

Monitoring of long-range transported air pollutants in Norway

Annual Report 2021

Wenche Aas, Tore Flatlandsmo Berglen, Sabine Eckhardt, Markus Fiebig, Sverre Solberg and Karl Espen Yttri



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ABSTRACT This report presents results from the monitoring of atmospheric composition and deposition of air pollution in 2021, 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 level of pollution in 2021 was generally low with few high episodes.		
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ABSTRACT (in Norwegian) Denne rapporten omhandler resultater fra overvåkningsprogrammet for langtransportert forurenset luft og nedbør og atmosfæriske tilførsler i 2021. Rapporten presenterer målinger av uorganiske hovedkomponentene i luft og nedbør, partikulært karbonholdig materiale, partikkelmasse og bakkenært ozon. Forurensningsnivået i 2021 var generelt lavt med få høye episoder.		
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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 (PM₁₀ og PM_{2.5}) og størrelsesfordeling av partikkelantall på 16 norske bakgrunnsstasjoner. I tillegg rapporteres målinger av levoglukosan på Birkenes og organisk karbon (OC) og elementært karbon (EC) for den arktiske stasjonen Zeppelin på Svalbard.

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

Birkenes i Agder observerer vanligvis de høyeste nivåene av luftforurensning på grunn av nærhet til utslippsområdene på kontinentet. Noen stasjoner i innlandet påvirkes av regional landbruksaktivitet som kan gi relativt høyt ammoniumnivå. De høyeste nivåene av EC, OC og NO₂ observeres på Hurdal i Akershus, sannsynligvis på grunn av at denne regionen er relativt tett befolket, og har relativt mye veitrafikk. Målestasjonen i Finnmark er noe påvirket av utslipp i Russland. Den høyeste våtavsetningen av svovel og nitrogen skjer langs kysten fra Agder til Hordaland.

Organisk materiale utgjorde den største fraksjonen av PM₁₀ ved alle stasjonene (32 – 46%), fulgt av enten sekundære organiske forbindelser (SIA) (16 – 28%) eller sjøsaltpartikler (6 – 22%), mens mineralstøv ble estimert å utgjøre 9% av PM₁₀ på Birkenes. Både konsentrasjonen og det relative bidraget til PM₁₀ av SIA og sjøsaltpartikler var betydelig høyere ved Birkenes-observatoriet enn for de to andre stasjonene, hvilket reflekterer områdets nærhet til henholdsvis store antropogene utslippsområder på det europeiske kontinentet og til havet. Det er beregnet at vedfyring bidrar mellom 6-9% av PM på Birkenes, 22-35% om vinteren og ≤1.8% på sommeren.

Overskridelser

Årsmiddelkonsentrasjonene av PM₁₀ og PM_{2.5} lå langt under nasjonale grenseverdier, de helsebaserte nasjonale målene og luftkvalitetskriteriene på alle målestasjonene. EUs målsettingsverdi («target value») for ozon knyttet til beskyttelse av vegetasjon og helse har ikke blitt overskredet på mange år i Norge. EUs langtidsmål for ozon («long-term objective») knyttet til helse ble brutt på to stasjoner. Verken EUs langtidsmål for beskyttelse av landbruksvekster eller UN-ECEs mål for beskyttelse av skog ble overskredet i 2021. WHO's retningslinjer for luftkvalitet for ozon, og luftkvalitetskriteriene satt av Folkehelseinstituttet overskrides i varierende grad hvert eneste år i Norge. Informasjonsterskelen for når publikum skal informeres ble ikke overskredet i 2021 og har heller ikke blitt brutt på mange år i Norge.

Trender

Forurensningsnivået i 2021 var generelt lavt og det var få høye episoder med forurenset luft. En oversikt over de langsiktige trendene er vist i tabell 1.1 (table 1.1 etter engelsk sammendrag). Da Norge er nedstrøms de største utslippskildene i Europa, gjenspeiler de observerte trendene i stor grad utslippsreduksjonene som har funnet sted på det europeiske kontinentet de siste tiårene, selv om årlige variasjoner i meteorologi kan maskere effekten av utslippsreduksjonene, spesielt for ozon. Reduksjonene i trender i utslipp for svovel- og nitrogenforbindelser er i samsvar med målet for utslippsreduksjoner satt av Gøteborg-protokollen.

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 (PM₁₀ and PM_{2.5}) and aerosol size distribution, at a total of 16 sites in the Norwegian rural background environment. In addition, observations of levoglucosan at the Birkenes Observatory and OC- and EC-measurements for the Arctic site Zeppelin are reported.

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 the influence on ecosystems, human health, materials and climate change. The programme started in 1973 with measurements of sulfur and nitrogen compounds and was later extended with ozone (1985), aerosol particles, carbonaceous aerosol (2000/1), and aerosol size distribution (2010).

Chemical composition and geographical distribution

Birkenes in Agder commonly observe the highest levels of air pollution due to its proximity to the emission-regions on the continent. Some inland sites are influenced by regional agricultural activities and experience relatively high ammonium levels. The highest EC-, OC- and NO₂-levels are seen in Hurdal in Akershus, likely due to influence from the more densely populated region surrounding this site, including road traffic. The site in Finnmark is influenced from emissions in Russia. The highest wet deposition of inorganic ions occurred along the coast from Agder to Hordaland.

Organic matter was the major fraction of PM₁₀ at all sites (32 – 46%), followed either by secondary inorganic aerosol (SIA) (16 – 28%) or sea salt aerosol (6 – 22%), whereas a 9% contribution of mineral dust was estimated at the Birkenes Observatory. The SIA and sea salt aerosol contribution was substantially higher at the southernmost site Birkenes due to the proximity to major anthropogenic emission regions in continental Europe and to the sea, respectively. Contribution from biomass burning emissions was estimated to be 6-9% to PM annually, considering both PM₁₀ and PM_{2.5}. The fraction attributed to biomass burning in winter was 22-35%, whereas it was ≤1.8% in summer.

Exceedances

The EU annual limit value and the national limit value for PM₁₀ and PM_{2.5} were far from being exceeded at any of the three sites in 2021. This was also the case when compared to the WHO Air-Quality Guidelines (AQG).

EU's ozone target values for protection of human health and vegetation have not been exceeded for many years in Norway. EU's long-term objective for protection of human health was violated at two stations in 2021. WHO's air quality guideline for ozone, as well as the national guidelines, are exceeded every year in Norway at a varying extent. EU's information threshold to the public was not exceeded in 2021 and has not been for many years in Norway. Neither EU's long-term objective for protection of vegetation or UN-ECE's critical level for forests, were exceeded in 2021.

Trends

The level of pollution in 2021 was generally low and there were few high episodes. An overview of the long-term trends are shown in Table S 1.1. Since Norway is downwind of the major emission sources in Europe, the trends in observations reflect to a large extent the emission reductions which have taken place in the European continent the last decades, although inter-annual variations in meteorology could mask the effect of the emission reductions, particularly for ozone.

Table S 1.1: 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	1990- 2021	2000-2021
SO ₂	4 sites ¹⁾	-86% - - ~100%	-46% - -84%
SO ₂	Zeppelin	-75%	-66%
SO ₄ ²⁻ in aerosols	4 sites ¹⁾	-78% - -92%	-64% - -90%
SO ₄ ²⁻ in aerosols	Zeppelin	-43%	-40%
SO ₄ ²⁻ in precipitation	11 sites ²⁾	-56% - - ~100%	-44% --89% ³⁾
NO ₂	4 sites ¹⁾	-41% - -~100%	-35% - -60%
NO ₃ ⁻ in precipitation	11 sites ²⁾	-39% - -61% ⁴⁾	-26% - -55% ⁴⁾
HNO ₃ +NO ₃ ⁻ in air	Hurdal	-86%	-58%
NH ₄ ⁺ in precipitation	11 sites ²⁾	7 sites: +53% - -70%	4 sites: -28% - -45%
NH ₃ +NH ₄ ⁺ in air	4 sites ¹⁾	3 sites: +55% - -65%	Tustervatn: -72%
PM ₁₀	Birkenes		-36% (2000-2021)
PM _{2.5}	Birkenes		-50% (2001-2021)
OC	Birkenes		-24% - -30% (2001-2021)
EC	3 sites		-58% - -62% (2001-2021)
TC	Birkenes		-28% - -37% (2001-2021)
O ₃ , 3-months AOT40	4 sites ⁵⁾		-57% - -71% (2000-2021)
O ₃ , 8h >100 µg/m ³	4 sites ⁵⁾		-67% - -90% (2000-2021)

¹⁾ Birkenes, Nordmoen/Hurdal, Kårvatn, Tustervatn.

²⁾ All the sites (Table 3,10) except Karbuk and Ny Ålesund

³⁾ Not significant trend at Tustervatn

⁴⁾ Not significant trend at Kårvatn and Tustervatn

⁵⁾ Kårvatn, Sandve, Tustervatn and Prestebakke

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1 The monitoring programme 2021

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 atmospheric long-range transported pollution. An important goal 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 sites being representative for a wider region. Regular sampling of precipitation on a daily basis in Southern Norway dates back to 1973. The measurement programme and the monitoring network was then 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 programme 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 seven sites (Birkenes, Tustervatn, Kårvatn, Zeppelin, Hurdal, Sandve and Prestebakke)
- Daily measurements of NO₂ at four sites (Birkenes, Hurdal, Tustervatn, Kårvatn)
- Weekly measurements of particulate matter (PM₁₀ 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 inorganic compounds in air and precipitation at the five EMEP sites (Birkenes, Hurdal, Kårvatn and Tustervatn and Zeppelin; though weekly precipitation at Ny-Ålesund-not EMEP)
- Meteorology at three sites (Birkenes, Zeppelin and Hurdal)
- Weekly measurements of main inorganic ions in precipitation at seven sites (Vikedal, Treungen, Brekkebygda, Høylandet, Nausta, Vatnedalen, Løken). Observations from Høylandet was not included for 2021 due to missing months and high uncertainty.
- Observations of Levoglucosan at Birkenes (financed by NILU)

Norway-Russia programme on behalf of The Norwegian Environment Agency (which ended 1. January 2022):

- Weekly measurements of main inorganic ions in air and precipitation at Karpbukt

Local air pollution programme, co-financed by the municipalities in Porsgrunn, Skien and Bamble:

- Ozone at Haukenes

Funding from the Ministry of Climate and Environment to support the monitoring activities at the Zeppelin Observatory

- EC/OC, levoglucosan and other organic tracers at Zeppelin

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., 2022), the second covers the monitoring of the ozone layer and UV (Svendby et al. 2021), whereas the third is on climate gases and aerosol particles influence on climate (Myhre et al., 2021). The site locations and key information on the monitoring programme at the actual sites are illustrated in Figure 1.1. Detailed station information, monitoring programme and measurement frequencies are provided in Annex 2, whereas sampling methods and chemical analysis are described in Annex 3.

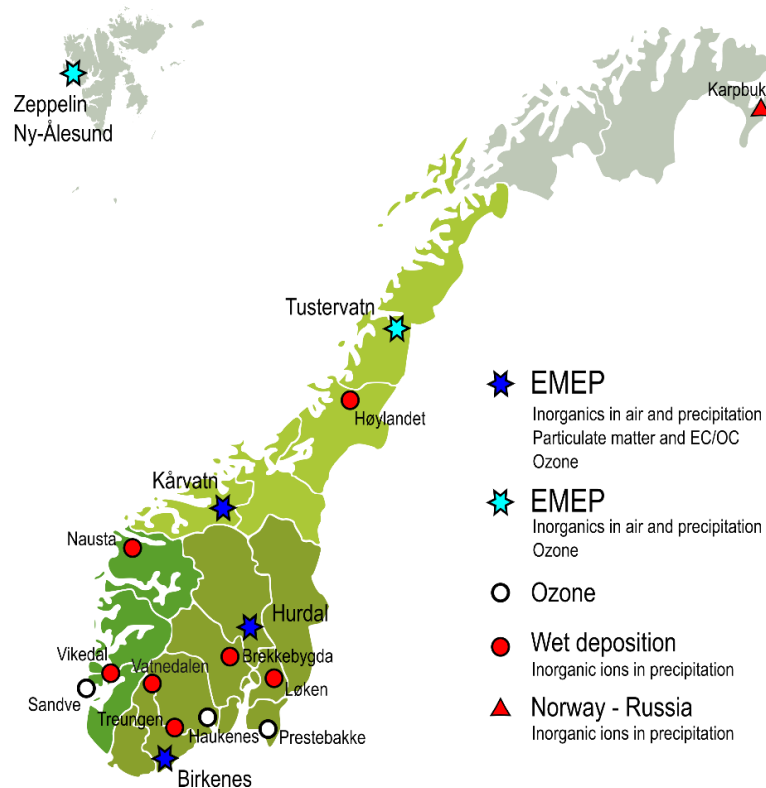


Figure 1.1: Norwegian background sites and their measurement programme 2021. Details are found in Annex 2. The colour codes indicate the different regions/zones used in EU's Ambient Air Quality Directive (2008). Note: Høylandet was not included for this 2021 report.

2 The weather in Norway 2021

The variation in meteorological conditions from year to year is decisive for the observed concentrations of pollutants in air and precipitation in Norway. At rural sites, the level of pollutants is mostly determined by atmospheric transport from other countries. The distribution of high- and low-pressure systems controls this transport, and temperature, humidity and precipitation are determining the degree of deposition, washout and chemical transformation in the air masses. Knowledge of the meteorological conditions and how it varies from day to day and from south to north is therefore important for understanding the air pollutant levels.

For the country as a whole, the mean temperature in 2021 was close to the normal with 10 % less precipitation than normal (when using the new 1991-2020 normal period).

The year started with colder and drier conditions in the two first months, particularly pronounced in the southern part of the country, whereas some areas in the north experienced more precipitation and more normal temperatures this period.

In March, these conditions changed and southern Norway had temperatures above the normal and several sites experienced more than 20°C at the end of the month. In April and May, the cold and dry conditions returned in the south whereas areas in the north received relatively more precipitation.

In June, most of the country was warmer than normal, typically around 2°C above the normal, and the month is the 5th warmest June since the start of the monitoring in 1900. Also July was warm with a mean temperature of 1.6°C above the 1991-2020 normal for the country as a whole.

August was a month with temperatures somewhat below normal and dry conditions in many parts of the country (although areas in Trøndelag received stronger precipitation than normal). September was a relatively warm and dry month in most areas, and the month was the 11th warmest September since 1900. The high temperatures continued in October, making the month the 8th warmest October since 1900. Many areas in the country received higher precipitation than normal, some sites up to 2-3 times the normal for this month.

November was a month close to the normal for the country as a whole, both with respect to mean temperature and precipitation. Then, the winter started with lower temperatures than normal in December in most of the country and also dry conditions, particularly in the south.

The temperature and precipitation for one site in the south (Landvik in Agder) and one site in the north (Svanvik) as reported by met.no for 2021 compared to the normal is shown in Figure 2.1.

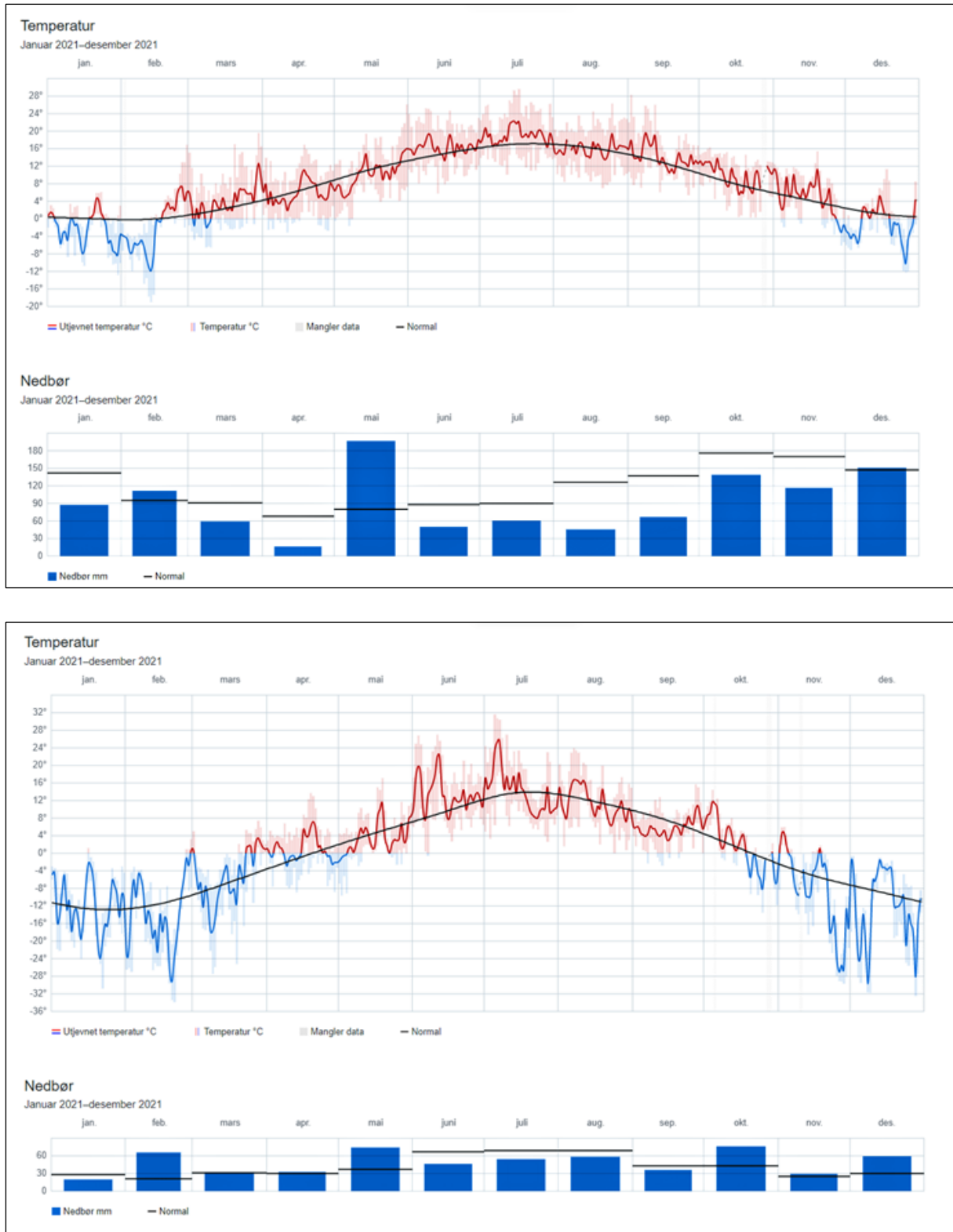


Figure 2.1: Daily observed temperature (shaded blue and red areas), smoothed temperature (blue and red lines), monthly precipitation (blue bars) in 2021 as well as normal temperature and precipitation (black) at Landvik in Agder in the south (top panels) and at Svanvik in the north (bottom panels). The plots are copied from the web page yr.no.

3 Inorganic components

3.1 Observations in 2021

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, 2014). 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 2021.

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 excluding the county of 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.

Table 3.1 shows that all regions, except the most continental parts of Norway 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. At Vatnedalen it seems to be a problem with the sea salt ions, too high sodium compared to magnesium and chloride. The pH is also relatively high compared to neighbouring sites, indicating some sort of contamination of sodium or sodium hydroxide of unclear origin.

As seen for previous years, the highest annual mean concentrations for the major components were generally observed at the Birkenes site (Table 3.1). Being situated only 20 km from the Skagerrak coastline, Birkenes is the site in Norway being the most influenced by long-range transport from the European Continent and UK, hence this finding is to be expected. The site in Finnmark, Karpbukt is influenced by emissions from Russia with elevated concentrations of especially sulfate, but the concentration levels have decreased dramatically after the smelter in Nikel closed down in December 2020 (Berglen et al., 2022). Some inland sites are influenced by regional agricultural activities and experience somewhat higher ammonium concentrations, i.e. Løken.

Table 3.1: Annual volume weighted mean concentrations and total wet deposition of inorganic ions at Norwegian background stations, 2021.

*: Corrected for contribution from sea salt.

Site	Volume weighted annual mean concentrations										Wet deposition								Volume weighted annual mean concentrations in equivalence units										Ion bal.		
	pH	SO ₄ *	NO ₃	NH ₄	Ca	K	Mg	Na	Cl		H+	SO ₄ *	NO ₃	NH ₄	Ca	K	Mg	Na	Cl	H+	SO ₄ *	SO ₄	NO ₃	NH ₄	Ca	K	Mg	Na		Cl	kat./an.
	mg	mg	mg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mm	µekv/m ²	S/m ²	N/m ²	N/m ²	mg/m ²	mg/m ²	mg/m ²	mg/m ²	mg/m ²	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l	µekv/l
Birkenes	5.02	0.167	0.328	0.304	0.20	0.10	0.16	1.29	2.21	1478	14181	246	485	450	289	141	229	1904	3270	10	10	17	23	22	10	2	13	56	62	1.10	
Vatnedalen	5.50	0.112	0.113	0.120	0.15	0.19	0.05	0.69	0.73	633	2025	71	72	76	97	120	32	439	463	3	7	9	8	9	8	5	4	30	21	1.59	
Treungen	5.11	0.123	0.198	0.166	0.15	0.09	0.06	0.42	0.71	1026	7991	127	203	171	156	91	65	426	730	8	8	10	14	12	8	2	5	18	20	1.21	
Løken	5.34	0.167	0.294	0.377	0.23	0.16	0.07	0.38	0.65	611	2804	102	180	230	143	96	45	232	398	5	10	12	21	27	12	4	6	16	18	1.37	
Hurdal	5.18	0.158	0.283	0.312	0.16	0.09	0.05	0.33	0.52	920	6142	146	260	287	147	81	43	302	478	7	10	12	20	22	8	2	4	14	15	1.25	
Brekkebygda	5.21	0.119	0.184	0.200	0.11	0.13	0.03	0.27	0.43	817	5099	97	150	163	89	110	27	223	347	6	7	9	13	14	5	3	3	12	12	1.33	
Vikedal	5.38	0.095	0.170	0.236	0.21	0.15	0.19	1.57	2.74	2266	9558	216	385	535	475	335	422	3567	6212	4	6	14	12	17	10	4	15	68	77	1.16	
Nausta	5.40	0.051	0.069	0.120	0.12	0.09	0.15	1.25	2.24	2013	7972	104	140	242	233	184	296	2519	4505	4	3	10	5	9	6	2	12	54	63	1.14	
Kårvatn	5.34	0.064	0.062	0.073	0.14	0.10	0.18	1.46	2.62	1893	8739	120	118	138	263	197	335	2758	4968	5	4	12	4	5	7	3	15	63	74	1.10	
Tustervatn	5.34	0.055	0.079	0.085	0.13	0.09	0.12	0.95	1.68	1119	5139	62	88	95	140	95	129	1057	1880	5	3	9	6	6	6	2	10	41	47	1.15	
Karpbukt	5.10	0.141	0.083	0.080	0.20	0.14	0.26	2.50	4.07	704	5581	99	59	57	138	100	183	1761	2866	8	9	21	6	6	10	4	21	109	115	1.12	
Ny-Ålesund	5.43	0.121	0.076	0.067	0.58	0.25	0.80	6.06	10.46	227	844	28	17	15	131	56	182	1379	2379	4	8	39	5	5	29	6	66	264	295	1.10	

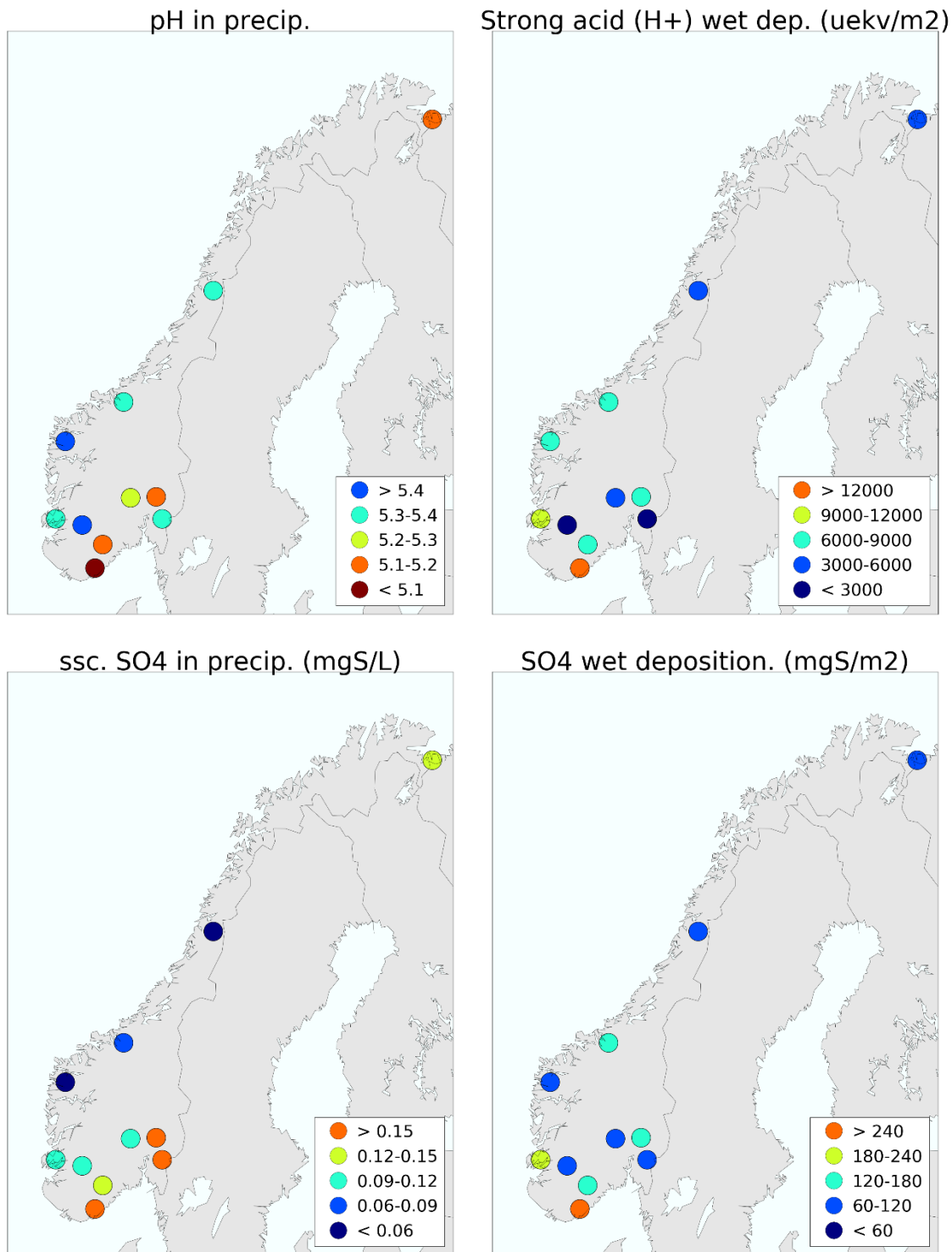


Figure 3.1: Annual volume weighted mean concentrations and total wet deposition of sulfate (sea salt corrected) and strong acid (pH), 2021. Note that the colours only resemble the spatial distribution and do not indicate any exceedances of limit values or similar.

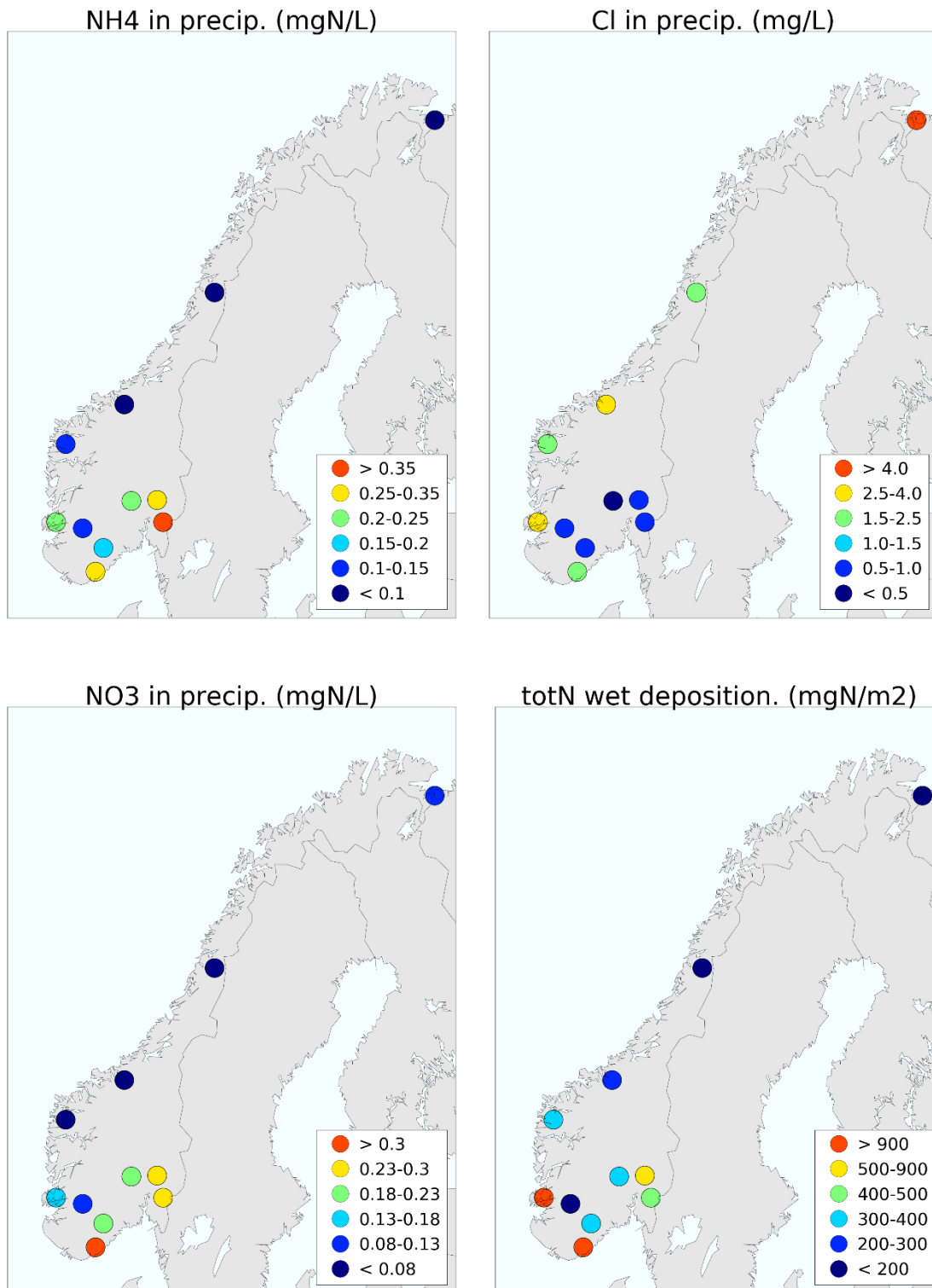


Figure 3.2: Annual volume weighted mean concentrations of nitrate, ammonium, chloride and total wet deposition of nitrogen (nitrate + ammonium), 2021. Note that the colours only resemble the spatial distribution and do not indicate any exceedances of limit values or similar.

Figure 3.3 shows average monthly volume weighted mean concentrations and wet deposition of the main components in precipitation from all the sites in Norway, 2021. The monthly data for each sites are given in the tables in Annex 1. There are quite large variabilities in the concentrations as well as depositions throughout the year. In 2021, the highest concentrations for sulfate was seen during the summer period, for ammonium highest in spring. For nitrate there is no pattern. Sea salt concentrations represented with sodium is highest in winter, while dust represented with Ca has some high concentrations in the spring and summer. The measured wet deposition of sulfate, shows that between 37% and 55% of the annual total deposition arrives during the ten days with highest deposition at the four sites with daily measurements during the whole year (Table A1.20).

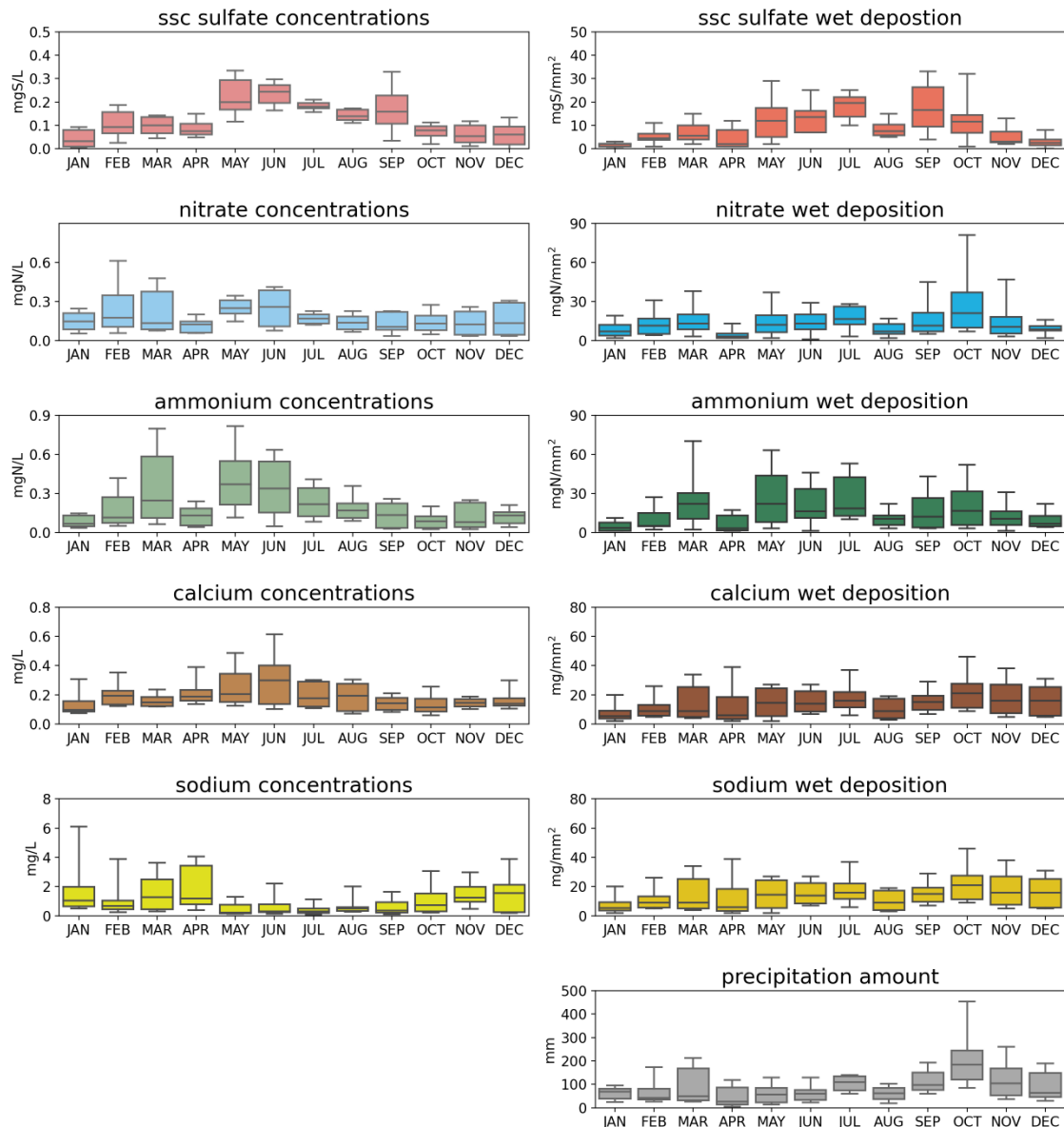


Figure 3.3: Box and whisker plots showing the median, lower and upper quartiles of the monthly volume weighted mean concentrations (left) and wet deposition (right) of major components in precipitation at the 12 sites in Norway, 2021.

