StrålevernRapport 2006:4

The Norwegian UV Monitoring Network
1995/96 - 2004

Statens strålevern

Norwegian Radiation Protection Authority
Postboks 55
N-1332 Østerås
Norway

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Ultraviolet radiation. UV. Solar UV. Solar UV index. UV dose. UV monitoring. UV trend. Alpine UV. CIE. Erythema. GUV. Multiband radiometer. UV biometer. Bentham spectroradiometer. Cloud transmittance. Ozone. Sky View Factor.

Abstract:
The implementation and operation for the national UV monitoring network are presented. Final results for UV indexes and UV doses for the period 1995/96 to 2004.

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Emneord:
Ultrafiolett stråling. UV. Naturlig UV. UV-indeks. UV-dose. UV-overvåking. UV-trend. Alpin UV. CIE. Erythem. GUV. Flerbåndsradiometer. UV-biometer. Bentham spektralradiometer. Skytransmittans. Ozon. Sky View Factor.

Resymé:
Oppbyggingen og driften av et nasjonalt UV overvåkingsprogram presenteres. Endelige resultater for UV-indeks og UV-doser foreligger for perioden 1995/96 til 2004.

Head of project: Merete Hannevik.
Approved:

Gunnar Saxebøl, Director, Department for Radiation and Nuclear Safety

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The Norwegian UV Monitoring Network
1995/96 - 2004

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Statens strålevern

Norwegian Radiation
Protection Authority
Østerås, 2006

Contents

1 Abstracts

1.1 Abstract in English

The Norwegian UV monitoring network has been operative since 1995/96 and currently consists of nine measurement locations from 58ºN to 79ºN, i.e. from Landvik in the south of Norway to Ny-Ålesund at Svalbard. The purpose is to provide high quality long-term UV data for use related to health and environmental issues. The data is used for research in Norway and other countries. The general use of and interest in the data is growing and easier access to the data through the Internet is an important factor. The data is also used in a European project, COST 726, which main objective is to understand the radiation distribution under various meterological conditions in Europe in order to determine UV radiation climatology and assess UV changes in Europe. Further, the results are used as important information to the public regarding UV radiation and health.

The data collection is automated and require minimal maintenance, but daily inspections of the UV measurement instruments are necessary. In the recent three years the continuity in the measurements has been improved. Results are presented on the web pages to the Norwegian Radiation Protection Authority (http://www.nrpa.no) and are updated every hour. Calibrations traceable to several European UV networks ensure high quality data, confirmed through intercomparisons between UV instruments from different countries. The measurement results from the Norwegian UV network show large annual variations in UV dose, but the last six years have been more stable than previous years. These natural variations in addition to the short time period make it difficult to see any long-term trends in the UV data so far. No conclusion regarding possible long-term changes is therefore drawn.

1.2 Abstract in Norwegian

Det norske UV-nettverket har vært i drift siden 1995/96 og består av ni målestasjoner fra Landvik i sør ved 58ºN til Ny-Ålesund på Svalbard ved 79ºN. Målet med nettverket er å gi langtids UV-data med høy kvalitet til bruk innen helse og forskning. Dataene fra nettverket er brukt til forskning i Norge og i andre land, og den generelle interessen for UV-data er økende. Lettere tilgang til data via Internett er her en viktig faktor. Dataene er også brukt i et europeisk prosjekt, COST 726, som har som hovedmål å se på fordelingen av UV-strålingen over Europa ved ulike meteorologiske forhold for å kunne si noe om UV klimaet og se på endringer i strålingsnivået. Dataene danner også grunnlag for publikumsinformasjon om UV-stråling og helseeffekter.

Datainnsamlingen er automatisk og trenger minimalt med vedlikehold, men det er nødvendig med daglige inspeksjoner av UV-instrumentene for å sikre kvaliteten på målingene. De siste tre årene har kontinuiteten i målingene blitt forbedret. Måleresultatene er tilgjengelig på Internett-sidene til Statens strålevern (http://www.nrpa.no) og blir oppdatert hver time. Kalibreringene er sporbare til flere europeiske UV-nettverk. Dette gir dataene høy kvalitet og bekreftes gjennom sammenligningsmålinger med instrumenter fra flere land. Måleverdiene fra det norske UV-nettverket viser stor variasjon i de årlige UV-dosene, men har de siste seks årene vært mer stabile enn de første årene. Disse naturlige variasjonene og den korte måleperioden gjør det så langt vanskelig å se noen trender, og det er ikke mulig å trekke noen konklusjoner om langtidstidstrender ennå.

2 Introduction

The Ministry of the Environment and the Ministry of Health and Care Services initiated the national UV monitoring network in 1994. The primary aim was to provide high quality long-term UV data for use related to health and environmental issues. In order to detect possible long-term changes in the UV radiation, the monitoring program was stated to last several decades.

Secondary aims of the UV network are:

- Documentation of annual and seasonal variations in UV radiation
- Documentation of geographical and topographical variations
- Analysis of UV trends as basis for public warning
- Public information about sun protection based on UV measurements
- Provide UV data to the scientific community for effect studies

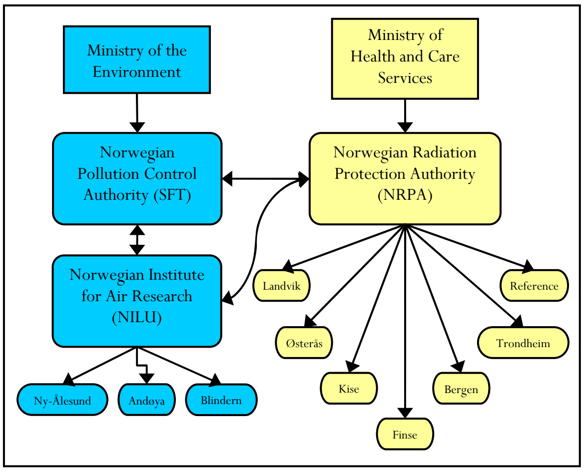

Figure 1. Organization of the Norwegian UV monitoring network.

Figure 1 shows the organization of the Norwegian UV network. Three of the network stations are operated by the Norwegian Pollution Control Authority via the Norwegian Institute for Air Research (NILU) and six are operated by the Norwegian Radiation Protection Authority (NRPA). The reference instrument is calibrated by the NRPA and it is also linked to a spectroradiometer located at Østerås.

3 The UV network

3.1 Locations

The Norwegian UV network consists of 9 measurement locations from Landvik in the south of Norway to Ny-Ålesund at Spitsbergen, Svalbard. The latitude ranges from 58°N to 79°N. Figure 2 shows where the network instruments are located.

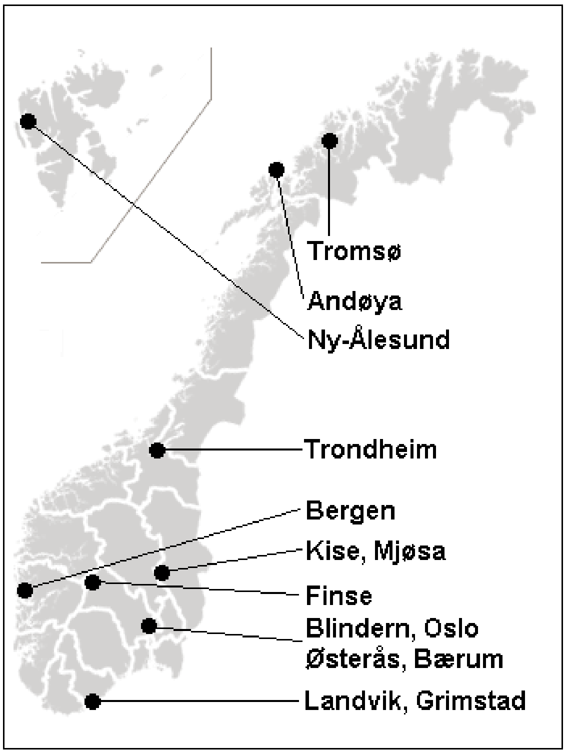

Figure 2. Map of the UV measurement locations.

Location	Latitude	Longitude	Altitude
Landvik	58°20’ N	8°31’ E	10 m
Blindern	59°56’ N	10°43’ E	95 m
Østerås	59°57’ N	10°36’ E	135 m
Bergen	60°23’ N	5°20’ E	40 m
Finse	60°36’ N	7°31’ E	1210 m
Kise	60°46’ N	10°48’E	130 m
Trondheim	63°25’ N	10°24’ E	65 m
Andøya	69°17’ N	16°01’ E	380 m
Tromsø	69°41’ N	18°58’ E	60 m
Ny-Ålesund	78°55’ N	11°55’ E	400 m

Table 1. Locations of the network instruments.

3.1.1 Finse

In 2003 Finse was formally included in the UV network, and a new GUV-instrument was set up at this location 1210 meters above sea-level. Finse is situated on the north-western part of Hardangervidda in south central Norway in the low alpine zone, about 250 meters above the tree line. Finse covers the need for an alpine location and was a natural choice since the NRPA has had a broadband UV instrument operating continuously at the Alpine Research Center – Finse since 1996.

Figure 3. The GUV instrument at Finse. Photo: NRPA.

Figure 3 shows the localization of the GUV, on a top about 100 meters from the Finse research station.

The GUV-instrument was set up in the beginning of March 2003 and a TV team from NRK, the Norwegian Broadcasting Corporation, made a documentary about UV and the new UV station at Finse shown in the scientific TV program "Schrödingers Katt". Figure 4 shows researcher Bjørn Johnsen filmed by the TV team while unwinding the GUV cable. The research station is in the background.

Figure 4. Bjørn Johnsen unwinds the signal cable between the GUV and the indoor monitoring PC. Photo: NRPA.

3.1.2 Landvik

The network location furthest south is located at the Norwegian Crop Research Institute, division Landvik close to the city of Grimstad. Research has been carried out here since the 1950s, and is now focused on vegetables, seed breeding and golf-green. The GUV at Landvik has been operative since 1996, and the location has the highest number of sunny days.

Figure 5. The Norwegian Crop Research facility at Landvik. Photo: NRPA.

3.1.3 Østerås

On the roof-top of the NRPA building, the solar calibration facilities of the NRPA is operative with both a spectroradiometer and a GUV measuring the UV radiation. The GUV has been operative since 1999. Østerås is situated in Bærum close to Oslo.

Figure 6. The calibration facilities at NRPA. Photo: NRPA.

3.1.4 Blindern

The GUV instrument located at the Department of Physics at the University of Oslo has been operative since 1994, before the network was formally established.

Figure 7. Instruments on the roof of the Department of Physics at the University of Oslo. Photo: NRPA

The instrument is operated by the University of Oslo on behalf of the Norwegian Pollution Control Authority (SFT) and the Norwegian Institute for Air Research (NILU).

3.1.5 Kise

Figure 8. The Norwegian Crop Research facility at Kise with the paddle steamer Skibladner in the background. The GUV is located in the bottom-right corner. Photo: NRPA.

Kise is a division of the Apelsvoll Research Center and has been a research farm since 1949. Current research focuses on fruits, berries and vegetables. The farm is located close to Mjøsa, the largest lake in Norway. The instrument has been operating since 1996. Late 2004 the GUV was moved some meters from the metal pole at the center of the hut to improve the viewed horizon.

