DOC / NOAA / OAR
National Severe Storms Laboratory

2021 NSSL Science Review

Observations and Understanding

Deployable Instrumentation used to collect observations

Sean Waugh Ph.D., NSSL Research Scientist, FOFS




NSSL Instrumentation – Driving observations

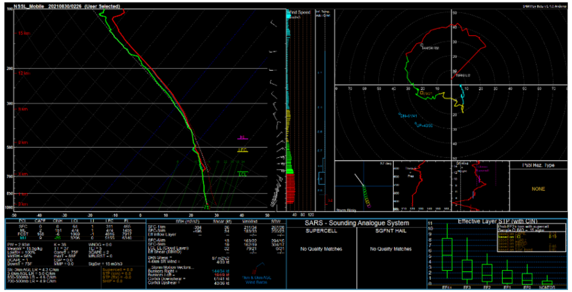
FOFS – Field Observing Facilities Support Division

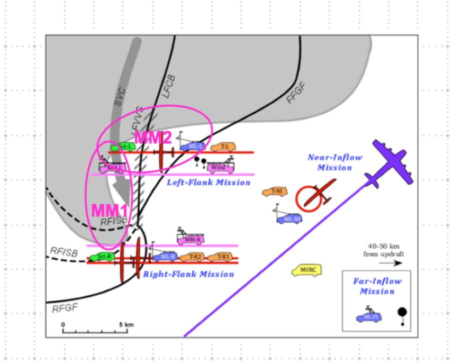
- Support the *entire* Lab's observational needs
- Develop and deploy innovative technologies – Goal 3 of the 2015 NSSL Strategic Plan

To understand severe weather, we must observe it

- New platforms, sensors, locations, strategies
- NSSL has and will continue to help lead/carry out field programs
- Understanding processes critical to the production of high-impact weather

Collecting high quality scientific observations is challenging



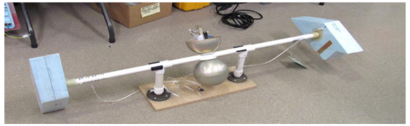


Instrumentation Platforms

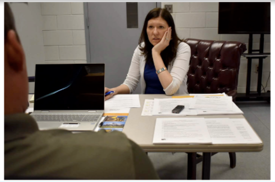
Coming up:

- Mobile Mesonet and Sounding vehicle
- CLAMPS
- Lightning Mapping Array
- Electric Field Meter
- Microphysics
- NOXP
- UAS
- Social Science







Observations and Understanding

Mobile Mesonet – Soundings/Windsond

Sean Waugh Ph.D., NSSL Research Scientist, FOFS



Mobile Mesonet Capabilities

A configurable vehicle for collecting mobile, in situ observations both at the surface and in the air. These vehicles have been in use for over 30 years and have become a standard in field work for various objectives due to their flexibility and versatility.

VORTEX (early 1990s) version

Current configuration as of 2021

Mobile Mesonet Capabilities

<u>Surface Observations</u>

Wind Speed/Direction:

- 0-100 m/s, ±0.3 m/s accuracy

Temperature/RH

- HMP155: 0-100% RH, -80°C to +60°C
- 109SS: -50°C to + 70°C

Pressure

- 500-1100 hPa, ±0.15 hPa

<u>Upper Air Observations</u>

- Vaisala and/or Windsond
- Similar observations as surface for full tropospheric (Vaisala) or semi-lagrangian (Windsond) soundings

<u>Hail Cage for added protection</u>

- Tested up to 4.5” hail




Mobile Mesonets - Relevance

Mission is to advance our understanding of severe weather
- Wide range of instruments
- Custom designed for specific properties/processes
- Calibration and field testing of equipment for accuracy
- In situ observations are essential for this

Highly configurable setups allow vehicles to be used for a variety of purposes
- Serves multiple scientific objectives
- Multiple field experiments with broad community engagement

Mobile Mesonets – Accomplishments

Collected observations in numerous projects & environments while serving a variety scientific objectives:

- Severe weather
- Hurricanes
- Boundary layer
- Mountain flows
- Winter weather

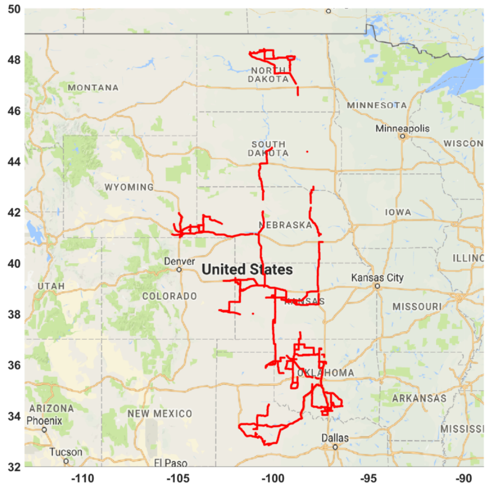
Updated technology to current, cutting edge instruments

- Increased accuracy, response time

Added capability for Windsonds in addition to traditional upper-air observations

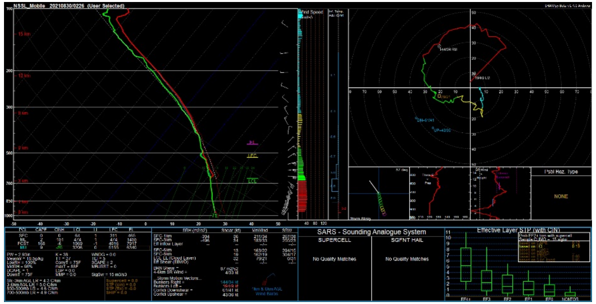
Streamlined processing of data post project for faster analysis and consistent format/quality control

Training of students/staff in observational equipment and general field work

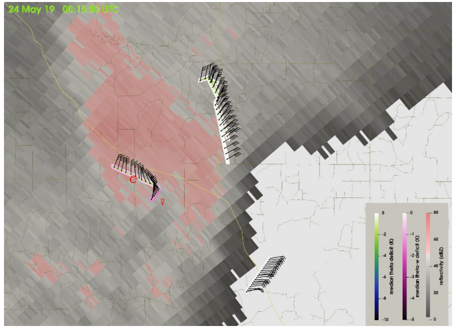


<u>Above</u>: Deployment map from RiVorS

<u>Below</u>: Analysis of thermo data in sampled supercell



Sounding taken in eye of Hurricane Ida - 2021



Mobile Mesonets – Future Work

Continued support of field work/observational needs

Upgrade sensors to newer technology and additional observations

- Scanning/remote sensing instruments in addition to current configuration
- Rapidly deployable sensor suits
- Redesign of wind sensing instrumentation

Evaluation of upper air observations – do they work in all environments?

Continued standardization of available data

<u>These platforms grow with the needs of the lab.</u> Where will they go next?

VORTEX

VORTEX 2

RiVorS/TORUS

?

Projected Growth of Mobile Mesonet

Observations and Understanding

Deployable Instrumentation used to collect observations: CLAMPS

Elizabeth Smith PhD, NSSL Research Meteorologist, FRDD

Capabilities

CLAMPS: Collaborative **L**ower **A**tmospheric **M**obile **P**rofiling **S**ystem

Wind profiles via Halo Doppler wind lidar

- Fully customizable scans, ±48 m/s max velocity
- Min. 18-m min gate (vertical resolution)
- 2-s resolution for stares, 30-s for PPIs (horiz. winds)

Thermodynamic profiles via Atmospheric Emitted Radiance Interferometer (AERI) & Microwave Radiometer (MWR)

- Temperature and water vapor profile retrievals
- TROPoe retrieval we develop and maintain
- 5-10 min/40-m resolution (stretches in vertical)

Lidar Truck: *nimble* truck based concept of CLAMPS

- Identical lidar system as CLAMPS
- More flexibility in deployment methods
- Potential to upgrade to include more observation capabilities (thermodynamic)

OU-NSSL CLAMPS1

NOAA-NSSL CLAMPS2

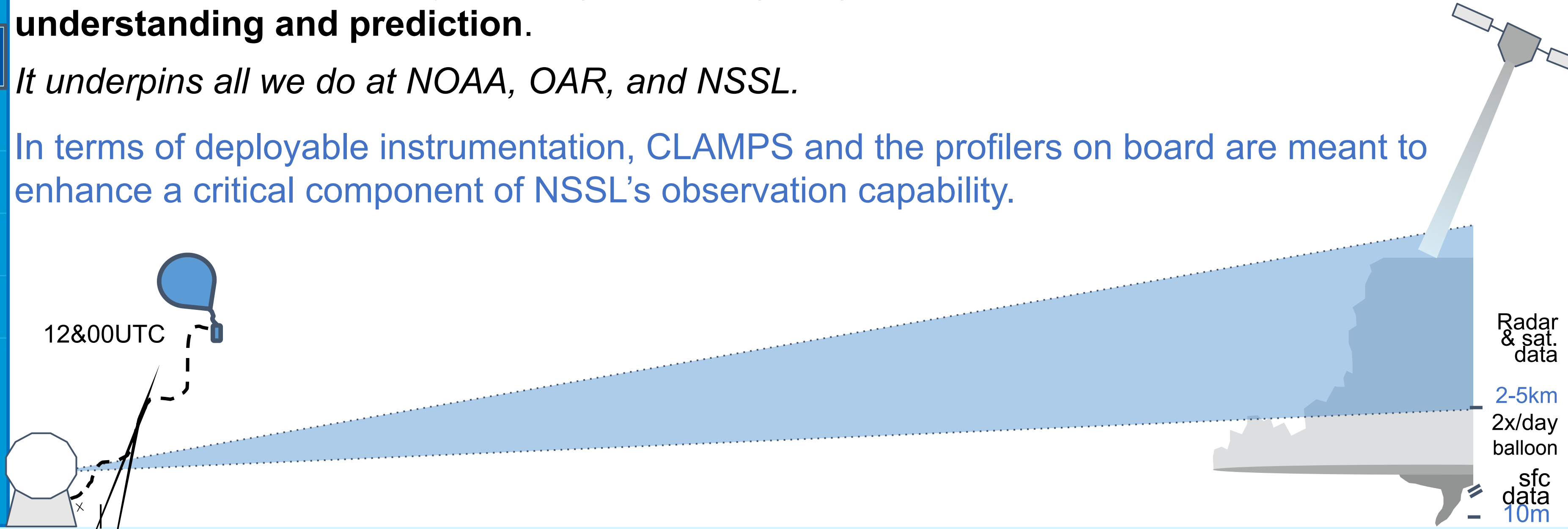
Relevance

The boundary layer is where society lives–yet it is critically under-observed.

