WORLD METEOROLOGICAL ORGANIZATION

GLOBAL OZONE RESEARCH AND MONITORING PROJECT

No. 3

Report of the

MEETING OF EXPERTS ON UV-B MONITORING AND RESEARCH

(Prepared in co-operation with UNEP)

GENEVA, 16 - 20 MAY 1977

1. OPENING OF THE MEETING

1.1 The participants (see Appendix A) were welcomed to the WMO headquarters by Dr. R.D. Bojkov, Chief of the Atmospheric Sciences Division of the Secretariat, on behalf of the Secretary-General. Dr. Bojkov informed the meeting of the course of events which had led to the initiation by the Executive Committee in June 1976 of the WMO Global Ozone Research and Monitoring Project.

1.2 In fulfilling its responsibility as leading agency in matters concerning atmospheric ozone, WMO works in close collaboration with the United Nations Environment Programme (UNEP), and the attention of the meeting was drawn to the comprehensive survey prepared by WMO for presentation to the UNEP Meeting on the Ozone Layer comprising experts designated by governments, intergovernmental and non-governmental organizations, and which took place at Washington D.C. (U.S.A.) from 1 to 9 March 1977 (Reference 1). The outcome of the UNEP meeting had been to endorse WMO's Global Ozone Research and Monitoring Project, and to allot responsibilities among the specialized agencies of the United Nations for co-ordinating the execution of the various tasks involved. Naturally, the greater part of these tasks fell to WMO, and one specific field in which WMO had been designated leading agency was the development of instrumentation, monitoring and the promotion of research relevant to UV-B radiation. It was also the role of WMO to ensure that all the relevant data and information produced by the Global Ozone Research and Monitoring Project would be readily available for appropriate bodies engaged in studying the various biological consequences of increased UV-B at the Earth's surface.

1.3 Therefore it had been decided to call the present meeting of experts in order to advise WMO on the future work programme in UV-B measurement and research. It was suggested that, among other relevant topics, the meeting might discuss:

i) useful instrumentation (broad- and narrow-band) and methods of measuring to provide precise levels of UV-B irradiance;

ii) the required network of stations measuring the spectral distribution and intensity of UV-B at the Earth's surface;

iii) future research relevant to UV radiation; and

iv) the question of data management.

The final agenda of the meeting is set out in Appendix B.

1.4 In conclusion, Dr. Bojkov assured the participants of the willing support of the Secretariat staff and of its facilities. He wished them an enjoyable and fruitful meeting and a pleasant stay in Geneva.

1.5 The representative of the World Health Organization (WHO) also referred to the recommendations from the UNEP Meeting of Experts on the Ozone Layer (Washington, 1-9 March, 1977) (Reference 2). He went on to say that WHO is interested in seeing improved monitoring of UV-B radiation at the Earth's surface with a view to determining whether there is an increased risk of incidence of various biological effects related to increased UV-B levels. In conclusion, he said that WHO would look forward to the results of the meeting and would give serious consideration to the recommendations made with a view to participating, to the extent possible, in a world-wide UV-B monitoring programme in collaboration with WMO.

1.6 The representative of the International Council of Scientific Unions (ICSU) expressed ICSU's interest in the work of the meeting.

1.7 Dr. C. Fröhlich was elected chairman of the meeting.

2. REVIEW OF EXISTING INSTRUMENTATION

2.1 Two different types of instrument exist for monitoring UV-B which can be classified by their spectral response. Each instrument will:

i) respond in accordance with a specific action spectrum such as, for example, the erythemal response of the human skin, or

ii) divide the UV-B region from about 290 to 325 nm into several more or less narrow bands, measuring the actual energy in each band.

2.2 The group discussed first the three instruments of which the designers were present, namely the instruments of:

i) Dr. Dehne,
ii) Dr. Robertson and Mr. Berger, and
iii) the Smithsonian Institution represented by Dr. Klein.

A summary of the specifications of these instruments is given in Appendices C, D and E respectively. It was stated that the most difficult problem is still the realization of a reliable and accurate calibration of each type of UV-B instrument. In this context, reference was made to "State-of-the-art uncertainties and limitations in UV spectroradiometry" (Optical Radiation News, NBS) (Reference 3), from which the uncertainty table reproduced in Appendix F is taken.

