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Deposition of major inorganic compounds in Norway 2007-2011

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Utført av NILU – Norsk institutt for luftforskning

NILU

Preface

Within the Convention on Long Range Transboundary Air Pollution (LRTAP), the members have decided that emission reductions should be based on the principle of critical loads. Every five year The Norwegian Institute for Water Research (NIVA) calculate exceedances of critical loads for water and soil in Norway based on atmospheric deposition estimates done by NILU – The Norwegian Institute for Air Research. This is done on behalf of The Climate and Pollution Agency (Klif). Estimates of critical loads and depositions cover periods from 1978-1982 up to this report which contains atmospheric deposition for 2007-2011. The maps of exceedances of critical loads are reported separately by NIVA.

The work in this report has been lead by Wenche Aas at NILU. Anne Hjellbrekke has been responsible for the mapping, while Lars Hole from met.no has been responsible for making metrological data available. NILU has been subcontracted by NIVA, who has been contracted by Klif. Main contact persons at NIVA and Klif are Thorjørn Larssen and Tor Johannessen, respectively.

Kjeller, November 2012

Wenche Aas
Senior scientist

Innhold

Summary

The total depositions of sulphur and nitrogen compounds in Norway have been estimated with a grid resolution of 50·50 km², based on available measurements of air and precipitation chemistry. The earlier five year deposition estimates covered the periods 1978-1982 (Hole and Tørseth, 2002), 1983-87 (Pedersen et al., 1990), 1988-1992 (Tørseth and Pedersen, 1994), 1992-1996 (Tørseth and Semb, 1997), 1997-2001 (Hole and Tørseth, 2002), and 2002-2006 (Aas et al., 2006). This report covers the period from 2007 to 2011. In addition, the depositions of sea-salts and non sea-salt potassium and calcium have been estimated. Results are presented as tabulated values to the individual grid cells, and visualised on geographical maps.

The average total deposition (2007-2011) of the non sea-salt compounds was highest in the south and western part of Norway with maximum sulphur deposition of 0.5 g S/m² in two 50·50 km² grids in Vest-Agder county. The lowest depositions were observed along the Swedish border from Finnmark in the north down to Oppland in central Norway with values approximately one order of magnitude lower than in the maximum areas. Similarly, deposition values for individual meteorological sites varied from 0.67 g S/m² to 0.03 g S/m². The largest grid cell depositions of oxidised and reduced nitrogen were 0.70 and 0.64 g N/m², respectively, whereas the lowest depositions were 0.06 g N/m² for both compounds.

Estimated total annual depositions for the period 2007-2011 were approximately 54 000 tonnes sulphur and 140 000 tonnes nitrogen. Compared with similar estimates for the period 2002-2006, there has been a significant reduction (27%) in the sulphur deposition as well as for the total nitrogen deposition (9%); the largest reduction was for the oxidised form.

Sammendrag

De totale avsetninger av svovel og nitrogenforbindelser til Norge har vært estimert basert på målinger av luft- og nedbørskjemi. Det første estimatet omfattet perioden 1978-1982 (Hole og Tørseth, 2002). Videre er det avsetningsestimater for periodene 1983-87 (Pedersen et al., 1990), 1988-1992 (Tørseth og Pedersen, 1994), 1992-1996 (Tørseth og Semb, 1997), 1997-2001 (Hole og Tørseth, 200)2 og 2002-2006 (Aas et al., 2006)). I denne rapporten presenteres beregninger for periodene 2007-2011 og disse er sammenlignet med de tidligere perioder. I tillegg er det beregnet avsetninger av sjøsalter og ikke-marint kalium og kalsium. Resultatene er vist som tabulerte verdier til et landsdekkende rutenett på 50·50 km^2, og visualisert på geografiske kart.

Total avsetning av ikke-marine komponenter var størst i de sørvestre deler av landet med maksimal svoveldeposisjon på 0,50 g S/m^2 i 2007-2011 i to 50·50 km^2 ruter i Vest-Agder. Laveste avsetninger (fra 0,05 g S/m^2) ble registrert langs svenskegrensen fra Finnmark og til Oppland fylke samt fjelltraktene i Sør Norge. Tilsvarende har avsetningsnivået på de individuelle meteorologiske stasjonene variert fra 0,67 g S/m^2 til 0,03 g S/m^2. Ruteverdiene for avsetning av oksidert nitrogen for 2007-2011 er fra 0,06 g N/m^2 til 0,69 g N/m^2. For redusert nitrogen er tallene for denne perioden 0,06 g N/m^2 til 0,64 g N/m^2.

Totale avsetninger for Norge i 2007-2011 er estimert til 54 000 tonn svovel og 140 000 tonn nitrogen. Det har vært en signifikant nedgang i den totale svovelavsetningen (27%) og en nedgang i nitrogen (både redusert og oksidert form) (totalt 9%) siden forrige periode, 2002-2006, størst reduksjon var for oksidert form.

Deposition of major inorganic compounds in Norway 2007-2011

1. Introduction

In order to evaluate the exceedance of critical loads to the ecosystems, quantified atmospheric input to the system is essential. The atmospheric input of pollutants can be determined from atmospheric dispersion models, by using emission data, meteorological data and parameters describing transformation and removal processes. Under the Co-operative programme for the monitoring and evaluation of long-range transmissions of air pollutants in Europe (EMEP), concentration and deposition fields of inorganic compounds are calculated at the Meteorological Synthesising Centre - West using a multi-layer Eulerian model with a grid size of 50·50 km^2 (Simpson et al., 2012).

Atmospheric inputs may also be inferred from measurements of air and precipitation chemistry. Particularly in a country like Norway, where topographical features cause large variations in depositions, use of measured concentrations and precipitation amounts makes it possible to determine the inputs by precipitation more directly and with more detailed spatial resolution than is available from models. Dry deposition may also be inferred from measured airborne concentrations. In this case it is essential to take into account seasonal variations and differences in ground cover. The heterogeneity of the surface characteristics are also reflected in the critical loads for specific receptor areas and ecosystems, which makes it desirable to determine atmospheric inputs with the same spatial resolution.

In this work, estimates of the total depositions of all major inorganic compounds of interest in the evaluation of critical loads for acidity and for nutrient nitrogen, are presented, i.e. sulphur, nitrogen, non sea-salt base cations (K^+ and Ca^{2+}) and sea-salts (Na^+, Mg^{2+}, Cl^-, K^+, Ca^{2+}, SO_4^{2-}). The estimates are based on data available through the national air- and precipitation monitoring program (Aas et al., 2008, 2009, 2010, 2011 and 2012), combined with information about precipitation amounts from the national meteorological network (met.no, 2007-2011). Estimates for the previous periods 1978-1982 (Hole and Tørseth, 2002), 1983-1987 (Pedersen et al., 1990), 1988-1992 (Tørseth and Pedersen, 1994), 1992-1996 (Tørseth and Semb, 1997), 1997-2001 (Hole and Tørseth, 2002), 2002-2006 (Aas et al., 2006) are compared for trend analysis.

2. Deposition processes

Sulphur and nitrogen compounds can be deposited either by precipitation (wet deposition) or by dry deposition. Wet deposition is far more important than dry deposition in most part of Norway. In precipitation, the major species are sulphate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+), chloride (Cl^-), sodium (Na^+), magnesium (Mg^{2+}), potassium (K^+) and calcium (Ca^{2+}). The major sulphur and nitrogen compounds in air are sulphur dioxide (SO_2) and particulate sulphate (SO_4^{2-}), nitrogen monoxide (NO), nitrogen dioxide (NO_2), nitric acid (HNO_3), particulate nitrate (NO_3^-), ammonia (NH_3) and particulate ammonium (NH_4^+).

Wet deposition is generally obtained from measured precipitation amounts and the concentration of chemical species in the precipitation samples. This procedure does not include deposition by fog or dew, since the usual precipitation sampler usually collects no precipitation sample from such events.

When using measured concentrations in ambient air to infer dry deposition of sulphur and nitrogen, seasonal deposition velocities (Voldner and Sirois, 1986), that summarise the transfer resistances calculated from more detailed dry deposition models (e.g. Hicks et al., 1987), may be used. Such extrapolation from detailed modelling also requires knowledge of climatic conditions and ground cover characteristics. In view of the large uncertainties involved, particularly in connection with variation in ground cover and climatic conditions within Norway, a simplistic approach was chosen. The various dry deposition processes and deposition of fog droplets are described in the literature e.g. Lövblad et al. (1993). Only parts of this discussion will be repeated here. Instead a short description will be given for each component on how the dry deposition has been estimated from the measured concentration of each airborne component. The procedures are chosen to be as simple and straightforward as possible, taking into account differences in ground cover, climatic conditions and exposure to pollutants, which show a considerable geographical variation.

Under dry conditions, the deposition of sulphur dioxide (SO_2) is mainly regulated by stomatal resistance. However, absorption of sulphur dioxide on wetted foliage seems to be an important explanation for “dry deposition” under wintertime conditions. Snow crystals, on the other hand, do not absorb sulphur dioxide. Therefore, the dry deposition of sulphur dioxide to snow surfaces depends on oxidation of absorbed sulphur dioxide in the liquid-films at the surface nucleated by impurities in the snow (Valdez et al., 1987). The result is a very small deposition of sulphur dioxide to snow surfaces as well as to snow-covered vegetation at temperatures below 0°C. Even nitric acid does not deposit onto snow surfaces below -2ºC (Johansson, 1987).

From catchment mass balances and canopy experiments in southern Sweden, Hultberg and Grennfelt (1992) found that coniferous forest stands in southern Sweden collected 2-3 times more sulphur than adjoining clear-cut areas. It was also shown that the deposition by throughfall was much larger at the forest edges than inside a larger plot of homogenous forest. The interpretation of these results is somewhat ambiguous, since the excess sulphate in throughfall may be caused both by deposition of sulphur dioxide and by deposition of sulphate aerosol particles. In the former case, the results point to deposition of sulphur dioxide in situations with wet foliage, when aerodynamic resistance is controlling the deposition. The observations were made in areas with typically wet and windy climate. In other areas it has been found that spruce stands will collect, on average, 30-70% more sulphur dioxide than stands of pine or deciduous trees. This is readily explainable on the basis of higher leaf area

index for spruce (Ivens et al., 1990). For sulphur dioxide, therefore, deposition velocity of 0.4 cm/s and 0.8 cm/s has been chosen for non-forested and forested areas, respectively. It is implicated that, while stomatal uptake rate is reduced during the non-growing season, this is largely compensated because of a higher occurrence of wet surfaces under typical Norwegian winter conditions, if there is no frost or snow. The deposition rate for SO_2 has been strongly reduced for all types of surface cover in the presence of a lasting snow cover.

The deposition velocity for NO_2 is not influenced by the presence of wet surfaces and has been shown to be mainly regulated by stomatal control. A generally low deposition velocity of 0.2 to 0.4 cm/s serves to keep the dry deposition of this component relatively insignificant (Johansson, 1987). In winter, stomatal uptake is insignificant, and deposition velocities correspondingly low (0.02 cm/s).

Sum of nitric acid and nitrate (in aerosol particles) is available from the monitoring programme. Measurements at Birkenes and Lista have shown that the concentration of nitric acid is only 10-30% of the sum of nitric acid and particulate nitrate (Sorteberg et al., 1998; Foltescu et al., 1996). Nitric acid is very reactive and only the aerodynamic transfer resistance is limiting the dry deposition velocity (Emberson et al., 2000; Simpson et al., 2001). Cascade impactor measurements indicate that the nitrate is mainly present in the form of particles larger than 2 µm (e.g. Hillamo et al., 1992). A relatively large deposition velocity has therefore been chosen for this component.

However, it is recognized that the latter decades there is more ammonium available due to large reductions in sulphur dioxide emissions, and this may have shifted the equilibrium towards more particulate ammonium nitrate relative to nitric acid (Fagerli and Aas, 2008) causing a change in deposition velocities for nitrogen (Fowler et al., 2009). This is not taken into account since we have chosen to use same procedure for all periods.

