Application of the MODE Object-based Verification Tool for the Evaluation of WRF Precipitation Fields

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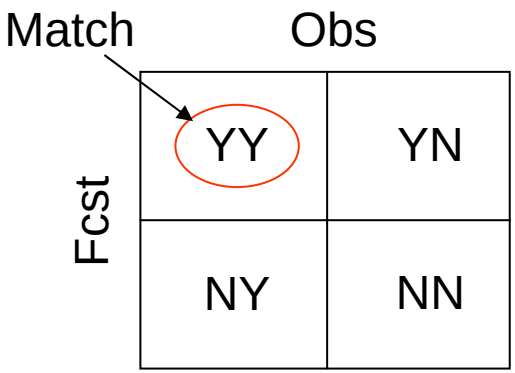
Traditional "Measures"-Based Approach

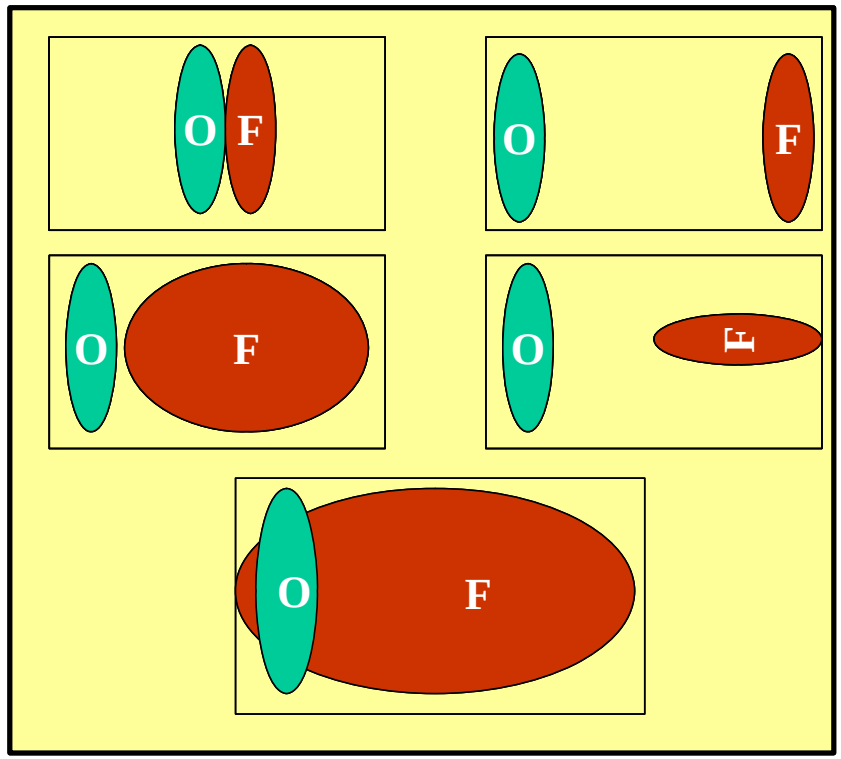
Consider forecasts and observations of some dichotomous field on a grid:



Critical Success Index
CSI=YY/(YY+NY+YN)

