Use of EPS to derive probabilistic forecasts and severe weather events

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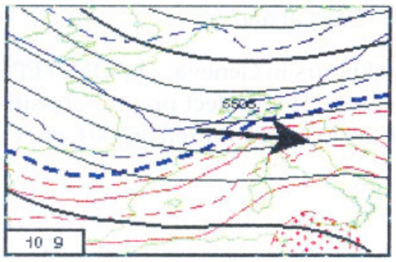
Introduction

This paper presents the use of the ensemble prediction system (EPS) of the ECMWF as a base to issue probabilistic forecasts and severe weather warnings. During the last years demands are increasing for issuing forecasts in a probabilistic form and now several MétéoSuisse products do include probabilities (essentially for the medium range). For example, probabilities of daily local winds exceeding 45 or 75 km/h and probabilities rainfall exceeding 1 or 10 l/m^2 are produced. In addition, most of the forecasts are quoted by a confidence index.

On the other hand, after a strong storm and a severe flooding, the issue of early warnings has become a crucial topic, so that efficient tools are needed to assess them. Among them numerical projections indicating the probable occurrence of severe or extreme events must be developed. Warnings have generally to be issued for strong winds, heavy precipitations, and also for snowfalls exceeding 1 m over 3 days in the Alps. The various thresholds are coordinated with the local authorities.

Post-processing technique

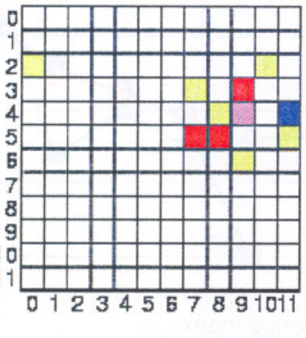
Our approach is based on a classification technique. A 12x12 unit classifier has been constructed using an artificial neural network. It classifies two meteorological fields: the 500hPa geopotential heights and the 850hPa temperatures. Each unit represents a typical weather situation (fig.1) to which one can associate probabilities of occurrence for local weather elements, such as sunshine, precipitations, winds, gusts, based on a 20 year long climatology.



Prob. wind gusts (24h) %			Prob. 24-h precipitations %			
>45km/h	>60km/h	>70km/h	>0.1mm	>1mm	>5mm	>10mm
50	33	9	100	89	39	17

Fig. 1: Unit (10,9) of the classifier and the corresponding probabilities of precipitation and gusts at Zürich.

The EPS members are classified for each time step. A confidence index is derived from the measure of the distribution of the EPS members on the classifier (fig.2). Moreover, by computing the weighted average of the probabilities corresponding to each occupied unit we obtain local weather probabilities for various weather events.



Unit	Occupation
(4,11)	15+control
(4,9)	13+operational
(5,7)	7
(3,9)	5
(5,8)	3
(6,9)	2

Fig. 2: Distribution of EPS members on the classifier. List of the most populated units. Run of 29th Oct. 2001, D+5. Corresponding confidence index is 6 over10.

Verification of precipitation probabilities

The precipitation probabilities for two thresholds of 1 mm / 24h and 10 mm / 24h are evaluated next. The DMO outputs from two different stations close to Geneva are presented together with forecast probabilities obtained from the classification approach (fig.3).

The DMO outputs suffer mainly from an over forecasting of the occurrence and quantity of precipitation. The classification method, although lacking of resolution (few probabilities close to 0 or 100%) gives better scores for 1 mm / 24h at all time-steps staying skilful up to day 10. For 10 mm / 24h, the DMO is better for the five first days, but the classification method takes over after. However, in order to be fair with the DMO, the observations should not be taken on just one station but should be upscaled to the resolution of the model.

