Validation of the high resolution numerical weather prediction model COSMO-2 with independent wind profiler measurement data

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ABSTRACT

Wind profiler data collected during a 3 months field campaign in late summer 2008 have been used as an independent measurement source to validate the high resolution numerical model COSMO-2 of MeteoSwiss. This action has taken place within a larger project aiming at the development of an improved high resolution weather prediction for the Swiss Plateau related to the safety of nuclear power plants.

Vertical profiles of wind direction and speed have been compared between wind profiler and model. The results of this verification over the entire measurement period show a bias close to zero for both parameters. This confirms that the model generally reproduces the air flow as observed at the location of the wind profiler. However standard deviation and quantile values of the model error are quite large, indicating that the model forecast is inaccurate for some time periods.

1 INTRODUCTION

In order to renew and improve the current Swiss warning and dispersion forecast system for nuclear power plants NPP, the Federal Office of Meteorology and Climatology MeteoSwiss has built up a new wind profiler network (Figure 1) and developed a new numerical model configuration COSMO-2 with a very high resolution of 2.2 km [1]. The tools created for this purpose are the essential component of the CN-MET project. As part of the validation process of this project, a field campaign took place over three months from August to October 2008. An independent wind profiler has been located close to the sites of two Swiss NPP and the data collected have been compared to model results.

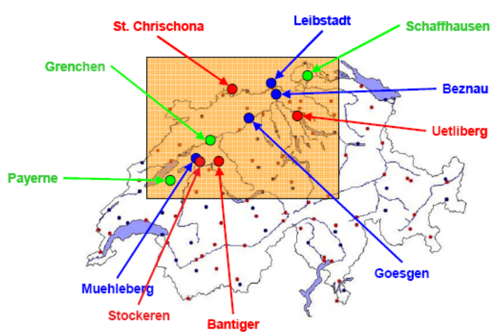

Figure 1.*Map of Switzerland with the locations of the Nuclear power plants (Blue) of the wind profilers (Green) and of additional measurement towers (Red). The independent wind profiler in Kleindöttingen was located between the NPP of Leibstadt and Beznau.*

1.1 COSMO Model

COSMO is the numerical weather prediction (NWP) model of the Consortium for Small Scale Modelling (COSMO). MeteoSwiss uses this model in two configurations: COSMO-7 with a grid spacing of 6.6 km for the short-range forecasting over the next 72 hours, and COSMO-2 with a grid spacing of 2.2 km for nowcasting over the next 24 hours. The development of the higher resolution of COSMO-2 was in particular induced by the performance expected for the new tools within CN-MET.

COSMO-7 uses the lateral boundary conditions from the Integrated Forecast System (IFS) provided operationally by the European Centre for Medium-Range Forecasts (ECMWF). A continuous assimilation cycle has been implemented, ingesting conventional surface observations as well as upper atmosphere soundings, aircrafts and wind profilers. Two daily 72 hours forecasts are calculated, based on the 00 and the 12 UTC analyses, with a 45 minutes cut-off time. At MeteoSwiss COSMO-7 is calculated on a 393×338 grid, with a grid size of about 6.6 km, on a domain covering most of Western Europe. COSMO-7 provides the lateral boundary conditions for COSMO-2. COSMO-2 gets its boundary conditions from the COSMO-7 and has a grid size of about 2.2 km. Its domain of 520×350 grid points is centred over the Alps.

Model data are available on the 60 model levels; each model value represents an instantaneous value in time averaged in space over one grid cell. In this sense velocity values turbulence is not represented on the model grid and its contribution to the model wind is not considered. Therefore the model wind relates to a measurement with the turbulent contribution filtered by averaging over a time of about half an hour.

The current configuration of COSMO-2 is operational since 27 February 2008. Assimilation of radar data with Latent heat nudging has been added in spring mainly in order to improve the reproduction of convective precipitation. The model has been run without any major configuration change during the period of comparison (August to October 2008).

Since a new COSMO-2 forecast is started routinely every three hours and covers the coming 24 hours, each point in time is available in 8 different model forecasts with different lead times. This redundancy is a crucial additional security element. Considering the normal production and delivery times, any moment in time is always covered at least twice in the first 4.5 hours of the last forecasts available.

