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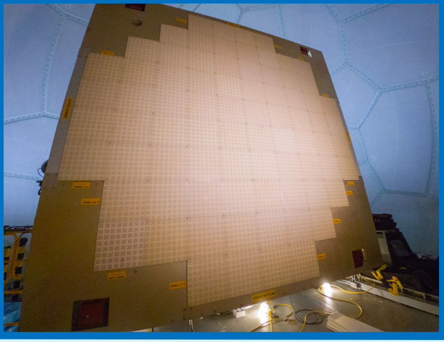
National Severe Storms Laboratory

2021 NSSL Science Review
Observations and Analysis

Part I of Fieldwork and Analysis Overview

Erik Rasmussen, NSSL Research Scientist, FOFS

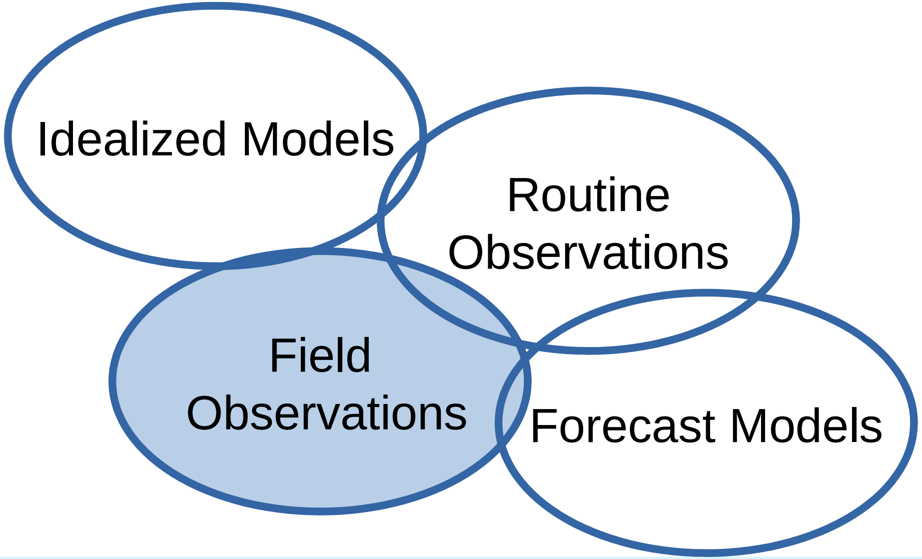





Field Work Addresses NSSL's Mission

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

We use a variety of tools and synergistic approaches to generate new knowledge...



Field Research Leadership

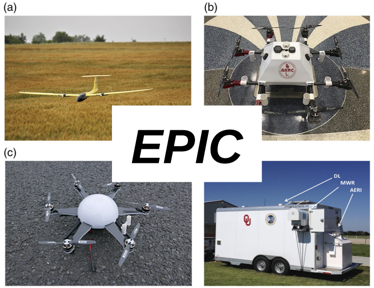
- NSSL scientists continue the tradition of leadership roles on field projects related to our mission.
- We design and improve instruments, *deploy* them, and use the data in internal and collaborative research.

PECAN

2015

VORTEX SOUTHEAST

2016-19
2022-23 (PERiLS)



2018

TORUS

RiVORS 2017
2019, 2022

Research Collaborations in Field Work

Introductions

1. Tornadoes


Dr. Erik Rasmussen

2. Storm Electrification and Microphysics


Dr. Vanna Chmielewski

3. Precipitation and Flooding


Dr. J. J. Gourley

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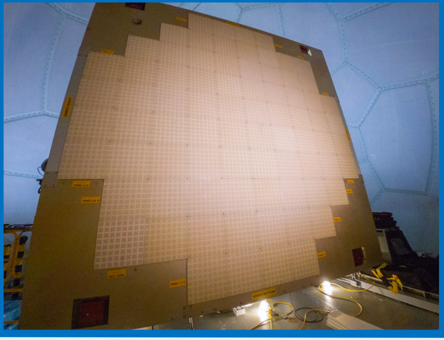
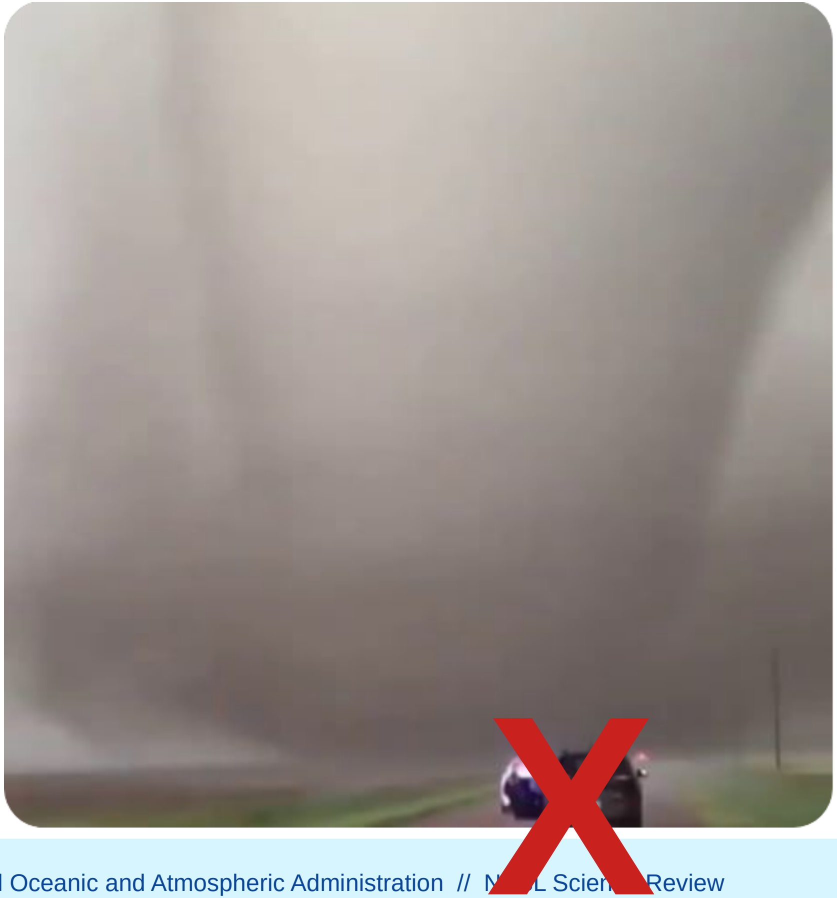
2021 NSSL Science Review
Field Work and Analysis
Tornadoes
Presented by Erik Rasmussen, Research Scientist, FOFS



