1. McMurdo Station (08/15/19 – 04/30/20)

Solar data of the SUV-100 spectroradiometer discussed in this quality control report were measured between 08/15/19 and 04/30/20 and were assigned to Volume 29. A site visit took place between 2/2/20 and 2/6/20 when the system was serviced and calibration standards were intercompared. The system's operating system was upgraded from Windows 7 to Windows 10 on 1/12/20. The system performed without important problems, although the wavelength stability was degraded, requiring frequent adjustment of the system's wavelength registration during post-processing. In addition, the system's GPS receiver, which is used to automatically update the computer time, failed on 1/14/20. From that time onward, the computer's clock was checked and adjusted manually. The clock of the system PC is fortunately very stable. Hence time errors in published data remain negligible.

The datasets consists of 16,804 solar spectra. The system's PSP radiometer installed before the site visit was unit 12257F3 and had a calibration factor of 8.714 x10^{-6} V/(W m^{-2}). The PSP radiometer installed after the site visit was unit 32760F3 and has a calibration factor of 7.501 x10^{-6} V/(W m^{-2}). Data of the collocated TUVR radiometer were erratic and were not published.

1.1. Irradiance Calibration

On-site irradiance standards used during the reporting period were the lamps M-543, 200W011, 200W019, 200WN007, and 200WN008. Lamp 200WN014 was used as a traveling standard during the site visit. Lamps M-543, 200W011 and 200W019, are "working standards" and are used on a regular basis. Lamps 200WN007 and 200WN008 were left at McMurdo in January 2014. Both lamps are designated "long-term" standards and are only used during site visits. The scales of spectral irradiance assigned to the three working and long-term standards were the same as those applied during the previous two season (Volumes 27 and 28), specifically:

- Lamps 200W011 and 200W019 had been recalibrated on 6/11/18 against the scale of the two long-term standards 200WN007 and 200WN008.
- Lamp M543 had been recalibrated on 8/8/16 against the working standard 200W011.

Traceability of long-term standards 200WN007 and 200WN008

Lamps 200WN007 and 200WN008 were calibrated by CUCF in August 2013 against lamps 200WN001 and 200WN002. The latter two lamps had in turn been calibrated by Biospherical Instruments in November 2012 against the NIST standard F-616 using a multi-filter transfer radiometer. NIST standard F-616 is traceable to the detector-based scale of irradiance established by NIST in 2000. At the time when lamps 200WN001 and 200WN002 were calibrated, they were also compared with the long-term traveling standard 200W017 of the NSF UV monitoring network. The irradiance scales of NIST standard F-616 and lamp 200W017 agreed to within 0.3%.

In early 2020, the chain of calibrations applied between 1996 and 2019 to solar data of the NSF and NOAA monitoring networks was re-evaluated. This analysis suggested that the scale of spectral irradiance of NIST standard F-616 is low compared to the scale of primary standards used before 2013. This bias ranges between –2% at 300 nm, –1% at 375 nm, and less than ±0.5% between 420 and 600 nm. **Version 2 solar data of Volume 29 were scaled upward accordingly, however, Version 0 remain traceable to the original scale of the primary standard F-616.**

Figure 1 shows a comparison of all lamps based on absolute scans taken on 5 and 6 February 2020. The scales of spectral irradiance of the three working and the two long-term standards agree to better than ±0.5% on average. In contrast, the scale of the traveling standard 200WN014 is biased by 1.1% compared to the scale of the other lamps. This bias is consistent to that observed during previous site visits and consistent to the bias observed at the South Pole. The analysis of the chain of calibrations performed in early 2020 suggests that the scale of the long-term standards is more accurate than that of the traveling standard 200WN014..

