Atmospheric Research 158–159 (2015) 210–215

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Invited review article

Severe convective storms in the European societal context

Charles A. Doswell III

Doswell Scientific Consulting, Norman, OK, USA

ARTICLE INFO

Article history:
Received 30 November 2013
Received in revised form 5 August 2014
Accepted 18 August 2014
Available online 27 August 2014

Keywords:
Europe
Societal
Severe storms
Convection
Infrastructure

ABSTRACT

Basic issues associated with how a forecast becomes effective in helping users make decisions based on weather information are described, with a special emphasis on how this might develop in Europe. The notion of a chain of events that begins when the forecast is issued and ends with the user taking effective actions is used to point out what needs to be done to make the process work properly. Geophysical hazard risks and how people respond to the risks associated with them are discussed, concluding that complacency is a major challenge to helping people make appropriate decisions when severe convective storms threaten them. The situation in Europe regarding the threat of severe convective storms is reviewed and some conclusions are drawn. The key conclusion is that there must be a substantial effort to convince Europeans that they are not immune to severe convective weather hazards, since without public support, the weather community in Europe can do little to mitigate the threats posed by severe convective storms.

Contents

1. Introduction

Meteorologists generally are educated and trained to use scientific tools and concepts for the purpose of research and forecasting the weather. They are not educated and trained in the methods associated with the social sciences and hence generally are not qualified to analyze and diagnose issues tied to the social sciences. Therefore, an important challenge to meteorologists is to understand how their forecasts might be perceived by the general public, because this is critical for knowing how best to create *effective* forecast products.

Of course, the purely meteorological challenge of producing highly accurate forecasts of severe convective weather is a difficult one in its own right, and surely deserves attention. There are two broad classes of forecast problems: the first is that group of forecasts for which the forecaster is unaware of, or unable to apply properly, existing understanding of atmospheric science to the forecast. Presumably, forecaster

http://dx.doi.org/10.1016/j.atmosres.2014.08.007

education and training can lead to improved forecasts for this first group. The second is that group of forecasts for which existing meteorological understanding is inadequate. This type of problem is a source for research, which may or may not be able to provide help for this challenge.

No matter how accurate the forecasts become, however, there is a chain of conditions that control how effective those forecasts might be in providing useful information to the forecast users. Any gap in this chain will render the forecasts completely ineffective, no matter how accurate those forecasts might be.

For severe convective storm forecasts to become effective, moreover, the challenge goes beyond the effort to communicate information. A substantial infrastructure must be in place prior to the issuance of those weather predictions. In the United States of America (USA), the infrastructure for dealing with severe convection developed in response to a growing public awareness of the importance of severe convective weather. There was no orderly, systematic process by which the necessary infrastructure was created — in fact, the process was basically done in an ad hoc fashion (Galway, 1989; Doswell et al., 1999). At first, no one knew how to do this, and so choices were made that subsequently became entrenched as a foundation on which new ad hoc decisions were made and implemented. There was never a careful, comprehensive study of how to convey information about, and respond to, the threat of severe convective weather in an optimal way.

Europe is in a unique position to create this infrastructure, as public sector severe convective storm forecasting is in its infancy in Europe; there is only limited existing structure upon which to build (Ruahala and Schultz, 2009). This is both a challenge and an opportunity — the challenge is to create a system that is closely matched to the European social context, and the opportunity is tied to the absence of much existing infrastructure to compete with new ideas of how best to serve the users of such forecasts.

In Section 2, the infrastructure requirements will be reviewed, followed in Section 3 by a review of how geophysical hazards lead to the potential for disastrous severe convective weather events. Section 4 reviews the existing situation in Europe and European societal perceptions, and Section 5 provides some concluding discussion.

2. The chain of conditions

Suppose that forecasts of severe convective weather have been created by someone and they are ready to be disseminated. What is needed for those forecasts to serve best the users of that weather information? The value of a forecast is not exclusively tied to its accuracy — see Murphy and Ehrendorfer (1987) for an extended discussion of the connection between forecast accuracy and forecast value. Value is always directly related to the needs of the users, whereas accuracy is mostly a meteorological topic. Given the existence of a forecast product in some weather forecasting office, the following must happen before the user is able to use that information effectively.

