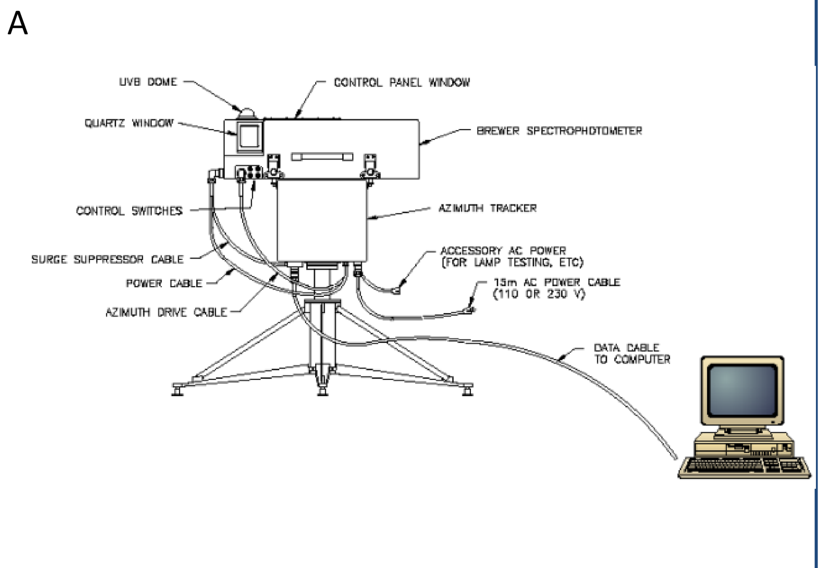
A New Data Product for the NOAA Environmental UV-ozone Brewer Network (NEUBrew): Aerosol Optical Depth in the UV Spectral Region

Patrick Disterhoft and Scott Stierle

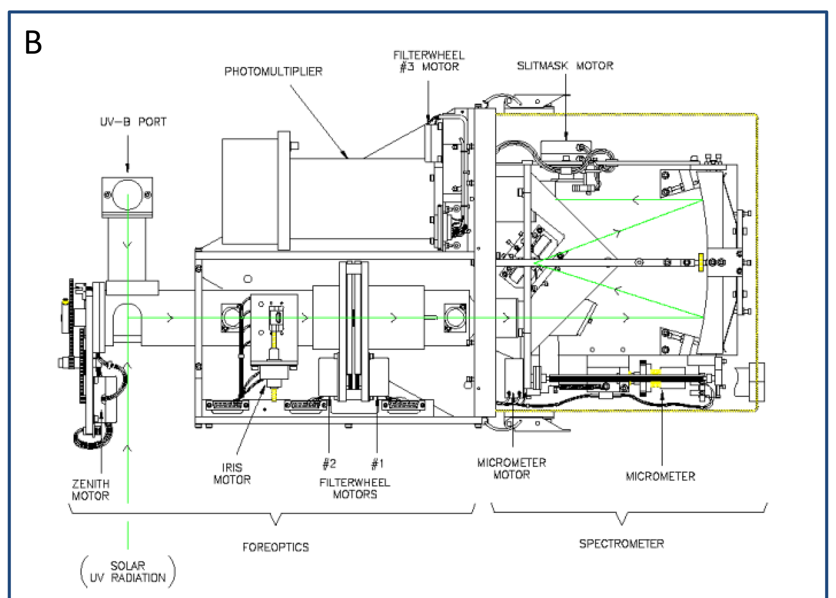
The Brewer Mark IV spectrophotometer was originally designed as an automated replacement for the Dobson spectrophotometer for the measurement of total column ozone. Additional functionality was added to include measurements of spectral UV irradiance. The UV data also provides for several derivative UV products, such as calculated action spectra, UV daily dose, etc. The Brewer can also make a direct-sun spectral UV measurement. The field of view of the Brewer is restricted during the measurement. Both the ozone and direct-sun spectral UV measurements are direct sun irradiance measurements and can be made as a function of solar zenith angle. We are implementing an algorithm to determine the aerosol optical depth at UV wavelengths. The basis of the algorithm is from previous work by Vignola/Michalsky/Stoffel. Our modified algorithm must adjust for some of the optical geometry and electronics that is unique to the Brewer.

