Nov 2017 Reprocessing, deployments M203-M248

In November 2017 we reprocessed the data for deployments M203-M248 to make a consistent straylight correction (SLC) in the data set. This new SLC is based on the same matrix approach we have used for M249 onwards. The important points are:

1) Deployments M203-M248 have been reprocessed with the new SLC technique.

2) Deployments M206, M208, M210 have had spectral data for wavelengths less than 380 nm deleted from the file.

A short history of the SLC with MOBY, and an explanation of the current process follows.

History

At the beginning of the MOBY project the necessity of applying an SLC was not known. As data were acquired, a consistent difference between the spectra from the red and blue spectrographs in the common spectral region (overlap region) was discovered. This difference was traced to straylight in the spectrographs, where light from a part of the spectrum where energy was abundant was scattered into a portion of the spectra where the spectrum was weaker.

Initially the SLC was modeled from less than 20 laser lines on each spectrometer, taken on site in Honolulu using portable lasers. Much of these data were also saturated, thus normalization by in-band area was not possible as is done now [Zong et al., “Simple stray light correction method for array spectrometers,” Applied Optics, 45(6) 1111-1119 (2006)]. All of the data from M203-M248 was processed using this modeled SLC data [Brown et al., “Stray-light correction of the Marine Optical Buoy,” in Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, NASA Tech. Memo NASA/TM-2003-211621/Rev4-Vol.VI, J. L. Mueller et al. Eds., NASA 87-124 (2003)]. These data were in wavelength space and the correction was done iteratively.

In 2008 measurements were made at NIST using the SIRCUS system, on both the odd and even buoys. Both the fibered and LuMOS inputs were measured, and the data were processed in pixel space (rather than wavelength space) at NIST and new SLC matrices were produced that were in pixel space and normalized to in-band area. This allowed the use of matrix math to do the straylight correction, and did not require interpolation of widely spaced, in wavelength, laser data. Learning how to interpret and start applying this new method and matrices took until 2011. In 2011 a refocusing of the odd buoy’s RSG required remeasurement of the SLC, and thus a new matrix was generated for the SLC of odd buoys using this new data. Going backwards, this new data for the odd buoy BSG was better behaved than the original 2008 data, so this could be used in retrospective work (as the BSG on the odd buoy had not been refocused or changed). For the RSG, the 2008 data were well behaved and thus was used in the reprocessing.

So starting at deployment 249 the 2011 Odd BSG and RSG matrices were applied to the data and all odd data going forward. For the next deployment, 250, we started using the NIST 2008 matrices for the even buoys.

To summarize the current status of SLC processing, before this reprocessing:

- M249 onward, Odd buoys use NIST2011_03 matrices called Version 6 SLC
- M250 onward, Even buoys use NIST2008_02 matrices called Version 6 SLC

- Before M249 all deployments used the even or odd modeled matrices (fibered inputs)-> SLC 2.1 and then in Jan 2005 the SLC changed to 4.021 and 5.021.

Looking at the changes from old SLC to new

Figure 1, below shows the effect of the new and old SLC on a MOBY even buoy set. This is for M240.

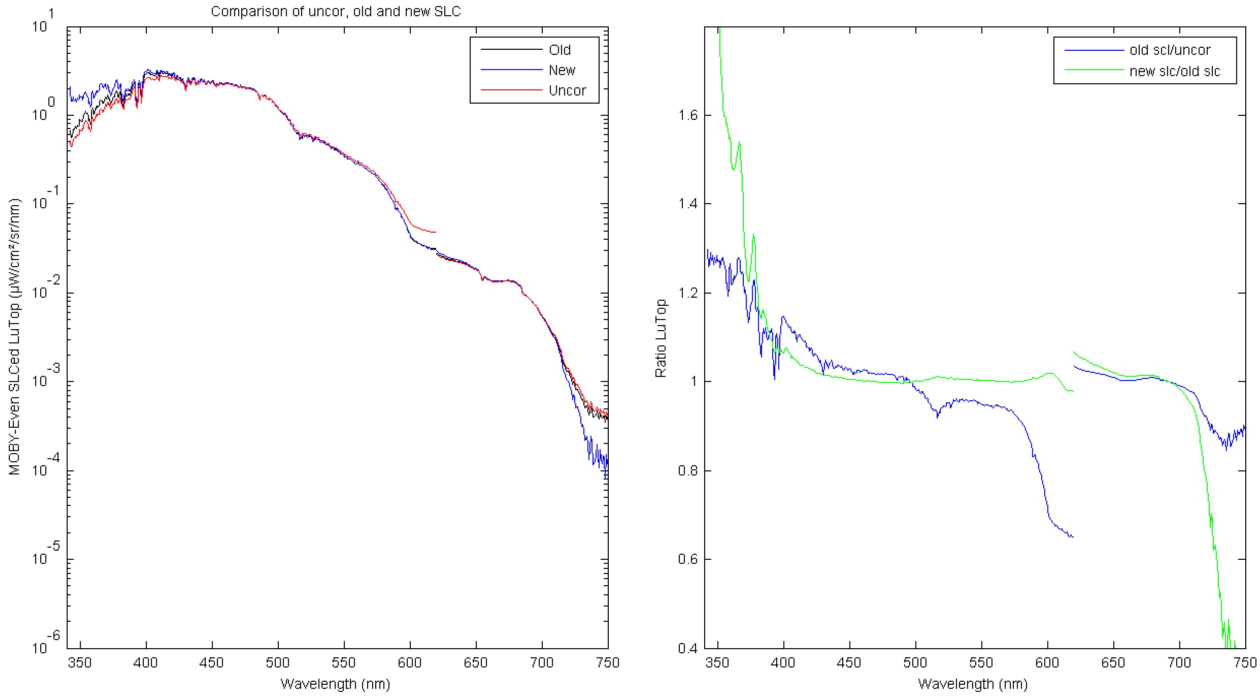

Figure 1) The changes in the LuTop data from uncorrected to the old SLC to the new. Left side is LuTop data, right side is ratio of old/uncorrected and new/old SLC.

