

# VORTEX2

## The Second Verification of the Origins of Rotation in Tornadoes Experiment

Howie Bluestein  
Don Burgess  
David Dowell  
Paul Markowski  
Erik Rasmussen  
Yvette Richardson  
Lou Wicker  
Josh Wurman

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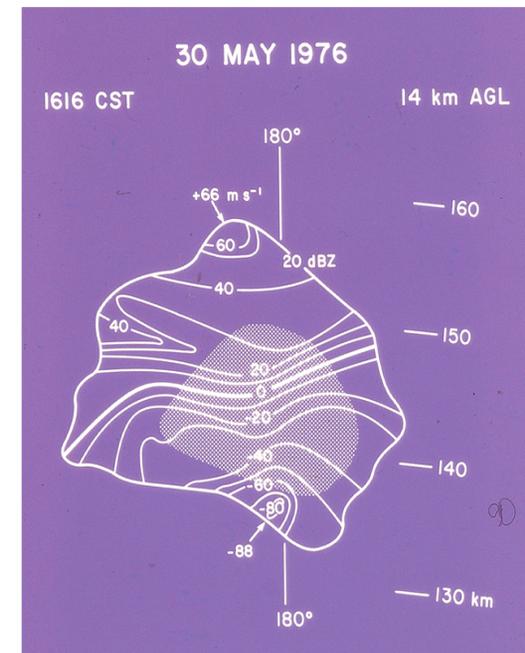
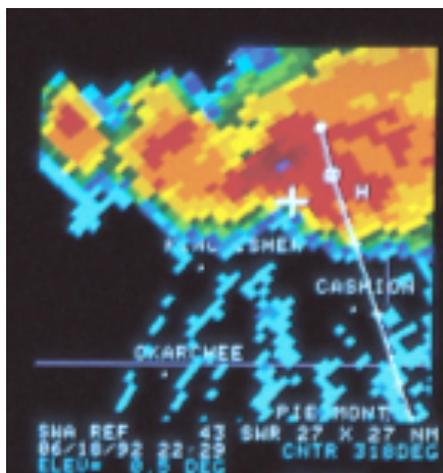
Photo by Herb Stein

# VORTEX2

- **Four foci**
  - **tornadogenesis**
  - **near-ground wind field in tornadoes**
  - **relationship between tornadoes, their parent thunderstorms, and the larger-scale environment**
  - **storm-scale NWP, supercell predictability**
- **Dates: 10 May-13 June, 2009 and 2010**

# Pre-VORTEX1 Methods

- **Visual observations**
- **Fixed site instrumentation**
- **Numerical simulations**
- **Limited mobile assets**



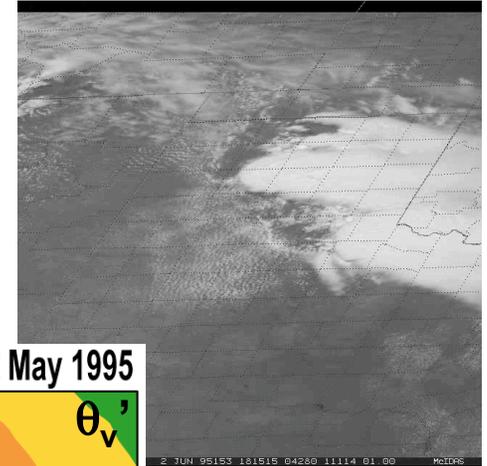
# What did VORTEX1 add?

- **Mobility!**
  - mobile soundings
  - mobile mesonets
  - mobile radars (mainly airborne)

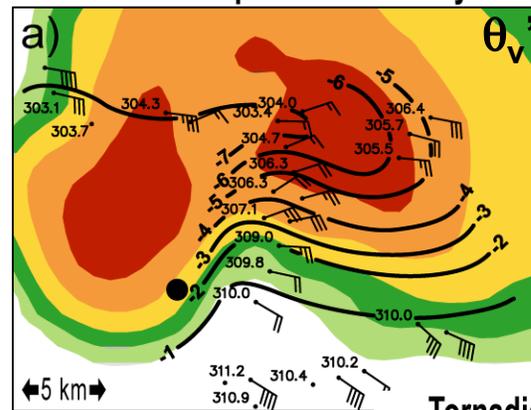


# Summary of VORTEX1 Findings

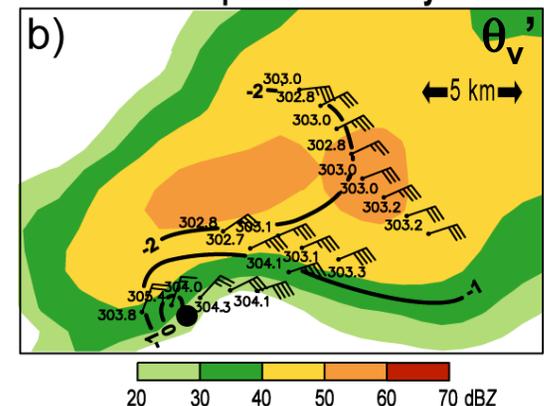
- Increased awareness of the sensitivity of supercells to the near-storm environment
  - storm-boundary interactions
  - mesoscale variability away from obvious mesoscale boundaries
- Modification of attitudes toward low-level mesocyclones
  - very large fraction of supercells contain circulations at low levels, and probably even at the surface
- The thermodynamic properties of the downdrafts may exert some control on tornado formation, intensity, and longevity
  - warmer downdrafts associated with tornadoes



