Verification of COSMO-2 with independent data from a wind profiler

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Abstract

Wind profiler data collected during two field campaigns of 3 months each 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 for nuclear safety and emergency preparedness, aiming at the development of an improved high resolution weather prediction model for the Swiss Plateau.

Vertical profiles of wind direction and speed have been compared between wind profiler and model. The results of this verification 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 the standard deviation of the model error is considerable, indicating that the model forecast cannot reproduce the profiler measurements during certains 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 (Calpini 2008). The tools created for this purpose are the essential component of the CN-MET project. As part of the validation process of this project, two three-months field campaigns took place, a first from August to October 2008 and a second from mid-March to mid-June 2009. An independent mobile wind profiler has been located close to the sites of two different Swiss NPP and the data collected have been compared to model simulations.

2 COSMO Configuration

MeteoSwiss uses COSMO 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 now-casting and short-range forecasting over the next 24 hours. The development of the higher resolution of COSMO-2 was for a large part induced by the performance expected from the new forecasting system developed in the framework of CN-MET.

COSMO-7 uses the lateral boundary conditions from the Integrated Forecast System (IFS) of 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 covering most of Western Europe. COSMO-7

provides the lateral boundary conditions for COSMO-2. The COSMO-2 domain of 520 × 350 grid points is centred over the Alps.

Model data are available on 60 model levels. Because model values represent a value averaged in space over one grid cell, turbulence is not represented on the model grid. The model wind therefore relates to a measurement with the turbulent contribution filtered by averaging over a time span of about half an hour to one 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 2008 mainly in order to improve the reproduction of convective precipitation. Because consecutive COSMO-2 forecasts are started every three hours and cover 24 hours, each verification time is available in 8 different model forecasts with the respective 8 different lead times. This redundancy is an additional security element.

3 Wind profiler data

The first field campaign took place in the northern part of Switzerland half way between the two NPPs Leibstadt and Beznau (Figure 1; Ruffieux et al. 2009). A site representative to the Leibstadt-Beznau region and to the confluence of the Aare valley with the Rhine Valley was chosen. It is located north of Kleindöttingen, halfway between Leibstadt and Beznau, next to the Aare River. The second field campaign was conducted near the NPP Mühleberg. The wind profiler was located in Wileroltigen, a site representative for the Saane and Aare valleys west of Mühleberg (Figure 2).

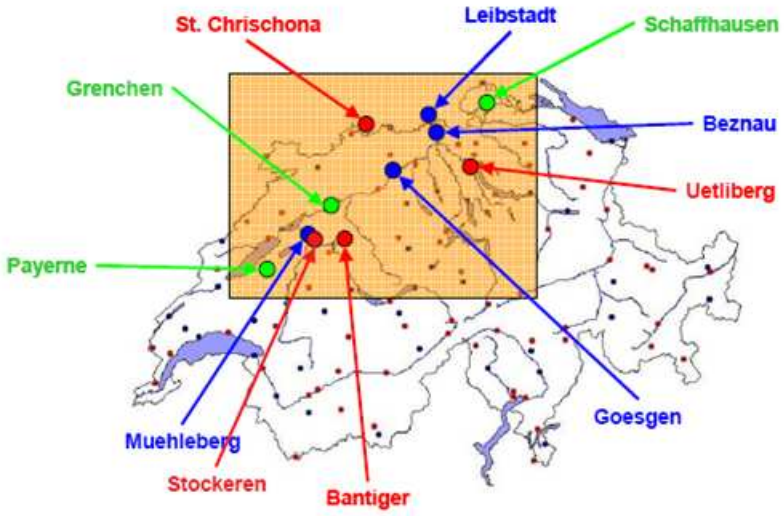

Figure 1: Overview of the CN-MET Network

The data were processed and went trough a 1^{st} level automatic quality control. At the end of the campaign, an operator made a manual 2^{nd} level QC. The wind profiler has been operated in two modes, delivering two sets of quasi simultaneous data. The low-mode measured up to 1'100 m above ground and the high mode went to almost 4'500 m. The characteristics of the mobile wind profiler are summarised in Table 1. The temporal resolution of the measurement available for the model comparison has been set to 30 minutes during the first campaign and to 60 minutes during the second campaign.

Figure 2: Vaisala mobile wind profiler during the second field campaign (March to June 2009) in the vincinity of the power plant of Mühleberg.

low mode	high mode
$\Delta H = 72$ m	$\Delta H = 205$ m
440 - 1452 m MSL	675 - 4773 m MSL

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

4 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 or 60 minutes, corresponding time stamps have then been used for the comparison. The observation data have been interpolated to model height to perform the comparison during the first campaign, and to profiler hight during the second campaign. Data of the 3 months field campaigns served as basis for the analysis. In order to avoid problems with high variability of the wind direction for low winds, winds with a speed lower than 3 m s^{-1} have been removed from the sample for wind statistics. The products that have been generated for the validation and assessment of the model quality include upper-air verification profiles, histograms of model error, and 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. The profile verification for two sites will be shown in the next section.