The biggest changes from the old SLC to the new SLC, which remember applies only to M203 to M248, for the BSG is in the UV. Most of the change in the UV is attributed to a "large bump" that was discovered in the data taken at the finer wavelength grid available at NIST, as opposed to the work in Honolulu. This is one of the largest changes from the modeled data that did not have a large bump to the interpolated new matrix that does. This also shows us that we needed to pay attention to the UV when applying the new matrices back in time, as it will be the most sensitive.

Deciding how to work backwards in time with the current SLC matrix

During the period from 1997 until 2008, we did not have sufficient data to produce, or validate the SLC matrix. As the instrument ages, it is expected that the SLC would slowly increase. So our hypothesis was that we did not have enough information to do anything more than apply a multiplier to the current SLC matrix for older data, and we would see how well this would do.

The first method to determine the matrix multiplier used the internal calibration reference lamp and LEDs to investigate the problem. Dennis Clark and Stephanie Flora found that for the blue LED, pixel 4 (in the UV) was very sensitive to changes in the stray light. This is because the system response is low in this region, and the measured response is strongly affected by grating scatter, creating stray light. This method used the absolute value of pixel 4 in the BSG as an indicator of how strong the SLC matrix multiplier should be. A plot of this is shown in Figures 2 and 3. The signals at the respective pixels (detector elements) have been normalized to the average for the entire time series.

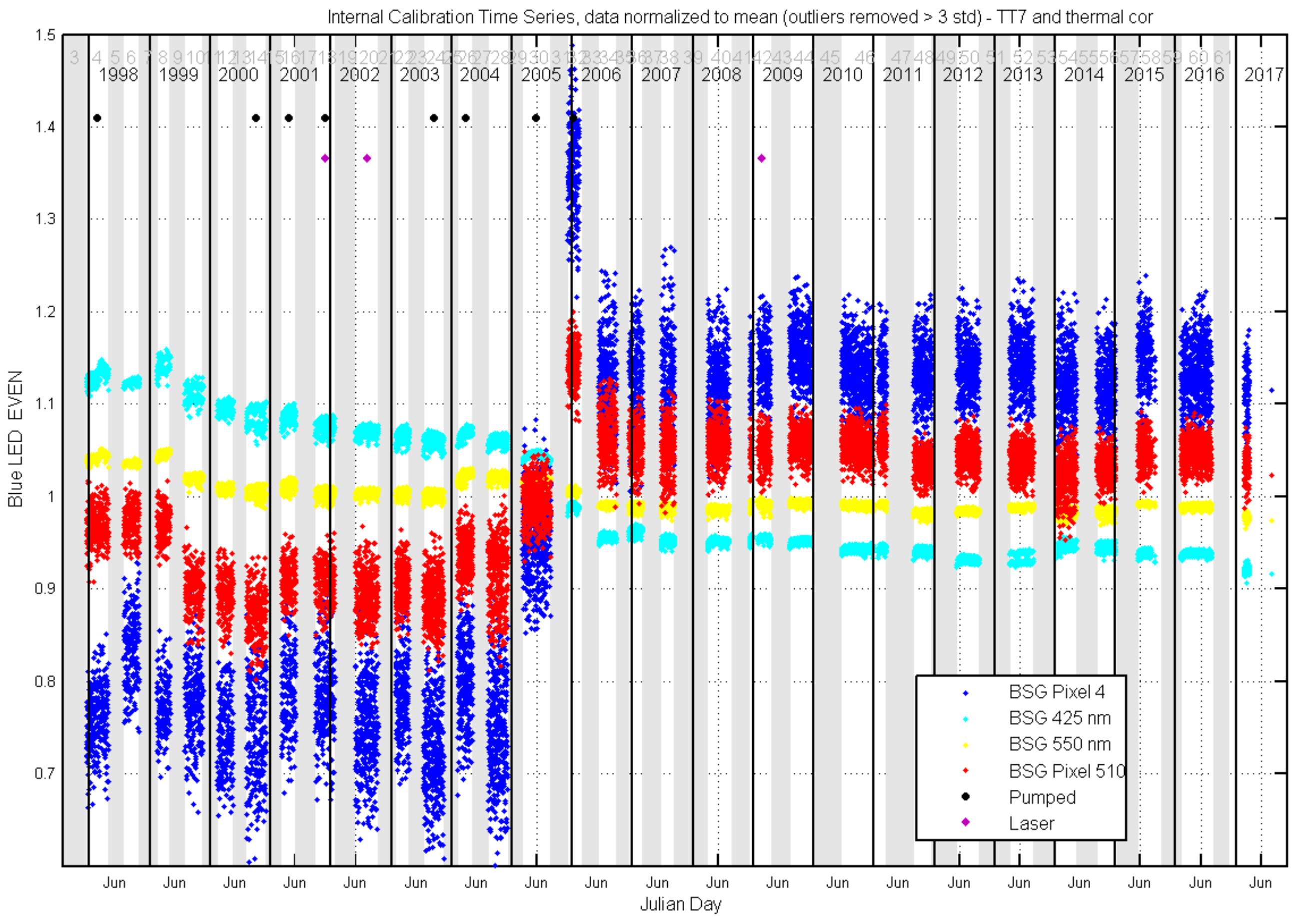

Figure 2) Plot of several pixels when illuminated by the internal calibration blue LED for the even buoy. This shows the large jump up in between 2005 and 2006. The spike around January 2006 was caused by an increase in humidity in the instrument, which settled out as the instrument dried out in later deployments.