Nontornadic supercell on 22 May 1995

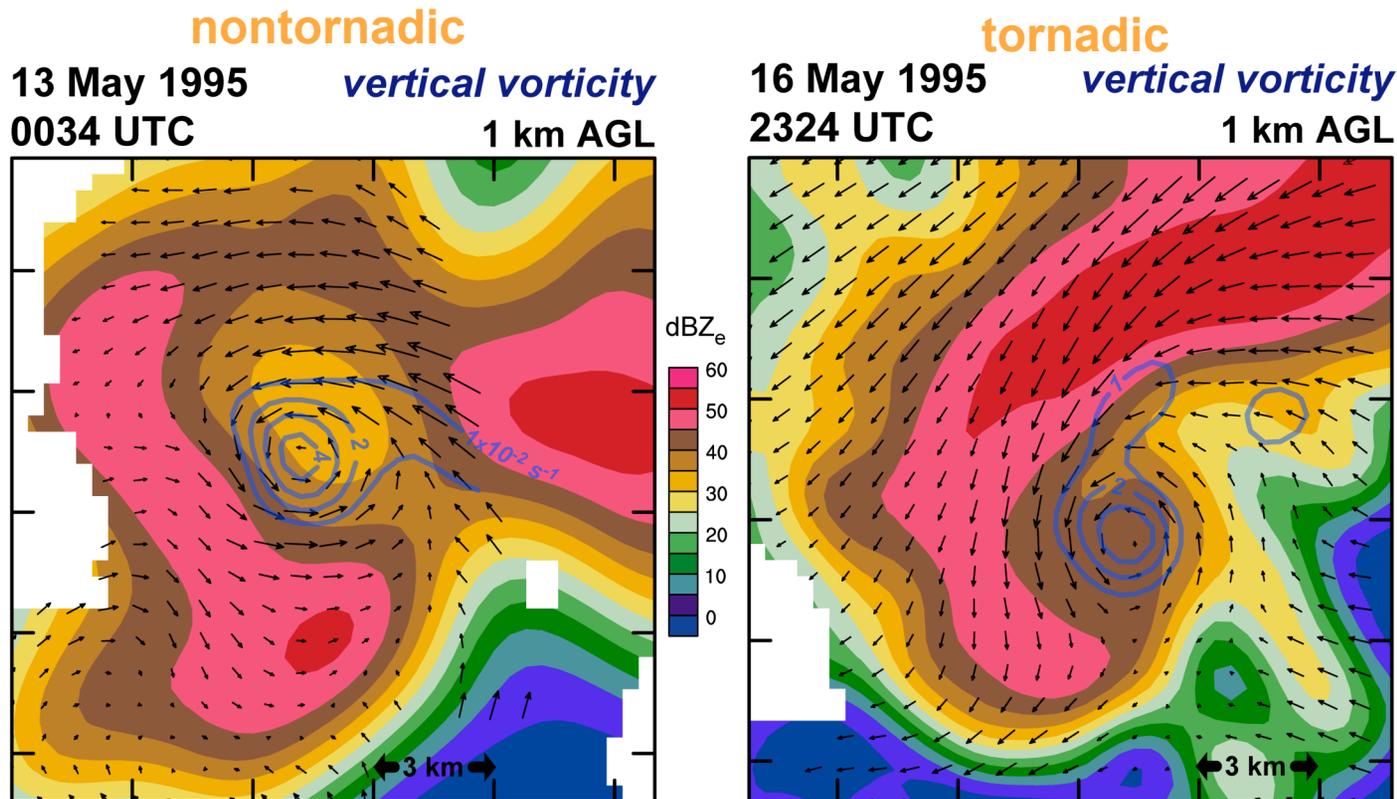


Tornadic supercell on 3 May 1999



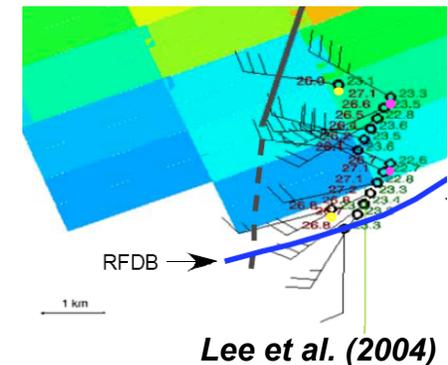
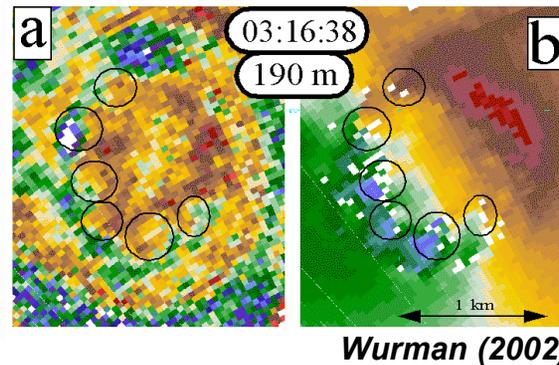
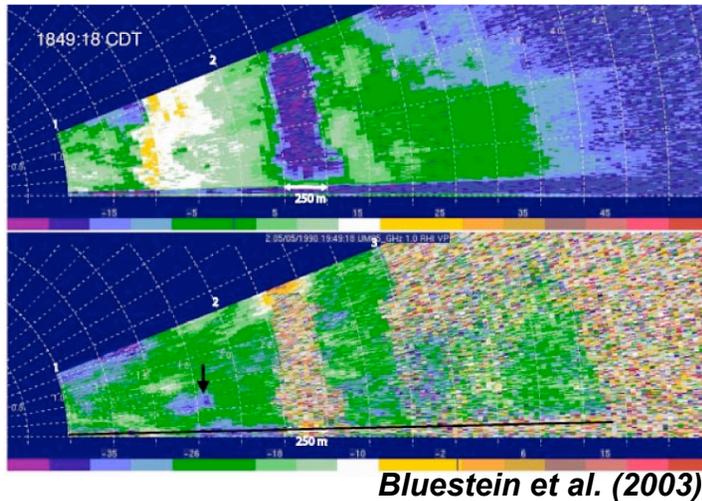
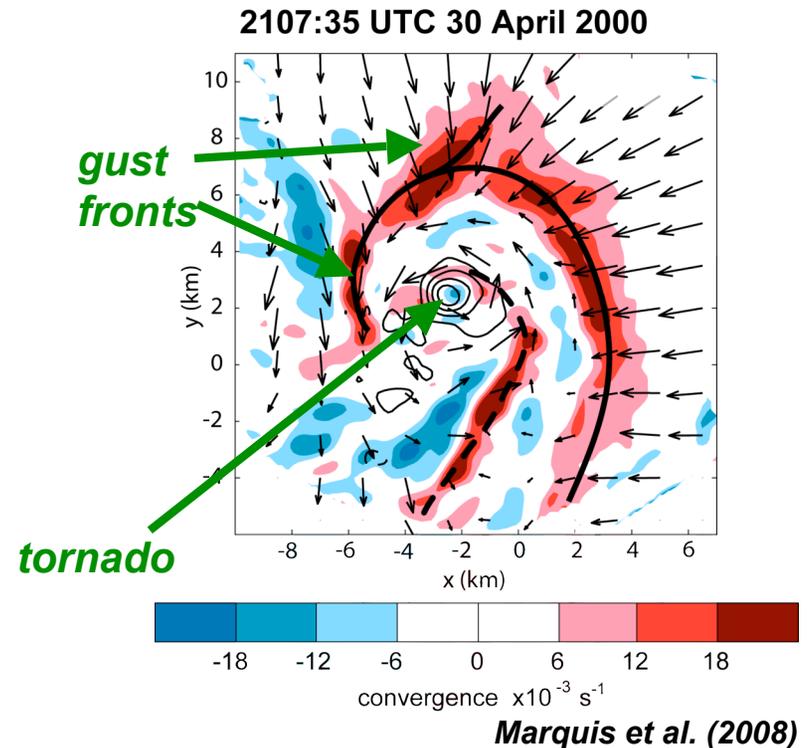
# Summary of VORTEX1 Findings

- **Striking kinematic similarities between tornadic and nontornadic supercells on the mesocyclone scale**
  - **88D at 30-60 km range:** marginally resolves mesocyclone scale
  - **VORTEX1:** observed mesocyclone scale well, but sub-mesocyclone scale only marginally resolved and tornado scale unresolved
  - **VORTEX2:** should observe sub-mesocyclone scale well and perhaps marginally resolve tornado scale on some occasions



# Smaller field campaigns after VORTEX1

- mobile dual-Doppler intercepts
- tornado-scale radar observations
- mobile mesonet intercepts

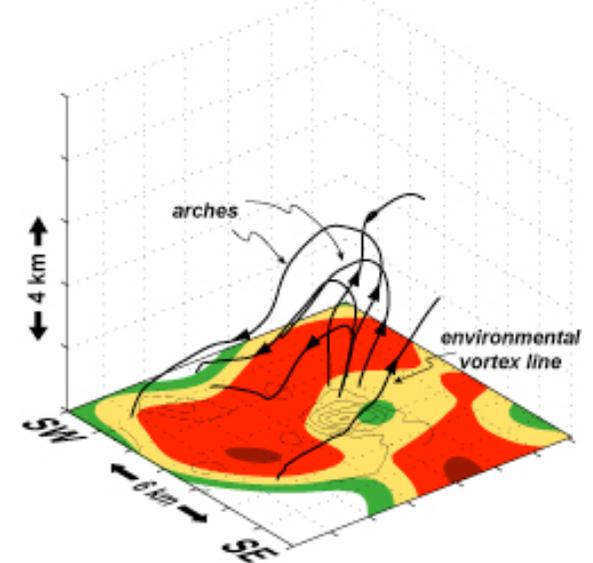
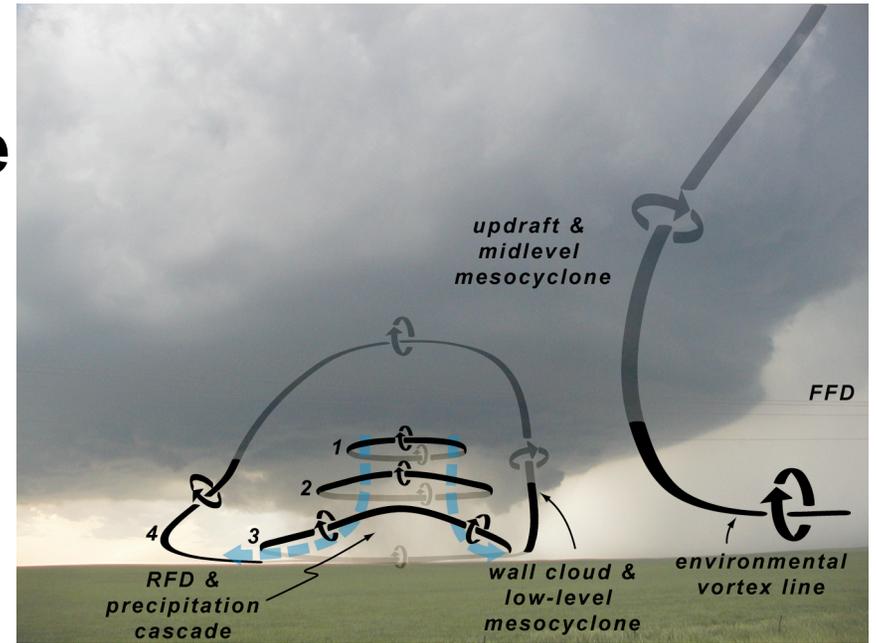
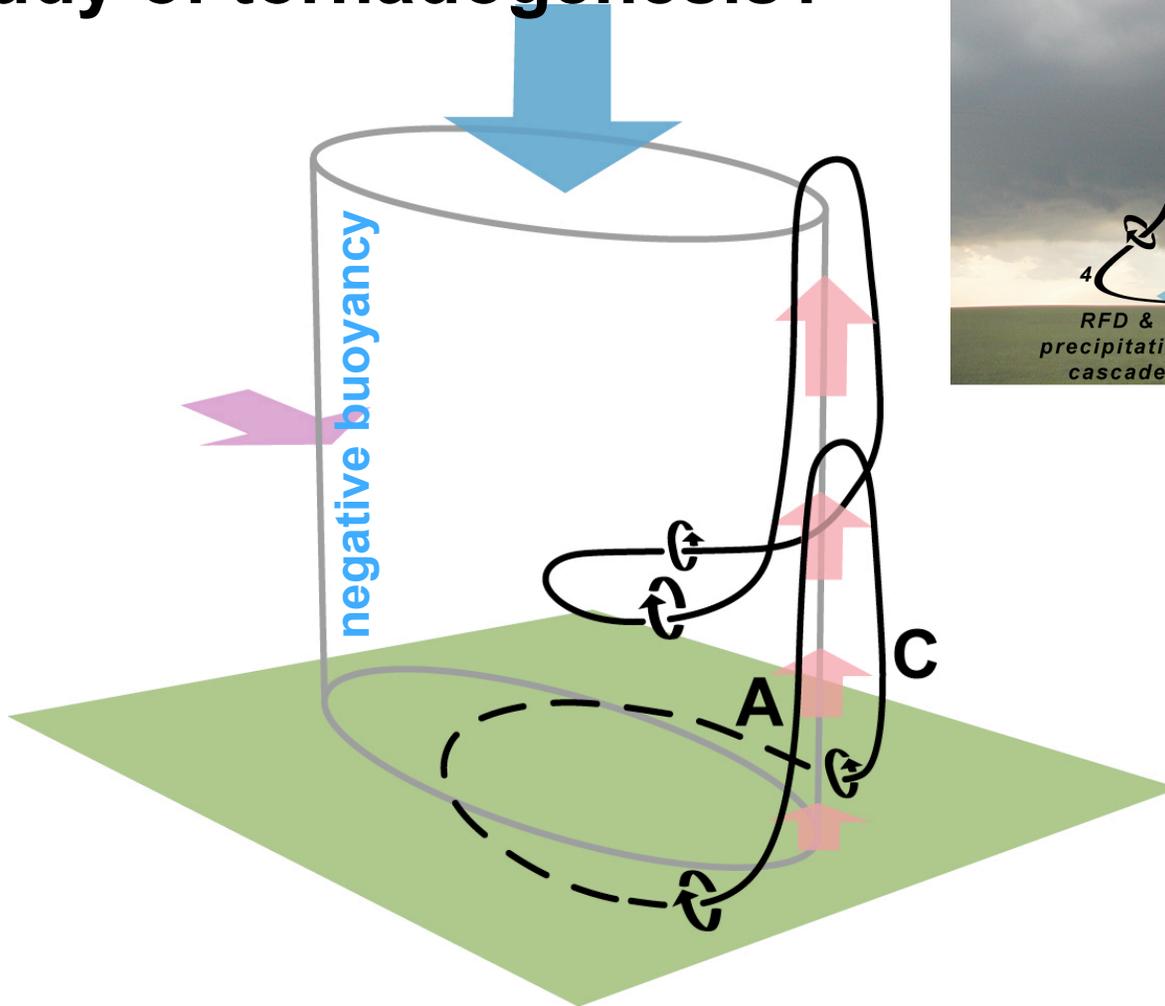