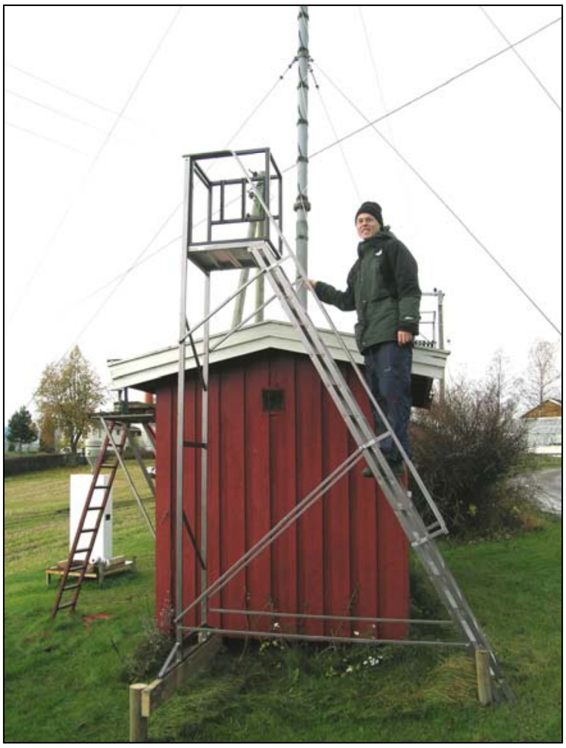

Figure 9. The new stand at Kise. Photo: NRPA.

3.1.6 Bergen

On the roof of the Geophysical Institute at the University of Bergen, the GUV has been operative since 1996. The roof also houses other solar radiation instruments, and Bergen has one of the longest records of solar radiation measurements in Norway.

Figure 10. Geophysical Institute, Bergen. Photo: NRPA.

3.1.7 Trondheim

One of the instruments is located at the Norwegian University of Science and Technology (NTNU - Gløshaugen) and is operated in collaboration with the Department of Physics at NTNU. The instrument has been operative since 1996 and is located on the roof-top together with several other instruments measuring spectral and total solar radiation in the ultraviolet and infrared region.

Figure 11. The GUV and the reference GUV in Trondheim. Photo: NRPA.

3.1.8 Andøya

The instrument at Andøya Rocket Range was originally located at the Auroral Observatory in Tromsø from 1995 and was moved to Andøya in 2000. SFT via NILU is responsible for the GUV at Andøya.

Figure 12. Andøya Rocket Range. Photo: Anette Jensen, Andøya Rocket Range.

3.1.9 Ny-Ålesund

The Norwegian Polar Institute has operated the GUV in Ny-Ålesund since 1995. The institute is Norway's central institution for research regarding environmental monitoring and mapping of the polar regions. SFT via NILU is responsible for the GUV at Ny-Ålesund.

Figure 13. Ny-Ålesund. Photo: Jan Børre Ørbæk, The Norwegian Polar Institute.

3.1.10 Sky View Factor

The Sky View Factor (SVF) is the fraction of the overlying hemisphere occupied by the sky. Fish-eye photos with 180° field of view have been used to calculate the SVF at most of the network locations.

Figure 14. Fish-eye photo from Landvik. Photo: NRPA.

Figure 14 shows a fish-eye photo from Landvik. The colour photograph is converted to a black & white bitmap, and a Matlab script made by NRPA calculates the SVF. The resulting factors are presented in table 2 below.

Location	SVF
Trondheim	0.994
Blindern	0.994
Østerås	0.988
Finse	0.986
Kise	0.969
Bergen	0.964
Landvik	0.949

Table 2. The Sky View Factors for seven of the network locations ranged after the best view of the sky.

Trondheim and Blindern has the best view of the sky, and Landvik has the worst with 5% of the sky hidden behind buildings, trees and a large pole. The pole alone contributes to a 2% loss. The new stand at Kise changed the SVF from 0.966 to 0.969, only a minor improvement.

Figure 15. Flattened fish-eye photo showing the horizon at Østerås. Photo: NRPA.

Figure 15 shows the whole overlying hemisphere at Østerås. The picture has actually a 190° field of view and has been made by stretching a fish-eye photo using Matlab. It gives a good impression of the horizon at this location.

3.1.11 Links

Links to all the institutions where the UV monitoring instruments are located are given below.

`Finse:`

`http://www.bio.uio.no/fellesavdelinger/finse/`

`Landvik and Kise:`

`http://www.bioforsk.no/`

`Østerås, NRPA:`

`http://uvnett.nrpa.no`

`http://www.nrpa.no`

`Blindern:`

`http://www.fys.uio.no/plasma/ozone`

`Bergen:`

`http://www.gfi.uib.no/`

`http://www.gfi.uib.no/index_e.html`

`Trondheim:`

`http://www.phys.ntnu.no/brukdef/prosjekter/uvstral/Home.htm`

`Andøya:`

`http://alomar.rocketrange.no/guv.html`

`Ny-Ålesund:`

`http://www.npolar.no/`

3.2 Instrumentation

The UV network consists of 11 multiband filterradiometers of model GUV 541 and one GUV 511 from Biospherical Instruments Inc. and one Bentham BM150BC double grating spectroradiometer from Bentham Instruments Inc. Nine of the GUVs are stationary at the measurement locations. The spectroradiometer is the primary reference instrument for the network.

The GUVs are temperature stabilized and have five detector channels at 305, 313, 320, 340 and 380 nm center wavelength with a 10 nm bandwidth.

For more details and spectral response functions of the instruments, see [1]. Long-term stability of the GUVs are shown in appendix A.3. The figures show the relative changes in the response of the GUV channels for all GUV instruments since they became operative.

Figure 16. The front optics of the GUV multiband filter-radiometer. Photo: NRPA.

3.3 Data access

Data from the network of GUVs is automatically collected from the remote logging computers. These PCs communicate with the GUVs and save irradiance data averaged over one minute intervals to file. Every hour a master computer located at NRPA downloads the data via modem or Internet connection and organizes the data in a database. If necessary, the internal clocks of the remote PCs are synchronized with the master PC at NRPA, which follows UTC time. The logging PCs are old and run Windows 3.11, and the logging software from Biospherical does not run satisfactorily on new Windows XP computers. New logging software compatible with Windows XP was developed at NRPA in 2004, and the replacement of old PCs will start in 2005.

The database is accessible from Internet or via SQL. On the website http://www.nrpa.no data is presented as UV index and UV dose in graphs and tables. The data is updated every hour.

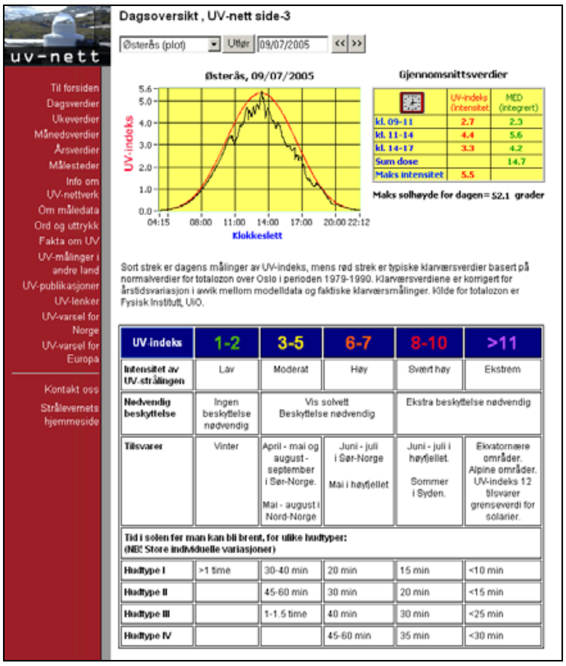

Figure 17. Graphical display of daily UV index at http://www.nrpa.no.

In 2004 a curve was added to the daily UV index plot showing the typical clear sky UV index values on any given day, see figure 17. This red curve makes it easy to say whether the UV index is higher or lower than expected. The clear sky curve represents an average based on measurements from the locations at normal ozone density. Annual plots of daily maximum UV index with normal values are also added. Figure 18 shows this plot for Landvik in 2004. Note the very high UV values in June 2004 due to drifting clouds.

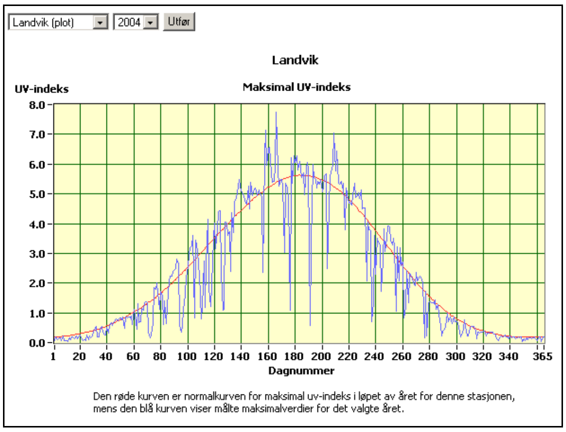

Figure 18. Plot of daily maximum UV index for Landvik in 2004, measured and normal values.

4 Measurement continuity

The continuity of the measurements has been good. Gaps in data collection are typically caused by power blockouts, calibration needs, phone line problems or other faults. Most locations are equipped with UPS – uninterruptible power supplies that can run the equipment up to an hour.

A day with gap, or significant loss of UV dose, is defined as a day where more than 10% of the daily dose is lost. Figure 19 shows the cumulated number of such days for all network locations since the year the measurements started at each location. The instrument in Bergen has had meny days with significant loss. However, most of these days are due to repair and calibration of the instrument in 1998 and 1999 and the fact that the measurements in 1996 started on February 9th. At Andøya there were start-up problems in 2000 and 2001 due to technical difficulties, but the continuity has been good the last three years. When we exclude days caused by calibration, building reconstruction work and days lost at start-up of the locations, we get the results in figure 20.

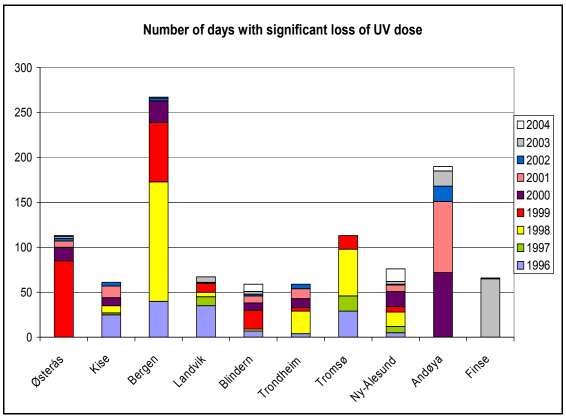

Figure 19. Number of days with significant loss of UV dose including calibration days and start-up days at each location.

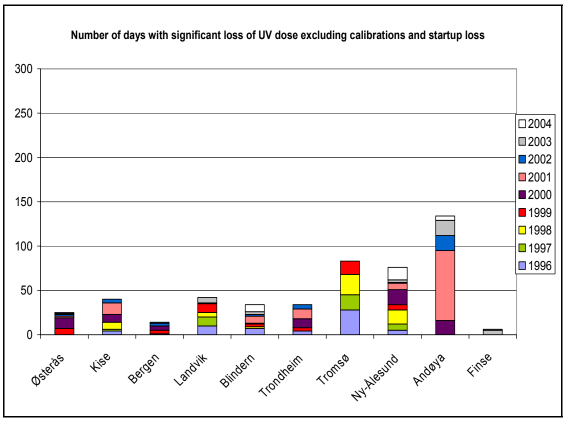

Figure 20. Number of days with significant loss of UV dose due to unexpected days with significant loss of UV dose.

