**Multi-Filter Rotating Shadow Band Radiometer (MFRSR-378)**
**Raw Count Calibration 2004 February.**

**Fred Denn**

The Yankee Environmental Systems Inc., Multi-Filter Rotating Shadow Band Radiometer (MFRSR-378) has been located at the Mauna Loa Observatory (MLO) island of Hawaii for several periods between 1999 January and 2002 December to perform calibration measurements. These measurements are used to calculate the Top Of Atmosphere (TOA) values as measured by MFRSR-378. The TOA results of these raw count measurements are present here. A discussion follows the results table.

Date of measurements, 1999 January through 2002 December.
Applicable period, 1999 January through the present.
NOTE: U95=2.0*standard_deviation

**Mean Value TOA Results**

| Wavelength | Top of Atmosphere value | Standard deviation |
|---|---|---|
| 415.6 nm** | 9449 counts | 214 counts |
| 497.3 nm | 6281 counts | 140 counts |
| 614.5 nm | 5876 counts | 99 counts |
| 672.4 nm | 10699 counts | 182 counts |
| 868.8 nm | 9698 counts | 138 counts |
| 939.8 nm | 13691 counts | 1094 counts |

****** **For wavelength 415.6 only**

1999 Jan 1 through 2000 Jan 1 use a linear interpolation.

| Wavelength | slope | Intercept | Standard Error |
|---|---|---|---|
| 415.6 nm | -1784 | 11221 | 178 |

Application
(For each given wavelength)

TOA(decimal year) = (decimal year – 1999)*slope + intercept

A change in sensitivity occurred between 1999 January and 2000 January for the 415.6nm channel. The other channels were quite constant during this period. A straight line fit should be used for the 415.6 nm before 2000 January while the mean value can be used after this date.

**Filters**

The wavelengths filters have been changed as required during the life of the instrument. A graphical representation of the filter changes and MLO measurement periods is presented in
Figure 1.

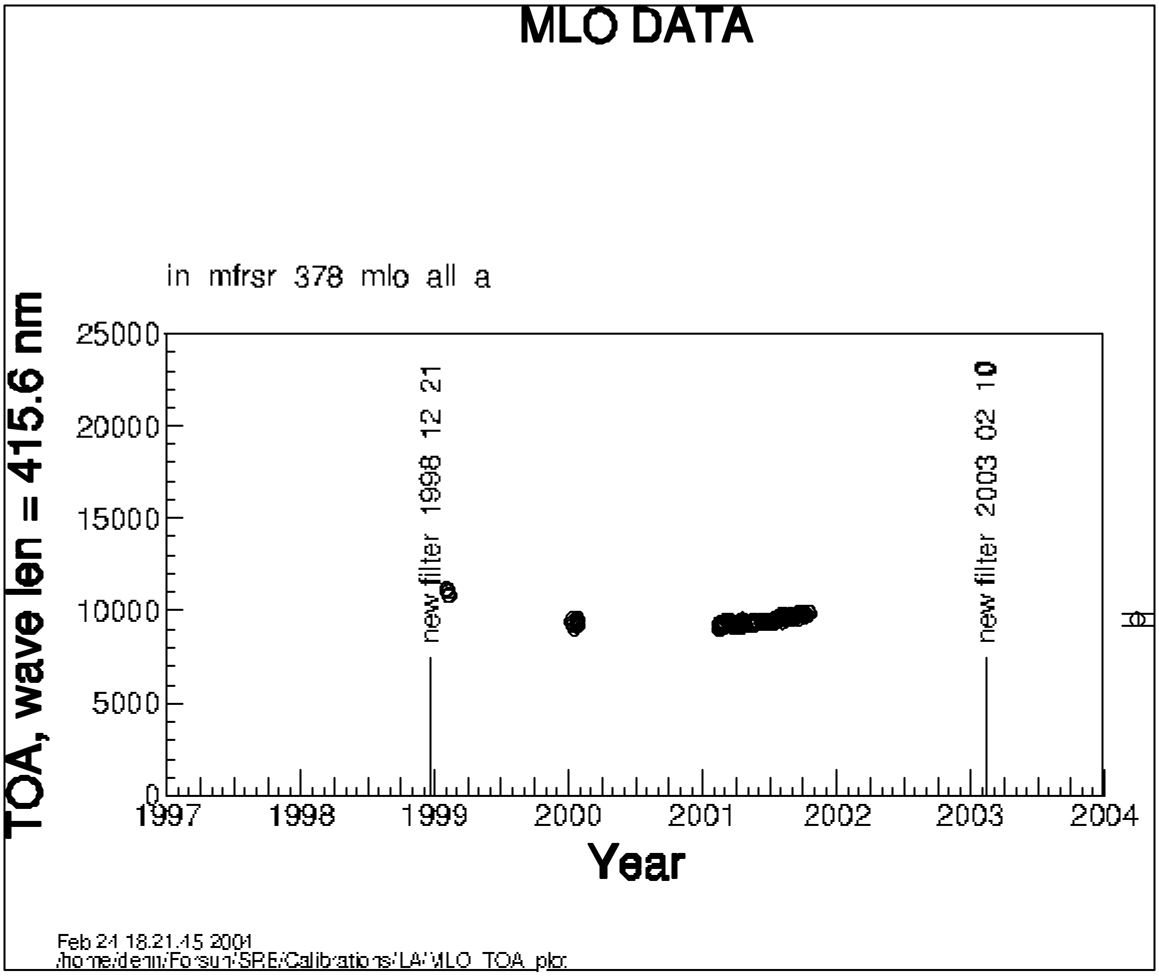


Figure 1. Graphical display of filter changes and MLO data collection periods. The circles are the Langley determined Top Of Atmosphere values. The filter changes are marked by vertical lines which are dated.

