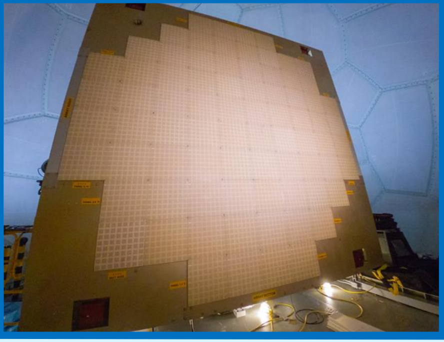
Observations and Analysis

Fieldwork and Analysis Overview, Part II

Michael Coniglio PhD, NSSL Research Scientist, FRDD






Introduction

Michael Coniglio, PhD

1. Understanding Storms and Their Environments

Elizabeth Smith, PhD

2. Planetary Boundary Layer (PBL) Research

Kimberly Hoogewind, PhD

3. Severe Weather Climatology and Sub-seasonal to Seasonal (S2S) Prediction

Kim Klockow-McClain, PhD

4. Social & Behavioral Data and Analysis

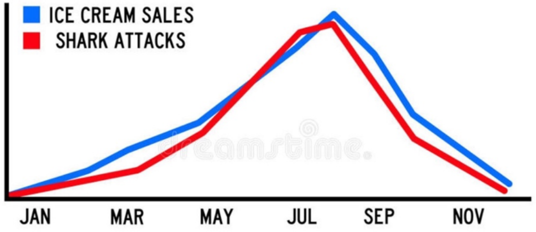
Topics span specific space/time scales to **broader, multi-scale efforts** seeing greater emphasis at NSSL

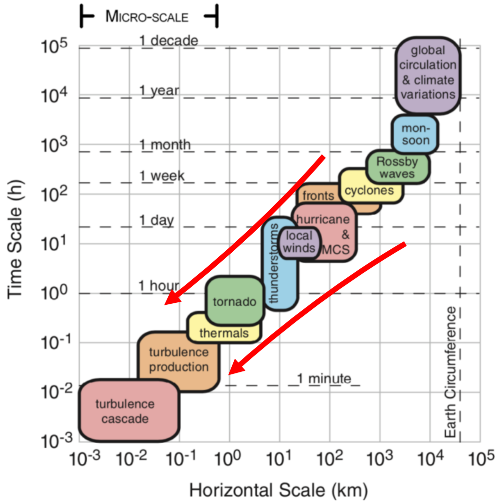
Addresses NOAA's basic science aim

NSSL mission: Conduct fundamental research to advance our understanding of processes associated with severe convective storms

NOAA mission: To understand and predict changes in climate, weather, oceans and coasts

Essential to guide applied research and operational tools; we shouldn't lose a grip on **understanding causation**





Quality & Performance

- NOAA Distinguished Career Awards

  *Dr. **Harold Brooks (2021)** "for extraordinary scientific contributions to climatology and prediction of severe thunderstorms and tornadoes, and their societal impacts in 30 years of service to NOAA."*

  *Dr. **Qin Xu (2016)** "for exemplary service as a research scientist with extraordinary contributions to theoretical understanding and fundamental applications of atmospheric dynamics, physics, and numerical prediction."*

- White House Presidential Early Career Award for Scientists and Engineers (PECASE)

  *Dr. **Corey Potvin (2017)** "for significant and innovative contributions to observational analysis of thunderstorms, assimilation of observed storms into numerical prediction models, and groundbreaking research to predict localized thunderstorm-related threats such as tornadoes."*

- NOAA Administrator's Award

  *Dr. **Conrad Ziegler** "for outstanding effort in the design, fabrication, and validation of the next-generation airborne dual-Doppler weather radar system" that is used in understanding of severe storm processes.*

- AMS Editor Award

  *Dr. **Michael Coniglio** (Weather and Forecasting)*

Quality & Performance

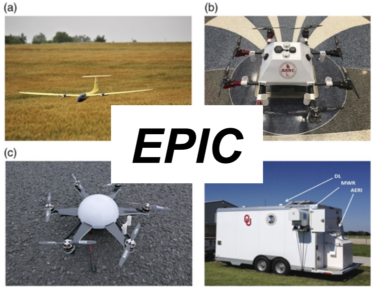
- ~95 peer-reviewed publications (59 *lead* authored)
- Leadership on multiple collaborative, multi-institutional field programs

PECAN

2015

VORTEX SOUTHEAST

2016-19
2022-23 (PERiLS)



2018

TORUS

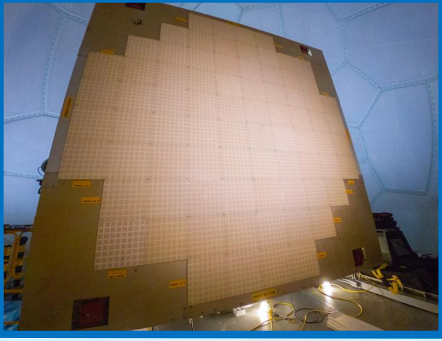
2019, 2022

Research Collaborations

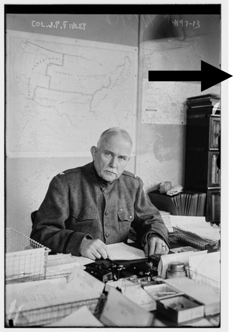
Observations and Understanding

Fieldwork and Analysis: Understanding Storms and their Environments

Michael Coniglio PhD, NSSL Research Meteorologist, FRDD



Fundamental to predicting storms



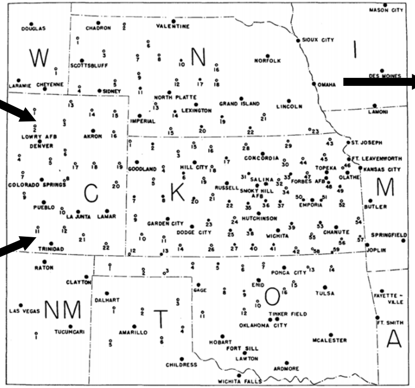
John Finley &
E.S. Holden (1880s)

US Weather Bureau

K. Showalter
H. Wexler
J. R. Fulks
J. R. Lloyd

Maj. Fawbush and Col. Miller 1948

Thunderstorm Project 1946-47



Tornado Project 1951-53

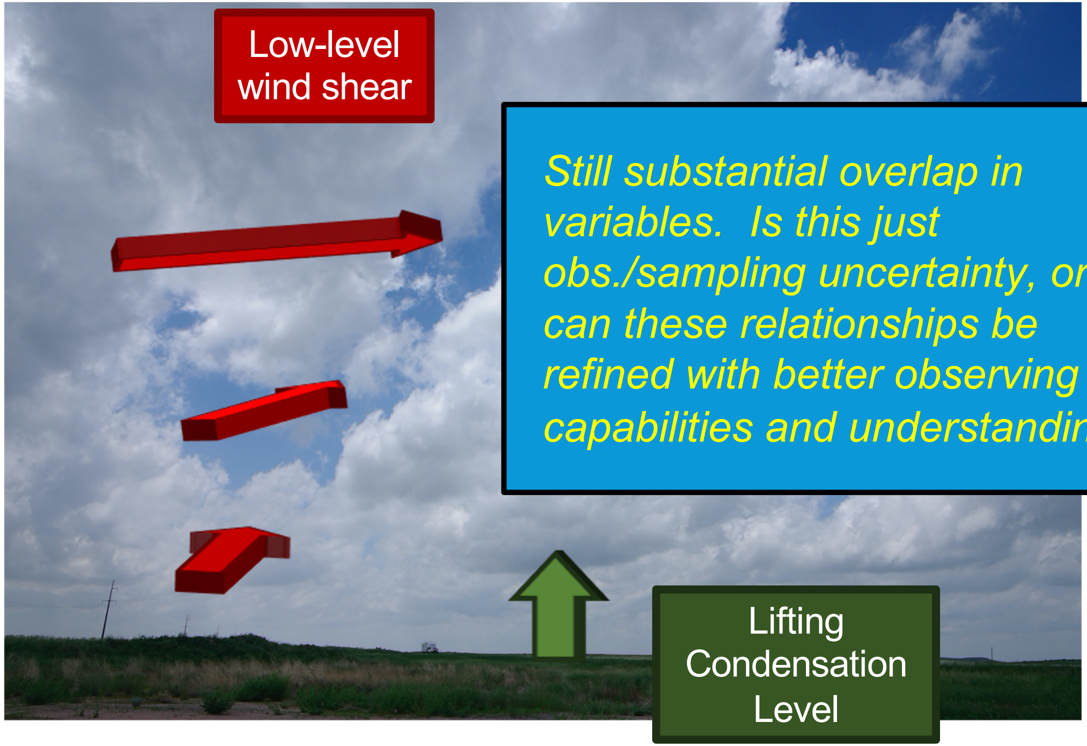
NSSL precursor → https://www.nssl.noaa.gov/about/history/

Using field observations to study storms and improve forecasts is in our DNA!

