Comparison of aLMo2 with WINDBANK Measurements

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1 Introduction

The local dispersion modelling for the Swiss emergency response system for airborne pollutants is currently based on a set of pre-determined wind fields, from which the most appropriate is selected based on current measurements or COSMO (Consortium for Small Scale Modelling) model forecasts. The statistical method of selecting the appropriate predefined wind pattern is called the WINDBANK diagnostic system. The project *Centrale Nucléaire et Météorologie* (CN-MET) has the purpose to replace the current system with a system based directly on a fine-grid (2 km) weather prediction model. The set-up of the COSMO model used for this purpose is named aLMo2.

A comparison between aLMo2 simulations with the near-surface wind measurements used to establish the WINDBANK system is the first step to establish the validity of this concept. The comparison serves to discuss changes in model setup and the model evaluation process before the start of a one-year evaluation period.

Because the WINDBANK wind measurements are near-surface measurements, the main advantage of aLMo2 over the WINDBANK diagnostic system, namely to deliver fully three-dimensional wind information over the whole volume of interest, does not come into play in this comparison. The WINDBANK diagnostic system on the other hand has a clear advantage in this comparison, because it is optimised for these measurement sites. Unfortunately, independent measurements are not available.

2 The weather prediction model

The current operational short-range forecasting system of MeteoSwiss is the Swiss set-up of the COSMO model centered over the Alps, the "Alpine Model". It uses the *Integrated Forecast System* (IFS) as lateral boundary conditions provided by the *European Centre for Medium-Range Forecasts* (ECMWF). At MeteoSwiss, the COSMO model is calculated with 1/16° grid spacing, corresponding to about 7 km, hence the here used abbreviation aLMo7. The aLMo7 is used for providing lateral boundary conditions for aLMo2.

The aLMo2 has a grid spacing of about 1/50° (2.2 km). Its current domain of 520×350 grid points is centered over the Alps (Figure 1). It uses the same assimilation scheme as aLMo, namely nudging. The wind measurements above 100 m *mean sea level* (MSL) are however currently not assimilated.

Experimental setup, dates and scheduling

Our aLMo2 simulations are carried out in two modes:

