Dissemination of data from the National Science Foundation's UV monitoring network

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ABSTRACT

The U.S. National Science Foundation's (NSF's) Ultraviolet Spectral Irradiance Monitoring Network (UVSIMN) has been measuring global UV irradiance at seven locations in Antarctica, South America, Southern California, and the Arctic, starting in 1988. Data products include spectra of global (sun and sky) irradiance, sampled quarter-hourly between 280 and 600 nm; integrated irradiance (e.g., UV-B, UV-A); biologically effective dose-rates (e.g., the UV Index); total ozone; effective albedo; cloud optical depth; actinic flux; photoloysis rates; and complementing spectra calculated with a radiative transfer model. Data are disseminated via the project's website www.biospherical.com/NSF. During the last year, data have also been submitted to international data repositories, including (1) the World Ozone and UV Data Center (WOUDC), which is part of the World Meteorological Organization's Global Atmosphere Watch (GAW) program; (2) the Cooperative Arctic Data and Information Service (CADIS), which supports the Arctic Observing Network (AON), an NSF initiative for the International Polar Year (IPY); and (3) the SeaWiFS Bio-optical Archive and Storage System (SeaBASS), which serves NASA's calibration and validation activities for ocean-viewing satellites. We also plan to submit a subset of the dataset to (4) the Network for the Detection of Atmospheric Composition Change (NDACC). The main objective of NDACC is to further understanding of stratospheric changes to the troposphere. UVSIMN data have been adjusted to better serve the needs of these diverse research communities. This paper details the background, format, and volume of these new datasets.

Keywords: Solar UV radiation, data archive, AON, SeaWiFS, SeaBASS, NDACC

1. INTRODUCTION

In 1987, responding to serious ozone depletion reported in Antarctica[1], the Division of Polar Programs of the National Science Foundation called for the establishment of an ultraviolet (UV) monitoring system in Antarctica. This system has become known as the NSF Office of Polar Programs Ultraviolet Spectral Irradiance Monitoring Network (UVSIMN)[2]. The network has been operated by Biospherical Instruments Inc (BSI) since 1988 and has expanded to seven sites (Table 1). To date, the network has produced one of the longest Climate Data Records (CDR) of UV radiation (UVR) in existence. Data are disseminated via the website www.biospherical.com/NSF. This data resource has been recognized by the World Meteorological Organization as an international data repository[3].

Table 1. UVSIMN sites.

Site	Latitude	Longitude	Elevation	Established	Season	Years CDR
McMurdo, Antarctica	77º50'S	166º40'E	183 m	Mar 1988	Aug-Apr	19
Palmer, Antarctica	64º46'S	64º03'W	21 m	May 1988	Year-round	19
South Pole, Antarctica	90º00'S	-	2841 m	Feb 1988	Sep-Mar	19
Ushuaia, Argentina	54º49'S	68º19'W	25 m	Nov 1988	Year-round	19
San Diego, California	32º46'N	117º12'W	22 m	Nov 1992	Year-round	17
Barrow, Alaska	71º19'N	156º41'W	8 m	Dec 1990	Jan- Nov	19
Summit, Greenland	72 34'N	38°27'W	3200 m	Aug 2004	Jan-Nov	5

About 900 data users have registered with UVSIMN to acquire data since its inception. Based on user interest, the network supports the following fields: atmospheric research (14%); validation of satellite data, radiative transfer models,

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and measurements by other instrumentation (11%); UV effects on algae, bacteria, primary production, plants, soil, fish, shrimp, larvae, insects, land animals, and humans (18%); and material research, engineering, and photovoltaic (6%). 29% of data access is related to education. We are aware of 173 publications that have used UVSIMN data, of which 102 are peer-reviewed. These publications include work in atmospheric sciences (45%); effects research (30%); and validation of satellite, model, and instrument data (25%). UVSIMN have been featured frequently in WMO/UNEP Scientific Assessments of Ozone Depletion[3]. A list of references is available at www.biospherical.com/nsf/references.asp.

