Severe-storm Targeted Observation and Robotic Monitoring (STORM)

Sara Swenson and Roger Laurence
University of Colorado

Motivation

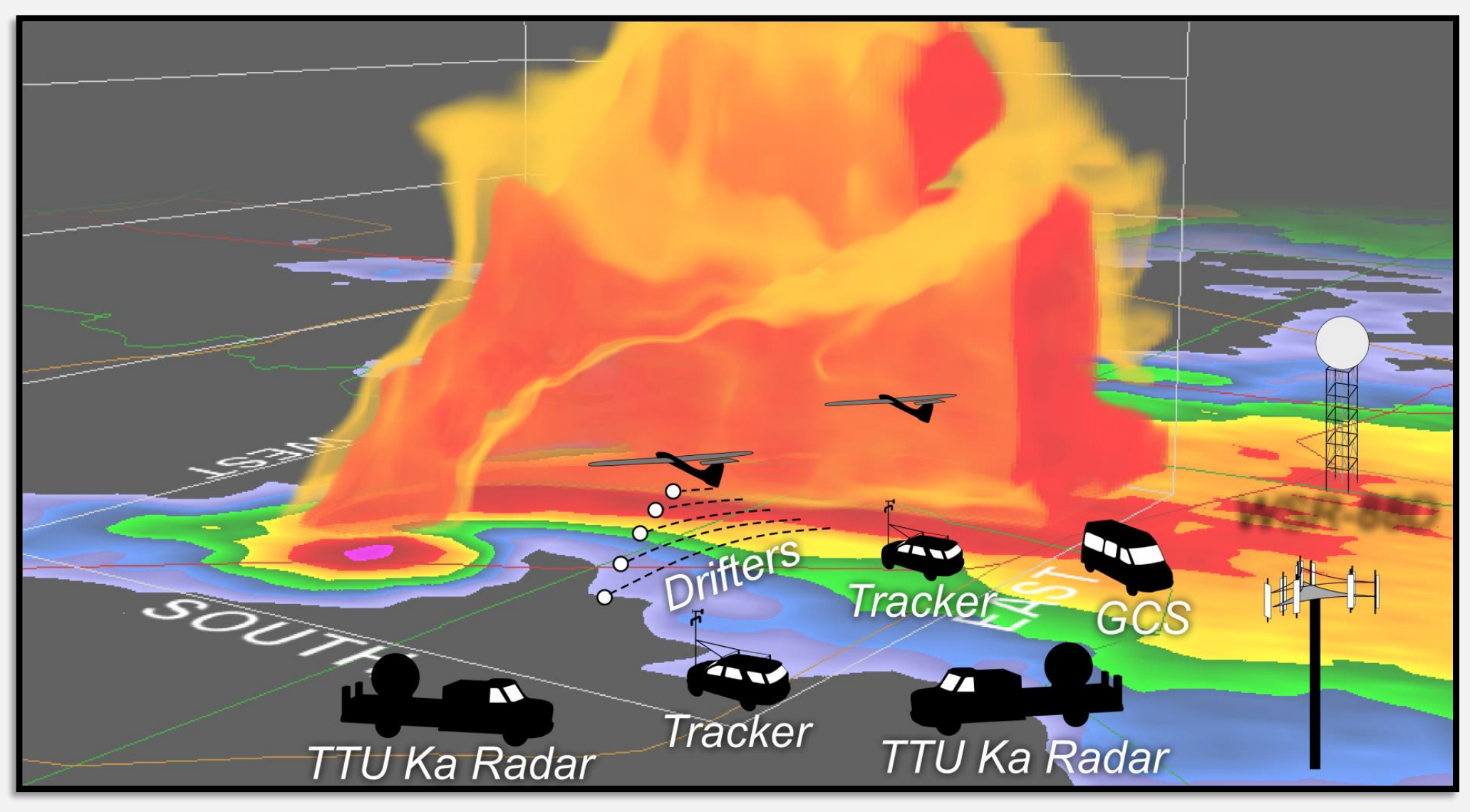
http://www.theatlantic.com/photo/2015/10/2015-national-geographic-photo-contest/409174/

- In the last two decades, thunderstorms in the U.S. have been responsible for more than 4,000 deaths, over 40,000 injuries, and nearly $100 billion in damage. More than half of all thunderstorm-related injuries and deaths are associated with tornadoes.
- To increase lead times and reduce losses, *in situ* sensing systems must be developed to collect targeted data in potentially severe thunderstorms that can be used to improve online predictions to direct data collection and to improve forecast reliability and accuracy.

