Monitoring, Modeling, and Assessing the Environmental Effects of Changes in Solar UV Radiation and Climate Workshop

September 18th, 2023

9:00 am to 5:30 pm

Co-Organized by

The USDA UV-B Monitoring and Research Program

and

The United Nations Environment Program Environmental Effects Assessment Panel

Supported by Colorado State University's Natural Resource Ecology Lab and the Department of Ecosystem Science and Sustainability

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Workshop Schedule

9:00 am – The Montreal Protocol and the scientific assessment of the effects of stratospheric ozone depletion and climate change, Dr. Paul Barnes, Department of Biological Sciences and the Environment Program, Loyola University; Co-Chair, UNEP Environmental Effects Assessment Panel.

9:05 am – The USDA UV-B Monitoring Network, Dr. Wei Gao, Director, USDA UV-B Monitoring and Research Program and Mr. George Janson, Research Associate, UV-B Monitoring and Research Program.

9:25 am – The benefits of the Montreal Protocol for stratospheric ozone, UV radiation, climate, and the biosphere, Dr. Germar Bernhard, Biospherical Instruments, Inc.

9:55 am – Skin cancers avoided in the USA by protecting the ozone layer, Dr. Sasha Madronich, Senior Scientist Emeritus, National Center for Atmospheric Research.

10:20 am - Morning Break

10:30 am – Welcome and Introductions

10:50 am – Challenges in assessing the interactive effects of changes in climate and solar UV radiation on the environment, Dr. Paul Barnes, Department of Biological Sciences and the Environment Program, Loyola University; Co-Chair, UNEP Environmental Effects Assessment Panel.

11:20 am – Climate Intervention and Stratospheric Ozone: An Introduction, Dr. David Fahey, Director, NOAA Chemical Sciences Laboratory, Boulder Colorado USA.

11:50 am – Lunch Break

1:20 pm – Ground-based measurements of aerosol absorption, Dr. Nickolay Krotkov, NASA Goddard Space Flight Center, Atmospheric Chemistry and Dynamics Laboratory.

1:50 pm – Satellite-based measurements of aerosol absorption, Dr. Omar Torres, NASA Goddard Space Flight Center, Atmospheric Chemistry and Dynamics Laboratory.

2:20 pm – Plastics, Microplastics, and UV Radiation, Dr. Anthony Andrady, Department of Chemical and Biomolecular Engineering, North Carolina State University.

2:50 pm – Afternoon Break

3:00 pm – Crop Responses to Ultraviolet-B Radiation and Other Climatic Stresses, Dr. Raja Reddy, Director, Soil-Plant-Atmosphere-Research Facility; Professor, Department of Plant and Soil Sciences, Mississippi State University.

3:30 pm – Predicting Climate Impacts on U.S. Crop Production through a Coupled System Approach, Dr. Xin-Zhong Liang, Department of Atmospheric and Oceanic Science, University of Maryland; Earth System Science Interdisciplinary Center, University of Maryland.

4:00 pm – Use of DayCent-UV-B Model to simulate UV-B radiation and climate change impacts on the US Great Plains Grasslands, Dr. William Parton, Professor Emeritus, Department of Forest Rangeland and Watershed Stewardship, Colorado State University, Senior Research Scientist, Natural Resource Ecology Laboratory, Colorado State University.

4:30 pm – Assessing UV Tolerance in Broadleaf Trees and Modeling Tree Canopy Interception of UV Radiation, Dr. Yadong Qi, Professor of Urban Forestry, Department of Urban Forestry and Natural Resources, College of Agricultural, Family and Consumer Sciences, Southern University and A&M College, Baton Rouge, LA.

5:00 pm – How spectral changes in solar radiation affect the photosynthetic performance of leaves and prospects for upscaling these effects in plant canopies, Dr. Matthew Robson, Principal Investigator, Canopy Spectral Ecology & Ecophysiology; UNEP Panel Member and Lead Author; Senior Lecturer, UK National Forestry School, University of Cumbria – Ambleside; Programme Lead, Woodland Ecology and Conservation, University of Cumbria – Ambleside.

5:30 pm – Closing Remarks, Dr. Sasha Madronich, Senior Scientist Emeritus, National Center for Atmospheric Research.

About the Organizers

The USDA UV-B Monitoring and Research Program

The USDA UV-B Monitoring and Research Program (UVMRP) manages a nationwide network, which measures surface UV-B irradiance and provides 8 other data products at 37 agro-climatological sites plus 4 long-duration research sites. These sites encompass 20 ecoregions and are mostly distributed across the U.S. with two additional sites in Canada and in New Zealand. In response to stakeholder feedback, the UVMRP focuses on the three primary programmatic areas:

- *Climatology Data Collection*: to collect high-quality and geographically-distributed solar ultraviolet and visible radiation measurements, and to make these data publicly available for the agricultural, ecological, and scientific communities;

- *Effects Research*: to quantify the isolated and combined effects of UV and other environmental stressors on economically important crops through experiments;

- *Integrated Assessment*: to develop a coupled modeling framework of climate-agroecosystem-UV interactions and economic impacts for science-informed decision support toward sustainable US agriculture.

