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Monitoring of long-range transported air pollutants in Norway, annual report 2013
Overvåking av langtransportert forurenset luft og nedbør. Atmosfæriske tilførsler 2013

Summary – sammendrag

The present report presents results from the monitoring of atmospheric composition and deposition of air pollution in 2013 in the Norwegian rural background environment, and focuses on particulate and gaseous phase of inorganic constituents, particulate carbonaceous matter, ground level ozone and particulate matter.
Denne rapporten omhandler resultater fra overvåkningsprogrammet for langtransportert forurenset luft og nedbør, og atmosfæriske tilførsler i 2013 på norske bakkgrunnstasjoner. Det fokuseres på uorganiske hoved¬komponentene i luft og nedbør, partikulært karbonholdig materiale, partikkelmasse og bakkenær ozon.

4 emneord

Atmosfære og klima
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Sur nedbør og overgjødsling

4 subject words

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Front page photo

Birkenes Observatory

Preface

This report presents results from the monitoring of atmospheric composition and deposition of air pollution in 2013 in the Norwegian rural background environment, and focuses on particulate and gaseous phase of inorganic constituents, particulate carbonaceous matter, ground level ozone and particulate matter. The observations made are part of the national monitoring programme of long-range transported air pollutants, which is conducted by NILU on behalf of The Norwegian Environment Agency, and the Ministry of Climate and Environment.

The present report is one of four reports, which cover the national monitoring of atmospheric composition in the Norwegian rural background environment. The other three reports are published separately, of which the first focuses on persistent organic pollutants and heavy metals, the second covers the monitoring of the ozone layer and UV, whereas the third is on climate gases and aerosol particles influence on climate.

Data and results from the national monitoring programme are also included in various international regional programmes, including: EMEP (European Monitoring and Evaluation Programme) under the CLTRAP (Convention on Long-range Transboundary Air Pollution), CAMP (Comprehensive Atmospheric Monitoring Programme) under OSPAR (the Convention for the Protection of the marine Environment of the North-East Atlantic) and AMAP (Arctic Monitoring and Assessment).

All measurement data presented in the current report can be received by contacting NILU, or they can be downloaded directly from the database: http://ebas.nilu.no/.

A large number of persons have contributed to the current report, including those responsible for sampling, technical maintenance, chemical analysis and quality control. Kristine Aasarød is especially acknowledged for compiling this report. Further, the constructive input and review of the report by the contact persons at the Norwegian Environment Agency is greatly appreciated.

Kjeller, June 2014

Wenche Aas
Senior Scientist, Atmospheric and Climate Research

Content

Summary

This report presents the 2013 monitoring results from the rural air- and precipitation chemistry monitoring network in Norway, which in total consist of seventeen sites. In 2013, main components in precipitation were measured at fourteen sites, whereof four had daily measurements the rest weekly. Daily concentrations of inorganic components in air were measured at five sites and ozone concentrations at eight sites. Measurements of PM_{10} and $PM_{2.5}$ mass were determined at three sites, including measurements of organic and elemental carbon (OC and EC) with a weekly sampling interval. Daily aerosol mass measurements is in addition, measured at one site.

The highest annual mean concentrations for most major components were in 2013 measured at Birkenes, which is the station in Norway most affected by long-range transport of pollutants, except for sulphur, which has a high level in Karpbukt due to emissions from the smelters in Kola Peninsula. The highest wet deposition loads of sulphate, nitrogen components and strong acid occurred along the coast from Aust-Agder to Hordaland. Annual mean concentrations of sulphur dioxide in air was highest in the most southern as well as the most northern sites, the Birkenes and Zeppelin observatories with 0.09 μg S/m^3. The relatively high levels of sulphur dioxide at Svalbard is due to some high episodes during winter with air masses from Russia, while Birkenes is influenced of air masses from Continental Europe and UK. Highest annual mean concentrations of particulate sulphate, nitrate and ammonium was measured at Birkenes while Hurdal had the highest level of nitrogen dioxide due to influence of the relatively high traffic load in this region of Norway.

Both dry and wet deposition of sulphur and nitrogen were higher in the summer period than during winter. Dry deposition of sulphur compounds in 2013 was assessed to be 5–19% of the total deposition during winter and 17–33% during the growing season. For nitrogen, the relative contribution of dry deposition is somewhat higher, 9-27% in winter and 16-46% in summer

Since 1980 the content of sulphate in precipitation in Norway has decreased by 76-94%. The reductions in airborne concentrations were between 93%-96% and 80-85% at the Norwegian mainland for sulphur dioxide and sulphate, respectively. Since 1990 the reductions have been between 43-68% (sulphate in precipitation), 60-84% (sulphur dioxide) and 50-68% (sulphate in air). Somewhat lower reductions are observed at Svalbard. The observed reductions in concentration levels are in agreement with reported downwards trends in pollutant emissions in Europe.

The nitrate and ammonium concentrations in precipitation have significantly decreased at most sites in southern Norway, 26%-51% for nitrate and 47%-50% for ammonium since 1980. For nitrate in precipitation, the sites in southern Norway show a significant decrease of about 30% from 1990-2013. There is also a decrease in the observed ammonium in air for the four sites at the mainland, between 30-55% since 1993, but for sum nitrate and sum of ammonium, it has rather been a significant increase, partly maybe due to changes in local emissions. The NO_2 concentration has decreased between 38-73% for the three sites with significant trends. The concentration of the base cation calcium has been reduced at several sites.

The annual mean concentration of OC ranged from 0.75 – 1.05 µg C/m^3 for PM_{10} and from 0.53 – 0.76 µg C/m^3 for $PM_{2.5}$. A significant downward trend was observed for the annual mean concentration of OC in PM_{10} (**; 35%) and OC in $PM_{2.5}$ (*; 39%) for the time period 2001 – 2013 at the Birkenes Observatory.

The annual mean concentration of EC ranged from 0.06 – 0.14 µg C/m^3 for both PM_{10} and $PM_{2.5}$. The annual mean EC concentration in $PM_{2.5}$ at the Birkenes Observatory was the lowest value observed since the measurements started in 2001, equalling that of 2008 and 2012. A significant downward trend was observed for the annual mean concentration of EC in PM_{10} (+; 33%) and EC in $PM_{2.5}$ (*; 39%) for the time period 2001 – 2013 at the Birkenes Observatory.

The annual mean concentration of aerosol mass ranged from 3.1 – 4.9 µg/m^3 for PM_{10} and from 2.2 – 3.1 µg/m^3 for $PM_{2.5}$. The annual mean concentration of PM_{10} and $PM_{2.5}$ observed at Birkenes for 2013 were the lowest values observed since the measurements started. There is a significant downward trend for the annual mean concentration of PM_{10} (+; 24%) and $PM_{2.5}$ (+; 36%) for the time period 2000/1 – 2013 at the Birkenes Observatory. The EU limit value, the WHO AQG and the National AQG for PM_{10} and $PM_{2.5}$ were all met by a wide margin on an annual basis, as was the 24-hours EU limit values and the WHO AQG. (24-hours measurements available at the Birkenes Observatory only). The 24-hours National AQG (30 µg/m^3 for PM_{10} and 15 µg/m^3 for $PM_{2.5}$) was violated on 2 days for PM_{10}, and on 8 days for $PM_{2.5}$ at the Birkenes Observatory.

The sea salt species (sum of Na^+, Cl^-, and Mg^{2+}) were the major contributors to PM_{10} at the Birkenes Observatory in 2013, accounting for 23%. For the sites Hurdal and Kårvatn OC was the major contributor, accounting for 23% and 24% of PM_{10}, respectively. When converting OC to OM (Organic Matter), OM was the major fraction all sites; i.e., 26% (Birkenes), 39% (Hurdal), and 41% (Kårvatn). There is a significant downward trend for the relative contribution of SO_4^{2-} (*; 37%) to PM_{10} at the Birkenes Observatory for the time period 2001 – 2013, whereas there is a significant upward trend for the relative contribution of NO_3^- (*; 74%) and the sea salts species (*; 88%).

EU's target value for ozone is met in Norway while the long-term objective (no days with a running 8-hour value> 120 µg/m^3) was broken at one station (Tustervatn) in 2013. There were no exceedances of UN-ECE's critical level for plant growth (three-month's AOT40) or forests (six-months' AOT40) at the Norwegian stations in 2013. The maximum hourly average in 2013 was 124 µg/m^3 at Tustervatn, and EU's information threshold of 180 µg/m^3 was thus not exceeded. This is the lowest annual peak value registered in the country since the ozone monitoring started. This corresponds with data from EEA's monitoring in the summer 2013 which showed few exceedances and generally low levels in Northern Europe.

Sammendrag

Denne rapporten omhandler målinger fra totalt sytten stasjoner. Måling av kjemiske hovedkomponenter i nedbør ble i 2013 utført på døgnbasis på fire stasjon og på ukebasis på ti stasjoner. De uorganiske hovedkomponentene i luft er bestemt på fem stasjoner med døgnoppløsning. Kontinuerlige målinger av ozonkonsentrasjoner i luft er utført på åtte stasjoner. Partikkelmålinger av PM_{10} og $PM_{2.5}$ er utført på tre stasjoner der både partikkelmasse og organisk og elementært karbon (OC og EC) er bestemt med ukentlige målinger. Døgnmålinger av partikkelmasse ble i tillegg er utført på én stasjon.

De høyeste årsmiddelkonsentrasjoner for de fleste hovedkomponentene ble i 2013 målt på Birkenes i Sør-Norge som er mest påvirket av langtransporterte luftforurensinger, utenom for sulfat hvor det observeres høye nivåer på Karbukt pga. utslipp fra smelteverkene på Kolahalvøya. Våtavsetningen av sulfat, nitrat, ammonium og sterk syre var høyest langs kysten fra Aust-Agder til Hordaland.

Årsmiddelkonsentrasjonene av svoveldioksid var like høye i sør Norge (Birkenes Observatoriet) som på Svalbard (Zeppelin Observatoriet) i 2013 med 0,09 µg S/m^3. Det relativt høye nivået av svoveldioksid på Svalbard skyldes flere høye episoder gjennom vinteren med luftmasser fra Russland. Birkenes er påvirket av luftmasser fra det Europeiske kontinentet og Storbritannia. Birkenes har også de høyeste nivåene av partikulært sulfat, nitrat og ammonium, mens på Hurdal observeres den høyeste konsentrasjonen i 2013 av nitrogendioksid som skyldes utslipp fra biltrafikken i denne regionen.

Både tørr- og våtavsetning av svovel- og nitrogenkomponenter var større om sommeren enn om vinteren. Bidraget av tørravsatt svovel til den totale avsetning var 17–33% om sommeren og 5–19% om vinteren. Tørravsetningen for nitrogenkomponenter bidrar relativt mer til den totale avsetningen enn for svovelforbindelser, 9-27% på vinteren og 16-46% i sommerhalvåret.

Årsmiddelkonsentrasjonene av sulfat i nedbør har siden 1980 blitt redusert mellom 76-94%. Reduksjonene for svoveldioksid med 1980 som referanseår er beregnet til å være mellom 93-96%, og for sulfat i luft mellom 80-85% på fastlands-Norge. Med 1990 som referanseår er også reduksjonene betydelige, 43-68% for sulfat i nedbør, 60-84% for svoveldioksid og 50-68% for sulfat i luft. Disse observasjonene er i samsvar med utslippsreduksjoner i Europe i denne perioden

Fra 1980 har årsmiddelkonsentrasjonene av nitrat i nedbør blitt redusert med 26-51% på stasjonene i Sør-Norge og mellom 47-50% for ammonium. Fra 1990 har reduksjonen vært ca. 30%. Årsmiddelkonsentrasjonen av ammonium i luft viser en signifikant reduksjon på 30-55% på fastlandsstasjonene siden 1993. For summen nitrat+salpetersyre og sum ammoniakk+ammonium har det derimot vært en økning i konsentrasjonsnivået på flere stasjoner, muligens pga av endringer i lokale utslipp. Det har imidlertid vært en tydelig og signifikant nedgang for NO_2 (38-73%) på de tre fastlandsstasjonene med målinger fra 1990. Innholdet av basekationet kalsium er redusert ved flere stasjoner.

Årsmidlet for OC på tre stasjonene med partikkelovervåkning varierte fra 0.75 – 1.05 µg C/m^3 i PM_{10} og fra 0.53 – 0.76 µg C/m^3 i $PM_{2.5}$. Det er en signifikant nedadgående trend for årsmidlet av OC in PM_{10} (**; 35%) og OC in $PM_{2.5}$ (*; 39%) på Birkenes for perioden 2001 – 2013.

Årsmidlet for EC varierte fra 0.06 – 0.14 µg C/m^3 for både PM_{10} og $PM_{2.5}$. Årsmidlet for EC i $PM_{2.5}$ ved Birkenes i 2013 er identisk med det som ble observert i 2008 og 2012, og er således en tangering av det laveste årsmidlet som er observert siden målingene startet. Det er en signifikant nedadgående trend for årsmidlet av EC i PM_{10} (+; 33%) and EC i $PM_{2.5}$ (*; 39%) ved Birkenes for perioden 2001 - 2013.

Årsmidlet for PM_{10} varierte fra 3.1 – 4.9 µg/m^3, mens det for $PM_{2.5}$ varierte fra 2.2 – 3.1 µg/m^3. Årsmidlet for PM_{10} og $PM_{2.5}$ på Birkenes Observatoriet i 2013 er det laveste som er observert siden målingene startet. Det er en signifikant nedadgående trend for årsmidlet av PM_{10} (+; 24%) og $PM_{2.5}$ (+; 36%) ved Birkenes for perioden 2000/1 – 2013. De observerte årsmidlene lå langt under EUs grenseverdier, samt under WHOs og de nasjonale AQG for PM_{10} and $PM_{2.5}$. Observerte 24 timers konsentrasjoner av PM_{10} og $PM_{2.5}$ (kun målt på Birkenes) lå under EUs 24 timers grenseverdi, samt under WHO 24 timers AQG. De nasjonale 24 timers AQG (30 µg/m^3 for PM_{10} and 15 µg/m^3 for $PM_{2.5}$) ble overskredet 2 dager for PM_{10} og 8 dager for $PM_{2.5}$.

Sjøsaltpartikler (her: summen av Na^+, Cl^-, and Mg^{2+}) bidro mest til PM_{10} ved Birkenes Observatoriet i 2013 med 23%. Ved stasjonene i Hurdal og Kårvatn dominerte OC (organisk karbon) med henholdsvis 23% og 24% av PM_{10}. Ved å konvertere OC til OM (Organisk Materiale), ble OM den dominerende bidragsyteren for alle lokalitetene med 26% (Birkenes), 39% (Hurdal), and 41% (Kårvatn). Det er en signifikant nedadgående trend for det relative bidraget av SO_4^{2-} (*; 37%) til PM_{10} ved Birkenes Observatoriet for perioden 2001 – 2013, mens det er en signifikant oppadgående trend for det relative bidraget av NO_3^- (*; 74%) og sjøsaltpartikler (*; 88%).

EUs luftkvalitetsmål («target value») for ozon er oppfylt i Norge, mens langtidsmålet (ingen dager med en løpende 8-timers verdi over 120 µg/m^3) ble brutt på en stasjon (Tustervatn) i 2013. Det var ingen overskridelser av UNECEs grenseverdi for planter (tre måneders AOT40) eller skog (seks-måneders AOT40) på norske stasjoner i 2013. Maksimal timeverdi i 2013 var 124 µg/m^3 på Tustervatn, og EUs terskelverdi på 180 µg/m^3 ble dermed ikke overskredet. Dette er det laveste årsmaksimum observert i landet siden ozonovervåkingen startet. Dette samsvarer med data fra EEAs overvåking sommeren 2013 som viste få overskridelser og generelt lave nivåer i Nord-Europa.

1. The monitoring programme, 2013

The atmospheric monitoring programme presented in this report focuses on particulate and gaseous phase inorganic constituents, particulate carbonaceous matter, ground level ozone and particulate matter in the Norwegian rural background environment. The main objective is to quantify the levels of these pollutants and to document any changes in the supply of atmospheric long-range transported pollution. Hence, the monitoring sites are located in areas where the influence of local sources are minimal, and thus the site being representative for a wider region. Regular sampling of precipitation on a daily basis in Southern Norway dates back to 1973. After that, the measurement program and the monitoring network was expanded to provide improved information on atmospheric contribution of air pollution for all of Norway.

After the conclusion of the SNSF *("acid rain's effects on forest and fish")* project in 1979, a national monitoring program organized by the Norwegian Environment Agency was initiated in 1980. Several changes in the content of the measurement programme, as well as in the number and distribution of monitoring sites, has taken place during the 40 years life-time of this monitoring programme, although only small changes since 2011.

The measurements presented in the current report are part of different national projects and programmes:

- *The National monitoring programme on behalf of The Norwegian Environment Agency:*
  - Ozone at four sites (Birkenes, Tustervatn, Kårvatn, Zeppelin)
  - Daily measurements of NO_2 at four sites (Birkenes, Hurdal, Tustervatn, Kårvatn)
  - Weekly measurements of particulate matter and EC/OC at three sites (Birkenes, Hurdal, Kårvatn)
  - High time-resolution measurements of PM at Birkenes
  - Daily measurements of particulate and gaseous inorganic compounds in air and precipitation at two sites (Birkenes and Zeppelin; weekly for precipitation at Ny-Ålesund)
  - Meteorology at three sites (Birkenes, Zeppelin and Hurdal)

- *Measurement programme to preserve long-time data series on behalf of the Ministry of Climate and Environment, co-financed by NILUs internal monitoring programme:*
  - Daily measurements of particulate and gaseous inorganic compounds in air and precipitation at three sites (Hurdal, Kårvatn and Tustervatn)
  - Weekly measurements of main inorganic ions in precipitation at eight sites (Vikedal, Treungen, Haukeland, Brekkebygda, Høylandet, Nausta, Vatnedalen, Løken)
  - Ozone at three sites (Hurdal, Sandve and Prestebakke)

- *Norway-Russia programme on behalf of The Norwegian Environment Agency:*
  - Weekly measurements of main inorganic ions in air and precipitation at Karpbukt

- *Local air pollution program, co-financed by the municipalities in Porsgrunn, Skien and Bamble:*
  - Ozone at Haukenes

Data and results from the national monitoring programme of air pollutants are also included in various international regional programmes. Five of the sites are part of EMEP (European Monitoring and Evaluation Programme) under the CLTRAP (Convention on Long-range

Transboundary Air Pollution, http://www.unece.org/env/lrtap). Data from several of the sites are also being reported to CAMP (Comprehensive Atmospheric Monitoring Programme) under OSPAR (the Convention for the Protection of the marine Environment of the North-East Atlantic, http://www.ospar.org); AMAP (Arctic Monitoring and Assessment http://www.amap.no) and WMO/GAW (The World Meteorological Organization, Global Atmosphere Watch programme, http://www.wmo.int). A subset of the data are also reported to EEA (European Environmental Agency, http://www.eea.europa.eu/) as required in the EU air quality directive (EU, 2008). All the data are openly available from http://ebas.nilu.no.

Results from previous monitoring are being published in a series of annual reports: 1980 (SFT 26/81), 1981 (SFT 64/82), 1982 (SFT 108/83), 1983 (SFT 162/84), 1984 (SFT 201/85), 1985 (SFT 256/86), 1986 (SFT 296/87), 1987 (SFT 333/88), 1988 (SFT 375/89), 1989 (SFT 437/91), 1990 (SFT 466/91), 1991 (SFT 506/92), 1992 (SFT 533/93), 1993 (SFT 583/94), 1994 (SFT 628/95), 1995 (SFT 663/96), 1996 (SFT 703/97), 1997 (SFT 736/98), 1998 (SFT 768/99), 1999 (SFT 797/00), 2000 (SFT 828/01), 2001 (SFT 847/02), 2002 (SFT 877/03), 2003 (SFT 903/04), 2004 (SFT 929/05), 2005 (SFT 955/06), 2006 (SFT 985/07), 2007 (SFT 1033/08), 2008 (SFT 1051/2009), 2009 (Klif 1074/2010), 2010 (Klif 1099/2011), 2011 (Klif 1126/2012) and 2012 (Klif-Miljødirektoratet M3/2013).

The site locations and key information on the monitoring programme at the actual sites are illustrated in Figure 1.1. Detailed station information, monitoring program and measurement frequencies are provided in Annex 2, whereas sampling methods and chemical analysis are described in Annex 3.

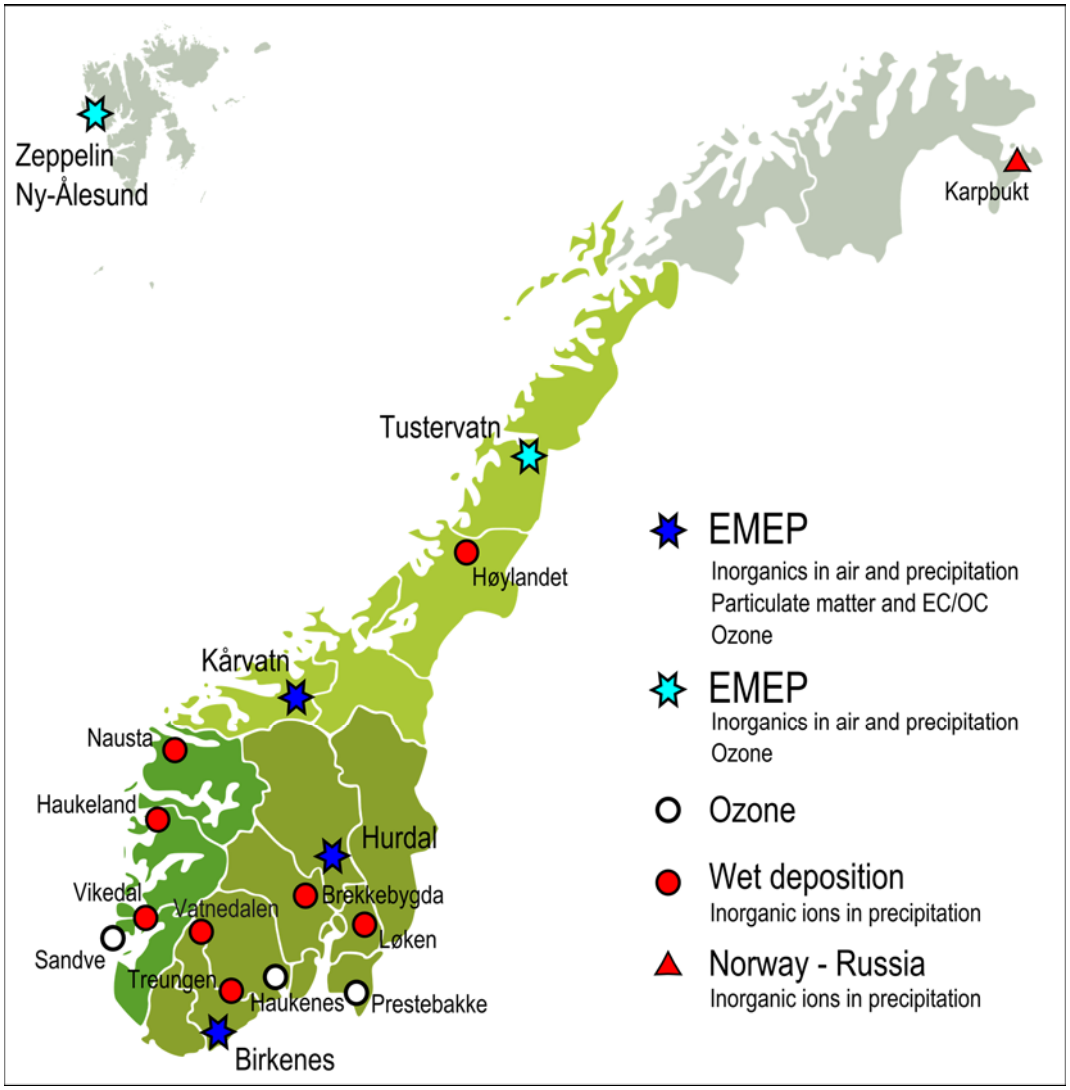


Figure 1.1: Norwegian background sites and their measurement programme 2013. Details are found in Annex 2. The colour codes indicate the different regions/zones used for the EU's ozone directive (Chapter 6, Table 6.1).

2. The weather in Norway 2013

The variation in meteorological conditions from year to year are decisive for the observed concentrations of pollutants in air and precipitation. The atmospheric state, i.e. the large-scale synoptic situation with distribution of high- and low-pressure systems, temperature, stability, humidity etc. are controlling the pollutant levels in air as well as the surface dry deposition and wash-out at the Norwegian monitoring stations.

For the country as a whole the annual average temperature was 1.0°C above the normal while the precipitation was 110 % of the normal (Met.no, 2014). The first months of the year (Jan-Mar) were characterized by cold and dry conditions in many parts of South Norway and milder and wetter conditions in the north. In January some areas in the north experienced a mean temperature 6° above normal and some areas in the south 4° below normal. In February and March the monthly precipitation was only 0-25% of the normal at various sites in South Norway, whereas areas in the north experienced a precipitation amount twice the normal.

In March the mean temperature for the country as a whole was 3° below the normal and the NAO index, measuring the strength of the westerly flow over the Atlantic, was extremely low corresponding with prevailing easterly winds that month.

June was one of the wettest June-months ever measured in Norway, mainly due to the extreme weather "Geir" with the highest precipitation in the western part of the country. July and August was dry and hot in South Norway with the country's max temperature of 33.4°C observed in Aust-Agder. August and September were warm in many parts of the country and some parts of South Norway had twice the monthly precipitation in August.

The last two months of 2013 were characterized by mild, windy and wet conditions in many parts of the country. The mean temperature was higher than normal; in December 4.2°C above the normal and even 6-8°C above normal for sites in South Norway. The extreme weather "Hilde" lead to very strong winds and precipitation amounts 200-250 % of the normal in Nordland and coastal areas of Møre and Trøndelag in November. December was a very wet month in Østfold, Agder and Rogaland with precipitation amounts 3-4 times the normal.

3. Inorganic components

There were only minor changes in the monitoring programme in 2013 compared to 2012, except for changes in the financial structure. A large fraction of the monitoring programme earlier financed by the Norwegian Environmental Agency, is in currently part of the long-term data series programme under the Ministry of Climate and Environment.

Measurements of inorganic ions at Svanvik reported for 2012 was only one year measurement campaign in support of the UNECE ICP Material programme, thus, no such measurements are reported for Svanvik for 2013.

Only one site (Birkenes) reported measurements of precipitation on a daily basis for 2012, which is not in accordance with the recommendations made by of EMEP and WMO/GAW. Hence, daily measurements were restarted at the other three EMEP sites at the Norwegian mainland (i.e., Hurdal, Kårvatn and Tustervatn). Not all sites changed from January, but during spring all the EMEP sites had started daily measurements.

3.1 Observations in 2013

3.1.1 Chemical composition in precipitation

All sulphate values given in the present report are adjusted for the contribution of sulphate associated with sea salt. The sea-salt sulphate content is preferably calculated based on the ratio of sodium, or magnesium and chloride, to sulphate in seawater, and is according to the procedures suggested by EMEP (EMEP/CCC, 1995).

Monthly and annual concentrations, and wet depositions for all sites are listed in Annex A.1.1-A.1.19, and all years in A.1.21, while Table 3.1 lists the annual mean concentrations and depositions at all stations for 2013.

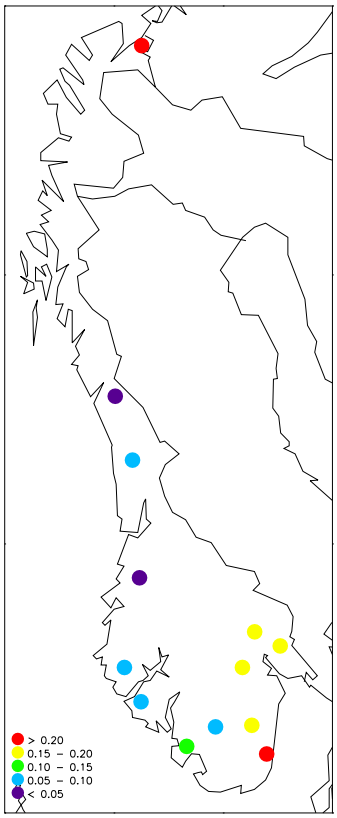
Regional distribution of mean concentrations and wet depositions are shown in Figure 3.1 and Figure 3.2. Table 3.1, Figure 3.1 and Figure 3.2 show that the ion content decreases along a South to North transect and that the lowest levels are observed for the counties reaching from Møre og Romsdal to Troms. The site in Finnmark is influenced by emissions from Russia and the content of sulphate is particularly high.

Table 3.1 shows that all regions, except the most continental parts of southern Norway and Finnmark, observed significant amounts of sea salts. At most sites there was an excess of cations, which probably is due to the content of bicarbonate or other anions of weak acids that are not determined. A particularly poor ion balance was observed for Vatnedalen in 2013; the relationship between the sea salt ions was not as expected, and it appears to be an excess of sodium. The reason for this finding is unclear, but it could be speculated that with a weekly sampling frequency, dry deposition of dust of miscellaneous origin, and chemical transformation in the sample is more likely to occur and thus to affect the ion balance and the chemical composition. From 2013, measurements of precipitation on a daily basis, as recommended by EMEP and WMO/GAW is conducted at the four EMEP sites on the Norwegian main land.

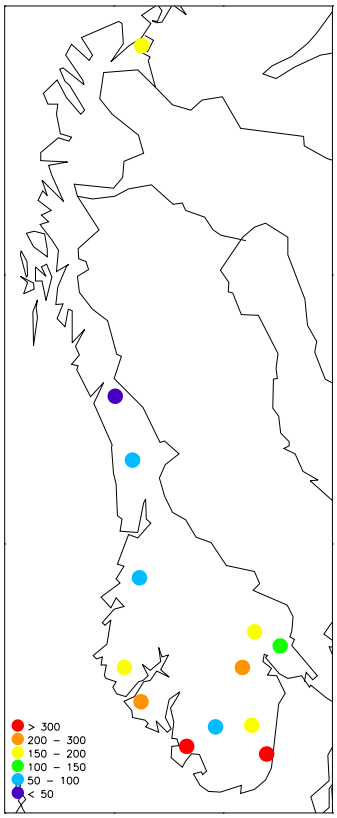
Table 3.1: Annual volume weighted mean concentrations and total wet deposition of inorganic ions at Norwegian background stations, 2013.
**: Corrected for contribution from sea salt.*

Site	Volume weighted annual mean concentrations									Wet deposition										Volume weighted annual mean concentrations in equivalence units										
	pH	SO_4*	NO_3	NH_4	Ca	K	Mg	Na	Cl		H+	SO_4*	NO_3	NH_4	Ca	K	Mg	Na	Cl	H(+)	SO_4*(2-)	SO_4(2-)	NO_3(-)	NH_4(+)	Ca(2+)	K(+)	Mg(2+)	Na(+)	Cl(-)	Ion bal.
		mg S/l	mg N/l	mg N/l	mg/l	mg/l	mg/l	mg/l	mg/l	mm	µekv/m^2	mg S/m^2	mg N/m^2	mg N/m^2	mg/m^2	mg/m^2	mg/m^2	mg/m^2	mg/m^2	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	kat./an.
Birkenes	4.97	0.21	0.35	0.37	0.17	0.10	0.16	1.34	2.29	1427	15401	303	501	522	239	140	228	1911	3274	11	13	21	25	26	8	3	13	58	65	1.09
Vatnedalen	5.50	0.09	0.14	0.35	0.14	0.15	0.05	0.60	0.78	983	3137	92	133	344	136	145	53	591	766	3	6	8	10	25	7	4	4	26	22	1.72
Treungen	5.12	0.17	0.27	0.30	0.09	0.08	0.06	0.42	0.71	1150	8638	190	305	349	101	87	71	482	821	8	11	12	19	21	4	2	5	18	20	1.13
Løken	5.22	0.17	0.27	0.49	0.14	0.11	0.09	0.70	1.17	834	4991	145	229	405	117	92	78	580	974	6	11	14	19	35	7	3	7	30	33	1.33
Hurdal	5.18	0.17	0.26	0.38	0.15	0.10	0.05	0.43	0.70	896	5912	156	233	340	134	91	47	386	629	7	11	13	19	27	7	3	4	19	20	1.29
Brekkebygda	5.21	0.17	0.22	0.25	0.13	0.14	0.04	0.26	0.41	1202	7440	207	268	304	151	162	44	309	488	6	11	12	16	18	6	4	3	11	12	1.24
Vikedal	5.48	0.12	0.18	0.41	0.21	0.13	0.29	2.43	4.18	2534	8363	304	467	1049	541	328	742	6155	10589	3	7	20	13	29	10	3	24	106	118	1.17
Haukeland	5.29	0.08	0.11	0.16	0.11	0.10	0.21	1.85	3.21	3415	17358	259	360	557	377	350	722	6303	10946	5	5	14	8	11	5	3	17	80	91	1.08
Nausta	5.55	0.07	0.09	0.29	0.08	0.07	0.14	1.22	2.20	2277	6392	153	207	666	187	147	327	2783	5005	3	4	11	6	21	4	2	12	53	62	1.19
Kårvatn	5.45	0.04	0.06	0.13	0.14	0.15	0.22	1.96	3.54	1432	5059	57	80	182	204	218	321	2808	5075	4	2	12	4	9	7	4	18	85	100	1.09
Høylandet	5.67	0.06	0.08	0.34	0.17	0.15	0.24	2.08	3.66	1551	3351	94	119	529	257	233	376	3231	5669	2	4	14	6	24	8	4	20	90	103	1.21
Tustervatn	5.39	0.04	0.05	0.14	0.09	0.06	0.10	0.86	1.57	1148	4709	49	60	164	100	64	118	985	1802	4	2	7	4	10	4	2	8	37	44	1.19
Karpbukt	4.93	0.33	0.09	0.16	0.25	0.18	0.44	3.66	6.29	516	6100	170	44	84	129	95	226	1892	3248	12	21	40	6	11	12	5	36	159	177	1.05
Ny-Ålesund	5.38	0.10	0.07	0.09	0.47	0.20	0.63	4.57	7.72	268	1125	27	18	24	125	54	167	1222	2066	4	6	30	5	6	23	5	52	199	218	1.15

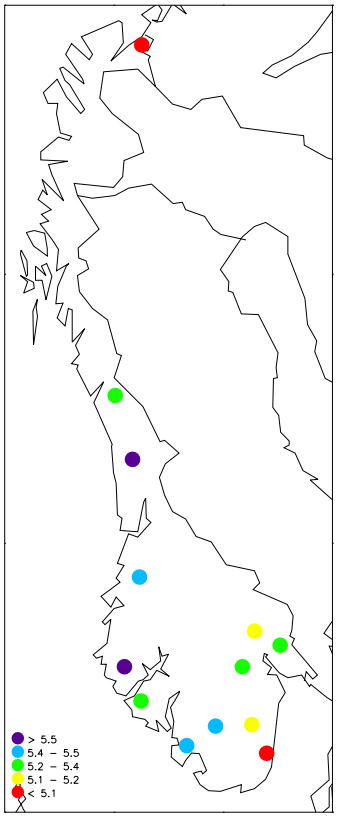
Sulphate concentration in precipitation, 2013
mg S/l



Sulphate – wet deposition. 2013
mg S/m^2



pH
2013



Strong acid (H^+) wet deposition, 2013
ueky/m^2

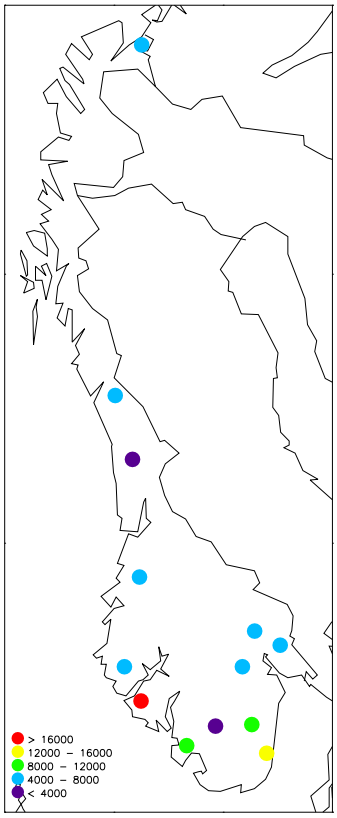
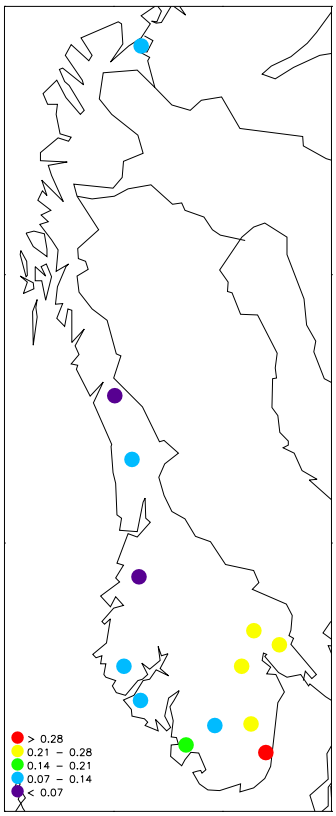
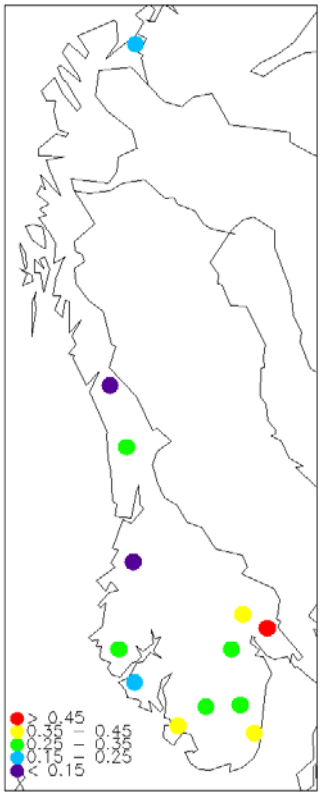


Figure 3.1: Annual volume weighted mean concentrations and total wet deposition of sulphate (sea salt corrected) and strong acid (pH), 2013.

