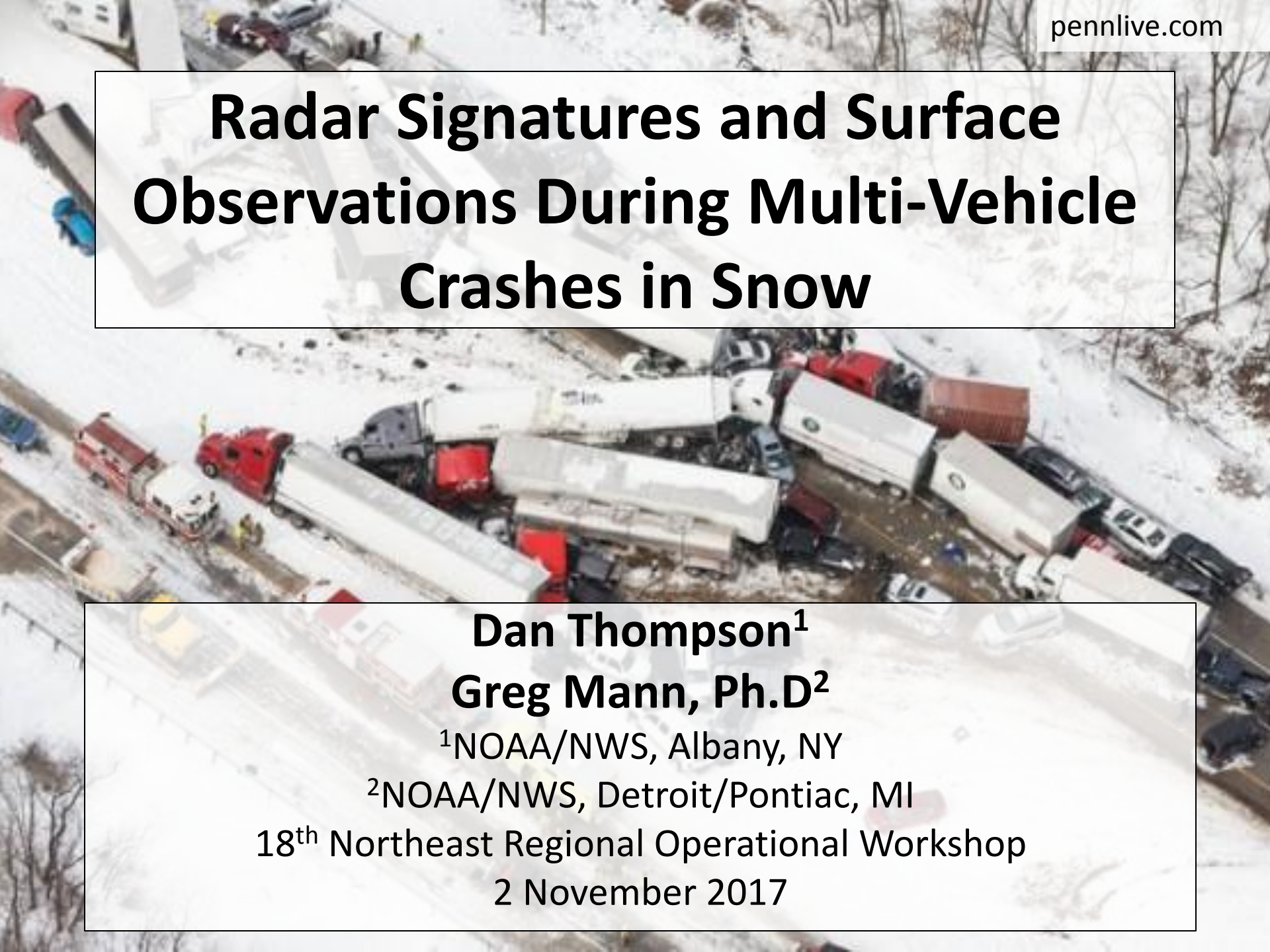


Radar Signatures and Surface Observations During Multi-Vehicle Crashes in Snow

Dan Thompson[1]
Greg Mann, Ph.D[2]
[1]NOAA/NWS, Albany, NY
[2]NOAA/NWS, Detroit/Pontiac, MI
18th Northeast Regional Operational Workshop
2 November 2017

Multi-Vehicle Crashes

Southbound US-23 reopens after massive pileup: 'It was like someone threw a pillow case over your head'

MLive

One dead, 23 hurt in fiery 193-vehicle I-94 pileup

WZZM Grand Rapids

Massive Canadian Pile-Up Crash Sends 100 People To The Hospital (Updated)

Jalopnik

At least 10 injured in 30-plus car pileup on Indiana interstate

Fox News

3 DEAD, AT LEAST 20 INJURED IN MULTI-VEHICLE CRASH ON I-94 NEAR MICHIGAN CITY

ABC7 Chicago

Highway 400 reopened after massive 96-car pileup near Barrie caused by snow squall shut it down for most of day

National Post

Multi-Vehicle Crashes: Causes

$= f$

Traffic Flow, Road Conditions, Driver Awareness/Skill

- *Density* — *Speed*
  - *Time of day*
  - *Speed limit*
  - *Location*
- *Road Design*
- *Road Treatment*

Weather

- ***(Δ) Visibility***
- ***(Δ) Precipitation***
  - ***Type***
  - ***Intensity***
- ***(Δ) Temperature***

Multi-Vehicle Crashes: Causes

= *f*

Direct impact on factors leading to pileups via information flow to partners/public

Traffic Flow, Road Conditions, Driver Awareness/Skill

Density — *Speed*

Time of day

Speed limit

Location

Road Design

Road Treatment

Weather

(Δ) Visibility

(Δ) Precipitation

Type

Intensity

(Δ) Temperature

Objectives

- Compile database of pileups

- Investigate common radar signatures and surface observations present during pileups
  - ➢ Convective vs. stratiform
  - ➢ Identify key factors to enhance forecaster situational awareness and provide guidance for short-fused products

- Better understanding of societal and meteorological factors behind pileups can help us provide critical info to our partners and the public

Data and Methods

1) Establish criteria for pileups
   - At least 15 vehicles involved
   - Occurring in east of the Rockies in US or Canada during snowfall

2) Compile list of pileups
   - Use simple internet search: keywords “car pileup snow”
   - Document location, time, # cars involved, injuries & fatalities, NWS product in effect

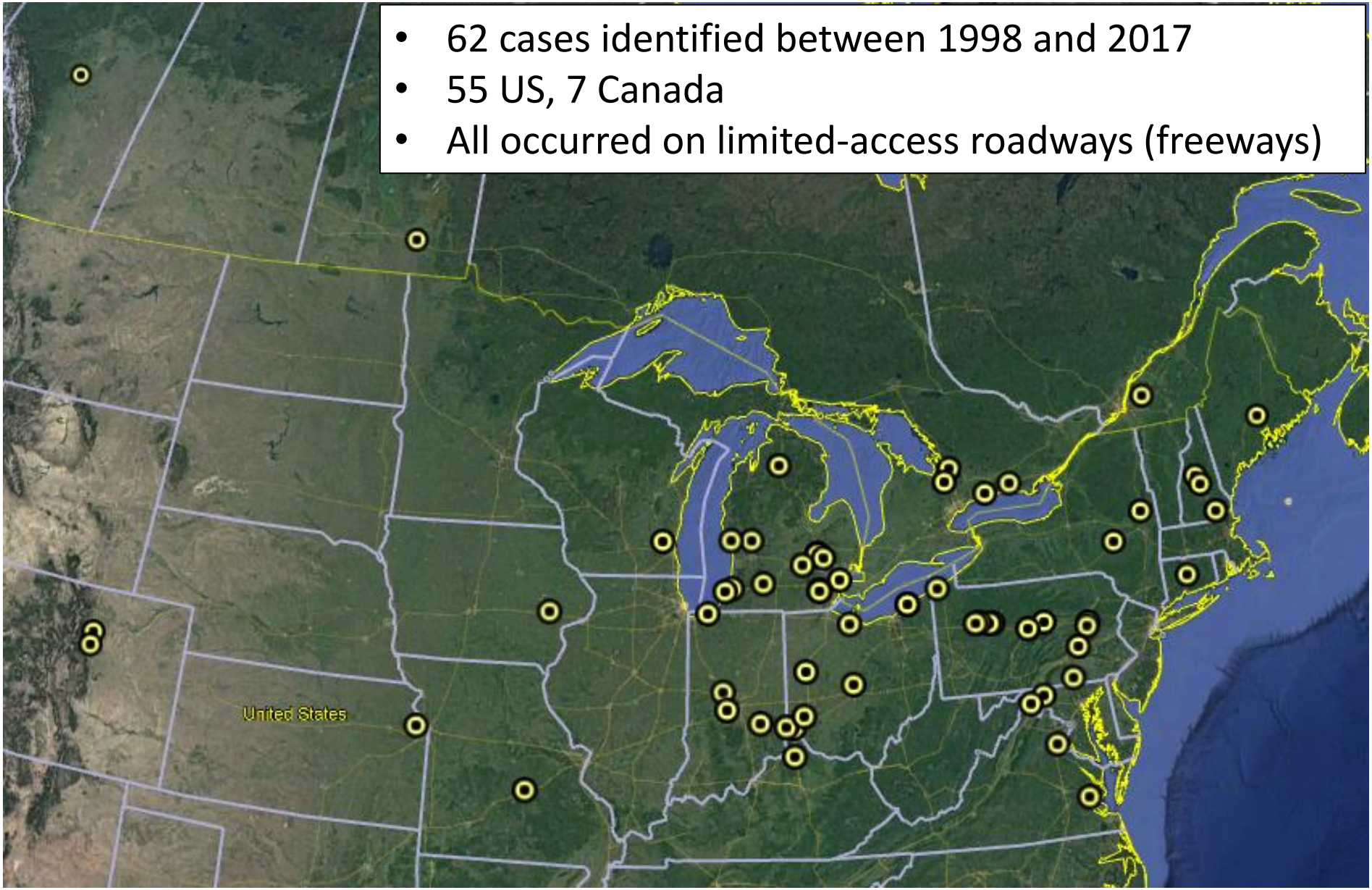
Data and Methods

3) Investigate radar signatures leading up to pileup
   - Classify – “convective,” “stratiform,” “hybrid”
   - Document 0.5° max dBZ and height AGL (GR2Analyst)
     - ➢ Within 2 miles and 1 hour of crash

