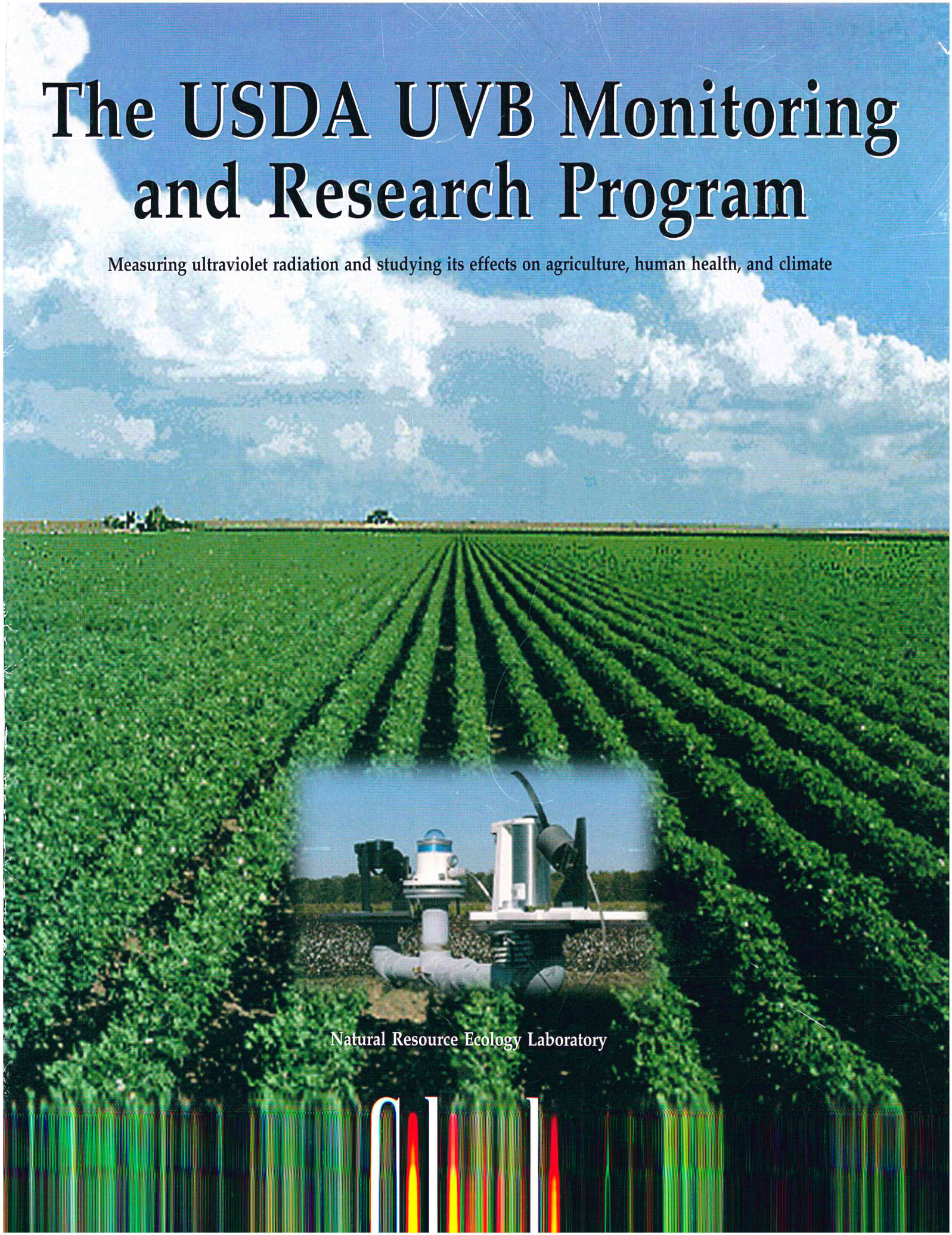
# The USDA UVB Monitoring and Research Program

Measuring ultraviolet radiation and studying its effects on agriculture, human health, and climate



Natural Resource Ecology Laboratory

This brochure is published by the USDA UVB Monitoring and Research Program.

Managing Editors: James R. Slusser and Wei Gao

Assistant Editors: James H. Gibson and George Janson

Writing: Kathy Hayes

Photography: Richard Grant, Joseph Sullivan, Raja Reddy, George Janson, and Bill Cotton

