SRNWP-PEPS
A regional multi-model ensemble in Europe

Summary

The promising results of the EUMETNET PEPS project are presented. The paper describes the method and representative evaluation results. It ends with the suggestion that PEPS products should be used operationally by all participating EUMETNET members.

Introduction

One of the most important challenges the operational forecaster is faced with is the effective usage of the existing variety of operational numerical weather forecasts. There is the feeling that joining these operational forecasts in a multi-model ensemble could lead to better results within the forecast and warning process.

Regional Modelling in Europe is organised in 4 consortia: HIRLAM, ALADIN, COSMO and the UK Met Office, each of them having their own regional model. A reasonable variety of operational forecasts exist, which are produced on different domains with different grid reso-lutions and use different model parametrizations and data assimilation techniques.

In 2002, DWD had the idea of bringing together all available high resolution numerical fore-casts in a **P**oor Man's **E**nsemble **P**rediction **S**ystem (PEPS). It was suggested at a EUMETNET Council meeting that a project should be started under the umbrella of EUMETNET.

The EUMETNET PEPS Project

In June 2003 the director of the SRNWP EUMETNET Program, Jean Quiby, started the project by asking the European National Meteorological Services to participate. At the time of writing, 20 Weather Services had joined the project, providing 23 forecast models (Table 1). As a result, 40 deterministic and probabilistic forecast products are distributed to the contributing members on an operational basis. One of the main goals of the project has been the evaluation of PEPS to decide whether it provides a significant support and improvement of the warning process.

Methodology within PEPS

The single model forecasts are interpolated onto a reference grid, the PEPS grid. It has a grid spacing of 0.0625° (~7 km) like the DWD Lokal Modell, covering Europe from 30°W to 30°E and 35°N to 70°N. Exceedance probabilities are calculated at each PEPS grid point from the ensemble members using a nearest neighbour approach. Because the individual members have different resolutions and integration areas, the ensemble size depends on location. At the moment all ensemble members are equally weighted and the probability P of forecast value x exceeding threshold T at location i is calculated according to:

Table 1: Contributing European Weather Forecast Models (Dec. 2005)

Meteorological Service	Regional Model	Coupling Model	Resolution (km)	Forecast Period (h)	Time Interval (h)	Main Run (UTC)
Belgium	ALADIN	ARPEGE	15	+60	1	0, 12
France	ALADIN	ARPEGE	11	+48	3	0, 12
Austria	ALADIN-AUSTRIA	ARPEGE	9.6	+48	1	0, 12
Croatia	ALADIN	ARPEGE	9	+48	3	0, 12
Czech. Repub.	ALADIN-LACE	ARPEGE	9	+48	3	0, 6, 12, 18
Hungary	ALADIN-LACE	ARPEGE	11	+48	1	0, 12
Slovakia	ALADIN-LACE	ARPEGE	11	+48	3	0, 12
Slovenia	ALADIN-LACE	ARPEGE	9.5	+48	3	0, 12
Denmark	HIRLAM	ECMWF	16	+60	1	0, 6, 12, 18
Finland	HIRLAM	ECMWF	22	+54	1	0, 6, 12, 18
Spain	HIRLAM	ECMWF	22	+24	1	0, 6, 12, 18
Netherlands	HIRLAM	ECMWF	22	+48	1	0, 6, 12, 18
Ireland	HIRLAM	ECMWF	16	+48	3	0, 6, 12, 18
Norway I	HIRLAM	ECMWF	11	+30	1	0, 12
Norway II	HIRLAM	ECMWF	22	+30	1	0, 12
Sweden I	HIRLAM	ECMWF	11	+48	3	0, 6, 12, 18
Sweden II	HIRLAM	ECMWF	22	+48	3	0, 6, 12, 18
Germany	LME	GME	7	+78	1	0, 12, 18
Switzerland	aLMo	ECMWF	7	+72	1	0, 12
Italy	EuroLM	EuroHRM	7	+60	3	0
Poland	LM	GME	14	+72	3	0, 12
United Kingdom I	UKMO-Meso	UM NAE	12	+48	3	0, 6, 12, 18
United Kingdom II	UKMO-NAE	UM global	12	+48	3	0, 6, 12, 18

