# C-RITE: Dynamics and Thermodynamics of Convection

## **Observing Priorities for Continental (Deep) Convection**

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Thanks to the following people for input/contributions:
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# 1. Background/Core values

I am a *consumer of observations*, not an instrument developer.

# 1. Background/Core values

General tools have more applications than specialized tools.

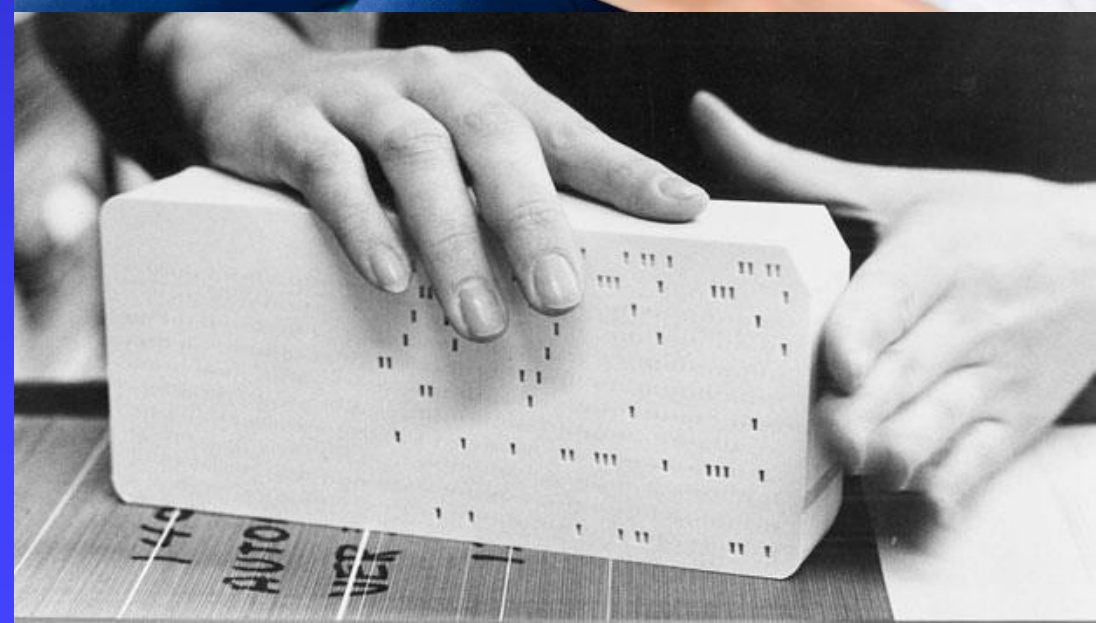
Today's priority may not be tomorrow's.


Slide courtesy of S. Yuter, NCSU

# 1. Background/Core values

Instruments and data types that are user-friendly stimulate more and better science.

If only one or two groups want to (or are able to) adopt them, then we underutilize the intellectual capacity of our discipline.



# 1. Background/Core values

Pooled resources (LAOF) are preferable to distributed resources (each university having its own instrument).

- Uniform quality
- Uniform access
- Competitions emphasize science merits, not “who will bring what”

