Using a Sun Photometer as a Narrow Field of View, Vertically Pointing, Narrowband Radiometer: Instrument Design and Concept Verification

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Introduction

The Pennsylvania State University (PSU) Sun Photometer, deployed as a vertically pointing, 2° field of view (FOV), shortwave spectral instrument, is capable of recording zenith cloud variability at high temporal resolution. Although the instrument is designed to directly view the sun, the instrument photodiode amplifier can increase the instrument sensitivity sufficiently that it can measure radiances as much as five orders of magnitude smaller than the direct solar beam. This provides adequate signal to measure rapid, narrow field of view (NFOV) cloud radiances at wavelengths of 780 nm, 870 nm, and 1030 nm.

Instrument Modification

Aside from simply pointing the PSU Sun Photometer vertically towards zenith, the system needs to be outfitted with an optics shield tube and a solar shield tube placed around the telescope. With an unshielded telescope and the amplifier set on the highest gain (five orders of magnitude higher than the sun-pointing mode), the system is sensitive to photons scattered into the optics from nearby bright surfaces or instrument components. The internally blackened tube and the solar shield are used to correct this problem (Figure 1).

The instrument has a 2° field of view. The sampling area (Figure 2) is directly proportional to the view diameter, which is a function of cloud base height. Table 1 lists view diameters for several different cloud base heights.

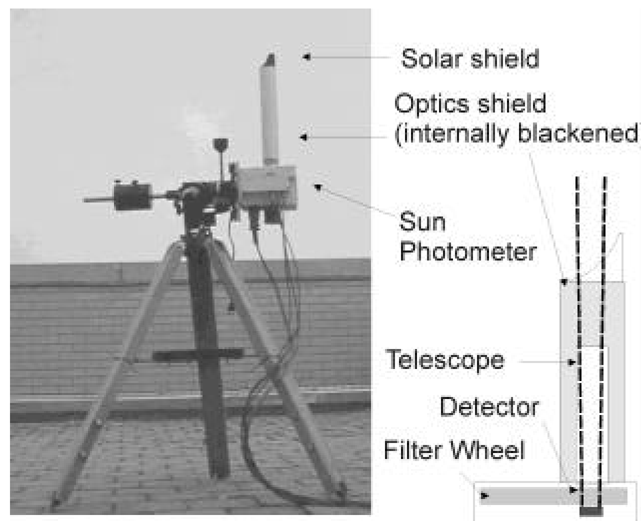

Figure 1. The modified setup of the PSU Sun Photometer to perform vertically pointing NFOV measurements.

Table 1. Calculated view diameters for several cloud base heights.

Cloud base height (m)	View diameter (m)
0	0.0
200	2.2
500	5.6
600	6.7
1000	11.1
2000	22.2
3000	33.3
5000	55.6
10,000	111.1

Clear Sky Test Case – December 15, 1997

Clear sky measurements at 780 nm, 870 nm, and 1030 nm were taken at State College, Pennsylvania, for approximately three hours on December 15, 1997 (Figure 3a). These observations were then modeled using Chandrasekhar's Rayleigh scattering model (Chandrasekhar and Elbert 1954). The comparison between the model and measured data is shown in Figure 3b. The model data and

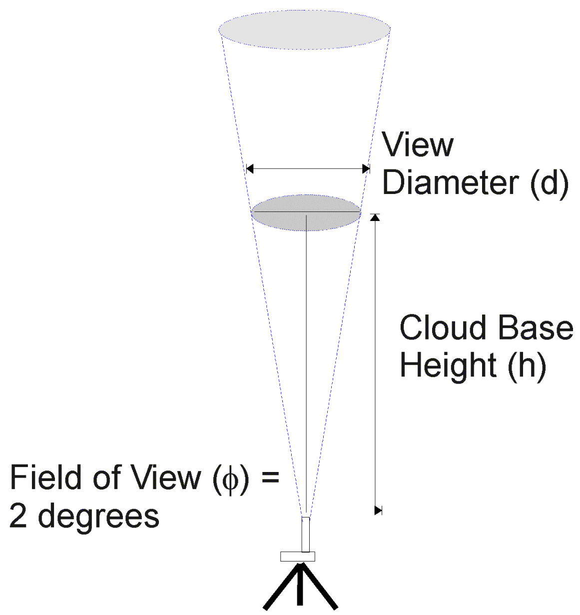

Figure 2. Instrument field of view geometry.

measurements seem to agree well through the first half of the period. The second half discrepancies are probably due to geometric errors in the model at low sun angles.