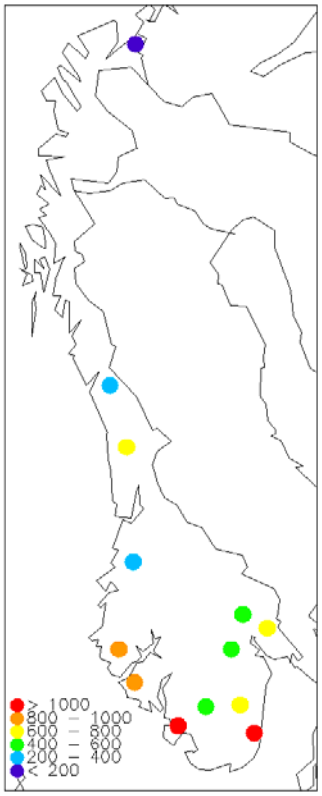
Nitrate concentration in precipitation, 2013
mg N/l



Ammonium concentration in precipitation, 2013
mg N/l



Sum nitrate and ammonium wet deposition
2013
mg N/m²



Chloride concentration in precipitation, 2013

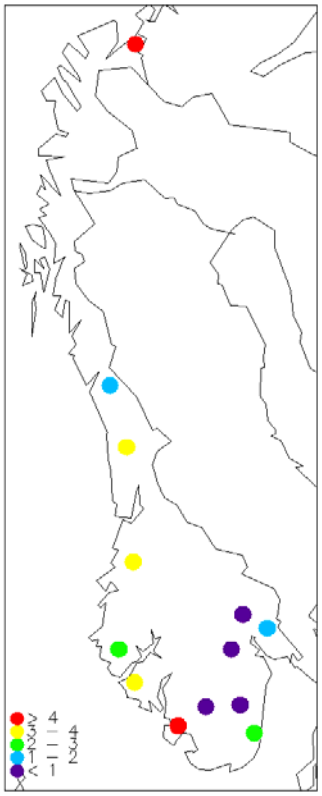


Figure 3.2: Annual volume weighted mean concentrations of nitrate, ammonium, chloride and total wet deposition of nitrogen (nitrate + ammonium), 2013.

As seen for previous years, the highest annual mean concentrations for the major components were observed at the Birkenes site (Table 3.1); the exceptions were observed for sulphate, which was higher for Karpbukt due to the influence of emissions from Nikel (Russia) and for ammonium where individual sites are influenced of the regional agricultural activities. Being situated only 20 km from the Skagerrak coastline, Birkenes is the site in Norway being the most influenced by long-range transport from the European Continent and UK, hence this finding is to be expected.

Figure 3.3 shows monthly volume weighted mean concentrations and wet deposition of sulphate, nitrate and, ammonium in different parts of Norway, 2013. All the monthly data are given in Annex 1.

Wet deposition of sulphate during the highest 10 days, shows that about 30% of the annual total deposition arrives during these ten days (Table A1.20) at the two sites with daily measurements during the whole year (Birkenes and Hurdal). Further, som sites are more influenced of sea salt than Birkenes.

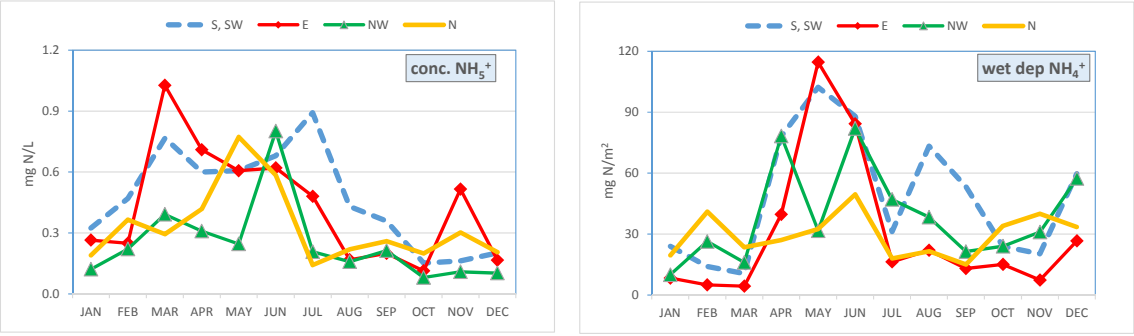


Figure 3.3: Monthly volume weighted mean concentrations (left) and wet deposition (right) of sea salt corrected sulphate (top) nitrate (middle), ammonium (bottom) in different parts of Norway, 2013, S, SW: South and South west is the average of the sites Birkenes, Vatnedalen, Treungen and Vikedal; E: East (Løken, Hurdal, Brekkebygda); NW: Northwest (Haukeland, Nausta and Kårvatn); N: North (Høylandet and Tustervatn).

3.1.2 Chemical composition in air

Daily measurements of inorganic components in air was measured at five sites in 2013. All EMEP sites, Figure 1.1. Table 3.2 shows the annual mean concentrations while the monthly data are given in A.1.22-A.1.33, though the monthly means of the sulphur and nitrogen components are illustrated in Figure 3.5. The maximum and percentile concentrations of SO_2, SO_4^{2-}, sum of (NO_3- + HNO_3), NH_4^+ and sum of (NH_3 + NH_4^+) are given in Table 3.3 to Table 3.8.

Annual mean concentrations of sulphur dioxide in air was highest in the most southern as well as the most northern sites, the Birkenes and Zeppelin observatories with 0.09 μg S/m³. Highest daily average for sulphur dioxide was measured at Zeppelin with 2.7 μg S/m³ at the 7 December 2013. Trajectories for that day showed that air masses are coming from Russia. In general, the highest concentrations at Zeppelin are, for most components, seen during winter (Figure 3.5), when it is more favorable meteorological conditions for transport of air masses into the Arctic.

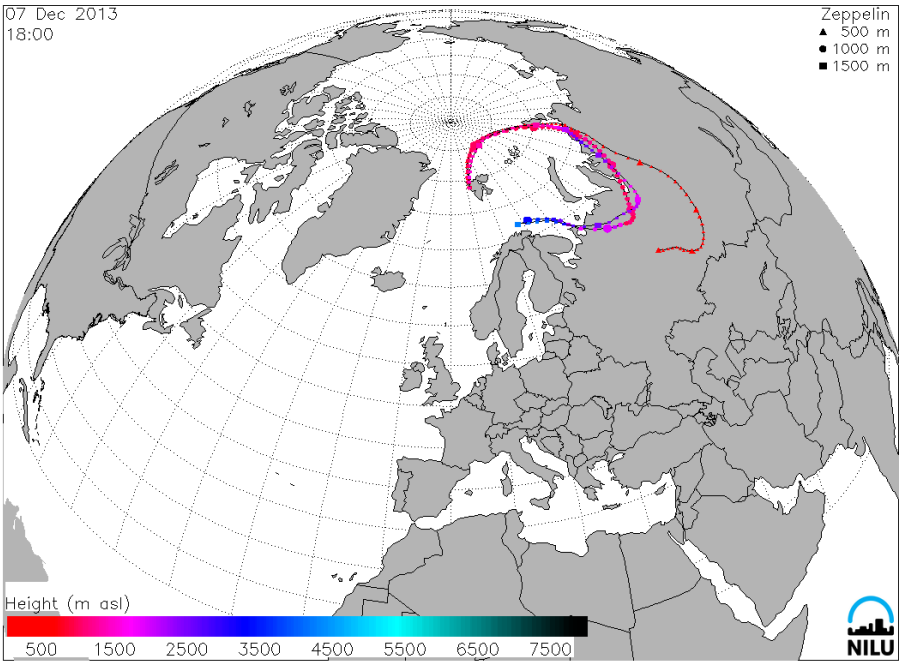


Figure 3.4: Air mass trajectories for air reaching the Zeppelin Mountain 7 Dec. 2013, calculated using the Flextra model.

The Highest annual mean particulate sulphate was measured at Birkenes (0.25 μg S/m^3), which also had the highest episode with 1.8 μg S/m^3, and the trajectories show that the air masses were coming from Eastern Europe that day .

Highest NO_2 levels were observed in Hurdal with an annual mean of 0.69 μg N/m^3. This station is influenced of the relatively high traffic emissions in this region. The highest daily mean of NO_2 was also measured at Hurdal with 8.4 μg N/m^3 the 26 November. Concentrations of NO_2 show an expected temporal pattern with a winter maxima and summer minima. During winter, the atmospheric residence time is longer due to low photochemically activity and reduced vertical mixing.

Highest annual mean values for sum of nitrate (NO_3^- + HNO_3), and NH_4^+ were observed at Birkenes with 0.29 μg N/m^3 and 0.23 μg N/m^3 respectively. Highest annual average of sum of ammonium (NH_3 + NH_4^+) was observed at Tustervatn due to the relatively high influence of agricultural activity in the area. Also Kårvatn has high levels of sum of ammonium (NH_3 + NH_4^+).

Table 3.2: Annual mean concentrations of inorganic components in air at Norwegian background stations, 2013.

	SO_2	SO_4^{2-}	NO_2	sum NO_3	NO_3	sum NH_4	NH_4	Mg	Ca	K	Cl	Na
	μg-S/m^3	μg-S/m^3	μg-N/m^3	μg-N/m^3	μg-N/m^3	μg-N/m^3	μg-N/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Birkenes II	0.09	0.25	0.28	0.29	0.21	0.47	0.23	0.06	0.06	0.06	0.57	0.51
Hurdal	0.04	0.17	0.69	0.18	0.12	0.37	0.15	0.02	0.05	0.06	0.14	0.17
Kårvatn	0.02	0.09	0.16	0.13	0.09	0.57	0.09	0.02	0.04	0.04	0.16	0.15
Tustervatn	0.03	0.08	0.13	0.13	0.09	0.69	0.09	0.03	0.04	0.03	0.25	0.20
Zeppelin	0.09	0.16	-	0.18	0.13	0.28	0.11	0.04	0.04	0.04	0.32	0.25

Table 3.3: Number of daily, observations 50-, 75-, 90-percentile concentrations, max and annual mean concentrations for SO_2 in air at Norwegian background station in 2013.

Site	No. of observations	SO_2 (μg S/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	364	0.05	0.11	0.23	0.78	27.07.2013	0.09
Kårvatn	358	0.01	0.02	0.04	0.24	22.03.2013	0.02
Tustervatn	328	0.01	0.03	0.06	0.89	19.03.2013	0.03
Zeppelin	310	0.01	0.07	0.25	2.74	07.12.2013	0.09
Hurdal	364	0.01	0.05	0.11	0.49	29.05.2013	0.04

Table 3.4: Number of daily, observations 50-, 75-, 90-percentile concentrations, max- and annual mean concentrations for SO_4 in aerosols at Norwegian background station in 2013.

Site	No. of observations	SO_4 (µg S/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	364	0.18	0.35	0.53	1.8	17.02.2013	0.25
Kårvatn	358	0.06	0.14	0.23	0.55	18.05.2013	0.09
Tustervatn	329	0.06	0.1	0.18	0.69	03.03.2013	0.08
Zeppelin	309	0.11	0.23	0.36	0.72	23.05.2013	0.16
Hurdal	364	0.11	0.22	0.39	1.38	27.01.2013	0.17

Table 3.5: Number of daily, observations 50-, 75-, 90-percentile concentrations, max and annual mean concentrations for NO_2 in air at Norwegian background station in 2013.

Site	No. of observations	NO_2 (µg N/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	365	0.20	0.33	0.56	2.64	12.12.2013	0.28
Kårvatn	363	0.12	0.18	0.26	1.47	05.03.2013	0.16
Tustervatn	363	0.12	0.17	0.21	1.39	21.01.2013	0.13
Hurdal	363	0.44	0.84	1.52	8.39	26.11.2013	0.69

Table 3.6: Number of daily, observations 50-, 75-, 90-percentile concentrations, max- and annual mean concentrations of the sum of nitrate and nitric acid in air at Norwegian background station in 2013.

Site	No. of observations	NO_3+HNO_3 (µg N/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	363	0.16	0.31	0.63	3.01	13.01.2013	0.29
Kårvatn	349	0.07	0.14	0.32	2.10	03.01.2013	0.13
Tustervatn	329	0.05	0.10	0.23	3.18	02.01.2013	0.13
Zeppelin	303	0.06	0.16	0.46	2.18	02.04.2013	0.18
Hurdal	363	0.10	0.21	0.43	1.17	19.12.2013	0.18

Table 3.7: Number of daily, observations 50-, 75-, 90-percentile concentrations, max- and annual mean concentrations of ammonium in aerosols at Norwegian background station in 2013.

Site	No. of observations	NH_4 (µg N/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	363	0.11	0.28	0.56	2.41	13.01.2013, 05.03.2013	0.23
Kårvatn	351	0.03	0.13	0.22	1.55	27.12.2013	0.09
Tustervatn	329	0.02	0.09	0.20	2.53	02.01.2013	0.09
Zeppelin	302	0.04	0.11	0.30	1.75	02.04.2013	0.11
Hurdal	363	0.08	0.21	0.42	1.15	07.05.2013	0.15

Table 3.8: Number of daily, observations 50-, 75-, 90-percentile concentrations, max- and annual mean concentrations of the sum of ammonium and ammonia in air at Norwegian background station in 2013.

Site	No. of observations	$NH_4 + NH_3$ (µg N/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	363	0.32	0.57	0.97	2.84	05.03.2013	0.47
Kårvatn	350	0.45	0.72	1.17	3.49	03.03.2013	0.57
Tustervatn	329	0.50	0.84	1.38	6.58	03.03.2013	0.69
Zeppelin	290	0.21	0.32	0.60	1.99	02.04.2013	0.28
Hurdal	341	0.30	0.48	0.78	1.33	07.05.2013, 19.12.2013	0.37

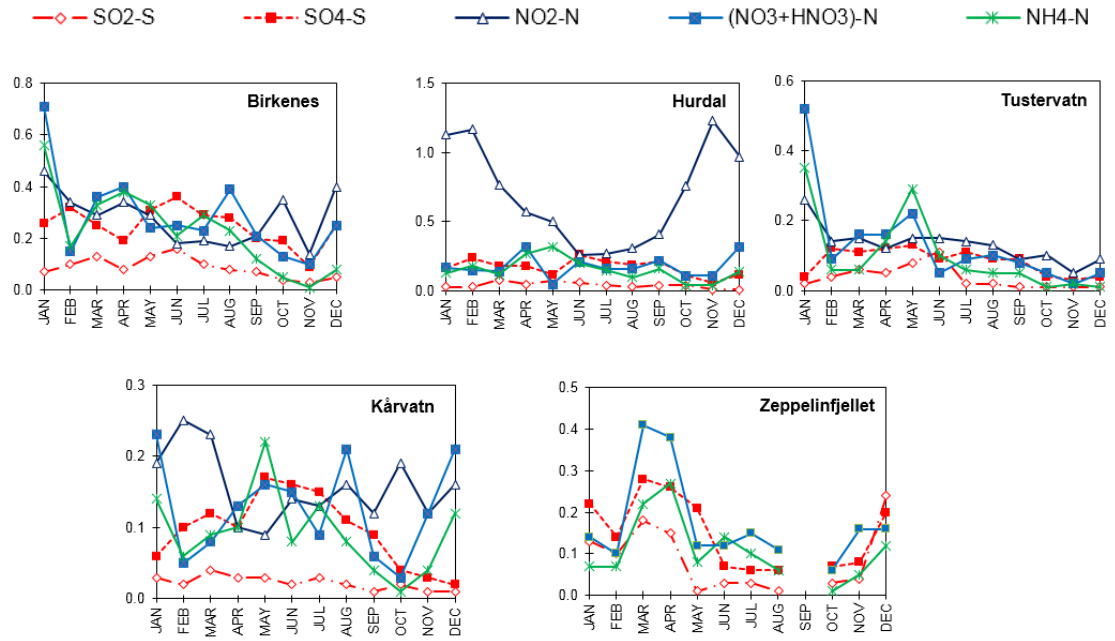


Figure 3.5: Monthly mean concentrations of sulphur and nitrogen components in air at the five EMEP sites in Norway in 2013. Unit: µg(S or N)/m^3.

3.1.3 Total deposition of sulphur and nitrogen

Table 3.9 and Figure 3.6 present estimates of the total dry deposition of sulphur and nitrogen compounds and measured wet deposition, in the growing season from May to October (summer) and winter months from January to April and November to December. Dry deposition is calculated on the basis of the mean concentrations of SO_2, SO_4^{2-}, NO_2, sum of nitrate (NO_3^- + HNO_3), and sum of ammonium (NH_3 + NH_4^+) and deposition velocities given in table text (Dovland and Eliassen, 1976; Dollard and Vitols, 1980; Fowler, 1980; Garland, 1978; Voldner and Sirois, 1986; Hicks et al., 1987).

In the sum of nitrate (NO_3^- + HNO_3), it is believed that HNO_3 contributes with 25 % and NO_3^- by 75 %. And in sum of ammonium (NH_3 + NH_4^+) NH_3 is believed to contribute with 8% and NH_4^+ by

92% (Ferm, 1988). The dry deposition velocities of gases and particles are highly variable and uncertain quantities. The deposition of particles (SO_4^{2-}, NO_3^-, and NH_4^+) increases with wind speed and with the ground's roughness (forest coverage etc.). The deposition of gases (SO_2, NO_2, HNO_3, and NH_3) depends on the biological activity of the vegetation, and surface type (water, mountains, etc.). The deposition is for most gases far greater on wet surfaces than when the surfaces are dry. In winter, the deposition is small because of low biological activity, and the surface is often covered in snow and ice. The stable layer of air close to the ground in winter also reduces the transport of contaminants to the ground.

The wet deposition contribute most to the total deposition at all the sites on the main land, for both nitrogen and sulphur, and the total deposition is highest in southern Norway (Figure 3.6 and Table 3.9). Dry deposition of sulphur contributes to the total deposition with 17-33 % in summer and 5-19 % in winter except at Svalbard where dry deposition is relatively much higher due low precipitation amount. For nitrogen, the dry deposition is relativity more important than for sulphur. Dry deposition of nitrogen contributes between 16-46% in summer in 9-27% in winter to the total nitrogen load.

Table 3.9: Estimated dry deposition and measured wet deposition of sulphur and nitrogen at Norwegian background stations 2013.

Dry deposition = measured air concentrations · dry deposition velocity from literature
Dry deposition velocities used: SO_2: 0.1 cm/s (winter) - 0.7 cm/s (summer). SO_4: 0.2-0.6 cm/s, NO_2: 0.1-0.5 cm/s, HNO_3: 1.5-2.5 cm/s, NO_3: 0.2-0.6 cm/s, NH_4: 0.2-0.6 cm/s, NH_3: 0.1-0.7 cm/s. Sum nitrate = 25% HNO_3 + 75% NO_3. Sum ammonium = 8% NH_3 + 92% NH_4.
The %- values indicate the estimated contributed of dry deposition to the total deposition for winter (W) and summer (S) Summer = May - October, winter = January - April and November - December.
For Zeppelin, wet deposition is taken from Ny-Ålesund.

	Sulphur (mg S/m²)						**Nitrogen (mg N/m²)**					
	Dry deposition		Wet deposition		% dry deposition		Dry deposition		Wet deposition		% dry deposition	
	Winter	Summer	Winter	Summer	% W	% S	Winter	Summer	Winter	Summer	% V	% S
Birkenes	8	37	143	163	5	18	50	103	497	532	9	16
Hurdal	5	23	44	113	11	17	28	154	196	386	12	29
Kårvatn	3	14	11	46	19	23	38	72	102	161	27	31
Tustervatn	3	13	22	27	12	33	36	101	105	120	26	46
Zeppelin	8	11	4	24	68	31	-	-	12	31	-	-

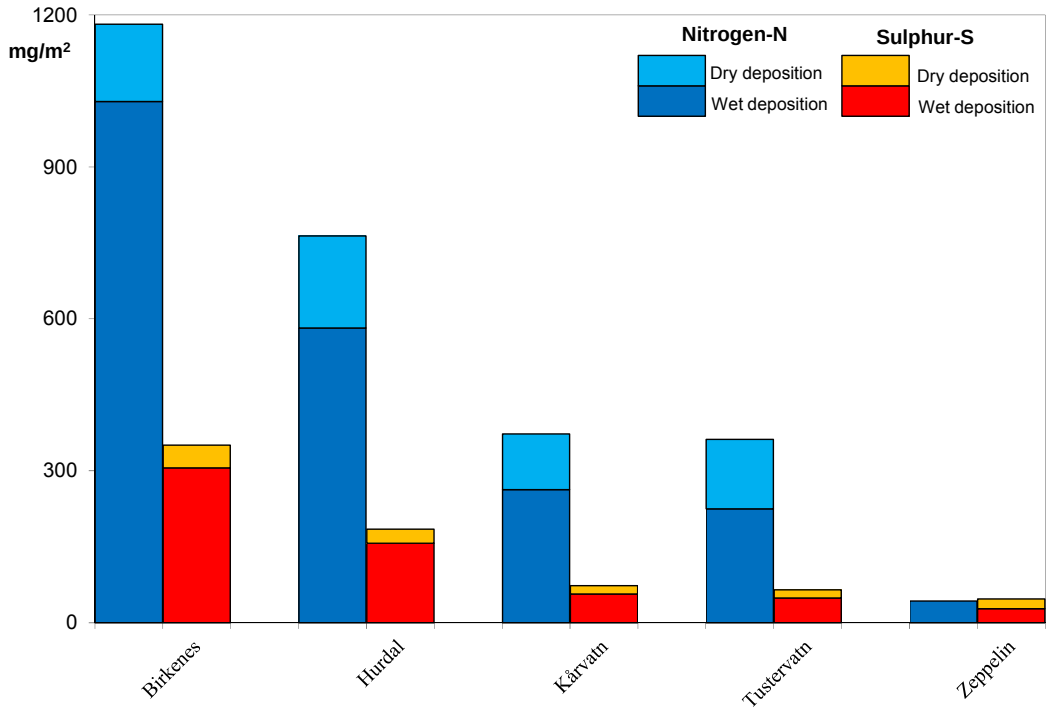


Figure 3.6: Total deposition (wet+ dry) of sulphur-S (SO_2, SO_4^{2-}) and nitrogen-N (NO_2, NH_4^+, NH_3, NO_3^-, HNO_3) at Norwegian background stations 2013.

3.2 Trends

An important goal of the monitoring programme is to measure the effectiveness of the protocols. Since Norway is downwind of the major emission sources in Continental Europe, the monitoring programme in Norway can indicate on the total emission reductions in Europe. The most relevant protocol is the Gothenburg Protocol (UN/ECE, 1999). This is a multicomponent protocol where the objective was to reduce European emissions of sulphur by 63% in 2010 compared to 1990. Similarly, the target for nitrogen oxides and ammonia were a reduction of respectively 41% and 17%. In 2012, the Gothenburg Protocol was revised and it was set new emissions targets for 2020 with 2005 as the base year. The 27 EU countries (Norway in brackets) has made the following commitments in emission reductions SO_2: 59% (10%), NO_x: 43% (23%), nmVOC: 28% (40%), ammonia: 6%, (8%) and $PM_{2.5}$: 22% (30%).

Figure 3.7-Figure 3.9 show the time series of annual mean concentrations of main ions in precipitation, in air and total deposition at selected sites in Norway with long time series. Table 3.10 and 3.11 shows the statistical trends for three different periods, 1980-, 1990-, and 2000-2013 for all sites with measurements in these respective periods.

For the statistical analysis, the non-parametric "Mann-Kendall Test" has been used on annual means for detecting and estimating trends (Gilbert, 1987). The Mann-Kendall test has become a standard method when missing values occurs and when data are not normally distributed. In parallel to this, the Sen's slope estimator has been used to quantify the magnitude of potential trends. Thus, the Sen's slope is used to estimate the percent reduction in the

concentration level while the Mann-Kendall test is used to indicate the significance level of the trend. Statistical calculations have been carried out using the MAKESENS software (Salmi et al., 2002).

For sulphur, there has been a significant reduction at all the sites for all the sulphur components in air and precipitation from both 1980 and 1990 to 2013. Since 1980, the content of sulphate in precipitation in Norway has decreased by 76-94%. The reductions in airborne concentrations were similar, between 93%-96% and 80-85% at the Norwegian mainland for sulphur dioxide and sulphate, respectively. Somewhat lower reductions are observed at the Zeppelin Observatory, 86% for sulphur dioxide and 63% for sulphate, Table 3.11.

Since 1990, the reductions have been between 43-68% (sulphate in precipitation), 60-84% (sulphur dioxide) and 50-68% (sulphate in air). From 2000, all the sites except Tustervatn observe a significant reduction of sulphate in precipitation, between 24-36%. For sulphur dioxide, there is significant reduction at three of the five sites with about 30% reduction, similar trends for sulphate in air though significant at four sites.

The nitrate and ammonium concentrations in precipitation have significantly decreased at most sites in southern Norway, 26%-51% for nitrate and 47%-60% for ammonium since 1980. At Tustervatn it has been an increase in ammonium in precipitation since 1980 maybe due to increased local influence. The air measurements did not start as early as the ones for precipitation, thus trend analysis for these have only been done from 1990.

For nitrate in precipitation, the sites south of Haukeland shows a significant decrease of about 30% from 1990-2013. Most of the sites also show a decrease of ammonium, but some with a significant increase. There is also a decrease in the observed ammonium in air for two of the sites at the mainland, between 29%-55% since 1990, but for sum nitrate and sum of ammonium it has rather been a significant increase maybe due to changes in local emissions.

The NO_2 concentration has decreased between 38%-72% for the three sites with significant trends. The observed reductions in concentration levels of sulphur and nitrogen species are in agreement with reported downwards trends in pollutant emissions in Europe (Tørseth et al., 2012).

Calcium is significantly reduced at most sites since 1980, which is consistent with emission reduction from anthropogenic sources in Europe (Hellsten et al., 2007).

The contribution of sea salts are influence by meteorological conditions and vary from year to year. A significant reduction is seen at Løken from 1980-2013 and at Vatnedalen from 1990-2013.

*Table 3.10: Trends in annual mean concentrations of inorganic ions in precipitation using. Mann-Kendall test and Sen slope estimates; *** is significant level 0.001; ** significant level 0.01; * significant level 0.05, + significant level 0.1.*

1980-2013									
site	SO_4	% change	NO_3	% Change	NH_4	% change	Ca	% change	Mg	% change
Birkenes	***	-86 %	***	-37 %	***	-50 %	***	-51 %		
Treungen	***	-87 %	***	-36 %	***	-47 %	***	-46 %		
Vatnedalen	***	-85 %	**	-31 %						
Løken	***	-94 %	***	-51 %	***	-60 %	***	-56 %	*	-35 %
Gulsvik/Brekkebygda	***	-91 %	***	-48 %	***	-58 %	*	-29 %		
Haukeland [1)]	***	-88 %	***	-37 %	**	-48 %	**	-38 %		
Kårvatn	***	-76 %	*	-26 %			**	-41 %		
Tustervatn	***	-86 %			*	48 %	**	-40 %		
Ny-Ålesund [2)]	***	-81 %								

[1)]From 1982 [2)] From 1981

1990-2013									
site	SO_4	% change	NO_3	% change	NH_4	% change	Ca	% change	Mg	% change
Birkenes	***	-56 %	***	-28 %	**	-29 %				
Treungen	***	-58 %	***	-32 %	**	-32 %				
Vatnedalen	***	-57 %	*	-27 %					**	-48 %
Nordmoen/Hurdal	***	-68 %	***	-28 %			+	64 %		
Løken	***	-61 %	***	-37 %	*	-35 %				
Gulsvik/Brekkebygda	***	-58 %	***	-38 %	*	-36 %				
Vikedal	***	-66 %	**	-22 %						
Nausta	***	-66 %	*	-25 %	**	105 %				
Høylandet	***	-65 %			***	125 %				
Haukeland	***	-62 %	*	-30 %	*	-36 %	+	-26 %		
Kårvatn	***	-43 %			*	56 %				
Tustervatn	***	-52 %					+	-29 %		
Ny-Ålesund	***	-60 %								

2000-2013									
site	SO_4	% change	NO_3	% change	NH_4	% change	Ca	% change	Mg	% change
Birkenes	**	-27 %					*	347 %		
Treungen	***	-29 %								
Vatnedalen	+	-28 %								
Nordmoen/Hurdal	**	-30 %					+	867 %		
Løken	**	-28 %	*	-15 %						
Gulsvik/Brekkebygda	**	-27 %							*	-26 %
Vikedal	**	-35 %	+	-18 %			+	371 %		
Nausta	**	-36 %			**	200 %				
Høylandet	*	-36 %			**	163 %				
Haukeland	**	-34 %	*	-22 %						
Kårvatn	*	-24 %			*	260 %				
Tustervatn										
Ny-Ålesund	*	-32 %					+	-32 %		

*Table 3.11: Trends in annual mean concentrations of inorganic components in air using Mann-Kendall test and Sen slope estimates; *** is significant level 0.001; ** significant level 0.01; * significant level 0.05, + significant level 0.1.*

1980-2013				
Site	SO_2	% change	SO_4	% change
Birkenes[1)]	***	-96 %	***	-81 %
Kårvatn[1)]	***	-94 %	***	-80 %
Tustervatn[1)]	***	-93 %	***	-85 %
Zeppelin	***	-86 %	***	-63 %

[1)] Sen slope gave more than 100% reduction, thus used upper 95% confidence level.

1990-2013												
Site	SO_2	% change	SO_4	% change	Sum NO_3	% change	Sum NH_4	% change	NH_4 (from 1993)	% change	NO_2	% change
Birkenes	***	-66 %	***	-53 %					**	-40 %	***	-48 %
Nordmoen/Hurdal	***	-84 %	***	-68 %					**	-55 %	***	-72 %
Kårvatn	***	-60 %	***	-50 %	+	85 %	***	329 %	+	-29 %		
Tustervatn	***	-62 %	***	-52 %	**	131 %	**	108 %	*	-31 %	***	-38 %
Zeppelin	***	-52 %	***	-32 %	*	458 %	***	362 %			-	-

2000-2013												
Site	SO_2	% change	SO_4	% change	Sum NO_3	% change	Sum NH_4	% change	NH_4	% change	NO_2	% change
Birkenes	+	-27 %	*	-26 %							**	-24 %
Nordmoen/Hurdal			*	-34 %								
Kårvatn			*	-26 %								
Tustervatn	*	-30 %	*	-29 %	+	413 %					+	-18 %
Zeppelin	**	-30 %			*	82 %	*	186 %	*	106 %	-	-

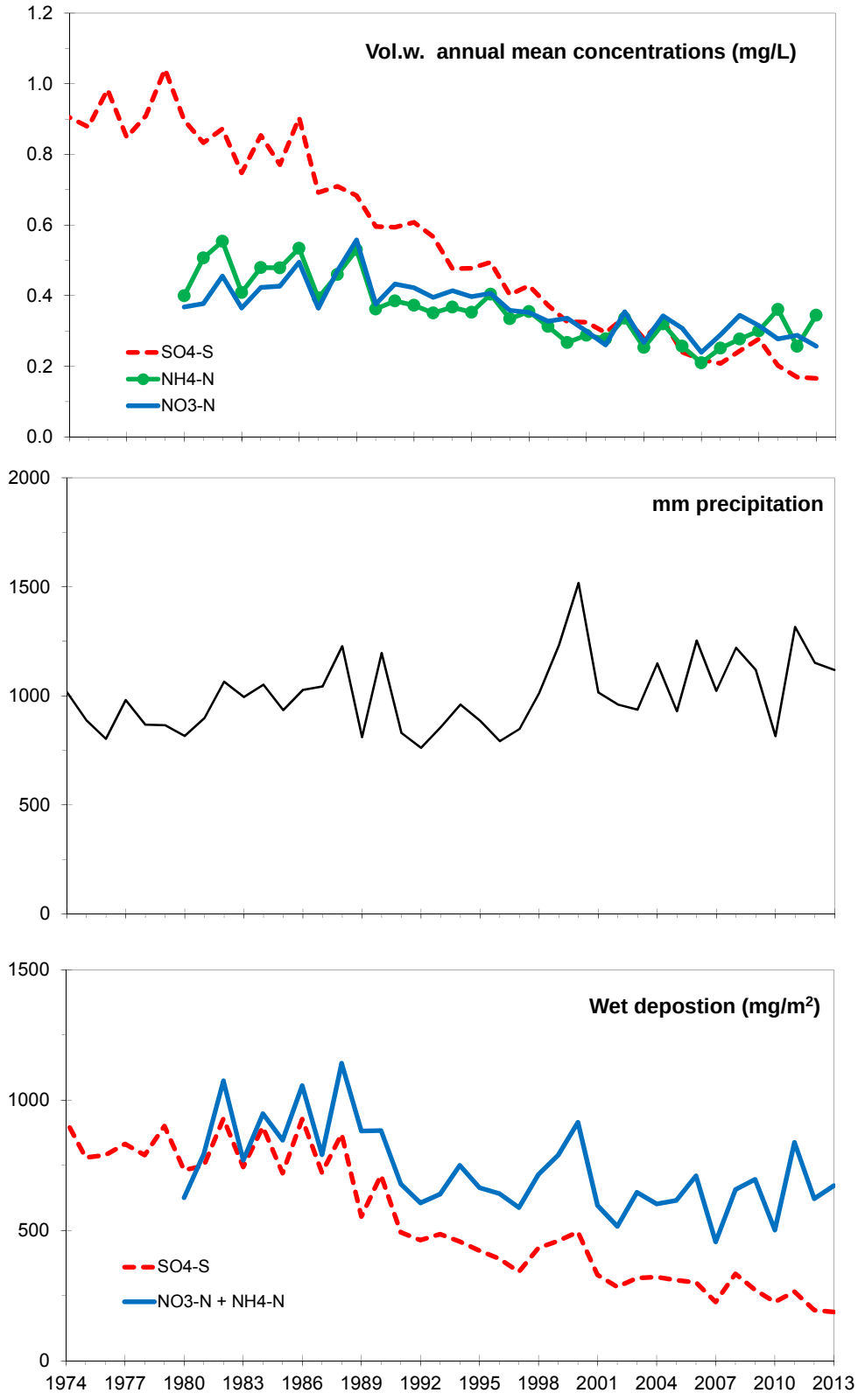


Figure 3.7: Volume weighted annual mean concentrations (top), precipitation amount (middle) and wet deposition) for sea salt corrected sulphate, nitrate and ammonium at five representative sites in southern Norway (Birkenes, Vatnedalen, Treungen, Gulsvik and Løken), 1974-2013.

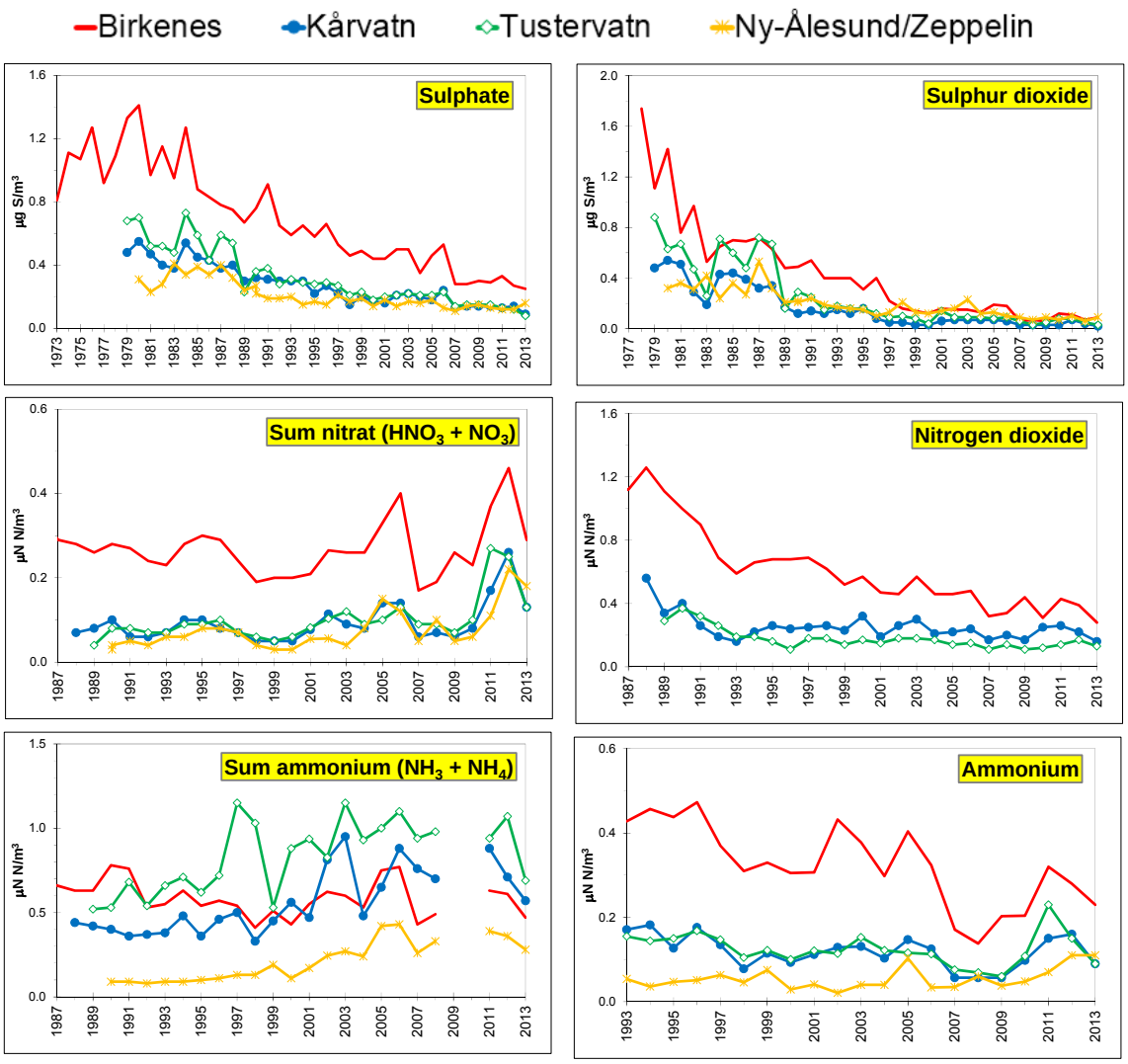


Figure 3.8: Annual mean concentrations of sulphur and nitrogen components in air at four Norwegian EMEP sites, 1973-2012.