5 Results

Vertical profiles of wind direction and speed have been compared between wind profiler and model. The verification shows a bias close to zero for both parameters (Figure 3). This confirms that the model generally reproduces the air flow as observed at the location of the independent wind profiler. However the standard deviation of the model error is quite large, indicating that the model forecast is inaccurate over short time periods. This occurs during rapidly changing weather conditions, when the model does not reproduce the fast changing and sometimes back and forth switching of the measured airflow. A comparison with the operationally assimilated wind profiler in Payerne (Figure 4) shows a smaller standard

deviation for the wind direction, although not as small as when the verification is done with the radio sonde (not shown), which is assimilated during the analysis cycle. The wind speed bias is very close to zero at Payerne, but the wind direction shows a small bias of about 5° below 4000 m a.s.l. 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 (Schubiger et al. 2008). The standard deviation is around 40° at the lower levels at both sites, and in Payerne decreases to around 10°-30° towards the top of the profile. The low-mode results (not shown here) show a value about 5° larger. Finally a very positive conclusion is that the quality of the forecast remains very high over the initial 6 hours of the model forecast, indicated by all curves in the Figures 3 and 4 that remain in the same range for bias and standard deviation.

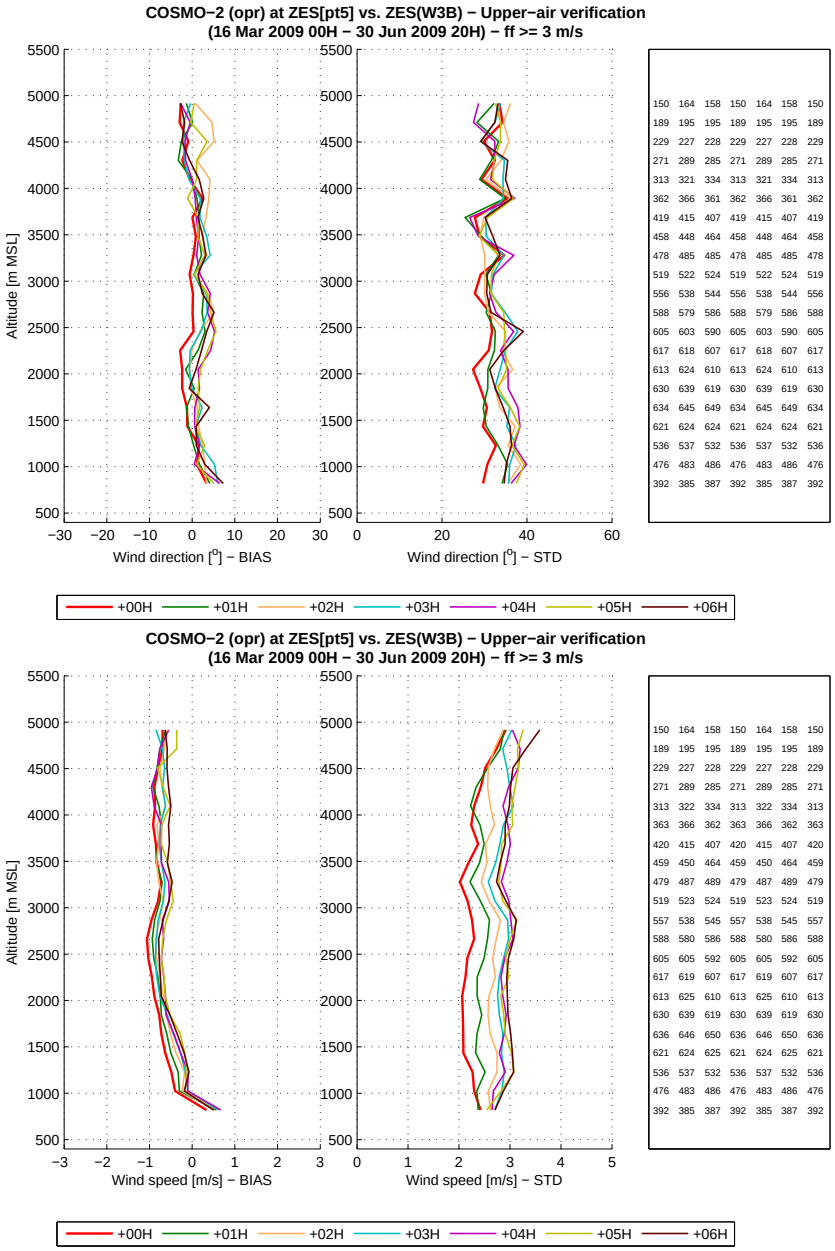

Figure 3: Vertical profiles of (left) model bias and (middle) standard deviation for the first 6 forecast hours versus wind profiler in Mühleberg. The numbers in the box on the right show the number of cases. The top figure shows the statistics for wind direction and the bottom figure for speed, in both cases restricted to measurements with wind speed above 3 m s^{-1}.

