Developments in Object-based Verification: Model Intercomparison and Incorporation of the Time Dimension

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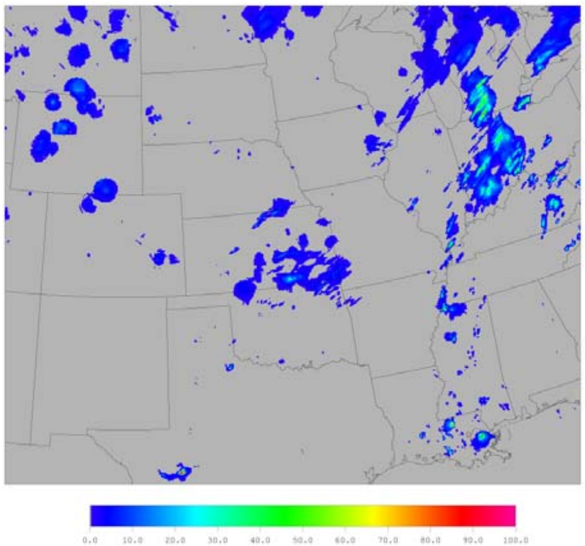
Comparison of Rainfall Forecasts

Stage 2 gauge+radar

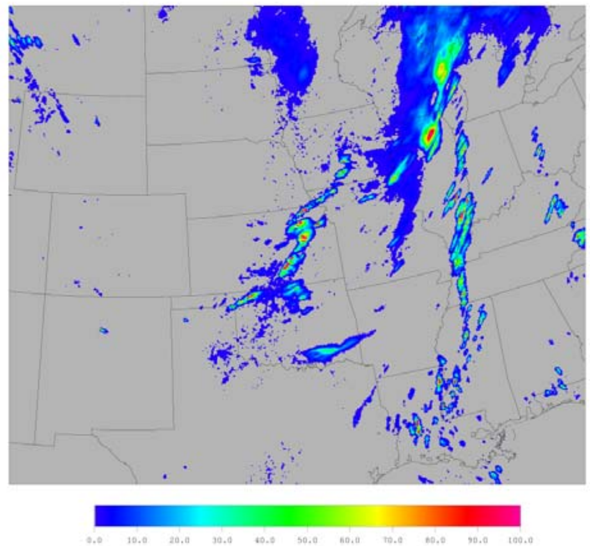
ST2ml_2005051321.g240.txt



0.01 1.0

NCEP WRF Δx=4.5 km

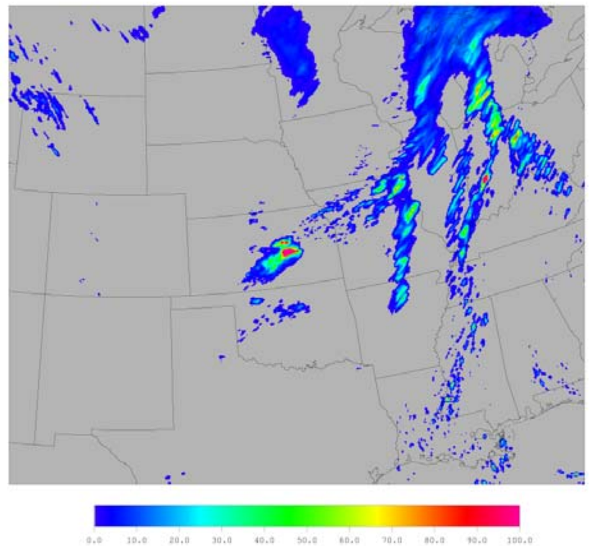
wrf4ncep_2005051300.g240.f21.txt



0.01 1.0

NCAR WRF Δx=4.0 km

wrf4ncar_2005051300.g240.f21.txt



0.01 1.0

Hourly rainfall in hundredths of inches

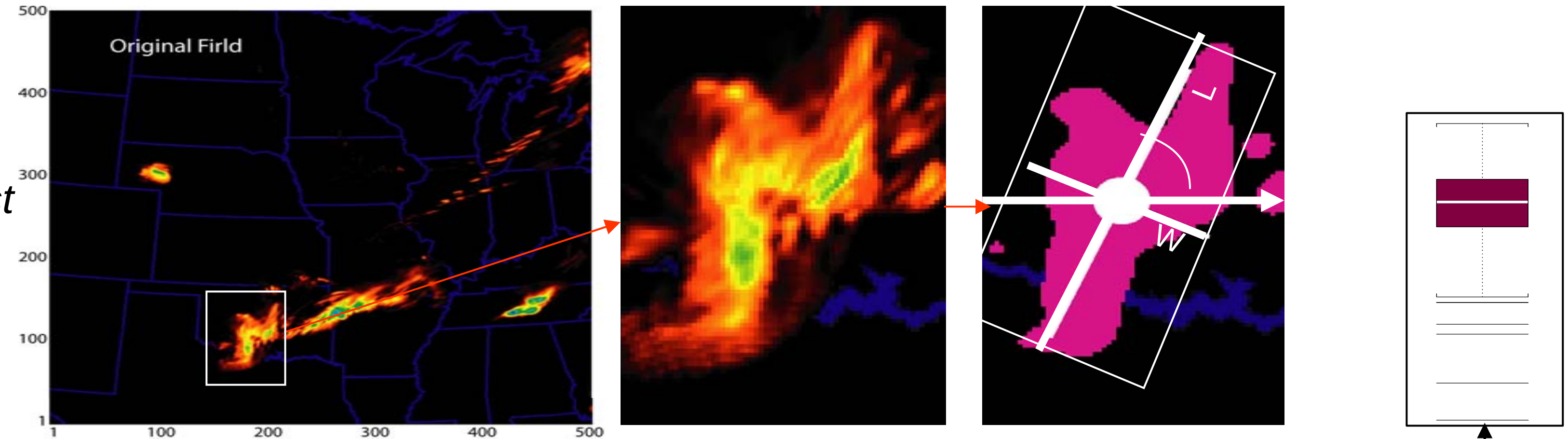
Data, Models and Method

- Study Domain: United States, Rocky Mountains (west) to Appalachian Mountains (east)
- Purpose: Evaluate 2 cores of the Weather Research and Forecasting (WRF) model using object-based verification methods
  - Advanced Research WRF (ARW), 4-km grid spacing
  - Nonhydrostatic Mesoscale Model (NMM), 4.5-km grid spacing
- Time Period: 18 April – 4 June, 2005
- 30-h forecasts initialized at 00 UTC from Eta initial condition
- Data: Hourly accumulated precipitation from NCEP – Stage IV on 4-km grid
- Method: MODE object identification and attribute definition
  - Examine statistics of unmatched objects
  - Perform merging and matching: compare stats of matched objects

Kain, J. S., S. J. Weiss, M. E. Baldwin, G. W. Carbin, D. Bright, J. J. Levit, and J. A. Hart, 2005: Evaluating high-resolution configurations of the WRF model that are used to forecast severe convective weather: The 2005 SPC/NSSL Spring Experiment. 17th Conference on Numerical Weather Prediction. American Meteorological Society, Paper 2A.5

Objects and Their Attributes

Raw Forecast



Steps:

➢**Convolution (disk of radius 5 grid points)**

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

➢**Thresholding: Rainfall > T (1.25 mm/h)**

➢**Compute geometric attributes**

➢**Restore precip values inside object, examine distribution (box and whisker plot)**