Recent national and international groups have identified PBL uncertainty and under-observation as a key challenge impeding progress in weather and climate **understanding and prediction**.

It underpins all we do at NOAA, OAR, and NSSL.

In terms of deployable instrumentation, CLAMPS and the profilers on board are meant to enhance a critical component of NSSL's observation capability.



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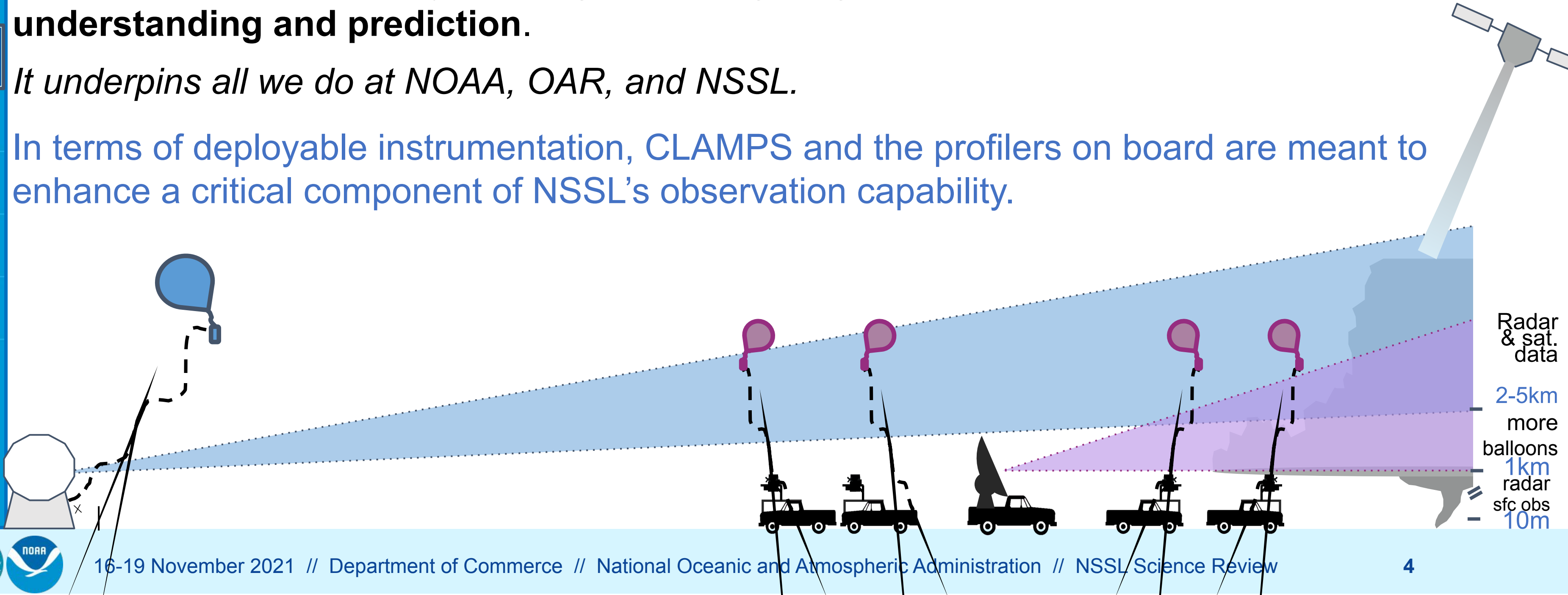

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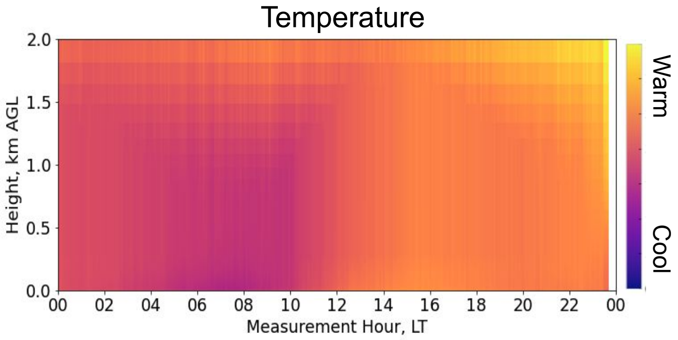
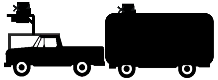
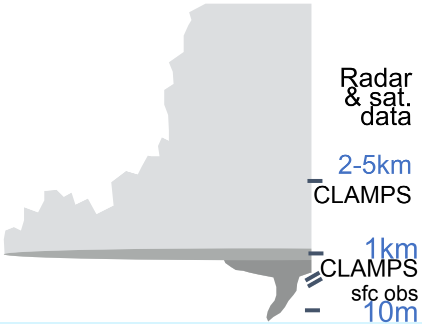
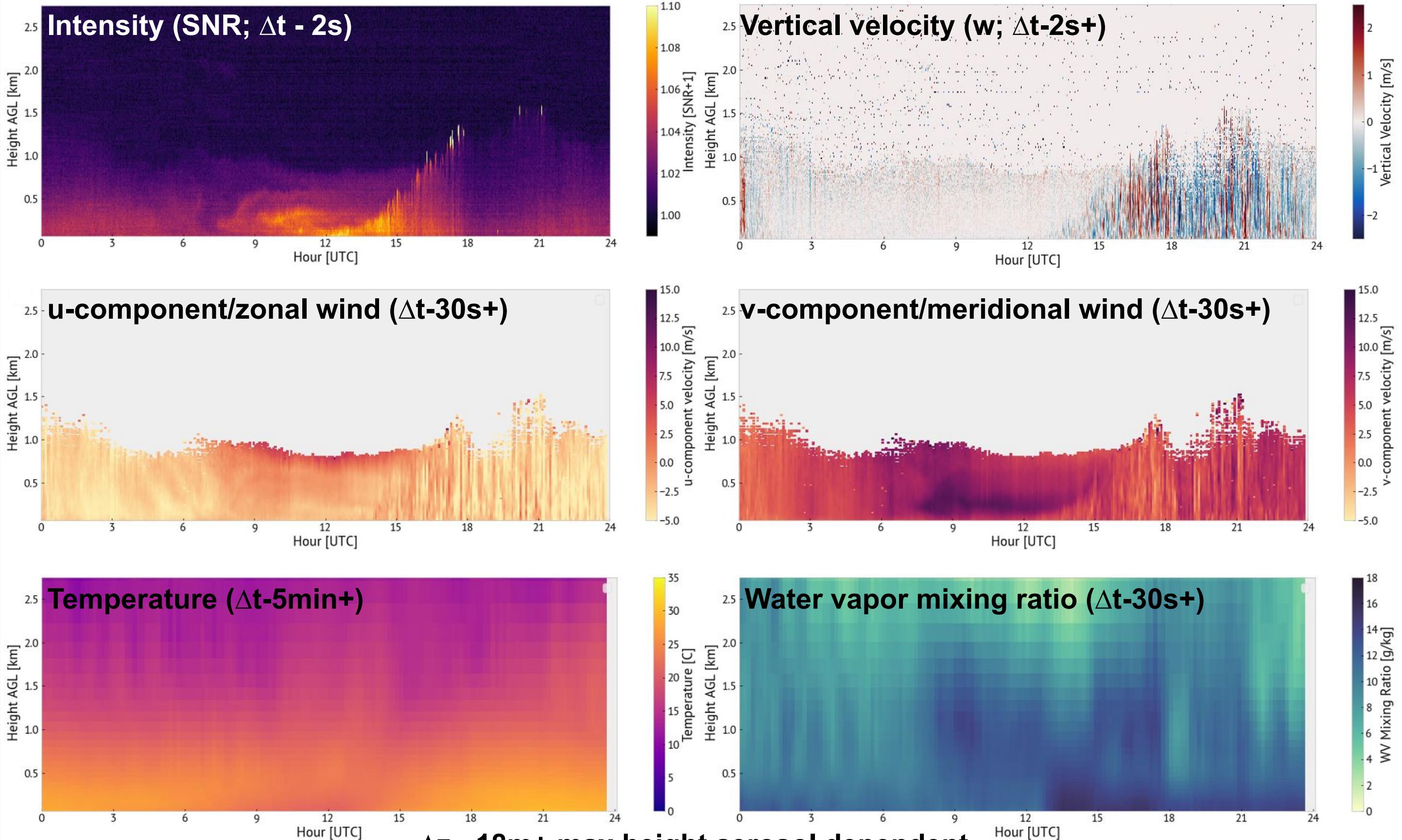




