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Monitoring of long-range transported air pollutants in Norway

Annual Report 2016

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Monitoring of long-range transported air pollutants in Norway, Annual Report 2016
Overvåking av langtransportert forurenset luft og nedbør. Atmosfæriske tilførsler 2016

Summary - sammendrag

This report presents results from the monitoring of atmospheric composition and deposition of air pollution in 2016, and focuses on main components in air and precipitation, particulate and gaseous phase of inorganic constituents, particulate carbonaceous matter, ground level ozone and particulate matter. The concentration levels were generally low in 2016 compared to previous years.

Denne rapporten omhandler resultater fra overvåkningsprogrammet for langtransportert forurenset luft og nedbør og atmosfæriske tilførsler i 2016 på norske bakgrunnsstasjoner. Rapporten presenterer målinger av uorganiske hovedkomponentene i luft og nedbør, partikulært karbonholdig materiale, partikkelmasse og bakkenært ozon. Konsentrasjonsnivået var generelt lavt i 2016 sammenlignet med tidligere år.

4 emneord	4 subject words
Atmosfære og klima	Atmosphere and climate
Aerosoler og partikler	Aerosols and particles
Bakkenært ozon	Ground-level ozone
Sur nedbør og overgjødsling	Acid rain and eutrophication

Front page photo

Birkenes Observatory

Content

Sammendrag

Overvåkingsprogrammet for langtransporterte luftforurensninger som presenteres i denne rapporten omhandler målinger av svovel- og nitrogenforbindelser i luft og nedbør, elementært og organisk karbon (EC/OC) i partikler, bakkenært ozon, partikkelmasse (PM_{10} og $PM_{2.5}$) og størrelsesfordeling av partikkelantall på 17 norske bakgrunnsstasjoner.

Hovedmålet er å kvantifisere nivåene og dokumentere eventuelle endringer i atmosfærisk tilførsel, noe som er viktig for å kunne evaluere luftforurensningenes effekt på økosystem, helse, materialer og klima. Programmet startet i 1973 med målinger av svovel- og nitrogenforbindelser og ble senere utvidet med bakkenært ozon (1985), partikler og EC/OC (2000/1) og størrelsesfordeling av partikkelantall (2010).

Kjemisk sammensetning og geografisk fordeling
De høyeste konsentrasjonene av svovel, nitrogen og PM måles vanligvis ved Birkenes i Aust-Agder. Dette skyldes nærhet til utslippsområdene på kontinentet. Noen stasjoner i innlandet påvirkes av regional landbruksaktivitet og kan ha noe høyere ammoniumnivå. De høyeste nivåene av EC, OC og NO_2 observeres på Hurdal i Akershus, sannsynligvis på grunn av relativt tett befolket område i denne regionen inkludert mye veitrafikk. Karpbukt i Finnmark opplever hvert høye nivåer av sulfat på grunn av påvirkning fra nærliggende smelteverk på Kola-halvøya i Russland. Den høyeste våtavsetningen av svovel og nitrogen skjer langs kysten fra Aust-Agder til Hordaland.

Sekundære uorganiske forbindelser (SIA: sulfat, nitrat og ammonium) utgjorde en større andel av PM_{10} (44%) på Birkenes enn på de to andre norske stasjonene, noe som reflekterer områdets nærhet til store antropogene utslippsområder på det europeiske kontinentet, mens organisk karbon hadde en relativt større andel på Kårvatn (48%) og Hurdal (40%). Sjøsaltpartikler utgjorde en betydelig andel (23%) av PM_{10} på Birkenes. Denne andelen var av samme størrelse som andelen organisk karbon (29%).

Episoder
Det var bare noen få episoder med høye døgnverdier av svovel- og nitrogenforbindelser i 2016, og nivåene var generelt lavere sammenlignet med tidligere år. Kildeområdene for episodene i Sør-Norge er hovedsakelig fra kontinentet, mens de høyeste episodene på Tustervatn i Nordland og Zeppelin på Spitsbergen ofte skyldes forurenset luft fra Russland.

Det ble observert enkelte korte episoder med moderate ozonnivåer i 2016. I første del av mai ble det målt forhøyede ozonnivåer på nesten alle stasjonene, i siste del av juli på de sørlige stasjonene, og i slutten av august en episode på Prestebakke. Utover dette var ikke værsituasjonen spesielt gunstig for fotokjemiske ozonepisoder sommeren 2016 i Norge.

Overskridelser
Årsmiddelkonsentrasjoner av PM_{10} og $PM_{2.5}$ lå langt under nasjonale og internasjonale grenseverdier (EU og WHO) og retningslinjer for luftkvalitet på alle målestasjonene.

Når det gjelder bakkenært ozon, har ikke EUs grenseverdi for helse (180 $\mu g/m^3$) blitt overskredet i Norge de siste årene. EUs langtidsmål (maks 8-timers verdi < 120 $\mu g/m^3$) ble derimot overskredet på de fleste stasjonene. Dette langtidsmålet ble overskredet 12 dager i 2016 (på en eller flere stasjoner).

Luftkvalitetskriteriene for ozon satt av WHO (maks 8h verdi < 100 µg/m^3) og av Folkehelseinstituttet (maks 8h verdi < 80 µg/m^3) ble overskredet på alle målestasjoner i 2016. Hverken grenseverdien for planter (3 måneders AOT40 < 3000 ppb timer) eller grenseverdien for skog (6 måneders AOT40 < 5000 ppb timer) ble derimot overskredet på norske stasjoner i 2016.

Trender

Konsentrasjonene av nitrogen- og svovelkomponenter i luft og nedbør i 2016 var noe høyere eller på samme nivå som nivåene i 2015 (som var rekordlave), mens våtavsetningen av sulfat var den laveste som har blitt observert i Sør-Norge siden målingene startet i 1974. Årsmiddelkonsentrasjonene av PM_{10} og $PM_{2.5}$ i 2016 var de laveste som har vært observert på Birkenes og Hurdal. Også EC- og OC konsentrasjonene var lave i 2016. De fleste ozonparameterne var noe høyere i 2016 sammenlignet med 2015, som var et år med spesielt lave ozonnivåer.

En oversikt over de langsiktige trendene er vist i tabell 1. Trendene gjenspeiler i stor grad utslippsreduksjonene som har skjedd på det europeiske kontinentet de siste tiårene, men årlige variasjoner i meteorologi kan imidlertid skjule noe av effekten av utslippsreduksjonene, og det gjelder spesielt for ozon.

Summary

The atmospheric monitoring programme presented in this report includes observations of sulfur and nitrogen compounds in air and precipitation, elemental- and organic carbon (EC/OC) in aerosols, ground level ozone, particulate matter (PM_{10} and $PM_{2.5}$) and aerosol size distribution, at a total of 17 sites in the Norwegian rural background environment. The main objective is to quantify the levels of these pollutants and to document any changes in atmospheric pollution, which is important for studies on its influence on ecosystems, human health, materials and climate change. The program started in 1973 with measurements of sulfur and nitrogen compounds and was later extended with ozone (1985), particulate and carbonaceous aerosols (2000/1), and aerosol size distribution (2010).

Chemical composition and geographical distribution
The highest concentrations of sulfur, nitrogen and PM are often measured at Birkenes in Aust-Agder. However, some inland sites are influenced by regional agricultural activities and experience somewhat higher ammonium levels. The highest EC, OC and NO_2 levels are seen in Hurdal in Akershus, likely due to influence from the more densely populated region surrounding this site, including road traffic. Karpbukt in Finnmark experiences high levels of sulfate due to influence from the nearby smelters at the Kola Peninsula in Russia. The highest wet deposition of inorganic ions occurred along the coast from Aust-Agder to Hordaland.

Secondary inorganic aerosols (SIA: sulfate, nitrate and ammonium) is the most abundant fraction of PM_{10} (44%) at Birkenes, reflecting the site's proximity to major anthropogenic emission regions in continental Europe, whereas organic carbon was relatively more abundant at Kårvatn (48%) and Hurdal (40%). Sea salt constitutes a substantial part of PM_{10} at Birkenes (23%), approaching that of organic carbon (29%).

Episodes
There were only a few episodes with elevated concentrations of sulfur and nitrogen compounds caused by long-range transport in 2016, and the levels were generally lower compared to previous years. Continental Europe was the source region for episodes influencing southern Norway, whereas the highest episodes at Tustervatn in Nordland, and Zeppelin at Spitsbergen in particular, can be attributed to polluted air from Russia.

A few shorter-term episodes with moderately elevated ozone levels were observed in 2016. One in the first part of May affecting nearly all stations, one in the last part of July at the southern sites, and one in the last part of August (Prestebakke). Except for these, the weather conditions in the summer of 2016 were not particularly favourable for photochemical ozone episodes in Norway.

Exceedances
For PM_{10} and $PM_{2.5}$, the observations at the three background PM sites were all well beyond the EU limit values, the national limit values, the WHO and the National AQG on an annual basis.

EU's target value of ozone for the protection of human health was met in Norway with a very clear margin. The EU long-term objective (i.e. max 8h value < 120 $\mu g/m^3$) was violated at

12 days in 2016 (at one or more sites). The WHO guideline (max 8h value < 100 µg/m^3) was violated at all the sites. The updated national guidelines are stricter than the WHO guidelines, and these were exceeded for long periods of the year in the entire country (except on Zeppelin). Neither the limit value for agricultural crops (3-months AOT40 < 3000 ppb hours) nor the limit value for forests (6-months AOT40 < 5000 ppb hours) were exceeded at Norwegian sites in 2016.

Trends

The concentrations of nitrogen and sulfur components in air and precipitation in 2016 were slightly higher than or similar to 2015 (which was record low), whereas the sulfur wet deposition was the lowest observed in southern Norway since the measurements started in 1974. The annual mean concentrations of PM_{10} and $PM_{2.5}$ were the lowest ever observed at Birkenes and Hurdal. Also the EC and OC concentrations were low in 2016. Most ozone parameters were somewhat higher in 2016 compared to 2015, which was a year with particularly low ozone levels.

An overview of the long-term trends are shown in Table 1. The trends reflect to a large extent the emission reductions which have taken place at the European continent the last decades, although inter-annual variations in meteorology could mask the effect of the emission reductions, particularly for ozone.

Table1: Trends in annual levels using Mann-Kendall test and Sen slope estimates. Note that trends are given for sites with significant change only.

Component	Sites	1980-2016	1990- 2016	2000-2016
SO_2	3-4 sites1)	-93 - -98%	-76% - -91%	-46% - -64%
SO_2	Zeppelin	-87%	-70%	-57%
SO_4^{2-}in aerosols	3-4 sites1)	-83 - -88%	-70% - -76%	-45% - -62%
SO_4^{2-} in aerosols	Zeppelin	-66%	-40%	-23%
SO_4^{2-} in precipitation	All (9 – 13 sites)	-77 - -95%	-49% - -88%	-46% --74% 2)
NO_2	4 sites1)		-39% - -77%	-41% - -48%
NO_3^- in precipitation	Southern Norway	-40 - -52%	-29% - -49%	-17% - -27%
HNO_3+NO_3^- in air	4 sites1)		2 sites: ca +75%	Not sign.trend
NH_4^+ in precipitation	Southern Norway	-54 - -63%	+100% - -40%	Not sign.trend
NH_3+NH_4^+ in air	4 sites1)		2 sites: +78% - -27%	Not sign.trend
PM_{10}	Birkenes			-29%
$PM_{2.5}$	Birkenes			-42%
OC	Birkenes			-32% - -43% (2001-2016)
EC	Birkenes			-43% - -50% (2001-2016)
TC	Birkenes			-38% - -42% (2001-2016)
O_3, 6-months AOT40	3 sites3)			-50% - 53% (1996-2016)
O_3, 3-months AOT40	Kårvatn4)			-62%(1996-2016)
O_3, 8h >100 µg/m^3	3 sites3)			-61% - -84% (1996-2016)

1) Birkenes, Nordmoen/Hurdal, Kårvatn, Tustervatn. Nordmoen/Hurdal was not part of 1980-2016

2) Kårvatn and Tustervatn without significant trend in this period

3) Kårvatn, Tustervatn and Prestebakke at 4)Tustervatn and Prestabekke have no sign trend

1. The monitoring programme, 2016

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. An important goal in this respect is to measure the effectiveness of the protocols, i.e. the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (UN/ECE, 1999)

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 (PM_{10} and $PM_{2.5}$) and EC/OC at three sites (Birkenes, Hurdal, Kårvatn)
    - High time-resolution measurements of particle number and size distribution 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 CLRTAP (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). Near real time data of ozone is reported continuously to both Norwegian (http://www.luftkvalitet.info) and European (EEA) air quality warning services). All the data are openly available at http://ebas.nilu.no.

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 (Nizzetto et al., 2017), the second covers the monitoring of the ozone layer and UV (Svendby et al. 2016), whereas the third is on climate gases and aerosol particles influence on climate (Myhre et al., 2016). 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. There were no changes in the monitoring programme in 2016.

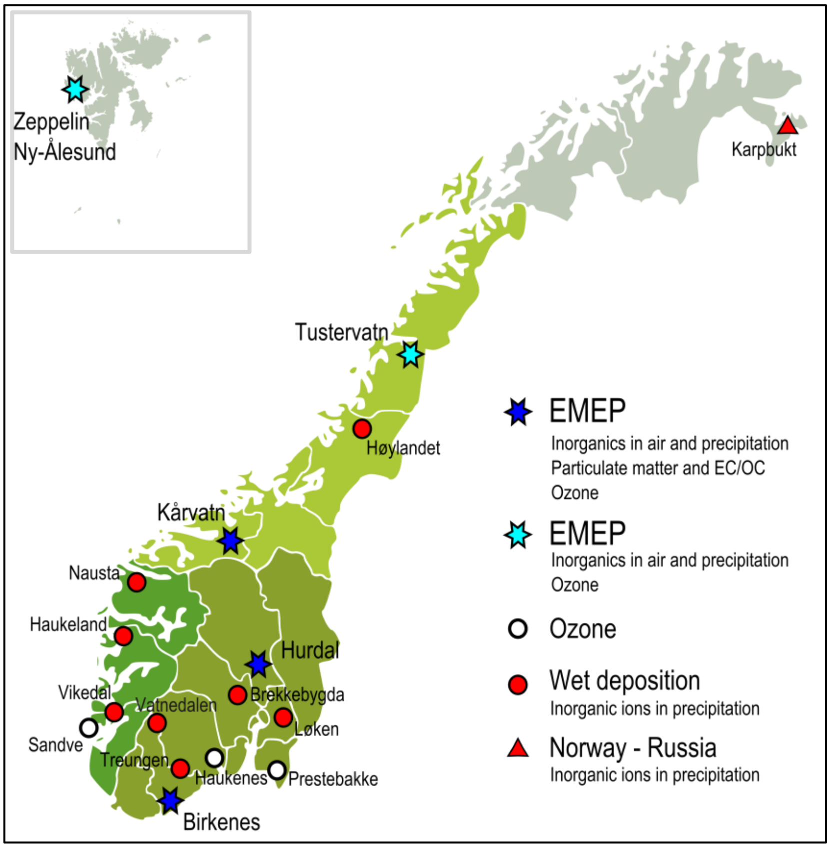


Figure 1.1: Norwegian background sites and their measurement programme 2016. Details are found in Annex 2. The colour codes indicate the different regions/zones used in EU's Ambient Air Quality Directive (2008).

2. The weather in Norway 2016

The variation in meteorological conditions from year to year is 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.

On average, the annual average temperature was 1.5°C above the normal (all normals refer to the 1961-1990 period) while the average precipitation was close to the normal (Met. Institute, 2016). This makes 2016 the 10th warmest year on average since 1900. The annual temperature anomaly was largest in Finnmark (2 - 3° above the normal) and southeast Norway (1.5 - 2.0° above the normal). Some inland regions in Troms and Finnmark received 150 – 175 % of the annual precipitation.

In the Norwegian Arctic, 2016 was an extreme year both with respect to temperature and precipitation. The mean annual temperature was 4.0 - 6.5° above the normal at met.no's monitoring sites and the precipitation was 150 - 200 % of the normal, making 2016 the hottest year ever. Ny-Ålesund received record-breaking 749 mm precipitation in 2016, and 87 mm fell on one single day, 8th November.

The year started with a January that was colder than average all over the country. The southern part received more precipitation than the normal while the northern part (Trøndelag and northwards) had dry conditions. In the end of January the extreme weather Tor gave strong winds in western and northern parts, and a mean wind speed of 48.9 m/s was registered, the highest mean wind speed ever measured in the country.

In the following months, February to May, most of the country experienced higher temperatures than the normal. Monthly mean temperatures were up to 4-6° above the normal in the southeast and the far north (Finnmark). May 2016 was the 4th warmest May measured in Norway since 1900.

The precipitation was characterized by dryer conditions than normal in many areas in western and northern Norway during March-May whereas areas in the southeast experienced more precipitation than the normal, in some regions twice the monthly mean precipitation. The mean precipitation in February was higher than the normal in many parts of the country (except some areas in the southeast), with up to 3-5 times the normal precipitation in the far north.

June was characterized by warmer and drier conditions in the southern part and cooler and wetter conditions in the north. July-August had higher precipitation than normal in most parts of the country, and strong local variations were seen due to a prominence of unstable, showery weather. The temperature was around (or somewhat above) the normal in the southeast while higher than the normal in the north in July. In August the temperature was close to the normal in most of the country.

Following this somewhat wet and cool summer in many parts of the country, September was on average the warmest September month ever measured in Norway, with a mean temperature anomaly of +3.6°. The month was drier than the normal in most areas.
The autumn months of October and November was colder than the normal in southern Norway and warmer than normal in the north. Very dry conditions were seen in most of the country in October. December was again very mild with a mean temperature of 4.6° above the normal for the country as a whole. Except for the southeast region, the precipitation well above the average was seen, in some regions up to 3 times the normal. The southeast areas had very dry conditions in December.

To concluding, the weather conditions in the summer of 2016 were not particularly favourable for photochemical ozone episodes in Norway as discussed in Chapter 6. The total precipitation amount is close to normal and thus not influencing the wet deposition on average, but there are regional- and temporal variations as discussed in Chapter 3.

3. Inorganic components

3.1 Observations in 2016

3.1.1 Chemical composition in precipitation

All sulfate values given in the present report are adjusted for the contribution of sulfate associated with sea salt. The sea-salt sulfate content is calculated based on the ratio of sodium, or magnesium and chloride, to sulfate in seawater, and is according to the procedures suggested by EMEP (EMEP/CCC, 2013). 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, the other sites with weekly sampling.

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 2016.

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 (when excluding the county of Finnmark). Except for the site in Finnmark, the highest concentrations of sulfate, nitrate and ammonium are seen in south and southeast while the wet depositions are highest in southwest, correlated to the high precipitation amount on the west coast. The site in Finnmark is influenced by emissions from Russia and the content of sulfate is particularly high.

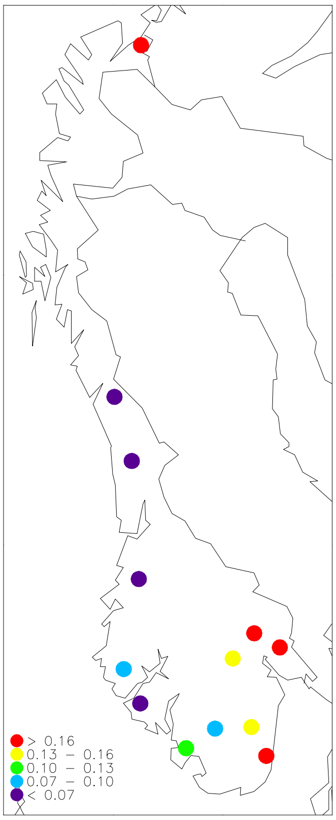
Table 3.1 shows that all regions, except the most continental parts of southern Norway and Finnmark, observed significant amounts of sea salts. At most sites there was an excess of cations, which probably is due to the content of bicarbonate or other anions of weak acids that are not determined.

As seen for previous years, the highest annual mean concentrations for the sulfate and nitrate were observed at the Birkenes site (Table 3.1); except for sulfate at Karpbukt, which was higher due to the influence of emissions from smelters at the Kola Peninsula in Russia. Being situated only 20 km from the Skagerrak coastline, Birkenes is the site in Norway being the most influenced by long-range transport of air pollution from the European Continent and UK, hence this finding is to be expected. However, some inland sites are influence by regional agricultural activities and experience somewhat higher ammonium concentrations, i.e. Treungen, Hurdal and Løken. The highest wet deposition loads of sulfate, nitrogen components and strong acid occurred along the coast from Aust-Agder to Hordaland.

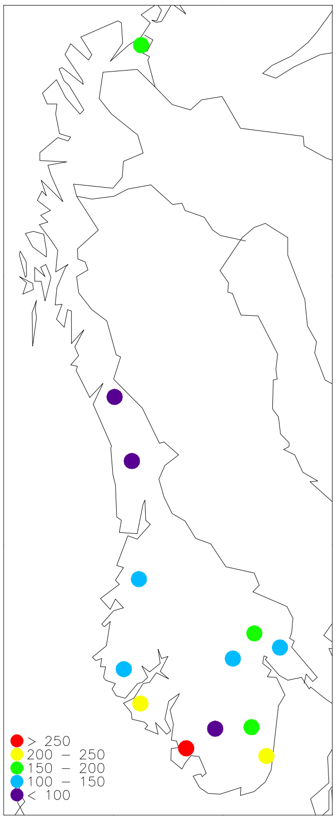
Table 3.1: Annual volume weighted mean concentrations and total wet deposition of inorganic ions at Norwegian background stations, 2016.
**: Corrected for contribution from sea salt.*

Site	Volume weighted annual mean concentrations (mg/L)									Wet deposition (mg/m^2 , H$^+$: µekv/m^2)										Volume weighted annual mean concentrations in equivalence units (µekv/L)										Ion bal.
	pH	$SO_4^{2-}S$*	NO_3^--N	NH_4^+-N	Ca^{2+}	K^+	Mg^{2+}	Na^+	Cl^-	mm	H^+	SO_4^{2-}-S*	NO_3^--N	NH_4^+N	Ca^{2+}	K^+	Mg^{2+}	Na^+	Cl^-	H^+	SO_4^{2-} *	SO_4^{2-}	NO_3^-	NH_4^+	Ca^{2+}	K^+	Mg^{2+}	Na^+	Cl^-	cat/an
Birkenes	4.91	0.17	0.35	0.29	0.15	0.12	0.16	1.32	2.27	1414	17528	245	489	414	206	169	231	1867	3204	12	11	17	25	21	7	3	13	57	64	1.07
Vatnedalen	5.30	0.09	0.08	0.11	0.14	0.17	0.17	1.83	2.72	814	4072	70	64	93	113	136	140	1489	2215	5	6	13	6	8	7	4	14	80	77	1.22
Treungen	4.98	0.16	0.27	0.30	0.09	0.09	0.07	0.47	0.77	957	10136	150	263	284	89	85	64	452	735	10	10	12	19	21	4	2	6	20	22	1.21
Løken	5.03	0.17	0.30	0.31	0.12	0.12	0.06	0.37	0.61	692	6432	117	210	217	82	81	40	258	424	9	11	12	21	22	6	3	5	16	17	1.20
Hurdal	5.01	0.18	0.31	0.32	0.13	0.13	0.04	0.29	0.45	866	8369	159	272	281	111	113	36	255	393	10	11	13	22	23	6	3	3	13	13	1.22
Brekkebygda	5.01	0.15	0.23	0.24	0.10	0.10	0.03	0.21	0.33	892	8789	136	209	217	93	85	28	191	292	10	9	11	16	17	5	3	2	9	9	1.27
Vikedal	5.14	0.10	0.18	0.25	0.15	0.18	0.33	2.69	4.66	2487	18165	258	439	615	367	458	808	6703	11595	7	6	21	13	18	7	5	27	117	131	1.10
Haukeland	5.14	0.06	0.08	0.11	0.13	0.17	0.32	2.71	4.76	3230	23542	207	267	350	431	554	1033	8755	15366	7	4	18	6	8	6	4	26	118	134	1.08
Nausta	5.13	0.07	0.09	0.15	0.13	0.16	0.29	2.39	4.15	1477	10888	104	136	227	186	243	423	3533	6125	7	4	17	6	11	6	4	24	104	117	1.11
Kårvatn	5.19	0.07	0.10	0.11	0.10	0.12	0.16	1.30	2.29	1543	9854	107	157	163	158	179	247	2001	3525	6	4	11	7	8	5	3	13	57	65	1.11
Høylandet	5.47	0.05	0.05	0.17	0.14	0.13	0.27	2.24	3.90	1283	4322	67	69	213	174	169	350	2871	5007	3	3	15	4	12	7	3	22	97	110	1.13
Tustervatn	5.24	0.05	0.07	0.09	0.09	0.11	0.13	1.06	1.88	1031	5914	55	73	93	91	118	136	1092	1936	6	3	9	5	6	4	3	11	46	53	1.14
Karpbukt	4.87	0.27	0.07	0.12	0.13	0.13	0.25	2.01	3.59	693	9271	185	51	84	88	92	174	1392	2492	13	17	27	5	9	6	3	21	87	101	1.05
Ny-Ålesund	5.49	0.07	0.06	0.08	0.30	0.17	0.48	3.66	6.53	490	1589	36	28	38	146	83	235	1795	3201	3	4	24	4	6	15	4	39	159	184	1.07

