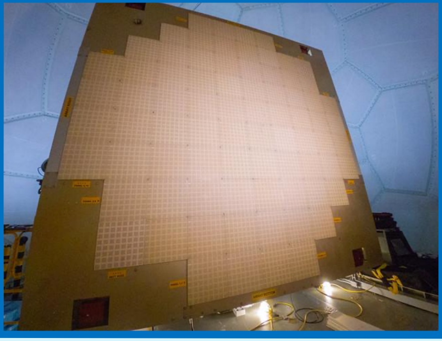
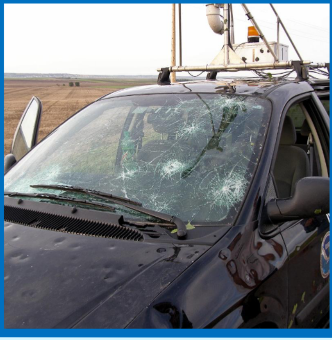
Forecast/Warning Tools and Techniques

WSR-88D Science and Engineering R&D Overview

Larry Hopper, PhD, NSSL Division Chief, RRDD

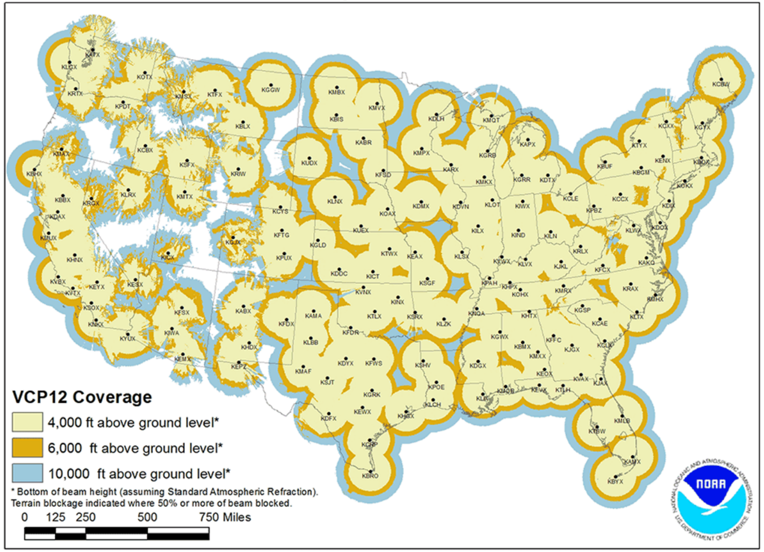


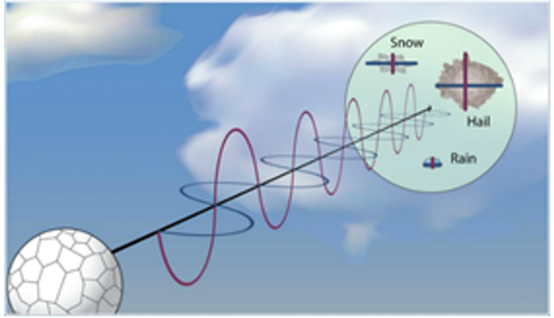
Why Do We Invest in WSR-88D R&D?

- **WSR-88D Science and Engineering R&D needed to:**
  - Improve and evolve the performance and utility of the WSR-88D network
  - Support weather enterprise through basic research, operational applications, and informing the private sector of novel technological developments
  - Provide foundation for enhancements to support tri-agency forecast and warning missions through the **Radar Product Improvement (RPI) Program**