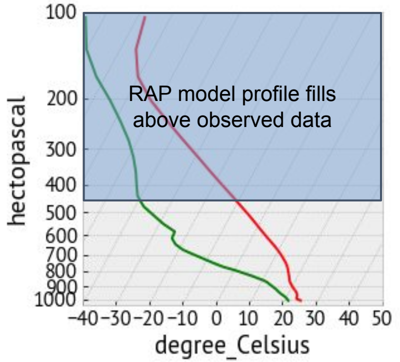


CLAMPS observations

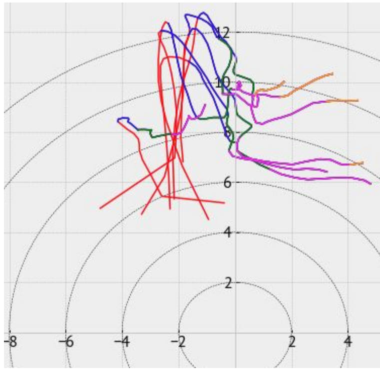


Δz ~18m+ max height aerosol dependent

07UTC



07 – 12 UTC



CLAMPS in the field

CLAMPS1 est. spring 2015 (PECAN)
CLAMPS2 est. spring 2016 (miniMPEX)

CLAMPS deployed on **20+ campaigns**; collected **1000s of hours of data**

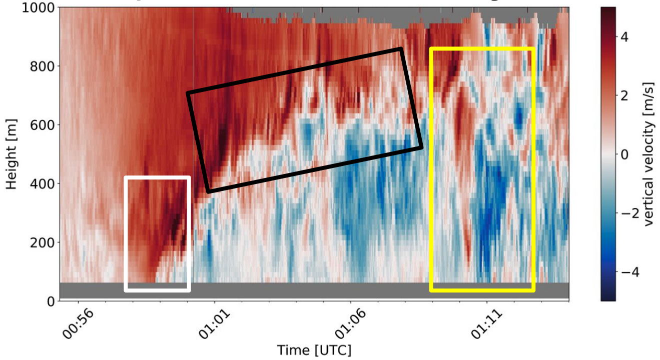
CLAMPS showed **success in mobile deployment frameworks**, but proved to be cumbersome and the retrievals **not adaptable in nimble deployment**

Mobile Lidar Data

To meet the nimble needs of some NSSL science goals (e.g., storm-following deployments), the CLAMPS concept was scaled to a more nimble and adaptable **truck-based system**. *NEW CAPABILITY!*

Lidar observed motions resemble structure suggested by cloud!

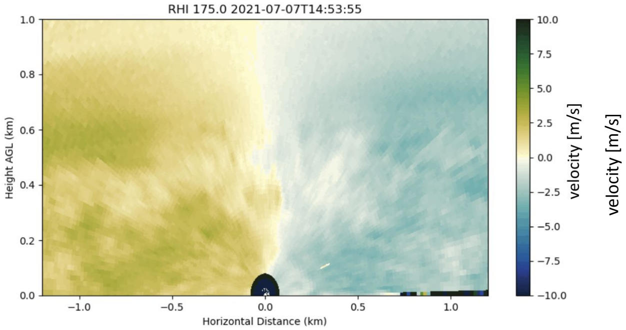
Updraft ○
Turbulence on interface ●
Possible internal rotor ●




Spring 2019 (V1)

Range-height indicator scans along the mean wind over 18 hours

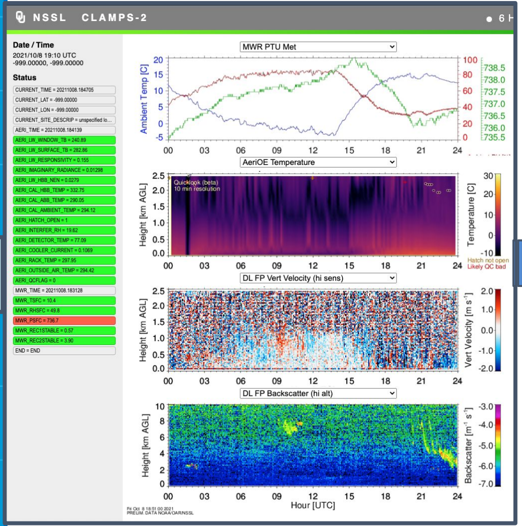
PBL structures evolve from convective to stratified with plumes!

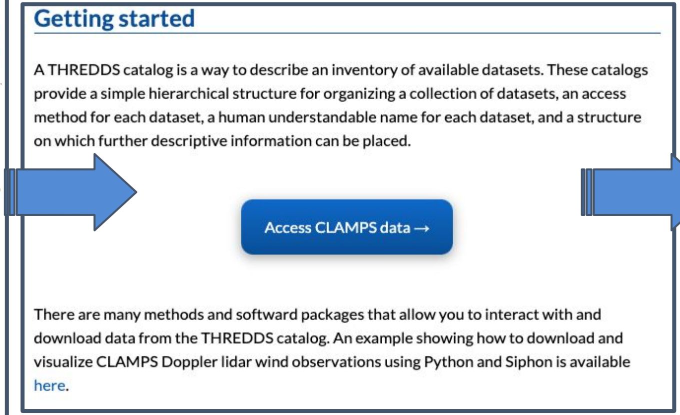


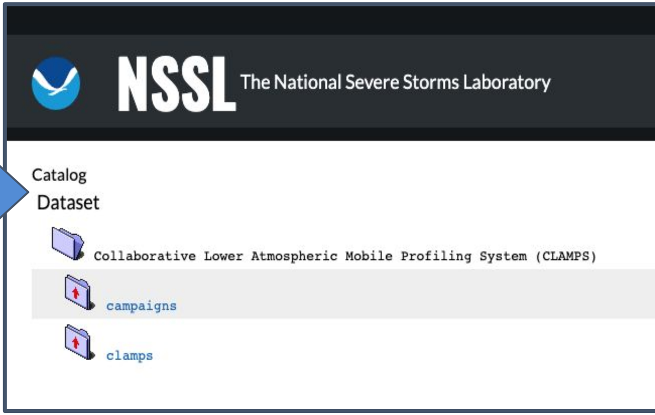

Spring 2021-Present (V2)

Summary

Real time and archived data and beginner analysis tools all provided online!
apps.nssl.noaa.gov/CLAMPS







CLAMPS and mobile Doppler lidar open doors for PBL & related research at NSSL!

(see my talk in Observations and Understanding Fieldwork and Analysis for more on PBL research!)

Observations and Understanding

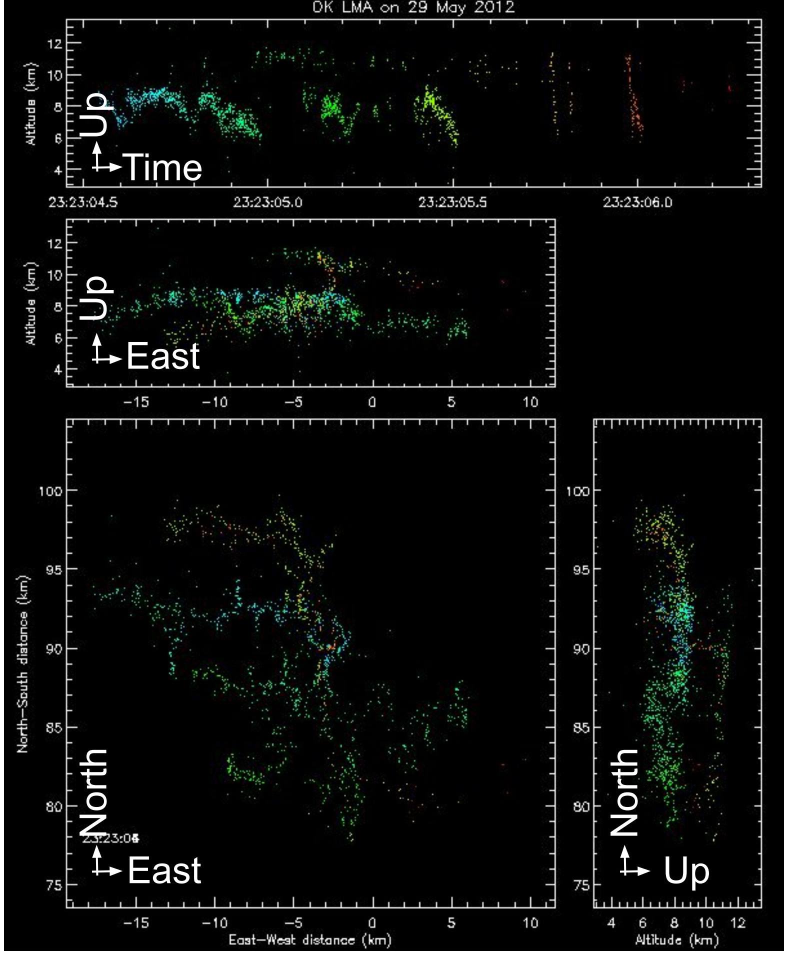
Oklahoma / Mobile Lightning Mapping Arrays

Vanna Chmielewski Ph.D., CIWRO Research Scientist, WRDD

Lightning Mapping Array (LMA) Capabilities

Very high frequency (VHF) receivers used to triangulate developing lightning channels in 4D with high resolution.

