2. Instrumentation

All sites of the NSF UV Monitoring Network are equipped with SUV spectroradiometers designed and manufactured by Biospherical Instruments Inc (BSI). Systems are accompanied by GUV multi-channel filter radiometers from BSI and two ancillary radiometers from Eppley Laboratory Inc.: a pyranometer (Model PSP) and a broadband UV-A radiometer (Model TUVR). Several mobile spectroradiometers were historically also part of the network and are described in previous operations reports.

2.1. SUV-100 UV-Visible Spectroradiometer

The SUV-100 Spectroradiometer System is deployed at all network sites, except Summit. It is built for permanent installation and continuous 24-hour operation in any climate including polar regions. The fully automated system only needs operator attention for periodic manual calibrations, operational checks, and occasional service.

Design, Specifications, and Installation of the SUV-100

The SUV-100 is based on a temperature-stabilized, scanning, double monochromator coupled to a photomultiplier tube (PMT) detector. The system is optimized for operation in the UV. All basic components are shown in the Figure 2.1.

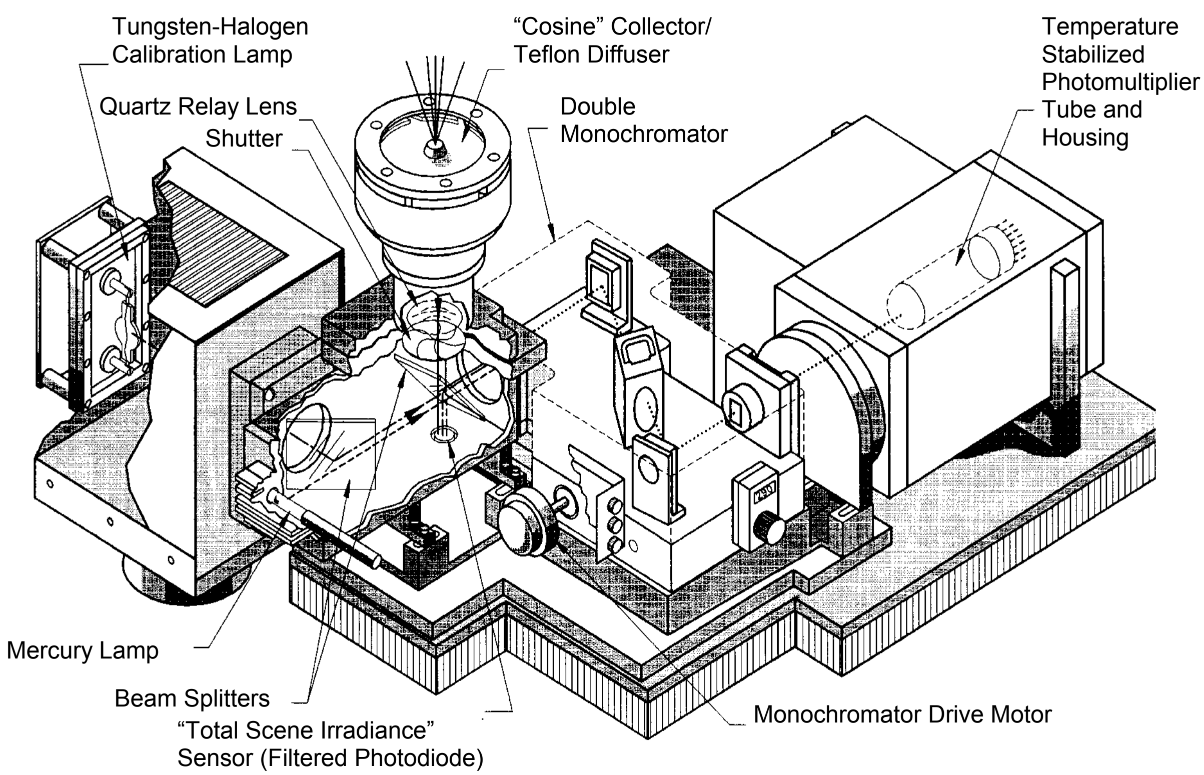

Figure 2.1. *Cutaway diagram of the SUV-100.*

Solar radiation enters the system through a weather-resistant irradiance collector, which is conductively heated to minimize ice and snow buildup. The collector's center piece is a shaped diffuser made of polytetrafluoroethylene (PTFE). The instrument has an internal mercury-vapor lamp for wavelength calibrations as well as a tungsten-halogen lamp, which serves as irradiance reference and is used for automatic system characterizations at programmed intervals (typically once per day). A data acquisition system and control instrumentation accompany the instrument. Starting in mid-1996, Pentium microprocessor-based personal computers (PC), using the Windows NT® operating system, were put into use for system control and data collection.

The f/3.5 0.10 meter double monochromator is the heart of the system and is configured with 167 µm wide input/output slits and a 250 µm wide intermediate slit. The monochromator's holographic gratings have 1200 grooves/mm, and are blazed at 250 nm. The resulting spectral bandwidth is approximately 1 nm full width at half maximum (FWHM) in the UV and 0.8-1.0 nm in the visible. A stepping motor with a minimum step size of 0.1 nm drives the monochromator. The PMT is a 28-mm diameter, 11-stage device with a bialkali cathode and a quartz window. The PMT is housed in a Peltier-cooled enclosure, which is maintained at approximately –2 °C to reduce dark current and noise. The temperature of the monochromator is controlled and monitored, and typically stable to within ±1.0 °C. In addition to daily calibrations with the internal sources, the system is calibrated periodically (typically biweekly) using a 200-Watt tungsten-halogen standard of spectral irradiance, traceable to the National Institute of Standards and Technology (NIST). All specifications of the system are detailed in Table 2.1.

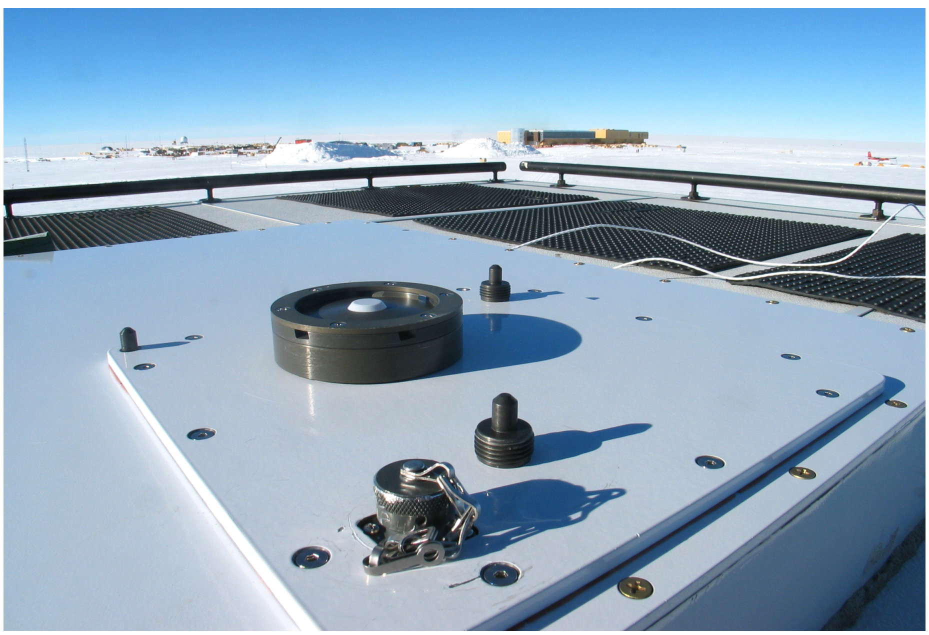

Figure 2.2. *Top part of the SUV-100 spectroradiometer at the installation at South Pole (ARO building). The irradiance collector is the short, black cylinder with the white PTFE diffuser in the center. The connector in the foreground provides power for the external calibration fixture, which is mounted on the three pins surrounding the collector.*

