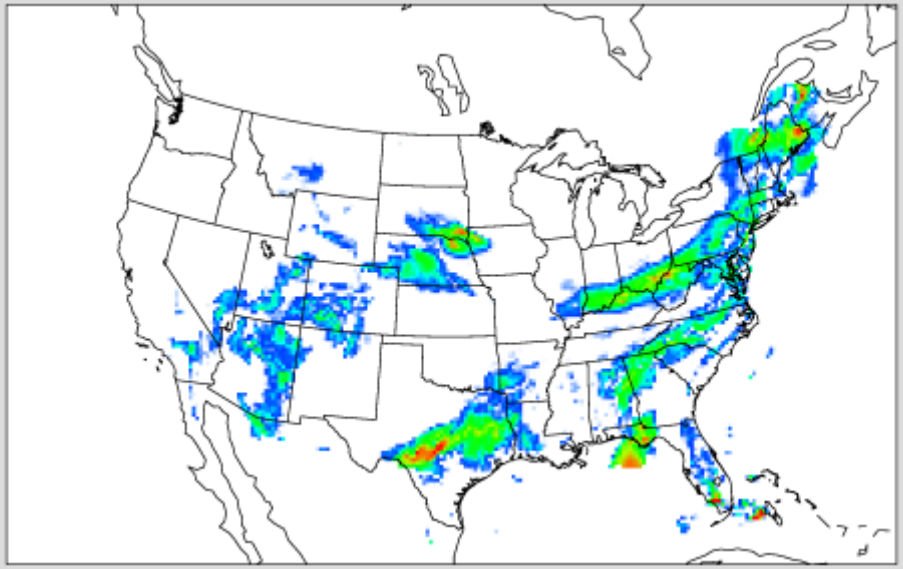
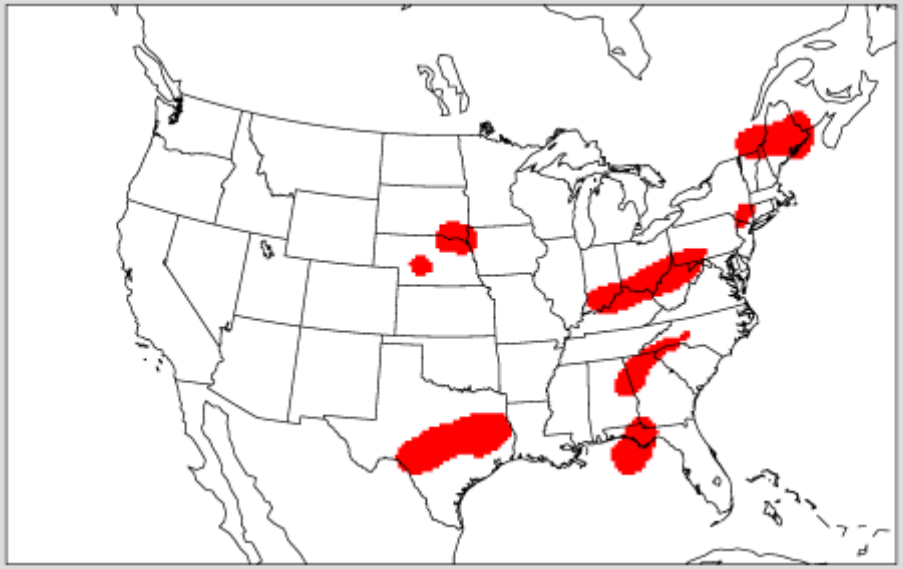
Randy Bullock

Defining Objects in MODE

What are Objects?



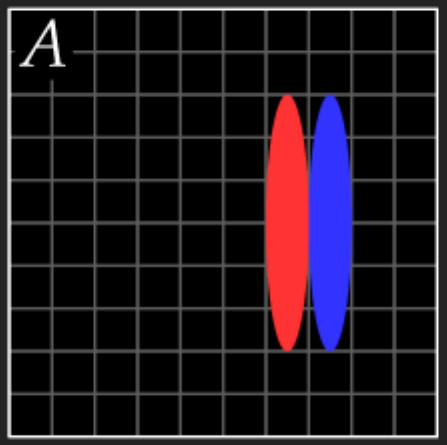
Raw Field

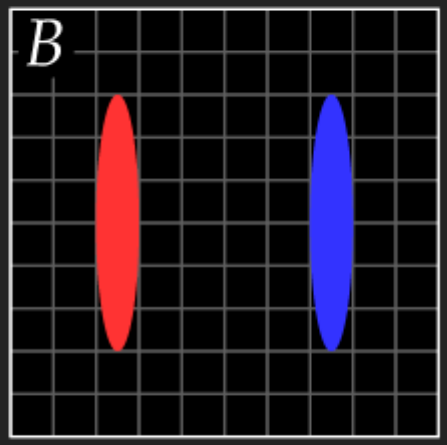


Object Field

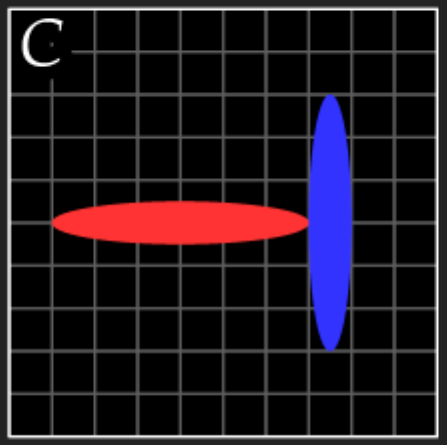
Objects are Regions of Interest

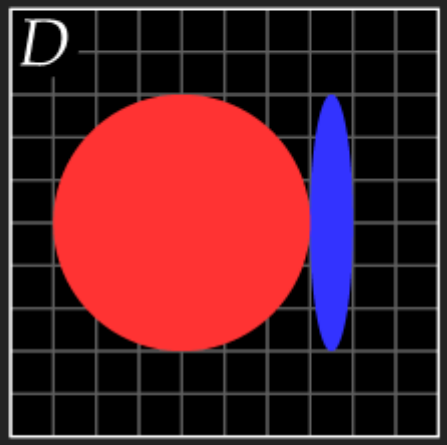
Background and Motivation

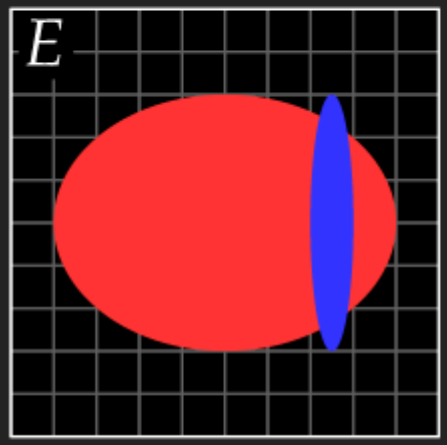




Score	A-D	E
Correlation Coefficient	0.0	0.2
Probability of Detection	0.0	0.9
False Alarm Ratio	1.0	0.9
Hanssen-Kuipers	0.0	0.7
Gilbert Skill Score	0.0	0.1





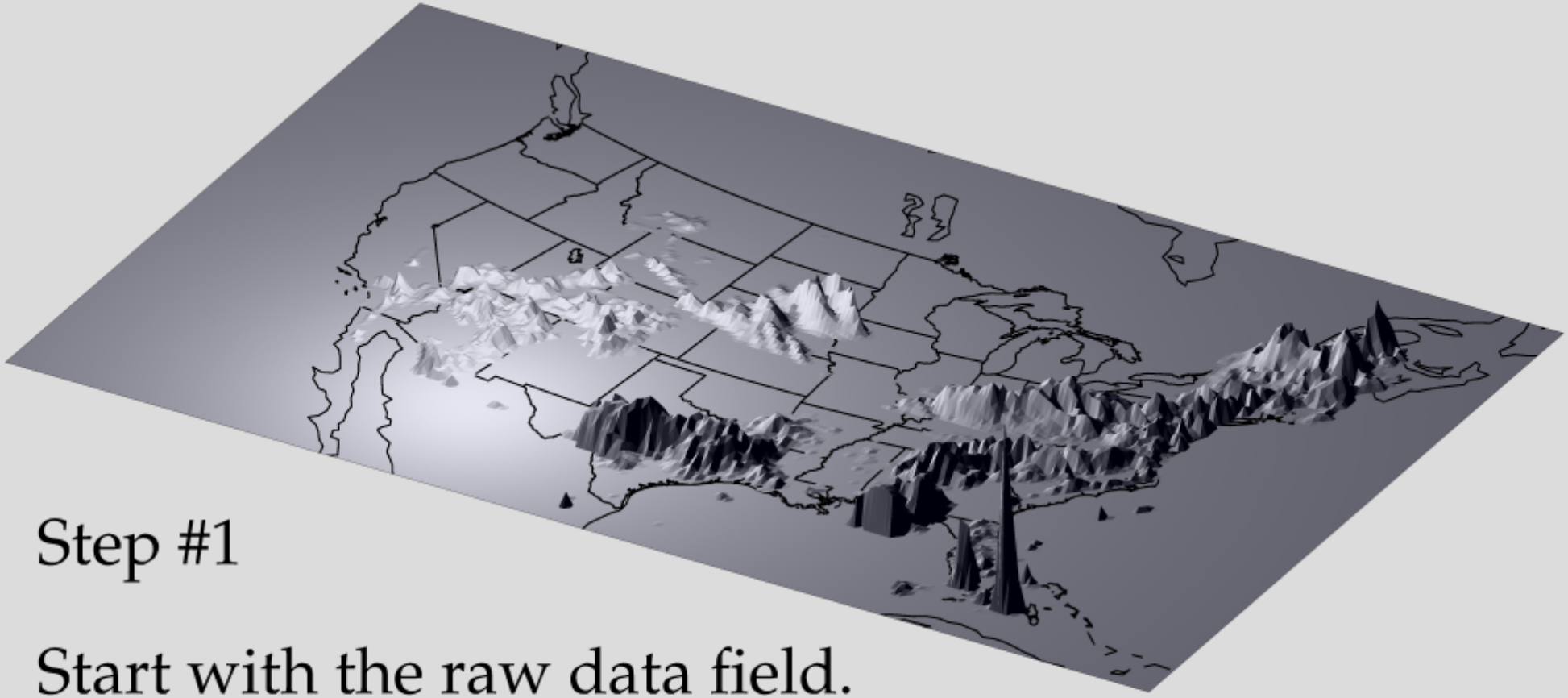


Forecast

Observation

Which forecast is better?