2.1. The forecast user must receive the information

For the information to be of any use at all, it must somehow be transmitted to those likely to be affected. For 24-h forecasts and longer, these can be disseminated at fixed times and would be for relatively large areas. This corresponds to the “outlooks” issued in the USA by the Storm Prediction Center (see http://www.spc.noaa.gov/misc/aboutus.html) of the National Weather Service. Presumably, if such forecasts are available, they can be spread widely by means of various media, as well as directly by the issuing office to specific forecast users (e.g., emergency managers). Convective storm forecasts on this scale could be included in routine weather forecast dissemination whenever the severe weather threat exceeds some threshold risk level.

Forecasts on time scales shorter than 24-h should not be issued at fixed times, but only when the threat level (again, some sort of threshold would have to be exceeded) is high enough to warrant notifying forecast users of the increasing threat. This includes both the so-called “watches” and “warnings” issued in the USA. Watches are for regions where the threat has increased and storms are either about to commence or have already begun. The warnings are for relatively small areas in the path of existing storms, either known to be producing severe weather or seem likely to produce severe weather as deduced from radar. Dissemination of this highly perishable, critical weather information must be done quickly and efficiently.

2.2. The forecast user must understand the information

Once the information has been received, the forecast user must understand what the forecast means. Although the meaning may seem obvious to a meteorologist, it may not be at all clear to the user. That understanding needs to include awareness of the inevitable *uncertainty* in the forecast information. It should not be necessary for the user to have to guess about the uncertainty associated with the forecast. Rather, uncertainly information should always be included.

2.3. The forecast user must know what to do with the information

This presumes, of course, that the user can actually do something to mitigate the hazard posed by potentially severe storms. A farmer can't do anything about a hailstorm threatening crops, but if that same hailstorm threatens a city, people can move their vehicles to a place of shelter and thereby prevent hail damage. A big concern is always for human casualties, and so users must be aware of what they can do to avoid becoming casualties, and also should know what not to do. This sort of knowledge cannot be conveyed effectively during the relatively short times available during an actual severe weather situation. What is necessary is a public education campaign long before severe convective storms become a potential hazard. There should be severe weather awareness exercises held every year and people should develop (and revise, if necessary) action plans and participate in drills practicing those plans at least once a year, if not more frequently.

2.4. The forecast user must believe the information

To some extent, this condition depends on the overall accuracy of the forecasts. There certainly is a tendency for false alarms to de-sensitize the forecast users, although this can be mitigated by including uncertainty information in the forecasts. But it also depends on other factors. What is the perceived expertise level of the person issuing/broadcasting the forecast information? Do the recipients trust the source? Answers to such questions should be provided from studies done by social scientists, in collaboration with forecasters (e.g., Keul and Holzer, 2013). The duties of a forecaster are already substantial and meteorologists usually are poorly qualified to do such studies on their own.

2.5. The forecast user must take effective action

Ultimately, the effectiveness of the process is determined by whether or not the information has helped forecast users make a decision to take action (or not). If the user has not been able to make a good decision based on the information provided, then the process has failed. The final decision is always up to the users, so we meteorologists cannot ignore this aspect of the situation. Although we can't control their decision process, we can do our best to help the user make good choices about actions.

Effective action need not be confined to the times when the severe weather is ongoing, but can take place months or years before hazardous weather approaches. For instance, if the user needs to have adequate shelter but does not have any such place to go because they chose not to spend the resources on a storm shelter, then our forecasts can do little to prevent them from becoming casualties. Therefore, we meteorologists have an obligation to convey an accurate perception of the severe weather threat. This is necessarily climate information, not weather information.

3. Risk perception and geophysical hazards

The situation depicted in Fig. 1 shows that many people live close enough to the Vesuvius volcano to be at risk from the next big eruption of that volcano. It is virtually certain that such an eruption eventually will occur, but at this time it is impossible to know when. Why would anyone choose to live so close to such an obvious hazard? There are many possible explanations, but the most prominent is apparently the relative rarity of really big eruptions. People have lived there for centuries, the soil is relatively rich, the scenery is spectacular, and so on. It is apparently easy for people to convince themselves that the risk is so small, it seems like a negligible chance a big eruption will affect them personally. This is referred to as the “normalcy bias” — in the relatively short lifetime of a human being, it has become “normal” for the volcano to not explode in a violent fashion. The normalcy bias is the catalyst for complacency. “It won't ever happen, or if it does, it won't happen to me!” And, for the vast majority of these people, that is indeed quite true. But when the big eruption does happen, and it inevitably will, it will happen to *someone*! Since we don't know when it will erupt, there is no logical reason to exclude the possibility for most people now living in the shadow of Vesuvius.

