Norsk institutt for luftforskning
Norwegian Institute for Air Research

Air Quality in Ny-Ålesund

Monitoring of Local Air Quality 2016-2017

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ABSTRACT

The concentrations of the measured components are generally low and below national limit values for the protection of human health and critical levels for the protection of vegetation.

Wind from northern sectors gave the highest average concentrations of nitrogen oxides and sulphur dioxide, which indicates the power station and the harbour as possible sources. The measurement results for CO_2 show an annual variation with higher concentrations in the winter and lower in summer. Measured concentrations of CO were most likely caused by local snowmobile traffic

NORWEGIAN TITLE

Luftkvalitet i Ny-Ålesund. Målinger av lokal luftkvalitet 2016-2017.

KEYWORDS

Air quality | Long-range transport of air pollutants | Polar regions

ABSTRACT (in Norwegian)

De målte konsentrasjonene var generelt lave for alle komponenter og under nasjonale grenseverdier for beskyttelse av menneskets helse og økosystemet.

Vind fra nordlige sektorer ga de høyeste gjennomsnittskonsentrasjonene av nitrogenoksider og svoveldioksid, noe som peker på kraftstasjonen og havnen som mulige kilder. Måleresultatene for CO_2 viser en årlig variasjon, med høyere konsentrasjoner om vinteren og lavere om sommeren. Kilder for de målte konsentrasjonene av CO var mest sannsynlig lokal snøskutertrafikk.

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Preface

The expressed mission of Ny-Ålesund is to serve as an international station for scientific research and monitoring. The activities are dependent on the near pristine environment and unique qualities of the Ny-Ålesund area, in particular research related to long range transported pollution, climate change and polar ecology.

Thus, it is essential to preserve the near pristine environment of the area and to keep local human environmental impacts at the lowest possible level so as not to jeopardise scientific research and monitoring. Ny-Ålesund is expected to be a prime example of the sustainable operation and development of a research station in the Polar Regions.

Comprehensive infrastructure and logistics are required to enable the extensive research activities in and around Ny-Ålesund. This cannot be done without any impact on the environment.

The project "Monitoring of Local Air Quality in Ny-Ålesund" ran from July 2008 until 2010. The main purpose of the project was to monitor a number of air pollutants to assess the impact of the activities in Ny-Ålesund on the environment and to detect possible influences on measurements in Ny-Ålesund and the nearby Zeppelin air-monitoring observatory.

Funding from the Svalbard Environmental Protection Fund made it possible to start up the project again, with the same type of measurements in the same location, in 2014 and continuing through 2015, to gather data for looking into changes since the previous project.

In 2016, NILU financed the continuation of the measurement program.

From 2017, contribution from Kings Bay AS has made it possible to establish the measurement activities on a more permanent basis, in connection with the project «Limits of Acceptable Change».

The contribution from Kings Bay AS includes providing the facilities needed for the instrumentation. Operation of instruments and samplers were carried out by the staff from the Norwegian Polar Institute at the Sverdrup station. The air samples were analysed at the chemical laboratory at NILU.

This report summarises the monitoring activities in 2016-2017 and presents the measurements and the results from the first comparisons with earlier measurements.

The measurement results will be freely available for scientists and others for use in further studies in the region.

Contents

Summary

NILU Norwegian Institute for Air Research are monitoring air quality and meteorology at the measurement station Nordpolhotellet in Ny-Ålesund, Spitsbergen. The main purpose of the project is to assess the impact of the activities in Ny-Ålesund and to detect possible influences on measurements in Ny-Ålesund and the nearby Zeppelin observatory.

The concentrations of the measured components are generally low and below national limit values for the protection of human health and critical levels for the protection of vegetation.

The highest average concentrations of nitrogen oxides and sulphur dioxide were measured with wind from northern sectors, which indicates the power station and the harbour as possible sources. The highest hourly sulphur-dioxide concentration was however measured during an episode most likely caused by long-range transport.

The measurement results for CO_2 show an annual variation with higher concentrations in the winter and lower in late summer. The maximum hourly concentration in the period was measured in April 2017 and the minimum in July 2016.

Measurements of CO gave higher concentrations in the spring, most likely caused by snowmobile traffic close to the station.

Total deposition of sulfur and nitrogen at Ny-Ålesund is estimated (Aas et al., 2017 and 2018) to be lower than on the Norwegian mainland, but may have an impact on biology in this pristine arctic environment.

Air Quality in Ny-Ålesund
Monitoring of Local Air Quality 2016-2017

1 Background

NILU have been measuring air quality and meteorological parameters at the measurement station Nordpolhotellet in Ny-Ålesund since June 2014. A corresponding measurement program was carried out at the same location in 2008-2010 (Hermansen et al., 2011). The purpose then and now is to investigate air pollution from local sources such as car traffic, the power station, boat traffic etc. Measurement results can be used to look at possible environmental impact from all activities in the area and to investigate any influence on scientific measurement activities in Ny-Ålesund and its surroundings. The measurement results from 2014-2015 are described in a previous report (Johnsrud et al., 2016).

The measurement results will be freely available for scientists and others for use in further studies in the region. This report gives an overview of the measurement program and a brief statistical summary of the results.

2 Measurement program

The measurement program is summarized in Table 1.

Table 1: Measurement program at Nordpolhotellet in Ny-Ålesund.

Compound	Description	Sampler	Time resolution
$NO/NO_2/NO_x$	Nitrous oxides	Continuous monitor, API	1 hour
SO_2	Sulphur dioxide	Continuous monitor, API	1 hour
Picarro	Carbon monoxide, carbon dioxide	Continuous monitor, Picarro	1 hour
Main inorganic compounds	Gaseous and particle bound inorganic compounds; HNO_3/NO_3^-, NH_4^+/NH_3, SO_2, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCl	Filter sampler, EK	1 week
Particles and soot		PSAP	
Meteorology	Temperature, wind direction, wind speed, relative humidity, barometric pressure, precipitation intensity	Automatic weather station, Vaisala	1 hour

3 Measurement station

The measurement station is located close to the center of Ny-Ålesund, slightly downwind, to provide representative measurements of the air quality in Ny-Ålesund. The location of the measurement station is shown in Figure 1. Data from the Zeppelin mountain observatory for advanced scientific measurements south of Ny-Ålesund, are also included in some figures.

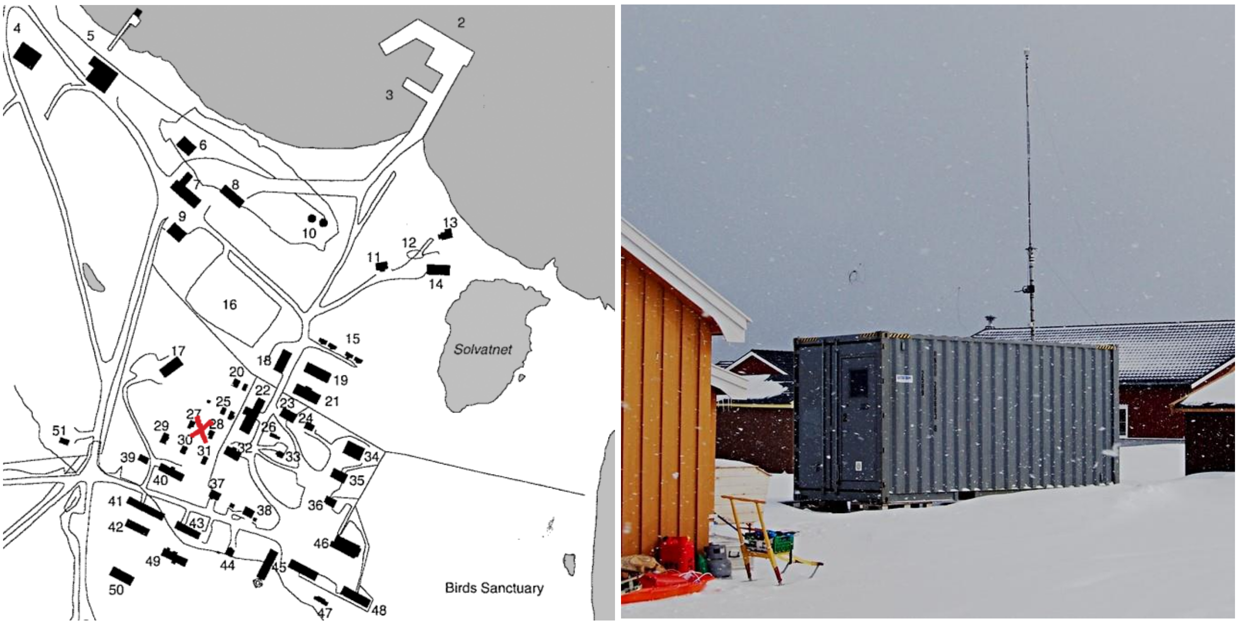

Figure 1: Location of the measurement station Nordpolhotellet in Ny-Ålesund.

4 Results

4.1 Data capture

For the two calendar years 2016 and 2017 the data capture was generally good, but there were a few periods missing data as summarised in Table 2.

Table 2: Periods of missing data (24 or more consecutive hours) from Nordpolhotellet January 2016 to December 2017.

Compound/sampler	Periods missing data	Reason
$NO/NO_2/NO_x$, monitor	23-26.6.2016 12-17.10.2016	Instrument failure Logger failure
SO_2, monitor	26.4.-2.5.2016 1-3.6.2016 4-13.6.2016 12-17.10.2016	Temperature too high Temperature too high Instrument failure Logger failure
CO, CO_2, Picarro	3-9.3.2016 11-13.3.2016 29.4-23.5.2016 24-25.5.2016 15-17.6.2016 20-26.6.2016 14-19.10.2016	
Main inorganic compounds, filter sampler	NH_3 and sum NH_4: 1-4.1.2016 SO_2, NO_3 and sum NO_3: 11-18.12.2017	
Particles and soot	Data not available for this report	Analysis not yet ready
Meteorology: Temperature, relative humidity, barometric pressure, precipitation intensity	12-17.10.2016 20-23.11.2017	Logger failure Power break
Meteorology: Wind speed, wind direction	Partially 21-31.8. and 13-24.9.2016 12-17.10.2016 20-23.11.2017	 Logger problems Logger failure Power break

4.2 Meteorology

Frequency of wind from 12 30-degrees sectors (wind roses) from Nordpolhotellet and Zeppelin mountain are presented in Figure 2. At Nordpolhotellet the prevailing wind direction is from east-southeast and the highest wind speeds are also registered from this sector. At Zeppelin mountain the wind direction is more from south and south-easterly directions than in Ny-Ålesund.

