Development of the CopterSonde and the 3D Mesonet

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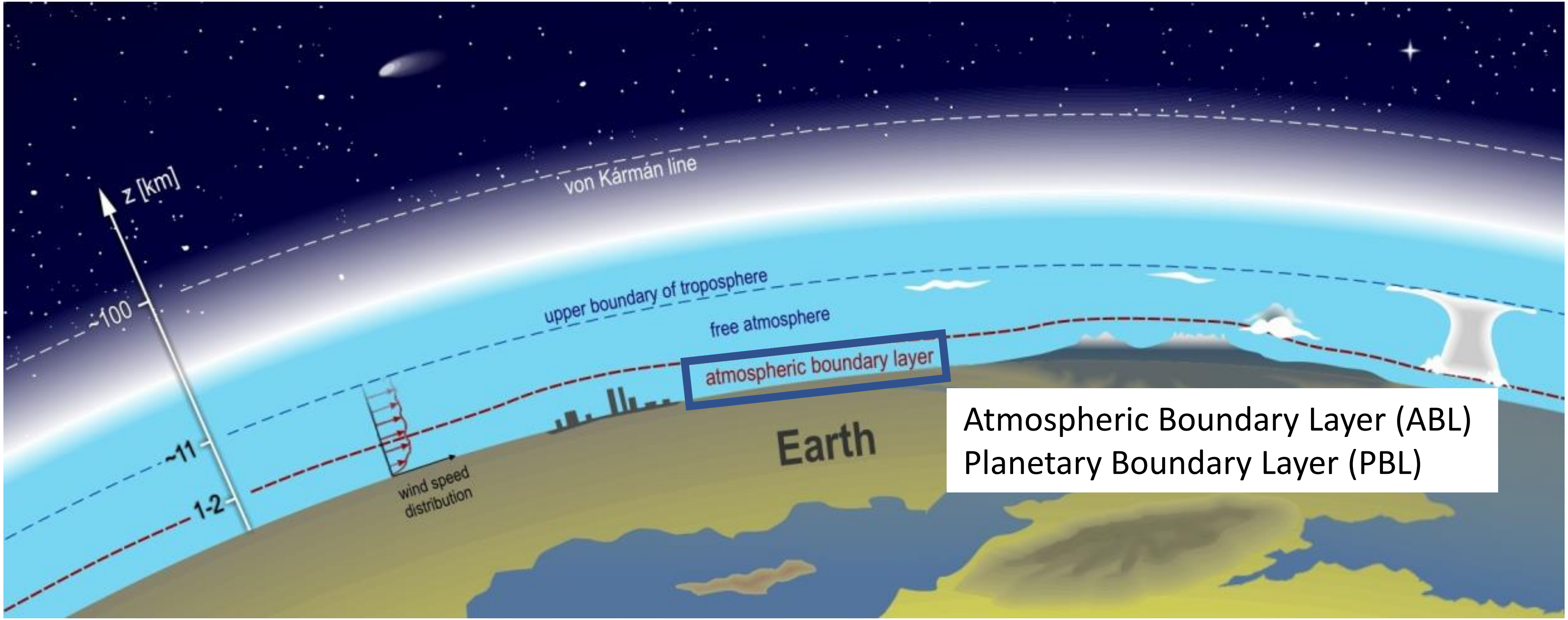
Scales of Motion

Scale	Approximate Length Scale	Approximate Time Scale	Types of Phenomena
Planetary	> ~ 6000 km > ~ 3700 miles	> 1 week	Jet Stream, Trade Winds, Longwave pattern
Synoptic Scale	1000 – 6000 km 620 - 3700 miles	1 day – 1 week	Shortwaves, Fronts, Jet Streaks
Mesoscale	1 – 1000 km 0.62 - 620 miles	1 hour – 1 day	Thunderstorms, Sea Breezes
Microscale	< 1 km < 0.62 miles	< 1 hour	Turbulence, Boundary Layer Phenomena