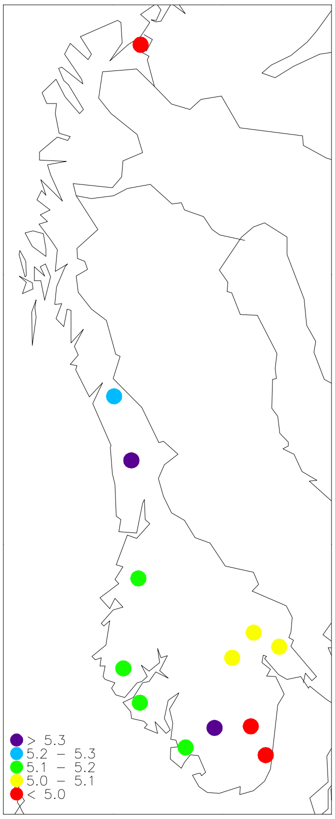
a) Sulfate concentration in precipitation, 2016
mg S/L



b) Sulfate – wet deposition. 2016
mg S/m^2



c) pH
2016



d) Strong acid (H^+) wet deposition, 2016

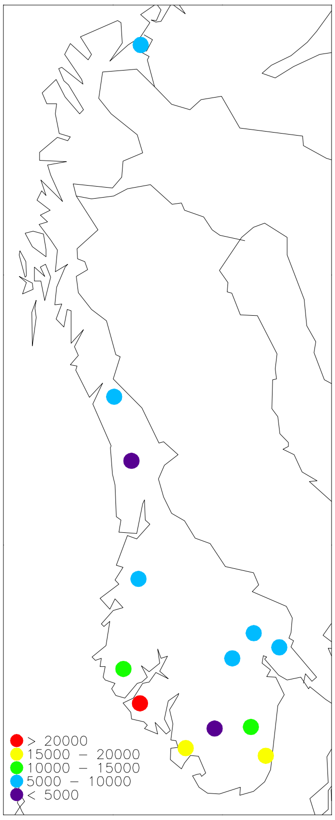
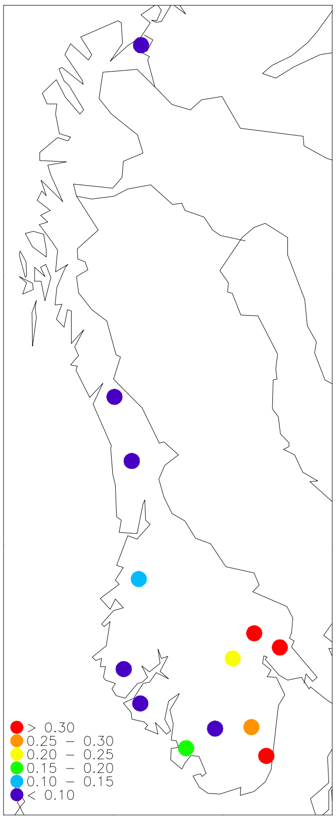
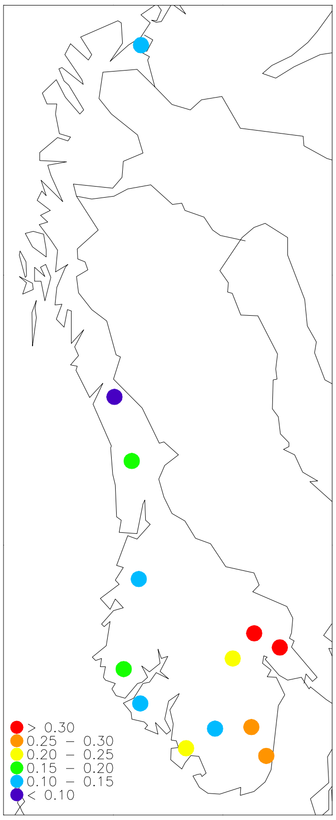


Figure 3.1: Annual volume weighted mean concentrations and total wet deposition of sulfate (sea salt corrected) and strong acid (pH), 2016.

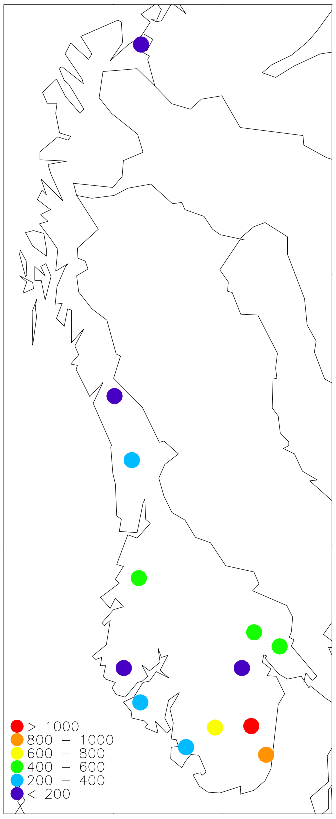
a) Nitrate concentration in precipitation, 2016
mg N/l



b) Ammonium concentration in precipitation, 2016
mg N/l



c) Sum nitrate and ammonium wet deposition 2016
mg N/m^2



d) Chloride concentration in precipitation, 2016

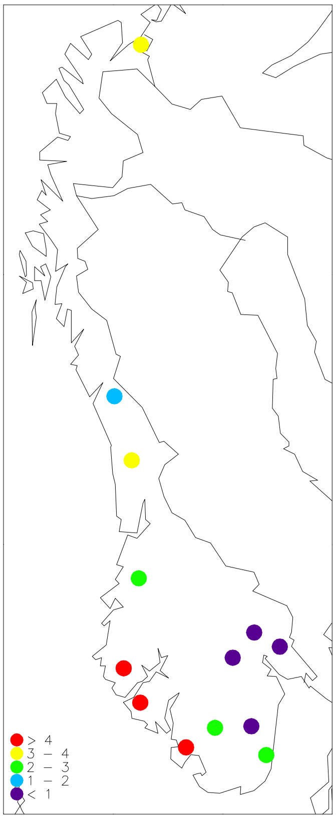


Figure 3.2: Annual volume weighted mean concentrations of nitrate, ammonium, chloride and total wet deposition of nitrogen (nitrate + ammonium), 2016.

Figure 3.3 shows monthly volume weighted mean concentrations and wet deposition of sulfate, nitrate and, ammonium in different parts of Norway, 2016. All the monthly data are given in the tables in Annex 1. There are quite large differences between the months, though it is not a general pattern common for all regions and components. In 2016, the highest concentrations were for most ions seen during March to May. East Norway also experienced high concentrations in September. For wet deposition, the highest levels were often observed during spring and early summer. Also in December, high loads of wet deposition were seen in many regions, especially for ammonium, reflecting the high precipitation amount that month. The sites in eastern Norway were an exception to this since. December was a dry month there (see table A1.10), as also discussed above in Chapter 2. Table A1.20 shows that between 25% and 35% of the total annual sulfate deposition arrived during ten peak days when looking at the four sites with daily measurements through the whole year.

Figure 3.3: Monthly volume weighted mean concentrations (left: a),c),e)) and wet deposition (right: b),d),f)) of sea salt corrected sulfate (top) nitrate (middle), ammonium (bottom) in different parts of Norway, 2016, 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 2016. All sites are EMEP sites as shown in Figure 1.1. Table 3.2 shows the annual mean concentrations while the monthly data are given in A.1.22-A.1.33. The monthly means of the sulfur and nitrogen components are illustrated in Figure 3.4. 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.

Table 3.2: Annual mean concentrations of inorganic components in air at Norwegian background stations, 2016.

	SO_2 µg-S/m^3	SO_4^{2-} µg-S/m^3	NO_2 µg-N/m^3	sum NO_3 µg-N/m^3	NO_3 µg-N/m^3	sum NH_4 µg-N/m^3	NH_4 µg-N/m^3	Mg µg/m^3	Ca µg/m^3	K µg/m^3	Cl µg/m^3	Na µg/m^3
Birkenes II	0.05	0.20	0.30	0.25	0.21	0.40	0.23	0.05	0.04	0.06	0.53	0.42
Hurdal	0.03	0.17	0.61	0.16	0.13	0.30	0.15	0.02	0.03	0.06	0.14	0.16
Kårvatn	0.03	0.11	0.15	0.07	0.04	0.44	0.06	0.02	0.02	0.03	0.17	0.15
Tustervatn	0.04	0.13	0.11	0.07	0.05	0.43	0.07	0.03	0.02	0.03	0.34	0.25
Zeppelin	0.06	0.11	-	0.05	0.03	0.17	0.03	0.04	0.02	0.05	0.33	0.23

The annual mean concentrations of sulfur dioxide in air are generally very low in Norway. In 2016 the highest concentrations were seen at the most northern site, Zeppelin, and the most southern site, Birkenes, with 0.06 and 0.05 µg S/m^3 respectively. The Zeppelin site is mainly influenced by emissions in Russia, while Birkenes is mainly influenced by emissions on the European continent. The highest daily average concentration in 2016 was, however, seen at Tustervatn with 2.1 µg S/m^3 on 7 January. Inspections of NILU's Flextra 4-days air-mass back trajectories arriving at these sites, indicate that at this day the air came from northeast and passed over the Kola Peninsula. The highest episode at Zeppelin (3 February) was probably also caused by emissions from the same smelters at the Kola Peninsula.

The highest annual mean particulate sulfate concentration was measured at Birkenes (0.20 µg S/m^3), although Hurdal experienced the highest one-day episode level (1.96 µg S/m^3) 19 February with air masses coming from the continent, as indicated by the trajectories.

The highest NO_2 levels were observed in Hurdal with an annual mean concentration of 0.6 µg N/m^3. This station is influenced by the relatively high traffic emissions in the region. The highest daily mean concentration of NO_2 was also measured at Hurdal with 5.2 µg N/m^3 on 7 December. The concentrations of NO_2 show a temporal pattern with a winter maxima and summer minima (Figure 3.5) which is to be expected. During winter, there is reduced vertical mixing and the atmospheric residence time is longer due to low photochemically activity.

The highest annual mean level of sum of nitrate (NO_3^- + HNO_3), and NH_4^+ were observed at Birkenes with 0.25 µg N/m^3 and 0.23 µg N/m^3 respectively. The highest annual mean level of sum of ammonium (NH_3 + NH_4^+) was observed at Kårvatn and Tustervatn, probably due to influence of agricultural activity in the region. The ammonium (NH_4^+) and sum of nitrate (NO_3 + HNO_3) show very similar seasonal distributions (Figure 3.4), with indication of elevated levels during winter. Sum ammonium (NH_3 + NH_4^+) on the other hand peaks in spring and summer showing the influence of ammonia from regional agricultural activitie.

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 2016.

Site	No. of observations	SO_2 (µg S/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	335	0.01	0.06	0.14	1.04	15.09.2016	0.05
Kårvatn	320	0.01	0.01	0.05	0.49	20.08.2016	0.03
Tustervatn	341	0.01	0.01	0.05	2.09	07.01.2016	0.04
Zeppelin	347	0.01	0.01	0.09	1.36	03.02.2016	0.06
Hurdal	304	0.01	0.03	0.06	0.67	08.11.2016	0.03

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 2016.

Site	No. of observations	SO_4^{2-} (µg S/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	365	0.16	0.29	0.46	1.03	21.10.2016	0.20
Kårvatn	352	0.07	0.14	0.25	1.03	16.09.2016	0.11
Tustervatn	356	0.1	0.17	0.29	0.81	17.09.2016	0.13
Zeppelin	366	0.06	0.13	0.29	0.85	25.03.2016	0.11
Hurdal	329	0.11	0.23	0.41	1.96	19.02.2016	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 2016.

Site	No. of observations	NO_2 (µg N/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	361	0.22	0.34	0.67	2.89	2016-12-07	0.30
Kårvatn	365	0.12	0.16	0.27	1.06	2016-01-20	0.15
Tustervatn	360	0.09	0.13	0.19	0.69	2016-02-18	0.11
Hurdal	364	0.36	0.66	1.30	5.23	2016-01-25	0.61

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 2016.

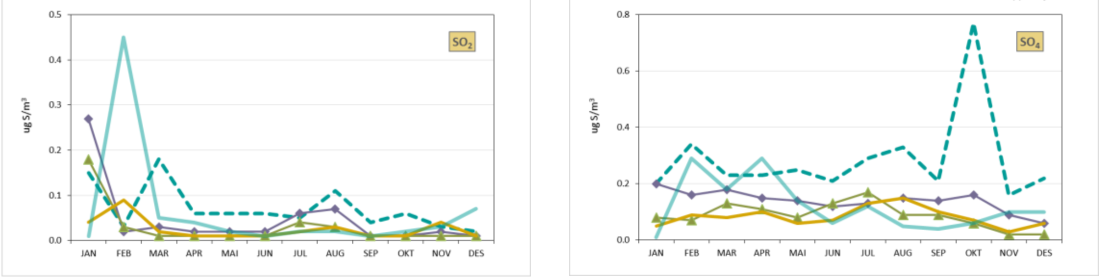
Site	No. of observations	NO_3^-+HNO_3 (µg N/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	312	0.11	0.26	0.65	3.56	06.02.2016	0.25
Kårvatn	318	0.05	0.08	0.12	0.55	05.05.2016	0.07
Tustervatn	333	0.04	0.08	0.14	1.22	11.03.2016	0.07
Zeppelin	314	0.03	0.06	0.09	1.12	31.12.2015	0.05
Hurdal	292	0.08	0.17	0.43	1.4	03.04.2016	0.16

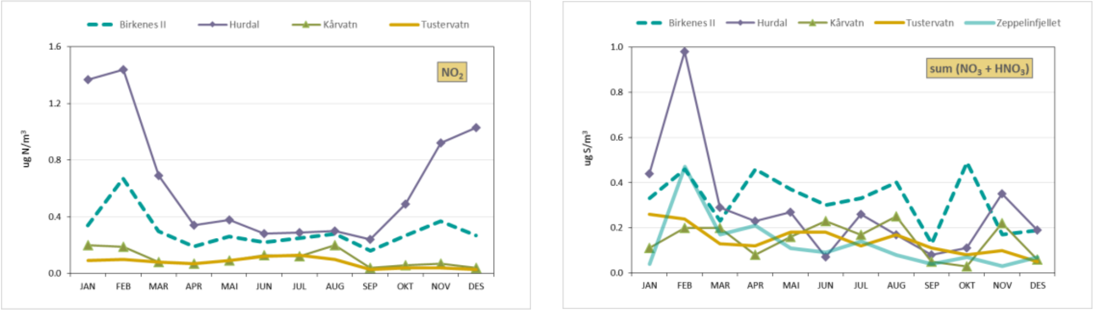
Table 3.7: Number of daily, observations 50-, 75-, 90-percentile concentrations, max- and annual mean concentrations of ammonium in aerosols at Norwegian background station in 2016.

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	342	0.08	0.25	0.65	3.41	06.02.2016	0.23
Kårvatn	353	0.03	0.07	0.17	0.78	16.09.2016	0.06
Tustervatn	348	0.02	0.07	0.18	1.31	11.03.2016	0.07
Zeppelin	334	0.01	0.03	0.08	0.25	31.12.2015	0.03
Hurdal	319	0.05	0.17	0.48	1.6	03.04.2016	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 2016.

Site	No. of observations	NH_4^+ (µg N/m^3)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	312	0.22	0.5	0.99	3.55	06.02.2016	0.40
Kårvatn	320	0.35	0.56	0.91	2.51	25.09.2016	0.44
Tustervatn	333	0.36	0.59	0.91	1.73	11.03.2016	0.43
Zeppelin	314	0.15	0.22	0.3	2.43	03.07.2016	0.17
Hurdal	293	0.21	0.37	0.69	1.85	03.04.2016	0.30


a) SO_2 b) SO_4 in aerosols


c) NO_2 d) sum (NO_3+HNO_3) in air

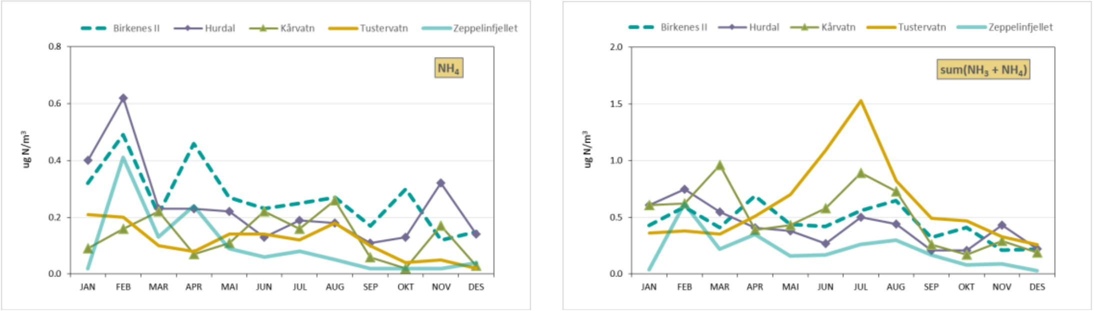

e) NH_4 in aerosols f) sum (NH_4+NH_3) in air

Figure 3.4: Monthly mean concentrations of sulfur- and nitrogen components in air at the five EMEP sites in Norway in 2016. Unit: μg(S or N)/m^3.

3.1.3 Total deposition of sulfur and nitrogen

Table 3.9 and Figure 3.5 present estimates of the total dry deposition of sulfur and nitrogen compounds and measured wet deposition in the growing season from May to October (summer) and the winter season defined as 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 the table text (Dovland and Eliassen, 1976; Dollard and Vitols, 1980; Fowler, 1980; Garland, 1978; Voldner and Sirois, 1986; Hicks et al., 1987).

For the sum of nitrate (NO_3^- + HNO_3), it is that HNO_3 contributes with 25% and NO_3^- by 75% of the air concentration. For the sum of ammonium (NH_3 + NH_4^+), NH_3 is assumed to contribute with 8% and NH_4^+ by 92% (Ferm, 1988) to the air concentration. 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 on the surface type (water, mountains, etc.). The deposition is for most gases far greater on wet surfaces than on dry surfaces. 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 contributes most to the total deposition at all the sites on the main land, for both nitrogen and sulfur, and the total deposition is highest in southern Norway (Figure 3.5 and Table 3.9). For sulfur, dry deposition contributes with 20-33% of the total deposition in summer and 4-15% in winter except at Svalbard where dry deposition is relatively much higher due to the low precipitation amounts. For nitrogen, the dry deposition is relativity more important than for sulfur. Dry deposition of nitrogen contributes between 19-45% in summer in 7-18% in winter to the total nitrogen load.

Table 3.9: Estimated dry deposition and measured wet deposition of sulfur and nitrogen at Norwegian background stations 2016.

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.

	Sulfur (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	5	32	120	124	4	21	40	93	508	395	7	19
Hurdal	4	21	75	83	5	20	21	121	276	279	7	30
Kårvatn	2	17	65	45	4	27	18	73	161	168	10	30
Tustervatn	5	14	25	29	15	33	18	69	83	86	18	45
Zeppelin*	6	10	12	24	32	30	-	-	20	46	-	-

*Used the wet deposition at Ny-Ålesund.

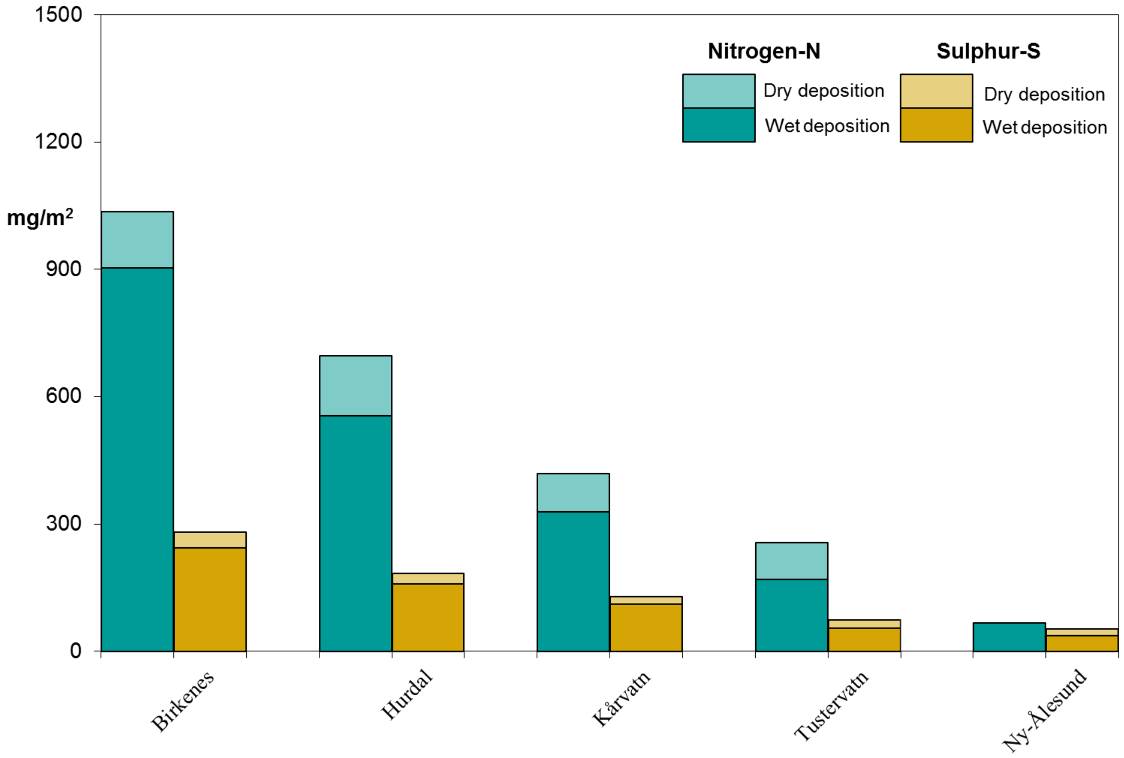


Figure 3.5: Total deposition (wet+ dry) of sulfur-S (SO_2, SO_4^{2-}) and nitrogen-N (NO_2, NH_4^+, NH_3, NO_3^-, HNO_3) at Norwegian background stations 2016.

3.2 Trends

An important goal of the monitoring programme is to measure the effectiveness of the protocols, i.e. the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (UN/ECE, 1999). Since Norway is downwind of the major emission sources in Continental Europe, the monitoring in Norway can to some extent be used to evaluate the overall emission reductions in Europe. The objective of the multicomponent Gothenburg Protocol from 1999 was to reduce European emissions of sulfur by 63% in 2010 compared to 1990. Similarly, the target for nitrogen oxides and ammonia was a reduction of 41% and 17%, respectively. In 2012, the Gothenburg Protocol was revised, and new emissions targets for 2020 with 2005 as the base year were defined. The 27 EU countries (with numbers for Norway in brackets) have committed to the following emission reductions SO_2: 59% (10%), NO_x: 43% (23%), nmVOC: 28% (40%), ammonia: 6%, (8%) and $PM_{2.5}$: 22% (30%).

Figure 3.6-Figure 3.8 show the time series of annual mean concentrations of main ions in precipitation and in air together with the total deposition at selected sites in Norway with sufficiently long time series. The concentration levels in 2016 was a bit higher compared to 2015, which was record low, but the sulfur wet deposition in 2016 was the lowest observed in southern Norway since the measurements started in 1974 (Figure 3.6). Total nitrogen wet deposition was also low in 2016, and 2010 was the only year with less wet deposition (Figure 3.6). The annual precipitation amount in southern Norway was relatively low compared to the previous years. Also for air concentration, the level in 2016 was generally lower compared to earlier years (Figure 3.7), except for NO_2 where the levels was either a bit higher or similar to what was observed in 2015.

Table 3.10 and 3.11 shows the statistical trends for three different periods, 1980-2016, 1990-2016, and 2000-2016 for all sites with measurements in these respective periods.

For the statistical analysis, the non-parametric “Mann-Kendall Test” has been used based on annual averages 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 the 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 calculate the significance level of the trend. Statistical calculations have been carried out using the MAKESENS software (Salmi et al., 2002).

