HPA Solar Radiation Measurements in the UK during 2004 and 2005

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ABSTRACT

A summary of the results of an ongoing survey of solar radiation levels at the HPA network of seven UK sites is presented, from January 2004 to December 2005. The network consists of three HPA sites at Chilton, Leeds and Glasgow (monitoring since 1988), three Meteorological Office stations at Camborne, Kinloss and Lerwick (monitoring since 1993–1995) and a site supported by a Welsh Assembly grant operating for part of the year on the summit of Mount Snowdon. Visible (400–770 nm), ultraviolet UVA radiation (320–400 nm) and erythemally weighted ultraviolet radiation UVR_{eff} (280–400 nm) have been measured simultaneously using a three detector measurement system. Results are compared with data for the measurement period from 1989 to 2003.

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EXECUTIVE SUMMARY

The results of the seventeenth and eighteenth years of a continuing survey of solar radiation levels at HPA sites at Chilton, Leeds and Glasgow, and over a shorter period at the Meteorological Office sites at Camborne, Kinloss and Lerwick, have confirmed the general levels observed during the previous measurement periods. However, a statistical analysis of the results shows evidence that the annual erythemally weighted ultraviolet radiation (UVR_{eff}) and UVA values are consistent with there being a small but significant positive trend in the annual integrated radiant exposures in England and West Central Scotland. These trends have not been shown to correlate with total column ozone, with sunspot numbers, or with total sunshine hours.

The data set at Chilton is complete over the full measurement period 1988–2005 and hence lends itself more readily to statistical analysis. The data sets at Leeds and Glasgow are complete over at least fourteen years of the measurement period, with a few breaks in the complete monthly data during the early years. The Meteorological Office sites have thirteen or less years of measurement data. Further measurement data will contribute to detailed statistical analysis at these sites in the future. The seasonal nature of the power supply available at the Snowdon site limits operation to about six months per year and it needs several more years of data to carry out statistical analysis.

Information about the solar measurement programme, the monthly bulletins and a service to provide data from each of the measurement sites on compact disk is available on the HPA website (www.hpa.org.uk).

CONTENTS

1 INTRODUCTION

In 1988, the then National Radiological Protection Board (NRPB) set up three monitoring stations to measure continuously terrestrial solar radiation at different latitudes within the UK. These were at NRPB sites at Chilton, Oxfordshire, at a latitude of approximately 52° N, Leeds (at about 54° N) and Glasgow (at about 56° N). This network was extended, in cooperation with the UK Met Office, to three sites at Met Office observatories at Camborne (since 1993, about 50° N), Lerwick (since 1993, about 60° N) and Kinloss (since 1995, about 58° N). In 2003 another site was established, at an elevation of 1 km, on the summit of Mt. Snowdon (about 53° N). This site is supported by a grant from the Welsh Assembly and is maintained by staff from the University of Wales, at Bangor. As there is no national grid power available at the summit, the Snowdon site is dependent on the Snowdon Railway Company for power, and can only operate during those months that the Company keeps the summit buildings operational (roughly April/May until September/October).

In April 2005, NRPB was absorbed into the HPA, becoming the Radiation Protection Division.

The three detectors used in the NRPB Solar Radiation Monitoring System (SRMS) were obtained from commercial suppliers, but have been incorporated in a high stability and environmentally controlled instrumentation system. The UVA and visible radiation detectors are Macam Photometrics detectors and the erythemally weighted UVR detector is a specially adapted version of the Robertson-Berger meter (Berger, 1976). The first six sites to be established incorporated the Robertson-Berger model 500 meter (RB-500), which is still deployed at some locations. The Snowdon site marked the first deployment of the more compact and temperature-stabilised Robertson-Berger 501 meter (RB-501). It is planned that all sites will have their monitoring systems replaced with new systems incorporating the RB-501: a new system was installed at Chilton in October 2004. Leeds and Glasgow were upgraded in May 2005 and the rest of the network should be upgraded during 2006. At each site in the network, measurements of solar UVR [erythemally weighted UVR_{eff} and UVA (320–400 nm)] and visible radiation (400–770 nm) are made simultaneously.

The results of measurements obtained from 1988 to 2003 have been published (Driscoll et al, 1989-2003; Pearson et al, 2004). The results for 2004 and 2005 are presented here and are compared with calculated and published data.

2 EXPERIMENTAL PROCEDURES

The erythemally weighted RB-500 UVR detector of the original NRPB Solar Radiation Monitoring Systems (SRMSs) incorporates a quartz hemispherical dome, while the two smaller detectors to measure UVA and visible radiation have flat diffusers as part of their input optics. Solar radiation incident upon the dome of the erythemally weighted detector passes through a pre-filter, which absorbs visible and infrared radiation. The solar UVR is then wavelength shifted by a magnesium tungstate phosphor deposited on a green filter. This filter absorbs residual UVR and the small amount of red light transmitted by the pre-filter. The emission from the fluorescing phosphor is centred at 500 nm and is detected by a vacuum photodiode. For the measurement of solar radiation, the erythemally weighted detector has a spectral response which approximates to the International Commission on Illumination (CIE) reference erythema action spectrum (McKinlay and Diffey, 1987).

The UVA detector (Model SD104A-Cos) consists of a polytetrafluoroethylene cosine diffuser, a UVA transmission filter and a large area gallium arsenide phosphide photovoltaic diode. The peak response is at 367 nm with a bandwidth (full width, half maximum) of 38 nm. The photopic (lux) detector (Model SD104L-Cos) consists of a white acrylic cosine diffuser, a transmission filter and a large area silicon photodiode. This detector has a spectral response which approximately matches the photopic curve (CIE, 1987). Both detectors have been calibrated using standards traceable to national standards laboratories.

The new SRMSs deployed at Snowdon, Chilton, Leeds and Glasgow incorporate the same Macam detectors, but have an RB-501 in place of the older RB-500 detectors. The RB-501 differs from its predecessor in that it is smaller, temperature stabilised and incorporates a solid state photodiode. The new SRMSs feature quartz domes covering all three detectors.

A standard SRMS is calibrated against solar exposure at various times at and around noon on a clear summer's day at Chilton. This is done with the aid of a scanning spectroradiometer and a photometer which are calibrated against lamps traceable to national standards. The standard SRMS is then sent to each site in turn for side-by-side calibration of the field SRMS.

The detectors are linked, with in-house designed preamplifiers and an analogue-to-digital converter, to microcomputers for data acquisition and analysis. The detectors are positioned on the roof of each of the sites, so that shadowing effects from nearby buildings and tall objects are kept to a practicable minimum. Data are recorded every 20 s to give mean irradiance and illuminance levels over 5 min periods throughout a 24 h cycle. These data are then available for compression and averaging over longer periods.

