Experiment of Sea Breeze Convection, Aerosols, Precipitation and Environment (ESCAPE)

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Field campaign management, radar meteorology, SBU mobile trucks microphysics and dynamics of convective clouds, urban boundary layer

Co-I's

Matthew Kumjian and Kelly Lombardo (Penn State)

Radar polarimetry, microphysics/dynamics, drifter sondes

Eric Bruning (Texas Tech) and Timothy Logan (Texas A&M)

Houston LMA operations, Lightning and mixed phase microphysics

Zachary Lebo (Wyoming) and Sue van den Heever (Colorado State)

High resolution modeling, updraft properties, aerosols and meteorology controls on deep convection, cold pools

Greg McFarquhar (Oklahoma)

Aerosol-cloud microphysics, aircraft operations

Greg Roberts (Scripps Institution of Oceanography)

Analysis of mini-CCNc's data and aerosol-convection interactions

Raymond Shaw (Michigan Tech)

Analysis of HOLODEC-II observations, entrainment and cloud microphysics

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Paul Lawson (SPEC Inc.) - SPEC Learjet 35A operations & C-130 user-supplied probes

Paul DeMott (Colorado State) - C-130 user-supplied probes

V. (Chandra) Chandrasekar (Colorado State) – C-band radar

Jeffrey Snyder and David Bodine (Oklahoma/NSSL) - 2 mobile X-band radars

ESCAPE Science Focus Areas

- *Investigate the control of meteorology, dynamics, and mixing on aerosol indirect effects on the early growth stage of convective clouds,*

- *Characterize the environment and physical processes leading to coastal convective initiation,*

- *Determine how mature convective updraft microphysical and kinematic properties relate to those earlier in the cloud lifecycle, its initiation mechanism, and heterogeneities of its parent environment*

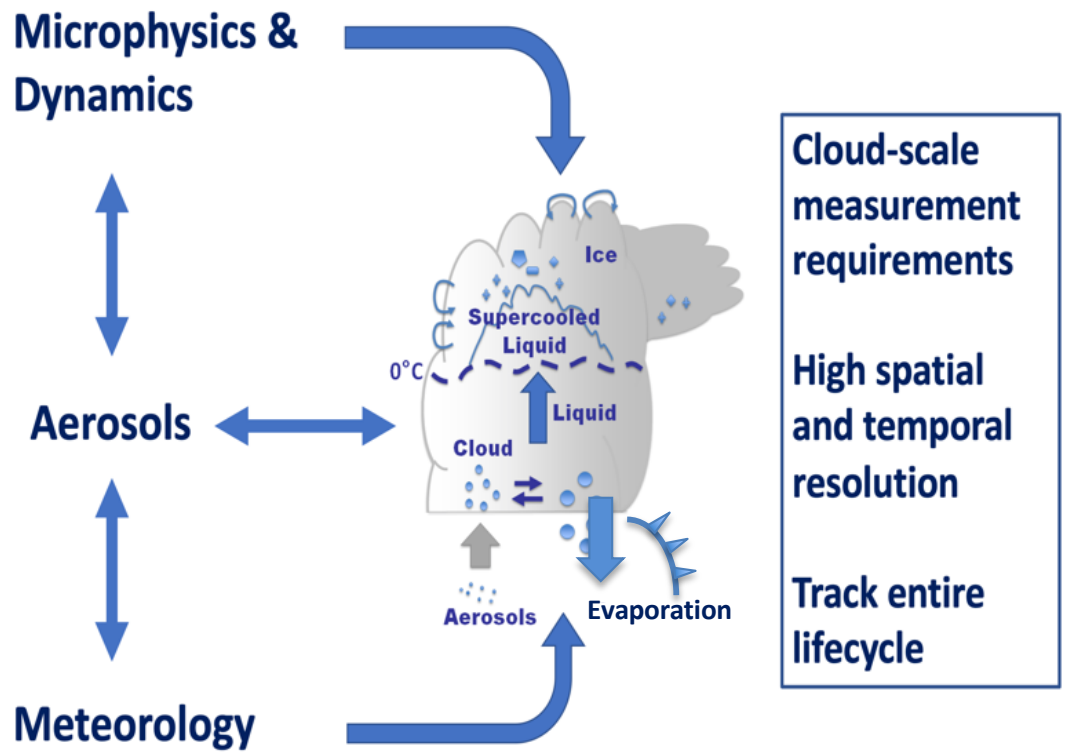
- *Quantify environmental thermodynamic and kinematic controls on convective lifecycle properties under different aerosol conditions.*

- *Quantify: (1) how cold pool properties and lifetimes vary as a function of precipitation amounts and precipitation size distributions, and how are these relationships modulated by the relative humidity,(2) what is the impact of aerosol number concentration on cold pool depth and intensity, and (3) how do different land-surface types determine the dissipation of cold pools.*

- *Characterize how the lightning flash size and energy depends on the modification of the supercooled liquid water content, scale and volume of the mixed-phase updraft, and hydrometeor populations.*

ESCAPE Experimental Design

In order to address the scientific objectives, observations of the various physical mechanisms within the clouds and local environment that act to produce precipitation are needed. This includes the cloud microphysical properties and the vertical motions within convective storms that are associated with heavy precipitation



ESCAPE measurement requirements

Airborne campaign:	June 15 – July 15, 2021
Ground-based campaign:	June 10 – July 25, 2021

SPEC LearJet 35A

32 research flight hours
8 flights

The SPEC Learjet will be equipped with state-of-the art in situ microphysical probes, air motion sensing and a Ka-band up/down radar.