# VORTEX2

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# What are the biggest unanswered questions in the study of tornadogenesis?

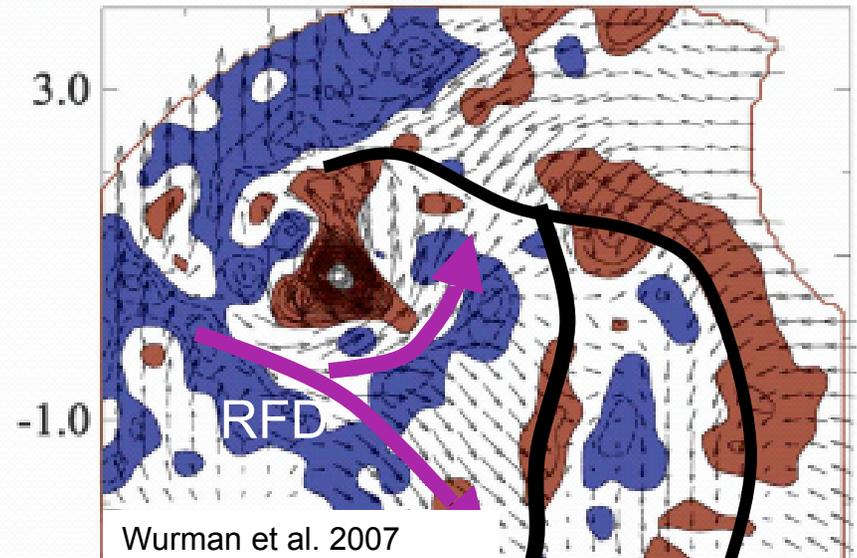
*purely baroclinic process*



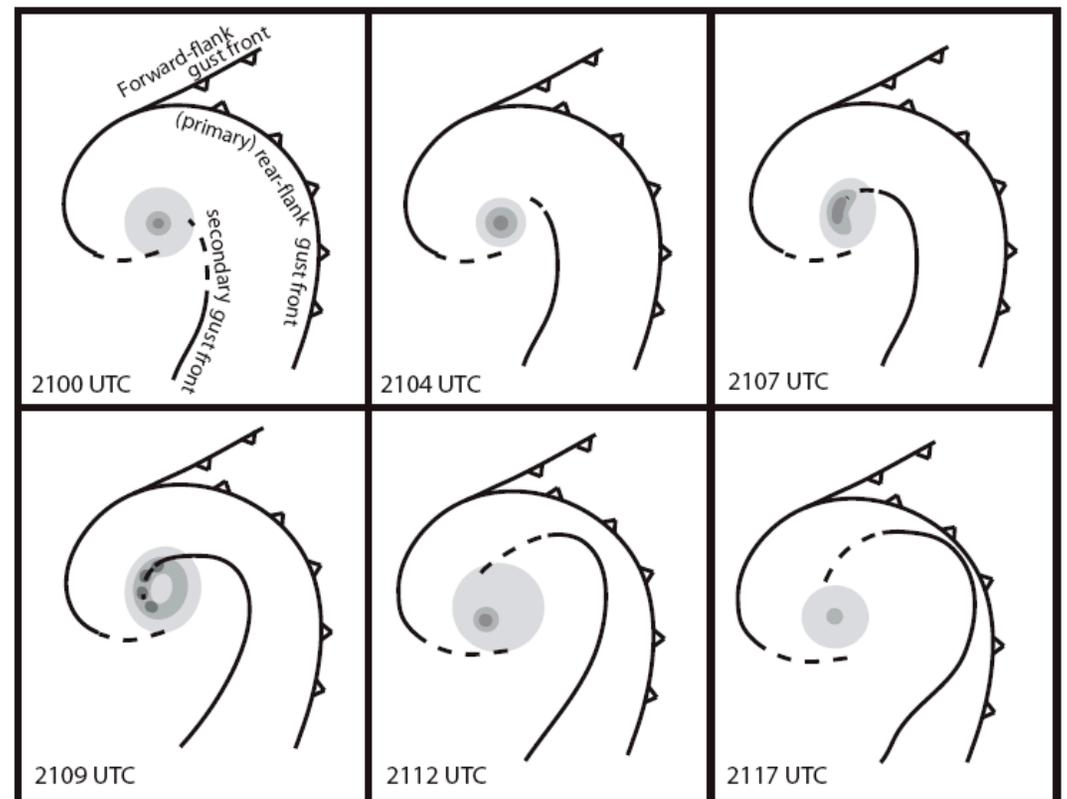
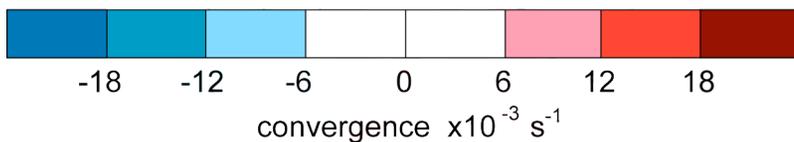
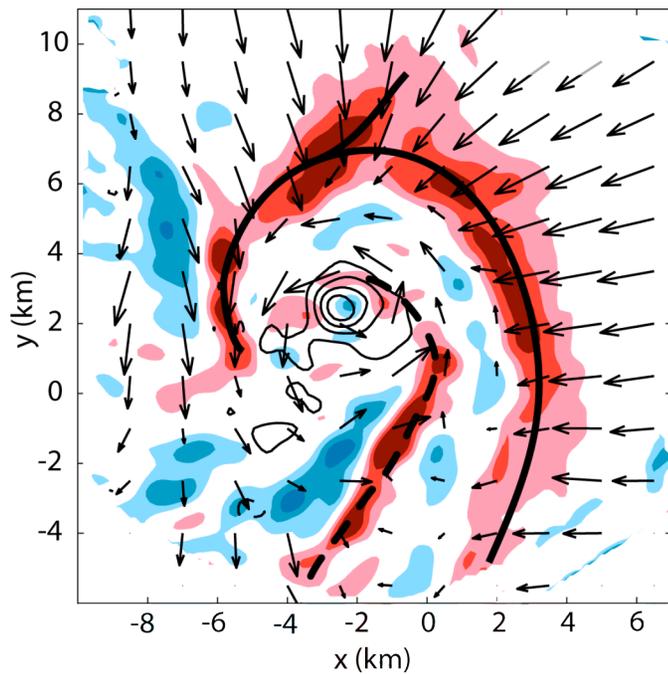
*observed case: vortex lines passing through low-level vorticity maximum form arches*

# What are the biggest unanswered questions in the study of tornadogenesis?

What role, if any, do secondary gust fronts play?



