

Ozone/UV monitoring and research in Norway

Ozone monitoring and related research activities in Norway involve several institutions and there is no distinct separation between research, development, monitoring and quality control. This report presents Norwegian ozone & UV related activities that have been carried out the last years.

1. OBSERVATIONAL ACTIVITIES

In 1990 the Norwegian Environment Agency (the former Norwegian Pollution Control Authority) established the programme “*Monitoring of the atmospheric ozone layer*”, which included measurements of total ozone at selected sites in Norway. Some years later, in 1994/95, the network was expanded and “*The Norwegian UV network*” was established. It consists of nine 5-channel GUV instruments located at sites between 58°N and 79°N. In addition the network included ozone lidar measurements until 2011. The measurements are undertaken by the Norwegian Radiation Protection Authority, and the Norwegian Institute for Air Research on behalf of the Norwegian Environment Agency. NRPA is responsible for the quality assurance program of the UV-network and for reporting relevant health effects of natural UV radiation. Table 1 gives an overview of the location of the various stations, the type of measurements, and the institutions/institutes responsible for the daily operation of the instruments. The measurement sites are marked in Figure 1: Blue circles represent sites where both quality assured total ozone and UV measurements are performed, whereas green circles represent sites with UV measurements only.

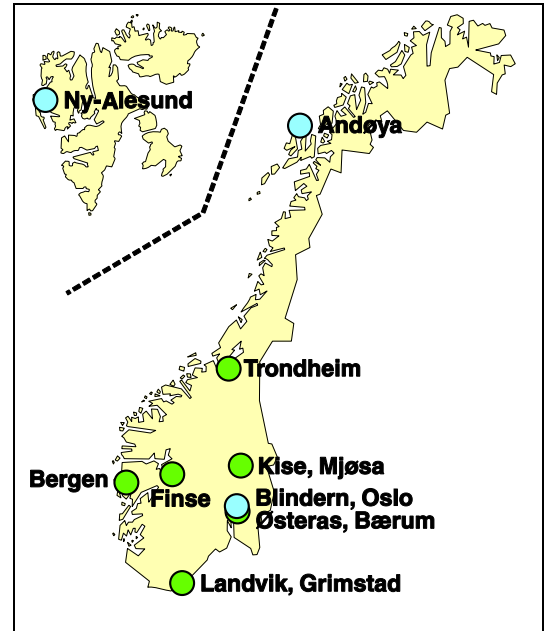


Figure 1: Map of Norwegian ozone and UV sites

Table 1: Overview of the locations and institutes involved in ozone and UV monitoring activities in Norway

Station	Location	UV	Total ozone	Ozone lidar	Institute
Landvik (Grimstad)	58°N, 08°E	GUV			Norwegian Radiation Protection Authority
Oslo	60°N, 10°E	GUV	Brewer, GUV		University of Oslo/ Norwegian Institute for Air Research
Østerås	60°N, 10°E	GUV, Bentham			Norwegian Radiation Protection Authority
Bergen	60°N, 05°E	GUV			Norwegian Radiation Protection Authority
Finse	60°N, 07°E	GUV			Norwegian Radiation Protection Authority
Kise	60°N, 10°E	GUV			Norwegian Radiation Protection Authority
Trondheim	63°N, 10°E	GUV			Norwegian Radiation Protection Authority
Andøya	69°N, 16°E	GUV	Brewer, GUV	x	Norwegian Institute for Air Research /Andøya Space Center
Ny-Ålesund	79°N, 12°E	GUV	SAOZ, GUV		Norwegian Institute for Air Research
Antarctica	72°S, 02°E	NILU-UV	NILU-UV		Norwegian Institute for Air Research

1.1 Column measurements of ozone

Total ozone measurements using the Dobson spectrophotometer D56 were performed on a regular basis in Oslo from 1978 to 1998. In Tromsø, Dobson measurements with D14 started back in 1939 and systematic measurements were performed until 1972. After a break of 12 years, the Tromsø

Dobson measurements started up again in 1985 and lasted until 1999. Quality-assured Dobson D8 measurements were also performed in Ny-Ålesund, Svalbard, from 1995 to 2007. In 2007 the measurements terminated due to technical failure.