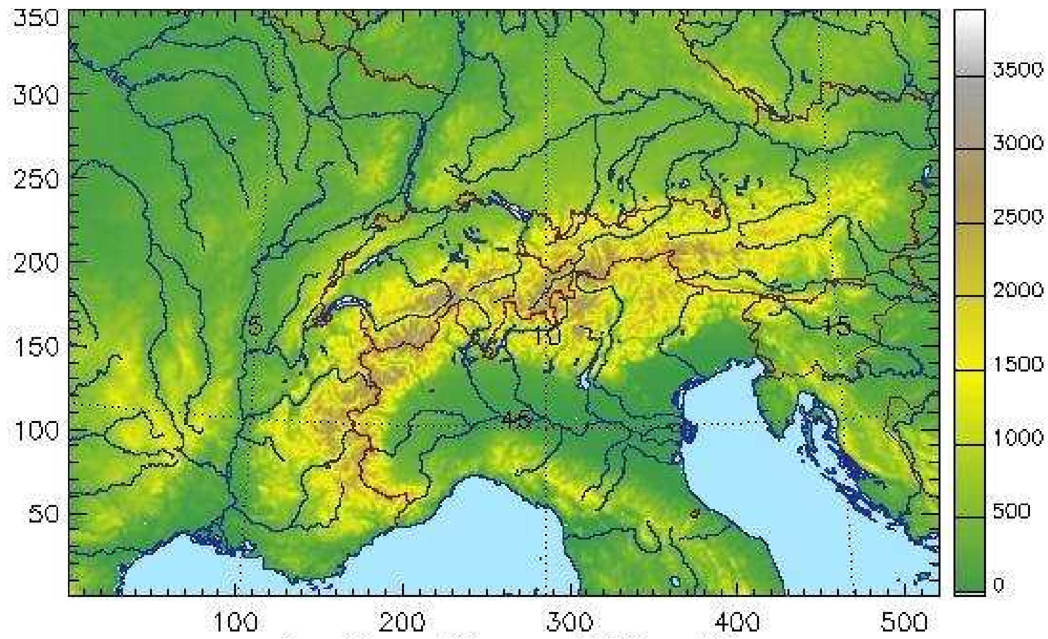

Figure 1: Domain of aLMo2

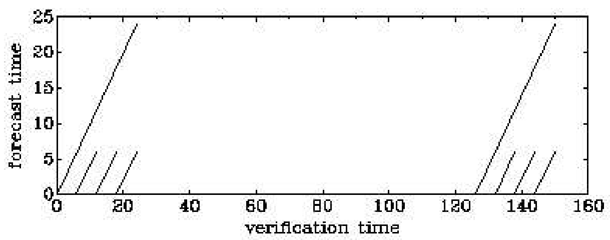

Figure 2: Schematic scheduling of the forecast modes of the aLMo2 simulations

Analysis mode Continuing assimilation with 24 hour spin-up with

- assimilation of observations,
- aLMo7 analysis as lateral boundary conditions.

Forecast mode 24h and 6h

- initialization with aLMo2 analysis,
- free forcast without assimilation of observations,
- with aLMo7 analysis as lateral boundary conditions.

The frequency of forecasts in the future aLMo2 system is planned to be every 3 hours, with a lead time up to 18 hours.

For a reduction of the needed computer capacity only 24 days from each measurement periode are chosen for the simulation. These days are spaced with a gap of 4 days, plus 6 hours to eliminate any systematic error introduced by a fixed initial time of day. Due to the fact that operationally the 3–6 h forecast will be of most interest, three forecasts are computed up to 6h lead time and one forecast is computed up to 24 h lead time for each selected day. Figure 2 shows schematically two blocks of 24 hour and 6 hour forecasts.

Nuclear Power Plant	Period	Permanent stations	Temporary stations
Beznau, Leibstadt	1 Jul. – 31 Oct. 1995	17	25
Mühleberg	1 Jul. – 31 Oct. 1997	20	22
Gösgen	1 Jul. – 31 Oct. 1999	21	22

Table 1: WINDBANK measurement campaigns

Verification of the COSMO model

The routine verification of the operational version of the COSMO model is done by several means. The vertical profiles are verified with the European radio soundings (Arpagaus 2005). The near-surface model predictions are verified on the European scale using SYNOP messages (Kaufmann 2005). A more detailed verification restricted to the Swiss area (Schubiger 2005) uses the Swiss network of automated measurements.

A similar suite of verifications has been applied to the aLMo7 version of this study to ensure the overall quality of the driving model for aLMo2. The description of these results however goes beyond the scope of this paper.

3 WINDBANK

A temporary network of wind measurements was installed in an area of approximately 20 km around each of the three sites with nuclear power plants in Switzerland to capture the near surface wind patterns. The three sites were under examination during four months from July to October, each site separately in a different year. The existing permanent stations in a larger area (out to approx. 60 km distance from the site) were also included in the studies. The four month period of all wind measurements conducted for a site form the data basis, to which the method of Kaufmann and Weber (1996; detailed description in Kaufmann, 1996) was applied to determine wind classes for the WINDBANK diagnostic system (Gassmann *et al.* 2005). The wind classes describe flow patterns with normalized wind speeds and are scaled to the actual wind speed before being provided to the dispersion model.

The observations of the three measurement campaigns (Gassmann *et al.* 2005) are present as hourly values of the wind, stored as components of the wind vector (Table). There are no common temporary sites among the three periods. The permanent stations are mostly part of the automated measurement network of MeteoSwiss, representing a larger area, and are partially used for more than one period.

4 Method

In this study we use traditional scores in meteorology, namely mean error and standard deviation of the error. DD and FF are used as superscripts for wind direction or wind speed, respectively. N^{DD} and N^{FF} indicate the number of matching pairs of values. The units are degree for wind direction and m/s for wind speed.

Points on a scatter-plot are located at the x–axis corresponding to the observation and at the y–axis correspoding to a model value (which might also be the WINDBANK diagnostic system). Due to the cyclic nature of the wind direction, the area of strong correlation is not only along the diagonal but also includes the upper left hand and lower right hand corners of the graph.

