THE DEVELOPMENT OF TORNADIC STORMS NEAR A SURFACE WARM FRONT IN CENTRAL ENGLAND DURING THE CONVECTIVE STORM INITIATION PROJECT (CSIP)

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I. INTRODUCTION

Strong tornadoes are a rare occurrence across the British Isles. Despite the fact that convective instability as measured by CAPE (latent instability) is usually rather low, they occasionally do occur. It is known that large CAPE is not required for the formation of strong tornadoes, proven by a large number of counter-examples, including the recent violent tornado in Hautmont, France (Mahieu and Wesolek, 2009). In such cases, other factors must play an especially important role. As will be shown, a frontal boundary proved to be very important in this specific case. The relevance of boundaries to the development of low-level rotation and tornadoes has been identified in the past by Markowski et al. (1998) and Rasmussen et al. (2000).

Here, we present an investigation of the mesoscale environment of severe convective storms that developed on July 28th 2005 during the CSIP field campaign (Browning et al., 2007). One of the storms produced an F2 tornado in downtown Birmingham at 1330 UTC (Marshall and Robinson, 2006), and two other tornadoes occurred later on the day near Peterborough and the village of Moulton (Fig. 1).

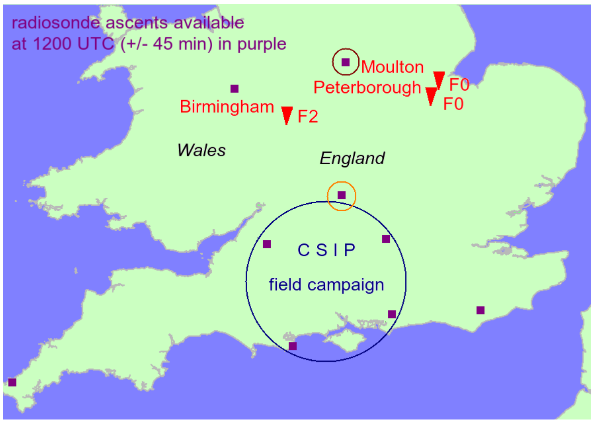

FIG. 1: Map of England and Wales showing the locations of the tornadoes, the available radiosondes and the CSIP field campaign area.

II. PRESENTATION OF RESEARCH

The presented analysis is based both on observational data and a numerical simulation. The observational data, that included both surface data and radiosonde data were interpolated on a Cartesian grid using a Barnes algorithm (details available upon request). Two near-surface fields are shown in Fig. 2: the 2 m temperature and 10 m wind at 1200 UTC, approximately 1:30 hours before the F2 tornado occurred. The location of a warm frontal boundary is displayed. From the three-dimensional fields, several parameters were calculated. These include the CAPE below 3 km AGL and the 0-1 km storm-relative helicity, displayed in Fig. 3. Note that the location of greatest overlap of these two quantities was near the location "B", which indicates the location of the storm that later produced the tornado.

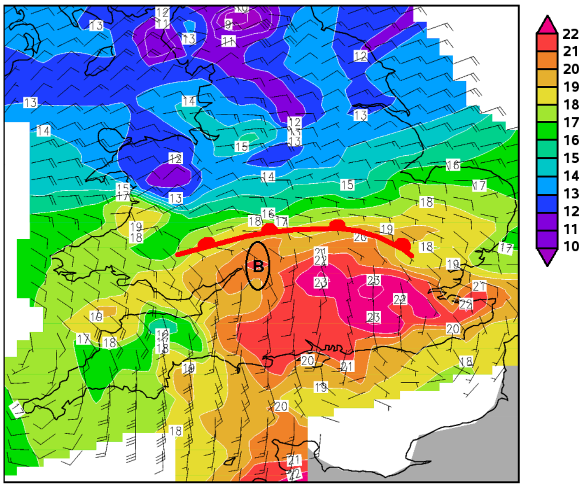

FIG. 2: Interpolated 2 m temperature in °C and 10 m wind fields at 1200 UTC. "B" represents the location of the storm that later produced the tornado in Birmingham.

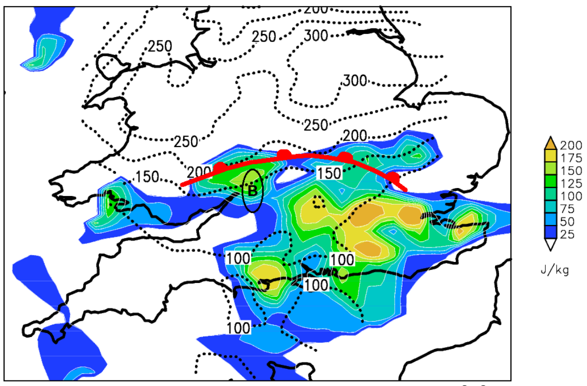

FIG. 3: Interpolated 0-1 km storm-relative helicity($m^2 s^{-2}$) and CAPE below 3 km (J/kg).