4) Examine surface observations from representative ASOS/AWOS near pileup
   - Examine Δ(visibility), Δ(temperature), wind speed
     - ➢ 1 hour before to 1 hour after crash

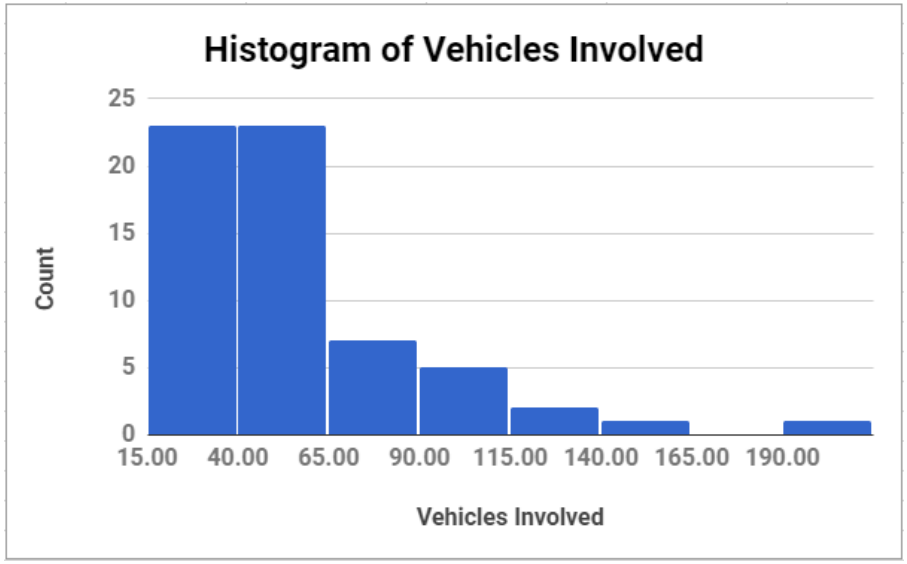
Results: Pileup Statistics

Pileups – Location



- 62 cases identified between 1998 and 2017
- 55 US, 7 Canada
- All occurred on limited-access roadways (freeways)

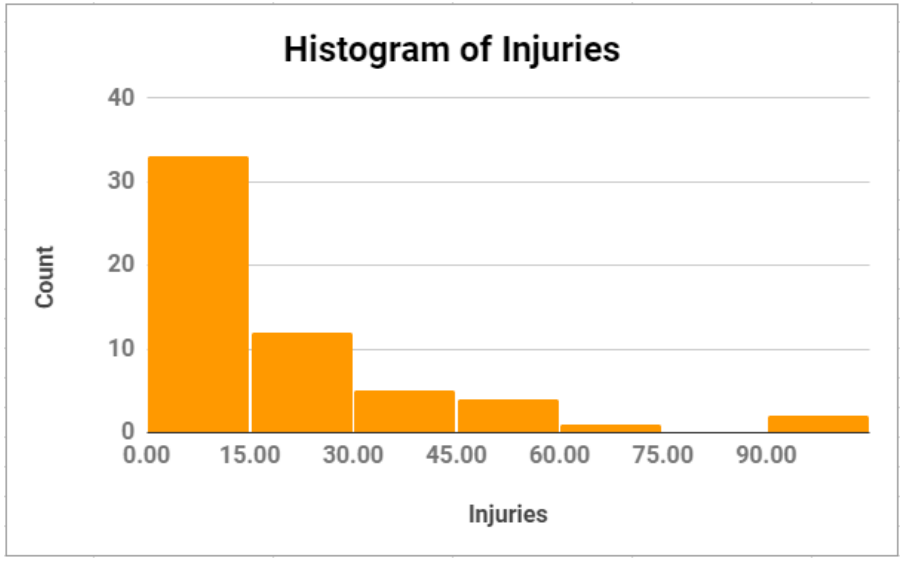
Pileups – Statistics



- Max: **193** @ *Galesburg, MI, 9 Jan 2015*
- Median: **42**
- Mean: **53**

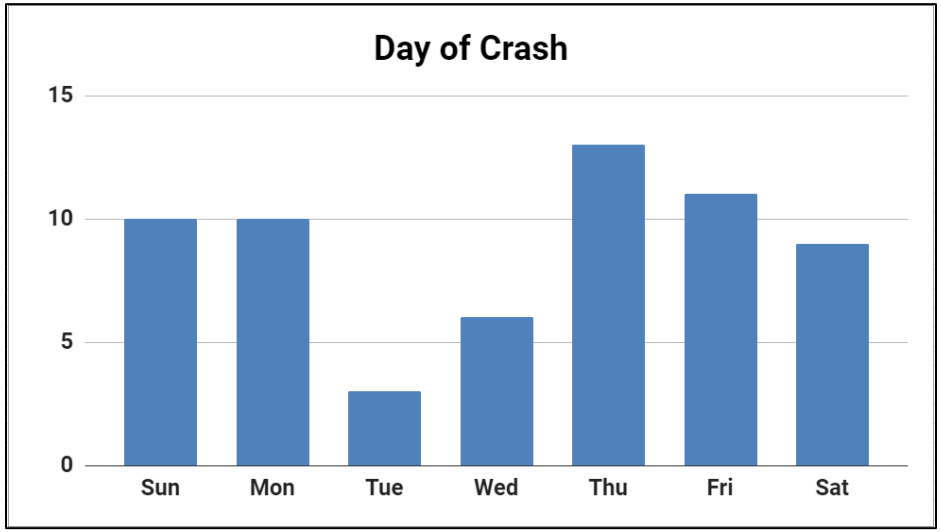
Fatalities

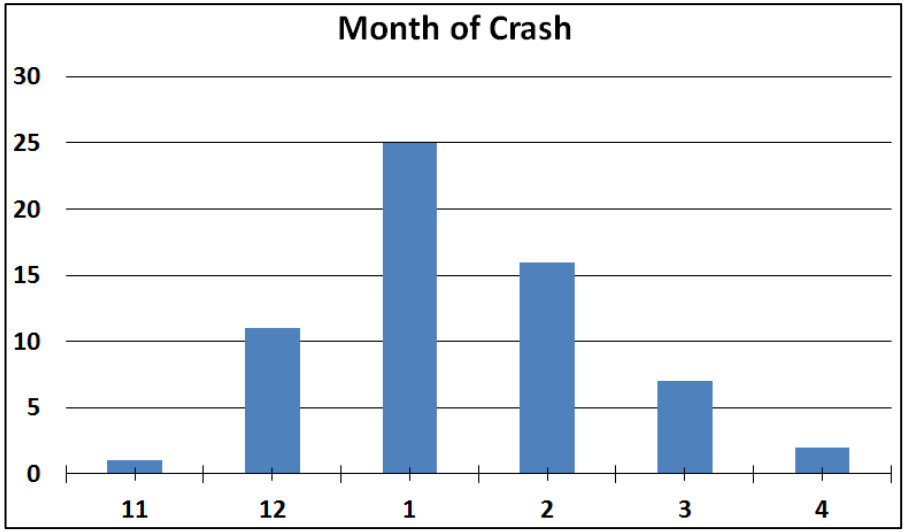
- Fatal Pileups: **25**
- Total Fatalities: **48**
- Max: **6** @ *Loganton, PA, 28 Dec 2001 & Bellefonte, PA 6 Jan 2004*

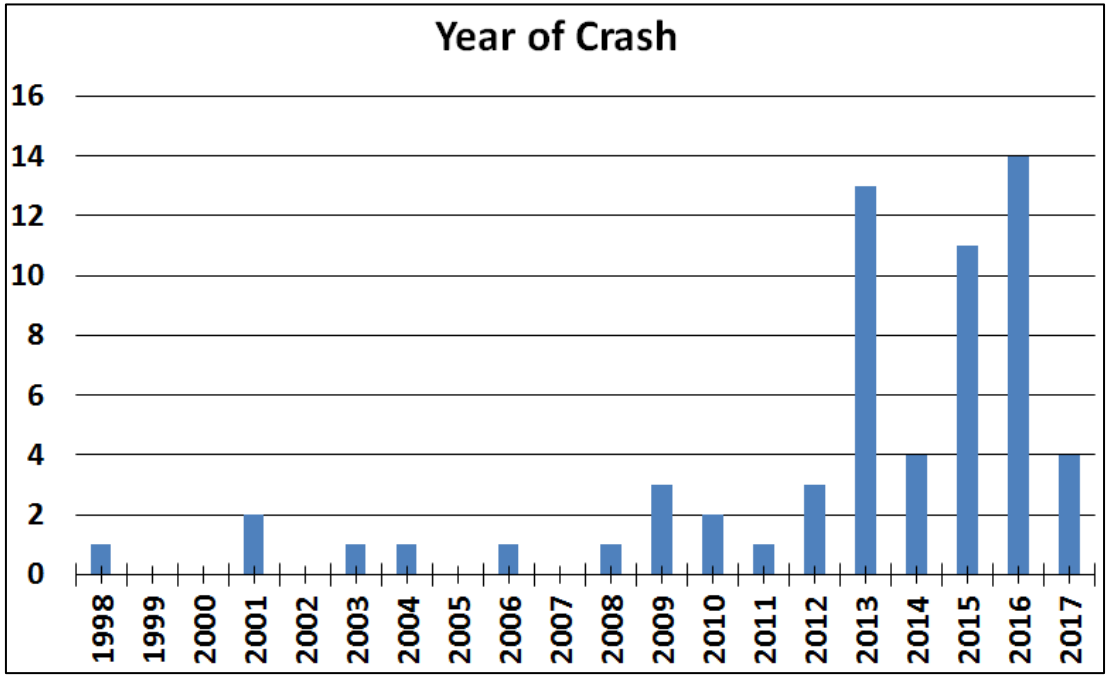


- Max: **100** @ *Wetaskiwin, AB, 21 Mar 2013 & Derry, NH, 11 Jan 2009*
- Median: **12**
- Mean: **19**

