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Severe thunderstorm and tornado warnings in Europe

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ABSTRACT

This study summarizes the current severe thunderstorm warning and forecast operations in different European National Hydro-Meteorological Services (NHMSs), and, in doing so, suggests ways for countries developing their own warning service to learn from experiences in other countries, as well as from the warning operations in the United States of America, the longest-lived severe thunderstorm warning operations in the world. This study is based on a questionnaire sent to 39 European NHMSs of which thirty-three (85%) responded. Currently, many European NHMSs are actively developing their severe thunderstorm forecast process and warning services with 26 (79%) of respondent countries issuing severe thunderstorm warnings and 8 (24%) issuing tornado warnings. Both warning criteria and methodologies used in the warning process vary from country to country. Lead-times range from 30 min to 96 h, indicating a range of different warning philosophies for each country. Major challenges toward improving the warning operations include obtaining observations of severe weather for real-time forecasting and post-event verification, educating forecasters, and having access to state-of-the-art forecaster workstations. An additional challenge is in communicating anticipated or ongoing severe thunderstorms, both internationally between NHMSs and nationally with media and emergency authorities.

1. Introduction

Severe thunderstorms have been observed in every country in Europe. In recent years, the increase in the number of documented severe thunderstorms in Europe (e.g., Brooks and Doswell, 2001) has improved awareness of that threat. Previously, the National Hydro-Meteorological Services (NHMSs) of many European countries had failed to even admit publicly the threat from tornadoes, let alone keep accurate records of severe weather occurrences. (This situation resembled the time before the 1950s in the United States of America (USA), as discussed by Galway (1989), Bradford (1999), and Doswell (2001, p. 14).) As Doswell (2001, pp. 14 and 181) has argued, the probability of severe weather reports being collected is proportional to the awareness of the threat and the efforts to mitigate the threat. Thus, the situation in Europe became what Doswell (2003, 148–149) has referred to as a self-fulfilling prophecy: no recognition of the threat led to no record keeping of events and no acknowledgement of the threat even when observations were reported.

Thus, the risk that severe thunderstorms pose to society depends not only on the climatological probability of the event to occur, but also on how well society is prepared to handle the event once it occurs. The impacts of severe thunderstorms and tornadoes on society can be mitigated by developing warning processes within each country. Lessening the impact has aroused demand for warning programmes and, therefore, severe thunderstorm warning operations are currently being developed in many European countries. These warning programmes tend to be located within the NHMSs, as they are the logically responsible agency and "single authoritative voice" for providing forecasts and information on natural hazards "to save lives, to sustain productivity, and to reduce damage to property" (quotations from the EC statement on the role and operation of National Meteorological and Hydrological Services. (EC-LVII,

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ANNEX VII) http://ftp.wmo.int/pages/governance/policy/ec_statement_nmhs_en.html).

Setting up a warning system for severe thunderstorms and tornadoes is complicated. Their forecasting and nowcasting require special knowledge and tools because their precise occurrence cannot be unambiguously anticipated from Numerical Weather Prediction (NWP) model fields and their small spatial extents elude detection by most operational observations. A special challenge lies in communicating the nowcasts and warnings to the emergency-management authorities, media, and public within the relatively short time scales upon which severe weather occurs.

Because of the large threat from severe weather faced by much of the USA, the forecasting, warning, and dissemination system in the USA is one of the most advanced in the world. As discussed by Doswell (2003, 2005), this system was developed mostly ad hoc rather than through a rigorous planning, implementation, and evaluation process. As such, pieces of the system exist that might have arisen differently had such a rigorous process been in place. Throughout this paper, we compare and contrast the European experience with that in the USA, looking for places where cross-cultural learning opportunities are possible.

In the present paper, severe weather is defined as damaging wind gusts, large hail, or a tornado, similar to the definition employed in the USA, where severe weather is defined as convectively induced phenomena that includes tornadoes, damaging winds or gusts $\geq$26 m/s (50 kt) or hail diameter $\geq$1.9 cm (3/4 in.) (e.g., Johns and Doswell, 1992). Specific quantitative criteria for the wind speed and size of the hail vary by country and are discussed later in the paper. Waterspouts are here considered severe weather, unlike in the USA. Heavy rain and lightning/thunder are not generally included in the definition of severe weather, although these processes commonly occur in association with severe weather-producing storms.