Cover Design: Julianne Schempf, Design Intern

Project Manager: Kathy Phifer

Production: Lisa Schmitz

Office of Publications and Printing, Colorado State University

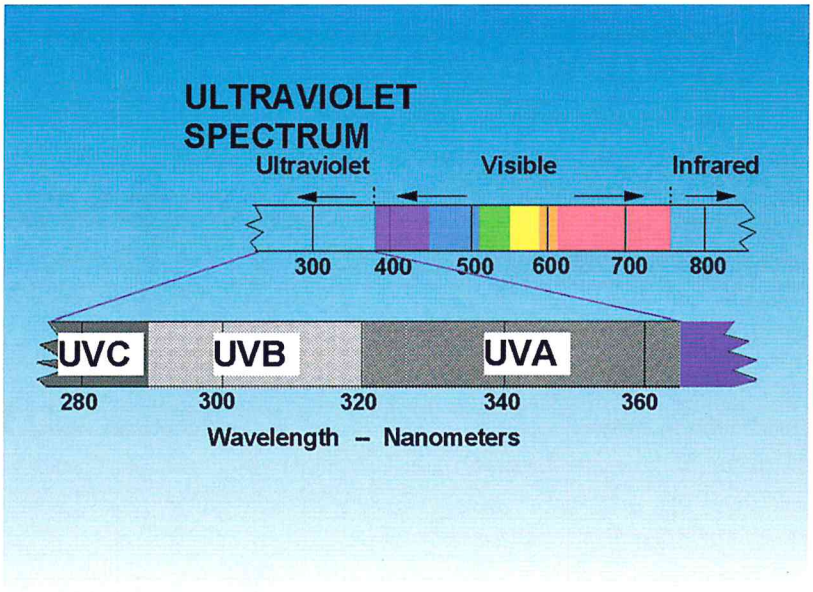


Located at Colorado State University's Natural Resource Ecology Laboratory, the USDA UVB Monitoring and Research Program:

- provides high-quality geographically distributed ultraviolet-B (UVB) radiation measurements to support atmospheric science research and studies regarding UVB effects on plants, ecosystems, humans, animals, and aquatic systems;
- conducts UVB impact studies on economically important crops, and collaborates with researchers nationwide studying the response of plants to UVB radiation and other environmental stress factors; and
- works with NASA to improve its satellite retrievals of ultraviolet radiation, ozone, and aerosols to develop the first United States UV climatology.

Aerial view of Colorado State University campus.

UVB is composed of invisible light that has a shorter wavelength than the light we can see. The illustration at right shows where UVB lies in relation to the visible light from the Sun.




radiation reaching Earth. UVB burns skin and is a major cause of skin cancers, cataracts, and immune-system damage to humans and animals. It can cause mutations and permanently harm plants, forests, and entire ecosystems. Materials used in daily living, such as plastics and paints, also deteriorate from exposure to UVB radiation.

At the root of ozone depletion are emissions from chloro-fluorocarbons (CFCs) used in refrigerators and air conditioners, as well as the agricultural fumigant methyl bromide. Even though recent legislation has helped reduce these pollutants, additional factors, such as global warming, are slowing down the rate of ozone recovery. Scientists now predict it will take 50 years or more to repair the ozone layer, if every nation does its part to stop releasing CFCs into the atmosphere.

As members of a global society we need to work together to address problems that affect the health of all living organisms on Earth. Taking steps now to replenish the ozone layer will help ensure the health of present and future generations. To protect humanity and the food, fiber, and water supplies that sustain us, we must act now to ameliorate the effects of too much UVB.

**Ozone:** Primarily located in the atmosphere 10 miles above the Earth, this trace gas filters out most of the Sun's burning ultraviolet radiation.

**Ozone depletion:** The effects of CFCs, bromine compounds, and other chemical pollutants that cause depletion of the ozone layer.

**UVB:** That portion of the light spectrum that is capable of damaging biological organisms.

# A USDA RESPONSE: UVB MEASUREMENT AND RESEARCH

What is too much UVB? No one really knows for sure. That was one conclusion reached among UVB experts worldwide who were brought together by the USDA in the early 1990s to discuss the potentially harmful effects of UVB, particularly on United States agriculture. At that time, no methods existed to measure accurately both the amounts of UVB reaching the Earth's surface and the factors affecting UVB transmission through the atmosphere. The group recommended that the USDA establish a network to do this.

In 1992, the USDA UVB Monitoring and Research Program was established. Its mission is to measure accurately the UVB at the ground and to develop a UVB climatology and critical data to support research on the effects of UVB on plants, humans, animals, and materials. In addition, program scientists actively participate in research projects designed to increase the understanding of the impacts of ultraviolet radiation on agriculture as well as human and ecosystem health.

In this publication, we will explain what the UVB Monitoring and Research Program does and how its measurements, research, and collaborations are advancing our understanding of UVB and its effects on U.S. agriculture, ecosystems, and human health.

The USDA UVB Monitoring and Research Program accurately and comprehensively measures UVB to establish baselines and to support ecological research. In addition, we provide data in the visible part of the spectrum. Each of the 30 stations in the program network provides temperature, relative humidity, and ground reflectivity data as well.

