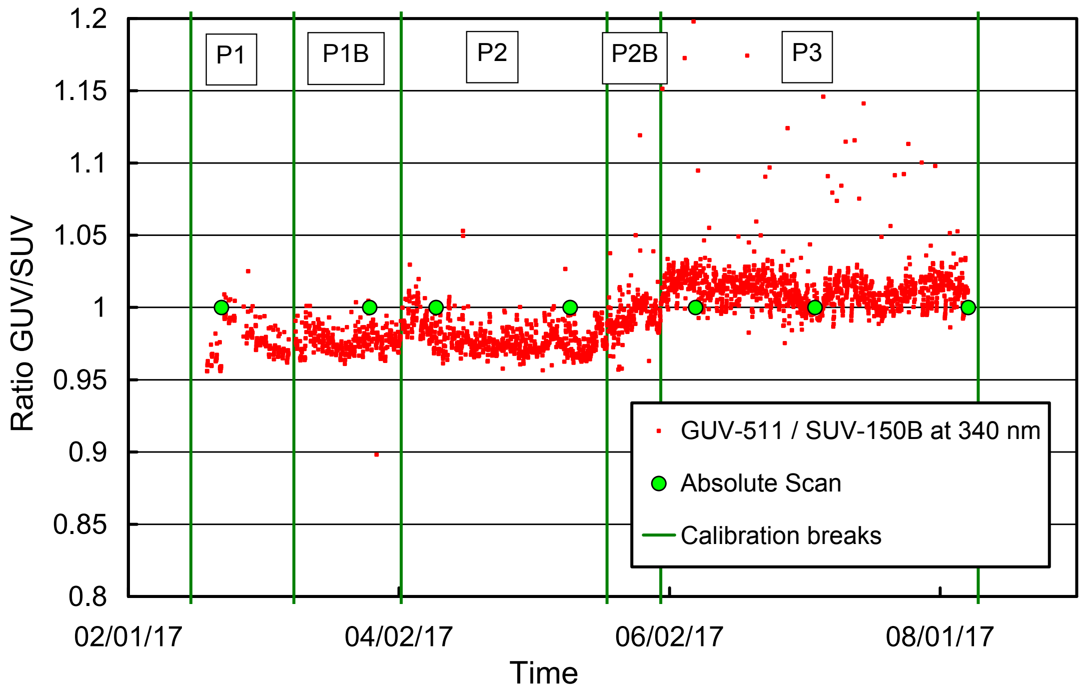

Figure 5.7.4. *Ratios of GUV-511 and SUV-150B measurements at 340 nm. Breaks in the calibration of SUV data and the times of absolute scans are also indicated. The reason of the apparent 4% step between Periods P2 and P3 is unknown.*

5.7.3. Wavelength Calibration

Up to 3/13/16, wavelength stability of the system was monitored with the internal mercury lamp. On this day, the electronics controlling the mercury lamp failed, and from then onward, it was no longer possible to turn off the lamp during solar scans under computer control. The mercury lamp had to be manually switched off, and no scans of this lamp were performed thereafter. Good wavelength stability could be achieved nonetheless because the SUV-150B system uses encoders to control the position of the monochromator's gratings.

The absolute accuracy of the monochromator's wavelength registration was checked and corrected with the Fraunhofer-line correlation method developed for processing of Version 2 data (*Bernhard et al., 2004*; see also Section 4.2.2.2). For the generation of Version 0 data, one correction function was calculated with this method (Figure 5.7.5). After data were corrected using this function, the wavelength accuracy of all noontime scans was verified by running the Fraunhofer-line correlation algorithm a second time, and results are shown in Figure 5.7.6. Residual wavelength errors are smaller than ±0.1 nm, with few exceptions.

For processing of Version 2 data, the wavelength correction was further refined. As a result, residual wavelength errors of Version 2 are smaller than ±0.03 nm throughout the reporting period, with few exceptions (Figure 5.7.7).