2.3 Further, it was noted that it is difficult to compare instruments of different design with responses which change with wavelength and in which the final evaluation is a weighted mean of the effectiveness of all the wavelengths present. The main reason is that it is difficult to realise with different methods the same spectral response curve, e.g. with the phosphor (Robertson-Berger) instrument and the interference filter (Dehne) instrument. To evaluate such differences quantitatively for the "weighted-spectrum" instruments as a function of solar spectrum depending on solar elevation <u>only</u>, the so-called "error angle" has been used. It was first introduced by Berger in Reference 4 and gives a measure of the deviation in the reading observed on an actual instrument from the response calculated according to an "ideal" action spectrum. It is determined from the relative

3.1 Purpose of the network

3.1.1 Because solar UV radiation is very strongly absorbed by ozone in the stratosphere, it is mainly the composition of the latter which determines the amount of UV-B reaching the Earth's surface. A possible reduction of the ozone content such as could be induced by an injection of pollutants into the stratosphere would increase the UV-B radiation reaching the ground. The details of this mechanism are described in Reference 1. Such a change might have consequences on humans and the biosphere because of the damaging potential of increased UV-B on biological systems. The possible effects of changes in UV-B radiation on human health are described in Reference 6. Such changes may also influence agricultural production. Tropospheric pollution may also affect the UV-B registered at the Earth's surface. However, it is known that the UV-B reaching the surface depends on aerosols, albedo, etc., and that there is still not any adequate global UV-B climatology. To estimate the eventual rate of change early enough, a world-wide monitoring network is needed. The main objective in UV-B monitoring is to document the world climatology of UV-B radiation received at the Earth's surface, particularly in those wavelength regions which are "active" on the human race and the biosphere during a period of at least one solar cycle (11 years) at globally distributed sites. In this connexion, reference is also made to recommendations on the UV-B radiation monitoring in the World Plan of Action on the Ozone Layer as approved by the UNEP meeting (Reference 2), the relevant part of which is reproduced as Appendix H.

3.2 Density of the network

3.2.1 The purpose of this monitoring network appears to require about 30-40 globally-distributed stations.

3.2.2 The siting criteria do not seem to involve any special constraints. However, it seems very useful to combine such UV-B monitoring stations with the following existing networks:

i) WMO background air pollution monitoring network;
ii) WMO Dobson ozone monitoring network; and
iii) WHO air pollution monitoring network in urban areas.

By this combination, a wide variety of environmental conditions are covered (e.g., at sea level and high altitude, in rural and urban situations). In every case the monitoring station should be within 250 km in longitude and 100 km in latitude from a Dobson spectrophotometer or similar ozone measuring station to enable correlation of ozone concentration and UV-B irradiance. The siting of monitoring instruments in the proximity of institutions performing skin cancer epidemiology studies would also be an advantage.

3.2.3 It is proposed to locate the stations along four north-south axes running through the following regions:

i) Europe-Africa;
ii) North-South America;
iii) Pacific;
iv) Siberia-Japan-Australia.

Appendix I suggests an adequate distribution of the UV-B monitoring stations.

3.3 Timing of the recording

3.3.1 For the biological effects short-term fluctuations can be important. Therefore, it is proposed to record half-hourly integrals for weighted-spectrum type instruments. From the experience of the Robertson-Berger network, this seems an acceptable compromise between short-term information and quantity of data. For the multi-spectral instruments, however, shorter integration intervals are needed because such data will also be used for atmospheric research. A 6-minute integration time seems adequate and will further allow a detailed quality control of the data.

3.4 Instrumentation

3.4.1 The UV-B monitoring stations could be divided into 3 groups according to the instrumentation used:

i) stations with multi-spectral instruments;
ii) stations with erythemal response spectrum instruments; and
iii) comparison stations for weighted-spectrum instruments of different design used in the network.

About half the stations the location of which are proposed in paragraph 3.2.3 and Appendix I, should be equipped with the multi-spectral, and the other half with the weighted-spectrum instrument. About 3 to 4 of the latter stations can be used as comparison stations.

3.4.2 At the moment, the only multi-spectral instrument available for monitoring which could be used in this type of network is the Smithsonian instrument (see Appendix E). However, the following specification should be met:

wavelength range:	290-330 nm
half bandwidth (HBW):	max. 5 nm
shape of bandpass:	
1% bandwidth:	1.2 x HBW
0.1% bandwidth:	1.5 x HBW
number of channels:	8
stability:	<5% per year
cosine error with reference to readings taken at noon on a clear day:	<3%.

The meeting was aware that this choice is a compromise in order to permit the monitoring network to be started as soon as possible, and it was agreed that further investigations should be initiated to develop more detailed specifications.