The USDA UV-B Monitoring and Research Program staff and affiliated scientists.

The United Nations Environment Program Environmental Effects Assessment Panel

The Environmental Effects Assessment Panel (EEAP) is tasked by the United Nations Environment Program (UNEP) with assessing the current and future impacts of stratospheric ozone depletion, changes in ultraviolet (UV) radiation, and their interactions with climate change. The panel's scientific expertise reflects the wide range of potential UV impacts on human health, natural and cultivated ecosystems, biogeochemical cycles, air and water quality, and materials including microplastics. The EEAP's periodic reports to UNEP are part of the scientific basis used by policymakers for ongoing adjustments and amendments to the international agreements protecting stratospheric ozone.

For more information, visit their website at https://ozone.unep.org/science/assessment/eeap.

UN environment

United Nations
Environment Programme

About the Presenters

Dr. Anthony Andrady

Tony Andrady is among the first researchers to study the degradation of plastics in the marine environment and has authored over 150 research papers and authored or edited five books with John Wiley on polymer-related subjects. As a senior researcher at the Research Triangle Institute, he directed research programs for the USEPA, the Department of Defense, the Department of Commerce, and the National Oceanic and Atmospheric Administration. He served as a member of the GESAMP WG4 panel on plastics pollution of the ocean. He recently edited the volume "Plastics and the Ocean" (Wiley, 2023) that summarizes the recent findings on the subject.

Dr. Paul Barnes

Dr. Paul W. Barnes holds the J.H. Mullahy Endowed Chair in Environmental Biology and is a Professor in the Environment Program and the Department of Biological Sciences at Loyola University New Orleans. Dr. Barnes received a B.A. in Biology from Augustana University, South Dakota, a M.S., and a Ph.D. in Biology/Ecology from the University of Nebraska-Lincoln and was a Postdoctoral Research Associate at Utah State University. Prior to coming to Loyola, he held faculty positions at St. Olaf College, Minnesota and Texas State University and was a Project Leader at the USEPA Environmental Research Laboratory, Corvallis, Oregon. Dr. Barnes is a plant physiological ecologist whose research examines plant carbon, water and light relations, grassland and savanna ecology, environmental UV photobiology, and plant and ecosystem responses to global environmental change. He has over 100 published articles and his research has been funded by grants from the US NSF, USDA, NASA, USEPA and various state and local agencies. He is currently a Co-Chair of the UNEP Environmental Effects Assessment Panel that provides scientific assessments on the effects of ozone depletion and climate change on human health and the environment. Dr. Barnes teaches courses in botany, ecology, and environmental science at Loyola.

Dr. Germar Bernhard

Dr. Germar Bernhard received a diploma in physics from the Technical University of Munich, Germany, in 1992 and a Ph.D. from the Karl-Franzens-Universität Graz, Austria, in 1997. As a part of his Ph.D. studies, he developed and characterized reference spectroradiometers for the measurement of solar UV radiation. He joined Biospherical Instruments in 1998 as the co-PI and later PI of the U.S. National Science Foundation's Ultraviolet Spectral Irradiance Monitoring Network, which operated UV spectroradiometers in Antarctica and the Arctic. He is still involved in analyzing UV radiation data of the instruments in Antarctica, which now make up NOAA's Antarctic UV Monitoring Network. He is a member of UNEP's Environmental Effects Assessment panel.

Dr. David Fahey

Dr. David W. Fahey is the Director of the Chemical Sciences Laboratory in the National Oceanic and Atmospheric Administration in Boulder, Colorado, USA. He joined the Laboratory after receiving advanced degrees in physics. The Laboratory's mission is to advance scientific understanding of climate change, air quality and stratospheric ozone through research on the chemical and physical processes that affect Earth’s atmospheric composition. He serves the Montreal Protocol as a Co-Chair of its Scientific Assessment Panel which produces the quadrennial assessments of stratospheric ozone depletion. He has authored other major assessments on the topics of climate change, black carbon and aviation to address their roles in the climate system and was a lead author of the 2017 Climate Science Special Report of the National Climate Assessment. He has received distinctions from the U. S. Department of Commerce, the Environmental Protection Agency, the American Meteorological Society, the American Geophysical Union, and the United Nations Environment Program.

https://csl.noaa.gov/

Dr. Wei Gao

Dr. Wei Gao is a Professor of the Department of Ecosystem Science and Sustainability, and the Senior Research Scientist/Director of the USDA UV-B Monitoring and Research Program, Natural Resource Ecology Laboratory at Colorado State University. A major focus of his research includes evaluating impacts of solar UV radiation and other environmental stress factors on crops/plants, atmospheric/vegetation canopy radiation transfer modeling, and regional climate/ecosystem modeling. Dr. Gao has published more than 200 scientific papers and edited 23 books, proceedings, and journal issues. He is a SPIE Fellow.