Four Step Process for Resolving Objects

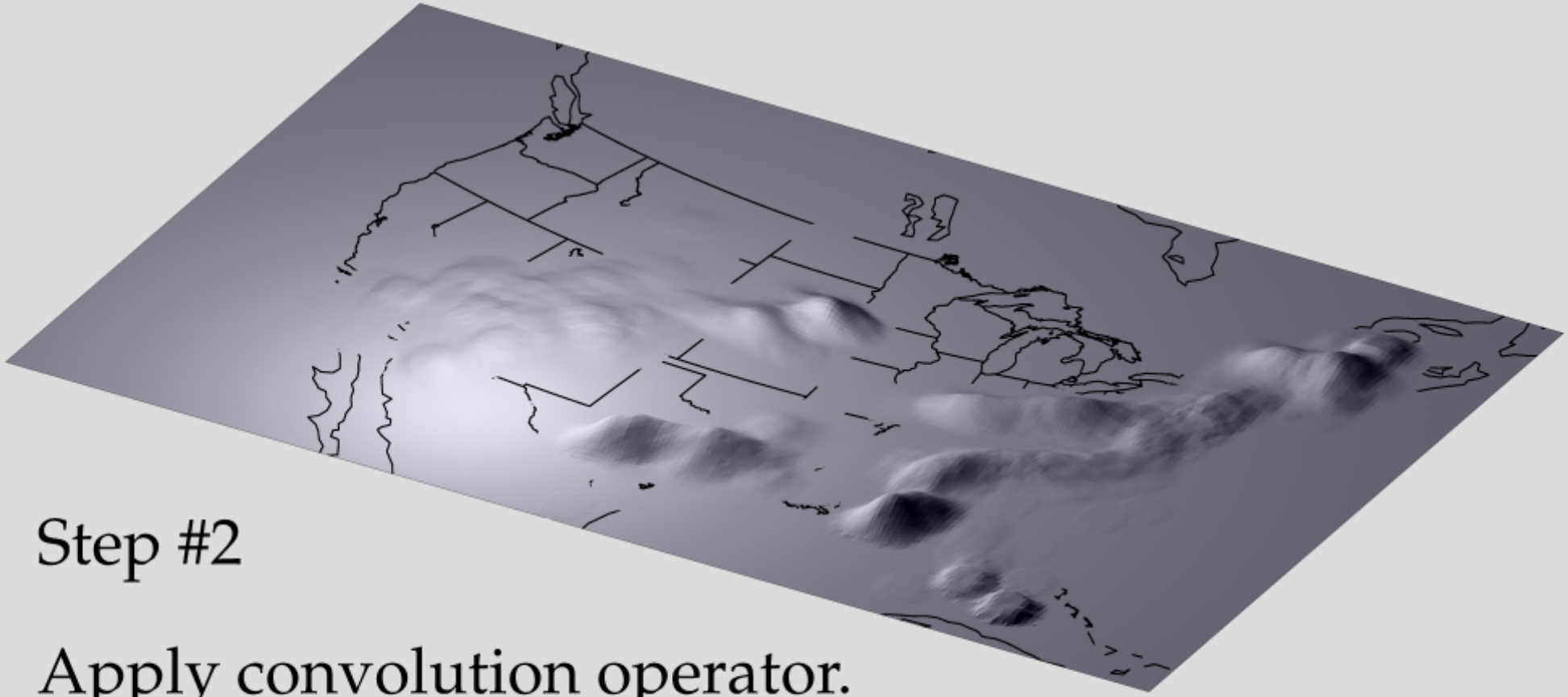


Step #1

Start with the raw data field.

In this case, a precipitation field.

Four Step Process for Resolving Objects

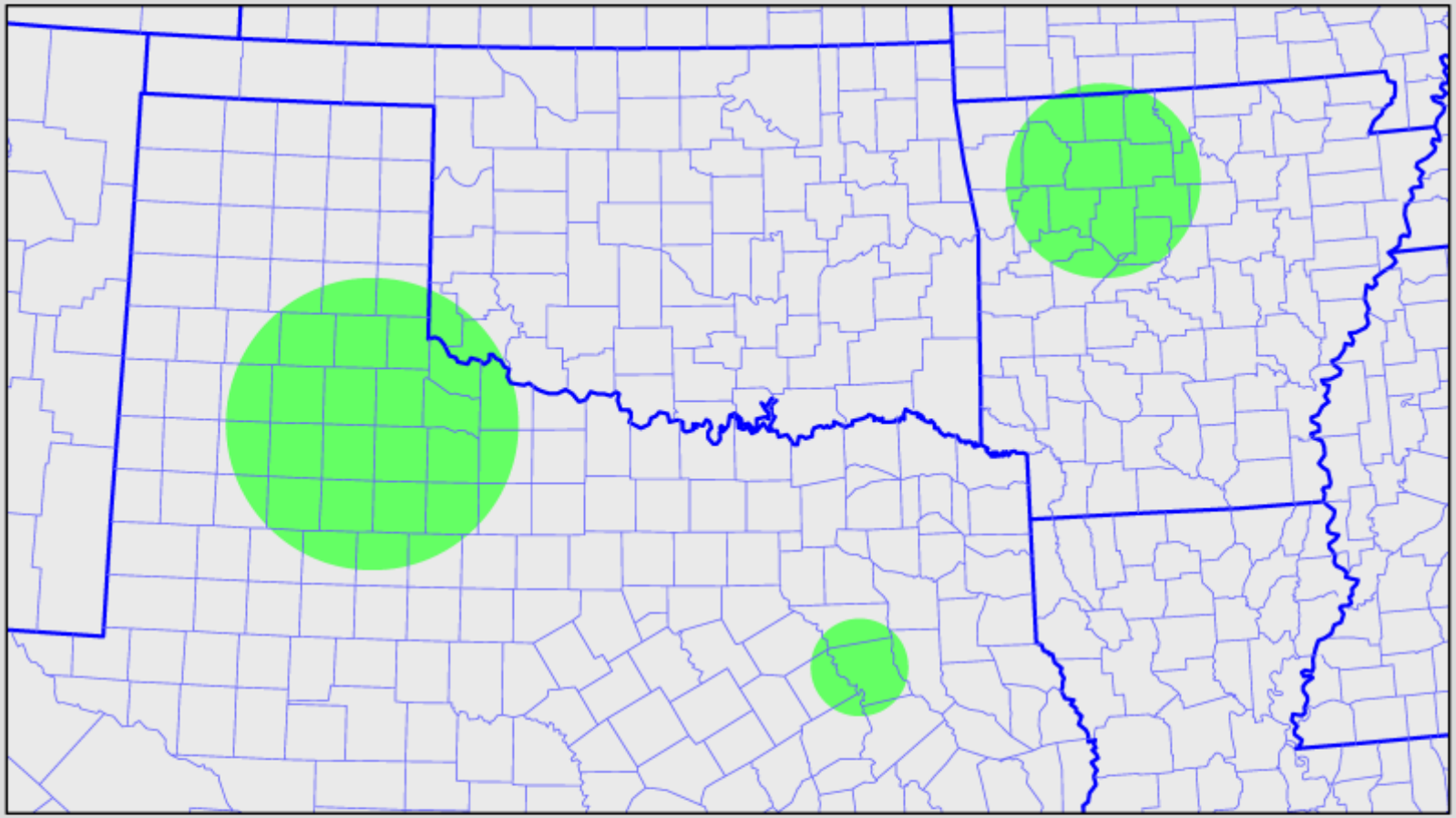


Step #2

Apply convolution operator.

This is basically a smoothing operation.

Convolution Radius



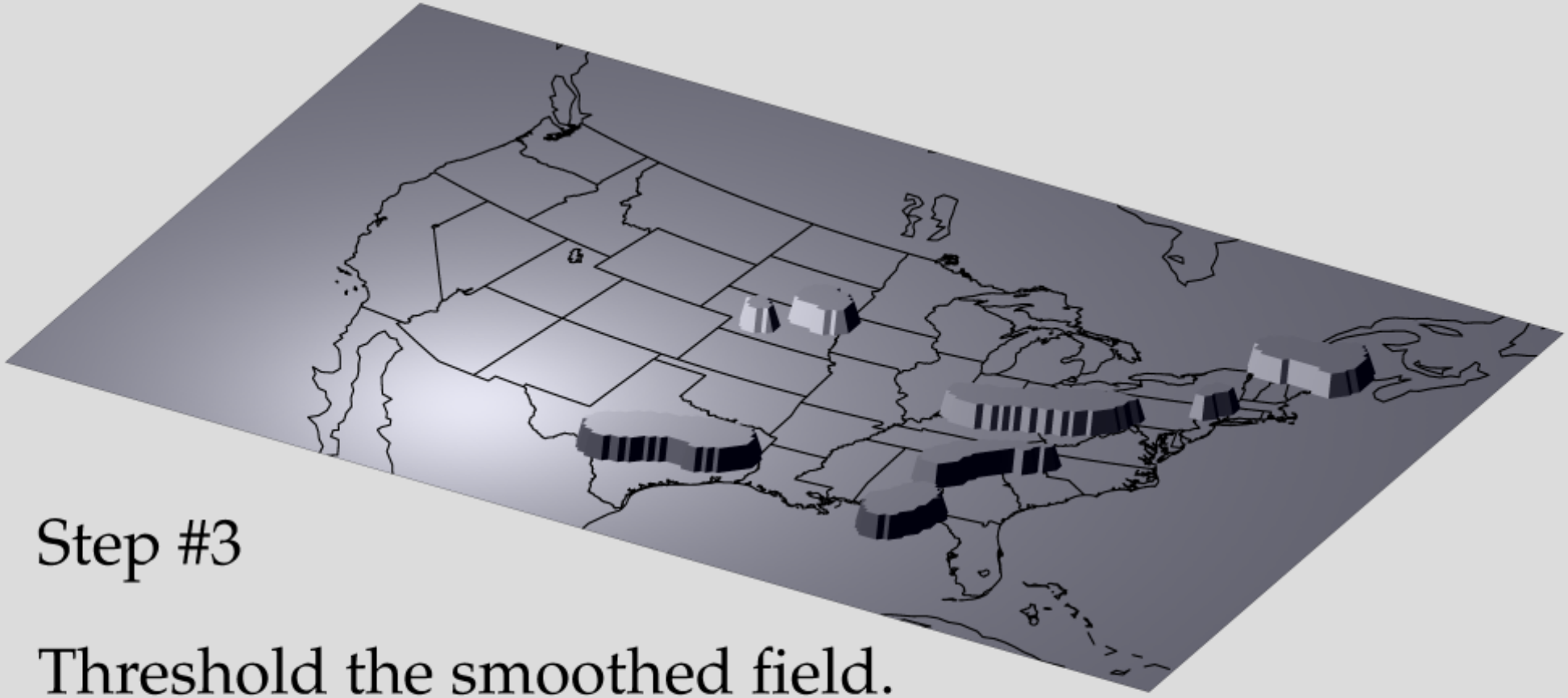
Radius of Influence

Convolution

Convolution operates on the raw data field $f(x, y)$ using a filter function $\phi(x, y)$. MODE uses a simple "circular" filter, so this operation amounts to taking a weighted average of the raw field values in some neighborhood of the point (x, y).

$$C(x,y) = \sum_{(x',y') \in G} f(x',y')\, \phi(x - x', x - y')$$

Four Step Process for Resolving Objects



Step #3

Threshold the smoothed field.

