A preliminary study of non-merger interactions between squall lines and isolated supercell thunderstorms

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Introduction and background:

Past research has documented cases where isolated thunderstorms appear to intensify as they approach a nearby squall line, prior to the two modes merging into a single system. This includes increases in low-level storm rotation and a relative increase in tornado production as an isolated supercell draws close to a nearby squall line (French and Parker 2012). These observations imply that these two storm modes may be interacting when in close proximity despite remaining separated in terms of their appearance on radar. As a first step toward quantifying the details of this interaction, the present study is employing output from idealized model simulations to address the following questions:

1) For a given background environment, how does the presence of a nearby squall line alter the stormscale characteristics of a supercell thunderstorm?

2) Can these changes in supercell structure and evolution be explained by squall line-induced changes to the local environment ahead of the line?

Methodology:

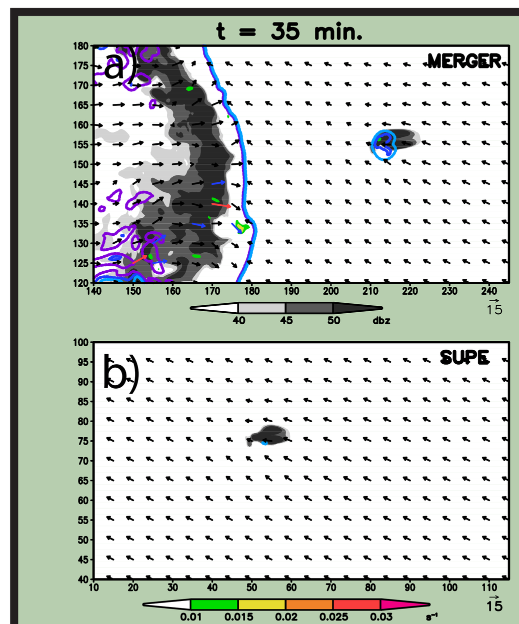

Figure 1: Initial positions of supercells in the (a) MERGER and (b) SUPE simulations. Fields plotted are as in Figure 3.

- Output from a pair of idealized CM1 (Bryan and Fritsch 2002) simulations run to study mergers between squall lines and isolated supercells.
  - o MERGER: supercell triggered 60 km ahead of a mature squall line (Fig. 1a).
  - o SUPE: isolated supercell (Fig. 1b).
- Both runs used the same initial homogeneous background thermodynamic and shear profiles (Fig. 2a).
- The MERGER simulation included perturbations that developed owing to the presence of the squall line (Fig. 2b).

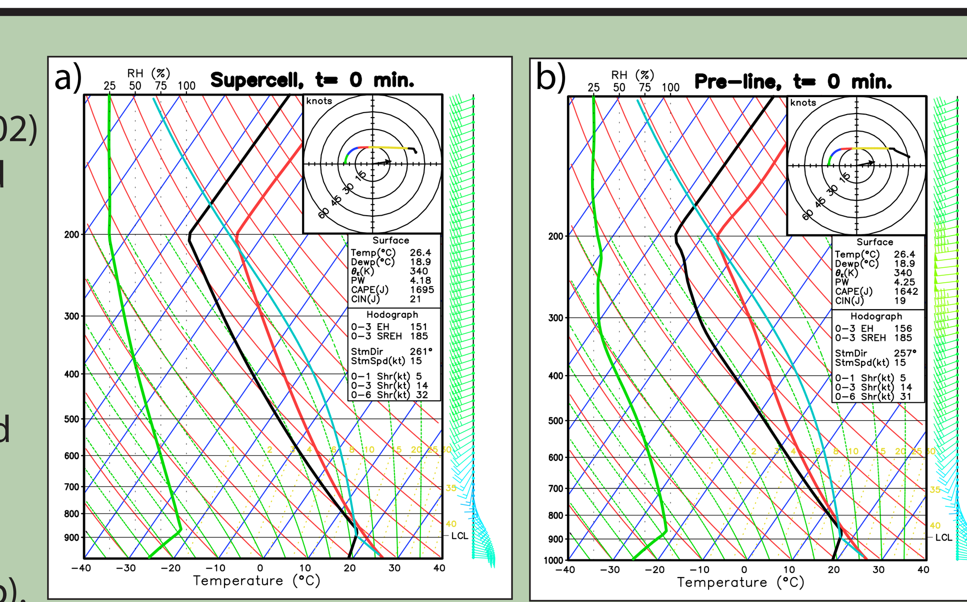

Figure 2: Initial environments at the time the supercell is triggered in the (a) SUPE and (b) MERGER simulations.

