Objective Identification of Supercellular Internal Momentum Surges Using a Cloud Model

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1. Introduction

Supercell thunderstorms are responsible for the vast majority of significant tornadoes, but the complete picture of spatial and temporal variability of their near-ground vorticity remains lacking. While it is well-established that tornadogenesis requires development of near-ground rotation following mid-level mesocyclone maturation (Davies-Jones 1993), the unsteady nature of the development of near-ground rotation is not fully understood. Previously identified horizontal surges of momentum associated with pulses within the storm (Skinner et al. 2014, among others) are often accompanied by vertical-vorticity extrema, some of which show a tendency to merge with and intensify existing near-ground vorticity (Dahl et al. 2014). Numerical simulations of a supercell using a mesoscale model are conducted to investigate the mechanics of surge generation and propagation. The first step, which is the focus of this poster, is to develop an algorithm that quantifies surge characteristic frequencies, magnitudes, and source regions.

2. Method

- Simulate an idealized, full-physics supercell using the Bryan cloud model (CM1, release 16), initialized with the Del City base state.
- Develop Surge Index Parameter.
- Use binary "flag" to identify surge extent.
- Test algorithm using idealized downdraft simulations.

Fig. 1 shows outflow surges and the associated vorticity extrema for the Del City simulation.

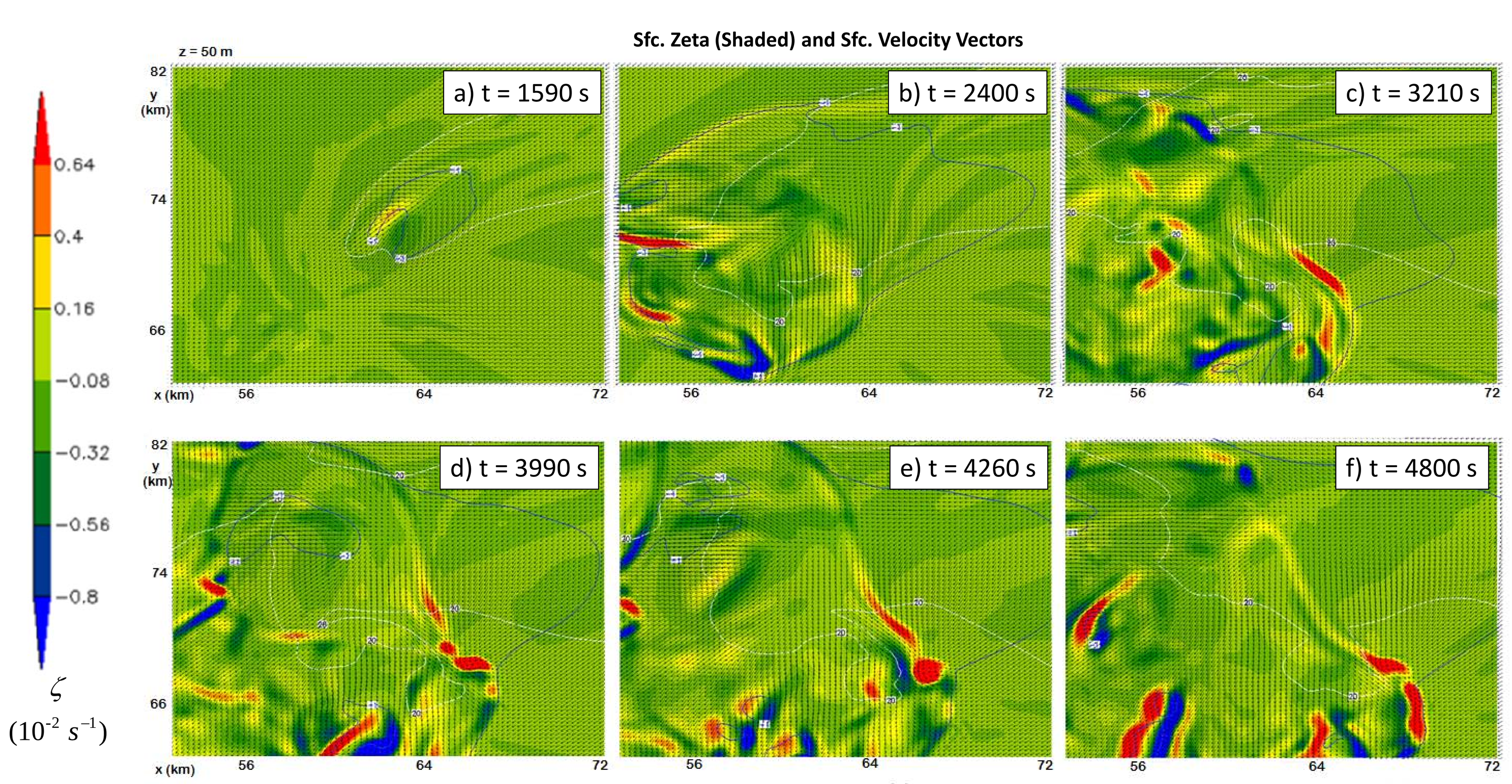

Fig. 1: Evolution of simulated supercell, from t=1600s to t=4800s, every 800s (a-d and f), and the time of maximum near-ground vorticity (e). Vertical vorticity is shaded, the blue contour represents the -1 K perturbation, and the white line is the 20 dbZ reflectivity contour.

2.1 Surge Flagging Algorithm

$$S = (u'^2 + v'^2)^{\frac{1}{2}},$$

where u' and v' are the storm-relative perturbation velocity components in x- and y- directions, respectively. The surge index is the magnitude of the storm-relative, storm-generated horizontal velocity perturbation. A flagging algorithm converts the index at each grid point to "1" or "0" dependent on if the index meets a chosen threshold.

