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UV IRRADIANCE MEASUREMENTS IN ANTARCTICA: Changes Seen in UV Environment at Palmer Station 1988-1998

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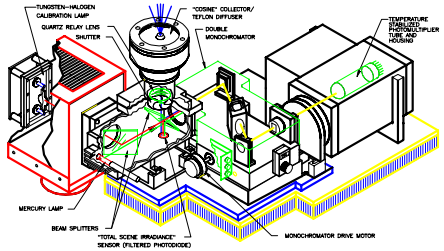
Abstract

The United States National Science Foundation's UV Monitoring Network for Polar Regions was established in 1988 to collect data on the impact of ozone depletion. This network of six sites, ranging from the South Pole, Antarctica, to Barrow, Alaska, makes routine high spectral resolution measurements of UV irradiance in the 290-600 nm region at 1 nm resolution. These data allow researchers to conduct field experiments on organisms, evaluate laboratory experiments, test models, and explore the impact of ozone depletion on the environment.

In the biologically important region around Palmer Station, significantly increased levels of UV-B have been recorded in the later years of this project related to the starting years. This increase has not been gradual, but appears related to the duration of ozone depletion rather than the extent at its maximum. Using ozone levels determined by Nimbus 7 TOMS, it is possible to correlate monthly average UV levels with ozone averages and, using this relationship, to project UV levels back as far as 1979. From this we can estimate the impact of Antarctic ozone depletion on the UV radiation climate.

Instrumentation

SUV-100 UV Spectroradiometer



The SUV-100 spectroradiometer is based on a temperature-stabilized, scanning double monochromator coupled to a photomultiplier tube (PMT) detector, and is optimized for operation in the UV. A vacuum-formed Teflon® diffuser serves as an all-weather irradiance collector and is conductively heated to minimize ice and snow buildup. The instrument has internal wavelength (Hg) and intensity reference (tungsten-halogen) lamps for automatic system performance characterizations at programmed intervals (typically once per day). Data acquisition system and control instrumentation accompanies the instrument. Starting in mid-1996, Pentium® microprocessor-based personal computers, using the Windows NT operating system, were put into use for system control and data collection.

Features of the SUV-100:

- Fully automated operation
- Spectral range: 280 - 610 nm
- Monochromator-bandwidth: 1.0 nm
- Calibration: Bi-weekly with 200-Watt lamps, NIST-traceable

Standard Data Products (available on CD-ROM):

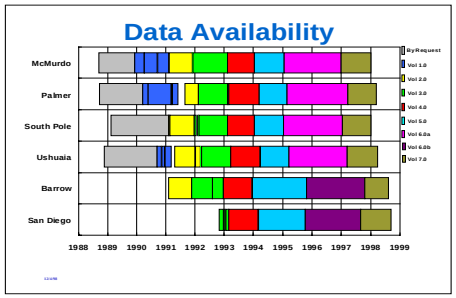
- Global spectral irradiance in <= 1 nm intervals
- Spectral integrals (e.g., UV-B, UV-A)
- Biologically weighted irradiance (e.g., CIE-erythema, DNA, Caldwell)
- Data from ancillary sensors (Eppley PSP and TUVR)

Network Sites

Site	Long.	Lat.	Estab.	Season
Antarctica:				
McMurdo	166E	77S	March, 88	Aug. - April
Palmer	64W	64S	May, 88	Year-round
South Pole	0	90S	Feb, 88	Sept. - March
South America:				
Ushuaia, Argentina[1]	68 W	54S	Nov, 88	Year-round
Valdivia, Chile[2]	*74W*	*40S*	*Oct, 96*	*Year-round*
North America:				
San Diego, California	117W	32N	Oct, 92	Year-round
Barrow, Alaska[3]	156W	71N	Dec, 90	Jan. - Nov.

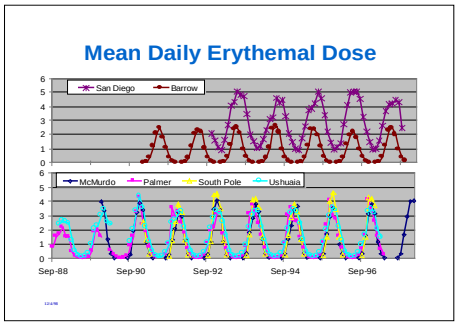
1: CADIC: Centro Austral de Investigaciones Cientificas, Argentina
2: WMO sponsored, not officially part of the NSF network. Operational support by Dirección Metereológica de Chile, installation at Universidad Austral de Chile
3: UIC/NARL Ukpeagvik Inupiat Corp. (formerly) Naval Arctic Research Lab

Data From Network Sites



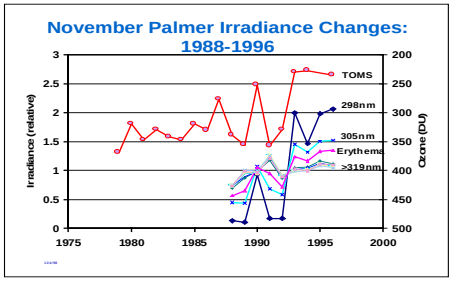
Volumes 1.0 to 6.0 are available on CD-ROM. Volume 7.0 is currently in preparation. For more information, contact Biospherical Instruments by e-mail at uvgroup@biospherical.com or use the data request form on our web site: www.biospherical.com.

