Severe Weather Forecasts at the German Weather Service

Thomas Schumann, Deutscher Wetterdienst, Kaiserleistr. 42, D-63067 Offenbach

1. Introduction

The prediction of severe weather events is of vital importance to the German Weather Service (DWD). The preparation, transmission and the monitoring of warnings in case of an approach or when such an event's development has been monitored are one of the main tasks of the DWD. Most severe events are of mesoscale nature and very rare, but they will require warnings with a lead time of several hours up to one day.

The prediction of such an event up to several days in advance is mostly not possible. If a synoptic scale event is approaching in some situations a severe weather indication up to 120 hours could be given, based on a probabilistic approach. This type of warning plays a minor role in the warning activity of the DWD. More important are very short range forecast techniques, especially during the last 24 hours before the event's onset. Then the highest warning level has to be started. Recent numerical weather prediction (NWP) models are often not able to predict this type of events because of their severity and rarity. Statistical NWP methods and high-resolution local area models (LAM) as well as the EPS at lead times above 24 hours give an alarm signal only. Classical analytical and diagnostic methods and a careful monitoring of the development and propagation of a severe event will become essential.

2. Warning procedure and -criteria at the DWD

The "operational core" of the DWD consists of 6 major branch offices (MBO) at Hamburg, Potsdam, Essen, Leipzig, Stuttgart and Munich. They are tasked with providing the public with detailed short-term (0 to 72 hour) forecasts and warnings for their region. Furthermore the MBOs have to supply customers and the general public with medium-range forecasts. The central forecast office (CFO), located at the DWD's headquarters in Offenbach, is pros the whole spectrum of weather forecasting. In the case of severe weather the CFO is coordinating and monitoring the warning activity of the MBOs. The CFO has to prepare, transmit and monitor guidance warnings to support the MBOs which provide warnings for the general public, authorities and for special customers needs, i.e. the end-users.

A severe weather warning will be issued if an event that is very likely will affect customers and general public endangering live and property. The maximum validity of this type of warning is 24 hours, a severe weather warning is like an alert to fire brigades, police and authorities. A severe weather pre-warning up to 36 hours in advance will be issued to make users and authorities aware if the event is very likely on public holidays or Sundays and/or if the event has been predicted, but still not monitored. It always depends on its impact on the general public and the user's activity whether an event is a severe event or not. Therefore user-tailored warning criteria will be applied

Event	Threshold	Remarks	Predictability
Gusts 10m-wind	> 28 m/s (11 Bft) > 21 m/s (9 Bft)	wide-spread and / or repeated	< 72 hrs, often < 24 hrs < 120 hrs (indication)
Severe convective outbreaks (hail, gusts, tornadoes, heavy rain)	danger, diameter of the hailstones above 5 mm	Severe thunderstorm warning	< 12 hrs, but often by nowcasting techniques only, difficult to predict
Heavy rain	25 mm / 6 hrs	Heavy rain warning convective intensified wide-spread areas	< 36 hrs, mostly < 12 hrs
Continuous rain	20 mm / 12 hrs snow cover exceeds 15 cm	Mostly used if the soil is still frozen, very wet and / or in combination with melting snow	< 72 hrs < 120 hrs (indication)
Freezing rain (drizzle)	occurence	Wide-spread areas	< 36 hrs, but often by nowcasting techniques
Snow (-drift)	15 cm / 12 hrs	Wide-spread areas, not used in highlands	< 72 hrs, often < 12 hrs

Table 1: Warning criteria, applied at the DWD

The most likely events that affecting users and the general public in Germany are severe storms. Wind gusts are predictable in the very short range only. Severe convective outbreaks are more difficult to predict, because of their rapid development forecasts are possible by using nowcasting and monitoring techniques only such as radar, satellite and lightning registrations. Heavy rain patterns in large-scale precipitation areas are also predictable at very short range lead times. Heavy continuous rain events, especially in combination with rapidly melting snow, will be detectable already by medium-range tools such as EPS methods. On the other hand, in the case of freezing rain warnings in most cases are not possible more than 36 hours before the onset of the event.