For sulfur, there has been a significant reduction at all the sites for all the sulfur components in air and precipitation from both 1980 and 1990 to 2016. Since 1980, the content of sulfate in precipitation in Norway has decreased by 77-95%. The reductions in airborne concentrations were similar, between 93%-98% and 83-88% at the Norwegian mainland for sulfur dioxide and sulfate, respectively. Somewhat lower reductions are observed at the Zeppelin Observatory, 87% for sulfur dioxide and 66% for sulfate, Table 3.10.

Since 1990, the reductions have been between 49-88% (sulfate in precipitation), 76-91% (sulfur dioxide) and 70-76% (sulfate in air) for the sites at the mainland. From 2000, all sites except Tustervatn and Kårvatn observe a significant reduction of sulfate in precipitation, between 46-74%. For sulfur dioxide, there is significant reduction at all sites except Kårvatn between 53-63%, and all the sites with significant reduction of sulfate in air, between 45-62% at the mainland.

The nitrate and ammonium concentrations in precipitation have significantly decreased at most sites south of Kårvatn, 40-52% for nitrate and 54-63% for ammonium since 1980. 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 in southern Norway shows a significant decrease between 29% and 49% from 1990-2016. 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 three of the sites at the mainland, between 39-57% since 1993, but for sum nitrate and sum of ammonium it has rather been a significant increase maybe due to changes in local emissions or change in chemical regime; *i.e.* less sulfate cause more ammonium associated to particulate nitrate.

The NO_2 concentration has decreased at all four sites, between 39-77% from 1990 and 41-48% from 2000. The observed reductions in concentration levels of sulfur and nitrogen species are in agreement with reported downwards trends in pollutant emissions in Europe (Tørseth et al., 2012; Colette et al., 2016).

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 1980-2016 and at Vatnedalen from 1990-2016.

*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.*

1980-2016										
site	SO_4	% change	NO_3	% Change	NH_4	% change	Ca	% change	Mg	% change
Birkenes	***	-89 %	***	-41 %	***	-54 %	**	-41 %		
Treungen	***	-93 %	***	-41 %	***	-50 %	**	-40 %		
Vatnedalen	***	-87 %	***	-40 %			+	21 %		
Løken	***	-95 %	***	-52 %	***	-62 %	***	-54 %	*	-25 %
Gulsvik/Brekkebygda	***	-94 %	***	-52 %	***	-63 %				
Haukeland 1)	***	-92 %	***	-45 %	***	-56 %	+	-27 %		
Kårvatn	***	-77 %					+	-29 %		
Tustervatn	***	-88 %					*	-33 %		
Ny-Ålesund 2)	***	-83 %								

1)From 1982 2) From 1981

1990-2016										
site	SO_4	% change	NO_3	% change	NH_4	% change	Ca	% change	Mg	% change
Birkenes	***	-78 %	***	-38 %	***	-38 %				
Treungen	***	-83 %	***	-42 %	***	-40 %				
Vatnedalen	***	-76 %	**	-39 %					+	-43 %
Nordmoen/Hurdal	***	-79 %	***	-31 %			*	63 %		
Løken	***	-85 %	***	-46 %	**	-41 %				
Gulsvik/Brekkebygda	***	-84 %	***	-49 %	***	-50 %				
Vikedal	***	-88 %	***	-29 %						
Nausta	***	-79 %	**	-30 %	**	90 %				
Høylandet	***	-78 %			***	100 %				
Haukeland	***	-87 %	***	-42 %	**	-46 %				
Kårvatn	***	-49 %			*	42 %				
Tustervatn	***	-64 %			*	-23 %				
Ny-Ålesund	***	-85 %					+	-35 %		

2000-2016										
site	SO_4	% change	NO_3	% change	NH_4	% change	Ca	% change	Mg	% change
Birkenes	***	-59 %	+	-22 %			**	70 %		
Treungen	***	-61 %	+	-17 %						
Vatnedalen	*	-53 %								
Nordmoen/Hurdal	**	-46 %	+	-16 %			+	77 %		
Løken	**	-53 %	*	-19 %					+	67 %
Gulsvik/Brekkebygda	***	-56 %								
Vikedal	**	-67 %	*	-27 %			*	76 %		
Nausta	**	-63 %	+	-20 %	**	96 %				
Høylandet	*	-65 %								
Haukeland	***	-74 %	**	-39 %	+	-36 %				
Kårvatn			+	61 %			+	52 %		
Tustervatn					**	-38 %				
Ny-Ålesund	+	-59 %					*	-73 %	+	-53 %

*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.*

1980-2016				
Site	SO_2	% change	SO_4	% change
Birkenes1)	***	-98 %	***	-83 %
Kårvatn1)	***	-97 %	***	-84 %
Tustervatn1)	***	-93 %	***	-88 %
Zeppelin	***	-87 %	***	-66 %

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

1990-2016												
Site	SO_2	% change	SO_4	% change	Sum NO_3	% change	Sum NH_4	% change	NH_4 (from 1993)	% change	NO_2	% change
Birkenes	***	-90 %	***	-71 %					**	-44 %	***	-65 %
Nordmoen/Hurdal	***	-91 %	***	-75 %			+	-27 %	**	-57 %	***	-77 %
Kårvatn	***	-76 %	***	-70 %	*	70 %	**	78 %			**	-39 %
Tustervatn	***	-90 %	***	-76 %	**	79 %			**	-39 %	***	-56 %
Zeppelin	***	-70 %	***	-40 %	**	158 %	***	417 %			-	-

2000-2016												
Site	SO_2	% change	SO_4	% change	Sum NO_3	% change	Sum NH_4	% change	NH_4	% change	NO_2	% change
Birkenes	+	-53 %	**	-52 %							***	-46 %
Nordmoen/Hurdal	+	-46 %	*	-50 %							*	-41 %
Kårvatn			**	-45 %							**	-48 %
Tustervatn	**	-63 %	**	-62 %							**	-44 %
Zeppelin	**	-57 %	+	-23 %	*	160 %			*	196 %	-	-

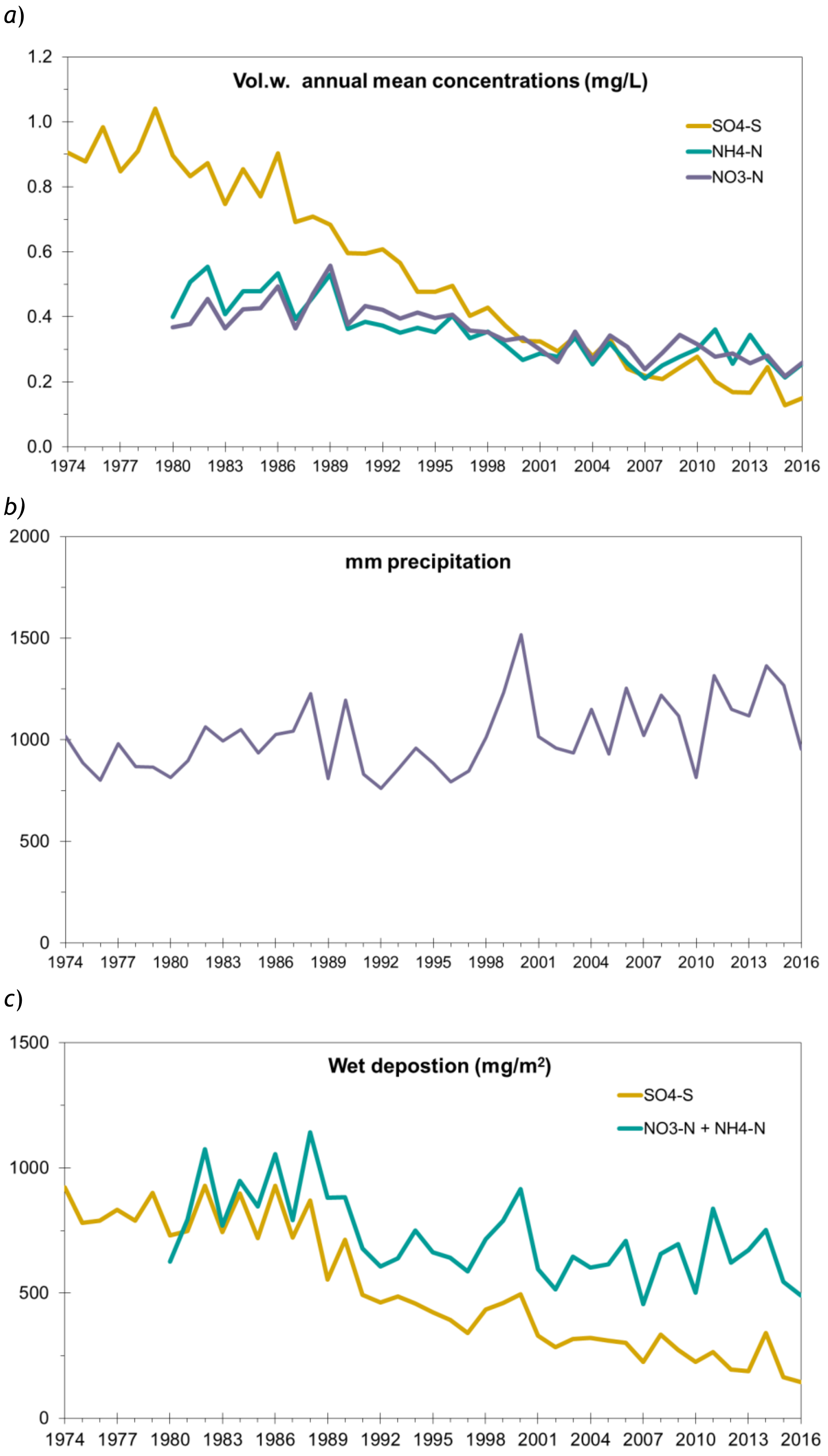
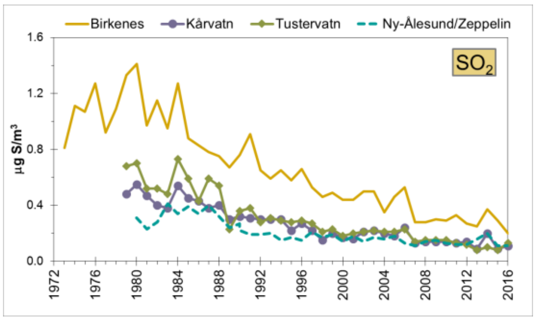
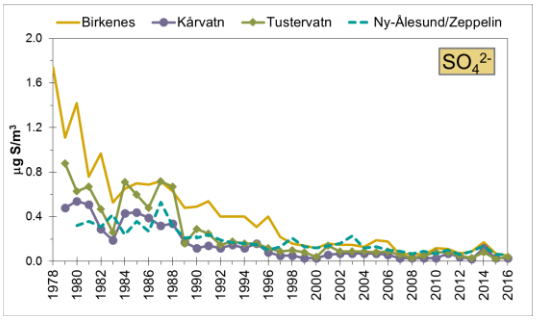


Figure 3.6: Volume weighted annual mean concentrations (a), precipitation amount (b) and wet deposition (c) for sea salt corrected sulfate, nitrate and ammonium at five representative sites in southern Norway (Birkenes, Vatnedalen, Treungen, Gulsvik and Løken), 1974-2016.

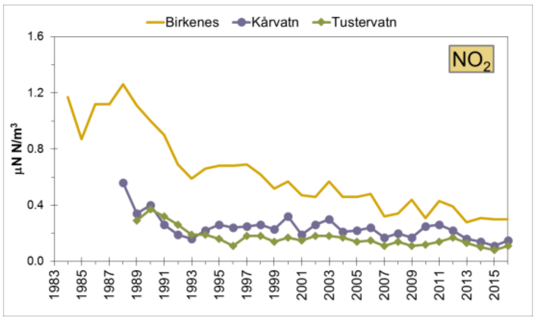
a) SO_2



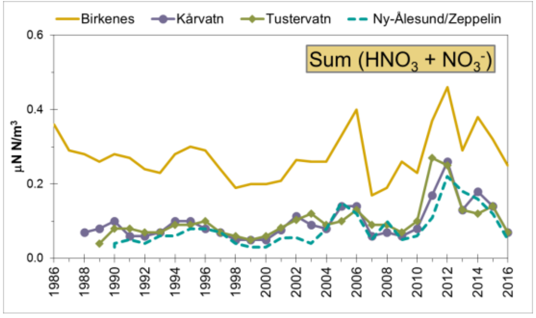
b) SO_4 in aerosols



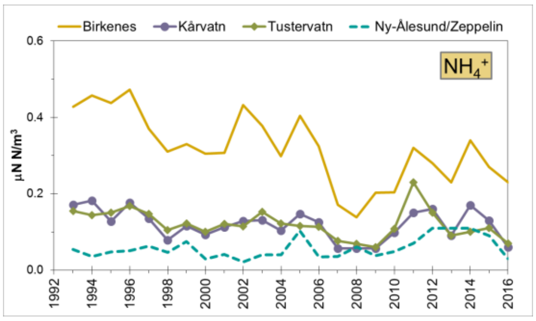
c) NO_2



d) sum (NO_3+HNO_3) in air



e) NH_4 in aerosols



f) sum (NH_4+NH_3) in air

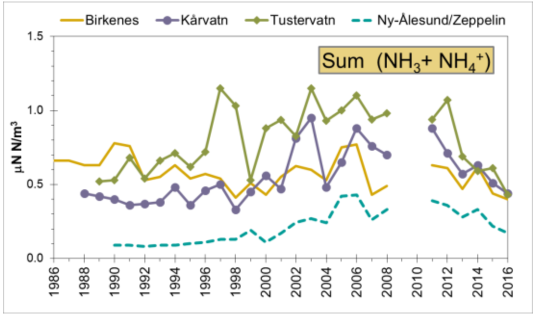


Figure 3.7: Annual mean concentrations of sulfur and nitrogen components in air at four Norwegian EMEP sites, 1973-2016.

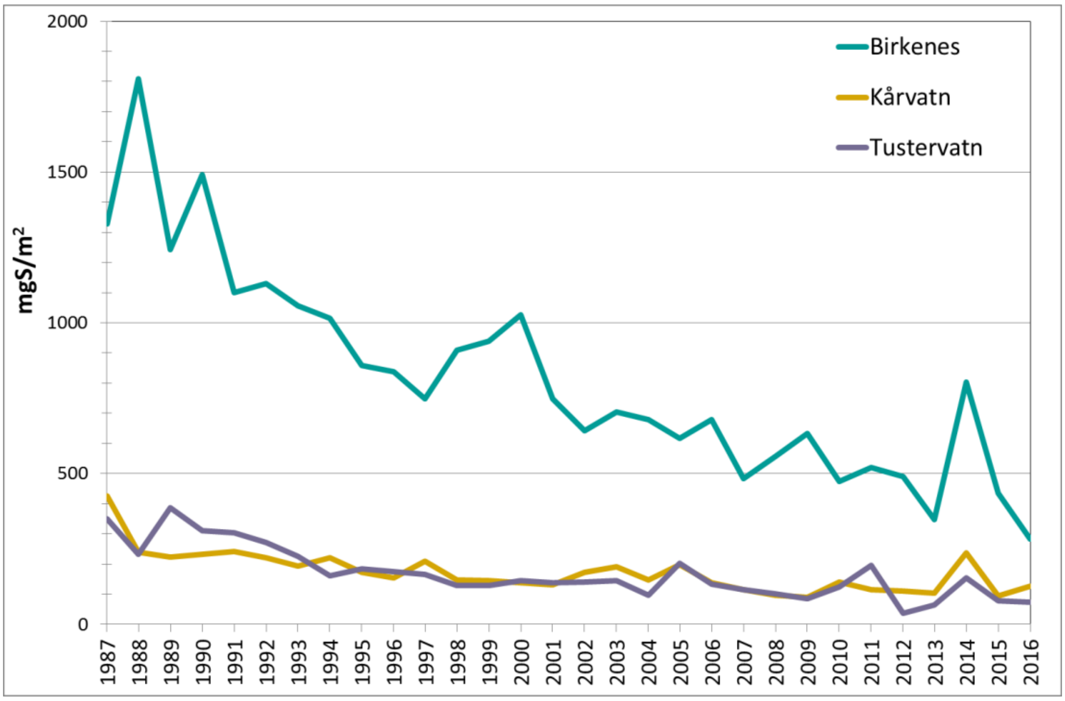


Figure 3.8: Trends in total deposition (wet + dry) of sulfur at three Norwegian EMEP sites, 1987-2016.

3.3 Summary

For sulfate and nitrate, the highest annual mean concentrations were in 2016 measured at Birkenes, which is the station in Norway most affected by long-range transport of pollutants. Except for sulfate at Karpbukt which is influence by the emissions from the smelters in the Kola Peninsula in Russia. Some inland sites are influence by regional agricultural activities and experience somewhat higher ammonium concentrations than Birkenes. For NO_2, the highest levels are seen in Hurdal, which is influence by the relatively high traffic emission in the region. The highest wet deposition loads of sulfate, nitrogen components and strong acid occurred along the coast from Aust-Agder to Hordaland.

The concentration levels in air and precipitation in 2016 was a bit higher or similar compared to 2015, which was record low, but the sulfur wet deposition in 2016 was the lowest observed in southern Norway since the measurements started in 1974. Wet deposition of total nitrogen was also low in 2016, less wet deposition only seen in 2010.

There are large reductions in sulfur in all parts of Norway, since 1980 up to more than 90%, since 1990, around 70% depending on which sulfur components one look at and since 2000 about 50% in Southern Norway. Nitrate and ammonium concentrations in precipitation have significantly decreased at most sites in southern Norway, around 50% for both components, somewhat less from 1990. NO_2 concentration has also decreased significantly, 39-77% from 1990. These observed reductions are in line with reported emission reduction at the European continent (Colette et al, 2015).

4. EC and OC

4.1 Introduction

Monitoring of Elemental Carbon (EC) and Organic Carbon (OC) in PM_{10} and $PM_{2.5}$ takes place at three rural background sites: the Birkenes Observatory and the Hurdal and Kårvatn sites. The time series at the Birkenes Observatory dates back to 2001 and to 2010 at the two other sites.

Annual and monthly mean concentrations of EC and OC in PM_{10} and $PM_{2.5}$ for 2016, are shown in Figure 4.1and Table 4.1 whereas annual mean concentrations for EC and OC in PM_{10} and $PM_{2.5}$ for the period 2001 – 2016 are listed in Table 4.2.

Incidences of $PM_{2.5} > PM_{10}$ on a monthly basis are typically due to a different number of samples for the two size fractions, but for low levels, measurement uncertainties can have an influence as well, in particular for EC. OC in $PM_{10-2.5}$ is derived from the observed values of OC in PM_{10} and $PM_{2.5}$ and is discussed in the report for a better understanding of the observed data, but is not listed in any table. Background information on the carbonaceous aerosol (here: OC and EC) can be found in Annex 3.

4.2 Concentrations of OC in PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$

The annual mean concentration of OC in PM_{10} (0.70 – 0.94 µg C/m^3) and $PM_{2.5}$ (0.49 – 0.66 µg C/m^3) at Norwegian rural background sites are amongst the lowest in Europe. Fine fraction OC (70 – 74%) was the major fraction of OC in PM_{10} at all sites on an annual basis. This is as expected as the major sources, primary emissions from combustion of fossil fuel and biomass and secondary particle formation from biogenic and anthropogenic precursors, typically generate fine aerosol particles. Coarse fraction OC occasionally dominates on a monthly basis. This is typically observed for the second half of the vegetative season and is attributed to the presence of primary biological aerosol particles (PBAP).

The annual mean concentration of OC in PM_{10} at Hurdal was approximately 30% higher than for the two other sites, and was attributed to higher levels of both its fine and coarse fraction (Table 4.1). We speculate that the more densely populated and anthropogenic influenced region surrounding the Hurdal site is the main explanation for the observed increment of fine fraction OC. This is also in line with the higher NO_2 concentrations seen for this site, which has been explained by high emissions from vehicular traffic in this region (See section 3.1.2).

There was a seasonal variability with increased levels of OC in summer (April - September) compared to winter (October - March) for all sites and size fractions; the seasonality being substantially more pronounced for the coarse than the fine fraction, and with large variability between sites. This reflects increased levels of Secondary Organic Aerosols (SOA), and Biogenic Secondary organic Aerosols (BSOA) in particular, contributing to the fine fraction, and PBAP contributing to the coarse fraction during the vegetative season (See Yttri et al. 2011 a, b).

A certain level of covariance was observed between the sites, both with respect to seasonality and episodes of increased levels. Seasonal covariance is likely climatological driven, e.g. temperature is decisive for the formation of SOA and pollen release, as well as the need for domestic heating. Episodes of long-range transported air pollution is well known to affect large regions. Finally, prolonged sampling time (here: weekly) could also contribute to mask differences between sites. Noticeably, the correlation seen for OC between Birkenes and Hurdal seems to be driven by its fine fraction, whereas it is the coarse fraction driving the correlation between Hurdal and Kårvatn.

The annual mean concentration of OC in PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$ was within one standard deviation (±SD) of the long-term mean at all sites. The annual mean of OC in PM_{10} and $PM_{2.5}$ was in the lower end of the long-term mean, whereas it ranged around the mean for OC in $PM_{10-2.5}$. Note that the measurements for Hurdal and Kårvatn only dates back to 2010, whereas for Birkenes it dates back to 2001.

4.3 Concentrations of EC in PM_{10} and $PM_{2.5}$

The annual mean concentration of EC in PM_{10} (0.04 – 0.09 µg C/m^3) and $PM_{2.5}$ (0.04 – 0.10 µg C/m^3) at Norwegian rural background sites are amongst the lowest in Europe. EC is a result of incomplete combustion of fossil fuel and biomass and emissions are thus almost exclusively associated with the fine fraction of PM_{10}. EC was a minor contributor to the total carbon (TC) concentration; i.e., 5 – 9% (PM_{10}) and 8 – 13% ($PM_{2.5}$). EC levels at Hurdal were 50 - 67% higher than at Birkenes and 125 – 150% higher than at Kårvatn, considering both the PM_{10} and $PM_{2.5}$ size fractions. The wide ranges and differences between size fractions are misleading and result from the very low levels and “decimal-issues”. As argued for OC in Chapter 4.2, we assume that the higher levels of EC at Hurdal is caused by the more densely populated and anthropogenic influenced region surrounding the site; albeit crude, EC is regarded as a tracer of anthropogenic activity.

There was a seasonal variability with increased levels of EC in winter (September - April) compared to summer (March - October) at all sites. This seasonality was only minor for Birkenes, but pronounced at Hurdal (Table 4.1). 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. Increased winter-time concentrations of levoglucosan at Birkenes for the period 2008 – 2015, clearly shows that EC from residential wood burning contributes to the observed seasonality of EC.

The annual mean concentration of EC was below -1 SD of the long-term mean at Birkenes and Hurdal, whereas it equalled -1 SD of the long-term mean at the Kårvatn site. For Birkenes and Hurdal, the annual mean EC concentration for 2016 was the lowest recorded so far, and by a noticeable margin, whereas for Kårvatn the annual mean equalled the previous year record low for EC in PM_{10}, whereas it was an all-time low for the EC in $PM_{2.5}$.

Table 4.1: 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 2016.

Month	PM_{10}			$PM_{2.5}$		
	OC	EC	TC	OC	EC	TC
Birkenes						
January	0.56	0.10	0.66	0.49	0.10	0.58
February	0.37	0.05	0.43	0.33	0.04	0.37
March	0.60	0.07	0.67	0.57	0.08	0.65
April	0.53	0.05	0.58	0.41	0.05	0.46
May	1.34	0.10	1.45	0.93	0.09	1.02
June	1.41	0.06	1.47	1.05	0.07	1.11
July	0.78	0.03	0.81	0.49	0.04	0.54
August	0.75	0.03	0.79	0.43	0.03	0.46
September	1.00	0.10	1.10	0.66	0.09	0.75
October	0.67	0.08	0.75	0.48	0.08	0.56
November	0.37	0.04	0.42	0.29	0.04	0.34
December	0.39	0.05	0.43	0.30	0.05	0.35
Annual mean	**0.73**	**0.06**	**0.80**	**0.54**	**0.06**	**0.60**
Hurdal						
January	0.87	0.13	1.00	0.82	0.15	0.96
February	0.45	0.07	0.52	0.44	0.08	0.52
March	0.58	0.09	0.67	0.50	0.09	0.59
April	0.58	0.08	0.66	0.43	0.07	0.50
May	1.21	0.10	1.32	0.85	0.09	0.94
June	1.45	0.08	1.53	1.05	0.08	1.12
July	1.25	0.06	1.31	0.78	0.06	0.84
August	1.08	0.06	1.14	0.50	0.05	0.56
September	1.60	0.11	1.71	0.75	0.11	0.86
October	0.83	0.10	0.94	0.58	0.09	0.68
November	0.61	0.11	0.72	0.53	0.11	0.64
December	0.72	0.18	0.90	0.69	0.17	0.87
Annual mean	**0.94**	**0.09**	**1.04**	**0.66**	**0.10**	**0.76**
Kårvatn						
January	0.29	0.05	0.34	0.29	0.05	0.34
February	0.29	0.04	0.33	0.31	0.04	0.35
March	0.36	0.04	0.40	0.33	0.04	0.37
April	0.27	0.02	0.28	0.23	0.02	0.25
May	0.70	0.03	0.73	0.59	0.03	0.62
June	1.37	0.02	1.39	1.13	0.03	1.17
July	1.35	0.03	1.37	0.86	0.03	0.89
August	1.08	0.02	1.10	0.56	0.02	0.58
September	1.53	0.09	1.60	0.77	0.07	0.84
October	0.51	0.06	0.57	0.37	0.06	0.43
November	0.42	0.04	0.45	0.33	0.03	0.37
December	0.21	0.03	0.24	0.18	0.02	0.20
Annual mean	**0.70**	**0.04**	**0.74**	**0.49**	**0.04**	**0.53**

Table 4.2: Annual mean concentrations of OC, EC and TC in PM_{10} and $PM_{2.5}$ at Birkenes Hurdal and Kårvatn for the period 2001 - 2016.