3.1.2 Chemical composition in air

Daily measurements of inorganic components in air were carried out at five sites in 2021. All of these are EMEP sites (Figure 1.1). Table 3.2 shows the annual mean concentrations while the monthly data are given in A.1.22-A.1.33. The monthly means of the sulfur and nitrogen components are illustrated in Figure 3.7. The maximum and percentile concentrations of SO₂, SO₄²⁻, NO₂, sum of (NO₃⁻ + HNO₃), NH₄⁺ and sum of (NH₃ + NH₄⁺) are given in Table 3.3 to Table 3.8. The individual concentration of the nitrogen compounds in gas phase (NH₃ and HNO₃) and in aerosols (NH₄⁺ and NO₃⁻) may be biased when using the filterpack method due to the equilibrium between the gaseous- and aerosol (NH₄NO₃) phases. Though especially for reduced nitrogen it is useful to look at the individual concentration due to often local influence of NH₃ from farming activities. NH₄⁺ is more a signal of long range transported air pollution.

For estimating the source regions of the air masses measured at the different stations, we performed backward calculations which the Lagrangian particle transport model FLEXPART (Pisso et al, 2019). For every 24 hours 50000 particles have been released and their trajectories have been followed for 20 days. The footprints indicate how many seconds the air masses stayed in the lowest model level before they reached the receptor.

Table 3.2: Annual mean concentrations of inorganic components in air at Norwegian background stations, 2021.

	SO ₂	SO ₄ ²⁻	NO ₂	sum of (HNO ₃ +NO ₃ ⁻)	NO ₃ ⁻	sum of (NH ₃ + NH ₄ ⁺)	NH ₄ ⁺	Mg ²⁺	Ca ²⁺	K ⁺	Cl ⁻	Na ⁺
	µg-S/m ³	µg-S/m ³	µg-N/m ³	µg-N/m ³	µg-N/m ³	µg-N/m ³	µg-N/m ³	µg/m ³	µg/m ³	µg/m ³	µg/m ³	µg/m ³
Birkenes II	0.070	0.187	0.248	0.120	0.094	0.274	0.134	0.047	0.042	0.040	0.464	0.373
Hurdal	0.022	0.121	0.395	0.074	0.059	0.216	0.092	0.015	0.026	0.029	0.107	0.117
Kårvatn	0.028	0.104	0.139	0.034	0.022	0.688	0.054	0.021	0.026	0.021	0.196	0.150
Tustervatn	0.027	0.108	0.128	0.030	0.019	0.397	0.049	0.023	0.022	0.018	0.262	0.178
Zeppelin	0.054	0.094	-	0.024	0.013	0.166	0.029	0.035	0.026	0.029	0.395	0.252

The highest annual mean concentrations of sulfur dioxide in 2021 were observed at Birkenes with 0.07 µg S/m³, followed by Zeppelin with 0.05 µg S/m³. The highest daily average was observed at Birkenes with 4.3 µg S/m³ on 21 May followed by Zeppelin with 1.6 µg S/m³ on 16 December Table 3.3. This high SO₂ daily mean has not been observed at Birkenes since 2014 and influence from the eruption of Holuhraun volcanic eruption in Iceland. It seems like this episode in May 2021 at Birkenes also is influenced by volcanic eruption. Even though not as massive as in 2014, there are indications from satellite images and reported emissions from the Krýsuvík-Trölladyngja volcanic system in this period (Global Volcanism Program, 2021). In addition the air mass trajectories (Figure 3.4) show that the pollution may origin from Iceland and none of the other species measured (i.e. NO₂, CO or SO₄ is elevated, which one would have expected if the source was anthropogenic.) The episode at Zeppelin in December is however influenced of emissions on the continent (Figure 3.4).

In 2021 the highest particulate sulfate concentration was measured at Birkenes (0.19 µg S/m³), while the highest episodes (2.14 µg S/m³), was observed Kårvatn 28 June while the second highest (1.55 µg S/m³) was measured at Tustervatn 26 October. The episode at Kårvatn are with air masses from west and possible sources from Iceland, while the one at Tustervatn was from south west and possible sources in UK, Figure 3.5.

Highest NO₂ levels were observed in Hurdal with an annual mean of 0.40 µg N/m³. This station is influenced by the relatively high traffic emissions in region. The highest daily mean level of NO₂ was measured at Hurdal with 5.7 µg N/m³ on 6 January, Table 3.5. The concentrations of NO₂ show a temporal pattern with a winter maximum and summer minimum (Figure 3.7). During winter, there is reduced vertical mixing and the atmospheric residence time is longer due to low photochemical activity.

The highest annual mean concentrations for the sum of nitrate (NO₃⁻ + HNO₃) and of ammonium (NH₄⁺) were observed both at Birkenes with 0.12 and 0.13 µg N/m³, respectively. There is an episode of NH₄NO₃ seen at Birkenes the 29 October and at Hurdal the 30 October shown as their highest daily average of nitrate (NO₃⁻ + HNO₃) and ammonium (NH₄⁺) (Table 3.6 and Table 3.7). It is likely that both these sites are influenced by a long range episode from the continent (Figure 3.6). For the sum of ammonium (NH₄⁺ + NH₃) high levels were also observed also at Tustervatn and Kårvatn (Table 3.8), these sites are more influenced of agricultural activity in their regions. The seasonality of reduced nitrogen components with largest levels during spring is clearly seen in Figure 3.7.

Table 3.3: Number of daily, observations 50-, 75-, 90-percentile concentrations, max and annual mean concentrations for SO₂ in air at Norwegian background station in 2021.

Site	No. of observations	SO ₂ (µg S/m ³)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	364	0.022	0.074	0.148	4.348	21/05/2021	0.070
Hurdal	353	0.010	0.024	0.049	0.221	21/04/2021	0.022
Kårvatn	360	0.010	0.029	0.063	0.382	20/04/2021	0.028
Tustervatn	366	0.010	0.025	0.069	0.477	21/01/2021	0.027
Zeppelin	349	0.010	0.024	0.120	1.637	16/12/2021	0.054

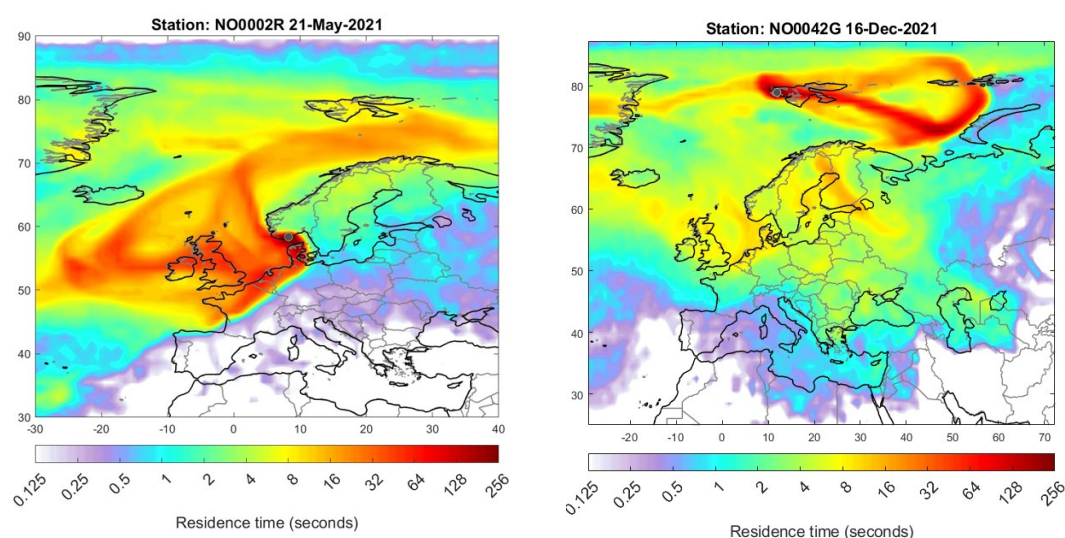


Figure 3.4: 20 days backward Flexpart footprints indicating the air mass source region (represented as residence time in the planetary boundary layer) for the episode at Birkenes 21-May and Zeppelin 16-December.

Table 3.4: Number of daily, observations 50-, 75-, 90-percentile concentrations, max- and annual mean concentrations for SO₄ in aerosols at Norwegian background station in 2021.

Site	No. of observations	SO ₄ ²⁻ (µg S/m ³)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
50%	75%	90%					
Birkenes II	364	0.149	0.263	0.397	0.897	29/06/2021	0.187
Hurdal	353	0.079	0.171	0.291	0.810	10/09/2021	0.121
Kårvatn	361	0.036	0.120	0.271	2.143	28/06/2021	0.104
Tustervatn	365	0.067	0.140	0.226	1.554	26/10/2021	0.108
Zeppelin	349	0.066	0.130	0.213	0.616	11/08/2021	0.094

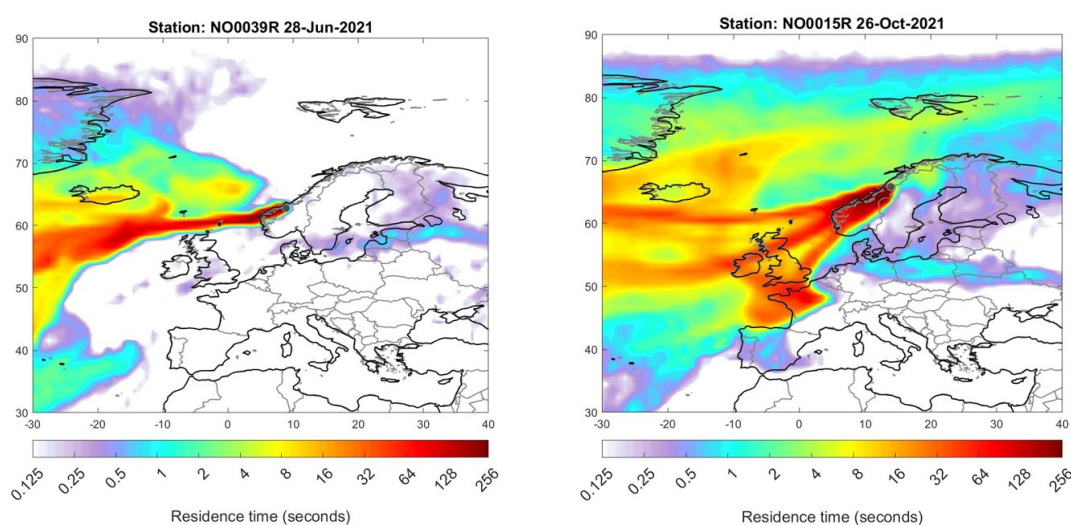


Figure 3.5: 20 days backward Flexpart footprints indicating the air mass source region for the episodes at Kårvatn 28 June and Tustervatn 26 October

Table 3.5: Number of daily, observations 50-, 75-, 90-percentile concentrations, max and annual mean concentrations for NO₂ in air at Norwegian background station in 2020.

Site	No. of observations	NO ₂ (µg N/m ³)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
50%	75%	90%					
Birkenes II	360	0.197	0.283	0.484	1.909	20/02/2021	0.248
Hurdal	335	0.252	0.463	0.797	5.688	06/01/2021	0.395
Kårvatn	365	0.111	0.161	0.256	0.871	01/02/2021	0.139
Tustervatn	366	0.092	0.144	0.244	1.755	23/06/2021	0.128

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 2020.

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	364	0.062	0.158	0.278	1.431	29/10/2021	0.120
Hurdal	352	0.044	0.085	0.165	0.918	30/10/2021	0.074
Kårvatn	360	0.020	0.038	0.063	0.276	28/06/2021	0.034
Tustervatn	365	0.020	0.035	0.053	0.177	25/07/2021	0.030
Zeppelin	349	0.020	0.020	0.036	0.068	20/05/2021	0.024

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 2020.

Site	No. of observations	NH ₄ ⁺ (µg N/m ³)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
50%	75%	90%					
Birkenes II	364	0.077	0.194	0.337	1.469	29/10/2021	0.134
Hurdal	352	0.043	0.128	0.238	1.034	30/10/2021	0.092
Kårvatn	361	0.005	0.047	0.162	1.192	28/06/2021	0.054
Tustervatn	364	0.012	0.065	0.136	0.823	28/05/2021	0.049
Zeppelin	349	0.007	0.041	0.077	0.244	04/04/2021	0.029

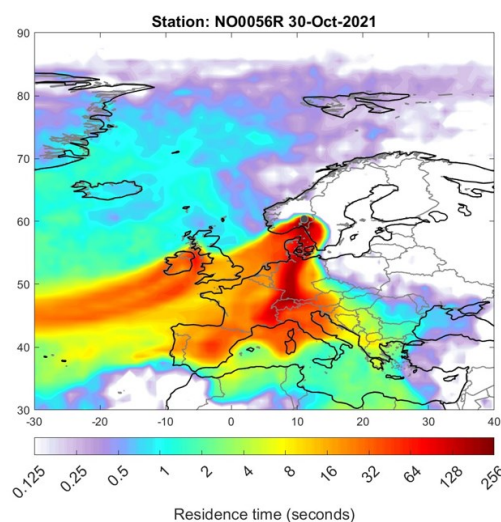


Figure 3.6: 20 days backward Flexpart footprints indicating the air mass source region for the episode 30 October at Hurdal.

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 2021.

Site	No. of observations	$\text{NH}_4^+ + \text{NH}_3$ ($\mu\text{g N}/\text{m}^3$)					
		Percentile conc.			Max concentration	Date	Annual mean concentration
		50%	75%	90%			
Birkenes II	364	0.175	0.341	0.589	5.378	21.05.2021	0.274
Hurdal	351	0.168	0.282	0.405	1.17	30.10.2021	0.216
Kårvatn	359	0.463	0.856	1.562	3.651	09.02.2021	0.688
Tustervatn	364	0.271	0.51	0.79	3.233	28.05.2021	0.397
Zeppelin	347	0.151	0.208	0.287	0.482	30.08.2021	0.166

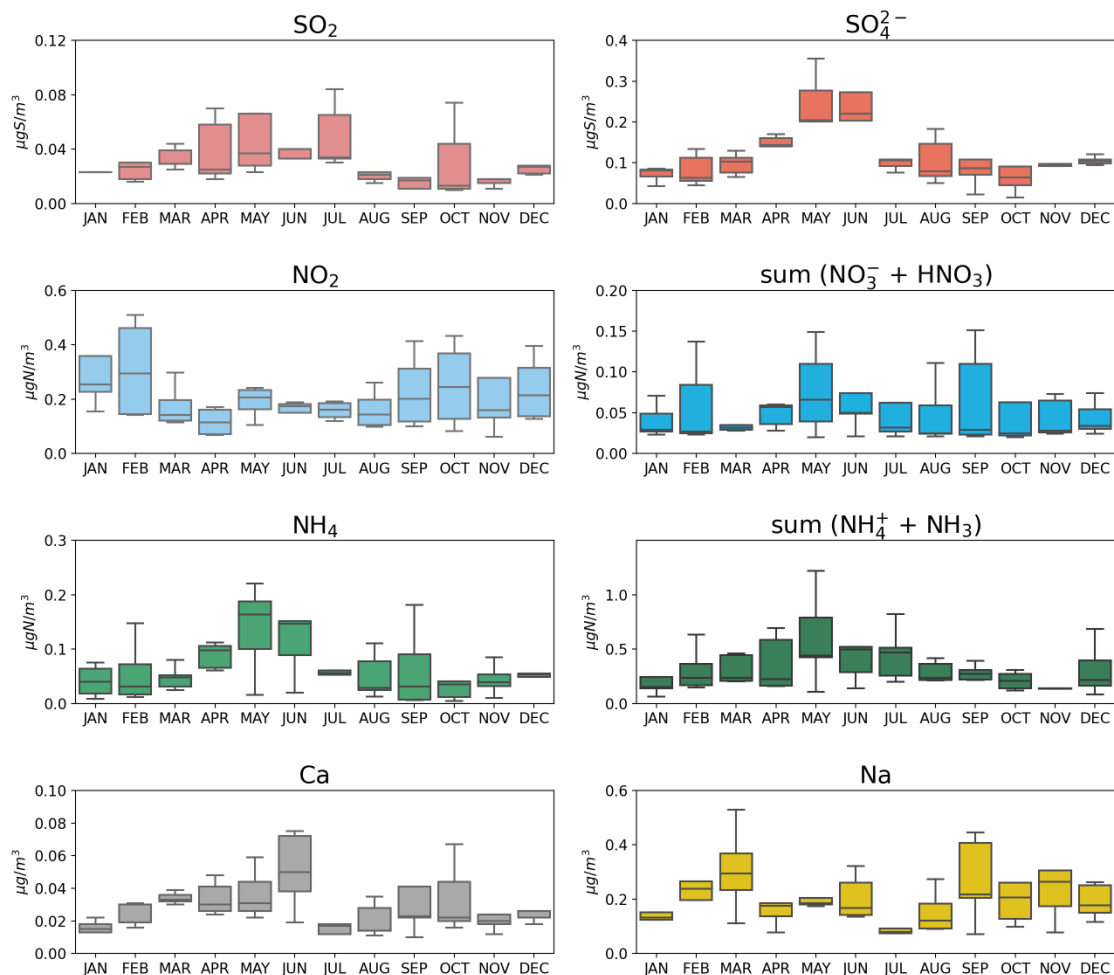


Figure 3.7: Box and whisker plots showing the median, lower and upper quartiles of the monthly mean concentrations of inorganic components in air at the five EMEP sites in Norway in 2021.

3.1.3 Total deposition of sulfur and nitrogen

Table 3.9 and Figure 3.8 present estimates of the total dry deposition of sulfur and nitrogen compounds and the measured wet deposition in the growing season from May to October (summer) and winter months from January to April and November to December. Dry deposition is calculated on the basis of the mean concentrations of SO₂, SO₄²⁻, NO₂, sum of nitrate (NO₃⁻ + HNO₃), and sum of ammonium (NH₃ + NH₄⁺) 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 (NO₃⁻ + HNO₃), it is assumed that HNO₃ contributes with 25% and NO₃⁻ with 75%, whereas for the sum of ammonium (NH₃ + NH₄⁺) NH₃ is presumed to contribute with 8% and NH₄⁺ by 92% (Ferm, 1988). The dry deposition velocities of gases and particles are highly variable and uncertain quantities. The deposition of particles (SO₄²⁻, NO₃⁻, and NH₄⁺) increases with wind speed and with the ground's roughness (forest coverage etc.). The deposition of gases (SO₂, NO₂, HNO₃, and NH₃) depends on the biological activity of the vegetation and surface type (water, mountains, etc.). The deposition is for most gases far greater on wet surfaces than when the surfaces are dry. In winter, the deposition is small because of low biological activity, and because the surface is often covered by snow and ice. The stable layer of air close to the ground in winter also reduces the transport of contaminants to the ground.

The wet deposition contribute most to the total deposition at all the sites on the mainland, for both nitrogen and sulfur, and the total deposition is highest in southern Norway (Figure 3.8 and Table 3.9). Dry deposition of sulfur contributes to the total deposition with 14-28% in summer and 4-14% in winter except at Svalbard where the contribution from dry deposition is higher due low precipitation amount. Dry deposition of nitrogen contributes between 13-40% in summer and 4-18% 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 2021.

	Sulfur (mg S/m ²)						Nitrogen (mg N/m ²)					
	Dry deposition		Wet deposition		% dry deposition		Dry deposition		Wet deposition		% dry deposition	
	Winter	Summer	Winter	Summer	% W	% S	Winter	Summer	Winter	Summer	% W	% S
Birkenes	4	37	94	151	4	20	20	77	440	496	4	13
Hurdal	2	19	28	117	8	14	11	89	185	367	6	19
Kårvatn	2	20	25	96	6	17	24	89	121	132	17	40
Tustervatn	3	16	18	42	14	28	13	67	83	101	14	40
Zeppelin*	4	11	12	16	27	41	-	-	25	11	-	-

Dry deposition = measured air concentrations · dry deposition velocity from literature Dry deposition velocities used: SO₂: 0.1 cm/s (winter) - 0.7 cm/s (summer). SO₄: 0.2-0.6 cm/s, NO₂: 0.1-0.5 cm/s, HNO₃: 1.5-2.5 cm/s, NO₃: 0.2-0.6 cm/s, NH₄: 0.2-0.6 cm/s, NH₃: 0.1-0.7 cm/s. Sum nitrate = 25% HNO₃ + 75% NO₃. Sum ammonium = 8% NH₃ + 92% NH₄.

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.

*Used the wet deposition at Ny-Ålesund.

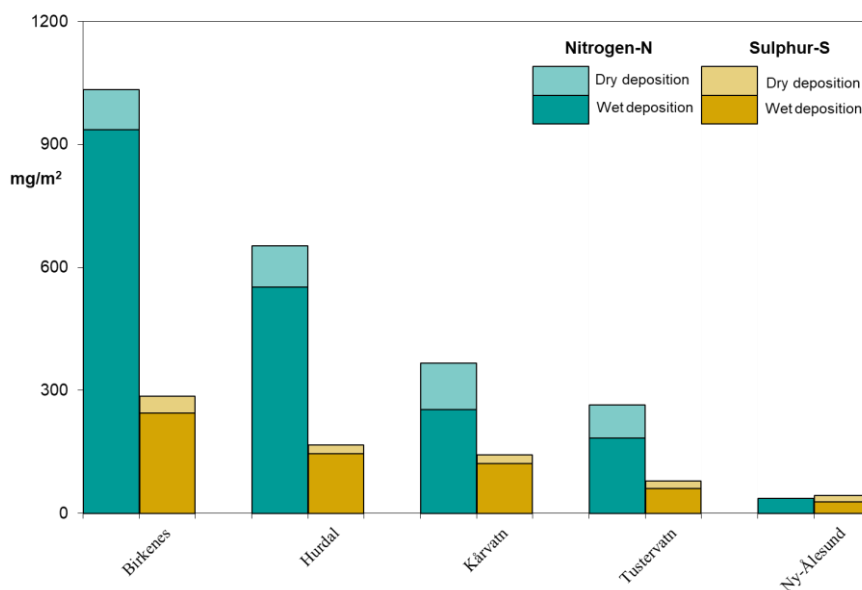


Figure 3.8: Total deposition (wet+ dry) of sulfur-S (SO_2 , SO_4^{2-}) and nitrogen-N (NO_2 , NH_4^+ , NH_3 , NO_3^- , HNO_3) at Norwegian background stations 2021.

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 give indications on 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 were defined for 2020 with 2005 as the base year. The 27 EU countries have committed to the following emission reductions with the numbers for Norway in brackets; SO_2 : 59% (10%), NO_x : 43% (23%), nmVOC: 28% (40%), ammonia: 6% (8%) and $PM_{2.5}$: 22% (30%).

Figure 3.9 - Figure 3.13 show the time series of annual mean concentrations of main ions in precipitation, in air and total deposition at selected sites in Norway with long time series. Table 3.10- Table 3.11 includes the calculated linear trends for different periods: 1980-2000, 1990-2010 and 1990-, 2000-, and 2005-2021 for all sites with measurements in these respective periods. Since the sulfur trend is not linear, it is not calculated trends for the whole period 1980-2021.

For the statistical analysis, the non-parametric “Mann-Kendall Test” has been used on annual means for detecting and estimating trends (Gilbert, 1987). The Mann-Kendall test has become a standard method when missing values occurs and when data are not normally distributed. In parallel to this, the Sen’s slope estimator has been used to quantify the magnitude of the trends. The python package pyMannKendall has been used to calculate the trends and Sen slope (Hussain et al. 2019).

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 2021. Since 1990, the content of sulfate in precipitation in Norway has decreased between 56% to almost 100%. The reductions in airborne concentrations of sulfate have been similar, between 78% and almost 92% at the Norwegian mainland, while for sulfur dioxide the trend is almost 100%. The calculated linear trend for this long period gives reductions

higher than 100%, which illustrates the problem of assuming linearity when the trend is higher in one part of the period. Somewhat lower reductions are observed at the Zeppelin Observatory; 75% for sulfur dioxide and 43% for sulfate, Table 3.11. For the period 2000-2021, sulfate in air are reduced between 64-90% at the mainland, while in precipitation between 44-89% for the sites south of Nordland county, similar for the period 2005-2021: 35-82% and 50-68% for sulfate in precipitation and aerosols, respectively. The largest sulfur reductions are seen in winter and spring for the period 2000-2021 (Figure 3.13).

The NO₂ concentration has decreased at all four sites, between 41% to almost 100% from 1990-2021 and 35-60% from 2000-2021 (Table 3.11), while between 40-47% since 2005 at two of the four mainland sites. Kårvatn and Tustervatn do not experience significant trends for this latter period. The nitrate concentrations in precipitation have significantly decreased at most sites, about 40-60% since 1990 for the mainland sites, around 30% reduction since 2000 at most sites (Table 3.10). This is not seen for sum(NO₃+HNO₃) in air where few sites show significant trends for the earlier periods, but from 2005 to 2021 there are significant reductions at three of the mainland sites between 56-65% while 91% reduction at Zeppelin (Table 3.11). The lowest reductions for the oxidised nitrogen compounds are seen during the summer months (Figure 3.13).

For ammonium in precipitation there are fewer sites than for nitrate with significant trends. Six of the sites show a decrease around 40% since 1990, at Nausta there is on the other hand an increase. From 2000, four of the sites experience a significant decrease. For sum(NH₄⁺+NH₃) in air it is only Tustervatn with significant reductions from 2000, though three sites with reductions between -61-82% for the period 2005-2021. When only looking at ammonium in aerosols it is a significant reduction of around 60-80% (not shown) at the mainland sites for the period 2000-2021. These large differences between the changes found for the different reduced nitrogen components (Figure 3.13) can be explained by the interaction of ammonia with the sulfur and oxidized nitrogen components. It can be noted that the results imply that the contribution of ammonia emissions to aerosols has been largely reduced during the 2000–2021 period, due to the impact of SO_x and NO_x emission reductions (EMEP, 2021). The lowest reductions for the reduced nitrogen compounds are seen during the winter months (Figure 3.13).

Calcium is significantly reduced at most sites since 1980, which is consistent with emission reductions from anthropogenic sources in Europe (Hellsten et al., 2007). However there is an increase in calcium at four mainland sites from 2000 indicating that the contributions from mineral dust are influencing the trends. The contribution of sea salts are influenced by meteorological conditions and vary from year to year. A significant increase in sodium is seen at Vatnedalen since 2000, but there is not a general trend in sea salt contribution.

The trends in wet deposition follow to a large extent the trends in concentrations in precipitation though with larger variabilities (not shown) due to the annual variations in precipitation amount. Change in climate may influence the trends in wet deposition. i.e. due to more or less precipitation. It seems to be an increase in precipitation at some of the sites in southern Norway since 1990 (Table 3.10) and this may counteract some of the decreasing trend in emission. Though the precipitation amount was low in 2021 causing relatively low wet deposition this year (Figure 3.9).

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; Colette et al., 2021; EMEP 2021).

Table 3.10: Trends in annual mean concentrations of inorganic ions in precipitation. Only significant trends are shown ($p=0.05$). Shaded area means not available data, while the signs indicate increase or decrease in percent change for the whole period. Reductions larger than 100% are due to uncertainties in the statistical method used and nonlinear trend.

Site	ssc SO ₄ ²⁻					NO ₃ ⁻					NH ₄ ⁺				
	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021
Birkenes	-68	-71	-88	-65	-61	-18	-35	-48	-33	-33	-46	-38	-40	-	-
Brekkebygda	-68	-81	-110	-89	-77	-	-44	-61	-29	-50	-56	-	-70	-45	-63
Hurdal		-55	-85	-85	-82		-	-46	-55	-71		87	-	-	-
Høylandet*		-75	-95	-62	-58		-24	-39	-30	-37		-	-	-	-40
Karpbukt		-74	-71	-33	-45		-60	-59	-	-		-66	-	-	-
Kårvatn	-83	-43	-56	-44	-	-27	-	-	-	-	-	-	-	-	-
Løken	-69	-86	-102	-66	-54	-38	-41	-53	-26	-28	-68	-45	-39	-	-
Nausta		-72	-93	-77	-58		-	-40	-32	-		-	53	-	-
Ny-Ålesund	-84	-81	-86	-	-	-	-	-30	-	-	615	-	-48	-	-
Treungen	-64	-79	-95	-72	-63	-	-34	-57	-37	-39	-25	-31	-48	-33	-
Tustervatn	-75	-56	-67	-	-	-	-	-	-	-25	99	-	-38	-42	-38
Vatnedalen	-62	-64	-82	-60	-35	-	-	-50	-32	-43	-	-	-	-	-
Vikedal		-74	-106	-82	-71		-19	-44	-44	-37		-	-	-28	-33

Site	Na ⁺					Ca ²⁺					mm				
	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021
Birkenes	-	-	-	-	-	-66	-	60	93	49	-	-	72	39	-
Brekkebygda	-	-	-	-	-	-37	-	-	-	-	-	75	116	-	-
Hurdal		-	-	-	-		-	-	-	-		-	-	-	-
Høylandet*		-	-	-	-		98	68	-	-		-	31	-	-
Karpbukt		-	-	-	-		-	-	-	-		122	67	-	-
Kårvatn	-	-	-	-	-	-53	-	-	-	-	-	-	-	-	-
Løken	-	-47	-	-	-	-52	-	-	70	70	-	-	-	-	-
Nausta		-	-	-	-	-	-	-	-	-		-	-	-	-
Ny-Ålesund	-	-	-41	-	-	-	-	-48	-64	-	-	-	-	-	-
Treungen	-	-	-	-	-	-50	-	-	48	-	-	-	45	-	-
Tustervatn	-	-	-	-	-	-	-	-	-	-	-	-	-18	-	-
Vatnedalen	-	-46	-	90	109	-	-	-	-	-	-	-	-	-	-
Vikedal		-	-	-	-	-	-	-	63	-		-	-	-	-

*Not included 2021 data for Høylandet

Table 3.11: Trends in annual mean concentrations of inorganic components in air. Only significant trends are shown ($p=0.05$). Shaded area means not available data, while the signs indicate increase or decrease in percent change for the periods. Reductions larger than 100% are due to uncertainties in the statistical method used.