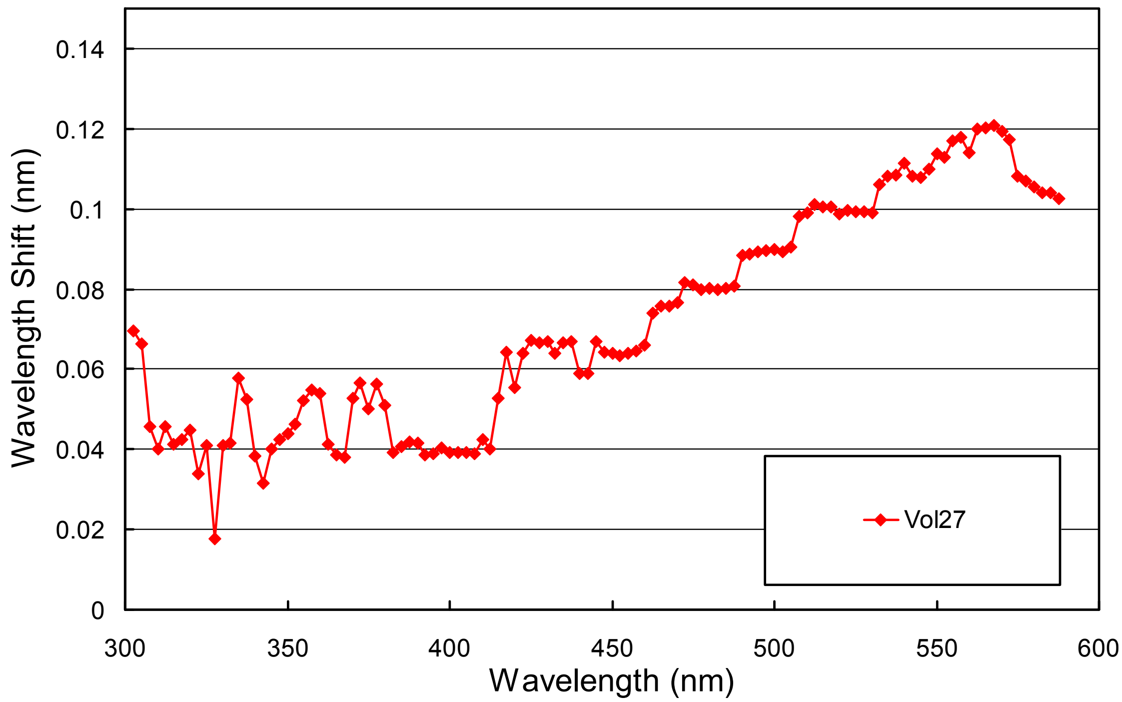

Figure 5.7.5. *Monochromator non-linearity correction functions of Volume 27 data.*