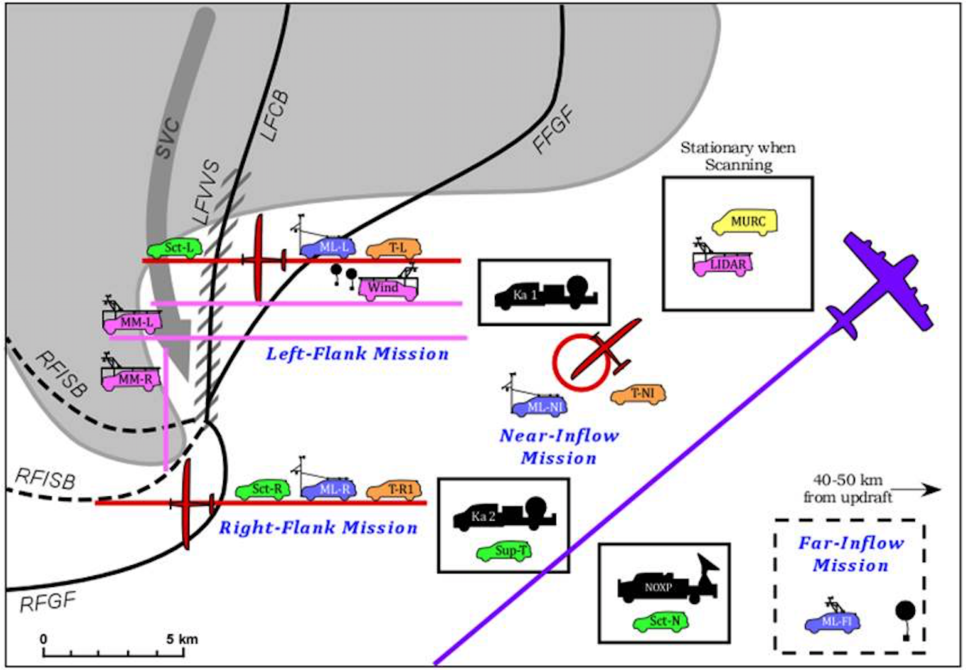



What we ^don't^ do in tornado field work…

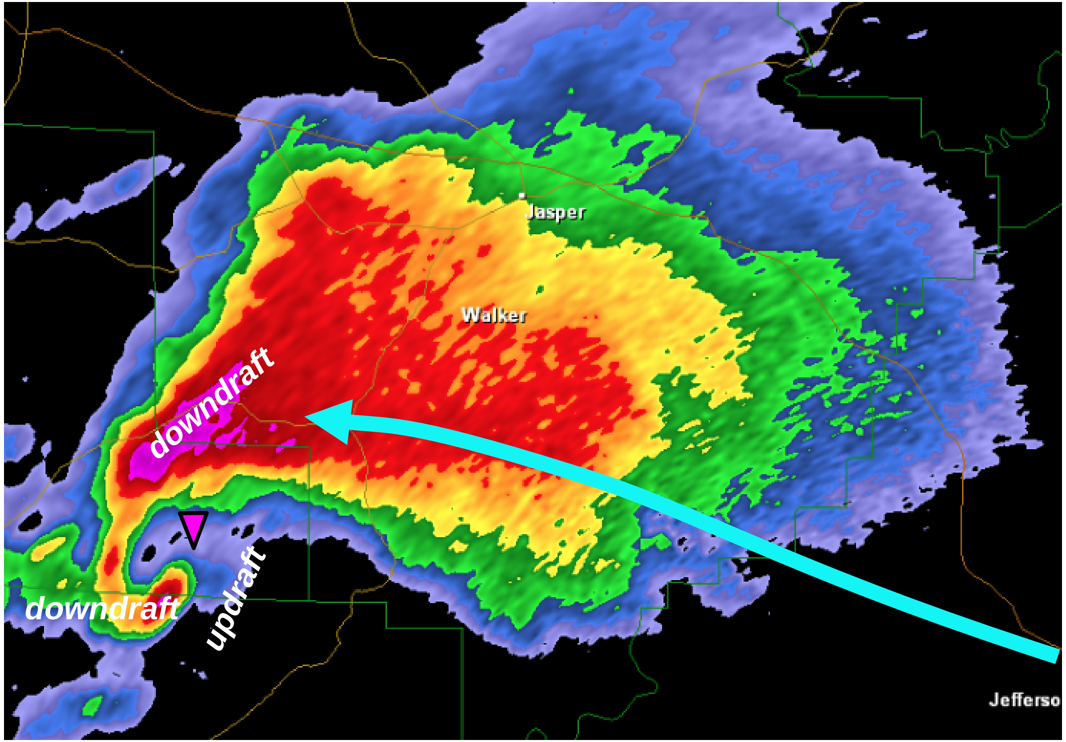


What we do in tornado field work...

- Develop hypotheses
- Detailed plans
- Multiple platforms with collaborative coordination



Knowledge to improve forecasts and warnings



Low-level inflow through the forward flank acquires more spin

What were initial environmental conditions?
What is role of precipitation?

Air turns toward updraft in a “streamwise vorticity current”

What is role of rain/hail/cooling?
How much spin is generated?

Air turns abruptly upward into the tornado cyclone

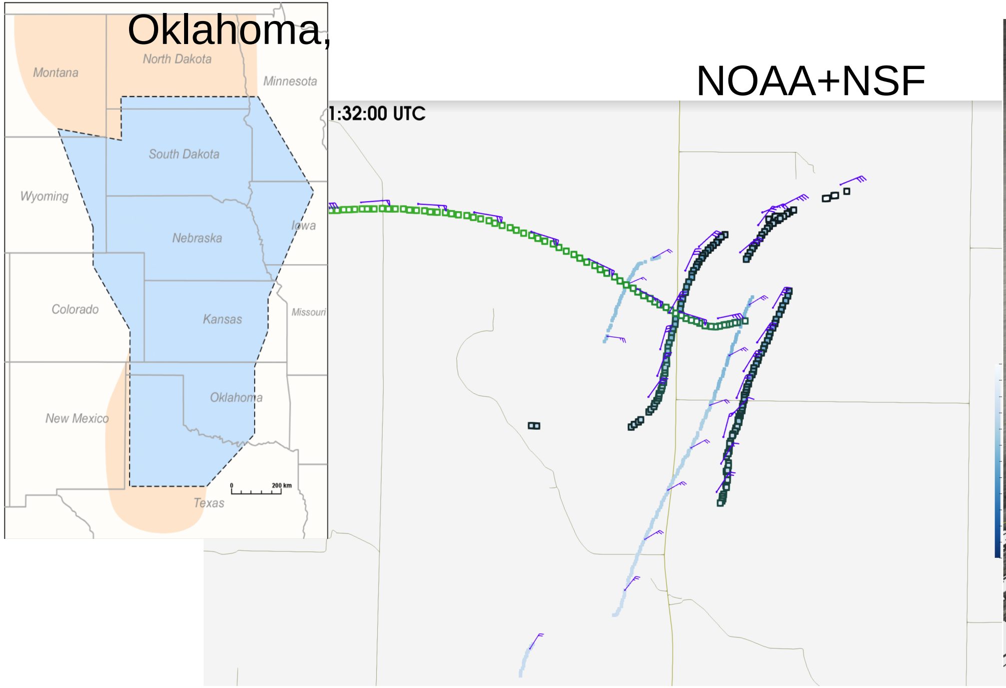
What is role of the rear-flank downdraft?
How intense must the low-level updraft be?
Can the spin-containing air “miss” the low-level updraft?

