SORCE SOLSTICE Release Notes for Version 17 through 09 (LEGACY)

Note: The final release version is V18. See the dedicated V18 release notes document for more details: https://lasp.colorado.edu/home/sorce/instruments/solstice/solstice-data-product-release-notes/

SORCE-SOLSTICE Release Notes for Version 17, Level 3 data products

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SOLSTICE data Version 17 (V17) appears in three locations:

1. On the LISIRD website: http://lasp.colorado.edu/lisird/sorce/)
2. On the SORCE website: http://lasp.colorado.edu/home/sorce/data/
3. On the NASA DAAC:
   FUV: https://disc.gsfc.nasa.gov/datasets/SOR3SOLFUVD_017/summary
   MUV: https://disc.gsfc.nasa.gov/datasets/SOR3SOLMUVD_017/summary

Table 1 below gives a description of available time and wavelength ranges for each location.

An IDL reader for the ASCII formatted data present on the SORCE web site is available at:
http://lasp.colorado.edu/data/sorce/file_readers/read_lasp_ascii_file.pro

Time Range	Wavelength Range (nm)	
04/14/2003 - present	. 115 - 180	.180 - 310
	. FUV .	. MUV

Table 1: Time and wavelength ranges for each repository location.

Calibration Changes:

V17 of SORCE SOLSTICE employs the same correction algorithms as V17 with the following changes:

I. Field-of-View (FOV) degradation correction.

An updated field-of-view (FOV) degradation correction was applied to the MUV channel on SOLSTICE B. Earlier in the mission this correction relied upon a cruciform alignment "haystack" scan which we performed at 8 discrete wavelengths. The center minimum in the haystack occurs at the center of the detector where daily irradiance measurements are made. The two peaks, or "shoulders", occur at the edges of the detector and are not exposed as often and are therefore less degraded. We take the ratio of the center value to the mean of the shoulders to calculate the FOV degradation. Figure 1 below illustrates one such scan.

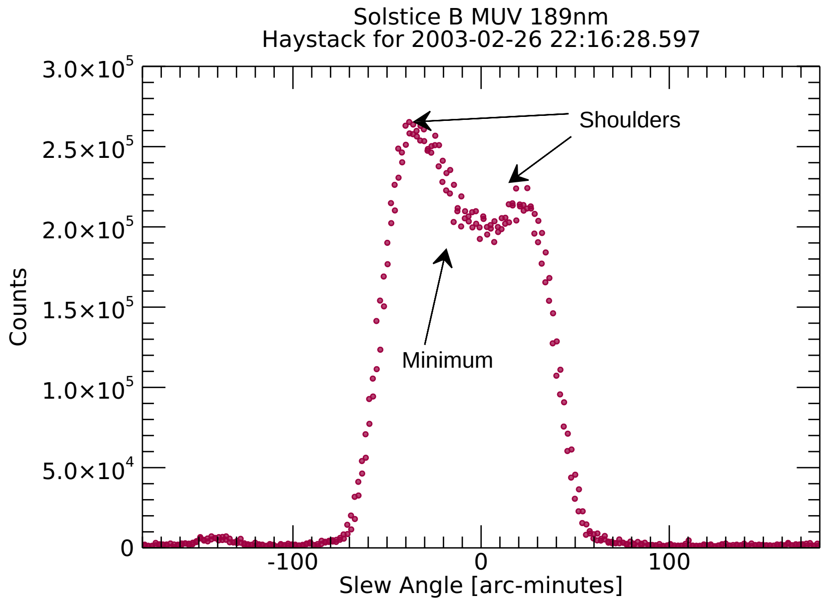

Figure 1: Cruciform alignment "haystack" scan at 189nm

However, these cruciform scans significantly under-sampled the wavelength range and therefore did not accurately capture the FOV degradation at all wavelengths. Further, the cruciform scans were no longer performed once the spacecraft entered the day-only-operations mode (DO-Op) of the mission. We instead began special “off-pointing” experiments which scan the entire wavelength range, while reducing the sampling in the slew (pointing) dimension, but still capturing the FOV measurement. These measurements occurred while the spacecraft was off-pointed directly at the shoulder location, and then at the center location. This allowed us to calculate the FOV degradation at a much finer wavelength scale than before (at 1nm intervals). Further, we model and extrapolate this new higher resolution degradation backward in time in order to apply it to the entire mission.