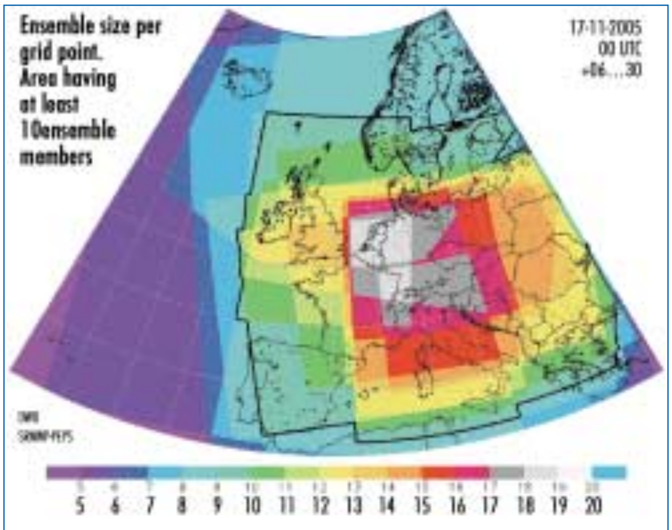


Figure 2: Number of ensemble members in the SRNWP-PEPS. The area having at least 10 ensemble members is enclosed by the black line.

$$P_i(x > T) = \frac{\sum_{k=1}^{N_i} H(x_k - T)}{N_i}$$

where N_i is the total number of forecasts at grid point i and $H(\theta)$ is the Heaviside function ($H = 1$, if $\theta \geq 0$; $H = 0$, if $\theta < 0$). Figure 2 shows an example of the variation of ensemble size with location.

Operational Suite

At the end of 2004 an operational suite was established at DWD. The ensemble products are calculated four times a day according to the cut-off times noted in Table 2:

Ensemble forecasts are calculated for the meteorological parameters

- Accumulated total precipitation
- Accumulated total snow fall
- Maximum 10 m wind speed
- Maximum 10 m gust speed
- Maximum and minimum 2 m temperature

Ensemble product	Cut-off time
00 UTC	05:30 UTC
06 UTC	11:30 UTC
12 UTC	17:30 UTC
18 UTC	23:30 UTC

Table 2: SRNWP-PEPS data cut-off times

Ensemble means and medians (precipitation and total snow) as well as probabilistic products are calculated. According to the requirements of operational forecasting, a 24h accumulation period was defined lasting from +06h to +30h relative to the 00 and 12 UTC runs. Additionally, 12h forecast products from +06h to +18h and from +18h to +30h are derived from the 0, 6, 12, and 18 UTC runs with slightly different thresholds for the prob-abilities.

As shown in Table 1, only the 00 UTC run incorporates the maximum number of model forecasts. Moreover, the ensemble size varies with parameter (Table 3) because not every model provides every forecast parameter, e.g. only some of the ALADIN and COSMO countries operate empirical parametrizations of wind gusts within their modelling environment. An ensemble size per grid point of at least 3 has to be reached to activate the calculation of the probabilistic products.

Model Lead Time	Total Precipitation	Total Snow	Wind Speed	Gust Speed	Temperature
00 UTC	23	22	23	9	23
06 UTC	10	9	10	1	10
12 UTC	22	21	22	9	22
18 UTC	11	10	11	2	11

Table 3. Maximum ensemble size depending on model lead time and on meteorological parameter

Visualisation

The forecasts are provided in a password protected area of the official SRNWP-PEPS web site for evaluation purposes. This site is updated every 6 hours. In addition to the European size standard products, plots of a smaller domain focused on Germany are made. These are available to the forecasters at DWD only and allow them to analyse the products in more detail. In the near future the PEPS products will be made available to the NinJo workstation system. Using NinJo it will be possible to combine the PEPS products with any other meteorological information available such as synoptic observations, radar products, satellite images or numerical models. The NinJo system was introduced in WGCEF Newsletter N° 10 (Heizenreder, Koppert 2005).

