# ARE CURRENT OPERATIVE NWP-MODELS ABLE TO PROVIDE THE METEOROLOGICAL CONDITIONS FOR REGULATORY AIR QUALITY MODELS IN FINNISH EPISODIC CONDITIONS?

*Rantamäki M[1], Gregow E[2], Valkama I[1] and Karppinen A[1]*
[1]Finnish Meteorological Institute (FMI), Air Quality Research, Helsinki, Finland
[2]Finnish Meteorological Institute (FMI), Expert Services, Helsinki, Finland



## INTRODUCTION

State-of-art air quality models utilise the analysed and predicted meteorological conditions provided by numerical weather prediction (NWP) models. However, there has been a lot of concern about the ability of the NWP-models to predict correctly especially the episodic conditions, which give rise to the highest pollutant concentrations (e.g., Rantamäki et al., 2005; Fay et al., 2004). In this study, we have analysed the performance of the new, nested meso-β-scale (MBE) version of the Finnish HIRLAM model and the non-hydrostatic MM5 model. The experimental MBE suite used here (referred to as MBEx, to differentiate from operative MBE) is based on the HIRLAM reference system 6.4. The purpose of the MBE system is to offer users more accurate forecast products as regards horizontal resolution.

The PSU/NCAR meso-scale model (known as MM5) is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict meso-scale atmospheric circulation. MM5 can be utilised to reach horizontal resolution of 1 km and higher vertical resolution in the lowest 500 meters. This is supposed to give an enhanced wind and temperature analysis in the lower atmospheric layer for the test cases. ECMWF's forecasted datasets are used as boundaries for the model runs.

The evaluations for different periods have been performed for selected relevant meteorological parameters, such as temperature, wind speed and relative humidity.

## MATERIALS AND METHODS

### The NWP models HIRLAM and MM5

Some properties of the numerical weather prediction models considered here are presented in Table 1.

*Table 9. Some characteristics of the NWP models included in this study.*

| Model and version | Horizontal Resolution And nesting | Number of vertical computational levels | Boundary values extracted from |
|---|---|---|---|
| HIRLAM MBE v 6.4 | 9 km, double nesting | 40 | ECMWF, HIRLAM (nested) |
| MM5 v 3.7.2 | 1 km, triple nesting | 41 | ECMWF operational analysis, 0.35*0.35 deg resolution, the boundary every third hours |

### The properties of the MBE suite of the HIRLAM model

The numerical weather prediction model HIRLAM is a hydrostatic limited area grid model with boundary values updated every 3 hours from the ECMWF global NWP model. For a more detailed description, the reader is referred to Undén et al. (2002).

In parallel with the operative RCR model suite (Kangas and Sokka, 2005), a meso-β-model suite called MBE (Järvenoja, 2005a) has been implemented and run operationally since November 2004 at the FMI. It is embedded within the RCR area and obtains its boundaries from the RCR forecasts at 3-hour intervals. In this study, we have utilised an experimental MBEx model suite. Physically, it is based on the HIRLAM model 6.4, with major differences being the horizontal resolution (0.08° or 9 km) and the dynamic time step (3 minutes). Also the MBEx suite uses the RCR boundaries from the same cycle with 3 h temporal resolution.

The numerical computations in this study were performed with the experimental HIRLAM MBEx suite for the period from 27-29 December 1995, 23-25 March 1998 and 8-11 April 2002.

**The properties of the MM5 model**

Numerical computations were performed with the non-hydrostatic, meso-scale MM5 model version 3.7.2 (more details in Dudhia, 1996) for the period from 8-11 April 2002. The MM5 model has 41 levels in vertical, 16 levels in the lowest 200 meters and with the closest level to ground at 10 meters height. The resolution has been nested down with 3 domains using two-way nesting option and the highest MM5 output resolution of 1 km is reached within the inner most domains. For the outermost domain (27 km), a model time step of 18 seconds has been used.

MM5's boundaries are driven by input from meteorological fields. For this case ECMWF, operative analysis and forecast fields have been used as input. Both are available at the resolution of 0.35*0.35 degrees.

The following options have been used in MM5-model:
- Explicit moisture scheme (IMPHYS); Mixed-Phase, (*Reisner et al.,* 1998)
- Cumulus parameterisation (ICUPA); for the outermost domain i.e. 9 km (*Grell et al*., 1994)
- PBL scheme (IBLTYP); ETA (*Janic et al.*, 1990)
- Radiation scheme; RRTM long wave scheme (*Mlawer et al*., 1997)
- 7-layer snow/soil model i.e. "Polar-MM5"

**Meteorological data**

The predicted model parameter values were compared with the observations from two locations: (i) a 330 m high mast in a suburban location at Kivenlahti, (ii) the synoptic station of Helsinki-Vantaa airport in the Helsinki Metropolitan Area. The most representative model grid points close to the Kivenlahti mast and the Helsinki-Vantaa Airport were used in comparing the forecasts to observations.

The Kivenlahti mast is situated about 6 km and the airport about 20 km north of the average southern coastline. Measurement instruments are installed on the mast at nine levels, from 5 m to 327 m. Wind speed and direction data are averaged at 10-minute intervals. The lowest height for wind speed observations is 26 m. The locations of the observation instruments are shown in figure 1.