Impact of nearby squall line on supercell evolution:

- The MERGER supercell began producing heavier precipitation (e.g., higher simulated reflectivity) very early in the simulation and ultimately evolved into a high-precipitation (HP) supercell prior to merging with the squall line (Fig. 3a-d).
- The MERGER supercell was characterized by a colder, larger cold pool beginning early in the simulation (e.g., Fig. 3 a-b and e-f).
- The MERGER supercell produced a larger, more persistent region of strong low-level vertical vorticity
  - o The MERGER supercell developed a region of strong low-level vertical vorticity approximately 65 minutes after the supercell was triggered (Fig. 3b).
  - o This region of vorticity intensified and grew in size, and was maintained continuously through the merger with the squall line approximately 25 minutes later (Fig. 3b-d).
  - o During this same period, the SUPE simulation produced a single short lived, comparatively weak low-level vortex (Fig. 3e-h).
- The increased outflow production in the MERGER supercell strengthened storm-scale buoyancy gradients, providing a source of horizontal vorticity for low-level mesocyclone genesis as shown by Rotunno and Klemp (1985) and Brooks et al. (1994).

Simulated radar reflectivity, vertical vorticity, and wind vectors at 1 km AGL, surface potential temperature perturbation

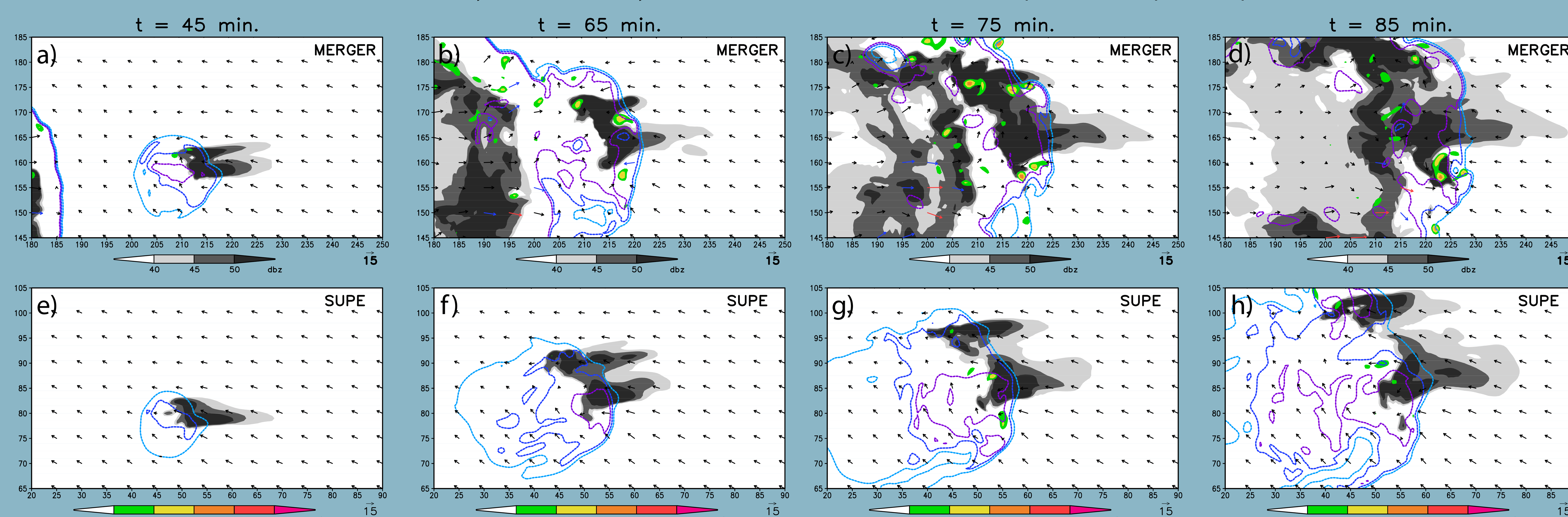

Figure 3: Simulated radar reflectivity (dBZ, grey shading as shown), vertical vorticity (s^{-1}, colored shading as shown), and wind vectors at 1 km AGL, and surface potential temperature perturbation (K, contoured at -2 K (light blue), -4 K (dark blue) and -6 K (purple)). Top panels show the MERGER simulation and bottom panels the SUPE simulation at (left to right) 45, 65, 75, and 85 minutes following supercell triggering in the respective simulations.

Evolution of the background environment ahead of the squall line:

- Thermodynamic profile moistened throughout the troposphere over the first 45 minutes, and remained nearly saturated through the merger.
- Low-level wind profile remained largely unchanged; however, the upper level winds weakened with time.
- This environmental evolution is in line with squall line-induced modifications to the pre-line environment owing to high-frequency gravity wave activity (e.g. Fovell 2002).
- The modified environment is favorable for HP supercells (e.g., Rasmussen and Straka 1998).

