

Creating spatio-temporal tornado probability forecasts using fuzzy logic and motion variability

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[Motivation]

- Create a probabilistic forecast for an entity which moves and changes shape with time
 - Can not just make pixel-by-pixel forecast
 - Because threat area moves
 - Clearly specify the space and time of forecast

[Method]

- Choose reflectivity/velocity/derived fields
- Compute a fuzzy average of fuzzy membership of some of the chosen fields to produce a “tornado possibility”
- Form clusters of “tornado possibility” to track
- Truth the clusters
- Use truth to train a neural network to produce temporal tornado probabilities for identified clusters
- Compute motion variability using K-Means hierarchical technique
- Use motion variability to spread probability forecast in space

[Tracked Fields]

- Reflectivity
 - Low level (up to the Level of Free Convection)*
 - Aloft (above LFC)*
 - Distance to certain dBZ values (40, 45* dBZ)
 - Reflectivity gradients
- Velocity
 - Azimuthal shear (derived from LLSD)&
 - Low level*
 - Mid-level (LFC to half of the LFC to Equilibrium Level layer)*
 - Distance to maximum low level shear (0.003 s^{-1})*
 - Low level divergence (derived from LLSD)

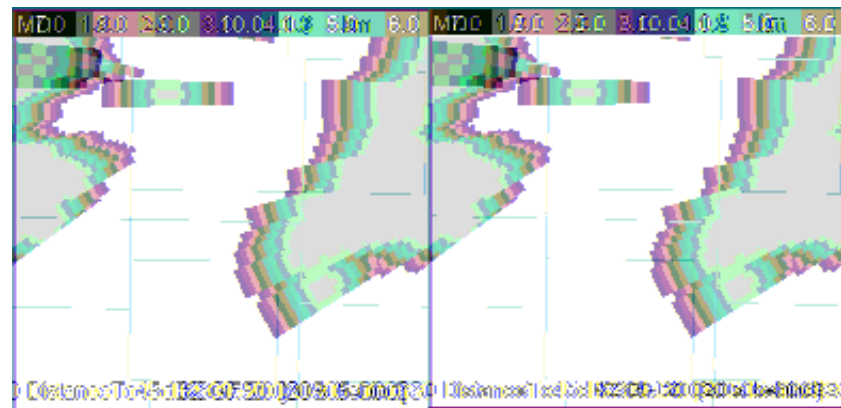
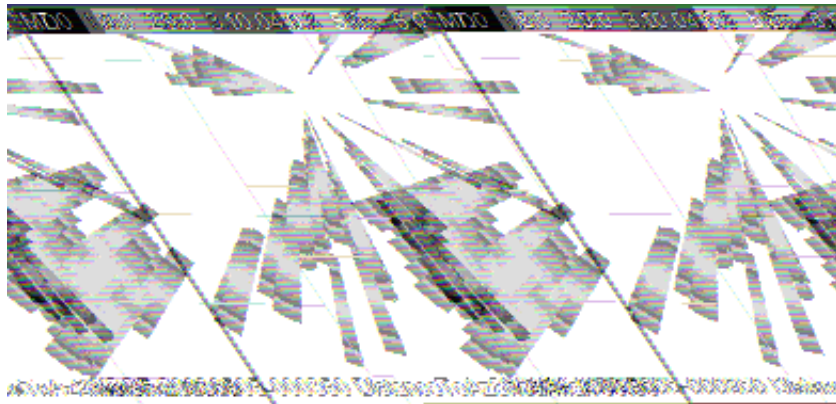
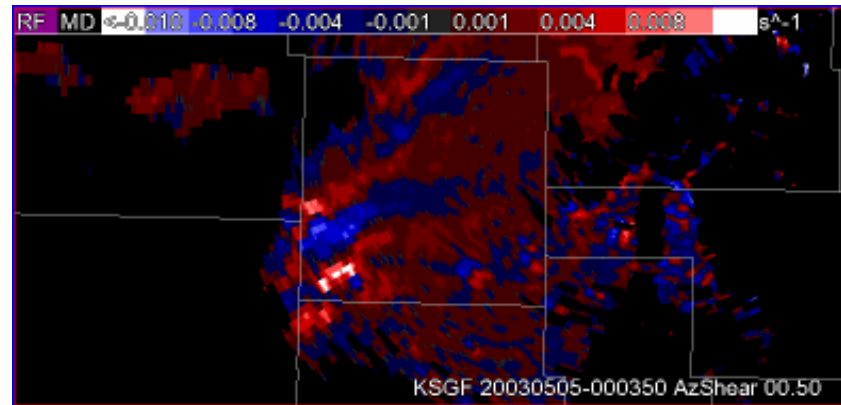
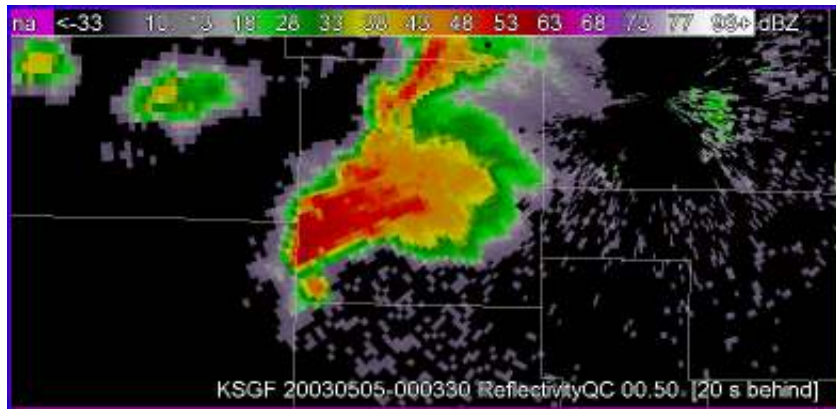
* Used for determining tornado possibility; other fields were used for NN training