A typical instrument installation is shown in the Figure 2.3. The system hardware is divided into two main sections. The first section—the irradiance collector, monochromator, PMT, data acquisition unit, thermal management components, and internal reference sources—are housed in a roof box. This insulated, weatherproof enclosure is designed to be built into the roof of an existing building. The remainder of the system (Figure 2.4.), consisting of power supplies, temperature controllers, electronic interfaces, and a PC, is located up to 15 meters away. A calibration fixture is provided for periodic manual calibrations.

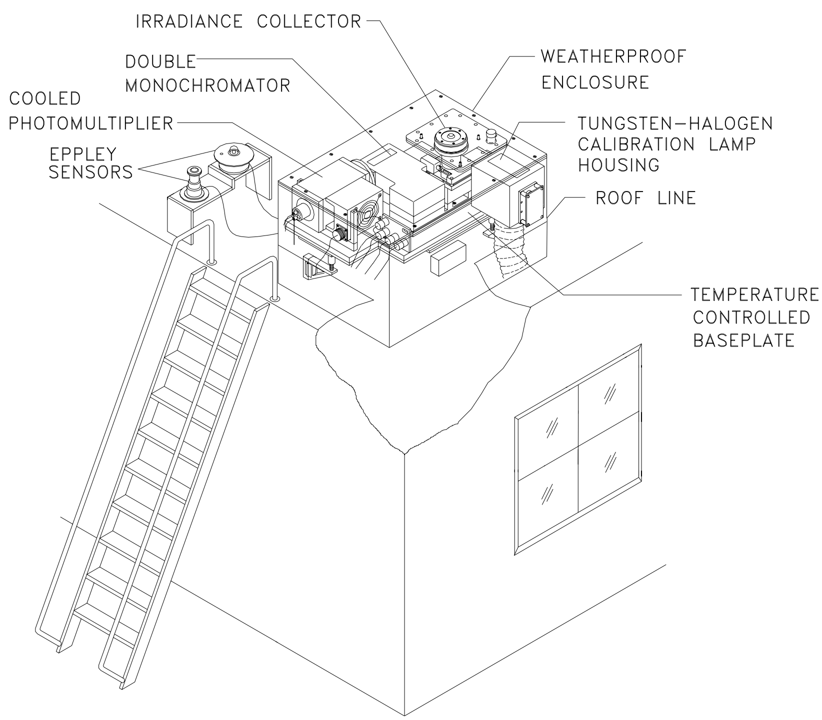

Figure 2.3. *The spectroradiometer shown in a typical installation.*

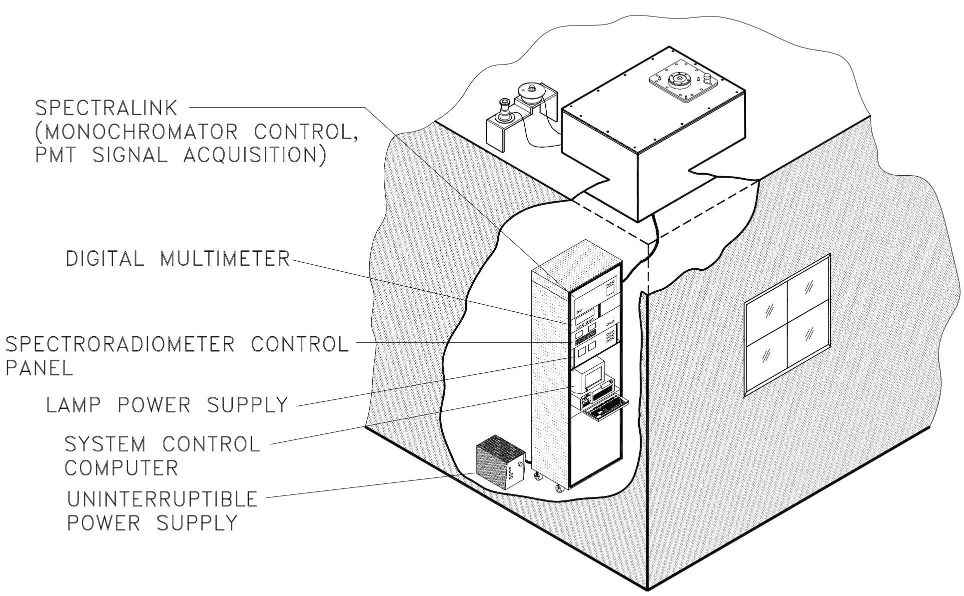

Figure 2.4. *Diagram of electronic components and computer.*

Table 2.1. SUV-100 spectroradiometer specifications, revision 2005/2006.