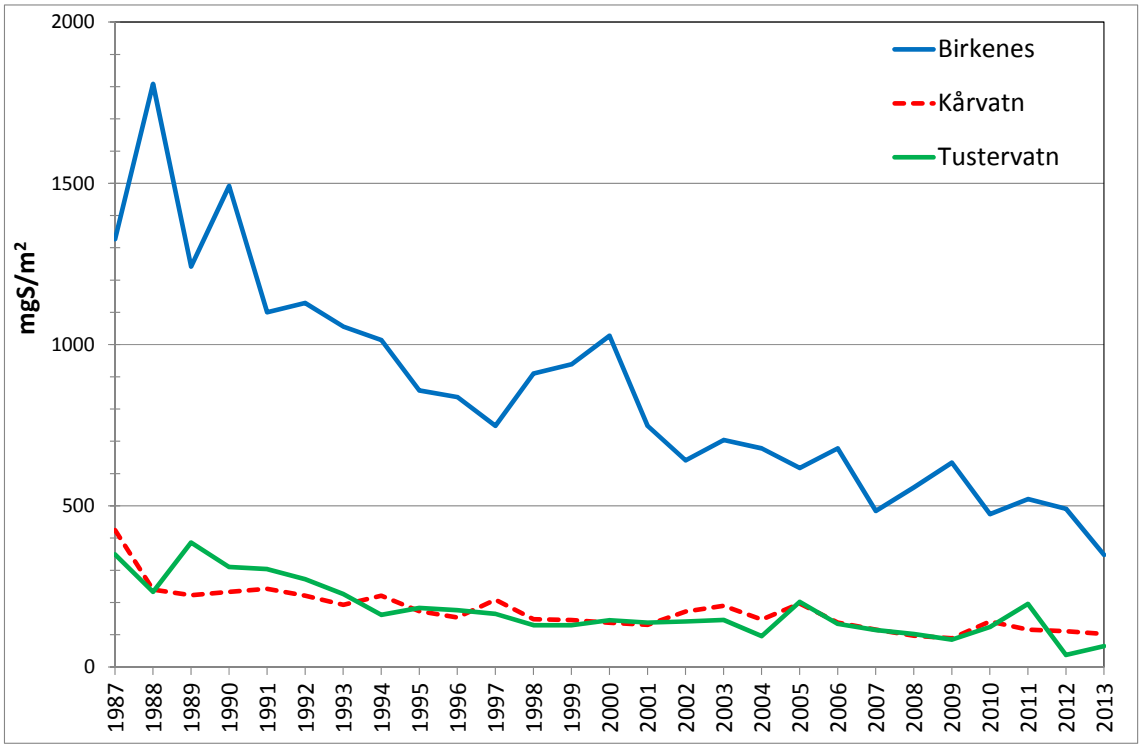


Figure 3.9: Trends in total deposition (wet + dry) of sulphur at three Norwegian EMEP sites, 1987-2013.

4. EC and OC

4.1 Introduction

Elemental (EC) and organic (OC) carbon are abundant fractions of the ambient aerosol particle, thus contributing to the aerosol particle influence on the radiation budget both directly, by scattering and absorption of sunlight, and indirectly, by cloud formation. Likewise does the carbonaceous fraction contribute to the adverse health effects observed; i.e., respiratory and cardiovascular diseases. EC enters the atmosphere exclusively as a primary (i.e., direct particulate) emission, whereas OC includes both primary aerosol particles and secondary aerosol particles, of which the latter is formed from gaseous precursors oxidized in the atmosphere. The carbonaceous fraction can be of both anthropogenic and natural origin; e.g., EC and OC from incomplete combustion of fossil fuel (e.g. vehicular tailpipe emissions) and biomass (residential wood burning and wild fires), OC from oxidation of gaseous emissions from coniferous and deciduous trees, and OC associated with primary biological aerosol particles (PBAP). EC and OC are typically associated with the fine aerosol particle, although OC can appear in the coarse fraction as well, e.g. the PBAPs or due to condensation of OC on coarse aerosol particles. Despite the importance of the carbonaceous aerosol, detailed apportionment and quantification of its sources is still difficult due to the large number of sources, the complexity of atmospheric formation and the vast number of organic compounds associated with the aerosol.

EC and OC are simply operational definitions, and do not provide information about the source *pr. se*, thus additional measurements to EC and OC are required to provide information about the carbonaceous aerosol sources and their relative share. Source apportionment studies (Yttri et al., 2011a, b), using a combination of ^{14}C and organic tracers, show that natural sources dominates OC in PM_{10} at Norwegian rural background sites in summer, of which OC associated with the biogenic secondary organic aerosol (BSOA) is the major source followed by OC associated with PBAP. In winter, anthropogenic sources dominates OC in PM_{10}, i.e., emissions from fossil fuel combustion and residential wood burning. The picture is rather similar for OC in PM_1, except that OC associated with PBAP is of much less importance in summer than seen for PM_{10}. Combustion of fossil fuel appears to be the major source of EC regardless of season and size fraction, but EC from residential wood burning increases substantially in winter.

Monitoring of ambient aerosol EC and OC in PM_{10} and $PM_{2.5}$ are currently taking place at three rural background sites; i.e., the Birkenes Observatory and the Hurdal and Kårvatn sites. The time series at the Birkenes Observatory dates back to 2001, whereas at the Hurdal and Kårvatn sites measurements were initiated in 2010.

4.2 Concentrations of OC

PM_{10}

The annual mean concentration of OC in PM_{10} ranged from 0.75 µg C m^3 (Kårvatn) to 1.05 µg C m^3 (Hurdal), being approximately 40% higher at Hurdal compared to Kårvatn and Birkenes (Table 4.1). The annual mean concentration of OC in PM_{10} was within one standard deviation (SD) of the long-term mean at all sites. For Birkenes, the annual mean OC concentration in

PM_{10} was the second lowest value observed since the measurements started in 2001 (Figure 4.1).

Table 4.1: Annual mean concentrations of OC, EC and TC in PM_{10} and $PM_{2.5}$ at the Birkenes Observatory and the sites Hurdal and Kårvatn for the period 2001 - 2013.

Year	PM_{10}			$PM_{2.5}$		
	OC	EC	TC	OC	EC	TC
Birkenes						
2001	1.10	0.13	1.3	1.00	0.16	1.20
2002	1.00	0.14	1.2	0.92	0.12	1.00
2003	1.00	0.11	1.2	0.86	0.12	0.98
2004	0.84	0.10	0.94	0.59	0.09	0.68
2005	0.93	0.15	1.10	0.64	0.12	0.75
2006	1.20	0.13	1.30	0.89	0.13	1.00
2007	0.84	0.14	0.98	0.63	0.12	0.75
2008	0.8	0.09	0.89	0.57	0.08	0.65
2009	0.79	0.10	0.89	0.58	0.09	0.67
2010	0.9	0.11	1.00	0.67	0.10	0.78
2011	0.92	0.12	1.00	0.68	0.11	0.8
2012	0.57	0.08	0.64	0.50	0.08	0.58
2013	0.76	0.09	0.84	0.57	0.08	0.65
Hurdal						
2010	1.30	0.16	1.40	0.87	0.15	1.00
2011	1.30	0.17	1.50	0.89	0.17	1.10
2012	0.86	0.13	0.99	0.60	0.12	0.73
2013	1.05	0.14	1.19	0.76	0.14	0.90
Kårvatn						
2010	0.98	0.06	1.00	0.85	0.07	0.92
2011	0.88	0.07	0.95	0.67	0.07	0.74
2012	0.72	0.05	0.78	0.56	0.05	0.62
2013	0.75	0.06	0.81	0.53	0.06	0.59

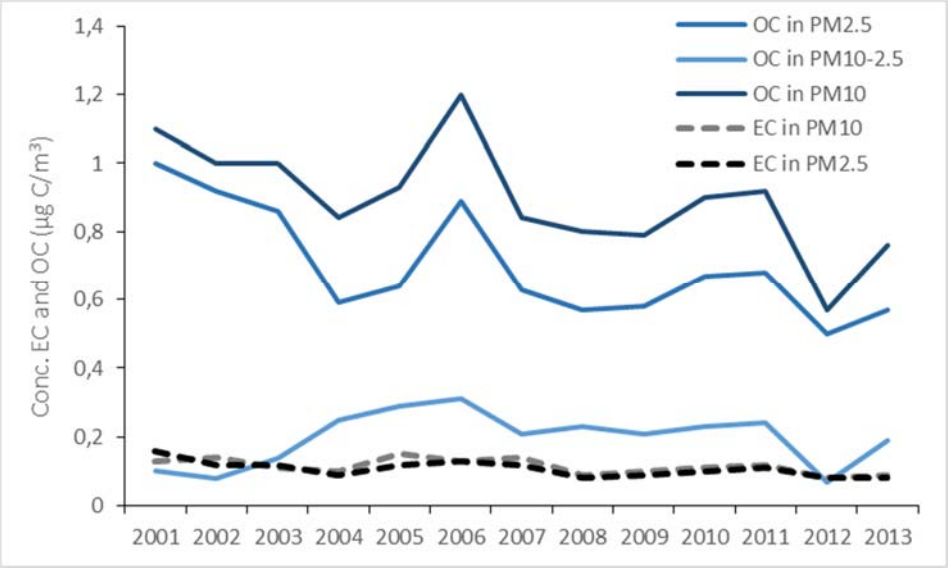


Figure 4.1: Annual mean time series of EC and OC, as observed at the Birkenes Observatory during the period 2001 - 2013.

The summertime (April - September) mean concentration of OC in PM_{10} was 2 (Birkenes and Hurdal) and 3 (Kårvatn) times higher than the wintertime (October - March) mean (Table 4.2). Increased levels of OC in summer are typically associated with increased levels of SOA, and BSOA in particular, and for Norwegian and Nordic rural background sites, PBAP is demonstrated to be a major contributor to the coarse fraction of PM_{10} ($PM_{10-2.5}$) as well. See Yttri et al. (2011 a, b) for a quantitative source apportionment of the carbonaceous aerosol particle in the Norwegian and Nordic rural background environment.

Table 4.2: Annual and monthly mean concentrations of OC, EC and TC in PM_{10} and $PM_{2.5}$ at the sites Birkenes, Hurdal and Kårvatn for 2013.

Month	PM_{10}			$PM_{2,5}$		
	OC	EC	TC	OC	EC	TC
Birkenes						
January	0.50	0.11	0.61	0.55	0.09	0.65
February	0.65	0.14	0.79	0.53	0.10	0.63
March	0.56	0.11	0.67	0.51	0.10	0.60
April	0.44	0.08	0.52	0.36	0.07	0.43
May	1.37	0.11	1.48	1.03	0.10	1.13
June	1.36	0.05	1.42	0.92	0.07	0.99
July	1.14	0.07	1.22	0.85	0.08	0.93
August	0.95	0.06	1.02	0.58	0.06	0.64
September	0.79	0.10	0.89	0.49	0.09	0.58
October	0.66	0.09	0.75	0.41	0.09	0.50
November	0.28	0.05	0.33	0.24	0.05	0.29
December	0.36	0.07	0.43	0.28	0.07	0.35
Annual mean	0.76	0.09	0.84	0.57	0.08	0.65
Hurdal						
January	0.72	0.19	0.91	0.82	0.20	1.0
February	0.81	0.20	1.02	0.74	0.18	0.92
March	0.61	0.15	0.76	0.59	0.14	0.73
April	0.44	0.09	0.53	0.36	0.09	0.46
May	1.70	0.14	1.83	1.29	0.15	1.45
June	1.89	0.10	1.99	1.38	0.11	1.49
July	1.43	0.08	1.51	1.05	0.08	1.13
August	1.23	0.09	1.32	0.67	0.08	0.75
September	1.54	0.14	1.68	0.69	0.13	0.82
October	0.98	0.16	1.14	0.49	0.15	0.64
November	0.70	0.18	0.88	0.58	0.18	0.76
December	0.51	0.15	0.66	0.49	0.15	0.63
Annual mean	1.05	0.14	1.19	0.76	0.14	0.90
Kårvatn						
January	0.34	0.08	0.42	0.32	0.08	0.39
February	0.40	0.07	0.47	0.37	0.07	0.44
March	0.33	0.07	0.40	0.32	0.07	0.39
April	0.27	0.03	0.29	0.26	0.03	0.29
May	1.45	0.07	1.52	1.14	0.08	1.23
June	1.36	0.06	1.39	0.89	0.08	0.97
July	1.31	0.06	1.36	0.94	0.05	0.99
August	1.01	0.07	1.08	0.65	0.07	0.72
September	1.24	0.07	1.32	0.66	0.08	0.74
October	0.63	0.06	0.69	0.33	0.06	0.39
November	0.34	0.04	0.38	0.21	0.04	0.24
December	0.22	0.03	0.24	0.25	0.03	0.28
Annual mean	0.75	0.06	0.81	0.53	0.06	0.59

Observed concentrations of OC, and EC, were higher at the Hurdal site compared to the Birkenes Observatory and the Kårvatn site regardless of season and size fraction (PM_{10} and $PM_{2.5}$), and the differences was larger in winter compared to summer. We speculate that the more densely populated region surrounding the Hurdal site, compared to those surrounding the two other sites, largely can explain the actual observation. Incidences of higher monthly mean concentrations for OC and EC in $PM_{2.5}$ than for PM_{10} seen in Table 4.1 are typically attributed to a deviating number of samples for the two size fractions or very low concentrations (typically for EC).

$PM_{2.5}$

The annual mean concentration of OC in $PM_{2.5}$ ranged from 0.53 µg C m^3 (Kårvatn) to 0.76 µg C m^3 (Hurdal), being 43% higher at Hurdal compared to Kårvatn and 33% higher at Hurdal compared to Birkenes (Table 4.1). The annual mean concentration of OC in PM_{10} was within the long-term mean at all sites. For Birkenes, the annual mean OC concentration in PM_{10} was the second lowest value observed since the measurements started in 2001 (Figure 4.1).

The summertime (April - September) mean concentration of OC in $PM_{2.5}$ was 1.5 (Hurdal), 1.7 (Birkenes) and 2.5 (Kårvatn) times higher than the wintertime (October - March) mean (Table 4.2). As already described, (B)SOA is a major contributor to OC in summer; PBAP, however, is not likely to contribute particularly to the observed seasonality of OC in $PM_{2.5}$ as it mainly reside in the $PM_{10\text{-}2.5}$ fraction.

$PM_{10\text{-}2.5}$

OC in $PM_{10\text{-}2.5}$ can be obtained by subtracting OC in $PM_{2.5}$ from that of OC in PM_{10}. The annual mean concentration of OC in $PM_{10\text{-}2.5}$ ranged from 0.19 µg C m^3 (Birkenes) to 0.29 µg C m^3 (Hurdal), being 53% higher at Hurdal compared to Birkenes and 32% higher at Hurdal compared to Kårvatn (Figure 4.1The annual mean concentration of OC in $PM_{10\text{-}2.5}$ was within 1SD of the long-term mean at all sites.

The summertime (April - September) mean concentration of OC in $PM_{10\text{-}2.5}$ was 2.8 (Birkenes) to 3.6 (Kårvatn) times higher than the wintertime (October - March) mean. The pronounced seasonality of OC in $PM_{10\text{-}2.5}$ strongly suggests that it is dominated by PBAP, which peaks during the vegetative season (see Yttri et al., 2007a; Yttri et al., 2011a, b).

4.3 Concentrations of EC

PM_{10}

The annual mean concentration of EC in PM_{10} ranged from 0.06 µg C m^3 (Kårvatn) to 0.14 µg C m^3 (Hurdal), being 56% higher at Hurdal compared to Birkenes and 133% higher at Hurdal compared to Kårvatn (Table 4.1). The annual mean concentration of EC in PM_{10} for 2013 was within 1 SD of the long-term mean at all sites. For Birkenes, the annual mean EC concentration in PM_{10} was the second lowest value observed since the measurements started in 2001 (Figure 4.1).

The wintertime (October - March) mean concentration of EC in PM_{10} was 1.2 and 1.6 times higher than the summertime (April - September) mean at the sites Birkenes and Hurdal,

respectively, whereas no seasonality was observed for Kårvatn (Table 4.2). Increased levels of EC in winter could be associated with increased emissions from e.g. residential wood burning, but also meteorological inversion, preventing dispersion could play an important role.

$PM_{2.5}$

The annual mean concentration of EC in $PM_{2.5}$ ranged from 0.06 µg C m^3 (Kårvatn) to 0.14 µg C m^3 (Hurdal), being 75% higher at Hurdal compared to Birkenes and 133% higher at Hurdal compared to Kårvatn (Table 4.1). The annual mean concentration of EC in PM_{10} for 2013 was within 1 SD of the long-term mean at all sites. The annual mean EC concentration in $PM_{2.5}$ observed at Birkenes for 2013 (i.e., 0.08 µg C/m^3) was the lowest value observed since the measurements started in 2001, equalling that of 2008 and 2012 (Figure 4.1).

The wintertime (October - March) mean concentration of EC in PM_{10} was 1.1 and 1.5 times higher than the summertime (April - September) mean at the sites Birkenes and Hurdal, respectively, whereas for Kårvatn the summertime mean was slightly higher than for the wintertime mean; i.e. 1.1 times higher (Table 4.2).

4.4 Relative contribution of EC/OC to PM

4.4.1 Relative contribution of OC in $PM_{2.5}$ and OC in $PM_{10\text{-}2.5}$ to OC in PM_{10}

On an annual basis, 71% (Kårvatn) to 75% (Birkenes) of OC in PM_{10} was attributed to OC residing in the fine fraction of PM_{10}, i.e., the $PM_{2.5}$ fraction, which is within 1SD of the long-term mean at all sites. These numbers reflect that OC mainly is associated with fine aerosol particles, as it is emitted from combustion processes or is a result of gas to particle conversion, by either formation of new particles or by condensation on existing ones. A 25% (Birkenes) to 29% (Kårvatn) contribution of OC in $PM_{10\text{-}2.5}$ to OC in PM_{10} on an annual basis is considered substantial, and during the vegetative season, OC in $PM_{10\text{-}2.5}$ can even be the major contributor to OC in PM_{10}, considered on a monthly basis. The pronounced seasonal variation of OC in $PM_{10\text{-}2.5}$, with increased levels during the vegetative season, suggest that this fraction is dominated by PBAP. This has also been documented in peer reviewed papers (Yttri et al., 2007a, b and 2011a, b).

4.4.2 Relative contribution of EC in $PM_{2.5}$ to EC in PM_{10}

On an annual basis, 89% (Birkenes) to 100% (Hurdal and Hurdal) of EC in PM_{10} was attributed to EC residing in the fine fraction of PM_{10}, i.e., the $PM_{2.5}$ fraction, which is within 1SD of the long-term mean at all sites. EC is exclusively emitted as primary aerosol particles during combustion of fossil fuel and biomass, hence their presence in the fine fraction of PM_{10} is as expected.

4.4.3 Relative contribution of OC and EC to TC for PM_{10} and $PM_{2.5}$

OC was the major contributor to TC at all sites, ranging from 88% (Hurdal) to 93% (Kårvatn) for PM_{10}, and from 84% (Hurdal) to 90% (Kårvatn) for $PM_{2.5}$, on an annual basis.

The relative share of EC and OC to TC had a pronounced seasonal variation, with the OC fraction increasing in summer and EC during winter. The observed seasonality largely reflects a change in sources according to season. Increased SOA formation and PBAP emissions in summer, and residential wood burning emissions in winter are the main drivers of the observed pattern. The larger fraction of OC seen for PM_{10} compared to $PM_{2.5}$ is attributed to

PBAP, which typically resides in the coarse fraction of PM_{10}, and that EC, being a result of combustion, is associated mainly with the fine fraction of $PM_{2.5}$.

4.4.4 Relative contributions of OC and EC to PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$

The relative contribution of OC to PM_{10} ranged from 16% (the Birkenes Observatory) to 24% (Kårvatn) on an annual basis. OC was a more abundant fraction of PM_{10} in summer (18-25%) compared to winter (14-22%) at all sites. A non-significant decrease in the relative contribution of OC to PM_{10} was observed for the time period 2001 – 2013 at the Birkenes Observatory, corresponding to a decrease of 0.2% yr^{-1} (17%).

The relative contribution of OC to $PM_{2.5}$ ranged from 20% (the Birkenes Observatory) to 25% (Kårvatn) on an annual basis. OC was a more abundant fraction of $PM_{2.5}$ in summer (21%) at the Birkenes Observatory compared to winter (16%), whereas it was the other way around at Hurdal; i.e., 23% in summer versus 25% in winter. No seasonal variability was observed for Kårvatn; i.e., 24%. A non-significant decrease in the relative contribution of OC to $PM_{2.5}$ was observed for the time period 2001 – 2013 at the Birkenes Observatory, corresponding to a decrease of 0.12% yr^{-1} (8%).

The relative contribution of OC to $PM_{10-2.5}$ ranged from 10% (the Birkenes Observatory) to 24% (Kårvatn) on an annual basis. OC was a more abundant fraction of $PM_{10-2.5}$ in summer (15-36%) compared to winter (8-14%) at all sites. A non-significant decrease in the relative contribution of OC to $PM_{10-2.5}$ was observed for the time period 2001 – 2013 at the Birkenes Observatory, corresponding to a decrease of 0.14% yr^{-1} (20%).

The relative contribution of EC to PM_{10} ranged from 1.8% (the Birkenes Observatory) to 3.0% (Hurdal) on an annual basis. EC was a more abundant fraction of PM_{10} in winter (2.6-4.7%) compared to summer (1.3-2.0%) at all sites; this seasonality was particularly pronounced at the sites Hurdal and Kårvatn. A non-significant decrease in the relative contribution of EC to PM_{10} was observed for the time period 2001 – 2013 at the Birkenes Observatory, corresponding to a decrease of 0.02% yr^{-1} (-11%).

The relative contribution of EC to $PM_{2.5}$ ranged from 2.8% (the Birkenes Observatory and Kårvatn) to 4.5% (Hurdal) on an annual basis. EC was a more abundant fraction of $PM_{2.5}$ in winter (3.4-6.8%) compared to summer (2.1-3.1%) at all sites; this seasonality was particularly pronounced at the site Hurdal. A non-significant decrease in the relative contribution of EC to $PM_{2.5}$ was observed for the time period 2001 – 2013 at the Birkenes Observatory, corresponding to a decrease of 0.004% yr^{-1} (-2%).

4.5 Trends for concentrations of EC and OC

The Mann Kendall method described in Chapter 3.2 is used also for trend analysis of concentrations of EC and OC. The shorter time series for the sites Hurdal and Kårvatn (4 years) allow for an assessment of the trend of EC and OC for the Birkenes site only. The time series of OC in PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$, and that of EC in PM_{10} and $PM_{2.5}$ at the Birkenes Observatory, are shown in Figure 4.1.

A significant downward trend in the observed annual mean concentration of OC in PM_{10} was seen for the time period 2001 – 2013 at the Birkenes Observatory, corresponding to a

decrease of 0.029 µg C/m^3 yr^{-1} (**; 35%). For the same time period, a significant downward trend in the observed annual mean concentration of OC in $PM_{2.5}$ was also observed, corresponding to a decrease of 0.028 µg C/m^3 yr^{-1} (*; 39%). A non-significant increase was observed for the annual mean concentration of OC in $PM_{10-2.5}$ for the actual time period, corresponding to an increase of 0.004 µg C/m^3 yr^{-1} (30%).

A significant downward trend in the observed annual mean concentration of EC in PM_{10} was seen for the time period 2001 – 2013 at Birkenes, corresponding to a decrease of 0.003 µg C/m^3 yr^{-1} (+; 33%). For the same time period, a significant downward trend in the observed annual mean concentration of EC in $PM_{2.5}$ was also seen, corresponding to a decrease of 0.004 µg C/m^3 yr^{-1} (*; 39%).

5. Particulate matter

5.1 Introduction

Size is the most fundamental parameter describing an aerosol, being decisive for transport and removal, and essential for understanding the effects of the ambient aerosol. Aerosol are most commonly defined by their equivalent aerodynamic diameter, defined as, that of a spherical particle of unit density (1 g cm^{-3}), having a settling velocity equal to that of the particle in question. The size distribution of the tropospheric aerosol is commonly divided into three major modes (Whitby, 1978); the nuclei mode, the accumulation mode and the coarse mode, all having different formation processes, leading to different characteristics of the aerosol. Tropospheric aerosols are either emitted directly (primary) or formed in the trophosphere by oxidation of precursor gases (secondary) (Seinfeld and Pandis, 1998). The sources of tropospheric aerosols are both natural (e.g. windborne dust, sea spray, volcanic activity, biomass burning) and anthropogenic (fuel combustion, industrial processes, non-industrial fugitive sources and transportation sources), and hence its chemical composition is highly diverse, including amongst others: sulphate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+), organic carbon (OC), which is a bulk fraction of numerous organic molecules, light absorbing/refractory carbon (BC/EC), aluminum and silicon (major constituents of mineral dust), inorganic cations (e.g., K^+, Na^+, Ca^{2+} $Mg^{2+)}$ and anions (e.g., Cl^-).

The adverse health effects of the ambient aerosol is well recognized (e.g., Dockery et al., 1993; Schwarz et al., 1996), causing various types of cardiopulmonary diseases, e.g., chronical obstructive pulmonary disease, ischemic heart disease, lung cancer and pneumonia. Although the statistical evidence between ambient air particulate mass (e.g., PM_{10} and $PM_{2.5}$) and adverse health effects are well documented, there is considerable doubt concerning the causal relationship. Thus, other relevant parameters such as the particle number size distribution, the surface and the chemical composition of the aerosol must be considered when addressing this issue. There is strong evidence that fine particles are more hazardous than coarse ones (Schwartz et al., 1996, Schwartz and Neas, 2000), although coarse particles are associated with adverse health effects as well (Castillejos et al., 2000; Ostro et al., 2000). An increasing number of experimental studies have been devoted to the number of ultrafine particles (d_p< 100 nm), which potentially play a role in the cardiovascular effects commonly associated with exposure to particulate matter (Donaldson et al., 2001). Concerning the chemical composition, WHO has given the general advice that that primary combustion derived particles are particularly important as they "*are often rich in transition metals and organic compounds, and also have a relatively high surface area*". However, more knowledge is needed concerning the ambient aerosol chemical composition and its contribution to the adverse effects seen on human health.

The tropospheric aerosol has an influence on the radiation budget both directly, by scattering and absorption of sunlight and terrestrial radiation, and indirectly, by influencing cloud reflectivity and lifetime. Both effects lead to a mostly cooling effect for the Earth's surface. The particle size distribution is essential for quantifying the magnitude of both direct and indirect aerosol climate effect, whereas particle chemical composition influences aerosol absorption and the lower size limit of particles acting as cloud condensation nuclei.

The tropospheric aerosol also plays an important role when it comes to acidification and eutrophication of water bodies. This is attributed to the content of secondary inorganic species such as SO_4^{2-}, NO_3^- and NH_4^+, which typically are associated with accumulation mode particles, enabling long-range transport and deposition in regions far from where the precursors where emitted.

Monitoring of the PM_{10} and $PM_{2.5}$ mass concentration are currently taking place at three rural background sites; i.e., the Birkenes Observatory and the Hurdal and Kårvatn sites. The time series at the Birkenes Observatory dates back to 2000/1, whereas at the Hurdal and Kårvatn sites measurements were initiated in 2010. At the Birkenes Observatory, high time resolution measurement of PM_{10}, $PM_{2.5}$ and PM_1 was initiated in 2010.

Annual and monthly mean mass concentrations of PM_{10}, $PM_{10\text{-}2,5}$ and $PM_{2.5}$, obtained by gravimetric measurements, are shown in Table 5.1, whereas annual mean mass concentrations for PM_{10}, $PM_{10\text{-}2,5}$ and $PM_{2.5}$ for the time period 2000 – 2013 are listed in

Table 5.2. Note that $PM_{10-2,5}$ is derived from the observed values of PM_{10} and $PM_{2.5}$. Time series of PM_{10} and $PM_{2.5}$ for 2013 are shown in Figure 5.1.

Table 5.1: Annual and monthly mean concentrations of PM_{10}, $PM_{10-2.5}$ and $PM_{2.5}$ at the Birkenes Observatory and the sits Hurdal and Kårvatn for 2013.

Month	***Birkenes***			***Hurdal***			***Kårvatn***		
	$PM_{2,5}$	$PM_{10-2,5}$	PM_{10}	$PM_{2,5}$	$PM_{10-2,5}$	PM_{10}	$PM_{2,5}$	$PM_{10-2,5}$	PM_{10}
JAN			2.5	3.6	0.5	4.1	1.1	0.2	1.2
FEB	3.4	0.7	4.2	3.0	0.6	3.5	1.4	0.4	1.8
MAR	3.6	1.9	5.4	3.1	1.4	4.5	1.9	0.5	2.4
APR	2.7	3.5	6.3	2.4	1.6	3.9	1.6	0.7	2.3
MAY	4.7	2.9	7.6	5.1	1.9	6.9	4.4	0.3	4.7
JUN	3.8	1.8	5.6	4.9	1.4	6.3	3.8	1.1	4.9
JUL	3.6	2.0	5.7	4.2	1.8	5.9	4.3	1.6	6.0
AUG	2.7	2.2	4.9	2.7	1.4	4.1	2.9	1.6	4.5
SEP	2.1	1.7	3.8	2.9	2.4	5.3	2.4	1.6	4.0
OCT	1.8	1.7	3.6	1.8	1.7	3.5	1.0	0.9	1.9
NOV	1.8	1.6	3.3	2.0	1.1	3.0	1.0	1.0	2.0
DEC	1.7	2.3	4.0	2.2	1.5	3.7	1.0	0.5	1.4
2013	*2.9*	*2.0*	*4.9*	*3.1*	*1.5*	*4.6*	*2.2*	*0.9*	*3.1*

Table 5.2: Annual mean mass concentrations of PM_{10}, $PM_{10-2.5}$, $PM_{2.5}$ and PM_1 at the Birkenes Observatory, and the sites Hurdal and Kårvatn for the period 2001 - 2013.

Year	PM_1	$PM_{2,5}$	$PM_{10-2,5}$	PM_{10}
Birkenes				
2000				6.8
2001		4.0	2.0	6.1
2002		4.8	2.3	7.1
2003		4.4	2.2	6.7
2004		3.3	2.1	5.4
2005		4.1	2.7	6.8
2006	3.7	5	3.1	8.1
2007	2.7	3.3	2.3	5.6
2008	2.2	3	2.9	5.9
2009		3.6	2.4	6.0
2010		3.4	3	5.1
2011		4.2	3.2	7.0
2012		3.0	2.2	4.9
2013		2.9	2.0	4.9
Hurdal				
2010		3.8	1.2	4.8
2011		4.3	1.6	5.8
2012		3.0	1.5	4.3
2013		3.1	1.5	4.6
Kårvatn				
2010		3.2	0.9	3.9
2011		2.6	1.1	3.6
2012		2.5	1.00	3.4
2013		2.2	0.9	3.1

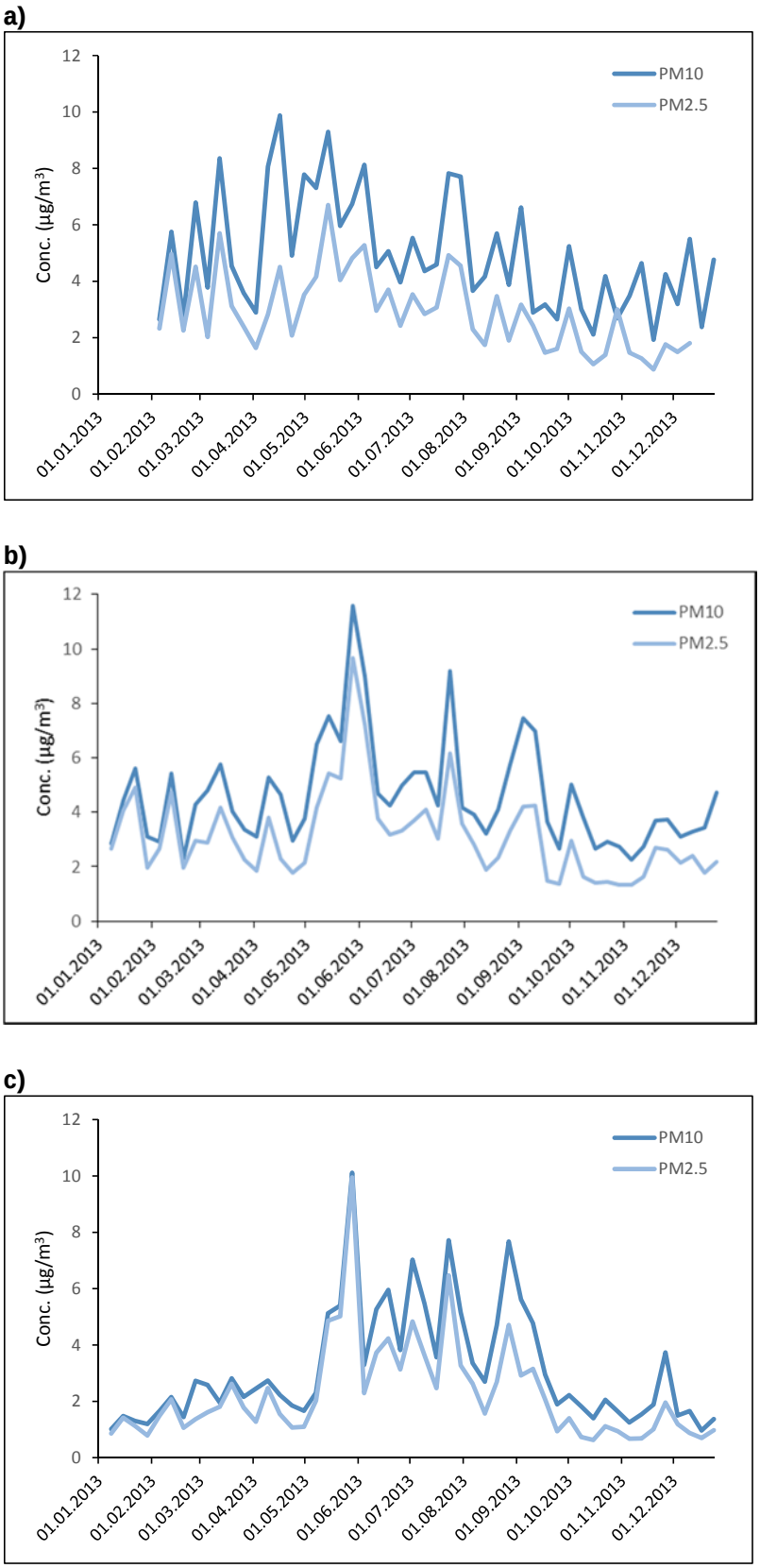


Figure 5.1: Time series of PM_{10} and $PM_{2.5}$ mass concentration for the Birkenes Observatory (a) and the Hurdal (b) and Kårvatn (c) sites. Unit µg/m³.

5.2 PM_{10}

The annual mean mass concentration of PM_{10} ranged from 3.1 µg/m^3 (Kårvatn) to 4.9 µg/m^3 (Birkenes), thus annual mean mass concentrations of PM_{10} (and $PM_{2.5}$) observed in the Norwegian rural background environment are considered amongst the lowest in Europe. The higher observed annual mean concentration of PM_{10} at Birkenes compared to Hurdal (4.6 µg/m^3) and Kårvatn is consistent with the pattern seen during the 4 years of concurrent measurements at these 3 sites. At all sites, the summertime (April - September) mean concentration of PM_{10} was higher than the wintertime mean (October - March); i.e., 1.5 times higher at Birkenes and Hurdal and 2.7 times higher at Kårvatn.

The annual mean concentration PM_{10} was within – 1SD of the long-term mean at Hurdal and Kårvatn, whereas it was slightly below this range at the Birkenes site. The annual mean concentration of PM_{10} observed at Birkenes for 2013, was the lowest value observed since the measurements started in 2000, equaling that of 2012.

The highest weekly mean concentrations of PM_{10} at the three sites ranged from 10 – 12 µg m^{-3}. Secondary inorganic constituents contributed the most to peak values at the Birkenes Observatory, indicating that long-range transported air pollution dominated the observed levels. For the sites Hurdal and Kårvatn, peak values appeared during the vegetative season and OC was the major fraction. Which source(s) making the largest contribution to these peak concentrations, is unknown. Source apportionment studies (Yttri et al., 2011a, b), using a combination of ^{14}C and organic tracers, show that natural sources dominates OC in PM_{10} at Norwegian rural background sites in summer, with BSOA being the major source followed by PBAP, whereas wild fires occasionally make a noticeable contribution.

5.3 $PM_{2.5}$

The annual mean mass concentration of $PM_{2.5}$ ranged from 2.2 µg/m^3 (Kårvatn) to 3.1 µg/m^3 (Hurdal). The higher observed annual mean concentration of $PM_{2.5}$ at Hurdal compared to Birkenes (2.9 µg/m^3) and Kårvatn is consistent with the pattern seen during the 4 years of concurrent measurements at these 3 sites. The difference observed between Hurdal and Birkenes, however, is particularly small. At all sites, the summertime (April - September) mean concentration of $PM_{2.5}$ was higher than the wintertime (October - March) mean; i.e., 1.3 (Birkenes), 1.5 (Hurdal) and 2.9 (Kårvatn) times higher.

The annual mean concentration $PM_{2.5}$ was within – 1SD of the long-term mean at Hurdal and Kårvatn, whereas it was slightly below this range at the Birkenes site. The annual mean concentration of $PM_{2.5}$ observed at Birkenes for 2013, was the lowest value observed since the measurements started in 2001.

The higher levels of $PM_{2.5}$ observed at the Hurdal site compared to the Kårvatn site appears to be explained by higher levels of OC and SIA (i.e., SO_4^{2-}, NO_3^-, NH_4^+) (typically residing in the fine fraction of PM_{10}) at the Hurdal site. While SIA is a result of gas to particle conversion during long-range transport, OC emissions might be both primary and secondary, and of both regional and local origin. Annual mean concentrations of OC (and EC) in $PM_{2.5}$ were noticeable

higher at the Hurdal site (0.76 µg C/m^3) compared to that observed at the Birkenes Observatory (0.57 µg C/m^3, see Chapter 4). For SIA, however, it was the other way around; i.e., the annual mean concentration of SIA at the Birkenes Observatory was 2.0 µg/m^3 compared to 1.2 µg/m^3 at the Hurdal site. One should notice that the measurements of SIA have no size cut off, but are estimated to be around PM_{10}, see Chapter 3. The most apparent explanation for at least a part of this discrepancy is that a larger fraction of the NO_3^- is associated with the coarse fraction of PM_{10} at the Birkenes Observatory, following from the reaction between gaseous HNO_3 and NaCl. Differences in the OC to OM conversion factor, a factor used to account for other elements than carbon associated with OC, between the two sites could contribute as well, but remains speculative.

The higher concentrations of $PM_{2.5}$ in summer compared to winter at all sites is reflected by the secondary inorganic constituents, as well as by fine mode OC.

5.4 $PM_{10-2.5}$

The annual mean mass concentration of $PM_{10-2.5}$ ranged from 0.9 µg/m^3 (Kårvatn) to 2.0 µg/m^3 (Birkenes). The higher observed annual mean concentration of $PM_{10-2.5}$ at Birkenes compared to Hurdal and Kårvatn is consistent with the pattern seen during the 4 years of concurrent measurements at these 3 sites. At all sites the summertime (April - September) mean concentration of $PM_{10-2.5}$ was higher than the wintertime mean (October - March) (

Table 5.2); 1.3 (Birkenes) 1.5 (Hurdal) and 2.3 (Kårvatn) times higher.

The annual mean concentration of $PM_{10-2.5}$ was within 1 SD of the long-term mean at Kårvatn, whereas it was slightly below this range at the Birkenes site. At Hurdal the annual mean concentration of $PM_{10-2.5}$ for 2013 equaled the long term mean. The annual mean concentration of $PM_{10-2.5}$ observed at Birkenes for 2013, was the lowest value observed since concurrent measurements of PM_{10} and $PM_{2.5}$ started in 2001, equaling that of 2001.