The reduced nitrogen species will mainly consist of submicron ammonium sulphates and gaseous ammonia. Several measurements have indicated that the concentration of gaseous ammonia is low (e.g. Tørseth and Semb, 1996). The only exception is in areas influenced by local emissions from farms in connection with animal husbandry and manure. Gaseous ammonia will have a relatively high deposition velocity. The deposition velocities chosen for sulphate and ammonium in aerosols also include deposition by deliquescenting sulphate droplets under conditions with high humidity and advection fogs. Particle growth in periods with high relative humidity (e.g. > 95%) may give significant deposition of sulphate particles and to coniferous stands in particular. The latter processes are important at sites which are frequently exposed to advection fogs and low clouds. In mountainous regions cloud water deposition may be comparable to annual precipitation (Lovett, 1990; Dollard et al., 1983), but is usually less than 10%. Occult deposition may have a strong effect in the ecosystems because of the relatively high concentrations of pollutants found in cloud and fog water, but is less important for estimating the total deposition in calculations of critical loads using a resolution of 50·50 km^2. The subject of exposure to pollutants in the mountainous areas of Norway has been discussed further by Lükewille and Semb (1997).

Sea-salts generally occur in the coarse particulate mode (>2 µm). In coastal areas sea spray may generate particles larger than 10 µm. These will however be deposited very fast and normally less than 1-5 km from the coast and will therefore not contribute to the deposition to larger areas. In addition, episodes with high concentration of sea-salts in air will normally be accompanied with large inputs as wet deposition, making the dry deposition of minor

importance to the total deposition. Relatively high deposition velocities were chosen for all sea-salt compounds, corresponding well with the excess throughfall of sodium estimated from the Norwegian monitoring programme for forest damage (Solberg et al., 1997).

The larger fraction of calcium and potassium is not derived from sea-salts. For calcium, the main source is assumed to be long-range transport of mineral matter (Semb et al., 1995). There are still large uncertainties with respect to emission, transport and deposition of these compounds. In addition, there may also be local sources by e.g. agricultural activities, soil dust, pollen and bird droppings. For potassium, domestic wood combustion may be of importance locally during winter.

Table 1 summarises the deposition velocities which have been used to infer dry deposition from measured concentrations of the various compounds in this work.

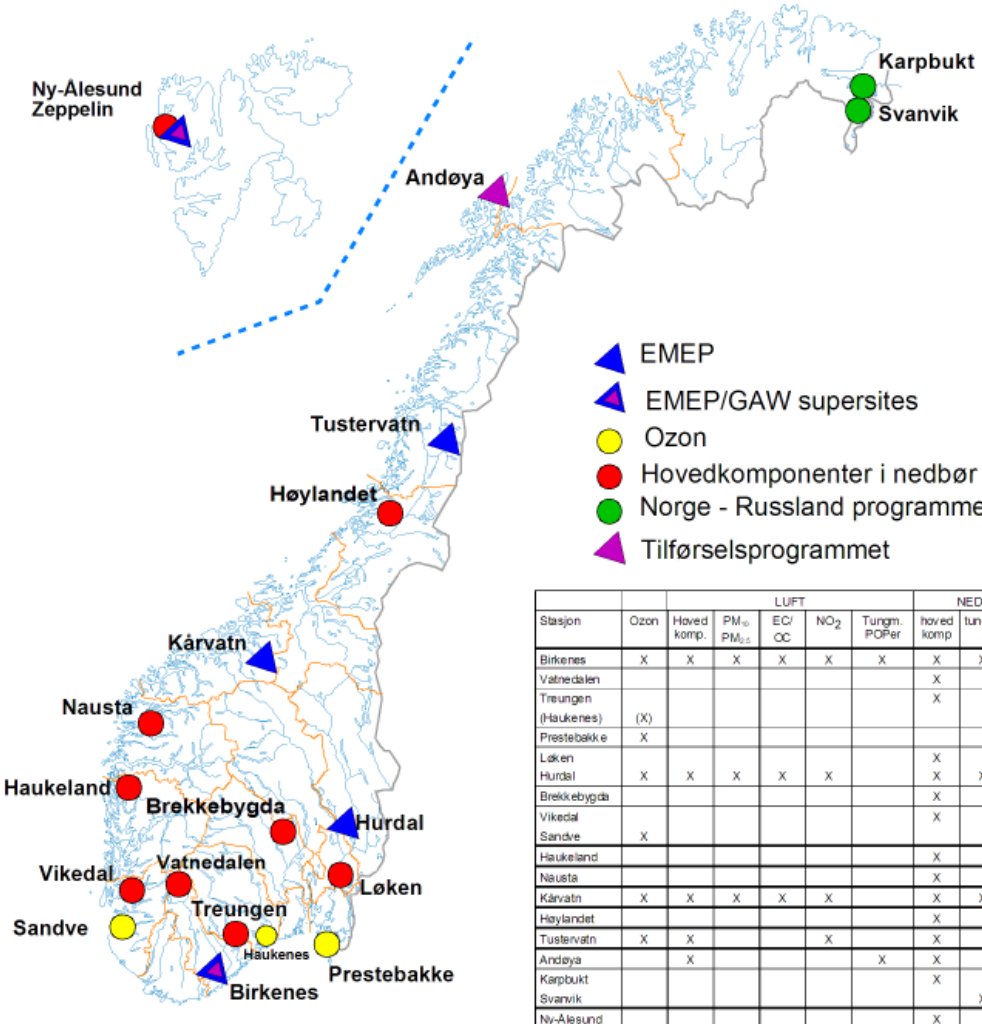
Table 1: Deposition velocities (cm/s) for different inorganic compounds applied to the different landscape types and seasons (nss: non sea salt; ss: sea salt).

	Land use classification			
Compound	Forest		Other	
	summer	winter	summer	Winter
SO_2	0.8	0.1	0.4	0.02
SO_4^{--}, Sum (NH_3+NH_4^+)	0.4	0.4	0.2	0.1
NO_2	0.4	0.02	0.2	0.02
Sum (HNO_3+NO_3)	2.0	2.0	1.0	0.25
nss K^+	1	1	0.25	0.1
nss Ca^{2+}	2	2	1	0.25
Na^+, Mg^{2+}, Cl^-, ss K^+, ss Ca^{2+}, ss S	2	2	1	0.25

3. Data used for mapping

NILU started routine sampling of precipitation and air in background areas on daily basis in 1971, with sites located in the southernmost parts of Norway. In later years the measuring network has expanded to cover all regions in Norway, though the latter 10 years the monitoring programme has been shrinking due less problems with acidification. In this investigation we have used 16 Norwegian stations for the period 2007-2011 (Figure 1) Karasjok and Søgne were sites in operation in 2007, but not in 2011, while Andøya have measurements from 2011.

In addition, concentrations in precipitation and air at the Swedish, Finnish and Russian EMEP stations have been used in the statistical analysis. These data has been taken from the EMEP web site (www.emep.int). Additional precipitation data from the Swedish sites connected to the national PMK network (17 sites) has also been included (Håkan Blomgren, IVL, data downloaded from http://www.ivl.se/miljo).



		LUFT					NEDBØR		
Stasjon	Ozon	Hoved komp.	PM_{10} $PM_{2.5}$	EC/ OC	NO_2	Tungm. POPer	hoved komp	tungm.	POPer
Birkenes	X	X	X	X	X	X	X	X	X
Vatnedalen							X		
Treungen (Haukenes)	(X)						X		
Prestebakke	X								
Løken Hurdal	X	X	X	X	X		X X	X	
Brekkebygda							X		
Vikedal Sandve	X						X		
Haukeland							X		
Nausta							X		
Kårvatn	X	X	X	X	X		X	X	
Høylandet							X		
Tustervatn	X	X			X		X		
Andøya		X				X	X		
Karpbukt Svanvik							X	X	
Ny-Ålesund Zeppelin	X	X				X	X		
Totalt antall	7+1	6	3	3	4	3	15	4	1

Figure 1: Norwegian background stations and measurement programme 2011.

All sites are located in rural areas and are believed to generally give good estimates of long range transported pollutants. In regions with local sources such as emissions from industry, traffic or agriculture, pollutant levels may be significantly higher. In this work no corrections for local sources have been performed. Information about the sites and the results for the years used in this report has been published in Aas et al. (2008-2012).

Precipitation samples are collected in bulk-samplers on a daily or weekly basis. Precipitation amounts are measured by local observers and the samples are sent to NILU for analysis of all main compounds. Analysis results are tested for ion balance and the measured conductivity is compared with calculated conductivity. Filter-pack samples are analysed for SO_2, SO_4^{2-}, HNO_3+NO_3- and NH_3+NH_4^+, while absorbing solutions or NaI-impregnated filters are analysed for NO_2. All results are checked against expected values and results from neighbouring sites. Obviously contaminated samples are rejected.

The precipitation amount data used for the calculations of the wet deposition is taken from the national meteorological observation network (met.no) in addition to the NILU sites. Data from in total 591 sites for the five-year period 2007-2011 have been applied (met.no, 2007-2011). Only sites with at least two years of precipitation data have been included.

4. Interpolation

The interpolation of the concentrations in precipitation and air from fixed sites to a regular grid is done by "kriging", which is a statistical method that can be used to estimate unknown data from neighbouring measurements. The method was originally developed for geostatistical purposes (Matheron, 1963; Journel and Huijbregts, 1981), but has also been used in connection with environmental studies, e.g. on long range transported air pollutants in Europe (Simpson and Olsen, 1990; Schaug et al., 1993).

Linear kriging provides the best linear unbiased estimator for a variable. Non-linear kriging (Armstrong and Matheron, 1986) may give more accurate estimates, but is far more complicated and requires much more statistical information. There are three levels of linear kriging: simple kriging where the expectations of the variable are known; ordinary kriging with unknown but stationary expectations, and universal kriging where there is a drift in the data. In universal kriging the expectations are neither stationary nor known, but their functional form has been identified.

The kriging weights are computed from a variogram, which measures the degree of correlation among sample values in the area as a function of distance and direction of samples. All interpolations in this work were performed using ordinary linear kriging. A grid size of 50·50 km^2 has been applied (EMEP sub-grid). The applied grid is shown in Figure 1.1 in Appendix.

5. Data analysis

Seasonal mean airborne concentrations during winter (Jan.-Apr., Nov.- Dec.) and summer (May-Oct.) were calculated for SO_2, non sea-salt (nss) SO_4^{--}, NO_2, sum $NO_3^-+HNO_3$, sum $NH_4^+ + NH_3$, Na^+, non sea-salt K^+ and non sea-salt Ca^{2+}. For all compounds but nss K^+, a significant seasonal variation was evident whereas the inter-annual variation was generally small. As a result of this the five year seasonal average concentration values measured at 16 Norwegian sites were interpolated to a 50·50 km^2 grid using the kriging technique to obtain values for the individual grid cells. Concentration fields for Cl^- and Mg^{2+} were estimated based on the ratio between these compounds and Na in seawater.

The dry deposition was estimated from the concentration fields and assessed dry deposition velocities for the two seasons, respectively. The dry deposition estimate was given for each meteorological site and for two land type categories; productive forests and other land use (e.g. unproductive land, rocks, agricultural land). When estimating the grid cell average dry deposition, deposition was weighted on the distribution of land use types in the individual grid cells. The applied statistics on percentage productive forest in each cell is shown in Figure 1.2 in Appendix.

The annual averages of non sea-salt sulphate, nitrate, ammonium, non sea-salt potassium and non sea-salt calcium in precipitation have been used to calculate a concentration field for each year using the kriging interpolation.