& Shear was distance weighted. Thus, closer to the radar → mid-level shear is given a weighting to lower its value

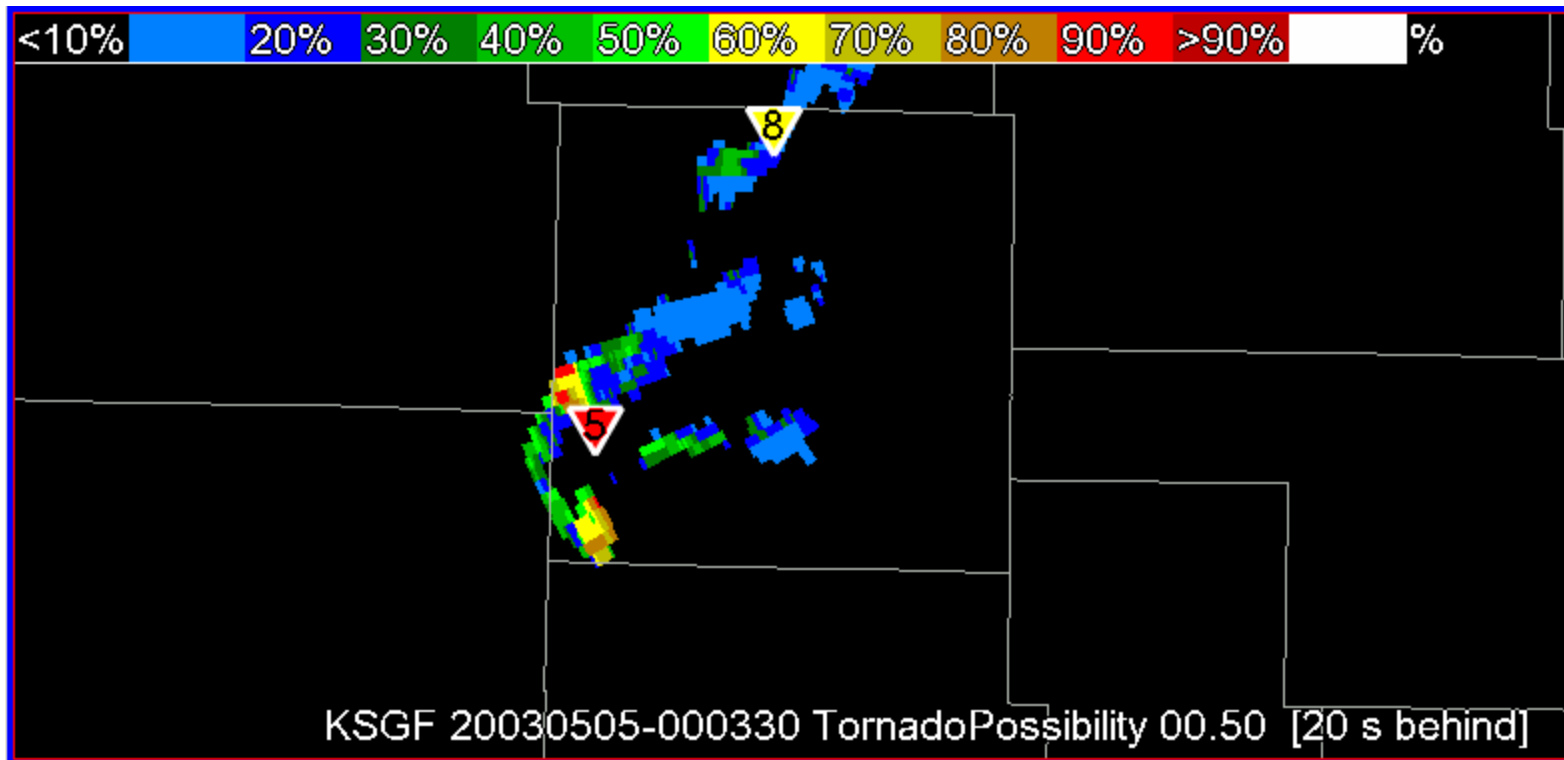
[Tornado Possibility]

