

## Acknowledgments

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## **Recommendations of the UV-B Monitoring Workshop**

### **CRITERIA FOR STATUS-AND-TRENDS MONITORING OF ULTRAVIOLET (UV) RADIATION**

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#### Introduction

The first USDA-sponsored UV-B workshop was held in Denver, Colorado, on January 22-25, 1991<sup>1</sup>. The second USDA workshop, the recommendations of which are summarized in this report, was held in conjunction with a program of technical presentations organized by the Alternative Fluorocarbons Environmental Acceptability Study (AFEAS) (the published proceedings will be available from AFEAS<sup>2</sup>). The purpose of the USDA-sponsored section of the workshop was to address UV-B monitoring issues not adequately resolved in the Denver workshop, with emphasis on developing requirements for a cost-effective monitoring network to obtain UV-B climatology over wide geographic areas of the U. S. For those not familiar with the objectives and report from the first workshop, it is instructive to repeat a portion of the introduction to the report.

*"As a result of stratospheric ozone reduction, there is a real potential for the flux of ultraviolet radiation (UV) to increase at the earth's surface. While there is little evidence that this has yet occurred to a measurable extent except in polar regions, this lack of evidence may be a result of an inadequate radiation measurement system or the fact that the incoming UV radiation is being filtered by our polluted atmosphere. However, based on the continuing emission of chloro-fluorocarbons and other ozone-reducing chemicals, there is every reason to believe that decreases in stratospheric ozone will continue and that the flux of UV radiation will eventually increase at mid-latitudes. There is concern that any*

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<sup>1</sup> Gibson, J. H., 1991. "Justification and Criteria for the Monitoring of Ultraviolet (UV) Radiation", Report of UV-B measurements workshop, Denver, CO, January 22-25, 1991. Natural Resource Ecology Laboratory Colorado State University, Fort Collins, Colorado 80523.

<sup>2</sup> UV-B Monitoring Workshop, 1992. "UV-B Monitoring Workshop: A Review of the Science and Status of Measuring and Monitoring Programs", AFEAS, Science and Policy Associates, Inc., West Tower, Suite 400, 1333 H Street, NW, Washington, DC.

*future increase poses a threat to the biosphere. All are aware of the human health effects resulting from long-term exposure of human skin and the fact that more attention is being paid to eye protection. Plants, both aquatic and terrestrial, have developed mechanisms to protect against UV radiation damage but still suffer reduced growth in response to increased UV irradiance (flux). Damage to man-made materials, plastics, paints, fabrics, etc., is well known. Any increase in irradiance will accelerate these effects and in the case of crops, could lead to decreases in agricultural productivity. For these reasons, and to gain a better understanding of the atmospheric processes that control the flux of UV radiation reaching the earth's surface, there is a need for an improved system for the monitoring of UV irradiance in order to provide information on the geographical patterns and temporal trends.*

*Because of the threat to plants and thus agricultural productivity, the U.S. Department of Agriculture (USDA), through the National Research Initiative Competitive Grants Program (NRICGP), has established a program to acquire better spatial and temporal data on UV irradiance in order to assess the effects on crops and to support research on the fundamental processes controlling biological response to UV radiation. An understanding of the response of living systems is needed to forecast effects resulting from a potential increase in UV irradiance and to develop strategies for mitigation. This USDA program will provide support for a national-scale monitoring network to measure UV irradiance, with emphasis on the 290-320 nanometer spectral region of the UV-B, the spectral range most important in assessing plant as well as human health effects.*

*Before launching this program, USDA scientists felt that it was important to gain the insight of the scientific community in identifying research needs and in establishing criteria for a measurement system to meet those needs. Scientific input was desired not only from the biological effects community but also from scientists involved in atmospheric studies and instrumentation design and measurements. It is also the desire of USDA to link a radiation monitoring program with other national and international efforts. In order to accomplish these objectives, a workshop was organized to address the information needs and measurement criteria. . . ."*

Participants at the Denver workshop were "asked to address the following:

