5.7. Summit, Greenland (01/20/16 – 11/23/16)

This section describes quality control of "Volume 26" solar data that were recorded by the SUV-150B spectroradiometer at Summit Station between 01/20/16 and 11/23/16. On-site support by research associates from CH2M HILL Polar Services with funding from the NSF ensured that the system was regularly calibrated and serviced during the reporting period (e.g., cleaning of irradiance collector, computer maintenance). However, there was no financial support to maintain the system otherwise, or to perform repairs.

The system was affected by several problems (see list below), which could not be fully 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 16,304 scans were published.

- Between 1/4/15 and 4/29/16, the internal "response" lamp of the instrument drifted greatly. As a consequence, measurements of this lamp could not be used to track changes of the instrument's sensitivity over this period. The effect on published solar data is fortunately small because the system's responsivity changed predictably during this period, allowing to correct the observed drift using bi-weekly calibration scans.
- 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. The calibration of the remaining two lamps agreed to within 1-2% on 2/9/16 when the lamps were compared with each other. Unfortunately, one (200W027) of the two lamps became unstable on 4/27/16, and calibrations of solar data after this date were exclusively based on the one remaining lamp (200W038). Comparison of solar data measured by the SUV-150B with measurements of the collocated GUV-511 confirmed that systematic errors due to potential changes in the output of lamp 200W038 between May and November 2016 remained below 3%.
- During periods of high winds, the system's data acquisition unit and computer frequently became unresponsive and had to be rebooted. We hypothesize that this problem is the result of static electricity, exacerbated by a poor ground connection due to the system's location on an ice sheet. This problem led to data loss (Section 5.7.4), but did not affect the accuracy of published data.
- Periodic changes in responsivity of the SUV-150B spectroradiometer observed during the last years continued in 2016. 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%.
- Measurements of the TSI sensor internal to the SUV-150B were not always correctly recorded. Defective data were not removed from the published databases. TSI measurements should therefore not be used.
- 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 30% during the reporting period. This large drift was 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. These standards were last compared with the traveling standard 200W017 on 7/23/2015. At this time, the scales of spectral irradiance of lamps 200W027 and 200W038 agreed with the scale of 200W017 to within ±2% and ±1%, respectively. (See the previous operations report for details!) The scales of spectral irradiance of the two on-site standards implemented in 2016 were identical to those used in 2014 and 2015.

Calibration history of on-site standards 200W027 and 200W038

Lamp 200W027 was originally calibrated on 3/28/01 by Optronic Laboratories. The lamp was recalibrated against the project's traveling standard, lamp 200W017, using "closing" scans performed at Summit on 7/11/07. The lamp was temporarily moved to San Diego and was recalibrated in March 2008 against lamps 200W028 and 200W022. It was recalibrated again in November 2011 against standards 200W017 and 200W038. This calibration also was used for processing of solar data of Volume 21 (2011), Volume 22 (2012), Volume 23 (2013), Volume 24 (2014), and Volume 25 (2015).

Lamp 200W038 was calibrated against lamps 200W028 and 200W022 in April 2008. At this time, the calibration of lamp 200W038 was consistent to that of 200W017.

Lamps 200W027 and 200W038 were compared with each other on 2/9/16. At this time, their calibrations agreed to within 1% in the UV-B, 1.5% in the UV-A, and 2% in the visible range. Lamp 200W027 became unstable on 4/27/16, and calibrations of solar data after this date were based exclusively on lamp 200W038.

Calibration history of traveling standard 200W017

Lamp 200W017 was calibrated in June 2007 at BSI with four 1000-Watt FEL lamps provided by the Central UV Calibration Facility (CUCF) at Boulder. This calibration procedure was complicated by the fact that the irradiance scale of the four FEL lamps refers to the detector-based scale of the National Institute of Standards and Technology established in 2000 (NIST2000; *Yoon et al*., 2002), whereas all solar data of the NSF UVSIMN refer to the source-based NIST scale from 1990 (NIST1990, *Walker et al*., 1987). The NIST2000 scale is about 1.3% larger than the NIST1990 scale. Values of spectral irradiance provided in certificates issued by the CUCF were converted to the NIST1990 scale before the calibration was transferred to lamp 200W017. The scale of spectral irradiance of lamp 200W017 was checked in March 2015 against a lamp that is traceable to the NIST primary standard F-616. It was concluded at this time that the June 2007 calibration of the lamp is still accurate to within ±1%.

