

**Instrument: NCAR CCD Actinic Flux Spectroradiometers (CAFS)**

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**Wavelength range:** 280-680 nm  
**Wavelength resolution:** ~1.8 nm FWHM at 297 nm  
**Accuracy:** 5% in UV-B, 3% in UV-A/VIS limited by NIST standards  
**Detection limit:** ~0.04 mW/m<sup>2</sup>/nm at 300 nm  
**Precision:** 1-2 % depending on wavelength  
**Data Rate:** 0.1 to 1 Hz  
**Weight:** <23 kg per instrument  
**Power:** <15 amps of 28 volt DC per instrument  
**Location on WB57F:** Radiation boat and lower transition region

New solid state, CCD based spectroradiometer instruments have been developed in the ARIM laboratory for deployment on the NASA WB-57 for the October 2004 AVE mission. The systems are based on the  $2\pi$  steradian hemispherical zenith and nadir viewing optical collectors connected with UV fiber optic bundles to small, lightweight, monolithic monochromators equipped with cooled, back-thinned, and blue enhanced CCD detectors, and small, lightweight, and low-power PC-104+ computer for autonomous instrument control and data acquisition.

The system employs a Zeiss MCS (Multi Channel Spectrometer) monolithic monochromator equipped with a Hamamatsu S 7301-906 windowless back-thinned blue enhanced 534 pixel cooled CCD detector. The combination of the monochromator, slit size and CCD provides a wavelength range of 280-680 nm with an effective ~1.8 nm Full Width at Half Maximum (FWHM) resolution with a 20 micron entrance slit. The CCD temperature is controlled at  $-1.0^{\circ}$  C by a piezoelectric cooler and control electronics. The system exhibits excellent sensitivity from the ultraviolet into the visible, which allows rapid full spectral acquisition times from 100 ms.

The monochromator/CCD assembly is contained in a sealed instrument box approximately 15"x 10"x 6" to prevent moisture condensation on the CCD elements and maintain temperature control. CAD renderings of the monochromator/CCD instrument box and the PC-104+/electronics box are shown in Figures 1, 2, and 3. An entire spectroradiometer system weighs approximately 23 kg and is designed to be mounted

in the radiation boat on the top of the fuselage and in the bottom transition area of the WB-57. The spectrometer and data systems require <math><15\text{ A}</math> of 28 VDC per instrument.

