The THOR Integrated Model System

A contribution to subproject GLOREAM

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Summary

An integrated model system, THOR, for air pollution applications has been developed. The model system includes several meteorological and air pollution models capable of operating for different applications at different spatial scales – ranging from hemispheric scale over European and urban background scales to urban street scale. 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. The main purposes of the system are forecasting, nowcasting, emission reduction scenarios, retrospective analysis and air pollution assessments. Furthermore, the system is used in connection with the urban and background monitoring programs in Denmark.

In this paper, an overview of the model system will be given, including a short description of the individual models. The integrated system was initially developed for air pollution forecasting. An example of the model performance with respect to forecasted air pollution concentrations in an urban street canyon is presented.

The THOR model system

The development of the THOR system, including detailed descriptions of some of the models in the system, have been documented in several publications (see e.g. Brandt et al., 1999a, b; 2000a, b; c; d; 2001a, b, c, d, e and references herein). A schematic diagram of the different modules and the data flow chart of the THOR system is shown in Fig. 1. The system consists of a coupling of several models, shortly described in the following:

The numerical weather forecast model, Eta, is applied (Nickovic et al., 1998). This model is initialised with data from a global circulation model run at the National Centres for Environmental Prediction, NCEP, USA. The weather forecast is used as input to a long-range air pollution transport model, the Danish Eulerian Operational Model, DEOM, producing air pollution forecasts on European scale. DEOM has been compared to other models with respect to the ozone forecasts within GLOREAM (Tilmes et al., 2001). Meteorological data from Eta and air pollution concentrations from DEOM are subsequently used as input to the Urban Background Model, BUM (Berkowicz 1999b) calculating the urban background pollution based on NO_x and CO emission inventories. This model is currently run on operational basis for the central city of Copenhagen with a 2 km x 2 km grid resolution and for the city of Aalborg with a 1 km x 1 km grid resolution.

The output from BUM is used as input to the Operational Street Pollution Model, OSPM, (Berkowicz 1999a) producing air pollution concentrations at street level at both sides of selected streets in the cities. The OSPM model is a parameterised semi-empirical model making use of a priori assumptions about the flow and dispersion conditions in a street canyon. The urban models calculate air concentrations of NO, NO_2, O_3, CO and benzene.

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These four models (Eta, DEOM, BUM and OSPM) constitutes the operational part of the THOR system. Operational three days air pollution forecasts are produced four times every day. The system can, in principle, be applied for any city in Europe. The model system has been operational since August 1998 and is continuously being validated against measurements from the Danish urban monitoring network (Kemp and Palmgren, 1999). The forecasts are available at the web page: http://www.aati.dk, for Aalborg, and http://luft.dmu.dk, for Copenhagen and the background concentrations. An example of comparison of results from the urban street canyon model, OSPM, with measurements for a street in the city of Aalborg is given in Fig. 2. The figure includes time series of hourly values of forecasted meteorological parameters and air pollution concentrations for January 2000.

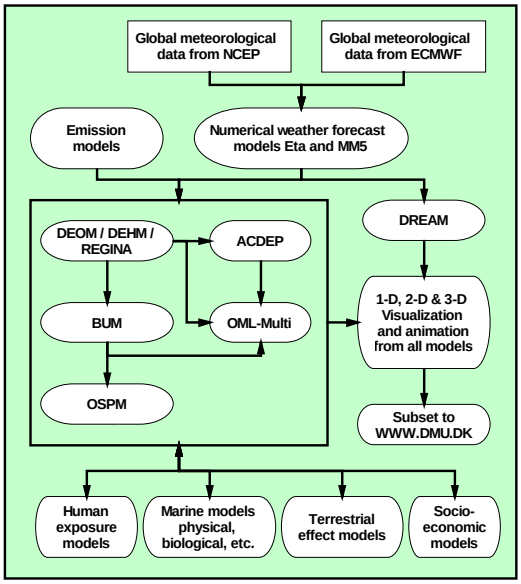

Figure 1. Schematic diagram and data flow for the different modules in the THOR air pollution forecast system.

The Atmospheric Chemistry and DEPosition model, ACDEP (Hertel et al., 1995), is a semi-operational Lagrangian long-range transport model, using four days back trajectories. Within the Danish national background monitoring program, the model is run at the beginning of a year for the previous year and used e.g. to estimate the total nitrogen deposition to the inner Danish waters. ACDEP receives initial concentrations from the DEOM model and meteorological data from the Eta model.

The MM5 model (Grell et al., 1995) coupled to ECMWF data is included in the system. This model drives the newly developed models DEHM and REGINA. DEHM is a comprehensive three-dimensional long-range transport air pollution model with nesting capabilities covering the Northern Hemisphere. The REGINA version of DEHM (Frohn et al, 2001) includes a high-resolution set up over Northern Europe and Denmark with spatial resolution down to 5 km x 5 km and more detailed nitrogen chemistry (ammonia and ammonium). Different model versions include different air pollution species, e.g.: sulphur oxides, lead, mercury (12 species) and CO_2. Furthermore a version of DEHM including aqueous chemistry and photo-chemistry with 53 species has been developed.