Quantity Measured	Global spectral irradiance
Spectral Range	250-750 nm; 280-605 nm is range used for solar measurements
Monochromator	ISA DH-10UV, 0.10-meter double monochromator with focal ratio f/3.5, equipped with holographic gratings, 1200 grooves/mm, 250 nm blaze wavelength (Note 1)
Bandwidth	1.0 nm ±0.1 nm in the UV and 0.8-1.0 nm in the visible (bandwidth varies from instrument to instrument; individual instruments are typically stable to ±0.015 nm) (Note 2)
Stray Light	Out-of-band rejection determined with a HeCd laser at 325 nm: $1x10^{-6}$. (According to specifications of the monochromator's manufacturer, out-of-band rejection is $2x10^{-9}$ at 8 band passes from a HeNe laser line at 632.8 nm.)
Wavelength Calibration	Based on a combination of internal mercury discharge lamp measurements and post-correction with a Fraunhofer-line correlation method. See Section 4.2.2.2. for details.
Minimum Useable Wavelength Increment	0.1 nm
Wavelength Precision	±0.025 nm (±1σ) (Note 3)
Wavelength Uncertainty	±0.04 nm (±1σ) (Note 4)
Detector	11-stage photomultiplier tube R269 from Hamamatsu with bialkali photocathode; thermoelectrically cooled
Measurement Mode	PMT operated in DC mode. PMT anode-current converted to frequency with variable integration time; 10^6 count maximum; 1 MHz count rate maximum
Integration Times	0.1 – 10 seconds under software control, typically set to 0.2 to 0.5 seconds
Dynamic Range	10^6, defined by the digitization scheme
Detection Limit	0.0005 μW cm^{-2} nm^{-1} for SZA > 70°, 0.001 μW cm^{-2} nm^{-1} for SZA < 70°; values refer to a signal-to-noise ratio of one (Note 5)
Offset Stability	Typically 10^{-5} relative to full scale, plus the contribution of PMT dark current
System Responsivity Stability	Depending on site and time period, see Chapter 5
PMT High voltage	0-1000 Volts under software control
Irradiance Collector	Diffuser with cosine response made of polytetrafluoroethylene (PTFE) covering a trapezoidally shaped quartz support. After modification in 2000, the cosine error is approximately –5% at 60° incidence angle, –10% at 70° incidence angle, and –5% for isotropic illumination. See introduction of Section 5 for details.
Operating Temperature Range	+40° to –80 °C outside environment
Utility Requirements	115 VAC, 15 Volt-Amps, and Internet access (Note 6). An uninterruptible power supply is provided for 1-hour minimum operation in the event of power failure.
Internal Standards and Time Source	45-Watt tungsten-halogen lamp, mercury vapor discharge lamp, and GPS
Primary System Calibration Sources	200-Watt tungsten-halogen Standards of spectral irradiance, NIST traceable
Signal Range	Maximum 250 microwatts cm^{-2} nm^{-1}, minimum limited by noise level, see Detection Limit
Monitored System Parameters	Monochromator temperature, enclosure temperature, TSI, monochromator wavelength position, and lamp current.
Ancillary Sensors	GUV multichannel radiometer, short-wave (0.3 μm-3 μm) pyranometer (Eppley PSP), UV-pyranometer (Eppley TUVR), and temperature and humidity sensors
Data Formats	Data recorded in Microsoft binary format. Transmission of data via the Internet (Note 6).

Note 1*:* Monochromator is modified and temperature stabilized.
Note 2: Testing indicates that the bandwidth, as measured with a HeCd laser or an external Hg lamp, completely illuminating the cosine collector, is approximately 1.0 nm in the UV. The specification on bandwidth stability was derived from all internal mercury scans of Volume 7. For site-specific information see Chapter 5.
Note 3: Wavelength *precision* specifies the change in the registered position of the 296.73 nm mercury line within one day. The value is the standard deviation of the difference in the position derived from two consecutive wavelength scans, which are performed on a daily basis. The wavelength precision is similar for all sites, see Chapter 5.
Note 4: Wavelength *uncertainty* is the square-root-sum of two components: The first component (±0.035 nm (±1σ)) is the standard deviation of the wavelength offset (measured minus target wavelength position) after the solar data have been corrected for wavelength errors. The residual offset was determined with the "Fraunhofer-line correlation method" described in Section 3.3.1.2. The second component (±0.02 nm (±1σ)) is the estimated uncertainty of the correlation method.
Note 5: Detection limit is defined as the standard deviation of the measured spectral irradiance at 285 nm. At this wavelength, all solar radiation is filtered out by the Earth's ozone layer. The measured value at 285 nm therefore reflects the magnitude of instrument noise, which causes the detection limit. At large solar zenith angles, the PMT is operates at a higher voltage, leading to better sensitivity and a lower detection limit.
Note 6: Except for the installation at Ushuaia, computers are locally networked and established as FTP servers, allowing for direct data access from San Diego and/or transmission by operators - limited only by satellite windows.

2.2. SUV-150B UV-Visible Spectroradiometer

The SUV-150B is a recently developed spectroradiometer system. It is currently deployed at Summit, Greenland. Compared to the SUV-100, it features better angular response, wavelength stability, and spectral resolution. The instrument's collector is connected to the main system with an optical fiber bundle, allowing more flexible installation and better serviceability. Like the SUV-100 the SUV-150B is designed for all-weather, automatic operation.

Design, Specifications, and Installation of the SUV-150B

The SUV-150B is based on a temperature-stabilized, scanning, double monochromator coupled to a photomultiplier tube (PMT) detector. The system is optimized for operation in the UV. All basic components are shown in the Figure 2.5.

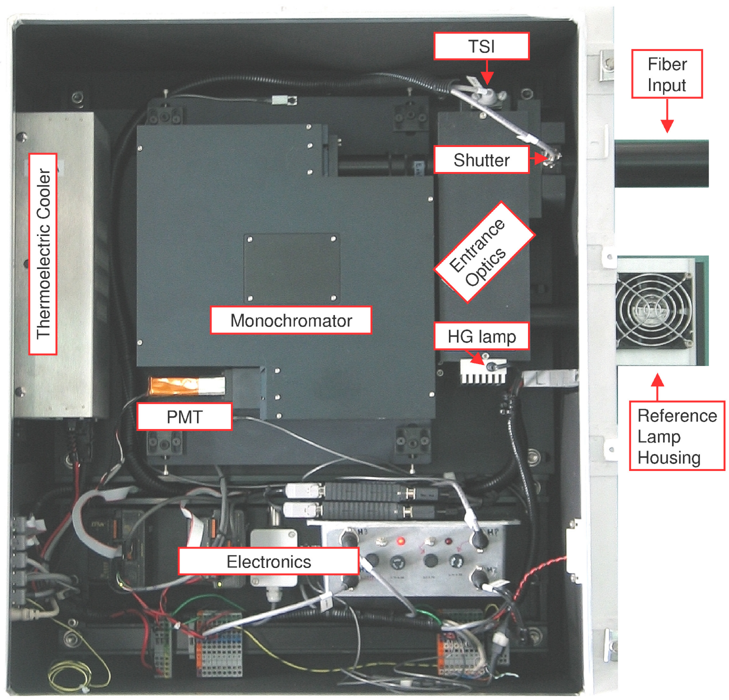

Figure 2.5. *Components inside the SUV-150B monochromator enclosure. The dimensions of the casing are 82 cm (H) x 71 cm (W) x 36 cm (D). The housing of the internal reference lamp is located outside the enclosure and heat from the lamp is dissipated into the laboratory with two fans attached to it. The interior of the lamp housing is sealed from the outside environment.*

The instrument's irradiance collector consists of a PTFE diffuser covering the entrance port of a baffled integrating sphere. This unit is fully weatherproof, heated to minimize ice and snow buildup, mounted into a roof hatch (Figure 2.6), and fiber-coupled to the monochromator. At the heart of the system is a 150 mm, f/4.4 Czerny-Turner double monochromator, designed by BSI and optimized for recording UV-B and visible solar radiation. The bandwidth is 0.63 nm FWHM. The monochromator uses two gratings, which are independently positioned by two micro-stepping motors. The drive mechanism uses high-resolution optical encoders, which provide real-time active-feedback position control. The monochromator's exit port is coupled to a bi-alkali PMT from Hamamatsu. All parts of the instrument are temperature stabilized to within ±0.5ºC by a thermoelectric heater/cooler. The system also features an entrance optics with an integral 45-Watt quartz tungsten-halogen lamp and a mercury discharge lamp for daily checks of the instrument's radiometric and spectral stability. The suite of ancillary sensors includes a GPS receiver for time synchronization, a pyranometer from Eppley Laboratory, and various temperature sensors. The system's control electronics and system control computer may be located up to five meters away from the monochromator enclosure (Figure 2.7). The system can be operated remotely via the Internet. Data is typically transferred to BSI once per day. In normal network operation, the SUV-150B executes four solar scans per hour between 280 nm and 605 nm. The absolute calibration is based on biweekly scans with 200-Watt irradiance standards traceable to NIST. Data processing includes checks for wavelength shifts by means of a Fraunhofer line correlation algorithm, and adjustment for the small but existent cosine error of the instrument's collector (Section 4). A complete list of specifications is provided in Table 2.2. The system participated successfully in the 5th North American UV Intercomparison for spectroradiometers, which was held at Table Mountain, located 8 km north of Boulder, Colorado, USA, from 13 to 21 June 2003 (Wuttke et al., 2006).