	Learjet 25	Learjet 35A
Maximum Takeoff Weight	15,000 lbs	18,300 lbs
Maximum Certificated Ceiling	45,000 ft	45,000 ft
Maximum Range	1,200 nmi	1,900 nmi
Maximum Airspeed	0.82 Mach (300 KIAS)	0.82 Mach (350 KIAS)
Number of Seats excluding pilots	3	3
Electrical Capability	(2) 400 A Generators Research Power = 7.2 KW 6.2 KW @ 110 VAC 60 Hz 1.0 KW @ 28 VDC	(2) 400 A Generators Research Power = 7.2 KW 6.2 KW @ 110 VAC 60 Hz 1.0 KW @ 28 VDC

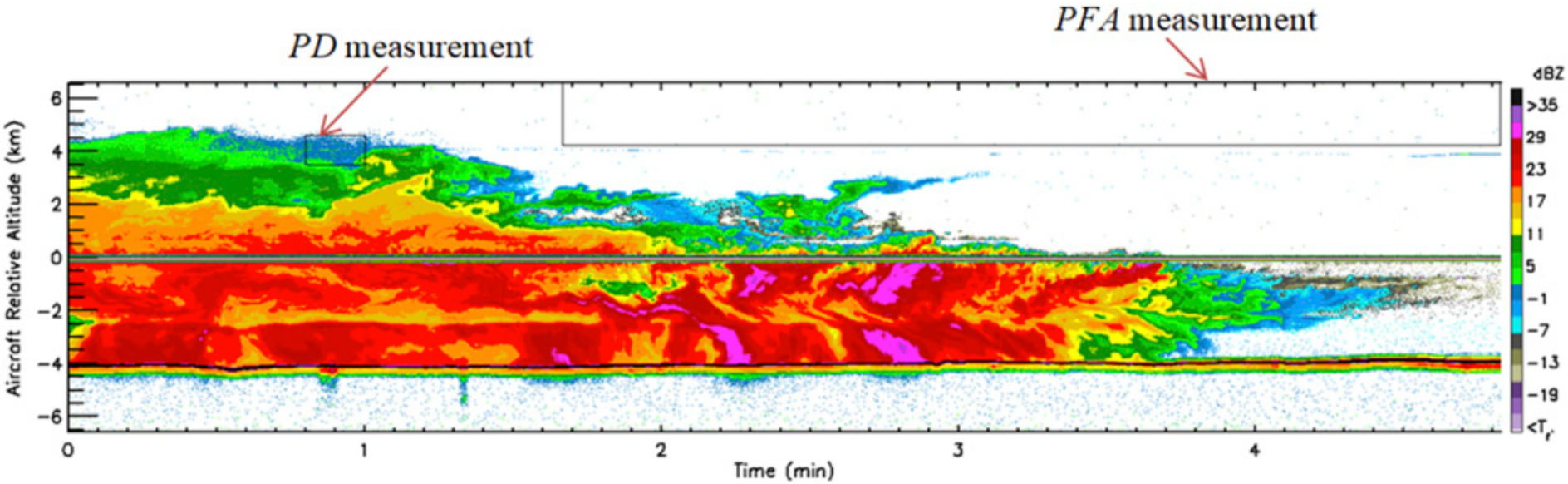
Equipment List	Manufacturer	Range	Accuracy
Temperature	Rosemount Model 102 & 510BH	-50 to +50 °C	0.5 °C
Altitude	FAA RVSM Certification	45,000 ft	60 ft (18.3 m)
Airspeed	FAA RVSM Certification	0 to 220 m s^{-1}	1 m s^{-1}
Dew Point Temperature	EdgeTech Chilled Mirror C-137	-50 to + 50°C	1°C
Cloud Liquid Water	Sky Tech Nevzorov LWC	0 to 4 g m^{-3}	0.05 g m^{-3}
Total Water Content	Sky Tech Nevzorov TWC	0 to 4 g m^{-3}	0.1 g m^{-3}
Icing Rate	Rosemount Icing Rod 871LM5	N/A	Sensitivity ~0.01 g m^{-3}
Aircraft Position	Aventech AIMMS-20 Dual GPS	N/A	10 m
Aircraft Heading	Learjet Sperry Directional Gyro	0 to 360°	1°
Horizontal Wind Vertical Wind	Aventech AIMMS - 20	0 to 360° 1 to 100 m s^{-1}	1° 1 m s^{-1}
Aerosols	PCASP	0.1 to 3 µm	1 µm
2D-S (Stereo) Optical Array Spectrometer	SPEC Model OAP 2D-S 2-D Gray probe	10 µm to 3 mm	10 µm
Fast Cloud Droplet Probe (FCDP)	SPEC Model FCDP-100	2 to 50 µm	2 µm
High Volume Precipitation Spectrometer (HVPS)	SPEC Version-3 HVPS Version-4 HVPS	150 µm to 2 cm	150 µm
Combination FCDP, 10 and 50 µm 2D-S, V 2.5 CPI	SPEC Hawkeye	1 µm to 6,400 µm	1 µm FCDP 10-50 µm 2D-S 2.3 µm CPI
Iso Inlet for aerosols < ~ 2µm	DU	0.01 to 2 µm	

Ka-band Probe Radar (KPR)

Specifications

Frequency:	35.6 GHz
Transmitter:	10 W solid state power amplifier
Antennas:	14 cm flat-plate array, 4.5 deg. beam-width
Pulsing:	Interleaved short RF and linear FM pulses
Range Resolution:	30, 75, 100 or 150 m
Delta T:	1 K @ 200 ms integration (5 Hz data rate)
Rec. Noise Temp.:	440 K
Radomes:	Matched Rexolite window
Weight:	25 lb (40 lb with canister)
Power:	50 W AC; 100 W 28 VDC

The first test flights were conducted on-board the Univ. of Wyoming KingAir research aircraft in January 2016.



