Classifying Rainfall Regions in Weather Radar Mosaics

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Useful Information

https://github.com/ahaberlie/unidata-workshop-2018

Haberlie and Ashley (2018)

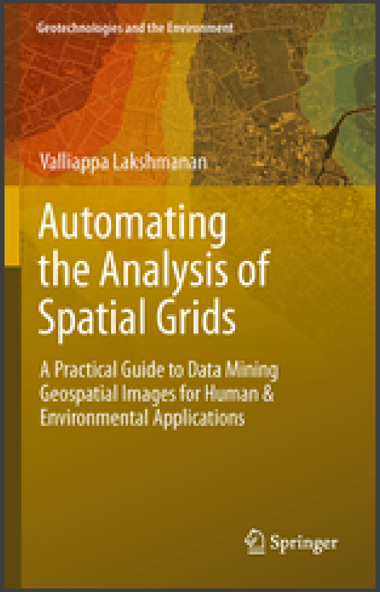
McGovern et al. (2017) – Great overview of current machine learning trends in Meteorology

Storm Identification and Feature Extraction

- WDSS-II (Lakshmanan et al. 2007)
- TITAN (Han et al. 2009)
- THoR (Houston 2015)
- Hagelslag (Gagne 2018)

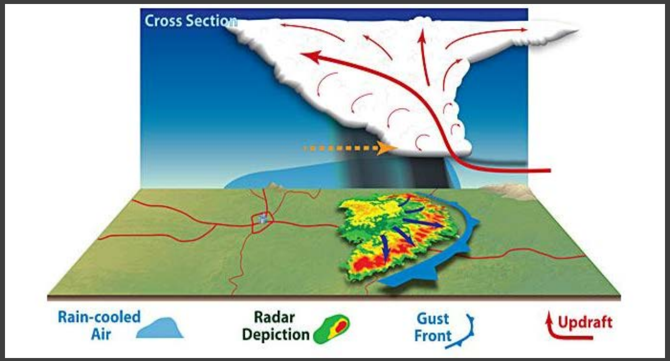
Machine Learning and Forecasting:

- MCS initiation (Ahijevych et al. 2016)
- Damaging Straight-Line Wind Prediction (Lagerquist et al. 2017)
- Heavy rain forecasting (Herman and Schumacher 2018)



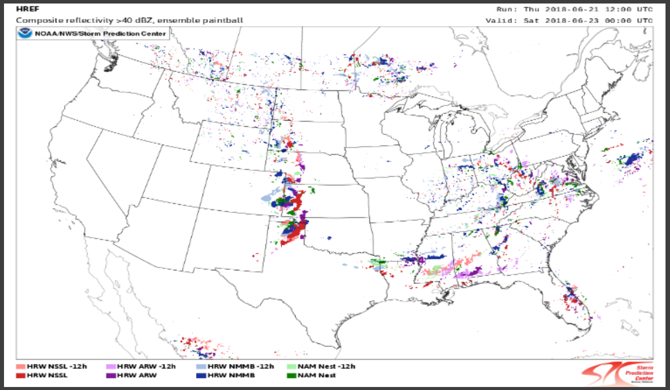
Mesoscale Convective Systems

Source: *NOAA Storm Prediction Center*

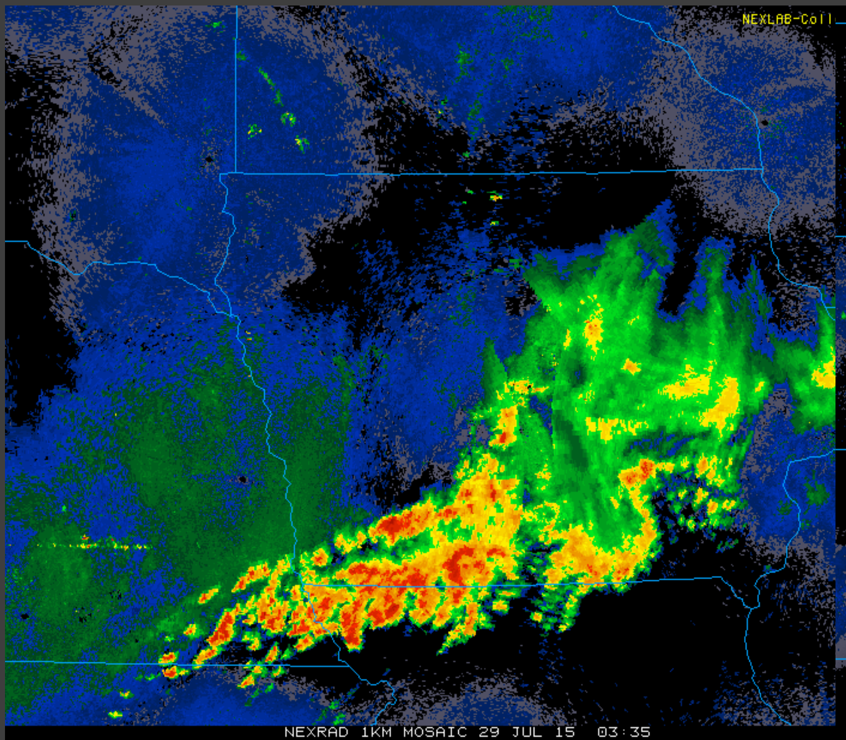


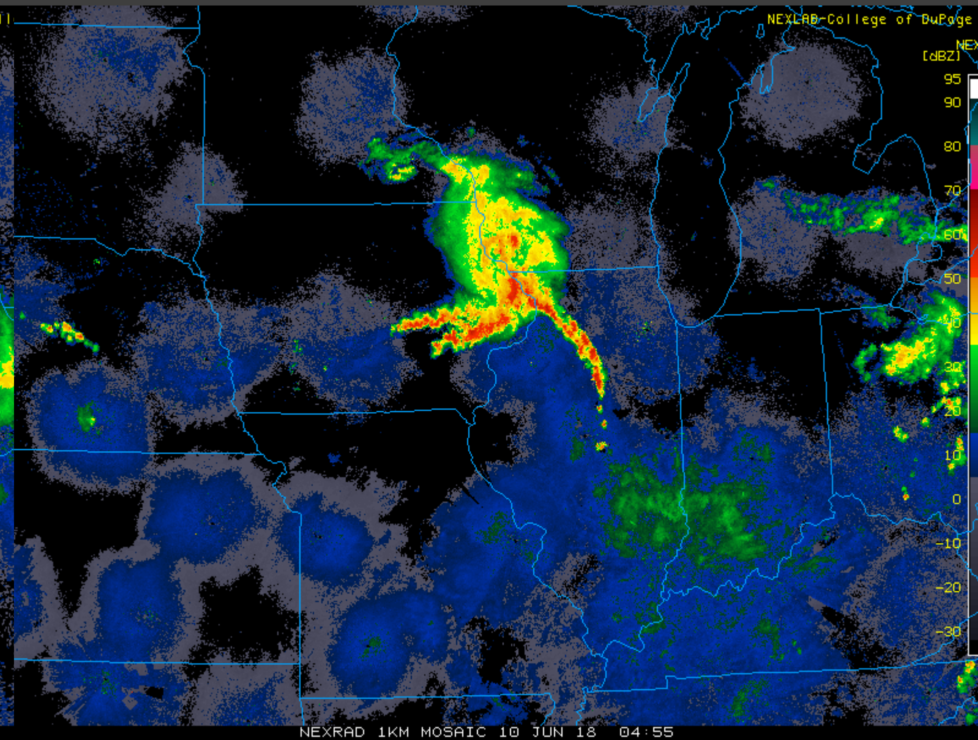
Source: Walker Ashley

Source:Arturo Fernandez/Rockford Register Star via AP.



