New Paths to Understanding Severe Storm Intensification: A Numerical Modeling Study

*Ann M. Syrowski, B. F. Jewett and R.B. Wilhelmson; University of Illinois, Urbana, IL

Severe Storms Research

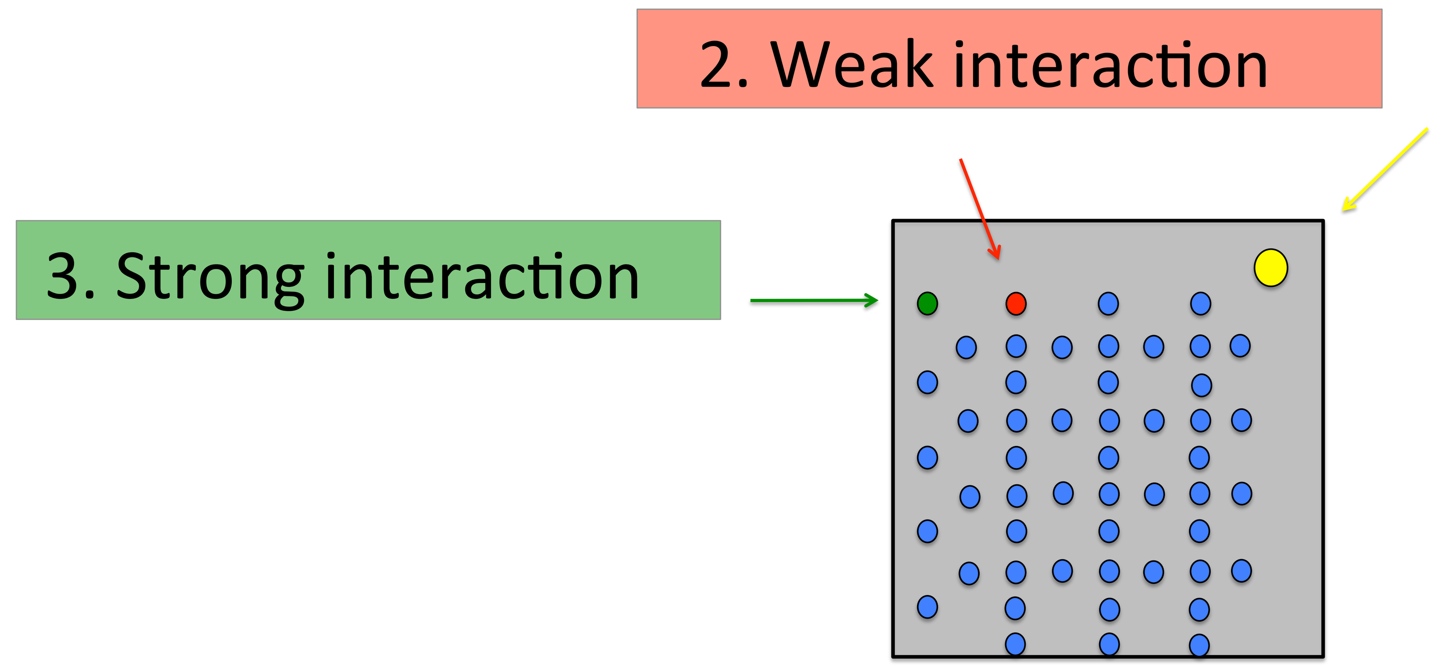
- Active research areas in the atmospheric sciences include understanding processes that lead to storm intensification and the possibility for tornadoes
- Interactions with nearby storms can modify storm evolution beyond what is expected from a given vertical profile of temperature, moisture, and wind that is typically associated with severe storms
- Research objective: Identify processes responsible for favorable vs. unfavorable storm interaction as a function of the initial positions of two interacting storms

Methods

- The shared-memory architecture of high-performance computers was used to generate and analyze an ensemble of Weather Research and Forecasting model (WRF v3.3) storm interaction simulations
- Used an ensemble approach to capture the sensitivity of interacting storms' intensities to the initial storm pair orientation, keeping the initial environment the same
- Control: One simulated storm
- Fifty-one additional simulations were initiated with a second storm placed to the southwest of the control at a varied location