Stratus Cloud Test Case – February 19, 1998

An example of the system's capability of recording cloud variability is demonstrated in the 5-hour stratus case shown in Figure 4a. For this case, a cloud base of 500 m to 600 m, as measured by ceilometer, corresponds to an instrument view diameter of approximately 5.6 m to 6.7 m. Rapid variations in the viewing area become more apparent in Figure 4b. Figure 4b shows a magnified, 15-min. segment of data.

Spectral Analysis and Fractal Dimension Analysis – February 19, 1988

A power spectrum analysis of the 3-hour period from 18:00 Z to 21:00 Z is shown in Figure 5a. The complementary fractal dimension analysis, using the fractal line lengths method developed by Higuchi, is shown in

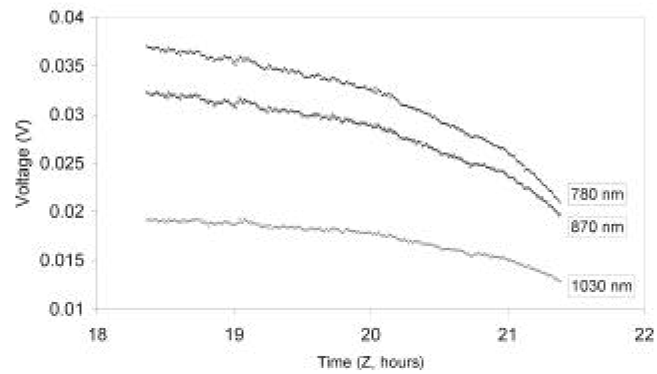

Figure 3a. Clear sky, zenith, NFOV measurements at 780 nm, 870 nm, and 1030 nm recorded at State College, Pennsylvania, on December 15, 1997.

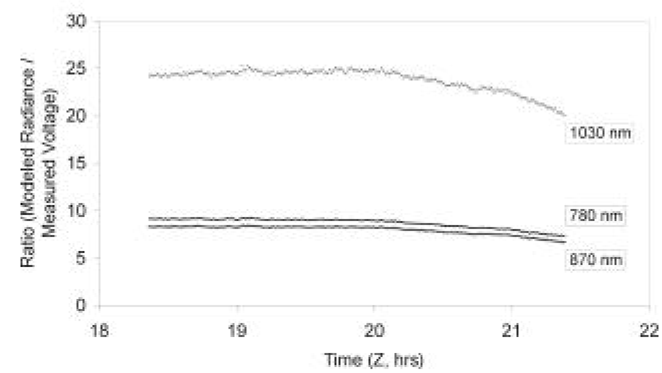

Figure 3b. Ratio of clear sky measurements to Chandrasekhar's Rayleigh scattering model for the December 15, 1997 case.

Figure 5B (Henderson and Thomson 1995). A detailed interpretation of the results from these analyses is currently being developed.

Further Testing and Calibration

Detector and data logger tests using a strobe light show that the instrument response is more than adequate to record variability within view diameters of a cloud encountered in test cloud cases.

Although extensive testing of the data acquisition and equipment is nearly complete, absolute calibration of the system is still needed. Because the system is sensitive to relatively low light sources, calibration using a known, laboratory light source is planned.