Even in the USA, there is complacency about severe convective storms. In the tornado prone regions (see Fig. 2), there is a relatively high awareness of the hazard and people living there mostly are well aware of the threat. But in some parts of the continental USA, tornadoes are about as infrequent as they are, on the average, in Europe, or even less frequent in some regions. In such places, complacency and a general lack of preparedness can be widespread. Generally speaking, the more frequent tornadoes are in some region, the lower the casualty counts tend to be. It should be noted that the major peaks in the annual fatality counts in the USA (Fig. 3) are closely related to the relatively rare occurrence of violent, long-track tornadoes hitting metropolitan areas. This combination – a violent tornado in a densely-populated region – is a primary source of the large interannual variability in tornado fatalities in the USA.

Generally speaking, the perception in Europe is that tornadoes are not a very significant threat. Even when tornadoes do occur in Europe, few people consider them to represent a serious hazard, as it is widely believed that large, violent tornadoes simply don't happen in Europe. This perception is a formula for complacency and, eventually, a disaster some time in the future. As seen in Dotzek et al. (2003), the frequency of tornadoes in Europe (ignoring the United Kingdom) as a function of intensity follows the same slope as that of tornadoes in the USA! The fraction of tornadoes that are violent in Europe is very nearly the same as in the USA. The fact is that most tornadoes in the USA are relatively weak and short-lived, and large, violent tornadoes certainly have occurred in Europe in the past and will occur in the future. But with an overall tornado frequency of about one-third that of the

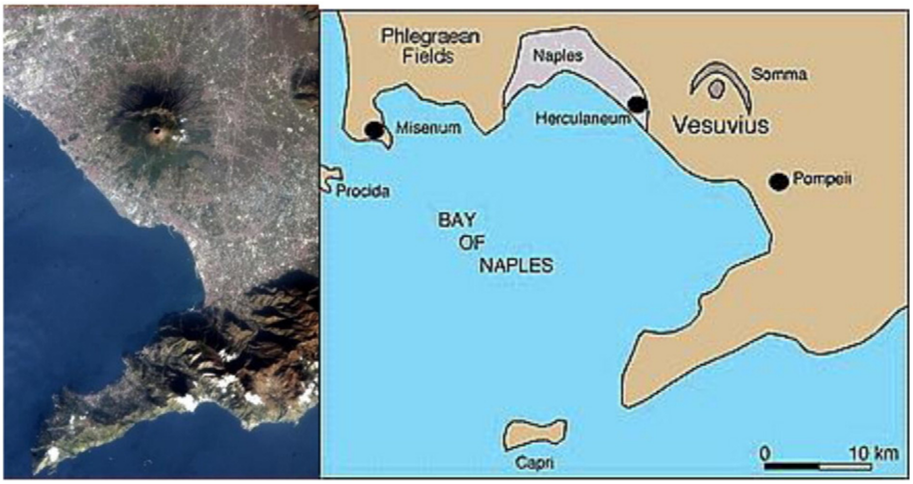

Fig. 1. (left) Satellite image of Vesuvius and vicinity, (right) simplified geopolitical map of the region including Vesuvius.