Model	ME^{DD}	σ^{DD}	N^{DD}	ME^{FF}	σ^{FF}	N^{FF}
aLMo2 analysis	3.230	47.22	23032	0.1722	1.749	64280
aLMo2 19-24h forecast	3.533	57.31	5424	0.0891	1.789	16347
aLMo7 analysis	8.257	53.49	15326	0.3606	1.743	44155
WINDBANK	0.151	30.62	23569	0.3116	1.281	66055

Table 2: Total scores for all stations (all WINDBANK campaigns)

Model	ME^{DD}	σ^{DD}	N^{DD}	ME^{FF}	σ^{FF}	N^{FF}
aLMo2 analysis	4.859	45.17	12115	0.4316	1.295	37911
aLMo2 01-06h forecasts	4.208	47.99	9125	0.3941	1.286	29261
WINDBANK	-0.091	28.14	12397	0.2540	1.047	38909

Table 3: Total scores for temporary stations (all WINDBANK campaigns)

For all statistical values related to *wind speed*, we use all matching data pairs. For the *wind direction* we use only samples where the *observation* of the matching pairs reports a wind speed larger than 2 m/s.

When interpreting the results, one should however keep in mind that the Windbank measurements are direct point-observations, whereas the aLMo2 forecasts represent a spatial mean over a whole grid cell. A perfect match thus cannot be expected.

5 Total scores for all stations and for temporary stations

Table 2 presents scores including all stations (temporary and permanent) and Table 3 for temporary stations only.

Mean error It is interesting to see that the bias of an aLMo7 analysis is significantly larger (8.257) compared to all other values reported for the bias (all $\leq$4.9; Table 2). Note that in the case of temporary stations the bias for an aLMo2 analysis is actually larger (4.859) than in the 6h forecast (4.208), but the difference is rather small (Table 3). This counter–intuitive order is common. Reasons can be a slightly unbalanced wind field in the analysis, the difference in number of verification pairs and the uncertainty in the statistical values itself.

Standard deviation of wind speed and direction

WINDBANK vs. aLMo The standard deviations reported for the wind speed for WINDBANK (1.047) are surprisingly close to those for aLMo ($\approx$1.3), when looking at Table 3.

A larger difference in standard deviation can be observed for the wind direction (45° for aLMo2 vs. 28° for WINDBANK). This shows the difficulty of aLMo2 to represent local effects, which seems to be more pronounced for the wind direction.

aLMo7 vs. aLMo2 Table 2 shows that aLMo2 is systematically better than aLMo7 in regards to standard deviation for both wind speed and wind direction.

analysis vs. 6h forecast The quality of the 6 hour forecast is almost equivalent to that of the analysis (Table 3). The loss of quality is obviously small for the first 6 hours (maybe even a quality gain !), which renders a recomputation of forecasts at a very high frequency (e.g. every hour) less relevant.

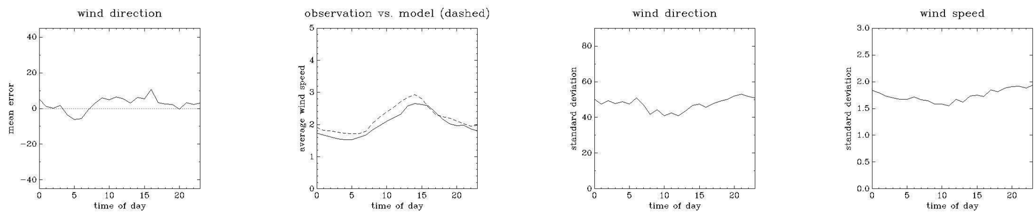

Figure 3: Mean error and standard deviation of the error for each time of the day for aLMo2 compared against WINDBANK data.

permanent vs. temporary stations Overall the results are essentially equivalent for "all stations" and "temporary stations".

6 Verification of the aLMo2 analysis

For the overall verification of the aLMo2 analysis, the simulated winds are compared for all stations (permanent and temporary) and all three WINDBANK campaigns. Figure 3 summarizes the mean error and standard deviation for each hour of the day. The wind direction bias is well below 10° and the wind speed bias is far below 1 m/s.