Pileups – Statistics (n=62)

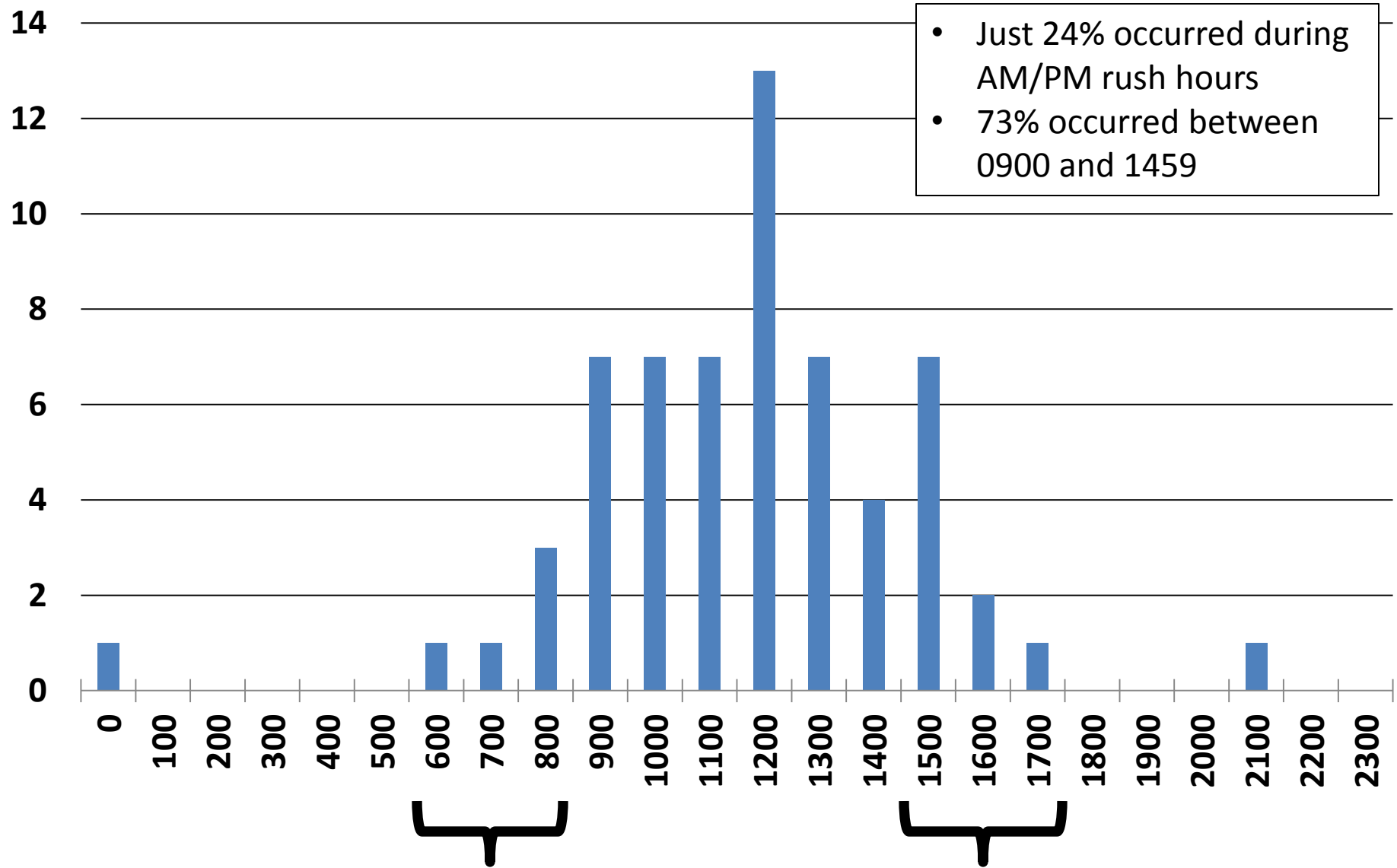






Pileups – Statistics (n=62)

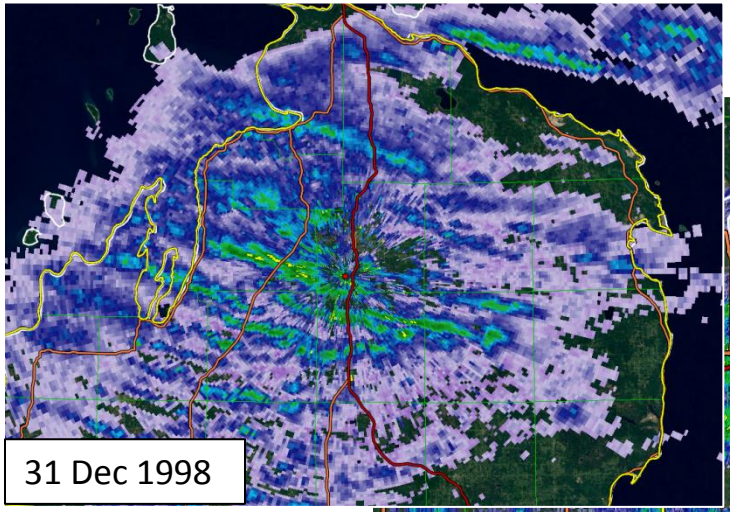
Hour of Crash (Local Time)

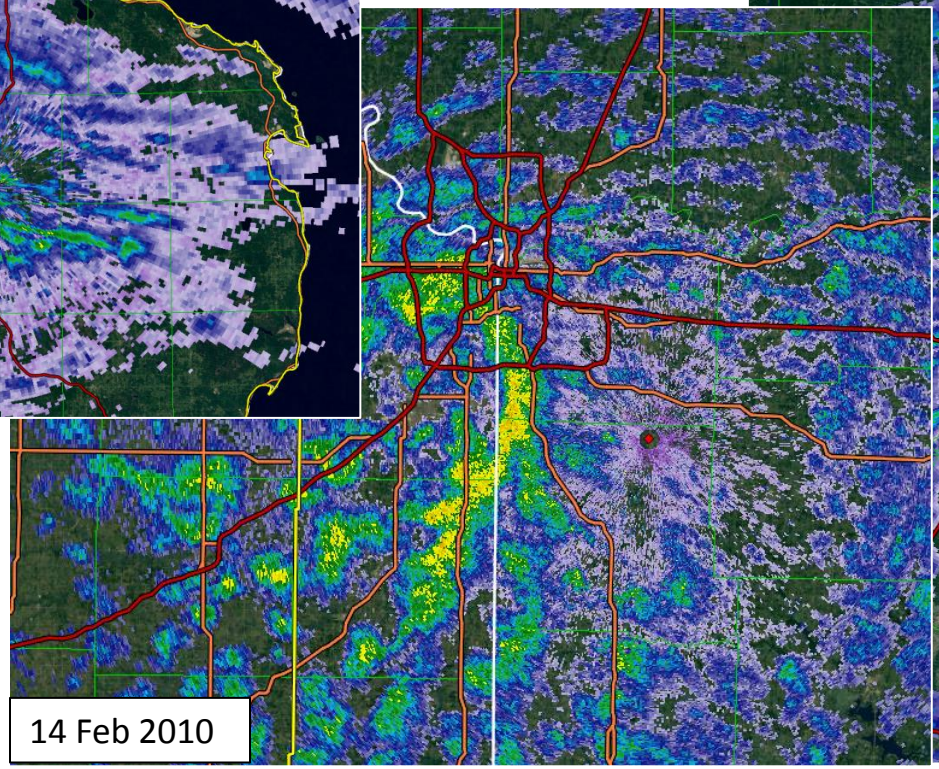


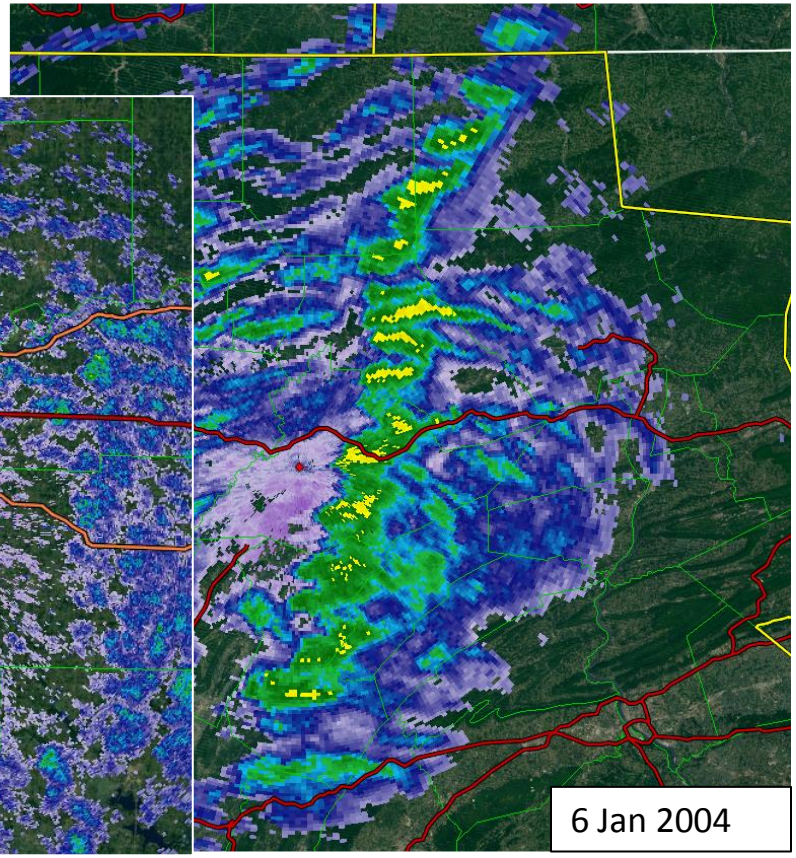
Precipitation Classification

Precipitation Classification

- Events were manually classified into three categories:
  1) **Convective-dominant**
     - ➢ Convection rooted in the boundary layer
     - ➢ Large Z gradients with banded or cellular features
     - ➢ Includes lake-effect snow and frontal squalls