Evaluation results

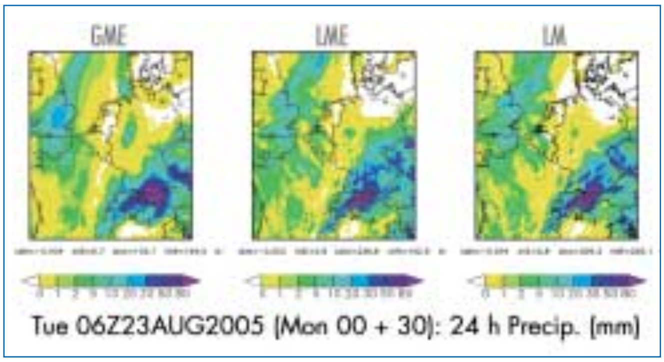
At the Central Forecast Office of DWD the pre-operational SRNWP-PEPS products were evaluated on a daily basis. First evaluation results were presented at the 11th Meeting of the WGCEF in De Bilt, September 2005. The results are promising and suggest that operational usage of the PEPS products will be useful, especially for short range forecasting and in the warning decision process.

The issue of severe weather warnings is often a very difficult matter due to the uncertainty in predicting the location, timing and intensity of extreme events. To quantify the forecast un-certainty in a reliable way a variety of different numerical models with slightly different analyses or physical parametrizations should be available. These are provided by the SRNWP-PEPS, incorporating the most sophisticated high-resolution numerical weather prediction models of Europe.

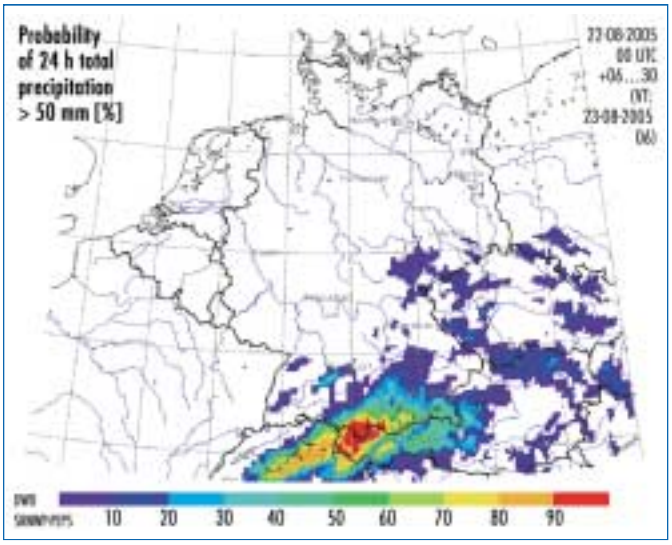
Representative example of evaluation results – synoptic scale situation

The PEPS products supported the signal of the deterministic forecasts for the 23rd August 2005 in Figure 4 relating to the location and the extreme values of the expected precipitation.

▲ *Figure 3. Impact of the flooding situation, 23.08.2005 in southern Germany* ▶

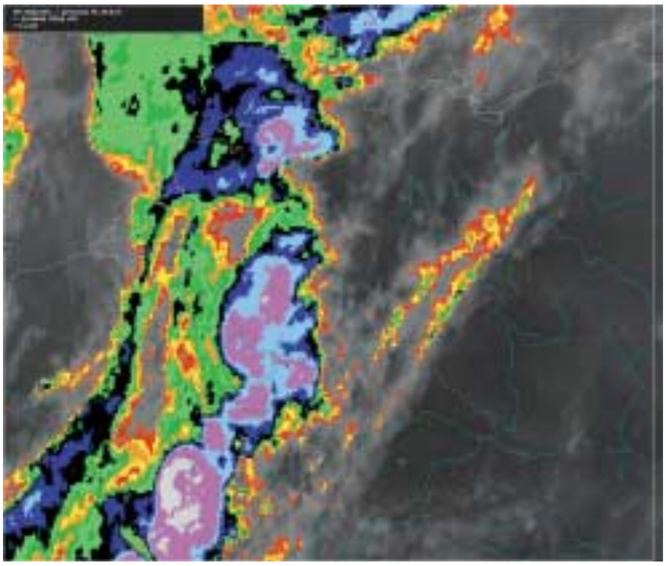


▲ *Figure 4. Deterministic model forecasts – Global Model and Local Model of DWD*