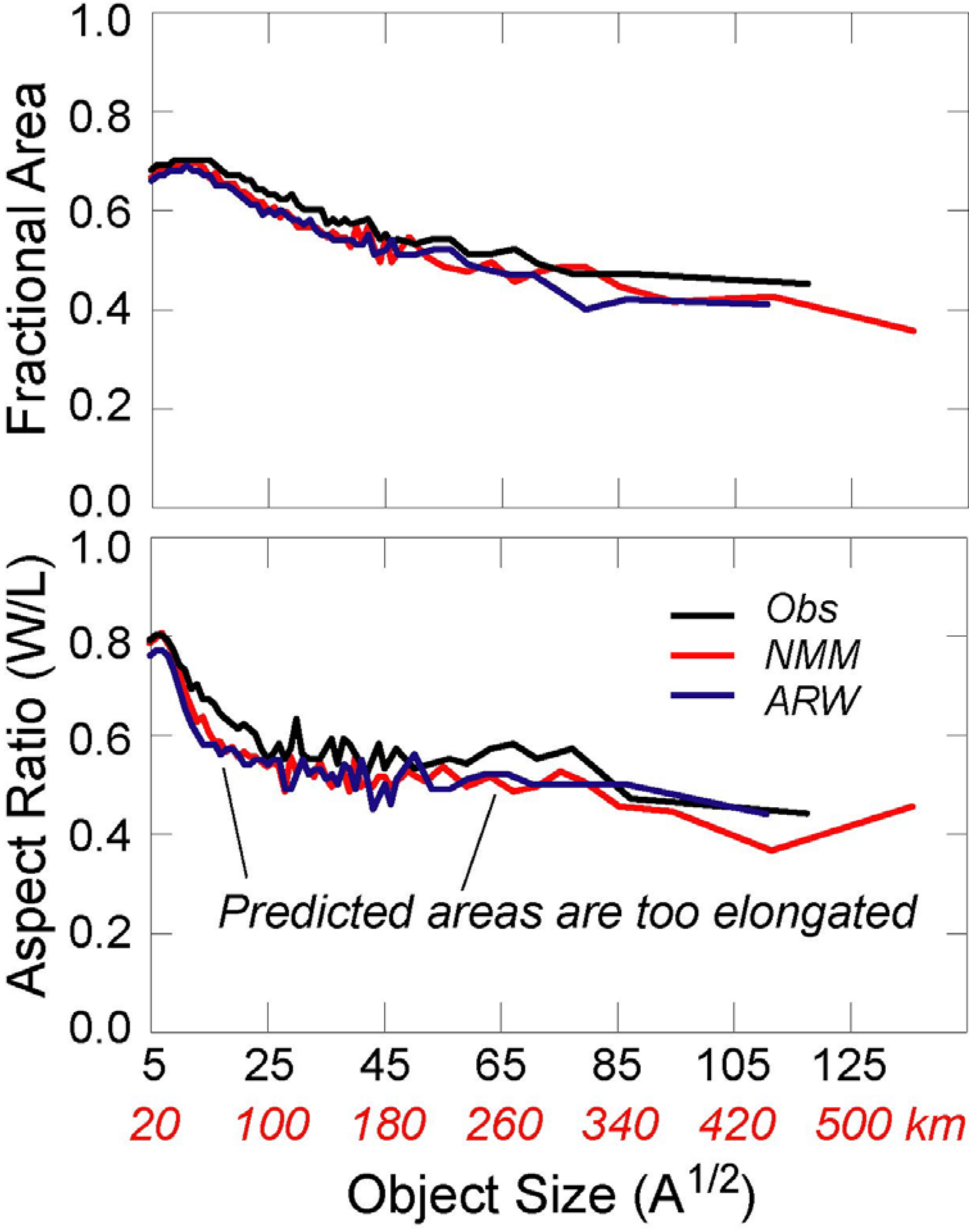
- **Intensity** (percentile value)
- **Area** (# grid points > T)
- **Centroid**
- **Axis angle** (rel. to E-W)
- **Aspect ratio** (W/L)
- **Fractional Area**

Merging and Matching

- Merging of objects in forecast and observed fields (done separately for each)
  - Based entirely on separation of object centroids (Less than min(400 km, W_1 + W_2)
  - Area, length and width of merged areas = sum of objects merged
  - Position = weighted average of objects merged (weighting by area):

$$x_{merged} = \frac{A_1}{A_1 + A_2} x_1 + \frac{A_2}{A_1 + A_2} x_2$$

- Matching of forecast and observed objects
  - Similar criteria for merging, except threshold is min(200 km, W_1 + W_2)