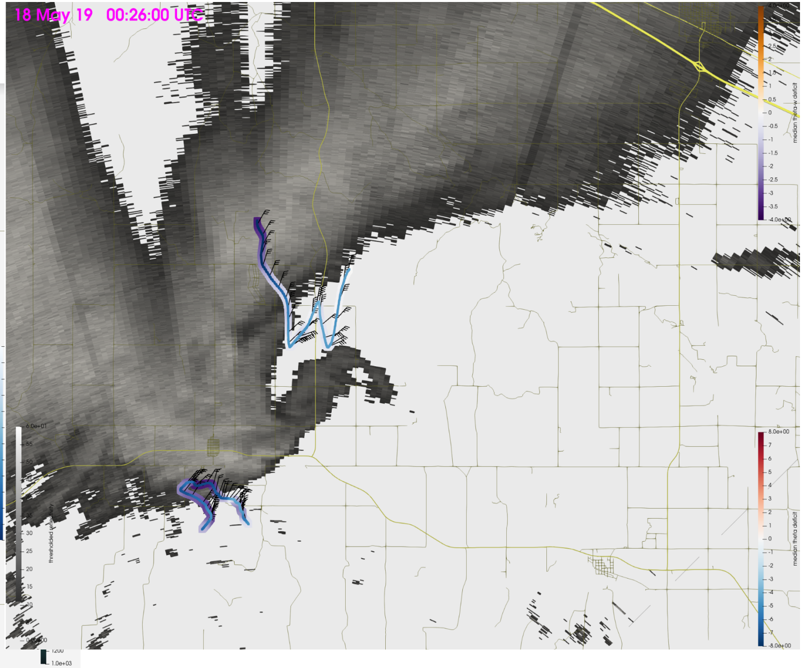
Recent accomplishments: TORUS

Target **O**bservations using **R**adar and **U**AS in **S**upercells… 2019, **2022**

Collaboration: U. Nebraska-Lincoln, Texas Tech, U. Colorado-Boulder, U. Oklahoma,