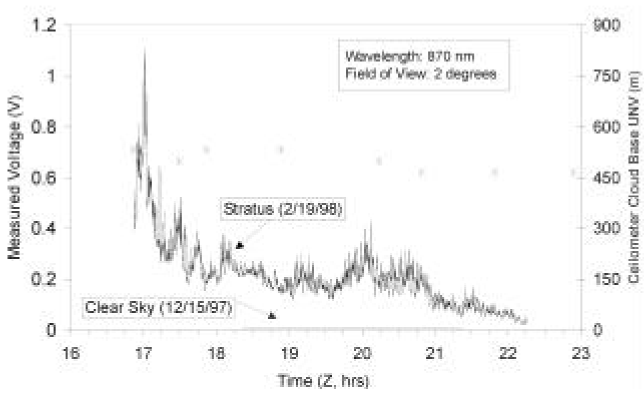

Figure 4a. Low stratus cloud NFOV measurements at 870 nm for a 5-hour period on February 19, 1998, at State College, Pennsylvania. Ceilometer cloud base heights at University Park airport (UNV) are also shown. The measured clear sky curve from Figure 3a is plotted for comparison.

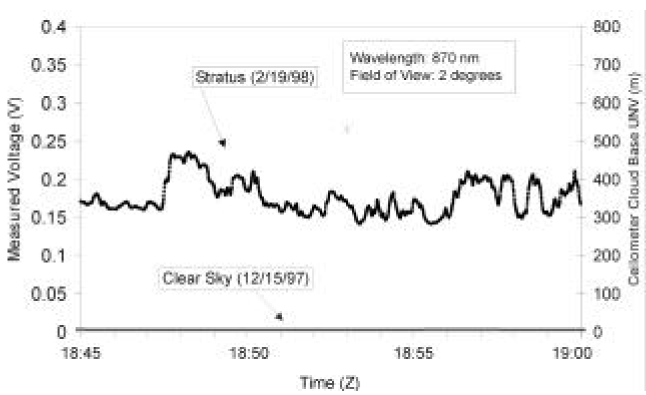

Figure 4b. A close up view of the February 19, 1998, NFOV measurements at 870 nm. The period shown here is from 18:45 Z to 19:00 Z.

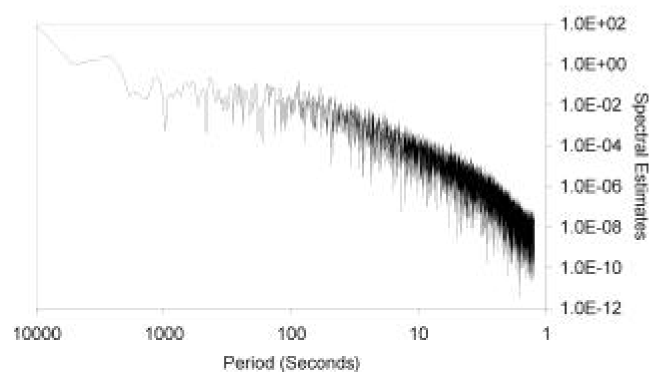

Figure 5a. Power spectrum analysis for the February 19, 1998, stratus case. The time period used in this analysis is from 18:00 Z to 21:00 Z.

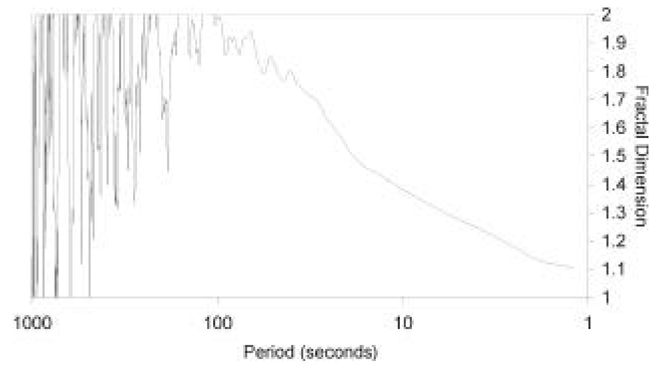

Figure 5b. Fractal dimension analysis for the February 19, 1998, stratus case. The time period used in this analysis is from 18:00 Z to 21:00 Z.

References

Chandrasekhar, S., and D. Elbert, 1954: The illumination and polarization of the sunlit sky on Rayleigh scattering. *Trans. Amer. Philosophical Soc.* **44**(6), 643-654.

Henderson, H. W., and D. W. Thomson, 1995: Fractal dimensions of remotely sensed atmospheric signals. *Proceedings of the Second Experimental Chaos Conference*, October 6-8, 1993, Arlington, Virginia. pp. 349-355.