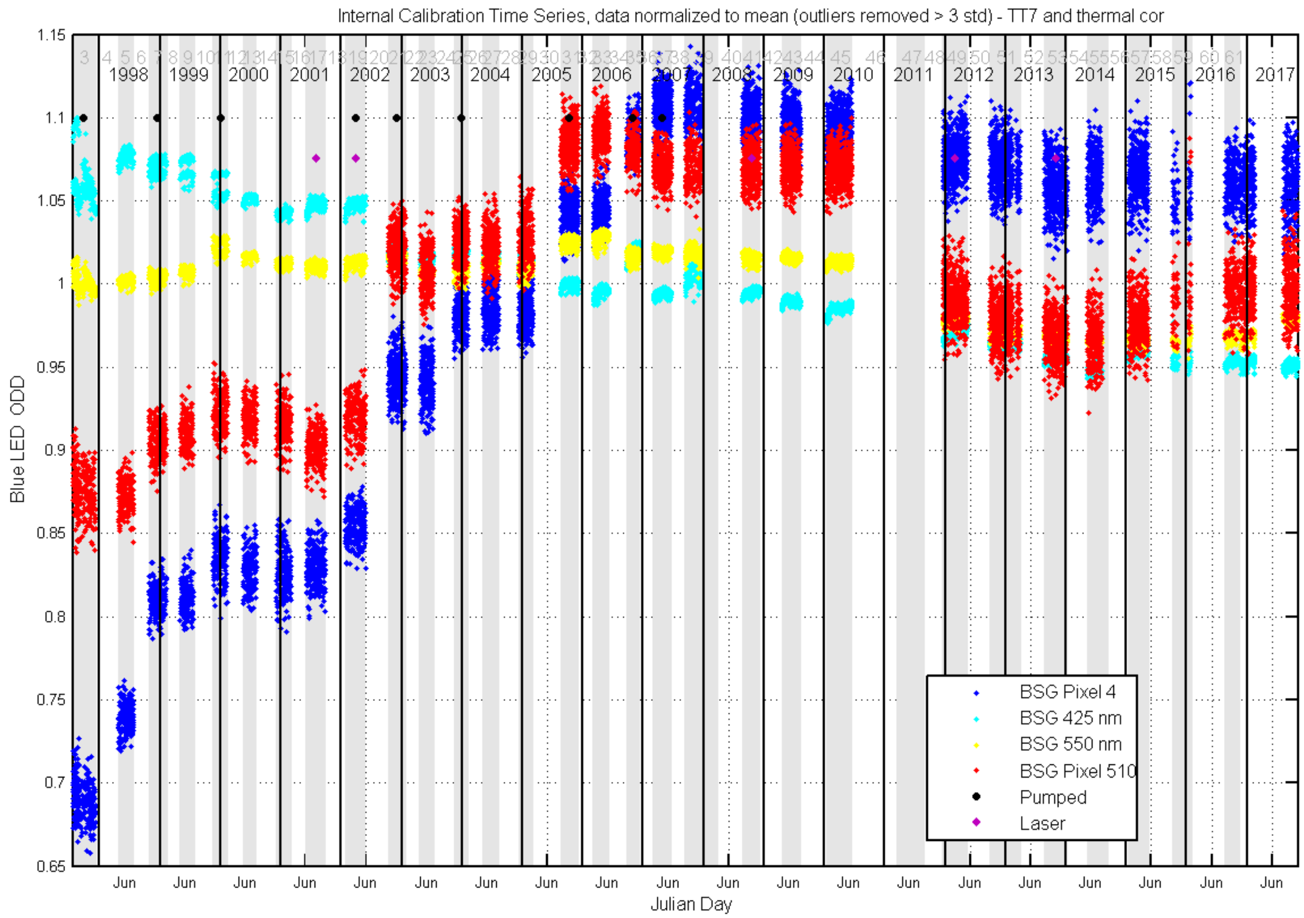

Figure 2) Plot of several pixels when illuminated by the internal calibration blue LED for the odd buoy. This shows the large jump up in between 2005 and 2006. The spike seen in the even buoy is not evident in this buoy.

The blue spectrograph multiplier was determined by using the ratio of the LED data in pixel 4, normalized to 2008. This multiplier was then adjusted in small amounts by looking at MOBY data in the UV and in the blue-red overlap region. A similar method was used to determine the multiplier for the RSG, however the RSG exhibited much less change over time then the BSG, and also had smaller straylight to start with. Thus the RSG multiplier stayed in the range of 0.9-1.0 over this period and the difference between 0.9 and 1.0 is subtle in the final product.