The instrument in Bergen has had very few days with unexpected gaps in the data collection. Each location has had between 0 and 15 days with significant loss of data each year, in average 7 days. The last three years the continuity is improved compared to previous years, and the average days with gap is reduced to 4. For a detailed look at days with gap see appendix A.1.

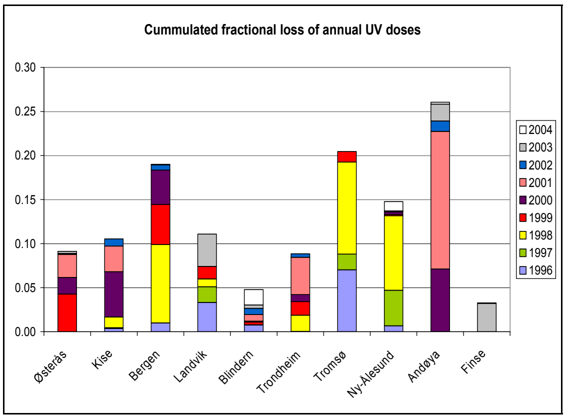

Figure 21. Cumulated fractional loss of annual UV doses including calibration days and start-up days at each location.

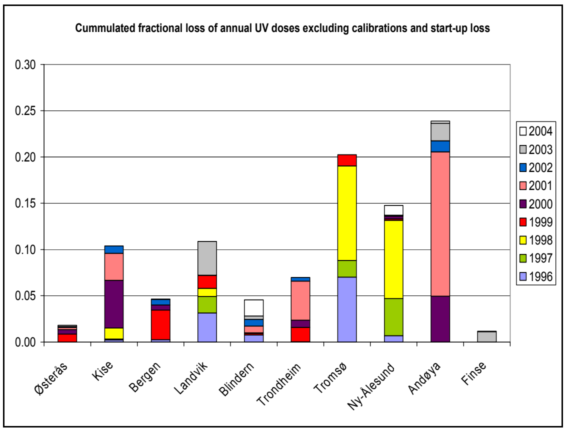

Figure 22. Cumulated fractional loss of annual UV doses due to unexpected days with significant loss of UV dose.

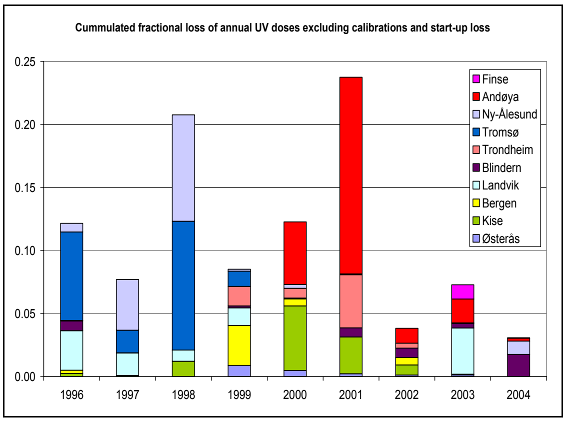

Figure 23. Cumulated fractional loss of annual UV doses due to unexpected days with significant loss of UV dose shown for each year.

Figures 21 to 23 show the cumulated fractional loss of annual UV doses. The loss of UV doses is calculated by estimating the total daily doses for all days with gaps. The estimates are based on expected values at the different stations when the weather and ozone is considered. In average 1.7% of the annual dose is lost and estimated at each location between 1996 and 2004. Østerås has the lowest average loss of 0.3% while Tromsø/Andøya has a 5% loss. The last three years the total average loss has been 0.5% and lower than previous years due to better continuity. For a detailed look at fractional loss of annual UV doses see appendix A.1.

5 Measurement uncertainty

The uncertainty budget for spectral sky UV-measurements with NRPA's spectroradiometer and GUVs are shown in appendix A.2.

The NOGIC (Nordic Ozone Group International Intercomparison) 2000 with reference spectroradiometers showed an agreement within -1%±2% (see figure 14 in [1]). Results from FARIN intercomparison (www.nilu.no/farin) at NRPA in May 2005 will show if consistency with the other UV monitoring networks is maintained. The main task of FARIN is to quantify effects of changes in the various parameters influencing UVR, based on the UV data collected from the Norwegian UV network instruments.

Figures showing the long-term stability of the GUVs are presented in appendix A.3. For a more detailed discussion about measurement uncertainty, calibration and quality control, see [1].

6 Results

At present nine UV monitoring stations are operative. Most of them were established in 1996, except for the one at Blindern which was established in 1994, the one at Østerås in 1999 and the one at Finse in 2003. The Andøya location replaced Tromsø in 2000 and has been operative since then.

The results are presented as erythemally (CIE) effective UV radiation dose measured in units of J/m² and as UV index, a number indicating the sunburn potential of the suns UV radiation, see [3]. The UV index is calculated by multiplying the CIE effective irradiance by 40. In Norway the maximum UV index during midsummer is typically between 6 and 7 in the south of Norway and between 4 and 5 in the northern part of the country. This corresponds to moderate to high solar intensity. In parts of the world closer to the equator the UV index can reach 15-20, causing severe sunburn risk for white people.

6.1 Annual UV doses

Figure 24 shows the annual UV doses for all UV monitoring locations for the complete measurement period. Missing UV doses due to calibrations or other temporary stops have been estimated and added to the measured values. The exact values are listed in appendix A.4.

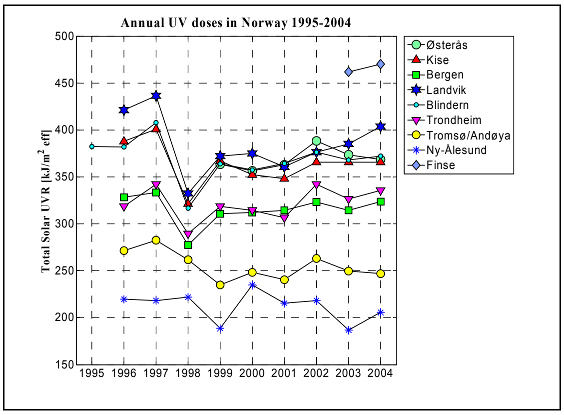

Figure 24. Annual UV doses for all monitoring locations.

The figure clearly shows a pattern. The values from the inland locations Kise, Blindern, Østerås and Landvik in the southern part of Norway follow pretty closely. Landvik is further south and has a somewhat higher dose. The values from Trondheim and Bergen also follow closely, both cities having a coastal climate. Finse, the only alpine site, is without doubt the location with the highest UV levels. The values are 15-20% higher than Landvik, the location with the second highest values. The high levels at Finse are caused by the high altitude and the fact that the snow normally does not melt before July. Due to high snow reflection, this results in especially high UV doses in May and June.

The monthly means of the daily UV doses for the months April to September for all locations are presented in the figures 25 to 33. In the southern part of Norway the months April and September also have about the same mean daily UV dose. The months May and August as well as June and July show similar UV doses. For Tromsø/Andøya and Ny-Ålesund the level in April is more similar to August and May is similar to July. At Finse April seem to be similar to August, but the UV doses in May an June show the same level due to the high snow reflection.

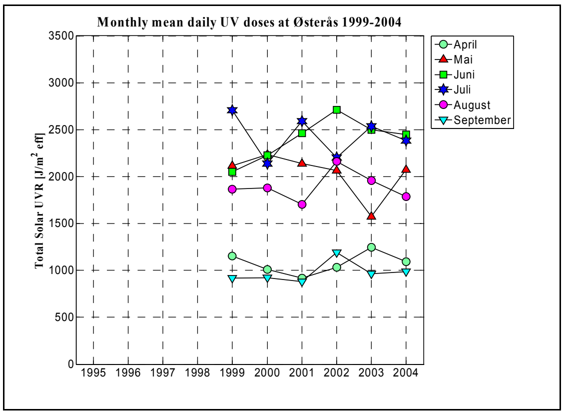

Figure 25. Monthly mean daily UV dose at Østerås.

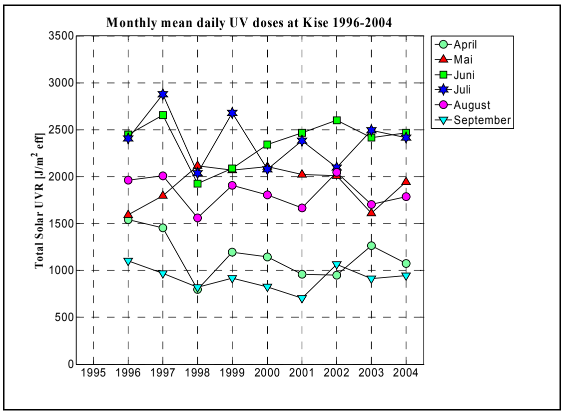

Figure 26. Monthly mean daily UV dose at Kise.

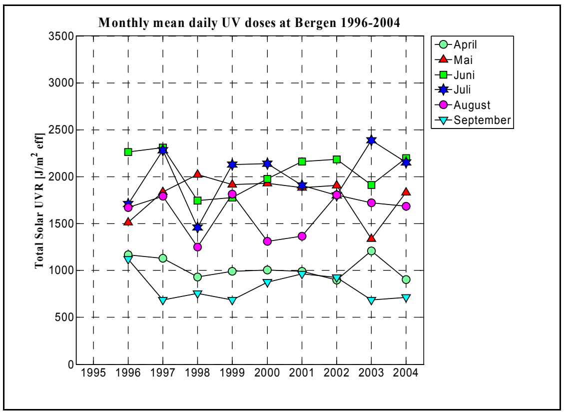

Figure 27. Monthly mean daily UV dose at Bergen.

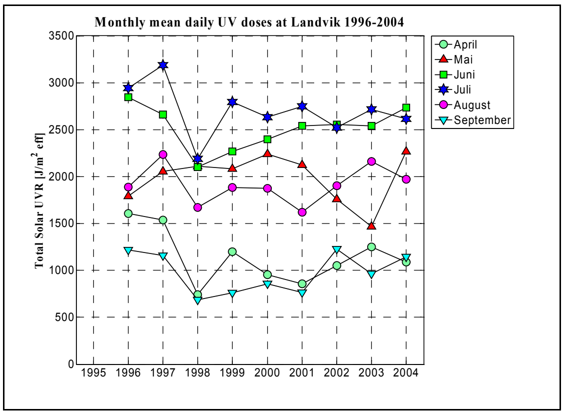

Figure 28. Monthly mean daily UV dose at Landvik.

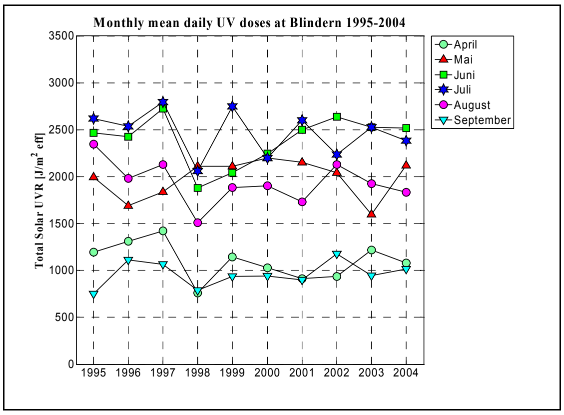

Figure 29. Monthly mean daily UV dose at Blindern.