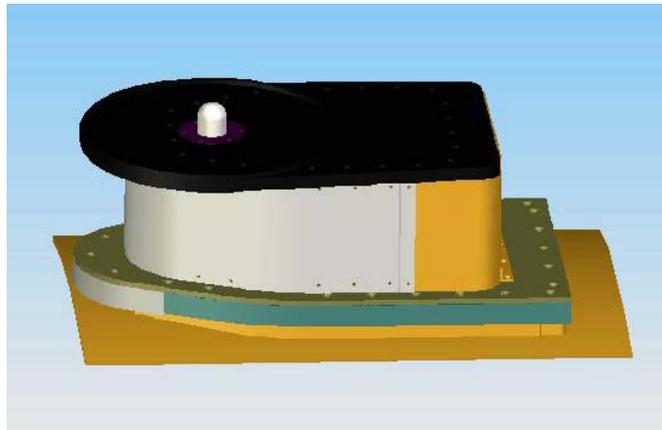


Figure 1. CCD monochromator assembly on WB-57 mounting plate

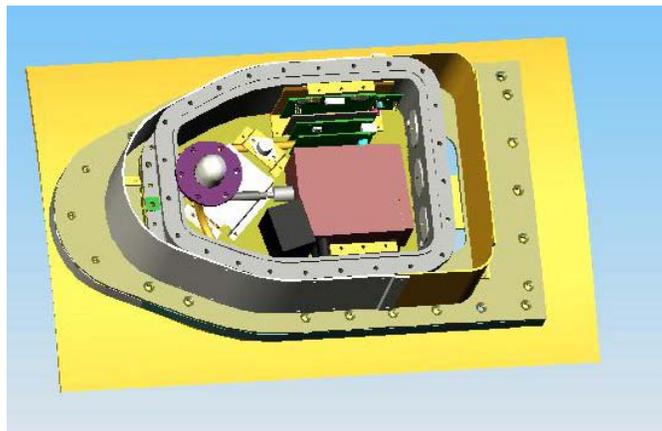


Figure 2. Monochromator and CCD cooling electronics

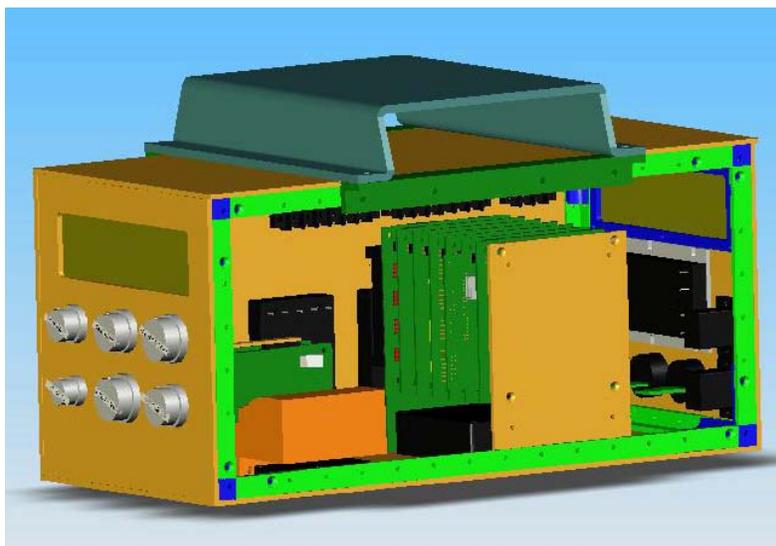


Figure 3. CCD detector electronics and PC-104 computer (15"x7"x7")

## Data Products

The CAFS systems can provide down and up-welling actinic flux from 280 to 680 nm at data frequencies between 1 and 10 seconds. The actinic flux data will be used to derive Total Ozone column product from upward looking actinic flux measurements based on an algorithm under development. The algorithm uses climatology of the spectrally resolved actinic flux measurements as function of total ozone and altitude of the measurement. It also utilizes the knowledge of the band-pass and scattered light specific for the instrument under investigation. The TO products will be compared against other references available from WB57 campaigns and other platforms including the AURA and other satellite instruments and ground-based measurements.

Our studies demonstrate that there is a strong relation between total ozone (TO) column and actinic flux at UV wavelengths (See Figure 1). However, contribution from scattered light depends on the underlying surface albedo, and can produce sizable effect in the measurement (see example for high albedo results in Figure 1). The methods proposed account for effects of the variation in the underlying scene (ground albedo under no-cloud conditions), as well as effects of underlying clouds and aerosols, on the downward looking UV actinic flux measurements. For the actinic-flux ozone column product atmospheric variability has to be minimized. The analyses show that when actinic flux measurements at several wavelength pairs are combined, the instrumental and background uncertainties can be successfully removed. Moreover, the procedure minimizes surface albedo effect on the measurement. A combination of actinic flux measurements taken at several wavelength pairs (similar to the double-pair Dobson direct-sun technique) provides a simple tool for eliminating cloud or aerosol interference from measurements (See Figure 2). The method works well when spectral contribution of the particulates in the measured actinic flux can be linearly approximated.