NCAR C-130

90 research flight hours
15 flights

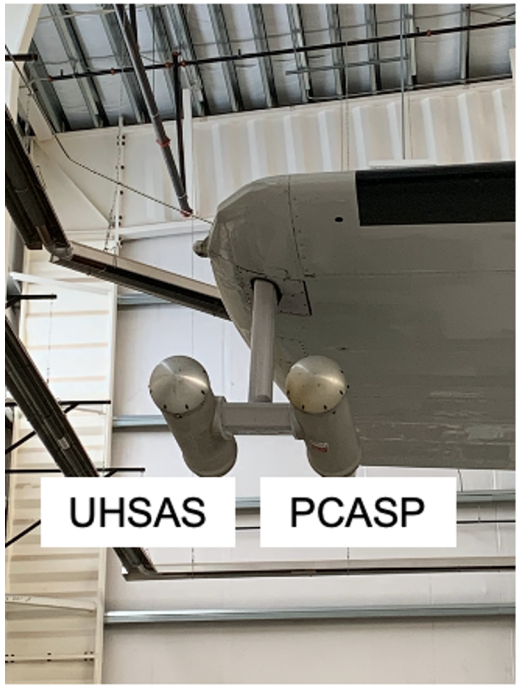
The C-130 will be equipped with in situ microphysical probes, aerosol measurements of CCN, IFP and biological aerosols, air motion sensors and the University of Wyoming cloud resolving radar (WCR).

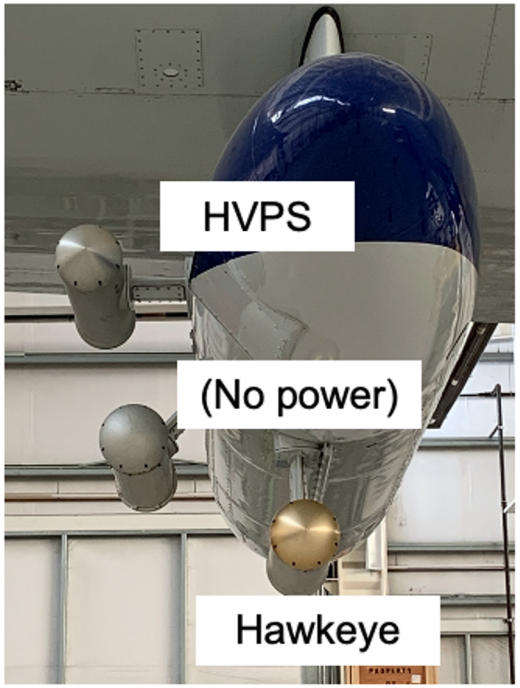
The NSF/NCAR C-130 is a versatile airborne research platform that is well suited for studies of the middle troposphere. With its 13,000 lbs payload capability and ~9 hour endurance, the C-130 is well suited for a variety of research tasks that do not require reaching altitudes in excess of 26,000 feet. With excellent low altitude performance the C-130 is used extensively for studies of the planetary boundary layer.

NCAR C-130 user-supplied in-situ probes ESCAPE/SPICULE field campaigns – Summer 2021			
No	Name	Measurements	PI
1	Continuous flow diffusion chamber (**CFDC**)	The CFDC will measure INP's concentrations in real-time at set point temperatures (usually also in the water supersaturated regime to stimulate immersion freezing).	Paul DeMott
2	Ice spectrometer (**IS**)	The IS product will be an INP temperature spectra over the temperature and concentration range defined by that sample volume and INP activity.	Paul DeMott
3	Wideband Bioaerosol Sensor (**WIBS-4A**)	The WIBS will provide real-time assessment of fluorescent particle concentrations at sizes larger than about 0.8 microns.	Paul DeMott
4	Cloud Condensation Nuclei Counter (**CCN-100**)	The CCN-100 measures the count and size of individual aerosol particles that can form into cloud droplets (single supersaturation level)	Paul Lawson
5	High Volume Precipitation Spectrometer (**HVPS**)	Captures two-dimensional images of large precipitation particles passing through sample volume where laser beams overlap.	Paul Lawson
6	Two-dimensional stereo (***2D-S***) probe	Captures two-dimensional images of particles passing through sample volume where laser beams overlap.	Paul Lawson
7	Fast Cloud Droplet Probe (**FCDP**)	The FCDP determines the cloud droplet distributions and concentrations in the range of 1.5 to 50 microns.	Paul Lawson
8	Holographic Detector for Clouds (**HOLODEC-II**)	The HOLODEC-II provides the size and relative position of small particles (liquid or ice) with sizes from 10-100 μm.	Raymond Shaw
9	Miniature Cloud Condensation Nuclei Counters (**mCCNcs**)	One mCCNc operates at a fixed supersaturation. The second mCCNc will scan supersaturations between 0.07 and 1% Sc every 5 min.	Greg Roberts

NCAR C-130 – Additional probes

Right Wing





Left Wing

NCAR C-130 in-situ probes ESCAPE/SPICULE field campaigns – Summer 2021		
No	Name	Measurements
1	Passive Cavity Aerosol Spectrometer Probe (PCASP)	Size distribution and concentration of aerosol particles ~0.1 to 3.0 micrometer diameter in 30 size bins (10 Hz)
2	Ultra-High Sensitivity Aerosol Spectrometer (UHSAS)	Size distribution and concentration of aerosol particles ~0.06 to 1.0 micrometer diameter in 100 size bins (10 Hz)
3	Hawkeye Combination Cloud Particle Probe	Cloud and Precipitation size distribution (1.5 to 6400) micrometer diameter
4	Cloud Droplet Probe (CDP)	Size distribution and concentration of cloud droplets in the range of 2-50 micrometers (10 Hz)

Colorado State U. C-band Radar

Parameter	Value
Frequency Range	5.5-5.7 GHz
Peak power	250 kW
Pulse width	0.5, 0.8, 1.0 or 2.0μs
Duty Cycle	0.12 %
PRF	50Hz-2.4kHz
Avg power	300W
Polarization modes	HV simultaneous, H-only
Antenna diameter	4.5 m
Beam width	1 degree

Radar electronics packaged in a 20-ft shipping container

Radome, positioner and antenna currently mounted on a 20-ft tower (or 10-ft).