Equitable Threat Score

ETS=(YY-ε)/(YY+NY+YN-ε), where
ε=success due to chance

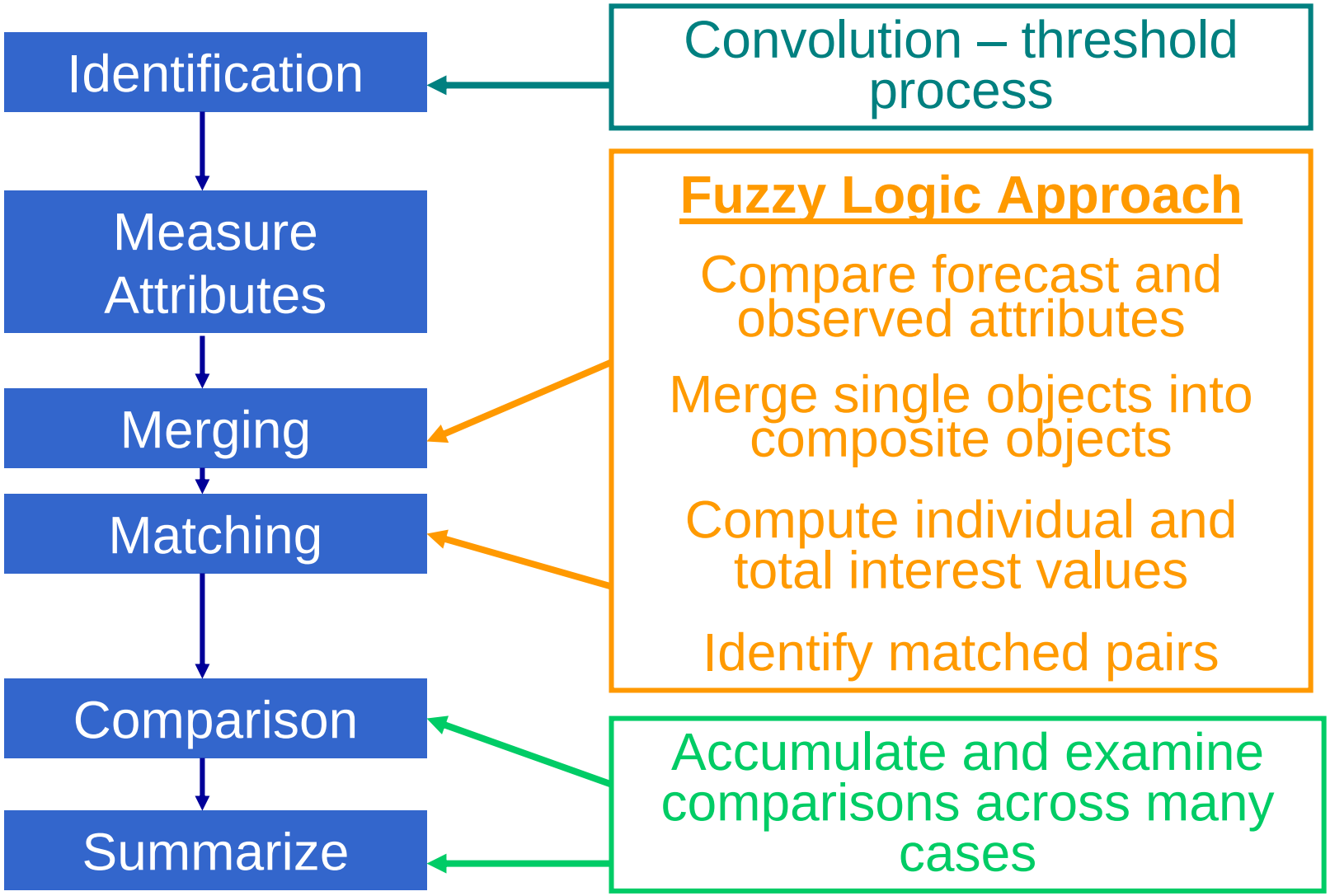


CSI = 0 for first 4;

CSI > 0 for the 5th

Non-diagnostic and utra-sensitive to small errors in simulation of localized phenomena