In 2002, a joint recommendation on a Global Solar UV Index was published by the World Health Organization, the World Meteorological Organization, the United Nations Environment Programme and the International Commission on Non-Ionizing Radiation Protection (WHO, 2002). This forms the basis of the Global Solar UV Index promulgated by HPA, the Department of Health and the Meteorological Office for media presentation in the UK regarding UV forecasting, as shown in Table 1. Data from the UK network are used to provide near real-time display throughout the year of the UVR_{eff} levels across the UK in terms of the Global Solar UV Index (WHO, 2002). This display can be found on the HPA website, via http://www.hpa.org.uk/radiation.

TABLE 1 Information on the Global Solar UV Index appropriate to Europe (WHO, 2002)

Colour code	Solar index	Skin type			
		Burns in the sun, may tan (Category 1)	Tans with little or no burning (Category 2)	Naturally pigmented skin	
				Brown (Category 3)	Black (Category 4)
Green	1	Low	-	-	-
	2				
Yellow	3	Moderate	Low	-	-
	4				
	5				
Orange	6	High	Moderate	Low	Low
	7				
Red	8	Very high	High	Moderate	Moderate
	9				
	10				

Notes and assumptions

A Global Solar UV Index does not exceed 8 in the UK; indices of 9 and 10 are common in the Mediterranean and high indices are observed nearer to the equator.

B Although the HPA Solar Index is generally quoted for sensitive white skin (200 J m^{-2} eff) (see Table 1), the Global Solar UV Index quotes for the average skin type in the following categories:

Category 1: 'Burner' – minimum erythemal dose (MED) ≈ 300 J m^{-2} eff (most UK indigenous groups),

Category 2: 'Tanners' – MED ≈ 600 J m^{-2} eff (most non-indigenous UK groups and non-naturally pigmented groups),

Category 3: 'Naturally brown' – MED ≈ 800 J m^{-2} eff (mainly Asian and middle and southern American groups),

Category 4: 'Naturally black' – MED ≈ 1000 J m^{-2} eff (African and Caribbean groups).

3 RESULTS

The results from January 2004 to December 2005 for each of the sites are presented in the form of the mean values averaged across an hour at noon GMT for each month in Figures 1-6. There is a gap in the data from Leeds, due a temporary interruption of measurements for roofing works. It can be seen that the further north a site is, the lower its mean noontime irradiance. This is due to the decreased solar elevation at noon as distance from the equator increases. The effects of latitude can also be seen by plotting monthly radiant exposure data from different sites on top of each other: this has been done for Camborne and Lerwick, which are the extreme southerly/northerly sites. These data, for the period January 1994 to December 2005, are presented in Figure 7.

As well as varying with latitude, solar altitude varies with time of the year. The effects of solar altitude can also be seen by looking at the mean monthly radiant exposure for a given site. Data for Chilton, from January 1989 to December 2005, are presented in Figure 8.

Figure 1 Mean noon illuminance (in klux) at the three sites in England and on Mt. Snowdon, 2004-2005

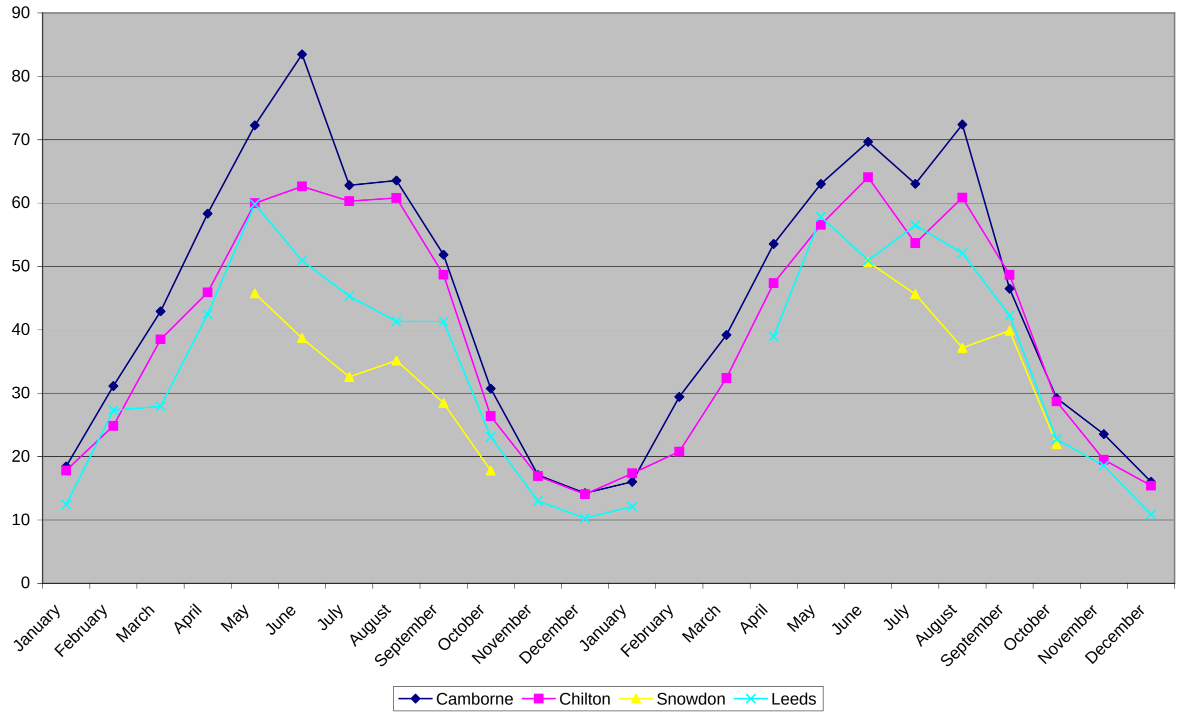


Figure 2 Mean noon illuminance (in klux) at the three sites in Scotland, 2004-2005