Figure 4 shows the results for each of the different measurement campaigns separately. The similarity of the plots shows that there is no substantial difference in representativity of the three campaigns. We see that both aLMo2 and WINDBANK show an intensification of the scatterpoints near the main diagonal (and the opposite corners for the wind direction due to its circular nature). Both methods also reveal considerable spread and cluttering of the whole plotting domain. Both methods show dense regions for the wind directions which can be derived from the histogram of wind directions over the Swiss plateau.

The scatterplots displaying wind speed for aLMo2 show that the dynamic range of the weather model seems too narrow. Low wind speeds are overestimated, while high winds are underestimated. The model tends to favor moderate wind speeds and in average overestimates the 10 m winds slightly. This effect can partly be due to the fact that COSMO model winds are representative winds for a grid cell. Obviously point measurements of winds will show a greater range in values than an average over a cell. With decreasing cell size, of course, one hopes to bring the two quantities in accordance.

One important feature is the quantization effect for the wind directions stemming from the wind classes in the WINDBANK diagnostic system, resulting in horizontal stripes in the plot.

The statistical values for the overall standard deviations of the wind directions already indicate that there is a considerable spread in both WINDBANK and aLMo2 wind directions. This is confirmed in the scatterplots.

7 Single station comparison of the aLMo2 analysis

General observations We observe in the wind direction histograms for the WINDBANK that the accentuation of the channeled flow in the Swiss plateau is overemphasized by WINDBANK. This is due to the absence of certain wind directions due to the grouping into wind classes. The aLMo2 on the other hand underestimates the channeling effect at many stations.

