MODE-3D: Incorporation of the time dimension

Randy Bullock, Chris Davis, and Barbara Brown*

National Center for Atmospheric Research

Boulder, Colorado, USA

**bgb@ucar.edu*

NCAR

Motivation

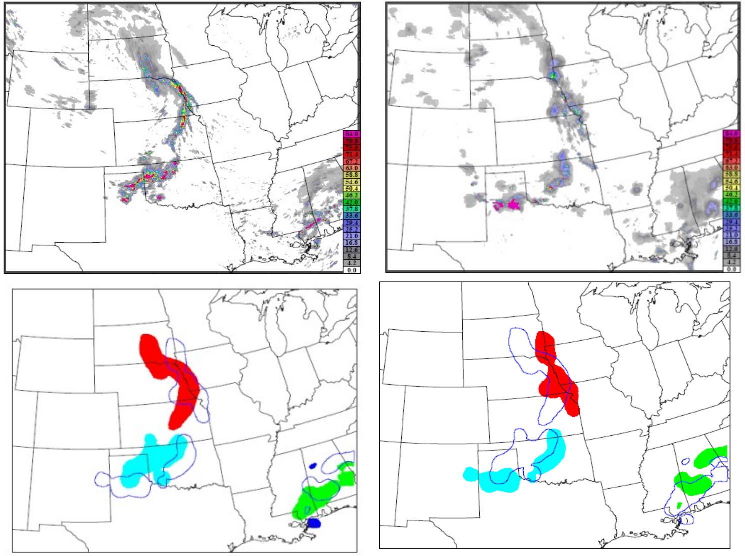
- Limitations of traditional metrics
- Advantages of feature-based verification methods
  - More diagnostic
  - Less sensitive to small errors
- Life-cycles of weather systems are foremost consideration to forecasters

➢ ***Extend spatial verification methods to include time***

MODE: Method for Object-based Diagnostic Evaluation

- Developed for 2-D fields
- Define objects by *convolution* and *thresholding* process
  - Radius and Threshold parameters define scale(s) of interest
- Measure meaningful object attributes
  - *Ex*: Location, Area, Intensity distribution
  - Can be user-defined
- Use attribute comparisons to
  - Identify matched forecast and observed objects using attributes
  - Measure and summarize forecast performance

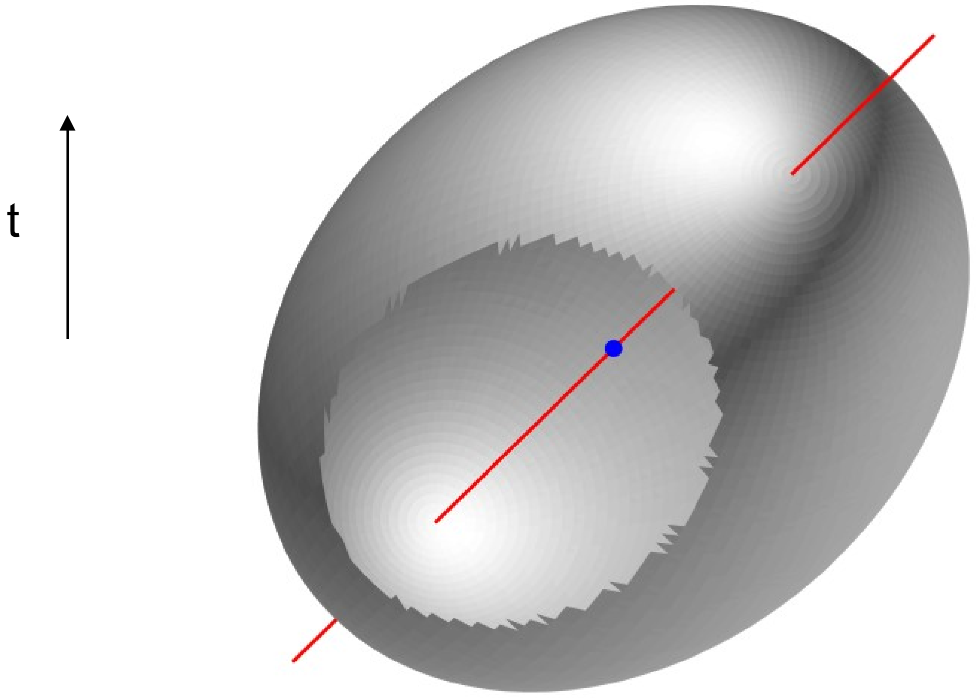
Example: Precipitation; 1 Jun 2005



Forecast Observed

MODE 2D Example: Forecast performance is poor (CSI=0.27) with traditional methods. MODE indicates good performance, with some errors in placement and intensity.

