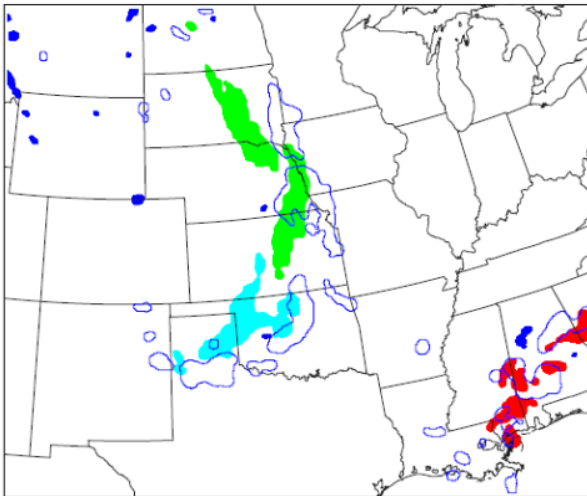


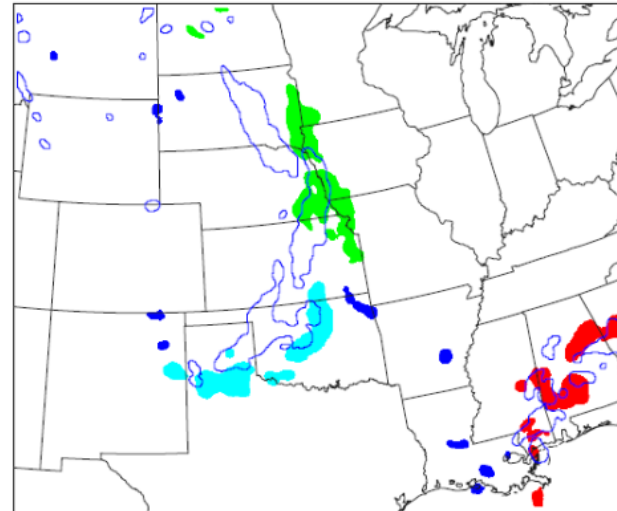
MODE Customization and Output

Verifying with Objects

WRF Objects with StageII Outlines

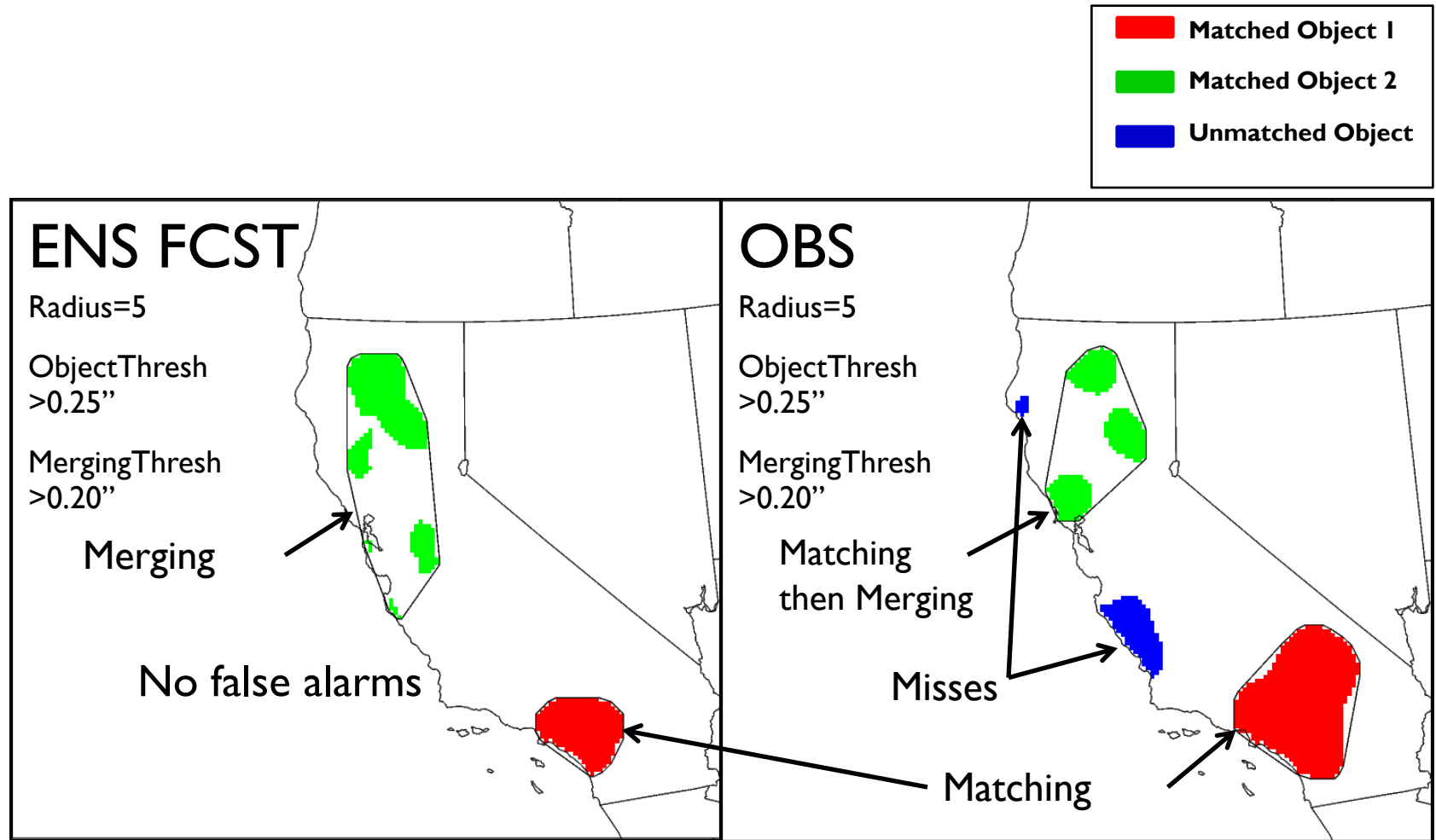


StageII Objects with WRF Outlines



Presenter: Tina Kalb

MODE Example



MODE Input and Usage

- Input Files: Gridded forecast and observation
 - GRIB1, GRIB2 (Unified Post-Processor, NCEP, other)
 - NetCDF (PCP-Combine, wrf_interp, CF-compliant)
- Usage: **mode**
 - **fcst_file**
 - **obs_file**
 - **config_file**
 - **[-config_merge merge_config_file]**
 - **[-outdir path]**
 - **[-log file]**
 - **[-v level]**

fcst_file	Gridded forecast file
obs_file	Gridded observation file
config_file	ASCII configuration file
-config_merge	Second configuration file for fuzzy engine merging
-outdir	Output directory to be used
-log	Optional log file
-v	Level of logging

Config File

https://dtcenter.org/met/users/support/online_tutorial/METv6.1/config/MODEConfig_default

```
// Run all permutations of radius and threshold
//
quilt = TRUE;

//
// Forecast and observation fields to be verified
//
fcst = {
  field = {
    name = "prAnom";
    level = "(*,*)";
  }

  file_type      = NETCDF_NCCF;
  censor_thresh  = [];
  censor_val     = [];
  conv_radius    = [0,2,4,8]; // in grid squares
  conv_thresh    = [<=-0.5,<=-0.75,<=-1.0,<=-1.25,>=0.5,>=0.75,>=1.0,>=1.25];
  vld_thresh     = 0.5;
  area_thresh    = NA;
  inten_perc_value = 100;
  inten_perc_thresh = NA;
  merge_thresh   = [>=1.25,>=1.25,>=1.25,>=1.25,>=1.25,>=1.25,>=1.25,>=1.25];
  merge_flag     = ENGINE;
}

obs = {
  field = {
    name = "prAnom";
    level = "(*,*)";
  }

  file_type      = NETCDF_NCCF;
  censor_thresh  = [];
  censor_val     = [];
  conv_radius    = [0,2,4,8]; // in grid squares
  conv_thresh    = [<=-0.5,<=-0.75,<=-1.0,<=-1.25,>=0.5,>=0.75,>=1.0,>=1.25];
  vld_thresh     = 0.5;
  area_thresh    = NA;
  inten_perc_value = 100;
  inten_perc_thresh = NA;
  merge_thresh   = [>=1.25,>=1.25,>=1.25,>=1.25,>=1.25,>=1.25,>=1.25,>=1.25];
  merge_flag     = ENGINE;
```

```
//
// Handle missing data
//
mask_missing_flag = BOTH;

//
// Match objects between the forecast and observation fields
//
match_flag = MERGE_BOTH;

//
// Maximum centroid distance for objects to be compared
//
max_centroid_dist = 800.0/grid_res;

////////////////////////////////////

//
// Verification masking regions

mask = {
  grid      = "";
  grid_flag = NONE; // Apply to NONE, FCST, OBS, or BOTH
  poly      = "";
  poly_flag = NONE; // Apply to NONE, FCST, OBS, or BOTH
}
```

Config File

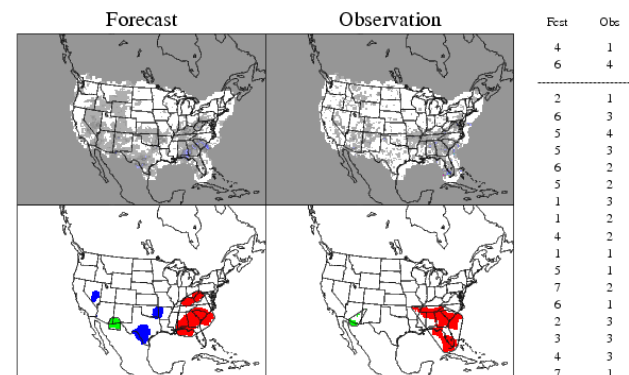
```
//  
// Fuzzy engine weights  
//  
weight = {  
    centroid_dist      = 2.0;  
    boundary_dist      = 4.0;  
    convex_hull_dist   = 0.0;  
    angle_diff         = 1.0;  
    area_ratio         = 1.0;  
    int_area_ratio     = 2.0;  
    complexity_ratio   = 0.0;  
    inten_perc_ratio   = 0.0;  
    inten_perc_value   = 50;
```

```
//  
// Total interest threshold for determining matches  
//  
total_interest_thresh = 0.5;  
  
//  
// Interest threshold for printing output pair information  
//  
print_interest_thresh = 0.0;
```

```
// Fuzzy engine interest functions  
//  
interest_function = {  
  
    centroid_dist = (  
        ( 0.0, 1.0 )  
        ( 60.0/grid_res, 1.0 )  
        ( 600.0/grid_res, 0.0 )  
    );  
  
    boundary_dist = (  
        ( 0.0, 1.0 )  
        ( 400.0/grid_res, 0.0 )  
    );  
  
    convex_hull_dist = (  
        ( 0.0, 1.0 )  
        ( 400.0/grid_res, 0.0 )  
    );  
  
    angle_diff = (  
        ( 0.0, 1.0 )  
        ( 30.0, 1.0 )  
        ( 90.0, 0.0 )  
    );  
  
    corner      = 0.8;  
    ratio_if = (  
        ( 0.0, 0.0 )  
        ( corner, 1.0 )  
        ( 1.0, 1.0 )  
    );  
  
    area_ratio = ratio_if;  
  
    int_area_ratio = (  
        ( 0.00, 0.00 )  
        ( 0.10, 0.50 )  
        ( 0.25, 1.00 )  
        ( 1.00, 1.00 )  
    );  
  
    complexity_ratio = ratio_if;  
  
    inten_perc_ratio = ratio_if;
```