However, in respect of the warning activity of the DWD, medium-range forecast methods like the EPS are of comparatively little importance. Deterministic forecasts and much more LAM will be applied, but nowcasting methods and a careful monitoring of the approaching event will be indispensable. Details are given in the next figure.

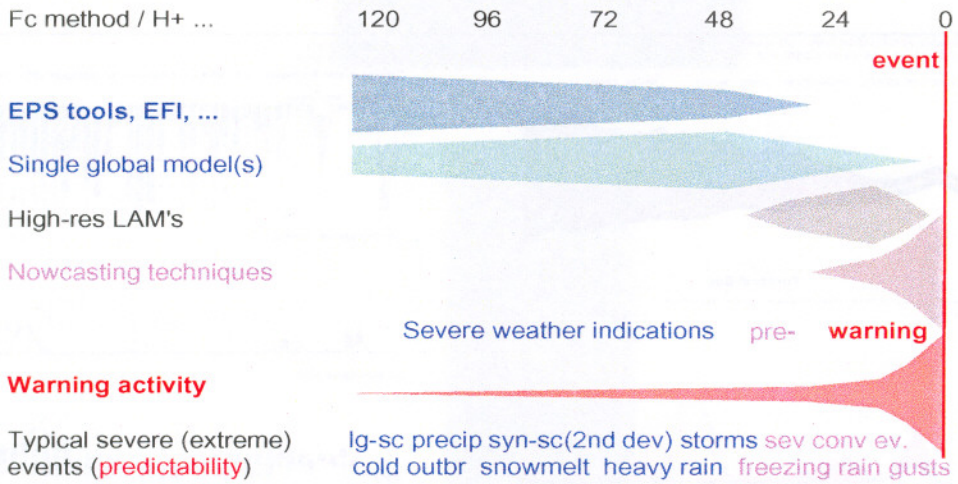

Fig. 1: Time dependency of forecast methods used for the preparation and maintenance of warnings at the DWD

2. Models and interpretation techniques used at the DWD in the medium range

Forecasters starting the decision making process with an evaluation of the deterministic NWP included other center's predictions and previous runs to validate the reliability of the current run. Results will be checked to determine whether there is an indication for a severe event or not. The forecaster never starts his shift's work with an inspection of the EPS because of its three-dimensionality. The EPS will be included later. If the EPS confirms the severe weather indication by giving persistent signals, a medium range indication could be prepared. Otherwise, if the signal is too weak (depends on user's needs such as the cost-loss ratio) the process will be repeated in the next run(s). The objective of this cascading process is to establish already at forecast lead times up to 120 hours and therefore at an early stage, an indication of severe weather (fig. 2).

Clusters, tubes and stamps for specifying a signal will be used regularly. Clusters are based on the root mean square error difference between the EPS members at the 500 hPa level. The purpose of the clustering is to combine "similar" EPS members into groups with a limited spread. On the other hand, tubes average the similar EPS members in respect of the EPS mean that allow a better visualization of different scenarios given by the EPS. The objective of the tubing is to present a sequential view of the various EPS tendencies of the current model run.

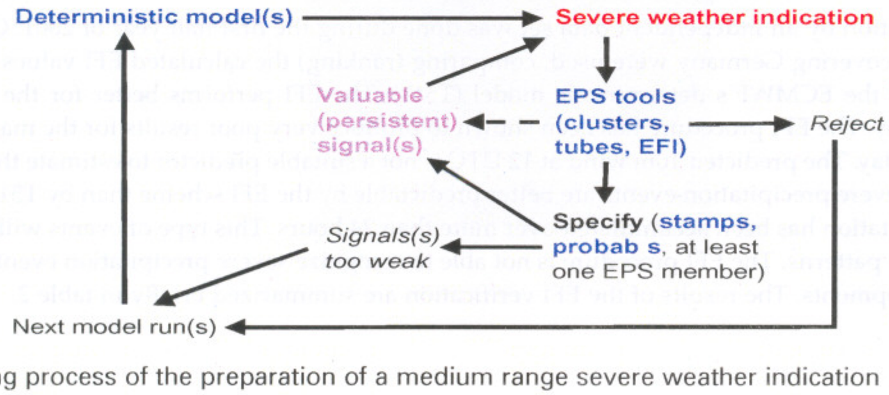

Fig..2: cascading process of the preparation of a medium range severe weather indication