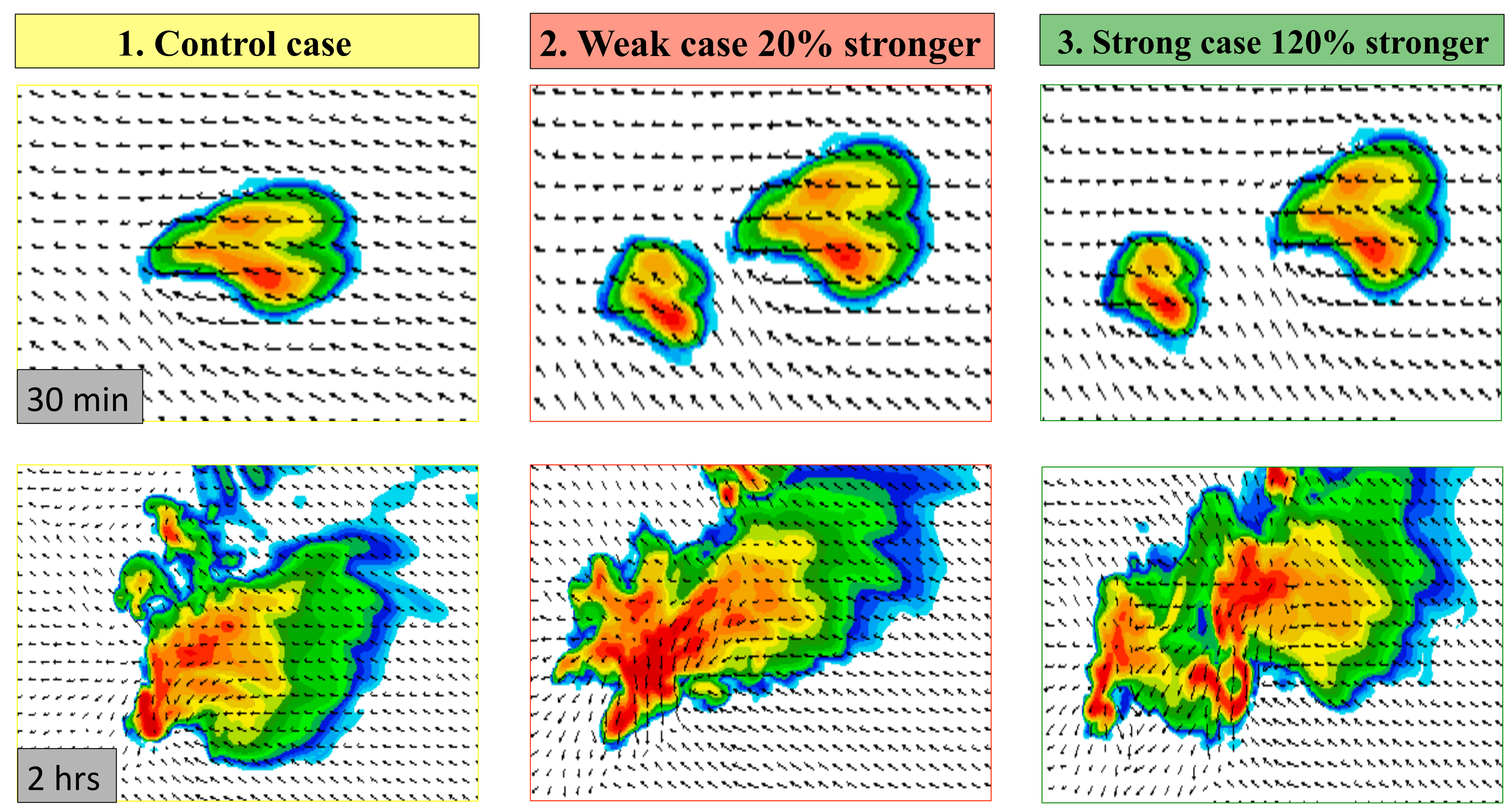
Ensemble schematic

3 key simulations:



- Data saved every minute
- Raw output, analysis files/run = 0.3 TB
- Total ensemble: 15.3 TB
- 6 hours/simulation @ 64 cpu = 384 SUs
- Ensemble total: 19,584 SUs
- Plotting and analysis of ensemble: 8200 SUs

