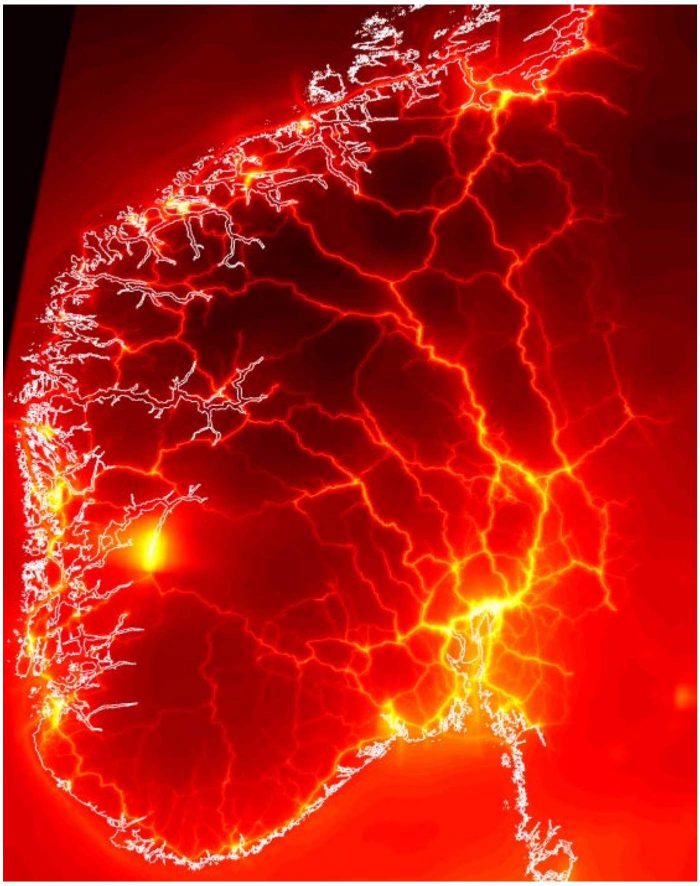
Norwegian Meteorological Institute

Air quality forecast fact sheet

This document provides background information on the air quality modelling system used for the Norwegian air quality forecasts, briefly describing the models and emission data used.



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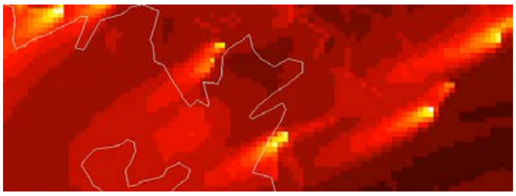
Air quality modelling



Air quality models are used to calculate the concentrations of pollutants resulting from emissions. These models use mathematical equations, which represent the physical and chemical processes in the atmosphere, and solve these using numerical models on computers. Such models are used to forecast air quality at high resolution for all of Norway and the forecast system consists of several parts:

- A modelled emission forecast
- A modelled meteorological forecast (AROME-MetCoOp)
- A modelled long range air quality forecast (EMEP MSC-W)
- A modelled local air quality forecast (uEMEP)

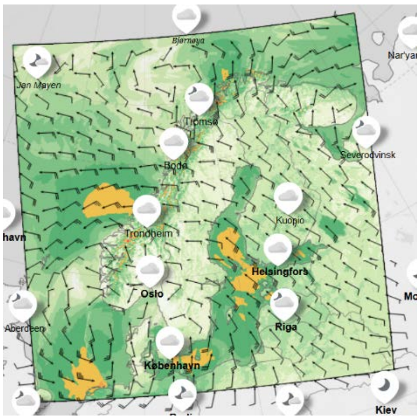
Emissions

Emissions are the cause of poor air quality. These can be in the form of gases, such as NO_2 from traffic exhaust, or in the form of small particles, particulate matter (PM), such as smoke from wood burning. In the high resolution modelling in Norway the most important emission sources have been selected and include:

- Traffic exhaust (NOx and PM)
- Traffic non-exhaust (PM road dust)
- Shipping emissions (NOx and PM)
- Residential wood burning emissions (PM)
- Industrial emissions (NOx and PM)