	SO ₂					SO ₄ ²⁻				
	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021
Birkenes	-88	-111	-112	-67	-	-58	-63	-79	-70	-55
Nordmoen/Hurdal		-104	-110	-84	-94		-76	-92	-90	-68
Kårvatn	-122	-88	-86	-46	-	-71	-61	-79	-64	-50
Tustervatn	-107	-91	-95	-83	-59	-70	-59	-78	-78	-66
Zeppelin	-82	-64	-75	-66	-44	-	-28	-43	-40	-39

	NO ₂					sum(NO ₃ +HNO ₃)				
	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021
Birkenes		-59	-71	-55	-40		-	-	-	-
Nordmoen/Hurdal		-121	-100	-60	-47		-	-86	-58	-59
Kårvatn		-	-41	-43	-		-	-	-	-65
Tustervatn		-52	-55	-35	-		-	-	-	-56
Zeppelin							-	-	-	-91

	sum(NH ₄ ⁺ +NH ₃)					Na ⁺				
	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021	1980-2000	1990-2010	1990-2021	2000-2021	2005-2021
Birkenes		-44	-42	-	-61		-	-	-	-
Nordmoen/Hurdal		-56	-65	-	-79		-	-	-	-27
Kårvatn		83	55	-	-		-	-	-20	-
Tustervatn		54	-	-72	-82		-	-	-	-
Zeppelin		265	115	-	-		-	-	-	-

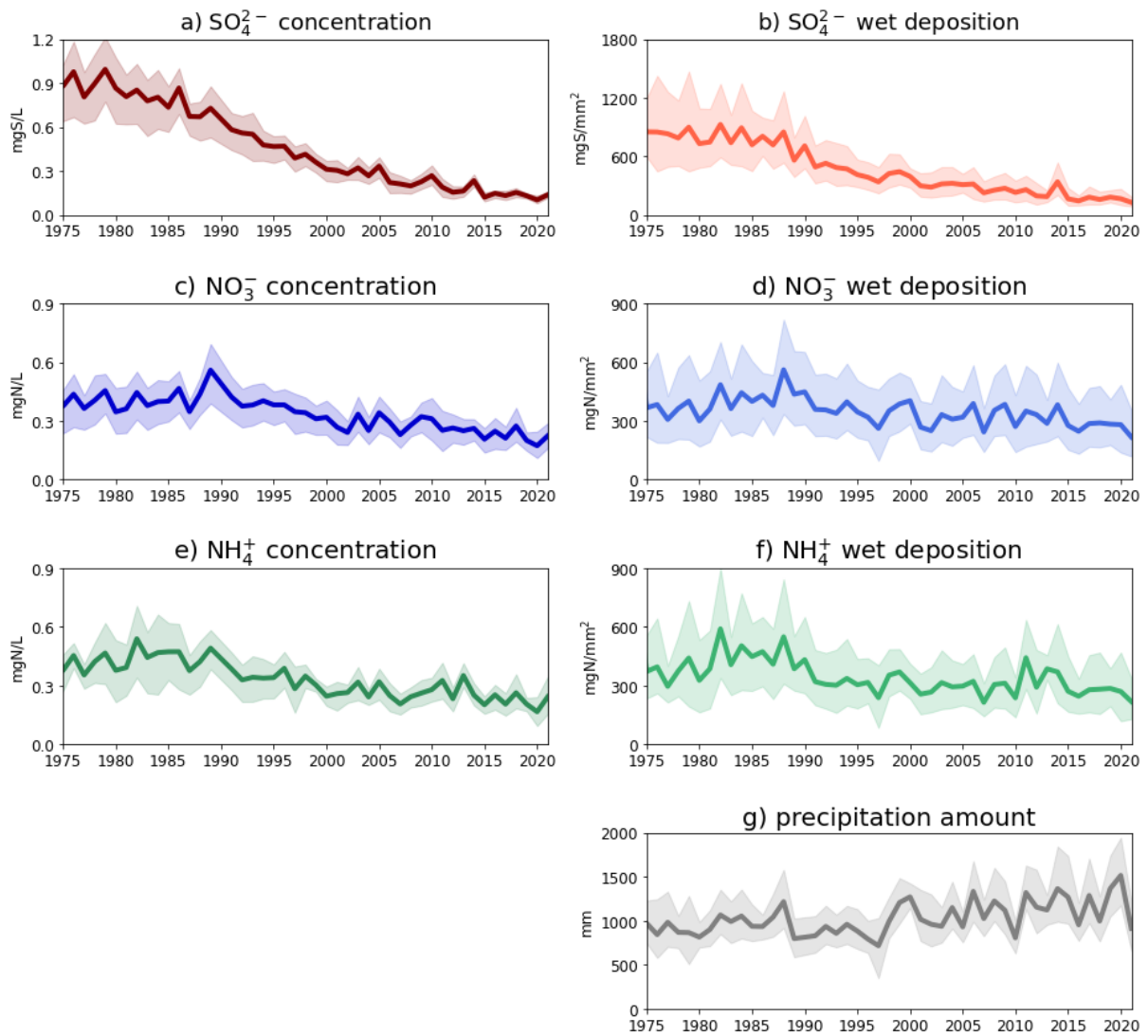


Figure 3.9: Average volume weighted annual mean concentrations and wet deposition of sea salt corrected sulfate, nitrate and ammonium at five representative sites in southern Norway (Birkesnes, Vatnedalen, Treungen, Gulsvik and Løken), 1975-2020. The solid lines are the average between the sites and the shaded areas indicate the 95% confidence interval around the mean.

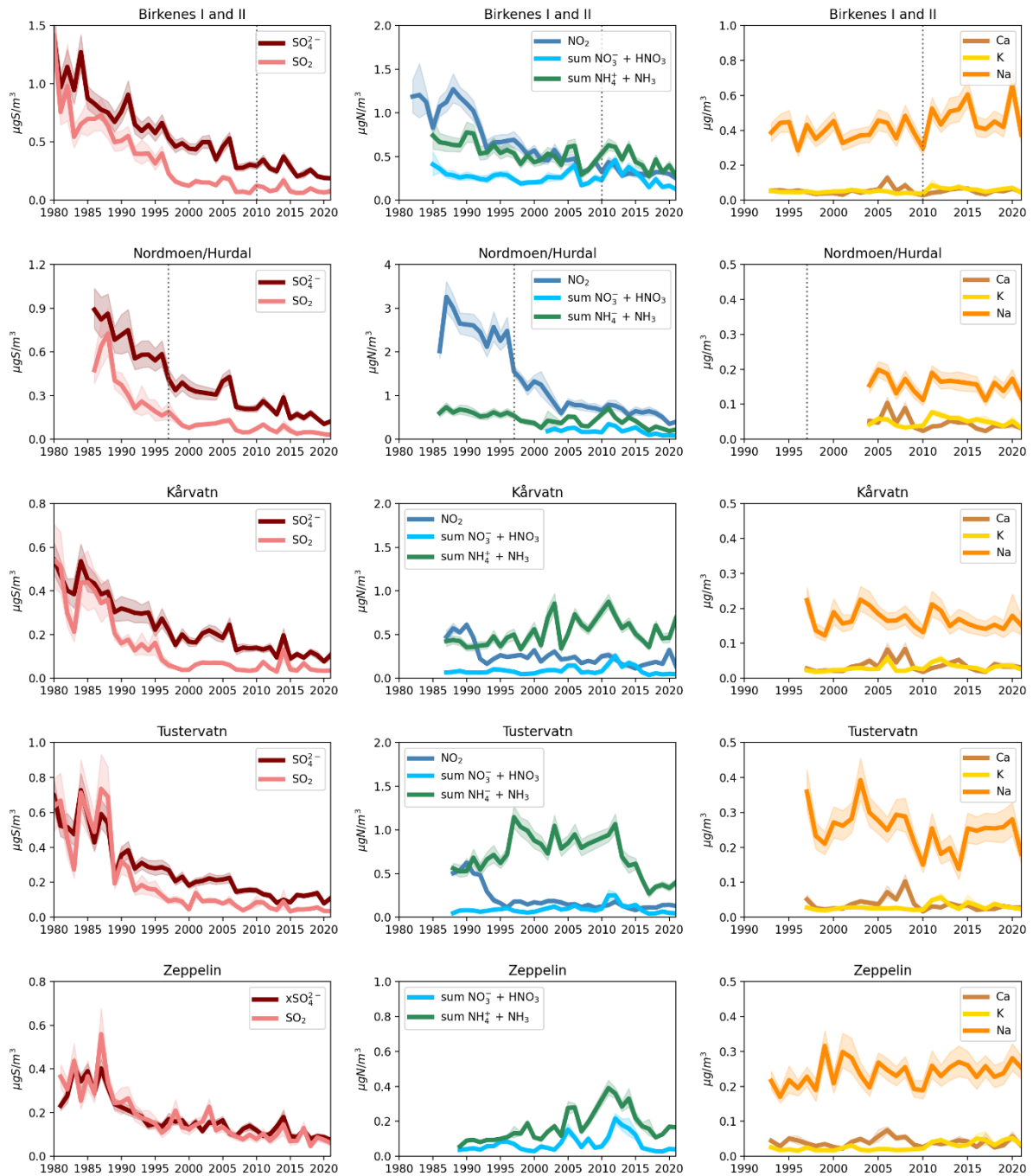


Figure 3.10: Average annual mean concentrations of the main components in air at the Norwegian EMEP sites, 1980–2021. The solid line is the annual averages and shaded areas indicate 95% confidence interval of daily or weekly concentrations around the mean.

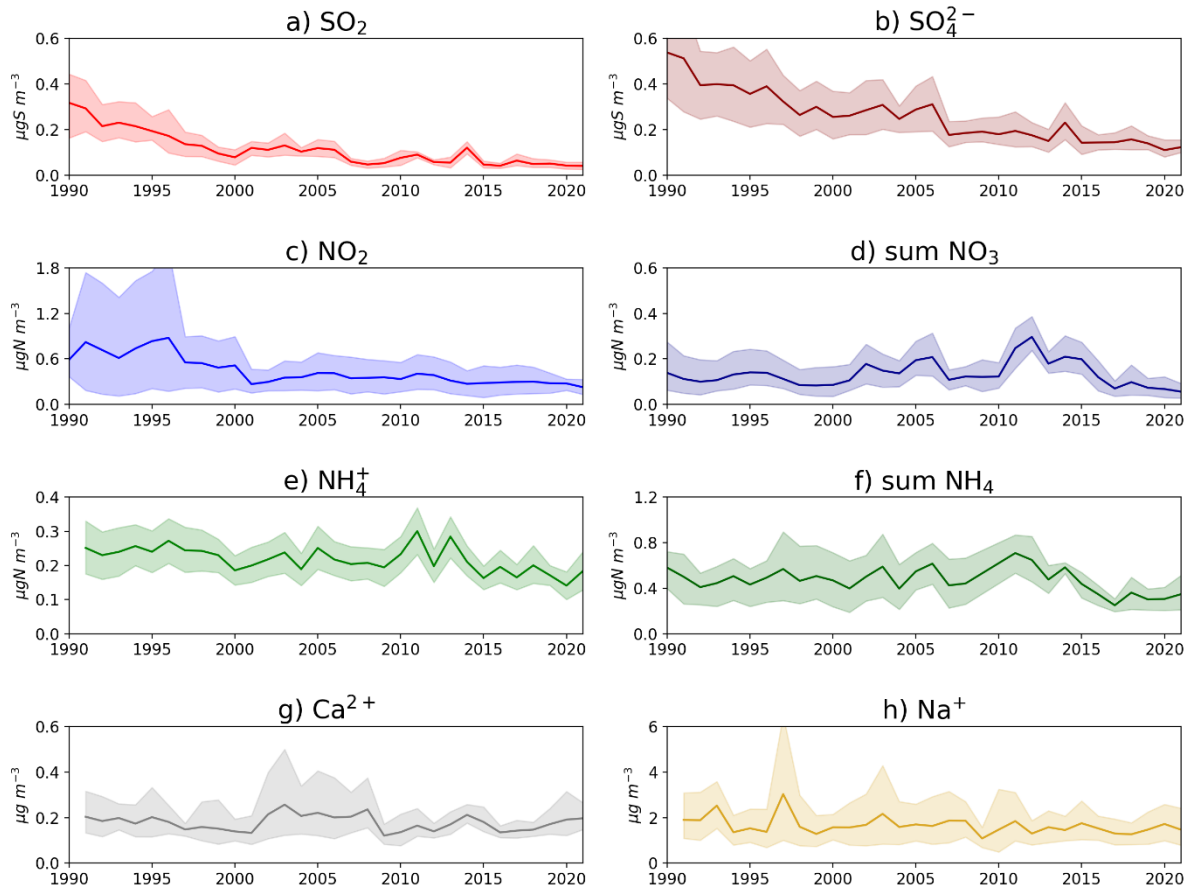


Figure 3.11: Average in annual mean concentrations in air at Birkenes, Hurdal/Nordmoen, Kårvatn, Tustervatn and Zeppelin, 1990–2021. Zeppelin not included for c) NO_2 . The solid line is the average between the sites and shaded areas indicate 95% confidence interval around the mean.

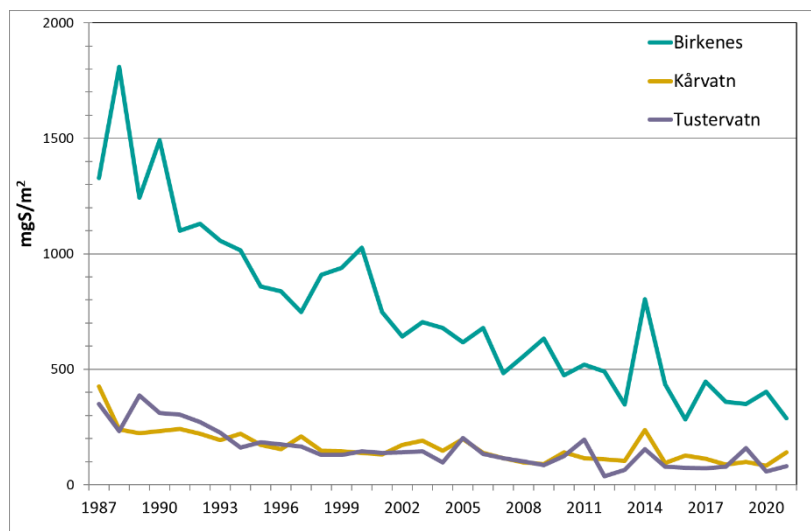


Figure 3.12: Trends in total deposition (wet + dry) of sulfur at three Norwegian EMEP sites, 1987–2021.

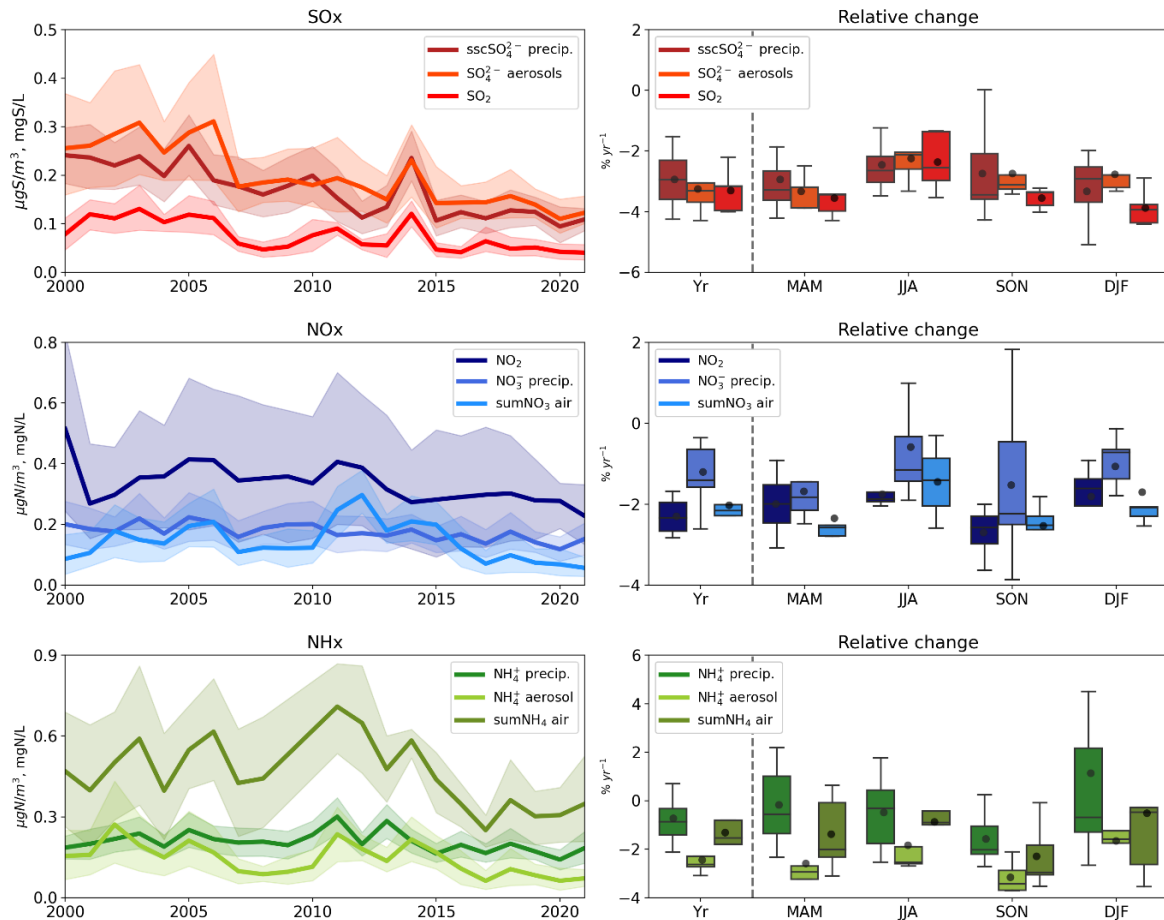


Figure 3.13: Annual and seasonal trends in sulfur and nitrogen components, 2000-2021. The solid line in the trend plots indicate the average annual mean concentrations for all the sites and the shaded area the 95% confidence interval. The box plot represent the 50th, 25th, and 75th percentiles and the whiskers lie within the 1.5 inter-quartile ranges for the trends of all the sites, including those with not significant trends. The black circle indicate the average relative trends. The trends in precipitation includes 13 sites while in air/aerosols 5 sites, except 4 sites for NO_2 .

3.3 Summary

For most of the main inorganic components, the highest annual mean concentrations in 2021 were measured at Birkenes, which is the station in Norway most affected by long-range transport of pollutants. The site in Finnmark, Karpbukt is influenced by emissions from Russia with elevated concentrations of especially sulfate, but the concentration levels have decreased dramatically after the smelters in Nikel were closed down in December 2020. Some inland sites are influenced by regional agricultural activities and experience somewhat higher ammonium concentrations. For NO_2 , the highest levels are seen in Hurdal, which is influenced 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 2021 were in general a somewhat higher than in 2020, which experiences very low concentrations due to special weather conditions and lower emissions due to the restrictions in connection with the pandemic in Europe. On the other hand it was relatively little precipitation in 2021 resulting in low wet deposition.

In a longer perspective, there are large reductions in sulfur in all parts of Norway, since 1990 around 80-90% (depending on the compound), and since 2000 about 50-80%. Nitrate and ammonium concentrations in precipitation have decreased significantly at most sites in southern Norway, around 30-60% for nitrate and 30-40 for ammonium since 1990. The NO_2 -concentration has also decreased significantly between 40-90% since 1990, and between 35-60% since 2000.

Since Norway is downstream of major emissions sources in Europe, these observed reductions reflect emission trends at the European continent. These reported emission reduction for the period 2000-2019 for the western European countries (EU27+UK+EFTA) are 80%, 38% and 12% for SO_x , NO_x and NH_x respectively (EMEP, 2021).

4 EC and OC

4.1 Introduction

Monitoring of Elemental Carbon (EC) and Organic Carbon (OC) in PM₁₀ 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 to 2001 and to 2010 at Hurdal and Kårvatn. OC and EC measurements in PM₁₀ for the remote Arctic site Zeppelin Observatory was included in 2019.

Annual and monthly mean concentrations of EC and OC in PM₁₀ and PM_{2.5} for 2021 are shown in **Table A1.35**; whereas annual mean concentrations for EC and OC in PM₁₀ and PM_{2.5} for 2001 – 2021 are listed in Table A1.36.

Incidences of PM_{2.5} > PM₁₀ (monthly) 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, particularly for EC. OC in PM_{10-2.5} is derived from the observed values of OC in PM₁₀ 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: EC and OC) can be found in Annex 3.

4.2 Concentrations of OC in PM₁₀, PM_{2.5} and PM_{10-2.5}

The annual mean concentration of OC in PM₁₀ (0.76–1.14 µg C/m³) and PM_{2.5} (0.53–0.73 µg C/m³) at Norwegian rural background sites are amongst the lowest in Europe. Fine fraction OC (64 – 78%) was the major fraction of OC in PM₁₀ 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 for certain months. This is typically observed for the second half of the growing season and is attributed to the presence of primary biological aerosol particles (PBAP), such as e.g. fungal spores.

The annual mean concentration of OC in PM₁₀ at Hurdal was approximately 50% higher than at Birkenes and at Kårvatn. Coarse fraction OC is noticeably higher at Hurdal compared to the two other sites, as seen for previous years, unknown for what reason, and we are left speculating that it reflects variability in PBAP from the local vegetation. Fine OC was highest at Hurdal and thus unchanged from previous years. The reduced concentration at Hurdal compared to Birkenes seen for the two previous years was not as pronounced for 2021. In previous year's report, we speculated that this was due to less influence of emissions from the densely populated and anthropogenic influenced region surrounding the Hurdal site, as a similar finding was made for fine EC and NO₂ (see Chapter 3.1.2), which typically are explained by emissions from vehicular traffic in this region.

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. This reflects increased levels of Secondary Organic Aerosol (SOA), and Biogenic SOA (BSOA) in particular, contributing to the fine fraction, and PBAP contributing primarily to the coarse fraction in the growing season (See Yttri et al., 2011 a, b; Yttri et al., 2021), as well as reduced emissions from residential heating in the non-heating season. A pronounced covariance was observed between sites with respect to seasonality and high concentration episodes; increased levels in the transition May/June, most of July and in the transition August/September was observed at all sites. Seasonal covariance is driven by climatological factors, e.g., temperature is decisive for the formation of SOA and pollen release in summer as well as for domestic heating in winter, and episodes of long-range atmospheric transport (LRT) air pollution is well known to affect large regions. Prolonged sampling time (here: weekly) could potentially mask differences between sites. The highest monthly mean for OC in PM₁₀ and PM_{2.5} was observed in June and July. The monthly mean for OC exceeded 2 µg C m⁻³ for the PM₁₀ fraction only at Hurdal.

Annual means of OC were generally low in 2021, equaling the long term mean or ranging within -SD of the long term mean.

The annual mean OC concentration at the Zeppelin Observatory was 9-13 times lower than that observed at rural background sites on the Norwegian mainland. A nearly 2.5 times reduction in the annual mean was observed compared to the previous year, characterized by two major LRT episodes. The highest monthly means were observed in March, corresponding to the Arctic Haze phenomenon, in August/September, corresponding to the peak in BSOA and in Boreal forests fires (Yttri et al., in prep.), and in December. The highest weekly mean in 2021 was one order of magnitude lower than for the highest weekly mean in 2020.

The OC level at Zeppelin was comparable in summer and in winter, a finding highlighted in a recent study (Moschos et al., 2022), and likely representative for a year not influenced by major Boreal forest fires episodes, as seen in 2020. Major sources in summer are BSOA and PBAP in addition to biomass burning (BB) from Boreal forest fires. BB emissions from residential wood burning contributes to OC in the heating season along with emissions from combustion of fossil fuel. Efficient transport of polluted air masses to the Arctic in winter and accumulation caused by the favourable conditions forming Arctic haze, cause increased levels in winter/spring.

4.3 Concentrations of EC in PM₁₀ and PM_{2.5}

The annual mean concentration of EC in PM₁₀ (0.04-0.09 µg C/m³) and PM_{2.5} (0.04-0.08 µg C/m³) at Norwegian rural background sites are amongst the lowest in Europe. EC results from incomplete combustion of fossil fuel and biomass and emissions are thus almost exclusively associated with the fine fraction of PM₁₀. EC levels were highest at Hurdal, as seen for previous years, being 50-60% higher compared to Birkenes and 100-125% higher than at Kårvatn. As argued for fine OC in Chapter 4.2, the increment observed for Hurdal compared to Birkenes has increased compared to the previous two years (2019 and 2020), when it was particularly low. We have previously argued that the increased levels of EC, fine OC and NO₂ at Hurdal compared to the other sites, are explained by emissions from the densely populated and anthropogenic influenced region surrounding the site; albeit crude, EC is regarded as a tracer of anthropogenic activity. EC was a minor contributor to the total carbon (TC) concentration, i.e., 5 – 7% (PM₁₀) and 7 – 10% (PM_{2.5}). EC levels were generally low in 2021, being lower than or equaling -SD of the long term mean. At Birkenes and Kårvatn, fine fraction EC equaled the lowest annual mean observed since the measurements started in 2001 and 2010, respectively.

EC levels are typically somewhat higher in winter compared to summer at the rural background sites, so also for 2021. Note though, that for such low levels observed at Norwegian rural background sites, seasonality becomes highly susceptible to occasional events. E.g., the monthly mean can vary by nearly a factor of four between two consecutive months and even more at the Arctic site Zeppelin.

The contribution of biomass burning to EC (and OC) have been estimated based on levoglucosan measurements (Chapter 4.6).

The annual mean EC concentration at the Zeppelin Observatory was 5-11 times lower than that observed at rural background sites on the Norwegian mainland, and was a factor of two lower compared to the previous year, characterized by two major LRT episodes. At Zeppelin, EC peaked in late winter/spring due to the Arctic Haze phenomenon. There was also a minor but characteristic peak in August attributed to emissions from Boreal forest fires, confirmed by levoglucosan measurements.

The annual mean EC/TC ratio at Zeppelin (9%) was comparable to the higher end of the range calculated for rural background sites. The EC/TC ratio seasonality largely resembles that seen for the

rural background sites, with deviations observed in the Arctic Haze period and when influenced by Boreal forest fires.

4.4 Relative contribution of EC and OC to PM

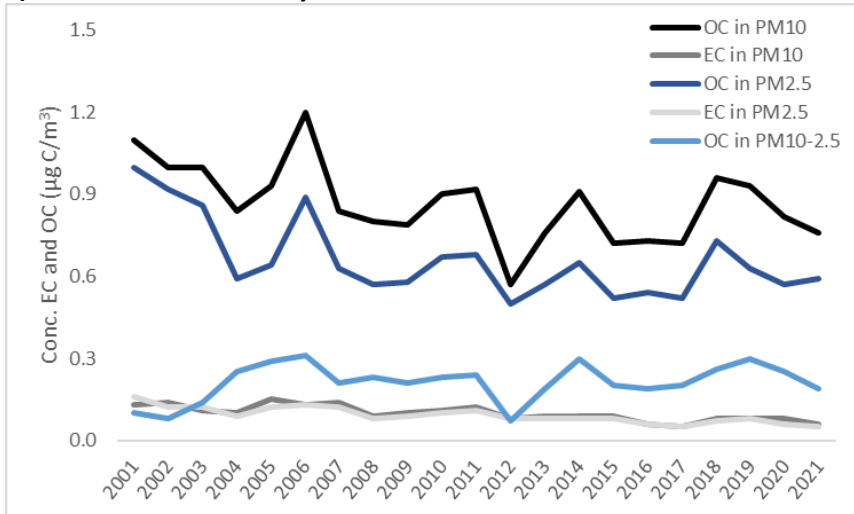
The relative contribution of OC ranged from 19 – 29% for PM_{10} and from 24 – 27% for $PM_{2.5}$ annually. The OC fraction was higher in summer than in winter for PM_{10} , but the other way around for OC in $PM_{2.5}$, except for Hurdal. The relative contribution of OC to $PM_{10-2.5}$ was 11 - 25% on an annual basis, and much more pronounced in summer than in winter.

EC accounted for 1.2 –2.3% of PM_{10} annually, whereas it was somewhat higher for $PM_{2.5}$ (1.8–3.0%), reflecting that EC is associated with fine aerosol particles. The EC fraction of PM was more abundant in the winter-time aerosol than in the summer-time aerosol.

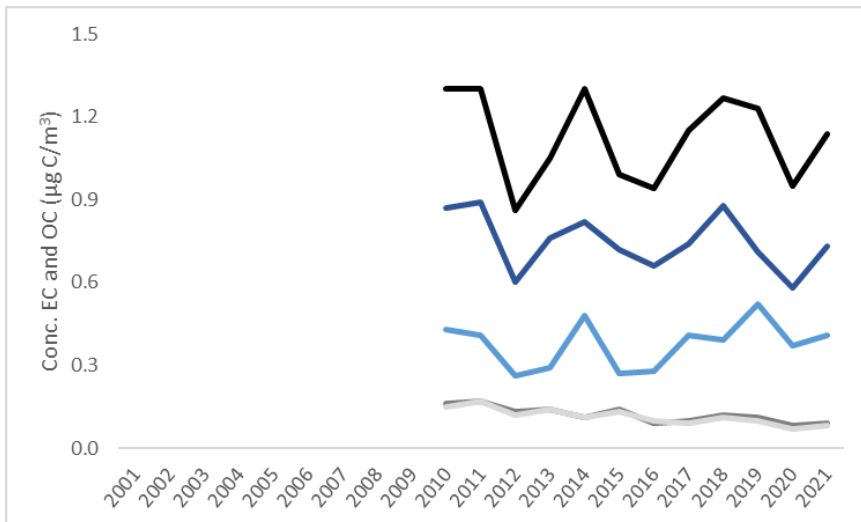
4.5 Trends for concentrations of EC and OC

The Mann Kendall method described in Chapter 3.2 was used for trend analysis of concentrations of EC and OC (Table 4.1). The time series of OC in PM_{10} , $PM_{2.5}$ and $PM_{10-2.5}$, and that of EC in PM_{10} and $PM_{2.5}$, are shown in Figure 4.1.

a) Birkenes Observatory



b) Hurdal



c) Kårvatn

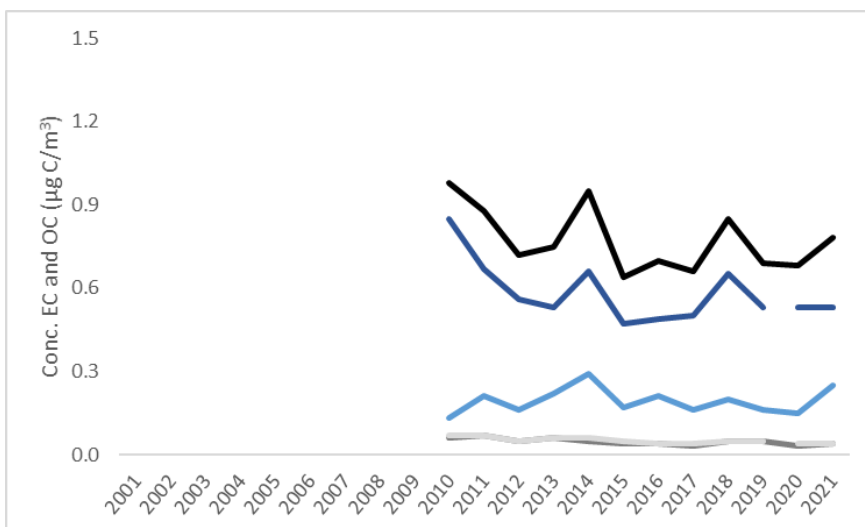


Figure 4.1: Annual mean time series of OC and EC at the Birkenes Observatory (2001 – 2021) (a), Hurdal (2010 - 2021) (b) and Kårvatn (2010 - 2021) (c). Unit $\mu\text{g C}/\text{m}^3$

There was a statistically downward trend for EC at all sites ranging from -42% to -58% for PM₁₀ and from -42% to -62% for PM_{2.5}, with the most pronounced decrease seen for Birkenes, having the longest time series. Significantly downward trends for OC (and TC) were calculated only for Birkenes, and the decrease was only half of that seen for EC. We explain this discrepancy by the substantial contribution from natural sources (BSOA and PBAP) that are not subject to abatement. The anthropogenic fraction of OC is likely to have decreased though given the observed decrease in EC, which albeit crude is a tracer of anthropogenic activity.

Table 4.1: Trends in annual mean mass concentration of OC, EC, and TC in PM₁₀ and PM_{2.5} using Mann-Kendall test and Sen slope estimates; significant level is set to 0.05.

Site	PM ₁₀	% change	Year	PM _{2.5}	% change	Year
Birkenes			2001-2021			2001-2021
OC	*	-24%		*	-30%	
EC	*	-58%		*	-62%	
TC	*	-28%		*	-37%	
Hurdal			2010-2021			2010-2021
OC		-			-	
EC	*	-47%		*	-50%	
TC		-			-	
Kårvatn			2010-2021			2010-2021
OC		-			-	
EC	*	-42%		*	-42%	
TC		-			-	

4.6 Concentrations of levoglucosan, mannosan and galactosan in PM₁₀

Measurements of levoglucosan, mannosan and galactosan in PM₁₀ takes place at the Birkenes Observatory and is used to estimate the contribution of biomass burning emission to the carbonaceous aerosol (here: OC and EC) and to PM.

The annual mean concentration of levoglucosan in PM₁₀ observed at the Birkenes Observatory was 9.0 ng m⁻³ (Table 4.2). The seasonality was pronounced with higher levels in the heating season. Low levoglucosan levels in summer may partly reflect increased degradation by the OH radical, but higher emissions from residential wood burning in winter compared to summer explains most of the seasonality. Spring and fall are transition seasons and with relative contributions typically lower than in winter and higher than in summer. Occasionally, high levels can be observed in these seasons as well. A seasonally consistent levoglucosan/mannosan ratio indicates that biomass burning emissions from one source category (residential wood burning) prevails throughout the year. This allows us to use one set of factors to calculate OC and EC from biomass burning based on levels of levoglucosan (12.7 for OC in PM₁₀, 11.1 for OC in PM_{2.5}, and 1.96 for EC (Yttri et al., 2021)). Some influence from wild and agricultural fires in the growing season is likely, but the magnitude of these sources remains speculative.

We estimate that biomass burning contributed 15-17% to OC and 31-34% to EC, annually, considering both PM₁₀ and PM_{2.5}. The fraction attributed to biomass burning in winter was 47-52% for OC and 52-56% for EC, whereas it was approximately 3% (OC) and approximately 11% (EC) in summer, considering both size fractions. Spring and fall are transition seasons with relative contributions typically lower than in winter and higher than in summer. Occasionally, LRT air pollution from continental Europe seems to explain elevated biomass burning aerosol levels observed at the Birkenes Observatory

(Yttri et al., 2021) and to be decisive not only for episodes of high concentrations, but also the mean concentration.

Table 4.2: Annual mean concentrations of levoglucosan, mannosan and galactosan in PM₁₀ at Birkenes for 2017-2021. Seasonal mean concentrations for 2020. Unit: ng m⁻³.

Year		Levoglucosan	Mannosan	Galactosan	
2017	Annual	8.2	1.3	0.32	
	2018	Annual	9.8	1.6	0.39
	2019	Annual	8.3	1.4	0.29
	2020	Annual	7.7	1.3	0.33
2021	Annual	9.0	1.4	0.34	
	Winter	19	2.7	0.76	
	Spring	11	1.9	0.41	
	Summer	2.7	0.42	0.06	
	Fall	4.3	0.89	0.17	

Winter = DJF; Spring = MAM; Summer = JJA; Fall = SON.

4.7 Summary

Observed annual mean concentrations of carbonaceous aerosol in the Norwegian rural background environment are amongst the lowest in Europe (OC < 1.1 $\mu\text{g C m}^{-3}$ and EC < 0.09 $\mu\text{g C m}^{-3}$), being approximately ten times higher compared to the remote Arctic environment (OC < 0.1 $\mu\text{g C m}^{-3}$ and EC < 0.008 $\mu\text{g C m}^{-3}$). Annual mean OC and EC concentrations at the Arctic Zeppelin observatory were halved compared to the previous year, emphasizing the influence of major LRT episodes on the Arctic carbonaceous aerosol burden. A statistically significant downward trend was observed for EC (-42% - -62%) at all rural background sites, whereas for OC (-24% - -30%) a statistically significant downward trend was seen exclusively for the Birkenes Observatory.

