

THE CANADIAN OZONE WATCH AND UV-B ADVISORY PROGRAMS

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ABSTRACT

The OZONE WATCH, initiated in March, 1992, is a weekly bulletin describing the state of the ozone layer over Canada. The UV-B advisory program, which started in May, 1992, produces daily forecasts of clear-sky UV-B radiation. The forecast procedure uses daily ozone measurements from the eight-station monitoring network, the output from the Canadian operational forecast model and a UV-B algorithm based on three years of spectral UV-B measurements with the Brewer spectrophotometer.

1. INTRODUCTION

In 1991 Environment Canada announced The Green Plan, a national agenda of research, regulation, provision of public information and other activities aimed at protecting the environment. The Green Plan initiative on stratospheric ozone includes a commitment to provide Canadians with information on the intensity of ultraviolet (UV-B) radiation reaching the ground and to provide forecasts of UV-B radiation by the summer of 1993.

In early February 1992 NASA reported new findings which suggested there was a potential for significant depletion of stratospheric ozone, based on satellite and aircraft measurements showing high levels of reactive chlorine in the stratosphere. The report generated a high degree of public anxiety which prompted Environment Canada to introduce the OZONE WATCH program in March, 1992 and to advance the launch of the Green Plan UV-B advisory program to May, 1992.

2. THE OZONE WATCH PROGRAM

It was reported in a recent study that total ozone levels over Toronto decreased by about 4% during the 1980's (Kerr, 1991). Comparison of total ozone measurements from recent years to those made before 1980 shows that the ozone decrease is due primarily to an 8% reduction during the winter/spring season, a time when total ozone is at its annual maximum. Despite this loss, ozone values during winter and spring remain significantly higher than those values during fall, a time of year which has shown little or no loss. The study also illustrated that the nature of the ozone trend during the 1980's was quite different from that during the smaller variations which occurred prior to 1980.

The ozone watch program is based on the idea of comparing recent data to the average values recorded prior to 1980, a time when there appears to have been little ozone loss attributable to CFC's. Figures 1-3 show the 1992 daily total ozone readings compared to the pre-1980 values for Toronto, Edmonton and Goose Bay. The ozone watch bulletins are issued weekly and an example is shown in Figure 4. The data are two-week averages of total ozone levels compared with the older records. Figure 5 is an example of the ozone watch information. The weekly bulletins include a brief description of the status of the ozone over the different regions in Canada, and

usually some form of public health message.

An update of the ozone trend for Toronto using data until May 28, 1992 is given in Figure 6.

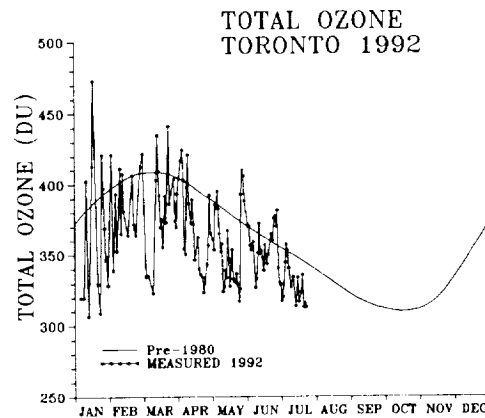


FIG. 1. Daily total ozone measurements in Toronto during 1992 compared with the average annual curve measured prior to 1980.

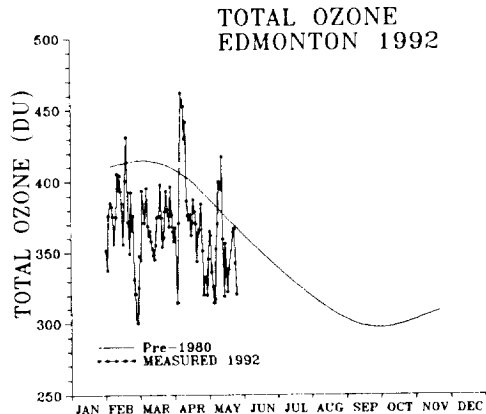


FIG. 2. Daily total ozone measurements in Edmonton during 1992 compared with the average annual curve measured prior to 1980.