Small changes in initial storm pair orientation = large differences in rotation



Simulated reflectivity 2 km above ground and surface winds at 0.5 hrs (top row, 56.7 x 35.0 km) and 2 hrs (bottom row, 164.8 x 48.6 km)

Computational Resources

- 5-hour storm simulations were integrated using the National Center for Supercomputing Applications' (NCSA) Ember, SGI Altix UV / 1,536 processor cores / 8 TB memory
- Data analyses were performed on Pittsburgh Supercomputing Center's Blacklight / 4096 processor cores / 32 TB memory

Conclusions

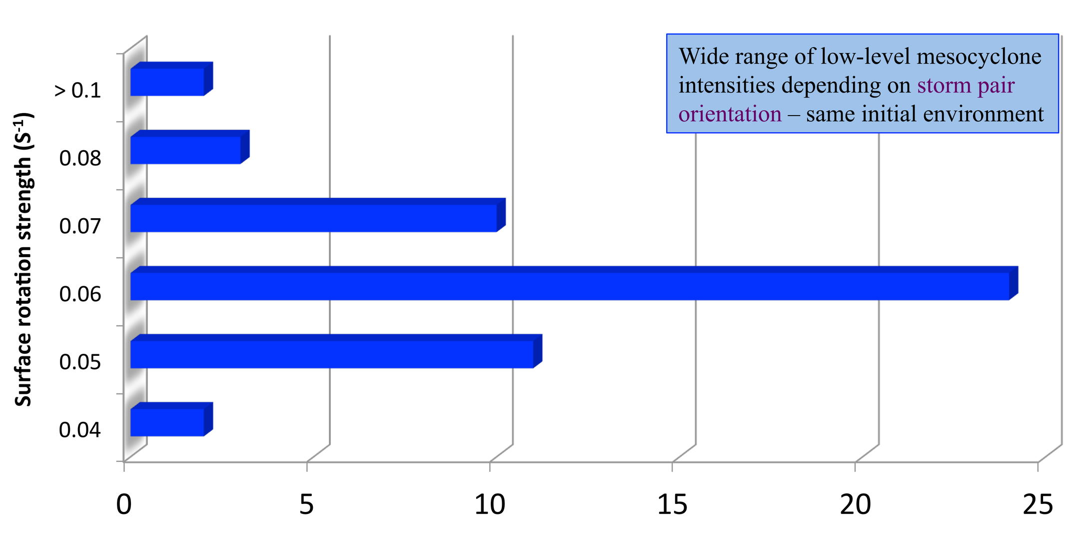
- Changing the initial orientation of an interacting storm pair results in a wide range of storm types, some strongly rotating, despite the same initial environment for each ensemble member
- Key finding: forward flank downdraft is *unsteady*
- Rain-laden downbursts disturb the storm forward-flank gust front, inducing rotation along its edge
- These discrete rotation centers propagate down the FFGF and merge with the storm's rotating updraft (mesocyclone) – increasing the storm's low-level rotation

Acknowledgements

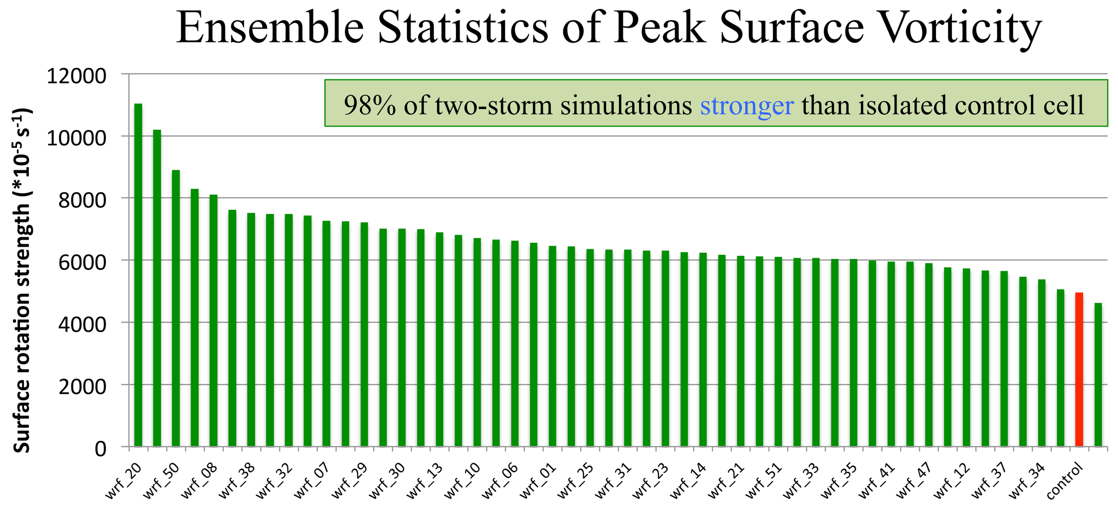
- XSEDE Awards TG-MCA94P023 and TG-ATM050014N
- Special thanks to technical support staff at NCSA and PSC