Stamps display each EPS member at a certain time step and parameter as a tiny chart. Thus the ECMWF's EPS plot contains 50 charts + two charts showing the control and the deterministic run. Because of the limited time during a forecaster's shift an evaluation of the stamps is only possible at certain time steps and pre-defined weather parameters. Plumes and EPSgrams (fig.3) allow a specification of the severity of an event. Plumes visualise EPS members' reaction for a given time period as a single line. The dark area indicates the variability the EPS. The EPSgram combines plumes and probabilities at a defined point. The variability of 50 % of all EPS members will be shown as a box divided by the EPS mean. Thin columns represent the upper and lower 25 % of the EPS distribution. The deterministic and control runs are displayed as a continuous thick and a dotted thin line.

Forecasters of the participating National Weather Services could access these tools via the ECMWF member state web site. To allow a better use of the EPS during the operational shift it is necessary to compress the information to extract any signal reflecting a severe event.

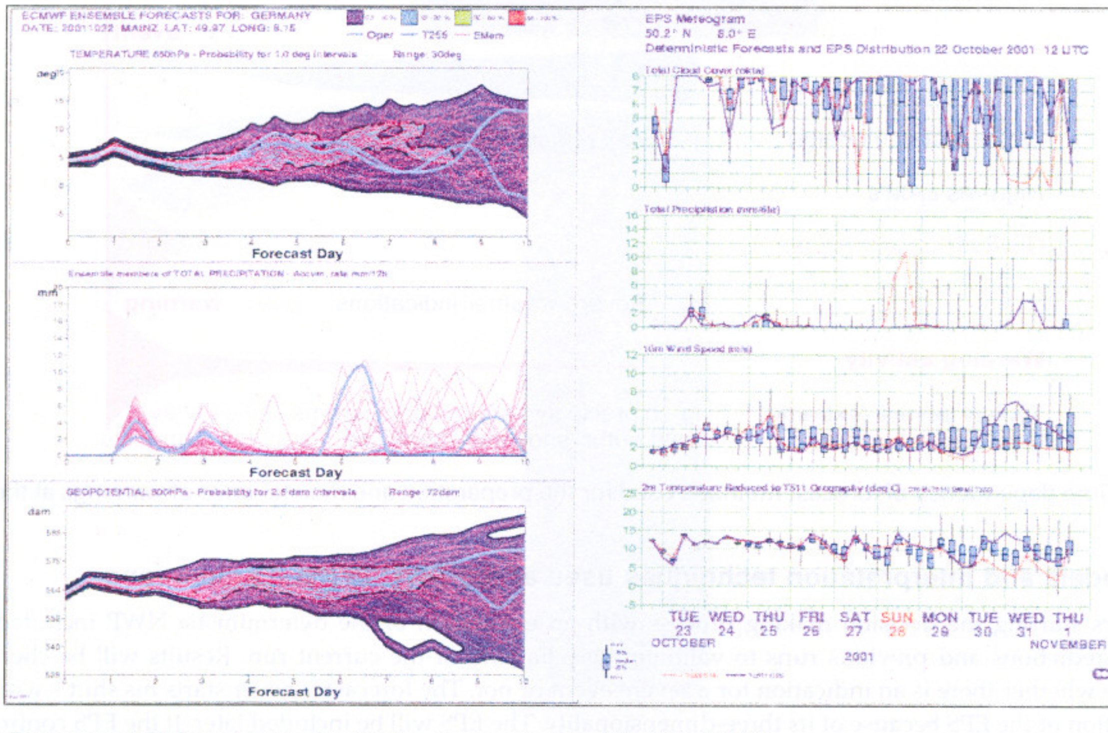

Fig. 3: Plume and EPS metgram for Mainz, forecast date 22nd Oct 2001

3. Experimental EPS products, still not used at the DWD

Comparing the predicted probability of an event with its probability derived from the climate, at a defined point the number or percentage of EPS members predicting a severe event will be calculated. Values could be plotted into a diagram as empirical distribution function. The EPS distribution at this point where the severe event has been predicted, could be compared with its climatological expectation at the given month (fig.4). The parameter that describes