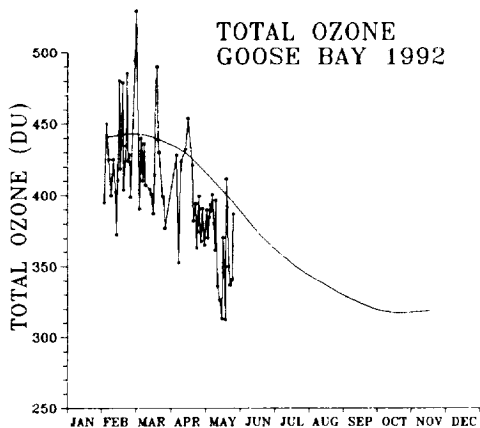


FIG. 3. Daily total ozone measurements in Goose Bay during 1992 compared with the average annual curve measured prior to 1980.

**OZONE WATCH - JUNE 19 1992**

- \* Lower ozone levels persist over western Canada
- \* Ozone levels below normal across Canada

Over the past 2 weeks, ozone levels over western Canada have been 12% below the pre-1980 average (normal). Over the rest of the country, including the Arctic, ozone levels have been 2 to 5% below normal.

UV information is now provided as part of the UV index program. Contact your local weather office for further information.

Ozone Watch is issued/weekly by Environment Canada as part of the Green Plan's commitment to keep Canadians informed on the state of the earth's protective ozone layer.

The next report in this weekly series will be available on Friday, June 26.

FIG. 4. Sample of OZONE WATCH bulletin issued weekly by Environment Canada. The bulletins are intended to inform the public on recent ozone measurements.

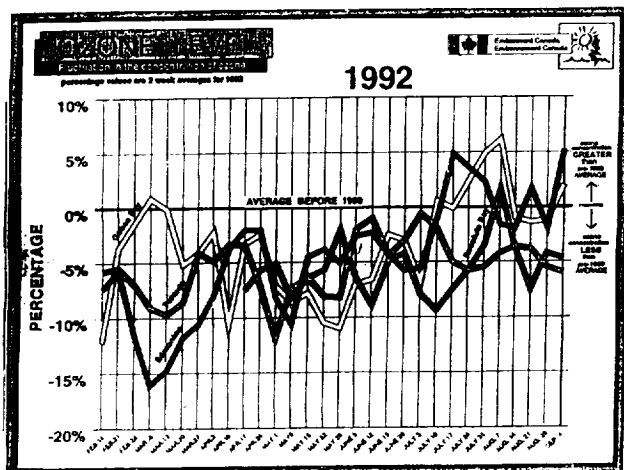


FIG. 5. Sample of graphical report issued weekly as part of OZONE WATCH. The weekly values are two week average measurements for Edmonton compared with seasonal averages for the same two week period based on data taken prior to 1980.

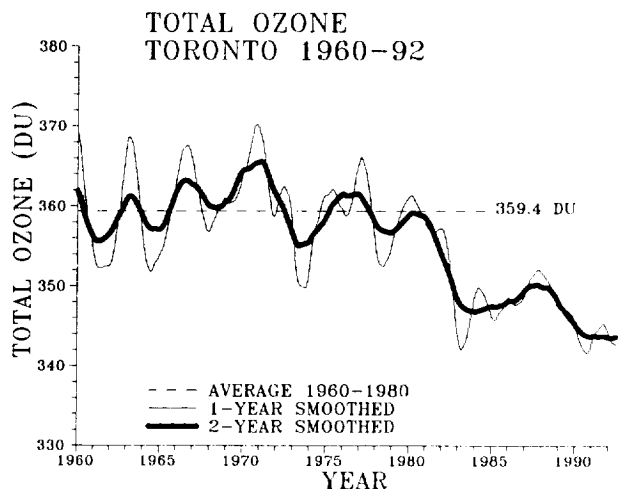


FIG. 6. Trend of total ozone over Toronto from 1960 to July 1992.