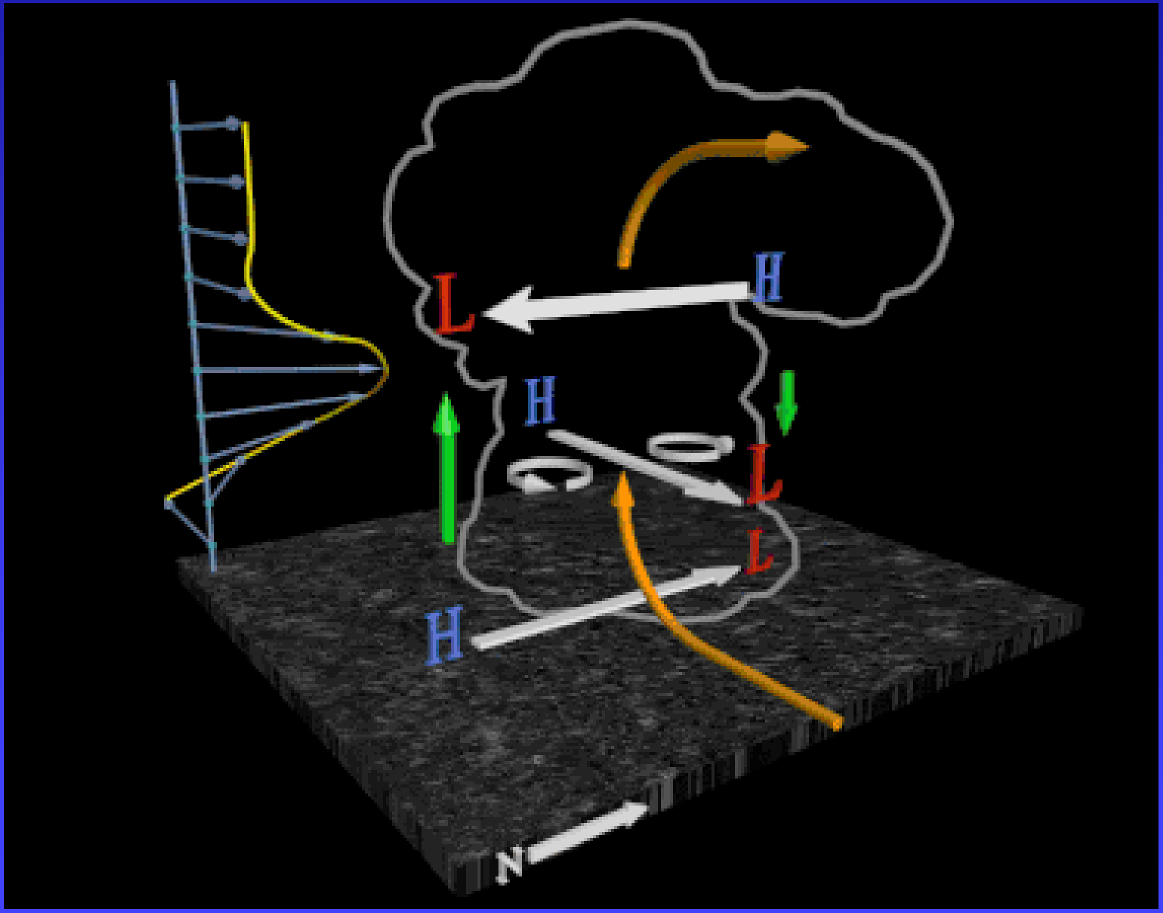
# 1. Background/Core values

Instrumentation is only the first step.  For data to be fully exploited, we also need  advances in analysis/assimilation tools.

- Open source
- Supported
- Widely adoptable
- In a modern language

# 2. State of the science

Most of the "first order" dynamical processes governing convective storms have been reasonably well articulated.




*From COMET (adapted from Klemp 1987)*

# 2. State of the science

Our present era is one in which we seek to understand how the important complexities of real world storms coincide with and differ from these first order conceptual models.

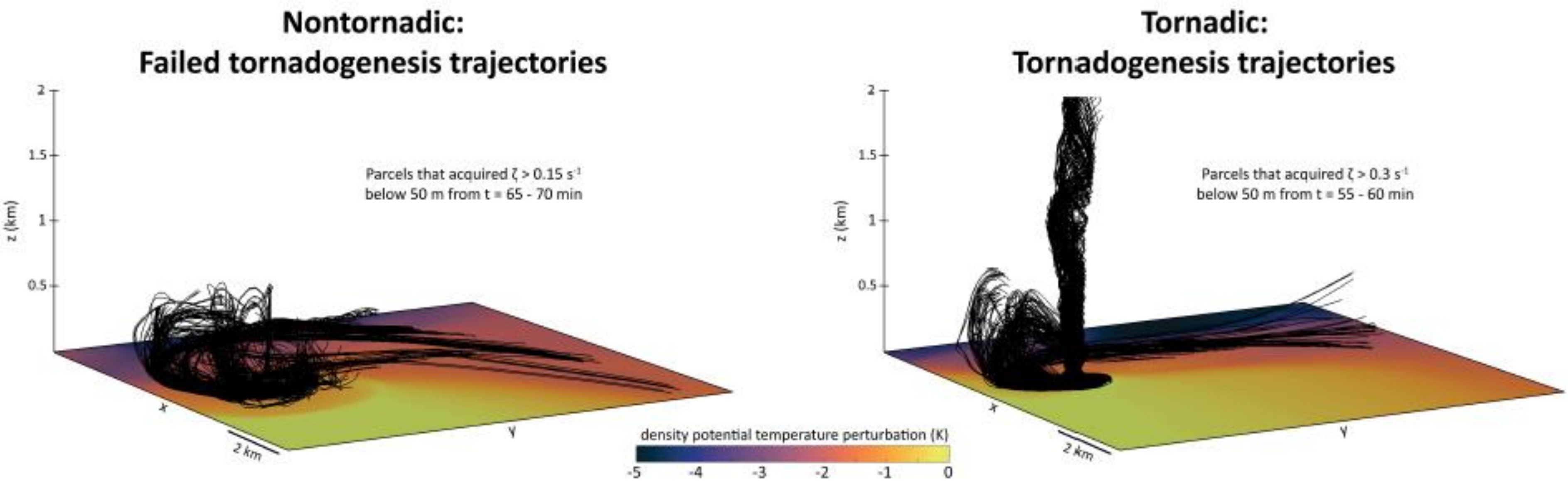
Some very computationally demanding problems are now within reach.