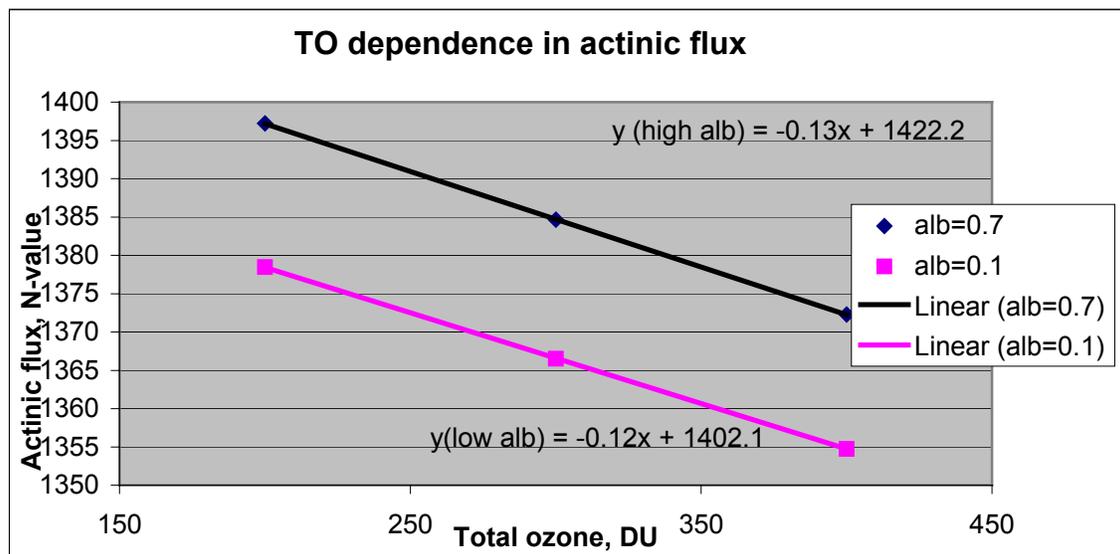


Figure 1. Total ozone information in actinic flux measurement (single wavelength at 310 nm) as modeled by the TUV code at 30-degrees SZA. N-value unit is defined as  $100 \cdot \log_{10}(\text{flux})$ . Effect of surface albedo on actinic flux is also shown.

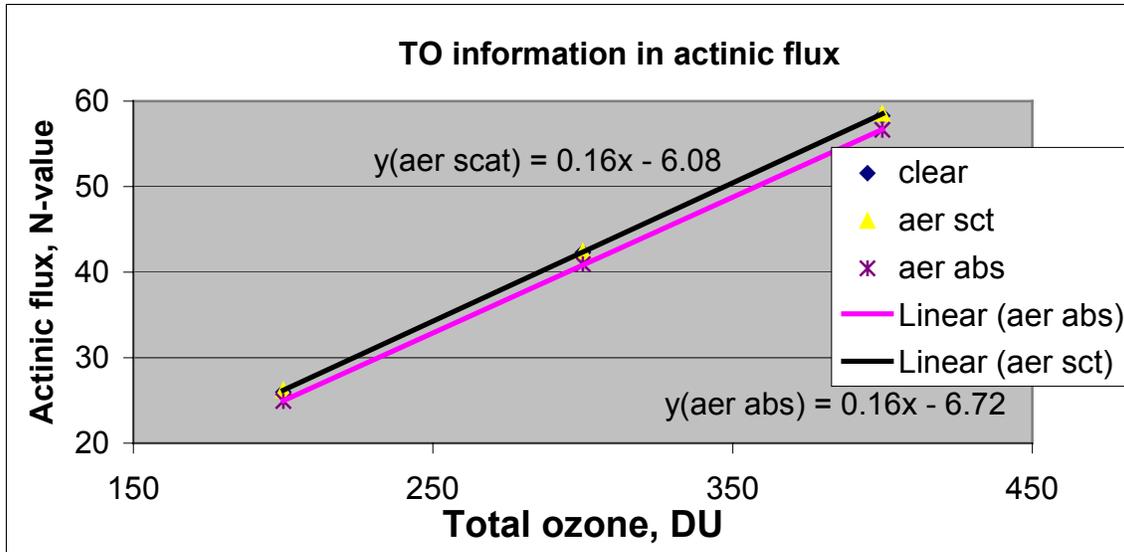


Figure 2. Total ozone information in actinic flux as modeled by the TUV code (double pairs) for 0.7 surface albedo. The effect of absorbing and non-absorbing aerosols (data overlap with clear-sky case) is included.

