REPORT OF THE WORKSHOP ON UV-B FOR THE AMERICAS

(Buenos Aires, Argentina, 22-26 August 1994)
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1. OPENING OF THE WORKSHOP

Comodoro Ramon A. Sonzini, Director-General of the National Meteorological Service in Argentina opened the workshop, and welcomed all participants to Buenos Aires. He stressed the importance of global UV-monitoring network, and noted that continuous measurements of UV radiation are important in areas where in addition to natural radiation, from time to time periods of exceptional UV-radiation occur over populated areas. Comodoro Sonzini gave credit to Global Environment Facility (GEF) projects that have supported the WMO Global Atmosphere Watch (GAW) to establish a GAW observatory in Ushuaia, Argentina, and will allow GAW to create more ozone and UV measuring stations in South America (CONE-project).

On behalf of the Secretary-General, Prof. G.O.P. Obasi, Dr. Antti Kulmala, welcomed the participants (see the list of participants, Appendix A). In his statement Dr. Kulmala noted that UV measurements and information on the possible effects of UV radiation to the public have rapidly gone up in the agenda for atmospheric research. He complimented the host country and the co-sponsoring countries, Canada and USA, for a timely organised workshop.

Mr. Craig S. Long, U.S. National Service, speaking for USA, noted that in this workshop experts with experience on UV-radiation will offer their latest knowledge for the benefit of countries that have just started, or are planning to start, their own research projects. He pointed out the need for qualified information for not only the skin effects of the UV radiation but also on its effects to the eyes and immune system.

Mr. Timothy Goos, Atmospheric Environmental Service, Edmonton, Canada, speaking for Canada noted that Canada looks forward to an interesting and interactive meeting amongst UV-scientist in the Americas. As one of the main goals of the workshop he pointed out discussion on the UV forecasting, reporting and public information programmes.

After opening statements, Mr. Goos, as the chairman of the workshop, introduced the agenda (see Appendix B), and stressed the goals of the workshop laid down in the agenda.

Next he called Professor John Frederick to give the keynote speech. An abstract of his lecture is to be found in Appendix D, together with the abstracts of other speakers in the workshop. Central information from his lecture is also included in the chapter 2.1.

2. SUMMARY OF LECTURES AND DISCUSSIONS

In this chapter condensed results of the discussions of the workshop are presented. For sessions A (Overview presentation) and B (Specific presentation) the results are summarized in bullet form whereas for session C (Information exchange) the presentations by country experts are mentioned, because they contributed new information on projects in South America.

2.1 Summary of Sessions A and B

2.1.1 Ozone depletion

From satellite information the ozone reduction per decade is 2.5 to 6% between 35 and 65 degrees in both hemispheres.

In Antarctica O₃ depletion reaches a maximum in September/October as a result of physical-chemical reactions occurring at the surface of ice crystals in extremely low temperatures.

There is 15% less naturally occurring ozone in the Southern Hemisphere due to variations in circulation patterns caused by geographical differences.
Scientists cannot yet account for all the ozone losses occurring.

The role of volcanic eruptions in ozone depletion is not fully understood.

There is a need for inter-disciplinary co-operation among the physical, biological and chemical sciences in order to fully understand the nature of ozone depletion.

Scientific findings have provided the lead role in the success of international agreements on controlling ozone depleting substances.

2.1.2 Changes in UV radiation

During the austral spring ozone hole, several observing sites in Antarctica reported UV radiation levels similar to that of mid latitudes.

In Antarctica the duration of ozone depletion is more important than the absolute ozone reduction.

In South America some days show an increase in UV of 60 to 70%. The monthly increase can be as high as 45%.

There are many factors which affect UV intensity - ozone thickness, time of day, season, latitude, surface reflectivity, haze and pollution.

2.1.3 Effects of UV radiation

Worldwide, 2M people per year develop non-melanoma skin cancer and 200,000 per year develop malignant melanoma.

Because of consensus about the effect of UV on the human immune system, WHO is concerned that increased UV will affect their world wide immunization programmes.

80% of lifetime UV dosage is received by the age of 18.

The tropics are often referred to as the cataract belt.

Both UV and thermal radiation contribute to eye cataracts.

While only 2% of incident UVB reaches the eye’s lens, it is the most biologically important.

In terms of eye damage from UV, the morning and afternoon sun is important.

Traditional headgear often provides very good UV protection.

UV has been found to affect the mass and size of selected cultivars.

Plants have adapted to increased UV and have preventive capabilities to adapt further but it is not known how much further they can adapt to increased UV.

The action spectra for plants is different from that of humans. Biologists’ needs are not well met by most of the broadband instruments.
2.1.4 UV monitoring

Monitoring needs must be carefully assessed before acquiring expensive UV instruments.

The wide variety of UV instruments in existence today makes comparison and sharing of data difficult.

Spectral and broadband instruments have their own unique calibration problems.

Multifilter instruments were also discussed.

Existing reports on intercomparison should be carefully considered.

2.1.5 UV indices and public education

The UV Index serves an important function in keeping UV issues and the need to take suitable precautions at the forefront of people’s minds.

In Canada the UV Index programme has been shown to provide a good long term tool to change people’s attitudes.

Existing organizations such as national meteorological services provide a variety means to deliver UV products.

14 countries are now producing regular UV Index forecasts.

Staff must be properly trained on ozone and UV climatology and variations so that they can properly distribute and explain products and programmes to the public.

WHO invites Latin American countries to adopt their UV health information.

Public education is an essential part of any UV Index programme.

It is difficult to relate a specific action to a particular UV Index value - UV affects the eyes and immune system as well as the skin.

2.2 Summary of Session C

Argentina, Chile, Colombia, Costa Rica and Cuba reported on existing UV-monitoring programmes. Some of these countries have several groups active in ozone and UV-research. Guatemala, Peru and Paraguay (CONE-project) presented their preliminary plans for starting UV-monitoring. Barbados, Bolivia and Trinidad and Tobago expressed their interest in UV-research.

At least one country has a UV-monitoring station with a spectral instrument (operational since 1988), and two more stations will start during the next years. Some countries have various types of multiband spectroradiometers, whereas for financial reasons many countries use broadband radiometers.

Several speakers noted that WMO should help in developing UV-instruments that technically fall between broadband and spectral instruments, they should be easy to operate, and they should be cheaper than spectral instruments. Some developments in that direction were reported.
The forthcoming WMO/GEF project for Southern American countries, CONE-project for additional ozone and UV-monitoring in Argentina, Brazil, Chile, Paraguay and Uruguay was reported.

The Workshop was also presented with the latest news on the WMO/GEF project to install two new GAW-observatories in the RA III. The Argentinean observatory near Ushuaia will start its first campaign at the beginning of September 1994. The meeting was informed on bilateral negotiations between Costa Rica and Japan to establish a GAW station in Costa Rica.

A few scientists reported on their ongoing or planned studies on biological and health effects of UV-radiation.

Some speakers showed measurements that highlighted the effect of high air pollution in attenuating UV-radiation. In Mexico City the attenuation as high as 30 per cent was reported. Santiago was shown to have a similar effect. In Santiago large increases in UV-radiation were observed once the pollution envelope was traversed rising from the city into the adjoining mountains.

In many presentations the need for intercomparisons, intercalibrations, international standard instruments, measuring and QA protocols, unified units, education and training as well as exchange of information and data was stressed. WMO was often pointed out as a source of information.

Mexico reported that they give out twice a day measured information on minimum erythemal doses. They also have information campaigns to educate local people and foreign tourists. In Argentina a discussion has started on the advantages to publish UV-indexes. A first information campaign is underway.

3. WORKSHOP RECOMMENDATIONS

At the end of session C a general discussion on workshop topics was organized. It resulted in the following recommendations. The wording of the recommendations has been drafted by Bob Saunders, Craig Long and Antti Kulmala as members of the scientific steering committee.

a. Software should be developed to facilitate comparison of data from different instruments.

b. Exchange of data should be improved:
   - through ensuring that data is forwarded to the WMO ozone and UV data banks in Toronto, Canada;
   - with interested RA III and IV countries for the exchange, in real time, of significant data;
   - through improvement of communication infrastructures;
   - through making intermediate technology (multi-channel instruments) available at reasonable costs;
   - by providing better access to training for the operation, calibration and maintenance of instruments for RA III and IV countries;
   - through inclusion of ancillary information to facilitate data interpretation.
c. Recommendations from the Expert Meeting at Les Diablerets should be considered by WMO and WHO (see Appendix C).

d. Instrument intercomparisons should be encouraged through cooperative sharing of high resolution equipment facilities.

e. Advice should be provided on the usefulness of broadband instruments currently in operation (e.g. Eppley).

f. Additional ozone and UV stations should be established in tropical belt countries.
1. APERTURA DEL CURSILLO

El Comodoro Ramón A. Sonzini, Director General del Servicio Meteorológico Nacional de Argentina, declaró abierto el Cursillo y dio la bienvenida a Buenos Aires a todos los participantes. Destacó la importancia de la red mundial de vigilancia de las radiaciones UV y señaló que se efectúan continuamente mediciones de radiaciones UV en zonas donde, además de la radiación natural, de vez en cuando se dan períodos de radiación UV excepcional en zonas pobladas. El Comodoro Sonzini encomió los proyectos del Fondo para el Medio Ambiente Mundial (FMAM), que han apoyado la Vigilancia de la Atmósfera Global (VAG) de la OMM con el fin de establecer un observatorio de la VAG en Ushuaia, Argentina, y que permitirá a la VAG crear más estaciones de medición de ozono y radiaciones UV en América del Sur (proyecto CONE).

En nombre del Secretario General, Prof. G.O.P. Obasi, el Dr. Antti Kulmala, dio la bienvenida a los participantes (véase la lista de participantes, Apéndice A). En su declaración, el Dr. Kulmala señaló que las mediciones de radiaciones UV y la información sobre los posibles efectos de éstas para el público han avanzado rápidamente en los programas de investigación de la atmósfera. Felicitó al país de acogida y a los países copatrocinadores, Canadá y Estados Unidos, por haber organizado tan oportunamente el cursillo.

El Sr. Craig S. Long, Servicio Nacional de Estados Unidos, hablando en nombre de este país, indicó que los expertos con experiencia en radiaciones UV expondrán en este cursillo los conocimientos más recientes, en beneficio de los países que acaban de iniciar, o piensan hacerlo, sus propios proyectos de investigación. Señaló la necesidad de información fidedigna no sólo de los efectos sobre la piel de las radiaciones UV sino también sobre los ojos y el sistema inmunario.

El Sr. Timothy Goos, Servicio del Medio Ambiente Atmosférico, Edmonton, Canadá, hablando en nombre de este país, señaló que Canadá espera una interesante e interactiva reunión entre científicos de UV en las Américas. Señaló que uno de los principales objetivos del cursillo es la discusión de la predicción de radiaciones UV, los informes al respecto y los programas de información al público.

Tras las declaraciones de apertura, el Sr. Goos presentó, como Presidente del Cursillo, el orden del día (véase el Apéndice B), y resaltó los objetivos del cursillo que figuran en el orden del día.

Luego pidió al Prof. John Frederick que pronunciara el discurso principal. En el Apéndice D figura un resumen del mismo, junto con los correspondientes a las disertaciones en el cursillo de otros oradores. La información más relevante de su disertación se incluye también en el Capítulo 2.1.

2. RESUMEN DE DISERTACIONES Y DISCUSIONES

En este capítulo se presenta una síntesis de los resultados de las discusiones del cursillo. Los resultados de las Sesiones A (Presentación general) y B (Presentación específica) se exponen en forma muy resumida, en tanto que con respecto a la Sesión C (Intercambio de información) se mencionan las disertaciones por los expertos nacionales, porque aportaron nueva información sobre proyectos en América del Sur.
2.1 Resumen de las Sesiones A y B

2.1.1 Agotamiento de la capa de ozono

Según la información obtenida por satélite, la reducción del ozono se sitúa entre 2,5% y 6% por decenio entre 35 y 65 grados en ambos hemisferios.

En la Antártida, el agotamiento de Oz alcanza su máximo en septiembre/octubre, como resultado de reacciones físico-químicas que se producen en la superficie de cristales de hielo en temperaturas sumamente bajas.

En el hemisferio sur hay naturalmente un 15% menos de ozono, debido a variaciones en los esquemas de circulación a causa de diferencias geográficas.

Los científicos todavía no pueden explicarse todas las pérdidas de ozono que se producen.

No se conoce plenamente la influencia de las erupciones volcánicas en el agotamiento del ozono.

Se requiere una cooperación interdisciplinaria entre las ciencias físicas, biológicas y químicas con el fin de comprender totalmente la naturaleza del agotamiento del ozono.

Gracias a conclusiones científicas se conoce el gran papel que han desempeñado los acuerdos internacionales en el éxito obtenido en el control de las sustancias que agotan el ozono.

2.1.2 Cambios en la radiación UV

En el período de duración del agujero del ozono en la primavera austral, varias estaciones de observación de la Antártida comunicaron niveles de radiación UV similares a los de latitudes medias.

La duración del agotamiento de la capa de ozono en la Antártida es más importante que la reducción absoluta de ozono.

En América del Sur, algunos días se registra un aumento de radiación UV del 60% al 70%. El aumento mensual puede llegar hasta 45%.

Hay numerosos factores que influyen en la intensidad de la radiación UV: espesor de la capa de ozono, momento del día, estación, latitud, reflectividad en superficie, calima y contaminación.

2.1.3 Efectos de la radiación UV

En el mundo entero, dos millones de personas desarrollan anualmente cáncer de la piel sin llegar a melanoma, y 200.000 al año desarrollan melanomas malignos.

En razón del consenso acerca del efecto de la radiación UV en el sistema inmunitario humano, la OMS está preocupada porque el aumento de la radiación UV afectará a sus programas mundiales de inmunización.

El 80% de la dosificación UV durante su ciclo de vida se recibe a la edad de 18 años.
Los trópicos se consideran a menudo generadores de cataratas.

Tanto la radiación UV como la radiación térmica contribuyen a las cataratas de los ojos.

Si bien sólo el 2% de la radiación UVB incidente llega al cristalino del ojo, es la más importante biológicamente.

En cuanto al daño causado por la radiación UV a los ojos, el más nocivo es el sol de la mañana y de la tarde.

El sombrero tradicional representa con frecuencia una protección muy buena contra la radiación UV.

Se ha observado que la radiación UV afecta a la cantidad y al tamaño de determinados cultivos.

Las plantas se han adaptado al aumento de la radiación UV y tienen capacidades preventivas para adaptarse todavía más, pero no se sabe hasta qué extremo pueden seguir adaptándose al aumento de la radiación UV.

El espectro de acción en el caso de las plantas y en el de los seres humanos difiere. La mayoría de los instrumentos de banda ancha no satisfacen las necesidades de los biólogos.

2.1.4 Vigilancia de la radiación UV

Las necesidades de vigilancia han de analizarse detenidamente antes de adquirir instrumentos UV costosos.

La comparación y el compartimento de datos es difícil con la amplia variedad de instrumentos UV existentes actualmente.

Los instrumentos espectrales y de banda ancha tienen sus problemas de calibración peculiares.

También se trató de instrumentos de varios filtros.

Deben examinarse detenidamente los informes existentes sobre intercomparaciones.

2.1.5 Índices de UV e instrucción del público

El Índice UV cumple una importante función al mantener vivas en la mente de la gente las cuestiones de la radiación UV y la necesidad de tomar las debidas precauciones.

En Canadá se ha mostrado que el programa del Índice UV proporciona un buen instrumento a largo plazo para modificar las actitudes de las personas.

Organizaciones como los Servicios Meteorológicos Nacionales proporcionan una variedad de medios para suministrar productos UV.

Actualmente, 14 países producen predicciones regulares del Índice UV.
Es preciso formar debidamente al personal sobre la climatología y las variaciones del ozono y de la radiación UV, de manera que puedan distribuir y explicar productos y programas al público.

La OMS invita a los países latinoamericanos a que adopten su información de salud sobre la radiación UV.

La instrucción del público forma parte esencial de todo programa de Índice UV.

Es difícil relacionar cualquier acción concreta con un valor particular del Índice UV: la radiación UV afecta a los ojos y al sistema inmunitario, así como a la piel.

2.2 Resumen de la Sesión C

Argentina, Chile, Colombia, Costa Rica y Cuba informaron sobre los programas de vigilancia de la radiación UV existentes. En algunos de esos países hay varios grupos consagrados activamente a la investigación UV del ozono y de la radiación. Guatemala, Perú y Paraguay (proyecto CONE) presentaron sus planes preliminares para iniciar la vigilancia de la radiación UV. Barbados, Bolivia y Trinidad y Tabago expresaron su interés en la investigación de la radiación UV.

Al menos un país tiene una estación de vigilancia de la radiación UV con un instrumento espectral (que funciona desde 1988), y otras dos estaciones empezarán a funcionar en los próximos años. Algunos países disponen de varios tipos de espectrorradiómetros multibanda, en tanto que, por razones económicas, muchos países utilizan radiómetros de banda ancha.

Varios oradores señalaron que la OMM debe ayudar a desarrollar instrumentos UV que se sitúen técnicamente entre los instrumentos de banda ancha y espectrales, sean más manejables, y más económicos que los instrumentos espectrales. Se comunicó alguna evolución en ese sentido.

Se informó acerca del próximo proyecto OMM/FMAM para países sudamericanos, del proyecto CONE para una mayor vigilancia del ozono y de la radiación UV, en Argentina, Brasil, Chile, Paraguay y Uruguay.

También se comunicaron en el cursillo las últimas novedades sobre el proyecto OMM/FMAM para instalar los nuevos observatorios de la VAG en la AR II. El observatorio argentino situado cerca de Ushuaia iniciará su primera campaña en los primeros días de septiembre de 1994. Se informó a la reunión de negociaciones bilaterales entre Costa Rica y Japón para establecer una estación de la VAG en Costa Rica.

Algunos científicos dieron a conocer sus estudios en curso o previstos sobre los efectos biológicos y para la salud de la radiación UV.

Algunos oradores presentaron mediciones que destacaban el efecto de la elevada contaminación de la atmósfera en la atenuación de la radiación UV. Se informó que en Ciudad de México la atenuación llegaba al 30%. Se mostró que en Santiago el efecto era similar. En Santiago se observaron grandes cantidades de radiación UV, una vez que se atravesaba la capa de contaminación elevándose desde la ciudad hasta las montañas vecinas.