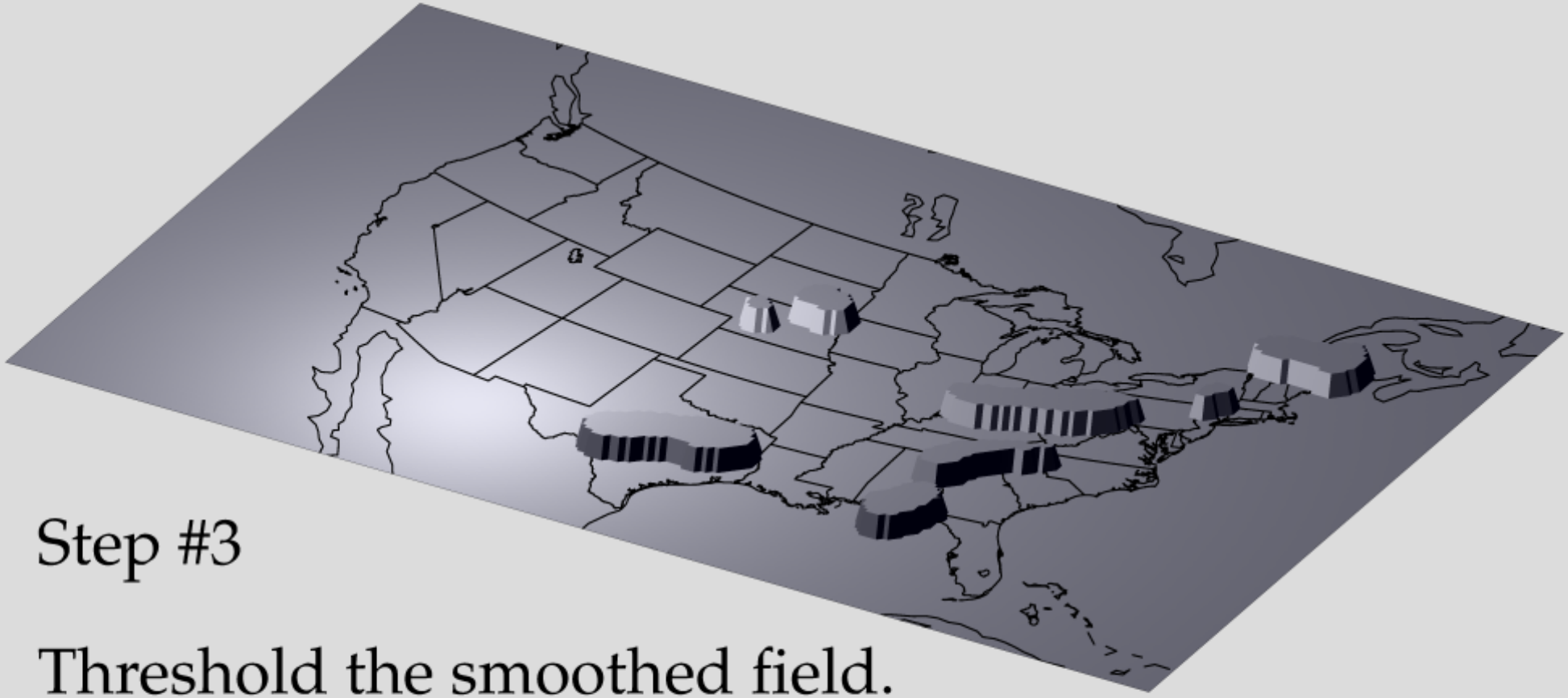
This produces an on/off mask field.

Masking

Masking uses the convolved field $C(x, y)$ and the threshold T to produce the masked field $M(x, y)$. This is set to 1 if the convolved field exceeds the threshold T, otherwise it's set to 0. That's why it's called a "mask."

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

Four Step Process for Resolving Objects

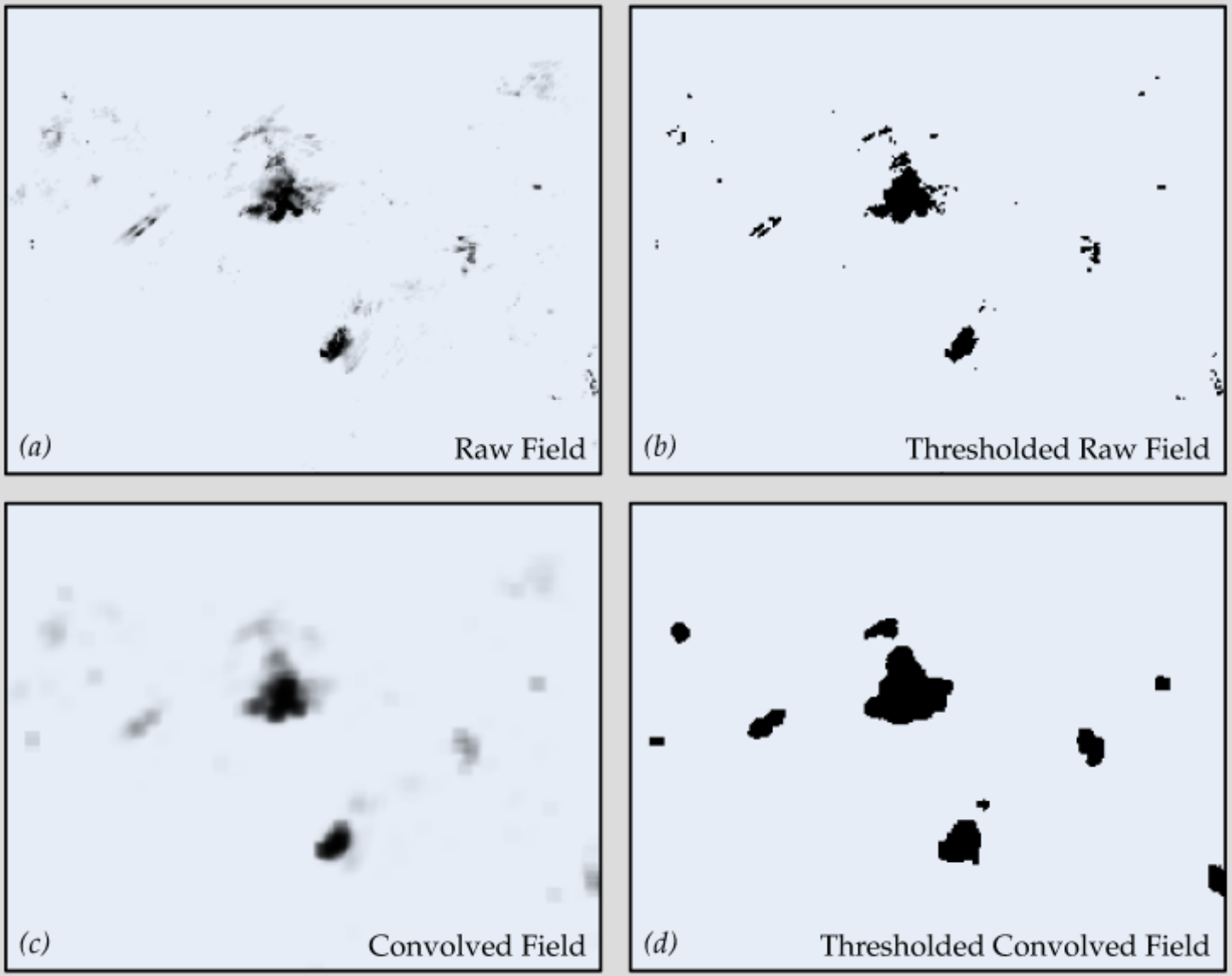


Step #3

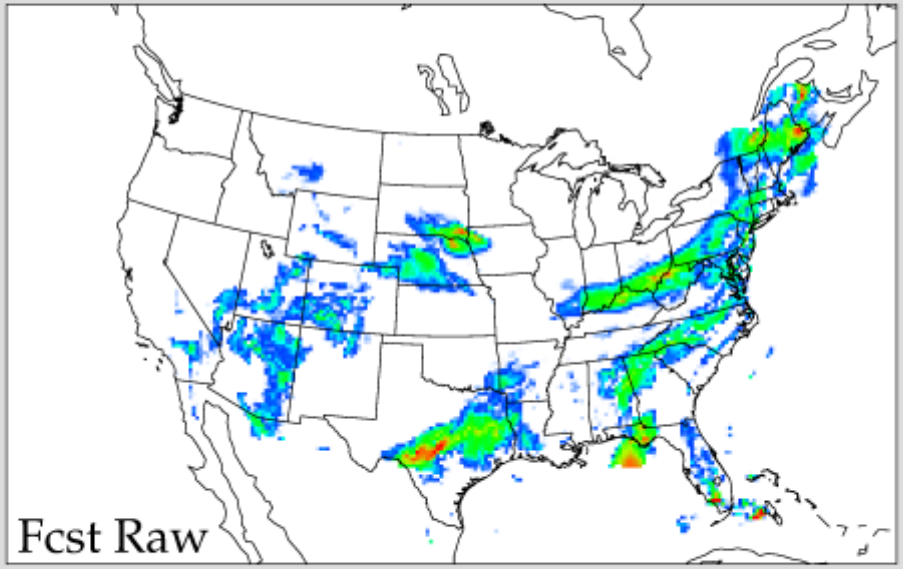
Threshold the smoothed field.

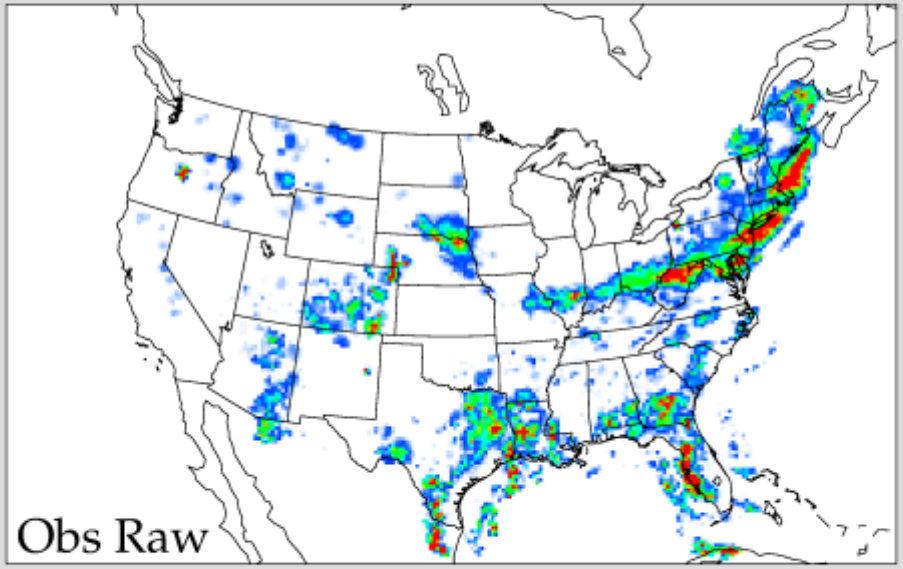
This produces an on/off mask field.

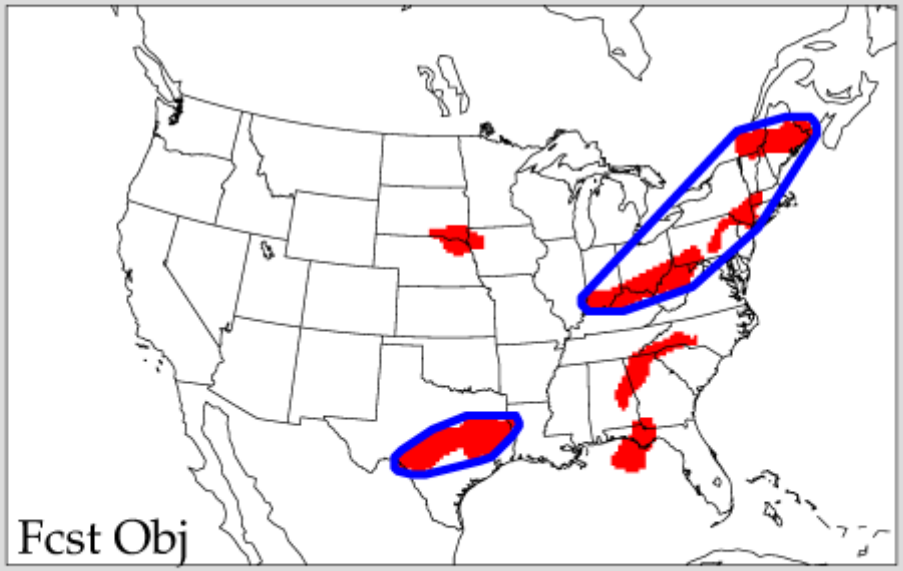
Just Threshold Raw Data?