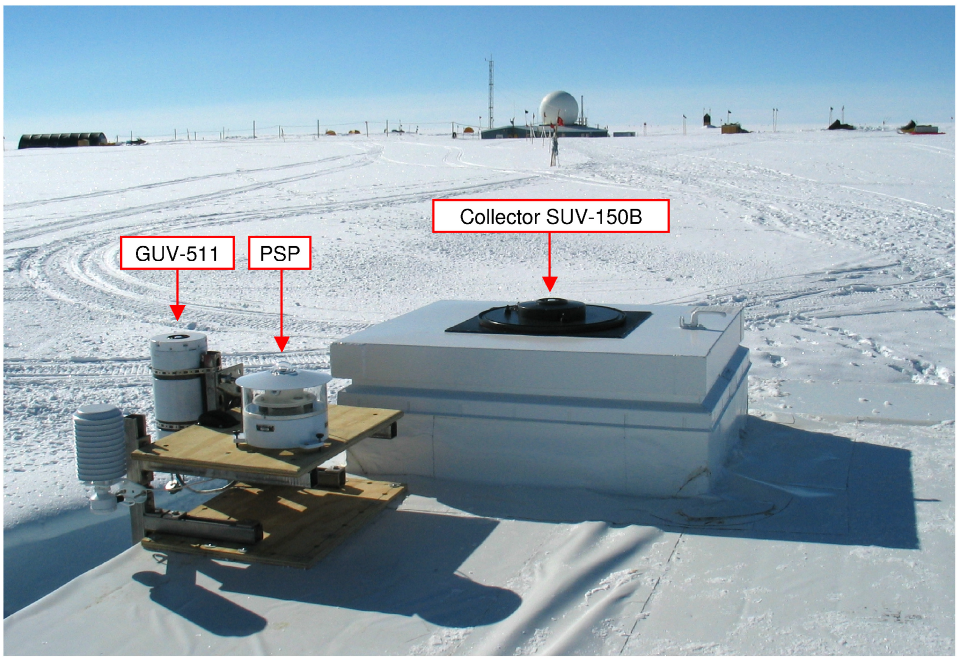

Figure 2.6. *SUV-150B spectroradiometer installation at Summit, Greenland. The collector of the SUV-150B is mounted into a roof hatch.*

Figure 2.7. *The SUV-150B spectroradiometer installation. at Summit Greenland. The monochromator enclosure (white box) is mounted on the wall. The collector is installed into a roof hatch above the instrument. System control computer and additional electronic equipment are installed in separate racks in the foreground.*

Table 2.2. SUV-150B spectroradiometer specifications, revision 2005/2006.

Quantity Measured	Global spectral irradiance between 280 and 605 nm
Monochromator	Double monochromator, developed by BSI
Type	Scanning Czerny-Turner double monochromator, additive dispersion, focal length 150 mm, focal ratio f/4.4
Control	Two micro-stepping motors (one for each grating turret), computer controlled via feedback from two 24-bit optical encoders; spectral resolution limit: 0.003 nm
Gratings	Plane, ruled, blaze wavelength 240 nm, 2400 grooves/mm
Spectral Range	200 – 700 nm (typically 280 – 605 nm for solar measurements)
Bandwidth	0.63 nm full-width at half-maximum (FWHM) at 325 nm, 1.8 nm full-width at 0.1% of maximum, (Figure 2.9)
Wavelength Precision	±0.004 nm (±2σ) (Note 1)
Wavelength uncertainty	±0.03 nm (±2σ) (Note 2)
Wavelength Calibration	Based on a combination of internal mercury discharge lamp measurements and post-correction with a Fraunhofer-line correlation method. (Section 4.2.2.2.)
Out-of-band Rejection	$> 5 \times 10^{-8}$. Stray light of terrestrial solar spectra is not detectable (Figure 2.10).
Sampling Step	User definable. Typically 0.2 nm (for 280 - 405 nm), 0.5 nm (for 406 - 600 nm).
Scan Time	User definable. Typically 9 min for 280 - 400 nm; 14 min for 280 - 600 nm.
Collector	
Design	Integrating sphere with center baffle; entrance port covered by a shaped PTFE diffuser; exit port coupled to the monochromator's entrance optics by a quartz optical fiber bundle; additional exit ports for four filtered photodiodes at 313, 340, 380, and 490 nm.
Cosine Error	< ±2% for all angles < 75°, –6% at 80°, <±1.5% for isotropic radiance (Figure 2.8)
Azimuthal Asymmetry	< 1%
Fluorescence	$< 1 \times 10^{-5}$ (Figure 2.10)
Temperature	User selectable; typically stabilized to 32±2 °C
Entrance Optics	
Purpose	To bring radiation to the monochromator's entrance from the collector (optical fiber-bundle coupling), the internal mercury lamp, and the internal tungsten-halogen calibration lamp.
Features	Shutter (Uniblitz Model VS25S2T1K) to block radiation from the collector during internal calibration lamp scans; relay optics to match monochromator's focal ratio.
Detector	
Type and Make	Photomultiplier (PMT), Hamamatsu Model R2371P. Selected for low noise; 9 stage dynodes; mounted in electrically and magnetically shielded housing with integral high-voltage power supply; 16-bit high-voltage control resolution.
Integration Times	0.1 – 10 seconds under software control, typically set to 0.2 to 0.5 seconds
Dark Current Stability	Typically 10^{-6} relative to full scale.
System Responsivity Stability	Depending on site and time period, see Chapter 5.
Saturation Irradiance	$> 2 \times 10^{-4}$ W/(cm^2 nm)
Noise Equivalent Irradiance	6×10^{-10} W/(cm^2 nm) (Note 3)
Data Acquisition	
PMT Signal	Electrometer, Keithley Model 6514
Ancillary Sensors	Agilent Model 34970A Data Acquisition Unit, BSI Q2100-Series Multi-Tag ADC
Lamp Current Control	Agilent Model 34401A Digital Multimeter, ISA-PLAN Precision Shunt type RUGZ-R010-0.1 (Zeranin)
System Control Computer	Intel Pentium® personal computer running the Microsoft® XP Professional operating system. SUV-150B System Control Software from BSI providing system control, data acquisition and recording. Remote access and data retrieval via Internet
Data File Formats	Microsoft® ACCESS and ASCII
Auxiliary Sensors	GUV-511 multi-channel filter radiometer (Section 2.3), filtered photodiodes integrated in collector; total scene irradiance (Section 2.4); Eppley PSP pyranometer (Section 2.4); internal temperature (monitored at PMT, monochromator, enclosure, internal lamp); room temperature; outdoor temperature; humidity inside enclosure; line voltage; system supply voltage; load-current thermoelectric cooler; GPS receiver for timekeeping; system status (monochromator control, PMT high-voltage, electrometer, digital multimeter, lamp power supply, data acquisition units)