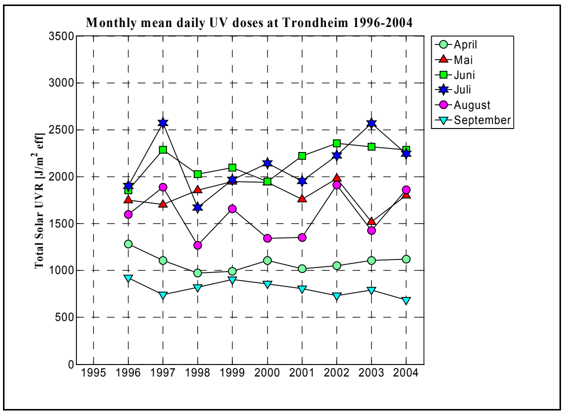

Figure 30. Monthly mean daily UV dose at Trondheim.

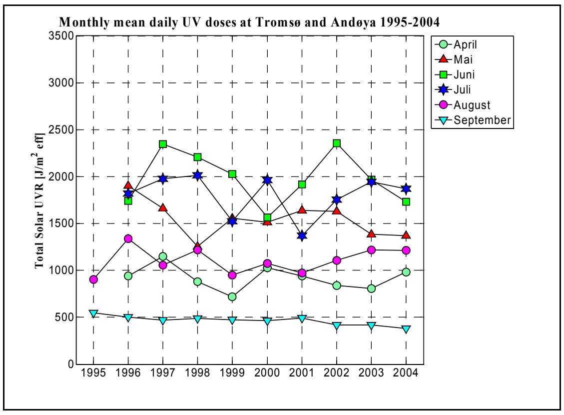

Figure 31. Monthly mean daily UV dose at Tromsø/Andøya.

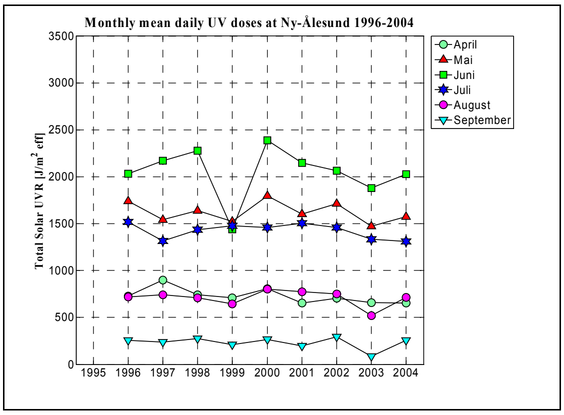

Figure 32. Monthly mean daily UV dose at Ny-Ålesund.

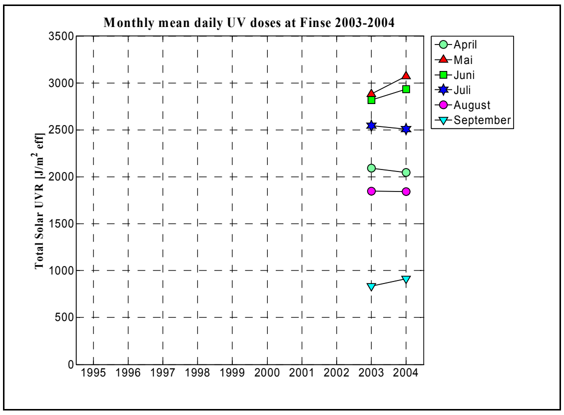

Figure 33. Monthly mean daily UV dose at Finse.

The pie charts in figure 34 and 35 show the monthly contribution to the UV dose at Landvik and Andøya.

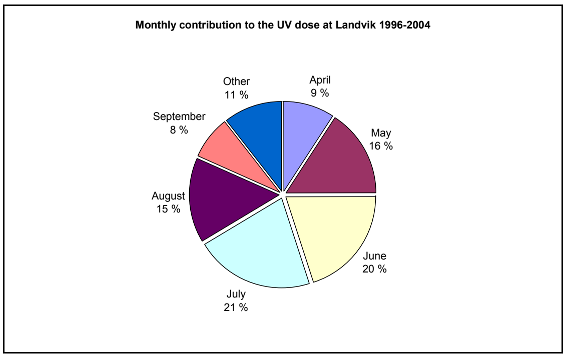

Figure 34. Monthly contribution to the UV dose at Landvik.

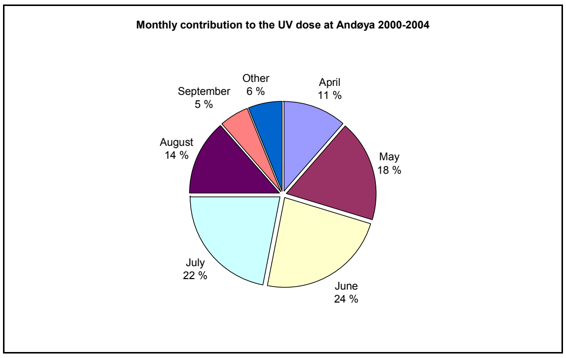

Figure 35. Monthly contribution to the UV dose at Andøya.

At Andøya the summer months and especially June contributes more to the total yearly UV dose than at Landvik, and the spring months contribute more than the autumn months compared with Landvik.

6.2 UV index

Figure 36 shows the average maximum UV index for each month over the measurement period 1996-2004 for all locations.

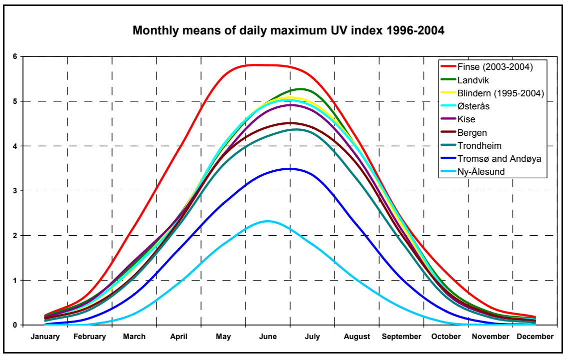

Figure 36. Monthly means of daily maximum UV index.

As for the annual dose there is little difference between the four locations in southern Norway. Landvik has slightly higher values than Østerås, Blindern and Kise, but the UV index typically tops around 5. Trondheim and Bergen have similar values with a maximum value around 4.5. The maximum UV index is in June or July except for Finse where the maximum so far has been in May. Finse has clearly the highest UV index over the whole year. Especially high are the values in April and May compared to the other locations. The UV index in late April at Finse is equal to the midsummer value in the south-eastern part of Norway.

Location	Absolute max	Typical max
Landvik	7.7	5.6
Blindern	6.6	5.4
Østerås	6.6	5.4
Bergen	6.7	5.2
Finse	7.7	6.8
Kise	6.9	5.3
Trondheim	6.8	5.2
Andøya	5.2	4.2
Tromsø	4.9	4.2
Ny-Ålesund	3.3	2.8

Table 3. The absolute maximum UV indexes measured at all locations around midsummer together with the typical maximum values with clear sky and normal ozone levels.

Table 3 shows the absolute maximum UV index recorded in the measurement period at each location. It also shows the typical maximum clear sky UV index at midsummer with normal ozone values. The high absolute maxima are caused by low ozone values or thin clouds reflecting the sunlight and thereby increasing the UV intensity for short time periods.

On a sunny midsummer day the maximum UV index at Landvik is twice the value at Ny-Ålesund. The daily dose is only 25% larger because of the dose contribution from the midnight sun at Ny-Ålesund, as shown in figure 37.

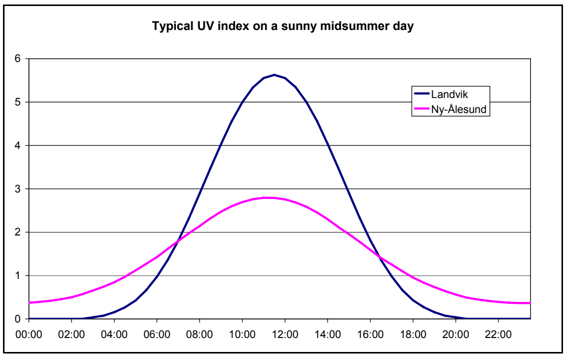

Figure 37. Typical UV index on a sunny midsummer day at Landvik and at Ny-Ålesund. The time scale is UTC.

6.3 UV trends

There are no statistically significant trends in the measured UV data. There are large natural fluctuations. 1997 was a year with high UV doses and in 1998 the UV doses were low. The values from all the other years lie between. The locations Tromsø/Andøya and Ny-Ålesund have smaller fluctuations. The measurement period is too short to observe possible long-term changes, and it is probably necessary to measure the UV for several decades to detect any trends. To be able to see small trends one has to exclude ozone and the attenuation of UV because of clouds. This has been done in a publication that has estimated the UV doses at Davos in Switzerland from 1926 to 2003, see [2]. The results show a distinct increase in the UV level since 1980 caused mainly by the reduction of total ozone.

7 Discussion

There are large natural daily and annual variations in the measurements. The solar zenith angle is the most important factor for the UV index, and the UV radiation decreases with increasing latitudes. Typical maximum UV indexes at 58°N, 69°N and 79°N (Landvik, Tromsø/Andøya and Ny-Ålesund) are 5.6, 4.2 and 2.8, referring to tables 1 and 3. The maximum UV index decreases with 1.4 with a 10° increase in latitude. The average annual UV doses at the three locations are 385, 255 and 212 kJ/m² and decrease less with increasing latitudes than the maximum UV index because of the long summer days in northern parts of Norway. The UV level at Finse is higher than one would expect from the latitude due to snow cover and higher altitude.

The logging PCs operate automatically and require minimal maintenance. However, daily inspections of the GUVs are required to maintain the quality of the UV measurements. The continuity in the UV measurements has been good and has become better the last three years compared to previous years giving lower total loss of UV data. The average total percentage loss of annual dose is 1.7% for the entire period, and the average loss over the last three years is reduced to 0.5%. All stations except Blindern show equal or less loss of data compared to previous years. Gaps in UV data are estimated giving low uncertainty in the UV doses for most locations. Blindern had more loss of data in 2004 due to technical data problems.

8 Conclusions and recommendations

The Norwegian UV network has provided high quality UV data from nine locations spread across the mainland and Svalbard. The UV instruments measure the daily and seasonal variations in the UV radiation from the sun, and the data is presented on the Internet. The accuracy of the measurements is very good, but the time period from 1996 to 2004 is too short to reach any conclusions about statistically significant trends because the natural variations from one year to another are large.

Recommendations for improvement mentioned in [1] have been followed up. Power backup systems with uninterruptible power supplies are now installed at all network locations where this is necessary. Lighting protection units which prevents electric shocks through the power line, phone line or network connection are also installed. Fractured end caps are replaced on the GUVs at Landvik, in Bergen and on the reference instrument.