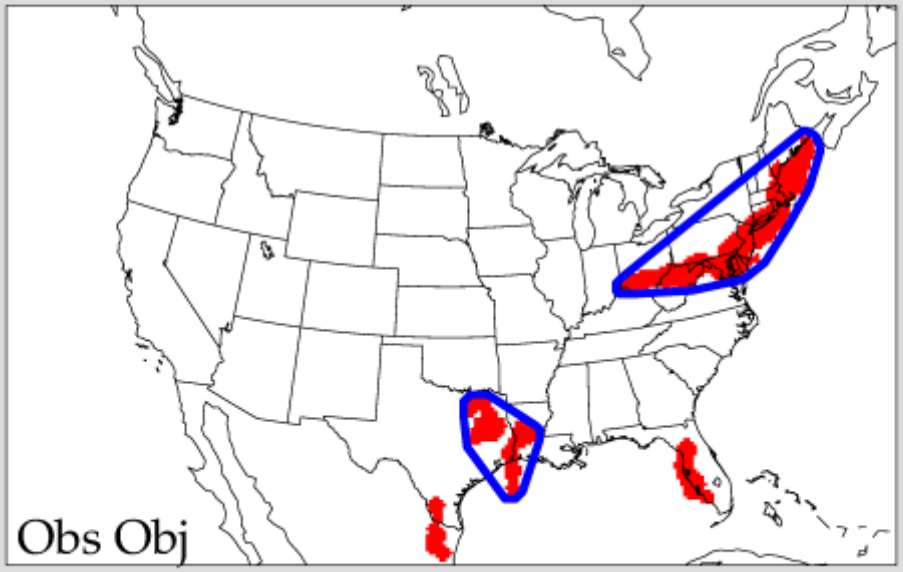


Example of Matching & Merging

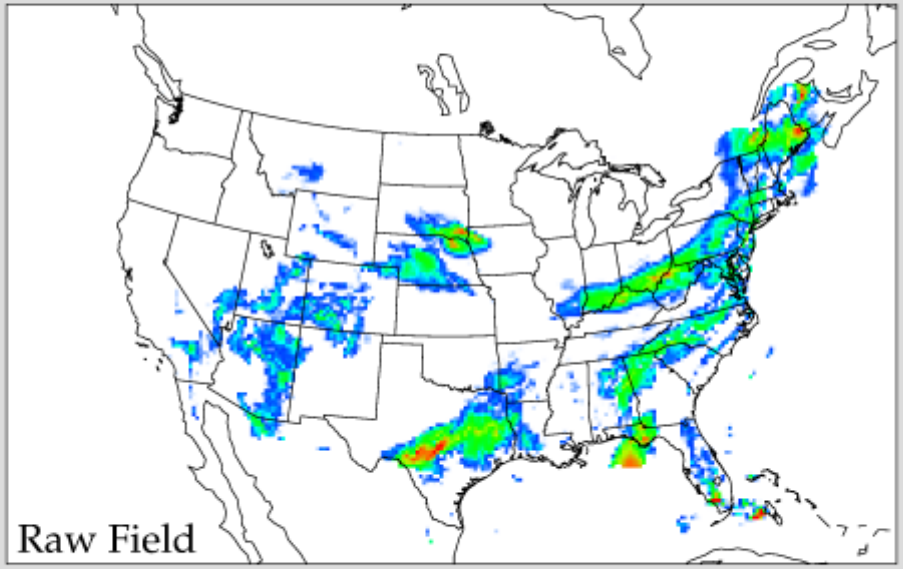


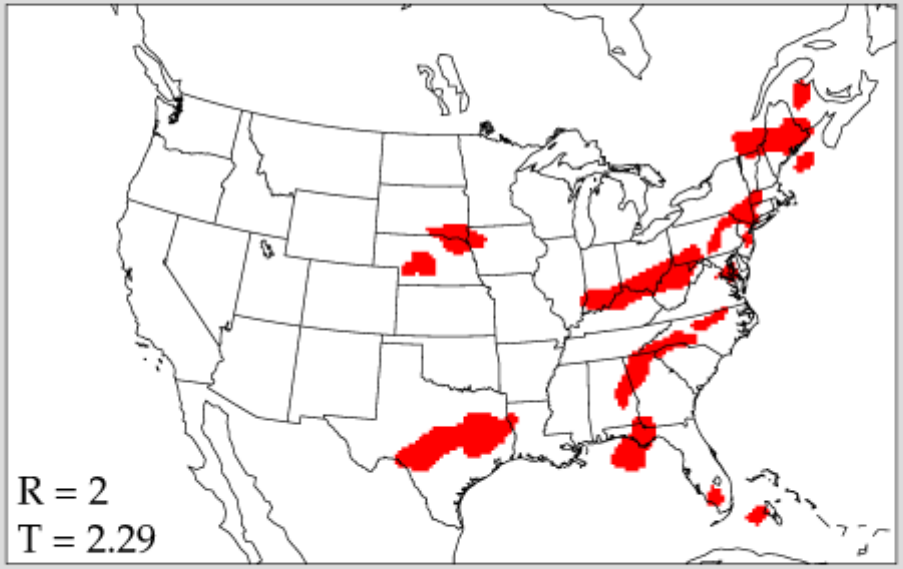


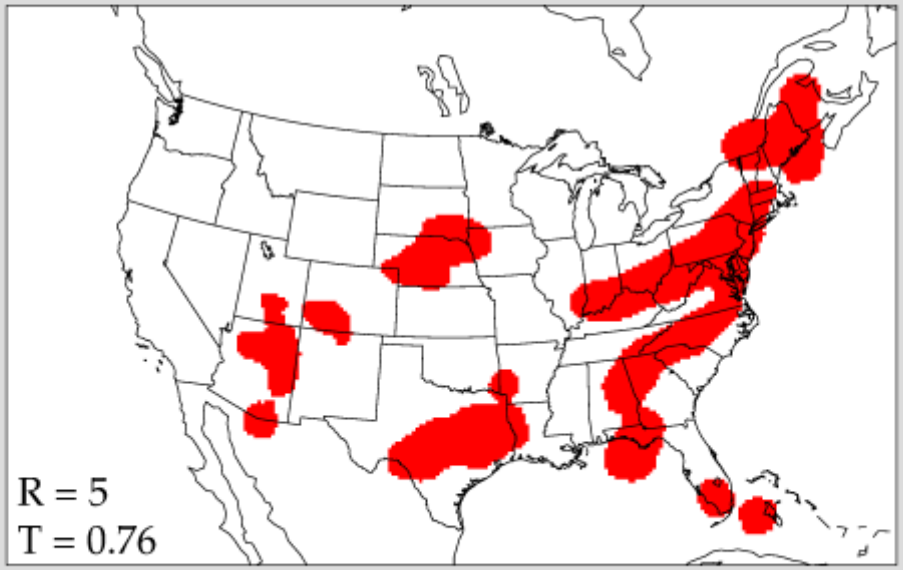


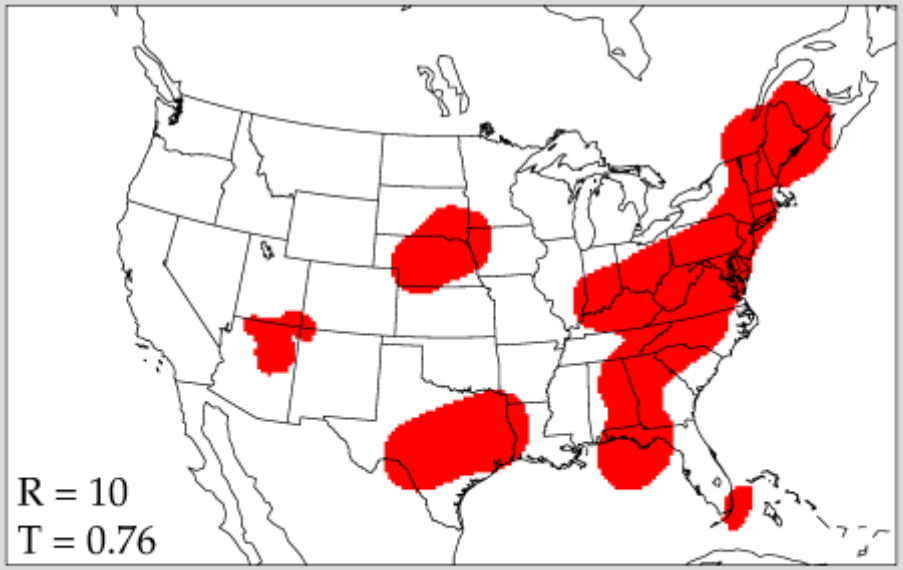


Note the Effect of Changing the Object-Definition Parameters









Matching & Merging

Merging: Associating objects in the same field.

Matching: Associating objects in different fields.

MODE does this using a Fuzzy-Logic engine.

Fuzzy Logic Intro

Attributes

Interest Maps

Confidence Maps

Weights

Total Interest

Object Attributes

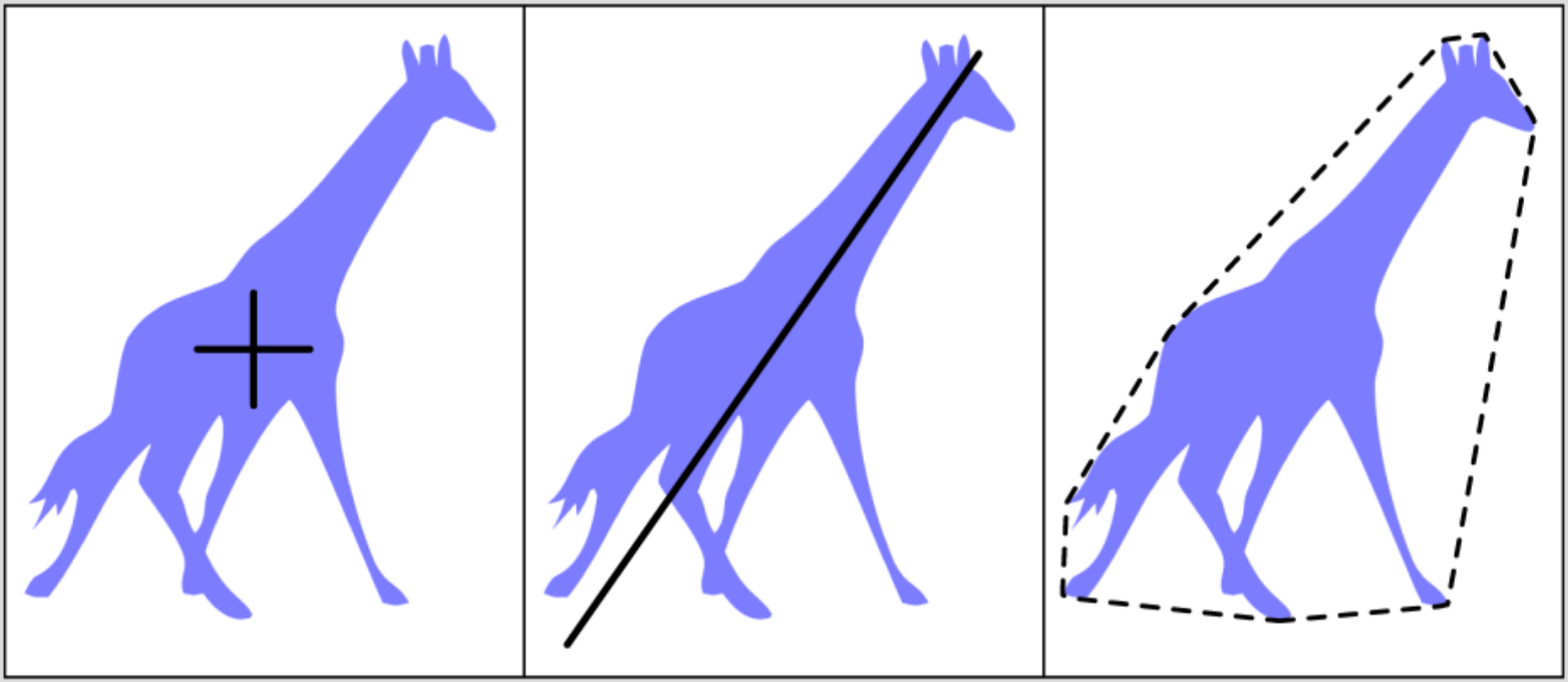
Single:

- Area
- Centroid
- Axis Angle
- Median Intensity
- Complexity
- Aspect Ratio
- Curvature

Pair:

- Centroid Distance
- Angle Difference
- Median Intensity Ratio
- Intersection Area
- Convex Hull Distance
- Boundary Distance
- Area Ratio

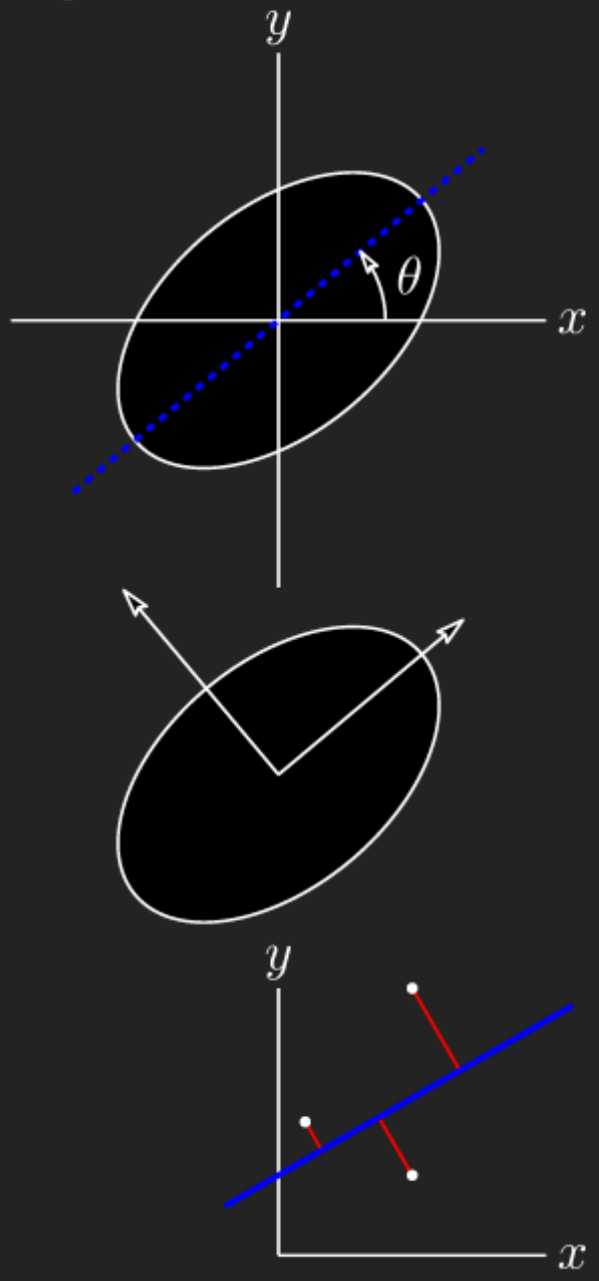
Example Single Attributes



Centroid Axis Convex Hull

Three Approaches to Calculating the Axis in 2D

- Maximize second moments
- Principal Components
- Total Least Squares

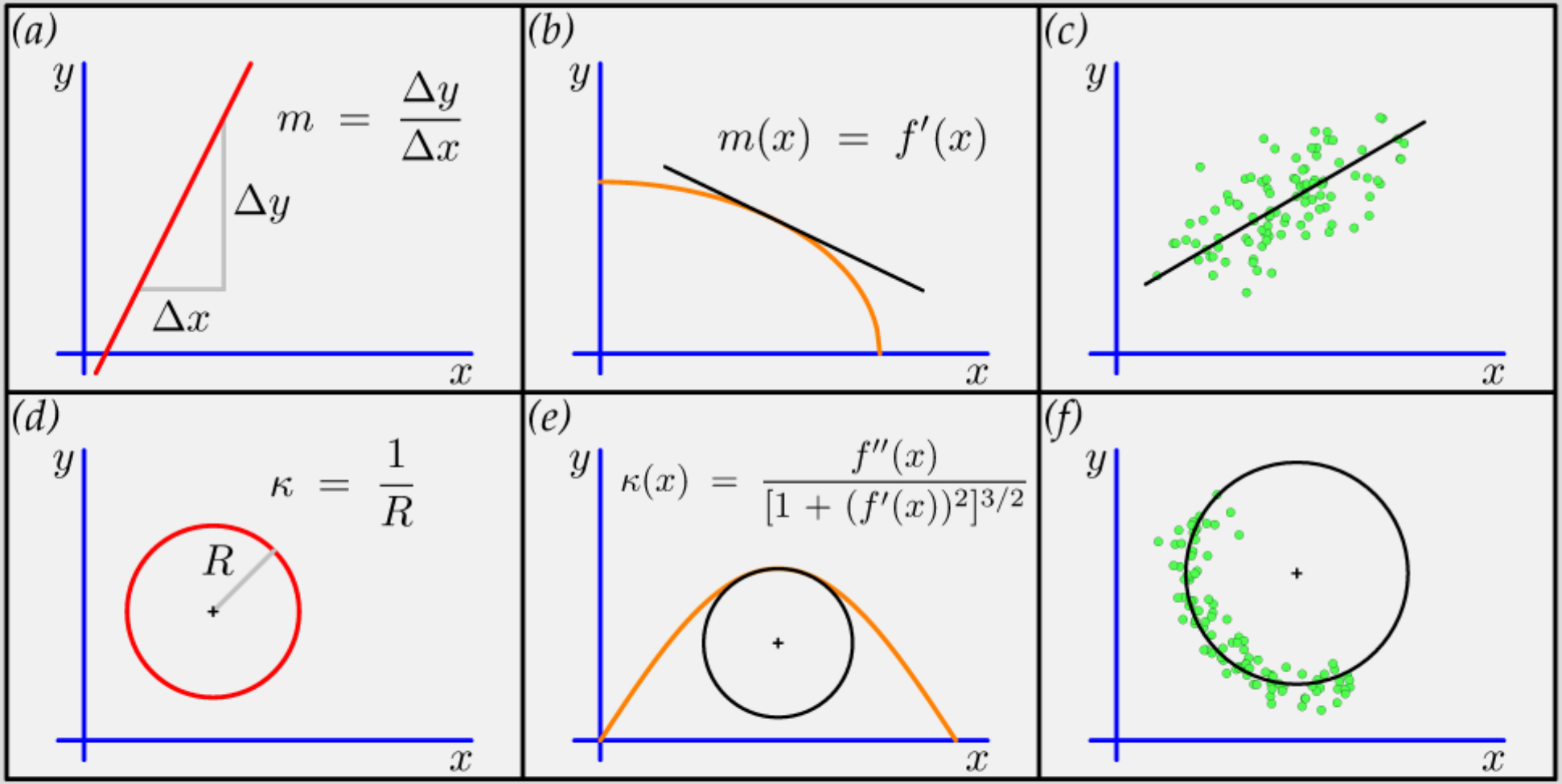


The Trouble with Least Squares

Axis

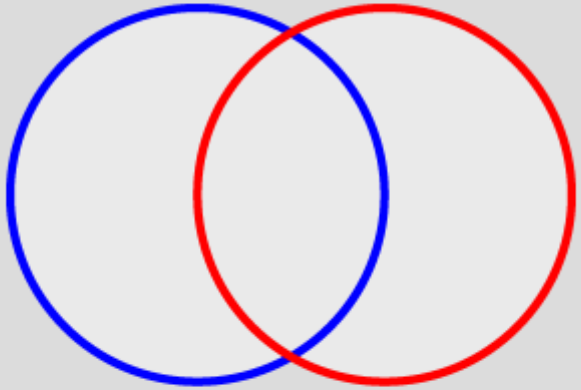
Least Squares

Object Curvature

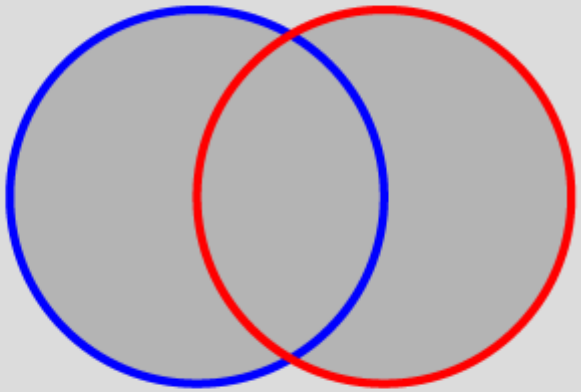


Example Pair Attributes

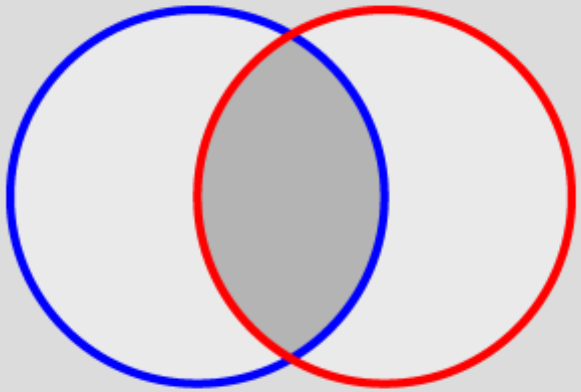
Forecast Object



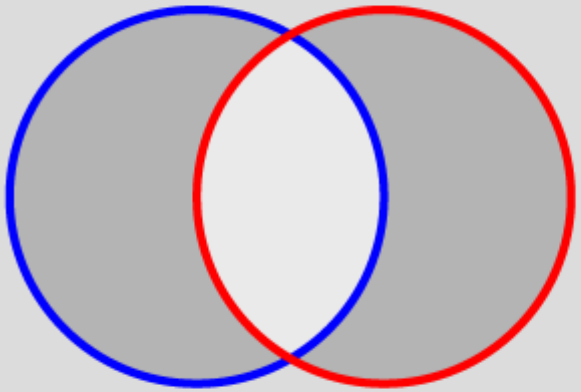
Observed Object



Union



Intersection

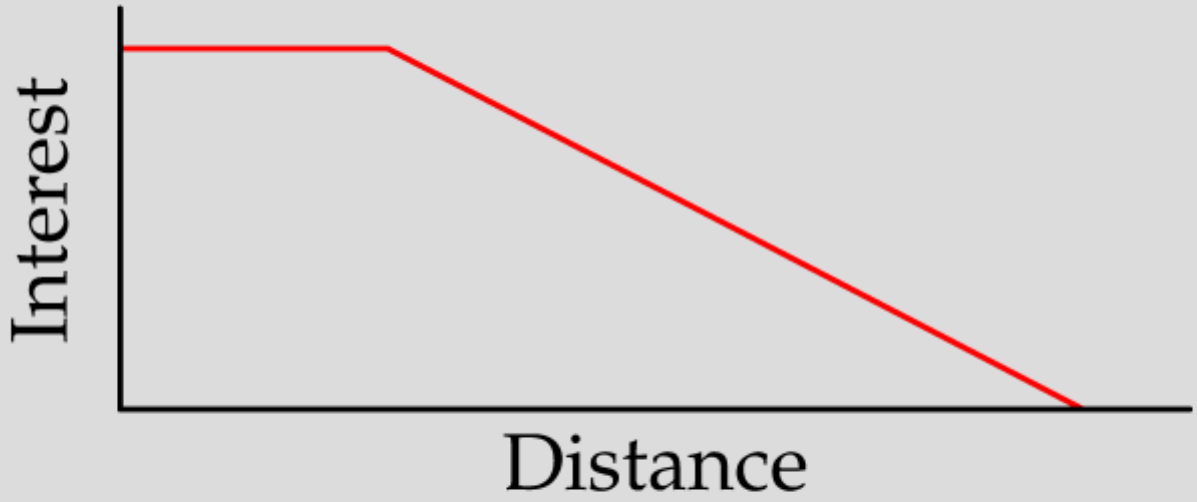


Symmetric Difference

Interest Maps

Map attributes to interest values.

