Rehabilitation of SRRL Aerosol Optical Depth Photometer Data

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Abstract

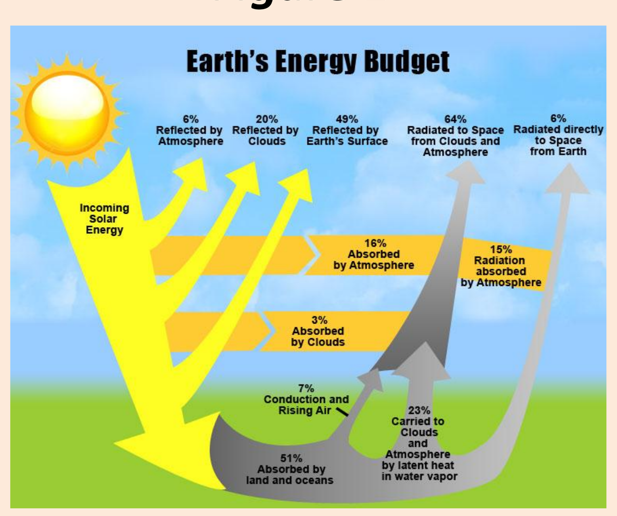
NREL's Solar Radiation Research Laboratory (SRRL) utilizes a Prede POM-01 Photometer to collect aerosol optical depth (AOD) information, necessary for determining the performance of solar collector systems. Inconsistencies and errors exist in SRRL's AOD data due to errors in the calibration factors as well as the data reduction algorithms. Langley plots of five of the channels were performed to calibrate the necessary constants for AOD calculations. Clear sky data was determined based on the ratio of direct to global radiation and on the scatter between morning and afternoon TWC 500 nm photometer (an NREL custom photometer) data. Plots of calculated intercept values over time indicate two filter channels have slightly degraded while five others have remained constant. Established coefficients were applied to reprocess AOD values, which were then compared with nearby Aeronet data at the BSRN-BAO Boulder site. Averages between the sites in comparison with the former AOD values indicate the new algorithm to be highly successful.

Project Goals

1) Evaluate analysis by outside contractor.
2) Test and compare data reduction schemes.
3) Determine calibration factors (CFs) and filter degradation equations for use in reprocessing all baseline data.
4) Compare results with NASA Aeronet data from Boulder.

Background and Purpose

Figure 1



Solar radiation is scattered, absorbed and reflected by atmospheric aerosols [1].

Figure 1

Concentrated solar collectors (CVCs) convert direct and some ground-reflected solar radiation. Flat-plate solar collectors (FPCs) also utilize diffuse and some reflected radiation [2]. Solar panel performance is thus dependent upon atmospheric conditions.

Figure 2

Prede POM-01 Sky Radiometer

Figure 2

- Single detector with rotating filter wheel.
- Measures direct radiation (DNI) in 7 narrow spectral bands.
- Data is used to calculate AOD, precipitable water (Pw), and other atmospheric components which may interact with incoming sunlight
- 315 nm band is damaged or mislabeled and requires replacement.

Equation 1 [3] [4]

$$\tau_{AOD,\lambda} = \tau_\lambda - \tau_{mg} - \tau_R\left(\frac{m_R}{m}\right) - \tau_{O_3}\left(\frac{m_{O_3}}{m}\right) - \tau_{Pw}\left(\frac{m_{Pw}}{m}\right)$$

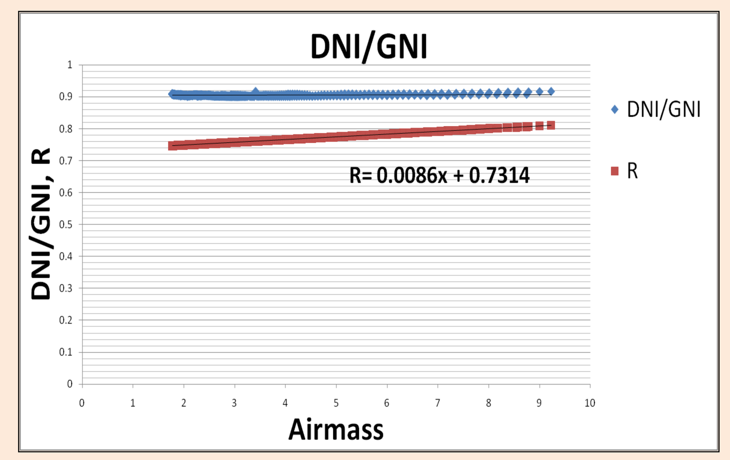
$$\tau_\lambda = \frac{-\ln\left(\frac{I_\lambda}{I_0}\right)}{m}$$