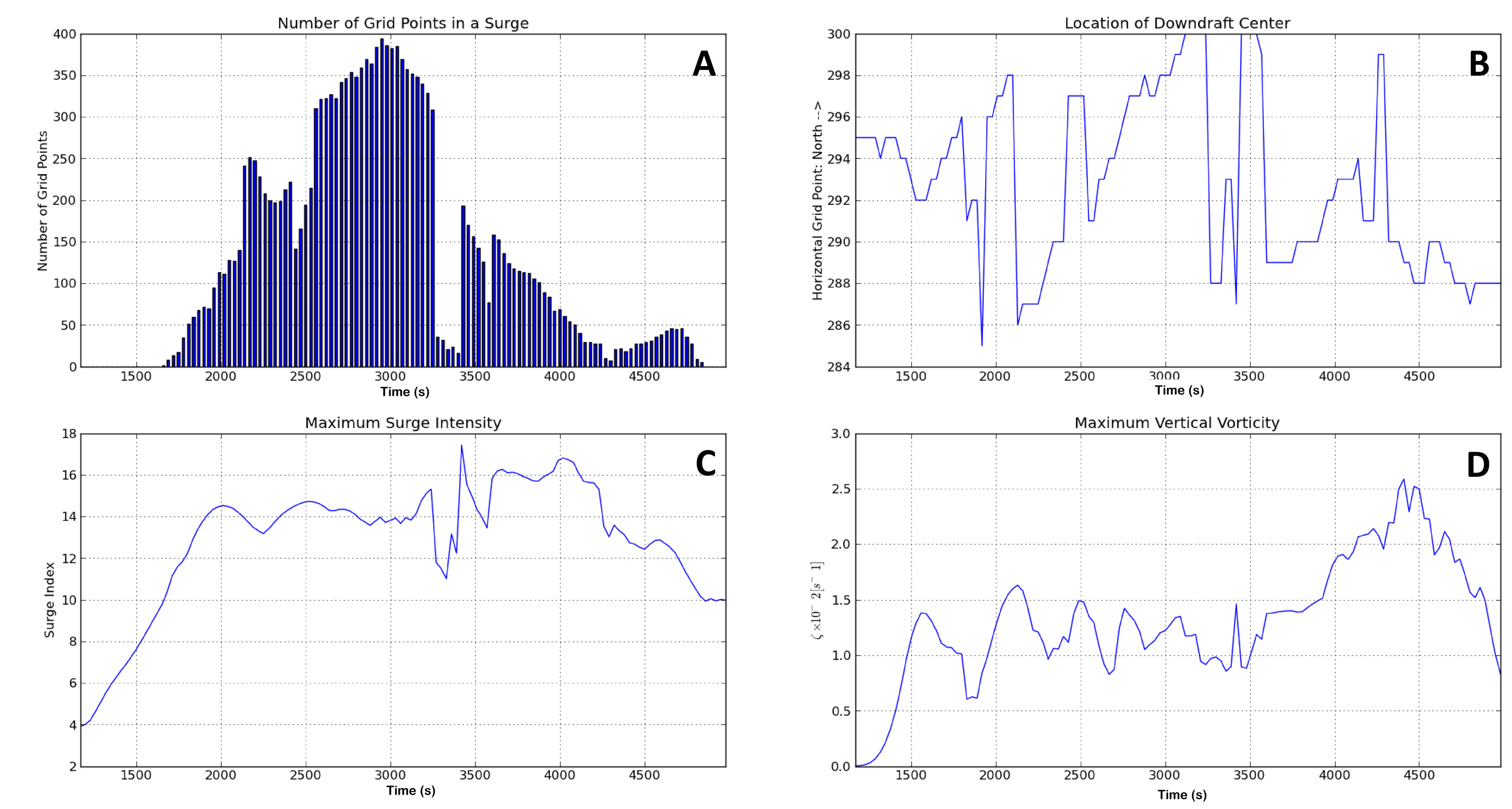

Fig. 2: Sample horizontal momentum surge statistics in a simulated supercell, including (a) total combined horizontal extent, (b) location of primary downdraft source, (c) maximum intensity, and (d) maximum vertical vorticity

3. Results

Statistics based on the flagging algorithm (using $S > 12$ m s^{-1}) are shown in Fig. 2. To test these results, a controlled downdraft simulation was used, and the algorithm's ability to measure prescribed surges was assessed.

a. Test Scenario 1: Single, Pulsing Downdraft