For wavelengths that have both cruciform scan data and off-pointing data, we can fit an exponential decay model for the entire mission and compare to the old haystack degradation model. And for wavelengths which only have off-pointing data but no haystacks, we can extrapolate backward in time. Figure 2 illustrates the two models independently while Figure 3 illustrates the new combined FOV degradation model. Off-pointing (blue points), FOV Model (green surface)

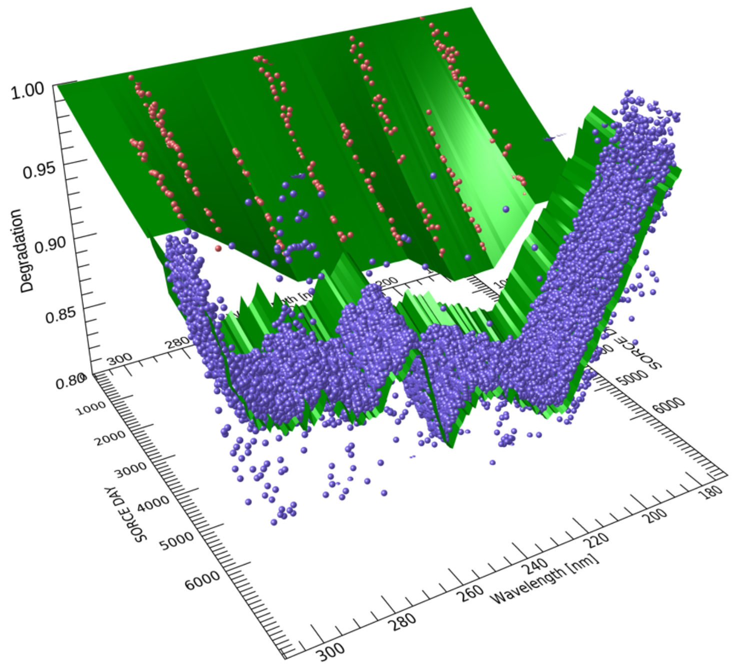

Figure 2: Haystack model (red points), Off-pointing (blue points), FOV Model (green surface)

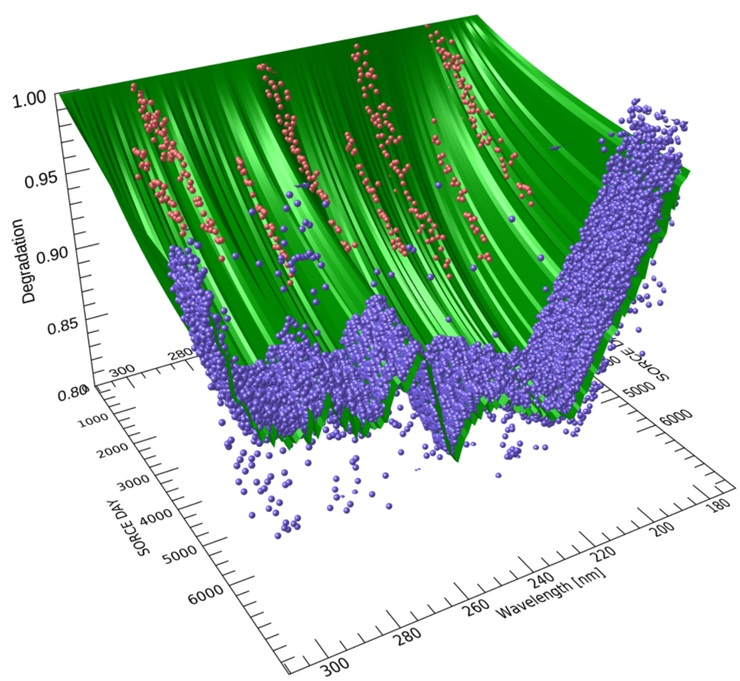

Figure 3: Combined FOV Model

II. Exposure-time based detector degradation.

Separate from the FOV degradation are the effects of detector degradation. Early in the mission this was measured by observing UV bright stars with known spectra in order to calibrate SOLSTICE. However, later in the mission (DO-Op) it was no longer possible to make stellar measurements, and so we had been extrapolating that earlier degradation model into DO-Op. However, due to operational changes we take MUV measurements on SOLSTICE B much more frequently in DO-Op than in the early part of the mission, and therefore are exposing the MUV detector much more than before. To account for this, we take the cumulative counts collected over the life of the mission to get an estimate of the equivalent "exposure days" as a function of "mission days". In addition, a pointing analysis was performed which showed that on each orbit prior to the beginning of an observation while the spacecraft was acquiring the sun, the detector can become illuminated which further degrades the detector. This additional exposure was also added to this exposure-time based model.