NEXRAD Coverage Below 10,000 Feet AGL

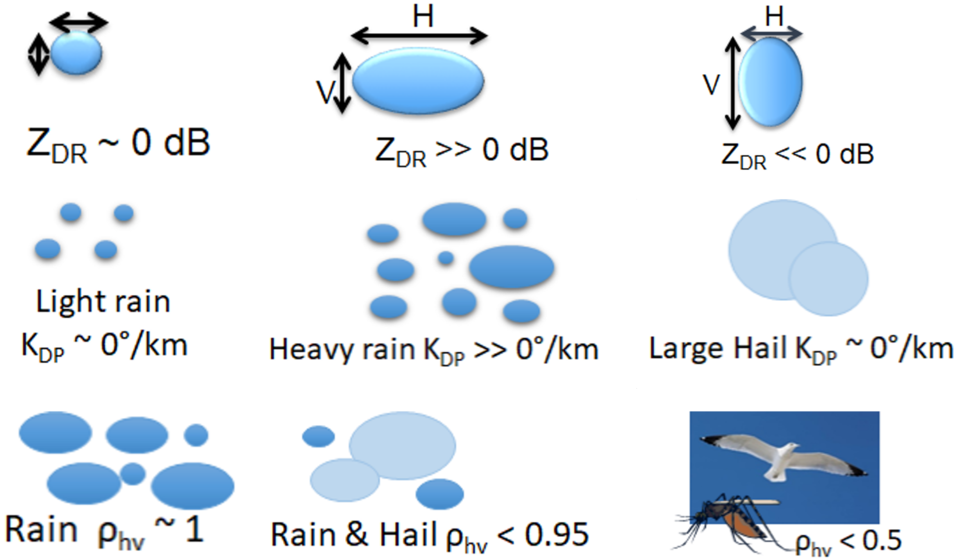


Dual Polarization: Latest Technology Transferred to NWS



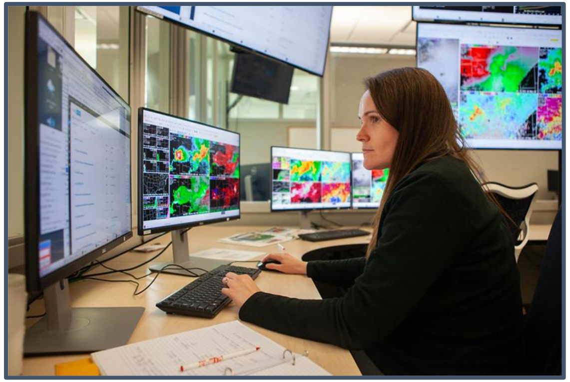
- **Differences in how horizontal and vertical fields interact with particles characterized by the polarimetric variables below:**

  - Differential Reflectivity ($Z_{DR} = Z_H - Z_v$)
  - Differential Phase (Φ_{DP}) and Specific Differential Phase (K_{DP})
  - Co-polar correlation coefficient (ρ_{hv})



WSR-88D R&D Makes Forecasts and Warnings Better!

- **Polarimetric capabilities across WSR-88D network make possible development of:**
  - New signal processing techniques to **help forecasters accurately interpret the data**
  - Radar algorithms to **increase warning lead times** for cold and warm-season weather hazards



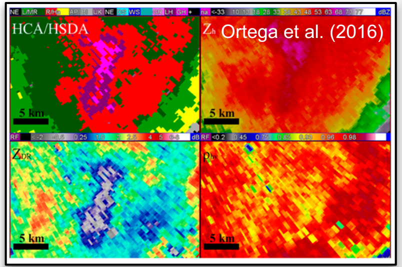
- **Work aligned with OAR Strategic Plan Goals and NOAA R&D Vision Areas:**
  - Reduces societal impacts from hazardous weather using a robust and effective research, development, and transition enterprise (Vision Areas #1 and #3)

Goal 3: Make Forecasts Better	3.1 Develop interdisciplinary Earth system models
	3.2 Design tools and processes to forecast high-impact weather, water, climate, ocean, and ecosystem events
	3.3 Transition science that meets users' current and future needs

How Do We Measure Quality and Performance?

ROC Deliverables & Products

Ex: Hail Size Descrimination (HSDA) & MetSignal Algorithms implemented in RPG Build 17.0



Technical Publications

(algorithms & upgrades for WSR-88D radars)

Applications of an Expanded ZDR Scale

Valery Melnikov[*], Richard Murnan[+], and Donald Burgess[*]

Target	Observed ZDR interval, dB
Precipitation and clouds	-4 to +15
Attenuation effects	-2 to 0
Dust storms	-2 to +12
Ground clutter	-20 to +20
Sea clutter	-15 to +15
Atmospheric biota	-12 to +17
Chaff	Less than -8 to more than +8
Wild fire smoke	-5 to +8 dB