Table 2.2, continued

Additional features	Temperature of enclosure stabilized to 25±0.5° by a thermoelectric heater/cooler; uninterruptible Power Supply (UPS).
Operating Temperature	+40° to –80 °C outside environment
Utility Requirements	115 VAC, 15 Volt-Amps, and Internet access (Note 6). An uninterruptible power supply is provided for 1-hour minimum operation in the event of power failure.
Internal Standards	45-Watt tungsten-halogen Lamp, mercury vapor discharge lamp
Primary System Calibration Sources	200-Watt tungsten-halogen standards of spectral irradiance, NIST traceable

Note 1: Wavelength *precision* was estimated from the standard deviation of the registered position of the 296.73 nm mercury line measured daily by the SUV-150B between January and August 2006

Note 2: Wavelength *uncertainty* mostly results from the uncertainty of the Fraunhofer-line correlation method described in Section 3.3.1.2.

Note 3: Noise Equivalent Irradiance is defined as the standard deviation of the measured spectral irradiance at 285 nm. At this wavelength, all solar radiation is filtered out by the Earth's ozone layer. The measured value at 285 nm therefore reflects the magnitude of instrument noise, which causes the detection limit.

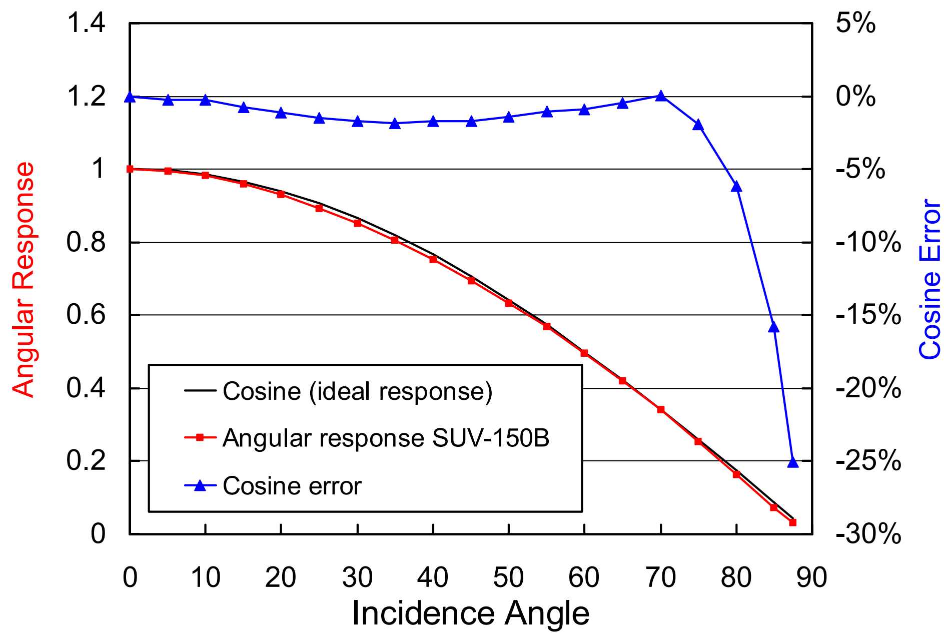

Figure 2.8. *Angular response and cosine error of the SUV-150B.*

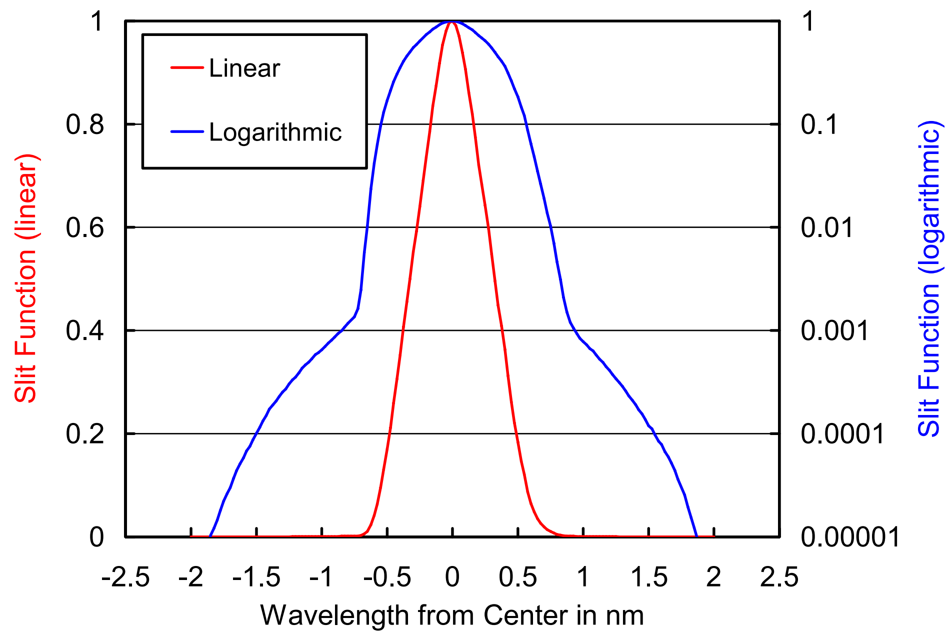

Figure 2.9. *Slit function of the SUV-150B measured with a HeCd Laser at 325 nm.*

