1. Introduction
The USDA Ultraviolet Radiation Monitoring and Research Program (UVMRP) was established in 1992 to provide the US Department of Agriculture with the information necessary to determine if changing levels of ultraviolet light have an effect on food and fibre production in the United States. Prior to the establishment of the program only limited information was available to make such an assessment, and the geographic distribution and quality of this information was insufficient to meet the requirements of the agency (Gibson, 1991; Gibson, 1992). Two different but complimentary actions were taken by the agency to obtain the information necessary to make its assessment. The first called for the establishment of an ultraviolet radiation monitoring program and the second solicited proposals for the development of an improved scanning high resolution spectroradiometer.

The primary objective of the USDA UVMRP is to provide information to the agricultural community about the geographic and temporal climatology of UV-B irradiance. Its data is intended to assist scientists in relating changes in stratospheric ozone, cloud cover, and aerosols to changes in ultraviolet light, and to improve the understanding of the factors which control ultraviolet light. Both are critical in assessing the potential impacts of changing UV light on agricultural systems. Since the establishment of the network the data has found use with agriculture and human health effects researchers, model developers, ecosystem scientists, scientists studying aerosols, and those seeking a ground truth measurement for satellite systems. In addition we are supporting research on plant responses to UV-B and other stress factors.

The initial network of twelve stations which was established in 1994, has expanded to 33 locations and includes four research sites. Collocations have been established with other federal agencies (EPA, NOAA, Smithsonian, NIST) that collectively define the UV research program of the US Global Change Research Program (Kaye et al., 1999) and also with the long-term Canadian Brewer Network and New Zealand’s UV program.

All data from the network is captured by on-site data loggers and downloaded over phone lines each evening. Data is made available to the scientific community as well as the general public the next day via the network’s World Wide Web site at URL http://uvb.nrel.colostate.edu. The network is further described in Bigelow et al. (1998).

2. Growth of the Network
Two new climatological network sites were established in 2002 bringing the total number of monitoring
locations in the network to 33. New sites were established at Raleigh, NC, and Fort Collins, CO, as well as a research site at NASA’s Goddard Space Flight Center in Greenbelt, MD.

3. Instrumentation

*Retrofit of failing photodiodes* - Beginning approximately six months after the initial deployment of the UV-MFRSRs, in 1998, channels started to fail. As of December 31, 2000 there had been 58 channel failures in 33 heads. This is out of a total of 215 channels in 43 instruments. Thus 27% of the possible channels have failed while 77% of the heads have had at least one channel failure. It was determined that the cause of failure was unstable GaP photodiodes. Therefore the network contracted in 2001 with YES to retrofit all 43 heads using more stable Si photodiodes in place of GaP photodiodes. The contract included a one year warranty. All retrofits have been accomplished and the filter functions measured by CUCF are “the best ever”. All the heads from the field received a closing calibration from CUCF before retrofitting and a second CUCF calibration after retrofitting before being fielded. Since the upgrade to Si photodiodes, the have been no channel failures.

*Stability of the UV Shadowbands* - Over the past few years the network has concentrated on determining the shadowband’s radiometric stability. Two articles detailing work performed at both the Mauna Loa Observatory and the Central Plains Experimental Range in Colorado (Bigelow and Slusser, 2000; Slusser et al., 2000) have been published. The research has been focused primarily on the stability of both the radiometric sensitivity and the interference filters. With the switch-over to the CUCF for our calibration laboratory more than four years ago and their recent completion of the characterization of all of the network instrumentation for at least the second time, the network is now able to investigate statistically and document the stability of the radiometric calibrations and the filter functions of its instrumentation.

The CUCF has performed 59 repeat filter spectral response functions (SRFs) of 34 UV-MFRSR heads and absolute response characterizations which allows the statistical assessment of the instruments’ stability. Since the CUCF’s wavelength measurement accuracy and repeatability is better than ± 0.02 nm and does not change over time (Slusser et al., 2000), all paired differences reflect real shifts in a channel’s SRF. The statistics of repeat channel SRF measurements of 34 UV-MFRSR performed at the CUCF during 2000 and 2001 showed a median shift in SRF that ranged from 0.028 to 0.043 nm with a standard deviation (S.D.) of between 0.088 to 0.108 for the 7 channels (Gao et al., 2001). This is an important result to the operation of this network. Since the SRFs are so stable, in-house calibration becomes feasible using the Langley calibration method and heliostat angular response measurement (see below). *Figure 1* shows the median annualized drift of all of the UV-MFRSR channels using the Langley technique (Bigelow and Slusser, 2000) which ranged from 1.1% to 3.1%. *Figure 2* summarizes the statistics of the drift of all of the channels of each head.
Quartz domes—Repeat lamp calibrations and Langley intercept time series indicate rather steep declines in the responsivity of heads located at a few places (e.g. El Centro, CA). Inspection of the heads have revealed dirt imbedded into the diffuser. To study this problem CUCF measured the transmission of the teflon diffusor and then placed it in the field at El Centro. Later transmission tests should showed the diffuser transmission to be reduced after 6 months at El Centro. Quartz domes might be affixed to heads going to such dusty climes.

Stability of the Broadband UVB Meters - The re-calibration of all of the USDA broadband meters against the CUCF triad was first accomplished in fall 2000. Diffey-weighted erythemal calibrations (Lantz et al., 1999) have been applied to all 2002 broadband data. The stability of the broadbands as judged against the triad is very good with the median change in scale factor for 30 instruments of 0.5% with a S.D. of 0.39% (Figure 3).

Barometers - Barometers have been placed at 10 sites to better correct the effect of molecular scattering on aerosol optical depth retrievals in the UV. These are sites where NASA has co-located a UVA broadband to interpret TOMS satellite UV retrievals. Barometers have been installed at Big Bend TX, Everglades FL, Table Mountain and CPER CO, Mauna Loa HI, Beltsville MD, Davis CA and Poker Flat AK, the Canadian sites of Bratt’s Lake and Toronto as well as New Zealand.

Repairs of Vis-MFRSRs - Due to the lower priority of the Vis-MFRSRs and their inherent instability (Bigelow et al., 1998), the network has stopped regularly repairing them. The problem of board failure at
low temperatures has been solved by replacing several capacitors on the circuit boards.

Smithsonian Spectral Radiometers - Several SR-18s have been incorporated into the NIST Degradation Network. These include instruments at Table Mountain, CO, West Lafayette, IN, Mead, NE. Data from the SR-18s is polled every week, checked for quality at Smithsonian, and then made available on the Web for general use.