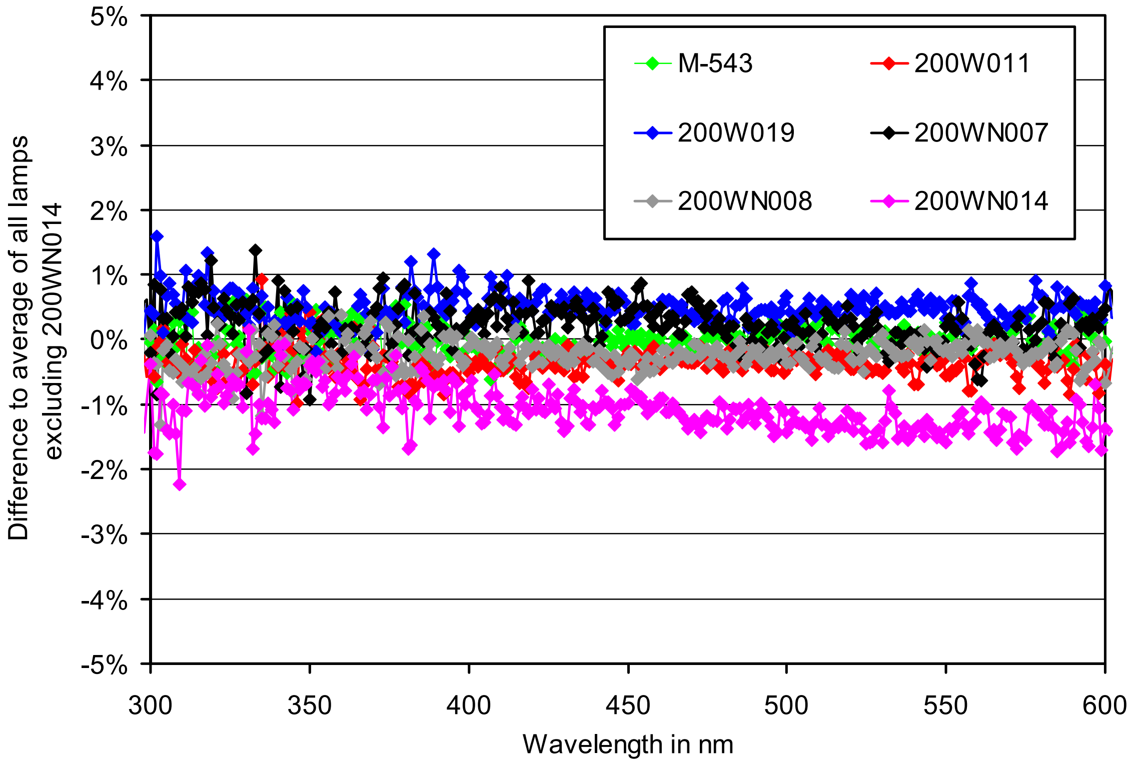

Figure 1. Comparison of McMurdo standards M-543, 200W011, 200W019, 200WN07, and 200WN008, plus the traveling standard 200WN014 using absolute scans performed on 2/5/20 and 2/6/20.

The scale of irradiance maintained by the five on-site standards was further checked by comparing SUV-100 measurements with data of the collocated GUV-511 radiometer. Like in the last years, the GUV radiometer was vicariously calibrated against the SUV's measurements. Calibration factors established for the GUV's 305, 340, 380 and PAR channels for the 2018/19 period agreed to within 1.2% with those calculated for the reporting period, confirming that the scales of irradiance applied to solar data of the SUV-100 in 2018/19 and 2019/20 are consistent within acceptable limits.

1.2. Instrument Stability

The temporal stability of the SUV-100 spectroradiometer was assessed by (1) analyzing measurements of the internal reference lamp, (2) analyzing absolute scans using the on-site standards, (3) comparing SUV-100 measurements with data of the collocated GUV-511 radiometer, and (4) comparing solar measurements with results of a radiative transfer model. Results of the four methods are reviewed below.

Figure 2 shows results from measurements of the internal lamp. Specifically, readings of the instrument's TSI sensor (a filtered photo diode with sensitivity mostly in the UV-A) are compared with measurements of the SUV-100's PMT at 300 and 400 nm. TSI readings decreased by about 2.5% between the start of the reporting period and time of the site visit when the internal lamp was replaced. TSI readings with the new lamp increased by about 2%. For a perfectly stable system, TSI and PMT measurements would track each other in response to a change in the lamp's output. In actuality, PMT measurements at both wavelengths varied by about ±1.5% during both periods and changes in PMT readings are not quite in sync with the TSI measurements. By pairing solar scans with scans of the internal response lamp that were performed on the same day as the solar measurements, changes of the system's sensitivity (as indicated by changes in PMT current and/or monochromator throughput) are corrected.