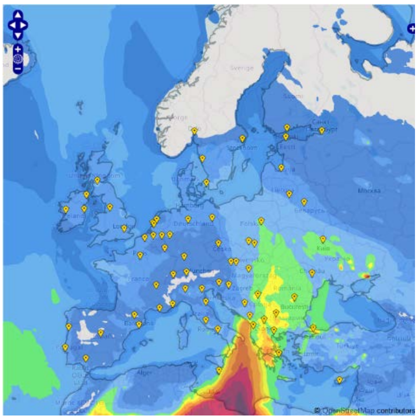
These emissions vary in both time and space. In addition, wood burning emissions and traffic non-exhaust emissions depend on meteorology. In the local air quality modelling the emissions from these sources are estimated and placed in small grids, from 250 to 50 m across, for use in the calculations.

Meteorology



Meteorological data, in particular wind speed and direction, is necessary to transport the emitted pollutants through the air. Turbulence, small eddies of air, will also disperse the pollutants. Emissions are diluted through both transport and dispersion. On windy or warm sunny days dispersion will dilute pollutant emissions much more than on calm cold days. On some winter days temperature inversions will hold pollutants close to the surface. The meteorological forecast data used by both the local and long range models is based on the meteorological forecast from the European Centre for Medium-Range Weather Forecasts (ECMWF, www.ecmwf.int) for the European and global long range calculations and the AROME-MetCoOp model for modelling meteorology over Norway (https://journals.ametsoc.org/doi/10.1175/WAF-D-16-0099.1). This last model calculates meteorology (wind, temperature, precipitation, humidity, radiation, etc.) at a resolution of 2.5 km. This is the same model used for the public forecasts provided by MET Norway and NRK (www.yr.no). This meteorological model provides forecasts for two days in advance.

Long range air quality model



Not all pollutants are produced from local sources. Pollutants such as particulate matter (PM) and ozone can be transported and created over long distances, for example from Northern Europe. For many places in Norway the long range transport is the most important contributor to PM concentrations. The long range transport model used in the forecasts is the EMEP MSC-W model (EMEP stands for the 'European Monitoring and Evaluation Programme', www.emep.int). This model has been developed at MET Norway over many years and is used as part of the Convention on Long-range Transboundary Air Pollution (CLRTAP) to help monitor air quality in Europe and globally. It is applied, together with six other models, to provide four day forecasts of air quality for all of Europe at roughly 150 km resolution (www.regional.atmosphere.copernicus.eu).

Local air quality model

The local air quality model applied is called uEMEP (urban EMEP). This type of model is known as a 'Gaussian' dispersion model. It calculates the concentration at any particular point in space (target grid) from any particular emission grid. uEMEP finds all upwind emission grids within a 10 x 10 km^2 area and calculates the contribution from each of these emission grids to that target grid. It also keeps track of which source created the emissions so that the contribution from each source can be estimated. uEMEP calculates concentrations at roughly 70 million target grids ranging in size from 50 to 250 m in Norway. These target grids are visible on the maps created by uEMEP. For emissions outside of the 10 x 10 km^2 region then the EMEP model provides these concentrations on 2.5 km grids.

Atmospheric chemistry

There are many chemical processes going on in the atmosphere. The long range transport model, EMEP MSC-W, takes into account many of these that occur on both short and long time scales. uEMEP only takes into account the most important and fastest of these reactions that affects NO_2 concentrations. During combustion, e.g. traffic and shipping exhaust emissions, both NO_2 and NO are produced. Roughly 80% of these emissions are in the form of NO. In the atmosphere NO quickly (a matter of minutes) reacts with ozone (O_3), creating more NO_2 and oxygen (O_2). This reaction is included in uEMEP along with the slightly slower (10's of minutes) chemical process where sunlight can breakdown NO_2 back down to NO.