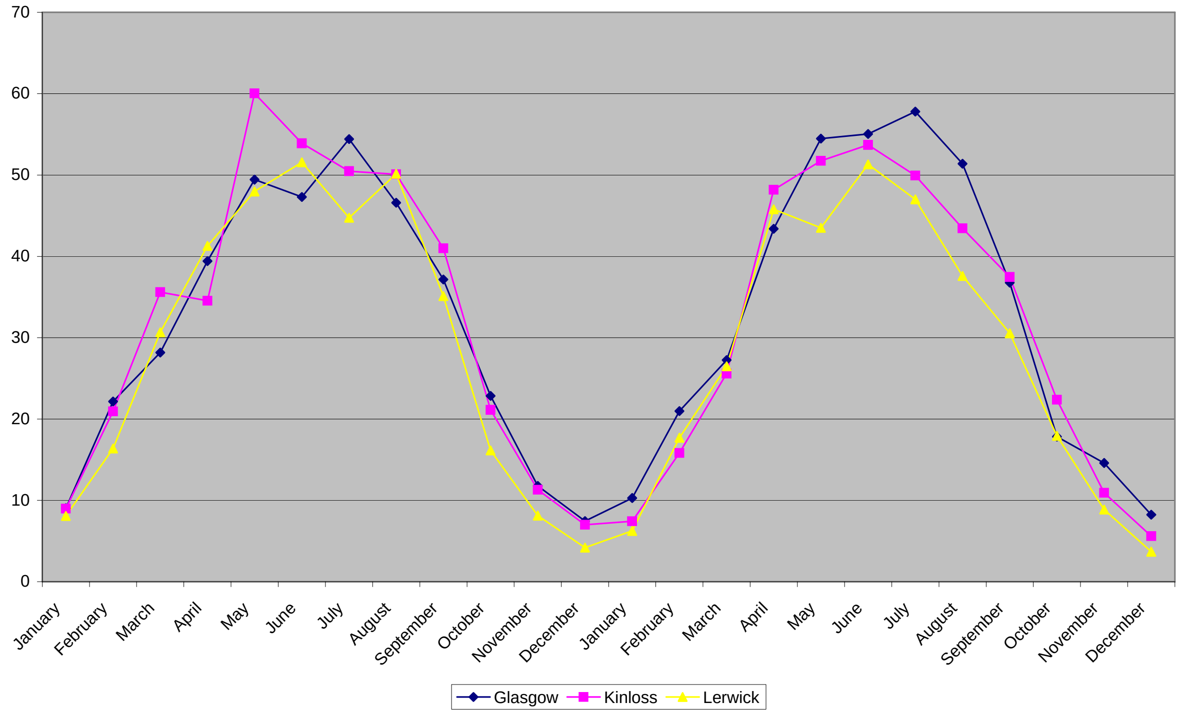


Figure 3 Mean noon UVA irradiance (in W m^{-2}) at the three sites in England and on Mt. Snowdon, 2004-2005

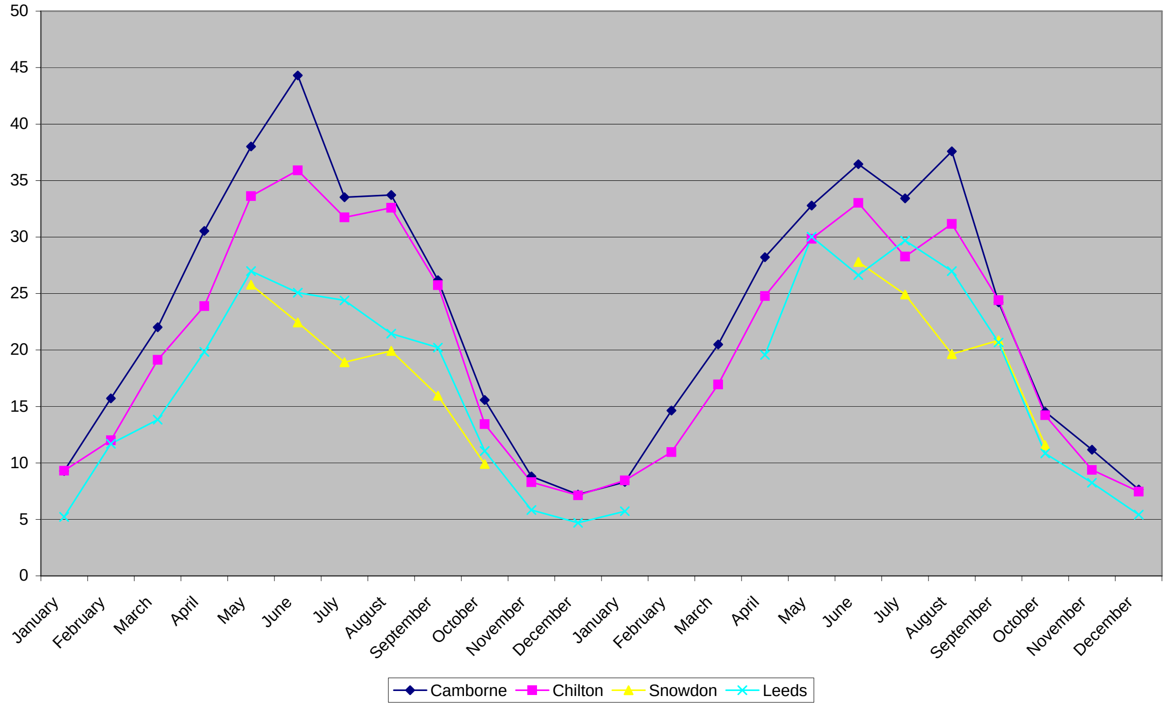


Figure 4 Mean noon UVA irradiance (in W m^{-2}) at the three sites in Scotland, 2004-2005

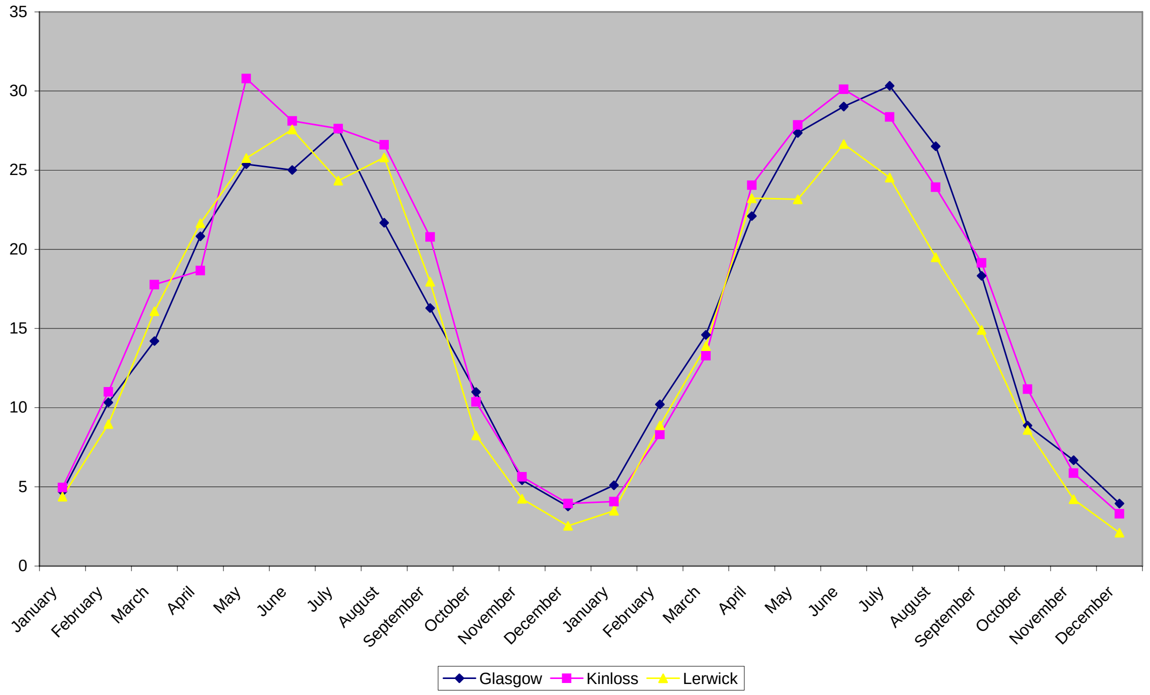


Figure 5 Mean noon erythemally weighted UVR irradiance (in mW m^{-2}) at the three sites in England and on Mt. Snowdon, 2004-2005

