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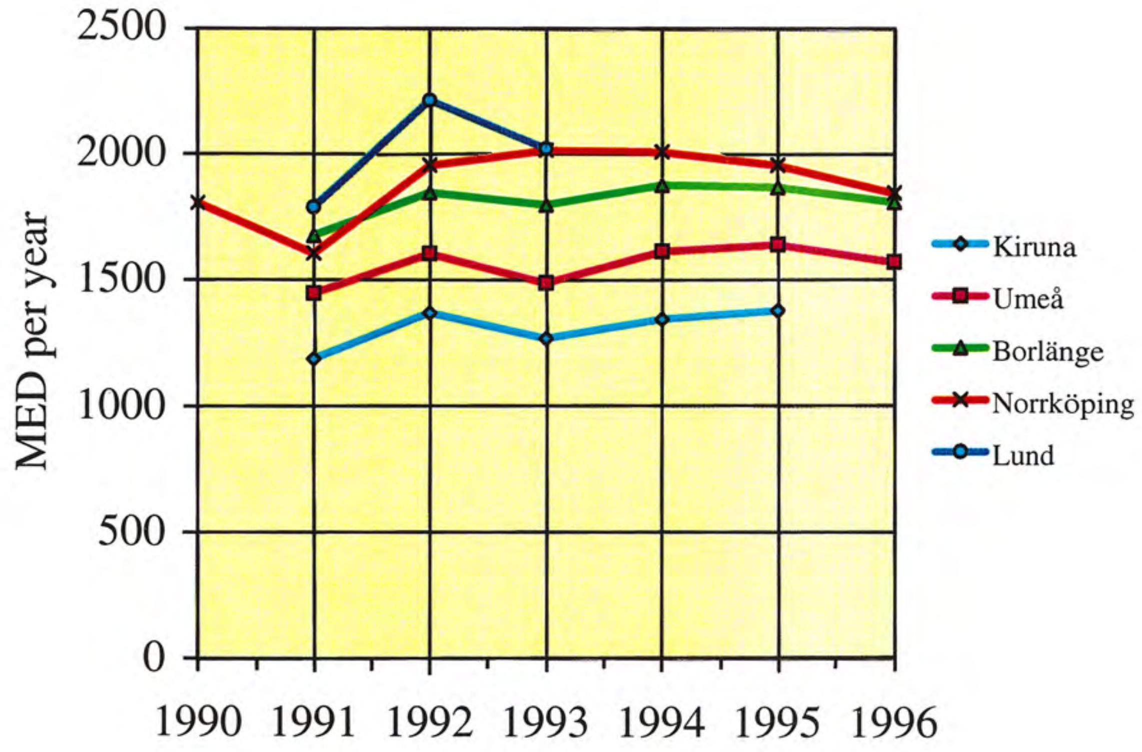

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Abstract/Sammandrag

Measurements of solar UV-radiation in a small Swedish network are presented for 1996. this report can be regarded as a supplement to a previous report, Josefsson (1996) where the results of the previous five years were reported, and where details not presented in this small report can be found. The quantity and unit of the UV-radiation in this presentation is CIE-weighted irradiance expressed as MED (minimum erythemal dose), where one MED equals 210 Jm^{-2}. The values have been re-computed to refer to the international intercomparison of broad-band meters at Helsinki in 1995. In the following referred to as the WMO-STUK 1995 scale.

Although, the stratospheric ozone was severely depleted during the early parts of 1996, the yearly UV radiation recorded was slightly less than in previous years. This was mainly due to the very cloudy months of May, June and July.

By combining the UV-record with concurrent records of the total ozone a small study of the anti-correlation of these two atmospheric parameters is illustrated. There are many sources of error and detailed studies are prevented by the large uncertainty connected with these data of UV-irradiance. Due to the short period of the record and the low accuracy no attempt to study trends is done.