Mr. George Janson

George Janson came to the USDA UVB Monitoring and Research Program in September 1996. His prior background includes over 8 years with Eastman Kodak Company at their Windsor, Colorado facility; a year with ANG Coal Gasification Company in Beulah, ND; over 5 years with Hartford Steam Boiler Inspection & Insurance Co, Denver; over 3 years with Choice Heat Company, Fort Collins; and over 3 years with Horizon West Property Management, Fort Collins; plus a few other short-term employments in the Front Range area. Each job involved hands-on maintenance-type work and considerable travel, providing him with an abundance of skills to meet the needs of the nascent UVMRP.

Dr. Nickolay Krotkov

Dr. Nickolay A. Krotkov is an atmospheric scientist at NASA's Goddard Space Flight Center. He specializes in modeling of UV radiation and satellite and ground-based retrievals of Earth's pollution gases and aerosols. His work has led to algorithms for operational satellite data production, such as the mapping of surface UV irradiance and volcanic sulfur dioxide (SO_2) from NASA's Total Ozone Mapping Spectrometers (TOMS) and gaseous pollution (SO_2 and NO_2) from the Ozone Monitoring Instrument (OMI) aboard NASA's Earth Observing System atmospheric chemistry mission (Aura). He currently serves as the Deputy Project Scientist for Aura and is science team member for Aura/OMI, SNPP/JPSS, DSCOVR/EPIC, TEMPO, and PACE missions, and NASA's Applied and Interdisciplinary science volcanic teams.

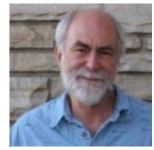
Dr. Xin-Zhong Liang

Dr. Xin-Zhong Liang is a professor in the Department of Atmospheric and Oceanic Science and the head of the Earth System Model (EaSM) Research and Development Laboratory in the Earth System Science Interdisciplinary Center at the University of Maryland since 2011. He earned a Ph.D. in 1987 from Chinese Academy of Sciences. He was a professor at the University of Illinois in 2010 and a senior scientist in the Illinois State Water Survey in 1999-2010 and the State University of New York in 1990-1999. He develops high-resolution EaSM integrating climate, hydrology, air quality, water quality, crop, biosphere, and their interactions to study Earth's climate variability, change, and environmental impacts. He is expanding the EaSM to incorporate interactive human dimensions and decision support systems, such as for agricultural, water resource, and public health management and strategic planning. He is applying the EaSM and machine learning ability along two streamlines: short-term climate prediction that supports actionable practices and real-time decisions for human-climate interactions, and climate change projection that addresses food-energy-water nexus, vulnerability, risk, and sustainability issues on decadal scales. He is leading a multi-institutional, transdisciplinary team project on improving agricultural water use and nutrient management to sustain food and energy crops production.

Dr. Sasha Madronich

Dr. Sasha Madronich is a Senior Scientist (Emeritus) at the National Center for Atmospheric Research (NCAR) in Boulder, and an Affiliated Scientist at in the USDA UV-B Monitoring and Research Program (UVMRP) of at Colorado State University in Fort Collins, Colorado, USA. He is trained in engineering physics (MEng 1975), electrical engineering (MS 1977), and chemistry (PhD 1982). His research interests focus on chemical pathways that control the life cycles of atmospheric constituents, and on the role of solar ultraviolet radiation in environmental photochemistry and photobiology. He has co-authored over 230 peer-reviewed publications spanning observations and modeling of atmospheric processes, is listed among the ISI Highly Cited Researchers in Geosciences, and was cited for contributions underlying the award of the 2007 Nobel Peace Prize to the Intergovernmental Panel on Climate Change (IPCC). He has participated in international assessments of the state of the atmosphere and continues serving as a member of UNEP's Environmental Effects Assessment Panel related to ozone depletion.

Dr. William Parton

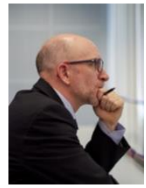


Dr. Bill Parton's primary research activities center around the study of greenhouse gas emissions, predictive modeling to help stakeholders (i.e. ranchers and farmers) make informed decisions on how the climate will affect them in the coming year, and how land use change effects the carbon cycle. He is the primary author of the ecosystem models: Century, DayCent, ForCent, and is currently working on the development of PhotoCent (see model descriptions). Additionally, he is working on the Grass-Cast Project which is a predictive above-ground grassland plant production (ANPP) model that uses current weather data, the DayCent model and precipitation forecasts to help ranchers predict what the grass production will be for the grazing season. Dr. Parton has published over 150 papers and book chapters. He is fellow for the Ecological Society of America and the American Geophysical Union and was honored as a Resident Distinguished Ecologist at Colorado State University. He has had numerous projects funded by NSF, USDA, DOE, EPA and NIH.