A numerical simulation was carried out using the COSMO model (Schättler et al., 2007). The grid spacing of the model was reduced to 1.1 km, compared with the operationally used 2.8 km.

The resulting simulation develops storms containing rotating convective updrafts that exhibit low-level rotation. Low-level moisture, wind and precipitation rates are displayed in Fig. 4. The low-level vertical vorticity (not shown) of the simulated storm "S" is maximized shortly after crossing the frontal boundary from the south. The Combination of relatively high values of storm-relative helicity and slightly higher CAPE in a narrow zone on the cold side of the boundary are thought to be the primary causes for this. The reason for the relatively high CAPE can be traced back to an accumulation of low level moisture north of the boundary. This accumulation likely occurs because of a relative lack of turbulent entrainment of drier air into a very shallow boundary layer, combined with relatively strong evapotranspiration.

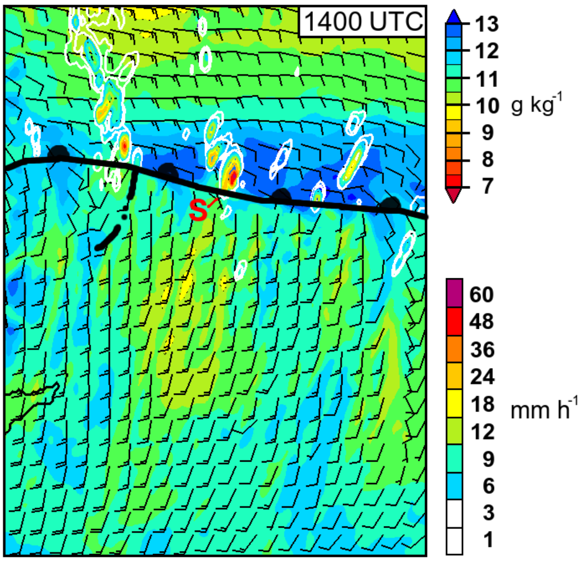

FIG.4: Mixing ratio at 1000 hPa, wind at 10m AGL, and precipitation rates, simulated with the COSMO model at 1.1. km grid-spacing, starting at 0600 UTC, and initialized with data from a coarser COSMO run at 7 km grid-spacing, which was nested into ECMWF IFS analyses.

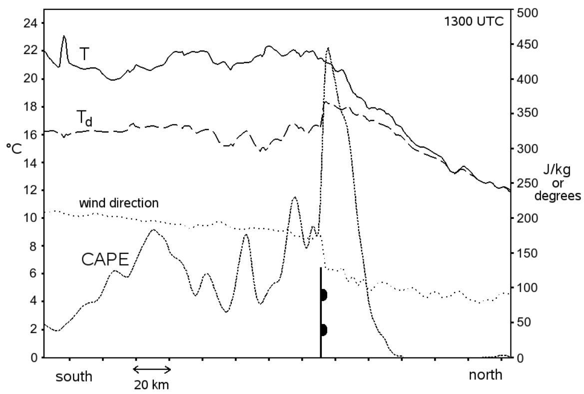

FIG.5: North-south profiles (from bottom to the top of Fig. 4, but at 1300 UTC) of temperature and dew point at 1000 hPa, the 10 m wind, and CAPE for a parcel lifted from the 1000 hPa-level.

A cross-section of various parameters can be seen in Fig. 5. It can be seen that CAPE is maximized in a 30 km-wide zone north of the wind-shift line. This is perhaps counter-intuitive because, on a larger scale, the thermodynamic properties of the air-mass south of the front appear to be more prone to convective development, as it is moister and warmer.

III. CONCLUSIONS

We have studied the development of a storm that developed with relatively low CAPE but within an otherwise favourable environment for updraught rotation. Using a combination of actual observations and numerical modelling. It was found that...

i) a narrow zone of increased low-level moisture formed north of the surface front, which created a narrow zone of enhanced, but still modest, CAPE values and very low cloud base heights.

ii) within the same zone, backed surface winds created ample storm-relative helicity, that probably played an important role in the development of rotation

iii) the COSMO model, being run at 1.1 km resolution, was able to reproduce weak storm rotation (vorticity on the order of $1 \cdot 10^{-2}$ s^{-1}), which was highest int he lowest kilometre of the atmosphere.

iv) weak mixing within the boundary layer north of the front was both responsible for the strongly veering wind profile with height that lead to the high storm-relative helicity, and for the accumulation of low-level moisture that created relatively strong low-level boundary for parcels lifted from the surface.

The combination of those factors proved sufficient for the development of a strong tornado.

IV. ACKNOWLEDGMENTS

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