◀ *Figure 5. PEPS Products - taking all available high-resolution models into account.*

Representative example of evaluation results – convective events



◀ *Figure 6. Satellite data, 03.06.2005, 18 UTC*

◀ *Figure 7. Damage caused by gusts of more than 130 km/hr.*

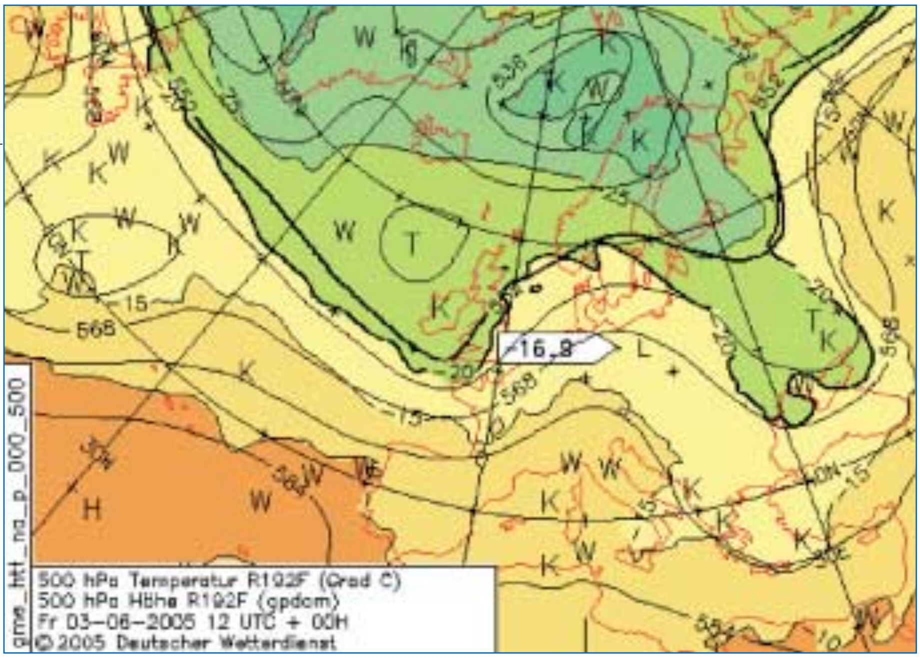


Figure 8. Geopotential height 500 hPa, 03.06.2005, 12 UTC

The most critical time span of the warning process is 24 to 48 hours before an expected severe weather event occurs. The evaluation of SRNWP-PEPS products at the Central Forecast Office of DWD has shown that, **for synoptic-scale events**, these products provide a very useful aid to the forecaster's decision-making process. There appears to be a clear correlation between PEPS forecast probability and frequency of occurrence of an appropriate event.

The examples above (Figure 4 – 14) show 2 representative cases demonstrating some strengths and weaknesses of the SRNWP-PEPS system. One particular weakness is the inability of the available current mesoscale models to predict convective events reliably. In the case of the severe thunderstorms over Germany on 3rd June 2005, model soundings and nowcasting products formed the basis of the issued severe weather warnings. PEPS products did not show an appropriate signal.

Figure 9. Severe weather warnings from DWD, 03.06.2005 (www.wettergefahren.de)

One strength of PEPS is related to the ability of its constituent mesoscale models to simulate synoptic-scale events reliably.