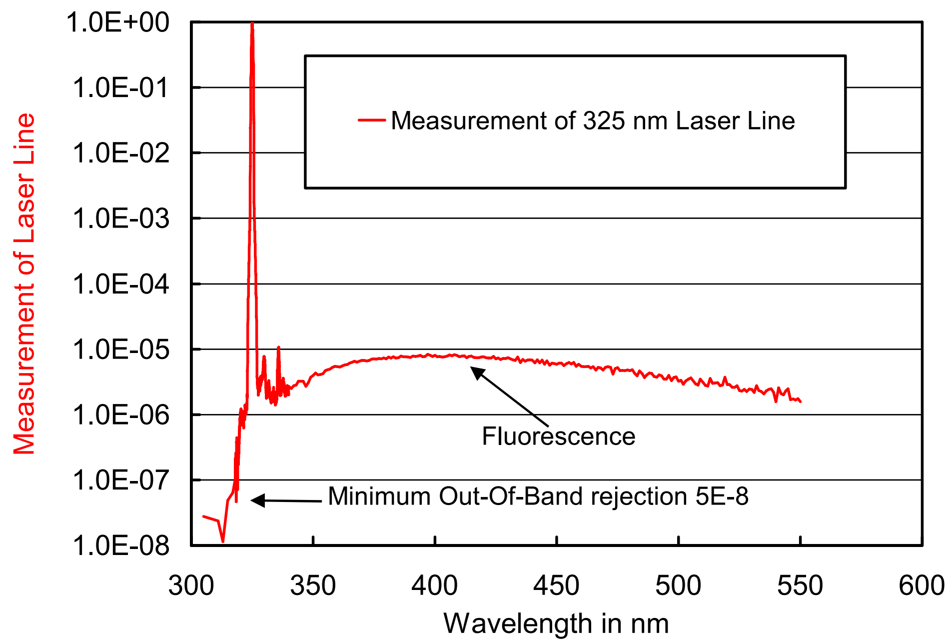

Figure 2.10. *Out-of-band rejection of the SUV-150B measured with a HeCd Laser at 325 nm. The out-of-band rejection is likely larger than $5x10^{-8}$ but the measurement is limited by the instrument's dynamic range of approximately 8 orders of magnitude. Fluorescence is less than $1x10^{-5}$ and therefore does not affect solar measurements.*

2.3. GUV Multi-Channel Filter Radiometers

Between 2001 and 2005, moderate-bandwidth, multi-channel filter Ground-Based Ultraviolet (GUV) radiometers, designed and manufactured by BSI were installed at all network sites. The instruments measure at high temporal resolution and are also used for the quality control of SUV data.

GUV instruments provide measurements at four approximately 10 nm wide UV bands nominally centered at 305, 320, 340, and 380 nm. A fifth channel either measures radiation at 313 nm (GUV-541C: at South Pole only) or Photosynthetically Active Radiation (PAR) (GUV-511C). From the instruments' irradiance measurements a variety of data products is derived, including spectral integrals (e.g. UV-B or UV-A), UV dose-rates (e.g. erythemal irradiance, the UV Index, DNA damaging UV), and total ozone. See Section 4.3.2 for more details about these data products. A photograph of the instrument is shown in Figure 2.11. Instrument specifications are in Table 2.3. Data are averaged over one-minute intervals prior to processing.

Figure 2.11. *GUV multi-channel ground-based filter radiometer.*

GUV instruments deployed in the NSF UV Monitoring Network are equipped with an irradiance collector with relatively small angular response errors (Figure 2.12). The small error was achieved by installing a secondary diffuser between the instrument's primary diffuser (which is exposed to the Sun) and the filter/detector assembly. The cosine error of the advanced collector (Figure 2.12) is smaller than ±3% (±7.5%) for zenith angles less than 65° (82°). All channels have a similar angular response. The dependence on the azimuth direction is smaller than the accuracy of the test apparatus.

Table 2.3. GUV radiometer specifications, revision 2005/2006.

Quantity Measured	Model GUV-541C: Global irradiance in five approximately 10 nm wide spectral bands centered at 305, 313, 320, 340 and 380 nm Model GUV-511C: Global irradiance in four approximately 10 nm wide spectral band centered at 305, 320, 340 and 380 nm, and photosynthetic photon flux density (PAR)
Irradiance Collector	
Design	Diffuser made of polytetrafluoroethylene (PTFE) covering a trapezoidally shaped quartz support; internal secondary PTFE diffuser
Cosine error	±3% (±7.5%) for zenith angles less than 65° (82°) (Figure 2.12)
Collector diameter	2.1 cm
Filter/Detector Array	
Filter Type	Custom low-fluorescence interference filters
Bandwidth	Approximately 10 nm full width at half maximum (except PAR channel)
Spectral Response	Measured at BSI prior to deployment (Figure 2.13)
Out-of-band rejection	305-nm channel: > $1x10^{-6}$; other channels: > $1x10^{-3}$ (Figure 2.13)
Detector Type	305-nm channel: phototube; other channels: silicon diode
Temperature Coefficient	< ±0.15% / °C
Saturation	No saturation when measuring solar irradiance at any place on Earth
Temperature Stabilization	40±0.5 °C
Data Acquisition	
Sampling Rate	Approximately 1 Hz. One-minute average is applied by software.
Computer Interface	Serial RS-232 at 9600 baud
Software	LOGGER, developed by BSI
Format of Raw Data	Microsoft ACCESS
Time Standard	Universal Time (UT), based on the logging computer's clock and updated by Internet time server or Global Positioning System Receiver
Monitored Parameters	Internal temperature, supply voltage
Calibration	Against SUV spectroradiometers, see Section 4.3
General	
Dimensions	Diameter: 15 cm; height: 30 cm
Weight	7 kg
Temperature Rating	–80 to +40 °C outside environment
Power Requirement	85-264 VAC, 47-63 Hz

Spectral response functions of some of the GUV instruments were measured in BSI's laboratory prior to site installation. Details on the apparatus and the measurement method were described by Bernhard et al. (2005b). As an example, Figure 2.13 shows spectral response functions of the 305, 320, 340, and 380 nm channels of two of the UV Monitoring Network's GUV radiometers (S/N 9298 and 29236) in linear and semi-logarithmic presentation. There are several points worth noting:

- The short-wavelength limits of the 305 channel of both radiometers are shifted by approximately 8 nm due to the different set of filters and detectors used in the instruments. This difference has very little impact on measurements of sunlight as solar radiation below 290 nm does not penetrate the Earth's atmosphere. Almost all contributions to the 305 nm GUV signal results from photons with wavelengths between 300 and 310 nm, where the response functions of the two instruments are very similar.
- The detector of the 305 nm channel is a phototube with no significant sensitivity above 315 nm. Photons with wavelengths in the UV-A or visible, which may reach the surface of the detector due to possible light leaks of the filters, are not detected.
- The responsivities of the 320, 340, and 380 nm channels are similar for both instruments, but are shifted by 0.6-0.9 nm relative to one-another. These shifts are caused by the different transmission characteristics of the interference filters used in the two instruments.
- The right panel of Figure 2.13 indicates that the 320 nm channel of GUV S/N 9298 is also sensitive to radiation in the 330-380 nm band. Such light leaks may introduce significant errors in

solar measurements, particularly when the detector is also sensitive to radiation in the visible. A comparison of simultaneous solar irradiance measurements with GUV S/N 9298 and a SUV spectroradiometer indicated that the leakage problem is too small to affect solar data appreciably.