For the sea-salt derived ions, the number and the location of the sites are not sufficient to generate concentrations fields. However, concentrations may be described as a function of distance from the coast weighted by the wind speed and direction in the prevailing precipitation forming air masses. Based on annual median values of sodium concentration in precipitation at the background sites for the period 2007-2011, a general function was fitted (Figure 2). From this function, concentration values were given to each individual meteorological site as a function of distance from the coast and by climatic regions. Further, concentrations for the other sea-salt derived ions were estimated by their expected ratio to sodium based on the content in sea-water.

To provide annual wet deposition values for each meteorological site, the precipitation amount at the site was multiplied with the interpolated concentration in the respective grid cell. The average wet deposition to each grid cell was estimated as the average deposition to the meteorological sites within the grid cell. For grid cells with no meteorological sites, the value of a representative neighbouring cell was chosen. The average precipitation amounts in the individual grid cells are given in Table 1.1 and 1.3 in Appendix.

The total deposition of the various inorganic compounds during 2007-2011 was calculated as the sum of the dry and wet deposition both for each meteorological site and for each grid cell. The results for the individual sites (deposition values to forested areas) are visualised on maps in Figures 5-17 whereas land use area weighted results for individual grid cells are given in Tables 1.1 in Appendix. The maps are produced using standard interpolation routines.

This report gives only a summary of the results. Deposition estimates for individual years and for the different landscape types are stored in our database, and are available upon request.

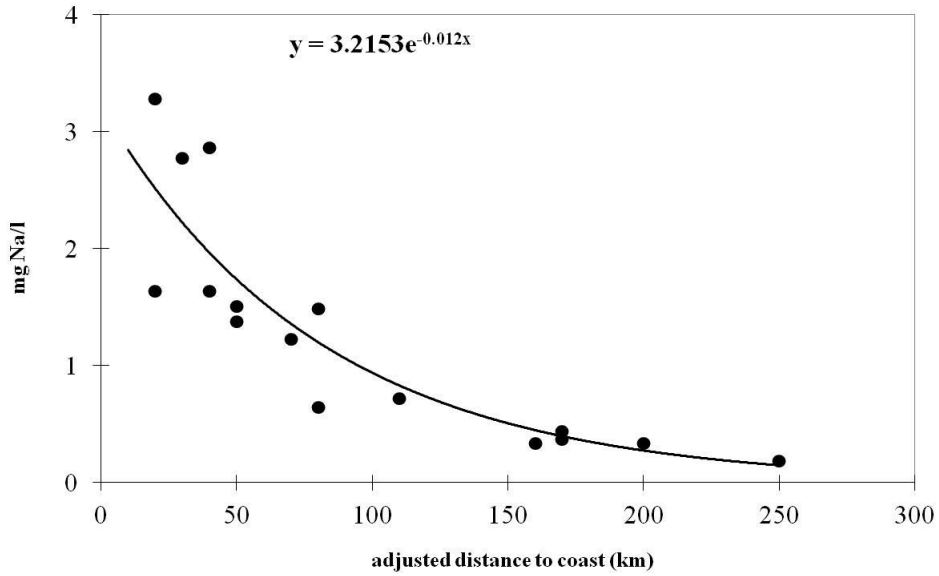


Figure 2: Sodium content in precipitation as a function of regionally adjusted distance to the coast.

6. Results and discussion, 2007-2011

Annual average precipitation amounts measured at the met.no sites varied between 186 and 3834 mm, with the highest amount on the west coast and lowest amounts along the Swedish border in northern Norway and in Oppland county, southern Norway (Table 2). Aggregated to grid cell averages, the amount varied from 381 in Finnmark County (cell no. 171) to 2959 mm in Sogn og Fjordane (cell no. 25).

Table 2: Minimum, median and maximum deposition for individual sites and 50·50 grid cells in the period 2007-2011.

Compound	Deposition to individual sites (n=591)			Grid cell averaged deposition (n=191)		
Units (mg/m2 yr)	**min.**	**med.**	**Max.**	**min.**	**med.**	**Max.**
Precip. (mm)	186	1004	3834	381	941	2959
nss S	31	157	667	54	135	499
N (oxi)	40	177	954	55	117	695
N (red)	50	251	856	56	205	640
N (oxi+red)	90	450	1810	118	330	1318
nss K	14	82	241	31	81	213
nss Ca	21	103	334	41	91	265
Na	136	1485	10124	147	1519	8229
Mg	16	179	1220	18	183	991
Cl	242	2652	18079	263	2713	14695
Ss S	11	124	847	12	127	689
Ss K	5	53	364	5	55	296
Ss Ca	5	56	383	6	58	312

The total deposition of the non sea-salt compounds were highest in the south-western part of Norway as a combination of relatively high concentrations and large precipitation amounts, whereas the lowest depositions were observed along the Swedish border from Finnmark in the north down to Oppland in central Norway as well as the mountain area in southern Norway. Maximum average annual depositions of non sea-salt sulphur was 0.50 g S/m^2 in grid cell no. 8 and 9 (Vest-Agder). This is approximately one order of magnitude higher than the sulphur depositions in grid cells 99 in Nordland. Similarly, deposition values for individual meteorological sites varied from at most 0.67 g S/m^2 down to 0.03 g S/m^2.

The nitrogen deposition pattern is similar to the deposition of sulphur. This is partly due to the strong influence of the precipitation frequency and amounts on the deposition of both species. The largest grid cell depositions of oxidised- and reduced nitrogen were 0.70 and 0.64 g N/m^2, whereas the lowest depositions were 0.06 g N/m^2 for both species. Total nitrogen deposition for the individual sites varies from 0.09 to 1.8 g N/m^2 as a annual mean.

Adding up the values in Table 1.1 gives a total annual mean deposition in Norway of approximately 54 000 tonnes sulphur and 140 000 tonnes nitrogen. Comparing with the previous period, there is a significant decrease in sulphur deposition (27%). Also for total

nitrogen there is a decrease (9%) with largest difference for oxidised nitrogen (17%) and only small difference for reduced (2%), Table 3. The same methodology was used in five of the periods (1978-1982, 1992-1996, 1997-2001, 2002-2006 and 2007-2011). For 1988-1992, the methodology was slightly different, but we assume that this has no relevance for the comparability of results. However, the number of measurement sites increased significantly from 1978-82 to 1988-92. It then has decreased again from the nineties up to 2011. For this reason, the deposition estimates for the five periods may not be directly comparable.

Table 3: Total deposition of inorganic compounds in Norway (tonnes/year).

Year	nss S	N (oxi)	N (red)	tot N	nss K	nss Ca
1978-1982	197368	83882	93342	177224	27702	43061
1983-1987	171710	93456	93602	187058		
1988-1992	149688	82462	76782	159245		
1992-1996	117289	80251	71602	151852	19989	33412
1997-2001	87206	73564	77572	151136	23769	25890
2002-2006	73852	75612	79244	154856	28092	34266
2007-2011	53724	62798	77524	140321	27360	32770

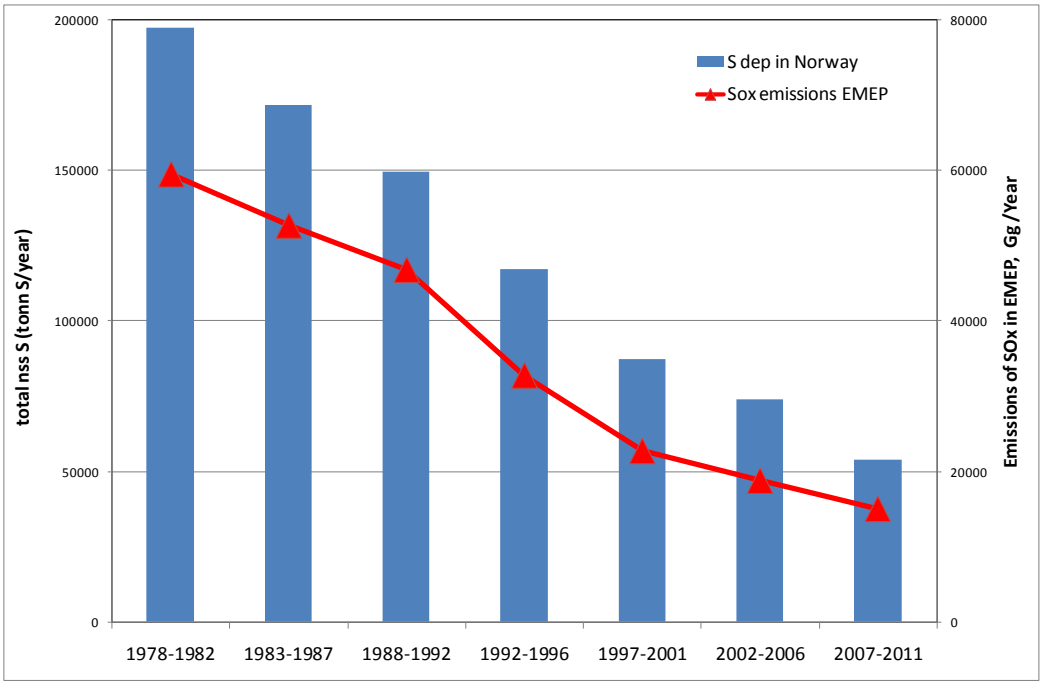


Figure 3: Deposition of non sea salt sulphur in Norway (tonnes/year) compared with total S (GgS/year) emissions in Europe.

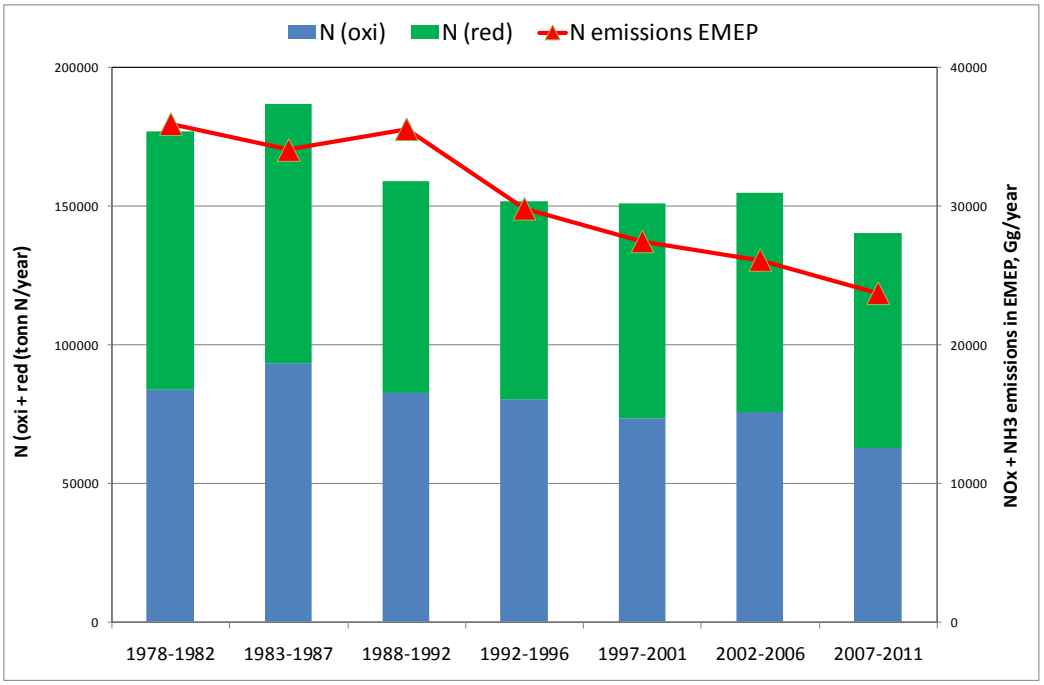


Figure 4: Deposition of nitrogen in Norway (tonnes/year) compared with total N (GgN/year) emissions in Europe.

The trend in sulphur deposition is very well correlated with the total emission trends in Europe, Figure 3, but also the nitrogen deposition follows the general trend in EMEP (Figure 4), but somewhat larger variations, which might be due to somewhat higher influence of local sources compared to sulphur.

These observations of trends are in line with the rest of Europe (Tørseth et al., 2012).