Peer-Reviewed Publications

Quasi-Vertical Profiles—A New Way to Look at Polarimetric Radar Data

ALEXANDER RYZHKOV, PENGFEI ZHANG, AND HEATHER REEVES
Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, and NOAA/OAR/National Severe Storms Laboratory, Norman, Oklahoma

MATTHEW KUMJIAN
The Pennsylvania State University, University Park, Pennsylvania

TIMO TSCHALLENER, SILKE TRÖMEL, AND CLEMENS SIMMER
Meteorological Institute, University of Bonn, Bonn, Germany

(Manuscript received 22 January 2015, in final form 26 December 2015)

ABSTRACT

A novel methodology is introduced for processing and presenting polarimetric data collected by weather surveillance radars. It involves azimuthal averaging of radar reflectivity Z, differential reflectivity Z_{DR}, cross-correlation coefficient ρ_{hv}, and differential phase Φ_{DP} at high antenna elevation, and presenting resulting quasi-vertical profiles (QVPs) in a height-versus-time format. Multiple examples of QVPs retrieved from the data collected by S-, C-, and X-band dual-polarization radars at elevations ranging from 6.4° to 28° illustrate advantages of the QVP technique. The benefits include an ability to examine the temporal evolution of microphysical processes governing precipitation production and to compare polarimetric data obtained from the scanning surveillance weather radars with observations made by vertically looking remote sensors, such as wind profilers, lidars, radiometers, cloud radars, and radars operating on spaceborne and airborne platforms. Continuous monitoring of the melting layer and the layer of dendritic growth with high vertical resolution, and the possible opportunity to discriminate between the processes of snow aggregation and riming, constitute other potential benefits of the suggested methodology.

1. Introduction

Polarimetric radars provide unique insight into microphysical processes in clouds and precipitation. This knowledge will create opportunities for better microphysical parameterizations in numerical weather prediction (NWP) models and for assimilation of dual-polarization data into storm-scale models. Different microphysical processes (size sorting, evaporation, melting, freezing, riming, aggregation, diffusional growth, etc.) are characterized by specific "polarimetric fingerprints" (e.g., Kumjian 2012). These can be used to evaluate and eventually improve the models via converting their outputs into fields of polarimetric radar variables and adjusting parameterizations in a way that the observed polarimetric fingerprints are adequately reproduced.

The routine presentation of radar data in the plan position indicator (PPI) mode is not convenient for linking polarimetric radar signatures aloft, associated microphysical processes, and precipitation near the surface. Most convenient for the latter are scans along vertical planes in the so-called range–height indicator (RHI) mode; however, such scans typically are not available from operational systems due to time constraints. In principle, vertical cross sections of different radar variables can be obtained from a series of PPIs at different elevations (i.e., reconstructed RHIs), but their quality and vertical resolution are usually worse than that of "genuine" RHIs. On the other hand, genuine RHIs yield information only in selected azimuthal directions and thus do not represent the general structure of the storm or its evolution.

To get a better understanding of the microphysical processes that govern precipitation generation and evolution, it is beneficial to complement polarimetric

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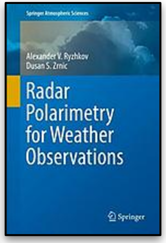
Awards

Alexander Ryzhkov and Dusan Zrnic:



2019 ASLI Choice Award: Best Sci & Tech Book

Jeff Snyder: 2019 Presidential Early Career Award for Scientists and Engineers (PECASE)

THE WHITE HOUSE

NSF

Stakeholder Engagement

Numerous interactions with domestic and international partners

Who Do We Collaborate with to Increase Performance?