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 5.7.1 shows changes in TSI readings and PMT currents at 320 and 400 nm, derived from response scans performed between 2/14/06 and 11/28/16. 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 11/28/16 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). The reason for the large drift of the internal lamp during these two periods is unknown. Of note, TSI readings after 4/29/16 were stable, indicating that the lamp has recovered.

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 seven 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 – P7 relative to the spectrum applied in Period P1 are shown in Figure 5.7.2. The large change in spectral irradiance between Periods P1 and P5 is due to the large decrease in the response lamp's intensity over these periods. During Periods P6 and P7, the lamp was very stable, and the two spectra for these periods are therefore in good agreement.

The quality of calibrated solar measurements of the SUV-150B was further assessed by comparison with data of the GUV-511 radiometer. Figure 5.7.3 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 ±3.5%, with the exception of several outliers (The standard deviation of the ratio is 1.8%.). 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 5.7.3 also indicates a step change of 2.7% between 4/25/16 and 4/28/16. This step occurred at the time when the calibration of the system was changed from being based on lamps 200W027 and 200W038 (before 4/25/16) to being based on lamp 200W038 alone (after 4/25/16). Around this time, also the response lamp of the system regained stability. These observations may suggest that the step change is caused by uncorrected changes in sensitivity of the SUV-150B's measurements. However, comparisons of clear sky spectra with a radiative transfer model do not clearly indicate that there is a problem in the SUV-150B dataset. It can be concluded that systematic errors caused by the reliance of only one calibration lamp are less than 3%, and likely smaller.

Table 5.7.1. Calibration periods for Summit Volumes 26.

Period name	Period range	Number of absolute scans
P1	01/01/16 – 01/31/16	1
P2	02/01/16 – 02/18/16	2
P3	02/19/16 – 03/12/16	1
P4	03/13/16 – 03/29/16	2
P5	03/30/16 – 04/26/16	1
P6	04/27/16 – 06/19/16	2
P7	06/20/16 – 11/28/16	4