A



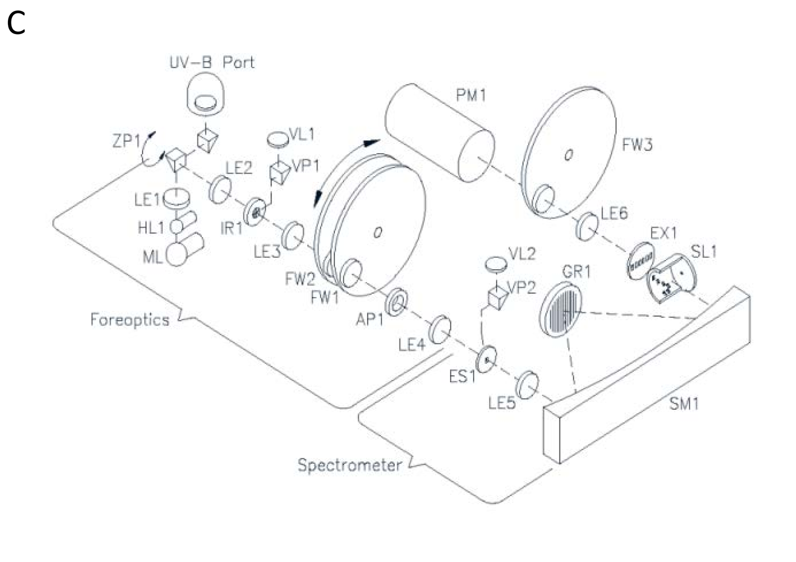
The Brewer Mark IV Spectrophotometer

B



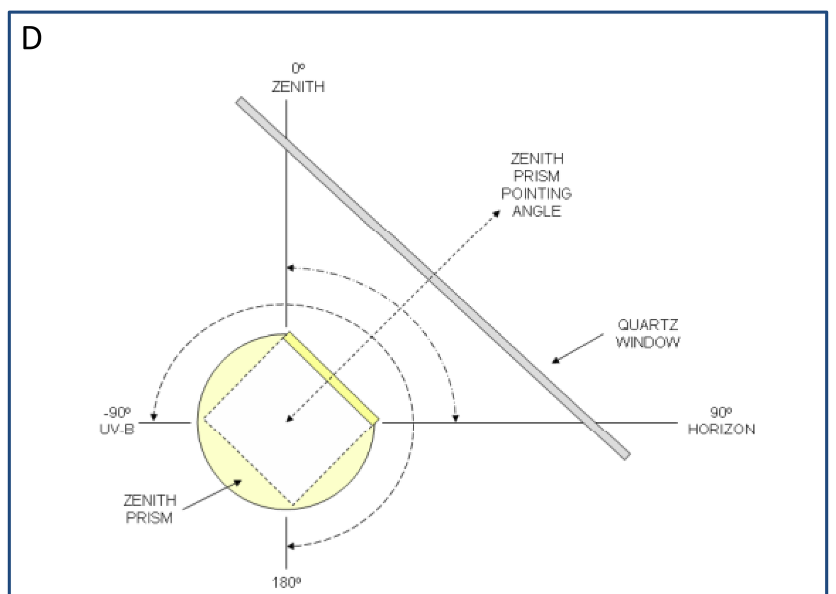
The total optical bench of the Brewer Mark IV Spectrophotometer

