



NCAR



Developmental Testbed Center

MET with Ensembles

John Halley Gotway

Tressa Fowler

NCAR/RAL/JNTP

and

Developmental Testbed Center (DTC)

Project Manager: Tara Jensen

MET Team: Randy Bullock, Tatiana Burek, Julie Prestopnik,

Minna Win, Howard Soh, Jim Frimel, Hank Fisher

Tina Kalb, Dan Adriaansen, Barb Brown



Developmental Testbed Center

Outline of Talk

- **Overview of MET software**
- **METViewer Database and Display**
- **MET+ Automation**
- **Ensemble Verification by Tressa Fowler**
- **Ensemble-Stat Tool**
- **met-7.0 (current) and met-7.1 (summer)**
- **Docker containers**

MET Package

First MET Release:
January 2008

- **MET is community code supported by DTC**
 - Feely available and open source
 - 3600+ registered users
 - 133+ countries, 30% from USA
 - Universities, Government, Private Companies, Non-Profits
- Download MET release and compile locally.
 - Register and download: www.dtcenter.org/met/users
 - C++ with calls to some Fortran libraries
 - Linux with GNU, PGI, or Intel compilers
- Support
 - Online tutorial and in-person tutorials given yearly
 - met_help@ucar.edu help desk
 - 250+ support tickets in past year

A Decade of
Community
Verification





MET USERS PAGE

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MODEL EVALUATION TOOLS

Welcome

Welcome to the users page for the Model Evaluation Tools (MET) verification package. MET was developed by the National Center for Atmospheric Research (NCAR) Developmental Testbed Center (DTC) through the generous support of the U.S. Air Force Weather Agency (AFWA) and the National Oceanic and Atmospheric Administration (NOAA).

Description

MET is designed to be a highly-configurable, state-of-the-art suite of verification tools. It was developed using output from the Weather Research and Forecasting (WRF) modeling system but may be applied to the output of other modeling systems as well.

MET provides a variety of verification techniques, including:

- Standard verification scores comparing gridded model data to point-based observations
- Standard verification scores comparing gridded model data to gridded observations
- Spatial verification methods comparing gridded model data to gridded observations using neighborhood, object-based, and intensity-scale decomposition approaches

EVENTS

No Upcoming Events

ANNOUNCEMENTS

[MET Version 7.0 Release](#)
03.05.2018

[End-To-End NWP Container Tutorial](#)
01.16.2018

[Release v3.9a of the HWRF system](#)
10.16.2017

MET NEWS

[Run MET in a Docker container](#)
New for Mac and Windows 10 users who wish to skip building and installing MET

MET SPONSORS





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National Center for Atmospheric Research (NCAR)



FAQs
Online Tutorial
Release Notes
Contact MET Help



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Download Source

Existing Builds

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03.05.2018

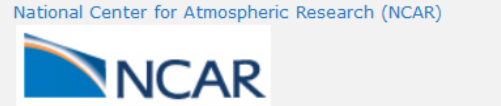
[End-To-End NWP Container Tutorial](#)
01.16.2018

[Release v3.9a of the HWRF system](#)
10.16.2017

MET NEWS

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New for Mac and Windows 10 users who wish to skip building and installing MET

MET SPONSORS



METV7.0 EXISTING MET BUILDS

METv7.0 Existing MET Builds

- NCAR RAL machines
 - MET BUILD: /usr/local/met
 - PATCH DATE:
- NCAR machine cheyenne
 - PATCH DATE:
 - MODULES:
 - module use /glade/p/ral/jnt/MET/MET_releases/cheyenne/modulefiles
 - module load met/7.0
- NOAA machine theia
 - PATCH DATE:
 - MODULES:
 - module use /contrib/modulefiles
 - module load met/7.0

