Model Evaluation Tools (MET)

Winter 2008 WRF Tutorial

DTC MET Development Team
RAL/NCAR

18 January 2008

MET Development Team

- Barb Brown (lead)
- John Halley Gotway (software engineer)
- Randy Bullock (software engineer)
- Lacey Holland (scientist/asst. lead)
- Eric Gilleland (scientist)
- Dave Ahijevych (scientist)

With thanks to the Air Force Weather Agency (AFWA) and NOAA for their support

Outline

- MET v1.0 Overview (Lacey)
- MODE Tool/MODE Analysis (Randy)
- MET Demonstration (John)
- Questions/Discussion

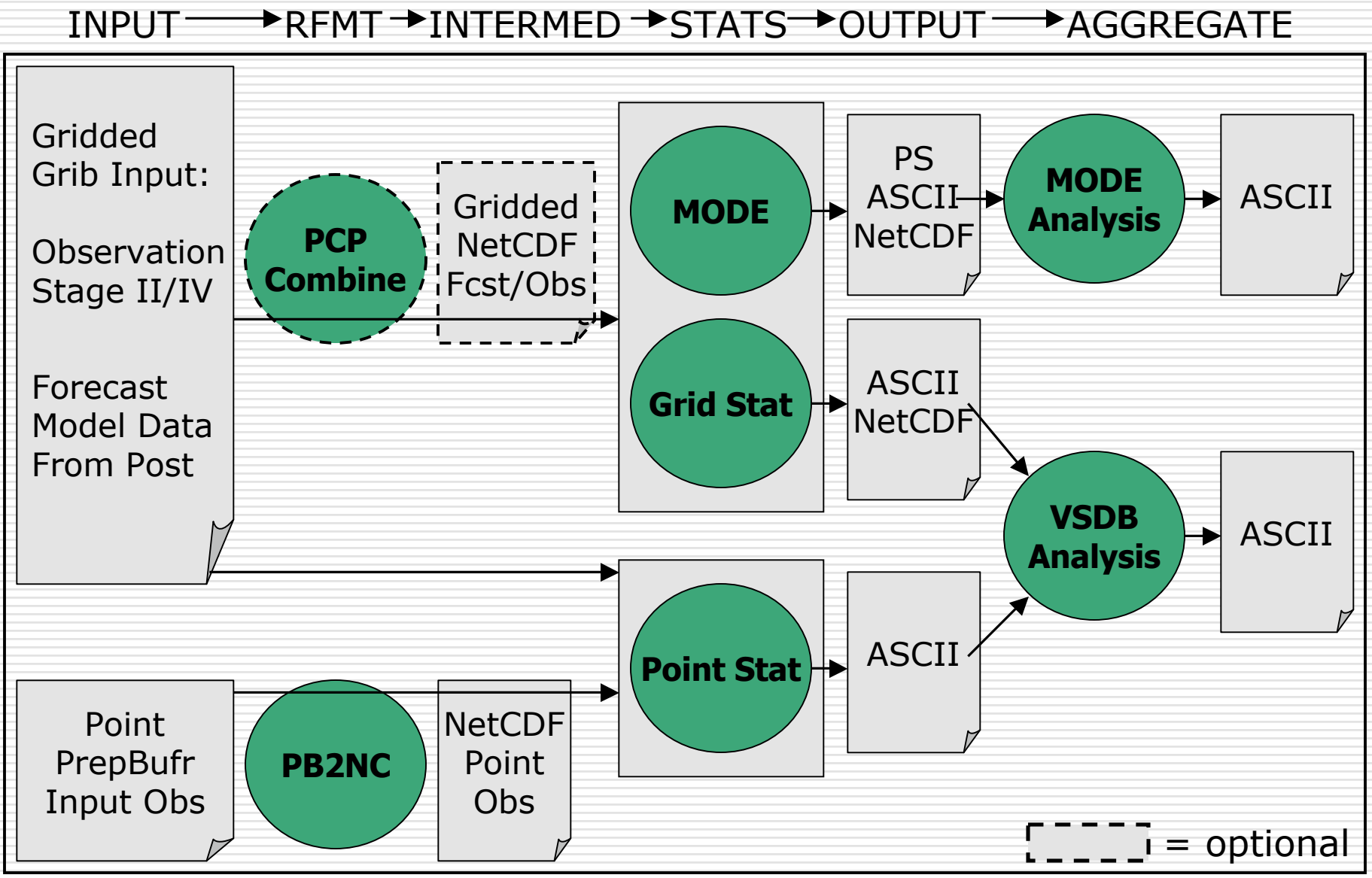
Background

- Developmental Testbed Center (DTC) and WRF communities were in need of verification tools with new capabilities, for use by
  - Model developers
    - Model evaluation, development and improvement
  - Operational model users
  - DTC
    - Model inter-comparisons
    - Testing and evaluating model configurations
- In response, AFWA provided support for this activity starting in late summer 2006
- METv0.9 (beta) version available as of 16 July 2007
- METv1.0 formal release 7 January 2008

Requirements

- The tools must include:
  - Standard verification approaches
  - Confidence intervals
  - Initial capability for spatial verification techniques
- Replicate existing NCEP operational verification capabilities (e.g., I/O, methods, statistics)
- Documentation
- Code maintenance
- Ability to implement additional capabilities (including contributed code)
- Freely available to the modeling, verification, and operational communities, including universities, private sector, NCEP, etc.

MET Overview v1.0



Data Formats

- Input gridded data in Grib format on a de-staggered, regular grid
  - Output of the WRF PostProcessor
- Input point observations in PrepBufr format available from NCEP
- Input ASCII configuration files
- Intermediate files written in NetCDF format
- Output files written in ASCII, NetCDF and PostScript

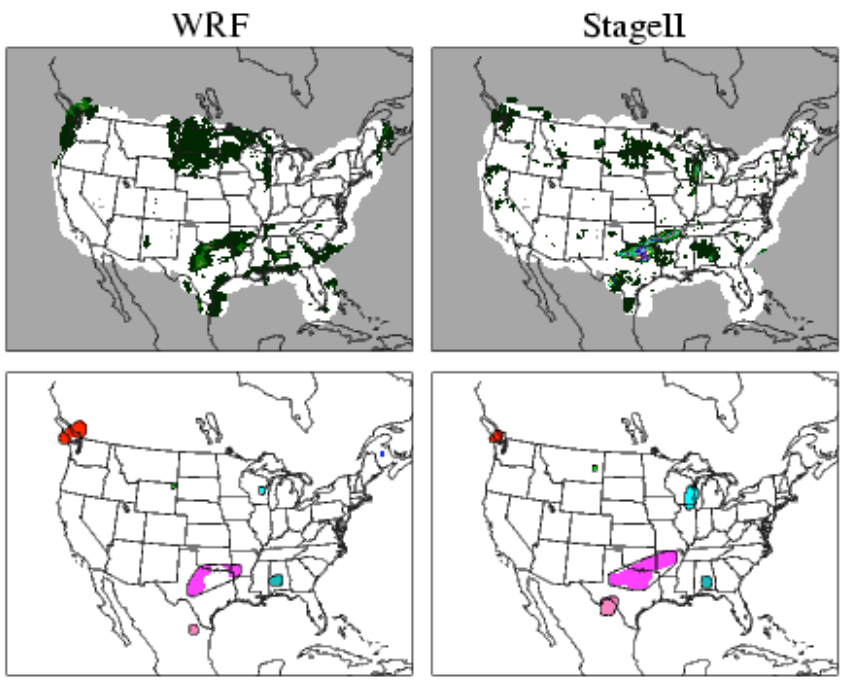
PCP Combine

- Precipitation combination utility
- Combine multiple grib files containing accumulated precipitation into a single file containing the sum of the precipitation
- Output NetCDF intermediate file

MODE: Spatial Verification Method

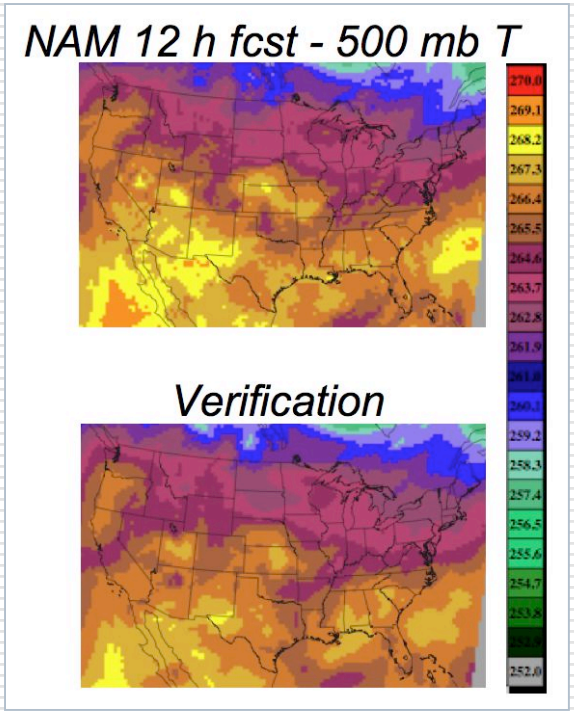
- Method for Object-based Diagnostic Evaluation
- Input Grib or NetCDF from PCP Combine
  - Select a single forecast variable and level
  - Select a single observation variable and level