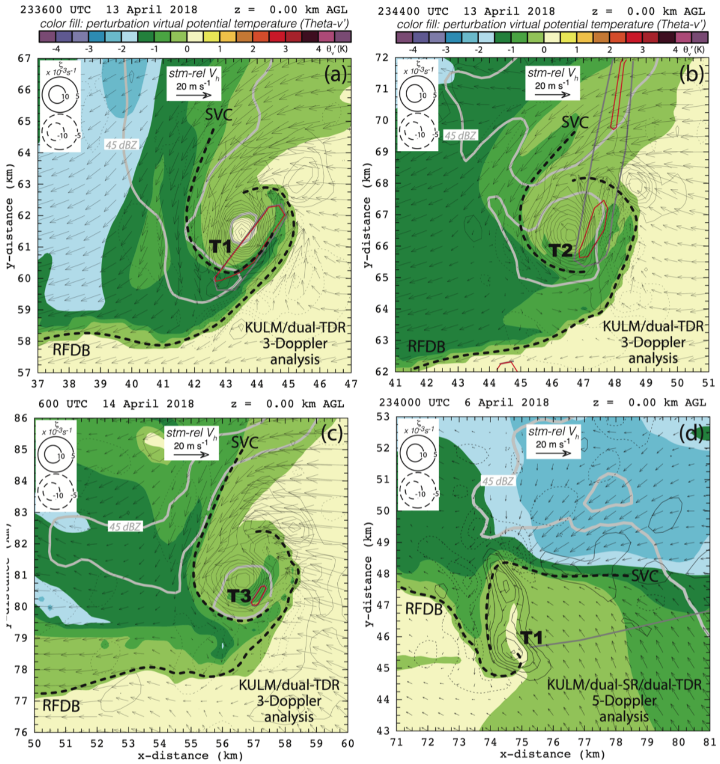
NOAA+NSF





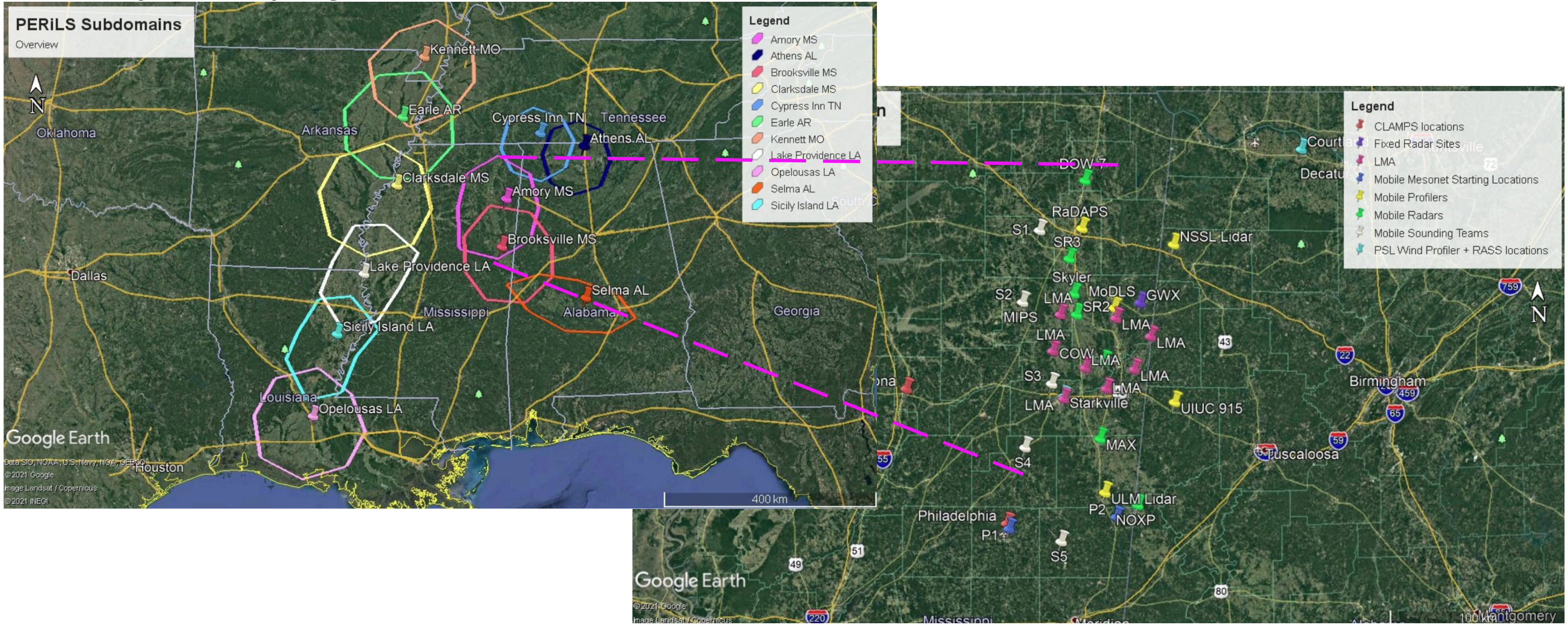
Recent accomplishments: VORTEX-SE

- Program to understand the out-sized impacts of tornadoes in the Southeast US
- Led by NSSL, involving a large number of universities and investigators
- Ongoing small field projects 2015-2019 (then COVID)
- NSSL scientist Conrad Ziegler led radar missions on NOAA hurricane hunter aircraft
- Data combined with ground-based Doppler radars



Plans: PERiLS (2022, 2023)

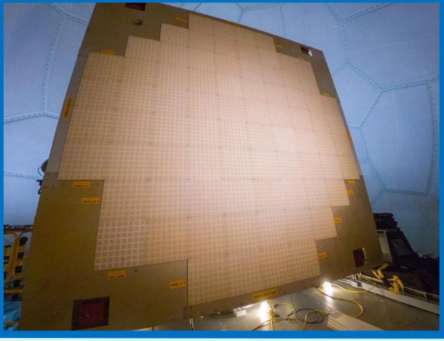
Propagation, **E**volution, and **R**otation in **L**inear **S**torms
A major field program of NOAA/VORTEX-SE and

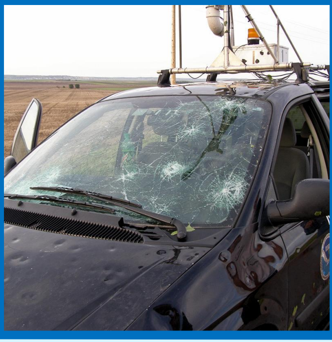


Observations and Understanding

Fieldwork and Analysis: Storm Electrification and Microphysics

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





Summarized Efforts

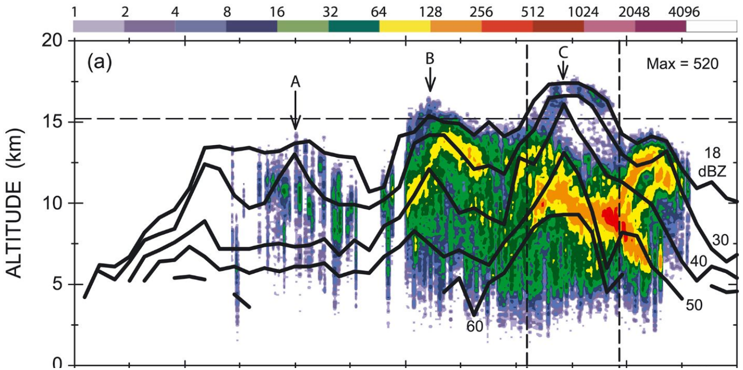
NSSL has a history of innovative electrification and microphysical field studies improving electrification understanding.

- Seminal observations of thunderstorm electrical structures
- Key analyses of lightning's relationships to storm properties

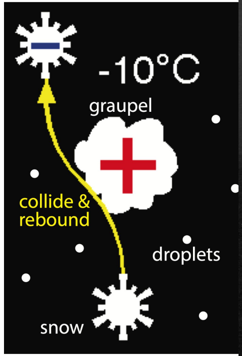
Electrification is dependent on microphysical processes. There are still many uncertainties and limited validation datasets.

Recent efforts include testing new observation platforms and analysis techniques

(MacGorman et al. 2017, Ortega and Waugh 2020)



Lightning sources (Oklahoma Lightning Mapping Array) and radar echo top height by time



Hailstone bounce off ground

Summarized Efforts

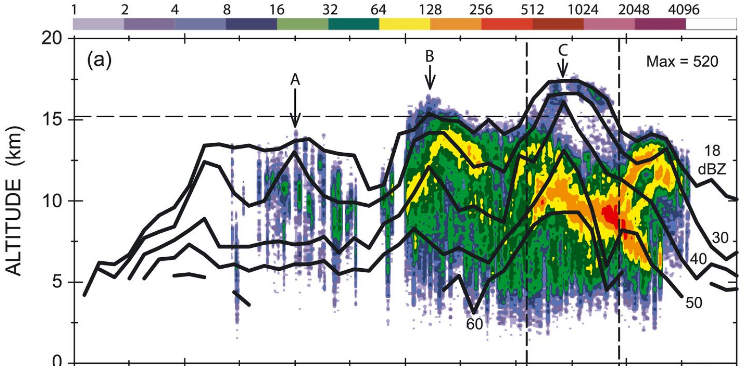
NSSL has a history of innovative electrification and microphysical field studies improving electrification understanding.

- Seminal observations of thunderstorm electrical structures - important for understanding cloud-to-ground flashes.
- Key analyses of lightning's relationships to storm properties - important for understanding the use of lightning data.

Electrification is dependent on microphysical processes, especially in hail-growth zones. There are still many uncertainties and limited validation datasets.