En muchas presentaciones se destacó la necesidad de intercomparaciones, intercalibraciones, instrumentos internacionales normalizados, protocolos de medición y de garantía de calidad, unidades unificadas, instrucción y formación, así como un intercambio de información y de datos. Se señaló frecuentemente que la OMM es una de las fuentes de información.
México comunicó que se proporciona información sobre mediciones dos veces al día acerca de dosis de eritema mínimas. También realizan campañas de información para instruir a la población local y a los turistas extranjeros. En Argentina se ha iniciado una discusión sobre las ventajas de publicar índices UV. Está en marcha una primera campaña de información.

3. RECOMENDACIONES DEL CURSILLO

Al final de la Sesión C se organizó una discusión general sobre los temas del cursillo, que dio como resultado las siguientes recomendaciones. Las recomendaciones han sido redactadas por Bob Saunders, Craig Long y Antti Kulmala, como miembros del Comité directivo científico.

a. Se debe preparar soporte lógico para facilitar la comparación de datos de diferentes instrumentos.

b. Debe mejorarse el intercambio de datos:

- asegurándose de que los datos se transmiten a bancos de datos de la OMM sobre el ozono y radiación UV en Toronto, Canadá;
- en colaboración con los países interesados de la AR III y la AR IV para el intercambio, en tiempo real, de datos significativos;
- mediante la mejora de infraestructuras de comunicaciones;
- poniendo a disposición tecnología intermedia (instrumentos multicanal) a costos razonables;
- proporcionando mejor acceso a la formación para el manejo, la calibración y el mantenimiento de instrumentos para países de la AR III y la AR IV;
- incluyendo información auxiliar para facilitar la interpretación de los datos.

c. La OMM y la OMS deben considerar recomendaciones de la reunión de expertos en Les Diablerets (véase el Apéndice C).

d. Deben estimularse las intercomparaciones de instrumentos compartiendo en cooperación instalaciones de equipo de alta resolución.

e. Debe asesorarse sobre la utilidad de los instrumentos de banda ancha utilizados actualmente (por ejemplo, Eppley).

f. Deben establecerse en países del cinturón tropical más estaciones sobre el ozono y la radiación UV.
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ANNEX B

WMO Workshop on UV-B for the Americas
(Buenos Aires, Argentina)
22-26 August 1994

AGENDA

Objectives:

1. To provide information on the nature of UV radiation, the health effects associated with over exposure of UV and UV measurement and prediction.

2. To exchange information on the status of stratospheric ozone and UV monitoring programmes in RA III and IV countries.

3. To describe UV information services and public education programmes operating in various countries.

4. To provide information which will assist interested countries to develop UV monitoring, forecasting and public education and information programmes.

TECHNICAL PROGRAMME

Chair: Tim Goos

Monday, 22 August

13:30 Opening session

14:00 Keynote speaker, John Frederick - the science health issue of overexposure to UV

A. OVERVIEW PRESENTATION - Session Chair - Susana Diaz

1. Nature of the Ozone Layer and UV Radiation

15:30 Stratospheric Ozone Layer - Jim Kerr, (Global Overview) and Michael Proffitt (Southern Hemisphere)

Tuesday, 23 August

09:00 UV Radiation - John Frederick

2. Effects of UV Radiation

10:30 Human Health - Mike Repacholi and David Sliney

12:00 LUNCH

13:30 Other biological effects of UV radiation - Manfred Tevini

B. SPECIFIC PRESENTATION - Session Chair - Betsy Weatherhead

1. UV Information Services and Public Education Programmes
   Description/discussion of national programmes and public reaction in:
14:30  Canada - Bob Saunders, Tim Goos, Yvon Deslauriers

16:00  Coffee Break

**Wednesday, 24 August**

09:00  United States - Craig Long

10:00  Review of other countries - Betsy Weatherhead

10:30  Coffee Break

11:30  UV Measurement Programmes - Rocky Booth, Jim Kerr

12:00  LUNCH

13:30  UV Forecasting - Craig Long

C.  INFORMATION EXCHANGE - Session Chair - Antti Kulmala

14:30  Introduction - Susana Diaz

15:00  Coffee Break

15:30  Exchange of information on the status of stratospheric ozone and UV monitoring programmes in RA III and IV countries.

Representatives of RA III and IV countries are invited to speak for 10-15 minutes on their UV activities and programmes.

**Thursday, 25 August**

09:00  Exchange of information to assist interested countries to develop UV monitoring, forecasting and public education and information programmes. All participants and Speakers to take part in these discussion.

10:30  Coffee Break

12:00  Summary of the Workshop - Tim Goos

13:00  Closing Session

******
EXECUTIVE SUMMARY

Because of stratospheric ozone decline, especially over the last five years, the relationship between the decrease of ozone and the increase of UV radiation reaching the ground has become a major public and scientific issue. In response to this problem, a number of UV monitoring stations have recently been put into operation, or are currently proposed, and in a few countries diagnostic and/or predictive indices have been designed as a public health warning.

Within the framework of the WMO Global Atmosphere Watch, the WMO organized, in collaboration with the UV Monitoring and Assessment Programme (UMAP) sponsored by an international group of chemical companies and the International Ozone Commission, a four day meeting of experts to discuss harmonization of present activities and to define future programme objectives of UV monitoring and index calculation.

During the first two days, discussions included describing on-going monitoring programmes, defining a quality assurance protocol to harmonize the measurements internationally and specifying techniques of data archiving. Specific recommendations that were made during this session were:

- Publish a catalogue/inventory of UV monitoring activities
- Develop international instrument calibration facility
- Produce a QA protocol and co-ordinate data availability
- Establish under the WMO's lead a global UV monitoring network to be guided by a scientific steering committee. Under this committee, an action plan for implementation will be designed.

During the second part, the participants unanimously recommended that a standard UV index be based on the following:

- A minimum requirement is to report irradiance values at local solar noon.
- The index is expressed by multiplying the weighted irradiance in W/m² by 40.0 (this will lead to an open-ended index which is normally between 0 and 16).

It was further recommended that the issue of utilization of the C.I.E. action spectrum be forwarded to the World Health Organization for consideration and possible endorsement.

All the participants agreed that important progress had been made in co-ordinating global UV activities.
ABSTRACTS AND SUMMARIES OF THE PRESENTATIONS

Ultraviolet Sunlight in an Evolutionary and Biological Context
John E. Frederick - The University of Chicago

An ozone layer did not exist in the earliest atmosphere of the earth. Under these conditions, approximately 3.5 to 4.0 billion years ago, ultraviolet light from the sun penetrated into the lower atmosphere and to the surface of the oceans. Here it initiated a complex series of chemical reactions leading to the formation of organic molecules that formed the building blocks of living tissue. Prior to the evolution of photosynthesis, simple one-celled life forms in the oceans used these organic molecules as a source of energy. In these early ecosystems life depended on a large influx of ultraviolet radiation for its survival. With the coming of photosynthesis, one-celled life was able to create organic molecules from carbon dioxide, water, and visible sunlight in the environment. An accidental byproduct of this process was the release of molecular oxygen (O₂) into the oceans and its accumulation in the atmosphere.

The interaction of ultraviolet sunlight with molecular oxygen led to the development of an ozone (O₃) layer around the earth during the time period from 3.0 to 1.0 billion years ago. The new ozone layer provided a shield that prevented all of the ultraviolet-C and much of the ultraviolet-B (UV-B) radiation from reaching the ground. The absence of short-wavelength ultraviolet sunlight terminated the production of organic molecules near the ground by atmospheric chemistry. The subsequent evolution of life on earth depended on the existence of photosynthesis as the ultimate source of organic molecules at the base of the food chain. Furthermore, the evolution of complex organisms, from early multicellular life to humans, took place on a world characterized by reduced levels of UV-B radiation.

The biological effects of ultraviolet sunlight begin when a quantum of radiation is absorbed by a molecule in a living cell, and a chemical change is initiated. The chain of cause and effect from the initial absorption to observable changes in an organism is lengthy and often poorly understood. The connection between ultraviolet radiation and biological effects can be described by an empirical
dose-response relationship. Here one needs a quantitative definition of the response. This is related to a dose of radiation via laboratory experiments or by using medical statistics for large populations with known radiation exposures. For example, a response could be defined as the number of cases of nonmelanoma skin cancer reported per year per 100,000 population. The dose should be the biologically effective ultraviolet radiation per year that strikes the target population. In practice the dose is approximated by the ultraviolet irradiance incident on a horizontal surface integrated over time.

A difficulty appears when attempting to characterize the biologically effective dose. Laboratory experiments show that different wavelengths of radiation have very different degrees of biological effectiveness. For example, a given amount of energy at a wavelength of 300 nm is approximately 1000 times more effective at causing sunburn than is the same amount of energy at 340 nm. This wavelength dependent sensitivity is described by an action spectrum. Action spectra can be determined empirically by measuring the biological response to monochromatic radiation over a range of wavelength. In sunlight one computes the biologically effective dose by weighting the irradiance at each wavelength with the appropriate value of the action spectrum.

If one knew the dose-reponse relationship and associated action spectrum for every conceivable biological effect, then it would be possible to estimate the consequences of changes in the ultraviolet radiation environment at the ground. However, this level of knowledge is far beyond the current capabilities in photobiology. At present a useful approach appears to be (1) establish worldwide programs for monitoring the sun's ultraviolet radiation and other environmental variables, (2) maintain detailed records of the incidence of health problems that could be related to ultraviolet exposure, and (3) develop approaches to monitoring the states of natural ecosystems with emphasis on the detection of small changes over time.
GLOBAL HABITABILITY

* What processes maintain the earth's environment in the narrow range that life can tolerate?

* Parts of the answer:

Electromagnetic Radiation

- Ultraviolet, visible, and infrared light

Trace Gases in the atmosphere

- Carbon Dioxide: Regulation of the earth's temperature via the "greenhouse effect"

→ Ozone: Absorption of biologically damaging solar ultraviolet radiation

The Extraterrestrial Solar Irradiance (*

<table>
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<tr>
<th>Spectral Region</th>
<th>Wavelengths (nm)</th>
<th>Irradiance (watts/sq m)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Constant</td>
<td>all</td>
<td>1370</td>
<td>100</td>
</tr>
<tr>
<td>IR &amp; Visible</td>
<td>&gt;400</td>
<td>1257</td>
<td>91.7</td>
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<td>UV-A</td>
<td>320-400</td>
<td>86</td>
<td>6.3</td>
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<tr>
<td>UV-B</td>
<td>280-320</td>
<td>21</td>
<td>1.5</td>
</tr>
<tr>
<td>UV-C &amp; Shorter</td>
<td>&lt;280</td>
<td>6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

(*) Solar energy that crosses unit area in unit time above the earth's atmosphere. The reference area is oriented perpendicular to the incoming solar beam. Values refer to the annual mean distance between the earth and the sun. Irradiance in early January exceeds that in early July by 6.9%.
The Budget of Biologically Active Ultraviolet Solar Radiation

Incident Solar Irradiance = 1

Backscattering (Clouds, Ground, Atmosphere)

Ozone Layer

Surface Albedo

Some Biological Effects of Solar Ultraviolet Radiation

* Nonmelanoma skin cancer
* Possible link to melanoma skin cancer
* Cataract formation
* Suppression of the immune system
* Inhibition of photosynthesis in plants
* Inhibition of plant growth and development
* Synthesis of vitamin D in humans and animals (a positive effect)
SENSITIVITY OF SURFACE ULTRAVIOLET IRRADIANCE TO CHANGES IN COLUMN OZONE

Flux Ratio: $F_{\text{Altered O}_3}/F_{\text{Standard O}_3}$

WAVELENGTH (nm)

PERCENTAGE CHANGE

-50
0
50
100

10% Ozone Decrease

10% Ozone Increase
ANNUAL CYCLE IN ERYTHEMAL IRRADIANCE:
24 HOUR INTEGRALS AT NORTH AMERICAN LATITUDES

(32-YEAR DOBSON OZONE)

Integrated Irradiance (J/m²)_eff

34.5°N
46.0°N
58.5°N

ERYTHEMA

Month

34.5°N = LOS ANGELES, CA
46.0°N = PORTLAND, OR
58.5°N = JUNEAU, ALASKA
Percent Difference in Erythemal Irradiance Between the Hemispheres

SUMMER

S.H.-N.H. Difference (%) vs Latitude (N or S)

- MEE48
- Plant
- Erythema
THE STRATOSPHERIC OZONE LAYER

J.B. Kerr

WMO Workshop on UV for the Americas
Buenos Aires, Argentina
August 22-25, 1994

ABSTRACT

Stratospheric ozone is an important atmospheric constituent primarily because of its radiative properties. Its absorption and emission of infrared radiation make it a significant contributor to the greenhouse radiation budget. Ozone also reduces the amount of solar radiative energy that reaches the earth's surface because it absorbs at visible and ultraviolet wavelengths. The fact that ozone absorbs ultraviolet radiation is very important since this radiation is generally detrimental to life at the earth's surface. Stratospheric ozone can be readily destroyed by trace gases in the stratosphere because ozone is a highly reactive oxidant. There is concern that the use of man-made chemicals such as chlorofluorocarbons (CFC's) results in an increase of reactive chlorine in the stratosphere that can potentially destroy stratospheric ozone.

Analysis of ozone records from the global ozone observing system has shown that the levels of stratospheric ozone have been decreasing in recent years. The most dramatic decrease has occurred over the Antarctic during October (the Antarctic ozone hole). Significant decreases over other regions of the world are also evident.

The importance of ozone as a stratospheric constituent and its radiative properties are reviewed. The processes involved in the destruction of ozone are described. Observed trends in stratospheric ozone are presented.
Stratospheric Ozone in the Southern Hemisphere

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The earth’s atmosphere is a tenuous feature of the global ecosystem. The stratospheric ozone layer is perhaps the most critical link between the sun, that drives the motions and chemical reactions of the atmosphere, and the biosphere. It regulates the quantity of UV-B radiation at the earth’s surface, thus affecting both the plant and animal kingdoms, and by virtue of the heating it provides for the stratosphere, it may contribute to the stability of the local meteorological conditions at the surface of the earth. In these ways, it is very likely that the health of the stratospheric ozone layer strongly influences the well-being of mankind.

Our atmosphere is complex, not only from the standpoint of chemistry and meteorology, but also in their interdependence. Ozone is created high in the stratosphere and it is destroyed naturally by various photochemical processes. Ozone is the only atmospheric trace species that significantly absorbs throughout the UV-B spectral region. The natural balance between ozone production and destruction can be disturbed by man’s activities and thus change the spectral balance of solar radiation striking the earth, particularly in the UV-B part of the spectrum. Because of this, we must understand how our activities cause changes in the ozone layer.

Early studies, 10 to 20 years ago, of stratospheric ozone loss, concentrated on gas-phase chemistry related to the release of chlorine from various stable molecules, primarily the CFC’s. These studies indicated that ozone would be lost due to chlorine catalyzed reactions high in the stratosphere, about 40 km altitude, where intense UV radiation was present. However, in 1985 large seasonal decreases in ozone were reported over Antarctica, with losses occurring during a period when there was little solar radiation. Subsequent reports showed that the losses were centered at about 20 km, well below the expected altitudes for gas-phase CFC induced ozone loss. Various explanations were offered for these changes in ozone, some chemical and due to man and others dynamical but purely natural. Early tests of these theories showed that the dynamical explanations were incorrect, leaving chemistry as the likely cause. Aircraft studies in 1987 verified that reactive chlorine was present in sufficient quantity to cause the so-called ozone hole. Measurements of other molecular species showed that unusual chemistry was taking place on the surfaces of particles produced by the cold Antarctic temperatures. These particles form polar stratospheric clouds and support reactions that release reactive forms of chlorine and that can precipitate carrying with them chemical species that allow the chlorine to remain available for ozone destruction. This was the advent of atmospheric heterogeneous chemistry studies. The continuation of these studies is still refining our understanding of stratospheric ozone loss. We now understand that the persistence of extremely low temperatures over Antarctica in the presence of sunlight trigger the chemistry that causes the ozone hole. Since the Arctic temperatures are not as cold, and they do not persist as long, there is far less change in ozone observed over the Arctic.
The spread of the region of ozone loss outside the ozone hole itself was also apparent when the data from 1987 were analyzed with greater scrutiny. In fact, satellites with their global coverage of ozone, have shown that ozone has decreased significantly at mid-latitudes over the past decade, with a seasonal dependence that is not completely understood. It is becoming increasingly apparent that the polar regions (vortices) are not isolated regions of ozone loss, but instead they act as flowing processers of ozone, accepting ozone rich air at upper altitudes and expelling ozone poor air back into the stratosphere at lower altitudes. This depleted air returns to mid-latitudes where it mixes and dilutes the mid-latitude ozone. A full explanation of the ozone changes occurring at mid-latitudes has not been found, although chemical loss occurring in the polar region or at mid-latitudes is certainly a significant contributor. Never-the-less, a dynamical explanation or other non-chemical explanation should not be ruled out as being partly responsible.
The Ultraviolet Radiation Environment of the Biosphere

John E. Frederick and Carynelisa Erlick
The University of Chicago

The ultraviolet-B (UV-B) component of sunlight, encompassing wavelengths from 280 to 320 nm, comprises approximately 1.5% of the total energy emitted by the sun. The corresponding number for the UV-A spectral region, from 320 to 400 nm, is 6.3%. Absorption of the incoming UV solar irradiance by stratospheric ozone essentially eliminates all of the energy at wavelengths shorter than 290-295 nm, but has little effect on energy at wavelengths greater than 320 nm. Although the absorption of UV radiation by ozone is extremely important, this process is well-understood and straightforward to include in calculations of the irradiance at the ground. The major uncertainties in radiative transfer involve the role of absorption and scattering in the lower atmosphere. Scattering by clouds and the possible absorption of radiation within clouds are significant factors in modulating the irradiance incident on the biosphere, but these processes are poorly modelled at present.

The UV solar irradiance at the ground varies greatly with local time, latitude, and season primarily because of the changing elevation of the sun in the sky. The erythemally-weighted irradiance received at the equator far exceeds that incident on higher latitudes. Summertime erythemal irradiances in the Southern Hemisphere exceed those at comparable latitudes in the North by approximately 15%. Part of this difference arises from the varying
distance between the earth and the sun over a year. The remainder comes from the naturally lower column ozone amounts in the South.