*From Orf et al (2017), image created by D. Bock*

# 3. Science frontiers

Lower tropospheric processes that produce (or fail to produce) tornadoes and intense mesovortices

*Simulated parcel trajectories associated with a non-tornadic vs. tornadic supercell*

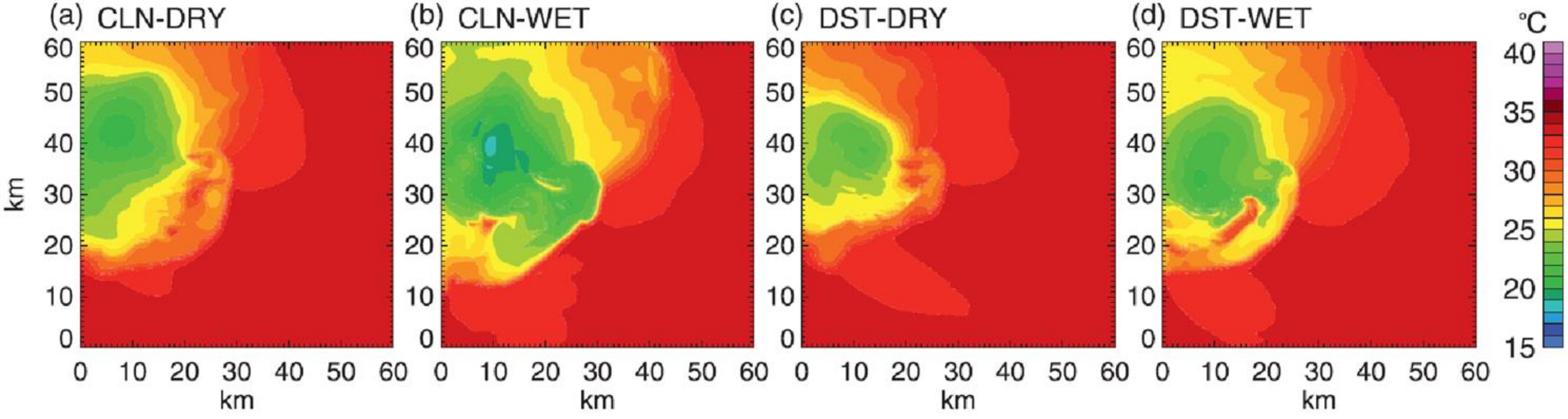



*Coffer and Parker (2017)*

# 3. Science frontiers

Precipitation pathways: Impacts of aerosols on storms, processes in the mixed-phase region, subsequent dynamical impacts

*Simulated surface outflow temperatures within environments having different aerosol concentrations*

