Norwegian
Meteorological
Institute

Assessment of air quality modelling at selected stations in Norway: Station study 2022 - 2024

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1.Introduction

The aim of this report is to improve mapping and forecasts of air quality in Norway by assessing why measurements from particular stations deviate from model calculations.

The “problematic” stations were identified in 2022, based on validation reports where the uEMEP model is compared to observations for previous forecast and rerun simulations (link). Stations with large and consistent deviations between model and observations were investigated further (see Chapter 2). Possible causes and measures for improvements were suggested. Some of the measures have since been implemented. Later model simulations have been subject to an assessment of the implemented changes. The results of this assessment, mainly based on the model validation of the forecast season 23/24 and the rerun for 2023, are presented in this document.

Chapter 3 contains a description and analysis of the issue at each station deemed as problematic. It also describes conclusions that were made the first time the station was investigated, as well as the most recent status of the model performance at the station. Chapter 4 presents measures that have been suggested to improve model performance at one or more of the stations discussed in Chapter 3 . Chapter 5 contains a summary table of the stations and whether the implemented changes have been successful or not. Appendix I contains figures of yearly mean concentration for the years 2019–2023 based on reruns for Fagbrukertjenesten.

2. Methodology

The conditions at the stations are analyzed in various ways. The assessments and conclusions are based on a combination of the methods in the bullet list below.

- Look at average deviations, which components are affected?
- Look at different time profiles, including the diurnal and weekly cycles. The pattern in these cycles can help identify possible sources of the emissions, e.g. traffic emissions have peaks in the morning and afternoon rush. Also seasonal patterns are investigated.
- For some stations an assessment of the wind direction in relation to high concentration episodes have been performed. This can help identify for example fugitive emissions from industrial areas.
- Assess the position and surroundings of the station, is the model station representative of the actual environment?
- Comparing modeled and observed traffic counts for nearby roads helps to identify discrepancies in traffic related compounds.
- Looking for any construction work going on in the surrounding area that could temporarily contribute to observed emissions.
- Compare results from nearby stations, is the problem only in one station or a bigger area?
- Comparing different years helps determine if the problem is caused by an unusual year, or if it is a consistent pattern.
- Municipalities have been consulted to get local information that is not captured in the general emissions/processes used in the model. For more information about this process, contact one of the authors of this document.

3. Stations

Each of the stations listed in this chapter have or had large biases in the modeled concentration of one or more of the following components: PM10, PM2.5, PMco, NO2, NOx.

3.1.Rolland, Åsane, Bergen (NO0108A)

The station is located in a residential area next to a small road, close to sports facilities, a kindergarten, and a school (lat, lon: 60.4627, 5.3324). E16 passes about 400 m away.

3.1.1. Problem

Modeled values of NO2 and NOx were overestimated compared to observations (Fig. 1). The bias for PM concentrations was within reasonable limits.

- Bias was less in winter when the concentrations are highest.
- The modeled diurnal traffic emission cycle was larger in the model than in the observations.
- The background levels were higher in the model than in the observations, based on night time concentrations.
- The observations regularly reported negative values, both before and after a change of the sensor in November 2021. Negative values can occur if concentrations are low.

Shipping emissions in the region were found to be too high, contributing to the overestimation of modeled NO2.

3.1.2. Conclusion 2021-2022

The bias in the model seems to be caused by both too high local traffic contributions and too high background contributions. Part, but not all, of the overestimation in background contributions is due to too high shipping emissions in Bergen and surroundings (emissions based on 2017 data). Traffic volume for the nearest major road E16 seems to be correct. The deviation in the diurnal emission cycle could be caused by too little dispersion over the 400 m distance from the E16. This may be due to the local terrain, which is generally uphill to the station, or that a significant length of the E16 is in a cut, obstructing the transport of pollution to the station. These terrain effects are not included in the model.

It was decided to update the shipping emissions as described in Sect. 4.1.

3.1.3.Status 2024

Ship emissions are now based on 2021 data, together with a correction for shore power, leaving the total emissions about the same as using the 2017 data. NOx is still overestimated, both for the forecast season 2023/2024 (Fig.2) and the rerun of 2023, but the background concentrations are slightly reduced. Deviations in daily and hourly mean values are still higher than desired. Nearby stations in Bergen do not see the same bias. Station NO0108A has markedly lower observed (and modeled) values than other stations in the area, which might affect the accuracy of the measurements. The effect of local terrain has not been further investigated. The large bias in NO2 and NOx persists at this station (Fig. 3 and 4).

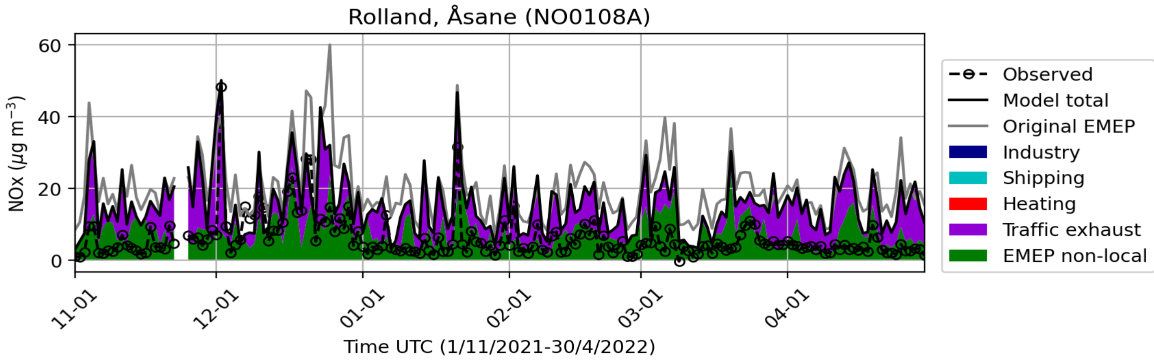


Fig. 1: NOx concentration for forecast season 2021/2022 for station NO0108A.

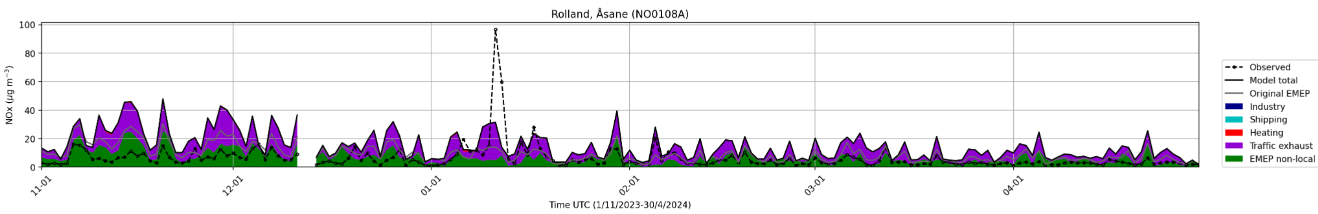


Fig. 2: NOx concentration for forecast season 2023/2024 for station NO0108A.

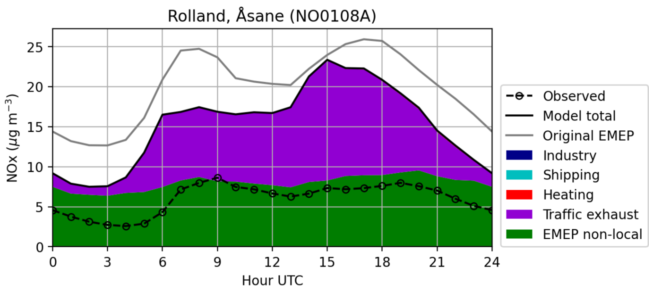


Fig. 3: Hourly mean concentration of NOx for the period 1/11/2021-30/04/2022.

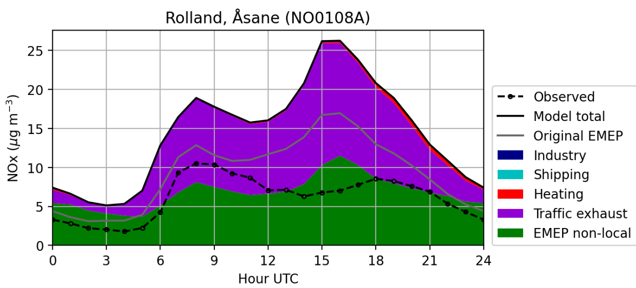


Fig. 4: Hourly mean concentration of NOx for the period 1/11/2023-30/04/2024.

3.2. Bekkestua, Bærum (NO0114A)

The station is located close to a car park, and had a construction site close by from 2019 until 2022 (lat, lon: 59.9182, 10.5839).

3.2.1. Problem

Measured PM10 concentrations were markedly higher than modeled concentrations. Modeled and measured NO2 agreed well.

3.2.2.Conclusion 2021-2022

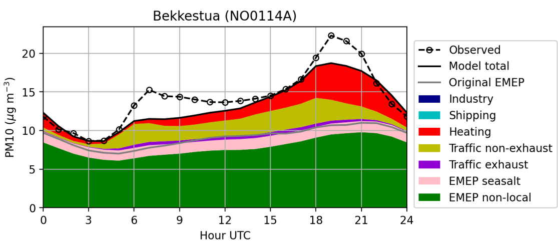
It was a construction site nearby from summer 2019 to summer 2022. Could try adding a fugitive amount as a test, or as sand.

3.2.3.Status 2024

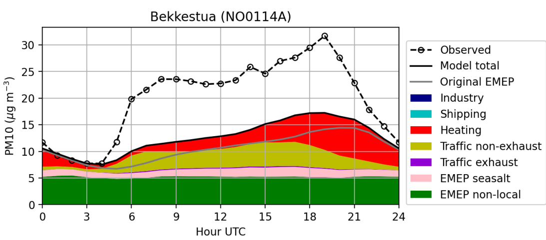
The construction work was finished in 2022. For the 2023/2024 forecast season and 2023 rerun, the modeled PM10 concentrations have been reasonable at the station. However, there is a slight tendency of underestimating PM10 during the warm season without heating in the rerun for 2023.

An assessment of the model bias for years with and without construction, indicates that construction activity surrounding the station site in 2021-2022 contributed 5-6 ug/m3 to the annual mean PM10 concentration.

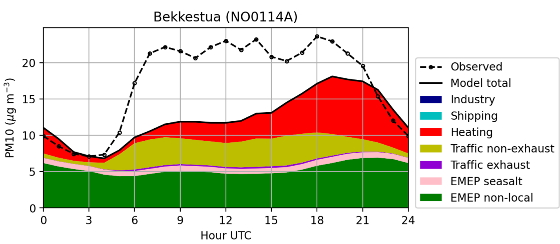
Figure 5 shows the hourly mean PM10 concentrations for years with and without nearby construction work. All years give similar model results but during the construction period 2021 and 2022 we see an increase in observed PM10, on average around 6 μg/m^3 for the annual average. The observed daily profiles are also quite flat indicating activity throughout the working day.



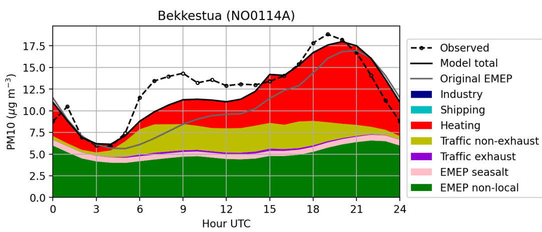
(a)



(b)



(c)



(d)

Fig. 5: Hourly mean PM10 concentrations for the years 2018 (a), 2021 (b), 2022 (c), and 2023 (d) at station NO0114A.

3.3. Drammen; Backeparken (NO0135A), Vårveien (NO0136A), Bangeløkka (NO0067A)

The Backeparken station is located on the roof of a building in Backeparken, and its measurements represent the urban background. Vårveien and Bangeløkka are located near main roads.
Backeparken lat, lon: 59.7495, 10.1653
Vårveien lat. lon: 59.7536, 10.1444
Bangeløkka lat, lon: 59.7332, 10.2119

3.3.1. Problem

For the forecast season 2021-2022, the modeled concentration of PM10 was too low compared to the measured concentrations at all three stations. PM2.5 was also underestimated at the two stations that measure it, Backeparken and Vårveien. NOx is only measured at Bangeløkka, and the agreement between model and observations was ok on average. PM2.5 was underestimated in the period November–February, while In March–April, PMco was underestimated.