Overview

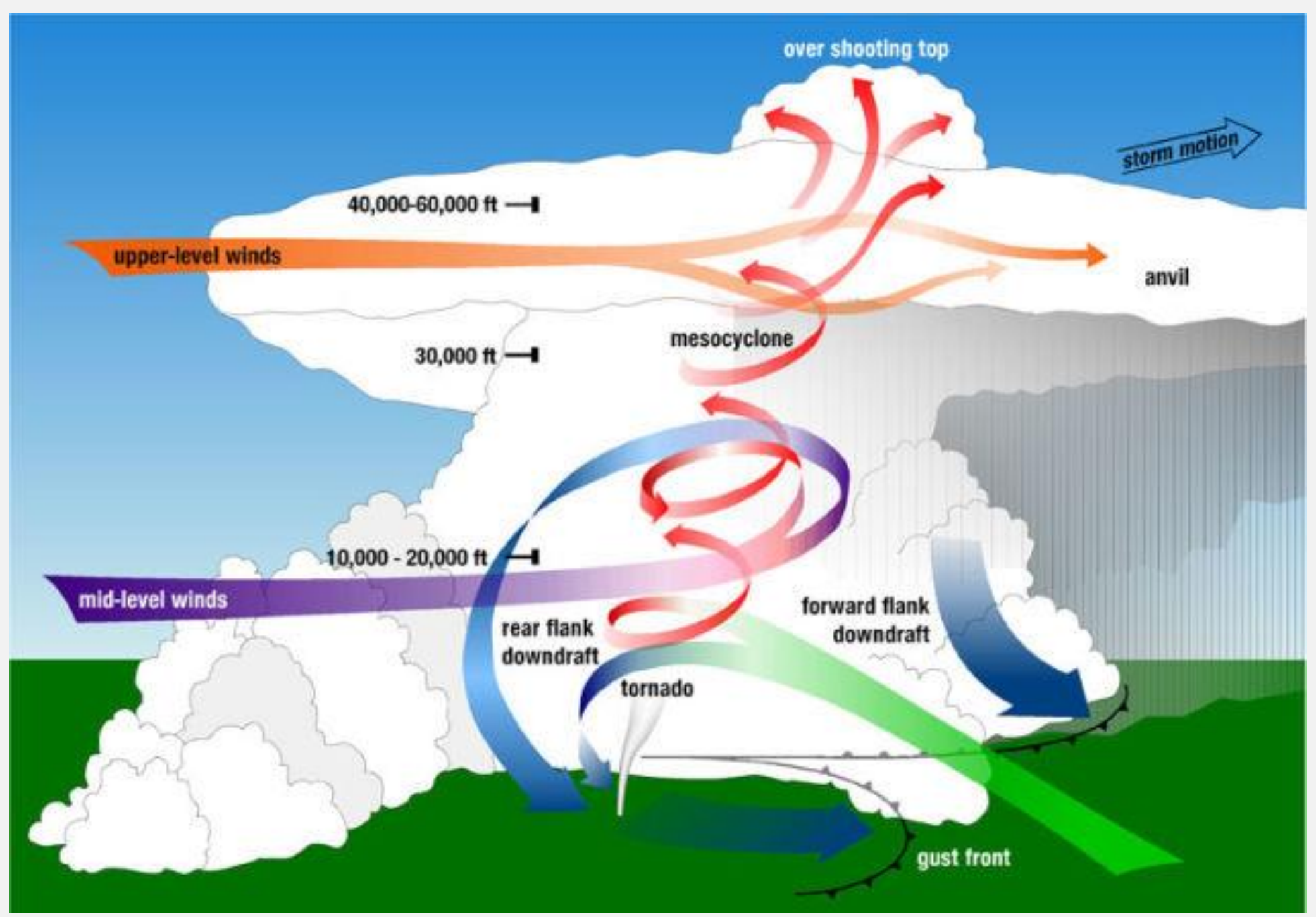
This project addresses the development of **Self-Deploying Aerial Robotic Systems (SDARS)** that will enable new *in situ* atmospheric science applications. Targeted observation of severe storms will be achieved by tracking coherent atmospheric features known to correlate strongly with forecast accuracy.

1) **Offline Sensitivity Analysis and Modelling** will develop strategies for online target identification based on offline sensitivity analysis.
2) **Autonomous Planning** focuses on the online planning algorithms that consider exploiting wind energy, coordinating sampling based on local spatio-temporal scales, and maintaining necessary communication levels.
3) **Hardware and Experimental Assessment** will develop a new Lagrangian sensor and flight experiments will assess system performance.



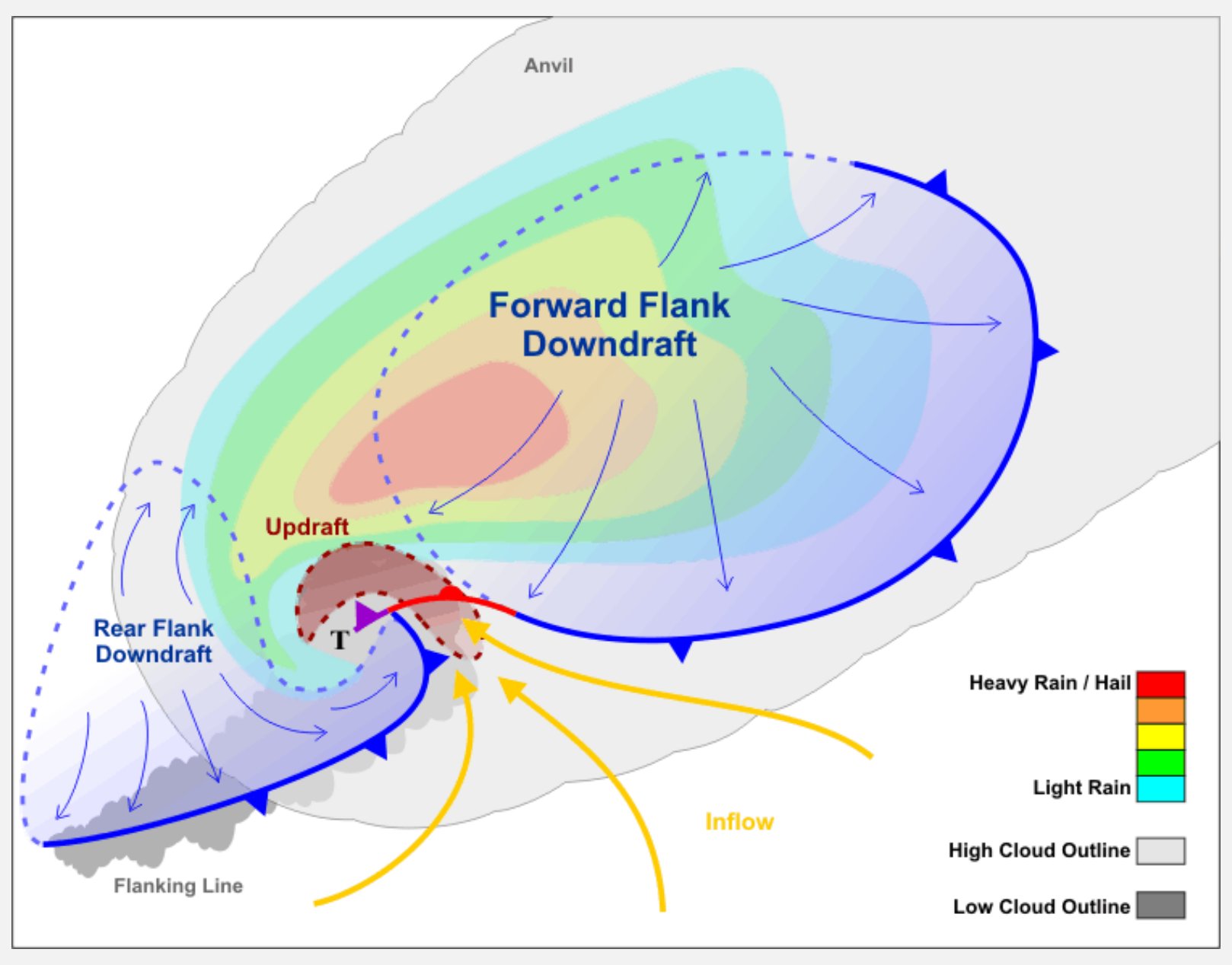
SDARS is comprised of dual Doppler radar, multiple unmanned aircraft, ground tracker vehicles, mobile ground control station, and deployable Lagrangian drifters connected to dispersed computing through meshed communication.