MODE Output

- PostScript
 - object pictures, definitions
 - matching/merging strategy
 - total interest for each object pair
- ASCII Text
 - attributes of simple, paired objects, clusters
 - size, shape, position, separation, total interest
 - verification scores (CSI, bias, etc.) for objects
- netCDF
 - gridded object fields
 - view with ncview

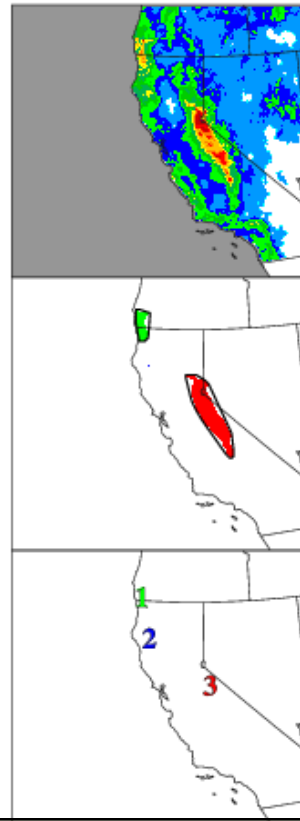
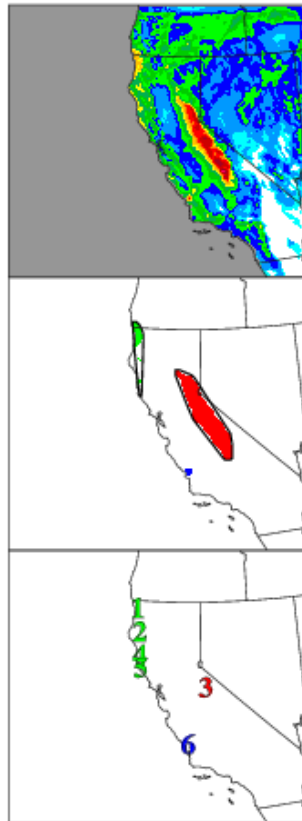


```
//  
// NetCDF matched pairs, PostScript,  
// and contingency table output files  
//  
ps_plot_flag      = TRUE;  
nc_pairs_flag     = {  
  latlon         = TRUE;  
  raw            = TRUE;  
  object_raw     = TRUE;  
  object_id      = TRUE;  
  cluster_id     = TRUE;  
  polylines      = TRUE;  
}  
ct_stats_flag    = TRUE;
```

IODE: APCP_24_A24_ENS_MEAN at A24 vs APCP_24 at A2

Forecast

Observation



Fest	Obs	Interest
3	3	1.0000
1	1	0.9360
<hr/>		
2	2	0.6436
5	2	0.6372
4	2	0.5085
2	1	0.4060
1	2	0.3871
4	1	0.3545
3	1	0.3422
6	3	0.3265
1	3	0.3141
4	3	0.2813
3	2	0.2719
2	3	0.2704
5	1	0.2406
5	3	0.2266
6	1	0.2203
6	2	0.1936

Total Interest of object pairs

Pairs above dashed line processed further

	Forecast	Observation
Model:	hmt-ens-d01	
Field:	APCP_24_A24_ENS_MEAN	APCP_24_A24
Level:	A24	A24
Units:	kg/m^2	kg/m^2
Initial:	20110216 12:00:00	20110216 12:00:00
Valid:	20110217 12:00:00	20110217 12:00:00
Accum:	24:00:00	24:00:00

Centroid/Boundary:	2.00	4.00
Convex Hull/Angle:	0.00	1.00
Area/Intersection Area:	4.00	4.00
Complexity/Intensity:	0.00	2.00
Total Interest Thresh:		0.70

	Forecast	Observation
Mask M/G/P:	on/off/off	on/off/off
Raw Thresh:	≥ 0.00	≥ 0.00
Conv Radius:	2 gs	2 gs
Conv Thresh:	≥ 25.40	≥ 25.40
Area Thresh:	≥ 0 gs	≥ 0 gs
Inten Thresh:	p100 ≥ 0.00	p100 ≥ 0.00
Merge Thresh:	≥ 20.00	≥ 20.00
Merging:	thresh	thresh
Matching:	match/merge	
Simple/M/U:	6/5/1	3/2/1
Area:	696 gs	589 gs
Area M/U:	674/22	585/4
Cluster:	2	2
MMI:	0.6404	0.9360
MMI (F+O):		0.6436

Definition of objects

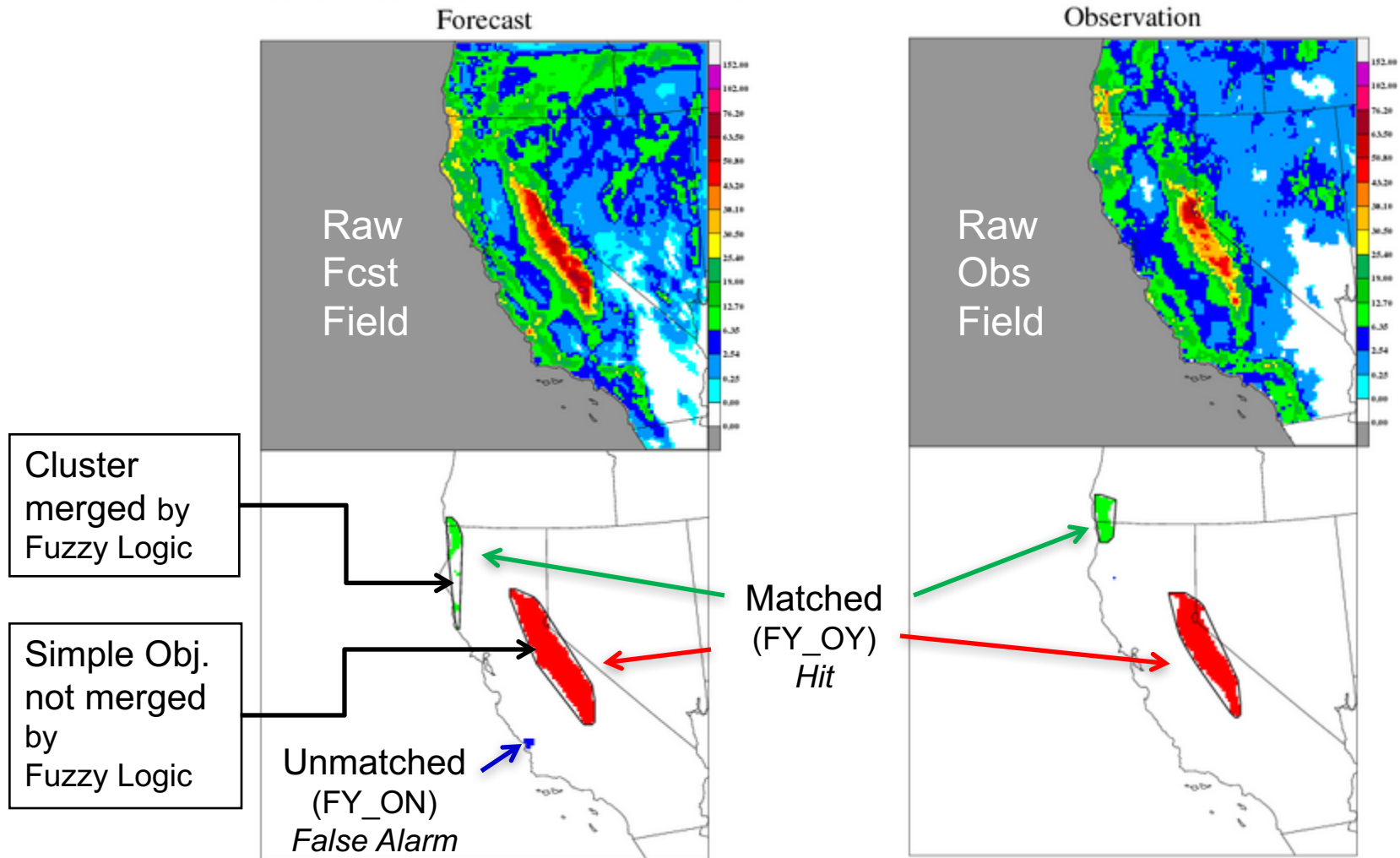
- smoothing radius
- intensity threshold
- area threshold
- matching and/or merging
- # and area of objects
- **Median Max. Interest (MMI)**

Field names
model description

Weight of object
attributes

Page 2 and 3 of PostScript:

- Band shows which Simple Objects are merged (aka Cluster)
- Colors show matching between Fcst and Obs.

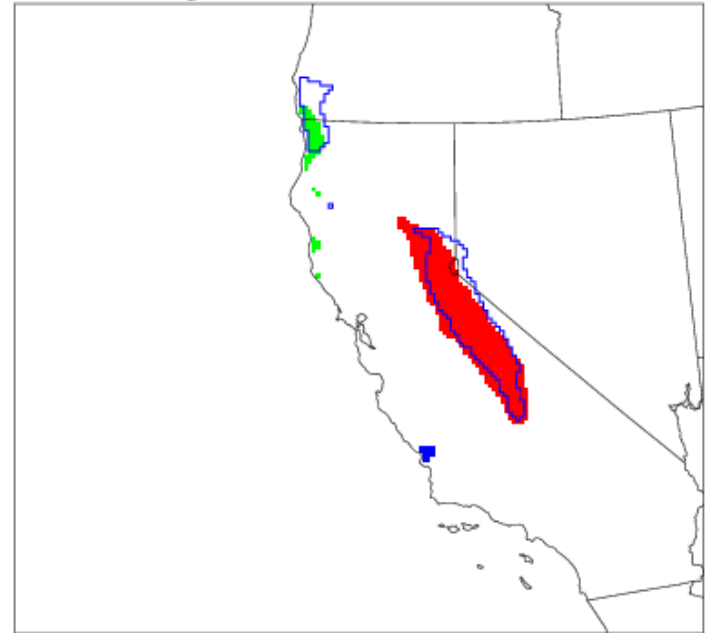


Page 4 of PostScript

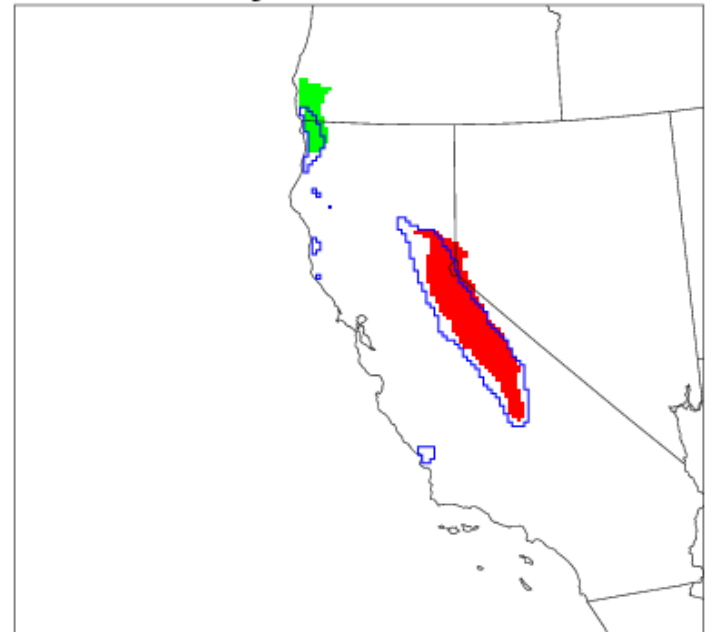
Objects overlapped
In two different views...

Which do you prefer?

