Tornadoes: *Increasing our understanding through basic science*

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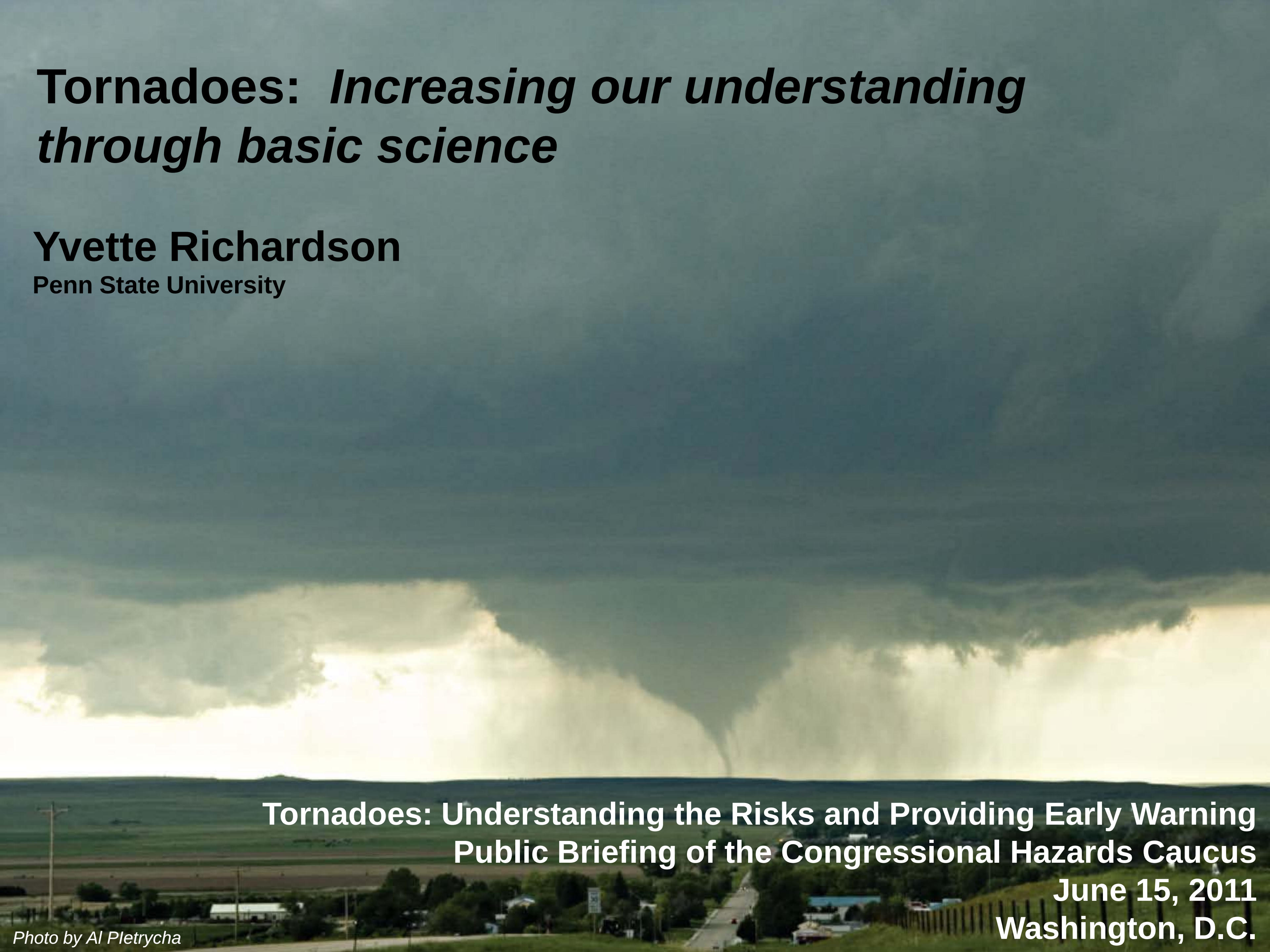