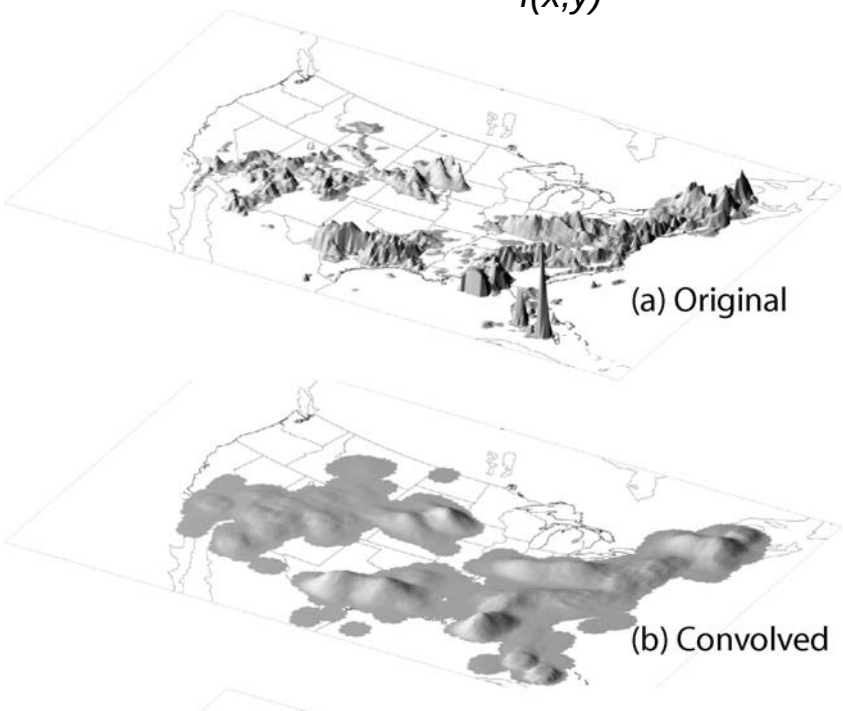
MODE*: Object-based approach



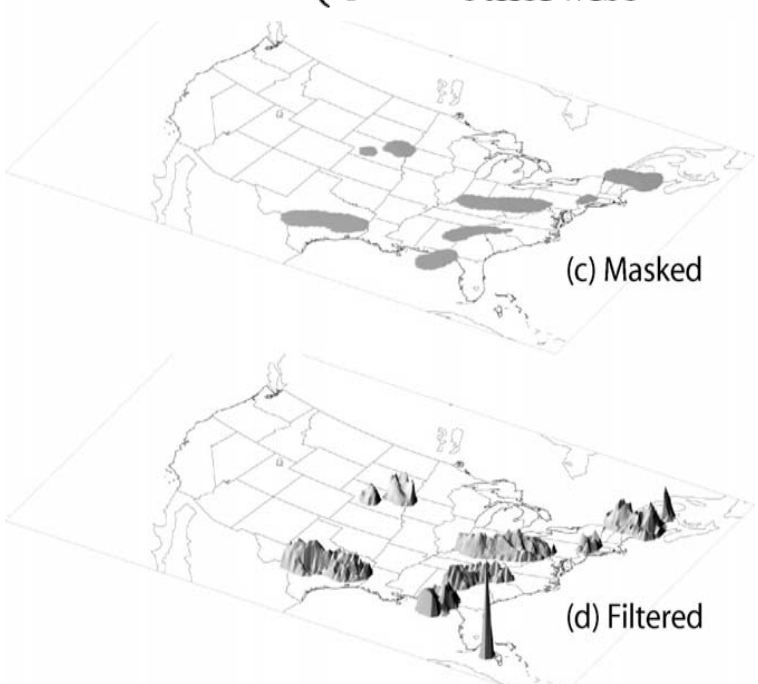
*Method for Object-based Diagnostic Evaluation

Object identification

f(x,y)



$$h(x,y) = \begin{cases} 1 & \text{if } g(x,y) \geq T \\ 0 & \text{otherwise} \end{cases}$$



Restore original field where h(x,y) =1

$$g(x,y) = \sum_{(u,v)\in G} \phi(u,v)\, f(x-u, y-v)$$

$$\phi(x,y) = \begin{cases} H & \text{if } x^2 + y^2 \leq R^2 \\ 0 & \text{otherwise} \end{cases}$$

$$\pi R^2 H = 1.$$

2 parameters:

1. Convolution radius, R
2. Threshold, T

Object merging and matching

- Definitions
  - *Merging*: Associating objects in the same field
  - *Matching*: Associating objects between fields
- Fuzzy logic approach
- *Attributes* – used for matching, merging, evaluation

Example single attributes:

- Location
- Size (area)
- Orientation angle
- Intensity (0.10, 0.25, 0.50, 0.75, 0.90 quantiles)

Example paired attributes:

- Centroid/boundary distance
- Size ratio
- Angle difference
- Intensity differences

