RESULTS FROM HIGH RESOLUTION OPERATIONAL METEOROLOGICAL FORECASTS IN COMPLEX TERRAIN DURING WINTERTIME INVERSIONS

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1 Introduction

The MM5 V2.12 modeling system has been run operationally with a 1 km resolution for the city of Oslo, Norway in order to produce high resolution meteorological data as input to an urban air pollution model during the winter season 1999/2000.

In order to investigate the gain by using higher resolution, results during days with low winds and stable stratification is evaluated against observations and against the HIRLAM10 (10 km res.) hydrostatic model currently in operational use at the Norwegian Meteorological Institute.

2 Model configuration

2.1 Model domain and physics options

The MM5 is set up with a outer mesh of 3 km resolution and an inner mesh with 1 km (Figure 1). Due to computational restrictions the horizontal grid is 31*31 with 17 vertical layers (9 below 1500 m). The physics options were: PBL Scheme: MRF; Soil: multi layer; Radiative Scheme: Cloud ; Explicit moist physics: Dudhia simple ice; Cumulus scheme: none and Shallow Convection: none

The MPP version of the model has been run on a CRAY T3E using 64 CPUs.

2.2 Initial and boundary conditions

The Nordic HIRLAM NWP model with a 10 km resolution is being used as initial and boundary conditions, supporting both atmospheric and soil parameters. In addition an algorithm for retrieval of snow cover from the AVHRR sensor on the NOAA polar satellites (resolution ~1.1 km in nadir) together with available synoptical observations within the model domain are used to initialize the snow cover. Observations of sea surface temperatures are used to initialize sea surface temperature. Topography and land-use are derived from the USGS data.

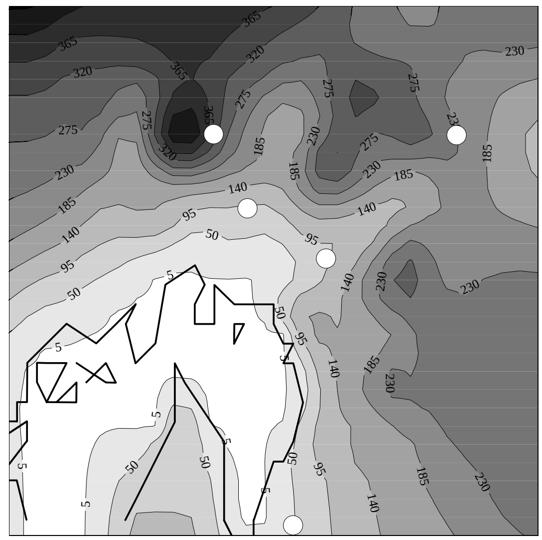

Figure 1: Domain and topography for the 1 km nest. Dots indicates the observation sites.

Since MM5 was used in evaluation of when to carry out traffic restrictions within the Oslo region, the focus was on the 24-48 h forecast in order for the traffic authorities to implement the practical details and inform the public of the restrictions. MM5 was therefore initialized with a 24 hour forecast from HIRLAM10 due to computational restrictions.

3 Results

22 days with calm winds during the winter 1999/2000 were chosen to evaluate the prognosis of MM5 against screen level observations of wind, temperature and humidity and the ability of MM5 to improve the HIRLAM10 prognosis that was used as initial and boundary conditions.

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SITE	Variable	Data	ME		MAE		SDE		RMSE	
			HI10	MM5	HI10	MM5	HI10	MM5	HI10	MM5
BLINDERN	WIND 10m	176	0.73	-0.08	1.21	0.95	1.34	1.22	1.53	1.22
TRYVANN[1]		96	-0.39	0.42	1.22	1.44	1.40	1.73	1.45	1.78
VALLE HOVIN[2]	WIND 25m	175	1.71	0.51	2.11	1.17	1.92	1.32	2.57	1.42
BLINDERN	RH 2m	176	11.36	5.67	15.32	12.17	17.42	15.15	20.8	16.18
TRYVANN		176	20.01	8.29	24.15	15.39	20.21	16.84	28.44	18.77
VALLE HOVIN		175	15.63	13.06	17.42	15.21	17.77	13.47	23.67	18.76
GJELLERAASEN		124	14.61	13.43	17.07	15.92	19.11	16.39	24.05	21.19
SVARTSKOG		133	11.16	9.56	13.75	13.54	16.00	14.63	19.51	17.48
BLINDERN	T 2m	176	-3.67	-4.39	4.48	4.80	3.86	3.46	5.33	5.59
TRYVANN		176	-4.42	-3.91	4.67	4.23	3.75	3.10	5.80	4.99
VALLE HOVIN		175	-3.34	-4.46	4.34	4.71	4.01	3.16	5.22	5.47
GJELLERAASEN		121	-3.62	-4.73	4.50	5.08	3.94	3.47	5.36	5.87
SVARTSKOG		130	-2.33	-3.90	3.52	4.18	3.82	3.23	4.47	5.07
BLINDERN[3]	T 0m	176	-2.85	-3.58	3.76	4.52	3.89	3.98	4.82	5.35
VALLE HOVIN[2]	T 25m	175		-1.62		3.04		3.20		3.59