Photo by Al PIetrycha

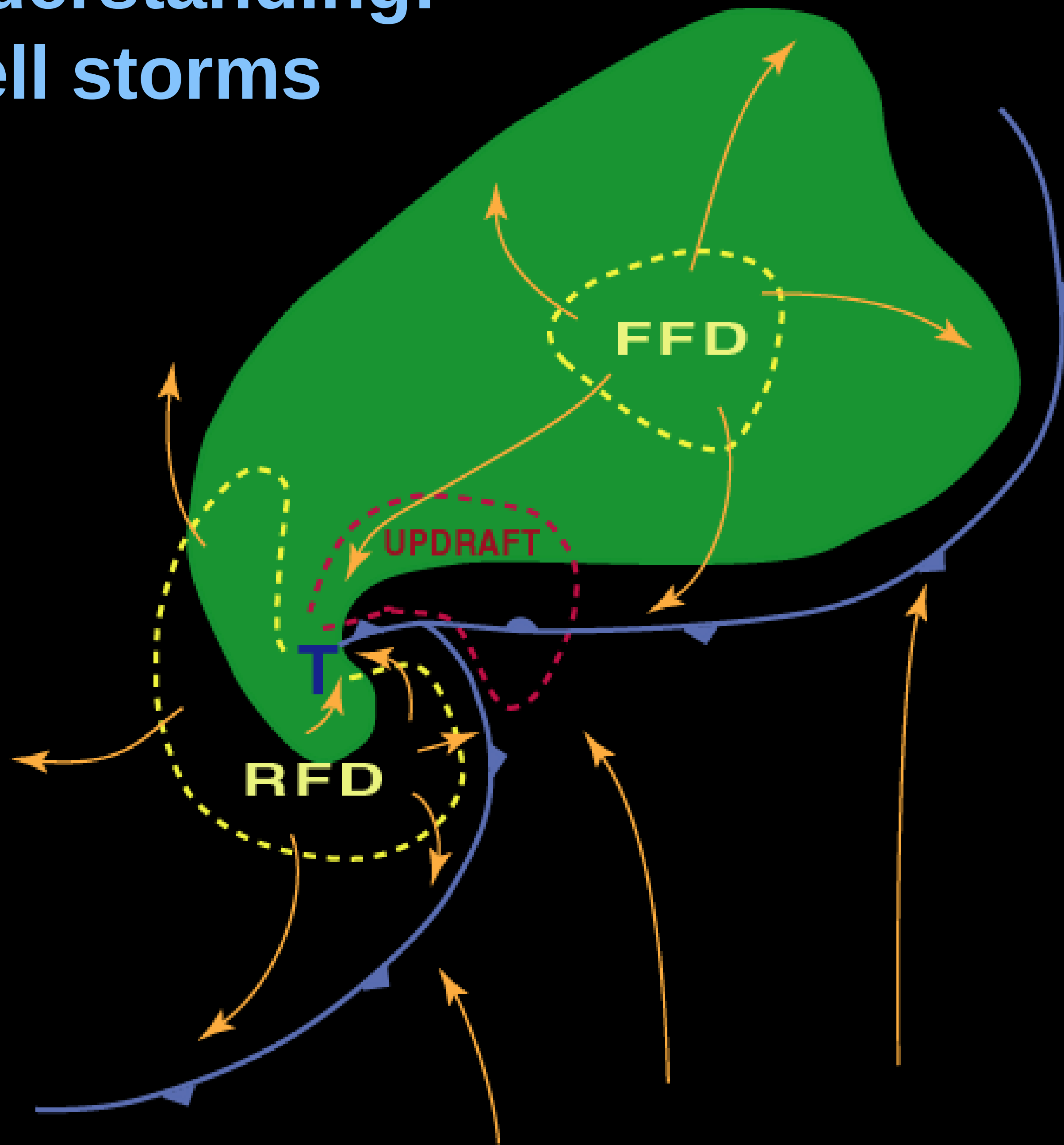
Tornadoes: Understanding the Risks and Providing Early Warning
Public Briefing of the Congressional Hazards Caucus
June 15, 2011
Washington, D.C.

Tornadoes

- What do we know well?
- What do we still struggle to understand?
- How do we gain new understanding from basic research?

Current understanding: Supercell storms

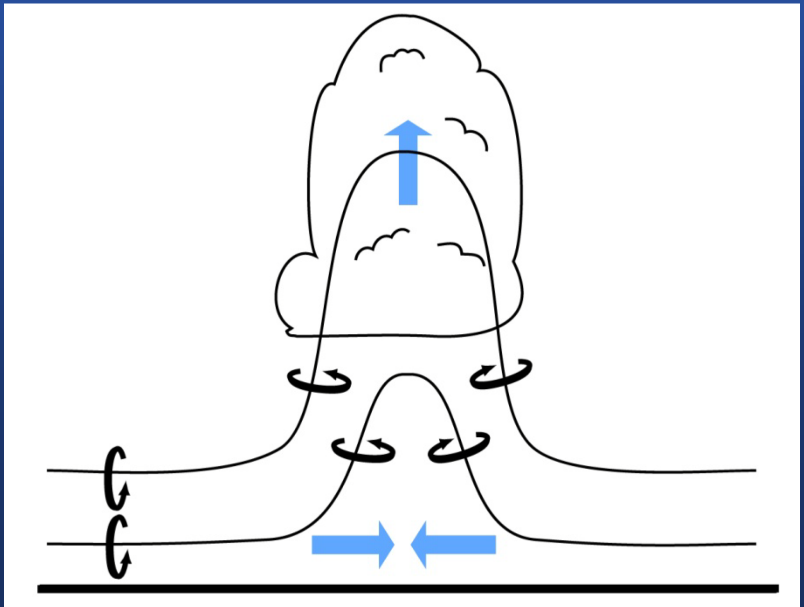
Most strong and nearly all violent tornadoes are associated with supercell storms that have an area of upward motion and two main areas of downward motion



after Lemon and Doswell (1979)