3.3.2. Conclusion 2021-2022

The PM2.5 underestimation in November–February was most likely caused by a too small contribution from wood-burning. To improve this, the wood-burning input was modified as described in Section 4.2.
The underestimation of PMco was assumed to be mainly due to missing road dust emissions in the period. According to the municipality, “pukk” is used on the municipality roads in the area. Analyses showed underestimation of PM concentrations also in summer, suggesting that there might also be other causes than missing wood burning and road dust emissions.

3.3.3. Status 2024

The modified wood burning is still used (Sect. 4.2). PM2.5 for the forecast season 2023/2024 for Backeparken generally agrees better with the observations than the previous season. However, there are peaks in the observations in December and January that are not captured by the model (Fig. 6). Comparing hourly mean values for the forecast season 2021/2022 with 2023/2024, there is an improvement in the total concentration of PM2.5 modeled by uEMEP (Fig. 7). There is however a chance that the wood-burning contribution is overestimated, and could compensate for inaccuracies in other emission sources.

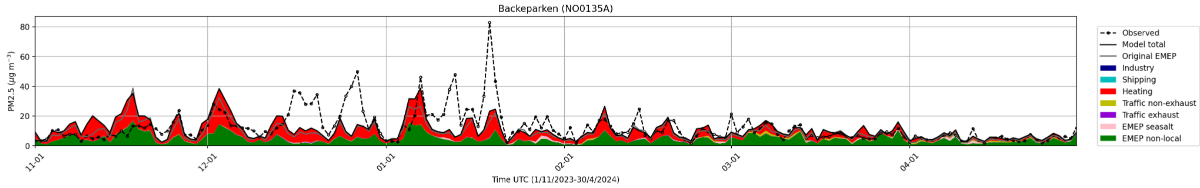
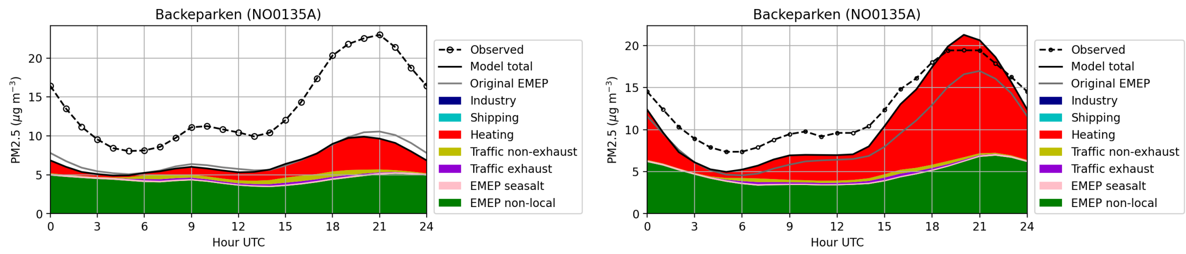


Fig. 6: Daily mean PM2.5 concentrations at station NO0135A for the forecast season 2023/2024.



(a) *(b)*

Fig. 7: Hourly mean PM2.5 concentrations at station NO0135A based on the period 1/11/2021-30/04/2022 (a) and 1/11/2023-30/04/2024 (b).

3.4.Harstad, Seljestad Rv83 (NO0127A)

The station is located along the main road in Harstad (traffic, rural, lat, lon: 68.7922, 16.5374). To the east is a large industrial building (Norsk stål). To the north is a tunnel entrance. The tunnel was opened in January 2020 (SVV).

3.4.1.Problem

The modeled concentrations of PM2.5 and were too low compared to the observations, while PM10 was ok. This means that the modeled concentration of PMco must be too high.
The temporal bias of the two PM components are different. PM2.5 is continually underestimated throughout the forecast season while PMco concentrations were low and correctly modeled most of the time. However, some strong modeled concentration peaks that were not present in the observations occurred. For some events modeled and observed peaks coincided.

3.4.2.Conclusion 2021-2022

The peaks in PMco suggest that the road sometimes dries up too fast in NORTRIP. A more detailed assessment of the road maintenance was suggested. It was also speculated if this is related to the tunnel entrance close to the station.
The modeled diurnal cycle matches observations fairly well, indicating that the wood-burning emission cycle is correct, but should be higher (Section 4.2). Underestimation of PM2.5 during summer also suggests that there could be other causes for the bias.

3.4.3.Status 2024

Wood-burning emissions have been scaled with a factor 2, which improves the total hourly concentrations of PM2.5. Diurnal PMco is still overestimated by the model, mainly due to high modeled peaks in road dust. Manual intervention was applied at the station during an event in the forecast season 2023/2024 where the modeled roads dried up too fast (Sect. 4.4).

3.5. Stener Heyerdahl, Kristiansand (NO0063A)

The station is located in a backyard in an urban area of old, wooden houses. The air intake is 4 m above ground. According to the municipality, the reason for the high placement is to capture as much road dust as possible (lat, lon: 58.1489, 7.99183).

3.5.1.Problem

The model underestimates concentrations of PM2.5, while overestimating PM10, NO2, and NOx. PM2.5 is underestimated for large parts of the season (2021-2022), especially Nov–Feb, but has a good diurnal cycle. PMco and NOx are both largely overestimated for nearly the whole period. However, the diurnal cycle of NOx has the right shape, with morning and afternoon peaks. Both PM10 and PM2.5 are underestimated during summer.

3.5.2.Conclusion 2021-2022

The wooden houses surrounding the station are assumed to use wood burning for heat, which might contribute to the higher observed PM2.5 concentrations. It was suggested to check if MetVed could capture this. Lower than average chimney heights was also proposed as a possible explanation for the underestimation of PM2.5.
PM10 and PM2.5 are underestimated during summer, which must be caused by something other than wood burning. PM10 seems to be overestimated every winter, likely because of road dust overestimation.
By comparing NOx concentrations from Stener Heyerdahl with older measurements from the two stations Gartnerløkka (NO0092A, discontinued), and Bjørndalsletta it looks like the model underestimates the concentration gradient between traffic and the urban background. The representation of altitude and sheltering by buildings was also proposed to affect the modeled results.
Both NO2 and PMco are overestimated by the model, both of these are due to traffic. Nearby roads and tunnel exits cause the overestimation. Shielding of the traffic emissions by the buildings in between is the most likely cause for why the observed concentrations are lower than the modeled. The model does not take this kind of shielding into account. Traffic volume looks OK. The closest road has an ADT of 6000 - 10000 in the model (which seems high?). The station height was 3 m in the model, but should ideally be changed to 4 m.

3.5.3.Status 2024

The station is still modeled at 3 m height, as a 1 m difference is thought to have minor influence. Wood burning has been scaled up with a factor 1.3.
For the 2023/2024 forecast season, PM2.5 is now generally overestimated, especially in winter and during evenings. However, there are peaks in observed concentrations that are markedly higher than the modeled peak. This is likely due to high emissions from wood-burning (Fig. 8). During summer 2023 (rerun) modeled and observed PM2.5 generally agrees well. NOx and PMco are still overestimated by the model, but the concentration

values are lower for both model and observations.

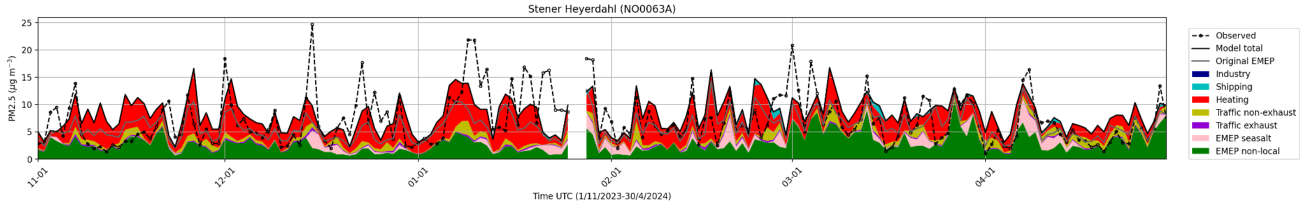


Fig. 8: Daily mean PM2.5 concentrations at station NO0063A for the forecast season 2023/2024.

3.6. Solheim, Lørenskog (NO0129A)

The station faces a highway (RV159), and has a large parking lot nearby. The height of the sensor is lower than the 3 m used in uEMEP (lat, lon: 59.9286, 10.9532) and the carpark behind the sensor is at the same height as the sensor intake.

3.6.1.Problem

There are some very high measured hourly concentrations of PM10 (highest in Norway) which are hard to explain, and not captured by the model. PMco is underestimated by the model during daytime. The diurnal cycle also differs between model and observations, as the model has peaks in morning and afternoon, while the peak in the observations happens at midday.

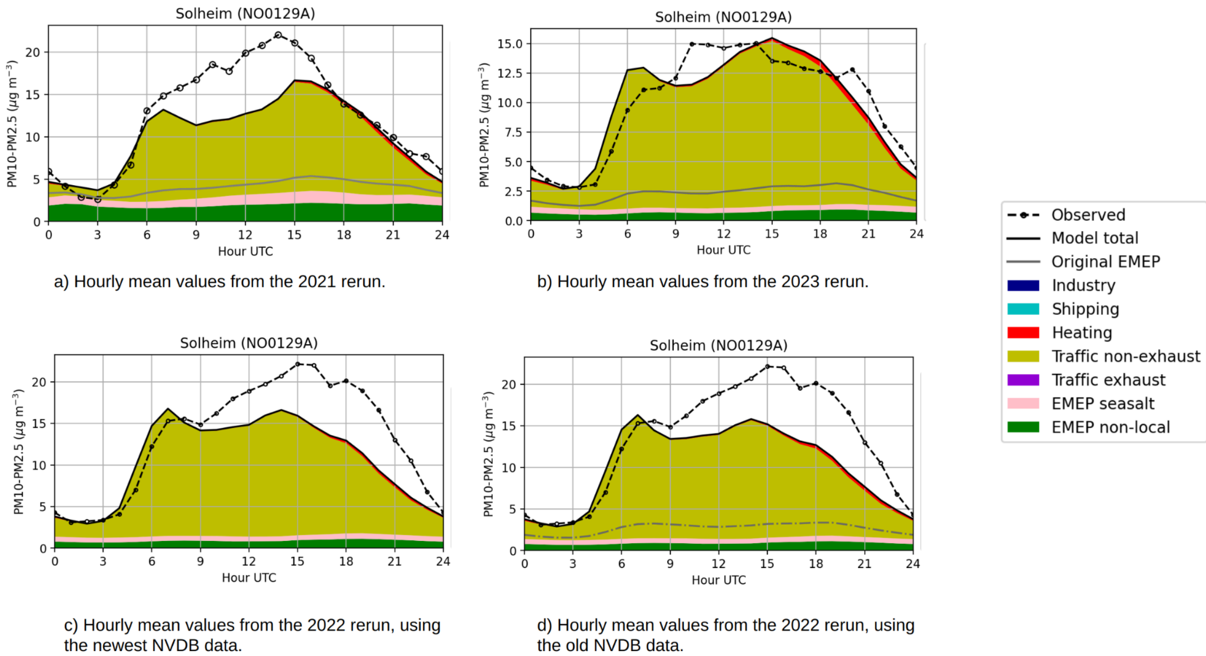
3.6.2.Conclusion 2021-2022

Based on traffic count, the heavy duty vehicle fraction is underestimated by a factor 2, which can contribute to the underestimation. Light vehicle traffic may also be underestimated, especially during the morning and afternoon peaks.
The difference between the actual and modeled height of the sensor may contribute to the discrepancy, and modeled height should ideally be 2 m (Section 4.5).
Also, misrepresentation of the emissions from the nearby car park may further contribute to the underestimation.

3.6.3.Status 2024

The model station height is not changed, as a 1 m difference is assumed to have a small impact on modeled concentrations.
The peaks in observed hourly concentrations are lower in recent years than for 2021-2022. The heavy duty vehicle fraction has been adjusted in recent NVDB updates (see Sect. 4.3). Modeled PMco concentrations match better with the observations in the rerun for 2023 than for 2021 and 2022. Figure 9, c) and d) show rerun simulations of 2022 using new and old NVDB numbers, respectively. The difference is minor, so the higher heavy duty fraction is not explaining the better match in 2023 alone. Instead, it is likely that the lower observed values in 2023 leads to a better match between model and measurements.
The underestimation during daytime is limited to a small bias between 9-14, but there is now a slight overestimation in early morning and afternoon.