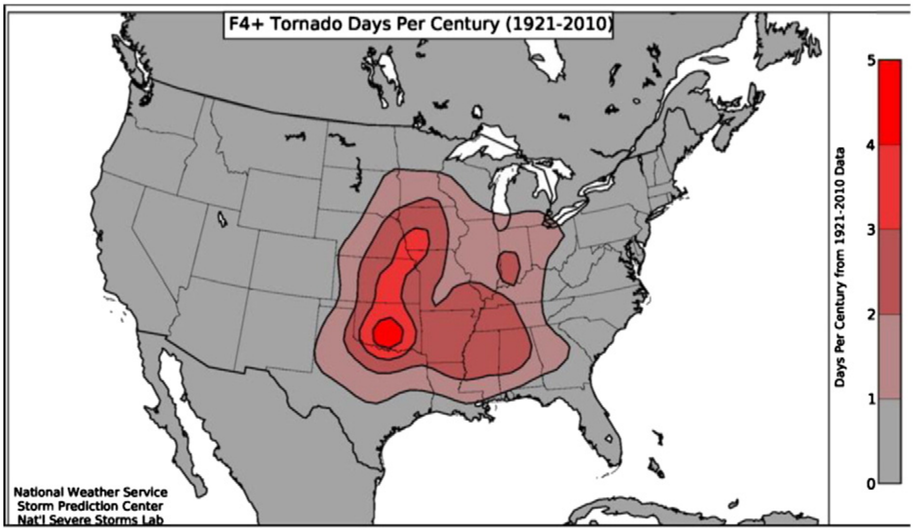

Fig. 2. Map of the frequency of EF4-5 tornadoes for the period 1921–2010, expressed in tornado days per century within a circle 40 km in diameter around any given point.

USA (Dotzek et al., 2003), one would expect violent tornadoes and, therefore, big tornado disasters to be roughly one-third as frequent. Given that really big tornado disasters in the USA occur about once every 20–30 years, this oversimplified calculation implies that big tornado disasters in Europe should occur roughly once every 60–90 years. This is a pretty crude estimate, but I believe it is roughly of the right order of magnitude. A major tornado disaster in Europe every 100 years or so is virtually certain to result in complacency, and I believe it has.

Part of the problem is the lack of consistent commitment to recording tornado events in Europe. This has been discussed at some length in Dotzek (2003) and I won't dwell on the point here, except to note that when detailed records of tornado occurrences are not kept, it's not difficult to imagine the growth of the public perception that tornadoes simply don't happen in Europe. There will be little or no public demand for real-time information about the threat of severe convective storms and, especially, tornadoes if they're not seen as a meaningful threat. Why spend the time and resources to build infrastructure for a hazard that occurs so infrequently? In difficult economic times, the resources are always needed desperately elsewhere.

4. The existing situation in Europe regarding severe storms

Some efforts to provide severe weather information are just beginning with some of the national meteorological services in Europe–Germany and France making some headway in creating forecast products associated with severe convection. Over most of Europe, however, such forecasting services are quite underdeveloped. It should be noted that when severe weather forecasting began in the USA during the early 1950s,

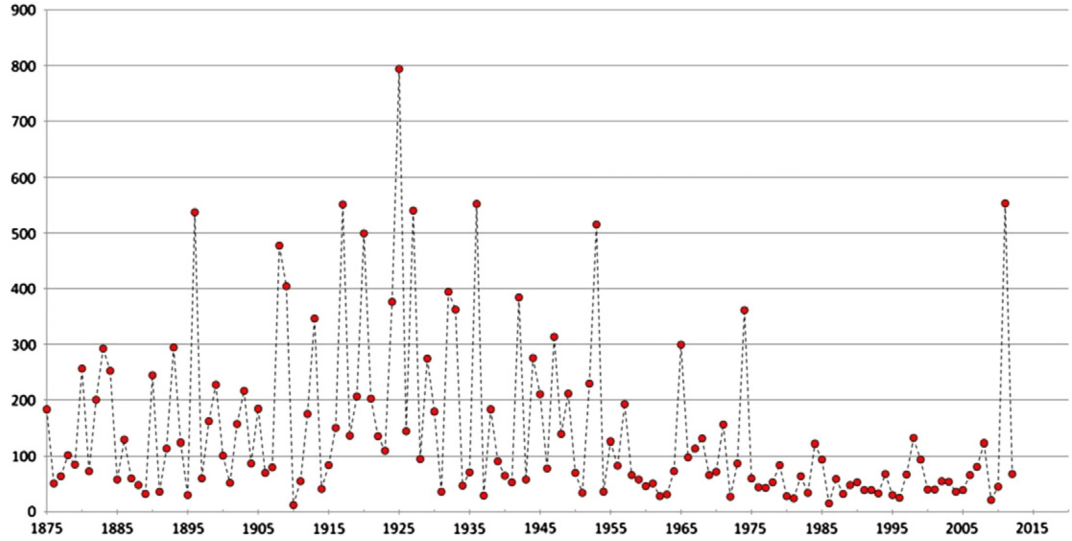

Fig. 3. Annual number of tornado fatalities in the USA for the period 1875–2012.

the situation in the USA was similar to where most of Europe is today. The forecasters assigned to the task of forecasting severe weather were not severe weather "experts" — such expertise did not exist in the USA (Doswell, 2007). Part of the reason for this absence of expertise was a policy decision made in the late 1880s that the word "tornado" was forbidden. It was not until the late 1940s that the situation in the USA began to change, and public demand for severe storm forecasting service arose. The need for research into methods for severe storm forecasting led to a rapid growth in the understanding of severe convective storms.