- 1. Information needs for research and monitoring: objectives to include the determination of spatial patterns (status) and characteristics of UV-B radiation as well as the documentation of temporal trends.*
- 2. Instrument characteristics including: wavelength range, resolution, and the photometric accuracy required to meet the identified information needs for research and monitoring as well as the need to consider the trade-off between cost, and resolution and accuracy.*
- 3. Ancillary atmospheric measurements necessary to interpret UV-B measurements including: cloud cover, aerosols and particulates, UV-absorbing gases (e.g., O<sub>3</sub>, SO<sub>2</sub> and NO<sub>2</sub>), surface albedo, etc.*
- 4. Frequency of sampling for a status-and-trends monitoring network.*

5. *Areal coverage required for a status-and-trends monitoring network.*
6. *Linkages with other UV-B or atmospheric measurement programs."*

Recommendations from the first workshop defined scanning spectroradiometer specifications more stringent than those of any readily available instrument which led to the award of a grant from the USDA CSRS to design and build an instrument which would meet or exceed the recommended specifications. It was recommended that six of the instruments be acquired and placed at locations yet to be determined. The deliberations, however, did not adequately address issues related to the acquisition of information on UV-B irradiance over broad geographical regions in order to gain an understanding of the "UV-B climatology". Because of the number of instruments that would be required, both the initial and operating costs of instruments meeting the specifications developed at the first workshop make them impractical for broad regional coverage. As a result, the second workshop was organized to address issues related to the "affordable" acquisition of data from a larger number of sites adequate to provide a realistic representation of the UV-B climatology. Since the geographical variability of UV irradiance is not known, the number of sites required is uncertain. It is estimated that the number in the continental U.S. would likely exceed 20.

#### Discussions of Information Requirements

The questions to be addressed in the second workshop were, to a large degree, the same as those in the first workshop but with emphasis on requirements for a network capable of determining UV-B climatology (status-and-trends) over large geographical areas. It was understood that in order to provide affordable instrumentation, it would be necessary to relax the specifications for irradiance and wavelength accuracy and the wavelength range (280-400 nm) developed at the first workshop. It was emphasized that the information needs should be based on issues requiring a knowledge of UV-B irradiance over broad geographical regions. For example, what is the range of UV exposure in different regions (i.e. a baseline data set) and is irradiance increasing and approaching levels that pose a threat to agricultural crops, forests or animals? Such information is needed, for example, by agricultural scientists to develop resistant crops and mitigation strategies that would be used by farmers to minimize productivity losses. A UV-B monitoring program could serve as an early warning system on a regional basis which would be of importance not only to agriculture but also to the well being of humans. The so-called "RB network" established to determine human exposure is the only such monitoring program active today in the U.S. This network is limited in size and sites are located in urban areas. Also, there has not been an adequate QA/QC program and future funding is uncertain. In general, status-and-trends data are needed to:

- ! Provide a basis for risk assessment on a regional and national basis.
- ! Establish baseline conditions in order to assess future trends and evaluate policy decisions regarding stratospheric ozone depletion.
- ! Justify development of future mitigation strategies.

- ! Provide input to and verification of radiation transfer models for estimating UV-B irradiance.
- ! Guide future research in effects on agriculture, materials, and human health and atmospheric properties affecting UV-B irradiance.

In order to meet the requirements for a status-and-trends network, it will be necessary that the measurements truly reflect the magnitude of UV-B irradiance (wavelengths < 320 nm) with sufficient accuracy and long-term stability to detect small trends ( $\approx 5\%$  per decade). It is acknowledged that a 5% trend in UV-B irradiance, despite the fact it might exist, might not be significantly determined from monitoring data alone because of the variability resulting from variations in cloudiness, tropospheric ozone, air pollution, surface reflectance, and annual variations.

The question posed to the second workshop was whether or not useful measurements could be made based on specifications which would permit the design of an affordable instrumentation which could be deployed and operated at a large number of sites. In the previous workshop, the recommended specifications reflected the information needs of the research communities and thus the requirements for state-of-the-art instrumentation. In this second workshop, it was not clear that the participants felt that relaxation of specifications to the point where significant reductions in equipment and operational costs could be achieved would provide data of adequate quality. Some strongly felt that it would be necessary to obtain irradiance data down to 295 nm. With the added requirement to detect trends of  $\approx 5\%$  per decade, specifications would approach those of a research instrument. Those involved in instrument design pointed out that in order to lower the cost significantly, it would be necessary to limit the shortest wavelength to 305 nm and even then accuracy and stability would be a problem. This dilemma was not satisfactorily resolved.