For the most recent years, the problem with very high peaks in observed PM10 concentrations are not evident anymore. However, the modeled underestimation of PMco still remains.



a) Hourly mean values from the 2021 rerun.

b) Hourly mean values from the 2023 rerun.

c) Hourly mean values from the 2022 rerun, using the newest NVDB data.

d) Hourly mean values from the 2022 rerun, using the old NVDB data.

Fig. 9: Hourly mean concentrations of PMco at station NO0129A.

3.7. Moheia Vest, Mo i Rana (NO0123A)

The station is located in between houses and a soccer field. Based on Google street view, there was road construction in the area in 2020 (lat, lon: 66.3122, 14.1499).

3.7.1.Problem

The modeled PM2.5 and PM10 concentrations are too low compared to the measurements.

3.7.2.Conclusion 2021-2022

The ADT from the nearest roads are likely underestimated, according to the municipality. The model uses an ADT of 600, while it should be 3000. The model input should therefore be updated. There might be fugitive emissions from a nearby industrial park that influence the measurements, which is not represented in the model. The municipality has limited information about these emissions.

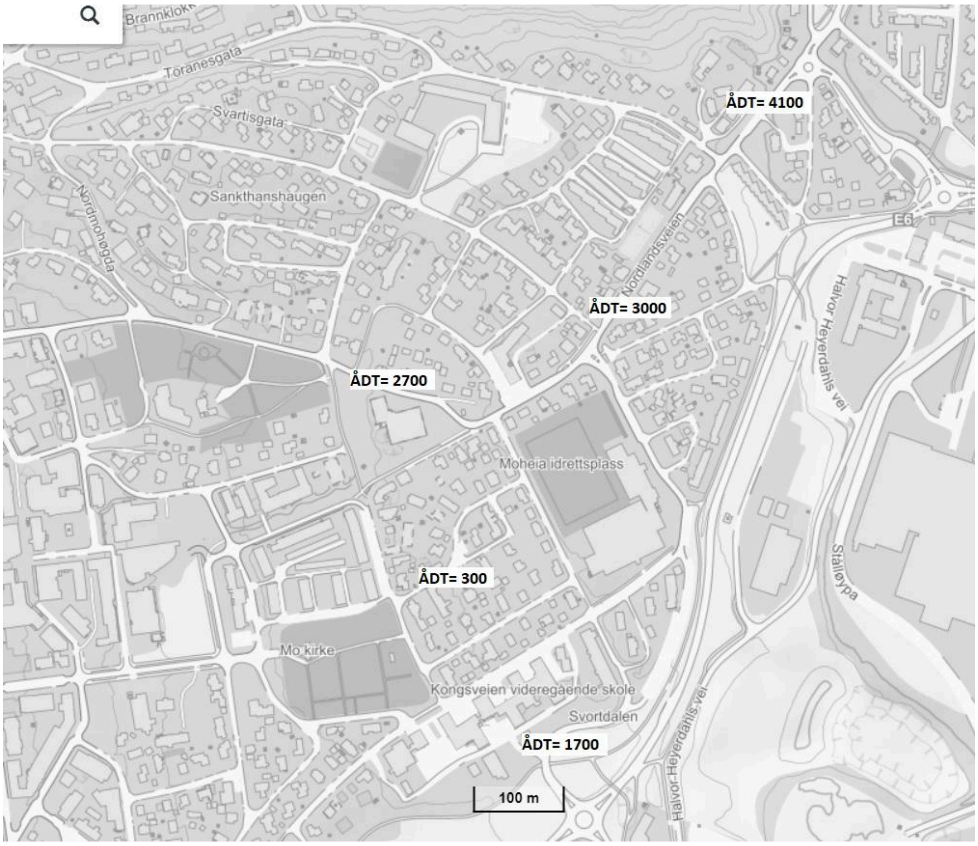


Fig 10: ADT numbers for roads in the area, provided by the municipality. The station is located to the north of the football field.

3.7.3.Status 2024

The road ADT has not been updated, and possible industrial emissions have not been investigated further. Generally the model still underestimates PM concentrations. In the 2023 rerun the model performs fairly well until mid October 2023, when there is a notable jump in observed concentrations (Figs. 11, 12).

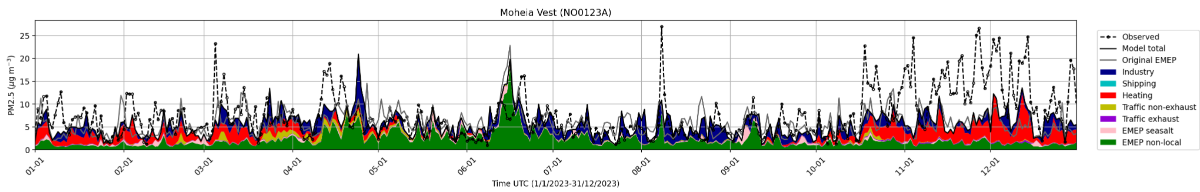


Fig. 11: Daily mean concentrations of PM2.5 at station NO0123A for the year 2023.

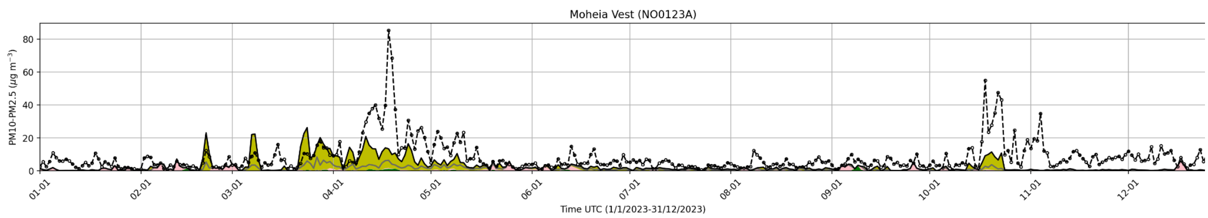


Fig. 12: Daily mean concentrations of PMco at station NO0123A for the year 2023.

3.8.Kongens gate (NO0148A)/Sentrum (NO0113A), Narvik

The station is located along a highway (E6), and has a parking lot nearby. At the end of 2022 this station was moved ca. 2 m and therefore changed name and ID from Sentrum (NO0113A) to Kongens gate (NO0148A, lat, lon: 68.4354, 17.4249).

3.8.1.Problem

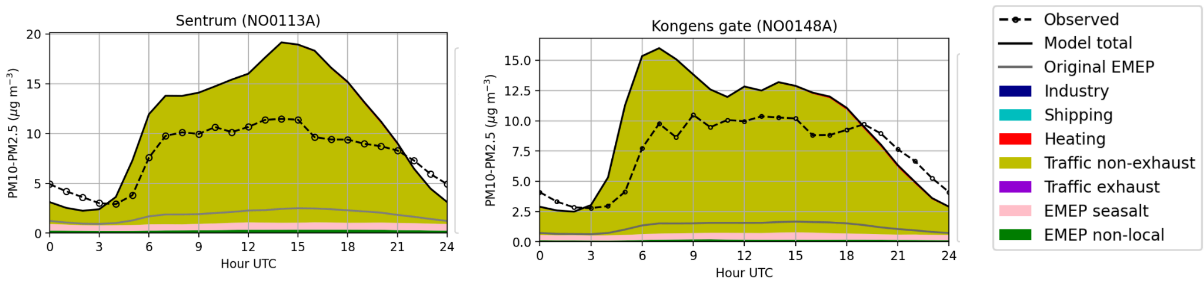
The timing of road dust events does not match measurements. The model overestimates PMco.

3.8.2.Conclusion 2021-2022

The road conditions on E6 are not well described in the model. This came about specifically after an update of the NORTRIP model (Section 4.6). There is often still snow on the road when the model says that it has been salted and the road therefore is bare. The modeling of road activities (salting, plowing etc.) should be revised.
Also, the wood burning emissions used are too low, and should be adjusted (Section 4.2).

3.8.3.Status 2024

An update of the NORTRIP model led to a reduction in concentrations at this site. This update led to an increase in the removal of road dust through drainage (Section 4.6). Modeled PMco is still overestimated in the 2023 rerun, and the largest modeled peak has shifted from afternoon to morning (Fig. 13). Manual intervention (adding water and/or reducing accumulated road dust) at specific times have been applied with general success (see Sect. 4.4).



a) Hourly mean values from the 2021 rerun.

b) Hourly mean values from the 2023 rerun.

Fig. 13: Hourly mean concentration of PMco for the station NO0113A.

3.9. Alnabru, Oslo (NO0057A)

The station is located close to a shopping center and connected car park. The road Strømsveien passes on the other side (lat, lon: 59.9277, 10.8466).

3.9.1.Problem

While modeled PM2.5 concentrations are reasonable, PMco is underestimated, with the largest bias during daytime in spring. NOx is also underestimated, especially during winter. There are also issues with the NO2/NOx ratio.

3.9.2.Conclusion 2021-2022

The road surface has obvious wear-and-tear, which could generate more PMco, but this is not considered by the model. The parking lot emissions are also not considered (see Sect. 4.8 for more details about proximity to car parks).
The real traffic seems heavier than what is reported and used in the model based on observations during a visit. A proper counting would be needed to be sure. The station is close to Alnabruterminalen and the area therefore sees a high amount of heavy vehicles. Alfasetveien, which is the entrance to the terminal, has 3 x more traffic (50% heavy) than in the model. This should be adjusted (Section 4.3).

3.9.3.Status 2024

For the 2023 rerun, the most recent version of traffic volume was used (NVDB). Here, the heavy duty fraction in the area was increased to a more realistic value. This increased the PMco concentration slightly, but not enough to match the observations. So the problem with underestimated PMco still remains, with the largest bias during spring. NOx is also still generally underestimated, indicating that an underestimation of traffic is the cause of the bias.

3.10.Vågen, Stavanger (NO0141A)

The station is located on the roof of a building close to the waterfront (lat, lon: 58.9726, 5.7265). There is also a car park nearby, but influence is suspected to be minor.

3.10.1.Problem

PMco is overestimated, while PM2.5 is underestimated, leading to a false good agreement between model and measured PM10 concentrations. A similar pattern is seen also at other stations in Stavanger.
NOx is overestimated by the model.

3.10.2.Conclusion 2021-2022

The station height used in the model was 3 m, while it should be 5-7 m (roof height). The height needs to be updated in the model (Section 4.5).
Modeled sea salt emissions seem too high in the area; the sea salt formation of PMco is not optimized in the EMEP model. PM2.5 in sea salt is either underestimated by the model, or measurement of sea salt particles in PM2.5 is problematic. Stations in Stavanger and Bergen reflect the issue. It seems like wood burning is underestimated as well judging by the daily cycle of PM2.5. According to the contact person at the municipality, relatively high concentrations of PM2.5 are expected because the station is close to a residential area with wood burning as the main heat source (Gamle Stavanger).
The overestimation of NOx is likely caused by too much light vehicle traffic, in addition to a too high emission of NO2 from ships. Sections 4.1 describe measures related to ship emissions.

3.10.3. Status 2024

Shipping emissions in Stavanger municipality have been modified (Sect. 4.1). Wood burning has been scaled with a factor 1.5 (Sect. 4.2). The station height has been increased from 3 m to 5 m (Sect. 4.5).

For the forecast season 2023/2024 and 2023 rerun the modeled PM2.5 concentrations match observations well, while PMco is overestimated as before. This means overestimation of PM10. Heating is a notably larger fraction of the emission for this season than for the 2021/2022 season. The overestimation of PMco is hypothesized to be caused by too much road dust emissions, and possibly also the fraction of PMco sea salt fraction.

NOx is still overestimated in the model.