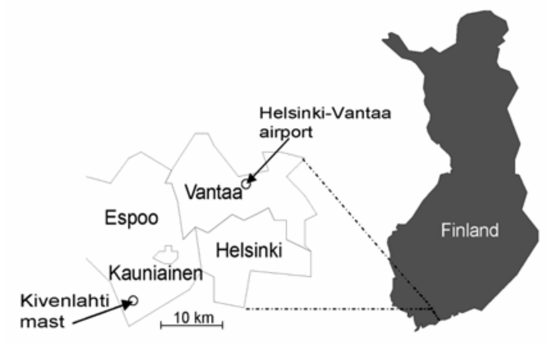


*Figure 17. The locations of the meteorological mast at Kivenlahti and the meteorological station of Helsinki-Vantaa airport.*

**RESULTS**

The forecasted time series in figure 2 and figure 3 were constructed from 24-hour prediction periods by combining them sequentially. Hourly output time step was used for both NWP models. Observations are available hourly from Kivenlahti mast and with 3-hour intervals from Helsinki-Vantaa airport.

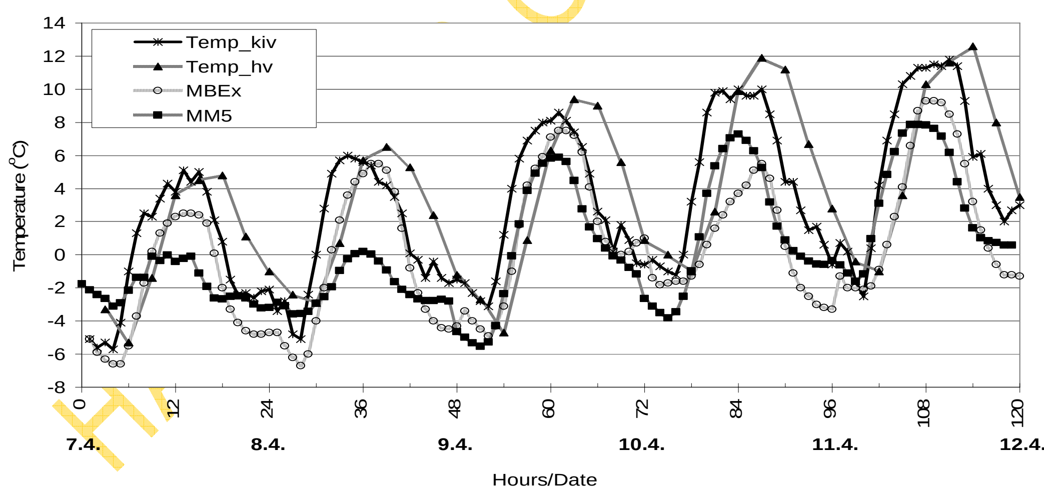


*Figure 18. Temperature predicted by the MBEx and the MM5 models in the vicinity of the Helsinki-Vantaa airport in the Helsinki Metropolitan Area, 7-12 April 2002. The figure also shows observations for Kivenlahti mast (kiv) and Helsinki-Vantaa airport (hv).*

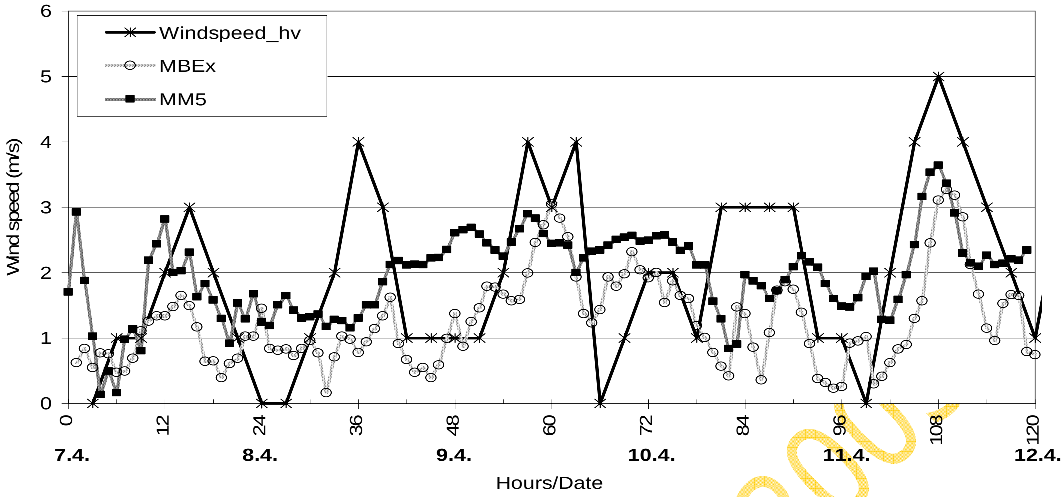


*Figure 19. Wind speeds predicted by the MBEx and the MM5 models in the vicinity of the Helsinki-Vantaa airport in the Helsinki Metropolitan Area, 7-12 April 2002. The figure also shows observations for Helsinki-Vantaa airport (hv).*

**DISCUSSION AND CONCLUSIONS**

The resolution of the NWP model does not necessarily directly relate to the ability of the model to predict temperatures correctly. Here, both NWP models predict the diurnal temperature variation, but there constantly exists a small difference between temperature forecasts and observations. Similar results have been observed by Järvenoja (2005b) with the RCR model suite. Different behavior between MM5 and MBEx models can be partially explained by the different boundary conditions (larger scale models) used by these two NWP-models. The results for the selected Helsinki episodes clearly show the limitations of even highly resolved mesoscale NWP models in predicting surface temperatures under temperature inversion conditions (not shown), as noticed also by Järvenoja (2005c).

The variation of wind speed during the study period was not very pronounced: the observed wind speed varied mostly between 0-3 m/s. Once again, the limitations of the NWP models in these meteorological conditions can be clearly seen; specifically, it is not possible to see any significant improvement in the predictions by switching to a higher resolution NWP-model.

Although the physics and resolution of the NWP-models used operationally today have been improving a lot during the last years, episodic conditions are still posing a serious challenge to model developers. Air quality modellers utilizing NWP-model fields as input for their modelling studies cannot forget this potentially huge error source.

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