- **NSSL recognized as a domestic and international leader in radar engineering and science, with numerous collaborations resulting in:**
  - Basic science advancements and associated resources supporting radar algorithm development and improvement
  - Additional support through external funding and participation in field projects

KMA Korea Meteorological Administration

Met Office

UNI BONN

Environment Canada

Kyungpook National University 경북대학교

Australian Government Bureau of Meteorology

Lunds Universitet

University of Colorado Boulder

Stony Brook University

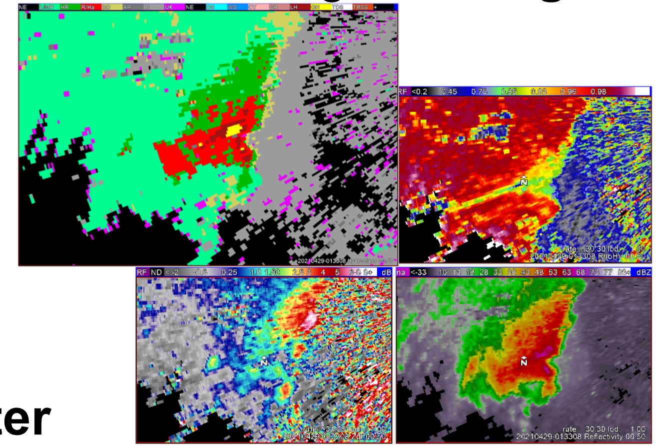
Pacific Northwest NATIONAL LABORATORY

MIT Lincoln Laboratory

האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM

How Do We Impact Stakeholder Goals & Performance?

- By developing **evolutionary signal processing techniques** and **new diagnostic capabilities** for the WSR-88D network, focusing on **using dual-polarization data** for improving:
    - Hydrometeor classification
    - Quantitative precipitation estimates (QPE)
    - Severe weather nowcasting
    - NWP models



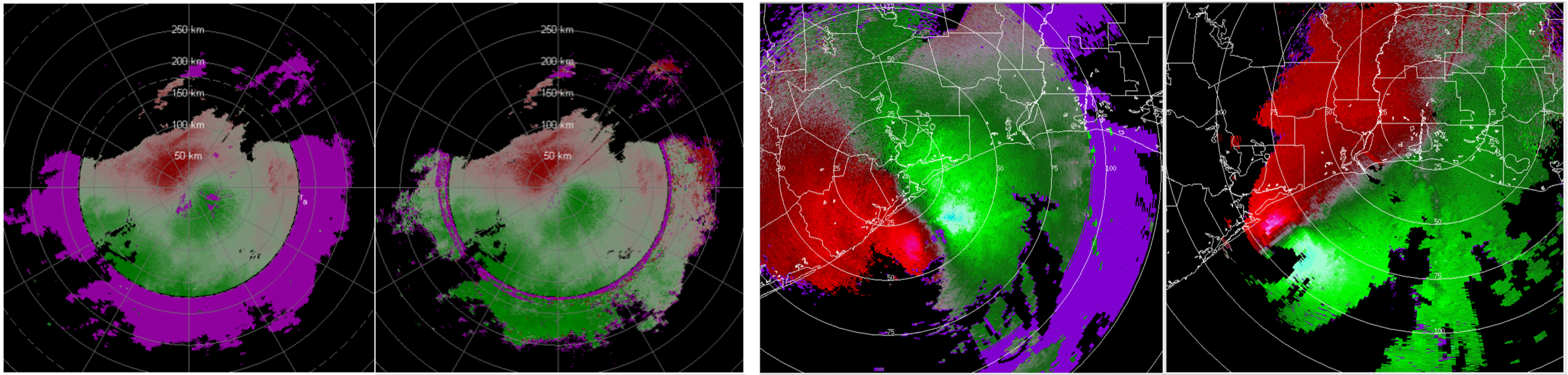
- **Collaborating with Radar Operations Center (ROC)** to ensure NWS forecasters have knowledge, capabilities, and technologies to communicate accurate, timely, and actionable forecasts