### 3. THE UV-B ADVISORY PROGRAM

The UV-B Advisory program was started on May 27, 1992. Its aim is to issue a UV-B index forecast for the next day. The index is valid for local noon (maximum) under clear sky conditions. The forecast takes into consideration the forecast for cloud cover. The index is proportional to the intensity of UV-B energy incident on a horizontal surface.

The forecast of a UV-B value is a two stage process. The first process is to predict an ozone field and the second step is to transform that ozone field to a UV-B radiation field.

The current procedure to forecast ozone, in operation since May 27, 1992, uses potential temperatures from the operational forecast model at the Canadian Meteorological Center to integrate an ozone mixing ratio distribution derived from ozone sonde data. In effect, the vertical distribution of ozone is being represented everywhere by

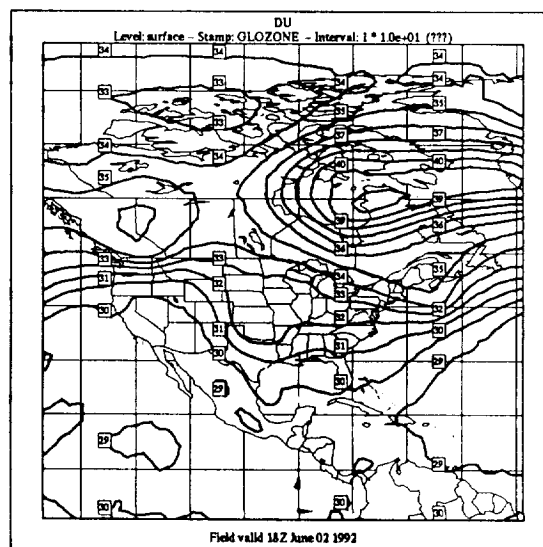


Fig. 7. Total ozone field as predicted by the operational forecast model at the Canadian Meteorological Center.

a single relationship between ozone mixing ratio and potential temperature. The height of the 500 mb surface, also from the model, is used with the potential temperature integral in a linear combination that varies with latitude. This simple scheme by itself shows typical errors of 20 to 30 Dobson units (DU) in total ozone from an analysis of four Canadian stations for which there are long term ozone sonde records. A daily residual correction field that is derived from the previous days measurement of total ozone at nine Brewer stations is added to the prediction. An example of the resulting ozone field is shown in Figure 7. Over the short time period for which the program has been operational, typical errors have been surprisingly small, about 10 DU.

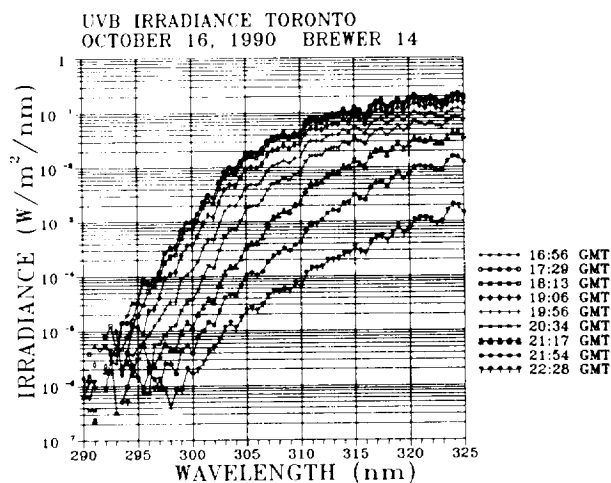


FIG. 8. Sample of UV-B flux spectral measurements made at different times of the day.