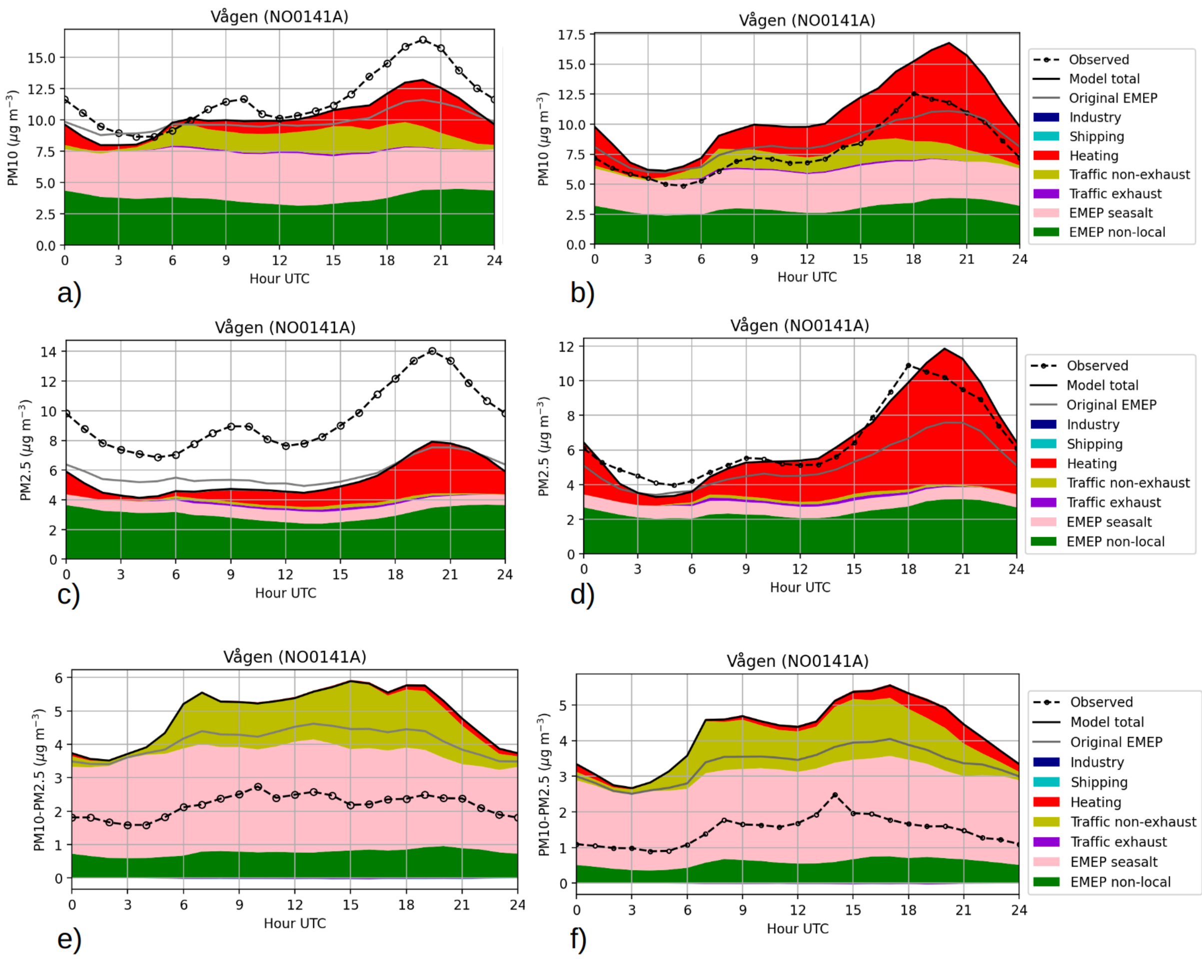


Fig. 14: Hourly mean concentrations of PM10 (top; a and b), PM2.5 (mid: c and d) and PMco (bottom; e and f) for the forecast season 2021/2022 (left; a, c, e) and 2023/2024 (right; b, d, c) for the station NO0141A.

3.11. Hansjordnesbukta, Tromsø (NO0079A)

The station is located close to a tunnel opening in an urban area (lat, lon: 69.6562, 18.9637). The station is also relatively close to the waterfront. The surface of the surrounding roads look worn based on google maps images.

3.11.1.Problem

Modeled summer PM is underestimated.

3.11.2.Conclusion 2021-2022

Based on Google Maps images, It seems like there is remaining dust on the roads in June. There is no traffic count on the closest road, but some nearby counts suggest underestimation of heavy duty traffic.

3.11.3.Status 2024

Looking at monthly mean concentration for the years 2021-2023, PM2.5 is underestimated during summer for all three years. For PM10, the modeled summer 2022 concentrations were well matched with the observations, while it was underestimating concentrations in both 2021 and 2023. The Tromsø station was affected by the manual intervention to the road dust model in the 2023/2024 forecast season with an improved result (Sect. 4.4).

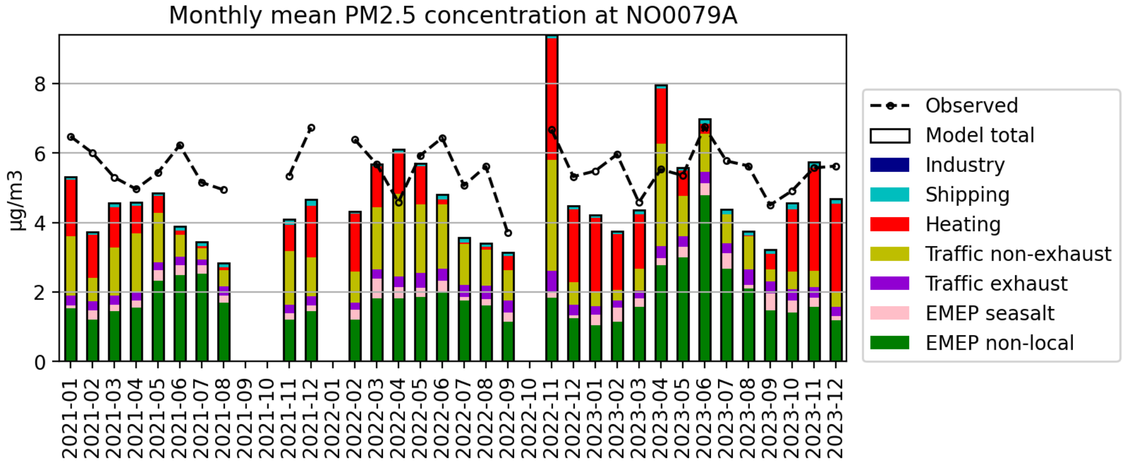


Fig 15: Monthly mean concentrations of PM2.5 at station NO0079A.

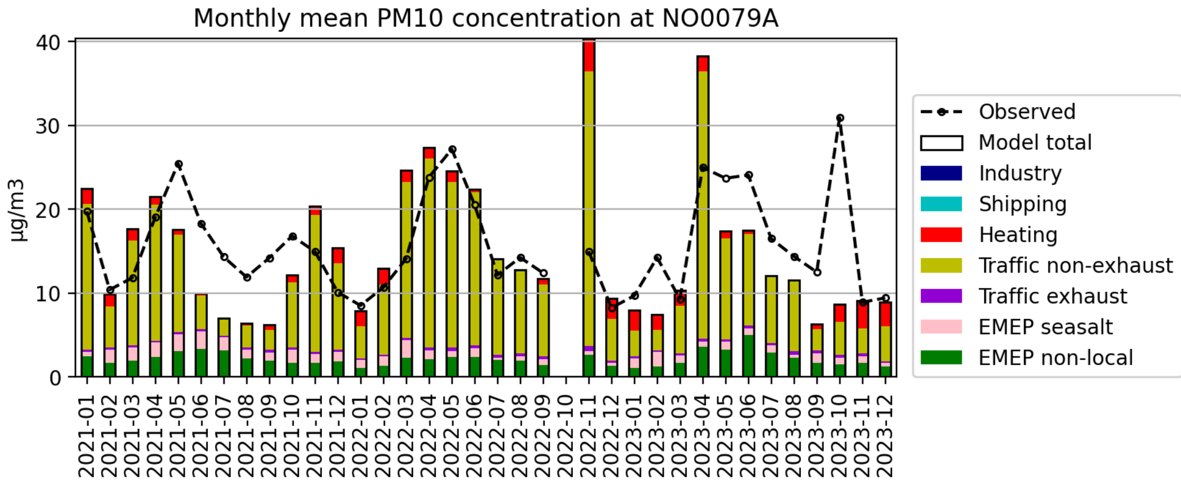


Fig 16: Monthly mean concentrations of PM10 at station NO0079A.

3.12.Porsgrunn/Brevik: Knarrdalstranda (NO0118A), Furulund (NO0115A)

Knarrdalstranda (NO0118A, lat, lon: 59.1335, 9.6219) station is located in a typical residential area with many houses. Furulund (NO0115A, lat, lon: 59.0573, 9.69557) is also located in a residential area, close to a sports field. Both stations are close to Herøya industrial park.

3.12.1.Problem

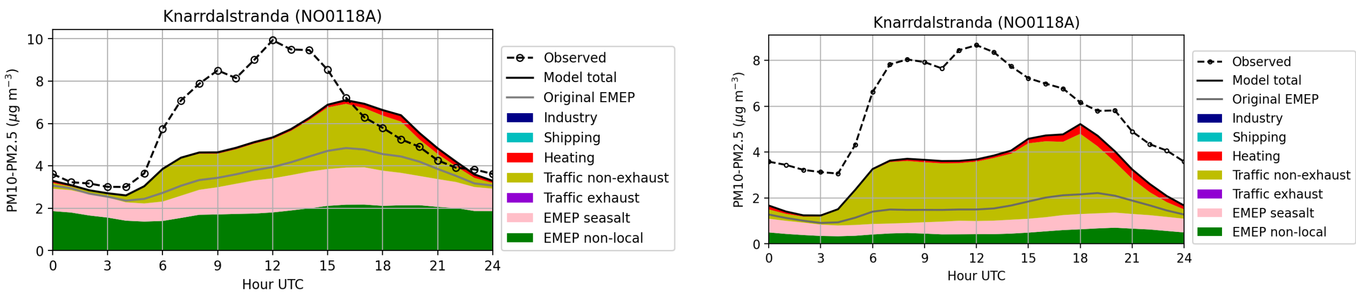
At Knarrdalstranda there is an observed midday peak in PMco that does not reflect traffic, and is not captured by the model. At Furulund there are observed irregular emissions of NOx likely caused by industrial emissions that are not captured by the model.

3.12.2.Conclusion 2021-2022

An assessment of the wind direction indicates that there might be fugitive contributions from Herøya (industry park) and commercial sites not captured by the model. It does not look like wind direction is measured at this air quality station. The nearest station for wind measurements is Porsgrunn Ås.

3.12.3.Status 2024

For the 2023 rerun, PMco is underestimated throughout the day, with the largest deviation during midday. The issues with underestimation of PMco and deviations in the diurnal cycle still remains. There are still irregular observed NOx peaks at Furulund, not captured by the model, leading to an underestimation. This is likely related to industrial emissions.



a) b)

Fig. 17: Hourly mean concentrations of PMco based on the 2022 rerun (left; a), and 2023 rerun (right; b) for station NO0118A.

3.13. Lensmannsdalen, Skien (NO0061A)

The station is located close to a major road, with vegetation and scattered houses around it (lat, lon: 59.1593, 9.6357).

3.13.1.Problem

The municipality has noted model overestimation of PM2.5 in the evenings.

3.13.2. Conclusion 2021-2022

Wood burning is likely too high, reducing by 30-40% would give a better match (Section 4.2). Road dust is generally well modeled at this site.

3.13.3. Status 2024

Below is hourly means of PM2.5 concentration from the reruns of the years 2021, 2022, and 2023, respectively. For the 2021 rerun, MetVed emissions were based on the year 2019. For the 2022 and 2023 reruns, the MetVed emissions are based on data from 2021. For Skien and Porsgrunn, these emissions were reduced by 30 %. The bias in late-day PM2.5 was smaller for 2022 than 2021, but for 2023 the bias has increased again.