Table 1: Error statistics for the 24 to 48 hour forecasts of temperature, wind and relative humidity for the HIRLAM10 forecast (HI10) and the MM5 1 km resolution forecast with 24 h. forecast from HIRLAM10 as initial conditions (MM5). Abbreviations: ME: Mean Error, MAE: Mean Absolute Error, SDE: Standard Deviation Error, RMSE: Root Mean Square Error. [1] Due to its location the Tryvann site is not representative for wind directions from north so only a subset of the observations containing windspeeds with observed wind directions between 45 and 315 degrees are used in this statistics. [2] Temperatures and winds in 25 m compared to the model levels nearest the observation height (22 m for MM5 and 30 m for HIRLAM10). [3]Observed hourly minimums of the grass temperature compared to the modeled skin temperatures.

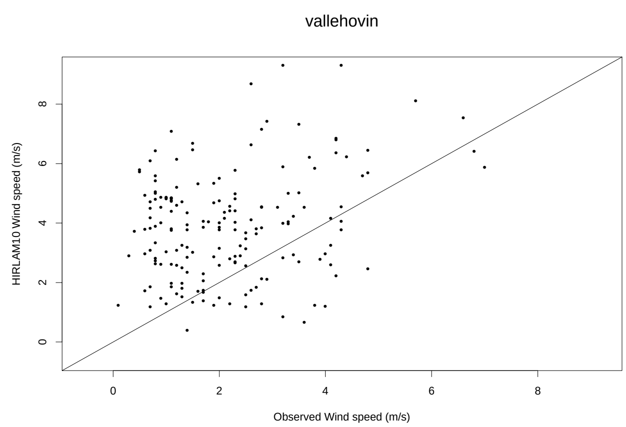
The two model configurations are: MM5 with a HIRLAM10 24 h. prognosis as initial conditions (denoted as MM5) and HIRLAM10 all the way up to 48 h (denoted as HI10). The measurements stations are displayed in Figure 1.

3.1 Wind

Forecasted MM5 wind in the lowest model level (7m) was compared directly with the observed 10 m winds and observed 25 m winds was compared to the second lowest level (22 m).

3.1.1 Wind speed

The MM5 forecasts gave a better wind speed prognosis than HIRLAM10 at 2 of 3 sites. The bias was below 1 m/s at all sites. The overall picture was an overestimation of the very low wind speeds (below 2.0 m/s) both in HIRLAM10 and MM5. Figure 2 shows the scatterplot of 24 to 48 hour forecasted windspeeds compared to observations at the Valle Hovin site.



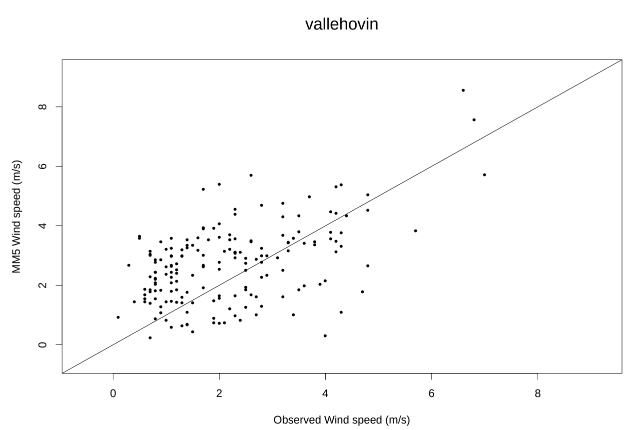


Figure 2: Scatter plot of observed windspeed versus forecasted HIRLAM10 (upper) and MM5 (lower) winds at 10 m for the Valle Hovin site.

In addition to the overestimation of the low wind speeds both models have a considerable scatter. The mean absolute error at the Valle Hovin site was 1.2 and 2.1 m/s for MM5 and HIRLAM10, respectively, while the mean observed windspeed was 2.2 compared to 2.7 and 3.9 for MM5 and HIRLAM10.