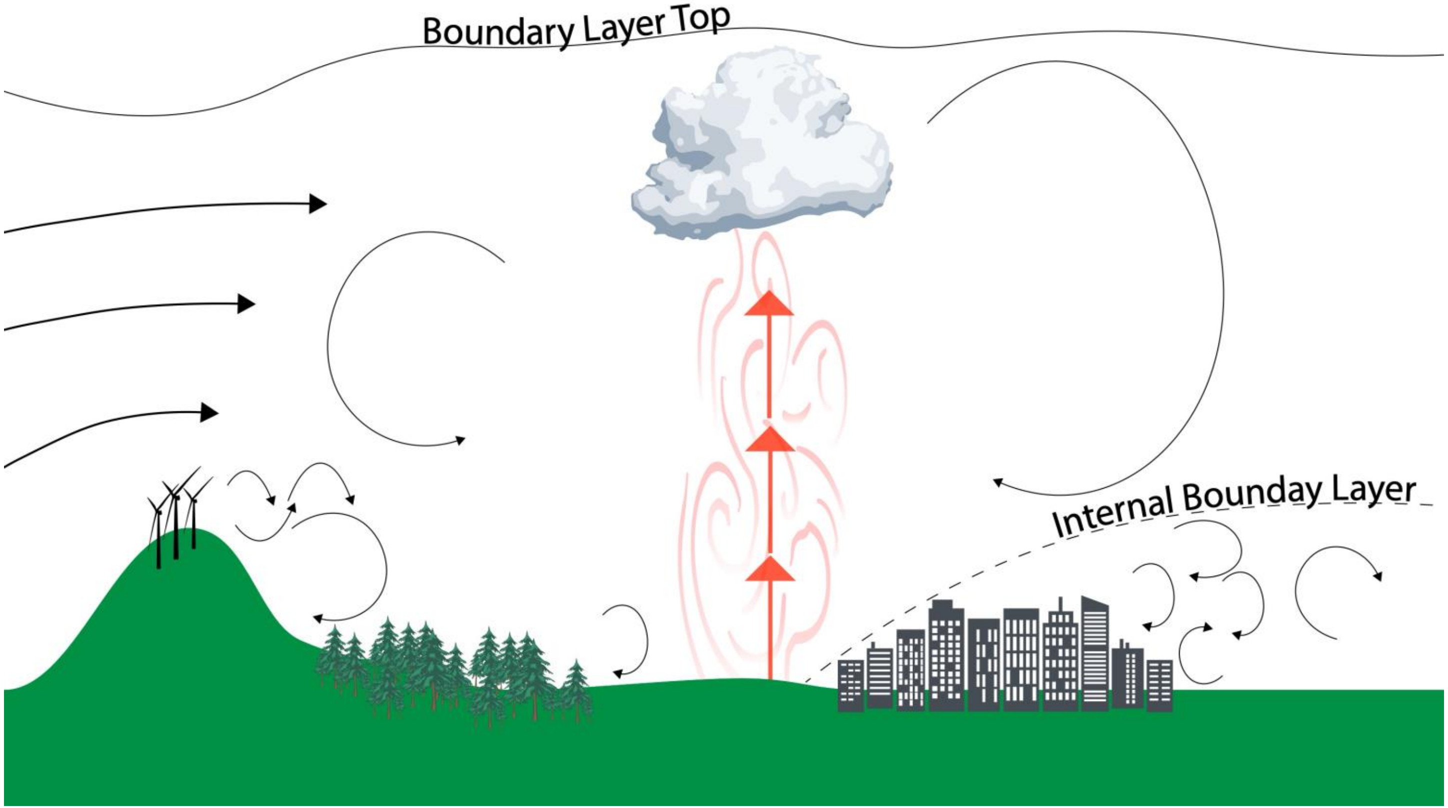
Structure of the Earth's Atmosphere



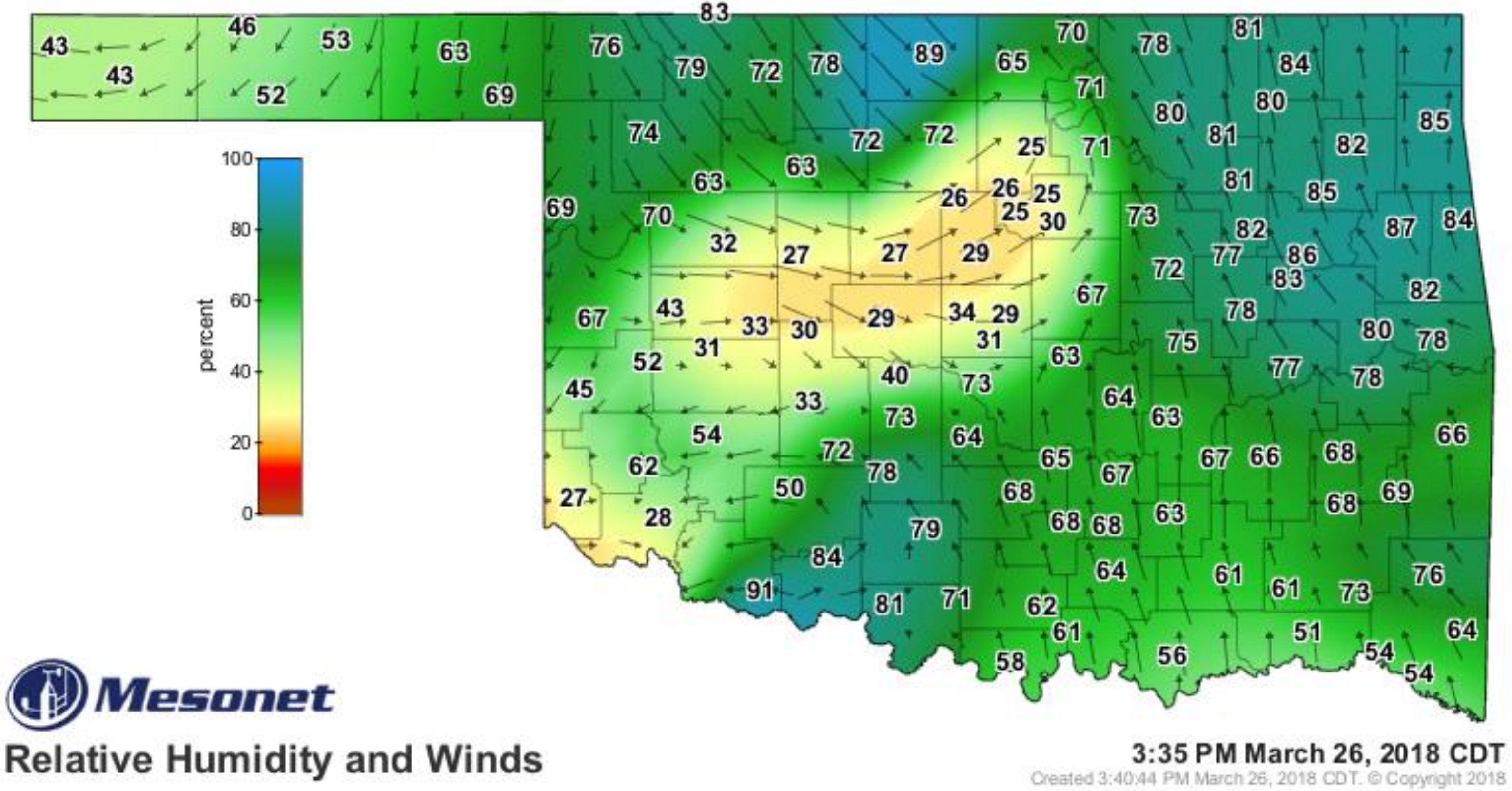
Atmospheric Boundary Layer (ABL)
Planetary Boundary Layer (PBL)