Weather-Ready Nation

Evolutionary Signal Processing Techniques

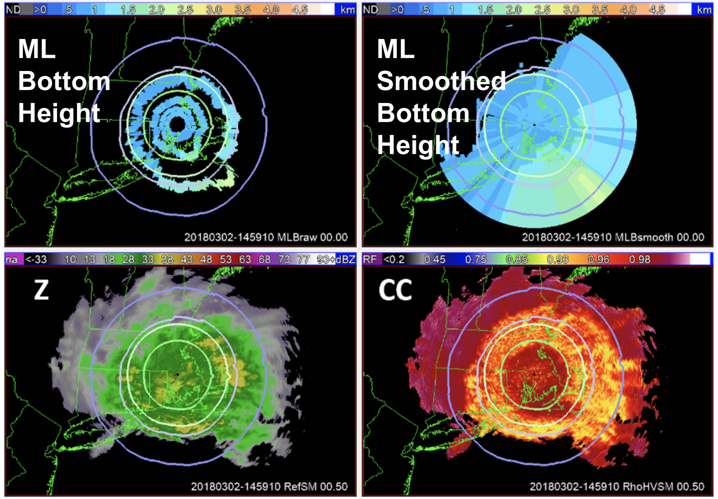
- Operational phase coding (SZ-2) algorithm helps **mitigate range-and-velocity ambiguity**

Before Phase Coding | After Phase Coding | Before Phase Coding | After Phase Coding

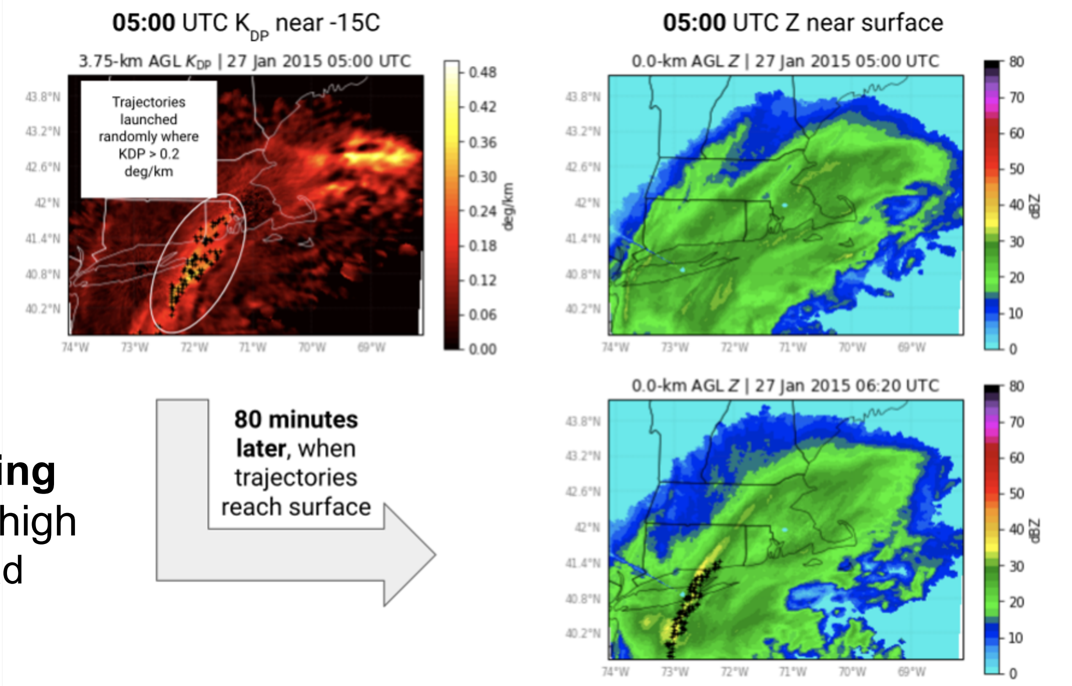


- Currently transferring WET/CLEAN-AP algorithm to WSR-88D to **enhance ground clutter mitigation** while minimizing its filtering of “pure” weather data
- Future: Transferring range oversampling to **improve radar-variable estimation**

Hydrometeor Classification and Winter Weather



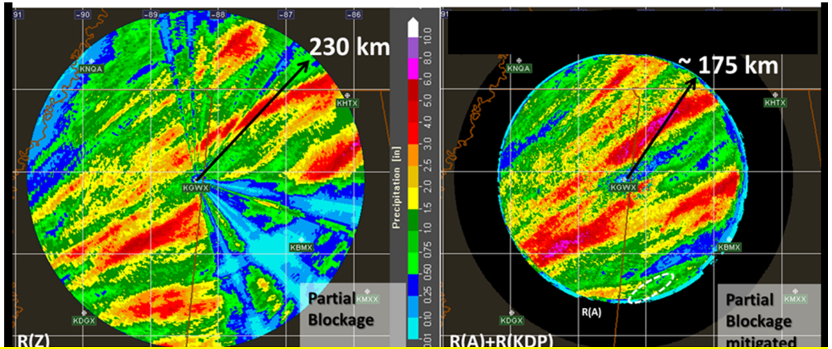
- **Tested new melting layer detection algorithm** with spatially variable melting layer top and bottom



