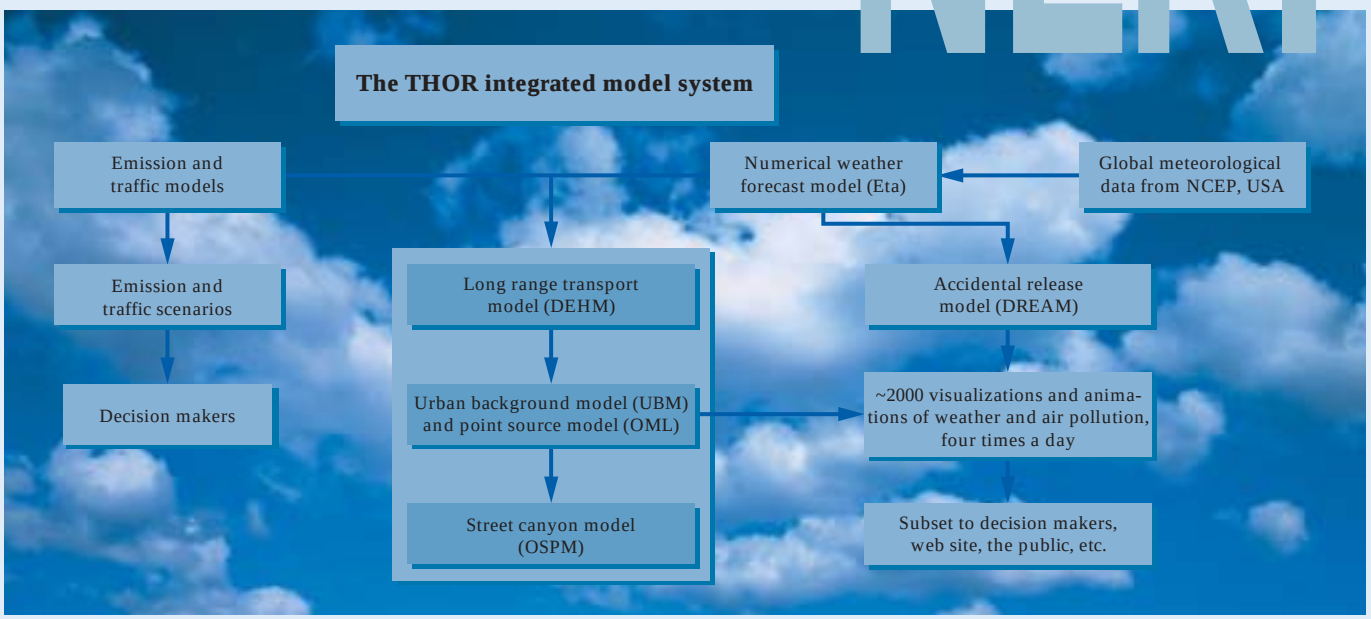
THOR – an Integrated Air Pollution Forecasting and Scenario Management System

NERI



The National Environmental Research Institute (NERI), Denmark, has developed a comprehensive and unique integrated air pollution model system, THOR. The model system includes several meteorological and air pollution models capable of operating for different applications and different scales. The system is capable of accurate and high resolution three-days forecasting of weather and air pollution from regional scale over urban background scale and down to individual street canyons in cities – on both sides of the streets. Coupling models over different scales makes it possible to account for contributions from local, near-local as well as remote emission sources in order to describe the air quality at a specific location – e.g. in a street canyon or in a park. Furthermore, the system can be used to forecast air pollution from accidental releases as e.g. power plants, industrial sites and natural or human made fires.

The main purposes of the THOR system are forecasting, nowcasting, emission reduction scenarios, retrospective analysis and air pollution assessments and management. The system can be used for information and warning of the public in cases of high air pollution levels and for policy management (e.g. by emission reduction or traffic scenarios) of many different chemical compounds.

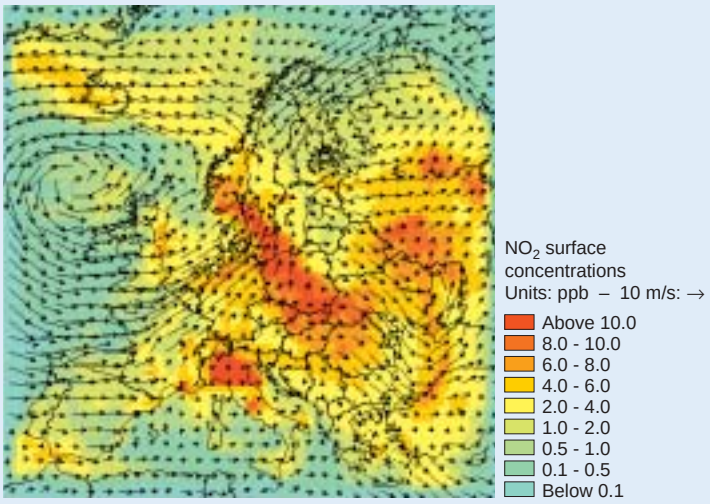
The system can be applied operationally for any location all over the world. The system consists of several different air pollution models – all developed at NERI during the last decades. A schematic diagram of the different modules and the data flow chart of the THOR system is shown in the figure above. The model system consists of a coupling of several models, shortly described in the following.