Deploy	BSG_factor	RSG_factor	Even/Odd	SLCnumber
204	0.8	0.9	0	63*
206	0.8	0.9	0	63*
208	0.8	0.9	0	63*
210	0.8	0.9	0	63*
212	0.8	0.9	0	63*

214	0.8	0.9	0	63*
216	0.8	0.9	0	63*
218	0.8	0.9	0	63*
220	0.8	0.9	0	63*
222	0.8	0.9	0	63*
224	0.8	0.9	0	63*
226	0.8	0.9	0	63*
228	0.8	0.9	0	63*
230	0.8	0.9	0	63*
232	0.92	0.9	0	62*
234	1	1	0	6.1
236	1	1	0	6.1
238	1	1	0	6.1
240	1	1	0	6.1
242	1	1	0	6.1
244	1	1	0	6.1
246	1	1	0	6.1
248	1	1	0	6.1
203	0.65	0.9	1	6.4
205	0.65	0.9	1	6.4
207	0.75	0.9	1	6.3
209	0.75	0.9	1	6.3
211	0.75	0.9	1	6.3
213	0.75	0.9	1	6.3
215	0.75	0.9	1	6.3
217	0.75	0.9	1	6.3
219	0.75	0.9	1	6.3
221	0.9	0.95	1	6.2
223	0.9	0.95	1	6.2
225	0.9	0.95	1	6.2
227	0.9	0.95	1	6.2
229	0.9	0.95	1	6.2
231	1	1	1	6.1
233	1	1	1	6.1
235	1	1	1	6.1
237	1	1	1	6.1
239	1	1	1	6.1
241	1	1	1	6.1
243	1	1	1	6.1
245	1	1	1	6.1
*SLC version number should have been 6.3 and 6.2 but the period was not put in. 63 and 62 are equivalent to 6.3 and 6.2, respectively.				

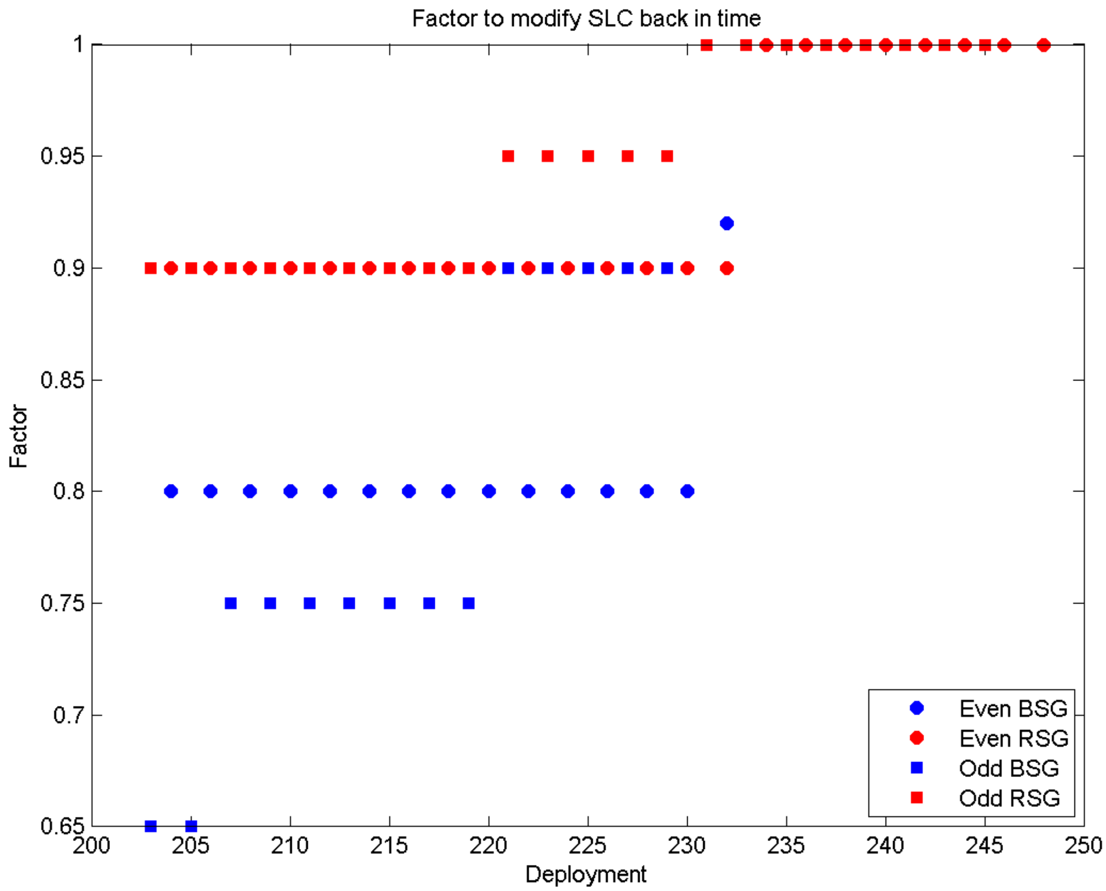

Figure 4) Multipliers for 2008 and 2011 SLC matrices to allow them to be used backwards in time, determined with the Blue LED pixel.

In Sep 2017 we went back to see if more work could be done or some other method could be determined to confirm these multipliers. The new method used LuTop data and the ratio between data, after SLC, at 350 nm to the data at 400 nm. The multiplier was adjusted for each deployment to make the average value of this ratio (350 nm/400 nm) be equivalent to the average value after 2012. Figure 5 shows the result of the two methods, the red dots correspond to the estimate using the Blue LED, while the black dots correspond to the method using this ratio. In general, the multiplier obtained is similar between both methods. The end product of applying these multipliers and the resulting SLC matrices was less noisy using the Blue LED method, so the multipliers used in the LED method were used for the reprocessing the blue and red spectrographs.