Source: *NOAA Storm Prediction Center*

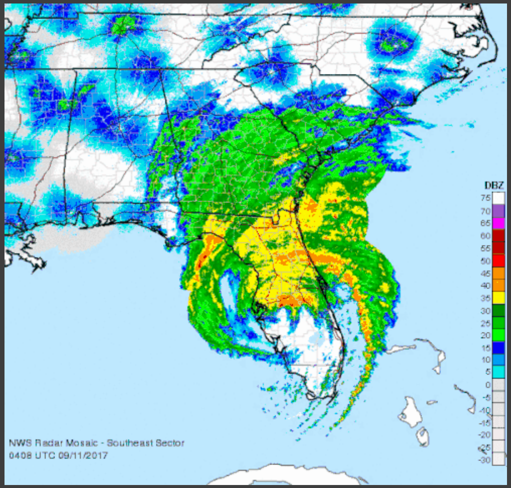


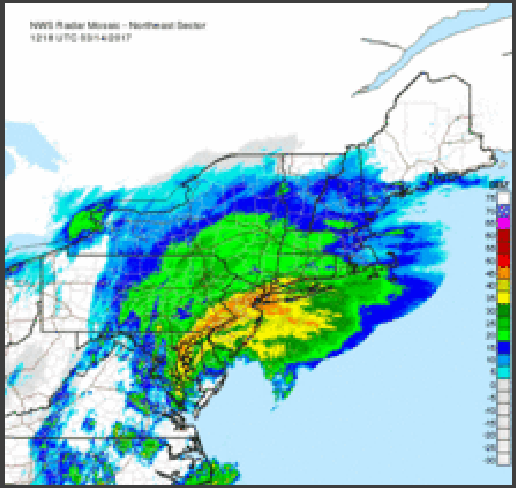


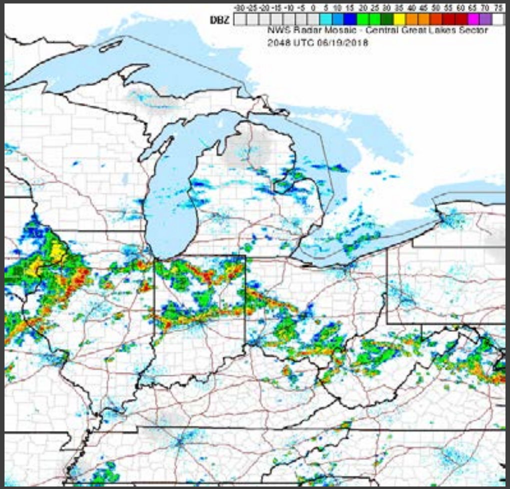
Parker and Johnson (2000)

Gallus et al. (2008)

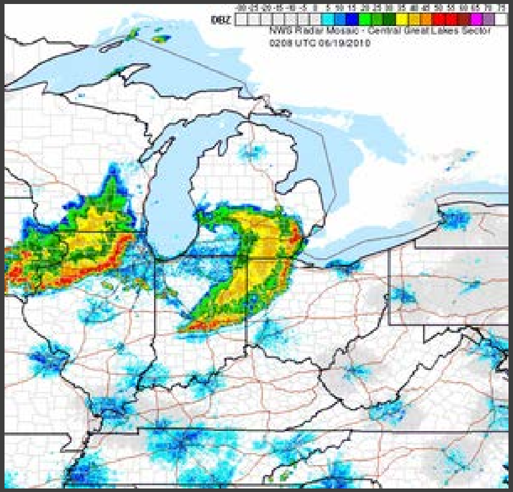
Are These MCSs?

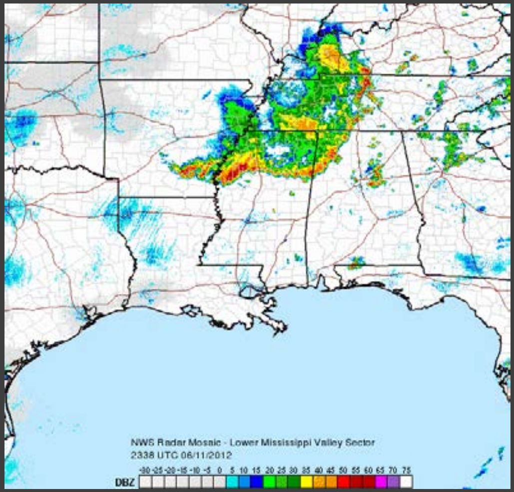






What about these?





Problem Description

How do you generate a climatology of mesoscale convective systems (MCSs) with a huge dataset of composite radar mosaics?

- NOWrad (~2 km)
- Over 95% of 15 minute periods from 1996-2017
- ~10^6 images
- Many well-known issues, but the analyses can be useful (Fabry et al. 2017)

Parker and Johnson (2000) **objective definition**:

- Convective cells organized on a horizontal scale of at least 100 km
- Must last for at least 3 hours

Computing Resources:

- Ryzen 1700 (8 C, 16 T), nVidia GTX 1070, 32 gb RAM

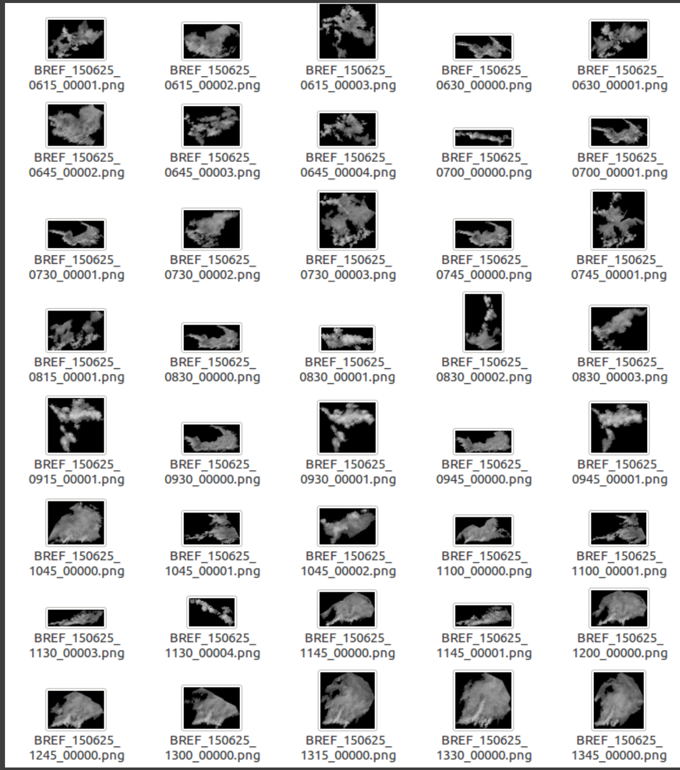
Why Machine Learning?

"Reducing time to science"

~5.5 million "MCS Snapshots"

Automate classification of MCSs and four common false positives after segmentation

- Tropical Systems
- Synoptic Systems
- Unorganized clusters
- Ground Clutter / Noise / Etc.



Related Work

Baldwin et al. 2005

- Linear, cellular, stratiform

Gagne et al. 2009

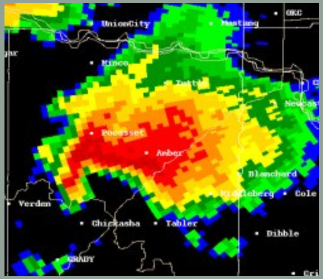
- Pulse, multicellular, MCSs

Lack and Fox 2012

- Supercell, QLCS, rotating storms, pulse, etc.