Forecast Objects with Observation Outlines



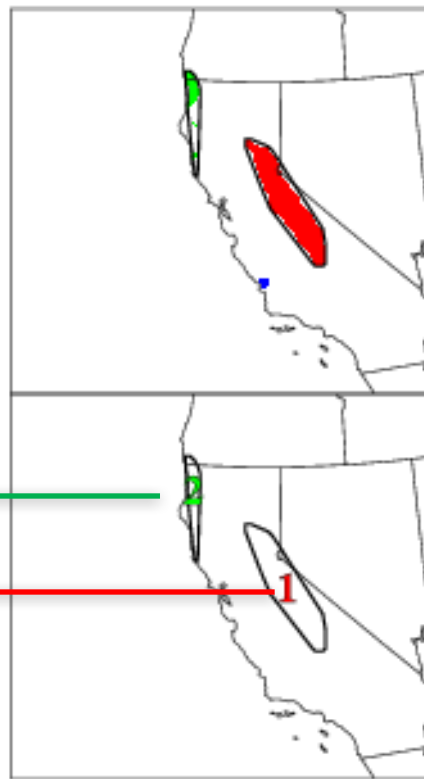
Observation Objects with Forecast Outlines



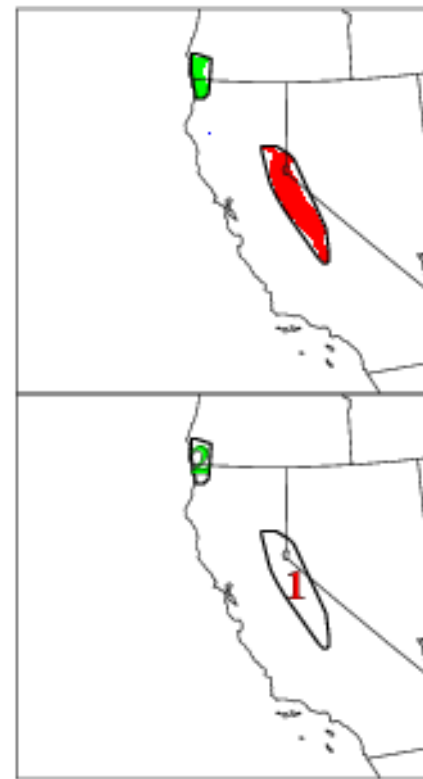
Page 5 of PostScript - Summary information for clusters in the domain

Cluster Object Information

Forecast



Observation



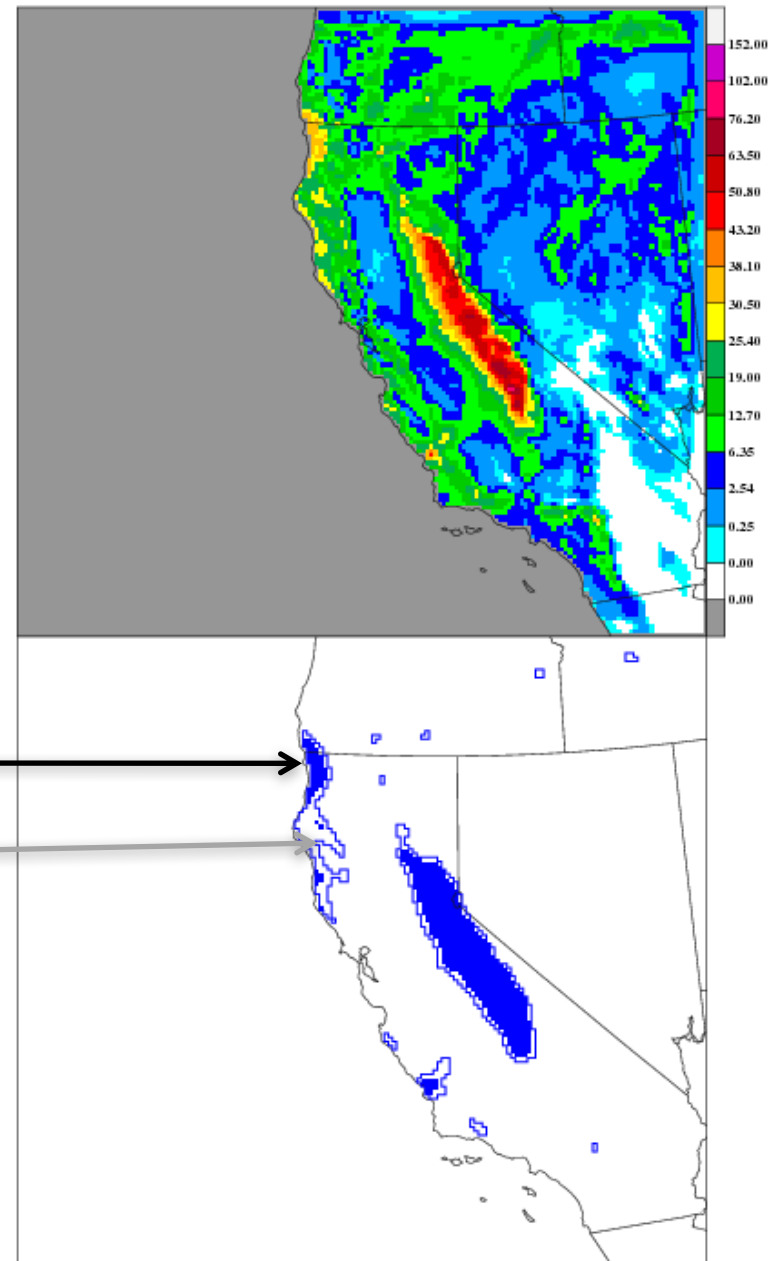
CLUS PAIR	CEN DIST	ANG DIFF	FCST AREA	OBS AREA	INTER AREA	UNION AREA	SYM DIFF	FCST INT50	OBS INT50	FCST INT90	OBS INT90	TOT INTR
1	1.51	3.65	579	466	418	627	209	39.89	34.95	56.20	49.70	1.0000
2	11.94	2.59	95	119	53	161	108	27.56	27.40	34.28	36.42	0.9909

Page 6+ of PostScript

Raw Field and Double Thresholding For Merging Process

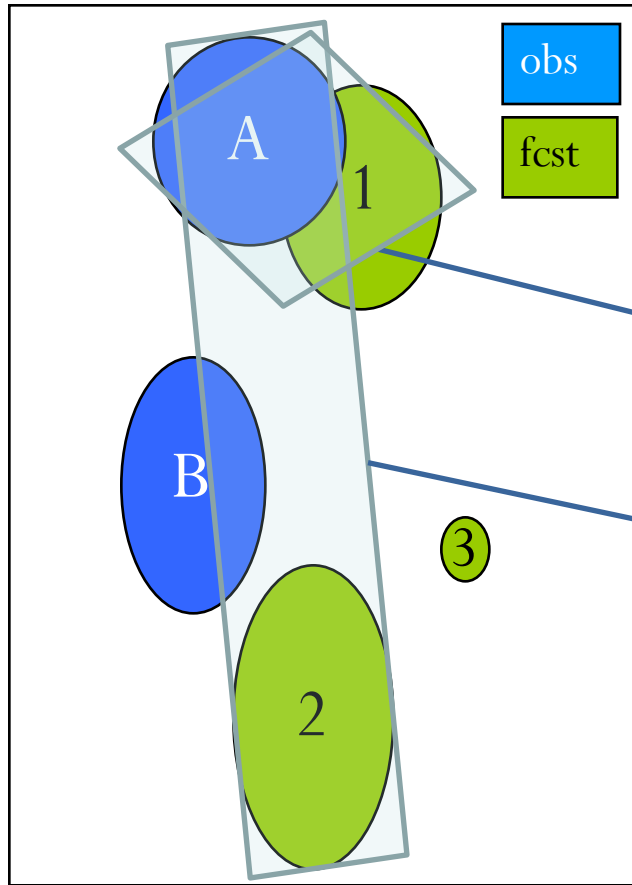
Convolution Threshold ($\geq 25.4\text{mm}$)

Double Thresholding Value ($\geq 22.5\text{mm}$)



Summary Score for Forecast

Median of the Max. Interest (MMI*)



Interest Matrix

observed

	observed	
	A	B
	0.90	0.65
	0.50	0.80
forecast	0.40	0.55

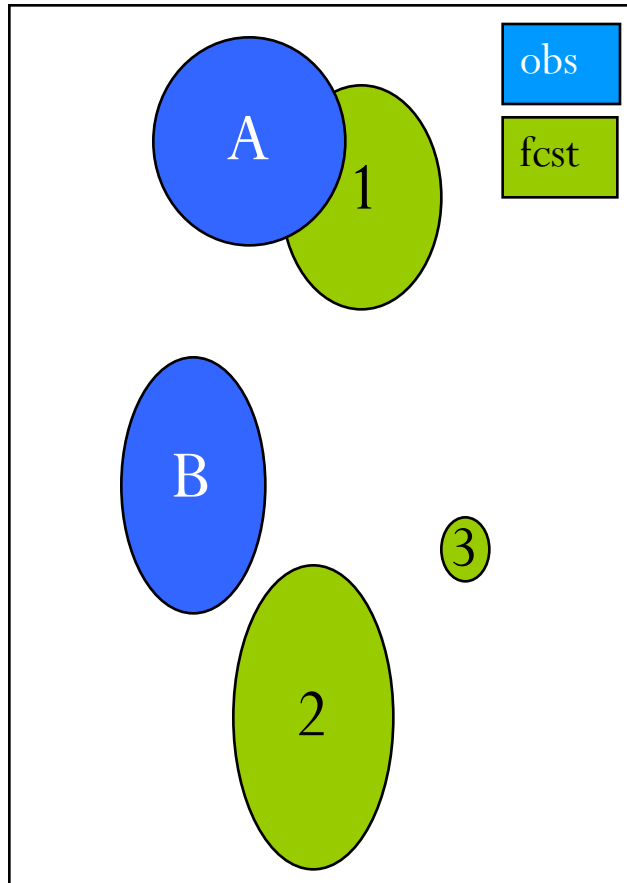
* Davis et al., 2009: The Method for Object-based Diagnostic Evaluation (MODE) Applied to WRF Forecasts from the 2005 SPC Spring Program. Weather and Forecasting

$$\text{MMI} = \text{median} \{ 0.90, \overset{\text{maximum interest}}{0.80}, 0.90, 0.80, 0.55 \} = 0.80$$

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Summary Score for Forecast

Median of the Max. Interest (MMI*)