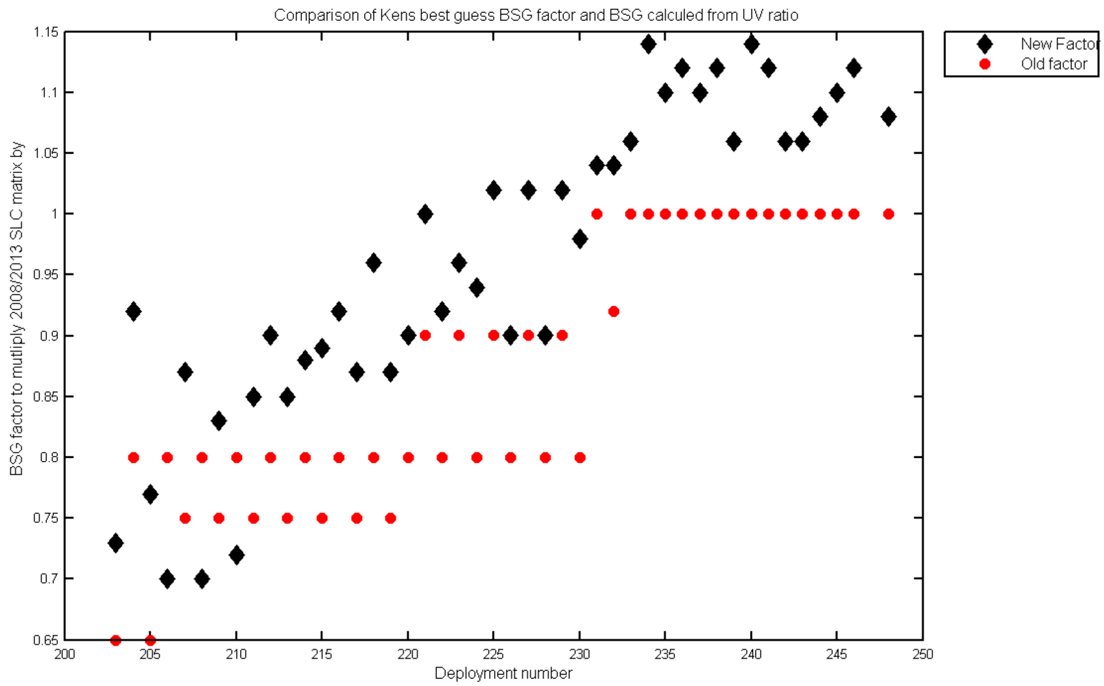

Figure 5) Multiplier determined with the Blue LED method (red dots) and the 350nm/400nm ratio (black diamonds).

Results of the Reprocessing

Figure 6-8 shows the 350 nm/400 nm ratio for MOBY products, before and after correction to the SLC. The black symbols for M202 to M248 are with the original modeling based on the sparse laser coverage; the colored symbols for these buoys are with the multipliers and the 2008 (even) and 2011 (odd) SLC laser characterization matrices.

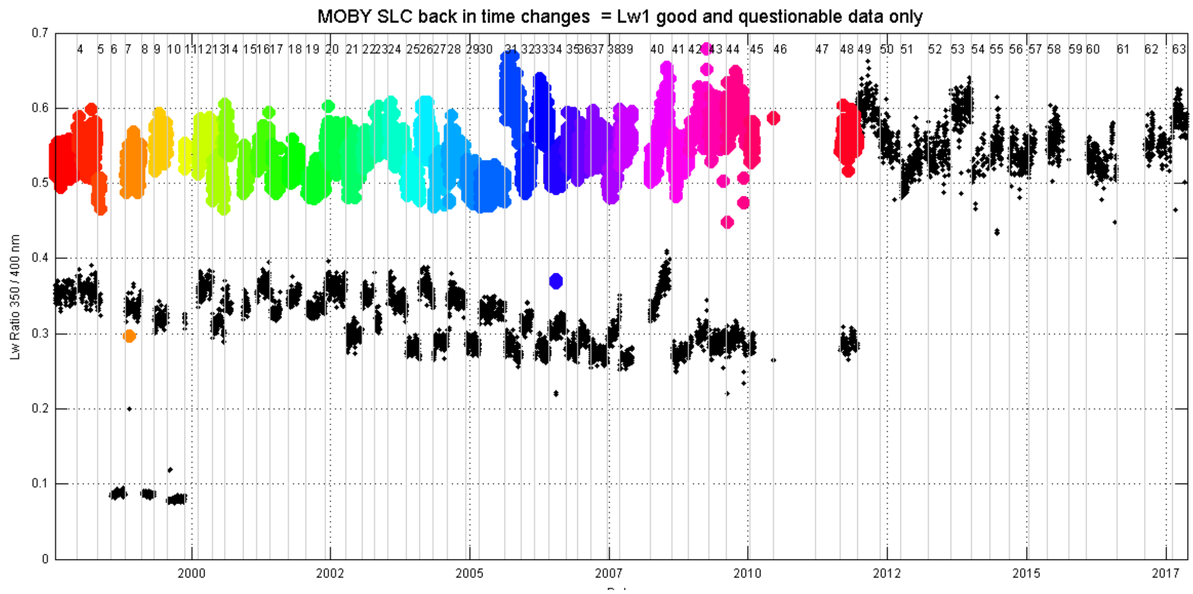

Figure 6) Ratio of Lw1 at 350 nm/400 nm. Black line is the data set before reprocessing with updated SLC. Colored dots are after the reprocessing. Note that the average of the colored dots is more consistent with the data taken after the modern SLC was applied.