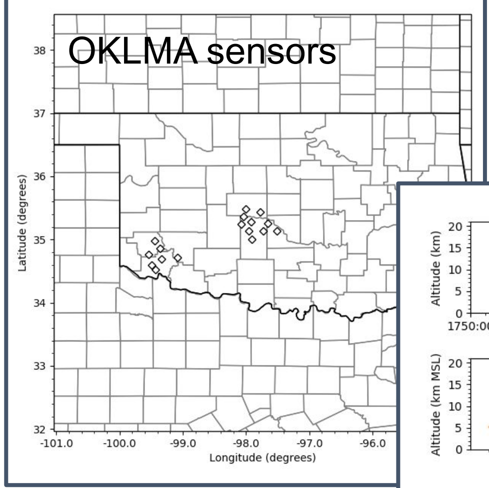
- Within 100 km detects >95% of total flashes, errors ~200 m
- Within 200 km detects >80% of total flashes, errors ~1.1 km

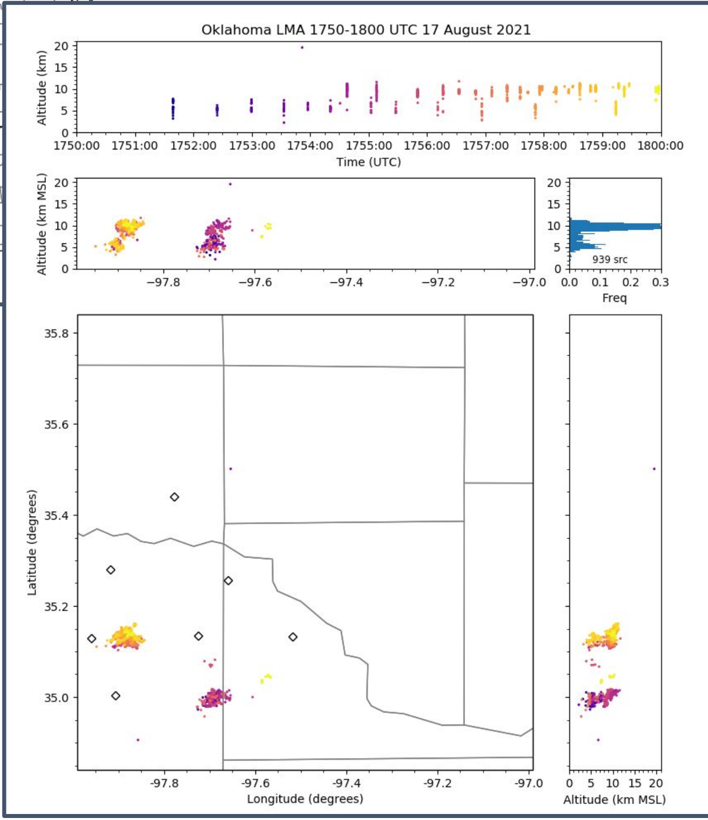


OKLMA flash May 29, 2012, 2 sec animation

Oklahoma (OKLMA) History and Uses

- Started in 2003
- SW Oklahoma addition in 2012
- Partnership with CIWRO
- Unique uses:
    - Validation of other measurements
    - High-resolution total flash extent
    - Net charge approximations
    - Altitudes of flashes
    - 3D initiation and propagation of flashes
    - 18-year record of total lightning





2 hr of OKLMA data from thunderstorms approaching OKC metro from real time data feed

Relevance to NSSL Mission

Part of the a holistic understanding of Earth systems.

Used to advance the understanding of weather processes, and to evaluate the operational applications of lightning data.

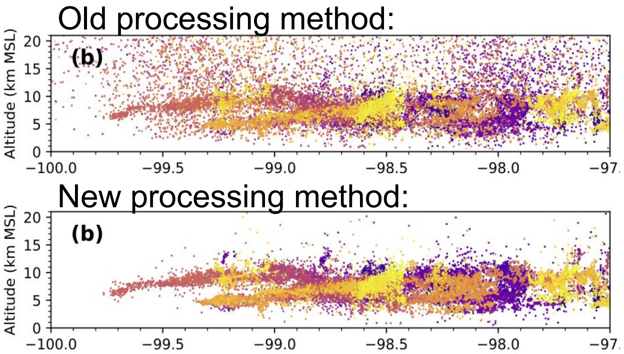
Necessary to detect and characterize lightning initiation and propagation.

Validation for the prediction of lightning activity one hour in advance (NSSL GSC4).

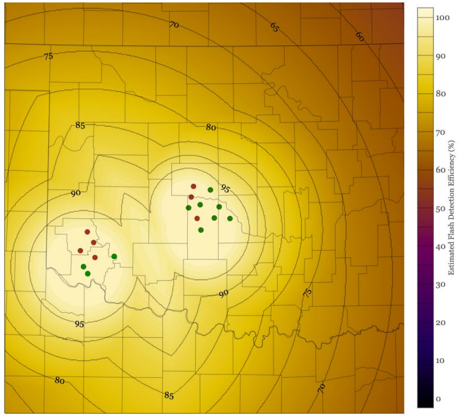
OKLMA site north of Chickasha, OK

Oklahoma (OKLMA) Achievements

- Increased sensitivity and reduced noise
- Computing time improved from hours to minutes
- New automated quality control maps
- Implemented a publicly-accessible archive of post-processed data



OKLMA flashes by longitude and altitude, June 16, 2019, 6 sec total



Example live flash detection efficiency map

THREDDS catalog screenshot

https://data.nssl.noaa.gov/thredds/catalog/WRDD/OKLMA/catalog.html

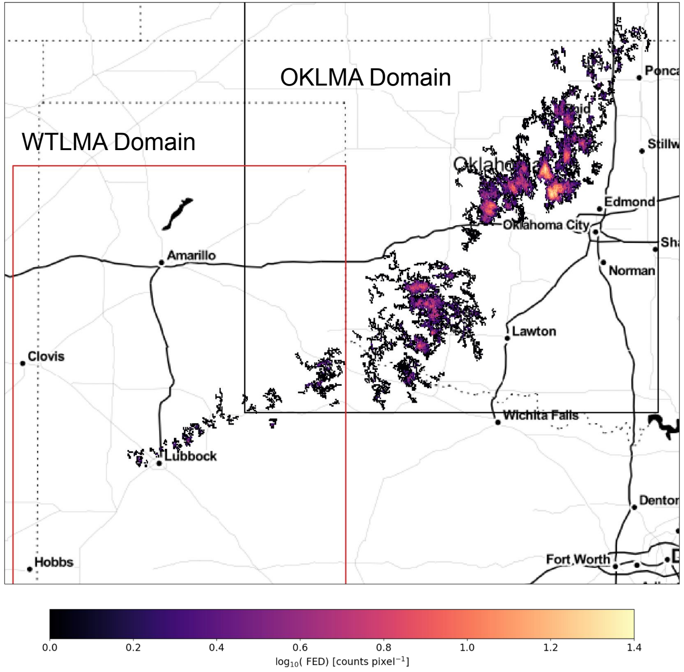
Mobile LMA

- 7 sensors
- Built in 2020-2021
- Designed for temporary deployment
- Can bolster existing LMA network
- Will be used in upcoming field campaigns as an independent network
- Real time capabilities

Future Work

- Hardware:
  - Transition 9 OKLMA sensors to solar power
  - Relocate 2 central OKLMA sensors
  - Build out additional mobile LMA sensors for a full, independent network
- Software:
  - Develop real time processing and dissemination for the mobile network
  - Develop real time LMA products merging multiple networks
  - Continue reprocessing and posting of full OKLMA archive

Flash Extent Density from Merging OKLMA and WTLMA



Observations and Understanding

Deployable Instrumentation used to collect observations

Balloon-Borne Electric Field Meter

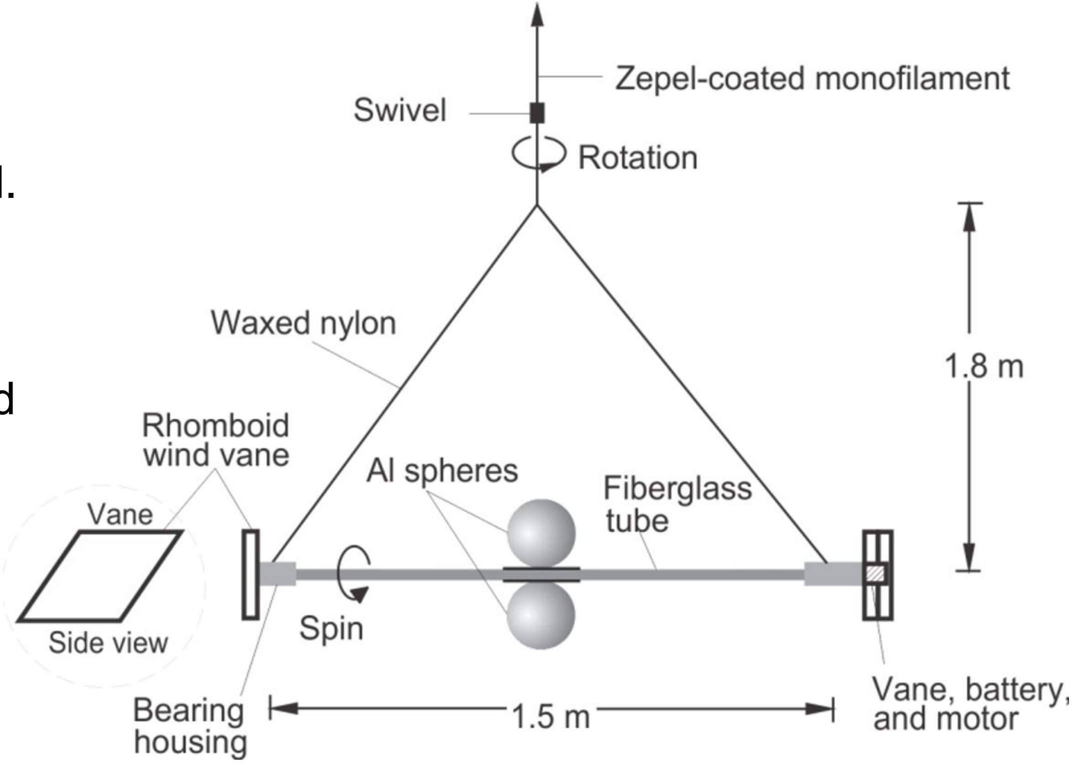
Dr. Kristin Calhoun
WRDD, Research Scientist




Electric Field Meter (EFM)

- The balloon-borne EFM provides in-situ measurements of a storm's vertical electric field.

