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 tornadogenesis, 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 tornadogenesis, while in the other tornadogenesis did not occur.

13 June 2016 tornadic case overview

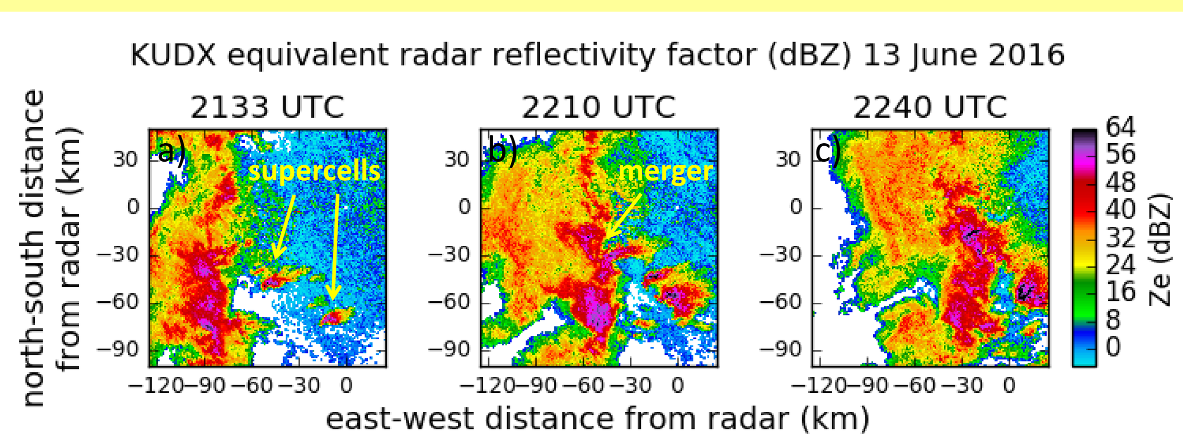


Figure 1: 0.5° radar reflectivity from the Rapid City, South Dakota WSR-88D (KUDX) for (a) 2133, (b) 2210 and (c) 2240 UTC 13 June 2016.

- Squall line formed over eastern Wyoming around 2000 UTC, and moved eastward over the Black Hills of western South Dakota.
- Two supercells developed ahead of the squall line, east of the Black Hills around 2130 UTC (Figure 1a).
- The squall line overtook the northernmost supercell around 2210 UTC (Figure 1b).
- As the squall line overtook the supercell, a tornado that ultimately produced EF-2 damage developed and persisted for 12 minutes..

18 July 2016 non-tornadic case overview

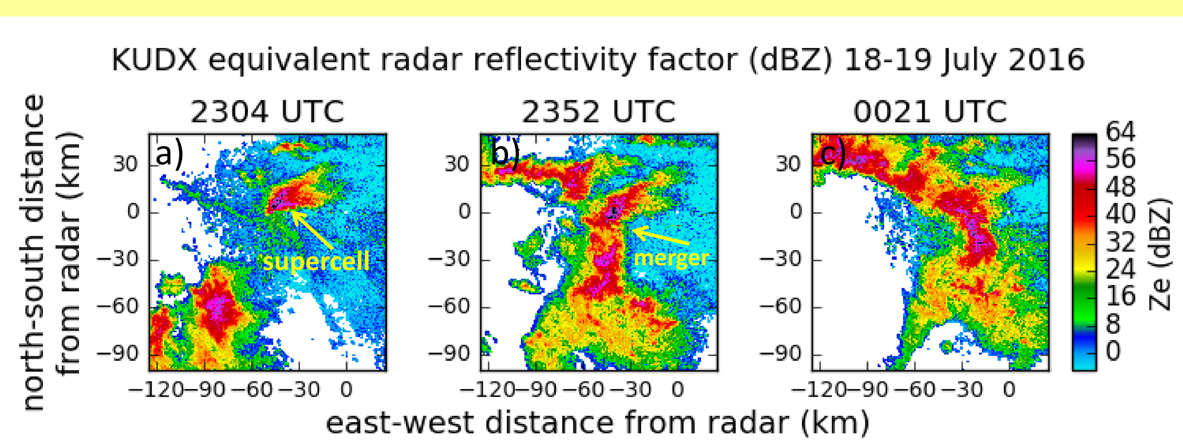


Figure 2: As in Figure 1 but for (a) 2304, and (b) 2352 UTC 18 July 2016 and (c) 0021 UTC 19 July 2016.