- Output files
  - PostScript summary plot
  - ASCII object attributes
  - NetCDF object fields
- Randy to discuss in more detail
- Other spatial methods to be included in the future



Grid Stat: Grid-to-Grid verification

- Input Grib or NetCDF from PCP Combine
- Select multiple…
  - Variables, levels, thresholds, masking regions, smoothing methods, and alpha values
- Output VSDB and ASCII
  - Contingency table counts and statistics with CI
  - Continuous statistics with CI
  - Partial sums
- Output NetCDF
  - Matched pairs and difference fields for each variable, level, masking region

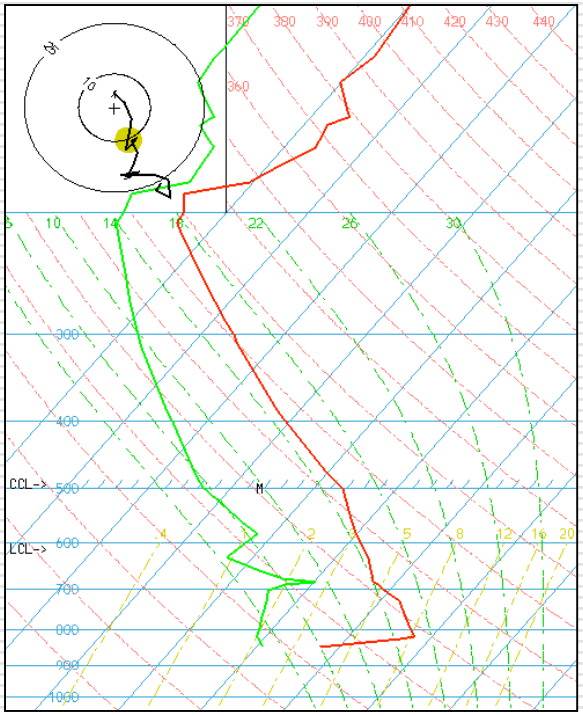


PB2NC: PrepBufr-to-NetCDF

- Utility for stratifying the input PrepBufr points observations by…
  - Variable type
  - Message, report, and instrument type
  - Station ID, location, elevation, and vertical level
  - Valid time and quality mark
- Isolates interface to the BUFR library
- Output NetCDF file containing point observations

Point Stat: Grid-to-Point Verification

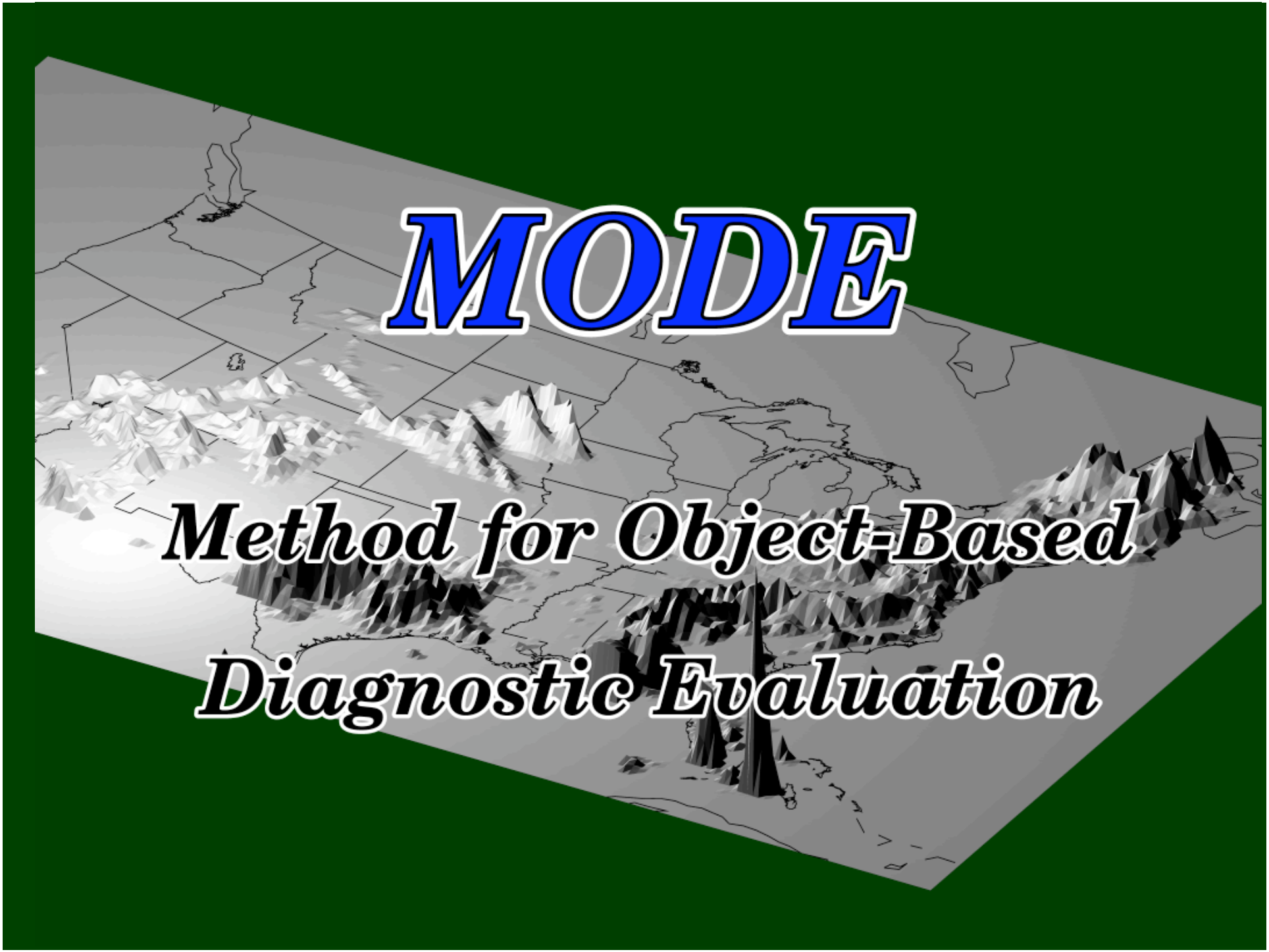
- Input Grib forecast and NetCDF from PB2NC
- Select multiple…
  - Variables, levels, thresholds, masking regions, interpolation methods, and alpha values



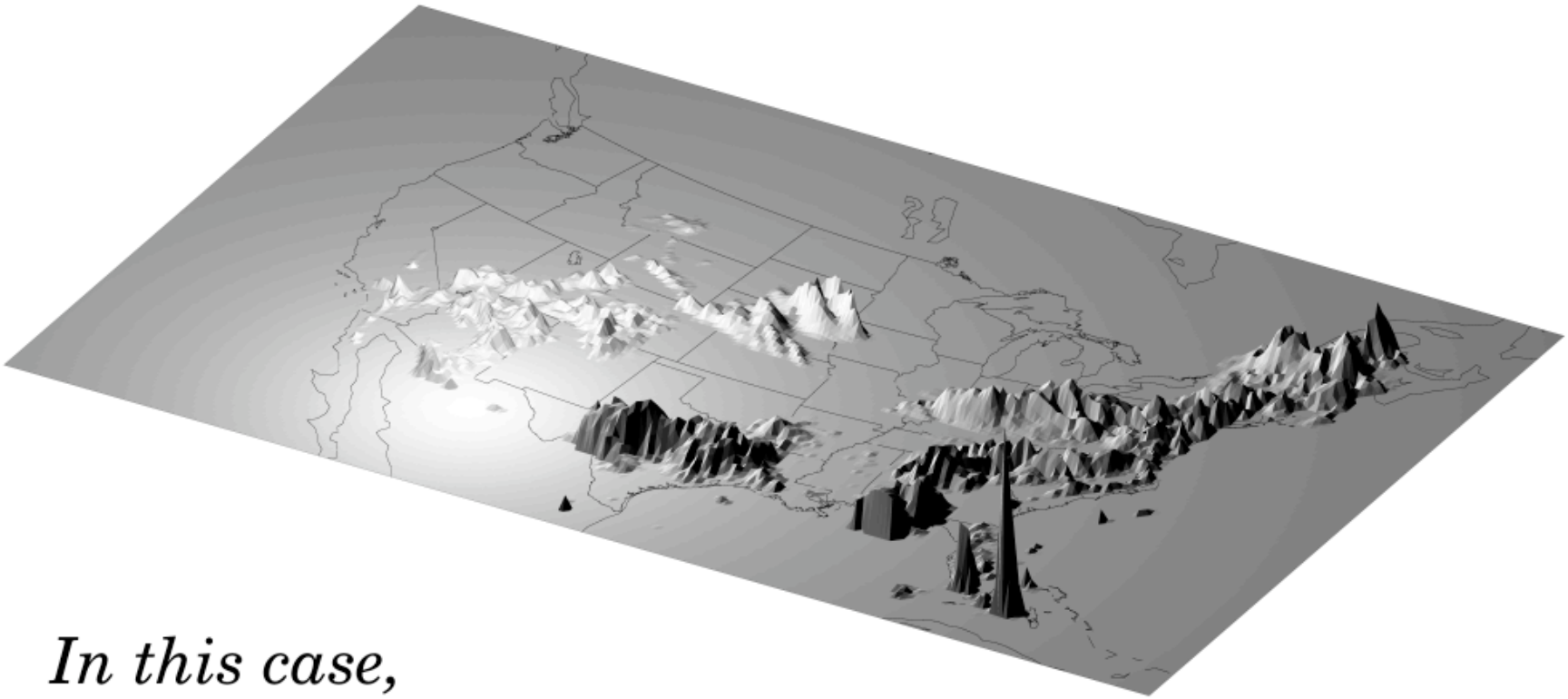
- Output VSDB and ASCII
  - Contingency table counts and statistics with CI
  - Continuous statistics with CI
  - Partial sums