A single downdraft is pulsed at a prescribed frequency. The surge index identifies surges and flagging algorithm records their position (Fig. 3). Generated statistics (Fig. 4) correlate with prescribed surge characteristics, most notably re-creating the period of pulsation.

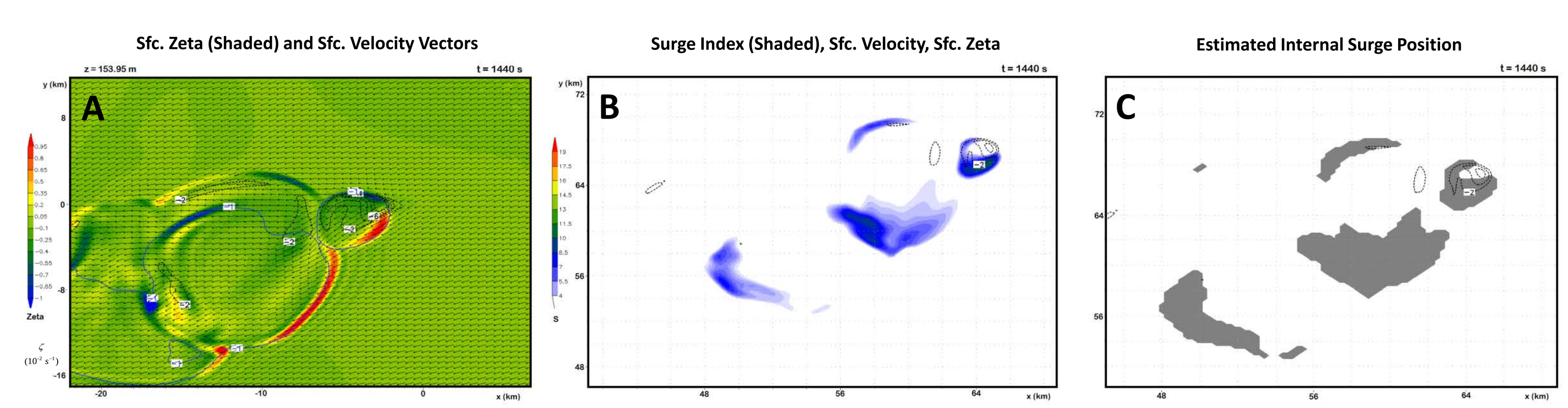

Fig. 3: Results of an algorithm test using a fully-idealized single downdraft with pulsing frequency of 400 s^{-1}, including (a) vertical vorticity (with -1K perturbation contour), (b) surge index, and (c) final location given by flagging algorithm. Each figure also shows downdraft velocity contours every -2 m s^{-1}.