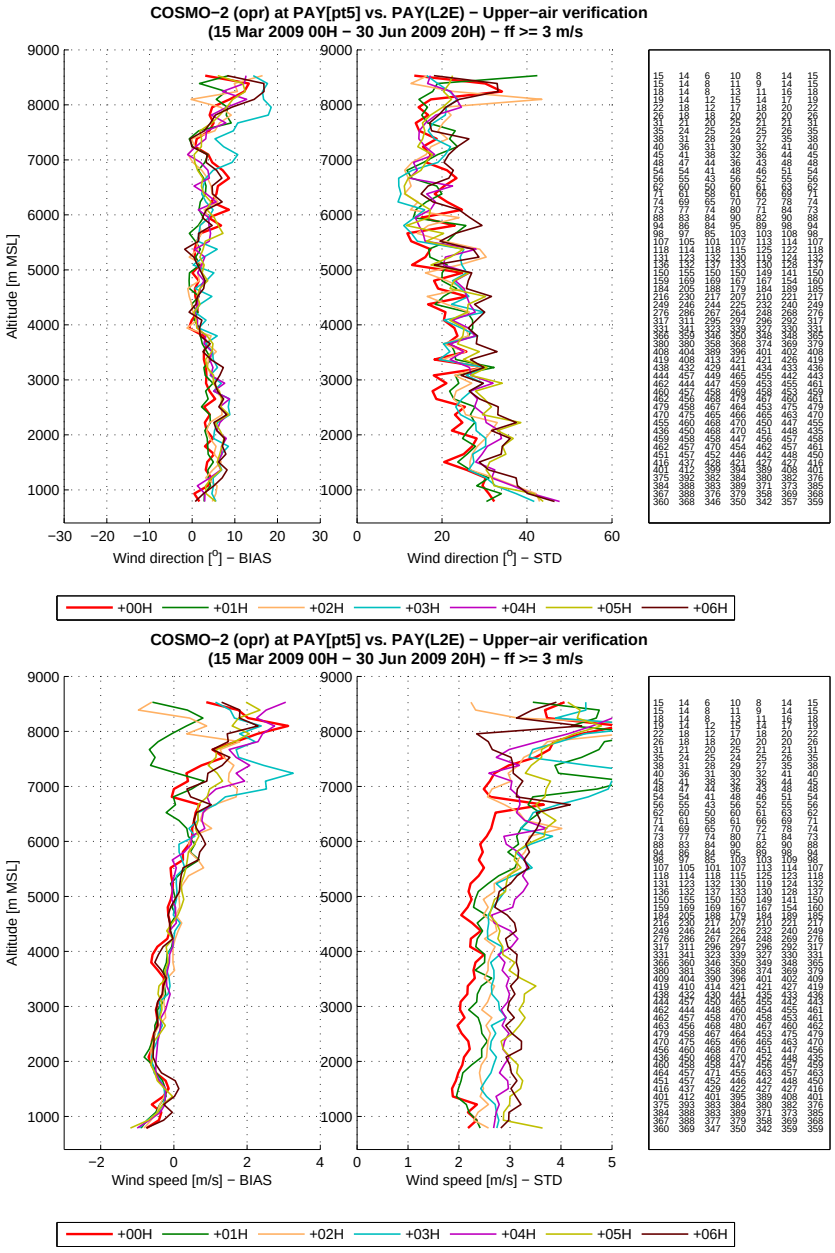

Figure 4: As Figure 3 but for the assimilated operational profiler in Payerne.

6 Conclusions

Wind profiler data have been collected during a three months field campaign in the complex topography of the Swiss Jura, and the north slope of the Alps. 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 especially for the upper levels of the vertical profile. In the lower part of the profile, a slight positive bias can be observed for both wind speed and wind direction. The results show only a minor decrease of quality of the forecast over the first 6 hours. The standard deviation however appears to be considerable. This indicates that the timing of the model is sometimes incorrect. Analysis of individual events demonstrate this behaviour (see for example Ruffieux et al. 2009).

Acknowledgments

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