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	0.80	0.09	0.89	0.57	0.08	0.65
2009	0.79	0.10	0.89	0.58	0.09	0.67
2010	0.90	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
2014	0.91	0.09	1.00	0.65	0.08	0.73
2015	0.72	0.09	0.81	0.52	0.08	0.60
2016	0.73	0.06	0.80	0.54	0.06	0.60
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
2014	1.30	0.11	1.42	0.82	0.11	0.93
2015	0.99	0.14	1.14	0.72	0.13	0.86
2016	0.94	0.09	1.04	0.66	0.10	0.76
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
2014	0.95	0.05	1.00	0.66	0.06	0.71
2015	0.64	0.04	0.68	0.47	0.05	0.52
2016	0.70	0.04	0.74	0.49	0.04	0.53

4.4 Relative contribution of EC and OC to PM

The relative contribution of OC to PM_{10} (17 - 28%) and $PM_{2.5}$ (22 - 31%) annually was rather similar, and for Birkenes somewhat lower than for the two other sites, in particular for the PM_{10} size fraction. The highest OC fraction was seen for Kårvatn. The OC fraction of PM was typically higher in summer than in winter, and more pronounced for PM_{10} than for $PM_{2.5}$. The contribution of OC to PM showed a downward trend for PM_{10} (-7%) and an upward trend for $PM_{2.5}$ (3%) for 2001 – 2016 at Birkenes, but neither were statistically significant (Table 5.5.).

The relative contribution of OC to $PM_{10-2.5}$ was 10 - 20% on an annual basis, and the fraction was approximately 3 times higher in summer (16 – 29%) compared to winter (5.3 – 8.7%), thus explaining the more pronounced seasonality observed for OC in PM_{10} compared to $PM_{2.5}$. An upward trend was shown for the OC fraction in $PM_{10-2.5}$ (20%) at Birkenes for the period 2001 – 2016, but as for the OC fraction in PM_{10} and $PM_{2.5}$, the trend was not statistically significant.

EC accounted for 1.4 – 2.3% of PM_{10} annually, whereas the range for $PM_{2.5}$ was somewhat higher (2.4 – 3.8%), reflecting that EC is associated with fine aerosol particles. EC was more abundant in the winter-time aerosol (1.7 - 3.2% for PM_{10} and 3.1 – 4.5% for $PM_{2.5}$) than the summer-time aerosol (1.0 – 1.9% for PM_{10} and 1.5 – 2.9% for $PM_{2.5}$). A decrease in the relative contribution of EC to PM_{10} (-22%) and $PM_{2.5}$ (-12%) was observed for 2001 – 2016 at Birkenes, although only statistically significant for the PM_{10} size fraction.

4.5 Trends for concentrations of EC and OC

The Mann Kendall method described in Chapter 3.2 was used for trend analysis of concentrations of EC and OC. The shorter time series for the sites Hurdal and Kårvatn (7 years) allow for an assessment of the Birkenes site only (Table 4.3). 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.

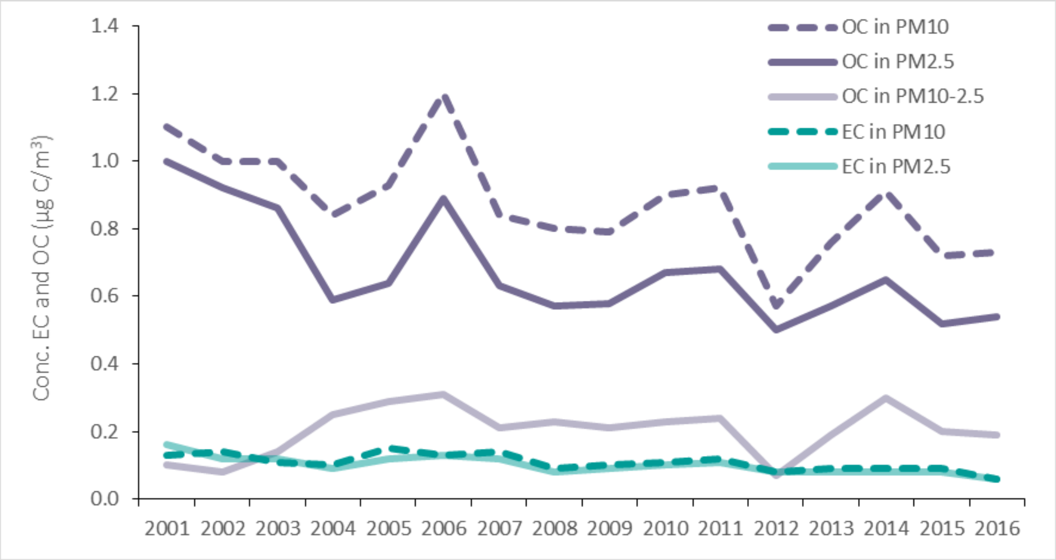


Figure 4.1: Annual mean time series of EC and OC, as observed at Birkenes during the period 2001 - 2016.

There was a statistically significant downward trend for the annual mean concentration of OC in both PM_{10} (-32%) and $PM_{2.5}$ (-43%) at Birkenes for the period 2001 – 2016. For OC in $PM_{10-2.5}$, a statistically non-significant increase of 18% was observed for the same period. EC showed a statistically significant downward trend for both PM_{10} (-43%) and $PM_{2.5}$ (-50%) for 2001 – 2016.

*Table 4.3: Trends in annual mean mass concentration of OC, EC and TC in PM10 (2001 - 2016) and PM2.5 (2001 - 2016) 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.*

Site	PM_{10}	% change	$PM_{2.5}$	% change
Birkenes				
OC	**	-32 %	**	-43 %
EC	**	-43 %	***	-50 %
TC	**	-38 %	**	-42 %

Trends are calculated for time series extending 10 years

4.6 Summary

Observed annual mean concentrations of carbonaceous aerosol in the Norwegian rural background environment are amongst the lowest in Europe (OC < 1 µg C m^{-3} and EC < 0.1 µg C m^{-3}), and a statistically significant downward trend was observed for OC (-32 - -43%) and EC (-43 - -50%) in PM_{10} and $PM_{2.5}$ for the period 2001 – 2016.

OC and EC are operational definitions and do not provide any insight per se about the contributing source(s), thus complementary measurements are needed for a more detailed assessment of sources and source regions. Previous source apportionment studies of the carbonaceous aerosol in the Norwegian rural background environment show that natural sources, biogenic secondary organic aerosol (BSOA) and primary biological aerosol particles (PBAP), dominate the organic aerosol in summer, whereas anthropogenic sources, fossil fuel and biomass burning, dominate in winter. With a few exceptions, elemental carbon can be considered exclusively anthropogenic.

5. Particulate matter, mass concentrations

5.1 Introduction

Monitoring of the PM_{10} and $PM_{2.5}$ mass concentration takes place at three rural background sites; the Birkenes Observatory and the Hurdal and Kårvatn sites. The time series at Birkenes dates back to 2000/1, whereas measurements were initiated in 2010 at the two other sites. At Birkenes, high time resolution measurement of the aerosol size distribution for the size range 0.01 – 10 µm, was initiated in 2010.

Annual and monthly mean mass concentrations of PM_{10}, $PM_{10-2.5}$ and $PM_{2.5}$ for 2016, obtained by gravimetric measurements, are shown in Table 5.1, whereas annual mean mass concentrations of PM_{10}, $PM_{10-2.5}$ and $PM_{2.5}$ for the time period 2000 – 2016 are listed in Table 5.2. Time series of PM_{10} and $PM_{2.5}$ for 2016 are shown in Note that $PM_{10-2.5}$ is derived from the observed values of PM_{10} and $PM_{2.5}$. Incidences of $PM_{2.5} > PM_{10}$ and $\Sigma PM_{2.5}, PM_{10-2.5} \neq PM_{10}$ on a monthly basis are typically due to a different number of samples for PM_{10} and $PM_{2.5,}$ but for low levels measurement uncertainties can have an influence as well. Annual means of aerosol particle number (N) concentrations for ultrafine ($0.02 < D_p < 0.1$ µm), accumulation mode ($D_p = 0.1 - 1.0$ µm) and coarse mode ($D_p = 1.0 - 10$ µm) particles, are shown in Table 5.6. Background information on the PM can be found in Annex 3.

Table 5.1: Annual and monthly mean concentrations of PM_{10}, $PM_{10-2.5}$ and $PM_{2.5}$ at Birkenes, Hurdal and Kårvatn for 2016. Unit µg/m^3.

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	2.4	1.7	4.1	3.6	0.8	4.5	1.0	0.4	1.4
FEB	2.0	1.8	3.8	2.0	1.3	3.3	0.8	0.4	1.2
MAR	3.7	1.4	5.1	2.7	1.4	4.1	1.1	0.6	1.7
APR	2.3	1.7	4.0	1.9	1.0	2.9	-	-	1.5
MAY	3.3	2.0	5.3	3.3	1.6	4.9	2.2	0.8	2.9
JUN	3.7	2.0	5.6	3.5	1.7	5.1	3.8	1.8	5.6
JUL	2.4	1.5	3.9	2.7	1.4	4.1	2.6	1.1	3.7
AUG	1.8	1.7	3.5	1.7	1.7	3.5	1.7	1.4	3.1
SEP	3.0	3.5	6.5	3.0	2.8	5.8	2.4	2.1	4.5
OCT	1.7	1.4	3.1	2.3	1.0	3.3	1.1	0.8	1.9
NOV	1.5	1.3	2.9	2.0	0.7	2.7	0.9	0.6	1.6
DEC	1.8	2.5	4.3	2.7	1.1	3.8	0.5	0.5	1.0
2016	*2.5*	*1.9*	*4.3*	*2.6*	*1.4*	*4.0*	*1.6*	*1.0*	*2.5*

Table 5.2: Annual mean mass concentrations of PM_{10}, $PM_{10-2.5}$, $PM_{2.5}$ and PM_1 at Birkenes, Hurdal and Kårvatn for the period 2000 - 2016.

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	5.0	3.1	8.1
2007	2.7	3.3	2.3	5.6
2008	2.2	3.0	2.9	5.9
2009		3.6	2.4	6.0
2010		3.4	3.0	5.1
2011		4.2	3.2	7.0
2012		3.0	2.2	4.9
2013		2.9	2.0	4.9
2014		3.4	2.6	6.1
2015		2.7	2.6	5.4
2016		2.5	1.9	4.3
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
2014		3.8	1.9	5.7
2015		2.8	1.5	4.2
2016		2.6	1.4	4.0
Kårvatn				
2010		3.2	0.9	3.9
2011		2.6	1.1	3.6
2012		2.5	1.0	3.4
2013		2.2	0.9	3.1
2014		3.3	1.1	4.3
2015		1.5	0.9	2.3
2016		1.6	1.0	2.5

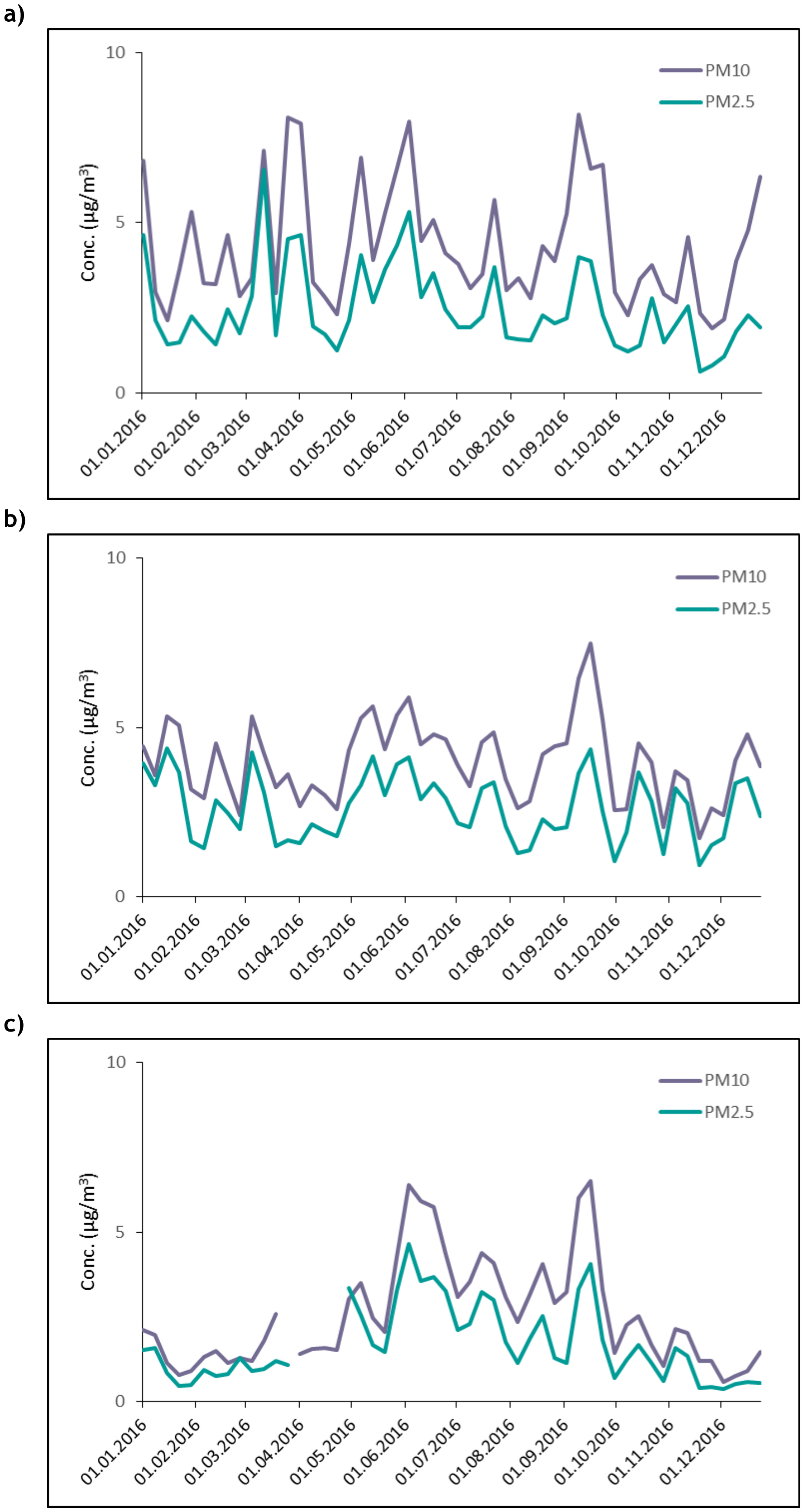


Figure 5.1: Time series of PM_{10} and $PM_{2.5}$ mass concentration for Birkenes (a), Hurdal (b) and Kårvatn (c) for 2016. Unit µg/m^3. Note that the time series have been harmonized in time for comparability; i.e. they all start on the same date (01.01.2016).

5.2 PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$ concentrations

The annual mean mass concentration of PM_{10} (2.5 - 4.3 µg/m^3) and $PM_{2.5}$ (1.6 – 2.6 µg/m^3) at the Norwegian rural background sites are amongst the lowest in Europe. $PM_{2.5}$ was the major fraction of PM_{10} at all sites on an annual basis, accounting for 58% at Birkenes, 66% at Hurdal and 62% at Kårvatn. $PM_{10-2.5}$ was occasionally the major fraction of PM_{10} on a monthly basis, and are typically attributed to natural sources, such as sea salts and primary biological aerosol particles (PBAP).

The annual mean concentration of PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$, was the lowest reported so far for Birkenes and Hurdal (2010 not accounted for at Hurdal, as it is not a full year). The annual means were also low at Kårvatn, although not record low. Except from $PM_{10-2.5}$ at Hurdal and Kårvatn, the annual means were below -SD of the long-term mean at all sites. Note that the measurements for Hurdal and Kårvatn only dates back to 2010, whereas measurements at Birkenes were initiated in 2000/2001.

Higher levels of PM_{10} at Birkenes compared to Hurdal and Kårvatn were consistent with previous years and can partly be explained by a higher $PM_{10-2.5}$ level at Birkenes. This difference was largely attributed to the sea salt concentration, which was 3 times higher at Birkenes compared to the two other sites, reflecting that Birkenes is situated no more than approximately 20 km from the coast. It is also likely that a larger fraction of NO_3^- reside in the coarse fraction of PM_{10} at Birkenes, following from the reaction between gaseous HNO_3 and coarse mode NaCl. Coarse mode organic matter (OM), dominated by PBAP, was noticeably higher at Hurdal compared to Birkenes and Kårvatn, counteracting some of the observed difference. At Kårvatn, also the $PM_{2.5}$ level was noticeably less than at Birkenes, thus contributing to the observed difference seen for the PM_{10} size fraction.

The annual mean $PM_{2.5}$ concentration was higher at Hurdal compared to Birkenes (marginally only) and Kårvatn, and is consistent with previous years. For Kårvatn the difference is explained by lower levels of OM, EC and secondary inorganic aerosol constituents (SIA) (i.e., SO_4^{2-}, NO_3^-, NH_4^+, typically residing in the fine fraction of PM_{10}). SIA levels are higher at Birkenes than at the two other sites, particularly compared to Kårvatn, even though a larger fraction of SIA, and NO_3^- in particular, likely is associated with the coarse fraction of PM_{10} at Birkenes. Higher OM levels at Hurdal counteract some of the difference gained by SIA at Birkenes. Differences in the OC to OM conversion factor, a factor used to account for other elements than carbon associated with OC, could contribute to the observed differences as well, but remains speculative.

The 2016 PM_{10} and $PM_{2.5}$ time series at Birkenes were episodic (Figure 5.1), reflecting episodes of long-range atmospheric transport, but also emissions from local to regional scale sources, such as e.g. sea spray. Some of these periods observed at Birkenes were also seen at Hurdal, and to some extent at Kårvatn, but with levels typically being somewhat lower. Weekly mean concentrations of PM_{10} and $PM_{2.5}$ did not exceed 10 µg m^{-3} at any of the sites.

Secondary inorganic aerosol (SIA) was the major fraction of PM_{10} for two of the four samples included in the 95 percentile at Birkenes, i.e. when PM_{10} levels were elevated, whereas the two others were where dominated by Organic matter (OM) and sea salt aerosol. At Hurdal and Kårvatn, the highest weekly means were all dominated by OM and appeared exclusively in summer. Source apportionment studies (Yttri et al., 2011a, b) show that natural sources dominate OM in PM_{10} at Norwegian rural background sites in summer, with biogenic secondary organic aerosol (BSOA) being the major source followed by primary biological aerosol particles (PBAP), whereas wild fires occasionally make a noticeable contribution. The fine fraction of PM_{10} was typically the most abundant when peak levels of PM_{10} were observed, although not by much, ranging from 57 – 65% on average. This reflect a noticeable influence of coarse fraction PM as well, originating mainly from sea salt aerosol, PBAP, and NO_3^- . Two of the four days included in the 95 percentile were identical at the three sites.

5.3 Trends

The Mann Kendall method described in Chapter 3.2 was used for trend analysis of PM concentrations. Only time series extending 10 years was assessed; i.e., Birkenes (Table 5.3). A statistically significant downward trend was observed for the annual mean concentration of PM_{10} at Birkenes, corresponding to a decrease of -29%. The observed downward trend for $PM_{2.5}$ was also statistically significant, corresponding to a decrease of -42%. A non-significant increase of 11% was observed for $PM_{10-2.5}$.

*Table 5.3: Trends in annual mean mass concentration of PM_{10} (2000 - 2016) and $PM_{2.5}$ (2001 – 2016 at Birkenes) 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.*

Site	PM_{10}	% change	$PM_{2.5}$	% change
Birkenes	*	-29 %	**	-42 %

5.4 Compliance with EU limit values and Air-Quality Guidelines for PM10 and PM2.5

The EU annual limit value for PM_{10} and $PM_{2.5}$ (See Table 5.4 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 approximately 10% of the annual limit values. This was also the case when compared to the WHO Air-Quality Guidelines (AQG); the highest annual mean concentrations accounting for 22 – 26% of the annual AQG.

New national limit values for PM_{10} and $PM_{2.5}$ were implemented from 1st of January 2016 (Table 5.4). These are less stringent than the WHO AQG, and thus far from being violated at any of the three sampling sites in 2016. The National Air-Quality Guidelines (FHI, 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 2016, accounted for no more than 22% and 33% of the PM_{10} and $PM_{2.5}$ National AQG, respectively.

Table 5.4 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
National Limit values[1)]		
PM_{10}	50 µg/m^3 (≤ 30 days yr^{-1})	25 µg/m^3
$PM_{2.5}$		15 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[1)]		
PM_{10}	30 µg/m^3	20 µg/m^3
$PM_{2.5}$	15 µg/m^3	8 µg/m^3

1) New national limit values. Implemented from the 1st of January 2016.

5.5 Chemical composition of particulate matter

EC and OC were measured in the PM_{10} and $PM_{2.5}$ size fractions at the Birkenes, 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^+) were obtained from open filter face samplers with a cut-off size exceeding 10 µm equivalent aerodynamic diameter (EAD). However, most of these species typically reside within the PM_{10} fraction. Occasionally, sea salt aerosol larger than PM_{10} could be collected, i.e., during stormy weather conditions at Birkenes, at a southerly wind direction. The data obtained from the monitoring program appear to be well suited for a mass closure for PM_{10}, except that species representing soil and 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 have to be made according to 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. The speciated mass explained 68 – 88% of the annual mean concentration of PM_{10} for the three sites, approaching full mass (84 – 100%) when allowing for other elements than carbon for OC and EC. The PM_{10} SIA fraction was noticeably higher at Birkenes (44%) compared to Hurdal (32%) and Kårvatn (24%), reflecting the higher relative contribution of NO_3^- (23%) at Birkenes compared to the two other sites (Hurdal: 14%; Kårvatn: 7.8%), as well as the proximity of Birkenes to important source regions in continental Europe. The relative contribution of NH_4^+ to PM_{10} mirrors that of NO_3^-, with higher levels at Birkenes (7.3%) compared to Hurdal (4.9%) and Kårvatn (3.2%), whereas the SO_4^{2-} fraction was rather similar at the three sites (13 – 14%). NO_3^- continued to be the most abundant single (SIA) species at Birkenes and Hurdal, which is consistent with the situation observed since 2011, except for 2014, for which emissions from the Bárðarbunga volcano on Iceland caused SO_4^{2-} to be higher than NO_3^- at Hurdal. At Kårvatn, SO_4^{2-} was more abundant than NO_3^- in 2016.

Converting OC to OM using a factor of 1.7 (Yttri et al., 2007), made OM (48%) twice as abundant as SIA at Kårvatn. OM (40%) was higher than SIA also at Hurdal, whereas OM (29%) was substantially less than SIA at Birkenes. The higher relative contribution of EC at Hurdal (2.3%) compared to Kårvatn (1.6%) and Birkenes (1.4%) is consistent with previous years, likely reflecting the more densely populated and anthropogenic influenced region surrounding the Hurdal site.

Situated approximately 20 km from the coastline, Birkenes experienced a substantial 23% sea salt aerosol contribution to PM_{10}, which is 2-3 times higher than for the other two sites. The sea salt aerosol fraction of PM_{10} has nearly doubled since 2010 compared to the previous 10 years period at Birkenes. This is mainly due to an increased sea salt aerosol level after 2010, but also to some extent due to lower PM_{10} levels for the same period.

Both the relative contribution of NO_3^- (23%) and sea salt aerosol (23%) to PM_{10} in 2016 were higher than + one standard deviation of the long term mean (±SD) at Birkenes, and thus contributes to the significant upward trend observed for these species/fraction (Table 5.5) for the period 2001 - 2016. The SO_4^{2-} (14%) and EC (1.4%) fractions of PM_{10} were the only ones with a statistically significant downward trend, and the 2016 annual mean was below – one standard deviation of the long term mean for both. TC is the most robust species obtained from TOA, as it is not associated with the uncertainties in the split between OC and EC; No statistically significant up or downward trend was observed for the fraction of TC in PM_{10}, nor in $PM_{2.5}$.