Supercell Structure



Structure of a Supercell storm with counterclockwise rotation , moving in the northeast direction. The Rear Flank Downdraft in the southwest corner of the storm is important in understanding tornadogenesis. Image courtesy of NOAA.

Tornadoes that form in supercells are often long-lasting, and extremely destructive. However, tornadoes only form in about 20% of supercells observed. While tornadogenesis is an active area of research, one of the theories is that tornadoes may form when the rear flank downdraft (RFD) interacts with the mesocyclone of the supercell. Direct sampling of this area is crucial in better understanding tornadogenesis. At ground levels, the Rear Flank Gust Front (RFGF) makes it extremely difficult to get direct measurements of the RFD from probes launched from the ground. Therefore, we will make use of the mid-level winds (purple and green) to attain favorable entrainment into the RFD.

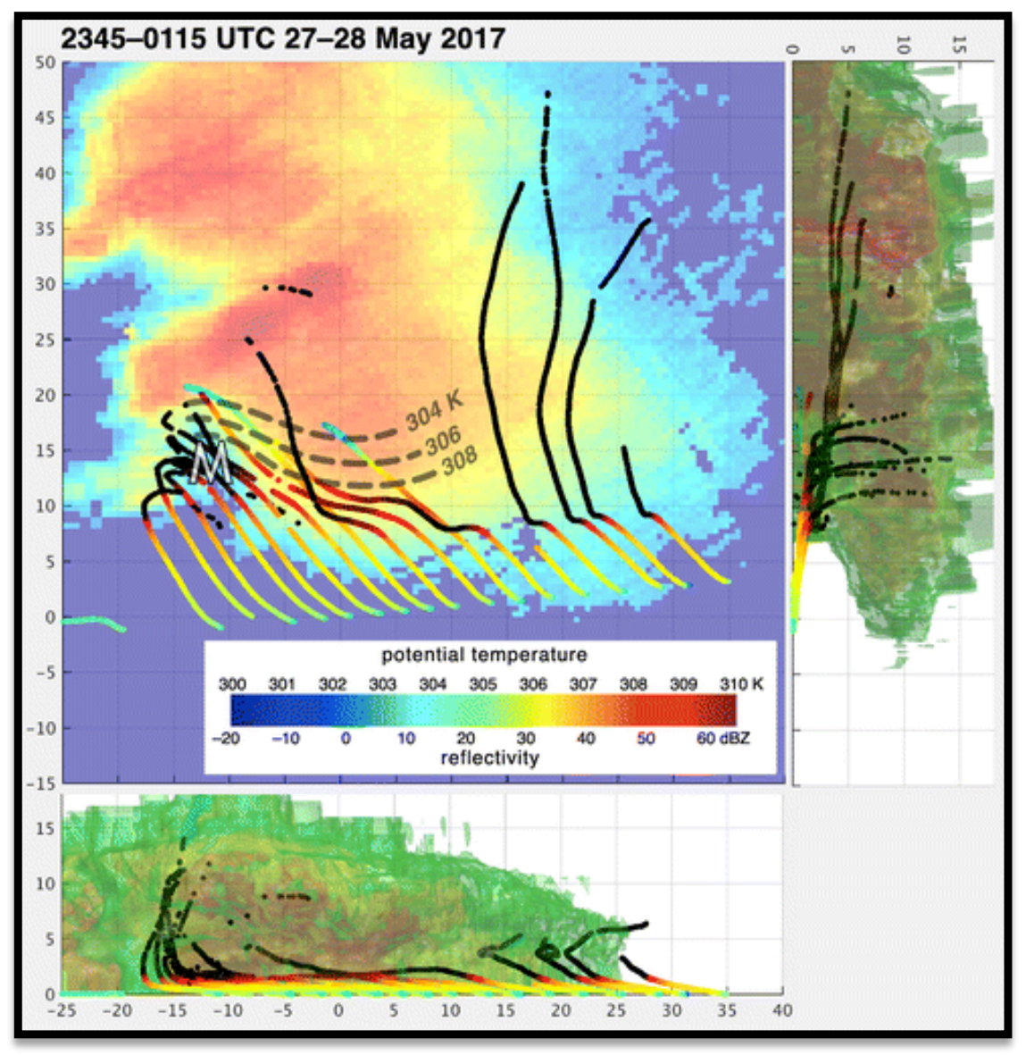


Rendering of a supercell as it would show up on a radar scan. Image courtesy of NOAA.

Pseudo-Lagrangian Drifters for Thermodynamic Sensing

Pseudo-Lagrangian Drifters

Lagrangian drifters (LD) are balloon-borne systems that can be deployed by UAS for targeted observations.



