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LIMITATIONS OF THE COMPARISONS MODEL VS. OBSERVATIONS ON THE EXAMPLE OF A COST728 MODEL EVALUATION STUDY

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Abstract: Progress in model developments is based on comparison with data. In this process it is crucial to discuss the uncertainties and representativiness inherent for both models and measurements. Models can be good enough without an exact match with the measurements, as often shown and aimed at. An important new emphasis in model evaluation is to consider vertical profiles of meteorological parameters, not just traditional surface measurements. This contributes to the understanding why different mesoscale meteorological models calculate quite different atmospheric boundary layer height even when using the same method, and thus influence significantly the air pollution models results. The availability of 3D measured fields of meteorological parameters provided by wind profile radars and recently developed lidars provide a new challenge for such studies. Therefore the model to measurements comparisons in 3D case have to develop further from the performance statistics elaborated for point measurements, which is not trivial task. The study is based on data from several European observatories (Lindenberg, Cabauw, Hamburg, and Risoe) that perform profile measurements on masts, with wind profilers and lidars.

Key words: *Mesoscale meteorological models, Evaluation of model results, Atmospheric Boundary Layer, Radiosonde measurements of vertical profiles, Eddy correlation measurements of surface turbulent fluxes, wind radars and wind lidars, sodars.*

INTRODUCTION

As part of the COST 728 action (Enhancing Mesoscale Meteorological Modelling Capabilities for Air Pollution and Dispersion Applications) a major model comparison and evaluation exercise is carried out.

One of the cases covers Central and Northern Europe in February and March 2003, when several PM10 episodes were observed. The predictions of several models were shown to differ widely by Stern *et al.,* 2008. Detailed analysis of meteorological conditions in the same paper pointed out large differences in the boundary layer height used in the chemical models.

Although the boundary-layer height plays a central role for the PM10 predictions by chemical transport models and is often output parameter from meso-scale meteorological models, the way it is obtained is not transparent. Therefore when modeled and measured heights of the boundary layer are compared it is often not clear if the values are based on the same definitions.

This problem is examined evaluating the vertical profiles of meteorological parameters, here wind speed. In the area of the case study two sites were identified where extensive vertical profile measurements are performed – Lindenberg (Germany) and Cabauw (The Netherlands). Specific runs with the same boundary conditions were performed with several models and profile data were stored. In this type of evaluation, many basic assumptions and methods developed for surface measurements cannot be applied directly.

NATURAL VARIABILITY

The natural variability in the measurements – also called representativeness – depends on the state of the atmosphere and the averaging time of the measurements. Here we evaluate a model by assuming that the model prediction of a given parameter represents the average (representative) value. Then the uncertainty due to the natural variability of the measurements is added as error bars on the results from the model simulation. The actual measurement represents one realization only; if the measurement is inside the error bar then it is within the expected natural variability of the model prediction.

Thus, the model evaluation method is used to associate the uncertainty that arises from the natural variability in the atmosphere for the parameter in question – in this paper we take wind speed as example – but the method is applicable for other parameters as well. The standard deviation in the measurements of the wind speed $\sigma_{u,T}$ depends on the averaging time T of the measurements. Under stationary conditions and for an the integration time scale T much longer than the integral time scale τ , Tennekes (1973) suggests:

$$\sigma_{u,T} \approx 2\sigma_u \, \tau/\mathrm{T} \tag{1}$$

where σ_u is the standard deviation of the fluctuating wind speed.

An applied method proposed by Sreenivasan *et al.* (1978) to determine the standard deviation of the wind speed for a given averaging time is used here:

$$\sigma_{u,T} = \sqrt{12} \quad \sqrt{z/Tu} \quad u \tag{2}$$

It can be seen that the standard deviation σ_u increases with height and decreases with averaging time. The method can also be applied to other parameters, for example the sensible heat flux. It is interesting to note that the higher the moments the larger the standard deviation. Thus, a longer averaging time is required for a higher order moment if the same standard deviation is aimed as for mean value or lower order moment.

The assumption of stationarity is typically not fulfilled in the atmosphere due to the daily variation of the insolation, but can be fulfilled in wind tunnel modeling. However, this deficit is a principal problem as stationarity is also a basic assumption in the Reynolds decomposition of fluxes, which is fundamental for all RANS models. The fundamental issue is discussed in Gryning and Batchvarova (2005) and with special emphasis in urban area in Gryning and Batchvarova (2009) and Batchvarova and Gryning (2010).

MAST MEASUREMENTS AND MODELS

Meteorological measurements from the Falkenberg site of Richard Assmann Observatorium near Lindenberg, Germany, has been used. The site is covered with grass; it is equipped with a 98 meter high meteorological tower as well as a 12 meter mast. Here measurements of wind speed at 98 and 10 meters height are used.

Cosmo and MM5 simulations performed at GKSS are compared with measurements. The new method is demonstrated on data only from one day, Figure 1. The line shows the model prediction. The full circles show the measurements. The error bars represent the standard deviation of the measurements due to natural variability for a given averaging time, in this case 30 min. It can be seen that the error bars are larger at 100 meters than 10 meters height, because the variability increases both as function of height and wind speed.

It can be seen in Figure 1, that at the 100 meter level, models suggest quite different predictions. The measurements fall inside the representativiness bars for very short intervals. MM5 performs better in the morning, while Cosmo around noon. Both models are away of measurements in the afternoon. However for the same period at the 10 meter level, the model prediction is higher than the measurements and the measurements are outside the range of the predictability. It is thus interesting to note that an evaluation study solely at the 100 meter level would suggest good agreement, but including the 10 meter level would show that the prediction of the profile is not good, emphasizing the importance of performing the evaluation of profiles and not single level measurements.