VSDB Analysis tool

- VSDB Analysis tool:
  - Filters a collection of VSDB files into user-specified subsets
  - Summarizes statistic values over time or combinations of regions
  - Aggregates statistics over time or combinations of regions
  - Calculates additional metrics that require a combination of statistics at different lead times


MODE
Method for Object-Based
Diagnostic Evaluation

Step # 1: Raw Data

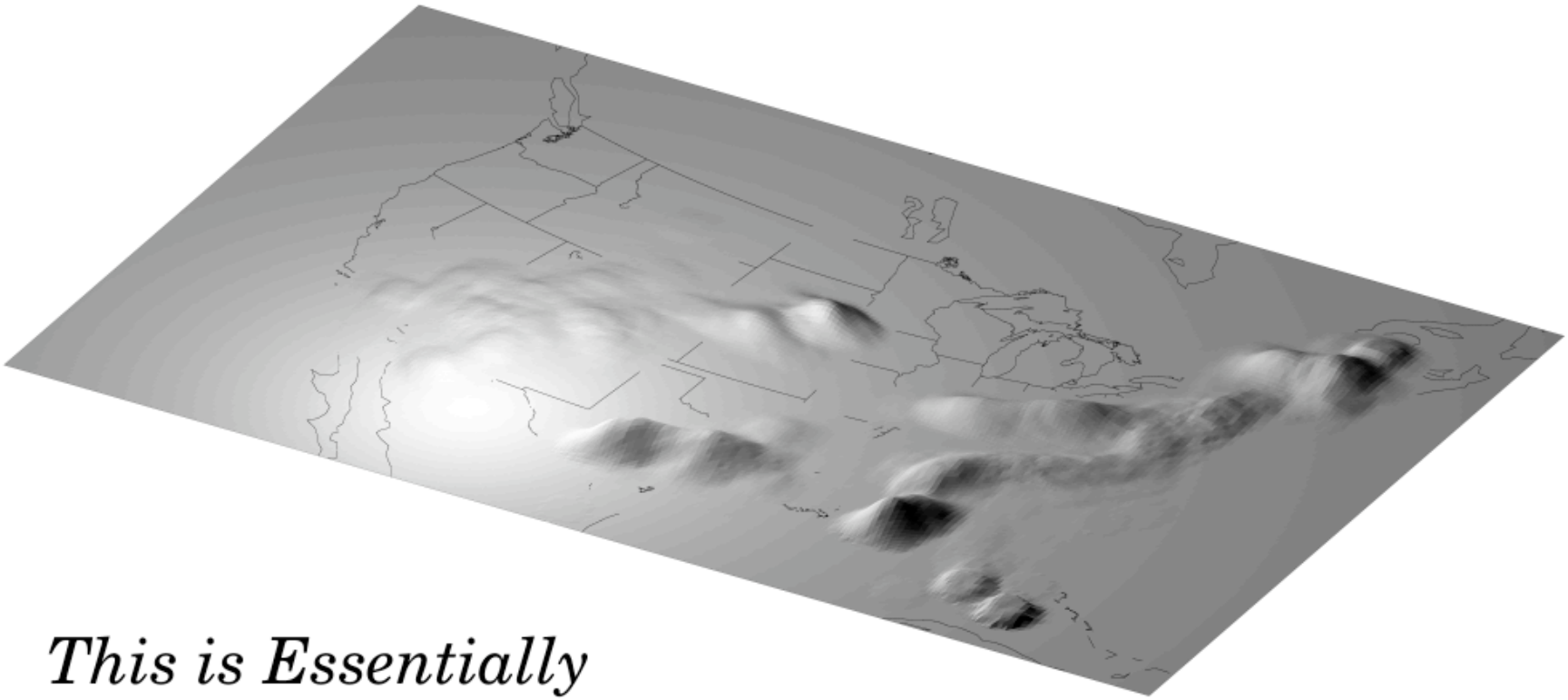


In this case,

Precipitation Data over the

Continental United States

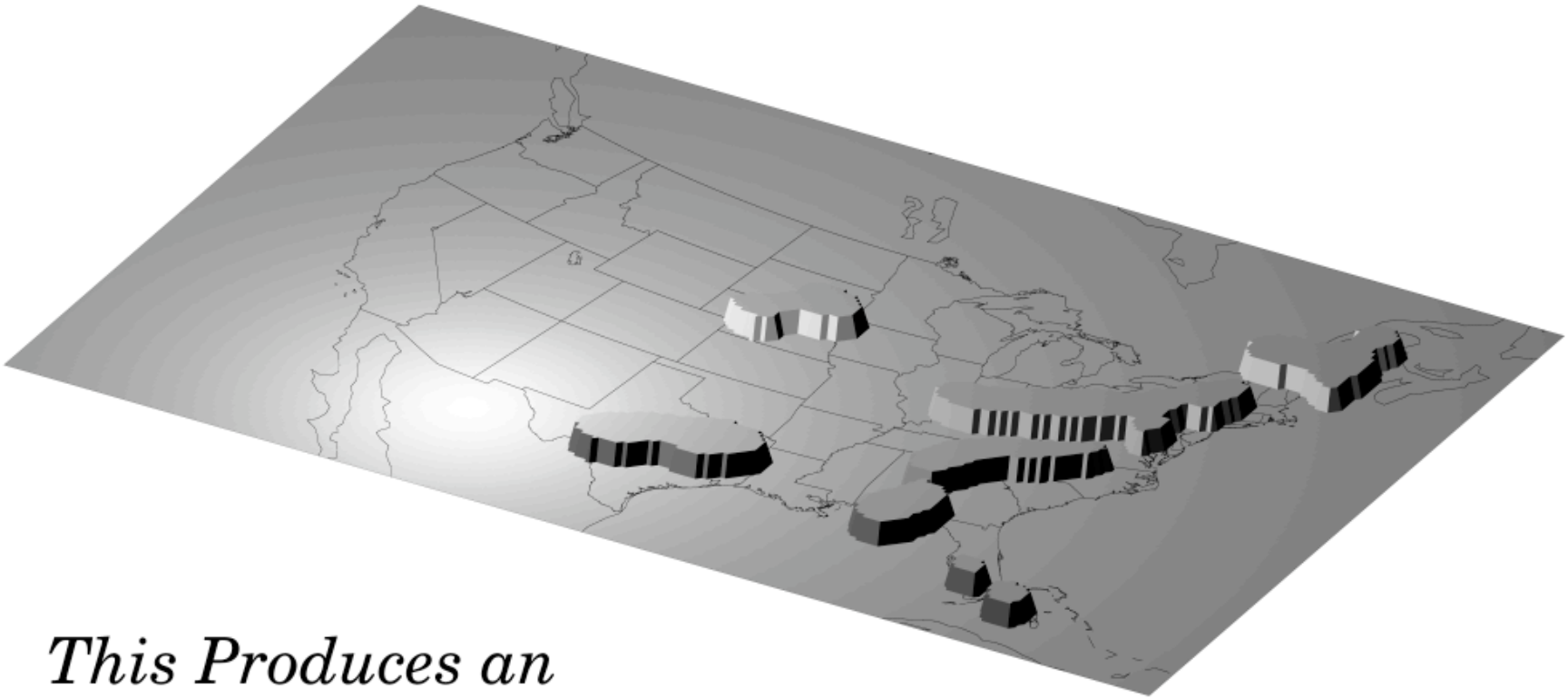
Step # 2: Convolution



