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16.2 A TORNADO-PRODUCING MESOSCALE CONVECTIVE SYSTEM IN NORTHERN SWITZERLAND

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1. INTRODUCTION

Hailstorms are one of the major severe weather threats in Switzerland. The larger storms are often accompanied by severe gusts or by downbursts. Very seldom tornadic events are observed. In the framework of the Swiss National Research Program 31 "Climate change and natural disasters" severe convective events were systematically monitored and documented during the years 1992-95 by means of the ETH Doppler radar and the operational radars from the Swiss Meteorological Institute (SMI), both having a wavelength of 5 cm. On 22 July 1995 a large Mesoscale Convective System (MCS) passed over Northern Switzerland and Southern Germany. Hail, water and severe wind damage were reported. One cell within the southern part of the system developed into an intense bow echo, which produced a weak tornadic event. Also the MCS's size and degree of organization according to the classification schemes of Houze et al. (1990) and Schiesser et al. (1995) was extraordinary for the Swiss environment. The purpose of the paper is to describe the life cycle of the MCS in Switzerland. The tornadic stage will be briefly discussed.

2. MESOSCALE ENVIRONMENT

A weak trough was positioned over southern England. A surface coldfront arrived in Central Europe in the afternoon of 22 July 1995 from the NW. At 12 UTC (Fig.1) a flat pressure distribution was found over that part of Europe with a heat low situated over SW-Germany.

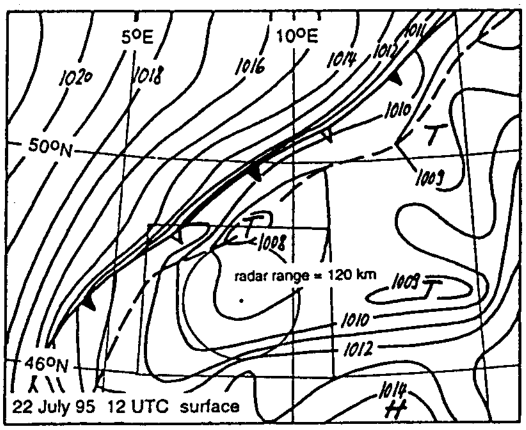

Figure 1. Surface weather map at 12 UTC given for Central Europe. The observational area of the ETH radar (circle) and the SMI radar (quadrangle) are indicated.

On the mesoscale, there was a distinct boundary between a moist air mass in the north of Switzerland and a drier one further southwest. The prestorm operational sounding from Payerne (12 UTC, location Fig.2.b) revealed no instability compared to the research sounding of Merenschwand (14 UTC), situated closer to the storm area (CAPE 1480 J/kg). Payerne was much drier throughout the lower troposphere (surface - 600 hPa) than Merenschwand, which showed a humid layer around 700 hPa. Therefore, the humid air was not advected during the storm day from the SW in advance of the coldfront as is usually the case in severe storm situations affecting Switzerland north of the Alps but was probably left over from the preceding thunderstorm days. The surface temperatures reached 35°C, and the humidity about 70 % (in the southwest as low as 28 %). The temperature dropped sharply after the front, 8°C within 10 min, 10°C within 30 min.

3. THE MCS IN SWITZERLAND

At 14 UTC the leading edge of the precipitating area (25 dBZ, Fig.2.a) of the MCS was west of the Jura mountains and extended northeast over the Black Forest. A prefrontal cell developed over the ridge of the Jura and grew within 80 min into a tornadic cell. At 1430 UTC it merged with the oncoming MCS and its leading edge advanced very quickly through the orographic gap between Jura and Black Forest. This rapid movement gave the line a bulge toward the SE. The cold air in the rear of the MCS advanced faster than to the north and south, where the line was retarded by the mountains. The cold air flowed into the Swiss "Mittelland" (enclosed by Jura and Alps) and triggered new convective cells in the warm and moist air. At 15 UTC these new cells merged again with the advancing MCS, the same happened at 1530 (tornadic stage) and at 16 UTC. The orientation of the system backed from SW-NE to S-N direction as soon as the MCS was halted by the alpine ridge in the SE. In the south the echo decayed (around 1530 UTC) in the dry environment. From 16 UTC onwards, the leading edge of the MCS echo was retarded at its southern end, evidently by the friction of the alpine chaine.

Fig.2.b shows the movement of the line of intense convective cells, indicated by the 40 dBZ radar contour in time steps of 30 min. From 14 until 1530 UTC a broken line of a maximum length of 240 km moved toward the east; part of the line had already developed into a continuous line (length 130 km). At 1520 UTC (Fig.2.c), the severe wind damage and tornado development occurred. A strong bow echo and large notch in the rear of that part of the system indicates a

rear inflow of cold air, according to the conceptual model of a leading line/trailing stratiform (ll/ts) MCS of Houze et al. (1989, 1990). The notch might be exaggerated by the attenuation of the radar beam by strong precipitation. Similar features were recently discussed by Funk et al. (1996) for a MCS during the great flood over Missouri 1993. After 1530 UTC the continuous line grew in length until 17 UTC when its greatest degree of MCS-organization was reached (length of continuous line about 200 km, total length of broken line at least 260 km, delimited by the edge of the SMI radar image). After 1730 UTC the line broke up into several cell complexes, decreased in size and left the radar observational area at about 1830 UTC in the east.