In 2008, the NSF decided to cease funding for the UVSIMN. As of July 2009 it seems likely that measurements at San Diego, Barrow, and Summit will continue for at least three additional years, partly with support by the NSF. The fate of the four austral sites remains uncertain.

For now, network data will remain accessible via the project's website. To preserve this valuable CDR for the long-term, UVSIMN data have also been submitted to several national and international archives, which serve different research communities. This paper details the background, contents, format, and volume of these new datasets.

2. UVSIMN INSTRUMENTATION AND DATA

2.1 Instrumentation

UVSIMN data are based on measurements of SUV-100 (SUV-150B at Summit) spectroradiometers and GUV-511C (GUV-541C at South Pole) multi-channel radiometers built by BSI. SUV systems use a temperature-stabilized, scanning, double-monochromator and a photomultiplier tube (PMT) detector. The SUV-100 uses a diffuser as irradiance collector. The SUV-150B employs an integrating sphere that is coupled via a quartz-fiber bundle to the monochromator. Both systems have internal mercury-vapor and tungsten-halogen lamps for monitoring the instruments' stability. Spectra of these lamps are typically recorded once per day.

Spectra of global spectral irradiance from 280 to 605 nm are measured every 15 minutes (60 minutes before 1997) when the solar zenith angle is smaller than 92°. The bandwidth of the SUV-100 is approximately 1.0 nm full width at half maximum (FWHM); that of the SUV-150B is 0.63 nm FWHM. More details on the instruments and their specifications can be found in Chapter 2 of UVISMN Operations Reports[4].

GUV radiometers provide measurements at four approximately 10 nm wide UV bands nominally centered at 305, 320, 340, and 380 nm. A fifth channel either measures radiation at 313 nm (GUV-541C; at South Pole only) or Photosynthetically Active Radiation (PAR) (GUV-511C). Data are averaged over one-minute intervals prior to processing. Data are recorded 24 hours per day. The cosine-error of the instruments is smaller than ±3% (±7.5%) for zenith angles less than 65° (82°). Spectral response functions of most instruments were measured in BSI's laboratory prior to site installation. Additional instrument specifications are available in Section 2.3. of UVISMN Operations Reports[4].

2.2 Network operation

Instruments are checked daily by technicians who clean collectors and verify that the systems are functioning normally. They also calibrate SUV instruments every two weeks using 200-Watt irradiance standards that are mounted on top of the instrument using a fixture designed for this purpose. The calibration of these standards is traceable to the source-based irradiance scale of NIST from 1990[5]. Data are downloaded daily from the systems' control computers, and are processed and reviewed and reviewed at least weekly. Remedial action is initiated if data review indicates problems. Network sites are visited by BSI personnel periodically for comparison of site irradiance standards with "traveling" standards; instrument characterization; maintenance and repairs; and hardware and software upgrades. Data collected during these visits are used for annual production of final, quality-controlled data products. Network instruments have been regularly participating in national and international intercomparison campaigns, and data quality has been certified by the Network of the Detection of Atmospheric Composition change (NDACC; formerly NDSC).

2.3 Data products

Data from SUV instruments are of two editions, named "Version 0" and "Version 2." Version 0 have been quality controlled but have not been corrected for the instruments' cosine errors. Version 2 data feature higher accuracy and additional data products, but are not available for San Diego. GUV data provide better time-resolution than SUV measurements but are not as accurate as spectroradiometer data, particularly at large solar zenith angles and short wavelengths. All datasets are provided in ASCII comma-separated tables at the project's website and are described in more detail below. Complete documentation can be found on the website and in UVSIMN Operations Reports[4].