Current understanding: Supercell storms

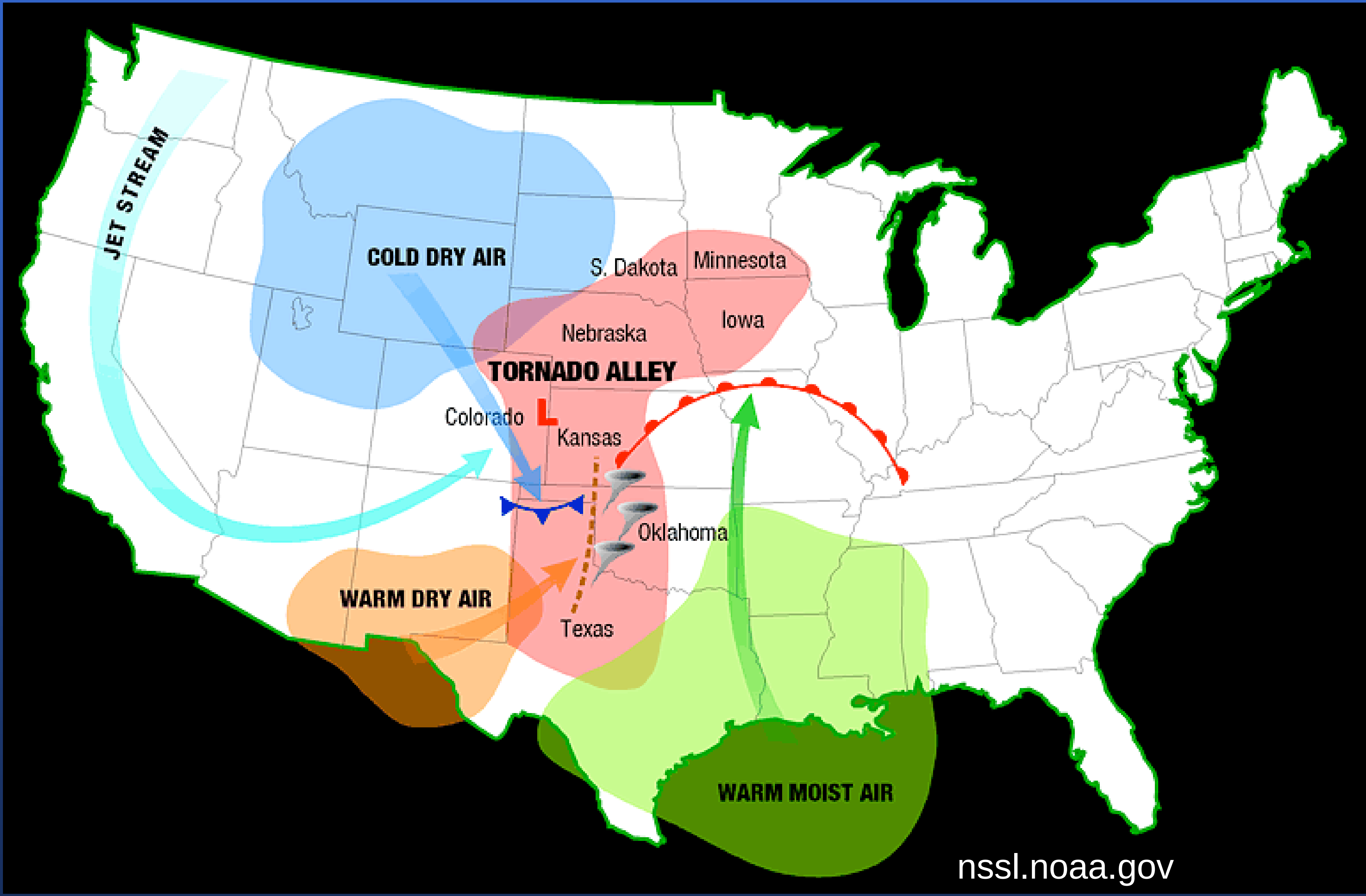
Supercells acquire rotation *aloft* from the spin in the environment
This is why supercell occurrence follows the jet stream (strong winds at high levels)



Markowski and Richardson (2009)

Supercells also need warm, moist air at the surface and cold air aloft so that the low-level air becomes buoyant if it gets lifted

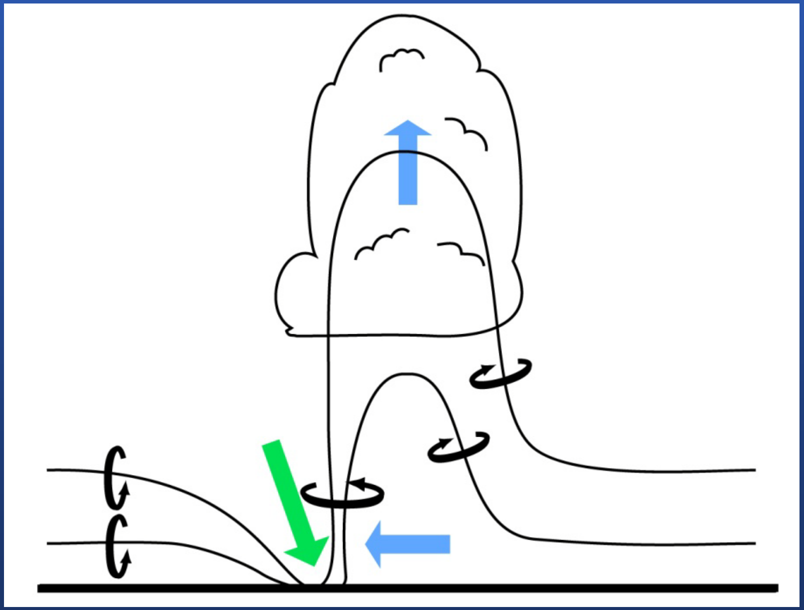
winds that change direction and/or speed with height
warm, moist air underneath cold air
thin layer of very warm air between them (allows energy to build up)