3.1 Calibration
The quality and frequency of calibrations continued to be a major concern in 2002. All calibrations are performed by the CUCF in Boulder CO. In order to increase our confidence in all calibrations and improve precision and accuracy, the network continues to develop alternate methods of establishing absolute, angular and spectral characterizations for its radiometers.

Broadband Calibration - Each of the 43 broadband meters was calibrated in 2002 by the CUCF which performs absolute, cosine, spectral and erythema characterizations for each instrument. Dr. Harrison’s 1.0 m USDA Reference Spectrometer (Harrison et al., 2002) is used to calibrate NOAA’s reference triad of UV broadbands. The calibration applied to the triad is then transferred to the USDA instruments by comparing daily irradiance integrals and applying a scale factor from the ratios obtained (Lantz et al., 1999). Erythemal calibrations have been applied to all 2002 data. Work is underway to extend these

Figure 2: Statistics of radiometer stability as determined by Langley technique.

<table>
<thead>
<tr>
<th>channel</th>
<th>min</th>
<th>mean</th>
<th>sd</th>
<th>median</th>
<th>max</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>drift300</td>
<td>-50.2</td>
<td>-1.2</td>
<td>13.9</td>
<td>-1.1</td>
<td>33.9</td>
<td>79</td>
</tr>
<tr>
<td>drift305</td>
<td>-48.9</td>
<td>-4.8</td>
<td>14.3</td>
<td>-1.7</td>
<td>42.2</td>
<td>127</td>
</tr>
<tr>
<td>drift311</td>
<td>-42.3</td>
<td>-2.6</td>
<td>12.1</td>
<td>-1.2</td>
<td>27.0</td>
<td>127</td>
</tr>
<tr>
<td>drift317</td>
<td>-46.3</td>
<td>-3.0</td>
<td>11.8</td>
<td>-1.6</td>
<td>26.7</td>
<td>125</td>
</tr>
<tr>
<td>drift325</td>
<td>-39.9</td>
<td>-4.8</td>
<td>10.3</td>
<td>-3.1</td>
<td>31.7</td>
<td>126</td>
</tr>
<tr>
<td>drift332</td>
<td>-50.8</td>
<td>-4.9</td>
<td>10.3</td>
<td>-2.7</td>
<td>17.7</td>
<td>128</td>
</tr>
<tr>
<td>drift368</td>
<td>-31.0</td>
<td>-3.7</td>
<td>8.4</td>
<td>-2.4</td>
<td>25.0</td>
<td>128</td>
</tr>
<tr>
<td>days</td>
<td>91</td>
<td>407</td>
<td>207</td>
<td>376</td>
<td>847</td>
<td>79</td>
</tr>
</tbody>
</table>
erythemal calibrations back to 1998 broadband data. A report of the 1997 North American Interagency Spectroradiometer Intercomparison has been published (Lantz et al., 2002).

**UV-MFRSR Calibration** - All 44 UV-MFRSR heads were characterized during 2002 at the CUCF for spectral response and absolute radiometric response. Regular cosine characterizations is now a part of the routine calibration.

**In-House Cosine Response Measurements** - Because of the difficulties in obtaining cosine characterizations from the CUCF and our concerns with different measurement strategies, we continued development of an *in situ* technique for measuring the cosine response of the UV-MFRSR. The prototype consists of a Sun tracker heliostat and a rotating turntable both driven by AC synchronous motors. The UV-MFRSR head is supported on the turntable and driven forward and reverse through 180 degrees. The heliostat uses two UV coated mirrors to direct a beam of UV light to the UV-MFRSR’s diffuser and the resulting time-stamped voltage outputs of the head are recorded using a standard Yankee data logger. Stray light is eliminated by placing the sun tracker outside of a plastic window while the turntable is inside.

The first series of tests using single readings each lasting 3 seconds produced measurements at 2° intervals. Intervals of 1° were also obtained by simply changing the table rotation speed. Presently we are working to reduce noise in the system through both mechanical improvements to the system, and statistical methods. A description of this new technique was presented along with preliminary results at the European Geophysical Union’s annual meeting held in Nice, France in April 2000 and a publication is in preparation. Spot checks of the CUCF cosine characterizations will be performed at Christman Field, CO.

**VIS-MFRSR Calibration** - Due to budget constraints, these instruments are no longer calibrated. With increased support it would be possible to use the Langley method to calibrate them *in situ* (Slusser et al., 2000).

**3.2 Quality Assurance**

Most of the work done in the area of quality assurance in 2000 focused on the completion of network shadowband quality assurance documentation (Bigelow and Slusser, 2000; Lantz et al., 1999; Slusser et al., 2000). These flags a attached re to the data record in a separate column to qualify the quality of the data. Table 1 shows the QA coding criteria for all USDA data. No re-evaluations of network precision or accuracy were undertaken although techniques for establishing error budgets were strongly pursued.

We have begun to screen voltage intercepts by visually examining plots of values produced by Langley regression (Slusser et al., 2000). If the time series is anything but flat or with a slight trend or slope, that channel is flagged. Each set of plots (one per wavelength) contains values for a single head deployment at a given site. Voltage intercepts are being screened for all ultraviolet sites and for those visible sites in which data users have expressed interest. The purpose of the screening is three-fold: a) to improve the quality of data products (e.g., aerosol optical depths) we provide to data users which depends on a current voltage intercept; b) to help to identify data that is of questionable quality due to past equipment failures or other problems at a site and c) to monitor recent equipment status to afford more timely repair.
Figure 3: Histogram of gain changes for 41 broadband measured at CUCF. Most gain changes are less than 1% per year.