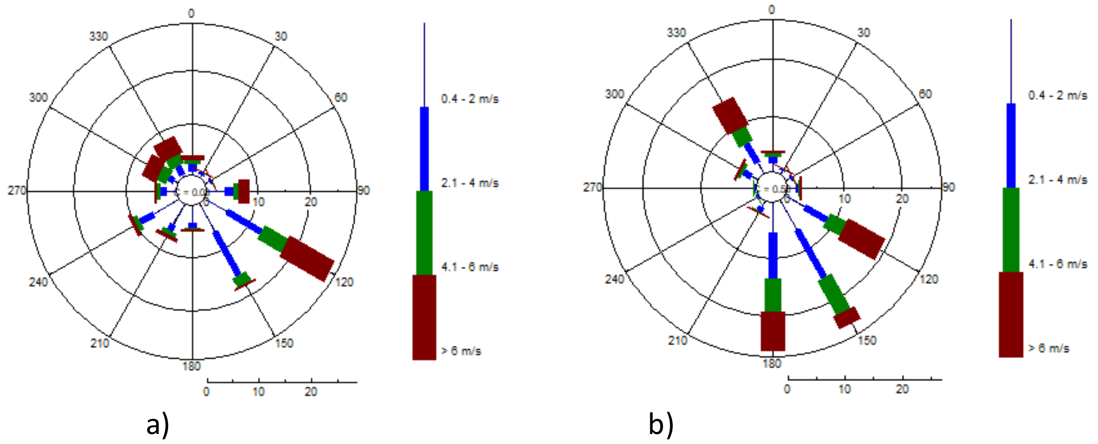

Figure 2: Wind roses from the measurement stations at Nordpolhotellet (a) and Zeppelin mountain (b) from January 2016 to December 2017.

Monthly average, maximum and minimum temperature from Nordpolhotellet are presented in Figure 3. The figure also shows monthly average temperatures at Zeppelin mountain as well as the monthly normal temperatures 1961-1990 from Ny-Ålesund given by DNMI.

The temperatures at Zeppelin mountain and Nordpolhotellet show similar variation during the period, with the monthly average temperatures at the mountain some degrees colder than down in Ny-Ålesund. For the entire period the monthly average temperatures at Nordpolhotellet were higher than the normal temperatures. The largest deviation was measured in January 2016, with 10˚C higher monthly average temperature than the normal.

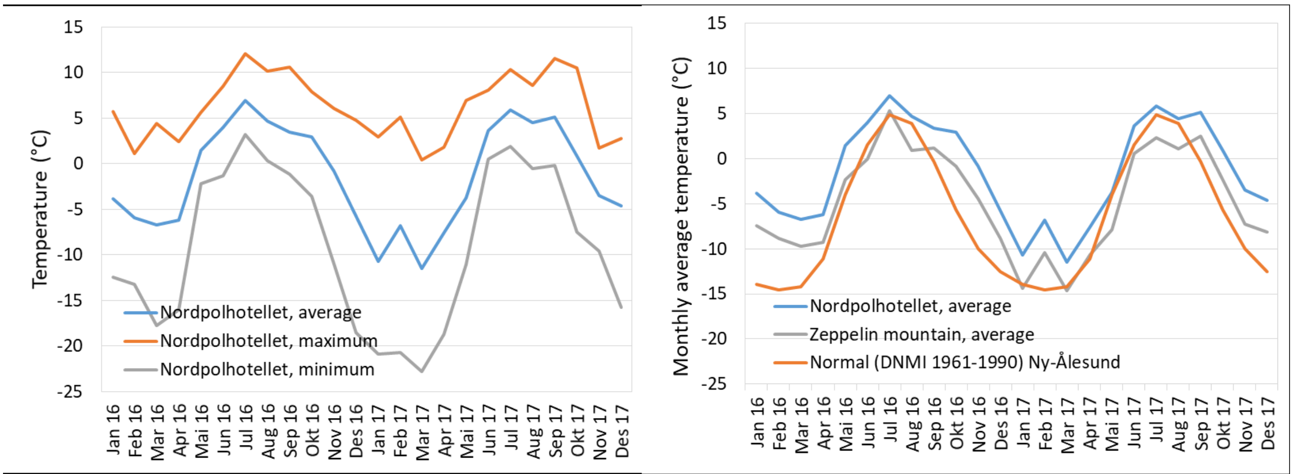

Figure 3: Monthly temperature statistics from Ny-Ålesund and Zeppelin mountain from January 2016 to December 2017.

4.3 Nitrogen oxides

Hourly concentrations of nitrogen oxides and nitrogen dioxide are shown as time series plots in Appendix A. Measurements of nitrogen dioxide are summarized in Table 3.

Table 3: Summary of hourly measurements of NO_2 at Nordpolhotellet January 2016 to December 2017.

Year	Month	Data coverage (%)	Average (µg/m³)	Maximum (µg/m³)	Time for maximum
2016	January	100	0.5	20.4	02.01.2016 16:00
	February	99	0.6	11.6	09.02.2016 12:00
	March	99	1.1	27.0	28.03.2016 10:00
	April	99	0.8	12.2	30.04.2016 23:00
	May	99	0.3	24.7	03.05.2016 11:00
	June	85	1.4	41.9	28.06.2016 15:00
	July	100	1.1	48.2	26.07.2016 16:00
	August	100	1.3	35.3	21.08.2016 16:00
	September	99	1.3	23.1	09.09.2016 01:00
	October	83	0.6	20.9	19.10.2016 09:00
	November	100	0.5	29.5	26.11.2016 10:00
	December	100	1.1	29.1	04.12.2016 23:00
2017	January	99	2.7	30.9	19.01.2017 10:00
	February	99	2.6	42.2	12.02.2017 17:00
	March	100	2.7	36.1	16.03.2017 21:00
	April	100	0.7	31.3	28.04.2017 18:00
	May	100	0.6	31.8	29.05.2017 21:00
	June	98	1.6	50.3	25.06.2017 13:00
	July	99	2.7	60.2	29.07.2017 14:00
	August	99	1.7	42.2	05.08.2017 14:00
	September	100	0.8	23.4	29.09.2017 15:00
	October	100	1.8	34.7	10.10.2017 23:00
	November	99	0.7	37.7	27.11.2017 17:00
	December	100	2.6	57.8	22.12.2017 09:00

The NO_2-concentrations are generally very low compared to measurements in cities and agglomerations. The highest monthly average was measured to 2.7 µg/m³ in March 2017. There are some episodes where the concentrations are elevated compared to the average concentrations at the station. The highest hourly average, measured to 60.2 µg/m³, was registered on 29 July 2017 from 13-14 hours. Observations from this episode are shown in Figure 4 with simultaneous SO_2 and wind direction measurements. The figure also shows ship activity counted as number of vessels arriving or departing at an approximate time. The figure shows that the maximum concentration occurred with wind from north and with some activity in the harbour.

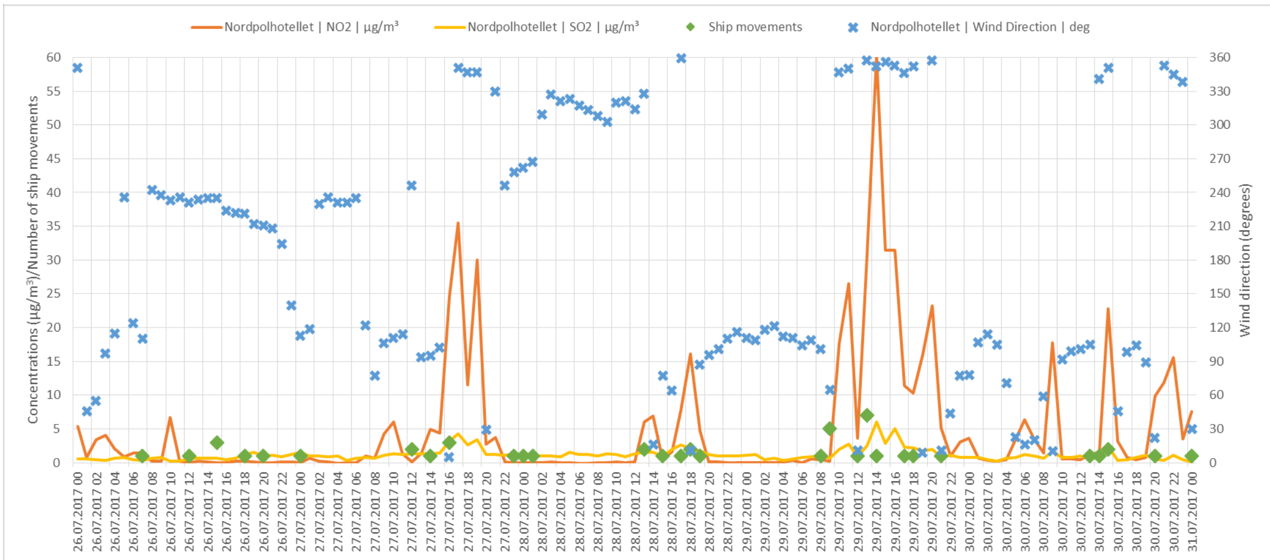

Figure 4: Hourly average concentrations of NO_2 and SO_2 and hourly registrations of wind direction at Nordpolhotellet on 26-30 July 2017. The graph also show approximate time for ship movements in the harbour.

Both the harbour and the power station are located north of the measurement station and may be possible sources for the measured concentrations.

Average concentrations of NO_x and NO_2 from 12 wind direction sectors at Nordpolhotellet for the two-year period 2016-2017 are shown in Figure 5 and Figure 6 respectively. The figures illustrates that the highest average concentrations occurs with wind from northern directions.

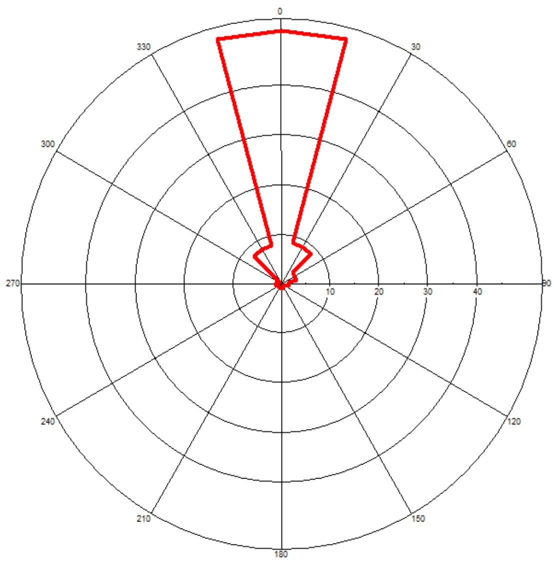

Figure 5: Average concentrations of NO_x ($\mu g/m^3$) with wind from 12 30-degrees sectors at Nordpolhotellet, January 2016 to December 2017.

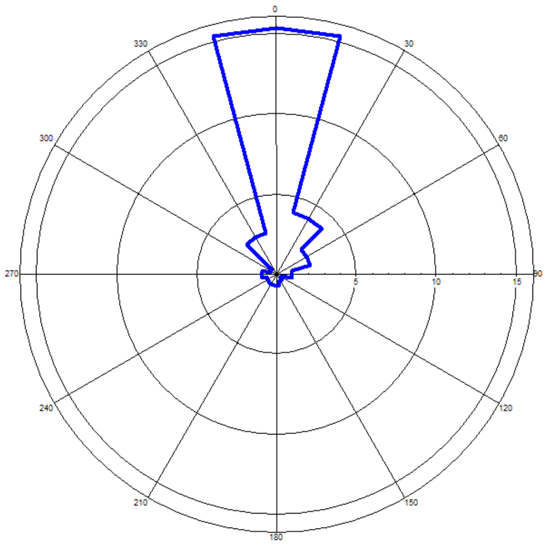

Figure 6: Average concentration of NO_2 ($\mu g/m^3$) with wind from 12 30-degrees sectors at Nordpolhotellet, January 2016 to December 2017.