- The combination of the spin (powered by the instrument) and rotation (caused by lift through the storm) provide the magnitude of the electric field.

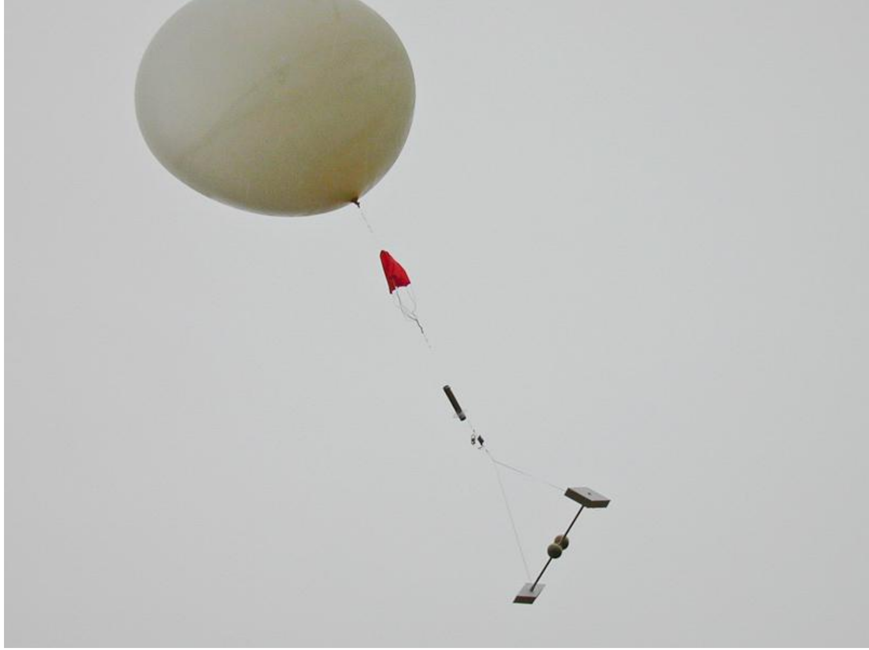


EFM Relevance

- In order to predict lightning we must improve understanding of thunderstorm electrification and electrical breakdown processes which contribute to lightning production.

- In situ measurements are critical to evaluate electrification hypotheses and to provide valuable background information for simulating storms and for interpreting some radar observations related to lightning initiation.

- The NSSL EFM is regarded as the standard within the field against which other EFMs are evaluated.



EFM Results

- In situ measurements of the vertical field have been a key component of multiple field programs including triggered-lightning comparisons in Florida and the DC3 field campaign.
- Allow for basic understanding of the distribution of charge in different thunderstorm modes and regions.
- Results have allowed us to evaluate hypotheses of thunderstorm charge and transport.

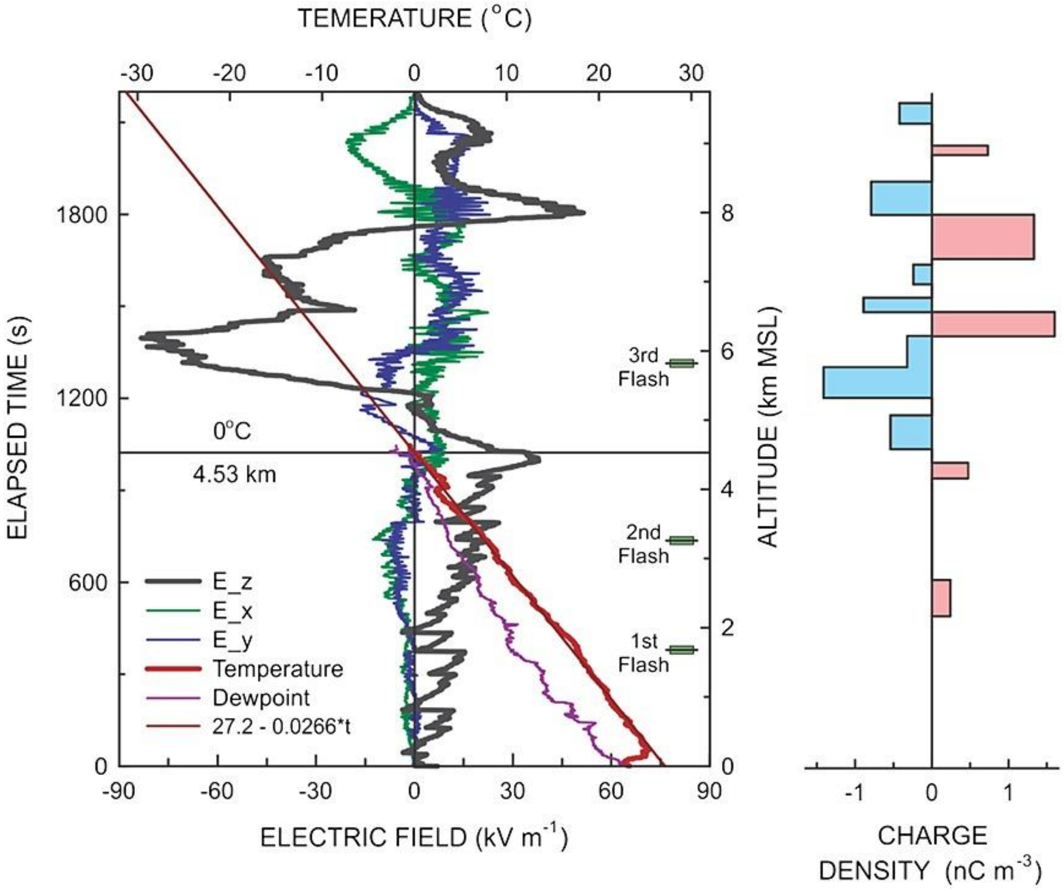


Fig. 2 of MacGorman et al (2015): **Coordinated lightning, balloon-borne electric field, and radar observations of triggered lightning flashes in North Florida**

EFM modernization

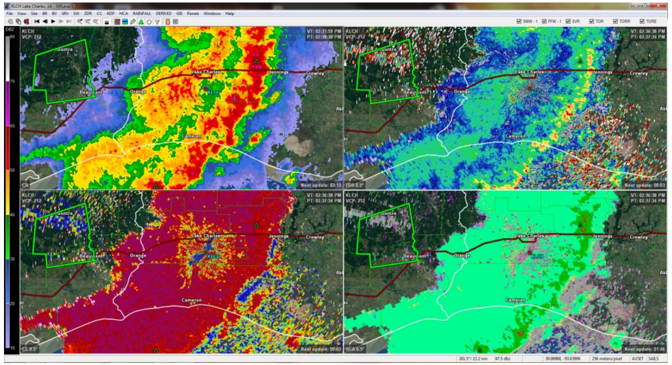
- Ongoing redesign of the internal electronics of the balloon-borne EFM (which had become outdated relative to modern technology)
- Modifications for new capabilities added to facilitate instrument flight operations and data analysis.
- Plans for deployment as part of future field campaigns to better understand charge characteristics of stratiform regions of MCS and also the charge structure and transport within lake effect snow bands.

Observations and Understanding

In Situ Microphysics – PASIV and Hail Camera

Sean Waugh Ph.D., NSSL Research Scientist, FOFS

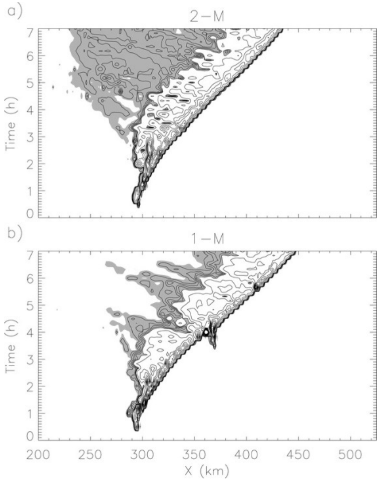
Microphysics observations



In situ observations of particle (precipitation) concentrations, habits, and characteristics are limited and difficult to obtain

Numerous applications however:

- Hydrometeor Classification Algorithm (HCA) validation
- Microphysical parameterizations
- Lightning/cloud electrification



Surface observations and aircraft only previous way to observe

This created a need for observations *inside* convective storms where traditional observations are unavailable

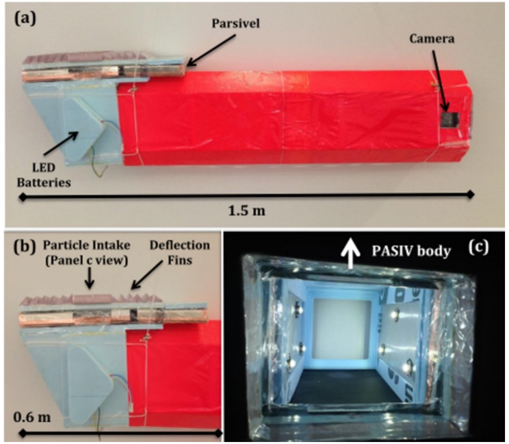
Microphysics observations - PASIV

Balloon-borne, camera based system records images of objects passing through volume

