Sunphotometric Measurement of Columnar H_2O and Aerosol Optical Depth During the 3rd Water Vapor IOP in Fall 2000 at the SGP ARM Site

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Introduction

We conducted ground-based measurements with the Ames Airborne Tracking 6-channel Sunphotometer (AATS-6) during the 3rd Water Vapor Intensive Operational Period (WVIOP3), September 18 to October 8, 2000 at the Southern Great Plains (SGP) Atmospheric Radiation Measurement (ARM) site.

For this deployment, our primary result was columnar water vapor (CWV) obtained from continuous solar transmittance measurements in the 0.94-micron band. In addition, we simultaneously measured aerosol optical depth (AOD) at λ = 380, 450, 525, 864, and 1020 nm. During the intensive operational period (IOP), preliminary results of CWV and AOD were displayed in real time. The result files were made available to other investigators by noon of the next day.

After conclusion of WVIOP3, AATS-6 was shipped directly to Mauna Loa, Hawaii for postmission calibration. The updated calibration, a cloud screening technique for AOD, along with other mostly cosmetic changes, were applied to the WVIOP3 dataset, which was released as Version 0.1. The resulting changes in CWV are small; the changes in AOD and Ångström parameter α are more noticeable. Data Version 0.1 was successfully submitted to the ARM External Data Center.

In this paper, we show data examples for both CWV and AOD. We compare our CWV results with those obtained from a Global Positioning System (GPS) method. We also compare our AOD retrievals with those from a Cimel Sunphotometer and a Multi-Filter Rotating Shadowband Radiometer (MFRSR) operated at SGP (a brief description of AATS-6, Cimel, and MFRSR can be found in Schmid et al. [1999]). We discuss correlations between AOD and α and between AOD and CWV. For select cases, we invert aerosol size distributions from the AOD spectra. Finally, we contrast two distinctly different aerosol events at SGP.

Columnar Water Vapor

During WVIOP3, the CWV data were shown on the daily intercomparison plots on the IOP Website: http://arm1.ssec.wisc.edu/~waynef/wviop2000/. Our preliminary results (Version 0.0) of AATS-6 CWV fell within the spread of values obtained from other techniques. The CWV in the archived Version 0.1 differs by only 0.5% from the Version 0.0 data produced during the IOP. For AATS-6, we have been using the retrieval described in Schmid et al. (2001) [Method A]. It is based on the recently corrected H_20 spectroscopy by Giver et al. (2000). Using the even newer spectroscopy by Belmiloud et al. (2000) decreased the mean CWV by 6%. In this paper we show results from our archived Version-0.1 retrievals (using the spectroscopy of Giver et al.).

The GPS data from the National Oceanic and Atmospheric Administration Forecast Systems Laboratory (NOAA/FSL) station in Lamont, Oklahoma and data from a GPS instrument located at the ARM central facility (CF) were analyzed as part of a network of 35 GPS receivers within the continental United States. These data were processed with the Bernese 4.2 software (Beutler et al. 2000) using International GPS Service (IGS) orbits, an elevation mask of 10 degrees, and a Niell mapping function (Niell 1996) to estimate CWV.

Figure 1 shows a scatter-plot comparison of CWV from AATS-6 and the two different GPS stations. Although AATS-6 was operated at the SGP CF, we find better agreement with the GPS receiver in Lamont (8.9 km from CF). Figure 2 shows the time series of CWV during WVIOP3 obtained from the same instruments.

Aerosol Optical Depth

AATS-6 AODs are retrieved according to Russell et al. (1993). For a previous integrated IOP conducted at SGP in fall 1997 (which included WVIOP2) we compared the AODs retrieved from five different sunphotometers (Schmid et al. 1999). The key result was agreement in AODs measured by 4 of the 5 instruments within 0.015 root mean square (rms). Here we compare the AODs obtained from AATS-6, Cimel, and MFRSR. As in the previous comparison, the AODs obtained from each instrument were derived independently of one another. The resulting scatter plots are shown in Figure 3. Table 1 shows that the level of agreement is similar for the two comparisons.