4.4 Sulphur-dioxide (SO_2)

At Nordpolhotellet, SO_2 is measured with two different methods, a filter sampler giving weekly averages, and a continuous monitor giving hourly averages. It is expected that the SO_2-concentrations measured with weekly filter sampling will differ from the concentrations measured with the continuous monitor. The concentrations are generally low and the filter sampling method is more accurate than the continuous monitor at such low concentrations. The disadvantage of the filter sampling method compared to the continuous monitor is the time resolution. The method gives no information on when episodes of higher concentrations occur within the weekly sampling period.

Most of the time the values are close to, or below, the detection limit of the continuous monitor and the uncertainty of the method is high at this low concentration level. The method is however good at capturing episodes of higher concentrations which is why the instrumentation is included in the program. The higher time resolution of results, as given by the continuous monitor, is especially important when studying impact from sources that are active for short periods of time and/or close to the measurement station.

Hourly concentrations of sulphur dioxide are shown as time series plots in Appendix A. Measurements of sulphur dioxide are summarized in Table 4.

Table 4: Summary of measurements of SO_2 at Nordpolhotellet January 2016 to December 2017. When monthly data coverage is below 75% no statistics are calculated.

Year	Month	Data coverage (%) (monitor)	Average (µg/m³) (monitor)	Maximum (µg/m³) (monitor)	Time for maximum (monitor)	Average (µg/m³) from filter sampler
2016	January	99	0.4	2.1	12.01.2016 00:00	0.07
	February	99	0.3	6.7	03.02.2016 18:00	0.27
	March	99	0.9	4.6	24.03.2016 04:00	0.38
	April	85	0.9	3.6	19.04.2016 06:00	0.23
	May	89	1.8	4.2	30.05.2016 18:00	0.02
	June	60	-	-	-	0.02
	July	99	0.1	4.3	26.07.2016 16:00	0.04
	August	98	0.2	4.0	21.08.2016 16:00	0.04
	September	98	1.0	2.7	18.09.2016 23:00	0.05
	October	82	0.9	2.8	01.10.2016 13:00	0.02
	November	98	1.2	4.9	14.11.2016 21:00	0.02
	December	97	0.8	3.8	21.12.2016 14:00	0.03
2017	January	99	0.6	4.0	30.01.2017 05:00	0.17
	February	98	0.7	13.2	23.02.2017 05:00	0.40
	March	99	1.4	9.5	21.03.2017 13:00	0.14
	April	97	0.1	3.9	28.04.2017 18:00	0.53
	May	97	0.2	2.7	31.05.2017 16:00	0.06
	June	98	-0.1	3.4	25.06.2017 16:00	0.03
	July	99	0.8	6.0	29.07.2017 14:00	0.03
	August	99	-0.3	4.4	05.08.2017 15:00	0.03
	September	97	-0.7	1.1	23.09.2017 13:00	0.04
	October	98	1.1	5.4	30.10.2017 10:00	0.01
	November	97	1.1	3.8	03.11.2017 23:00	0.05
	December	99	1.7	8.7	22.12.2017 09:00	0.10

The highest monthly average SO_2-concentrations based on the filter sampling results were found from mid-winter to spring with the maximum measured in April 2017 to 0.53 µg/m³. The highest monthly average, based on the hourly measurements, was 1.8 µg/m³ in May 2016, but this value is very uncertain.

The highest hourly SO_2-concentrations were measured in the evening of the 22nd and the early morning of the 23rd of February 2017 with 13.2 µg/m³ as the highest concentration at 04-05 hours. At this time there was at gentle breeze from north-northeast and an ambient temperature of -12.1 ˚C. There were no registered harbour activity or ship traffic. We can also see elevated SO_2-concentrations in the weekly filter sample covering these hours, as well as the daily filter sample from Zeppelin mountain, which indicates that this may be an episode of long-range transport. We can even see elevated CO_2-concentrations during this episode. The trajectory plots from this period, as visualised in Figure 7, show transport of air masses from Siberia, east of the Ural mountains.

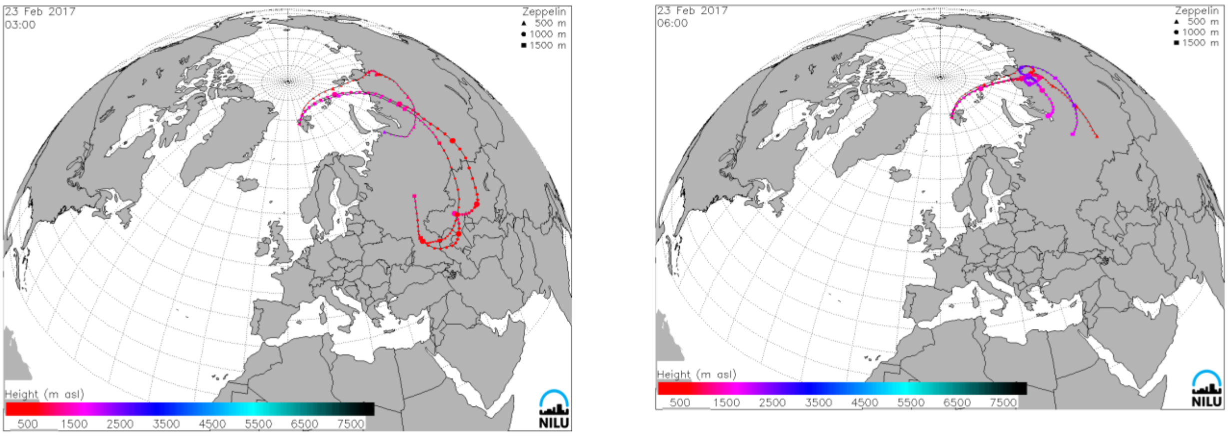

Figure 7: Trajectory plots for Zeppelin mountain, Ny-Ålesund, for the early morning of 23. February 2017.

Average concentrations of SO_2 for January 2016 to December 2017 from 12 wind direction sectors at Nordpolhotellet for the two-year period 2016-2017 are shown in Figure 8. The highest average concentrations occurs with wind from north and northerly directions.

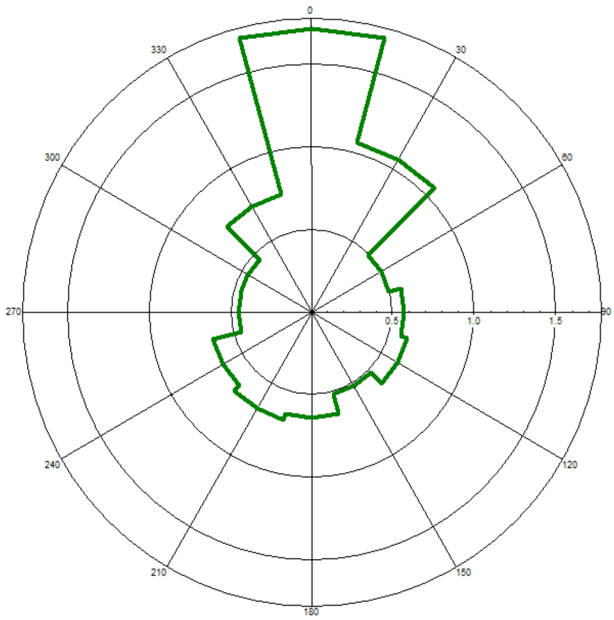

Figure 8: Average concentration of SO_2 ($\mu g/m^3$) with wind from 12 30-degrees sectors at Nordpolhotellet, January 2016 to December 2017.

4.5 Carbon-monoxide (CO) and carbon-dioxide (CO_2)

Hourly concentrations of carbon-monoxide and carbon-dioxide measured with the Picarro instrument at Nordpolhotellet are shown as time series plots in Appendix A, along with simultaneous measurements with the same method at Zeppelin mountain.

The measurement results for CO_2 show an annual variation with higher concentrations during the winter and lower in late summer. The maximum hourly concentration at Nordpolhotellet was measured to 421 ppm on 28 April 2017 and the minimum hourly concentration was measured to 390 ppm on 20 July 2016.

The CO-measurements at Nordpolhotellet show the highest concentrations and more variation in the hourly results in the spring, with the maximum measured to 637 ppb at 6 April 2017. Hourly data from April 2017 are shown in Figure 9. The higher concentrations are measured during daytime and are most likely caused by human activity with snowmobiles in the vicinity of the measurement station. The data from Zeppelin mountain does not show these elevated daytime concentrations.

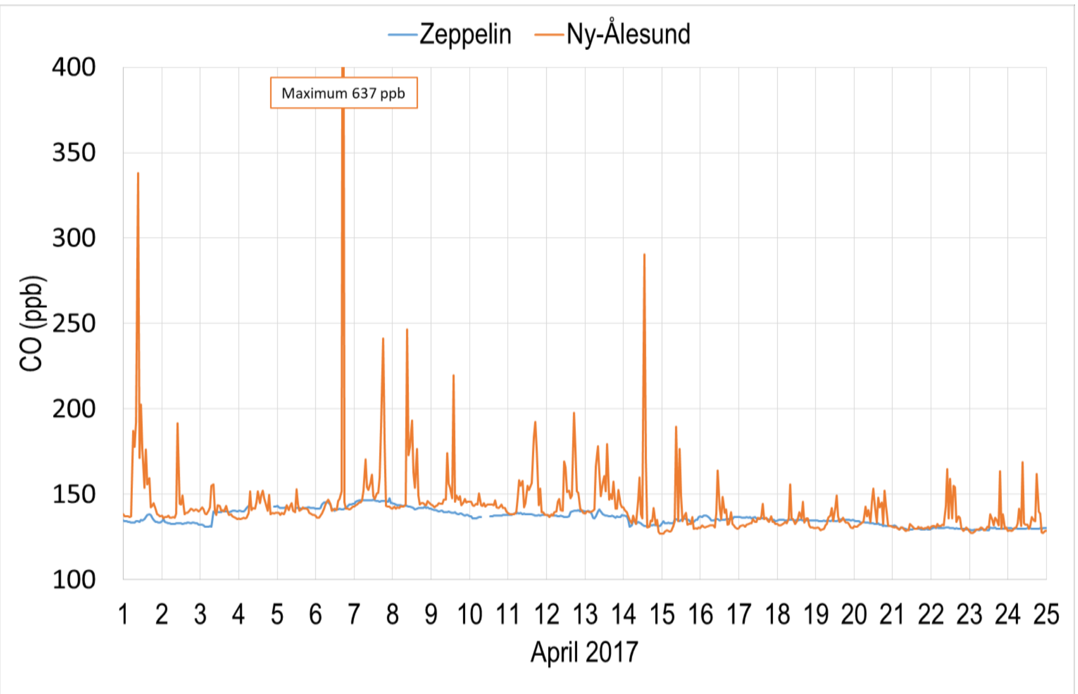

Figure 9: Hourly average concentrations of CO (ppb) from Ny-Ålesund and Zeppelin from 1- 25 April 2017.