Original version capable of detecting, sizing, and counting particles (on the order of 0.5-1 mm) through image analysis

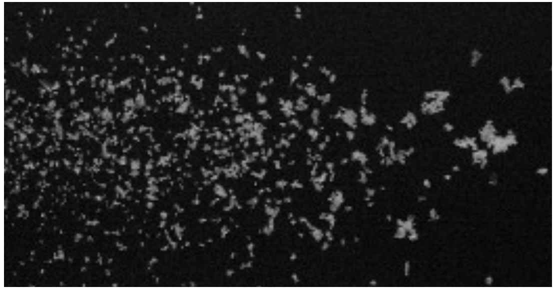
- Effective radius
- Particle concentration
- Major/minor axis length
- Particle Type/habit
- Eccentricity
- Irregularity
- Thermodynamic profile

Recent upgrade to 4K camera for enhanced resolution (0.05 mm per pixel)

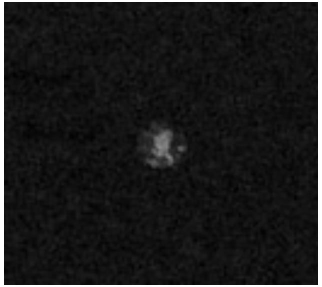


Original

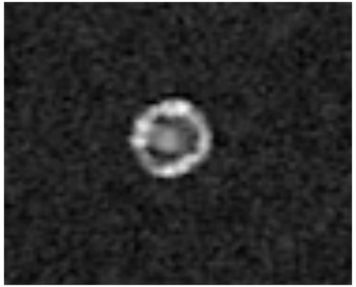
Updated



Freezer ice, several sub D = 1 mm



Liquid drop in process of freezing with interior core



Sleet pellet, D = 1 mm, variations in ice density

Microphysics observations – Hail Camera

Dual camera setup for high speed captures

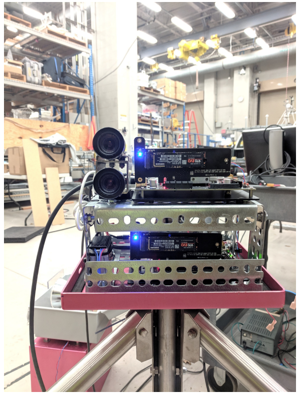
- 12.4 MP cameras, 4112 x 3008 pixels, 31 fps
- 50 µs exposure for fast moving objects

Short exposure requires a lot of light

- 100W LED for front illumination - 14,000 lumens
- Side LED panels for side illumination – 1300 lumens per ft^2

Self contained for safe deployments

- ~5 min setup/tear down
- 15-20 mins of data collection
- Hardened to survive impacts from large stones



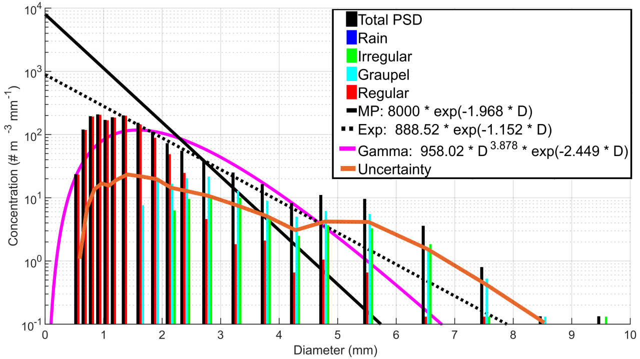
Microphysics - Relevance

- In situ microphysics observations are widely applicable to a number of scientific goals/research foci

- Both the PASIV and the Hail Camera are extremely unique, targeted instruments

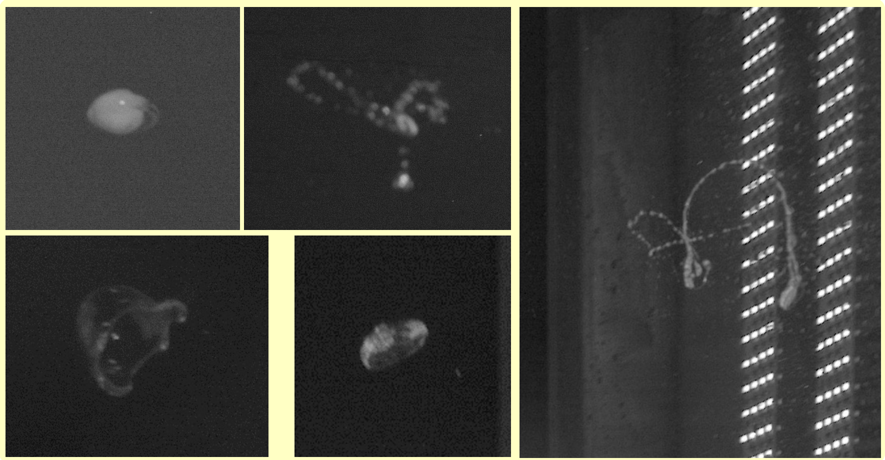
- Microphysics observations are critical for improvements to real-time nowcasting, WSR-88D capabilities, and modelling efforts

- Particle information also useful for lightning prediction/research



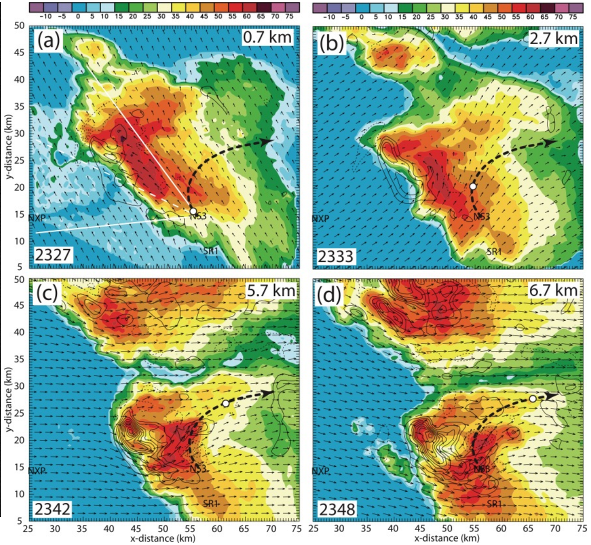
Above: PSD of PASIV data compared with assumed parameter fits to distribution

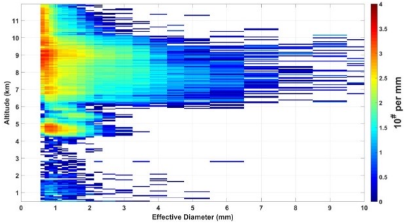
Right: Example hail camera observations

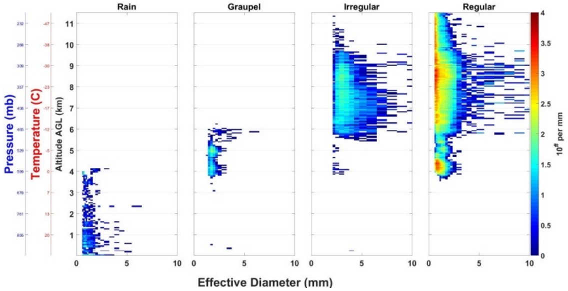


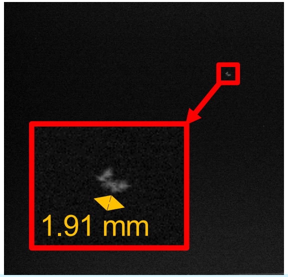
Microphysics - Accomplishments

- Multiple operations in DC3 and DARPA funded project on triggered lightning with PASIV
- Several deployments with Hail Camera in various conditions
- Demonstrated capability to collected desired observations
- Recent upgrade to PASIV for 4K resolution, still in prototype stage









Microphysics - Future Work

PASIV

Rework detection algorithm on PASIV for more particle types

Include onboard GPS for image geotagging

Reduce weight for easier flights & UAS

Utilize in other convective environments

Hail Camera

Truck mounted version for ease of deployment

Balloon-borne system for vertical spacing

Faster cameras for tumbling/particle interactions

Observations and Understanding

Mobile, Dual Polarized, X-Band Radar - NOXP

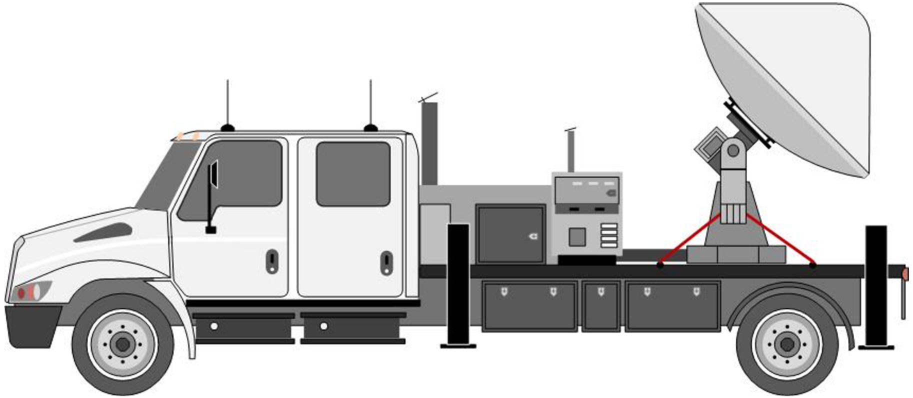
Jonathan J. Gourley Ph.D., NSSL Research Hydrologist, WRDD




Capability

- The NOAA X-band polarimetric mobile radar (NOXP) has been used in multiple US and international field experiments
- The unique datasets have provided microphysical, dynamical, and kinematic insights into severe weather occurrence, magnitude, and type
- Given flexible scanning of the antenna and control of the radar pulse, NOXP has been used to enhance NEXRAD coverage and operations