Total depositions of sea-salt ions, non sea-salt potassium and non sea-salt calcium were estimated in four of the previous six year periods. There are relatively large uncertainties in these estimates due to possible influence of local sources, uncertain deposition velocities and the effect of sea salt correction. There is a significant reduction in the calcium concentrations in precipitation (Aas et al., 2012) and the deposition (Table 3) since the late seventies, but no major change since the 1992-1996 period. For potassium the level is varying with no clear trend, 1992-1996 was significant lower the other periods.

The deposition amounts of sea-salts will be dependent on the frequency of westerly winds, and in particular the frequency of winter storms. It is assumed that there are no other significant sources of sodium, magnesium or chloride than from sea-spray. Deposition of sea-salts is particularly large in the coastal zone (0-20 km from the coast) and decreasing exponentially with distance. This deposition pattern is not taken into account in the presented maps, and deposition estimates will be significantly underestimated to these areas.

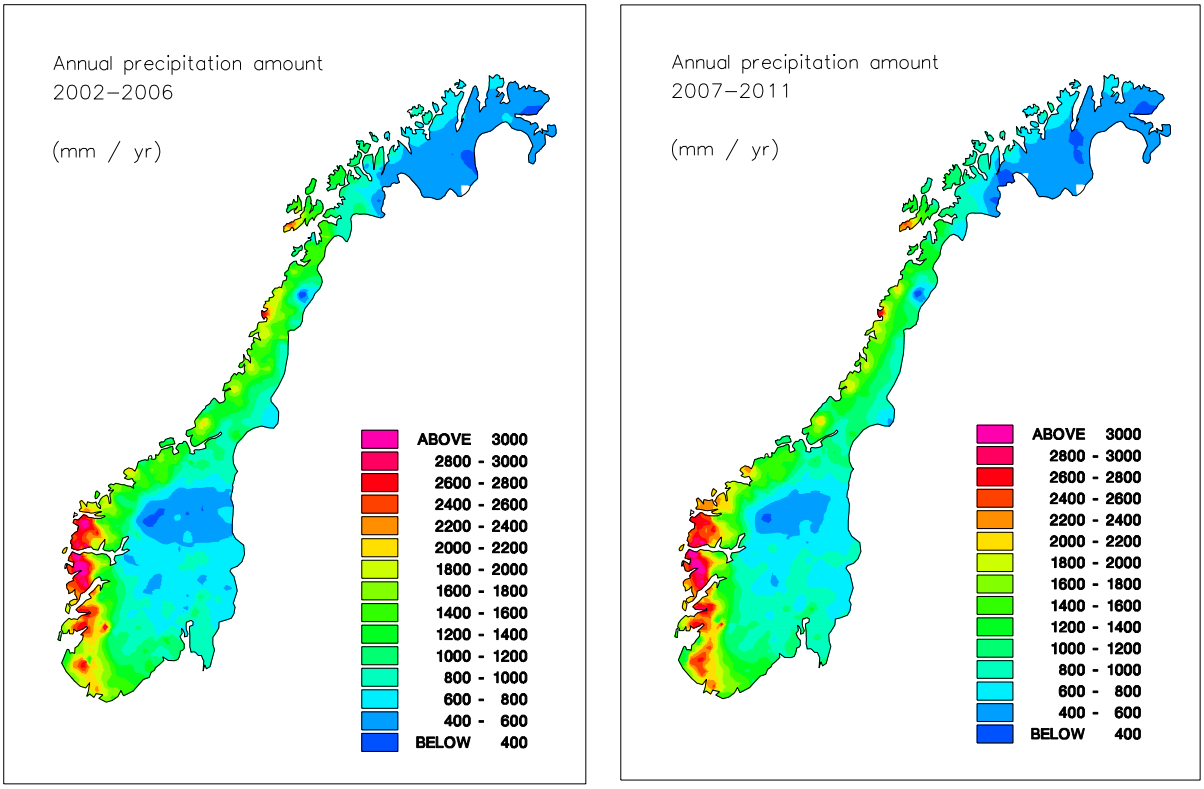


Figure 5: Average precipitation amount 2002-2006 and 2007-2011.

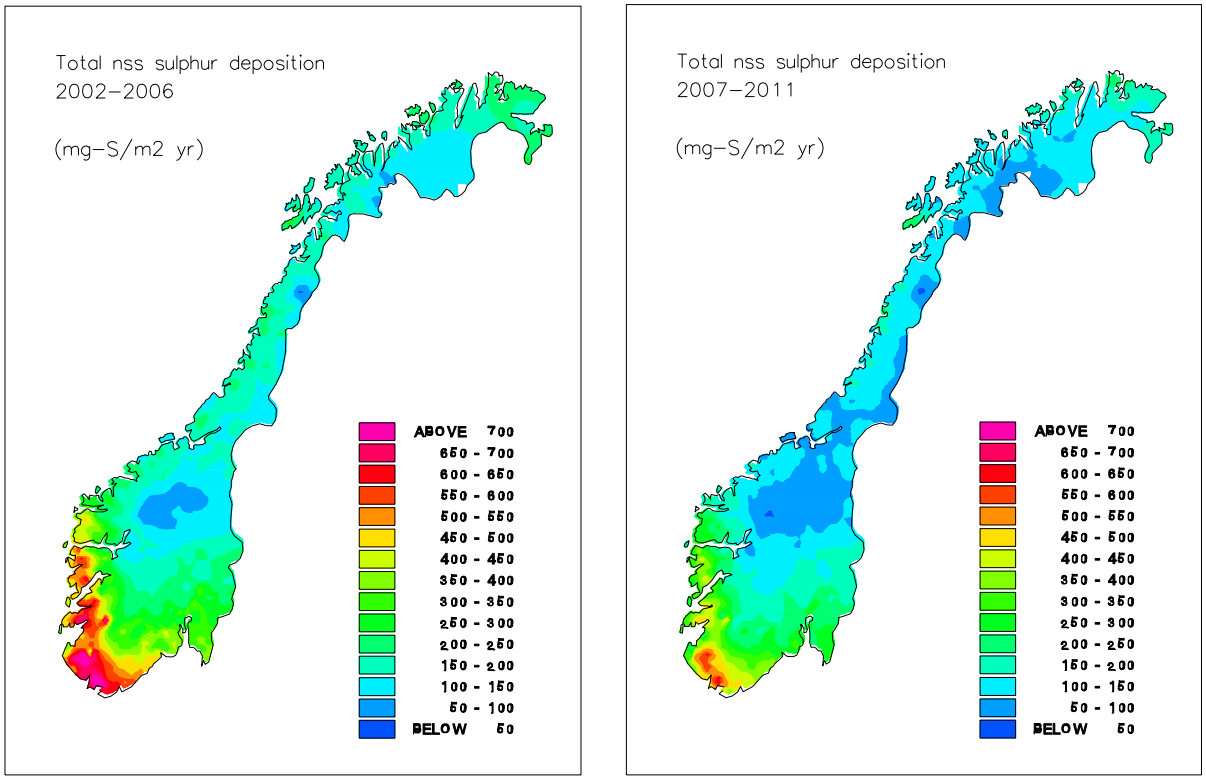


Figure 6: Total nss sulphur deposition 2002-2006 and 2007-2011.

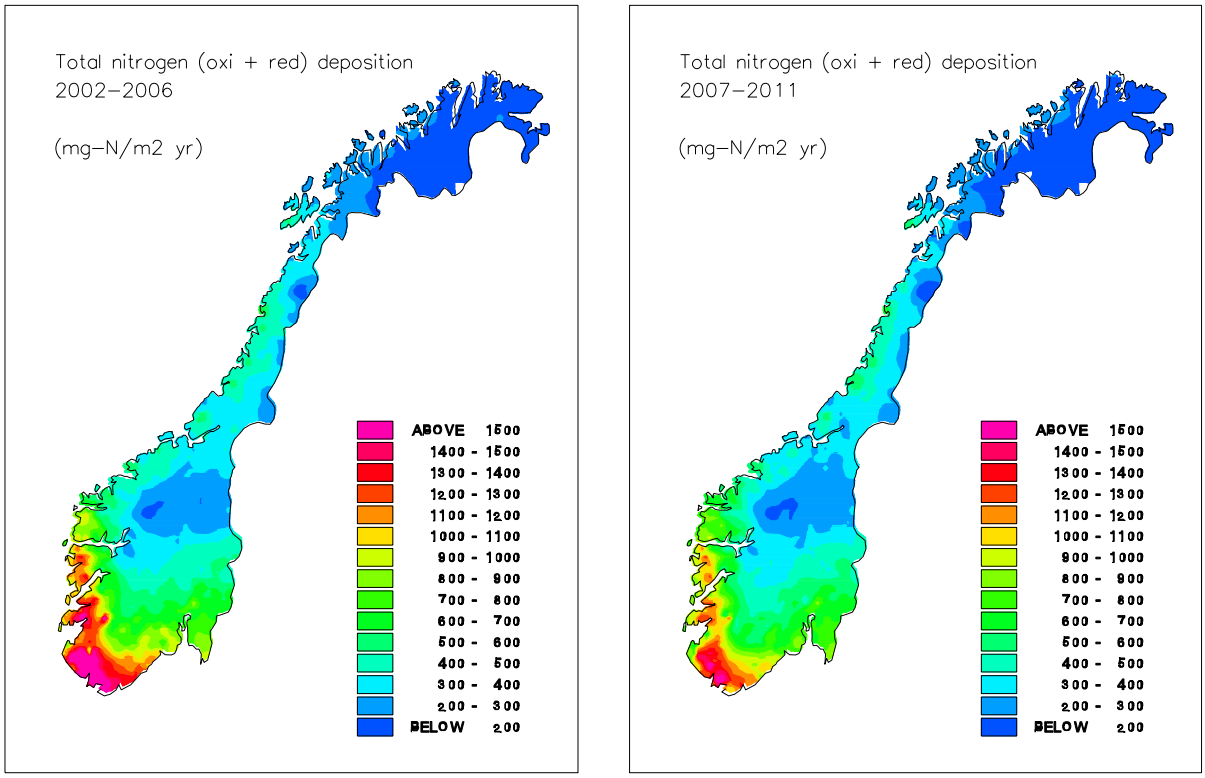


Figure 7: Total deposition of nitrogen (oxi+red) (mg N/m^2 year) 2002-2006 and 2007-2011.

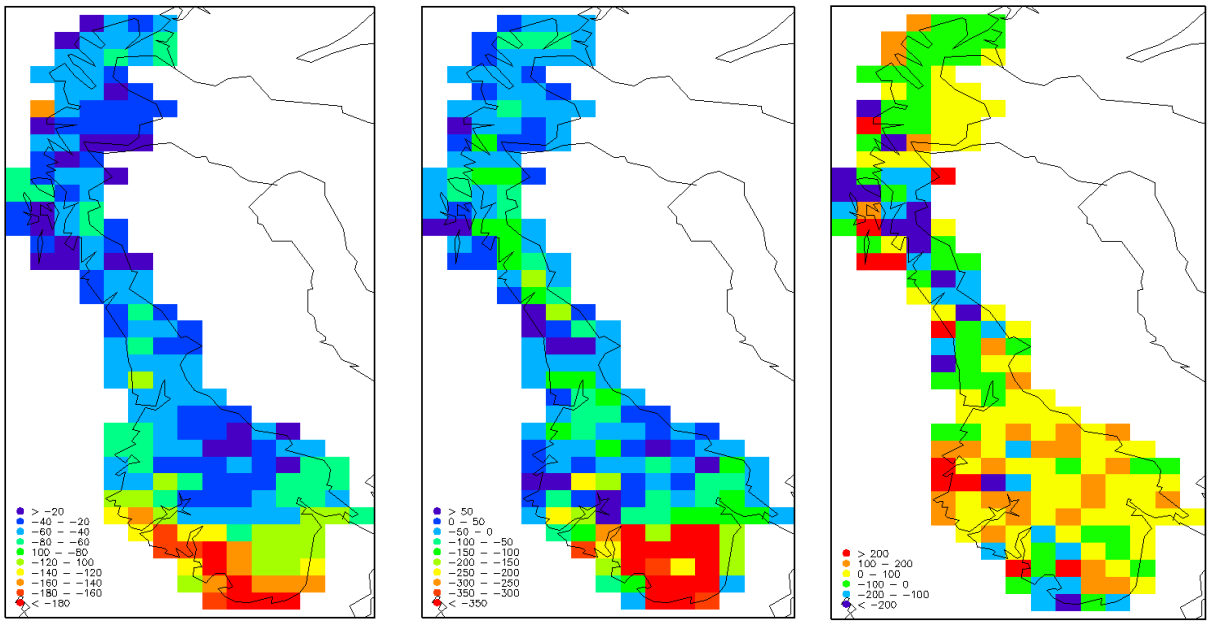


Figure 8: Difference in nss sulphur deposition (left), total nitrogen deposition (middle) and precipitation amount (right) between the periods 2002-2006 and 2007-2011 (50 x 50 km grid).