Interest Matrix

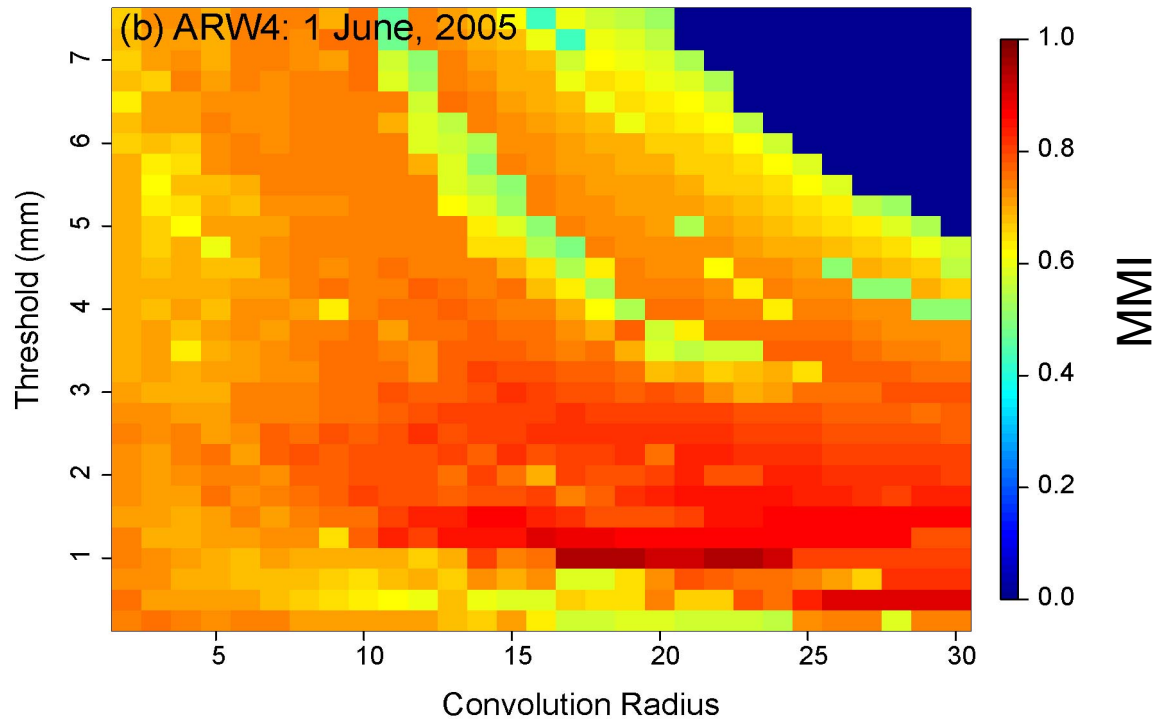
observed

		A	B
forecast	1	0.90	0.65
	2	0.50	0.80
	3	0.40	0.55

* Davis et al., 2009: The Method for Object-based Diagnostic Evaluation (MODE) Applied to WRF Forecasts from the 2005 SPC Spring Program. Weather and Forecasting

MMI = median { 0.90, 0.80, 0.90, 0.80, 0.55 } = 0.80

Median of the Max. Interest (MMI) Quilt Plot

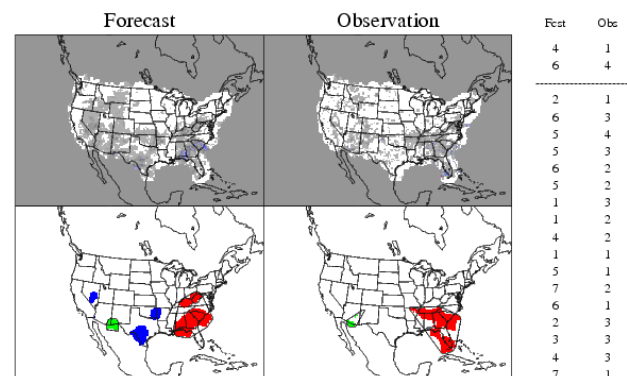


MMI as a function of convolution radius (grid squares) and threshold (mm) for 24-h forecast of 1-h rainfall

- Each pixel is a MODE run.
- This graphic is not in MET, but R code on MET website.

MODE Output

- PostScript
 - object pictures, definitions
 - matching/merging strategy
 - total interest for each object pair
- ASCII Text
 - attributes of simple, paired objects, clusters
 - size, shape, position, separation, total interest
 - verification scores (CSI, bias, etc.) for objects
- netCDF
 - gridded object fields
 - view with ncview



```
//  
// NetCDF matched pairs, PostScript,  
// and contingency table output files  
//  
ps_plot_flag      = TRUE;  
nc_pairs_flag     = {  
  latlon          = TRUE;  
  raw             = TRUE;  
  object_raw      = TRUE;  
  object_id       = TRUE;  
  cluster_id      = TRUE;  
  polylines       = TRUE;  
}  
ct_stats_flag     = TRUE;
```

ASCII Output

Object Attribute file (*_obj.txt)

- Header with fields names and object definition info
- Object ID and Category
- Simple Object Attributes
 - Simple Obj. Centroid info, Length, Width, Area, etc...
- Matched Pair/Composite information
 - Centroid Distance, Angle Difference, Symmetric Difference, etc...
- NA's for not relevant output

Contingency Table Stat file (*_cts.txt)

- Header with fields names and object definition info
- Contingency Table counts
 - hits, false alarms, misses and correct negs (FY|FN_OY|ON notation)
- Contingency Table statistics such
 - BASER, FBIAS, GSS, CSI, PODY, FAR etc...

ASCII Output

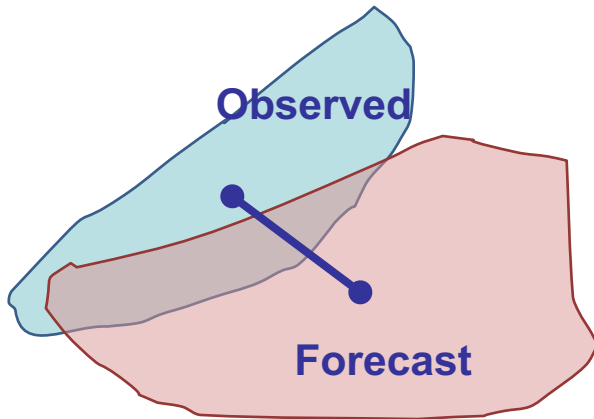
Object Attribute file (*_obj.txt)

OBJECT_ID	OBJECT_CAT	CENTROID_X	CENTROID_Y	CENTROID_LAT	CENTROID_LON	AXIS_ANG	LENGTH	WIDTH	AREA
F001	CF000	1088.10939	419.8381	35.38308	-91.24656	35.0499	159.73583	69.37881	6625
0001	C0000	1072.24122	767.62874	44.75884	-90.95277	48.23578	202.68348	82.43007	10024
0002	C0000	899.80285	567.40078	39.53595	-97.47192	48.70561	39.12947	25.76823	707
F001_0001	CF000_C0000	NA	NA	NA	NA	NA	NA	NA	NA
F001_0002	CF000_C0000	NA	NA	NA	NA	NA	NA	NA	NA

Contingency Table Stat file (*_cts.txt)

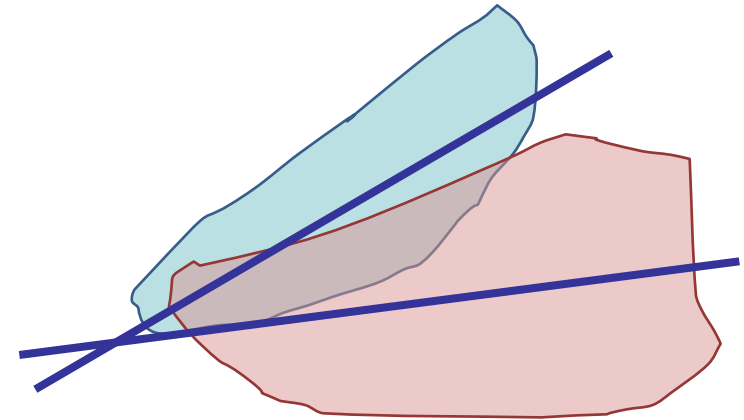
OBTYP	FIELD	TOTAL	FY_OY	FY_ON	FN_OY	FN_ON	BASER	FMEAN	ACC	FBIAS	PODY	PODN	POFD	FAR	CSI
GPCP	RAW	1714176	51313	51666	95113	1516084	0.085421	0.060075	0.91437	0.70328	0.35044	0.96704	0.032956	0.50171	0.25904
GPCP	OBJECT	1714176	48522	49626	82152	1533876	0.076231	0.057257	0.92312	0.75109	0.37132	0.96866	0.031339	0.50562	0.26912

Use of MODE Pair Attributes



Centroid Distance: Quantitative measure of forecast spatial Displacement.

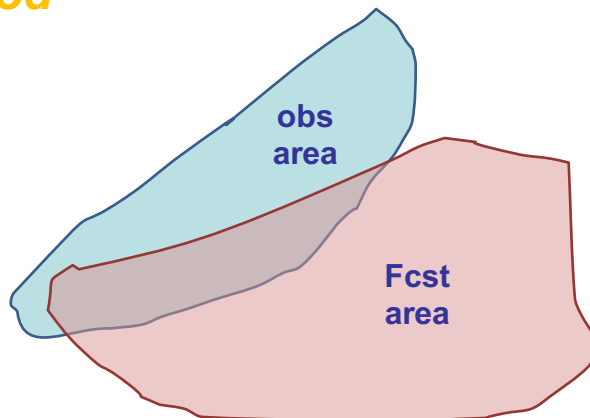
Small is good



Axis Angle: For non-circular Objects, measure of orientation errors.

Small is good

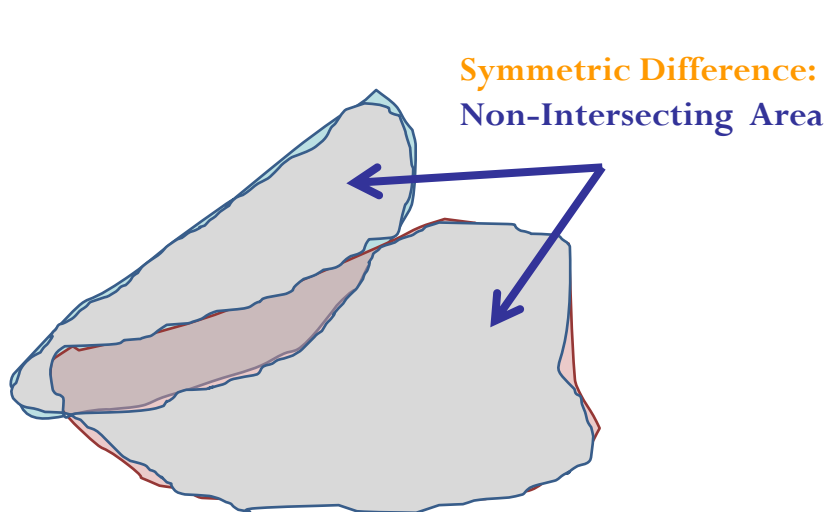
Area Ratio =
$$\frac{\text{small Area}}{\text{Large Area}}$$



Area Ratio: Provides an objective measure of whether there is an over- or under-prediction of areal extent of forecast.

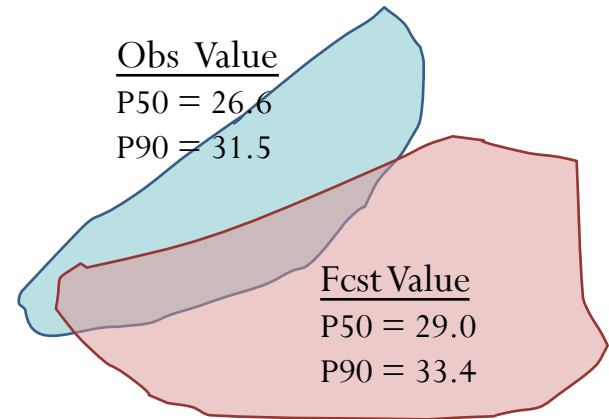
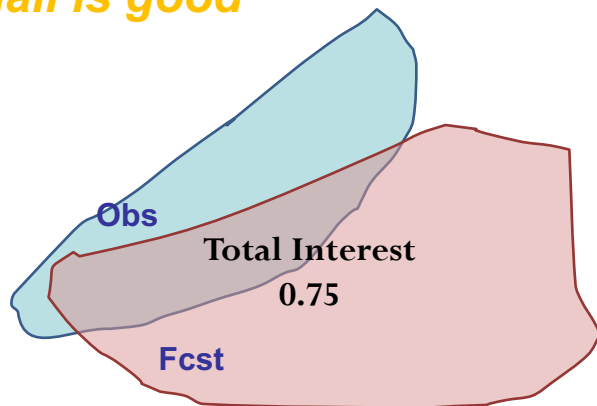
Close to 1 is good

Use of MODE Pair Attributes



Symmetric Diff: Summary statistic for how well Forecast and Observed objects match.