This is Essentially

a Smoothing Operation

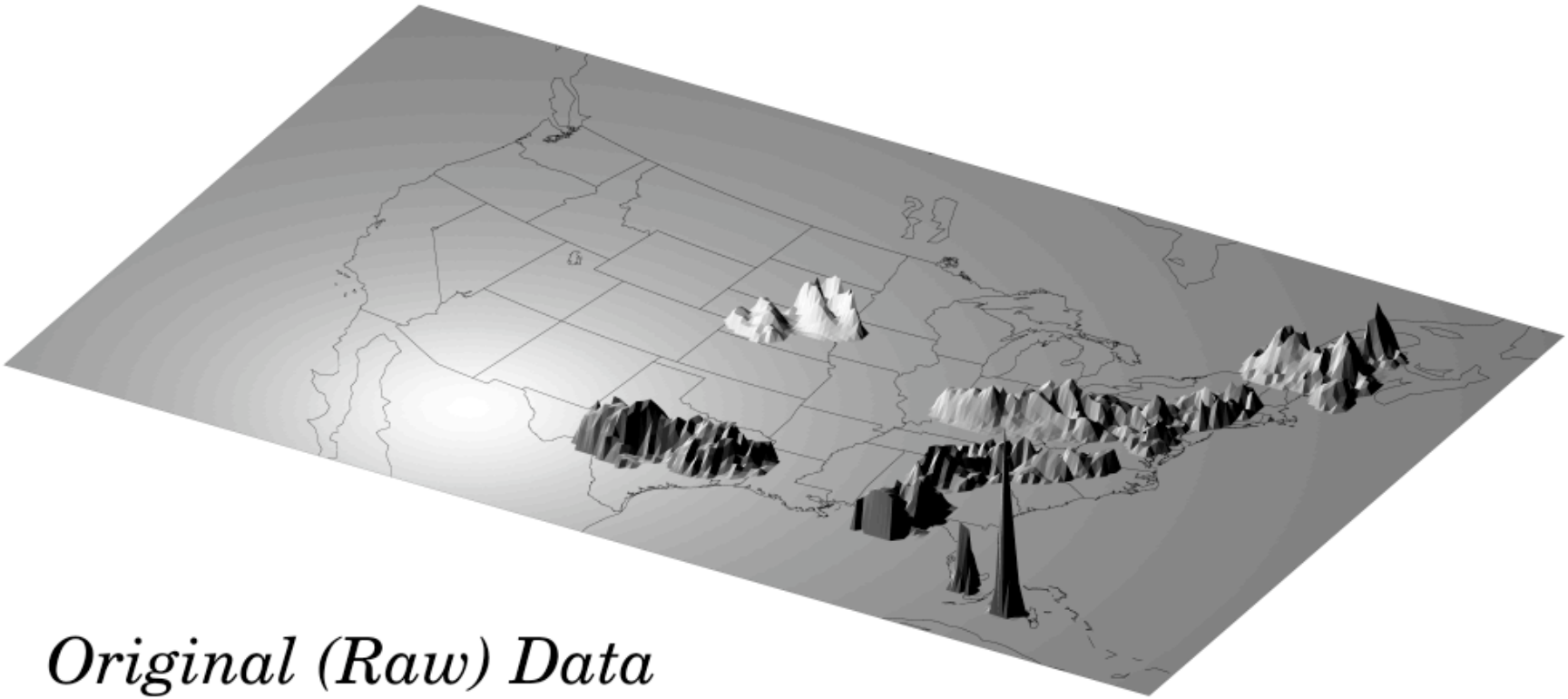
Step # 3: Thresholding



This Produces an

On/Off Mask Field

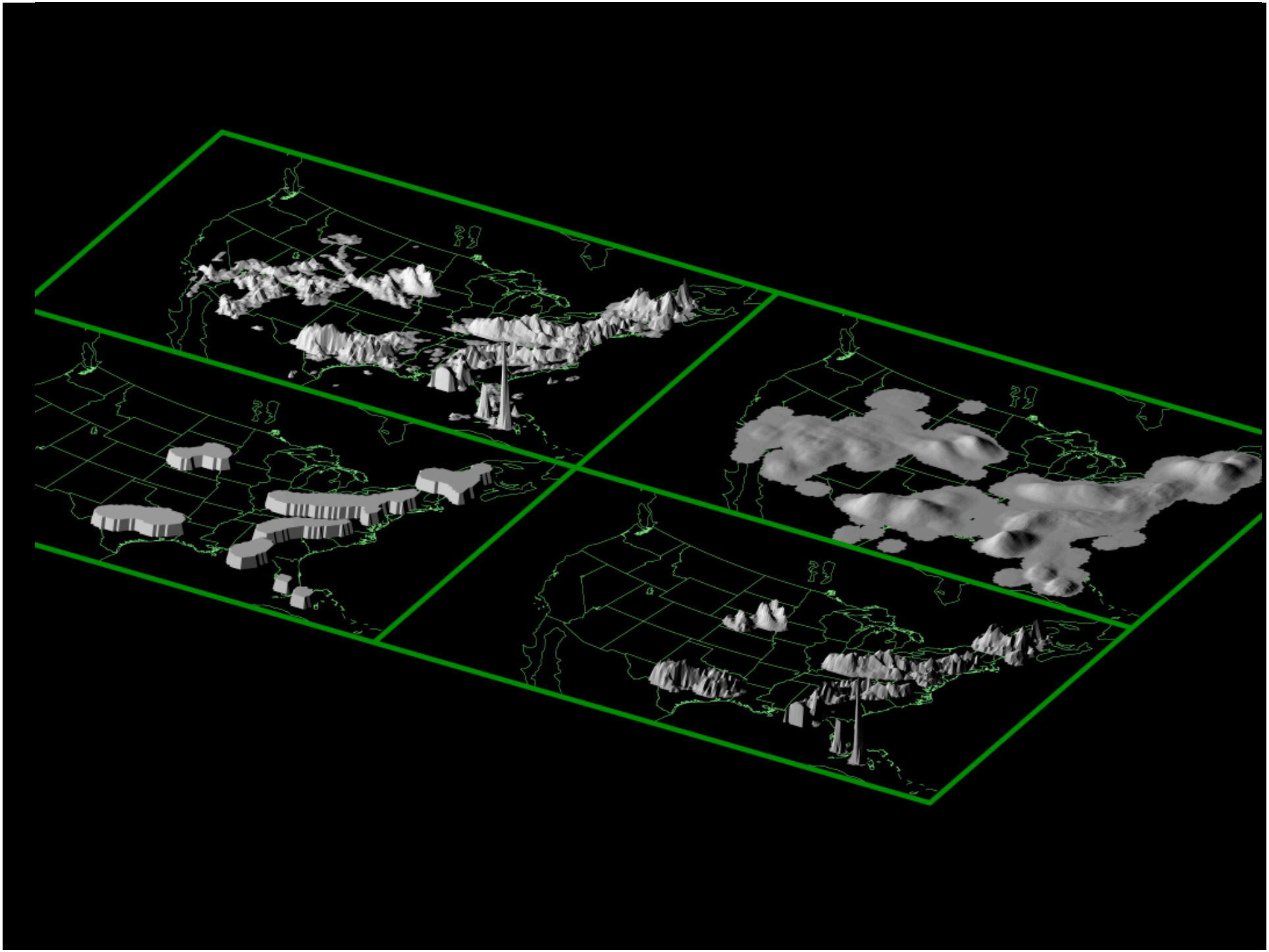
Step # 4: Restoration



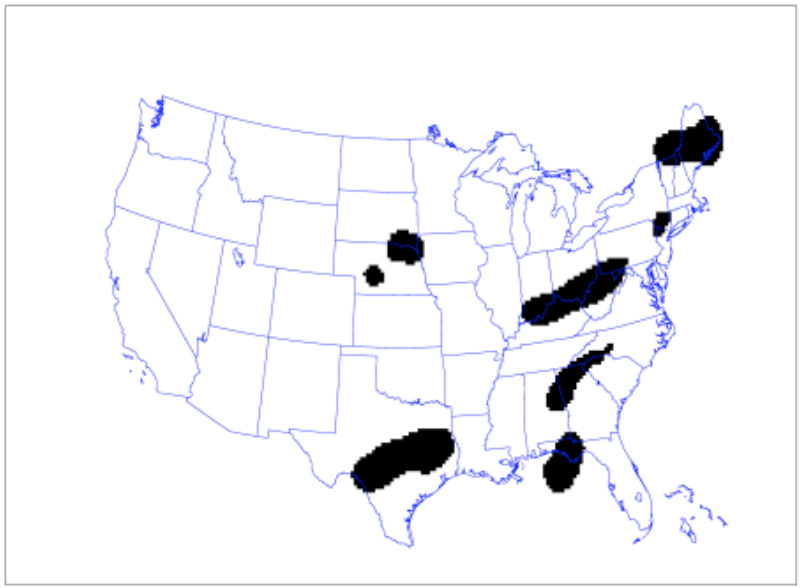
Original (Raw) Data

is Restored to

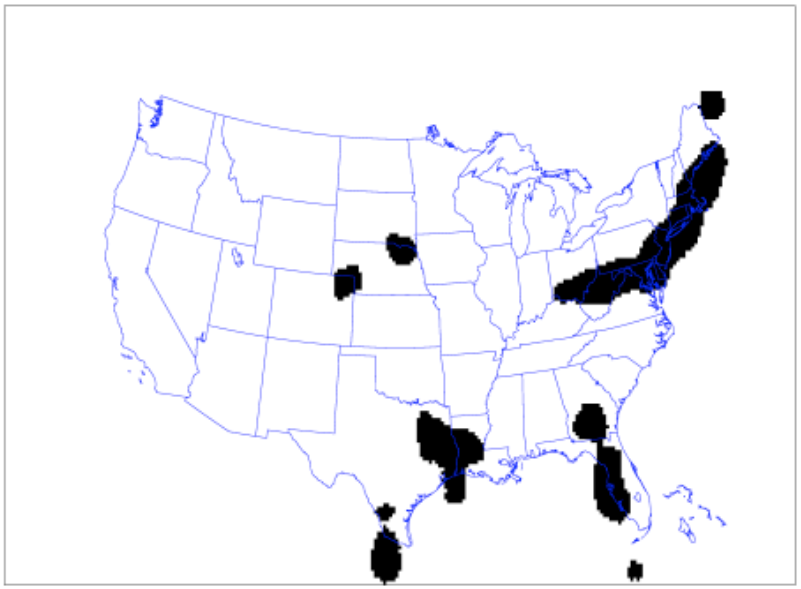
Object Interiors

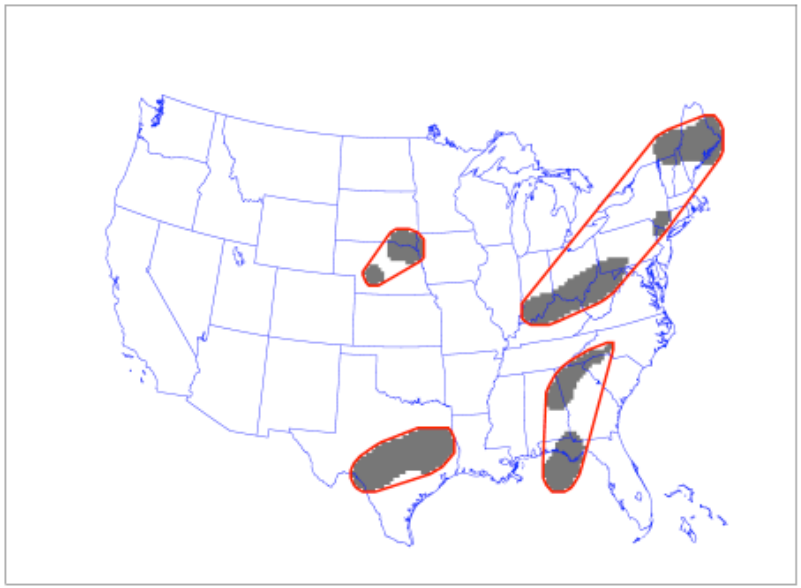


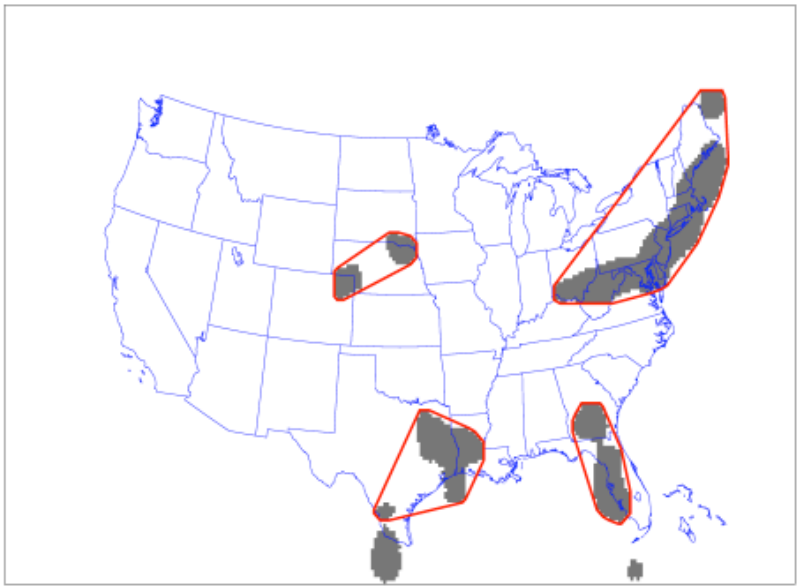
Forecast

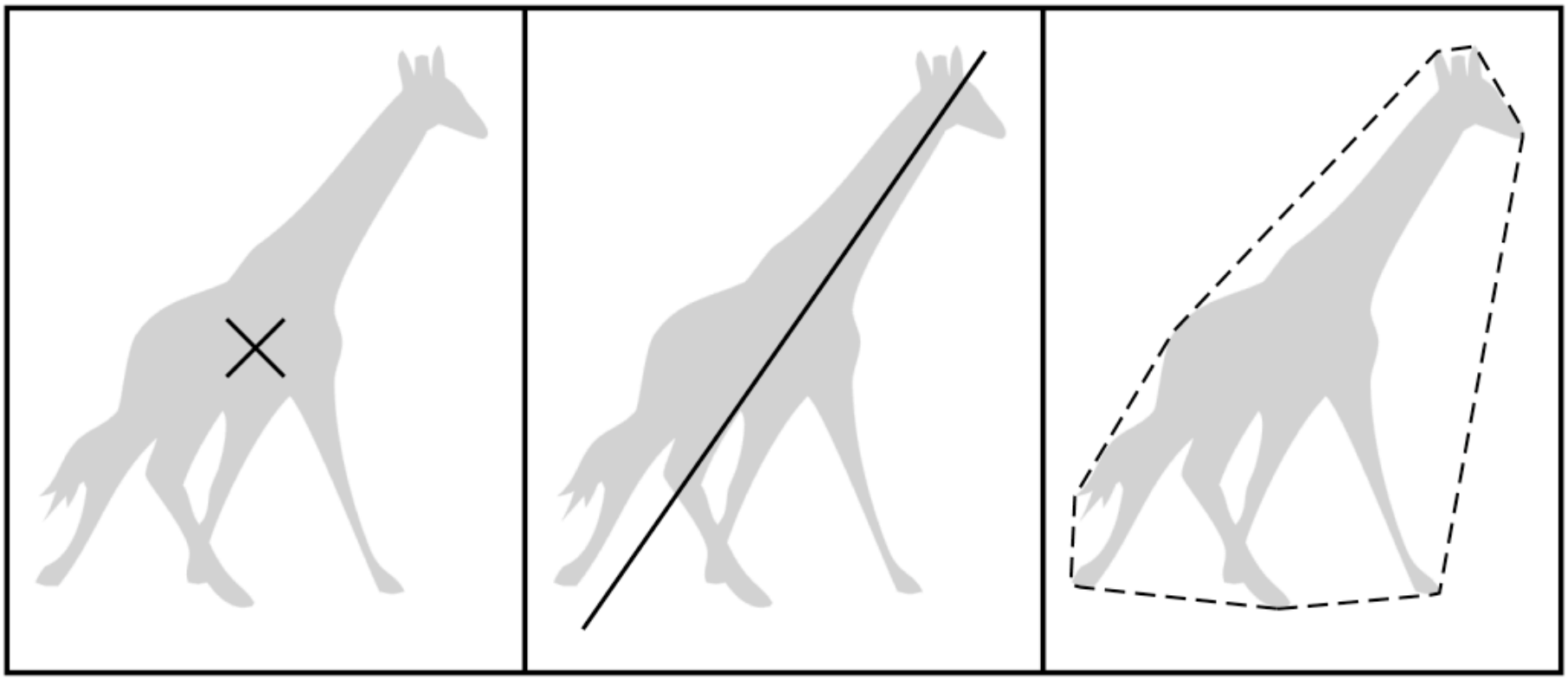


Observed

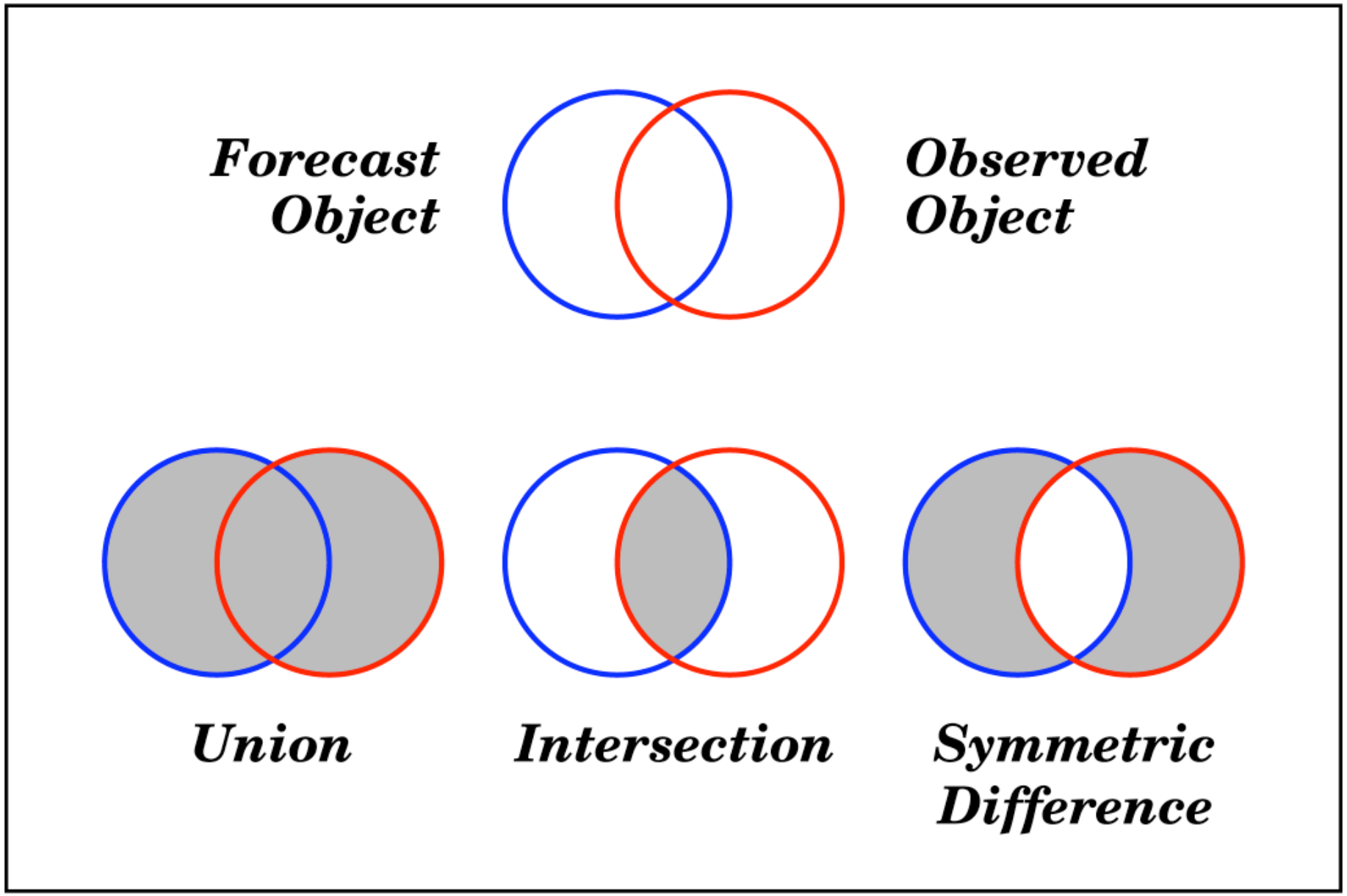








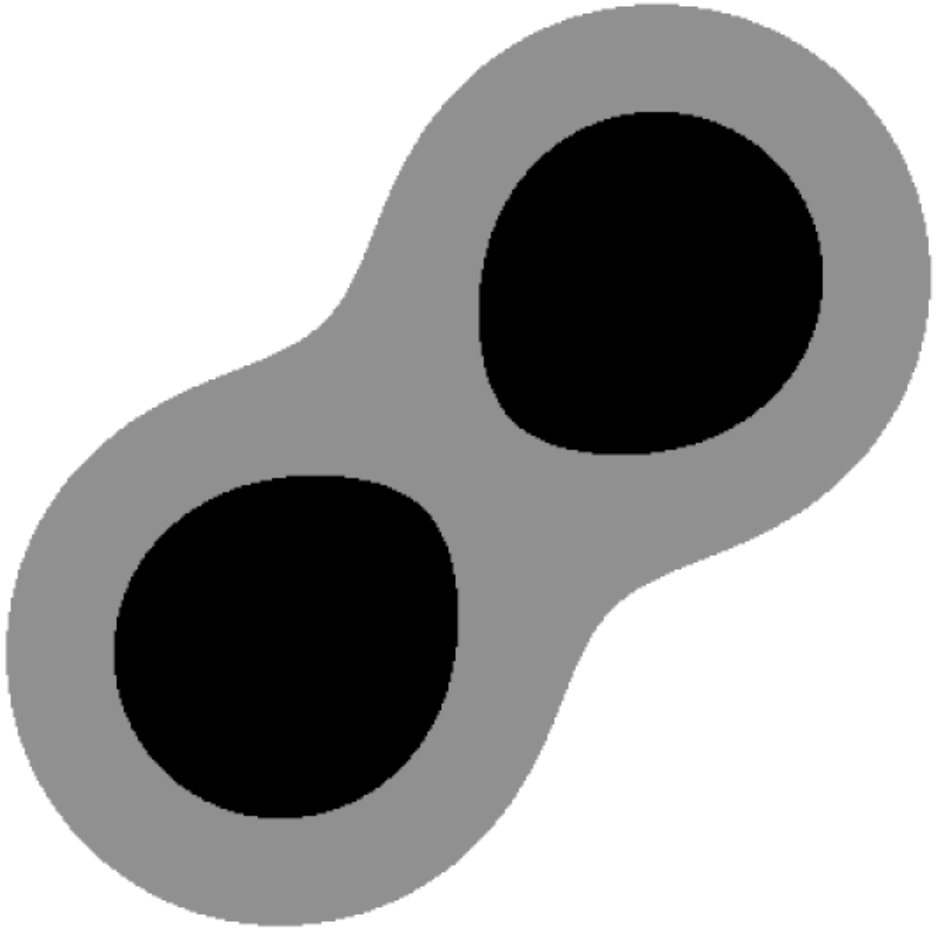