the distance between the EPS distribution of the event and its climatological distribution (or expectance) are the EFI, the Extreme Forecast Index. The spatial distribution of the EFI at a certain time step allows creating alarm bell maps as a product to predict severe weather events. This is illustrated in fig. 4 (next page).

The EFI verification by an independent data set was done during the first half year of 2001. Observations at 12 synoptic stations covering Germany were used, comparing (ranking) the calculated EFI values against the corresponding runs of the ECMWF's deterministic model (T511). The EFI performs better for the wind speed over northeast Germany. The EFI procedure has been shown to produce very poor results for the maximum wind gust prediction of the day. The predicted 10m wind at 12 UTC is not a suitable predictor to estimate the maximum wind gust of the day. Severe precipitation events are better predictable by the EFI scheme than by T511, especially if the amount of precipitation has been accumulated over more than 24 hours. This type of events will mostly be caused by major synoptic patterns. The EFI procedure is not able to recognize severe precipitation events caused by rapid convective developments. The results of the EFI verification are summarized briefly in table 2.

Weather parameter	Method	time step H+96 (H+114)	time step H+168 (H+186)
10m-wind (12 UTC)	EFI	fair (better in the NE part)	*mostly no skill*
	T511	fair (better in the S part)	*no skill*
Max gust (12 UTC)	EFI	poor	*no skill*
	T511	*mostly no skill*	*no skill*
Temp Max	EFI	good	fair
	T511	excellent	good
Total precip (24 hours)	EFI	fair	*no skill*
	T511	fair	*mostly no skill*
Total precip (120 hours)	EFI	good	-
	T511	fair	-
Total precip (240 hours)	EFI	-	fair
	T511	-	-