Small is good



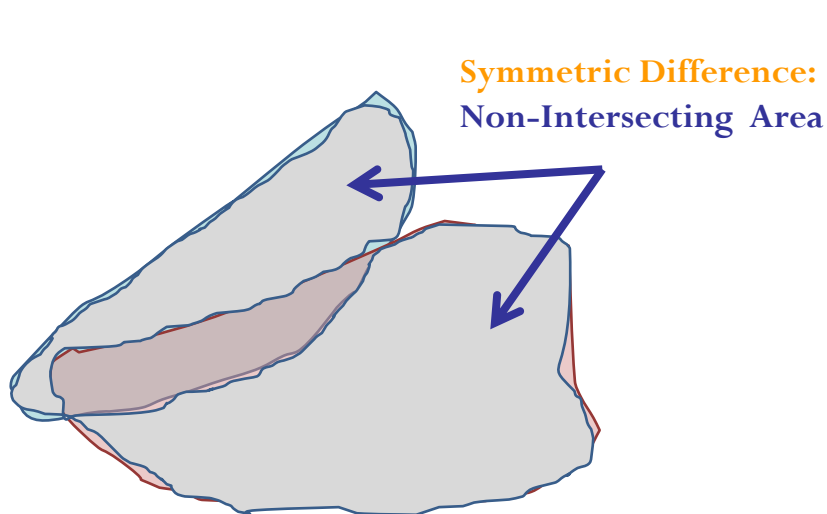
P50 | P90 Int: Objective measures of Median (50th percentile) and near-Peak (90th percentile) intensities in objects.

Ratio close To 1 is good

Total Interest: Summary statistic derived from fuzzy logic engine with user-defined Interest Maps for all these attributes plus some others.

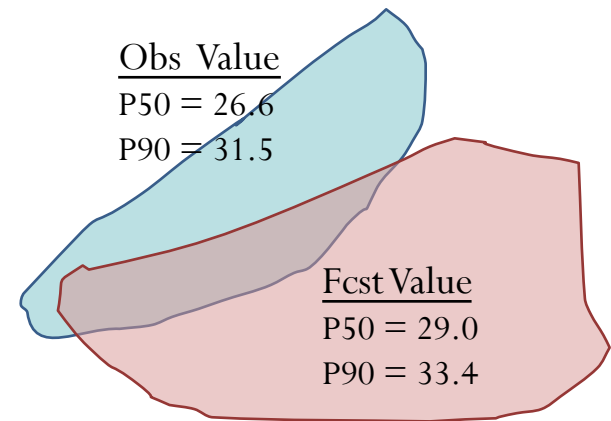
Close to 1 is good

Use of MODE Pair Attributes



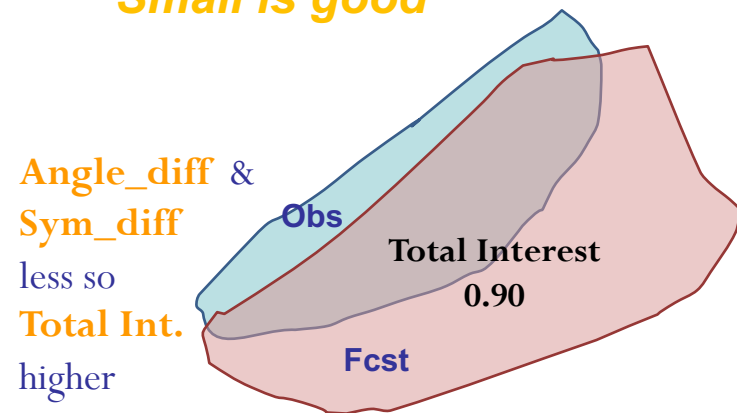
Symmetric Diff: Summary statistic for how well Forecast and Observed objects match.

Small is good



P50 | P90 Int: Objective measures of Median (50th percentile) and near-Peak (90th percentile) intensities in objects.

Ratio close To 1 is good



Total Interest: Summary statistic derived from fuzzy logic engine with user-defined Interest Maps for all these attributes plus some others.

Close to 1 is good

Scoring MODE Objects

use total interest threshold to separate matched objects,
or “hits” from false alarms and misses

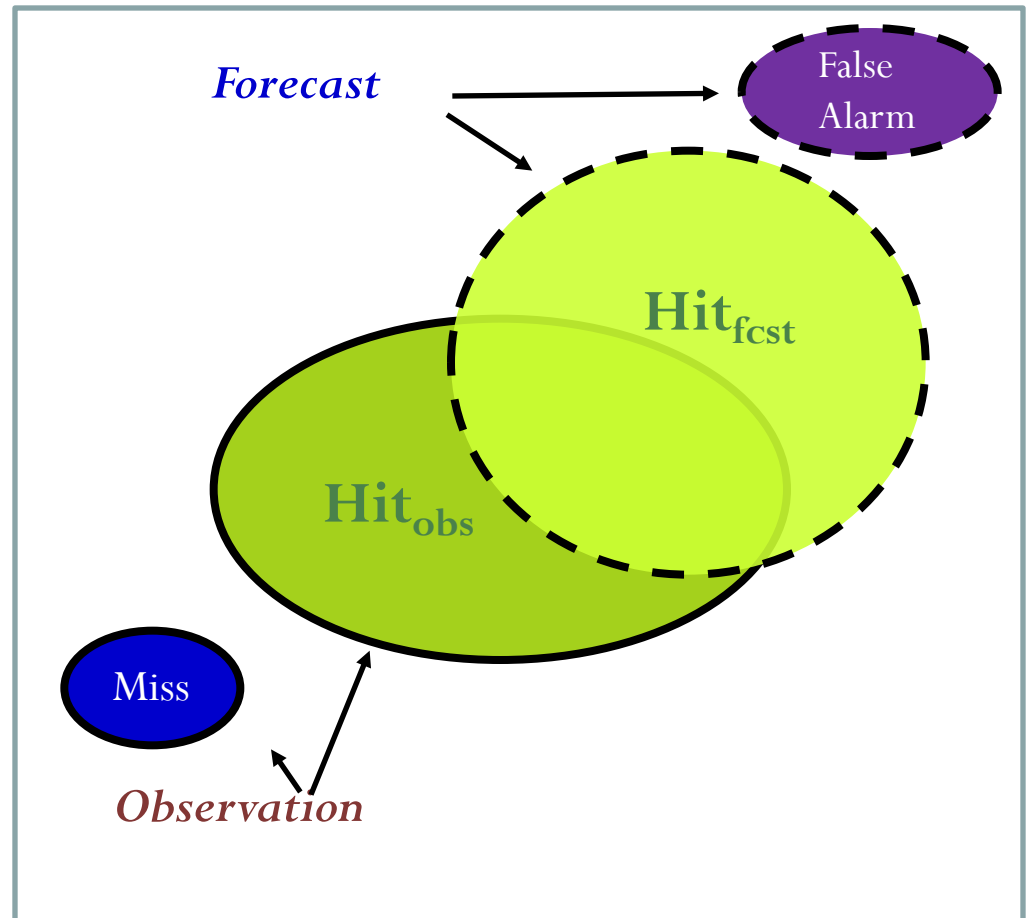
Traditional Categorical Statistics

critical success index (CSI) =

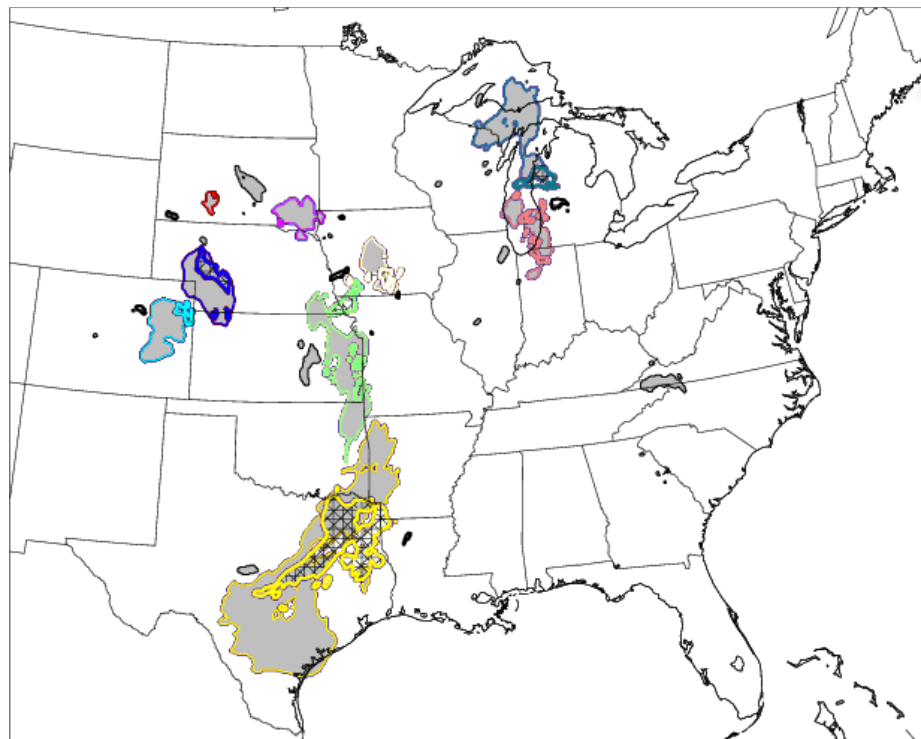
$$\frac{\text{Hit}}{\text{Hit} + \text{Miss} + \text{False Alarm}}$$

$$\text{bias} = \frac{\text{Hit} + \text{False Alarm}}{\text{Hit} + \text{Miss}}$$