interest

$$T(\alpha) = \frac{\sum_i w_i C_i(\alpha) I_i(\alpha)}{\sum_i w_i}$$

Initial weights

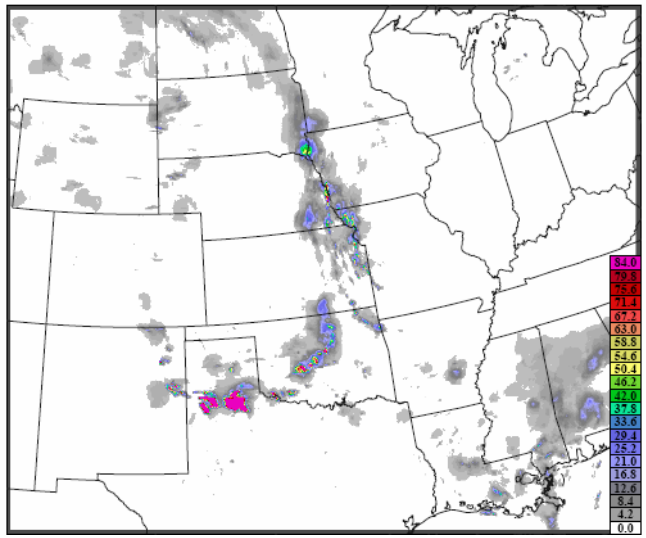
- Centroid distance: 2
- Boundary distance: 4
- Angle difference: 2
- Intensity ratio: 0
- Area ratio: 1
- Intersection/Area: 2

Apply threshold to Total Interest to determine merges/matches.

Initial threshold: 0.7

Observations and model

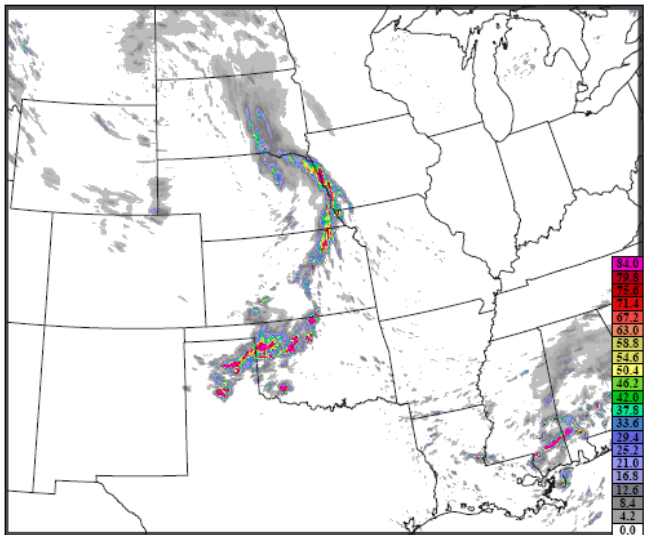
- *Forecasts*: Weather Research and Forecasting (WRF) model
  - Advanced Research WRF (ARW), 2-km mapped to 4-km grid spacing
  - Forecasts initialized at 0000 UTC from Eta initial conditions
  - 24-h lead
  - 1-h precipitation accumulation
  - 18 April – 4 June, 2005; 9 cases selected for extensive study
  - Study Domain: United States, Rocky Mountains (west) to Appalachian Mountains (east)
- *Observations*: Multi-sensor hourly accumulated precipitation
  - Stage II on 4-km grid