## Langley Analysis

Langley analysis consists of determining the irradiance as the sun rises or sets. Sunrise periods are preferred because the afternoon atmosphere is less stable due to solar heating. During these periods the direct beam irradiances are measured at one minute or smaller intervals. The atmospheric path lengths are calculated (directly overhead is defined as an atmospheric path length of 1 regardless of the measurement location). A straight line is fit to the log of the irradiance (y value) and the atmospheric path length (x value). This straight line is then extrapolated zero atmospheric path lengths. This extrapolated value is the Langley determined Top Of Atmosphere value. The range of atmospheric path lengths chosen here is 2 to 5. Below 2, the data points are too numerous and will unduly influence the fit. The maximum of 5 was chosen because a similar analysis has been preformed on data collected at the Clouds and Earth's Radiant Energy System (CERES) Ocean Validation Experiment (COVE) Site. COVE data for atmospheric path lengths greater than 5 are unusable because of haze. A sample plot of Langley analysis is shown in Figure 2.

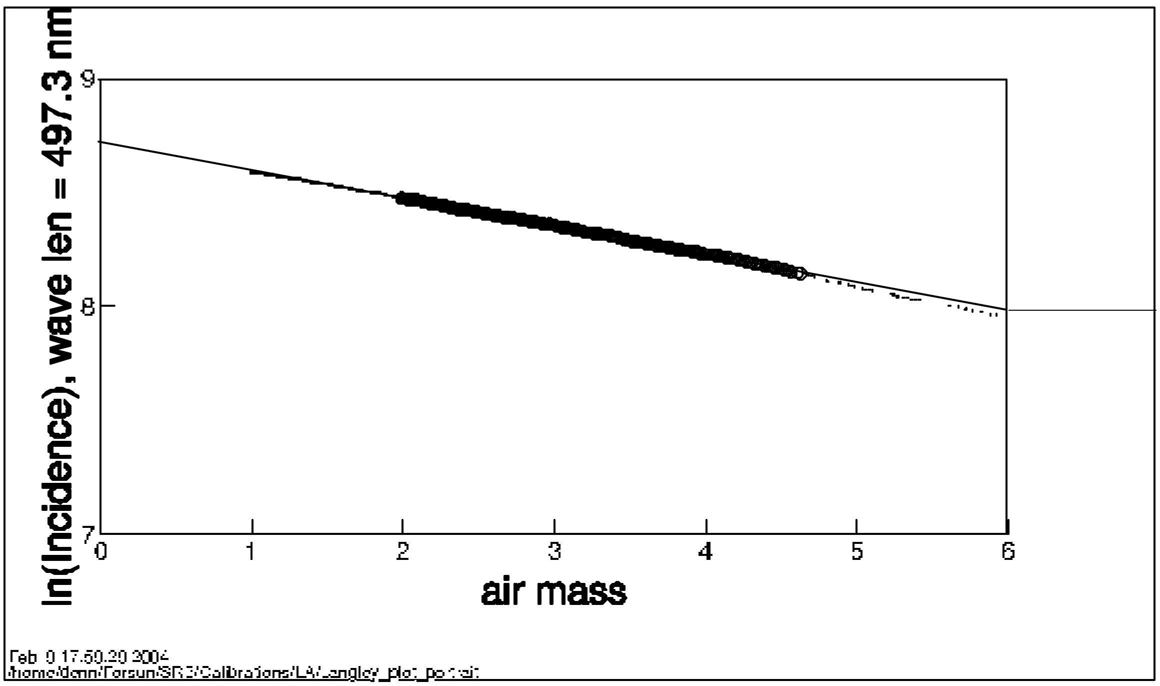


Figure 2. An example of Langley analysis. The vertical axis is the log of the direct beam irradiance. The horizontal axis is the atmospheric path length, in atmospheric path length units. The symbols and dots are the logs of the direct beam irradiance. A straight line is fit to this data and extrapolated to zero atmospheric path lengths.

**Spectral Response**

Figures 3 is an example of the spectral response of  MFRSR-378.  These measurements were provided by the manufacturer.