Dr. Raja Reddy

Dr. K. Raja Reddy received all his BS, MS, and Ph.D. degrees from Sri Venkateswara University, Tirupati, India. He joined the Plant and Soil Sciences Department at Mississippi State in 1988 and became a Research Professor in 1992. He was named a William L. Giles Distinguished Professor in 2021. Dr. Reddy's research interests include the impact of anthropogenic climate change, remote sensing, and crop modeling applications on agricultural resource management through the lens of environmental plant physiology. He has over 35 years of research experience at Mississippi State and manages the state-of-the-art sunlit plant growth chambers known as Soil-Plant-Atmosphere-Research (SPAR, https://www.spar.msstate.edu/). He is responsible for and credited with many critical discoveries across multiple facets of agriculture. His research includes the impact of climate change on crop physiology, growth, and development of several outstanding foods, fiber, and native grassland and forages crops of global importance - cotton, soybean, rice, corn, sorghum, sweet potato, switchgrass, Bahiagrass, many horticultural crops, and domain expertise areas of remote sensing and stress physiology; and crop model applications.

Dr. Matthew Robson



Matthew Robson, Associate Professor, is Programme Lead for Woodland Ecology & Conservation and Associate Professor in Forestry at the University of Cumbria, Ambleside, UK National School of Forestry. He holds a dual affiliation with the University of Helsinki where he leads the Research Group in Canopy Ecology & Ecophysiology (CanSEE) as well as being a Principal Investigator (PI) in Viikki Plant Science Centre. He is additionally, Finance Office for *UV4Plants International Association for Plant-UV research.* His research focuses on the dynamic response of photosynthesis and leaf traits to sunflecks in canopies and the potential consequences of increases in future diffuse radiation in plant canopies due to climate change. His recent publications highlight the mechanisms of light and water use by plants in canopies; process-based species distribution models; radiative transfer modelling in canopies; UV radiation adaptation under extreme conditions; technological solutions for monitoring canopy processes; paleoecological proxies to assess past UV radiation; applications of increased robustness of plants following UV radiation exposure. His research into the management of spectral radiation in agricultural and horticultural environments involves the modelling of solar spectral radiation using *libRadtran* to calculate the most appropriate controlled environment (greenhouse/polytunnel) materials for growers from their spectral properties and experimental attenuation of regions of the solar spectrum of sunlight to identify photoreceptor-induced responses in the UV and blue regions of the spectrum controlling photosynthetic induction and recovery, chloroplast movement, photoprotection and photorepair. He is co-author of the *Handbook for best practice in UV photobiology*, and of *R for Photobiology* which supports a suite of R packages allowing the processing of photobiological data. He has published a series of protocols for field measurements of spectral radiation at high frequency and new approaches utilizing drones to construct vertical profiles of spectral irradiance and leaf area index in canopies.

Dr. Omar Torres

Dr. Omar Torres is a researcher at the NASA Goddard Space Flight Center in the Atmospheric Chemistry and Dynamics Laboratory. Dr. Torres received a B.S. degree in geodetic engineering from Universidad Distrital Francisco Jose de Caldas, Bogota, Colombia, an M.S. degree in meteorology from the University of The Philippines, Quezon City, Philippines, and a Ph.D. degree in atmospheric sciences from Georgia Institute of Technology, Atlanta, GA, USA, in 1990. In 1999 he became a research Associate Professor at the University of Maryland, Baltimore County, Baltimore, MD, USA. He joined Hampton University (Hampton, Virginia) in 2008 as an Associate Professor at the Department of Atmospheric Sciences. In 2011, he accepted a position at NASA Goddard Space Flight Center, Greenbelt, MD, where he continues to carry out research work in UV atmospheric remote sensing applications with special emphasis on the characterization of aerosol absorption properties from satellite UV observations by currently operational UV-capable sensors such as OMI, EPIC and TROPOMI..

Dr. Yadong Qi

Dr. Yadong Qi is currently a professor in urban forestry and the master's degree program leader in the Department of Urban Forestry and Natural Resources, College of Agriculture, Family and Consumer Sciences, Southern University (SU), Baton Rouge, Louisiana, USA. She was a co-founder of the nation's first Bachelor of Science Degree Program in Urban Forestry in 1992; a key faculty member responsible for the subsequent establishment of urban forestry Master's Degree Program in 1998 and Ph.D. Degree Program in 2004 at Southern University (SU) and A&M College, Baton Rouge LA, and a contributor for the designation of the Urban Forestry Program as the Department Excellence through Faculty Excellence (DEFE) Program by the Louisiana Board of Regents in 2000. For the last 30 years, Dr. Qi has served as PD/CoPD for research and teaching grants of over $13 million dollars. She made significant research contributions to (1) understanding of UV-B tolerance mechanism in 35 southern tree species, (2) application of nanotechnology in forest disease control, and (3) biochemistry and antioxidant properties of more than 30 accessions of Roselle Hibiscus (Hibiscus Sabdariffa) and their utilization in the Southern USA.

Presentations and Abstracts

Abstracts are shown in the order in which they will be presented.

Introduction to the USDA UV-B Monitoring and Research Program

Wei Gao[1,2] and George Janson[1]
[1]USDA UV-B Monitoring and Research Program, [2]Department of Ecosystem Science and Sustainability, Colorado State University.