C



Cartoon of the optical components of the Brewer Mark IV Spectrophotometer

D



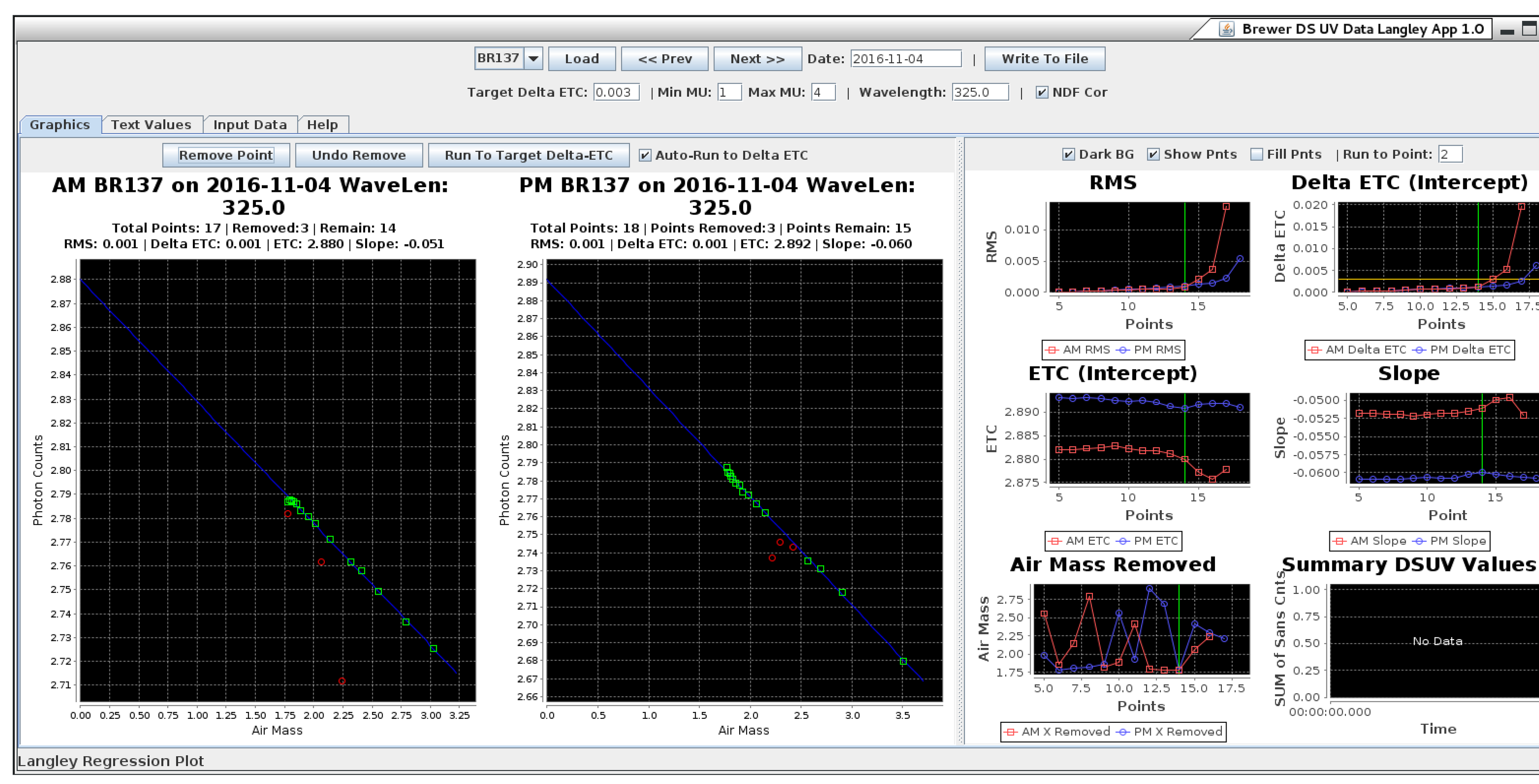
Slanted quartz window and sun-director prism of the Brewer Mark IV Spectrophotometer

Figure A. is a picture of the Brewer Mark IV spectrophotometer. It is a single-monochromator dispersion optics. It uses a photomulitplier tube to measure the incident UV radiation. The amplitude of the radiation can extend to over six orders of magnitude across the UV spectral range. Figure B. is the layout of the Brewer's optical system. The major components are noted. Figure C. details each component on the optical axis. Of specific note are the three filter wheels, the PMT, and slanted quartz window, which all need to be accounted for when calculating AOD. Figure D. show the relationship between the sun-director prism and the slanted quartz window. This arrangement is the forefront of the input optics for both the direct-sun UV and direct-sun ozone measurements.

$$(1)\quad \ln(I(\lambda)) + \tau_{ozone} * m_{ozone} + \tau_{rayleigh} * m_{rayleigh} = \ln(I_0(\lambda)) - \tau_{aerosol} * m_{aerosol}$$

$$(2)\quad \tau_{aerosol} = (\ln(I_0(\lambda)) - [\ln(I(\lambda) + \tau_{ozone} * m_{ozone} + \tau_{Rayleigh} * m_{Rayleigh}])/m_{aerosol}$$