*Table 5.5: Trends in relative contribution of selected aerosol particle species and fractions to mass concentration of PM_{10} and $PM_{2.5}$ 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.*

Site	Species/Fraction	Time period	Change (%)
Birkenes	SO_4^{2-} to PM_{10}	2001 – 2016	* -33%
	NO_3^- to PM_{10}	2001 – 2016	** 106%
	NH_4^+ to PM_{10}	2001 – 2016	15%
	$\Sigma Na^+, Cl^-, Mg^{2+}$	2001 – 2016	*** 173%
	OC_{PM10} to PM_{10}	2001 – 2016	-7%
	EC_{PM10} to PM_{10}	2001 – 2016	+ -22%
	TC_{PM10} to PM_{10}	2001 – 2016	-19%
	$OC_{PM2.5}$ to $PM_{2.5}$	2001 – 2016	3%
	$EC_{PM2.5}$ to $PM_{2.5}$	2001 – 2016	-12%
	$TC_{PM2.5}$ to $PM_{2.5}$	2001 – 2016	3%

Trends are calculated for time series extending 10 years

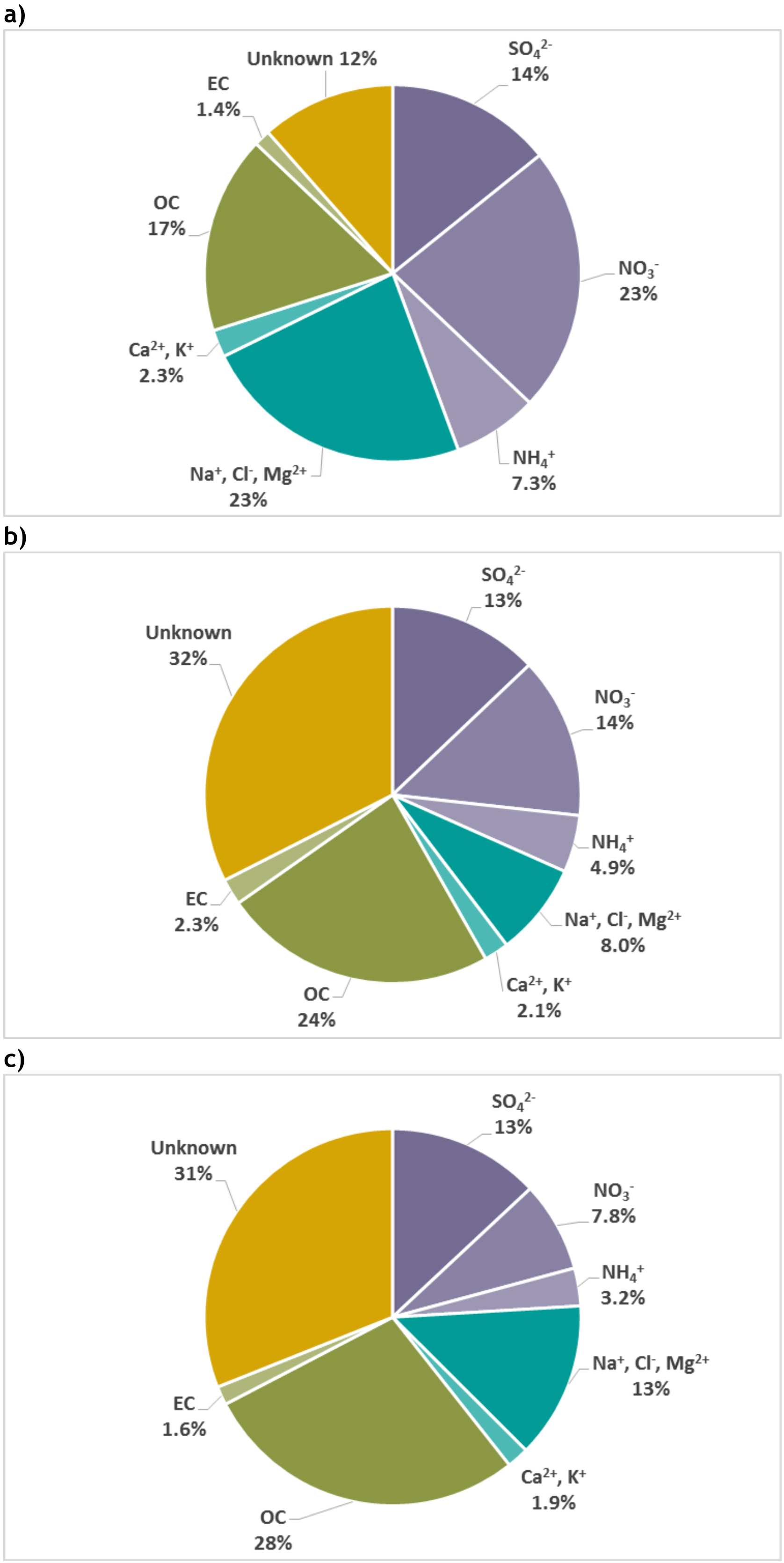


Figure 5.2: Annual mean chemical composition of PM_{10} at the Birkenes Observatory a), the Hurdal site b) and the Kårvatn site c) for 2016. The annual mean mass concentration for PM_{10} in 2016 was 4.3 µg/m^3 at the Birkenes Observatory, 4.0 µg/m^3 at the Hurdal site, and 2.5 µg/m^3 at the Kårvatn site.

5.6 Particle number concentrations

The annual mean particle number concentration for the size range 0.02 – 10 µm (N_{Tot}) at Birkenes for 2016 was comparable to the long-term mean of the six proceeding years, being only 2% lower. Also the N_{UF} (0.01 – 0.1 µm) and the N_{Acc} (0.1 – 1.0 µm) size fractions were highly comparable to the long-term mean, which is to be expected as nuclei and Aitken mode particles, and to some extent the lower size fractions of the accumulation mode, dominates the particle number concentration.

75% of N_{Tot} was attributed to N_{UF} and 25% to N_{Acc} at Birkenes for 2016, whereas a negligible fraction was assigned to particles in the range 1.0 – 10 µm; i.e., the coarse mode. The fraction of N_{tot} attributed to N_{UF}, N_{Acc} and N_{CM} do not vary much between years. N_{UF} was the dominating fraction regardless of season, accounting for 70 – 75% of N_{tot}, which is consistent with previous years. Typically, the N_{UF} fraction drops in winter, whereas the N_{Acc} fraction increases correspondingly, so also for 2016.

Table 5.6.: Number concentrations for ultrafine, accumulation mode and coarse mode particles at Birkenes for 2010 - 2016 and their relative share to the total concentration. Unit: cm^{-3}.

Year	**Ultrafine particles**		**Accumulation mode particles**		**Coarse mode particles**		**Total concentrations**
N (cm^{-3})	**(*Dp* <0.1µm)**	(%)	**(0.1 µm < *Dp*. < 1.0 µm)**	(%)	**(1.0 µm < *Dp* < 10 µm)**	(%)	**(*Dp* = 0.01 - 10 µm)**
2010	973	73	362	27	0.256	0	1336
2011	1047	74	371	26	0.565	0	1418
2012	889	77	263	23	0.375	0	1152
2013	1020	77	304	23	0.391	0	1324
2014	1279	74	456	26	0.338	0	1735
2015	1326	77	390	23	0.340	0	1717
2016	1063	75	357	25	0.392	0	1421

5.7 Summary

Observed annual mean concentrations of PM_{10} and $PM_{2.5}$ in the Norwegian rural background environment are amongst the lowest in Europe (<5 µg/m^3), and do not exceed international and national limit values and air quality guidelines in 2016. Secondary inorganic aerosol constituents dominate PM_{10} at the southernmost site assessed, reflecting the proximity to major anthropogenic emission regions in continental Europe, then organic aerosol, and sea salt aerosol. Organic aerosol dominate at the two other sites.

There is a significant downward trend for both PM_{10} and $PM_{2.5}$ (-29% - -42%) for the period 2000/01 – 2016, which is in line with emission reductions of primary and secondary sources in Europe. However, measurements of source specific compounds and high time resolution measurements along with transport modelling are needed for a for a more detailed assessment of sources and source regions.

6. Ground-level ozone

Ozone in the troposphere originates from photo-chemical reactions in the atmosphere between volatile organic compounds (VOCs), CO, methane (CH_4) and nitrogen oxides (NOx) under the influence of solar radiation, as well as from the transport of stratospheric ozone into the troposphere. VOCs, CO and CH_4 are emitted from anthropogenic sources such as road and ship traffic, leakage of natural gas, use of solvents and chemicals etc., and NOx is mainly emitted from traffic and power plants. In addition, biogenic sources (trees and plants) contribute significantly to the emission of VOCs and CH_4 and to a smaller extent to NOx (microbiological activity in soils). On a global basis lightning is also an important source of NOx in the troposphere. Thus, tropospheric ozone is the result of what is produced by both natural and man-made processes. Furthermore, the weather conditions have a strong influence on the efficiency of the ozone formation since the chemical reactions are generally favoured by solar radiation and high temperatures.

Once formed, tropospheric ozone is only slowly degraded by chemical reactions with OH, HO_2 and NO_2. The chemical lifetime of ozone in the free troposphere is of the order of several weeks. At the land surface, however, dry deposition and uptake in vegetation are effective loss mechanisms for ozone. Ozone dry deposition is determined by the local topography and land use and could be very important for the concentrations observed at surface monitoring sites in summer, particularly at continental stations with a strong diurnal cycle in surface temperature. 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. According to European Environment Agency (EEA) particulate matter (PM) and surface ozone are Europe's most problematic pollutants in terms of harm to human health (EEA, 2014). Furthermore, surface ozone is considered to be the most damaging air pollutant to vegetation in Europe today, with significant effects on the growth of trees, on vegetation in general, and on important agricultural crops.

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. Materials such as rubber and other polymer compounds can also be damaged by ozone. As opposed to other pollutants, the baseline level of ozone, i.e. the concentration level in remote areas far from emission source regions, is fairly close to the threshold levels for effects on human health and vegetation. Thus, the environmental problems related to surface ozone is a regional and widespread phenomenon.

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 Table 6.1. The stations in the individual zones as of 2016 are indicated in the map in chapter 1 (Figure 1.1) and the details regarding the zone characteristics are given in Table 6.1. The directive gives requirements for the minimum number of monitoring sites within each zone and for the country as a whole, which is reflected 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 2016 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 were reported to the air quality database at NILU where a final validation is done by the National Reference Laboratory for ambient air quality measurements. 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 2016, which was 94% or higher at all stations. The measuring method and principles are given in Annex 3. The data capture was

Table 6.1: The Norwegian zones and the requirements as to the number of monitoring sites based on EU's ambient air quality directive . The situation in 2016 is also shown.

Zone	Region	Type	Area (km^2)	Population (1000)	Ozone [1]	VOC [1]	Stations
1	Greater Oslo	Urban/suburban		1030	2 (3)	0 (1)	Lommedalen[2] Grønland[2]
2	Bergen	Urban/suburban		270	1 (1)		Rådhuset[2]
3	Trondheim	Urban/suburban		180	0 (0)		
4	Østlandet	Rural	110 000	1800	4 (4)		Prestebakke Hurdal Haukenes Birkenes
5	Rogaland, Hordaland, Sogn- og Fjordane	Rural	43 000	790	1 (2)		Sandve
6	Møre og Romsdal, S- og N-Trøndelag, Nordland	Rural	94 000	760	2 (2)		Kårvatn Tustervatn
7	Troms, Finnmark	Rural	74 000	230	0 (1)		
Total	Whole country	Rural background	385 000		11 (13)		All above + Zeppelin

[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 2016.

St.nr.	Station name	Period	Data capture
NO0043	Prestebakke	01.01.16 - 31.12.16	100 %
NO0056	Hurdal	01.01.16 - 31.12.16	96 %
NO0489	Haukenes	01.01.16 - 31.12.16	95 %
NO0002	Birkenes II	01.01.16 - 31.12.16	99 %
NO0052	Sandve	01.01.16 - 31.12.16	97 %
NO0039	Kårvatn	01.01.16 - 31.12.16	99 %
NO0015	Tustervatn	01.01.16 - 31.12.16	94 %
NO0042	Zeppelin	01.01.16 - 31.12.16	94 %

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 increase the ozone levels regularly during the summer season. 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 NOx 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 NOx 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 2016

Time series of daily maximum ozone values through 2016 are given in Figure 6.1 together with the climatological mean seasonal cycle (30 days running mean) based on the previous 16 years of data. Note that for Birkenes, the 2016 data are from the Observatory (Birkenes II), whereas the climatological means are based on measurements at the old location, which gave systematically lower levels due to stronger surface dry deposition.

The time series indicate a few shorter-term episodes with moderately elevated ozone levels in 2016: One in the first part of May affecting nearly all stations, one in the last part of July (the southern sites), one in the last part of August (Prestebakke) and some small short peaks in September at a few of the sites.

No peak levels above 140 $\mu g/m^3$ were observed and thus no severe episodes occurred in 2016 at the Norwegian monitoring sites. As explained in Chapter 2 the weather conditions in the summer of 2016 (July-August) were not particularly favourable for photochemical ozone episodes in Norway (except for the end of July) and the time series in Figure 6.1 reflects this. The peak episode in early May seen at many sites reflect the relatively dry and warm weather conditions this month in large parts of the country. The many smaller ozone peaks in September reflect the dry and very warm conditions that month although at the end of the photochemically avtive period of the year.

The seasonal cycles in ground-level ozone in 2016 are shown in Figure 6.2 together with the climatological mean seasonal cycles for the period 2000-2015 for each site. These figures give the 14 days centred running mean concentrations.

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 during April-September 2016 are shown for three selected sites in Figure 6.3. 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 are less frequent. In contrast to this, the ozone values at the Zeppelin Mountain shows no diurnal cycle.

The diurnal cycle in ground-level ozone is a result of dry deposition to the surface combined with increased atmospheric stability during night-time. Since the deposition of ozone to water and ice/snow surfaces is very small and the monitoring site on the Zeppelin mountain is located above the planetary boundary layer there is no visible diurnal cycle in ozone at that site.

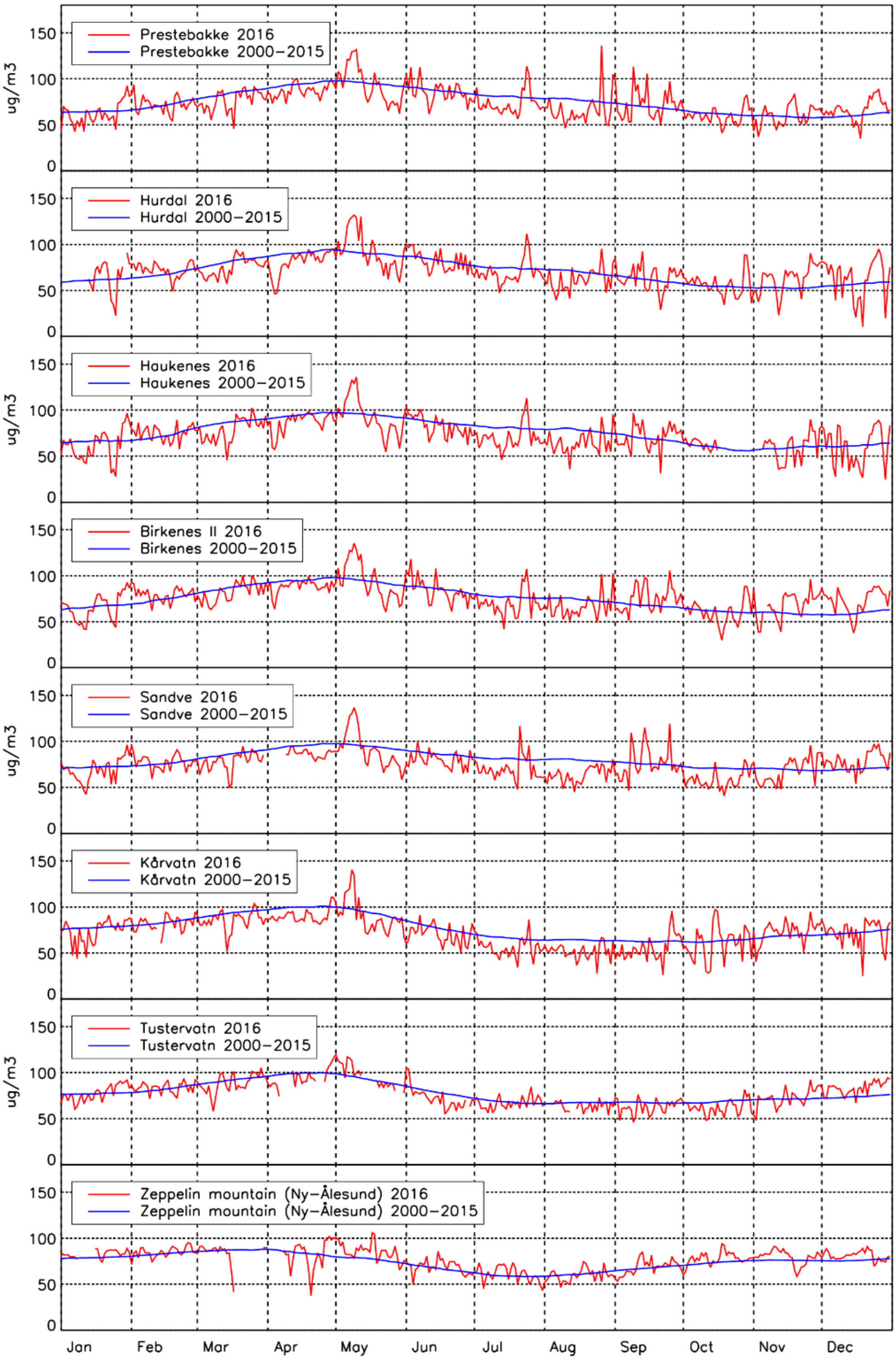


Figure 6.1: Daily maximum ozone concentrations in 2016 (red) together with the 30 days' running mean of the daily maxima for the years 2000-2015 (blue).

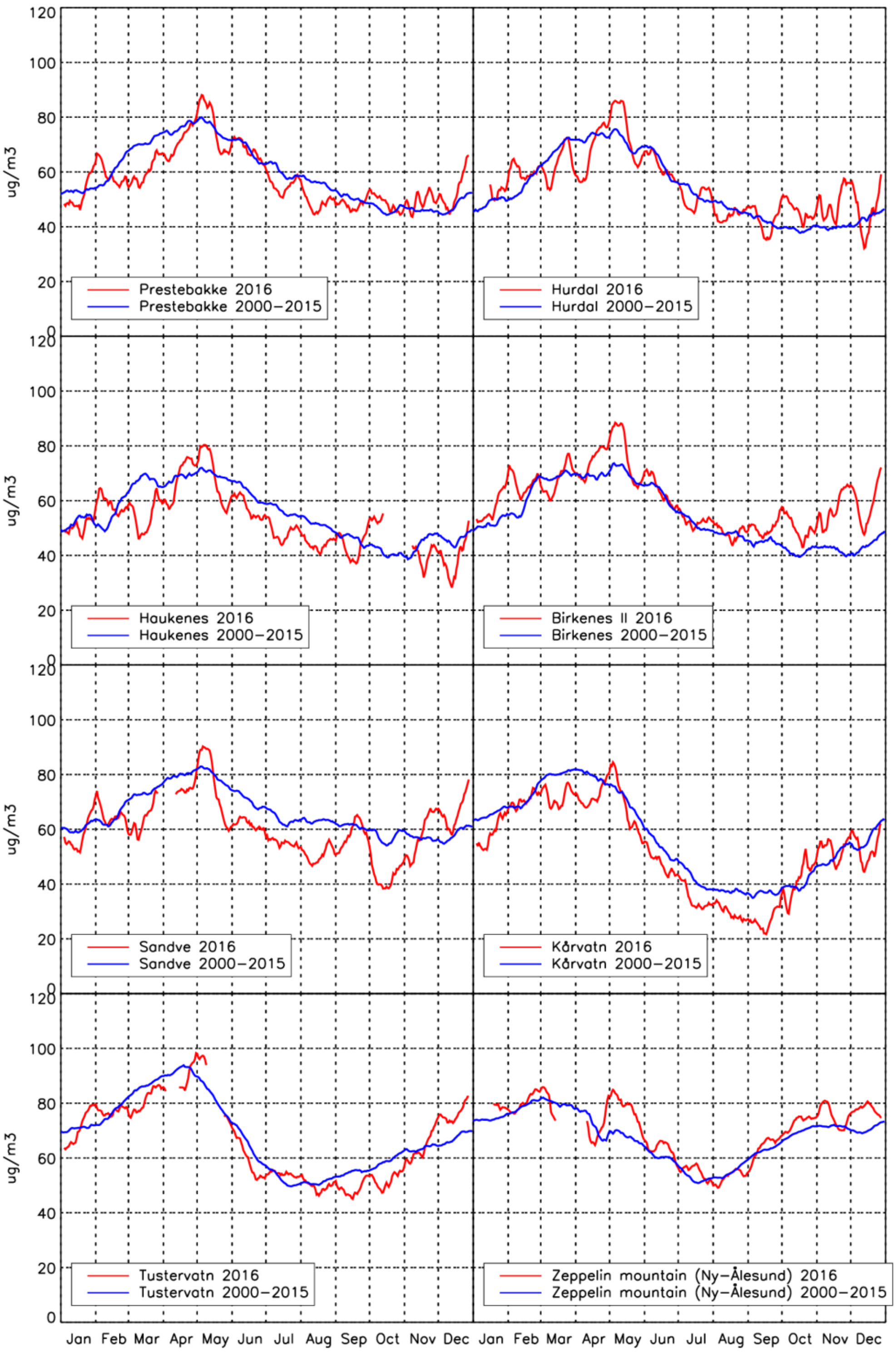


Figure 6.2: The 14 days' running mean ozone concentrations in 2016 (red) together with the corresponding mean concentrations based on all years 2000-2015 (blue).

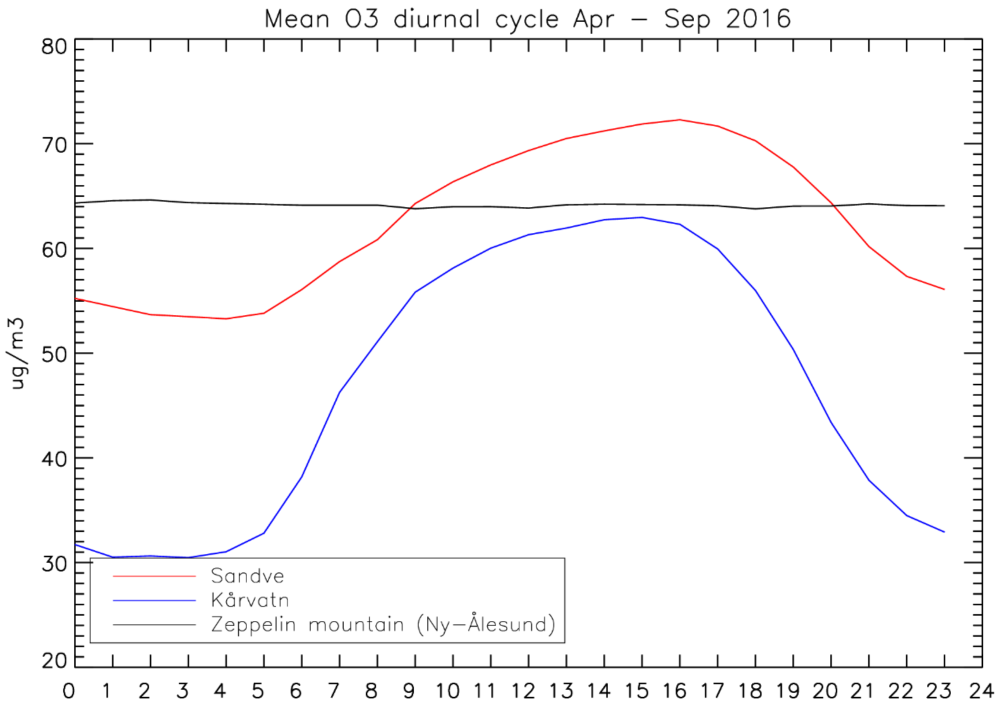


Figure 6.3: *The mean diurnal cycle in ozone at three of the monitoring sites; Sandve, Kårvatn and Zeppelin Mountain during April-September 2016.*

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. EU's third daughter directive relating to ozone in ambient air 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 for ground-level ozone (WHO, 2006). 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.

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.