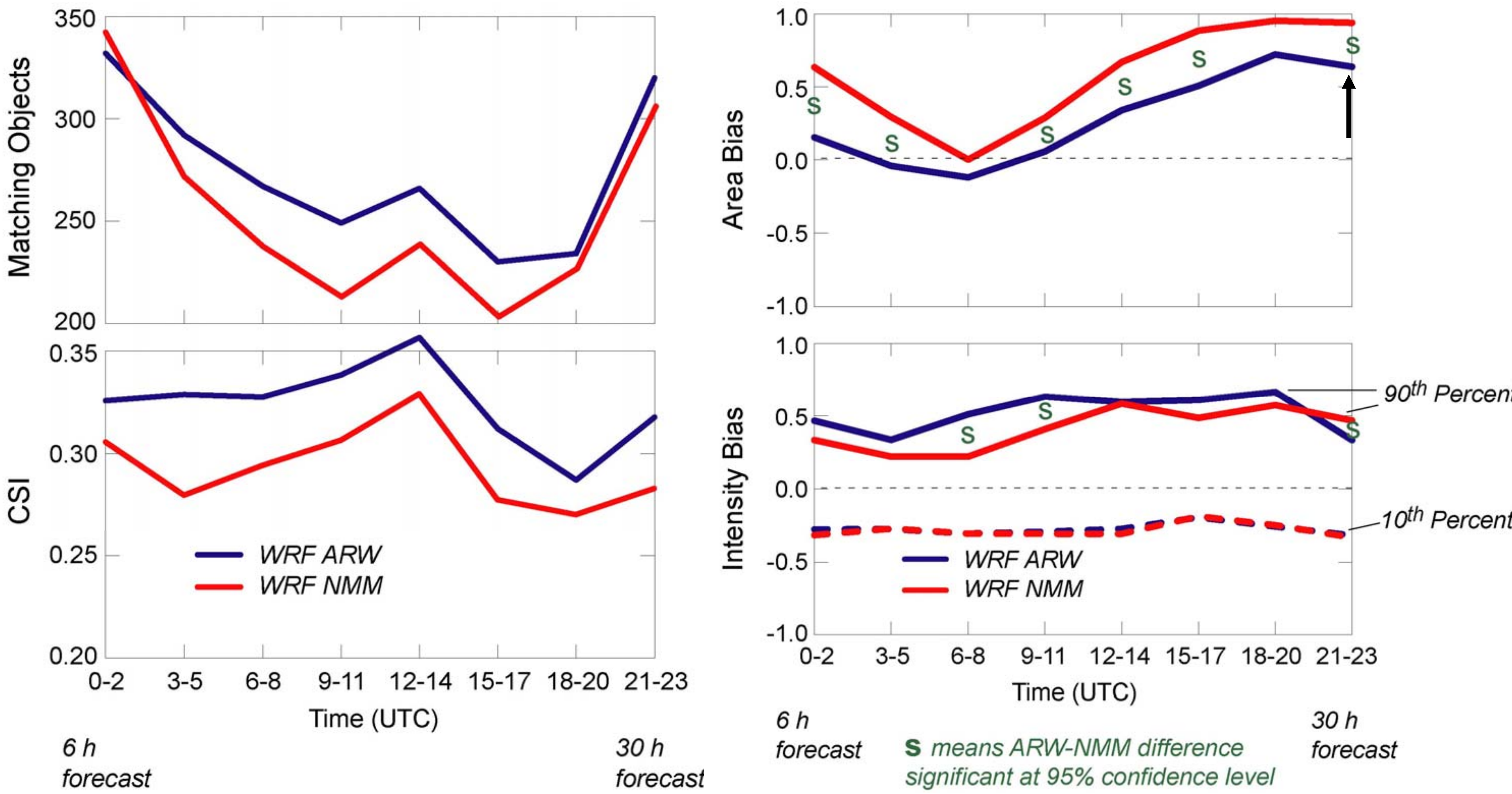
Attributes:

Fractional Area (top panel): Fraction of the minimum bounding rectangle that an object occupies

Aspect ratio (bottom panel): W/L

Abscissa: object size = square root of object area, expressed as number of grid cells and as kilometers.

- Objects too narrow
  - Insufficient stratiform precip?
  - Response to frontal forcing?