Below are recommendations for future improvement of the UV network:

- Purchase and implement one new GUV instrument each year to replace old instruments.
- Replace fractured end caps on top of GUVs at Kise and in Trondheim.
- Do lamp calibrations more often to increase and test the stability of the GUVs, maybe twice a year instead of once a year.
- Further develop NRPA's Internet pages and make it possible to download UV data via Internet.
- Install new logging PCs with new software developed at NRPA to ensure logging stability at the network locations.

9 Acknowledgements

We would like to thank the personnel at the network sites and NILU/SFT for the cooperation. We also would like to thank Jon Harald Tallhaug at Statens kartverk (Norwegian Mapping Authority) for the altitude information of the measurement locations.

10 References

1. Johnsen BJ, Mikkelborg O, Hannevik M, Nilsen LT, Saxebøl G, Blaasaas KG. The Norwegian UV monitoring program. Period 1995/96 to 2001. Strålevern-Rapport 2002:4. Østerås: Norwegian Radiation Protection Authority, 2002.
2. Lindfors, A. and L. Vuilleumier (2005). Erythemal UV at Davos (Switzerland), 1926-2003, estimated using total ozone, sunshine duration and snow depth. J. Geophys. Res., 110, D02104, doi:10.1029/2004JD005231.
3. WHO's pages about INTERSUN and UV, http://www.who.int/uv/en/

A Appendix

A.1 Number of days with gaps and fractional loss of UV dose

Table 4 below shows annual number of days with significant (>10%) loss of UV dose at each measurement location for the different years. There are three columns for each year and location. The first number is the total number of days with gaps. The second number excludes calibration days and the third number also excludes data lost during start-up days at the locations. The "Total"-columns show the added number of days with gaps for each location. The "Total"-row shows the added number of days with gaps for each year.

	1996			1997			1998			1999			2000		
Østerås										85	85	7	15	12	12
Kise	25	25	4	2	2	2	8	8	8	0	0	0	9	9	9
Bergen	40	40	1	0	0	0	133	0	0	66	4	4	24	5	5
Landvik	35	35	10	10	10	10	5	5	5	10	10	10	0	0	0
Blindern	7	7	7	0	0	0	2	2	2	21	3	3	8	1	1
Trondheim	4	4	4	0	0	0	25	0	0	4	4	4	10	10	10
Tromsø	29	29	28	17	17	17	52	23	23	15	15	15			
Ny-Ålesund	5	5	5	7	7	7	16	16	16	6	6	6	17	17	17
Andøya													72	72	16
Finse															
Total	145	145	59	36	36	36	241	54	54	207	127	49	155	126	70

	2001			2002			2003			2004			Total		
Østerås	7	2	2	3	2	2	2	1	1	1	1	1	113	103	25
Kise	13	13	13	4	4	4	0	0	0	0	0	0	61	61	40
Bergen	0	0	0	3	3	3	1	1	1	0	0	0	267	53	14
Landvik	0	0	0	1	1	1	6	6	6	0	0	0	67	67	42
Blindern	8	8	8	2	2	2	3	3	3	8	8	8	59	34	34
Trondheim	11	11	11	5	5	5	0	0	0	0	0	0	59	34	34
Tromsø													113	84	83
Ny-Ålesund	7	7	7	1	1	1	3	3	3	14	14	14	76	76	76
Andøya	79	79	79	17	17	17	17	17	17	5	5	5	190	190	134
Finse							65	65	5	1	1	1	66	66	6
Total	125	120	120	36	35	35	97	96	36	29	29	29	1071	768	488

Table 5 below shows the fractional loss of annual UV dose. The first number in each column is the fraction of the total dose that is lost that year, while the second column excludes loss due to calibrations and start-up delays. The column "Total" shows the cummulated fractional loss of dose for each station for the complete measurement period of that location. The values are calculated by dividing the added estimated lost dose by the added estimated total dose for all days in each year.

	1996		1997		1998		1999		2000	
Østerås							4.28%	0.87%	1.87%	0.48%
Kise	0.38%	0.24%	0.09%	0.09%	1.21%	1.21%	0.00%	0.00%	5.13%	5.13%
Bergen	1.00%	0.26%	0.00%	0.00%	8.91%	0.00%	4.54%	3.19%	3.90%	0.55%
Landvik	3.33%	3.14%	1.79%	1.79%	0.89%	0.89%	1.40%	1.40%	0.00%	0.00%
Blindern	0.77%	0.77%	0.01%	0.01%	0.01%	0.01%	0.30%	0.15%	0.12%	0.07%
Trondheim	0.04%	0.04%	0.00%	0.00%	1.84%	0.00%	1.55%	1.55%	0.79%	0.79%
Tromsø	7.03%	7.03%	1.79%	1.79%	10.42%	10.21%	1.21%	1.21%		
Ny-Ålesund	0.69%	0.69%	4.02%	4.02%	8.45%	8.45%	0.15%	0.15%	0.30%	0.30%
Andøya									7.13%	4.96%
Finse										

	2001		2002		2003		2004		Total	
Østerås	2.62%	0.22%	0.13%	0.12%	0.23%	0.13%	0.00%	0.00%	1.49%	0.30%
Kise	2.92%	2.92%	0.81%	0.80%	0.00%	0.00%	0.00%	0.00%	1.13%	1.11%
Bergen	0.00%	0.00%	0.59%	0.59%	0.06%	0.06%	0.00%	0.00%	1.99%	0.51%
Landvik	0.00%	0.00%	0.01%	0.01%	3.66%	3.66%	0.01%	0.01%	1.27%	1.25%
Blindern	0.73%	0.73%	0.73%	0.73%	0.36%	0.36%	1.75%	1.75%	0.54%	0.51%
Trondheim	4.22%	4.22%	0.40%	0.40%	0.00%	0.00%	0.00%	0.00%	0.94%	0.75%
Tromsø									5.16%	5.11%
Ny-Ålesund	0.05%	0.05%	0.00%	0.00%	0.05%	0.05%	1.06%	1.06%	1.70%	1.70%
Andøya	15.61%	15.61%	1.18%	1.18%	1.90%	1.90%	0.22%	0.22%	5.10%	4.67%
Finse					3.23%	1.12%	0.05%	0.05%	1.62%	0.58%

A.2 Measurement uncertainty

Table 6. Uncertainty budget for spectral sky measurements with NRPA's spectroradiometer Bentham DM150 in the wavelength interval 300-400 nm.

Error sources, 2 sigma level	**Uncertainty [%]**
Calibration lamps	3
Transfer of calibrations	2
Relative lamp measurements	1
Wavelength shift accuracy, 0.05 nm	1
Intensity linearity	1
Intensity hysteresis effects	1.5
Repeatability	1
Integrated cosine error	1.6
Total uncertainty, 2 sigma level	**5**

Table 7. Uncertainty budget for spectral sky measurement with GUV instruments.

Error sources, 2 sigma level	**Uncertainty [%]**
Absolute calibration, NOGIC 2000	5
Estimated drift in transfer-standard-GUVs from lamp calibrations	1
Estimated drift in local GUVs from annual solar intercomparisons	2
Intensity linearity	1
Dirt accumulation	2
Temperature	0.5
Total uncertainty, 2 sigma level	**6**

A.3 Long-term GUV stability

The figures below show the relative changes in the absolute response of the five detector channels for all the GUV instruments.

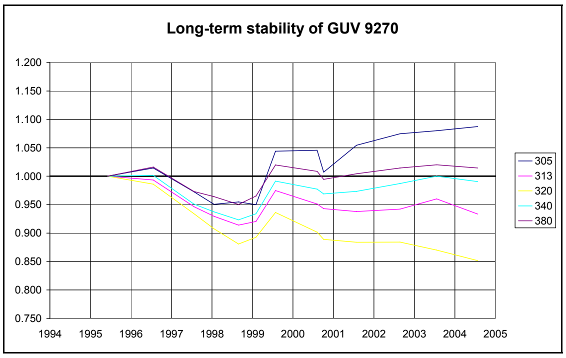

Figure 38. Annual drift factors for GUV 9270 - Bergen. In 1998-1999 this GUV had a water leakage.

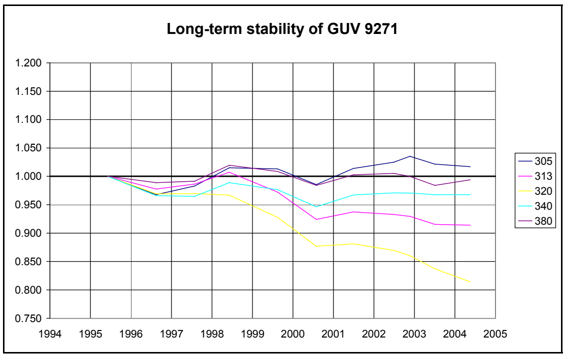

Figure 39. Annual drift factors for GUV 9271 - Landvik.

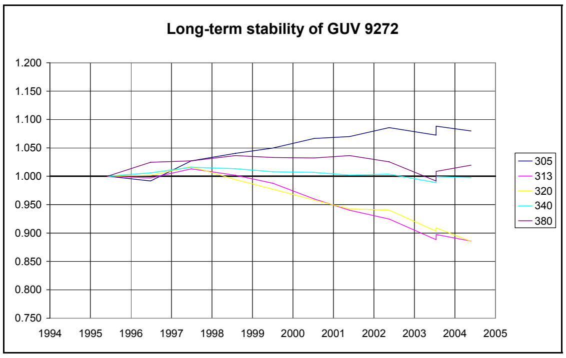

Figure 40. Annual drift factors for GUV 9272 - Kise. An attempt to replace the top in 2003 failed, and the old top was put back. The operation caused a small jump in the response.

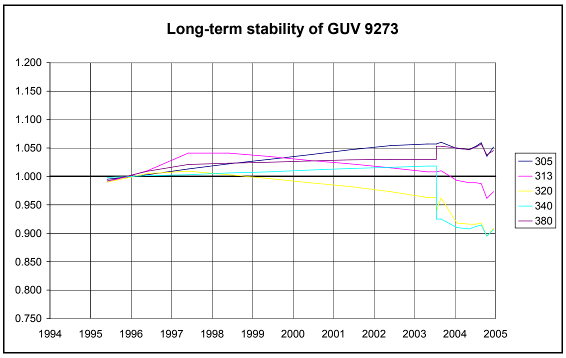

Figure 41. Annual drift factors for GUV 9273 - reference. In 2002 Biosperical Instruments changed the old cracked end cap, and in 2003 the instrument failed due to water leakage in the new cap. The instrument was dried out and the filters cleaned, but the stability has been poor since the incident.

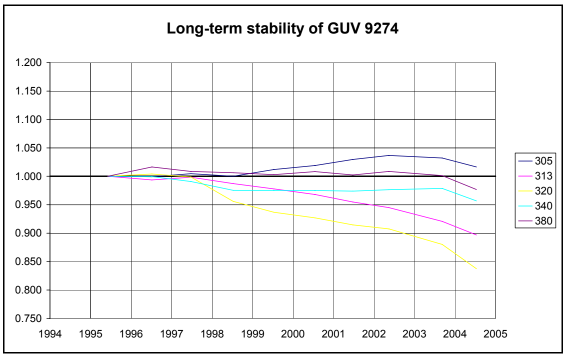

Figure 42. Annual drift factors for GUV 9274 - Trondheim.