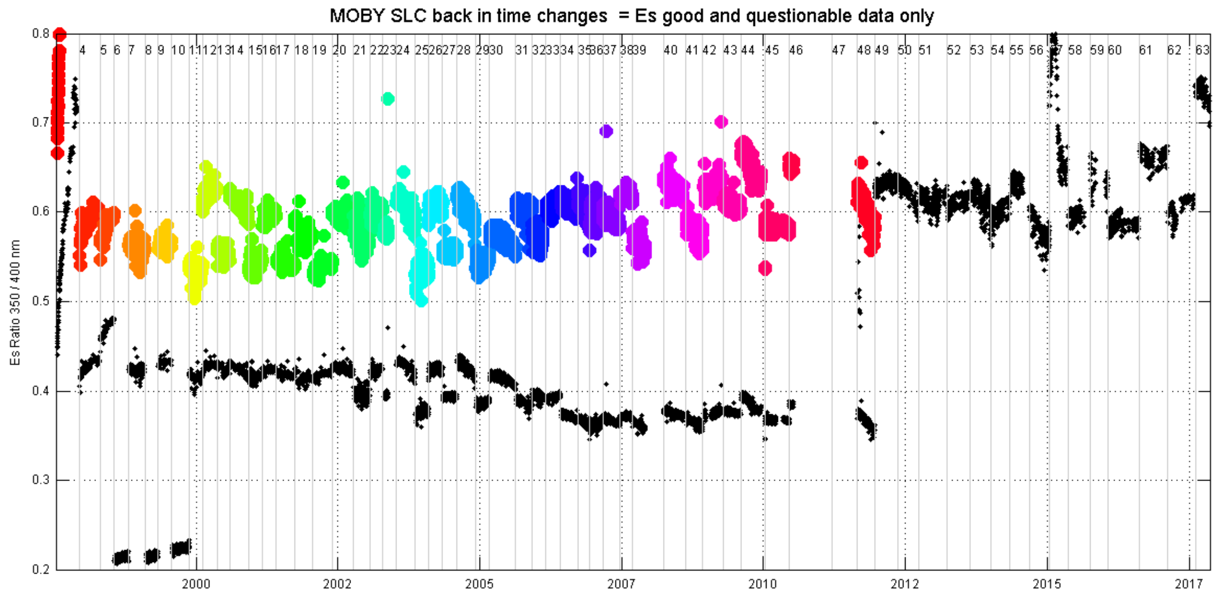

Figure 7) Ratio of Es at 350 nm/400 nm. Black line is the data set before reprocessing with updated SLC. Colored dots are after the reprocessing. Note that the average of the colored dots is more consistent with the data taken after the modern SLC was applied.

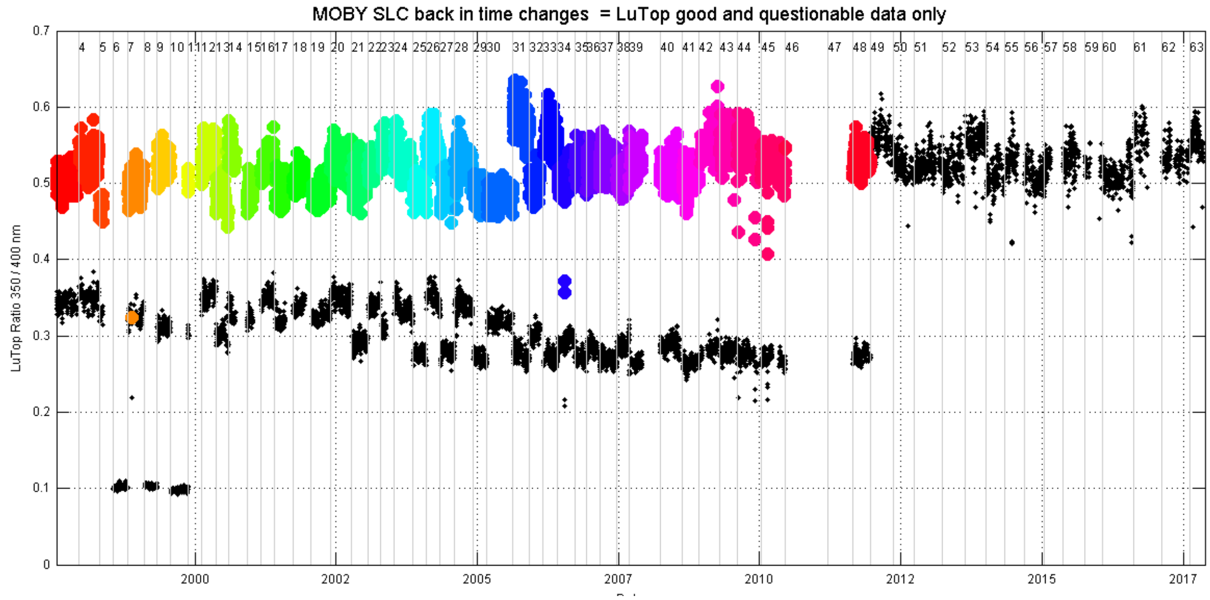

Figure 8) Ratio of LuTop at 350 nm/400 nm. Black line is the data set before reprocessing with updated SLC. Colored dots are after the reprocessing. Note that the average of the colored dots is more consistent with the data taken after the modern SLC was applied.