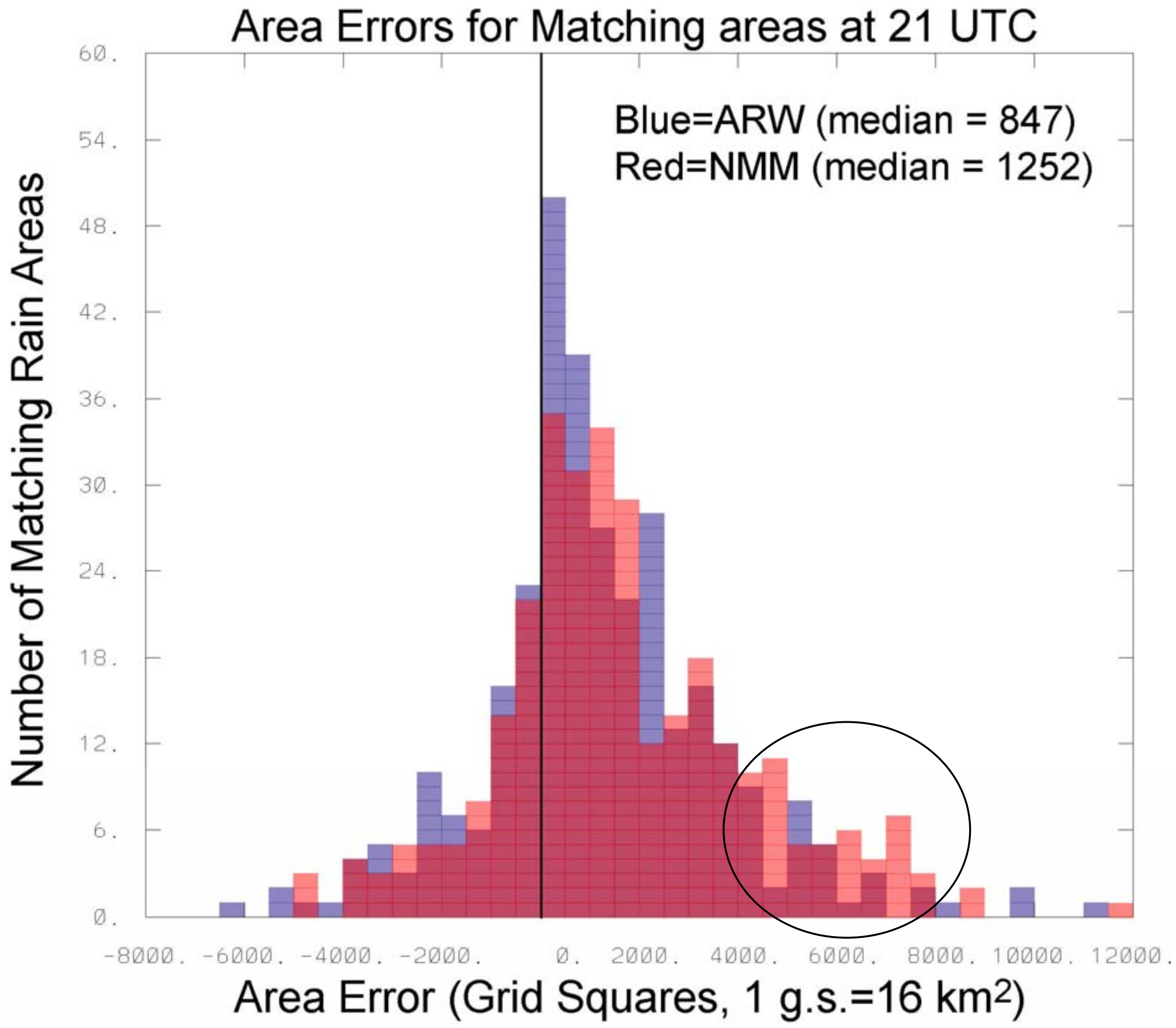


Matching Objects
350
300
250
200
CSI
0.35
0.30
0.25
0.20
WRF ARW
WRF NMM
0-2
3-5
6-8
9-11
12-14
15-17
18-20
21-23
Time (UTC)
6 h forecast
30 h forecast
Area Bias
1.0
0.5
0.0
-0.5
-1.0
S
Intensity Bias
90th Percent
10th Percent
WRF ARW
WRF NMM
Time (UTC)
6 h forecast
30 h forecast
S means ARW-NMM difference significant at 95% confidence level