Table 6.4: For all sites in 2016 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 air quality guidelines, WHO guideline and EU’s limit values as given in Table 1.3 as well as the annual maximum and the date when it occurred.

			National AQ guidelines		WHO	EU directive			
Station	Hours	Days	Days	Hours	Days	Days	Hours	Max. hourly	Date
		>75%	8h > 80 µg/m^3	1h > 100 µg/m^3	8h > 100 µg/m^3	8h > 120 µg/m^3	1h > 180 µg/m^3	value (µg/m^3)	
Prestebakke	8745	366	92	146	16	3	0	136	26.08.2016
Hurdal	8453	355	70	93	9	4	0	132	09.05.2016
Haukenes	8323	348	91	85	9	3	0	136	10.05.2016
Birkenes II	8717	366	108	140	13	4	0	135	09.05.2016
Sandve	8542	359	96	125	12	4	0	137	09.05.2016
Kårvatn	8716	366	108	96	9	2	0	140	08.05.2016
Tustervatn	8237	357	129	165	12	0	0	119	01.05.2016
Zeppelin	8222	348	134	19	3	0	0	106	17.05.2016

EU’s target value for the protection of human health are met in Norway with a very good margin. The long-term objective (=LTO, i.e. max 8h value < 120 µg/m^3) and thereby also WHO’s and Norwegian air quality 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 2016 this LTO was broken at 12 days. Tustervatn and Zeppelin were the only sites where this limit was not exceeded. Thus, although there were no very high ozone episodes in 2016, the number of exceedances of the LTO and the general levels of ozone where higher than in 2015 when very few episodes were seen. The WHO guideline was broken at all sites in 2016 as in all previous years. This reflects that the WHO guideline level of 100 µg/m^3 is close to the mean peak level, implying that a small reduction in the mean level will lead to a large reduction in the number of days with exceedances. The highest hourly ozone concentration in 2016 was 140 µg/m3 observed at Kårvatn 8 May.

The ozone levels and exceedances vary strongly from year to year which is also indicated by Figure 6.4, showing the time trend of the number of days with exceedance of the 8-hour mean value of 120 µg/m^3. Table 6.5 gives the annual peak values and number of days with exceedance from 2003 to 2016. 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 NOx 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.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Annual hourly max. (µg/m^3)	162	150	144	186	139	160	142	145	168	130	124	147	148	140
Number of dates with exceedance of EU's long-term objective of 120 µg/m^3 [a)]	15	21	7	28	8	16	9	3	12	2	2	4	2	12

[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 6.4, 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.

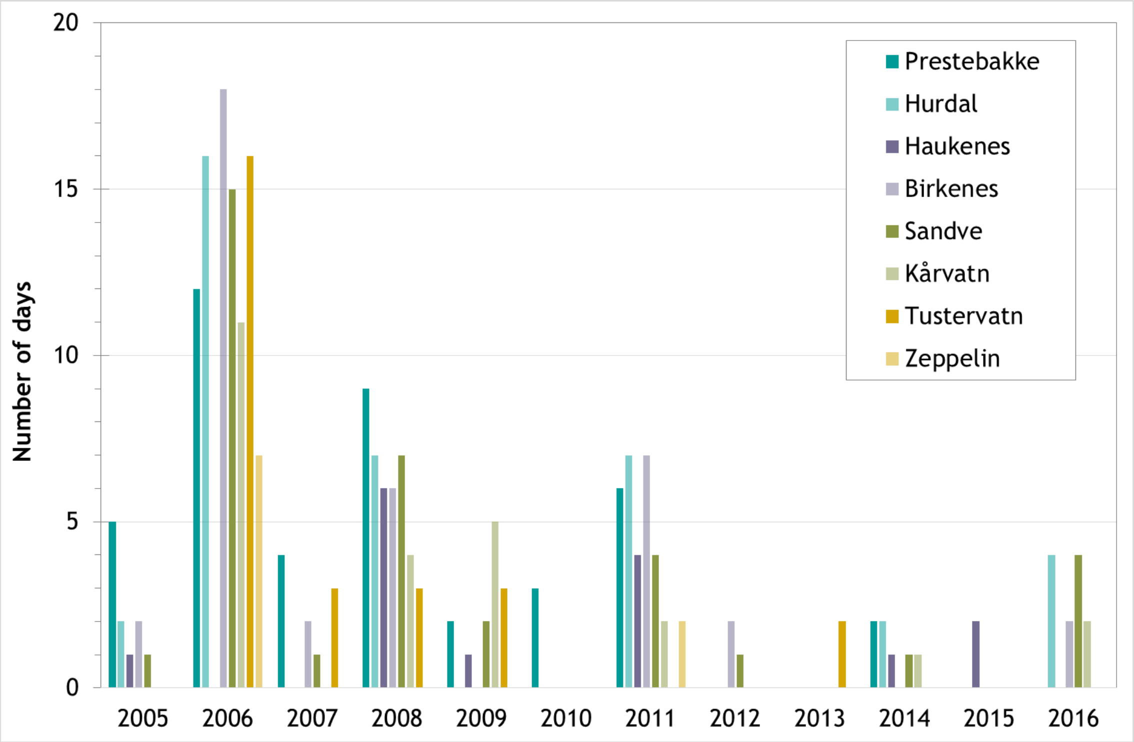


Figure 6.4: The number of days with a maximum daily 8-h mean ozone concentration above 120 µg/m^3 for the period 2005-2016. Note that the Birkenes site has been moved, and data before 2012 refer to the old location. See text for more explanations

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/m^3) 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 the Norwegian sites in 2015. The highest value occurred at Presetbakke with 983 ppb hours which is very low compared to previous years.

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 2016 at the Norwegian sites. The highest value of this parameter was seen at Prestebakke with 3113 ppb hours.

Table 6.7: Data capture and 3-month's AOT40 values for agricultural crops for the period 15 May - 15 August 2016 (unit: ppb hours).

Station	**Data capture (%)**	**AOT40 (corrected for data capture)**
Birkenes II	99	789
Tustervatn	87	362
Kårvatn	99	152
Zeppelin	99	288
Prestebakke	99	983
Sandve	85	348
Hurdal	99	569
Haukenes	100	626

Table 6.8: Data capture and 6-month's AOT40 values for forests for the period 1 April – 1 October 2016 (unit: ppb hours).

Station	**Data capture (%)**	**AOT40 (corrected for data capture)**
Birkenes II	99	3079
Tustervatn	87	3052
Kårvatn	99	2503
Zeppelin	98	1074
Prestebakke	99	3113
Sandve	96	2563
Hurdal	99	2120
Haukenes	100	2647

EU's target value of 9000 ppb hours is met at all the Norwegian stations (Figure 6.5). 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 6.5 refer to the 3 month's period May-July as given in the EU 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 6.5 are based on UN-ECE's definition (global radiation > 50 W/m2) and could therefore not be compared directly with the EU directive.

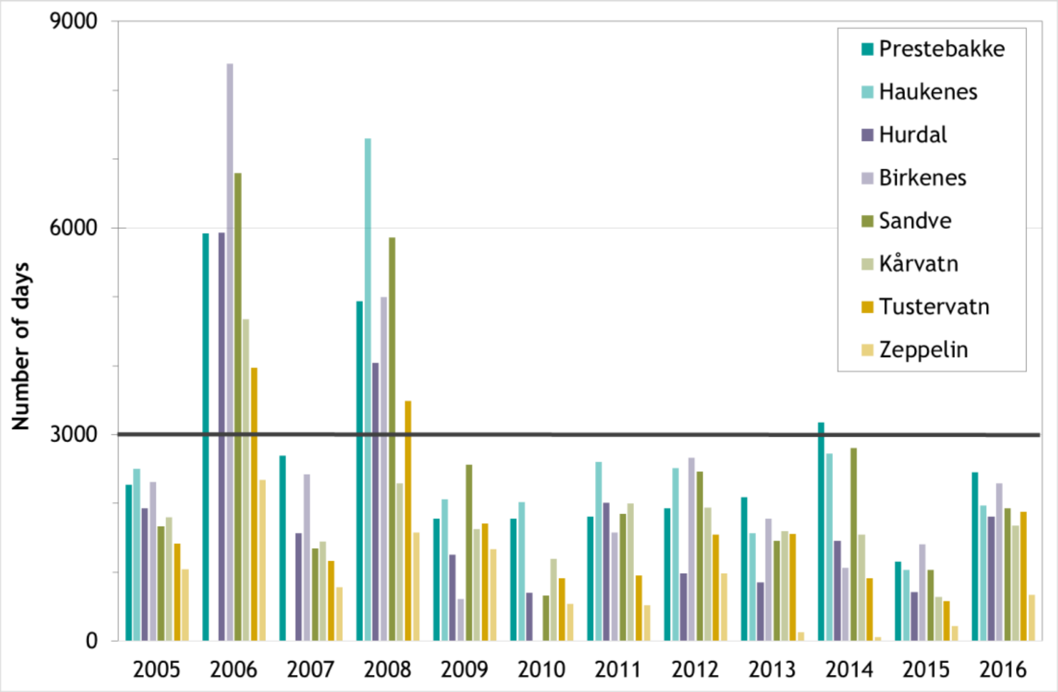


Figure 6.5: 3 months' AOT40 values (1 May - 31 July) for the years 2005 - 2016 (based on UN-ECE's definition of daylight hours). The EU directive's long-term objective of 3000 ppb hours is indicated by the line. The definition of daylight hours given by the EU directive differs somewhat from that given by UN-ECE. Note that the Birkenes site has been moved, and data before 2012 refer to the old location. See text for more explanations

6.6 Long-term trends in ground-level ozone

Owing to its long atmospheric lifetime the long-term trends of ground-level ozone in Norway are the net result of large-scale trends in the hemispheric baseline level with regional/European effects superimposed. Recent studies of the hemispheric baseline ozone indicates a doubling of the mean O_3 from the 1950s up to about the year 2000 followed by a decade with no growth or even reductions in O_3 at some sites, particularly in summer (Logan et al., 2012). Recent studies also indicate a change in the mean seasonal cycle of the baseline O_3 with the seasonal maximum being shifted from summer to spring in recent years.
In contrast to the consistent picture for the baseline, the findings are more mixed for European monitoring stations. Tørseth et al. (2012) found strong declines in the highest O_3 values in the UK and Netherlands and no clear trends in Austria and Switzerland for the period 1990-2010.

Changes in monitoring network (both station locations and instrumentation/methods) is an obstacle to trend assessments. One needs consistent time series from stations running over multiple decades to detect surface ozone trends. A detailed inspection of the Norwegian monitoring history of ground-level ozone was carried out in 2003 (Solberg, 2003) which revealed many technical issues related to the monitoring procedures before 1997 when much more strict guidelines for the QA/QC work was put in operation. Before that year, a monitor in the field could be operating for years without calibration until it finally broke down and, additionally, the performance and stability of the ozone monitors were generally of poorer quality. The review in 2003 provided recommendations for selection of time periods with more reliable ozone for each station to be used for trend analyses. For simplicity we decided to base the trends only on the years from 1996 and onwards in the present chapter.

Figure 6.6 - Figure 6.9 show the development in four ozone metrics from 1990 to 2016; 6 months AOT40 (April-September), 3-months AOT40 (May-July), the number of days with an 8-h running max exceeding 100 $\mu g/m^3$ (WHO guideline) and the 97-percentile of the daily max 8-h running mean April-September. The latter metric corresponds approximately to the annual 4th highest value use in the ozone trend assessment within the EMEP TFMM (Colette et al., 2016) and IGAC TOAR (Tropospheric ozone assessment research) programs.

Results for three stations with long-term monitoring history are given: Prestebakke, Kårvatn and Tustervatn. The values for all years are shown, however only the data from 1996 and onwards were included in the Mann-Kendall/Sen's slope trend estimate. Furthermore, the data from 1998 from Prestebakke were excluded from the analyses based on the mentioned evaluation of the monitoring history (see Solberg, 2003 for details). The trend lines are only given when a statistically significant ($p=0.05$) trend is found. These calculations indicate a downward trend in most metrics/stations based on the 21-years period 1996-2016. For the 3-months AOT40, however, only Kårvatn shows a significant trend.

It should be stressed that with the more unreliable data from the first years (1990-1995) included, clearly less significant trends would be found and that was the basis for the mentioned EMEP TFMM assessment. This reflects a general low level of ozone in 1990-1991 which very likely was a real effect. In addition comes the problem with more uncertain monitoring data in the same period making it somewhat uncertain to what extent these low ozone levels could be attributed to poorer data quality in the early years of monitoring.

It is thus an open question whether the data from this first period should be included in the trend analyses or not.

A reduction in high ozone concentrations are expected due to the substantial reduction in European man-made emissions of NOx and VOC the last decades. The analyses shown here are in line with this. The selection of ozone metric, time period, station and the monitoring procedures are, however, crucial for the estimated trend values. Within the IGAC initiative TOAR a very long list of various ozone metrics is presently used for global trend assessments. Whereas trends in ozone guideline metrics (AOT, exceedance of limit values etc.) are the main interest of the effect community, these metrics are not necessarily the metrics most relevant for evaluating the effect of man-made emission abatement.

Furthermore, observational trends are the combined result of the influence from inter-annual meteorological variability and changes in man-made emissions of ozone precursors. Only supporting modelling data could indicate the influence of each of these effects separately.

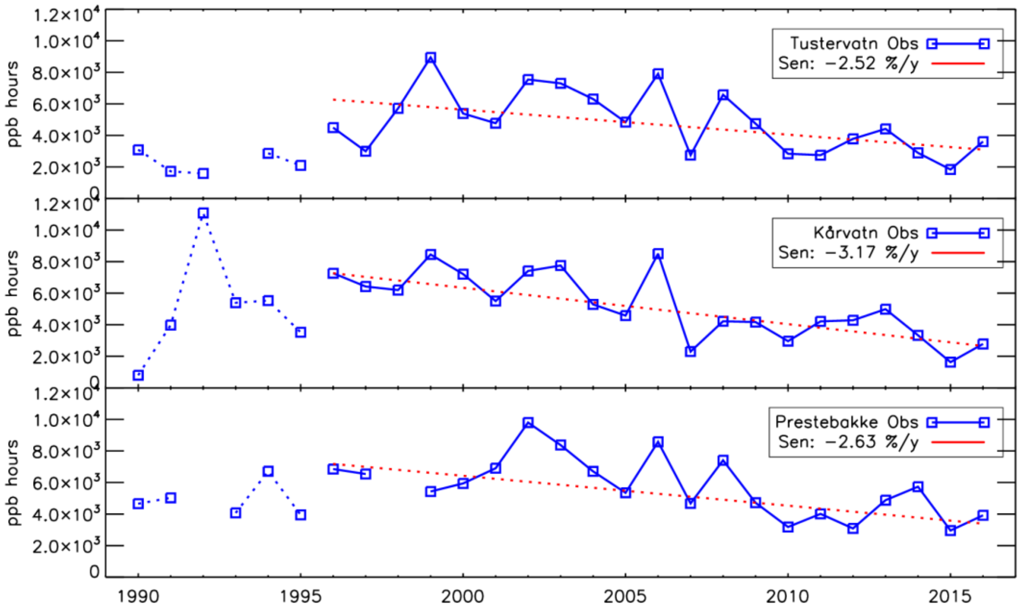


Figure 6.6: The 6-months AOT40 value (April - September, hours 8-20) during 1990-2016 for three sites. The estimated Sen's slope based on annual data for 1996-2016 are marked in red. Data from the first years (1990-1995) are uncertain and not included in the trend calculations and marked with a dotted line.

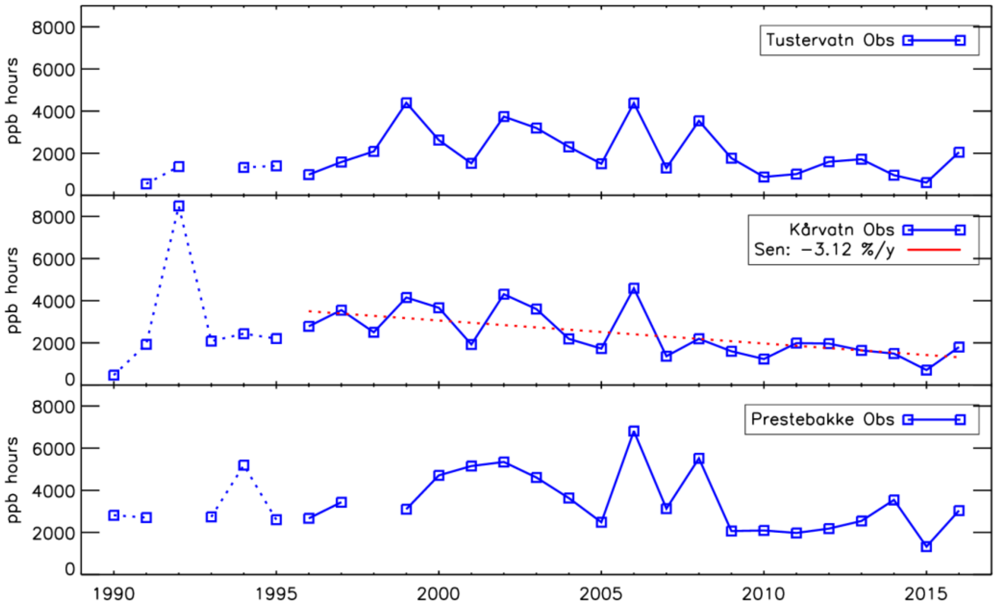


Figure 6.7: Same as Figure 6.6 for the 3-months AOT40 value (May - July, hours 8-20).

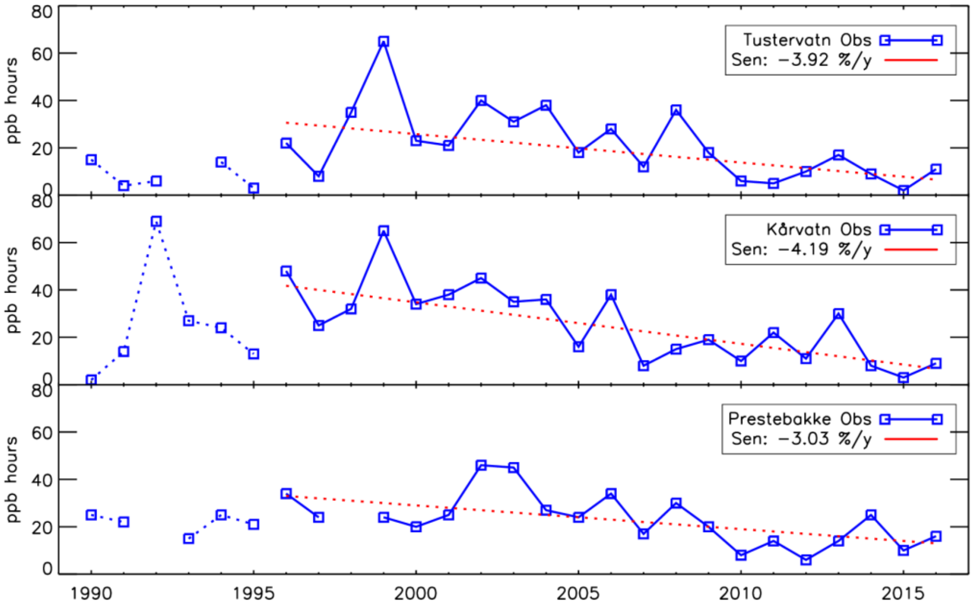


Figure 6.8: Same as Figure 6.6 for the number of days with a maximum 8-h running mean ozone concentration exceeding 100 µg/m^3 (WHO guideline).

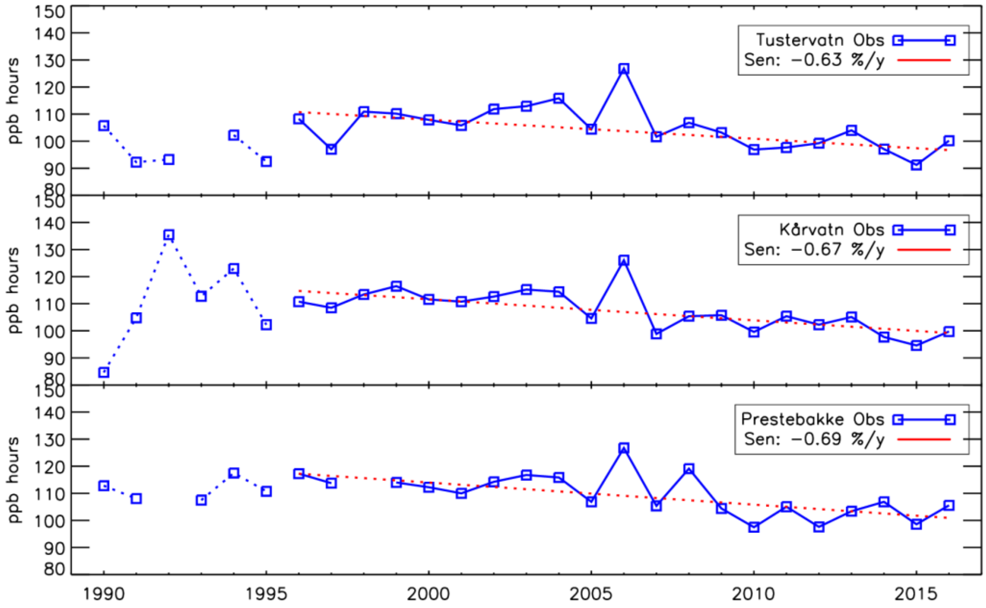


Figure 6.9: Same as Figure 6.6 for the 97-percentile of the daily maximum 8-h running mean ozone concentration April-September.

6.7 Summary

In Norway the levels of ground level ozone is determined by a baseline level varying between 50-100 μg/m^3 (minimum in autumn, maximum in late spring) with a number of summertime photochemical ozone episodes superimposed on this baseline. The baseline doesn't change that much from year to year whereas the photochemical episodes vary substantially with time depending on the summer weather conditions and the European emissions. Whereas the former vary more randomly, the European precursor emissions have been steadily reduced over the last 10-20 years, and thus the severity of the ozone episodes are expected to be reduced as well. The inter annual variations in meteorology could however, mask the effect of the emission reductions.

The levels in 2016 were generally low, reflected by a peak hourly maximum of only 140 μg/m^3. EU's target value (max 25 days with a max 8-h concentration exceeding 120 μg/m^3) and the 1-h information level (180 μg/m^3) has not been exceeded for several years in Norway. The much stricter long-term goal of EU and in particular the WHO and national guidelines, all related to human health, are exceeded every year, reflecting that these limit values are close to the baseline levels. There were more exceedances in 2016 compared to the very low year 2015, presumably reflecting the weather conditions in 2016 vs that for 2015. None of the threshold values for vegetation as based on AOT40 were exceeded in 2016.