3.4.3 The instruments with an erythemal spectral response must fulfil the following specification:

error angle for fixed
ozone concentration: max. 2°
stability: <5% drift per year
cosine error with reference to readings taken at noon on a clear day: <3%.

The error angle is calculated by convoluting the experimental erythemal action spectrum given in Appendix J with the reference UV-B global spectra deduced from Bener's data and tabulated in Appendix K for different solar angles and different ozone concentrations.

3.5 Calibration procedures

3.5.1 The present methods of calibrating UV-B instruments are based on standard lamps. The accuracy achieved is about ± 3% when neither the character of the radiation nor the conditions of measurement contribute significantly to the uncertainty. Some details on the state-of-the-art concerning the accuracy uncertainty in UV spectral radiometry are given in Appendix F. However, it is known that the spectral irradiance standards used at the different national standards laboratories differ by more than 3% in this region of the spectrum. It is hoped that in the near future this situation will change when new sources will become available and/or new methods based on radiometry will be developed.

3.5.2 With the above in mind, it is recommended to use for the time being 1000 W quartz-halogen lamps as primary standards for the calibration of the UV-B instruments. These lamps should be calibrated at only one Standards Laboratory. This will ensure more homogeneous and hence comparable results from all over the network.

3.5.3 Further, it is recommended that three regional calibration centres be established which would be responsible for the calibration of all instruments in their region. It is desirable that these centres be located in America, Europe and Australia or Japan, and each could cover two WMO Regions, namely, III and IV, I and VI, II and V. These centres should each be equipped with at least 3 standard lamps as described above, as well as the laboratory equipment needed to perform the calibration and to test each instrument thoroughtly. Further, one of the standard lamps from each centre should be recalibrated at the standard laboratory at regular intervals, if possible annually. The procedures for transferring the calibration to the field instruments are described in the following paragraphs.

3.5.4 The weighted-spectrum instruments in the field have to be calibrated by comparison with a travelling reference instrument of the same type which is calibrated at the centre against the primary standard, the lamp. The comparison should be conducted on days when noon solar elevation is about 35 degrees. The laboratory calibration should be performed before and after each field comparison. The rotation of the travelling reference instrument within the network should be such that each field instrument is compared at least once a year.

3.5.5 The multi-spectral instruments can only be calibrated directly against the primary standard. Therefore, they should be exchanged approximately once a year for recalibration at the centre. In the field a checking procedure will be necessary to confirm correct functioning of the instrument. This procedure could utilise a lamp of "standard" quality which, however, does not need absolute calibration. This field check should be performed at least twice a month.

3.5.6 It is noted that the availability of new radiation sources to be used as primary standards will be discussed at a meeting to be held about this topic in June at the National Bureau of Standards, Gaithersburg, U.S.A. Dr. W. Klein, who will attend the meeting, is asked to provide information on the prospects for new, more powerful sources (to be included in Appendix L).

3.6 Data Management

3.6.1 From a weighted-spectrum instrument, about 2,700 digits will be gathered during a month when half-hour integrals are recorded during the day. In the same period, the multi-spectral instrument will yield up to 300,000 digits. In both instruments, automatic recording on some computer-compatible medium is needed to enable easy handling of these data. The Smithsonian instrument already uses magnetic tape cassettes for storage of the instrument output, providing easy and reliable transfer later to a computer. The Robertson-Berger instrument will soon be equipped with a similar device. The prices quoted in Appendices C, D and E already include computer-compatible data storage.

3.6.2 It is proposed that WMO, in collaboration with WHO, arrange that the data on computer-compatible media be collected, controlled for quality and stored at the three regional centres (see paragraph 3.5.3). With the proposed number of stations, they will have to deal with about 12 million digits a year.

3.6.3 From such individual data, at least daily totals for the weighted-spectrum and the multi-spectrum instruments should be published yearly. The detailed data should be made available in computer-readable form for individual scientists and for agencies upon request. It is proposed that WMO in collaboration with WHO be responsible for the printing and dissemination of the yearly publications.

4. RECOMMENDATION FOR UV-B RESEARCH

4.1 From data already available, it seems that the processes determining the distribution of UV-B irradiance in space and time under clear sky conditions are fairly well understood. However, the influence of clouds and aerosols on the UV radiation needs to be investigated in more detail, both theoretically and experimentally.

4.2 In order to determine eventual trends in UV-B radiation, it is very important to get more accurate information about the magnitude and variability of the sun's output in this spectral region. Such determination can only be done from stratospheric balloons or satellites. It is strongly recommended that such experiments be initiated as soon as possible. To improve our knowledge about ozone absorption, the solar irradiance data should be determined as an integral over the solar disc and with high resolution in wavelength (about 2 picometer). It is desirable that the ozone absorption spectrum also be determined with the same resolution.