The springtime depletion in column ozone over Antarctica has been accompanied by enhanced UV-B irradiances at polar latitudes. The effects of this polar ozone loss can be seen at lower latitudes owing to the action of atmospheric transport processes. On occasion large declines in column ozone and enhanced UV-B irradiances have been observed over Tierra del Fuego. These events are characterized by large erythemal irradiances compared to the normal values for this latitude. However, these locally enhanced values are still typical of a normal summer day at the latitude of Buenos Aires.

Satellite-based data from the Total Ozone Mapping Spectrometer (TOMS) exist for the entire globe over the period from November 1978 to May 1993. A radiative transfer model can use the archived information on ozone and atmospheric reflectivity to estimate trends in erythemal irradiance under both clear and cloudy skies. At tropical latitudes, 0 to 6°N, no statistically significant trends in irradiance appear. A study for a restricted geographic region containing Buenos Aires produced an upward trend in erythemal irradiance of $+4.5\pm3.0\%$ per decade under clear skies for the month of January 1979 through 1993. When the effects of clouds are included the random interannual variability in irradiance increases, and this obscures the systematic behavior expected from the behavior of ozone alone. A similar analysis for Tierra del Fuego produced a trend for clear-sky erythemal irradiance of $+6.2\pm3.4\%$ per decade in January.
Some Conclusions

* Over Antarctica:

- From the standpoint of biologically effective UV radiation levels, the duration of each year's ozone depletion is as significant as the maximum magnitude of the depletion.

- Biologically effective UV irradiances (306.5 nm) as much as double the climatological expectation for summer solstice have occurred over Palmer Station (64.8°S).

* Over South America:

- In December 1990 the biologically effective UV irradiance over Ushuaia (55°S) was 45% above climatological expectations in a monthly mean sense, and 60-70% above expectations on some days.

- Monthly mean UV irradiances over Ushuaia since 1989 exceed expectations based on column ozone measurements made prior to 1986.
DAILY MEASUREMENTS OF UV-B IRRADIANCE AT LOCAL NOON
FROM PALMER STATION: SEPTEMBER 21-DECEMBER 21, 1988

Irradiance ($10^2$ Watts/m$^2$)

Day Number of 1988

--- CLEAR SKY,
UNPERTURBED O$_3$
Ozone Abundance Over Palmer Station
Computed from NSF UV-Monitor Local Noon Data

1988

Ozone Column (Dobson Units)

UNPERTURBED AMOUNT

Julian Date

MEASURED IRRADIANCES AT 306.5 NM: LOCAL NOON VALUES AT PALMER STATION FOR SEPTEMBER-DECEMBER 1990

Irradiance Ratio: F(306.5)/F(350.0) x 10^2

40°S Summer
40°N Summer

Climatological

2x Climatological

Day Number of 1990

260 280 300 320 340 360

Dec.
Erythemal Irradiance over Buenos Aires
January 1979-1993

Ultraviolet Irradiance Measured at Ushuaia, Argentina
Local Noon: September 1990 - March 1991

Wavelength = 306.5 nm
The influence of cloudiness has been removed.

[Proxy for erythemal irradiance]
The Big Unknown: Biological and Ecological Consequences of Enhanced Solar UV Radiation Levels

* Aside from nonmelanoma skin cancer, current knowledge does not allow reliable quantitative predictions of biological and ecological effects of enhanced radiation levels.

  - Many laboratory experiments are not applicable to the changes in UV irradiance encountered in the "real world".

  - Focused studies of biological and ecological effects should receive a high priority similar to that already given to studies of changes in ozone.

* Speculation and exaggeration can flourish when definitive knowledge of biological and ecological effects is lacking.
Introduction

At the 1992 United Nations Conference on the Environment and Development (UNCED) it was declared under Agenda 21 that there should be activities on the effects of UV. Specifically:

(i) Undertake as a matter of urgency, research on the effects on human health of increasing UV reaching the earth's surface as a consequence of depletion of the stratospheric ozone layer;

(ii) On the basis of the outcome of this research, consider taking appropriate remedial measures to mitigate the above mentioned effects on human beings.

A monograph entitled "Ultraviolet Radiation: An authoritative scientific review of UV with reference to global ozone layer depletion" was published by WHO in 1994. Jointly sponsored with the United Nations Environment Programme and International Commission on Non-Ionizing Radiation Protection, this Environmental Health Criteria monograph number 160 gives a thorough review of the health hazards of UV exposure. However, although it is known that the burden of UV-related diseases on human populations is high, the exact nature and extent of these diseases is still largely unknown.

There is great uncertainty about future trends in atmospheric ozone. For example the Antarctic holes and large depletions of ozone that have occurred recently were not predicted in any of the ozone depletion models. While agreements have been reached to reduce releases of CFCs into the environment, and this will have future benefit on the ozone layer, there is uncertainty about the extent of ozone depletion caused by chemical pollutants. What is apparent is that decreased ozone levels will persist for many years to come and the corresponding increases in UV intensities will result in more significant adverse health effects on all populations of the world for many decades to come (WMO 1993).

The health effects of UV are not restricted to fair skinned populations. UV exposure is thought to cause diseases of the eye and suppression of the immune system in all populations of the world. UV induced immune suppression may have adverse consequences on infectious disease immunization programmes, particularly in areas where the UV intensities are high. The possibility that UV will cause progression of various diseases such as for HIV positive patients still has to be elucidated. Many such important issues need to be resolved as a matter of urgency.

The WHO Task Group meeting reviewing the scientific literature strongly urged action and coordination of UV research at the international level. In particular the Task Group supported the concept of the International Research Programme on Health, Solar UV Radiation and Environmental Change (INTERSUN). INTERSUN is a collaborative effort between WHO, the United Nations Environment Programme (UNEP) and the International Agency on Cancer Research (IARC). The Group recognized specific research needs in areas of exposure assessment, terrestrial plants, aquatic ecosystems,
and human health effects related to the skin, immune system and eye. Some of these could be accomplished under the umbrella of INTERSUN, and some would require more basic laboratory research to be undertaken.

**Objectives**

The objectives of INTERSUN are to:

(i) accurately evaluate the quantitative relationship between solar UV at the surface of the earth and human health effects;

(ii) develop reliable predictions of health consequences of changes in UV;

(iii) to provide baseline estimates of the occurrence of health effects of UV in representative populations around the world; and

(iv) to develop practical ways of monitoring change in these effects over time in relation to environmental and behavioral change.

Over the next 2 years it is hope to develop a global UV information network that will build the necessary infrastructure to support future research projects. This is described below.

**Global UV Information Network**

The objectives of this 2-year program are as follows:

1. Develop a global UV network containing 4 components:

   a. Maintain an updated bibliography of research, including copies of all reports and journal references (copies available on hard copy or diskette)

   b. Listing of active researcher and institutions involved in research

   c. Inventory of ongoing research projects and a catalogue of research recommendations by various peer review groups

   d. Newsletter giving dates of INTERSUN activities - first newsletter would contain the aims and objectives of INTERSUN and a listing of its preliminary activities. The newsletter would also be available to all researchers, institutions and learned societies to announce their activities.

2. Prepare a popular booklet and brochures on UV hazards and protective measures, using EHC 160 as a basis.

3. Provide training packages on UV protection for use in developing countries. This would need to be translated into a number of different languages.
4. Conduct workshops on UV protection in 2 developing countries.

5. Develop in conjunction with the World Meteorological Organization (WMO), a universally accepted UV Index that can be used as a tool to educate the general public about the hazards of UV and its increasing intensities and hazards associated with ozone layer depletion.

6. Complete the drafting of an international protocol for conducting epidemiological studies in various countries to determine the association between UV exposure and various diseases of the eye.

Achievements

Achievements by INTERSUN up to August 1994 are given below.

1 Environmental Health Criteria monograph

EHC number 160 entitled "Ultraviolet radiation. An authoritative scientific review of environmental and health effects of UV, with reference to global ozone layer depletion" has been completed and sent to the printers (should be published end September 1994). This will serve as a scientific database for future projects under INTERSUN. This monograph contains a listing of various research projects that need to be conducted to progress our knowledge in key areas that will allow better health risk assessments to be made, and in particular the impact of increased UV levels on health and the environment resulting from ozone layer depletion.

2 Protocol for epidemiological studies on UV exposure and cataract

A protocol to conduct epidemiological studies on the relationship between UV exposure and diseases of the eye, primarily cataract, has been drafted. The purpose of developing the standardized protocol is to provide guidance on the conduct of epidemiological studies investigating UV exposure and various eye diseases. To date there has been a mixed research effort in this area primarily because of the lack of understanding of the variables involved in UV exposure of the eye. To complete the protocol, contracts have been let for:

- the development of a dosimetry algorithm for UV exposure to the eye, and
- a standardized method for classifying eye cataracts.

These contracts should be completed by the May 1995, so that the standardized protocol can be published in the peer reviewed scientific literature and taken up by various research organizations. The results of various research projects using this common protocol will be able to be properly compared and possibly suitable for meta-analysis.
3 **UV Index**

WHO is collaborating with the World Meteorological Organization (WMO) to develop a universally accepted index of UV exposure. Such an index would be promoted for use in various media news and weather programs and would be a valuable tool to educate the public on the dangers of excessive UV exposure. The advantage of a universally accepted UV Index is that people traveling to different countries or states will be familiar with the index and hopefully want to obtain information about it on a daily basis as they would for the weather.

The first meeting to investigate developing a UV Index was held in Les Diableret, Switzerland at the end of July 1994. This was attended by Dr R Schmidt and a separate report has been prepared. Dr M Repacholi attended a WMO meeting in Buenos Aires (22-26 August 1994) to discuss the health effects of UV and the basis for the UV Index. A WHO meeting sponsored by the German Government is scheduled to be held towards the end of 1994 in Munich and another meeting in Boulder, Colorado in February 1995 to progress the preparation of the UV Index. It is hoped that a joint effort between WHO and WMO will result in a universally accepted UV Index before the end of 1995.

4 **Immune system effects**

A meeting sponsored by the USEPA was held on 12 August 1994 in Washington to discuss collaboration on the INTERSUN project and, in particular, the possibility of joint efforts on the conduct of research into the effects of UV on the immune system.

5 **UV Protective Measures**

A meeting sponsored jointly by WHO, the US Army Environmental Hygiene Agency and the Japanese Government was be convened between the 15-17 August 1994 in Baltimore, Maryland. The purpose of the meeting was to draft a publication on measures that can be taken by the general public and workers to protect against excessive exposure to UV. The publication will be in a form easily understood by workers and the public and can either be distributed as is, or used by governmental and other health authorities in the development of their own educational programs. It is expected that the publication will be available in 1995.

This meeting also reviewed the first draft of a report on ocular UV dosimetry.

6 **New Collaborating Centre for INTERSUN**

The German Government Institute of Radiation Hygiene in Neuherberg has indicated its willingness like to collaborate with WHO on the development of a program on non-ionizing radiation protection, and in particular on UV. A collaborative program which incorporates INTERSUN projects is now being discussed.

7 **Newsletter updating INTERSUN**
A newsletter summarizing the achievements of INTERSUN is in preparation and the first issue should be published later this year. This newsletter will be published on a regular basis and distributed to all INTERSUN collaborators.

8. Database of UV references

A database of almost 1000 scientific references and publications has been compiled on disk. Most of these publications are available in text form. It is hoped that in the near future this database can be expanded to include full abstracts on disk and a library of original papers available to the collaborators of the INTERSUN project.

Collaboration

National authorities or institutions interested in participating in INTERSUN are asked to contact:

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Health effects of UV exposure on the skin and immune system

1. Skin

The skin is a large organ with an area of more than 1.5 m² in adults. It provides the first stage of protection for chemicals, radiations, infection and also prevents the evaporation of water and the loss of ions and proteins. The skin has developed specific mechanisms for photoprotection and biological responses to UV as discussed below.

UV incident on human skin can undergo absorption, reflection, and scattering. Thus, the actual radiant exposure received by the various layers of the skin will be lower than the incident exposure. The depth of penetration is wavelength dependent the longer the wavelength the deeper the penetration.

The sensitivity of skin to UV has been defined by six phototypes: types I to IV are characteristics of caucasoid populations; type V represents mongoloid, Middle Eastern populations; and type VI represents Aboriginal, African and American negroid populations. The capacities to acquire natural tan or to present naturally a deep pigmentation are keys to the response to UV exposure. Among caucasians, there is a general correlation between skin type and resistance to sunburn and capacity to tan. Skin types I and II (solar incompetent) are the most sensitive to UV exposure while skin types III and IV (solar competent) are the least sensitive to exposure among the caucasian populations.
Thickness of the epidermis (natural or UV-acquired) plays an important role in protecting the basal epidermal layer. Constitutional pigmentation also provides some degree of protection, the UV-acquired pigmentation (tan) increases protection significantly in melano-competent population (types III to V) but minimally in melano-incompetent population (types I and II)

Health effects

The health risks associated with exposure to UV include those of both acute and chronic effects and will vary according to the nature of the exposure. Factors important in assessing such risks include: the biologically-effective irradiance of the UV impinging on the person exposed; the duration and frequency of occurrence of exposures; and the individual sensitivity of the person to UV as determined by genetic and other factors.

UV exposure of the skin causes such harmful effects as sunburn, damage to the immune system, phototoxicity, photoallergy, benign abnormalities of melanocytes (freckles, melanocytic naevi and solar or senile lentigines) a range of other chronic abnormalities resulting from UV injury to keratinocytes, blood vessels and fibrous tissue, often described together as "photoageing", skin cancer (melanoma and non-melanocytic cancer) and possibly cancer of the lip.

2. Immune system

There is suggestive evidence that UV exposures at environmental levels suppress immune responses in humans. It is therefore reasonable to assume that exposure to UV may enhance the risk of infection and decrease the effectiveness of vaccines in humans, and reduce host defenses against skin cancer. The action spectrum for immune effects remains unknown.
SUNLIGHT UVR EXPOSURE OF THE EYE

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Aberdeen Proving Ground, MD 21010-5422 USA

ABSTRACT

There is currently some degree of controversy as to the magnitude of cataract and other ocular diseases related to one's lifetime exposure to ultraviolet radiation (UVR). Concerns about the depletion of stratospheric ozone and the related increase in terrestrial UVR exposure has emphasized the importance of resolving this controversy. A careful study of ocular exposure to environmental sunlight demonstrates that it is not at all simple to accurately assess the level of solar UVR exposure of the human eye. Past attempts to measure or calculate UVR exposure of the eye have generally relied upon measurement of ambient UVR in sunlight with global monitors. Unfortunately, such attempts have seldom properly assessed the large role of ground reflection, the horizon sky contribution, the degree of lid opening and the extreme lateral component of UVR incident on the eye. A series of recent ocular dosimetry studies are described which have considered all of these factors and include the value of different types of eye protection.

INTRODUCTION

The exposure to UVR and light outdoors constantly changes during the day. Subjectively, we are largely unaware of the degree of these changes. For example, the exposure rate of UV-B (the shortest wavelengths in sunlight) varies remarkably with the time of day. When the sun is overhead at noon, the level of UVR at a wavelength of 300 nm is ten times greater than at either three hours before or three hours after noon. An untanned person with fair skin would receive a mild sunburn in 25 minutes at noon, but would have to lie in the sun for at least two hours to receive the same dose after 3:00 (standard time). The integrated total exposure dose of ACGIH biologically-weighted UVR\(^1\) falling on a horizontal surface (the global UVR exposure) occurs primarily during the midday hours, and 70% occurs during the four hours centered on noon-time zenith (Table 1). This enormous spectral change does not occur in the visible part of the sun's spectrum, but some change still occurs. We are all aware of the red color of the sun at sunset; and an attempt to take a color photograph either very early or very late in the day will result in a picture that is yellowish or orange in hue. We are fortunate that the scattering of sunlight by air molecules (due to Raleigh scattering) favors UVR and blue light (hence the blue sky). For longer pathlengths through the atmosphere when the sun is low in the sky, much more UVR and sunlight is scattered and the sun which is white at noonday becomes yellow and
then orange as less UVR and blue light are present in the direct rays. When the sun is overhead and "white," it would take only 90 seconds to stare at the sun and receive solar retinitis. A few hours later, with the sun much lower in the sky, it would take several minutes to reach a hazardous retinal dose, and it is virtually impossible at sunset. Thus, the geometry of exposure as well as the spectrum (hue) plays a major role in determining the hazards from direct viewing the sun. Fortunately, we seldom look directly overhead when the sun is very hazardous to view, and the sun is not very hazardous to view when the sun is sufficiently low in the sky to fall within our normal field-of-view. Furthermore, when the sun is greater than about 10° above the horizon, we squint, thus shielding the retina from direct exposure. These factors are calculated to reduce the exposure to the cornea to a maximum of about 5% of that falling upon the exposed top of head, but the exact fraction remains unknown. If the squint and other behavioral factors are not considered, the dose to the eyelid is approximately 20% of the dose falling on a horizontal surface.

**Exposure Geometry**

Although the cornea is more sensitive to UVR injury than the skin, one seldom experiences a corneal burn when out in sunlight. Using the action spectrum for human photokeratitis and mathematically weighting this with the midday solar spectrum, one calculates a time to achieve threshold of 100 seconds. Again, the geometry of exposure of exposure precludes photokeratitis except when ground reflectance exceeds approximately 10%. When the sun is overhead and UVR exposure is most severe, the brow ridge and upper lid shield the cornea, and if the eye is turned away from the sun, the more intense scattered UVR from overhead strikes the cornea at a grazing angle of incidence where most is reflected and little is absorbed. Only when the incident UV rays are parallel to the pupillary axis are most rays absorbed (in fact, 98% are absorbed). When one looks down at the snow, the UVR is reflected directly into the eye; hence, the traditional eye protector of the Inuit or Eskimo, the slit in whalebone or in a seal-skin mask, provided geometrical rather than spectral protection against the UVR exposure. The lack of protection above and to the sides of sunglasses is therefore a serious shortcoming. However, to obtain a quantitative idea of this component of exposure to the eye, measurements using a simulated ocular geometry were made in sunlight. The human eye receives approximately 10 to 25% of the UVR dose when wearing lenses opaque to the UVR compared to the eye without a lens. Furthermore, some scientists warn that the lateral rays entering the eye from the side of the sunglass may be particularly dangerous to the lens. Even if one were wearing lenses that virtually block all of the radiation of concern. Therefore, unless one employs a goggle geometry with side-shields, etc., UVR transmission factors in lenses much less than 2.5% become misleading. Ground reflectance is a major source of ocular exposure.