# WHAT THE USDA UVB MONITORING AND RESEARCH PROGRAM DOES

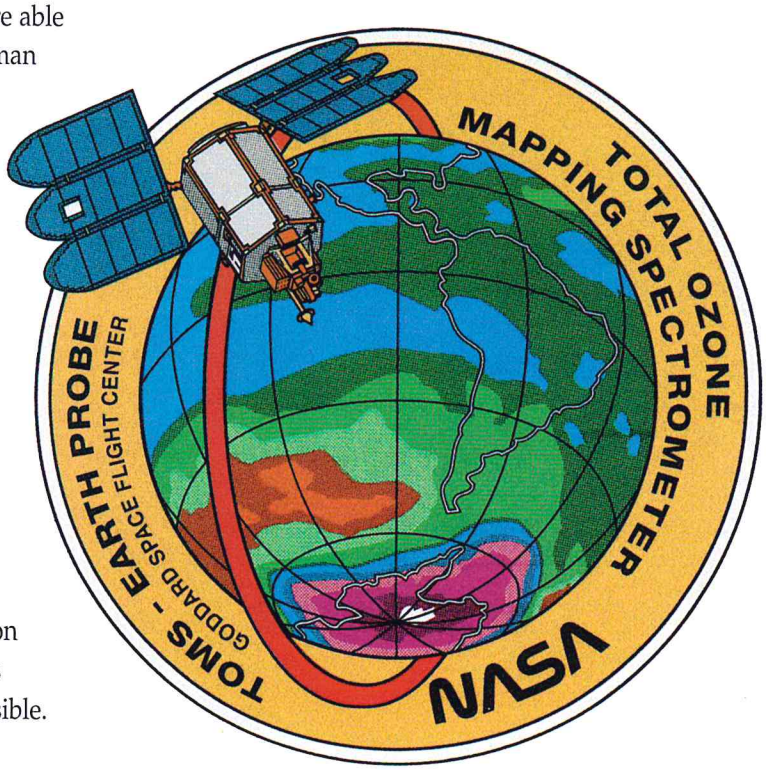
When the USDA established the UVB Monitoring and Research Program at Colorado State University in 1992, its intent was multifold: we were to develop the instrumentation, infrastructures, and networks that would allow us to provide accurate and comprehensive high-quality UVB measurements. These measurements were then to be used to develop seasonal and geographical baselines for ultraviolet radiation and to support biological and atmospheric science research.

Because we are a USDA program, our foremost goal has always been to generate UVB radiation measurements that can be used to ensure the vitality of U.S. agriculture and livestock, which support our nation both nutritionally and economically. More than that, with the instruments we've developed and the collaborations we've established, we are able to extend our data beyond agriculture and into the realms of human and environmental protection. In partnership with NASA, for example, we are working to develop the first United States UVB climatology. Such climatologies are needed to establish baselines for agricultural experiments and human health and materials protection studies.

We are also involved in ongoing, long-term research collaborations to study the effects of UVB on some of our nation's most economically important crops – namely, cotton, soybeans, corn, wheat, rice, sorghum, and grasslands. Additionally, we provide information to others who are doing UVB impact studies.

In a broader sense, we support research that increases our understanding of the factors that govern UVB radiation, and we provide the data needed to assess how UVB impacts plants, ecosystems, people, and materials. Scientists and the public rely on us for the most accurate and easily accessible UVB measurements available. Our instruments, network, and web site make this possible.

The USDA UVB Monitoring and Research Program is working closely with the NASA TOMS group to develop the first U.S. UV climatology.



# STATE-OF-THE ART INSTRUMENTS YIELD PRECISE INFORMATION

In 1990 and 1992, when experts in the UVB measurement, modeling, and effects community convened at the behest of the USDA, they acknowledged that attaining accurate UVB measurements was an essential first step to understanding and responding to the effects of UVB. While UVB had been measured for many years, existing instruments were unable to simultaneously measure UVB and the factors affecting its transmission through the atmosphere.

Once the USDA UVB Monitoring and Research Program was established, our first task was to develop state-of-the-art instrumentation that would provide accurate, reliable, and comprehensive measurements of UVB and related factors.

The shadow-band radiometers we now use are superior to other instruments that measure UVB. We still have broadband UV meters measuring ultraviolet radiation. Broadband measurements date back to the 1980s. Our broadband measurements maintain a continuation of these important records. Our advanced instruments measure total, direct, and diffuse radiation at 300, 305, 311, 317, 325, 333, and 368 nanometers, each of which characterizes a specific factor affecting UVB. With these tools, we are providing the quality and breadth of data needed to support biological and atmospheric research on the effects of UVB.

Our shadow-band radiometers use a computer-controlled, automatic rotating shadow-band, which determines near-simultaneous measurement of total horizontal, direct normal, and diffuse radiation at each filtered passband.

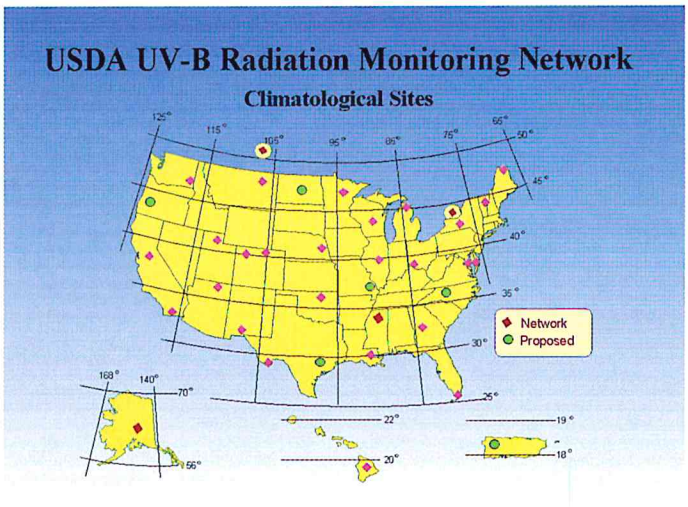
Our broadband UV meters measure ultraviolet radiation in the UVB spectral range of 280-330 nanometers.

# MEASURING GEOGRAPHIC DISTRIBUTION OF UVB

Our program is part of the first nationwide attempt to monitor ultraviolet radiation levels and the factors affecting UV transmission through a network of computerized, remotely driven radiation sensors.