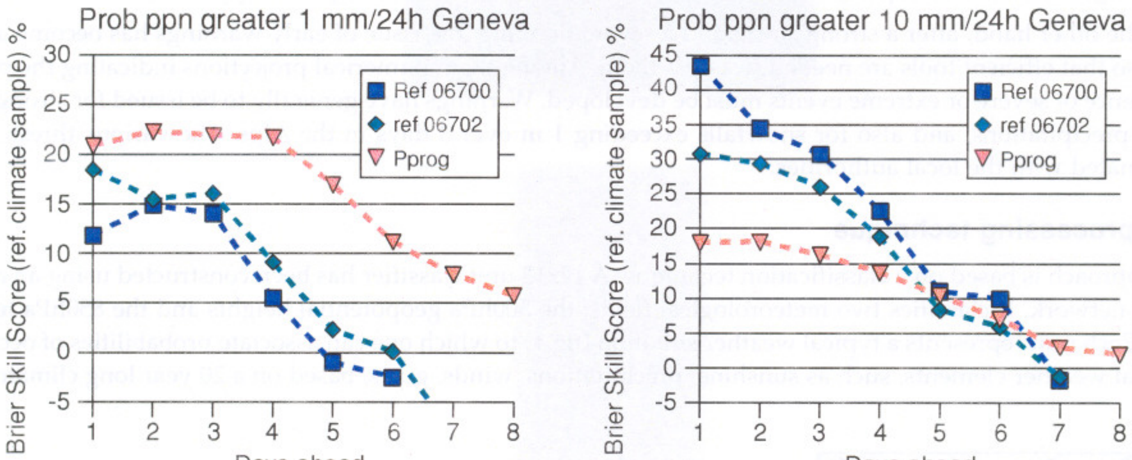


Fig. 3: Skill of the precipitation probabilities greater than 1 mm and 10 mm in 24 hours in Geneva. The DMO EPS probabilities use two different references, respectively La Dole and Geneva. The perfect prog or classification method is described in the text. The periods covered are 16.2.2000 to 30.4.2001 for ref. 06700 Geneva and 1.1.1999 to 30.4.2001 for ref 06702 La Dole.

Confidence index as a quality indicator for the deterministic run

The confidence index deduced from the dispersion of the EPS members on the classifier can be related to the skill of the operational model. The verification of the occurrence of precipitation greater than 1 mm/day in Geneva is presented. The skill is given by the difference between the hit rate and the false alarm rate. For day+4 to day+6 there is a good relation between the skill of the forecasts and the value of the confidence index (fig. 4).

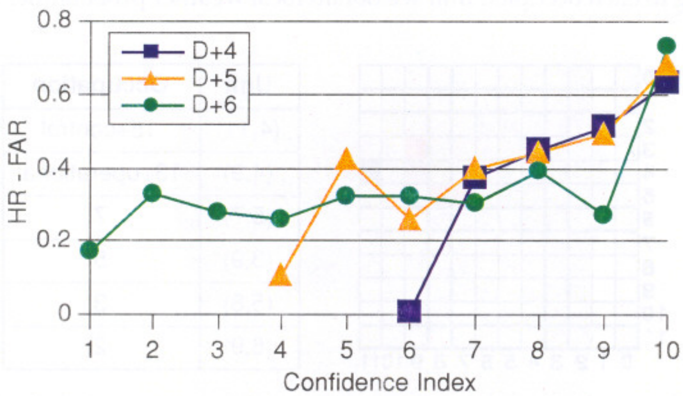


Fig. 4: Skill of precipitation forecast of the operational run, for precipitation greater than 1mm/24h in Geneva, period 1997-1999.

The confidence index can be used as a good indicator of the quality of the operational run (at least for the precipitations), showing that there is a complementarily between the EPS and the deterministic forecast

Synoptic verification of the confidence index

A medium-range forecast is issued by the bench forecasters every day based on all available models including the EPS. Various weather parameters must be given for 6 stations in Switzerland. A score is then build where precipitation counts for 40%, sunshine for 40% and temperature for 20%. This score is compared with the confidence index (fig. 5). It is only possible to find a very little dependency between both parameters. This indicates that the confidence index computed as such from the synoptical patterns cannot be diffused directly to quote the forecasts. The problem is that different situations can give rise to the same local weather observation. The issued confidence index should take into account the local weather element probabilities as well as the synoptical confidence index.