τ_λ = extinction optical depth
m = airmass
λ = waveband of filter
I_λ = measured current in microamps
I_0 = CF (when $m = 0$)

mg = mixed gases
R = Rayleigh Scattering
O_3 = Ozone
Pw = Precipitable water
m_R = Rayleigh airmass
m_{O_3} = O_3 airmass
m_{Pw} = Pw airmass

Calibration Process

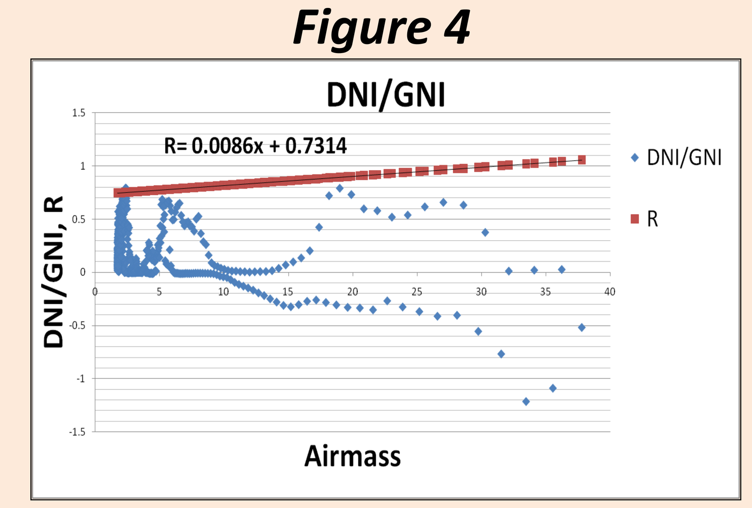
Figure 3



Clear Day

Figures 3 and 4: DNI/Global Normal Irradiance (GNI): for identifying clear and overcast conditions and eliminate outliers. DNI/GNI values should be >R [3] [5].

Figure 4



Overcast Day

Figure 5

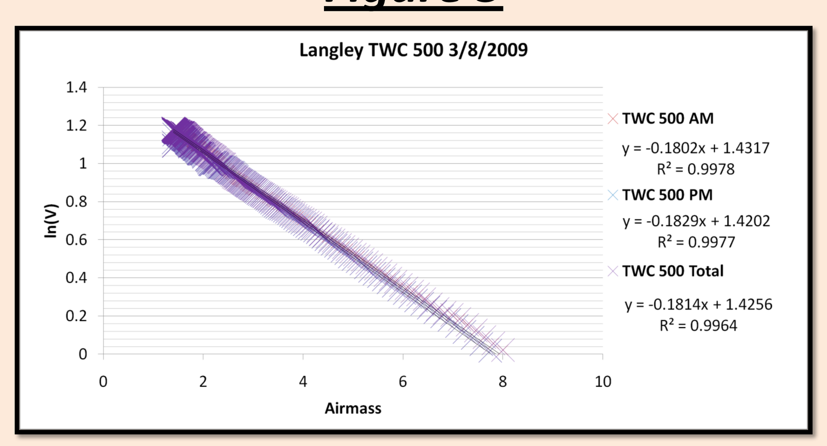


Figure 5: Plot of TWC 500 nm sky radiometer data. If AM and PM values overlap, conditions have remained relatively stable throughout the day [4].

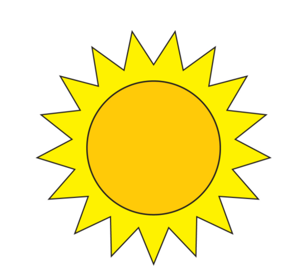


Figure 6

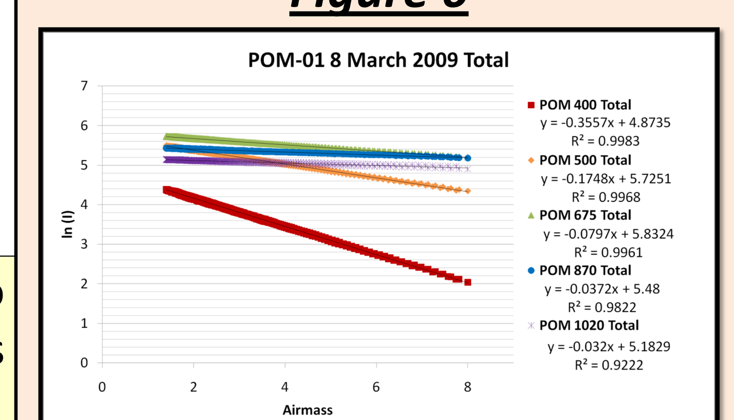


Figure 6: Plot of POM-01 data (airmass vs. log of current) to determine AM0 intercepts (CFs). AM, PM, and total values were compared [4].