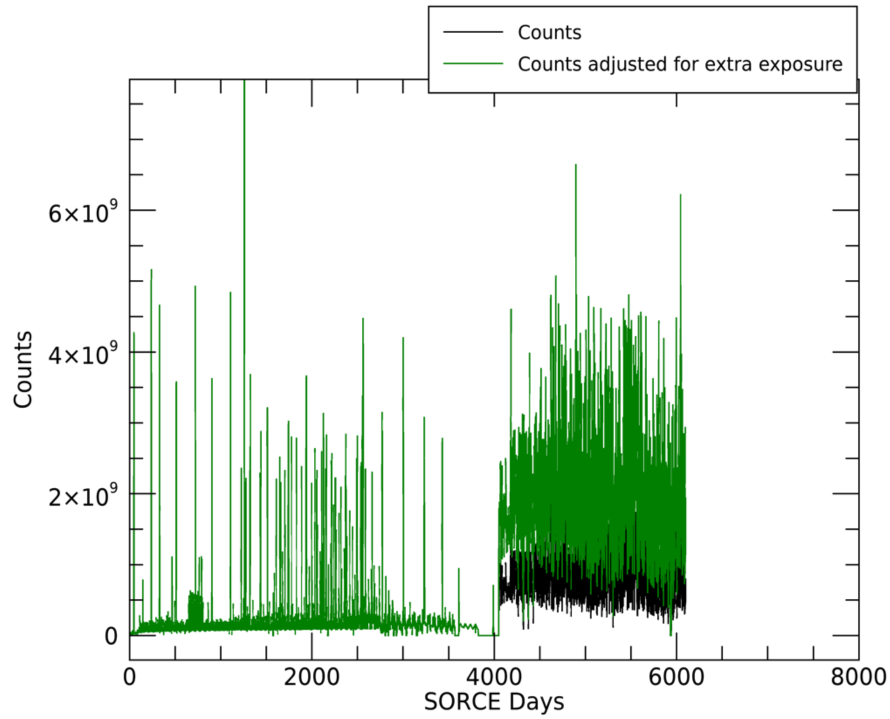

Figure 4: Counts adjusted for extra exposure time.