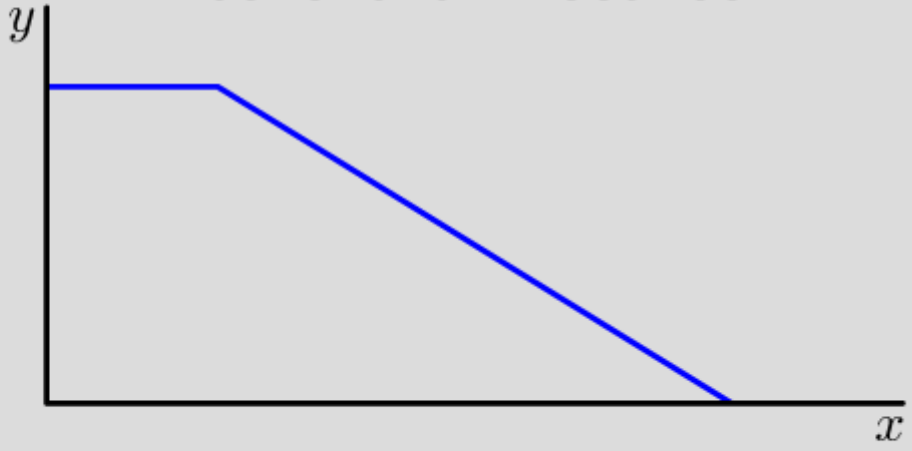
Example: Centroid Distance



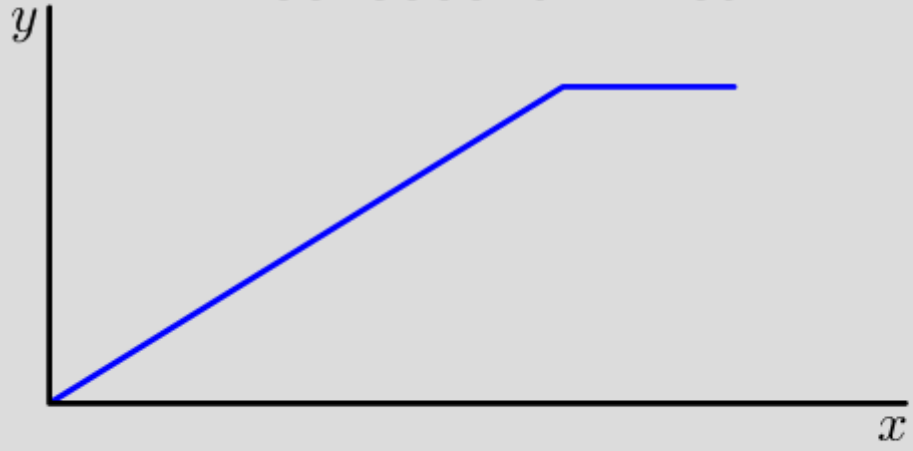
All interest maps can be changed in the config file.

Interest Maps

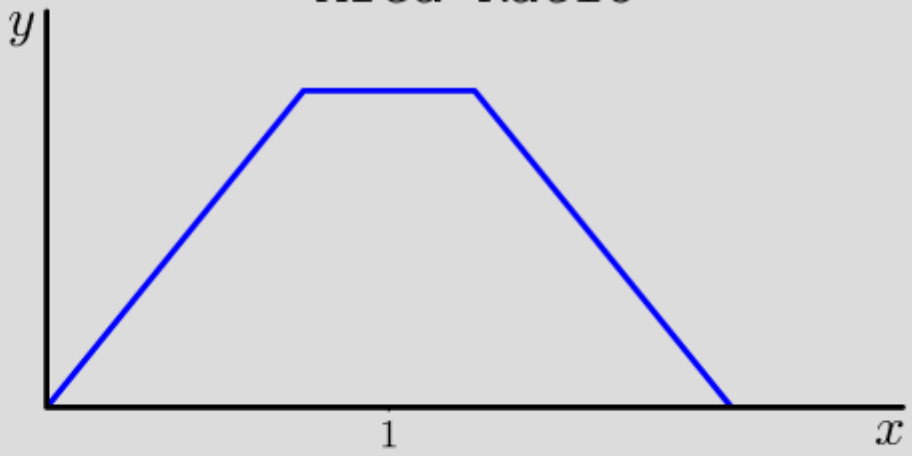
Centroid Distance



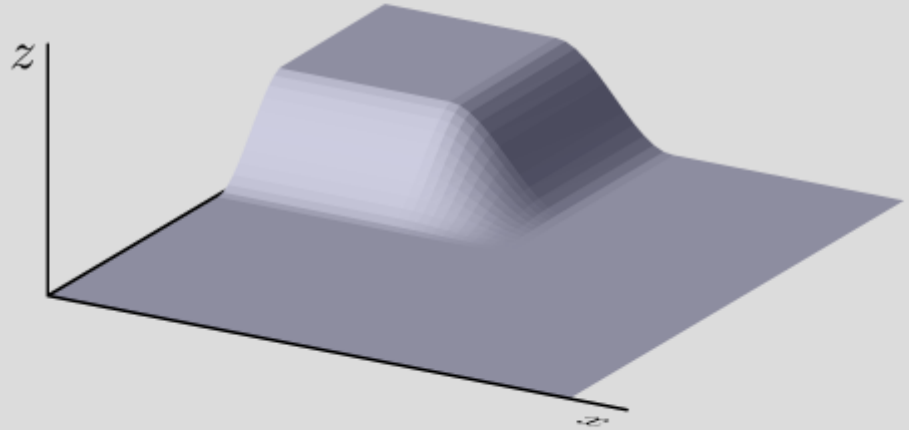
Intersection Area



Area Ratio



2-variable Interest Map $I(x, y)$



Weights

Express relative importance of different attributes in matching and merging.

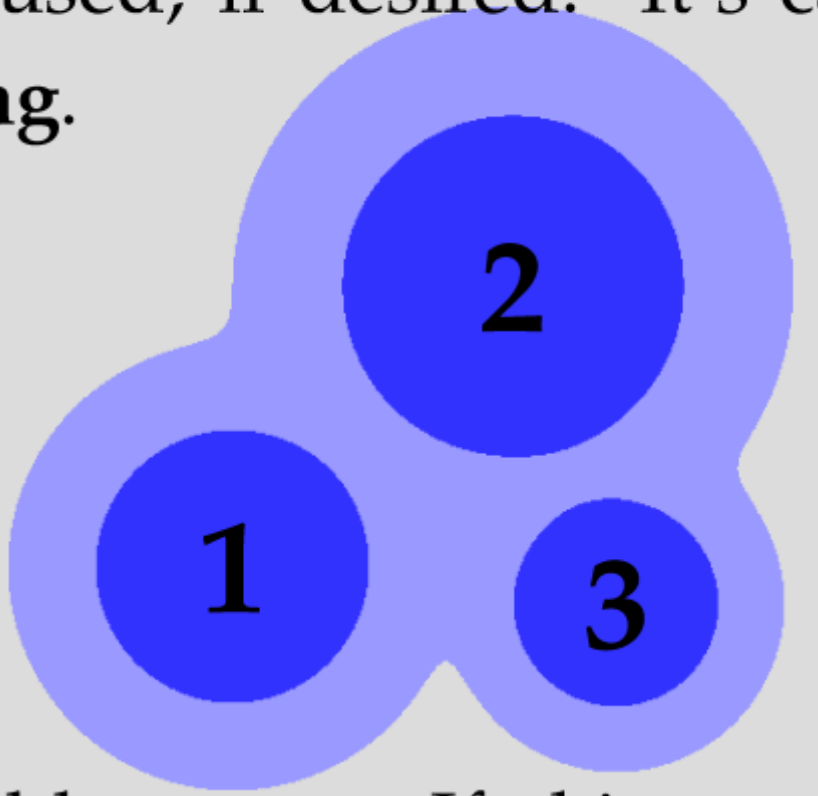
All weights can be changed in the config file.

Total Interest

Calculated from weights, attributes, and interest maps.

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

MODE also has an alternative merging method that can be used, if desired. It's called **Double Thresholding**.



Two thresholds are set. If objects are separate at the higher threshold, but run together at the lower threshold, this can be used to help with the overall object merging.

MODE Output

Attributes file

Netcdf Objects file

Contingency Table Counts & Stats

PostScript Graphics file

Why use PostScript?

Library available

Easier to program

PDF not yet dominant then

No external libraries needed

Conversion available

```
ps2pdf -dPDFSETTINGS=/prepress
```

Displacement methods: Pros & Cons

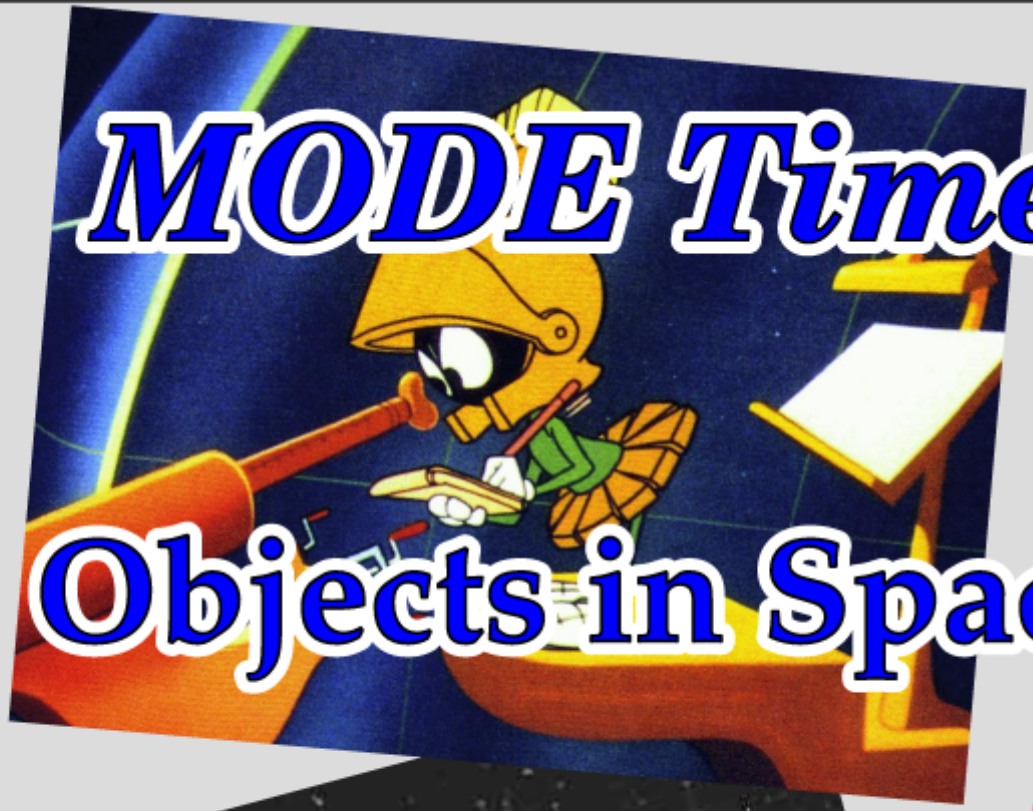
- Information on location errors and some structural errors.
- Intuitive and physically meaningful.
- Information on both large-scale and small-scale errors.
- Information on individual features.
- Hits, misses and false alarms.