Actinic flux measurements at individual wavelengths are also sensitive to underlying albedo (see Figure 3) and aerosols (see Figure 4). Therefore, we can exploit the information contained in spectral measurements to derive some of the aerosol properties (e. g. single scattering albedo, SSA) in the UV part of solar spectrum. In addition, we plan to derive aerosol absorption and scattering optical depths and some limited information about particulate size distribution available from spectral signatures in actinic flux measurements. The combination of scattering and absorbing properties of tropospheric aerosols will have different effects on short and long wavelengths in the measured actinic flux spectrum (see Figure 5), thus allowing for detection of aerosol properties. Effect of size distribution on spectral actinic flux measurements will be assessed. We will develop methodology to derive aerosol optical properties in the UV part of solar spectrum from downward looking actinic flux measurements on the board WB57: extinction, single scattering albedo and limited information on size distribution. Other possible instruments on board the WB57 (CAPS, MACS and others) may provide data that will be used to validate our size-distribution product, or, as an alternative, we will use independent size-distribution information to constrain our solution for SSA product.

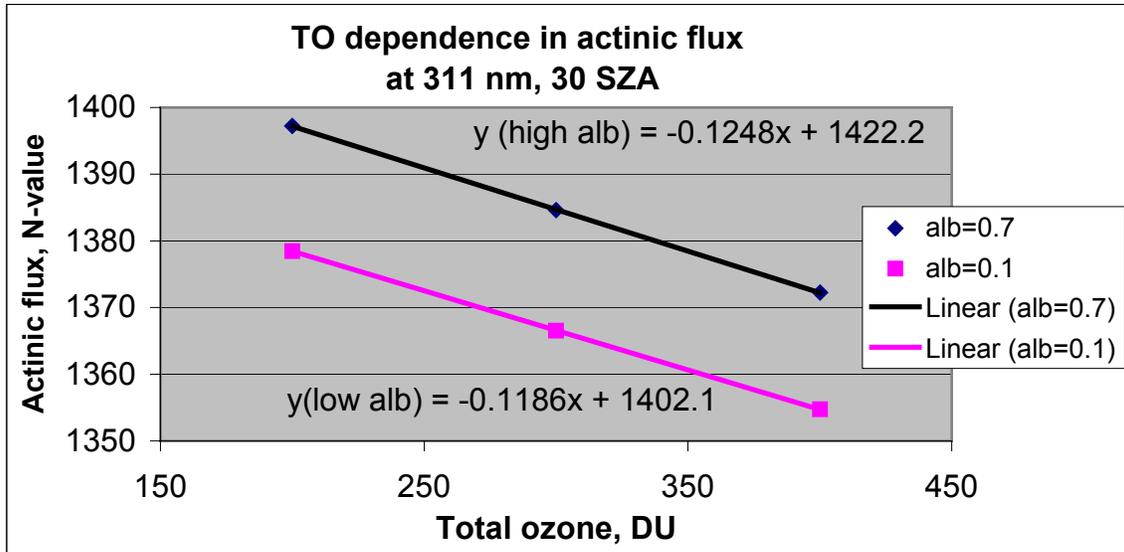


Figure 3. Total ozone information in actinic flux at 311 nm as modeled by the TUV code (individual measurements) for 0.7 and 0.1 surface albedo. The atmosphere has no aerosols.