John Manobianco et. al. "How Nanotechnology Can Revolutionize Meteorological Observing with Lagrangian Drifters." American Meteorological Society 2008.

Ground-released LD have successfully been used to measure the forward flank downdraft[1].

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[1] Markowski, P. M., Richardson, Y. P., Richardson, S. J., and Peterson, A. "Abovegroung thermodynamic observations in convective storms from balloon borne probes acting as pseudo-lagrangian drifters". *Bulletin of the American Meteorological Society 99* (2018).

Air-launched Drifter (ALD) Design

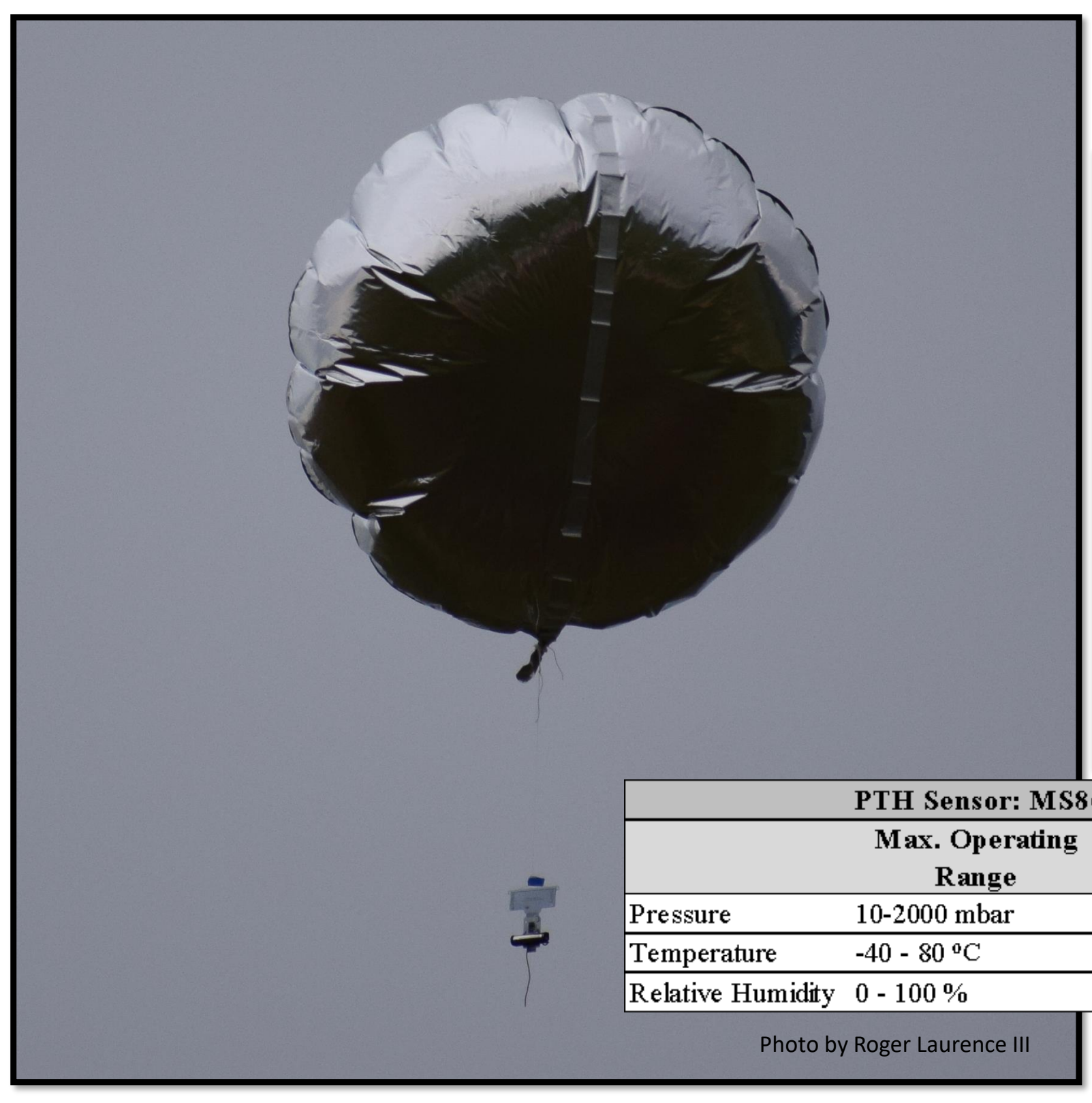
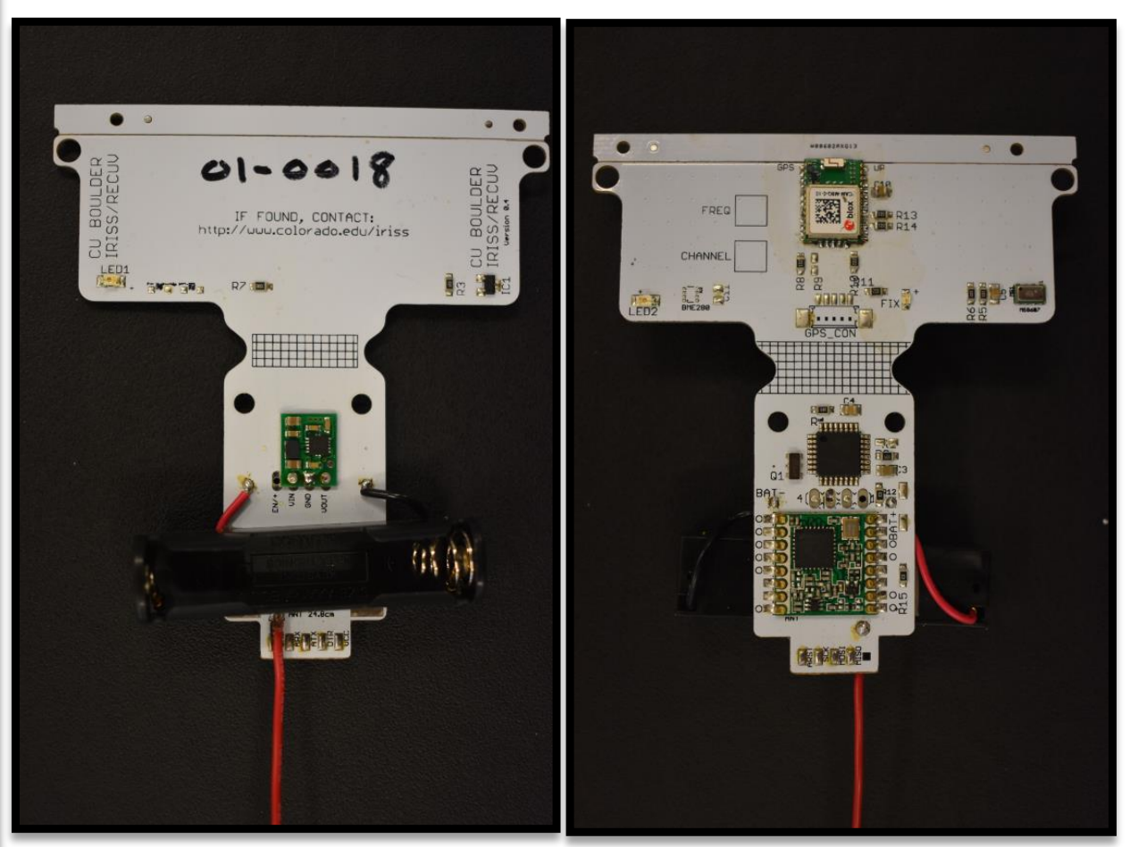