The higher levels at Birkenes compared to the two other sites is consistent both during summer and winter and is largely attributed to the presence of a stronger sea salt aerosol source, typically residing in the coarse fraction of PM_{10}, as the Birkenes Observatory is situated only 20 km from the coastline. Indeed the, the annual mean concentration of the sum of the sea salt species sodium (Na^+), chloride (Cl^-) and magnesium (Mg^{2+}) (1.1 µg/m^3) was 3.5 times higher at the Birkenes Observatory compared to the sites Hurdal and Kårvatn (both 0.33 µg/m^3). Coarse mode OC, which likely is dominated by PBAP, appears to be the other major source contributing to $PM_{10-2.5}$ at the three sites. By assuming an OC to OM (organic matter) conversion factor of 1.75 (see Yttri et al., 2011a) for coarse mode OC, this source would amount to approximately 0.3 µg/m^3 (Birkenes), 0.4 µg/m^3 (Kårvatn) and 0.5 µg/m^3 (Hurdal). Part of NO_3^- can be present in the coarse fraction of PM_{10} following from the reaction between gaseous HNO_3 and coarse mode NaCl. Hence, NO_3^- could be another species contributing noticeably to $PM_{10-2.5}$, particularly at Birkenes.

The higher concentrations of $PM_{10-2.5}$ in summer compared to winter at all sites is consistent with the seasonality of coarse mode OC, and thus PBAP. For sea salt species, however, concentrations are higher in winter compared to summer. Any potential seasonality of coarse mode nitrate and mineral dust are not known.

5.5 Relative contribution of $PM_{2.5}$ and $PM_{10-2.5}$ to PM_{10}

$PM_{2.5}$ was the major fraction of PM_{10} at all sites on an annual basis, accounting for 59% at Birkenes, 67% at Kårvatn, and 71% at Hurdal. This picture was consistent also as a function of season. Birkenes was the only site at which $PM_{10-2.5}$ was the major fraction of PM_{10} on a monthly basis, i.e. for April and December, and was likely attributed to sea salt aerosol.

5.6 Trends for PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$

The shorter time series for the sites Hurdal and Kårvatn (4 years) allow for an assessment of the trend of PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$ for the Birkenes Observatory only.

A significant downward trend in the observed annual mean concentration of PM_{10} was seen for the time period 2000 – 2013 at Birkenes, corresponding to a decrease of 0.12 µg/m^3 yr^{-1} (+; 24%). For the same time period, a significant downward trend in the observed annual mean concentration of $PM_{2.5}$ was observed, corresponding to a decrease of 0.13 µg/m^3 yr^{-1} (+; 36%). A non-significant increase was observed for the annual mean concentration of $PM_{10-2.5}$ for the actual time period, corresponding to an increase of 0.04 µg/m^3 yr^{-1} (26%).

5.7 Compliance with EU limit values and Air-Quality Guidelines for PM_{10} and $PM_{2.5}$

The EU annual limit value for PM_{10} and $PM_{2.5}$ (See Table 5.3 for EU limit values and Air-Quality Guidelines for PM_{10} and $PM_{2.5}$) was far from being violated at any of the three sites; the highest annual mean concentrations observed being just in excess of 10% of the annual limit values. This was also the case when compared to the WHO Air-Quality Guidelines (AQG). The National Air-Quality Guidelines (Nasjonalt folkehelseinstitutt, 2013), revised in 2013, are even more stringent than the WHOs with respect to $PM_{2.5}$, still, the highest annual mean observed for PM_{10} and $PM_{2.5}$ in the Norwegian rural background environment in 2013 accounted for less than 25% and 40% of the PM_{10} and $PM_{2.5}$ National AQG, respectively.

Table 5.3: EU limit values and Air-Quality Guidelines for PM_{10} and $PM_{2.5}$.

	24-hours	Annual
EU limit values		
PM_{10}	50 µg/m^3 (< 35 days yr^{-1})	40 µg/m^3
$PM_{2.5}$		25 µg/m^3
WHO Air-Quality Guidelines		
PM_{10}	50 µg/m^3	20 µg/m^3
$PM_{2.5}$	25 µg/m^3 (the 99th percentile)	10 µg/m^3
National Air-Quality Guidelines		
PM_{10}	30 µg/m^3	20 µg/m^3
$PM_{2.5}$	15 µg/m^3	8 µg/m^3

24-hours mean mass concentrations of PM_{10} and $PM_{2.5}$ at Birkenes were derived from high time-resolution measurements, showing maximum values of 30.8 µg/m^3 for PM_{10} and 29.8 µg/m^3 for $PM_{2.5}$. Hence, no violation of the 24-hour EU limit value for PM_{10} was observed. When comparing the daily values of $PM_{2.5}$ for 2013 with that of the WHO 24-hour AQG, no violation was observed.

The 24-hour National AQG (Nasjonalt folkehelseinstitutt, 2013), revised in 2013, are more stringent than the WHO AQG, and for PM_{10} it was violated on two days (i.e., 5 – 6 March (30.1 µg m^{-3}) and 26 - 27 of January (30.8 µg m^{-3})), but by a minimal margin only. For $PM_{2.5}$, the 24-hour National AQG was violated on 8 days, all during the period January 26th to May 18th, with observed concentrations ranging from 15.1 – 29.8 µg m^{-3} Noticeable, violations of the National AQG all occurred during the first 5 months of the year, a period of the year that has been associated with an increased frequency of episodes with high concentrations of PM, associated with long-range transported pollution. Indeed, SIA were major constituents of PM on most of the days during which the National AQG were violated in 2013.

5.8 Chemical composition of particulate matter

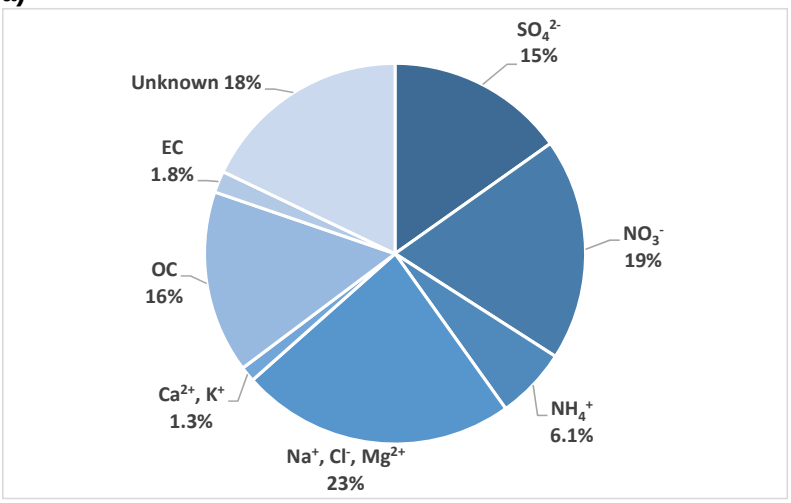
EC and OC are measured in the PM_{10} and $PM_{2.5}$ size fraction at the Birkenes Observatory and at the Hurdal and Kårvatn sites, whereas the major inorganic anions (SO_4^{2-}, NO_3^-, Cl^-) and cations (Ca^{2+}, Mg^{2+}, K^+, Na^+ NH_4^+) are obtained from open filter face samplers with a cut-off size in excess of 10 µm equivalent aerodynamic diameter (EAD). However, most of these species reside within the PM_{10} fraction, and even within $PM_{2.5}$, such as the secondary inorganic aerosol (SIA) constituents (SO_4^{2-}, NO_3^-, NH_4^+). Occasionally, sea salt particles larger than PM_{10} could be collected, i.e., during stormy weather conditions at the Birkenes Observatory, at a southerly wind direction. In order to attempt a mass closure for the particulate mass concentration, the data obtained from the monitoring program appear to be well suited for PM_{10}, except that species representing mineral dust are not included. Mass closure of $PM_{2.5}$ and $PM_{10-2.5}$ would include a larger degree of uncertainty, as default assumptions would be made according the size distribution of the inorganic species analyzed, of which the largest uncertainty would be associated with that of NO_3^-. The chemical mass composition of PM_{10} is shown in Figure 5.2.

Based on annual means, the speciated mass accounted for 82% of the annual mean concentration of PM_{10} at the Birkenes Observatory in 2013. SO_4^{2-} accounted for 15% of PM_{10},

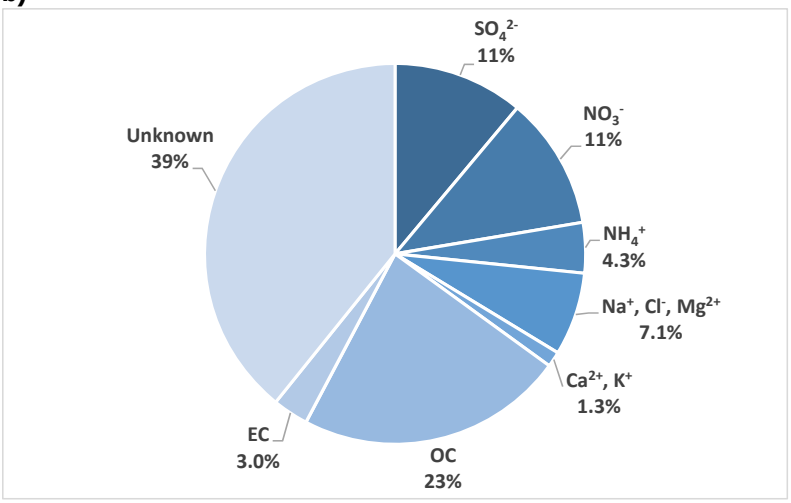
which is, within the long-term mean (18 ± 3%). A significant downward trend was observed concerning SO_4^{2-} relative contribution to PM_{10} for the time period 2001 – 2013, corresponding to a decrease of 0.62 % yr^{-1} (*; 37%). A substantial decrease in the relative contribution of NO_3^- (19%) to PM_{10} was observed for 2013 compared to the previous year (28%). Still, it was the second highest contribution observed for NO_3^- for the period 2001 – 2013, and it made NO_3^- the most abundant single species contributing to PM_{10} in 2013. A significant upward trend was observed for NO_3^- concerning its relative contribution to PM_{10} for the time period 2001 – 2013, corresponding to an increase of 0.6 % yr^{-1} (*; 74%). The relative contribution of NH_4^+ to PM_{10} (6.1%) was within the long-term mean (5.7 ± 1.7%). A substantial 23% contribution to PM_{10} was observed for the sea-salt species (Na^+, Cl^-, Mg^{2+}), which is the highest relative contribution observed for the period 2001 – 2013, and well above the long-term mean of 14 ± 4%. A significant upward trend was observed for the sea-salt species with respect to their relative contribution to PM_{10} for the time period 2001 – 2013, corresponding to an increase of 0.64 % yr^{-1} (*; 88%). OC accounted for 16% of PM_{10}, which is within the long term mean for the period 2001 – 2013 (15 ± 2%). By applying an OC to OM conversion factor of 1.7 (see Yttri *et al.*, 2007a), the relative contribution of OM to PM_{10} was 26%. The relative contribution of EC to PM_{10} (1.8%) was within the long-term mean (1.9 ± 0.3%). By applying a conversion factor of 1.1, the relative contribution of EC to PM_{10} was 2.0%. When accounting for OM and EC x 1.1, instead of OC and EC, in the mass closure of PM_{10}, the speciated mass accounted for 93% of PM_{10}.

Based on annual means, the speciated mass accounted for 61% of the annual mean concentration of PM_{10} at the Hurdal site in 2013. SO_4^{2-} and NO_3^- both accounted for 11% of PM_{10}, thus sharing the position of being the most abundant single species contributing to PM_{10} in 2013. The OC fraction dominated PM_{10} by a 23% contribution, which increased to a substantial 39% when applying an OC to OM conversion factor of 1.7. The contribution of the sea salt species (7.1%), NH_4^+ (4.3%) and EC (3.0%), were all less than 10%. The relative contribution of EC to PM_{10} increased to 3.3% when applying a conversion factor of 1.1. When accounting for OM and EC x 1.1, instead of OC and EC, in the mass closure of PM_{10}, the speciated mass accounted for 77% PM_{10}.

a)



b)



c)

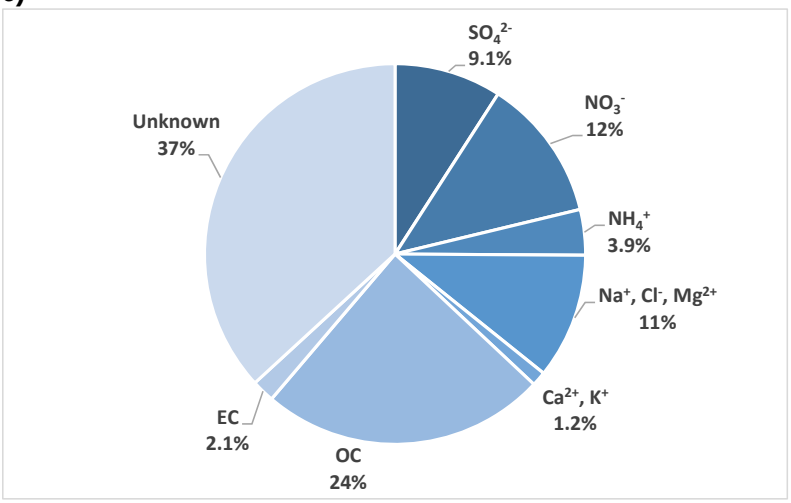


Figure 5.2: Annual mean chemical composition of PM_{10} at the Birkenes Observatory a), the Hurdal site b) and the Kårvatn site c) for 2013. The annual mean mass concentration for PM_{10} in 2013 was 4.9 µg/m³ at the Birkenes Observatory, 4.6 µg/m³ at the Hurdal site, and 3.1 µg/m³ at the Kårvatn site.

Based on annual means, the speciated mass accounted for 63% of the annual mean concentration of PM_{10} at the Kårvatn site in 2013. NO_3^- accounted for 12% of PM_{10}, thus being the most abundant single species contributing to PM_{10} in 2013, followed by SO_4^{2-} (9.1%). The OC fraction dominated PM_{10} by a 24% contribution, which increased to a substantial 41% when applying an OC to OM conversion factor of 1.7. The contribution of the sea salt species was 11%, whereas NH_4^+ (3.9%), and EC (1.9%) accounted for less than 4%. The relative contribution of EC to PM_{10} increased to 2.1% when applying a conversion factor of 1.1. When accounting for OM and EC x 1.1, instead of OC and EC, in the mass closure of PM_{10}, the speciated mass accounted for 80% PM_{10}.

The major features separating the relative chemical composition of PM_{10} at the three sites was the noticeably larger contribution of OC at the sites Hurdal (23%) and Kårvatn (24%), compared to the Birkenes Observatory (16%). Further, the sea salt species accounted for a substantial 23% at the Birkenes Observatory, whereas they constituted no more than 11% (Kårvatn) and 7.1% (Hurdal) at the two other sites. The higher relative contribution of EC at the Hurdal site (3.0%) compared to Kårvatn (1.9%) and Birkenes (1.8%) is also worth noting. The relative contribution of SIA to PM_{10} was noticeable higher at the Birkenes Observatory (40%) compared to Hurdal (27%) and Kårvatn (25%) sites.

6. Ground-level ozone

Ozone in the troposphere originates from photo-chemical reactions between volatile organic compounds and nitrogen oxides under the influence of solar radiation, as well as from the transport of stratospheric ozone down into the atmosphere. Volatile organic compounds are emitted from both anthropogenic sources such as road and ship traffic, leakage of natural gas, use of solvent and chemicals etc. as well as from biogenic sources (trees and plants). Nitrogen oxides are mainly emitted from anthropogenic sources such as e.g. traffic and power plants although a small fraction is emitted microbiological activity in soils and by lightning. Thus, tropospheric ozone is the sum of what is produced by both natural and man-made processes.

Once formed, tropospheric ozone is only slowly degraded by chemical reactions with OH, HO_2 and NO_2 (lifetime of the order of several weeks). Surface dry deposition and uptake in vegetation is, however, an effective loss mechanism for ozone. Ozone dry deposition is determined by the local topography and land use and could be important for the surface concentrations observed at some of the sites, particularly at the inland stations. This influence will be most apparent during nights with stable atmospheric conditions while the daytime values will be less affected due to a deeper atmospheric mixing layer.

Ozone has negative impacts on health, vegetation and materials. The health effects regards particularly asthmatics and people with chronic respiratory disorders. Effects on the vegetation regards particularly crops but also forests and natural vegetation. Prolonged exposure have shown negative impacts on forests. As opposed to other pollutants, the baseline level of ozone is close to the limits for effects on human health and vegetation. Materials such as rubber and other polymer compounds can also be damaged by ozone.

6.1 Monitoring network

Measurements of ozone has been going on in Norway since 1975, first in Telemark and from 1977 also around the Oslo fjord and in subsequent years extended to the whole country. EU's air quality directive (AQD) (EU, 2008: Directive 2008/50/EC) which is implemented in Norwegian legislation contains the thresholds and objectives regarding ozone levels and the requirements as to the number of monitoring sites. According to the directive, the country should be divided into a number of zones, and the zones presently used in Norway are shown in Figure 1.1. The stations in the individual zones as of 2013 are indicated in the map and the details regarding the zone characteristics are given in Table 6.1. As seen from Table 6.1 there is a small shortage of stations for ozone and VOC relative to the directive's requirements.

The ozone monitoring network in 2013 consisted of eight stations. Seven of these were operated by NILU, while the Porsgrunn municipality was operating the station at Haukenes. The station at Haukenes can be classified as suburban while the rest are rural background stations which implies that the sites are not affected by local emissions. The data from Haukenes was reported to NILU and checked here. In addition there were a few urban sites relevant for the AQD, but not presented in this work, but indicated in Table 6.1.

Table 6.2 shows the monitoring sites and data capture for 2013. The measuring method and principles are given in Annex 3. Except for Birkenes which experienced extended periods with technical problems, the data capture was 95% or higher at the stations.

Table 6.1: The Norwegian zones and the requirements as to the number of monitoring sites based on EU's ozone directive. The situation in 2013 is also shown.

Zone	Region	Type	Area (km^2)	Population (1000)	Ozone [1)]	NO_2 [1)]	VOC [1)]	Stations
1	Greater Oslo	Urban/suburban		1030	2 (3)	1	0 (1)	Lommedalen[2)] Grønland[2)]
2	Bergen	Urban/suburban		270	1 (1)	1		Rådhuset[2)]
3	Trondheim	Urban/suburban		180	0 (0)			
4	Østlandet	Rural	110 000	1800	4 (4)	3		Prestebakke Hurdal Haukenes Birkenes
5	Rogaland, Hordaland, Sogn- og Fjordane	Rural	43 000	790	1 (2)	0		Sandve
6	Møre og Romsdal, S- og N-Trøndelag, Nordland	Rural	94 000	760	2 (2)	2		Kårvatn Tustervatn
7	Troms, Finnmark	Rural	74 000	230	0 (1)			
	Whole country	Rural background	385 000		7 (7)	4		Prestebakke Hurdal Birkenes Sandve Kårvatn Tustervatn Zeppelin
Total					18 (20)	11 (10)	0 (1)	

1) The present number of stations with the EU directive's requirements in brackets.
2) Urban stations not discussed in this report

Table 6.2: Ozone monitoring sites and data capture based on hourly values in 2013.

St.nr.	Station name	Period	Data capture
NO0043	Prestebakke	01.01.13 - 31.12.13	99 %
NO0056	Hurdal	01.01.13 - 31.12.13	100 %
NO0489	Haukenes	01.01.13 - 31.12.13	99 %
NO0002	Birkenes II	01.01.13 - 31.12.13	81 %
NO0052	Sandve	01.01.13 - 31.12.13	95 %
NO0039	Kårvatn	01.01.13 - 31.12.13	99 %
NO0015	Tustervatn	01.01.13 - 31.12.13	99 %
NO0042	Zeppelin	01.01.13 - 31.12.13	100 %

6.2 Ground-level ozone in Norway

In the scientific literature one often distinguishes between the "background" and the "baseline" level (e.g. Oltmans et al., 2013), in which the former refers to the pre-historic levels in an unpolluted atmosphere whereas the latter refers to the present levels in the northern hemisphere, far away from any emission areas.

The northern hemispheric ozone baseline level varies between 40 and 80 $\mu g/m^3$ throughout the year and is typically highest in spring. On top of this baseline level, episodes with long-range transport of more polluted air masses to Norway increase the ozone levels regularly during the summer half year. During winter the situation is the opposite, i.e. the transport of polluted air masses from the European continent leads to reduced ozone levels due to the titration reaction $O_3 + NO \rightarrow NO_2$. This difference between winter and summer is explained by the intensity of the solar UV-radiation which leads to a fast photochemistry in summer and a corresponding slow and inefficient photochemistry in winter.

The ozone levels at a monitoring site is also influenced by local effects near the station such as dry deposition to the surface and episodes of local NO_x emissions. In general, the Norwegian rural ozone stations are not much influenced by nearby emissions, but occasional short-term episodes of ozone degradation due to local NO_x sources cannot be ruled out totally. These local effects will result in a reduction in ozone and thus an underestimation of the regional ozone exposure. Hence, in summary, the level of ozone is the net result of a hemispheric, a regional and a local component.

In Norway summertime episodes of elevated ozone are often associated with a high pressure located over the European continent, typically over Central or Eastern parts, setting up a southerly or southwesterly transport of warm, polluted air masses to the country. Ozone episodes are typically a fair-weather phenomenon associated with hot and sunny days. Furthermore, the highest ozone levels are often experienced just at the end of such fair-weather periods which is explained by an approaching cold front setting up an effective transport of photochemically processed air masses from the continent.

6.3 Norwegian ozone levels in 2013

The seasonal cycles in ground-level ozone in 2013 are shown in Figure 6.2 together with the mean seasonal cycles for the period 2000-2012 for each site as a reference. These figures give the 14 days centred running mean concentrations. It should be noted that for Birkenes the time series are not directly comparable since the 2013 data are based on measurements from the new observatory while the 2000-2012 data are based on measurements at the old location which gave systematically lower levels due to stronger surface dry deposition.

These time series show that mean ozone levels in 2013 peaked relative to the 2000-2012 mean in March-April at most sites in S-Norway; Prestebakke, Hurdal, Haukenes, Birkenes and Kårvatn. The 14 days running mean values were close to 100 $\mu g/m^3$ at several sites in this period. Most of these sites also show a peak in late July, most noticeable at Haukenes, Sandve and Kårvatn. The data from sites in the north, Tustervatn and Zeppelin Mountain, indicate a seasonal cycle in 2013 close to the 2000-2012 mean levels without any strong episodes.

The hourly annual maximum values for each of the stations are given in Table 6.4. The dates of the occurrence of the peak values range from 13 April (Haukenes) to 2 August (Sandve). This is somewhat unusual since the peak values are most often observed during the same episodes and normally in May-June. Furthermore, the highest observed level in 2013 was very low; 124 µg/m^3 (Tustervatn 17 May), which is the lowest annual maximum value observed since the monitoring started in Norway.

The low peak concentrations and the few exceedances (see below) in 2013 is in line with the summer ozone data from North Europe as reported by EEA (EEA, 2014). According to that report the summer in Europe was characterised by a very low incidence of exceedances prior to mid-June and after August, but with frequent incidences in Central and South Europe during July and the first days of August.

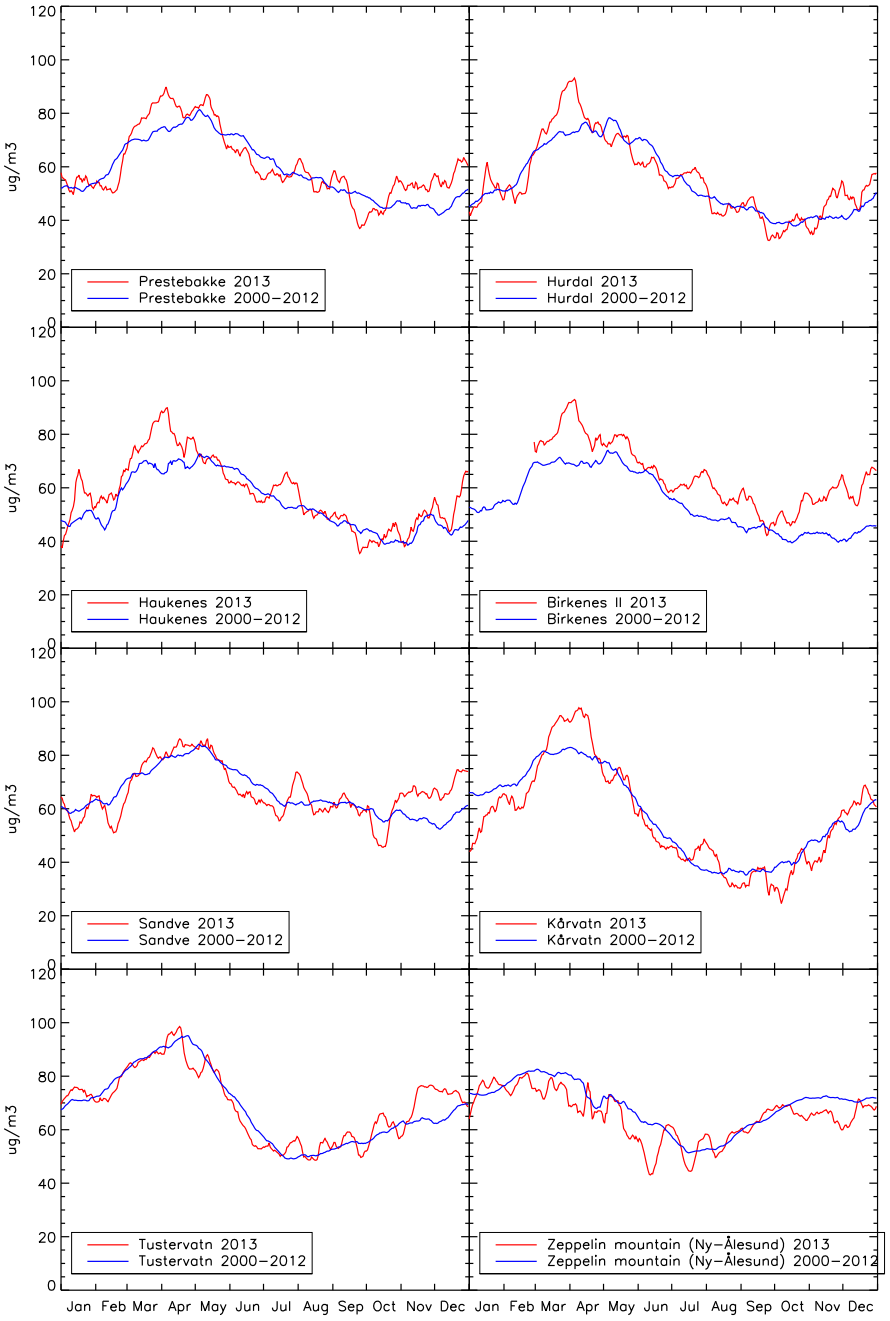


Figure 6.1: The 14 days' running mean ozone concentrations in 2013 (red) together with the corresponding mean concentrations based on all years 2000-2012 (blue).

In the summer season the ozone concentrations at many stations vary systematically over the day, particularly on days without strong winds. The concentration is low during stable night-time conditions, e.g. when inversions develop, and then rises quickly in the morning when the

heating of the ground leads to the ozone rich air being mixed down. The highest levels are typically observed in the afternoon. This diurnal cycle is the result of ozone deposition to the ground combined with the daily cycle in vertical atmospheric exchange. The mean diurnal cycle in ozone in during April-September 2013 are shown for three selected sites in Figure 6.2. The strongest cycle is seen at Kårvatn, a valley inland station with a strong cycle in the height of the atmospheric mixed layer. A less pronounced ozone cycle is seen at Sandve, a coastal station where night-time inversions as less frequent. In contrast to this, the ozone values at the Zeppelin Mountain shows no diurnal cycle.

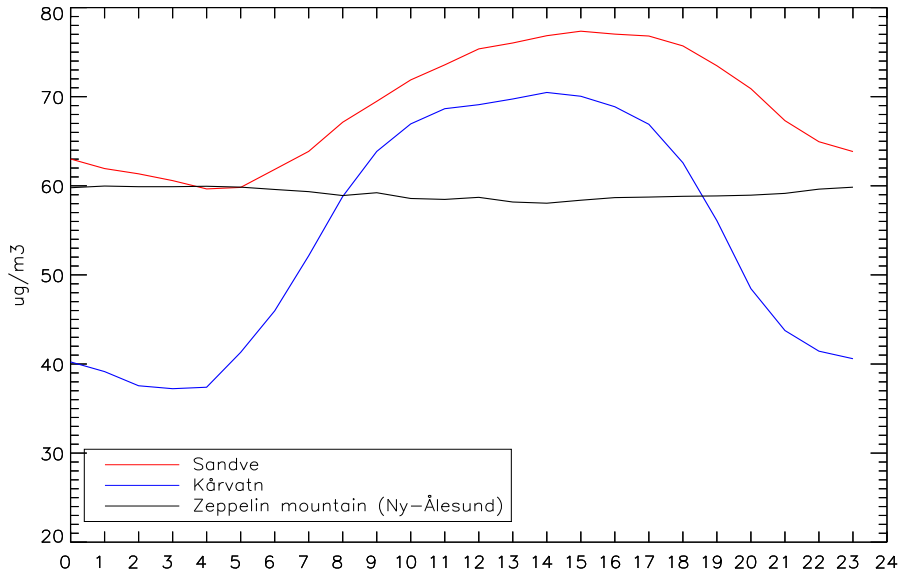


Figure 6.2: The mean diurnal cycle in ozone at three of the monitoring sites; Sandve, Kårvatn and Zeppelin Mountain during April-September 2013.

6.4 Exceedances of the limit values for protection of human health

Ground-level ozone can cause health problems, and the concentration level should not exceed certain limit values. Various air quality criteria for ozone for the protection of health are given in Table 6.3. Norway has implemented EU's air quality directive and information and warning bulletins are broadcasted to the public in case of exceedance of the information threshold (180 μg/m^3) and alert threshold (240 μg/m^3), respectively.

EU's third daughter directive was derived in 2002 (EU, 2002), and in 2008 a new air quality directive was adopted (EU, 2008). WHO has also defined certain air quality guidelines and provided a global update of these levels including a new guideline for ground-level ozone in 2005 (WHO, 2006).

In 2013 a new set of national air quality guidelines were defined for ozone and other species. The national and the WHO guidelines as well as the EU directive values are given in Table 6.3.

Table 6.3: Limit values for ground-level ozone for the protection of human health.

Value (μg/m^3)	Averaging time (hours)	Ref	Description
180	1	EU (2008)	EU's information threshold
240	1	EU (2008)	EU's alert threshold
120	8[1)]	EU (2008)	EU's target value. 8-hour mean value not to be exceeded on more than 25 days per year averaged over 3 years. To be fulfilled by 1.1.2010
120	8[1)]	EU (2008)	EU's long-term objective.
100	8[1)]	WHO (2006)	WHO's air quality guideline (global update 2005)
100	1	FHI (2013)	National air quality guideline (update 2013)
80	8[1]	FHI (2013)	National air quality guideline (update 2013)

[1)] The highest 8-hour running mean value for each day calculated such that the 8-hour periods are assigned to the day on which the period ends.

The exceedances of the limit values for health are given in Table 6.4. The table shows the number of days with exceedance of WHO's air quality guideline of 100 μg/m^3 and EU's long-term objective of 120 μg/m^3. The number of hours with exceedance of EU's information threshold of 180 μg/m^3 is also given as well as the annual hourly max value together with the date(s) that value occurred. The total number of hours with ozone data and days with at least 75 % data capture through the year is given for reference. The exceedances based on the 8-hour mean values were only calculated for days with at least 75 % data capture.

Ozone concentrations above EU's alert threshold (240 μg/m^3) are never experienced in Norway and values above the information threshold (180 μg/m^3) is experienced only occasionally. The limit was not exceeded in 2013. EU's long-term objective was exceeded on two days at Tustervatn in 2013 while WHO's air quality guideline was exceeded at all sites on the Norwegian mainland, most frequently at Kårvatn with 31 days of exceedances.

Table 6.4: For all sites in 2013 the number of hours with data and the number of days with at least 75% data capture together with the exceedances of health related air quality limits; national guidelines, WHO guideline and EU's limit values as given in Table 6.3 as well as the annual maximum and the date when it occurred.

			National guidelines		WHO	EU directive			
Station	Hours	Days >75%	Days 8h > 80 μg/m^3	Hours 1h > 100 μg/m^3	Days 8h > 100 μg/m^3	Days 8h > 120 μg/m^3	Hours 1h > 180 μg/m^3	Max. hourly value (μg/m^3)	Date
Prestebakke	8703	365	118	177	14	0	0	118	08.05.13
Hurdal	8731	365	82	123	17	0	0	116	26.07.13
Haukenes	8625	363	135	238	25	0	0	117	13.04.13
Birkenes II	6946	292	109	154	13	0	0	120	07.07.13
Sandve	8325	352	132	140	15	0	0	121	02.08.13
Kårvatn	8666	364	122	371	31	0	0	120	14.04.13
Tustervatn	8684	365	134	246	18	2	0	124	17.05.13
Zeppelin	8648	364	87	0	0	0	0	100	24.04.13

EU's target value for the protection of human health are met in Norway with a very good margin. The long-term objective (and thereby also WHO's and Norwegian guidelines) is on the other hand exceeded to a variable extent every year. The EU directive does not give any deadline to achieve this goal. In 2013 it was broken only at Tustervatn, and in 2012 at Birkenes and Sandve. In 2011, however, all stations except Tustervatn exceeded this limit. This reflects that the ozone levels vary strongly from year to year which is also indicated by Figure 6.3, showing the time trend of the number of days with exceedance of the 8-hour mean value of 120 μg/m3. Table 6.5 gives the annual peak values and number of days with exceedance from 2001 to 2013. The main reason for the inter-annual variations is variations in the large scale weather conditions from one year to another. Over time, long-term changes in the European emissions of NO_x and VOC as well as gradual trends in the hemispheric baseline level of ozone will be important.

Table 6.5: The maximum hourly ozone value each year and the number of days exceeding EU's long-term objective.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual hourly max. (μg/m^3)	144	151	162	150	144	186	139	160	142	145	168	130	124
Number of dates with exceedance of EU's long-term objective of 120 μg/m^3 [a)]	5	18	15	21	7	28	8	16	9	3	12	2	2

a) Running 8-h mean

EU's long-term objective for the protection of health is the governing air quality requirement for ozone in Norway. The directive requires the countries to sustain monitoring stations in all air quality zones where the long-term objective has been broken in the last five years. As shown in Figure 6.3, this limit value has been exceeded at all stations the last five years.

The updated national guidelines (FHI, 2013) are even stricter than the WHO guideline (Table 6.3) and both the 80 μg/m^3 (8-h mean) and 100 μg/m^3 (1-h mean) are exceeded for long periods of the year in the whole country (except on Spitsbergen) as shown by Table 6.4.

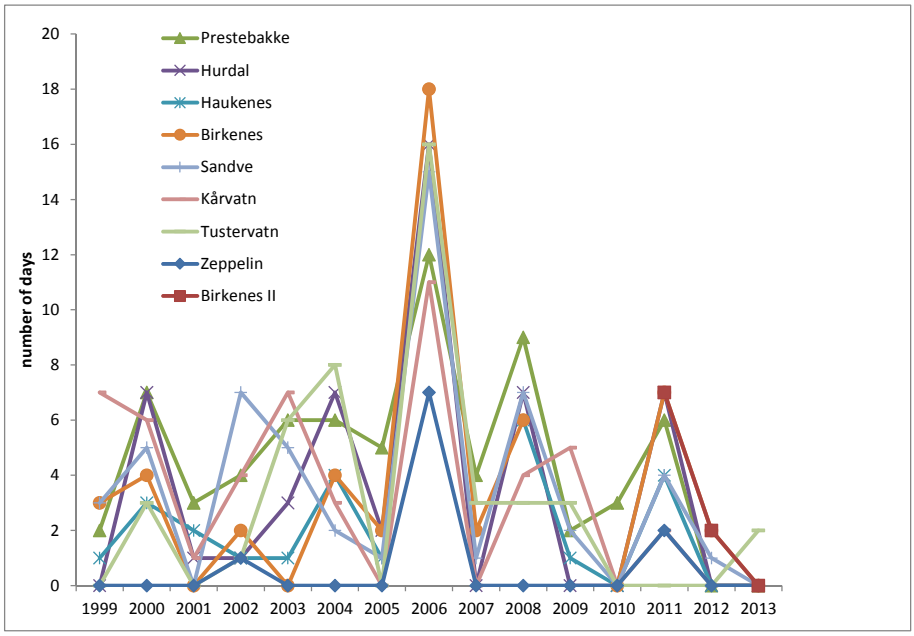


Figure 6.3: The number of days with a maximum daily 8-h mean ozone concentration above 120 µg/m³ for the period 1999-2013.

6.5 Exceedance of the threshold values for protection of vegetation

Threshold levels for ozone exposure to vegetation has been prepared by Kärenlampi and Skärby (1996). EU's air quality directive (EU, 2008) also lays down limit values for ozone related to protection of vegetation. The limit values by both UN-ECE and EU are based on cumulative exposure over the threshold value of 40 ppb (= 80 µg/m³) and the parameter is termed AOT40 ("Accumulated exposure over the threshold of 40 ppb"). AOT40 is calculated as the sum of the differences between the hourly mean concentration and 40 ppb for each hour where the ozone concentration exceeds 40 ppb.

Research in recent years have shown, however, that the AOT40 based critical levels for vegetation defined in the Gothenburg Protocol should be replaced with the so-called flux based critical levels. Flux based levels reflect better the real consequences of the ozone that is transported into the leaves, while AOT40 is only based on the concentration of ozone at the monitors inlet height (Mills et al., 2011).

Flux based critical levels for different types of vegetation have been approved by UN/ECE (LRTAP, 2011). Concentration based AOT40 values continue to be used, however, where the meteorological data and calculations from flux models are not available.

Flux based and concentration (AOT) based critical levels have been determined for both crops, forests and natural vegetation (LRTAP, 2011). The limits given by UN-ECE and EU are shown in Table 6.6. UN-ECE also recommends that the ozone levels should be based on the concentration at canopy height, while the ozone monitor's inlet height traditionally is at 2 m above ground. It is furthermore recommended to adjust the measurement data to values

relevant for the canopy height by assumptions about the vertical distribution of ozone near the ground for different land use categories. This report only presents AOT40 values based on the actual measurements of ozone.