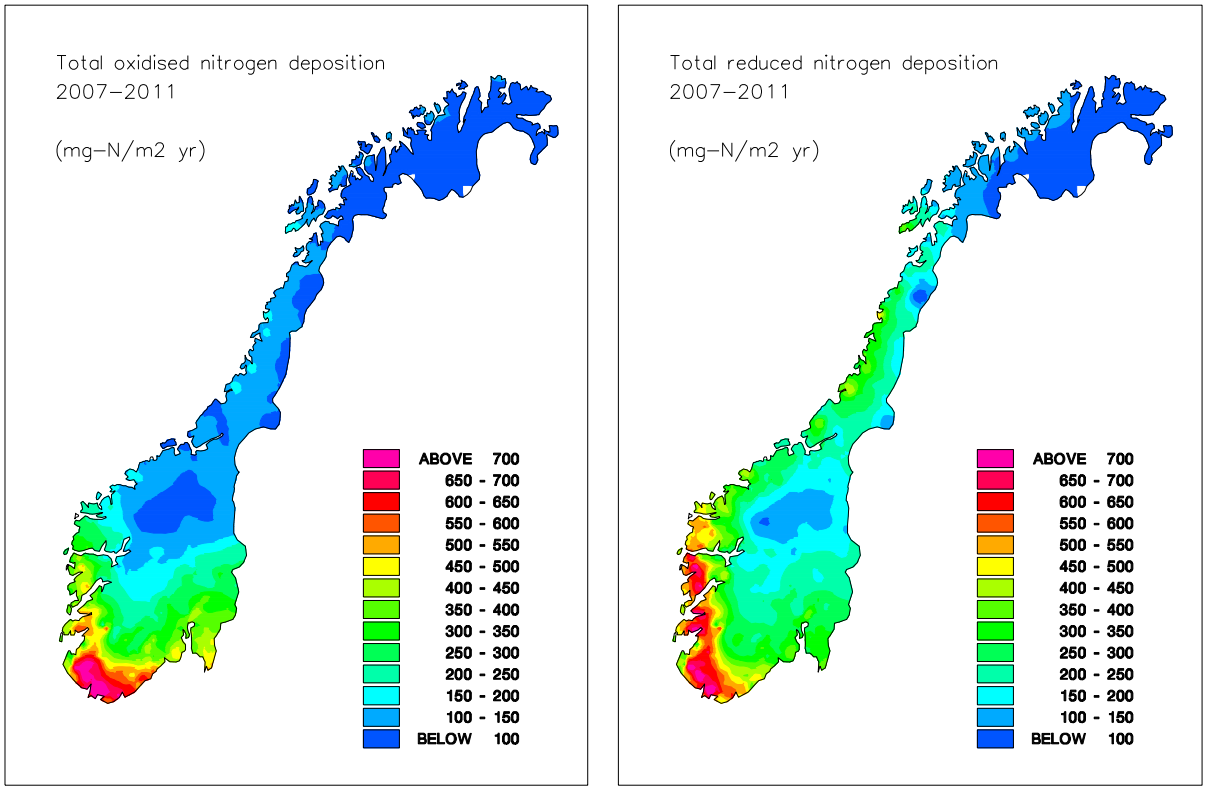


Figure 9: Total deposition oxidised and reduced nitrogen (mg N/m^2 year) in 2007-2011.

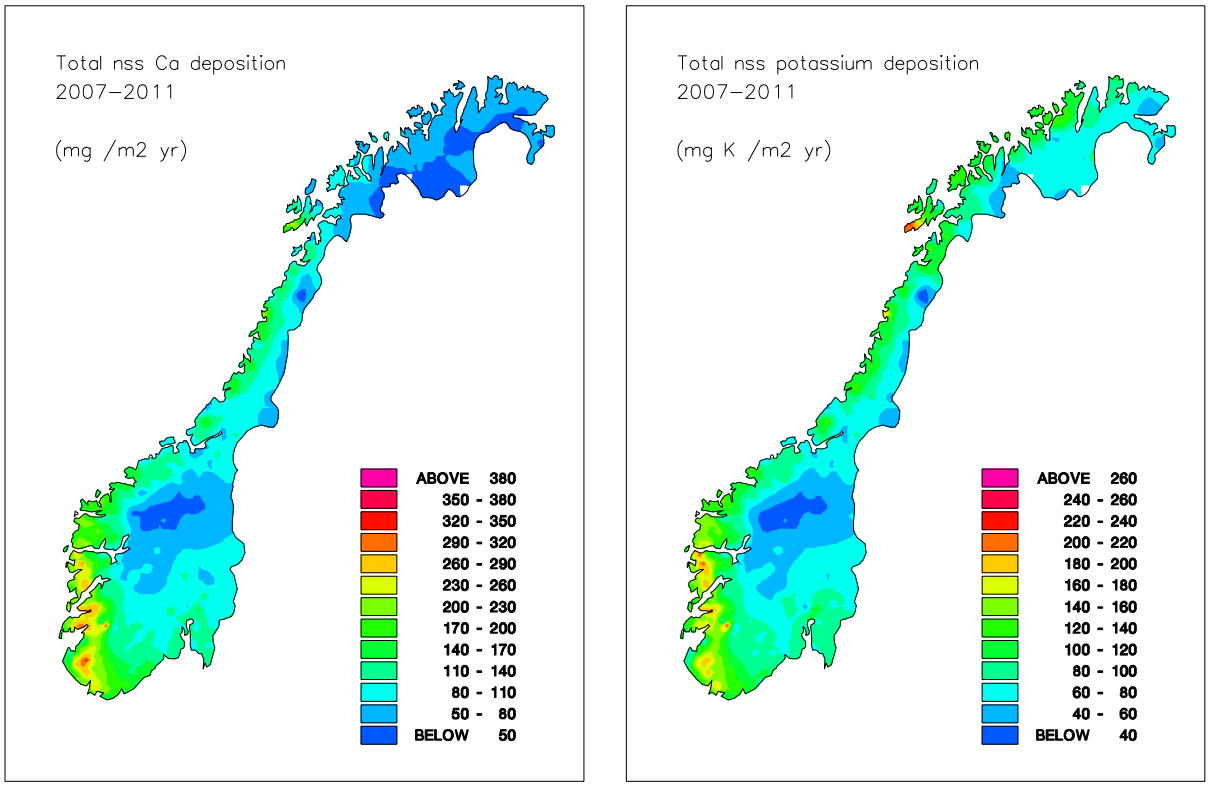


Figure 10: Total deposition of non sea salt calcium (mg Ca/m^2 year) non sea salt potassium (mg K/m^2 year) 2007-2011.

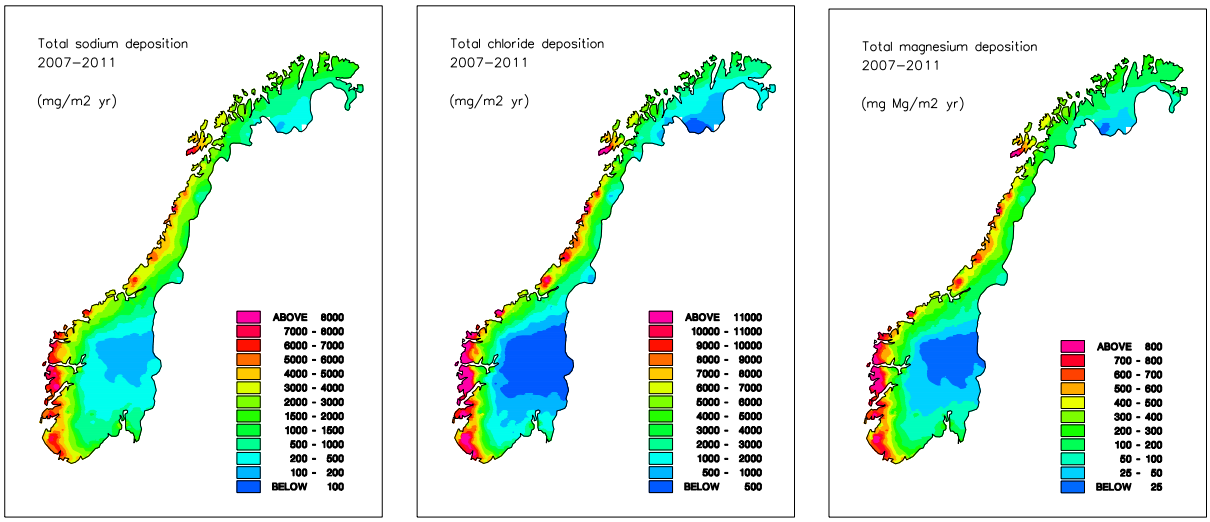


Figure 11: Total deposition of sodium (mg Na/m^2 year), chloride (mg Cl/m^2 year) and magnesium (mg Mg/m^2 year) in 2007-2011.

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Appendix A

Figures 1.1-1.2 and Table 1.1

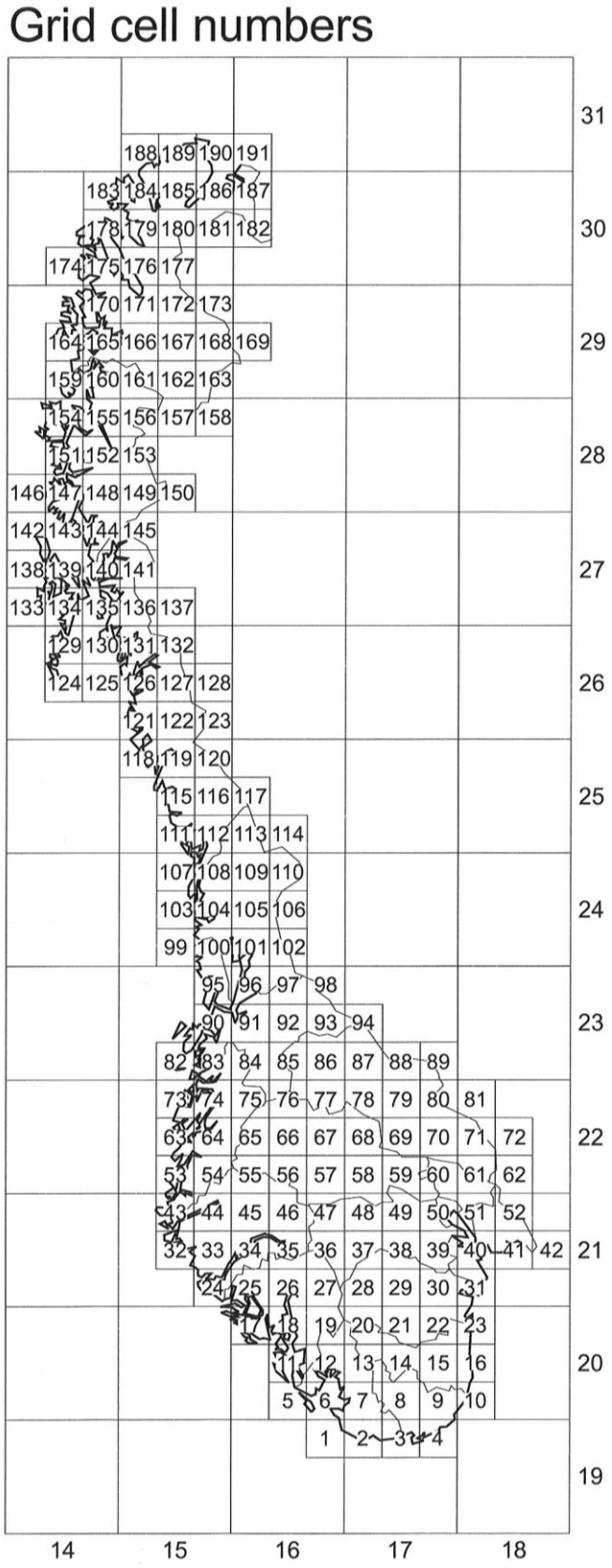

Figure 1.1: The 50·50 km² grid and grid cell numbers (EMEP sub-grid) used for interpolating concentration fields.