Storms are extremely sensitive to perturbations in their environment

Ensemble Peak Vertical Vorticity Distribution



Ensemble Statistics of Peak Surface Vorticity

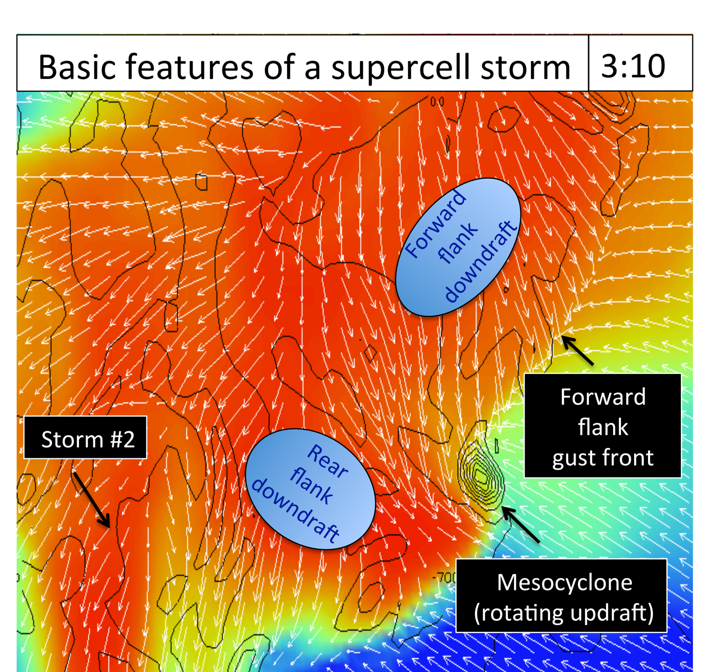


Supercell: An often dangerous convective storm that consists of a single, quasi-steady rotating updraft

Mesocyclone: A cyclonically-rotating vortex, approx. 2-10 km wide

- AMS Glossary

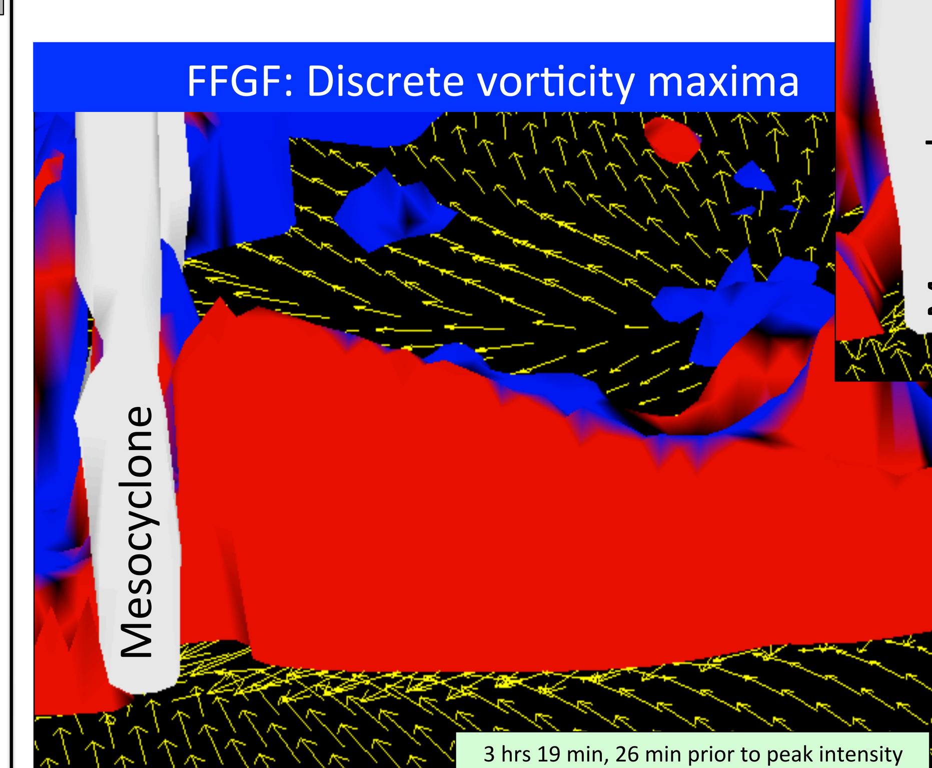
Vorticity (s^{-1}) = rotation produced by a storm	
Mesocyclone: 0.01 s^{-1}	Tornado: 1.0 s^{-1}