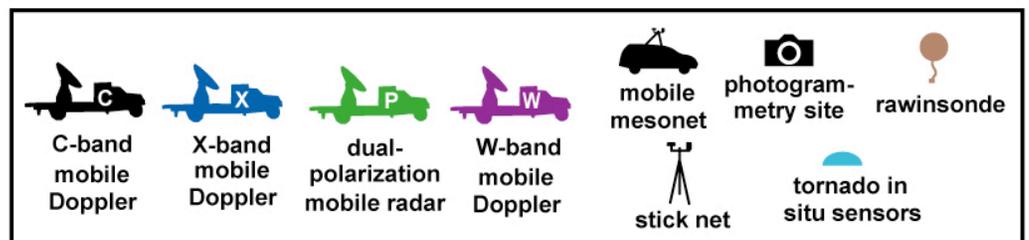
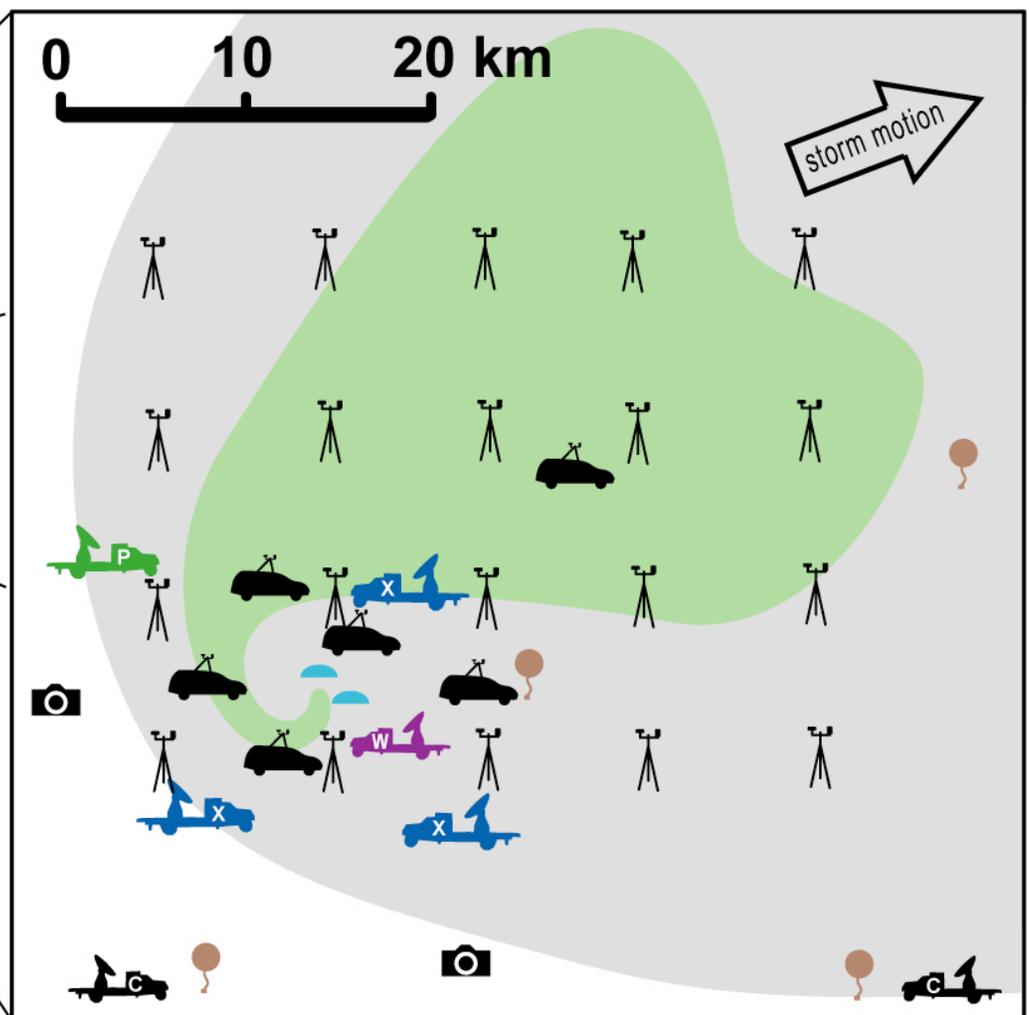
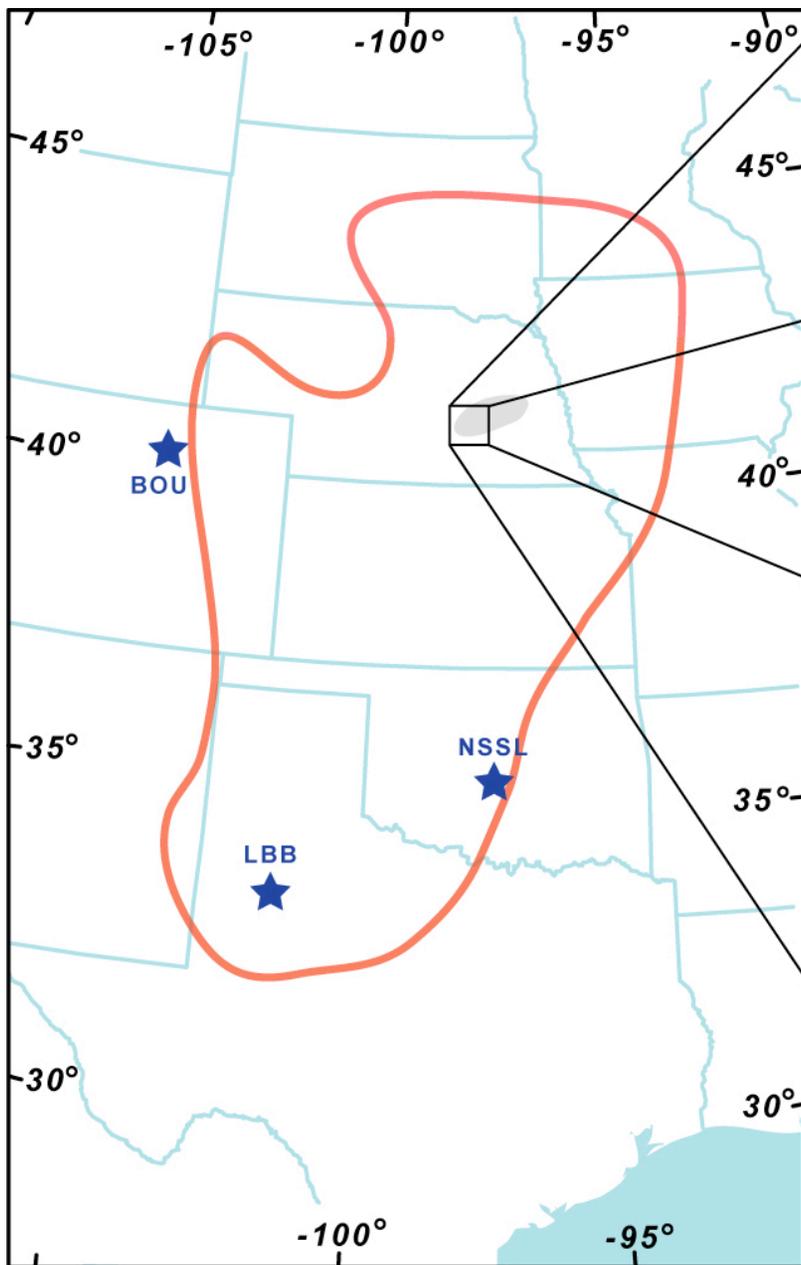
2107:35 UTC 30 April 2000