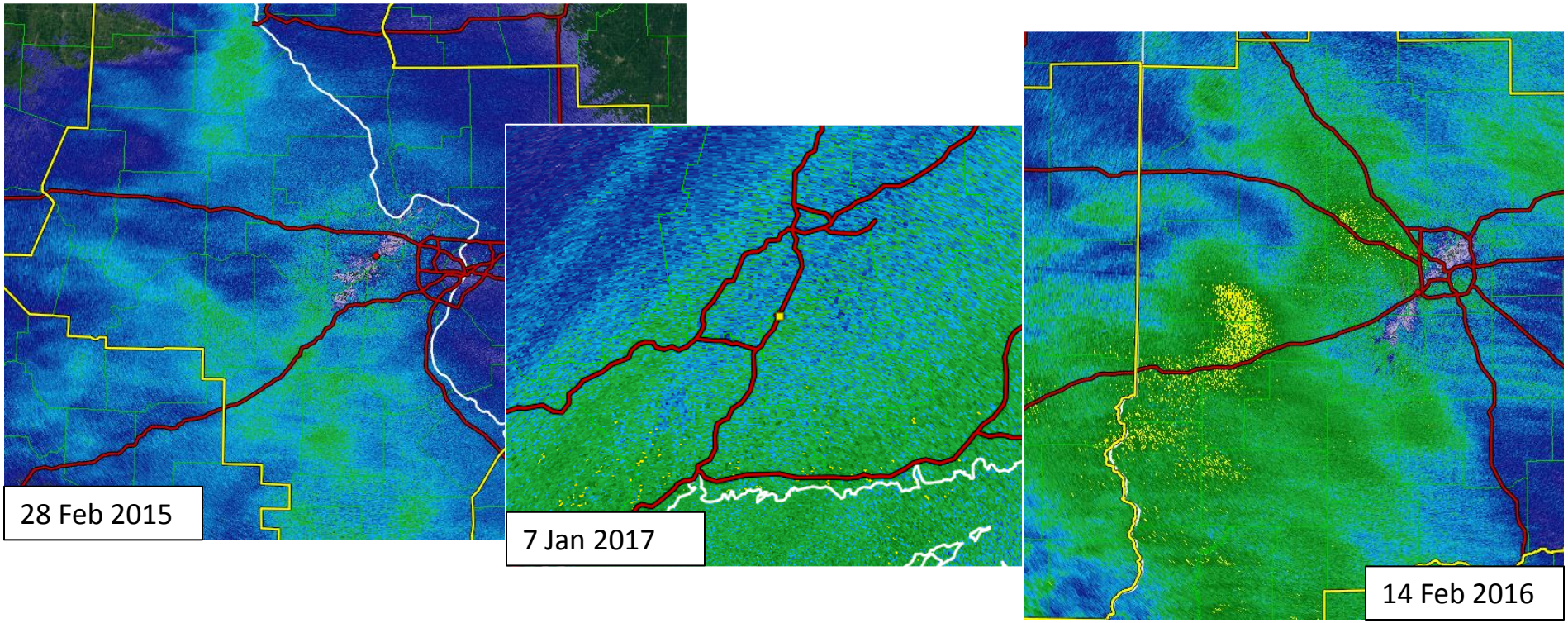






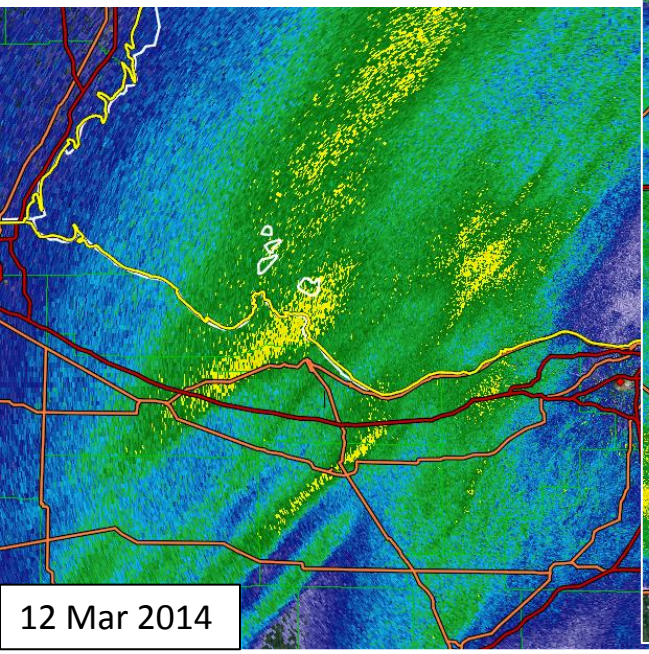
Precipitation Classification

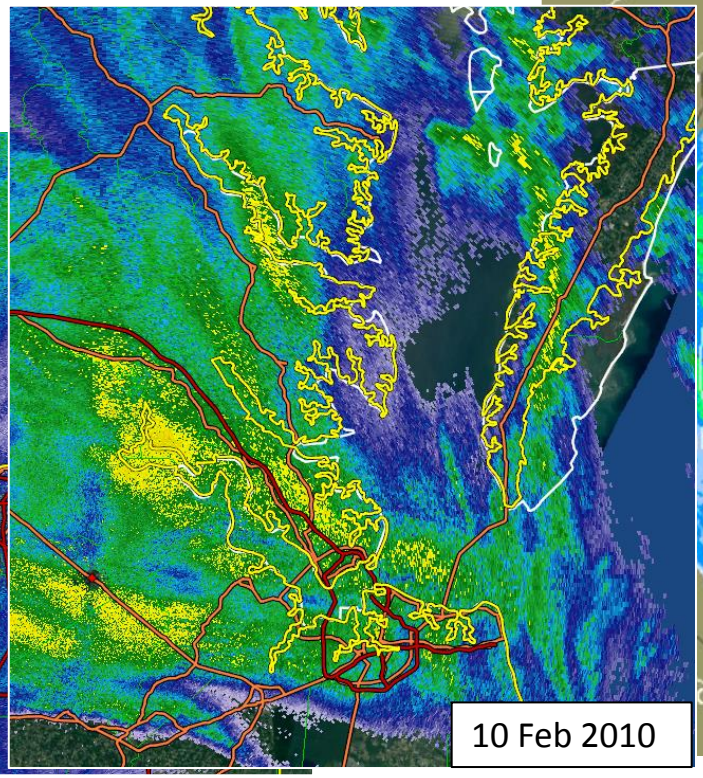
- Events were manually classified into three categories:
  2) **Stratiform-dominant**
     - Relatively uniform echoes/small Z gradients
     - No clearly-defined banded or cellular features
     - Includes mid-latitude cyclones and other synoptic-scale systems