Platform and container sit on a 30-ft square area (Concrete pad at CSU)

Platform legs have 3-6 ft deep concrete piers, depending on soil conditions and height

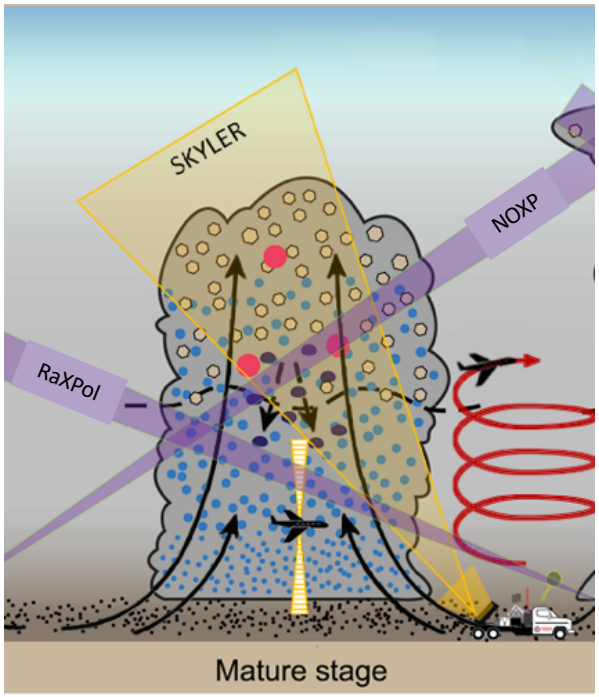
Oklahoma U. Mobile X-band radars

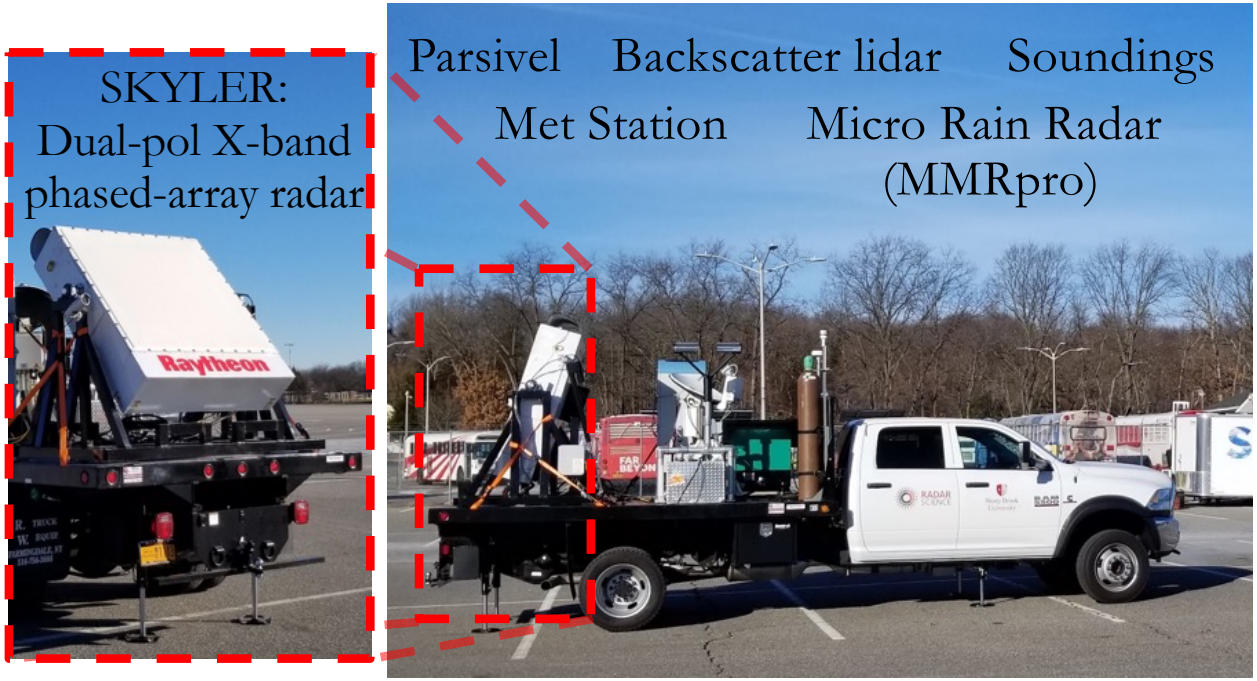
Parameter	Value
Center frequency	9.73 GHz ±20 MHz
Transmit power	20-kW peak, 200-W avg
Transmit pulse width	0.1–40 us
Transmit waveform	RF pulse, linear or custom chirp
Transmit polarization	Equal power V and H
PRT	Uniform or staggered
Antenna type	Dual-linear polarized parabolic reflector
Antenna diameter	2.4 m
Antenna beamwidth	1.0° half power
Antenna gain	44.5 dB
First sidelobe	27 dB
Pedestal type	Elevation over azimuth
Pedestal scan rate	180° s^{-1} in azimuth 36° s^{-1} in elevation

DETAILS ABOUT NOXP

- Wavelength/frequency: 3cm/X-Band/9415 Mhz
- Peak Power: 250kW
- Beamwidth: .9 degrees
- Operational range: 130 km (weather deper
- Deploy time: 5 minutes