nssl.noaa.gov

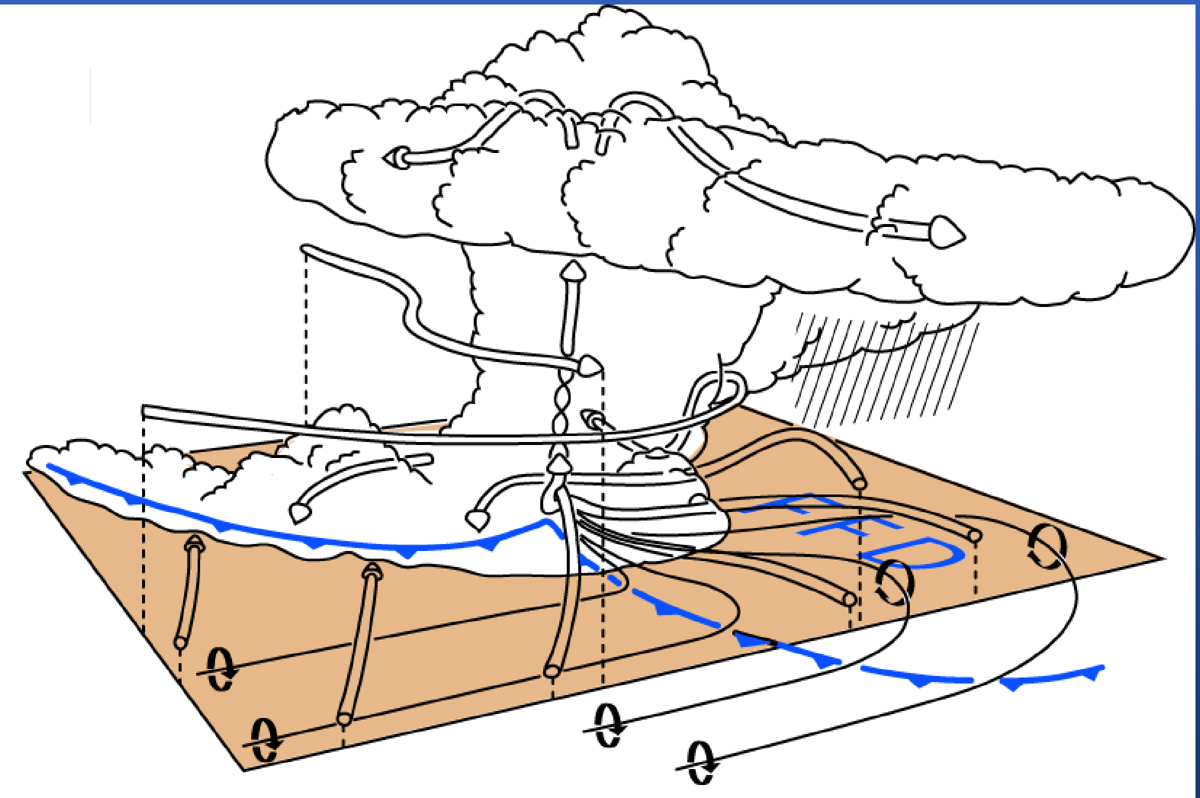
Current Understanding: What we know about making a tornado

1) Need to get rotation vertically oriented and get it to the ground (requires a downdraft)



Markowski and Richardson (2009)

Current Understanding:
The importance of storm-generated spin



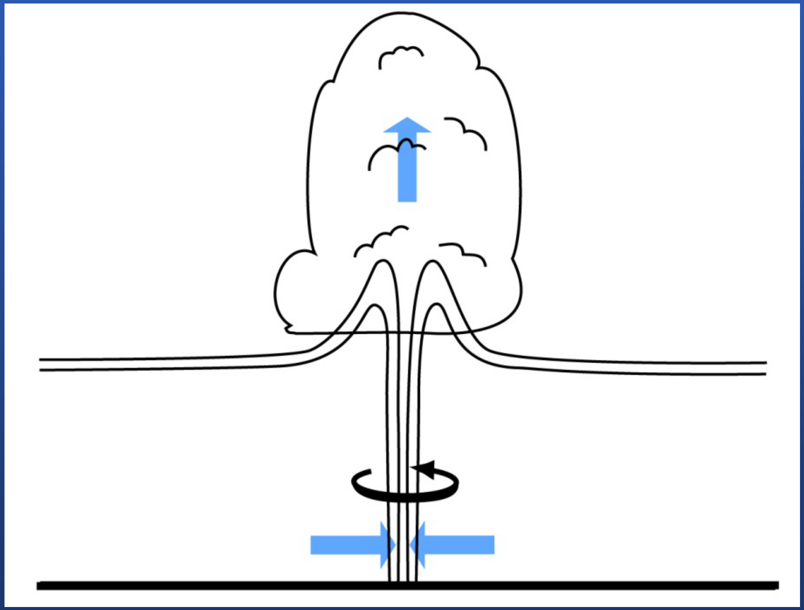
adapted from Klemp (1987)

Spin (about the horizontal) can also can be generated by temperature variations associated with a storm's cool outflow

This can be tilted to develop low-level rotation in supercells.

Current Understanding: What we know about making a tornado

2) Need to “Stretch” the rotation (requires getting the rotation under an updraft)



Markowski and Richardson (2009)

Outstanding questions

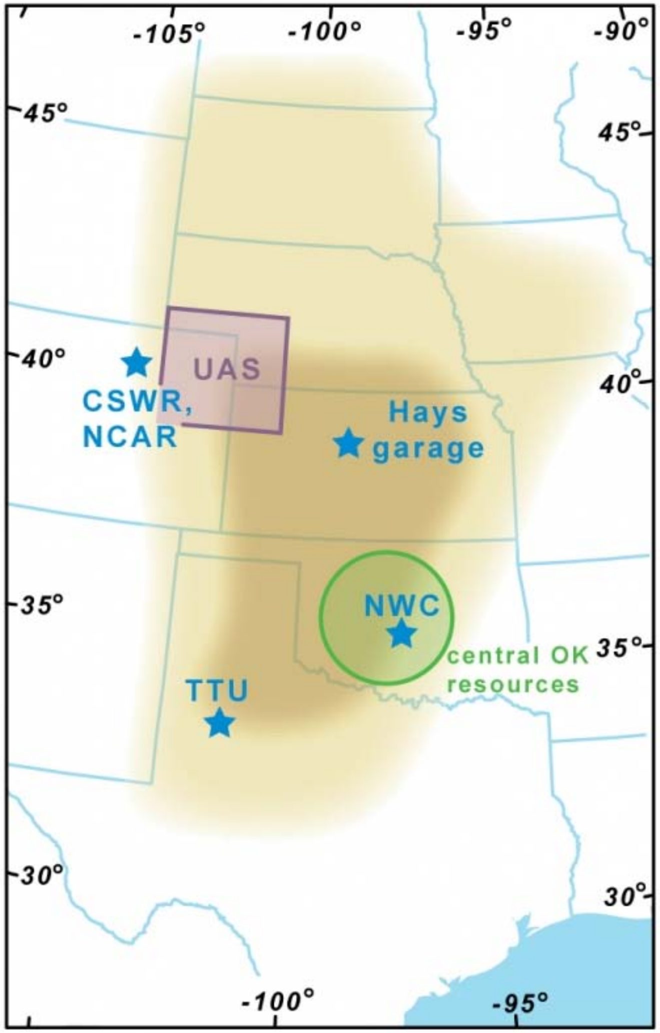
- Why do some supercells succeed in this process while others fail?
- Why do some tornadoes go on to last a long time while others quickly die?
- What is the relationship between the rotation aloft and that near the surface?
- What are the relative contributions from spin in the environment and storm-generated spin?
  - Models suggest storm-generated spin is important, but we know models have a hard time getting the temperature variations under the storm right because they have a hard time getting the rain and hail distributions right
  - Observations of both the winds and the temperatures on all the scales needed (i.e., over the whole storm but also in detail near the tornado) are RARE