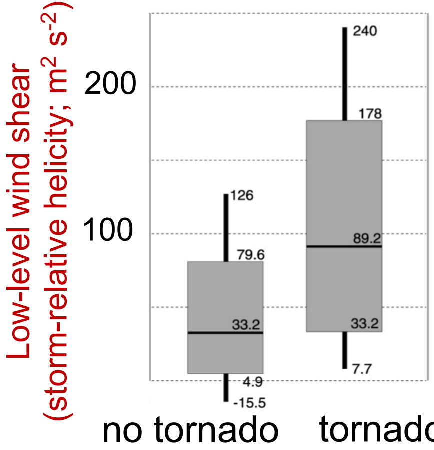
2015-present: NSSL continues as leader in understanding storms/environments

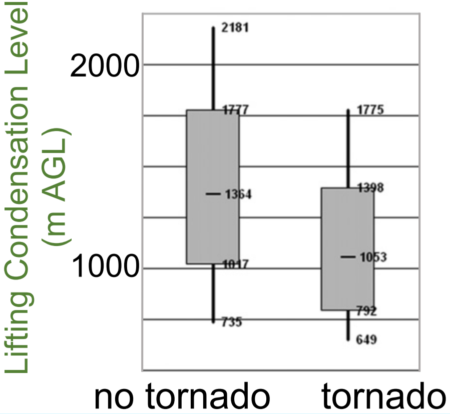
- Small, homegrown efforts to large, collaborative, multi-institutional field programs
- Pure observations, pure modeling studies, and in between
- **All thunderstorm types and hazards (coming focus on QLCSs)**

Storm-environment relationships still guide forecasts of storms (GSC1)

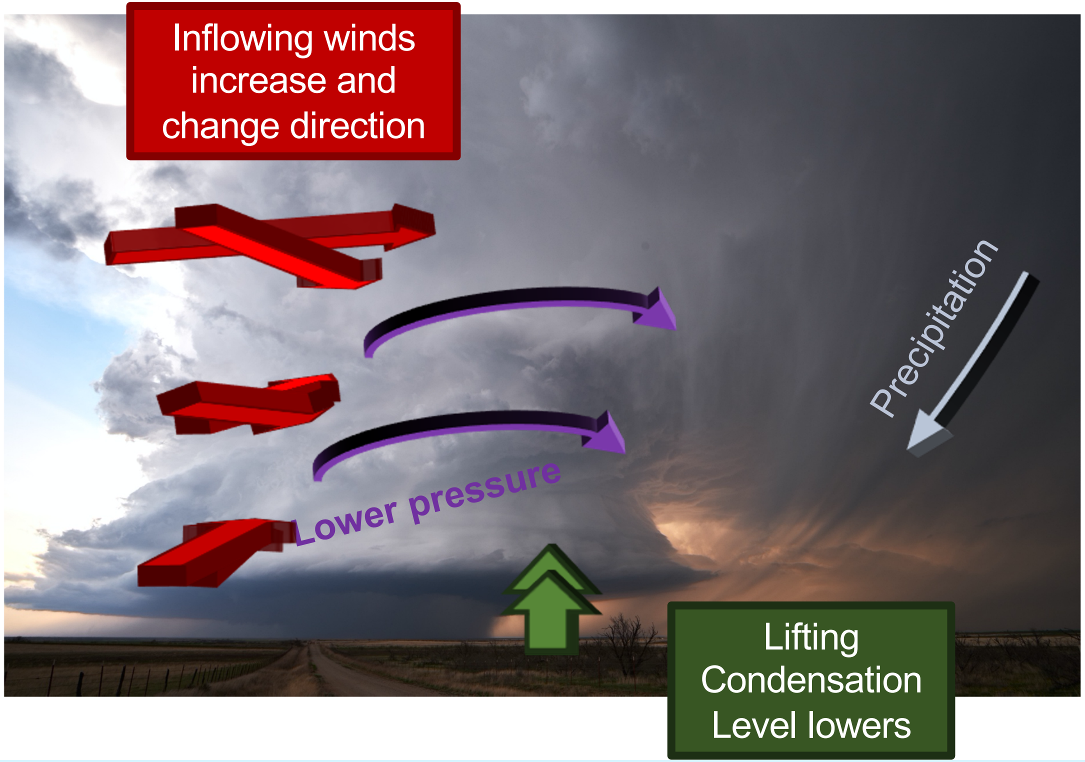


Still substantial overlap in variables. Is this just obs./sampling uncertainty, or can these relationships be refined with better observing capabilities and understanding?



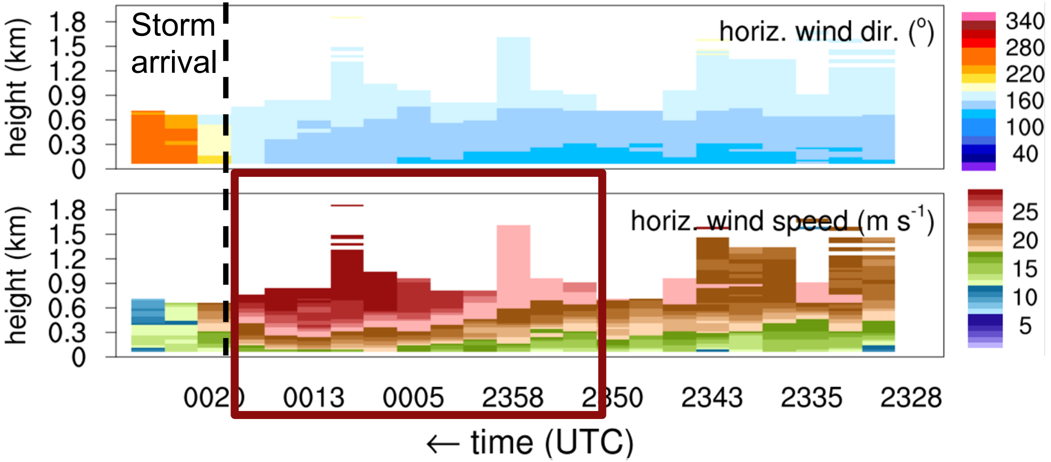


What happens when a storm develops and churns through the environment?



Do these local-scale modifications, and better understanding of these processes, hold a key to improving our skill of forecasting storm behavior through storm-environment relationships?

Inflow observations and storm environments

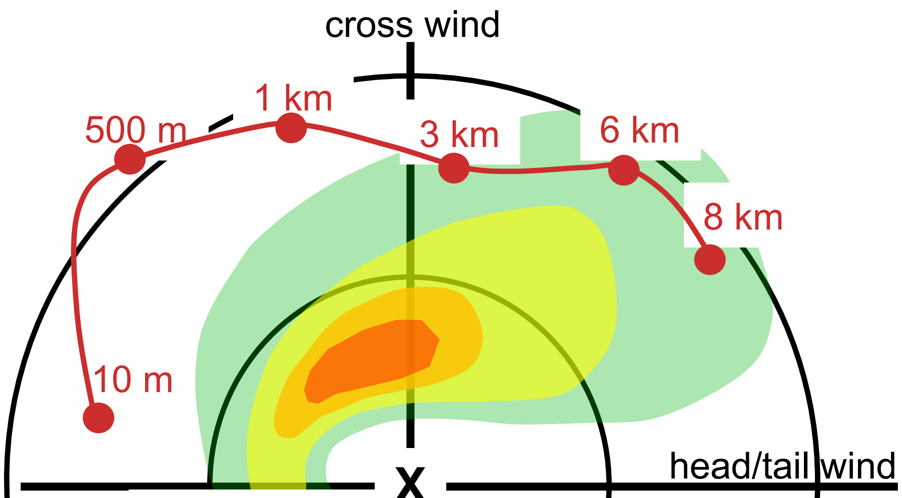


Inflow winds strengthen over a deep layer

Currently have 28 deployments in supercell inflow like this to being looking for consistent characteristics and discrimination of nontornadic and tornadic supercells

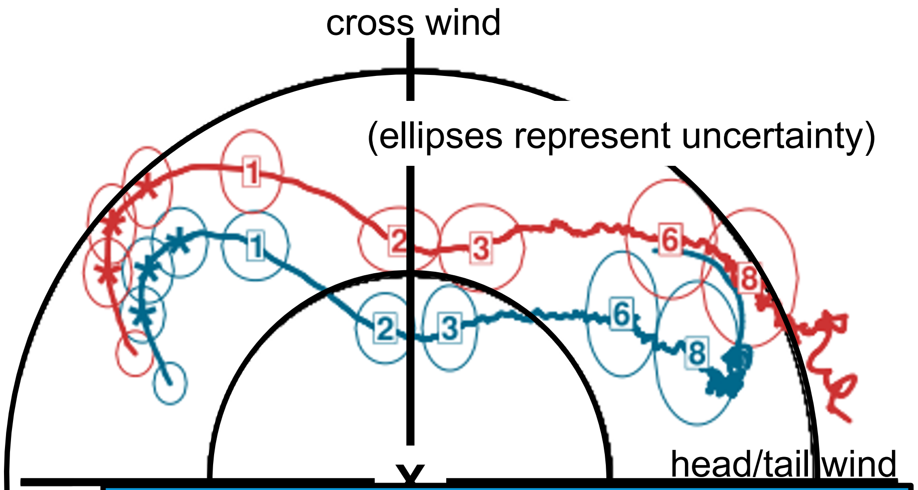
Inflow observations and storm environments

