Automated Solar Tracking Spectrophotometer for Remote Sensing of Column Aerosol Optical Depth
Bryan Rainwater1, William P Arnott2, Hans Moosmüller2, David Carr1
1. Department of Physics and Atmospheric Science, University of Nevada, Reno, Reno, NV, United States
2. Division of Atmospheric Science, Desert Research Institute, Reno, NV, United States

Introduction
- Ground based spectral radiance plays a critical role in determining the optical effects of atmospheric constituents and their effects upon radiative forcing [1]. An automated solar tracking spectrophotometer has been constructed to facilitate measurement of these optical properties (Figure 1).
- An automated solar tracking spectrophotometer in place of manual distinct wavelength photometers provides continuous data acquisition and information into spectral information that would otherwise be neglected.
- A manual sun photometer was used in preliminary work to identify benefits and applicability. The blue curve in Figure 2 shows a data retrieval of combined aerosol and gas optical depth from the manual sun photometer, demonstrating spectral recovery of O3, NO2, O2, and H2O, which would otherwise be less obvious to distinct wavelength devices. Additionally, Figure 3 shows more detailed information pertaining to atmospheric gases and their corresponding cross section affecting direct column solar radiance and optical depth.
- Once the automated alignment system was verified by parallel comparison with the manual spectrophotometer, the instrument was replaced by the automated version.

Instrument Description
- This instrument is composed of a pointed apparatus (Figure 4) and the controlling components (Figure 5). The aiming apparatus is composed of a camera for aligning to the sun and verifying alignment, a Telemac, an electronic shutter, a collimator, integrating sphere, and a fiber optic cables for collimating and diffusely transmitting solar radiance, a sensor for spectrometer calibration, and a stepper motor driving system for movements. The controlling components include stepper motor controllers, a data acquisition card, a power supply, a thermoelectrically cooled software, and a computer that controls everything via LabView (Figure 6).
- The instrument measures solar radiance in two minute intervals. By comparison with an extrapolated calibration file for top of atmosphere (TOA) solar radiance, the Beer-Lambert-Bouguer Law is then used to calculate total optical depth (TOD) in the measured column (1). The Rayleigh optical depth (ROD) is calculated and subtracted to provide a measure of aerosol and gas optical depth (Figure 9) [4].
- Eventually, from various spectral information we will automatically process the contribution due to gases, calculate the solar radiance, column water vapor, Angstrom turbidity exponent relating to particle size distribution, and the single scattering albedo for insight into radiative forcing. Mechanical improvements will also be made including uplifting the geyser system, computer and collimator, weather-prooﬁng the device, and incorporating additional atmospheric instrumentation.

Comparisons
- The CIMEL CE-318 sun photometer is operated as part of NASA’s AERONET network. It was used for preliminary comparisons with the instrument to determine precision and accuracy. The CIMEL CE-318 sun photometer has eight broadband wavelengths at 440, 670, 870, 950, 440, 675, 750, and 1020 nm. The aforementioned spectrophotometer runs an Ocean Optics Red Tide USB650 spectrometer with a spectral range from 340 to 1024 nm at a less than two nm resolution. Figure 10 shows a comparison made between the 870, 675, 550, and 440 nm wavelengths as shown in Figures 10 and 11. Each of these wavelengths has been averaged across a 10 nm band and temporally averaged for the most accurate comparison to the CIMEL CE-318 sun photometer. Overall shape and trend of the aerosol optical depth with 300 Dobson units of O3 related absorption subtracted out correlates relatively well with the CIMEL CE-318 data. Discrepancies can be accounted for in the lack of the subtraction of light absorption by NO2 and the improvement of the TOA calibrated radiance.

Conclusion
- The instrument is completely functioning in regard to tracking and programmable function; however, the instrument still needs minor adjustments to be sufficiently comparable to the CIMEL CE-318 sun photometer. Furthermore, the CIMEL CE-318 sun photometer includes single scattering albedo measurements which in time will also be incorporated into this spectrophotometer. Before this can be done, the system needs to be improved for the sensitivity required for principal and airmounter scans or an algorithm for Bishop ring analysis using the camera needs to be implemented. In final phases of construction, we plan that this instrument will become completely self-sufﬁcient and will be replicated and distributed as a low cost, spectral alternative to the CIMEL CE-318 sun photometer for atmospheric research among numerous academic and industrial institutions.

References and Acknowledgements

*A. Rainwater@unr.edu