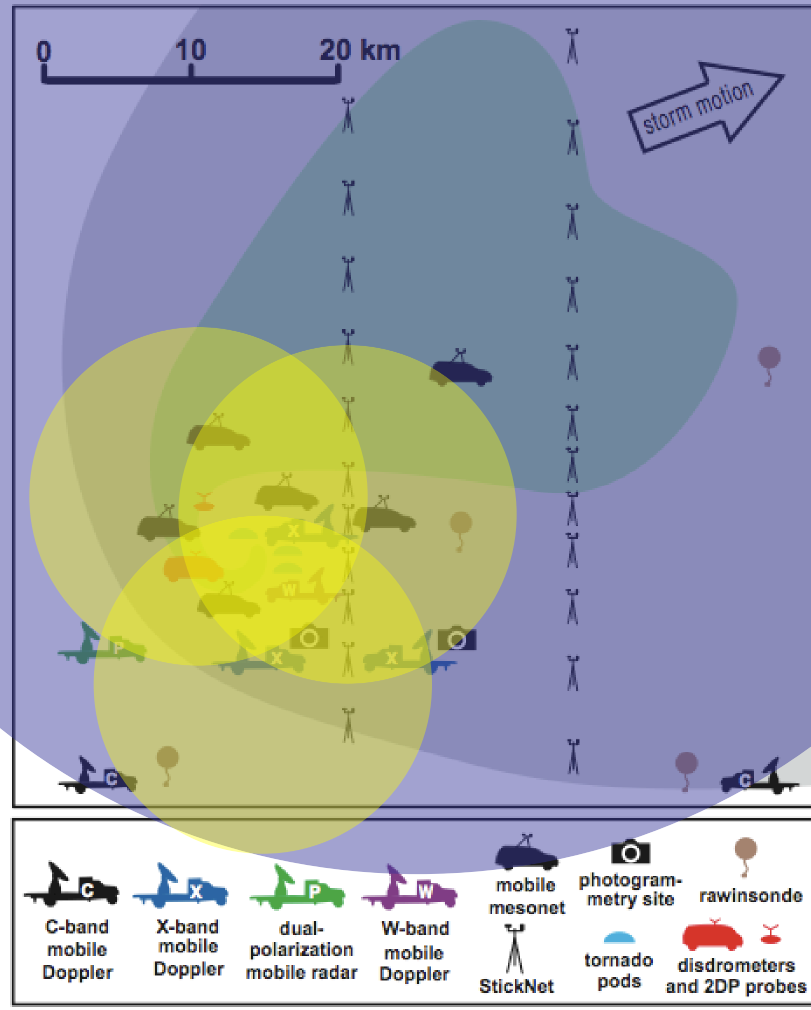
PENNSTATE 1855

VORTEX2

- 10 May – 13 June 2009, 1 May – 15 June 2010
- Largest field project ever to study tornadoes
- 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
- Funded by National Science Foundation and National Oceanic and Atmospheric Administration ($10+ M)

"Fully nomadic"





storm-scale radars (C-band)

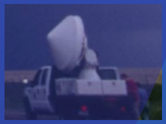
SR1

SR2

mesocyclone-scale radars (X-band, two dual-pol)

DOW6

DOW7



UMASS XPOL

NOAA XP

tornado-scale radars (W-, Ka-, X-band)

RapidScan DOW

UMASS W-band

CIRPAS MWR-05XP (phased array)

TTU Ka-band

in situ tornado probes (12)

rawinsondes (4)

StickNet (24)

mobile mesonet (8-10)