Centroid *Axis* *Convex Hull*


Forecast Object
Observed Object
Union
Intersection
Symmetric Difference

Total Interest

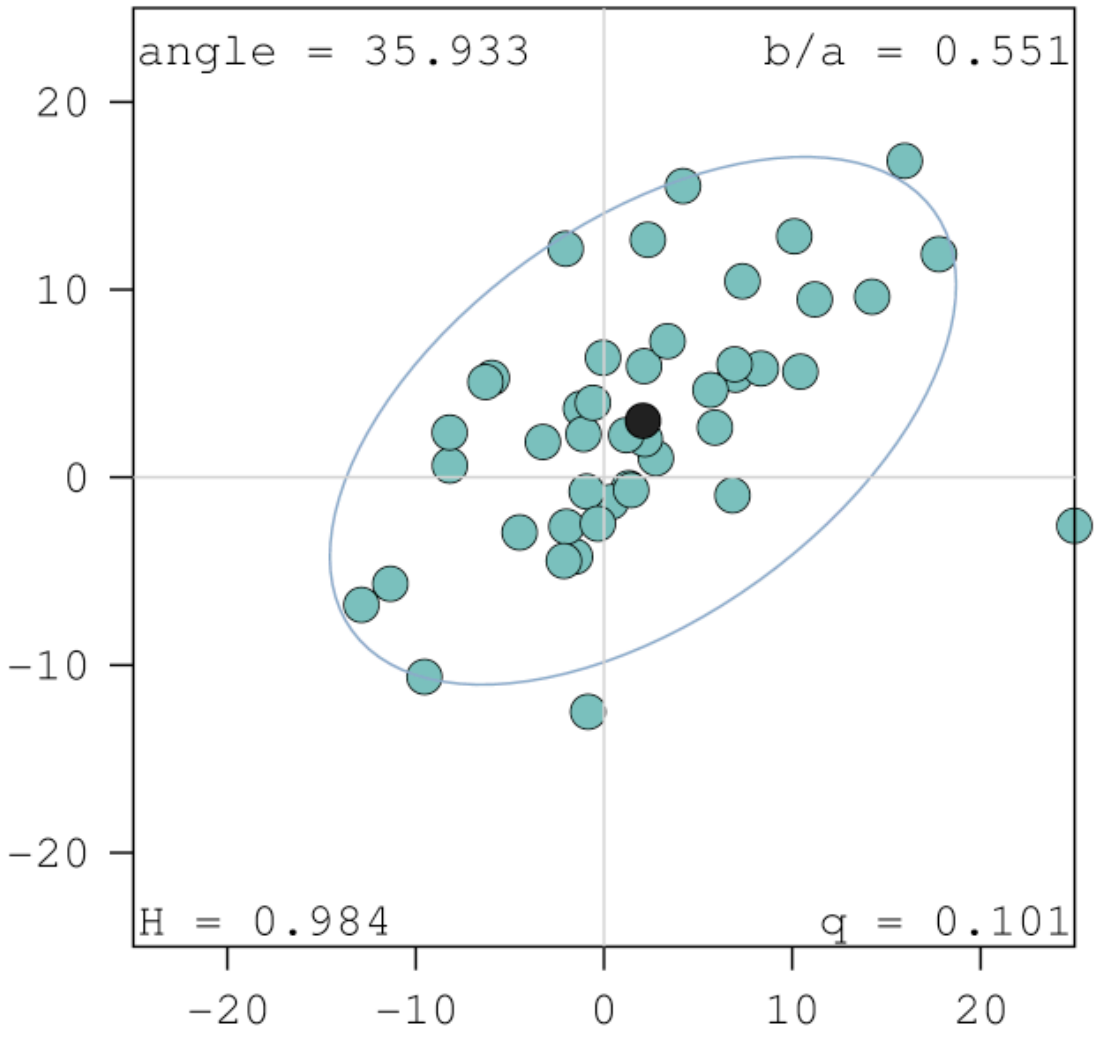
$$T(\alpha) = \frac{\sum_i w_i \, C_i(\alpha) \, I_i(\alpha_i)}{\sum_i w_i \, C_i(\alpha)}$$

Alternative Merging Method



Double Thresholding

Composite Object Centroid Differences over the Appalachian Mountains



MODE Analysis Tool

- ***Provides a method of summarizing MODE output files***
- ***Gives quick statistics for users who don't want to write their own scripts***
- ***Can be used to filter or pre-process MODE output files***

MODE Analysis Tool
SUMMARY Example

Command Line

```
mode_analysis -summary
              -mask_file ttt -config config/mode_test_config    \
              -dump_lines out -lookin /d1/score/mode_files  \
              -fcst -composite -area_min 3000    \
              -centroid_x_min 600
              -centroid_x_max 1100    \
              -column CENTroid_x   \
              -column centroid_y    \
              -column centroid_lat   \
              -column centroid_lon    \
              -column area   \
              -column axis_ang   \
              -column length
```