Hobson et al. 2012

- Supercell, pulse, multicellular, linear

Visual Depiction	Features
 User Label: Supercell	Area: 9,000 sq. km Mean Intensity: 35 dBZ Eccentricity: 0.3 …
 User Label: Linear	Area: 70,000 sq. km Mean Intensity: 31 dBZ Eccentricity: 0.8 …

Sample Training Workflow

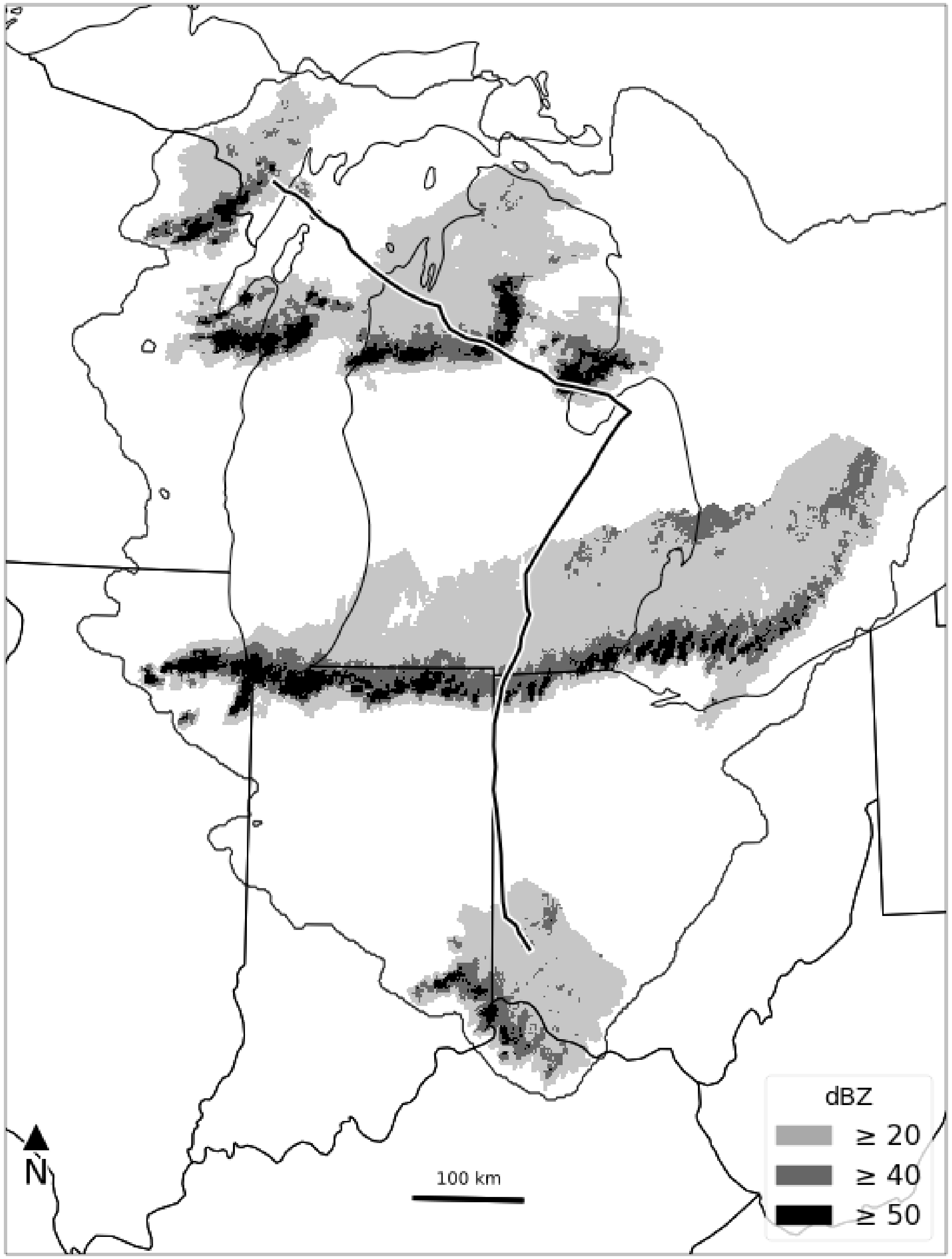
1) Ask yourself a few questions:
   - What are the classes you want to identify?
   - What are distinguishing features of each class?
   - What data do you need to gather samples?
   - What algorithm should I use?

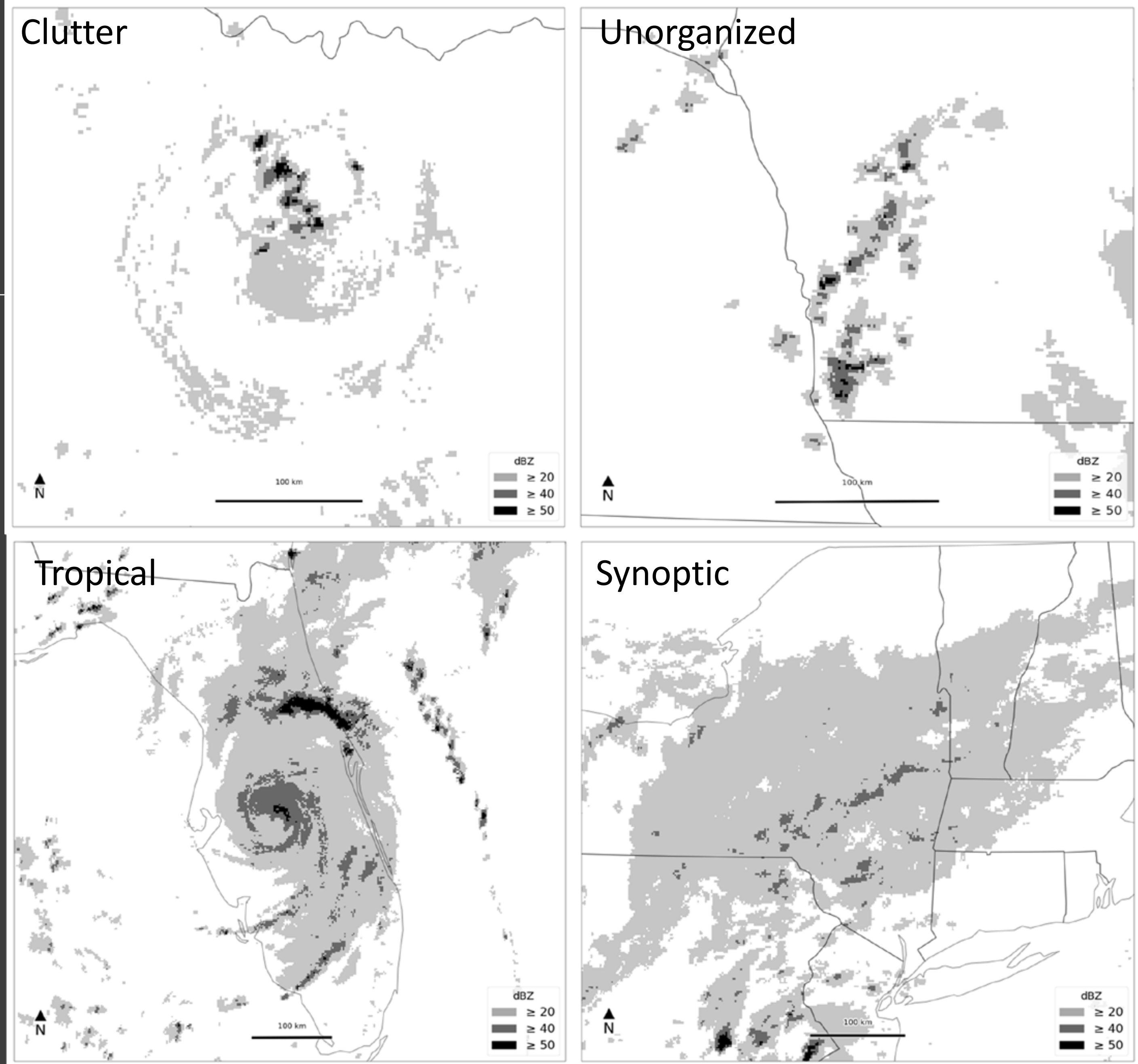
2) Identify class examples

3) Extract features
   - Area, Shape, Intensity, etc.