- **Developing heavy snow nowcasting techniques** based on polarimetric (high K_{DP}) signatures aloft with over 1 hr lead time due to slow fall speed of snow

Quantitative Precipitation Estimation (QPE)

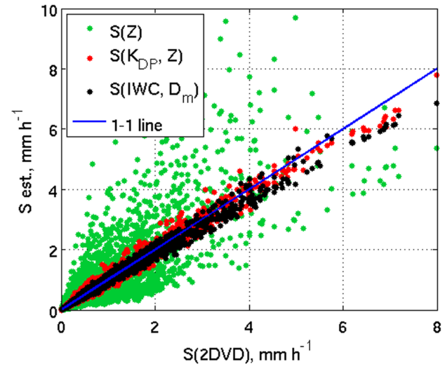
- **Operational MRMS QPE algorithm based on specific attenuation (A) and K_{DP}**
  - Less sensitive to DSD variability, attenuation, miscalibration, **partial beam blockage**, etc.



The impact of the partial beam blockage caused by nearby trees is completely eliminated in the rainfall map retrieved from A

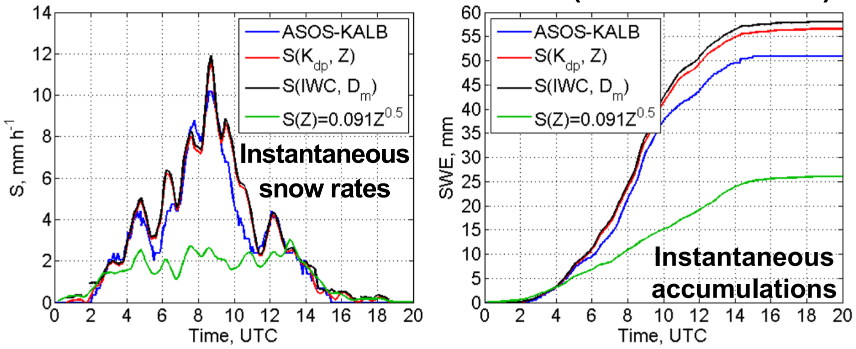
- **Polarimetric methods demonstrated for snow QPE** for the first time

Simulations based on the disdrometer snow data



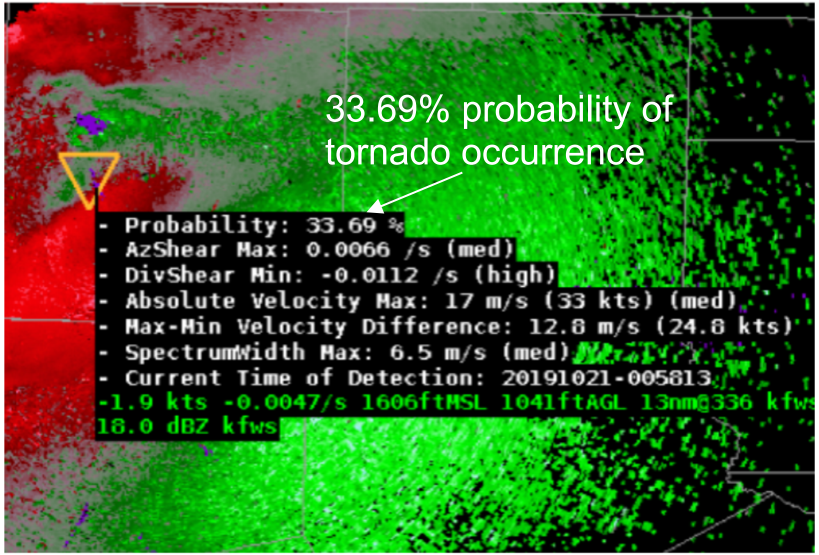
The polarimetric estimates of snow rate are much less sensitive to the variability of snow size distribution than the conventional S(Z) estimates