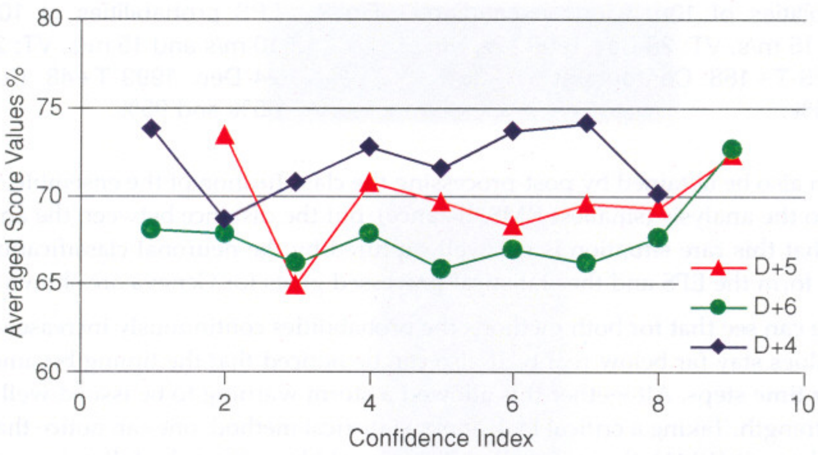


Fig. 5: Synoptic scores of forecasts D+4 to D+6, the period is 1.1.1998 - 30.4.2001.

Severe events

1. Prediction of the storm Lothar on the 26th of December 1999

The case of the storm Lothar will teach us about forecasting extreme events using either the operational model and the EPS with a post-processing. In fact three storms hit central Europe between the 25th and the 27th December 1999. The most extended took place on the 26th when the gusts reached up to 150 km/h at lower altitudes and up to 250 km/h in the mountains. A strong almost straight jetstream extended through the Atlantic with a diffluence at 10 degrees east. This baroclinically very unstable situation was globally well predicted by the operational forecast and the EPS (fig. 6), but the precise position of the cyclogenesis was only captured in the 24 hour forecast.

Winds have then been forecasted to be strong already a few days before but the real strength of the storm was caught only a few hours before the event. The wind speed DMO probabilities from the EPS showed high probabilities over the Atlantic, with some tendency to penetrate also inland, which is quite rare for the model to produce. This tendency increased between the 168 and 48 hour forecast (fig. 7 and 8).

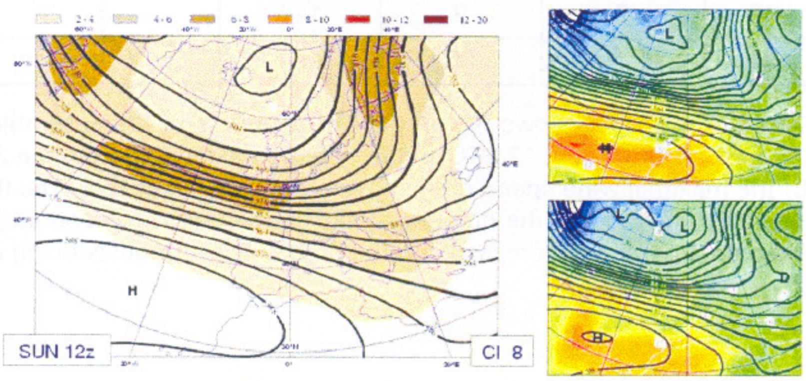


Fig. 6: a) T+96 ensemble mean and Std deviation of 500hPa geopotential heights. Run 22 Dec. 1999 12z, VT: 26 Dec. 1999 12z. b) Most populated unit (10,11) with 30 members, the operational and control run. c) Second populated unit (10,4) 10 members.