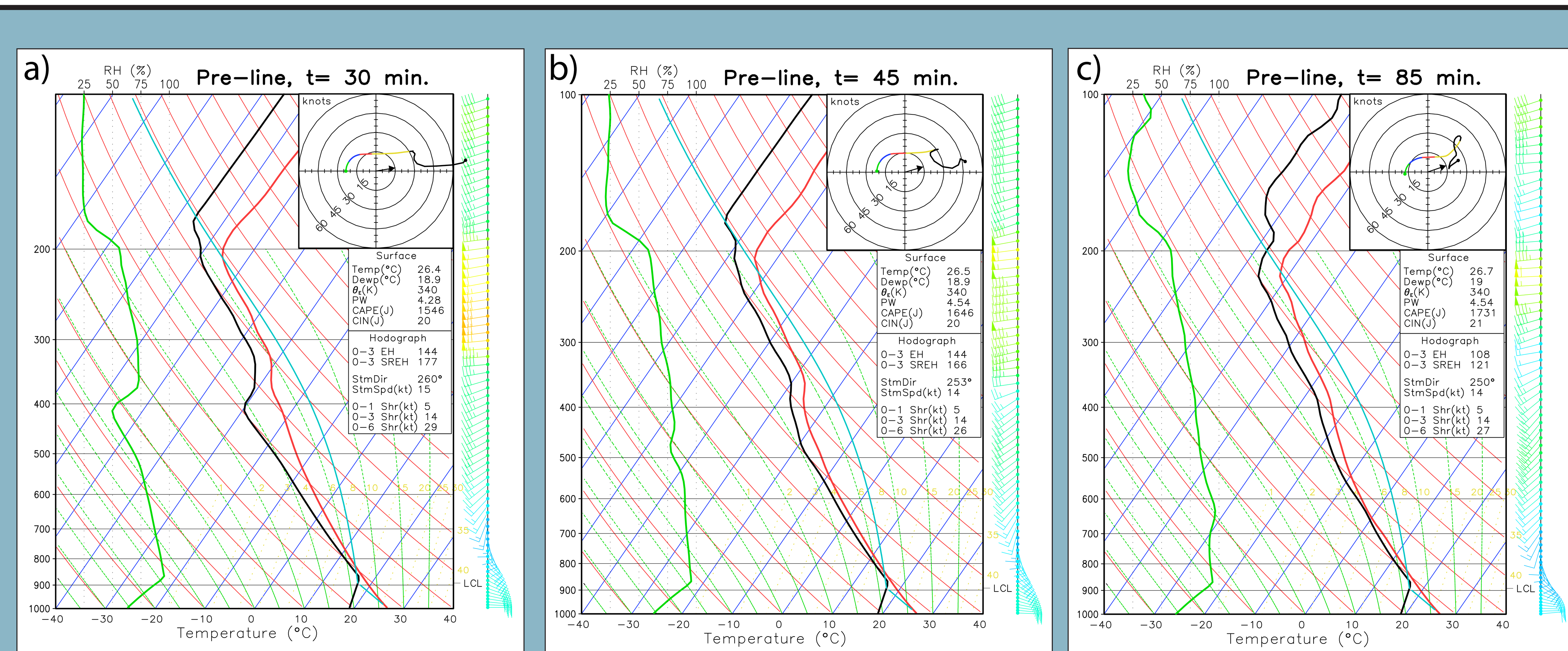

Figure 4: Skew-T log-P diagrams, wind profiles, and hodographs depicting the background environment ahead of the squall line in the vicinity of the pre-line supercell sampled at (a) 30, (b) 45 and (c) 85 minutes after the supercell was triggered. The green line on the left side of the plots shows the relative humidy profile. These were plotted from a simulation without the pre-line supercell in order to isolate the effects of the squall line on the environment.

Planned Future work:

To more fully test the impact of squall-line induced perturbations to the background environment on supercell evolution, additional simulations are planned that include:

- Simulating isolated supercells in time-varying background environments based on observed and simulated pre-squall line environments.
  - o Isolate effects of environmental changes from other "direct" interactions.
  - o Evaluate which environmental changes have the largest impact.
- Full physics squall line-supercell interaction simulations
  - o Current simulations neglect radiation, surface fluxes, and other potentially important processes.
  - o Combined squall line and supercell simulations that include effects of anvil shading, surface fluxes, and surface drag.
- Testing different storm configurations (e.g. storm motion vectors, initial distances, and relative storm maturity).

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