Marquis et al. 2008

# What is needed?

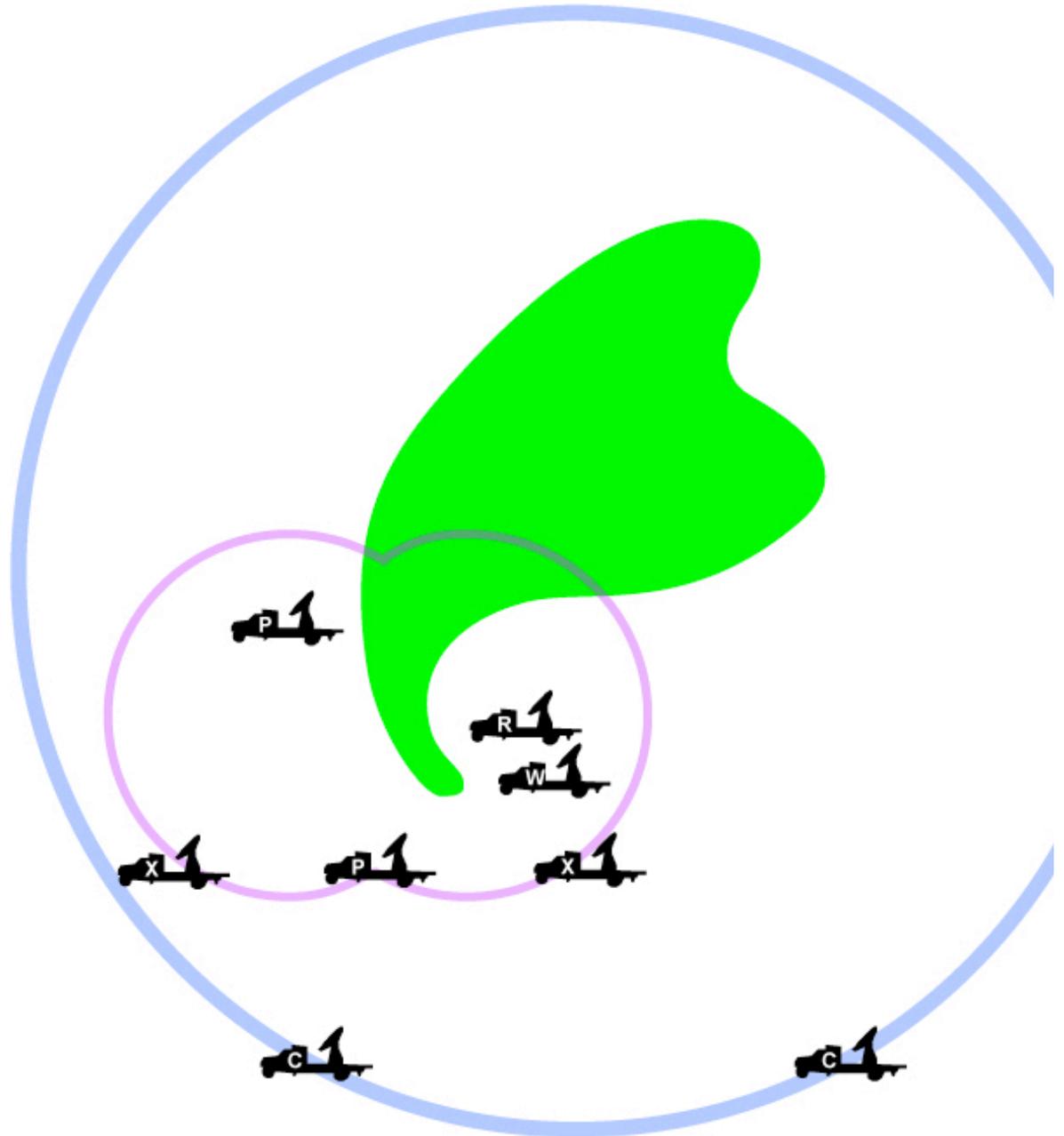
- **Integrated wind and thermodynamic data with high temporal resolution covering spatial scales from tornado to whole storm**
- **Detailed analyses of the vorticity budgets of tornadoes and their antecedent circulations**
  - precluded in the past by insufficient temporal and spatial resolution
- **Thermodynamic observations above the ground**
  - Previously limited to a paucity of direct measurements made by soundings and suspect indirect observations from retrievals based on Doppler wind syntheses
- **Dual-polarization measurements to characterize hydrometeors, particularly in the rear-flank region**



# VORTEX2 Participating Instruments

- Radars:
  - 2 X-band DOW mobile radars
  - 2 C-band SMART-Radar mobile radars
  - Rapid-scan X-band DOW mobile radar
  - NOXP, X-band, dual-pol mobile radar
  - W-band UMASS mobile radar
  - XPOL, X-band, dual-pol mobile radar
- Mobile mesonets
- Mobile soundings
- Stick Net
- In situ tornado probes
- UAV systems
- Photography units

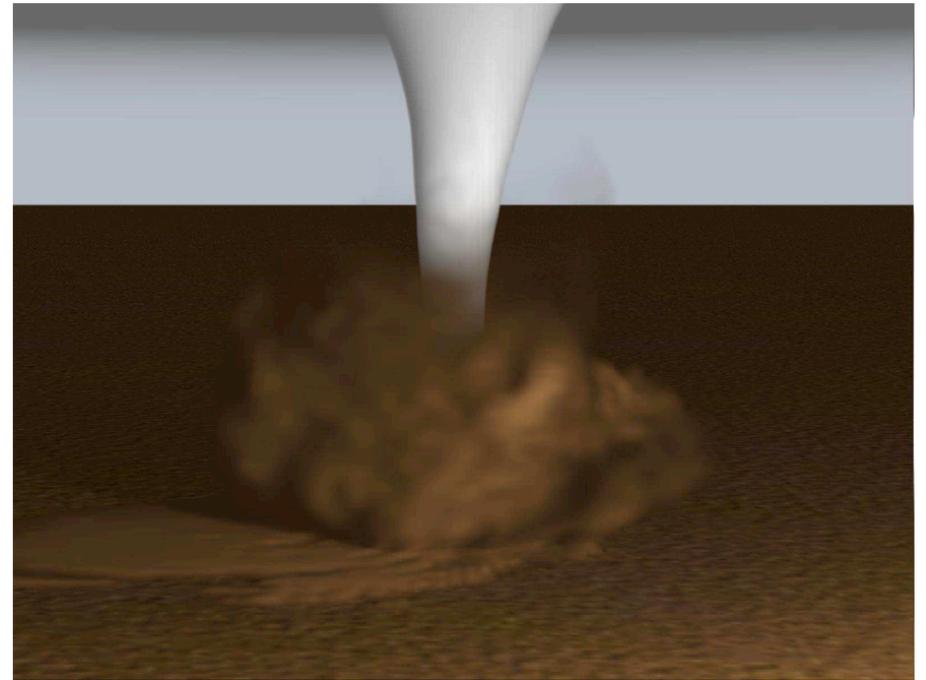
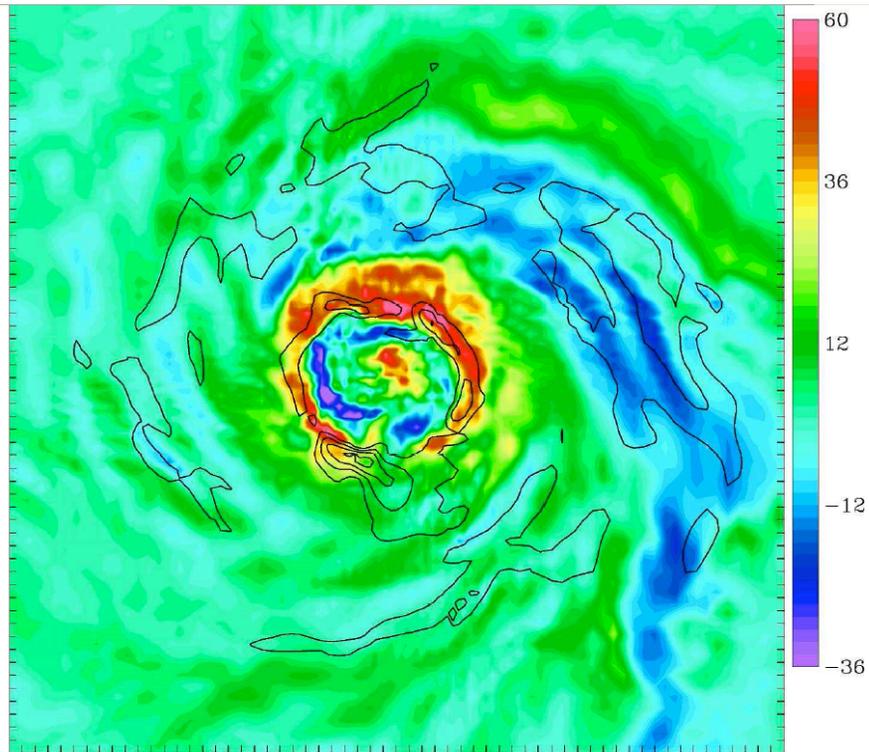
# Nested deployment strategy