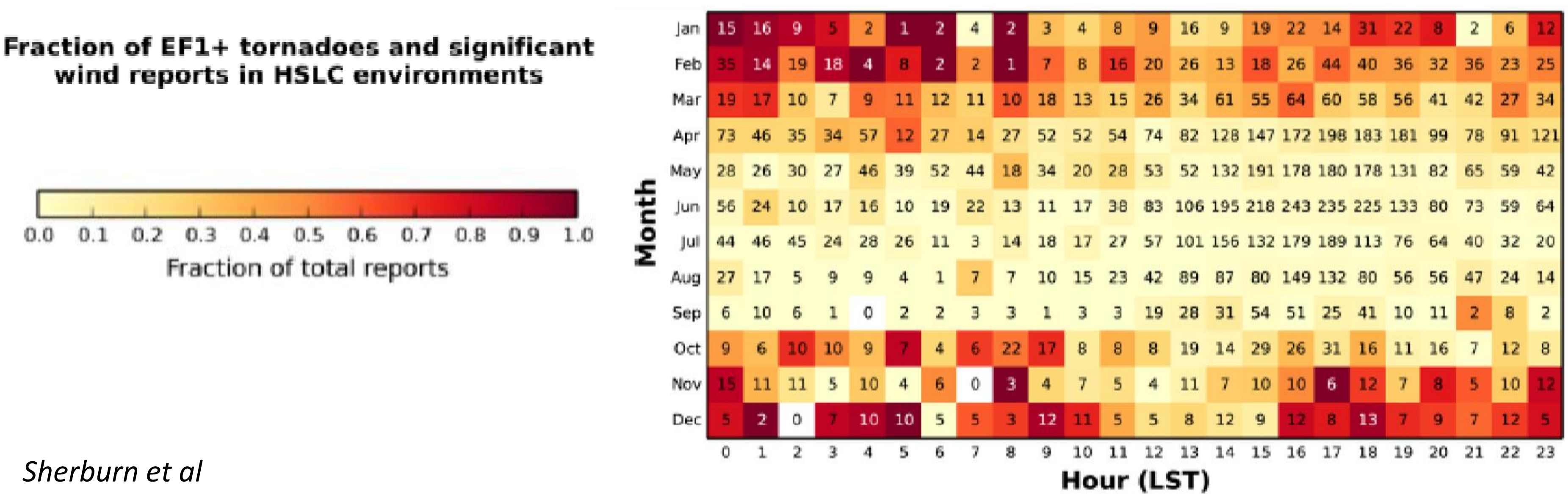



*Lerach and Cotton (2012)*

# 3. Science frontiers

Storms in non-classical environments (at night, during the cold season)

*Diurnal – annual frequency distribution of severe weather in conditions with limited instability*

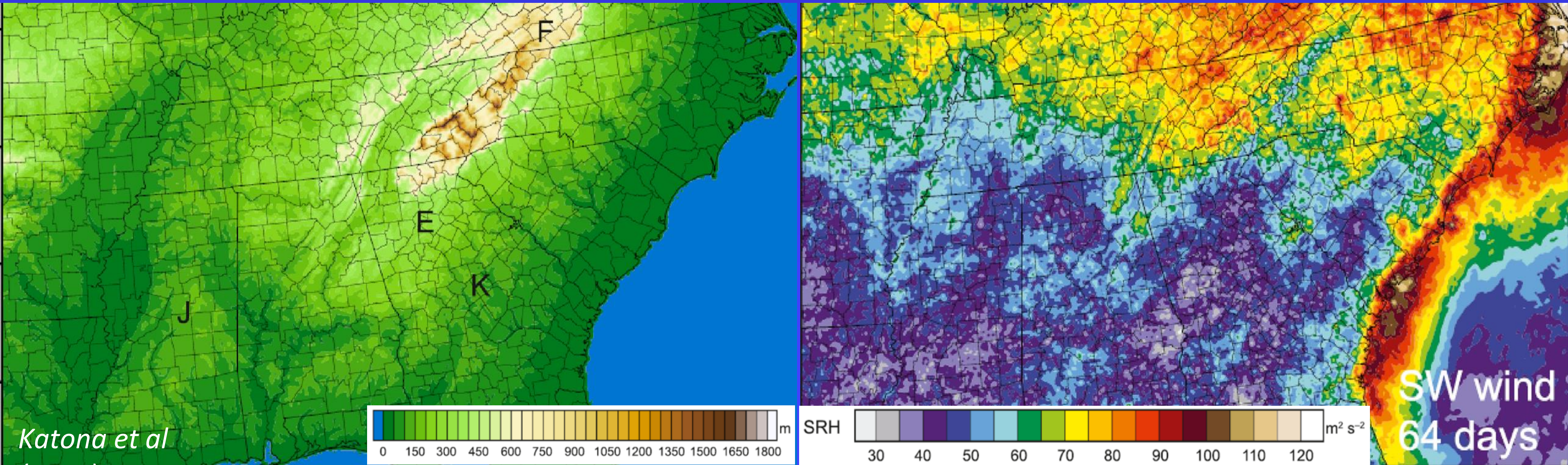



*Sherburn et al (2016)*

# 3. Science frontiers

Impacts of mesoscale variability (terrain, land-cover, etc.)