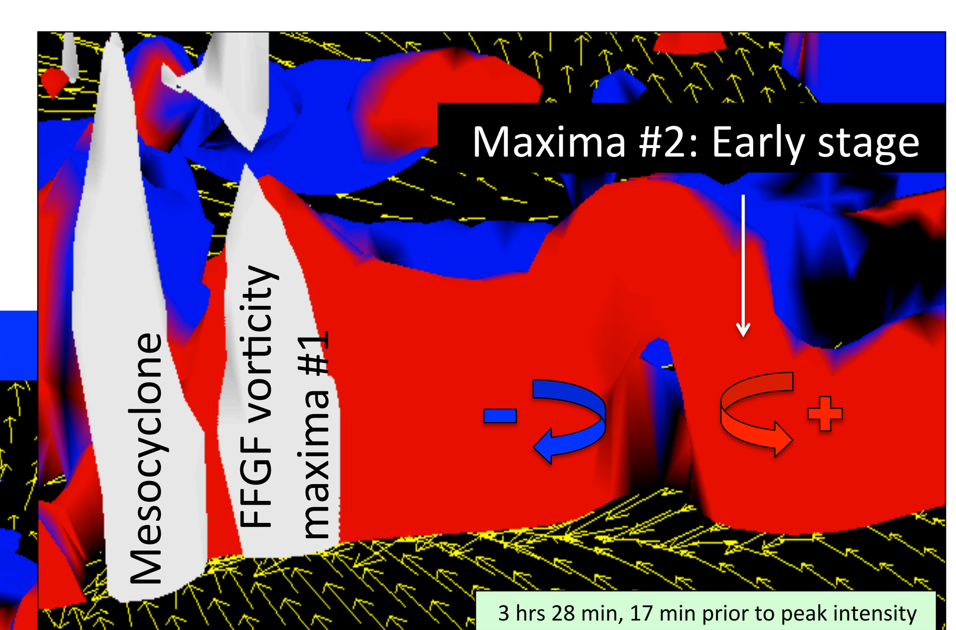
Simulated surface reflectivity, wind, and 0.07 s^{-1} vertical vorticity contours at 3 hours 10 min (top view)

Strong case example

Forward flank gust front (FFGF): Intensification (perturbation) source

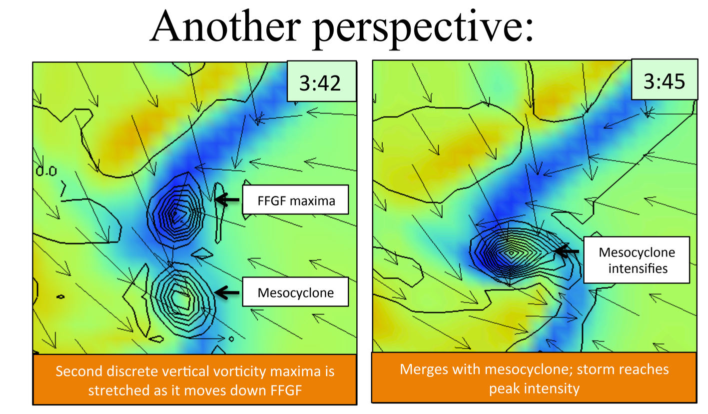


Strong case at 3 hrs 19 min. Looking northwest at forward flank gust front. Horizontal vorticity surface color-shaded by positive and negative vertical velocity. Vertical vorticity isosurface shaded in white is associated with supercell's mesocyclone. Yellow arrows depict winds at the surface; FFGF separates warm inflow air in foreground from cold downdraft air behind it.