Key words/sök-, nyckelord

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1 Introduction

Since 1990-1991 there has been a small network for the monitoring of UV (ultraviolet) radiation in Sweden initiated by SSI (Swedish Radiation Protection Institute). The network is operated by SMHI (the Swedish Meteorological and Hydrological Institute). In the years 1990-1995 it was supported by grants from SSI. As the funding from SSI ceased the Swedish Environmental Protection Agency decided to fund the measurements for one year awaiting a decision of its future. This report summarizes the results for this year, 1996.

Only the most important information is repeated in this report. To find information on details of the measurements, interested are directed to the report for the 1990-1995 period, Josefsson (1996).

2 Network

In the table below the stations are listed by latitude as well as the period of available data. The station number is according to the WMO station code. The start and end dates of the period of available data is on the format year-month-day (yymmdd). It should be noted that there are many short periods of missing data.

Data have been inserted into these gaps by using a rough relation between UV and the global radiation that is measured at each site. This was done to get a data set as complete as possible. Please note that there has been a long break in the measurements at Kiruna in 1996. Data are missing completely for the periods 960424-25, 960506-08, 960516-961014.

Table 2.1 Stations and period of record.

Station	Number	Latitude	Longitude	Start	End
Kiruna	2045	67.83°N	20.43°E	901008	961231
Umeå	2283	63.82°N	20.25°E	910417	961231
Borlänge	2749	60.48°N	15.43°E	910411	961231
Norrköping	2071	58.58°N	16.15°E	900426	961231
Lund	2627	55.72°N	13.22°E	901024	940606

3 Instruments, units and calibration

The radiometer type that have been used for these measurements is the Model 500 sunburning meter from Solar Light Co. Basically, it is similar to the so called Robertson-Berger meter. But, the spectral responsivity is supposed to relatively be shifted towards shorter wavelengths and the directional responsivity is completely different.

The UV-radiometers used in this network have a spectral responsivity that tries to mimic the erythemal response of fair skinned people. There is an international recommendation to use the so called CIE-action spectrum, McKinley and Diffey (1987), for this purpose. Therefore, the unit used for the measured UV-irradiance was chosen to be MED per hour, per day, per year etc., where **one MED** (Minimum Erythemal Dose) is the CIE-weighted irradiance of **210 Jm^{-2}**. Recalling this it is possible to convert to other definitions of MED.

To convert the output of the individual instrument to the CIE-weighted irradiance, expressed as number of MED's, constant factors are used. The constants have been selected to be representative for the WMO-STUK 1995 scale for solar elevations larger than 30°. But, the relation between the individual instrument and the reference may not be constant. For example, there is usually a solar elevation dependence. Therefore, at low solar elevations as in the winter and in the morning and evening there will be an offset from the WMO-STUK 1995 scale. One of the reasons for not applying variable corrections is of course that the instruments have not been fully characterized, which makes this method impossible to utilize.

The results presented in this report are all referring to the WMO-STUK intercomparison in Helsinki 1995 with a cosine corrected reference.

This would make the results more useful as they can be compared with data recorded by other instruments that are traceable to this intercomparison. A measure of the UV-intensity that has reached a wide spread use during the last few years is the so called UV-index. In its general and internationally recommended form, ICNIRP (1995), it represents the UV-irradiance weighted by the CIE-action spectrum on a horizontal surface. The <u>hourly</u> MED-values measured in the network can be converted to the UV-index scale by $UV\text{-}index = 40 * (210/3600) * UV\text{-}irr._{MED}$ or shorter

$$\boldsymbol{UV\text{-}index = 2\ 1/3\ * UV\text{-}irr._{MED}}$$

The measurements, 1990-1996, show that in Kiruna the UV-index reach about 5.5 in the summer. In southern Sweden the highest UV-index has been around 7.5 as most.

4 Uncertainties

The uncertainty in the measurements of this network is discussed in Josefsson (1996). For non-temperature stabilized broad-band UV-radiometers as those used in this network, Leszczynski et al.(1994) estimate the overall uncertainty to be ± 19 %, 2σ estimate. As the presented data are roughly corrected for the temperature dependence it is plausible to assume that the overall uncertainty will be slightly lower. These numbers are of course estimates for high solar elevations.