Image source: https://bmeafl.com/the-project-proposal/

The ABL: Well, It's Complicated



Complex Flow Fields

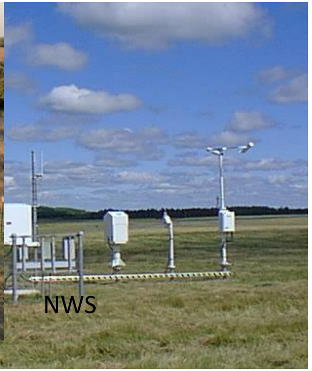


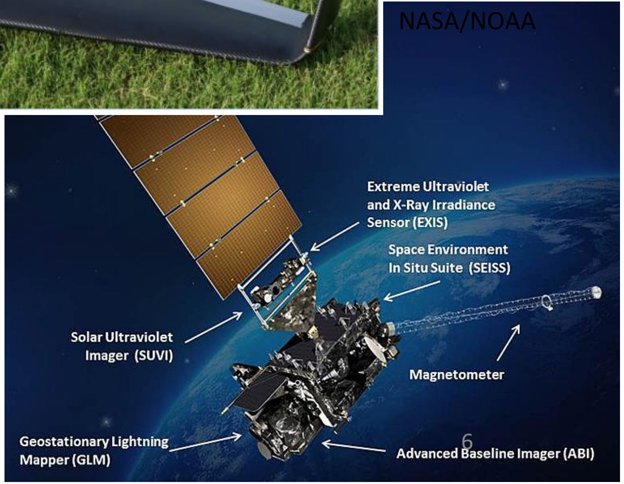
Observational Networks

Upper air sounding
surface stations, g
Meso
Plus many









CLOUD-MAP

CLOUD-MAP: Collaboration Leading Operational UAS Development for Meteorology and Atmospheric Physics

Four-Year Collaborative Project Supported by the National Science Foundation

July 2015 – July 2019

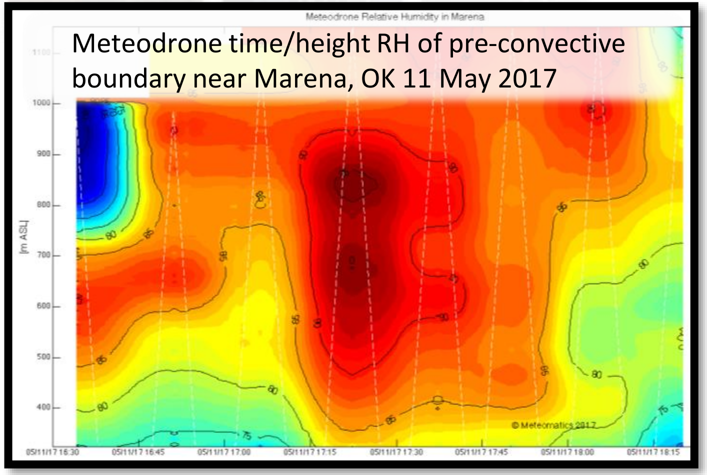
Creation of the Center for Autonomous Sensing and Sampling

April 1st 2016

Environment Profiling and Initiation of Convection (EPIC) – Spring 2017

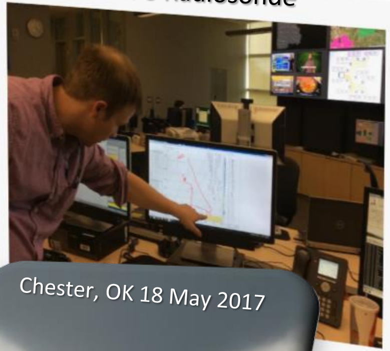
High-resolution profile data from drones and radiosondes was uploaded in real-time for operational use, as well as transects from fixed-wing UAVs. This data allowed forecasters to:

- Monitor capping inversions
- Recognize NWP biases in low-level moisture
- Interrogate low-level wind profiles
- Revise local severe weather outlooks



Meteodrone time/height RH of pre-convective boundary near Marena, OK 11 May 2017

NSSL CLAMPS Radiosonde



Chester, OK 18 May 2017

Todd Lindley
Norman, OK
Forecast Office SOO

EPIC: Views from the field


OU CopterSonde

CU Tempest


NSSL Radiosonde


Meteomatics Meteodrone

April/May 2017, Oklahoma

ISOBAR (Innovative Strategies for Observations in the arctic atmospheric Boundary lAyeR)


On the sea ice

Phil Chilson, Meteorology
Bill Doyle, Electrical Engineering
Brian Greene, Meteorology
Santiago Mazuera, Aerospace Engineering
Liz Pillar-Little, Chemistry
Tony Segalés, Electrical Engineering

The UNIVERSITY of OKLAHOMA
CASS
CENTER FOR AUTONOMOUS SENSING & SAMPLING

OU Vehicles Used During Campaign

Tuffwing
Plane 1 used for photogrammetry
Plane 2 used for CO_2 sampling
Equipped with safety parachute
Equipped with Pixracer autopilot
Records wind speed and direction

CopterSonde 2.1
Pressure, temperature, humidity, wind speed, and wind direction
Sensors aspirated by props
RTK DGPS
Rotates into wind
Equipped with Pixracer autopilot

CopterSonde 2.1
Pressure, temperature, humidity, wind speed, and wind direction
Sensors aspirated with ducted fan
Standard GPS
Equipped with Pixracer autopilot

LAPSE-RATE: Lower Atmosphere Process Studies at Elevation: A Remotely Piloted Aircraft Team Experiment

July 2018, Colorado

Flux Capacitor

Soundings

CLAMPS

CopterSone

September/October 2018, Oklahoma

It’s a Long Way to the Top (If You Wanna Rock ‘n’ Roll)
~ AC/DC


August 2015


December 2015


May 2016


October 2015


February 2016

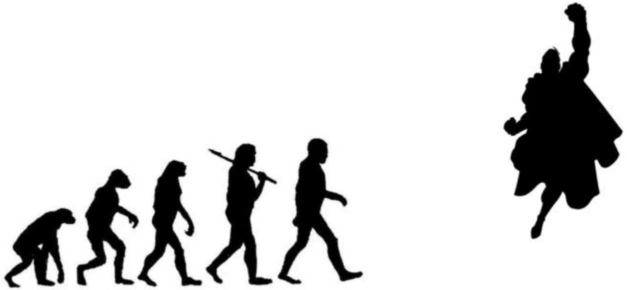

October 2016

Evolution

Iris

CopterSonde Family Album

CopterSonde 2



The OU CopterSonde

- Specifically designed for thermodynamic and kinematic profiling
- Customized autopilot software
- Sensor data are passed through the autopilot; opens door for adaptive sampling
- Pixhawk 2 running APM Copter, with integrated inertial measurement unit (IMU), GPS and differential GPS
- Position accuracy of ~10 cm in flight
- Has flown to a height of 6,000’ AGL in Finland and 10,000’ MSL in Colorado