Located at 28 sites across the United States, including Alaska and Hawaii, and two sites in Canada, our instruments are spaced in a grid to allow coverage of the entire United States. Through this network, we can provide comparable, standardized measurements of ground UVB radiation. We purposefully located most of our sites in areas where agricultural research is being done.

Every 20 seconds, we take radiation readings via unmanned instruments that are connected to a dedicated phone line. That data is collected and synthesized each night, and by the next morning, the calibrated data have been posted on our web page. In addition to helping agricultural researchers and other scientists in related fields, our web site and research results are used in schools, seminars, and press releases to educate students, teachers, and the public about UVB and its effects.




Every 20 seconds, remotely driven shadow-band radiometers at 28 U.S. rural sites and 2 Canadian sites take readings of ultraviolet radiation reaching the ground. These uniform, standardized UVB measurements are then posted to our web site the next day.

# GUARANTEEING ACCURACY

Although we use the most sophisticated UVB-measurement instruments available, we must regularly calibrate them to ensure their accuracy. To this end, we support a facility at Boulder, Colorado's, National Oceanic and Atmospheric Administration (NOAA) laboratories where our instruments are accurately calibrated. This facility has been recognized as the premier UV calibration facility by the World Meteorological Organization and is in direct contact with the National Institute of Standards and Technology, which oversees the accuracy of all procedures.

In addition, our shadow-bands use the Sun itself to calibrate the instruments automatically in the field, so their accuracy can be determined on location to supplement the costly and time-consuming laboratory calibrations.

Our state-of-the-art Central UV Calibration Facility in Boulder, Colorado, allows the most accurate characterizations of our instruments' stability and calibrations.

# FACTORS AFFECTING UVB RADIATION AT THE GROUND

If we lived in a world that was static and two-dimensional . . . if solar radiation reaching the Earth's surface didn't travel through clouds or pollution . . . if it struck every surface at the same angle all the time . . . if every place on our planet were at the same altitude . . . if the Earth's reflective surfaces were identical across the board . . . if seasons and temperatures remained constant, it's remotely conceivable we could measure ultraviolet radiation in one place and simply apply that same measurement to other areas to study and assess the effects.

But we live in a world of constant fluctuations and variations. Differences in latitude, altitude, season, climate, and other variables play a huge role in determining the amount – and the effects – of UVB radiation that reaches any point on Earth at any particular time.

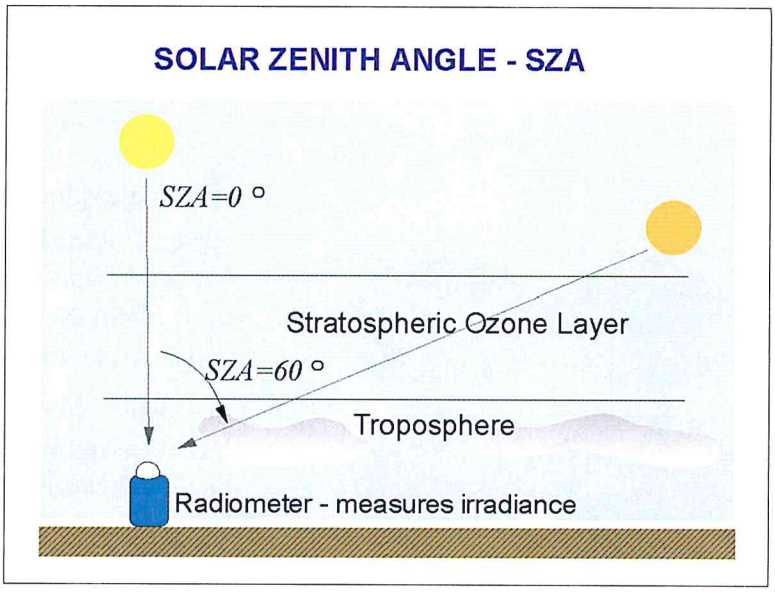
Because ozone absorbs UVB, it is important to know the total amount of ozone that solar radiation encounters before reaching the Earth's surface. This is referred to as "column ozone," because it is the total amount of ozone in a column between the Earth's surface and the top of the atmosphere. Column ozone is measured in Dobson Units, or DUs.

It is also important to measure ozone under all sky conditions; our instruments allow us to do this.

The amount of radiation that passes through the atmosphere also depends on the elevation above sea level and the angle of the Sun with respect to a point on the Earth's surface. The higher the elevation above sea level, the shorter the path through the atmosphere that the radiation has to travel, which results in increased radiation.

The lower the Sun is in the sky, the longer the path through the atmosphere and the greater the amount of ozone and air molecules that UV radiation encounters as it passes to the Earth's surface, thus lowering radiation.

The angle of the Sun depends on three factors: latitude, time of year, and time of day. This angle is called the solar zenith angle and is the angular




The angle of the Sun determines the length of the path of radiation before it reaches the Earth's surface.

difference in degrees between directly overhead and the Sun's actual position.