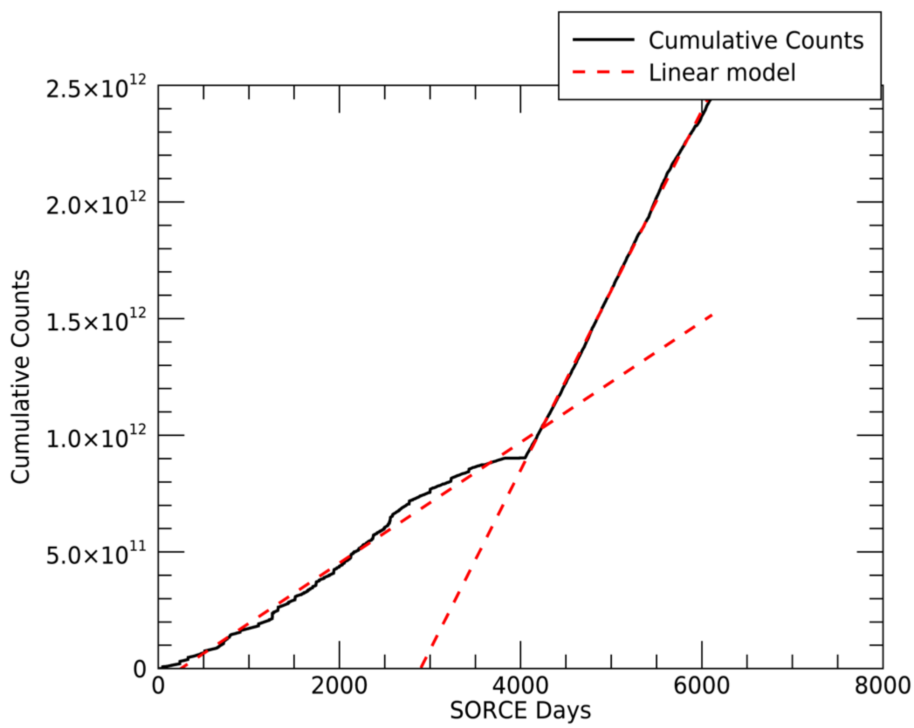

Figure 5: Cumulative Counts

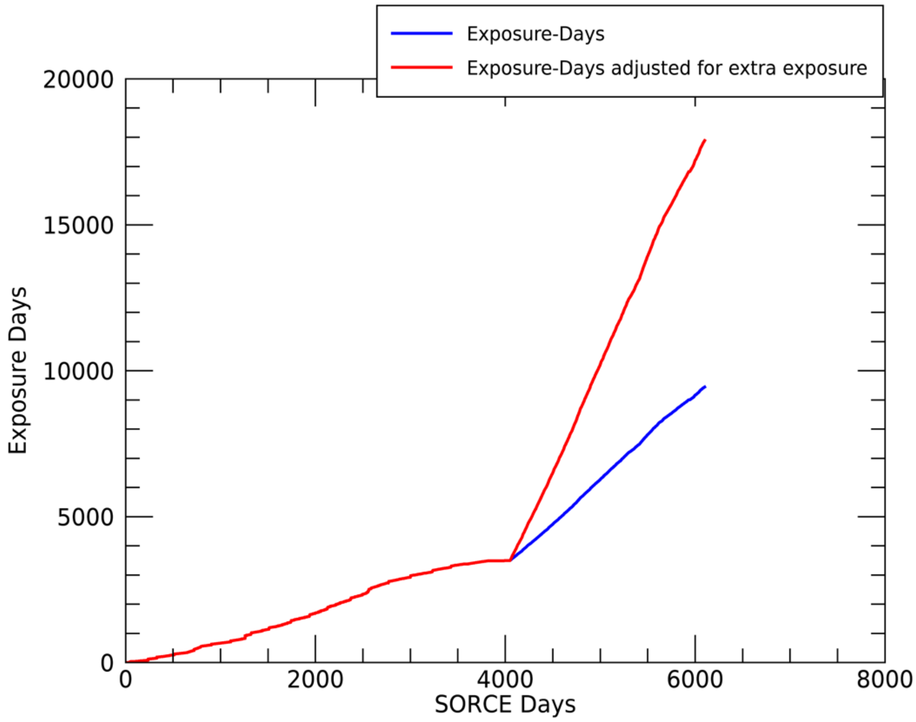

Figure 6: Exposure Day model.

III. Solar image spot size correction.

We improved the second-order 1AU correction for the SOLSTICE B MUV detector based on the size of the solar image incident on the detector as it changes throughout the year. This is in addition to the usual 1AU normalization correction that is performed. When the solar image is larger the sun illuminates part of the optics with less degradation resulting in an apparent higher sensitivity of the detector. Conversely, when the spacecraft is farther away, the sun's image is smaller and it falls on the less sensitive regions of the optics. To make this correction we integrate the haystack over the nominal size of the sun on the optics at 30 arcminutes.

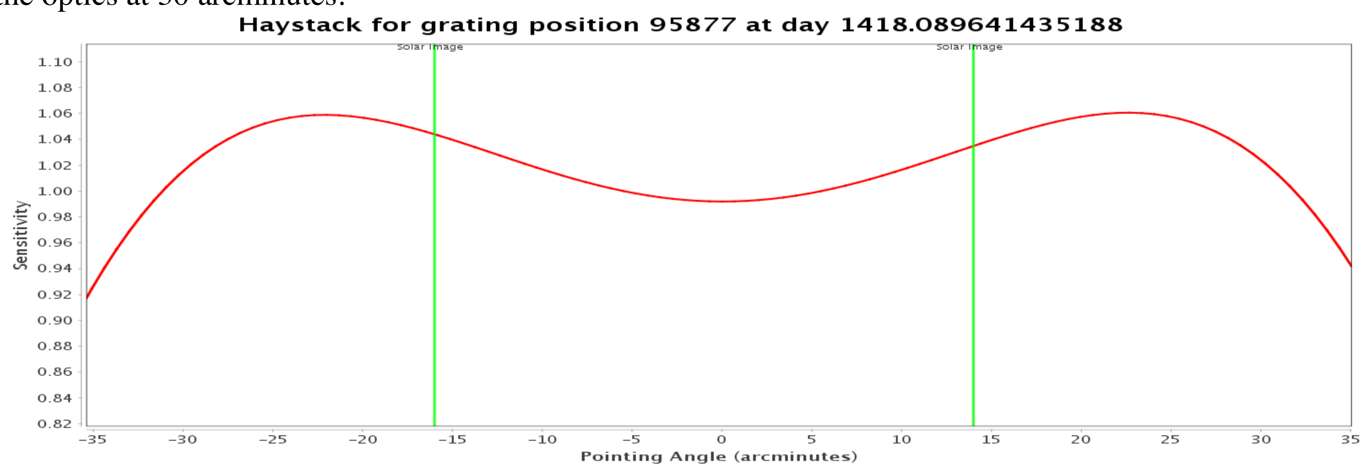

Figure 7: Example haystack with Solar image size boundary over plotted.