Since the summer 1990 Brewer instrument no. 42 has been in operation at the University of Oslo (Blindern). In 1994 Brewer measurements (with B104) started up in Tromsø, but after the termination of other ozone-related activities at the Auroral Observatory in Tromsø in 1999, the instrument was moved to Andøya, 130 km southwest of Tromsø. Today daily total ozone values from Oslo and Andøya are primarily based on measurements with these Brewer spectrometers. The ozone values are derived from direct sun measurements when available. On overcast days and days where the solar zenith angle is large, the ozone values are calculated from the global irradiance (GI) method (Stamnes et al., 1991). Except for the period from 1973 to 1984, total ozone has been measured on a regular basis in Tromsø/Andøya since 1939, which makes this time series the second longest in the world. The Andøya site is no longer included in the national ozone monitoring programme, but financial funding from the Norwegian Ministry of Climate and Environment will ensure measurements in the future.

NILU - The Norwegian Institute for Air Research is also measuring total ozone in Svalbard. Since 1991 there has been a DOAS instrument (type SAOZ) in Ny-Ålesund measuring total columns of ozone and NO₂. These NO₂ and ozone measurements are a part of the Network for the Detection of Atmospheric Composition Change (NDACC). As SAOZ measurements only can provide ozone values at solar zenith angles > 85°, a GUV instrument is used to derive total ozone in Ny-Ålesund during summer. Recently, NILU has started a cooperation with CNR, Italy, to operate and quality-control common measurements with a Brewer instrument owned by CNR in Ny-Ålesund.

Since 2007, total ozone has also been measured by NILU at the Norwegian station Troll in Antarctica. This is done with the NILU-UV radiometer (see section 1.3). Currently, the complete data series is under re-evaluation.

1.2 Ozone profile measurements

An ozone lidar has been operated at ALOMAR (Andøya) since 1995. Initially, this was a cooperation project of the Norwegian Defence Research Establishment (FFI), NILU, and Andøya Rocket Range, from which FFI withdrew in 2006. Unfortunately the ozone lidar measurements were excluded from the national monitoring programme in 2011 due to lack of financial support with the consequence that also NILU had to withdraw from the cooperation. The lidar is still operational, but only operated occasionally by Andøya Rocket Range (now Andøya Space Center), and there is currently no funding for data analysis.

The lidar instrument was approved as a complementary site of the NDACC in 1997, and data were submitted to the NDACC database until 2011. The ozone lidar was also used to measure polar stratospheric clouds and stratospheric temperature profiles. Recently, all PSC observations have been re-evaluated systematically, both from ozone lidar measurements and measurements with the co-located Rayleigh-Mie-Raman lidar owned by the Leibniz Institute of Atmospheric Physics, Kühlungsborn, Germany. These data are available on request.

Ozonesonde measurements were performed from 4 sites on Norwegian territory in the 1990s and 2000s, but since 2007 only ozonesonde launches at Ny-Ålesund by Alfred-Wegener Institute, Germany, have continued. These are not part of the Norwegian ozone monitoring activities.

1.3 UV measurements

In total, nine sites are included in the Norwegian UV network. The instruments, GUV from Biospherical Instruments Inc, are designed to measure UV irradiances in 5 channels (except one instrument, which only has 4 channels). Using a technique developed by Dahlback (1996), it is possible to derive 9 different irradiance parameters, including complete UV spectra from 290 to 400 nm, biologically weighted UV doses for any action spectrum in the UV wavelength region, as well as total ozone column and cloud cover information.

Spectral UV irradiances (global scans) are measured regularly with the Brewer instruments at the Department of Physics, University of Oslo, and at Andøya (ALOMAR).