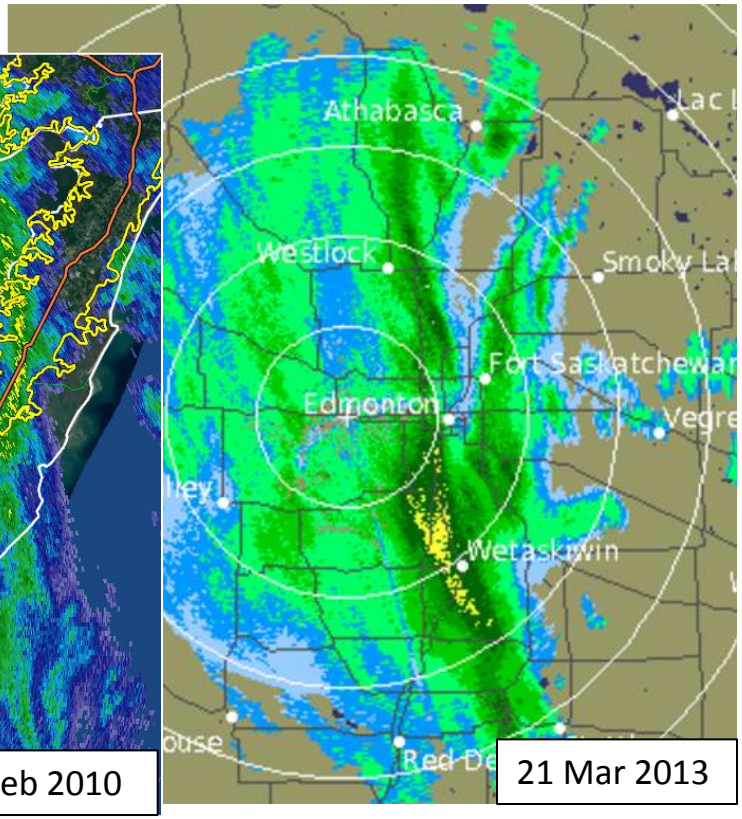


Precipitation Classification

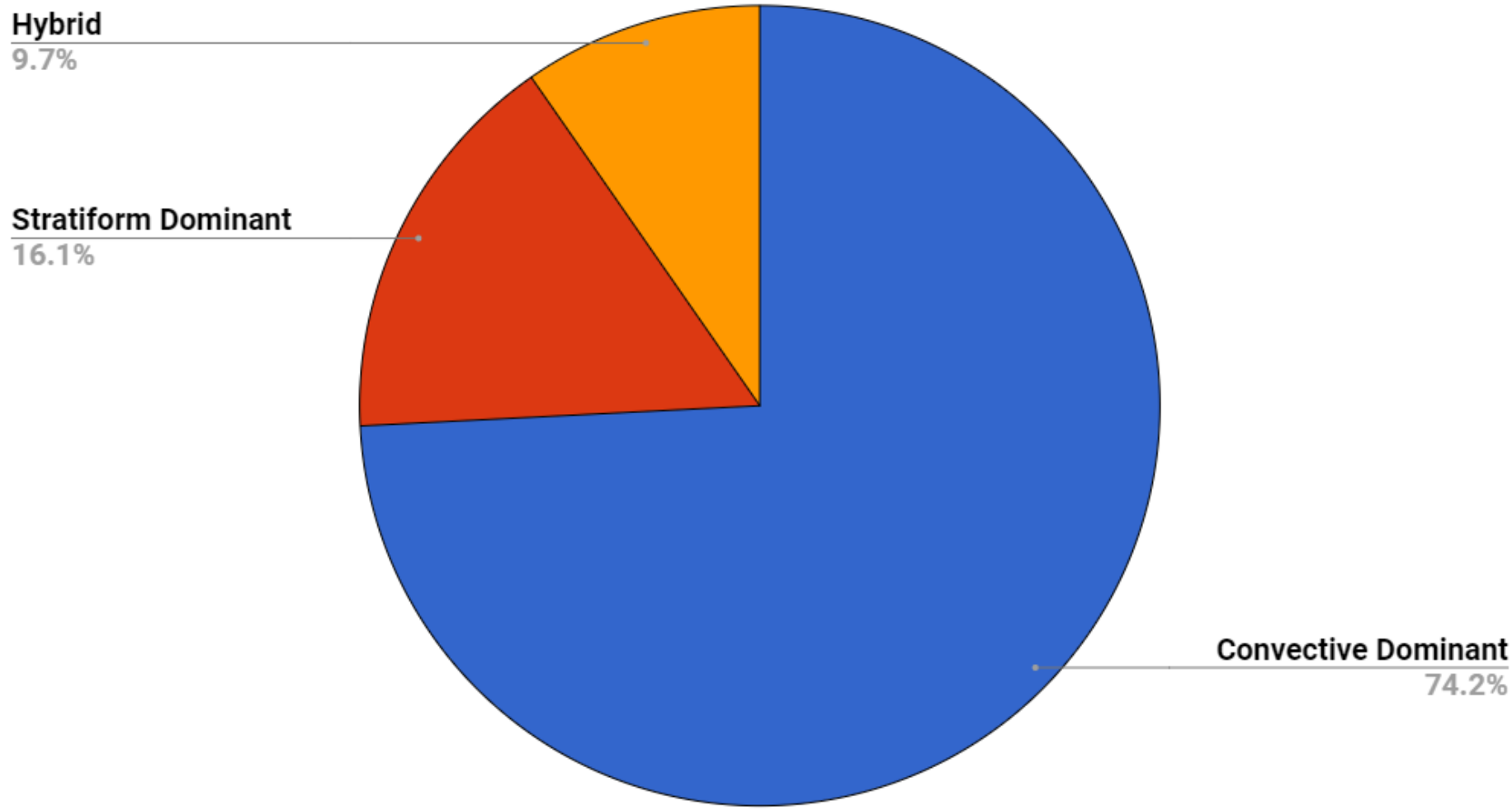
- Events were manually classified into three categories:
  - **3) Hybrid**
    - ➢ Clearly-defined banded/cellular features (large Z gradients) embedded within larger area of stratiform precipitation
    - ➢ Includes mid-latitude cyclones and other synoptic-scale systems



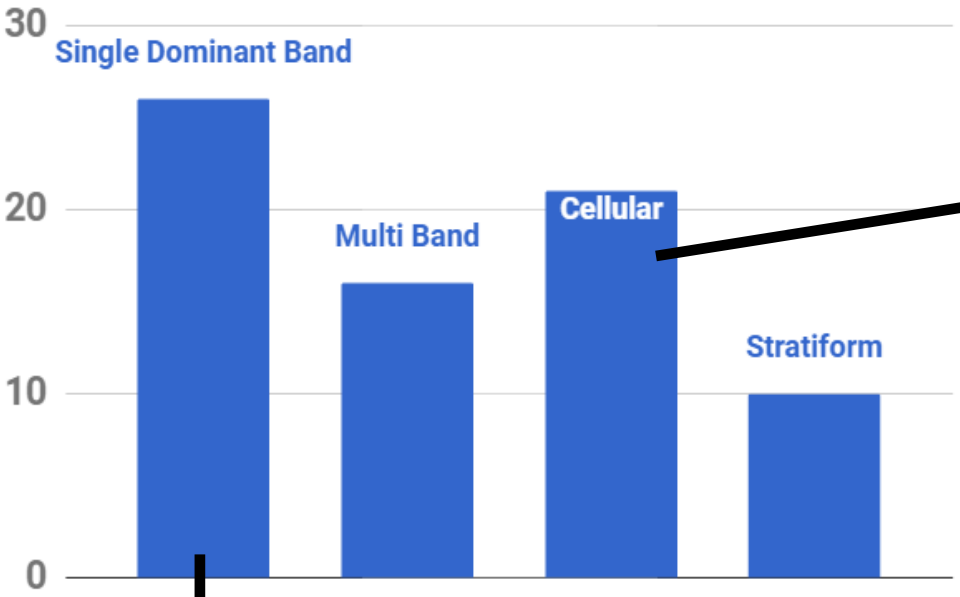


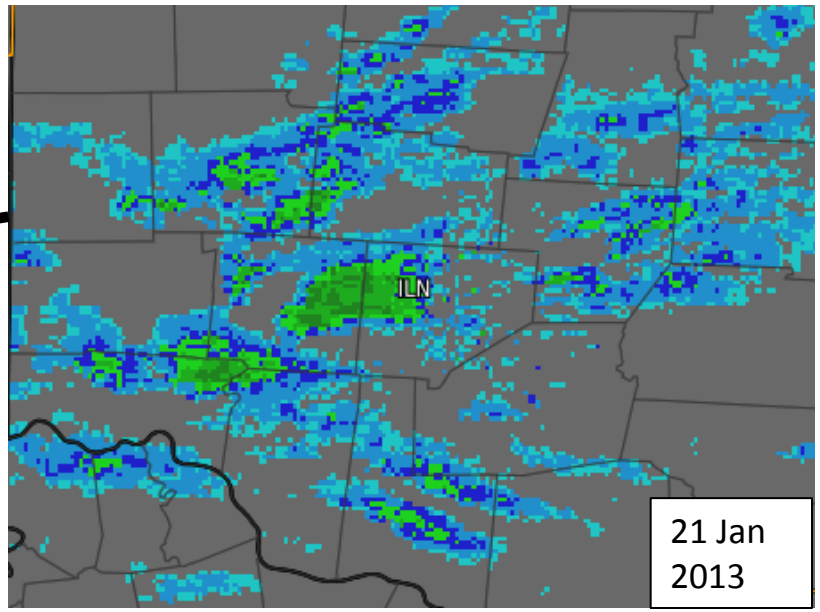


Precipitation Classification (n=62)

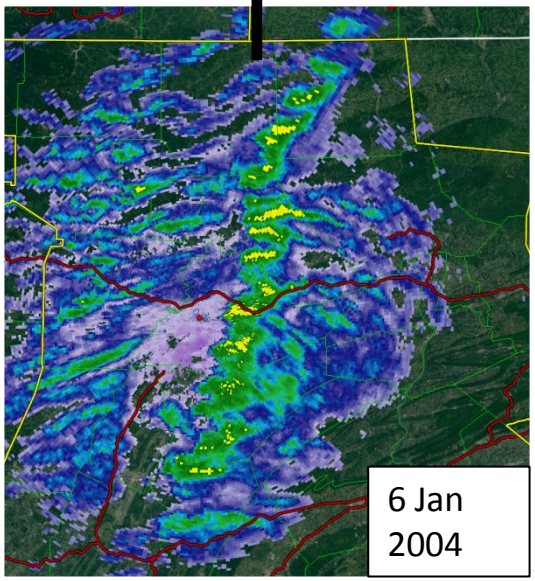


Precipitation Subclassification (n=62)





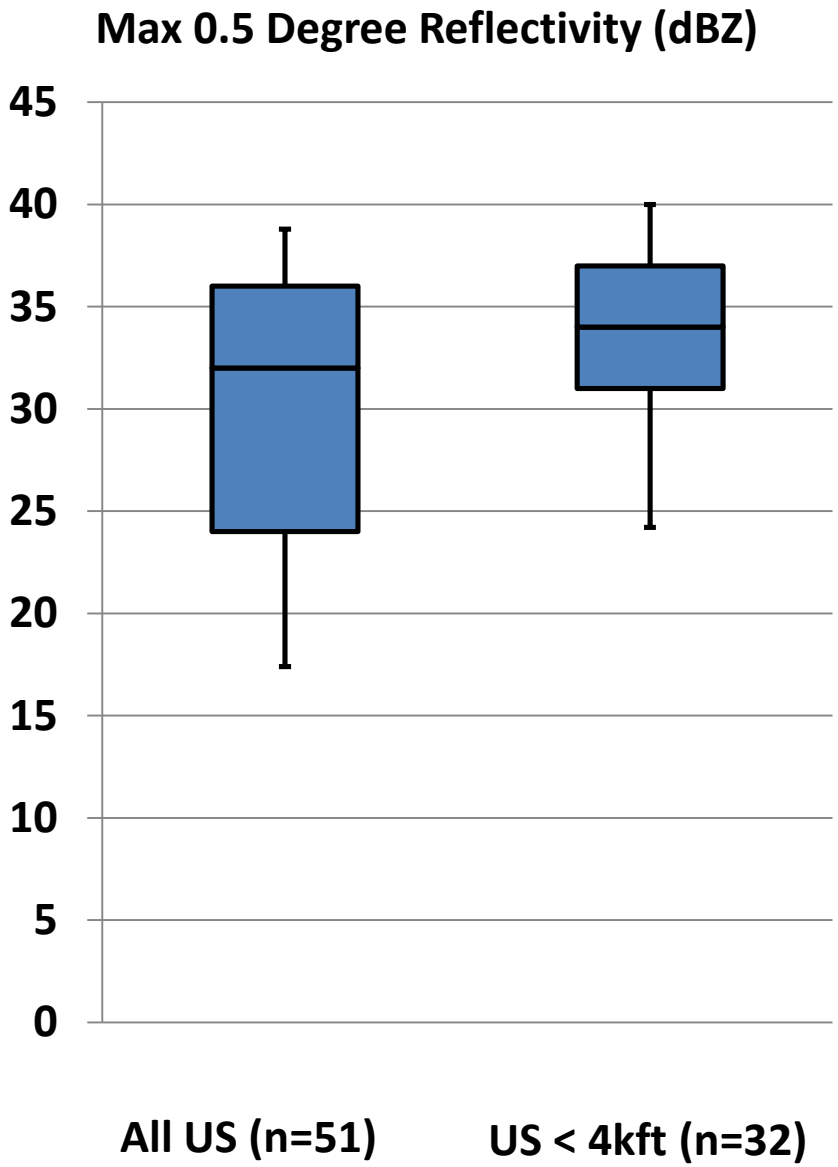
- Cold pool aloft/upper-level disturbance
- Lake-effect snow
- Elements are more transient and small-scale, more difficult to message/track