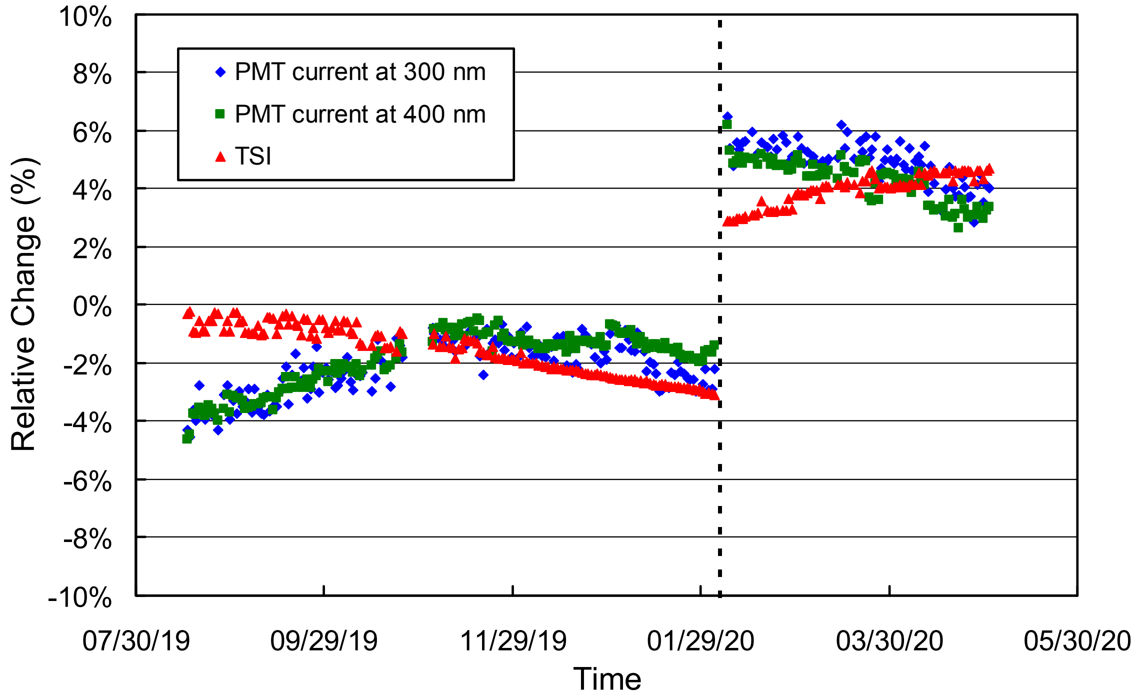

Figure 2. *Measurements of the SUV-100's TSI sensor and PMT currents at 300 and 400 nm. Data are shown as relative change and normalized to the average of the entire period. The broken vertical line indicates the time when the internal lamp was changed during the site visit.*

Examination of scans of the on-site standards confirmed that the system was quite stable during the reporting period. Normal calibration procedures were applied, resulting in seven calibration periods, labeled P1 – P7 (Table 1). Figure 3 shows ratios of irradiance spectra assigned to the internal reference lamp during these periods relative to the spectrum of Period P1. Changes in responsivity between periods are generally smaller than 1%, with the exception of the difference between the pre-visit period P5 and the post-visit period P6. The large change of about 13% between these two periods can be explained by the actions taken during the site visit when the instrument was dismantled, cleaned, serviced, and re-assembled.

Table 1: Calibration periods for McMurdo Volume 29 SUV-100 data.

Period	Period range	Number of absolute scans	Remark
P1	05/02/19 – 10/22/19	7	
P3	10/23/19 – 12/31/19	4	
P3B	01/01/20 – 01/06/20	0	Average of periods P3 and P4
P4	01/07/20 – 01/31/20	3	
P5	02/01/20 – 02/04/20	2	
P6	02/05/20 – 02/08/20	9	
P7	02/08/20 – 05/01/20	5	