*Surface elevation (left) and multi-case averaged storm-relative helicity (right)*



# 4. Observing needs

- Mesoscale mapping of the lower troposphere <u>*outside*</u> of storms
  - ➢ Water vapor
    - ✓ Major impacts on convective predictability
  - ➢ Temperature
    - ✓ Fluctuations in near-ground lapse rates (linked to cloudiness, land cover, etc.): how much do they matter to storms?
  - ➢ Wind profile
    - ✓ Boundary layer circulations, storm-induced perturbations, mesoscale heterogeneity: how much do they matter to storms?
  - ➢ Instantaneous vertical columns
    - ✓ It's very difficult (with sondes, e.g.) to separate the local state from the horizontal and temporal variability
  - ➢ Aerosols
    - ✓ What is actually flowing into a storm's updraft?

***We need to move beyond the era of***
***"a single sounding representing a homogeneous environment"***

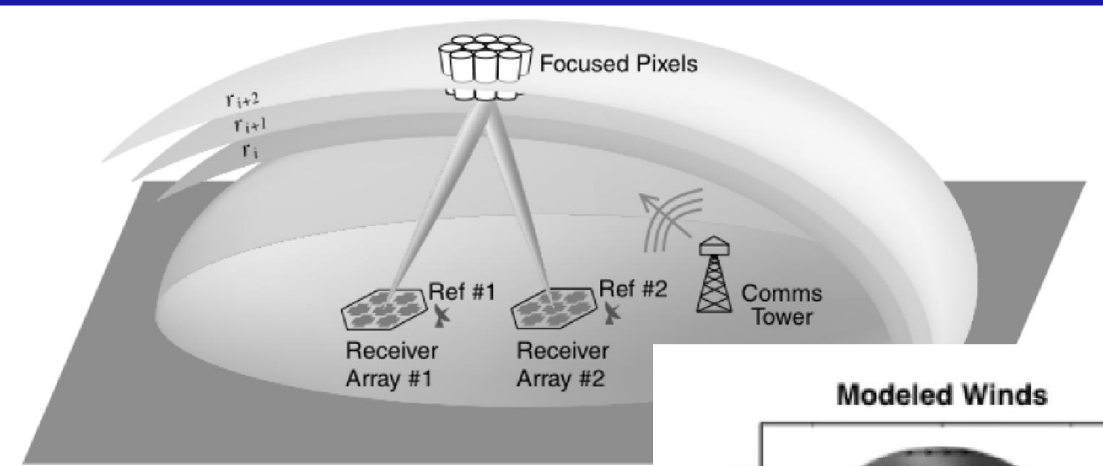
# 4. Observing needs

- Mesoscale mapping of the lower troposphere *outside* of storms

| Instrument | Advantages | Drawbacks |
| --- | --- | --- |
| Upsondes | Cheap; user-friendly; easily relocatable; proven technology | Many systems and operators needed to map temporal and spatial variability; large downstream drift |
| Dropsondes | Closer to instantaneous vertical column than upsondes; can quickly cover a large footprint | Cost of flight hours; inability to drop over land |
| Ground-based lidars/profilers/ sounders/etc. | True vertical column, in many cases nearly instantaneously; capture continuous evolution | Shallow sampling depth (some cases); inoperable in precipitation; attenuation by cloud (some cases); thermodynamic profiles can be poorly constrained |
| Airborne lidars | Instantaneous vertical column; can quickly cover a large footprint | Cost of flight hours; inoperability in precipitation; attenuation by cloud; thermodynamic profiles can be poorly constrained; no wind information |
| UAVs | Cheaper way for a single system to cover a large-ish footprint | Unclear what kinds of vertical profiling payloads are possible; FAA restrictions |