- Frontal snow squalls
- Lake-effect snow
- Best opportunity to precisely delineate threat

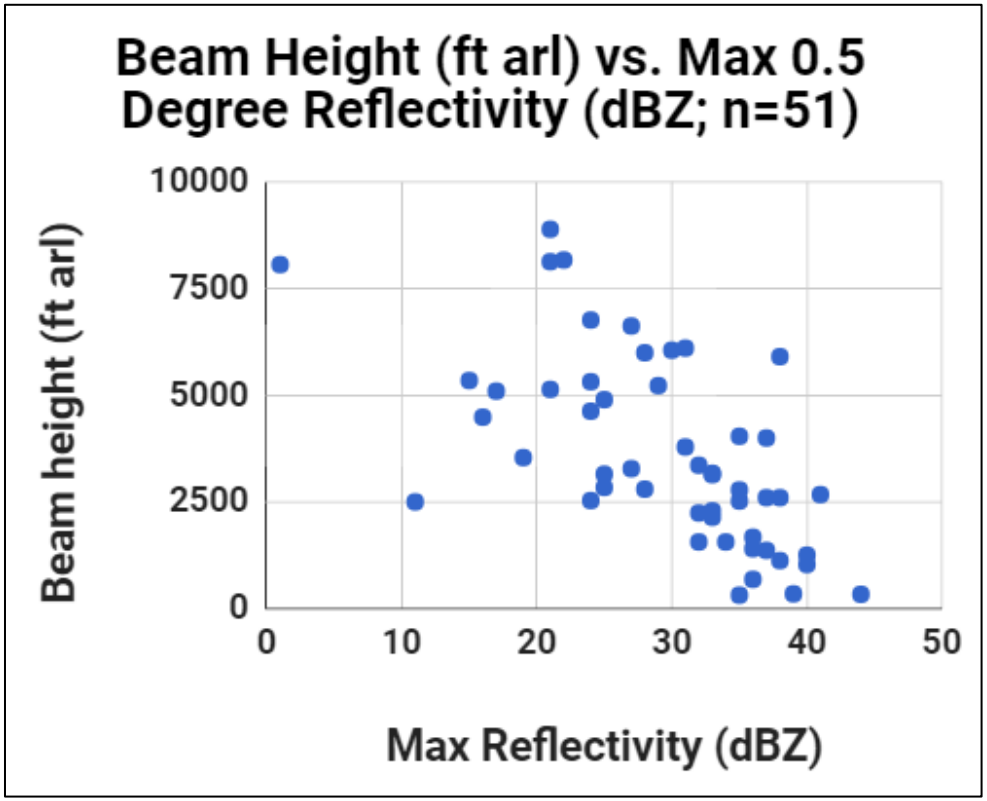
Maximum 0.5° Reflectivity

Maximum 0.5° Reflectivity



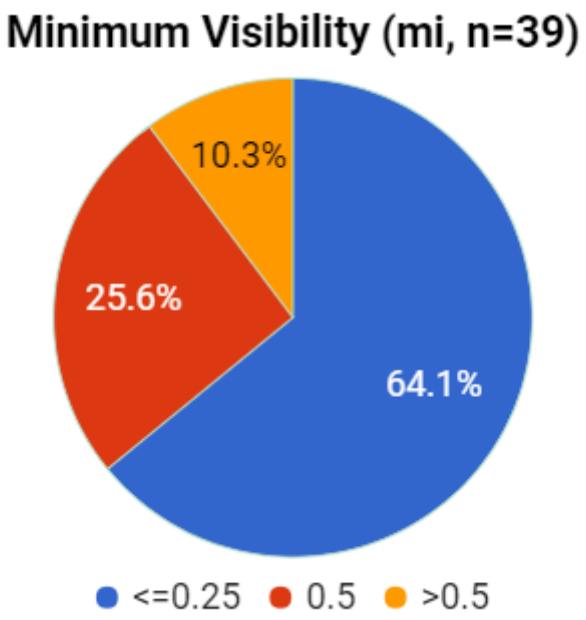
- *Criteria: Within 2 mi and 1 hour of pileup*

Box and whiskers plots: whisker edges are 10th and 90th percentiles, box edges are 25th and 75th percentiles, horizontal line is median



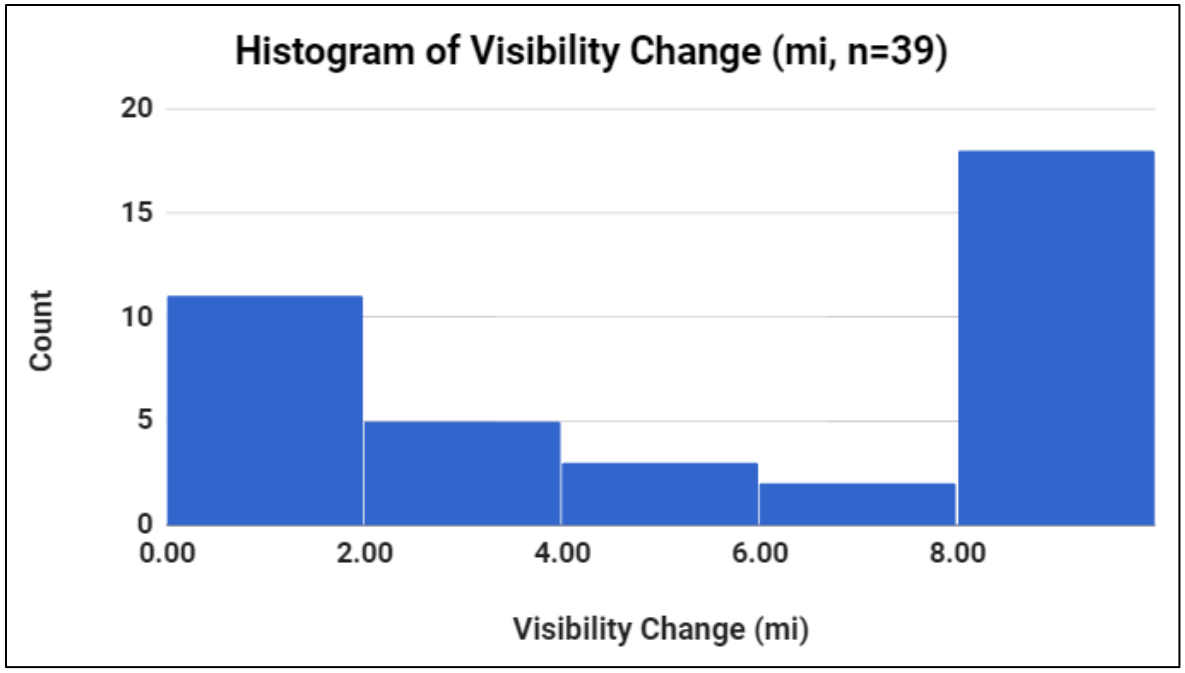
Surface Observations

Visibility



- *Criteria: Representative ASOS/AWOS 1h before to 1h after pileup*

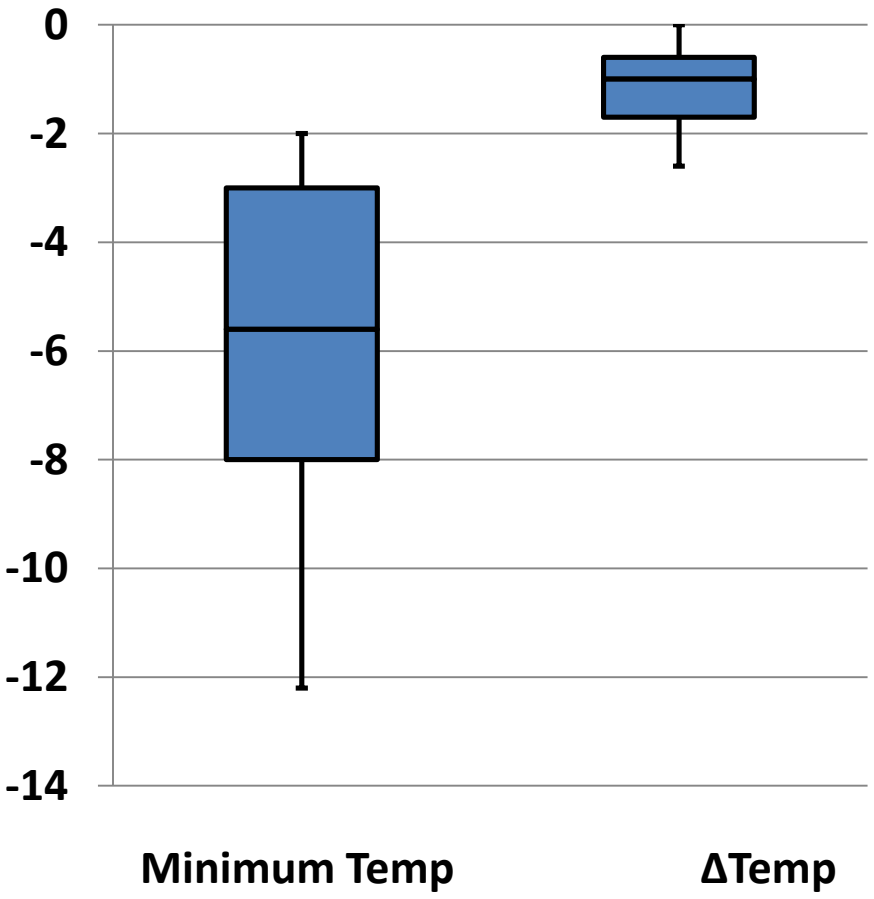
- Vis change > 4 mi in 59% of events
- All events had vis ≤ 0.5 mi or vis change > 4 mi