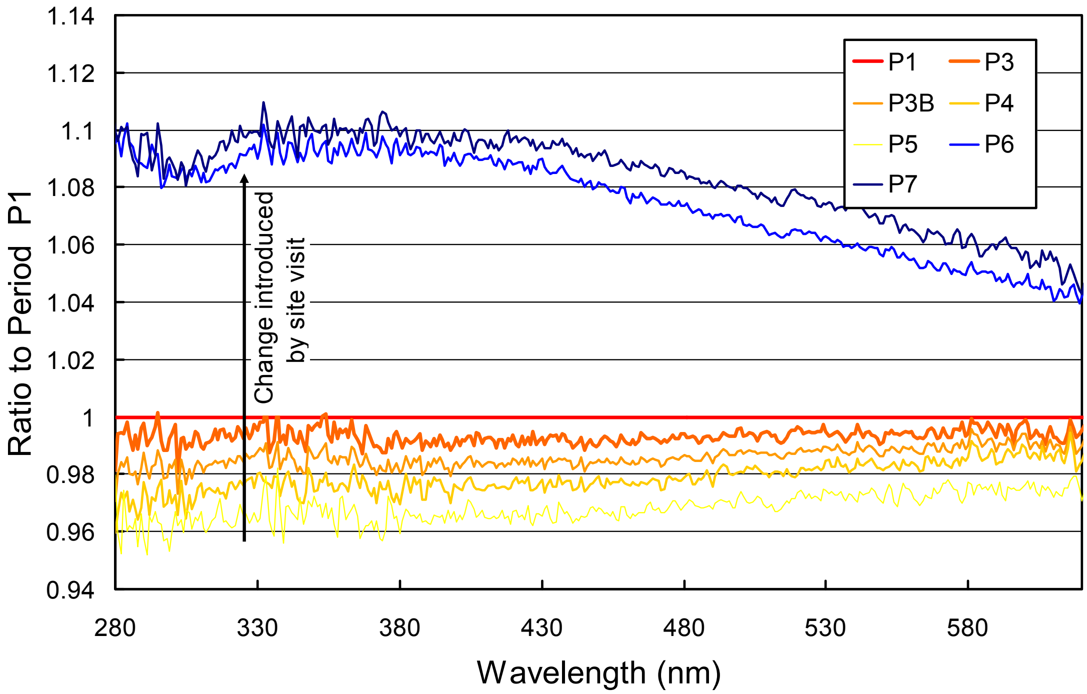

Figure 3. *Ratios of spectral irradiance assigned to the internal reference lamp during Periods P3 through P7, relative to Period P1.*

Figure 4 shows the ratio of measurements of the 340 nm channel of the GUV-511 radiometer, which is installed next to the SUV-100 system, and final SUV-100 measurements. The latter measurements were weighted with the spectral response function of the GUV's channel. The ratio is normalized and should ideally be one. The graph indicates that GUV and SUV measurements are consistent to within about ±5% during most periods, however, there are four periods (indicated with ellipses in Figure 4 and labeled A, B, C, and D) where the ratio of GUV/SUV measurements deviate by more than 10%. Low SUV-100 measurements are likely caused by snow accumulation on the instrument's irradiance collector.. A description of these periods is provided in Table 2. Scans are part of the Version 0 dataset and were flagged in the SUV-100 Version 2 dataset.

Table 2: Description of outliers in the GUV/SUV ratio of Figure 4.

Period	Period range	Remark
A	09/08/19 19:45 – 09/08/19 23:45	SUV data potentially biased low by 15 – 20%
B	10/01/19 16:45 – 10/02/19 04:45	SUV data potentially biased high by 5 – 15%
C	12/08/20 00:00 – 02:00 and 12/09/20 00:00 – 04:00	SUV data potentially biased low by 20 – 50%
D	03/24/20 18:30 – 03/25/20 07:00	SUV data potentially biased high by 5 – 30%

Several other outliers can be attributed by shading from obstacles that are in the field of view of the instruments. Because GUV and SUV radiometers are not positioned at exactly the same location, shadows from these obstacles fall on the collectors of the two instruments at different times. Scans affected by shadowing were flagged in the SUV-100 Version 2 dataset, removed from the GUV dataset, but remain part of the SUV-100 Version 0 dataset.