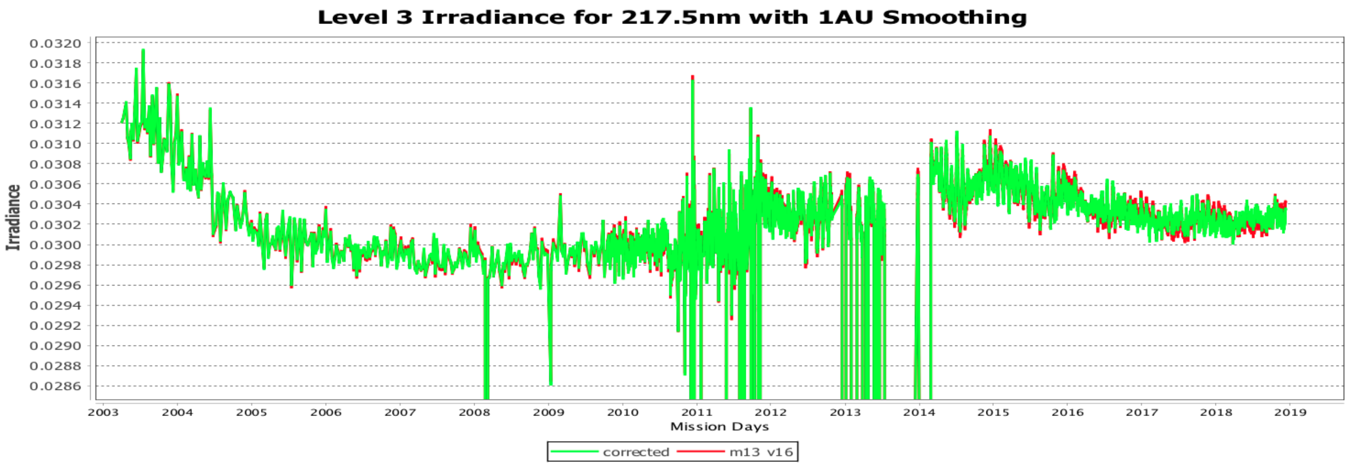

Figure 8: Example time series at 217.5nm showing the spot-size corrected irradiance.

IV. Gain uncertainty calculation.

An improved gain-uncertainty dependent on detector temperature in order to improve our to improve our L3 data product uncertainty.

An error was discovered by an external user in the V16 (L3) SOLSTICE irradiance uncertainties. The reported uncertainties in the MUV at long wavelengths were too large and displayed odd time-dependent characteristics. Analysis of the calculation pipeline revealed that the problem with the uncertainties was originating in the code that calculates the temperature gain uncertainties. An incorrect equation, using improperly derived temperature coefficients, was being used to find the temperature gain as a function of wavelength, and the associated uncertainties were also incorrect.

The incorrect temperature gain uncertainties were carried forward through the processing pipeline to the corrected count rate, L2 systematic, L2 combined and ultimately the L3 combined uncertainties. The incorrect uncertainties were present in all modes but were most noticeable in the MUV (modes 9 (SOLSTICEA) and 13 (SOLSTICEB)) detectors.

The new temperature gain uncertainties significantly reduce the uncertainty values and rely only data that is obtained from spacecraft telemetry rather than on the previous model.

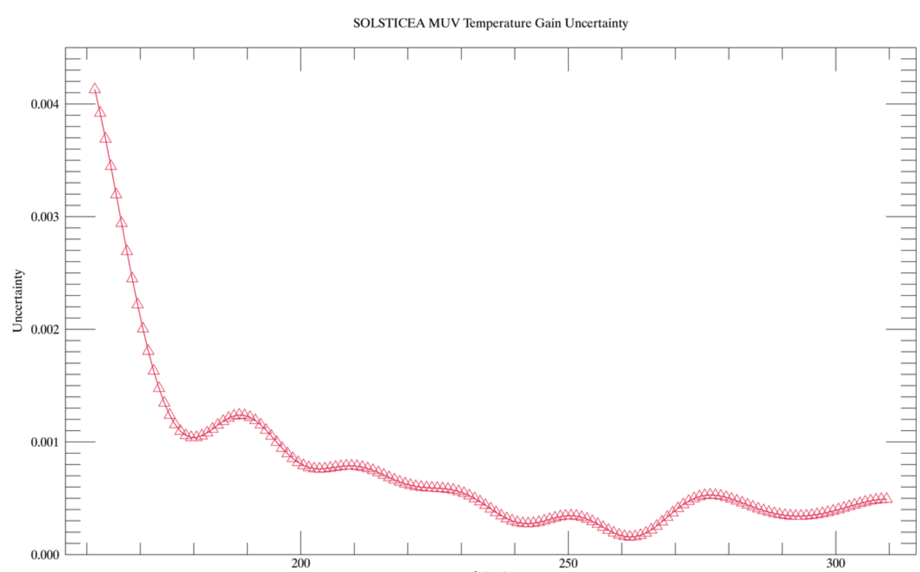

Figure 9: Gain uncertainty as a function of wavelength.

The plot above shows temperature gain uncertainty vs. wavelength, independent of temperature. Each point is the uncertainty of the slope of the fit of temperature gain vs. temperature at that single wavelength.