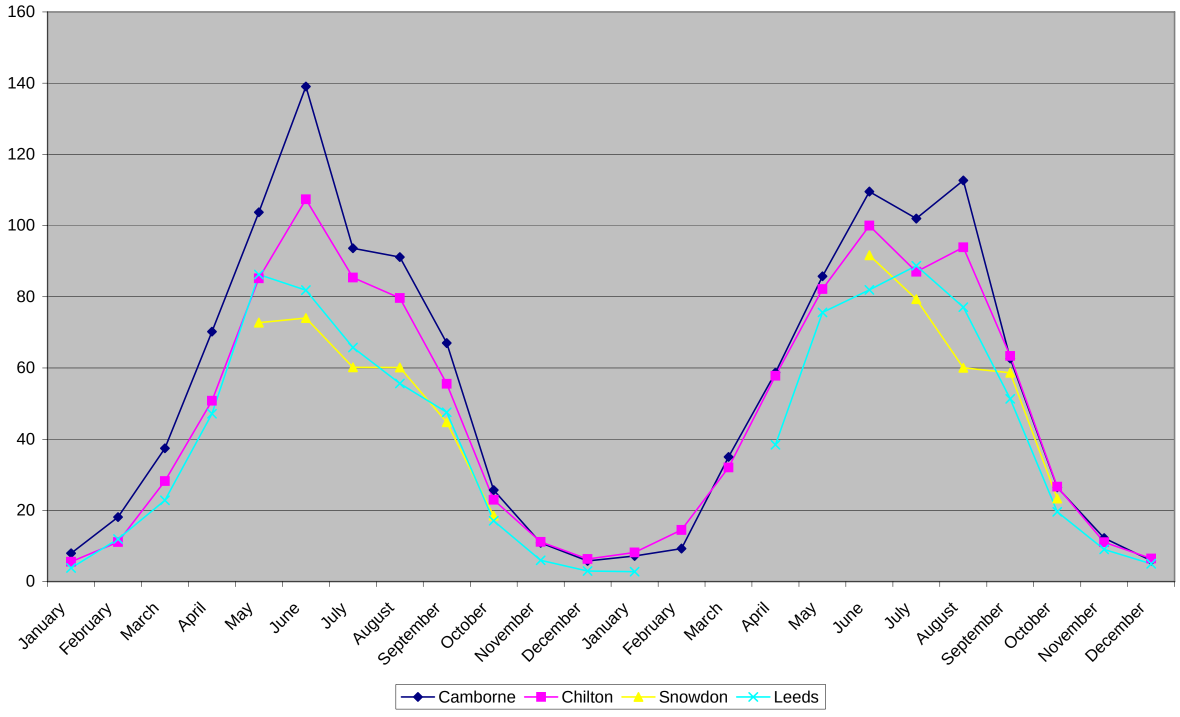


Figure 6 Mean noon erythemally weighted UVR irradiance (in mW m^{-2}) at the three sites in Scotland, 2004-2005

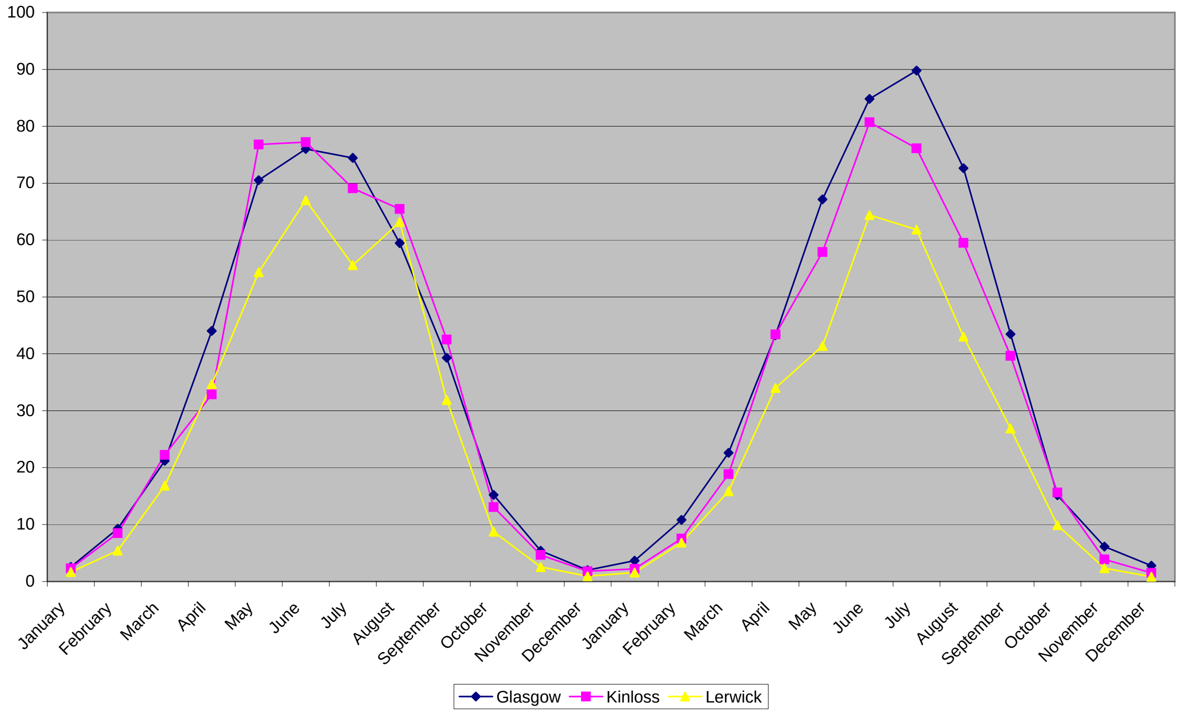


Figure 7 Monthly erythemally effective radiant exposures, 1994-2005, (in kJ m^{-2}) for Camborne and Lerwick