The strong dependence of specular reflectance with angle of incidence is known as Fresnel's Law of Reflection. This law not only explains the survivability of the cornea in an overhead bath of UVR, but also the glare experienced over water. When the sun is overhead, a body of water reflects the UVR upward, but only approximately 2% is reflected. When the sun is low in the sky, much of the incident light is reflected, but now
the UVR and blue light have been filtered out of the direct rays by the atmosphere and are therefore harmless. Nevertheless, the strong reflections from water at these low sun angles create discomfort glare and UVR exposure of the cornea is further reduced because of the squint.\textsuperscript{4} Table 3 provides diffuse reflectance values for terrain surfaces.

The other evidence just reviewed would suggest that if dark lenses were placed over our eyes, our natural aversion to bright light—which leads to the squint that normally greatly lowers the UVR and retinal exposure to the eye—would be "disabled. This may appear to be an unusual way to consider the comfort that shaded lenses bring about. But, just consider that some of our "discomfort" derived from not wearing sunglasses or a brimmed hat stems from muscle fatigue associated with the squint. We must, therefore, ask whether sunglasses may not actually lead to a higher UVR exposure condition rather than provide reduction. Of particular interest recently, has been the observation of Coroneo that extreme peripheral rays falling on the edge of the cornea can be focussed in the nasal sector of the lens behind the pupil.\textsuperscript{9,11} Since most cortical cataracts begin in this sector, it has been theorized that these rays, unattenuated by sunglasses or a brimmed hat may play an etiologic role in cataract. If this were so, measurement of this extreme peripheral UVR must also be made under different environmental conditions.

The problem then remains to quantify the protective value of the upper and lower lids when they close down to provide a squint. In terms of UVR exposure, at least a twenty-fold reduction is likely. In terms of shielding the retina from the direct image of the sun, the upper lid probably provides a protection factor exceeding a thousand. If one wears a brimmed hat, then the direct image of the sun on the retina is rare and overhead UVR exposure is virtually eliminated; however, the lid opening may increase, and the ground reflection of UVR becomes important. To do this, either contact-lens dosimeters or a photographic study of lid opening of different peoples and UVR directional field measurements in different environmental conditions around the world. Furthermore, specific, off-axis lateral UVR must be measured by a special probe.

On an overcast day, the lids are more open, and although the UV-B irradiance is reduced by cloudcover, the actual UV-B dose rate to the eye from sky scatter near the horizon may be reduced by only a factor of two.\textsuperscript{3} Hence, on a cloudy day the eye may actually experience a greater UV-B dose than on a bright sunny day. Of course a heavy overcast may sufficiently attenuate the UV-B, that this observation would not be true. As sunglasses are not typically worn on an overcast day, one could argue that the concern over sunglasses increasing total ocular exposure is unimportant. However, it does seem reasonable that sunglasses should have sufficient UVR filtration such that the ocular exposure does not actually increase when they are worn on a sunny day.

Eye and head movements further reduce exposure. If one observes human behavior in bright sunlight, one is struck by the fact that most people squint or avoid looking into the sun sector of the sky. These behavioral and physiological factors are not at all taken into account by simple UVR measurements; hence, there is an obvious need for an in-depth
study to properly determine corneal and lenticular exposure to ambient UVR. Indeed, the results of the previous epidemiological studies of cataract can be thrown into question, because of inadequate dosimetry. The failure of some epidemiological studies to demonstrate an increased risk from UVR or sunlight exposure could well have resulted from wrongly assigning different exposure levels to different population groups based upon an assumption that overhead UVR exposure predicts corneal exposure. As shown above, this assumption is generally wrong. The use of global UVR measurements which have value in studies of UVR and skin cancer are inappropriate for eye studies. Under the same overhead UVR measurement, the critically important horizon-sky contribution to ocular dose can vary by a factor of ten or more depending upon terrain and weather conditions as shown in Table 2.4

Table 1. Calculated ACGIH Effective UV-B and Total UV-A Exposure Dose on a Horizontal Surface from Data of Bener: Davos, Switzerland in June5

<table>
<thead>
<tr>
<th>Exposure Duration Centered on Noon (hours) (% of 8 h)</th>
<th>Effective UV-B (J/cm²) (% 8h)</th>
<th>Total UV-A (J/cm²) (% 8h)</th>
<th>Total Irradiance in 315-500 nm (estim. J/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 hours (25%)</td>
<td>0.023 (40%)</td>
<td>39.1 (32%)</td>
<td>140 (31%)</td>
</tr>
<tr>
<td>4 hours (50%)</td>
<td>0.042 (72%)</td>
<td>77.4 (63%)</td>
<td>290 (64%)</td>
</tr>
<tr>
<td>6 hours (75%)</td>
<td>0.053 (91%)</td>
<td>105 (86%)</td>
<td>390 (87%)</td>
</tr>
<tr>
<td>8 hours (100%)</td>
<td>0.058 (100%)</td>
<td>122 (100%)</td>
<td>450 (100%)</td>
</tr>
<tr>
<td>12 hours (150%)</td>
<td>0.060 (103%)</td>
<td>145 (118%)</td>
<td>540 (120%)</td>
</tr>
</tbody>
</table>

Note: The percentage of the total possible exposure relative to an 8-hour day centered on noon is provided within the parentheses.

Table 2. Measured ACGIH Effective UV-B from the Sky with a 40° Cone Field of View (FOV) from Sliney (1983).4

<table>
<thead>
<tr>
<th>Sky Conditions and Location, Elevation</th>
<th>Zenith Reading (∅W/cm²)</th>
<th>Directly at Sun (∅W/cm²)</th>
<th>Opposite Sun (∅W/cm²)</th>
<th>Horizon Sky (∅W/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Sky (dry), 5 m</td>
<td>0.036</td>
<td>0.5, Z = 70°</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>Clear Sky (humid), 5 m</td>
<td>0.10</td>
<td>1.5, Z = 50°</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td>Ground Fog, 5 m</td>
<td>0.016</td>
<td>0.07, Z = 75°</td>
<td>0.015</td>
<td>0.01</td>
</tr>
<tr>
<td>Hazy, Humid, 5 m</td>
<td>0.005</td>
<td>0.50, Z = 70°</td>
<td>0.08</td>
<td>0.20</td>
</tr>
<tr>
<td>Cloudy Bright, 700 m</td>
<td>0.20</td>
<td>0.16, Z = 45°</td>
<td>0.10</td>
<td>0.02</td>
</tr>
<tr>
<td>Hazy, Beach, 0.3 m</td>
<td>0.20</td>
<td>0.22, Z = 75°</td>
<td>0.20</td>
<td>0.22</td>
</tr>
<tr>
<td>Hazy, Beach, 0.3 m</td>
<td>0.14</td>
<td>1.30, Z = 40°</td>
<td>0.20</td>
<td>0.16</td>
</tr>
<tr>
<td>Clear, Mtn Top 2750 m</td>
<td>0.20</td>
<td>0.60, Z = 25°</td>
<td>0.30</td>
<td>0.03</td>
</tr>
<tr>
<td>Clr, Mtn Village, 2500m</td>
<td>0.14</td>
<td>1.5, Z = 45°</td>
<td>0.08</td>
<td>0.03</td>
</tr>
</tbody>
</table>

NOTE: Z = 70° refers to the Zenith Angle of 70° (i.e., Elevation Angle of 20°).
Table 3. Reflectance of ACGIH-Effective Solar UV-B from Terrain Surfaces

<table>
<thead>
<tr>
<th>Representative Terrain Surfaces</th>
<th>Diffuse Reflectance ACGIH-Weighted Solar UV-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Mountain Grassland</td>
<td>0.8 - 1.6 %</td>
</tr>
<tr>
<td>Dry, parched Grassland</td>
<td>2 - 3.7 %</td>
</tr>
<tr>
<td>Wooden Boat Dock</td>
<td>6.4 %</td>
</tr>
<tr>
<td>Black Asphalt</td>
<td>5 - 9 %</td>
</tr>
<tr>
<td>Concrete Pavement</td>
<td>8 - 12 %</td>
</tr>
<tr>
<td>Atlantic Beach Sand (Dry)</td>
<td>15 - 18 %</td>
</tr>
<tr>
<td>Atlantic Beach Sand (Wet)</td>
<td>7 %</td>
</tr>
<tr>
<td>Sea Foam (Surf)</td>
<td>25 - 30 %</td>
</tr>
<tr>
<td>Aged, &quot;Dirty&quot; Snow</td>
<td>50 %</td>
</tr>
<tr>
<td>Fresh Snow</td>
<td>88 %</td>
</tr>
</tbody>
</table>

CONCLUSION

Past studies of solar UVR effects upon the eye frequently have relied on one or more of the following apparently reasonable, but simplistic and false or misleading assumptions:

1. The place of residence defines a person's UVR exposure.
2. The UVR dose to the eye is directly proportional to the number of hours spent outdoors.
3. The number of sunny days in a subject's environment will predict a relative life-time UVR exposure dose to the lens.
4. Cloudcover or overcast will decrease the eyes' exposure.
5. At sites of high elevation (e.g., in mountains), the ocular exposure will be higher than near sea-level.
6. Wearing sunglasses or a hat will necessarily reduce the ocular exposure.
7. UVR exposure of the lens should be directly correlated with skin exposure (as determined by personal dosimetry or by, e.g., accelerated ageing of the skin).
8. UVR exposures of the eyes are directly proportional to meteorological measures of global UVR.
9. UVR exposure conditions vary in the same way as visible light conditions vary with season and time of day.

All of the above assumptions can be in error. Conditions which many scientists might expect to lead to high UVR exposure of the lens may in fact produce a lower dose than under conditions thought to be relatively "safe." Fortunately, it is possible to provide a much more accurate estimate of relative ocular exposure to UVR for any subject, provided the right questions are asked of the subject and some physical factors are known about the subject's environment. The use of a UV Index based upon global measurements of UVR clearly does not apply to the human eye!
Future epidemiological studies of ocular effects resulting from environmental UVR exposure need to take into account, geometrical, physiological and behavioral factors that have not all been previously considered. Only one previous major study attempted to consider personal dosimetry, and this did not consider lid closure or the Corneo Effect. Either contact-lens dosimeters or a photographic study of lid opening of different peoples and UVR directional field measurements in different environmental conditions around the world. This could be done in conjunction with the epidemiological multi-center study of UVR and cataract. Horizon-sky measurements must also be taken under different meteorological conditions to provide improved environmental UVR dose assessments.

REFERENCES

1. American Conference of Governmental Industrial Hygienists (ACGIH) (1994), TLV’s, Threshold Limit Values and Biological Exposure Indices for 1994-1995, American Conference of Governmental Industrial Hygienists, Cincinnati, OH.


Figure 1. The Coroneo Effect. Oblique rays can be focused into the nasal equatorial region of the lens. UVR can only reach the critically important germinative, equatorial region of the lens by focused oblique rays and by intra-lenticular scattering (shown by small arrows).

Figure 2. Photograph of mannequin head with biologically weighted detector mounted in the position of the eye. Not shown is a cover to simulate the slit aperture resulting from squinting.
Enhanced UV-B-radiation: A risk for terrestrial and aquatic ecosystems!

Summary

Ozone depletion over the southern and northern hemisphere and increases in UV-B radiation will impact plants and aquatic organisms. The assessment of biological consequences of solar UV-B radiation requires the determination of the biological effectiveness of UV-B radiation, which increases with shorter wavelengths. Different action spectra imply different biological effectiveness of UV-B radiation. Morphological, physiological, or biochemical changes as a response to enhanced UV-B radiation are typical for UV-B sensitive organisms. Growth reductions, decreased photosynthetic activity as well as reduced biomass are commonly observed in UV-sensitive plants and aquatic organisms. Yield reductions have been reported in soybean and rice cultivars, sensitive to enhanced UV-B. Recent studies on several plant species showed also a general delay of development and flowering under higher UV-B radiation. Changes in DNA and/or phytokinones are the probable molecular reasons for changes in growth, general development and flowering. In some species e.g. rye plants the accumulation of UV-B absorbing compounds in the epidermal layer of rye seedlings, can protect those plants from UV-B damage. This protection phenomenon could result in a competitive shift of protected and unprotected species in natural ecosystems and thus lead to changes in biodiversity.

Aquatic organisms, mainly phytoplankton as the basis of the marine food web, exhibit impaired motility and orientation accompanied by losses in productivity, which increases the danger of lower food supply, changes in species composition, and a higher greenhouse effect as this CO$_2$ sink diminishes.

1. General

In the last few years many publications appeared on anthropogenic ozone depletion and changes in UV-B radiation, Blumthaler and Ambach 1990, Gleason et al. 1993, Kerr and McElroy 1993)

Damaging solar radiation to life on earth is usually entirely (UV-C-radiation <280nm), or partly (UV-B-radiation 280-320nm) absorbed by stratospheric ozone.

Any reduction of the ozone column results in an increase of UV-B-radiation reaching the earth's surface. Manifold biological effects are the result of this change in UV-B-radiation. The genetic substance DNA, for example, is highly susceptible to UV-damage, which subsequently can result in cell death or death of the entire organism.

Increases of solar UV-B-radiation are regularly observed in the Antarctic and surrounding areas during the annual appearance of the "ozone-hole". The effects of which have been seen in reduced productivity of phytoplankton by 6-12%. Ozone reductions have also occurred above
Europe by about 4% per decade which correlates with enhanced levels of UV-B in the Austrian Alps.
Industrial areas, on the other hand, do not indicate such an UV-B trend, probably as increasing air pollution and tropospheric ozone have a compensatory effect.
Under certain meteorological conditions during the winter months, local depletion of the ozone layer is possible above the northern hemisphere. Emerging plant seedlings in the spring would than be subjected to elevated UV-B-radiation. Chlorofluorocarbons (CFC) have been identified as the main cause for the anthropogenic ozone depletion in the stratosphere. Although the phase out of all CFCs was scheduled for 1996 following the revised Montreal-Protocol in November 1992, it will take some decades until the stratosphere is restored. Therefore, humans, animals, and plants will have to live with elevated UV-B-radiation in the future.
The biological consequences for neither terrestrial- nor aquatic ecosystems are sufficiently known.

2. Effects on terrestrial plants


Studies on more than 300 plant species and cultivars have been carried out and the results show that more than 50% of these plants can be determined as sensitive to UV-B-radiation. In most cases reduced leaf- and stem growth, partial reduction of photosynthetic activity as well as decreased biomass have been observed under enhanced UV-B radiation. Yield reductions occurred in several UV-B sensitive cultivars of soy bean, bean and rice with an amplification of 1, that means one percent ozone depletion results in 1% yield reduction. In a few cases delay or suppression of flowering had been observed. Although biological targets have been studied intensively on the molecular level, an UV-B receptor responsible for regulating processes such as the synthesis of UV-protective pigments has not been found yet. Comparisons of greenhouse- and growth chamber studies with field studies indicate that high levels of solar white light reduce UV-damage, possibly by way of UV-damage repair via the enzyme photolyase or by accumulating UV-protective pigments.
Experiments with trees indicate a lower susceptibility to UV-B due to their robust leaf structure. However, over a period of time damages could also accumulate in these plants. The production of lateral shoots to secure a more effective light utilization as a response to UV-B-radiation has also been observed. In ecosystems where those species have a competitive advantage over other species, changes in species composition were to follow, an effect which could also arise from suppressed- or delayed flowering. Although some plants can counteract damaging UV-B radiation by synthesizing protective pigments, mainly flavonoids (especially in
tropical plants), the upper limit of their adaptability might have been reached already. The extent of this adaptability has to be determined with respect to future increases of UV-B-radiation. It seems necessary to select more adaptable or resistant species for agriculture and forestry or to change the genetic material that more genes for protection or repair are present in the genom. In conclusion, a multitude of morphological, physiological and genetical consequences are to be expected for single plants and ecosystems under conditions of increased UV-B radiation. Present results indicate a considerable danger to agricultural plants and thus to yield and food quality. However the global risk for all terrestrial plants and ecosystems arising from all these responses cannot be assessed at this stage of knowledge.

3. Effects on aquatic ecosystems

Effects of increased UV-B radiation have been described in the following papers: Häder et al. 1991, Karentz 1991, Smith et al. 1992, Häder 1993.

Phytoplankton present in the oceans and sweet waters" consists mainly of cyanobacteria, algae and diatoms and has been classified as very UV-sensitive. Negative UV-effects have also been observed on zooplankton, fish larvae, crustaceae, young fishes and frogs eggs. Since phytoplankton species of aquatic ecosystems are primary producers for the zooplankton and other aquatic animals they form the first link of the marine food web. Therefore, losses in their productivity must have severe consequences for fisheries and human food supply. UV-sensitivity of phytoplankton was mainly identified by changes in motility and orientation as well as in physiological functions such as photosynthesis or nitrogen fixation. Being plant organisms the phytoplankton need light for the photosynthetic reactions and thus orientate in the water column for optimum light conditions. However, too high white light intensities lead to photobleaching of pigments in many organisms whereas low light conditions result in lower photosynthesis and thus lower productivity. UV-B radiation impairs the motility of motile microorganisms such as flagellates or cyanobacteria by reducing the speed of moving and/or by disordering their orientation to the sun or away from it.

This impairment of adaptive strategies may also have consequences for the species composition of an aquatic ecosystem. Furthermore, it has been shown that many of these organisms are already at a very high adaptation capacity. Even small increases in solar UV-B radiation may lead to a high percentage of dead organisms within a short period of time as shown for *Chlamydomonas* when transferred from low elevations to alpine regions with higher UV-B radiation.

Newest experiments performed in Antarctica in and outside of the "ozone hole" have shown, that the biomass production of the phytoplankton populations inside the ozone hole has declined by 6-12% compared to those outside the hole. This loss in biomass is equivalent to losses in CO₂-fixation. There is concern that loosing sink capacity for CO₂ may lead to an indirect
increase of the greenhouse effect. It has been calculated that this loss is equivalent to all the anthropogenic output to the atmosphere assuming a 10% decrease in phytoplankton productivity. Cyanobacteria are capable to fix atmospheric nitrogen and serve as nitrogen fertilizer in rice paddies. These microorganisms are highly sensitive to UV-B radiation. Therefore, losses in natural fertilizers must be compensated for by artificial fertilization which may lead to higher prices in rice.