Error Distributions

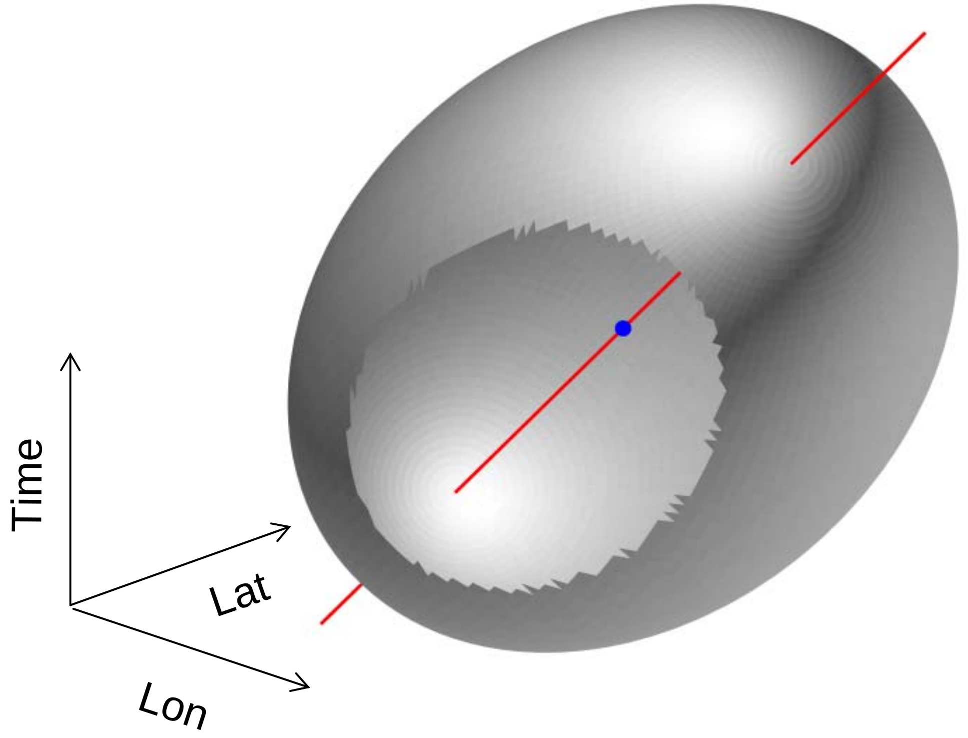
Both models produce areas that are too large