The MM5 model also drives the Danish Rimpuff and Eulerian Accidental release Model, DREAM (Brandt et al., 1999b), used in connection with accidental releases, 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 ~200 km from

the source) and the Eulerian part calculates transport and dispersion in an area covering Europe.

Conclusions and future work

An integrated model system, THOR, has been developed. Different models are coupled within the system covering different scales and applications. The system e.g. includes operational weather and air pollution forecast capabilities from European scale to urban street scale. The system and the individual models in the system have been validated against existing measurement data and an example is shown in this paper (Fig. 2).

The next step in the system development is the implementation of the OML-Multi model, which is a Gaussian plume model used to describe the near-source (up to 20 km) transport and dispersion of air pollution from multiple point sources (Olesen et al., 1992). The model will be included in the system in the near future. The model can be used to estimate the concentration fields from industrial stacks and area sources (e.g. domestic heating), and will be further developed to calculate with high resolution the near field dispersion of ammonia from agricultural activities and smoke release from local fires (e.g. from factories). The model receives time series from a long-range transport model (i.e. ACDEP, DEOM, DEHM or REGINA, which in the future will be merged) and meteorological time series from the Eta model.

The final objective is to couple the THOR system to models within different effect sectors. This makes the THOR system suitable as a tool for policy analysis of effects from air pollution. These effect sectors cover, e.g.: 1) human exposure, 2) physical and biological marine environment, 3) terrestrial eco-systems and 4) socio-economic effects.

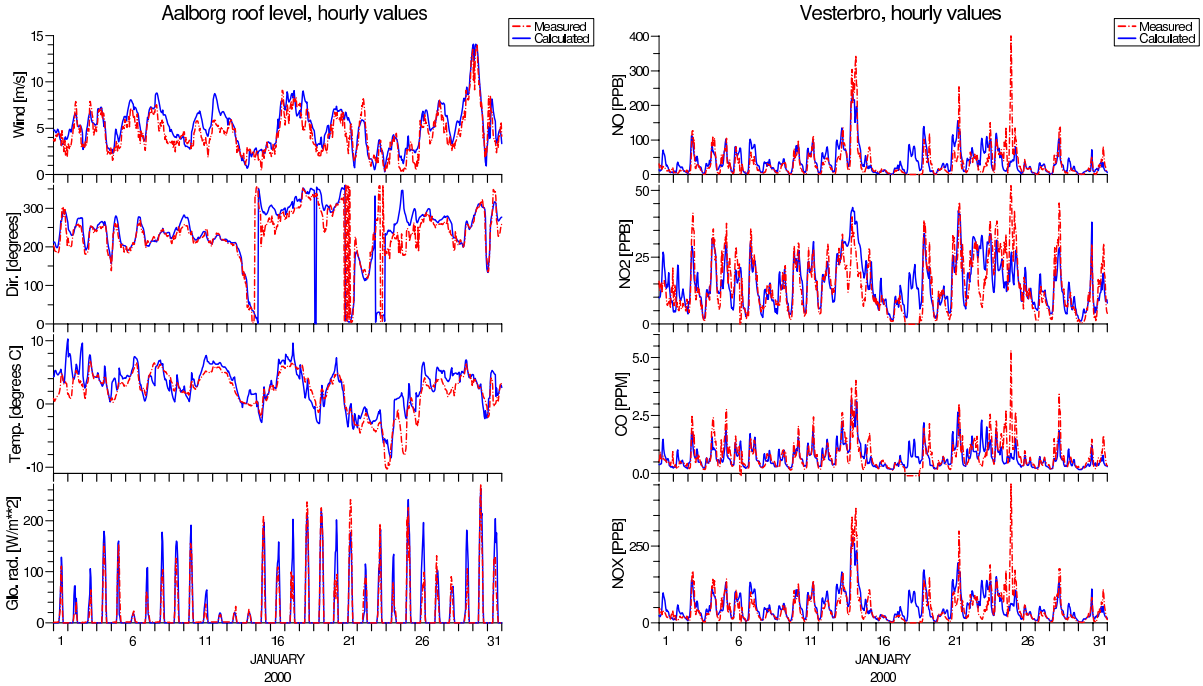

Figure 2. Left figure: Comparison of hourly values of measurements at the roof of the Technical Department building in Aalborg and the weather forecast using the Eta model for January 2000. Right figure: Comparison of hourly values of measurements and air pollution forecast using the Operational Street Pollution Model for January 2000 at the street Vesterbro, Aalborg.

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