Applications

Present capabilities of the THOR system include all aspects within forecasting, nowcasting, supplement to monitoring programs, scenarios, retrospective analysis, assessment and management of air pollution. Some examples are:

- Three-day high-resolution regional weather forecasts
- Three-day regional air pollution forecasts of 60 chemical compounds, e.g. ozone, sulphur, nitrate, particles, etc.
- Three-day urban background air quality forecasts in cities
- Three-day urban air quality forecasts at street level in cities at both sides of the streets
- Three-day forecasts of accidental releases into the atmosphere from e.g. nuclear power plants, fires, chemical industries, etc.
- Emission and traffic reduction scenarios for air pollution management and decision making
- Multiple-point and area source dispersion modelling, for determining the effects on air quality caused by proposed new emission sources (e.g. new power plants, chemical industries, commercial activities)
- Automated production of data, visualisations (maps and time series), information and warnings
- Data, forecasts and warnings are disseminated to the authorities and decision-makers
- Data can be disseminated to the public via the Internet or other media

The long-range transported air pollution

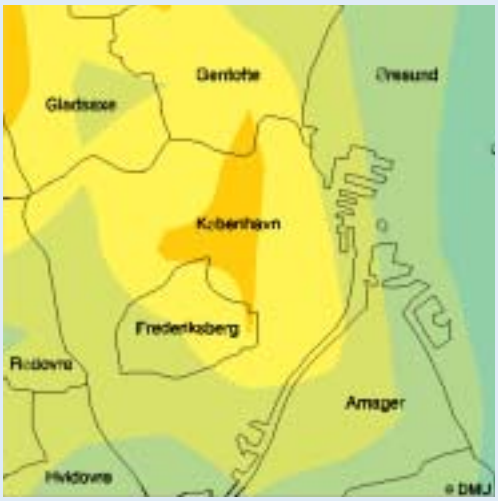


DMU-ATMI THOR air pollution forecast for 12/11 2002, 12 UTC
Forecast started at: 12/11 2002, 00 UTC

The weather forecast is used as input to a long-range transport air pollution model, the Danish Eulerian Hemispheric Model, DEHM, producing air pollution forecasts on regional background scale (e.g. the greater European scale).

The operational version of the model calculates transport, dispersion, deposition and chemistry (including photochemistry) of 60 chemical compounds. Furthermore, the model can be used to describe and forecast sand / dust storms. The emission data used in DEHM are derived from a combination of information provided by the European Monitoring and Evaluation Programme (EMEP) and global emission databases. The figure above shows forecasted concentrations of nitrogen dioxide over Europe at November 12th 2002.

Air pollution in the urban background



Air pollution forecast for NO_2 over the city of Copenhagen

Meteorological data from the weather forecast and air pollution concentrations from the long-range transport model are subsequently used as input to the Urban Background Model, UBM, calculating the urban background air pollution based on emission inventories with a spatial resolution down to one kilometre or even less. The model is e.g. run operationally for the central city of Copenhagen and for the city of Aalborg, Denmark, and the results of these calculations are updated on the Internet four times each day. The UBM model, in the version presently applied in Denmark, is suitable for calculations of urban background concentrations when the dominating source is the road traffic and / or large point sources. The figure above shows concentrations of nitrogen dioxide over the city of Copenhagen.