Model limitations

A mathematical model of air quality requires information on emissions and meteorology in order to calculate concentrations. Models are a representation of reality and have limitations, which means that not every detail of reality can be included in the models. Never the less such models can provide very good estimates of air quality. The following limitations exist:

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- The emissions used in the forecasts are based largely on a statistical analysis of ‘normal’ activities. Deviations from this, which occur every day, are not included in the model emission forecasts
- The Gaussian model used does not take into account obstacles such as buildings. The calculations are made as if no buildings exist
- Terrain is included in the meteorological calculations at 2.5 km. Variations in the wind within this grid size are not represented in the modelling

Further descriptions of EMEP and uEMEP can be found in the annual EMEP-MSCW reports (http://emep.int/mscw/mscw_publications.html).

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Traffic emissions

Traffic emissions from both exhaust and non-exhaust sources are used in the air quality forecasts. The following elements are included in the road traffic emissions:

- Road network data
- Traffic volume and traffic time profile data
- Exhaust emission factors
- Non-exhaust road dust emission modelling

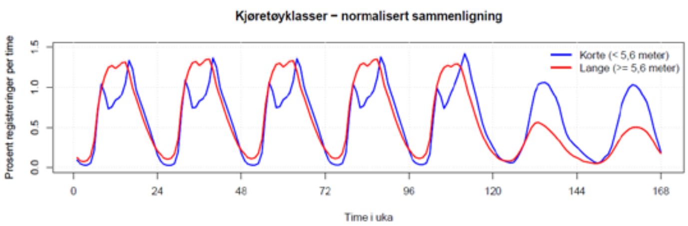
Road network data

Road network data is provided by the Norwegian Public Roads Administration (Statens Vegvesen, SVV) and is freely available through the National road database (NVDB, https://www.vegvesen.no/fag/teknologi/nasjonal+vegdatabank). All roads owned and maintained by state and municipal authorities are included. Information used from these roads include geographical position, number of lanes, road category type, bridge or tunnel, signed speed, etc.. Though this database is comprehensive it is not entirely complete, so some roads may not contain all the relevant data for producing traffic emissions.

Traffic volume data

Most state roads in NVDB include information on traffic volume, specifically the average number of vehicle passages per day (ADT, Annual Daily Traffic). In addition, the fraction of heavy duty vehicles is also provided. Most municipal roads are not provided with ADT in the database. A traffic model, developed by SSB (https://www.ssb.no/transport-og-reiseliv/artikler-og-publikasjoner/modellering-av-trafikk-pa-kommunale-veier) for noise modelling provides these additional municipal road data. In total 45 million kilometers are driven by vehicles each year in Norway (https://www.ssb.no/transport-og-reiseliv/statistikker/klreg).

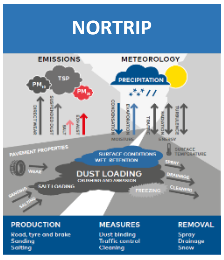
To determine hourly traffic volumes from the daily traffic data then time profiles for light and heavy duty vehicles are used. These are derived from traffic counts made by SVV at over 2000 sites throughout Norway. SVV has provided time profiles for each county in Norway as average hourly time profiles over a week, 168 hours. Currently a single average time profile is used for all of Norway, derived from these county data, for both light and heavy duty traffic. Time profiles are very similar over most of Norway but local variations do occur.



Exhaust emissions

Exhaust emissions per hour for a road are determined by multiplying the number of vehicles per hour on the road with the length of the road and with an emission factor, given as g/vehicle/km. These emission factors vary significantly between vehicle types and so average emission factors are determined based on the vehicle fleet makeup. For the current implementation of the air quality forecast use is made of average emission factors derived at national level by SSB (www.ssb.no/natur-og-miljo/statistikker/agassn) and applied everywhere in Norway. Different emission factors for light and heavy duty vehicles are used. Emission factors for NOx and particle exhaust are included.