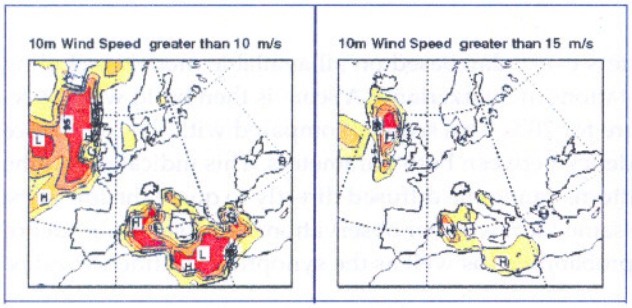


Fig. 7: EPS probabilities of 10m winds exceeding 10 m/s and 15 m/s, VT: 26 Dec 1999 12z, run 19 Dec. 1999 T+168. Contours at 5%, 35%, 65% and 95%.

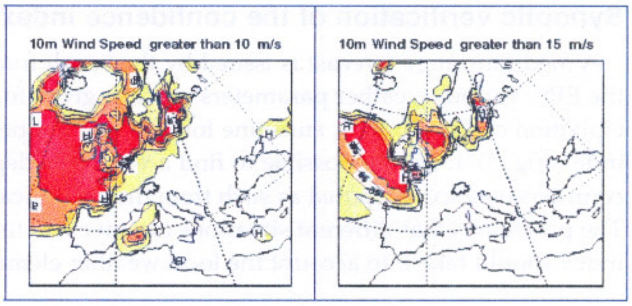


Fig. 8: EPS probabilities of 10m winds exceeding 10 m/s and 15 m/s, VT: 26 Dec 1999 12z, run 24 Dec. 1999 T+48. Contours at 5%, 35%, 65% and 95%.

The wind gusts can also be obtained by post-processing the classification of the ensemble. The unit (10,11) is the unit corresponding to the analysis (smallest RMS distance), but the distance between the analysis and this unit is quite big, showing that this rare situation is not well captured by the neuronal classification system. The winds forecasted at la Dôle form the EPS and the statistical processed gusts for Geneva are shown in the table 1.

From this table one can see that for both methods the probabilities continuously increase when getting closer to the event, but the values stay far below reality. It also can be noticed that the timing became sharper targeted on the 26th with shorter time steps. Altogether this allowed a storm warning to be issued well in advance, but with an underestimated strength. Taking a critical look at our statistical method, one can notice that even if all ensemble members predicted the unit (10,11), the gust probabilities would have been the following:

gust > 60 km/h: unit(10,11) 18%, climatology for winter is 4%

gust > 75 km/h: unit(10,11) 7%, climatology for winter is 0.8%

Analysis	Step to 26.12	# members v >10 m/s 26.12 12z	# members v >10 m/s 25 0z-28 0z	Ensemble v max 26.12	Hits on unit (10,11)	Prob (gust > 60 km/h)	Prob (gust > 75km/h)
17.12	216	0	0	6.1	0	6%	1%
18.12	192	1	1	10.1	1	4%	0%
19.12	168	2	5	10.3	5	5%	1%
20.12	144	2	5	10.3	16	3%	3%
21.12	120	0	5	10.5	18+c+o	16%	5%
22.12	96	5	10	13.8	30+c+o	17%	5%
23.12	72	7	15	13.5			
24.12	48	8	9	14.5			
25.12	24	17	20	15.5			

Table 1: The second block of the table shows the amount of members of the ensemble with mean speeds greater than 10 m/s for the 26th at 12 UTC and for a period extending from the 25th at 00 UTC to the 28th at 0 UTC; the maximal wind speed of the ensemble is shown as well. The third block shows the statistical interpretation, with first the number of hits on the unit corresponding to the analysis (c is the control and o the operational forecast) and the probabilities for gusts being greater than 60 km/h and 75 km/h.