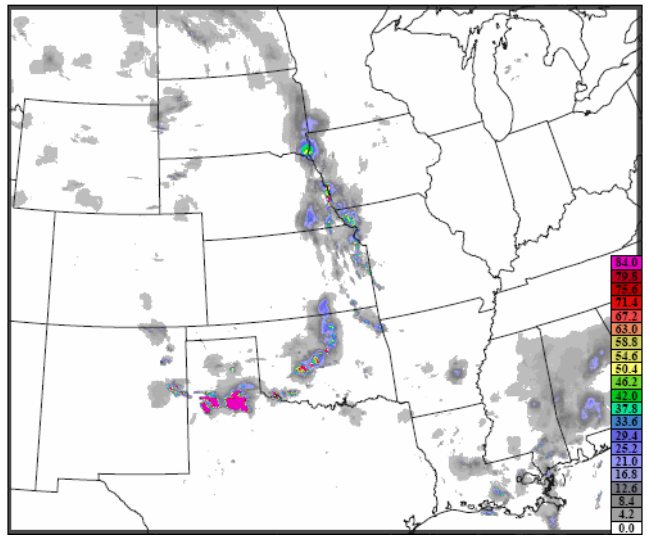


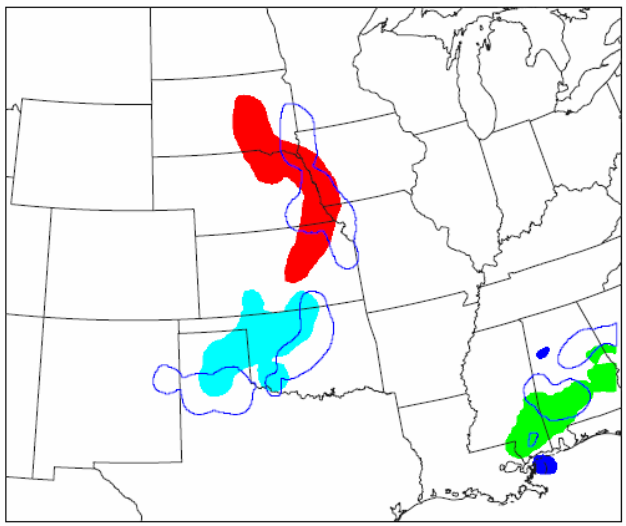
Stage II precipitation estimate; 1 June 2005, 0000 UTC

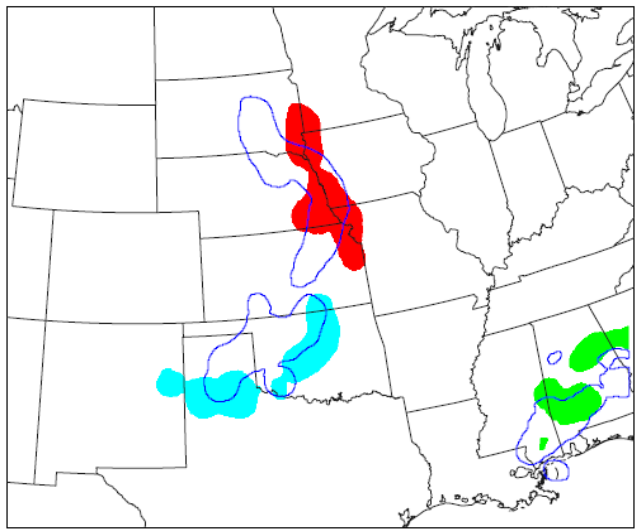
Object-based example: 1 June 2005

WRF (24-h)





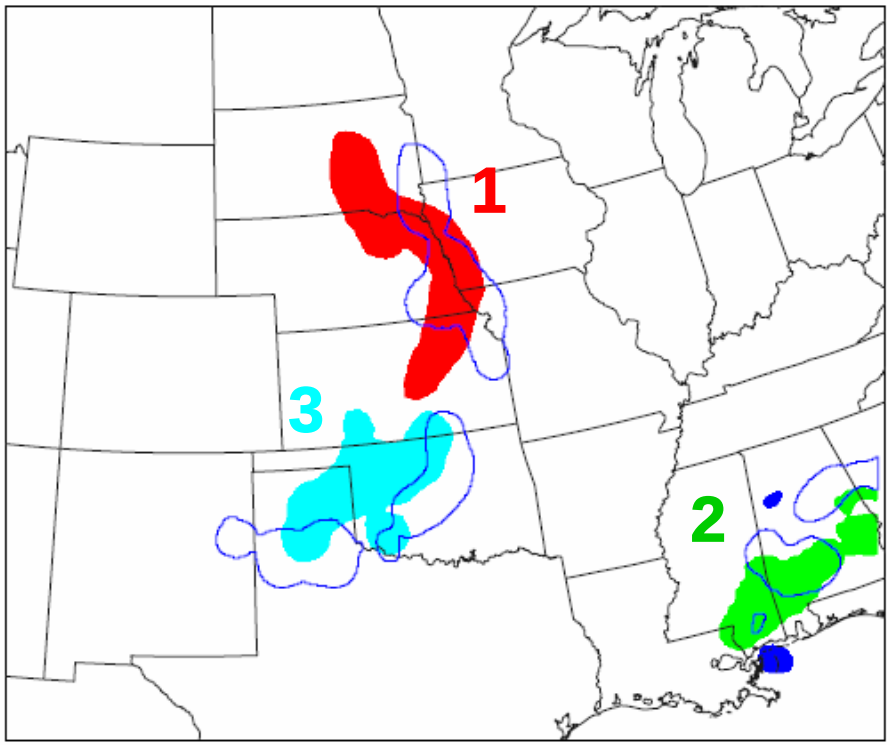




Stage II

Radius = 15 grid squares, Threshold = 0.05”