Measurements complementary to OC and EC are needed for an assessment of sources. 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. Work in progress suggest a similar pattern for the remote Arctic. With a few exceptions, EC can be considered exclusively anthropogenic, as also wildfires, typically are initiated by anthropogenic activity. Estimates based on levoglucosan measurements suggest that biomass burning contributed 15-17% to OC and 31-34% to EC at the Birkenes Observatory annually, considering both PM₁₀ and PM_{2.5}, and 47-52% for OC and 52-56% for EC in winter.

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 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 0.02 – 10 μm , was initiated in 2010, whereas high time resolution measurements of PM_{10} started in 2017.

Annual and monthly mean mass concentrations of PM_{10} , $PM_{10-2.5}$ and $PM_{2.5}$ for 2021, obtained by gravimetric measurements, are shown in Table A1.37; whereas annual mean mass concentrations of PM_{10} , $PM_{10-2.5}$ and $PM_{2.5}$ for the time period 2000 – 2021 are listed in Table A1.38. Time series of PM_{10} and $PM_{2.5}$ for 2021 are shown in Figure 5.1. Note that $PM_{10-2.5}$ is derived from the observed values of PM_{10} and $PM_{2.5}$; i.e., the difference between PM_{10} and $PM_{2.5}$. Incidences of $PM_{2.5} > PM_{10}$ and $\Sigma PM_{2.5}$, $PM_{10-2.5} \neq PM_{10}$ at monthly time resolution 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 ($0.02 < D_p < 0.1 \mu\text{m}$), accumulation mode ($D_p = 0.1 - 1.0 \mu\text{m}$) and coarse mode ($D_p = 1.0 - 10 \mu\text{m}$) particles, are shown in Figure 5.4. 4 hours mean concentrations of PM_{10} derived from high time resolution measurements, were used to assess violation of national and international limit values and air quality guidelines. Background information on PM can be found in Annex 3.

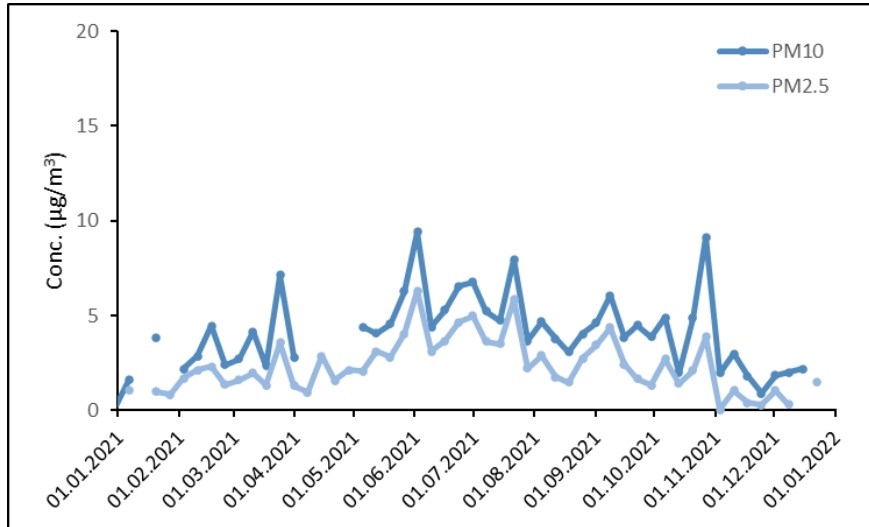
5.2 PM_{10} , $PM_{2.5}$ and $PM_{10-2.5}$ concentrations

The annual mean mass concentration of PM_{10} (3.3 – 4.1 $\mu\text{g}/\text{m}^3$) and $PM_{2.5}$ (2.2 – 2.7 $\mu\text{g}/\text{m}^3$) 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 56% at Birkenes and 67% at Kårvatn and Hurdal. $PM_{10-2.5}$ was the major fraction of PM_{10} for 4 months at Birkenes, one at Hurdal and three at Kårvatn and is typically attributed to natural sources, such as sea salts, primary biological aerosol particles (PBAP), and mineral dust.

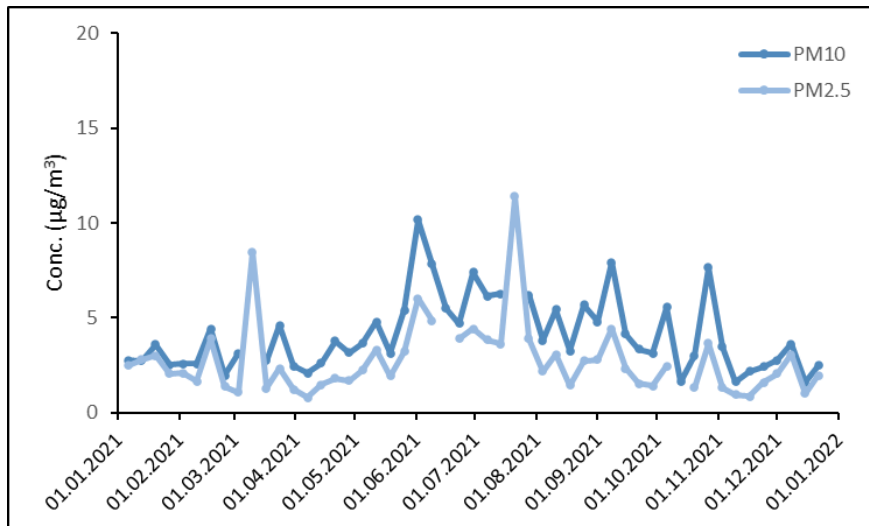
The PM_{10} annual mean was outside $-SD$ of the long-term mean at Birkenes, within $-SD$ at Hurdal and within $+SD$ at Kårvatn. For $PM_{2.5}$, the annual mean was within $-SD$ of long-term mean at Hurdal and Kårvatn, but outside $-SD$ at Birkenes, whereas for $PM_{10-2.5}$ the annual mean was within $+SD$ of the long-term mean at Hurdal and Kårvatn and outside $-SD$ at Birkenes. Note that the measurements for Hurdal and Kårvatn started in 2010, whereas measurements at Birkenes were initiated in 2000/2001.

The PM_{10} annual mean at Birkenes and Hurdal was comparable, deviating by 0.1 $\mu\text{g m}^{-3}$, being 21% higher compared to Kårvatn. A higher PM_{10} level at Birkenes has typically been attributed to a higher $PM_{10-2.5}$ fraction when compared to Hurdal, as well as a higher $PM_{2.5}$ fraction when compared to Kårvatn, but not so for 2021. Sea salt aerosol, a major contributor to the $PM_{10-2.5}$ fraction, was still 2.5 – 4 times higher at Birkenes compared to the two other sites, and we have previously speculated that a larger fraction of NO_3^- reside in the $PM_{10-2.5}$ fraction at Birkenes, following from the reaction between gaseous HNO_3 and coarse mode NaCl . Coarse fraction organic matter (OM) was 2.2 times higher at Hurdal compared to Birkenes, counteracting a substantial part of the discrepancy attributed to the lower sea salt aerosol contribution when compared to Birkenes. The equal $PM_{2.5}$ level at Kårvatn and Birkenes is not easily explained; although fine fraction OC is close to similar at the two sites, the SIA level is 2.5 times higher at Birkenes.

a) Birkenes



b) Hurdal



c) Kårvatn

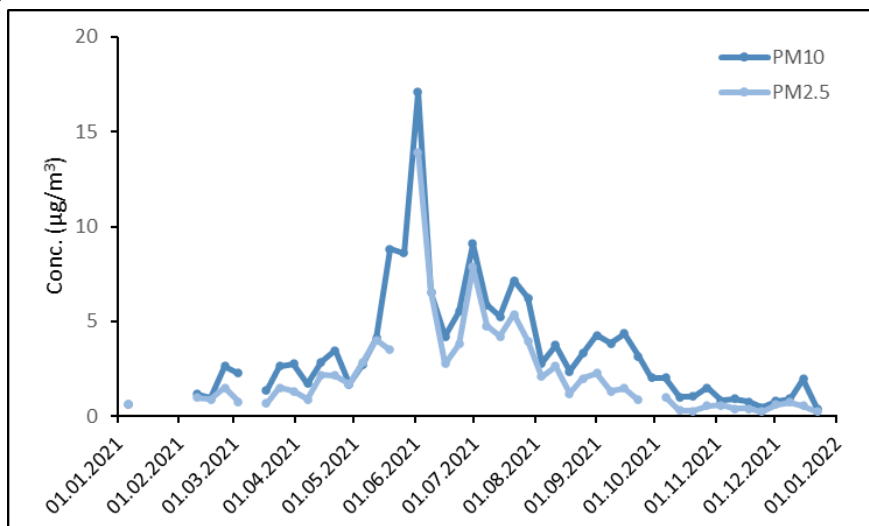


Figure 5.1: Time series of PM₁₀ and PM_{2.5} mass concentration for Birkenes (a), Hurdal (b) and Kårvatn (c) for 2021. Unit $\mu\text{g}/\text{m}^3$.

The annual mean $PM_{2.5}$ concentration was 17-23% higher at Hurdal compared to Birkenes and Kårvatn. This difference is partly attributed to the higher concentration of fine fraction OM at Hurdal. Secondary inorganic aerosol constituents, typically residing in the fine fraction of PM_{10} , is however lower at Hurdal than at Birkenes, which could indicate that a larger fraction of these species are associated with the coarse fraction of PM_{10} at Birkenes.

The 2021 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 sea spray. Some weeks with increased PM levels observed at Birkenes were also seen at Hurdal, and to some extent at Kårvatn. Weekly mean concentrations exceeding $10 \mu\text{g m}^{-3}$ were observed at Hurdal and Kårvatn for both PM_{10} and $PM_{2.5}$. The highest weekly mean PM_{10} concentration was observed at Kårvatn ($17.1 \mu\text{g m}^{-3}$), with the majority residing in the fine fraction ($13.9 \mu\text{g m}^{-3}$). Common for weeks with $PM_{10} > 10 \mu\text{g m}^{-3}$, and for the highest weekly levels in general, was a major OM fraction, although a sea salt aerosol episode was observed at Birkenes. The fine fraction typically dominates when PM_{10} levels are elevated, so also for 2021, except for the sea salt episode at Birkenes.

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 wildfires occasionally make a noticeable contribution.

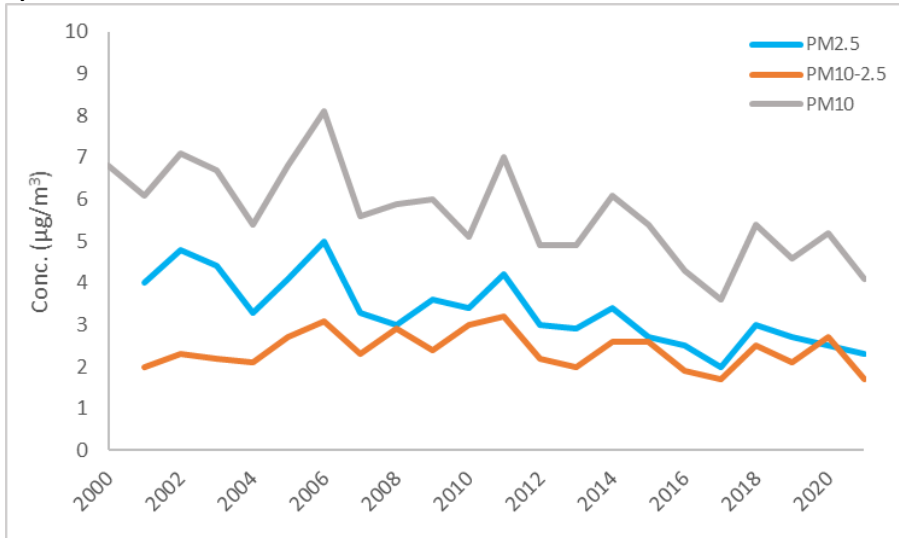
5.3 Trends

The Mann Kendall method described in Chapter 3.2 was used for trend analysis of PM concentrations. In 2021, all PM time series extended 10 years and were thus assessed (Table 5.1). A statistically significant downward trend for the annual mean concentration of PM_{10} was only observed at Birkenes (-36%). For $PM_{2.5}$, there was a statistically significant downward trend both for Birkenes (-50%) from 2000 and for Hurdal (-37%) from 2011.

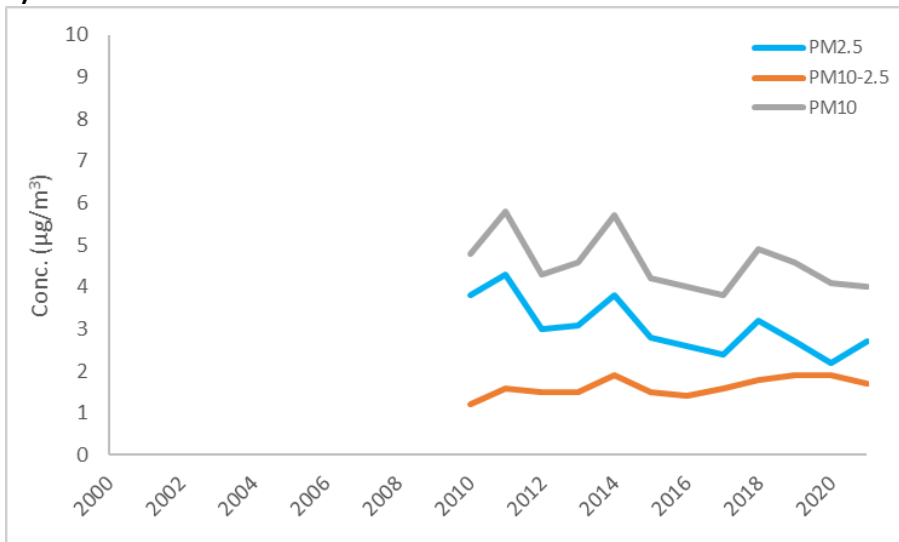
Table 5.1: Trends in annual mean mass concentration of PM_{10} and $PM_{2.5}$, using Mann-Kendall test and Sen slope estimates; * significant level 0.05.

Site	PM_{10}	% change	Year	$PM_{2.5}$	% change	Year
Birkenes	*	-36%	2000-2021	*	-50%	2000-2021
Hurdal		-	2011-2021	*	-37%	2011-2021
Kårvatn		-	2011-2021		-	2011-2021

a) Birkenes



b) Hurdal



c) Kårvatn

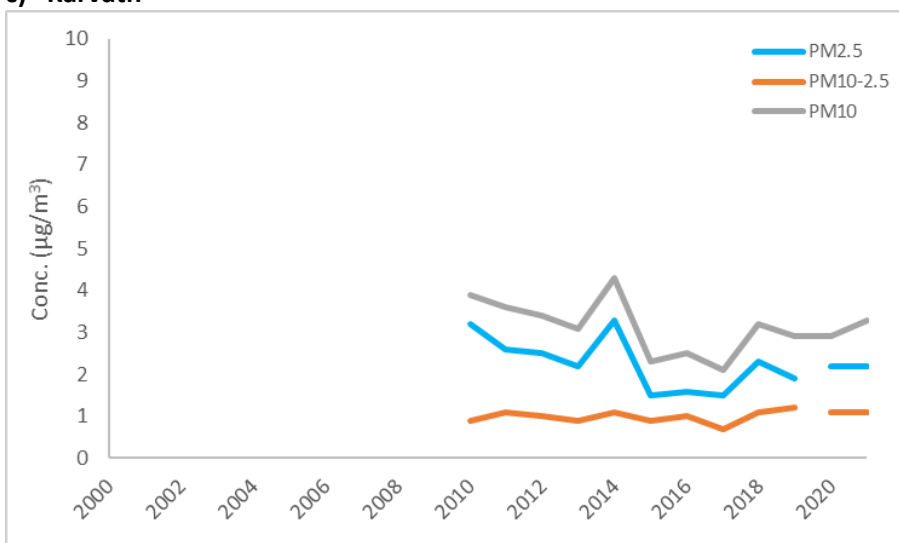


Figure 5.2: Annual mean time series of PM_{10} , $PM_{2.5}$ and $PM_{10-2.5}$ mass concentration for Birkenes (a), Hurdal (b) and Kårvatn (c) for 2001 – 2021. Unit $\mu\text{g}/\text{m}^3$.

5.4 Compliance with EU limit values and Air-Quality Guidelines for PM₁₀ and PM_{2.5}

The EU annual limit value for PM₁₀ and PM_{2.5} (See Table 5.2) was far from being violated at any of the three sites in 2021; the highest annual mean PM concentrations observed being approximately 10% of the annual limit value. The WHO AQG were revised in 2021 (WHO, 2021) and are now more stringent, but still far from being violated at the sites considered; the highest annual mean PM₁₀ and PM_{2.5} concentrations accounting for 27% and 54% respectively of the annual WHO AQGs.

Revised national limit values for PM₁₀ and PM_{2.5} are to be implemented from 2022 (See Table 5.2). The highest annual mean observed for PM₁₀ and PM_{2.5} in the Norwegian rural background environment in 2021 accounted for no more than 21% and 27% of the PM₁₀ and PM_{2.5} national AQG, respectively. The national AQG are less stringent than the those of the WHO, and thus not violated.

The highest 24-hour mean PM₁₀ concentration observed for 2021 was 17 µg m⁻³, thus not exceeding any limit values and AQG. No 24-hour measurements are performed for PM_{2.5}.

Table 5.2: EU and National limit values and Air-Quality Guidelines for PM₁₀ and PM_{2.5}.

	24-hours	Annua
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		
PM ₁₀	50 µg/m ³ (≤ 25 days yr ⁻¹)	20 µg/m ³
PM _{2.5}		10 µg/m ³
WHO Air-Quality Guidelines		
PM ₁₀	45 µg/m ³ (the 99 th percentile)	15 µg/m ³
PM _{2.5}	15 µg/m ³ (the 99 th percentile)	5 µg/m ³
National Air-Quality Guidelnies ¹⁾		
PM ₁₀	30 µg/m ³	20 µg/m ³
PM _{2.5}	15 µg/m ³	8 µg/m ³

1) National limit values. Implemented from the 1st of January 2022.

5.5 Chemical composition of particulate matter

EC and OC were measured in the PM₁₀ and PM_{2.5} size fractions at the Birkenes, Hurdal and Kårvatn sites, whereas the major inorganic anions (SO₄²⁻, NO₃⁻, Cl⁻) and cations (Ca²⁺, Mg²⁺, K⁺, Na⁺, NH₄⁺) 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 PM₁₀ fraction. Occasionally, sea salt aerosol larger than PM₁₀ could be collected, i.e., during stormy weather conditions at Birkenes, at a southerly wind direction. The data obtained from the monitoring programme appear to be well suited for a mass closure of PM₁₀, except that species representing mineral dust are not included. For 2014 - 2021, the PM₁₀ filter samples collected at Birkenes were analyzed with respect to iron (Fe), which allows for calculating/estimating the mineral dust content. Mass closure of PM_{2.5} and PM_{10-2.5} would include higher uncertainty than for PM₁₀, 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 NO₃⁻, thus this is not performed.

The annual mean chemical mass composition of PM₁₀ is shown in Figure 5.3. The speciated mass explained 57 – 72% of the annual mean concentration of PM₁₀ for the three sites, and 77 – 85% when allowing for other elements than carbon for OC and EC (e.g., hydrogen, oxygen, nitrogen, sulphur). The PM₁₀ SIA (SO₄²⁻, NO₃⁻ and NH₄⁺) fraction (and levels) was somewhat higher at Birkenes (28%) compared to Hurdal (19%) and Kårvatn (16%), reflecting the proximity of Birkenes to important SIA-precursor emission source regions in continental Europe. SO₄²⁻ was the most abundant single (SIA) species at all sites, and equally high as the sum of NO₃⁻ and NH₄⁺ at Birkenes and Hurdal and nearly twice as high at Kårvatn.

The OM fraction (32-46%) (here: OM:OC = 1.7; See Yttri et al., 2007) was higher than for SIA (19-28%) at all sites, and by as much as a factor of two to three at Hurdal and Kårvatn. The higher relative contribution of EC at Hurdal (2.3%) compared to Birkenes (1.5%) and Kårvatn (1.4%) was consistent with previous years.

Situated approximately 20 km from the coastline, Birkenes experienced a substantial 22% sea salt aerosol contribution to PM₁₀, which was substantially higher than at Kårvatn (13%) and at Hurdal (6%).

Based on Fe measurements in PM₁₀ at Birkenes and knowledge about mineral dust composition in Europe (Alastuey et al., 2016), an annual mean mineral dust concentration of 0.4 µg m⁻³ was estimated for Birkenes for 2021, corresponding to 9% of PM₁₀ annually. This was comparable to the period 2014-2017 (7-10%), but less than for the three previous years (13%) and allows for a more complete mass closure of PM₁₀ of 94% for 2021; i.e., when using OM for mass closure. Mineral dust levels and its relative contribution to PM₁₀ was elevated in the growing season, accounting for 8 – 14% of PM₁₀ in April – September, compared to 6 – 8% in October – March. Weeks with a mineral dust contribution exceeding 30% all experienced PM₁₀ levels lower than the annual mean.

Statistically significant downward trends were observed for fractions of SO₄²⁻ (-40%), NH₄⁺ (-27%) and EC (-29%) at Birkenes for 2001 - 2020, whereas there was as substantial significant upward trend for the sea salt fraction (152%) (Table 5.3), all for PM₁₀. Indeed, the annual mean of SO₄²⁻ and NH₄⁺ in 2021 were the lowest recorded for the period covered by PM measurements at Birkenes (since year 2000). was by far the lowest observed, being less than two times the negative standard deviation of the long-term mean, reflecting the lowest annual mean SO₄²⁻ concentration observed at Birkenes. The increasing sea salt fraction was explained both by an increased sea salt aerosol level and a decreasing PM₁₀ level.

At Hurdal, there was a statistically significant downward trend for the fraction of all SIA constituents to PM₁₀, being somewhat more pronounced for NO₃⁻ (-65%) and NH₄⁺ (-72%) than for SO₄²⁻ (-45%). Annual means of the SIA constituents were low at Hurdal, as for Birkenes, although record low for NO₃⁻ only. A statistically significant downward trend in the EC fraction of PM₁₀ of -35% was calculated. The OC fraction of PM₁₀ (31%) and PM_{2.5} (24%) was significantly increased. We explain this by OC being dominated by natural sources not subject to abatement, whereas there at the same time has been a noticeable reduction in PM mainly driven by reduced SIA levels

At Kårvatn, statistically significant changes were observed for the NO₃⁻ (-96%), NH₄⁺ (-80%) and EC (-32%) fractions of PM₁₀. Care should be made not to compare percentages calculated for Hurdal and Kårvatn with Birkenes, as trend calculations were made for 2001 – 2020 at Birkenes and for 2011 – 2021 at the two other sites.

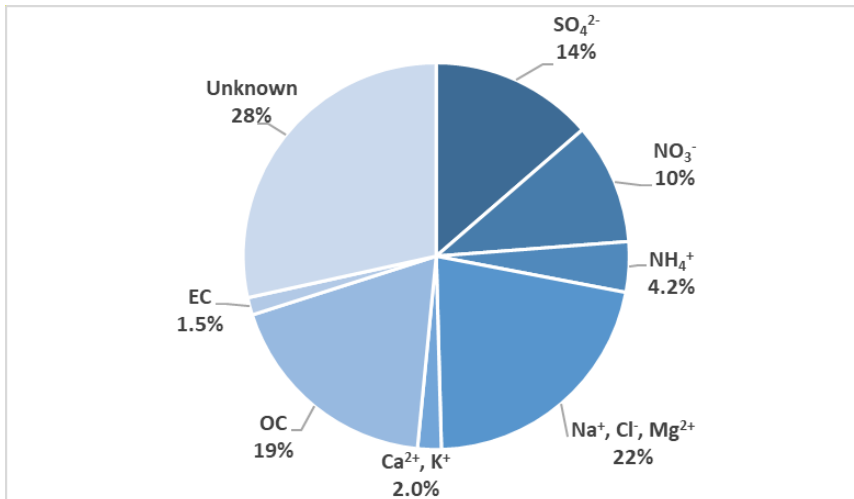
Based on levoglucosan measurements (Table 4.2) we estimate that biomass burning emissions contributed 6-9% to PM annually, considering both PM₁₀ and PM_{2.5}. The fraction attributed to biomass

burning in winter was 22-35%, whereas it was $\leq 1.8\%$ in summer, considering both size fractions. Spring and fall are transition seasons with relative contributions typically lower than in winter and higher than in summer. Biomass burning was the major contributor to PM for quite a few weeks, particularly for $PM_{2.5}$, in the heating season, thus emissions are attributed to wood burning for residential heating. Notably, these weeks are typically those experiencing the lowest PM levels.

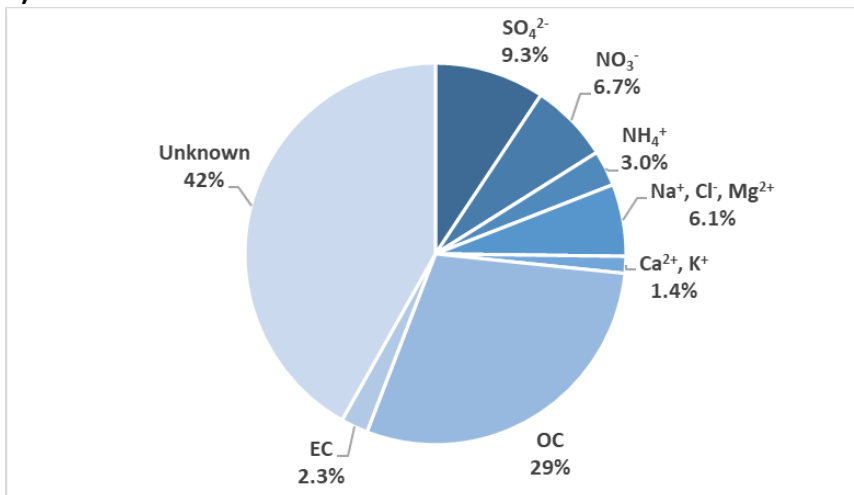
*Table 5.3: Trends in aerosol particle species fractions of PM_{10} and $PM_{2.5}$ mass concentration using Mann-Kendall test and Sen slope estimates, *significant level 0.05. Only statistically significant results are shown in the table.*

Site	Species/Fraction	Year		Change (%)
Birkenes	SO_4^{2-} to PM_{10}	2001 – 2021	*	-40
	NH_4^+ to PM_{10}	2001 – 2021	*	-27
	$\Sigma Na^+, Cl^-, Mg^{2+}$ to PM_{10}	2001 – 2021	*	152
	$EC_{PM_{10}}$ to PM_{10}	2001 – 2021	*	-29
	$OC_{PM_{2.5}}$ to PM_{10}	2001 – 2021	*	40
Hurdal	SO_4^{2-} to PM_{10}	2011 – 2021	*	-45
	NO_3^- to PM_{10}	2011 – 2021	*	-65
	NH_4^+ to PM_{10}	2011 – 2021	*	-72
	$EC_{PM_{10}}$ to PM_{10}	2011 – 2021	*	-35
	$OC_{PM_{10}}$ to PM_{10}	2011 – 2021	*	31
	$OC_{PM_{2.5}}$ to $PM_{2.5}$	2011 – 2021	*	24
Kårvatn	NO_3^- to PM_{10}	2011 – 2021	*	-96
	NH_4^+ to PM_{10}	2011 – 2021	*	-80
	$EC_{PM_{10}}$ to PM_{10}	2011 – 2021	*	-32

a) Birkenes



b) Hurdal



c) Kårvatn

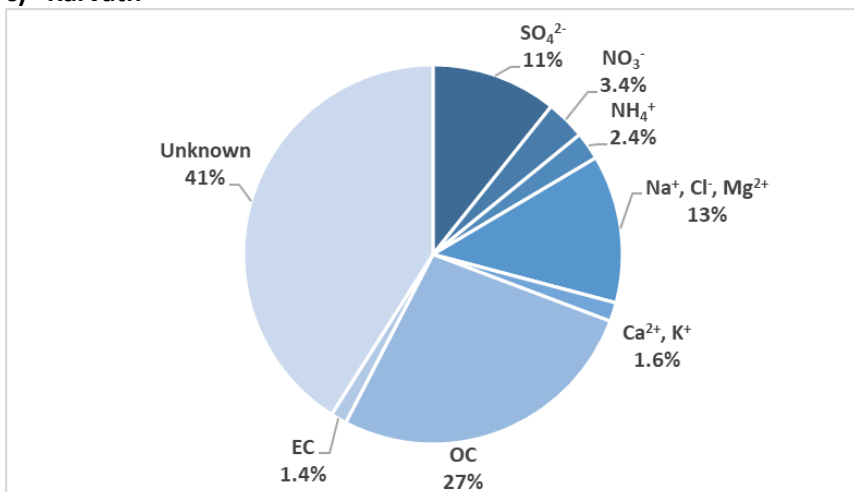


Figure 5.3: Annual mean chemical composition of PM₁₀ at the Birkenes Observatory a), the Hurdal site b) and the Kårvatn site c) for 2021. The annual mean mass concentration for PM₁₀ in 2021 was 4.1 µg/m³ at the Birkenes Observatory, 4.0 µg/m³ at the Hurdal site and 3.3 µg/m³ at the Kårvatn site.

5.6 Particle number concentrations

The annual mean particle number concentration for the size range in particle diameter $0.02 < Dp < 1.0 \mu\text{m}$ (N_{Tot}) at Birkenes for 2021 was close to (-1%) the long-term mean, as was the annual mean number concentration of the ultrafine particles N_{Uf} ($0.02 < Dp < 0.1 \mu\text{m}$) (1% higher). The accumulation mode particles N_{Acc} ($0.1 < Dp < 1.0 \mu\text{m}$) were 7% lower than the long-term mean. Nuclei and Aitken mode particles, and to some extent the lower size fractions of the accumulation mode, dominate the particle number concentration, thus comparable results for N_{Uf} and N_{Tot} are expected. The annual mean N_{Cm} (1 – 10 μm) size fraction could not be established for the entire year of 2021 due to problems with the optical particle counter. The missing N_{Cm} data have no detectable influence on determining N_{Tot} .

77% of N_{Tot} was attributed to N_{Uf} and 23% to N_{Acc} at Birkenes for 2021, whereas the fraction associated with particles in the range 1.0 – 10 μm , i.e. the coarse mode, could not be established. However, the fraction of particle number in the coarse mode is typically negligible (<1%) at Birkenes. The fraction of N_{Tot} attributed to N_{Uf} and N_{Acc} do not vary much between years, whereas the variability is slightly higher for N_{Cm} , due to low levels and thus larger uncertainty. N_{Uf} was the dominating fraction regardless of season, accounting for 70 – 81% of N_{Tot} . Typically, the N_{Uf} fraction drops in winter, whereas the N_{Acc} fraction increases correspondingly, so also for 2021.

No significant upward or downward trends were calculated for N_{Tot} , N_{Acc} , N_{Uf} . (Figure 5.4).

Table 5.4: Number concentrations for ultrafine, accumulation mode and coarse mode particles at Birkenes for 2010 – 2021 and their relative share to the total concentration. Unit: cm^{-3} .

Year	Ultrafine particles		Accumulation mode particles		Coarse mode particles		Total concentrations ($Dp = 0.02 - 10 \mu\text{m}$)*
	N (cm^{-3})	(%)	N (cm^{-3})	(%)	N (cm^{-3})	(%)	
2010	1101	69	412	31	0.575	0	1593
2011	1215	73	417	27	1.427	0	1644
2012	951	75	288	25	0.912	0	1258
2013	1107	76	335	24	0.951	0	1454
2014	1333	73	488	27	0.859	0	1821
2015	1363	77	395	23	0.963	0	1758
2016	1167	75	391	25	0.804	0	1558
2017	1256	75	424	25	0.721	0	1679
2018	1255	73	460	27	--	--	1715
2019	1163	77	356	23	--	--	1519
2020	1133	79	306	21	--	--	1439
2021	1204	77	358	23	--	--	1562

*The total concentration for the period 2018-2021 includes only particles in the size range 0.02 – 1 μm .

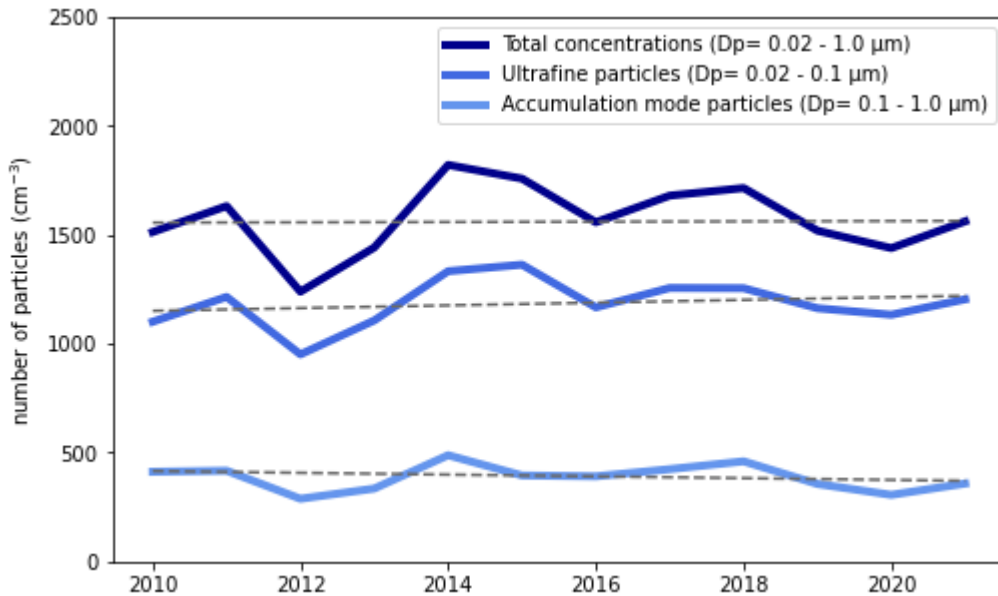


Figure 5.4: Trends in size distribution at Birkenes, 2010-2021. Dashed line indicate the non-significant Sen slopes.