Output

```
Total mode lines read =  73,330
Total mode lines kept =     539
```

Field	Min	Max	Mean	StdDev	P10	P25	P50	P75	P90
centroid_x	600.23	914.61	779.36	97.98	626.36	687.96	804.30	866.75	894.24
centroid_y	55.22	560.08	335.55	113.08	189.48	240.58	333.51	421.06	496.82
centroid_lat	22.00	40.14	32.08	4.06	26.83	28.66	32.00	35.15	37.87
centroid_lon	-107.03	-95.01	-100.18	3.75	-106.03	-103.67	-99.23	-96.84	-95.79
area	3210.00	85486.00	12680.96	9931.67	4935.00	6256.00	9445.00	16106.00	23678.00
axis_ang	-88.84	89.90	13.54	44.82	-55.80	-16.36	17.28	48.23	71.27
length	100.57	494.54	200.08	82.11	112.44	133.62	179.96	249.06	315.33

MODE Analysis Tool
By Case Example

Command Line

```
mode_analysis -bycase
              -dump_lines out
              -mask_file ttt -config config/mode_test_config
              -fcst_valid_min 20070702 -fcst_valid_max 20070702_12
              -area_min 3000
              -centroid_x_min 600 -centroid_x_max 1100
               /d1/score/mode_files/ncwf2_vs_ncwdp/* /d1/score/mode_files/rcpf_vs_ncwdp/*
```

Output

Fcst Valid Time	Area Matched	Area Unmatched	# Fcst Matched	# Fcst Unmatched	# Obs Matched	# Obs Unmatched
Jul 2, 2007 00:00:00	12392	20786	0	1	1	1
Jul 2, 2007 01:00:00	6706	11038	0	0	1	2
Jul 2, 2007 02:00:00	7507	18696	0	0	1	3
Jul 2, 2007 03:00:00	19401	32268	2	3	1	2
Jul 2, 2007 04:00:00	0	16551	0	2	0	1
Jul 2, 2007 05:00:00	15311	29730	1	2	1	2
Jul 2, 2007 06:00:00	4730	8182	0	0	1	2
Jul 2, 2007 07:00:00	3733	13285	0	1	1	2
Jul 2, 2007 08:00:00	6994	6994	0	0	1	1
Jul 2, 2007 09:00:00	15981	15981	0	0	2	2
Jul 2, 2007 10:00:00	51501	53427	2	2	4	4
Jul 2, 2007 11:00:00	15779	21089	1	1	1	2
Jul 2, 2007 12:00:00	31339	40665	1	2	2	2

Technical Information

- MET distributed as a tarball to be downloaded and compiled locally
- Platform and Compilers:
  - Developed and tested using Debian/GNU Linux 3.1 and GNU g++/g77
- Language:
  - Written in C and C++ with calls to a Fortran 77 library

Technical Information

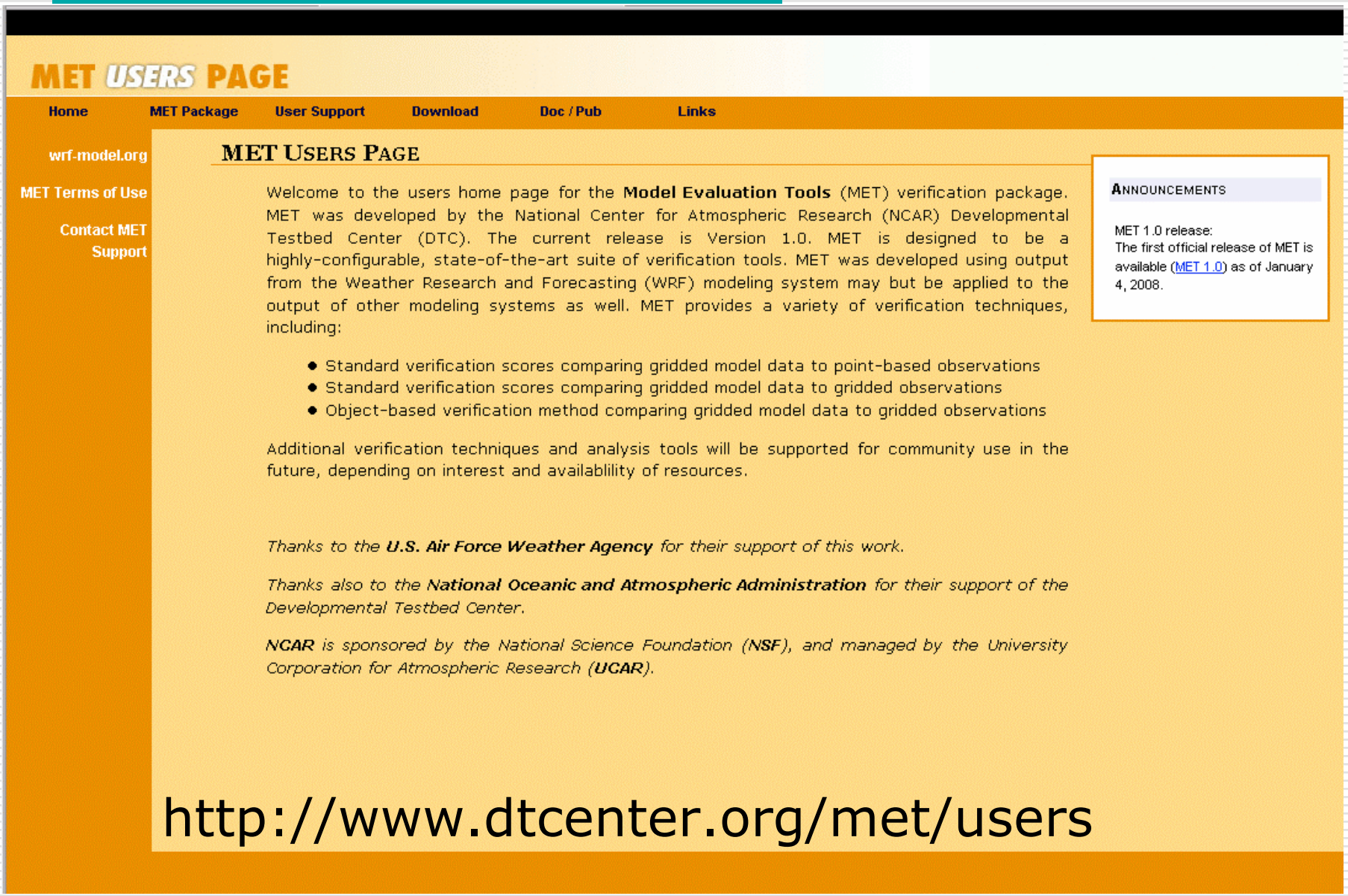
- Dependencies:
  - Required to compile:
    - C++ and Fortran compilers (GNU or PGI)
    - BUFRLIB
    - NetCDF
    - GSL (GNU Scientific Library)
    - F2C Library (f2c or g2c)
  - Recommended for use:
    - WRF Post-Processor
    - COPYGB (included with Post)
    - CWORDSH

Information on obtaining these is available in the documentation and on the MET website!

How to get MET

- Available through the MET website:
  - http://www.dtcenter.org/met/users
  - Includes detailed documentation
- About 180 registered users from 30 countries
- Future releases will be announced through WRF-News and directly to registered users

MET Website



http://www.dtcenter.org/met/users

The Future…

Future Plans

- Future releases:
  - Expand verification methods
  - New input formats
  - New output
  - MET GUI