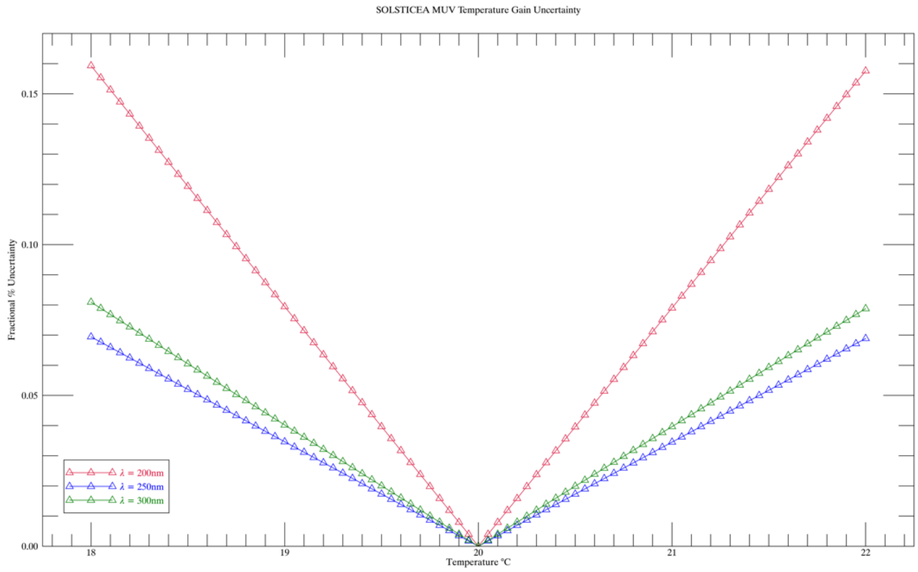

Figure 10: Temperature gain uncertainty as a fractional percentage of temperature gain vs. temperature

This plot shows temperature gain uncertainty as a fractional percentage of temperature gain vs. temperature at 200, 250 and 300nm for SOLSTICEA MUV. A reference grid of temperature values was used in the temperature gain and uncertainty equations described above to generate this plot. In the data processing pipeline, the actual temperature at the time of the scan is used to generate a single gain uncertainty value at each wavelength.

The plots below show the L3 combined irradiance uncertainties as a fractional percentage of the L3 irradiance. Red is V16, blue is V17. The improvement in the uncertainties due to the new temperature gain uncertainty is obvious and significant.