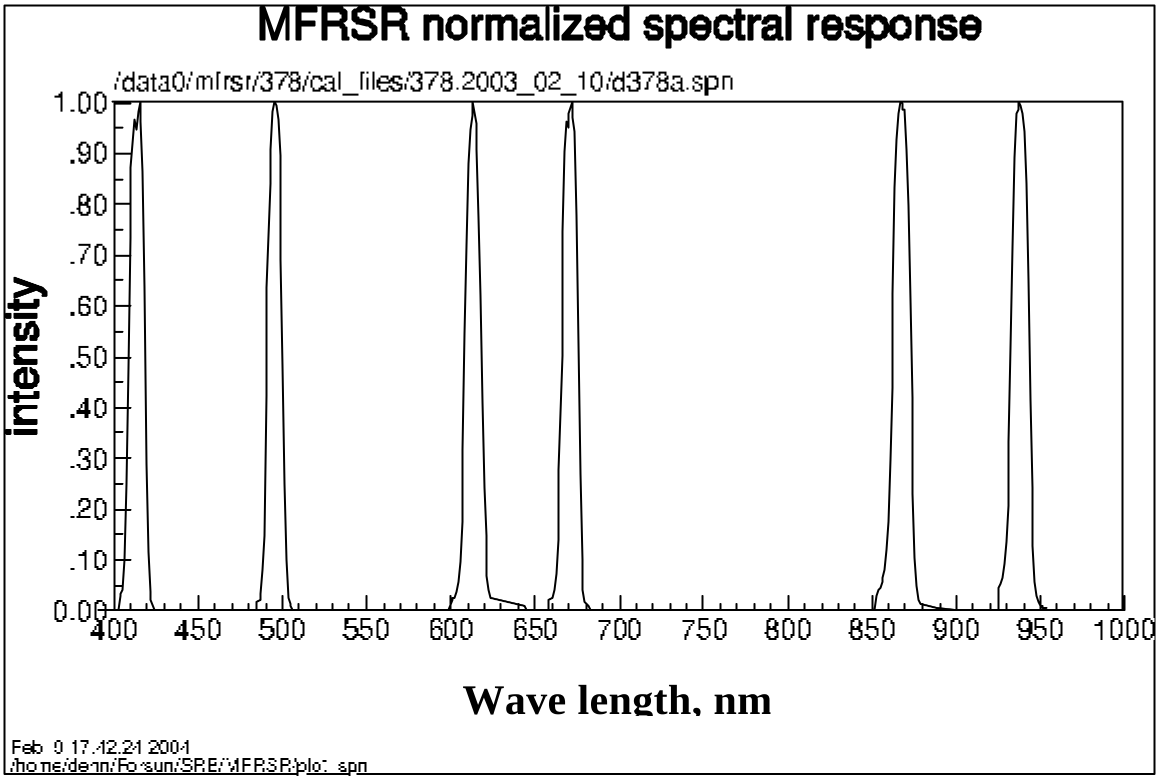


Figure 3.  An example of normalized spectral response data for the 6 MFRSR-378 narrow-band channels.  Nominally 416,  497, 613,  672,  868 and 938 nm.  This data is from the 2000 February filter change.

## Top Of Atmosphere Results

Figures 4 through 9 show the TOA results for each wavelength. The mean and standard deviation of the TOA values are determined. Another parameter, ‘std_dev_mean’, comes from the Langley fit for each point and is the mean of these points. This mean is then combined with the standard deviation of the TOA values using the root some square method to get ‘std_dev_combined’. A horizontal line with no diamonds represents the mean. These values are displayed in each figure in the left column above the plot. The column to the right (red) displays the slope and intercept for a straight line fit to the data, as well as a ‘combined std error’ which is equivalent to the ‘std dev combined’. The least squares fit line is also displayed; it is red and has diamonds on it.

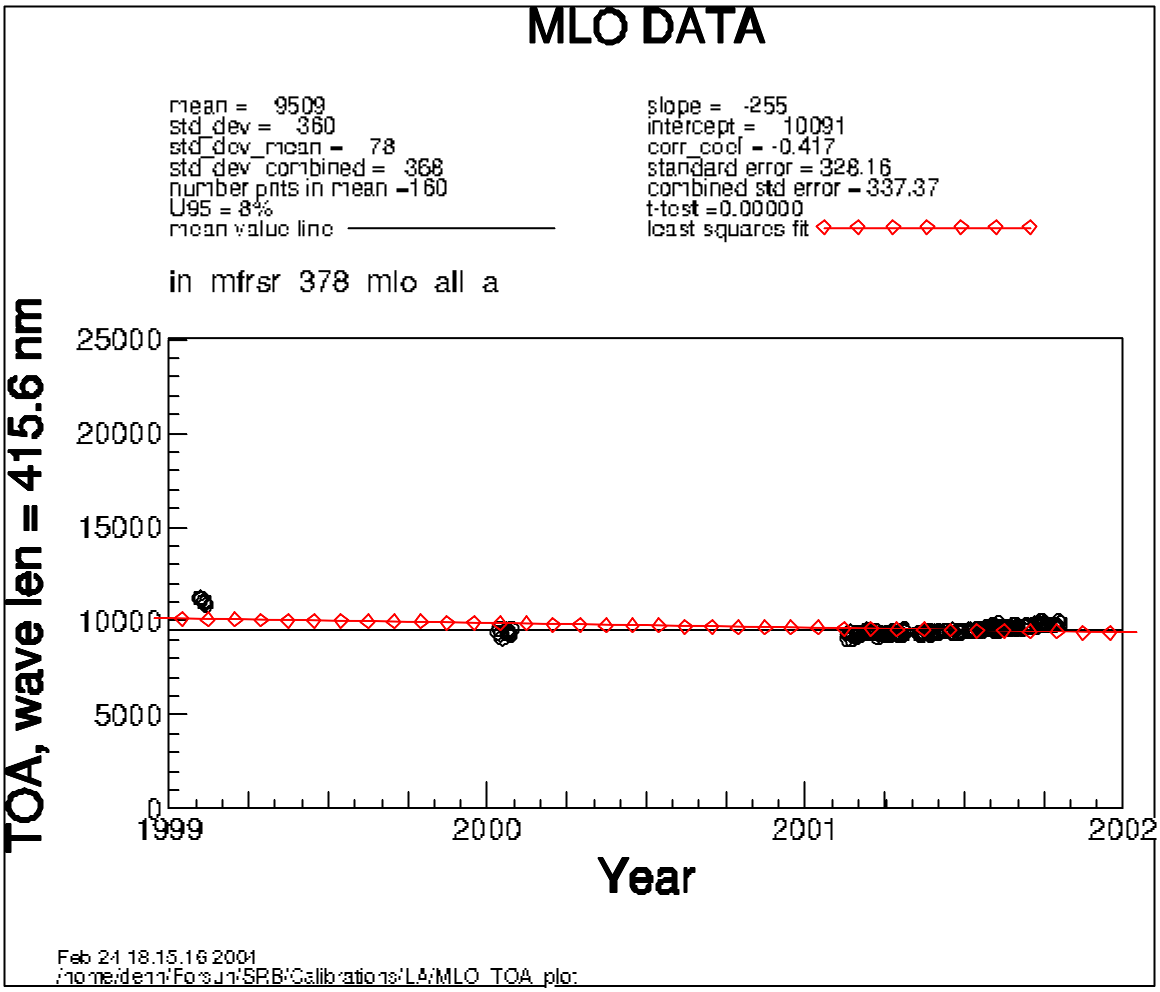


Figure 4a. MLO TOA data collected during years 1999 through 2001 for wavelength 415.6 nm. The change in sensitivity appears significant between 1999 February and 2000 January. An interpolation during this period should be used for the monthly TOA values. Interpolation parameters are shown in Figure 4b.