sometimes *area-weighted*

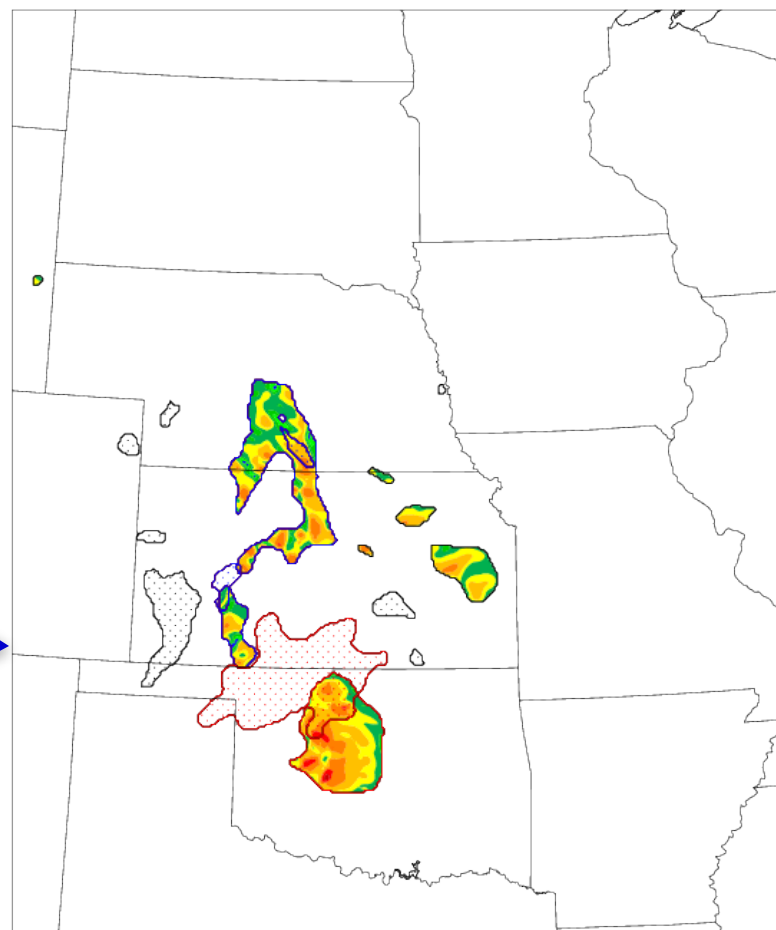


How netCDF could be used



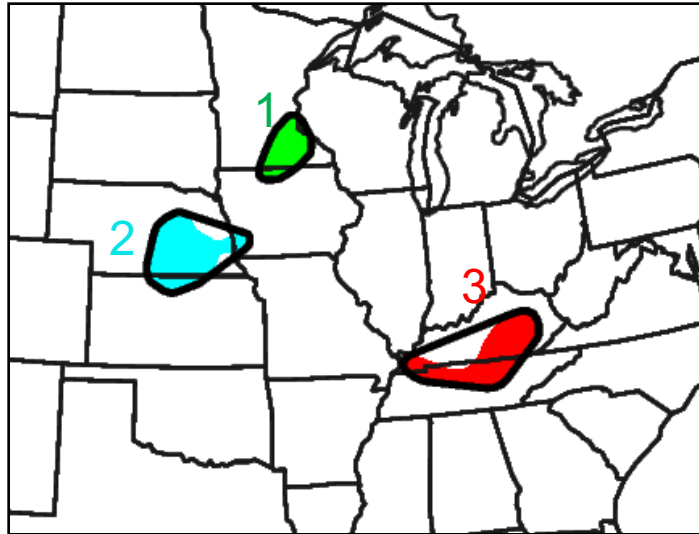
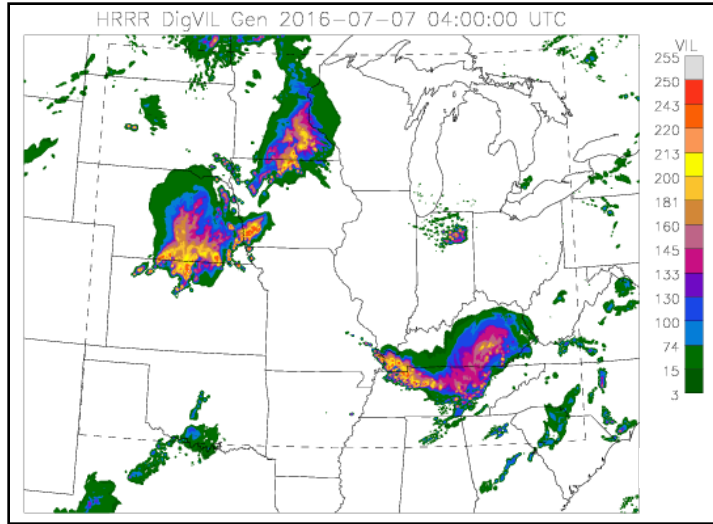
Employ a different plotting approach to show matched clusters

Display actual intensities inside objects
(in this case Reflectivity)



Plots generated using NCL

MODE Example: Traditional



Object #3

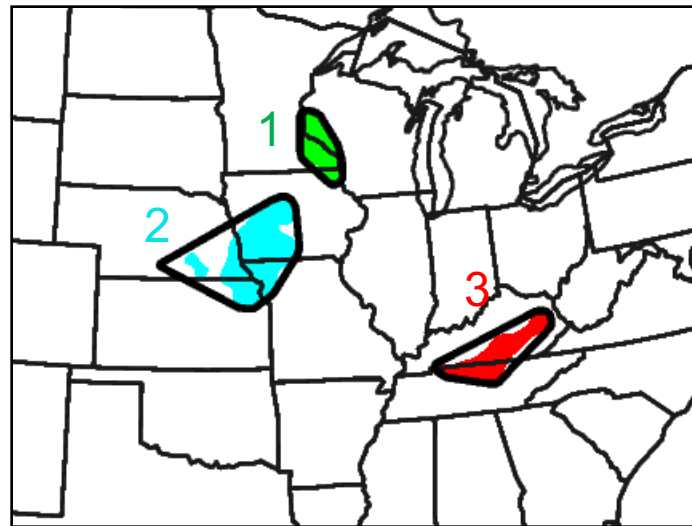
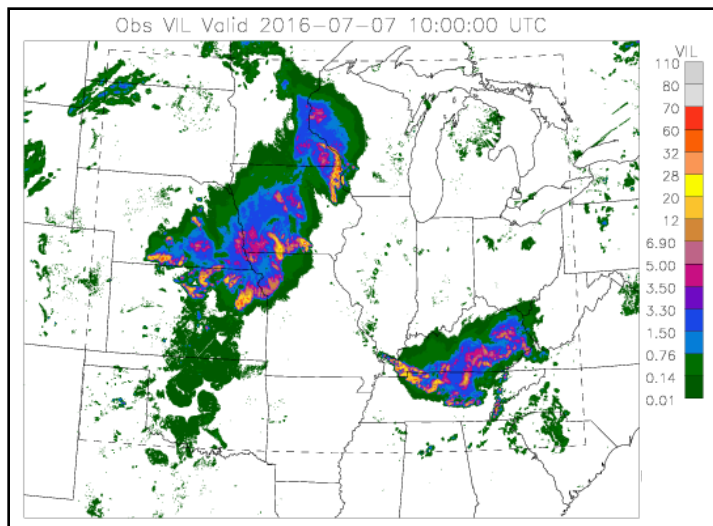
Fcst Area: 6302