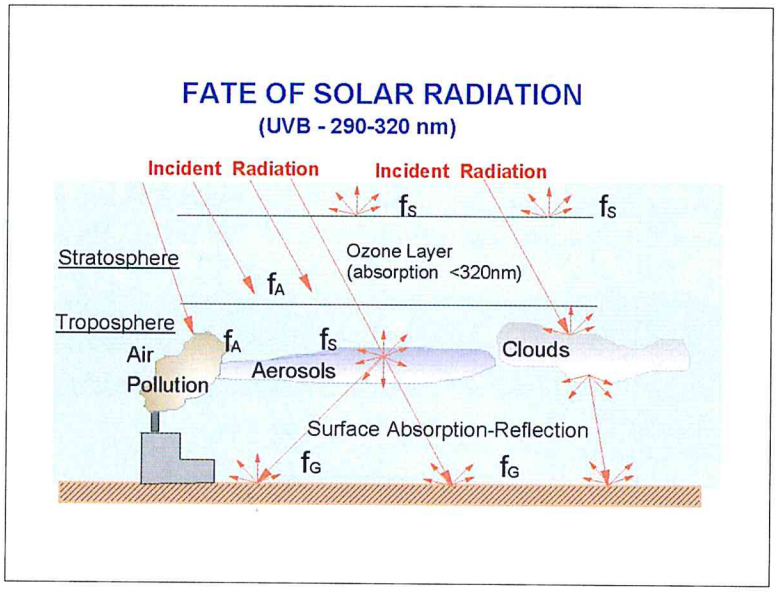
Where you are has a large effect on the UVB radiation you may receive for a given exposure time. If you're in Las Cruces, New Mexico, on June 21, for example, at 32.6° north latitude, on a clear day with an ozone level of 300 DU, you would receive UVB radiation 1.24 times greater than the radiation you would receive in Seattle, Washington, at 47.7° north under the same atmospheric conditions. At lower latitude the Sun is higher in the sky, resulting in a shorter path length through the atmosphere.

Clouds and pollution, which scatter radiation, also have a large effect on UVB levels at the Earth's surface. Other factors affecting UV amounts include the Earth's reflective surfaces and canopies that provide partial or complete shade from the Sun.

All these factors govern the amount of ultraviolet radiation that actually penetrates a particular location at a particular time, making it a challenge to measure precisely ultraviolet radiation at the Earth's surface.

The instruments we use in the USDA UVB Monitoring and Research Program measure these variables and provide important data not available elsewhere. Our shadow-band spectrometers can separate direct radiation from diffuse radiation and provide corresponding measurements of each. These measurements are critical to the accuracy of studies on the effects of UVB radiation on crops and air pollution.

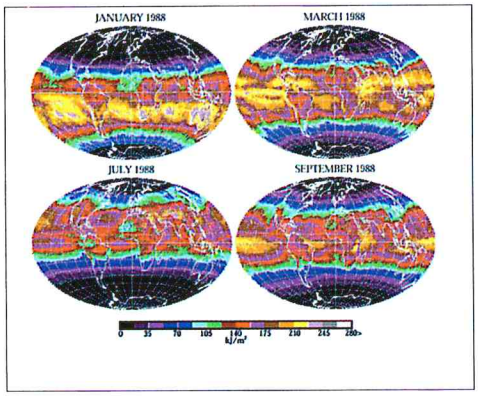
The variables we retrieve from our UVB measurements are total ozone, and cloud and aerosol optical depth.




The illustration depicts the three factors that affect the transmission of solar radiation to the Earth's surface. These are absorption in the atmosphere ($f_A$) by ozone and air pollutants, scattering back to space ($f_S$) by molecules, clouds, and aerosols (haze), and absorption by the ground ($f_G$).

Spectrometers, which measure the entire UV spectrum, typically take more than 10 minutes to complete measurements. From our seven-channel data we can construct a continuous spectrum that simulates a spectrometer measurement. A major advantage of our instrumentation over all others is that the shadow-bands measure these seven channels simultaneously.

# APPLYING THE DATA



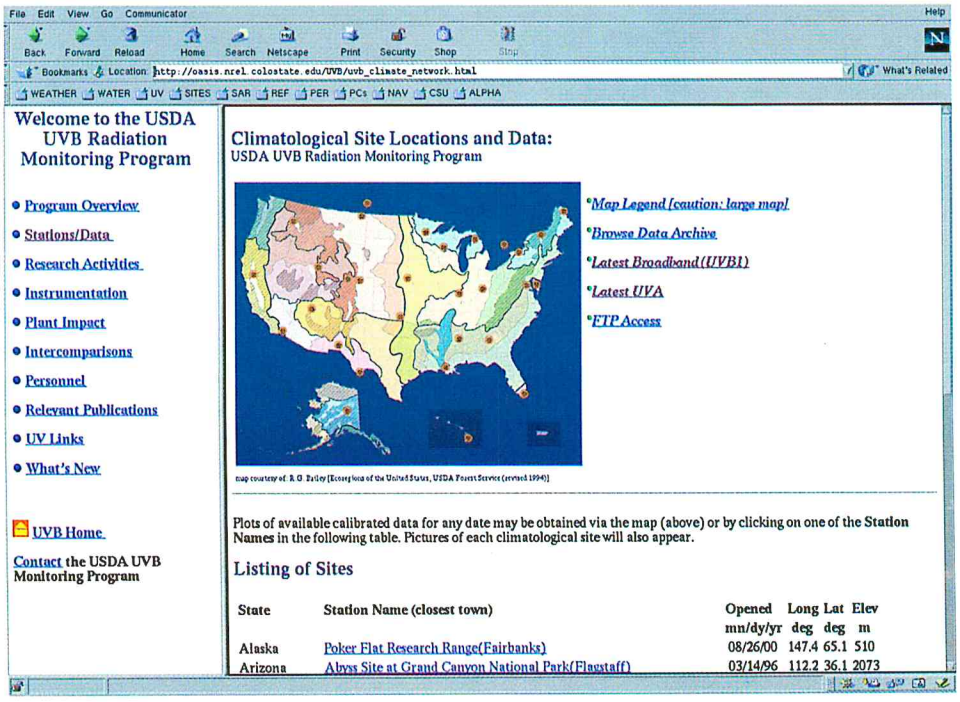

The UVB Monitoring and Research Program provides NASA with ground-retrieval data to enhance the accuracy of global maps generated from satellite measurements. (Courtesy of Jay Herman, NASA TOMS group)