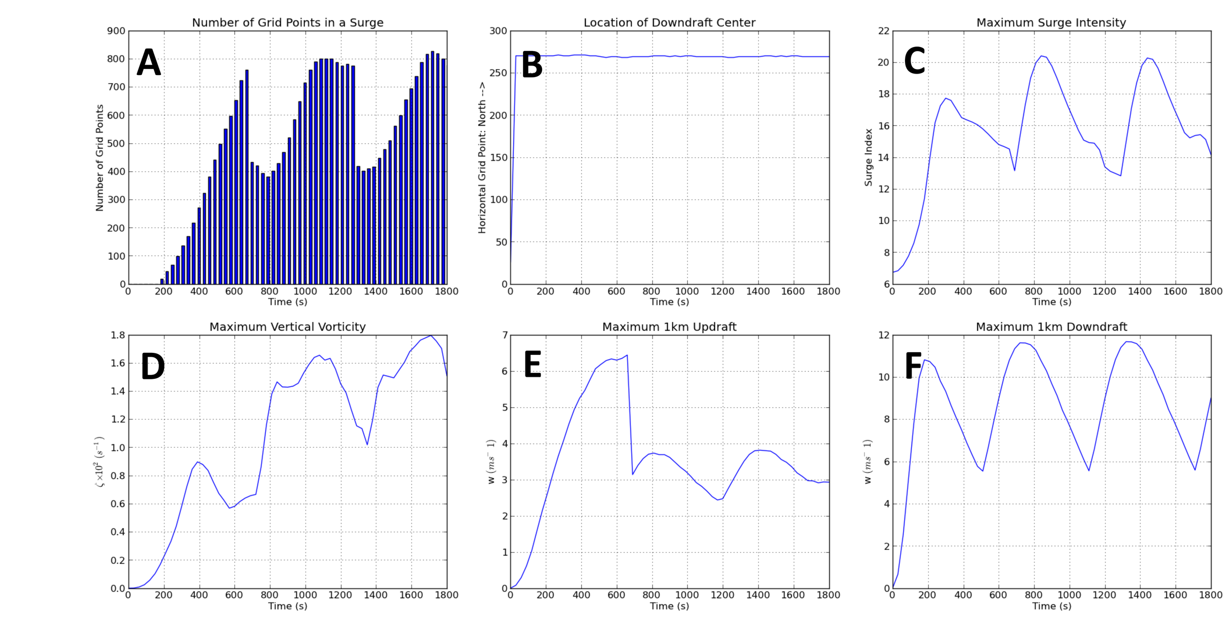

Fig. 4: Statistics for the case in Fig. 3, including (a) combined horizontal extent, (b) location of downdraft source, (c) maximum surge intensity, (d) maximum vertical vorticity, (e) maximum updraft velocity, and (f) maximum downdraft velocity

b. Test Scenario 2: Two Pulsing Downdrafts

Two downdrafts are pulsed out of phase, at a 90° phase shift. The surge index and flagging algorithm again faithfully identifies and tracks individual surges (Figs. 5 and 6).