Much of the given uncertainty is systematic. Comparing data from different periods for a single station will only introduce the random part of the uncertainty. This so called precision of the measurements is better. Although, it is not easy to state a specific number, a rough estimate would be less than ± 10% for the presented records. Intercomparing data from different stations (networks) will probably give a precision slightly larger than ± 10 %.

5 Results

The primary data from the stations are hourly values. In this report most presentations use various types of monthly values. The monthly as well as all the yearly values of 1996 are given in Table 5.1. Monthly values from the previous period can be found in Josefsson (1996), along with several graphs and comments on this period.

Table 5.1 Monthly and yearly values during 1996. Values strongly affected by Interpolation areindicated by **i**.

Month	Kiruna	Umeå	Borlänge	Norrköping
Jan	0.91	2.90	5.52	5.45
Feb	10.20	17.73	25.94	23.10
Mar	63.86	78.23	95.70	80.05
Apr	155.80	178.49	204.63	214.30
May		287.94	259.26	228.81
Jun		318.34	398.34	383.30
Jul		270.68	339.95	358.75
Aug		281.59	304.09	352.33
Sep		110.48	i 131.37	151.60
Oct		25.75	i 40.42	41.94
Nov	0.72	3.74	6.04	7.56
Dec	0.00	0.76	2.46	3.01
Year		1576.61	1813.74	1850.21

In Figure 5.1 all the monthly values for all stations are plotted from 1990 to the end of 1996. Please note the unfortunate gap during summer 1996 for Kiruna. Due to the large seasonal variation it is not easy to compare individual months from one year to the other in the graph. Even the difference between the various stations is hard to distinguish. Most apparent in this graph are the differences during different summer seasons. Compare for example the summer 1991 with the summer of 1992. On average the summer of 1996 was not very sunny as can be seen.

In Figure 5.2, tracking the recorded yearly sums, the latitudinal dependence is more clear than in Figure 5.1. In Kiruna, the northernmost site, there is roughly some 1300 MED per year whilst in the southern sites Lund and Norrköping there is about 2000 MED. So in one year there is about 35% less UV in the north compared with the south of Sweden.

The range of variation during this short record is roughly 20%. The lowest value is found in 1991, which was the year with the thickest ozone layer within this period. There has evidently been a decline in the yearly UV-dose in 1996 compared with the previous years. Mostly explained by the relatively cloudy summer months of May, June and July in this year. There is also a contribution, but in a less degree, by a relatively thicker layer of ozone during these months. It is worth noting that in general the whole period 1992 to 1996 has shown very low values of total ozone. It would have been interesting to have more data from the 1980-ties, because during that decade the ozone was more abundant in this part of the world.