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1.2 Location of the field campaign

The field campaign took place in the northern part of Switzerland half way between Basel and Schaffhausen. Figure 2 shows the topography of the investigation area, overlapped with grid of the two model resolutions. The coarse grid of COSMO-7 (blue) has barely a hint of the lower Aare valley, within which Kleindöttingen (red triangle) is located. The fine grid of COSMO-2 (black) contains at least the large scale features of the topography with the Rhine valley running from east to west at the top of the chart, and the lower Aare valley running south to north through the centre of the area.

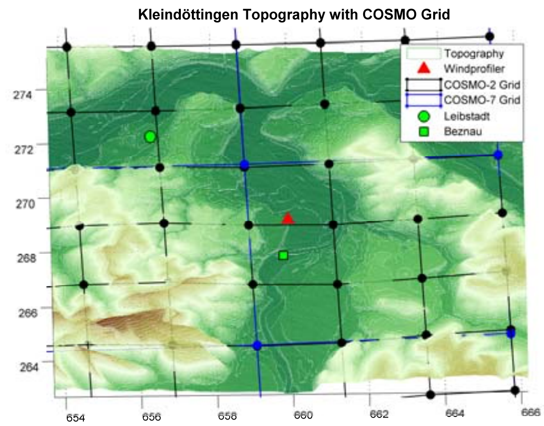

Figure 2.*Topography at a horizontal resolution of 25 m of the regions around the wind profiler site in Kleindöttingen (Red triangle). The numerical grid of the COSMO model is shown in Blue (COSMO-7) and Black (COSMO-2). (DHM25 © swisstopo DV063970)*

1.3 Wind profiler

A site representative to the Leibstadt-Beznau region and representative to the confluence of the Aare valley with the Rhine Valley was chosen [2]. It is located north of Kleindöttingen, half-way between Leibstadt and Beznau, next to the Aare River. The Data were processed and went trough a 1st level automatic quality control. At the end of the campaign, an operator made a manual 2nd level QC.

Figure 3.*Vaisala wind profiler on-site during the field campaign from August to October 2008.*

The wind profiler has been operated in two modes, delivering two sets quasi simultaneous data. The low-mode measured up to 1'100 m above ground and the high mode went to a little bit less than 4'500 m. The characteristics of the wind profiler are summarised in Table 1. The temporal resolution of the measurement available for the model comparison has been set to 30 minutes.

Table 1. Key numbers of the wind profiler configurations for low-mode and high-mode operation modes.

Kleindöttingen (Vaisala)

Height of site: 321 m. MSL

low - mode	high-mode
∆H = 72 m	∆H = 205 m
440 – 1452 m MSL.	675 – 4773 m MSL

2 VERIFICATION METHOD

Model outputs were available every 10 minutes for the purpose of the validation study. Since wind profiler data have been produced every 30 minutes, corresponding time stamps have then been used for the comparison. The observation data have been interpolated to model height to perform the comparison.

Data of the 3 months field campaign have be aggregated and served as basis for the analysis. In order to avoid problems with high variability of the wind direction for low winds, the situation where wind speed has been lower than 2 m/s have been removed from the sample for wind direction statistics. In order to minimise the effect of strong winds, the values with wind speed above 10 m/s were also removed from the standard verification products and treated separately.

The products the have been generated for the validation and used to assess the quality of the model forecasts and analyses include upper-air verification profiles, histograms of model error, scatter plots of observed values versus mode values. All products have been created for both low-mode and high-mode wind profiler data and for the wind speed threshold mentioned above.

3 RESULTS

Vertical profiles of wind direction and speed have been compared between wind profiler and model. The results of this verification over the entire measurement period show a bias close to zero for both parameters (Figure 4). This confirms that the model generally reproduces the air flow as observed at the location of the wind profiler. However standard deviation and quantile values of the model error are quite large, indicating that the model forecast is inaccurate over short time periods. This occurs by rapidly varying weather conditions when the model does not react as fast of the actual airflow.

This systematic bias is to a smaller extent also found in the operational COSMO-2 verification with the radio soundings of Payerne and in the surface verification [3]. The reason for this behaviour is probably due to differences in the actual model orography compared to the real topography at both locations. The standard deviation STD is around 40° at the lower levels and decreases to around 20°-30° towards the top of the profile. The low-mode result shows a STD ~5° larger. It is about twice as large as the standard deviation of the verification with radio soundings in Payerne; this result however is obtained with COSMO-7 data. This large difference between wind profiler and radiosonde probably lies in the measurement devices themselves.