AIRFRAME

Body	Carbon fiber tube (arms), G10 fiberglass (internal body), and aluminum (connectors and spacers)
Shell	3D printed PLA
Diagonal	50.8 cm
Height	15.2 cm
Fight Controller	Pixhawk 2.1 Cube

COMMUNICATIONS

Telemetry Frequency	915 MHz
Radio Frequency	2.4 GHz
Transmission Distance	up to 5 km

GPS ACCURACY

Horizontal (RTK enabled)	± 3 cm
Horizontal (RTK disabled)	± 1.5 m
Vertical (RTK enabled)	± 5 cm
Vertical (RTK disabled)	± 3 m

PROPULSION SYSTEM

Brushless Electric Motor

Lifespan	1600 hrs
kV Rating	700 RPM/V
Maximum Thrust	1.23 kg / rotor
Maximum Power	500 W/rotor

T-Style Propellers

Diameter x Pitch	11 x 5.5 in
Material	Carbon Fiber

ESC

Maximum Continuous Current	35 A
Burst Current	45 A
Maximum Voltage	14.8 V (4S LiPo)

POWER

Battery Type	4S LiPo
Capacity	6750 mAh
Typical Endurance	15 min

Meteorological Specifications

THERMODYNAMIC

Primary Variables	T, RH, p
Derived Variables	T_d, T_v, θ, θ_e, θ_ω, r, r_s, q, q_s, e, e_s, LCL, Γ
Accuracy	T: ± 0.1 °C RH: ± 2 % p: ± 1.5 mbar
Logging Rate	20 Hz