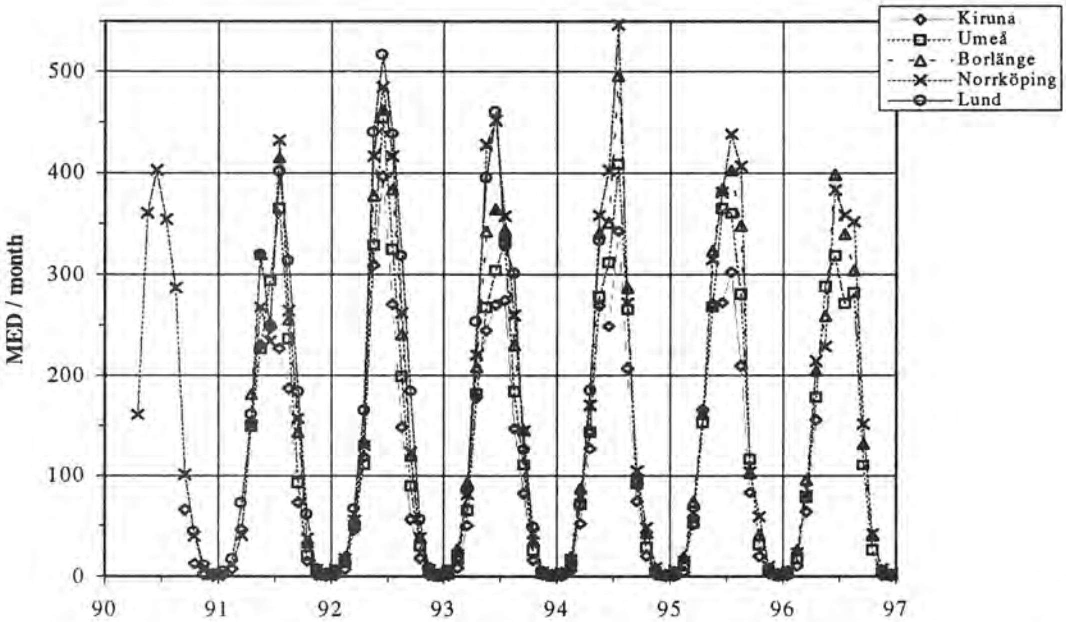

Figure 5.1 Monthly values from the five stations of the Swedish network. Unit: MED/month. MED= Minimum Erythemal Dose corresponding to 210 Jm^{-2} CIE-weighted irradiance, WMO-STUK 1995 scale.

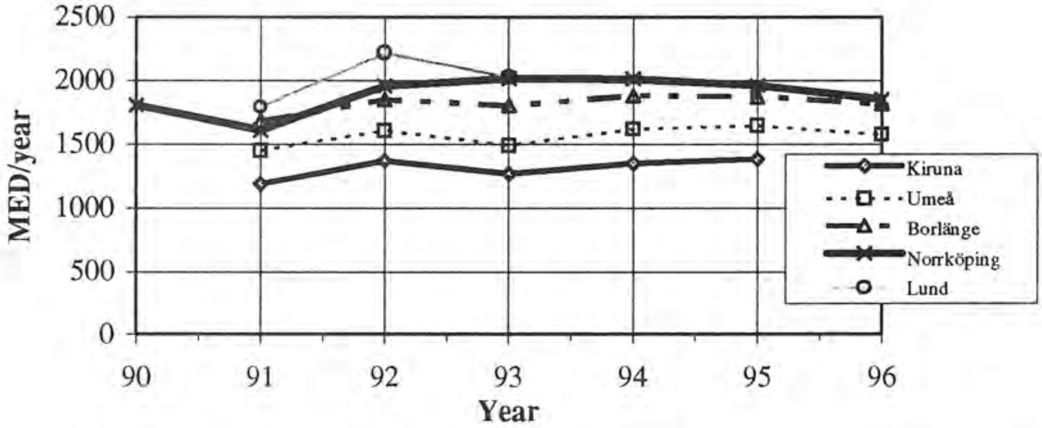

Figure 5.2 Yearly values from the five stations of the Swedish network. Unit: MED/year. MED= Minimum Erythemal Dose corresponding to 210 Jm^{-2} CIE-weighted irradiance, WMO-STUK 1995 scale.

6 Discussion

The used radiometers have shown several technical problems over the years as illustrated by the vast amount of missing data at Kiruna in 1996. This in combination with high inaccuracy will limit the usefulness of the available data. But, the records of the sunburning UV can be used to retrieve a rough climatology, which may be useful for many applications. In particular since the data now are referring to an internationally recognized scale for UV.

For example, by combining the UV-record with concurrent records of the total ozone a small study of the anti-correlation of these two atmospheric parameters was performed. Because, it has often been questioned if these relatively simple Robertson-Berger type of instruments are sensitive to the change in UV-irradiance caused by variation in the total ozone. In particular after the contradicting results presented by Scotto et al. (1988), where a decline in the total ozone was observed along with a downward trend in the UV as measured by Robertson-Berger instruments in the USA .