Table 2: Main results of the EFI verification

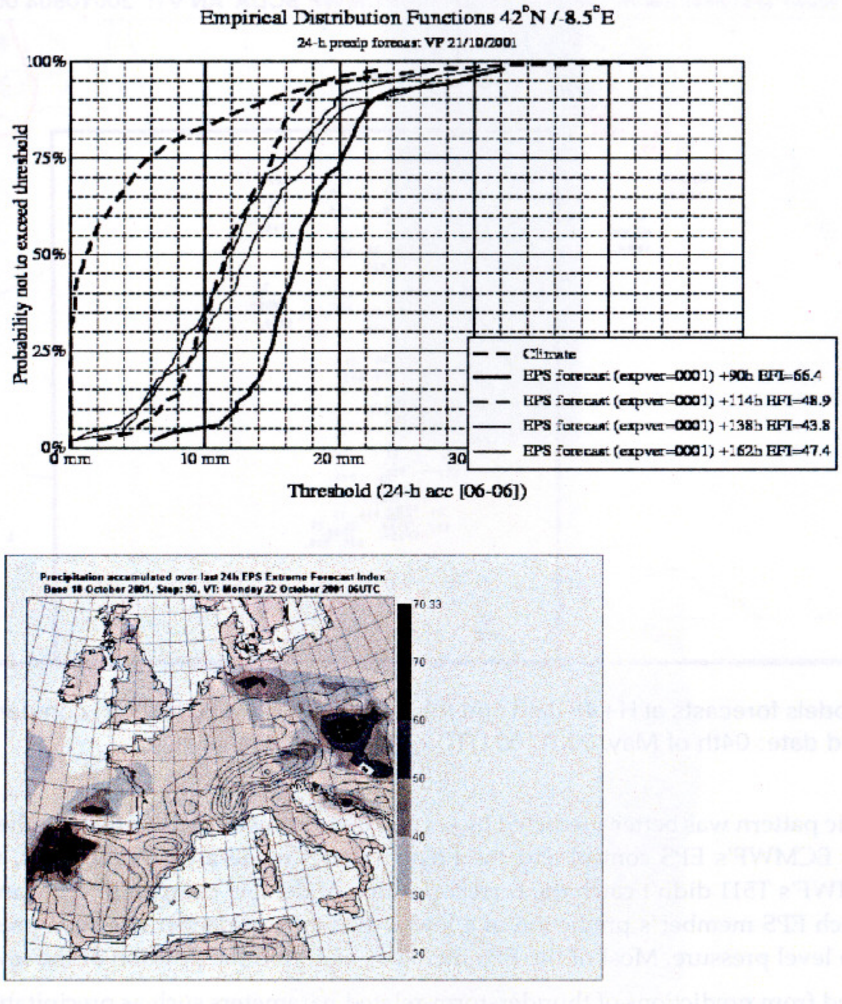

Fig. 4: Empirical distribution function and EFI map valid at the 22 Oct 2001 (step H+90)

Calculating probabilities of exceeding certain thresholds by related parameters at forecast steps up to 10 days in 12 hour-intervals several parameters are available: T2m, T850 hPa, wind gust, 10m-wind, precipitation, snow and cloud cover. Taking into consideration that higher probabilities underestimate an event and an event is very unlikely if it's percentage drops below 10% probability maps providing useful guidance to predict severe weather.

4. An example - thunderstorm outbreak 3 May 2001

The majority of severe events will be caused in an unstable environment by a short-wave structure producing a rapid development. Typical events are mesoscale convective systems. The physics of these processes are not completely understood yet. Warnings could be issued a few hours in advance only. Thus a comprehensive analysis of the situation and a careful monitoring of the event or its development using satellite, radar, lightning registration and a dense synoptic observation network are essential. In order to save money in recent years in central Europe the observation network has been reduced or automated. The monitoring of a severe event becomes more and more difficult.

One of these events affecting the general public in certain areas was the thunderstorm outbreak at the 3rd of May, 2001. Regions hit by this mesoscale convective system were located in western Germany, like the Hochsauerland and the Hamburg-Luebeck area near the Baltic Sea coast. Precipitation totals of up to 80 mm caused heavy local flooding. Wind gusts up to 34 m/s were reported.