4.6 Filter sampling of inorganic compounds

Main inorganic compounds are measured with a filter sampler on a weekly basis. A summary of the results are given in Table 5.

Table 5: Monthly averages of main components in air measured at Nordpolhotellet January 2016 to December 2017. Concentrations are given in µg/m³.

Year	Month	SO_2	SO_4-S	Sum NO_3-N	Sum NH_4-N	Mg	Ca	K	Cl	Na
2016	January	0.07	0.16	0.02	0.06	0.08	0.04	0.04	0.83	0.65
	February	0.27	0.26	0.03	0.07	0.10	0.06	0.05	1.02	0.73
	March	0.38	0.24	0.03	0.08	0.07	0.04	0.03	0.42	0.53
	April	0.23	0.31	0.03	0.09	0.04	0.03	0.02	0.31	0.30
	May	0.02	0.15	0.11	0.15	0.07	0.04	0.03	0.76	0.52
	June	0.02	0.12	0.03	0.08	0.06	0.06	0.02	0.51	0.34
	July	0.04	0.10	0.03	0.17	0.07	0.09	0.03	0.64	0.55
	August	0.04	0.07	0.01	0.11	0.07	0.06	0.03	0.86	0.46
	September	0.05	0.08	0.02	0.13	0.06	0.05	0.02	0.73	0.46
	October	0.02	0.12	0.02	0.06	0.12	0.08	0.05	1.52	0.91
	November	0.02	0.08	0.01	0.04	0.07	0.05	0.02	0.94	0.50
	December	0.03	0.11	0.01	0.05	0.10	0.06	0.05	1.23	0.62
2017	January	0.17	0.16	0.02	0.05	0.10	0.04	0.04	1.17	0.74
	February	0.40	0.21	0.03	0.06	0.13	0.06	0.05	1.53	0.99
	March	0.14	0.30	0.03	0.08	0.06	0.20	0.03	0.48	0.42
	April	0.53	0.26	0.02	0.08	0.12	0.25	0.05	1.15	0.60
	May	0.06	0.24	0.03	0.09	0.05	0.04	0.02	0.52	0.36
	June	0.03	0.14	0.05	0.31	0.07	0.09	0.02	0.52	0.34
	July	0.03	0.10	0.03	0.17	0.06	0.07	0.02	0.51	0.35
	August	0.03	0.08	0.02	0.10	0.07	0.06	0.02	0.84	0.49
	September	0.04	0.20	0.04	0.10	0.09	0.07	0.04	1.26	0.83
	October	0.01	0.12	0.02	0.07	0.08	0.21	0.02	0.67	0.50
	November	0.05	0.07	0.00	0.03	0.07	0.15	0.02	0.47	0.36
	December	0.10	0.10	0.02	0.03	0.09	0.13	0.04	0.74	0.51

The SO_2-concentrations are discussed further in chapter 4.4.

The highest monthly average SO_4-concentrations were found from mid-winter to spring with the maximum measured in April 2016. The nitrate and ammonium concentrations shows a different yearly variation with higher values in the spring and summer months. The highest monthly average nitrate concentration was found in May 2016 and the highest monthly average ammonium concentration in June 2017.

The highest monthly concentrations of the sea-salt components magnesium, sodium and chloride were found in February 2017, while the highest calcium concentration was found in April the same year. The highest monthly average potassium concentration was found for five different months, including February and April 2017.

5 Comparison with previous years

Monthly maximum SO_2-concentrations from 2008 to 2010 and 2014 to 2017 are presented in Figure 10 and monthly average SO_2-concentrations from the same years are presented in Figure 11. The highest hourly concentrations occur in the period September 2014 to January 2015, which coincides with the volcanic eruption at Holuhraun, Iceland. Apart from this period, the highest hourly concentrations seems to be in winter and early summer months, with the maximum in February 2017. For all years with measurements, except for the period when the measurements were influenced by the volcanic eruptions, the months January to April had the highest monthly average concentrations of SO_2, with the maximum in April 2017.

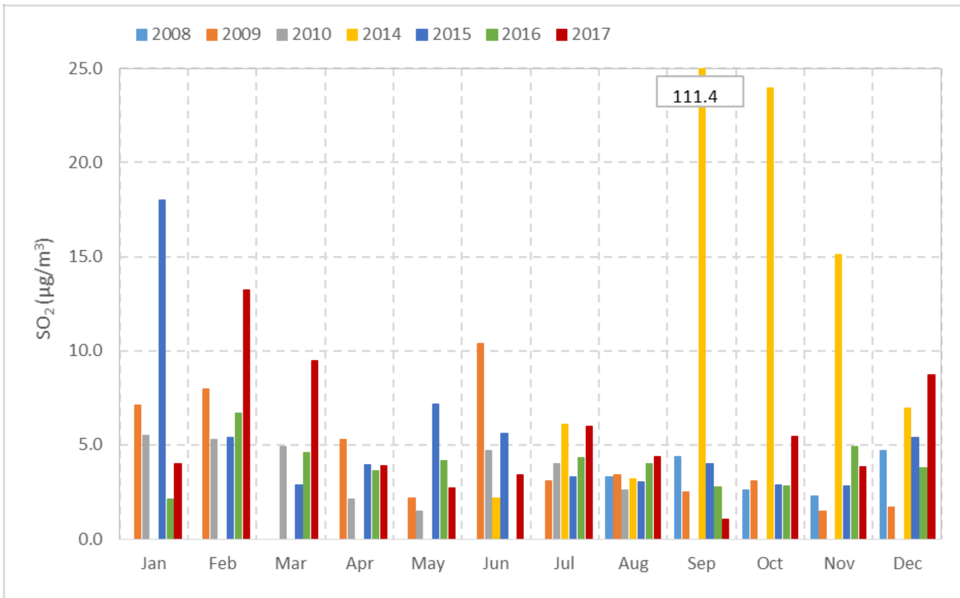

Figure 10: Monthly maximum hourly SO_2-concentrations from Nordpolhotellet for 2008-2010 and 2014-2017. Data from continuous monitor.

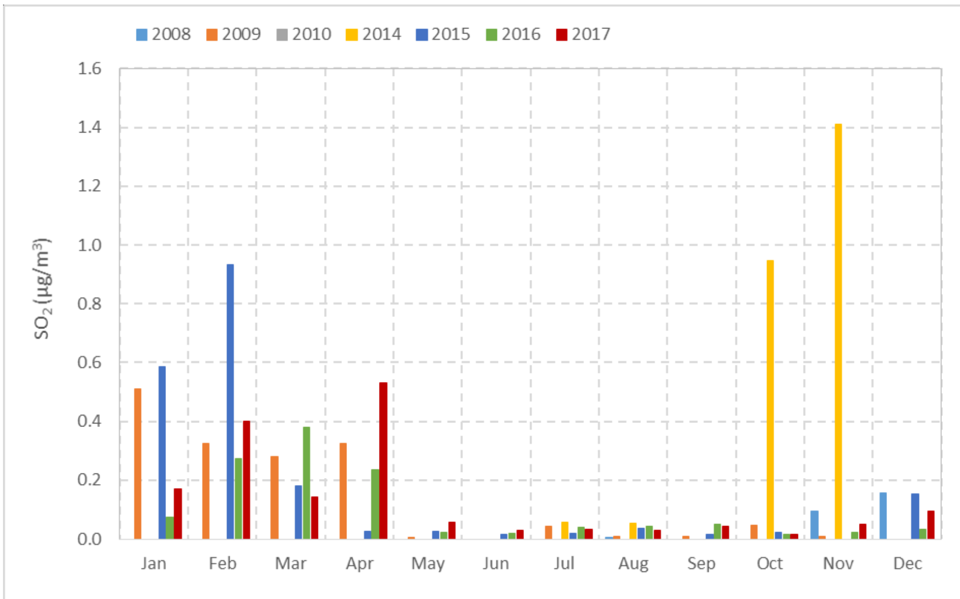

Figure 11: Monthly average SO_2-concentrations at Nordpolhotellet 2008-2010 and 2014-2017. Data from filter sampler.

Monthly maximum NO_2-concentrations from 2008-2010 and 2014-2017 are presented in Figure 12 and monthly average NO_2-concentrations from the same period are presented in Figure 13.

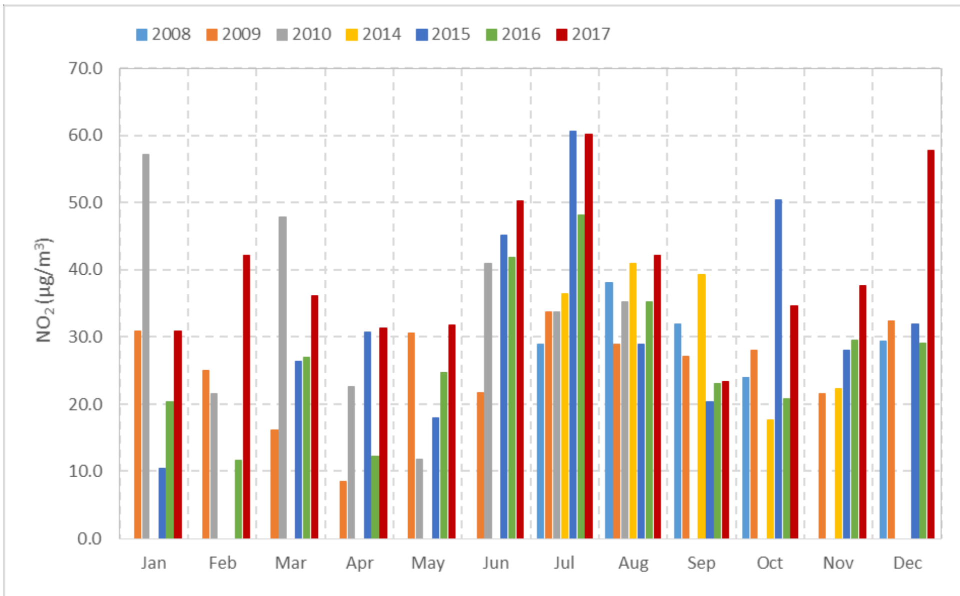

Figure 12: Monthly maximum hourly NO_2-concentrations at Nordpolhotellet for 2008-2010 and 2014-2017. Data from continuous monitor

The highest hourly concentration was measured in July 2015, but also July and December 2017 had high maximum hourly values.