In 1990, the USDA became concerned about the decreasing stratospheric ozone over North America, and the potential for increases of crop- and biosphere-damaging levels of ultraviolet radiation. In January 1991 and March 1992, they sponsored two workshops to develop their concept of a national UV monitoring network. Later in 1992, the USDA initiated and funded the UV-B Monitoring and Research Program (UVMRP), headquartered at Colorado State University (CSU) in Fort Collins, Colorado. The UVMRP consists of both a research component and a climatologic network. The climatologic network is designed to provide an adequate density of measurement sites to establish the spatial and temporal characteristics of UV-B irradiance. These climatological monitoring stands are located at many land-grant and other universities and some governmental facilities, selected primarily for proximity to agricultural production and/or research fields, and forested areas, and secondarily for availability of interested personnel to perform the routine cleaning and minding of the instrument suite. In a broader sense, the UVMRP supports research that increases our understanding of the factors controlling surface UV-B irradiance and provides the data necessary for assessing the impact of UV-B radiation on ecosystems, human health, materials and agricultural commodities.

The benefits of the Montreal Protocol for stratospheric ozone, UV radiation, climate and the biosphere

Germar Bernhard
Biospherical Instruments, Inc, San Diego, USA.

The Montreal Protocol is an international treaty designed to phase out the production of ozone depleting substances (ODS). The main goal of the treaty is to protect the Earth's stratospheric ozone layer, which shields life on our planet from harmful ultraviolet radiation (UV). In addition, the Montreal Protocol has mitigated climate change because ODSs, such as chlorofluorocarbons, are also potent greenhouse gases. The Montreal Protocol is therefore hailed as the most successful treaty to protect the biosphere both from increases in UV radiation and global warming. This presentation is based on the latest assessment prepared by the Environmental Effects Assessment Panel (EEAP) of the Montreal Protocol under the umbrella of the United Nations Environment Programme

(Bernhard et al., 2023) and additional findings that were published since the assessment's cut-off date of September 2022.

Changes in UV radiation at low- and mid-latitudes (0–60°) during the last 25 years have generally been smaller than 4% per decade and were mostly driven by changes in cloud cover and atmospheric aerosol content. Without the Montreal Protocol, erythemal (sunburning) UV irradiance would have increased between 1996 and 2020 by 10–20% at mid-latitudes, by about 25% at the southern tip of South America, and by more than 100% at the South Pole in spring (Figure 1). Under the presumption that all countries will adhere to the Montreal Protocol in the future, erythemal irradiance at mid-latitudes is projected to decrease between 2015 and 2090 by 2–5% in the north and by 4–6% in the south due to recovering ozone. Furthermore, the phase-out of ODSs may have avoided warming by 0.5 to 1.0 °C over midlatitude regions of the continents, and by more than 1.0 °C in the Arctic. Stratospheric ozone depletion over Antarctica also led to a poleward shift of climate zones. Resulting changes in precipitation have affected ecosystems in South America and Australia.

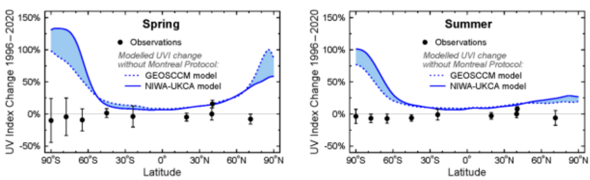


Figure 1: Comparison of observed changes in the UV Index between 1996 and 2020 (black circles) and changes without the Montreal Protocol estimated by two models (blue lines) for spring (left) and summer (right).

Reference

Bernhard, G. H., Bais, A. F., Aucamp, P. J., Klekociuk, A. R., Liley, J. B., & McKenzie, R. L. (2023a). Stratospheric ozone, UV radiation, and climate interactions. Photochemical & Photobiological Sciences. https://doi.org/10.1007/s43630-023-00371-y

Skin cancers avoided in the USA by protecting the ozone layer

Sasha Madronich
Affiliated Scientist, USDA UV-B Monitoring and Research Program Natural Resource Ecology Laboratory Colorado State University, Fort Collins, Colorado, Senior Scientist Emeritus, National Center for Atmospheric Research Boulder, Colorado, USA

Ultraviolet (UV) radiation is known to induce skin cancers, with increasing efficacy at shorter wavelengths (UV-B) that are most sensitive to atmospheric ozone. The link between emissions of ozone-depleting substances (ODSs) and increases in skin cancer is explored with the Atmospheric Health Effects Framework (AHEF), that parameterizes how ODS emissions increase equivalent effective stratospheric chlorine (EESC), deplete stratospheric ozone, and enhance biologically active surface UV radiation, using epidemiological estimates of dose-responses and demographic data to scale baseline incidence (1980). A scenario in which ODS emissions continue to increase from 1980 at 3% per year (no Montreal Protocol - the world avoided) is compared to the successful implementation of the protocol and its amendments that have limited ozone reductions to a few percent at midlatitudes. The 3% growth scenario would have added some 443 million cases of skin cancer, and 2.3 million deaths, to people born in the United States between 1890 and 2100. Uncertainties stem mostly from ozone-EESC correlations, biological dose-response functions and, for the unabated growth scenario, the choice of the calculation's final year.