NMM has more large errors



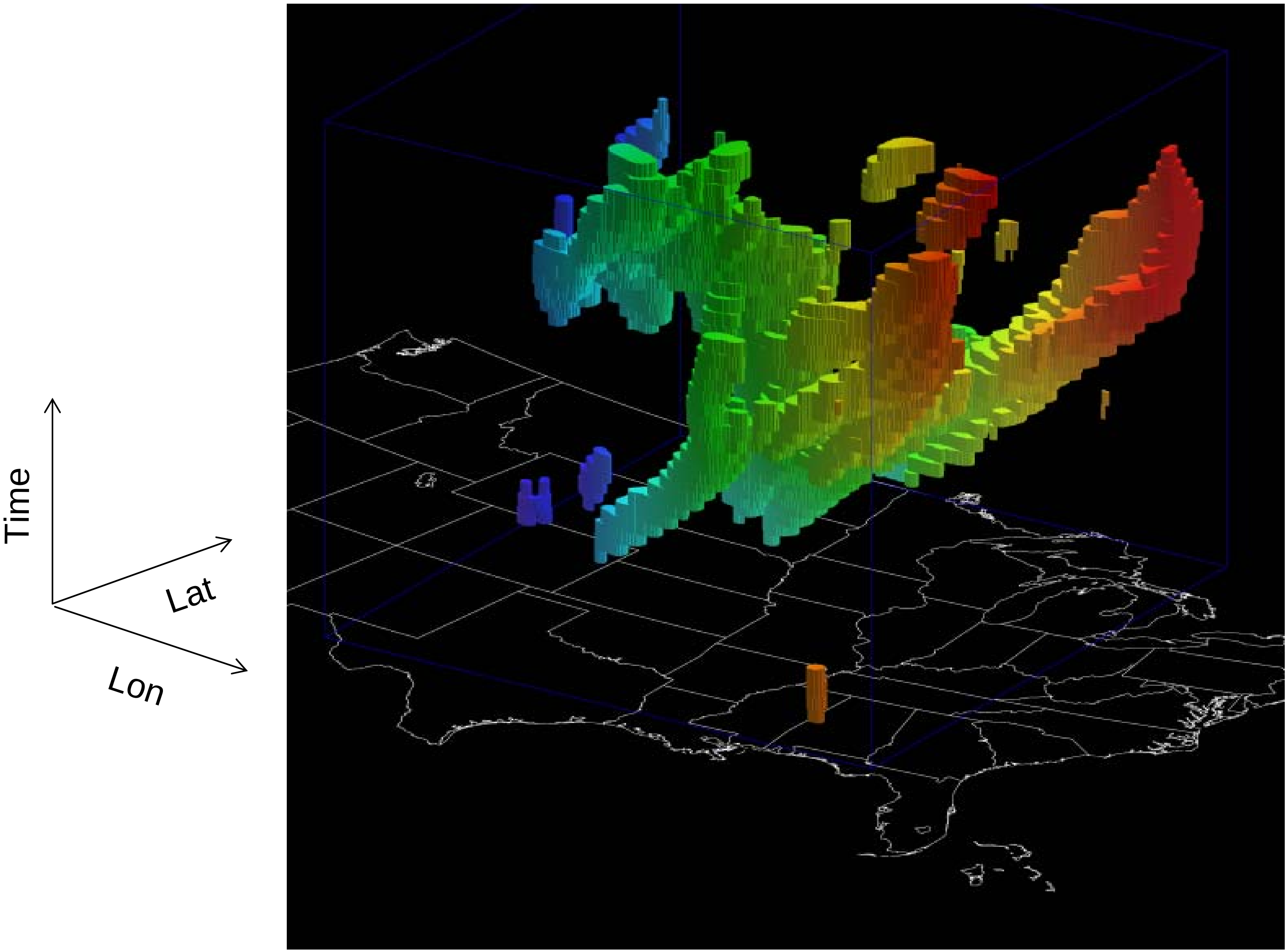
Objects in Three Dimensions

(x,y,t)