Nor'easter "Gail" on 17 Dec 2020 (KENX WSR-88D)



Severe Weather Research

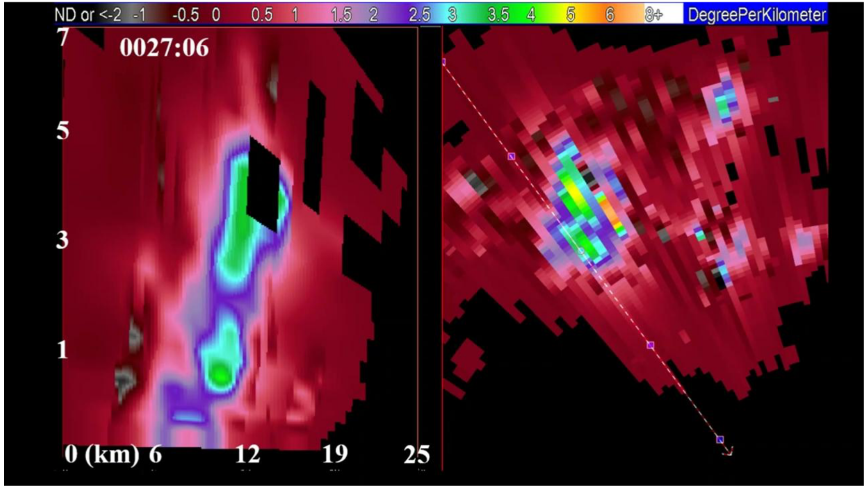
New (Probabilistic) Tornado Detection Algorithm



- Areas of high concentration of melting hail and rain ("K_{DP} cores") **identified as prime regions for downburst development**

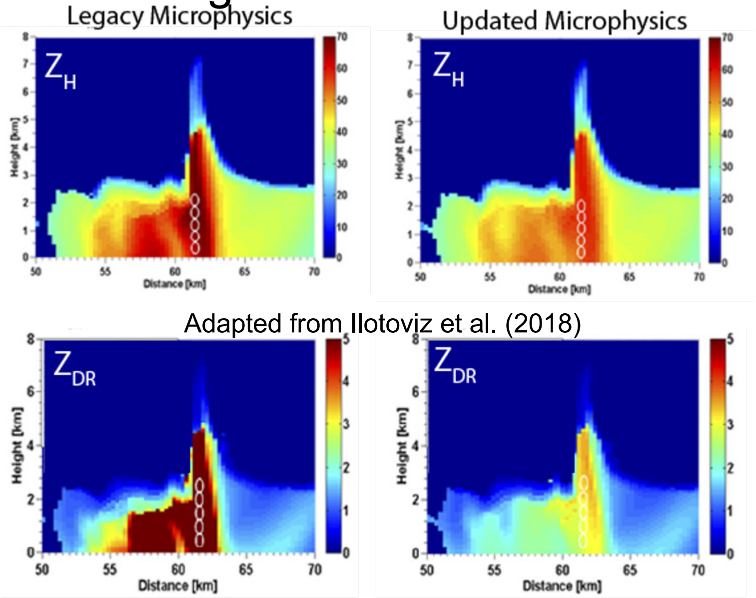
- **Hail Size Discrimintation Algorithm (HSDA) made operational** in 2016-2017

- Leveraging dual-polarization radar and advanced shear detection (e.g., LLSD) to provide **probabilities of tornado occurrence**



Research Priorities through 2025

- Supporting ROC implementation, validation, and testing of evolutionary signal processing techniques and meteorological algorithms
- Fusing additional observational platforms with existing WSR-88D network
- Validating and refining polarimetric snow QPE algorithms
- **Continued synergy of polarimetric radar data and NWP for model validation and nowcasting**
  - Porting over advanced polarimetric radar forward operator (PRFO) to high-resolution models for community use



Adapted from Ilotoviz et al. (2018)


Larry Hopper


Dusan Zrnic


Terry Schuur


Chris Curtis


Jacob Carlin


Alexander Ryzhkov


Jeff Snyder


Sebastian Torres

Questions for the WSR-88D panel?