Time Series of Erythemal Doses at Network Sites



Monthly means of the daily erythemal dose for all sites between 1988 and 1998. Due to 24 hours of sunlight at the South Pole, summer values at this site almost reach summer values in San Diego.

Changes Observed at Palmer Station



Monthly averaged irradiance levels for November at Palmer Station (left axis). The data are normalized to the average of all years (1988-1996) and plotted at several wavelengths and for erythemal[1] weighting. The upper curve represents the TOMS ozone monthly averages over Palmer Station (right axis, plotted in reverse order). The years can be grouped in two groups:

Group 1—Years where the ozone hole dissipated by November and the average ozone was high

Year	1988	1989	1991	1992	Averages
TOMS	339	356	358	329	345
Erythemal	1.98	2.28	3.35	2.51	2.53
DNA[2]	0.022	0.023	0.059	0.036	0.035

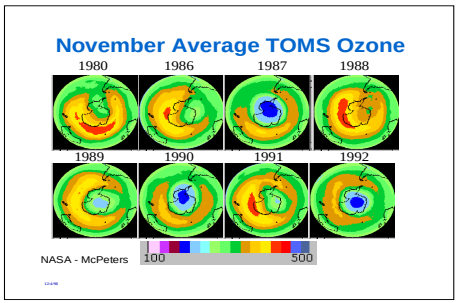
Group 2—Years where the ozone hole persisted later in the year

Year	1993	1994	1996	1990	Averages
TOMS	230	228	235	253	236
Erythemal	4.37	4.12	4.69	3.71	4.22
DNA[2]	0.080	0.070	0.083	0.087	0.080

The average ozone depletion among these two groups is -32% while the average increase in erythemal and DNA irradiances are 67% and 163%, respectively.

Changes between Group 1 and Group 2:

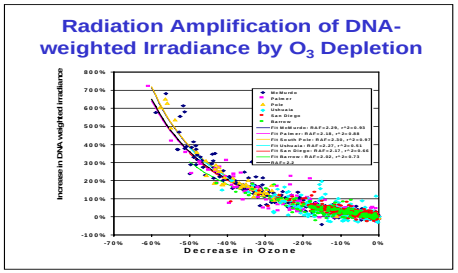
TOMS	-32%	Ozone Depletion
Erythemal	67%	UV Increase
DNA[2]	163%	UV Increase



Monthly average southern hemisphere ozone maps for November. The year 1987 marked the first year of this series showing significant depletion in November. The NSF Network began in 1988, which appears representative of years earlier than 1987. Year 1990 shows significant ozone depletion persisting into November, and years 1993 and after show depletion patterns similar to 1990.

Summary

- On a monthly averaged basis San Diego exhibits the highest daily UV doses of the NSF sites, with the Antarctica sites a close second.
- Significant increases in UV have been seen at Palmer during our monitoring effort.
- These increases are larger with decreasing wavelength below 340 nm. The greatest increases at Palmer occur in November, resulting in November being the month with the highest UV-B flux.
- Changes at Palmer inversely correlate with changes in monthly average average ozone, and approximate the RAF power relationship for DNA described by Booth and Madronich[3].
- Data are available on request by e-mailing uvgroup@biospherical.com or visiting www.biospherical.com.



Increase in DNA weighted irradiance at all network sites as a function of the decrease in ozone. The relationship can be well described by the "Power RAF formula," introduced by Booth and Madronich[3], where

$$\text{Power RAF} = \ln(E^*/E)/\ln(O_3/O_3^*)$$

Here, E*/E is the change in irradiance matching the change in ozone O_3/O_3^*. By least square approximation, the "Power RAF" was calculated for all sites and ranges from 2.02 to 2.30. This in close agreement with the value of 2.2 suggested by Booth and Madronich[3].

Acknowledgements

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References

[1] McKinley, A.F. and B.L. Diffey (eds.) (1987). A reference action spectrum for ultraviolet induced erythema in human skin. CIE Research Note, 6(1), 17-22.
[2] Setlow, R.B. (1974). The wavelength in sunlight effective in producing skin cancer: A theoretical analysis. Proc. Nat. Acad. Sci. USA, 71(9), 3363-3366.
[3] Booth, C.R. and S. Madronich (1994). Radiation amplification factors: improved formulation accounts for large increases in ultraviolet radiation associated with Antarctic ozone depletion. *Antarctic Research Series*, edited by C.S. Weiler and P.A. Penhale, 62, 39-42.

In addition, NSF network data has been referenced in more than 100 research papers, most published in refereed journals. For a full bibliography, please visit our web site at www.biospherical.com.