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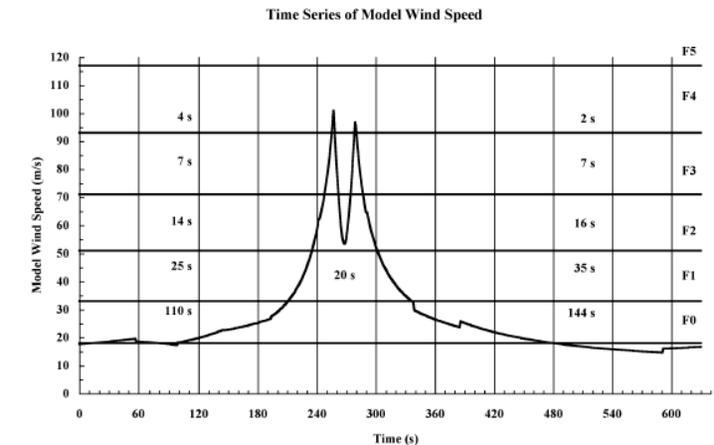
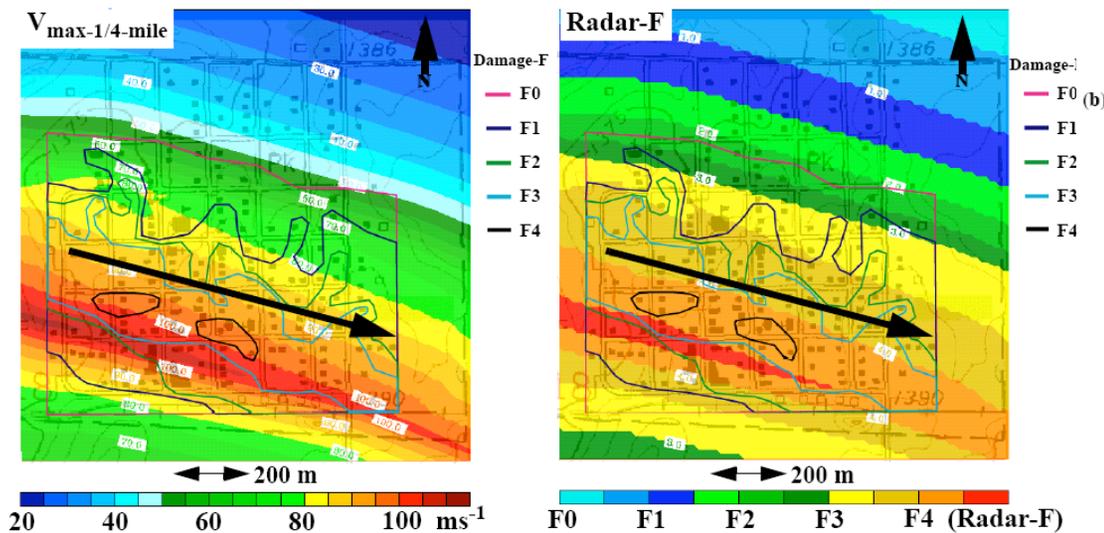
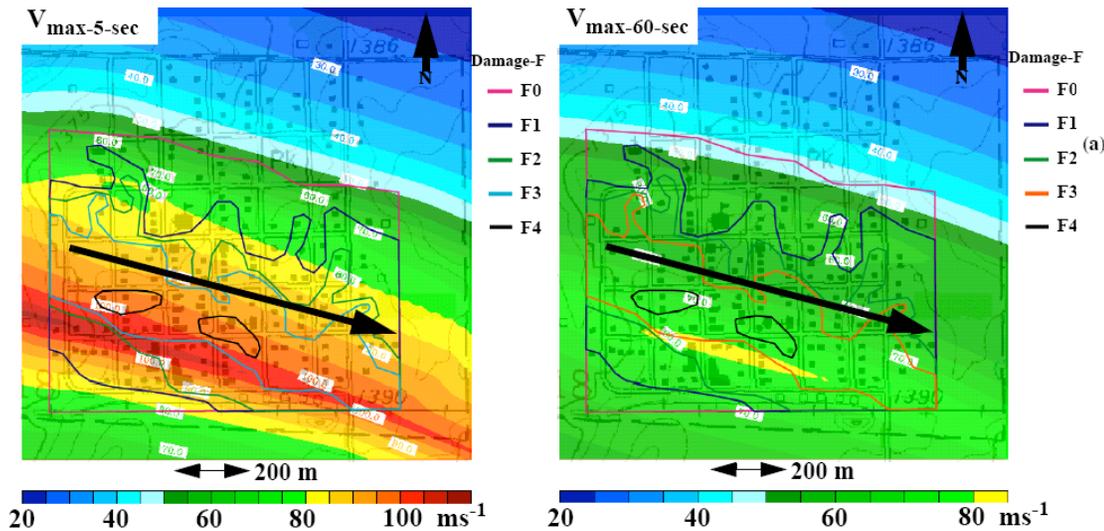
# What are the biggest unanswered questions regarding the near-ground wind field in tornadoes?



Lewellen et al. (1997,2000,2004)

- **How valid is our understanding of the corner flow region and low-level structure of tornadic flow, which is based on laboratory studies, numerical simulations, and very limited observations?**

# What are the biggest unanswered questions in the study of tornadoes?



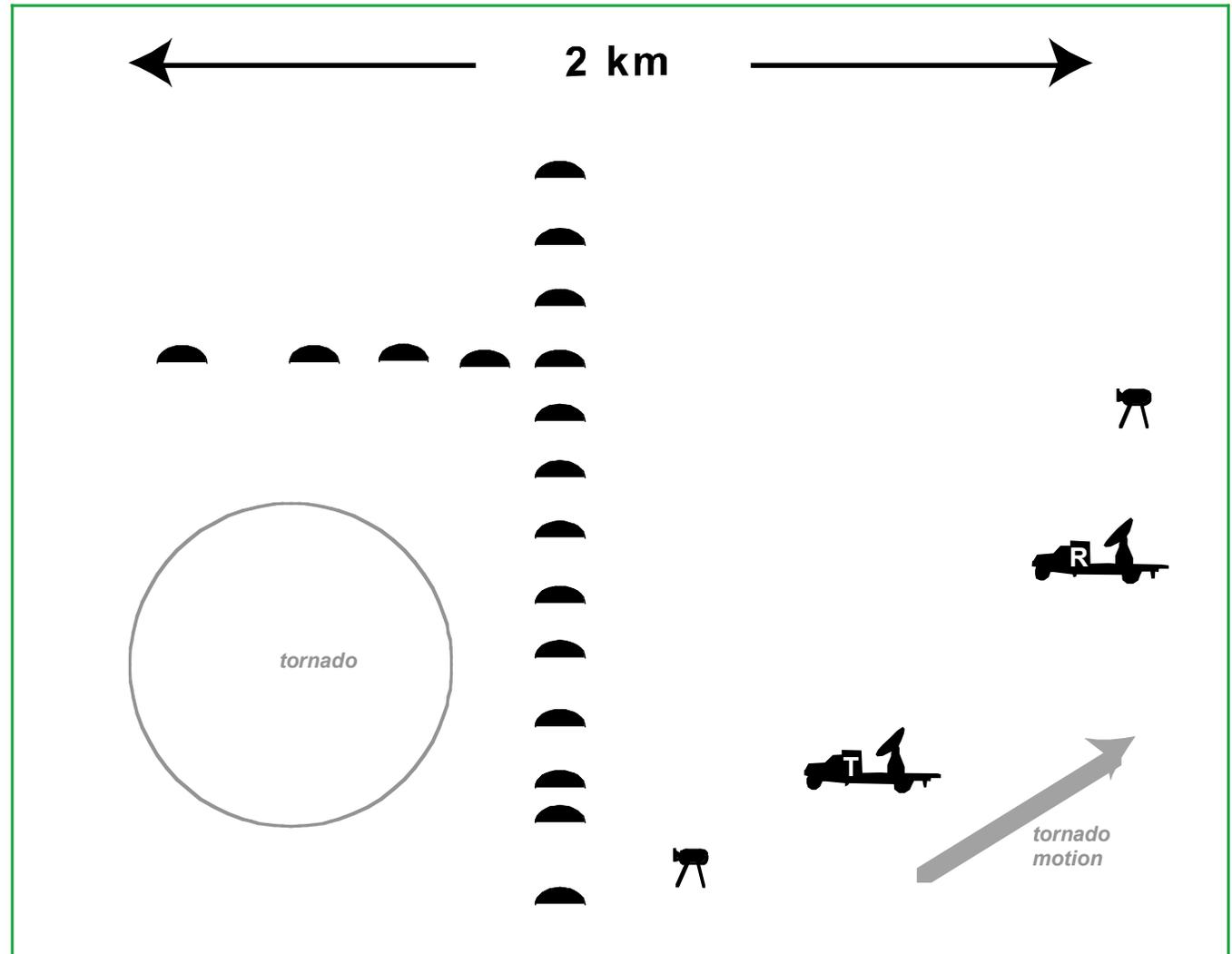
Wurman and Alexander (2004)