Challenges in assessing the interactive effects of changes in climate and solar UV radiation on the environment.

Paul W. Barnes
Department of Biological Sciences and the Environment Program, Loyola University New Orleans, 6363 St. Charles Avenue, New Orleans, LA 70118; Co-Chair, UNEP Environmental Effects Assessment Panel

The United Nations Environment Programme (UNEP) Environmental Effects Assessment Panel (EEAP) is one of three scientific and technical panels that prepares regular assessments in support of the Montreal Protocol on Substances that Deplete the Ozone Layer. The EEAP consists of seven Working Groups that address interactive effects of changes in stratospheric ozone and climate on UV radiation, human health, terrestrial ecosystems and biogeochemical cycles, aquatic ecosystems, tropospheric chemistry, natural and synthetic materials, and plastics. Presently, a number of challenges exist that limit our ability to adequately assess these effects. These challenges include: 1) uncertainties about how future changes in stratospheric ozone and climate, including any climate interventions (e.g., stratospheric aerosol injection), will affect surface UV irradiances; 2) a lack of data on how human activities, including climate change, are altering the exposure of organisms and ecosystems to UV radiation via shifting species distributions, loss of ice and snow cover, altered clouds and aerosols, extreme events (e.g., storms and wildfires) and other effects; 3) gaps in knowledge on how UV radiation and climate change factors (e.g., temperature, drought) interact to affect organisms, species interactions, biodiversity and feedbacks to the climate system; and 4) a lack of modeling studies aimed at quantifying the magnitude of these effects at landscape, regional and global scales. Examples of these challenges and possible approaches to address these challenges will be presented using findings from the most recent Quadrennial Assessment Report on the interactive effects of stratospheric ozone depletion, climate change and UV radiation on terrestrial ecosystems and biogeochemical cycles.

Climate Intervention and Stratospheric Ozone: An Introduction

David Fahey
Director, NOAA Chemical Sciences Laboratory

Climate intervention refers to cooling the Earth by human means to offset the warming and other impacts due to greenhouse gas accumulation. Should it ever become important for society to cool Earth rapidly, climate intervention by solar radiation modification (SRM) methods is the only way that has been suggested by which humans could potentially cool Earth within years after deployment. Projections of continuing emissions of greenhouse gases and growing impacts from climate change are increasing global interest in climate intervention. The leading SRM method is stratospheric aerosol injection (SAI), which would inject aerosol or aerosol precursors into the stratosphere. Observations following explosive volcanic eruptions along with model simulations confirm that increasing stratospheric sulfate aerosols can substantially cool the planet. SAI is expected to change stratospheric ozone chemistry and stratospheric heating which potentially alters the global ozone distribution. In response to the potential importance of SAI to the future ozone layer, the parties to the Montreal Protocol have made an initial assessment of the potential effects on the stratospheric ozone layer in its 2022 assessment cycle. In this lecture, I will introduce the concept of climate intervention and describe SAI strategies, and briefly describe the expected changes in stratospheric ozone from SAI based on global model results and climate intervention research in my laboratory the USA.

References:

1. UNEP One Atmosphere Report, https://www.unep.org/resources/report/Solar-Radiation-Modification-research-deployment
2. 2022 UNEP/WMO Scientific Assessment of Ozone Depletion: Ch. 6, https://csl.noaa.gov/assessments/ozone/2022/
3. NOAA Earth's Radiation Budget Program, https://csl.noaa.gov/research/erb/
4. Congressionally-Mandated Report on Solar Radiation Modification, https://www.whitehouse.gov/ostp/news-updates/2023/06/30/congressionally-mandated-report-on-solar-radiation-modification/

Ground-based measurements of spectral aerosol absorption

Nickolay Krotkov
NASA Goddard Space Flight Center, Atmospheric Chemistry and Dynamics Laboratory

Aerosol absorption refers to the process in which aerosol particles in the atmosphere interact with solar radiation and absorb a portion of its energy. The extent of aerosol absorption depends on particle size, composition, and concentration of the aerosol particles. Column average particle size distribution and optical properties are retrieved by the AERONET network of sun-sky filter radiometers, but only in the visible and near-infrared wavelengths, while extrapolating these retrievals to the biologically and chemically important UV wavelengths is subject to large uncertainties. We developed a synergy algorithm that combines AERONET (A) measurements with direct and diffuse irradiance measurements from UV- and Vis-Multifilter Rotating Shadowband Radiometers (M) and trace gas measurements from Brewer or Pandora (P) spectrometers to retrieve column average spectral absorption parameters: effective imaginary refractive index (k), single scattering albedo (SSA), and absorption aerosol optical depth (AAOD). Our multi-instrument (AMP) inversions ensure consistent aerosol absorption retrievals from ultraviolet (UV) to visible (VIS) wavelengths and accurate partition between aerosol and gaseous (ozone, NO2, SO2) absorption. Our AMP retrievals show that dust, smoke (i.e., "brown" organic carbon), and urban aerosols exhibit enhanced absorption at UV wavelengths, reducing the amount of UV radiation reaching the surface and slowing tropospheric photochemistry, which can have implications for air quality, human health, ecosystem dynamics, and the photodegradation of certain materials.