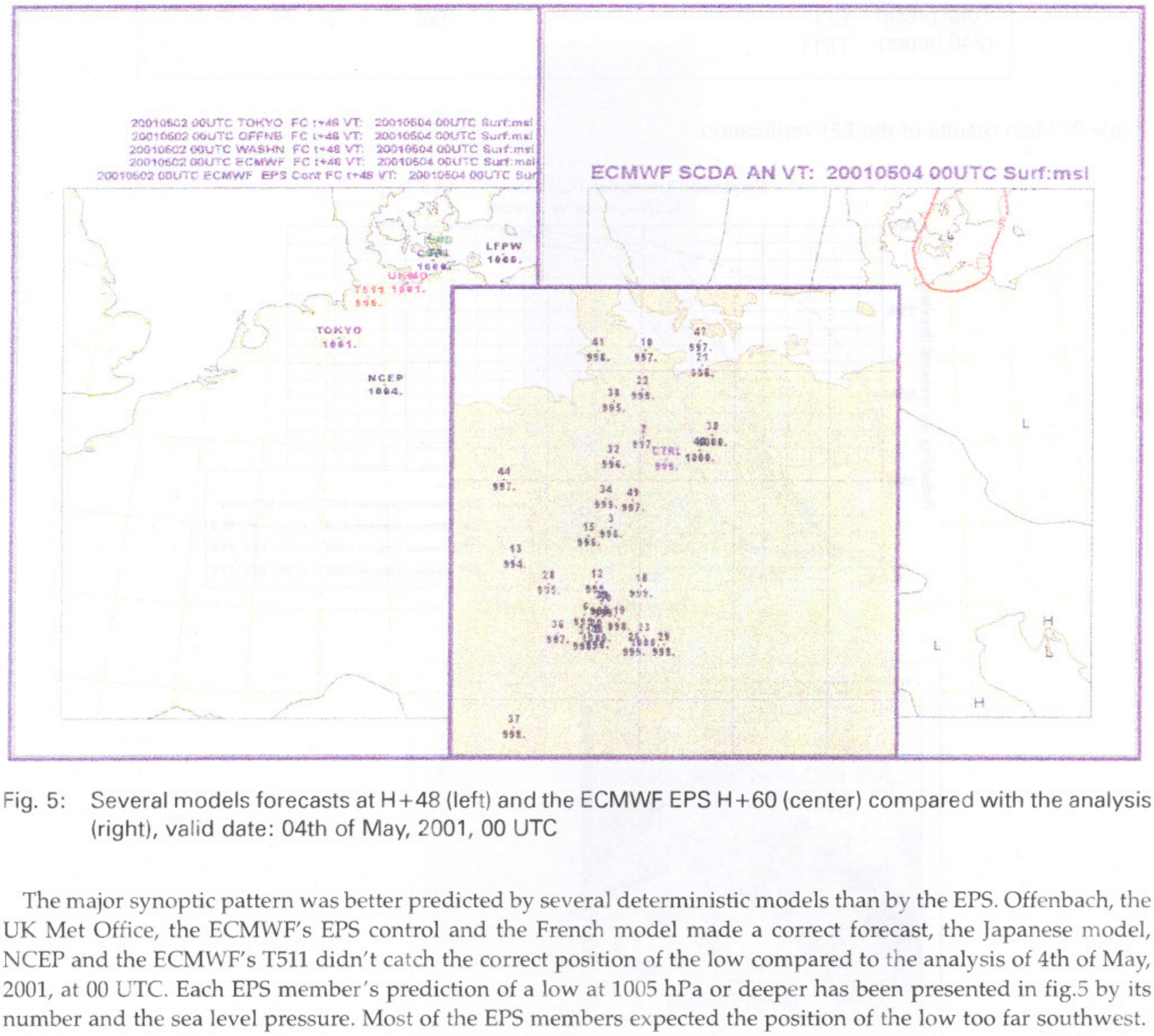

Fig. 5: Several models forecasts at H+48 (left) and the ECMWF EPS H+60 (center) compared with the analysis (right), valid date: 04th of May, 2001, 00 UTC

The major synoptic pattern was better predicted by several deterministic models than by the EPS. Offenbach, the UK Met Office, the ECMWF's EPS control and the French model made a correct forecast, the Japanese model, NCEP and the ECMWF's T511 didn't catch the correct position of the low compared to the analysis of 4th of May, 2001, at 00 UTC. Each EPS member's prediction of a low at 1005 hPa or deeper has been presented in fig.5 by its number and the sea level pressure. Most of the EPS members expected the position of the low too far southwest.

Indications derived from predictions of thunderstorm-related parameters such as precipitable water content and CAPE were given (fig.6).