MCSs have a tendency to consist of a group or line of convective showers adjoining a large region of stratiform precipitation. A common pattern is a leading line of convective showers trailed by a region of stratiform rain. Houze et al. (1990) identified two main forms taken by mid-latitude MCSs with ll/ts structure: a symmetric form in which the most intense convective cells are in the central portion of the line and the stratiform region is centered behind the line, and an asymmetric form in which the convective cells are strongest and newest at one end of the line (see Fig.8 of Houze et al. 1990). At 17 UTC (Fig.2.d), the Swiss MCS had a structure almost identical to the archetypical asymmetric ll/ts structure. This degree of mesoscale organization has not been observed previously in Swiss thunderstorms, at least it was not seen in the entire five-year radar-echo climatology of Schiesser et al. (1995). The system travelled with an average speed of 22 m/s, which is rather fast. Only one out of 82 severe MCS investigated by Schiesser et al. (1995) reached a higher speed.

Since the MCS was too large to be seen in its entirety by the Swiss radar, the maximum size of the MCS was estimated using the relation of Fig.3, which shows a scatterplot of the length of convective line versus the maximum dimension for 25 MCSs with ll/ts organization investigated by Schiesser et al. (1995) and the two additional cases from Houze et al. (1990, Oklahoma) and Hagen and Heimann (1994, Bavaria). The maximum dimension in N-S direction was thus estimated as about 380 km, larger than all other known 25 Swiss cases.

4. THE DAMAGE AND TORNADIC STAGE

191 communities (out of 2400 north of the Alps) were hit by damaging hail, which is in the upper segment of severe Swiss hail days. Some communities also suffered from water damage. The area covered by the bow echo in Fig.2.c experienced the most damaging gusts. In a strip roughly 15 km long and 1 km wide about 400 incidents of damage to buildings within 10 communities were reported. Mostly tiles were lifted from roofs, and one roof was completely blown off. Trees were uprooted and broken. Some showed signs of rotating forces as their stems were twisted. A maximum windspeed of 44 m/s was measured. An eyewitness within the damage strip reported a tornado. He observed a funnel cloud stretching from the cloud base to the ground, whirling up leaves from a maize field (Furger and Schmid 1996).