**What is the relationship between observed winds and structural damage?**

# What is needed?

- **Observations in the corner flow region**
  - Radars must be close to sample low levels
  - Rapid update beneficial
  - In situ measurements
- **Photogrammetry**
- **Damage Surveys**

# Radars and rapidly deployable in situ probes (“plunger net?”)



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# Storm-environment interactions

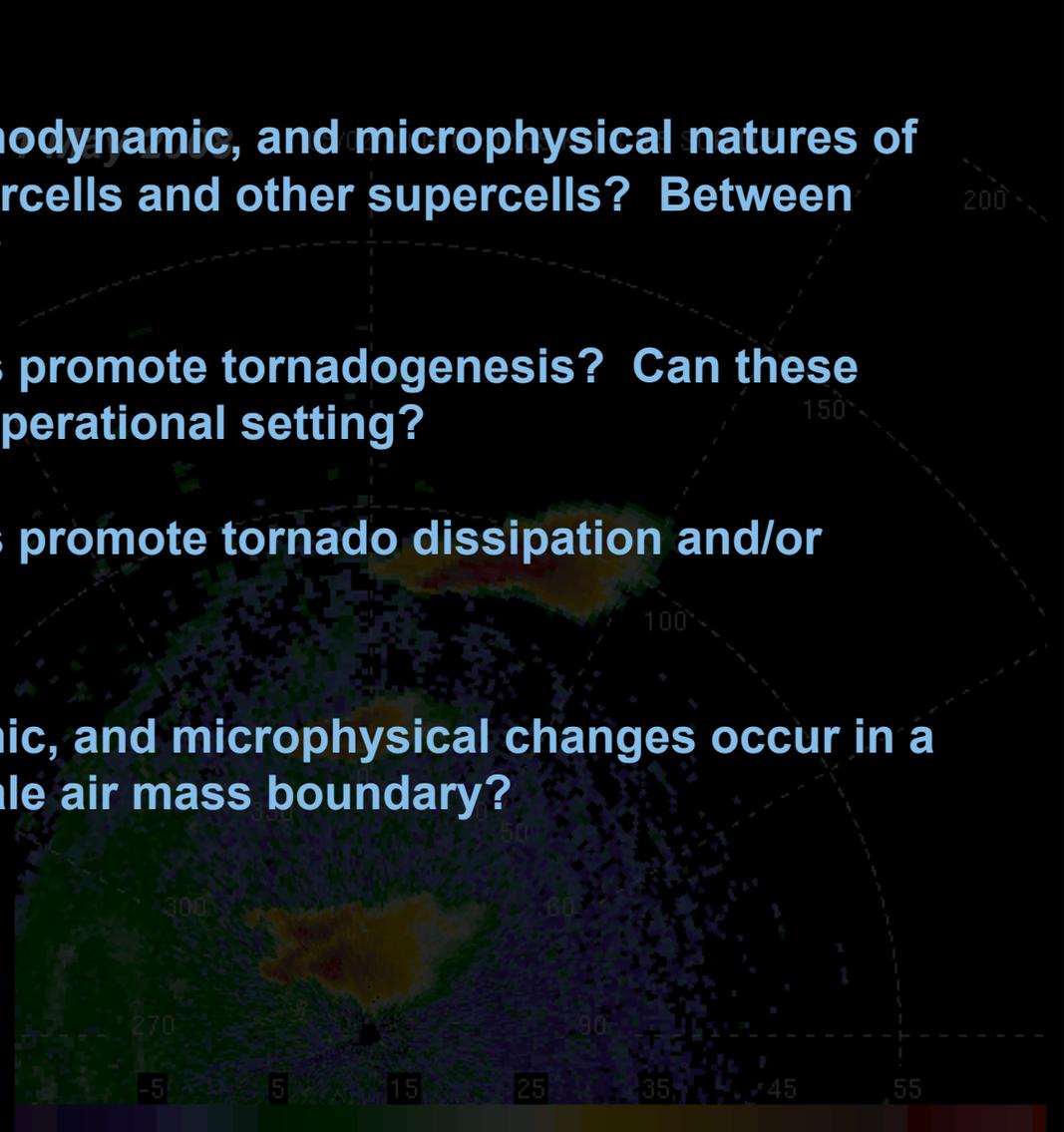
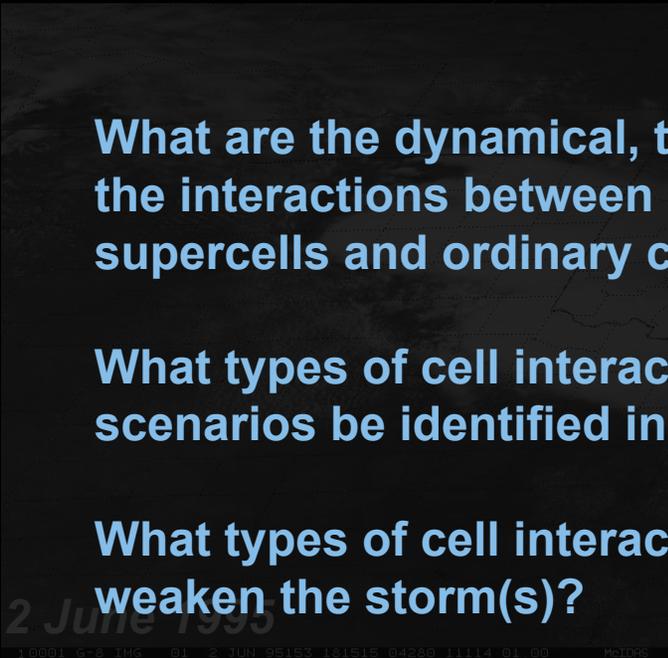
(on days when storm motion or road network is not conducive to tornadogenesis mission)

What are the dynamical, thermodynamic, and microphysical natures of the interactions between supercells and other supercells? Between supercells and ordinary cells?

What types of cell interactions promote tornadogenesis? Can these scenarios be identified in an operational setting?

What types of cell interactions promote tornado dissipation and/or weaken the storm(s)?

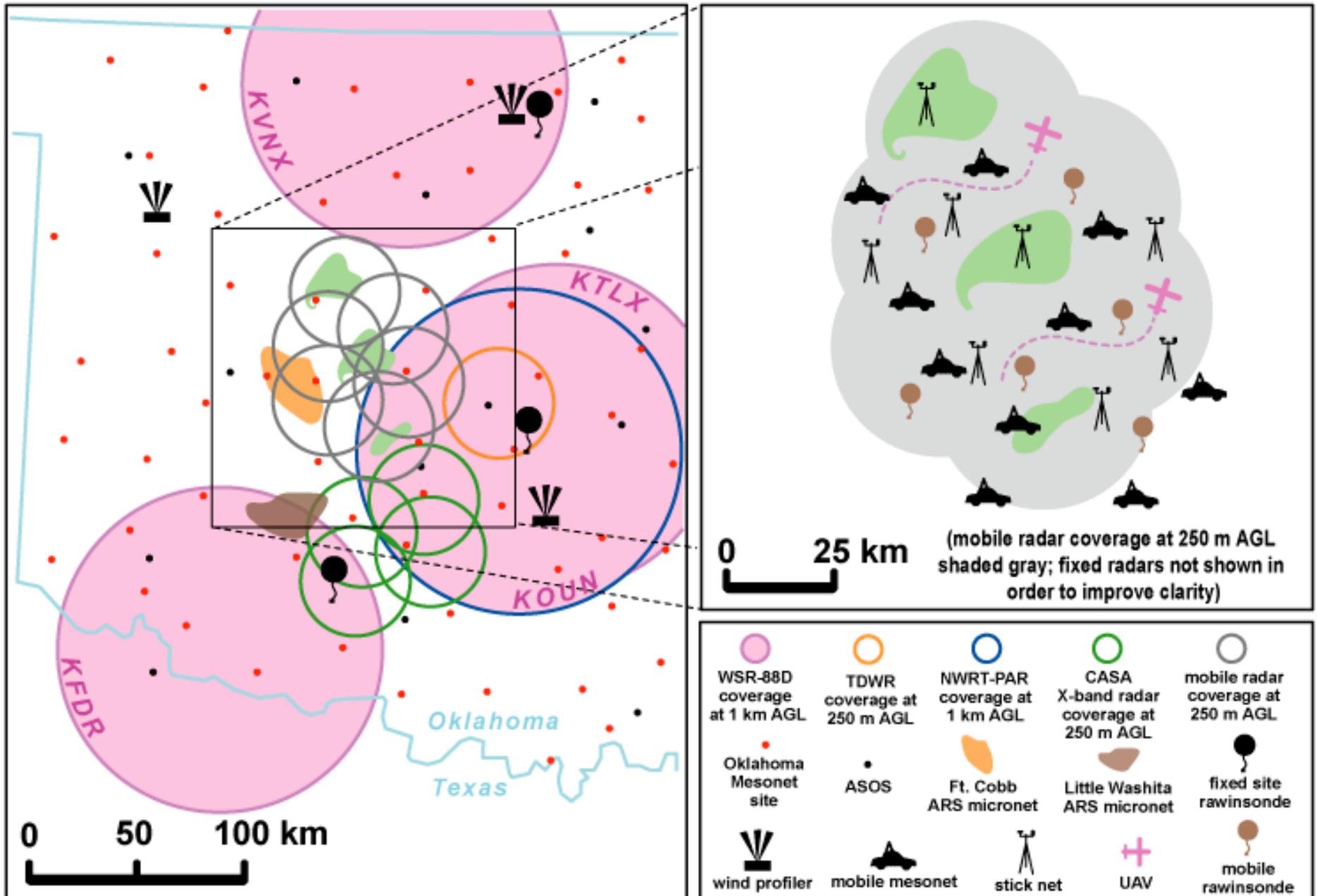
What kinematic, thermodynamic, and microphysical changes occur in a storm as it crosses a mesoscale air mass boundary?