4) Generate training and testing data

5) Train machine learning model
   - Always test model performance on data **not** used to generate model


dBZ
≥ 20
≥ 40
≥ 50
100 km
N



Clutter
Unorganized
Tropical
Synoptic
dBZ
≥ 20
≥ 40
≥ 50
N
100 km

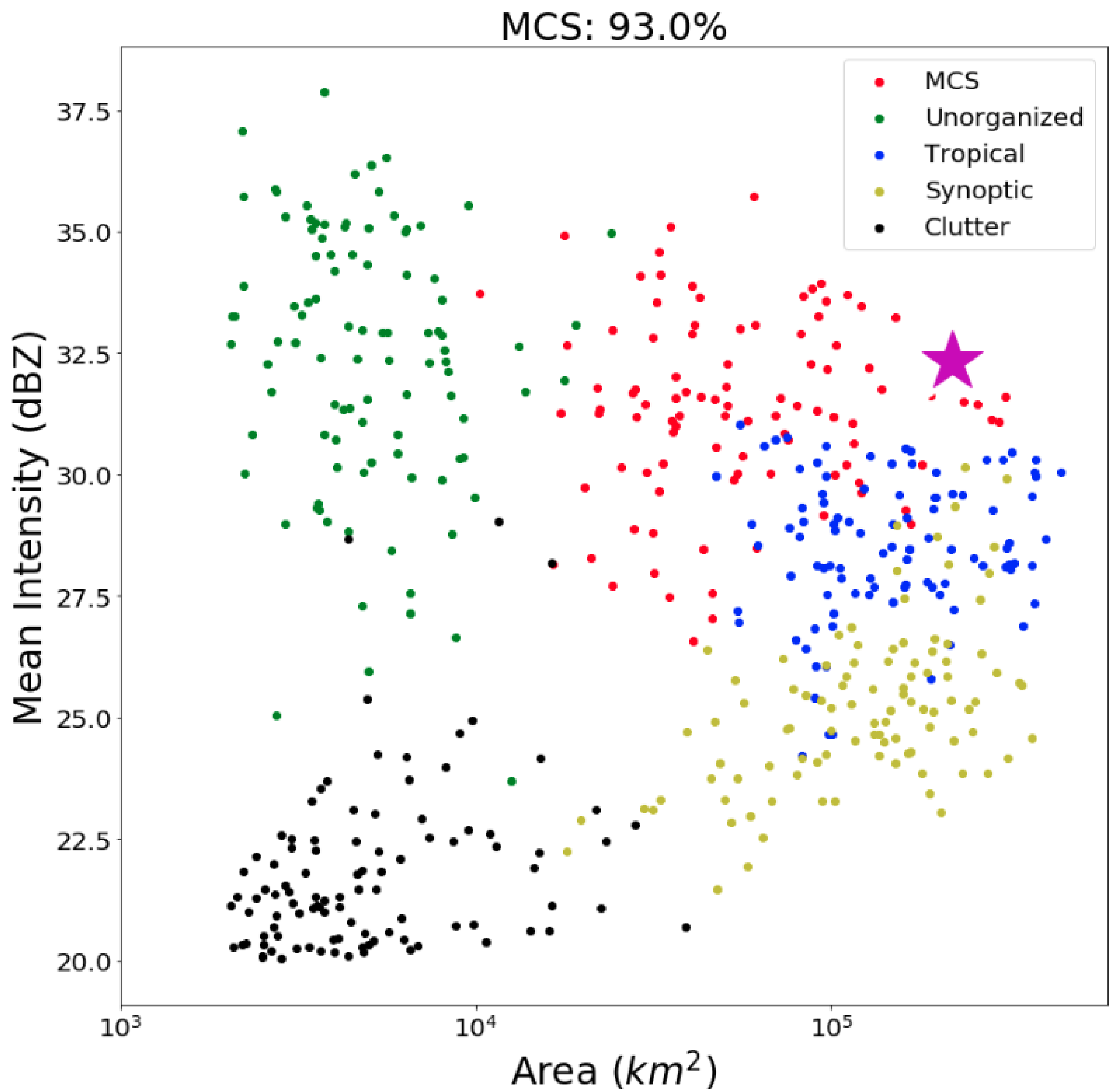
Notebook Examples

Training Process

Extraction Process

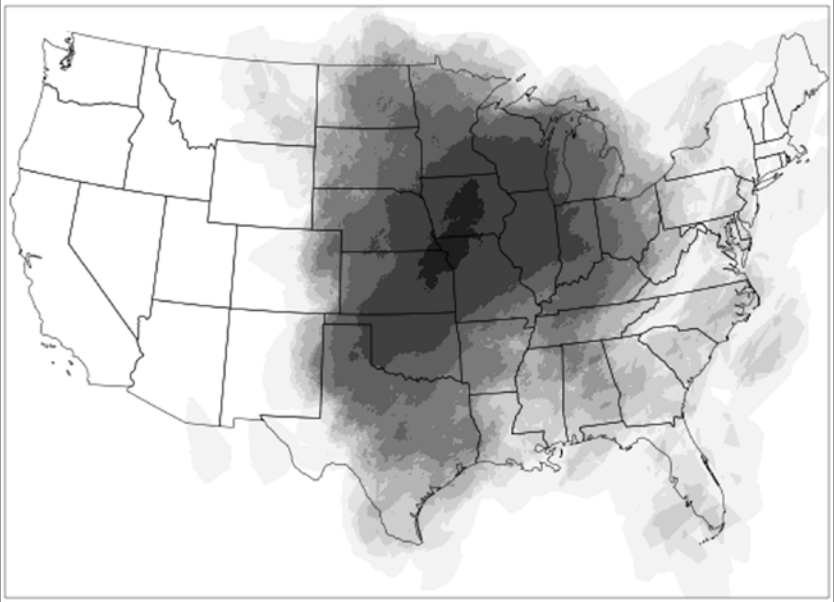
Area 218872

Mean Inten... 32.3364340802

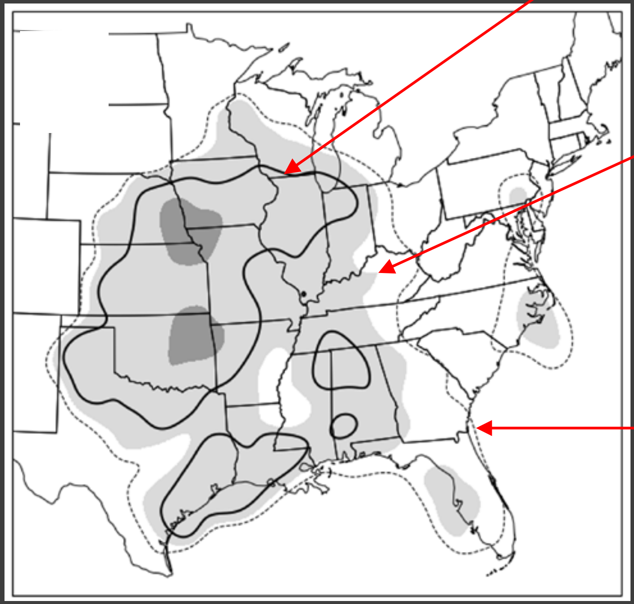


Machine Learning vs. Manual

Manual MCS slice positions (2003-2013)



Automated Approach (2015)



0.95 threshold 40-hr isopleth

0.5 threshold 40-hr fill

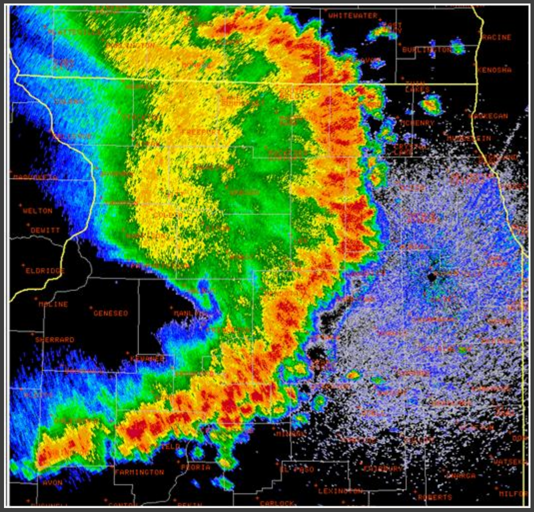
No threshold 40-hr isopleth

Quasi-linear convective systems

Quasi-linear convective systems (QLCSs) can produce severe weather (Trapp et al. 2005)

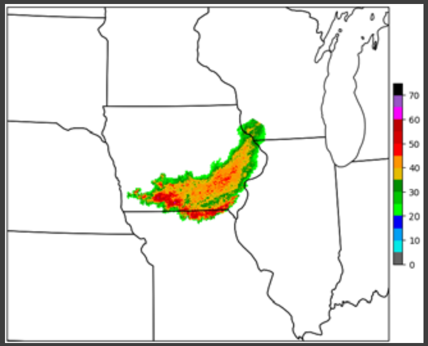
Convection-permitting models have trouble with QLCSs (Lawson and Gallus 2016)