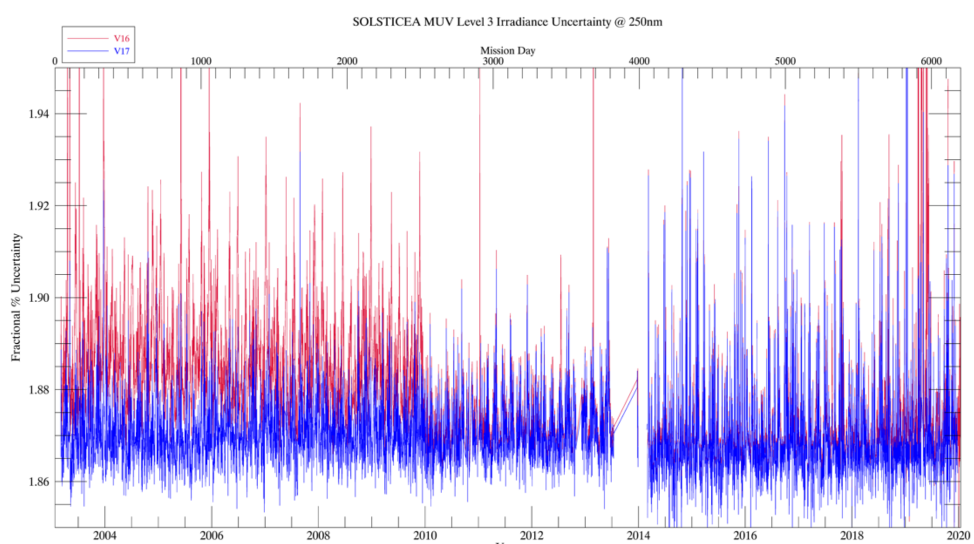

Figure 11: L3 Uncertainty for 250nm

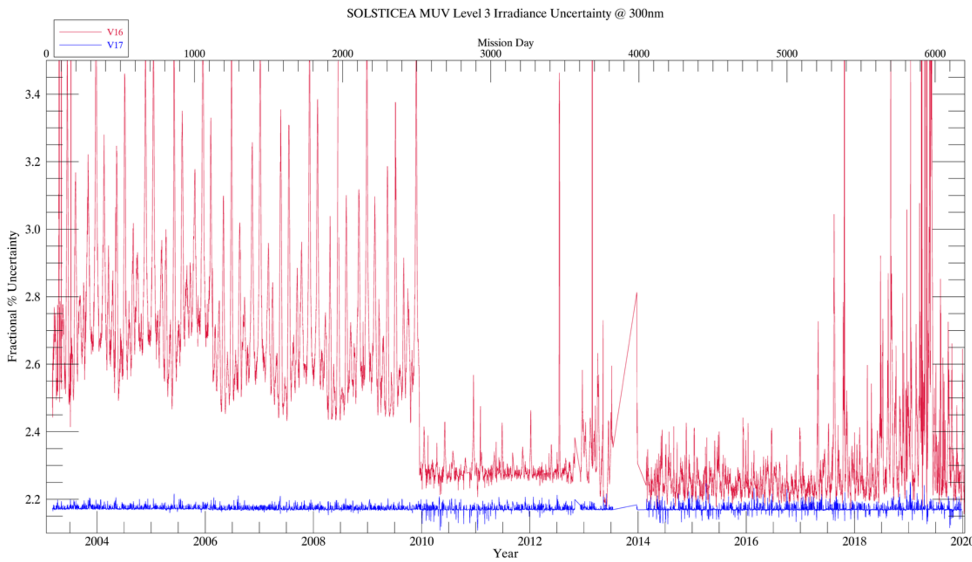

Figure 12:L3 Uncertainty for 300nm

SOLSTICE Version 16 (January 2019):

SOLSTICE version 16 introduces two improvements over past versions.

The first is an improved cross-calibration between SOLSTICE A and SOLSTICE B for the MUV instrument channel. Particularly in the 230nm-260nm range, this updated calibration addresses a trending issue that was present in the previous data product versions. This improves upon our previous implementation of this correction, introduced back in version 10.

The second improvement corrects several data gaps that were present in the MUV time series. Occasionally, our processing framework inappropriately excluded data points that should otherwise have been included in the daily data product. This resulted in a missing Level 3 data product for 16 days. This bug has been corrected and the data have now been processed for these days.

SOLSTICE Version 15 (October 2015):

The version 15 data is mostly an improvement in the level 3 degradation with smaller improvements to the underlying processing. There is also a new correction that helped to reduce the 1AU affects. Additionally we are releasing data with a reduced delay.

Level 3 Updates:
- Switching to a 1 day delayed processing.
- Improved responsivity correction for the RTS and DO-Op mode.
- Improved AB comparison correction around the SOLSTICE A slit anomaly and during DO-Op mode.
- Added a solar image correction (2nd order 1AU correction).

Level 2 Updates:
- Switched to processing up to the latest full mission day.
- Added a Doppler Factor correction to the Wavelength determination.
- Updated Dark values for all modes.

SOLSTICE Version 14 (May 2015):

The Version 14 data is mostly a maintenance update for the processing code and data product. There are no significant calibration adjustments with this version. This version includes data up to the current time and updates daily.

Uncertainty:
The uncertainty values in the level 3 data product have been reevaluated. They more accurately reflect the uncertainties due to systematic uncertainties and counting statistics.

Do-op Mode Correction for MUV:
During the second half of 2013 when the spacecraft was in safe hold, the calibration of SOLSTICE changed by a small amount. We derived a correction factor for the DO-op period based on a proxy model. The model was adjusted to fit the SOLSTICE irradiances as a function of wavelength for the first half of 2013. This correction factor has been applied to the irradiances starting in 2014. The size of the correction is about one percent for 180-260 nm, and then decreases to zero at longer wavelengths.

Level 3 Updates:

- Improved data filtering for the level 2 data going into the level 3 data product.
- Improved 1 nm bin integration processing.

Processing changes:

- South Atlantic Anomaly Data rejection improvement.
- Pointing requirement reduced to +/- 2.5 arcminutes from +/- 10 arcminutes.
- Improved code performance for the primary mission and more specifically for the Do-op mode.
- Updated temperature input to gain correction to more accurately capture the temperature trends later in the mission for each orbit.

SOLSTICE Version 13 (August 2014):

Version 13 has significant improvements to the level 2 and level 3 data product. We switched to a more accurate thermostat for detector temperature corrections. We also improved the corrected count rate equation. This improvement included updates to the scattered light values which are now dependent on the filter configuration and a more accurate filter transmission profile. The dead time correction for the MUV detectors was also improved and has been shown to increase several nanoseconds over the course of the mission. The dark values have also been updated for the entire mission. We added a new correction to account for a degradation hit for SOLSTICE B in July 2006 due to solar exposure with the stellar slit. This correction also helped to improve the AB comparison correction for the SOLSTICE A MUV detector. The MUV stellar correction was also updated.

SOLSTICE Version 12 (September 2012):

For version 12, we updated the data processing to only use data from solar experiment activities. We also improved the optical degradation correction derived from the weekly alignment measurements.