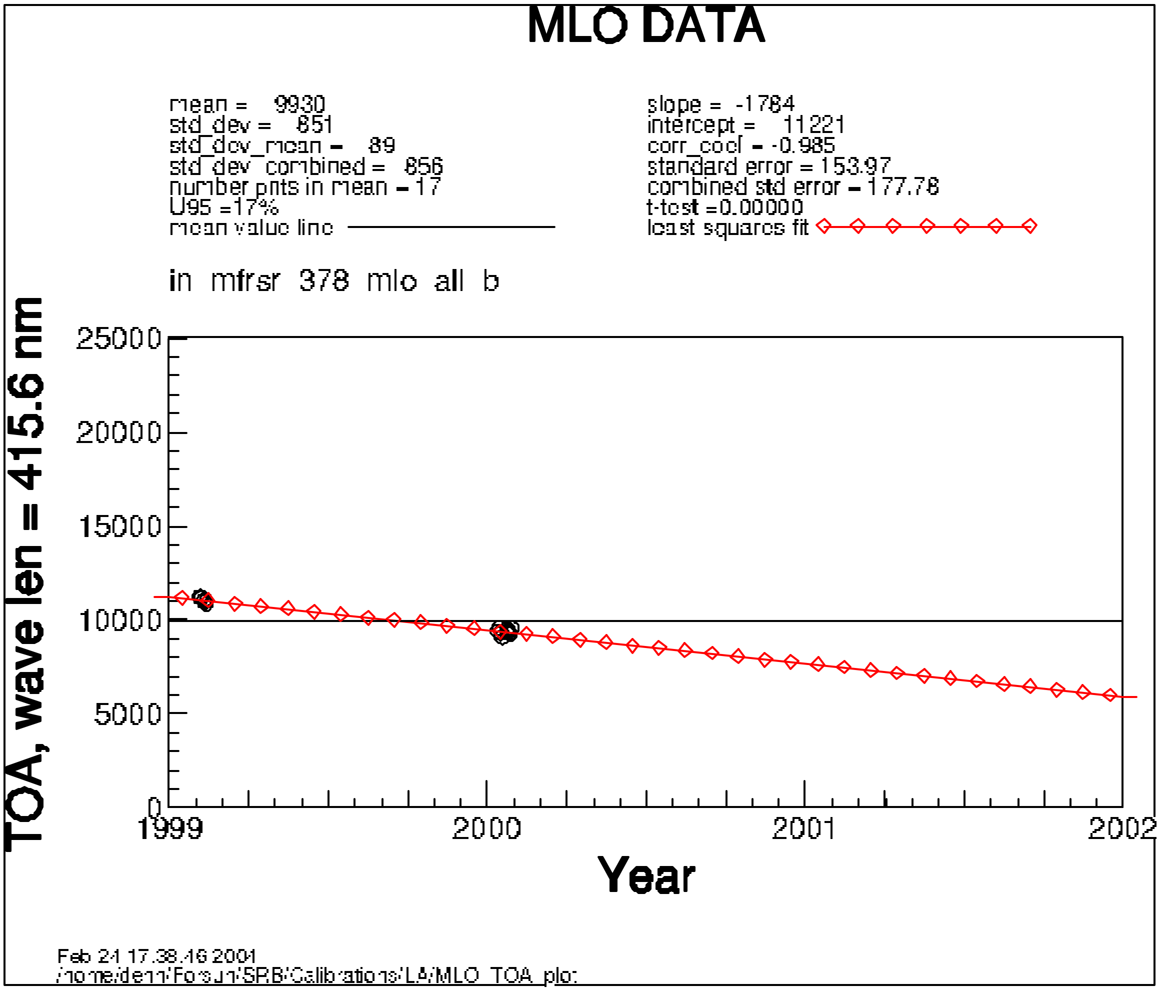


Figure 4b. MLO TOA data collected during 1999 and 2000 January for wavelength 415.6 nm. The change in sensitivity is large between these two time periods. The interpolated TOA values would be most appropriate for this time period.