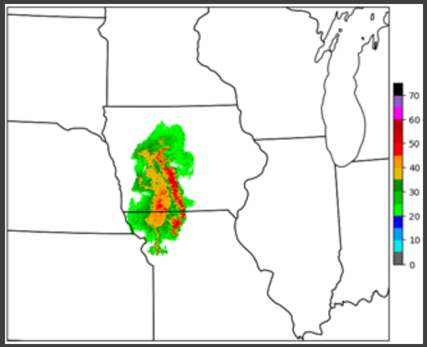
Implications for people, weather forecasting, and high resolution climate simulations

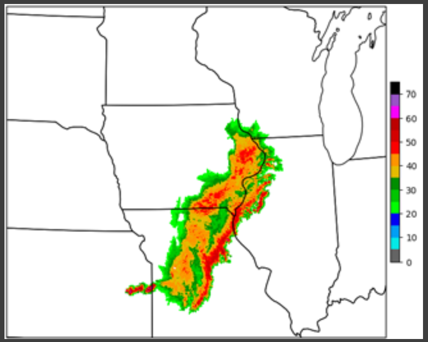


Visual differences

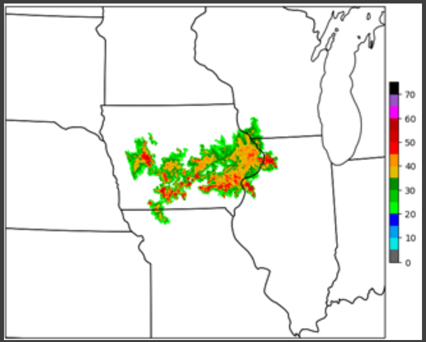
QLCS

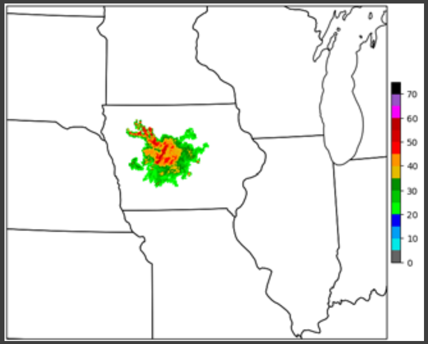


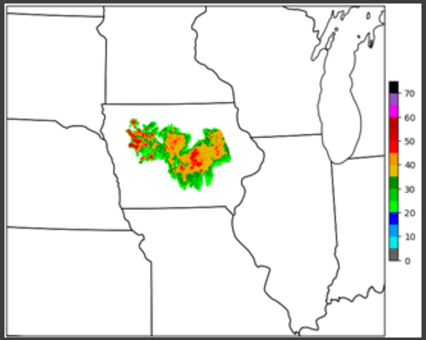




Non-QLCS







First Try

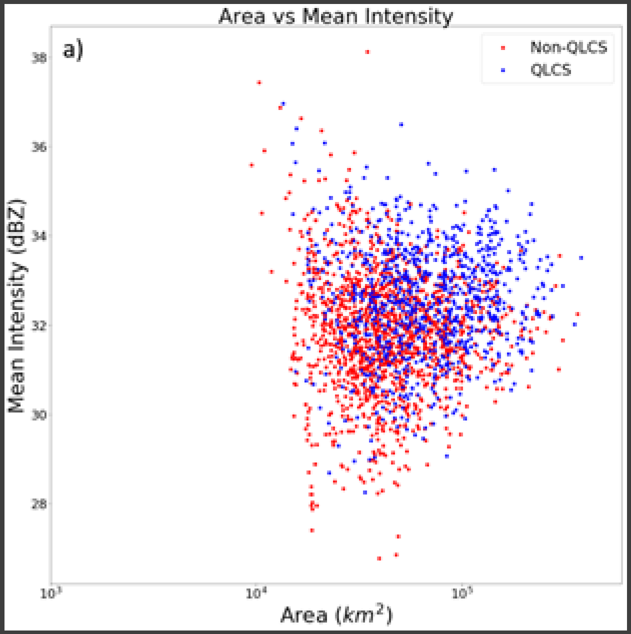
Select 3000 random high-probability MCS "snapshots"

Label as QLCS or Non-QLCS based only on their visual features

- Subjective
- Looking for common visual traits

Use features to train tree-based ensemble

  - ~70% accuracy

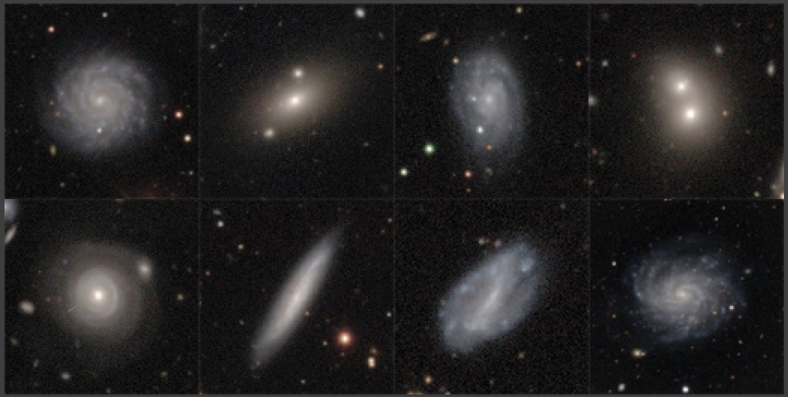


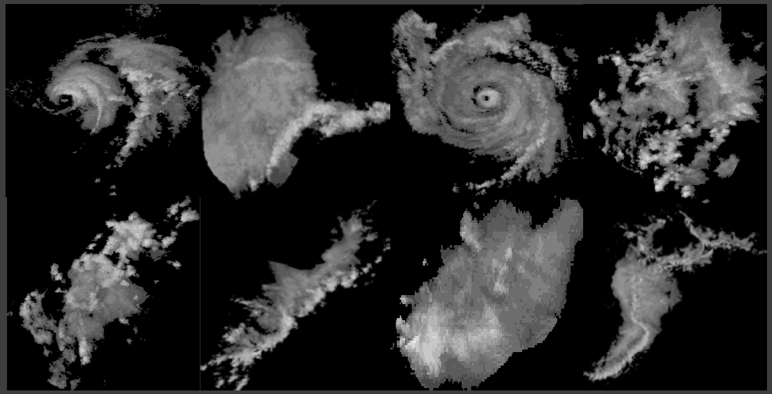
Second Try

Employ a convolutional neural network (Krizhevsky et al. 2012)

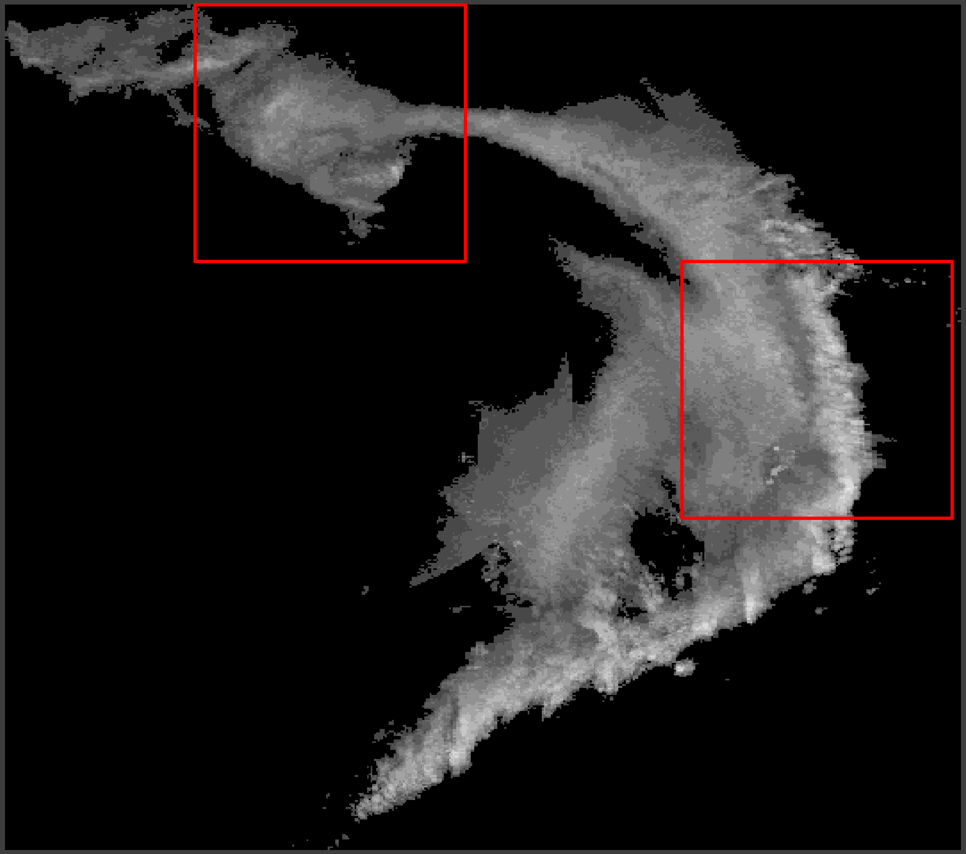
Inspiration / model configuration came from astronomy (Dieleman et al. 2015)