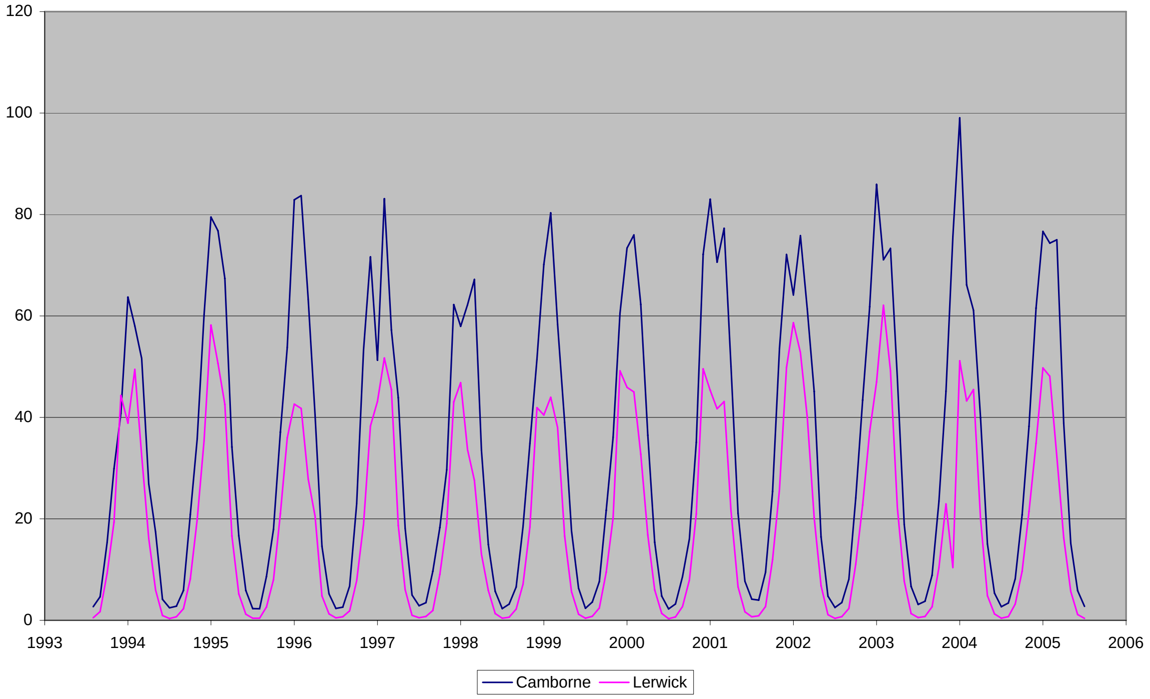
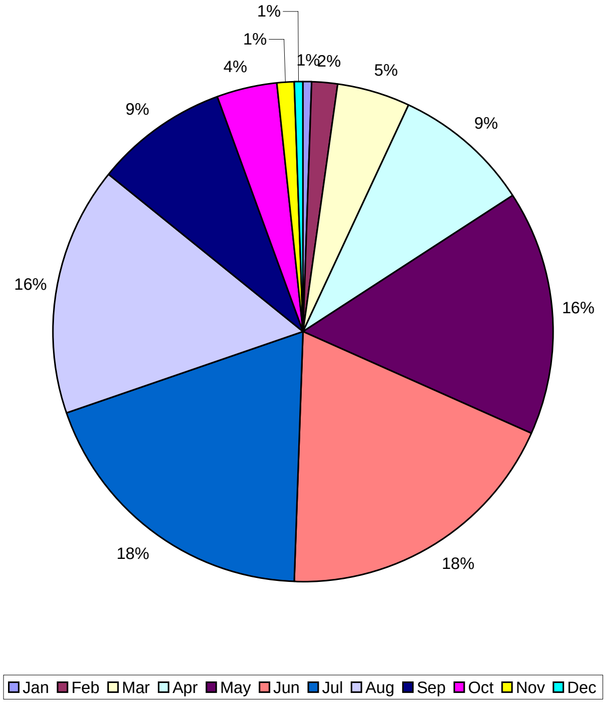


Figure 8 Mean Monthly erythemally effective radiant exposures, 1989-2005, (expressed as approx. % of mean annual exposure) for Chilton.



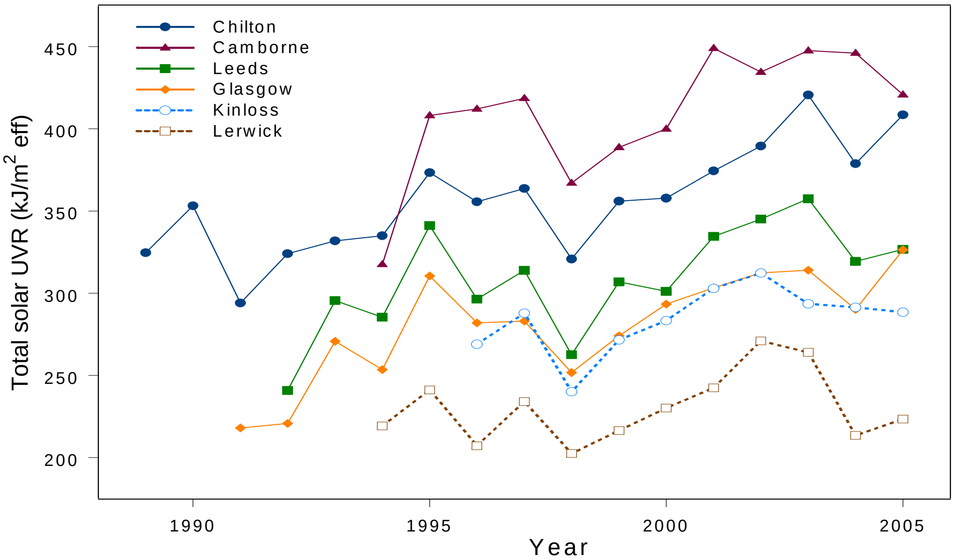
4 STATISTICAL ANALYSIS

The aim of our statistical analysis is to investigate the long-term trend behaviour of erythemally weighted ultraviolet radiation UVR_{eff} and ultraviolet UVA radiation at different latitudes with year from different sites in UK. The extent to which the long term behaviour of the measured UV irradiances can be explained by known geophysical factors, e.g. ozone depletion, sunspots and sunshine is also examined.

4.1 Erythemally weighted ultraviolet radiation (UVR_{eff})

Figure 9 shows the seasonal variations of total erythemally weighted UVR_{eff} radiant exposure for the UK sites. It should be noted that the year in which reliable data started to be collected varies by site. The Figure illustrates that the pattern of the trend is similar for all of the UK sites. There was no significant upward trend before 1998, but a consistent rise till 2003 thereafter. A clear peak was observed in 1995 and 2003 for most sites. It now appears that the trend is falling for some sites.

Figure 9: Total yearly erythermal UVR_{eff} data for the six UK sites. Chilton (1989- 2005), Glasgow (1991–2005), Leeds (1992–2005), Camborne (1994-2005), Lerwick (1994-2005) and Kinloss (1996-2005).



As expected, the highest and lowest UVR_{eff} radiant exposures throughout the year were measured in Camborne and Lerwick respectively. The remainder of the sites in descending order were Chilton, Leeds, Glasgow and Kinloss (see fig 9). Considering the sites in detail, the highest annual total UVR_{eff} values were measured in 2001 for Camborne (449 kJ m^{-2}). For Chilton and Leeds, the highest UVR_{eff} measurements were observed in 2003 (421 kJ m^{-2} and 358 kJ m^{-2} respectively) and for Glasgow was observed in 2005 (326 kJ m^{-2}). For Kinloss and Lerwick, the highest total UVR_{eff} radiant exposures were measured in 2002 (312 kJ m^{-2} and 271 kJ m^{-2} respectively)

A linear regression analysis was carried out for each site in order to test whether the estimated slope in this particular sample of measurements reflects a real trend in the underlying UVR_{eff} data. Table 2 shows the results from the linear regression fit to the data, including the slope of straight line and the percentage change in UVR_{eff} per year for each site. A t-test was carried out comparing the estimated slope with a slope of zero for all of the UK sites. The trend was statistically significant at Glasgow ($P<0.01$), Chilton ($P<0.01$), Leeds ($P=0.01$) and Camborne ($P=0.01$). However, the trend was statistically insignificant for Kinloss ($P=0.09$) and Lerwick ($P=0.33$). In Table 2, the highest and the lowest increase per year were observed in Glasgow (2.64%) and Lerwick (0.82%) respectively. For Camborne, the increase was 2.27% and these rates correspond to 2.04%, 1.59% and 1.38 per year for Leeds, Chilton and Kinloss respectively. A test of heterogeneity in slopes between sites was also performed and the test showed that there was no statistically significant difference in the slopes between sites ($P=0.10$).