Finally a very positive conclusion is that the quality of the forecast remains very high over the initial 6 hours of the model forecast since all curves remains in the same range.

Scatter plots of wind direction are presented on Figure 5. They confirm a good general agreement between model and observation. Wind directions from east to south are almost completely missing, both in the mode and observation data. The spread is larger at lower levels than for higher ones. The result does not change a lot with increasing lead times. Apparently there is not systematic model bias. A few outlier pairs can be identified but the core of the data are still located around the diagonal of the plots.

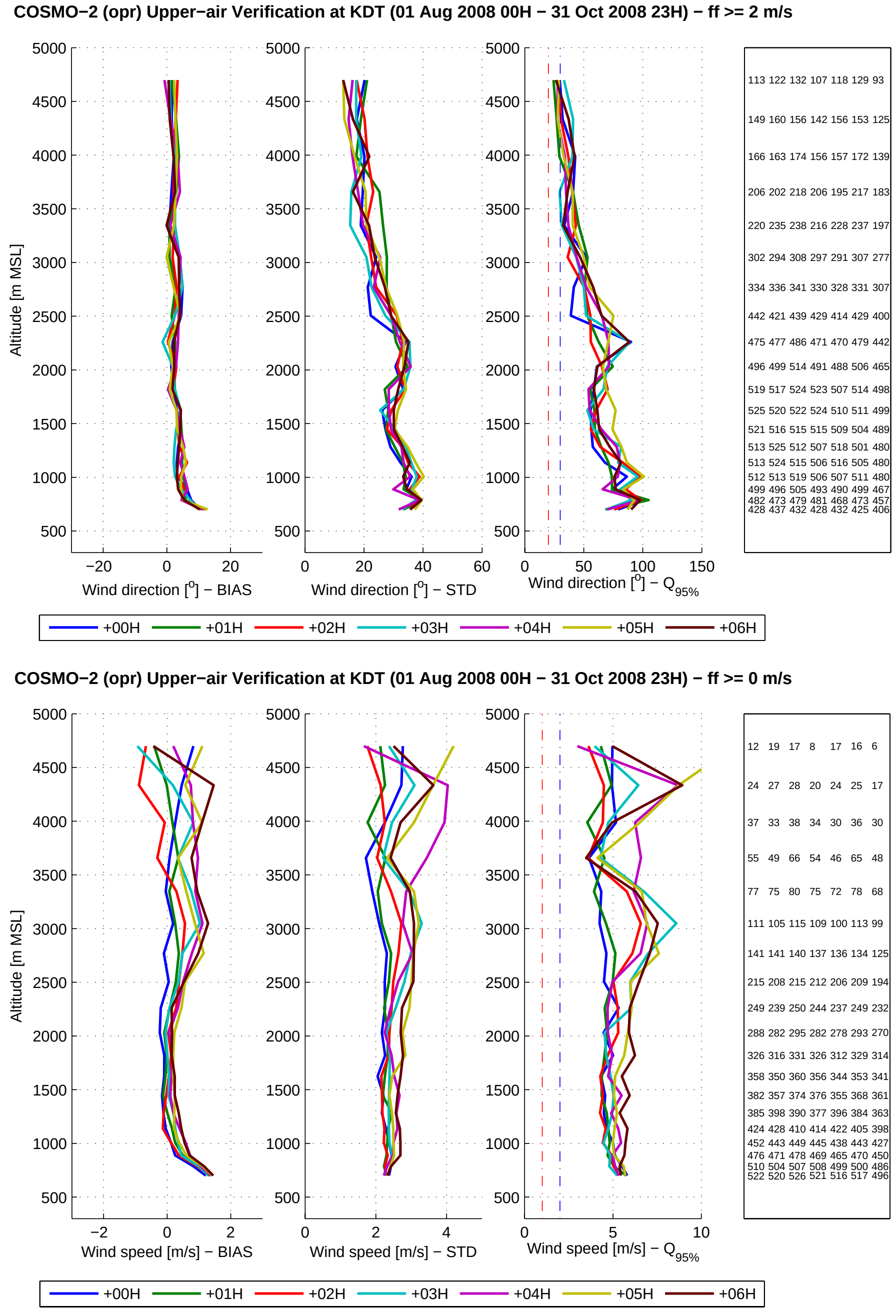

Figure 4. *Vertical profiles of model bias (left), standard deviation (middle) and 95% quantiles for the first 6 forecast hours. The top figure shows the wind direction for wind speed above 2 m/s and the bottom figure shows the wind speed for wind speed values between 0 and 10 m/s. The red line shows the threshold values that should be me according to the accuracy standard based on traditional anemometer devices.*