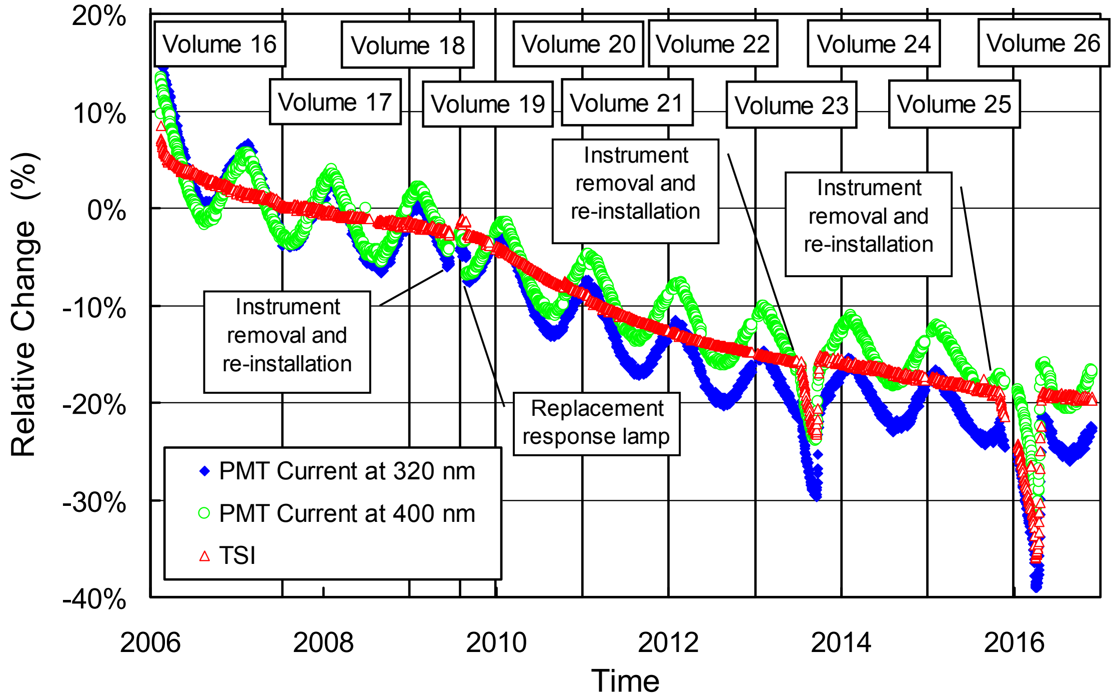

Figure 5.7.1. *Time-series of TSI signal and PMT currents at 320 and 400 nm during measurements of the internal reference lamp performed at Summit between 2/15/06 and 11/28/16. Data from 9/2/10 (date of response lamp replacement) onward were scaled downward to fit into the existing pattern. Data are normalized to the period 2/14/06 - 6/20/09.*

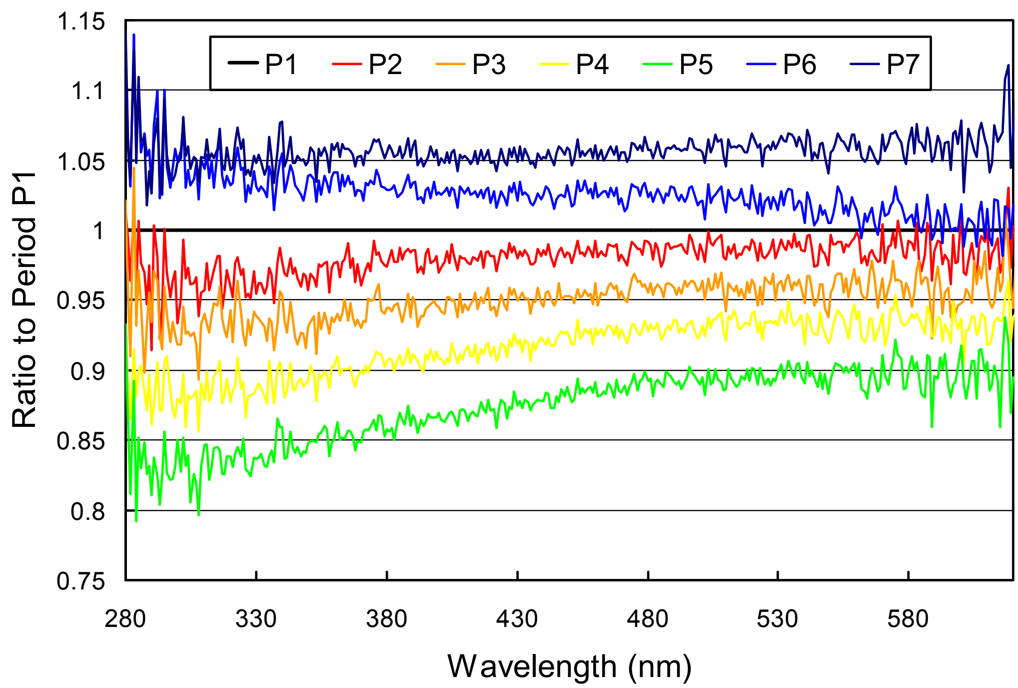

Figure 5.7.2. *Ratios of irradiance assigned to the internal reference lamp in Periods P1 – P7, referenced to the irradiance of Period P1.*