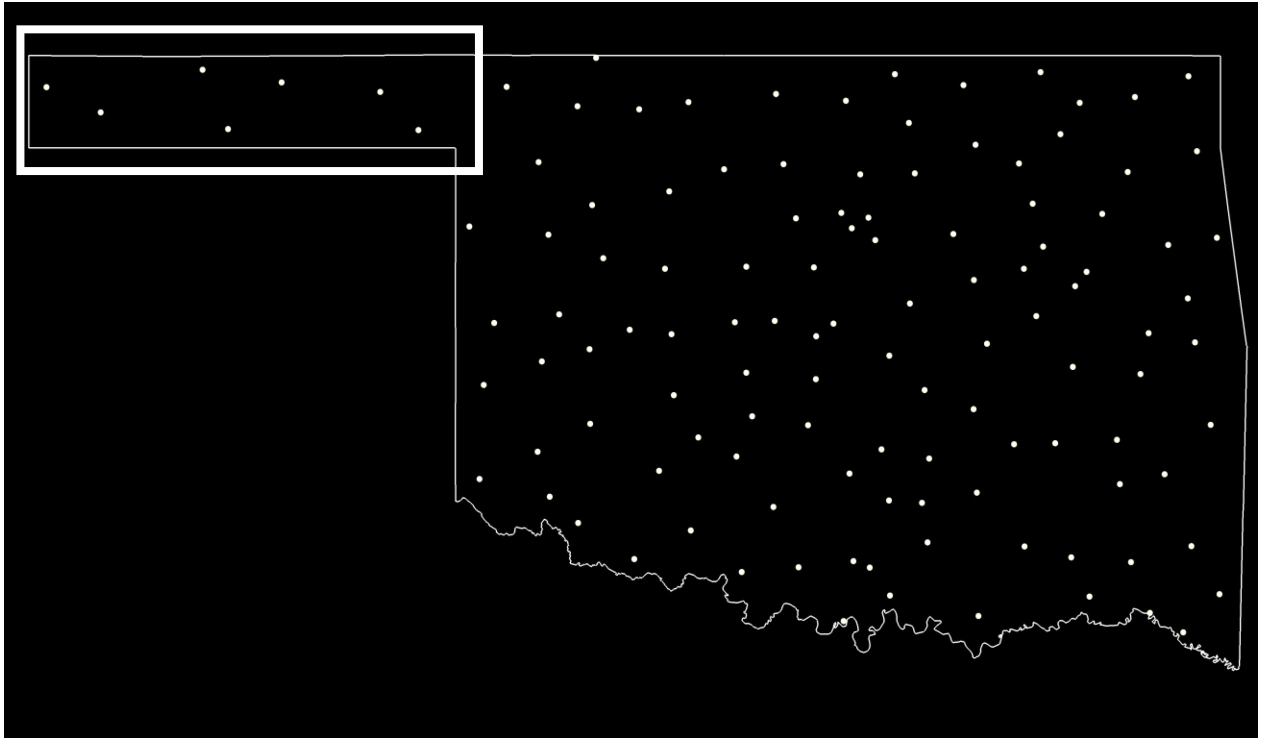
KINEMATIC

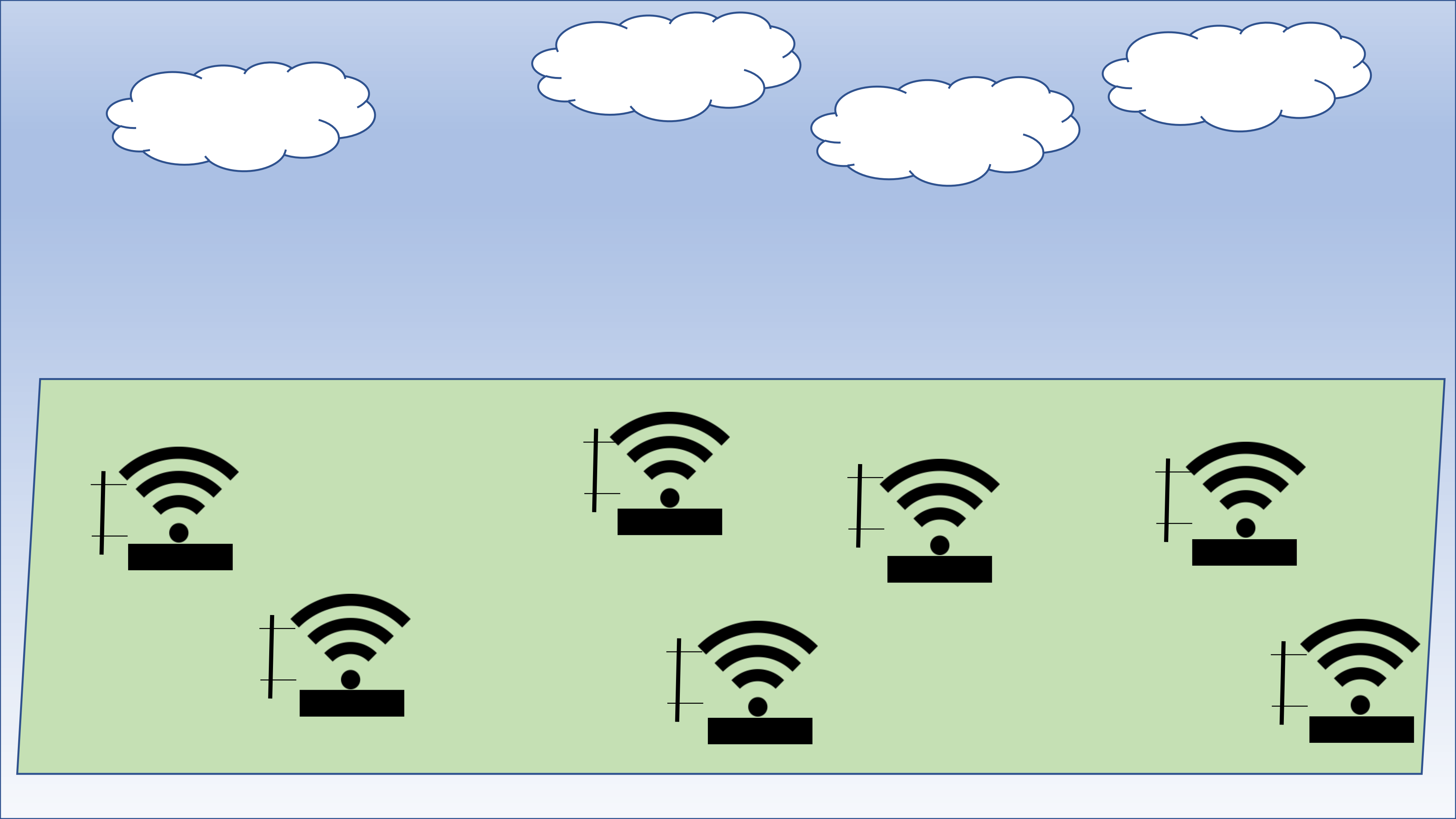
Primary Variables	Tilt Angles
Derived Variables	Horizontal wind speed and direction
Accuracy	Speed: ± 0.6 m/s Direction: ± 4°
Logging Rate	50 Hz

Flight Parameters

Maximum Tilt Angle	40°
Maximum Wind Resistance	22 m/s
Maximum Operating Speed	26 m/s
Maximum Flight Ceiling	6,000 ft AGL
Recommended Operating Temperatures	-20 – 40 °C
Typical Ascent Rates	1 – 5 m/s
Typical Descent Rates	4 – 6 m/s
Weight (sans battery)	1.61 kg
Average All-up Weight	2.25 kg