In summary, UV-B radiation effects on aquatic microorganisms resulting in reduced motility, orientation and photosynthesis, will have severe consequences for productivity and thus for marine food supply. Species composition, CO_2 and nitrogen sink capacity may also be impaired.

4. References


## INCREASE OF UV-B RADIATION

### PLANTS

<table>
<thead>
<tr>
<th>Effects</th>
<th>Predictions</th>
<th></th>
</tr>
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<tr>
<td></td>
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</tr>
<tr>
<td>Growth</td>
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<td>Biomass</td>
<td>↓</td>
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<tr>
<td>Yield</td>
<td>↓</td>
<td>-</td>
</tr>
<tr>
<td>Secondary plant compounds</td>
<td>↑</td>
<td>-</td>
</tr>
<tr>
<td>Induction of screening pigments</td>
<td>↑</td>
<td>-</td>
</tr>
<tr>
<td>Biomassproduction</td>
<td>↓↑?</td>
<td>-</td>
</tr>
<tr>
<td>Global yield</td>
<td>↓↑?</td>
<td>-</td>
</tr>
<tr>
<td>Food quality</td>
<td>↓↑?</td>
<td>-</td>
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<tr>
<td>Ecosystems</td>
<td>?</td>
<td>-</td>
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<tr>
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<td>?</td>
<td>-</td>
</tr>
<tr>
<td>Selection and breeding</td>
<td>?</td>
<td>-</td>
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</table>

(Tevini, 1992)

### AQUATICS

<table>
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<td>-</td>
</tr>
<tr>
<td>N₂-Fixation</td>
<td>↓</td>
<td>-</td>
</tr>
<tr>
<td>Motility</td>
<td>↓</td>
<td>-</td>
</tr>
<tr>
<td>Orientation</td>
<td>↓</td>
<td>-</td>
</tr>
<tr>
<td>UV-Protection</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>Induction of screening pigments</td>
<td>?</td>
<td>-</td>
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<tr>
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<td>±</td>
</tr>
<tr>
<td>Global biomass</td>
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<td>-</td>
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<tr>
<td>Food chain</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>CO₂- Fixation (greenhouse)</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>Diversity of species</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>DMS-Production</td>
<td>?</td>
<td>-</td>
</tr>
</tbody>
</table>

(Häder, 1992)
Aquatics

- Reductions of phytoplankton biomass (Smith 1992)
  - 10% within ozone hole
  - Consequences: Effects on food chain
    Increase of greenhouse effect

- Frog egg sensitivity (Blausteen 1994)
  - Eggs of some species are more sensitive than others
  - These populations are already decreasing world wide
  - Consequences: Changing of diversity of species

- Bacteria living from phytoplankton are very sensitive (Prof. Bothwell)
  - Food chain disturbance
  - Competition changes → Biodiversity changes

- Effects on organic compounds (Prof. Lean)
  - Development of radicals and toxic substances
  - Consequences: Toxic influences on aquatic organisms
The Canadian UV Index Program

Robert B. Saunders
Atmospheric Environment Service
Environment Canada

In May, 1992, Canada launched a program to provide information to Canadians on the status of the ozone layer and on the next day’s expected values of UV.

The presentation will trace the events leading up to, and the reasons for Canada’s decision to embarked on a UV Program. As the organization responsible for Canada’s weather service and atmospheric research, Environment Canada was well equipped to develop and implement a UV program.

The presentation will also discuss the close working relationships which were developed with medical associations and health agencies to ensure that all facets of the UV program’s development were in harmony with their goals and objectives. A partnership was formed with Health Canada to collaborate on the development of health messages.

Because of the short time available to implement such a program, intensive efforts on four fronts – science, training, public communications and product development – took place. These self directed work teams working under loose management direction, developed credible methodologies for monitoring, forecasting and explaining UV radiation; training staff to effectively deliver the UV Program; develop the UV and Ozone Watch products and the strategies for effective delivery of the UV Program.

The Ozone Watch and UV Index programs are described and the associated public education efforts are discussed.
CANADA'S OPERATIONAL UV INDEX PROGRAM

T.O. Goos
Environment Canada

WMO Workshop on UV for the Americas
Buenos Aires, Argentina
August 22-25, 1994

The introduction and subsequent operational delivery of a new program for a totally new meteorological parameter poses several challenges. In the spring of 1991, Canada introduced the UV Index program. The presentation will describe the operational implementation of this program as part of the suite of public forecast products including a discussion of some of the options considered during implementation. Particular approaches to making the information accessible and valuable to specific user groups will be described.

Alternative methods for delivery of the information will be described along with a description of the public education and communication methods used to inform and educate people. Information will be presented demonstrating the degree to which the public is using the information in routine decisions.
Ozone and Ultra-violet Products and Services in Canada

Tim Goos
Atmospheric Environment Service
Environment Canada
Edmonton, Alberta, Canada

Abstract:

The introduction and subsequent operational delivery of a new program for a totally new meteorological parameter poses several challenges. In the spring of 1992, Canada introduced the Ozone Watch and UV Index\(^1\) programs. The presentation will describe the operational implementation of this program as part of the suite of public forecast products including a discussion of some of the options considered during implementation. Particular approaches to making the information accessible and valuable to specific user groups will be described.

Alternative methods for delivery of the information will be described along with a description of the public education and communication methods used to inform and educate people. Survey results will be presented demonstrating the degree to which the public is using the information in routine decisions.

Introduction

Canada initiated public products on the status of the ozone layer and the level of ground level ultra-violet radiation during the spring of 1992. This was in response to public concern about the possible impact on public health of enhanced radiation due to losses in ozone.

Products

Ozone Watch
Ozone Watch was initiated on March 11, 1992. Ozone Watch is issued once each week in both tabular and graphical formats. Ozone Watch reports the two week average deviation from normal in the total column ozone from the 10 observing stations in Canada. Summary Ozone Watch products are also prepared for monthly, seasonal and annual deviations.

Advisories
Special advisories are issued during unusual conditions. When ozone values are unusually low (more than 25% below pre-1980 average levels) and there is a high sun angle with generally clear skies, a public advisory is issued to emphasize the need to act prudently.

\(^1\) UV Index is a registered trademark of Environment Canada.
UV Index

UV Index was initiated on May 27, 1992. The UV Index is issued daily in tabular formats (for specific cities) and graphical formats. For a given day, the expected UV Index is calculated by:

- applying a long-term correlation between upper atmospheric potential temperatures and ozone values to the forecast upper atmospheric pattern to determine the days expected ozone value.
- correcting the ozone values using the errors determined from the verification of prior day(s) ozone observations.
- calculating ground-level UV radiation in the range between 290-325 nm adjusting it to mimic the response of human skin by applying the McKinley-Diffey curve.
- integrating the total UV flux across the band and dividing the result by 25 to produce an index value with a range from 0 to 15 (or so) under most conditions.

The Index is further broken into four categories: low (<4.0), moderate (4.0-6.9), high (7.0-8.9), extreme (>9.0).

A daily UV Index bulletin identifies the UV index for the major cities in Canada. This bulletin includes an assessment of the effect of clouds and precipitation on the UV Index. If sky conditions are expected to be overcast with continuous precipitation, values are reduced by 60%; if sky conditions are overcast with showery precipitation, values are reduced by 30%. Public health messages (titled Sun Tip's) are included to assist the public in developing an appropriate response to the information.

Public Education

The introduction of these new products required a parallel development of information to educate and inform the public on the usage. As mentioned above, health messages are included within the UV Index products to provide continuing education. Brochures and information publications were prepared on the products and provided on request to citizens etc. Public service organizations and/or business organizations (e.g. Canadian Cancer Society; Pharmaceutical associations etc.) have also produced and disseminated information to the public. In many cases, these products and services have been cooperative productions between government and industry.

Dissemination and Delivery

Environment Canada

The UV Index information has been incorporated within the suite of public products available to Canadians. In delivering these products, we use our own weather radio network and include the information on our automated telephone answering systems. The UV Index is included both as a separate bulletin and part of the routine daily public forecast.

Media

The electronic (television and radio) and print (newspapers) media are significant partners in the delivery of our products.
Results

Public Surveys
Along with the implementation of the new products, we either initiated or participated with other partners in surveys of the general public. These surveys provide information on the degree to which people are aware of the product, understand how to use the product and then actually use the product in their activities. These surveys have been conducted on a national basis as well as a regional basis. During the first year of the program, we found awareness was very high - approaching 80% in some populations but understanding and use of the product was very much lower. The 1993 Canadian Environmental Monitor survey found that 81% of the population surveyed now actually are taking steps to avoid the UV rays.

Verification
Verification methods of the ozone and UV forecast have been developed although complete national results were not available were not available. The ozone verification is relatively more straightforward and results show the procedures being used have good reliability and accuracy. The verification of the UV index is more difficult as the observations of UV are necessarily "contaminated" by the existence of cloud in the sky. Accordingly, verification is focussing on first verifying the forecast for clear days.
UV INDEX

UV INDEX

EXTREME

SUNBURN TIME (APPROX.)

LESS THAN 15 MINUTES

HIGH

20 MINUTES

MODERATE

30 MINUTES

LOW

MORE THAN ONE HOUR
ADVISORIES

A special advisory is issued as a special alert during unusual situations of high UV values which are determined by a combination of one or more of the following characteristics:

a. Thin stratospheric ozone thickness
   25% below pre-1980 average levels

b. High solar elevation angle

c. Conducive atmospheric conditions
   clear skies or thin clouds with little or no opacity

d. High albedo
   snow cover

e. High altitude
Specific Action to Reduce UV Exposure

- Using more/stronger sunscreen: 68%
- Reducing exposure to the sun: 67%
- Wearing protective clothing: 49%
- Wearing sunglasses: 12%
- Keeping children out of the sun: 4%
- Keeping track of daily UV readings: 2%
FACTS REGARDING SUN AWARENESS FOR THE PUBLIC
APPROVED BULLETS FOR THE UV INDEX BULLETINS
REVISED

* You can burn on a cloudy day. Up to 80% of the sun’s rays can penetrate light clouds, mist and fog.

* Most skin cancers occur on areas of the skin which have been exposed to the sun over a long period of time.

* Exposure to ultraviolet rays is the main cause of skin cancer.

* Eyes do not develop a tolerance to the sun. Wear Sunglasses that screen out UV rays.

* Exposure to ultraviolet rays can damage the eye. Wear sunglasses that screen out UV.

* Ultraviolet rays can contribute to cataracts which impair vision.

* Sunburn should be avoided. Sunburned skin is damaged skin.

* Sun screen offers moderate protection from UV. Reapply often - or you could burn.

* Children’s skin is more sensitive than adult’s skin. As a result, they sunburn more easily. Protect your children from sunburn.

* Babies under one year old should be kept out of direct sunlight.

* Beware of reflected light from snow, sand, concrete or water. Be smart - use a sunscreen.

* Slip on a shirt. Non-sheer clothing is the easiest way to protect your skin.

* For the best protection, cover up! Wear long sleeved shirts and pants that protect your legs from the sun.

* It’s not “cool” to burn! Apply a broad spectrum sunscreen with a sun protection factor of at least 15.

* When the sun’s rays are strongest - around the hours of 11 am and 4 pm - retreat to a shady spot!

* Be sun sensible! Wear a broad-brimmed hat and cover your arms and legs when out in the sun.

Input received from:  - Health and Welfare Canada
                      - Canadian Dermatology Association
                      - Canadian Cancer Society
                      - Canadian Ophthalmological Society
                      - Canadian Association of Optometrists

March 31, 1993
UV Index™ Forecasts

- Forecast Upper Air Fields
- Historical Correlations
- Recent Error Field
- Forecast Ozone Field
- Corrected Ozone Field

- McKinlay-Diffey Function
- Solar Zenith Angle

- UV Flux Field
- Divide by 25

- UV Index Field
ENVIRONMENT CANADA FORECAST ULTRAVIOLET (UV) INDICES FOR SELECTED CANADIAN CITIES FOR MONDAY AUGUST 15 1994. THE UV INDEX BULLETIN IS ISSUED TWICE DAILY EVERY 12 HOURS.

THE FORECAST UV INDEX GENERALLY INDICATES THE UV INTENSITY IN FULL SUNLIGHT AT MIDDAY. ULTRAVIOLET INTENSITIES ARE LOWER UNDER THICK CLOUD COVER AND/OR PRECIPITATION.

VARIABLE CLOUD DAYS ALLOW FULL ULTRAVIOLET EXPOSURE DURING THE SUNNY PERIODS.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>WEATHER</th>
<th>FCST UV INDEX</th>
<th>CATEGORY</th>
<th>TIMES UV ABOVE 4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>IQALUIT</td>
<td>MAINLY CLOUDY</td>
<td>3.4</td>
<td>LOW</td>
<td>NIL</td>
</tr>
<tr>
<td>RESOLUTE</td>
<td>MAINLY CLOUDY</td>
<td>2.0</td>
<td>LOW</td>
<td>NIL</td>
</tr>
<tr>
<td>INUVIK</td>
<td>MAINLY SUNNY</td>
<td>3.0</td>
<td>LOW</td>
<td>NIL</td>
</tr>
<tr>
<td>RANKIN INLET</td>
<td>MAINLY CLOUDY</td>
<td>3.5</td>
<td>LOW</td>
<td>NIL</td>
</tr>
<tr>
<td>YELLOWKNIFE</td>
<td>SUNNY</td>
<td>4.2</td>
<td>MODERATE</td>
<td>1 TO 3</td>
</tr>
<tr>
<td>WHITEHORSE</td>
<td>AFTERNOON CLOUD</td>
<td>4.5</td>
<td>MODERATE</td>
<td>1 TO 3</td>
</tr>
<tr>
<td>VANCOUVER</td>
<td>ISOLATED SHOWERS</td>
<td>6.2</td>
<td>MODERATE</td>
<td>11 TO 4</td>
</tr>
<tr>
<td>VICTORIA</td>
<td>CLOUDY PERIODS</td>
<td>6.4</td>
<td>MODERATE</td>
<td>11 TO 4</td>
</tr>
<tr>
<td>KAMLOOPS</td>
<td>PARTLY CLOUDY</td>
<td>6.0</td>
<td>MODERATE</td>
<td>11 TO 3</td>
</tr>
<tr>
<td>NANAIMO</td>
<td>ISOLATED SHOWERS</td>
<td>6.2</td>
<td>MODERATE</td>
<td>11 TO 4</td>
</tr>
<tr>
<td>PORT HARDY</td>
<td>FEW SHOWERS</td>
<td>5.7</td>
<td>MODERATE</td>
<td>11 TO 4</td>
</tr>
<tr>
<td>SANDSPIT</td>
<td>SHOWERS</td>
<td><em>4</em></td>
<td>LOW DUE CLOUD/PRECIP</td>
<td>NIL</td>
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<tr>
<td>PRINCE RUPERT</td>
<td>ISOLATED SHOWERS</td>
<td>5.0</td>
<td>MODERATE</td>
<td>12 TO 4</td>
</tr>
<tr>
<td>SAINT JOHN NB</td>
<td>MAINLY SUNNY</td>
<td>6.6</td>
<td>MODERATE</td>
<td>11 TO 4</td>
</tr>
<tr>
<td>HALIFAX</td>
<td>CLEARING</td>
<td>7.2</td>
<td>HIGH</td>
<td>10 TO 4</td>
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<tr>
<td>CHARLOTTETOWN</td>
<td>PARTLY CLOUDY</td>
<td>6.6</td>
<td>MODERATE</td>
<td>11 TO 4</td>
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<tr>
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<td>10 TO 3</td>
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<tr>
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<td>SHOWERS</td>
<td><em>3</em></td>
<td>LOW DUE CLOUD/PRECIP</td>
<td>NIL</td>
</tr>
</tbody>
</table>

* ESTIMATE OF UV UNDER CLOUD AND/OR PRECIPITATION *

ALL TIMES MENTIONED IN THIS BULLETIN ARE IN LOCAL TIME.

SUN TIP:
MOST SKIN CANCERS OCCUR ON AREAS OF THE SKIN WHICH HAVE BEEN EXPOSED TO THE SUN OVER A LONG PERIOD OF TIME.

UV CATEGORIES

<table>
<thead>
<tr>
<th>UV INDEX RANGE</th>
<th>AVERAGE TIME TO BURN</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXTREME</td>
<td>LESS THAN 15 MINUTES</td>
</tr>
<tr>
<td>HIGH</td>
<td>AROUND 20 MINUTES</td>
</tr>
<tr>
<td>MODERATE</td>
<td>AROUND 30 MINUTES</td>
</tr>
<tr>
<td>LOW</td>
<td>ONE HOUR OR MORE</td>
</tr>
</tbody>
</table>

NOTE: AVERAGE TIME TO BURN ONLY ADDRESSES UV EFFECTS ON THE SKIN. UV ALSO AFFECTS THE EYES.

THIS BULLETIN WILL NOT BE AMENDED. CONTACT YOUR LOCAL ENVIRONMENT CANADA WEATHER OFFICE TO OBTAIN THE MOST UP-TO-DATE WEATHER AND UV INDEX INFORMATION.
CANADIAN PUBLIC EDUCATION PROGRAM AGAINST UV OVER-EXPOSURE

J.D.Yvon Deslauriers, Ph.D.
Radiation Protection Bureau
Health Canada

UV Workshop for the Americas
Buenos Aires, Argentina
August 22-25, 1994

ABSTRACT

The UV radiation protection program of the department of Health aims at reducing the ultraviolet exposure of Canadians. The rationale for this direction is based on the increasing incidence of skin disorders, particularly malignant melanoma skin cancer. This disease has the highest increase in yearly incidence within the Canadian population after lung cancer in women. However, the incidence rates are still low at this time (i.e., approximately 10/100,000 population). New malignant melanoma cases this year will total approximately 3000 and will likely account for more than 600 deaths in Canada alone. Malignant melanoma is indirectly related to UV exposure, UV probably acting as a promoter. Non-melanoma skin cancer is estimated at over 50,000 new cases per year. This is one-third to one-half of all new cancer cases for 1994. There are also concerns about the short- and medium-term effects of UV exposure: sunburn, tanning, immune system effects, premature skin aging and effects on the eyes.

