A tale of two mergers: Comparing examples of tornado-producing and non-tornado producing QLCS-supercell mergers in Western South Dakota

Adam J. French, South Dakota School of Mines and Technology, Rapid City, SD

Introduction and background

Mergers between convective storms can lead to a variety of potential outcomes. This includes triggering of tornadoogenesis, cessation of tornado production, and/or changes in convective morphology.

This work seeks to further our understanding of the processes that contribute to differing results from storm mergers by comparing two similar cases of squall lines merging with supercells in Western South Dakota. In one case, the merger appeared to trigger tornadoogenesis, while in the other tornadoogenesis did not occur.

13 June 2016 tornadic case overview

- Squall line formed over eastern Wyoming around 2000 UTC, and moved eastward over the Black Hills of western South Dakota.
- A broad region of enhanced low-level circulation was observed.
- The squall line overtook the northernmost supercell around 2110 UTC (Figure 1a).

18 July 2016 non-tornadic case overview

- High-precipitation supercell developed over the northern Black Hills of South Dakota around 1930 UTC and slowly moved southeast. The supercell produced numerous reports of large hail.
- Compact bow echo developed over eastern Wyoming around 2200 UTC and quickly moved northeastward across the Black Hills.

Stormscale radar analysis

13 June 2016 tornadic merger (upper figure)

- Squall line merged with rear flank of supercell.
- Multiple meso-gamma regions of enhanced momentum within outflow (e.g., M1 and M2 in Figure 3).
- Region of enhanced momentum (M3 in Figure 3) appeared to instigate tornadoogenesis as squall line/outflow overtook supercell.
- Tornado persisted for 12 minutes, a second storm merger led to its demise.

18 July 2016 non-tornadic merger (lower figure)

- Compact bow merged with southern rear flank of supercell.
- Squall line outflow rapidly overtook supercell updraft, cutting off inflow.
- A broad region of enhanced low-level storm rotation developed following the merger (LLM in Fig. 4).
- Supercell evolved into line-end vortex/mesovortex (MV in Figure 4).

Mesoscale environmental conditions

<table>
<thead>
<tr>
<th>Case</th>
<th>Mixed Layer (°C)</th>
<th>Effective-layer bulk shear (m/s)</th>
<th>Effective-layer storm relative vorticity (°/s)</th>
<th>Lifting condensation level (kPa)</th>
<th>Significant tornado parameter (g)</th>
<th>Supercell composite parameter (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 June</td>
<td>1500</td>
<td>30</td>
<td>50</td>
<td>1250</td>
<td>0.25</td>
<td>1.5</td>
</tr>
<tr>
<td>18 July</td>
<td>3000</td>
<td>45</td>
<td>100</td>
<td>1500</td>
<td>0.25</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 1: Representative values for selected Storm Prediction Center mesoscale analysis parameters characterizing the background environment at the time of storm development across the Black Hills of Western South Dakota on 13 June and 18 July 2016.

Squall line cold pool characteristics

<table>
<thead>
<tr>
<th>Case</th>
<th>ΔT (°C)</th>
<th>ΔP (hPa)</th>
<th>wind gust (m/s^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 June</td>
<td>-8.9</td>
<td>-10.0</td>
<td>15.9</td>
</tr>
<tr>
<td>18 July</td>
<td>-11.2</td>
<td>-11.1</td>
<td>15.7</td>
</tr>
</tbody>
</table>

Table 2: Average change in surface air temperature (ΔT), potential temperature (Δθ), surface pressure (ΔP), and max wind gust following passage of outflow for 13 June and 18 July 2016 cases. Data are from National Weather Service, US Forest Service, and private surface weather stations. Eight sites were used for the 13 June case, seven for 18 July.

Discussion and concluding remarks

- Tornadic case characterized by a squall line with comparatively weak outflow, which overtook the rear flank of the supercell, acting analogous to a rear-flank downdraft momentum surge leading to tornadoogenesis.
- Non-tornadic case characterized by a squall line with comparatively strong outflow, which overtook the supercell from the southwest, acting to rapidly undercut the supercell’s updraft. A short-lived, broad low—level circulation was observed.
- Neither environment was particularly conducive to tornado development, with the non-tornadic environment being more favorable for supercells.

The author was partially funded by NSF grant ATM-1261123 while conducting this research. Radar data were produced using the Python ARM Radar Toolkit (PyART). This work benefited from several conversations with staff at the National Weather Service tornado office in Rapid City, SD.