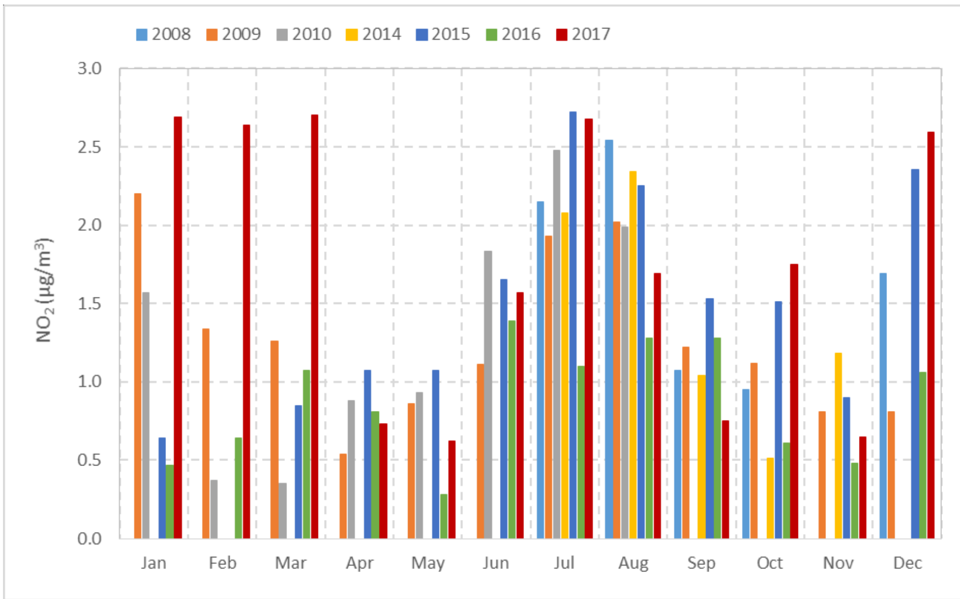

Figure 13: Monthly average NO_2-concentrations at Nordpolhotellet for 2008-2010 and 2014-2017. Data from continuous monitor

The monthly average NO_2 concentrations seems to have a yearly variation with higher averages in the summer months July and August, and the winter months December and January. For 2017, the average concentrations are in general somewhat higher than the previous years and show a different pattern, with elevated monthly average concentrations also in February and March. This may be explained by a change in the wind-pattern. As shown in Figure 14, during the months January to March in 2017 the frequency of wind from north and north-northwest were higher than during the same months the previous years.

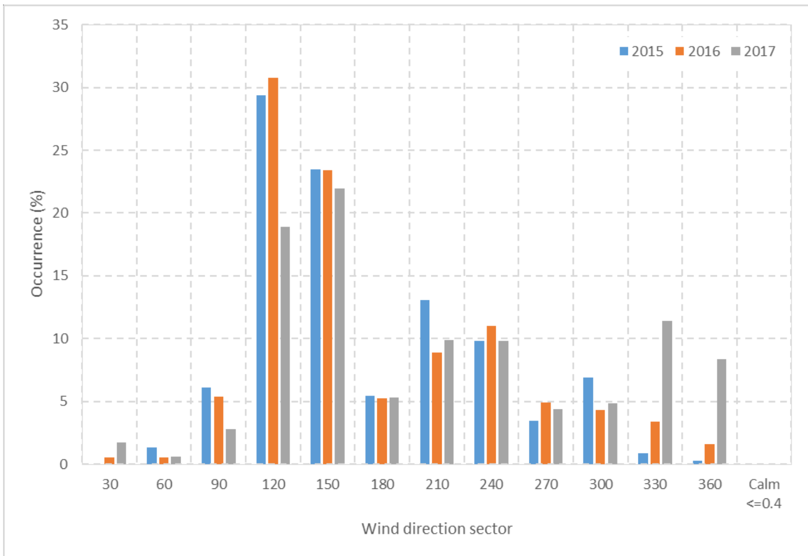

Figure 14: Frequency (% of the time) of wind from 12 30-degrees wind direction sectors at Nordpolhotellet for the period January to March for the years 2015 to 2017.

6 Deposition

Aas et.al. (2017 and 2018) present yearly estimates of the total dry deposition and the measured wet deposition of sulfur and nitrogen compounds at Norwegian background stations, as shown in Figure 15 and Figure 16. The values given for Ny-Ålesund consist of estimated values for dry deposition, based on the concentrations measured at Zeppelin mountain, and wet deposition measured at the Sverdrupstation in Ny-Ålesund. The figures illustrate the decrease in deposition load moving from Birkenesobservatoriet in southern Norway to Svalbard in the far north.

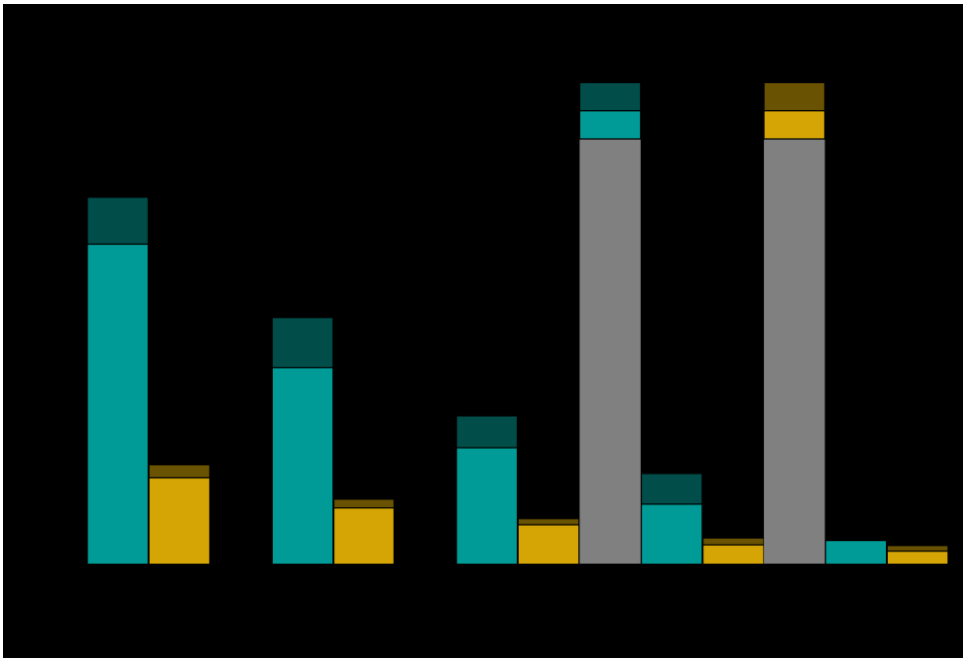

Figure 15: Total deposition (wet+ dry) of sulfur-S (SO_2, SO_4^{2-}) and nitrogen-N (NO_2, NH_4^+, NH_3, NO_3^-, HNO_3) at Norwegian background stations 2016 (Aas et al., 2017, Figure 3.5)

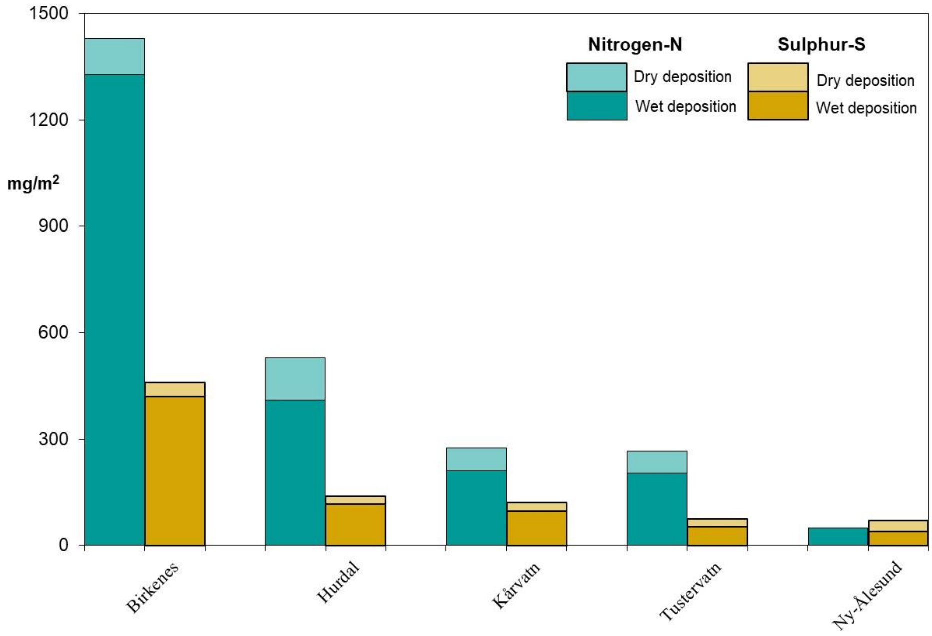

Figure 16: Total deposition (wet+ dry) of sulfur-S (SO_2, SO_4^{2-}) and nitrogen-N (NO_2, NH_4^+, NH_3, NO_3^-, HNO_3) at Norwegian background stations 2017 (Aas et al., 2018, Figure 3.5)

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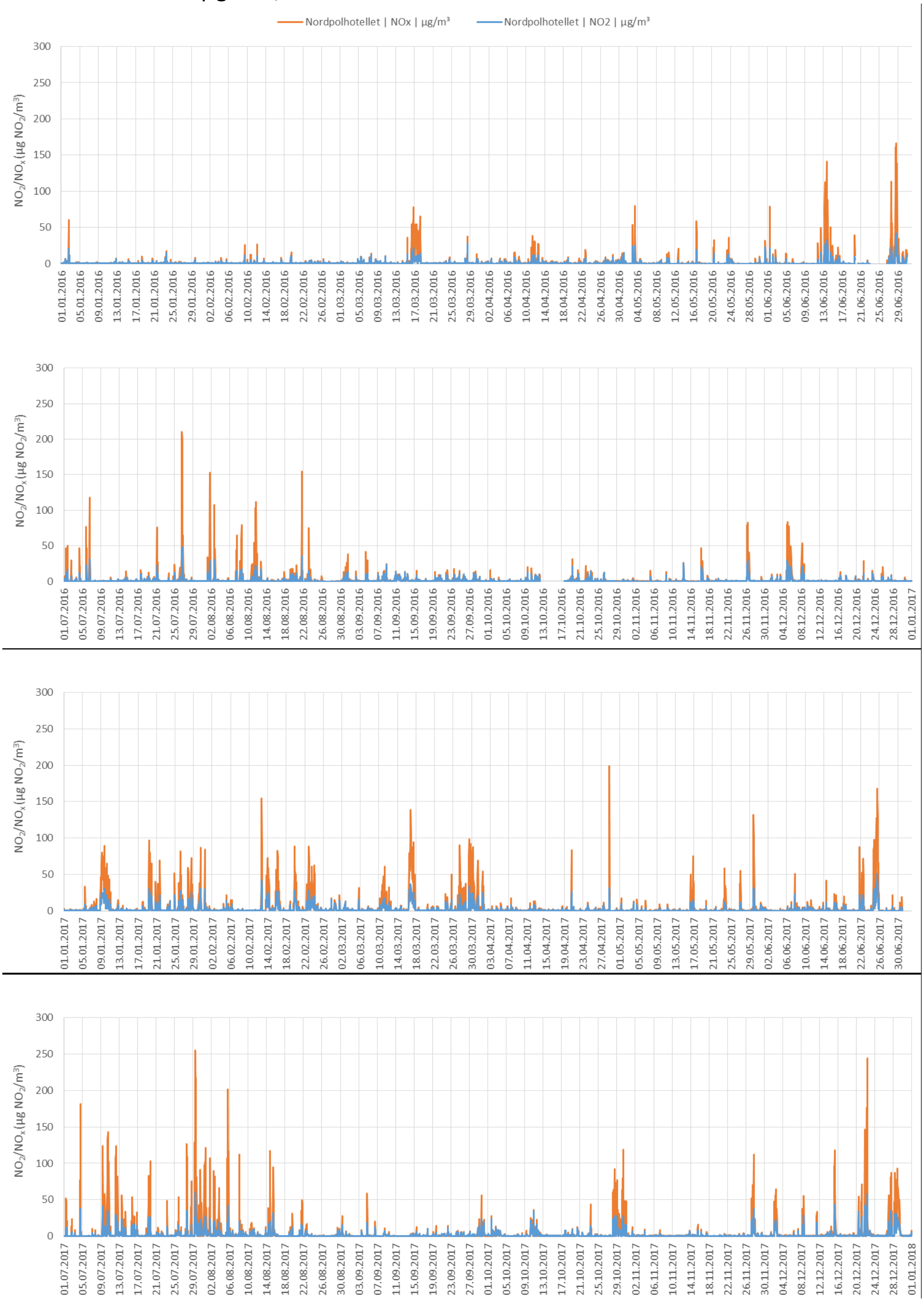
Aas, W., Fiebig, M., Solberg, S., Yttri, K.E. (2018) Monitoring of long-range transported air pollutants in Norway, Annual Report 2017. Kjeller, NILU (Miljødirektoratet rapport, M-1064/ 2018) (NILU report, 10/2018).