The targets of our program are (a) to reduce long-term UV effects in the Canadian population by modifying mainly the attitudes of young people toward sunbathing and sun over-exposure, (b) to help reduce the present mortality due to skin cancer.

To induce a small but significant change in the attitudes and behaviours of Canadians, we have to draw attention to this issue by disseminating impact messages about our concerns. At the same time, the messages have to be buffered to retain scientific credibility, and to avoid instilling unreasonable fear of outdoor activities. This delicate balance is not easy to maintain because of the many types of organizations and interests in the area of UV protection.

The past, present and future means that are at the disposal of the department's UV program will be discussed.
EXPERIMENTAL ULTRAVIOLET INDEX (UVI)

Craig S. Long & Alvin J. Miller
NOAA/NWS/NMC/Climate Analysis Center

Hai Tien Lee & Jeannette D. Wild
Research and Data Systems, Corp.

UVI- METHODOLOGY

> CAC Produces DAILY, GLOBAL (Sunlit Portion) Analyses of Total Ozone from SBUV/2 Instrument

> Utilize a Total Ozone - Pressure (Height), Temperature Relationship to Provide a Forecast of the Total Ozone Field for Tomorrow

500 hPa height, 100 hPa height & 50 hPa temperature

\[ O_3(d+1) = O_3(d-1) + \sum (\delta O_3/\delta X) \times \Delta X \]

Operational Job includes Decision Tree for Missing Data

> Radiative Transfer Model Determines Noon, Clear Sky Surface UV Irradiances (290-400 nm)

> Irradiances are Weighted by CIE (McKinlay-Diffey) Action Spectrum.

> 1 Hour Dosage Centered about Solar Noon Scaled to Single Digits (hJoule/m²)

> Adjust for Elevation (~ 6%/km)

> Adjust for Forecasted Cloud Conditions for Selected Cities
UVI - Development of Cloud Attenuation Scheme

> Used NOAA & EPA UV Observations for 1992

EPA- Spectroradiometer
Raleigh, N.C.

NOAA- Broad Band Radiometers*
   Albuquerque, N.M.
   Concord, N.H.
   Detroit, Mi.
   El Paso, Tx.
   Minneapolis, Mn.
   Salt Lake City, Ut.
   Seattle, Wa.

* Required adjustment for thermal sensitivity and non-accurate erythemal response

> Regressed against Forecasted Cloud Probabilities

> Verified against 1993 UV Observations
APPROACH

USE RB METER APRIL-OCTOBER 1993 DATA

- RB SCALED FOR TEMPERATURE ETC. EFFECTS
- MOS CLOUD PROBABILITIES, DEW POINT TEMPERATURE...
- REGRESS RATIO: OBSERVED/(CLEAR SKY VALUE)

RESULTS: 1320 OBSERVATIONS

1) REGRESS WITH PROBABILITY EACH OF CLEAR, SCATTERED, BROKEN CLOUDS (no overcast since sum = 1)

R SQUARED: .436  R: .660
CONSTANT: .316  SE: .172
COEF CLEAR: .676  SE: .037
COEF SCATTERED: .580  SE: .033
COEF BROKEN: .410  SE: .077

2) REGRESS WITH CLOUD PROBABILITY & DEW PT.

R SQUARED: .438  R: .662
CONSTANT: .261  SE: .172
COEF CLEAR: .693  SE: .038
COEF SCATTERED: .583  SE: .033
COEF BROKEN: .419  SE: .077
COEF DEW POINT: .00102  SE: .00047

REGRESSION vs OBSERVATIONS & CLEAR SKY
RALEIGH, N.C. 1993

CLOUD COEFFICIENTS

CASE (UV Forecast/UV Clear Sky)

100% PROB. CLEAR: .99
100% PROB. SCATTERED: .90
100% PROB. BROKEN: .73
100% PROB. OVERCAST: .316
NOAA/EPA EXPERIMENTAL ULTRAVIOLET INDEX (UVI) FORECAST
CLIMATE ANALYSIS CENTER NMC
NATIONAL WEATHER SERVICE WASHINGTON, D. C.
01:58 PM EDT Fri Jul 8 1994

VALID DATE: JUL 09, 1994

THE UVI IS AN EXPERIMENTAL PRODUCT CATEGORIZED BY EPA AS FOLLOWS:

<table>
<thead>
<tr>
<th>UVI</th>
<th>EXPOSURE LEVEL</th>
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</thead>
<tbody>
<tr>
<td>0,1,2</td>
<td>MINIMAL</td>
</tr>
<tr>
<td>3,4</td>
<td>LOW</td>
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<tr>
<td>5,6</td>
<td>MODERATE</td>
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<tr>
<td>7,8,9</td>
<td>HIGH</td>
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<tr>
<td>10+</td>
<td>VERY HIGH</td>
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FOR HEALTH RELATED ISSUES, CONTACT EPA AT 1-800-296-1996 OR CDC 404-488-4347. FOR TECHNICAL INFORMATION ON HOW UVI VALUES ARE GENERATED, CONTACT THE NATIONAL WEATHER SERVICE AT 301-713-0622.

<table>
<thead>
<tr>
<th>CITY</th>
<th>STATE</th>
<th>UVI</th>
<th>CITY</th>
<th>STATE</th>
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<td>DC</td>
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<td>10</td>
<td>WICHITA</td>
<td>KS</td>
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ERROR DISTRIBUTION OF UV INDEX
FORECAST - OBSERVATION

UVI - Future Work

> Evaluation of UVI Product after Sun Season

- Expansion to all US locations
- 12 Hourly Updates
- Extension to 2 Day Forecast
- Adjustment of Central Product by Local Forecasters

> Inclusion of Ozone into Numical Model Forecasts

> Change to Model Generated Clouds (Global)

> Change to Operational TOMS Ozone and Cloud UV Reflectivity Products

> Integrate Regional and Local Pollution Effects
UV Indexes
E. C. Weatherhead
CIRES, University of Colorado

Public concern over changing UV levels has not been accompanied by widespread understanding of UV climatology or trends. While most of the public is aware that UV levels change in response to ozone levels, most are not aware that UV is strongly affected by time of year and latitudinal changes. Further confusion over how much UV may have changed during the past decade, have left many with the impression that biologically harmful UV may be two to three times what it was ten to twenty years ago. To alleviate this confusion and allow people the information useful in avoiding excessive UV exposure, several countries have begun educational efforts which include a daily UV level, what has become known as a UV index.

UV index programs presently exist in Canada, Australia, New Zealand, The Netherlands, Finland, Japan, Sweden and parts of the U.S. In general, these indexes use different tools to produce their daily index and different methods to communicate the information to the public. The two primary methods for producing a daily index are to use radiative transfer models or measurements--either broad-band or spectral. The UV values are then released to the public either in terms of a report on the present day's UV level, or more commonly as a forecast as to the next day's UV level. The UV index is almost always combined with an educational campaign to educate the public on appropriate interpretation of the index. The structure of the educational information often involves three levels of education. The first is to inform the public on the meaning of the index values and how they may relate differently from individual to individual. The second level of education is to inform the public on the general nature of UV: that in addition to harmful skin effects, UV can damage eyes as well as inhibit the immune system. The third level of education is to explain what measures can be taken to minimize UV exposure, this can include avoidance, protective clothing and eye wear and sunscreens.

When spectral instruments or radiative transfer models are used to implement the index, a method of summing the spectral information to result in a single UV number must be employed. Often the summing of radiation from the UVB and UVA regions weighted by the biological effectiveness at each wavelength is used. The most frequently used biological weighting function is the McKinlay-Diffey spectrum which has been adopted as the CIE standard. It represents the propensity of fair skin to redden when exposed to UV radiation. Another action spectrum, the ACGIH standard for health and safety has been used, and in the cases where the UV index is based on broad-band meters, the spectral response of the meter is used.
Most of the daily UV dose occurs in the few hours around noontime. Some educational index systems incorporate this into their index. For instance, the UK uses the total UV from 10 a.m. until 4 p.m. to represent to indicate the index level. Other systems use the total daily dose, or the dose in the one hour around noon. Instantaneous irradiance at noon is also a common quantity to use for a UV index. The choice of each of these time scales may not make as much difference as it may appear once a global scaling factor is incorporated into the index. Each of the choices results in values which are highly correlated with the other choices.

A common practice is to scale the global irradiance numbers by a factor which makes the indices more easily interpreted by the general public. Some countries have chosen to scale their index so that the indices in the southernmost area of that country will reach a ten in the summer. Some index systems have scaled so that the highest equator index expected would be a 100, allowing for relative values to be readily understood. Concern over confusion with temperature numbers and SPF factors have figured into many decisions about UV scales.

Some countries with a homogeneous population have chosen to express the UV level in a "minutes to burn" conversion based on the sensitivity of the skin type in their country. This choice gives an meaning to the UV indices which the public can immediately understand. However, this choice has been considered inappropriate for heterogeneous populations. Furthermore, the health community has expressed concern that a "minutes to burn" scale puts too much emphasis on burning, instead of communicating that UV exposure which does not result in a burn is also harmful. "Minutes to burn" may overemphasize the skin effects, while not communicating the importance of UV to the eyes and immune system. Confusion can also result when the medical community's definition of a burn (which often requires the use of a magnifying glass to diagnose) does not coincide with the general public's understanding of a burn.

Once a UV index is implemented, quality assurance of the index are necessary for scientific credibility. Two phases of quality assurance are important: the scientific defensibility of the indices themselves and the effect of the index-educational package on human understanding and behavior. The accuracy of the index, particularly when the index is a predictive one is vital to the credibility of the index. For most regions, the accuracy of the index is highly dependent on the accuracy of cloud prediction models. In some areas clouds are considerably more difficult to predict than in others. Ground-truthing of the index with actual measurements of UV is crucial to the verification of any index. Furthermore, it is important to communicate the uncertainty of any UV prediction in clear, understandable terms. The second aspect of quality assurance of an index
is to assess it’s impact on the public. UV index values have actually been used by those wishing to maximize their UV exposure to get a tan. The evaluation of people’s understanding, attitude and behavior are necessary for a complete understanding of the impact of a UV index.

The different choices of a UV index have all been made carefully and appropriately for the individual countries or areas being addressed. Unfortunately, the choices have not result in a single UV index which can be understood by travelers from one country to another. Serious confusion can result when vacationers who believe they understand how much radiation is being expressed when the UV index is, for instance, 7, can get seriously burned because they do not realize that a 7 in one country may be a 14 in another country. Because the world’s population is becoming more and more fluid, a standard UV index system is strongly needed. Both the WHO and the WMO are addressing the issue of creating a standard UV index scale. Hopefully standardization will take place this year as several countries are in the process of bringing a UV system into existence. The creation of a UV index standard will require a re-education program for all countries which need to change their present index into line with the international standard. Presently, all parties contacted have shown a willingness to do so.
Invited talk at the “WMO Workshop on UV-B for the Americas”
Buenos Aires, Argentina 22-26 August 1994

Talk presented in “UV Measurement Programmes” Session on August 24, 1994

The United States National Science Foundation’s Monitoring Network for Polar Regions

C. R. Booth, Tanya Mesteckkina, Timothy Lucas, John Tusson IV and John H. Morrow

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San Diego, CA 92110 USA
VOX: (619) 686-1888, FAX: (619) 686-1887
Internet: BOOTH@biospherical.com

I. INTRODUCTION

The Antarctic Ultraviolet Spectroradiometer Monitoring Network was established by the United States National Science Foundation (NSF) in 1988 in response to predictions of increased UV radiation in the polar regions. The network consists of several automated, high resolution spectroradiometers: five placed in strategic locations in Antarctica and the Arctic (Table 1), and one established in San Diego to collect data and serve as a training and testing facility. The network makes essential measurements of UV spectral irradiance and provides a variety of biological dosage calculations of UV exposure. Biospherical Instruments Inc. (San Diego, CA), under contract to Antarctic Support Associates (ASA), directed by the National Science Foundation (NSF), is responsible for operating and maintaining the network and distributing data to the scientific community.

### Table 1. Installation Sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Established</th>
<th>Location</th>
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<td>0°</td>
<td>February 1988</td>
<td>Clear Air Building</td>
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<tr>
<td>McMurdo</td>
<td>77.51S</td>
<td>166.40E</td>
<td>March 1988</td>
<td>Arrival Heights</td>
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<tr>
<td>Palmer</td>
<td>64.46S</td>
<td>64.03W</td>
<td>May 1988</td>
<td>Clean Air Building</td>
</tr>
<tr>
<td>Ushuaia, Argentina</td>
<td>54.49S</td>
<td>68.19W</td>
<td>November 1988</td>
<td>CADIC*</td>
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<td>Barrow, Alaska</td>
<td>71.18N</td>
<td>156.47W</td>
<td>December 1990</td>
<td>UIC-NARL**</td>
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<tr>
<td>San Diego, California</td>
<td>32.45N</td>
<td>117.11W</td>
<td>October 1992</td>
<td>Biospherical Instruments Inc.</td>
</tr>
</tbody>
</table>

*CADIC: Centro Austral de Investigaciones Cientificas, Argentina.  
**Ukpeagvik Inupiat Corporation-National Arctic Research Laboratory

II. INSTRUMENTATION AND DATA ACQUISITION

The spectroradiometers used in the system are Biospherical Instruments, Inc. Model SUV-100. Each instrument contains an irradiance diffuser, a double holographic grating monochromator, a photomultiplier tube (PMT), and calibration lamps. A vacuum-formed Teflon diffuser serves as an all-weather irradiance collector and it is heated by the system to deter ice and snow accumulation. Tungsten-halogen and mercury vapor calibration lamps are used for automatic internal calibrations of both responsivity and wavelength, which occur two to four times daily.

All instrument functions, calibration activities and data acquisitions are controlled by an MSDOS-compatible computer. Biospherical Instruments collects the data from the host computer through Internet or dial-up telephone lines and then processes them on a NT Server.

II. QUALITY CONTROL

Over-all quality assurance of the data has been achieved by standardizing all operation protocols, data processing and instrument configurations. Meanwhile, site-based quality control is maintained through frequent automatic performance checks, manual calibrations and careful monitoring of the data. System responsivity and wavelength stability are calibrated several times daily using internal lamps. Data analysis and manual instrument calibrations are performed on a bi-weekly basis. Finally, on a yearly basis, an engineer from Biospherical Instruments travels to each installation and calibrates all instruments using a single standard of irradiance. These calibrations are then transferred to all internal lamps for the next year of operation.
IV. DATA APPLICATIONS AND ANALYSIS

Data from the UV Monitoring Network have been used to support a variety of research programs. Some of these include the testing of radiative transfer models, derivation of ozone concentrations, and examination of the biological impact of enhanced UV. For example, by comparing time series of the UV-B and UV-A irradiances at the South Pole with TOMS data, the relationships between UV-B and ozone concentration have become evident. By including changes in solar angle with such a study, the summer amplifications of UV-B by ozone concentration have been analyzed and quantified.

Data have also been used to study the biological effects of UV irradiance. The UV-B measure, frequently defined as the integral of the spectral irradiance between 290 and 320 nm, is the irradiance that is potentially harmful to biological systems. By performing weighting functions over UV-B data, the true impact of UV irradiance has been explored. Several weighting functions have been developed, but the two most commonly used are Setlow's (1974) action spectra for DNA damage and the CIE sanctioned action spectra for human erythema (McKinlay and Difley, 1987).

IV. SUMMARY

High spectral resolution scanning UV spectroradiometers have been established at six sites and are successfully providing highly accurate multi-year data sets. These data have been used to support a variety of research programs worldwide.

The data recorded by the NSF UV Monitoring Network are available through Internet or CD-ROM's to all qualified researchers. It is divided into three classes. Level 1 data are in their original, uncorrected binary form and Level 2 data have been referenced to beginning-of-season calibration constants. These two classes are available only to NSF-sponsored researchers upon special request. Level 3 data are referenced to both beginning- and end-of-season calibration constants. These data are distributed on CD-ROM and are available to any qualified researcher upon request.

For more information about data availability or any aspect of the NSF UV Monitoring Network, please contact:

C.R. Booth
Biospherical Instruments Inc.
5340 Riley St.
San Diego, CA 92110 USA
VOX: (619) 686-1888, FAX: (619) 686-1887
Internet: BOOTH@biospherical.com

V. ACKNOWLEDGEMENTS

This research and monitoring activity was funded by contract AIT-M1743 from Antarctic Support Associates under the direction of Dr. Polly Pethale at the National Science Foundation, Office of Polar Programs. Dr. B. Mendonça of NOAA/CMDL assisted in providing operators and support for the installations at Barrow. Dr. R. McPeters of NASA/GSFC provided TOMS Total Ozone data for comparison purposes. TOMS Update CD-ROM is available from the National Space Science Data Center (NSSDC), Goddard Space Flight Center, 1992. Barrow operators include Dr. D. Norton (Arctic Sivumun Ilisagvik College), D. Endres and B. Halter (NOAA/CMDL). The Ukpeagvik Inupiat Corporation of Barrow provided assistance in the installation. Operators at Palmer and McMurdo have been provided by ASA. Special thanks go to John Gress of ASA who has been invaluable in the operation of the network.
To insure that the lamps kept on site maintain their calibration, a lamp comparison experiment is conducted at each annual site visit. There are several phases to this comparison. First, the visiting project engineer watches while the site operator conducts a routine calibration scan. This acts as a check that the operator’s methodology conforms with our established procedures. Next, the project engineer runs calibrations of both of the lamps kept on site then the “traveling lamp” of known value.

This table summarizes the results of a standards intercomparison conducted at the beginning and ending of several seasons during the annual site visits. In this table, the bold-faced, italicized numbers represent the averaged ratios of the measured brightness of the indicated lamps, while the remaining values are the brightness ratios inferred by comparison of different measurements. For example, a value of 1% indicates that the calibrated irradiances of the two lamps disagree on intercomparison by 1%. This disagreement may be due to actual lamp calibration shifts or measurement error. Lamp M552, compared with several other lamps, was approximately 3% high, and was subsequently retired. Details of the methods of calibration are found elsewhere (Booth, et al., 1992).
In an instrument confined to a field location where it cannot be subjected to laboratory analysis, wavelength calibration stability of the spectroradiometer can be estimated by examining a time series of the measured location of the 297 nm calibration line. For example, in this figure, scans taken on the McMurdo instrument were tracked. Analysis of this series showed that 95% of the readings showed wavelength uncertainty less than ±0.05 nm. The standard deviation was approximately 0.02 nm. Such details of instrument performance are recorded for all instruments and are published in yearly reports (Booth, et al., 1992, 1993, 1994).