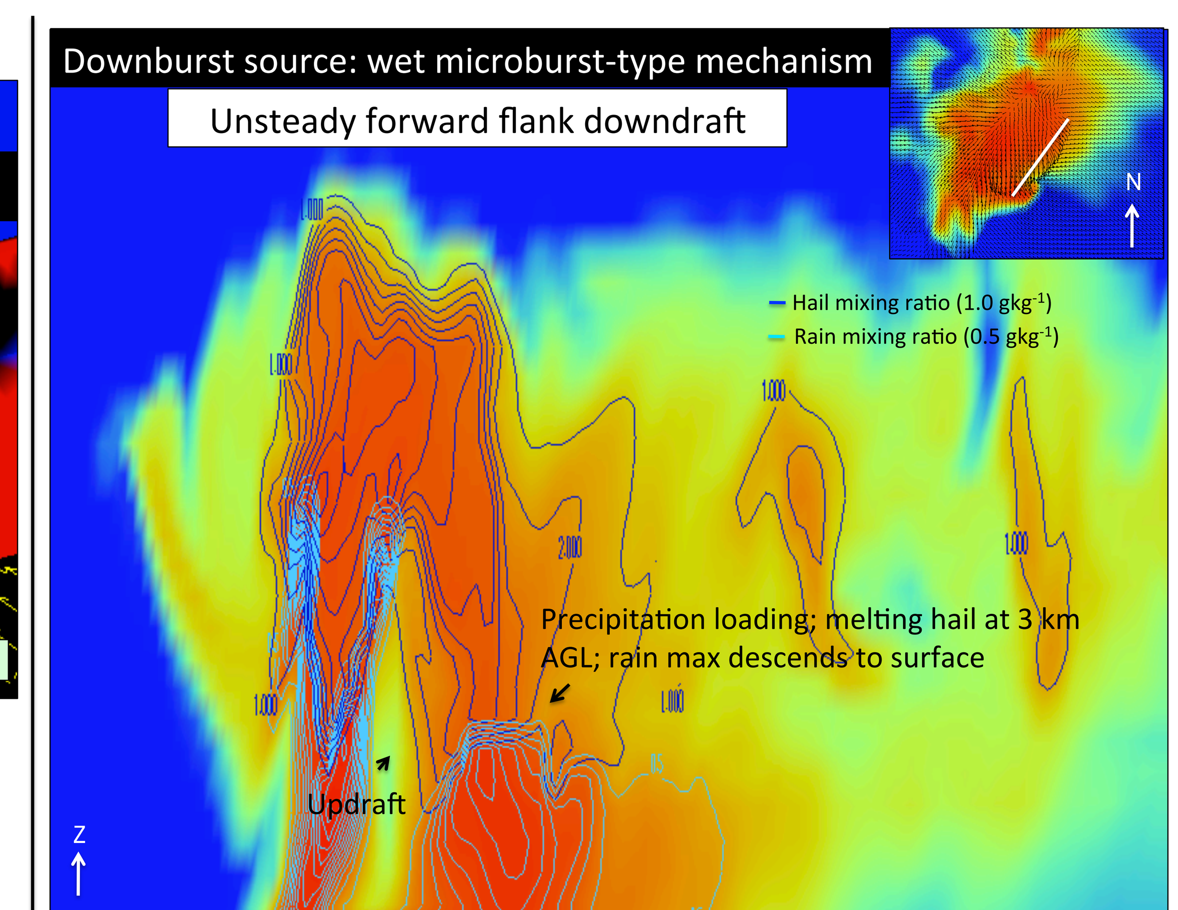


Strong case at 3 hrs 28 min, 17 min prior to the storm's peak intensity

Another perspective:



Surface convergence, divergence, wind, and 0.07 s^{-1} vertical vorticity contours for strong two-cell simulation



Vertical cross-section of simulated reflectivity at 3 hrs 20 min, 25 min prior to time of storm's peak intensity

Q. How does horizontal vorticity along the FFGF tilt into the vertical?

A. Episodic downbursts behind the forward flank gust front

* ann.syrowski@gmail.com