Table 2: Quality Assurance Coding of UVB data records

<table>
<thead>
<tr>
<th>Data Record Code</th>
<th>Reason</th>
<th>Rule</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>bt</td>
<td>broadband dome temp problem</td>
<td>dome temp is &lt;= 750 millivolts or dome temp is &gt;= 850 millivolts</td>
<td>aux</td>
</tr>
<tr>
<td>at</td>
<td>uva dome temp problem</td>
<td>dome temp is &lt;= 900 millivolts or dome temp is &gt;= 1100 millivolts</td>
<td>aux</td>
</tr>
<tr>
<td>hh</td>
<td>humidity high</td>
<td>humidity &gt; 1030 milivolts</td>
<td>aux</td>
</tr>
<tr>
<td>hf</td>
<td>humidity failure</td>
<td>humidity &lt; 0 milivolts</td>
<td>aux</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td>Condition</td>
<td>Module</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------</td>
<td>------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>tf</td>
<td>air temperature failure</td>
<td>air temp &lt; 2300 millivolts</td>
<td>aux</td>
</tr>
<tr>
<td>s[n], n is 1-7 channel</td>
<td>signal saturated for channel n</td>
<td>total channel # &gt; 4094 or diffuse channel # &gt; 4094</td>
<td>channel</td>
</tr>
<tr>
<td>i[n], n is 1-7 channel</td>
<td>signal interference for channel n</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>bf</td>
<td>barometer failure</td>
<td></td>
<td>aux</td>
</tr>
<tr>
<td>a[n]</td>
<td>averaging interval is n minutes not 3 minutes</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>fp</td>
<td>power failure</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>fe</td>
<td>polling failure</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>db</td>
<td>board damaged</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>dd</td>
<td>diffuser damaged</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>dr</td>
<td>diffuser dirty</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>dh</td>
<td>head damaged</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>ba</td>
<td>band alignment problem</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>bm</td>
<td>band motion problem</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>tx</td>
<td>timekeeping problem</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>ma</td>
<td>annual maintenance</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>mt</td>
<td>troubleshooting maintenance</td>
<td></td>
<td>channel</td>
</tr>
<tr>
<td>bd</td>
<td>broadband dark count problem</td>
<td>if elevation &lt;= -1.0 and uvb sensor &gt; 5.0</td>
<td>aux</td>
</tr>
<tr>
<td>bz</td>
<td>broadband dome crazed</td>
<td></td>
<td>aux</td>
</tr>
<tr>
<td>ad</td>
<td>uva sensor problem</td>
<td></td>
<td>aux</td>
</tr>
<tr>
<td>az</td>
<td>uva dome crazed</td>
<td></td>
<td>aux</td>
</tr>
<tr>
<td>ed</td>
<td>epply sensor problem</td>
<td></td>
<td>aux</td>
</tr>
<tr>
<td>ld</td>
<td>licor sensor problem</td>
<td></td>
<td>aux</td>
</tr>
<tr>
<td>sd[n]</td>
<td>solar light n problem</td>
<td></td>
<td>aux</td>
</tr>
<tr>
<td>f[n], n is 1-7 channel</td>
<td>channel failure for channel n</td>
<td>one of the total channels at local noon is below 150 mv that channel has failed. If all channels at local noon are below threshold then no failure</td>
<td>channel</td>
</tr>
<tr>
<td>bc1</td>
<td>no des_factor in broadband_calibrations</td>
<td>for this serial_num</td>
<td>aux</td>
</tr>
</tbody>
</table>
Completeness - The network continues to maintain a high degree of data capture. In 2002 the median number of 3-minute measurements captured by VIS-MFRSRs at network sites was 99.3%. This compares with 99.4% in 2001. The fourth full year of UV-MFRSR operation, 2002, resulted in a median of 99.5% of the 3-minute data being captured compared with 99.2% in 2001.

Comparability - The network continues to maintain collocations with the Canadian Brewer Network (2 sites), the US EPA Brewer Network (three sites) and New Zealand’s National Institute of Water and Atmospheres (NIWA).

A comparison of aerosol optical depths retrieved from the USDA VIS-MFRSR at Bratt’s lake against three photometers such as NASA’s CIMEL demonstrated agreement to ±0.02 (MacArthur et al., 2003).

4. Research: Radiation Measurements and Atmospheric Physics
Research at the UVMRP was focused on six areas: calibration improvements, retrieving aerosol properties, ozone retrievals, synthetic spectra verification, comparison of UV-MFRSR measurements with satellite and model retrievals, and a study of long term UVB broadband time series. A number of
publications resulted from this work. In addition the UVMRP is performing research on the response of plants, forests, and ecosystems (see Section 5)

4.1 Langley Calibrations
Accurate calibration of UV ground-based radiometers is crucial in identifying trends in UV radiation, developing UV climatologies, and quantifying the amount of shortwave radiation absorbed by clouds and aerosols. The Langley method of calibrating UV multi-filter shadow-band radiometers (UV-MFRSR) is explored in a paper by Slusser et al. (2000). This method has several advantages over the traditional standard lamp calibrations: radiometer signal level is optimal during the Langley event, the Sun is a free, universally available and very constant source (to within <0.5% between 300 nm and 400 nm over the 11-year solar cycle) and nearly continual automated field calibrations can be made for each Langley event. Difficulties arise as a result of changing ozone optical depth during the Langley event and the breakdown of the Beer-Lambert law over the finite filter band-pass since optical depth changes rapidly with wavelength. The Langley calibration of the radiometers depends critically upon the spectral characterization of each channel and on the wavelength and absolute calibration of the extraterrestrial spectrum used.

Results of Langley calibrations made over a period from January 1 through September 30, 1998 for two UV-MFRSRs at Mauna Loa HI (3.4 km elevation) were compared to calibrations made at CUCF using two National Institute of Standards and Technology (NIST) traceable lamps. The objectives of this study were to compare Langley calibration factors with those from standard lamps and to compare field-of-view effects. The two radiometers were run simultaneously: one on a Sun tracker with a collimated full field of view of about 2.0° and the other in the conventional shadow-band configuration. After 2 months the positions of the radiometers were switched. After another 2 months the radiometers were left in place but the field-of-view for the tracker radiometer was narrowed to 1.5°. Both radiometers were calibrated May 15, 1998 at the CUCF with two secondary 1000-W lamps. The spectral response functions of the channels were measured at the CUCF on October 15, 1998. Over a 9 month period the ratio of Langley to lamp calibration factors for the 7 channels from 300 nm to 368 nm using the shadow-band configuration ranged from 0.948 to 1.025. The estimated uncertainty in the Langley calibrations ranged from ±5.5% at 300 nm to ±2.4% at 368 nm. For all channels calibrated with CUCF lamps the estimated uncertainty was ±1.6%. Thus for each channel of the two radiometers the agreement between the two methods was within the combined uncertainties of the two methods. Differences between the Langley and lamp calibration factors were much larger at shorter wavelengths using the Langley tracker results, probably due to changing ozone during the Langley event.