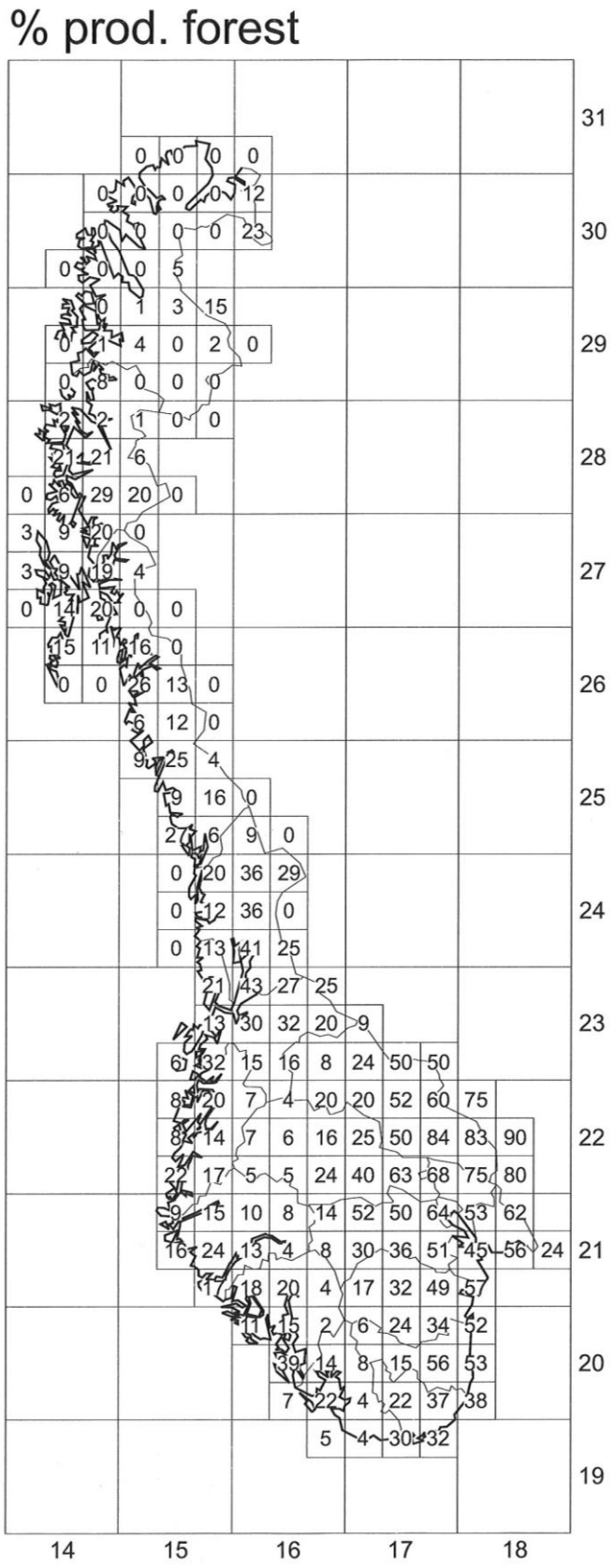

Figure 1.2: Percent productive forest used in estimating dry deposition.

Table 1.1: Values of each 50·50 km² grid cell, 2007-2012 (see Figure 1.1).

Grid cell no.	Total area (km2)	Average precipitation amount (mm)	Total nss S dep. (mg S/m2 yr)	Total N (oxi) (mg N/m2 yr)	Total N (red) (mg N/m2 yr)	Total N (red+oxi) (mg N/m2 yr)	Total nss K (mg/m2 yr)	Total ss K (mg /m2 yr)	Total nss Ca (mg/m2 yr)	Total ss Ca (mg/m2 yr)	Total Na (mg/m2 yr)	Total Mg (mg/m2 yr)	Total Cl (mg/m2 yr)	Total ss S (mg S/m2 yr)	Total nss S deposition (ton S in grid)	Total N (oxi) deposition (ton N in grid)	Total N (red) deposition (ton N in grid)	Total N deposition (ton N in grid)	Total nss K deposition (ton K in grid)	Total nss Ca deposition (ton Ca in grid)	Number of meteorol. Sites in grid
1	100	1346	287	379	401	780	95	157	144	166	4372	527	7807	366	29	38	40	78	10	14	1
2	1270	1482	350	462	447	909	108	166	165	175	4611	556	8234	386	444	587	567	1155	137	210	7
3	1060	1846	461	654	589	1243	136	203	201	214	5656	681	10100	473	489	693	624	1318	144	213	4
4	950	1649	454	665	586	1251	123	163	178	171	4525	545	8081	379	432	632	557	1188	117	169	4
5	430	1203	215	288	323	611	80	140	121	148	3906	471	6974	327	93	124	139	263	35	52	1
6	450	1283	274	353	386	739	90	146	145	154	4071	491	7270	341	123	159	174	333	41	65	7
7	2480	1990	422	542	562	1104	137	202	215	213	5622	677	10038	471	1045	1345	1394	2739	341	533	7
8	2500	2127	499	679	639	1318	155	160	231	168	4442	535	7932	372	1248	1697	1598	3295	388	578	8
9	2480	1823	489	695	581	1276	134	143	204	151	3984	480	7114	333	1212	1722	1442	3164	333	506	5
10	280	1406	419	654	510	1164	114	135	163	142	3742	451	6683	313	117	183	143	326	32	46	2
11	1310	2079	325	410	485	894	133	209	216	220	5809	700	10373	486	425	537	635	1172	174	283	4
12	2450	2406	424	521	640	1161	160	207	265	218	5755	693	10277	482	1040	1277	1569	2846	391	648	7
13	2500	2120	374	496	574	1071	141	148	219	155	4105	495	7330	344	936	1241	1436	2677	352	547	2
14	2450	1449	330	446	426	872	110	80	161	84	2227	268	3977	186	809	1092	1044	2136	270	394	3
15	2500	1417	385	566	465	1031	107	60	159	63	1675	202	2991	140	963	1414	1163	2578	268	398	7
16	750	1184	362	551	406	957	93	87	138	92	2428	293	4337	203	271	413	305	718	70	103	6
17	1830	2196	295	354	488	842	133	231	193	244	6428	775	11479	538	539	648	893	1541	244	354	4
18	1950	2576	381	445	613	1058	166	219	250	231	6091	734	10878	510	744	868	1195	2063	323	488	6
19	2500	2101	331	398	512	910	146	138	224	146	3844	463	6865	322	827	995	1281	2276	366	559	6
20	2500	1465	273	337	374	711	117	76	166	80	2101	253	3752	176	682	842	935	1776	292	415	6
21	2500	1017	227	308	284	592	86	23	117	24	634	76	1132	53	567	771	710	1481	216	293	6
22	2500	1076	280	400	335	735	81	23	119	24	644	78	1149	54	700	1000	838	1838	204	298	7
23	1350	1218	347	537	414	951	95	57	140	60	1584	191	2828	133	469	725	559	1284	129	189	2
24	1150	2491	279	319	504	823	149	245	193	258	6818	821	12175	571	321	367	579	946	171	222	7
25	2500	2959	354	416	621	1037	175	228	236	240	6346	765	11332	531	886	1040	1551	2592	439	590	8

Table 1.1, cont.

Grid cell no.	Total area (km2)	Average precipitation amount (mm)	Total nss S dep. (mg S/m2 yr)	Total N (oxi) (mg N/m2 yr)	Total N (red) (mg N/m2 yr)	Total N (red+oxi) (mg N/m2 yr)	Total nss K (mg/m2 yr)	Total ss K (mg /m2 yr)	Total nss Ca (mg/m2 yr)	Total ss Ca (mg/m2 yr)	Total Na (mg/m2 yr)	Total Mg (mg/m2 yr)	Total Cl (mg/m2 yr)	Total ss S (mg S/m2 yr)	Total nss S deposition (ton S in grid)	Total N (oxi) deposition (ton N in grid)	Total N (red) deposition (ton N in grid)	Total N deposition (ton N in grid)	Total nss K deposition (ton K in grid)	Total nss Ca deposition (ton Ca in grid)	Number of meteorol. sites in grid
26	2250	1837	261	307	416	723	114	120	164	126	3335	402	5955	279	586	691	935	1626	256	369	7
27	2450	1140	182	214	255	469	80	37	117	39	1020	123	1822	85	445	523	625	1148	197	286	2
28	2400	904	173	223	241	464	76	13	100	14	359	43	641	30	415	535	579	1114	182	241	4
29	2500	893	198	276	254	530	79	20	102	21	552	67	986	46	495	690	635	1325	197	256	6
30	2500	962	245	363	308	671	78	21	108	22	588	71	1049	49	613	907	770	1678	195	269	6
31	1930	1047	292	465	360	825	88	46	123	48	1278	154	2281	107	564	898	694	1592	170	237	4
32	940	2855	259	288	531	819	162	296	208	312	8229	991	14695	689	244	271	499	770	152	195	1
33	2450	2688	271	309	504	813	149	195	201	206	5427	654	9692	454	663	757	1234	1991	366	493	5
34	2360	1597	189	225	311	536	91	94	125	99	2608	314	4657	218	446	532	733	1265	215	295	6
35	2450	1340	179	208	310	518	85	47	110	50	1316	159	2350	110	440	510	759	1269	207	269	6
36	2500	853	144	171	215	386	63	9	80	10	259	31	463	22	360	427	537	964	158	200	4
37	2500	838	152	209	240	449	64	10	87	11	283	34	506	24	380	522	600	1122	160	219	2
38	2500	860	184	264	240	505	73	12	99	12	321	39	573	27	461	661	601	1261	183	248	4
39	2500	941	231	353	291	644	83	22	109	23	607	73	1085	51	577	881	728	1609	207	272	6
40	1730	998	265	414	331	746	89	31	117	32	848	102	1515	71	459	717	573	1290	155	202	4
41	1250	915	263	440	329	768	85	69	115	73	1922	232	3432	161	329	550	411	961	106	144	10
42	125	920	277	444	341	785	89	45	117	47	1239	149	2212	104	35	56	43	98	11	15	1
43	1375	2259	194	210	447	658	128	218	167	229	6051	729	10805	506	266	289	615	904	176	230	5
44	2500	2173	201	227	432	658	120	134	166	141	3733	450	6667	312	502	567	1079	1646	300	414	8
45	2500	1747	186	218	355	573	100	74	139	78	2069	249	3694	173	464	544	887	1432	249	346	6
46	2400	770	105	137	192	330	52	29	66	30	798	96	1425	67	251	330	462	791	125	158	5
47	2500	812	132	159	209	368	61	10	77	11	282	34	504	24	330	397	523	919	151	193	3
48	2500	676	138	198	202	400	59	8	77	9	234	28	417	20	345	495	504	999	147	191	5
49	2500	913	196	290	263	553	80	10	103	11	289	35	517	24	489	724	658	1382	201	256	6
50	2500	944	225	365	292	657	88	17	113	17	459	55	820	38	561	912	731	1643	221	283	15

Table 1.1, cont.