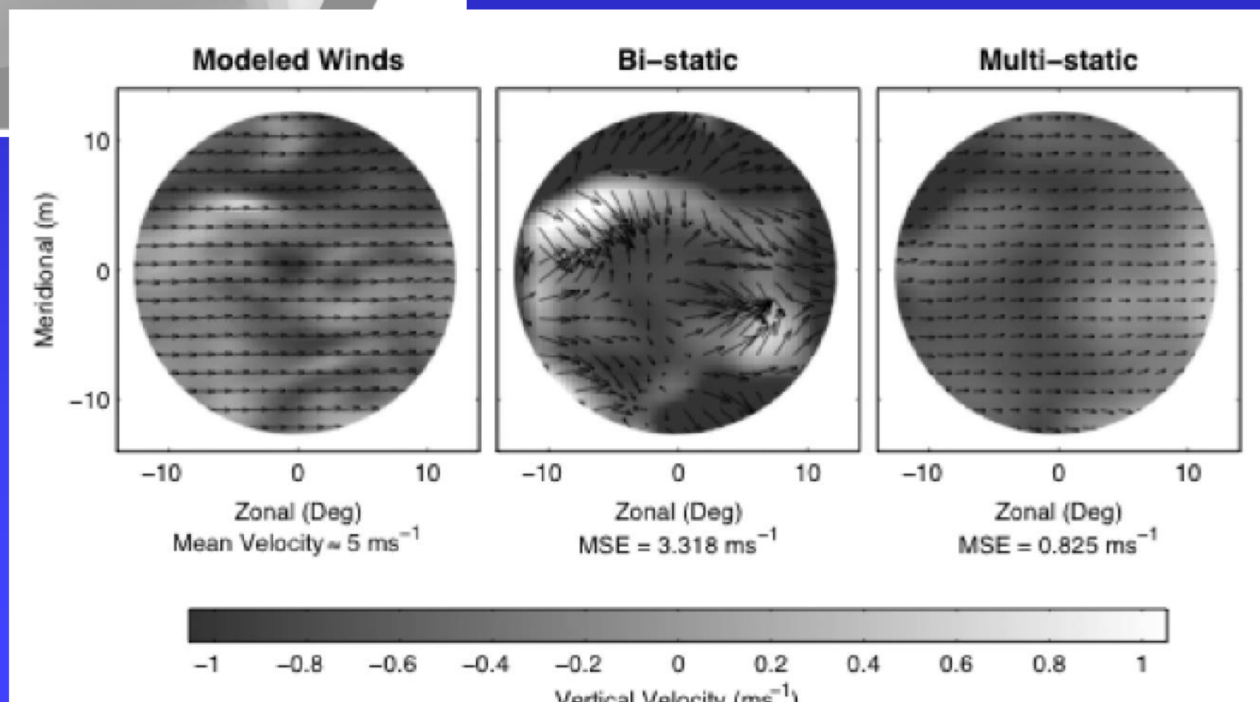
# 4. Observing needs

Some alternative ideas…




**Cheap, low-power, single chip receivers could potentially be used to create a network of passive (parasitic) multi-static wind profiling radars**

*Schematic showing multi-static atmospheric imaging by parasitically using transmissions from a cellular tower.*




*Simulation of the wind components retrieved using the proposed technique.*

*Images from proposal by Hoffman, Balkir, Palmer, and Parker*

# 4. Observing needs

- Measurements above the ground *within* storms
  - ➢ Thermodynamic properties
    - ✓ Cold pools and baroclinic zones are likely very important to tornado/vortex-genesis (and convective evolution overall)
  - ➢ Microphysical properties
    - ✓ Many hypothesized aerosol impacts on storm properties
    - ✓ Hail formation and other mixed-phase processes are still very unclear
  - ➢ Updraft core characteristics
    - ✓ 3D updraft area may be quite relevant to precipitation processes, vorticity dynamics, storm-environment interactions

***We need to move beyond "just dual-Doppler wind fields" and find reliable ways to fully characterize the processes in storms.***

# 4. Observing needs

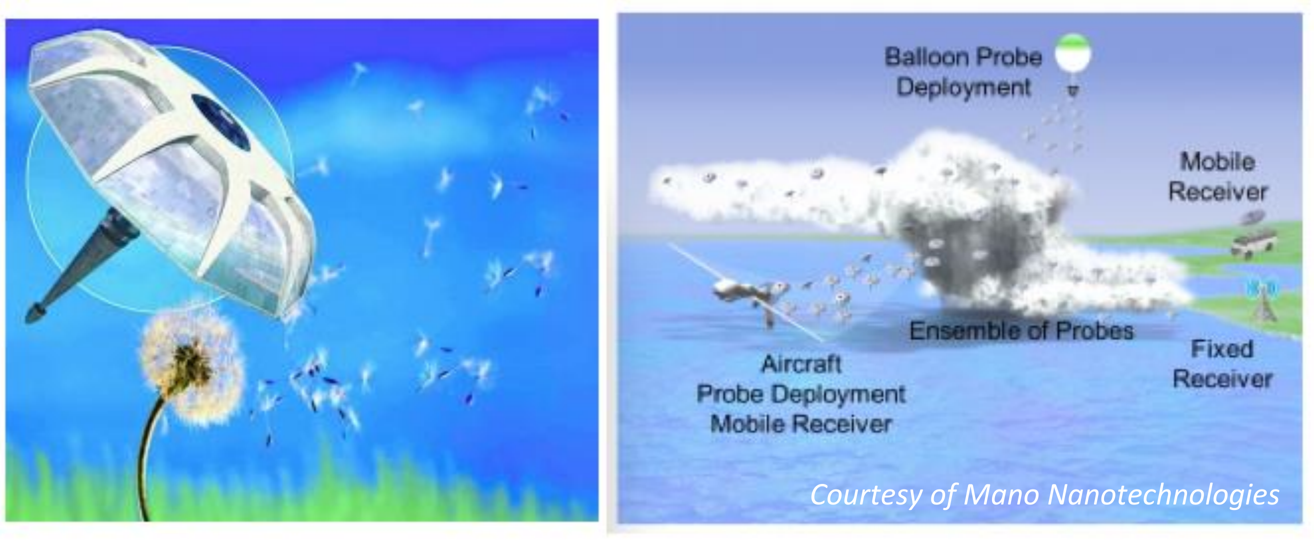
- Measurements above the ground *within* storms