Oklahoma Mesonet

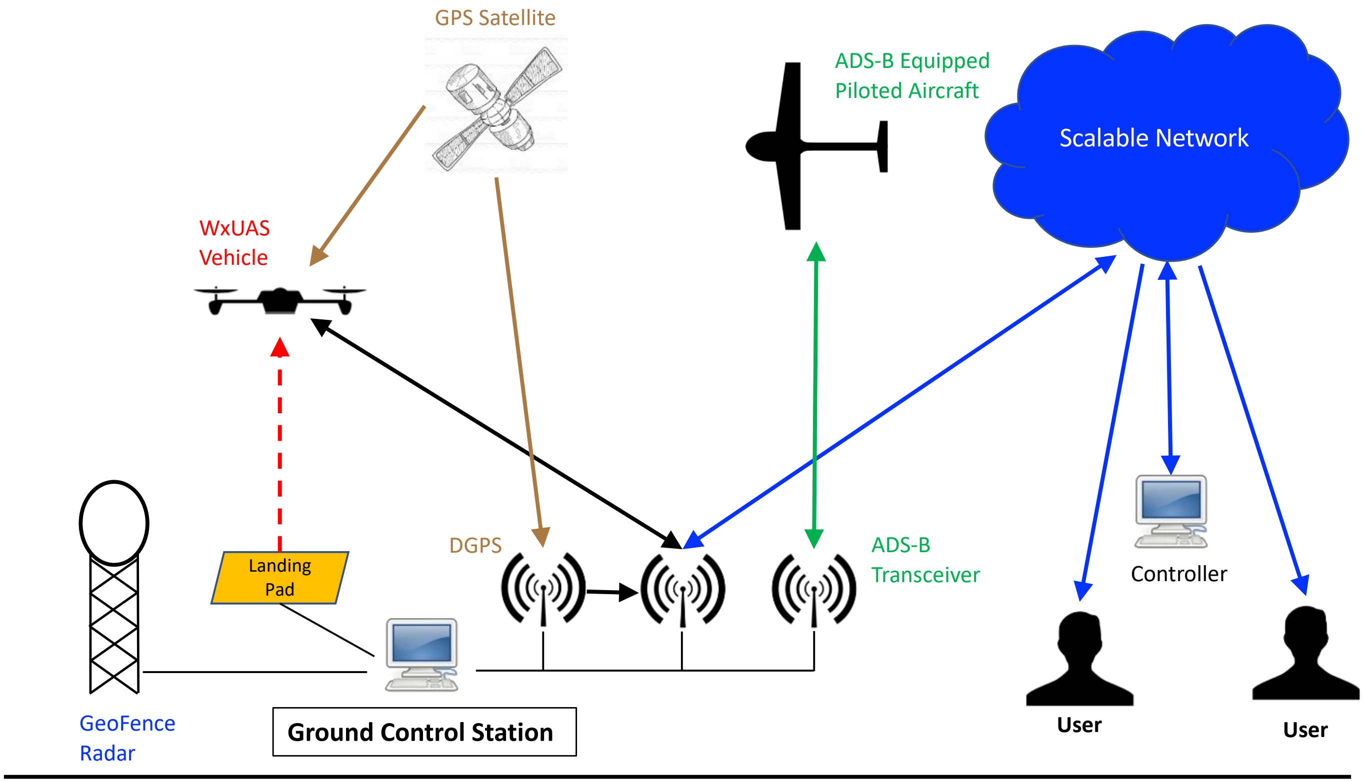




Components of a 3D Mesonet Station

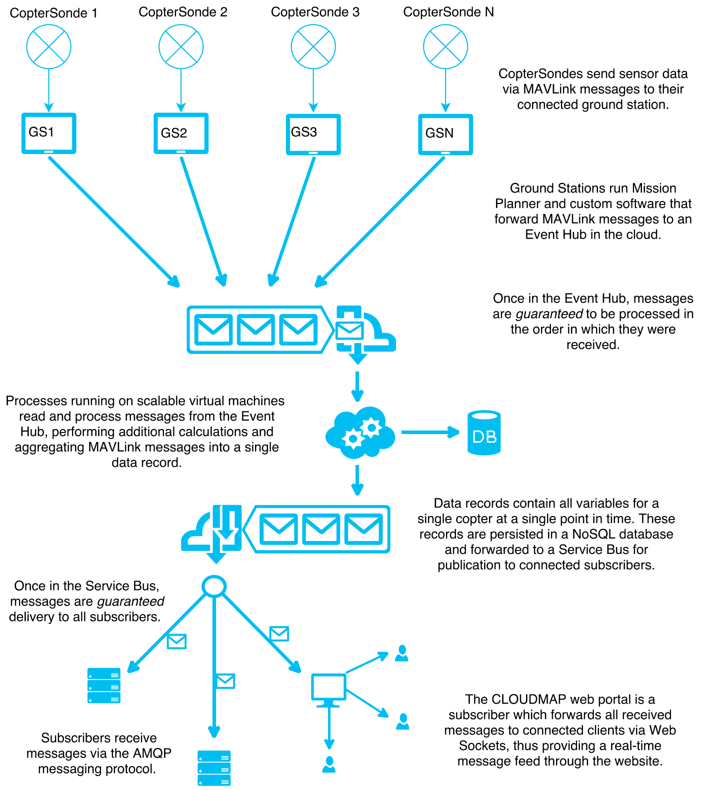
- Robust and Reliable UAV with Accurate Sensors
- Ground Control Station
- Precision Landing
- Enclosure/Housing
- Automatic Charging
- Risk Mitigation Measures for Unattended Operations
- Data Sharing and Remote Control Capabilities

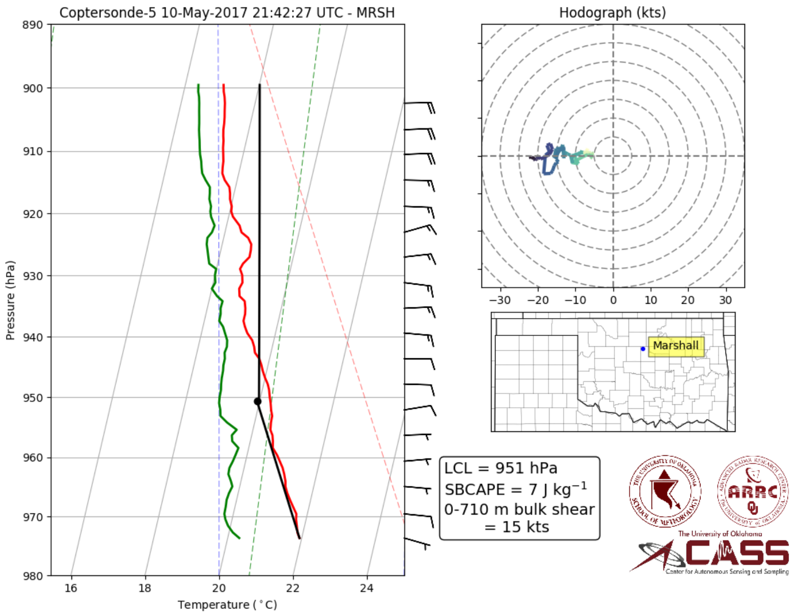
Ground Control Station and CONOPS



Data Packaging and Communication

Providing a method to communicate data from various field observations to a central processing station and the generate products, which can be shared





Sample output available to a subscriber of the data feed.

Sensors **2019**, *19*(12), 2720; https://doi.org/10.3390/s19122720 Open Access

Review

Moving towards a Network of Autonomous UAS Atmospheric Profiling Stations for Observations in the Earth's Lower Atmosphere: The 3D Mesonet Concept

Phillip B. Chilson [1,2,3,*], Tyler M. Bell [1,2], Keith A. Brewster [1,4], Gustavo Britto Hupsel de Azevedo [2,5], Frederick H. Carr [1], Kenneth Carson [6], William Doyle [2], Christopher A. Fiebrich [1,7], Brian R. Greene [1,2,3], James L. Grimsley [8], Sai Teja Kanneganti [2,9], Joshua Martin [1,2], Andrew Moore [1], Robert D. Palmer [1,3], Elizabeth A. Pillar-Little [1,2], Jorge L. Salazar-Cerreno [2,3,5], Antonio R. Segales [2,3,5], Mark E. Weber [10], Mark Yeary [3,5] and Kelvin K. Droegemeier [1]

Weather Geeks Podcast https://weloveweather.tv/weathergeekspodcast/
Episodes 51 (TORUS) & 79 (3D Mesonet)