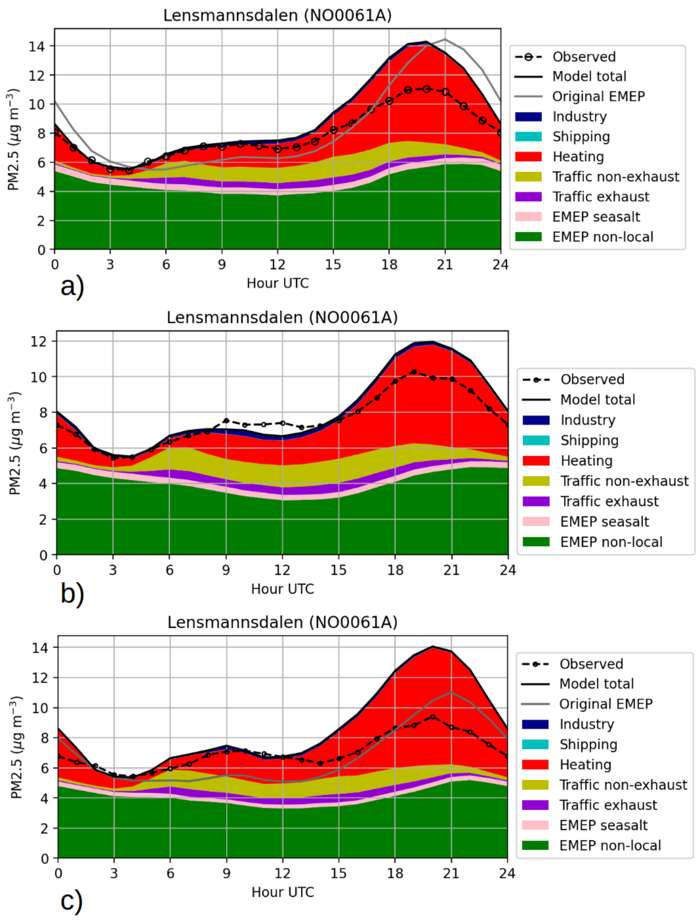


Fig. 18: Hourly mean concentrations of PM2.5 based on reruns of years 2021 (a), 2022 (b), and 2023 (c) for station NO0061A.

4. Measures

This section describes suggested measures to improve the model performance at the stations described in Chapter 2. A summary of updates of emissions data from year to year can be found here https://www.met.no/prosjekter/luftkvalitet/oppdaterte-utslipp.

4.1. Update shipping emissions

Before the 2022 reruns and forecast season 2023/2024 the ship emissions (input data to uEMEP) were updated from 2017 to 2021 data (AIS data from Havbase, Kystverket). In addition, a correction for shore power use was implemented for seven municipalities (see Table 1). The correction was based on voluntarily reported shore power use for 2021 (GWh) together with an assumed fuel saving of 0.23 kg/kWh.

Endring i totalt NO_x-utslipp fra skip

Kommune	Landstrøm (GWh)	Utslippsår 2017 → 2021	Reduksjon fra landstrøm 2021	Total endring utslipp
Oslo	20,7	+74 %	-47 %	-7 %
Bergen	19,7	+11 %	-11 %	-1 %
Stavanger	1,6	-10 %	-2 %	-11 %
Kristiansand	18,9	+39 %	-16 %	+17 %
Sandefjord	12,7	+15 %	-16 %	-4 %
Haugesund	2,0	-26 %	-5 %	-30 %
Risør	4,2	+183 %	-29 %	+100 %

Table 1: Changes in NOx emissions from shipping from 2017 to 2021 for seven municipalities that were corrected for shore power use.

4.2. Wood burning emission changes

Emissions of PM2.5 from wood burning comes from simulations by the MetVed2 model. For the reruns of 2020 and 2021 MedVed emissions based on data from 2019 were used. For the rerun of 2022 and 2023, updated emissions based on 2021 numbers were used. The updated emissions did not always match with station observations. Therefore, a multi-linear regression analysis was carried out in the municipalities with measurement data for PM2.5 to identify under- or over-estimated wood burning (see 4.7). Based on this analysis, the emissions from wood burning from 2021 have been scaled by -30% in Lillestrøm, Porsgrunn and Skien, by -20% in Oslo and Trondheim, by +30% in Kristiansand, by +50% in Stavanger and Bergen, and by +100% in Narvik, Drammen and Harstad.

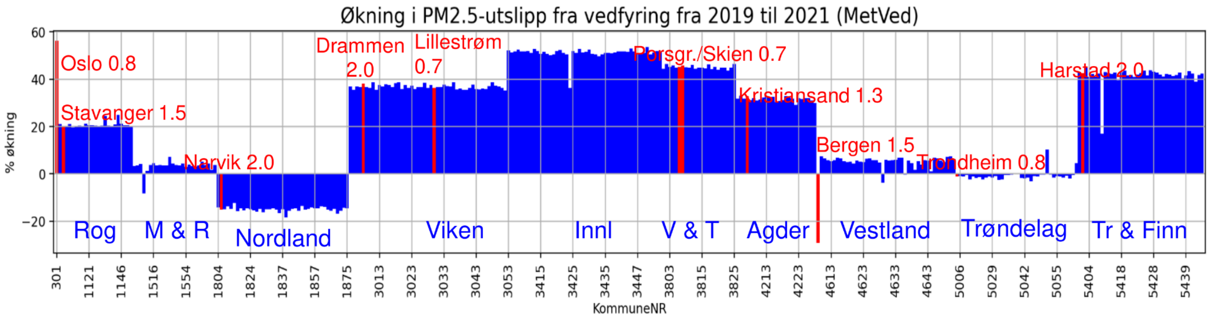


Fig. 19: Changes in PM2.5 emissions from wood burning from the 2019 to 2021 MetVed data. The red bars mark municipalities that were manually scaled as described in the text.

4.3.Update NVDB data

Before the 2022 reruns and forecast season 2022/2023 the emission factors for exhaust were updated from 2019 to 2021. In addition, traffic volume has been scaled with counts from 2022, and the trend in NOx emissions for change after 2021 was applied (SSB: https://www.ssb.no/statbank/table/08941/). In April 2024 NVDB data was updated, representing 2023 traffic data. These updated values were used for the 2023 rerun and 2024/2025 forecast season, as well as updated emission factors from NERVE (2022). Trends in NOX and PM exhaust emissions (-7.5% per year) were included. Updating of NVDB data did not give any significant improvements in the modelled concentrations at traffic stations.

4.4. Manual intervention

For some stations in Northern Norway manual intervention into the road dust model was tested for the first time during the forecast season 2023/2024. For a period in March, the modeled emissions of dust were unrealistically high due to dry modeled roads. It was decided to reduce the accumulated dust on the road, as well as adding water/snow to the modeled roads (based on observed road conditions). This brought modeled concentrations closer to the observed values, and will be considered applied in future similar scenarios.

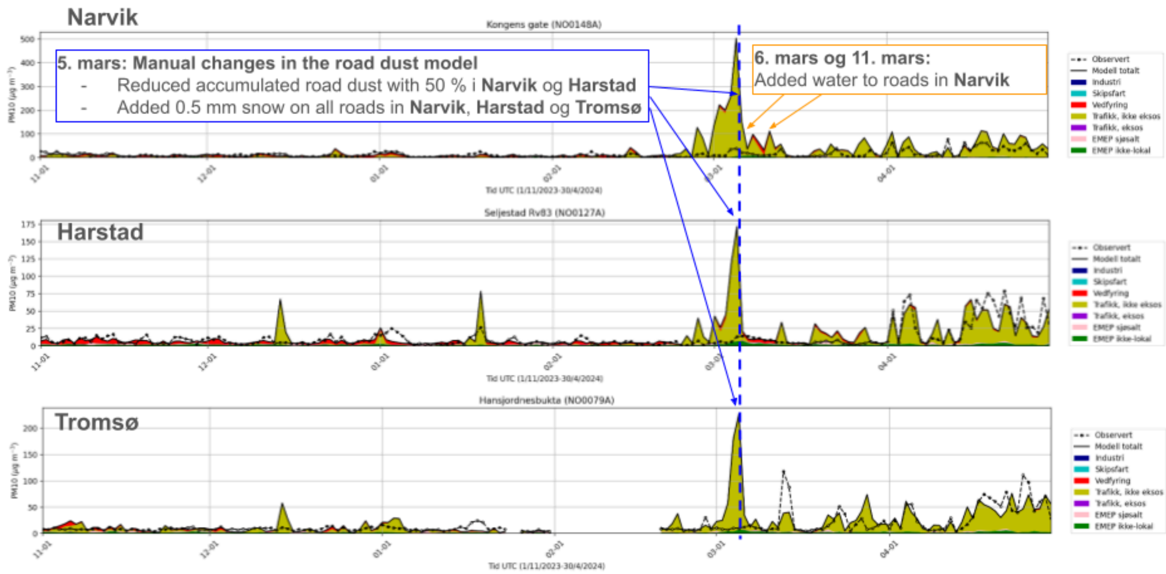


Fig. 20: Illustration of the effect of manual intervention on PM10 concentrations in Narvik, Harstad, and Tromsø.

4.5. Adjust modeled station height

All stations were assessed as to their positions relative to roads and their heights. Some stations, see text, were repositioned or had their heights adjusted. Stations on roof tops were allocated a height that was around half of the building height. This was a compromise because buildings and air flows around buildings is not part of the model parameterisation.

4.6. Updates in NORTRIP parameters

As part of the overall updates made to improve the non-exhaust emissions a number of parameters were changed in the NORTRIP non-exhaust emission model, which included the following:

- Suspension rates for heavy duty vehicles were enhanced by a factor of 2 and suspension rates for cars were reduced by a factor of 2. Prior to this change HDV suspension was 10 times higher than cars. After this they were 40 times higher. This change was intended to address the commonly observed feature of peak PM10 emissions in the middle of the day. Since HDV traffic peaks in the middle of the day it was hypothesized that this was because the suspended emissions from HDV is much higher than for cars. This change slightly improved the modelled daily cycle, but not sufficiently to reproduce the observed daily cycle of PM10.
- In the model, road wear under dry conditions can be both directly emitted or accumulated on the road surface. Till now wear has been completely emitted directly. This parameter was changed so that half of the wear is deposited on the surface. The effect of this is to increase the dust loading on the road surface, leading to a longer emission season after the end of the studded tyre season, as observed. This also, however, reduced the emissions in the start of the studded tyre season.

Increasing the road surface dust loading also allowed HDV to more strongly influence the emissions.

- To better reflect the observed emissions wet removal processes were reduced in the model. Spray removal of both water and dust was reduced by a factor of 5 and drainage removal was reduced by a factor of 2. Initially drainage removal was reduced also by a factor of 5, however, this led to large overestimates at some stations, notably in Narvik.

4.7. Multilinear regression analysis for PM2.5

In order to make an objective estimate in model errors a multilinear regression assessment was carried out. The method follows Denby, 2012. For all available stations the hourly modelled concentrations and source contributions from traffic, wood burning and the non-local contribution were fitted to the observed concentrations. This provided an objective estimate of the likely error in source contributions. The regression factors derived in this way minimise the mean squared error and represent a scaling factor for the particular sources emissions. Monte Carlo methods were applied to estimate the uncertainty in the derived parameters. Results for 2022 are shown below.

On average this analysis indicates that the non-local contribution is underestimated by around 22%, traffic by 12% and wood burning is overestimated by 7%. Uncertainty is estimated to be around 10% in these factors. For individual stations there is larger variation and uncertainty. This analysis was used to estimate scaling factors for wood burning in some of the municipalities, Section 4.2.