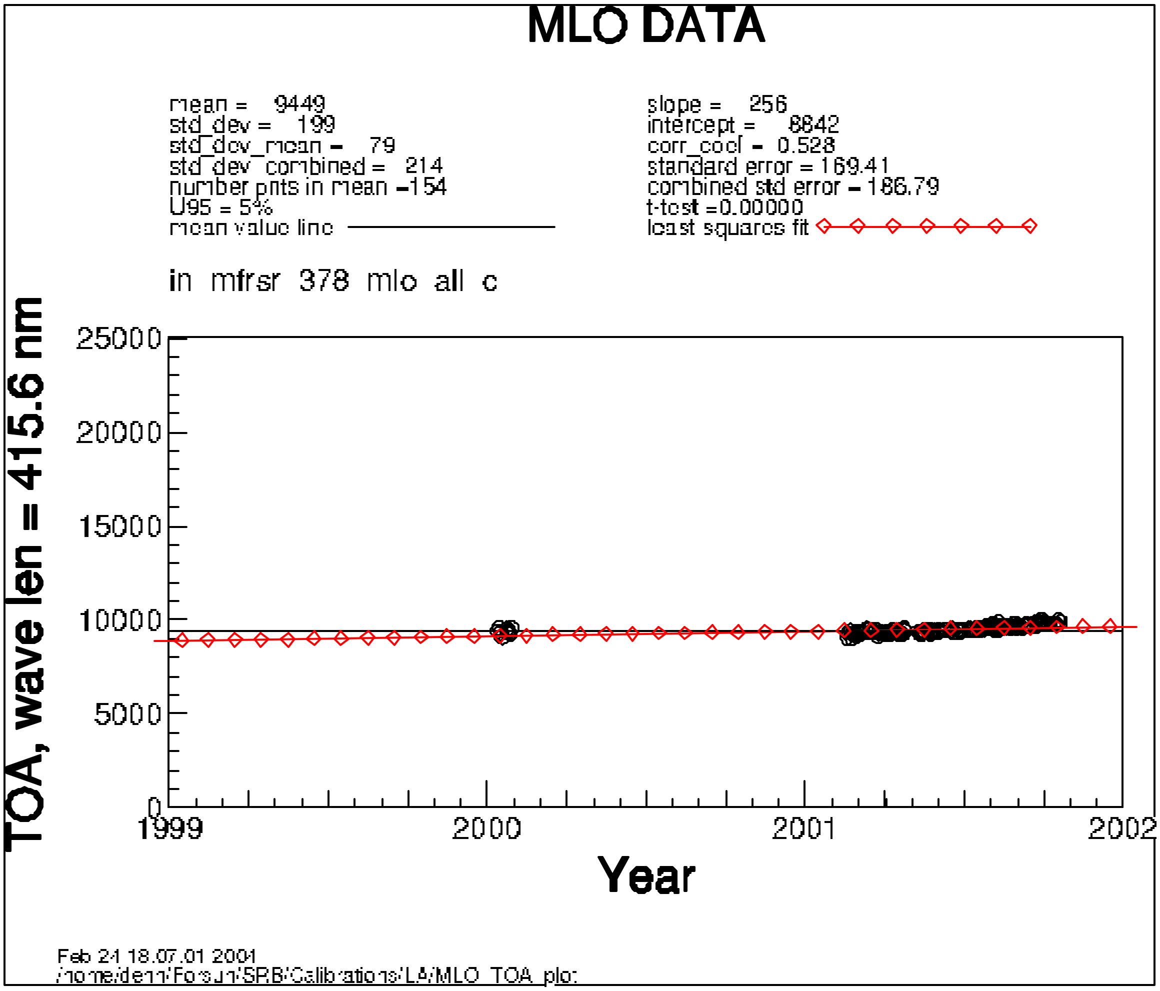


Figure 4c. MLO TOA data collected during years 2000 and 2001 for wavelength 415.6 nm. The data collected during January 2000 falls within the range of the data collected in 2001. A simple mean can be used for this time period.