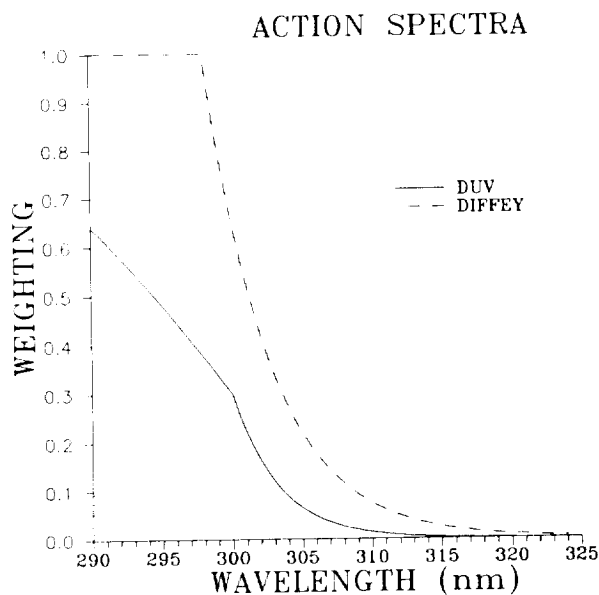


FIG. 9. The spectral measurements of UV-B flux are weighted by the Diffey erythral action curve to yield a UV-B energy value.

The transformation of the forecast ozone field to a UV-B index field is based on three years of near-simultaneous UV-B and total ozone measurements made with the Brewer ozone spectrophotometer. Examples of UV-B spectral intensity measurements are given in Figure 8.

These measured spectra are weighted according to the Diffey erythral action spectrum shown in Figure 9, so as to give an equivalent flux at 298 nm (McKinley and Diffey, 1987). The Diffey weighting curve was selected in order to give meaningful comparisons with other (broad band) types of UV-B monitoring devices whose optical transmission characteristics are intended to reproduce the Diffey function.

Typical daytime values of the Diffey weighted UV-B energy measurements from clear days are shown in Figure 10. This shows how the amount of UV-B flux varies as a function of time of day as well as a function of time of year. Data from 66 days on which there were no clouds and variations of total ozone were less than 2% were analyzed.

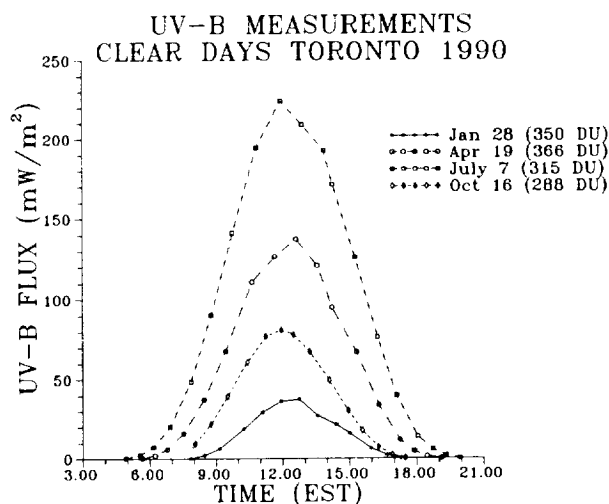


FIG. 10. Examples of Diffey weighted daytime UV-B flux measurements for four days at different times of the year.

The data expressing UV-B flux values as a function of total ozone and solar zenith angle are summarized in Figure 12. Here some of the UV-B values are plotted as a function of total ozone using different symbols for values of solar zenith angles within  $\pm 2.5^\circ$  of the indicated angles. These data were used to establish an empirical formulation expressing the intensity of UV-B flux as a function of total ozone and solar zenith angle. The formulation is given by:

$$\log(F) - \log(\cos(za)) = A + B\mu X + C\mu + D(\mu X)^2 + E\mu^2$$

where:

F is the UV-B flux (Diffey weighted) in milliwatts/meter<sup>2</sup>/nm  
 za is the solar zenith angle  
 $\mu$  is the ratio of the slant path of sunlight through the ozone layer to the vertical path  
 X is the amount of total ozone in cm at STP  
 A = 7.093  
 B = -3.927  
 C = -.636  
 D = 1.525  
 E = .1183

A, B, C, D and E are coefficients of the best least-squares fit. The RMS error of the fit at all solar zenith angles less than  $70^\circ$  is about 8%. The departures of the data from the best fit are most likely due to real atmospheric variations such as haze conditions. The best fit formulation is shown in Figure 12 for solar zenith angles between  $20^\circ$  and  $70^\circ$ .

The expression given above is used to derive a UV-B flux field at local noon from a total ozone field. Additional information required is the latitude and solar declination (dependent on the date). Both of these pieces of information are available in the forecast model. The forecast model generates a field of noontime UV-B flux values similar to the example shown in Figure 12.