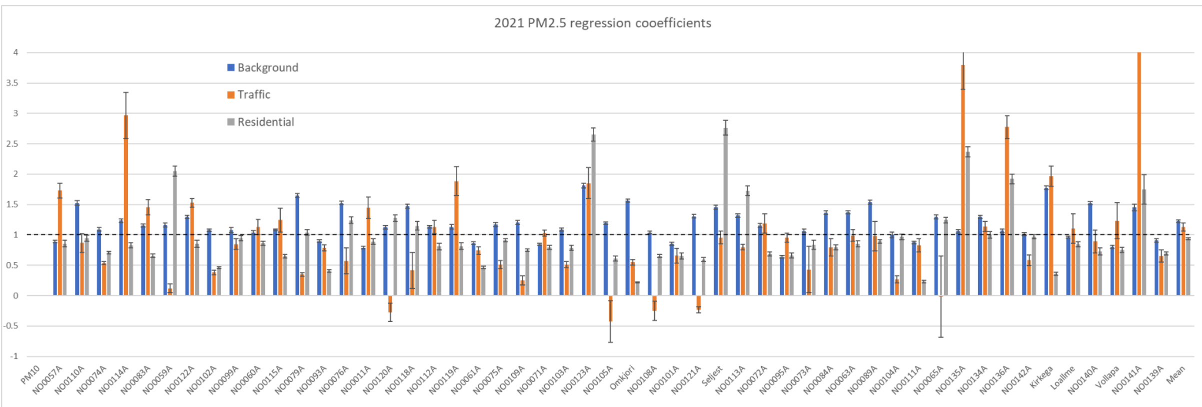


Fig. 21: Derived regression factors for PM2.5 in 2021 based on hourly mean regression analysis.

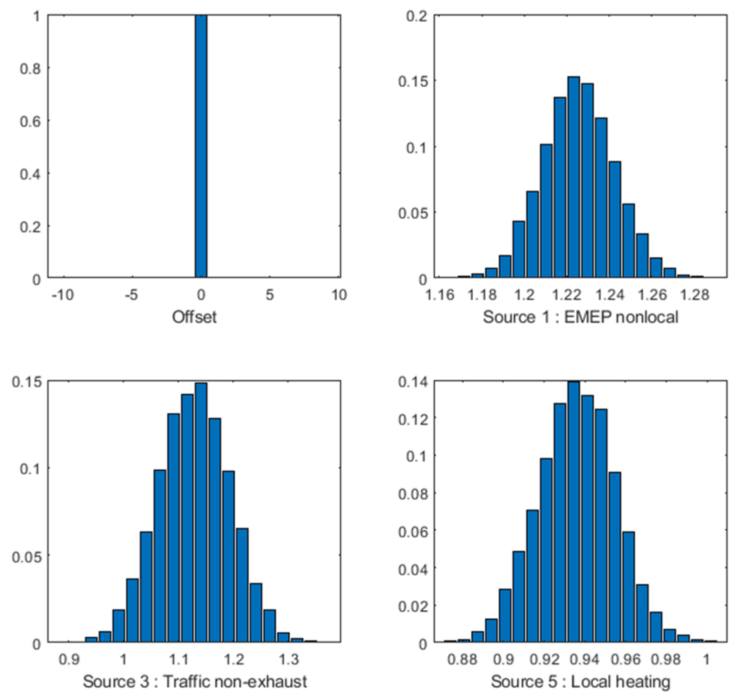


Fig. 22: Frequency distribution of the derived regression factors for all stations.

4.8. General assessment of road dust daily mean profiles

It has been noticed that many observed daily mean PMco profiles at traffic stations show a peak in the concentrations in the middle of the day, even though traffic peaks occur in the morning and evening rush hours. The hypothesis for this is that the road dust suspension is primarily caused by heavy duty vehicles since the daily temporal profile of these vehicles also peaks in the middle of the day.

An assessment was carried out where daily cycles were categorised into three types:

A. profiles with a peak in the middle of the day
B. profiles that were flat most of the day
C. profiles that showed peaks in the rush hours

These were then compared to a number of model input parameters to assess if there was some relation to these parameters. These included:

1. Traffic ADT
2. Traffic ADT for heavy duty vehicles
3. Traffic speed
4. Proximity of car parks

These parameters were compared to both the model bias and to the 3 temporal profile categories to assess any relationships

4.8.1.Conclusion

No clear relationships between any of the parameters and the model bias or profile shape were found. However, some NORTRIP parameters were changed to try to address this hypothesis, see Section 4.6.

Though this assessment provided no clear results it is worth noting that the application of NORTRIP in Sweden has shown that some high speed roads have a large positive bias. We do not find any relationship between signed speed and modelled PM10 bias for the traffic stations examined.

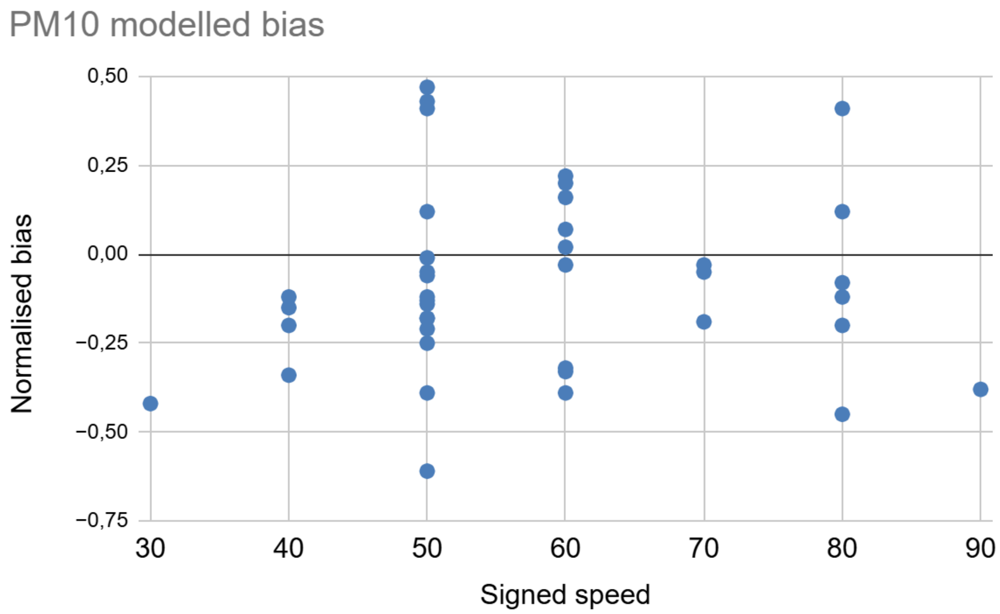


Fig. 23: Example of the assessment carried out on station bias as a function of signed speed.

5.Summary

The table below contains a summary of the problems, measures, and status for each component and station discussed in this document. The status is either “fixed”, “improved”, or “remains”.

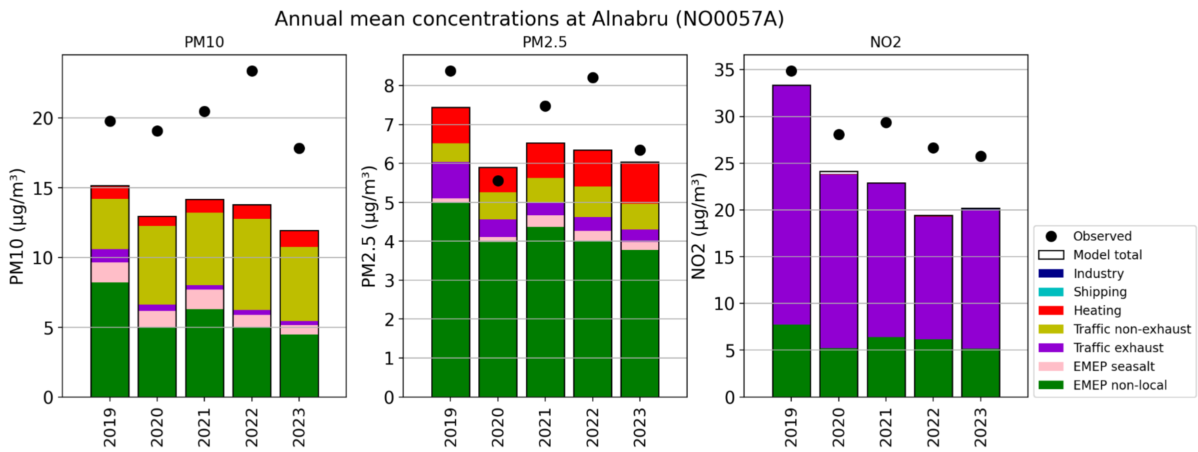
Station	Problem (model perspective)	Measure(s)	Success?
Bergen	Overestimate NO2	Shipping emissions	Remains
Bærum	Underestimate PM10	Finished construction	Fixed
Drammen x3	Underestimate PM	Wood burning changes	Improved
Harstad	Underestimate PM2.5	Wood burning changes	Improved
Harstad	Overestimate PMco	Manual intervention	Remains
Kristiansand	Underestimate PM2.5	Wood burning changes	Improved
Kristiansand	Overestimate PM10		Remains
Kristiansand	Overestimate NO2,NOx		Remains
Lørenskog	Not capturing observed peaks in springtime PM10	Lower measured values	Fixed
Lørenskog	Underestimate PM	Update NVDB	Remains
Mo i Rana	Underestimate PM		Remains
Narvik	Mismatch in road dust episodes	Manual intervention Wood burning changes	Improved
Alnabru	Underestimate PMco	Update NVDB	Remains
Alnabru	Underestimate NO2	Update NVDB	Remains
Stavanger	Overestimate NOx	Shipping emissions Adjust station height	Improved
Stavanger	PMco	Adjust station height	Remains
Stavanger	Underestimate PM2.5	Wood burning changes	Improved
Tromsø	Underestimate PM	Manual intervention	Improved
Porsgrunn/Brevik	Underestimate PM	Wood burning changes	Remains
Porsgrunn/Brevik	Irregular observed NOx emis.		Remains
Skien	Overestimate PM2.5	Wood burning changes	Remains

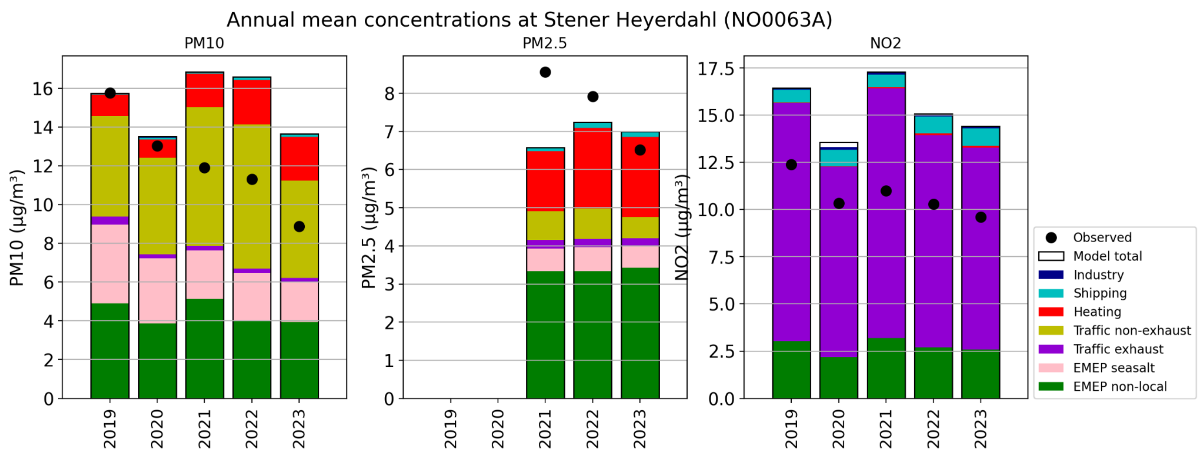
6. Conclusion

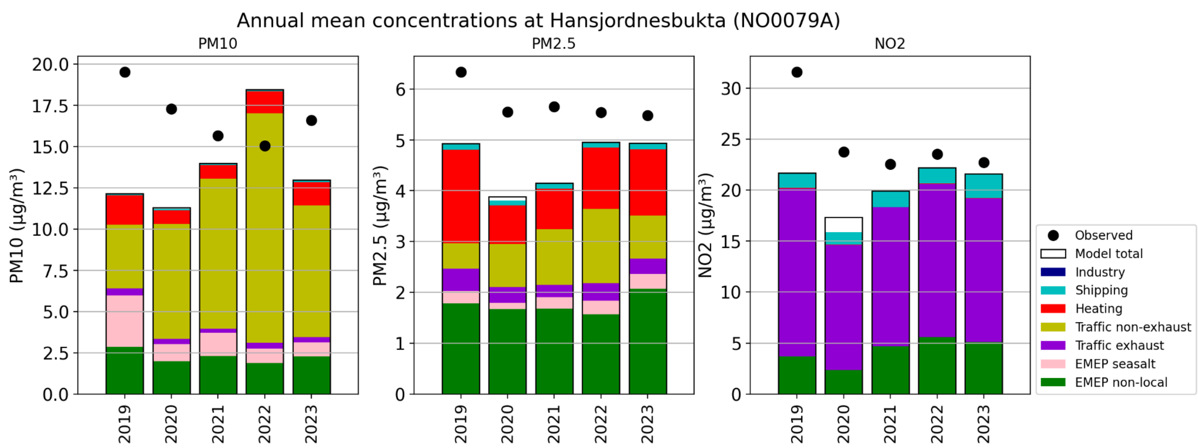
This report presents an assessment of a number of air quality stations where modeled and observed pollutant concentrations consistently deviate. Measures to reduce the biases have been presented and applied, with variable results. The assessment highlights that some issues are common for several of the problematic stations. These issues include the representation of emissions from wood burning, shielding by buildings or topography (not captured by the model), and a mismatch in timing of drying of road surfaces in the road dust model (NORTRIP). In addition, model performance at sites affected by industrial emissions is often poor, as these emission inputs are highly uncertain.