# What is needed?

- **Largely the same measurements as needed for tornadogenesis, plus:**
  - Larger-scale environment including other storms and mesoscale boundaries
- **Fixed assets likely required**
  - Will favor central Oklahoma when possible

# fixed observing systems



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# Storm-Scale NWP Efforts

- Real-time high-resolution (1-2 km) storm-scale ensemble and deterministic forecasts
- Impact of microphysical processes and their parameterizations on cold pools, gust fronts, etc. as related to tornadogenesis
- Assimilation of data for the understanding of dynamics as well as predictability at the thunderstorm through tornado scales

# Federal Aviation Administration (FAA) regulatory clarification circa 2002.

- Unmanned aeronautical vehicles (UAVs), including model aircraft, are subject to *all* civil aviation regulations except when operated at a model aircraft field.
- For example, they must be operated by licensed pilot, rated for instrument flight rules (IFR) if the plane is operated out-of-sight.
- All safety, communication, and navigation capabilities of civilian aircraft, etc. Exceptions granted only through FAA Certificate of Authorization or Waiver (COA).
- Much confusion and people “exempting themselves.”

# COA

- Prove to the FAA that a UAV operation poses no risk of injury or property damage to other aircraft or those on the ground.
- Eventually regulations will replace the COA, and may depend on the size of the aircraft.

# **VORTEX2 UAS approach to regulations**

- No self-exemption.
- Collaboration between OU, NU, Rasmussen, and CU RECUV.
- Incremental approach to building UAS that can satisfy FAA.
- CU RECUV is one of only a few organizations to receive a COA to date.

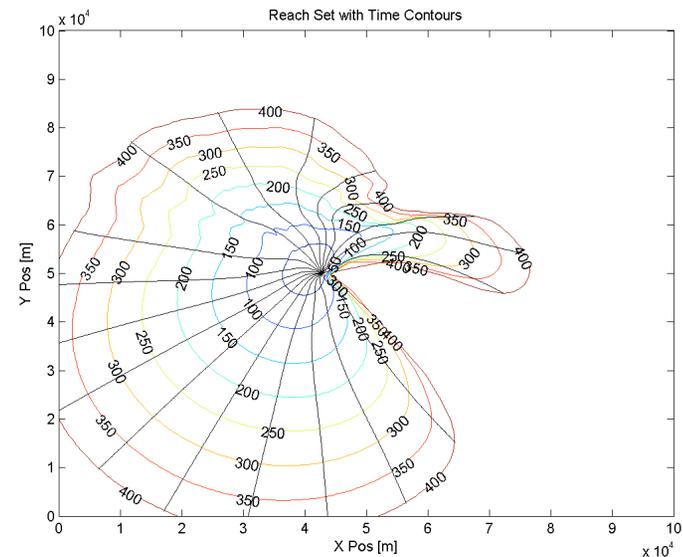
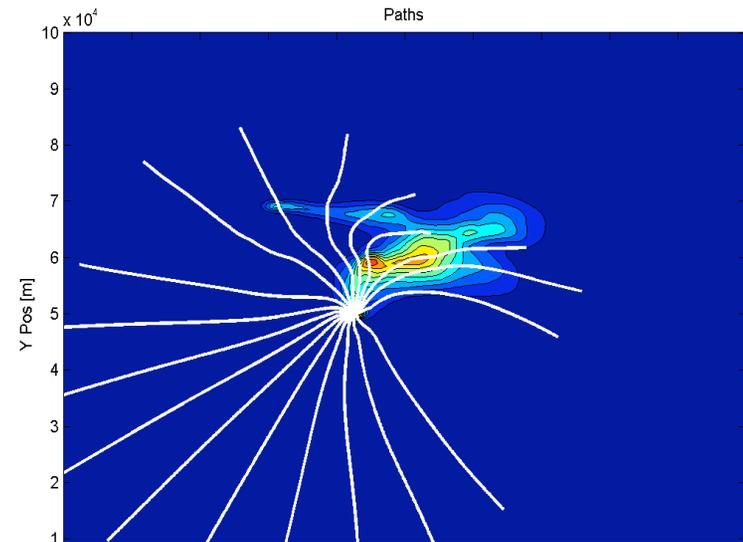
# VORTEX2 UAS approach to regulations

- Must identify an aircraft suitable for supercell operations.
- Must identify takeoff/landing sites
- Must have pilots and spotters for each aircraft who have passed FAA medical exam requirements.
- Must have aircraft in sight.
- COA is uncertain.



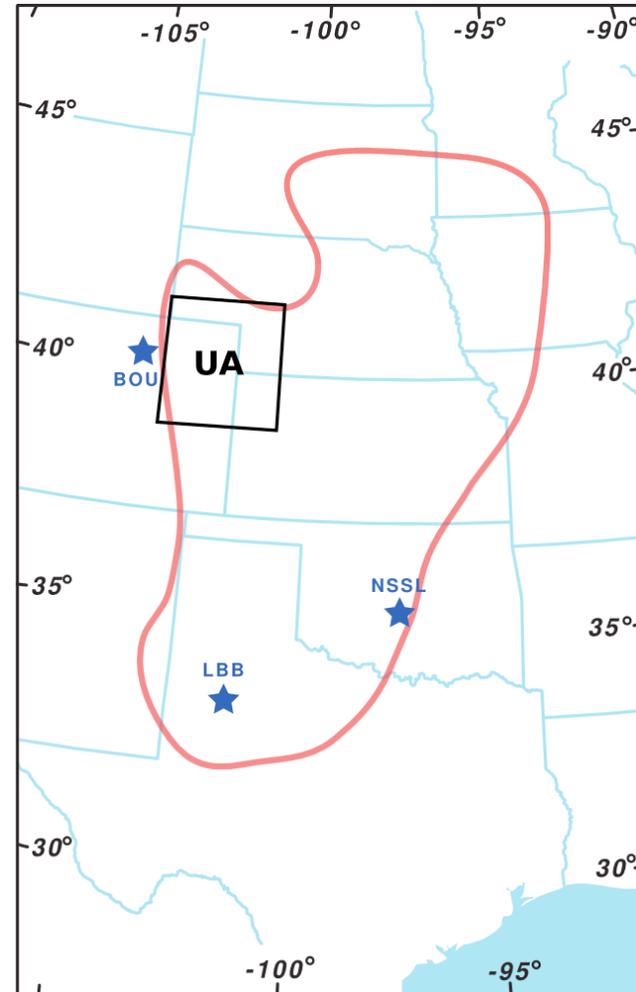
# VORTEX2 UAV

- Work supported by NSF.
- Aircraft chosen through detailed modeling studies using supercell simulations (Straka model) and aerodynamic models.
- Several aircraft will be modeled, including the Velocity XL.
- Once a suitable aircraft is identified, a COA application will be written.



# VORTEX2 Domain

- Because a COA for wide-ranging operations across the VORTEX2 domain is not yet possible, we will operate in a subdomain whenever the VORTEX2 armada is present.
- Domain could be altered somewhat for second season.



# VORTEX2 Emphasis

- This is a Pilot Program with emphasis is on gaining experience and capabilities for UAV sampling in supercells.
- Targets will be whatever phenomena can be confidently sampled, including supercell rear-flanks and updraft regions, forward flank baroclinic zones, and pre-existing boundaries.
- Logistics will be the primary factor in operations.

<http://www.vortex2.org>