Recent efforts include testing new observation platforms and analysis techniques

(MacGorman et al. 2017, Ortega and Waugh 2020)



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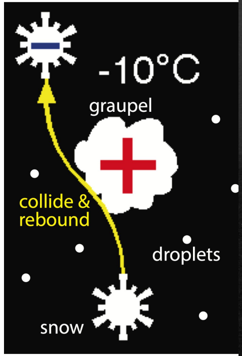


Hailstone bounce off ground

Relevance to NSSL Mission

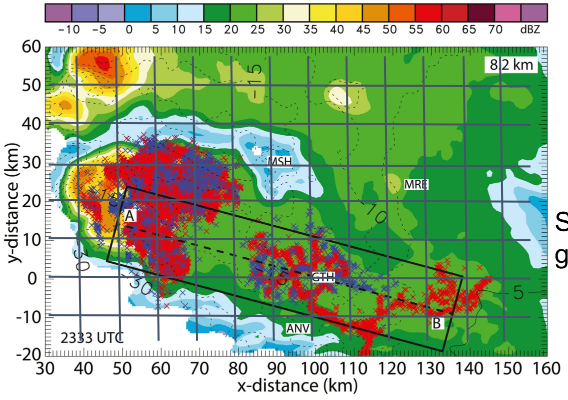
Storm electrification is part of a holistic understanding of Earth systems and weather processes.

In order to predict lightning (NSSL GSC4) we must improve the understanding of electrification.

Conversely, lightning observations portray information about storm processes which can improve forecasting and warning techniques.

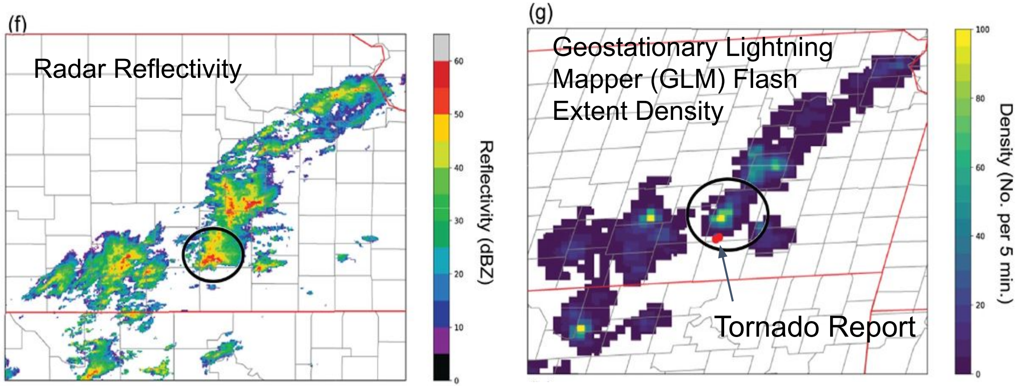
Datasets collected during field campaigns provide valuable background information for simulating storms and interpreting observations.

(DiGangi et al. 2020, Thiel et al. 2021)



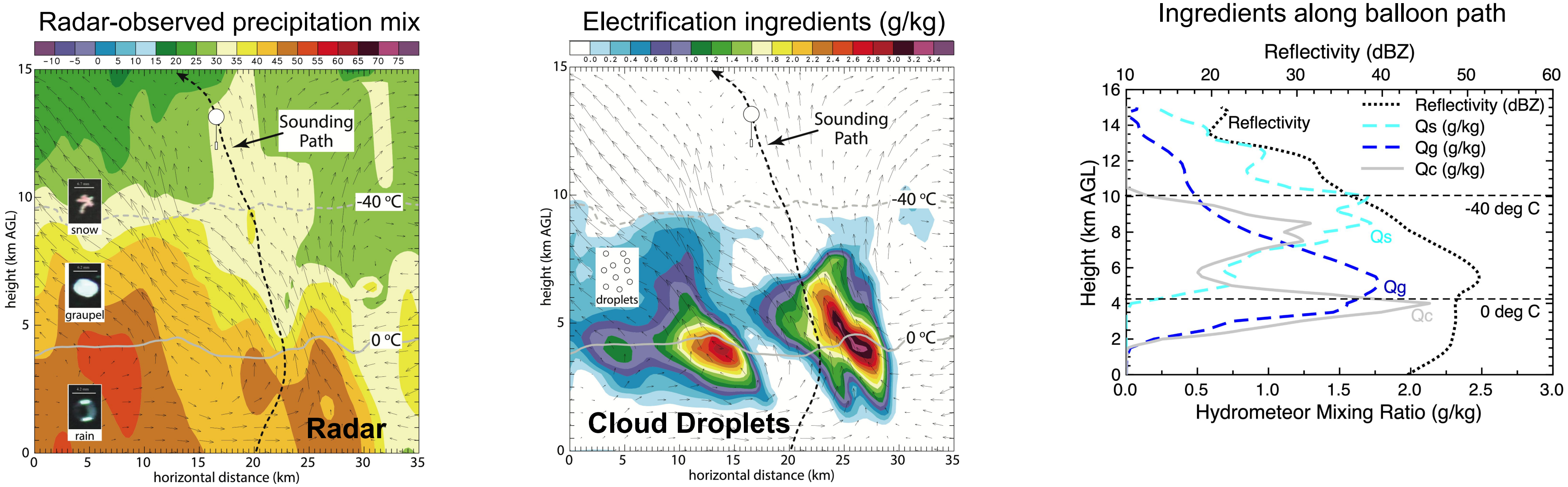
Space-based lightning grid cell coverage

Radar and Oklahoma Lightning Mapping Array (OKLMA) analysis: secondary convection responsible for initiating lightning in anvil



Radar and satellite analysis: intensity observed in tornadic storm

Study of Storm Processes



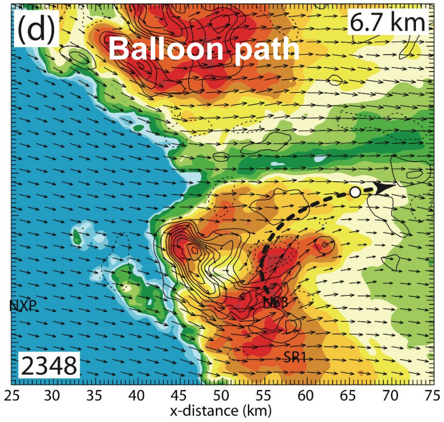
Radar-based analysis of 4D cloud properties used to retrieve fields which cannot be directly radar-observed throughout the storm volume or along a path.