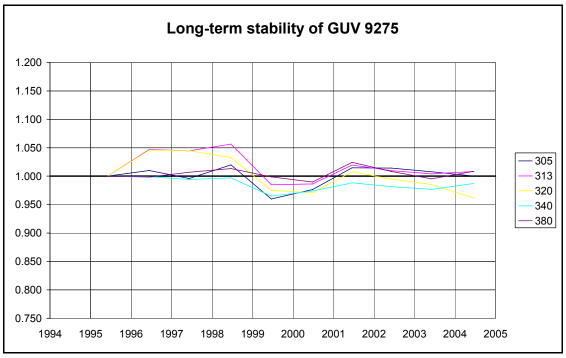

Figure 43. Annual drift factors for GUV 9275 - Ny-Ålesund.

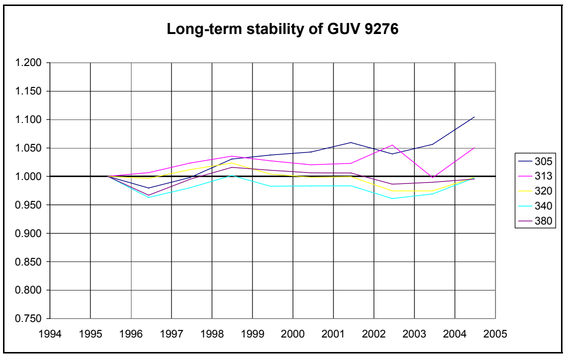

Figure 44. Annual drift factors for GUV 9276 - Tromsø/Andøya. Water leakage in February 2005 was attempted fixed by NILU. Total water leak in May/June 2005. Top replaced and filters cleaned in July 2005.

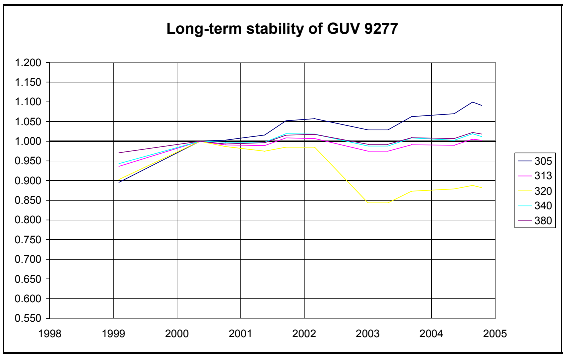

Figure 45. Annual drift factors for GUV 9277 – Østerås. The 320-channel failed in 2002. The GUV was sent to Biospherical Instuments for service. Note shift in response after service.

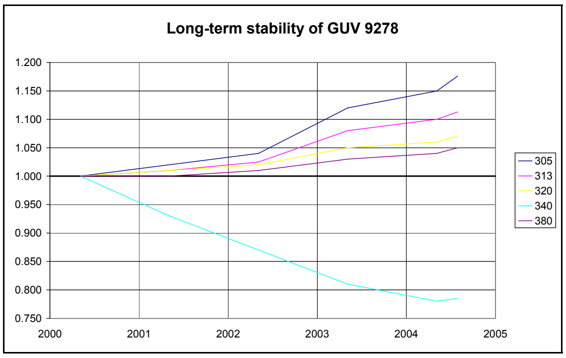

Figure 46. Annual drift factors for GUV 9278 – Østerås/backup.

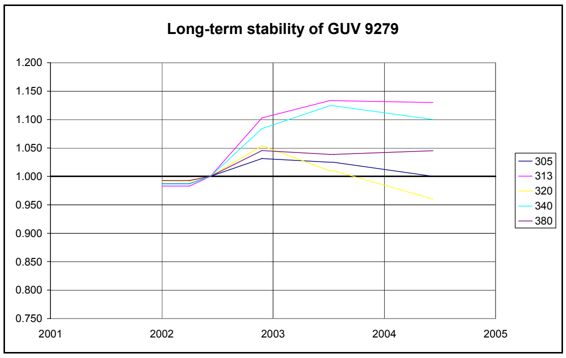

Figure 47. Annual drift factors for GUV 9279 - Finse.

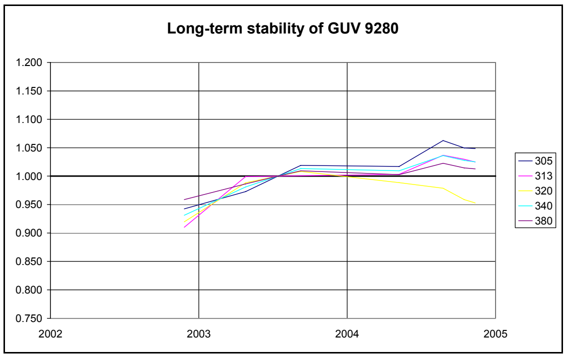

Figure 48. Annual drift factors for GUV 9280 - backup.

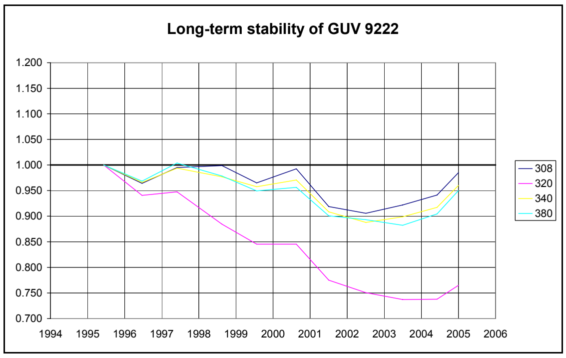

Figure 49. Annual drift factors for GUV 9222 - Blindern.

Table 8. Annual drift factors for GUV instruments.

The tables below show the correction factors presented in the previous graphs.

GUV 9270 - Bergen					
Year	305	313	320	340	380
1995.43	1.000	1.000	1.000	1.000	1.000
1996.55	1.014	0.993	0.986	1.001	1.016
1997.56	0.973	0.946	0.934	0.951	0.973
1998.05	0.951	0.930	0.908	0.938	0.964
1998.66	0.955	0.914	0.881	0.923	0.950
1999.09	0.950	0.921	0.893	0.934	0.965
1999.57	1.044	0.975	0.936	0.991	1.020
2000.60	1.046	0.951	0.901	0.977	1.009
2000.76	1.007	0.943	0.889	0.969	0.995
2001.57	1.054	0.938	0.884	0.973	1.004
2002.65	1.075	0.942	0.884	0.987	1.014
2003.55	1.080	0.960	0.870	1.000	1.020
2004.57	1.087	0.933	0.851	0.991	1.014

GUV 9271 - Landvik					
Year	305	313	320	340	380
1995.43	1.000	1.000	1.000	1.000	1.000
1996.62	0.968	0.977	0.969	0.966	0.989
1997.57	0.983	0.986	0.970	0.965	0.991
1998.43	1.015	1.007	0.967	0.989	1.019
1999.62	1.013	0.972	0.928	0.976	1.009
2000.58	0.985	0.924	0.877	0.946	0.984
2001.49	1.014	0.937	0.881	0.967	1.002
2002.49	1.025	0.933	0.869	0.971	1.005
2002.89	1.035	0.929	0.860	0.970	1.000
2003.51	1.022	0.915	0.837	0.968	0.984
2004.38	1.017	0.914	0.814	0.968	0.994

GUV 9272 - Kise					
Year	305	313	320	340	380
1995.43	1.000	1.000	1.000	1.000	1.000
1996.48	0.992	0.997	1.001	1.006	1.025
1997.49	1.027	1.013	1.017	1.016	1.027
1998.58	1.040	1.002	0.994	1.013	1.036
1999.50	1.050	0.988	0.977	1.008	1.033
2000.52	1.067	0.960	0.958	1.007	1.032
2001.40	1.070	0.940	0.942	1.002	1.036
2002.38	1.086	0.925	0.940	1.004	1.025
2003.53	1.072	0.888	0.904	0.989	0.992
2003.54	1.088	0.897	0.909	0.999	1.009
2004.40	1.080	0.886	0.885	0.998	1.019

GUV 9273 - Reference					
Year	305	313	320	340	380
1995.41	0.995	0.990	0.990	0.998	0.992
1996.41	1.003	1.010	1.005	1.001	1.009
1997.41	1.013	1.041	1.009	1.003	1.021
1998.41	1.022	1.041	1.003	1.006	1.023
1999.41	1.030	1.035	0.996	1.008	1.025
2000.41	1.038	1.028	0.989	1.011	1.027
2001.41	1.047	1.022	0.982	1.014	1.029
2002.41	1.054	1.015	0.973	1.016	1.030
2003.32	1.057	1.008	0.963	1.018	1.030
2003.54	1.057	1.008	0.963	1.018	1.030
2003.54	1.057	1.008	0.939	0.925	1.053
2003.66	1.060	1.010	0.962	0.925	1.053
2004.04	1.049	0.993	0.918	0.910	1.050
2004.35	1.047	0.989	0.916	0.907	1.047
2004.52	1.053	0.989	0.916	0.912	1.052
2004.65	1.059	0.987	0.918	0.915	1.057
2004.79	1.035	0.961	0.895	0.895	1.038
2004.95	1.051	0.973	0.909	0.906	1.046

GUV 9274 - Trondheim					
Year	305	313	320	340	380
1995.43	1.000	1.000	1.000	1.000	1.000
1996.52	0.999	0.994	1.004	1.000	1.016
1997.48	1.005	0.998	0.999	0.991	1.009
1998.52	1.000	0.987	0.956	0.975	1.006
1999.53	1.012	0.978	0.937	0.975	1.003
2000.54	1.019	0.968	0.927	0.975	1.008
2001.48	1.030	0.955	0.915	0.974	1.002
2002.37	1.037	0.945	0.907	0.977	1.009
2003.68	1.032	0.921	0.880	0.979	1.001
2004.53	1.016	0.897	0.837	0.957	0.977

GUV 9275 - Ny-Ålesund					
Year	305	313	320	340	380
1995.43	1.000	1.000	1.000	1.000	1.000
1996.45	1.010	1.047	1.046	0.999	0.998
1997.44	0.996	1.045	1.045	0.994	1.007
1998.47	1.020	1.056	1.033	0.997	1.013
1999.46	0.960	0.985	0.975	0.965	0.999
2000.48	0.976	0.986	0.971	0.974	0.990
2001.46	1.015	1.019	1.008	0.988	1.024
2002.43	1.014	1.010	0.995	0.981	1.008
2003.42	1.008	1.004	0.985	0.977	0.995
2004.47	1.000	1.008	0.961	0.987	1.009

GUV 9276 - Tromsø/Andøya					
Year	305	313	320	340	380
1995.43	1.000	1.000	1.000	1.000	1.000
1996.44	0.979	1.007	0.997	0.963	0.967
1997.47	0.998	1.023	1.012	0.980	0.995
1998.49	1.031	1.036	1.023	1.002	1.016
1999.45	1.037	1.027	1.004	0.983	1.011
2000.45	1.043	1.020	0.998	0.983	1.006
2001.43	1.060	1.023	0.999	0.984	1.006
2002.45	1.040	1.055	0.974	0.961	0.986
2003.45	1.056	0.998	0.975	0.969	0.990
2004.48	1.105	1.050	0.999	0.997	0.995