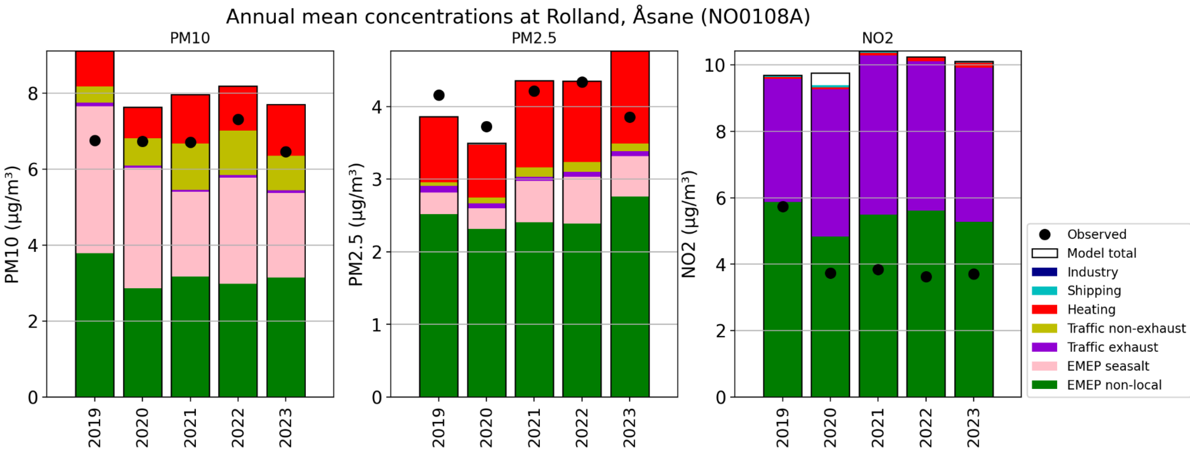
For several stations we see improvements, and scaling of wood burning emissions and manual intervention appears to be particularly effective measures. However, there are only two stations where we can consider the problems to be fixed, neither of which are consequences of model improvements (finished construction site in Bærum, and lower measured values in Lørenskog). There are also many stations where the bias still remains. Future work should include improved representation of the drying process in NORTRIP and getting better data on industrial emissions.

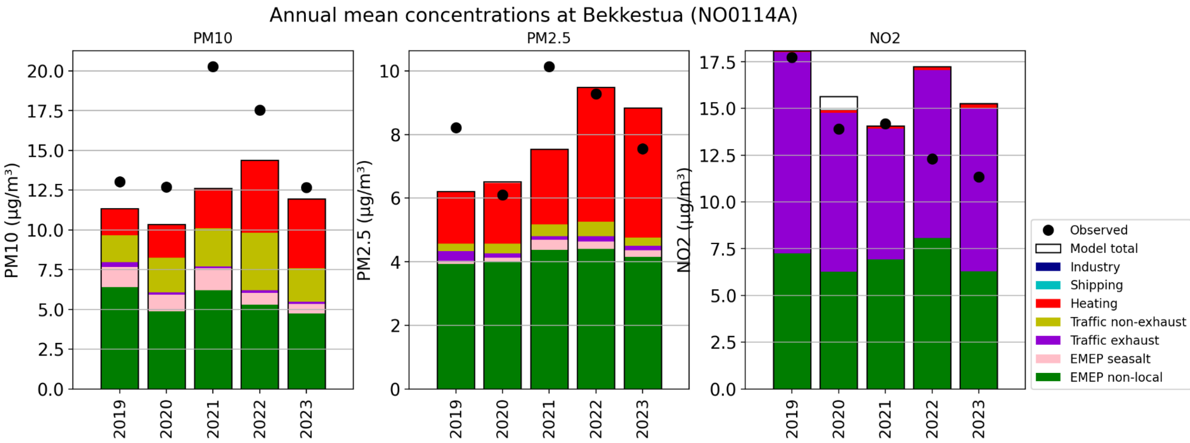
Appendix I: Yearly mean plots

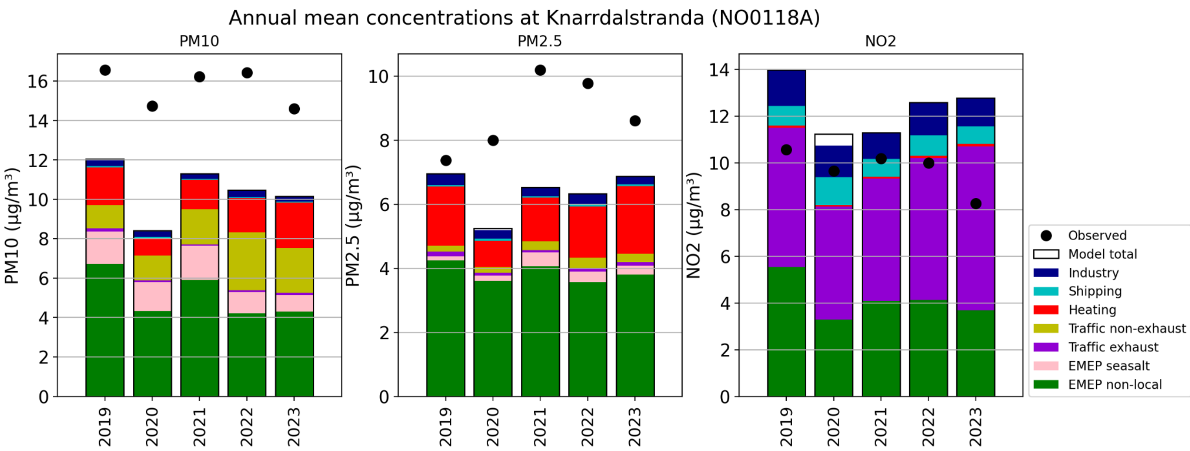


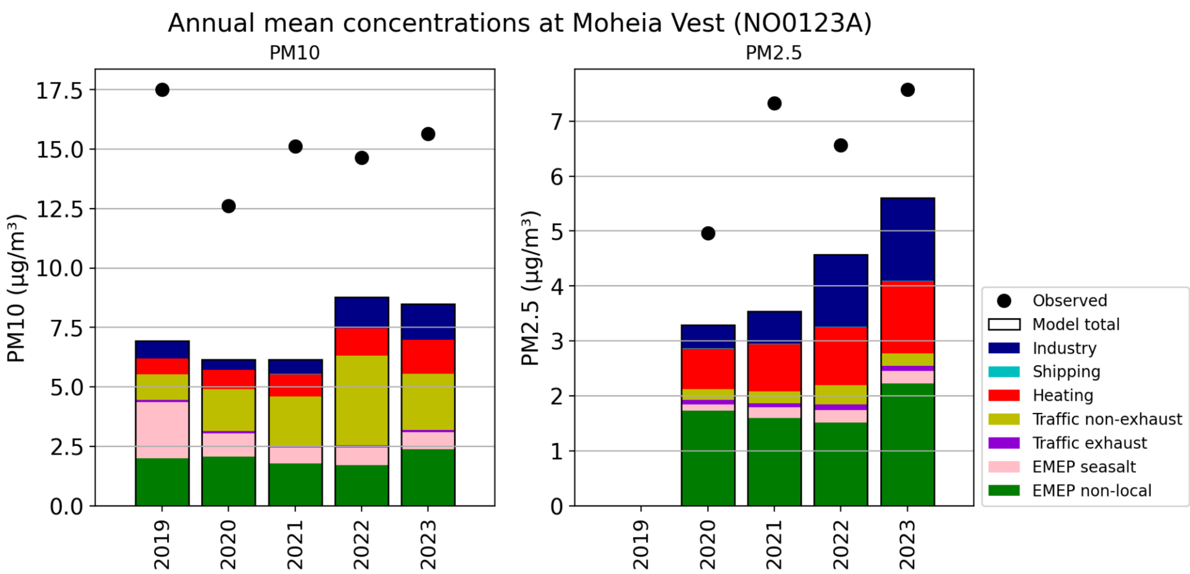


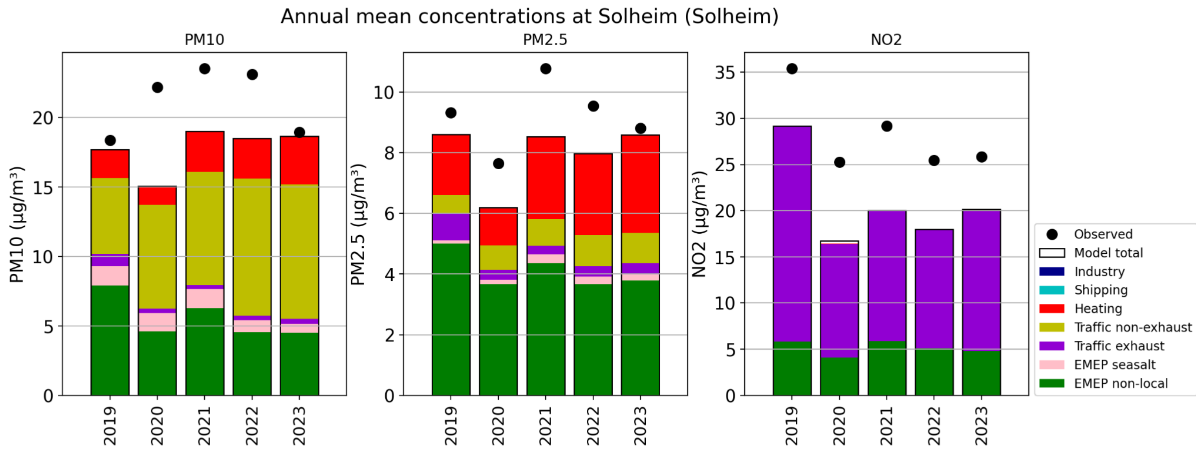


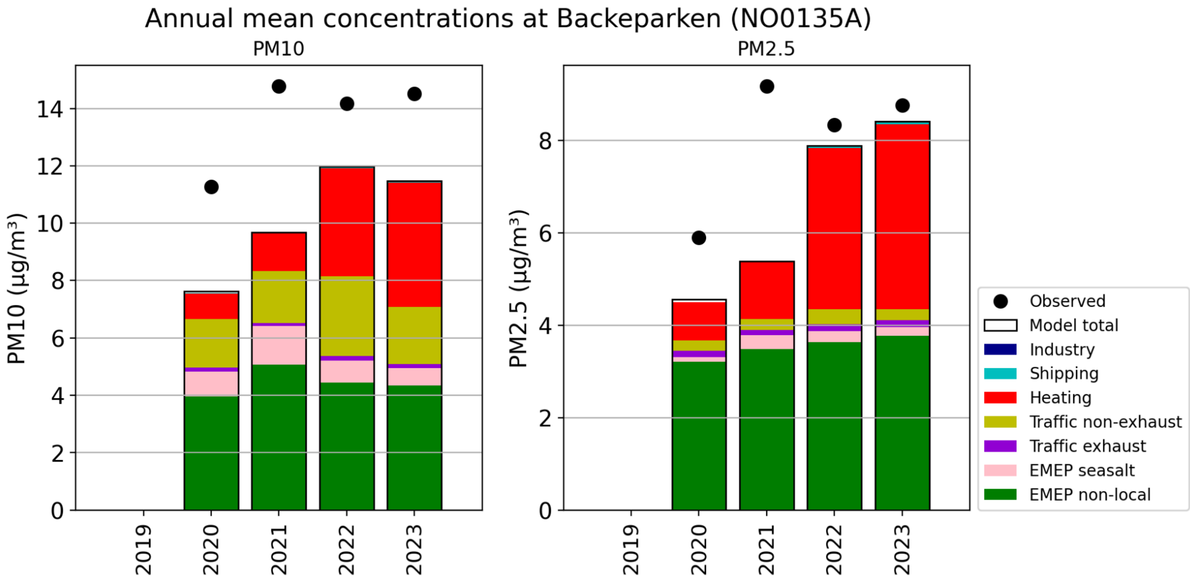

Annual mean concentrations at Rolland, Åsane (NO0108A)
PM10
PM2.5
NO2
PM10 (µg/m³)
PM2.5 (µg/m³)
NO2 (µg/m³)
2019
2020
2021
2022
2023
Observed
Model total
Industry
Shipping
Heating
Traffic non-exhaust
Traffic exhaust
EMEP seasalt
EMEP non-local