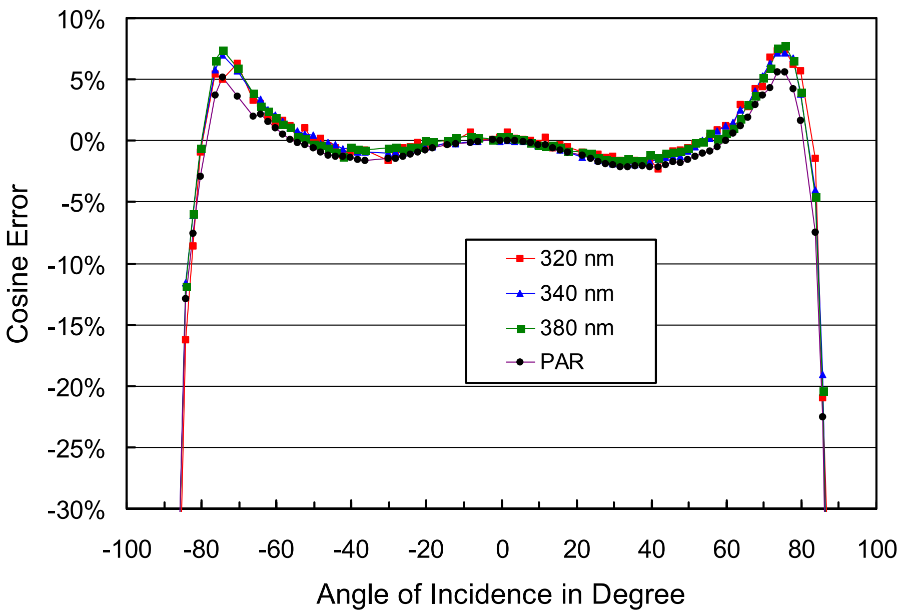

Figure 2.12. *Cosine error of GUV-511C radiometer, S/N 29236, measured in BSI's laboratory with a 1000-Watt FEL tungsten-halogen lamp as light source. Measurements for the 305 nm channel were not included due to low light levels.*

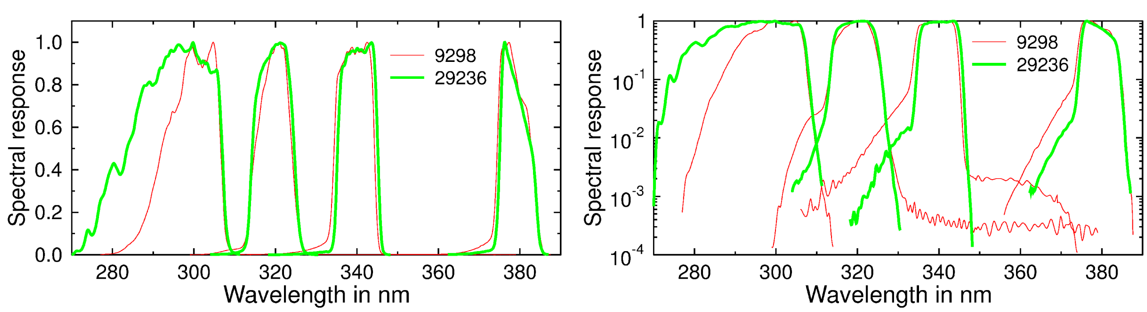

Figure 2.13. *Spectral response functions of the 305, 320, 340, and 380 nm channels of two GUV radiometers (S/N 9298 and 29236) in linear (left panel) and semi-logarithmic (right panel) presentation.*

2.4. Ancillary Sensors

All SUV systems are equipped with several ancillary sensors, including broadband radiometers, a filtered photodetector, several sensors for monitoring instrument parameters, and a Global Positioning System (GPS) receiver. Ancillary sensor data are recorded during high-resolution spectral scans (several sets of readings per minute) and between the scans at a selectable rate ranging from a reading every one to sixty minutes. Since all sensors are directly interfaced with the SUV, data sets are fully synchronized without the need for additional data recording or handling.

2.4.1. Eppley Radiometers

Two radiometers from Eppley Laboratory Inc are deployed at network sites: the Precision Spectral Pyranometer (Model PSP with WG7 hemisphere) and the Total UV Radiometer (Model TUVR), see Figure 2.14. Calibration coefficients of both instruments are provided by Eppley Laboratory. Many instruments have been recalibrated during the Volume 14 season; see Chapter 5 for details. The PSP measures short-wave (0.3 – 3 µm) solar irradiance. The TUVR is sensitive in the 295-385 nm range. The output of these sensors is collected automatically with the System Control Software, and a pre-amplifier designed by BSI. Raw data is converted to irradiance units (mW/cm²) and published together with the spectral measurements. Calibrated values of the TUVR agree to within ±20% with spectral measurements of SUVs, integrated over the UV-A (320-400 nm). TUVR data are less accurate than integrated spectral data and should therefore not be used in place of SUV measurements. TUVR measurements are valuable for quality control purposes. For example, by comparing time-series of TUVR and SUV measurements data that might be affected by snow accumulation on one of the sensors can be detected. The TUVR is not heated and more subject to snowfall and ice buildup on its diffuser than SUV systems.

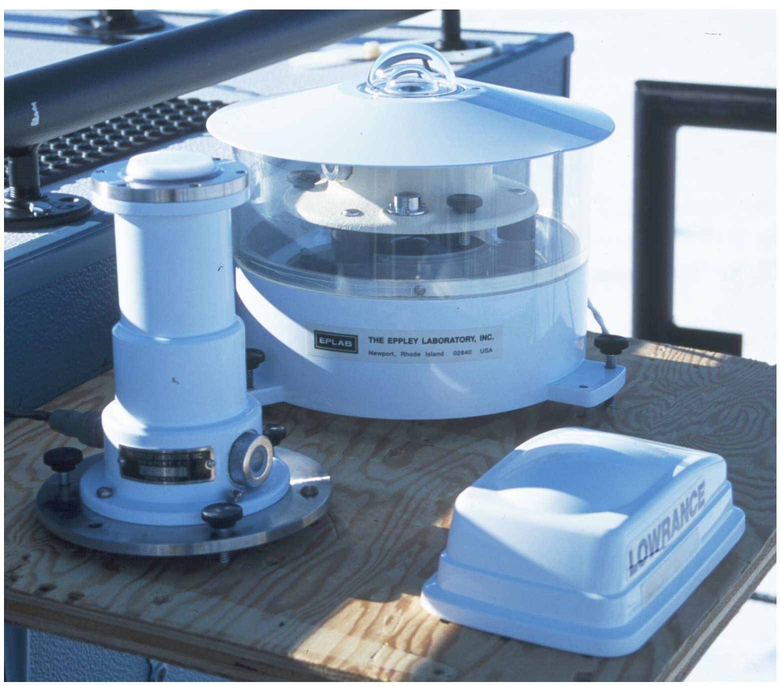

Figure 2.14. *Eppley radiometers and GPS receiver. The PSP shown in the background is equipped with a ventilator that continuously blows air over the instrument case and its quartz dome, minimizing frost and snow buildup on the dome. The TUVR radiometer is on the left; the GPS receiver is on the right.*

2.4.2. Total Scene Irradiance Sensor

For quality control purposes, a filtered photodiode with response in the UV-A, called "Total Scene Irradiance sensor" (TSI), is integrated into SUV spectroradiometers (Figures 2.1 and 2.5). It serves several functions. First, the sensor is used to monitor changes in the system's internal irradiance reference lamp on a daily basis. Second, the TSI is used to track changes in the 200-Watt calibration standards that are used biweekly for the instrument's irradiance calibration. Third, the TSI provides an indication of changes in irradiance that may occur during a solar scan (e.g., due to changes in cloud cover). Finally, the TSI provides an independent measure of UV-A solar irradiance that can be compared with long-term spectral solar measurements of SUV spectroradiometers. The ratio of solar TSI measurements and spectral measurements, weighted with the spectral response function of the TSI (Figure 2.15), is a useful tool for detecting system drift. The TSI is not a calibrated sensor, but is used referentially; results are expressed in Volts. Please note that TSI readings from one season to another, or from one site to another, are not directly comparable.