GUV 9277 - Østerås					
Year	305	313	320	340	380
1999.09	0.895	0.936	0.903	0.943	0.970
2000.36	1.000	1.000	1.000	1.000	1.000
2000.76	1.003	0.991	0.987	0.997	0.993
2001.38	1.016	0.989	0.974	0.997	0.996
2001.71	1.052	1.009	0.985	1.019	1.015
2002.16	1.057	1.007	0.985	1.018	1.017
2003.00	1.028	0.975	0.843	0.987	0.992
2003.32	1.028	0.975	0.843	0.987	0.992
2003.69	1.062	0.991	0.873	1.008	1.009
2004.36	1.070	0.990	0.879	1.002	1.007
2004.65	1.099	1.005	0.887	1.019	1.022
2004.79	1.091	1.002	0.882	1.012	1.018

GUV 9278 - Østerås / backup					
Year	305	313	320	340	380
2000.34	1.000	1.000	1.000	1.000	1.000
2001.34	1.020	1.010	1.010	0.930	1.000
2002.34	1.040	1.025	1.020	0.870	1.010
2003.34	1.120	1.080	1.050	0.810	1.030
2004.34	1.150	1.100	1.060	0.780	1.040
2004.58	1.176	1.113	1.070	0.785	1.050

GUV 9279 - Finse					
Year	305	313	320	340	380
2002.00	0.987	0.983	0.991	0.986	0.993
2002.25	0.987	0.983	0.991	0.986	0.993
2002.44	1.000	1.000	1.000	1.000	1.000
2002.90	1.031	1.103	1.054	1.084	1.045
2003.51	1.025	1.133	1.010	1.124	1.039
2003.54	1.025	1.133	1.010	1.124	1.039
2004.44	1.000	1.130	0.960	1.100	1.045

GUV 9280 - Backup					
Year	305	313	320	340	380
2002.90	0.943	0.910	0.920	0.931	0.959
2003.32	0.973	0.999	0.988	0.981	0.986
2003.53	1.000	1.000	1.000	1.000	1.000
2003.69	1.019	1.001	1.008	1.013	1.009
2004.35	1.017	1.003	0.989	1.009	1.003
2004.65	1.062	1.037	0.979	1.036	1.023
2004.79	1.049	1.029	0.959	1.028	1.014
2004.86	1.048	1.025	0.953	1.025	1.013

GUV 9222 - Blindern					
Year	308	313	320	340	380
1995.43	1.000	-	1.000	1.000	1.000
1996.47	0.964	-	0.941	0.966	0.969
1997.41	0.995	-	0.947	0.994	1.004
1998.62	0.999	-	0.884	0.977	0.979
1999.56	0.965	-	0.845	0.958	0.949
2000.63	0.992	-	0.845	0.971	0.956
2001.50	0.919	-	0.775	0.908	0.901
2002.50	0.906	-	0.751	0.888	0.893
2003.50	0.922	-	0.737	0.899	0.882
2004.42	0.941	-	0.738	0.917	0.904
2005.00	0.985	-	0.765	0.960	0.950

A.4 UV doses and UV index

Table 9 below shows the annual integrated UV doses for the whole measurement period 1995/1996 to 2004. Table 10 shows the monthly means of daily UV doses, and table 11 shows the monthly means of the daily maximum UV index.

Dose in kJ/m²	**1995**	**1996**	**1997**	**1998**	**1999**
Østerås	0.00	0.00	0.00	0.00	363.37
Kise	0.00	388.02	400.76	321.52	367.28
Bergen	0.00	328.31	333.28	277.56	310.80
Landvik	0.00	421.17	436.24	332.17	372.33
Blindern	382.26	381.75	407.60	316.82	363.89
Trondheim	0.00	318.31	342.30	289.59	318.59
Tromsø	0.00	271.19	282.30	261.58	234.88
Ny-Ålesund	0.00	219.80	218.19	221.76	188.63
Andøya	0.00	0.00	0.00	0.00	0.00
Finse	0.00	0.00	0.00	0.00	0.00

Dose in kJ/m²	2000	2001	2002	2003	2004
Østerås	356.23	363.04	388.47	373.51	368.23
Kise	352.37	348.13	365.85	365.46	365.49
Bergen	312.16	314.56	323.33	314.57	323.54
Landvik	374.98	360.74	376.32	384.99	403.65
Blindern	357.58	364.44	376.48	367.96	371.94
Trondheim	314.35	306.67	342.18	326.39	335.44
Tromsø	0.00	0.00	0.00	0.00	0.00
Ny-Ålesund	234.95	215.22	218.30	186.96	205.70
Andøya	248.37	240.61	263.07	249.68	246.74
Finse	0.00	0.00	0.00	461.72	470.25

Table 10. Monthly means of daily UV doses.

Østerås	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January	0	0	0	0	50	71	50	60	59	49
February	0	0	0	0	203	196	200	180	207	219
March	0	0	0	0	369	678	532	717	661	604
April	0	0	0	0	1154	1011	916	1034	1245	1095
May	0	0	0	0	2116	2237	2140	2063	1572	2072
June	0	0	0	0	2050	2228	2460	2711	2499	2449
July	0	0	0	0	2706	2137	2590	2204	2536	2383
August	0	0	0	0	1867	1878	1706	2160	1960	1786
September	0	0	0	0	918	924	883	1190	963	989
October	0	0	0	0	315	205	250	265	412	261
November	0	0	0	0	87	45	101	85	68	99
December	0	0	0	0	42	29	44	42	40	35

Kise	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January	0	62	67	63	51	62	47	57	61	42
February	0	293	185	195	209	201	191	187	258	224
March	0	908	673	592	473	687	579	599	796	689
April	0	1541	1456	800	1194	1145	961	948	1267	1076
May	0	1592	1797	2115	2070	2106	2023	2008	1610	1945
June	0	2449	2655	1925	2086	2340	2467	2603	2417	2465
July	0	2405	2876	2038	2677	2079	2381	2098	2494	2415
August	0	1964	2007	1558	1905	1808	1665	2047	1705	1789
September	0	1103	969	819	917	825	704	1066	915	947
October	0	262	334	303	307	198	238	248	355	248
November	0	88	69	69	84	51	92	74	58	84
December	0	35	24	31	32	19	35	36	30	29

Bergen	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January	0	55	40	41	31	42	48	38	38	42
February	0	174	103	109	115	138	148	128	172	153
March	0	716	349	376	323	446	481	437	425	503
April	0	1167	1133	932	992	1003	991	897	1208	906
May	0	1514	1839	2022	1917	1931	1885	1907	1337	1834
June	0	2264	2308	1743	1777	1975	2162	2185	1910	2199
July	0	1707	2283	1457	2130	2140	1905	1800	2386	2153
August	0	1673	1792	1251	1816	1311	1367	1807	1722	1686
September	0	1123	689	758	688	876	962	929	685	713
October	0	247	254	290	277	237	240	332	307	295
November	0	82	78	74	58	84	75	81	73	69
December	0	29	30	24	26	22	31	33	25	20

Landvik	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January	0	57	82	77	64	92	42	62	72	50
February	0	260	186	218	220	213	215	191	182	261
March	0	740	672	614	386	629	479	639	687	617
April	0	1607	1538	742	1199	955	856	1052	1249	1089
May	0	1792	2053	2112	2082	2242	2125	1759	1469	2267
June	0	2846	2660	2100	2267	2397	2543	2553	2539	2733
July	0	2941	3189	2187	2795	2635	2748	2523	2718	2616
August	0	1890	2236	1670	1884	1875	1622	1901	2163	1973
September	0	1218	1157	688	762	858	765	1229	964	1146
October	0	274	381	315	357	253	242	284	428	290
November	0	114	72	88	106	67	119	80	72	112
December	0	51	38	41	48	32	40	44	50	48

Blindern	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January	57	55	60	56	50	65	46	51	52	37
February	173	247	160	180	203	180	197	168	179	202
March	498	732	671	586	347	656	502	546	603	577
April	1193	1311	1422	762	1143	1031	913	936	1217	1081
May	1997	1691	1839	2111	2110	2198	2152	2042	1596	2119
June	2465	2426	2725	1881	2041	2246	2500	2640	2525	2519
July	2620	2535	2796	2060	2748	2200	2600	2236	2525	2383
August	2348	1983	2130	1507	1883	1902	1732	2129	1924	1835
September	752	1110	1067	790	935	941	900	1176	943	1017
October	253	272	368	313	316	201	245	271	386	269
November	102	93	68	72	82	43	94	83	60	96
December	36	36	28	33	37	23	38	38	28	29

Trondheim	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January	0	40	25	29	23	24	31	27	29	33
February	0	163	117	102	114	121	119	118	151	116
March	0	605	438	402	410	475	473	442	431	450
April	0	1283	1107	975	992	1108	1020	1051	1109	1119
May	0	1752	1703	1858	1949	1939	1760	1980	1519	1800
June	0	1858	2288	2028	2095	1948	2222	2353	2317	2288
July	0	1903	2573	1671	1966	2142	1953	2228	2567	2246
August	0	1597	1887	1267	1658	1342	1352	1911	1428	1862
September	0	921	744	822	902	856	806	734	793	688
October	0	222	232	245	248	254	234	255	267	281
November	0	53	59	64	47	54	51	64	55	59
December	0	15	17	15	15	13	15	22	16	19

Tromsø	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January	0	4	5	2	5	0	0	0	0	0
February	0	76	64	52	59	0	0	0	0	0
March	0	405	378	312	264	0	0	0	0	0
April	0	939	1149	882	719	0	0	0	0	0
May	0	1905	1662	1255	1554	0	0	0	0	0
June	0	1741	2345	2208	2026	0	0	0	0	0
July	0	1821	1978	2015	1523	0	0	0	0	0
August	903	1340	1058	1217	950	0	0	0	0	0
September	550	500	469	489	473	0	0	0	0	0
October	135	107	119	108	103	0	0	0	0	0
November	13	15	14	16	11	0	0	0	0	0

December	2	3	0	2	0	0	0	0	0	0

Ny-Ålesund	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January	0	2	2	0	1	0	0	1	1	1
February	0	9	7	6	5	5	3	5	9	7
March	0	149	202	146	120	153	121	130	145	156
April	0	728	899	743	708	807	654	703	657	653
May	0	1740	1544	1641	1523	1795	1604	1712	1472	1573
June	0	2030	2171	2277	1439	2387	2149	2065	1879	2028
July	1554	1518	1313	1434	1479	1457	1506	1457	1333	1312
August	877	720	741	711	645	801	774	752	521	716
September	283	258	237	274	210	264	196	293	84	257
October	33	29	28	27	29	22	30	23	13	25
November	2	2	1	1	1	1	1	1	1	1
December	2	2	1	1	0	0	1	1	1	1

Andøya	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January	0	0	0	0	0	3	3	4	6	6
February	0	0	0	0	0	59	53	47	40	52
March	0	0	0	0	0	309	332	296	224	297
April	0	0	0	0	0	1029	940	841	807	981
May	0	0	0	0	0	1515	1639	1630	1387	1370
June	0	0	0	0	0	1566	1918	2354	1968	1733
July	0	0	0	0	0	1963	1373	1753	1943	1872
August	0	0	0	0	0	1074	973	1105	1218	1216
September	0	0	0	0	0	464	491	419	418	383
October	0	0	0	0	0	118	137	143	136	127
November	0	0	0	0	0	14	15	15	12	10
December	0	0	0	0	0	0	2	1	3	17