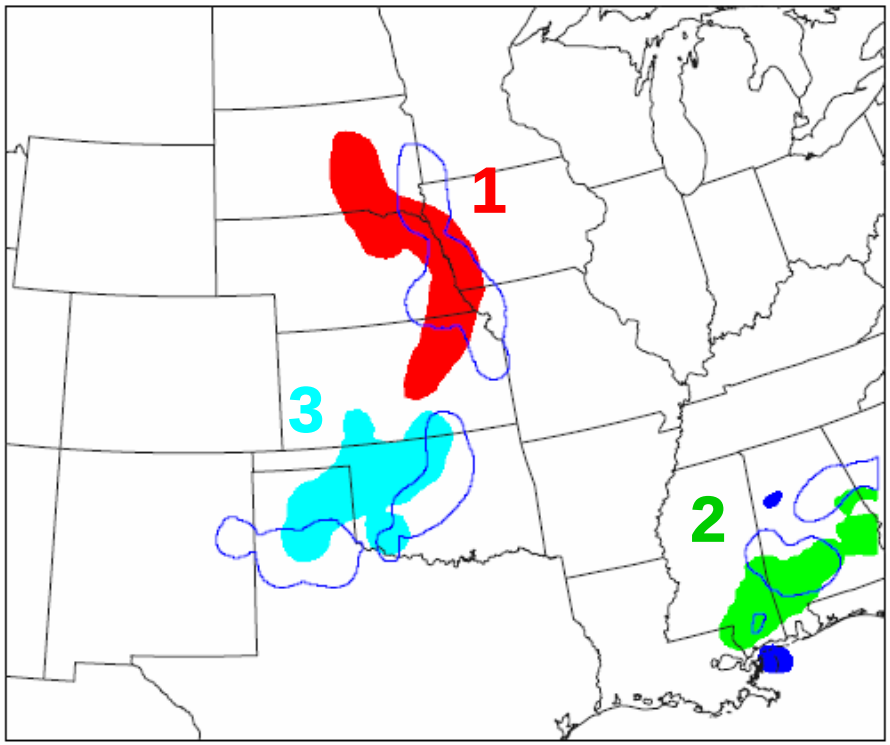
Object-based example 1 June 2006



WRF ARW-2 Objects with Stage II Objects overlaid

- Area ratios
  - (1) 1.3
  - (2) 1.2
  - (3) 1.1
  - All forecast areas were somewhat too large
- Location errors
  - (1) Too far West
  - (2) Too far South
  - (3) Too far North

Object-based example 1 June 2006

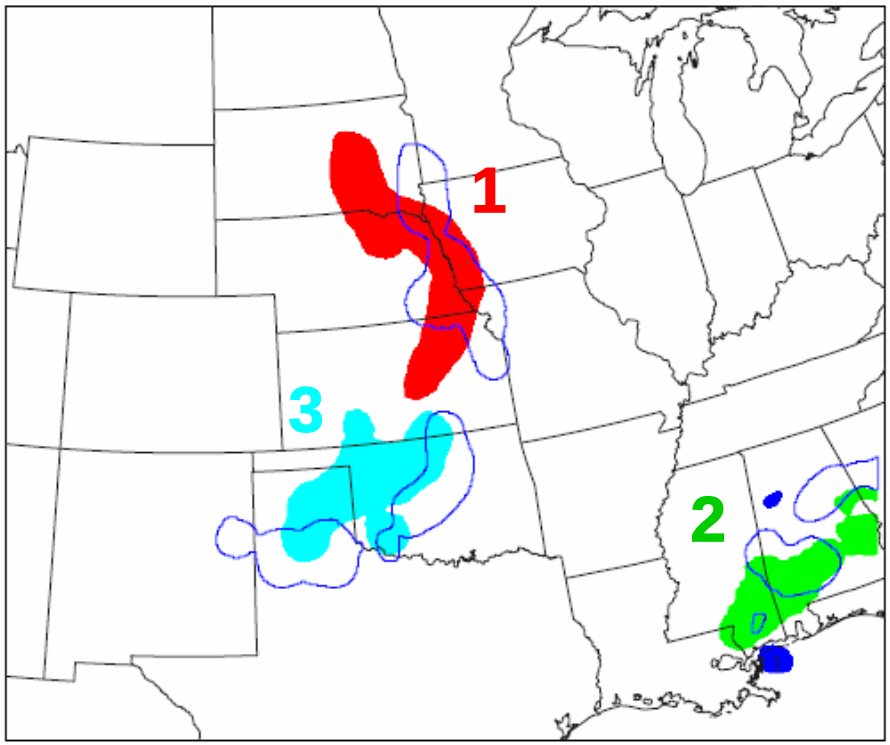


WRF ARW-2 Objects with Stage II Objects overlaid

- Median intensity ratio
  - (1) 1.3
  - (2) 0.7
  - (3) 1.9
- 0.90th intensity ratio
  - (1) 1.8
  - (2) 2.9
  - (3) 1.1