Photo by Roger Laurence III

Drifter He Capacity: 125L
Can lift a payload of 92.5g to 10,000 ft.



PTH Sensor: MS8607			
	Max. Operating Range	Accuracy @ 25°C	Resolution
Pressure	10-2000 mbar	±2 mbar	0.016 mbar
Temperature	-40 - 80 °C	± 1 °C	0.01 °C
Relative Humidity	0 - 100 %	± 3 %	0.04%

Component	Mass (g)
1.5V Battery and Holder	10.5
PCB	6
Radio	2
GPS Module	0.5
Microcontroller	0.01
PTH Sensor	0.01
Miscellaneous Parts	1
Total:	~ 20

Air-launched Drifter (ALD) System on Mistral UAS

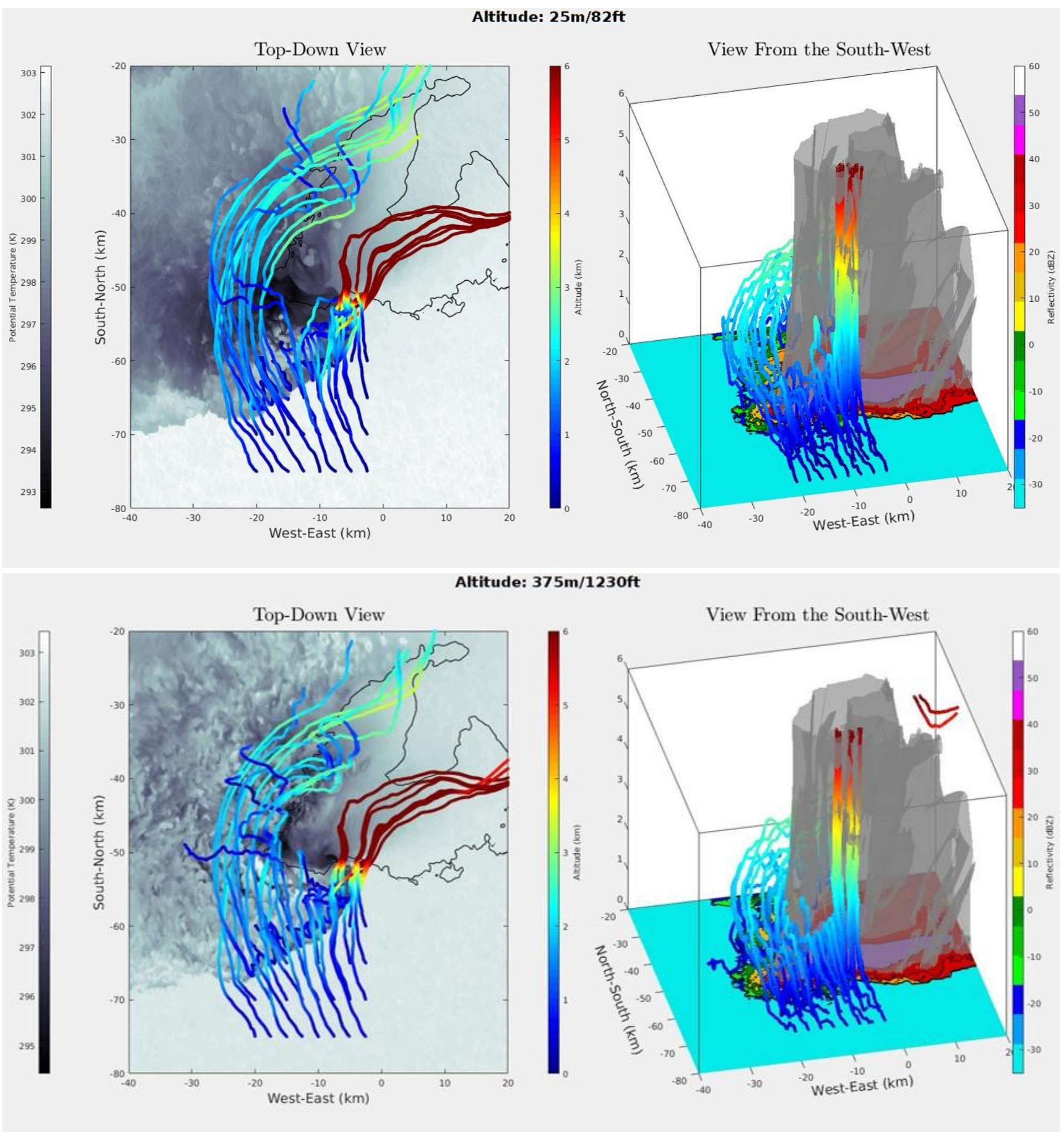
Aspect	Value
Empty Weight	18 lb
Max. Payload Capacity	15 lb
Wingspan	16 ft
Autopilot	Pixhawk
Max. Speed	90kts (~ 104 mph 46 m/s)
Loiter Speed	38 kts (~ 44 mph 20 m/s)
Endurance*	2-6 hrs