Some features of the UVB Monitoring and Research Program web site are current UVB data, an illustration of our data-collection network, descriptions of our research activities, and links with other ultraviolet radiation web sites.

The USDA UVB Monitoring and Research Program generates data that is used to assess long-term trends in UVB radiation and climate changes. Many environmental factors affect climate change, and UVB is one of them. NASA, NOAA, and the U.S. Department of Energy all make use of our data to study the factors that lead to climate change.

In addition, NASA relies on our data as ground-truth for its satellite measurements. While NASA's satellite can produce full spatial maps of the Earth's climate, it must defer to our ground measurements to ensure high accuracy of its UV retrievals. Eventually, through this collaboration, we will be able to create climatological maps that will help farmers plan and manage their crops for optimal results. People will also be able to use this information to reduce their UV risk and to develop new materials that will better withstand ultraviolet radiation.

By generating new information every day and posting it to our web site within 24 hours, we're able to share our data with agencies, scientists, universities, K-12 teachers and students, and companies worldwide. Teachers may access this information to help students learn about ultraviolet radiation, ozone, pollution, clouds, and aerosols, as well as how these factors interact. The U.S. Weather Service relies on our data to validate its UVB index, which warns the public of high-radiation days. Our data has also been used for pollution studies, sunburn research of schoolchildren in Denver, Colorado, and by the U.S. Army to study the effects of UVB on outdoor workers.



# CRITICAL RESEARCH: HOW UVB AFFECTS AGRICULTURE

One of the greatest concerns about UVB radiation is the serious threat it poses to agriculture and ecosystems. Increased UVB radiation affects crops by reducing yield and quality, altering growth, increasing susceptibility to insects and disease, and changing a plant's genetic structure. Left alone, these factors could seriously impact U.S. and global food and fiber production.

Better understanding of the effects of elevated UVB on crops calls for more complete and precise studies of how UVB affects various crops. This knowledge will enable us to develop solutions that will allow plants to cope with these effects and ensure crop productivity. Studies like these, conducted in partnership with the nation's leading UVB agricultural researchers, are an important part of the USDA UVB Monitoring and Research Program.

The results of this research are being used, and will continue to be used, to improve crop endurance and productivity and ensure the nutritional and economic vitality of U.S. agriculture.

## DEVELOPING A FOCUS

The USDA is the steward of our nation's 192 million acres of forests and also assists 2 million farmers whose crops cover more than 9 million acres in the U.S. Contributing to research that will optimize all the plant life that sustains us is a major focus of the USDA UVB Monitoring and Research Program.

As we've targeted locations for our data-collection sites, our strategy has been to measure the UVB in those areas that produce our nation's most economically important crops. The plants that provide the greatest economic benefits to the United States are cotton, soybeans, corn, wheat, rice, sorghum, and grasslands. In addition to creating jobs and supporting local and regional economies, these plants are primary sources of food, fiber, and other products for human consumption, and are also food sources for livestock.

The data we collect daily from the 30 sites in our climatological network support our ongoing, long-term, collaborative research on the crops identified above. We are engaged in two types of studies: those that determine how UVB affects plant growth, development, and yield, and studies that evaluate the impact of these effects on economically important crops.

The focus of our research is the nation's most economically important crops. Through our studies, we are discovering how UVB affects plant growth, development, and yield, as well as the economic impact of these effects.

Through collaborative research we've developed a useful 3-D model that calculates the amount of UVB radiation in and below tree and other vegetation canopies.

The value of the versatile, high-quality data we provide extends even further by furnishing important information to other researchers who are also studying the effects of UVB on plants nationwide.

Each research activity we're involved in evaluates UVB effects on different plants growing under different conditions. We also collaborate with other universities, agencies, and scientists who are studying UVB effects on economically important crops in different areas of the United States.

## UVB EFFECTS ON LIFE BELOW CANOPIES

We're aware that some plants are sensitive to present levels of UVB and others are apparently not affected by the same or even greater doses of ultraviolet radiation. Equally puzzling is the fact that the response to UVB can vary greatly among plants within the same species. We do know that about two-thirds of some 300 plant species tested are susceptible to damage from increased UVB radiation.

But how do vegetative canopies alter a plant's response to UVB? That was the question we sought to answer in a study we completed with our research partners, Dr. Richard Grant at Purdue University and Dr. Gordon Heisler at the USDA Forest Service. Our goal was to develop and evaluate an analytical model to predict the amount of UVB radiation on potentially sensitive surfaces as influenced by vegetation.