Table 2: Linear regression estimates for the UVR_{eff} data, with their standard error (± SE) for six UK sites.

Sites	Latitude, ° N	Measurement period (year)	Estimated linear slope ± SE (kJ/m^2 eff)	Increase per year (%) ± SE	Durbin-Watson statistics
Camborne	50	1994-2005	0.60 ± 0.20*	2.27 ± 0.76	1.64
Chilton	52	1989-2005	0.43 ± 0.09*	1.59 ± 0.33	2.09
Leeds	54	1992-2005	0.41 ± 0.14*	2.04 ± 0.70	1.72
Glasgow	56	1991-2005	0.48 ± 0.10*	2.64 ± 0.55	1.94
Kinloss	58	1996-2005	0.31 ± 0.16	1.38 ± 0.72	1.82
Lerwick	60	1994-2005	0.15 ± 0.15	0.82 ± 0.82	1.63

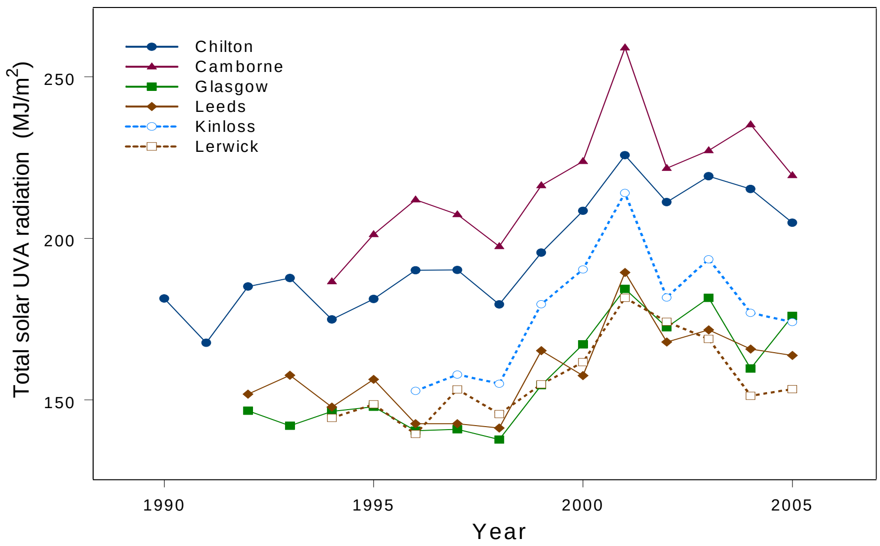
*: Significant at 5% level

To examine whether the data were normally distributed around the regression line, a normal probability plot of the residuals (i.e. the differences between the observed and fitted values) was performed for each site. These plots indicated that the data for each site seemed to be normally distributed. The evidence for autocorrelation in the residuals of the regression analysis was tested for each site using the Durbin-Watson statistic (see Table 2). The test compares the residual for time period t with the residual from time period t-1 and develops a statistic that measures the significance of the correlation between these successive comparisons (Chatfield 1984). We found no evidence for autocorrelation in the errors for any of the sites.

4.2 UVA radiation

The total annual solar UVA radiant exposure values are shown in Figure 10 for all of the UK sites. From this plot, it can be seen that the UVA data for all sites follow similar patterns of variation. There was no apparent upward trend till 1998 for the UVA data. However, there was a consistent rise between 1998-2001 with a clear peak in 2001 for all of the UK sites. UVA values now appear to be decreasing for most sites. This means that the time trends appear to have changed direction, in other words both linear and quadratic changes in trend over time were seen for some sites (e.g. Chilton, Leeds, Kinloss and Lerwick). However, including a quadratic term in addition to the linear term for Chilton, Leeds and Lerwick did not improve the model and the linear-quadratic fit was not statistically significant compare to the linear fit (P>0.05). On the other hand, for Kinloss, the linear-quadratic trend was more statistically significant than the linear fit (P=0.02).

Figure 10: Total Yearly UVA dose for the six UK sites. Chilton (1990- 2005), Glasgow (1992 – 2005), Leeds (1992 – 2005), Camborne (1994-2005), Lerwick (1994-2005) and Kinloss (1996-2005).



The highest annual UVA radiant exposures were measured in 2001 for Camborne (259.0 MJ m^{-2}), Chilton (225.7 MJ m^{-2}), Kinloss (214.1 MJ m^{-2}), Leeds (189.4 MJ m^{-2}), Glasgow (184.3 MJ m^{-2}) and Lerwick (181.6 MJ m^{-2}). As expected, Camborne recorded the highest total annual UVA radiant exposures. However, at Kinloss solar UVA radiant exposure was higher than was recorded at Leeds or Glasgow. Moreover, Leeds, Glasgow and Lerwick were observed to be reasonably consistent in UVA data throughout the year (see Fig.10).

Table 3 shows the estimates of the linear slopes with their standard errors (SE) of the UVA data for the six UK sites, together with the percentage change in UVA per year for each site. A t-test was applied for each site to investigate the evidence for a trend in the underlying solar UVA. There is evidence of an increasing trend for all of the UK sites.

The observed increasing trends were found to be statistically significant for Glasgow ($P<0.01$), Chilton ($P<0.01$), Leeds ($P=0.03$) and Camborne ($P=0.01$), but not for Lerwick ($P=0.07$) or Kinloss ($P=0.12$). The Glasgow site had the highest increase in UVA radiation (2.05 %). The lowest increase in UVA radiation per year was for the Leeds site (1.19 %). For Camborne, the increase was 1.93 %, and these rates correspond to 1.65 % and 1.33 % per year for Chilton and Lerwick respectively. However, a test of heterogeneity in slopes between sites found no statistically significant differences ($P=0.6$) in slopes between sites for the UVA data.

Normal probability plots of the residuals for each site were also conducted for the UVA data and again the residuals seem to be normally distributed for each site. There was no evidence of autocorrelation in the residuals for all of the UK sites (see Table 3).

Table 3: Linear regression estimates for the UVA data, with their standard error (SE) for six UK sites.