Stony Brook U. Weather Truck

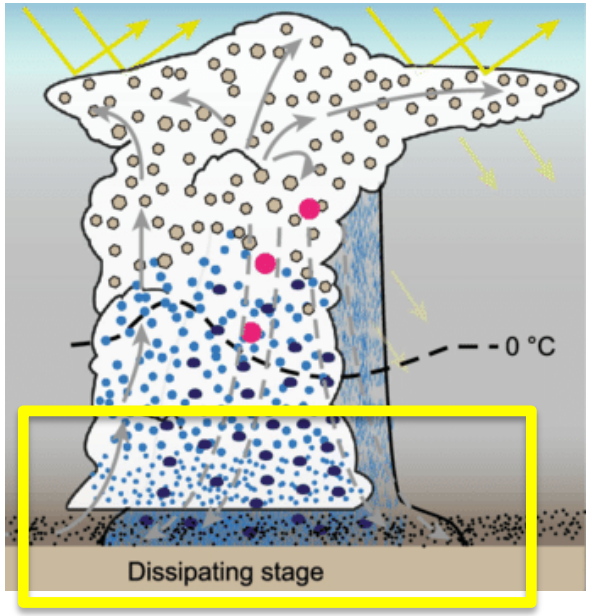


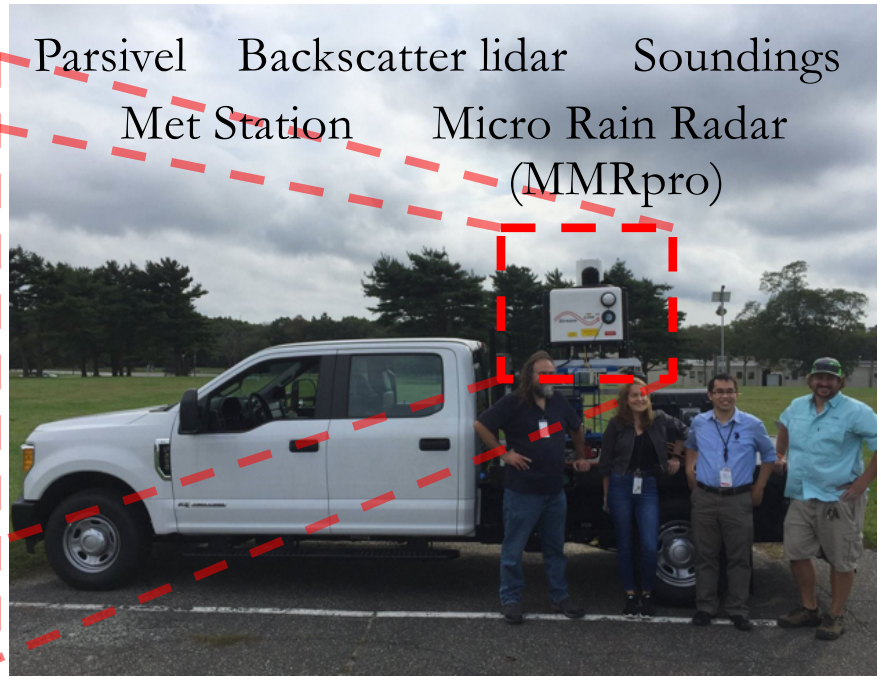


The OU mobile X-band radars along with the SBU-SKYLER will be used to establish a multi-Doppler network, with ~30-km baselines and volumetric scans every ~2 min to provide fine spatial-temporal scale sampling of evolving 3D structures from very near the surface to boundary layer or storm top

The OU radars will focus on dual-Doppler analysis focusing on the low- and mid-level structure (0-6 km) and the SBU SKYLER will be positioned within the dual-Doppler lobe and cover the upper part of the convective clouds

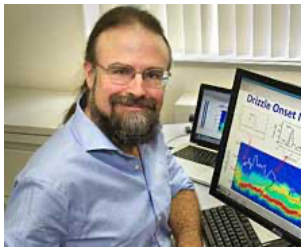
Brookhaven NL Research Truck





www.bnl.gov/cmas

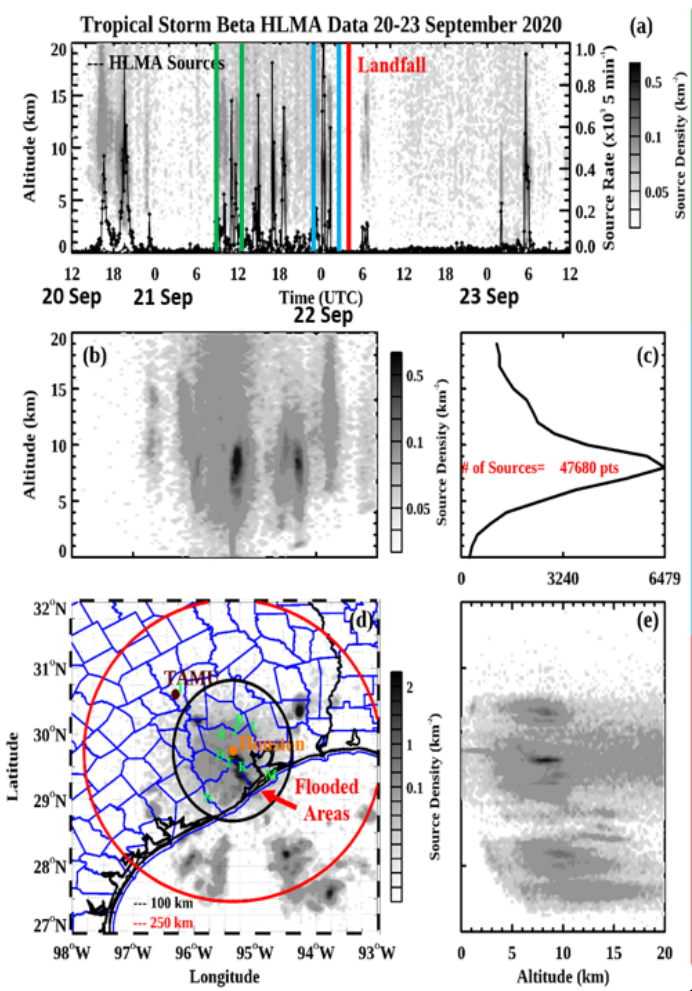
Characterize the cold pool thermodynamical structure
Using the scanning Doppler lidar, soundings, profiling radar/lidar, disdrometer and surface meteorology