Grid cell no.	Total area (km2)	Average precipitation amount (mm)	Total nss S dep. (mg S/m2 yr)	Total N (oxi) (mg N/m2 yr)	Total N (red) (mg N/m2 yr)	Total N (red+oxi) (mg N/m2 yr)	Total nss K (mg/m2 yr)	Total ss K (mg /m2 yr)	Total nss Ca (mg/m2 yr)	Total ss Ca (mg/m2 yr)	Total Na (mg/m2 yr)	Total Mg (mg/m2 yr)	Total Cl (mg/m2 yr)	Total ss S (mg S/m2 yr)	Total nss S deposition (ton S in grid)	Total N (oxi) deposition (ton N in grid)	Total N (red) deposition (ton N in grid)	Total N deposition (ton N in grid)	Total nss K deposition (ton K in grid)	Total nss Ca deposition (ton Ca in grid)	Number of meteorol. sites in grid
50	2500	944	225	365	292	657	88	17	113	17	459	55	820	38	561	912	731	1643	221	283	15
51	2500	907	237	384	297	681	84	22	111	23	613	74	1094	51	592	961	742	1703	211	278	9
52	1210	944	272	454	338	792	92	31	119	33	866	104	1547	73	329	550	409	959	111	145	4
53	900	1883	143	168	389	556	115	178	147	187	4949	596	8837	414	128	151	350	501	103	132	4
54	2400	2001	172	195	396	591	116	125	156	132	3481	419	6216	291	413	467	951	1418	278	373	3
55	2500	641	77	96	151	247	40	15	49	16	413	50	737	35	193	240	379	618	99	122	2
56	2500	530	73	98	128	226	38	7	48	7	194	23	346	16	182	246	321	566	94	121	1
57	2500	742	118	152	190	342	57	7	73	8	208	25	371	17	295	381	475	856	141	183	3
58	2500	771	143	201	214	415	65	7	82	7	195	23	348	16	358	503	534	1037	164	205	5
59	2400	793	167	263	224	487	72	8	97	9	230	28	411	19	401	630	538	1168	172	234	3
60	2500	858	203	331	262	593	83	13	106	13	348	42	621	29	507	827	656	1483	208	264	6
61	2400	782	207	364	269	633	81	18	100	19	503	61	898	42	498	873	646	1519	194	240	5
62	250	782	228	405	276	682	81	11	108	12	314	38	560	26	57	101	69	170	20	27	1
63	900	1596	127	135	301	435	92	146	123	154	4057	489	7245	340	114	121	271	392	83	111	3
64	2100	1336	106	128	272	400	82	73	109	77	2040	246	3642	171	223	269	572	841	172	229	6
65	2300	671	63	86	147	233	45	19	65	20	535	64	955	45	144	197	338	536	104	149	3
66	2500	461	62	83	111	194	34	6	44	6	163	20	291	14	154	208	277	485	86	111	8
67	2500	645	96	120	155	275	49	5	66	6	152	18	272	13	241	300	388	687	123	166	7
68	2550	716	127	168	197	365	63	6	72	6	160	19	286	13	323	429	503	932	160	184	5
69	2500	681	143	217	205	422	65	6	78	7	176	21	314	15	359	542	513	1056	163	195	8
70	2500	881	209	345	278	624	88	8	108	9	227	27	406	19	523	863	696	1559	219	269	2
71	2300	693	180	306	248	554	74	8	87	8	215	26	384	18	413	703	570	1273	170	200	2
72	200	683	201	363	243	605	72	10	97	11	291	35	520	24	40	73	49	121	14	19	1
73	620	1912	133	137	361	498	109	206	142	217	5723	689	10219	479	82	85	224	309	68	88	3
74	2300	1519	117	135	279	413	88	90	125	95	2501	301	4466	209	269	310	641	951	203	289	6

Table 1.1, cont.

Grid cell no.	Total area (km2)	Average precipitation amount (mm)	Total nss S dep. (mg S/m2 yr)	Total N (oxi) (mg N/m2 yr)	Total N (red) (mg N/m2 yr)	Total N (red+oxi) (mg N/m2 yr)	Total nss K (mg/m2 yr)	Total ss K (mg /m2 yr)	Total nss Ca (mg/m2 yr)	Total ss Ca (mg/m2 yr)	Total Na (mg/m2 yr)	Total Mg (mg/m2 yr)	Total Cl (mg/m2 yr)	Total ss S (mg S/m2 yr)	Total nss S deposition (ton S in grid)	Total N (oxi) deposition (ton N in grid)	Total N (red) deposition (ton N in grid)	Total N deposition (ton N in grid)	Total nss K deposition (ton K in grid)	Total nss Ca deposition (ton Ca in grid)	Number of meteorol. sites in grid
76	2500	452	55	72	113	186	33	6	41	7	180	22	321	15	138	181	283	464	82	103	1
77	2500	598	87	117	154	271	47	6	57	6	161	19	288	14	218	293	384	677	117	143	3
78	2500	624	105	138	165	303	52	5	65	6	148	18	265	12	262	346	412	758	131	163	1
79	2500	810	155	223	209	431	72	7	95	8	203	24	363	17	388	556	522	1079	180	238	3
80	2000	758	169	255	218	473	72	8	92	8	222	27	396	19	338	510	436	946	144	184	2
81	200	758	189	303	223	526	73	9	99	9	246	30	439	21	38	61	45	105	15	20	1
82	770	1221	88	91	238	329	72	139	91	147	3872	466	6914	324	68	70	183	253	56	70	1
83	1900	1444	115	124	266	391	86	90	120	95	2504	302	4471	210	218	236	506	742	164	228	3
84	2500	931	78	92	185	277	59	40	81	42	1110	134	1983	93	194	231	462	693	147	203	4
85	2500	580	66	84	138	222	42	14	52	15	390	47	697	33	165	209	345	554	104	130	4
86	2500	552	75	93	128	221	43	6	55	6	171	21	305	14	187	232	320	552	106	136	4
87	2450	618	96	132	149	281	52	6	73	6	161	19	288	13	234	323	366	689	127	179	2
88	1400	818	151	207	222	429	72	7	94	8	204	25	365	17	212	289	311	601	101	131	2
89	400	947	198	260	241	501	84	8	115	9	226	27	404	19	79	104	96	200	34	46	1
90	1500	1231	90	95	239	334	77	114	96	120	3164	381	5650	265	136	142	358	500	115	144	3
91	2300	1019	92	105	203	308	66	55	90	57	1516	183	2708	127	213	242	466	708	151	207	6
92	2500	880	100	115	169	283	61	25	83	26	686	83	1225	57	249	287	422	709	151	208	3
93	2450	641	87	106	155	260	50	10	60	10	265	32	473	22	213	259	379	638	123	148	4
94	800	720	114	136	174	309	60	5	75	6	147	18	263	12	91	108	139	247	48	60	3
95	1400	1660	129	127	319	446	106	183	127	192	5081	612	9074	425	180	178	447	625	148	178	2
96	2100	1063	100	115	228	343	72	64	91	68	1792	216	3200	150	209	242	479	721	151	192	8
97	2230	956	102	113	186	299	65	24	90	25	664	80	1185	56	227	252	414	666	146	200	5
98	600	919	115	132	200	331	70	15	90	16	413	50	737	35	69	79	120	199	42	54	1
99	100	793	54	55	154	209	48	91	68	96	2523	304	4505	211	5	6	15	21	5	7	2
100	2150	1409	99	107	260	367	88	151	126	159	4197	506	7495	351	214	231	558	789	189	270	5

Table 1.1, cont.

Grid cell no.	Total area (km2)	Average precipitation amount (mm)	Total nss S dep. (mg S/m2 yr)	Total N (oxi) (mg N/m2 yr)	Total N (red) (mg N/m2 yr)	Total N (red+oxi) (mg N/m2 yr)	Total nss K (mg/m2 yr)	Total ss K (mg /m2 yr)	Total nss Ca (mg/m2 yr)	Total ss Ca (mg/m2 yr)	Total Na (mg/m2 yr)	Total Mg (mg/m2 yr)	Total Cl (mg/m2 yr)	Total ss S (mg S/m2 yr)	Total nss S deposition (ton S in grid)	Total N (oxi) deposition (ton N in grid)	Total N (red) deposition (ton N in grid)	Total N deposition (ton N in grid)	Total nss K deposition (ton K in grid)	Total nss Ca deposition (ton Ca in grid)	Number of meteorol. sites in grid
101	2450	960	91	102	201	303	64	58	87	61	1610	194	2875	135	223	250	494	743	157	214	6
102	800	1158	119	125	223	348	78	42	105	45	1178	142	2104	99	95	100	178	278	62	84	1
103	400	767	60	62	169	232	48	87	60	91	2412	291	4308	202	24	25	68	93	19	24	1
104	2500	1315	102	102	281	383	82	127	105	134	3524	425	6294	295	254	255	703	958	205	262	3
105	2500	1000	95	105	225	329	66	55	89	58	1519	183	2713	127	237	262	562	823	165	223	3
106	300	1079	110	106	201	307	71	31	95	32	854	103	1524	71	33	32	60	92	21	29	1
107	400	1225	91	96	256	352	71	139	91	147	3869	466	6909	324	36	38	102	141	29	36	1
108	2500	1592	131	135	356	491	103	150	129	158	4160	501	7428	348	326	337	890	1227	258	323	2
109	2500	1203	120	130	290	420	81	78	102	83	2181	263	3895	183	300	325	724	1050	203	255	3
110	2100	727	90	96	164	260	54	25	71	26	688	83	1229	58	189	201	344	545	113	150	2
111	1100	1597	130	141	326	467	108	172	135	182	4793	577	8559	401	143	155	359	514	119	149	2
112	2500	1448	130	132	306	438	96	140	121	147	3883	468	6933	325	325	331	764	1095	240	302	4
113	2200	808	87	94	189	283	55	41	71	43	1143	138	2041	96	191	206	416	622	122	157	1
114	100	798	95	93	175	267	58	23	75	24	641	77	1144	54	9	9	17	27	6	8	1
115	2350	1529	122	120	301	421	100	149	117	157	4134	498	7381	346	288	281	708	989	234	275	6
116	2450	1218	118	121	252	373	80	81	104	85	2239	270	3998	187	289	296	618	915	195	255	1
117	700	832	93	93	175	268	56	44	73	46	1224	147	2185	102	65	65	123	188	39	51	1
118	1100	1625	123	122	278	399	102	175	134	185	4874	587	8703	408	135	134	305	439	113	147	3
119	2390	1559	140	137	279	416	101	112	132	118	3113	375	5558	261	334	328	666	994	242	316	4
120	1200	1079	110	105	205	310	69	66	91	70	1838	221	3282	154	132	127	246	372	82	110	4
121	2000	1642	141	121	260	382	98	158	116	166	4393	529	7845	368	282	243	521	763	196	232	2
122	2500	1139	109	102	203	305	74	75	88	79	2080	251	3714	174	273	255	507	762	185	221	2
123	400	1119	119	107	190	297	73	65	93	69	1813	218	3237	152	47	43	76	119	29	37	1
124	300	2319	181	156	332	488	140	261	181	275	7261	875	12965	608	54	47	100	146	42	54	1
125	100	1785	152	132	256	388	109	202	142	212	5604	675	10008	469	15	13	26	39	11	14	1

Table 1.1, cont.