### Recommendations

Rather than addressing the information needs which would help to define specifications for wavelength range, wavelength and irradiance accuracy, and long-term stability, recommendations reflected the urgency in organizing a network which would require evaluation of readily available instruments including broad-band. It was recognized that available instruments might only partially serve user needs and thus, a parallel effort to encourage prompt development of cost effective instruments capable of providing the information needed by important user groups would be critical. Five major recommendations were made to guide the USDA/CSRS in the development of their future monitoring efforts. These were:

1. There should be continuing strong support for the procurement and deployment of the scanning spectroradiometers based on specifications developed at the Denver workshop. Adequate support should be available for operation of this reference network. The original recommendation for six sites should be

reviewed and consideration given to increasing the number. These sites should serve as reference sites for monitoring programs in the U.S. and for evaluating the performance of the monitoring instruments deployed at the status-and-trends network sites.

2. A status-and-trends monitoring network should be initiated with the deployment of 10 to 20 sites, including co-deployment with the reference instruments at the intensive sites. Ancillary measurements at all sites should provide information on solar radiation and cloud cover, surface albedo and if practical, aerosol optical depth and surface meteorology. One or more teams of scientists should be appointed to advise on a number of issues:

- ! Information needs of data users: research, risk assessment and mitigation, and policy development
- ! Selection of instrumentation
- ! Calibration and characterization procedures
- ! Future instrument selection/development
- ! Necessary ancillary measurements
- ! Site selection
- ! Network organization, operations, and management; data management and QA/QC program
- ! Coordination with programs of other agencies and non-governmental organizations
- ! Linkages to establish comparability with non-U.S. monitoring programs

3. The development of instrumentation alternatives should be strongly encouraged with the emphasis on increased information content, long-term stability, reproducibility, and accuracy of the irradiance measurements. These could take the form of instruments with scanning monochromators or instruments measuring several fixed wavelengths. Specific recommendations for photometric accuracy and wavelength range were not offered. A wavelength limit below 300 nm would be desirable and a long term stability adequate to detect a change in UV-B irradiance of 5% per decade. Specific recommendations included:

- ! Sensitivity to UV-B with a radiation amplification factor of 0.5-2.0 with respect to ozone
- ! Lower wavelength limit below 300 nm desirable
- ! Spectrally scanned data are desirable but if multi-wavelength, values should be chosen to optimize modeling of spectra
- ! Total horizontal irradiance
- ! Direct/diffuse ratio measurements desirable
- ! Long-term stability of  $\pm 2\%$  of reference radiation between calibrations
- ! Temperature independent

! Autonomous operation

4. With the many instruments being used world-wide in research and deployed in monitoring networks, an instrument intercomparison program should be planned for the summer of 1993 to be carried out at the Department of Energy (DOE) Atmospheric Radiation Measurements (ARM) site in Oklahoma. Based on previous such intercomparisons in the U. S. and Europe, there should be careful planning with adequate facilities for characterization and calibration. NIST should take the lead in organizing the program.
5. Future development of UV-B climatology information may be possible using satellite derived information as input parameters in radiation transfer models. Close coordination should be maintained with the modeling community to assure that the reference and regional climatology network will provide ground truth for model estimates. In addition, an evaluation should be initiated to determine the uncertainties in modeling UV-B irradiance at wavelengths shorter than 300 nm from irradiance measurements made above 300 nm.

### Summary

There was general agreement that there is a need to provide status-and-trends information on UV-B irradiance in the U.S. While many workshop participants were not enthusiastic about the prospect of deploying available broad-band instruments, it was generally recognized that this might be the only alternative, given the immediate urgency of establishing a network. The agreement to possibly proceed with broad-band instruments at a limited number of sites was based on a commitment to carefully evaluate the performance of candidate instruments before making a choice and to seek better qualified alternative instrumentation as soon as possible. It was recommended that a panel(s) of scientists be formed to provide guidance for instrument and site selection and network operations.

# UV-B MONITORING WORKSHOP

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