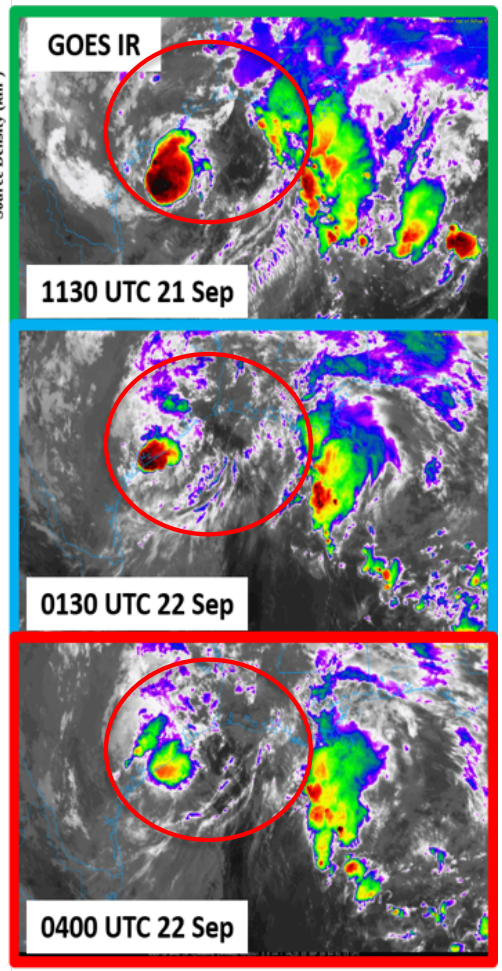


Houston Lightning Mapping Array (HLMA)

The Houston Lightning Mapping Array (HLMA) was established in April 2012. It is currently a network of 10 time-of-arrival lightning sensors centered on the Houston Metropolitan area that provide 3D lightning information to a range of 100 km and 2D mapping and acceptable flash counts within a 250 km radius of the network center.

In preparation for ESCAPE, the Bay City Airport Sensor (N) has been added and all other stations (A, B, D, F, I, J, K, L, and M) have been refreshed to ensure quality 3D mapping and mapping of small flashes over expected IOP domain.





(Credit COD Weather for GOES IR imagery)

HLMA captured lightning activity during Tropical Storm Beta.

Radiosondes and Swarmsondes

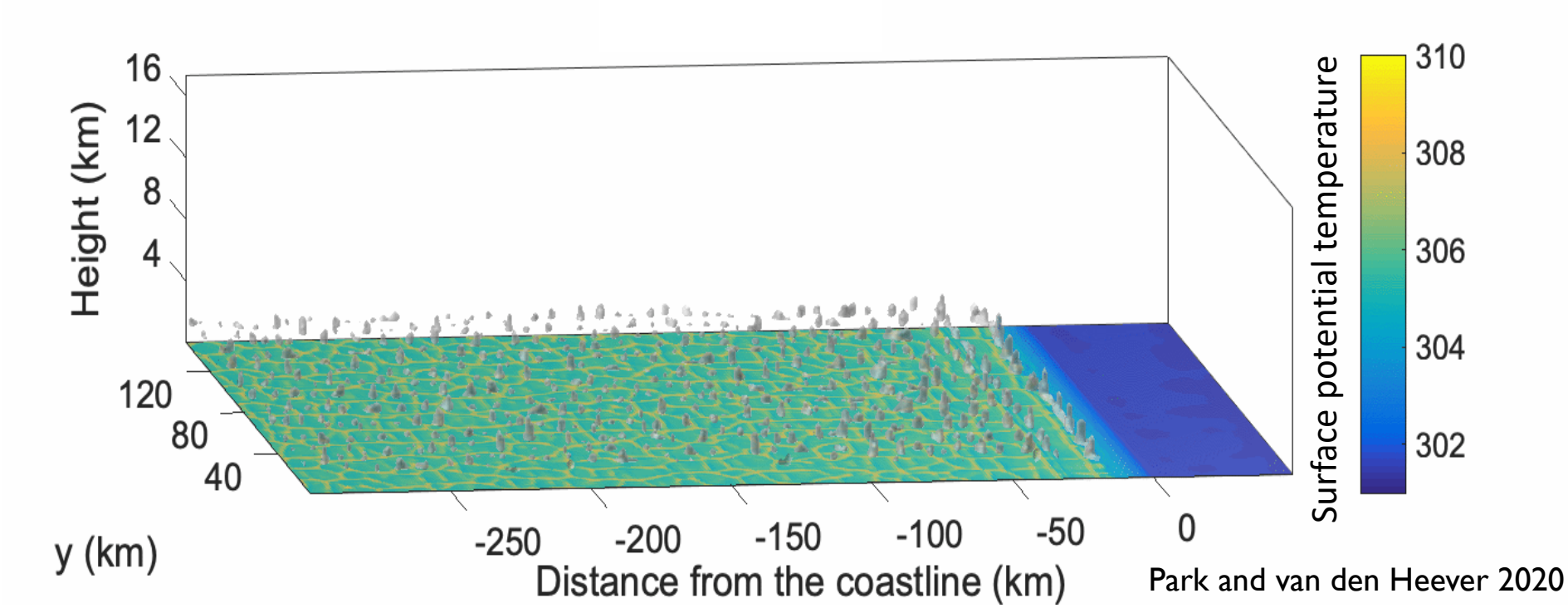
200 DFM-09 Radiosondes
5 per IOP x 2 mobile trucks
20 IOP days

A Swarmsonde is released with two balloons attached to the sonde

32/IOP x 10 IOPs

Specifications	
Balloon size	8 gram, 20 liters of helium. 2 balloons needed per sonde.
Payload	12 grams
Sondes per radio frequency	16 (can be customized)
Radio transmission range	> 15 km from air-borne sonde
Sonde recovery	Transmitted GPS location. Buzzer. Strong LED. (Option)
Measurement period	~1 hour (can be customized)
Parameter	**Measurement interval**
Wind	2 sec
Position	6 sec
Geopotential altitude	12 sec
Temperature	2 sec
Humidity	2 sec
Pressure	6 sec