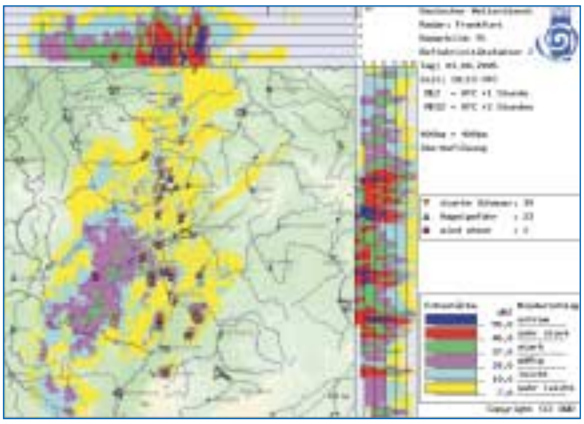


Figure 10. Radar data, 03.06.05, 18:13 UTC

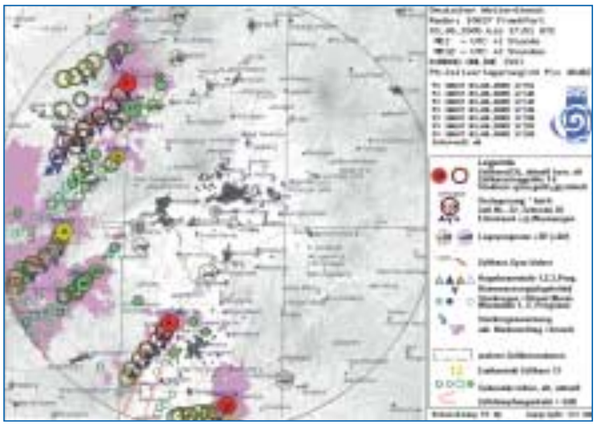


Figure 11. KONRAD, 03.06.05, 17:51 UTC

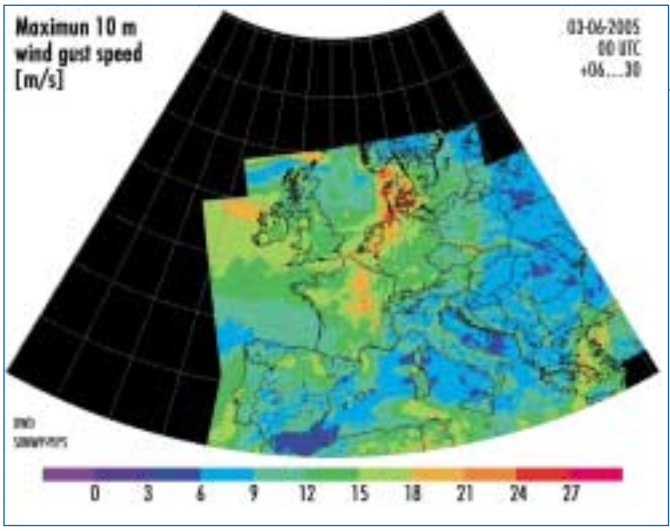


Figure 12. PEPS Forecast Product, 03.06.05, 00 UTC T+06...T+30

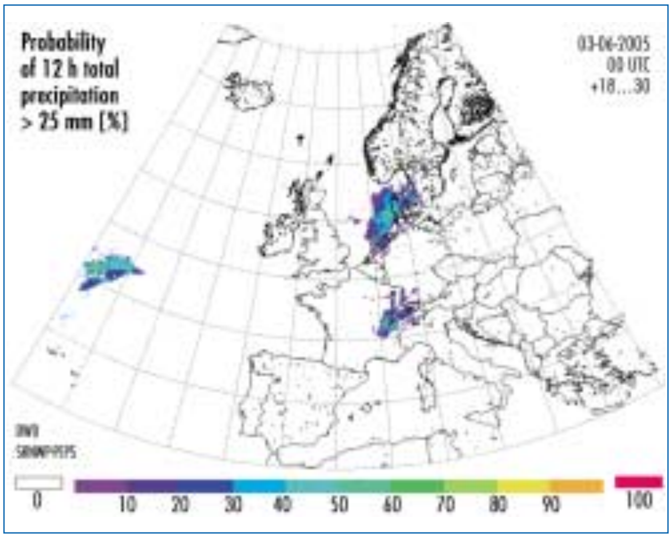


Figure 13. PEPS Forecast Product, 03.06.05, 00 UTC T+18...T+30

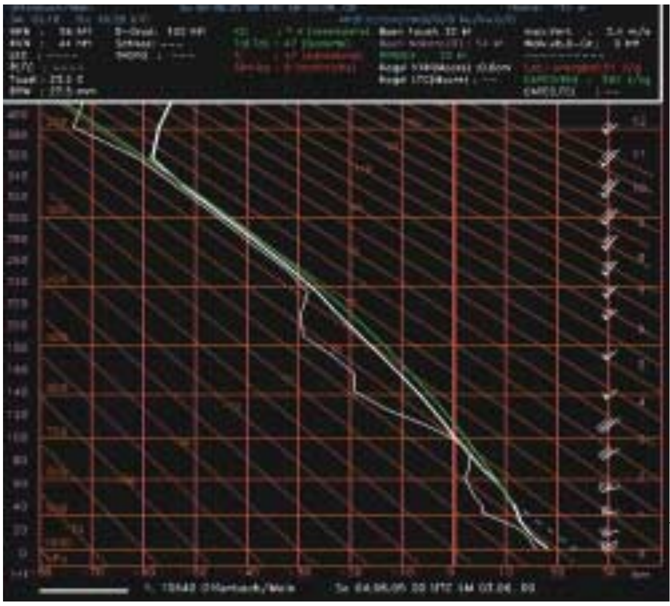


Figure 14. LM-Forecast Sounding used for warnings, 03.06.05, 00 UTC T+24

Several severe weather situations have supported this conclusion during the evaluation phase at the Central Forecast Office of DWD.

Outlook

The first evaluation of the SRNWP-PEPS is promising, though many questions still remain open. These concern for example, the simple assumption of giving equal weights to the individual ensemble members and using the total number of forecasts as a proxy of the actual probability of an event. Furthermore, it can be seen from Figure 15 that the system is biased and uncalibrated. To tackle these problems we will continue to verify the SRNWP-PEPS in a systematic way and we will implement a statistical post-processing package to calibrate the ensemble based on Bayesian Model Averaging (BMA).