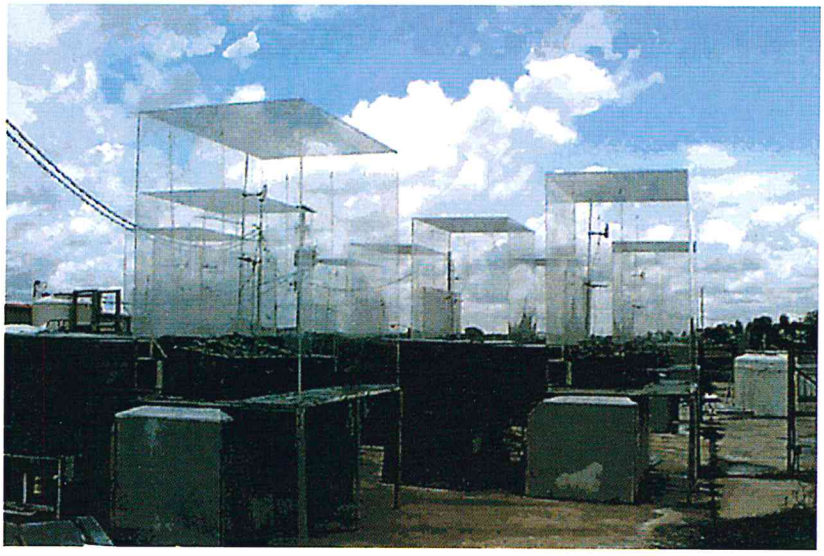
The distribution of UVB radiation varies with different vegetative canopies. Tree canopies often have large natural openings between crowns, whereas incomplete row crops have wide spaces between rows of vegetation. Urban environments consist of complex three-dimensional (3-D) arrangements of trees and buildings.

To evaluate the amount of UVB stress in various plant canopies and under different sky conditions requires a 3-D model. Our research resulted in developing this much-needed tool, a 3-D UV Radiation Transfer model, which calculates the amount of UVB radiation passing through a canopy at any location within or below an open vegetation canopy.

This model can now be used to assess UVB levels below dispersed canopies, including agricultural crops, orchards, and trees in urban areas, given initial sky conditions and canopy composition and structure where the individual crown shape can be described as an ellipsoid. This model can also be used to examine amounts of UVB reaching people and other life in and below vegetative canopies. Sky radiance distributions for use in the model are available for clear and overcast conditions. With additional research, we could create a model for partly cloudy conditions.

## OTHER RESEARCH ACTIVITIES

The USDA UVB Monitoring and Research Program is involved in numerous agricultural collaborations and research activities, that have widespread applications. Here are highlights of some of the research now in progress:



Computer-controlled environmental chambers, known as the Soil-Plant-Atmosphere-Research facility, at Mississippi State University are used to study the effects of multiple environmental factors, including UVB radiation, on crops.

**Cotton** is one of the most versatile of all crops grown in the United States. It provides not only fiber for this country's population, but jobs as well. The cotton industry creates more than 450,000 jobs on farms and in mills, stores, warehouses, and other types of businesses nationwide. In Mississippi alone, cotton-related endeavors account for over 29,000 jobs and generate more than $800 million in revenue each year.

We are presently working with the research group of Dr. K. Raja Reddy in the Department of Plant and Soil Sciences at Mississippi State University to study the effects of enhanced UVB on cotton growth, development, and yield. We are testing the hypothesis that elevated UVB radiation will modify the response of transpiration, respiration, carbon acquisition, development, and reproduction and yield of cotton.

Our long-term goal is to better understand the interactive effects of environmental stress factors, including UVB radiation, on cotton. One outcome of this research will be the development of a computer model of UVB radiation effects on cotton physiology and growth. Our intent is to incorporate this model into the existing cotton simulation model to predict cotton responses to future climate change, including UVB radiation – information that can be used for impact assessment and analysis, as well as policy decisions.

Scientists and farmers will be able to use this research to improve the cotton industry as a whole, in terms of both productivity and economic return.

Below-canopy UV radiation sensors in a cornfield located at Purdue University's Agronomy Research Center.

In our studies with Dr. Richard Grant's research group in the Agronomy Department at Purdue University, we are evaluating the risk of **soybeans** to enhanced UVB. We expect these research results, combined with USDA UVB Monitoring and Research Program measurements, will enable us to provide potential UVB impact maps for various cultivars across the soybean growing region.

Another research project we are engaged in with the same Purdue research group is evaluating the influence of leaf waxes on the optical properties of **sorghum**. This study will further our understanding about leaf characteristics that reflect UVB. Knowing precisely how these

reflective qualities protect the plant will help us to more completely understand the factors that allow sorghum to thrive in low-latitude areas where UVB levels are high.

In our work with the Dr. Joseph Sullivan's research group at the Department of Natural Resource Sciences and Landscape Architecture, the University of Maryland, we are studying how UVB affects leaf development and chemistry, as well as the level of DNA dimers produced in plants growing in contrasting UVB environments. The plants we are testing are **soybeans, cucumbers,** and **melons.** This research will help us to better understand the mechanisms of various plant responses to UVB.

In partnership with Dr. Daniel Milchunas and his research group at Colorado State University, we are looking at **shortgrass steppe** to determine the effects of UV and moisture on decomposition. This study will uncover important information about the interaction of UV and carbon in the soil – data that is critical to current studies of ways to mitigate global warming by reducing carbon dioxide emissions. If crop and grazing land were to be left fallow, for example, how quickly could $CO_2$ be returned to the soil? Our shortgrass steppe research is determining the rate at which plants left out in the fields decompose into $CO_2$ and how UVB affects this decomposition.