Cloud Resolving Modeling

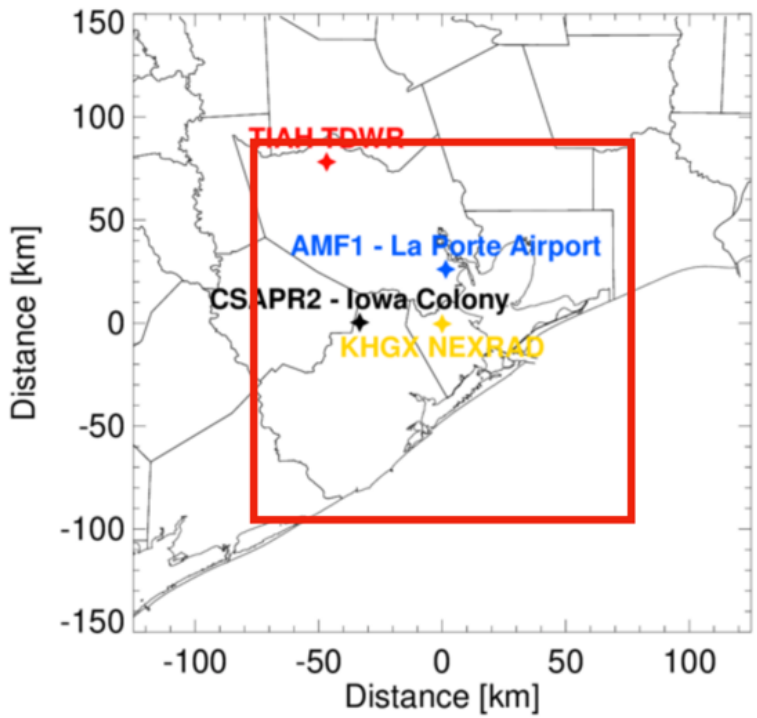


Park and van den Heever 2020

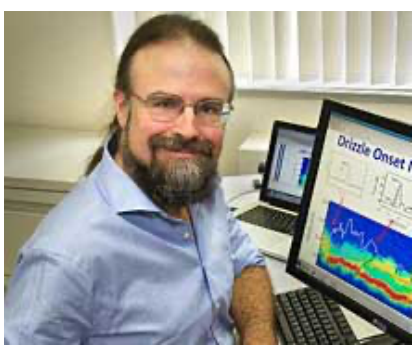
Quantify environmental thermodynamic and kinematic controls on convective lifecycle properties under different aerosol conditions.

Quantify: (1) how cold pool properties and lifetimes vary as a function of precipitation amounts and precipitation size distributions, and how are these relationships modulated by the relative humidity,(2) what is the impact of aerosol number concentration on cold pool depth and intensity, and (3) how do different land-surface types determine the dissipation of cold pools.

Multisensor Agile Adaptive Sampling (MAAS)



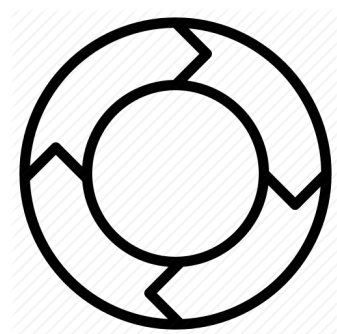
Kollias, et al., 2020: https://doi.org/10.1029/2020GL088440



Software-defined convective cell tracking using radar and non-radar data sources for optimum resource allocation in the field (i.e. airborne/ground-based platforms)

Input:
NEXRAD KHGX
TDWR TIAH
GOES-16 ABI (Ch. 2 & 13)
GLM Lightning data
Houston LMA

Data gridding
Co-registration
Nowcasting
Convective cell(s) selection
Radar steering and sampling



Multiple outputs for distributed sensors network

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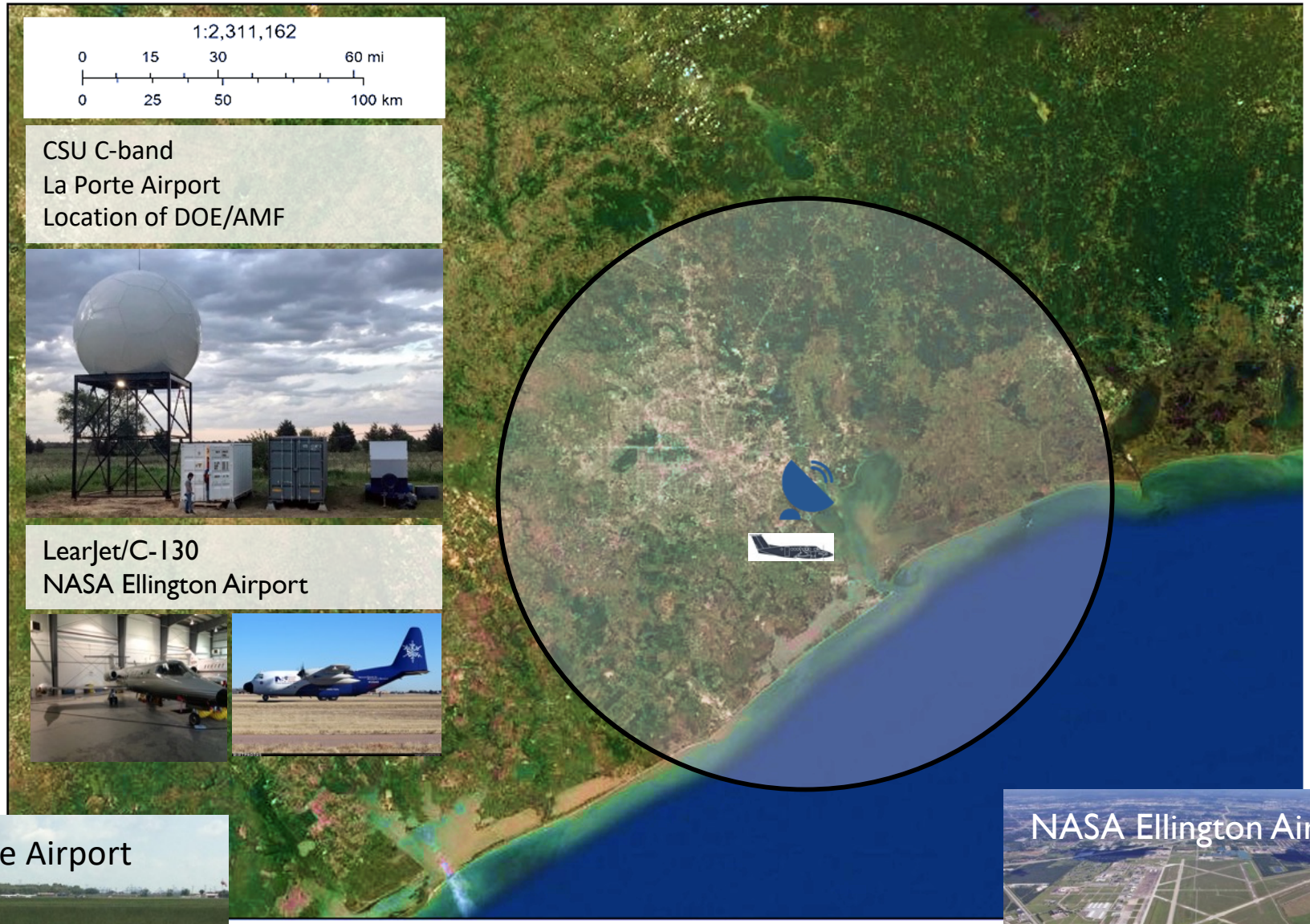