In January 2007 NILU started measurements with a filter instrument (the NILU-UV radiometer) at the Norwegian research station Troll in Antarctica, financed by the Norwegian Research Council. The instrument is calibrated every month against relative calibration lamps in order to keep track of instrument drift. In 2016, the instrument had to be replaced due to technical problems.

1.3 Measurements of Ozone-Depleting Substances (ODSs)

NILU is running an ADS-GCMS and a Medusa-GCMS at the Zeppelin Observatory, Svalbard, which provides high quality measurements of more than 20 ODSs regulated through the Montreal Protocol (Myhre et al, 2015). This is a part of the national programme for monitoring of greenhouse gases, financed by the Norwegian Environment Agency. Several CFCs are also measured at the Troll Observatory in Antarctica (www.nilu.no/Miljøovervåkning/Trollobservatoriet/tabid/213/Default.aspx).

1.4 Calibration activities

1.4.2 The Brewer instruments

The Brewer instruments in Oslo and at Andøya have been in operation for more than 20 years. Every year International Ozone Services, Canada, calibrates the Brewer instruments at both sites, and the instruments are also regularly calibrated against standard lamps in order to check their stability. The calibrations show that the Brewer instruments have been stable for most of the years of observations. The Andøya Brewer instrument has shown increased calibration instabilities since 2013, and especially in 2015 and early 2016. The issue is currently under discussion at IOS. Total ozone measurements from the Oslo Brewer instrument agreed well with the Dobson measurements performed during the period of overlapping measurements from 1991 to 1998.

1.4.3 The GUV instruments

As a part of the Norwegian FARIN project a major international UV instrument intercomparison was arranged back in 2005. Altogether 51 UV radiometers from various nations participated, among them 39 multiband filter radiometers (MBFR's). The instruments were also characterized on site. In addition to measurements of spectral responses, measurements against QTH lamps and cosine responses were performed for a selection of instruments. The main results have been published by Johnsen et al. (2008).

NRPA houses an optical calibration laboratory and facilities for outdoor calibrations. All the 13 GUV instruments in the Norwegian UV network are yearly calibrated on site against a travelling reference GUV, managed by NRPA. The travelling reference is traceable to the European travelling reference spectroradiometer QASUME, and regularly operated side by side a Bentham spectroradiometer operating at the roof of the NRPA building. Either reference instruments are regularly participating in blind test intercomparisons. Annual calibration factors are calculated for the GUV instruments prior to final publications of ozone and UVI. Currently, efforts are made to finance new instrumentation at the network locations, in order to ensure still continuous, high quality measurements, and to provide a wider spectral range and versatility of use of monitoring data.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Results from the national programme "*Monitoring of the atmospheric ozone layer and natural ultraviolet radiation*" are published by the Norwegian Environment Agency and NILU every year. Below are trend results from the last report (Svendby et al., 2016).

2.1 Ozone observations in Oslo

In order to detect possible ozone reductions and trends over Oslo, total ozone values from 1979 to 2015 have been investigated. For the period 1979 to 1998 data from the Dobson instrument has been applied, whereas for the period 1998 to 2015 the Brewer measurements have been used. The results of the trend analysis are summarized in Table 2. The second column indicates that a large ozone

decrease occurred during the 1980s and first half of the 1990s. For the period 1979-1997 there was a significant decline in total ozone for all seasons. For the winter and spring the decrease was as large as -6.2 %/decade and -8.4 %/decade, respectively. The negative ozone trend was less evident for the summer, but nevertheless it was significant to a 2σ level.