5.7 Summary

Observed annual mean concentrations of PM₁₀ and PM_{2.5} in the Norwegian rural background environment are amongst the lowest in Europe (< 4.1 μg/m³). International and national limit values and air quality guidelines were not violated on an annual or daily basis in 2021.

Organic matter (32–46%) was the major fraction of PM₁₀ at all sites, followed by secondary inorganic aerosol (SIA) (16-28%) and sea salt aerosol (SSA) (6-22%), whereas a 9% contribution from mineral dust was estimated for the Birkenes Observatory. The SIA and SSA contribution were substantially higher at the southernmost site Birkenes due to the proximity to major anthropogenic emission regions in continental Europe and to the sea, respectively. Estimates based on levoglucosan measurements suggest that biomass burning contributed 6-9% to PM₁₀ and PM_{2.5} at Birkenes annually.

There was a significant downward trend for PM₁₀ (-36%) (2000-2021) at Birkenes and for PM_{2.5} at Birkenes (-50%) (2001-2020) and Hurdal (-37%) (2011-2021), which is in line with emission reductions of primary and secondary sources in Europe.

6 Ground-level ozone

Ozone in the troposphere originates from photo-chemical reactions in the atmosphere between volatile organic compounds (VOCs), carbon monoxide (CO), methane (CH₄) and nitrogen oxides (NO_x) under the influence of solar radiation, as well as from the transport of stratospheric ozone into the troposphere. VOCs, CO and CH₄ are emitted from anthropogenic sources such as road and ship traffic, leakage of natural gas, use of solvents and chemicals etc., and NO_x is mainly emitted from traffic and power plants. In addition, biogenic sources (trees and plants) contribute significantly to the emission of VOCs and CH₄ and to a smaller extent to NO_x (microbiological activity in soils). On a global basis lightning is also an important source of NO_x 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, HO₂ and NO₂. 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 regard particularly asthmatics and people with chronic respiratory disorders. Effects on the vegetation regards particularly crops but also forests and natural vegetation. Prolonged exposure has 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. The stations in the individual zones as of 2019 are indicated in the map in chapter 1 (Figure 1.1). The EU directive gives requirements for the minimum number of monitoring sites within each zone and for the country as a whole.

The ozone monitoring network in 2021 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.

Table 6.1 shows the monitoring sites and data capture for 2021, which was 92% or higher at all stations. The measuring method and principles are given in Annex 3.

Table 6.1: Ozone monitoring sites and data capture based on hourly values in 2021.

St.nr.	Station name	Period	Data capture
NO0043	Prestebakke	01.01.21-31.12.21	98%
NO0056	Hurdal	01.01.21-31.12.21	92%
NO0489	Haukenes	01.01.21-31.12.21	94%
NO0002	Birkenes II	01.01.21-31.12.21	99%
NO0052	Sandve	01.01.21-31.12.21	97%
NO0039	Kårvatn	01.01.21-31.12.21	99%
NO0015	Tustervatn	01.01.21-31.12.21	97%
NO0042	Zeppelin (Ny-Ålesund)	01.01.21-31.12.21	99%

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 $\mu\text{g}/\text{m}^3$ 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 $\text{O}_3 + \text{NO} \rightarrow \text{NO}_2$. This difference between winter and summer is explained by the intensity of the solar UV-radiation which leads to a fast photochemistry in summer and a corresponding slow and inefficient photochemistry in winter.

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

In Norway summertime episodes of elevated ozone are often associated with a high pressure located over the European continent, typically over Central or Eastern parts, setting up a southerly or south-westerly 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 2021

Time series of daily maximum ozone values through 2021 are given in Figure 6.1 together with the climatological mean seasonal cycle (30 days running mean) based on previous years of data (2001-2020). The time series indicate that 2021 was a year with very few episodes. Elevated levels were observed at Prestebakke in June, and then most sites in the south experienced an ozone episode as late as September this year. The peak levels were, however, fairly moderate. The annual hourly peak concentration in 2021 was $135 \mu\text{g}/\text{m}^3$ (measured at Prestebakke and Birkenes II in September) which is a very low level in a historical perspective.

The smoothed seasonal cycles (14 days' running mean) in ground-level ozone in 2021 are shown in Figure 6.2 together with the climatological mean seasonal cycles for the period 2001-2020 for each site. These time series confirm the few peak episodes in 2021 and also show that the levels in the beginning of the "ozone season", i.e. in May, was lower than previously observed at most stations.

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 2021 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.

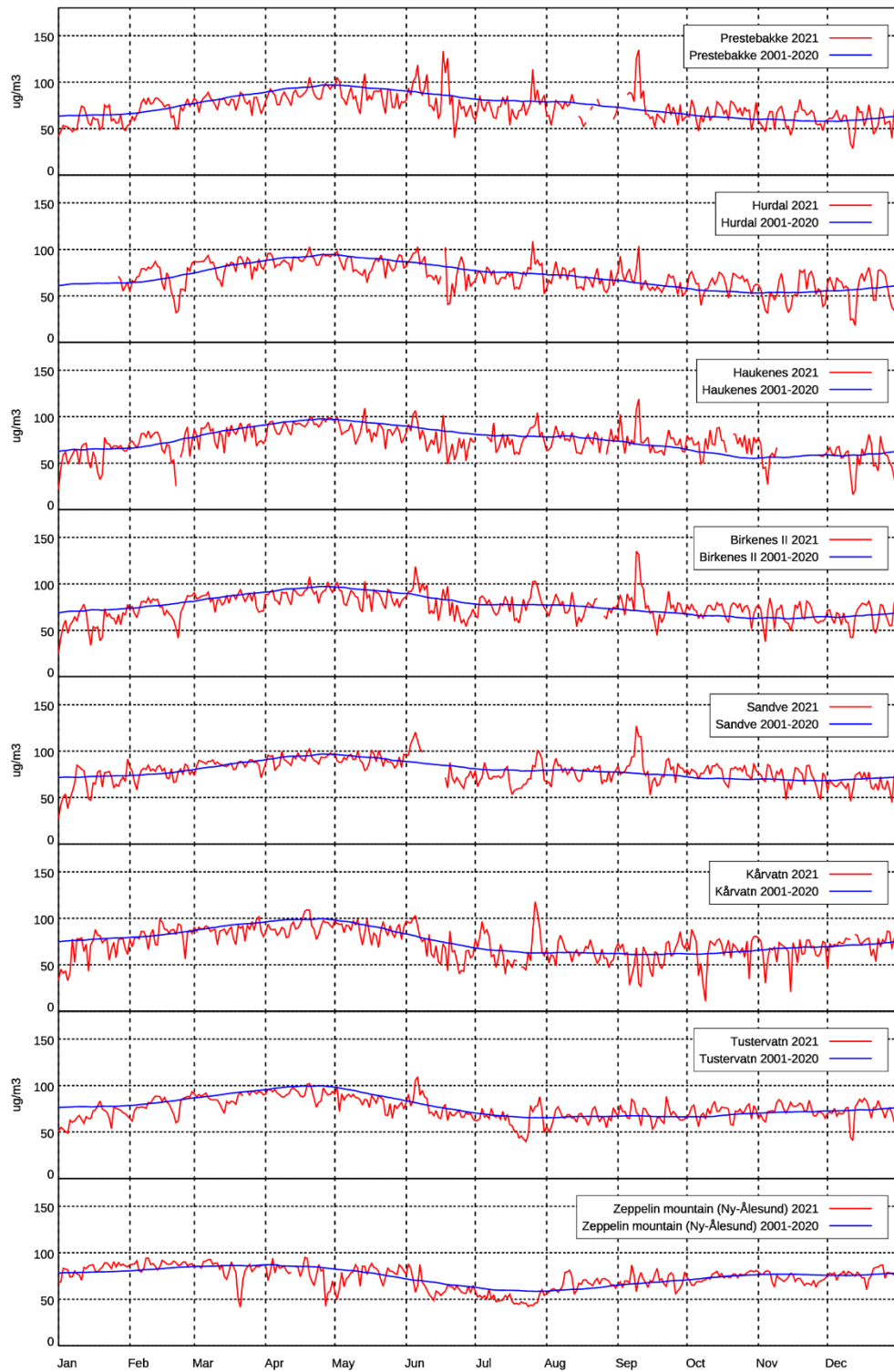


Figure 6.1: Daily maximum ozone concentrations in 2021 (red) together with the 30 days' running mean of the daily maxima for the years 2001-2020 (blue).

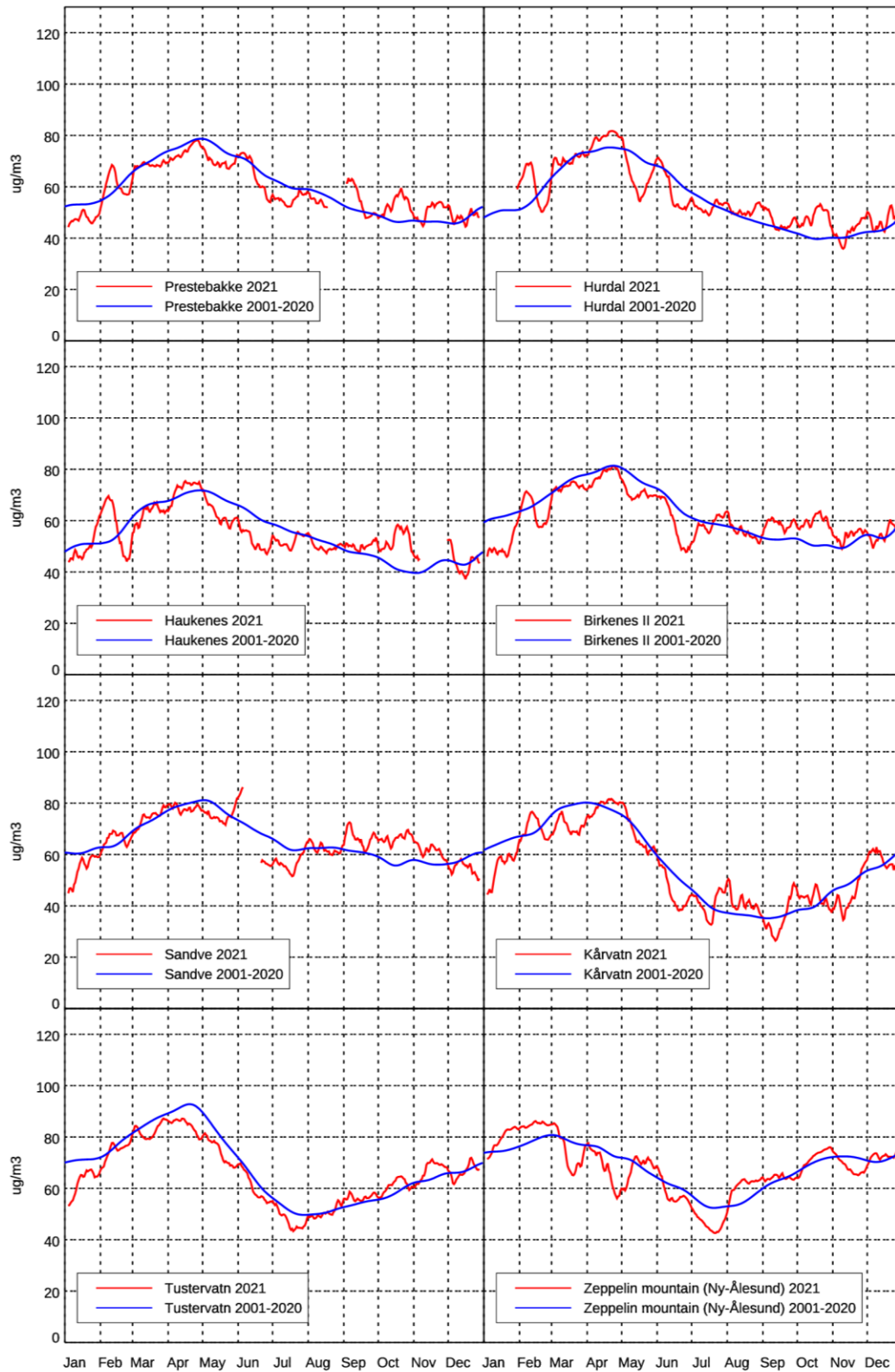


Figure 6.2: The 14 days' running mean ozone concentrations in 2021 (red) together with the corresponding mean concentrations based on all years 2001-2020 (blue).

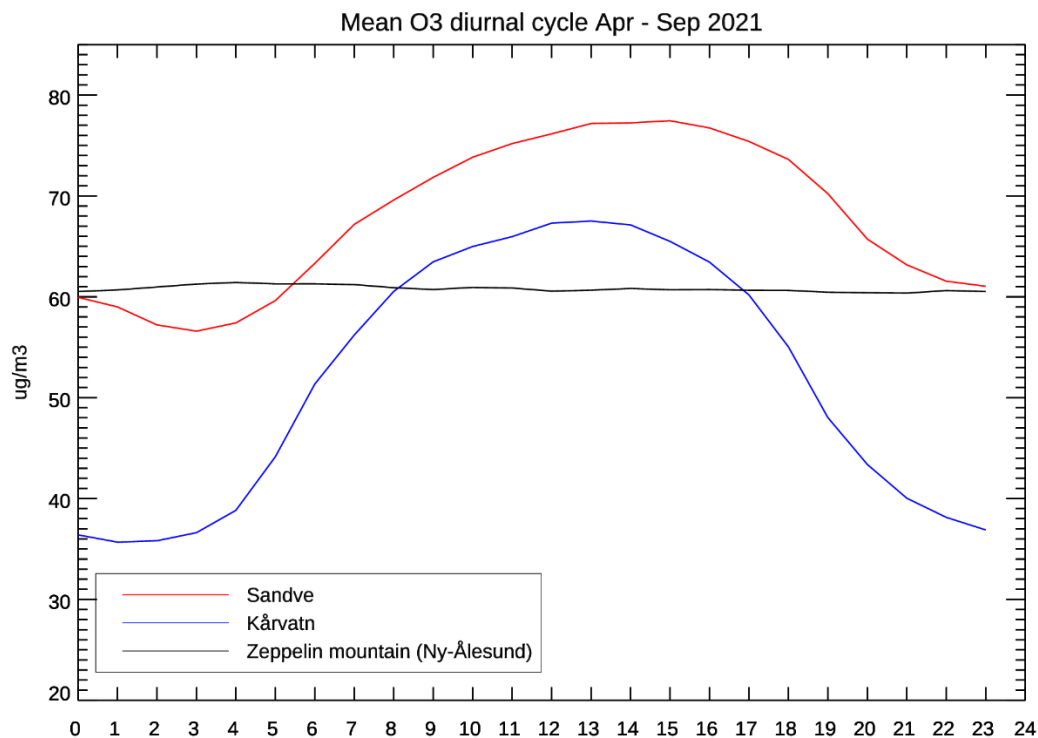


Figure 6.3: The mean diurnal cycle in ozone at three of the monitoring sites; Sandve, Kårvatn and Zeppelin Mountain during April-September 2021.

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 6.2. 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) and provided a revised set of guidelines in 2021 that also included O₃ (WHO, 2021). The new guideline set by WHO is 60 ug/m³ as an average of the daily maximum 8h mean O₃ concentration in the six consecutive months with the highest six-month running-average O₃ concentration. 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 ug/m³) and alert threshold (240 ug/m³), respectively.

In 2013 a 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 6.2.

Table 6.2: Limit values for ground-level ozone for the protection of human health.

Value ($\mu\text{g}/\text{m}^3$)	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.
120	8 ¹⁾	EU (2008)	EU's long-term objective.
100	8 ¹⁾	WHO (2006)	WHO's air quality guideline (global update 2005)
60	8 ²⁾	WHO (2021)	Mean over the peak season
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.

²⁾ Defined as the average of the daily maximum 8h running mean concentration in the six consecutive months with the highest 6-months running O_3 concentration.

The exceedances of the limit values for health are given in Table 6.3. The table shows the number of days with exceedance of WHO's air quality guideline of $100 \mu\text{g}/\text{m}^3$ and EU's long-term objective of $120 \mu\text{g}/\text{m}^3$. The number of hours with exceedance of EU's information threshold of $180 \mu\text{g}/\text{m}^3$ 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 hours mean values were only calculated for days with at least 75% data capture.

Table 6.3: For all sites in 2021 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 6.2 as well as the annual maximum and the date when it occurred.

Station	Hours	National AQ guidelines			WHO	EU directive		Max. hourly value ($\mu\text{g}/\text{m}^3$)	Date
		Days	Days	Hours	Days	Days	Hours		
		>75%	8h > $80 \mu\text{g}/\text{m}^3$	1h > $100 \mu\text{g}/\text{m}^3$	8h > $100 \mu\text{g}/\text{m}^3$	8h > $120 \mu\text{g}/\text{m}^3$	1h > $180 \mu\text{g}/\text{m}^3$		
Prestebakke	8592	365	74	83	10	2	0	135	10.09.2021
Hurdal	8086	3540	81	20	2	0	0	112	17.06.2021
Haukenes	8210	347	78	24	2	0	0	119	10.09.2021
Birkenes II	8694	365	101	53	7	1	0	135	09.09.2021
Sandve	8510	357	118	96	8	0	0	127	09.09.2021
Kårvatn	8689	365	100	50	5	0	0	118	27.06.2021
Tustervatn	8727	365	108	14	2	0	0	109	06.06.2021
Zeppelin	8700	365	105	0	0	0	0	95	18.04.2021

EU's information threshold (hourly value $> 180 \mu\text{g}/\text{m}^3$) has not been exceeded since 2006 and in 2021 the highest hourly ozone level was $135 \mu\text{g}/\text{m}^3$. Only three years (2012, 2013, and 2020) have had a lower annual maximum level than this.

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 $< 120 \mu\text{g}/\text{m}^3$) and thereby also WHO's and Norwegian

air quality guidelines is on the other hand exceeded to a variable extent every year. In 2021 the LTO was exceeded at only two stations: Prestebakke and Birkenes. The highest number of days with exceedances was seen at Prestebakke with 2 days.

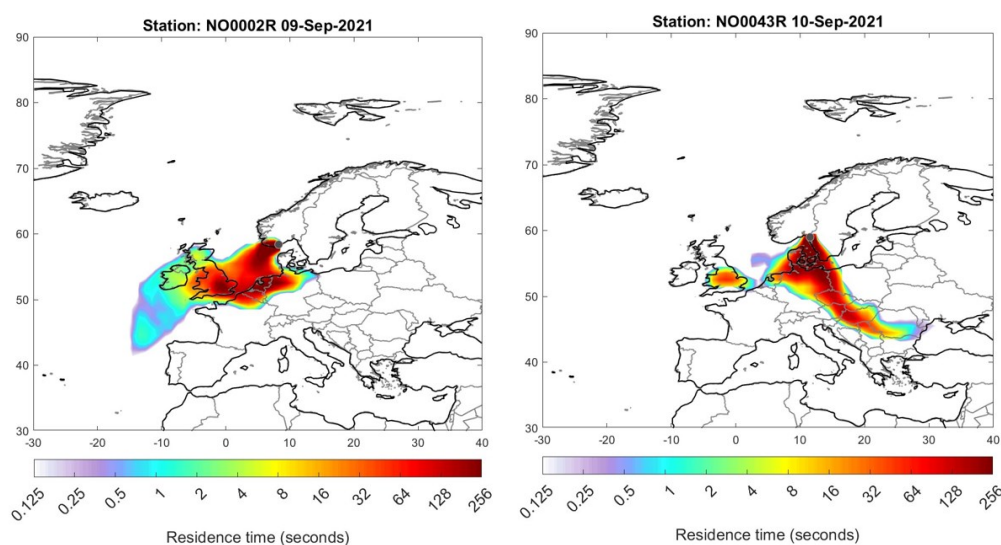


Figure 6.4: 4 days backward Flexpart footprints indicating the air mass source region for the annual peak ozone episodes in 2021, for Birkenes 9 Sept (left) and Prestebakke 10 Sept (right).

The WHO guideline of $8\text{h O}_3 > 100\ \mu\text{g}/\text{m}^3$ was exceeded at all sites except Zeppelin Mountain in 2021. This reflects that the WHO guideline level of $100\ \mu\text{g}/\text{m}^3$ as an 8-hours mean is close to the baseline level, implying that a small change in the mean level will lead to a large change in the number of days with exceedances.

The ozone levels and exceedances vary strongly from year to year which is also indicated by Table 6.4, showing the number of days with exceedance of the 8-hour mean value of $120\ \mu\text{g}/\text{m}^3$ for the period 2000-2021. Table 6.4 gives the annual peak values and number of days with exceedance of the LTO from 2006 to 2021. The main reason for the inter-annual variations is variations in the large-scale weather conditions from one year to another. Over time, long-term changes in the European emissions of NO_x and VOC as well as gradual trends in the hemispheric baseline level of ozone will be important.

Table 6.4: The annual maximum hourly ozone concentration and the number of days that EU's long-term objective was exceeded during 2006-2021 at one or more stations. Note that the monitoring network have changed over this period and thus the values are not directly comparable from year to year.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Annual hourly max. ($\mu\text{g}/\text{m}^3$)	186	139	160	142	145	168	130	124	147	148	140	135	148	165	134	135
Number of dates with exceedance of EU's long-term objective of $120\ \mu\text{g}/\text{m}^3$ ^{a)}	28	8	16	9	3	12	2	2	4	2	4	1	22	17	3	3

1. Running 8-h mean

The EU directive requires the countries to sustain monitoring stations in all air quality zones where the long-term objective has been exceeded in the last five years. As shown in Figure 6.5, this limit value has been exceeded at all stations except Zeppelin Mountain the last five years.

The national guidelines (FHI, 2013) are even stricter than the WHO guideline (Table 6.2) and the $80 \mu\text{g}/\text{m}^3$ (8-h mean) and $100 \mu\text{g}/\text{m}^3$ (1-h mean) were exceeded for long periods of the year in the whole country as shown by Table 6.3 except for the Zeppelin Mountain which had no ozone levels above $100 \mu\text{g}/\text{m}^3$ in 2021.

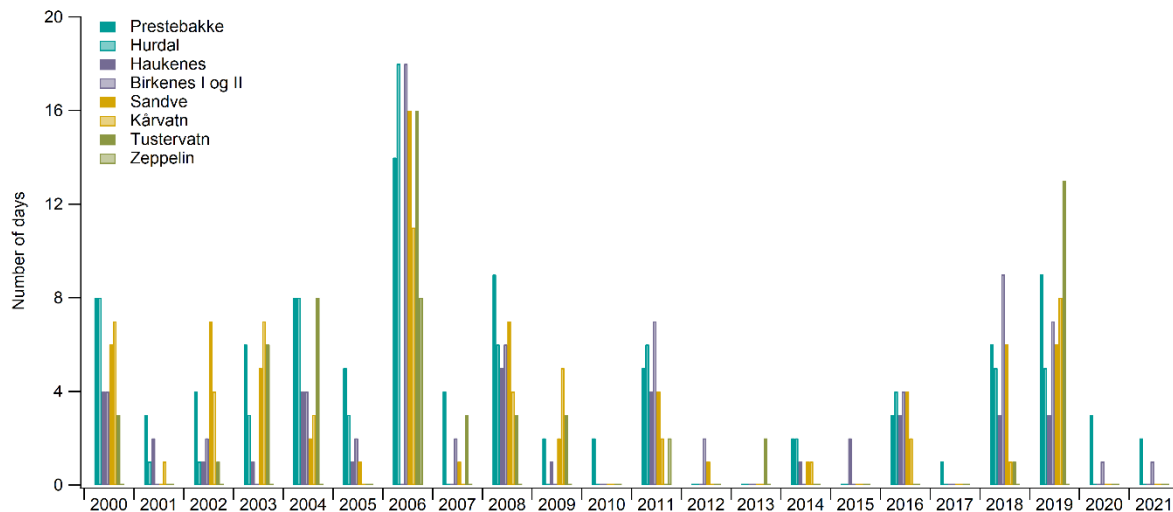


Figure 6.5: The number of days with a maximum daily 8-h mean ozone concentration above $120 \mu\text{g}/\text{m}^3$ for the period 2000-2021. Note that the Birkenes site has been moved, and data before 2010 refer to the old location. See text for more explanations.

6.5 Exceedance of the threshold values for protection of vegetation

Threshold levels for ozone exposure to vegetation has been set both by EU and UN-ECE. Within EU and to some extent within UN-ECE the limit values are based on the cumulative exposure over the threshold value of 40 ppb ($= 80 \mu\text{g}/\text{m}^3$) and the parameter is termed AOT40 (“Accumulated exposure over the threshold of 40 ppb”) as listed in Table 6.5. 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 during a certain pre-defined growing season.

EU's air quality directive (EU, 2008) includes both a target value and a long-term objective for a 3-months AOT40 value relevant for semi-natural vegetation (Table 6.5). UN-ECE (the Mapping Manual published by Mills et al., 2017) also provides 3-months critical levels for agricultural crops and semi-natural vegetation as well as a 6-months critical level for forests.

The procedure for calculating AOT40 differs, however, between the EU legislation and UN-ECE. According to the EU directive (EU, 2008) AOT40 should be based on the measured hourly ozone values from 08:00 – 20:00 CET (Central European Time) from 1 May – 31 July. UN-ECE on the other hand defines the hours with a global radiation $> 50 \text{ W}/\text{m}^2$ to be included in the AOT calculation. Furthermore, UN-ECE defines growing seasons that vary with geographical location and altitude and, in addition, they require that the ozone values should be interpolated to the canopy height before calculating AOT40. When local meteorological measurements are not available, the Mapping Manual

(Mills et al., 2017) includes tables for converting the measured ozone data to ozone levels at canopy height based on the land cover and surface data. Due to these complications, we use the much simpler 3-months AOT40 definition as stated in the EU directive in this report.

There is no critical level for 6-months AOT40 in the EU directive, and thus we use the UN-ECE definition for this although in a simplified way. For calculation of the 6-months AOT40 we use the measured data directly without any interpolation to canopy height. This is justified by the fact that the difference between ozone at the inlet height (typically 3-10 m above ground) and the typical canopy height for forests is small. Since the vertical gradient in ozone is largest near the surface, the main problem of interpolation is from the monitor's inlet height to the canopy height of smaller plants.

Table 6.5: Limit values for the protection of vegetation from ozone exposure.

AOT40 (ppb hours)	Period	Reference	Comment
3000	3-months growing season	Mills et al., 2017	UN-ECE's critical level for agricultural crops and semi-natural vegetation ¹⁾
5000	1 April – 30 Sept	Karlsson et al., 2003; 2005	UN-ECE's critical level for forests ¹⁾
9000	1 May – 31 July	EU, 2008	EU's target value for vegetation. Should be averaged over five years ²⁾
3000	1 May – 31 July	EU, 2008	EU's long-term objective for vegetation ²⁾

1) UN-ECE's AOT values should be based on the hours with global incoming radiation > 50 W/m²

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

Research in recent years have shown that the AOT40 based critical levels for vegetation should be replaced with the so-called flux based critical levels (Mills et al., 2011) when assessing the actual impact on plants. The flux-based levels (named POD_y) takes into account various environmental conditions such as soil moisture, solar radiation, leaf area, vertical stability of the atmosphere, land cover etc, and thus provides a better estimate of the real ozone exposure of the plants. Comparison between AOT40 based levels and POD_y levels with ozone exposure experiments in the field have indeed confirmed that the flux approach is better suited for direct assessments of the actual effect from ozone on vegetation. Concentration based AOT40 values continue to be used, however, where the meteorological data and calculations from flux models are not available.

Table 6.6 shows the 3-months AOT40 values based on the definition in the EU directive (08:00-20:00 CET) for the period 1 May – 31 July 2021. Figure 6.5 shows the same 3-months AOT40 value for the years 2000-2021. EU's target value of 9000 ppb hours has not been exceeded for many years in Norway. The long-term objective of 3000 ppb hours was not exceeded in 2021 and the values were substantially below this limit value at all stations (Sandve was highest with 1668 ppb hours).

Table 6.7 shows the 6 months AOT40 values for forests (April-September) 2021 as based on the UN-ECE definition (using the hours with a global radiation > 50 W/m²), and the corresponding plot for the years 2000-2021 are shown in Figure 6.7. The critical level of 5000 ppb hours for forests was not exceeded in 2021. The highest 6-months AOT40 value was seen at Sandve with 3728 ppb hours.

Table 6.6: Data capture and 3-month's AOT40 values for vegetation for the period 1 May - 31 July 2021 (unit: ppb hours) according to the definitions in the EU directive.

<i>Station</i>	<i>Data capture (%)</i>	<i>AOT40</i> <i>(corrected for data capture)</i>
Prestebakke	97	1097
Hurdal	98	649
Haukenes	95	583
Birkenes II	99	818
Sandve	90	1668
Kårvatn	99	934
Tustervatn	99	372
Zeppelin	99	110

Table 6.7: Data capture and 6-month's AOT40 values for forests for the period 1 April – 30 September 2021 (unit: ppb hours) according to the definitions in UN-ECE's Mapping Manual.

Station	Data capture (%)	AOT40 (corrected for data capture)
Prestebakke	96	2475
Hurdal	98	1824
Haukenes	96	2121
Birkenes II	98	2393
Sandve	94	3728
Kårvatn	99	2806
Tustervatn	99	1636
Zeppelin	99	220

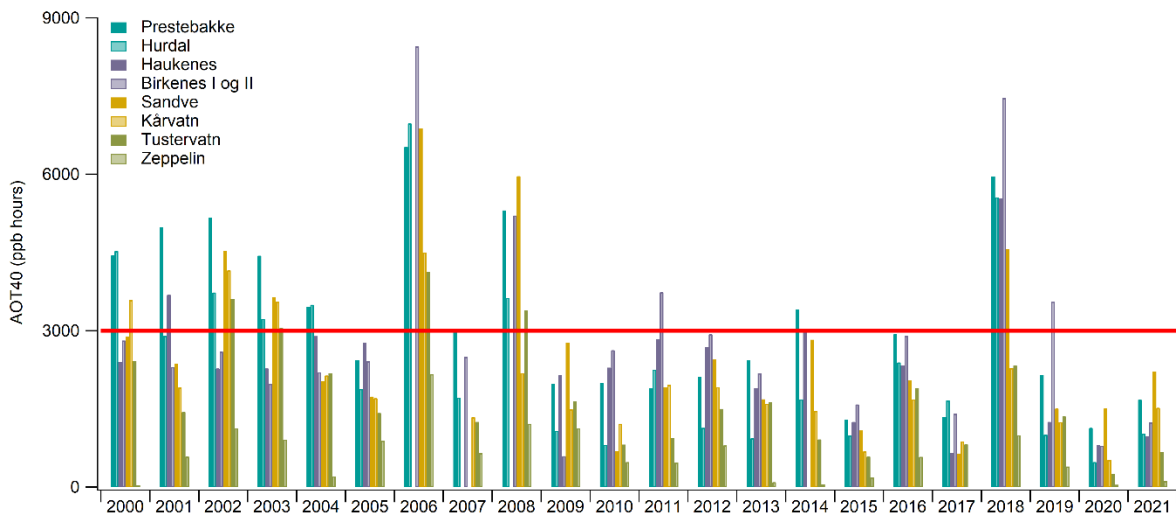


Figure 6.6: 3 months' AOT40 values (1 May - 31 July) for the years 2000 - 2021 (based on UN-ECE's definition of daylight hours). The EU directive's long-term objective of 3000 ppb hours is indicated by the line. Note that the Birkenes site has been moved, and data before 2010 refer to the old location. See text for more explanations.

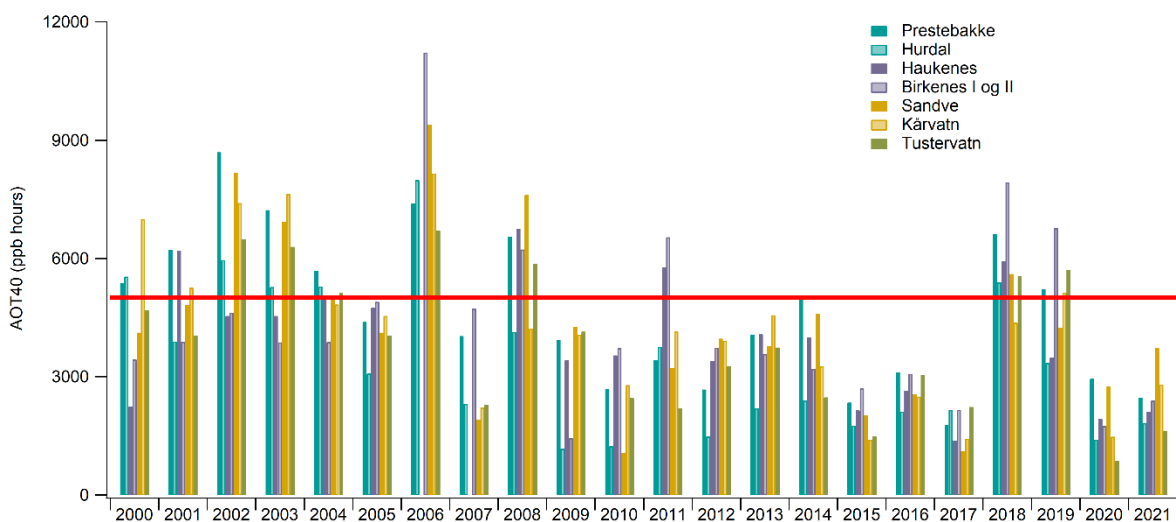


Figure 6.7: 6 months' AOT40 values (1 April - 30 September) for the years 2000 - 2021 (based on UN-ECE's definition of daylight hours, $> 50 \text{ W/m}^2$). The critical level for forests (5000 ppb hours) is indicated by the line. Note that the Birkenes site has been moved, and data before 2010 refer to the old location.