Non-exhaust emissions



Non-exhaust emissions from road, tyre and brake wear are calculated using a special emission model called NORTRIP. This model uses information on studded tyre share, traffic volume data, meteorological data and winter maintenance data to calculate these emissions. The model also predicts road surface conditions and includes the build up of road dust on the road surface during the winter months and its suspension during dry periods. Information on this model and road dust in general can be found in an overview document published by the Nordic Council of Ministers (http://norden.diva-portal.org/smash/get/diva2:1069152/FULLTEXT02.pdf).

Other assumptions and limitations

- Most emissions within a tunnel exit at the tunnel portals, but a fraction will remain in the tunnels through deposition. This effect is most important for particles in long tunnels. Ventilation towers are not currently included in the model. Tunnels are also assumed to always be dry, so road dust is continuously emitted within them even when it is wet outside
- No information on salting, sanding, snow removal, cleaning or dust binding is currently available for use with the forecasts. These activities can have an important impact on the conditions on the road surface and therefore on the emissions. Salting and snow removal activities are predicted based on forecast meteorology. The other maintenance activities are currently not included.
- All roads are taken to be on the surface, including bridges. The emission from vehicles is taken to be at 1 m height.
- No real time information is included in the traffic data. So if roads are closed or traffic deviates from the normal statistical pattern then this does not impact on the model.

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Industrial emissions

Industrial emissions can be the result of many processes including combustion, chemical processing or other activities associated with, for example, cement production, quarry work, etc.

Emissions

Industrial emissions for 300 industrial sites in Norway are available from a database maintained by The Norwegian Environmental Agency (*Miljødirektoratet*) and the Statistical Bureau of Norway (SSB) (www.norskeutslipp.no/). This database contains annual emissions for a range of pollutants. The database is however limited, as it provides no information on temporal variation of the emissions, provides just one single geographical coordinate for the emissions and provides no information on the heights or the areal distributions of the emissions. Only the largest industrial emission sources are included. These data, though currently limited, will be progressively updated as more information becomes available.

Emission heights

Many industrial emissions are emitted from high stacks. The height of these stacks has usually be determined before construction to avoid exposing the population to pollutants emitted from them. In addition many stacks emit air that is warm and sometimes at high exit velocities. Thus the plumes from these stacks are often much higher than the stacks themselves. As previously mentioned information on these stacks is limitted so in the current model version all industrial emissions are set to an effective height of 100 m. These will be updated as more information becomes available.

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Residential wood burning emissions

Residential wood burning is estimated to be the single largest emission source for particulate matter in Norway (https://www.ssb.no/natur-og-miljo/statistikker/milgiftn). Wood burning emissions are dependent on many factors. On the type of oven or fireplace used, the type and wetness of the wood, the way in which the wood is burned and the stage of wood burning. Wood burning emissions require information on

- The type of oven in use
- The amount of wood used in the ovens
- The spatial distribution of the ovens and their level of use in residential areas
- The time of day and day of week when ovens are used
- The weather conditions, particularly temperature
- The height of the chimneys

This information is not directly available for all households in Norway so special methods have been used to try to determine these.

The MetVed model

In order to determine the emissions from wood burning the Norwegian Institute for Air Research (NILU) has developed a model called 'MetVed'. The model uses a combination of several data sources with information at a high level of detail. Information used to determine where wood burning occurs includes the number and type of dwellings, e.g. houses or apartments, the energy consumption of the dwellings as well as the number and type of fireplaces and stoves in use. The different data sources are combined to provide a 'wood burning potential' for any particular group of households. This information has been made to cover all of Norway at 250 m resolution.

In addition to the spatial distribution of the wood burning potential it is necessary to know the amount of wood used. This information is derived from questionnaires regularly sent out by SSB to a few thousand households who are asked, amongst other questions, about their wood burning habits. From this the total wood consumption per year and per county in Norway is estimated and the wood consumption is distributed using the 'wood burning potential' determined with the MetVed model.