2. The October 2000 flooding

Strong precipitation fall during three days over the alpine region between the 13th and the 15th October 2000 and more than 300 mm of rainfall south of the Alps. A cut-off low developed over the western Mediterranean which generated a strong southern current towards the Alps. This situation is classical and gave rise to a substantial elevation of the Lago Maggiore. Due to the temperature of the sea a lot of convection also developed and allowed the precipitation to pass over the first barrier of the Alps. Around 200 mm fell in three days in the upper Rhone valley, locally even more. Landslides produced about 20 casualties.

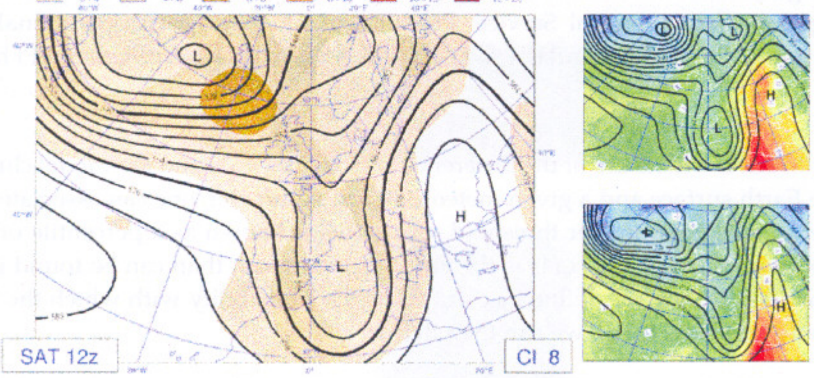


Fig. 9: a) T+96 ensemble mean and Std deviation of the 500hPa geopotential heights. Run 10 Oct. 2000 12z, VT:14 Oct. 2000 12z. b) Most populated unit (6,4) with 26 members, the operational and control run. c) Second populated unit (7,3) 9 members.

Figure 9 shows the ensemble mean and the two main possible 4-day forecasts for the 14th October. It can be seen that the position of the cut-off low and the southerly current over the Alps is forecasted with a good confidence. The calculated confidence index is 8 over 10. But, although the synoptical situation has been described correctly, the interpretation in terms of precipitation is rather poor. The DMO probabilities of exceeding 20 mm in 24 hours lies around 20%. The statistical classification forecast gives a little better result, but the probabilities to exceed 50 mm are still small.

Analysis	Lead to 14.10	Opr (mm/24h)	EPS # members		PP prob %		ci
			>20mm	>50mm	>20mm	>50mm	
08.10.2000	D+6	28	9	1	45	18	7
09.10.2000	D+5	10	2	0	50	20	8
10.10.2000	D+4	29	6	0	45	18	8
11.1020.00	D+3	51	21	0	48	19	8
12.10.2000	D+2	36	23	0	58	24	10
13.10.2000	D+1	20	16	0	60	25	10

Table 2. Precipitations amounts over 24-h forecasted by the operational run at station Cimetta (above Locarno), number of EPS-members showing precipitations amounts greater than 20 and 50 mm/24-h. Probabilities issued from the classification method and confidence index.

Conclusions

Both the verification of precipitation probabilities and the analyses of severe events show that we have to combine the EPS DMO, statistical approaches on the EPS and the deterministic forecasts in order to produce the relevant information for the forecast guidance.

Although the synoptical situations (at upper level) are correctly forecasted either by the EPS and the operational runs, the difficulties appear with the values of wind speed or precipitations. In order to capture such events more precisely a higher resolution of the models are needed. Since the relevant resolution to mesoscale events will not be reached in the near future, various downscaling procedures can be proposed. On of them is the so-called LAM EPS consisting of starting a limited area model from different EPS initial states.

Further development will also be done in order to improve the statistical interpretation, with a special weight on strong events.