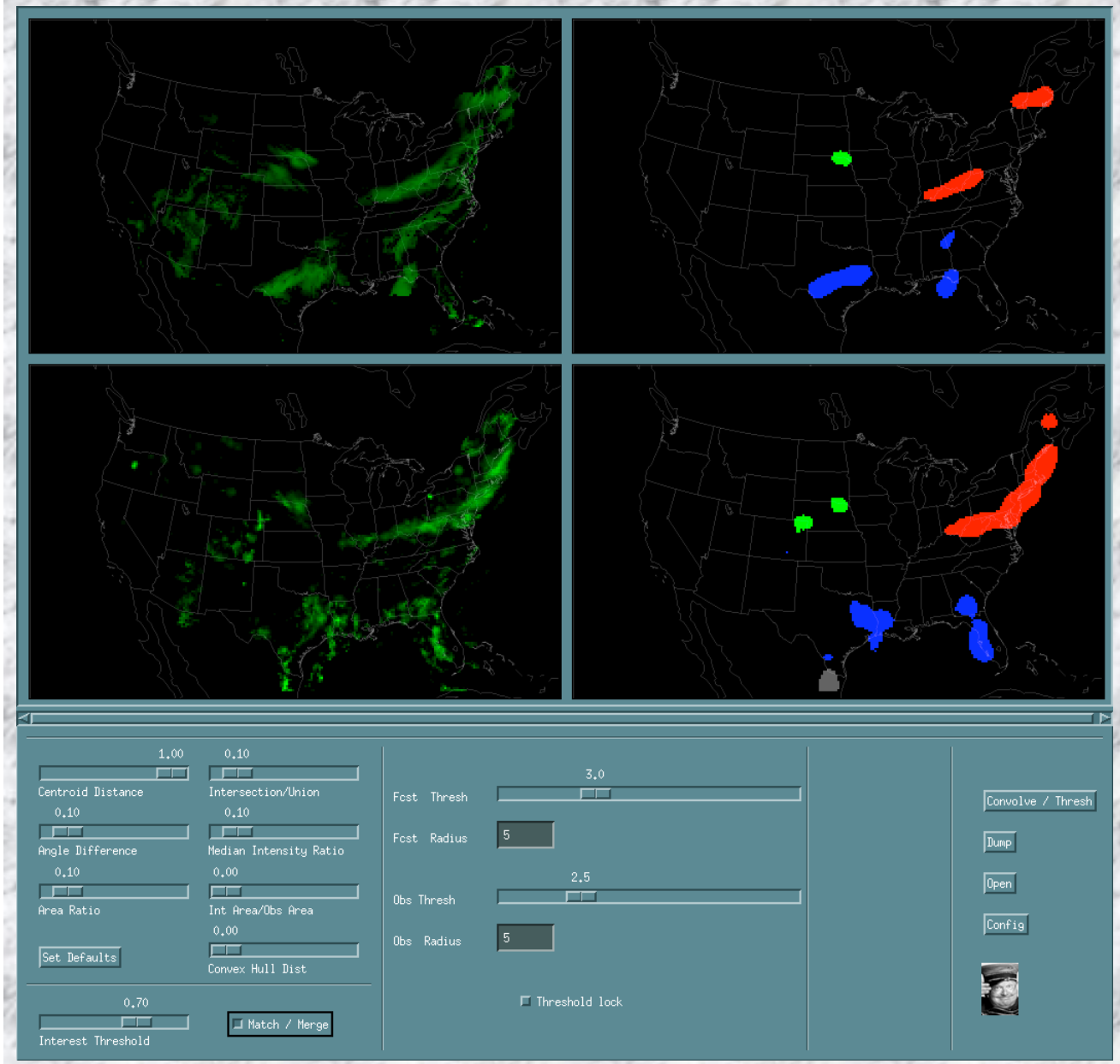
New methods…

- Additions to spatial methods:
  - Scale decomposition method
  - Neighborhood method
  - CRA (Contiguous Rain Area)
  - Hurricane track verification
  - MODE with time-domain information
- Probabilistic and Ensemble forecasts
- Gridded statistics computed over time
- Provide sample scripts/programs (R, IDL, NCL, GrADS, MATLAB, etc.) for analysis

New formats…

- Observation and gridded analysis formats
  - ASCII (to be determined)
  - NetCDF
  - Grib2
- Forecast formats
  - Grib2
  - NetCDF

MET GUI



Adding a GUI would make configuration files easier to adjust for each module

Example taken from a GUI built for MODE

Questions and Discussion?

- Thanks to AFWA and NOAA!

Model Evaluation Tools (MET) DEMONSTRATION

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18 January 2008

Outline - Demonstration

- Technical Information
- Compiling
- Test scripts
- Configuration files
- Output

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- MET distributed as a tarball to be downloaded and compiled locally
- Platform and Compilers:
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  - Support for the Portland Group (PGI) compilers
- Language:
  - Written in C and C++ with calls to a Fortran 77 library

Technical Information

- Dependencies:
  - Required to compile:
    - C++ and Fortran compilers (GNU or PGI)
    - BUFRLIB
    - NetCDF
    - GSL (GNU Scientific Library)
    - F2C Library (f2c or g2c)
  - Recommended for use:
    - WRF Post-Processor
    - COPYGB (included with WRF-Post)
    - CWORDSH

Compiling MET

- Choose Makefile or Makefile_pgi
- Configure the top-level Makefile
  - Set the following:
    - CPP_COMPILER, F77_COMPILER
    - MET_BASE
    - NETCDF_INCS, NETCDF_LIBS
    - BUFR_INCS, BUFR_LIBS
    - GSL_INCS, GSL_LIBS
    - F2C_INCS, F2C_LIBS
    - F2C_LIBNAME (-lf2c or -lg2c)
- Run the make utility to build MET
  - make >& make_met.log
  - make -f Makefile_pgi >& make_met.log

Test Scripts

- Provided with tarball as a sanity check on the installation
- One script for each of the 7 MET tools
- Use sample data distributed with the tarball
- Write output to the "out" directory
- Run the top-level test script:
  - cd scripts
  - ./test_all.sh >& test_all.log

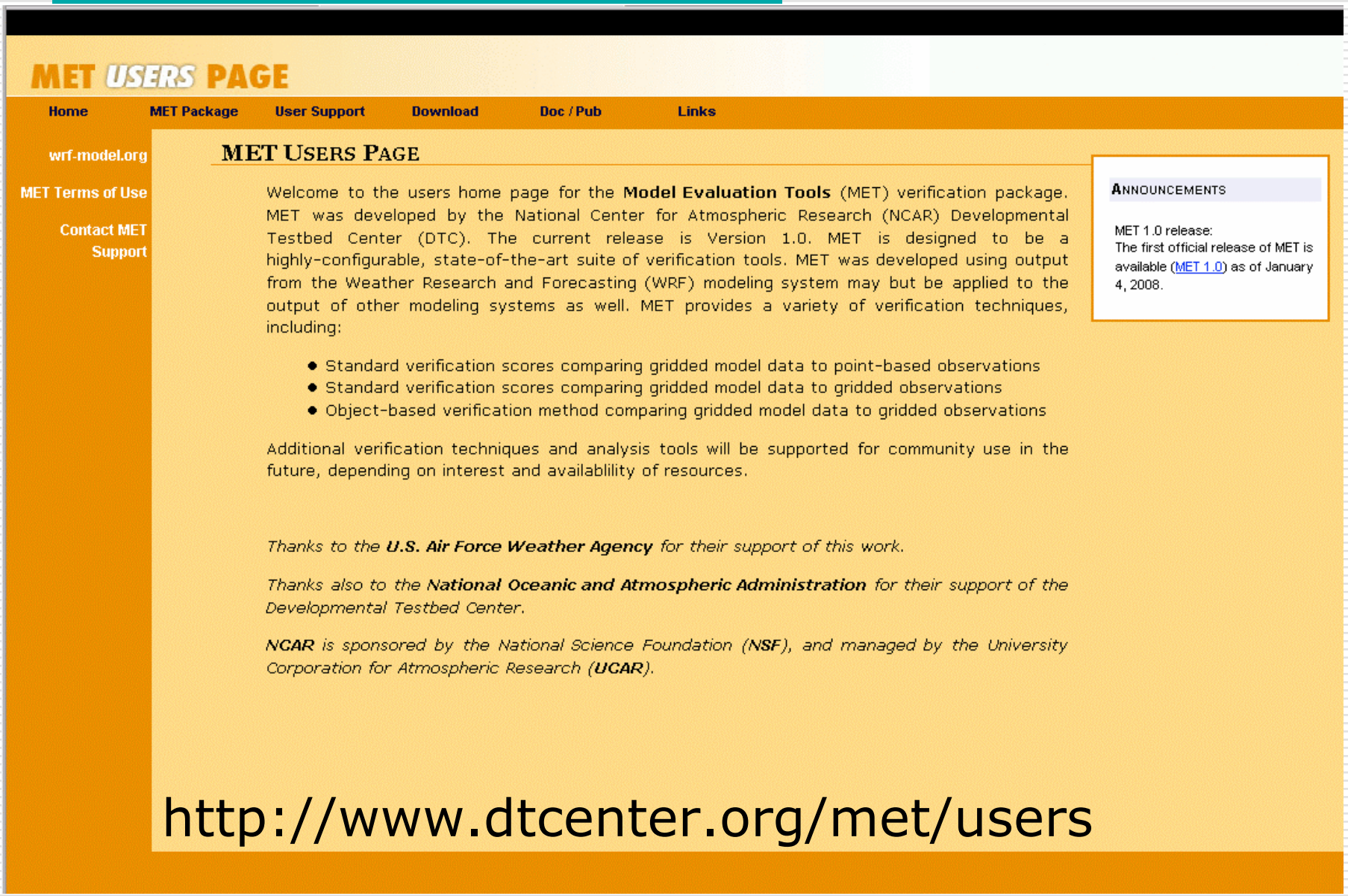
Configuration Files

- ASCII configuration files used for most MET tools
- Copy first, then modify
- Passed to the MET tools via the command line
- No naming requirements
- Sample configuration files in two places:
  - METv1.0/scripts/config
  - METv1.0/data/config
    - PB2NCConfig_default (req)
    - PointStatConfig_default (req)
    - GridStatConfig_default (req)
    - VSDBAnalysisConfig_default (opt)
    - WrfModeConfig_default (req)
    - MODEAnalysisConfig_default (opt)

Output

- Output of the test scripts written to the "out" directory and organized by MET tool name
- Very generally...
  - PCP_Combine and PB2NC data reformatting and write out NetCDF files
  - Grid_Stat, Point_Stat, and MODE do number crunching and output statistics in ASCII
  - VSDB_Analysis and MODE_Analysis aggregate those ASCII files and output ASCII
- See MET User's Guide for details of output formats

MET Website



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