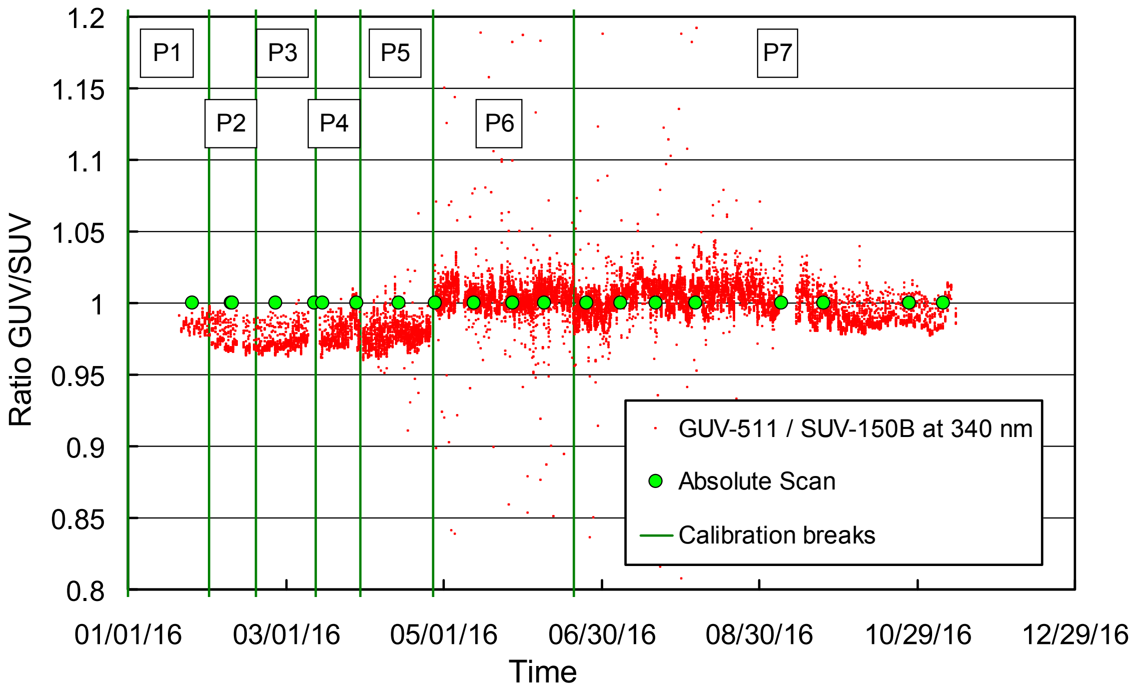

Figure 5.7.3. *Ratios of GUV-511 and SUV-150B measurements at 340 nm. Breaks in the calibration of SUV data and the times of absolute scans are also indicated. The apparent step change between Periods P5 and P6 is discussed in the text.*

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 for the rest of the reporting period. 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, three correction functions were calculated with this method (Figure 5.7.4). After data were corrected using these functions, 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 5.7.5. For periods 1/20/16 – 6/10/16 and 7/30/16 – 11/14/16, residual wavelength errors are smaller than ±0.03 nm, with few exceptions. However, larger wavelength errors of up to 0.1 nm are observed for the period 6/1/16 – 7/29/16.

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 5.7.6).