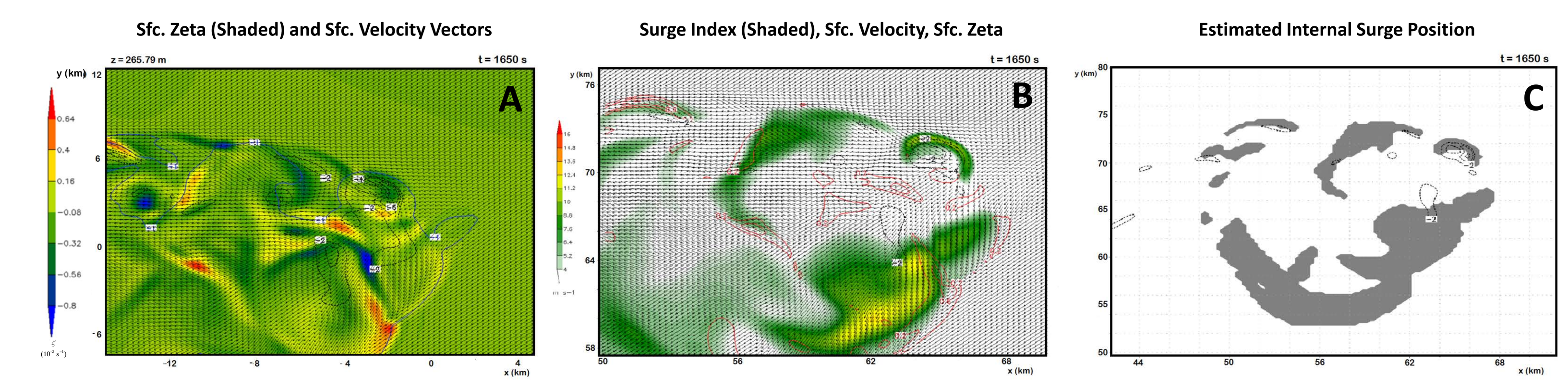

Fig. 5: Same as in Fig. 3, but for two out-of-phase, pulsing downdrafts

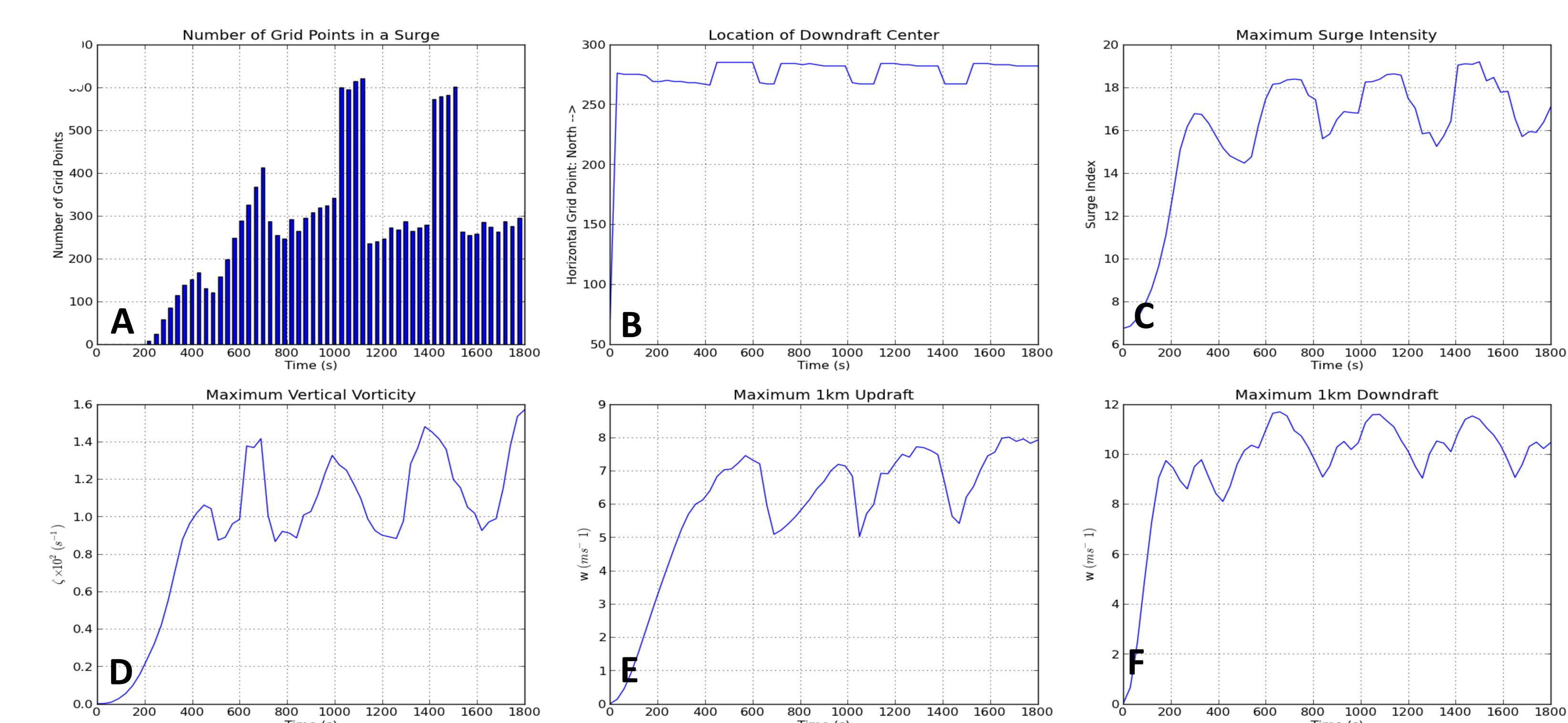

Fig. 6: Same as in Fig. 4, but for two out-of- phase, pulsing downdrafts

4. Summary and future work

A new algorithm was developed that identifies outflow surges and their source locations, as well as their frequencies and sizes. Future work includes a Fourier analysis to quantify surge frequency and testing the sensitivity of surges to different storm environments and microphysics parameterizations.

5. Acknowledgments

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References: J. Dahl, M. Parker, and L. Wicker, *J. Atmos. Sci*, 71(8), 3027 (2014)
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