Figure 7

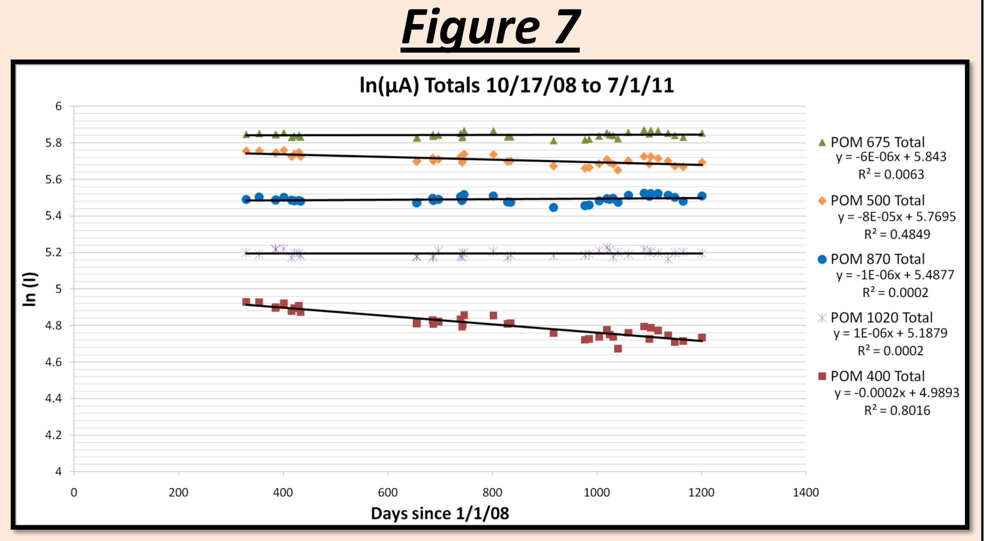


Figure 7

- Examine slopes of CFs vs. time to determine filter degradation.

400 nm degradation:	500 nm degradation:
$\ln(I_0)$ = -0.0002d + 4.9893	$\ln(I_0)$ = -8E-05d + 5.7695
d=days since 1/1/2008	d=days since 1/1/2008

- Average CFs for filters with little to no degradation (slopes $<10^{-6}$):

POM Filter	POM 675	POM 870	POM 1020
$\ln(I_0)$	5.8430	5.4910	5.1937

AOD Processing

- AOD values were calculated using Equation 1, the values in figure 7, accounting for degradation. Ozone, Rayleigh, and Pw values are site and filter-specific values as determined by SMARTS [3].
- Compared POM-01 AOD data with comparable NASA Aeronet (BSRN-BAO) Boulder data [6].

Comparison of AOD values: old SRRL values vs. new SRRL values vs. Boulder BSRN-BAO values.

	TWC 500	POM 400	POM 500	POM 675	POM 870	POM 1020	Standard Dev. Range
Old AOD average	0.052	0.108	0.067	0.045	0.035	0.049	0.010 to 0.047
New AOD average	0.041	0.060	0.042	0.030	0.024	0.024	0.013 to 0.033
Aeronet average	0.043	0.057*	0.043	0.027	0.027	0.026	0.012 to 0.018

*Interpolated from Aeronet 380 nm and 440 nm filter data

Conclusion and Next Steps

- 675, 870 and 1020 nm filters show almost no degradation. A noticeable degradation in the 500 nm and especially 400 nm filters was observed.
- Despite not utilizing a modified version of equation 1 for Langley plots, AM0 intercept values closely matched those of the contractor's report.
- Although large variations sometimes exist between Aeronet and SRRL values on a given day, the average NREL AOD values were approximately the same as Boulder Aeronet average values.
- Comparisons of historical to new AOD values indicates the new algorithm to be suitable for reprocessing all historic POM data.
  - POM 500 and TWC 500 values match each other more closely
  - Newer values more closely match Aeronet values.
- Report to be provided to SRRL containing CFs and calibration procedure, AOD processing procedure and important constants.
- Next steps: Replace 315 nm filter; characterization of 940 nm bandwidth and installation of GPS station for improved Pw measurement; additional analysis of TWC central wavelength and bandwidth; continued calibration of POM alongside TWC (after re-calibrated and characterized) and/or Aeronet instrument; and/or join a network similar to Aeronet (SkyNet).

References

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