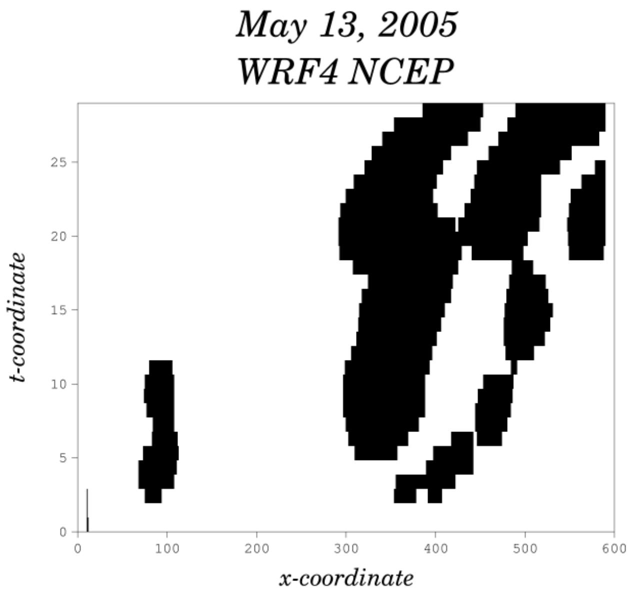
Centroid

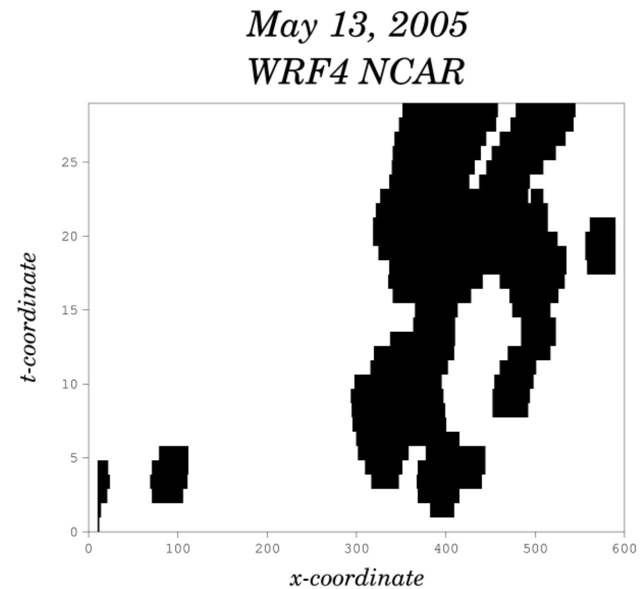
and Axis


Time
Lat
Lon

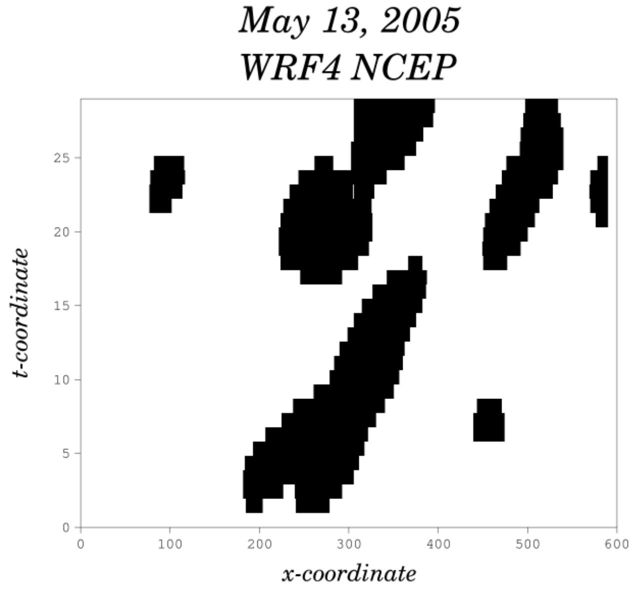
2-D Slices of 3-D Objects

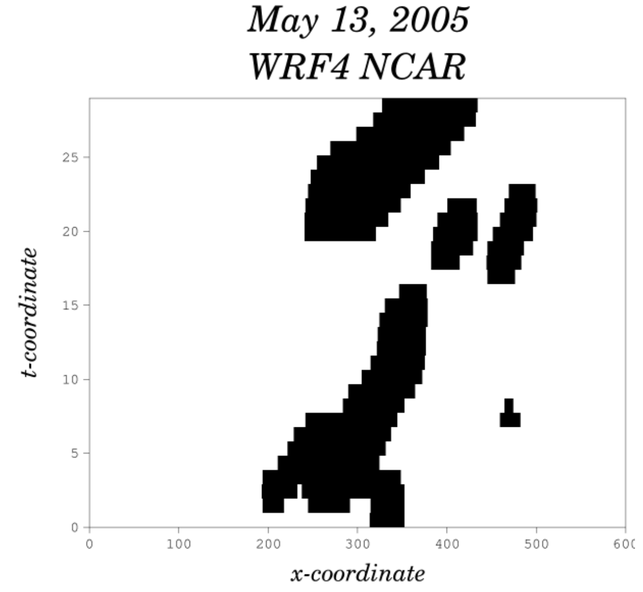
Y=300
(1200 km)





Y=200
(800 km)





Conclusions

- Models make rain areas too narrow; lack of stratiform rain?
- Significant positive bias in size of rain areas in both models, larger for NMM
- Too much heavy rain. Rainfall distributions too broad.
- CSI for matching lowest in the afternoon, slightly higher for ARW.
- Not enough moderate (stratiform) rainfall
- Object definitions generalizable to 3-D.
    - Timing and propagation errors can be assessed
    - Fewer objects to compare