Table 2: Percentage changes in total ozone over Oslo for the period 1.1.1979 to 31.12.2015. The numbers in parenthesis represent uncertainty (1σ)

Time period	Trend (%/decade) 1979-1997	Trend (%/decade) 1998-2015
Winter (Dec – Feb)	-6.2 (2.4)	2.2 (2.3)
Spring (Mar– May)	-8.4 (1.4)	0.0 (1.9)
Summer (Jun – Aug)	-3.4 (1.1)	0.1 (1.0)
Fall (Sep – Nov)	-4.3 (1.0)	1.8 (1.2)
Annual (Jan-Dec)	-5.8 (1.0)	0.9 (1.1)

change compared to the trends in the previous report, which only included data until 2012 and which were still negative in 3 out of 4 seasons.

2.2 Ozone observations at Andøya

As mentioned above, ozone measurements in Northern Norway were performed in Tromsø until 1999 and at ALOMAR/Andøya from 2000. Correlation studies have shown that the ozone climatology is very similar at the two locations and that the two datasets are considered as equivalent representing one site.

Table 3: Percentage changes in total ozone over Andøya/Tromsø for the period 1979 to 2015. The numbers in parenthesis represent uncertainty (1σ).

Time period	Trend (%/decade) 1979-1997	Trend (%/decade) 1998-2015
Spring (Mar – May):	-8.4 (1.5)	0.7 (1.8)
Summer (Jun – Aug):	-2.8 (0.9)	0.5 (1.0)
Autumn (Sept – Oct):	-4.2 (1.1)	3.1 (0.7)
Annual (Mar – Oct):	-5.5 (0.9)	1.1 (1.0)

from 1979 to 1997. This decline was evident for all seasons. The negative trend for the spring season was as large as -8.4%/decade, whereas the negative trend for the summer months was -2.8%/decade and for autumn (September/October only) -4.2%/decade. The trend in annual (March – October) total ozone was -5.5%/decade. In contrast, all trends were positive in the period 1998 – 2015, but only the autumn value (+3.1%/decade) is significant at a 2σ level. Both trends in the autumn months are probably not caused by ozone depletion, but, as pointed out in Hansen and Svenøe (2005), due to long-term atmospheric changes (stratospheric temperature, tele-connection patterns).

For the period 1998-2015 the picture is very different. All seasonal trends as well as the annual trend are either zero or positive. However, none of the trend values are significant on a 2σ level. The largest positive trend (2.2%/decade) occurs in winter, while it is zero in summer. Although the trends are not significant on a 2σ level, they manifest a marked

During the years with absent Dobson total ozone measurements in Tromsø in 1979 and the 1980s, total ozone values from the satellite instrument TOMS (Total ozone Mapping Spectrometer) over Andøya were used in the trend studies. The results of the analyses are summarized in Table 3.

Similar to Oslo, the ozone layer above Andøya declined significantly

2.3 Ozone observations in Ny-Ålesund

The first Arctic ozone measurements started in Svalbard almost 65 years ago. In 1950 a recalibrated and upgraded Dobson instrument (D8) was sent to Longyearbyen, and Søren H.H. Larsen was the first person who performed systematic ozone measurements in polar region (Henriksen and Svendby, 1997).

Regular Dobson ozone measurements were performed in Svalbard until 1962. The data have been reanalyzed and published by Vogler et al. (2006). After 1962 only sporadic measurements were performed in Longyearbyen, but after the instrument was moved to Ny-Ålesund in 1994 more systematic measurements took place. However, the Dobson instruments require manual operation

and it soon became more convenient to replace the Dobson instrument with the more automatic SAOZ and GUV instruments.

Table 4: Percentage changes in total ozone over Ny-Ålesund for the period 1979 to 2015. The numbers in parenthesis represent uncertainty (1σ).