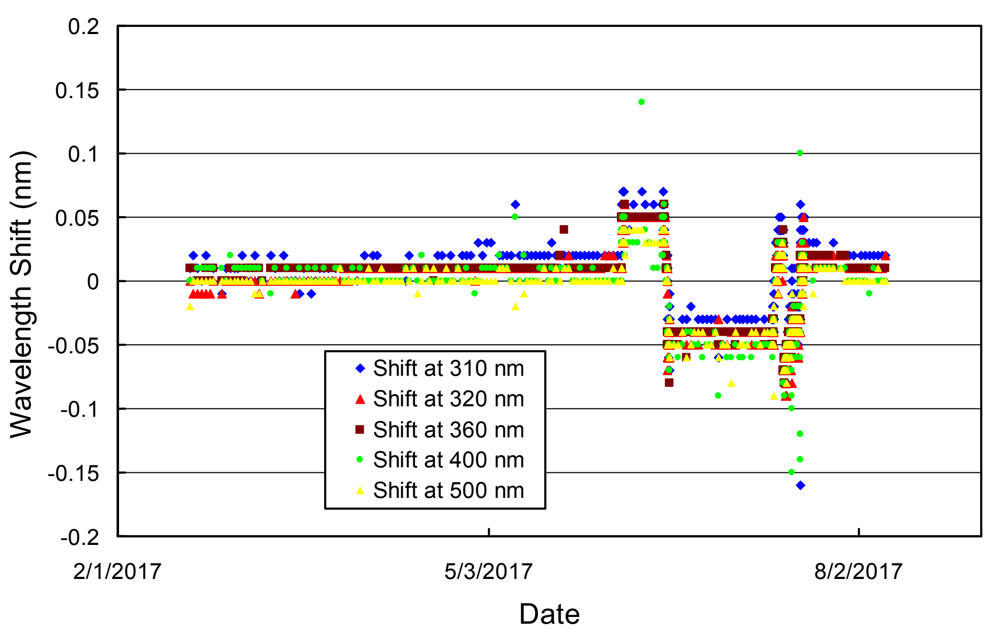

Figure 5.7.6. *Wavelength accuracy check of "Version 0" Volume 27 data at five wavelengths in the UV and visible by means of Fraunhofer-line correlation. All noontime measurements have been evaluated.*

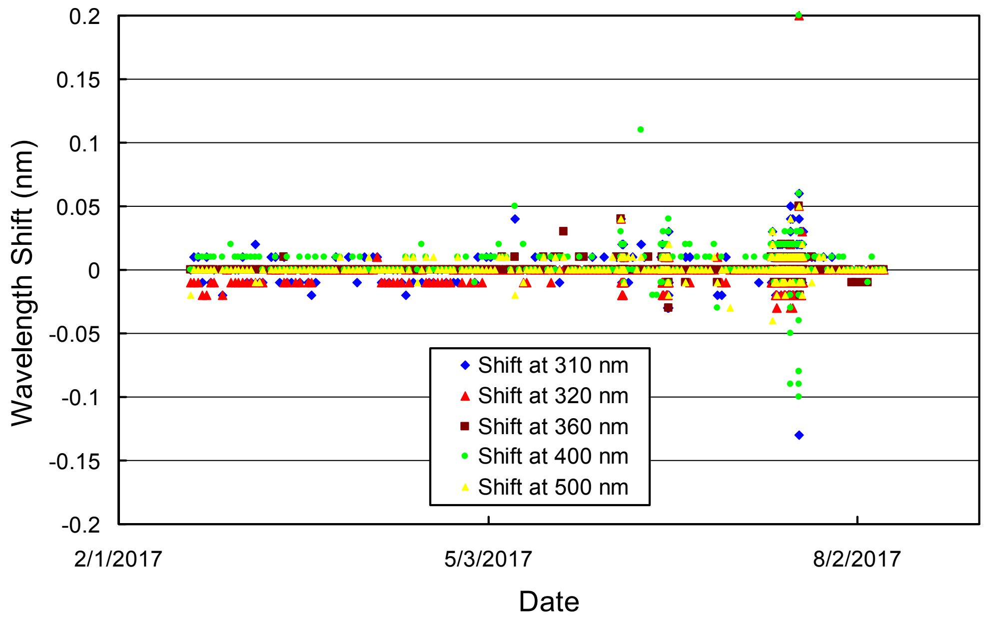

Figure 5.7.7. *Wavelength accuracy check of "Version 2" Volume 27 data at five wavelengths in the UV and visible by means of Fraunhofer-line correlation. All noontime measurements have been evaluated.*

5.7.4. Missing Data

A total of 12,406 SUV-150B spectra are part of the Summit Volume 27 dataset. Missing periods are summarized in Table 5.7.2.

Table 5.7.2. Incomplete days in the Summit Volume 27 dataset.

Period	Reason
01/20/17 – 02/17/17	Data lost due to computer failure. The hard drive of the computer is not readable.
03/09/17	Monochromator lost its position
06/15/17	Monochromator lost its position
07/12/17	Monochromator lost its position
07/17/17	Monochromator lost its position
07/27/17	Data file error