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 indicate 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

O₃ at some sites, particularly in summer (Logan et al., 2012). Recent studies also indicate a change in the mean seasonal cycle of the baseline O₃ 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 O₃ 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 6.8-Figure 6.10 show the development in three ozone metrics from 2000 to 2021; 3-months AOT40 (May-July), the number of days with an 8-h running max exceeding 100 µg/m³ (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 used in the ozone trend assessment within the EMEP TFMM (Colette et al., 2016) and IGAC (International Global Atmospheric Chemistry project) TOAR (Tropospheric ozone assessment research) programmes.

Results for four stations with long-term monitoring history are given: Prestebakke, Sandve, Kårvatn and Tustervatn. The trend lines are only given when a statistically significant ($p=0.05$) trend is found.

Downward levels are calculated for the 3-months AOT40 at all four sites, and all are found to be statistically significant ($p=0.05$) with very consistent rates (2.7-3.4 %/y). A similar pattern is found for the number of days with a maximum 8-h concentration exceeding 100 µg/m³. This also shows a significant reduction at all sites with rates of 3.2-4.3 %/y. The data also gives a decline in the annual 97 percentile of the daily max 8-h running mean April-September but are found to be not statistically significant for Tustervatn.

A reduction in high ozone concentrations are expected due to the substantial reduction in European man-made emissions of NO_x 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 long list of various ozone metrics was 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.

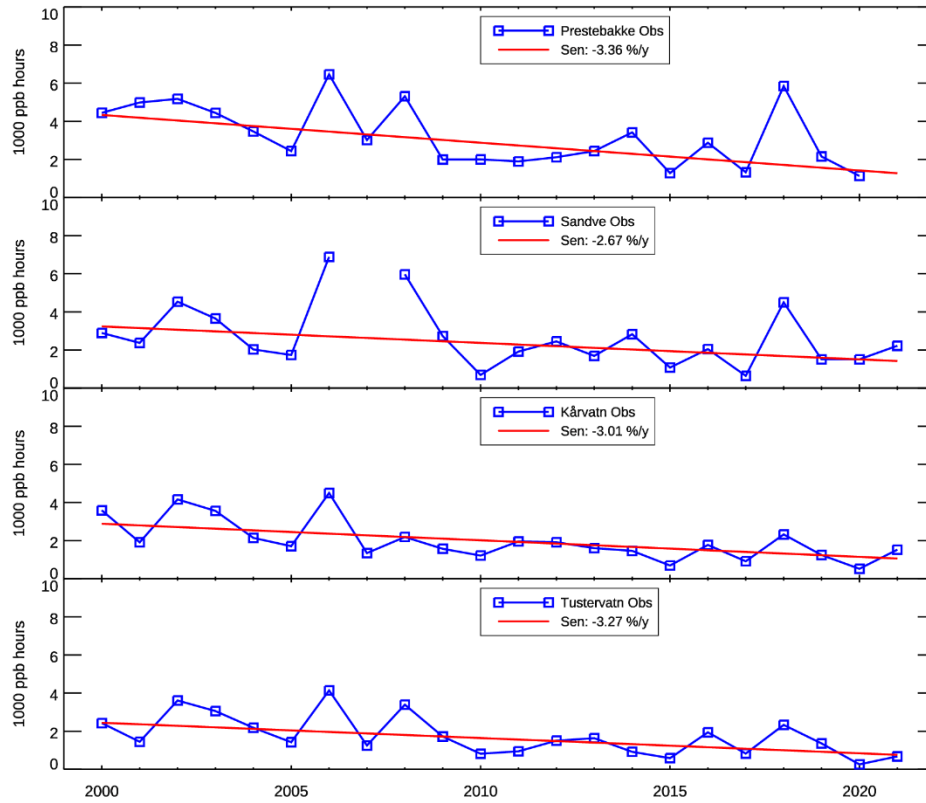


Figure 6.8: The 3-months AOT40 value according to the EU directive (May - July, hours 8-20 CET) during 2000-2021 for four sites. The estimated Sen's slope based on annual data for 2000-2021 are marked in red. The percentage trend value refers to 2000 as the start year.

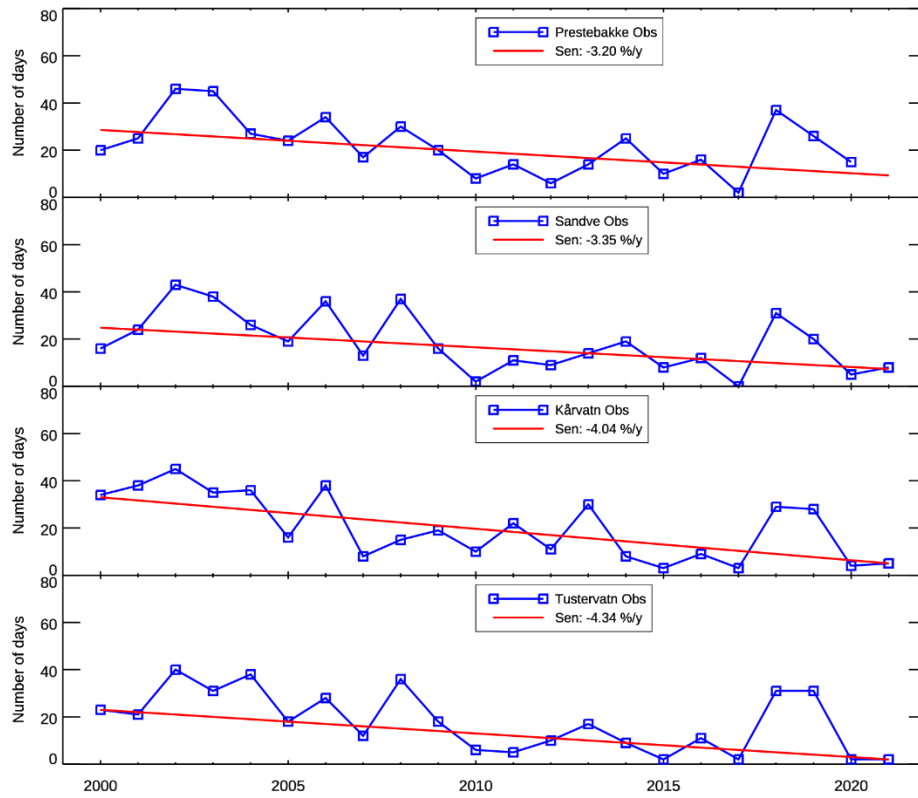


Figure 6.9: Same as Figure 6.8 for the number of days with a maximum 8-h running mean ozone concentration exceeding $100 \mu\text{g}/\text{m}^3$ (WHO guideline).

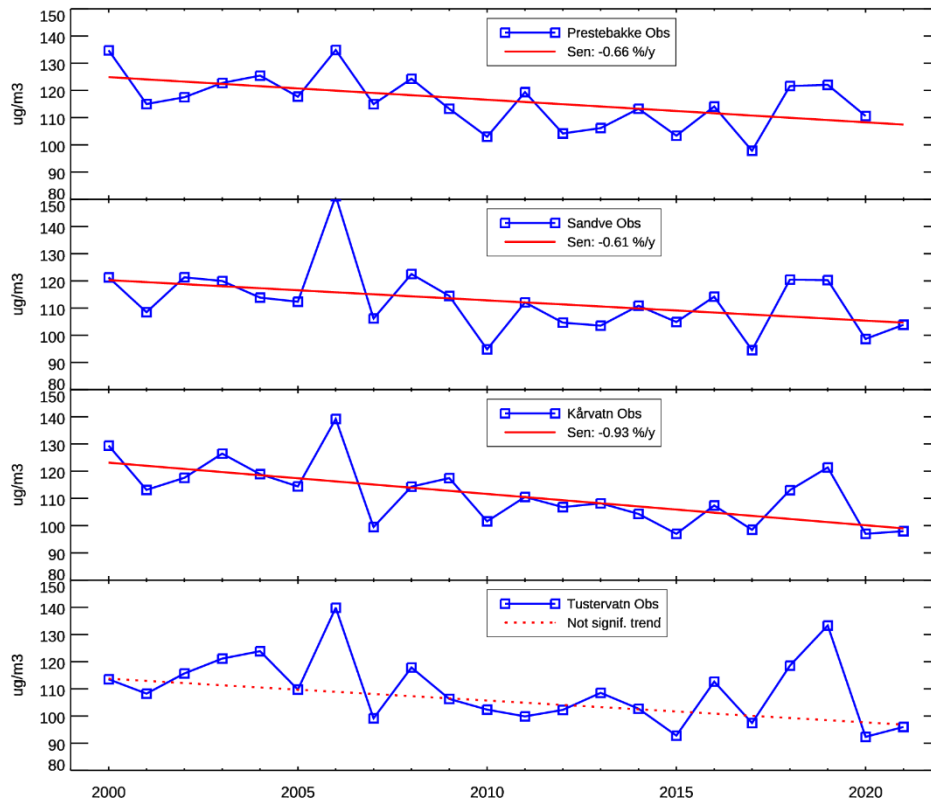


Figure 6.10: Same as Figure 6.8 for the 97-percentile of the daily maximum 8-h running mean ozone concentration April-September.

6.7 Summary

The surface ozone levels in Norway 2021 were characterized by few high episodes. Neither the critical level for vegetation linked to 3-months AOT40 for plants (May-July) or the 6-months AOT40 for forest (April-September) were exceeded. The highest hourly ozone concentration in 2021 was $135 \mu\text{g}/\text{m}^3$ (at Prestebakke and Birkenes) which is the 4th lowest maximum level since the start of the ozone monitoring. EU's long-term objective of max 8-hours daily max of $120 \mu\text{g}/\text{m}^3$ relevant for human health was exceeded at only 3 days in 2021 and at only 2 sites. WHO's air quality guideline for human health linked to the maximum 8h running mean concentration that should be lower than $100 \mu\text{g}/\text{m}^3$ was broken at all sites except Zeppelin Mtn in 2021.

In Norway, the levels of ground level ozone are determined by a baseline-level varying between 50 - $100 \mu\text{g}/\text{m}^3$ (minimum in autumn, maximum in late spring) with a number of summertime photochemical ozone episodes superimposed on this baseline. The baseline does not change that much from year to year, but the photochemical episodes vary substantially between years depending on the summer weather conditions and the European emissions. Whereas the summer weather conditions vary considerably from one year to another, the European precursor emissions have been steadily reduced over the last 20 years. Thus, a gradual decline in ozone episodes are expected in Norway although a certain amount of "noise" in the time series is expected due to the variation in the weather conditions, and to some extent this noise could mask the effect of the emission reductions.

In 2021, the particularly low ozone levels were a net result of few episodes as well as low mean levels during most of the summer season. It is likely that the consistently lower ozone levels is a combined effect of the long-term precursor emission reductions in Europe the last decades. Numerical models are required to quantify these effects for the Norwegian ozone levels in 2021.

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Appendix A Annex 1

Results from the monitoring programme

Table A1.1: Monthly and annual volume weighted mean pH at Norwegian background stations

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	5.210	4.947	5.549	5.340	5.360	5.600	5.084	5.341	5.060	5.019	4.884	4.591	5.018
Vatnedalen	5.576	5.524	5.660	5.606	5.726	5.556	5.482	5.756	5.574	5.459	5.281	5.521	5.495
Treungen	5.106	5.000	5.539	5.104	5.231	5.358	4.892	5.348	5.052	5.242	5.049	4.896	5.109
Løken	5.088	4.824	5.840	5.514	6.030	nan	5.498	5.410	5.342	5.458	5.493	5.041	5.338
Hurdal	4.893	4.799	5.630	5.720	5.637	5.511	5.209	5.093	5.065	5.174	5.258	4.740	5.175
Brekkebygda	5.239	5.120	5.448	nan	5.345	5.420	5.394	5.163	5.165	5.127	5.559	4.821	5.205
Vikedal	5.513	5.817	5.556	5.674	5.642	5.070	5.480	5.717	5.227	5.267	5.267	5.540	5.375
Nausta	5.544	5.627	5.233	5.371	5.363	5.170	5.268	5.535	5.575	5.404	5.465	5.439	5.402
Kårvatn	5.451	5.494	5.418	5.336	5.299	5.149	5.547	5.127	5.022	5.571	5.611	5.554	5.336
Tustervatn	5.023	5.526	5.318	5.317	5.425	5.186	5.140	5.380	5.459	5.382	5.360	5.403	5.338
Karpbukt	4.793	4.897	4.947	4.867	4.984	5.417	5.568	5.366	5.339	5.222	5.185	4.932	5.101
Ny-Ålesund	5.669	5.225	5.362	6.130	nan	6.285	5.241	4.658	5.470	5.817	5.802	6.300	5.431

Table A1.2: 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	2021
Birkenes	0.016	0.153	0.143	0.075	0.153	0.252	0.201	0.130	0.328	0.118	0.152	0.243	0.167
Vatnedalen	0.076	0.092	0.072	0.057	0.288	0.200	0.179	0.146	0.136	0.100	0.027	0.048	0.112
Treungen	-0.004	0.092	0.126	0.048	0.175	0.236	0.186	0.135	0.236	0.067	0.061	0.073	0.123
Løken	0.043	0.200	0.135	0.079	0.309	0.362	0.181	0.171	0.224	0.094	0.118	0.083	0.167
Hurdal	0.025	0.187	0.178	0.063	0.225	0.282	0.156	0.166	0.338	0.080	0.100	0.126	0.158
Brekkebygda	0.009	0.106	0.123	nan	0.172	0.296	0.135	0.110	0.196	0.077	0.054	0.134	0.119
Vikedal	0.008	0.084	0.076	0.125	0.172	0.268	0.210	0.142	0.117	0.071	0.040	0.024	0.095
Nausta	0.006	0.028	0.046	0.089	0.355	0.197	0.176	0.173	0.077	0.020	0.011	-0.004	0.051
Kårvatn	0.040	0.013	0.044	0.048	0.115	0.163	0.193	0.125	0.179	0.006	0.002	0.001	0.064
Tustervatn	0.091	0.025	0.037	0.064	0.058	0.113	0.176	0.065	0.035	0.023	0.026	-0.005	0.055
Karpbukt	0.092	0.166	0.138	0.150	0.287	0.256	0.161	0.118	0.122	0.093	0.101	0.082	0.141
Ny-Ålesund	0.127	0.079	0.077	0.410	0.334	0.191	0.354	0.618	0.029	0.113	0.052	0.048	0.121

*Negative values due to uncertainties in the correction of sea salt

Table A1.3: 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	2021
Birkenes	0.204	0.423	0.479	0.200	0.270	0.383	0.260	0.208	0.356	0.298	0.356	0.420	0.328
Vatnedalen	0.035	0.145	0.133	0.058	0.299	0.238	0.137	0.060	0.090	0.090	0.049	0.166	0.113
Treungen	0.129	0.252	0.263	0.123	0.212	0.323	0.198	0.177	0.220	0.152	0.196	0.205	0.198
Løken	0.258	0.613	0.456	0.152	0.338	0.459	0.227	0.226	0.224	0.275	0.259	0.304	0.294
Hurdal	0.234	0.667	0.612	0.140	0.289	0.398	0.196	0.309	0.227	0.229	0.224	0.305	0.283
Brekkebygda	0.166	0.324	0.352	nan	0.224	0.413	0.145	0.088	0.105	0.146	0.227	0.285	0.184
Vikedal	0.094	0.205	0.137	0.125	0.228	0.281	0.207	0.142	0.208	0.178	0.148	0.101	0.170
Nausta	0.061	0.075	0.076	0.061	0.480	0.145	0.130	0.130	0.107	0.034	0.034	0.047	0.069
Kårvatn	0.053	0.115	0.082	0.061	0.187	0.102	0.191	0.068	0.035	0.046	0.034	0.025	0.062
Tustervatn	0.245	0.046	0.070	0.054	0.126	0.110	0.129	0.084	0.055	0.067	0.099	0.035	0.079
Karpbukt	0.121	0.057	0.098	0.085	0.148	0.039	0.041	0.103	0.091	0.085	0.060	0.083	0.083
Ny-Ålesund	0.170	0.120	0.086	0.242	0.346	0.075	0.120	0.142	0.033	0.115	0.017	0.039	0.076

Table A1.4: 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	2021
Birkenes	0.188	0.359	0.655	0.129	0.379	0.396	0.182	0.148	0.418	0.201	0.231	0.311	0.304
Vatnedalen	0.016	0.043	0.219	0.026	0.407	0.337	0.215	0.180	0.065	0.036	0.023	0.145	0.120
Treungen	0.049	0.072	0.561	0.039	0.362	0.597	0.081	0.088	0.184	0.081	0.090	0.035	0.166
Løken	0.147	0.524	0.807	0.209	0.815	nan	0.408	0.357	0.221	0.269	0.373	0.211	0.377
Hurdal	0.082	0.417	0.797	0.237	0.494	0.634	0.290	0.177	0.258	0.154	0.227	0.152	0.312
Brekkebygda	0.033	0.133	0.412	nan	0.349	0.671	0.319	0.099	0.035	0.113	0.248	0.166	0.200
Vikedal	0.084	0.239	0.272	0.376	0.706	0.491	0.600	0.237	0.192	0.114	0.098	0.148	0.236
Nausta	0.131	0.094	0.105	0.143	0.925	0.245	0.214	0.533	0.225	0.030	0.066	0.074	0.120
Kårvatn	0.048	0.116	0.113	0.064	0.233	0.184	0.401	0.055	0.019	0.024	0.043	0.040	0.073
Tustervatn	0.131	0.050	0.113	0.122	0.092	0.120	0.125	0.116	0.080	0.021	0.059	0.091	0.085
Karpbukt	0.039	0.074	0.062	0.042	0.149	0.023	0.122	0.156	0.034	0.091	0.022	0.058	0.080
Ny-Ålesund	0.050	0.114	0.050	0.156	0.115	0.046	0.025	0.216	0.027	0.053	0.027	0.111	0.067

Table A1.5: 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	2021
Birkenes	0.308	0.189	0.166	0.240	0.126	0.298	0.289	0.305	0.210	0.162	0.187	0.164	0.196
Vatnedalen	0.101	0.201	0.137	0.181	0.334	0.344	0.121	0.124	0.125	0.088	0.074	0.298	0.152
Treungen	0.075	0.093	0.112	0.109	0.140	0.429	0.120	0.273	0.179	0.125	0.118	0.126	0.152
Løken	0.081	0.198	0.137	0.189	0.486	nan	0.303	0.283	0.305	0.139	0.149	0.165	0.234
Hurdal	0.040	0.218	0.119	0.166	0.228	0.372	0.176	0.218	0.142	0.102	0.119	0.125	0.160
Brekkebygda	0.094	0.263	0.170	nan	0.166	0.615	0.080	0.052	0.071	0.052	0.102	0.094	0.109
Vikedal	0.147	0.352	0.124	0.390	0.374	0.258	0.299	0.170	0.144	0.214	0.164	0.143	0.210
Nausta	0.102	0.136	0.124	0.224	0.183	0.155	0.109	0.072	0.091	0.061	0.146	0.134	0.116
Kårvatn	0.087	0.122	0.226	0.228	0.119	0.091	0.206	0.072	0.098	0.101	0.147	0.124	0.139
Tustervatn	0.189	0.125	0.158	0.137	0.153	0.118	0.179	0.096	0.083	0.081	0.135	0.107	0.125
Karpbukt	0.088	0.179	0.236	0.153	0.318	0.102	0.118	0.242	0.158	0.256	0.188	0.210	0.196
Ny-Ålesund	0.550	0.561	0.580	2.134	0.894	0.642	0.631	0.392	0.182	0.984	0.696	0.839	0.576

Table A1.6: 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	2021
Birkenes	0.291	0.046	0.144	0.087	0.062	0.101	0.102	0.058	0.065	0.074	0.092	0.098	0.095
Vatnedalen	0.139	0.168	0.272	0.187	0.315	0.256	0.203	0.276	0.315	0.158	0.070	0.128	0.189
Treungen	0.054	0.017	0.146	0.015	0.100	0.213	0.061	0.103	0.122	0.069	0.080	0.086	0.088
Løken	0.072	0.062	0.070	0.155	0.219	nan	0.133	0.355	0.343	0.128	0.141	0.072	0.157
Hurdal	0.043	0.095	0.148	0.163	0.122	0.163	0.093	0.108	0.059	0.041	0.102	0.064	0.088
Brekkebygda	0.138	0.123	0.127	nan	0.118	0.802	0.083	0.034	0.126	0.072	0.322	0.162	0.134
Vikedal	0.203	0.259	0.130	0.272	0.480	0.137	0.150	0.078	0.083	0.105	0.112	0.128	0.148
Nausta	0.081	0.093	0.077	0.118	0.178	0.130	0.067	0.163	0.094	0.048	0.133	0.111	0.091
Kårvatn	0.049	0.106	0.112	0.174	0.074	0.067	0.176	0.071	0.059	0.139	0.112	0.074	0.104
Tustervatn	0.062	0.042	0.114	0.062	0.033	0.054	0.186	0.110	0.087	0.027	0.069	0.128	0.085
Karpbukt	0.082	0.118	0.153	0.074	0.066	0.113	0.196	0.217	0.142	0.166	0.112	0.149	0.142
Ny-Ålesund	0.379	0.426	0.419	0.810	0.118	0.136	0.073	0.091	0.095	0.173	0.213	0.340	0.247

Table A1.7: 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	2021
Birkenes	0.689	0.097	0.141	0.143	0.042	0.045	0.069	0.085	0.056	0.154	0.186	0.194	0.155
Vatnedalen	0.020	0.038	0.078	0.074	0.068	0.052	0.034	0.031	0.058	0.043	0.041	0.110	0.050
Treungen	0.118	0.040	0.058	0.037	0.022	0.054	0.030	0.041	0.051	0.060	0.159	0.035	0.064
Løken	0.136	0.052	0.046	0.106	0.141	0.111	0.042	0.070	0.046	0.068	0.072	0.044	0.073
Hurdal	0.073	0.059	0.060	0.051	0.034	0.075	0.034	0.068	0.021	0.034	0.089	0.021	0.047
Brekkebygda	0.033	0.036	0.064	nan	0.029	0.086	0.023	0.036	0.015	0.020	0.106	0.019	0.033
Vikedal	0.211	0.094	0.194	0.508	0.119	0.120	0.061	0.073	0.165	0.231	0.203	0.192	0.186
Nausta	0.113	0.049	0.170	0.383	0.079	0.080	0.040	0.047	0.040	0.078	0.319	0.259	0.147
Kårvatn	0.079	0.068	0.331	0.497	0.026	0.045	0.053	0.047	0.025	0.115	0.118	0.198	0.177
Tustervatn	0.064	0.109	0.293	0.120	0.029	0.035	0.075	0.041	0.043	0.026	0.139	0.270	0.116
Karpbukt	0.246	0.452	0.457	0.211	0.180	0.059	0.063	0.258	0.158	0.367	0.263	0.357	0.260
Ny-Ålesund	1.027	1.136	1.141	2.852	0.408	0.483	0.342	0.297	0.328	0.548	0.808	1.256	0.802

Table A1.8: 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	2021
Birkenes	6.098	0.895	0.983	1.028	0.288	0.131	0.468	0.623	0.443	1.371	1.574	1.592	1.288
Vatnedalen	0.628	0.702	1.189	1.180	1.024	0.675	0.490	0.585	0.785	0.697	0.488	0.766	0.693
Treungen	1.049	0.199	0.331	0.194	0.119	0.090	0.207	0.268	0.134	0.307	1.388	0.150	0.415
Løken	1.152	0.390	0.316	0.654	0.160	0.267	0.086	0.174	0.106	0.678	0.486	0.201	0.379
Hurdal	0.670	0.489	0.488	0.404	0.170	0.323	0.153	0.551	0.117	0.265	0.761	0.265	0.329
Brekkebygda	0.505	0.245	0.307	nan	0.147	0.211	0.076	0.303	0.356	0.152	1.027	0.234	0.273
Vikedal	1.962	1.031	1.548	4.057	0.677	1.089	0.307	0.575	1.412	2.008	1.733	1.542	1.574
Nausta	1.021	0.556	1.387	3.048	0.540	0.657	0.322	0.345	0.320	0.748	2.698	2.110	1.251
Kårvatn	0.718	0.654	2.859	3.824	0.138	0.309	0.315	0.442	0.272	1.041	1.043	1.599	1.457
Tustervatn	0.511	1.069	2.387	0.940	0.173	0.280	0.540	0.337	0.375	0.226	1.125	2.162	0.945
Karpbukt	2.025	3.898	3.635	1.616	1.314	2.212	1.139	2.325	1.641	3.076	2.984	3.880	2.503
Ny-Ålesund	8.120	9.668	9.085	22.503	2.240	3.433	1.801	2.014	2.747	3.720	5.724	8.904	6.063

Table A1.9: Monthly and annual volume weighted average concentrations of chloride in precipitation at Norwegian background stations. Unit: mg/L.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	10.339	1.574	1.647	1.796	0.451	0.236	0.744	1.097	0.756	2.375	2.821	2.724	2.213
Vatnedalen	0.571	0.758	1.561	1.571	0.909	0.440	0.416	0.452	0.759	0.764	0.690	0.849	0.730
Treungen	1.440	0.393	0.586	0.316	0.190	0.157	0.353	0.440	0.276	0.574	2.446	0.297	0.712
Løken	1.942	0.705	0.575	1.174	0.346	0.438	0.172	0.332	0.386	1.013	0.869	0.361	0.651
Hurdal	0.993	0.618	0.611	0.648	0.273	0.430	0.254	0.850	0.246	0.443	1.335	0.493	0.519
Brekkebygda	0.860	0.471	0.513	nan	0.253	0.319	0.133	0.536	0.277	0.274	1.641	0.362	0.425
Vikedal	3.347	1.661	2.701	7.071	1.109	1.914	0.491	0.900	2.545	3.528	3.090	2.636	2.741
Nausta	1.628	0.999	2.505	5.444	0.834	1.187	0.555	0.592	0.608	1.347	4.922	3.641	2.238
Kårvatn	1.339	1.057	5.082	7.252	0.226	0.513	0.445	0.770	0.483	1.851	1.789	2.762	2.624
Tustervatn	0.962	1.895	4.275	1.695	0.311	0.514	1.021	0.559	0.691	0.385	1.935	3.784	1.680
Karpbukt	3.558	6.729	6.296	2.924	2.386	1.743	1.065	3.781	2.586	5.522	5.141	6.225	4.074
Ny-Ålesund	12.507	16.648	16.079	38.913	3.956	6.129	3.275	3.648	4.989	6.974	10.280	15.413	10.463

Table A1.10: Monthly and annual precipitation amount at Norwegian background stations. Unit: mm.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	95	74	106	15	213	60	70	89	139	282	177	158	1478
Vatnedalen	41	41	25	31	22	40	100	35	59	105	85	49	633
Treungen	69	42	43	12	112	59	133	68	104	208	129	47	1026
Løken	49	26	33	13	53	36	122	37	64	125	24	30	611
Hurdal	81	28	54	20	128	72	139	19	80	202	71	27	920
Brekkebygda	67	37	29	0	76	22	165	55	90	166	54	57	817
Vikedal	133	173	275	100	65	143	140	102	218	454	318	146	2266
Nausta	72	194	212	118	20	129	59	41	193	527	260	189	2013
Kårvatn	84	43	196	257	13	86	76	245	185	232	164	313	1893
Tustervatn	7	101	158	82	39	63	119	83	122	152	123	70	1119
Karpbukt	24	66	37	38	59	27	82	70	82	85	51	82	704
Ny-Ålesund	30	11	15	4	1	15	3	16	52	7	36	37	227

Table A1.11: Monthly and annual wet deposition of strong acid (H^+) at Norwegian background stations. Unit: $\mu\text{ekv}/\text{m}^2$.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	588	841	300	1350	928	151	580	404	1211	2646	2254	4040	14181
Vatnedalen	110	122	370	75060	42	4783	10998	382014	159	67490	1114	997	2025
Treungen	544	642	126	108	656	258	1705	265	921	1124	1134	495	7991
Løken	400	398	3897	39	49	nan	387	6103	292	426	1723	276	2804
Hurdal	1032	443	125	38	294	223	860	137	692	1386	351	489	6142
Brekkebygda	386	278	104	nan	341	85	666	279518	614	1191	6672	11464	5099
Vikedal	407	2589	178353	16229	148	1212	463	13305	1291	2431	1887	706	9558
Nausta	206	1287	65189	501	85	873	318	116	514	2133	1601	62740	7972
Kårvatn	299	13196	748	1165	66	612	215	111463	1472	15013	401	67667	8739
Tustervatn	68	301	12066	380	145	408	860	345	61391	632	532	278	5139
Karpbukt	394	822	412	519	610	105	221	12670	375	510	331	960	5581
Ny-Ålesund	64	68	66	3	nan	8	291742	347	175	11	43083	7938152	844

Table A1.12: Monthly and annual wet deposition of sulfate (sea salt corrected) at Norwegian background stations. Unit: $\text{mg S}/\text{m}^2$.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	2	11	15	1	32	15	14	11	46	33	27	38	246
Vatnedalen	3	4	2	2	6	8	18	5	8	10	2	2	71
Treungen	0	4	5	1	19	14	25	9	25	14	8	3	127
Løken	2	5	4	1	16	13	22	6	14	12	3	2	102
Hurdal	2	5	10	1	29	20	22	3	27	16	7	3	146
Brekkebygda	1	4	4	0	13	7	22	6	18	13	3	8	97
Vikedal	1	15	21	13	11	38	29	15	26	32	13	3	216
Nausta	0	5	10	10	7	25	10	7	15	11	3	-1	104
Kårvatn	3	1	9	12	2	14	15	31	33	1	0	0	120
Tustervatn	1	3	6	5	2	7	21	5	4	3	3	0	62
Karpbukt	2	11	5	6	17	7	13	8	10	8	5	7	99
Ny-Ålesund	4	1	1	2	0	3	1	10	1	1	2	2	28

Table A1.13: Monthly and annual wet deposition of nitrate at Norwegian background stations.
Unit: mg N/m².

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	19	31	51	3	57	23	18	18	50	84	63	66	485
Vatnedalen	1	6	3	2	7	10	14	2	5	9	4	8	72
Treungen	9	11	11	2	24	19	26	12	23	32	25	10	203
Løken	13	16	15	2	18	16	28	8	14	34	6	9	180
Hurdal	19	19	33	3	37	29	27	6	18	46	16	8	260
Brekkebygda	11	12	10	nan	17	9	24	5	9	24	12	16	150
Vikedal	12	36	38	13	15	40	29	15	45	81	47	15	385
Nausta	4	15	16	7	9	19	8	5	21	18	9	9	140
Kårvatn	4	5	16	16	2	9	14	17	7	11	6	8	118
Tustervatn	2	5	11	4	5	7	15	7	7	10	12	2	88
Karpbukt	3	4	4	3	9	1	3	7	7	7	3	7	59
Ny-Ålesund	5	1	1	1	0	1	0	2	2	1	1	1	17

Table A1.14: Monthly and annual wet deposition of ammonium at Norwegian background stations.
Unit: mg N/m².

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	18	27	70	2	81	24	13	13	58	57	41	49	450
Vatnedalen	1	2	5	1	9	14	22	6	4	4	2	7	76
Treungen	3	3	24	0	40	35	11	6	19	17	12	2	171
Løken	7	14	26	3	43	0	50	13	14	33	9	6	230
Hurdal	7	12	43	5	63	46	40	3	21	31	16	4	287
Brekkebygda	2	5	12	0	26	15	53	5	3	19	13	9	163
Vikedal	11	41	75	38	46	70	84	24	42	52	31	22	535
Nausta	9	18	22	17	18	32	13	22	43	16	17	14	242
Kårvatn	4	5	22	16	3	16	30	13	4	6	7	12	138
Tustervatn	1	5	18	10	4	8	15	10	10	3	7	6	95
Karpbukt	1	5	2	2	9	1	10	11	3	8	1	5	57
Ny-Ålesund	1	1	1	1	0	1	0	3	1	0	1	4	15

Table A1.15: Monthly and annual wet deposition of calcium at Norwegian background stations.
Unit: mg/m².

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	29	14	18	4	27	18	20	27	29	46	33	26	289
Vatnedalen	4	8	3	6	7	14	12	4	7	9	6	15	97
Treungen	5	4	5	1	16	25	16	19	19	26	15	6	156
Løken	4	5	4	2	26	0	37	10	20	17	4	5	143
Hurdal	3	6	6	3	29	27	25	4	11	20	8	3	147
Brekkebygda	6	10	5	0	13	14	13	3	6	9	5	5	89
Vikedal	20	61	34	39	24	37	42	17	31	97	52	21	475
Nausta	7	26	26	26	4	20	6	3	17	32	38	25	233
Kårvatn	7	5	44	59	2	8	16	18	18	23	24	39	263
Tustervatn	1	13	25	11	6	7	21	8	10	12	17	8	140
Karpbukt	2	12	9	6	19	3	10	17	13	22	10	17	138
Ny-Ålesund	16	6	9	9	1	9	2	6	9	7	25	31	131

Table A1.16: Monthly and annual wet deposition of potassium at Norwegian background stations.
Unit: mg /m².

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	28	3	15	1	13	6	7	5	9	21	16	15	141
Vatnedalen	6	7	7	6	7	10	20	10	19	17	6	6	120
Treungen	4	1	6	0	11	13	8	7	13	14	10	4	91
Løken	4	2	2	2	12	0	16	13	22	16	3	2	96
Hurdal	3	3	8	3	16	12	13	2	5	8	7	2	81
Brekkebygda	9	5	4	0	9	18	14	2	11	12	17	9	110
Vikedal	27	45	36	27	31	19	21	8	18	48	35	19	335
Nausta	6	18	16	14	3	17	4	7	18	25	35	21	184
Kårvatn	4	5	22	45	1	6	13	17	11	32	18	23	197
Tustervatn	0	4	18	5	1	3	22	9	11	4	9	9	95
Karpbukt	2	8	6	3	4	3	16	15	12	14	6	12	100
Ny-Ålesund	11	5	6	3	0	2	0	1	5	1	8	12	56

Table A1.17: Monthly and annual wet deposition of magnesium at Norwegian background stations.
Unit: mg /m².

