Evaluation of Severe Weather Warnings at the Austrian National Weather Service

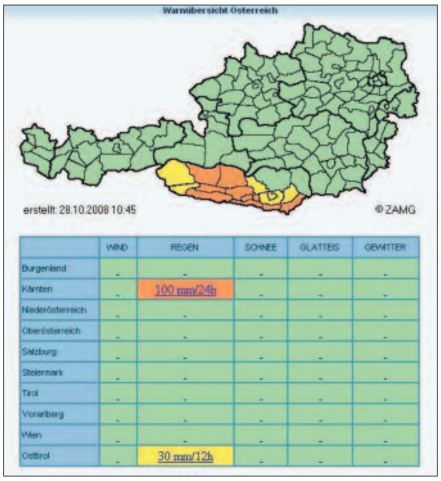

Figure 1: Example of a public warning.

Introduction

During recent years the importance of severe weather warnings has grown significantly. The Austrian national weather service ZAMG provides warnings of several high-impact weather parameters for the public and for governmental institutions. The meteorological parameters included in the current warning system are wind, rain, snow, thunderstorms/hail and freezing rain. Figure 1 shows an example for a public warning as it can be seen on the ZAMG website. The warnings are issued for the different political districts in Austria.

Knowledge of the quality of the warnings, and the resulting information about the potential for further improvement of the system, is of similar importance to the existence of the warning system itself. In order to obtain this information, resources at ZAMG were invested to perform an objective evaluation of the warning system. At present, objective verification is computed for the parameters wind, rain and thunderstorms. In this article, the verification method is briefly described.

Method

For each parameter there are three categories used to indicate the severity of the warning situation (colours yellow, orange and red corresponding to increasing severity levels 1, 2 and 3, respectively). The thresholds used to determine these levels are based on climatological information, and so vary from district to district.

As the severe weather warnings are issued for the different political districts in Austria the verification is done for each district separately.

Wind

The verification of wind warnings is done using station observations, so in the first step the available stations have to be assigned to the different districts. As some of the stations are not representative for a given district due to their location (e.g. in a mountainous area), special care has to be taken during the assignment. Another complication is the fact that there are some districts with no station situated inside. To guarantee that there is at least one station used for verification per district, representative stations in the surrounding districts have to be chosen instead. Once this assignment is done, the verification works in the following way.

The chosen verification period is split into intervals of 12 hours. For each district the maximum wind gust occurring in each 12 hour interval is determined. In a case where the maximum wind gust exceeds the threshold it has to be verified whether a warning is covering the given 12 hour interval. The resulting

Figure 2: Storm event in Vienna, picture by Georg Pistotnik (ZAMG).

observation-forecast pairs can be arranged in a 4x4 contingency table, which finally allows computation of several scores (ETS, POD, FAR, …) yielding numerical values to give objective interpretations concerning the skill of the warning. The used sample size is thus simply twice the number of days used for verification.

As wind is in general one of the parameters with good forecast skill, the first results surprisingly showed rather low scores (especially for POD). In fact that the scores were significantly lower for verification periods in summer, so it was easy to isolate strong wind events connected to thunderstorms as the main reason for this behavior.

The possible occurrence of strong winds during thunderstorms is explicitly included in the thunderstorm warning and therefore no separate wind warning is issued in these situations, and the existence of a valid thunderstorm for a given interval has to be counted as a correct warning during the wind warning verification.

Besides this there are some other aspects to be considered (e.g. the minimum period length for the time between the issue time of the warning and the occurrence of the event), but as the impact on the final scores is rather low (compared to the counting of thunderstorm warnings), it is not necessary to mention all of them in detail in this article.

Rain

For the evaluation of the heavy rain warnings, INCA (Integrated Nowcasting through Comprehensive Analysis) rain analysis fields are used on observational data. INCA is an analysis and nowcasting tool which is being developed at ZAMG. INCA produces 2D analysis and nowcasting fields for precipitation (and other parameters) on a grid with a horizontal resolution of 1km by combining rain gauge and radar data. A detailed description can be found in Haiden et. al 2007.

The splitting of the verification period into intervals of 12 hours is not so easily applicable for rain. The main reason for this is the fact that the definition of a "no-observation" event is more difficult. In the case of wind warnings the occurrence of the maximum gust can be easily assigned to a 12 hour period. In the case of rain this assignment would be more arbitrary, as the final sum of rain falling is the crucial ingredient for flooding and not the maximum rain rate during a given interval. Further, a heavy rain warning showing high skill by forecasting the exact amount of rain can easily turn into a wrong forecast in the case of using the interval-splitting method when the exact timing for the beginning and the end of a precipitation period is not predicted correctly but shifted in time. That is why it was decided not to use split intervals. As a consequence one has to abstain from having full 4x4 contingency tables at present. The verification is therefore done in two separate parts.