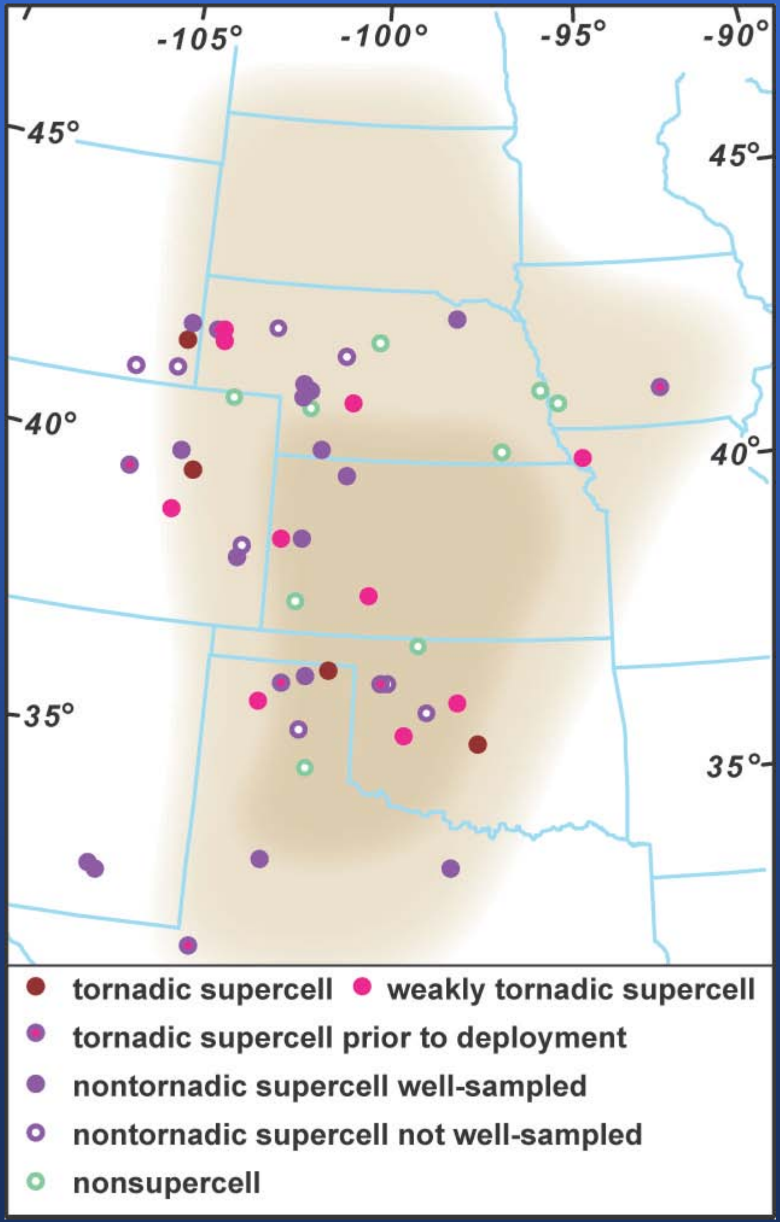
laser disdrometers and video particle probes

UAS

coordination vehicle

V2 Operations Center (VOC) in Norman, OK

VORTEX2 Highlights



- **Data collected on 43 supercells**
  - **13 of these were tornadic during our deployment**
- **~30,000 miles driven by each vehicle (times ~50 vehicles = ~1.5 million vehicle-miles > 50 times around the equator)**
- **~6800 hotel rooms (~100 participants plus media)—Logistics Coordinator was indispensable**

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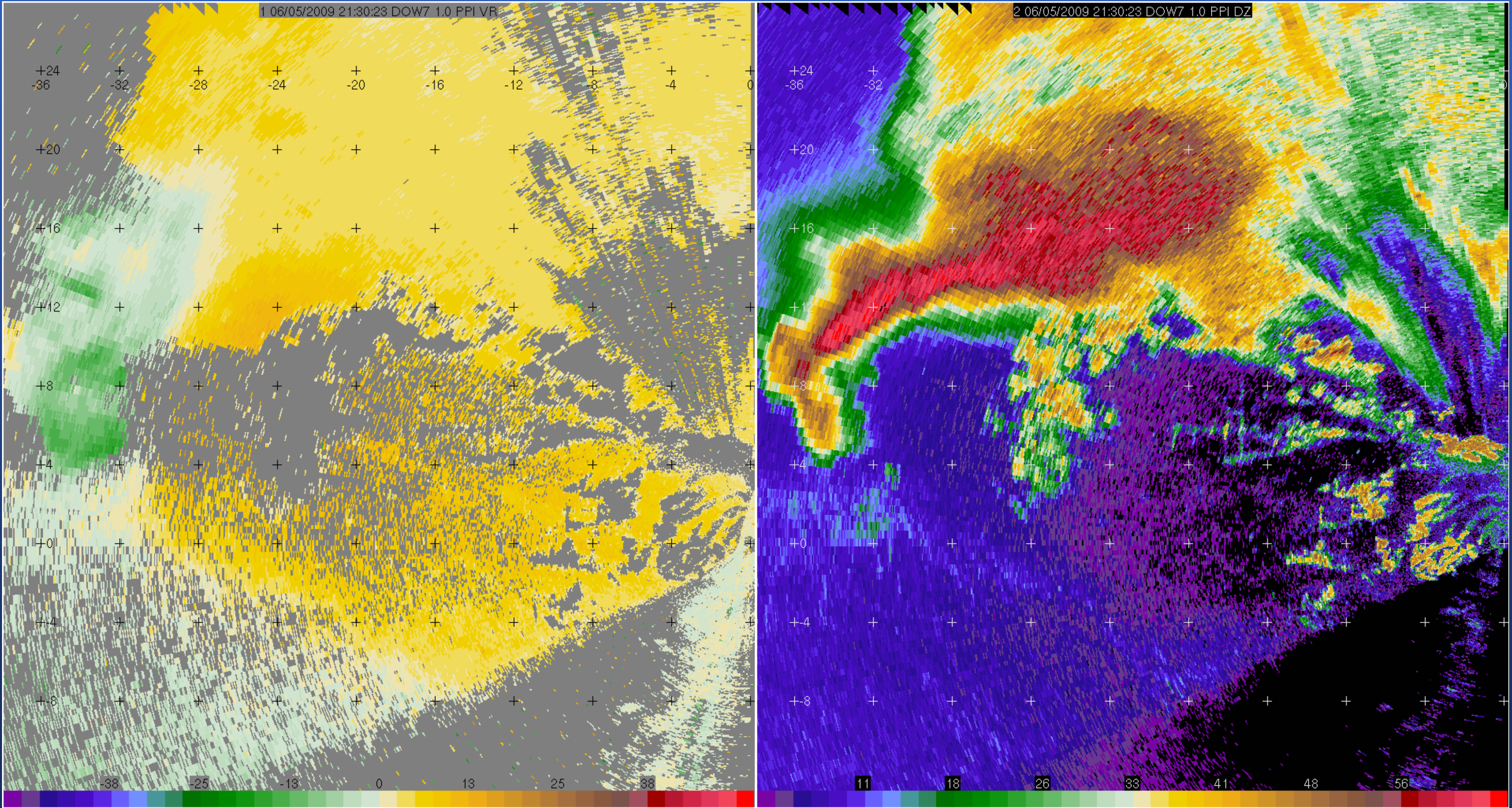
Radar observations of entire tornado lifecycle