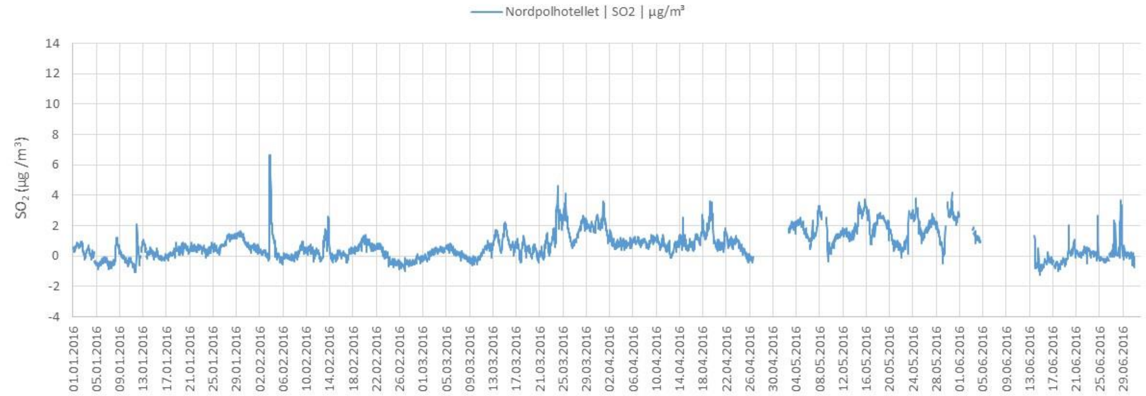
Appendix A

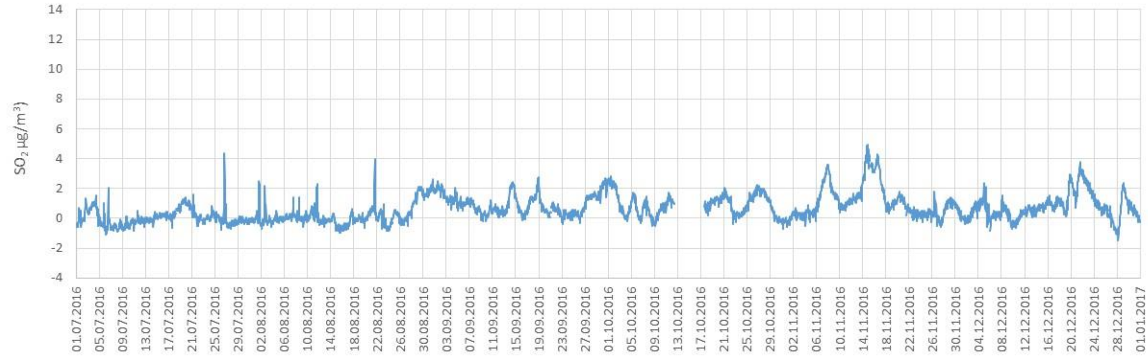
Measurement data

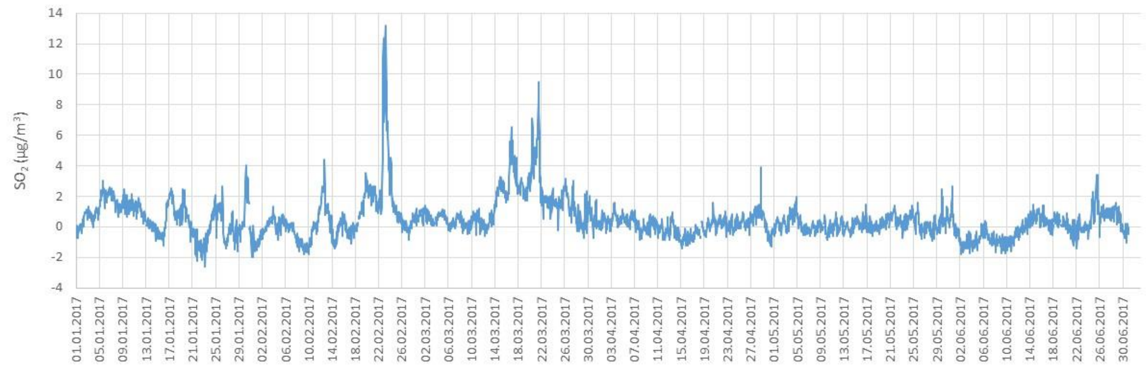
Hourly measurement data for NO_x and NO_2 at Nordpolhotellet, Ny-Ålesund 1.1.2016-31.12.2017. NO_x as µg NO_2/m^3.

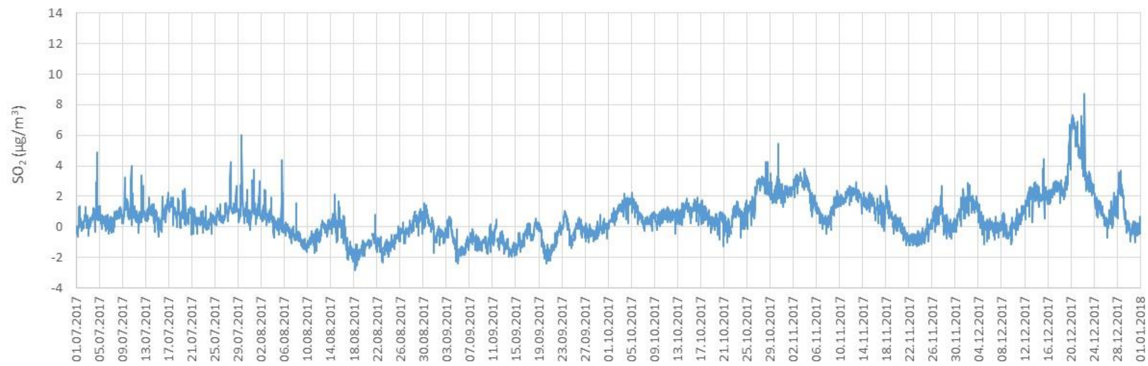


Hourly measurement data for SO_2 at Nordpolhotellet, Ny-Ålesund 1.1.2016-31.12.2017.

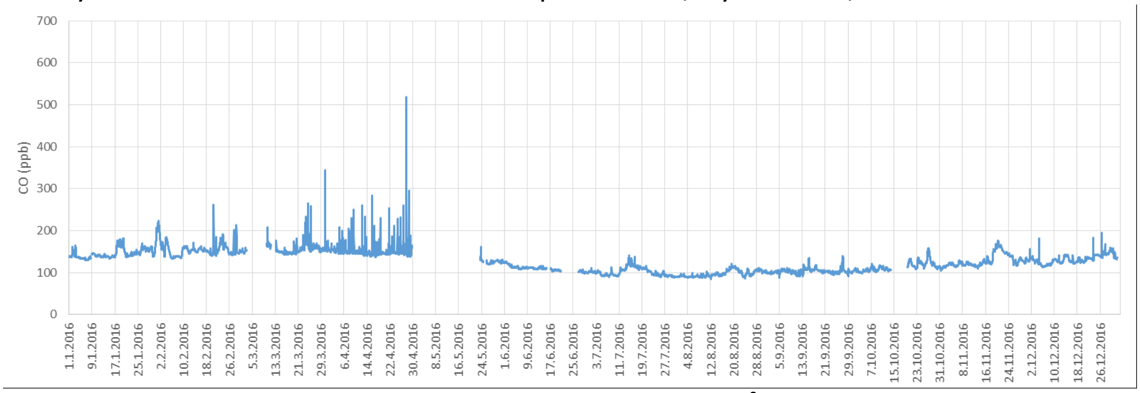




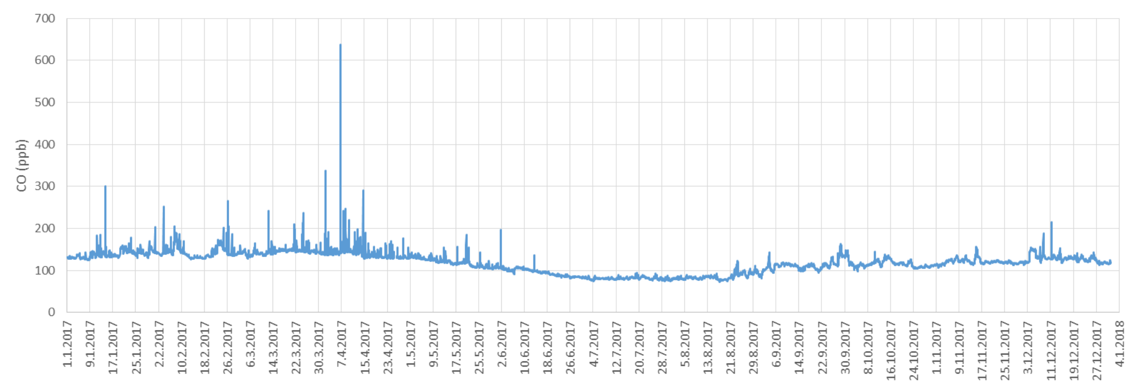




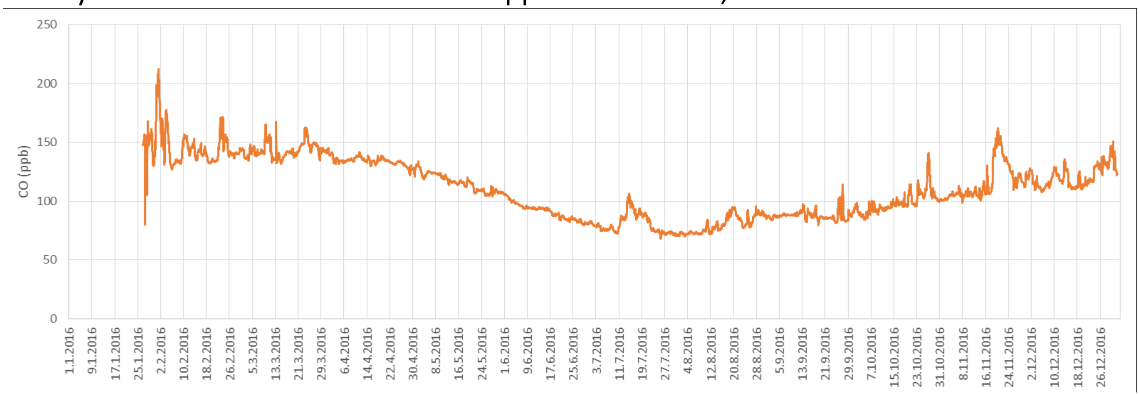
Hourly measurement data for CO at Nordpolhotellet, Ny-Ålesund, 1.1.-31.12.2016.