Satellite-based measurements of UV Aerosol Absorption

Omar Torres
NASA Goddard Space Flight Center, Atmospheric Chemistry and Dynamics Laboratory

Satellite observations of upwelling radiances in the UV have been used over the last 40 years to retrieve total column ozone amount as well as its vertical distribution. Because of the need to characterize total ozone retrieval uncertainties associated with other components of the Earth-Atmosphere system, the radiative interactions in the near UV spectral region among the ocean, land, aerosols and clouds need to be considered. As a result, a great deal of knowledge has been accumulated over the last 20 years on the value of satellite near UV observations for atmospheric and oceanic remote sensing applications. The evolution of space UV remote sensing from its main application to monitor the stratospheric ozone layer to initially unintended uses such as detection and retrieval of aerosol absorption will be discussed.

Plastics, Microplastics and UV Radiation

Anthony Andrady
Department of Chemical and Biomolecular Engineering, North Carolina State University, Raleigh NC 27606

The global production of commodity thermoplastics, particularly polyolefins, especially polyethylene, and polypropylene is projected to increase in the near term leading to a corresponding surge in plastic waste, especially in urban areas. Unmanaged plastic waste, especially litter, undergoes photo-initiated degradation when exposed to UVR, increasing their likelihood of fragmentation into microplastics. Microplastics are ubiquitous in the environment, especially in the ocean, where they pose a potential threat to the ecosystem. As plastic resin production is projected to rise, the problem of microplastic pollution of the environment is anticipated to increase dramatically, raising among others the concern pf their ingestion by human consumers.

While the photodegradation mechanisms of common plastics in air are relatively well understood, the same process in seawater environments remains largely unexplored. Of all the environmental compartments, the contamination of the ocean with microplastics is the most alarming issue.

The presentation will discuss insights from laboratory-accelerated weathering of polyethylenes in both air and seawater that suggest diffusion-controlled oxidation of the polymer results in localized degradation in a thin surface layer. The presentation will discuss the differences oxidation of the plastic in air and seawater environments, highlighting how the mechanistic changes affect their environmental fragmentation into microplastics.

Crop Responses to Ultraviolet-B Radiation and Other Climatic Stresses

Raja Reddy
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Today's world faces many challenges in producing adequate food, fiber, feed, industrial products, and ecosystem services for 8 billion people. With nearly 76 million people added annually, we must develop agricultural food production and ecosystem goods and services to meet the future population of over 8 billion by 2025 and more than 9.7 billion by 2050. Added to these stresses is a threat of global climate change resulting from increased greenhouse gas concentrations in the atmosphere and depletion of the ozone layer assumed due to anthropogenic activities. Agriculture production and productivity are susceptible to changes in climate and weather conditions. Therefore, regional and global climate changes, particularly climatic variability, have been implicated in affecting local and international food, fiber and forest production, and ecosystem goods and services. Rapid climate changes challenge breeders to develop new cultivars to sustain such harsh conditions. For over 30 years, experiments have been conducted in sunlit plant growth chambers to study the impacts of climate change factors (atmospheric CO2, temperature, drought, nutrients, UV-B radiation) in several crops, including native rangeland grass species. Our studies have shown that more carbon was fixed in high-CO2-grown plants at all levels of water and nutrient-deficient conditions and across a wide range of temperatures, water regimes, and UV-B levels. Furthermore, developmental events such as flowering, crop maturity, and leaf initiation were relatively insensitive to high-CO2, UV-B, or nutrients and were mostly temperature-dependent. Since crop growth in indeterminate crops such as cotton is very plastic, additional carbon in a high-CO2 environment favors more vegetative and reproductive development under optimal conditions. However, crop reproductive processes were susceptible to higher and extreme climatic conditions predicted in the future climate (higher and more frequent temperatures and UV-B radiation). Elevated CO2 did not alleviate the damaging effects of higher temperatures or UV-B radiation on processes related to crop yield. More recently, we have been exploring genotype-by-environment interactions to understand the variability and assist breeders in selecting the best lines suited to a changing climate in their breeding programs. We need tools and technologies from all fronts to meet the increased populations' future goods and services.

Predicting Climate Impacts on U.S. Crop Production through a Coupled System Approach

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Crop production critically depends on optimal temperature and reliable water supply. Under climate change, severe weather events such as heat waves, droughts, and floods are projected to increase in frequency and intensity, leading to significant consequences for crop production. Water scarcity, variability, and uncertainty are already threatening U.S. agriculture resilience. The Cotton Belt is facing depleted resources, and even the water-rich Corn Belt is increasingly vulnerable to droughts and floods. Moreover, increased land conversion for crop production is altering regional climate, water distribution, and the environment, causing cascading effects downstream. Predicting these complex interactions requires a coupled Earth system approach that captures feedbacks across different regions, times, and processes. In this presentation, we will apply a coupled dynamic crop-climate modeling system to understand these interactions and feedback processes, and to explore how U.S. crop production will be affected by impeding changing climate.