Grid cell no.	Total area (km2)	Average precipitation amount (mm)	Total nss S dep. (mg S/m2 yr)	Total N (oxi) (mg N/m2 yr)	Total N (red) (mg N/m2 yr)	Total N (red+oxi) (mg N/m2 yr)	Total nss K (mg/m2 yr)	Total ss K (mg /m2 yr)	Total nss Ca (mg/m2 yr)	Total ss Ca (mg/m2 yr)	Total Na (mg/m2 yr)	Total Mg (mg/m2 yr)	Total Cl (mg/m2 yr)	Total ss S (mg S/m2 yr)	Total nss S deposition (ton S in grid)	Total N (oxi) deposition (ton N in grid)	Total N (red) deposition (ton N in grid)	Total N deposition (ton N in grid)	Total nss K deposition (ton K in grid)	Total nss Ca deposition (ton Ca in grid)	Number of meteorol. sites in grid
126	2300	1308	120	114	198	312	84	117	113	123	3253	392	5810	272	275	262	455	717	194	260	5
127	2400	442	55	58	79	138	31	25	41	26	685	83	1224	57	132	139	191	330	74	99	3
128	200	431	56	55	79	134	32	27	41	28	744	90	1328	62	11	11	16	27	6	8	1
129	400	1342	123	109	214	323	120	150	113	157	4157	501	7422	348	49	44	85	129	48	45	1
130	900	1182	115	99	187	286	104	132	99	139	3665	442	6544	307	104	90	168	258	94	89	2
131	2500	1132	120	99	185	283	102	72	87	76	2001	241	3573	167	301	247	462	708	254	218	3
132	1300	850	90	78	129	207	69	40	83	42	1108	133	1978	93	117	101	168	269	90	108	3
133	700	806	84	75	149	224	79	91	67	96	2536	306	4529	212	59	53	104	157	55	47	1
134	700	2373	236	170	351	521	213	262	213	276	7284	878	13007	610	166	119	246	365	149	149	3
135	1500	949	102	87	149	236	85	77	86	81	2144	258	3829	179	154	131	223	354	127	129	3
136	1400	1248	131	100	183	283	100	81	102	86	2264	273	4042	189	183	140	256	396	140	143	1
137	100	1248	142	109	185	293	102	58	106	61	1600	193	2857	134	14	11	18	29	10	11	1
138	400	1344	136	99	196	295	115	153	117	161	4243	511	7577	355	54	39	78	118	46	47	2
139	1000	1387	140	110	210	320	117	154	103	163	4292	517	7665	359	140	110	210	320	117	103	1
140	1400	1199	129	104	187	291	100	104	97	109	2888	348	5157	242	181	146	262	408	140	135	3
141	1400	962	100	86	155	242	95	54	85	57	1495	180	2670	125	140	121	217	338	133	119	2
142	400	973	100	80	128	208	84	112	66	117	3100	373	5535	259	40	32	51	83	34	26	1
143	900	1019	116	92	132	224	96	115	75	121	3189	384	5695	267	104	83	119	202	86	68	2
144	1600	961	112	94	152	246	96	71	82	75	1969	237	3516	165	179	151	243	394	153	131	2
145	1100	829	101	77	127	204	78	31	72	33	875	105	1562	73	111	85	140	224	86	80	1
146	100	1003	108	89	131	220	105	118	80	124	3267	394	5833	273	11	9	13	22	10	8	1
147	1600	1097	142	98	124	223	124	123	88	129	3411	411	6092	286	227	157	199	356	199	141	2
148	2450	838	115	90	120	210	89	60	72	63	1662	200	2967	139	282	222	294	515	217	178	3
149	2450	598	86	71	100	172	61	30	53	31	822	99	1468	69	210	175	246	421	148	130	2
150	200	639	101	68	104	173	62	30	60	32	843	102	1506	71	20	14	21	35	12	12	1

Table 1.1, cont.

Grid cell no.	Total area (km2)	Average precipitation amount (mm)	Total nss S dep. (mg S/m2 yr)	Total N (oxi) (mg N/m2 yr)	Total N (red) (mg N/m2 yr)	Total N (red+oxi) (mg N/m2 yr)	Total nss K (mg/m2 yr)	Total ss K (mg /m2 yr)	Total nss Ca (mg/m2 yr)	Total ss Ca (mg/m2 yr)	Total Na (mg/m2 yr)	Total Mg (mg/m2 yr)	Total Cl (mg/m2 yr)	Total ss S (mg S/m2 yr)	Total nss S deposition (ton S in grid)	Total N (oxi) deposition (ton N in grid)	Total N (red) deposition (ton N in grid)	Total N deposition (ton N in grid)	Total nss K deposition (ton K in grid)	Total nss Ca deposition (ton Ca in grid)	Number of meteorol. sites in grid
151	1400	965	133	102	136	238	104	100	82	105	2781	335	4967	233	186	143	191	334	145	114	3
152	2400	827	129	92	119	211	95	74	82	78	2047	247	3655	171	310	220	286	505	228	197	2
153	1800	759	121	84	112	196	81	31	69	33	865	104	1544	72	218	151	201	352	147	124	1
154	1550	888	135	95	125	220	106	99	79	105	2764	333	4936	231	208	148	194	342	164	123	1
155	2300	514	89	65	83	148	65	35	51	37	965	116	1723	81	205	148	191	339	148	116	4
156	2100	555	100	69	89	158	68	21	54	23	596	72	1065	50	210	145	186	331	142	113	1
157	1300	500	96	66	83	149	62	19	50	20	539	65	962	45	125	86	107	193	81	65	1
158	300	448	92	63	76	138	52	52	45	54	1438	173	2568	120	28	19	23	42	16	13	1
159	900	985	168	110	128	238	132	65	94	68	1806	218	3225	151	151	99	116	214	119	85	1
160	2500	476	92	68	74	142	70	30	49	32	832	100	1485	70	231	170	185	355	175	122	1
161	2500	461	94	64	71	135	69	15	48	15	407	49	726	34	236	161	177	338	171	121	1
162	2500	445	96	64	78	142	64	6	47	7	180	22	322	15	239	161	195	356	161	118	1
163	1500	449	103	68	78	146	58	9	45	10	260	31	464	22	154	102	117	219	86	68	1
164	300	1045	195	117	136	253	149	101	104	106	2806	338	5011	235	58	35	41	76	45	31	2
165	1800	732	148	94	107	201	113	49	76	51	1357	164	2424	114	266	168	193	361	204	137	1
166	2500	451	101	67	71	138	65	28	52	29	769	93	1374	64	254	167	177	345	163	130	2
167	2500	443	104	68	77	145	78	13	50	14	371	45	662	31	259	169	193	362	196	125	1
168	2400	446	111	70	78	148	76	8	50	8	217	26	388	18	266	168	188	356	182	119	1
169	300	448	116	71	72	142	64	40	47	42	1115	134	1991	93	35	21	22	43	19	14	1
170	2000	800	152	104	129	233	142	69	69	73	1917	231	3423	160	305	208	258	466	285	138	2
171	2400	381	97	63	68	130	68	21	41	22	585	70	1044	49	234	151	162	313	164	100	1
172	2300	398	108	65	72	137	72	16	51	17	440	53	785	37	248	150	166	316	166	117	2
173	400	435	121	76	90	166	92	51	55	54	1414	170	2525	118	48	30	36	66	37	22	1
174	300	717	170	96	98	193	103	72	73	76	1998	241	3567	167	51	29	29	58	31	22	1
175	2200	584	136	82	89	171	95	57	62	60	1578	190	2817	132	299	181	196	377	210	137	3

Table 1.1, cont.

Grid cell no.	Total area (km2)	Average precipitation amount (mm)	Total nss S dep. (mg S/m2 yr)	Total N (oxi) (mg N/m2 yr)	Total N (red) (mg N/m2 yr)	Total N (red+oxi) (mg N/m2 yr)	Total nss K (mg/m2 yr)	Total ss K (mg /m2 yr)	Total nss Ca (mg/m2 yr)	Total ss Ca (mg/m2 yr)	Total Na (mg/m2 yr)	Total Mg (mg/m2 yr)	Total Cl (mg/m2 yr)	Total ss S (mg S/m2 yr)	Total nss S deposition (ton S in grid)	Total N (oxi) deposition (ton N in grid)	Total N (red) deposition (ton N in grid)	Total N deposition (ton N in grid)	Total nss K deposition (ton K in grid)	Total nss Ca deposition (ton Ca in grid)	Number of meteorol. sites in grid
176	2340	547	142	80	86	165	95	37	61	38	1016	122	1815	85	333	187	200	387	222	142	1
177	1300	407	117	68	73	141	75	19	48	20	531	64	948	44	153	88	95	184	98	63	1
178	900	868	191	108	127	235	124	91	74	96	2542	306	4539	213	172	98	114	212	112	67	1
179	2300	486	136	73	74	147	75	55	54	58	1526	184	2725	128	312	168	170	338	173	123	2
180	2000	468	134	73	75	149	73	22	45	23	599	72	1069	50	267	146	151	297	145	89	2
181	1300	445	142	69	67	136	62	23	48	24	635	77	1135	53	184	89	87	176	81	63	1
182	1300	509	175	86	82	167	60	27	52	28	751	90	1341	63	227	111	106	218	78	67	1
183	300	793	225	108	100	207	105	89	68	94	2470	298	4411	207	67	32	30	62	31	20	1
184	1600	693	213	95	91	186	96	65	69	68	1808	218	3229	151	340	152	146	298	153	111	1
185	2500	522	166	78	70	148	70	52	57	55	1459	176	2606	122	416	194	175	369	176	141	1
186	2300	403	143	62	56	118	60	32	50	34	894	108	1596	75	328	142	130	272	137	116	2
187	1400	464	167	78	69	147	51	29	49	30	802	97	1432	67	234	109	97	206	72	69	3
188	400	717	229	97	95	192	99	82	72	87	2290	276	4090	192	91	39	38	77	39	29	1
189	1400	532	182	80	72	152	70	60	60	63	1673	202	2988	140	255	113	101	213	98	84	1
190	700	483	178	73	66	139	64	54	59	57	1508	182	2692	126	125	51	46	97	45	42	2
191	300	506	185	76	69	145	59	56	55	59	1558	188	2783	130	56	23	21	44	18	17	1
Sum															53724	62798	77524	140321	27360	32770	

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Tittel - norsk og engelsk
Avsetning av svovel og nitrogenforbindelser i Norge, 2007-2011
Deposition of major inorganic compounds in Norway, 2007- 2011

Sammendrag – summary
Avsetning av svovel og nitrogenforbindelser i Norge i perioden 2007-2011 er beregnet på basis av målinger av luft- og nedbørkjemi samt nedbørmengder. Avsetning av ikke-marine basekationer er også beregnet. Resultatene er sammenlignet med tidligere estimater for 2002-2006.
The total deposition of sulphur and nitrogen compounds in Norway during the period 2007-2011 has been estimated on the basis of available measurement data for concentrations and precipitation. Deposition of non-marine base cations is also estimated. Results are compared with previous estimates for 2002-2006.

4 emneord	4 subject words
Svovel	Sulphur
Nitrogen	Nitrogen
Bakgrunnsforurensning	Background air pollution
Grenseoverskridende luftforurensning	Transboundary air pollution

Statlig program for forurensningsovervåking

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www.klif.no

Om Statlig program for forurensningsovervåking

Statlig program for forurensningsovervåking omfatter overvåking av forurensningsforholdene i luft og nedbør, skog, vassdrag, fjorder og havområder. Overvåkingsprogrammet dekker langsiktige undersøkelser av:

- overgjødsling
- forsuring (sur nedbør)
- ozon (ved bakken og i stratosfæren)
- klimagasser
- miljøgifter

Overvåkingsprogrammet skal gi informasjon om tilstanden og utviklingen av forurensningssituasjonen, og påvise eventuell uheldig utvikling på et tidlig tidspunkt. Programmet skal dekke myndighetenes informasjonsbehov om forurensningsforholdene, registrere virkningen av iverksatte tiltak for å redusere forurensningen, og danne grunnlag for vurdering av nye tiltak. Klima- og forurensningsdirektoratet er ansvarlig for gjennomføringen av overvåkingsprogrammet.

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