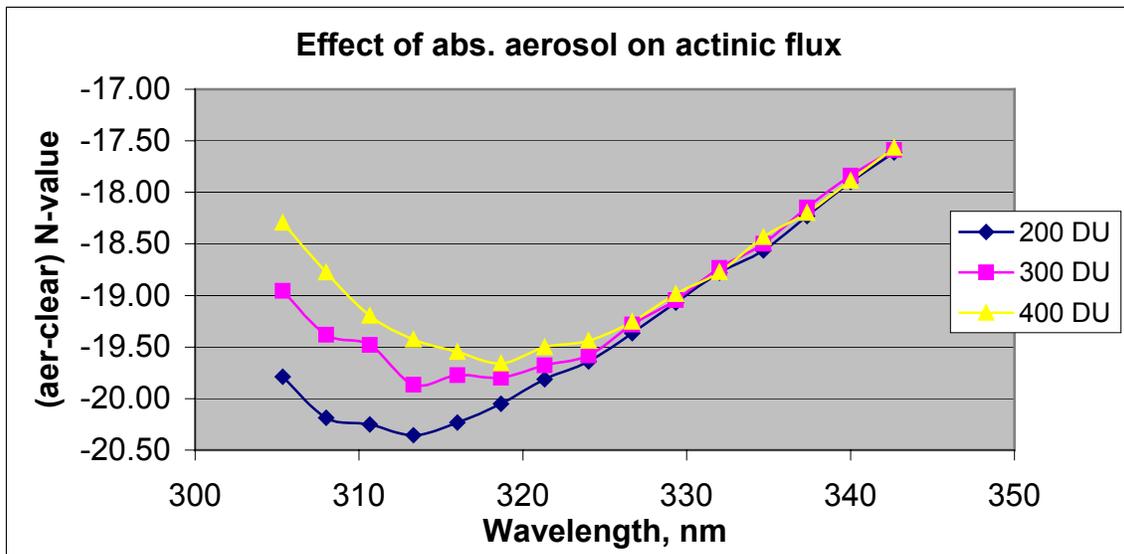


Figure 4. Spectral dependency of changes in actinic flux due to absorbing aerosols. Results are modeled by the TUV code for 0.7 surface albedo, and 0.3 aerosol optical depth, where aerosols single scattering albedo is 0.7. Three cases for 200, 300, and 400 DU ozone profiles are presented.

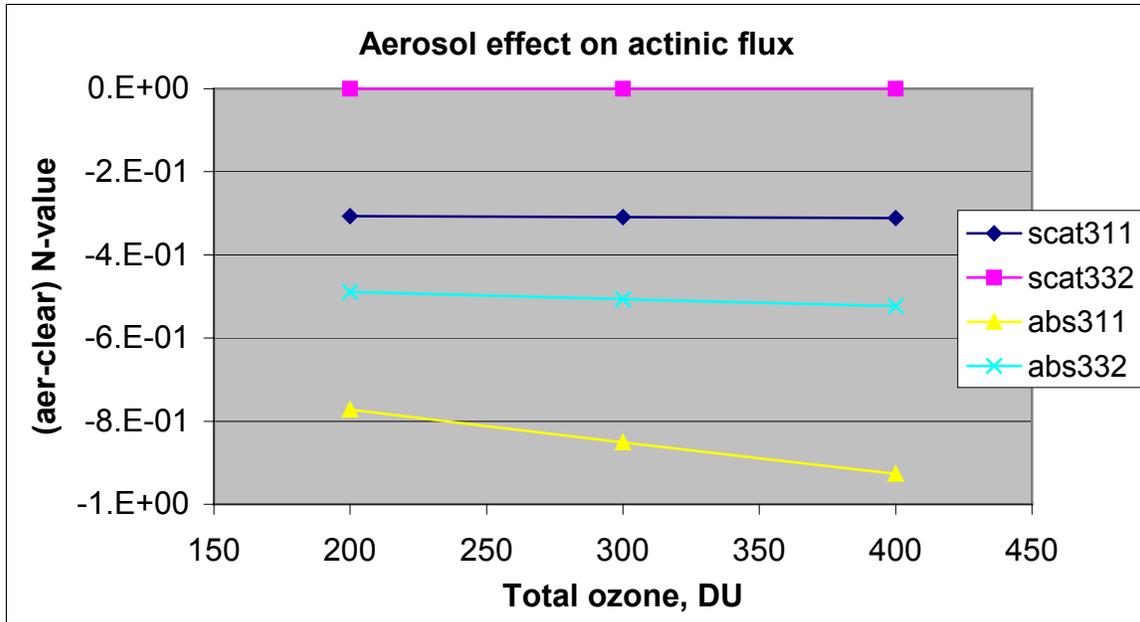


Figure 5. Changes in actinic flux due to absorbing and scattering aerosols as function of total ozone column. Results are modeled by the TUV code for 0.7 surface albedo, and 0.3 aerosol optical depth, where aerosols single scattering albedo is 0.99 (non-absorbing, marked as “scat”) and 0.7 (absorbing, marked as “abs”). Three cases for 200, 300, and 400 DU ozone profiles are presented. Results are given at two wavelengths: 311 nm (strong ozone absorption), and 332 nm (weak ozone absorption).

To study tropospheric ozone information (with limited resolution) in the actinic flux measurements we will utilize downward actinic flux measurements. We will calculate the vertical weighting function, which would help us to define the vertical resolution of the ozone profile below the aircraft. Then we will validate tropospheric product by comparing ground-based TO (or satellite-based) with TO above the aircraft.