In a storm-relative reference frame:



Average storm-relative wind profiles

TOR (n = 190) **NO TOR (n = 240)**

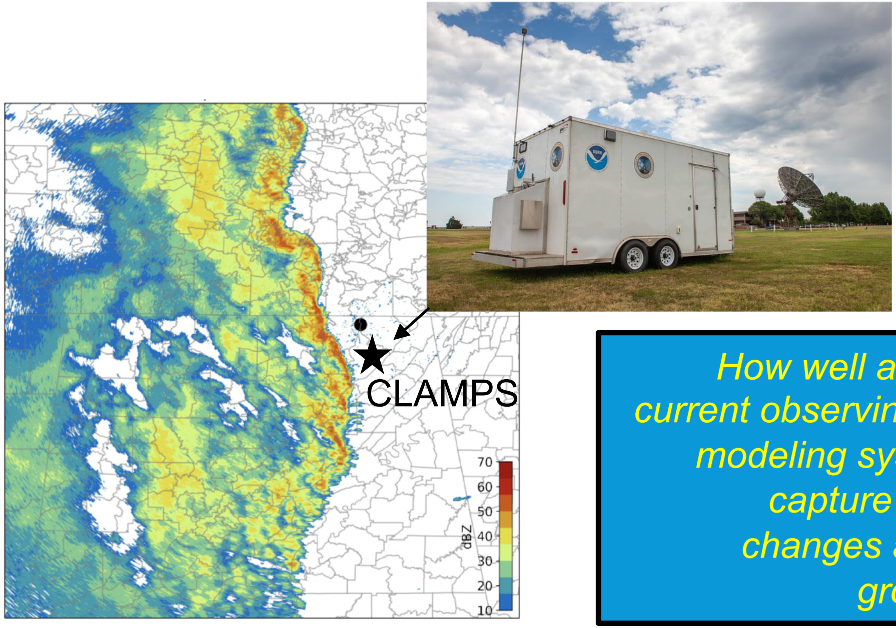


These differences have not been seen in other past studies using different cases/datasets -- what does this mean for supercell dynamics and forecast applications

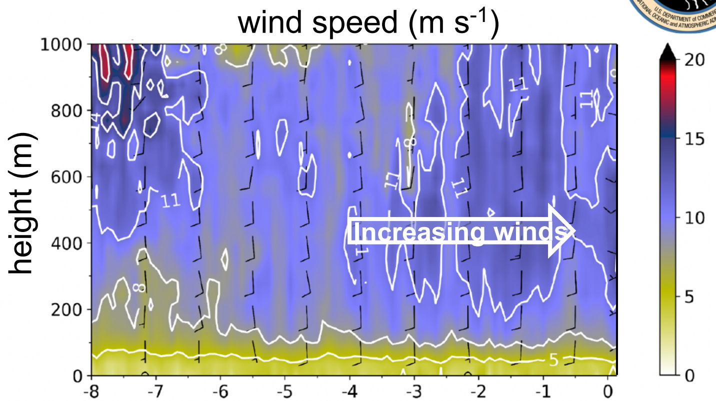
Inflow observations and storm environments

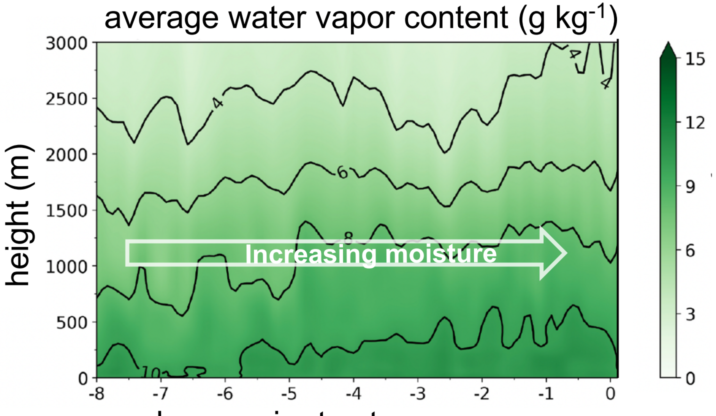
Quasi-linear convective systems (QLCSs)

- QLCS mesovortices and tornadoes difficult to forecast
- Hazards span all times of day



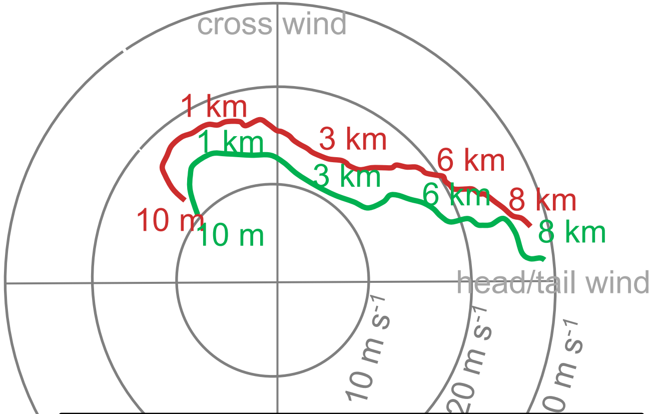
How well are our current observing and modeling systems capture these changes above ground?



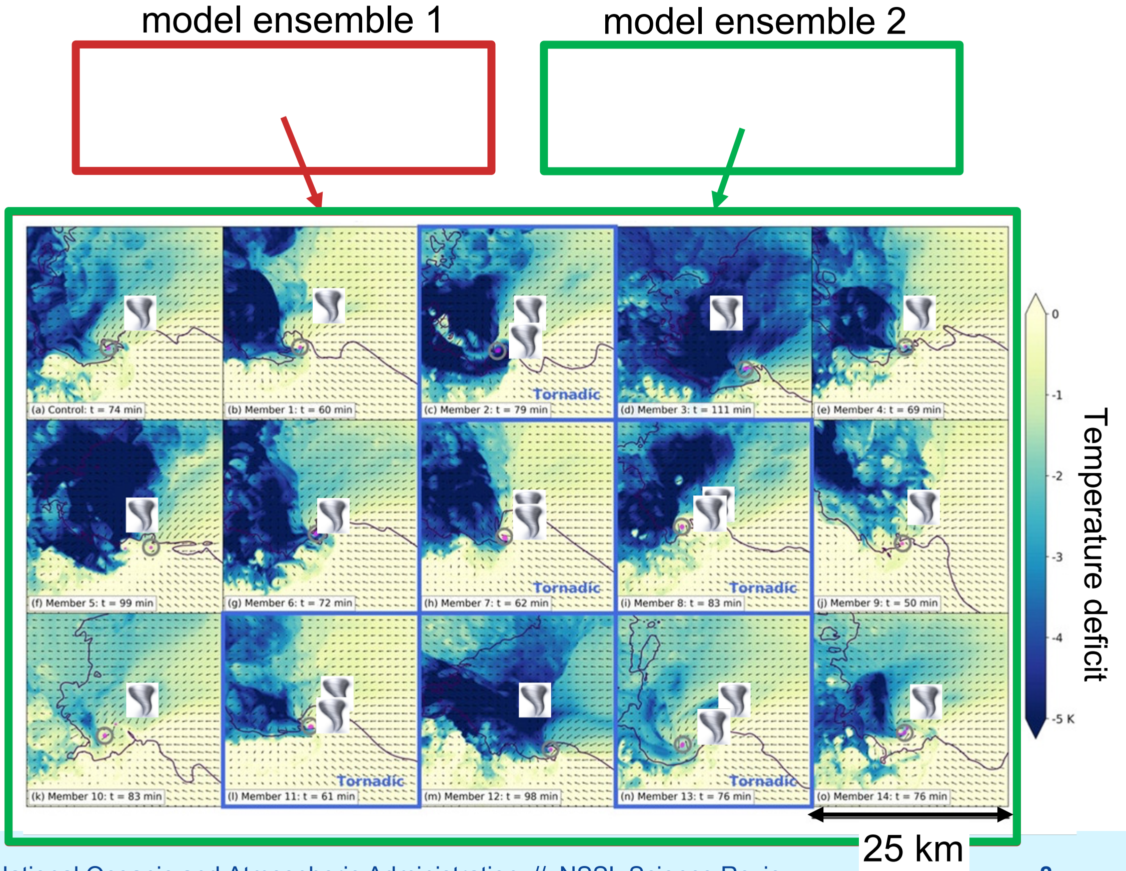


Modeling of storm/environment behavior

Average storm-relative wind profiles

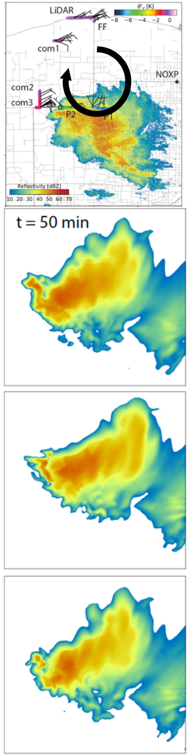


Providing clues to how storm-relative winds and cold air influence supercells and the features we need to explore further in the real atmosphere