4.2 Aerosol Properties
Aerosols are suspended atmospheric particles in the solid or liquid phase excluding cloud droplets or precipitation. These particles are of critical importance to the hydrological cycle because they provide condensation sites upon which cloud droplets form in slightly supersaturated air. In addition aerosols scatter and absorb solar radiation, changing the amount of UV reaching the earth's surface as well as modifying the heating of the atmosphere. The USDA UV-B Monitoring Network has the capability to report optical depths, a measure of the total aerosol loading, at 33 sites across the continental U.S. Each of the sites of the UV-B Monitoring Network is equipped with both a UV-MFRSR and a Visible-MFRSR which by measuring the direct beam return the total optical depths on clear days at a total of 13 wavelengths from 300 nm to 940 nm. This constitutes the largest U.S. network of ground-based aerosol optical depths and thus provides atmospheric scientists with a unique data set with which to constrain their models which quantify precipitation processes, aerosol and cloud formation, and global warming.

The Southern California Ozone Study (SCO97) involved a whole suite of chemical, optical, and meteorological measurements taken in an effort to understand the causes of urban tropospheric pollution in the Los Angeles basin. Two USDA UV-MFRSRs were loaned to the experiment to determine UV
irradiances and aerosol optical depths (Vuilleumeir et al. 2001). One was placed atop Mt. Wilson and the other in urban Riverside. As a follow-up to the SCOS97 study, a UV-MFRSR and Vis-MFRSR pair of radiometers were placed in Houston to study air quality (Shetter et al., 2002). A UV-MFRSR has been lent to NCAR to study aerosol attenuation of UV in highly polluted Mexico City.

4.3 Ozone Retrievals
Column ozone has been retrieved by Slusser et al. (1999) under all sky conditions at Table Mountain, Colorado (40.177°N, 105.276°W) from global irradiances of the UV-MFRSR 332 nm and 305 nm channels (2 nm FWHM) using lookup tables generated from a multiple scattering radiative transfer code suitable for solar zenith angles up to 90°. For five months in 1996-97 the mean ratio of column ozone retrieved by the UV-MFRSR divided by that retrieved by the collocated Brewer was 1.024 and for the UV-MFRSR divided by those from a nearby Dobson was 1.025. The accuracy of the retrieval becomes unreliable at large SZA > 75° as the detection limit of the 305 nm channel is reached and due to overall angular response errors.

Direct Sun column ozone has been retrieved under all sky conditions in Mauna Loa HI and the Canadian sites of Bratt’s Lake and Toronto (Gao et al., 2001). The mean ratio of column ozone retrieved by the UV-MFRSR divided by that retrieved by the collocated Dobson was 0.969 in Mauna Loa between Julian date 150 and 270 in 1999. Comparisons were also made with Brewers in Canada. The ratio of column ozone retrieved by the UV-MFRSR divided by that of a Brewer was 1.022 in Toronto between Julian date 120 and 240 in 1999, and 1.001 in Regina between Julian date 160 and 250. The UV-MFRSR advantages of relatively low cost, unattended operation, automated calibration stability checks using Langley plots, and minimal maintenance make it a unique instrument for column ozone measurement.

4.4 Synthetic Spectra
Plant, animal, and materials effects researchers often want to multiply their particular action spectrum by the spectra measured to estimate damage due to UV. Because of this a study was initiated to use a model to “fill in the pieces” from the 7 channel UV radiometer measurements and construct the entire spectrum. Using the methodology of Min and Harrison (1998) we retrieved a number of synthetic spectra from the 7 channel UV-MFRSR data. We made comparisons of these spectra with spectral measured from collocated spectrometers at Boulder CO (Gao et al., 2002). Erythemal doses are generally within ±5% for all SZA < 75°. The study was presented at the Society of Photo-Optical Instrumentation Engineers UV Meeting in San Diego in July 2001.

4.5 Radiometric Stability
Bigelow and Slusser (2000) evaluate the stability of the Ion-Assisted-Deposition (IAD) filters used in both prototype and production models of the UV-MFRSR. Based upon an initial examination of a few prototype and production instruments it appeared that there was an approximate 1% per year decline in each instruments’ I∞ values due to filter instability. The IAD filters are much more stable than the filters in VIS-MFRSR’s as reported by Bigelow et al. (1998).

4.6 Comparisons of UV-MFRSRs with TOMS and Radiative Transfer Model
Slusser et al. (2002) compared irradiances from a UV-MFRSR with those from a radiative transfer model (TUV) (Madronich, 1993) and NASA TOMS retrievals. Clear sky retrievals at NM and OK generally agreed to within ±4% of the TUV model and the satellite retrievals. Sensitivity tests of the modeled ratio of direct to diffuse irradiances for different aerosol absorption were made for Big Bend of Texas.

4.7 Spectrometer Research Network
Six high resolution U-1000 1.0 m double spectrometers have been developed by Dr. Lee Harrison of SUNY Albany (Harrison et al., 2002). The first has been completed and installed at the NOAA research
site at Table Mountain CO. This instrument has been operating since December 1998 and the performance has been good although there has been a steady decline in responsivity. The instrument resolution (0.1 nm), out-of-band rejection \((10^{-10})\), wavelength accuracy and repeatability \((\pm 0.02 \text{ nm})\), and cosine response exceed the specifications of any spectrometer in the world. Unlike the Brewer, the instrument is tightly temperature controlled, making it extremely reliable for periods of time directly following a calibration. Data from the instrument are being used to calibrate the triad of UVB-1 broadbands which in turn are used to calibrate the 44 USDA UVB1s. The second instrument was installed at the DOE Central Plains ARM CART site near Billings, Oklahoma in September, 1999. The third instrument was sited at the Agricultural Research Service Phyto-nutrients Laboratory at Beltsville Maryland in November 1999. The fourth instrument was sited at Christman Field, Fort Collins, CO in October 2003. This site, local to the UVMRP, will serve as an in-house calibration and research test bed. As a result of budget pressure, there are currently no plans to deploy the remaining two instruments. Budget constraints will make even the routine operation of these four instruments difficult. Currently only the Table Mountain CO instrument has been calibrated. Three automated portable calibrators have been completed and during 2004 will compared to CUCF/NIST 1000 W standards and then be cycled through the four sites to establish calibration. NASA has expressed interest in the data to validate their retrievals, in particular at wavelengths shorter than 305 nm. NASA is also interested in the magnitude of Raman scattering which can be addressed with U-1000 due to its very fine resolution.

4.8 Long Term UVB Broadband Time Series
Frederick et al. (2000) analyzed a four-year time series at 10 USDA sites to determine the influence of solar zenith angle, column ozone, and clouds on seasonal and year-to-year variability in UV irradiances. One conclusion is that variations in cloud cover contribute more than variations in column ozone in the observed year-to-year changes in UV irradiances. The UVMRP collected the broadband monthly sums for all of its sites. These sums show a maximum yearly total at FL and a minimum at ME.