Rain Systems (x,y,t)



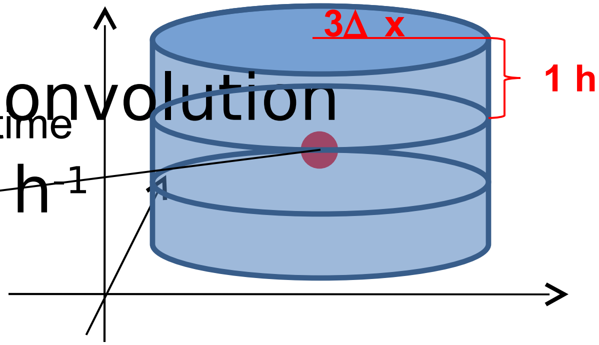
Centroid

and Axis

Angle the axis makes with the (x,y) plane determines the system speed

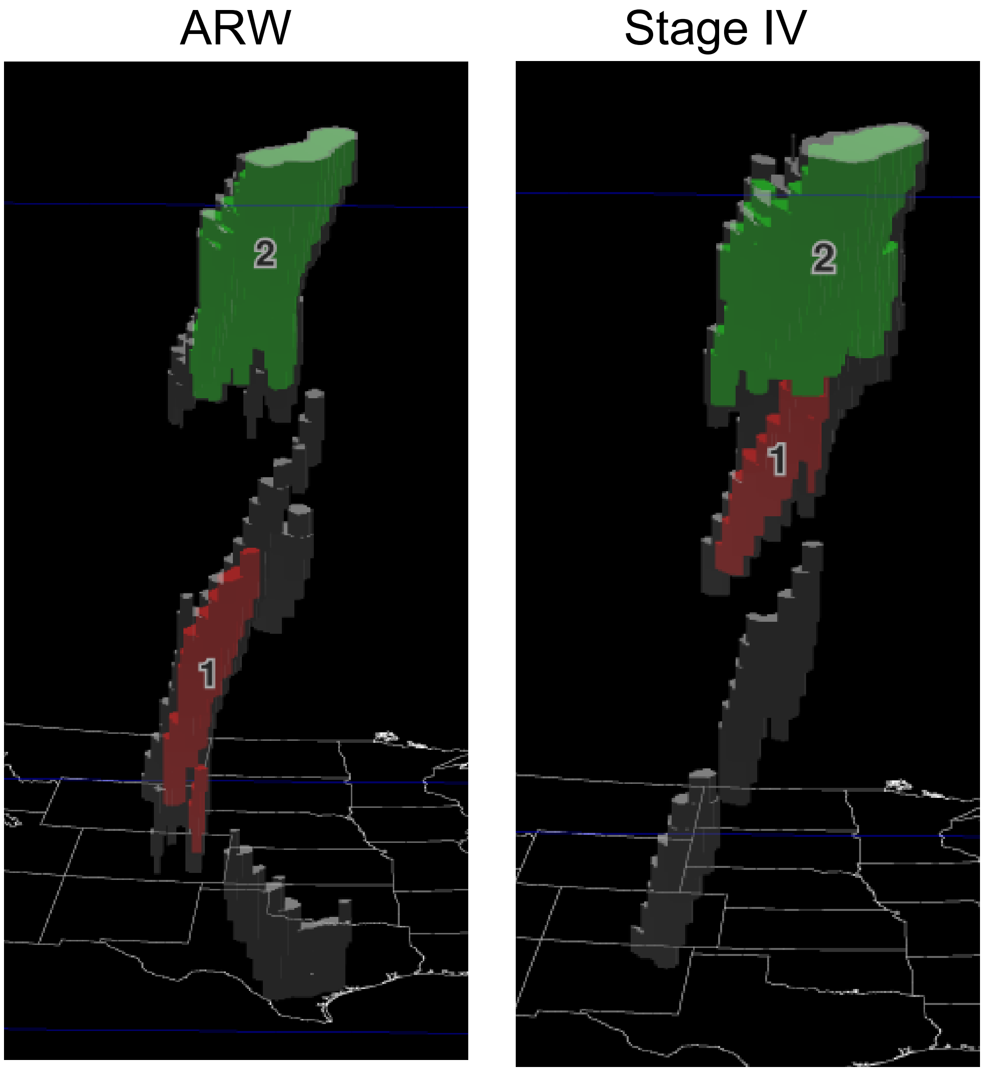
Object Identification in 3-D

- Begin with WRF ARW (4-km) and Stage IV (4-km) hourly accumulated precipitation data.
- Coarsen both to identical grid of 12-km spacing