3.1.2 Wind direction

Figure 3 shows the frequency plot of observed, forecasted HIRLAM10 and MM5 wind directions for Valle Hovin.

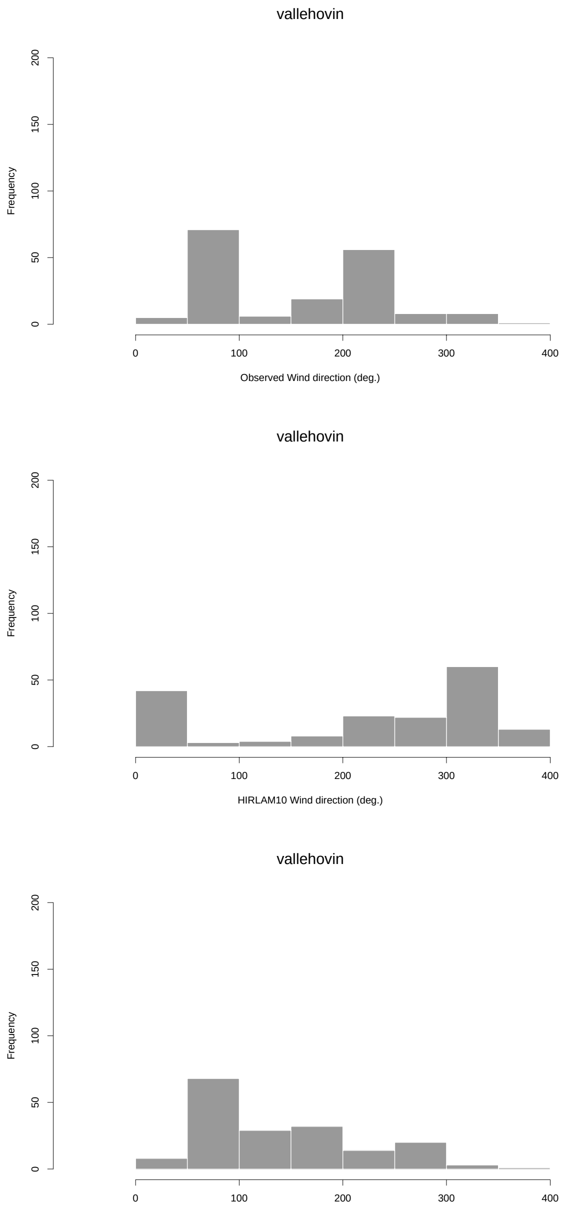


Figure 3: Frequency plot of wind direction for observations (upper), forecasted HIRLAM10 (middle) and MM5 (lower) at the Valle Hovin site.

In the observations there are two pronounced wind directions, north-east and south-west, related to the fact that the site is situate in a shallow valley with considerable topographic forcing of the wind direction. HIRLAM10 is describing the more large scale wind direction from north and north-west. This has been modified to some extent by the finer scale MM5 run which have managed to capture the north-easterly flow, but to a lesser extent the south-westerly flow.

3.2 Temperature

The lowest MM5 model layer (7 m) is reduced to 2 m in order to compare against screen level observations using the formulations of Sass et al. (1999) in the unstable case and Delage ()1997 in the stable case. Table 1 show the error statistics for the HIRLAM10 and the MM5 24 to 48 hour forecast.