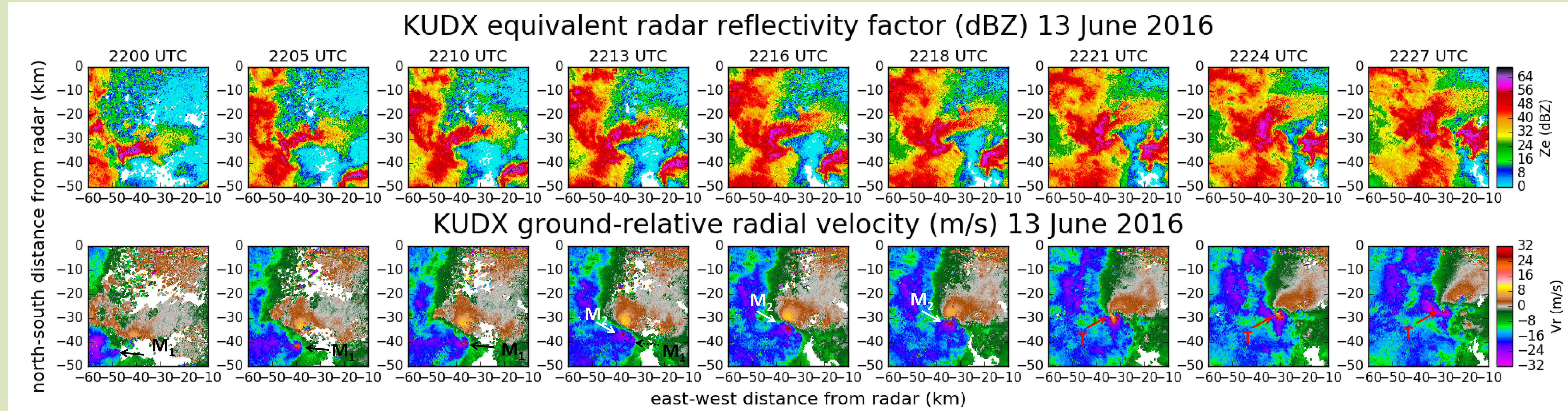
- High-precipitation supercell developed over the northern Black Hills of South Dakota around 1930 UTC and slowly moved south-southeast. The supercell produced numerous reports of large hail.
- Compact bow echo developed over eastern Wyoming around 2200 UTC and quickly moved northeastward across the Black Hills.
- The bow echo merged with the nearly stationary supercell just east of the Black Hills around 2350 (Figure 2b).
- Large hail production rapidly diminished following the storm merger.

Mesoscale environmental conditions

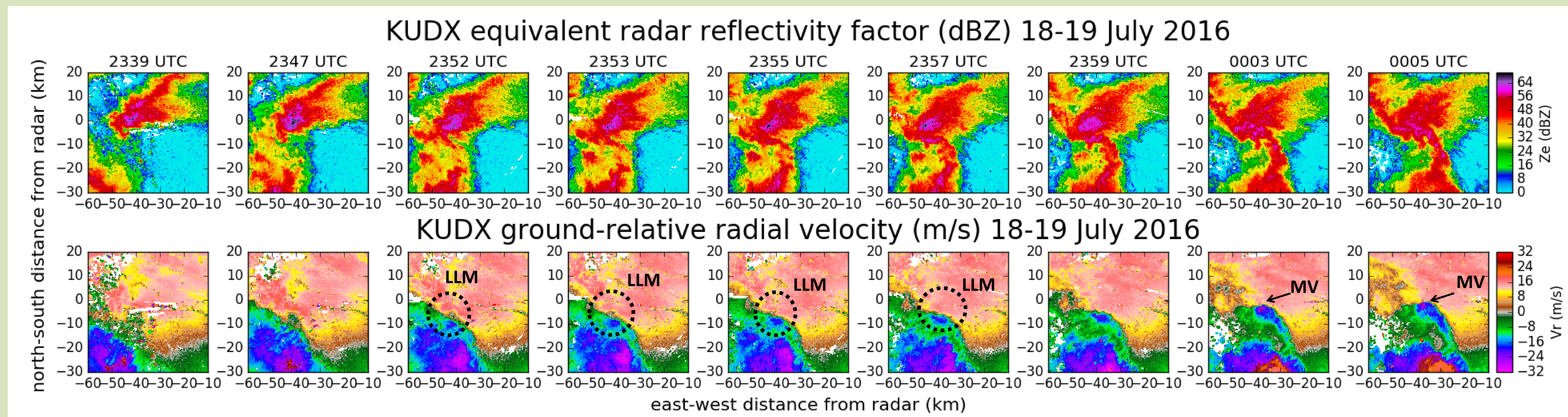
Case	Mixed Layer CAPE	Effective - layer bulk shear	Effective-layer storm relative helicity	Lifting condensation level	Significant tornado parameter	Supercell composite parameter
13 June	1500 J kg^{-1}	30 kt	50 m^2s^{-2}	1250 m	0.25	1.5
18 July	3000 J kg^{-1}	45 kt	100 m^2s^{-2}	1500 m	0.25	6

***Table 1:** Representative values for select 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.*

Stormscale radar analysis



***Figures 3 (above) and 4 (below)**. Rapid City, SD WSR-88D equivalent radar reflectivity (top panels) and ground-relative radial velocity (bottom panels) at 0.5° elevation for 2200 -2227 UTC 13 June 2016 (Figure 3) and 2339 UTC 18 July 2016 – 0005 UTC 19 July 2016 (Figure 4). For both cases the KUDX WSR-88D was operating with the MESO-SAILS scan strategy, providing low-level scans every 2-3 minutes, compared to 4-5 minutes for legacy scan strategies.*



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., M_1 and M_2 in Figure 3).
- Region of enhanced momentum (M_2 in Figure 3)appeared to instigate tornado genesis 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).

Squall line cold pool characteristics

Case	ΔT	$\Delta\theta$	ΔP	wind gust
13 June	-8.9°C	-10.0 K	+1.9 hPa	18.8 m s^{-1}
18 July	-11.2°C	-12.1 K	+3.0 hPa	13.7 m s^{-1}

***Table 2:** Average change in surface air temperature (ΔT), potential temperature ($\Delta\theta$), 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.*

- 18 July case observed to have larger temperature deficit and pressure increase within the squall line cold pool.
- Result is consistent with radar-observed outflow behavior.

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 tornadogenesis.
- 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 AGS - 1339469 while conducting this research. Radar plots were produced using the Python ARM Radar Toolkit (PyART). This work benefited from several conversations with staff at he National Weather Service forecast office in Rapid City, SD.