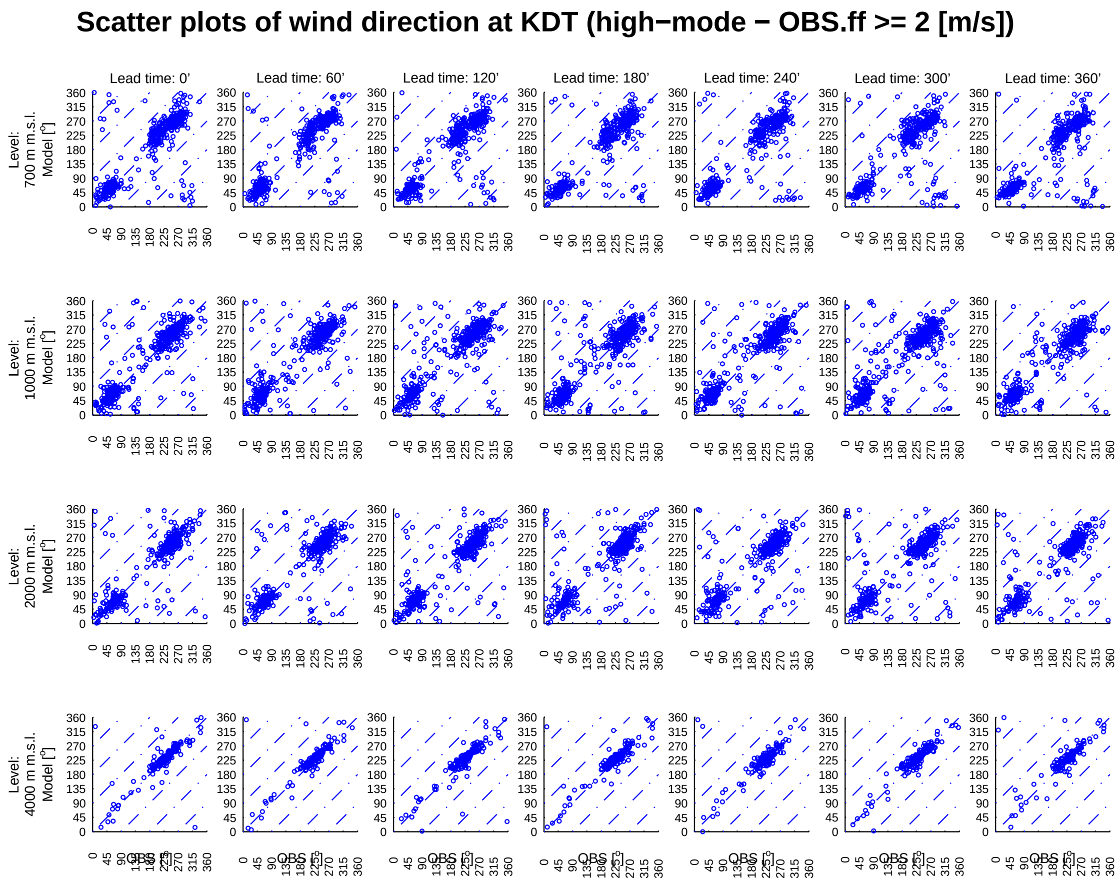

Figure 5.*Scatter plots of observation versus model values for wind direction for selected comparison levels and varying lead times.*

4 CONCLUSION

Wind profiler data have been collected during a three months field campaign in the complex topography of the Swiss Jura, between the Swiss Plateau and the Rhine Valley. The high resolution model COSMO-2 has been compared to these data for the first 6 hours of forecast and a good average agreement between observation and model could be found for the upper levels of the vertical profile. In the lower part of the profile, a positive bias can be observed for both wind speed and wind direction. The results show no major decrease of quality of the forecast over the first 6 hours. Standard deviation and quantile 95% values however appear to be quite high. This indicates that the timing of the model is could be better. Analysis of individual events can demonstrate this behaviour (see [2]).

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