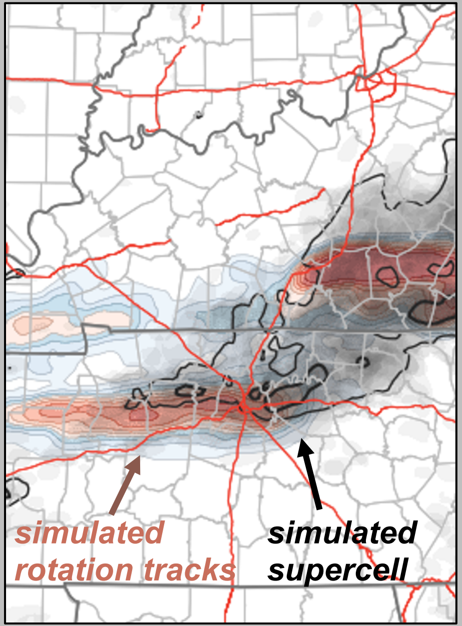


Modeling of storm/environment behavior

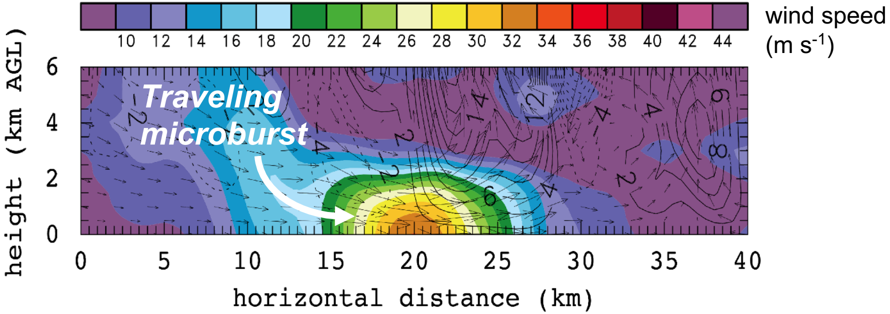
TORUS anticyclonic supercell

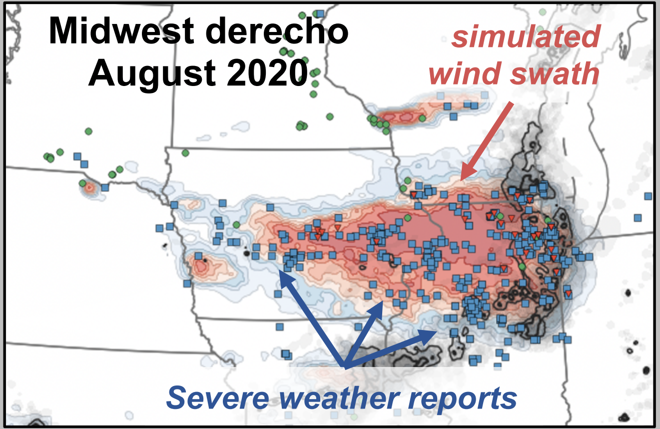


Nashville, TN tornado March 2020



PECAN severe-wind nocturnal convective systems



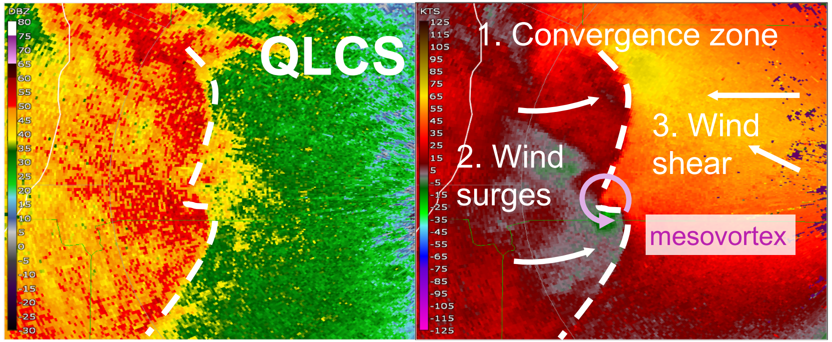


Focus the next 1-3 years

Continued collection and analysis of storm environment observations

TORUS 2022 – Complete year 2 and composite analyses of inflow environments

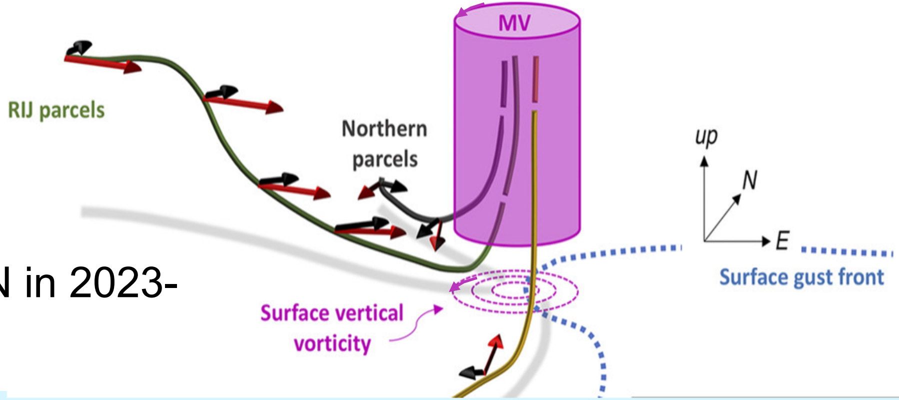
PERiLS 2022-23 – Influx of OU graduate students and postdocs



radar reflectivity radial velocity

Physical understanding-based forecast-tool evaluation (e.g. “the three-ingredients method”)

Diagnosis of mesovortex genesis mechanisms from model simulations



Convective Initiation with TRACER & AWAKEN in 2023-24

Observations and Understanding
Fieldwork and Analysis: PBL Research

Elizabeth Smith PhD, NSSL Research Meteorologist FRDD




Summarized story to tell

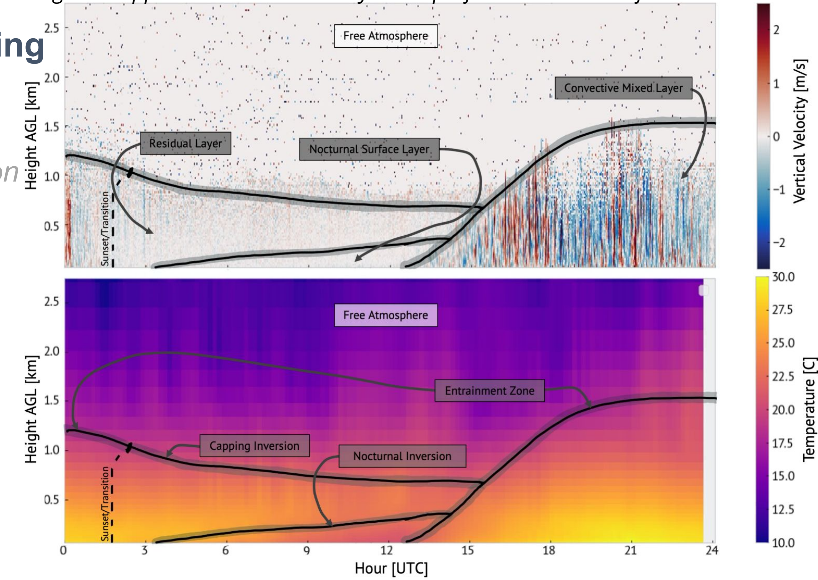
- The planetary boundary layer (PBL) is where we live our lives, yet it is critically under-observed

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

- Continuous, wide-coverage **PBL observations are challenging**

- NSSL **new research themes** related to PBL science
  NSSL GSC 5: Develop reliable nowcasting system for convection initiation
  NSSL GSC 1: Develop reliable probabilistic guidance products
  - *Which scales of PBL motion are occurring prior to severe convection and are they well-represented in forecasts?*
  - *Can PBL observations be useful in operational settings? If so, which ones and how?*
  - *How common are PBL features/structures across regions, seasons, and regimes?*
  - *If a single PBL observation solution appears unlikely, what observation combinations and/or configurations may be effective for specific applications?*

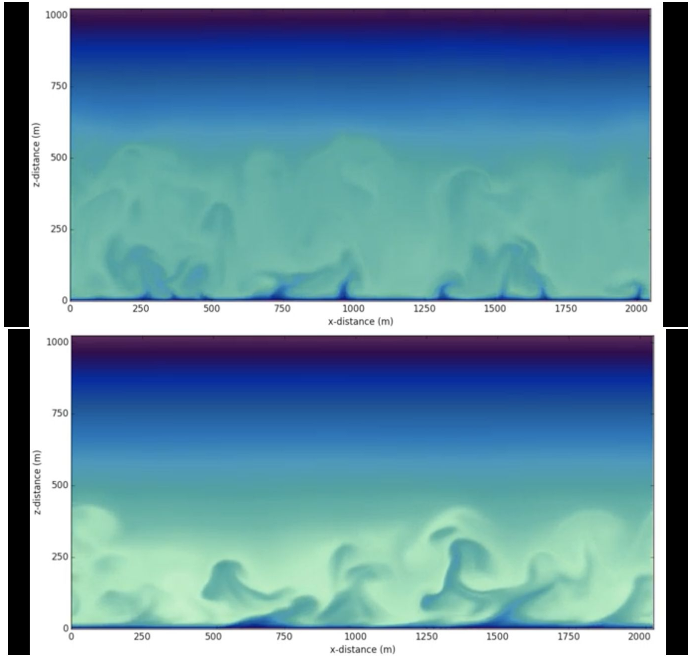
Figure: Doppler lidar and thermodynamic profile observations of PBL evolution.