Equations 1 and 2 are the basis of the Brewer spectrophotometer calibration and aerosol optical depth retrieval. Measurements of the solar UV irradiance are taken at each wavelength across its spectral range as a function of air mass. The natural logarithm of the measured signal is plotted against the aerosol air mass. It is then extrapolated to zero air mass, which determines the calibration factor (the extra-terrestrial constant, ETC). The ETC, along with the other calculated parameters are then used to determine the aerosol optical depth for each measurement.



The Langley Analyzer tool develop to facilitate efficient and accurate calibrations of each Brewer spectrophotometer for aerosol optical depth retrieval.

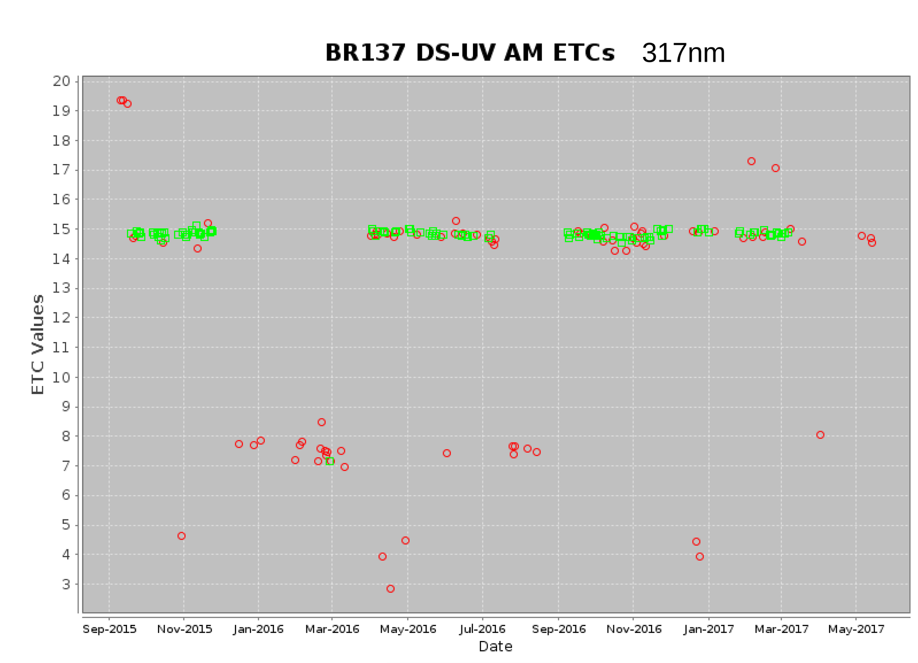
Brewer direct-sun UV scans

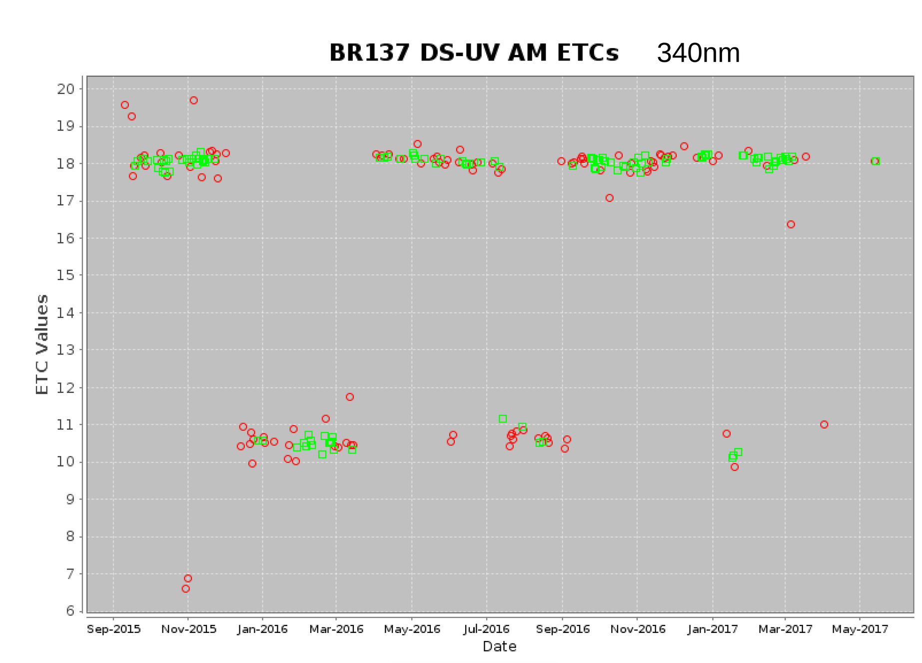
- ✓ Scan range 290-363 nm @ 0.5 nm steps
- ✓ Raw count is dark corrected
- ✓ Dead-time corrected (Poisson statistics assumed)
- ✓ Normalized to remove effects from changing NDF's
- ✓ Natural log of corrected raw counts plotted
- ✓ ln(corrected counts) vs aerosol air mass
- ✓ Langley regression technique used to calculate ETC