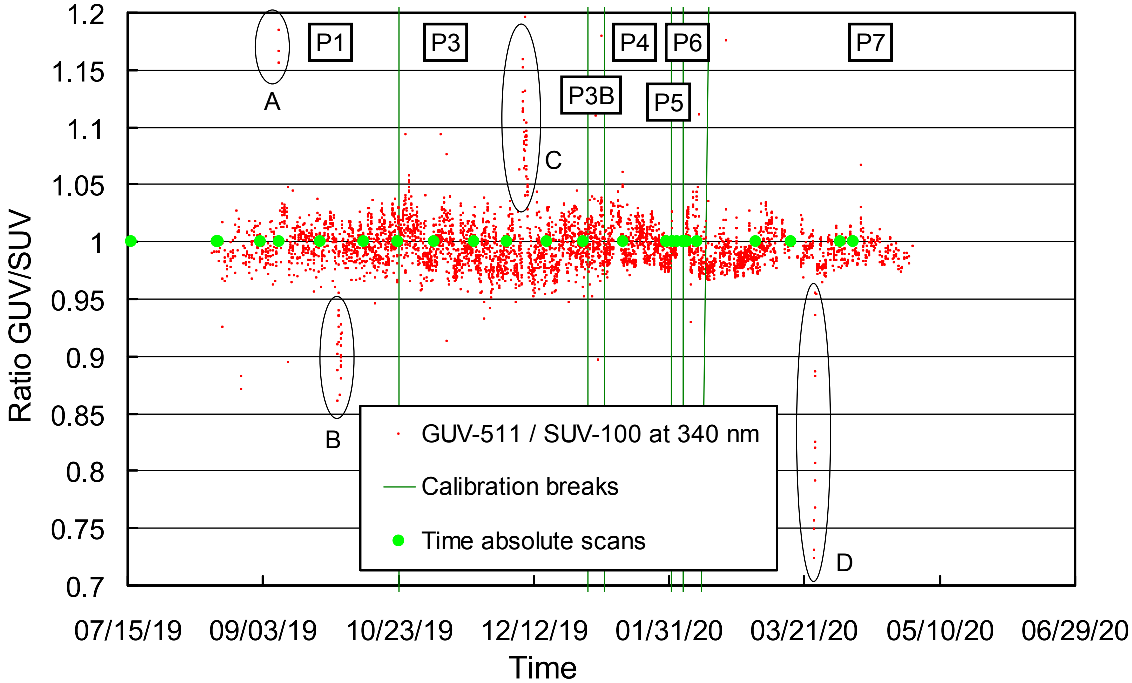

Figure 4. *Ratio of GUV-511 (340 nm channel) and SUV-100 measurements. Green vertical lines indicate times when the SUV-100 calibration was changed. The times when "absolute" calibration scans of the SUV-100 were performed are also indicated. Periods with outliers are marked with ellipses and discussed in the text.*

1.3. 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. The wavelength-dependent bias of this homogenized dataset and the correct wavelength scale was determined with the Version 2 Fraunhofer-line correlation method (Bernhard et al., 2004). Figure 5 shows the correction functions calculated with this algorithm.

Figure 6 indicates the wavelength accuracy of Version 0 data for six wavelengths in the UV and visible range, which was established by running the Version 2 Fraunhofer-line correlation method for a second time. Shifts are typically smaller than ±0.1 nm, but these residuals are not uniformly distributed over the reporting period. Instead shifts vary between +0.1 nm and -0.1 nm and have a periodicity of about 14 days. The reason of this periodicity could not be unambiguously identified. For some periods, there is some correlation with the timing of absolute scans, but not for all periods. (During absolute scans, the system scans up to 700 nm while the terminal wavelength during solar scans is 605 nm. It is possible that scanning over the longer range affects the wavelength mapping of the monochromator.)

The wavelength correction was further improved when processing Version 2 data by breaking the dataset into 54 sub-periods with a different correction function applied in each sub-period. Figure 7 shows the residuals of the wavelength offsets for the Version 2 dataset. The improvement of the wavelength accuracy compared to the Version 0 dataset (Figure 6) is obvious.

