CCD Actinic Flux Spectroradiometers (CAFS)

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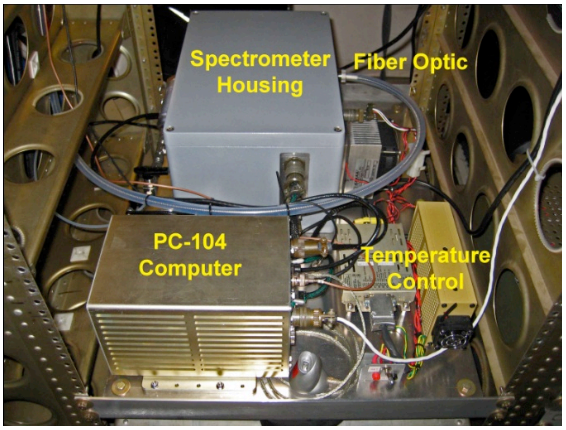
Summary
The CCD Actinic Flux Spectroradiometers (CAFS) developed in the ARIM laboratory will be deployed on the NASA DC-8 for SEAC4RS and DC3 field campaigns. The instruments measure spectrally resolved down- and up-welling *in situ* ultraviolet and visible actinic flux from approximately 280-650 nm. Photolysis frequencies for photodissociation reactions for species including O_3, NO_2, CH_2O, HONO, HNO_3, N_2O_5, HO_2NO_2, PAN, H_2O_2, CH_3OOH, CH_3ONO_2, $CH_3CH_2ONO_2$, CH_3COCH_3, CH_3CHO, CH_3CH_2CHO, CHOCHO, CH_3COCHO, $CH_3CH_2CH_2CHO$, $CH_3COCH_2CH_3$, Br_2, BrO, Br_2O, $BrNO_3$, BrCl, HOBr, $BrONO_2$, Cl_2, ClO, and $ClONO_2$ are calculated from the radiative measurements. Careful calibration techniques and comparison to the NCAR/TUV radiative transfer model improves the accuracy and precision of the measurements. CAFS instruments have a successful heritage of radiation measurements during atmospheric chemistry and satellite validation missions including NASA AVE, PAVE, CR-AVE, TC-4 and ARCTAS campaigns on the WB-57 and DC-8 platforms and during the NSF OASIS ground campaign in Barrow, AK. Similar instruments will be deployed on the NCAR G-V platform as part of the HIAPER Airborne Radiation Package (HARP) as a part of DC3 and SEAC4RS.

In situ solar radiation measurements are critical to NASA atmospheric composition research. Actinic flux radiation drives the chemistry of the atmosphere, including the evolution of ozone, greenhouse gases, biomass burning, and other anthropogenic and natural trace constituents. The evolution of boundary layer and tropospheric constituents convected to the upper troposphere and lower stratosphere requires knowledge of the complex radiative fields expected during the campaigns. The gases, in turn, control the chemical evolution of aerosols.

Instrument Description
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 deg C by a piezoelectric cooler and control electronics.

CAFS optics are based on 2π steradian hemispherical zenith and nadir viewing optical collectors connected by UV enhanced fiber optic bundles to the CCD detectors. Small, lightweight, and low-power PC/104+ computers autonomously control the instruments and data acquisition.



CAFS detector installed on the NASA DC-8 (left) is linked by fiber optic to the nadir actinic flux collector (right, with artificial horizon).

Single monochromator systems traditionally have difficulties measuring ultraviolet radiation due to stray light contamination of the UV-B signal. This monolithic monochromator/CCD combination minimizes the stray light by careful optical design and the use of a windowless CCD, eliminating a scattering source at the detector. Cutoff filters are used to enhance the stray light rejection by elimination of some visible radiation. The detectors exhibit excellent sensitivity from the ultraviolet into the visible. Operationally, the instrument has run successfully on aircraft with a 50 ms spectral acquisition time. Thus, studies of cloud and aerosol radiation field perturbations and fast photochemistry are possible at rates up to 20 Hz. However, better precision is achieved with longer integration times and averaging scans.

Calibration

The absolute spectral sensitivity of the instruments is determined in the laboratory with 1000 watt NIST-traceable tungsten-halogen lamps with an uncertainty of 2-4%, depending on the wavelength. In addition, the optical collectors are characterized for angular and azimuthal response and the effective planar receptor distance. During deployments, spectral sensitivity and wavelength assignment calibrations are performed using secondary quartz-tungsten-halogen calibration lamps and Hg line sources in a field calibration unit that attaches directly to the optical collector assembly of the actinic flux instruments. Final primary calibrations are performed in the laboratory after each mission. In addition, comparisons to extraterrestrial flux have been used to ensure proper wavelength assignment throughout the spectra.

The system operates with exceptional stability. Through 4 months during the NASA ARCTAS campaign, the standard deviation of 17 field calibrations at 300 nm was only 0.8% and 1.0% for the zenith and nadir systems, respectively. The instruments have a detection limits of 5×10^{-8} sec^{-1} for $jO(^1D)$ and 1×10^{-6} sec^{-1} for jNO_2 with a 3 second scan time.