The weather forecast

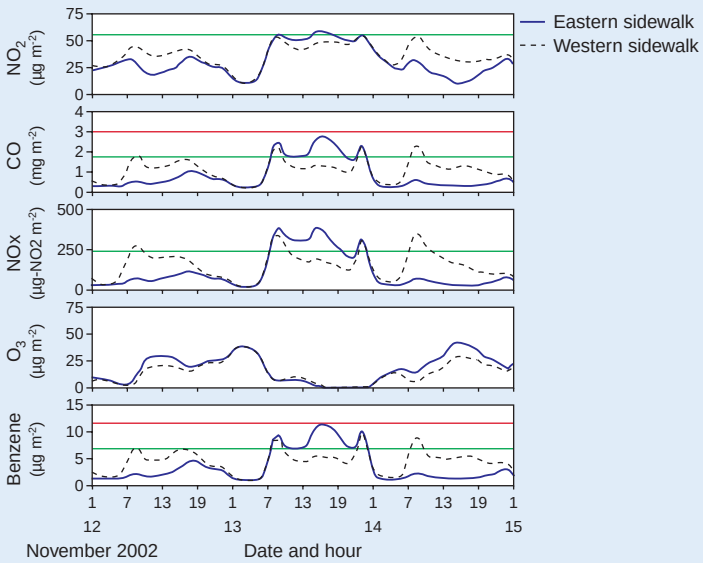
A three-dimensional numerical weather forecast model (Eta) is applied. This model is initialised with data from a global circulation model, run at the National Centres for Environmental Prediction, NCEP, USA. Data from this global circulation model are the starting point for nearly all weather forecasts in the USA, and for many forecasts in Europe.

The spatial resolution of the weather forecast model is e.g. 39 km x 39 km over the global grid and 10 km x 10 km over a sub-domain. Three-dimensional information on winds, temperature, humidity, clouds, precipitation, turbulent fluxes, radiation, etc. can be visualised e.g. every six hours as maps and e.g. every one hour as time series for specific locations.

Local scale releases from point sources

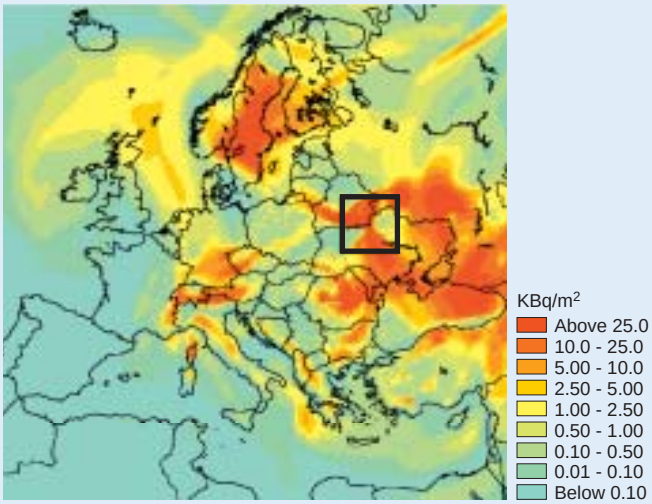
In addition to urban air quality forecasting, the multi-point (plus area source) dispersion model, OML, has been integrated into the THOR system. This new feature is based on the coupling of the OML point and area dispersion model to the urban background model (UBM). The OML model is the standard model applied to routine application testing within the Danish Environmental Protection Agency for e.g. estimating the optimal heights of industrial stacks. OML is a local-scale operational air pollution model for estimating dispersion of a passive, or possibly buoyant, gas from strong point and area sources. It can be applied to distances up to approximately 30 km from the source.

Air pollution in street canyons



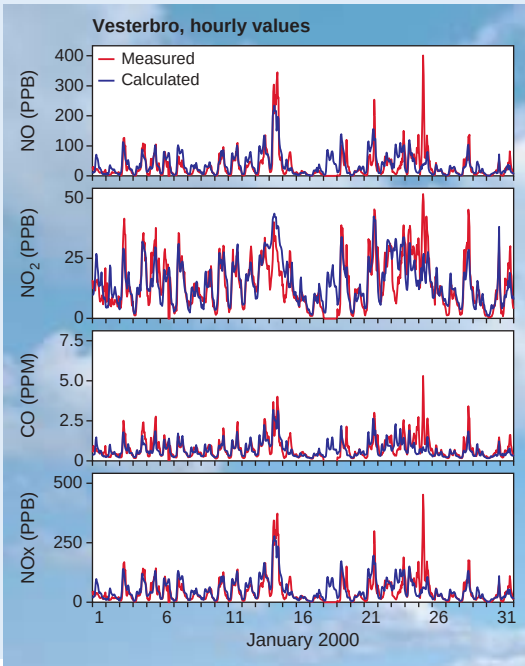
The output from the urban background model is used as input to the Operational Street Pollution Model, OSPM, producing the air pollution concentrations at street level at both sides of the streets in cities. The model calculates air concentrations of NO, NO_2, NOx, O_3, CO and benzene in the street canyon at both sides of the street. Particles will be included in the model in the near future. The OSPM has been successfully tested under specific European field campaigns in a variety of different climatic and air quality conditions in, e.g., Copenhagen, Gothenburg, Helsinki, Oslo, Brussels, Berlin, Hanover, and Milan. It has also been tested and applied in Beijing, China, under a co-operation agreement with Tsinghua University. Due to the circulation of air in street canyons, the air pollution concentrations can be very different at the two sides of a street. This is illustrated in the figure above that shows a three-day forecast of air pollution concentrations at the western (black dotted line) and eastern (blue line) side of a street in Copenhagen for different chemical compounds. Depending on the meteorological situation, the concentration levels are very different.