Much harder to generate training / testing data for CNNs



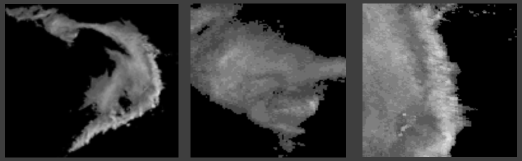


Training data approach



What is visually important for classifying this as a QLCS?

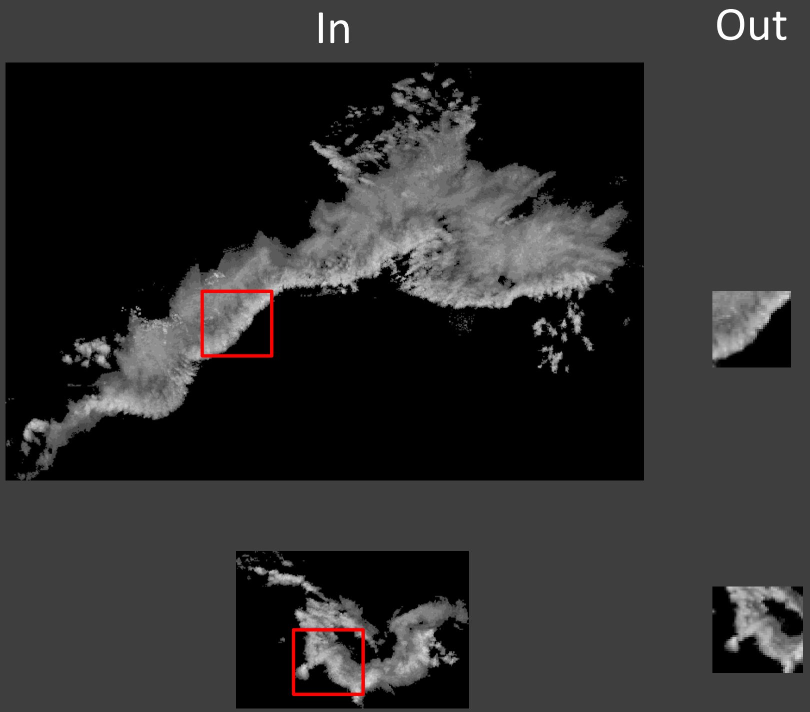
1) The entire structure?
2) Stratiform features?
3) Convection features?



"I'm looking for an intense line with a strong reflectivity gradient."

Training / testing data creation

- All images must be the same size
- Find largest contiguous region of 50+ dBZ
- Center a box on the intensity-weighted centroid
- Extract intensity information within box



Data Augmentation

Addressing overfitting

- Only ~3000 samples

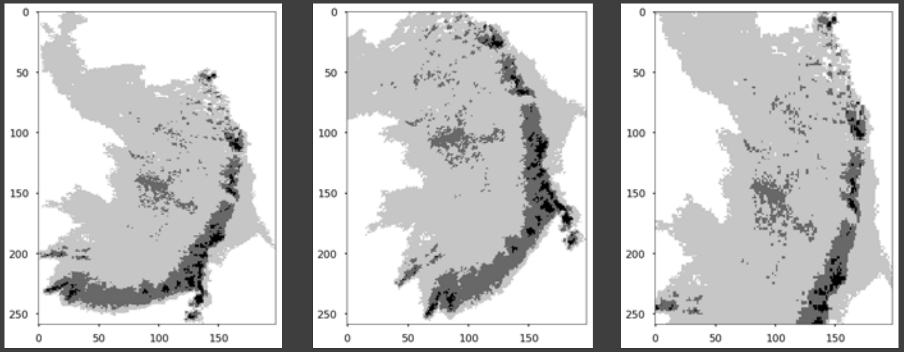
Keras ImageDataGenerator

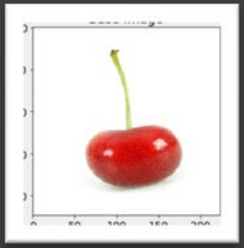
- Randomly apply slight modifications to images during training

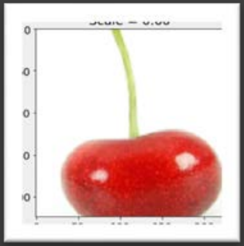
Physically Reasonable?

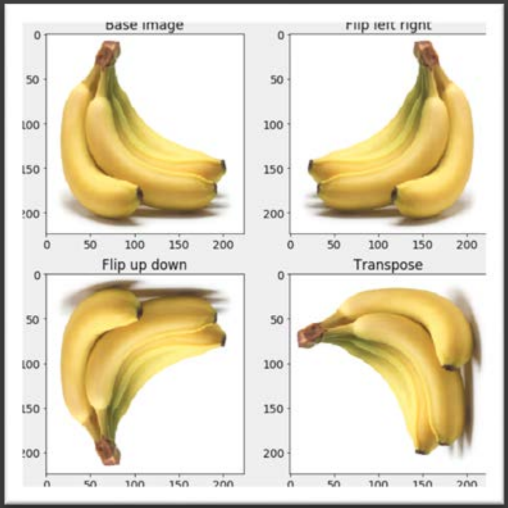
- Scale is important
- Orientation might be important