The present study is largely based on a questionnaire sent to 39 European NHMSs. The purpose of this paper is threefold: (a) report on the results of that questionnaire, thus obtaining a general overview of severe thunderstorm and tornado forecasting and warning operations in Europe, (b) provide other NHMSs new ideas (from practices in other countries) on how to develop their severe thunderstorm warnings and warning process, and (c) identify areas that need improvement in Europe, possibly through international co-operation.

Section 2 of this paper reviews the severe thunderstorm warning system in the USA. Section 3 discusses the questionnaire and its dissemination. The results from the questionnaire addressing European severe thunderstorm and tornado warnings operations are presented in Sections 4 and 5, respectively. Communication issues related to the questionnaire results are discussed in Section 6. Section 7 discusses the challenges faced by European NMHSs and provides suggestions for improvement. Finally, Section 8 concludes this paper.

2. The warning process in the USA

The modern forecasting and warning process for severe weather in the USA occurs in three steps (outlook, watch, and warning), products issued primarily by two different organizations within the NOAA National Weather Service (NWS) (e.g., Johns and Doswell, 1992; McNulty, 1995; Moller, 2001). (Tornado forecasts and warnings in the USA before World War II are described by Bradford (1999).) One to several days in advance of the forecasted severe weather, an *outlook* may be issued by the NWS Storm Prediction Center (SPC). The SPC provides forecasts of severe weather for the 48 continental United States (excluding Alaska and Hawaii). The history of the SPC is described in Galway (1989), Ostby (1992, 1999), Corfidi (1999) and Doswell (2007). In producing an outlook, forecasters primarily use guidance from numerical weather prediction models, looking for evidence of environments favourable for severe weather. In the second step, if severe weather is threatening to develop within 1–6 h, the SPC may issue a severe thunderstorm *watch* or tornado *watch*, if the threat includes a specific potential for tornadoes. The watch is issued by county, for an area loosely corresponding to a rectangular-shaped box, covering an average of 80,400 km^2 (in 2006) where severe weather is expected. The third step is the *warning*. If individual storms have formed, or are about to form, and have a strong possibility of producing severe weather within the next 30–60 min or tornadoes within the next 15–45 min, an individual NWS Forecast Office (NWSFO) may issue a severe thunderstorm warning or a tornado warning, respectively, for a specific county (or portion of a county). Because the USA has 122 NWSFOs, the area of responsibility is much smaller than that of the SPC, allowing more specific warnings and careful localized attention to the severe weather, as well as a closer working relationship with the local emergency-management authorities, media, and public. An example of how NWSFOs make warning decisions is described in Hoium et al. (1997).

A specific example of how this forecasting process worked during the most damaging tornado outbreak in USA history (the Oklahoma–Kansas tornado outbreak of 3 May 1999, where over 60 tornadoes inflicted over a billion dollars in damage and 46 deaths) is described from two perspectives. The experiences of the SPC and Norman, Oklahoma, NWSFO are described in Edwards et al. (2002) and Andra et al. (2002), respectively.

3. The questionnaire and methodology

This study is based on a questionnaire sent to all European NHMSs in October 2006–November 2007. The questionnaire was sent by email and in person to selected persons who are experts on weather warning operations at each NHMS (Appendix A). Additional questions were asked of these persons if clarifications were needed to their initial answers. The questionnaire addressed severe thunderstorm and tornado warning operations, warning criteria and methods, and challenges faced by individual NHMSs in developing their warning operations. A large portion of the questionnaire considered the severe thunderstorm warning process (e.g., NHMS co-operation with media, emergency-management authorities, and neighbouring countries; dissemination of warnings; use of ground-truth reports). The questionnaire considered only warnings on severe thunderstorms and tornadoes; ordinary thunderstorms or other warning operations were not considered in this questionnaire. Severe thunderstorms were defined in the questionnaire as convective