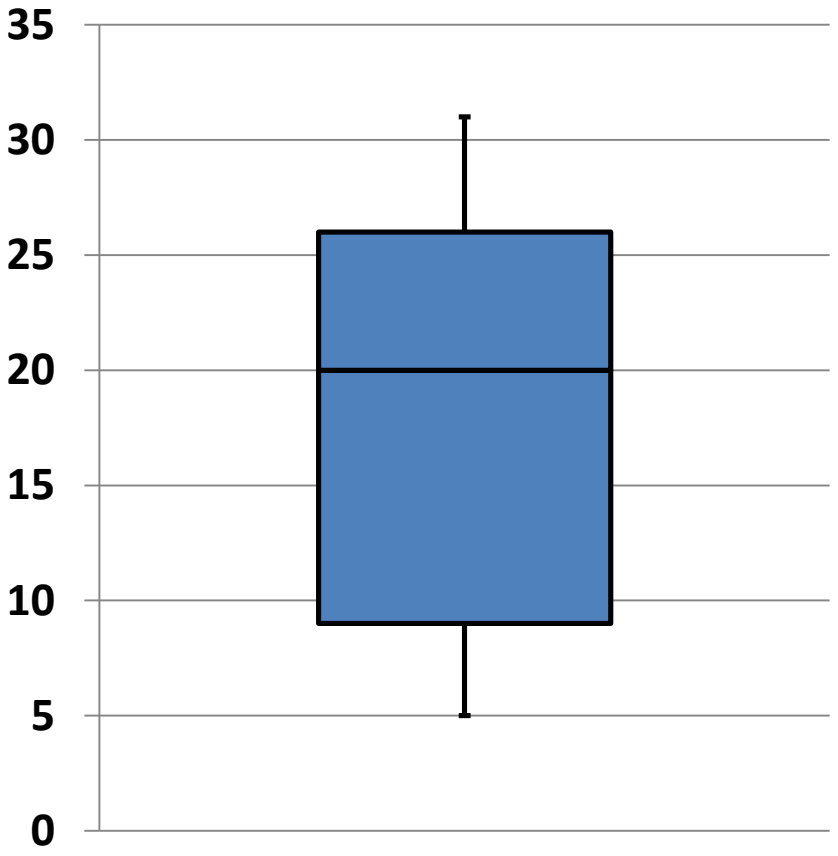
Temperature and Wind

- *Criteria: Representative ASOS/AWOS 1h before to 1h after pileup*

Temperature (°C; n=39)



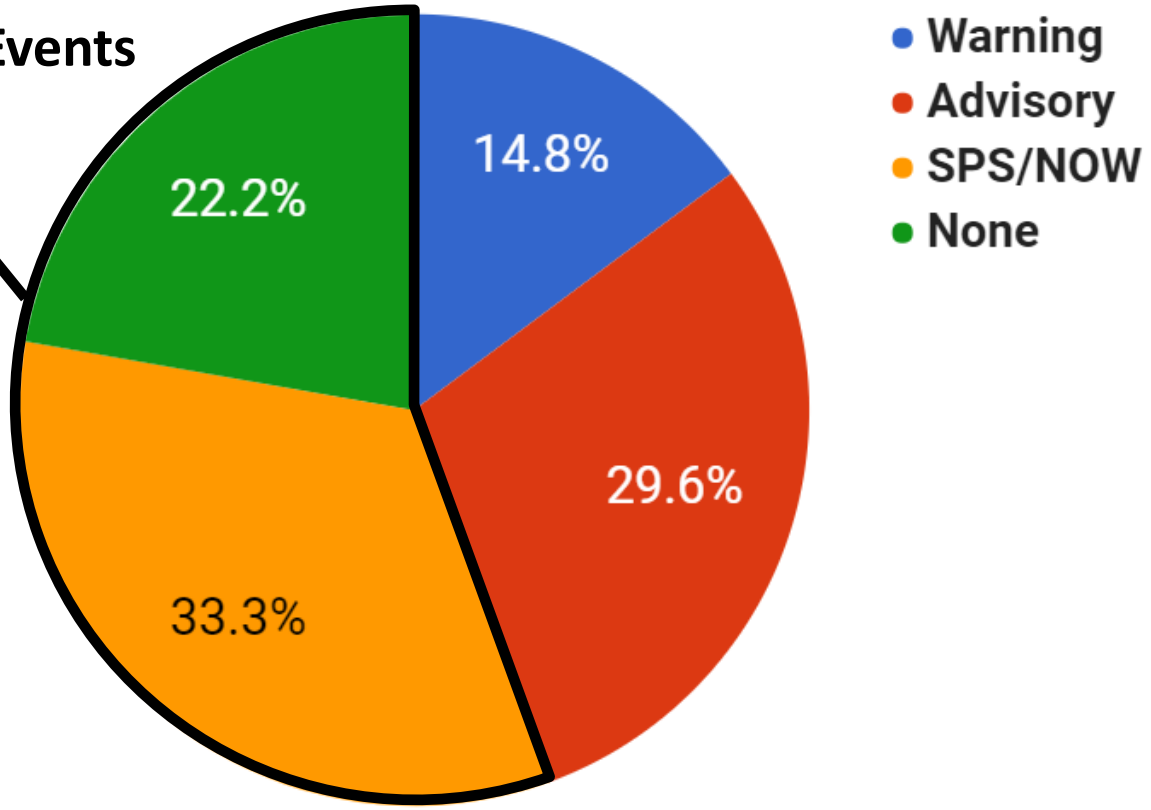
Peak Wind Gust (kt, n=39)



NWS Products in Effect During Pileups

NWS Products (n=54)

High-Impact, Sub-Advisory Events
(Devoir and Ondrejik 2008)
56% (n=30)



Median # cars involved: **41**
Median # injuries: **12**
Total # fatalities: **26**

Similar impacts to pileups that occurred during a headline event

NEW FOR 2017–18:
Snow Squall Warning
Being tested at 8 offices including BUF, BGM, BTV

Summary – Key Points

- Knowledge of key factors present during pileups can enhance forecaster confidence and allow for stronger wording in short-fuse products

- Enhanced risk of pileups – what to look for
  - Time between 9 am and 3 pm
  - Visibility ≤ 0.5 mi (0.8 km) and/or sharp visibility changes
  - 0.5° Reflectivity ≥ 30 dBZ with large gradients
    - *Be aware of heavily trafficked/dangerous stretches of roadway with poor radar coverage*
  - Dominant bands allow best opportunity to precisely delineate threat

- Future work
  - Evaluate Snow Squall Warning
  - Study traffic rates, SNSQ parameter, road temps, snow amounts, etc.
  - Continue to communicate with public and partners about pileups, snow squalls

References & Acknowledgements

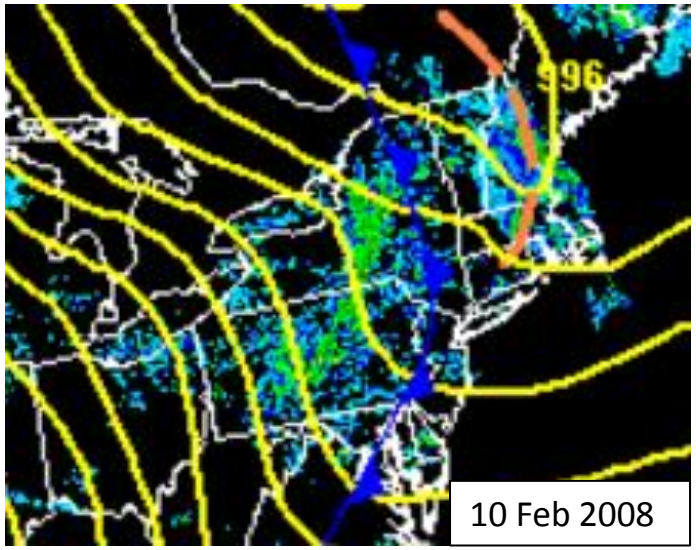
Banacos, P. C., A. N. Loconto, and G. A. DeVoir, 2014: Snow squalls: Forecasting and hazard mitigation. *J. Operational Meteor.,* **2** (12), 130–151, doi: http://dx.doi.org/10.15191/nwajom.2014.0212.

Devoir, G. and D. Ondrejik, 2008: NWS expands efforts to mitigate effects of high impact sub-advisory snowfall. *NWS Aware*, **2**, 15–16. [Available online at www.nws.noaa.gov/os/Aware/pdfs/08spring-aware.pdf.]