4.3 Existing calibration procedures for UV-B measurement (as outlined in Section 3 of this report) are still inadequate as regards the accuracy needed for determining slow trends. Therefore, it is recommended that high priority be given to:

i) improvement in the accuracy of the standards;
ii) development of procedures and techniques which inherently guarantee greater accuracy.

4.4 The monitoring network proposed in the preceeding paragraphs will not yield any medium-resoultion data such as that measured and published by Dr. P. Bener (Reference 7). However, this data set does not include original data for solar elevations between 60°-90°. This gap needs to be filled with measurements from an equatorial or near-equatorial station. On the other hand, Bener's final tables give intensity values only for discrete solar elevations of 5°, 10°, 20°, 40°, 60° and 90° (extrapolated) although in the region from 5° to 60° more data exist. It is therefore considered useful if selected sets of Bener's originally measured data be made available on magnetic tape so that interested persons may take out those data required, particularly with regard to consistent intensities at intermediate values of solar elevation and for wavelengths down to about 295 and 292.5 nm.

4.5 In order to achieve better understanding of the influence of aerosols and thin clouds on the UV-B radiation, it is recommended that measurements of direct solar radiation and of sky radiance distribution should be made at several suitably located stations.

4.6 It is further recommended that, if any research on instrumentation has resulted in the development of a sophisticated UV measuring instrument with high/medium resolution which could be used for UV monitoring, such an instrument should be included in the network, at least for use at the three regional centres proposed in paragraph 3.5.3.

5. CLOSING OF THE MEETING

5.1 The meeting was able to agree on the text of the draft report prepared by the chariman during the session, and Dr. Bojkov undertook to see that all amendments introduced at the final session as well as necessary editorial improvements would be incorporated in the final version. The meeting recommended that the report be given wide distribution to serve as guidance for further action to be taken by WMO in collaboration with UNEP, WHO, FAO and other organizations as appropriate.

REFERENCES

(1) WMO Report on "The Atmospheric Ozone" submitted to the UNEP Meeting on the Ozone Layer (Washington, D.C., March 1977) (UNEP/WG.7/5, 77 pages)

(2) World Plan of Action on the Ozone Layer adopted by the UNEP Meeting on the Ozone Layer (Washington, D.C., March 1977)

(3) Optical Radiation News No. 20, April 1977, U.S. Department of Commerce, National Bureau of Standards, Washington D.C.

(4) (i) D. Berger - The Sunburning UV-Meter Design and Performance, Photochemistry and Photobiology, 1976, Vol. 24, pp. 587-593, and

(ii) D.F. Robertson - Solar Ultra-violet Radiation in Relation to Human Sunburn and Skin Cancer, Ph.D. Thesis, University of Queensland, 1972

(5) L. Machta, G. Cotton, W. Hass and W.D. Komhyr - CIAP Measurements of Erythemal Solar UV Radiation, Final Report, U.S. Department of Commerce, NOAA, August 1975

(6) WHO Report on "Effects of Ultra-Violet Radiation on Human Health" submitted to the UNEP Meeting (Washington, D.C., March 1977) (UNEP/WG.7/4, 19 pages)

(7) P. Bener - Approximate Values of Intensity of Natural UV Radiation for Different Amounts of Atmospheric Ozone, Final Technical Report, U.S. Army, DAJA 37.68.C.1017, Davos 1972

(8) K. Dehne - Design and Performance of a New Instrument for Measuring UV-B Global Radiation (Paper to be presented to WMO Technical Conference (TECIMO) in Hamburg, August 1977)

(9) B. Goldberg and W.H. Klein - Radiometer to Monitor Low Level of Ultraviolet Irradiance, Applied Optics, Vol. 13, No. 3, March 1974

Meeting of Experts on UV-B Monitoring and Research
(Geneva, 16 - 20 May 1977)

LIST OF PARTICIPANTS

Mr. D. Berger	Temple University Philadelphia, Penn., U.S.A
Dr. K. Dehne	Deutscher Wetterdienst Hamburg, F.R.G.
Dr. C. Fröhlich	World Radiation Centre Davos, Switzerland
Dr. W. Klein	Smithsonian Radiation Biology Lab. Rockville, Maryland, U.S.A.
Dr. D.F. Robertson	University of Queensland Brisbane, Australia

Invited observers from other international organizations

Dr. H. de Koning	World Health Organization
Dr. E.A. Komarov	" " "
Dr. M. Errera	ICSU