EU's air quality directive (EU, 2008) includes a 3-month's target value for AOT40 of 9 000 ppb hours (May-July) averaged over 5 years and a long-term objective of 3 000 ppb hours for the protection of vegetation. As opposed to UN-ECE's limit values the EU directive does not contain separate threshold values for crops and forests. Table 6.6 shows the various limit values for protection of vegetation.

Table 6.6: Limit values for the protection of vegetation from ozone exposure.

AOT40 (ppb hours)	Period	Reference	Comment
3000	15 May - 15 Aug	UN-ECE (1996)	Growing season for agricultural crops adjusted to Nordic conditions. 1)
5000	1 April - 1 Oct	UN-ECE (1996)	Growing season for forests 1,2)
9000	1 May – 1 Aug	EU (2008)	EU's target value for vegetation 3)
3000	1 May - 1 Aug	EU (2008)	EU's long-term objective for vegetation 3)

1) ECE's AOT values should be based on the hours with global incoming radiation > 50 W/m^2

2) Changed from 10 000 to 5000 ppb hours according to the Mapping manual (Mills et al., 2011)

3) EU's AOT values should be based on the period 08-20 CET

Table 6.7 shows the 3 months AOT40 values for daylight hours (global radiation > 50 W/m^2) for the period 15 May - 15 August (referring to Table 6.6). The limit value for agricultural crops of 3000 ppb hours was not exceeded at any of the sites in 2013. The highest value occurred at Birkenes with 1425 ppb hours.

Table 6.8 shows the 6 months AOT40 values for daylight hours (April-September). The limit value of 5000 ppb hours for forests was not exceeded in 2013. The highest value occurred at Kårvatn with 4361 ppb hours.

Table 6.7: Data capture and 3-month's AOT40 values for agricultural crops for the period 15 May - 15 August 2013 (unit: ppb hours).

Station	Data capture (%)	AOT40 (corrected for data capture)
Prestebakke	99	1417
Hurdal	99	683
Haukenes	99	1292
Birkenes	99	1425
Sandve	99	1292
Kårvatn	98	1126
Tustervatn	98	1103
Zeppelin Mountain.	95	100

Table 6.8: Data capture and 6-month's AOT40 values for forests for the period 1 April – 1 October 2013 (unit: ppb hours).

Station	Data capture (%)	AOT40 (corrected for data capture)
Prestebakke	99	3703
Hurdal	99	1993
Haukenes	99	3691
Birkenes	94	3237
Sandve	91	3528
Kårvatn	98	4361
Tustervatn	99	3651
Zeppelin Mountain	100	423

EU's target value of 9000 ppb hours is met at all the Norwegian stations (Figure 6.4). Values above the long-term objective of 3000 ppb hours have, however, occurred in several of the past ten years. It should be noted that the AOT values shown in Figure 6.4 refer to the 3 month's period May-July as given in the directive without any "Nordic adaption" to the growing season. With a Nordic adaptation as given by UN-ECE, i.e. with the calculation period 15 May to 15 August, the AOT values would become somewhat lower since the ozone levels are generally lower in August than in May in Norway. One should also note that EU's directive gives a different definition on the hours of day that should be included in the AOT-calculation compared to the definition by UN-ECE.

The values in Figure 6.4 are based on UN-ECE's definition (global radiation > 50 W/m^2) and could therefore not be compared directly with the EU directive.

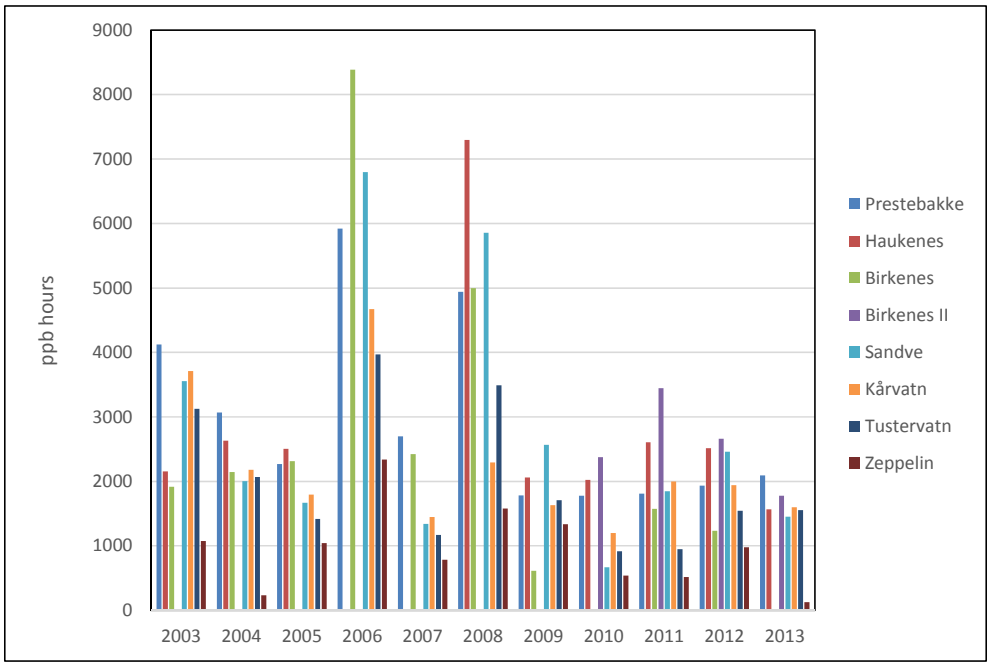


Figure 6.4: 3 months' AOT40 values (1 May - 31 July) for the years 2003-2013 (based on UN-ECE's definition of daylight hours). The EU directive's long-term objective of 3000 ppb hours is indicated by the red line. The definition of daylight hours given by the EU directive differs somewhat from that given by UN-ECE.

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Annex 1

Results from the monitoring programme

Table A.1.1: Monthly and annual volume weighted mean pH at Norwegian background stations

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	4.65	4.22	4.68	5.20	5.22	5.30	5.07	4.93	5.07	4.94	4.93	4.93	4.97
Vatnedalen	5.45	5.90	5.80	5.62	5.77	5.89	6.11	5.94	5.20	5.16	5.58	5.43	5.50
Treungen	4.65	4.53	4.79	5.54	5.53	5.26	4.70	5.22	5.33	5.12	5.25	4.95	5.12
Løken	4.63	4.77	4.92	5.42	5.40	5.64	5.15	5.10	5.49	5.20	5.11	5.17	5.22
Hurdal	4.75	4.90	4.54	5.62	5.57	5.57	4.82	5.02	5.46	5.23	5.14	5.00	5.18
Brekkebygda	5.03	5.10	4.88	5.62	5.65	5.44	5.00	5.22	5.11	5.18	5.32	4.86	5.21
Vikedal	5.41	4.95	5.39	5.67	5.86	5.60	5.09	5.51	5.55	5.27	5.50	5.63	5.48
Haukeland	5.24	5.18	5.01	5.28	5.26	5.32	5.07	5.38	5.31	5.31	5.47	5.30	5.29
Nausta	5.69	5.87	5.61	5.60	5.64	6.10	5.23	5.30	5.52	5.54	5.60	5.63	5.55
Kårvatn	5.56	5.48	5.35	5.33	5.51	5.24	5.43	5.64	5.69	5.58	5.54	5.59	5.45
Høylandet	5.71	5.47	5.51	5.76	5.89	5.51	5.54	5.76	5.72	5.74	5.87	5.68	5.67
Tustervatn	5.47	5.32	5.24	5.31	5.33	5.74	5.39	5.43	5.25	5.43	5.45	5.39	5.39
Karpbukt	5.16	5.44	4.96	4.41	5.03	5.12	4.86	5.02	5.03	4.92	5.25	4.89	4.93
Ny-Ålesund	4.88	5.52	5.16	6.29	5.28	5.49	5.26	5.47	5.51	5.43	5.67	5.58	5.38

Table A.1.2: Monthly and annual volume weighted average concentrations of sulphate (sea salt corrected) in precipitation at Norwegian background stations. Unit: mg S/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.27	0.77	0.21	0.36	0.33	0.17	0.42	0.23	0.17	0.18	0.16	0.14	0.21
Vatnedalen	0.03	0.10	0.17	0.12	0.18	0.14	0.20	0.13	0.11	0.05	0.03	0.03	0.09
Treungen	0.20	0.34	0.24	0.29	0.23	0.17	0.38	0.20	0.11	0.08	0.07	0.09	0.17
Løken	0.25	0.21	0.29	0.26	0.23	0.20	0.42	0.18	0.09	0.12	0.12	0.08	0.17
Hurdal	0.29	0.17	0.32	0.21	0.23	0.22	0.46	0.15	0.26	0.09	0.11	0.09	0.17
Brekkebygda	0.14	0.20	0.34	0.32	0.26	0.14	0.36	0.13	0.14	0.05	0.34	0.13	0.17
Vikedal	0.02	0.20	0.06	0.17	0.24	0.18	0.28	0.13	0.12	0.09	0.06	0.07	0.12
Haukeland	0.04	0.04	0.12	0.08	0.15	0.16	0.20	0.08	0.08	0.05	0.03	0.04	0.08
Nausta	-0.01	0.03	0.13	0.11	0.13	0.16	0.12	0.08	0.08	0.04	0.03	0.04	0.07
Kårvatn	0.00	-0.01	-0.02	0.09	0.06	0.08	0.08	0.08	0.04	0.01	0.02	-0.02	0.04
Høylandet	0.01	0.06	0.04	0.08	0.31	0.14	0.14	0.05	0.07	0.04	0.00	0.04	0.06
Tustervatn	0.03	0.04	0.03	0.08	0.14	0.09	0.07	0.06	0.07	0.02	0.03	0.02	0.04
Karpbukt	0.12	0.19	0.35	0.90	0.98	0.67	0.44	0.36	0.14	0.19	0.15	0.28	0.33
Ny-Ålesund	0.06	0.10	0.50	0.20	0.41	0.22	0.22	0.05	0.03	0.05	0.04	-0.20	0.10

Table A.1.3: Monthly and annual volume weighted average concentrations of nitrate in precipitation at Norwegian background stations. Unit: mg N/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.47	0.61	0.50	0.63	0.54	0.23	0.57	0.38	0.23	0.30	0.33	0.28	0.35
Vatnedalen	0.11	0.23	0.58	0.16	0.21	0.13	0.26	0.20	0.19	0.07	0.05	0.08	0.14
Treungen	0.45	0.45	0.71	0.50	0.35	0.20	0.43	0.33	0.16	0.14	0.18	0.19	0.27
Løken	0.50	0.33	1.37	0.55	0.25	0.23	0.53	0.29	0.10	0.22	0.27	0.21	0.27
Hurdal	0.55	0.24	0.99	0.41	0.28	0.24	0.47	0.23	0.17	0.16	0.25	0.25	0.26
Brekkebygda	0.33	0.30	1.19	0.54	0.32	0.15	0.34	0.15	0.11	0.05	0.20	0.28	0.22
Vikedal	0.13	0.23	0.12	0.23	0.31	0.25	0.37	0.20	0.23	0.15	0.08	0.13	0.18
Haukeland	0.10	0.20	0.67	0.12	0.16	0.18	0.20	0.09	0.16	0.06	0.03	0.07	0.11
Nausta	0.04	0.06	0.12	0.11	0.13	0.14	0.15	0.11	0.16	0.05	0.04	0.07	0.09
Kårvatn	0.03	0.03	0.04	0.07	0.10	0.07	0.07	0.08	0.05	0.05	0.04	0.05	0.06
Høylandet	0.09	0.10	0.07	0.09	0.13	0.11	0.14	0.06	0.06	0.05	0.02	0.07	0.08
Tustervatn	0.07	0.07	0.03	0.17	0.14	0.09	0.06	0.06	0.08	0.04	0.01	0.03	0.05
Karpbukt	0.08	0.12	0.07	0.12	0.18	0.12	0.12	0.09	0.08	0.05	0.06	0.08	0.09
Ny-Ålesund	0.04	0.06	0.05	0.11	0.24	0.10	0.11	0.06	0.07	0.03	0.03	0.10	0.07

Table A.1.4: Monthly and annual volume weighted average concentrations of ammonium in precipitation at Norwegian background stations. Unit: mg N/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.39	0.61	0.41	1.11	0.76	0.31	0.69	0.39	0.19	0.22	0.18	0.19	0.37
Vatnedalen	0.30	0.51	1.25	0.27	0.50	1.00	0.76	0.74	0.16	0.01	0.05	0.09	0.35
Treungen	0.33	0.40	0.71	0.76	0.54	0.41	0.35	0.33	0.13	0.07	0.16	0.11	0.30
Løken	0.35	0.27	1.30	0.82	0.91	0.78	1.50	0.19	0.20	0.23	0.21	0.19	0.49
Hurdal	0.43	0.23	0.68	0.75	0.53	0.75	0.58	0.23	0.37	0.13	0.19	0.16	0.38
Brekkebygda	0.20	0.25	1.17	0.68	0.48	0.20	0.28	0.12	0.09	0.05	0.57	0.16	0.25
Vikedal	0.31	0.47	0.34	0.52	0.68	0.83	0.95	0.37	0.64	0.20	0.17	0.25	0.41
Haukeland	0.09	0.20	0.51	0.32	0.26	0.54	0.23	0.09	0.15	0.05	0.09	0.11	0.16
Nausta	0.24	0.33	0.53	0.39	0.24	1.23	0.25	0.18	0.37	0.13	0.17	0.20	0.29
Kårvatn	0.09	0.13	0.21	0.17	0.22	0.11	0.12	0.29	0.18	0.10	0.06	0.05	0.13
Høylandet	0.33	0.37	0.32	0.47	1.13	0.54	0.17	0.32	0.35	0.35	0.33	0.24	0.34
Tustervatn	0.10	0.34	0.25	0.28	0.55	0.80	0.10	0.05	0.07	0.05	0.03	0.01	0.14
Karpbukt	0.09	0.40	0.23	0.26	0.38	0.44	0.15	0.15	0.13	0.06	0.22	0.16	0.16
Ny-Ålesund	0.04	0.08	0.15	0.96	0.49	0.10	0.12	0.05	0.06	0.05	0.05	0.09	0.09

Table A.1.5: Monthly and annual volume weighted average concentrations of calcium in precipitation at Norwegian background stations. Unit: mg/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.10	0.09	0.11	0.12	0.15	0.09	0.25	0.16	0.17	0.20	0.29	0.22	0.17
Vatnedalen	0.08	0.16	0.14	0.12	0.15	0.12	0.20	0.21	0.08	0.07	0.18	0.13	0.14
Treungen	0.03	0.04	0.06	0.15	0.10	0.05	0.15	0.14	0.09	0.07	0.10	0.08	0.09
Løken	0.08	0.07	0.56	0.14	0.10	0.07	0.59	0.16	0.15	0.15	0.13	0.18	0.14
Hurdal	0.09	0.06	0.22	0.23	0.21	0.10	0.21	0.11	0.24	0.16	0.20	0.11	0.15
Brekkebygda	0.16	0.14	0.23	0.27	0.13	0.08	0.30	0.10	0.16	0.05	0.09	0.16	0.13
Vikedal	0.23	0.17	0.09	0.17	0.10	0.06	0.12	0.07	0.39	0.16	0.26	0.31	0.21
Haukeland	0.13	0.18	0.25	0.11	0.12	0.07	0.06	0.04	0.05	0.07	0.12	0.18	0.11
Nausta	0.07	0.03	0.11	0.10	0.08	0.04	0.05	0.04	0.08	0.02	0.13	0.15	0.08
Kårvatn	0.06	0.11	0.19	0.12	0.09	0.04	0.06	0.05	0.15	0.16	0.32	0.25	0.14
Høylandet	0.06	0.07	0.11	0.07	0.26	0.13	0.10	0.24	0.15	0.20	0.34	0.14	0.17
Tustervatn	0.04	0.02	0.04	0.05	0.17	0.06	0.03	0.04	0.03	0.14	0.17	0.10	0.09
Karpbukt	0.17	0.15	0.24	0.16	0.98	0.48	0.16	0.11	0.33	0.26	0.26	0.11	0.25
Ny-Ålesund	0.34	0.25	0.43	0.68	0.83	0.59	0.67	0.18	0.42	0.42	0.56	2.13	0.47

Table A.1.6: Monthly and annual volume weighted average concentrations of potassium in precipitation at Norwegian background stations. Unit: mg/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.10	0.13	0.02	0.10	0.06	0.09	0.14	0.08	0.07	0.07	0.17	0.14	0.10
Vatnedalen	0.15	0.13	0.20	0.10	0.11	0.10	0.19	0.27	0.09	0.11	0.10	0.18	0.15
Treungen	0.04	0.05	0.07	0.10	0.11	0.09	0.08	0.03	0.05	0.06	0.10	0.09	0.08
Løken	0.09	0.08	0.22	0.10	0.09	0.06	0.45	0.11	0.25	0.12	0.08	0.12	0.11
Hurdal	0.12	0.12	0.17	0.13	0.11	0.14	0.14	0.04	0.06	0.09	0.12	0.10	0.10
Brekkebygda	0.19	0.12	0.22	0.25	0.05	0.16	0.17	0.06	0.32	0.18	0.12	0.15	0.14
Vikedal	0.22	0.17	0.14	0.17	0.08	0.07	0.10	0.05	0.04	0.10	0.14	0.20	0.13
Haukeland	0.09	0.14	0.16	0.07	0.04	0.06	0.04	0.04	0.13	0.11	0.12	0.17	0.10
Nausta	0.10	0.02	0.20	0.09	0.04	0.04	0.04	0.04	0.04	0.02	0.09	0.09	0.07
Kårvatn	0.02	0.13	0.21	0.08	0.10	0.06	0.07	0.21	0.23	0.26	0.27	0.16	0.15
Høylandet	0.14	0.13	0.13	0.12	0.30	0.08	0.12	0.07	0.17	0.12	0.32	0.11	0.15
Tustervatn	0.03	0.03	0.03	0.04	0.03	0.04	0.05	0.05	0.04	0.05	0.11	0.05	0.06
Karpbukt	0.06	0.11	0.18	-	0.11	0.18	0.16	0.11	0.35	0.27	0.27	0.07	0.18
Ny-Ålesund	0.37	0.13	0.21	0.25	0.17	0.14	0.07	0.07	0.29	0.19	0.22	1.88	0.20

Table A.1.7: Monthly and annual volume weighted average concentrations of magnesium in precipitation at Norwegian background stations. Unit: mg/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.16	0.07	0.20	0.11	0.04	0.03	0.06	0.07	0.08	0.11	0.29	0.37	0.16
Vatnedalen	0.10	0.05	0.04	0.07	0.02	0.01	0.05	0.04	0.02	0.03	0.09	0.10	0.05
Treungen	0.06	0.04	0.05	0.05	0.06	0.01	0.06	0.03	0.03	0.04	0.13	0.15	0.06
Løken	0.08	0.04	0.13	0.08	0.03	0.02	0.15	0.06	0.05	0.05	0.14	0.31	0.09
Hurdal	0.04	0.01	0.06	0.06	0.03	0.02	0.08	0.03	0.05	0.04	0.08	0.12	0.05
Brekkebygda	0.04	0.02	0.12	0.05	0.02	0.02	0.06	0.03	0.05	0.03	0.17	0.07	0.04
Vikedal	0.61	0.37	0.16	0.27	0.13	0.03	0.08	0.08	0.06	0.17	0.37	0.56	0.29
Haukeland	0.36	0.37	0.14	0.20	0.11	0.03	0.05	0.08	0.05	0.10	0.30	0.42	0.21
Nausta	0.19	0.07	0.24	0.23	0.06	0.03	0.04	0.06	0.04	0.04	0.29	0.25	0.14
Kårvatn	0.11	0.32	0.56	0.12	0.08	0.02	0.03	0.02	0.08	0.07	0.64	0.30	0.22
Høylandet	0.10	0.18	0.24	0.15	0.27	0.03	0.11	0.09	0.09	0.21	0.72	0.22	0.24
Tustervatn	0.09	0.04	0.07	0.12	0.04	0.01	0.04	0.05	0.01	0.09	0.31	0.07	0.10
Karpbukt	0.42	0.30	0.61	0.19	0.11	0.30	0.11	0.06	0.89	0.71	0.66	0.22	0.44
Ny-Ålesund	1.14	0.42	0.68	0.63	0.61	0.41	0.26	0.19	0.84	0.70	0.76	5.18	0.63

Table A.1.8: Monthly and annual volume weighted average concentrations of sodium in precipitation at Norwegian background stations. Unit: mg/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	1.42	0.58	1.74	1.10	0.36	0.27	0.42	0.53	0.63	0.86	2.42	3.12	1.34
Vatnedalen	1.11	0.45	0.66	0.99	0.57	0.52	0.84	0.46	0.16	0.18	0.76	0.89	0.60
Treungen	0.47	0.32	0.44	0.43	0.19	0.10	0.44	0.20	0.22	0.23	1.08	1.23	0.42
Løken	0.74	0.40	2.45	0.78	0.18	0.09	0.64	0.33	0.38	0.36	1.16	2.40	0.70
Hurdal	0.43	0.20	0.73	0.63	0.19	0.10	0.49	0.16	0.28	0.28	0.90	1.09	0.43
Brekkebygda	0.52	0.23	0.91	0.51	0.11	0.16	0.29	0.10	0.37	0.25	1.09	0.53	0.26
Vikedal	5.64	3.17	1.60	2.55	1.07	0.23	0.54	0.67	0.40	1.35	3.04	4.48	2.43
Haukeland	3.16	3.96	4.35	1.89	0.91	0.27	0.40	0.63	0.37	0.70	2.56	3.59	1.85
Nausta	1.99	0.72	2.45	2.20	0.48	0.26	0.28	0.44	0.28	0.34	2.41	1.93	1.22
Kårvatn	0.77	2.86	5.17	1.10	0.75	0.17	0.24	0.29	0.70	0.71	5.16	2.96	1.96
Høylandet	1.14	1.96	2.29	1.67	2.84	0.20	0.64	0.69	0.59	1.61	6.13	1.74	2.08
Tustervatn	0.73	0.49	0.75	1.02	0.43	0.12	0.29	0.42	0.07	0.81	2.52	0.56	0.86
Karpbukt	3.55	2.76	5.15	1.44	0.49	2.50	0.47	0.45	7.79	6.24	5.64	1.61	3.66
Ny-Ålesund	9.13	3.67	5.35	6.97	4.15	1.98	0.75	1.46	6.96	4.91	5.13	42.47	4.57

Table A.1.9: Monthly and annual volume weighted average concentrations of chloride in precipitation at Norwegian background stations. Unit: mg N/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	2.51	1.10	2.74	1.91	0.63	0.41	0.61	0.80	1.08	1.48	4.35	5.35	2.29
Vatnedalen	1.67	0.86	1.06	1.40	0.47	0.35	0.60	0.38	0.24	0.24	1.23	1.46	0.78
Treungen	0.90	0.66	0.74	0.77	0.35	0.18	0.50	0.28	0.35	0.39	1.90	2.13	0.71
Løken	1.31	0.74	3.46	1.40	0.28	0.16	0.84	0.47	0.59	0.66	2.02	4.03	1.17
Hurdal	0.76	0.42	1.00	0.99	0.30	0.19	0.65	0.22	0.49	0.45	1.52	1.79	0.70
Brekkebygda	0.77	0.39	1.25	0.89	0.17	0.25	0.43	0.14	0.41	0.46	1.80	0.90	0.41
Vikedal	9.72	5.76	2.68	4.35	1.96	0.40	0.82	1.06	0.69	2.37	5.35	7.63	4.18
Haukeland	5.26	6.70	7.27	3.29	1.57	0.45	0.70	1.09	0.63	1.22	4.48	6.29	3.21
Nausta	3.35	1.30	4.45	4.25	0.94	0.43	0.48	0.75	0.50	0.61	4.24	3.37	2.20
Kårvatn	1.39	4.70	8.56	2.12	1.38	0.30	0.44	0.53	1.25	1.21	9.89	5.18	3.54
Høylandet	1.89	3.57	3.69	3.08	4.99	0.35	1.09	1.20	1.06	2.87	10.70	3.11	3.66
Tustervatn	1.35	0.93	1.32	1.94	0.83	0.22	0.48	0.68	0.11	1.43	4.69	1.04	1.57
Karpbukt	6.40	5.09	9.21	2.55	0.77	4.55	0.65	0.63	13.60	10.44	9.60	2.83	6.29
Ny-Ålesund	16.12	6.59	10.11	12.69	6.68	3.14	1.18	2.56	12.21	8.38	9.21	64.57	7.72

Table A.1.10: Monthly and annual precipitation amount at Norwegian background stations. Unit: mm.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Vatnedalen	33	7	2	68	112	111	11	161	85	101	97	195	983
Treungen	37	12	23	49	212	172	25	121	120	154	45	185	1150
Løken	17	21	2	58	150	140	19	107	38	112	35	137	834
Hurdal	24	16	2	64	151	131	18	129	48	109	43	163	896
Brekkebygda	43	21	8	36	264	234	39	137	157	101	10	162	1202
Vikedal	143	70	14	284	205	123	111	243	248	230	296	575	2534
Haukeland	108	121	24	354	205	158	270	345	165	491	457	720	3415
Nausta	66	110	40	273	111	112	241	272	83	309	220	444	2277
Kårvatn	45	146	73	100	62	193	184	119	48	116	241	105	1432
Høylandet	108	148	82	80	50	78	151	123	71	173	222	267	1551
Tustervatn	32	80	84	59	15	72	104	67	78	129	186	244	1148
Karpbukt	51	14	50	22	23	15	70	40	37	131	19	44	516
Ny-Ålesund	19	12	2	4	6	34	31	67	27	36	24	6	268

Table A.1.11: Monthly and annual wet deposition of strong acid (H^+) at Norwegian background stations. Unit: µekv/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	1705	1425	876	608	778	1119	32	1354	1154	1989	1100	3690	15401
Vatnedalen	119	9	3	163	191	141	8	185	530	695	253	721	3137
Treungen	819	345	375	142	632	944	490	736	568	1176	256	2084	8638
Løken	398	360	23	218	597	319	132	852	121	700	276	937	4991
Hurdal	424	196	69	151	405	351	267	1238	169	644	306	1610	5912
Brekkebygda	403	167	100	87	596	847	390	826	1230	667	48	2230	7440
Vikedal	561	773	56	602	285	309	907	756	699	1226	928	1351	8363
Haukeland	619	798	234	1853	1137	753	2278	1432	811	2384	1531	3568	17358
Nausta	135	150	98	687	251	89	1425	1369	251	883	546	1047	6392
Kårvatn	122	478	324	463	191	1110	676	272	97	304	692	271	5059
Høylandet	208	502	256	140	65	240	435	214	134	312	300	557	3351
Tustervatn	110	389	479	285	68	131	421	247	441	481	666	986	4709
Karpbukt	353	49	558	866	218	114	962	386	342	1571	106	567	6100
Ny-Ålesund	252	35	16	2	33	110	171	223	84	132	51	17	1125

Table A.1.12: Monthly and annual wet deposition of sulphate (sea salt corrected) at Norwegian background stations. Unit: mg S/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	20	18	9	35	43	38	2	26	23	31	15	46	303
Vatnedalen	1	1	0	8	20	15	2	21	9	5	3	6	92
Treungen	7	4	6	14	50	30	9	25	14	12	3	17	190
Løken	4	5	1	15	34	28	8	19	3	13	4	11	145
Hurdal	7	3	1	13	35	28	8	20	12	10	5	15	156
Brekkebygda	6	4	3	12	68	33	14	18	22	5	3	21	207
Vikedal	2	14	1	49	49	22	31	31	29	21	17	41	304
Haukeland	4	5	3	30	31	25	53	26	13	24	14	32	259
Nausta	-1	3	5	29	14	18	29	22	6	11	6	16	153
Kårvatn	0	-1	-1	9	3	15	14	10	2	2	6	-2	57
Høylandet	0	9	3	6	16	10	21	6	5	6	-1	11	94
Tustervatn	1	3	3	5	2	6	7	4	6	2	6	4	49
Karpbukt	6	3	17	20	23	10	31	14	5	25	3	12	170
Ny-Ålesund	1	1	1	1	3	8	7	3	1	2	1	-1	27

Table A.1.13: Monthly and annual wet deposition of nitrate at Norwegian background stations. Unit: mg N/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	36	14	21	61	69	52	2	44	31	53	31	89	501
Vatnedalen	4	2	1	11	23	15	3	32	16	7	5	16	133
Treungen	16	5	16	25	74	34	11	40	19	22	8	35	305
Løken	9	7	3	31	38	33	10	31	4	25	9	30	229
Hurdal	13	4	2	26	43	31	8	30	8	17	11	41	233
Brekkebygda	14	6	9	19	85	34	13	20	17	5	2	46	268
Vikedal	18	16	2	64	63	30	41	49	56	34	23	74	467
Haukeland	11	24	16	44	33	29	54	30	26	31	14	47	360
Nausta	3	6	5	31	15	15	36	30	13	17	10	33	207
Kårvatn	1	4	3	7	6	13	12	9	3	6	10	5	80
Høylandet	10	15	6	7	7	9	22	8	4	9	5	18	119
Tustervatn	2	5	2	10	2	6	6	4	6	5	2	7	60
Karpbukt	4	2	4	3	4	2	8	4	3	6	1	4	44
Ny-Ålesund	1	1	0	0	2	3	3	4	2	1	1	1	18

Table A.1.14: Monthly and annual wet deposition of ammonium at Norwegian background stations. Unit: mg N/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	30	14	17	108	99	70	3	45	26	38	17	59	522
Vatnedalen	10	4	3	19	56	110	8	120	14	1	5	17	344
Treungen	12	5	17	37	114	70	9	39	15	11	7	21	349
Løken	6	6	2	47	136	109	28	20	8	26	8	27	405
Hurdal	10	4	2	48	80	98	10	29	18	14	8	27	340
Brekkebygda	9	5	9	24	128	46	11	17	13	5	6	26	304
Vikedal	44	33	5	148	140	102	105	89	158	46	52	142	1049
Haukeland	10	24	12	113	54	86	61	31	24	22	43	77	557
Nausta	16	37	21	105	27	138	59	49	31	39	37	90	666
Kårvatn	4	18	15	17	14	22	21	35	9	11	13	5	182
Høylandet	36	55	26	37	57	42	26	39	25	61	74	64	529
Tustervatn	3	27	21	17	8	57	10	4	5	7	6	3	164
Karpbukt	5	5	12	6	9	7	11	6	5	8	4	7	84
Ny-Ålesund	1	1	0	4	3	3	4	3	1	2	1	1	24

Table A.1.15: Monthly and annual wet deposition of calcium at Norwegian background stations. Unit: mg Ca /m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	8	2	4	12	20	21	1	19	22	34	27	70	239
Vatnedalen	3	1	0	8	17	14	2	34	6	7	17	25	136
Treungen	1	0	1	7	20	8	4	18	11	11	5	15	101
Løken	1	1	1	8	14	11	11	17	6	17	5	25	117
Hurdal	2	1	1	15	31	13	4	14	12	18	8	17	134
Brekkebygda	7	3	2	10	34	18	12	13	24	5	1	26	151
Vikedal	33	12	1	49	21	7	13	18	96	37	77	180	541
Haukeland	14	22	6	39	26	10	16	16	9	32	56	131	377
Nausta	4	3	4	28	9	4	11	11	7	7	28	68	187
Kårvatn	3	16	14	12	5	8	10	6	7	19	77	26	204
Høylandet	6	11	9	5	13	10	16	30	11	34	76	36	257
Tustervatn	1	2	3	3	2	4	3	3	2	18	32	26	100
Karpbukt	8	2	12	4	23	7	11	5	12	34	5	5	129
Ny-Ålesund	6	3	1	3	5	20	21	12	11	15	14	13	125

Table A.1.16: Monthly and annual wet deposition of potassium at Norwegian background stations. Unit: mg K/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	8	3	1	9	8	19	1	10	10	12	16	45	140
Vatnedalen	5	1	0	7	12	11	2	43	7	11	10	35	145
Treungen	1	1	2	5	23	15	2	3	6	9	5	16	87
Løken	2	2	0	6	13	8	8	11	9	14	3	16	92
Hurdal	3	2	0	9	17	19	2	5	3	10	5	17	91
Brekkebygda	8	2	2	9	13	37	7	8	50	18	1	24	162
Vikedal	32	12	2	47	16	8	11	13	10	22	41	114	328
Haukeland	10	17	4	23	9	9	11	16	21	54	55	121	350
Nausta	6	2	8	25	5	4	10	12	3	7	20	42	147
Kårvatn	1	19	15	8	6	12	12	26	11	30	64	17	218
Høylandet	15	19	11	10	15	7	18	9	12	20	71	29	233
Tustervatn	1	3	3	3	0	3	5	3	3	7	20	12	64
Karpbukt	3	2	9	-	3	3	12	4	13	36	5	3	95
Ny-Ålesund	7	2	0	1	1	5	2	5	8	7	5	12	54

Table A.1.17: Monthly and annual wet deposition of magnesium at Norwegian background stations. Unit: mg /m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	13	2	8	11	5	7	0	8	11	19	27	118	228
Vatnedalen	3	0	0	5	2	1	1	7	2	3	8	20	53
Treungen	2	0	1	2	13	2	1	4	4	7	6	28	71
Løken	1	1	0	5	4	3	3	6	2	6	5	43	78
Hurdal	1	0	0	4	5	3	1	3	3	4	3	20	47
Brekkebygda	2	1	1	2	6	4	2	4	8	3	2	12	44
Vikedal	88	26	2	75	27	3	9	20	14	39	110	324	742
Haukeland	39	45	3	70	23	4	14	26	9	48	138	304	722
Nausta	12	7	10	63	6	3	9	16	3	13	64	110	327
Kårvatn	5	46	41	11	5	4	5	2	4	8	153	32	321
Høylandet	11	27	20	12	13	2	16	11	6	36	160	59	376
Tustervatn	3	4	6	7	1	1	4	3	1	12	58	18	118
Karpbukt	21	4	31	4	2	4	8	2	33	94	13	9	226
Ny-Ålesund	22	5	2	3	4	14	8	13	23	25	18	33	167

Table A.1.18: Monthly and annual wet deposition of sodium at Norwegian background stations. Unit: mg /m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	109	14	74	107	47	60	2	61	86	149	225	985	1911
Vatnedalen	37	3	1	68	64	57	9	74	13	18	73	172	591
Treungen	17	4	10	21	41	17	11	25	26	35	49	228	482
Løken	13	9	5	45	27	13	12	35	14	41	41	328	580
Hurdal	10	3	2	40	29	13	9	20	13	30	38	178	386
Brekkebygda	22	5	7	19	30	37	11	13	58	25	11	85	309
Vikedal	808	221	22	724	220	28	60	163	98	310	900	2577	6155
Haukeland	341	477	105	670	187	42	107	217	61	345	1169	2584	6303
Nausta	131	79	97	600	53	28	67	119	23	105	529	859	2783
Kårvatn	34	417	379	110	47	33	44	34	34	83	1240	311	2808
Høylandet	123	290	188	133	142	16	97	85	42	278	1358	463	3231
Tustervatn	24	39	63	60	6	8	30	28	6	105	470	138	985
Karpbukt	180	37	260	32	11	37	33	18	288	820	107	70	1892
Ny-Ålesund	173	42	12	29	26	68	23	97	188	175	124	268	1222

Table A.1.19: Monthly and annual wet deposition of chloride at Norwegian background stations. Unit: mg /m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	193	26	116	186	82	93	2	92	146	257	406	1687	3274
Vatnedalen	56	6	2	95	52	39	6	61	20	24	120	284	766
Treungen	33	8	17	38	73	30	12	34	42	60	86	392	821
Løken	22	16	7	80	42	22	16	51	22	74	72	553	974
Hurdal	18	7	2	63	45	25	12	28	24	49	65	291	629
Brekkebygda	33	8	10	32	46	59	17	19	64	46	18	145	488
Vikedal	1393	401	37	1235	402	49	91	258	172	544	1583	4387	10589
Haukeland	568	809	175	1163	322	70	190	378	105	598	2047	4533	10946
Nausta	221	144	177	1157	104	48	115	205	42	189	932	1498	5005
Kårvatn	62	684	626	212	86	58	81	64	60	140	2379	544	5075
Høylandet	204	528	303	245	250	27	165	148	76	496	2369	829	5669
Tustervatn	43	75	111	114	12	16	50	46	8	185	874	253	1802
Karpbukt	325	69	464	57	18	68	46	25	503	1371	181	124	3248
Ny-Ålesund	305	76	23	52	41	108	37	170	330	299	222	407	2066

Table A.1.20: The 10 highest daily wet deposition of sea salt corrected sulphate, 2013.