- The educated guess
- Varied weights to fuzzy for fields until a satisfactory result was obtained
 - Wanted to focus on shear (received the largest weight)
 - Limit size of clusters with large probabilities

Tornado Possibility



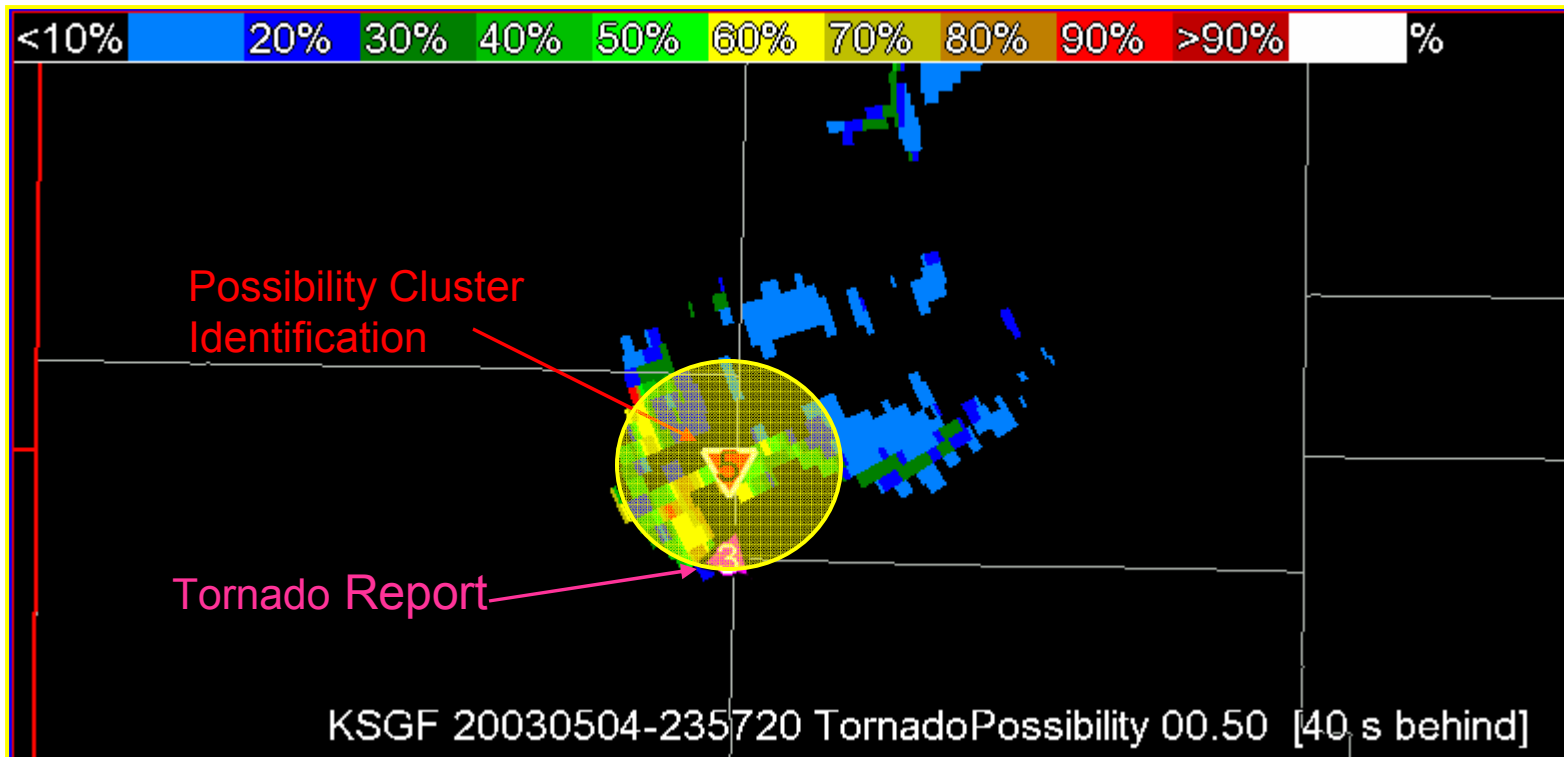
[Tornado Possibility]