Severe storm forecasters in the USA's Storm Prediction Center (SPC) work possible severe weather situations on more than half of the days in a year. This means that they have a considerable opportunity to gain experience, and it is generally accepted that experience is a major factor in forecast accuracy. Anecdotally, it is estimated that a lead forecaster in the SPC needs at least five year's worth of experience to become successful with this challenging task.

In any given European nation, the fraction of days in a year when their forecasters have an opportunity to work a potential severe weather situation is much less than for SPC forecasters. Hence, it will take forecasters working for individual national meteorological services in Europe much longer to be as successful as SPC forecasters.

Of course, it is possible to automate such forecast services (as with the Meteoalarm product from MeteoFrance — http://www.meteoalarm.eu/), but the consensus is that human forecasters are substantially more successful at forecasting severe convection than existing automated systems. If human forecasters are chosen, one way to solve the need for experience would be the development of a pan-European version of the SPC (Doswell, 2003). Such an agency would not compete with the individual national meteorological services at all, but would provide guidance to them about the specific issue of severe convective storms.

An unfunded, informal group of European meteorologists developed a severe weather forecasting system in 2002 called the European Storm Forecasting Experiment (ESTOFEX: http://www.estofex.org/) which constitutes a *prototype* of a pan-European severe weather forecasting unit. ESTOFEX forecasters have developed considerable expertise (Brooks et al., 2009) and many people use ESTOFEX forecast products. Forecast team members contribute their time and effort outside of their regular work/study responsibilities, so sometimes, because of those responsibilities, no ESTOFEX products are available. This is not acceptable for an operational forecasting agency.

Nevertheless, even if accurate severe weather forecasts were available immediately in Europe, the infrastructure for making those forecasts useful to the potential users of that information does not yet exist, for the most part. The general public in Europe has little perception of the actual risk associated with severe convection and so is more or less unaware of any need for such services. The national meteorological services across Europe are experiencing the negative consequences of a difficult economic situation: resources are being cut back and it seems unclear why a new service, associated with severe convective storms, is needed. Even if a need were to be recognized, where would the resources come from to implement such a service?

To make all the links in the chain described in Section 2 (above) operate successfully, it is not just the responsibility of the national meteorological services to develop and issue severe storm forecasting products. Pathways for dissemination must be chosen and developed, likely in collaboration with the media and via new electronic technologies.

National meteorological services would need to decide in detail the number and type of new forecast products they want to implement and how to make those new products as effective as possible. This necessarily involves non-meteorologists in the process of developing forecasts in a form that is easily understood and used. This is not something to be decided at the last minute, just before going public with the new forecasts. It requires time to use the methods of social science to guide the process of forecast development.

Months before any new forecast products are issued and disseminated, a massive public information campaign would be needed to let people know that new forecast products will be coming, and provide examples of how to understand and make effective use of the information that these new products are intended to convey. To allow new forecast products simply to appear likely would result in mass confusion and probably would cause a very negative public reaction.

All the forecast users, including specialists like emergency managers and first responders (firefighters, police, civil protection agencies, etc.) will need to learn about the new products and consider just how that information would influence *their* decision-making. The general public needs to be informed of what to do and what not to do when severe weather is imminent. Emergency managers need to have action plans for dealing with immediate hazards, as well as the aftermath of a damaging storm. Having reasonably accurate forecasts is only the beginning of a complex and likely expensive process of implementing action plans and disaster responses.

As the situation exists now in Europe, on the relatively few occasions that tornadoes and other severe weather strike a populated area, there is little or no warning to most people. Many have no idea what to do, including emergency managers and first responders. Search and rescue operations need to go on after a storm passes, perhaps throughout the first night — lights and power generators as well as heavy equipment would be needed in such operations. Are they readily available? A seriously damaging storm event can result in widespread disruptions of public services and overwhelm local resources for dealing with the situation. In the USA, there are many organizations that are geared toward the post-storm recovery operations, and those operations may go on for many weeks after a large event.