Original Rotation Zoom

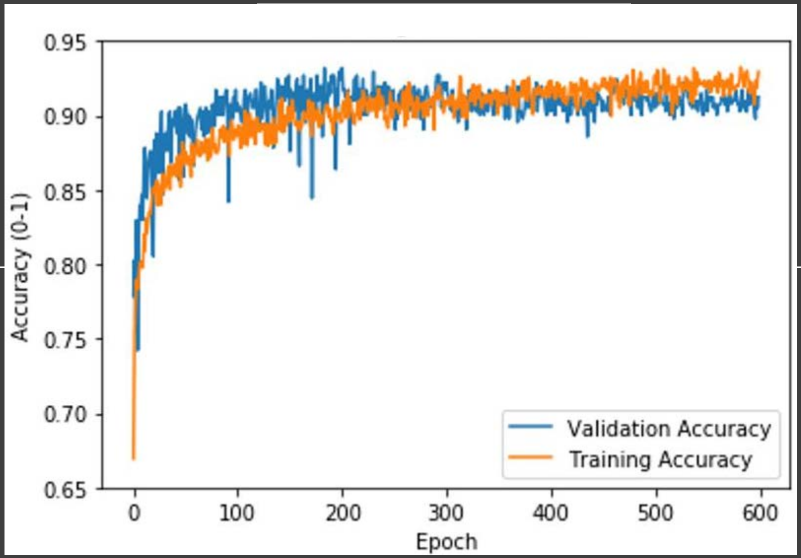




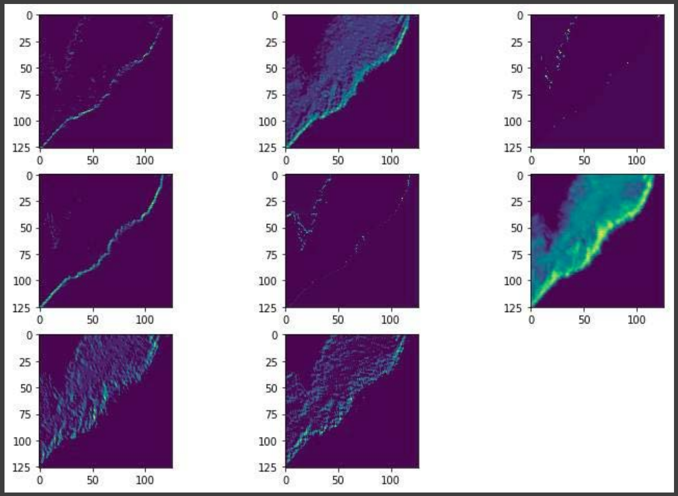




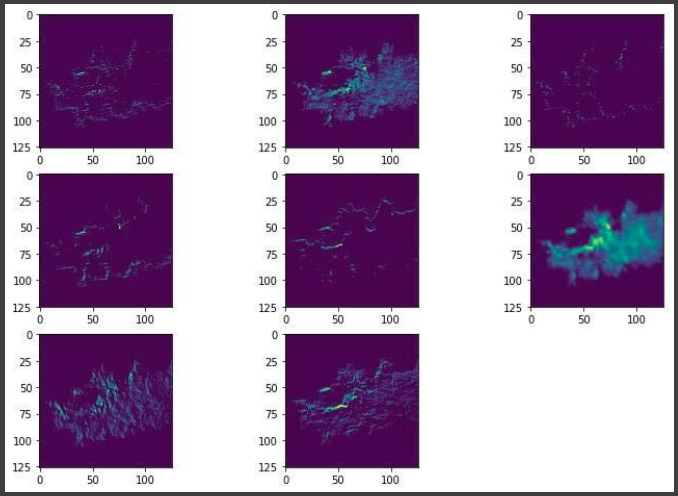
Fruit examples from : https://medium.com/ymedialabs-innovation/data-augmentation-techniques-in-cnn-using-tensorflow-371ae43d5be9