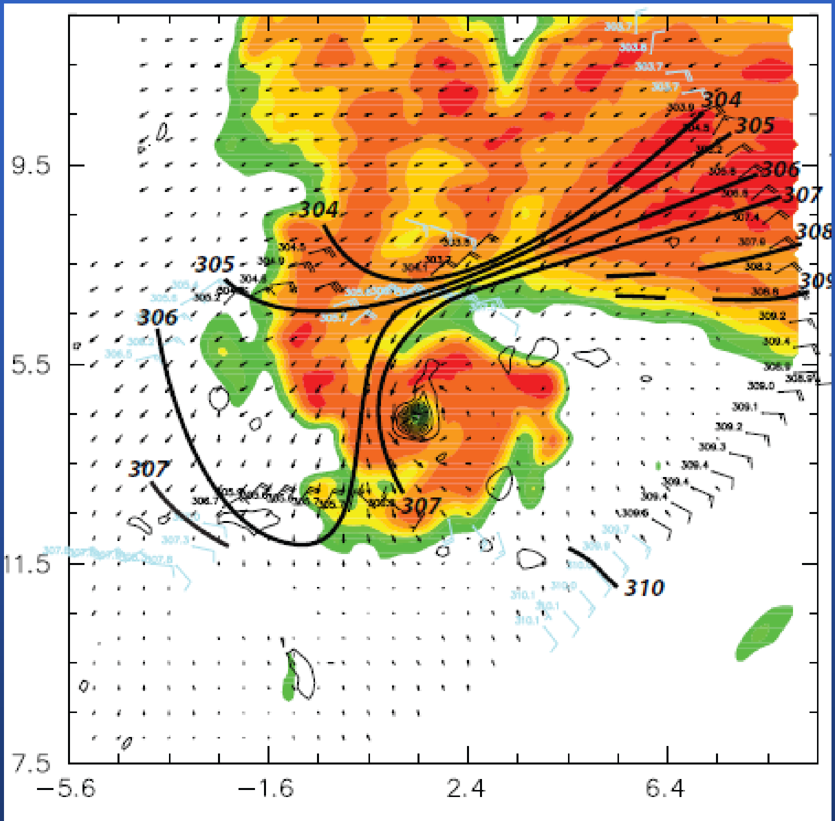
(Radar loop courtesy Joshua Wurman)

5 June 2009
near LaGrange, Wyoming

DOW7



Combining wind and temperature data
(an example of what makes VORTEX2 datasets precious)