Obs Area: 4020

Centroid Dist: 12.4

Int Area: 3189

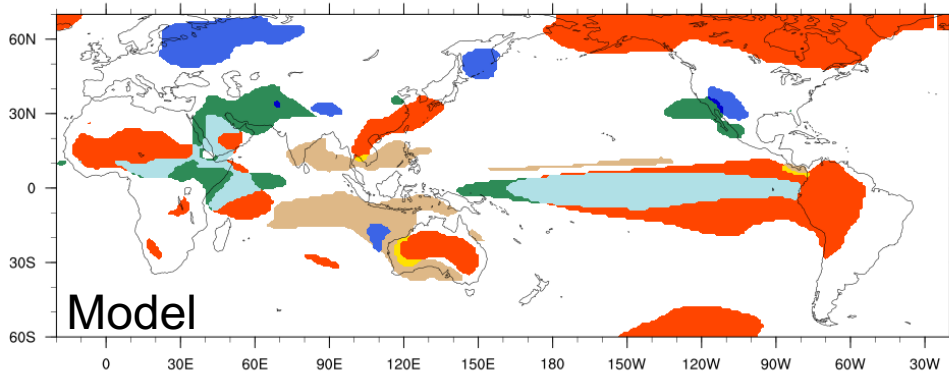
Interest: 0.98



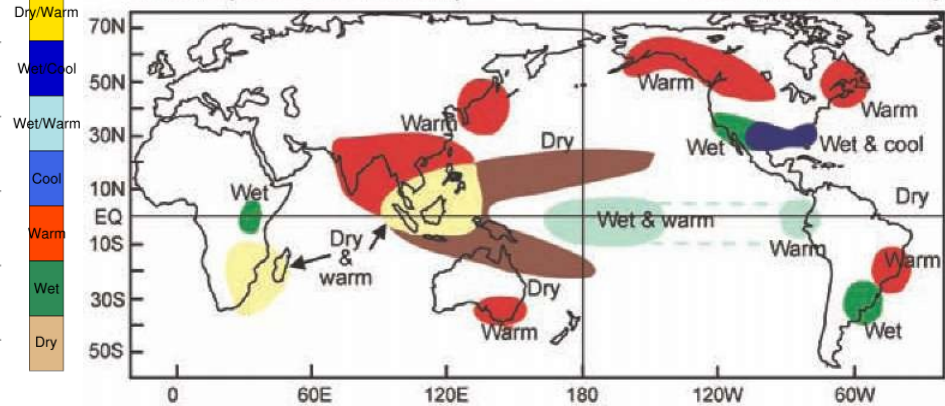
No False
alarms or
misses

MODE Example: El Nino Climate

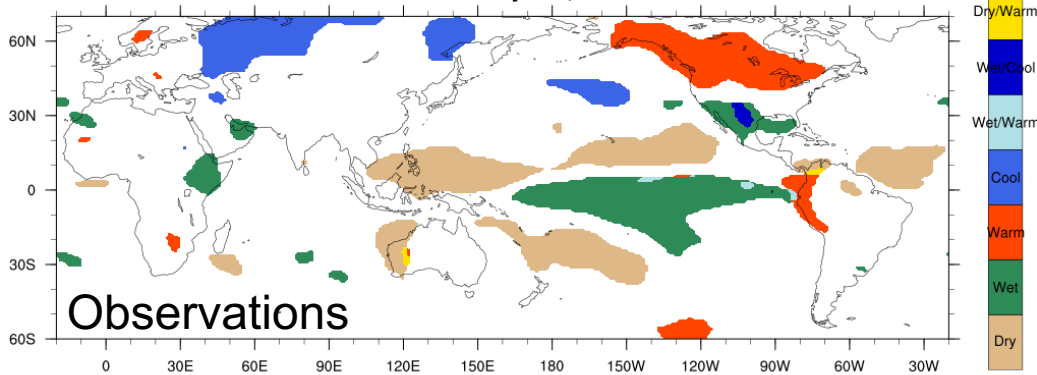
El Nino CESM Objects, DJF 1979 - 2012



Warm episode relationship

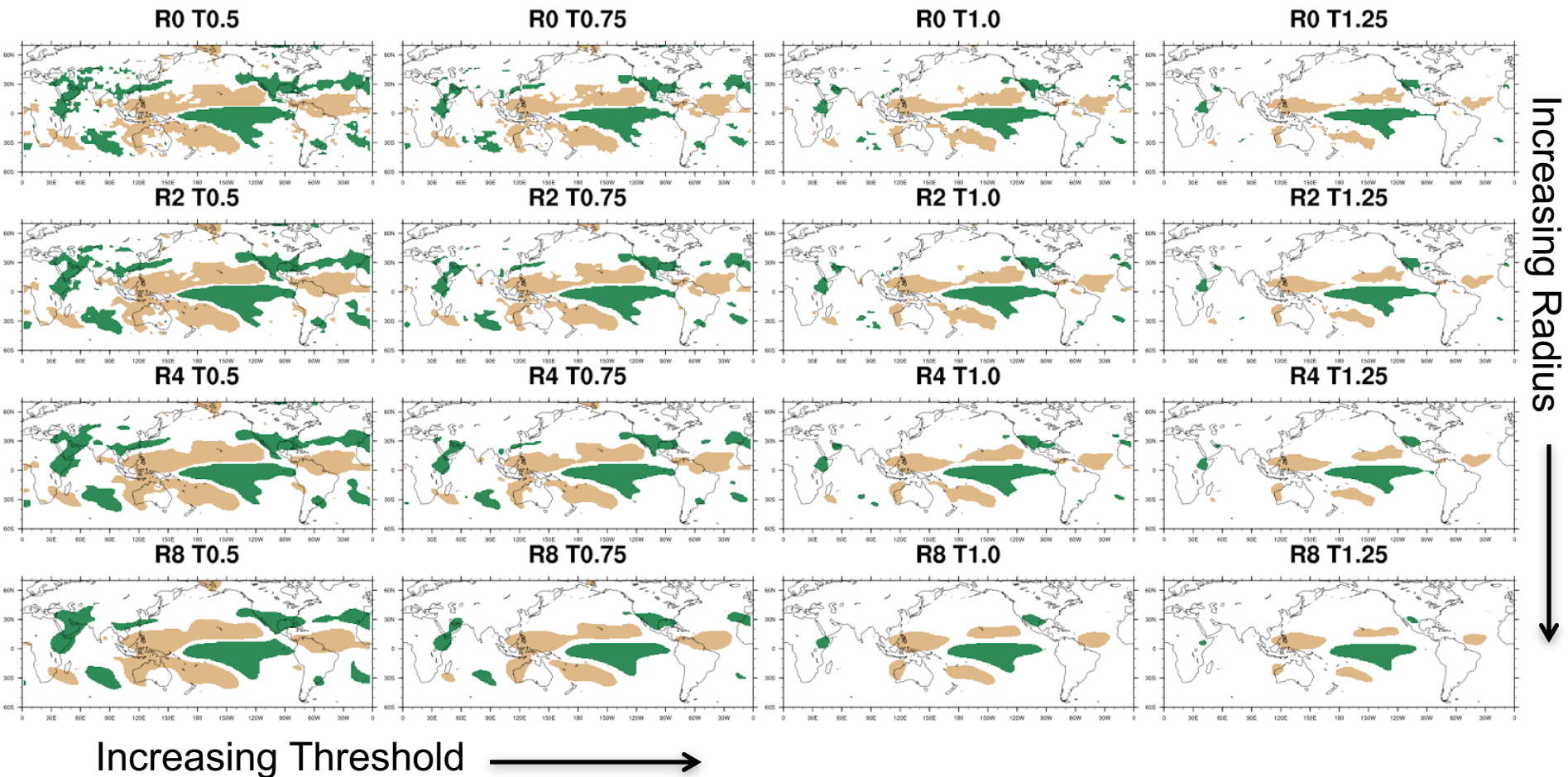


El Nino Observation Objects, DJF 1979 - 2012



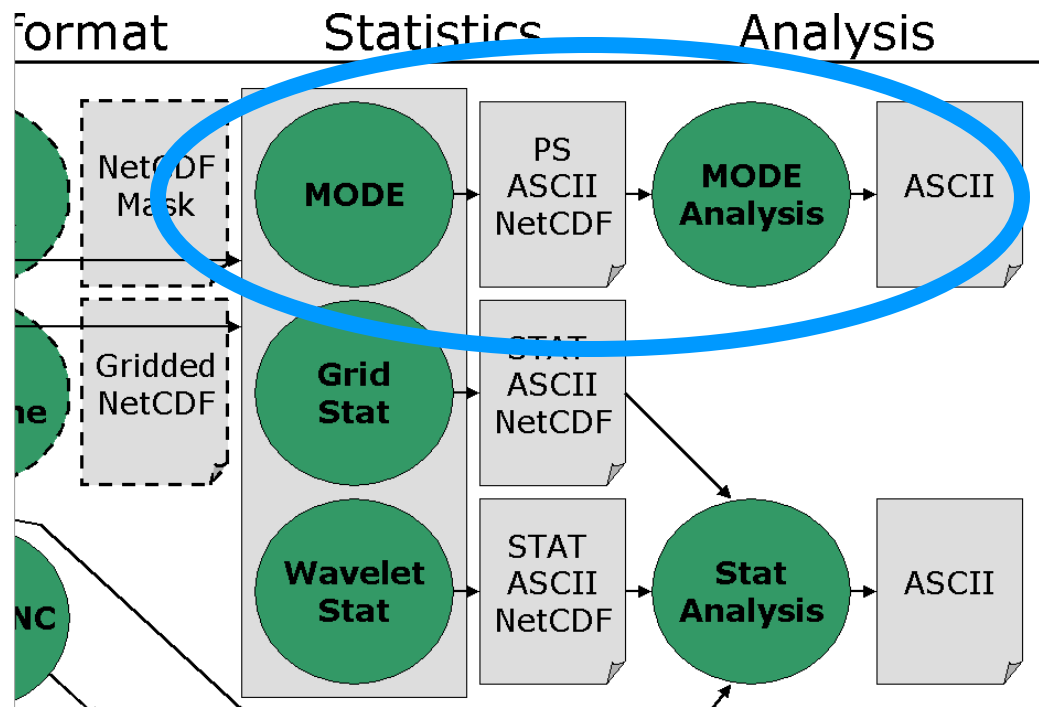
- Not individual forecasts
- Quantify differences in each anomaly type separately

Effect of Radius and Threshold



MODE Analysis Tool

- mode_analysis



MODE_Analysis Usage

Usage: *mode_analysis*

-lookin path

-summary or -bycase

[-column name]

[-dump_row filename]

[-out filename]

[-log filename]

[-v level]

[-help]

[MODE FILE LIST]

[-config config_file]

or [MODE LINE OPTIONS]

MODE LINE OPTIONS

Object Toggles

-fcst versus **-obs**

Selects lines pertaining to forecast objects or observation objects

-single versus **-pair**

Selects single object lines or pair lines

-simple versus **-cluster**

Selects simple object lines or cluster

-matched versus **-unmatched**

Selects matched simple object lines or unmatched simple object lines.

Other Options (each option followed by value)

-model, -fcst|obs_thr , -fcst_var , etc...

-area_min|max, -intersection_area_min|max , etc...

-centroid_x_min|max , -centroid_y_min|max,
-axis_ang_min|max, -int10_min|max,
-centroid_dist_min|max, -angle_diff_min|max,
etc...

MODE_Analysis Config File

```
// Integer min/max options
//
//area_min           = 0;
//area_max           = 0;

//area_filter_min    = 0;
//area_filter_max    = 0;

//area_thresh_min    = 0;
//area_thresh_max    = 0;

//intersection_area_min = 0;
//intersection_area_max = 0;

//union_area_min     = 0;
//union_area_max     = 0;

//symmetric_diff_min  = 0;
//symmetric_diff_max  = 0;
```

```
////////////////////////////////////
//
// Date/time min/max options
//
// Date/time strings of the form YYYYMMDD, YYYYMMDD_HH, or YYYYMMDD_HHMMSS
//
//fcst_valid_min = "";
//fcst_valid_max = "";
```

```
// MODE line type toggle options
//
fcst      = FALSE;
obs       = FALSE;
```

```
// Multiple set string options
//
//model     = [];
//desc      = [];
//fcst_thr   = [];
//obs_thr    = [];
//fcst_var   = [];
//fcst_lev   = [];
//obs_var    = [];
//obs_lev    = [];
```

MODE Analysis Tool

-summary Example

Command Line

```
mode_analysis -summary \  
-lookin mode_output/wrf4ncep/40km/ge03.\  
-fcst -cluster \  
-area_min 100 \  
-column centroid_lat -column centroid_lon \  
-column area \  
-column axis_ang \  
-column length
```

Provides summary statistics for Forecast Clusters with minimum area of 100 grid-sq for the specified MODE output columns

Output

```
Total mode lines read = 393  
Total mode lines kept = 17
```

Field	N	Min	Max	Mean	StdDev	P10	P25	P50	P75	P90	Sum
-----	--	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
centroid_lat	17	31.97	46.24	38.65	3.81	33.89	36.13	38.54	40.12	43.99	657.00
centroid_lon	17	-103.89	-85.20	-96.32	5.91	-103.15	-102.65	-96.26	-93.95	-86.78	-1637.49
area	17	180.00	8393.00	2955.06	2246.49	624.80	1206.00	2662.00	3958.00	5732.20	50236.00
axis_ang	17	-88.63	85.66	12.62	64.35	-70.77	-63.86	35.04	74.37	79.24	214.60
length	17	25.25	234.76	124.41	60.99	48.85	65.37	116.67	169.37	204.57	2114.90

MODE Analysis Tool

-bycase Example

Command Line

```
mode_analysis -bycase -lookin mode_output/wrf4ncep/40km/ge03. -single -simple
```

Output

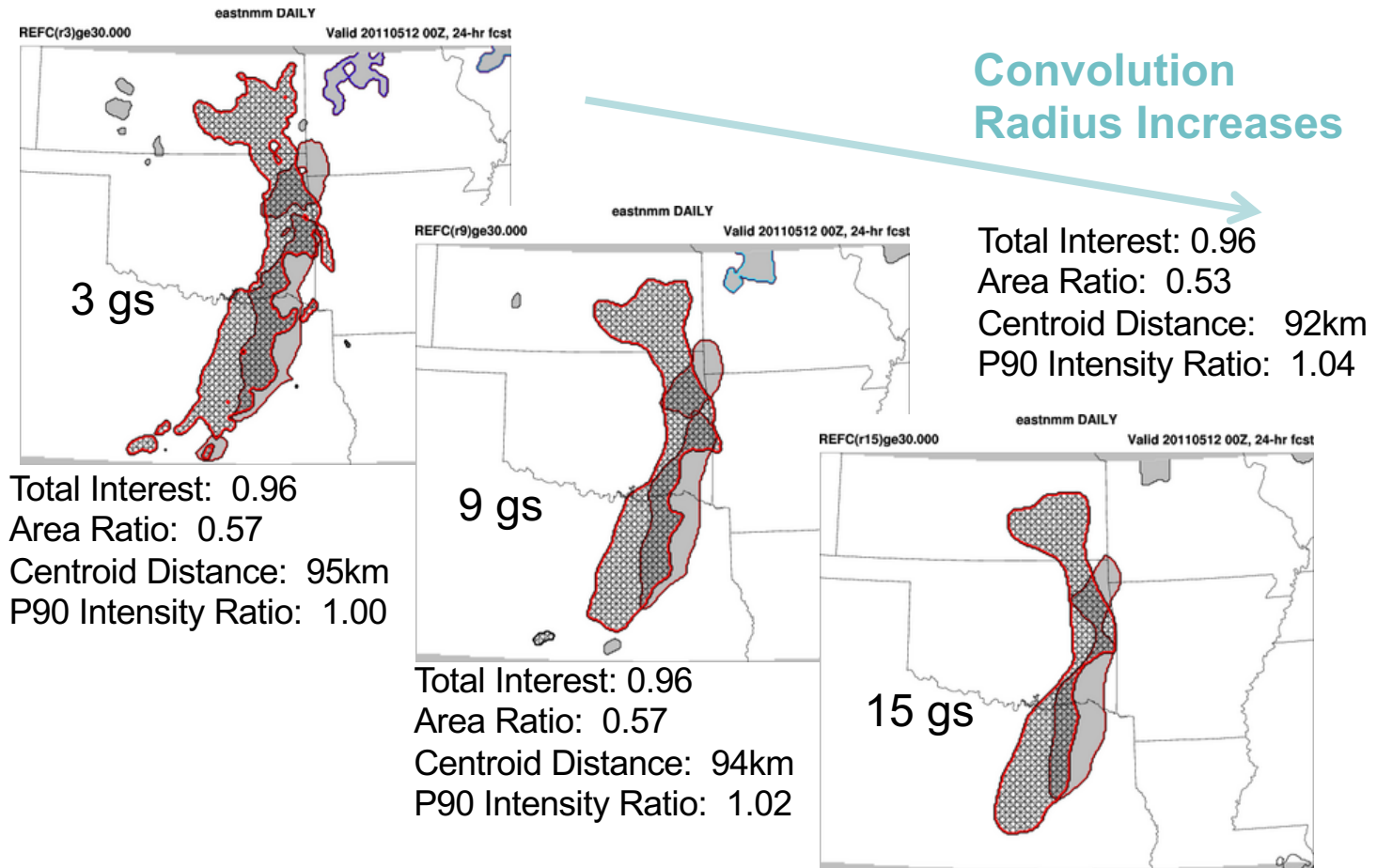
Total mode lines read = 393

Total mode lines kept = 141

Fcst Valid Time	Area Matched	Area Unmatched	# Fcst Matched	# Fcst Unmatched	# Obs Matched	# Obs Unmatched
Apr 26, 2005 00:00:00	3210	1046	2	4	1	1
May 13, 2005 00:00:00	8892	9320	2	19	1	2
May 14, 2005 00:00:00	16994	4534	7	4	5	3
May 18, 2005 00:00:00	6057	852	3	2	2	1
May 19, 2005 00:00:00	1777	1624	1	5	2	1
May 25, 2005 00:00:00	8583	928	4	2	4	2
Jun 1, 2005 00:00:00	12456	2657	5	6	6	2
Jun 3, 2005 00:00:00	7561	102	11	1	5	0
Jun 4, 2005 00:00:00	11464	5715	6	12	4	3