[Truthing]

- Tornado possibility output was clustered together to make “cell” identifications
 - Possibility values were modified until a satisfactory result was obtained
- NN trained on 72 storm days
 - 51374 detections (3490 associated with tornadoes)
 - Used a 7.5 km search radius and a +/-5 minute time window

[Truthing]



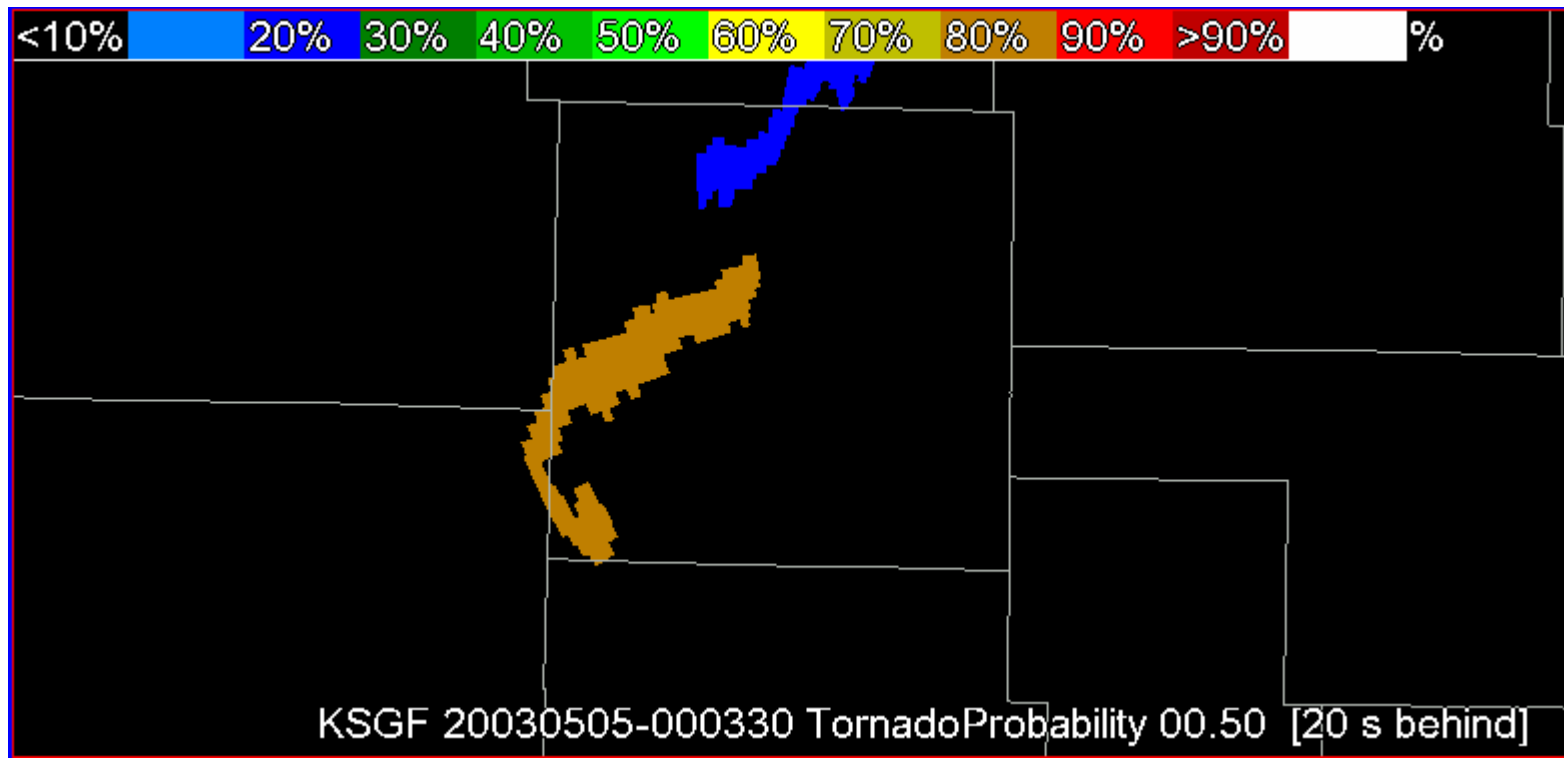
NN training: preparation

- Preparation of dataset
 - 51374 detections (3490 associated with tornadoes)
 - Split 60:40 into training/validation set
 - Repeat tornado observations until apriori probability of tornadoes is 50% in both training and validation data sets
- Used to train NN
 - Minimize cross-entropy on training set
 - Stop training if cross-entropy of validation set starts to increase