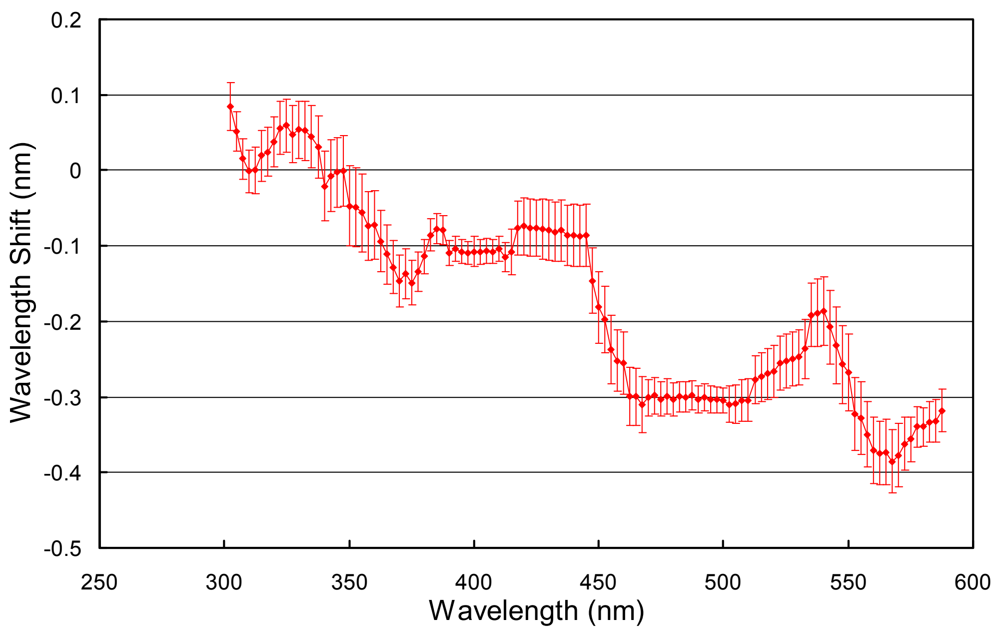

Figure 5. *Monochromator non-linearity correction function for the Volume 29 period. Error bars indicate the 1σ-variation.*