Wood burning varies with time. Most wood burning occurs in the evenings and in the weekends when people are at home. In addition wood burning is dependent on the outside temperature and to a lesser extent precipitation and humidity. In the MetVed model a daily and weekly burning cycle is used, based on questionnaire data about when people use their wood stoves. This cycle covers each hour of the week and is the same for all of Norway. The influence of temperature is included in the model. When daily mean temperatures fall below a certain limit, in this case 11^{o}C, then wood burning will start to take place. The amount of wood burning increases with decreasing daily mean temperature. A single emission height of 15 m is used which reflects wood burning emissions from free standing houses.

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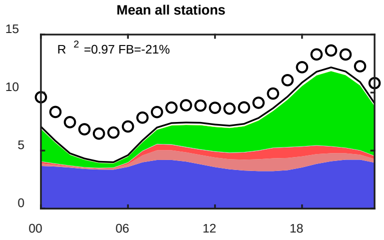
Comparison to measurements



Almost all wood burning emissions are in the particle size range less than 2.5 µm ($PM_{2.5}$). The uEMEP model has calculated $PM_{2.5}$ concentrations at all measurement sites (37 stations) for the period November 2017 – April 2018 and compared model calculations of $PM_{2.5}$ with observed concentrations. On average the contribution of wood burning is well represented but the average $PM_{2.5}$ concentrations are underestimated by 21% (FB). A number of other sources also contribute to $PM_{2.5}$ concentrations, particularly non-local (long range transport), so this underestimation may be due to any of the other sources as well.

For more information concerning the MetVed model contact NILU (www.nilu.no)

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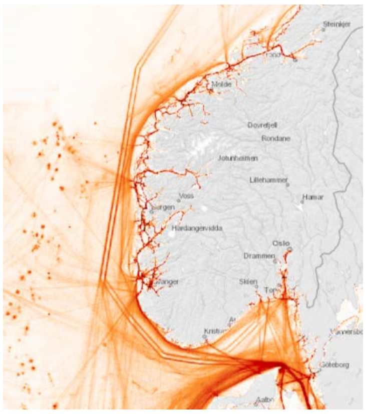
Shipping emissions

Near ports shipping can be an important contributor to air pollution, particularly for NO_2. Shipping emissions are calculated with the help of AIS (Automatic Identification System) data. All ships of any reasonable size have an AIS transmitter installed. This sends the position and identity of the ship to both satellite and mast receivers every few minutes. With this the ships position is continuously tracked. Emissions are calculated using a model, hosted by the Norwegian Coastal authorities (https://havbase.no/). This model takes into account the ship type, size, weight and engine type and uses the change of position of the ship to calculate speed and engine load. When the ship is not moving it is assumed to be at port. While the AIS transmitter is on, then the ship engines are assumed to be running and the ship will be emitting exhaust pollutants. The Norwegian coastal authorities (*Kystverket*) provide this information along with a public website for viewing ship movements using the AIS data (https://havbase.no/). A description of AIS data can be found at https://havbase.kystverket.no/havbase_report/doc/AIS.pdf .



Shipping emission data are aggregated into 250 x 250 m^2 grids along the coast of Norway. Montly means are made for each month of the year (2017) and these monthly means are used for the same month next year. In addition an average daily time profile (24 hours) is made every month at 2.5 km resolution to take into account regular variations in shipping emissions. As in industry large ships emit exhaust from high stacks. The emitted exhaust is most often warmer than the surrounding air and will rise. Also, as in industrial emissions, information necessary to calculate the emission height is not easily available. Since the largest emitters have high stacks and warm emissions then ship emissions are currently set to a height of 70 m. This will be updated as more information becomes available.

There are a number of uncertainties in the shipping emission data which include:

- AIS data is sometimes missing at certain spots. But this generally occurs far from ports
- Some ports provide electricity to the ships (land lines) so that ships do not have to generate their own electricity on board, using the motors. This is not included in the emissions but is planned to be covered in future developments
- Emission heights vary from ship to ship but the largest emitters will generally have the highest emission heights. This will be updated as more information becomes available.
- There is uncertainty in the assumption that the same month last year is representative for this year. However, it is not possible to ‘predict’ the next two days of shipping movement without significant effort.