- Apply convolution (smoothing) and filtering in 3-D
  - 3Δ x, ±1-h “cylindrical” convolution
  - Threshold = 2 and 4 mm h^{-1}



Replace value of rainfall at central point with average rainfall within cylinder

IHOP, June 15, 2002

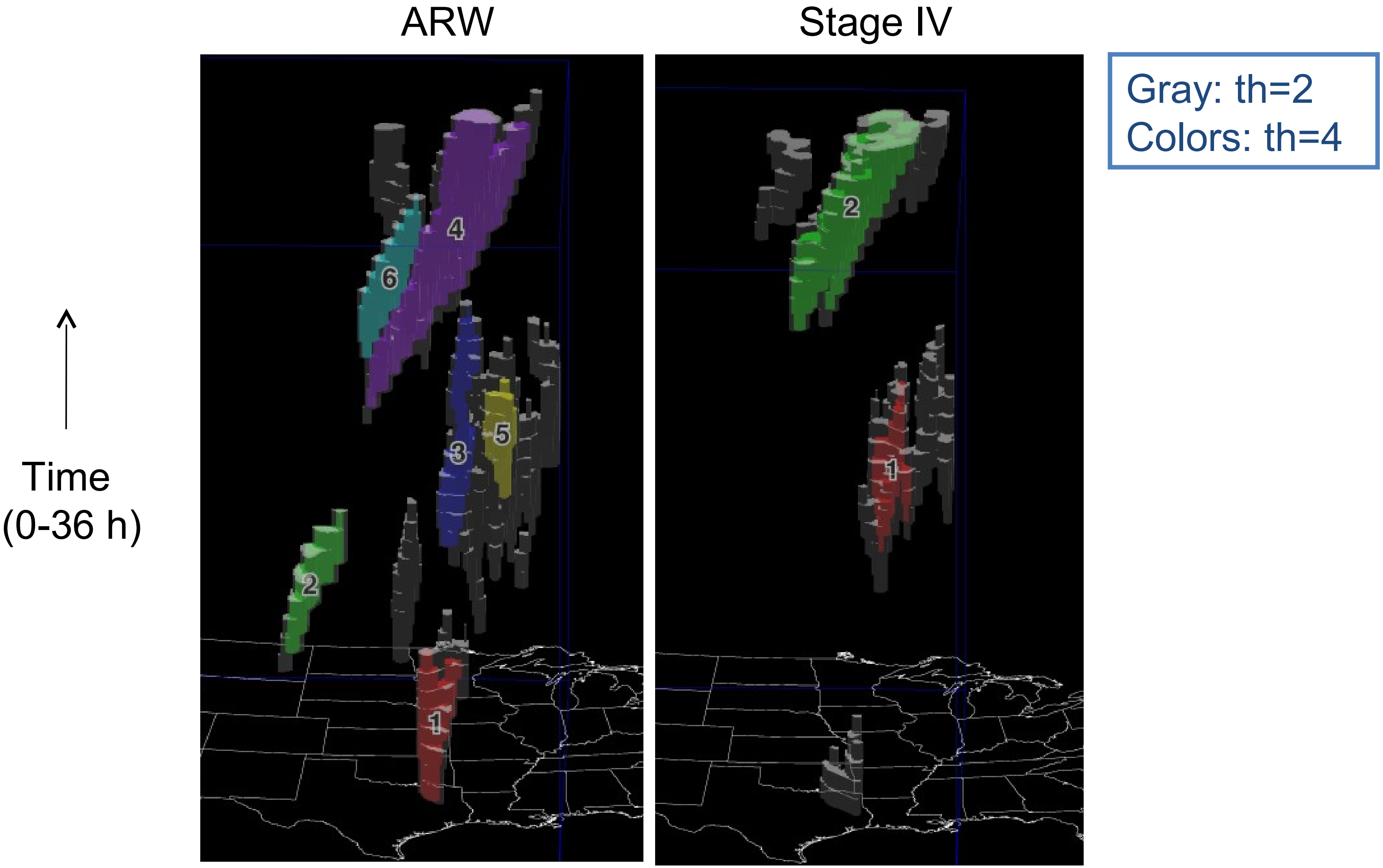


Gray: th=2
Colors: th=4

Time
(0-36 h)