Brewer direct-sun ozone measurements

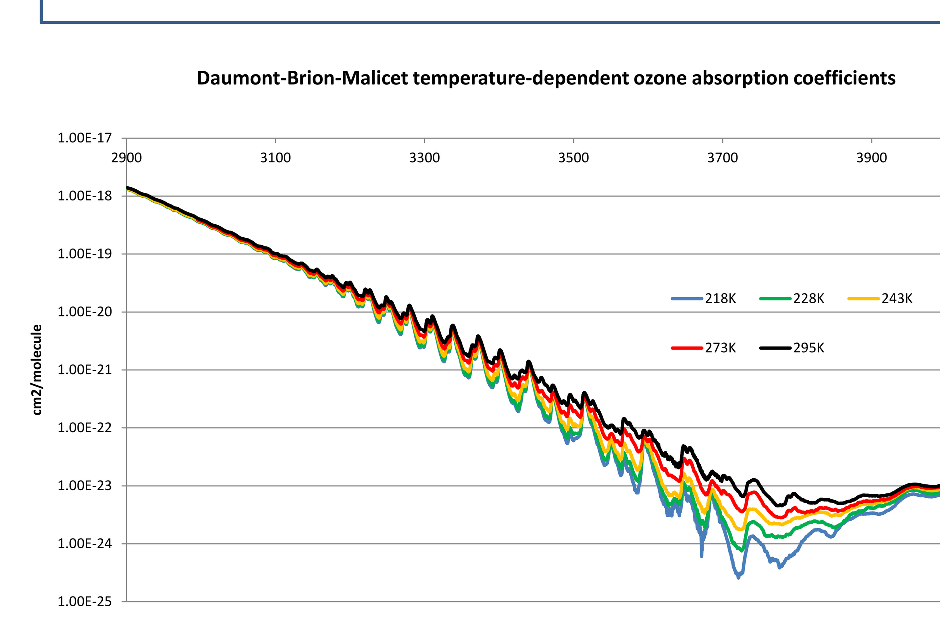
- ✓ Long history of measurements (EPA, NEUBrew, etc.) that can be post-processed
- ✓ Data is preprocessed by Brewer software
- ✓ Preprocessing must be removed to obtain raw data
- ✓ Data are available at five discrete wavelengths, which are nominally: 306.3, 310.1, 313.5, 316.8, and 320.1 nanometers.

The direct-sun UV scans provide a total spectrum of aerosol optical depth measurements. This allows critical insight into the Angstrom exponent at the UV wavelengths. However, at this time there is only one Brewer Mark IV in the NEUBrew network that is making direct-sun irradiance measurements, so the total amount of those measurements is small. On the other hand, there are a large number of direct-sun ozone measurements that are also spatially distributed across the United States. There are measurements beginning as far back at 1994.