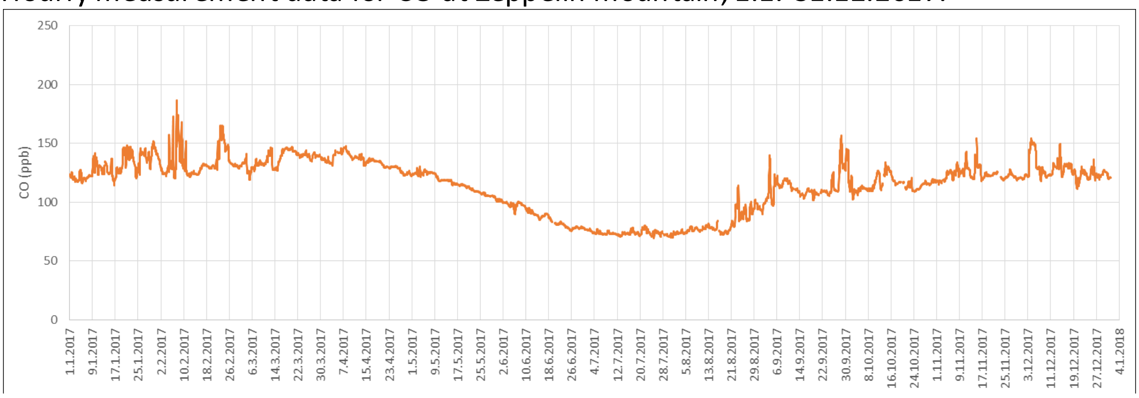
Hourly measurement data for CO at Nordpolhotellet, Ny-Ålesund, 1.1.-31.12.2017.



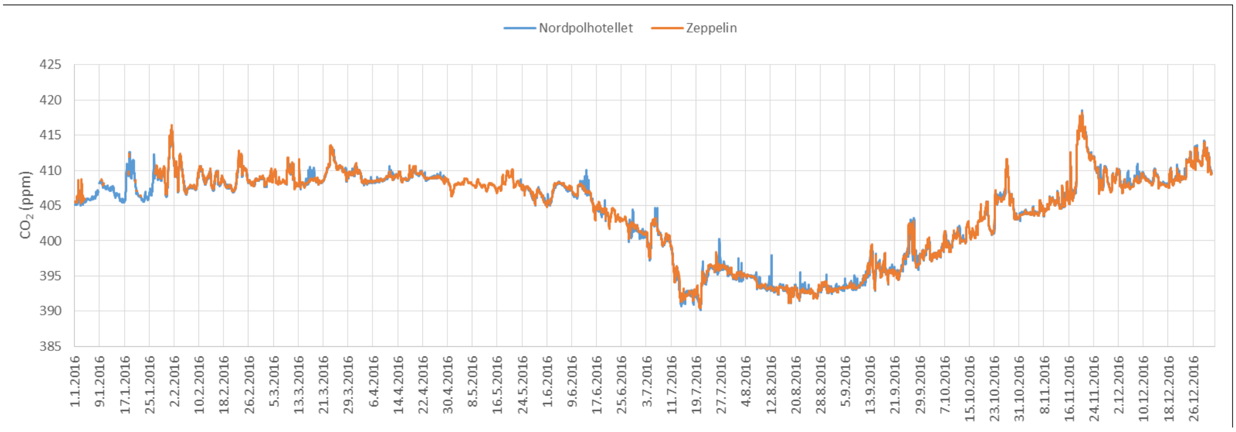
Hourly measurement data for CO at Zeppelin mountain, 1.1.-31.12.2016.



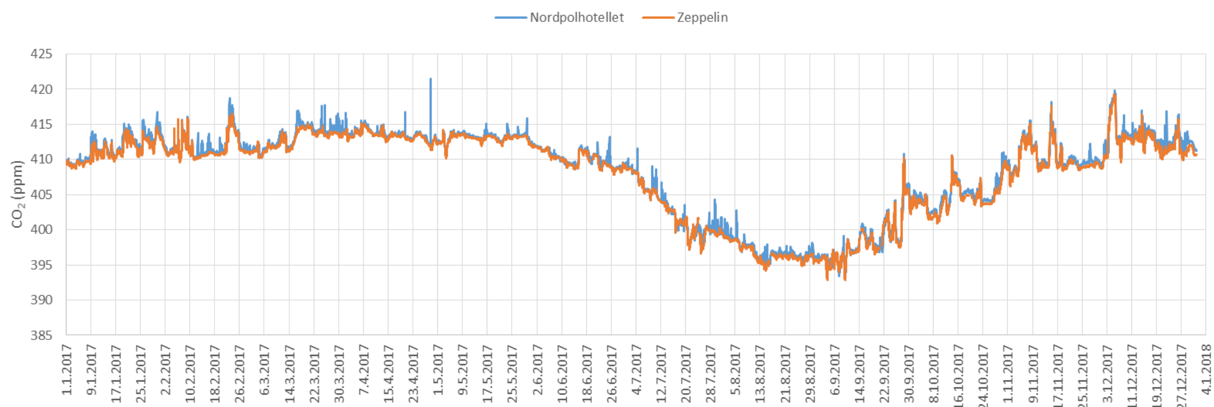
Hourly measurement data for CO at Zeppelin mountain, 1.1.-31.12.2017.



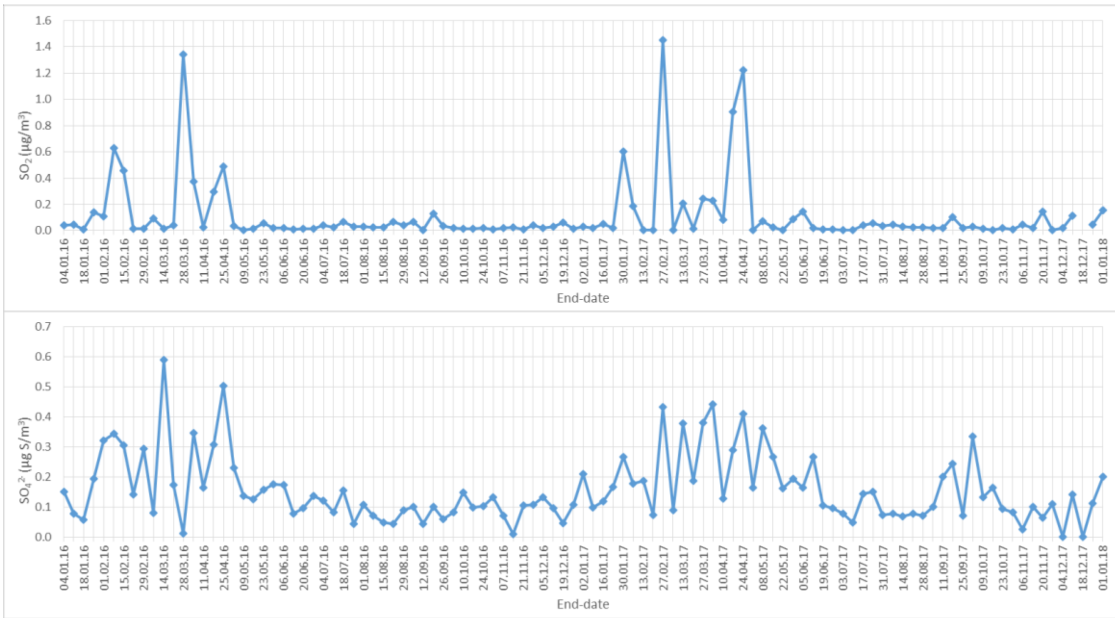
Hourly measurement data for CO_2 at Nordpolhotellet, Ny-Ålesund and at Zeppelin mountain, 1.1.-31.12.2016.