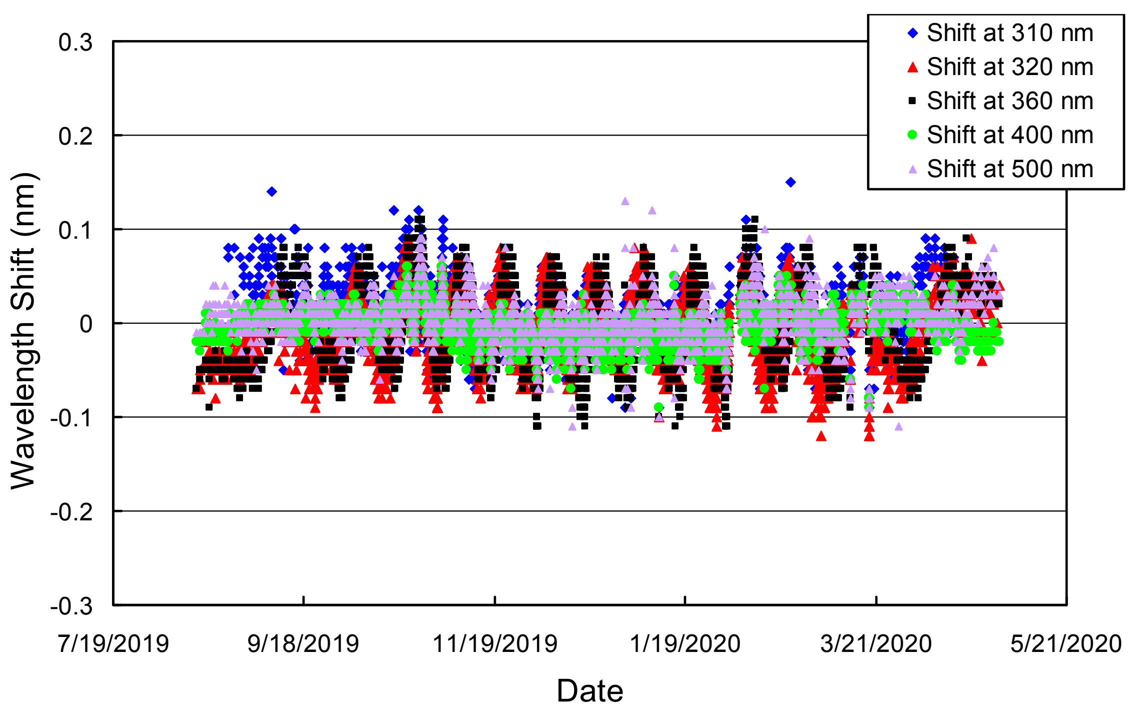

Figure 6. *Check of the wavelength accuracy of* <u>*Version 0*</u> *data at six wavelengths by means of Fraunhofer-line correlation. The plot is based on hourly measurements.*

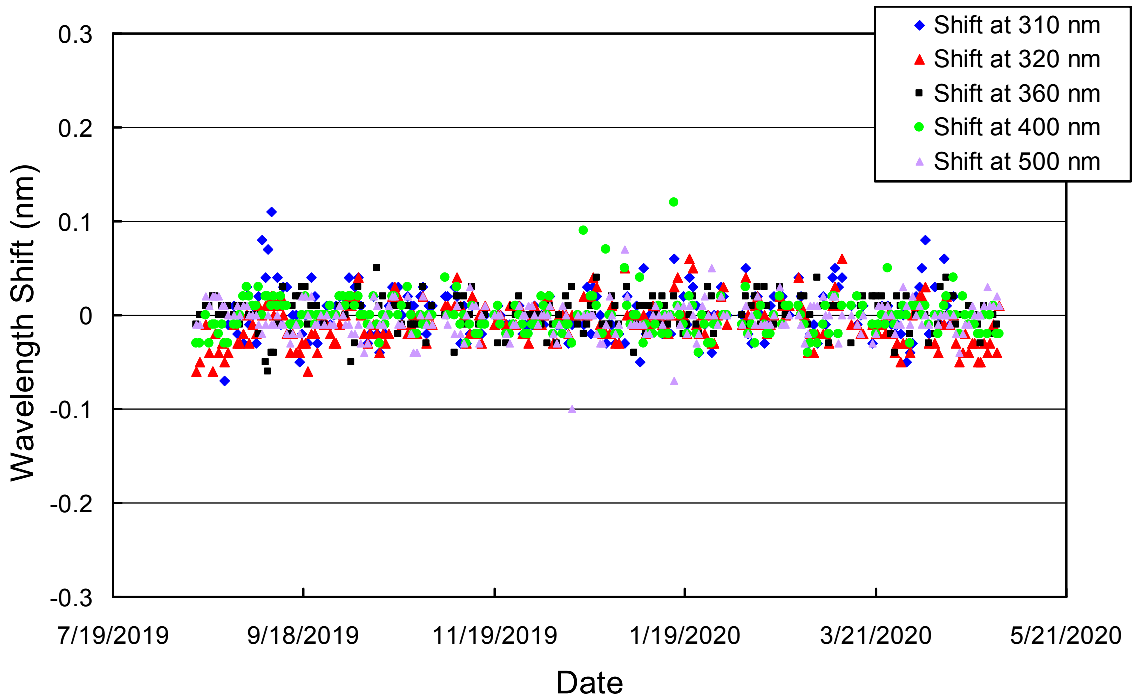

Figure 7. *Check of the wavelength accuracy of Version 2 data at six wavelengths by means of Fraunhofer-line correlation. The plot is based on measurements at 01:00 UT (approximate local solar noon at McMurdo).*

1.4. Missing data

Table 3 provides a list of days that have substantial data gaps, plus indications of their causes.

Table 3: Days with substantial data gaps.

Date	Reason
08/26/19	No data due to power outage
02/02/20 – 02/06/20	Site visit
02/23/20	Communication problem between computer and radiometer
03/11/20	Computer reboot after forced operating system update
03/14/20	Communication problem between computer and radiometer
03/17/20	Communication problem between computer and radiometer

References

Bernhard, G., C. R. Booth, and J. C. Ehramjian. (2004). Version 2 data of the National Science Foundation's Ultraviolet Radiation Monitoring Network: South Pole, *J. Geophys. Res., 109,* D21207, doi:10.1029/2004JD004937.