Colors do not indicate matching

IHOP, June 10, 2002



ARW

Stage IV

Gray: th=2
Colors: th=4

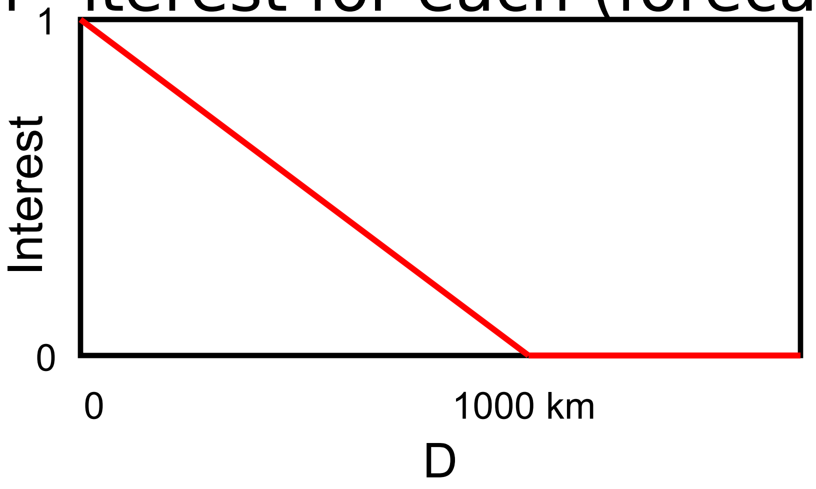
Time
(0-36 h)

Colors do not indicate matching

Interest Maps for 3-D Objects

$$D_{i,j} = \left((x_{f_i} - x_{o_j})^2 + (y_{f_i} - y_{o_j})^2 + c^2 (t_{f_i} - t_{o_j})^2 \right)^{\frac{1}{2}}$$

- For the *i*th forecast object and *j*th observed object, compute $D_{i,j}$
- Choose c = 30 ms^{-1} (3 h ~ 300 km)
- Apply an interest map to D
- Compute an interest for each (forecast, observed) object pair



Total Interest Matrix (15 June 2002)

Observed Object

Forecast Object	1	2	3	Max Int (fcst)
1	0.06	0.00	0.00	0.06
2	0.14	**0.67**	0.00	0.67
3	0.00	0.27	0.00	0.27
4	0.00	0.00	**0.72**	0.72
Max Int (obs)	0.14	0.67	0.72	

Median = 0.47

Median = 0.67

Median of Maximum Interest (MMI)

- Compute MMI for
  - Forecast objects (= 0.47)
  - Observed objects (= 0.67)
- Average = Median of Maximum Interest (MMI) = 0.57