SOLSTICE Version 11 (January 2012):

The MUV degradation correction (180-310 nm) has been significantly improved. In this version, the weekly alignment measurements have been used at eight wavelengths to measure the degradation of the optics as a function of field-of-view (FOV) angle. In previous versions, only four wavelengths were used. The algorithm for calculating this FOV correction was revised and produces a much better statistical uncertainty in each week's measurement. The MUV degradation correction uses the stellar calibration data, the new FOV correction, plus the calibration transfer from the redundant SOLSTICE B instrument. An error in the version 10 degradation correction in the A/B transfer is now believed to have produced the unusually large variation at some wavelengths in the MUV data. The FOV correction in the 180-190 nm range is still preliminary. The correction factor for this wavelength range is currently extrapolated based on longer wavelength trends in the FOV measurement, but analysis of the alignment data from the FUV channel in the wavelength overlap region will reduce the uncertainty of this correction for the next data version. The FUV degradation correction extends the stellar calibration observations to the current epoch but no changes in the FUV algorithm have been implemented version 11. The overall uncertainty in the SOLSTICE degradation correction is still meeting the 0.5% per year requirement.

SOLSTICE Version 10 (September 2009):

Degradation Correction:
The SOLSTICE A MUV channel observations have been corrected for degradation by cross-calibration to SOLSTICE B. Only SOLSTICE B makes stellar calibration observations, due to the anomalous behavior of SOLSTICE A's entrance aperture mechanism. Weekly A/B comparison experiments are used to correct any drift between the two instruments. Corrections for differences in field of view between solar and stellar modes at four wavelengths have been included. Future versions will include an additional four wavelengths. The uncertainty in the long-term degradation is currently about 2% (1-sigma).

SOLSTICE Version 9 (March 2007):

The following updates and modifications have been made to the SOLSTICE calibration data and processing code. Improvements have allowed the extension of the wavelength range to 310 nm bridging the gap to the SIM spectral data.

- **Slit Anomaly:** In January of 2006, an anomaly became apparent which was contributing to a 1 to 3% (depending on wavelength) increase in subsequent irradiance data for the SOLSTICE A instrument, which provides the MUV data. Analysis showed that the anomaly is due to a slit misalignment which directs the incident light to a different region of the detector which has a higher sensitivity due to less degradation. A new instrument misalignment calibration was applied with a map of the sensitivities in the instrument's field of view derived from an in-flight experiment performed shortly after the anomaly. A small discontinuity can still be seen at some wavelengths at the time of the anomaly. More detailed analysis remains to be done.
- **Instrument Misalignment:** Improved analysis of the cruciform alignment experiments (haystacks) have yielded a better set of data for quantifying the relative misalignment of the SOLSTICE instruments and the SORCE spacecraft. Instead of the constant misalignment use in previous data versions, a time dependent model is now applied. A

simple step function was used to account for the apparent difference in pointing before and after the slit anomaly. The effect on the data is as described above for the slit anomaly. More analysis remains to be done of the haystack measurements and the time dependent behavior of the instrument misalignment.

- **Field of View Maps:** The pre-flight data from SURF was reprocessed to generate a new map of the sensitivities in the field of view of the SOLSTICE instruments as a function of wavelength. These maps, with the target coordinates, were applied to the FUV data. New MUV field of view maps were derived from an in-flight experiment performed shortly after the slit anomaly. The impact of the new FUV maps was minimal. However, the new MUV maps brought the irradiance down from 0.5 to 1% before the slit anomaly and 2 to 4% after the anomaly. Note that the map, with the new instrument misalignment calibration, introduces a larger variation with wavelength after the slit anomaly. Further analysis of the field of view maps remains to be done.
- **Responsivity:** The responsivity of the SOLSTICE A instrument, the source of the MUV data, is based on pre-flight data collected at SURF. The responsivity of the SOLSTICE B instrument, the source of the FUV data, is based on an in-flight AB comparison experiment conducted on mission day 69. The new pre-flight field of view maps were used to recalibrate the SOLSTICE B FUV responsivity. This is one of the prominent difference in the FUV irradiance data, introducing changes up to plus or minus 1% depending on wavelength.
- **Temperature Gain:** An in-flight experiment was performed on mission day 862 to assess the effects of temperature change. The FUV data proved to be too noisy, so only an improved model of the pre-flight data was use introducing minimal differences. Models of the new MUV temperature gain corrections were applied and yielded some improvement in the data, however, more analysis remains to be done.
- **Degradation:** The FUV detector degradation derived from stellar measurements has adequately corrected the FUV irradiance in previous data versions. However, the stellar data have failed to completely account for the MUV degradation due to different properties of the solar and stellar images on the detector’s filed of view. A new field of view component of the degradation was added based on an analysis of the change in count rate during cruciform scans. The result is an increase of the MUV irradiance by up to 1% per year depending on wavelength.