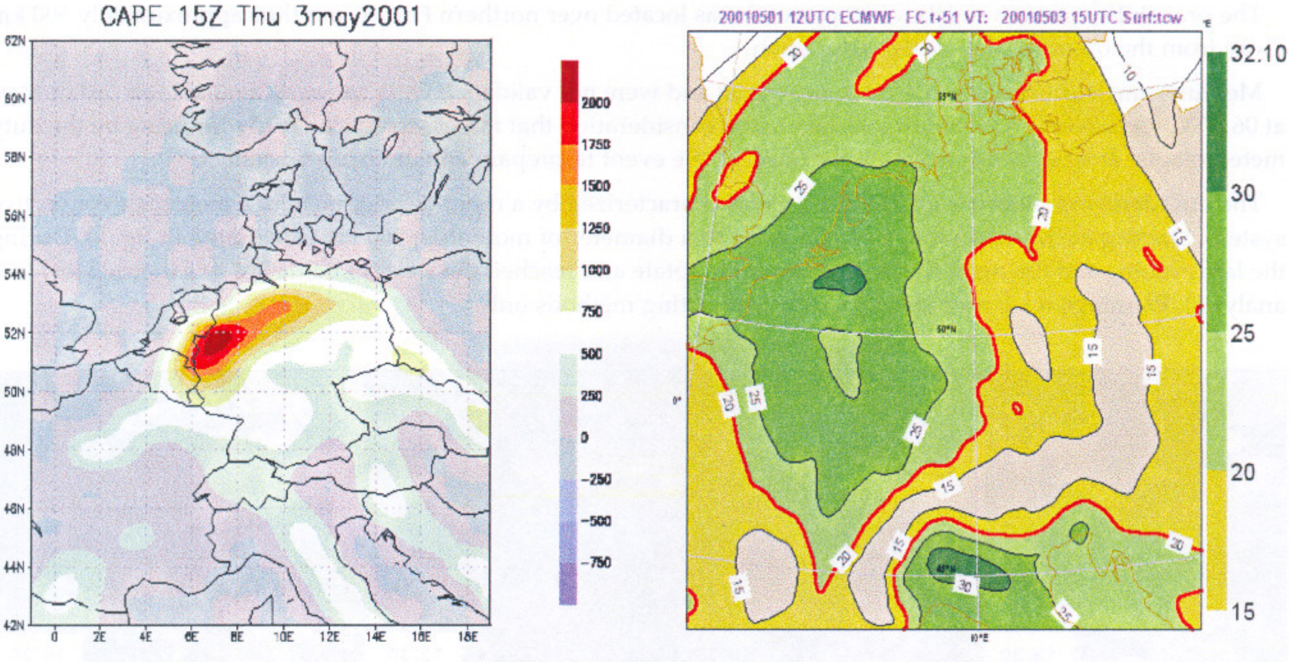

Fig.6: CAPE, 02nd of May, 00 UTC, H+39 NCEP (left) and precipitable water content, 01st May, 12 UTC, H+51, ECMWF (right)

Neither the precipitation forecast from the ECMWF's deterministic model nor the EPS (convective precipitation probability, threshold 10 mm, fig.7, below) performed well.