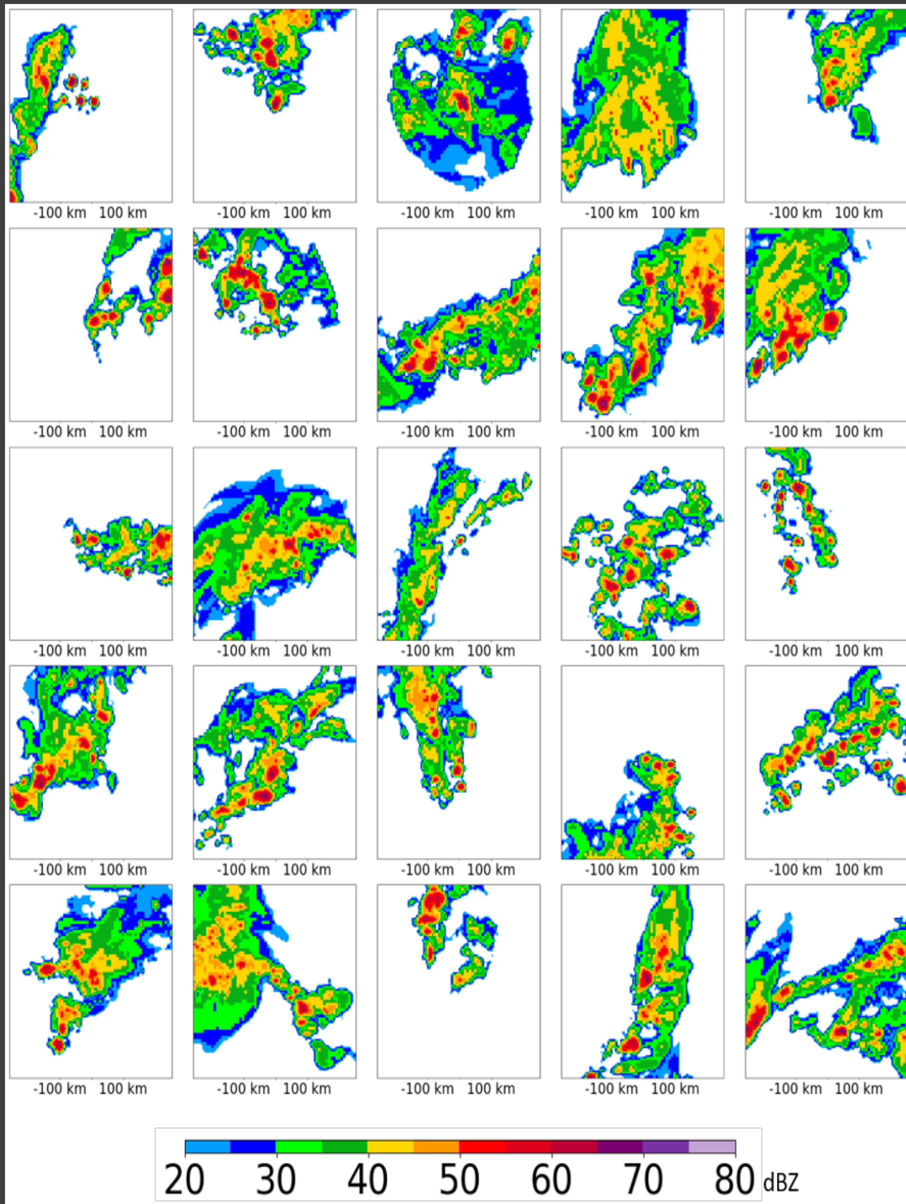


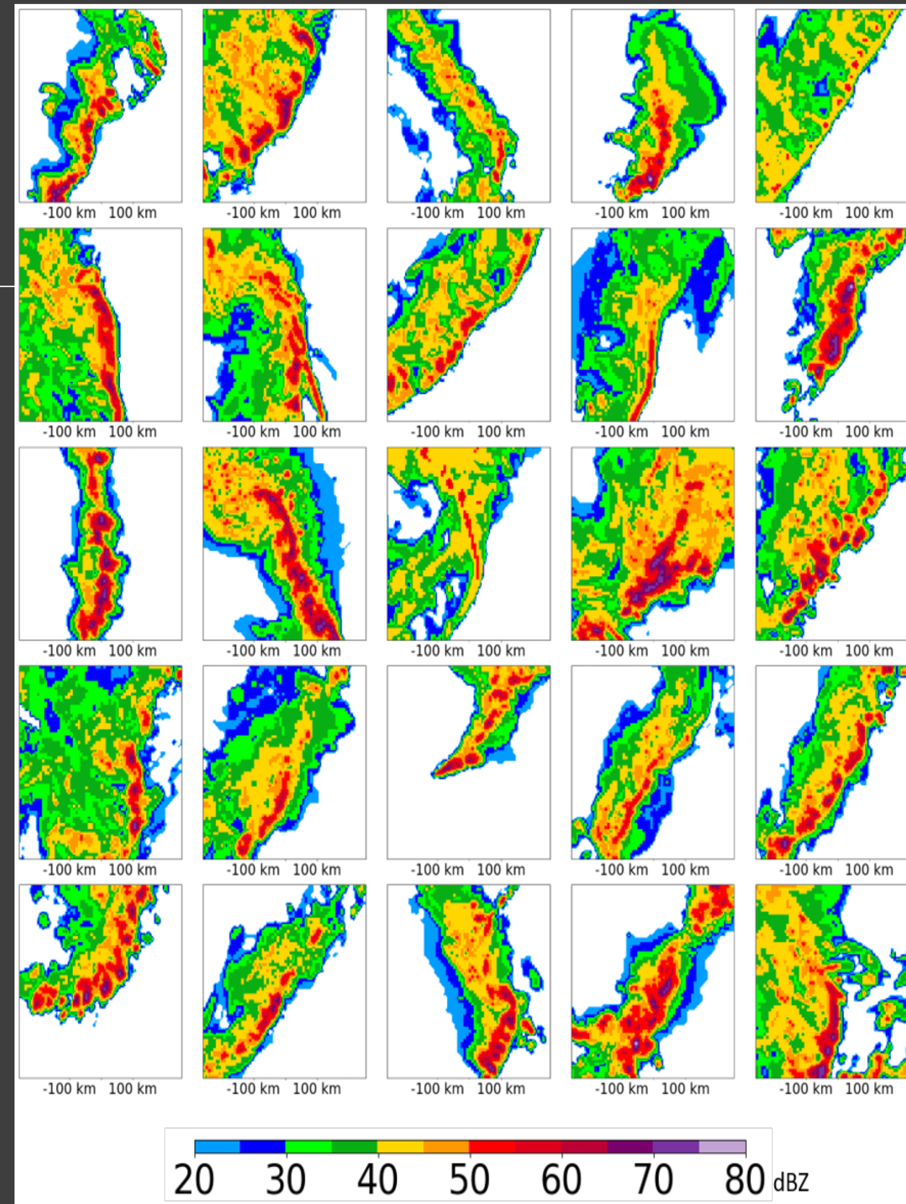
QLCS Sample



Non-QLCS Sample



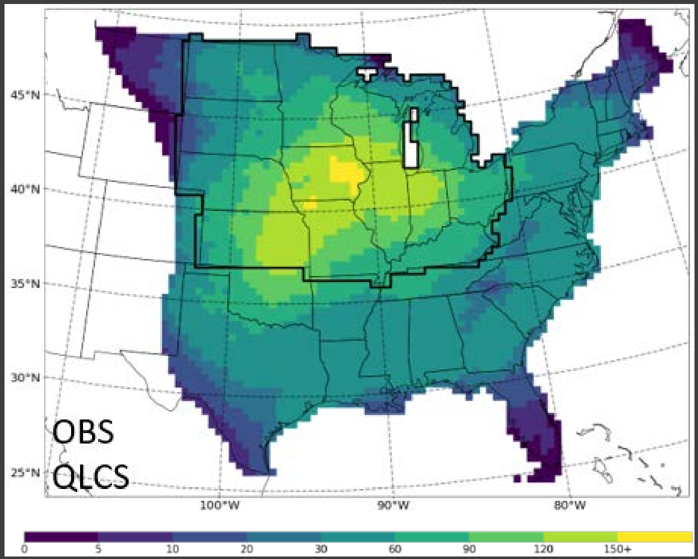

-100 km 100 km
20 30 40 50 60 70 80 dBZ


-100 km 100 km
20 30 40 50 60 70 80 dBZ

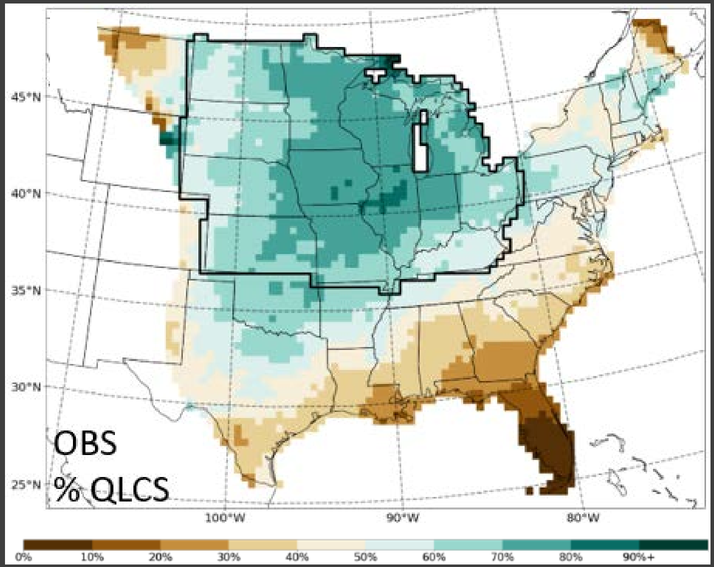
Notebook Examples

QLCS Detection

Application



QLCS Occurrence
June – August (2001-2013)



Percent of MCS events that were QLCSs
June – August (2001-2013)

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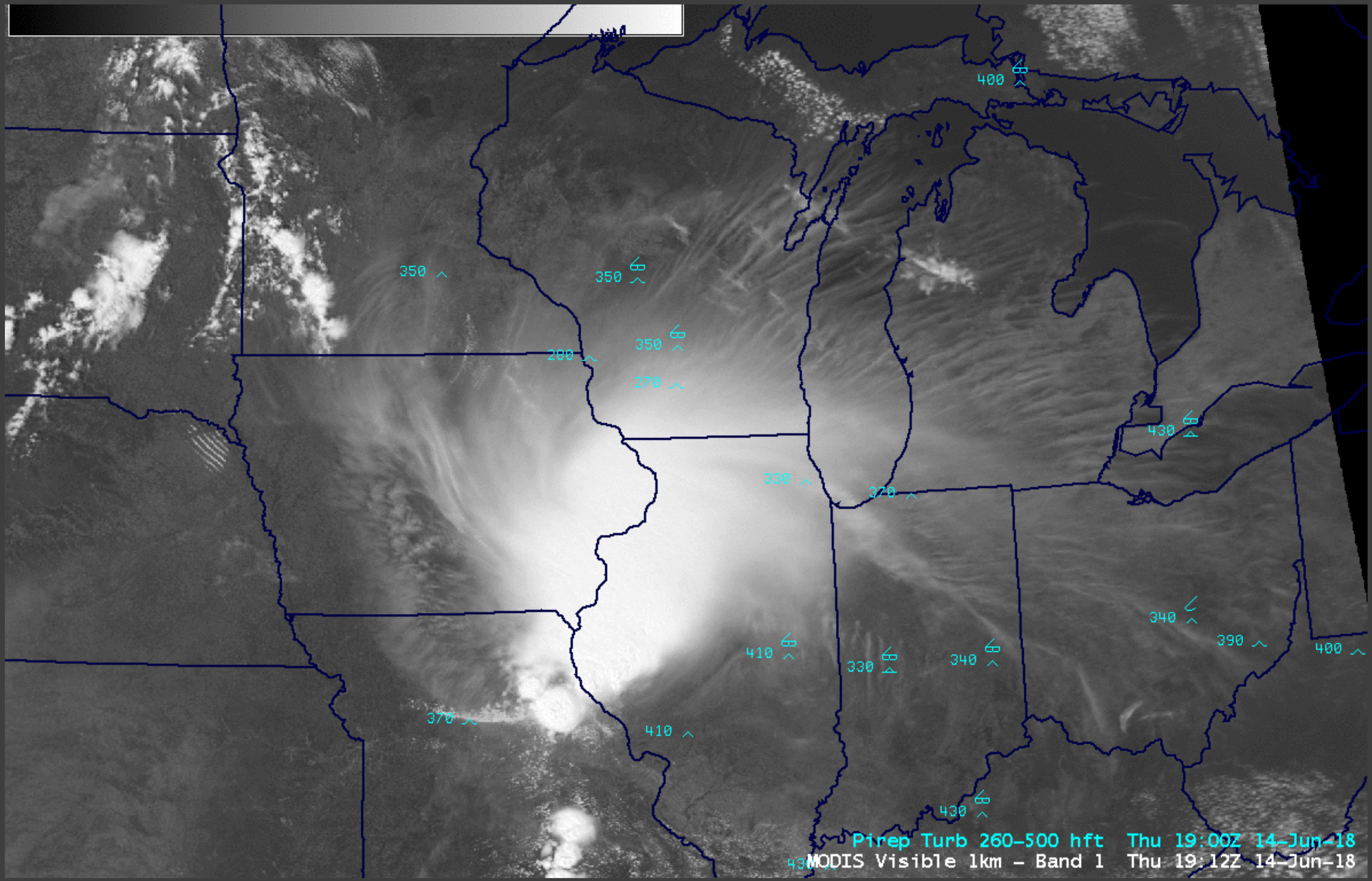
Thank You



Pirep Turb 260-500 hft Thu 19:00Z 14-Jun-18
MODIS Visible 1km - Band 1 Thu 19:12Z 14-Jun-18