Data and instrument control flow from the remote sites to Biospherical occurs over both Internet and dial-up telephone lines. Scientists can access data through the Internet or by CD-ROMS. At Biospherical, a variety of personal computers are linked to a Sun-type workstation via a local area network (LAN). UV data are processed on a NT Server.
Quality Control

- Anomaly detection in the operating software (alarms for site operators)
- Internal, fully automatic calibrations (daily) with automatic quality checks
- Bi-weekly processing of calibration and performance measures
- On-site standards for bi-weekly or monthly calibrations
- Yearly intercomparisons of standards

Quality control for the Spectroradiometer network is conducted on many levels. As the instrument is operated, automatic performance checks are conducted every minute. If normal operating bounds are exceeded, then warning messages to the site operator are generated. Several times per day, an automatic calibration cycle is performed to check system wavelength calibration and responsivity. Data transmitted to San Diego is examined for stability and accuracy on a bi-weekly basis. The site operator conducts monthly or bi-weekly calibration checks by mounting a Standard of Spectral Irradiance on the instrument. Finally, on a yearly basis, an engineer from Biospherical Instruments visits all installations, carrying standards that are compared with the standards maintained on site.

Quality Assurance

- Standardization of instruments in network
- Standardized data processing procedures
- Standardized procedures, parts and supplies
- Centralized operator training
- Scheduled instrument maintenance
- Publication of operating history of instruments
- Participation in instrument intercomparisons
- Data analysis and publication by independent scientists
- Publication in refereed journals

In addition to the quality control procedures that are operated at each site, we have made additional quality assurances by standardizing the operation protocols, data processing, and instrument configurations. All site operators are trained at our San Diego facility and documented operating procedures are used. We schedule instrument maintenance to coincide with the yearly site visits.

Yearly reports are published by Biospherical Instruments to detail the operating history of each instrument and present quality control data that can aid the researcher using data from the instruments. BSI also participates in both regional and international intercomparisons of spectroradiometers and standards. Many researchers have had access to our data; they have conducted their own independent analysis and have published their results.
Historical observations of ozone over Palmer Station, Antarctica from the Nimbus-7 TOMS sensor are shown in this figure. The red line shows the data from 1990 to illustrate how large variations at periods of one to two weeks are observed. The violet (smoothly increasing) line shows the progression of solar angle as the sun gets higher in the sky approaching summer solstice. In 1990, low ozone concentrations late in the season combined with high solar angles to give elevated UV.

Irradiance integrated over the 296.504 to 303.03 nm spectral region are shown in red (left axis) and irradiance integrated over the 338-442 nm spectral region shown in blue (right axis). Superimposed is the solar zenith angle (right axis) with vertical axis lines marking the solstices.

While the UV-A irradiance is symmetrical about the solstices, the UV-B is very asymmetrical with significantly higher irradiances occurring in the springtime when ozone depletion is severe. The units of irradiance are microwatts/cm² and the sun angle is in degrees zenith angle, with sunset marked with a vertical line.
NSF Monitoring Network data is used to calculate the impact of spectral irradiance on biological systems. This impact is called the UV "dose" to the system, and it is determined by using several published weighting functions such as those listed above. Two commonly used weighting formulations are Saito's (1974) action spectra for DNA damage and the CIE sanctioned action spectra for human erythema (McKinlay and Difley, 1987).

Data from the day of highest erythema at Palmer (12/2/90), compared with data from approximately one year later. Both scans were taken at the same solar angle (42-43°), and both were under relatively clear conditions. The inset plot is the ratio of the two scans. It is of interest to note that values as low as 155 DU were recorded at Ushuaia on October 5, 1992 and even in December. Meanwhile, a level of 228 DU was seen in the first year of the "ozone hole" (12/4/87) according to the Nimbus-7 TOMS (NASA GSFC).
Comparison of the 295 nm irradiance and TOMS (Meteor 3) ozone measurements made at Palmer Station during the spring of 1993. Notice that the right axis is inversely oriented. Thus, the effect of decreasing ozone on increasing irradiance is more readily apparent.

Comparison of the CIE sanctioned erythema-weighted UV dosage (McKinlay and Diffey, 1987) with the TOMS (Meteor 3) ozone measurements for Palmer Station during the spring of 1993. Notice that the right axis is inversely oriented. Thus, the effect of decreasing ozone on increasing UV doses is more readily apparent.
Spectral Ultraviolet Radiation Measurements in Canada: The Environment Canada Brewer Network.

94 07 20.

Spectrally resolved measurements of ultraviolet horizontal irradiance are made by Environment Canada (EC) at twelve locations with Brewer spectrophotometers (Fig 1). In addition, there are two networks of broadband UV radiometers in Canada. EC operates an experimental network using Vital Technologies’ BW100 instruments. Télémédia, the company that provides 24-hour television weather programming in Canada, operates a network of twenty Robertson-Berger meters.

The UV measurements at the Brewer sites were started at various times between 1988 and 1993. Three of the sites are in cities and two are within 50 km of cities; the remainder are isolated. The Brewer is a grating spectrometer with an F/6 aperture ratio and a focal length of 160 mm. Its features are shown in Fig 2. It is designed for ultra-stable wavelength setting and high spectral purity in the 305-330 nm region (achieved with a NiSO₄·6H₂O crystal filter which attenuates progressively above 315 nm and blocks above 330 nm). There are 7 or 8 motorized controls. The controls are effected by simple commands from a host personal computer via an RS232 interface. The operation is normally programmed to be completely automatic. About seven observing routines have been developed. These and five self-test routines are used in the observing schedule.

The two most important routines used in Canada are the Ozone Direct Sun Observation (DS) and the UV scan routine. These are outlined in Fig 3. In the DS routine, only the radiation from within 3 degrees of the sun’s centre is measured. Five wavelengths are sampled with 0.8 seconds, using five of the six exit slits, and the signals are co-added for about 30 seconds; the five co-added signals are recorded and four more 30-second sub-observations are made. The column ozone and SO₂ values are computed for each sub-observation and corresponding means and standard deviations of the two sets of five values are calculated. If the ozone standard deviation is less than 2.5 DU, the observation is considered good and is used to compute the daily mean ozone. Fig 4 contains the results of several DS observations during a period when the ozone was steady. UV-Index measurements are also shown in Fig 4.

The standard UV scan is made with just one slit is open, and the horizontal irradiance, incident on a teflon diffuser on top of the instrument, is measured. A series of 71 measurements are made while the wavelength is scanned from 290 to 325 to 290 nm at 0.5 nm intervals. This takes about eight minutes. (Some double-monochromator Brewers scan over the range 290-360 nm). Since the bandwidth is only 0.55 nm fwhm, the spectrum is slightly undersampled. All the spectral measurements are recorded; as well, the spectrum is weighted by the CIE erythemal spectrum, integrated and divided by 25 mW.m⁻² to yeild a value of the
UV-Index. Regular calibration is done by making observations with a variety of internal and external radiation sources listed in Fig 5. Instruments generally remain at their respective sites. A travelling standard instrument and standard lamps are taken to each site every year in order to calibrate the local instrument. Our estimate of the current overall uncertainty in the measurements is about 7%. We hope to improve the calibration by using our newly developed 1000W transportable lamp and lamp housing. This can easily be mounted on a Brewer in its operating location, day or night.

It is important to note that any user can programme a new observing routine for some specific requirements. A new routine now in operation in Canada measures the horizontal irradiance at the five wavelengths of the DS routine with the same sampling technique (i.e. every 0.8 seconds). This is providing data which is good for studying the spectral effects of clouds, which are not well reflected in slow spectral scans. We are also starting to analyze the DS data for the UV optical depth which is equivalent to studying the direct solar UV.

Each Brewer in the Canadian network produces about 250Kbytes of raw data each day. Currently, a small summary of these, of which Fig 4 is an example, is transmitted every hour or so as a bulletin on the EC Wide Area Net. These summaries are immediately available in Toronto, or elsewhere in Canada, for examination. The ozone values from the summaries are read automatically in Montreal for use in the operational forecast of ozone and UV. The raw data are archived in the Brewer Data Management System which is a relational database in Toronto. The transfer is currently by mail on floppy discs. A new mode of operation is being developed. In this all the data transfer will be in near real time and all the programs in the local host computers will be instantly modifiable from Toronto. With this new arrangement, it will be easy to effect special measurements or diagnostic routines at any of the twelve sites.

The UV data from Toronto during the period May 1989 to Sept 1993 have been used in an analysis of spectral UV changes which suggests there have been significant changes in UV irradiation due to ozone depletion (Kerr & McElroy, Science 262, 1032-1034, 1993). Fig 6 is an extension of this study which includes preliminary data for the winter of 1993-94. The UV data shown for 300 nm and 324 nm are not just for clear skies; they reflect the total UV irradiation during the 4-month periods. This figure shows that the four mean measurements of the 324 nm irradiation, which is not significantly affected by ozone, vary over a range of about 10%. Meanwhile, the 300nm irradiation, changes by more than a factor three, clearly in response to the changes in the mean ozone. The main ozone change was between 1993 and the other three years. The difference between the mean ozone of the 1990’s, excluding 1993, and the pre-1980 mean is about the same as the 1993 anomaly. We believe therefore that these data demonstrate conclusively that the ozone-induced winter enhancement at 300nm of pre-1980 radiation is much larger than the variability due to clouds and other factors. The summer data also show enhancement.
Fig 1: Map of Canada showing the locations of Brewers and ozonesonde stations.

Fig 2  BREWER SPECTROMETER - Overview

1. Modified Ebert Grating Spectrometer with 
   Photon counting detection and 
   SIX exit slits.  ? HEXACHROMATOR ? slit widths 0.55nm fwh

2. 7-8, computer-set, motorised controls
   * 1 Azimuth
   * 2 Elevation / mode (solar, zenith, irradiance, internal lamps)
   3 Field of view
   4 ND filters
   5 Polarizations / diffuser
   * 6 Grating angle (wavelength)
   7 Exit slit openings (wavelengths)
   8 (Extra filters) "continuous controls".

3. Basic design to measure ozone (precision ~ 1:500)
   1 ULTRA-Stable Wavelength (.01nm ; .006nm steps; .0006nm finding)
   2 Spectral Purity
   3 Stable Spectral Responsivity.

4. LIVES OUTSIDE. (~ 250 instrument years to date)
Fig 3  BREWER Routines

OZONE DS  Measure the direct solar beam at FIVE wavelengths in
          RAPID cycle (~1.6 seconds up - down)
          Centre wavelengths: 306.3  310.0  313.4  316.7  320.0 nm
          Co-add for a total of ~3 minutes.

UV-B SCAN  OPEN ONE SLIT
          Scan up then down 290 - 325 - 290nm, in 0.5nm steps
          Co-add up and down scans
          71 spectral elements ~ 8 minutes

Many other observing and diagnostic routines are used.
New routines can be programmed. UV-B codevelopers GREECE, SWEDEN, JAPAN

Fig 4:  Bulletin: SXCN10 CWTO 161522
TORONTO OZONE - BREWER # 014

PRELIMINARY DATA  -  LOCAL DATE SEP 16/93
LATITUDE - 43.782  :  LONGITUDE - 79.47
ETC'S - O3/SO2 - 3243 / 3229 :  ABSORPTION -.3408 / 1.1452

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<th>AIRMASS</th>
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DAILY MEANS 17  1.835  267.6  -1.1
STANDARD DEVIATION  +0.5  0.1

cont.
Fig 4 cont.  Bulletin sxcn10-  continued

SUMMARY OF BREWER UVB SCAN MEASUREMENTS FOR SEP 16/93

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An example of the near real time data that are put onto the Environment Canada Wide Area Net from the 12 stations in the Canadian Brewer Ozone and UV-B observing network.

Fig 5 Brewer calibration for UV-B

TOOLS
Reference Instruments
Reference Brewers reside at Toronto
Travelling Standard Brewers travel to and from Toronto

Internal lamps
Spectral lamp  Hg
20 watt quartz halogen lamp

External lamps
Small 200W lamp + housing...  can be used in-situ but is not
good between instruments.
1000W Optronics/NIST...    indoor use mainly.
1000W lamp housing for outdoor use...  being tested.

SITE CALIBRATION (ANNUAL)
Take 1000W Optronics lamp AND
Standard Brewer to the site.

Performance 1992-1994:
Lamp and Standard agree within 2-3%.

OVERALL UNCERTAINTY ？ 5％ ？ + NIST  (2σ)
Ozone and UV data transfer in Environment Canada and the World Ozone and Ultraviolet Radiation Centre (WOUDC)

---

**BREWER**
- Phone

**BREWER**
- Direct

Environment Canada WAN
- CMIO1
  - Toronto
- CIDSVO8
  - Montreal
- NWPM
  - Montreal

---

Toronto Experimental Studies LAN

S1 S2 S3

Carries relational database tables for: WODC, WUDC and the Brewer Data Management System - 50 Brewer years (currently 15 Gbytes)

---

EC internal access

World user access

---

WOU DC ftp server (currently 5 Gbytes)
ip address number: 142.97.22.42
alias: cmits02.dow.on.doe.ca
USER: woudc
PASSWORD: woudc*
UV Monitoring Around the World
E. C. Weatherhead
CIRES, University of Colorado

The political, environmental and scientific communities have taken a strong interest in UV reaching the biosphere over the past several years because of changes in ozone concentrations. A great deal of this interest has been manifested in the establishment of ground-based UV monitoring efforts. Ground based UV monitoring efforts can vary enormously in their cost, focus, and quality. The purpose for UV monitoring often determines the standards maintained in the monitoring effort. The results of these efforts has been a rapid increase in UV detection around the globe. Unfortunately the spatial distribution of these monitoring efforts is not optimal for global coverage to determine a climatology or to detect future changes in UV. The efforts to measure UV will be summarized here.

Monitoring takes place for a variety of reasons. Generally these reasons reflect the goal of the monitoring agency. The four general categories of reasons for monitoring of UV include:
- trend detection
- climatology
- public awareness
- cause and effect

While many monitoring programs attempt to span several of these goals, usually one goal is dominant and determines the course of the monitoring project.

Trend detection is the most demanding and costly of the monitoring goals. Because the trend is small compared to the daily and seasonal variations observed, extreme care in calibration, site selection, site maintenance, and documentation are necessary to be confident of trend results. All of these factors involve high expense either in terms of equipment of manpower. In many cases, factors beyond the control of the monitoring team can render worthless the results from a particular site. Because of these complications, networks are often more reliable, but again more costly, for the detection of trends in surface UV radiation.

Often the UV monitoring is designed to establish a basic climatology for a particular region. The basic UV climatology includes diurnal, seasonal and inter-annual means and variations which can represent an area. This information can be useful for establishing a baseline level of UV for future reference as well as to allow epidemiologists and biological effects communities to quantify exposure with UV related effects.

Public awareness has become a growing reason to monitor UV
radiation. Public interest in the subject of UV has been very high during the past decade. Unfortunately, much of this public interest has not been accompanied with strong public understanding. Basic knowledge of how UV varies with season, latitude and ozone are lacking in the public sector. One educational tool used in recent years has been a UV index delivered on a daily basis informing the public of the day's UV intensity. More on this subject will be discussed later.

The desire to establish cause and effect relationships, either biological as in the effects of UV on phytoplankton, or physical as in the effects of tropospheric pollutants on UV transmission, often lead to intense studies to monitor UV radiation over a limited period of time. These monitoring efforts can last days to years depending on the scope of the study and can contribute significantly to our scientific understanding of UV.

All of these purposes of UV monitoring can be supported with a variety of available instrumentation. The two basic categories instrumentation which have been used in the past include broad band meters and spectral-radiometers. Both classes of instrumentation have their advantages and disadvantages associated with their use.

Broad band instruments are generally filter or chemoluminescence based. Their spectral response in the UV generally mimics biological responsiveness—that is, highly responsive in the shorter wavelengths near 300 nm, and significantly less responsive toward the longer wavelengths. However the match of an instrument to a particular biological response function can introduce added uncertainty in the interpretation of the data. One of the strong advantages of broad-band instruments is their ease in use and longevity. Generally broad-band meters have no moving parts and stability over the period of decades has been documented for chemo-luminescence meters. Recent advances in filter technology promises similar stability for filter based instruments with the added benefit of being able to tailor the spectral response of the instrument to specified functions. The primary disadvantage of broad-band instruments is their inherent inability to assess changes in spectral characteristics of UV. This can be particularly important for trend studies where changes in UV can be due to a variety of factors including clouds, aerosols and pollutants, as well as changes in stratospheric ozone.

Spectral instruments have the ability to resolve various regions of the UV, generally with a 2nm bandwidth or less. These instruments are usually based on monochromator or double monochromator technology. The most frequently used type of spectral instrument for UV monitoring is a scanning instruments which can take several minutes to scan the UVB region. This time of measurement can introduce uncertainty
in individual scans because of atmospheric changes which can alter the UV spectrum during the middle of a scan. Scanning instruments are also subject to wear and degradation because of the moving parts. In general, spectral instruments supply greater information, with added initial and maintenance costs. The costs are high enough to prohibit extensive world-wide use in as many locations as are desired.

Recent advances in filter technology have introduced a third option to the broad-band versus spectral instrument choice. Temperature controlled filter instruments have been developed which can measure to as small as 2nm bandwidth (FWHM) in several different regions of the UV spectrum simultaneously. The simultaneity of these measurements from the different channels is an advantage over scanning instruments. The absence of moving parts promises mechanical longevity. The usefulness of such limited data is presently being explored by a variety of scientists. While the filter technology appears to be stable over many years, the filters have not been used in this application for enough years to adequately assess their stability.

Five years ago, UV was being monitored at less than fifty locations around the world. Presently, over 250 instruments are being used for daily UV monitoring. This explosion of UV instruments has followed the public and scientific concern over UV radiation. The instruments, purposes, maintenance and calibrations procedures differ greatly among the known monitoring efforts. Roughly half of the instruments are broad-band meters and half are spectral instruments. The purposes of each monitoring effort strongly effects the style in which these instruments are maintained and calibrated. A little more than half of the instruments presently in use are part of networks of UV monitoring instruments set up by individual countries and are maintained in a documented, similar manner. Calibration for the instruments can vary in approach and frequency: many of the instruments are calibrated with standard lamps weekly, while some of the instruments have not been calibrated since they were established.