WMO Secretariat

Dr. R.D. Bojkov	Chief, Atmospheric Sciences Division
Mr. N. Suzuki	Atmospheric Sciences Division

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AGENDA

1. Opening of the meeting
2. Review of existing instrumentation
3. Recommendations for a UV-B monitoring network
   - 3.1 Purpose of the network
   - 3.2 Timing of the recording
   - 3.3 Density of the network
   - 3.4 Instrumentation
   - 3.5 Calibration procedures
   - 3.6 Data management
4. Recommendations for UV-B research
5. Closing of the meeting

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SPECIFICATION OF THE ROBERTSON-BERGER UV-B INSTRUMENT

1. General

The Robertson-Berger meter measures the UV-B approximately according to its sunburning effect. The spectral response of the meter varies with wavelength in a similar way to the erythema action spectrum of the skin. The meter spectral response essentially depends on the fluorescence of a magnesium tungstate phosphor. A pair of filters, one before and one after the phosphor, eliminate interfering wavelengths. A photo-diode transduces the emitted fluorescent energy of the phosphor into a proportional electrical signal. Neither the filters nor the photo-diode have a significant direct effect on the spectral response of the instrument.

Instruments are presently in use at 17 different stations in Australia, the Federal Republic of Germany, Poland, Switzerland, U.S.A., etc., of which 10 have been operating for over 3 years. Data from all units are handled by NOAA, U.S.A., and are intercomparable.

2. The angular response is hemispheric, that is, it measures the global UV-B radiation on a horizontal surface. The deviation from ideal cosine response yield a maximum possible uncertainty of ± 10%.

3. The spectral response is such that it follows as nearly as possible the erythemal action spectrum.

The response of the filter-phosphor-detector combination peaks at 295 nm and decreases to about 1/20,000 at 335 nm. Convoluted with global UV-B radiation, the peak response shifts from 305 nm to longer wavelengths depending on the solar elevation and the total ozone amount.

4. The full-scale response in one hour is equivalent to 90 $mJcm^{-2}$ or 5 sunburn units with a noise of less than 4 μJcm^{-2}. The sensitivity is 45 μJcm^{-2} for one count. The error angle equals 6.5° (see paragraph 2.3 of main report for explanation of term).

5. The calibration of the standard instrument is performed with a 250 W Quartz Halogen lamp, which is in turn calibrated with a NBS calibrated 1000 W lamp. All the field instruments arecalibrated by comparison to the standard instrument.

6. The precision is estimated to ± 3%. This figure follows from the calibration history of some 10 instruments over 3 years. The sensitivity of the response to changes in ambient temperature depend also on solar spectrum and has not yet been categorized. However, the difference between a thermostated and normal instrument equals about 500 counts a day averaged increase throughout the year at Philadelphia. Possible differences in the spectral response of two instruments yield maximum differences in the reading of ± 2%.

7. The reliability of the instruments has proven to be very good. A 96% data collection efficiency was achieved during the last 2 years.

8. The cost of the instrument is estimated to be $ 2,000 to $ 3,500 depending on the data acquisition system used (sodeco-printer or cassette).

9. For further details, see Reference 2 or contact:

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Phone: 215 927 4206 or FAX: 215 927 6347

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STATE-OF-THE-ART UNCERTAINTIES AND LIMITATIONS IN UV SPECTRORADIOMETRY

Extract from "Optical Radiation News" (No. 20, April 1977)
(U.S. Department of Commerce,
National Bureau of Standards, Washington, D.C.)

The accuracy with which spectral irradiance measurements can be performed depends not only on the instruments, standards and techniques available but also on the detailed character of the radiation (magnitude; spectral, spatial and temporal distribution; and polarization) and on the conditions under which the measurements are performed (ambient temperature, frequency of calibration, etc.). Therefore, in this article, uncertainties are estimated for both simple and complex UV radiation and for measurements made in the field as well as in the laboratory.

Two factors that affect the accuracy of any measurement are a) the uncertainty of the standards used to calibrate the instrument and, b) the imprecision of the calibration and the measurement.

Currently, the easiest and only practical way to calibrate a spectroradiometer is by using a standard source. In the wavelength region from 250 nm to 350 nm, the most accurate standard source for spectral irradiance, and the one usually recommended, is the 1000-watt tungsten-filament, quartz-halogen lamp. Those issued by NBS have an uncertainty ranging from 2.6% at 250 nm to 1.7% at 350 nm. The imprecision of calibrating the best spectroradiometers in this wavelength region with such a tungsten standard is only a few tenths of a percent (standard deviation of a single measurement) for time constants of 10 seconds or more. Thus, the state-of-the-art uncertainty of spectral irradiance measurements in this UV region is about 3% when neither the character of the radiation nor the conditions of measurement contribute significantly to the uncertainty.