Time period	Trend (%/decade) 1979-1997	Trend (%/decade) 1998-2015
Spring (Mar – May):	-11.8 (1.9)	0.1 (2.4)
Summer (Jun – Aug):	-2.2 (1.6)	-1.6 (1.0)
Autumn (Sept - Oct):	-3.8 (1.9)	0.6 (1.4)
Annual (Mar – Sep):	-6.2 (1.2)	-0.4 (1.4)

The ozone trend studies presented in Table 4 are based on a combination of Dobson, SAOZ, GUV and satellite measurements. For the years 1979 to 1994 the monthly mean ozone values have been based on TOMS Nimbus 7 and Meteor-3 overpass data. For the latest 22 years only ground based measurements have been used in the trend studies: Dobson data have been included when available, SAOZ

data have been 2nd priority, whereas GUV data have been used when no other ground-based measurements have been available. Autumn observations have been made possible by the SAOZ instrument, which yields reliable data even at solar elevations close to zero.

As seen from Table 4 the ozone trend pattern in Ny-Ålesund has many similarities to the Oslo and Andøya trend series. A massive ozone decline was observed from 1979 to 1997, especially during winter and spring. The trend for the spring season was as large as -11.8%/decade, whereas the negative trend for the summer months was only -2.2%/decade. The annual trend in total ozone was -6.2%/decade during these years. In contrast, no significant trends were observed for the second period from 1998 to 2015. During this period virtually no change in total ozone was observed for the spring months, whereas a trend of -1.6%/decade was found for the summer months and a positive trend of 0.6%/decade in autumn. The annual trend for the period 1998-2015 was -0.4% /decade. None of these results are significant at a 2σ significance level.

2.4 UV observations

The Norwegian UV network, established in 1994/95, consists of nine 5-channel GUV instruments located from 58°N to 79°N (see Figure 1). NILU is responsible for the daily operation of three of the instruments, located at Oslo (60°N), Andøya (69°N) and Ny-Ålesund (79°N). The Norwegian Radiation Protection Authority (NRPA) is responsible for the operation of the measurements performed at Trondheim, Bergen, Kise, Landvik, Finse and Østerås.

Table 5: Annual integrated UV doses (kJ/m^2) at three stations during the period 1995 - 2015.

Year	Oslo	Andøya	Tromsø*	Ny-Ålesund
1995	387.6			
1996	387.4		253.6	218.5
1997	415.0		267.0	206.5
1998	321.5		248.4	217.7
1999	370.5		228.0	186.1
2000	363.0	239.7		231.0
2001	371.0	237.0		208.6
2002	382.5	260.0		201.8
2003	373.2	243.4		No measurements
2004	373.2	243.7		190.5
2005	No annual UV doses due to calibration campaign			
2006	372.4	219.4		No measurements
2007	351.8	253.3		No measurements
2008	375.3	266.5		No measurements

2009	278.6	254.1		No measurements
2010	360.5	225.6		201.6
2011	365.2	254.8		200.8
2012	352.6	227.5		211.6
2013	362.4	247.0		178.9
2014	396.4	249.7		215.0
2015	358.9	219.2		213.6
*The GUV instrument at Andøya was operating in Tromsø for the period 1996 – 1999				

Annual UV doses for the period 1995 - 2015 at the three GUV instruments in Oslo, Andøya and Ny-Ålesund are shown in Table 5.. For days with missing data daily UV doses are calculated from a radiative transfer model, FastRt, <http://nadir.nilu.no/~olaeng/fastrt/fastrt.html>. UV measurements in Ny-Ålesund were excluded from the national monitoring programme from 2006 to 2009 due to lack of financial support, but the GUV instrument is now back in daily operation.

At all three stations the annual integrated UV dose reveals a negative trend in the order of -2.5%/decade, being largest in Oslo (-3.2%/decade) and smallest in Ny-Ålesund (-2.0%/decade). However, none of the UV trends derived is significant at a 2- σ confidence level. It is also worth noting that although the three stations are rather evenly spaced geographically, UV levels at Tromsø/Andøya are much closer the Ny-Ålesund values than to Oslo values.