Relevance

Severe storms--and most high impact weather events--occur in the boundary layer.

Addressing NOAA, OAR, and NSSL mission goals to *advance understanding of the Earth system through research* conducting fundamental research to understand PBL processes is key.



Simulated boundary layer temperature with and without 5 m/s mean u wind [J. Gibbs]

- Examples of high impact weather
  - *Storms, flooding rains, mixed winter precipitation*
  - *Understanding conditions near the surface but above the ground necessary*
- Model grid spacing and resolution
  - *Climate models→weather forecasting models→ large-eddy simulations (LES)*
  - *Fundamental understanding of PBL processes is critical to PBL parameterization scheme development (scale-aware, stochastic implementation)*
  - *Proper PBL observation datasets are needed*
  - *Subject matter experts crucial in understanding when/where to apply parameterization*

Goals and Accomplishments

Goal: Identifying observation needs & fulfilling them locally and/or via collab.

✓OU-NSSL CLAMPS1 & NOAA-NSSL CLAMPS2 successfully developed, deployed, and maintained

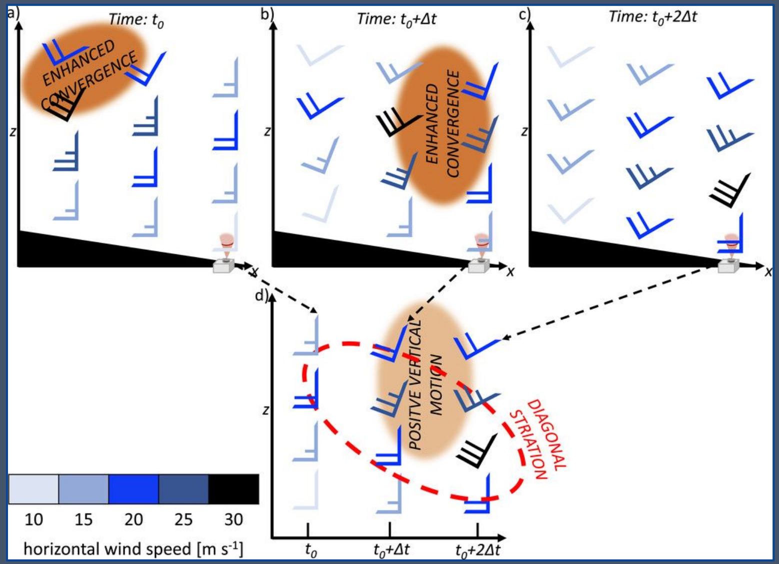
- CLAMPS filled critical observation gaps in the PBL, particularly in terms of **thermodynamic profiling**
- Advance understanding of **nocturnal convection initiation** *(PECAN)*, **low-level jets** *(PECAN)*, **storm-scale data assimilation** *(PECAN, mini-MPEX, VORTEX-SE)*
- Efforts led to important **collaborative relationships**, *enhancing NSSL's ability to achieve more science*
- **Collaborations matured into campaigns specifically designed to leverage *multi-OAR lab expertise***

VORTEX-SE 2016-Present: severe storms, data assimilation, PBL scales
Deployment complete/in planning, analysis complete/ongoing

CHEESEHEAD 2019: PBLs in season change forested region, model evaluation
Deployment complete, analysis complete/ongoing

SPLASH 2021: PBLs in cold season complex terrain
Deployment ongoing, analysis in planning

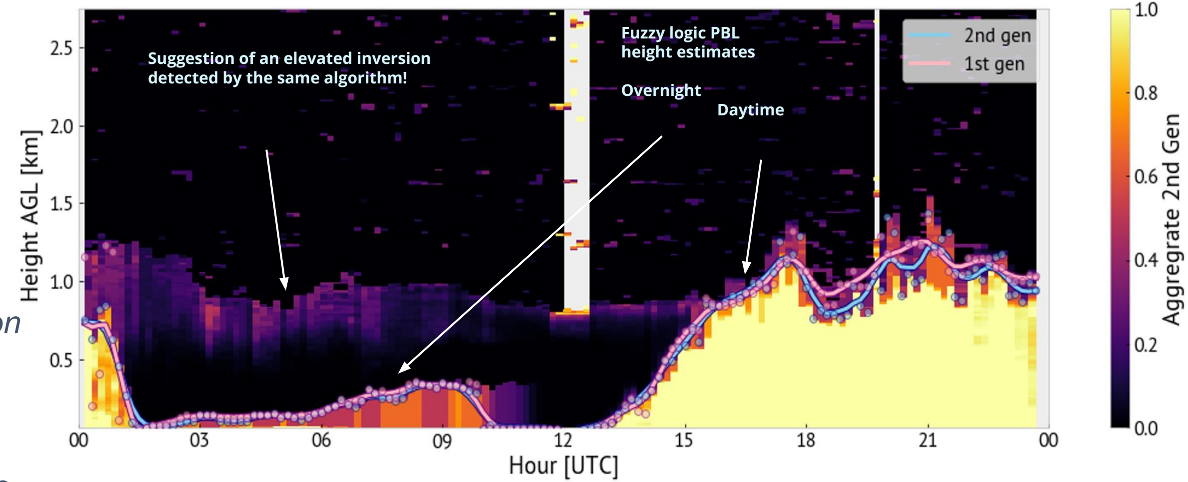
TRACER 20~~21~~22: seabreeze/urban PBLs, convection initiation, model evaluation
Deployment in planning, analysis in planning (COVID delayed)



Goals and Accomplishments

Goal: Improving observation products for users

Given NSSL's developing collection of PBL instrumentation and frequent deployment with partner platforms, there are opportunities to develop tools and explore ways to combine instruments to provide **value added products**



- **Value added products**
  - ✓ TROPoe: *AERIoe retrieval improved, broadened beyond AERI only, open source language;containerized; now called **T**hermodynamic **R**emotely **O**bserved **P**rofiling by **O**ptimal **E**stimation*
  - ✓ Fuzzy logic PBL height: *in collaboration between NSSL (FRDD & RRDD) and NWS (Norman & Shreveport) observations were collected which led to the development of a new fuzzy logic PBL height detection algorithm. This work also is enhancing understanding of dual-pol radar detection of PBL structures (NSSL GSC 2).*
  - ○ WINDoe: *in collaboration with NCAR EOL, a new multi-instrument retrieval of wind information is in development.*

Goals and Accomplishments

Goal: Integrating PBL science into severe storm science missions

With stronger observation and science capability in the realm of PBL research, NSSL has started directly including PBL science in severe storms project milestones and goals when applicable. Examples:

- PECAN
    - *PBL specific science goals (low-level jet, pristine nocturnal convection initiation)*
    - *Interaction of PBL structures with mesoscale structures*
- VORTEX-SE and PERiLS
    - *Support longer deployment of PBL profiling systems for various goals*
    - *Elevate PBL profiler planning to “main” PI planning levels*
    - *Integrate PBL experts into planning and science discussions with other science area PIs*
    - *Include pre-storm PBL processes in targets of interest for analysis and deployments*
- TORUS2019
    - *Integrate PBL experts into planning and science discussions with PIs*
    - *Include pre-storm PBL process observations when practical*
    - *Connections between fundamental PBL processes and near storm environmental processes considered*

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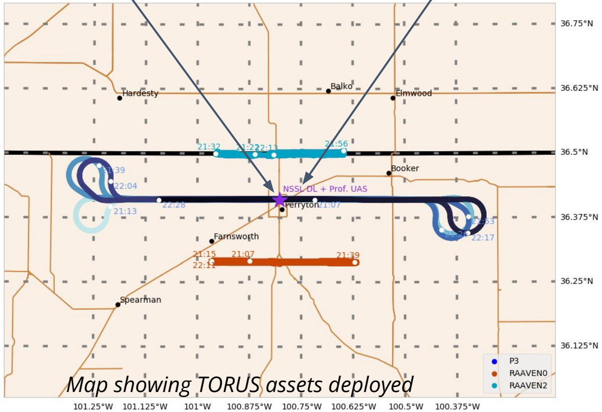

Map showing TORUS assets deployed

TORUS clear air 14 June 2019 - dryline case: While the dryline boundary was amorphous, we were able to sample as dry air entered the area (see UAS profiles). We observed uptick in turbulence intensity right before dry air, followed by rapid shutdown when anvil shading occurred after 2220 UTC.