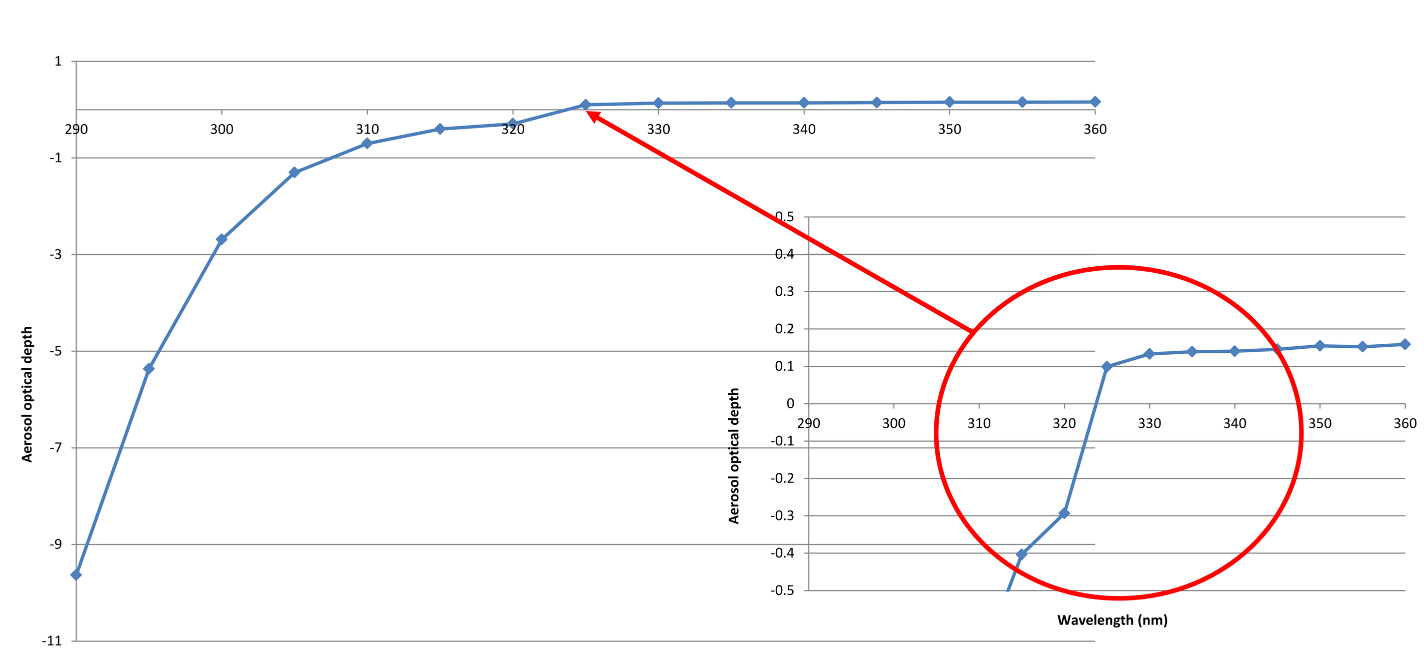


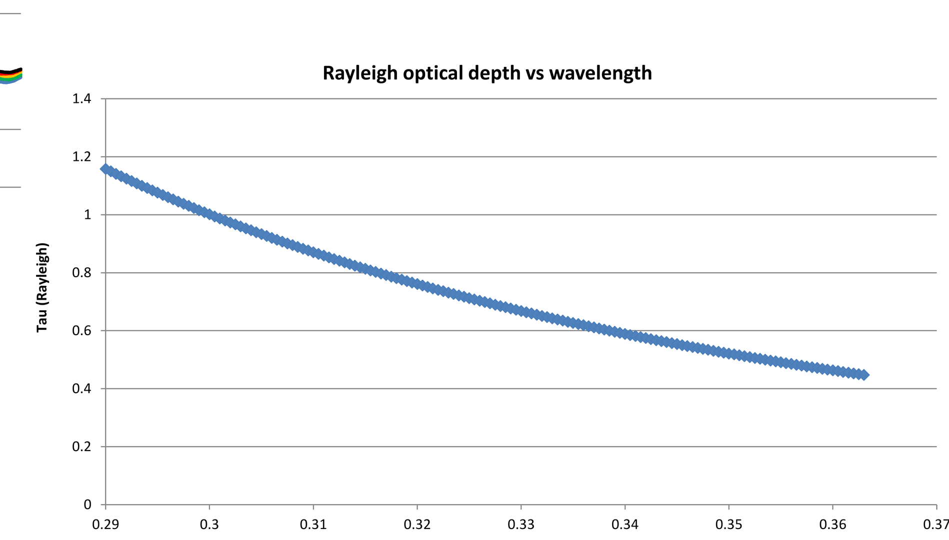
AM sample ETC's at two wavelengths, 317 nm strongly affected by ozone, and 340 weekly affected by ozone.