2.3.1 SUV Version 0 data

SUV Version 0 data include the following data products:

- Solar spectra in full spectral resolution between 280 and 605 nm (one file per spectrum)
- Time series of spectral irradiance at various wavelengths
- Tables with spectral integrals (e.g., UV-B and UV-A) and weighted spectral irradiances ("dose rates"). A total of six biological action spectra have been implemented, including the CIE action spectrum for erythema[6] and action spectrum for DNA damage[7].
- Tables with daily doses that were calculated by integrating spectral integrals and dose rates over time
- Measurements of PSP pyranometers
- Databases with system parameters used for quality control purposes

2.3.2 SUV Version 2 data

Version 2 have been consistently corrected for wavelength shifts using a Fraunhofer line correlation algorithm and for the cosine-error of the instruments' entrance optics. In addition, data were regridded to a uniform wavelength scale, and normalized to a wavelength-independent bandwidth of 1.0 nm FWHM (0.65 nm for SUV-150B). The uncertainty (95.5% confidence interval) of biologically effective UVR is 6% for most data[8]-[10]. The Version 2 dataset is more accurate and more homogenous than Version 0 data. Furthermore, all measured spectra are complemented with two sets of spectra calculated with the radiative transfer model UVSPEC/libRadtran[11]. One set is based on the assumption that the scene is free of clouds; the second set uses the measured cloud optical depth as an additional input parameter of the model. Model calculations are also a prerequisite for the cosine-error correction.

SUV Version 2 data include the following data products:

- Solar spectra with a bandwidth of 1.0 nm (0.65 nm for SUV-150B) from 280 to 600 nm. These files also include time, solar zenith and azimuth angles, cosine-error correction factors, and results of model calculations.
- Time series of spectral irradiance at various wavelengths
- Tables with spectral integrals and dose rates. A total of 15 biological action spectra have been implemented.
- Time series of daily doses
- Total ozone column
- Cloud optical depth at 450 nm
- Effective surface albedo
- Actinic flux and photolysis rate data for the reactions $O_3 \rightarrow O(^1D) + O_2$ and $NO_2 \rightarrow NO + O(^3P)$ (South Pole and Summit only for some years)
- Tables with quality indicators ("flags") such as residual wavelength shifts, spikes, minimum useable wavelength, manually-added quality-related comments, etc.
- Documentation of model input and parameters of correction algorithms
- Plots in PDF format, showing the ratio of measured and modeled spectra

2.3.3 GUV data

From the GUVs' measurements at five wavelength bands several secondary data products have been produced, including spectral integrals, biologically effective dose-rates, and total ozone[12]. Some data products are identical with those of the SUV, but have a better time-resolution (1 minute versus 15 minutes). GUV measurements are regularly compared with measurements of the collocated SUV spectroradiometers to ensure good accuracy and consistency with SUV data.

3. DATA ARCHIVAL

Considering that the future of the UVSIMN is uncertain, it is paramount that UV data collected during the last 20 years are archived at long-term data repositories. Data have consequently been submitted to (1) the World Ozone and UV Data Center (WOUDC, www.woudc.org), (2) the Cooperative Arctic Data and Information Service (CADIS, www.eol.ucar.edu/projects/aon-cadis); and (3) the SeaWiFS Bio-optical Archive and Storage System (SeaBASS, seabass.gsfc.nasa.gov/). We also plan to submit a subset of the dataset to (4) the Network for the Detection of Atmospheric

Composition Change (NDACC, www.ndsc.ncep.noaa.gov/). As the foci of these archives are different, UVSIMN data have been adjusted to best serve the needs of these organizations.

3.1 World Ozone and UV Data Center (WOUDC)

The World Ozone and UV Data Center (WOUDC, www.woudc.org) is an important data repository of the World Meteorological Organization's Global Atmosphere Watch (GAW) program. The WOUDC was established 1961, is located in Toronto, and operated by the Experimental Studies Section of Environment Canada. It currently contains UV data from about 90 sites and is regarded as the most important source for UV measurements worldwide. All data products described in Section 2.3 have been submitted to WOUDC and will soon be available via ftp. In addition, SUV Version 2 spectra (Version 0 for San Diego) and 1-minute GUV measurements were converted to the official WOUDC format and are now accessible through the WOUDC catalogue. WOUDC-format SUV data files include wavelength, spectral irradiance, time, solar zenith angle, solar azimuth angle, sky condition, minimum useable wavelength, UV-B, UV-A, and the UV Index.