The data used in this study are monthly values of ultraviolet radiation, **UV**, global solar radiation, $\mathbf{G_h}$, and total ozone, **Oz**, from Norrköping March 1990 to December 1996. These values are standardized in the following manner. Due to the large annual variation data are binned and processed by month. This will remove (detrend) most of the annual course. For the full period and for each month the mean value, indicated by <..>, and the standard deviation, SD, is computed. The standardized parameters are then given as follows

$$\Omega = (\mathrm{Oz} - \langle\mathrm{Oz}\rangle) / \mathrm{SD_{Oz}}$$

$$UV = (\mathrm{UV} - \langle\mathrm{UV}\rangle) / \mathrm{SD_{UV}}$$

$$UV/G_h = (\mathrm{UV/G_h} - \langle\mathrm{UV/G_h}\rangle) / \mathrm{SD_{UV/Gh}}$$

The latter parameter, which is the ratio between ultraviolet and global radiation, is used to reduce the eventual influence of variable cloudiness. It is assumed that the ultraviolet and the global radiation roughly are affected in the same relative amount by clouds. By studying the ratio most of the cloud influence will be removed. The standardized parameters have some nice characteristics, e.g. mean value is zero.

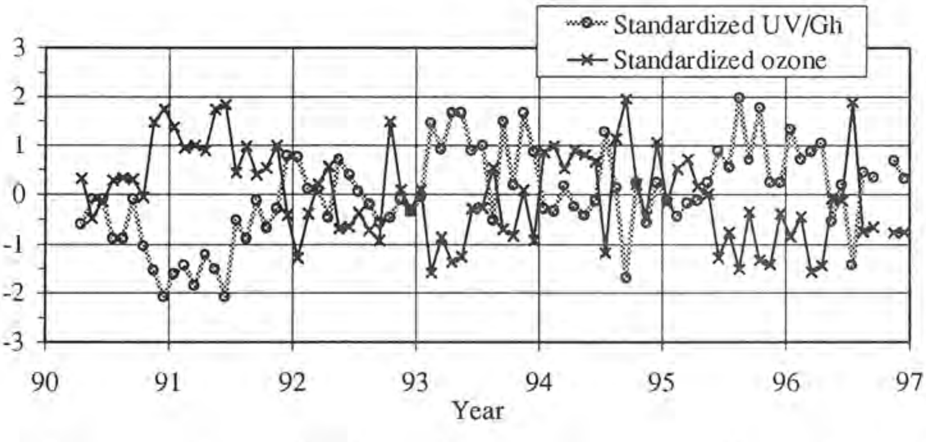

Figure 6.1 Standardized monthly values of total ozone and standardized monthly ratio between ultraviolet and global radiation for Norrköping 1990-1996.

The anti-correlation between the standardized ozone and the standardized ratio is easily seen in Figure 6.1. Periods with relatively thick ozone layer and the corresponding low UV is also apparent, as during 1991. Plotting the standardized parameters versus each other gives Figure 6.2, which even further illustrates the anti-correlation between ultraviolet radiation and total ozone. If the standardized ozone was plotted versus the standardized UV the anti-correlation still exists but with a lower correlation, Figure 6.3.