| Instrument | Advantages | Drawbacks |
|---|---|---|
| Upsondes | Cheap; user-friendly; easily relocatable; proven technology | Highly erratic trajectories; no aerosol or precipitation information |
| Dropsondes | Can quickly cover a large footprint | Cost of flight hours; inability to drop over land; sonde drawbacks above |
| Radars (fixed, truck-borne, airborne) | Three-dimensional depictions from one sensor; somewhat easily relocatable | Wind and bulk precipitation information only; assumptions needed for dual-Doppler; short wavelengths lead to attenuation and dual-pol issues |
| Airborne in-situ sensors | Perform horizontal transects; characterize aerosols/precipitation | Cost of flight hours; information only along flight track |
| UAVs | Perform horizontal transects more cheaply and closer to the ground | Unclear what kinds of payloads are possible; FAA restrictions; in-situ drawbacks above |
| Lidars/profilers/ sounders/etc. | True vertical column, in many cases nearly instantaneously | Inoperability in precipitation, fragility of sensors are deal-breakers |

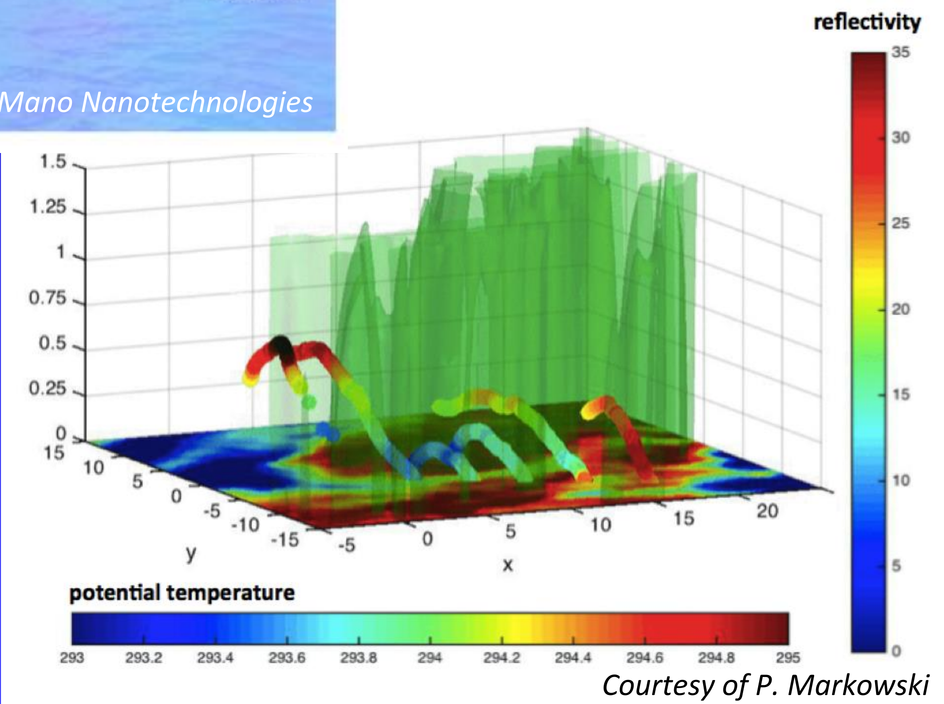
# 4. Observing needs

Some alternative ideas…

**Swarms of small, light-weight (~1 m/s fallspeed), biodegradable "drifter" probes could be dropped from aircraft, UAVs, or balloons. They would "float" downward while sampling for quite some time.**




*Schematic showing what a drifter probe might look like, and how an ensemble might be used to map a large 3D area.*