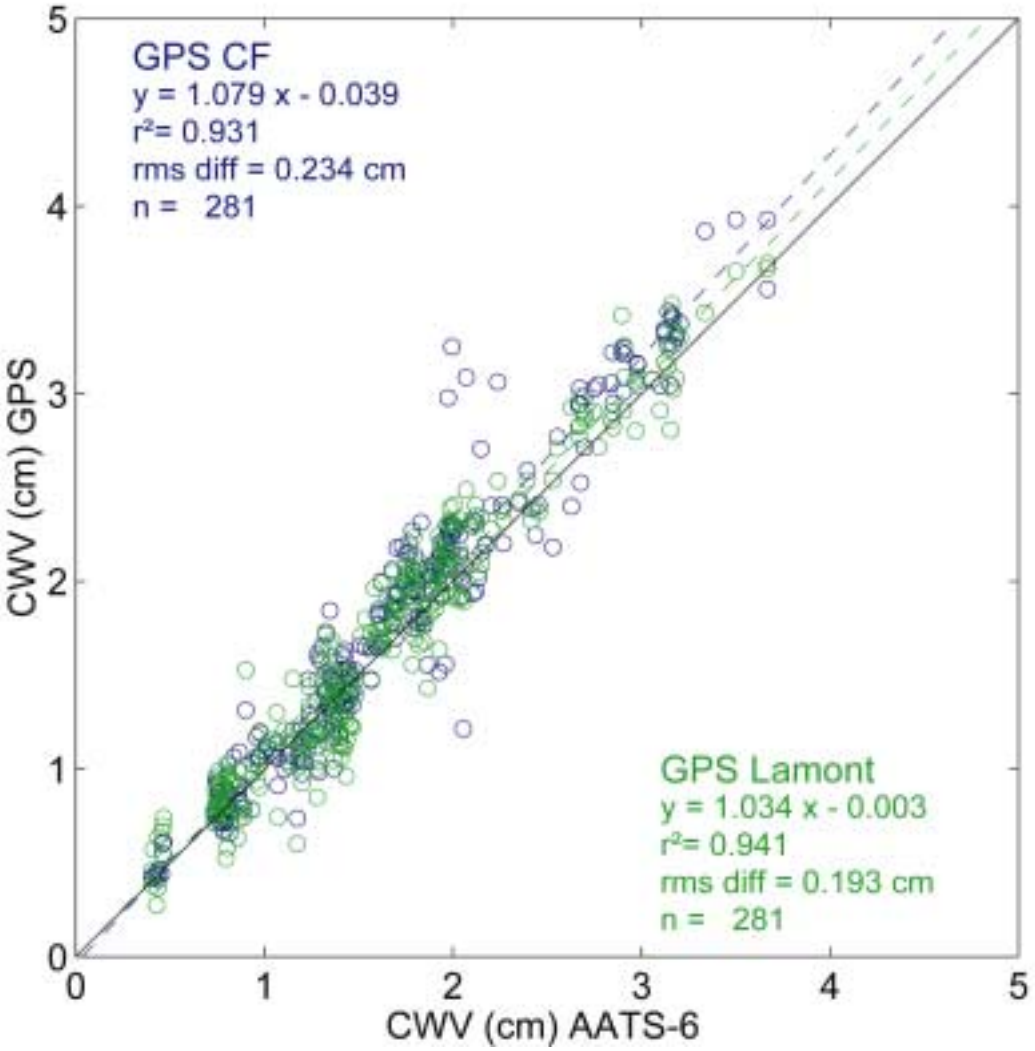

Figure 1. Comparison of CWV from AATS-6 and two GPS receivers located at SGP CF and at Lamont (8.9 km from CF).

Aerosol Optical Depth and CWV Correlations and Case Studies

Figure 2 shows the evolution of mid-visible AOD during WVIOP3. Values range from less than 0.05 to over 0.5. By comparing with the evolution of CWV shown in the same Figure 1, observes a generally good correlation between CWV and AOD: For the entire WVIOP3 period we found $r^2 = 0.64$, 0.69, 0.70, 0.73 and 0.75 for $\lambda = 380$, 450, 525, 864 and 1020 nm, respectively. However, there are times when there is no correlation between CWV and AOD (e.g., days 264 and 270 in Figure 2). In the following we discuss two days with distinctly different AOD and CWV evolution:

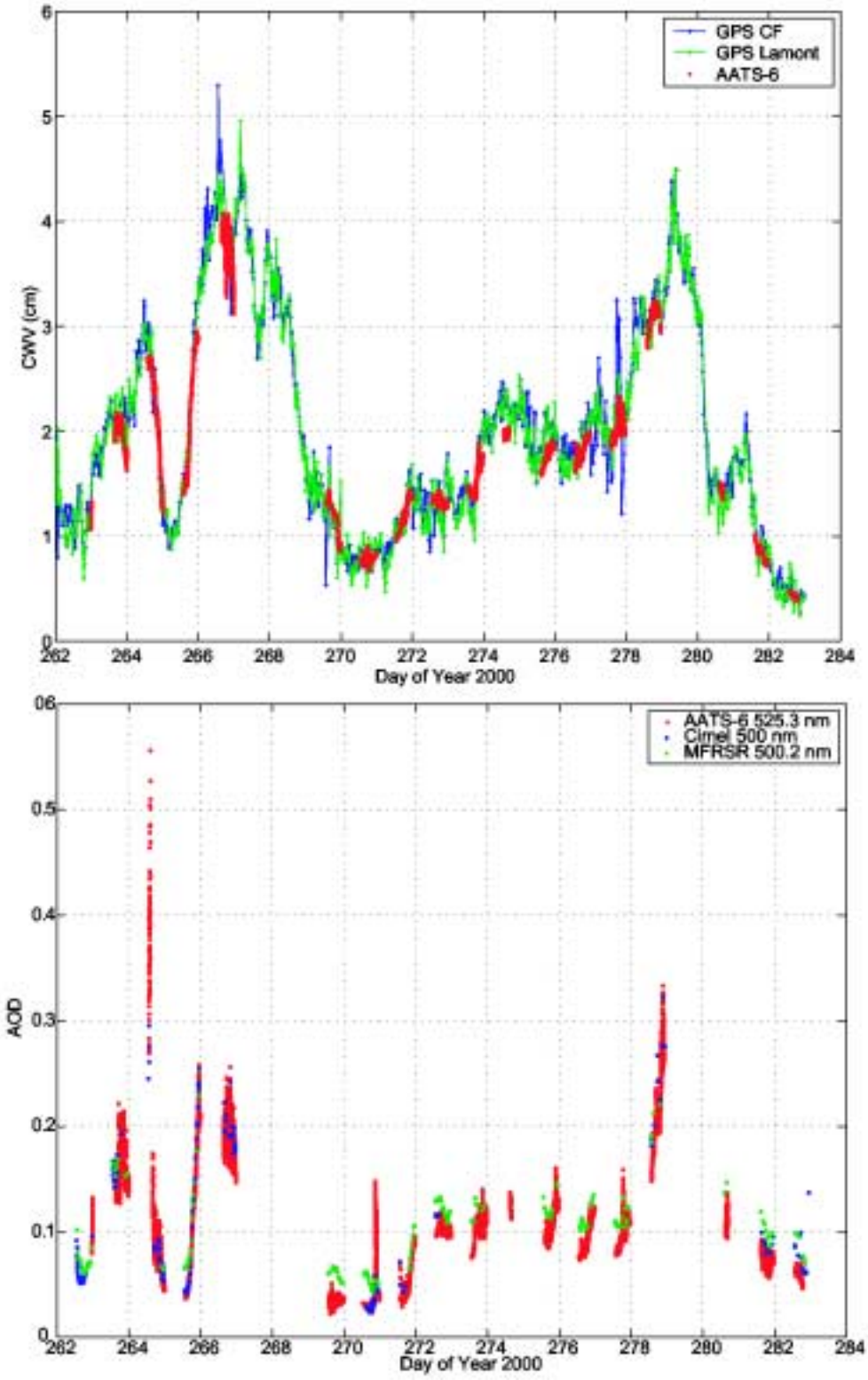

Figure 2. Time Series of (top) CWV from AATS-6, and 2 GPS receivers and AOD (bottom) from AATS-6, Cimel, and MFRSR during WVIOP3.