Sites	Measurement period (year)	Estimated linear slope ± SE (kJ m^{-2} eff)	Increase per year (%) ± SE	Durbin-Watson statistics
Camborne	1994-2005	0.30 ± 0.10*	1.93 ± 0.64	1.81
Chilton	1990-2005	0.25 ± 0.04*	1.65 ± 0.26	1.50
Leeds	1992-2005	0.15 ± 0.06*	1.19 ± 0.47	1.67
Glasgow	1992-2005	0.25 ± 0.06*	2.05 ± 0.49	1.24
Lerwick	1994-2005	0.16 ± 0.08	1.33 ± 0.66	1.01

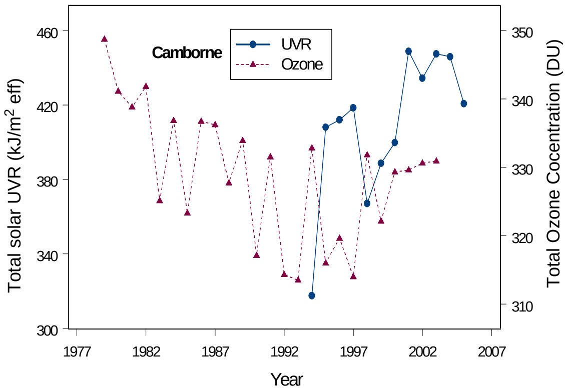
*: Significant at 5% level

The relation between UVR_{eff} and UVA values was investigated for each site by performing regression analysis. Using a t-test, it was found that these values were positive and correlated a statistically significant extent for all sites, suggesting that UVA values increase significantly with UVR_{eff} for all of the UK sites.

4.3 UVR_{eff} versus Ozone

Whether this long-term behaviour of the measured UV irradiances can be explained by known geophysical factors, e.g. ozone depletion, has been examined. Data points on ozone concentrations at ground level were available for Camborne and Lerwick sites only and were obtained from the web sites (Environment Agency website, Air Quality website).

Figures 11: Total annual erythemally weighted UVR $_{eff}$ for Lerwick (1994-2005) and Camborne (1994-2005) and ozone concentrations (DU: Dubson Unit) for Lerwick (1981-2005) and Camborne (1979-2003).



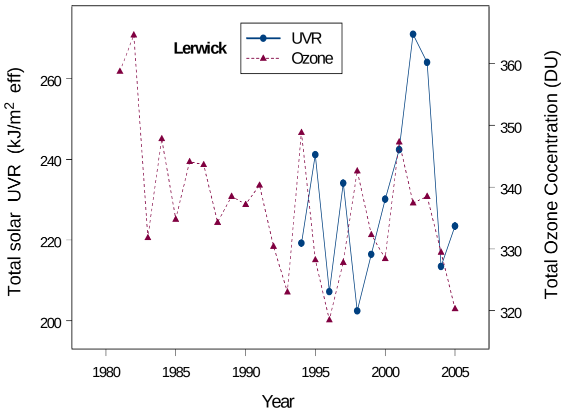


Figure 11 shows the relationship between annual total solar UVR $_{eff}$ values and ozone concentrations at ground level for Lerwick and Camborne. Total atmospheric ozone values at both sites showed a consistent drop in levels between 1980 and 1999. However, it now appears that the ozone values at Camborne are levelling off while values at Lerwick have continued to decrease. In contrast, solar UVR $_{eff}$ values at Camborne increased between 1994 and 2001, but started to decrease subsequently while values at Lerwick showed a decrease between 1994 and 1999, a sharp increase after 1999 and followed by a rapid fall from 2002. The relationship between ozone and UVR $_{eff}$ appeared to be reciprocal; UVR $_{eff}$ being low when ozone is high, and vice versa (see Fig.11).

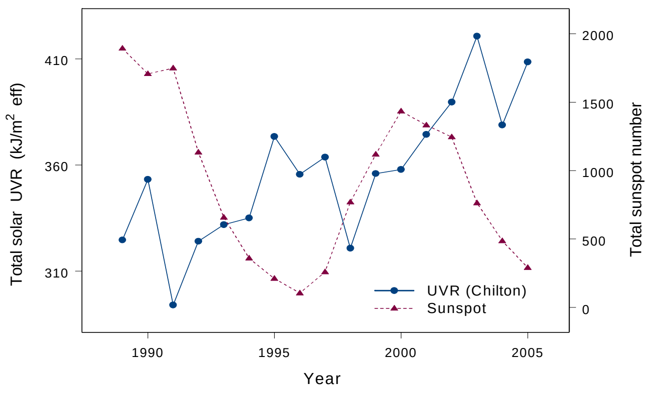
The relation between UVR $_{eff}$ and ozone data was investigated using a t-test for Lerwick and Camborne during the time period from 1994 to 2005 and from 1994 to 2003 respectively. The correlation between UVR $_{eff}$ data and ozone concentration data was not statistically significant for Lerwick (P=0.80) and Camborne (P=0.34), indicating the absence of a linear relationship for both sites. Hence, the changes in UVR $_{eff}$ data and ozone concentrations make it impossible to draw conclusions regarding any underlying dependence of ozone concentration on changes in UVR $_{eff}$.

4.4 UVR $_{eff}$ versus Sunspots

Although the Sun does not look very different from day to day, it is in fact a very active object, just like other stars. One of the ways of measuring this solar activity is by counting the number of sunspots that can be seen every day. The amount of solar activity slowly changes from year to year reaching a maximum about every 11 years. It is not known why the Sun does this. We investigated whether these changes have an impact on changes in UV radiation, e.g. at Chilton. Figure 12 shows the relationship between annual total solar UVR_{eff} values at Chilton and annual total sunspot numbers obtained from NASA (NASA, website). The relationship between sunspots and UVR_{eff} also appeared to be reciprocal; UVR_{eff} being high when sunspots is low, and vice versa.

Using t-test, the correlation between UVR_{eff} values at Chilton and Sunspot numbers was not statistically significant (P>0.1) during the time period from 1989 to 2005. Other sites were also investigated and again the relationship between these values was also not statistically significant for any of the sites.

Figure 12: Total annual erythemally weighted UVR_{eff} (1989-2005) at Chilton and total sunspot numbers.