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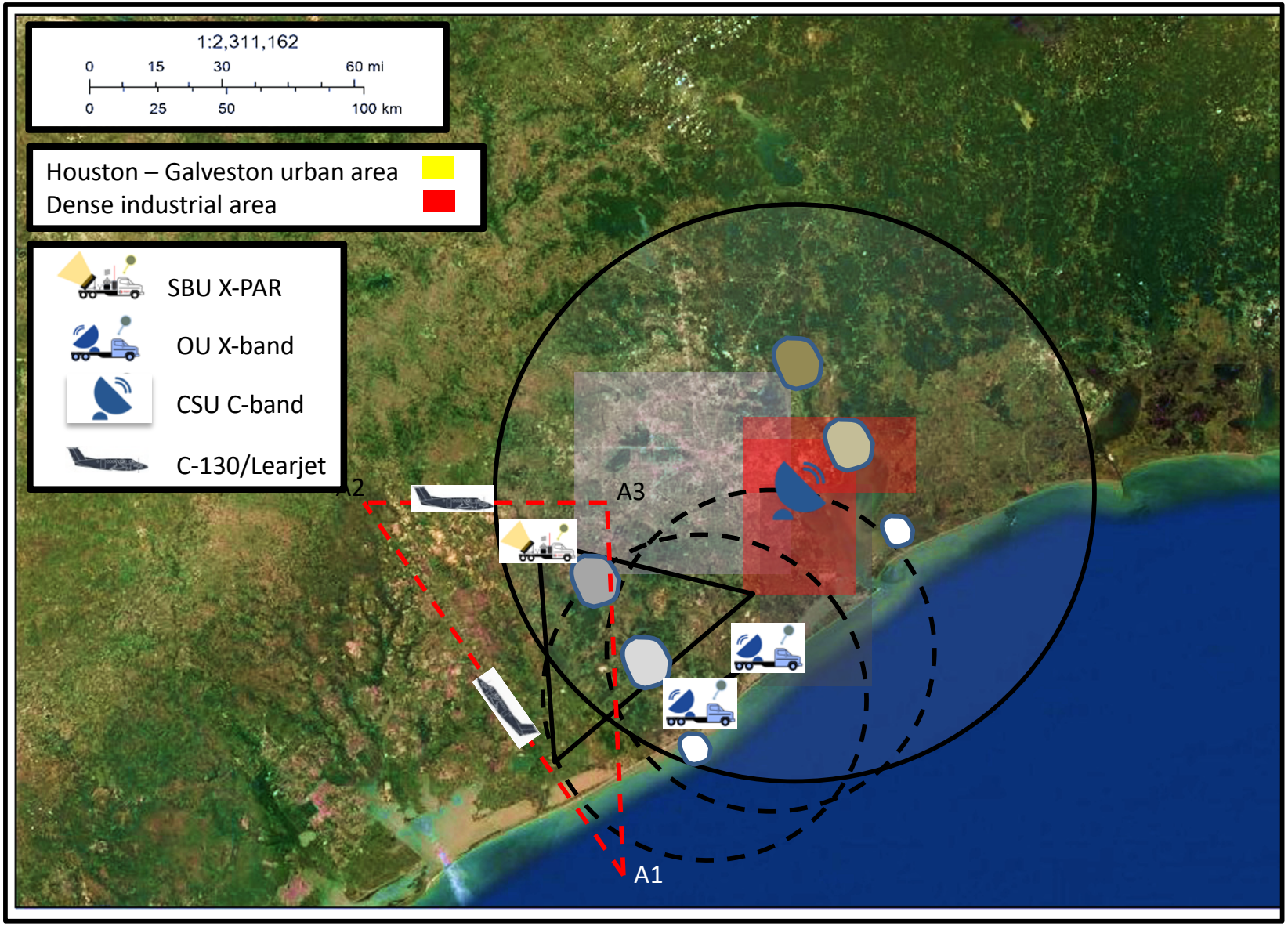

Summary

- The NSF-supported ESCAPE field experiment brings considerable observational capabilities in Houston

- Coordination with DOE/TRACER and other agencies is highly desirable
  - Combine (coordinate?) observational resources
  - Delta-t measurements
  - Deployment preparation and logistics
  - Forecast
  - Soundings/Radars
  - Planning/science meetings