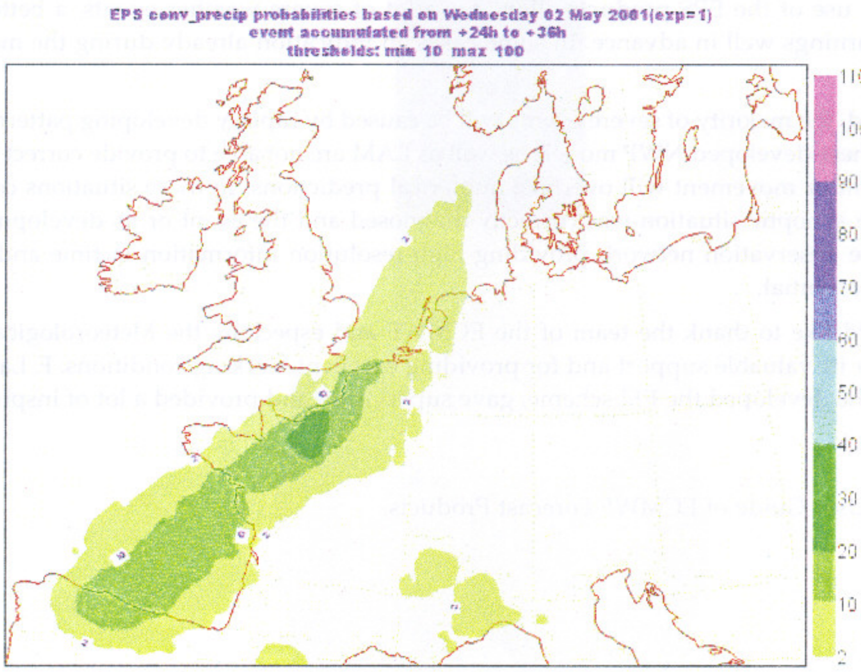

Fig. 7: Probability of 12-hour convective precipitation, exceeding 10 mm.

The probability maximum (above 20 percent) was located over northern France and thus approximately 500 km away from the observed heaviest precipitation.

Medium-range forecasts didn't show any signal and were not validated. Only forecasts available on 3rd of May, at 06 UTC, have been presented. It was taken into consideration that forecasts must be ready for using by the duty meteorologist at least 12 hours before the onset of the event to prepare and maintain warnings.

The thunderstorm outbreak on 3rd of May was characterized by a rapid development of a mesoscale convective system. Starting in the afternoon, a cluster grew to a diameter of more than 200 km (illustrated in fig. 8). During the late evening and the night the system started to rotate and reached the western Baltic Sea as a thermal low (see analysis). Warnings were prepared by using nowcasting methods only.

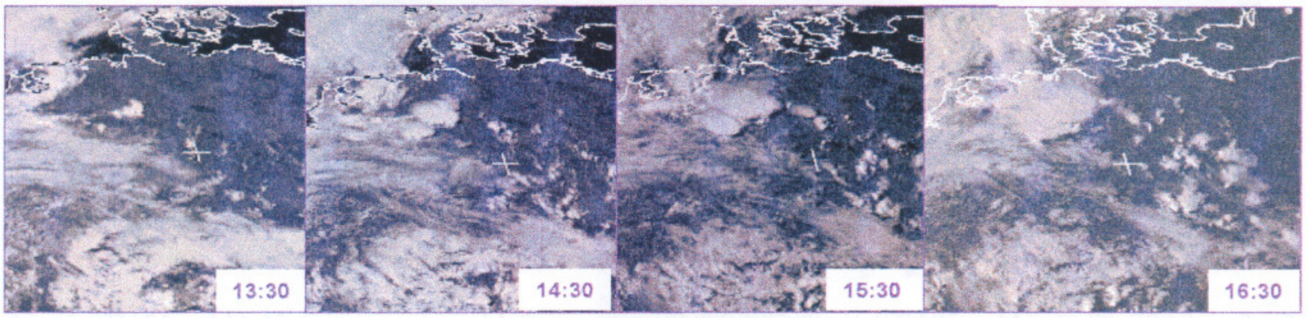

Fig. 8: The rapid development of the mesoscale convective system, illustrated by a sequence of satellite pictures (Meteosat 7, VIS)

5. Concluding remarks, acknowledgments

Improvements of NWP models in horizontal and vertical resolution and model physics, but especially and much more an enhanced use of the EPS products allow, for a lot of severe weather events, a better preparation and maintenance of warnings well in advance. In some cases an indication already during the medium range could be given.

On the other hand, the majority of severe events will be caused by rapidly developing patterns of a sub-synoptic scale. Even the highest-developed NWP models as well as LAM are not able to provide correct forecasts. Often the event's development or movement will overtake numerical predictions. In these situations correct warnings are possible only if the synoptic situation was correctly diagnosed and the event or its development were carefully monitored. A dense observation network providing high-resolution information in time and space over highly populated areas is essential.

The author would like to thank the team of the ECMWF and especially the Meteorological, Operational and Graphic Groups for its valuable support and for providing excellent working conditions. F. Lalaurette has played an important role, he developed the EFI scheme, gave supervision and provided a lot of inspiration.

References:

Persson, A., 2000: User Guide of ECMWF Forecast Products.