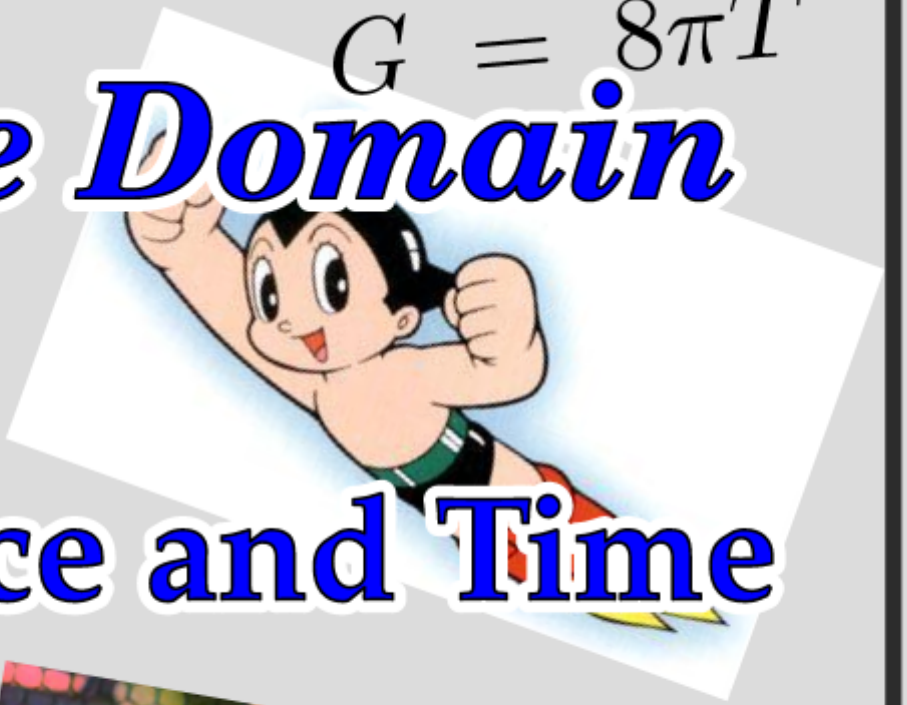
Displacement methods: Pros & Cons

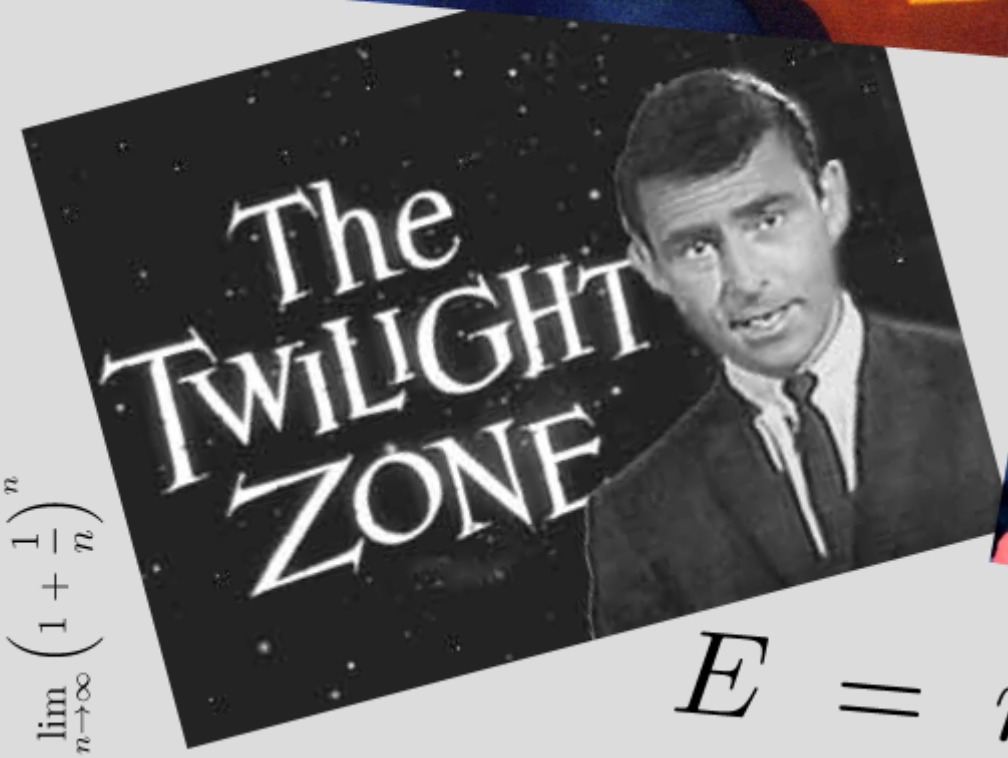
- Often need to merge and match features, which can be tricky.
  (Note: MODE does this.)
- Wealth of information can be difficult to summarize.
- Lots of decisions on how to configure.