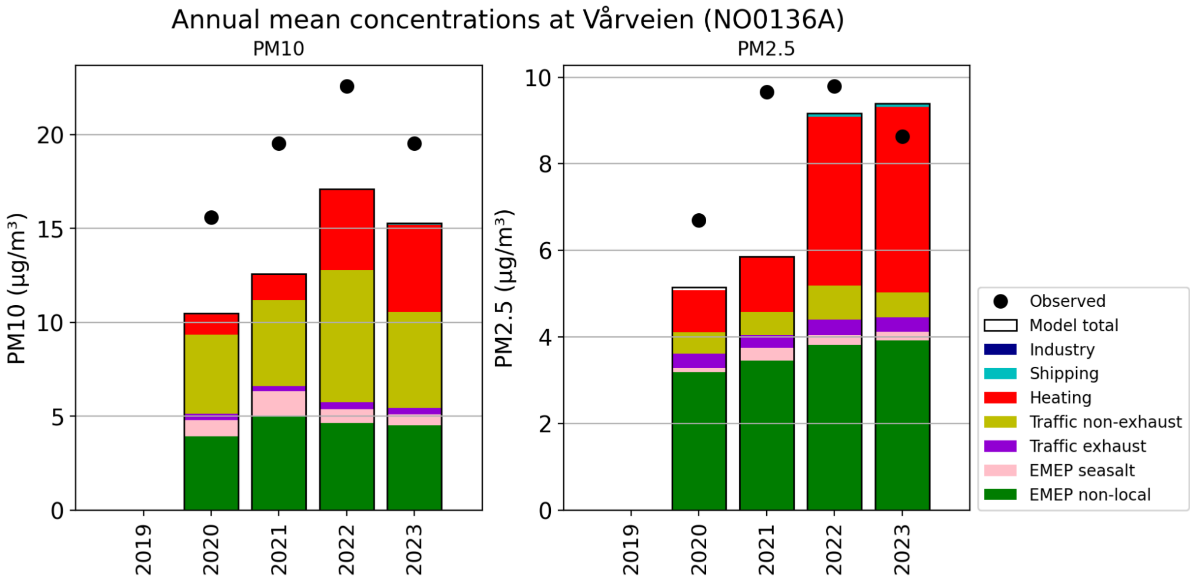

Annual mean concentrations at Bekkestua (NO0114A)
PM10
PM2.5
NO2
PM10 (µg/m³)
PM2.5 (µg/m³)
NO2 (µg/m³)
2019
2020
2021
2022
2023
Observed
Model total
Industry
Shipping
Heating
Traffic non-exhaust
Traffic exhaust
EMEP seasalt
EMEP non-local

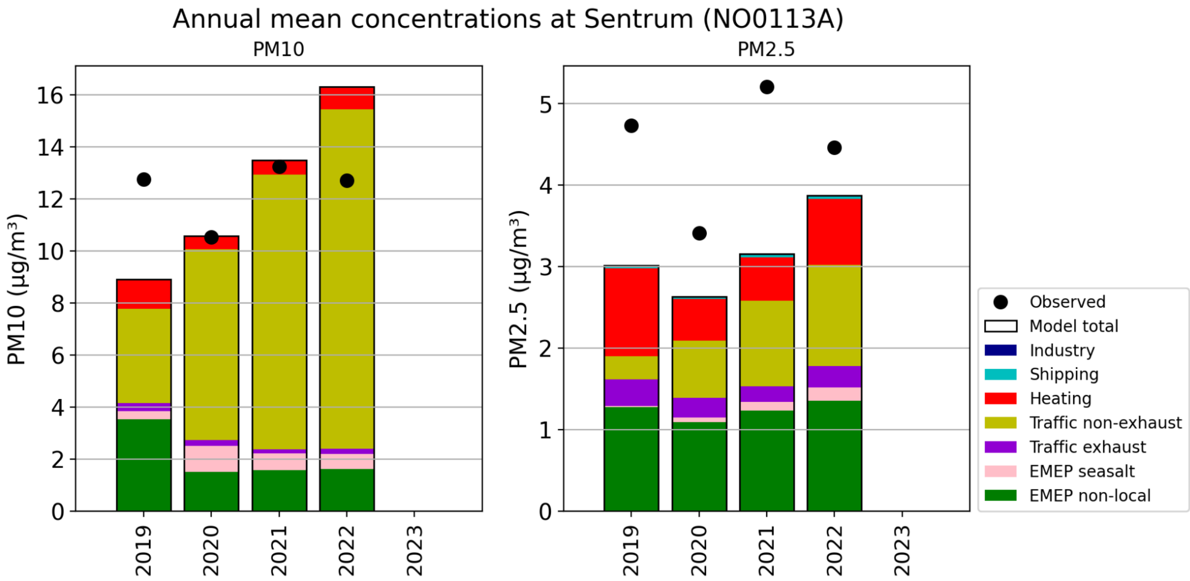

Annual mean concentrations at Knarrdalstranda (NO0118A)
PM10
PM2.5
NO2
PM10 (µg/m³)
PM2.5 (µg/m³)
NO2 (µg/m³)
2019
2020
2021
2022
2023
Observed
Model total
Industry
Shipping
Heating
Traffic non-exhaust
Traffic exhaust
EMEP seasalt
EMEP non-local


Annual mean concentrations at Moheia Vest (NO0123A)
PM10
PM2.5
PM10 (µg/m³)
PM2.5 (µg/m³)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
0
1
2
3
4
5
6
7
2019
2020
2021
2022
2023
Observed
Model total
Industry
Shipping
Heating
Traffic non-exhaust
Traffic exhaust
EMEP seasalt
EMEP non-local

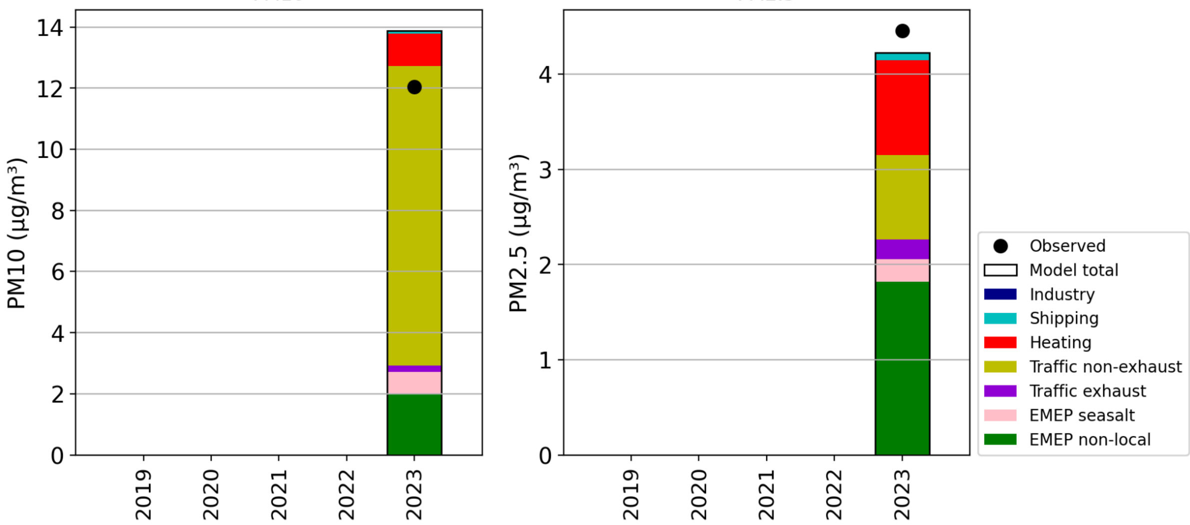

Annual mean concentrations at Solheim (Solheim)
PM10
PM2.5
NO2
PM10 (µg/m³)
PM2.5 (µg/m³)
NO2 (µg/m³)
0
5
10
15
20
0
2
4
6
8
10
0
5
10
15
20
25
30
35
2019
2020
2021
2022
2023
Observed
Model total
Industry
Shipping
Heating
Traffic non-exhaust
Traffic exhaust
EMEP seasalt
EMEP non-local


Annual mean concentrations at Backeparken (NO0135A)
PM10
PM2.5
PM10 (µg/m³)
PM2.5 (µg/m³)
2019
2020
2021
2022
2023
Observed
Model total
Industry
Shipping
Heating
Traffic non-exhaust
Traffic exhaust
EMEP seasalt
EMEP non-local

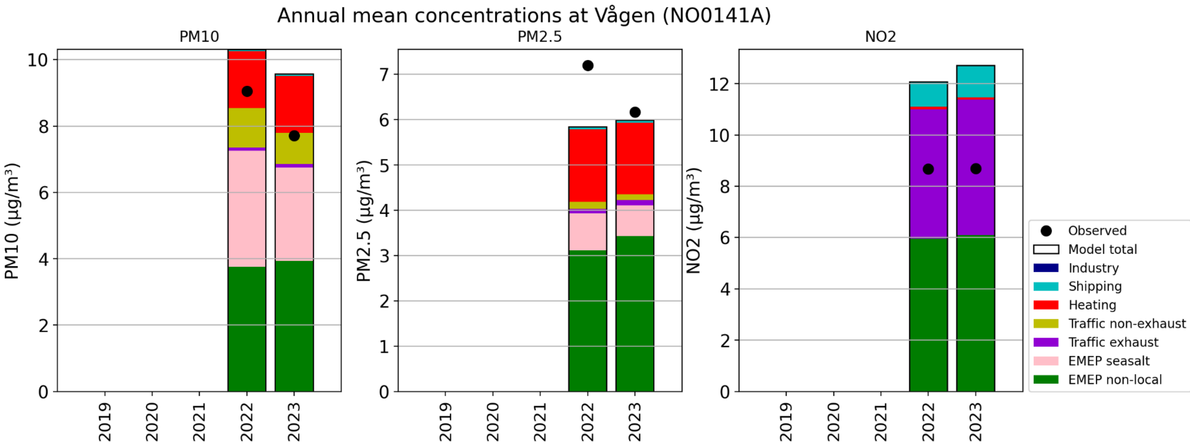

Annual mean concentrations at Vårveien (NO0136A)
PM10
PM2.5
PM10 (µg/m³)
PM2.5 (µg/m³)
2019
2020
2021
2022
2023
Observed
Model total
Industry
Shipping
Heating
Traffic non-exhaust
Traffic exhaust
EMEP seasalt
EMEP non-local


Annual mean concentrations at Sentrum (NO0113A)
PM10
PM2.5
PM10 (µg/m³)
PM2.5 (µg/m³)
2019
2020
2021
2022
2023
Observed
Model total
Industry
Shipping
Heating
Traffic non-exhaust
Traffic exhaust
EMEP seasalt
EMEP non-local

Annual mean concentrations at Kongens gate (NO0148A)



Annual mean concentrations at Vågen (NO0141A)



Annual mean concentrations at Seljestad Rv83 (Seljest)