Figures 9 and 10 show the effect of the SLC change on the time series data for both Lw (Fig. 9) and Es (Fig. 10). For early deployments the effect is small, as the SLC was smaller in this period. As one goes on in time, there was a big jump at M221, and the change in the 410 nm band was an approximately 6% increase in the UV. It is important to note that the SLC process is not a simple linear process, as both the calibration data and the field data must be processed with the same SLC procedure to maintain consistency, hence the counter-intuitive result that correcting the SLC actually causes an increase in the UV, not a decrease. The spectral changes due to stray light are strongly dependent on the spectral distributions of the calibration source, the field sources, and the details of the SLC matrix.

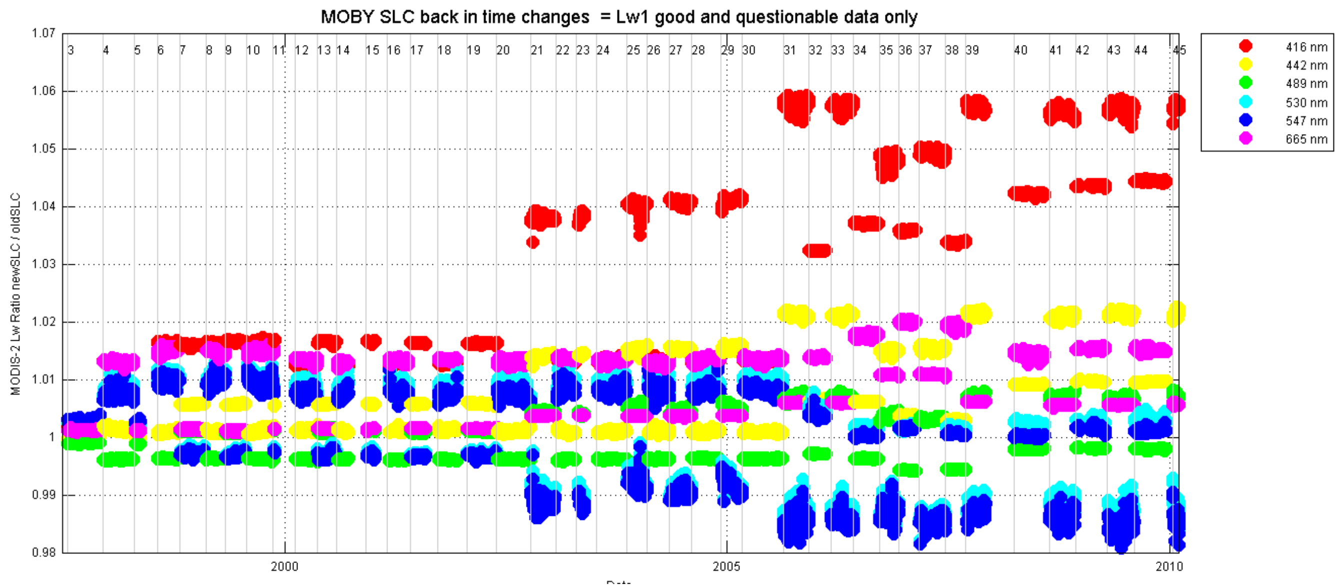

Figure 9) ratio of post reprocessing/pre-reprocessing on Lw. Note biggest change is at 410 nm and below.

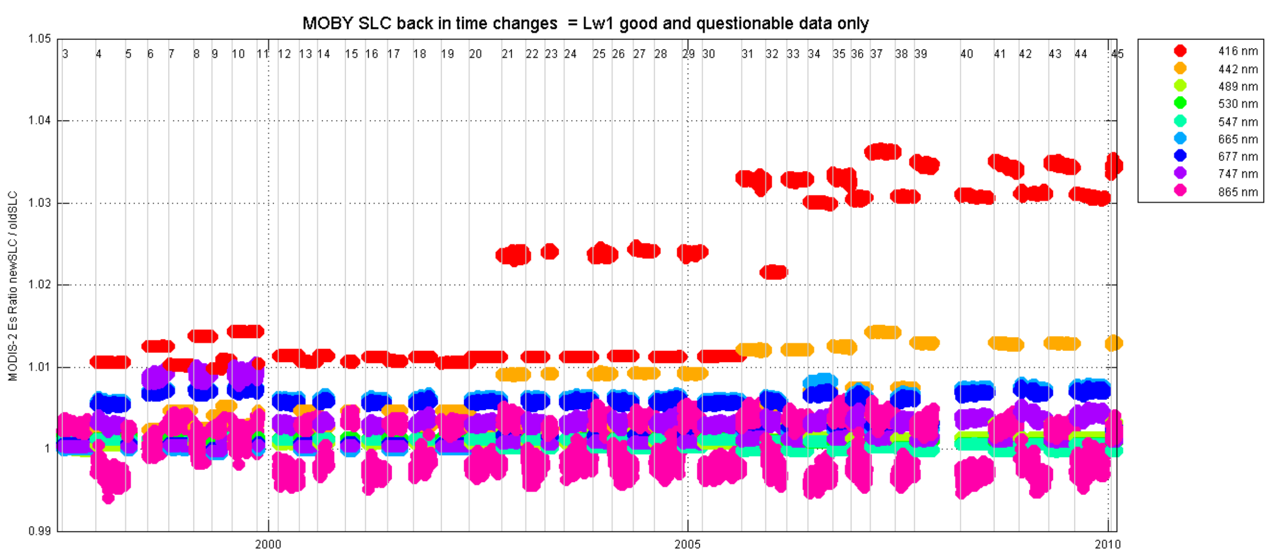

Figure 10) ratio of post reprocessing/pre-reprocessing on Es. Note biggest change is at 410 nm and below.