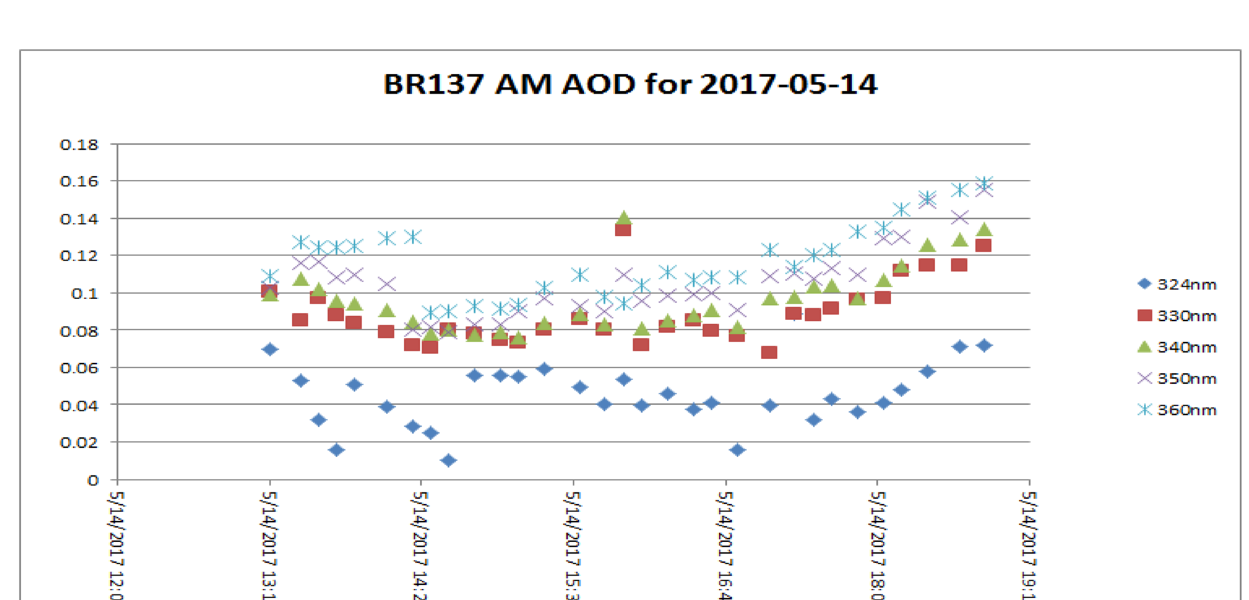


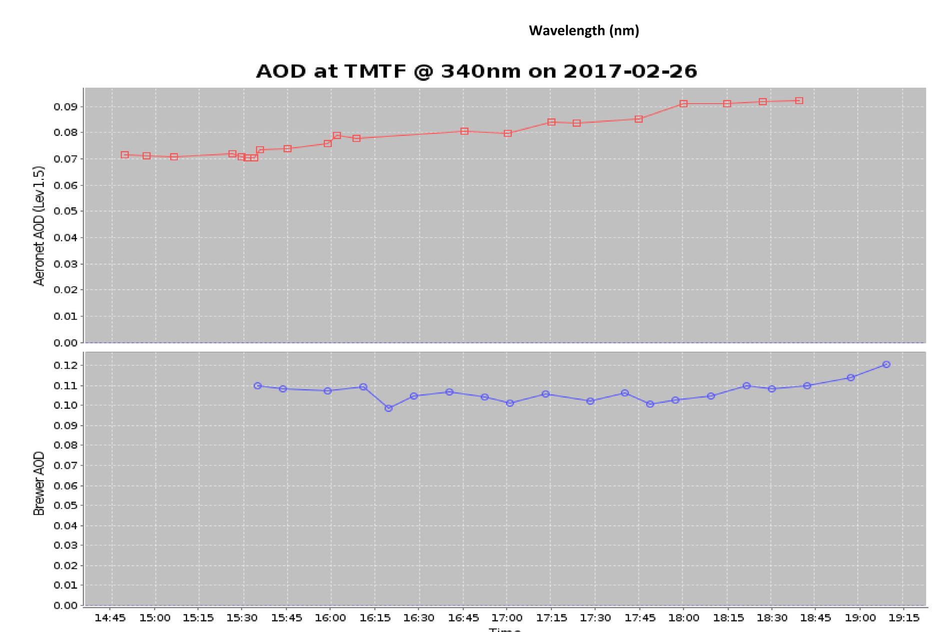
Adaptive Retrieval Algorithm Inputs for Automated Processing of AOD's