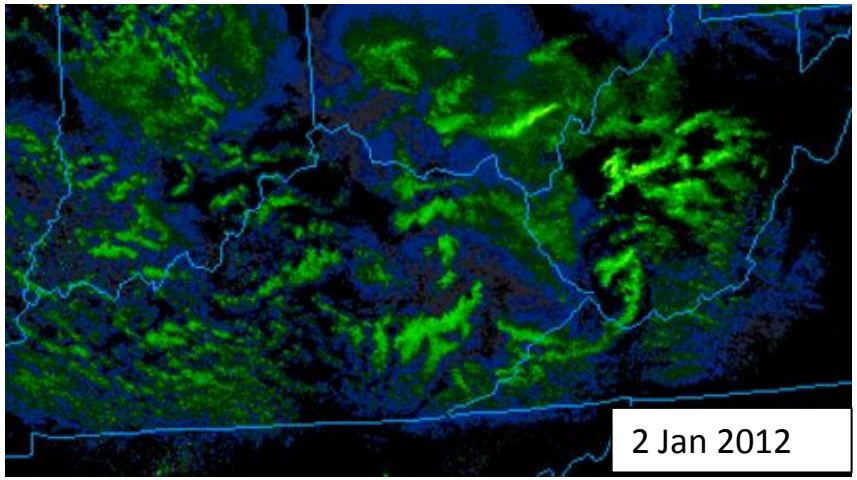
Thanks to Greg DeVoir (NWS CTP) and Pete Banacos (NWS BTV) for consultation

Dominant Forcing Classification

- Events were manually classified into six categories:
  1) **Cold Front**
     - Narrow band(s) along or immediately behind front
     - Convective-dominant radar classification



  2) **Cold Pool Aloft**
     - Cellular or banded echoes
     - Diurnally-enhanced
     - Non-lake effect snow
     - Convective-dominant radar classification

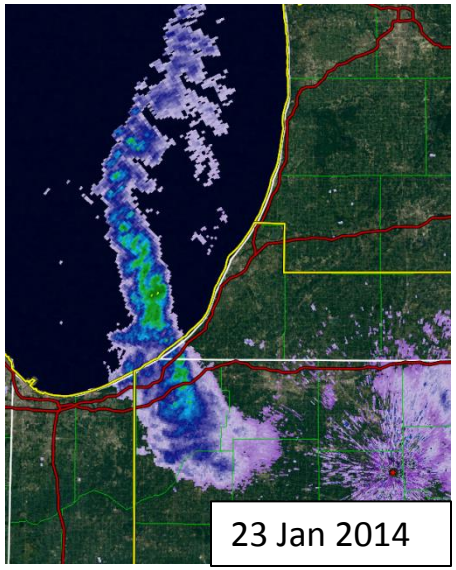


Dominant Forcing Classification

- Events were manually classified into six categories:

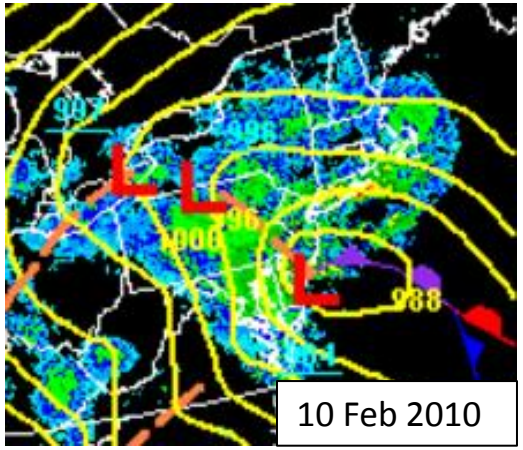
3) Pure Lake-Effect Snow (LES)

- Banded or cellular echoes
- Not augmented by synoptic-scale forcing
- Convective-dominant radar classification



4) Deformation

- E.g., NW quadrant of mid-latitude cyclone
- Stratiform-dominant or hybrid radar classification

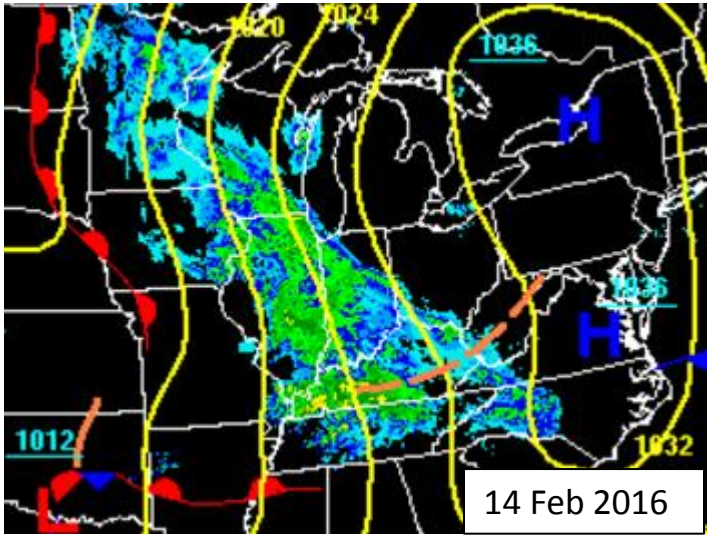


Dominant Forcing Classification

- Events were manually classified into six categories:

5) Warm-Air Advection (WAA)

- E.g., WAA region of mid-latitude cyclone
- Isentropic lift
- Stratiform-dominant or hybrid radar classification

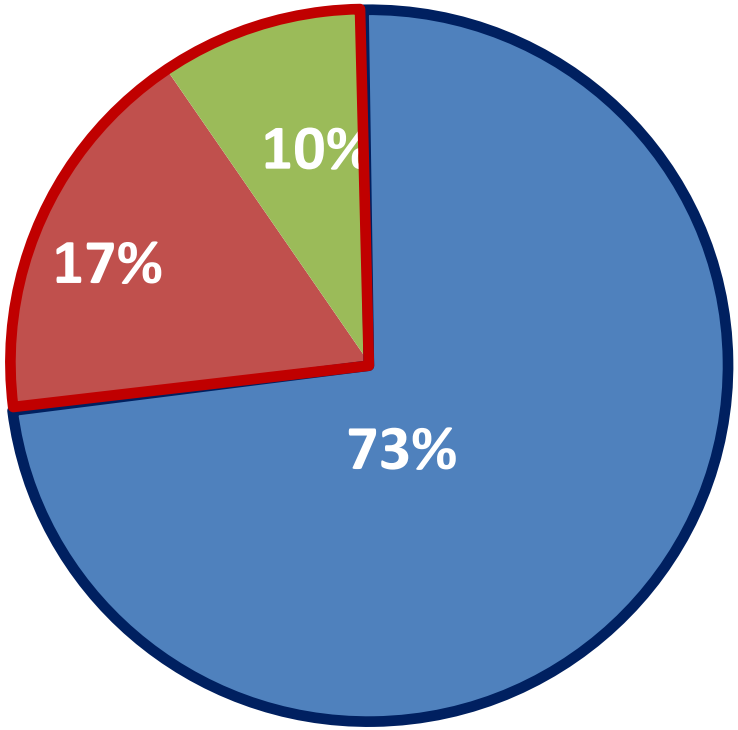


6) Other

- Events that do not fit the prior categories
- E.g., upslope flow
- Banded, cellular, or stratiform echoes

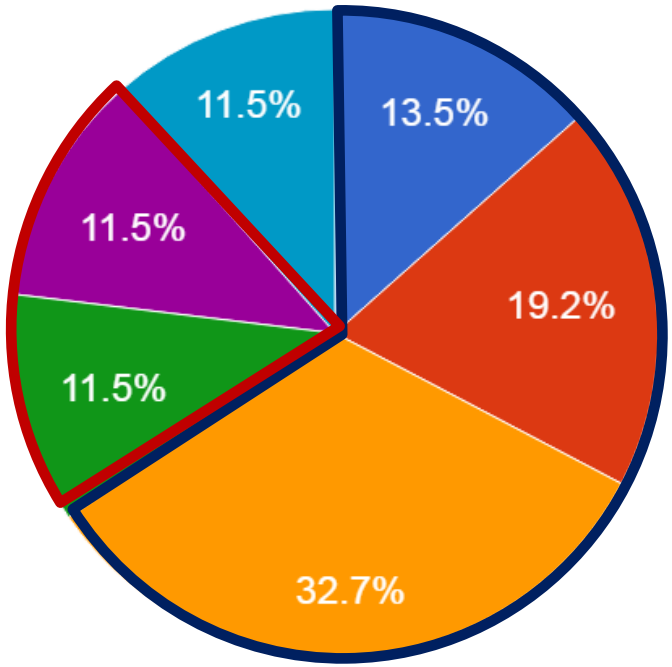
Event Classification (n=52)

Radar Classification



Convective-Dominant
Stratiform-Dominant
Hybrid

Dominant Forcing Classification



Cold Front
Cold Pool Aloft (Non-LES)
LES
Deformation
WAA
Other

HISA Events: NWS Mitigation Efforts

- DeVoir and Ondrejik, 2008 (NWS State College, PA)
  - Partner project with PennDOT and PA State Police along I-80
- Long term:
  - Email notification to partners 1–2 days in advance
- Short term:
  - Highly detailed SPS including mile markers
  - Originate phone call chain

  - PennDOT activates digital highway signs and advisory radio
  - State police cruisers slow traffic on edge of affected area
- Similar partner project between NWS Albany/Binghamton, NY and NYSDOT

Prior Work – Snow Squalls

- Experience suggests many pileups occur during rapidly deteriorating weather conditions
  - E.g., snow squalls or snow bursts → shallow, vigorous convection rooted in the boundary layer

- Snow squall climatology – Banacos et al. (2014)
  - Searched for vis ≤ 0.5 mi (0.8 km) preceded by increase in wind speed 1h prior
  - Constructed composite snow squall parameter:

$$SNSQ = \left(\frac{\overline{RH}_{sfc-2km} - 60\%}{15\%}\right) * \left(\frac{4K - (\theta_e|_{2km} - \theta_e|_{sfc})}{4K}\right) * \left(\frac{\|\vec{\bar{v}}\|_{sfc-2km}}{9\ m\ s^{-1}}\right)$$

Low-level RH

Low-level θ_e lapse rates

Mean low-level wind speed

High-Impact, Sub-Advisory Events

- Snow squalls identified in Banacos et al. (2014) typically lasted < 30 min with accumulation ~ 1 in (2.5 cm)
  - Most of these events would not reach Winter Weather Advisory criteria (~4 in/10 cm)
  - These events referred to as High-Impact, Sub-Advisory (HISA; DeVoir and Ondrejik 2008)

- Routine legacy NWS products to handle HISA events:
  - Special Weather Statement (SPS)
  - Short Term Forecast (NOW)
    - May not properly convey the impact of the situation
    - Not as widely disseminated