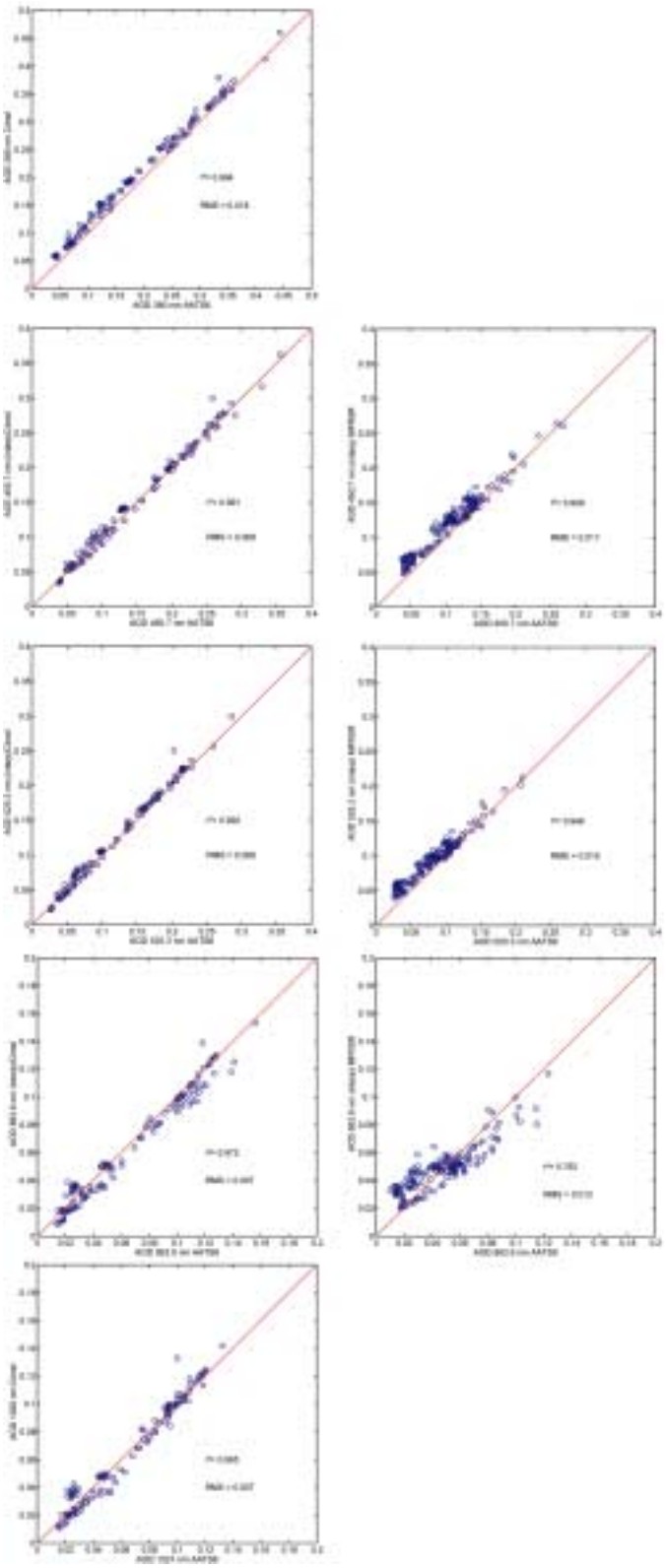

Figure 3. AOD comparison during WVIOP3 from AATS-6, Cimel, and MFRSR.

Table 1. RMS differences for AOD intercomparisons performed during two IOPs at SGP.

	Cimel		MFRSR	
Wavelength	**rms difference**		**rms difference**	
λ(nm)	**IOP 1997**	**IOP 2000**	**IOP 1997**	**IOP 2000**
380	0.012	0.018		
450	0.008	0.008	0.013	0.017
525	0.012	0.008	0.011	0.016
864	0.009	0.007	0.012	0.012
1020	0.012	0.007		

On September 21, 2000 (Figure 4), we observe a steady increase of the AOD from 0.05 to more than 0.2 (at 525 nm). The CWV follows a very similar pattern leading to correlation coefficients r^2~0.97. Also shown in Figure 4 is the temporal evolution of the AOD spectrum. It is evident that the AOD spectrum is shifting upwards throughout the day, whereas the slope remains unchanged. Consequently we observe only very little change in the angstrom parameter α. Inverting the AOD spectra leads to an estimate of the columnar volume size distribution. The inversion method we used here varies the amplitudes of a predetermined multi-modal lognormal size distribution (mode radii and widths remain fixed and are chosen according to an aerosol climatology by Remer et al. [1999]). For September 21, 2000, we find that throughout the day the amplitudes of both modes increase comparably causing the size distribution to retain its shape. This suggests that the incoming airmass is bringing in moisture and aerosol without changing the character of the aerosol ("more of the same").