Unfortunately, one is usually required to make UV measurements of rather complex radiation and to make these measurements in other than a well-controlled radiometric laboratory. The table below lists the major factors, involving both the characteristics of the radiation and conditions of measurement, that are likely to increase the measurement uncertainty. Also included in this table is the cause of the additional uncertainty and an estimate of the uncertainty itself. The value given applies when using the best instruments and techniques currently available.

Major Factors that Increase the Uncertainty beyond that of the Standards

Increased Complexity in the Character of the Radiation	Cause of Additional Uncertainty	Additional Uncertainty*
Radiant power varies significantly in position and direction	Responsivity of spectroradiometer is not independent of position and direction	1%
The spectral irradiance varies significantly with wavelength	Inaccuracy of wavelength calibration	negligible to 3%
The spectral irradiance varies non-linearly with wavelength over the bandpass of the spectroradiometer	Output signal of the spectroradiometer is not proportional to the spectral irradiance being measured but a convolution of it and the slit function of the spectroradiometer	1%
The spectral irradiance to be measured is much greater or much smaller than that of the standard	Non-linearity in the detector or amplifier	½%
Radiant power is highly polarized	Responsivity of the spectroradiometer is not independent of polarization	½%
The spectral irradiance is very small at the wavelength where it is to be measured compared to that at longer or shorter wavelengths	Radiation outside of the instrument bandpass is scattered into the exit slit and detected along with the radiation within the bandpass	negligible
Spectral irradiance is a periodic function of time	Time constant of the spectroradiometer is not sufficiently large or small compared to the period of the incident radiation	negligible

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* Assuming that the best currently available instrumentation and measurement techniques are employed. Otherwise the uncertainties would be much greater. Also, extreme situations such as measurements on the steep side of a spectral line or at its peak, which are usually of little interest in radiometry, are not considered.

Unfavorable Conditions of Measurement	Cause of Additional Uncertainty	Additional Uncertainty*
Temperature of spectroradiometer is significantly different when calibrated and when measurement is performed	Change in wavelength calibration and/or responsivity of the spectroradiometer	negligible to 10%
Unavailability of a recently calibrated spectral irradiance standard (less than 50 hours' burning time)	Long-term instability of the standard	2%
Measurement is made at a time considerably different from that of the spectroradiometer calibration (more than a few hours)	Long-term instability of the spectroradiometer	1%
Frequent and rough handling of the spectroradiometer and use in a contaminating environment	Changes in optical alignment, wavelength calibration and transmittance and scattering of optical elements	negligible to several percent
Presence of nearby walls or objects that scatter or reflect the radiation	Spectroradiometer responds to scattered radiation as well as that which is meant to be measured	negligible

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EXTRACT FROM THE WORLD PLAN OF ACTION ON THE OZONE LAYER

as approved at the UNEP Meeting of Experts on the
Ozone Layer, Washington, D.C., March 1977

Recommendations:

A wide variety of investigations of the impact of ozone layer modification and increased ultra-violet radiation (UV-B) on man, the biosphere and climate should be encouraged, supported and co-ordinated. Specifically, it is proposed that action be undertaken to:

1. UV Radiation

(i) Monitor UV-B Radiation (WMO/WHO, FAO)

Monitor as far as possible, using best available technology, the spectral distribution and intensity of the UV-B radiation at the earth's surface. This should be done for at least a complete solar cycle at globally distributed sites (and where possible at stations where ozone is being measured and/or skin cancer data being collected and/or plant effects being studied).

(ii) Develop UV-B Instrumentation (WMO, WHO, FAO)

Develop improved instrumentation and methods, including improved artificial sources, for measuring and providing precise levels of UV-B irradiance (both broad-band and narrow-band).

(iii) Promote UV-B Research (WMO, WHO, FAO)

Develop standardized methodologies for conducting UV-B research. Promote investigations to enable a better understanding of the spectral distribution of UV radiation, effects of flux, and effects of factors other than ozone such as atmospheric conditions, ground albedo, etc., in determining the amount and wavelength of UV reaching the ground.

2. The Impact of Changes in the Ozone Layer on Man, the Biosphere and Climate

A prediction of depletion of ozone and increased UV-B due to man's activities would have little meaning unless it could be shown, at least qualitatively, that it would have significant effects on man and his environment.