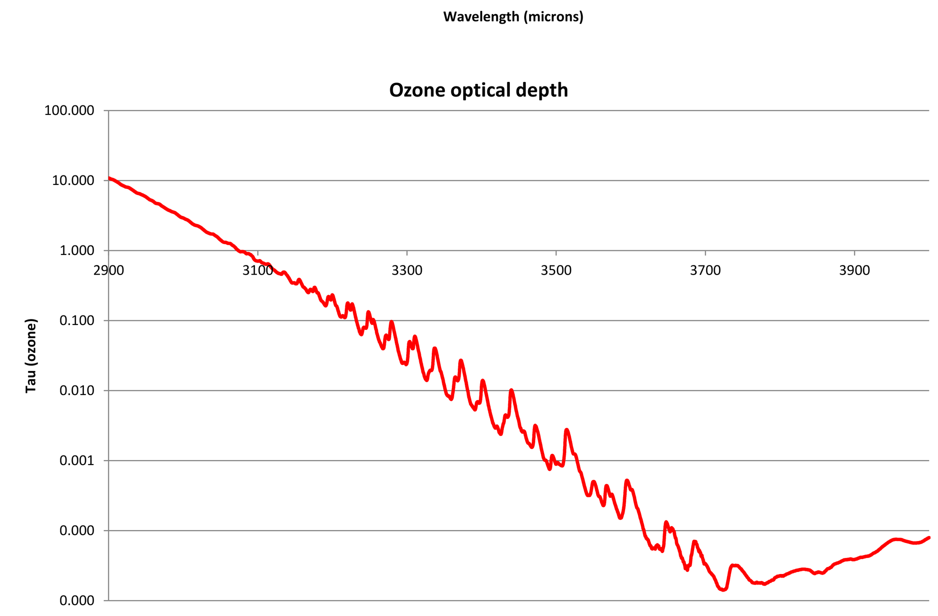
- Ozone CM height and temperature
- Station Pressure
- CO_2 content (Bodhaine's air mass)
- Fresnel's coefficients updated against SZA











1. Frank Vignola, Michalsky, J.J., Stoffel , T., *Solar and Infrared Radiation Measurements*, CRC Press, 2012
2. P. Sellitto, di Sarra, A., and Siani, A.M**.** *An improved algorithm for the determination of aerosol optical depth in the ultraviolet spectral range from Brewer spectrophotometer observations,* Journal of Optics A: Pure and Applied, **8**, 849-855 July 25, 2006
3. Alkiviadis F. Bais, *Absolute spectral measurements of direct solar ultraviolet irradiance with a Brewer spectrophotometer***,** Applied Optics, **36**, 5199-5204, July 20, 1997
4. Ilias Fountoulakis, et al., *Dead-time effects on the Brewer measurements: correction and estimated uncertainties*, Atmos. Meas. Tech., **9**, 1799-1816, 2016
5. Tomi Karppinen, et al., *Compensating for the Effects of stray Light in Single-monochromator Brewer Spectrophotometer Ozone Retrieval,* Atmosphere-Ocean, **53**, 66-73, 2015
6. K. Fragos, et al., *The Effect of Three Different Absorption Cross-Sections and their Temperature Dependence on Total Ozone Measured by a Mid-Latitude Brewer Spectrophotometer,* Atmosphere-Ocean, **53**, 19-28, 2015