Site	Date	SO_4 wet dep mgS/m^2	Precip mm'	% av annual SO_4 dep	pH
Birkenes	15.05.2013	13.8	37.7	4.6	5.43
	08.05.2013	11.5	35.8	3.8	5.37
	14.04.2013	11.2	26.4	3.7	6.37
	15.02.2013	10.5	4.3	3.5	3.96
	26.01.2013	10.1	8.9	3.3	4.10
	22.10.2013	8.4	28.0	2.8	4.97
	12.06.2013	7.1	32.2	2.4	5.59
	11.04.2013	6.5	15.8	2.2	4.98
	21.06.2013	6.4	46.7	2.1	5.19
	30.12.2013	6.3	36.5	2.1	4.87
	sum			30.4	
Hurdal	14.09.2013	7.5	21.3	4.8	5.81
	21.06.2013	5.5	11.3	3.5	5.66
	08.08.2013	5.0	40.9	3.2	4.91
	28.04.2013	4.6	24.2	3.0	5.75
	08.05.2013	4.6	11.8	2.9	5.96
	21.05.2013	4.2	30.6	2.7	5.58
	14.04.2013	4.2	11.6	2.7	6.06
	20.05.2013	4.0	18.9	2.6	-
	03.05.2013	3.9	15.3	2.5	5.89
	02.06.2013	3.8	22.9	2.5	5.58
	sum			30.3	

Table A.1.21a: Volume weighted annual mean concentrations and wet deposition of main components in precipitation at Norwegian background stations in 1973-2013, and estimated dry deposition of sulphur and nitrogen for the 1987-2013.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Birkenes	1973	1.06				0.11	4.27	1072	1136			58		
	1974	1.11	0.50	0.52	0.23	0.19	4.25	1563	1735	782	813	88		
	1975	1.01	0.49	0.45	0.19	0.17	4.27	1341	1354	657	603	72		
	1976	1.18	0.63	0.50	0.17	0.12	4.21	1434	1692	903	717	88		
	1977	1.04	0.54	0.54	0.17	0.17	4.27	1597	1661	862	862	86		
	1978	1.17	0.62	0.57	0.17	0.12	4.11	1242	1453	770	708	96		
	1979	1.25	0.57	0.65	0.22	0.15	4.09	1560	1950	889	1014	127		
	1980	1.23	0.57	0.63	0.22	0.11	4.16	1160	1427	661	731	80		
	1981	1.04	0.52	0.53	0.20	0.13	4.21	1316	1369	684	697	81		
	1982	1.05	0.56	0.72	0.22	0.21	4.27	1592	1663	887	1140	86		
	1983	0.91	0.49	0.50	0.24	0.17	4.33	1313	1195	646	650	62		
	1984	1.09	0.57	0.63	0.21	0.19	4.24	1603	1755	905	1003	93		
	1985	0.98	0.58	0.57	0.16	0.09	4.24	1409	1375	810	805	80		
	1986	1.01	0.60	0.69	0.19	0.15	4.26	1613	1622	966	1108	88		
	1987	0.74	0.43	0.46	0.13	0.13	4.38	1576	1168	671	719	65	159	248
	1988	0.83	0.58	0.61	0.15	0.13	4.25	1986	1649	1159	1211	113	159	257
	1989	0.90	0.76	0.63	0.19	0.19	4.27	1228	1106	934	776	67	136	238
	1990	0.71	0.47	0.46	0.14	0.21	4.37	1861	1325	869	852	79	167	254
	1991	0.75	0.57	0.50	0.14	0.19	4.33	1247	930	710	618	59	170	232
	1992	0.74	0.52	0.44	0.12	0.13	4.37	1344	991	703	589	57	138	188
	1993	0.77	0.55	0.51	0.15	0.23	4.37	1245	960	683	634	54	96	158
	1994	0.63	0.55	0.51	0.15	0.12	4.48	1397	886	768	707	46	128	212
	1995	0.53	0.48	0.42	0.09	0.14	4.47	1411	743	684	589	47	115	213
	1996	0.60	0.53	0.47	0.12	0.15	4.42	1192	714	630	563	45	123	205
	1997	0.52	0.50	0.45	0.10	0.13	4.50	1244	648	618	559	40	100	207
	1998	0.52	0.44	0.41	0.10	0.12	4.50	1596	836	710	649	53	74	143
	1999	0.47	0.43	0.36	0.11	0.15	4.59	1843	856	794	659	48	83	171
	2000	0.40	0.45	0.34	0.10	0.19	4.56	2415	949	1083	823	67	78	164
	2001	0.43	0.42	0.39	0.08	0.10	4.63	1604	673	680	629	38	75	177
	2002	0.35	0.33	0.32	0.10	0.12	4.72	1574	558	516	497	30	83	204
	2003	0.46	0.50	0.47	0.12	0.11	4.59	1375	630	693	644	35	74	171
	2004	0.36	0.36	0.33	0.12	0.14	4.69	1700	615	617	567	35	63	178
	2005	0.43	0.47	0.42	0.13	0.18	4.68	1241	531	586	522	26	86	226
	2006	0.32	0.42	0.34	0.10	0.15	4.70	1833	582	775	624	36	96	269
	2007	0.30	0.33	0.28	0.11	0.12	4.75	1441	439	471	400	26	45	122
	2008	0.26	0.35	0.29	0.13	0.20	4.77	1990	511	692	570	34	46	141
	2009	0.33	0.44	0.36	0.10	0.15	4.72	1807	591	792	660	34	43	-
	2010	0.38	0.46	0.36	0.10	0.08	4.69	1113	421	511	401	23	53	*106*
	2011	0.26	0.39	0.42	0.12	0.19	4.86	1779	461	685	752	25	60	*162*
	2012	0.23	0.38	0.33	0.16	0.13	4.86	1989	448	756	648	28	43	215
	2013	0.21	0.35	0.37	0.17	0.16	4.97	1427	303	501	522	15	45	152
Vatnedalen	1974	0.54				0.06	4.59	884	477			23		
	1975	0.53	0.17	0.22		0.09	4.85	994	527	169	219	14		
	1976	0.50	0.20	0.36	0.12	0.10	4.85	715	358	143	257	10		
	1977	0.44	0.21	0.25	0.13	0.06	4.71	761	335	160	190	15		
	1978	0.41	0.17	0.23	0.14	0.10	4.62	862	353	147	198	21		
	1979	0.56	0.22	0.20	0.20	0.06	4.38	948	531	209	190	40		
	1980	0.45	0.16	0.10	0.14	0.06	4.55	799	360	128	80	23		
	1981	0.49	0.19	0.18	0.14	0.09	4.49	900	441	171	162	29		
	1982	0.38	0.18	0.17	0.13	0.08	4.62	967	366	174	159	23		
	1983	0.29	0.13	0.10	0.14	0.08	4.76	1249	363	166	130	22		
	1984	0.40	0.18	0.13	0.16	0.08	4.59	762	306	138	102	20		
	1985	0.43	0.22	0.18	0.15	0.04	4.57	794	343	173	145	21		
	1986	0.51	0.21	0.19	0.13	0.07	4.54	987	506	212	183	29		
	1987	0.41	0.17	0.15	0.12	0.04	4.60	732	298	122	107	19		
	1988	0.37	0.23	0.20	0.13	0.08	4.55	898	334	207	182	25		
	1989	0.34	0.22	0.29	0.13	0.08	4.78	980	337	218	285	16		
	1990	0.27	0.14	0.12	0.14	0.11	4.71	1465	394	203	169	28		
	1991	0.32	0.20	0.17	0.29	0.12	4.69	865	280	172	147	18		

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Vatnedalen cont.	1992	0.29	0.17	0.11	0.15	0.10	4.75	1055	301	175	112	19		
	1993	0.23	0.18	0.10	0.23	0.44	4.82	891	203	159	92	13		
	1994	0.28	0.22	0.15	0.08	0.08	4.75	1006	286	217	155	18		
	1995	0.25	0.18	0.13	0.11	0.10	4.82	823	206	147	108	12		
	1996	0.32	0.23	0.21	0.16	0.04	4.78	601	191	140	124	10		
	1997	0.24	0.15	0.14	0.22	0.10	4.95	858	204	130	121	10		
	1998	0.25	0.18	0.28	0.13	0.06	5.01	903	232	163	260	9		
	1999	0.24	0.16	0.24	0.12	0.08	5.05	1132	265	184	277	10		
	2000	0.15	0.14	0.15	0.11	0.08	5.02	1296	199	184	189	12		
	2001	0.15	0.09	0.10	0.12	0.05	5.27	709	103	65	73	4		
	2002	0.22	0.14	0.17	0.15	0.08	5.02	590	129	82	98	6		
	2003	0.17	0.17	0.14	0.16	0.06	4.97	802	140	132	117	9		
	2004	0.16	0.12	0.20	0.19	0.06	5.30	970	158	122	192	5		
	2005	0.18	0.15	0.14	0.16	0.05	5.17	1071	197	161	148	7		
	2006	0.12	0.16	0.12	0.12	0.06	5.17	1011	119	163	116	7		
	2007	0.10	0.11	0.13	0.17	0.10	5.31	845	84	89	110	4		
	2008	0.10	0.17	0.13	0.24	0.14	5.35	1016	104	171	135	5		
	2009	0.17	0.18	0.15	0.20	0.04	5.35	815	139	147	120	4		
	2010	0.19	0.15	0.19	0.17	0.04	5.40	619	115	91	118	2		
	2011	0.09	0.11	0.24	0.17	0.07	5.51	1225	115	132	294	4		
	2012	0.08	0.13	0.12	0.15	0.04	5.44	828	67	109	95	3		
	2013	0.09	0.14	0.35	0.14	0.05	5.50	983	92	133	344	3		
Treungen	1974	0.94	0.38	0.33	0.14	0.07	4.27	1039	977	395	343	56		
	1975	0.91	0.37	0.34	0.15	0.06	4.26	894	814	331	304	49		
	1976	1.05	0.50	0.42	0.11	0.06	4.20	706	741	353	297	45		
	1977	0.81	0.44	0.39	0.11	0.05	4.32	1165	944	513	454	56		
	1978	0.87	0.38	0.41	0.14	0.04	4.21	945	822	359	387	58		
	1979													
	1980	0.88	0.37	0.39	0.14	0.04	4.23	759	668	281	296	45		
	1981	0.86	0.39	0.46	0.12	0.05	4.29	949	816	370	437	49		
	1982	0.84	0.45	0.50	0.14	0.07	4.32	1130	948	504	563	54		
	1983	0.83	0.40	0.43	0.18	0.05	4.35	1091	908	431	471	48		
	1984	0.77	0.36	0.27	0.15	0.05	4.27	1196	919	436	325	64		
	1985	0.68	0.39	0.37	0.13	0.04	4.33	892	608	350	333	41		
	1986	1.07	0.57	0.63	0.14	0.07	4.19	1030	1097	582	650	66		
	1987	0.68	0.37	0.37	0.13	0.07	4.39	1133	768	424	418	46		
	1988	0.75	0.50	0.45	0.10	0.05	4.27	1348	1006	670	612	73		
	1989	0.76	0.61	0.44	0.10	0.06	4.26	754	572	456	329	41		
	1990	0.63	0.42	0.37	0.06	0.07	4.37	1184	747	503	433	51		
	1991	0.59	0.42	0.34	0.13	0.06	4.42	811	480	343	278	31		
	1992	0.60	0.40	0.34	0.08	0.05	4.44	923	556	365	310	33		
	1993	0.59	0.41	0.32	0.11	0.09	4.46	803	472	329	258	28		
	1994	0.54	0.44	0.35	0.08	0.05	4.49	1016	544	448	356	33		
	1995	0.50	0.44	0.40	0.09	0.08	4.48	903	452	394	361	30		
	1996	0.49	0.40	0.37	0.10	0.05	4.49	838	408	335	312	27		
	1997	0.41	0.37	0.32	0.12	0.06	4.56	887	364	330	282	24		
	1998	0.48	0.40	0.41	0.09	0.04	4.53	959	462	386	397	28		
	1999	0.35	0.32	0.31	0.06	0.06	4.67	1329	463	427	406	28		
	2000	0.33	0.36	0.31	0.08	0.07	4.59	1563	510	566	483	40		
	2001	0.30	0.28	0.27	0.05	0.04	4.77	1141	346	324	314	19		
	2002	0.32	0.27	0.28	0.08	0.04	4.79	933	295	251	262	15		
	2003	0.35	0.36	0.35	0.09	0.04	4.67	1002	349	366	350	22		
	2004	0.31	0.30	0.26	0.10	0.06	4.79	1271	393	379	336	21		
	2005	0.34	0.38	0.37	0.11	0.06	4.75	897	308	338	329	16		
	2006	0.23	0.28	0.20	0.09	0.05	4.79	1522	355	433	310	25		
	2007	0.23	0.24	0.18	0.08	0.04	4.82	1006	226	243	178	15		
	2008	0.21	0.28	0.26	0.11	0.08	4.93	1150	239	318	294	13		
	2009	0.21	0.34	0.25	0.07	0.06	4.82	1213	260	408	302	18		
	2010	0.28	0.34	0.32	0.07	0.03	4.79	849	241	289	271	14		
	2011	0.19	0.26	0.23	0.09	0.05	4.95	1177	227	308	270	13		
	2012	0.15	0.28	0.23	0.07	0.05	4.96	1092	167	307	247	12		
	2013	0.17	0.27	0.30	0.09	0.06	5.12	1150	190	305	349	9		

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S mg/l	NO_3-N mg/l	NH_4-N mg/l	Ca mg/l	Mg mg/l	pH	mm	SO_4-S mg/m²	NO_3-N mg/m²	NH_4-N mg/m²	H+ mekv/m²	S mg/m²	N mg/m²
Løken	1973	1.03				0.06	4.48	569	586			19		
	1974	0.94				0.08	4.43	831	781			31		
	1975	1.03	0.41	0.42		0.08	4.32	657	677	269	276	31		
	1976	1.20	0.49	0.50	0.40	0.09	4.39	533	640	261	267	22		
	1977	0.96	0.41	0.43	0.22	0.07	4.41	699	671	287	301	27		
	1978	1.10	0.48	0.52	0.24	0.07	4.25	597	657	287	310	34		
	1979	1.03	0.49	0.57	0.30	0.07	4.22	784	808	384	447	47		
	1980	0.97	0.39	0.49	0.25	0.08	4.33	695	674	271	341	33		
	1981	0.77	0.36	0.51	0.20	0.06	4.48	700	539	252	357	23		
	1982	1.06	0.60	0.79	0.24	0.11	4.33	885	908	515	679	40		
	1983	0.91	0.47	0.62	0.28	0.10	4.42	656	595	311	404	25		
	1984	0.91	0.49	0.76	0.30	0.10	4.45	747	678	365	567	27		
	1985	0.86	0.47	0.51	0.30	0.09	4.36	894	768	421	459	39		
	1986	0.96	0.57	0.56	0.26	0.08	4.31	701	671	399	391	34		
	1987	0.79	0.40	0.45	0.17	0.06	4.40	861	679	348	387	35		
	1988	0.76	0.49	0.49	0.20	0.08	4.31	882	669	435	429	43		
	1989	0.92	0.69	0.57	0.18	0.10	4.26	421	389	292	239	55		
	1990	0.74	0.47	0.44	0.12	0.08	4.36	719	530	337	313	31		
	1991	0.65	0.50	0.44	0.18	0.09	4.41	722	467	359	320	28		
	1992	0.61	0.44	0.38	0.11	0.05	4.46	686	418	302	261	24		
	1993	0.66	0.44	0.38	0.18	0.05	4.46	714	468	316	270	25		
	1994	0.43	0.37	0.29	0.30	0.06	4.64	740	316	277	213	17		
	1995	0.52	0.43	0.36	0.24	0.09	4.56	656	340	282	235	18		
	1996	0.51	0.39	0.39	0.28	0.09	4.62	673	344	264	264	16		
	1997	0.42	0.40	0.41	0.16	0.06	4.63	549	229	220	223	13		
	1998	0.45	0.39	0.38	0.14	0.07	4.63	717	319	278	272	17		
	1999	0.38	0.36	0.35	0.10	0.06	4.71	1011	383	362	353	20		
	2000	0.33	0.33	0.24	0.07	0.06	4.60	1053	332	349	249	26		
	2001	0.33	0.31	0.26	0.13	0.04	4.75	818	265	253	213	14		
	2002	0.26	0.29	0.25	0.12	0.04	4.84	856	226	244	215	12		
	2003	0.33	0.37	0.34	0.15	0.05	4.72	651	212	244	221	12		
	2004	0.23	0.28	0.20	0.13	0.07	4.80	953	222	267	189	15		
	2005	0.34	0.38	0.32	0.14	0.06	4.77	686	236	260	217	12		
	2006	0.21	0.34	0.30	0.09	0.06	4.79	967	205	324	287	16		
	2007	0.24	0.30	0.28	0.16	0.06	4.92	727	177	216	204	9		
	2008	0.19	0.28	0.22	0.13	0.09	4.90	997	192	283	223	13		
	2009	0.17	0.32	0.29	0.11	0.06	5.06	837	140	267	247	7		
	2010	0.23	0.29	0.24	0.12	0.04	4.95	664	150	193	158	8		
	2011	0.21	0.25	0.41	0.14	0.08	5.12	1100	228	278	452	8		
	2012	0.16	0.27	0.23	0.12	0.05	5.04	762	124	204	173	7		
	2013	0.17	0.27	0.49	0.14	0.09	5.22	834	145	229	405	5		
Nordmoen	1987	0.72	0.37	0.33	0.14	0.03	4.34	1016	727	375	335	46	148	348
	1988	0.88	0.48	0.46	0.13	0.04	4.25	1085	960	519	500	61	171	357
	1989	0.88	0.57	0.40	0.14	0.05	4.26	816	719	463	328	44	144	356
	1990	0.77	0.44	0.35	0.10	0.05	4.31	822	636	366	286	40	137	332
	1991	0.59	0.40	0.31	0.09	0.04	4.43	781	459	312	240	29	117	284
	1992	0.58	0.40	0.27	0.10	0.03	4.42	821	473	327	218	31	99	276
	1993	0.56	0.37	0.25	0.08	0.03	4.45	927	517	340	236	33	84	246
	1994	0.45	0.39	0.29	0.07	0.03	4.55	828	373	326	242	23	97	280
	1995	0.53	0.37	0.33	0.12	0.06	4.49	791	415	292	257	25	88	279
	1996	0.43	0.34	0.23	0.14	0.04	4.52	837	358	286	195	25	91	303
	1997	0.33	0.31	0.26	0.07	0.02	4.63	775	254	240	202	18		
	1998	0.36	0.28	0.21	0.11	0.03	4.64	817	293	224	173	19		
	1999	0.37	0.31	0.26	0.08	0.03	4.65	1014	376	316	262	22		
Hurdal	1998	0.38	0.29	0.28	0.09	0.03	4.68	853	325	249	236	18	54	172
	1999	0.39	0.33	0.31	0.08	0.03	4.67	1110	434	367	344	24	64	169
	2000	0.31	0.31	0.24	0.07	0.05	4.64	1336	418	408	314	30	57	170
	2001	0.33	0.36	0.29	0.08	0.03	4.69	961	318	347	275	20	52	
	2002	0.25	0.27	0.26	0.09	0.03	4.79	732	183	197	187	12	60	
	2003	0.32	0.35	0.32	0.09	0.04	4.66	830	263	289	268	18	63	
	2004	0.24	0.27	0.28	0.11	0.03	4.84	903	219	241	248	13	53	189

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Hurdal	2005	0.35	0.43	0.44	0.12	0.05	4.89	739	258	317	324	9	65	268
cont.	2006	0.23	0.33	0.35	0.15	0.05	5.06	1043	245	348	370	9	74	273
	2007	0.26	0.28	0.36	0.23	0.05	5.13	809	208	228	295	6	37	195
	2008	0.20	0.32	0.31	0.19	0.06	5.10	1068	219	338	335	8	32	189
	2009	0.21	0.27	0.24	0.14	0.04	5.09	909	188	249	222	7	29	-
	2010	0.28	0.35	0.36	0.09	0.02	4.88	809	224	283	291	11	34	*144*
	2011	0.23	0.32	0.47	0.13	0.04	5.04	1300	295	415	605	12	49	*203*
	2012	0.17	0.27	0.21	0.07	0.03	4.93	1129	186	308	239	13	35	*230*
	2013	0.17	0.26	0.38	0.15	0.05	5.18	896	156	233	340	6	28	182
Gulsvik	1974	0.81	0.38	0.28	0.13	0.04	4.28	783	634	298	219	41		
	1975	0.89	0.40	0.34	0.21	0.05	4.36	560	498	224	190	24		
	1976	0.85	0.38	0.30	0.10	0.03	4.35	641	545	244	192	29		
	1977	0.77	0.39	0.35	0.13	0.03	4.35	683	526	266	239	31		
	1978	0.94	0.40	0.38	0.16	0.03	4.22	693	651	277	263	42		
	1979	1.27	0.53	0.62	0.23	0.04	4.11	790	1003	419	490	61		
	1980	0.78	0.25	0.27	0.13	0.03	4.33	667	520	167	180	31		
	1981	0.86	0.35	0.40	0.13	0.03	4.30	628	540	220	251	31		
	1982	0.89	0.44	0.52	0.22	0.05	4.38	778	696	346	408	33		
	1983	0.94	0.40	0.58	0.25	0.05	4.39	664	623	263	384	27		
	1984	0.87	0.40	0.58	0.25	0.04	4.41	946	819	382	547	37		
	1985	0.73	0.35	0.72	0.16	0.04	4.55	686	499	240	492	20		
	1986	0.89	0.48	0.51	0.15	0.04	4.30	804	711	382	409	40		
	1987	0.74	0.37	0.46	0.14	0.03	4.42	916	679	337	421	35		
	1988	0.67	0.41	0.38	0.09	0.03	4.33	1023	688	420	386	48	136	
	1989	0.76	0.54	0.55	0.15	0.06	4.42	668	507	360	369	25	88	
	1990	0.75	0.45	0.53	0.09	0.03	4.43	753	562	338	398	28	100	
	1991	0.60	0.42	0.46	0.13	0.04	4.58	506	302	212	235	13	97	
	1992	0.56	0.35	0.38	0.13	0.03	4.60	666	371	235	255	17	83	
	1993	0.50	0.33	0.40	0.12	0.03	4.66	680	343	222	269	15	60	
	1994	0.50	0.43	0.39	0.23	0.03	4.61	643	320	277	249	16	72	
	1995	0.56	0.39	0.42	0.12	0.04	4.54	634	354	249	268	18	64	
	1996	0.48	0.37	0.51	0.16	0.06	4.71	657	318	241	335	13	67	
	1997	0.35	0.32	0.33	0.12	0.04	4.74	704	247	225	232	13	52	
Brekkebygda	1998	0.38	0.29	0.25	0.08	0.02	4.62	886	336	256	224	21	36	
	1999	0.38	0.30	0.27	0.09	0.02	4.71	845	318	254	227	16	41	
	2000	0.37	0.29	0.23	0.17	0.06	4.69	1261	451	363	285	26	40	
	2001	0.31	0.25	0.29	0.08	0.04	4.81	*865*	*269*	*223*	*265*	*13*		
	2002	0.25	0.18	0.30	0.15	0.04	5.10	*839*	*208*	*155*	*255*	*7*		
	2003	0.30	0.26	0.28	0.17	0.06	4.89	852	257	224	242	11		
	2004	0.26	0.19	0.21	0.22	0.07	5.03	851	218	159	180	8		
	2005	0.36	0.33	0.35	0.12	0.03	4.87	754	275	249	267	10		
	2006	0.26	0.26	0.29	0.12	0.04	4.92	934	243	247	268	11		
	2007	0.18	0.18	0.16	0.13	0.03	4.98	1093	201	196	175	11		
	2008	0.23	0.31	0.32	0.12	0.03	4.94	950	220	298	299	11		
	2009	0.25	0.33	0.25	0.09	0.03	4.96	924	233	308	228	10		
	2010	0.24	0.24	0.33	0.07	0.02	5.03	831	200	203	272	8		
	2011	0.23	0.28	0.45	0.09	0.03	5.04	1387	320	388	629	13		
	2012	0.15	0.26	0.27	0.16	0.03	5.17	1086	165	282	289	7		
	2013	0.17	0.22	0.25	0.13	0.04	5.21	1202	207	268	304	7		
Vikedal	1984	0.51	0.24	0.27	0.24	0.25	4.57	1932	985	465	516	52		
	1985	0.63	0.30	0.33	0.21	0.20	4.45	2223	1390	672	734	79		
	1986	0.56	0.25	0.30	0.15	0.26	4.53	3017	1680	752	898	89		
	1987	0.54	0.27	0.34	0.13	0.18	4.51	1943	1059	519	663	60		
	1988	0.43	0.26	0.25	0.13	0.24	4.51	2694	1163	712	684	84		
	1989	0.53	0.32	0.23	0.14	0.26	4.46	2998	1582	949	704	104		
	1990	0.44	0.22	0.31	0.15	0.35	4.58	3341	1463	724	1036	88		
	1991	0.44	0.26	0.27	0.14	0.33	4.60	2962	1293	764	797	75		
	1992	0.40	0.22	0.24	0.12	0.22	4.70	3214	1281	710	771	64		
	1993	0.41	0.24	0.27	0.22	0.48	4.69	2009	818	484	545	41		
	1994	0.47	0.28	0.30	0.15	0.36	4.64	2744	1277	780	833	63		
	1995	0.35	0.23	0.23	0.13	0.24	4.72	2635	914	607	609	50		
	1996	0.31	0.23	0.28	0.16	0.16	4.78	1819	556	416	513	30		

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Vikedal cont.	1997	0.35	0.20	0.28	0.24	0.39	4.75	2472	870	504	684	44		
	1998	0.32	0.24	0.25	0.11	0.21	4.77	2690	872	646	678	46		
	1999	0.27	0.22	0.22	0.12	0.27	4.82	3108	840	689	675	47		
	2000	0.25	0.22	0.22	0.12	0.26	4.82	2918	734	645	631	45		
	2001	0.26	0.22	0.28	0.11	0.20	4.96	2353	616	529	652	26		
	2002	0.29	0.26	0.39	0.14	0.24	4.94	2239	658	574	878	26		
	2003	0.26	0.25	0.29	0.11	0.21	4.86	2792	714	708	805	38		
	2004	0.17	0.19	0.29	0.12	0.23	5.08	2816	488	532	819	23		
	2005	0.21	0.21	0.29	0.15	0.31	5.07	3033	639	646	888	26		
	2006	0.18	0.22	0.24	0.15	0.28	5.10	2771	500	607	679	22		
	2007	0.14	0.17	0.28	0.22	0.40	5.24	3147	435	532	865	18		
	2008	0.14	0.17	0.20	0.22	0.42	5.24	2986	434	506	612	17		
	2009	0.17	0.20	0.26	0.10	0.20	5.33	2545	430	500	673	12		
	2010	0.29	0.28	0.31	0.28	0.12	5.26	1834	529	506	569	10		
	2011	0.11	0.18	0.37	0.15	0.34	5.33	3319	364	612	1224	16		
	2012	0.10	0.17	0.28	0.12	0.21	5.34	2557	268	427	724	12		
	2013	0.12	0.18	0.41	0.21	0.29	5.48	2534	304	467	1049	8		
Haukeland	1974	0.31	0.13	0.15	0.17	0.29	4.70	3901	1207	522	582	78		
	1975	0.36	0.10	0.17	0.17	0.37	4.73	4551	1636	431	753	85		
	1976	0.59	0.23	0.45	0.18	0.25	4.59	1808	1060	417	813	46		
	1982	0.48	0.18	0.20	0.14	0.24	4.56	3688	1756	674	722	101		
	1983	0.32	0.14	0.14	0.15	0.26	4.70	4769	1536	647	687	96		
	1984	0.42	0.16	0.28	0.20	0.22	4.63	2792	1157	454	783	65		
	1985	0.44	0.21	0.26	0.13	0.15	4.61	2930	1276	606	768	71		
	1986	0.36	0.16	0.20	0.12	0.20	4.71	4009	1459	621	796	77		
	1987	0.44	0.20	0.28	0.16	0.18	4.61	2493	1100	498	692	61		
	1988	0.35	0.21	0.28	0.14	0.24	4.63	3123	1096	642	872	74		
	1989	0.32	0.18	0.15	0.13	0.26	4.71	4525	1426	798	691	88		
	1990	0.27	0.13	0.15	0.11	0.29	4.79	5017	1364	665	744	82		
	1991	0.30	0.16	0.18	0.15	0.29	4.75	3744	1126	617	678	66		
	1992	0.32	0.17	0.17	0.14	0.22	4.77	4436	1421	768	771	76		
	1993	0.34	0.19	0.26	0.26	0.65	4.77	2891	974	556	760	50		
	1994	0.30	0.18	0.20	0.16	0.28	4.83	3670	1108	668	751	55		
	1995	0.21	0.14	0.17	0.11	0.22	4.89	3631	766	505	616	47		
	1996	0.27	0.19	0.26	0.11	0.14	4.85	2201	586	416	566	31		
	1997	0.17	0.14	0.12	0.08	0.14	4.87	3569	769	550	844	36		
	1998	0.22	0.15	0.19	0.09	0.17	4.93	3492	760	513	649	41		
	1999	0.21	0.15	0.17	0.11	0.23	4.99	4315	864	641	743	44		
	2000	0.20	0.15	0.15	0.13	0.28	4.95	3692	752	557	539	41		
	2001	0.18	0.15	0.22	0.09	0.18	5.08	2865	518	442	637	24		
	2002	0.23	0.19	0.22	0.16	0.25	4.97	2644	603	496	576	29		
	2003	0.15	0.14	0.13	0.11	0.18	4.96	3624	540	496	476	40		
	2004	0.12	0.12	0.10	0.09	0.19	5.01	3669	436	452	372	36		
	2005	0.19	0.14	0.14	0.11	0.17	5.06	4394	818	624	610	39		
	2006	0.15	0.17	0.13	0.12	0.17	5.03	3454	504	594	462	32		
	2007	0.09	0.09	0.10	0.12	0.23	5.18	4124	367	374	424	27		
	2008	0.09	0.13	0.12	0.15	0.31	5.16	3649	342	475	441	25		
	2009	0.11	0.12	0.11	0.07	0.15	5.20	3105	335	362	328	19		
	2010	0.17	0.19	0.16	0.05	0.08	5.13	2355	407	438	375	18		
	2011	0.08	0.11	0.20	0.11	0.25	5.22	4196	343	465	823	25		
	2012	0.07	0.10	0.09	0.09	0.19	5.27	3707	254	383	336	20		
	2013	0.08	0.11	0.16	0.11	0.21	5.29	3415	259	360	557	17		
Nausta	1985	0.29	0.13	0.09	0.09	0.12	4.70	1943	561	246	177	39		
	1986	0.27	0.10	0.08	0.09	0.16	4.74	2314	614	227	176	42		
	1987	0.27	0.12	0.11	0.09	0.11	4.72	1969	523	236	213	37		
	1988	0.21	0.13	0.09	0.14	0.23	4.68	2253	476	302	193	47		
	1989	0.21	0.12	0.07	0.10	0.23	4.80	3330	708	407	227	53	91	
	1990	0.23	0.11	0.07	0.09	0.23	4.78	3549	808	380	254	58	72	
	1991	0.19	0.12	0.09	0.12	0.30	4.83	2411	470	291	219	35	80	
	1992	0.21	0.13	0.07	0.09	0.15	4.80	2962	633	373	205	47	73	

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Nausta	1993	0.23	0.13	0.10	0.17	0.39	4.87	2215	509	277	211	30	78	
cont.	1994	0.20	0.12	0.15	0.10	0.19	4.96	2747	563	339	415	30	66	
	1995	0.18	0.11	0.13	0.08	0.17	4.91	2510	451	283	321	31	64	
	1996	0.20	0.15	0.14	0.07	0.10	4.87	1575	312	241	225	21		
	1997	0.15	0.12	0.13	0.11	0.23	5.01	2428	361	294	316	24		
	1998	0.13	0.12	0.12	0.07	0.15	5.00	2583	346	298	317	26		
	1999	0.14	0.10	0.08	0.07	0.16	4.99	2880	400	300	225	30		
	2000	0.14	0.10	0.08	0.11	0.26	4.98	2272	314	238	192	24		
	2001	0.13	0.10	0.09	0.06	0.14	5.01	2173	284	226	196	21		
	2002	0.16	0.13	0.13	0.09	0.16	5.00	1852	290	246	244	19		
	2003	0.12	0.12	0.14	0.11	0.21	5.01	2615	322	319	355	25		
	2004	0.10	0.10	0.08	0.07	0.13	5.12	2803	280	286	233	21		
	2005	0.19	0.12	0.14	0.07	0.15	5.10	3195	597	369	435	25		
	2006	0.11	0.13	0.11	0.07	0.17	5.09	2341	264	309	261	19		
	2007	0.07	0.08	0.10	0.10	0.20	5.26	3084	211	239	313	17		
	2008	0.06	0.10	0.13	0.18	0.45	5.24	2464	140	247	327	14		
	2009	0.09	0.09	0.10	0.06	0.13	5.27	2074	183	181	208	11		
	2010	0.11	0.14	0.16	0.03	0.05	5.23	1588	172	214	255	9		
	2011	0.07	0.09	0.21	0.10	0.17	5.41	2814	197	254	587	11		
	2012	0.04	0.08	0.17	0.10	0.17	5.50	2180	83	174	363	7		
	2013	0.07	0.09	0.29	0.08	0.14	5.55	2277	153	207	666	6		
Kårvatn	1978	0.16	0.05	0.09	0.11	0.13	4.98	1317	211	66	119	14		
	1979	0.23	0.09	0.08	0.10	0.10	4.63	1248	287	112	100	29		
	1980	0.20	0.07	0.08	0.11	0.13	4.88	1225	245	86	98	16		
	1981	0.20	0.08	0.15	0.17	0.25	4.96	1101	220	88	165	12		
	1982	0.26	0.08	0.11	0.15	0.16	4.87	995	256	78	112	13		
	1983	0.14	0.05	0.06	0.18	0.20	5.08	1918	265	100	106	16		
	1984	0.24	0.10	0.18	0.22	0.18	5.04	914	216	91	166	8		
	1985	0.20	0.07	0.10	0.15	0.11	5.00	1462	298	100	149	15		
	1986	0.20	0.07	0.13	0.10	0.11	4.95	1277	260	89	162	14		
	1987	0.24	0.09	0.12	0.15	0.17	4.87	1464	357	129	176	20	68	
	1988	0.11	0.06	0.09	0.13	0.19	5.09	1550	164	91	143	13	76	149
	1989	0.11	0.06	0.12	0.13	0.26	5.11	1539	168	97	187	12	55	116
	1990	0.11	0.05	0.07	0.07	0.14	5.07	1520	173	69	105	13	60	107
	1991	0.12	0.06	0.10	0.12	0.24	5.14	1619	190	102	170	12	52	89
	1992	0.10	0.07	0.06	0.11	0.18	5.17	1620	159	113	94	11	62	97
	1993	0.10	0.06	0.12	0.12	0.18	5.16	1423	148	87	169	10	45	88
	1994	0.11	0.07	0.08	0.12	0.15	5.12	1475	168	100	120	11	53	124
	1995	0.08	0.05	0.06	0.10	0.15	5.17	1661	134	80	106	11	39	107
	1996	0.09	0.07	0.10	0.10	0.13	5.16	1170	107	79	115	8	47	126
	1997	0.09	0.06	0.11	0.12	0.23	5.22	1842	171	109	208	11	38	129
	1998	0.08	0.06	0.11	0.09	0.19	5.21	1451	123	86	164	9	25	90
	1999	0.09	0.07	0.08	0.07	0.13	5.22	1304	115	93	100	8	31	107
	2000	0.09	0.05	0.08	0.10	0.23	5.26	1243	110	63	104	7	27	135
	2001	0.07	0.05	0.07	0.07	0.21	5.31	1523	103	71	113	7	28	108
	2002	0.10	0.07	0.10	0.08	0.11	5.26	1295	135	88	132	7	37	185
	2003	0.09	0.08	0.12	0.12	0.23	5.19	1664	154	128	192	11	36	196
	2004	0.06	0.04	0.07	0.11	0.16	5.40	2001	110	75	129	8	37	105
	2005	0.09	0.05	0.08	0.12	0.19	5.33	1733	162	93	139	8	35	153
	2006	0.08	0.08	0.14	0.09	0.13	5.29	1218	96	93	167	6	42	199
	2007	0.05	0.04	0.11	0.11	0.22	5.40	1930	94	74	220	8	22	129
	2008	0.05	0.07	0.08	0.13	0.22	5.37	1426	74	106	115	6	23	127
	2009	0.05	0.05	0.08	0.06	0.09	5.46	1310	69	68	102	5	20	-
	2010	0.08	0.05	0.12	0.03	0.06	5.36	1465	119	74	176	6	22	*47*
	2011	0.06	0.05	0.17	0.10	0.20	5.48	1500	85	70	259	5	31	*70*
	2012	0.06	0.06	0.12	0.12	0.21	5.42	1523	85	91	179	6	26	170
	2013	0.04	0.06	0.13	0.14	0.22	5.45	1432	57	80	182	5	16	110
Høylandet	1987*	0.34	0.15	0.36	0.14	0.18	4.98	803	269	124	292	9	97	
	1988	0.22	0.11	0.17	0.16	0.20	5.00	1311	283	147	224	13	95	
	1989	0.17	0.10	0.14	0.20	0.45	5.11	1590	270	162	220	12		
	1990	0.21	0.10	0.13	0.14	0.26	4.92	1605	337	162	214	19		
	1991	0.23	0.11	0.20	0.21	0.31	5.10	1312	302	146	257	10		

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Høylandet cont.	1992	0.15	0.09	0.15	0.16	0.36	5.16	1415	214	122	215	10		
	1993	0.20	0.12	0.20	0.17	0.35	5.10	1145	230	138	234	9		
	1994	0.15	0.09	0.22	0.12	0.25	5.23	1182	175	107	265	7		
	1995	0.17	0.10	0.22	0.17	0.27	5.20	1509	259	153	332	9		
	1996	0.16	0.10	0.21	0.16	0.26	5.11	813	132	84	167	6		
	1997	0.14	0.10	0.22	0.17	0.32	5.25	1418	196	145	308	8		
	1998	0.12	0.08	0.22	0.13	0.19	5.46	1456	173	123	316	5		
	1999	0.14	0.10	0.27	0.13	0.19	5.41	1195	171	125	342	5		
	2000	0.12	0.08	0.21	0.18	0.35	5.36	1183	150	95	248	5		
	2001	0.14	0.08	0.24	0.17	0.38	5.37	1282	177	107	314	5		
	2002	0.14	0.11	0.27	0.16	0.22	5.40	855	117	91	233	3		
	2003	0.11	0.10	0.23	0.22	0.37	5.25	1536	170	154	359	9		
	2004	0.06	0.08	0.21	0.21	0.35	5.57	1390	87	105	298	4		
	2005	0.15	0.10	0.26	0.16	0.29	5.44	1786	263	180	470	7		
	2006	0.11	0.14	0.32	0.17	0.33	5.47	1182	131	160	381	4		
	2007	0.08	0.12	0.38	0.25	0.49	5.88	1070	85	126	407	1		
	2008	0.11	0.11	0.33	0.32	0.51	5.78	1030	117	109	337	2		
	2009	0.07	0.11	0.27	0.11	0.18	5.68	1152	85	122	315	2		
	2010	0.13	0.09	0.31	0.07	0.10	5.68	926	124	83	284	2		
	2011	0.06	0.07	0.49	0.19	0.35	5.86	1632	101	111	797	2		
	2012	0.04	0.11	0.32	0.21	0.33	5.83	1360	61	155	440	2		
	2013	0.06	0.08	0.34	0.17	0.24	5.67	1551	94	119	529	3		
Tustervatn	1973	0.24				0.18	4.94	1336	321			15		
	1974	0.28				0.11	4.88	695	195			9		
	1975	0.25				0.33	4.91	1756	439			22		
	1976	0.27				0.16	4.97	1064	287			11		
	1977	0.30	0.09	0.11	0.17	0.16	4.91	1111	333	100	122	14		
	1978	0.23	0.08	0.10	0.16	0.16	4.85	1128	259	90	113	16		
	1979	0.28	0.08	0.13	0.15	0.11	4.73	1168	327	93	152	22		
	1980	0.27	0.08	0.14	0.47	0.16	4.98	858	229	71	122	9		
	1981	0.18	0.07	0.10	0.21	0.15	5.00	1099	198	77	110	11		
	1982	0.16	0.08	0.09	0.22	0.47	4.98	1385	227	109	121	15		
	1983	0.20	0.06	0.09	0.16	0.22	4.90	1665	337	101	142	21		
	1984	0.24	0.09	0.09	0.12	0.10	4.85	1056	250	94	89	15		
	1985	0.22	0.08	0.10	0.12	0.15	4.93	1344	298	107	132	16		
	1986	0.26	0.09	0.12	0.12	0.15	4.88	1060	278	94	131	14		
	1987	0.22	0.08	0.11	0.12	0.12	4.89	1163	253	98	133	15	96	
	1988	0.13	0.07	0.09	0.13	0.15	5.04	1159	145	83	106	10	88	131
	1989	0.19	0.08	0.10	0.18	0.40	5.00	1825	346	137	178	18	40	119
	1990	0.16	0.09	0.14	0.11	0.21	4.99	1508	245	133	214	16	65	125
	1991	0.17	0.10	0.14	0.14	0.21	5.04	1400	242	137	197	13	62	148
	1992	0.15	0.08	0.15	0.19	0.37	5.12	1507	223	126	221	11	49	123
	1993	0.14	0.08	0.16	0.24	0.50	5.19	1340	182	111	209	9	44	126
	1994	0.10	0.08	0.13	0.12	0.15	5.24	1117	114	87	144	6	48	147
	1995	0.09	0.06	0.12	0.13	0.21	5.22	1515	136	96	186	9	47	132
	1996	0.12	0.09	0.16	0.15	0.18	5.11	1084	132	97	176	8	44	139
	1997	0.08	0.06	0.18	0.17	0.30	5.34	1528	121	98	271	7	44	199
	1998	0.07	0.06	0.16	0.11	0.18	5.39	1407	100	90	230	6	30	178
	1999	0.09	0.08	0.17	0.07	0.08	5.38	1133	96	90	191	5	34	180
	2000	0.10	0.06	0.15	0.11	0.20	5.33	1313	116	80	191	6	29	164
	2001	0.08	0.06	0.15	0.10	0.19	5.36	1449	107	94	223	6	31	182
	2002	0.09	0.07	0.14	0.11	0.17	5.38	1162	103	82	157	5	38	207
	2003	0.07	0.07	0.18	0.16	0.26	5.32	1513	111	112	274	7	35	196
	2004	0.04	0.07	0.17	0.20	0.23	5.50	1428	62	97	243	5	34	167
	2005	0.12	0.08	0.18	0.15	0.19	5.39	1302	163	109	241	5	39	185
	2006	0.08	0.10	0.13	0.12	0.20	5.30	1208	97	119	153	6	37	219
	2007	0.07	0.08	0.14	0.13	0.26	5.28	1293	91	106	174	7	24	163
	2008	0.07	0.08	0.09	0.16	0.22	5.33	1165	80	93	101	5	22	172
	2009	0.05	0.06	0.11	0.06	0.10	5.40	1155	63	71	126	5	22	-