All WRF 0.90th intensities were too large; 2 of 3 median intensity values were too large

Object-based example 1 June 2006

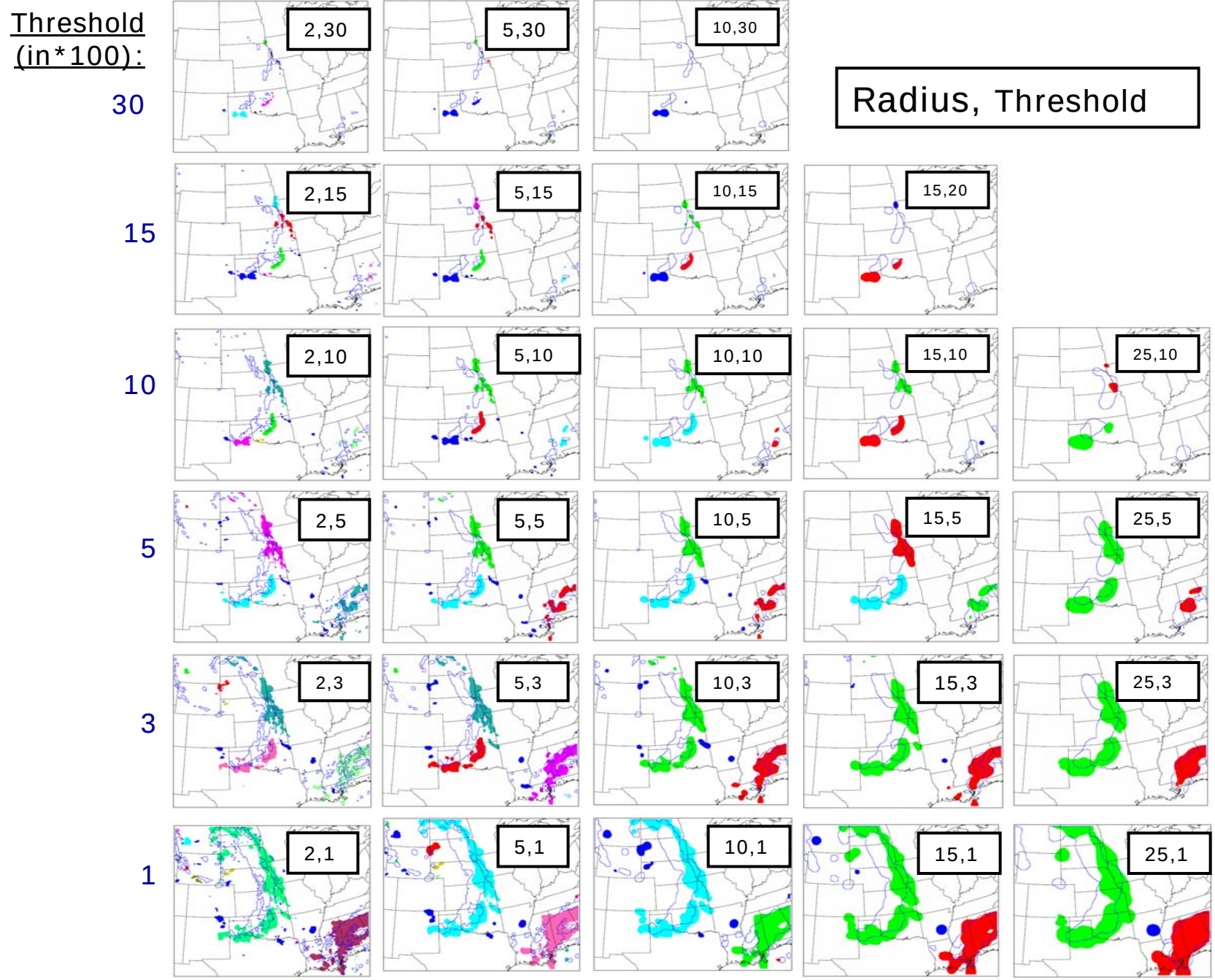


WRF ARW-2 Objects with Stage II Objects overlaid

- MODE provides info about areas, displacement, intensity, etc.
- In contrast:
  - POD = 0.40
  - FAR = 0.56
  - CSI = 0.27