Use of DayCent-UVB Model to simulate UVB radiation and climate change impacts on the US Great Plains Grasslands

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The DayCent-UV model was used to simulate the impact of UV-B radiation and climate changes (2020 to 2100) on Great Plains grasslands. Extensive observed plant productivity, UV-B litter decay, and soil C and N data from

1980 to 2020 were used to calibrate and validate the model. The observed mean above ground net plant productivity (ANPP) data came from two sources: mean NRCS county-level measured ANPP (2004-2014) and annual measurements from five sites with long-term measurements (20 to 40 years of observations). Observed LIDET litter decay data from dryland grassland sites in the Great Plains were used to develop the UV-B litter decay submodel. Observed regional NRCS soil C and N data were used to calibrate model parameters and validate model performance.

Additionally, the DayCent-UV model has been calibrated using the observed site-level mineral associated organic matter (MAOM) and particulate organic matter (POM) data to represent measurable soil C pools. A major impact of climate change was to increase precipitation and plant productivity in the northern Great Plains. The expected increased air temperatures with climate change had a negative impact on ANPP, but this impact was mitigated by elevated atmospheric CO2 levels that reduced transpiration rates. A statistical analysis showed that cumulative growing season (April to August) rainfall was the major factor controlling mean ANPP. Results also showed that the major impact of UV-B radiation in dry grasslands was to increase decay rates of surface litter and release of N, and to reduce soil C levels.

Assessing UV Tolerance in Broadleaf Trees and Modeling Urban Tree Canopy Interception of Solar UV Radiation

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Stratospheric ozone depletion has resulted in a significant increase in solar ultraviolet radiation (UVB, 280-315nm and UVA, 315-400nm) on Earth's surface. Forests account for the largest biomass on Earth and play a significant role in regulating global climate. With the future uncertainty of ozone recovery and global climate change, there is a critical need for systematic evaluation of UV impacts on trees and forests. The main purpose of this research was to investigate UV tolerance mechanisms in diverse broadleaf tree species in southern USA and assess tree canopy reduction power of UV radiation in urban environments. Very little such information was available prior to our research. This presentation highlights our research results on how diverse southern broadleaf tree species interacting with solar UVB and UVA radiation, their biophysical, biochemical, anatomical, and genetic aspects of UV tolerance characteristics, and how urban tree canopy reducing solar UVA and UVB radiation using live oak (Quercus virginiana) as a model tree species. The results have implications in better understanding UV-tolerance mechanism in diverse broadleaf tree species in Southern USA, modeling urban forest benefit on reduction of solar UV radiation in the changing climate. The project has trained undergraduate and graduate students and strengthened our institutional research competitiveness and partnerships with USDA-NIFA, USDA-UVB Monitoring and Research Network, USDA-FS, USDA-ARS, and several research institutions including Colorado State University, LSU, University of Maryland, and University of Wyoming. Current research is investigating the ability of mixed forest canopies (e.g., in the park) on UV (A/B) reduction and assess UV (A/B) induced DNA damage and repair mechanism in selected group of southern broadleaf tree species. The goal is to fully understand urban forest interaction with UV radiation and their genetic aspect of UV tolerance mechanism.

How spectral changes in solar radiation affect the photosynthetic performance of leaves and prospects for upscaling these effects in plant canopies

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Ecosystem primary productivity is underpinned by light capture through photosynthesis by leaves. Leaves are able to adjust their capacity for photosynthesis according to the light conditions through structural and physiological acclimation. These adjustments occur in response to diurnal and seasonal changes in the light environment according to cloudiness, atmospheric chemistry, sun angle and a leaf's positions within a plant canopy.

I will first describe how these factors affect the dynamics of incident sunlight; its spectral composition and strength. These patterns in solar radiation trigger physiological and morphological responses of leaves. In this way, leaves acclimate to their light environment through timely induction of photoprotection and photosynthesis, avoiding damage while maximizing light capture. Focusing on the key differences between the photosynthetic assimilation by plant canopies under diffuse radiation (as found under cloudy, smoky, polluted and otherwise aerosol-heavy skies) and direct radiation (which creates sunflecks in canopies), I will consider our capacity to upscale carbon budgets from leaves to canopies and further to the ecosystem level.

To date, most modelling has drawn on our knowledge of immediate responses to diffuse radiation but neglects resultant longer-term acclimation of canopy structure and changes in allocation patterns. As with carbon dioxide fertilization, persistent shifts in the prevalence of diffuse radiation is likely to affect ecosystem processes and carbon budgets. Identifying seasonal changes in these processes will require experimental manipulation and long-term monitoring of ecosystems. This knowledge is needed to forecast how on-going changes in cloudiness and increases in wildfires under climate change, and even potential solar radiation modification through stratospheric aerosol injection, are likely to affect primary productivity, and feedback to ecosystem carbon sinks and food production.

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