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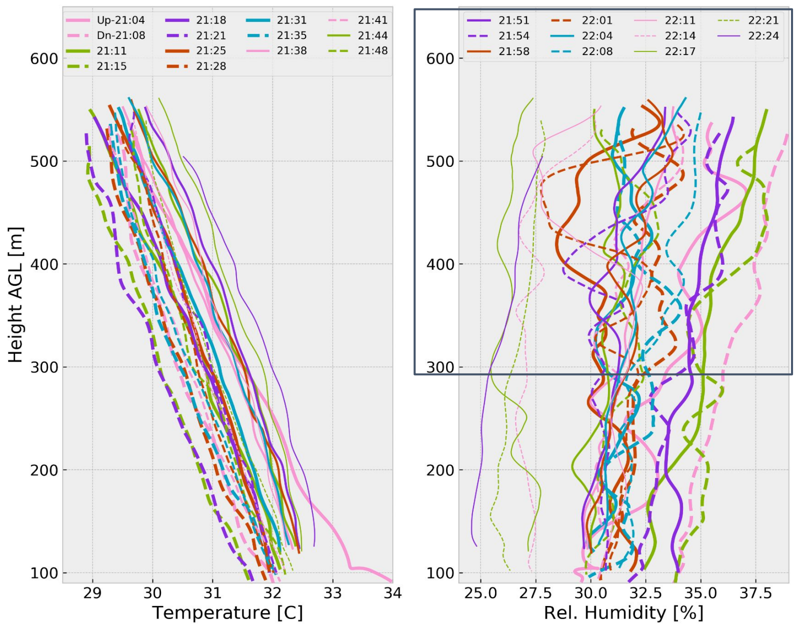
UAS profiles



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Main contributors to these efforts:
T. Bell, M. Coniglio, E. Rasmussen, E. Smith

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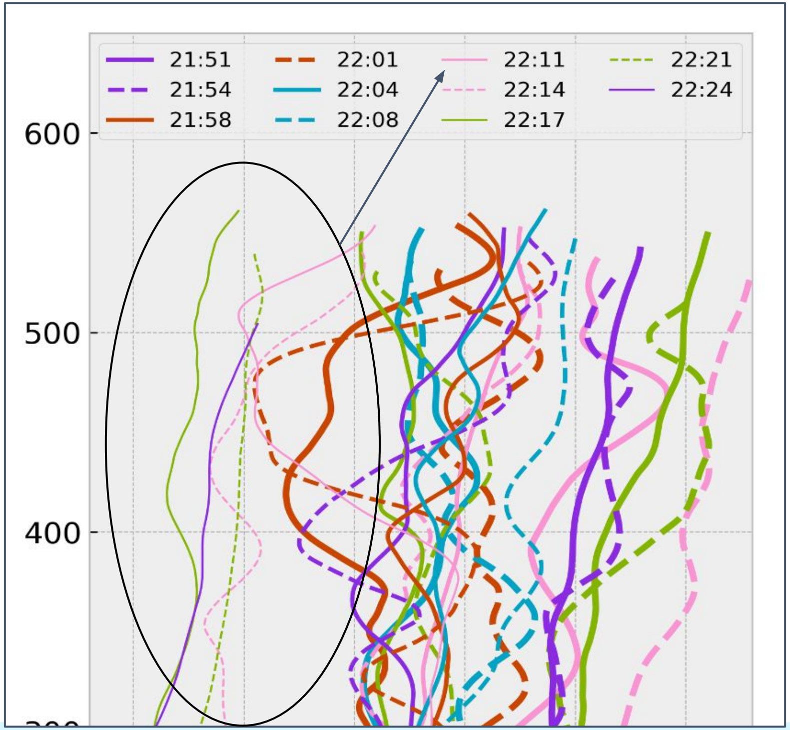
UAS profiles



Dry air UAS profile observations beginning around 2210 UTC

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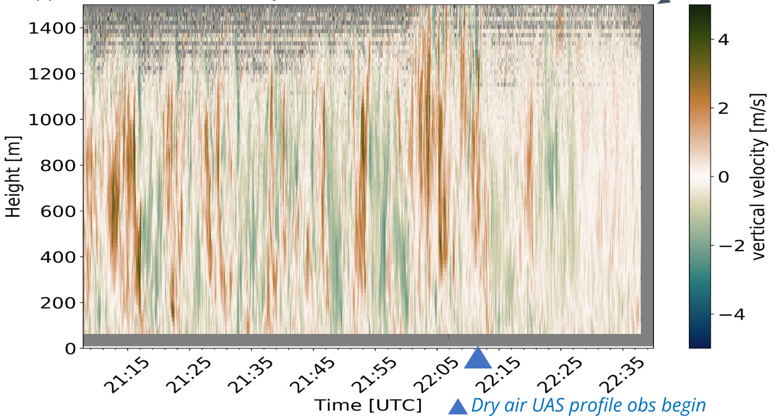

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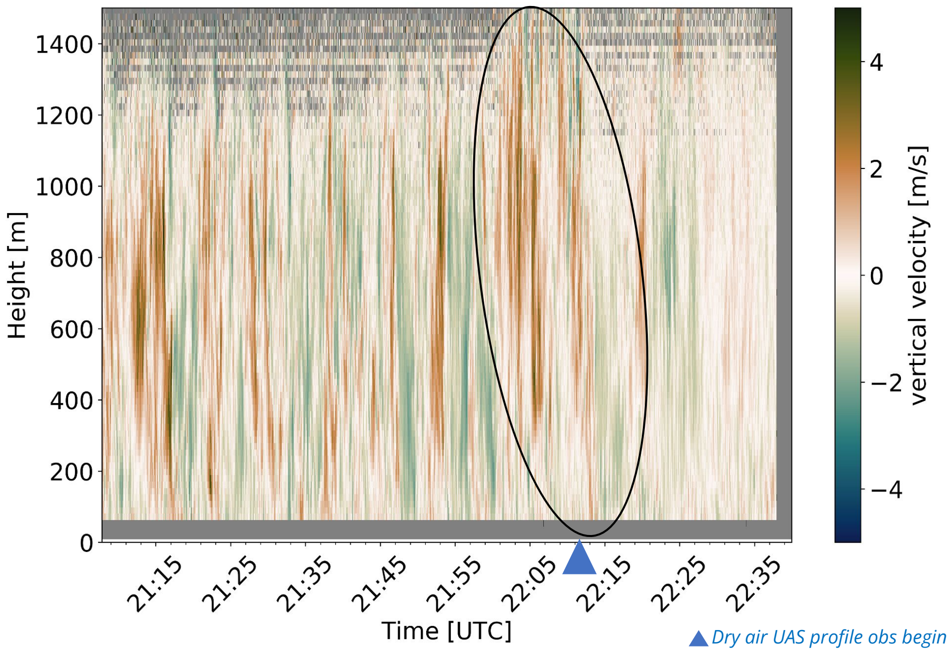
Doppler lidar vertical velocity



▲ Dry air UAS profile obs begin

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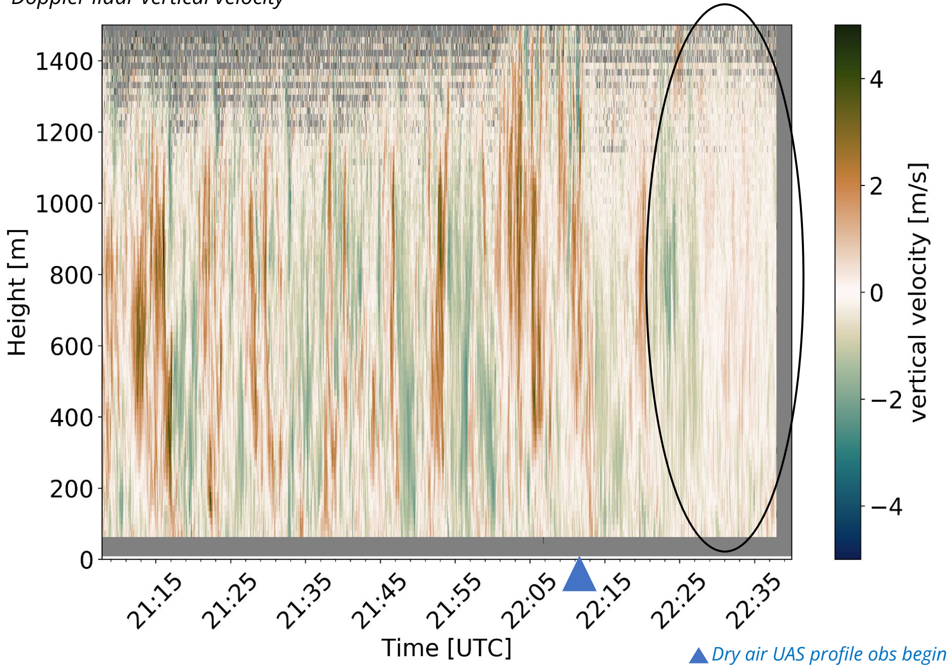

