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Fully automated thunderstorm warnings and operational nowcasting at MeteoSwiss

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I. INTRODUCTION

Short-term severe thunderstorm warnings are one of the main tasks for a national weather service. Convective storms can cause substantial damage and can represent a serious danger to population and infrastructure. In case of severe thunderstorms MeteoSwiss alerts emergency services, authorities and population by means of flash-news warnings, sent as app, with a lead-time of some tens of minutes. These short-term warnings are based mainly on the operational, multi-sensor nowcasting system TRT (Thunderstorms Radar Tracking), as well as other systems. TRT includes a classical cell tracking and position extrapolation module (Hering et al. 2004) based on the volumetric measurements of the Swiss Dual-polarization Doppler radar network. Every 5 minutes this module computes individual motion vectors for each identified cell, extrapolates their position based on Lagrangian persistence rules, and estimates the uncertainty of the cell position forecast (Hering et al. 2008; Rotach et al. 2009). The uncertainty is computed from the standard deviation of the velocity vectors from the last three time steps.

TRT also runs a heuristic cell severity ranking algorithm (Hering et al. 2008; Rotach et al. 2009). This algorithm integrates the most significant radar-based severity attributes from the 3D storm structure into a single numerical parameter, in order to assess the potential danger posed by the individual cells. The severity rank is computed by integrating the cell-based attributes Vertically Integrated Liquid (VIL), the EchoTop 45dBZ altitude, the maximum cell reflectivity, and the area above 55 dBZ with a fuzzy-logic-like scheme.

II. CURRENT THUNDERSTORM FLASH WARNINGS

At present the operational severe thunderstorms warning process is driven by the forecaster on duty. Although the current nowcasting systems run fully-automatically, the final decision for the warning issue, as well as the regions to be alerted, are taken by forecasters. If a thunderstorm is identified as ‘moderate’ or ‘severe’ for at least two consecutive 5 minutes steps, a warning is issued. In the current manually driven system 159 warning regions are used, with a median size of about 260 km^2.

The investigation of the typical timing shows that the total duration of the process, including the analysis of the situation, the edition of the message and the issue of the warning, can sometimes take up to several minutes depending on many factors, starting from the end of the volumetric radar scans. On the other hand, fully automated information is already available after about two and a half minutes.

III. THE NEW AUTOMATED WARNING SYSTEM

To speed up the whole warning process and to allow the final users (such as emergency services and specific users) to save several valuable minutes to take action, a fully automated, short-term, small-scale real-time warning system was developed. The system has been tested with more than 300 beta testers during the summer seasons 2014-2015. The full warning chain was completely automatized, including decision making and warning issuing. During the test phase the alerts are issued by SMS, whereas for the future operational implementation an app will be used.

To enhance the spatial resolution, the new automatic warnings are issued for the ZIP-code areas (nearly 3200) instead of the 159 current warning regions. The mean size of these areas is less than 10 km^2 in populated regions, and therefore much smaller than the warning regions used for the current warnings. The tool allows a user to receive thunderstorm information for a given specific location directly and automatically on his mobile phone, whenever the system detects an approaching convective cell that exceeds a defined severity threshold.

The new algorithm integrates the cell severity ranking product and the latest cell motion vectors from the TRT system to extrapolate cell position, taking into account the uncertainty of the position forecast. Every 5 minutes an analysis of the current time is generated and the detected thunderstorm cells are approximated by an ellipse. The same numerical rank value is assigned to all pixels of the cell, even when intensity gradients are present, because of the intrinsic uncertainty of the thunderstorm structure evolution inside the cells. Then the forecast for the next six time steps from +5 to +30 minutes is computed. Each 1x1 km pixel of the entire radar domain contains the coded information about the severity of the present storms. For the evolution of the cell severity for the next half an hour, the system is based on the assumption of persistence. Thunderstorms exceeding the maximum allowed uncertainty of the position forecast are rejected and no extrapolation is computed for these storms.

In the next step the numerical severity ranking values are aggregated into four empirical thunderstorm warning classes: developing, moderate, severe, and very severe. Forecasts for the next six 5 minutes time steps are analyzed. If a "storm-pixel" is found, a corresponding message is prepared and issued automatically. The short message contains information on the position, the severity, and the expected time of arrival of the thunderstorm cell. During the test phase, each beta tester registered in the user database automatically receives a message with the thunderstorm information. Currently the algorithm aggregates the warning information based on the ZIP-codes. Since all computation is done pixelwise, this information is available for each 1x1 km pixel and represents an interesting potential for future warnings based on specific coordinates.

Considering the feedbacks from the beta-tester during the test phase, a latency time was introduced. After the first warning message issued for a ZIP-code area, for the next 59 minutes no new SMS is transmitted for the same ZIP area, unless the severity of the thunderstorm increased moving the cell to a higher warning class, or if a second, stronger cell will reach the same area.

One of the main goals of automated systems is to speed up the whole thunderstorm warning process and to save valuable minutes for the final users to take action. The new automatic system was able to send out warnings in average 10-15 minutes before the current manual system. This is a substantial improvement for thunderstorm warnings and nowcasting.

IV. SUBJECTIVE VALIDATION WITH BETA TESTERS

During the summer (June-August) seasons 2014-2015 two test campaigns were carried out in real-time with more than 300 beta testers. The results of these pilot campaigns are promising. Overall more than 1600 short feedback forms were filled out online by the beta testers after the warnings, during the 2015 pilot campaign. Quantitative analysis shows an encouraging scenario from the user’s viewpoint with a probability of detection (POD) of 86% and a false alarm rate (FAR) of 31%. Certainly this is a subjective evaluation and not fully representative. However, it should be considered that such systems should satisfy the user's needs in their decision processes. Some concerns were expressed about the number of false alarms and cases of late warnings (i.e. shorts lead-times).

From the extensive questionnaires returned at the end of the summer test phase (more than 100), the final users were generally fairly satisfied with the automatic warnings and they appreciate the new opportunities offered by such systems (e.g. adaptation to customer-specific requirements). In particular, the possibility to get thunderstorm warnings for a specific location defined by geographical coordinates was appreciated.

V. CONCLUDING REMARKS

The aim of the new automatic thunderstorm warnings is to directly alert the final users (emergency services, authorities and population) and to support the whole storm warning system at MeteoSwiss. So far, the thunderstorm warnings are manually edited and issued for each of the 159 warning regions of Switzerland. During intense convective situations with several storm cells of different severities, the limits of this manual approach will be reached soon. The new system is able to produce automatic alerts with the resolution of a kilometric grid. One of the main advantages of automatic systems is the reduction of the issue time: automatic warning systems are faster compared to the manual ones.

The new automatic thunderstorm warning system allows a faster issue of the messages, a higher spatial resolution up to 1x1 km and in addition gives the possibility to alert for a larger number of less severe storms. The system shows a good real-time performance and should therefore be integrated into the operational warning system.

VI. REFERENCES

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