4.9 Other Cooperative Research
In addition to the more formal collaborations noted above the network is often asked to participate in or contribute to other projects. While in general we believe these collaborations to be of benefit to the network technology, we must choose these opportunities with care so as not to overextend our resources.

Funding was secured from NOAA for a full climatological site at Poker Flat, AK. This new site will be an integral part of NOAA’s effort to study the effects of ozone and aerosols on Arctic UV. It was installed in September 2000. This is the first use of a UV-MFRSR in the Arctic. A new site was installed in September in Starkville, MS. Data from the site in MS will be used in collaboration with the research of Dr. K. R. Reddy of Mississippi State University who is studying UV effects on cotton. This data will also be used by Remote Sensing Technology Center at MSU to provide accurate information to support Precision Farming.

5. Agricultural Effects Research
The decrease in stratospheric ozone has prompted renewed efforts in assessing the potential damage to plant and animal life due to enhanced levels of solar UV-B radiation. The effect of UV-B enhancements on plants includes reduction in yield and quality, alteration in species competition, decrease in photosynthetic activity, susceptibility to disease, and changes in plant structure and pigmentation. The enhanced UV-B radiation generally has negative impacts on growth, yield and quality of some crop plants such as soybean, winter wheat, rice, sorghum, cotton and corn. It has been shown that approximately two-thirds of 300 plant species and cultivars are susceptible to damage from UV-B radiation. Better understanding of the effects of elevated UV-B on crops call for more complete and precise studies of how UV-B affects various crops. A wide range of UV impact and other climate stress factors (moisture, temperature, soil nutrients, and CO2) research problems on agriculture have been addressed by the Program. We have developed extensive collaborations and interactions with researchers in agricultural,
natural resources, and science communities.

5.1 The Development of UV Radiation Canopy Transfer Models
The distribution of UV-B radiation varies with different vegetative canopies. Tree canopies often have large natural openings between crowns, whereas incomplete row crops have wide spaces between rows of vegetation. Urban environments consist of complex 3-D arrangements of trees and buildings. Obviously, an advanced 3-D radiation model which considers anisotropic sky radiance penetrating through heterogeneous canopies is needed to evaluate UV-B radiation loading in many plant canopies. We have completed the development of this 3-D UV radiation model with Dr. Richard Grant at Purdue University and Dr. Gordon Heisler at the USDA Forest Service. Tests of the model accuracy were made using field measurements in an open canopy apple orchard and in a closed canopy of maize for cloudless sky conditions. Measured and predicted values of UV-B canopy transmittance generally agreed well. This model can be used to assess the UV-B irradiance below dispersed canopies (agricultural crops, orchards, and trees in urban areas) given initial sky conditions and canopy composition and structure where the individual crown can be described as an ellipsoid. Sky radiance distributions for use in the model are available for clear and overcast conditions. Additional testing would be needed to determine the applicability of the model for partly cloudy conditions. Results of this research were presented in American Society of Agronomy 2000 annual meeting held in Minneapolis in November. The attached paper by Gao et al., “A Geometric UV-B Radiation Transfer Model Applied to Vegetation Canopies” was published in Agronomy Journal 94:475-482. We also compared spatially and temporally averaged measurements of UV-B canopy transmittance through a maize canopy to that predicted by two 1-D models with differing treatments of sky radiance. A 1-D model commonly assumes the canopy structure is horizontally homogeneous with foliage elements randomly dispersed in the canopy horizontal space. This kind of model has been widely applied in dense canopies and usually only requires inputs of leaf area index and angular distribution of foliage surfaces. A newly developed 1-D model by Gao, etc., and a modified 1-D model developed by Meyers and Paw. U were used to simulate the UV-B transmittance in a maize canopy. The paper attached by Gao et al., “Ultraviolet-B Radiation in a Row-crop Canopy: An Extended 1-D Model” will be published on June or July, 2003 in Journal of Agricultural and Forest Meteorology.

5.2 Effects of UV-B Radiation on Cotton Growth, Development and Physiology: Experimentation and Model Development
This research effort is ongoing in cooperation with the research group of Dr. K. Raja Reddy at Department of Plant and Soil Sciences of Mississippi State University. This work addresses our long-term goal of understanding the interactive effects of environmental factors including UV-B radiation on cotton growth, development and yield. The objectives of this study are to test the hypothesis that elevated UV-B radiation will modify the response of transpiration, respiration, carbon acquisition, development, reproduction and yield of cotton, and to understand the physiological, anatomical and phenological basis of these effects. This study is using an internationally unique system of daylight chambers that allow the growth of row crops under complete control of microclimate and atmosphere, with simultaneous precise monitoring of water, carbon, and nitrogen balance throughout the experimental period of the crop. We intend to incorporate the effects of UV-B radiation effects into a physiologically-based crop model, GOSSYM / COMAX, by coupling with the new generation regional climate model built upon the WRF (Weather Research and Forecast Model) framework to assess the effect of future climate changes in the fourteen Southern contiguous states cotton cropping regions of the U.S.

In the year of 2002, the experiment was conducted at the Agriculture and Forestry Experiment Station of Mississippi State, MS using six soil-plant-atmosphere research (SPAR) units. Six treatments include two CO₂ levels of 360 µL L⁻¹ (ambient) and 720 µL L⁻¹ (elevated), and three daily biologically effective UV-B radiation intensities of 0 (control), 8, and 16 kJ m⁻² within each CO₂ level. The [CO₂] and UV-B radiation treatments were imposed from emergence. The UV-B doses of 8 and 16 kJ m⁻² d⁻¹ are designed to
simulate the maximum level of UV-B that would be received on a clear day on the summer solstice with either ambient levels of ozone or with 30% ozone depletion in Mississippi’s cotton production region as calculated by an Green empirical model. Seeds of cotton, cv. NuCOTN 33B, were sown in fine sand of the SPAR soil bins in 3 rows, spaced 67 cm apart. Seedlings were thinned to five per row after emergence. Temperatures in all units were maintained at 30/22°C (day/night) during the experiment. Plants were watered three times a day with half-strength Hoagland’s nutrient solution delivered at 0800, 1200 and 1700 h to ensure favorable nutrient and water conditions for plant growth. Irrigation was provided through an automated and computer-controlled drip system. Variable-density black shade cloths around the edges of plants were adjusted regularly to match plant height in order to simulate natural shading in the presence of other plants. Square-wave UV-B supplementation systems were used to provide respective UV-B radiation under near ambient PAR. The UV-B radiation was delivered to plants for eight hours, each day, from 0800 to 1600 h by eight fluorescent UV-313 lamps (Q-Panel Company, Cleveland, Ohio, USA) driven by 40 W dimming ballasts. The lamps were wrapped with presolarized 0.08 mm cellulose diacetate film to filter UV-C (<280 nm) radiation. The cellulose diacetate film was changed at every 3 to 4 days. The amount of UV-B energy delivered at the top of the plant canopy was checked daily at 1000 h with a UVX digital radiometer (UVP Inc., San Gabriel, California, USA) and calibrated against an Optronic Laboratory (Orlando, Florida, USA) Model 754 Spectroradiometer, which was used to initially quantify lamp output. The lamp power was adjusted, as needed, to maintain the appropriate UV-B radiation level in each treatment and to maintain the distance from lamps to the top of plants at about 0.5 m throughout the experiment. After averaging, the radiation dosages for the plants within UV-B treatments, the actual dosages for the two levels of UV-B treatments were 7.7 and 15.1 kJ m\(^{-2}\) d\(^{-1}\), respectively.