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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	2016
Birkenes	4.7	5.07	5.32	5.11	5.06	4.81	4.87	5	4.64	4.65	5.03	4.8	4.91
Vatnedalen	5.34	5.43	5.36	5.45	5.3	5.33	4.86	5.39	5.38	5.45	5.59	5.22	5.3
Treungen	4.8	5.05	5.26	5.11	5.16	4.83	4.85	5	4.78	5.05	5	5.05	4.98
Løken	4.88	5.12	5.04	5.12	5.47	4.99	5.04	4.99	4.97	4.85	4.94	5.12	5.03
Hurdal	4.73	5.04	5.03	5.1	5.13	5.2	4.85	5.13	5.07	4.65	5.1	5.21	5.01
Brekkebygda	4.92	5.39	4.97	5.21	5.08	4.98	4.92	5.24	4.9	4.6	4.99	5.39	5.01
Vikedal	5.13	5.05	5.23	5.19	5.14	4.96	5.12	5.2	5.1	5	5.25	5.23	5.14
Haukeland	5.29	4.92	5.19	5.09	5.05	4.97	5.11	5.17	5.15	5.42	5.28	5.22	5.14
Nausta	5.39	5.31	5.93	5.69	5.62	4.96	4.86	5.26	5.27	-	5.57	4.68	5.13
Kårvatn	5.37	5.42	5.27	5.25	4.76	4.2	5.16	5.3	5.46	5.42	5.53	5.41	5.19
Høylandet	5.57	5.49	5.47	5.65	6.03	5.48	5.33	5.21	5.37	5.55	5.72	5.54	5.47
Tustervatn	5.28	5.08	5.05	5.15	5.23	5.07	5.21	5.27	5.34	5.41	5.36	5.25	5.24
Karpbukt	4.73	5	4.73	4.58	4.63	4.95	4.64	4.85	4.96	4.95	5.32	5.26	4.87
Ny-Ålesund	5.3	5.12	5.65	5.06	5.53	4.81	6.02	5.7	5.51	5.4	5.61	5.84	5.49

Table A.1.2: Monthly and annual volume weighted average concentrations of sulfate (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	2016
Birkenes	0.20	0.16	0.16	0.22	0.21	0.20	0.15	0.12	0.38	0.25	0.07	0.16	0.17
Vatnedalen	0.04	0.13	0.22	0.22	0.16	0.15	0.1	0.17	0.02	0.08	0.07	0.02	0.09
Treungen	0.17	0.14	0.17	0.2	0.18	0.18	0.14	0.09	0.29	0.16	0.11	0.07	0.16
Løken	0.16	0.15	0.16	0.25	0.38	0.19	0.1	0.09	0.2	0.10	0.21	0.15	0.17
Hurdal	0.17	0.18	0.18	0.24	0.23	0.21	0.13	0.07	0.25	0.30	0.1	0.17	0.18
Brekkebygda	0.19	0.14	0.16	0.22	0.22	0.15	0.08	0.09	0.34	0.24	0.08	0.07	0.15
Vikedal	0.03	0.09	0.2	0.21	0.17	0.13	0.14	0.15	0.08	0.11	0.06	0.04	0.1
Haukeland	0.00	0.07	0.14	0.15	0.12	0.13	0.1	0.05	0.08	0.03	0.03	0.03	0.06
Nausta	-0.07	0.09	0.16	0.13	0.16	0.15	0.12	0.07	0.07	-	0.02	0.04	0.07
Kårvatn	0.07	0.09	0.14	0.13	0.16	0.19	0.13	0.05	0.06	0.01	0.02	0.01	0.07
Høylandet	0.07	0.11	0.12	0.12	0.11	0.18	0.08	0.05	0.05	0.01	0.03	0.01	0.05
Tustervatn	0.08	0.1	0.13	0.13	0.14	0.13	0.06	0.03	0.04	0.03	0.02	0.01	0.05
Karpbukt	0.28	0.29	0.38	0.68	0.53	0.2	0.31	0.29	0.23	0.38	0.15	0.10	0.27
Ny-Ålesund	0.09	0.35	0.06	0.37	0.16	1.2	0.22	0.06	0.07	0.08	0.00	-0.02	0.07

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	2016
Birkenes	0.29	0.37	0.41	0.43	0.39	0.37	0.17	0.15	0.98	0.49	0.22	0.42	0.35
Vatnedalen	0.09	0.08	0.41	0.32	0.26	0.09	0.01	0.07	0.01	0.01	0.12	0.06	0.08
Treungen	0.28	0.14	0.33	0.39	0.31	0.22	0.2	0.14	0.65	0.27	0.23	0.2	0.27
Løken	0.29	0.32	0.35	0.47	0.69	0.24	0.13	0.1	0.42	0.21	0.47	0.39	0.3
Hurdal	0.36	0.38	0.38	0.39	0.36	0.24	0.2	0.1	0.47	0.35	0.21	0.36	0.31
Brekkebygda	0.32	0.29	0.42	0.36	0.38	0.1	0.08	0.05	0.58	0.28	0.17	0.22	0.23
Vikedal	0.16	0.13	0.44	0.35	0.26	0.16	0.1	0.18	0.15	0.19	0.13	0.17	0.18
Haukeland	0.11	0.07	0.2	0.15	0.09	0.12	0.06	0.02	0.1	0.02	0.07	0.08	0.08
Nausta	0.08	0.06	0.37	0.12	0.25	0.15	0.07	0.04	0.09	-	0.08	0.06	0.09
Kårvatn	0.04	0.03	0.18	0.14	0.41	1.2	0.09	0.05	0.09	0.05	0.03	0.03	0.1
Høylandet	0.07	0.06	0.12	0.08	0.14	0.11	0.02	0.02	0.02	0.03	0.08	0.05	0.05
Tustervatn	0.07	0.06	0.21	0.16	0.23	0.13	0.05	0.04	0.05	0.03	0.05	0.04	0.07
Karpbukt	0.1	0.14	0.05	0.23	0.12	0.06	0.08	0.05	0.11	0.15	0.07	0.04	0.07
Ny-Ålesund	0.06	0.09	0.04	0.07	0.08	0.35	0.12	0.06	0.05	0.09	0.01	0.02	0.06

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	2016
Birkenes	0.16	0.39	0.63	0.43	0.44	0.15	0.1	0.13	0.81	0.31	0.1	0.37	0.29
Vatnedalen	0.12	0.14	0.73	0.39	0.43	0.03	0.01	0.01	0.01	0.02	0.28	0.11	0.11
Treungen	0.14	0.14	0.67	0.5	0.41	0.12	0.24	0.17	0.49	0.19	0.15	0.24	0.3
Løken	0.15	0.34	0.54	0.55	1.16	0.12	0.09	0.09	0.26	0.08	0.37	0.44	0.31
Hurdal	0.16	0.37	0.42	0.42	0.54	0.31	0.18	0.08	0.53	0.23	0.11	0.28	0.32
Brekkebygda	0.24	0.31	0.53	0.45	0.48	0.08	0.09	0.15	0.52	0.17	0.05	0.32	0.24
Vikedal	0.21	0.2	0.8	0.48	0.33	0.14	0.15	0.23	0.12	0.19	0.14	0.32	0.25
Haukeland	0.16	0.11	0.29	0.19	0.06	0.03	0.04	0.01	0.05	0.02	0.05	0.21	0.11
Nausta	0.26	0.07	0.44	0.33	0.44	0.1	0.06	0.05	0.08	-	0.16	0.12	0.15
Kårvatn	0.04	0.09	0.25	0.12	0.3	0.34	0.14	0.06	0.17	0.04	0.07	0.08	0.11
Høylandet	0.18	0.2	0.39	0.31	0.32	0.13	0.08	0.03	0.04	0.07	0.2	0.21	0.17
Tustervatn	0.07	0.09	0.23	0.11	0.26	0.18	0.07	0.07	0.09	0.04	0.03	0.07	0.09
Karpbukt	0.09	0.26	0.2	0.43	0.11	0.07	0.08	0.03	0.14	0.26	0.19	0.15	0.12
Ny-Ålesund	0.09	0.29	0.07	0.12	0.08	0.29	0.23	0.09	0.09	0.07	0.01	0.13	0.08

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	2016
Birkenes	0.14	0.18	0.18	0.18	0.19	0.17	0.1	0.09	0.23	0.07	0.13	0.17	0.15
Vatnedalen	0.25	0.1	0.15	0.21	0.2	0.12	0.04	0.07	0.05	0.15	0.22	0.17	0.14
Treungen	0.08	0.08	0.13	0.1	0.09	0.1	0.1	0.05	0.16	0.1	0.07	0.09	0.09
Løken	0.09	0.09	0.11	0.15	0.23	0.18	0.07	0.06	0.21	0.15	0.15	0.11	0.12
Hurdal	0.09	0.1	0.15	0.21	0.1	0.17	0.14	0.04	0.09	0.07	0.13	0.31	0.13
Brekkebygda	0.22	0.15	0.1	0.22	0.06	0.09	0.03	0.05	0.21	0.09	0.09	0.14	0.1
Vikedal	0.27	0.13	0.11	0.23	0.08	0.12	0.04	0.09	0.12	0.17	0.09	0.29	0.15
Haukeland	0.28	0.1	0.09	0.13	0.06	0.06	0.04	0.03	0.09	0.17	0.08	0.28	0.13
Nausta	0.51	0.06	0.27	0.09	0.09	0.09	0.03	0.03	0.03	-	0.1	0.07	0.13
Kårvatn	0.1	0.09	0.08	0.17	0.17	0.17	0.07	0.05	0.06	0.08	0.13	0.12	0.1
Høylandet	0.15	0.09	0.08	0.21	0.08	0.34	0.06	0.04	0.15	0.09	0.13	0.19	0.14
Tustervatn	0.11	0.06	0.16	0.2	0.18	0.1	0.04	0.03	0.03	0.05	0.06	0.15	0.09
Karpbukt	0.13	0.06	0.2	0.18	0.23	0.12	0.06	0.04	0.04	0.15	0.12	0.22	0.13
Ny-Ålesund	0.23	0.92	0.35	0.38	0.46	1.05	0.62	0.28	0.23	0.19	0.3	0.52	0.3

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	2016
Birkenes	0.17	0.26	0.19	0.09	0.08	0.04	0.04	0.03	0.16	0.06	0.13	0.2	0.12
Vatnedalen	0.26	0.17	0.16	0.2	0.22	0.1	0.04	0.07	0.08	0.13	0.36	0.23	0.17
Treungen	0.08	0.15	0.12	0.06	0.13	0.07	0.05	0.03	0.08	0.18	0.05	0.18	0.09
Løken	0.09	0.17	0.08	0.12	0.43	0.1	0.05	0.06	0.15	0.05	0.21	0.16	0.12
Hurdal	0.15	0.21	0.15	0.14	0.13	0.22	0.08	0.05	0.09	0.09	0.09	0.26	0.13
Brekkebygda	0.19	0.21	0.15	0.13	0.06	0.05	0.06	0.04	0.14	0.07	0.06	0.39	0.1
Vikedal	0.3	0.22	0.1	0.17	0.06	0.05	0.04	0.05	0.09	0.17	0.38	0.33	0.18
Haukeland	0.3	0.19	0.09	0.14	0.04	0.05	0.01	0.03	0.17	0.26	0.19	0.3	0.17
Nausta	0.6	0.06	0.1	0.1	0.09	0.03	0.03	0.02	0.04	-	0.1	0.42	0.16
Kårvatn	0.1	0.11	0.09	0.09	0.1	0.24	0.1	0.05	0.13	0.23	0.13	0.14	0.12
Høylandet	0.17	0.17	0.1	0.17	0.19	0.3	0.06	0.03	0.05	0.08	0.12	0.21	0.13
Tustervatn	0.13	0.1	0.17	0.07	0.08	0.08	0.05	0.07	0.04	0.04	0.16	0.22	0.11
Karpbukt	0.13	0.12	0.23	0.2	0.04	0.11	0.12	0.1	0.05	0.2	0.17	0.21	0.13
Ny-Ålesund	0.26	0.69	0.18	0.18	0.22	0.26	0.2	0.13	0.13	0.07	0.19	0.3	0.17

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	2016
Birkenes	0.31	0.35	0.15	0.1	0.04	0.06	0.05	0.09	0.23	0.07	0.18	0.42	0.16
Vatnedalen	0.5	0.09	0.08	0.08	0.07	0.02	0.01	0.01	0.05	0.14	0.1	0.4	0.17
Treungen	0.1	0.1	0.09	0.05	0.02	0.02	0.02	0.03	0.1	0.11	0.07	0.22	0.07
Løken	0.08	0.13	0.07	0.04	0.05	0.03	0.03	0.03	0.11	0.04	0.07	0.13	0.06
Hurdal	0.06	0.08	0.07	0.03	0.02	0.05	0.03	0.01	0.05	0.02	0.05	0.07	0.04
Brekkebygda	0.09	0.05	0.06	0.05	0.02	0.01	0.01	0.01	0.07	0.03	0.02	0.07	0.03
Vikedal	0.73	0.32	0.13	0.25	0.03	0.04	0.06	0.09	0.27	0.43	0.19	0.85	0.33
Haukeland	0.67	0.25	0.11	0.23	0.04	0.04	0.03	0.06	0.18	0.41	0.14	0.85	0.32
Nausta	1.55	0.08	0.06	0.12	0.06	0.04	0.04	0.03	0.05	-	0.26	0.13	0.29
Kårvatn	0.16	0.19	0.1	0.16	0.09	0.06	0.03	0.02	0.05	0.04	0.27	0.31	0.16
Høylandet	0.31	0.18	0.13	0.22	0.08	0.32	0.03	0.04	0.14	0.27	0.24	0.58	0.27
Tustervatn	0.18	0.07	0.07	0.06	0.05	0.04	0.01	0.01	0.02	0.09	0.09	0.43	0.13
Karpbukt	0.33	0.08	0.52	0.33	0.03	0.27	0.05	0.05	0.06	0.13	0.19	0.67	0.25
Ny-Ålesund	0.39	1.62	0.54	0.43	0.71	0.77	0.43	0.37	0.42	0.27	0.59	0.95	0.48

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	2016
Birkenes	2.53	3.06	1.23	0.63	0.18	0.47	0.33	0.69	1.87	0.53	1.33	3.72	1.32
Vatnedalen	4.89	1.45	1.11	1.2	0.29	0.51	0.46	1.02	0.44	1.67	0.99	3.57	1.83
Treungen	0.7	0.82	0.66	0.32	0.13	0.13	0.17	0.25	0.74	0.17	0.56	1.79	0.47
Løken	0.46	1.04	0.55	0.19	0.23	0.11	0.22	0.19	0.65	0.14	0.48	1.01	0.37
Hurdal	0.42	0.71	0.53	0.2	0.1	0.2	0.19	0.11	0.27	0.12	0.4	0.69	0.29
Brekkebygda	0.63	0.49	0.48	0.24	0.07	0.03	0.12	0.07	0.47	0.15	0.14	0.74	0.21
Vikedal	6.2	2.57	0.84	1.99	0.2	0.23	0.49	0.67	2.08	3.48	1.52	7.35	2.69
Haukeland	5.81	2.13	0.87	2.02	0.28	0.27	0.25	0.5	1.35	3.08	1.18	7.35	2.71
Nausta	13.14	0.69	0.4	0.85	0.36	0.2	0.32	0.24	0.46	-	2.16	1.05	2.39
Kårvatn	1.19	1.54	0.74	1.12	0.56	0.5	0.16	0.2	0.37	0.28	2.24	2.65	1.30
Høylandet	2.4	1.52	0.9	1.74	0.66	2.53	0.19	0.33	1.16	2.17	1.99	4.89	2.24
Tustervatn	1.3	0.55	0.52	0.41	0.49	0.32	0.06	0.15	0.17	0.71	0.75	3.52	1.06
Karpbukt	2.59	0.62	4.15	2.81	0.14	2.12	0.29	0.24	0.35	0.93	1.51	5.78	2.01
Ny-Ålesund	3.1	12.4	4.24	3.29	5.32	4.3	2.3	2.61	3.16	1.81	4.73	8.09	3.66

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	2016
Birkenes	4.45	5.37	2.09	1	0.3	0.62	0.54	1.16	2.93	0.93	2.32	6.43	2.27
Vatnedalen	8.02	1.7	0.91	1.12	0.25	0.31	0.26	0.58	0.66	2.42	1.53	6.14	2.72
Treungen	1.21	1.35	1.04	0.47	0.2	0.2	0.27	0.41	1.11	0.31	0.86	3.17	0.77
Løken	0.76	1.75	0.88	0.26	0.38	0.18	0.37	0.32	1.05	0.29	0.8	1.72	0.61
Hurdal	0.61	1.17	0.8	0.24	0.15	0.29	0.31	0.18	0.4	0.19	0.67	1.09	0.45
Brekkebygda	0.93	0.76	0.72	0.34	0.13	0.05	0.18	0.14	0.67	0.09	0.26	1.11	0.33
Vikedal	10.43	4.53	0.61	3.44	0.33	0.42	0.8	1.17	3.77	6.22	2.79	12.76	4.66
Haukeland	9.89	3.79	1.42	3.5	0.43	0.44	0.42	0.87	2.43	5.54	2.12	13.01	4.76
Nausta	22.79	1.21	0.79	1.41	0.52	0.32	0.52	0.46	0.8	-	3.71	1.91	4.15
Kårvatn	2.04	2.68	1.24	1.9	0.86	0.76	0.26	0.35	0.65	0.5	4.01	4.75	2.29
Høylandet	4.27	2.69	1.53	2.99	1.07	4.54	0.3	0.58	2.08	3.84	3.59	8.41	3.9
Tustervatn	2.28	0.98	0.95	0.68	0.82	0.55	0.1	0.27	0.31	1.26	1.39	6.24	1.88
Karpbukt	4.84	1.1	7.26	4.63	0.25	3.8	0.46	0.42	0.63	1.57	2.65	10.41	3.59
Ny-Ålesund	5.45	21.43	7.49	5.8	9.36	7.3	4.2	4.71	5.7	3.2	8.42	14.76	6.53

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	2016
Birkenes	148.4	145.2	130.2	101.36	112.58	95.27	113.31	139.45	47.1	123.16	203.67	54.1	1413.8
Vatnedalen	105.08	82.62	9.42	22.83	40.53	64.35	53.17	68.8	116.27	69.25	53.59	127.99	813.91
Treungen	75.68	62.02	95.74	97.01	92.77	85.99	108	96.57	57.55	47.68	89.19	48.97	957.17
Løken	48.9	61.4	49.99	123.05	30.65	59.72	79.26	127.73	29.19	26.38	27.32	28.02	691.59
Hurdal	51.67	67.6	84.33	108.54	136.33	54.1	70.3	90	60.9	36.52	74.97	30.4	865.67
Brekkebygda	78.58	56	35.9	81.09	127.41	98.6	129.01	91.52	29.77	37.3	115.4	11.3	891.88
Vikedal	186.68	339.4	94.02	132.48	161.67	94.7	281.16	236.38	230.51	96.24	256.12	377.91	2487.27
Haukeland	307.93	404.19	160	138.56	135.07	150.54	274.59	325.36	304.01	138.99	325.45	565.56	3230.26
Nausta	201.92	107.3	28.7	148.1	80.89	97.45	213.65	214.87	177.53	0	74.5	132.5	1477.42
Kårvatn	98.24	225.36	116.73	114.77	42.2	42.1	113.2	199.76	75.55	57.57	150.03	307.05	1542.56
Høylandet	113.42	99.58	68.26	56.09	33.76	28.51	107.28	120.26	120.54	73.32	157.87	304.55	1283.43
Tustervatn	52.15	62.08	48.48	38	41.7	54.22	91.88	105.1	141.55	57.04	129.77	209.4	1031.36
Karpbukt	55.39	36.01	32	14.59	50.34	122.59	52.8	130.89	26.86	18.4	40.96	112.65	693.49

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	2016
Birkenes	2952	1234	623	791	946	1482	1455	1396	1067	2748	1942	861	17528
Vatnedalen	480	870	20	81	881	202	958	257	67918	616	691	774	4072
Treungen	1187	621	529	32017	612	2006	1506	937	950	400	991	434	10136
Løken	650	456	457	928	77	618	722	1302	310	360	4006	214	6432
Hurdal	957	613	786	865	885	342	988	670	519	823	576	188	8369
Brekkebygda	955	16678	387	495	1046	1042	1564	475	377	937	1177	46	8789
Vikedal	1389	3005	556	840	1180	1050	2058	1504	1809	938	1554	3610	18165
Haukeland	1571	16453	1042	940	1207	1472	2060	2181	1796	6392	3627	3012	23542
Nausta	823	525	34	304	196	35636	2910	1193	921	-	201	2751	10888
Kårvatn	416	1514	633	636	738	2678	784	1180	33410	200	460	724067	9854
Høylandet	303	11450	233	16410	29	93	594	57089	504	4877	302	1694	4322
Tustervatn	276	715	431	271	247	461	553	606	1008	324	563	21267	5914
Karpbukt	1040	355	590	381	1192	1360	1188	1804	286	202	196	614	9271
Ny-Ålesund	268	37	3022	66	61	30	14	45805	254	992437	257	12497	1589

Table A.1.12: Monthly and annual wet deposition of sulfate (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	2016
Birkenes	30	23	21	22	24	19	17	16	18	30	15	9	245
Vatnedalen	4	11	2	5	7	9	5	12	3	6	4	3	70
Treungen	13	8	16	19	17	16	15	9	17	8	9	4	150
Løken	8	9	8	31	12	11	8	11	6	3	6	4	117
Hurdal	9	12	15	26	31	11	9	6	15	11	8	5	159
Brekkebygda	15	8	6	18	27	15	11	8	10	9	9	1	136
Vikedal	6	31	19	28	27	13	40	35	17	10	14	17	258
Haukeland	1	30	22	20	17	19	28	16	24	4	10	16	207
Nausta	-14	10	5	20	13	15	26	15	13	-	1	5	104
Kårvatn	7	20	17	15	7	8	15	10	4	1	2	4	107
Høylandet	8	11	8	7	4	5	9	6	5	1	5	0	67
Tustervatn	4	6	6	5	6	7	5	4	6	1	3	1	55
Karpbukt	15	10	12	10	27	25	17	38	6	7	6	12	185
Ny-Ålesund	5	2	2	3	3	2	3	2	6	8	0	-1	36

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	2016
Birkenes	43	54	54	44	44	35	20	21	46	61	45	22	489
Vatnedalen	9	6	4	7	11	6	0	5	1	0	6	8	64
Treungen	21	9	32	38	29	19	22	13	37	13	21	10	263
Løken	14	20	18	58	21	15	10	13	12	5	13	11	210
Hurdal	18	26	32	42	49	13	14	9	29	13	16	11	272
Brekkebygda	25	16	15	29	48	10	11	5	17	11	20	3	209
Vikedal	31	45	41	46	43	15	29	41	34	18	34	63	439
Haukeland	33	29	32	20	13	18	16	6	29	2	23	46	267
Nausta	15	6	11	18	21	15	14	10	15	-	6	9	136
Kårvatn	3	7	21	16	17	51	10	11	7	3	5	9	157
Høylandet	8	6	9	4	5	3	2	2	2	2	13	14	69
Tustervatn	4	4	10	6	10	7	5	4	7	2	6	9	73
Karpbukt	5	5	2	3	6	7	4	6	3	3	3	4	51
Ny-Ålesund	3	0	1	0	2	1	2	2	4	10	1	1	28

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	2016
Birkenes	23	56	83	43	49	14	11	18	38	38	21	20	414
Vatnedalen	13	11	7	9	18	2	1	0	1	2	15	14	93
Treungen	10	9	64	48	38	10	26	17	28	9	13	12	284
Løken	7	21	27	68	36	7	7	11	8	2	10	12	217
Hurdal	8	25	35	46	74	17	13	7	32	9	8	9	281
Brekkebygda	19	17	19	36	61	8	12	14	16	6	6	4	217
Vikedal	39	67	76	64	54	13	43	54	28	18	36	123	615
Haukeland	50	44	47	26	8	5	12	5	16	3	16	117	350
Nausta	52	8	13	49	35	10	12	10	14	-	12	16	227
Kårvatn	4	20	29	14	13	14	16	11	13	2	10	23	163
Høylandet	20	20	26	17	11	4	9	4	5	5	32	63	213
Tustervatn	4	5	11	4	11	10	7	8	13	2	4	16	93
Karpbukt	5	9	7	6	6	9	4	4	4	5	8	17	84
Ny-Ålesund	5	1	2	1	2	1	3	3	8	8	1	4	38

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	2016
Birkenes	21	26	23	18	22	16	11	13	11	9	27	9	206
Vatnedalen	26	8	1	5	8	8	2	5	6	10	12	22	113
Treungen	6	5	13	10	8	8	11	5	9	5	6	4	89
Løken	5	5	5	19	7	10	6	8	6	4	4	3	82
Hurdal	5	7	13	23	14	9	10	4	6	2	10	9	111
Brekkebygda	17	8	4	18	8	9	4	4	6	3	10	2	93
Vikedal	50	43	10	30	13	12	11	21	27	16	22	110	367
Haukeland	86	42	14	18	8	9	10	10	29	23	26	156	431
Nausta	103	6	8	14	7	9	7	6	5	-	7	9	186
Kårvatn	10	21	9	19	7	7	8	11	4	4	20	36	158
Høylandet	18	9	6	12	3	10	7	5	18	7	21	59	174
Tustervatn	6	4	8	8	7	6	3	4	4	3	8	32	91
Karpbukt	7	2	7	3	12	15	3	6	1	3	5	25	88
Ny-Ålesund	12	5	10	3	9	2	9	11	19	20	32	15	146

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	2016
Birkenes	25	37	24	9	9	4	5	4	7	7	27	11	169
Vatnedalen	28	14	2	5	9	6	2	5	9	9	20	29	136
Treungen	6	9	11	6	12	6	5	3	5	9	4	9	85
Løken	4	11	4	14	13	6	4	8	4	1	6	4	81
Hurdal	8	14	13	15	18	12	6	4	6	3	7	8	113
Brekkebygda	15	12	5	11	8	5	8	4	4	3	7	4	85
Vikedal	55	76	10	23	10	5	11	12	21	16	97	124	458
Haukeland	94	78	15	19	6	7	4	11	53	36	63	168	554
Nausta	122	6	3	14	8	3	6	4	8	-	7	55	243
Kårvatn	10	26	11	11	4	10	11	10	10	13	20	43	179
Høylandet	19	17	7	10	6	9	6	3	6	6	19	62	169
Tustervatn	7	6	8	3	3	5	4	8	6	2	21	46	118
Karpbukt	7	4	7	3	2	14	6	12	1	4	7	24	92
Ny-Ålesund	14	3	5	1	5	0	3	5	10	8	20	8	83

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	2016
Birkenes	45	51	19	10	4	6	5	12	11	9	36	23	231
Vatnedalen	52	8	1	2	3	2	0	1	5	10	6	51	140
Treungen	8	6	9	4	2	2	2	3	6	5	6	11	64
Løken	4	8	3	4	2	2	3	4	3	1	2	4	40
Hurdal	3	6	6	3	3	3	2	1	3	1	4	2	36
Brekkebygda	7	3	2	4	2	1	1	1	2	1	2	1	28
Vikedal	137	107	12	33	5	4	17	21	61	42	49	320	808
Haukeland	206	100	17	33	5	5	9	20	53	56	46	482	1033
Nausta	312	9	2	17	4	3	8	7	10	-	19	17	423
Kårvatn	16	42	12	18	4	3	4	5	3	2	40	96	247
Høylandet	35	18	9	12	3	9	3	5	17	20	38	177	350
Tustervatn	9	4	3	2	2	2	1	2	3	5	12	90	136
Karpbukt	18	3	17	5	2	33	3	7	2	2	8	75	174
Ny-Ålesund	21	8	15	3	15	1	6	14	35	28	61	27	235

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	2016
Birkenes	375	444	160	64	21	45	38	96	88	65	270	201	1867
Vatnedalen	514	120	10	27	12	33	25	70	51	116	53	457	1489
Treungen	53	51	63	31	12	11	18	24	42	8	50	88	452
Løken	22	64	28	24	7	6	17	25	19	4	13	28	258
Hurdal	22	48	44	21	13	11	14	10	16	4	30	21	255
Brekkebygda	49	27	17	19	9	3	15	6	14	6	16	8	191
Vikedal	1158	872	79	264	33	22	137	158	478	335	390	2776	6703
Haukeland	1789	862	140	280	38	40	68	164	410	428	383	4155	8755
Nausta	2654	74	11	126	29	20	68	53	81	-	161	140	3533
Kårvatn	117	347	87	128	24	21	19	41	28	16	336	814	2001
Høylandet	272	152	62	98	22	72	20	40	140	159	315	1489	2871
Tustervatn	68	34	25	15	21	17	5	16	25	41	97	738	1092
Karpbukt	144	22	133	41	7	259	15	31	9	17	62	651	1392
Ny-Ålesund	166	62	120	25	109	8	33	101	261	193	490	227	1795

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	2016
Birkenes	661	780	272	102	34	59	61	162	138	114	472	348	3204
Vatnedalen	843	140	9	26	10	20	14	40	77	168	82	786	2215
Treungen	92	84	100	46	19	17	29	39	64	15	77	155	735
Løken	37	107	44	32	12	11	29	41	31	8	22	48	424
Hurdal	32	79	68	26	20	16	22	16	24	7	51	33	393
Brekkebygda	73	42	26	28	17	5	23	13	20	3	30	13	292
Vikedal	1947	1539	58	456	53	40	224	276	868	598	714	4823	11595
Haukeland	3045	1530	228	485	58	66	114	283	737	770	691	7360	15366
Nausta	4602	130	23	209	42	31	112	98	143	-	276	253	6125
Kårvatn	200	605	144	218	36	32	30	71	49	29	602	1459	3525
Høylandet	485	267	105	167	36	129	32	70	251	281	566	2562	5007
Tustervatn	119	61	46	26	34	30	9	28	43	72	181	1306	1936
Karpbukt	268	40	232	68	13	466	24	54	17	29	108	1173	2492
Ny-Ålesund	291	106	213	44	193	14	59	182	471	341	872	415	3201

Table A.1.20: The 10 highest daily wet deposition of sea salt corrected sulfate, 2016.