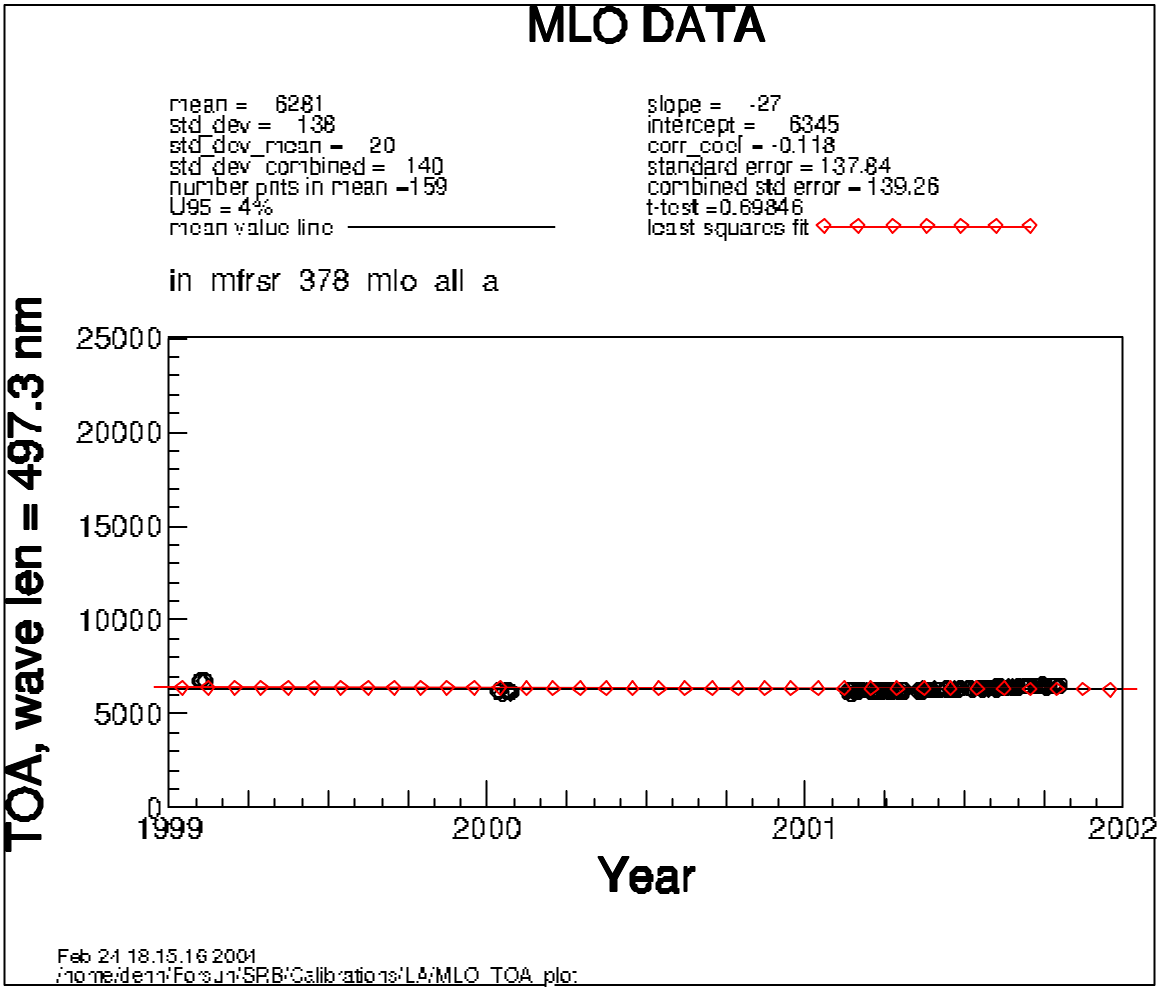


Figure 5. MLO TOA data collected during years 1999 through 2001 for wavelength 497.3 nm

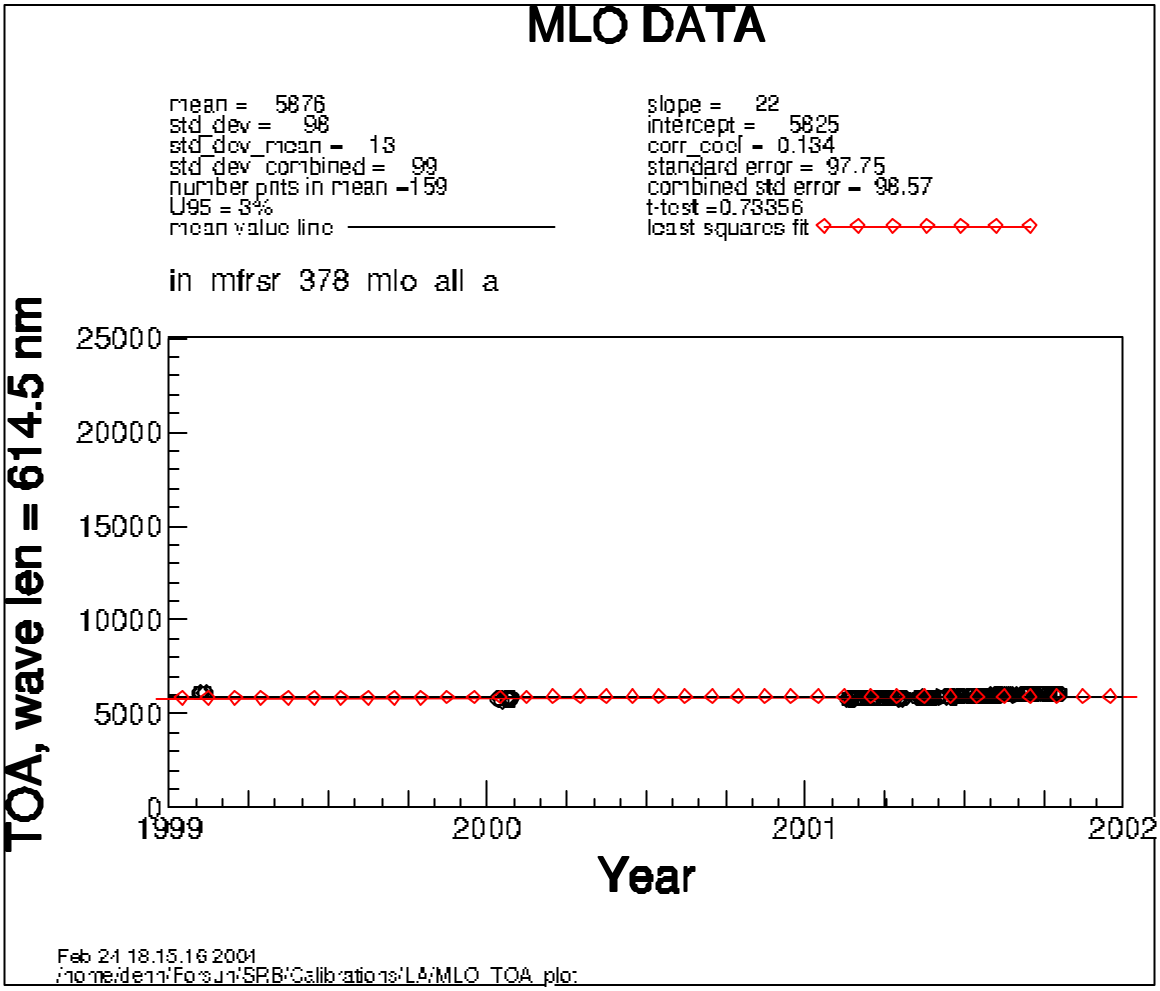


Figure 6. MLO TOA data collected during years 1999 through 2001 for wavelength 614.5 nm.