→ Sub-freezing cloud liquid supports important graupel-ice electrification in the Mesoscale Convective System (MCS)

(Ziegler 2013a,b; DiGangi et al. 2016; Miller, Ziegler, Biggerstaff 2020)

In-Situ Analyses

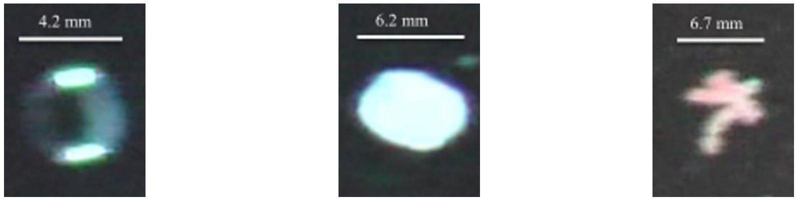
Observations of precipitation particles and electric fields from balloon-borne instruments (PASIV and EFM).

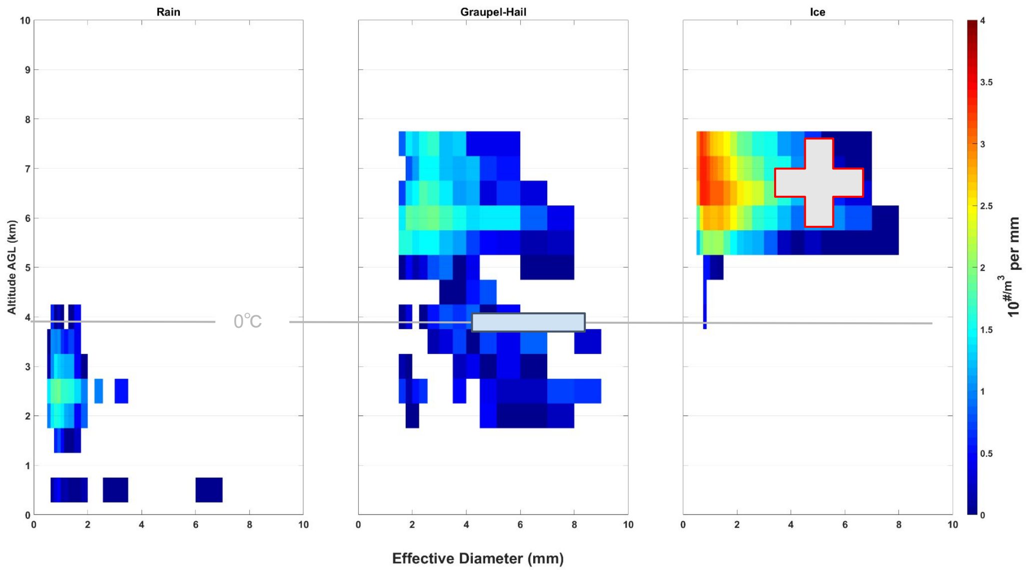


In this case negative charge corresponded with graupel, positive charge with ice.

(Waugh 2016, Waugh et al. 2018, DiGangi 2019)

PASIV-imaged precipitation particles



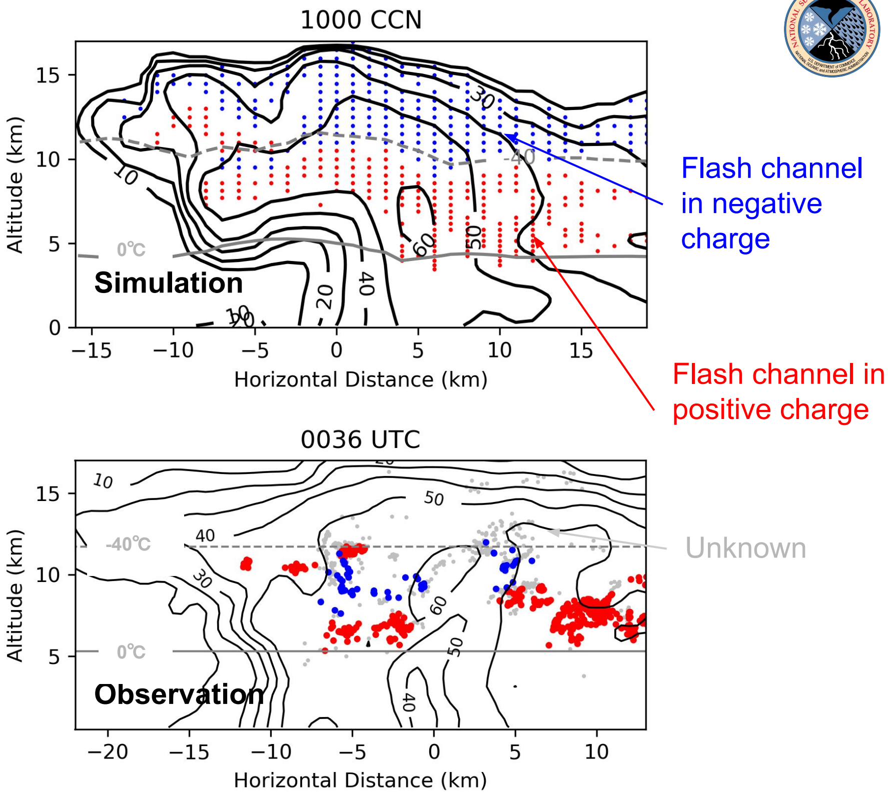


PASIV-imaged precipitation particle concentrations

Extensions from rich datasets

- Electrification is influenced by cloud condensation nuclei (CCN) that seed droplets
- Ice precipitation particle histories result in distinct lightning structures
- Storm air motions contribute to lightning production
- Production of oxidants by lightning is higher than expected
- Relationships applied to other storm modes such as hurricanes

(Fierro and Mansell 2018, Blair 2021, Chmielewski et al. 2020, Chmielewski et al. 2021, MacGorman et al. 2017, Brune et al. 2021)



Radar reflectivity, lightning channel polarity, and temperature in cross sections of a high precipitation supercell