The results indicated that there was some CO\(_2\) × UV-B interactive effects on cotton leaf Pn, phenolics, wax, nonstructural carbohydrate concentrations and other physiological parameters measured (Fig.4). Near current solar UV-B radiation (8 kJ m\(^{-2}\) d\(^{-1}\)) normally observed in US Midsouth cotton production area on sunny days between May and August did not affect cotton leaf Pn and total biomass production,
but significantly increased fruit abscission and decreased fruit dry matter accumulation compared to plants that received no UV-B radiation. A doubling of the current UV-B radiation to 16 kJ m\(^{-2}\) d\(^{-1}\) further reduced not only fruit production, but also total biomass. Decreased biomass from high UV-B radiation was closely related to both smaller leaf area and lower leaf Pn. Elevated [CO\(_2\)] significantly increased Pn, growth and dry matter accumulation in cotton under no UV-B or 7.7 kJ m\(^{-2}\) d\(^{-1}\) UV-B conditions. However, elevated atmospheric [CO\(_2\)] did not alleviate the detrimental effects of high UV-B radiation on cotton Pn and growth, particularly on reproductive growth. Decreased number of fruits in cotton exposed to UV-B radiation suggests that breeding UV-B radiation-tolerant cultivars is important even in the ambient [CO\(_2\)] and UV-B levels, and that tolerance to UV-B radiation will be even more important in future higher [CO\(_2\)] and solar UV-B radiation environments. The data collected will help in our
understanding cotton responses to enhanced UV-B radiation and to develop process-level crop models that can be used in impact analysis and assessment to assist science-based policy decision.

In the year of 2002 this group has presented the research results at the national/international conferences (10 presentations). One graduate student (MS) we supported graduated with his thesis work on UV impact on Cotton. One best student paper award was received by this graduate student from Beltwide Cotton Conference in Atlanta, GA. There were four manuscripts which were in press or submitted for refereed publications.

In summary, our preliminary studies and analysis show that cotton is fairly sensitive to changes projected UV-Radiation in the near future. Important questions to be addressed in the near future should include: how will food and fiber crops will respond to simultaneous changes in climate including UV-B radiation, and what are the thresholds of environmental change (magnitude or rate) above which the existing crop cultivars are unable to adapt to changes projected in climate? Also, research is needed to develop and test tools (simulation models) which can be integrated with climate change and economic analysis models to be used in integrated assessments of impacts of climatic changes on food and fiber crops.

5.3 Application of the aerosol correction into the site-specific agriculture studies
Site-specific agriculture is a new technique that allows farmers to determine exactly how much fertilizer to put on each part of their crop fields. This knowledge helps them to save money on fertilizers and reduces the contamination of the runoff water. Recent advances in satellite remote sensing of agricultural and grazing lands hold the promise of making fine-scale maps available to farmers indicating where the fertilizer needs to go. We provide our data for the atmospheric correction (of remote sensing data from NASA satellite) to the Remote Sensing Technology Center (RSTC) at Mississippi State University. We loaned and managed three additional visible shadow-band radiometers to RSTC to extend the area where they can perform their site-specific agriculture studies.

5.4 Evaluation of UV-B impacts on soybean growth and development and sorghum wax - UV relations
A preliminary experiment to determine how the soybean plant responds to UV-B stress was conducted. Changes in biomass, leaf area, and leaf thickness due to UV-B exposures at 1.8x ambient were completed on the 6 public varieties. The UV exposure significantly decreased plant biomass of Bay, Essex, Forrest, and James cvs. The total plant biomass of York and Williams 82 cv. were not significantly affected by the UV-B exposure. The UV impact was least on Williams 82 which had the largest leaf area of all six cultivars, and dry leaf weight with leaf weight measures were above those of the control group. These results in combination with last years’ 5x ambient exposure and values from the literature suggests that the biomass impacts of UV-B reach a maximum at approximately 1.5x ambient with the plant mitigating any additional impacts on biomass with higher UV-B. These results were presented at the ASA Conference in November.

The exposure needed to induce “sunburn” was evaluated for four soybean cultivars – James, Pioneer 92B91 and 92B63, and Becks 367NRR. Leaf reflectances of the top 3 trifoliates were measured before UV exposure as a control after which the whole plant was exposed to enhanced UV-B (only) irradiance for consecutive periods of 2, 4, (6), 8, or 16 hours. Reflectance measurements were repeated to ascertain how the reflectance varied with time after exposure to UV-B. The largest differences between the control and post exposure measurements appeared within the first 5 hours; after 40 hours the differences were small. Results have been in process to be analyzed. The UV-B+UV-A response of many public soybean varieties (Williams 82, Bay, York, Forrest, Essex, James) were evaluated assuming an increased UV-B exposure of 1.8x ambient. Leaf spectral reflectance measurements were made to determine the degree of ‘sunburn’ evident on the leaves and correlate chronic exposure to ‘sunburn’.
The sorghum epicuticular wax experiments were completed. Results showed that the reflectance could be related to wax amount for only the stalks of the ‘wild type’ P954035 variety. Mutants with similar amounts of wax but with different distributions did not show correlations of wax amount and reflectance. The wax-free UVB reflectance of sorghum leaves and sheaths was 0.04 to 0.05, similar to most tree and crop UVB reflectances. The wax on the mutant leaves and sheaths did not correlate with changes in UV reflectance. The wax on the wild-type caused an 0.10 increase in UVB reflectance based on a wax removal experiment. UVB exposure in the greenhouse increased the wild-type’s leaf reflectance (and wax production) by 0.03 while reducing the sheath reflectance by 0.09, suggesting redistribution of fixed carbon to the leaves under UVB exposure. Part of this work was presented at the ISB conference in October 2002. The above research activities are in cooperation with the research group of Dr. Richard Grant at Purdue University. There were 5 referred papers published or in press and 10 scientific presentations presented in national/international conferences.