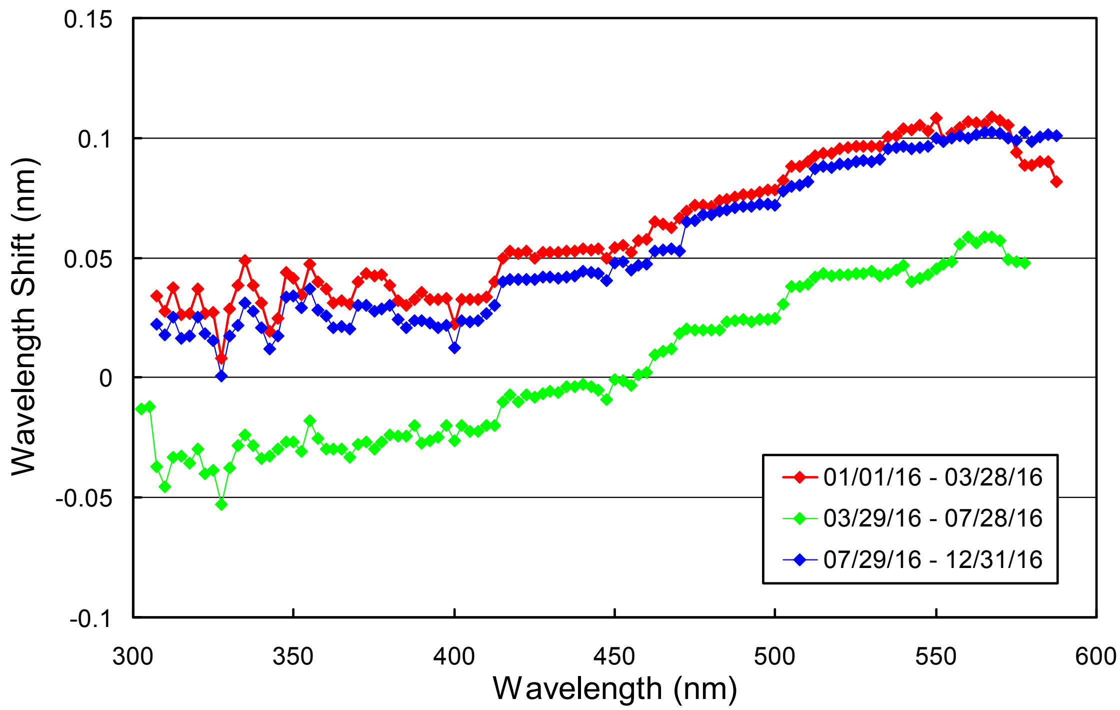

Figure 5.7.4. *Monochromator non-linearity correction functions of Volume 26 data.*

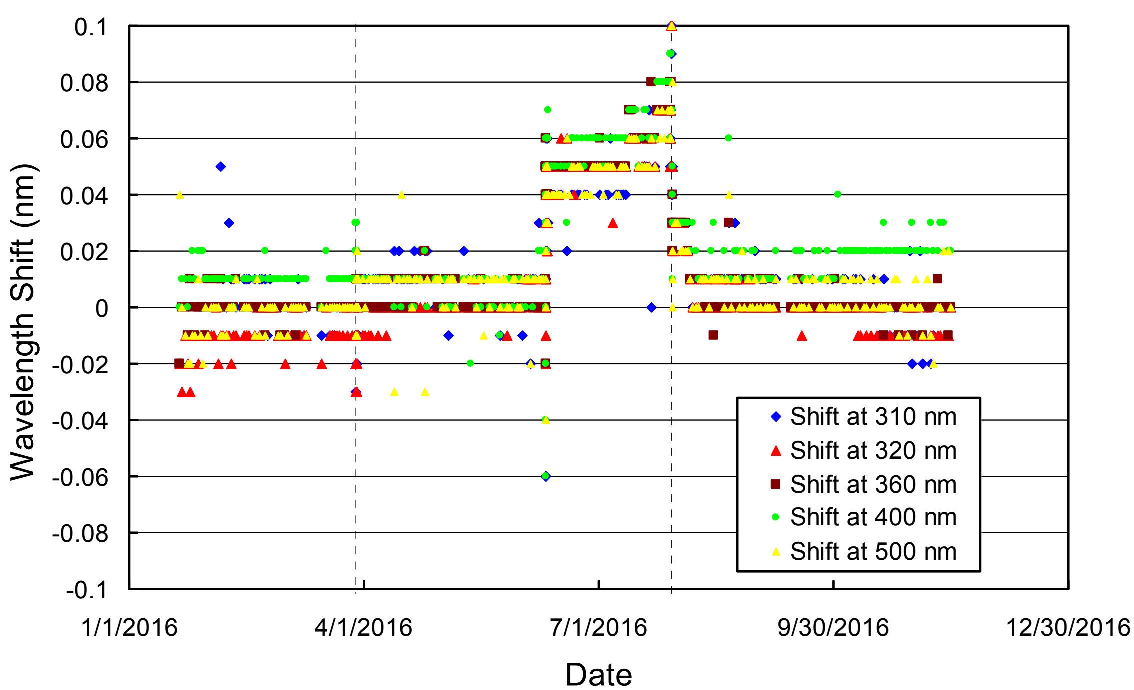

Figure 5.7.5. *Wavelength accuracy check of "Version 0" Volume 26 data at five wavelengths in the UV and visible by means of Fraunhofer-line correlation. All noontime measurements have been evaluated. Vertical broken lines indicate times when wavelength correction functions were changed.*