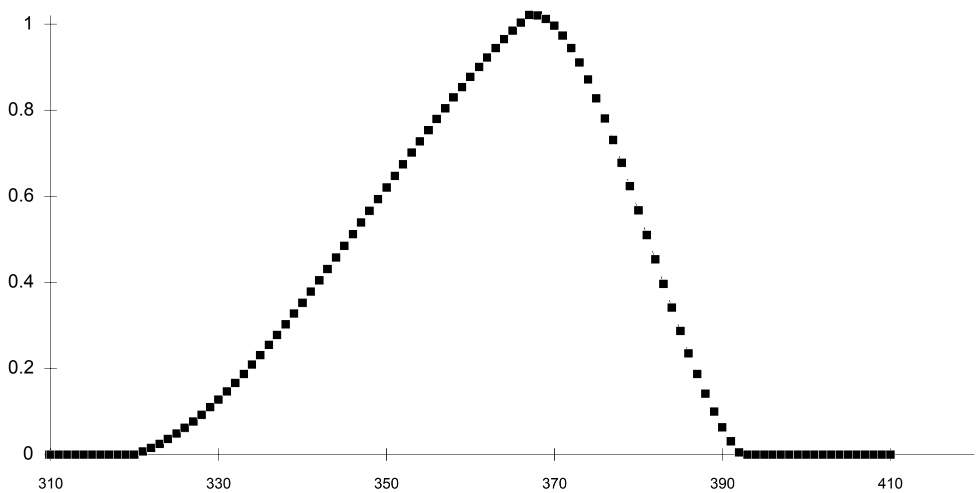

Figure 2.15. *Spectral response of the TSI sensor.*

2.5. Operation, Maintenance and Calibration of SUV Systems

During the 2005-2006 season, the instruments at South Pole, McMurdo, and Palmer Stations were operated year-round by personnel from Raytheon Polar Services Company (RPSC). The Ushuaia site is maintained by the Centro Austral de Investigaciones Cientificas, Argentina. The installation in Barrow was operated up to February 2006 by personnel from the Climate Monitoring and Diagnostics Laboratory (CMDL) of the National Oceanic and Atmospheric Administration (NOAA). From March 2006 onward, personnel from the Department of Energy's (DOE) Atmospheric Radiation Measurement (ARM) Program took over operations. The instrument at Summit was operated by VECO Polar Resources. Operator duties include the performance of data transmission, daily verification of the system operation, inspection/cleaning of the irradiance collector, biweekly calibrations with standards of spectral irradiance, and routine and emergency service. Daily maintenance activities typically require less than 15 minutes; the biweekly system calibration takes about 1-2 hours.

Each site is visited approximately annually by Biospherical Instruments personnel. During these "site visits," the on-site irradiance standards are validated and the spectroradiometers are serviced, cleaned, upgraded, and repaired as needed. The results of the site visit are a prerequisite for the processing and the quality control of final data.

For the purpose of an irradiance calibration with a NIST-traceable 200-Watt standard, the operator mounts a specially designed fixture (or "stand") on top of the instrument (Figure 2.16). To minimize systematic errors in the process, the stand is designed so that it can only be mounted onto the system in one orientation. The lamp holders are keyed such that they can also only be mounted in one orientation to the calibration stand. The lamp is then energized and, after a 10-minute warm-up period, a spectrum of the lamp is measured by the SUV. This measurement is then used to determine the spectral responsivity of the system. The whole procedure is described in more detail in Chapter 4.

In order to maximize the accuracy of calibrations, each SUV system includes an IEEE-488 controlled power supply (PS), a high-precision shunt, and a digital multimeter (DMM) for regulating and monitoring lamp currents of both the internal 45-Watt and external 200-Watt lamps. The drifts of the lamps kept on-site are checked with independent "traveling" standards of spectral irradiance during the annual site visits. The same traveling standard is usually used at all network sites to ensure consistent calibrations at all locations.

Figure 2.16. *Calibration stand with a 200-Watt lamp mounted on top of a SUV-100 spectroradiometer. The lamp power is connected to the roofbox immediately below the fixture. Baffles limit stray light. During operation, an internally-blackened barrel is placed over this fixture.*

2.6. Software for Instrument Operation and Data Reduction

Network operation software is comprised of several elements: *SUV-100 and SUV-150 System Control* software, *Logger*, *SUV_Read*, software tools to organize processed data into databases, and software to produce "Version 2" network data.

- The *SUV-100 System Control Software* is installed on the system control computers at site equipped with SUV-100 spectroradiometers and automatically controls the instruments and records data. Compiled in Visual Basic®, the software offers ease of control, is intuitive to use, and runs under the Windows NT® operating system. The software features user-selectable graphic and numeric display of raw data in real-time, and alarms with an indicating status bar. Displayed error conditions include failures in specific system operations and functions. A "front panel" scrollable event log informs the operator of system malfunctions (achieved by defining a series of different alarms utilizing settable limits). This program also offers real-time display of data from the suite of ancillary sensors, and has built-in capability for additional sensors.

- *The SUV-150 System Control Software* controls the SUV-150B instrument. It has similar features than the software for SUV-100s and runs on the Windows XP® operating system.

- *Logger* is a software for controlling GUV radiometers and is installed on the same computers that run SUV instruments.

- *SUV_Read* is used at BSI, and occasionally by site operators to decode binary raw data from the instruments and apply wavelength and irradiance calibrations. The software allows the user to display both calibration and data results graphically. It can also be used to calculate solar zenith and azimuth angles, spectral integrals, and weighted doses.

- Since 1999, processed network data are stored in Microsoft®-ACCESS databases. Tools to maintain these databases have features to display time-series spanning multiple years of data, and to evaluate the performance of network instruments. With these tools, which are continuously developed, the quality control of data became more efficient, leading to a shorter period between the recording and publication of data.

- In 2002, we started to produce a new edition of NSF network data labeled "Version 2." Version 2 data have a higher accuracy and feature a larger number of data products than "Version 0" data, which are the focus of this report. Version 2 data have been corrected for deviations of the angular response of SUV spectroradiometers from the ideal cosine response (i.e. the cosine-error) and for wavelength errors affecting data measured before 1997. New data products includes total ozone column, surface albedo, cloud optical depth, and results from radiative transfer calculations. Software tools for generating the new version comprise the radiative transfer model UVSPEC/libRadtran (Mayer et al., 2005) and Unix-style programs for applying various corrections to data and creating the new data products. More information on Version 2 can be found at www.biospherical.com/nsf/Version2.

- Additional software was developed in 2003 to automate the processing of SUV and GUV data for display on the project's website. To improve the response time of graph and data file generation, we transitioned some of our webpages to ASP.NET.