September 26, 2000 (Figure 5), was a very clear and dry day at SGP with AOD<0.04 (525 nm) throughout most of the day. Until around 20:30 local time, α decreases steadily and the inverted volume size distribution shows a steady increase of coarse mode aerosol. This behavior might have been caused by small amounts of local dust. At 21:12 local time, the AATS-6 operator (J. E.) makes the following logbook entry "[The day] was exceptionally clear but see haze and smell smoke outside now. It shows in the aerosol data starting about 45 min ago." This event is nicely captured in Figure 5. For this day, there is no correlation between CWV and AOD, but during the smoke event the AOD and α are highly correlated. During the smoke episode, the inverted volume distributions show significantly increased levels of accumulation mode aerosol.

Hence, September 21st depicts an example of long-range aerosol transport whereas on September 26th, the measurements are influenced by local sources of aerosol. Correlations between AOD and α and between AOD and CWV can serve as a tool to identify such cases.

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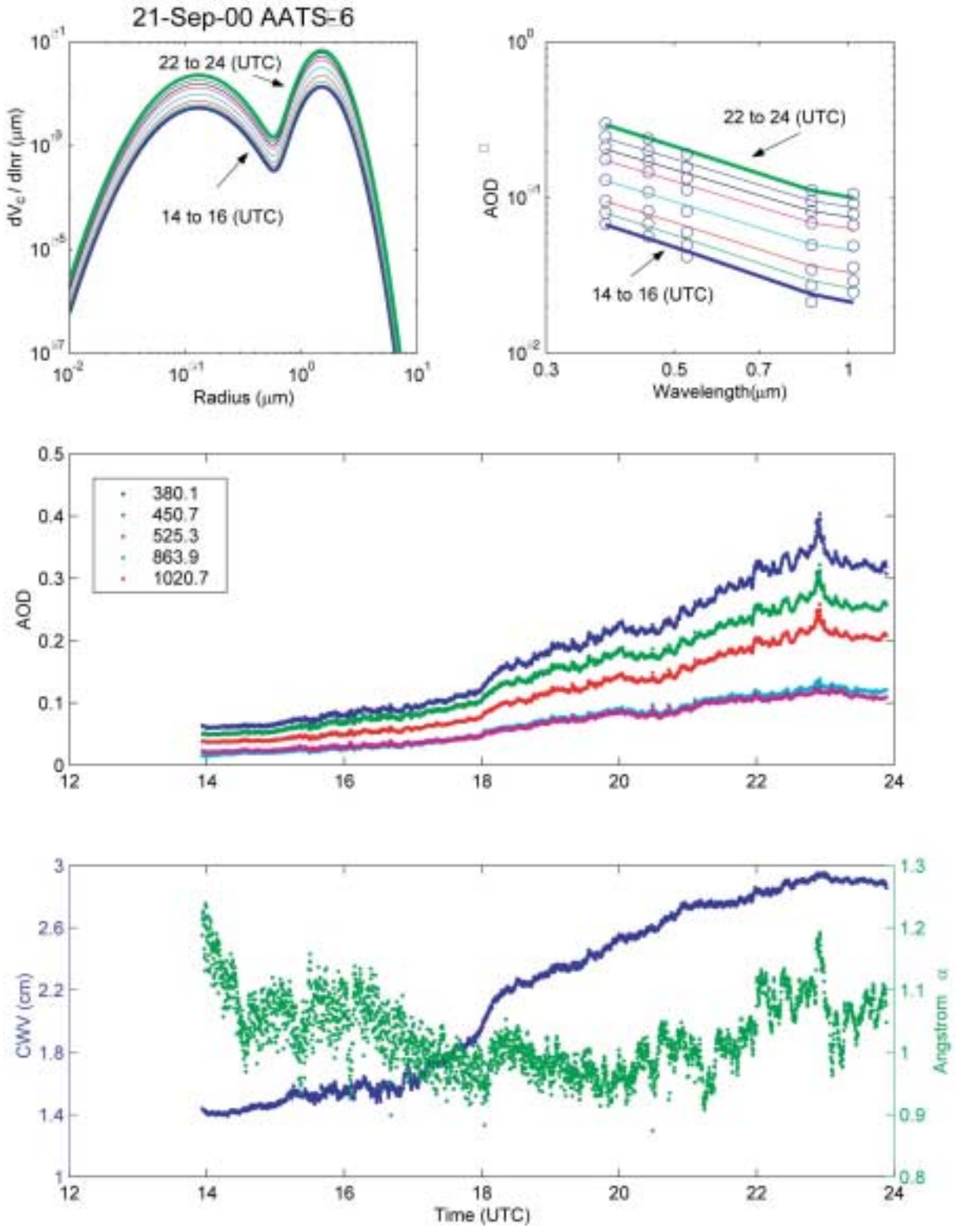

Figure 4. Diurnal variation of AOD, α, and CWV on September 21, 2000. Also shown are AOD spectra and inverted columnar volume size distributions (for time intervals of 30 mins).