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Future work

- PBL research serving NSSL mission continues to grow
  - NSSL leading NWC collaborative PBL community building; whitepaper published, new faculty hires at OU already approved!
  - OAR cross-lab collaborations continue to be fruitful
- New and growing access to UAS platforms opens doors to new methods and new scientific questions: *combined remote/in-situ platforms, nimble thermodynamics, land surface characterization, connections with NWS/stakeholders, and more!*

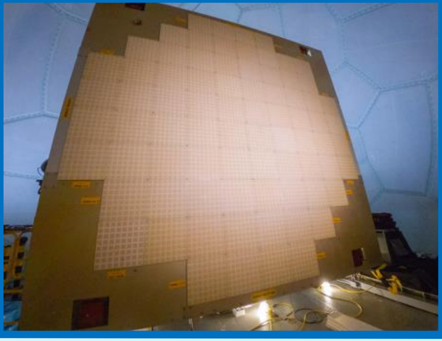
Some upcoming projects:

- BLISSFUL(2021): observations already completed; a **unique opportunity to develop methods** for dual- and triple-lidar scans, specialized lidar-UAS paired deployments, and UAS mapping providing lower surface info for LES modeling.
- VORTEX-SE/PERiLS(2022/2023): PBL focus on **multi-scale network-in-network observation framework** and applicability for data assimilation and observation product development; further TROPoe retrieval development; **investigation of the scales of PBL motion**.
- TORUS(2022): more **connections between fundamental PBL processes and the near-storm processes**; lidar platform performance evaluation; study **anvil shading** impacts
- TRACER-CUBIC(2022): PBL observation and modeling of interaction between sea-breeze and urban boundary layer circulations; how **frontal boundaries (e.g., drylines) and can initiate convection**.
- AWAKEN(2022/2023): ARM SGP site wind turbine interactions; **mesoscale flow interactions** and possible **airmass modification**; convection and convection initiation (e.g., outflow boundaries, storm motion modifications, low-level jets, nocturnal turbulence, etc.)

Observations and Understanding
Fieldwork and Analysis: Severe weather climatology and S2S prediction

Kimberly Hoogewind PhD, CIWRO Research Scientist, FRDD






Summary of Efforts

- Long history of estimating severe weather climatology from reports and ingredients-based approaches

- Participation in an experimental seasonal severe weather outlook group with NOAA research laboratories, NWS operational centers, and academic partners for several years
  - Overall, there has been *limited* success because of the complex nature of subseasonal-to-seasonal (S2S) severe weather prediction

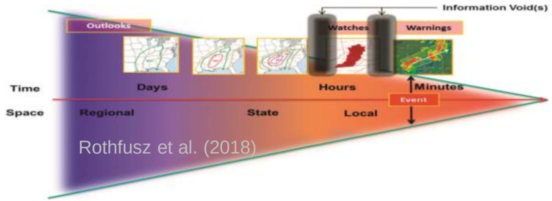
- Current research focus on S2S predictability at 2 weeks to 3+ month lead times

Relevance to NSSL Mission

- S2S prediction is becoming more important within NOAA (2017 Weather Act)

- NSSL has severe weather and growing climate expertise

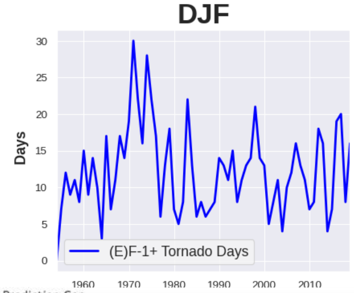
- Fits within the FACETs paradigm



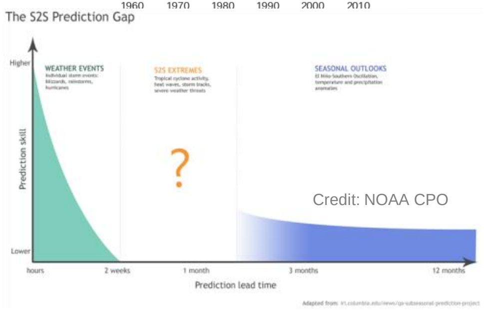
- S2S prediction is one of the main research themes of NOAA's CIWRO

Goals

1) Improve understanding of severe weather and climate variability



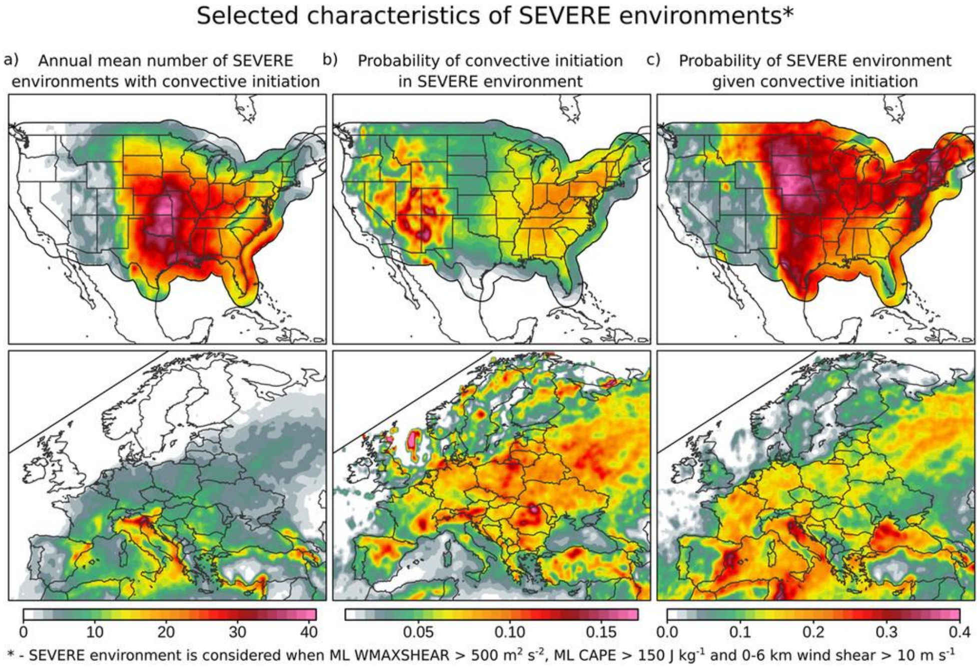
2) Determine what is predictable *and* useful



3) Develop reliable probabilistic experimental guidance (GSC 1) for severe weather frequency 2 weeks to 3+ months in advance

Severe Weather Climatology

- Long history of understanding severe weather reports
- Ingredients-based approach
  - Severe storm-environment relationship
- Past contributions to IPCC and national assessment reports



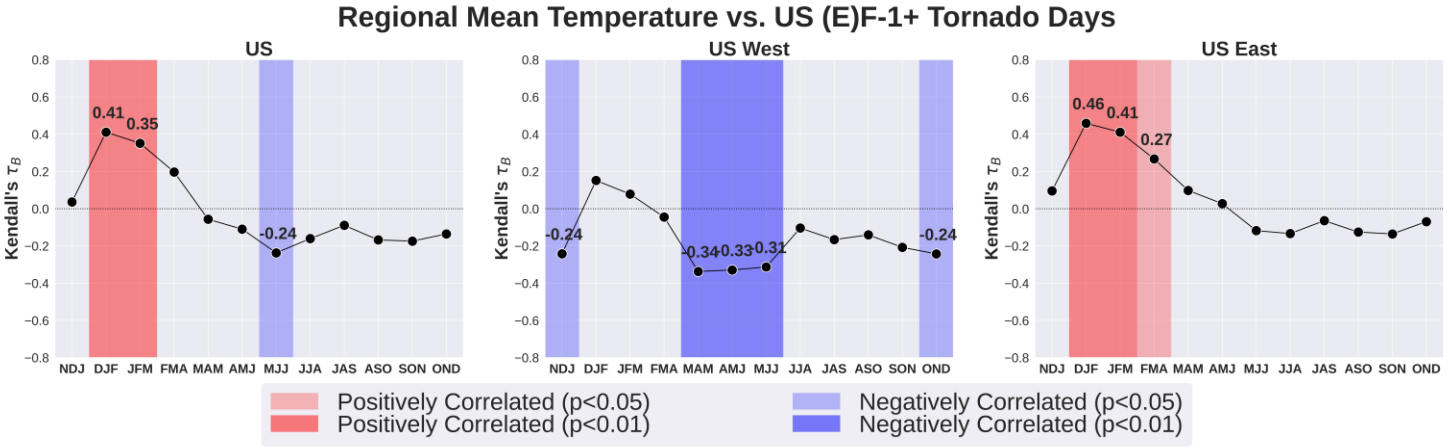
Taszarek et al. (2020; *Journal of Climate*)

Seasonal Severe Weather

- Can seasonal temperature outlooks be used to infer above/below normal tornado frequency?