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Tustervatn	2010	0.11	0.08	0.15	0.06	0.08	5.35	913	101	75	141	4	23	*42*
cont.	2011	0.11	0.07	0.14	0.12	0.20	5.34	1535	168	100	216	7	28	*97*
	2012	0.03	0.07	0.14	0.11	0.23	5.41	769	20	56	105	3	17	215
	2013	0.04	0.05	0.14	0.09	0.10	5.39	1148	49	60	164	5	16	137
Karpdalen	1991	0.91	0.16	0.14	0.16	0.28	4.33	256	233	42	36	12		
	1992	0.96	0.20	0.31	0.26	0.35	4.43	315	302	62	98	12		
	1993	0.86	0.24	0.23	0.29	0.43	4.41	258	223	61	59	10		
	1994	0.60	0.23	0.18	0.15	0.21	4.58	414	250	96	73	11		
	1995	0.63	0.19	0.18	0.35	0.31	4.52	383	241	71	69	11		
	1996	0.49	0.15	0.17	0.20	0.24	4.62	458	224	69	76	24		
	1997	0.60	0.12	0.13	0.17	0.31	4.52	264	158	31	34	8		
Karpbukt	1999	0.36	0.13	0.13	0.11	0.13	4.74	551	198	72	73	10		
	2000	0.38	0.10	0.10	0.11	0.20	4.66	507	193	52	52	11		
	2001	0.40	0.09	0.11	0.14	0.21	4.79	612	241	58	67	10		
	2002	0.25	0.18	0.30	0.15	0.04	5.10	839	208	155	255	7		
	2003	0.27	0.09	0.11	0.18	0.29	4.88	582	158	54	66	8		
	2004	0.34	0.09	0.06	0.19	0.22	4.85	613	208	56	35	9		
	2005	0.42	0.11	0.19	0.16	0.26	4.84	633	264	68	120	9		
	2006	0.39	0.14	0.11	0.12	0.21	4.73	506	195	71	54	9		
	2007	0.39	0.10	0.14	0.15	0.21	5.00	678	265	65	94	7		
	2008	0.37	0.12	0.12	0.19	0.29	4.83	507	186	60	60	8		
	2009	0.41	0.12	0.09	0.12	0.20	4.88	526	218	64	47	7		
	2010	0.30	0.07	0.07	0.12	0.21	4.83	595	178	45	43	9		
	2011	0.38	0.11	0.15	0.12	0.15	4.76	553	212	61	85	10		
	2012	0.20	0.07	0.13	0.12	0.21	4.91	593	117	44	76	7		
	2013	0.33	0.09	0.16	0.25	0.44	4.93	516	170	44	84	6		
Ny-Ålesund	1981	0.24	0.05	0.05	1.03	0.41	5.11	366	88	20	17	3		
(tørravsetning	1982	0.39	0.08	0.05	0.92	2.01	5.01	206	80	16	10	2		
fra Zeppelin)	1983	0.25	0.05	0.10	0.40	0.42	5.13	237	59	11	24	2		
	1984	0.64	0.17	0.21	0.71	0.93	4.60	366	233	62	76	9		
	1985	0.61	0.14	0.13	0.71	1.29	4.72	237	144	33	31	5		
	1986	0.40	0.07	0.49	0.55	0.58	4.98	306	122	20	150	3		
	1987	0.69	0.12	0.10	0.64	0.91	4.63	390	271	46	40	9		
	1988	0.27	0.07	0.21	0.54	0.58	5.18	307	84	21	64	2		
	1989	0.38	0.05	0.06	0.87	1.48	5.55	295	113	15	19	1	35	
	1990	0.33	0.07	0.06	0.52	0.79	4.92	410	137	30	26	5	41	20
	1991	0.34	0.11	0.10	0.80	1.13	4.96	424	145	47	44	5	35	27
	1992	0.43	0.10	0.11	0.80	1.03	5.11	272	116	27	29	2	31	21
	1993	0.29	0.10	0.08	0.51	0.91	5.02	489	140	47	41	5	32	29
	1994	0.32	0.08	0.29	0.59	0.63	5.35	280	90	22	80	1	24	30
	1995	0.30	0.10	0.15	0.89	0.79	5.26	238	71	23	36	1	25	
	1996	0.36	0.13	0.32	0.56	0.90	4.92	504	181	64	162	6	26	
	1997	0.34	0.10	0.44	1.46	2.98	5.60	320	109	32	139	8	27	
	1998	0.27	0.13	0.19	0.78	1.18	5.24	193	42	24	35	1	31	
	1999	0.31	0.19	0.21	1.06	1.30	5.04	227	61	43	50	2	29	
	2000	0.16	0.08	0.10	0.47	0.49	5.37	423	63	32	42	2	24	
	2001	0.15	0.08	0.07	0.56	0.83	5.35	358	52	27	24	2	35	
	2002	0.10	0.08	0.11	1.31	1.34	5.41	544	53	44	61	2	30	
	2003	0.26	0.11	0.12	1.67	2.21	5.50	207	53	23	25	1	32	
	2004	0.23	0.12	0.10	0.93	1.01	5.13	253	57	29	25	2	26	
	2005	0.19	0.09	0.09	1.28	0.89	5.45	212	40	19	18	1	32	
	2006	0.20	0.08	0.18	1.21	1.19	5.43	341	70	27	61	1	22	
	2007	0.19	0.05	0.12	0.79	1.11	5.89	304	59	14	37	1	19	
	2008	0.11	0.1	0.26	1.09	0.8	5.74	282	32	28	72	1	22	
	2009	0.13	0.09	0.05	0.35	0.44	5.45	219	28	20	11	0.8	21	
	2010	0.11	0.11	0.2	0.51	1.21	5.23	211	23	22	42	1.2	18	
	2011	0.07	0.08	0.3	0.56	1	5.51	294	21	24	89	0.9	25	
	2012	0.06	0.06	0.05	0.3	0.47	5.51	373	23	22	17	1.1	20	
	2013	0.10	0.07	0.09	0.47	0.63	5.38	268	27	18	24	1.1	19	

Table A.1.21b: Volume weighted annual mean concentrations and wet deposition of main components in precipitation and estimated dry deposition of sulphur and nitrogen at Norwegian background stations which has been closed down.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S mg/l	NO_3-N mg/l	NH_4-N mg/l	Ca mg/l	Mg mg/l	pH	mm	SO_4-S mg/m^2	NO_3-N mg/m^2	NH_4-N mg/m^2	H+ mekv/m^2	S mg/m^2	N mg/m^2
Lista	1973	1.01				1.31	4.33	851	860			40		
	1974	1.06				1.00	4.28	1208	1280			63		
	1975	1.10				1.06	4.30	1109	1220			56		
	1976	1.37				1.21	4.23	922	1263			54		
	1977	0.95				1.09	4.34	1114	1058			51		
	1978	1.01	0.50	0.45	0.51	1.07	4.27	931	940	466	419	50		
	1979	1.27	0.63	0.57	0.53	1.04	4.09	1157	1469	729	659	94		
	1980	1.05	0.59	0.54	0.47	1.00	4.22	953	1001	562	515	57		
	1981	0.90	0.47	0.50	0.60	1.36	4.34	1037	933	487	519	47		
	1982	1.09	0.65	0.60	0.85	1.82	4.29	1070	1161	699	645	55		
	1983	0.88	0.49	0.40	0.77	1.69	4.36	1198	1051	584	480	53		
	1984	0.92	0.61	0.47	0.86	2.12	4.28	1002	923	613	474	53		
	1985	1.11	0.80	0.68	0.76	1.74	4.20	996	1110	793	681	63		
	1986	0.95	0.63	0.57	1.06	2.66	4.30	1293	1230	816	739	65		
	1987	0.86	0.55	0.55	0.65	1.48	4.35	1169	1004	647	638	52		
	1988	0.75	0.67	0.57	0.82	2.02	4.28	1585	1189	1054	895	84		
	1989	0.83	0.86	0.52	1.21	3.23	4.30	1053	877	904	552	53		
	1990	0.74	0.55	0.42	1.07	3.01	4.38	1565	1156	856	653	65		
	1991	0.75	0.83	0.60	1.36	3.76	4.32	1031	771	858	615	49		
	1992	0.72	0.60	0.41	1.02	2.54	4.38	1376	985	826	561	57		
	1993	0.81	0.80	0.68	2.10	1.79	4.39	845	686	673	579	34		
	1994	0.56	0.57	0.52	0.91	2.37	4.56	1180	659	678	615	33		
	1995	0.67	0.73	0.62	1.15	3.05	4.48	896	599	658	555	30		
	1996	0.62	0.74	0.67	0.88	2.20	4.42	910	564	673	607	35		
	1997	0.55	0.55	0.56	0.94	2.54	4.52	1219	666	666	682	37		
	1998	0.59	0.62	0.53	0.97	2.44	4.46	1240	637	767	661	43		
	1999	0.44	0.60	0.48	1.11	3.00	4.63	1273	547	762	614	30		
	2000	0.45	0.64	0.49	1.28	3.45	4.54	1651	711	1064	808	47		
	2001	0.45	0.59	0.55	0.63	1.55	4.77	1428	639	847	787	24		
	2002	0.47	0.71	0.56	0.99	2.18	4.69	1132	534	808	628	23		
Søgne	1989	1.12	0.93	0.91	0.31	0.43	4.34	1151	1289	1067	1050	53	212	
	1990	0.79	0.60	0.48	0.25	0.52	4.33	1807	1425	1084	872	85	237	612
	1991	0.94	0.66	0.58	0.23	0.47	4.30	1133	1063	750	662	57	245	559
	1992	0.79	0.59	0.49	0.19	0.34	4.33	1280	1011	752	623	60	192	365
	1993	0.95	0.71	0.63	0.26	0.26	4.33	1112	1061	786	699	52	148	326
	1994	0.76	0.62	0.54	0.19	0.31	4.39	1441	1092	894	781	58	173	349
	1995	0.61	0.54	0.45	0.19	0.34	4.45	1213	735	651	552	43	151	350
	1996	0.87	0.75	0.69	0.31	0.36	4.32	1044	910	786	725	50	175	305
	1997	0.67	0.60	0.63	0.20	0.34	4.46	1215	809	733	760	42	123	304
	1998	0.70	0.60	0.55	0.24	0.39	4.45	1333	939	812	740	45	110	268
	1999	0.63	0.57	0.50	0.21	0.34	4.50	1667	1 053	947	840	53	112	249
	2000	0.47	0.54	0.48	0.21	0.38	4.53	2029	980	1100	975	60	96	245
	2001	0.48	0.52	0.47	0.14	0.21	4.61	1569	756	816	737	38	106	
	2002	0.44	0.42	0.34	0.20	0.28	4.64	1608	704	679	552	37	114	
	2003	0.59	0.68	0.68	0.29	0.28	4.59	1271	749	863	865	32	101	
	2004	0.43	0.47	0.45	0.24	0.36	4.72	1601	697	760	717	30	89	
	2005	0.46	0.59	0.55	0.28	0.44	4.64	1176	535	700	644	27	99	
	2006	0.41	0.52	0.41	0.23	0.37	4.68	1714	707	884	707	35	156	
	2007	0.31	0.43	0.29	0.23	0.40	4.80	1237	379	538	362	20	70	
	2008	0.36	0.40	0.35	0.28	0.54	4.83	1697	610	676	601	25	62	
	2009	0.36	0.47	0.43	0.25	0.38	4.77	1633	592	763	699	27	63	
Skreådalen	1973	0.50				0.19	4.60	2185	1093			55		
	1974	0.55				0.18	4.47	2460	1350			83		
	1975	0.57	0.18	0.17		0.19	4.55	2436	1389	438	414	69		
	1976	0.60	0.24	0.23		0.17	4.55	1687	1012	405	388	48		
	1977	0.57	0.27	0.28	0.15	0.13	4.55	2057	1174	550	569	57		
	1978	0.49	0.20	0.26	0.20	0.29	4.52	1769	867	354	460	53		
	1979	0.61	0.26	0.28	0.16	0.14	4.33	2311	1410	601	647	108		
	1980	0.48	0.21	0.21	0.15	0.17	4.54	1949	936	409	409	56		

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S mg/l	NO_3-N mg/l	NH_4-N mg/l	Ca mg/l	Mg mg/l	pH	mm	SO_4-S mg/m²	NO_3-N mg/m²	NH_4-N mg/m²	H+ mekv/m²	S mg/m²	N mg/m²
Skreådalen cont.	1981	0.49	0.20	0.28	0.16	0.18	4.58	2260	1107	452	633	59		
	1982	0.57	0.28	0.37	0.17	0.22	4.52	2519	1436	709	933	76		
	1983	0.43	0.19	0.26	0.18	0.23	4.70	2843	1221	551	734	57		
	1984	0.46	0.24	0.23	0.16	0.21	4.59	1762	802	415	401	46		
	1985	0.59	0.32	0.33	0.15	0.12	4.48	1895	1117	610	616	63		
	1986	0.53	0.29	0.30	0.15	0.19	4.51	2439	1289	698	734	75		
	1987	0.47	0.28	0.29	0.14	0.16	4.54	1639	767	451	471	48	152	
	1988	0.41	0.28	0.28	0.12	0.14	4.55	2255	926	622	632	64	153	
	1989	0.43	0.28	0.28	0.15	0.20	4.56	2519	1087	704	696	70	143	355
	1990	0.39	0.23	0.22	0.13	0.26	4.61	3346	1293	775	732	82	170	415
	1991	0.41	0.27	0.25	0.15	0.24	4.61	2172	894	583	547	53	125	279
	1992	0.37	0.24	0.23	0.12	0.16	4.70	2728	1017	647	627	55	118	254
	1993	0.29	0.22	0.25	0.30	0.56	4.81	2006	586	437	493	31	82	256
	1994	0.38	0.28	0.31	0.31	0.25	4.77	2214	842	619	695	37	104	330
	1995	0.30	0.24	0.24	0.16	0.21	4.75	2083	624	510	500	37	96	257
	1996	0.30	0.28	0.31	0.14	0.12	4.78	1463	438	404	455	25	91	329
	1997	0.25	0.23	0.29	0.21	0.33	4.92	2071	508	472	609	25	73	280
	1998	0.32	0.27	0.31	0.17	0.15	4.83	1961	636	525	621	29	53	254
	1999	0.25	0.23	0.24	0.14	0.23	4.93	2521	618	583	606	30	60	229
	2000	0.23	0.24	0.25	0.14	0.21	4.90	2997	671	705	750	37	58	225
	2001	0.23	0.23	0.33	0.12	0.11	5.10	1887	424	435	619	15	56	260
	2002	0.22	0.23	0.35	0.19	0.20	5.17	1996	443	461	698	14	63	270
	2003	0.24	0.26	0.28	0.14	0.14	4.89	2115	501	545	600	27	48	165
	2004	0.16	0.19	0.21	0.14	0.15	5.07	2531	401	487	528	22	50	239
Valle	1990	0.40	0.27	0.20	0.07	0.11	4.51	1504	607	409	306	46		
	1991	0.47	0.32	0.25	0.14	0.10	4.52	912	432	287	227	28		
	1992	0.46	0.28	0.22	0.13	0.10	4.59	1120	519	318	242	29		
	1993	0.42	0.26	0.23	0.19	0.27	4.66	1052	445	276	243	23		
	1994	0.49	0.37	0.30	0.17	0.11	4.58	1230	608	461	373	32		
	1995	0.33	0.28	0.20	0.13	0.11	4.63	926	303	256	183	22		
	1996	0.38	0.33	0.25	0.17	0.07	4.60	836	316	273	206	21		
	1997	0.30	0.26	0.20	0.12	0.11	4.70	1085	323	280	220	22		
	1998	0.33	0.28	0.29	0.09	0.05	4.67	1179	393	330	336	25		
	1999	0.28	0.22	0.15	0.08	0.07	4.74	1284	335	281	192	23		
	2000	0.26	0.29	0.24	0.10	0.07	4.70	1618	422	467	395	32		
Solhomfjell	1991	0.63	0.44	0.40	0.14	0.08	4.44	878	552	389	355	32		
	1992	0.69	0.47	0.39	0.12	0.07	4.44	958	662	447	376	35		
	1993	0.66	0.45	0.38	0.15	0.08	4.47	920	611	412	347	31		
	1994	0.60	0.48	0.38	0.12	0.06	4.50	1150	686	550	442	36		
	1995	0.55	0.45	0.43	0.14	0.08	4.51	1073	590	484	464	33		
	1996	0.61	0.45	0.41	0.17	0.07	4.46	908	551	410	377	31		
Møsvatn	1993	0.28	0.22	0.14	0.07	0.07	4.69	699	194	155	99	14		
	1994	0.32	0.27	0.17	0.07	0.02	4.66	788	250	209	136	17		
	1995	0.28	0.22	0.14	0.06	0.02	4.65	660	186	147	92	15		
	1996	0.30	0.27	0.21	0.07	0.02	4.66	592	178	161	126	13		
	1997	0.21	0.22	0.18	0.08	0.03	4.77	705	150	155	129	12		
	1998	0.24	0.20	0.15	0.07	0.02	4.79	783	188	154	114	13		
	1999	0.22	0.21	0.16	0.08	0.03	4.89	777	171	169	125	10		
	2000	0.19	0.21	0.16	0.06	0.03	4.79	1000	189	212	159	16		
Lardal	1990	0.70	0.45	0.35	0.09	0.07	4.33	1340	938	599	469	62	99	199
	1991	0.72	0.47	0.36	0.12	0.08	4.38	847	609	401	306	35	144	231
	1992	0.68	0.47	0.38	0.13	0.07	4.42	892	610	421	338	34	91	154
	1993	0.65	0.42	0.32	0.09	0.05	4.45	967	625	402	313	35	66	134
	1994	0.52	0.45	0.35	0.08	0.05	4.53	1216	631	542	429	36	78	159
	1995	0.65	0.47	0.42	0.11	0.09	4.42	1179	764	556	497	45		
	1996	0.50	0.36	0.29	0.11	0.06	4.49	940	472	341	269	30		
	1997	0.58	0.45	0.43	0.31	0.17	4.61	640	373	288	276	16		
	1998	0.52	0.42	0.36	0.12	0.07	4.50	975	505	414	362	31		
	1999	0.43	0.36	0.31	0.08	0.05	4.61	1371	581	492	424	33		
	2000	0.39	0.38	0.30	0.09	0.09	4.54	1809	703	693	550	53		
	2001	0.36	0.33	0.31	0.09	0.05	4.71	1224	442	408	381	24		
	2002	0.34	0.25	0.25	0.10	0.04	4.82	1142	383	285	288	17		

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Prestebakke	1986	1.08	0.54	0.47	0.23	0.19	4.20	699	753	380	328	44		
	1987	0.78	0.42	0.37	0.16	0.08	4.37	830	650	349	307	35	212	343
	1988	0.77	0.47	0.37	0.16	0.15	4.25	989	758	466	370	55	219	307
	1989	0.97	0.69	0.47	0.18	0.21	4.22	697	678	478	330	42	191	301
	1990	0.87	0.57	0.42	0.18	0.18	4.28	816	710	465	342	42	157	252
	1991	0.79	0.55	0.43	0.20	0.25	4.37	805	638	445	346	35	98	190
	1992	0.83	0.60	0.47	0.16	0.15	4.35	832	687	497	392	37	140	154
	1993	0.74	0.47	0.36	0.17	0.13	4.41	775	573	364	278	30	119	228
	1994	0.53	0.39	0.24	0.17	0.13	4.48	892	477	352	216	29	138	234
	1995	0.65	0.54	0.46	0.18	0.17	4.45	746	487	406	346	26	126	
	1996	0.64	0.56	0.43	0.27	0.18	4.42	656	419	368	283	25	126	
	1997	0.42	0.39	0.29	0.08	0.06	4.52	813	338	317	237	24	97	
	1998	0.53	0.45	0.38	0.32	0.20	4.66	842	449	377	328	18	77	
	1999	0.50	0.48	0.34	0.15	0.17	4.52	1182	590	564	394	36	90	
	2000	0.36	0.40	0.30	0.20	0.15	4.60	1181	449	474	351	30	84	
Fagernes	1990	0.41	0.22	0.16	0.10	0.02	4.53	550	228	119	86	16		
	1991	0.38	0.21	0.24	0.22	0.04	4.75	395	150	84	94	7		
	1992	0.43	0.24	0.19	0.10	0.01	4.63	656	279	160	126	15		
	1993	0.26	0.15	0.12	0.08	0.02	4.77	619	162	95	74	10		
	1994	0.28	0.25	0.15	0.08	0.02	4.70	586	166	146	88	12		
	1995	0.32	0.22	0.29	0.14	0.07	4.81	465	151	101	134	7		
	1996	0.25	0.23	0.20	0.17	0.03	4.78	635	159	145	124	11		
	1997	0.21	0.15	0.16	0.09	0.02	4.89	565	116	83	92	6		
	1998	0.21	0.17	0.16	0.13	0.03	4.87	583	125	97	92	8		
	1999	0.20	0.18	0.12	0.08	0.01	4.86	633	125	113	75	9		
	2000	0.19	0.19	0.19	0.10	0.02	4.85	757	150	147	145	11		
	2001	0.16	0.16	0.14	0.12	0.02	5.01	649	103	104	92	6		
	2002	0.19	0.15	0.15	0.13	0.02	4.99	632	119	94	96	6		
Osen	1988	0.53	0.31	0.26	0.13	0.02	4.43	832	442	254	215	31	139	
	1989	0.52	0.27	0.15	0.14	0.03	4.47	786	410	214	122	27	95	145
	1990	0.55	0.28	0.27	0.23	0.03	4.48	711	393	198	192	23	90	123
	1991	0.34	0.26	0.20	0.08	0.02	4.58	647	222	168	129	17	77	107
	1992	0.44	0.37	0.18	0.13	0.02	4.55	725	318	207	133	20	68	103
	1993	0.37	0.26	0.18	0.10	0.02	4.62	764	283	195	140	18	53	94
	1994	0.30	0.27	0.19	0.08	0.02	4.69	636	192	172	120	13	69	112
	1995	0.44	0.27	0.26	0.12	0.03	4.59	612	271	167	157	16	62	108
	1996	0.32	0.26	0.26	0.14	0.03	4.71	574	183	147	151	11	64	112
	1997	0.22	0.20	0.18	0.10	0.02	4.83	708	158	139	126	11	48	108
	1998	0.30	0.23	0.24	0.09	0.02	4.77	655	198	152	155	11	35	97
	1999	0.26	0.24	0.20	0.08	0.02	4.83	750	191	182	149	11	46	114
	2000	0.22	0.20	0.17	0.06	0.03	4.72	971	229	198	165	18	38	118
	2001	0.20	0.20	0.20	0.07	0.01	4.95	768	150	152	153	9	38	137
	2002	0.25	0.19	0.25	0.11	0.03	4.91	738	182	140	184	9	44	157
	2003	0.20	0.22	0.20	0.09	0.02	4.87	661	135	146	133	9	41	138
Valdalen	1994	0.32	0.29	0.19	0.10	0.03	4.70	536	172	153	103	11		
	1995	0.43	0.30	0.37	0.13	0.04	4.68	518	221	153	194	11		
	1996	0.27	0.20	0.29	0.11	0.03	4.91	724	193	142	211	9		
	1997	0.26	0.21	0.22	0.13	0.03	4.89	710	185	152	154	9		
	1998	0.22	0.19	0.16	0.08	0.02	4.88	700	156	130	115	9		
	1999	0.21	0.22	0.19	0.12	0.02	5.05	692	147	150	131	8		
	2000	0.20	0.19	0.20	0.07	0.03	4.92	817	165	154	165	10		
Ualand	1992	0.49	0.30	0.22	0.16	0.31	4.53	2404	1171	714	530	71		
	1993	0.49	0.32	0.24	0.22	0.56	4.53	1531	745	492	365	46		
	1994	0.52	0.38	0.30	0.15	0.33	4.51	2125	1106	802	630	65		
	1995	0.45	0.37	0.27	0.14	0.31	4.51	1838	824	682	499	57		
	1996	0.40	0.32	0.24	0.14	0.23	4.54	1561	631	496	375	45		
	1997	0.44	0.33	0.32	0.19	0.36	4.58	1948	855	648	622	51		
	1998	0.47	0.38	0.29	0.16	0.31	4.52	1992	928	761	584	59		
	1999	0.32	0.30	0.20	0.16	0.37	4.65	2487	798	736	509	55		
	2000	0.31	0.31	0.21	0.19	0.41	4.65	2681	819	832	572	61		

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH		SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m²	mg/m²	mg/m²	mekv/m²	mg/m²	mg/m²
Voss	1990	0.29	0.15	0.08	0.10	0.15	4.68	2053	595	300	169	43		
	1991	0.28	0.18	0.11	0.10	0.18	4.67	1214	342	213	130	26		
	1992	0.27	0.16	0.07	0.06	0.07	4.70	1627	436	255	110	32		
	1993	0.24	0.13	0.08	0.16	0.31	4.82	1162	282	148	96	17		
	1994	0.28	0.16	0.12	0.21	0.14	4.79	1473	408	234	178	24		
	1995	0.21	0.14	0.12	0.08	0.11	4.82	1439	303	208	168	22		
	1996	0.26	0.20	0.19	0.08	0.05	4.76	869	222	174	163	15		
	1997	0.22	0.15	0.24	0.16	0.34	5.00	1275	220	181	152	17		
	1998	0.18	0.14	0.11	0.06	0.10	4.87	1411	250	204	159	19		
	1999	0.18	0.13	0.09	0.06	0.11	4.88	1641	178	211	157	22		
	2000	0.16	0.14	0.12	0.08	0.13	4.91	1844	296	249	214	23		
	2001	0.15	0.13	0.11	0.06	0.07	5.02	1256	183	164	137	12		
	2002	0.18	0.14	0.13	0.08	0.10	4.92	1078	191	149	140	13		
Selbu	1990	0.16	0.06	0.02	0.06	0.10	4.84	1339	220	83	31	19		
	1991	0.18	0.09	0.06	0.11	0.22	4.94	1336	240	125	80	15		
	1992	0.14	0.07	0.03	0.11	0.20	4.95	1402	193	103	45	16		
	1993	0.15	0.09	0.06	0.11	0.17	5.01	1290	193	117	80	13		
	1994	0.16	0.09	0.11	0.07	0.12	5.02	1143	179	105	129	11		
	1995	0.15	0.08	0.12	0.08	0.13	5.01	1411	206	113	166	14		
	1996	0.13	0.08	0.13	0.19	0.18	5.15	1039	132	86	131	7		
	1997	0.11	0.06	0.10	0.16	0.20	5.26	1682	183	105	172	9		
	1998	0.10	0.06	0.10	0.09	0.13	5.20	1333	139	80	131	8		
	1999	0.10	0.07	0.06	0.09	0.10	5.17	1303	133	93	82	9		
	2000	0.14	0.08	0.09	0.15	0.26	5.11	1138	162	87	98	9		
	2001	0.11	0.05	0.06	0.15	0.22	5.19	1540	166	84	86	10		
Namsvatn	1991	0.18	0.11	0.20	0.08	0.12	5.13	1014	181	115	198	8		
	1992	0.14	0.10	0.12	0.12	0.19	5.12	1081	155	105	129	8		
	1993	0.14	0.10	0.17	0.15	0.16	5.20	1004	144	98	172	6		
	1994	0.14	0.10	0.17	0.29	0.11	5.18	902	129	94	152	6		
	1995	0.16	0.10	0.20	0.11	0.15	5.18	1201	188	121	243	8		
	1996	0.17	0.12	0.20	0.11	0.11	5.10	697	117	86	139	6		
Øverbygd	1987*	0.23	0.05	0.08	0.12	0.14	4.92	424	100	23	35	5		
	1988	0.20	0.06	0.05	0.09	0.10	4.84	555	112	33	30	8		
	1989	0.16	0.06	0.06	0.09	0.18	4.98	794	125	45	51	8		
	1990	0.22	0.06	0.07	0.10	0.15	4.90	708	152	44	52	9		
	1991	0.25	0.09	0.07	0.11	0.18	4.90	706	176	60	49	9		
	1992	0.17	0.07	0.06	0.12	0.18	5.08	662	109	44	38	6		
	1993	0.17	0.07	0.07	0.26	0.43	5.06	680	117	48	45	6		
	1994	0.20	0.10	0.13	0.12	0.14	5.03	538	108	56	68	5		
	1995	0.11	0.06	0.11	0.14	0.11	5.13	659	73	42	74	5		
	1996	0.14	0.07	0.10	0.10	0.15	5.01	527	72	35	52	5		
	1997	0.10	0.06	0.11	0.16	0.28	5.13	603	59	37	69	4		
	1998	0.13	0.05	0.06	0.08	0.07	5.13	576	73	32	34	4		
	1999	0.13	0.05	0.07	0.06	0.07	5.13	811	103	44	53	6		
	2000	0.10	0.04	0.05	0.06	0.09	5.18	750	76	33	39	5		
	2001	0.11	0.04	0.05	0.09	0.15	5.24	721	75	30	38	4		
	2002	0.12	0.05	0.07	0.15	0.15	5.30	654	79	33	47	3		
	2003	0.07	0.04	0.08	0.14	0.16	5.25	907	65	40	72	5		
	2004	0.10	0.04	0.05	0.08	0.10	5.23	818	82	35	44	5		
	2005	0.16	0.06	0.14	0.08	0.06	5.26	745	118	43	105	4		
	2006	0.11	0.07	0.10	0.10	0.15	5.26	671	76	47	68	4		
Jergul	1977	0.45	0.13	0.11	0.20	0.04	4.75	344	155	45	38	6		
	1978	0.43	0.10	0.11	0.13	0.02	4.52	351	151	35	39	11		
	1979	0.59	0.18	0.13	0.14	0.03	4.33	306	181	55	40	14		
	1980	0.42	0.12	0.09	0.12	0.03	4.57	262	110	31	24	7		
	1981	0.46	0.13	0.12	0.11	0.02	4.57	434	200	56	52	12		
	1982	0.36	0.13	0.14	0.10	0.03	4.65	473	172	62	65	11		
	1983	0.41	0.11	0.11	0.13	0.04	4.60	382	156	41	43	10		
	1984	0.50	0.15	0.22	0.14	0.03	4.50	342	172	50	76	11		
	1985	0.43	0.12	0.34	0.13	0.05	4.63	406	174	49	137	10		
	1986	0.49	0.16	0.14	0.12	0.04	4.60	250	122	40	34	6		
	1987	0.41	0.12	0.10	0.11	0.03	4.67	296	121	35	29	6	180	

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
		SO_4-S mg/l	NO_3-N mg/l	NH_4-N mg/l	Ca mg/l	Mg mg/l	pH	mm	SO_4-S mg/m^2	NO_3-N mg/m^2	NH_4-N mg/m^2	H+ mekv/m^2	S mg/m^2	N mg/m^2
Jergul	1988	0.30	0.13	0.10	0.09	0.03	4.65	406	122	54	40	9	134	81
cont.	19T89	0.42	0.14	0.15	0.09	0.03	4.63	385	163	54	59	9	77	66
	1990	0.22	0.15	0.08	0.04	0.03	4.69	276	62	41	23	6	114	68
	1991	0.31	0.14	0.10	0.05	0.03	4.65	377	118	51	37	8	108	100
	1992	0.23	0.13	0.05	0.08	0.03	4.80	449	101	60	22	7	92	66
	1993	0.29	0.14	0.07	0.11	0.06	4.74	343	99	47	22	6	97	53
	1994	0.24	0.15	0.07	0.06	0.03	4.78	269	65	41	17	4	65	58
	1995	0.25	0.11	0.07	0.06	0.03	4.76	459	116	49	32	8	94	62
	1996	0.18	0.12	0.10	0.14	0.06	4.91	310	56	38	29	4	63	53
Karasjok**	1997	0.15	0.11	0.13	0.10	0.06	5.03	212	32	23	27	9	81	45
	1998	0.35	0.14	0.16	0.09	0.03	4.81	354	124	50	59	6	131	61
	1999	0.20	0.12	0.13	0.07	0.02	5.04	410	76	50	56	4	75	53
	2000	0.25	0.11	0.13	0.07	0.03	4.97	303	68	34	40	3	70	67
	2001	0.24	0.13	0.23	0.11	0.04	5.22	366	82	49	83	2	60	57
	2002	0.21	0.13	0.19	0.12	0.06	5.11	297	62	38	57	2	49	40
	2003	0.18	0.14	0.18	0.12	0.07	5.12	307	56	43	55	2	55	53
	2004	0.20	0.13	0.16	0.11	0.04	5.14	332	65	43	54	2	54	62
	2005	0.24	0.13	0.16	0.08	0.03	5.12	410	98	54	64	3	66	63
	2006	0.22	0.17	0.21	0.12	0.05	5.14	351	77	59	74	3	57	74
	2007	0.20	0.13	0.18	0.13	0.06	5.15	398	78	81	73	3	38	38
	2008	0.17	0.14	0.14	0.26	0.07	5.22	372	64	53	52	2	42	43
	2009	0.32	0.13	0.16	0.19	0.06	5.14	345	111	45	56	2	49	53
Andøya	2011	0.06	0.08	0.16	0.24	0.61	5.23	1345	75	102	212	8		
Svanvik	1987	0.68	0.12	0.21	0.13	0.10	4.49	365	247	42	76	12	711	173
	1988	0.57	0.13	0.13	0.18	0.14	4.49	390	221	52	50	13	602	160
	1989	0.72	0.12	0.10	0.19	0.12	4.47	424	306	50	42	14	571	130
	1990	0.48	0.13	0.08	0.11	0.13	4.50	266	127	36	22	8	691	123
	1991	0.56	0.14	0.16	0.08	0.09	4.55	389	218	55	61	11	652	139
	1992	0.51	0.12	0.22	0.10	0.10	4.71	432	220	53	93	8	422	165
	1993	0.62	0.16	0.23	0.16	0.14	4.66	331	207	52	78	7	530	135
	1994	0.58	0.17	0.35	0.12	0.12	4.71	379	219	66	132	7	541	111
	1995	0.59	0.11	0.19	0.13	0.13	4.62	395	233	45	74	9	642	133
	1996	0.44	0.16	0.22	0.22	0.17	4.73	352	154	57	76	7	471	125
	1997	0.48	0.14	0.29	0.20	0.14	4.79	278	134	39	82	4	637	145
	1998	0.50	0.13	0.27	0.13	0.15	4.74	346	168	44	89	6	947	157
	1999	0.36	0.13	0.18	0.08	0.07	4.86	463	164	59	84	6	444	175
	2000	0.52	0.15	0.24	0.11	0.10	4.69	436	222	64	106	9	388	159
	2001	0.65	0.13	0.30	0.15	0.14	4.90	374	239	50	114	5	461	
	2002	0.45	0.11	0.30	0.20	0.24	4.96	425	190	45	129	5	569	
	2003	0.33	0.13	0.27	0.17	0.16	4.97	371	121	47	99	4		
	2004-8													
	2009	0.82	0.14	0.16	0.13	0.09	4.40	323	257	44	51	13		
	2012	0.32	0.09	0.08	0.10	0.08	4.86	522	169	47	43	7		

Table A.1.22: Monthly and annual mean concentration of sulphur dioxide in air at Norwegian background stations. Unit: µg S/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.07	0.10	0.13	0.08	0.13	0.16	0.10	0.08	0.07	0.04	0.03	0.05	0.09
Hurdal	0.03	0.03	0.08	0.05	0.07	0.06	0.04	0.03	0.04	0.04	0.01	0.01	0.04
Kårvatn	0.03	0.02	0.04	0.03	0.03	0.02	0.03	0.02	0.01	0.02	0.01	0.01	0.02
Tustervatn	0.02	0.04	0.06	0.05	0.08	0.11	0.02	0.02	0.01	0.01	0.01	0.01	0.03
Zeppelin	0.13	0.10	0.18	0.15	0.01	0.03	0.03	0.01	-	0.03	0.04	0.24	0.09

Table A.1.23: Monthly and annual mean concentration of sulphate in aerosol at Norwegian background stations. Unit: µg S/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.26	0.32	0.25	0.19	0.31	0.36	0.29	0.28	0.20	0.19	0.09	0.25	0.25
Hurdal	0.17	0.24	0.18	0.18	0.12	0.26	0.21	0.19	0.21	0.11	0.06	0.12	0.17
Kårvatn	0.06	0.10	0.12	0.10	0.17	0.16	0.15	0.11	0.09	0.04	0.03	0.02	0.09
Tustervatn	0.04	0.12	0.11	0.12	0.13	0.09	0.11	0.09	0.09	0.04	0.03	0.04	0.08
Zeppelin	0.22	0.14	0.28	0.26	0.21	0.07	0.06	0.06	-	0.07	0.08	0.20	0.16