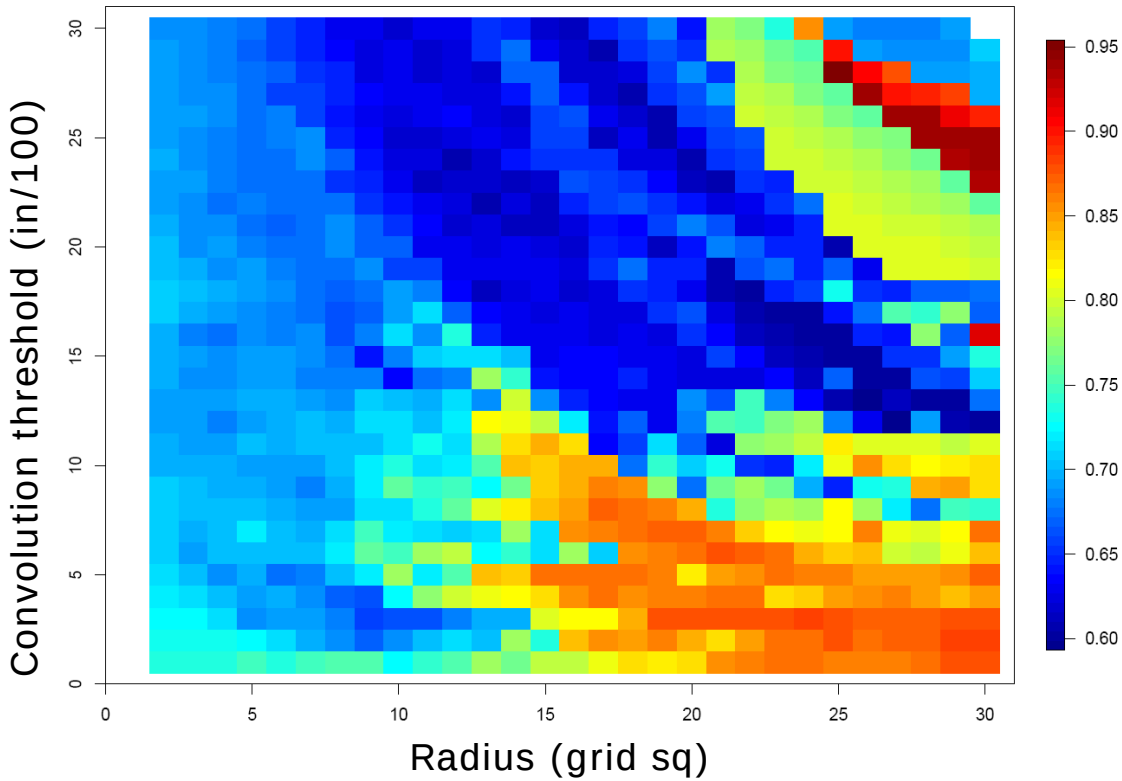
Issues: Object scale

- How should object identification parameters (radius, threshold) be selected?
- Alternative question: What scale(s) are appropriate and meaningful?


Threshold (in*100):
30
15
10
5
3
1
2,30
5,30
10,30
2,15
5,15
10,15
15,20
2,10
5,10
10,10
15,10
25,10
2,5
5,5
10,5
15,5
25,5
2,3
5,3
10,3
15,3
25,3
2,1
5,1
10,1
15,1
25,1
Radius, Threshold
Radius (grid boxes):
2
5
10
15
25

Verification "Quilts"

- Forecast performance attributes as a function of spatial scale
- Similar to charts developed by Casati, Marzban, Ebert
- Can be created for almost any attribute or statistic



Verification quilt showing a measure of matching capability. Warm colors indicate stronger matches.

Based on 9 cases

Summary and Conclusions

- MODE tool is one (of several) new diagnostic approaches for evaluating spatial forecasts
- MODE will be included in the DTC's new "Model Evaluation Tools" (MET)
- Verification "quilts"
  - Help define scales with potential skill
  - Allow examination of attributes and skill as a function of scale