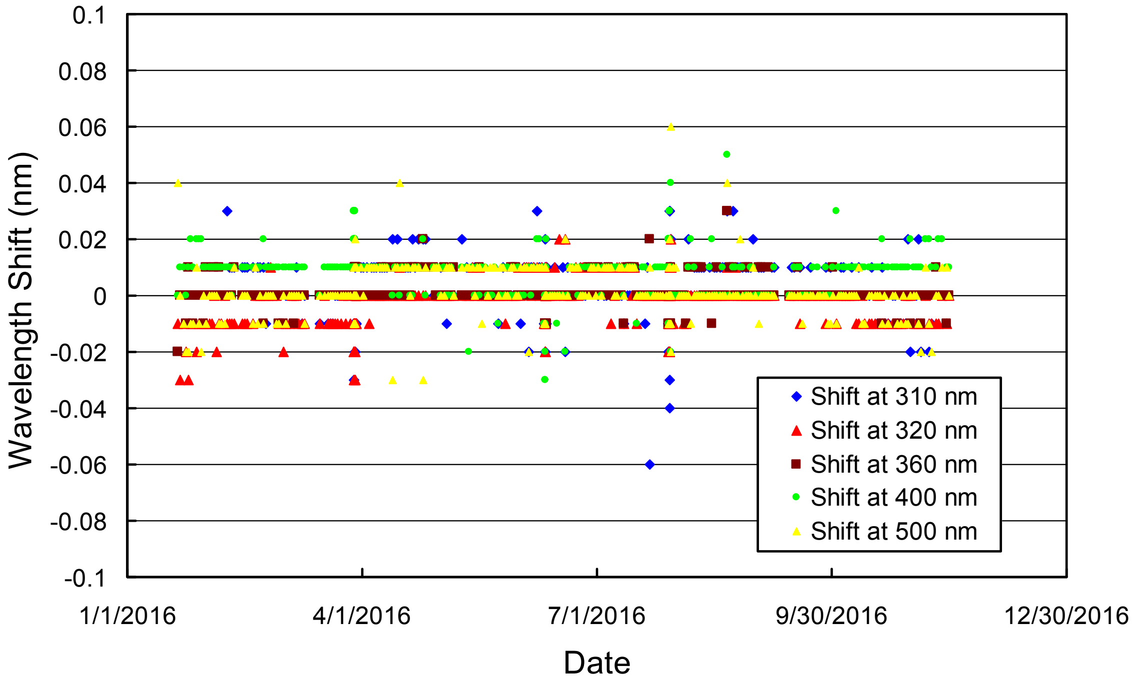

Figure 5.7.6. *Wavelength accuracy check of "Version 2" Volume 26 data at five wavelengths in the UV and visible by means of Fraunhofer-line correlation. All noontime measurements have been evaluated.*

5.7.4. Missing Data

A total of 16,304 SUV-150B spectra are part of the Summit Volume 26 dataset. Missing periods are summarized in Table 5.7.2.

Table 5.7.2. Incomplete days in the Summit Volume 26 dataset.

Period	Reason
02/12/16 – 02/13/16	Computer problem
03/10/16 – 03/14/16	Failure of the data acquisition system due to static electricity caused by high winds; failure of electronics controlling mercury lamp
03/30/16	Unknown
04/23/16	Failure of the data acquisition system due to static electricity caused by high winds
04/26/16 – 04/27/16	Failure of the data acquisition system due to static electricity caused by high winds
05/07/16 – 05/08/16	Construction on "Green House" (Building where instrument is located)
09/08/16 – 09/13/16	Computer problem
09/23/16	Computer problem
10/22/16	Computer problem
11/04/16	Computer problem
11/12/16	Failure of the data acquisition system due to static electricity caused by high winds
11/15/16 – 11/22/16	Failure of the data acquisition system due to static electricity caused by high winds