



The F4 tornado of August 3, 2008, in Northern France: Case study of a tornadic storm in a low CAPE environment

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ARTICLE INFO

Article history:

Received 15 February 2010

Received in revised form 1 September 2010

Accepted 7 September 2010

Keywords:

Tornado

France

Case study

ABSTRACT

A strong tornado hit seven cities of northern France in the late evening of Sunday, 3 August 2008, causing severe damage along its 19 km path from Pont-sur-Sambre to Boussois. Three people were killed in the collapse of their house and 18 were injured. More than 1000 houses were damaged and several thousand trees were uprooted or fallen down.

The authors led a damage survey in the hours that followed the disaster, then investigated this case, in order to determine the characteristics of this tornado precisely and to better understand the conditions that led to its formation. Weather radar analysis shows that the convective cell that gave rise to the tornado took on a fairly pronounced S-shaped structure, with a persistent mesocyclone in the central part of the convective system. The synoptic and mesoscale pattern associated with this severe storm was very dynamic, and characterized by a coupling between a low-level jet and a highly divergent jet-stream. The authors have reconstructed a vertical profile for this case study, in order to describe the tornadic environment precisely. The reconstructed profile reveals two main elements, namely an environment having a very modest vertical instability on one hand, and the presence of intense wind shear, notably in the lowest layers of the atmosphere on the other hand. This conclusion is supported by the analysis of many instability and shear parameters.

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1. Introduction

The powerful tornado that struck northern France on August 3, 2008 was probably the most violent tornado to hit Europe in 2008. Despite its remarkable power, it is worth noting that this tornado developed within an air mass whose vertical instability was quite normal for the summer months in France. In fact, cases of tornadoes in low Convective Available Potential Energy (CAPE) environments have already been the subject of studies in the United States and in Europe: e.g., Clark (2008); Geerts et al. (2009) and Groenemeijer et al. (2009), have studied the subject quite recently. Nevertheless, most of these case studies generally deal with low to

moderate intensity tornadoes (<F3). The fact that the Hautmont tornado, a F4 intensity tornado, was produced despite a very limited CAPE, makes it unique from this standpoint, insofar as tornadoes of this intensity are more commonly associated with strong vertical instability, especially in the lowest 3 km above the level of free convection (Rasmussen and Blanchard, 1998). The purpose of this study therefore consists of detailing the meteorological governing the formation of this tornado and identifying the key atmospheric elements in this situation, in particular to improve the forecastability of this type of event.

2. Damage survey

The site investigation shows that the tornado first touchdown occurred in a corn field at 20.28 UTC with an F1 intensity. A few houses suffered minor damage and large branches of hard wood were broken.

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Only 2 min later, the tornado reached an F2 intensity (many uprooted trees and several damaged houses), then, at 20.31 UTC, an F4 intensity, causing the total destruction of one solidly built house (see Fig. 1). Many trees were uprooted and some of them were completely debarked.

Keeping its F4 intensity for 2.5 km (up to 20.33 UTC), the tornado crossed the Fayt Wood, uprooting and debarking all the trees on its 150 m wide path. Then, it hit the city of Hautmont, where 3 people were killed by the total destruction of their house. Hundreds of houses were severely damaged all around the tornado path (sometimes as far as 500 m from it), some of them were demolished down to the foundations in the central part of the path. Many cars were thrown to significant distances, and one was lifted up to the first floor of a severely damaged house. Some trees were thrown to more than 500 m. Little objects, like photographs or chequebooks, were thrown to more than 30 km.

A few minutes later, the tornado weakened to F2 intensity, causing significant damage on the boroughs of Maubeuge. The bell-tower of a church collapsed. Many other infrastructures (factories, hospitals, the city-hall, the zoo) sustained moderate damage. Hundreds of trees were knocked down at the Public Garden and all around.

About 12 km after its touchdown, the tornado weakened to F1 intensity. It hit the Military Cemetery of Assevent, where large branches of hard wood were broken. Many little trees were also uprooted. Finally, at 20.40 UTC, the tornado weakened to F0 intensity on a 50 m wide path. Two minutes later, it caused little damage on trees again, then it dissipated at 20.42 UTC near the Belgian border.

The damage survey reveals that this tornado case is of the greatest significance, because it hit a wide variety of terrain with a wide variety of intensities (see Fig. 2), from corn fields and woods to highly populated areas, from a narrow F0 vortex to a 150 m wide severe F4 tornado.

3. Radar echo features

In order to identify the mechanisms involved at the local scale in the production of the Hautmont tornado, a detailed

analysis was performed using images produced by weather radar.

It appears that the convective cell that gave rise to the Hautmont tornado was part of a series of prefrontal convective storms, and took on a fairly pronounced S-shaped structure in the 45 min before the tornado formed (see Fig. 3). Analysis of images from a Doppler radar located 40 km from Hautmont (images provided by Météo France) shows the presence of a persistent mesocyclone in the central part of this S-shaped convective system, during more than 30 min. The radial velocity dipole gradually becomes more pronounced, reaching its maximum intensity at the time of the tornado. Moreover, it is worth noting that during this 45-minute pre-tornadic period, the convective system took on a gradual deviation of 15 to 20° to the right of the average flow. These elements in fact suggest a possible supercell structure embedded in an S-shaped convective system.

Furthermore we note a perceptible increase in the storm system's precipitation activity around ten minutes before the tornado touched down. The convective system is characterized by a double heavy precipitation core, the first and main one imbedded in the northern part of the system and the second one, later, in the southern part of the system. Both produced heavy rain, but a major axis of 30 to 80 mm hourly rain accumulation is noticeable about 4 km north of the tornado path, i.e. under the northern precipitation core. During this period, witnesses reported nonstop intracloud electrical activity. Analysis of lightning strikes detected by the METEORAGE detection system shows a small number of cloud-to-ground lightning strikes, but which were distinguished by being mostly positive in polarity.

The tornado touched the ground during the mature stage of the convective system, at the beginning of the outflow-dominated phase of the storm. Indeed, we note that the cell began breaking down within minutes of the tornado touchdown, forming a dying and disorganized convective cell just fifteen minutes later (see Fig. 4).

All of these characteristics suggest the pattern of a high-precipitation supercell embedded in an S-shaped convective system. The result in terms of radar reflectivity is fairly similar to that observed by Wolf (1998), even if the



Fig. 1. Total destruction of a solidly built house in Boussières-sur-Sambre (F4 intensity).

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