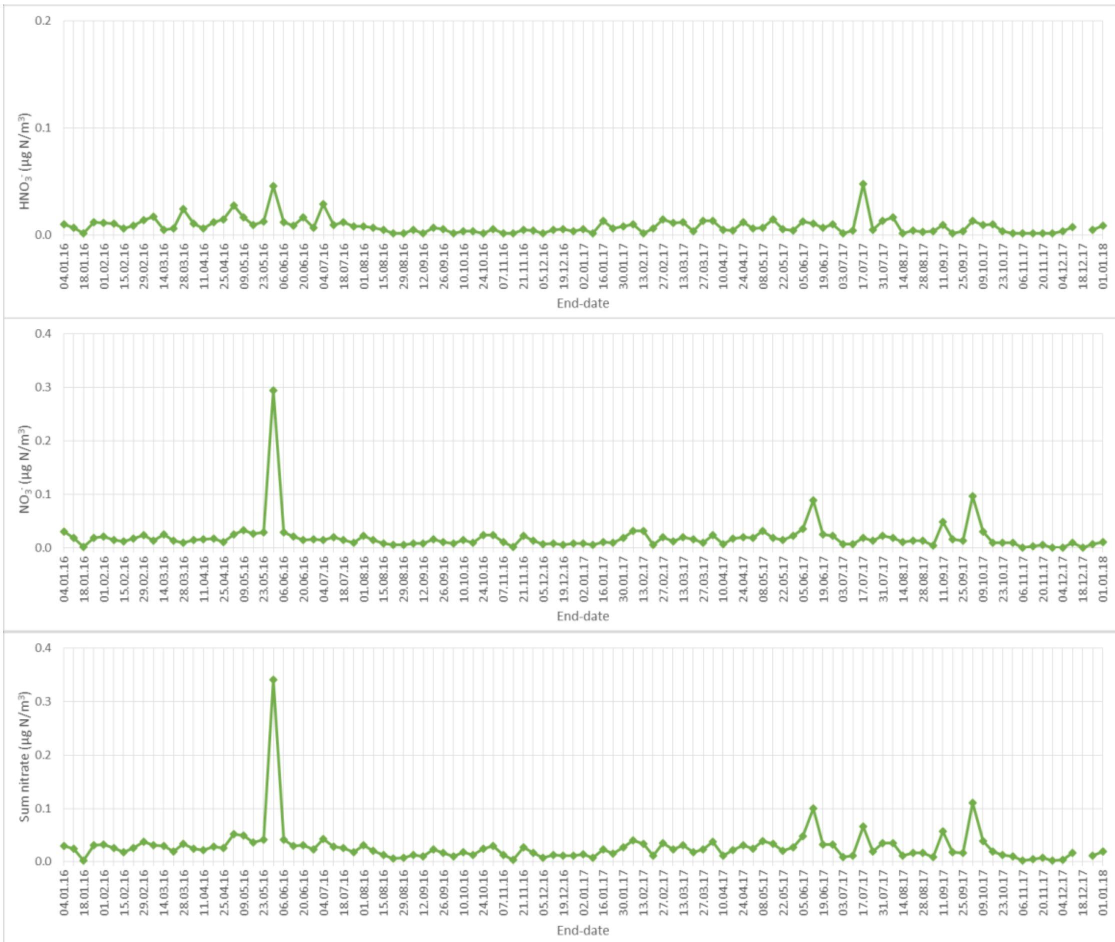


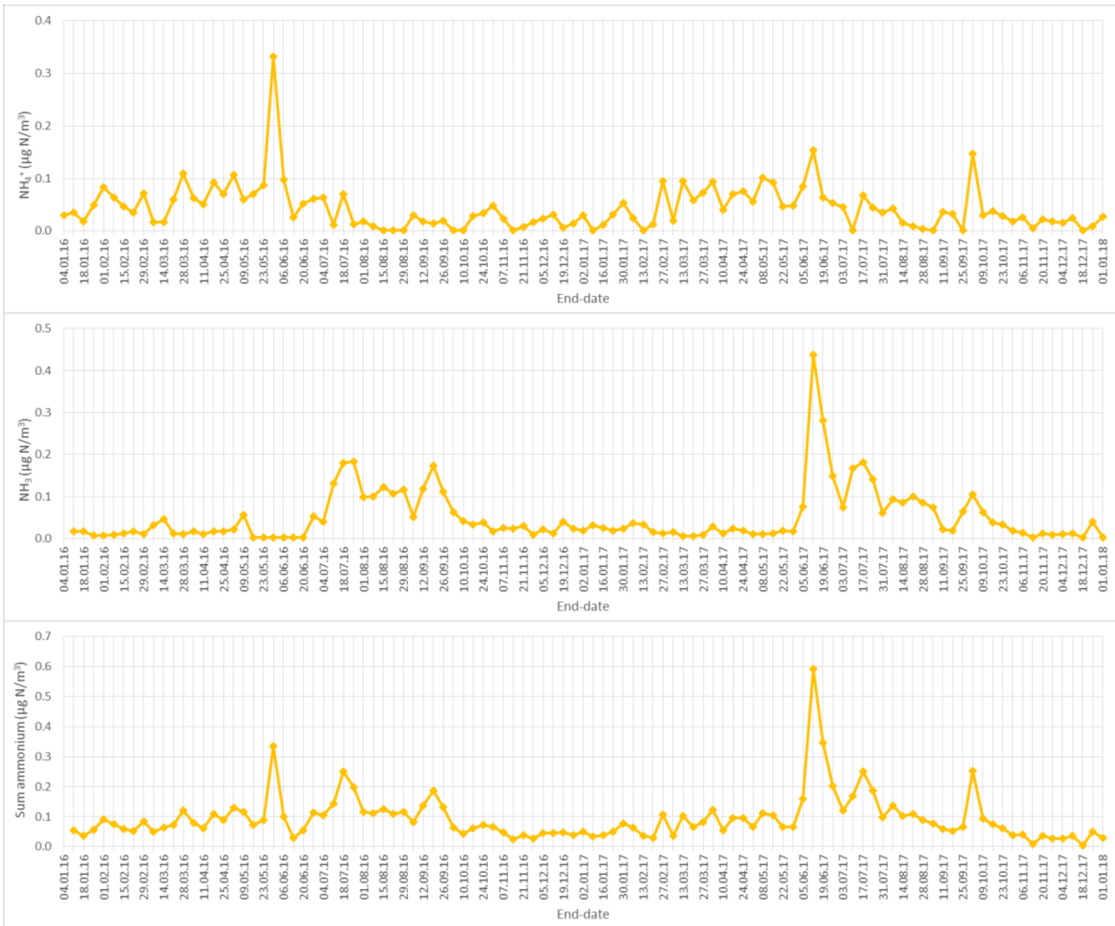
Hourly measurement data for CO_2 at Nordpolhotellet, Ny-Ålesund and at Zeppelin mountain, 1.1.-31.12.2017.

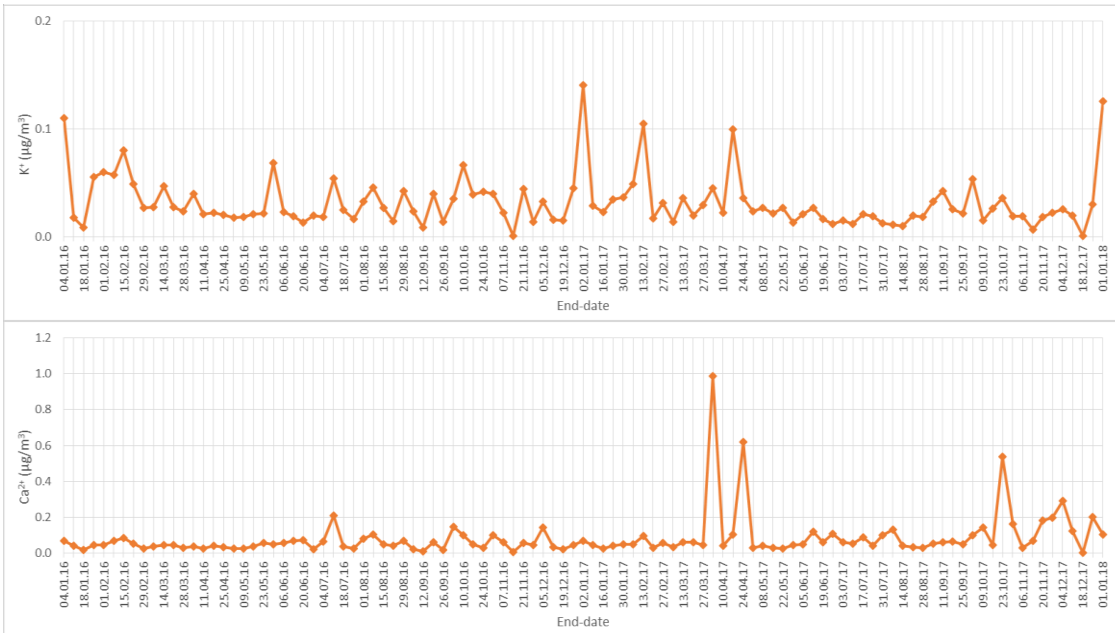


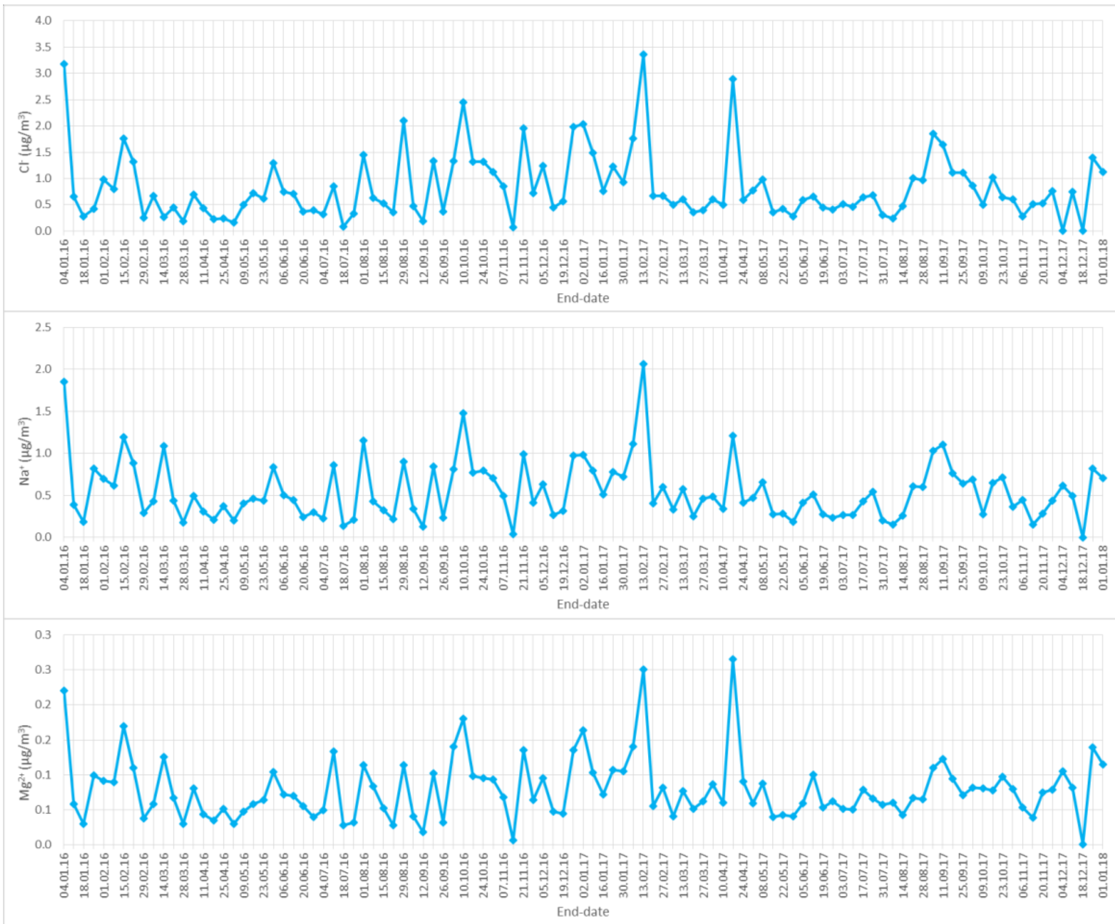
Analysis results of weekly filter sampling at Nordpolhotellet, Ny-Ålesund 1.1.2016-31.12.2017.






NH$_4^+$ (µg N/m³)
NH$_3$ (µg N/m³)
Sum ammonium (µg N/m³)
End-date


K$^+$ (µg/m³)
Ca^{2+} (µg/m³)
End-date


Cl⁻ (µg/m³)
End-date
Na⁺ (µg/m³)
End-date
Mg²⁺ (µg/m³)
End-date

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