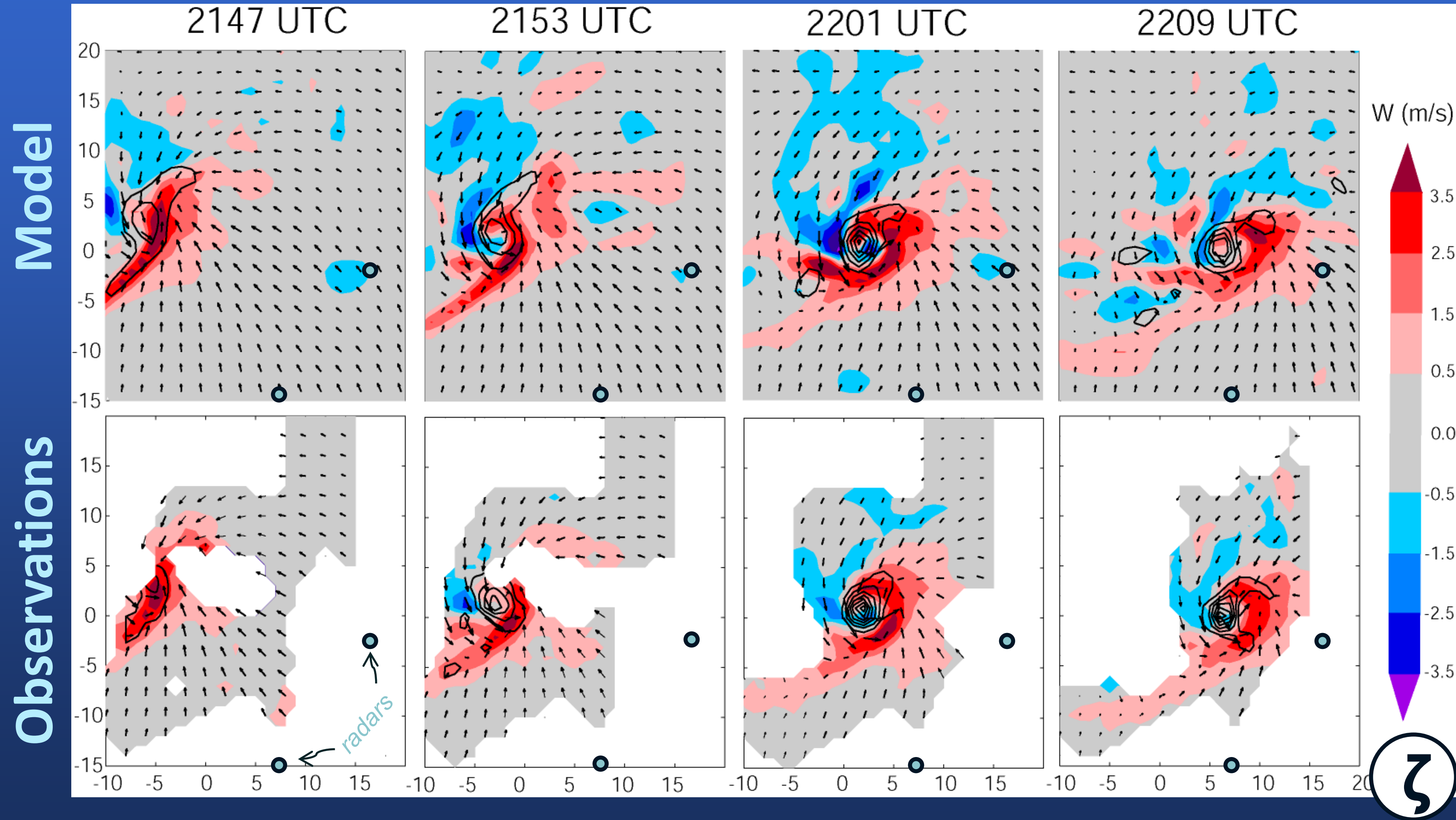


Radar Reflectivity (color)

Subjective analysis of virtual potential temperature (bold lines)

Data assimilation for VORTEX2 case:

Using the observations to drive the model toward the right solution



Z = 400 m AGL

Slide courtesy Jim Marquis

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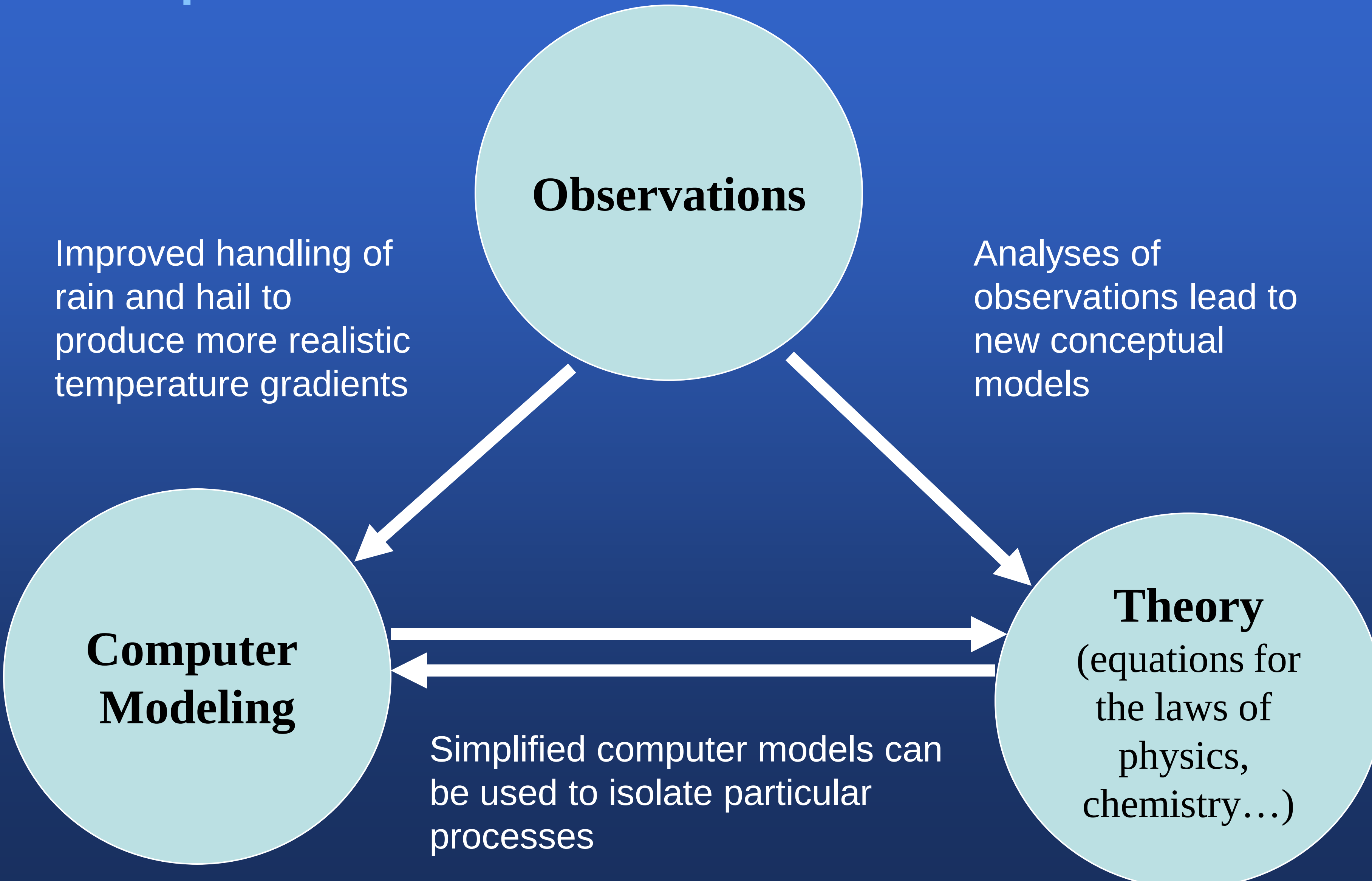
Impact of VORTEX2 observations



Summary

- We understand some parts of the tornado problem well, but others have eluded us owing to deficiencies in the models or in the observations

- Methods of discovery include direct observations, computer modeling, and theory all working together to get the answers; this requires
  - Supercomputing capabilities
  - Observational infrastructure

- The ultimate goal of the basic research is to feed into operations to improve watches and warnings → this research-to-operations transfer is strong in the severe storms community

Thank you!