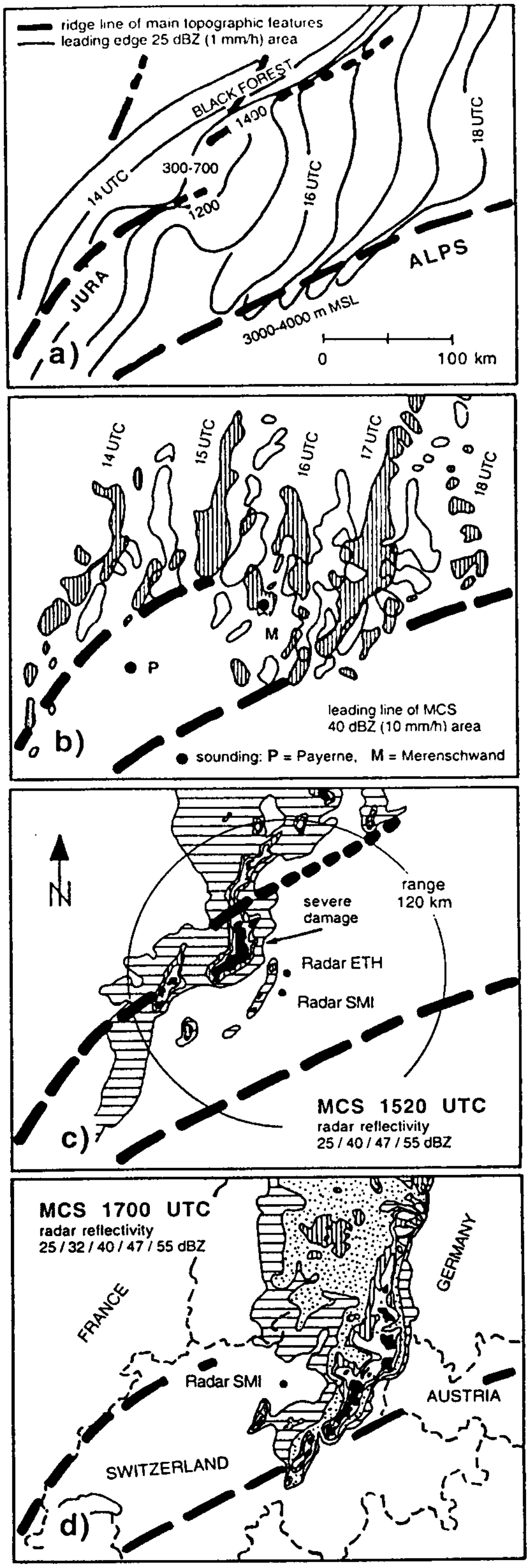

Figure 2. Development of MCS on 22 July 1995. a) movement of the leading edge (25 dBZ) and b) of the line of intense echo (40 dBZ), c) MCS at 1520 UTC (tornadic stage), d) MCS at 17 UTC (maximum organization).

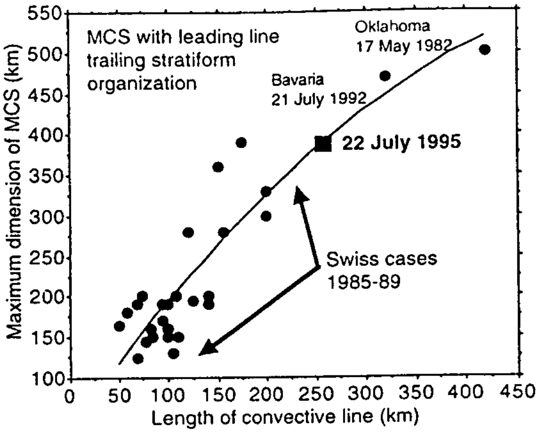

Figure 3. Scatterplot length of convective line versus maximum dimension of ll/ts-MCSs.

The damage area was at a range of 30 to 40 km from the ETH Doppler radar, and volume scans have been made in intervals of 2.5 min from that region. A vortex signature (VS), defined by a shear > 0.005 s^{-1} between the extremes in Doppler velocity, moved over the location of the eyewitness at 1515 UTC. This signature within a weak echo region was bounded by a hook echo of strong reflectivity. The VS developed at 3 km altitude within a shear line, visible at 1443 UTC in the area of the strongest radar echo. 20 min later, the VS extended rapidly upward toward high altitudes and down to the ground (Fig.4). This extension was associated with explosive cellular growth (Linder and Schmid 1996). The azimuthal shear of the VS reached 0.038 s^{-1} at 1513 UTC, indicating that the vertical vorticity was amplified through convergence and vortex streching (Wakimoto and Wilson 1989). The location of the VS "touch down" corresponds to the starting point of the damage strip. Since all preconditions known to be necessary for tornado development were fulfilled and the observed funnel cloud reached the ground, the occurrence of a weak tornado is taken as real.

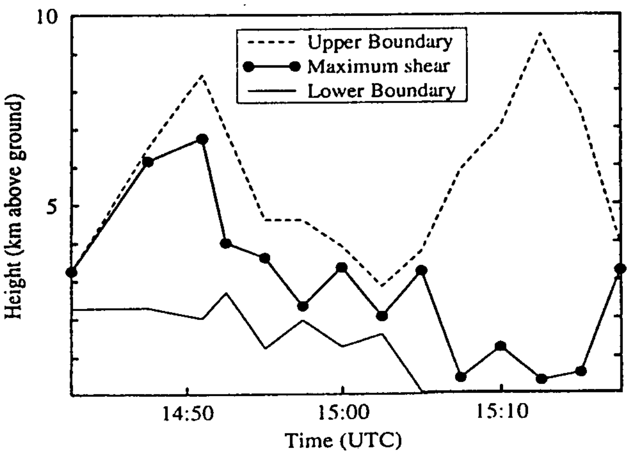

Figure 4. Height-time diagram of a "tornadic" vortex signature, observed on 22 July 1995.

5. CONCLUSIONS

The nearly ideal asymmetric ll/ts organization of the MCS is rare in Northern Switzerland, compared to a five year climatology showing only moderately and weakly classifiable systems (Schiesser et al. 1995). Also the size of the discussed MCS was extraordinary.

The southernmost part of the leading line developed into a significant bow echo, indicating a strong rear inflow into the system. The inflow might have been enhanced by the channeling effect of the terrain gap between the Jura mountains in the south and the Black Forest in the north. The strong gustfront several times triggered new convection about 30 min in advance of the approaching system. Each merger intensified the bow echo cell.

The Doppler radar volume-scans revealed a vortex signature, which developed to the ground and its "touch down" coincided with 1) the starting point of the wind damage strip and 2) an eyewitness account of a weak tornado. Observations of tornadoes are very rare in Central Europe, especially in Switzerland, where the hilly terrain restricts the visual observation of low-level cloud features. Because the storm happened in an ideal distance to the research Doppler radar of ETH, the true nature of the event could have been revealed. The question arises: could there be many other such events?

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