5.5 Evaluation of the impact of heliotropism on the reported susceptibility of various soybean cultivars

Heliotropic measurements continued using an improved UV-B+UV-A lighting setup in the UV-enhanced area in the greenhouse and included 4 modern commercially-developed soybean varieties. As in 2001, work was repeated using Bay, Essex, Forrest, York and Williams 82 cultivars, and now included James cv. and one commercial GM cultivar (Becks 367NRR, Roundup ready), and three non-GM commercial cultivars (Pioneer 92B91, 93B82, 92B63). Results showed: 1. Soybean leaf heliotropic movements were complex with leaf movements per hour exceeding solar movement by an average of 28%, 35% and 111% for York, Bay and Williams 82 cultivars respectively. Williams 82 cv. had the greatest heliotropic response of the three cultivars, resulting in the greatest exposure to UV-B under clear and hazy skies. York and Bay cultivars showed less heliotropic movement and this is reflected in the lower UV exposures over the same time period; 2. The absence of significant differences in $\theta$ between the field and greenhouse plants for all three cultivars indicated that the greenhouse environment did not inhibit the heliotropic response of the soybean plants. This signified that the greenhouse provided a satisfactory environment for measuring soybean heliotropic movement if land is not available for field studies; 3. The modeled exposure of Williams 82, Bay and York cultivars demonstrated the differences between the UV-B exposure obtained from assuming the leaves are horizontal compared with realistic leaf angle information. The UV-B exposure of all three cultivars were between 84-94% of the horizontal sensor exposure. This result indicates that an assumption of horizontal soybean leaves in UV-B exposure calculations can overestimate the exposure by up to 22%. A 30% enhancement of UV-B from a combination of UV-B lamps (isotropic) and anisotropic UV-B sky radiance distribution produces in an even greater exposure of Williams 82 and lesser of York and Bay, limiting any direct comparison of UV-B effects between cultivars during the growing season. These results were presented at the AMS Conference in May; 4. The relative exposures between cultivars differed between clear and cloudy sky conditions. Under clear sky conditions and an assumed anisotropic sky radiance distribution, the daily exposure of Williams 82 was greater than Bay and York and lesser in cloudy conditions. Results showed that the proportional exposure depended on the partitioning of diffuse and direct beam and on the percentage of clear versus cloudy sky conditions. UV effects research may misclassify the sensitivity of cultivars to UV-B radiation due to the variation in the ability of the cultivars to track the sun, and may mis-rank the sensitivity of cultivars as a result of the proportion of clear to cloudy skies at the research location. Additional work is needed to understand what proportion of the plant leaves are heliotropic and how the leaves orient under cloud cover. These results were presented at the AMS Conference in May. These research activities are ongoing in cooperation with the research group of Dr. Richard Grant at Purdue University.

5.6 Integrating plant biochemical and phytochemical responses to incident levels of solar UV-B radiation
This research activity is ongoing in cooperation with the research group of Dr. Joseph Sullivan at the University of Maryland. It provides evaluation of short-term plant responses to UV-B such as leaf development, foliar chemistry (photosynthetic and putative UV-screening phenolics) and level of DNA dimers produced in plants developing under contrasting UV-B environments. These responses will be linked with ambient UV-B fluxes obtained from the USDA UV-B monitoring network. The research results could also lead to further understanding about the mechanisms of UV-B responses. Field studies continued over the past year on the responses of plants to UV-B radiation. Particular emphasis was placed on rapid responses that may be modulated by short-term (daily) fluctuations in ambient levels of UV-B radiation, as measured and quantified by the USDA UV-B monitoring network. The season included continued work on a barley model system where we are quantifying the increases in UV-screening compounds in response to a changing UV-B radiation environment. In this system we also sought to assess the protective roles of these compounds in terms of protecting DNA from molecular damage (dimerization). We also initiated new studies on soybean and corn in which the role of ambient levels of UV-B on growth and on photoinhibition were assessed. The long-term goal of these studies was to determine if day-to-day differences in solar UV-B affect the content of phenolic compounds of nutritional interest in the leaves of green-leafy vegetables, in this case Kale. In the initial year of this study, rather than initiate long-term growth studies in the field comparing plants that were adapted to UV-B, we attempted first to determine if plants not adapted to UV-B were capable of rapid responses to short-term (1 day) ambient solar UV-B exposure. A positive relationship was found between ambient levels of UV-B radiation and the amount of UV-B absorbing compounds quantified. However, it was clear from these data that, as expected, factors other than UV-B contributed to changing flavonoid levels in barley primary leaves. McClure and others have previously shown that a suite of environmental factors such as temperature, UV-A, PAR, drought and nutrient status alter foliar levels of flavonoids. Nonetheless, DNA damage levels were inversely related to absorbance levels indicating that increases in flavonoids did provide some preconditioned protection from subsequent exposure to UV radiation. However, we could not show that growth in higher levels of UV-B provided greater protection against DNA damage. This was probably because of the confounding effects of other environmental factors, besides UV-B, on leaf flavonoids. We expand to expand and refine this study for the 2003 field season in an effort to resolve some of these issues.

During the summer of 2002 two exclusion shelters were erected for the purpose of a pilot study of whether ambient levels of UV-B radiation exert a photoinhibitory influence on plants in field situations. Soybean cultivars CNS and Clark and Silver queen corn were grown under either Teflon or Mylar films, which transmit or attenuate UV-B radiation, respectively. Data from these studies are currently being analyzed but in general support the results of the predawn studies. Further data analysis and method development is currently underway in an effort to modify the design as needed for 2003. The research on UV-B impact on vegetable quality was initiated in the year of 2002. The long-term goal was this part of our studies is to determine if day-to-day differences in solar UV-B affect the content of phenolic compounds of nutritional interest in the leaves of green-leafy vegetables.

Three presentations have been made in national/international conferences. Three papers were published or submitted from Dr. Sullivan’s group in 2002.