Site	Date	SO$_4$ wet dep mgS/m^2	Precip mm'	% av annual SO$_4$ dep	pH
Birkenes	17.10.2016	9.5	22.6	3.9	4.50
	18.10.2016	8.7	48.1	3.5	4.67
	22.05.2016	6.1	35.7	2.5	5.55
	21.12.2016	6.0	8.8	2.4	4.39
	10.01.2016	5.6	26.8	2.3	4.56
	06.02.2016	5.3	26.4	2.2	5.13
	23.09.2016	5.1	9.0	2.1	4.20
	26.03.2016	4.9	20.4	2.0	6.24
	02.05.2016	4.6	17.7	1.9	4.69
	20.06.2016	4.6	25.3	1.9	4.89
	Sum			24.6	
Hurdal	30.04.2016	12.5	39.2	7.9	4.97
	29.05.2016	9.1	30.4	5.7	4.86
	22.05.2016	6.6	26.4	4.2	5.33
	09.09.2016	5.2	5.6	3.3	4.95
	19.02.2016	4.4	14.3	2.8	4.75
	15.06.2016	3.8	11.9	2.4	5.35
	04.04.2016	3.6	11.0	2.3	5.74
	10.09.2016	3.4	11.1	2.2	5.41
	21.12.2016	3.4	6.8	2.1	4.79
	29.04.2016	3.3	18.3	2.1	5.21
	sum			34.9	

Table A.1.20 continued:

Site	Date	SO4 wet dep mgS/m2	Precip mm'	% av annual SO4 dep	pH
Tustervatn	10.03.2016	2.1	19.5	3.9	4.92
	07.06.2016	1.9	12.1	3.5	4.91
	20.05.2016	1.5	19.1	2.8	5.47
	09.05.2016	1.3	3.9	2.3	5.35
	31.07.2016	1.3	31.9	2.3	5.30
	16.12.2016	1.2	11.0	2.2	4.69
	14.09.2016	1.1	6.7	2.1	5.16
	03.02.2016	1.0	12.4	1.8	5.04
	16.03.2016	1.0	5.2	1.8	5.87
	29.01.2016	1.0	14.0	1.8	5.28
	sum			24.5	

Site	Date	SO4 wet dep mgS/m2	Precip mm'	% av annual SO4 dep	pH
Kårvatn	25.02.2016	6.2	51.3	5.8	5.51
	17.03.2016	5.4	22.6	5.1	5.49
	21.04.2016	3.9	35.4	3.6	5.38
	26.08.2016	3.6	59.9	3.4	5.42
	18.04.2016	3.4	30.6	3.1	5.29
	05.07.2016	3.2	11.0	3.0	5.68
	03.02.2016	2.7	34.2	2.6	5.49
	24.02.2016	2.7	30.4	2.6	5.40
	06.04.2016	2.7	11.3	2.5	4.83
	18.01.2016	2.6	25.5	2.4	5.30
	sum			34.0	

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 sulfur and nitrogen for the 1987-2016.

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
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

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/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
Birkenes	2014	0.31	0.35	0.35	0.16	0.18	4.77	2331	732	813	818	17	71	193
(cont.)	2015	0.18	0.29	0.28	0.15	0.16	4.91	2173	387	633	614	27	48	165
	2016	0.17	0.35	0.29	0.15	0.16	4.91	1414	245	489	414	12	37	133
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		
	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		

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/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
Vatnedalen (cont.)	2014	0.17	0.15	0.17	0.23	0.07	5.44	957	160	141	167	4		
	2015	0.07	0.09	0.12	0.16	0.10	5.50	1166	84	105	140	4		
	2016	0.09	0.08	0.11	0.14	0.17	5.30	814	70	64	93	5		
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/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
Treungen (cont.)	2014	0.21	0.28	0.26	0.11	0.07	4.90	1463	312	406	384	13		
	2015	0.12	0.21	0.19	0.11	0.07	4.96	1153	143	243	214	13		
	2016	0.16	0.27	0.30	0.09	0.07	4.98	957	150	263	284	10		
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		

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/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
Løken (cont.)	2014	0.23	0.28	0.25	0.18	0.09	4.91	965	225	275	244	12		
	2015	0.12	0.26	0.23	0.15	0.08	5.01	851	105	223	195	8		
	2016	0.17	0.30	0.31	0.12	0.06	5.03	692	117	210	217	9		
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
	2005	0.35	0.43	0.44	0.12	0.05	4.89	739	258	317	324	9	65	268
	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
	2014	0.24	0.28	0.25	0.17	0.06	4.88	1172	278	327	293	13	52	190
	2015	0.14	0.25	0.24	0.10	0.05	4.98	1059	149	267	255	11	22	183
	2016	0.18	0.31	0.32	0.13	0.04	5.01	866	159	272	281	10	26	142

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/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
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		
	2014	0.24	0.25	0.21	0.24	0.05	4.94	1105	269	276	234	11		
	2015	0.10	0.18	0.19	0.14	0.04	5.13	997	105	178	187	7		
	2016	0.15	0.23	0.24	0.10	0.03	5.01	892	136	209	217	10		

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/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
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		
	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		
	2014	0.17	0.18	0.27	0.22	0.27	5.21	2891	480	516	788	6		
	2015	0.06	0.15	0.22	0.21	0.47	5.24	3283	182	490	729	19		
	2016	0.10	0.18	0.25	0.15	0.33	5.14	2487	258	439	615	7		

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/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
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		
	2014	0.10	0.11	0.12	0.16	0.19	5.15	3512	359	400	437	7		
	2015	0.05	0.10	0.08	0.19	0.31	5.06	4324	230	440	364	7		
	2016	0.06	0.08	0.11	0.13	0.32	5.14	3230	207	267	350	7		

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/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
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	
	1993	0.23	0.13	0.10	0.17	0.39	4.87	2215	509	277	211	30	78	
	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		
	2014	0.10	0.10	0.19	0.15	0.18	5.24	1725	178	170	326	6		
	2015	0.05	0.08	0.13	0.15	0.21	5.27	2533	124	198	327	14		
	2016	0.07	0.09	0.15	0.13	0.29	5.13	1477	104	136	227	7		
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

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/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
Kårvatn (cont.)	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
	2014	0.18	0.11	0.10	0.21	0.16	5.03	1099	193	124	109	9	45	146
	2015	0.06	0.08	0.09	0.15	0.18	5.20	1343	79	111	118	8	15	112
	2016	0.07	0.10	0.11	0.10	0.16	5.19	1543	107	157	163	6	19	91
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		
	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		

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/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
Høylandet (cont.)	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		
	2014	0.20	0.11	0.34	0.29	0.25	5.28	999	197	109	338	5		
	2015	0.03	0.06	0.14	0.13	0.21	5.46	1148	31	64	163	4		
	2016	0.05	0.05	0.17	0.14	0.27	5.47	1283	67	69	213	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

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/m^2	NO_3-N mg/m^2	NH_4-N mg/m^2	H+ mekv/m²	S mg/m^2	N mg/m^2
Tustervatn (cont.)	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	-
	2010	0.11	0.08	0.15	0.06	0.08	5.35	913	101	75	141	4	23	42
	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
	2014	0.14	0.08	0.11	0.19	0.25	5.06	893	128	74	94	9	27	123
	2015	0.05	0.07	0.09	0.17	0.24	5.26	1444	65	106	134	8	14	137
	2016	0.05	0.07	0.09	0.09	0.13	5.24	1031	55	73	93	6	19	87
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		
	2014	0.40	0.11	0.15	0.18	0.21	4.84	571	229	64	88	14		
	2015	0.29	0.08	0.11	0.19	0.23	4.87	403	116	33	46	5		
	2016	0.27	0.07	0.12	0.13	0.25	4.87	693	185	51	84	13		

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/m^2	mg/m^2	mg/m^2	mekv/m^2	mg/m^2	mg/m^2
Ny-Ålesund (tørravsetning fra Zeppelin)	1981	0.24	0.05	0.05	1.03	0.41	5.11	366	88	20	17	3		
	1982	0.39	0.08	0.05	0.92	2.01	5.01	206	80	16	10	2		
	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	
	2014	0.47	0.09	0.08	0.44	0.6	4.78	311	145	29	25	16.6	35	
	2015	0.11	0.1	0.09	0.55	0.79	5.12	356	40	36	30	2.7	16	
	2016	0.07	0.06	0.08	0.30	0.48	5.49	490	36	28	38	3.2	16	

Table A.1.21b: Volume weighted annual mean concentrations and wet deposition of main components in precipitation and estimated dry deposition of sulfur 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	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
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.

		Annual vol. weighted mean concentrations						Annual	Annual total wet deposition				Dry deposition	
Site	Year	SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH	precip	SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m^2	mg/m^2	mg/m^2	mekv/m²	mg/m^2	mg/m^2
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.

		Annual vol. weighted mean concentrations						Annual	Annual total wet deposition				Dry deposition	
Site	Year	SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH	precip	SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m^2	mg/m^2	mg/m^2	mekv/m^2	mg/m^2	mg/m^2
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.

		Annual vol. weighted mean concentrations						Annual precip	Annual total wet deposition				Dry deposition	
Site	Year	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/m^2	mg/m^2	mg/m^2	$mekv/m^2$	mg/m^2	mg/m^2
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.

		Annual vol. weighted mean concentrations						Annual	Annual total wet deposition				Dry deposition	
Site	Year	SO_4-S	NO_3-N	NH_4-N	Ca	Mg	pH	precip	SO_4-S	NO_3-N	NH_4-N	H+	S	N
		mg/l	mg/l	mg/l	mg/l	mg/l		mm	mg/m^2	mg/m^2	mg/m^2	$mekv/m^2$	mg/m^2	mg/m^2
Jergul cont.	1988	0.30	0.13	0.10	0.09	0.03	4.65	406	122	54	40	9	134	81
	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 sulfur dioxide in air at Norwegian background stations. Unit: µg S/m^3.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2016
Birkenes II	0.07	0.03	0.03	0.02	0.09	0.1	0.04	0.04	0.11	0.04	0.03	0.02	0.05
Hurdal	-	0.03	0.01	0.03	0.03	0.05	0.03	0.02	0.03	0.02	0.05	0.02	0.03
Kårvatn	0.03	0.01	0.02	0.03	0.02	0.05	0.01	0.04	0.02	0.01	0.04	0.01	0.03
Tustervatn	0.21	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.03	0.01	0.04
Zeppelin	0.08	0.12	0.13	0.14	0.01	0.02	0.05	0.01	0.05	0.03	0.03	0.02	0.06

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

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2016
Birkenes II	0.2	0.13	0.09	0.17	0.24	0.31	0.26	0.19	0.35	0.19	0.13	0.16	0.2
Hurdal	-	0.21	0.15	0.2	0.22	0.21	0.13	0.13	0.25	0.19	0.12	0.09	0.17
Kårvatn	0.08	0.04	0.06	0.09	0.15	0.19	0.15	0.11	0.19	0.1	0.09	0.03	0.11
Tustervatn	0.22	0.1	0.13	0.08	0.15	0.16	0.15	0.09	0.14	0.1	0.11	0.08	0.13
Zeppelin	0.12	0.2	0.17	0.25	0.1	0.08	0.09	0.05	0.06	0.06	0.03	0.07	0.11

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	2016
Birkenes II	0.65	0.28	0.35	0.35	0.27	0.22	0.19	0.15	0.27	0.25	0.32	0.32	0.3
Hurdal	1.16	1.01	0.81	0.39	0.33	0.26	0.24	0.23	0.43	0.27	0.84	1.29	0.61
Kårvatn	0.21	0.27	0.17	0.11	0.09	0.12	0.11	0.1	0.14	0.16	0.1	0.17	0.15
Tustervatn	0.18	0.16	0.13	0.1	0.09	0.11	0.1	0.06	0.09	0.06	0.1	0.09	0.11

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	2016
Birkenes II	0.3	0.64	0.39	0.14	0.33	0.27	0.18	0.14	0.33	0.07	0.03	0.11	0.25
Hurdal	-	0.27	0.22	0.25	0.23	0.23	0.07	0.09	0.15	0.06	0.11	0.12	0.16
Kårvatn	0.09	0.09	0.06	0.08	0.11	0.09	0.05	0.04	0.05	0.04	0.02	0.02	0.07
Tustervatn	0.11	0.09	0.16	0.05	0.14	0.08	0.04	0.03	0.05	0.04	0.03	0.03	0.07
Zeppelin	0.05	0.05	0.06	0.06	0.1	0.04	0.06	0.05	0.03	0.02	0.02	0.03	0.05

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	2016
Birkenes II	0.25	0.62	0.35	0.12	0.26	0.2	0.13	0.11	0.26	0.05	0.13	0.14	0.21
Hurdal	-	0.19	0.16	0.21	0.17	0.18	0.05	0.06	0.13	0.05	0.08	0.13	0.13
Kårvatn	0.07	0.08	0.04	0.06	0.07	0.07	0.03	0.02	0.04	0.02	0.01	0.01	0.04
Tustervatn	0.07	0.07	0.13	0.03	0.11	0.06	0.03	0.02	0.03	0.03	0.01	0.02	0.05
Zeppelin	0.03	0.04	0.05	0.05	0.08	0.02	0.03	0.04	0.01	0.01	0.01	0.01	0.03

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	2016
Birkenes II	0.34	0.66	0.59	0.33	0.62	0.51	0.33	0.28	0.53	0.21	0.08	0.09	0.4
Hurdal	-	0.32	0.4	0.41	0.39	0.47	0.18	0.28	0.31	0.18	0.18	0.15	0.3
Kårvatn	0.23	0.24	0.4	0.41	0.5	0.72	0.42	0.52	0.83	0.41	0.12	0.22	0.44
Tustervatn	0.33	0.32	0.51	0.42	0.71	0.64	0.75	0.45	0.49	0.2	0.1	0.07	0.43
Zeppelin	0.1	0.25	0.12	0.17	0.27	0.22	0.26	0.25	0.11	0.13	0.1	0.05	0.17

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	2016
Birkenes II	0.28	0.59	0.43	0.15	0.3	0.24	0.16	0.1	0.28	0.11	0.14	0.11	0.23
Hurdal	-	0.15	0.2	0.25	0.22	0.26	0.06	0.08	0.17	0.1	0.09	0.12	0.15
Kårvatn	0.09	0.04	0.03	0.06	0.11	0.08	0.09	0.06	0.12	0.04	0.03	0.01	0.06
Tustervatn	0.12	0.09	0.16	0.05	0.11	0.08	0.05	0.02	0.05	0.05	0.03	0.01	0.07
Zeppelin	0.03	0.05	0.06	0.06	0.05	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.03

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	2016
Birkenes II	0.05	0.08	0.05	0.02	0.03	0.05	0.06	0.04	0.09	0.03	0.04	0.09	0.05
Hurdal	-	0.03	0.02	0.02	0.02	0.04	0.02	0.02	0.03	0.01	0.02	0.02	0.02
Kårvatn	0.01	0.02	0.03	0.02	0.02	0.03	0.02	0.01	0.02	0.01	0.03	0.02	0.02
Tustervatn	0.03	0.03	0.03	0.02	0.03	0.04	0.02	0.03	0.04	0.02	0.02	0.07	0.03
Zeppelin	0.04	0.05	0.03	0.03	0.03	0.03	0.02	0.03	0.06	0.06	0.02	0.04	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	2016
Birkenes II	0.03	0.04	0.04	0.03	0.08	0.07	0.03	0.03	0.07	0.02	0.02	0.04	0.04
Hurdal	-	0.04	0.03	0.03	0.04	0.05	0.02	0.02	0.04	0.01	0.02	0.02	0.03
Kårvatn	0.01	0.02	0.03	0.01	0.03	0.04	0.01	0.02	0.02	0.02	0.02	0.01	0.02
Tustervatn	0.02	0.02	0.02	0.01	0.03	0.03	0.02	0.01	0.02	0.01	0.01	0.02	0.02
Zeppelin	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.05	0.03	0.03	0.02	0.02

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	2016
Birkenes II	0.06	0.15	0.08	0.06	0.07	0.05	0.04	0.03	0.07	0.04	0.03	0.05	0.06
Hurdal	-	0.09	0.08	0.05	0.06	0.05	0.02	0.03	0.06	0.04	0.08	0.07	0.06
Kårvatn	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.02	0.03	0.02	0.02	0.01	0.03
Tustervatn	0.02	0.06	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.02	0.01	0.03	0.03
Zeppelin	0.15	0.06	0.04	0.05	0.07	0.03	0.03	0.03	0.04	0.05	0.01	0.03	0.05

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	2016
Birkenes II	0.67	0.97	0.57	0.21	0.17	0.24	0.35	0.36	0.83	0.29	0.6	1.15	0.53
Hurdal	-	0.26	0.17	0.17	0.04	0.12	0.06	0.08	0.21	0.09	0.11	0.26	0.14
Kårvatn	0.1	0.22	0.19	0.2	0.18	0.29	0.06	0.06	0.15	0.07	0.27	0.27	0.17
Tustervatn	0.36	0.38	0.27	0.2	0.32	0.38	0.06	0.26	0.36	0.21	0.26	0.97	0.34
Zeppelin	0.49	0.4	0.25	0.19	0.16	0.18	0.1	0.28	0.61	0.75	0.15	0.44	0.33

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	2016
Birkenes II	0.44	0.68	0.42	0.21	0.24	0.33	0.36	0.33	0.66	0.21	0.39	0.78	0.42
Hurdal	-	0.27	0.17	0.19	0.12	0.16	0.09	0.1	0.24	0.07	0.12	0.21	0.16
Kårvatn	0.08	0.17	0.16	0.16	0.17	0.29	0.09	0.08	0.13	0.07	0.19	0.17	0.15
Tustervatn	0.25	0.28	0.22	0.16	0.26	0.3	0.08	0.18	0.28	0.15	0.17	0.62	0.25
Zeppelin	0.28	0.35	0.18	0.18	0.15	0.15	0.09	0.2	0.34	0.41	0.09	0.3	0.23

Table A.1.34a: Annual mean concentrations of sulfur and nitrogen components in air at Norwegian background stations from 1973-2015. Units μg *S/m*^{3} and μg *N/m*^{3}.

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
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		0.20
Birkenes II	2010	0.12	0.29	0.31	0.23		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
	2014	0.17	0.37	0.31	0.38	0.62	0.34
	2015	0.07	0.29	0.30	0.32	0.44	0.27
	2016	0.05	0.20	0.30	0.25	0.40	0.23

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
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		0.12
	2010	0.07	0.21	0.66	0.16		0.18
	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
	2014	0.09	0.29	0.55	0.22	0.49	0.25
	2015	0.05	0.14	0.64	0.27	0.42	0.24
	2016	0.03	0.17	0.61	0.16	0.30	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	

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
Kårvatn (cont.)	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		0.06
	2010	0.03	0.14	0.25	0.08		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
	2014	0.12	0.20	0.14	0.18	0.63	0.17
	2015	0.03	0.09	0.11	0.14	0.51	0.13
	2016	0.03	0.11	0.15	0.07	0.44	0.06
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

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.)	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
	2009	0.05	0.15	0.11	0.07		0.06
	2010	0.08	0.15	0.12	0.10		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
	2014	0.08	0.10	0.10	0.12	0.59	0.10
	2015	0.02	0.08	0.08	0.14	0.61	0.11
	2016	0.04	0.13	0.11	0.07	0.43	0.07
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

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
Zeppelin (cont.)	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		0.04
	2010	0.07	0.13		0.06		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
	2014	0.14	0.20		0.16	0.33	0.11
	2015	0.06	0.11		0.12	0.22	0.09
	2016	0.06	0.11		0.05	0.17	0.03

1) Due to contamination of ammonia, only NH4-N concentrations are reported in 2009 and 2010.

Table A.1.34b: Annual mean concentrations of sulfur and nitrogen components in air at Norwegian background stations which has been closed down. Units μ*g S/m*^{3} and μ*g N/m*^{3}.

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 2014.

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
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 2016, including the environmental contaminants reported in Nizzetto et al. (2017).

	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

(incl. background information on PM and EC/OC)

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.

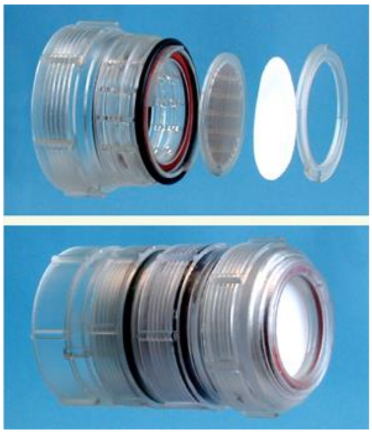
pH is measured with potentiometric method and conductivity with a conductivity meter. Anions and cations are measured with an ion chromatograph. The detection limit for the different ions are given in the table below:

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 sulfur 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 sulfate 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 sulfate. 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)

Background

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: sulfate (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.

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.

Sampling and chemical analysis

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 $\mu g/m^3$ 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 $\mu g/m^3$.

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 $\mu g\ C/cm^2$.

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The Norwegian Environment Agency is working for a clean and diverse environment. Our primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

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

We implement and give advice on the development of climate and environmental policy. We are professionally independent. This means that we act independently in the individual cases that we decide and when we communicate knowledge and information or give advice.

Our principal functions include collating and communicating environmental information, exercising regulatory authority, supervising and guiding regional and local government level, giving professional and technical advice, and participating in international environmental activities.