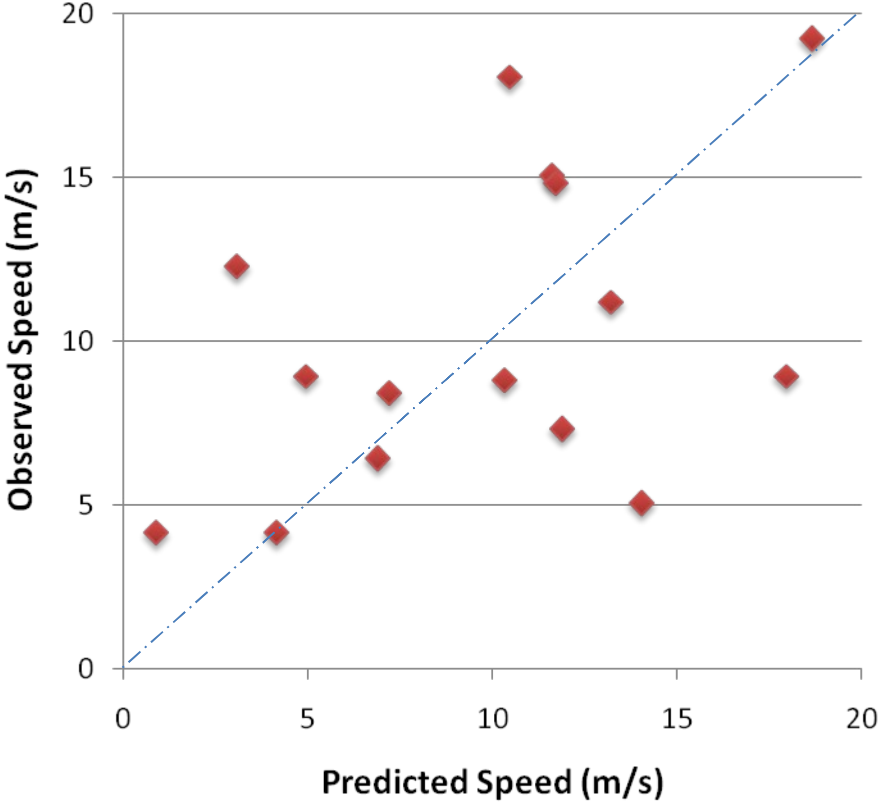
MMI Results

Including systems with duration > 300 grid volumes*

Date of initialization (00 UTC)	MMI (T=2)	MMI (T=4)
10 June	0.56	**0.75**
11 June	**0.42**	0.59
12 June	**0.75**	**0.70**
13 June	**0.34**	0.56
15 June	0.57	0.50

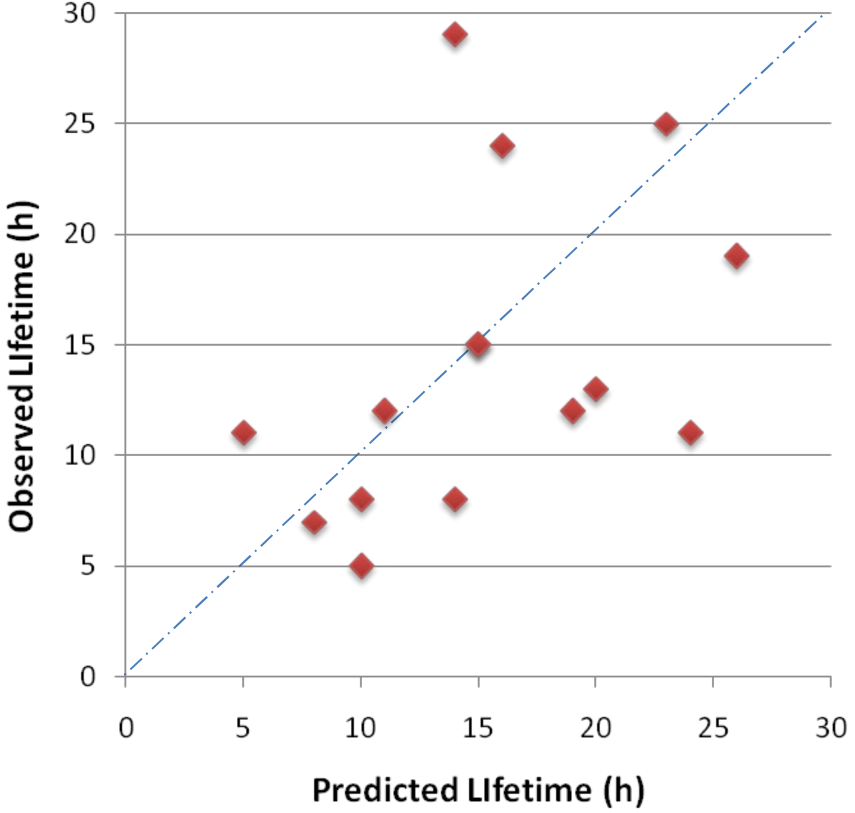
*a rain system 120 km x 120 km x 3 h would be 300 grid volumes

Attributes of Rain Systems



System Speed

No obvious bias
Limited skill



System Lifetime

Small high bias in
predicted lifetime

Summary

- Results
  - Object-based method extended to time dimension
    - Full evolution of systems considered
    - Relatively small number of systems
  - Simple algorithm determines forecast quality
  - Discriminates forecast quality on different days
  - Quantifies errors in feature attributes
- Near future
  - Include more attributes in determination of quality
  - Intercompare different models
  - Extend datasets to larger samples