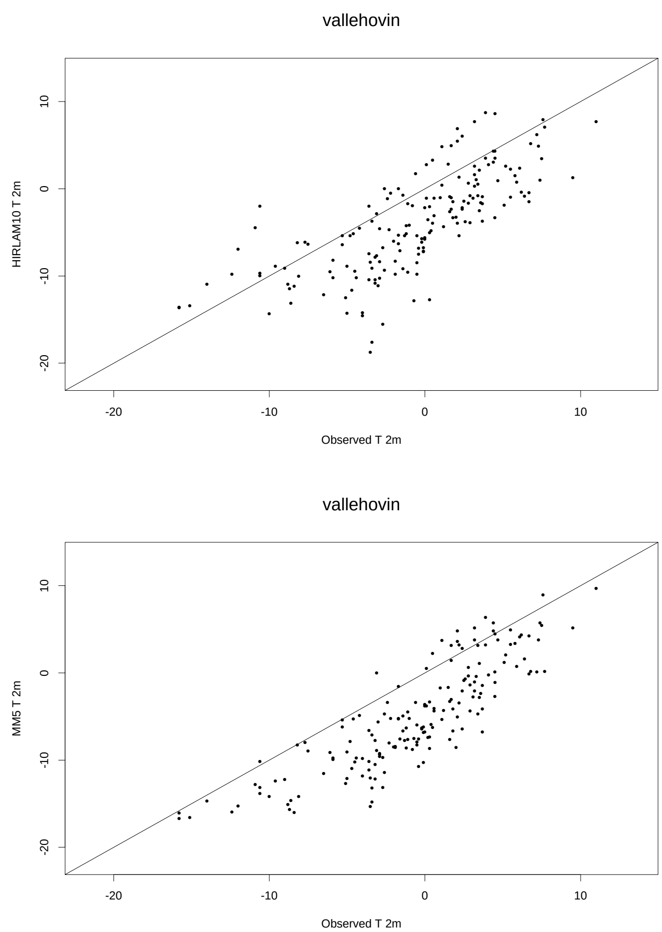


Figure 4: Scatter plot of observed temperature versus forecasted HIRLAM10 (upper) and MM5 (lower) temperatures at the Valle Hovin site

Both models show a considerable bias in mean temperature. Despite the better representation of the topography in MM5 the mean error is about 1 degree larger than in HIRLAM10.

The standard deviation error (SDE) gives a measure of the error when the bias is removed (SDE = $\sqrt{RMSE^2 - ME^2}$) and shows that the SDE for the MM5 is lower at all model sites compared to HIRLAM10. The observations of temperature were fairly normal distributed thus the linear correlation coefficient for the hourly data may be interpreted as a measure of how well the models simulate the daily temperature cycle. At all sites the MM5 has a better correlation coefficient ranging from 0.8 to 0.85 compared to 0.74-0.75 for HIRLAM10.

It is interesting to see that the Svartskog site that is in the outskirt of the 1 km model domain (see Figure 1) and therefore represents the 3 km domain does not have worse error statistics than the other sites.

Figure 4 shows the scatter plot of observed 2 m temperatures against HIRLAM10 and MM5 forecasts. For the Valle Hovin site the mean error was -3.3° and -4.5° for HIRLAM10 and MM5, respectively, but with MM5 having a standard deviation error of 3.2° compared to 4.0° for HIRLAM10. At the Valle Hovin site both 2 and 25 m temperature was measured and the bias in 25 m for MM5 was much smaller than in 2m (mean error of -1.6°).

3.3 Relative humidity

Relative humidity is an important factor in simulating the sources of PM10 and PM2.5 (Particulate Matter with diameters below 10 and 2.5 microns, respectively) from traffic.

Even though relative humidity is a strong function of the temperature, the MM5 forecast is better than the HIRLAM10 both in means of bias and standard deviation errors (see Table 1). This is mainly due to the better estimation of daily maximum temperatures especially in late winter and therefore better estimation of the low humiidities. Due to the biases in temperature, both models overestimates the relative humidity and the mean error is ranging from 5.7 to 13.4% in MM5 compared to 11.1 to 20.0% for HIRLAM10. The overestimation is especially pronounced when low relative humidities are observed.

4 Ongoing work

MM5 V3 will be run for the calm winds and inversion days and compared against observations and MM5 V2.12 in order to investigate the differences and possible gains by running the newer version. If the comparison is in favor of the new version this will be implemented as the operational system the comming winter.

Preliminary high resolution runs (3 to 1 km and 30 vertical layers) with MM5 V3 for coastal areas with complex terrain have been done in order to investigate possible gain in forecasting coastal winds (Sorteberg and Tallhaug, 2000) Results are being evaluated against HIRLAM10 forecasts and observations from 50 m masts within an area of 100*100 km.

MM5V3, HIRLAM V4.7 and the Canadian MC2 have been set up with 10 km resolution and 30 vertical layers. The domain is covering Scandinavia (approx. 200 * 300 grid-squares) and ECMWF analysis are used as initial and boundary conditions. Four 2 weeks run covering the different seasons are being run to compare the models performance against each other and synoptical observations.

5 Conclusion

In order to investigate the gain by using higher resolution non-hydrostatic models, results during days with low winds and stable stratification are evaluated.

Comparisons of 24 to 48 hour forecasts of wind, temperature and relative humidity for a 10 km resolution hydrostatic model (HIRLAM10) and 1 km forecasts with MM5 based on 24 hour forecasts from HIRLAM10 have been conducted. The finer resolution MM5 runs compared better for wind and relative humidity both with respect to bias and non-systematic errors. Despite the better representation of the topography biases in 2m temperature were greater in MM5, though the non-systematic errors was smaller. The cold bias in the MM5 runs is a result of too cold initial soil temperatures from HIRLAM10 and there are some indications of to little heat exchange in the MRF scheme near the surface during stable conditions.

References

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