TEDxOU Presentation: How Drones Can Improve Weather Prediction Available on Youtube

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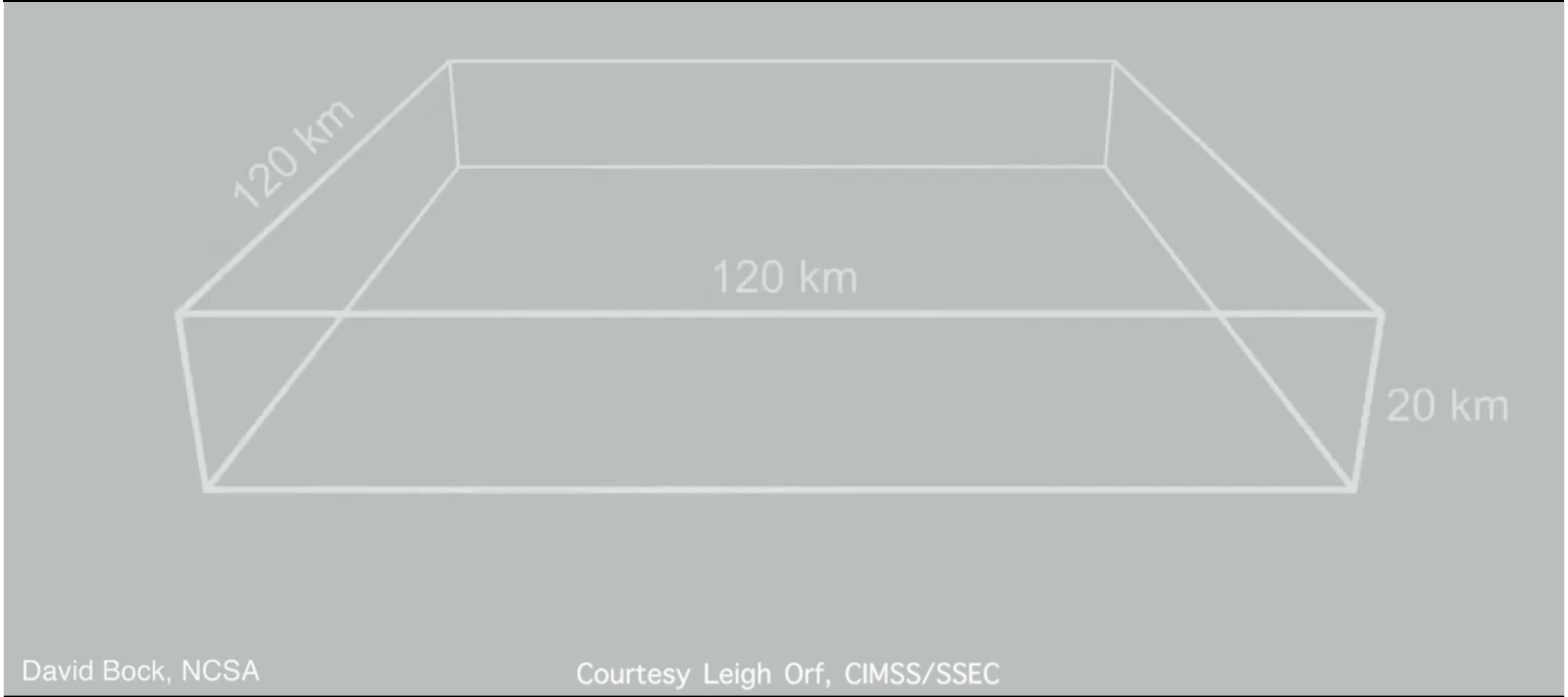
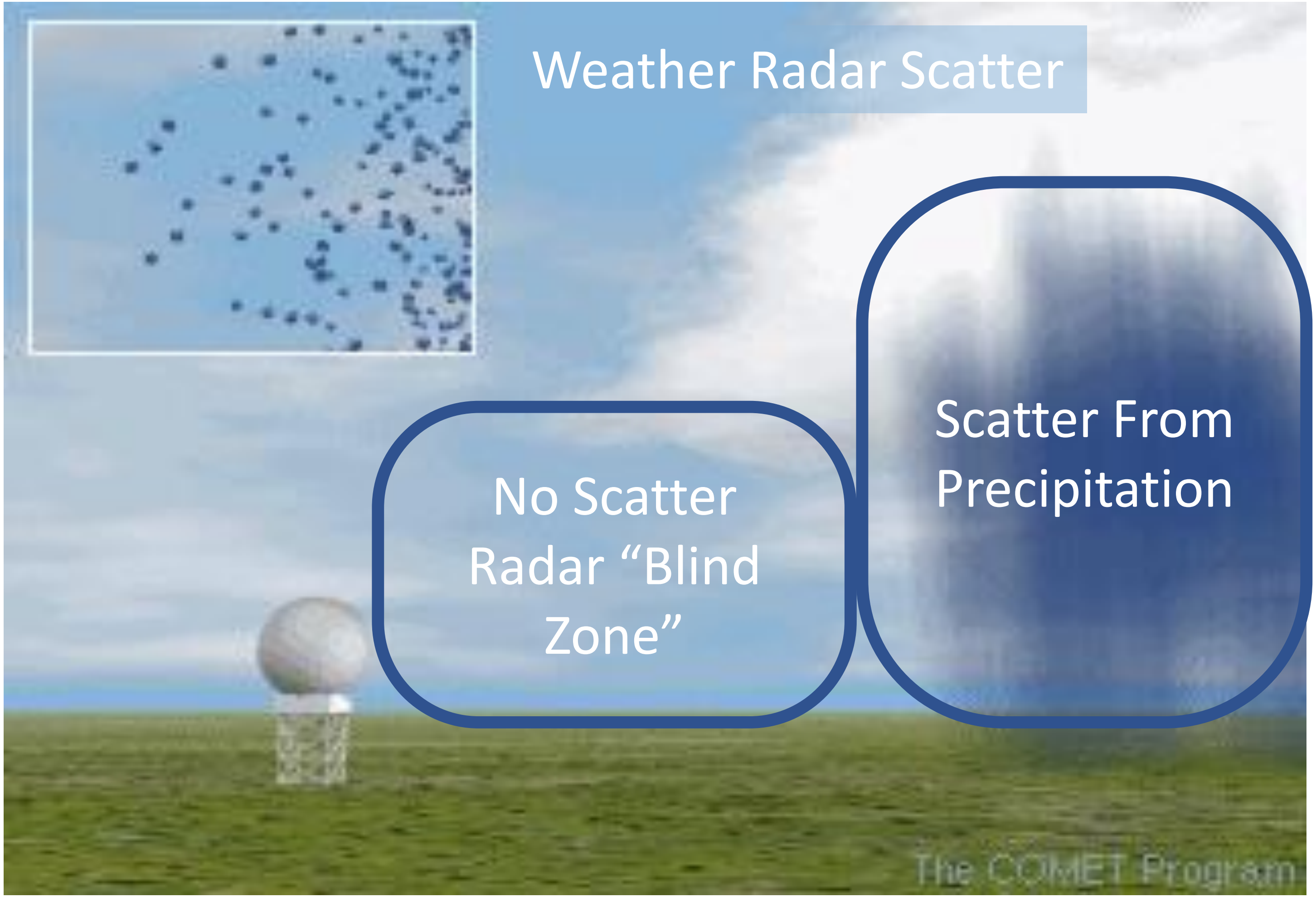
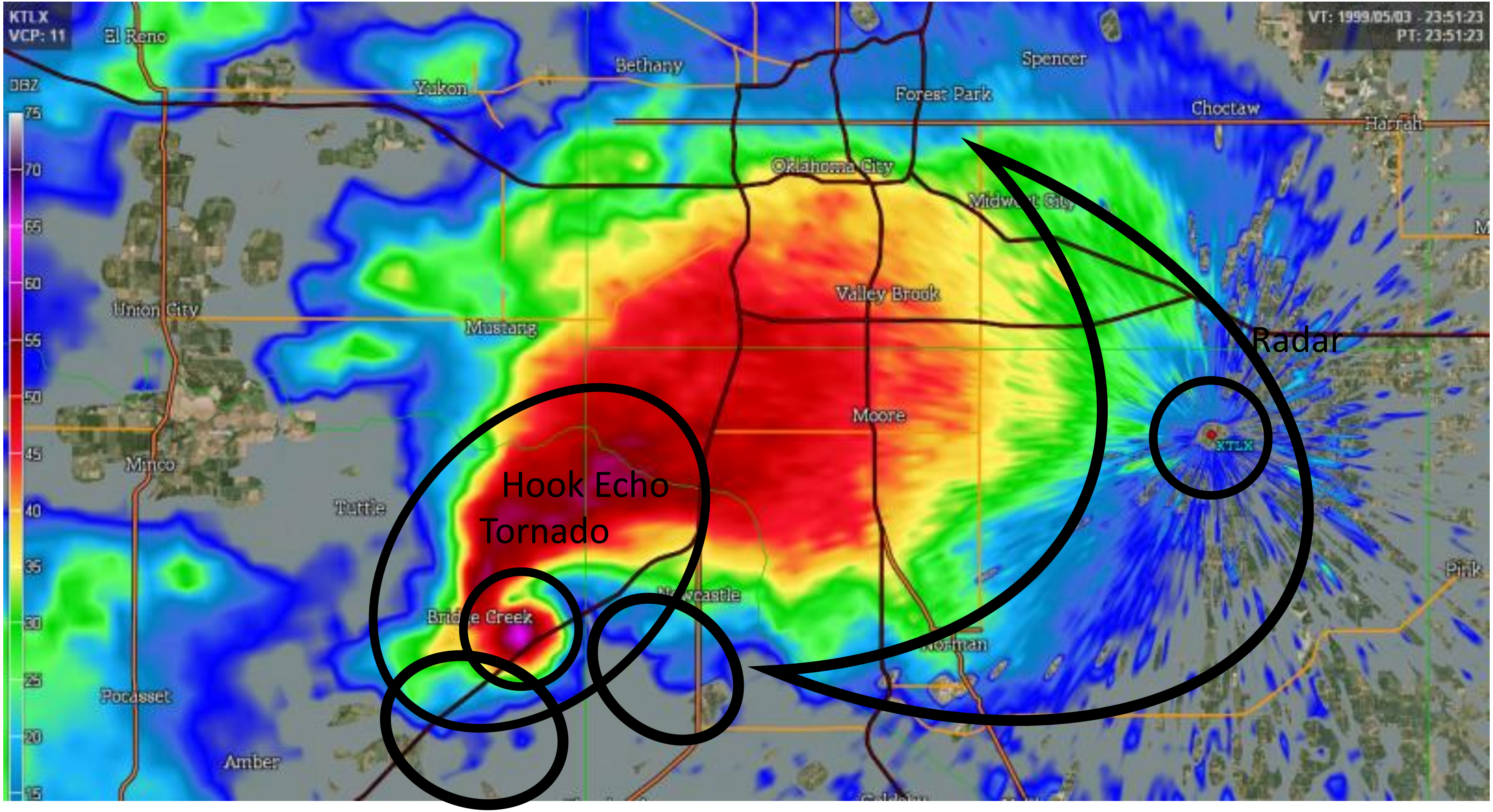
Received: 1 April 2019 / Accepted: 12 June 2019 / Published: 17 June 2019

Tracer particles can be released into the storm to visualize air flows




Weather Radar Scatter
No Scatter
Radar "Blind Zone"
Scatter From Precipitation
The COMET Program


KTLX
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VT: 1999/05/03 - 23:51:23
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DBZ
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El Reno
Bethany
Yukon
Spencer
Forest Park
Choctaw
Harrah
Oklahoma City
Midwest City
Valley Brook
Union City
Mustang
Moore
Minco
Tuttle
Pink
Bridge Creek
Pocasset
Amber
Norman
KTLX
Hook Echo
Tornado
Radar

Questions

Strength Through Partnership

"Oklahomies"

Funding for this study provided in part by the National Science Foundation: Award #1539070 (CLOUD-MAP)