3 THEORY, MODELLING, AND OTHER RESEARCH

3.1 University of Oslo

Department of Physics is operating the Brewer instrument and a GUV instrument at the roof of the Chemistry building at the University of Oslo. The institute has also been involved in ground-based measurements of solar UV radiation in developed countries with extreme UV levels, e.g. at the Tibetan Plateau (Norsang et al., 2014). The University of Bergen and NTNU have also participated in these studies.

At the Physics department there has been a focus on developing tools for deriving total ozone and cloud parameters from filter instruments and global irradiance UV measurements (Dahlback et al., 2005). Radiative transfer models are used for many purposes, including UV effect studies related to various cancer types and Vitamin D production (e.g. Moan et al., 2012).

3.2 NILU - Norwegian Institute for Air Research

At NILU there has been a main research focus on understanding the dynamical influence on the variability in total ozone, especially at the northern hemisphere at mid and high latitudes. Several studies and research activities are done in collaboration with Birkeland Center for Space Research (University of Bergen), the University of Oslo, CICERO and the Norwegian Radiation Protection Authority. Some of the more recent activities and results are listed below:

- Using a data assimilation technique and satellite observations by the SMR instrument aboard the Odin satellite, the inter-annual variability in ozone depletion over the Arctic has been quantified homogeneously between 2002 and 2013. The two ozone destruction mechanisms involving halogen and nitrogen chemical families play differently between cold and warm winters in the stratosphere. In cold winters, like in 2010/2011, characterized by a very stable vortex associated with particularly low temperatures, there is an important halogen-induced loss occurring inside the vortex in the lower stratosphere. We found a loss of 2.1 ppmv at an altitude of 450K in the end of March 2011, which corresponds to the largest ozone depletion in the northern hemisphere observed during the last decade. In warm winters affected by major sudden stratospheric warmings, such as 2003/2004,

2005/2006, 2008/2009 and 2012/2013, the ozone loss occurring in the middle stratosphere, driven by nitrogen oxides can outweigh the effects of halogens (Sagi et al., 2016)

- Transient increases in mesospheric ozone following stratospheric sudden warmings in the northern hemisphere and southern hemisphere (in 2002) have been studied (Tweedy et al., 2013; Smith-Johnsen et al., 2016) using simulations with the Whole Atmosphere Community Climate Model (WACCM), and also the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) observations aboard the NASA TIMED satellite.
- The role of planetary, gravity and tidal waves in driving the transport of the nitrogen oxides produced by energetic particle precipitation from the lower thermosphere to the stratosphere has been studied with WACCM including detailed comparisons with Odin SMR observations during elevated stratopause events (Orsolini et al., 2016). Noticeably, change in low-latitude ozone drives anomalously strong excitation of semi-diurnal tide (Limpasuvan et al., 2016), as observed by radar measurements in Trondheim (64° N).

3.3 NRPA – the Norwegian Radiation Protection Authority

A continuous focus is kept on ensuring well calibrated UV monitoring data and developing data products relevant to health and environmental assessments. QA involves participation and arrangement of solar intercomparisons, and administration of annual calibrations with the travelling reference. The methodology involves corrections for spectral and angular characteristics of individual instruments, in combination with spectroradiometer operation and RT modelling. Time series of measurements for the UV stations are compared with RT modelling results, applying ancillary observation data to include the impact of variations in total ozone, surface albedo and cloud optical depth. Gaps in measurements series are substituted with modelled data in order to get continuous series of station data. NRPA is participating in the CERAD CoE, a research programme dedicated to environmental impacts of ionizing radiation in combination with UV radiation and other environmental stressors.

4. DISSEMINATION OF RESULTS

4.1 Data reporting and storage

The complete set of revised Dobson total ozone values from Oslo is available at The World Ozone and Ultraviolet radiation Data Centre (WOUDC), <http://www.woudc.org/>. Also, Brewer DS measurements are regularly submitted to WOUDC.

Submission of Brewer data from Andøya was set on halt after problems with instrument drift stability were detected. It is envisaged that they will be resumed after re-calculation of all measurements since. This may, however, be delayed because of the severe funding reduction for this site.