Photo by Roger Laurence III

Photo by Cole Kenny

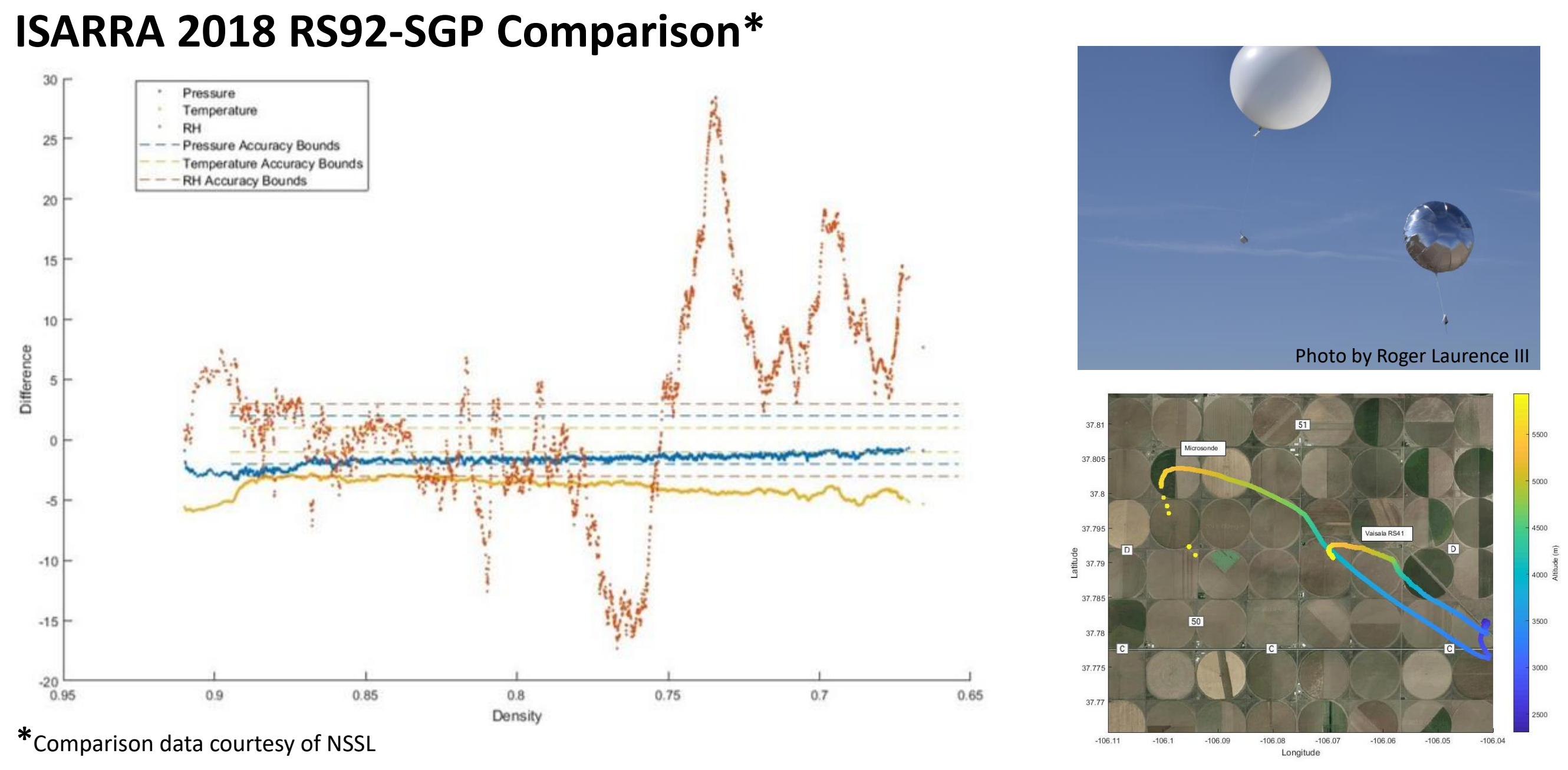
System Testing

Release Analysis



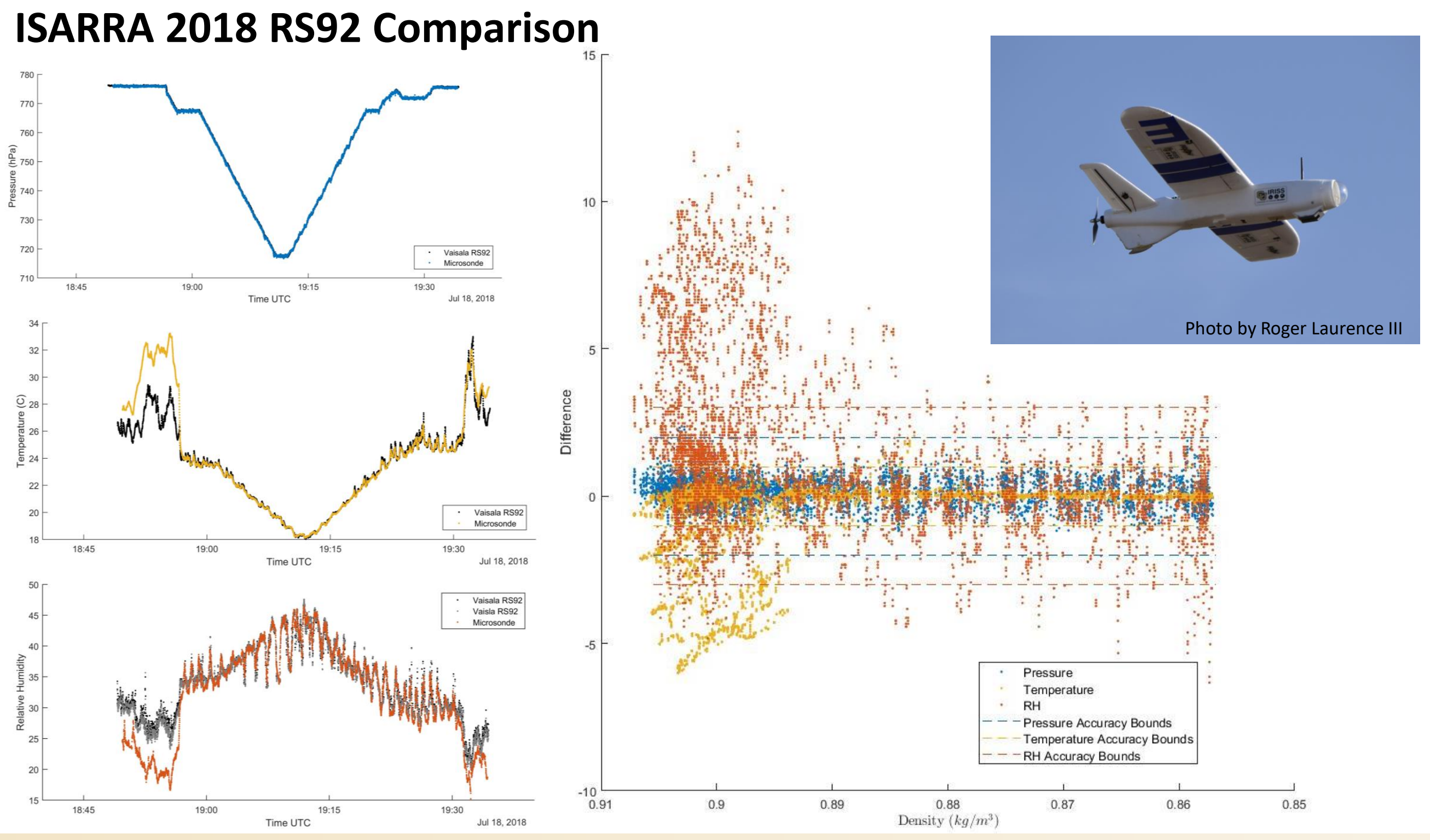
Trajectories for 125L helium-filled Lagrangian drifters released into high-fidelity supercell simulated data. Black line on left plot and gray surface indicate the 45 dBz reflectivity surface where much of the precipitation is located within the supercell.