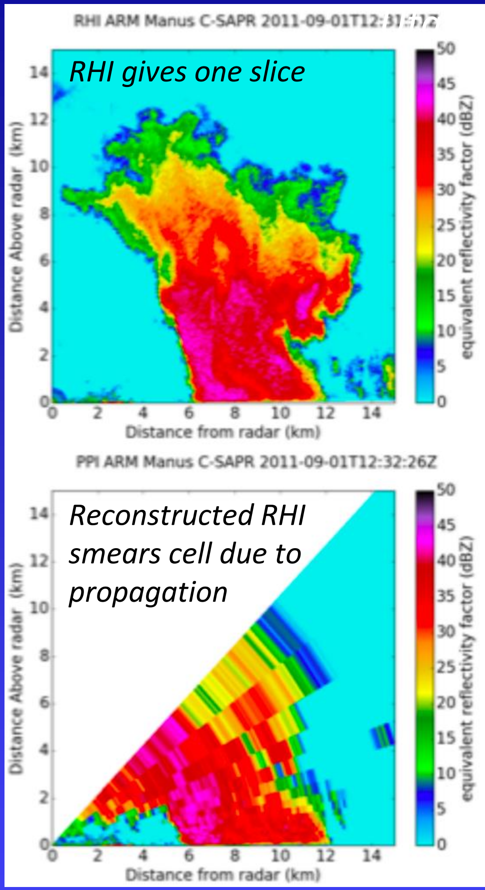

*Potential temperature data along the descent paths of six prototype drifter probes released from a balloon near a cold frontal rainband by Paul Markowski.*

# 4. Observing needs

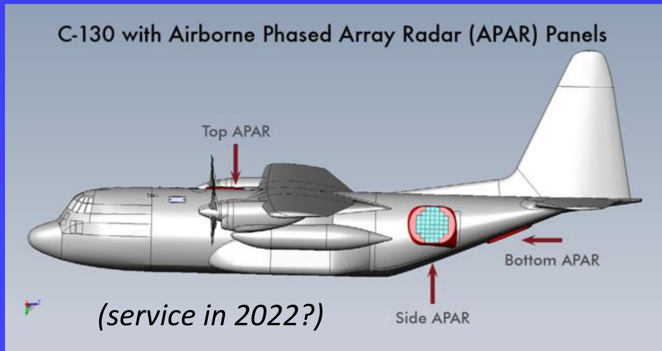
Some additional thoughts on radars (our “bread and butter”)…

- Dish-scanning radars in traditional scan strategies provide limited detail on fine-scale processes
  - ➢ Update times > convective evolution timescale
  - ➢ Reconstructed RHIs and dual-Doppler syntheses smear cores and do not resolve turbulent and microphysical processes
  - ➢ RHIs are more detailed, but only in one slice
- Perfection and widespread deployment of phased-array/imaging radars will be a great leap forward
  - ➢ Update times < convective evolution timescale
  - ➢ Frequent volumes enable accurate trajectories from dual/multi-Doppler synthesis
  - ➢ Off-axis polarimetry is still in development

*Courtesy A. Varble, U.*





# 4. Observing needs

A final plug… we are here to talk about the future, but some existing systems have an excellent track record and provide great bang for the buck.  These should continue to be supported as a community resource.

<u>The backbone of almost all continental deep convection projects ought to be:</u>

- surface-based mobile radars
- surface-based mobile sounding systems
- mobile surface stations ("mesonets") and disdrometers

These systems are:

✓ relative inexpensive (especially compared to airborne systems)
✓ very user-friendly (high measurement quality, straightforward QC)
✓ easily redeployed and not especially fragile


# 5. Summary/Prompts for breakout discussions

- Science frontiers for continental deep convection require a more complete depiction of 4D fields both inside and outside of storms
  - ➢ Above the ground
  - ➢ Winds, thermodynamic fields, aerosols, and precipitation particles

- Systems to remotely sense vertical profiles are attractive, but…
  - ➢ Issues with sampling depth, operability in precipitation, and attenuation by cloud need to be overcome
  - ➢ These systems will need to be more durable and scalable if they are to be deployed for "mapping" the environment

- More and better in situ observations aloft are highly desirable, but…
  - ➢ At least as a start, it would be a big step forward to have either dropsondes (need permission) or drifters (need development)
  - ➢ An airborne profiling instrument that works within cloud/ precipitation ("more than just flight path") would be transformative
  - ➢ We shouldn't abandon the suite of backbone observations produced by surface-based dual-Doppler + sondes + mesonet + disdrometers
  - ➢ Evolution to widespread use of imaging radar would push the envelope of what we can do under our current paradigms