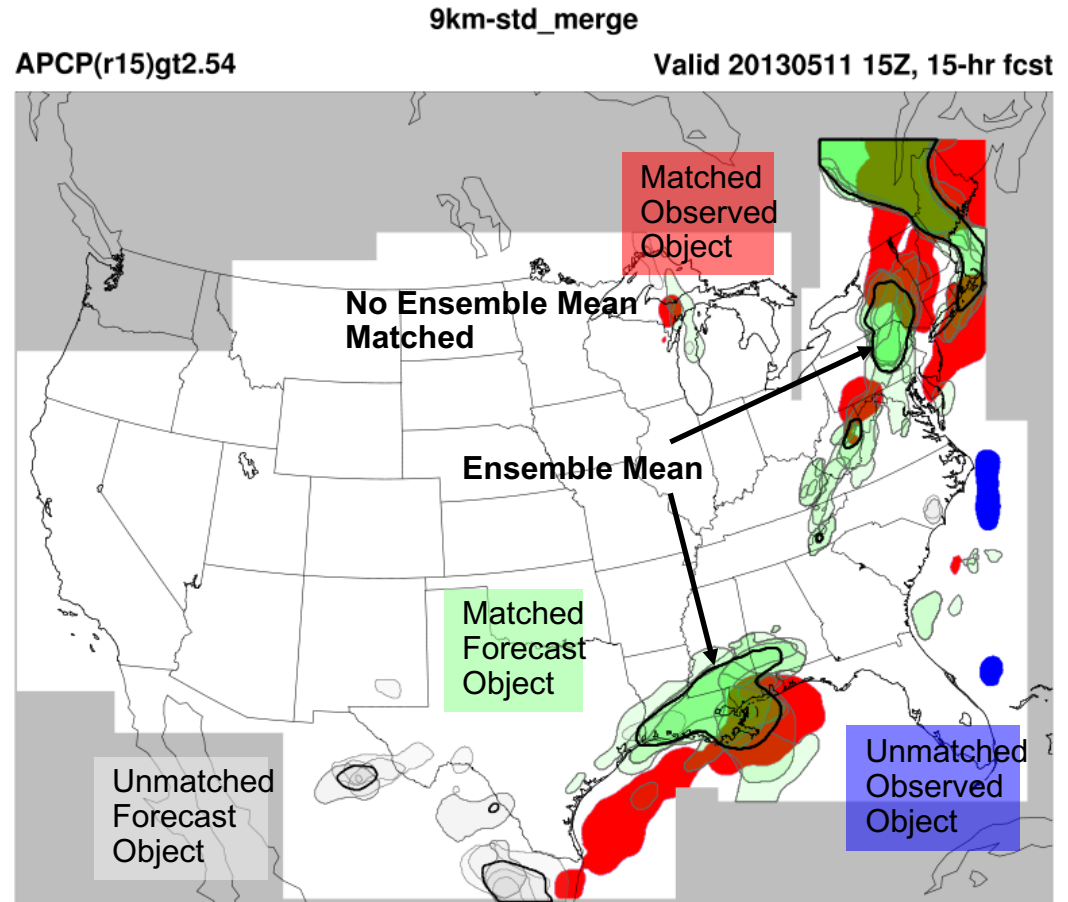
Provides tallied information
for all Simple Objects for
each case in directory

Example – REFC > 30 dBZ – Impact of smoothing radius

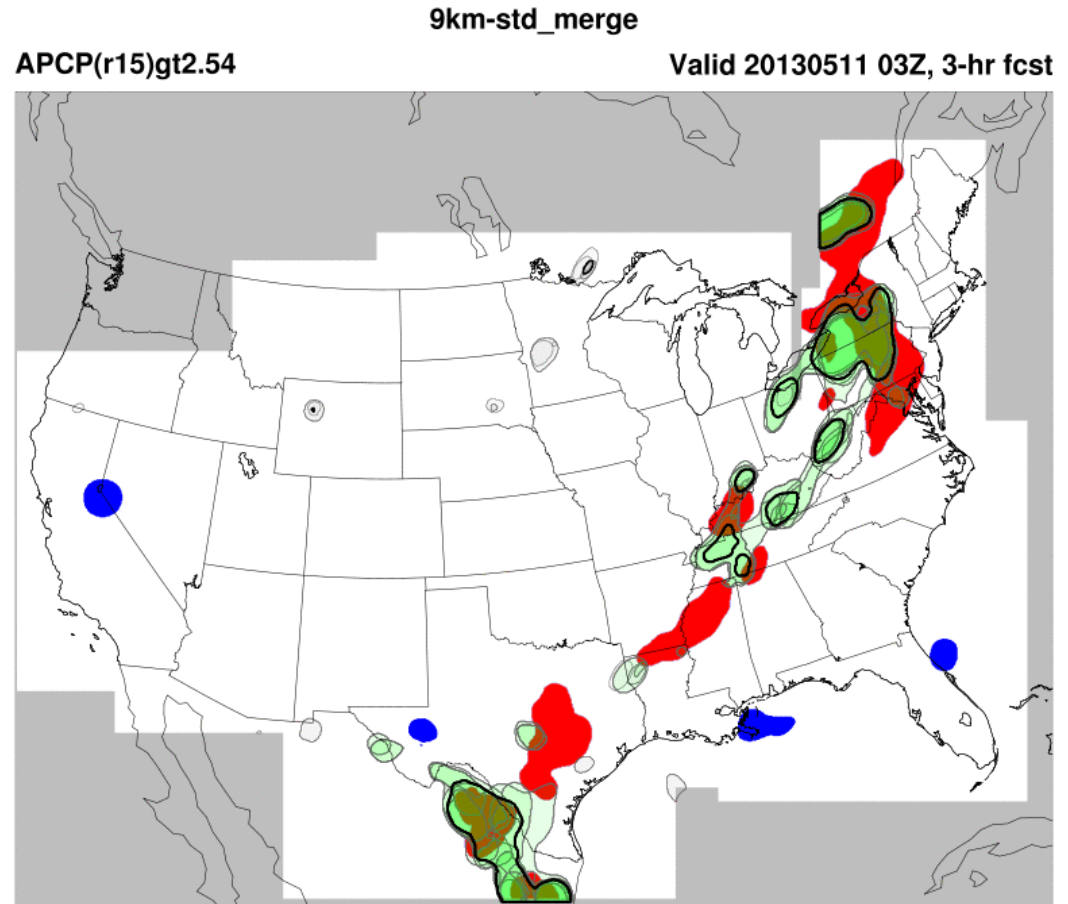


Example
May 11,
2013

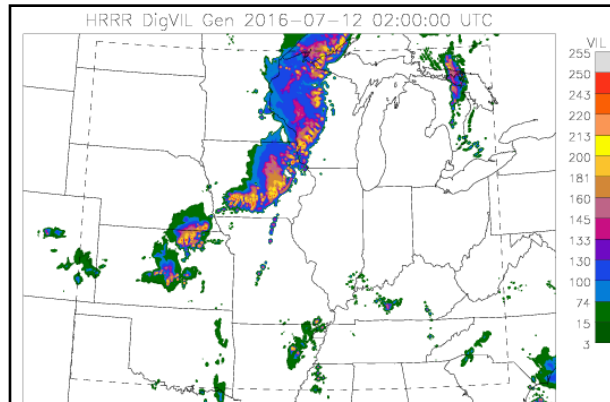
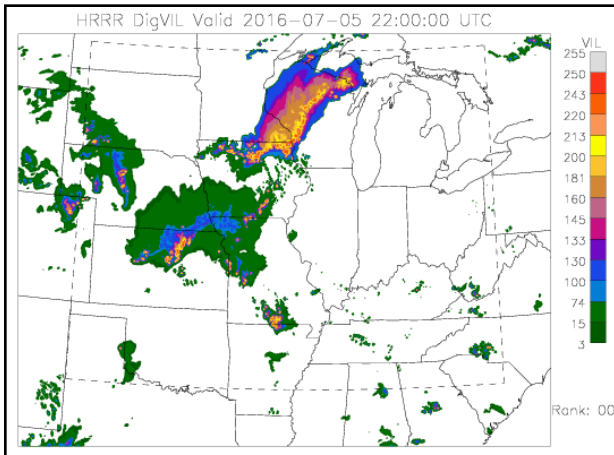
DTC SREF
Tests – ARW
Members



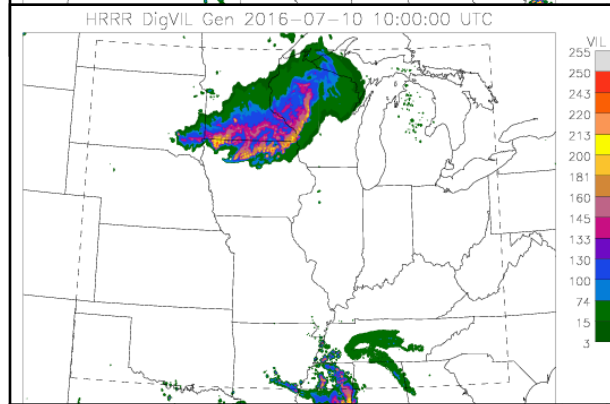
Spread
increases
With
Time



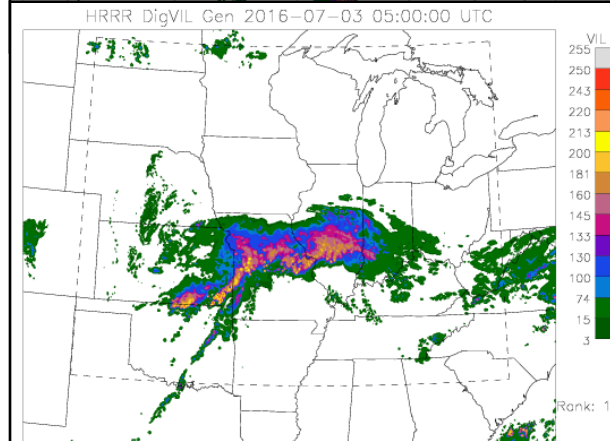
MODE Example: Fcst Analogs



Area ratio: 1.19
Centroid dist: 27.92
Angle Diff: 25.00



Area ratio: 0.81
Centroid dist: 58.15
Angle Diff: 20.41



Area ratio: 1.09
Centroid dist: 205.00
Angle Diff: 34.20