Warmer spring/summer
⬇
fewer tornado days

Warmer winters
⬇
more tornado days



Subseasonal Severe Weather

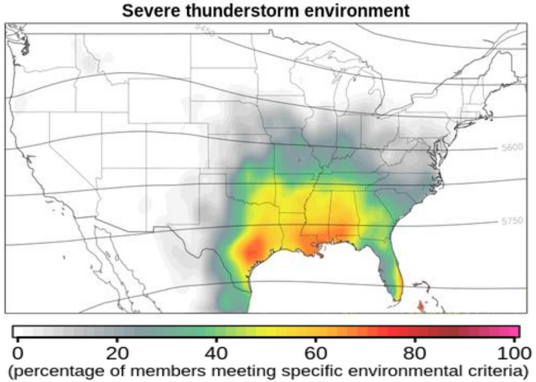
- Multiday severe weather events

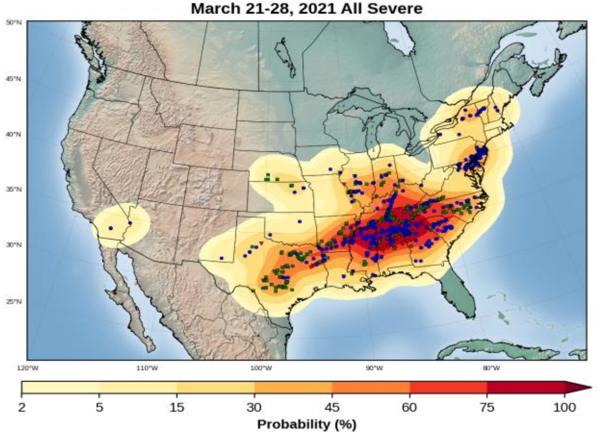
- Predictability
  - Teleconnections
  - Dynamical models
  - Experimental 2–5 week predictions

- Machine learning

Forecast made 3 March 2021

Week 3 Forecast
Valid 03/21-03/28



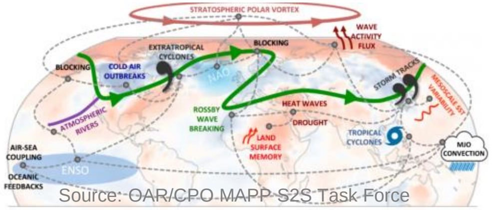


Preliminary Severe Storm Reports
March 21-28, 2021

Tornado	86	306% above normal
Hail	325	153% above normal
Wind	482	431% above normal

Future Work

- Predictability
  - Important to gain knowledge prior to developing guidance products



Source: OAR/CPO MAPP S2S Task Force

- Users of S2S severe weather forecasts
  - What is useful and to whom?

- Utilize remotely-sensed observations of severe storms
  - Leverage Multi-Radar Multi-Sensor dataset

- Expand temporal record of atmospheric data
  - 20th Century Reanalysis (180+ years)

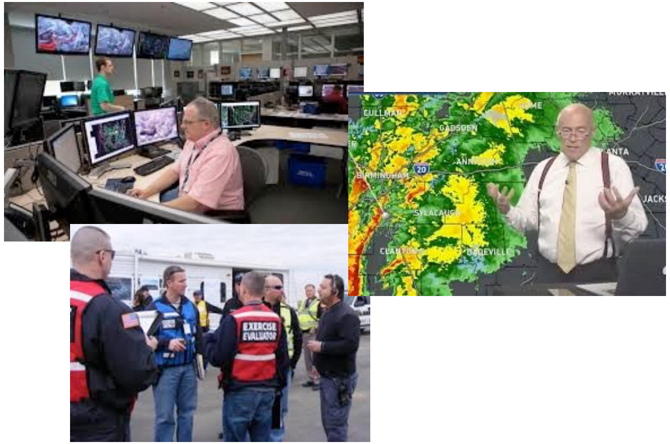
Fieldwork and Analysis

Social and Behavioral Data

Kim Klockow McClain PhD, CIWRO Research Scientist, WRDD

Summarized Story to Tell

We collect observations of the weather forecast and warning communication system, as well as public decision-making processes

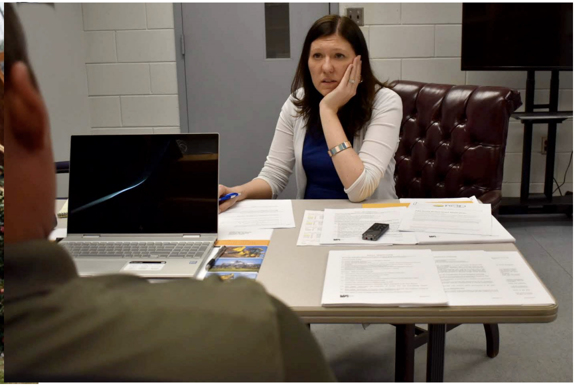


Relevance

Connect forecast and warning methods to the needs of users and publics

Accomplishments

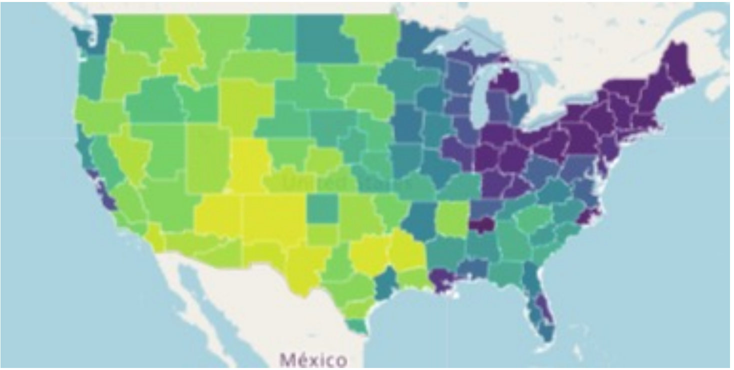
Deploy after tornado events; interview survivors, emergency managers, broadcasters, NWS forecasters

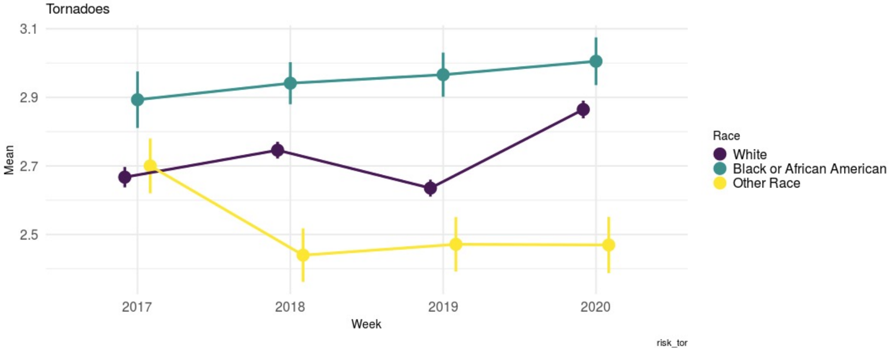


Accomplishments

Scaling up: Routine annual public survey

How do individuals think they generally receive, understand, and respond to severe weather forecasts and warnings?





Accomplishments

Scaling up: Standardized post-event survey, delivered in three ways

*Directly observe: In real events of various kinds, how **DO** people receive, understand, and respond to weather forecasts and warnings?*

Tornado Touchdown Web Application

NWS Damage Assessment Tool (DAT)

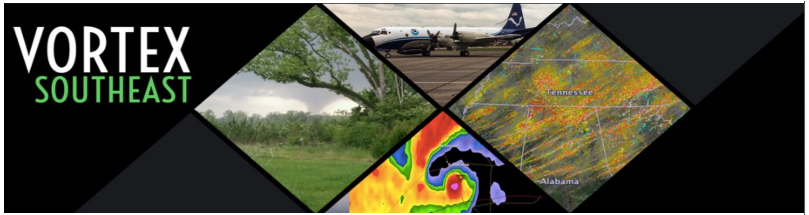
NATURAL HAZARDS CENTER

NHC Quick Response Grants Program – Special Tornado Call

Accomplishments

VORTEX-SE (USA) SeaGrant Extension & Advisory Council

Bring local concerns into program research & operational priorities



Sea Grant
Mississippi-Alabama

Future Work

Deploy novel observing systems, promote their use by publics and users.

Collation of observations across several years, many events, many experiments; foster scientific discovery and new applications.