5.7 UV, abiotic and biotic components of production and decomposition in shortgrass steppe: interactions with CO₂ enrichment
This work investigates the effects of UV and moisture on decomposition and address an important UV plus CO₂ interaction. We intend to assess UV effects on decomposition of plant tissues and fibre qualities. We have focused on three aspects of UV-radiation effects: litter decomposition, litter-dwelling arthropods, and aboveground primary production/tissue quality/plant community composition. For all three, we assess how UV interacts with other multiple stressors under field conditions in native shortgrass steppe. In order to maintain a focus on ‘abiotic’ versus ‘biotic’ components of decomposition, we used
the biocide treatment and added the arthropod/microorganism component. The fauna-decomposer work is mostly supported through the CO2 project at USDA-ARS/CSU and John Moore’s lab at University of Northern Colorado. This work is closely linked to the decomposition part of the study, and is important in the context of the ‘abiotic’ versus ‘biotic’ components of decomposition focus as explained below. To date, three sets of litterbags have been collected. The most recent samples have been analyzed for mass loss and are currently being processed for chemical and quality analyses. The UV-B impact on decomposition, arthropod, and plant community has been assessed. This research activity is ongoing in cooperation with the research group of Dr. Daniel Milchunas at Colorado State University. Three presentations have been delivered in national conferences.

6. Publications and Conference Presentations

6.1 Referred publications


6.2 Proceedings publications


Bawhey, C., R.H. Grant and W. Gao. 2002. Soybean heliotropism and UVB dose estimation. pp 55-56 In:


### 6.3 Conference talks


6.4 Subcontracts publications


7 Recommendations for Future Work and Five Year Plan

7.1 Recommendations

Calibration and instrument stability will continue to be major areas of concern in 2004 and beyond. We will to support the CUCF and SUNY Albany in addition to the various UVB agricultural effects subcontracts. In response to the direct request from Congress that we supply more of our data to
agricultural effects researchers, we will support several of these efforts. Wherever possible we will pursue strategies that increase our independence from costly CUCF calibrations. During FY 2004 the UVB Monitoring and Research Program will:

- Continue the development of *in-situ* techniques that establish reliable calibrations for its instrumentation. The recently implemented Langley calibrations allow the network to gain independence from expensive calibration facilities as well as track stability. If it can be demonstrated that the filters are stable, repeat spectral calibrations will be no longer required. The triad of UV-MFRSRs at CPER, designed to transfer calibrations to other heads, will be used to explore transfer calibration techniques. The in-house cosine response measurements will be pursued.

- Continue to fund the calibration of all of its instrumentation at the CUCF in Boulder CO during FY 2004.

- Continue UV agricultural impact studies.

In addition the network has collected collocated data with 2 sites of the Canadian Brewer Network, and 3 sites of the US EPA Brewer Network. Although available manpower limits the amount of time available for analysis, it is of enormous benefit to the networks and the UV Global Change Research Program to know how comparable these networks and instruments are to one another. In addition we will:

- Compare UV retrievals for several sites where NASA has expressed particular interest. Include USDA data, TOMS and standard UV radiative transfer models.

- Use broadband data to develop the first US UV climatology.

- Provide ground-truth (UV, aerosol optical depths, and column ozone) for existing and new NASA satellites.

- As time permits compare USDA measurements with the Canadian and US-EPA Brewer Networks. This will establish a firm relationship between the principle North American USCRCP ground-based satellite based UV monitoring programs.

To complete the original design of 30-40 stations the network will need to establish partnerships with local research and monitoring programs:

- Develop and establish a partnership program for those willing to follow network protocols to enable local UV research data to be brought into the network data system.

The longest network record of UV measurements has been collected with broadband meters (Frederick et al., 2000). Recent scientific literature (Bodhaine et al., 1998; Lantz et al., 1999) has demonstrated that ozone and solar zenith angle need to be considered when establishing calibration for this class of radiometers. All 44 of the network’s broadband meters have been re-characterized to these new scientific standards.

- The erythemal broadband calibration should be applied, first to all new and second to all old data. This will allow most of the historical data in the network to be re-processed thus allowing the previously established 5 year measurement record to continue without interruption.
The network continues to be a leader in providing radiometric data to the scientific community and the public at large. The data however only meets minimal quality standards. A more robust and lasting quality coding system needs to be implemented to ensure data users can have confidence in the quality of all data.

- Quality coding should be developed for and implemented with the current data set to elevate the data to a Level II quality product (Gibson et al., 1998; Table 1).

- Old data (back to January 1, 1998) should be coded when time permits

7.2 Five Year Plan
During the next five years the UVB Program will continue its leadership in providing quality UV data to interested users, especially to agricultural effects researchers. The first requirement is that we have good data. To accomplish this goal we will continue efforts at improving calibrations of the UV-MFRSR and broadband as well as implementing QA and QC of all our data. To further this goal we will continue research of the Langley method and support of the CUCF. The CUCF has become the world’s premier UV calibration facility and should be given our continued support. We will cooperate with Yankee to keep open a fall-back calibration option should potential budget restrictions ever make CUCF unaffordable. We will evaluate the single diode array spectrometer (UV-RSS), manufactured by Yankee. The UV-RSS is a single prism array spectrometer which retrieves the entire spectrum simultaneously but may suffer from stray light contamination at wavelengths shorter than 305 nm. The SUNY 1.0 m double scanning spectrometer is promising but has not yet established sufficient stability to warrant unconditional 5 year support. Nor have compelling scientific objectives for the data of the 1.0 m instrument been identified. The instrument is a scanning device that has superb stray light rejection and wavelength accuracy. Therefore we will evaluate its continued support on a year-to-year basis.

We will continue work with the NASA TOMS group to help them to improve their satellite based UV retrievals. TOMS UV retrievals also form an important QC check on our data. This collaboration will involve research on the role of clouds, aerosol optical depth, and aerosol single scattering albedo on UV transmission. This collaboration will lead to the first US UV climatology which is one of the major goals of the USDA UVB Monitoring Program. New satellites such as the Triana Mission will allow continuous retrievals of UV instead of the once per day TOMS overpass, thus improving the ability of satellite UV retrievals for the UV climatology.

Where appropriate we will continue our support of research in agricultural responses to increased UV. The criteria for selecting potential projects to support are: cutting edge crop research on economically and politically important crops; researchers with outstanding publication records.

We are in a unique and fortunate position to lobby Congress, which specifies the funding levels for our Program. We consult regularly with them on what they perceive our priorities should be. As a direct result of the feedback we received from key Congressional aides during 2000, we commenced the support of four subcontracts that investigate the response of agricultural plants to UV. This resulted in a restoration of $434,000 of previously cut funds in FY 2002 and in an increase of $847,000 for FY 2004.

8 References