[NN training: architecture]

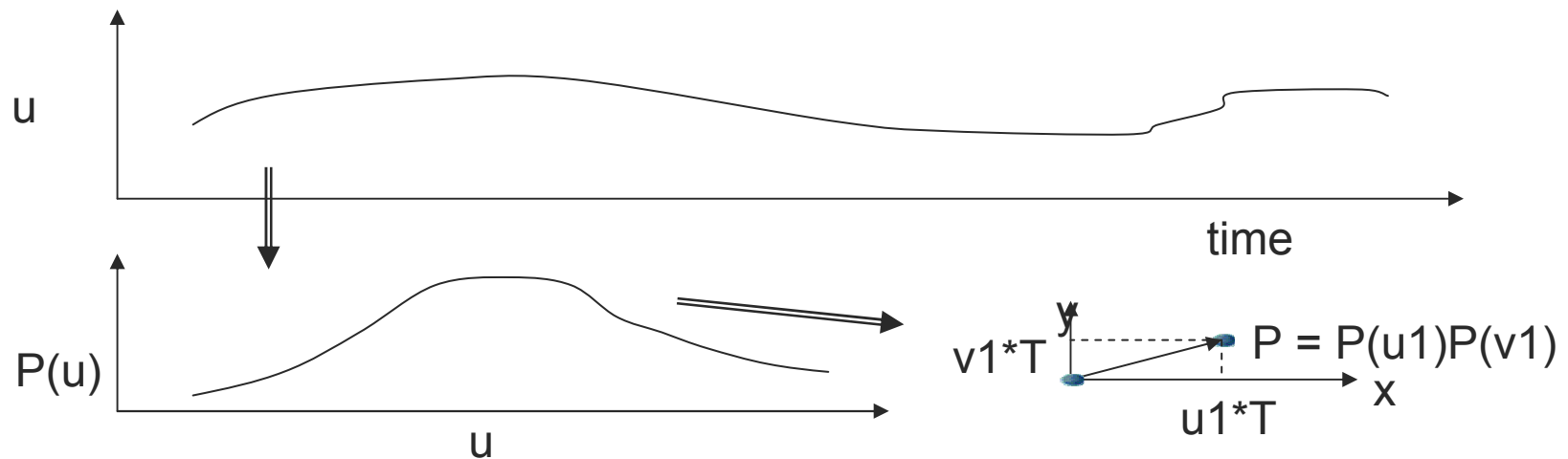
- One hidden layer with 1 to 8 hidden nodes
 - Ridge backpropagation
 - Final network had only one hidden node
- Heidke skill score on validation set of 0.53
 - No independent test set yet

[Tornado Probability]



Motion variability

- Track reflectivity composite across volume scans
 - Map motion variability in time to forecast of tornado location in the future



[Probability forecast swathe]

- Add snapshot here

[Summary]

- Probabilities looked okay
 - Temporal probabilities are realistic
 - Skill equivalent to WSR-88D TDA
- Clusters still too large
 - Tornado probability over time occupy unrealistically large areas
 - Spatial probabilities are not realistic