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	66	7	15	2	9	3	5	8	8	43	33	31	229
Vatnedalen	1	2	2	2	2	2	3	1	3	5	3	5	32
Treungen	8	2	3	0	2	3	4	3	5	12	20	2	65
Løken	7	1	1	1	7	4	5	3	3	8	2	1	45
Hurdal	6	2	3	1	4	5	5	1	2	7	6	1	43
Brekkebygda	2	1	2	0	2	2	4	2	1	3	6	1	27
Vikedal	28	16	53	51	8	17	9	7	36	105	64	28	422
Nausta	8	10	36	45	2	10	2	2	8	41	83	49	296
Kårvatn	7	3	65	128	0	4	4	12	5	27	19	62	335
Tustervatn	0	11	46	10	1	2	9	3	5	4	17	19	129
Karpbukt	6	30	17	8	11	2	5	18	13	31	13	29	183
Ny-Ålesund	31	13	18	12	0	7	1	5	17	4	29	46	182

Table A1.18: Monthly and annual wet deposition of sodium at Norwegian background stations.
Unit: mg /m².

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	582	66	104	15	61	8	33	55	62	387	278	251	1904
Vatnedalen	26	29	30	37	23	27	49	20	47	73	42	37	439
Treungen	73	8	14	2	13	5	27	18	14	64	179	7	426
Løken	56	10	10	8	8	10	11	6	7	84	12	6	232
Hurdal	54	14	26	8	22	23	21	11	9	53	54	7	302
Brekkebygda	34	9	9	0	11	5	13	17	32	25	56	13	223
Vikedal	261	179	425	406	44	155	43	59	308	912	550	226	3567
Nausta	74	108	294	359	11	85	19	14	62	394	702	398	2519
Kårvatn	61	28	560	982	2	27	24	108	50	242	171	501	2758
Tustervatn	4	108	378	77	7	18	64	28	46	34	139	152	1057
Karpbukt	49	256	133	62	78	61	93	164	135	261	151	319	1761
Ny-Ålesund	242	110	141	97	2	51	6	32	142	28	205	327	1379

Table A1.19: Monthly and annual wet deposition of chloride at Norwegian background stations.
Unit: mg/m².

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes	987	116	175	27	96	14	52	97	105	670	499	429	3270
Vatnedalen	24	31	39	49	20	18	42	16	45	80	59	41	463
Treungen	100	17	25	4	21	9	47	30	29	119	315	14	730
Løken	95	19	19	15	18	16	21	12	25	126	21	11	398
Hurdal	80	17	33	13	35	31	35	16	20	89	94	13	478
Brekkebygda	58	17	15	0	19	7	22	29	25	45	89	21	347
Vikedal	445	288	742	707	72	273	69	92	555	1602	981	386	6212
Nausta	117	194	531	641	16	153	33	24	117	710	1281	688	4505
Kårvatn	113	45	995	1863	3	44	34	189	89	429	292	865	4968
Tustervatn	7	191	677	139	12	32	121	46	84	59	239	266	1880
Karpbukt	87	441	231	112	142	48	87	266	212	469	260	511	2866
Ny-Ålesund	373	190	249	168	4	90	11	58	257	52	368	565	2379

Table A1.20: The 10 highest daily wet deposition of sea salt corrected sulfate, 2021.

Site	Date	SO ₄ wet dep mgS/m ²	Precip mm'	% av annual SO ₄ dep	pH
Birkenes	27.09.2021	33.7	61.1	13.7	4.98
	08.12.2021	16.6	43.0	6.7	4.51
	16.11.2021	12.9	21.3	5.2	4.54
	10.03.2021	9.1	61.1	3.7	5.67
	09.12.2021	8.1	18.5	3.3	4.49
	30.10.2021	7.7	52.0	3.1	5.19
	07.12.2021	6.8	32.0	2.8	4.55
	24.05.2021	6.4	33.3	2.6	5.27
	04.05.2021	6.4	52.5	2.6	6.03
	03.06.2021	5.6	10.5	2.3	5.61
	sum			46.1	
Hurdal	27.09.2021	16.5	34.1	11.3	5.53
	11.05.2021	11.7	29.1	8.0	5.81
	17.06.2021	9.6	41.7	6.6	5.51
	29.09.2021	7.4	17.9	5.1	4.81
	30.10.2021	5.6	23.0	3.8	5.15
	14.05.2021	5.1	13.1	3.5	5.61
	10.03.2021	5.0	28.2	3.5	5.68
	06.07.2021	4.6	18.1	3.1	5.00
	27.07.2021	4.4	22.9	3.0	5.91
	20.06.2021	4.1	8.1	2.8	5.58
	sum			50.8	
Tustervatn	19.07.2021	4.9	21.6	7.8	5.00
	15.07.2021	3.1	2.9	4.9	4.47
	21.07.2021	2.8	12.0	4.5	5.82
	18.07.2021	2.5	16.1	4.1	5.08
	03.04.2021	2.3	18.8	3.7	5.24
	30.07.2021	1.9	8.8	3.0	4.96
	17.07.2021	1.6	9.9	2.6	5.07
	17.06.2021	1.5	10.8	2.4	5.21
	31.08.2021	1.4	4.3	2.3	5.88
	29.03.2021	1.2	14.4	2.0	5.21
	sum			37.4	
Kårvatn	31.08.2021	21.4	5.3	17.9	3.74
	01.09.2021	19.0	53.3	15.8	4.80
	17.07.2021	4.7	18.5	3.9	5.33
	02.09.2021	4.2	11.8	3.5	-
	01.03.2021	3.0	98.4	2.5	5.46
	18.08.2021	2.9	51.2	2.4	5.31
	24.08.2021	2.8	62.3	2.3	5.21
	25.06.2021	2.8	6.8	2.3	5.65
	29.07.2021	2.7	15.5	2.3	5.98
	11.06.2021	2.6	15.1	2.2	4.88
	sum			55.1	

Table A1.21a: 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 1987-2021.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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 mm	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		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 (cont.)	2014	0.31	0.35	0.35	0.16	0.18	4.77	2331	732	813	818	17	71	193
	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
	2017	0.20	0.31	0.29	0.17	0.14	4.95	2088	408	648	611	11	39	102
	2018	0.20	0.43	0.44	0.14	0.18	4.95	1515	310	655	673	11	49	152
	2019	0.16	0.26	0.24	0.12	0.09	4.99	2010	313	526	481	10	37	109
	2020	0.16	0.29	0.28	0.16	0.17	5.04	2286	363	664	646	9	37	128
	2021	0.17	0.33	0.30	0.20	0.16	5.02	1478	246	485	450	10	41	97
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			

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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.)	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			
	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			
	2017	0.08	0.10	0.12	0.08	0.03	5.52	1272	106	132	155	3			
	2018	0.10	0.13	0.13	0.10	0.04	5.51	967	94	122	127	3			
	2019	0.10	0.11	0.14	0.08	0.03	5.72	1033	105	111	140	2			
	2020	0.07	0.06	0.03	0.17	0.05	5.53	1280	88	81	41	3			
	2021	0.11	0.11	0.12	0.15	0.05	5.50	633	71	72	76	3			
Treungen	1974	0.94	0.38	0.33	0.14	0.07	4.27	1039	977	395	343	56			
	1975	0.91	0.37	0.34	0.15	0.06	4.26	894	814	331	304	49			
	1976	1.05	0.50	0.42	0.11	0.06	4.20	706	741	353	297	45			
	1977	0.81	0.44	0.39	0.11	0.05	4.32	1165	944	513	454	56			
	1978	0.87	0.38	0.41	0.14	0.04	4.21	945	822	359	387	58			
	1979														
	1980	0.88	0.37	0.39	0.14	0.04	4.23	759	668	281	296	45			
	1981	0.86	0.39	0.46	0.12	0.05	4.29	949	816	370	437	49			
	1982	0.84	0.45	0.50	0.14	0.07	4.32	1130	948	504	563	54			
	1983	0.83	0.40	0.43	0.18	0.05	4.35	1091	908	431	471	48			
	1984	0.77	0.36	0.27	0.15	0.05	4.27	1196	919	436	325	64			
	1985	0.68	0.39	0.37	0.13	0.04	4.33	892	608	350	333	41			
	1986	1.07	0.57	0.63	0.14	0.07	4.19	1030	1097	582	650	66			
	1987	0.68	0.37	0.37	0.13	0.07	4.39	1133	768	424	418	46			
	1988	0.75	0.50	0.45	0.10	0.05	4.27	1348	1006	670	612	73			
	1989	0.76	0.61	0.44	0.10	0.06	4.26	754	572	456	329	41			
	1990	0.63	0.42	0.37	0.06	0.07	4.37	1184	747	503	433	51			
	1991	0.59	0.42	0.34	0.13	0.06	4.42	811	480	343	278	31			
	1992	0.60	0.40	0.34	0.08	0.05	4.44	923	556	365	310	33			
	1993	0.59	0.41	0.32	0.11	0.09	4.46	803	472	329	258	28			
	1994	0.54	0.44	0.35	0.08	0.05	4.49	1016	544	448	356	33			
1995	0.50	0.44	0.40	0.09	0.08	4.48	903	452	394	361	30				
1996	0.49	0.40	0.37	0.10	0.05	4.49	838	408	335	312	27				
1997	0.41	0.37	0.32	0.12	0.06	4.56	887	364	330	282	24				
1998	0.48	0.40	0.41	0.09	0.04	4.53	959	462	386	397	28				
1999	0.35	0.32	0.31	0.06	0.06	4.67	1329	463	427	406	28				
2000	0.33	0.36	0.31	0.08	0.07	4.59	1563	510	566	483	40				
2001	0.30	0.28	0.27	0.05	0.04	4.77	1141	346	324	314	19				
2002	0.32	0.27	0.28	0.08	0.04	4.79	933	295	251	262	15				
2003	0.35	0.36	0.35	0.09	0.04	4.67	1002	349	366	350	22				
2004	0.31	0.30	0.26	0.10	0.06	4.79	1271	393	379	336	21				
2005	0.34	0.38	0.37	0.11	0.06	4.75	897	308	338	329	16				
2006	0.23	0.28	0.20	0.09	0.05	4.79	1522	355	433	310	25				
2007	0.23	0.24	0.18	0.08	0.04	4.82	1006	226	243	178	15				

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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.)	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		
	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		
	2017	0.14	0.22	0.24	0.11	0.05	5.12	1186	169	265	288	8		
	2018	0.15	0.30	0.28	0.10	0.05	5.02	878	133	260	247	10		
	2019	0.12	0.19	0.20	0.11	0.03	5.15	1644	196	307	326	7		
	2020	0.09	0.15	0.16	0.10	0.04	5.21	1587	145	233	253	6		
2021	0.12	0.20	0.17	0.15	0.06	5.11	1026	127	203	171	8			
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			

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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.)	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		
	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		
	2017	0.12	0.25	0.21	0.18	0.06	5.12	797	96	196	169	8		
	2018	0.17	0.27	0.26	0.21	0.10	5.14	619	103	167	161	7		
	2019	0.13	0.23	0.25	0.17	0.05	5.23	1004	134	231	254	6		
2020	0.10	0.22	0.23	0.14	0.07	5.19	1000	101	217	233	6			
2021	0.17	0.29	0.38	0.23	0.07	5.34	611	96	180	230	5			
Nordmoen	1987	0.72	0.37	0.33	0.14	0.03	4.34	1016	727	375	335	46	148	348
	1988	0.88	0.48	0.46	0.13	0.04	4.25	1085	960	519	500	61	171	357
	1989	0.88	0.57	0.40	0.14	0.05	4.26	816	719	463	328	44	144	356
	1990	0.77	0.44	0.35	0.10	0.05	4.31	822	636	366	286	40	137	332
	1991	0.59	0.40	0.31	0.09	0.04	4.43	781	459	312	240	29	117	284
	1992	0.58	0.40	0.27	0.10	0.03	4.42	821	473	327	218	31	99	276
	1993	0.56	0.37	0.25	0.08	0.03	4.45	927	517	340	236	33	84	246
	1994	0.45	0.39	0.29	0.07	0.03	4.55	828	373	326	242	23	97	280
	1995	0.53	0.37	0.33	0.12	0.06	4.49	791	415	292	257	25	88	279
	1996	0.43	0.34	0.23	0.14	0.04	4.52	837	358	286	195	25	91	303
	1997	0.33	0.31	0.26	0.07	0.02	4.63	775	254	240	202	18		
	1998	0.36	0.28	0.21	0.11	0.03	4.64	817	293	224	173	19		
1999	0.37	0.31	0.26	0.08	0.03	4.65	1014	376	316	262	22			
Hurdal	1998	0.38	0.29	0.28	0.09	0.03	4.68	853	325	249	236	18	54	172
	1999	0.39	0.33	0.31	0.08	0.03	4.67	1110	434	367	344	24	64	169
	2000	0.31	0.31	0.24	0.07	0.05	4.64	1336	418	408	314	30	57	170
	2001	0.33	0.36	0.29	0.08	0.03	4.69	961	318	347	275	20	52	
	2002	0.25	0.27	0.26	0.09	0.03	4.79	732	183	197	187	12	60	
	2003	0.32	0.35	0.32	0.09	0.04	4.66	830	263	289	268	18	63	
	2004	0.24	0.27	0.28	0.11	0.03	4.84	903	219	241	248	13	53	189
	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	

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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			mg/m ²	mg/m ²	mg/m ²	mekv/m ²	mg/m ²	mg/m ²
Hurdal (cont.)	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
	2017	0.12	0.19	0.24	0.12	0.03	5.23	956	115	181	228	6	24	118
	2018	0.17	0.30	0.31	0.14	0.06	5.04	901	156	270	278	9	29	151
	2019	0.14	0.20	0.20	0.13	0.03	5.12	1260	181	254	258	8	23	123
	2020	0.10	0.20	0.19	0.10	0.04	5.20	1441	149	290	277	6	18	96
	2021	0.16	0.28	0.31	0.16	0.05	5.18	920	146	260	287	7	22	100
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		

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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			mg/m ²	mg/m ²	mg/m ²	mekv/m ²	mg/m ²	mg/m ²
Brekkebygda (cont.)	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		
	2017	0.12	0.17	0.15	0.09	0.02	4.98	1092	130	190	167	10		
	2018	0.15	0.24	0.20	0.15	0.05	4.98	1003	151	245	197	10		
	2019	0.14	0.21	0.20	0.14	0.03	5.10	1135	163	244	223	8		
	2020	0.09	0.15	0.12	0.10	0.03	5.22	1420	132	210	172	6		
2021	0.12	0.18	0.20	0.11	0.03	5.21	817	97	150	163	6			
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			

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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 (cont).	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		
	2017	0.06	0.12	0.16	0.14	0.26	5.25	3570	227	421	564	6		
	2018	0.09	0.16	0.22	0.17	0.25	5.38	2807	250	449	618	4		
	2019	0.09	0.11	0.14	0.16	0.22	5.38	2937	253	319	405	4		
	2020	0.06	0.11	0.19	0.21	0.31	5.44	3560	224	396	683	4		
	2021	0.10	0.17	0.24	0.21	0.19	5.38	2266	216	385	535	4		
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			
2017	0.08	0.10	0.15	0.10	0.16	5.17	1293	99	126	196	7			

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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 (cont.)	2018	0.05	0.09	0.13	0.08	0.13	5.40	2045	94	179	263	4		
	2019	0.06	0.10	0.17	0.12	0.17	5.45	1876	118	186	320	4		
	2020	0.04	0.07	0.12	0.11	0.20	5.48	3047	120	212	355	3		
	2021	0.05	0.07	0.12	0.12	0.15	5.40	2013	104	140	242	4		
Kårvatn	1978	0.16	0.05	0.09	0.11	0.13	4.98	1317	211	66	119	14		
	1979	0.23	0.09	0.08	0.10	0.10	4.63	1248	287	112	100	29		
	1980	0.20	0.07	0.08	0.11	0.13	4.88	1225	245	86	98	16		
	1981	0.20	0.08	0.15	0.17	0.25	4.96	1101	220	88	165	12		
	1982	0.26	0.08	0.11	0.15	0.16	4.87	995	256	78	112	13		
	1983	0.14	0.05	0.06	0.18	0.20	5.08	1918	265	100	106	16		
	1984	0.24	0.10	0.18	0.22	0.18	5.04	914	216	91	166	8		
	1985	0.20	0.07	0.10	0.15	0.11	5.00	1462	298	100	149	15		
	1986	0.20	0.07	0.13	0.10	0.11	4.95	1277	260	89	162	14		
	1987	0.24	0.09	0.12	0.15	0.17	4.87	1464	357	129	176	20	68	
	1988	0.11	0.06	0.09	0.13	0.19	5.09	1550	164	91	143	13	76	149
	1989	0.11	0.06	0.12	0.13	0.26	5.11	1539	168	97	187	12	55	116
	1990	0.11	0.05	0.07	0.07	0.14	5.07	1520	173	69	105	13	60	107
	1991	0.12	0.06	0.10	0.12	0.24	5.14	1619	190	102	170	12	52	89
	1992	0.10	0.07	0.06	0.11	0.18	5.17	1620	159	113	94	11	62	97
	1993	0.10	0.06	0.12	0.12	0.18	5.16	1423	148	87	169	10	45	88
	1994	0.11	0.07	0.08	0.12	0.15	5.12	1475	168	100	120	11	53	124
	1995	0.08	0.05	0.06	0.10	0.15	5.17	1661	134	80	106	11	39	107
	1996	0.09	0.07	0.10	0.10	0.13	5.16	1170	107	79	115	8	47	126
	1997	0.09	0.06	0.11	0.12	0.23	5.22	1842	171	109	208	11	38	129
	1998	0.08	0.06	0.11	0.09	0.19	5.21	1451	123	86	164	9	25	90
	1999	0.09	0.07	0.08	0.07	0.13	5.22	1304	115	93	100	8	31	107
	2000	0.09	0.05	0.08	0.10	0.23	5.26	1243	110	63	104	7	27	135
	2001	0.07	0.05	0.07	0.07	0.21	5.31	1523	103	71	113	7	28	108
	2002	0.10	0.07	0.10	0.08	0.11	5.26	1295	135	88	132	7	37	185
	2003	0.09	0.08	0.12	0.12	0.23	5.19	1664	154	128	192	11	36	196
	2004	0.06	0.04	0.07	0.11	0.16	5.40	2001	110	75	129	8	37	105
	2005	0.09	0.05	0.08	0.12	0.19	5.33	1733	162	93	139	8	35	153
2006	0.08	0.08	0.14	0.09	0.13	5.29	1218	96	93	167	6	42	199	
2007	0.05	0.04	0.11	0.11	0.22	5.40	1930	94	74	220	8	22	129	
2008	0.05	0.07	0.08	0.13	0.22	5.37	1426	74	106	115	6	23	127	
2009	0.05	0.05	0.08	0.06	0.09	5.46	1310	69	68	102	5	20	-	
2010	0.08	0.05	0.12	0.03	0.06	5.36	1465	119	74	176	6	22	47	
2011	0.06	0.05	0.17	0.10	0.20	5.48	1500	85	70	259	5	31	70	
2012	0.06	0.06	0.12	0.12	0.21	5.42	1523	85	91	179	6	26	170	
2013	0.04	0.06	0.13	0.14	0.22	5.45	1432	57	80	182	5	16	110	
2014	0.18	0.11	0.10	0.21	0.16	5.03	1099	193	124	109	9	45	146	

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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			mg/m ²	mg/m ²	mg/m ²	mekv/m ²	mg/m ²	mg/m ²
Kårvatn (cont.)	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
	2017	0.05	0.04	0.06	0.09	0.11	5.26	1758	88	75	111	5	24	64
	2018	0.05	0.08	0.09	0.11	0.16	5.34	1196	66	96	111	5	21	117
	2019	0.05	0.07	0.09	0.13	0.19	5.30	1508	77	107	138	5	23	123
	2020	0.04	0.04	0.09	0.11	0.20	5.49	1773	68	74	167	3	15	90
	2021	0.06	0.06	0.07	0.14	0.18	5.34	1893	120	118	138	5	21	113
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		
	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			
2017	0.04	0.04	0.18	0.14	0.25	5.47	1502	65	64	277	3			
2018	0.06	0.05	0.18	0.16	0.28	5.63	948	53	51	169	2			
2019	0.06	0.07	0.20	0.16	0.33	5.51	1221	76	90	249	3			
2020	0.02	0.04	0.17	0.16	0.33	5.62	1207	21	53	208	2			
2021							951							

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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			mg/m ²	mg/m ²	mg/m ²	mekv/m ²	mg/m ²	mg/m ²
Tustervatn	1973	0.24				0.18	4.94	1336	321			15		
	1974	0.28				0.11	4.88	695	195			9		
	1975	0.25				0.33	4.91	1756	439			22		
	1976	0.27				0.16	4.97	1064	287			11		
	1977	0.30	0.09	0.11	0.17	0.16	4.91	1111	333	100	122	14		
	1978	0.23	0.08	0.10	0.16	0.16	4.85	1128	259	90	113	16		
	1979	0.28	0.08	0.13	0.15	0.11	4.73	1168	327	93	152	22		
	1980	0.27	0.08	0.14	0.47	0.16	4.98	858	229	71	122	9		
	1981	0.18	0.07	0.10	0.21	0.15	5.00	1099	198	77	110	11		
	1982	0.16	0.08	0.09	0.22	0.47	4.98	1385	227	109	121	15		
	1983	0.20	0.06	0.09	0.16	0.22	4.90	1665	337	101	142	21		
	1984	0.24	0.09	0.09	0.12	0.10	4.85	1056	250	94	89	15		
	1985	0.22	0.08	0.10	0.12	0.15	4.93	1344	298	107	132	16		
	1986	0.26	0.09	0.12	0.12	0.15	4.88	1060	278	94	131	14		
	1987	0.22	0.08	0.11	0.12	0.12	4.89	1163	253	98	133	15	96	
	1988	0.13	0.07	0.09	0.13	0.15	5.04	1159	145	83	106	10	88	131
	1989	0.19	0.08	0.10	0.18	0.40	5.00	1825	346	137	178	18	40	119
	1990	0.16	0.09	0.14	0.11	0.21	4.99	1508	245	133	214	16	65	125
	1991	0.17	0.10	0.14	0.14	0.21	5.04	1400	242	137	197	13	62	148
	1992	0.15	0.08	0.15	0.19	0.37	5.12	1507	223	126	221	11	49	123
	1993	0.14	0.08	0.16	0.24	0.50	5.19	1340	182	111	209	9	44	126
	1994	0.10	0.08	0.13	0.12	0.15	5.24	1117	114	87	144	6	48	147
	1995	0.09	0.06	0.12	0.13	0.21	5.22	1515	136	96	186	9	47	132
	1996	0.12	0.09	0.16	0.15	0.18	5.11	1084	132	97	176	8	44	139
	1997	0.08	0.06	0.18	0.17	0.30	5.34	1528	121	98	271	7	44	199
	1998	0.07	0.06	0.16	0.11	0.18	5.39	1407	100	90	230	6	30	178
	1999	0.09	0.08	0.17	0.07	0.08	5.38	1133	96	90	191	5	34	180
	2000	0.10	0.06	0.15	0.11	0.20	5.33	1313	116	80	191	6	29	164
	2001	0.08	0.06	0.15	0.10	0.19	5.36	1449	107	94	223	6	31	182
	2002	0.09	0.07	0.14	0.11	0.17	5.38	1162	103	82	157	5	38	207
	2003	0.07	0.07	0.18	0.16	0.26	5.32	1513	111	112	274	7	35	196
	2004	0.04	0.07	0.17	0.20	0.23	5.50	1428	62	97	243	5	34	167
	2005	0.12	0.08	0.18	0.15	0.19	5.39	1302	163	109	241	5	39	185
	2006	0.08	0.10	0.13	0.12	0.20	5.30	1208	97	119	153	6	37	219
	2007	0.07	0.08	0.14	0.13	0.26	5.28	1293	91	106	174	7	24	163
	2008	0.07	0.08	0.09	0.16	0.22	5.33	1165	80	93	101	5	22	172
	2009	0.05	0.06	0.11	0.06	0.10	5.40	1155	63	71	126	5	22	-
	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

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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
Tustervatn (cont).	2017	0.04	0.05	0.10	0.10	0.16	5.34	1318	50	72	125	5	21	62
	2018	0.05	0.07	0.09	0.09	0.10	5.36	1192	58	81	107	4	20	72
	2019	0.12	0.07	0.13	0.15	0.26	5.18	1133	138	79	144	7	21	78
	2020	0.03	0.05	0.11	0.12	0.20	5.49	1360	44	63	143	3	14	75
	2021	0.06	0.08	0.09	0.13	0.12	5.34	1119	62	88	95	5	19	80
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		
	2017	0.27	0.08	0.16	0.16	0.20	4.95	594	159	46	96	11		
	2018	0.32	0.10	0.21	0.16	0.14	4.91	567	181	58	118	12		
2019	0.24	0.09	0.08	0.20	0.21	4.96	527	125	49	40	11			
2020	0.31	0.08	0.05	0.14	0.15	4.95	504	157	42	25	11			
2021	0.14	0.08	0.08	0.20	0.26	5.10	704	99	59	57	8			

Table A.1.21a, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual preci p mm	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		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
Ny-Ålesund (tørr-avsetning 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		
2017	0.13	0.09	0.07	0.37	0.53	5.20	313	40	27	22	6.3	31		
2018	0.10	0.07	0.06	0.29	0.46	5.39	484	49	33	31	4.1	14		
2019	0.20	0.11	0.19	0.56	0.73	5.61	162	32	18	31	2.5	19		
2020	0.11	0.07	0.08	1.00	1.29	5.76	228	25	16	19	1.7	17		
2021	0.12	0.08	0.07	0.58	0.80	5.43	227	28	17	15	3.7	15		

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 mm	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		SO ₄ -S mg/m ²	NO ₃ -N mg/m ²	NH ₄ -N mg/m ²	H+ mekv/m ²	S mg/m ²	N mg/m ²
Lista	1973	1.01				1.31	4.33	851	860			40		
	1974	1.06				1.00	4.28	1208	1280			63		
	1975	1.10				1.06	4.30	1109	1220			56		
	1976	1.37				1.21	4.23	922	1263			54		
	1977	0.95				1.09	4.34	1114	1058			51		
	1978	1.01	0.50	0.45	0.51	1.07	4.27	931	940	466	419	50		
	1979	1.27	0.63	0.57	0.53	1.04	4.09	1157	1469	729	659	94		
	1980	1.05	0.59	0.54	0.47	1.00	4.22	953	1001	562	515	57		
	1981	0.90	0.47	0.50	0.60	1.36	4.34	1037	933	487	519	47		
	1982	1.09	0.65	0.60	0.85	1.82	4.29	1070	1161	699	645	55		
	1983	0.88	0.49	0.40	0.77	1.69	4.36	1198	1051	584	480	53		
	1984	0.92	0.61	0.47	0.86	2.12	4.28	1002	923	613	474	53		
	1985	1.11	0.80	0.68	0.76	1.74	4.20	996	1110	793	681	63		
	1986	0.95	0.63	0.57	1.06	2.66	4.30	1293	1230	816	739	65		
	1987	0.86	0.55	0.55	0.65	1.48	4.35	1169	1004	647	638	52		
	1988	0.75	0.67	0.57	0.82	2.02	4.28	1585	1189	1054	895	84		
	1989	0.83	0.86	0.52	1.21	3.23	4.30	1053	877	904	552	53		
	1990	0.74	0.55	0.42	1.07	3.01	4.38	1565	1156	856	653	65		
	1991	0.75	0.83	0.60	1.36	3.76	4.32	1031	771	858	615	49		
	1992	0.72	0.60	0.41	1.02	2.54	4.38	1376	985	826	561	57		
	1993	0.81	0.80	0.68	2.10	1.79	4.39	845	686	673	579	34		
	1994	0.56	0.57	0.52	0.91	2.37	4.56	1180	659	678	615	33		
	1995	0.67	0.73	0.62	1.15	3.05	4.48	896	599	658	555	30		
1996	0.62	0.74	0.67	0.88	2.20	4.42	910	564	673	607	35			
1997	0.55	0.55	0.56	0.94	2.54	4.52	1219	666	666	682	37			
1998	0.59	0.62	0.53	0.97	2.44	4.46	1240	637	767	661	43			
1999	0.44	0.60	0.48	1.11	3.00	4.63	1273	547	762	614	30			
2000	0.45	0.64	0.49	1.28	3.45	4.54	1651	711	1064	808	47			
2001	0.45	0.59	0.55	0.63	1.55	4.77	1428	639	847	787	24			
2002	0.47	0.71	0.56	0.99	2.18	4.69	1132	534	808	628	23			
Søgne	1989	1.12	0.93	0.91	0.31	0.43	4.34	1151	1289	1067	1050	53	212	
	1990	0.79	0.60	0.48	0.25	0.52	4.33	1807	1425	1084	872	85	237	612
	1991	0.94	0.66	0.58	0.23	0.47	4.30	1133	1063	750	662	57	245	559
	1992	0.79	0.59	0.49	0.19	0.34	4.33	1280	1011	752	623	60	192	365
	1993	0.95	0.71	0.63	0.26	0.26	4.33	1112	1061	786	699	52	148	326
	1994	0.76	0.62	0.54	0.19	0.31	4.39	1441	1092	894	781	58	173	349
	1995	0.61	0.54	0.45	0.19	0.34	4.45	1213	735	651	552	43	151	350
	1996	0.87	0.75	0.69	0.31	0.36	4.32	1044	910	786	725	50	175	305
	1997	0.67	0.60	0.63	0.20	0.34	4.46	1215	809	733	760	42	123	304
	1998	0.70	0.60	0.55	0.24	0.39	4.45	1333	939	812	740	45	110	268
	1999	0.63	0.57	0.50	0.21	0.34	4.50	1667	1053	947	840	53	112	249
	2000	0.47	0.54	0.48	0.21	0.38	4.53	2029	980	1100	975	60	96	245
	2001	0.48	0.52	0.47	0.14	0.21	4.61	1569	756	816	737	38	106	
	2002	0.44	0.42	0.34	0.20	0.28	4.64	1608	704	679	552	37	114	
	2003	0.59	0.68	0.68	0.29	0.28	4.59	1271	749	863	865	32	101	
	2004	0.43	0.47	0.45	0.24	0.36	4.72	1601	697	760	717	30	89	
	2005	0.46	0.59	0.55	0.28	0.44	4.64	1176	535	700	644	27	99	
2006	0.41	0.52	0.41	0.23	0.37	4.68	1714	707	884	707	35	156		
2007	0.31	0.43	0.29	0.23	0.40	4.80	1237	379	538	362	20	70		
2008	0.36	0.40	0.35	0.28	0.54	4.83	1697	610	676	601	25	62		
2009	0.36	0.47	0.43	0.25	0.38	4.77	1633	592	763	699	27	63		
Skreådalen	1973	0.50				0.19	4.60	2185	1093			55		
	1974	0.55				0.18	4.47	2460	1350			83		
	1975	0.57	0.18	0.17		0.19	4.55	2436	1389	438	414	69		
	1976	0.60	0.24	0.23		0.17	4.55	1687	1012	405	388	48		
	1977	0.57	0.27	0.28	0.15	0.13	4.55	2057	1174	550	569	57		
	1978	0.49	0.20	0.26	0.20	0.29	4.52	1769	867	354	460	53		
	1979	0.61	0.26	0.28	0.16	0.14	4.33	2311	1410	601	647	108		
	1980	0.48	0.21	0.21	0.15	0.17	4.54	1949	936	409	409	56		

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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
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		
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			

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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 cont.	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		
2017	0,06	0,09	0,10	0,14	0,23	5,21	3607	211	328	350	6			
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			
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		

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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
Fagernes (cont.)	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		
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			

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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
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	
	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	

Table A.1.21b, cont.