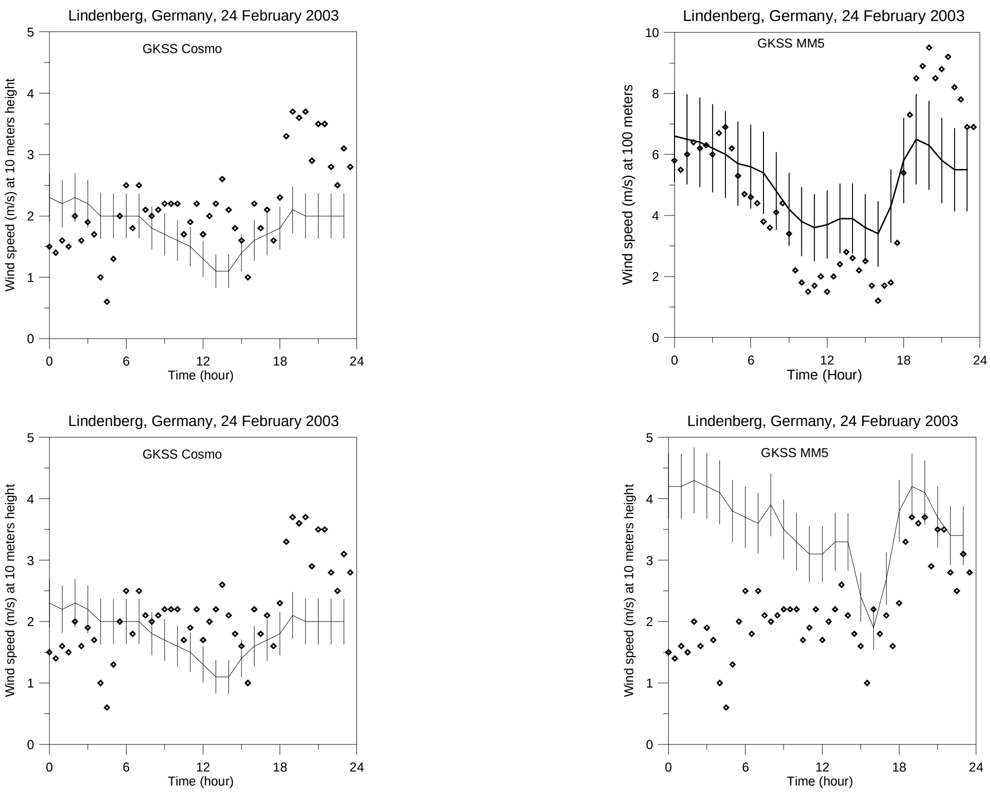

Figure 1. Wind speed at 100 (upper level) and 10 (lower level) meters height at Lindenberg on 24 February 2003. The line shows the model prediction. The circles show the measurements from mast. The error bars represent the standard deviation of the measurements due to natural variability for 30 minutes averaging time.

WIND PROFILER DATA

Wind profiler data were provided for this comparison from Lindenberg and Cabauw. The comparisons of modelled and measured wind profiles showed significant spread. Radiosonde and radar profiles were in good agreement at Lindenberg. In general, all models over predict the wind within the ABL (Batchvarova *et al.*, same conference) and under predict the wind speed above the ABL.

Wind profiler data are extremely useful for the evaluation of meteorological models. Compared to radio sonde data wind profiler observations have the advantage of much higher time resolution (at least hourly data). In order to use these data extensively a number of steps a required to unify and simplify the presentation of data. Essential practical problems are the different formats used for the data and the non-standard and non- transparent way the missing data (in time and space) are treated.

Among other results, a study of the wind speed spectra was performed at different heights. Modelled (GKSS MM5, 54 km resolution) and measured u-wind component spectra at 2.7 km height are presented in Figure 2.

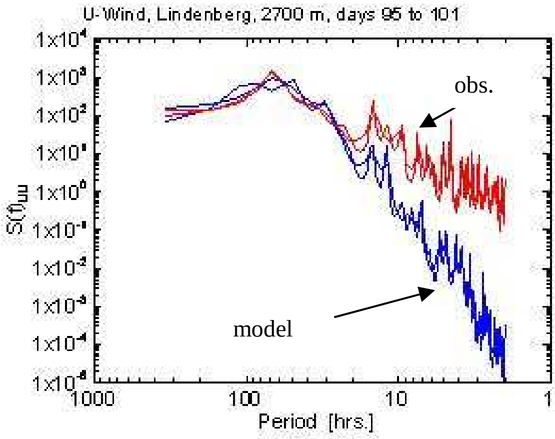

Figure 2. Power spectra of u-wind component at 2.7 km height at Lindenberg for a period of a week during the case study.

The spectra comparison shows that the models remove significantly the short period variably of meteorological parameters. In this case the resolution is very course, but the feature is observed also at less than 5 km resolution of the model. From a number of comparisons performed for the study it can be concluded that the effective resolution of a mesoscale meteorological model is larger than 4 times the grid resolution used.

CONCLUDING REMARKS

- Progress in model developments is based on comparison with data.
- It is essential to evaluate the models on profile measurements, not just traditional surface measurements.
- The variability of the meteorological parameters should be taken into account in any model evaluation against measurements.
- The variability is a function of the length scale of turbulence (height in the surface layer) and averaging time of the measurements.
- A good model performance does not require exact match with data.
- In other words a model cannot be improved if the measurements fall within the statistical range defined by the variability.
- Wind profiler data should be used for model evaluation.
- The use of wind profiler data is presently limited by the lack of unified formats and methods to interpolate missing data.

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