In the first part the issued rain warnings are verified by determining the corresponding observed value for the given warning period and district. As the observational data is available in gridded format, one has to search for the maximum value of precipitation among the grid points belonging to the given district. In order to account for the fact that predicting the correct amount of rain should be counted as a correct warning even in situations when warning and observed period are not identical, a time shift (warning period – observed period) is allowed up to a certain extent. Finally it is possible to fill a 4x3 matrix with observation-forecast pairs and compute scores like FAR.

Figure 3: Flooded street, picture by Georg Pistotnik (ZAMG).

The second part evaluates to what extent observed rain events are covered by warnings. The most difficult part here is to determine start, duration, end and intensity for a single observed rain event. One has to take into account several things in order to be able to build up a representative data set for the observed events (e.g. the maximum period length between two rainfall periods with zero observations for counting it as a single event, etc.). Once this is done it is again possible to fill a contingency table (this time 3x4) and compute scores like POD. As with wind one also has to account for the fact that in the case of heavy rainfall events connected with thunderstorms, the meteorologist does not necessarily have to issue a separate rain warning, as this information is explicitly included in the thunderstorm warning.

Figure 4: Thunderstorm over Vienna, picture by Christoph Wittmann (ZAMG).

Thunderstorms

The verification of thunderstorm warnings is done similarly, in that it is a two-way verification, again abstaining from the existence of a full 4x4 contingency table. For thunderstorms it might be easier to apply a split-interval technique (e.g. 24h intervals), but for the moment this is not used.

As with rain warnings, one verifies the issued warnings by determining whether lightning is registered during the given warning period in the area of the district first. In the second step one has to build up a data set with observed thunderstorm events (based on lightning) and determine whether warnings can be found for these events. Building up a data set of thunderstorm events again raises certain difficulties when trying to determine start, end and duration of a single thunderstorm event. But this task is easier to accomplish than in the rain case. Finally, the resulting 3x4 and 4x3 contingency tables again allow the computation of scores like POD and FAR.

Results and Conclusions

An example for a wind warning verification for a district located in the northeastern part of Austria can be found in figure 2. The scores calculated based on the contingency tables shown yield: 0.78 for ETS, 0.92 for POD, 0.87 for SR and 1.06 for BIAS. So 92.47 percent of the cases when the observed gust speed exceeded the lowest threshold within a 12 hour period a warning was issued (in time) by the forecasters (POD). The 4x4 table gives more details about a slight tendency for overwarning, which can also be seen in the BIAS value. ETS is remarkably high (0.78) indicating a significant gain in skill compared to a system issuing random warnings based on the sample climatology.

		Forecasting				
		0	1	2	3	Σ
Observation	0	442	13	0	0	**455**
	1	7	64	6	0	**77**
	2	0	3	5	3	**11**
	3	0	1	3	1	**5**
	Σ	**449**	**81**	**14**	**4**	**458**

		Forecasting		
		Yes	No	Σ
Observation	Yes	66	7	**93**
	No	13	442	**455**
	Σ	**99**	**81**	**548**

Figure 5: Example of a contingency table for wind warnings.

In general, the results for the evaluation of the wind warnings are encouraging, yielding average values for POD, SR, ETS and BIAS for Austria of 0.84, 0.62, 0.53 and 1.36.

The results for rain and thunderstorm warnings clearly show that in general, the skill of rain and thunderstorm warnings is lower compared to wind, but this fact is not surprising as these parameters are known to have less predictability compared to wind. The average results for Austria are rain and thunderstorm: 0.54 and 0.51 for POD, 0.78 and 0.59 for SR.

The evaluation of the warning system yields objective information about the overall quality of the severe weather warnings. Detailed study of the verification result can bring valuable information for the forecasters by exposing districts and/or regions with significant

high or low skill of the warnings, suggesting areas for an extensive study. Up to now the warning verification is done for the severe events wind, snow and thunderstorm. Evaluating other parameters like snow and especially freezing rain is more difficult due to the lack of explicit measurements, but possibilities for doing that have to be further explored anyway.

References

Haiden, T., A. Kann, K. Stadlbacher, M. Steinheimer, and C. Wittmann, 2007: Integrated Nowcasting through Comprehensive Analysis (INCA) - System overview. *ZAMG report*, 49p. Available at **http://www.zamg.ac.at/fix/INCA_system.doc**

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