Site	Year	Annual vol. weighted mean concentrations						Annual precip mm	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		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
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			
2013-2017														
2018	0.33	0.12	0.08	0.12	0.11	4.83	356	117	42	29	15			

Table A1.22: Monthly and annual mean concentration of sulfur dioxide in air at Norwegian background stations. Unit: $\mu\text{g S}/\text{m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.015	0.030	0.044	0.070	0.212	0.170	0.084	0.065	0.064	0.044	0.018	0.021	0.070
Hurdal	0.012	0.023	0.018	0.029	0.022	0.037	0.033	0.034	0.021	0.011	0.011	0.011	0.022
Kårvatn	0.011	0.023	0.016	0.029	0.058	0.066	0.040	0.033	0.023	0.011	0.013	0.015	0.028
Tustervatn	0.062	0.028	0.027	0.025	0.025	0.028	0.040	0.030	0.015	0.017	0.010	0.018	0.027
Zeppelinfjellet	0.024	0.023	0.113	0.039	0.018	0.023	0.021	0.065	0.018	0.019	0.074	0.194	0.054

Table A1.23: Monthly and annual mean concentration of sulfate in aerosol at Norwegian background stations. Unit: $\mu\text{g S}/\text{m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.081	0.134	0.103	0.103	0.201	0.405	0.367	0.183	0.259	0.203	0.096	0.098	0.187
Hurdal	0.066	0.066	0.063	0.065	0.160	0.277	0.220	0.108	0.146	0.108	0.064	0.092	0.121
Kårvatn	0.019	0.043	0.045	0.112	0.143	0.355	0.273	0.106	0.067	0.022	0.015	0.033	0.104
Tustervatn	0.100	0.083	0.055	0.076	0.170	0.204	0.203	0.092	0.079	0.087	0.045	0.097	0.108
Zeppelinfjellet	0.055	0.085	0.112	0.129	0.140	0.075	0.083	0.076	0.050	0.070	0.091	0.144	0.094

Table A1.24: Monthly and annual mean concentration of nitrogen dioxide in air at Norwegian background stations. Unit: $\mu\text{g N}/\text{m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.258	0.510	0.297	0.171	0.183	0.188	0.138	0.178	0.278	0.347	0.163	0.289	0.248
Hurdal	0.809	0.662	0.445	0.163	0.158	0.241	0.167	0.192	0.260	0.414	0.432	0.624	0.395
Kårvatn	0.249	0.252	0.145	0.122	0.072	0.105	0.100	0.119	0.108	0.100	0.143	0.157	0.139
Tustervatn	0.103	0.154	0.142	0.115	0.068	0.230	0.180	0.183	0.098	0.123	0.083	0.061	0.128

Table A1.25: Monthly and annual mean concentration of sum of nitrate and nitric acid in air at Norwegian background stations. Unit: $\mu\text{g N}/\text{m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.049	0.137	0.121	0.060	0.149	0.150	0.154	0.111	0.151	0.233	0.065	0.054	0.120
Hurdal	0.098	0.071	0.084	0.032	0.059	0.110	0.074	0.062	0.059	0.110	0.063	0.073	0.074
Kårvatn	0.016	0.027	0.025	0.035	0.057	0.066	0.050	0.032	0.025	0.023	0.020	0.024	0.034
Tustervatn	0.028	0.029	0.027	0.029	0.036	0.039	0.049	0.027	0.024	0.029	0.022	0.026	0.030
Zeppelinfjellet	0.022	0.023	0.023	0.028	0.028	0.020	0.021	0.021	0.021	0.021	0.025	0.028	0.024

Table A1.26: Monthly and annual mean concentration of nitrate in aerosol at Norwegian background stations. Unit: $\mu\text{g N/m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.039	0.117	0.097	0.042	0.095	0.108	0.112	0.086	0.114	0.213	0.055	0.043	0.094
Hurdal	0.082	0.058	0.073	0.021	0.044	0.084	0.051	0.044	0.046	0.100	0.053	0.060	0.059
Kårvatn	0.006	0.016	0.015	0.023	0.038	0.055	0.039	0.021	0.015	0.013	0.010	0.013	0.022
Tustervatn	0.016	0.018	0.016	0.019	0.026	0.028	0.032	0.017	0.014	0.019	0.012	0.016	0.019
Zeppelinfjellet	0.009	0.013	0.013	0.017	0.018	0.010	0.011	0.011	0.011	0.011	0.015	0.018	0.013

Table A1.27: Monthly and annual mean concentration of sum of ammonium and ammonia in air at Norwegian background stations. Unit: $\mu\text{g N/m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.142	0.238	0.208	0.163	0.442	0.520	0.471	0.215	0.391	0.272	0.128	0.084	0.274
Hurdal	0.223	0.153	0.148	0.203	0.226	0.425	0.289	0.202	0.236	0.216	0.120	0.137	0.216
Kårvatn	0.783	1.084	0.635	0.445	0.585	1.218	1.293	0.822	0.419	0.308	0.309	0.408	0.688
Tustervatn	0.207	0.246	0.363	0.460	0.695	0.790	0.497	0.515	0.363	0.272	0.208	0.140	0.397
Zeppelinfjellet	0.141	0.065	0.169	0.238	0.161	0.107	0.141	0.255	0.214	0.221	0.141	0.139	0.166

Table A1.28: Monthly and annual mean concentrations of ammonium in aerosols at Norwegian background stations. Unit: $\mu\text{g N/m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.064	0.148	0.080	0.066	0.164	0.283	0.244	0.111	0.181	0.175	0.039	0.055	0.134
Hurdal	0.123	0.075	0.072	0.025	0.112	0.188	0.152	0.061	0.078	0.091	0.041	0.085	0.092
Kårvatn	0.007	0.009	0.012	0.048	0.098	0.221	0.147	0.056	0.025	0.006	0.005	0.010	0.054
Tustervatn	0.049	0.040	0.017	0.031	0.106	0.100	0.089	0.053	0.029	0.031	0.012	0.032	0.049
Zeppelinfjellet	0.014	0.018	0.031	0.052	0.061	0.016	0.020	0.018	0.013	0.007	0.035	0.054	0.029

Table A1.29: Monthly and annual mean concentrations of magnesium in aerosols at Norwegian background stations. Unit: $\mu\text{g/m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.020	0.024	0.073	0.033	0.026	0.042	0.042	0.032	0.052	0.116	0.067	0.031	0.047
Hurdal	0.008	0.008	0.020	0.012	0.012	0.024	0.020	0.014	0.014	0.024	0.015	0.010	0.015
Kårvatn	0.009	0.018	0.030	0.030	0.021	0.034	0.037	0.012	0.015	0.009	0.014	0.024	0.021
Tustervatn	0.009	0.016	0.032	0.036	0.026	0.021	0.023	0.012	0.015	0.028	0.025	0.033	0.023
Zeppelinfjellet	0.026	0.043	0.056	0.052	0.026	0.024	0.023	0.009	0.024	0.056	0.038	0.042	0.035

Table A1.30: Monthly and annual mean concentrations of calcium in aerosols at Norwegian background stations. Unit: $\mu\text{g}/\text{m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.013	0.030	0.039	0.048	0.031	0.075	0.063	0.035	0.041	0.067	0.040	0.018	0.042
Hurdal	0.010	0.013	0.031	0.033	0.024	0.059	0.038	0.018	0.028	0.022	0.022	0.012	0.026
Kårvatn	0.006	0.018	0.019	0.036	0.041	0.044	0.072	0.017	0.011	0.010	0.016	0.020	0.026
Tustervatn	0.010	0.015	0.016	0.030	0.026	0.026	0.050	0.012	0.014	0.023	0.020	0.018	0.022
Zeppelinfjellet	0.014	0.022	0.030	0.032	0.030	0.022	0.019	0.012	0.014	0.041	0.044	0.024	0.026

Table A1.31: Monthly and annual mean concentrations of potassium in aerosols at Norwegian background stations. Unit: $\mu\text{g}/\text{m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.028	0.044	0.050	0.018	0.033	0.042	0.039	0.032	0.038	0.082	0.046	0.021	0.040
Hurdal	0.050	0.039	0.026	0.012	0.028	0.026	0.030	0.028	0.024	0.033	0.032	0.029	0.029
Kårvatn	0.014	0.017	0.019	0.022	0.023	0.044	0.030	0.021	0.024	0.011	0.011	0.014	0.021
Tustervatn	0.012	0.027	0.027	0.013	0.018	0.011	0.033	0.018	0.013	0.021	0.013	0.013	0.018
Zeppelinfjellet	0.014	0.034	0.036	0.019	0.035	0.022	0.043	0.028	0.060	0.021	0.016	0.015	0.029

Table A1.32: Monthly and annual mean concentrations of chloride in aerosols at Norwegian background stations. Unit: $\mu\text{g}/\text{m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.221	0.250	0.767	0.358	0.138	0.204	0.240	0.229	0.618	1.302	0.869	0.365	0.464
Hurdal	0.037	0.050	0.247	0.132	0.050	0.084	0.086	0.051	0.084	0.234	0.126	0.075	0.107
Kårvatn	0.070	0.170	0.352	0.352	0.139	0.238	0.313	0.095	0.128	0.112	0.152	0.247	0.196
Tustervatn	0.052	0.203	0.441	0.465	0.220	0.240	0.180	0.112	0.206	0.302	0.327	0.400	0.262
Zeppelinfjellet	0.362	0.512	0.580	0.599	0.248	0.287	0.248	0.053	0.320	0.662	0.385	0.457	0.395

Table A1.33: Monthly and annual mean concentrations of sodium in aerosols at Norwegian background stations. Unit: $\mu\text{g}/\text{m}^3$.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Birkenes II	0.152	0.197	0.529	0.259	0.204	0.322	0.346	0.273	0.446	0.885	0.594	0.262	0.373
Hurdal	0.034	0.049	0.197	0.111	0.077	0.174	0.135	0.092	0.093	0.205	0.127	0.078	0.117
Kårvatn	0.049	0.124	0.239	0.234	0.138	0.255	0.261	0.074	0.091	0.072	0.098	0.174	0.150
Tustervatn	0.047	0.132	0.265	0.295	0.185	0.181	0.142	0.079	0.121	0.217	0.207	0.264	0.178
Zeppelinfjellet	0.207	0.343	0.369	0.369	0.175	0.185	0.168	0.034	0.183	0.407	0.261	0.305	0.252

Table A1.34a: Annual mean concentrations of sulfur and nitrogen components in air at Norwegian background stations from 1973-2020. Units $\mu\text{g S}/\text{m}^3$ and $\mu\text{g N}/\text{m}^3$.

Site	År	Annual mean concentrations of main components in air ($\mu\text{g}/\text{m}^3$)					
		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

Table A.1.34a, cont.

Site	År	Annual mean concentrations of main components in air ($\mu\text{g}/\text{m}^3$)					
		SO ₂ -S	SO ₄ -S	NO ₂ -N	(HNO ₃ +NO ₃)-N	(NH ₄ +NH ₃)-N	NH ₄ -N
Birkenes II (cont.)	2016	0.05	0.20	0.30	0.25	0.40	0.23
	2017	0.06	0.22	0.27	0.15	0.27	0.13
	2018	0.10	0.26	0.32	0.24	0.47	0.25
	2019	0.07	0.20	0.32	0.15	0.32	0.16
	2020	0.06	0.19	0.30	0.17	0.40	0.15
	2021	0.07	0.19	0.25	0.09	0.27	0.13
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
	2017	0.04	0.14	0.64	0.09	0.20	0.09
2018	0.04	0.18	0.60	0.13	0.29	0.13	
2019	0,04	0.14	0.50	0.09	0.24	0.10	
2020	0.03	0.10	0.35	0.08	0.18	0.08	
2021	0.02	0.12	0.40	0.06	0.22	0.09	

Table A.1.34a, cont.

Site	År	Annual mean concentrations of main components in air ($\mu\text{g}/\text{m}^3$)					
		SO ₂ -S	SO ₄ -S	NO ₂ -N	(HNO ₃ +NO ₃)-N	(NH ₄ +NH ₃)-N	NH ₄ -N
Kårvatn	1979	0.48	0.48				
	1980	0.54	0.55				
	1981	0.51	0.47				
	1982	0.29	0.40				
	1983	0.19	0.38				
	1984	0.43	0.54				
	1985	0.44	0.45				
	1986	0.39	0.43				
	1987	0.32	0.38				
	1988	0.34	0.40	0.56	0.07	0.44	
	1989	0.17	0.30	0.34	0.08	0.42	
	1990	0.12	0.32	0.40	0.10	0.40	
	1991	0.14	0.31	0.26	0.06	0.36	
	1992	0.12	0.30	0.19	0.06	0.37	
	1993	0.15	0.30	0.16	0.07	0.38	0.17
	1994	0.12	0.30	0.22	0.10	0.48	0.18
	1995	0.16	0.22	0.26	0.10	0.36	0.13
	1996	0.08	0.27	0.24	0.08	0.46	0.18
	1997	0.05	0.22	0.25	0.07	0.50	0.14
	1998	0.05	0.15	0.26	0.05	0.33	0.08
	1999	0.03	0.20	0.23	0.05	0.45	0.12
	2000	0.03	0.17	0.32	0.05	0.56	0.09
	2001	0.06	0.16	0.19	0.08	0.47	0.11
	2002	0.07	0.21	0.26	0.11	0.81	0.13
	2003	0.07	0.22	0.30	0.09	0.95	0.13
	2004	0.07	0.20	0.21	0.08	0.48	0.10
	2005	0.07	0.18	0.22	0.14	0.65	0.15
	2006	0.06	0.24	0.24	0.14	0.88	0.13
	2007	0.03	0.13	0.17	0.06	0.76	0.06
	2008	0.03	0.14	0.20	0.07	0.70	0.06
	2009	0.03	0.14	0.17	0.06		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
	2017	0.06	0.09	0.17	0.04	0.36	0.03
	2018	0.03	0.12	0.18	0.05	0.60	0.06
	2019	0.03	0.10	0.16	0.04	0.46	0.06
	2020	0.03	0.07	0.15	0.04	0.46	0.04
2021	0.03	0.10	0.14	0.02	0.69	0.05	

Table A.1.34a, cont.

Site	År	Annual mean concentrations of main components in air ($\mu\text{g}/\text{m}^3$)					
		SO ₂ -S	SO ₄ -S	NO ₂ -N	(HNO ₃ +NO ₃)-N	(NH ₄ +NH ₃)-N	NH ₄ -N
Tustervatn	1979	0.88	0.68				
	1980	0.63	0.70				
	1981	0.67	0.52				
	1982	0.47	0.52				
	1983	0.26	0.48				
	1984	0.71	0.73				
	1985	0.60	0.59				
	1986	0.48	0.43				
	1987	0.72	0.59				
	1988	0.67	0.54				
	1989	0.16	0.23	0.29	0.04	0.52	
	1990	0.29	0.36	0.37	0.08	0.53	
	1991	0.25	0.38	0.32	0.08	0.68	
	1992	0.15	0.28	0.26	0.07	0.54	
	1993	0.18	0.31	0.19	0.07	0.66	0.16
	1994	0.16	0.29	0.19	0.09	0.71	0.14
	1995	0.16	0.28	0.16	0.09	0.62	0.15
	1996	0.12	0.29	0.11	0.10	0.72	0.17
	1997	0.09	0.27	0.18	0.07	1.15	0.15
	1998	0.10	0.21	0.18	0.06	1.03	0.11
	1999	0.08	0.23	0.14	0.05	0.53	0.12
	2000	0.04	0.18	0.17	0.06	0.88	0.10
	2001	0.14	0.20	0.15	0.08	0.94	0.12
	2002	0.09	0.21	0.18	0.10	0.83	0.11
	2003	0.09	0.22	0.18	0.12	1.15	0.15
	2004	0.09	0.21	0.17	0.09	0.93	0.12
	2005	0.08	0.21	0.14	0.10	1.00	0.12
	2006	0.09	0.23	0.15	0.13	1.10	0.11
	2007	0.06	0.14	0.11	0.09	0.94	0.08
	2008	0.03	0.15	0.14	0.09	0.98	0.07
	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
	2017	0.04	0.12	0.11	0.04	0.27	0.03
	2018	0.04	0.13	0.11	0.04	0.35	0.06
	2019	0,05	0,14	0,14	0,06	0,37	0,08
	2020	0.03	0.08	0.14	0.03	0.33	0.03
2021	0,03	0,11	0,13	0,02	0,40	0,05	

Table A.1.34a, cont.

Site	År	Annual mean concentrations of main components in air ($\mu\text{g}/\text{m}^3$)					
		SO ₂ -S	SO ₄ -S	NO ₂ -N	(HNO ₃ +NO ₃)-N	(NH ₄ +NH ₃)-N	NH ₄ -N
Ny-Ålesund	1980	0.32	0.31				
	1981	0.36	0.23				
	1982	0.31	0.28				
	1983	0.42	0.41				
	1984	0.24	0.34				
	1985	0.36	0.39				
	1986	0.27	0.34				
	1987	0.53	0.40				
	1988	0.32	0.32				
	1989	0.21	0.24				
	1990	0.22	0.27		0.03		
Zeppelin	1990	0.21	0.22		0.04	0.09	
	1991	0.24	0.19	0.02	0.05	0.09	
	1992	0.19	0.19	0.02	0.04	0.08	
	1993	0.17	0.20	0.03	0.06	0.09	0.05
	1994	0.16	0.15	0.05	0.06	0.09	0.04
	1995	0.15	0.17		0.08	0.10	0.05
	1996	0.10	0.15		0.08	0.11	0.05
	1997	0.13	0.21		0.07	0.13	0.06
	1998	0.21	0.17		0.04	0.13	0.05
	1999	0.13	0.19		0.03	0.19	0.08
	2000	0.12	0.14		0.03	0.11	0.03
	2001	0.14	0.18		0.06	0.17	0.04
	2002	0.16	0.14		0.06	0.24	0.02
	2003	0.23	0.17		0.04	0.27	0.04
	2004	0.12	0.16		0.08	0.24	0.04
	2005	0.13	0.18		0.15	0.42	0.10
	2006	0.10	0.13		0.12	0.43	0.03
	2007	0.09	0.11		0.05	0.26	0.04
	2008	0.07	0.14		0.10	0.33	0.06
	2009	0.09	0.15		0.05		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	
2017	0.12	0.14		0.04	0.16	0.03	
2018	0.04	0.10		0.03	0.11	0.02	
2019	0.08	0.11	-	0.03	0.12	0.03	
2020	0.07	0.11		0.03	0.16	0.02	
2021	0.05	0.09		0.01	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 $\mu\text{g S}/\text{m}^3$ and $\mu\text{g N}/\text{m}^3$.

Site	År	Annual mean concentrations of main components in air at closed sites, ($\mu\text{g}/\text{m}^3$)				
		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	

Table A.1.34b, cont.

Site	År	Annual mean concentrations of main components in air at closed sites, ($\mu\text{g}/\text{m}^3$)				
		SO ₂ -S	SO ₄ -S	NO ₂ -N	(HNO ₃ +NO ₃)-N	(NH ₄ +NH ₃)-N
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	
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		

Table A.1.34b, cont.

Site	År	Annual mean concentrations of main components in air at closed sites, ($\mu\text{g}/\text{m}^3$)				
		SO ₂ -S	SO ₄ -S	NO ₂ -N	(HNO ₃ +NO ₃)-N	(NH ₄ +NH ₃)-N
Jergul (cont.)	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.

Table A1.35: Annual and monthly mean concentrations of OC, EC and TC in PM₁₀ and PM_{2.5} at the sites Birkenes, Hurdal, Kårvatn and Zeppelin for 2021.

Month	PM ₁₀			PM _{2.5}		
	OC	EC	TC	OC	EC	TC
Birkenes						
January	0.47	0.06	0.54	0.49	0.06	0.55
February	0.50	0.09	0.59	0.46	0.08	0.53
March	0.42	0.05	0.47	0.42	0.05	0.46
April	0.35 ¹⁾	0.03 ¹⁾	0.39 ¹⁾	0.42	0.04	0.49
May	1.02	0.05	1.07	0.70	0.05	0.74
June	1.50	0.06	1.56	1.11	0.06	1.17
July	1.32	0.05	1.37	0.99	0.04	1.03
August	1.02	0.04	1.06	0.71	0.04	0.75
September	0.89	0.06	0.95	0.67	0.05	0.72
October	0.60	0.06	0.66	0.39	0.05	0.43
November	0.40	0.04	0.45	0.28	0.04	0.33
December	0.41	0.06	0.47	0.39	0.07	0.45
Annual mean	0.77	0.06	0.83	0.59	0.05	0.64
Hurdal						
January	0.77	0.14	0.91	0.70	0.13	0.83
February	0.66 ¹⁾	0.12 ¹⁾	0.78 ¹⁾	0.60 ¹⁾	0.11 ¹⁾	0.70 ¹⁾
March	0.48	0.07	0.55	0.39	0.06	0.45
April	0.49	0.05	0.54	0.36	0.05	0.41
May	1.20	0.07	1.27	0.81 ¹⁾	0.07 ¹⁾	0.89 ¹⁾
June	2.14	0.08	2.21	1.42	0.08	1.50
July	1.98	0.06	2.05	1.19	0.06	1.25
August	1.73	0.08	1.81	0.82	0.06	0.88
September	1.46	0.10	1.55	0.76	0.08	0.84
October	1.00	0.08	1.09	0.49	0.08	0.58
November	0.71	0.10	0.82	0.42	0.09	0.51
December	0.74	0.15	0.89	0.68	0.14	0.82
Annual mean	1.14	0.09	1.23	0.73	0.08	0.81
Kårvatn						
January	0.42	0.07	0.49	0.33	0.07	0.39
February	0.52 ¹⁾	0.10 ¹⁾	0.62 ¹⁾	0.51 ¹⁾	0.10 ¹⁾	0.61 ¹⁾
March	0.33	0.03	0.36	0.26	0.03	0.28
April	0.28	0.04	0.32	0.26	0.04	0.30
May	0.81	0.06	0.87	1.02	0.05	1.07
June	1.34	0.02	1.37	0.98	0.07	1.03
July	1.63	0.04	1.67	1.27	0.05	1.32
August	1.22	0.04	1.25	0.67	0.03	0.71
September	1.62	0.05	1.67	0.51	0.04	0.55
October	0.58	0.02	0.61	0.26	0.02	0.28
November	0.26	0.03	0.29	0.19	0.03	0.22
December	0.24	0.04	0.28	0.21	0.04	0.25
Annual mean	0.78	0.04	0.82	0.53	0.04	0.57
Zeppelin						
January	0.054	0.006	0.059			
February	0.072	0.010	0.083			
March	0.127	0.023 ¹⁾	0.151			
April	0.085	0.012	0.097			
May	0.097	0.009 ¹⁾	0.105			
June	0.058	0.002	0.057			
July	0.077	0.003	0.080			
August	0.111	0.007	0.118			
September	0.103	0.004	0.106			
October	0.044	0.002 ¹⁾	0.046			
November	0.041	0.003 ¹⁾	0.044			
December	0.128	0.013 ¹⁾	0.142			
Annual mean	0.085	0.008	0.093			

1) Data capture <75%

Table A1.36: Annual mean concentrations of OC, EC and TC in PM10 and PM2.5 at Birkenes Hurdal, Kårvatn and Zeppelin for the period 2001 - 2021.

Year	PM ₁₀			PM _{2.5}		
	OC	EC	TC	OC	EC	TC
Birkenes						
2001	1.10	0.13	1.30	1.00	0.16	1.20
2002	1.00	0.14	1.20	0.92	0.12	1.00
2003	1.00	0.11	1.20	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	0.80
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
2017	0.72	0.05	0.78	0.52	0.05	0.58
2018	0.96	0.08	1.03	0.73	0.07	0.80
2019	0.93	0.08	1.01	0.63	0.08	0.71
2020	0.82	0.08	0.90	0.57	0.06	0.63
2021	0.76	0.06	0.83	0.59	0.05	0.64
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
2017	1.15	0.10	1.25	0.74	0.09	0.84
2018	1.27	0.12	1.39	0.88	0.11	0.99
2019	1.23	0.11	1.34	0.71	0.10	0.81
2020	0.95	0.08	1.03	0.58	0.07	0.65
2021	1.14	0.09	1.23	0.73	0.08	0.81
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
2017	0.66	0.03	0.69	0.50	0.04	0.53
2018	0.85	0.05	0.89	0.65	0.05	0.69
2019	0.69	0.05	0.74	0.53	0.05	0.58
2020	0.68	0.03	0.71	-	-	-
2021	0.78	0.04	0.82	0.53	0.04	0.57
Zeppelin						
2019	0.102	0.013	0.115	-	-	-
2020	0.197	0.016	0.214	-	-	-
2021	0.085	0.008	0.093	-	-	-

Table A1.37: Annual and monthly mean concentrations of PM_{10} , $PM_{10-2.5}$, and $PM_{2.5}$ at Birkenes, Hurdal and Kårvatn for 2021. Unit $\mu\text{g}/\text{m}^3$.

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	1.0	1.3	2.3	2.5	0.2	2.8	0.7 ¹⁾	0.0 ¹⁾	0.4 ¹⁾
FEB	1.8	1.1 ¹⁾	3.0	2.1	0.7	2.8	1.1	0.5 ¹⁾	1.5
MAR	1.9	1.7	3.6	3.1	1.8	3.4	1.1	1.0 ¹⁾	1.9
APR	1.7	1.5 ¹⁾	2.8 ¹⁾	1.4	1.4	2.8	1.7	0.9	2.5
MAY	2.8	1.8	4.8	2.7	1.6	4.3	3.6	1.6	6.0
JUN	4.4	2.0	6.4	4.8	2.6	7.1	6.7	1.5	8.2
JUL	4.2	1.7	5.9	5.6	2.5	6.4 ¹⁾	5.1	1.5	6.5
AUG	2.2	1.7	3.9	2.4	2.2	4.6	2.1	1.2	3.3
SEP	2.9	1.8	4.7	2.6	2.2	4.8	1.4	2.5	3.7
OCT	2.2	2.5	4.7	2.3	2.8	4.3	0.5	0.9	1.5
NOV	0.7	1.8	2.5	1.3	1.2	2.5	0.4	0.3	0.7
DEC	1.0	1.2 ¹⁾	2.1 ¹⁾	2.3	0.6	2.9	0.6	1.0	1.6
2021	2.3	1.7	4.1	2.7	1.7	4.0	2.1	1.1	3.3

1) Data capture <75%

Table A1.38: 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 – 2021.

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
2017		2.0	1.7	3.6
2018		3.0	2.5	5.4
2019		2.7	2.1	4.6
2020		2.5	2.7	5.2
2021		2.3	1.7	4.1
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
2017		2.4	1.6	3.8
2018		3.2	1.8	4.9
2019		2.7	1.9	4.6
2020		2.2	1.9	4.1
2021		2.7	1.7	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
2017		1.5	0.7	2.1
2018		2.3	1.1	3.2
2019		1.9	1.2	2.9
2020		-	-	2.9
2021		2.2	1.1	3.3

Appendix B Annex 2

Detailed information of the monitoring programme

Table A2.1: Site locations and station keepers for the background sites in 2021.

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	60° 22'	11° 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
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	69° 40'	30° 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 A2.2: Measurement programme at Norwegian background stations in 2021, including the environmental contaminants reported in Nizzetto et al. (2022).

	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 Vatnedalen	X	X	X	X	X	X ^b	X ^d	X	X	X ^b	X ^e
Treungen Haukenes		X							X		
Prestebakke Løken Hurdal	X	X	X	X	X			X	X	X ^a	
Brekkebygda									X		
Vikedal Sandve		X							X		
Nausta									X		
Kårvatn		X	X	X	X			X		X ^a	
Høylandet									X		
Tustervatn		X	X	X				X			
Andøya						X ^b	X ^g				
Karpbukt									X		
Zeppelin, Ny-Ålesund	X	X	X			X ^c	X ^g		X		
Total number	3	7+1	5	4	3	3	3	4	9	4	1

Metr. = meteorology

main.precip = amount (mm), pH, conductivity, SO₄, NO₃, Cl, NH₄, Ca, K, Mg, Na

main air = SO₂, SO₄, HNO₃ + NO₃; NH₄+ NH₃, 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, MCCC

Appendix C Annex 3

Sampling and chemical analysis (incl. background information on PM and EC/OC and levoglucosan)

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)

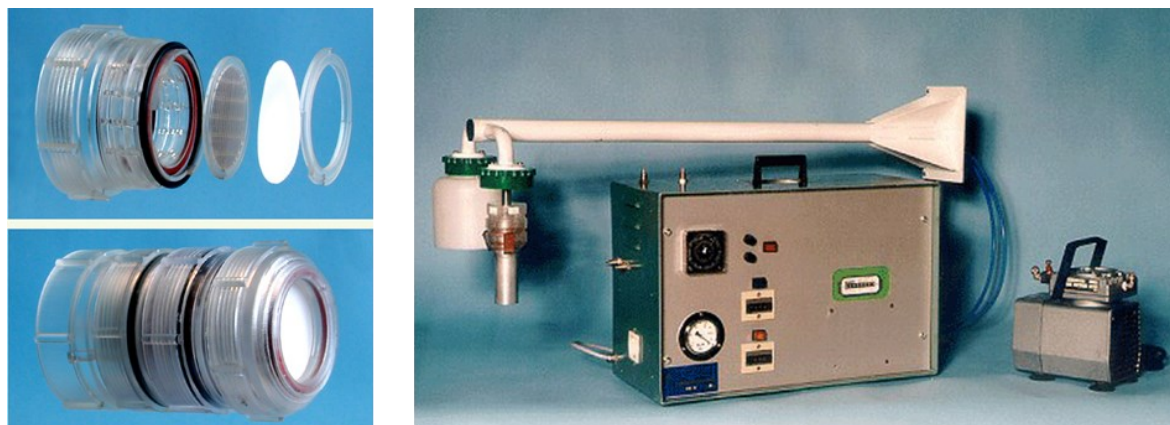


Main components in air

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 SO₄²⁻, NH₄⁺, NO₃⁻, Ca²⁺, K⁺, Cl⁻, Na⁺. This is followed by an alkaline (KOH) impregnated filter (Whatman 40), which will collect HNO₃, SO₂, HNO₂, 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 NH₃. 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 PM₁₀ 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 HNO₃ 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 (unit)	limit
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

NO₂ 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 NO₂ 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/m³.

Ozone

Ozone (O₃) 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, EC/OC, and levoglucosan)

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. Aerosols 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 troposphere 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 are well recognized (e.g., Dockery et al., 1993; Schwarz et al., 1996), causing various types of cardiopulmonary diseases, e.g., chronic obstructive pulmonary disease, ischemic heart disease, lung cancer and pneumonia. Although the statistical evidence between ambient air particulate mass (e.g., PM_{10} and $\text{PM}_{2.5}$) 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 ($d_p < 100 \text{ nm}$), 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 were 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 dominate 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.

Levoglucosan is a thermal degradation product of cellulose with a low vapor pressure and a high emission factor from combustion of biomass (Locker, 1988; Simoneit et al., 1999; Oja and Suuberg, 1999), and thus well suited to trace biomass-burning aerosol in the ambient atmosphere. Aqueous-phase reaction with OH radical in deliquescent particles appears to be the most efficient pathway causing depletion of levoglucosan in the atmosphere. The $\frac{1}{2}$ values (the time until half of the levoglucosan has been degraded) for levoglucosan in the atmosphere is debated and likely to vary with photochemical activity and OH concentrations, being a function of temperature and season (Hennigan et al., 2010; Yttri et al., 2014).

Levoglucosan is considered the most robust and reliable tracer of biomass burning, and is commonly used to trace biomass burning aerosol, not only qualitatively, but also quantitatively by combining ambient concentrations with emission ratios, or as input along with other species to e.g. positive matrix factorization (PMF). For studies using levoglucosan as biomass burning tracer in Norway, see Yttri et al., 2005, 2007a, b, 2009, 2011a, b, 2014, 2019, in prep. Although levoglucosan appears to be best suited to trace biomass burning emissions in winter and on a local to regional scale, conservative estimates of the biomass burning aerosol concentration can still be provided for the remote environment. Emission ratios used to convert observed ambient concentrations of levoglucosan to OC and EC from biomass burning, are associated with great uncertainty. In the present report, we use an OC/levoglucosan ratio of 12.7 for PM_{10} and 11.1 for $\text{PM}_{2.5}$ and an EC/levoglucosan ratio of 2. These ratios are based on positive matrix factorization (PMF) analysis results for PM and PM species observed at Birkenes (Yttri et al., 2021), which are consistent with results presented in the scientific literature e.g., by Zotter et al. (2017). A factor of 2 was used to convert biomass burning OC to OM, and a factor of 1.1 for biomass burning EC.

Sampling and chemical analysis

PM₁₀ and PM_{2.5} are obtained using Kleinfiltergerät samplers (one sampler pr. size fraction), collecting filter samples on a weekly basis. The ambient aerosol particles are collected on pre-fired (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 is determined gravimetrically. The uncertainty of the PM mass concentrations obtained for PM₁₀ and PM_{2.5} is estimated to be around 0.1 – 0.15 µg/m³ for a sampling volume of 386 m³.

Number concentration measurements at Birkenes dates to 2010. The number concentration of ultrafine particles ($D_p < 0.1 \mu\text{m}$), accumulation mode particles ($0.1 \mu\text{m} < D_p < 1.0 \mu\text{m}$) and coarse mode particles ($D_p = 1.0 - 10 \mu\text{m}$) are obtained by combined measurements of a Differential Mobility Particle Spectrometer (DMPS) and an Optical Particle Spectrometer (OPS). The DMPS measures the particle number size distribution ranging from 0.01 – 0.8 µm particle diameter, whereas the OPS covers the range from 0.25 µm to 30 µm. The DMPS and the OPS provide method specific measures of the particle diameter, i.e., the electrical mobility particle diameter and the optical particle diameter, respectively. Thus, when merging these two measures into one particle number size distribution (PNSD) time series, the PNSD must agree within 25% in particle diameter in their overlapping size range. For comparability of long-term measurements, the 0.01 – 0.02 µm size range is not reported.

In May 2017, a continuous, direct aerosol mass instrument was installed at Birkenes, a so-called tapered element oscillating microbalance (TEOM) instrument with a size cut off to measure PM₁₀ mass. The TEOM Monitor draws (then heats) ambient air through a filter at constant flow rate, continuously weighing the filter and calculating near real-time mass concentrations of particulate matter. The mass is corrected with a factor 1.1 and -2.8 µg m⁻³ based on intercomparison with gravimetric measurements, which is the reference method.

Thermal-Optical Analysis of EC, OC and TC in PM₁₀ and PM_{2.5} are performed on the same filter samples as the mass concentration of PM₁₀ and PM_{2.5} are obtained from at the three rural background sites. For the remote site Zeppelin, analysis is performed on pre-fired (850 °C for 3 hrs) quartz fibre filters (PALLFLEX Tissuequartz 2500QAT-UP; 150 mm in diameter) obtained from a Digitec high-volume sampler with a PM₁₀ inlet, operating at a flowrate of 40 m³ h⁻¹, collecting aerosol filter samples on a weekly basis. The T-O analysis are performed according to the EUSAAR-2 protocol (Cavalli *et al.*, 2010). The analytical detection limit of the TOA instruments is 0.2 µg C/cm². This corresponds to a methodological detection limit of 0.007 µg C m⁻³ for a sampling volume of 386 m³ and an exposed filter area of 13.4 cm² for the rural background sites and, and a methodological detection limit of 0.005 µg C m⁻³ for a sampling volume of 6720 m³ and an exposed filter area of 153.9 cm² for the remote site.

Concentrations of the biomass burning tracers levoglucosan, mannosan and galactosan are determined from the same PM₁₀ filter samples as the mass concentration and EC/OC/TC at the rural background sites and from the same PM₁₀ filter samples as EC/OC/TC at the remote site. Analysis is performed using ultra-high performance liquid chromatography (UHPLC) in combination with high-resolution time-of-flight mass spectrometry (HR-TOF-MS) operated in the negative electrospray ionization (ESI-) mode, and according to a modified version of the analytical method described by Dye and Yttri (2005) (Yttri *et al.*, 2021). The methodological detection limit is approximately 1-20 pg m⁻³ for the rural background sites and 1-4 pg m⁻³ for the remote site.

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