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2. The Impact of Changes in the Ozone Layer on Man, the Biosphere and Climate

A prediction of depletion of ozone and increased UV-B due to man's activities would have little meaning unless it could be shown, at least qualitatively, that it would have significant effects on man and his environment.

It has been demonstrated that excessive exposure to ultra-violet radiation at 254 nm (radiation of a shorter wavelength than the UV-B which reaches the ground) causes tumors in laboratory animals and has deleterious effect on certain plants. Extensions of the studies to that part of the UV-B band from 290-320 nm have been made by theoretical and experimental work and by a series of epidemiological studies. There is some evidence that increased UV-B would be associated with an increase in skin cancer and possibly in eye damage in susceptible sections of the human population. It is also likely that large increases in UV-B would cause biological damage including damage to nucleic acids and proteins and thereby have deleterious effects on terrestrial and aquatic communities, but the effects of smaller changes in UV-B are highly uncertain because of the capability of biological systems to compensate, to a certain extent, for harmful influences. Although it is clear that significant progress has been made in a wide range of related research activities in the biological and medical sciences there are still many gaps in our knowledge of the effects of increased UV-B. Other effects of modification of the ozone layer, e.g. climatic effects, might be relevant for the biosphere. The problem being extremely complicated, research results are not yet accurate enough to indicate the possible nature to the effects.

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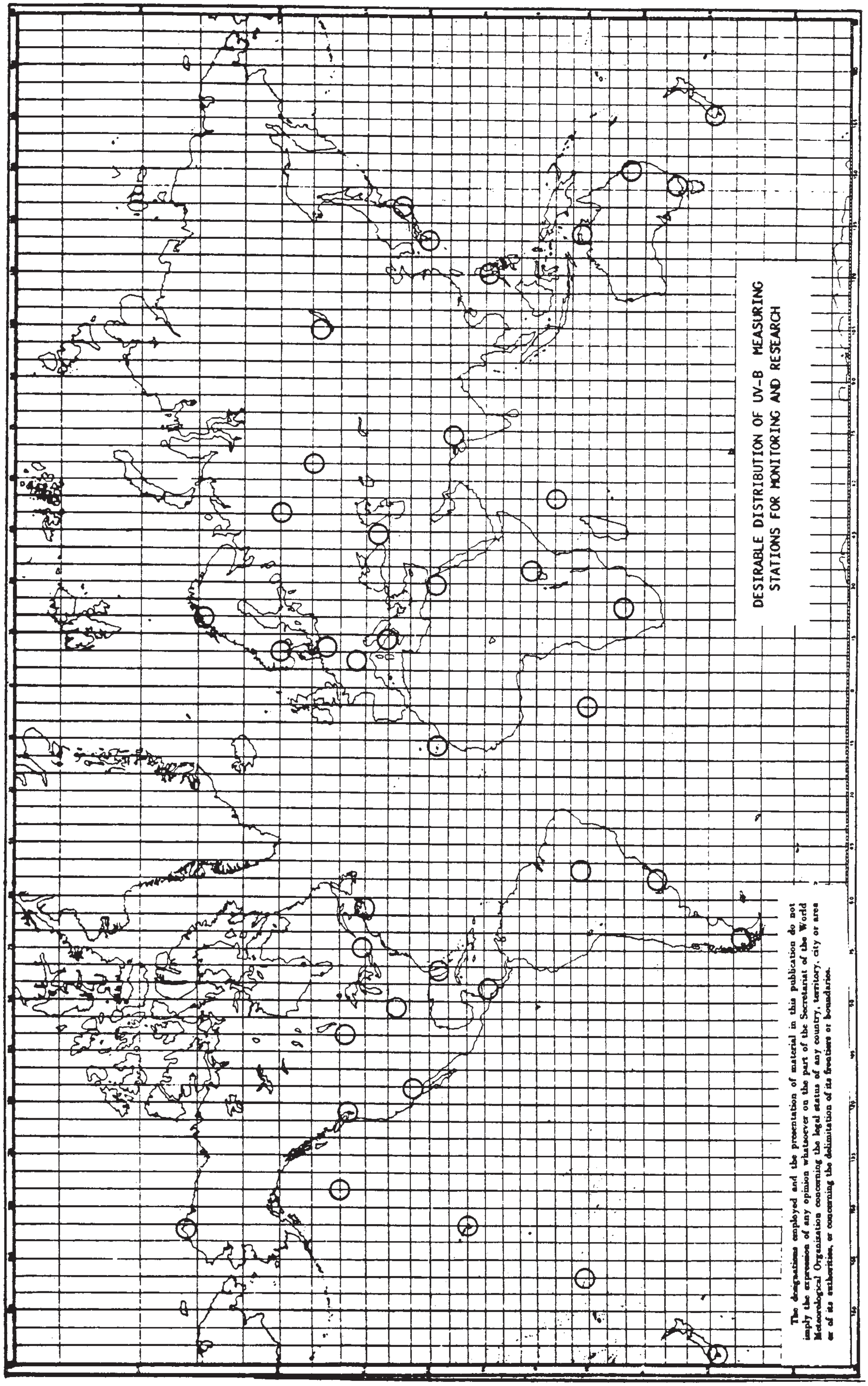
APPENDIX I