3.2 Cooperative Arctic Data and Information Service (CADIS)

The Cooperative Arctic Data and Information Service (CADIS, www.eol.ucar.edu/projects/aon-cadis) supports the Arctic Observing Network (AON). It was conceived as a portal for data discovery with tools to mine data. AON is an NSF initiative for the International Polar Year (IPY) to improve observational capabilities in the Arctic and leave a long-term legacy for the benefit of science and society. It is envisioned that AON data will contribute to scientific research leading to (1) increased knowledge and understanding of the regional and global causes and consequences of present-day environmental Arctic Change; (2) scenarios for, and prediction of, the course of future Arctic Change and its regional and global consequences; and (3) the development of adaptive responses to Arctic Change. AON is integral to the Study of Environmental Arctic Change (SEARCH)[13].

All data products listed in Sections 2.3.2 and 2.3.3 for Barrow and Summit are available on the CADIS website. As this repository focuses on Arctic data only, measurements from San Diego and the Antarctic sites will not be available from CADIS.

3.3 SeaWiFS Bio-optical Archive and Storage System (SeaBASS)

The SeaWiFS Bio-optical Archive and Storage System (SeaBASS, seabass.gsfc.nasa.gov/) serves NASA's calibration and validation activities for ocean-viewing satellites. High-quality in-situ measurements are used for satellite data product validation, algorithm development, and many climate-related inquiries. The archive is maintained by NASA's Ocean Biology Processing Group (OBPG). SeaBASS was initiated by the "Sea-viewing Wide Field-of-view Sensor" (SeaWiFS) project and will be used for the validation of SeaWiFS, the "Moderate-resolution Imaging Spectroradiometer" (MODIS), and future ocean color satellite missions, as well as in the development of new ocean color algorithms.

Most data products listed in Sections 2.3.2 are available on the SeaBASS website for all sites. Datasets have been reformatted to meet SeaBASS requirements and do not include results of radiative transfer model calculations, photolysis rates, or quality control documentation.

3.4 Network for the Detection of Atmospheric Composition Change (NDACC)

If funding becomes available, we plan to submit a subset of the dataset to the Network for the Detection of Atmospheric Composition Change (NDACC, www.ndsc.ncep.noaa.gov/), formerly known as Network for the Detection of Stratospheric Change (NDSC). The network is composed of more than 70 high-quality, remote-sensing research stations for observing and understanding the physical and chemical state of the stratosphere and upper troposphere and for assessing the impact of stratospheric changes on the underlying troposphere and on global climate. While the NDACC remains committed to monitoring changes in the stratosphere with an emphasis on the long-term evolution of the ozone layer, its priorities have broadened considerably to encompass issues such as the detection of trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere.

To ensure high data quality, NDACC has stringent requirements for data submitted to its database. For example, UV spectroradiometers have to meet performance specifications and their measurements must have been compared to data of an instrument that has already been certified by NDACC[14] SUV-100 and SUV-150B spectroradiometers have recently passed these criteria[15]-[17].

The following data products are planned for inclusion with the NDACC submission:

- UV-B (285-315 nm)
- UV-A (315-400 nm)
- Erythemal UV (CIE action spectrum by McKinlay and Diffey[6])
- DNA-damaging UV (action spectrum by Setlow[7])
- Generalized Plant damage (action spectrum by Caldwell[18])
- Vitamin D production (CIE Action spectrum by Bouillon[19])

We note that UV data weighted with the action spectrum for Vitamin D production[19] are currently not part of the Version 2 dataset and will be produced as part of the NDACC data submission.

4. CONCLUSIONS

The UVSIMN has produced a high-quality Climate Data Record of UV radiation that includes a period of almost 20 years. The continuation of measurements as well as the upkeep of the project's website and data portal are currently threatened by lack of funding. To preserve this valuable resource for the long-term, UVSIMN data have been submitted to several national and international archives serving different research interests.

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