Extension topics from rich, field project datasets

- Cloud condensation nuclei (CCN)
- Ice precipitation particle histories
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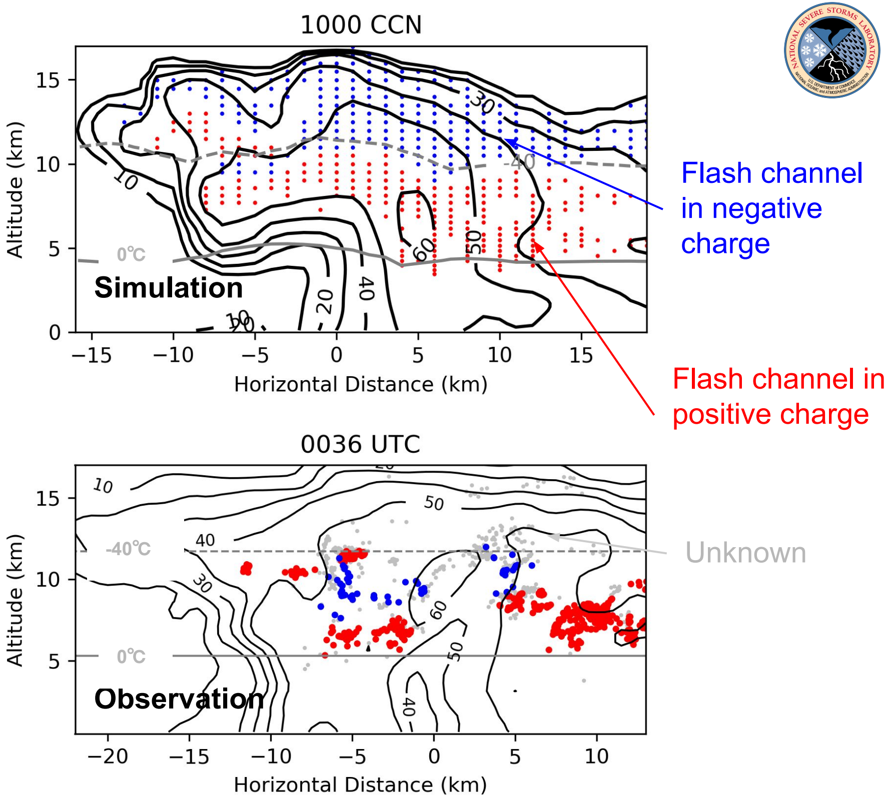
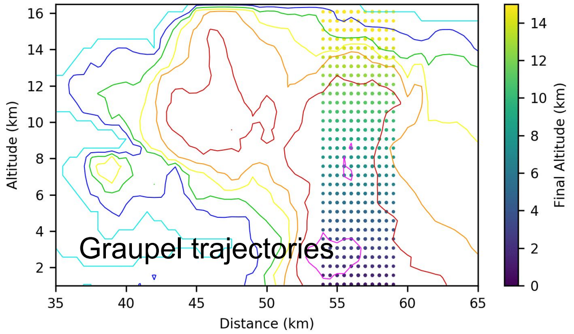
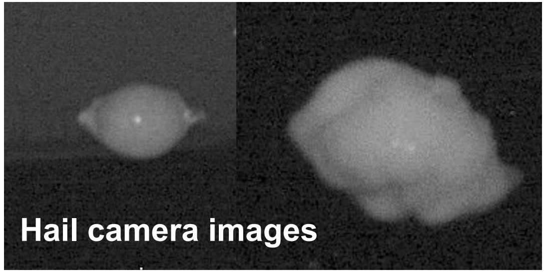


Radar reflectivity, lightning channel polarity by simulation and OKLMA analysis, and temperature in cross sections of a high precipitation supercell

Collaborators and Future Work

Ongoing studies of hail growth and fall





Upcoming field studies

TORUS

PERiLS / VORTEX-SE

- Investigate links between cloud particles, lightning, and cold pool evolution
- Optimize dataset differences for operational use

Storm processes field studies in development

- Stratiform cloud electrification (MILLS)
- Snow electrification (LEE)
- Summer Monsoon (CREST/TOPO)

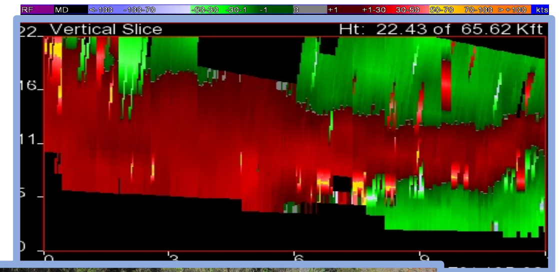
Observations and Understanding

Fieldwork and Analysis: Unique observations of rainfall and hydrologic responses

Jonathan J. Gourley PhD, NSSL Research Hydrologist, WRDD

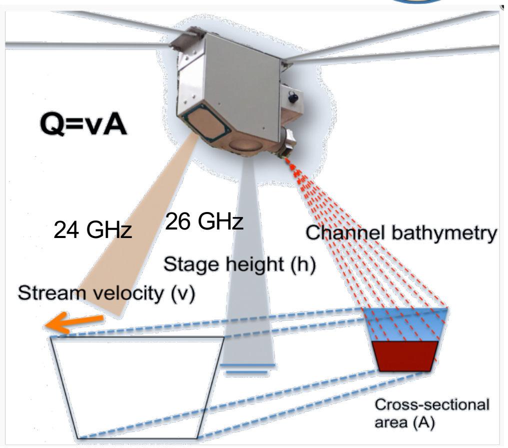
Summary

- After a wildfire has been contained, the threat of a natural hazard is not over!
- **Burn scars** are often situated in complex terrain, which challenges low-level surveillance by NEXRAD
- Quantitative observations of flash floods and debris flows are rare relative to other severe weather phenomena
- Field experiments have been conducted to collect unique observations of rainfall and hydrologic responses using **NOXP mobile weather radar** and **stream radars,** a new observing facility for NSSL



Relevance to NSSL Mission

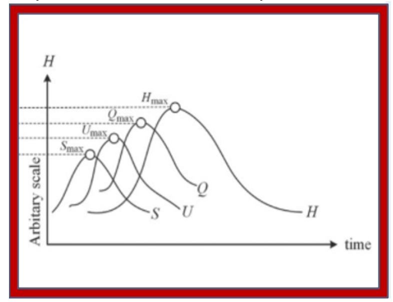
- **Mobile weather radar data** are transmitted in real time using cellular communications and images are made available to NWS forecast offices to improve situation awareness
- Fourteen K-band **stream radars** have been deployed on burn scars and above streams that have a history of posing a flash flooding threat to downstream communities
- Insights are incorporated into future versions of Flooded Locations and Simulated Hydrographs (**FLASH**) software, thus providing improved operational tools for NWS forecasters
- Effort directly contributes to **GSC 3: Reliably predict flash flooding**



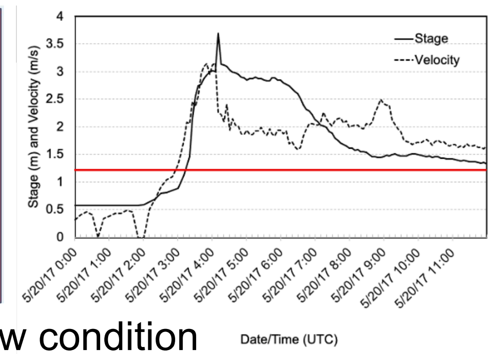
Goals and Accomplishments (I)