Frequency (MHz)	9415
Wavelength	3.19 cm
Peak Power	250 kW
Antenna type	2.4-m Parabolic Dish
Antenna Gain (dBi)	45.5
-3 dB Antenna aperture	0.9°
Polarization	Linear; simultaneous H&V
Rotation speed	36 deg/s (max)
Pulsewidth	0.5-2.0 µs
Duty cycle	.001



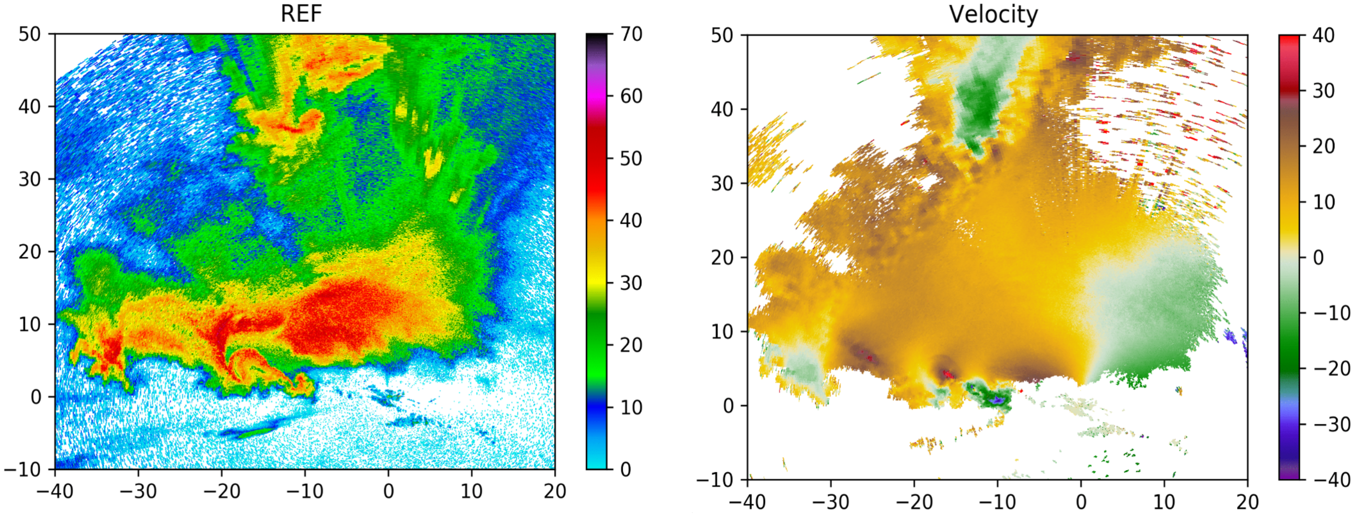
Relevance to NSSL Mission

- NOXP is one of NOAA's premiere facilities for studying severe weather, improving our understanding of physical processes, ultimately leading to better forecasts and warnings

- Mobile weather radar data can be transmitted in real time using cellular communications and images are made available to NWS forecast offices to improve situation awareness

- NOXP enables the testing of new technologies such as dual-polarization and optimized scanning strategies to enhance the function and calibration of the operational NEXRAD network (**GSC 2**)

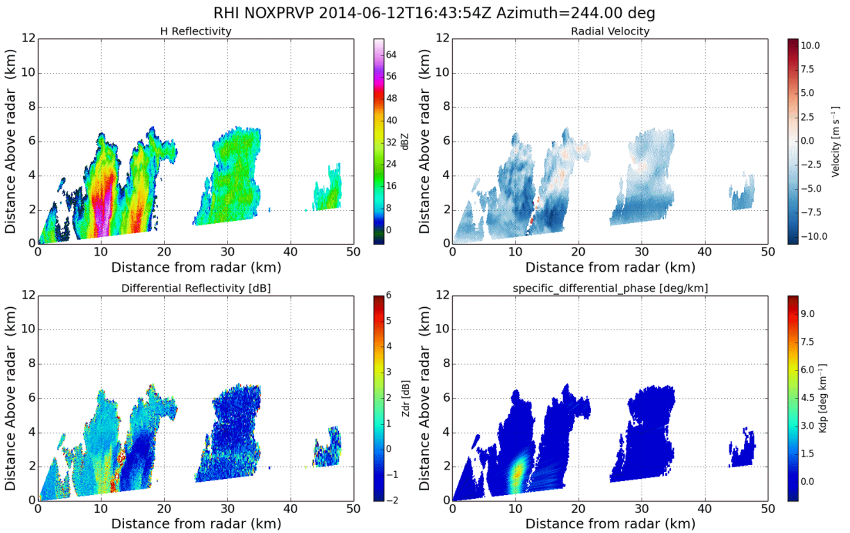
NOXP Deployments



- NOXP was deployed on several major field campaigns including RiVorS, VORTEX-SE, TORUS, IPHEx, and HyMeX
- Deployed during the winters to estimate snowpack in the Rio Grande basin in Colorado
- Operated in several complex terrain locations in the West to provide high-resolution radar data and rainfall estimates on burn scars

NOXP Accomplishments

- Determination of the transmitted differential phase from measurements at vertical incidence
- Comparisons with the KOUN (polarimetric prototype of WSR-88D) aiming to estimate the differential phase of KOUN (can't point vertically)
- Collected data on over 120 events since 2015 and data is used across Universities, NOAA laboratories, NASA, and NWS



Future Work

- Upgrade the antenna controller and enable fully remote operations when using commercial power
- Continued support for providing enhanced radar coverage to NEXRAD over burn scars following the active 2021 wildfire season
- Continued to support the community by participating in field campigns
- Assist in the understanding of severe convection and its impact on society
- Estimate the linear and circular depolarization ratios on radars operating in the Simultaneous transmission and reception of the H and V (SHV) polarized returns

Observations and Understanding

UAS

Melissa Wagner Ph.D., CIWRO/NSSL Post Doc

UAS - Platforms and Capabilities

Platform: Quadcopter
Camera: Sony IMX577 RGB

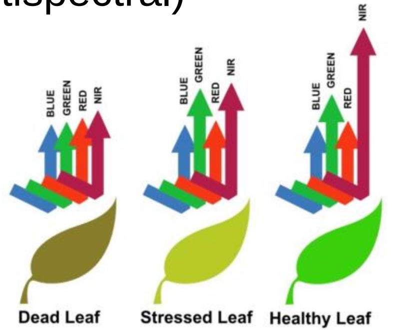
Aerial photos/videos

Flight time: 23 mins
Wind Tolerance: 25 mph

Platform: Fixed Wing with VTOL
Cameras: Micasense RedEdge-MX (multispectral)
Sony UMC R10C (visible)

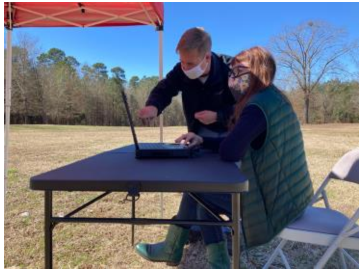
Large-scale mapping & 3D Modeling

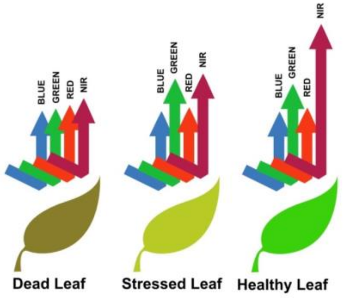
Flight time: 90 mins
Wind Tolerance: 25 mph