One of the primary goals of the scientific monitoring community is to have measurements which are accurate and inter comparable. With the inherent differences in instruments, a limited level of comparability is achievable. Several methods have been used to try to achieve accuracy and inter comparability in the past several years. One of the most useful methods for achieving scientific understanding is instrument intercomparisons. Scientists from different monitoring networks compare their instruments' performances and calibration procedures in a single location. These intercomparisons have shown highly successful in determining instrument specific idiosyncrasies as well as to help quantify inter comparability of measurements from different networks.
An important step toward national coordination of the UV monitoring efforts in the U.S. is the establishment of a central UV calibration facility. NOAA and NIST are working together to establish a national facility for the calibration of UV monitoring instruments in the U.S. The facility will coordinate with international UV calibration laboratories to develop and share calibration techniques and results. The goal will be toward absolute as well as relative accuracy on spectral and angular response.

Continued efforts to coordinate UV monitoring on a worldwide basis will be necessary to establish an understanding of what is happening to UV on a global basis. Continued cooperation among the major networks will be crucial to establishing relative precision. The development of applicable calibration techniques which can be used by the world-wide networks will be very helpful. Several efforts are underway to establish traveling standard instruments as well as traveling standard lamps. The further development of instrumentation as well as the data analysis necessary to interpret the data will be crucial to the final conclusions which can be drawn from the UV monitoring efforts.
WMO WORKSHOP ON UV-B FOR THE AMERICAS

UV FORECASTING
Craig S. Long
NOAA/National Weather Service

> Why Forecast?

Provides information so public can take ACTION!

Reports of days UV dosage arrives to the public after the fact - damage has already been done.

> Which Countries Presently Provide Forecasts?

Canada
United States

England
Germany
Denmark
Sweden
Finland
Norway
Netherlands
Portugal
Spain

Australia (later this year)
New Zealand
UV FORECASTING

> Ingredients Needed to Make a Forecast

Ozone
  Sources
  Surface Obs
    Spectral
    BroadBand
  Satellite Obs
    SBUV/2
    TOVS
    TOMS/METEOR
    TOMS (later in 1994)
  Climatology (TOMS)
Forecast for Tomorrow
  Persistence
  Regression w/ Meteorological Parameters
  Adveected Parameter in a NWP Model

UV FORECASTING

> Ingredients - continued

Radiative Transfer Model
  Most Commonly Used
    Frederick
    Green
Inputs:
  Total Ozone
  Ozone Profile
  Surface Albedo
  Optical Thickness
  Latitude
  Day of Year
  Time of Day (Solar)
Output:
  UV Irradiances (W/m²/nm)
  Wavelengths: 290 - 400nm
  (range over 5 magnitudes of order)
**UV FORECASTING**

> Ingredients - continued

**Action Spectrum**

Skin:
- CIE*(McKinlay-Diffey)

Eyes:
- ACGIH

Others:
- DNA

**Dose Rate : Instantaneous**
- Canada UVI* = DR/25 mW/m²

or

**Dosage: Accumulation over period of Time**

**Attenuations/Enhancements**
- Air Pollution
- Haze
- Elevation
- Clouds

* WMO Standard

---

**UV FORECASTING**

> Relate to Erythema or "Time to Burn"

1 Minimum Erythemal Dose (MED) = 21 mJ/cm²  
(Commonly used for Type II Skin)

**Homogenous Skin Type**
- can get by with 1 standard

**Heterogenous Skin Types**
- may need to have multipul standards

**Issues Presenting "Time to Burn" with UV Index**

> Operational Timing for Newspaper, TV and Radio
SESSION C

Susana T.S. Diaz - Information exchange: Introduction (Abstract)

There is a considerable amount of information on ozone and UV radiation.

Since global ozone measurements have been made for many years now, the information on this subject is better organized, but for UV radiation, there is a great diversity of equipment and networks, and the information is more dispersed. Hence the need to consider information exchange.

This topic can be viewed from various points of view, and is described here as regards levels, users, data description, network standards, physical information exchange, and data-quality levels.

Levels

- Global organizations
- Regional organizations
- National institutions
- Groups

In the latter three cases, lists are needed of who performs the measurements and what exactly is measured.

Users

Users may be scientists working in various fields, generally divided into two groups:

- Atmospheric sciences,
- Biology (including medicine).

The data required for each of these groups differ: for climatology and atmospheric sciences, the data must be as detailed as possible, while for biology less detail is needed and the amount of data is generally less, though they must have biological implications. In the latter type of studies, it is sometimes sufficient to have some standard information, while for other studies specific data are needed, in which case there the group making biological research and that making geophysical research must together determine, through direct contacts, which type of information is the most suitable.

Data description

To make information exchange possible, it is necessary to have a description of the measurements, including the instrument used to obtain them and the observing conditions. Data quality and control should also be ensured as well as consistency in the measurement procedures. The history of the data should also be indicated, i.e. whether corrections were made to the raw data.

Network standards

For the data to be valid, each piece of equipment should be calibrated regularly, and, in the case of networks, using the same standard. In order to be able to compare data from different networks of instruments, these should also be calibrated using the same standard. There are various procedures for this: one consists in using solar light as a source for the calibration (intercomparison) and another in using a standard reference, which may be a lamp or an instrument.
Physical information exchange

One widely used method is to exchange data via the communication networks, particularly in the case of real-time and provisional information. The most common carrier for distributing definitive data is the diskette or CD-ROM, especially since the latter can store a large amount of information in a small physical volume.

Data-quality levels (quality v. time)

Real-time data generally contain more errors, and to obtain the definitive data, it is necessary to wait a certain length of time, but since the resultant data have been properly amended and calibrated, the quality is better.
**Additional Papers presented for Session C**


2. Ovidio Simbaqueva Fonseca, Colombia: Monitoreo Nacional de Radiación Ultravioleta en Colombia.


11. Jorge Carreño Campos, Chile: UV Radiation in Chile: Preliminary Results for Two Years of Measurements.

12. Humberto A. Fuenzalida Ponce, Chile: Altitudinal Variations of UV Radiation and Anomalies Due to Heavy Air Pollution.


15. Carreño Campos (Chile): Radiacion Solar Ultravioleta en Chile: Resultados Preliminares de Dos Años de Mediciones.

16. Eudimio Martínez Chapman, Cuba: Irradiancia UV de diferentes rangos espectrales, mediciones y cálculos teóricos en el Caribe.


19. (Uruguay) no presentation, but text.
1. L.R. Acosta (Mexico)

International System of Environmental Monitoring (SIMA).
UV-B Programme, consists of 27 stations to measure:
UV-B
UV-A
Total Radiation
Tropospheric Ozone

Analysis of hourly values of radiation, including the effect of clouds, altitude and tropospheric ozone (which is a big problem in Mexico City)
Inform to the public twice a day the erythema dose used by dermatologists.

2. O.S. Fonseca (Colombia)

Measurements of UV with instruments Eppley.
Campaigns in four locations (Leticia, Tres Gaviotas, Bogotá, Río Hacha). Latitudinal distribution of sites, except two of them which are at approx. the same latitude but present a big variation in altitude. These four sites were chosen due to their ozone sondes measurements.
Also measurements of global radiation (pyranometer), reflected radiation (with the same pyranometer they measure the reflected radiation turning it), direct radiation (pyrheliometer) and IR are performed.
Recently a procedure to obtain a percentage of direct and diffuse radiation is being applied.
It was proposed that all countries in Region III make four campaigns per year (that is during solstices and equinoxes) for the period 1994-97, measuring the parameters Colombia is measuring.

3. R. Maharaj (Trinidad y Tobago)

The first country of the Caribbean Commonwealth to sign the Vienna Convention document.
Plans related to the control of CFC manufacturing and effects on the atmosphere of CFC and substitutes.

4. Margaret Schaeffers (Barbados)

In this country there is a WMO Center.
In the English speaking Caribbean no measurements in O$_3$ or UV are being made.

5. A. Liao Lee (Costa Rica)

Measurements of UV-A + UV-B are being performed at two fixed locations (from Heredia measurements for the period 1991-1993 were shown).
With one of them short campaigns are being done (generally 4 days, maximum 11 days) in four positions. These are places of high altitude and sea level and the campaigns are done just to know how much radiation is in there.
Negotiations with Japan are being carried out to install a GAW station in this country.
6. M.A. Villegas Quinonez (Guatemala)

Due to the characteristics of the territory there are 8 weathers with 27 micro weathers in this country (moving from the pacific coast, at sea level, 40 km inside the continent the height is 3000km). Next year a project for environmental monitoring will begin, which will include UV measurements.

7. C. Bustios Davila (Peru)

Presentation of the Programme on Environmental Contamination at Lima. Measurements of ozone at high altitude regions in the Andes (Cosmos) were done. These measurements are interrupted now, but next year they will be initiated again with the visit of experts and the calibration of the Dobson equipment in Tenerife. Studies of environmental contamination and the micro weather of that region will be performed due to its influence on the vegetation and fauna.

8. G.R. Talamoni (Argentina)

A Regional Network for Ozone and Greenhouse Gases Measurement will be installed in South America sponsored by WMO/UNEP. The principal aim of the network is oriented towards the biological effects of UV. Also the development of models and the research on the dynamic and chemistry of the atmosphere will be done. The Meteorological Service of Argentina will be the Regional Center for Concentration and Distribution of ozone and UV data and the Meteorological Services of each country will be responsible for distribution in their countries.

9. Norma del Punta (Argentina)

The Secretary of Public Health is planning studies referred to health problems related with UV radiation, especially cancer. On one side the high risk groups are formed by people that are exposed due to professional reasons (rural workers and fishermen), on the other side are formed by the people that are exposed to the sun during sports or due to esthetic reasons. A brochure to educate the public is being prepared with the cooperation of some sociologists.

10. Luis Orce (Argentina)

A network of interference filter equipments will be installed in the next few months in Argentina. The equipment (GUV 511) have 4 bands in the UV and the PAR band. They will be installed in: Jujuy, Buenos Aires, Puerto Madryn and Ushuaia covering the territory in intervals of around 10° in latitude. Also biological research will be conducted in three freshwater places where underwater measurements will be carried out with a profiling radiometer (PUV), which have the same bands as the GUV but also a band to measure fluorescence due to chlorophyll in phytoplankton.

11. Jorge Tocho (Argentina)

In 1993 a programme began to construct 16 equipments to measure ozone. These are manual equipments which measure two bands in the UV-B and work with interference filters. At the
beginning it was a programme thought to connect the university with the community. At present most of the equipments are handled by physicists in Argentina and Chile. The ratio of the bands is used as parameter to compare with ozone concentrations. The equipment installed in Río Grande (South of Argentina) was correlated with TOMS Meteor 3 data and they adjust between 7%.

12. Carrero Campos (Chile)

In 1992 eight UV stations were installed in Chile. Six of the equipments are Eppley (UV-A + UV-B) and two Yankee (UV-B). These equipments are distributed in latitude, since most of them are installed at 70°W, they give a good latitudinal profile. The monthly mean radiation values show an inversion in some stations (that means higher values at higher latitudes), especially in November and December. This is more obvious when only clear days are considered.

13. Humberto Fuenzalida (Chile)

One interference filter equipment of 5 bands (PUV 500) is used to make measurements in locations at different latitudes and altitudes. The sites where measurements were done are: Arica, Santiago, Puerto Montt and Punta Arenas (latitude variation from 18 to 53°S). Only clear days maximum values are considered in the analysis. When monthly mean values are compared Santiago shows values anomaly low, which is related with the heavy pollution in this city. Also a strong variation with altitude (higher UV at higher altitudes) was observed especially in Santiago, where the effect of pollution at low heights is added to the changes in altitude.

14. Margarita Prendez (Chile)

Project 1

The project refers to the correlation between solar radiation and air pollution in Santiago. This is a joint project of the Universidad de Santiago (Chile) and the Universidad de Salamanca (Spain). The amount of particulated material and the global radiation (measured) and the diffuse (computed by a model) are correlated. In the first study the considered data series were from 1978 to 1988, in two urban and two suburban sites. In the urban sites very good correlations were observed, while in the sub-urban were not. A second study is being finished with only one urban site and data from 1988 to 1993. Then a model will be developed to make retrospective studies.

Project 2

A dermatologic study was performed in Punta Arenas to determine the possible effects of the ozone hole. Three different populations were considered: fishermen, urban workers and employees of the hospital. The analyzed period was 1989-1992.

No meaningful differences were observed in the photodermatitis acute between the three groups.
15. Consuelo Gamboa (Chile)

A Masters Degree Course in Environmental Chemistry at the University of Santiago (Chile) is available to form people that will be able to work in multidisciplinary environmental problems.

16. Martínez Chapman (Cuba)

Due to the geographical position of the country and the tourist and economical activities there is a need to begin UV measurements. Around 1980 the measurement of total ozone column with filter photometers M124 began and since middle 80’s the measurement of UV with broad band instruments (UV-311, 303-320nm; UV334, 320.346nm; Total UV, <385nm).
Mean monthly values were calculated for clear sky, partially cloudy and cloudy days (the condition of cloudiness refers just to the sun, not the whole sky).
They use simple three layers radiative transfer models which provide UV spectral values in 5nm bands.

17. Genaro Coronel (Paraguay)

WMO will install a spectroradiometer at the Universidad Nacional de Paraguay, Asunción (250°S, 57°W), as part of the Regional Network for Ozone and Greenhouse Gases Measurement. At this moment the group that will be in charge of the equipment is carrying out activities related with compiling technical information on the installation and use of the equipment and scientific bibliography on UV.

18. E.J.H. Imaña (Bolivia)

Due to the altitude of this country (4000m) and the low cloudiness (2/8 in Winter and 4/8 in Summer) there is concern about the effect on UV on plant and skin cancer in agriculturers. There is interest in making UV measurements.
ENVIRONMENTAL POLLUTION MONITORING AND RESEARCH PROGRAMME REPORT SERIES


7. Fourth Analysis on Reference Precipitation Samples by the Participating World Meteorological Organization Laboratories by Robert L. Lampe and John C. Puzak, December 1981*

8. Review of the Chemical Composition of Precipitation as Measured by the WMO BAPMoN by Prof. Dr. Hans-Walter Georgii, February 1982


11. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at May 1982

12. Report on the Mount Kenya Baseline Station Feasibility Study edited by Dr. Russell C. Schnell


14. Effects of Sulphur Compounds and Other Pollutants on Visibility by Dr. R.F. Pueschel, April 1983

15. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1981, May 1983


17. General Consideration and Examples of Data Evaluation and Quality Assurance Procedures Applicable to BAPMoN Precipitation Chemistry Observations by Dr. Charles Hakkarinen, July 1983

19. Forecasting of Air Pollution with Emphasis on Research in the USSR by M.E. Berlyand, August 1983

20. Extended Abstracts of Papers to be Presented at the WMO Technical Conference on Observation and Measurement of Atmospheric Contaminants (TECOMAC), Vienna, 17-21 October 1983


23. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1982. November 1984


26. Sulphur and Nitrogen in Precipitation: An Attempt to Use BAPMoN and Other Data to Show Regional and Global Distribution by Dr. C.C. Wallén. April 1986


29. Recommendations on Sunphotometer Measurements in BAPMoN Based on the Experience of a Dust Transport Study in Africa by Dr. Guillaume A. d’Almeida. September 1985


35. Provisional Daily Atmospheric CO$_2$ Concentrations as Measured at BAPMoN Sites for the Year 1983. December 1985


43. Recent progress in sunphotometry (determination of the aerosol optical depth). November 1986


46. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1984. December 1986


50. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1985. December 1987


53. WMO Meeting of Experts on Strategy for the Monitoring of Suspended Particulate Matter in BAPMoN - Reports and papers presented at the meeting (Xiamen, China, 13-17 October 1986). October 1988


55. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at 31 December 1987


58. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at BAPMoN sites for the years 1986 and 1987


62. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at BAPMoN sites for the year 1988


64. Report of the consultation to consider desirable locations and observational practices for BAPMoN stations of global importance (Bermuda Research Station, 27-30 November 1989)


68. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data For 1989, Volume I: Atmospheric Aerosol Optical Depth

69. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at Global Atmosphere Watch (GAW)-BAPMoN sites for the year 1989


72. Integrated Background Monitoring of Environmental Pollution in Mid-Latitude Eurasia by Yu.A. Izrael and F.Ya. Rovinsky, USSR

73. Report of the Experts Meeting on Global Aerosol Data System (GADS) (Hampton, Virginia, 11-12 September 1990)

75. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at Global Atmosphere Watch (GAW)-BAPMoN sites for the year 1990

76. The International Global Aerosol Programme (IGAP) Plan: Overview

77. Report of the WMO Meeting of Experts on Carbon Dioxide Concentration and Isotopic Measurement Techniques (Lake Arrowhead, California, 14-19 October 1990)

78. Global Atmospheric Background Monitoring for Selected Environmental Parameters BAPMoN Data for 1990, Volume I: Atmospheric Aerosol Optical Depth


80. Report of the WMO Meeting of Experts on the Quality Assurance Plan for the GAW (Garmisch-Partenkirchen, Germany, 26-30 March 1992)


83. Report on the Global Precipitation Chemistry Programme of BAPMoN

84. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at GAW-BAPMoN sites for the year 1991

85. Chemical Analysis of Precipitation for GAW: Laboratory Analytical Methods and Sample Collection Standards by Dr. Jaroslav Santoch


88. Guide to the observations by E. Meszaros

89. 4th International Conference on CO₂ (Carqueiranne, France, 13-17 September 1993)


91. Extended Abstracts of Papers Presented at the WMO Region VI Conference on the Measurement and Modelling of Atmospheric Composition Changes Including Pollution Transport (Sofia, 4-8 October 1993)


94. Report on the Measurements of Atmospheric Turbidity in BAPMoN

96. Global Atmospheric Background Monitoring for Selected Environmental Parameters WMO GAW Data for 1993, Volume I: Atmospheric Aerosol Optical Depth

97. Quality Assurance Project Plan (QAP) for Continuous Ground Based Ozone Measurements


99. Status of the WMO Global Atmosphere Watch Programme as at 31 December 1993