Table A.1.24: Monthly and annual mean concentration of nitrogen dioxide in air at Norwegian background stations. Unit: µg N/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.46	0.34	0.29	0.34	0.29	0.18	0.19	0.17	0.21	0.35	0.14	0.40	0.28
Hurdal	1.13	1.17	0.77	0.57	0.50	0.26	0.27	0.31	0.41	0.76	1.23	0.97	0.69
Kårvatn	0.19	0.25	0.23	0.10	0.09	0.14	0.13	0.16	0.12	0.19	0.12	0.16	0.16
Tustervatn	0.26	0.14	0.15	0.12	0.15	0.15	0.14	0.13	0.09	0.10	0.05	0.09	0.13

Table A.1.25: Monthly and annual mean concentration of sum of nitrate and nitric acid in air at Norwegian background stations. Unit: µg N/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.71	0.15	0.36	0.40	0.24	0.25	0.23	0.39	0.21	0.13	0.10	0.25	0.29
Hurdal	0.17	0.15	0.14	0.32	0.05	0.21	0.16	0.16	0.22	0.11	0.11	0.32	0.18
Kårvatn	0.23	0.05	0.08	0.13	0.16	0.15	0.09	0.21	0.06	0.03	0.12	0.21	0.13
Tustervatn	0.52	0.09	0.16	0.16	0.22	0.05	0.09	0.10	0.08	0.05	0.02	0.05	0.13
Zeppelin	0.14	0.10	0.41	0.38	0.12	0.12	0.15	0.11	-	0.06	0.16	0.16	0.18

Table A.1.26: Monthly and annual mean concentration of nitrate in aerosol at Norwegian background stations. Unit: µg N/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.56	0.06	0.27	0.34	0.16	0.19	0.15	0.23	0.15	0.10	0.08	0.21	0.21
Hurdal	0.11	0.09	0.11	0.25	0.02	0.14	0.09	0.10	0.13	0.07	0.09	0.23	0.12
Kårvatn	0.17	0.03	0.06	0.07	0.12	0.10	0.06	0.11	0.04	0.02	0.08	0.16	0.09
Tustervatn	0.44	0.05	0.10	0.12	0.16	0.04	0.05	0.06	0.05	0.03	0.01	0.04	0.09
Zeppelin	0.11	0.07	0.30	0.27	0.10	0.10	0.09	0.08	-	0.03	0.09	0.11	0.13

Table A.1.27: Monthly and annual mean concentration of sum of ammonium and ammonia in air at Norwegian background stations. Unit: µg N/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.71	0.34	0.57	0.69	0.67	0.45	0.61	0.61	0.35	0.21	0.13	0.24	0.47
Hurdal	0.23	0.35	0.31	0.59	0.60	0.40	0.45	0.28	0.43	0.23	0.19	0.35	0.37
Kårvatn	0.88	0.94	0.79	0.93	0.72	0.42	0.51	0.47	0.38	0.19	0.24	0.51	0.57
Tustervatn	1.07	0.77	0.79	0.74	1.09	1.22	0.77	0.65	0.50	0.41	0.23	0.29	0.69
Zeppelin	0.28	0.14	0.34	0.46	0.19	0.33	0.32	0.22	-	0.11	0.26	0.34	0.28

Table A.1.28: Monthly and annual mean concentrations of ammonium in aerosols at Norwegian background stations. Unit: µg N/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.56	0.17	0.33	0.38	0.33	0.21	0.29	0.23	0.12	0.05	0.01	0.08	0.23
Hurdal	0.13	0.18	0.12	0.27	0.32	0.20	0.15	0.10	0.16	0.04	0.04	0.14	0.15
Kårvatn	0.14	0.06	0.09	0.10	0.22	0.08	0.13	0.08	0.04	0.01	0.04	0.12	0.09
Tustervatn	0.35	0.06	0.06	0.14	0.29	0.10	0.06	0.05	0.05	0.01	0.02	0.01	0.09
Zeppelin	0.07	0.07	0.22	0.27	0.08	0.14	0.10	0.06	-	0.01	0.05	0.12	0.11

Table A.1.29: Monthly and annual mean concentrations of magnesium in aerosols at Norwegian background stations. Unit: µg/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.06	0.02	0.04	0.05	0.04	0.04	0.05	0.07	0.04	0.06	0.08	0.19	0.06
Hurdal	0.01	0.01	0.02	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.05	0.02
Kårvatn	0.01	0.01	0.02	0.02	0.01	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.02
Tustervatn	0.02	0.02	0.03	0.02	0.01	0.01	0.03	0.02	0.02	0.03	0.05	0.04	0.03
Zeppelin	0.04	0.02	0.04	0.03	0.03	0.02	0.01	0.02	-	0.03	0.08	0.06	0.04

Table A.1.30: Monthly and annual mean concentrations of calcium in aerosols at Norwegian background stations. Unit: µg/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.03	0.02	0.05	0.04	0.05	0.06	0.07	0.10	0.07	0.06	0.07	0.08	0.06
Hurdal	0.02	0.01	0.04	0.04	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.06	0.05
Kårvatn	0.01	0.01	0.03	0.03	0.05	0.05	0.08	0.07	0.06	0.05	0.07	0.03	0.04
Tustervatn	0.02	0.02	0.03	0.02	0.04	0.03	0.06	0.06	0.04	0.04	0.06	0.04	0.04
Zeppelin	0.02	0.02	0.03	0.04	0.03	0.02	0.06	0.05	-	0.04	0.05	0.04	0.04

Table A.1.31: Monthly and annual mean concentrations of potassium in aerosols at Norwegian background stations. Unit: µg/m3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.06	0.04	0.06	0.05	0.05	0.08	0.07	0.10	0.07	0.05	0.04	0.10	0.06
Hurdal	0.03	0.07	0.05	0.04	0.06	0.09	0.08	0.07	0.07	0.05	0.06	0.07	0.06
Kårvatn	0.01	0.01	0.04	0.04	0.04	0.06	0.07	0.07	0.04	0.03	0.03	0.02	0.04
Tustervatn	0.02	0.02	0.03	0.02	0.03	0.04	0.05	0.05	0.05	0.02	0.03	0.05	0.03
Zeppelin	0.02	0.05	0.04	0.05	0.04	0.02	0.03	0.04	-	0.01	0.05	0.03	0.04

Table A.1.32: Monthly and annual mean concentrations of chloride in aerosols at Norwegian background stations. Unit: µg/ m3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.73	0.17	0.44	0.58	0.33	0.23	0.17	0.37	0.21	0.51	0.97	2.13	0.57
Hurdal	0.11	0.06	0.17	0.13	0.24	0.05	0.10	0.06	0.05	0.10	0.15	0.42	0.14
Kårvatn	0.11	0.14	0.28	0.20	0.07	0.07	0.25	0.21	0.14	0.08	0.29	0.14	0.16
Tustervatn	0.29	0.17	0.47	0.27	0.01	0.08	0.19	0.11	0.16	0.31	0.42	0.36	0.25
Zeppelin	0.48	0.27	0.26	0.21	0.05	0.35	0.09	0.19	-	0.26	0.80	0.47	0.32

Table A.1.33: Monthly and annual mean concentrations of sodium in aerosols at Norwegian background stations. Unit: µg/ m3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes II	0.53	0.18	0.41	0.44	0.34	0.40	0.35	0.51	0.27	0.46	0.65	1.51	0.51
Hurdal	0.12	0.07	0.18	0.15	0.12	0.15	0.21	0.16	0.11	0.14	0.16	0.42	0.17
Kårvatn	0.09	0.11	0.20	0.17	0.09	0.14	0.26	0.22	0.11	0.07	0.21	0.13	0.15
Tustervatn	0.20	0.14	0.34	0.19	0.02	0.07	0.18	0.12	0.13	0.22	0.34	0.29	0.20
Zeppelin	0.31	0.21	0.24	0.20	0.22	0.22	0.07	0.16	-	0.20	0.53	0.38	0.25

Table A.1.34a: Annual mean concentrations of sulphur and nitrogen components in air at Norwegian background stations from 1973-2013. Units μg S/m³ and μg N/m³.

Site	År	Annual mean concentrations of main components in air (μg/m³)					
		SO_2-S	SO_4-S	NO_2-N	(HNO_3+NO_3)-N	(NH_4+NH_3)-N	NH_4-N
Birkenes	1973		0.81				
	1974		1.11				
	1975		1.07				
	1976		1.27				
	1977		0.92				
	1978	1.74	1.09				
	1979	1.11	1.33				
	1980	1.42	1.41				
	1981	0.76	0.97				
	1982	0.97	1.15				
	1983	0.53	0.95				
	1984	0.65	1.27	1.17			
	1985	0.70	0.88	0.87			
	1986	0.69	0.83	1.12	0.36	0.66	
	1987	0.72	0.78	1.12	0.29	0.66	
	1988	0.63	0.75	1.26	0.28	0.63	
	1989	0.48	0.67	1.11	0.26	0.63	
	1990	0.49	0.76	1.00	0.28	0.78	
	1991	0.54	0.91	0.90	0.27	0.76	
	1992	0.40	0.65	0.69	0.24	0.53	
	1993	0.40	0.59	0.59	0.23	0.55	0.43
	1994	0.40	0.65	0.66	0.28	0.63	0.46
	1995	0.31	0.58	0.68	0.30	0.54	0.44
	1996	0.40	0.66	0.68	0.29	0.57	0.47
	1997	0.22	0.53	0.69	0.24	0.54	0.37
	1998	0.16	0.46	0.62	0.19	0.41	0.31
	1999	0.14	0.49	0.52	0.20	0.51	0.33
	2000	0.12	0.44	0.57	0.20	0.43	0.31
	2001	0.16	0.44	0.47	0.21	0.55	0.31
	2002	0.15	0.50	0.46	0.27	0.62	0.43
	2003	0.15	0.50	0.57	0.26	0.60	0.38
	2004	0.13	0.35	0.46	0.26	0.53	0.30
	2005	0.19	0.46	0.46	0.33	0.75	0.40
	2006	0.18	0.53	0.48	0.40	0.77	0.32
	2007	0.06	0.28	0.32	0.17	0.43	0.17
	2008	0.07	0.28	0.34	0.19	0.49	0.14
	2009	0.06	0.30	0.44	0.26	1)	0.20
Birkenes II	2010	0.12	0.29	0.31	0.23	1)	0.20
	2011	0.11	0.33	0.43	0.37	0.63	0.32
	2012	0.07	0.27	0.39	0.46	0.61	0.28
	2013	0.09	0.25	0.28	0.29	0.47	0.23
Nordmoen	1986	0.50**	0.90**	2.00**	0.30**	0.60*	
	1987	0.60	0.80	3.30	0.40	0.70	
	1988	0.70	0.90	3.00	0.30	0.60	
	1989	0.40	0.80	2.60	0.30	0.70	
	1990	0.40	0.70	2.50	0.30	0.70	
	1991	0.30	0.80	2.60	0.20	0.60	
	1992	0.21	0.56	2.43	0.21	0.53	
	1993	0.25	0.59	2.09	0.21	0.54	0.42
	1994	0.23	0.58	2.56	0.28	0.62*	0.45
	1995	0.19	0.54	2.25	0.27	0.54	0.44
	1996	0.16	0.58	2.48	0.28	0.60	0.48
	1997			2.00			
	1998			1.64			
	1999			1.71			
Hurdal	1997	0.18	0.41	1.10		0.53	0.29
	1998	0.14	0.33	1.12	0.18	0.42	0.21
	1999	0.09	0.39	1.04	0.18	0.39	0.27
	2000	0.08	0.35	1.00	0.19	0.37	0.25
	2001	0.10	0.33		0.17	0.34	0.21
	2002	0.10	0.37		0.25	0.46	0.25
	2003	0.11	0.43		0.23	0.48	0.27
	2004	0.11	0.31	0.59	0.18	0.51	0.18
	2005	0.12	0.40	0.83	0.24	0.66	0.29
	2006	0.13	0.43	0.78	0.26	0.66	0.24
	2007	0.06	0.22	0.78	0.17	0.45	0.15
	2008	0.04	0.21	0.73	0.16	0.44	0.11
	2009	0.04	0.21	0.71	0.17	1)	0.12

Table A.1.34a, cont.

Site	År	Annual mean concentrations of main components in air (µg/m^3)					
		SO_2-S	SO_4-S	NO_2-N	(HNO_3+NO_3)-N	(NH_4+NH_3)-N	NH_4-N
Hurdal	2010	0.07	0.21	0.66	0.16	1)	0.18
cont.	2011	0.10	0.26	0.79	0.34	0.71	0.41
	2012	0.06	0.22	0.76	0.30	0.49	0.19
	2013	0.04	0.17	0.69	0.18	0.37	0.15
Kårvatn	1979	0.48	0.48				
	1980	0.54	0.55				
	1981	0.51	0.47				
	1982	0.29	0.40				
	1983	0.19	0.38				
	1984	0.43	0.54				
	1985	0.44	0.45				
	1986	0.39	0.43				
	1987	0.32	0.38				
	1988	0.34	0.40	0.56	0.07	0.44	
	1989	0.17	0.30	0.34	0.08	0.42	
	1990	0.12	0.32	0.40	0.10	0.40	
	1991	0.14	0.31	0.26	0.06	0.36	
	1992	0.12	0.30	0.19	0.06	0.37	
	1993	0.15	0.30	0.16	0.07	0.38	0.17
	1994	0.12	0.30	0.22	0.10	0.48	0.18
	1995	0.16	0.22	0.26	0.10	0.36	0.13
	1996	0.08	0.27	0.24	0.08	0.46	0.18
	1997	0.05	0.22	0.25	0.07	0.50	0.14
	1998	0.05	0.15	0.26	0.05	0.33	0.08
	1999	0.03	0.20	0.23	0.05	0.45	0.12
	2000	0.03	0.17	0.32	0.05	0.56	0.09
	2001	0.06	0.16	0.19	0.08	0.47	0.11
	2002	0.07	0.21	0.26	0.11	0.81	0.13
	2003	0.07	0.22	0.30	0.09	0.95	0.13
	2004	0.07	0.20	0.21	0.08	0.48	0.10
	2005	0.07	0.18	0.22	0.14	0.65	0.15
	2006	0.06	0.24	0.24	0.14	0.88	0.13
	2007	0.03	0.13	0.17	0.06	0.76	0.06
	2008	0.03	0.14	0.20	0.07	0.70	0.06
	2009	0.03	0.14	0.17	0.06	1)	0.06
	2010	0.03	0.14	0.25	0.08	1)	0.10
	2011	0.07	0.13	0.26	0.17	0.88	0.15
	2012	0.04	0.14	0.22	0.26	0.71	0.16
	2013	0.02	0.09	0.16	0.13	0.57	0.09
Tustervatn	1979	0.88	0.68				
	1980	0.63	0.70				
	1981	0.67	0.52				
	1982	0.47	0.52				
	1983	0.26	0.48				
	1984	0.71	0.73				
	1985	0.60	0.59				
	1986	0.48	0.43				
	1987	0.72	0.59				
	1988	0.67	0.54				
	1989	0.16	0.23	0.29	0.04	0.52	
	1990	0.29	0.36	0.37	0.08	0.53	
	1991	0.25	0.38	0.32	0.08	0.68	
	1992	0.15	0.28	0.26	0.07	0.54	
	1993	0.18	0.31	0.19	0.07	0.66	0.16
	1994	0.16	0.29	0.19	0.09	0.71	0.14
	1995	0.16	0.28	0.16	0.09	0.62	0.15
	1996	0.12	0.29	0.11	0.10	0.72	0.17
	1997	0.09	0.27	0.18	0.07	1.15	0.15
	1998	0.10	0.21	0.18	0.06	1.03	0.11
	1999	0.08	0.23	0.14	0.05	0.53	0.12
	2000	0.04	0.18	0.17	0.06	0.88	0.10
	2001	0.14	0.20	0.15	0.08	0.94	0.12
	2002	0.09	0.21	0.18	0.10	0.83	0.11
	2003	0.09	0.22	0.18	0.12	1.15	0.15
	2004	0.09	0.21	0.17	0.09	0.93	0.12
	2005	0.08	0.21	0.14	0.10	1.00	0.12
	2006	0.09	0.23	0.15	0.13	1.10	0.11
	2007	0.06	0.14	0.11	0.09	0.94	0.08
	2008	0.03	0.15	0.14	0.09	0.98	0.07

Table A.1.34a, cont.

Site	År	Annual mean concentrations of main components in air (µg/m^3)					
		SO_2-S	SO_4-S	NO_2-N	(HNO_3+NO_3)-N	(NH_4+NH_3)-N	NH_4-N
Tustervatn							
cont.	2009	0.05	0.15	0.11	0.07	1)	0.06
	2010	0.08	0.15	0.12	0.10	1)	0.11
	2011	0.08	0.13	0.14	0.27	0.94	0.23
	2012	0.05	0.12	0.17	0.25	1.07	0.15
	2013	0.03	0.08	0.13	0.13	0.69	0.09
Ny-Ålesund	1980	0.32	0.31				
	1981	0.36	0.23				
	1982	0.31	0.28				
	1983	0.42	0.41				
	1984	0.24	0.34				
	1985	0.36	0.39				
	1986	0.27	0.34				
	1987	0.53	0.40				
	1988	0.32	0.32				
	1989	0.21	0.24				
	1990	0.22	0.27		0.03		
Zeppelin	1990	0.21	0.22		0.04	0.09	
	1991	0.24	0.19	0.02	0.05	0.09	
	1992	0.19	0.19	0.02	0.04	0.08	
	1993	0.17	0.20	0.03	0.06	0.09	0.05
	1994	0.16	0.15	0.05	0.06	0.09	0.04
	1995	0.15	0.17		0.08	0.10	0.05
	1996	0.10	0.15		0.08	0.11	0.05
	1997	0.13	0.21		0.07	0.13	0.06
	1998	0.21	0.17		0.04	0.13	0.05
	1999	0.13	0.19		0.03	0.19	0.08
	2000	0.12	0.14		0.03	0.11	0.03
	2001	0.14	0.18		0.06	0.17	0.04
	2002	0.16	0.14		0.06	0.24	0.02
	2003	0.23	0.17		0.04	0.27	0.04
	2004	0.12	0.16		0.08	0.24	0.04
	2005	0.13	0.18		0.15	0.42	0.10
	2006	0.10	0.13		0.12	0.43	0.03
	2007	0.09	0.11		0.05	0.26	0.04
	2008	0.07	0.14		0.10	0.33	0.06
	2009	0.09	0.15		0.05	1)	0.04
	2010	0.07	0.13		0.06	1)	0.05
	2011	0.10	0.12		0.11	0.39	0.07
	2012	0.06	0.12		0.22	0.36	0.11
	2013	0.09	0.16		0.18	0.28	0.11

1) Due to contamination of ammonia, only ammonium is reported in 2009 and 2010.

* One month missing.

** Two months missing.

Table A.1.34b: Annual mean concentrations of sulphur and nitrogen components in air at Norwegian background stations which has been closed down. Units μg S/m3 and μg N/m3.

Site	År	Annual mean concentrations of main components in air at closed sites, (μg/m^3)				
		SO_2-S	SO_4-S	NO_2-N	(HNO_3+NO_3)-N	(NH_4+NH_3)-N
Søgne	1989	1.00	1.00	3.10	0.50	1.50
	1990	0.90	1.00	2.70	0.50	1.80
	1991	1.10*	1.20*	2.80*	0.50*	1.70*
	1992	0.62**	0.87**	1.54**	0.42**	0.94**
	1993	0.68	0.81	1.80	0.40	0.88
	1994	0.77	0.77	1.62	0.44	0.89
	1995	0.51	0.72	1.19	0.43	0.98
	1996	0.83	0.85	1.33	0.46	0.95
	1997	0.47	0.63	1.11	0.38	0.94
	1998	0.40	0.55	1.04	0.32	0.87
	1999	0.30	0.57	0.96**	0.33	0.68
	2000	0.27	0.48	1.12	0.33	0.62
	2001	0.28	0.58		0.31	0.72
	2002	0.29	0.59		0.33	0.67
	2003	0.31	0.64		0.41	0.89
	2004	0.29	0.44		0.31	0.69
	2005	0.30	0.55		0.62	1.06
	2006	0.41	0.75		0.48	0.94
	2007	0.21	0.37		0.23	0.61
	2008	0.15	0.32		0.26	0.42
	2009	0.24	0.36		0.31	0.52
Skreådalen	1975		1.00			
	1976		1.09			
	1977		0.80			
	1978	1.62	0.96			
	1979	0.95	0.95			
	1980	1.32	1.18			
	1981	0.72	0.86			
	1982	0.82	0.90			
	1983	0.50	0.82			
	1984	0.80	1.04	0.73		
	1985	0.59	0.79	0.52		
	1986	0.82	0.83	0.70		
	1987	0.66	0.74	0.76		
	1988	0.71	0.67	0.80		
	1989	0.44	0.64	0.63	0.25	1.66
	1990	0.46	0.70	0.62	0.23	2.07
	1991	0.49	0.67	0.61	0.21	1.37
	1992	0.32	0.56	0.41	0.19	1.26
	1993	0.39	0.53	0.45	0.21	1.38
	1994	0.32	0.57	0.63	0.24	1.44
	1995	0.22	0.43	0.46	0.22	1.45
	1996	0.30	0.54	0.42	0.25	1.66
	1997	0.14	0.42	0.53	0.18	1.41
	1998	0.13	0.34	0.51	0.15	1.34
	1999	0.09	0.37	0.40	0.15	1.17
	2000	0.09	0.35	0.38	0.15	1.13
	2001	0.11	0.34	0.29	0.23	1.38
	2002	0.11	0.39	0.39	0.26	1.21
	2003[1)]	*0.07*	*0.33*	*0.34*	*0.15*	*0.94*
	2004	0.09	0.30	0.43	0.24	1.01
Prestebakke	1986	1.10	1.20	1.50	0.40	0.80
	1987	1.30	1.10	1.80	0.40	0.90
	1988	1.00	1.10	1.7**	0.3**	0.7**
	1989	0.70	0.90	1.50	0.30	0.80
	1990	0.50	0.80	1.30	0.30	0.70
	1991	0.50	0.80	1.40	0.30	0.70
	1992	0.48	0.70	1.02	0.28	0.65
	1993	0.50	0.75	1.20	0.28	0.68
	1994	0.48	0.73	1.03	0.29	0.68
	1995	0.39	0.66		0.31	0.67
	1996	0.35	0.76		0.32	0.81
	1997	0.26	0.54		0.24	0.58
	1998	0.19	0.52		0.24	0.56
	1999	0.17	0.55		0.27	0.39
	2000	0.16	0.46		0.27	0.57

Table A.1.34b, cont.

Site	År	Annual mean concentrations of main components in air at closed sites, (µg/m^3) SO_2-S	SO_4-S	NO_2-N	(HNO_3+NO_3)-N	(NH_4+NH_3)-N
Osen	1988	0.67	0.72			
	1989	0.38	0.52	0.88	0.15	0.39
	1990	0.22	0.46	0.64	0.12	0.36
	1991	0.25	0.49	0.59	0.12	0.36
	1992	0.17	0.37	0.50	0.11	0.30
	1993	0.22	0.38	0.53	0.11	0.28
	1994	0.19	0.42	0.44	0.14	0.34
	1995	0.19	0.38	0.41	0.15	0.31
	1996	0.13	0.40	0.40	0.14	0.37
	1997	0.09	0.30	0.48	0.10	0.35
	1998	0.08	0.26	0.45	0.10	0.37
	1999	0.06	0.20	0.38	0.08	0.31
	2000	0.04	0.24	0.38	0.08	0.29
	2001	0.08	0.24	0.33	0.12	0.38
	2002	0.07	0.28	0.38	0.11	0.51
	2003	0.08	0.29	0.45	0.13	0.46
Svanvik	1987	6.40	0.90	1.00	0.10	0.60
	1988	5.80	0.90	0.9**	0.1**	0.5**
	1989	5.40	0.60	0.70	0.10	0.40
	1990	7.20	0.70	0.80	0.10	0.40
	1991	5.90	0.70	0.80	0.10	0.50
	1992	3.25	0.57	0.76	0.07	0.67
	1993	4.32	0.53	0.57	0.07	0.51
	1994	4.15	0.37	0.56	0.07	0.42
	1995	5.07	0.48	0.58	0.10	0.49
	1996	3.30	0.47	0.54	0.07	0.55
	1997	4.85	0.49	0.59	0.07	0.63
	1998	6.83	0.54	0.70	0.07	0.78
	1999	3.92	0.53	0.53	0.06	0.91
	2000	3.15	0.45	0.51	0.05	0.84
	2001	4.07	0.52		0.08	0.90
	2002	4.31	0.43		0.10	0.75
Jergul	1977		0.58			
	1978	0.89	0.54			
	1979	1.52	0.74			
	1980	1.55	0.75			
	1981	1.28	0.56			
	1982	0.79	0.54			
	1983	0.81	0.65			
	1984	1.18	0.79	0.43		
	1985	1.42	0.80	0.29		
	1986	1.01	0.69	0.46		
	1987	1.67	0.77	0.51		
	1988	1.23	0.66	0.45	0.09	0.22
	1989	0.40	0.39	0.28	0.08	0.20
	1990	0.81	0.45	0.35	0.07	0.19
	1991	0.80	0.47	0.31	0.08	0.18
	1992	0.53	0.40	0.28	0.07	0.17
	1993	0.58	0.44	0.21	0.08	0.17
	1994	0.44	0.31	0.16	0.09	0.16
	1995	0.59	0.34	0.16	0.11	0.15
	1996	0.32	0.30	0.18	0.08	0.15
Karasjok	1997	0.48	0.32	0.20	0.07	0.16
	1998	0.91	0.34	0.25	0.06	0.19
	1999	0.51	0.36	0.25	0.05	0.18
	2000	0.35	0.27	0.25	0.08	0.16
	2001	0.40	0.29	0.20	0.06	0.14
	2002	0.30	0.24	0.18	0.08	0.11
	2003[1)]	0.20	0.26	0.21	0.08	0.14
	2004	0.32	0.25	0.19	0.11	0.15
	2005	0.31	0.30	0.17	0.11	0.16
	2006	0.29	0.28	0.14	0.16	0.12
	2007	0.19	0.19	0.14	0.08	0.11
	2008	0.35	0.22	0.19	0.07	0.10
	2009	0.18	0.25	0.15	0.09	0.12
Andøya	2010	0.11	0.20		0.05	
	2011	0.05	0.17		0.06	0.11

1) Measured from 25 May 2003.
* One month missing.
** Two months missing.

Annex 2

Detailed information of the monitoring programme

Table A.2.1: Site locations and station keepers for the background sites in 2013.

Stasjon	Fylke	m.o.h.	Bredde N	Lengde E	Start dato	Stasjonsholder	Adresse
Birkenes	Aust-Agder	190	58° 23'	8° 15'	nov-71	Olav Lien	4760 Birkeland
Birkenes II		219					
Vatnedalen	Aust-Agder	800	59° 30'	7° 26'	nov-73	Lilly Vatnedalen	4694 Bykle
Treungen	Telemark	270	59° 01'	8° 32'	sep-74	Per Ø. Stokstad	4860 Treungen
Haukenes	Telemark	20	59° 12'	9° 31'	apr-79		
Prestebakke	Østfold	160	59° 00'	11° 32'	nov-85	NILU	2027 Kjeller
Løken	Akershus	135	59° 48'	11° 27'	mar-72	Anne Mørch	1960 Løken
Hurdal	Akerhus	300	60º 22’	11º 04’	jan-97	Thomas Sørlien	2090 Hurdal
Brekkebygda	Buskerud	390	60° 18'	9° 44'	des-97	Anton Brekka	3534 Sokna
Vikedal II	Rogaland	60	59° 32'	5° 58'	jan-84	Harald Leifsen	4210 Vikedal
Sandve	Rogaland	40	59° 12'	5° 12'	jun-96	Jan M. Jensen	4272 Sandve
Haukeland	Hordaland	204	60° 49'	5° 35'	aug-81	Henning Haukeland	5198 Matredal
Nausta	Sogn og Fjordane	230	61° 34'	5° 53'	des.84	Sverre Ullaland	6043 Naustdal
Kårvatn	Møre og Romsdal	210	62° 47'	8° 53'	feb-78	Erik Kårvatn	6645 Todalen
Høylandet	Nord-Trøndelag	60	64° 39'	12° 19’	feb-87	Jakob Olav Almås	7977 Høylandet
Tustervatn	Nordland	439	65° 50'	13° 55'	des-71	Are Tustervatn	8647 Bleikvassli
Andøya	Nordland	380	69º16’	16º0’	sep-09	Andøya Rakettskytefelt	8483 Andenes
Karpbukt	Finnmark	20	69º 40’	30º 22’	okt-98	Roy Hallonen	9900 Kirkenes
Ny-Ålesund	Svalbard	8	78° 55'	11° 55'	1974	NP forskningsst.	9173 Ny-Ålesund
Zeppelin	Svalbard	474	78° 54'	11° 53'	sep-89	NP forskningsst.	9173 Ny-Ålesund

Table A.2.2: Measurement programme at Norwegian background stations in 2013, including the environmental contaminants reported in Nizzetto et al. (2014).

	Air							precipitation			
	hourly		daily		weekly		2d per week	Daily	Weekly		monthly
Stasjon	Metr.	Ozone	main	NO_2	$PM_{2.5}$, PM_{10} + EC/OC	HM.	POPs	main	main	HM	POPs
Birkenes	X	X	X	X	X	X[b]	X[d]	X		X[b]	X[e]
Vatnedalen									X		
Treungen									X		
Haukenes		X									
Prestebakke		X									
Løken									X		
Hurdal	X	X	X	X	X			X		X[a]	
Brekkebygda									X		
Vikedal									X		
Sandve		X									
Haukeland									X		
Nausta									X		
Kårvatn		X	X	X	X			X		X[a]	
Høylandet									X		
Tustervatn		X	X	X				X			
Andøya	X					X[b]	X[g]				
Karpbukt									X		
Svanvik										X[b]	
Zeppelin, Ny-Ålesund	X	X	X			X[c]	X[g]		X		
Total number	4	7+1	5	4	3	3	3	4	9	4	1

Metr. = meteorology

main.precip = amount (mm), pH, conductivity, SO_4, NO_3, Cl, NH_4, Ca, K, Mg, Na

main air = SO_2, SO_4, HNO_3 + NO_3 ; NH_4+ NH_3, Ca, K, Mg, Na, Cl

HM [a] = Pb, Cd and Zn

[b] = Pb, Cd, V, Cr, Co, Ni, Cu, Zn, As and Hg

[c] = Pb, Cd, V, Cr, Mn, Co, Ni, Cu, Zn, As

POPs [d] = α- og γ-HCH, HCB, DDTs, Chlordanes, PCBs, PBDE, HBCD, PAHs, PFAS

[e] = α- og γ-HCH, HCB, PCB

[f] = α- og γ-HCH, HCB, HCHs, DDTs, PCBs, PBDEs, PFAS

[g] = α- og γ-HCH, HCB, DDTs, Chlordanes, PCBs, BDE, HBCDs, PAHs, PFAS, Siloxanes, SCCP, MCCP

Annex 3

Sampling and chemical analysis

Main components in precipitation

For precipitation sampling, a NILU Precipitation Collector (funnel + bucket type) is used (P.no. 9713,RS1). The bucket has a size of 2.5 litre, and the diameter of the collecting surface is 200 mm. The collector is placed 2 meters above ground. In winter, during snow conditions, the bulk + funnel collector is exchanged with a so-called Particulate Fallout Collector (P.no. 9711, SF1), see figure on the right of the two bulk collector types. The material used for the collectors is high density polyethylene.

The precipitation sampler is emptied and cleaned with distilled water between each sampling period (daily or weekly), also in periods when there has been no precipitation. The precipitation amount is measured by volume at the site, and an aliquot of the sample is sent to NILU for chemical analysis.

pH is measured with potentiometric method and conductivity with a conductivity meter. Anions and cations are measured with an ion chromatograph. The detection limit for the different ions are given in the table below:

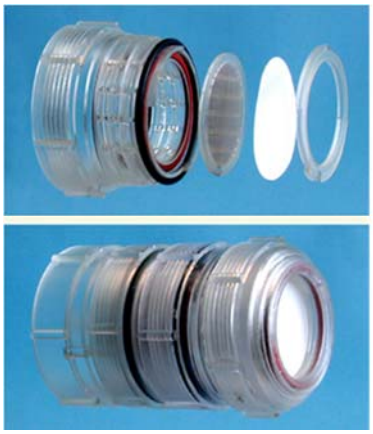
Parameter	Detection limit (unit)
SO_4^{2-}	0.01 (mg S/l)
NO_3^-	0.01 (mg N/l)
NH_4^+	0.01 (mg N/l)
Na^+	0.01 (mg Na/l)
Cl^-	0.01 (mg Cl/l)
K^+	0.01 (mg K/l)
Ca^{2+}	0.01 (mg Ca/l)
Mg^{2+}	0.01 (mg Mg/l)

Main components in air

The main ions in air is sampled with a three stage filterpack using the NILU filter holder system designed for sampling of particles and gaseous compounds, see figure below. The first filter in the air stream is an aerosol filter (Zeflour 2 µm) for collecting the airborne particles containing SO_4^{2-}, NH_4^+, NO_3^-, Ca^{2+}, K^+, Cl^-, Na^+. This is followed by an alkaline (KOH) impregnated filter (Whatman 40), which will collect HNO_3, SO_2, HNO_2, HCl, and other volatile acidic substances. Nitric acid and sulphur dioxide will react with potassium hydroxide on this impregnated filter to give potassium nitrate and potassium sulphite. Oxidizing species in air e.g. ozone are believed to convert most of the sulphite to sulphate during the sampling. The third filter (Whatman 40) is acid-impregnated (oxalic acid) for absorbing alkaline air component such as NH_3. The filter pack method is biased in separating gaseous nitrogen compounds from aerosols and therefore the sum is reported. In other words, the concentration of nitrates in air equals the sum of the nitrate found on the aerosol filter and

nitrate found on the alkaline impregnated filter. The same for ammonium, where the sum of ammonium concentration equals the sum of ammonium collected on the aerosol front filter and ammonia collected on the acid impregnated filter.

The filterpack samplers does not have a pre-impactor, but the air intake has a cylindrical vertical plastic section covering the filter holder – about 15 cm wide and 25 cm high. This air intake reduces the sampling efficiency for large particles such as soil dust particles, large sea spray droplets, large pollen, and fog droplet, thus the size cut off is approximately PM_{10} except for strong sea salt episodes when larger particles are collected.



After exposure, the filter holders are sent to NILU for chemical analysis. The filters are put into a test tubes with additions of extraction solution. Hydrogen peroxide solution is used for the alkaline filter in order to oxidize any remaining sulphite to sulphate. An HNO_3 is added to the acid impregnated filter. The aerosol Teflon© filters are given an ultrasonic treatment before analysis in order to obtain a complete extraction. The ions are analysed using an ion chromatograph, and the detection limits are given below:

Parameter	Detection limit (unit)	
SO_2	0.01	(µg S/m^3)
SO_4^{2-}	0.01	(µg S/m^3)
Sum (NO_3^-+HNO_3)	0.01	(µg N/m^3)
Sum (NH_4^++NH_3)	0.05-0.1	(µg N/m^3)
Na^+	0.02	(µg Na/m^3)
Cl^-	0.02	(µg Cl/m^3)
K^+	0.02	(µg K/m^3)
Ca^{2+}	0.02	(µg Ca/m^3)
Mg^{2+}	0.02	(µg Mg/m^3)

Nitrogen dioxide

NO_2 is determined with the manual NaI glass sinter method. Ambient air with a flow rate of about 0.5 l/min is drawn through an air intake (inverted funnel) and a glass filter impregnated with sodium iodide (NaI) and sodium hydroxide (NaOH). Nitrogen dioxide is absorbed in the filter, and the iodide reduces NO_2 to nitrite. The nitrite formed on the glass filter is extracted with deionized water. After extraction the nitrite concentration can be determined spectrophotometrically at 540 nm after a reaction with sulphanilamide and N-(1-naphthyl)-ethylenediamine (NEDA). The detection limit for this method is 0.03 µg N/m^3.

Ozone

Ozone (O_3) is determined with the UV-absorption method (UV light at 254 nm) using a monitor with continuous measurements. The results are given in hourly resolution.

Particles (Mass and EC/OC)

Daily measurements of PM_{10} at the Birkenes Observatory started in 1999 using a High-volume sampler. From 2000 – 2005, PM_{10} was obtained by a Ruprecht and Patashnick Dichotomus Partisol-plus, model 2025, which separated PM_{10} into its coarse ($PM_{10-2.5}$) and fine ($PM_{2.5}$) fraction. From 2006 (the Birkenes Observatory) and from 2010 (the Hurdal and Kårvatn sites), PM_{10} and $PM_{2.5}$ (PM_1 measurements at the Birkenes Observatory from 2006 - 2008) are obtained using Kleinfiltergerät samplers (one sampler pr. size faction), collecting filter samples on a weekly basis. The ambient aerosol particles are collected on prefired (850 °C for 3 hrs) quartz fibre filters (Whatman QM-A, 47 mm). The quartz fibre filters are conditioned (20 °C; 50% RH; 48 hrs) prior to and after being exposed. The mass concentration of the quartz fibre filters are determined gravimetrically. The uncertainty of the PM mass concentrations obtained for PM_{10} and $PM_{2.5}$ is estimated to be around 0.1 – 0.15 µg/m^3 for a sampling volume of 386 m^3.

At Birkenes, high–time resolution measurements of PM_{10}, $PM_{2.5}$ and PM_1 by an OPC (optical particle counter) (GRIMM 190) instrument were started in 2010. The detection limit of the OPC is approximately 0.1 µg/m^3.

Thermal-Optical Analysis of EC, OC and TC in PM_{10} and $PM_{2.5}$ are performed on the same filter samples as the mass concentration of PM_{10} and $PM_{2.5}$ are obtained from. The T-O analysis are performed according to the EUSAAR_2 protocol (Cavalli *et al*., 2010). The analytical detection limit of the TOA instruments is 0.2 µg C/cm^2.

Norwegian Environment Agency
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The Norwegian Environment Agency's primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

We are under the Ministry of Climate and Environment and have over 700 employees at our two offices in Trondheim and Oslo and at the Norwegian Nature Inspectorate's more than sixty local offices.

Our principal functions include monitoring the state of the environment, conveying environment-related information, exercising authority, overseeing and guiding regional and municipal authorities, cooperating with relevant industry authorities, acting as an expert advisor, and assisting in international environmental efforts.