The total ozone and NO₂ measured from the SAOZ instrument at Ny-Ålesund are submitted to the Network for the Detection of Atmospheric Composition Change (NDACC).

An sql database at NRPA holds GUV measurements data for the whole period since 1995. A library of station data are stored as structured Matlab binary files, containing a complete archive of measurement data, meta data, and reconstructed data, as well as a number of data products to be disseminated in the near future. UVI measurements for the nine stations in the network are regularly disseminated for use in the annual State of the Climate report series, issued by BAMS.

4.2 Information to the public

Real-time values of total ozone, UV indices and cloud thickness (CMF) for Oslo are available at <http://tid.uio.no/ozone/>. Also, near real time data and historical ozone time series from the SAOZ instrument in Ny-Ålesund can be found at <http://saoz.obs.uvsq.fr>.

NILU operates a web portal for dissemination of UV observations and UV forecasts for Norway and common global tourist destinations, available at <http://uv.nilu.no>. The content of the UV web pages are:

- UV forecast for three days for user-selected locations in Norway. The UV forecast is given for clear-sky, partly cloudy and cloudy conditions. Snow cover is also taken into account.
- Global UV forecast for common tourist destinations
- Measured UV doses and total ozone values measured at the Norwegian stations
- Facts on UV radiation and the ozone layer
- Information about sun protection for different locations and situations
- Preliminary total ozone values derived from the GUV instruments.

The public may receive ozone and UV forecasts at user-selected locations by e-mail. The web application has been developed by NILU in co-operation with the Norwegian Radiation Protection Authority, Storm Weather Center, and the Norwegian Environment Agency. The Norwegian Meteorological Institute has developed an additional UV forecast service, where the weather forecast is an integrated part of the forecasted UV index.

Observations performed by the Norwegian Radiation Protection Authority and NILU are also available at the web portal <http://www.nrpa.no/uvnett/> together with annual doses and information on sun protection.

In 2013 the Norwegian Environment Agency co-funded the production of a UNEP movie "[The Arctic & the Ozone Layer: Stabilizing our Environment and Climate](#)". Several Norwegian key researchers participated in the movie, together with the personnel operating the monitoring stations.

4.3 Relevant scientific papers

The ozone and UV monitoring and model studies in Norway give rise to research collaboration with national and international partners. In chapters 3 and 8 some of the most relevant publications are referred and listed. They give an impression of international collaboration and ongoing research in the Norwegian ozone and UV scientific community the last few years.

5. PROJECTS AND COLLABORATION

Norwegian institutions and scientists are participating in some international and national projects related to ozone and UV. However, the number of projects have decreased significantly the last years due to reduced funding and little focus on stratospheric ozone. Below is an overview of some of the most important projects related to ozone and UV research in Norway:

International projects

NDACC: *The Network for the Detection of Atmospheric Composition Change (1991-> present)* is a set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the stratosphere. Ozone and key ozone-related chemical compounds and parameters are targeted for measurement. The NDAAC is a major component of the international middle atmosphere research effort and has been endorsed by national and international scientific agencies, including the International Ozone Commission, the United Nations Environment Programme, and the World Meteorological Organization. Web-site: <http://www.ndsc.ncep.noaa.gov/>

HEPPA-SOLARIS: This is an international cooperation including SPARC focusing on observational and modelling studies of the influences of solar radiation and energetic particle precipitation (EPP) on the atmosphere and climate. Topics covered include the causes and phenomenology of solar radiation and energetic particle variability, mechanisms by which radiative and particle forcing affect atmospheric chemistry and dynamics, contributions of solar and EPP forcing to climate variability and space weather.

Annual contributions to the 'State of the Climate' report serie of BAMS.

National projects

Solar-Terrestrial Coupling through High Energy Particle Precipitation in the Atmosphere: a Norwegian contribution (HEPPA-Norway): see HEPPA-SOLARIS.