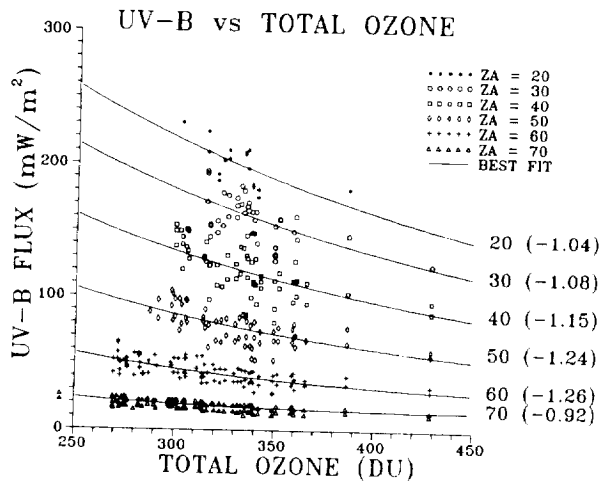


FIG. 11. This diagram illustrates how UV-B flux varies as a function of total ozone at different solar zenith angles. The empirical best fit curves for the different zenith angles are illustrated together with the Radiation Amplification Factors (RAF) for the fit at each zenith angle.

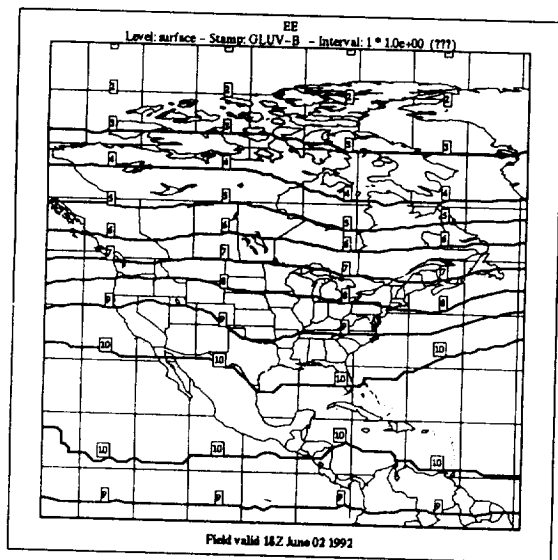


FIG. 12. Transformation of the predicted ozone field to a predicted UV-B field.

Local weather stations are given an index that is valid for local noon. The index is determined by dividing the Diffey weighted UV-B flux value by 25. This scaling gives a value for the index of 10 for a typical tropical location. The index generally will be less than 9 for most of Canada under usual ozone conditions. It can reach 12 at tropical locations when ozone is particularly low.

The weather stations have been provided with an algorithm that yields the variation of UV-B as a function of time of day. The input for this algorithm is the noontime index value and the station's latitude and longitude. A graphical output is given showing the bell-shaped daily curve for UV-B with times indicated when the UV-B index crosses from one category to another (e.g. from moderate to high, etc.). The UV-B index is distributed with regular weather forecasts. The local forecasters have guidelines on integrating the cloud cover and precipitation information with the UV-B index.

The program described here is complemented by a monitoring program run by Météomédia, Inc. of Montreal which distributes weather information through cable television. Météomédia use real-time measurements and display them with the previous days forecast from Environment Canada.

The UV-B advisory program is still under development. Expansion of the ozone monitoring network, modification of the ozone prediction algorithm and more extensive use of real-time ozone measurements as well as UV-B measurements will be implemented prior to 1993.

#### REFERENCES

- Kerr, J.B., 1991: Trends in total ozone at Toronto between 1960 and 1991. *J. Geophys. Res.*, **96**, D11, 20703.
- McKinley, A. and B.L. Diffey, 1987: A reference action spectrum for ultra-violet induced erythema in human skin. In *Human Exposure to Ultraviolet Radiation: Risks and Regulations*, Edited by W.F. Passchier and B.F.M. Bosnjakovic, pp 83- 87, Elsevier, Amsterdam.