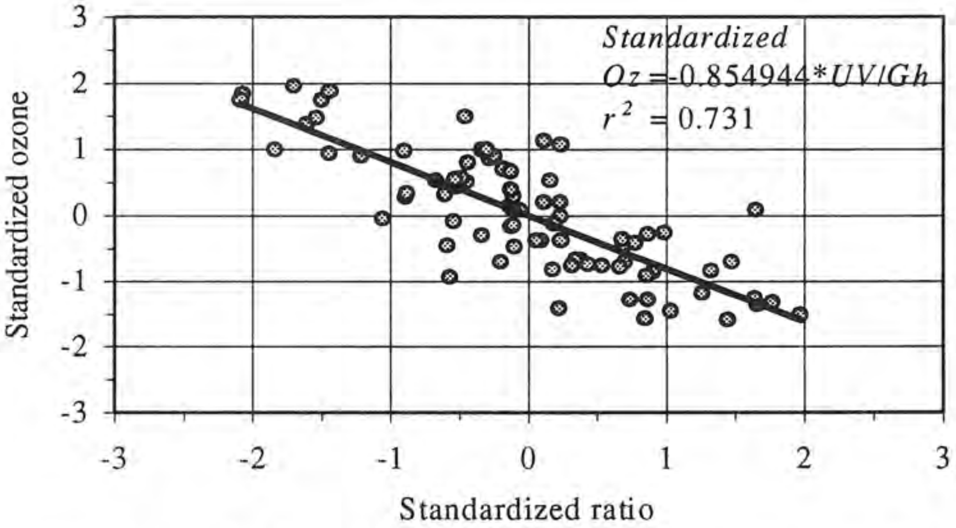

Figure 6.2 Standardized monthly values of total ozone versus standardized monthly ***ratio*** *between ultraviolet and global radiation for Norrköping 1990-1996. A linear model is fitted and the square of the correlation-coefficient is given.*

The conclusion is that these rather simple instruments actually are sensitive to variations in the ozone layer. A more refined study would probably give more precise results than this rather rough approach.

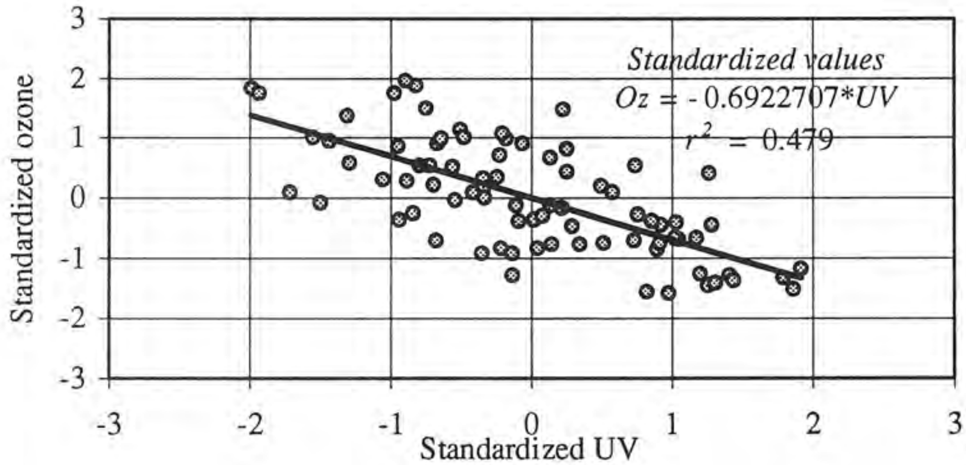

Figure 6.3 Standardized monthly values of total ozone versus standardized monthly ***ultraviolet*** *for Norrköping 1990-1996. A linear model is fitted and the square of the correlation-coefficient is given.*

7 References

ICNIRP (1995), Global Solar UV Index, A joint recommendation of WHO, WMO, UNEP and ICNIRP, ICNIRP-1/95, ISBN 3-9804789-0-4

Josefsson W., 1996, Five years of solar UV-radiation monitoring in Sweden, RMK No.71, SMHI, Oct. 1996, ISSN 0347-2116.

Leszczynski K., Wester U., Johnsen B., Bais A., and Kyrö E., 1994, Sources of error in solar ultraviolet radiation and ozone measurements, In The Nordic Intercomparison of Ultraviolet and Total Ozone Instruments at Izaña From 24 October to 5 November 1993. Final Report (Ed. Koskela T.), pp. 51-61, Finnish Meteorological Institute, Meteorological Public. No.27, Helsinki, ISBN 951-697-412-0.

McKinley A.F. and Diffey B.L. (1987), A reference spectrum for ultraviolet induced erythema in human skin, CIE-Journal 6, pp.17-22.

Scotto J., Cotton G., Urbach F., Berger D., and Fears T. (1988), Biologically effective ultraviolet radiation: Surface measurements in the United States, 1974-1985. Science 239, pp. 762-764.

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Luftföroreningsepisoden över södra Sverige 2 - 4 februari 1987.

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An operational air pollution model.

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