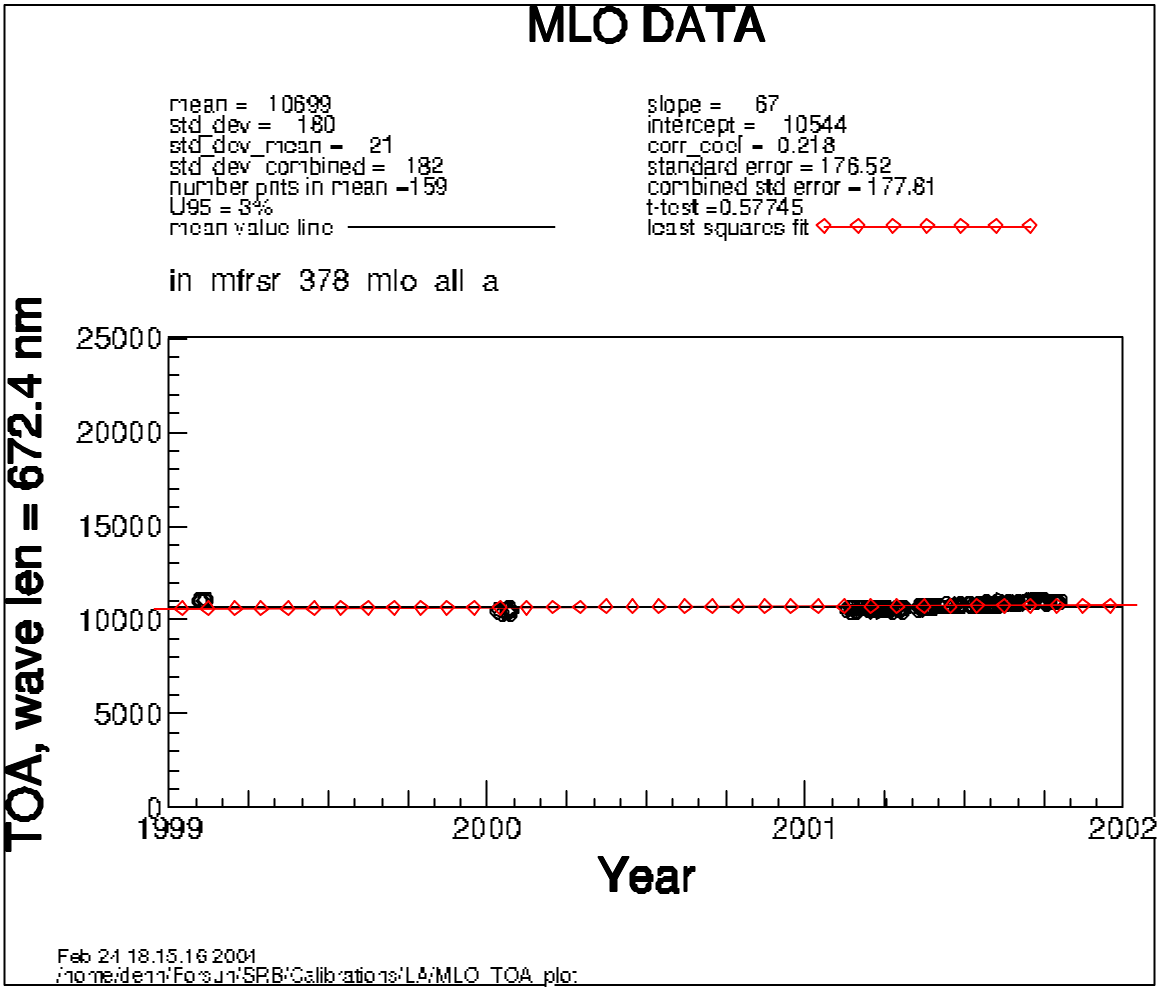


Figure 7. MLO TOA data collected during years 1999 through 2001 for wavelength 672.4 nm.