Finse	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January	0	0	0	0	0	0	0	0	56	95
February	0	0	0	0	0	0	0	0	267	340
March	0	0	0	0	0	0	0	0	1015	1025
April	0	0	0	0	0	0	0	0	2094	2048
May	0	0	0	0	0	0	0	0	2883	3074
June	0	0	0	0	0	0	0	0	2819	2935
July	0	0	0	0	0	0	0	0	2547	2510
August	0	0	0	0	0	0	0	0	1845	1841
September	0	0	0	0	0	0	0	0	836	913
October	0	0	0	0	0	0	0	0	537	389
November	0	0	0	0	0	0	0	0	141	155
December	0	0	0	0	0	0	0	0	69	61

Table 11. Monthly means of daily maximum UV index

Østerås	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January					0.13	0.20	0.15	0.18	0.18	0.16
February					0.51	0.50	0.49	0.45	0.49	0.53
March					0.81	1.47	1.17	1.55	1.42	1.38
April					2.53	2.33	2.05	2.27	2.37	2.55
May					4.12	4.21	4.03	4.04	3.65	4.11
June					4.56	4.77	4.78	5.22	5.14	5.11
July					5.24	4.55	5.06	4.74	4.94	4.80
August					3.85	4.10	3.82	4.09	3.97	3.86
September					2.24	2.09	2.29	2.67	2.35	2.38
October					0.83	0.67	0.71	0.73	0.99	0.77
November					0.25	0.17	0.27	0.24	0.21	0.29
December					0.12	0.09	0.13	0.13	0.14	0.11

Kise	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January		0.18	0.19	0.17	0.15	0.18	0.15	0.17	0.18	0.13
February		0.70	0.48	0.51	0.53	0.50	0.47	0.48	0.62	0.54
March		1.89	1.44	1.37	1.06	1.48	1.21	1.31	1.65	1.48
April		3.04	2.96	1.84	2.56	2.50	2.01	2.07	2.42	2.31
May		3.18	3.81	3.87	3.99	3.94	3.94	4.01	3.62	3.89
June		5.12	5.26	3.87	4.47	4.71	4.85	5.22	4.64	4.90
July		4.93	5.20	4.32	5.01	4.49	4.79	4.58	4.94	4.85
August		4.02	3.91	3.44	3.81	3.87	3.60	3.88	3.63	3.75
September		2.33	2.29	1.93	2.12	1.95	1.79	2.38	2.16	2.25
October		0.67	0.83	0.75	0.76	0.62	0.65	0.65	0.85	0.69
November		0.26	0.20	0.20	0.24	0.18	0.26	0.21	0.18	0.26
December		0.11	0.08	0.10	0.10	0.06	0.11	0.12	0.10	0.11

Bergen	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January		0.18	0.14	0.14	0.09	0.16	0.15	0.14	0.14	0.14
February		0.50	0.34	0.37	0.33	0.43	0.42	0.39	0.44	0.42
March		1.54	0.90	1.07	0.89	1.16	1.05	1.05	1.06	1.21
April		2.65	2.59	2.07	2.32	2.28	2.24	2.14	2.43	2.11
May		3.44	3.91	3.90	3.75	4.07	3.86	4.12	3.27	3.72
June		4.77	4.48	3.94	4.22	4.56	4.55	4.66	4.09	4.54
July		3.85	4.72	3.76	4.55	4.45	4.47	4.13	5.02	4.75
August		3.63	3.67	3.21	3.58	3.48	3.51	3.71	3.97	3.63
September		2.41	1.92	1.94	1.82	2.00	2.31	2.17	1.81	1.87
October		0.75	0.73	0.74	0.76	0.68	0.76	0.84	0.84	0.78
November		0.26	0.25	0.23	0.21	0.26	0.26	0.23	0.23	0.23
December		0.10	0.11	0.08	0.10	0.08	0.10	0.11	0.09	0.08

Landvik	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
January		0.17	0.23	0.22	0.19	0.27	0.14	0.19	0.21	0.16
February		0.67	0.53	0.62	0.59	0.56	0.54	0.53	0.46	0.63
March		1.68	1.54	1.43	0.96	1.47	1.07	1.40	1.46	1.33
April		3.34	3.08	1.78	2.47	2.19	1.89	2.33	2.53	2.27
May		3.63	4.19	3.99	4.09	4.31	4.08	3.77	3.38	4.29
June		5.37	4.99	4.21	4.76	5.14	4.83	5.15	4.93	5.43
July		5.46	5.51	4.85	5.17	4.96	5.21	5.00	5.39	5.30
August		3.82	4.31	3.81	3.84	4.15	3.61	3.65	4.48	4.07
September		2.75	2.66	1.84	1.95	2.16	1.99	2.65	2.36	2.55
October		0.73	0.98	0.88	0.97	0.79	0.73	0.80	1.05	0.83

November		0.33	0.22	0.26	0.31	0.25	0.33	0.25	0.23	0.32
December		0.16	0.13	0.13	0.15	0.11	0.12	0.14	0.16	0.16

Blindern	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January	0.17	0.16	0.18	0.17	0.15	0.19	0.14	0.15	0.16	0.12
February	0.44	0.61	0.44	0.49	0.52	0.47	0.47	0.44	0.43	0.49
March	1.14	1.59	1.49	1.39	0.85	1.43	1.10	1.21	1.34	1.31
April	2.58	2.80	3.00	1.89	2.57	2.39	2.00	2.05	2.32	2.45
May	4.09	3.66	3.97	4.01	4.14	4.23	4.18	3.96	3.67	4.16
June	5.29	4.95	5.32	3.90	4.85	4.94	4.82	5.18	5.16	5.26
July	4.92	5.15	5.31	4.64	5.32	4.66	5.25	4.72	4.91	4.68
August	4.36	3.97	4.19	3.39	3.95	4.09	3.88	4.06	3.90	3.95
September	1.93	2.35	2.46	1.84	2.28	2.14	2.26	2.59	2.29	2.36
October	0.73	0.74	0.91	0.81	0.84	0.66	0.70	0.72	0.93	0.77
November	0.28	0.28	0.22	0.21	0.24	0.17	0.26	0.23	0.19	0.27
December	0.11	0.11	0.09	0.11	0.10	0.08	0.12	0.12	0.09	0.09

Trondheim	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January		0.12	0.09	0.10	0.08	0.09	0.10	0.10	0.09	0.10
February		0.45	0.33	0.30	0.30	0.33	0.33	0.34	0.37	0.33
March		1.31	1.11	0.96	0.95	1.16	1.03	1.04	1.04	1.00
April		2.56	2.50	1.86	2.11	2.33	2.06	2.20	2.11	2.33
May		3.49	3.44	3.63	3.66	3.89	3.43	3.87	3.24	3.56
June		4.19	4.05	3.90	4.19	4.26	4.17	4.59	4.35	4.27
July		4.12	4.61	3.64	4.36	4.09	4.14	4.43	4.81	4.39
August		3.26	3.65	2.99	3.26	2.91	2.97	3.54	3.18	3.53
September		2.05	1.82	1.78	2.01	1.93	1.78	1.78	1.88	1.68
October		0.59	0.63	0.62	0.65	0.62	0.59	0.62	0.68	0.67
November		0.16	0.18	0.18	0.15	0.16	0.18	0.18	0.16	0.16
December		0.05	0.06	0.05	0.05	0.04	0.05	0.07	0.06	0.05

Tromsø	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January		0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00
February		0.20	0.17	0.15	0.15	0.00	0.00	0.00	0.00	0.00
March		0.83	0.78	0.66	0.56	0.00	0.00	0.00	0.00	0.00
April		1.80	2.12	1.57	1.38	0.00	0.00	0.00	0.00	0.00
May		3.09	2.82	2.43	2.56	0.00	0.00	0.00	0.00	0.00
June		3.28	3.77	3.47	3.40	0.00	0.00	0.00	0.00	0.00
July		3.28	3.62	3.25	3.14	0.00	0.00	0.00	0.00	0.00
August	2.11	2.45	2.12	2.20	2.06	0.00	0.00	0.00	0.00	0.00
September	1.19	1.13	1.05	1.05	1.01	0.00	0.00	0.00	0.00	0.00
October	0.33	0.29	0.29	0.27	0.26	0.00	0.00	0.00	0.00	0.00
November	0.03	0.04	0.04	0.05	0.03	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Ny-Ålesund	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
February		0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.02	0.02
March		0.26	0.33	0.25	0.20	0.27	0.20	0.22	0.25	0.26
April		0.93	1.18	0.93	0.88	1.04	0.86	0.90	0.85	0.87
May		1.91	1.72	1.82	1.73	1.96	1.73	1.86	1.69	1.76
June		2.28	2.33	2.49	1.87	2.63	2.42	2.34	2.17	2.34
July	1.95	1.98	1.87	1.71	1.77	1.85	1.84	1.79	1.70	1.70
August	1.25	1.07	1.12	1.00	0.93	1.14	1.07	1.04	0.68	1.01

September	0.44	0.44	0.41	0.44	0.38	0.44	0.36	0.48	0.14	0.42
October	0.07	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.03	0.06
November	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Andøya	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January						0.00	0.01	0.02	0.02	0.02
February						0.17	0.14	0.14	0.13	0.14
March						0.71	0.67	0.70	0.60	0.63
April						1.87	1.65	1.53	1.54	1.76
May						2.93	2.62	2.81	2.63	2.53
June						3.09	3.32	3.72	3.25	3.30
July						3.40	2.95	3.42	3.58	3.50
August						2.22	1.95	2.31	2.39	2.37
September						1.06	1.05	0.98	1.03	0.99
October						0.31	0.32	0.36	0.34	0.32
November						0.05	0.05	0.06	0.04	0.03
December						0.00	0.00	0.00	0.00	0.02

Finse	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
January									0.17	0.25
February									0.65	0.81
March									2.21	2.20
April									3.82	4.03
May									5.39	5.72
June									5.62	5.98
July									5.56	5.49
August									4.15	4.19
September									2.27	2.49
October									1.33	1.02
November									0.38	0.42
December									0.19	0.17

A.5 Glossary

action spectrum Indicates how effective the electromagnetic radiation causes a certain biological effect at different wavelengths.

CIE Spectral irradiance weighted with the action spectrum from Commision International de l'Eclairage for induction of erythema in caucasian skin types.

GUV Multiband filter-radiometer from Biospherical Instruments Inc. It measures UV radiation on different wavelength bands between 305 and 380 nm. See chapter 2.2.

irradiance Incoming radiation effect per unit area measured in W/m^2.

SQL Structured query language. Language for communication with databases.

UTC Coordinated Universal Time. International basis of civil and scientific time obtained from atomic clocks.

UV Ultraviolet radiation. Electromagnetic radiation in the wavelength region from 100 to 400 nanometer (10^{-9} m).

UV dose Measured amount of UV radiation energy over a given period of time in units of J/m^2.

UV index A number typically between 0 and 15 indicating the strength of the UV radiation from the sun. The number is calculated as CIE weighted irradiance given in units of W/m^2 multiplied by 40.

StrålevernRapport 2006:1
Virksomhetsplan 2006

StrålevernRapport 2006:2
Statens strålevern i Mammografiprogrammet
Resultater fra teknisk kvalitetskontroll hentet fra databaseprogrammet TKK

StrålevernRapport 2006:3
Avvikshåndtering ved norske stråleterapisentre

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