Above-canopy UV radiation sensors in a sorghum field located at the Purdue Agronomy Research Center.

# DEVELOPING SOLUTIONS

The USDA UVB Monitoring and Research Program is engaged in collaborative research across the nation to provide important information and models that will heighten our understanding of the effects of ultraviolet radiation on Earth and strengthen agriculture in the United States and, ultimately, worldwide.

Current research is already providing invaluable information that benefits agriculture and humankind. Potential impacts of ongoing and future research are profound. Working with remote-sensing specialists who use airplanes and satellites to measure radiation from crops and determine the health of particular parts of fields, eventually we can apply our data to provide accurate and definitive information for precision agriculture. Farmers using this information will be able to determine precise quantities of seed, fertilizer, water, nutrients, and pesticide needed to optimize their crop yield.

Other research and information generated by the USDA UVB Monitoring and Research Program will be critical to a more comprehensive understanding of the effects of UVB not only on agriculture and climate, but also on human health and the health of forests, ecosystems, and aquatic systems.

With this information, we will be able to develop solutions to prevent or counter the harmful effects of UVB. Through new methods of plant breeding and genetic engineering, for example, we may soon be able to develop UV-resistant plant strains, thus ensuring the future health of those crops we depend on for food, jobs, clothing, and other products.

The measurement and research activity of the USDA UVB Monitoring and Research Program is ongoing and continually expanding. It is vitally important to the health of our nation.

The research results and information generated by the USDA UVB Monitoring and Research Program will help scientists develop ways to prevent or counter the harmful effects of UVB.

# PLANNING FOR THE FUTURE

Producing a UVB climatology and collaborating with agricultural researchers to study the effects of UVB radiation on plants are the first steps to preventing and minimizing its damaging effects to food and fiber supplies.

The USDA UVB Monitoring and Research Program is focused on enhancing our understanding of factors that control ultraviolet radiation and on improving the quality of UVB monitoring instruments and data. We work both alone and in tandem with other prominent UV scientists on cutting-edge research that contributes to solutions that will help ensure the long-term viability of this nation's agriculture.

The data we generate is of inestimable value to those who now use it, and it will continue to be used by atmospheric scientists and remote-sensing specialists, as well as by health-effects researchers and in pollution studies, thus contributing to the health of our population.

As we learn more about UVB and its effects, we will continue to disseminate this information daily via our web site. The information we now provide is being used by 41 federal agencies and 260 universities in 66 countries, and the number of people using our data is continually increasing. Users include schools, universities, government agencies, and private companies.

The measurements we provide are unique and more comprehensive than those provided by any other network. We continue to report on research developments through peer-review publications and national and international meetings. These presentations demonstrate the exceptional quality of our instrumentation and calibrations, and advance our understanding of the factors affecting UVB and its influence on agriculture.

The contributions we're making toward better measurements of ultraviolet radiation and its effects are long-term and ongoing and require continued support and commitment.

We are involved with other prominent UV scientists in cutting-edge research that is contributing to solutions to ensure the long-term viability of this nation's agriculture.

# WHAT CAN I DO?

Ozone depletion and increasing ultraviolet radiation are serious global problems requiring the understanding and action of the world's citizens. Here are some ways that you can help.

*As an individual, you can:*

1. Avoid the use of products that emit CFCs, which deplete ozone. If you have an old car or air conditioner, consider retrofitting it so it can use CFC substitutes.
2. Learn about the effects of UVB radiation, and lifestyle changes you can make to protect yourself from overexposure. Share that information with others.
3. Write to your Congressional representatives, and ask them to support programs that study the effects of UVB radiation and contribute to solutions.
4. Support the worldwide phase-out of CFCs and methyl bromide.

*As a teacher, you can:*

1. Educate your students about the relationship between ozone, harmful chemical emissions, and ultraviolet radiation – and the effects of UVB on living organisms.
2. Have your class write a letter to your Congressional representatives to encourage continued support of programs that study the effects of UVB radiation and contribute to solutions.

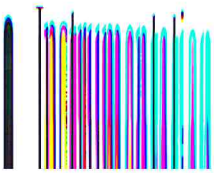
*As a legislator, you can:*

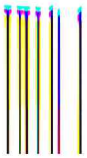
1. Familiarize yourself with the USDA UVB Monitoring and Research Program and its collaborations with NASA, NOAA, and researchers studying the effects of UVB on U.S. agriculture.
2. Lobby for continued support of the USDA UVB Monitoring and Research Program.

You can learn more about ultraviolet radiation and the USDA UVB Monitoring and Research Program by visiting our web site:
**http://uvb.nrel.colostate.edu/UVB**

The web site includes:

- Program description and objectives
- Our climatological network
- Research activities
- Intercomparisons
- Personnel
- Related publications





For further information, contact:

Dr. James R. Slusser
USDA UVB Monitoring and Research Program
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, CO 80523-1499
Phone: (970) 491-3623
E-mail:
sluss@uvb.nrel.colostate.edu

Colorado State University

USDA UVB Monitoring and Research Program
Natural Resource Ecology Laboratory
Fort Collins, CO 80523-1499