ISARRA 2018 RS92-SGP Comparison*



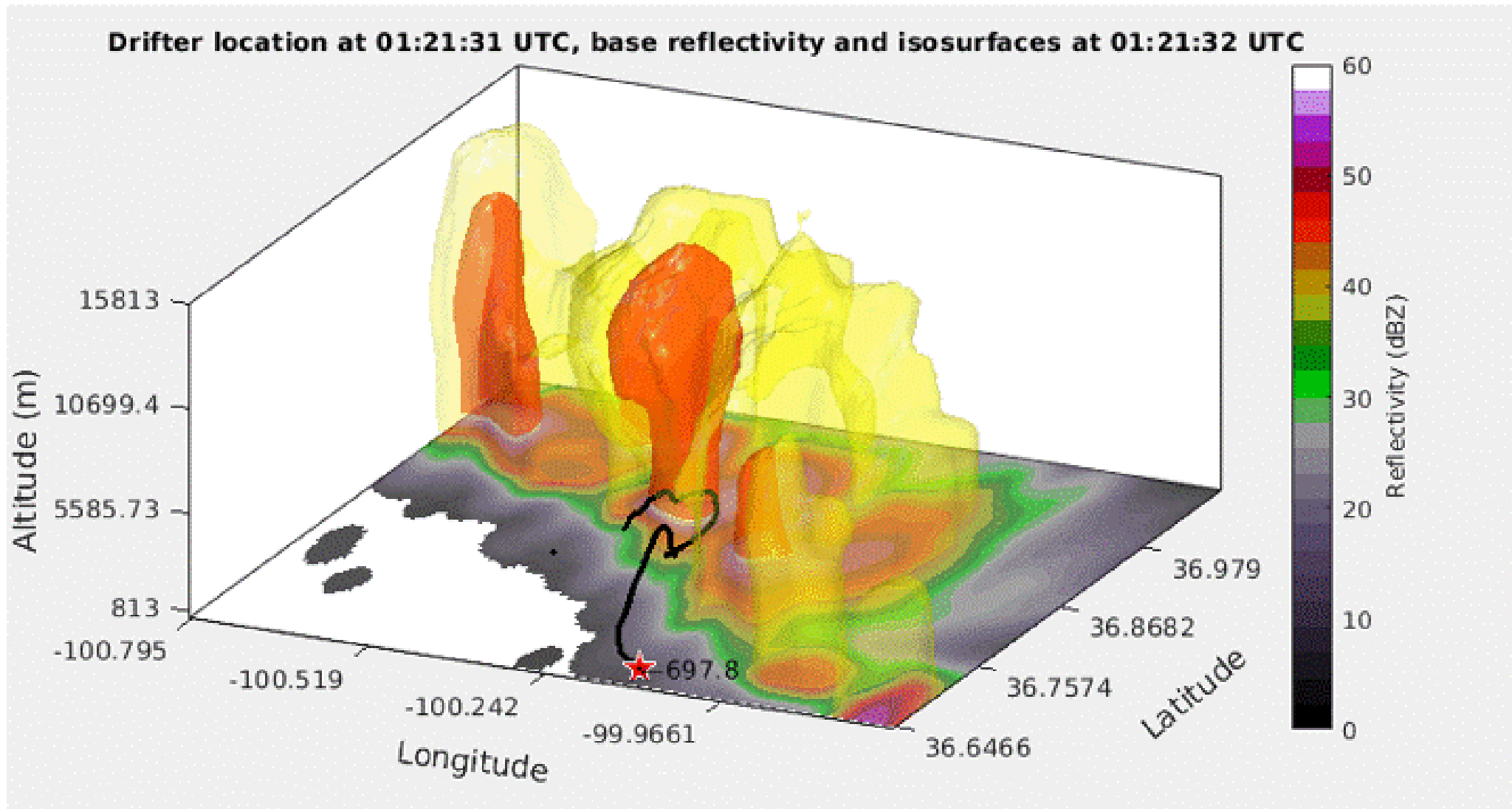
*Comparison data courtesy of NSSL

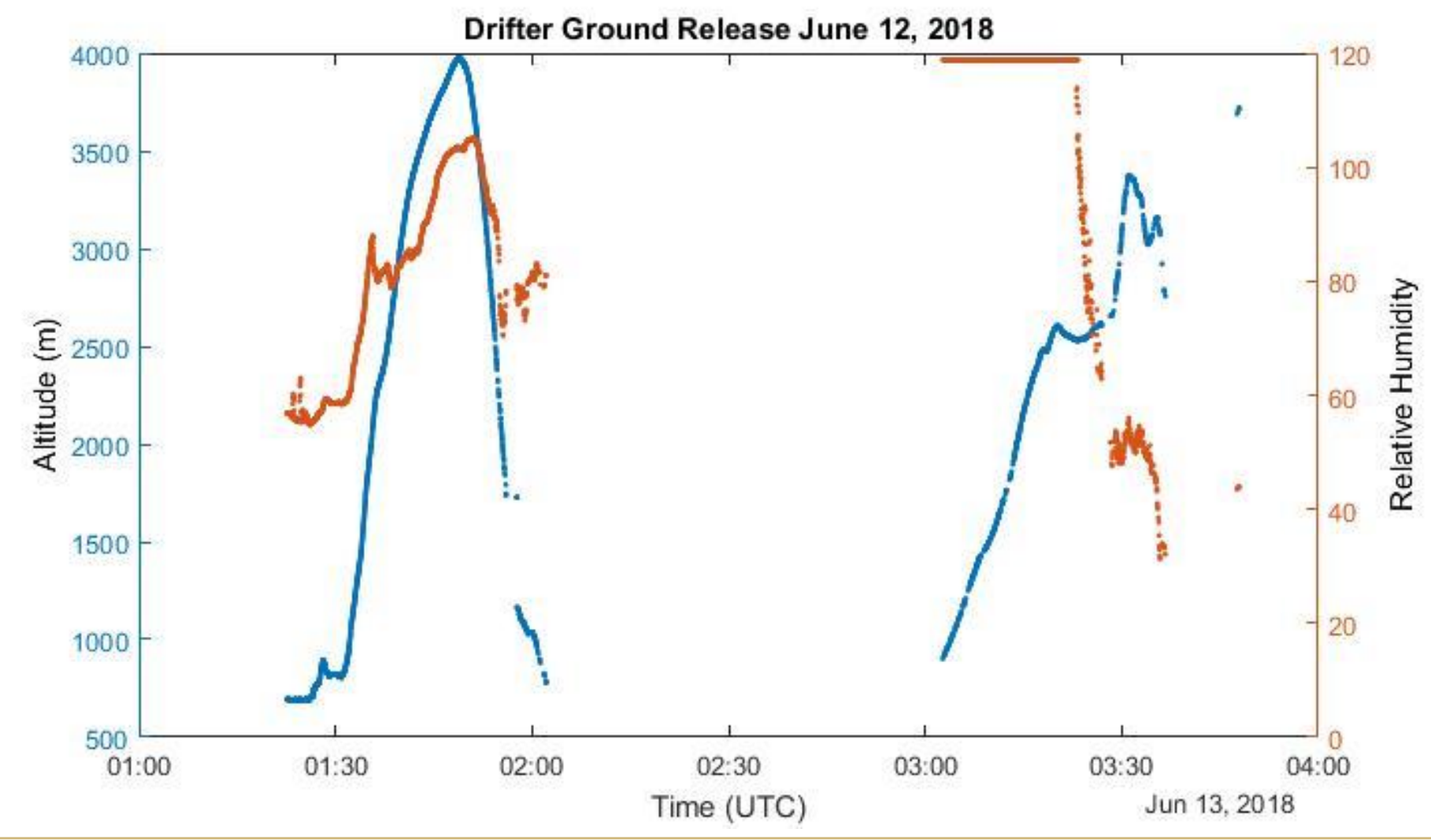
ISARRA 2018 RS92 Comparison



Ground Deployment into a Supercell June 12, 2018

Photo by Roger Laurence III





LD was ground released into a supercell moving to the southeast.

Contact with the LD was lost over an hour period after the LD had decreased in altitude back to ground level.

When contact was regained, microsonde relative humidity had saturated. It is believed the LD was forced down either due to the weight of precipitation or in the presence of a downdraft.

Communication with the LD was matained over a distance of 110km and 2.5 hours. By comparing LD trajectory to Nexrad data, it was seen that the LD entrained into the storm and then turned back towards storm direction after regaining altitude.

Dr. Eric Frew
(eric.frew@colorado.edu)
Dr. Volkan Isler
(isler@cs.umn.edu)

Dr. Brian Argrow
(brian.argrow@colorado.edu)
Dr. Dezhen Song
(dzsong@cse.tamu.edu)

Dr. Adam Huston
(ahouston2@unl.edu)
Dr. Chris Weiss
(Chris.weiss@ttu.edu)