Solar effects on natural climate variability in the North Atlantic and Arctic (SOLENA): This project will investigate possible effects of the solar cycle on atmospheric dynamics, especially on tele-connection patterns such as the NAO/AO. This may happen through a modulation of atmospheric chemistry in the upper stratosphere and the mesosphere. The project will apply coupled atmosphere-ocean models including relevant atmospheric chemistry in the 50-100 km altitude range.

Atmo-TROLL: *Atmospheric research and monitoring at Troll – a long-term observational program (2007->).* This program intends to establish new knowledge on annual and short-term variability as well as long-term changes of climate and pollution parameters. The list of parameters comprises physical, optical and chemical properties of aerosols, ozone and UV, organic and inorganic pollution including Hg, CO and NMHC and surface ozone. The project is coordinated by NILU and funded by The Research Council of Norway.

NRPA is involved in two **community medicine projects**, utilizing UV network data: A melanoma project in co-operation with the Norwegian Cancer Registry and University of Oslo, and a project on porphyriae patients, in co-operation with NAPOS (Haukeland University Hospital).

6. FUTURE PLANS

A short presentation of future plans are summarised below:

- The existing ozone and UV monitoring activity will continue, with a focus on long-term continuity and high-level quality assurance
- The cooperation with CNRS, France, regarding long-term series of O₃ and NO₂ measurements with the SAOZ instrument in Ny-Ålesund will continue.
- Cooperation has been established with CNR, Italy, regarding ozone and UV research in Ny-Ålesund in the frame of the Ny-Ålesund Atmospheric Flagship programme. In particular, it is envisaged to re-start Brewer operations and thus complement ozone monitoring with this instrument.
- The University of Oslo and NILU are already involved in community medicine activities related to ozone/UV and health and will continue to establish cooperation with the community medicine institutions.
- Efforts on improving measurement accuracy will continue at NRPA, implementing a newly designed instrument for monitoring long term drift in QTH secondary standard lamps for network instrument calibrations.
 - NILU has deployed a NILU-UV instrument that is installed at the Norwegian Antarctic Troll Station (71° S). Analysis of the data and a publication are in progress.
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Apart from the activities listed above, there are no immediate plans for changes in the ozone monitoring programs in Norway.

7. NEEDS AND RECOMMENDATIONS

While Ny-Ålesund ozone and UV monitoring has been included in the monitoring programme, total ozone and UV monitoring at Andøya is no longer covered by funding from the Norwegian Environment Agency. Instead, NILU receives direct support from the Ministry of Climate and Environment to continue this longest Norwegian ozone measurement series as well as UV measurements. The only ozone profiling measurements on Norwegian territory are weekly ozonesonde launches performed by Alfred Wegener Institute, Germany, at Ny-Ålesund, Svalbard. A long-term commitment to perform such measurements again at Ørlandet (the programme was stopped in 2007) would be highly welcome, as it fills a latitudinal gap between the closest remaining ozonesonde stations, Sodankylä, Finland (68°), and Lerwick (60°), UK.

The UV-monitoring programme in Norway is a split cooperation between the Norwegian Radiation Protection Authority (NRPA) and NILU, but is funded from different state agencies/ministries. This situation is untenable, as the funding to NRPA is on a long-term basis, and the funding to NILU relies more on short-to medium-term decisions.

In general there is a need for predictable multi-annual funding schedules in order to free operations from additional funding sources, which become ever fewer. In order to manage surveillance programmes and run instruments properly and continuously, stable long-term economic support is indispensable. The trend over the last decade has been that long-term monitoring programmes have been supported through other channels, like satellite validation or short-term research projects of typically 3 years duration. In recent years, also this source has become very small, so that the need for a genuine and stable long-term solution is even more urgent.

The UV-network has been operating since 1995. Spare parts are limited, and in order to continue high quality measurements, the instrumentation has to be replaced in the near future.

8. PUBLICATIONS

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