The system for dealing with severe convective storms in the USA was not developed in a systematic way, but it has evolved to serve the needs of the nation in response to devastating severe storms reasonably well. It may need some adaptation to fit the different circumstances in Europe, but it needs to be considered as at least a starting point for designing a similar system that will work in European conditions.

5. Concluding discussion

With the preceding fact in mind, the question is, where does a process that eventually will result in effective severe weather forecasts begin? First of all, the European meteorological community must embrace the reality of the hazard posed by severe convective storms. There must be a strong consensus that this is a real hazard that can be mitigated with accurate, timely forecast products. If many meteorologists don't accept this as a real problem, that will serve to stop any efforts to initiate such services.

Assuming that the European meteorological community accepts this reality, then a major task that must be undertaken is the education of the general public about the reality of the threat. Although the historical record of severe convective storms is far from adequate owing to the absence of a firm commitment to record severe weather events, we now have the European Severe Weather Database (ESWD — see: http://www.essl.org/cgi-bin/eswd/eswd.cgi, and Dotzek et al. (2009)), so that in the future, a more complete picture of severe weather occurrences in Europe will emerge. Despite the known deficiencies of the historical record, as suggested in Section 3 (above), major tornado disasters can be expected roughly once every 50–100 years. More frequently, flash floods and hailstorms can have a large societal impact. Hailstorms cause extensive property damage, whereas flash floods can result in many fatalities. I believe it would be in all of Europe's national meteorological service's best interests to convince the public that there are important hazards posed by convective storms that they should learn about and prepare themselves for dealing with those hazards.

Without the support of the public, it will never be possible to obtain the resources for the necessary infrastructure. Unfortunately, nothing galvanizes interest in natural hazards more than a disaster. We meteorologists can see such disasters in the future but it's not possible to know when and where they will occur — only that they are inevitable. The heartbreaking losses when disasters happen might be preventable, with accurate forecasts and proper preparation, but it appears that people need to experience such things firsthand before they believe it can happen to them. Perhaps the most effective way to get things moving on developing a system for dealing with them is for one or more disasters to occur, unfortunately.

References

Brooks, H.E., Marsh, P.T., Kowaleski, A.M., Groenemeijer, P., Thompson, T.E., Schwartz, C.S., Shafer, C.M., Kolodziej, A., Dahl, N., Buckey, D., 2009. Evaluation of European Storm Forecast Experiment (ESTOFEX) forecasts. Atmos. Res. 100, 538–546.

Doswell III, C.A., Moller, A.R., Brooks, H.E., 1999. Storm spotting and public awareness since the first tornado forecasts of 1948. Weather Forecast. 14, 544–557.

Doswell III, C.A., 2003. Societal impacts of severe thunderstorms and tornadoes: lessons learned and implications for Europe. Atmos. Res. 67–68, 135–152.

Doswell III, C.A., 2007. Historical overview of severe convective storms research. Electron. J. Severe Storms Meteor. 2 (1), 1–25.

Dotzek, N., 2003. An updated estimate of tornado occurrence in Europe. Atmos. Res. 67–68, 153–161.

Dotzek, N., Grieser, J., Brooks, H.E., 2003. Statistical modeling of tornado intensity distributions. Atmos. Res. 67–68, 163–187.

Dotzek, N., Grieser, J., Brooks, H.E., Groenemeijer, P., Feuerstein, B., Holzer, A.M., 2009. Overview of ESSL's severe convective storms research using the European Severe Weather Database ESWD. Atmos. Res. 93, 575–586.

Galway, J.G., 1989. The evolution of severe thunderstorm criteria within the Weather Service. Weather Forecast. 4, 585–592.

Keul, A.G., Holzer, A.M., 2013. The relevance and reliability of radio/TV reports to the Austrian public. Atmos. Res. 122, 32–42.

Murphy, A.H., Ehrendorfer, M., 1987. On the relationship between the accuracy and value of forecasts in the cost-loss ratio situation. Weather Forecast. 2, 243–251.

Ruahala, J., Schultz, D.M., 2009. Severe thunderstorm and tornado warnings in Europe. Atmos. Res. 93, 369–380.