Large scale releases from point sources



^{137}Cs total deposition

Furthermore, the weather forecast drives the Danish Rimpuff and Eulerian Accidental release Model, DREAM, used in connection with accidental releases at greater scales as e.g. the Chernobyl accident. DREAM is a combined Lagrangian and Eulerian model, where the Lagrangian part handles the initial near-source transport and dispersion (up to ~300 km from the source) and the Eulerian part calculates transport and dispersion in an area covering e.g. Europe. The model can be used for any accidental release from power plants, industrial sites, natural and human made fires, etc. The figure above shows the total deposition of ^{137}Cs two weeks after the Chernobyl accident in 1986.

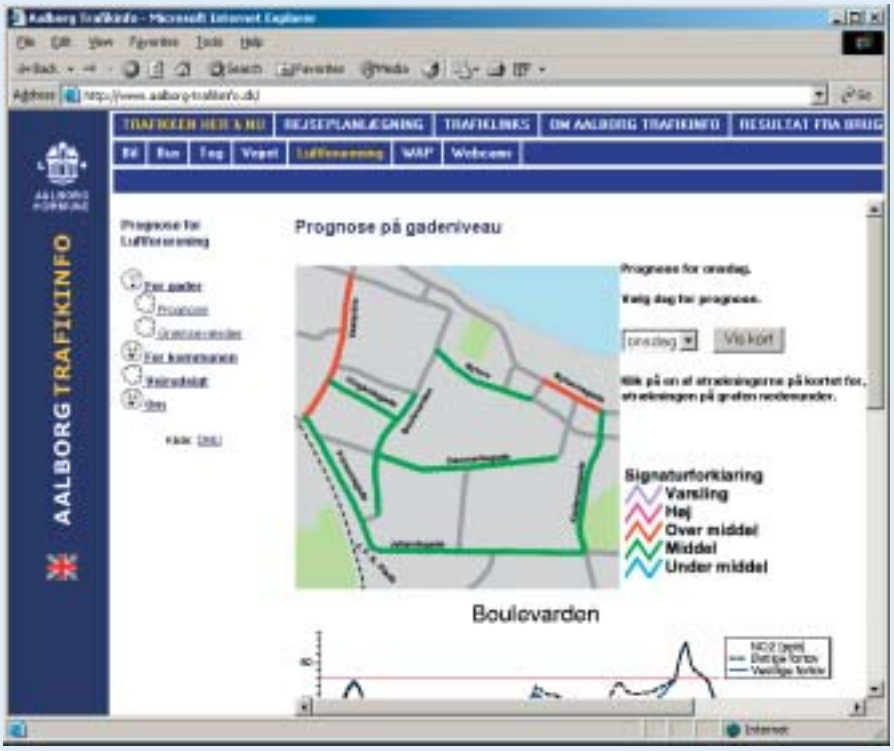


Operational procedure and comparison to measurements

The whole THOR system is currently run operationally, up to four times every day initiated with data at 00 UTC, 06 UTC, 12 UTC and 18 UTC. The system is fully automated – meaning that the entire procedure of receiving the data, running the models, producing the visualisations and sending the specified results to the end-users is controlled by automated procedures. The operational performance of the system is monitored every day. The whole system and the operational procedure have been run, tested and validated since August 1998.

Example of comparison of some model results with measurements as time series for January 2000 is shown in the figure to the left. The figure shows a comparison of hourly values of measured concentrations and the air pollution forecast at the street Vesterbro, Aalborg. As seen in the figures, the models produce very accurate forecasts of air pollution concentrations.

Dissemination of results to end-users



All weather and air pollution data from the system can be disseminated to the authorities, decision-makers and the public. The raw data can be displayed as maps or time series. Furthermore, information about exceedances of critical air pollution levels can be extracted and displayed as colour codes or given as compressed information, as e.g. "below mean", "mean", "above mean", "high" or "warning".

The home page (in Danish) displays the air pollution at ten streets in the city centre of Aalborg. The streets are coloured according to the five possible information levels described above. Furthermore, time series including the air pollution concentrations are given.

Further Information

Please contact: Jørgen Brandt

National Environmental Research Institute, Department of Atmospheric Environment
Frederiksborgvej 399, P.O.Box 358, DK-4000 Roskilde, Denmark
Phone: +45 4630 1157, Fax: +45 4630 1214
E-mail: jbr@dmu.dk
Home page: http://thor.dmu.dk