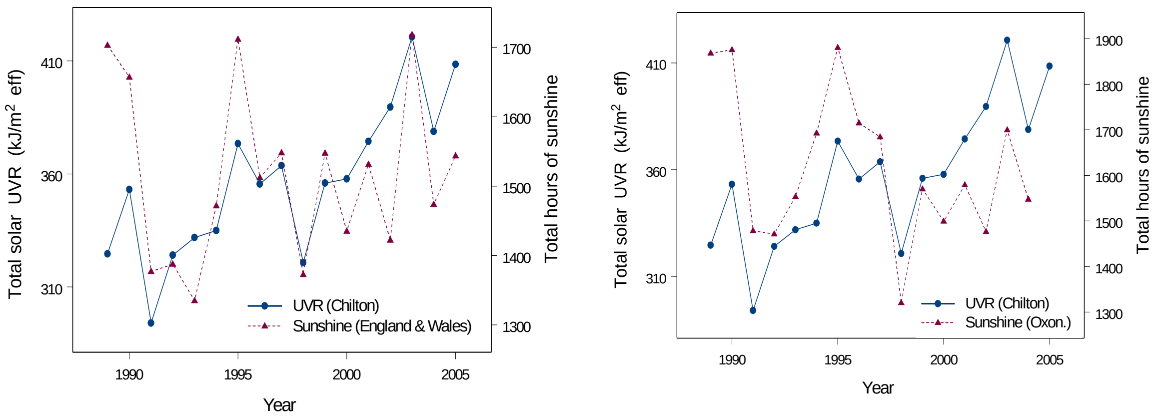


4.5 UVR_{eff} versus Sunshine hours

Sunshine duration is known to be the most relevant proxy for cloud cover. Monthly records of duration of bright sunshine have been obtained from the Met Office (http://www.metoffice.com/climate/uk/seriesstatistics/ewsun.txt) for England & Wales and Scotland (http://www.metoffice.gov.uk/climate/uk/seriesstatistics/scotsun.txt). In addition to this, sunshine hours have also been recorded locally at the Radcliffe Meterological Station in Oxford, (http://www.geog.ox.ac.uk/research/rms/series.php) 30 km distant from Chilton. Figure 13 shows the relationship between both sunshine hours for England & Wales and Oxford versus UVR_{eff} values at Chilton. Both Figures illustrate clear peaks in 1995 and 2003 and a sharp fall in 1998 for both total hours of sunshine and UVR_{eff} .

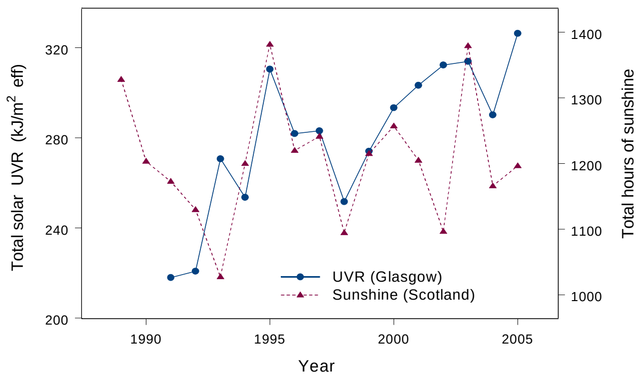
Figure 13 shows that there could be a weak relationship for either England & Wales as a whole or Oxford specifically during the time period from 1989 to 2005. A t-test was employed in order to check the statistical significance of a correlation between these values. When UVR_{eff} values at Chilton were compared to sunshine hours in England & Wales, the correlation was positive and the t-test result was statistically significant at borderline level (P=0.054), but the data fit was extremely poor. Whilst, when sunshine hours in Oxford were compared to UVR_{eff} values at Chilton, we found that the t-test result was not statistically significant (P=0.37).

Figure 13: Total annual erythemally weighted UVR_{eff} at Chilton (1989-2005) and total annual sunshine hours for England & Wales (1989-2005) and for Oxford (1989-2005)



The UVR_{eff} values at the Glasgow site were compared with total hours of sunshine recorded in Scotland (Fig.14). We found no significant linear correlation between UVR_{eff} values at the Glasgow site and sunshine hours in Scotland (P=0.80). We had tried to obtain the sunshine data locally for Glasgow, but no data were available at this location.

Figure 14: Total annual erythemally weighted UVR $_{eff}$ at Glasgow (1991-2005) and total annual sunshine hours for Scotland (1991-2005)



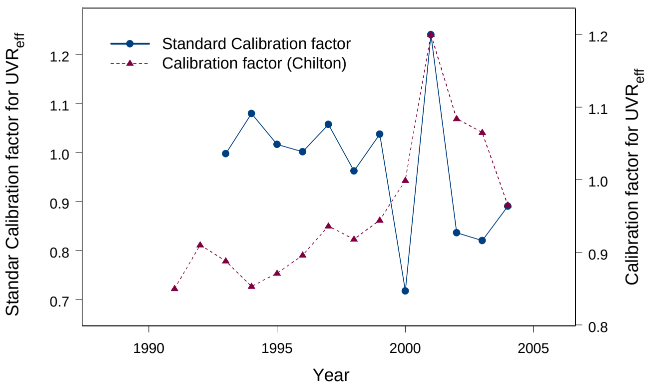
The sunshine data have been shown to be a good proxy for total yearly cloud cover. Unfortunately the sunshine records are related only to the total cloud factor and do not give us any information on cloud type.

4.6 Calibration factor

All calibrations carried out during this project are traceable to the National Physical Laboratory (NPL). One or more deuterium discharge lamps are routinely sent from HPA to NPL to be calibrated for absolute spectral irradiance. In order to calibrate field solar radiation measurement sytems (SRMSs), a standard SRMS is calibrated against a scanning spectroradiometer (SSR) at Chilton, then transported to each site for side-by-side calibration of the field instrument (Pearson 2004). Thus, whether the data may have a calibration error for the Chilton site has been investigated.

Figure 15 shows the relationship between standard calibration factor for UVR $_{eff}$ and the calibration factor for UVR $_{eff}$ at Chilton. It is apparent from the Figure that there is a clear peak in 2001 for both calibration factors. Data points in 2001 and 2004 were overlapped with each other. The correlation between standard calibration factor and calibration factor at Chilton was investigated using the t-test and the result was not statistically significant (p=0.99). Thus, no calibration error was observed.

Figure 15: Standard calibration factor for erythemally weighted UVR $_{eff}$ (1993-2004) and calibration factor for erythemally weighted UVR $_{eff}$ at Chilton (1991-2004)



5 CONCLUSIONS

The results of the seventeenth and eighteenth years of a continuing survey of solar radiation levels at the HPA establishments at Chilton, Leeds and Glasgow, and over a shorter period at the sites at Camborne, Snowdon, Kinloss and Lerwick, have confirmed the general trends observed during the previous measurement periods. There are clear increasing trends in UVR $_{eff}$ and UVA radiation at four UK sites (Camborne, Chilton, Leeds and Glasgow). A peak was observed in 1995 and 2003 for UVR $_{eff}$ values recorded at these sites due to hot summers for these years. These findings are consistent with findings of Outer and colleagues. (2005) who also reported the highest annual UVR $_{eff}$ doses were recorded in 1995 and 2003 at Bilthoven (Netherlands). The authors suggested that their results in 1995 could be explained by extremely low ozone values and moderate cloud reduction and for 2003 extremely low cloud reduction combined with moderately low ozone values. A clear peak was also observed in 2001 for solar UVA, this may be explained by an overall reduction in cloudiness in UK during this year.

Although significant evidence exists for upward trends for both UVR $_{eff}$ and UVA radiation, a longer time period of solar UV radiation measurements will clarify the understanding of whether these increases continue or not. Moreover, the changes in UVR solar radiation were also influenced by the changes in other identified factors, such as climate (Diffey, 2004).

Please note that information about the solar measurement programme, monthly bulletins and a service to provide data from each of the measurement sites on compact disk is available on the HPA website (www.hpa.org.uk).

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