- Burn scars provide a unique research opportunity to collect **rainfall-runoff behavior** for extreme hydrologic events
- A rarely observed **phase sequencing** between surface velocity and stage occurred with a major flash flooding event, validating theoretical results
- Rise in surface velocity led the stage by ~30 min, providing an early indication of an impending event
- Time series of surface velocity now regarded as a valuable indicator of a major flash flooding signature

Analytic solution (Muste et al. 2020)



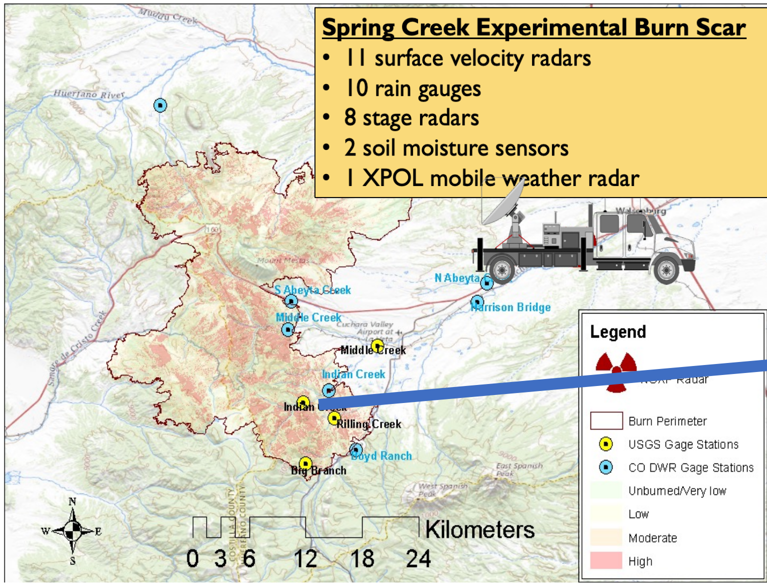
Stream Radar observation

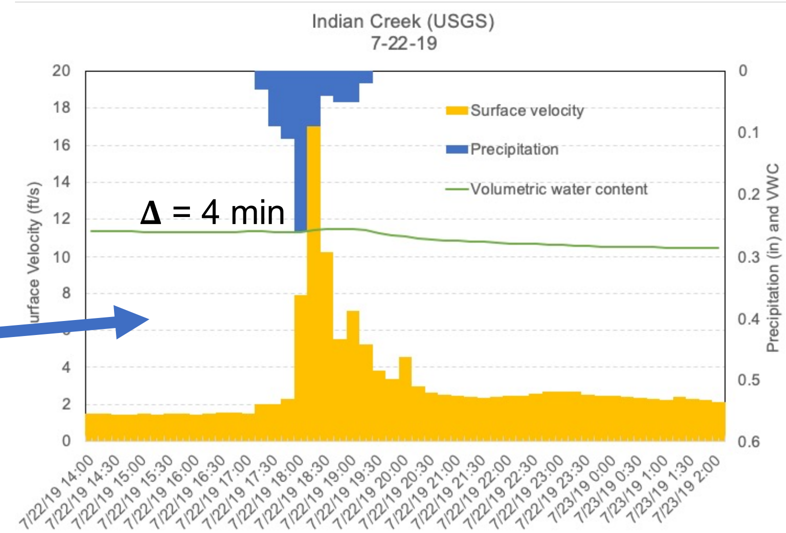


Unsteady flow condition

Flash flood reached the height of the stream radar and debris damaged the cables

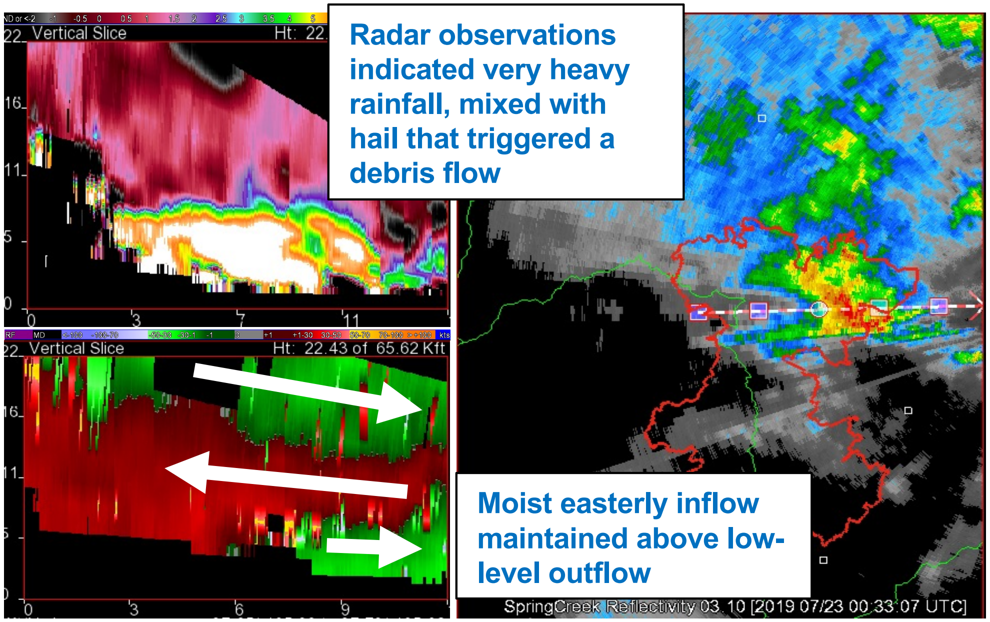
Goals and Accomplishments (II)





- In collaboration with the USGS and State of CO, deployed a **Post Wildfire Hydrometeorological Observatory** on the Spring Creek burn scar in Colorado from 2019-2021
- Most comprehensively instrumented burn scar to date
- Instruments show surface velocity response in stream closely following peak in rainfall rates

Goals and Accomplishments (III)



- NOXP radar observations near storms over burn scar reveal kinematic and microphysical signatures of storms triggering debris flows
- Mid-level inflow enhanced rainfall rates and enabled storms to persist longer by sustaining updrafts

Future Work

- Continue to work with State partners and local communities to deploy **Post Wildfire Hydrometeorological Observatory** to help forecast storm-triggered debris flows and flash floods
- Identify **rainfall-runoff signatures** using new observations of stream velocity
- Use results from field observations of rainfall-runoff behavior on burn scars to adapt model parameters in **FLASH** hydrologic modeling system
- Develop and transition products to the NWS