MODE Time Domain

Objects in Space and Time



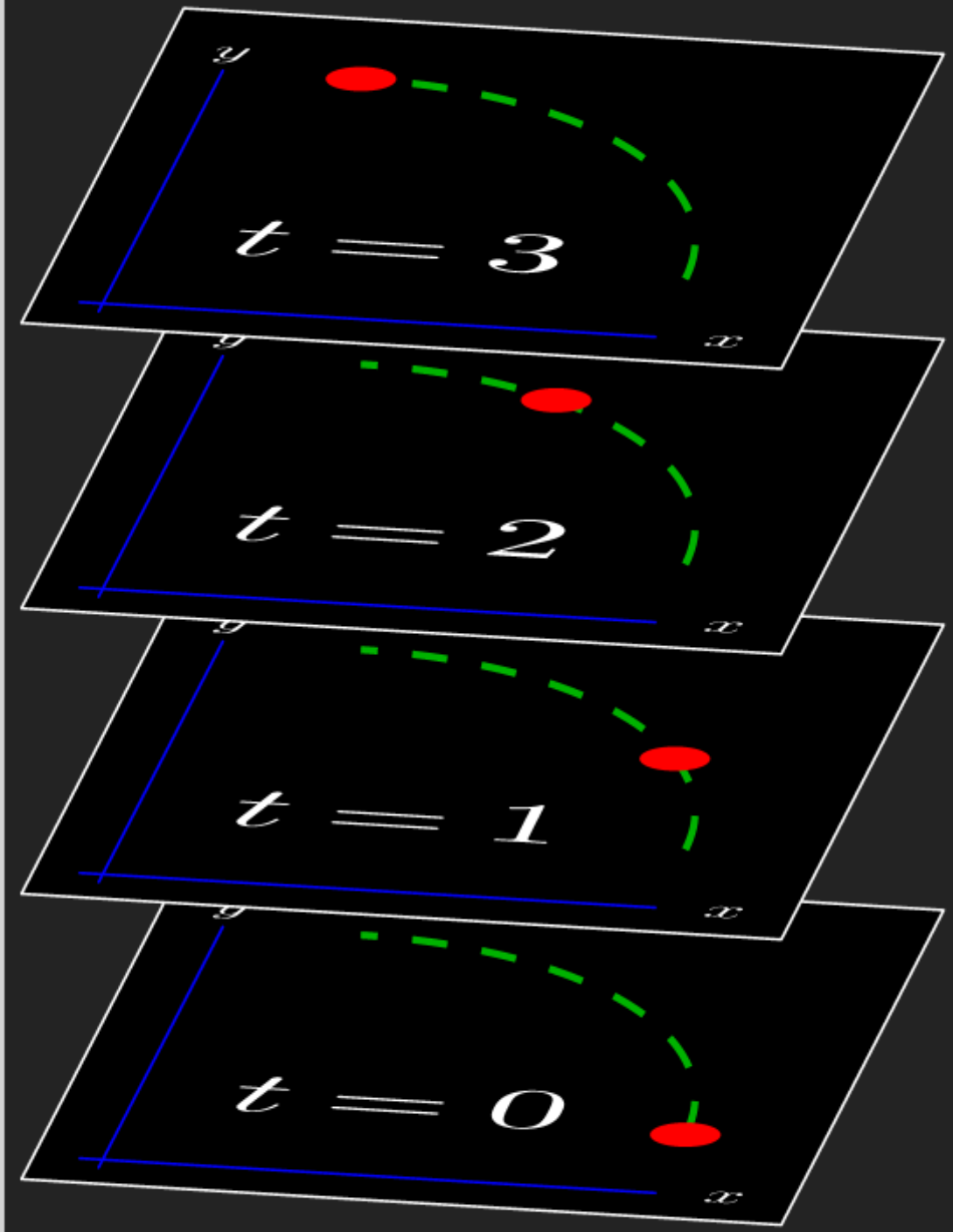




$$G = 8\pi T$$

$$\lim_{n\to\infty}\left(1+\frac{1}{n}\right)^n$$

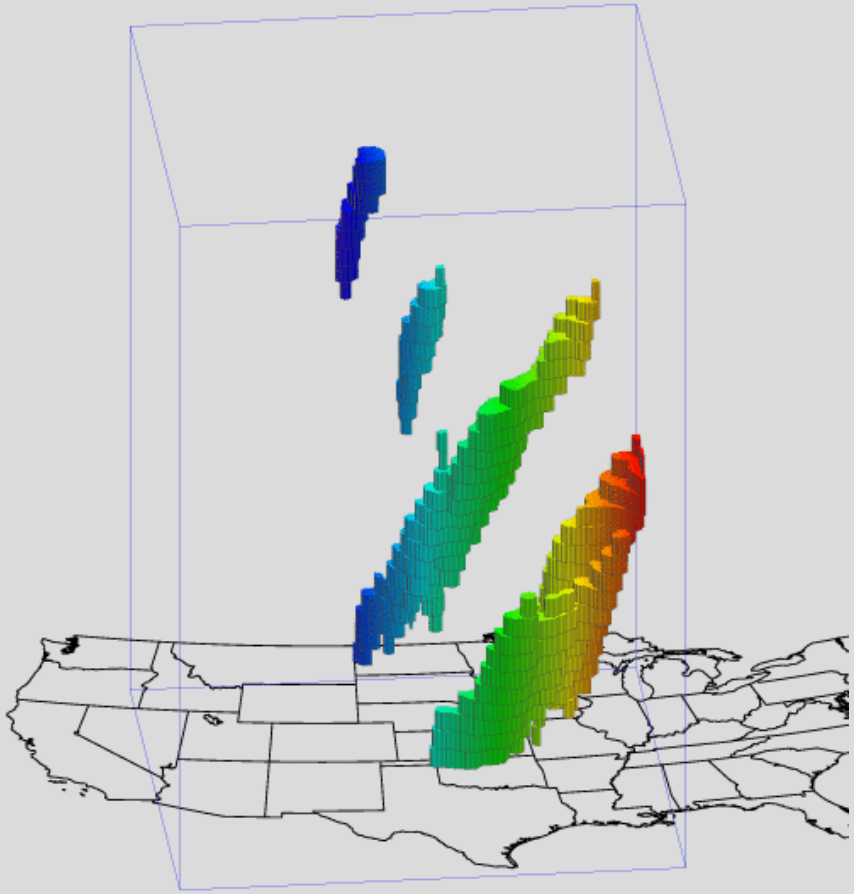
$$E = mc^2$$



Time Slices
Stacked Vertically

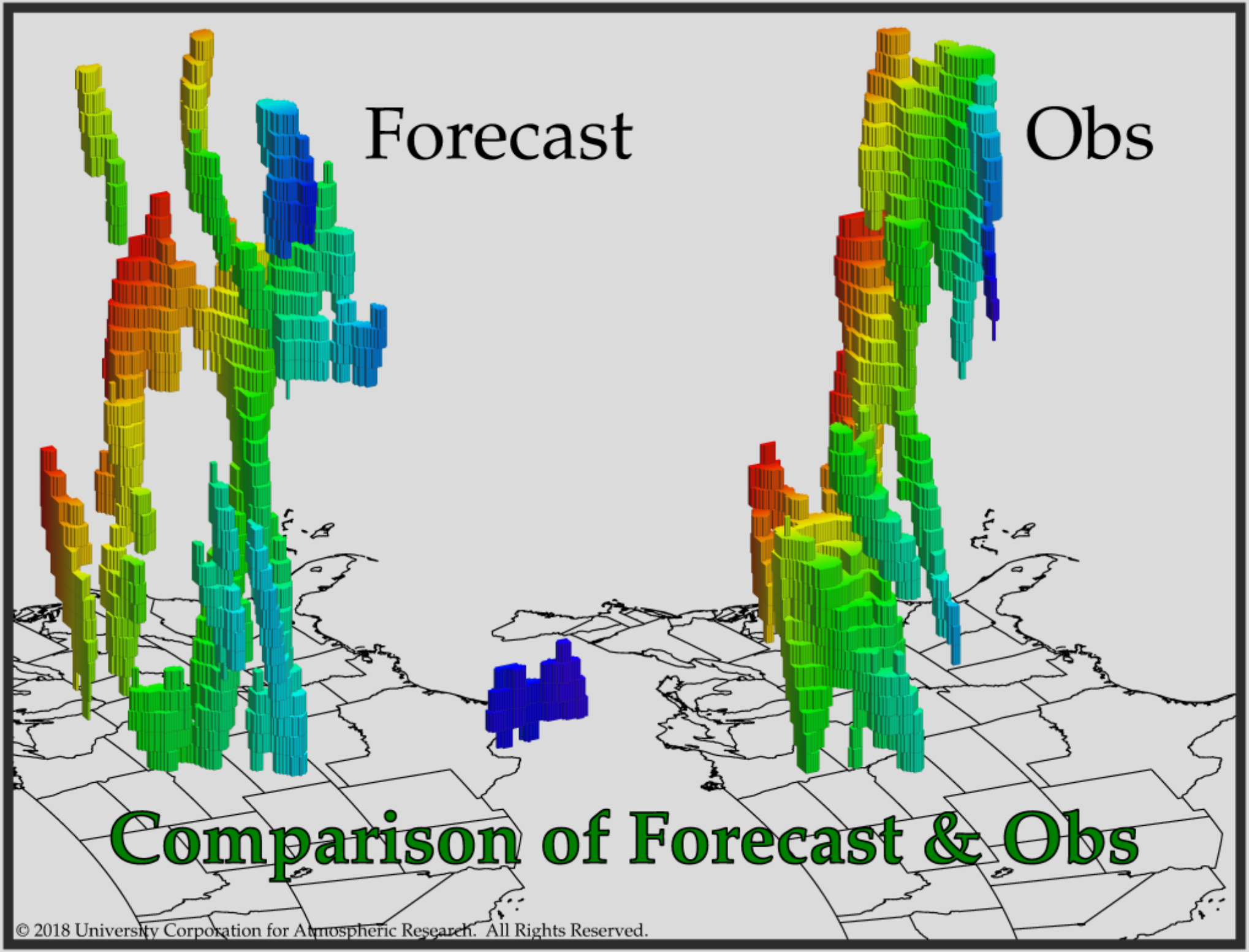
Moving 2D Object
Sweeps Out
3D Spacetime Object

3D Objects



June 13, 2002
IHOP Precip Data

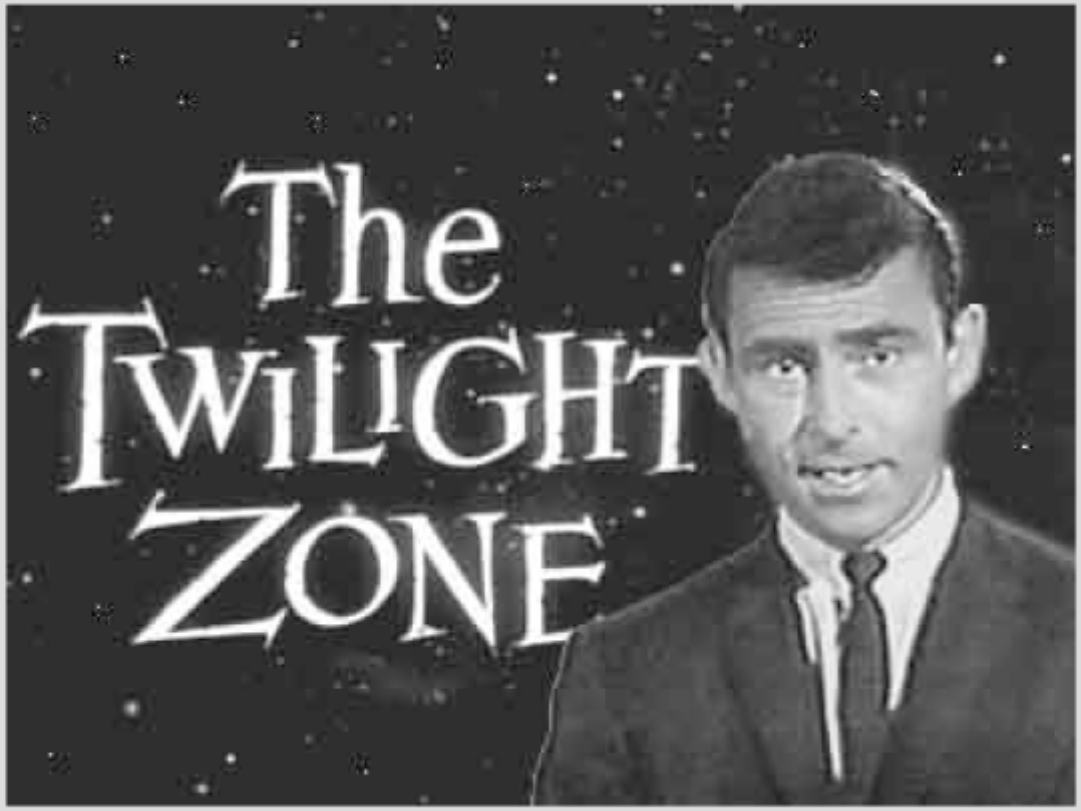
Vertical Dimension
is Time



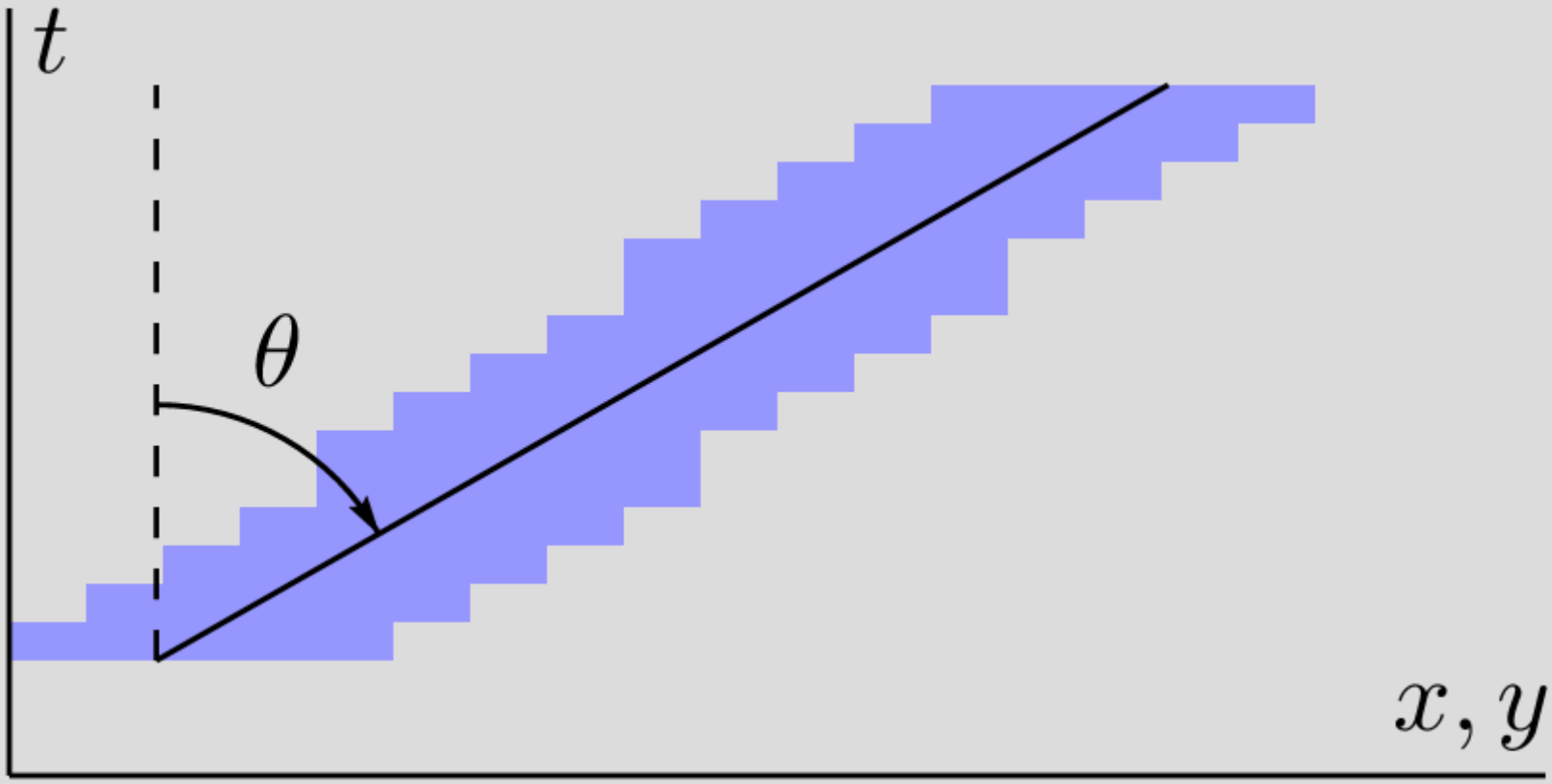
2D vs. 3D Convolution

2D points feel "influence" from spatially nearby points

3D points also feel "influence" from temporally nearby points



Object velocity is related to the tilt angle of the axis



The inclination of the axis from the vertical (time) direction increases with object speed.

Drought Objects

Worldwide Drought Index Dataset

Spans Several Decades

Forecast Errors

2D MODE

Location Errors

Intensity Errors

Shape Errors

Size Errors

Orientation Errors

MTD

Timing Errors

Velocity Errors

Duration Errors

Buildup & Decay

Visualization Issues

- Could distribute my code.
  --- Don't want to.
- Which graphics systems?
  --- Proprietary vs. Free ?
  --- Open Source ?
- Which file formats?
  --- Input and Output formats
  --- Vector vs. Raster
- Can't see inside objects!

Summary of MTD

- MODE 3D is a generalization of MODE 2D that incorporates the time dimension.
- Object matching and merging are done with a fuzzy-logic engine, as in the 2D case.
- Because one of the dimensions is not spatial, some object attributes have new interpretations.
- The addition of the time dimension produces a few new wrinkles.

Summary

- Object tracking over time is a freebie.
- Spacetime graphs may give some measure of storm complexity.
- Plan to adapt algorithms and data structures from image analysis and computational geometry to this situation.
- Lots of both meteorology and computer science in this project.

Wrap Up

Questions?

Comments?

Ideas?

Opinions?