We can also examine the resulting time series for Lw and Es as shown in Figures 11 and 12. The time series is very consistent throughout the MOBY period. However, it is probably true that on this logarithmic graph, the 6% effect would not be very obvious.

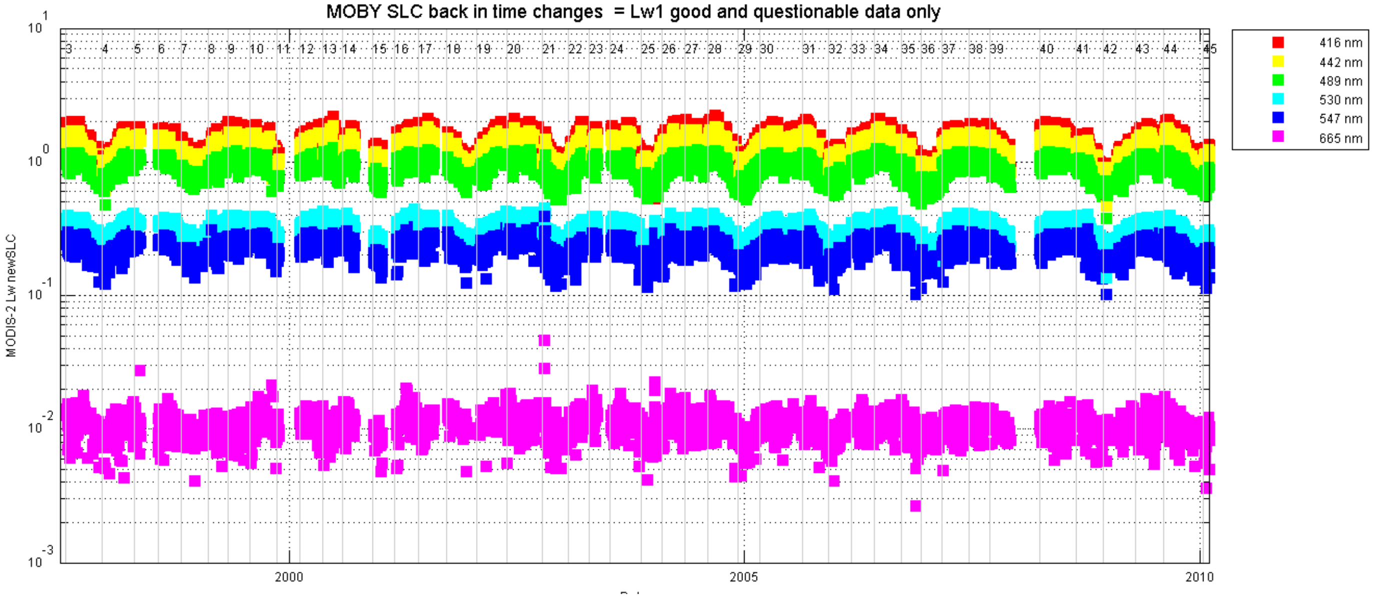

Figure 11) MOBY time series after reprocessing for Lw.

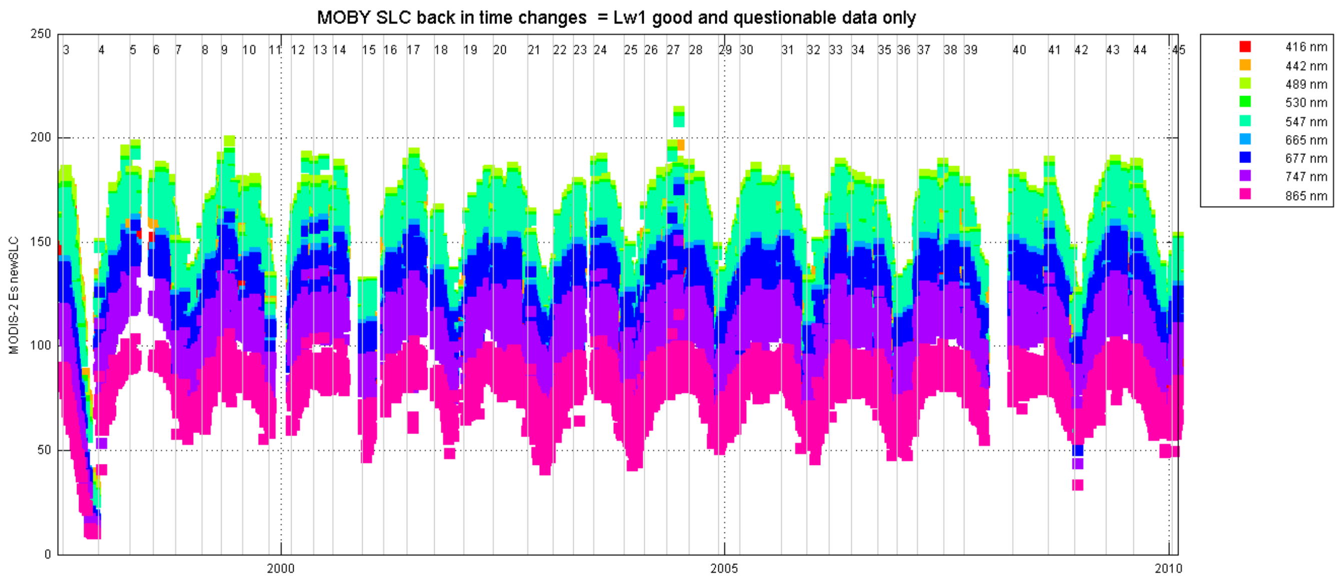

Figure 11) MOBY time series after reprocessing for Es.