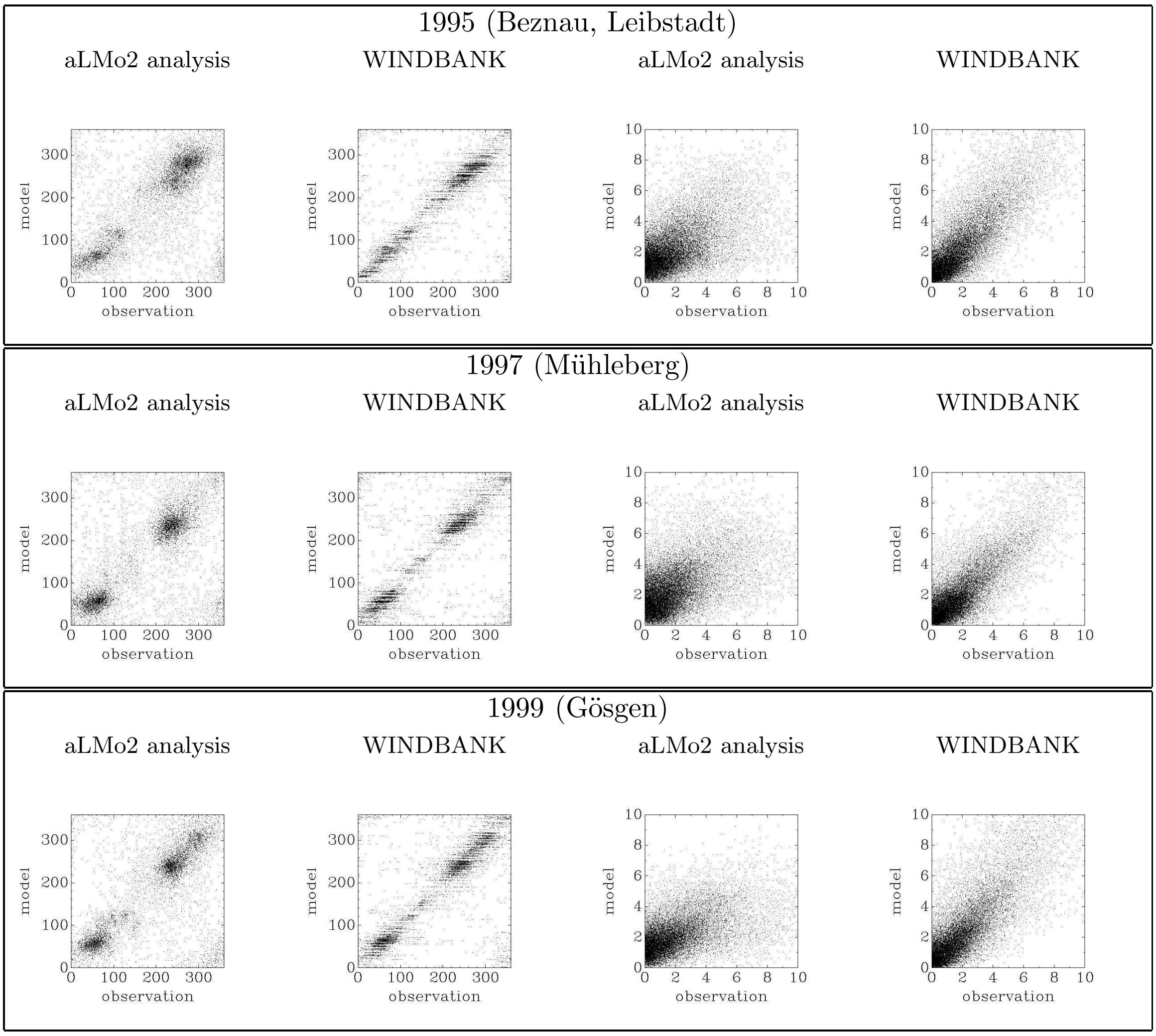

Figure 4: Scatterplots of wind direction and wind speed using all stations (permanent and temporary) for each of the three measurement campaigns.

Wind direction

- In some cases, aLMo2 and the WINDBANK reconstructed wind directions are of similar quality.
- The WINDBANK reconstructed directions are better at a number of stations. The exact number depends on the criteria, it lies however between 20 to 30 of the about 40 stations each year. This is expected due to the mesh size of aLMo2 that cannot resolve local orography, the possible influence of trees, buildings and the like on the stations, and WINDBANK being optimized for the station locations.
- aLMo2 wind directions are better at a few Stations.
- Some stations are badly reproduced by both aLMo2 and WINDBANK. High vertical bands appear in the direction scatterplot for aLMo2 and wide horizontal bands in the scatterplot for the WINDBANK system. These bands are partially the result of the under- and overestimation of the channeling effect by aLMo2 and the WINDBANK diagnosis system, respectively. For aLMo2, a phase shift might be adding to the broadness of the scatter plot.

Wind speed

- In general, the wind speed is too strong in both aLMo2 and the WINDBANK reconstructed winds.
- At locally influenced, sheltered, low wind speed stations, aLMo2 tends to overpredict the wind speed.
- In very few cases, the distribution of aLMo2 wind speeds is better than the WINDBANK reconstructed speeds.
- Some stations are grossly underestimated by the aLMo2 10 m wind, because the measurements are located much higher above ground than 10 m.
- Some mountain-top wind speeds are underestimated by aLMo2 due to inadequate representation of the boundary layer at the mountain top. The parameterization of the boundary layer in aLMo2 is representative for the whole grid cell (2 km by 2 km) and does not reflect the local effect of a mountain top.

8 Interpretation of the results

This study was proposed as a first "screening" of the quality of aLMo2 ground winds. We are satisfied by the statistical results, because

- aLMo2 compares quite well to WINDBANK, despite the fact that the WINDBANK diagnostic system is made solely for the purpose of 10 m wind analysis, and aLMo2 was not run with all available improvements available today. Particularly, the wind direction and speed of the Swiss (and many other) stations have not been assimilated.
- aLMo2 was proven to be systematically better than aLMo7, especially with respect to wind directions.

The overall results show that the dynamic range of the wind speed of aLMo2 seems to be too narrow. Individual station plots show that aLMo2 is very well suited for simulating local effects. For some stations aLMo2 has even been shown to provide a better model climatology for the wind directions than the existing WINDBANK system.

Concluding, aLMo2 has the potential to replace a statistical tool such as WINDBANK for simulating local winds.

References

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