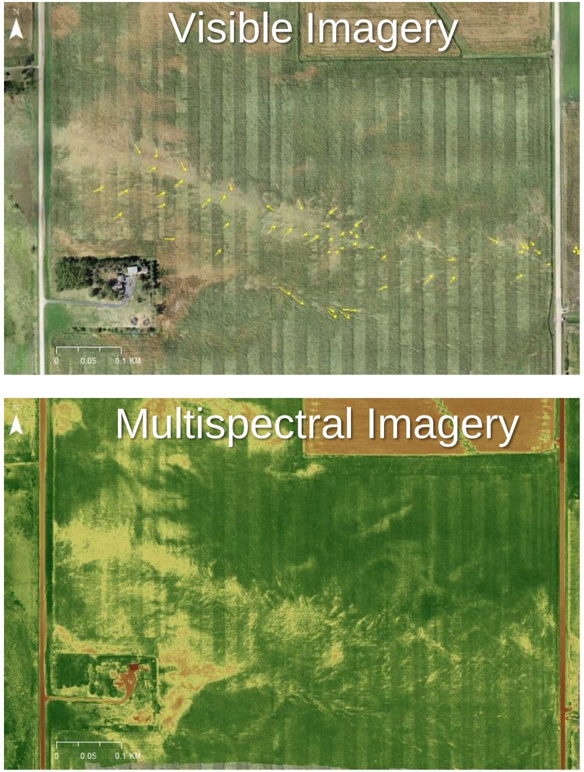


UAS - Relevance to NSSL mission

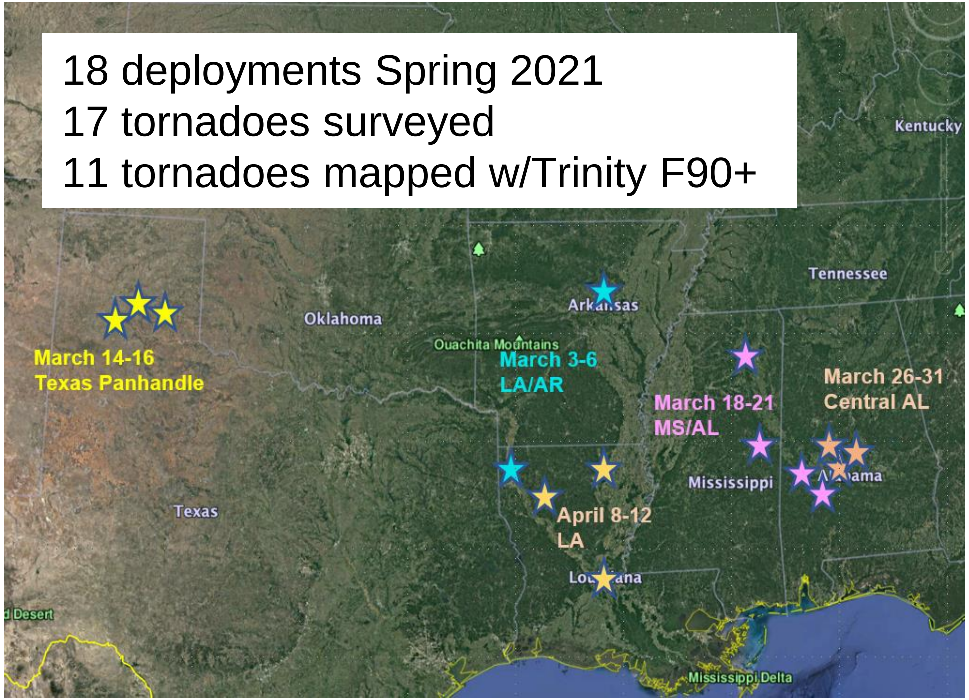
- Coordinate with NWS WFOs & emergency managers
  - *Disaster response & recovery*
- Better characterize damage impacts
  - *Improve severe storm climatology, risk, & disaster preparedness*
- Correlate storm signatures with UAS damage information
  - *Improve understanding of severe storm dynamics in SE US*







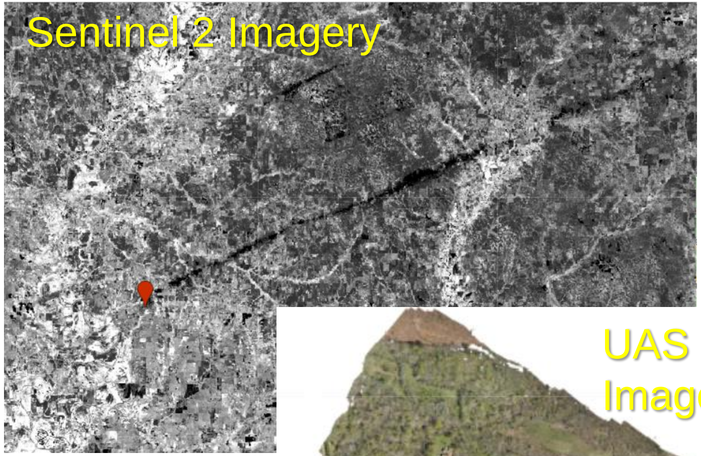
UAS - Accomplishments

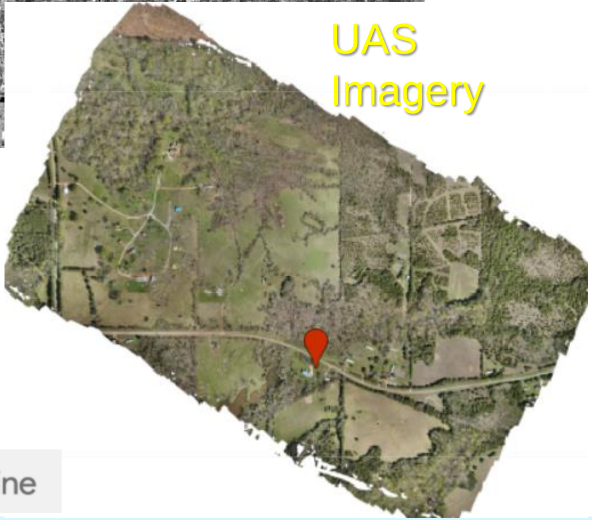


- Coordinated with NWS WFOs damage assessments
- Better estimate damage & high wind intensity
  - *11 tornadoes identified or refined*
- Mapped 5+ miles of EF-3 April 9, 2021 Palmetto, LA tornado

UAS - Accomplishments

- Developed near-real time image processing using Amazon AWS Cloud Services
- Data sharing via NOAA ESRI products & Google Earth Engine



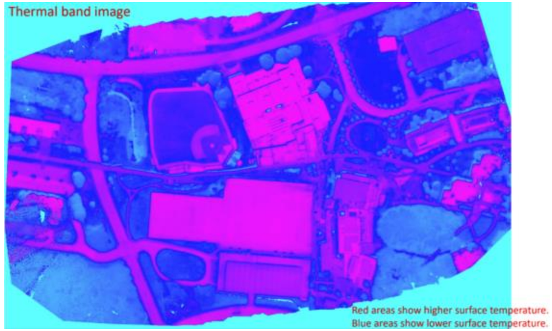


Red Marker corresponds to damaged house

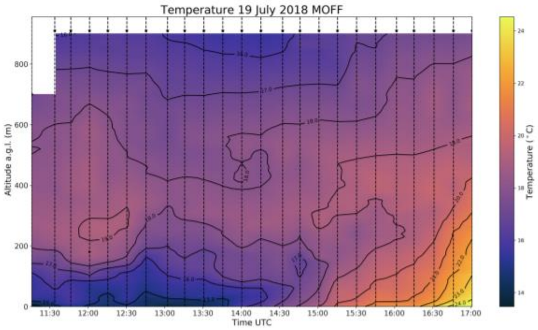
Google Earth Engine

UAS - Future Work

- Continue damage surveys to understand land cover impacts and radar signatures
- Assess land-atmosphere interaction through land surface characteristics, environmental monitoring, modeling
  - Terraview X8Pro Multispectral & Thermal
- UAS atmospheric profiling (coptersondes)
  - Better understand boundary-layer and evolution
  - Improve modeling & weather forecasting
  - Observation network



Source: Wang 2021



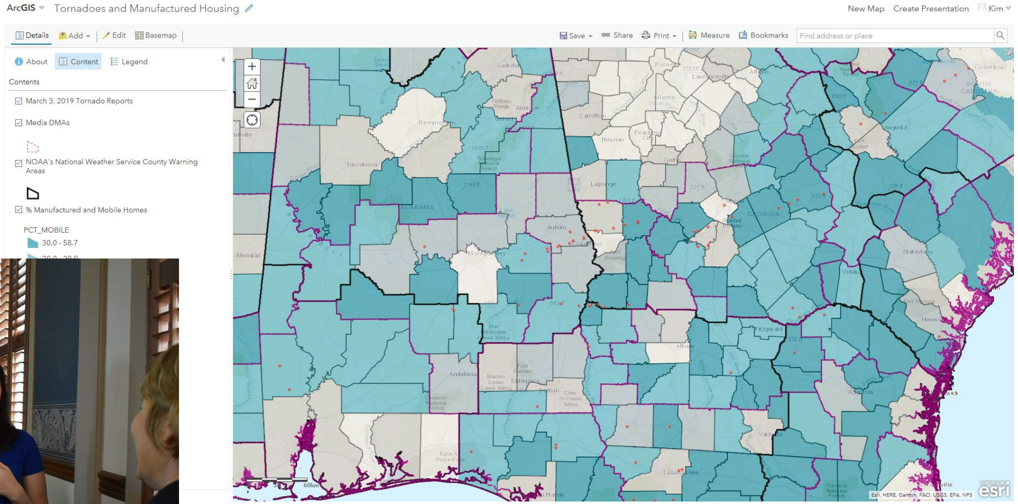
Source: Segales et al. 2020

Deployable Instrumentation Used to Collect Observations
Social Science

Kim Klockow McClain, PhD; CIWRO Research Scientist; WRDD



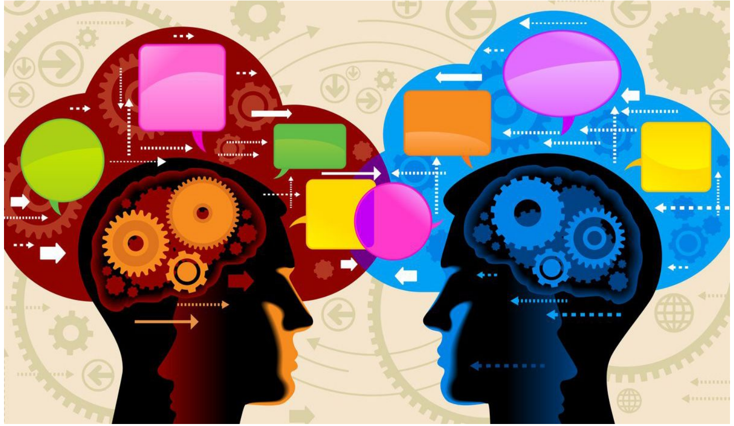

Fieldwork in the social sciences: data collection tools **include the researcher**



Data collection considers the intersection of hazards and societal factors.

We do this to **provide a more complete view** of the outcomes of weather events; better understand the human side of the equation: **how** do we impact decisions, save lives, protect property?

We include a wide array of disciplinary perspectives and cultural backgrounds. This improves linkages to the many diverse US populations affected by severe weather.



We employ mixed methods approaches to balance context with generalizability.

Future Work

- Strategy for publishing routine data/reports
- Cultivate best practices for deploying
  - When is best to go afterwards?
  - Can we be in-situ during events?
  - Can we be integrated with physical science teams?