From the results presented here we want to encourage the European weather services to start their own evaluation processes. We are very optimistic that the SRNWP-PEPS will provide reliable estimates of forecast uncertainty and enhance the quality of severe weather warnings. The question of using SRNWP-PEPS products for operational purposes will appear on the agenda of the next SRNWP ensemble meeting. Commercial applications will be discussed under the umbrella of ECOMET.

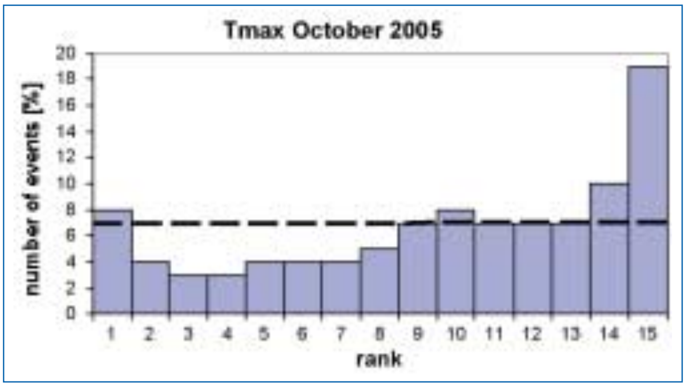


Figure 15. Rank histogram of maximum temperature in October 2005. The expected distribution of an unbiased and calibrated system is indicated by the dashed line. The SRNWP-PEPS underestimates the maximum temperature and the forecast uncertainty.

References

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Internet:
http://www.dwd.de/PEPS,
http://srnwp.cscs.ch/

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