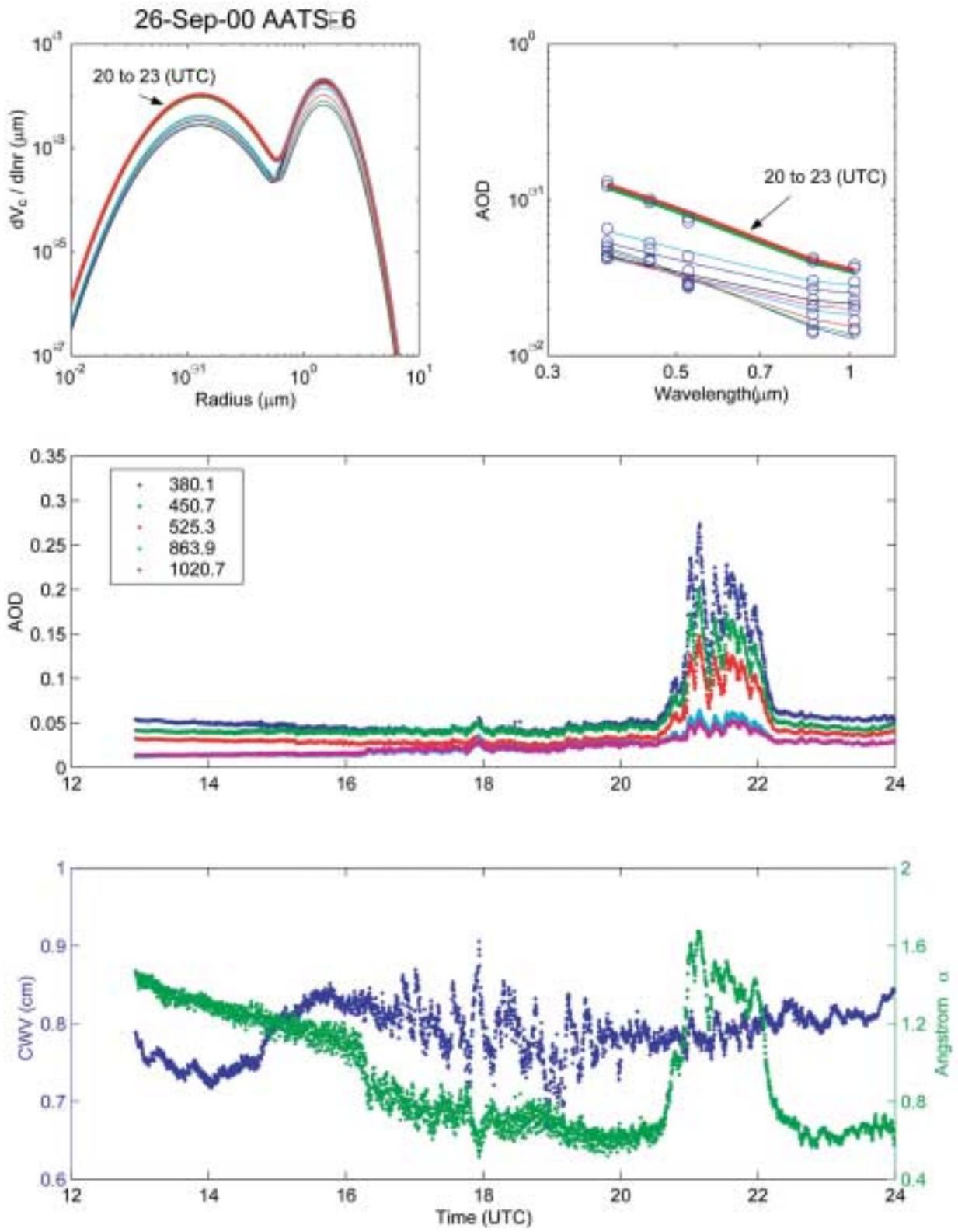

Figure 5. Same as Figure 4 but for September 26, 2000.

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