DESIRABLE DISTRIBUTION OF UV-B MEASURING STATIONS FOR MONITORING AND RESEARCH

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Meeting of Experts on UV-B Monitoring and Research
(Geneva, 16 - 20 May 1977)

RELATIVE ERYTHEMAL EFFECTIVENESS OF UV-B
BEST FIT (LEAST SQUARE) ANALYSIS

Wavelength (nm)	Relative Effectiveness (%)
297	100
300	65
305	20
310	5
315	1.40
320	0.39
325	0.10
330	0.02

Reference: D. Berger, F. Urbach and R.E. Davis (1968). The Action Spectrum of Erythema Induced by Ultra-violet Radiation. Proceedings of the 13th Congressus Internationalis Dermatologicae, Munich, 1967 - reproduced on p. 525, Proceedings of Third Conference on Climatic Impact Assessment Program, 1974

APPENDIX K

Meeting of Experts on UV-B Monitoring and Research

(Geneva, 16 - 20 May 1977)

INTENSITY OF GLOBAL UV-B FOR CLOUDLESS SKY AT SEA LEVEL

(Intensity in $Wm^{-2}\mu m^{-1}$)

Bener, 1972 (Reference 7)

Wavelength → (nm) / Solar Elevation ↓	297.5	300.0	302.5	305.0	307.5	310.0	312.5	315.0	317.5	320.0	325.0	330.0
											OZONE 0.240 cm.	
90°	6.44	15.3	35.9	73.7	111.0	164.0	218.0	266.0	320.0	365.0	487.0	540.0
60°	3.46	9.11	23.5	52.5	84.0	123.0	173.0	211.0	262.0	300.0	399.0	446.0
40°	0.446	2.00	7.44	20.4	39.0	56.0	93.4	118.0	152.0	186.0	235.0	285.0
20°	-	0.088	0.450	2.24	6.30	12.0	23.4	35.1	48.3	65.2	91.2	119.0
10°	-	-	0.066	0.286	1.00	2.16	5.80	8.60	17.2	22.3	35.5	48.8
5°	-	-	0.022	0.070	0.239	0.485	1.20	2.24	4.37	6.95	14.4	20.3
											OZONE 0.032 cm.	
90°	2.19	7.21	20.7	49.7	82.2	130.0	187.0	241.0	293.0	339.0	465.0	534.0
60°	1.07	4.04	12.9	34.3	60.3	96.6	146.0	189.0	237.0	277.0	379.0	441.0
40°	0.116	0.766	3.62	11.7	24.7	39.9	74.6	102.0	132.0	166.0	220.0	281.0
20°	-	0.022	0.116	0.660	2.20	5.24	13.7	25.1	35.6	50.7	77.0	115.0
10°	-	-	0.018	0.079	0.293	0.705	2.42	4.91	10.1	14.4	27.0	46.1
5°	-	-	0.007	0.025	0.093	0.208	0.613	1.31	2.67	4.49	10.3	19.2
											OZONE 0.400 cm.	
90°	0.743	3.41	12.0	33.6	60.7	104.0	160.0	218.0	269.0	316.0	444.0	528.0
60°	0.334	1.80	7.09	22.4	43.4	75.6	123.0	170.0	216.0	256.0	360.0	436.0
40°	0.032	0.299	1.77	6.73	15.7	28.4	59.5	88.1	115.0	149.0	206.0	277.0
20°	-	0.006	0.030	0.195	0.773	2.30	8.01	17.9	26.2	39.4	65.1	110.0
10°	-	-	0.005	0.022	0.086	0.231	1.01	2.81	5.95	9.34	20.6	43.7
5°	-	-	0.002	0.009	0.036	0.089	0.314	0.772	1.63	2.90	7.45	18.2