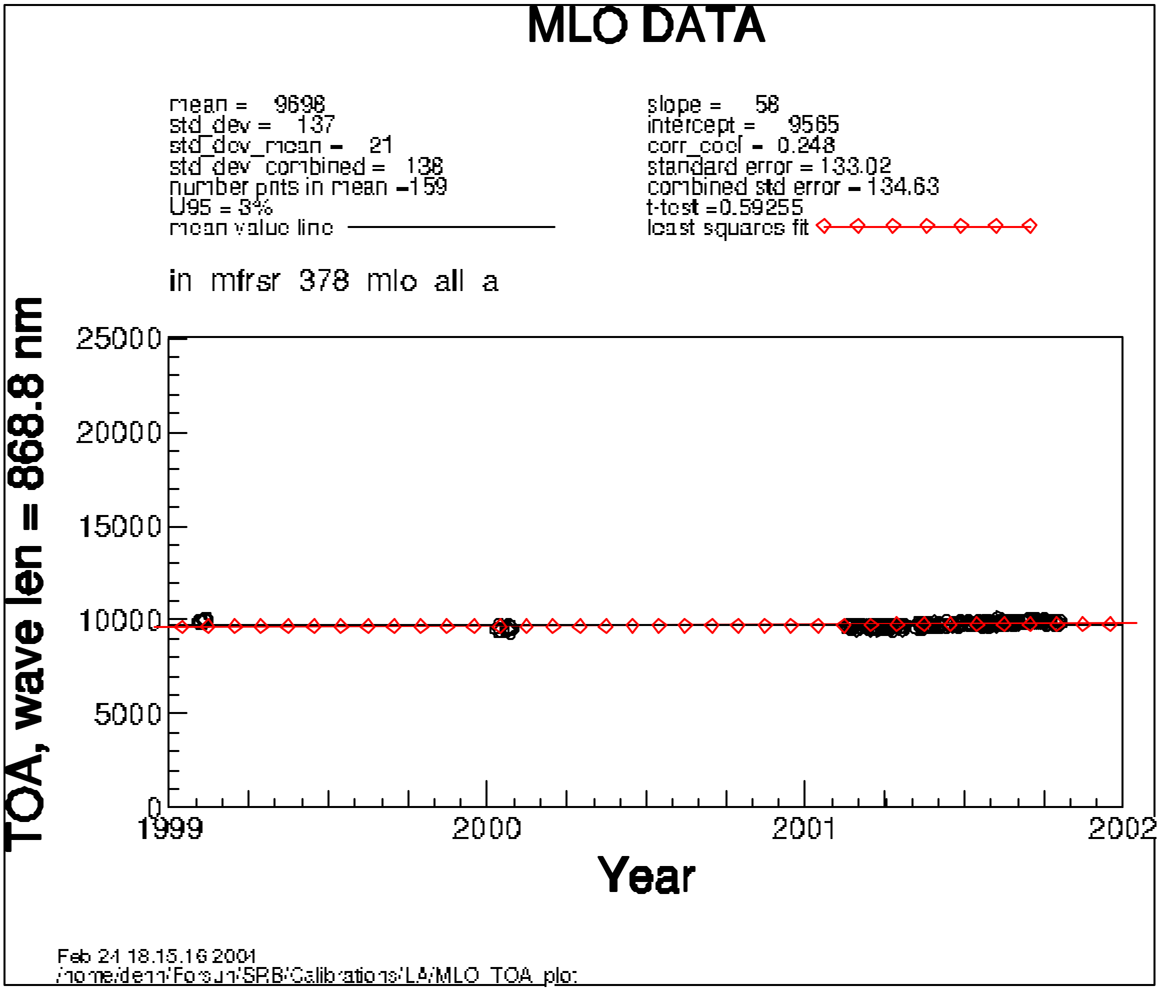


Figure 8. MLO TOA data collected during years 1999 through 2001 for wavelength 868.8 nm.

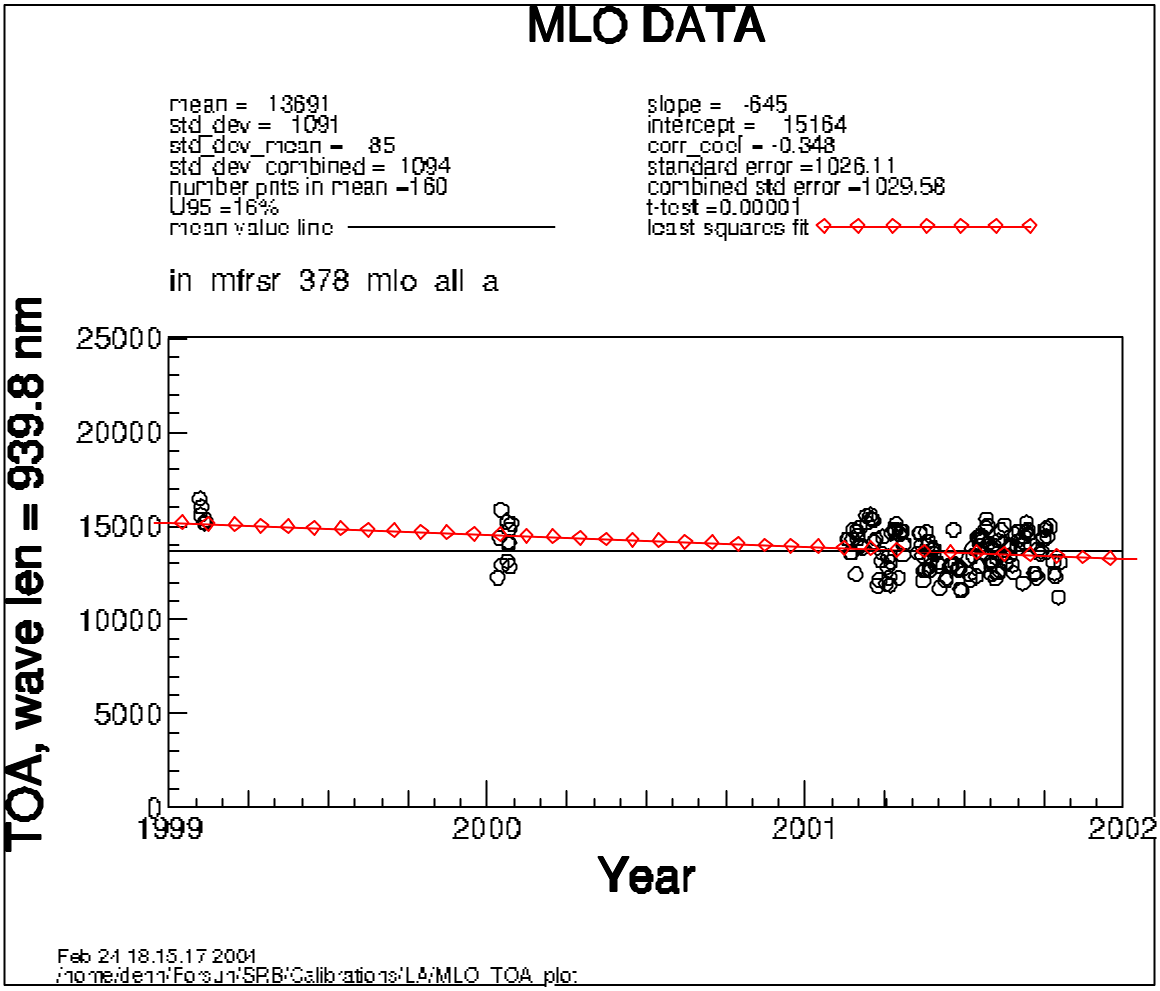


Figure 9. MLO TOA data collected during years 1999 through 2001 for wavelength 939.8 nm. This is a water vapor absorption wavelength, therefore the Langley TOA extrapolation does not work well.

## Results

The final results of this analysis are presented here and at the beginning of the report.

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