NCAR-RAL Machines

Cheyenne

Theia

Gaea

Jet

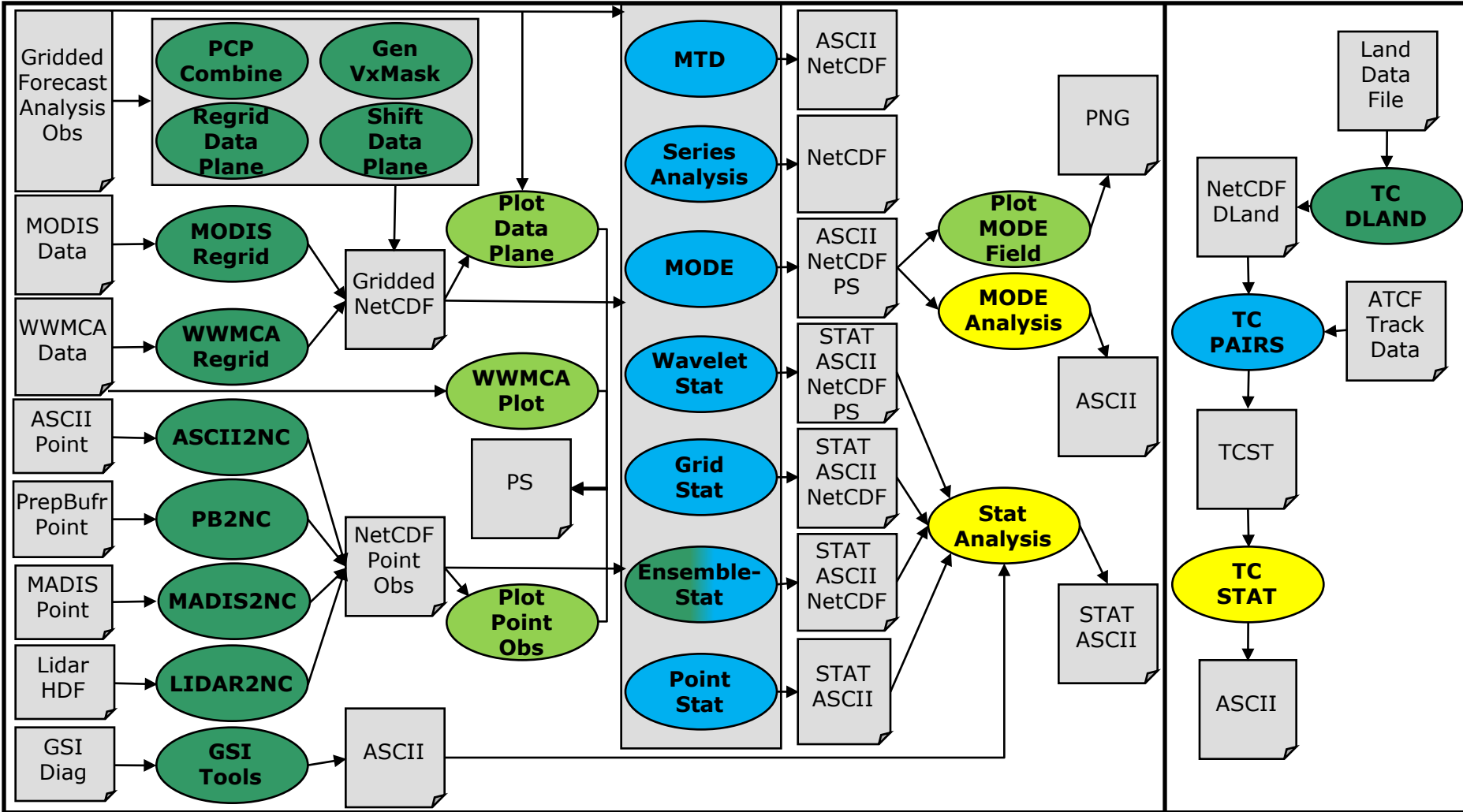
WCOSS Machines

Docker Container:

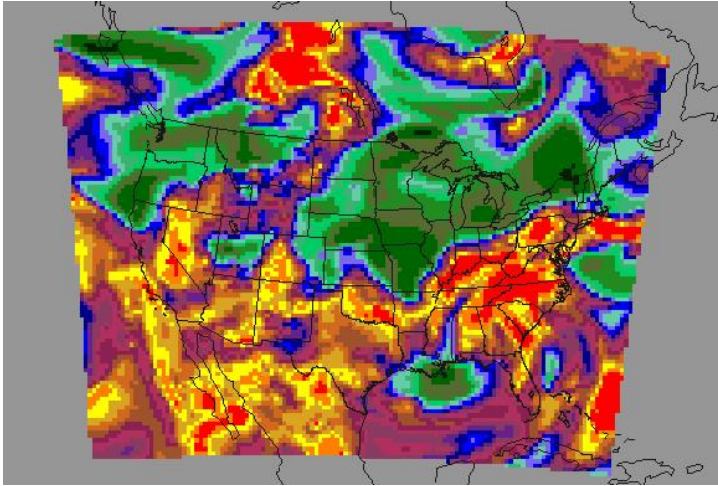
**[https://github.com/NCAR/
container-dtc-met](https://github.com/NCAR/container-dtc-met)**

MET Overview v7.0

Input Reformat Plot Statistics Analysis MET-TC

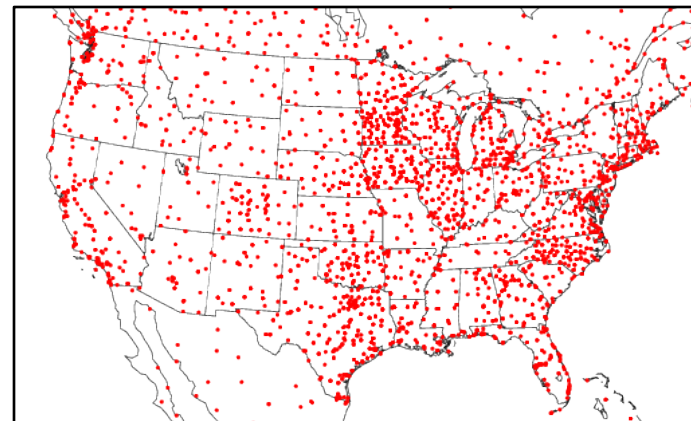


Point-Stat: Overview

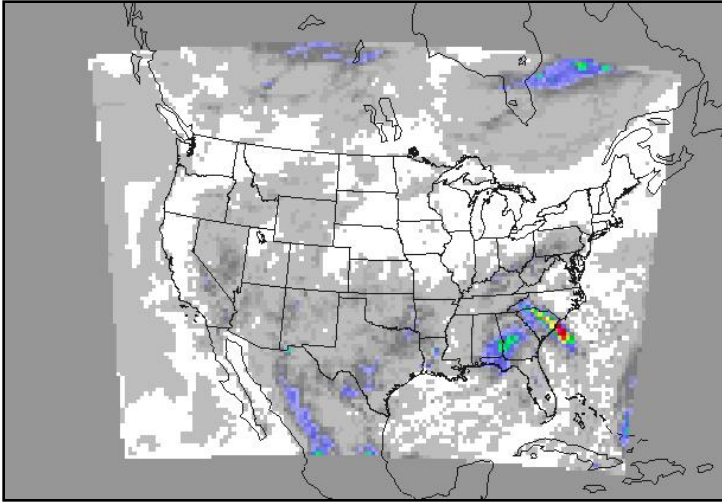


- Compare **gridded forecasts** to **point observations**.
- Accumulate matched pairs over a defined area at a **single** point in time.
- Verify one or more variables/levels.
- Analysis tool provided to aggregate through time.

- Verification methods:
 - **Continuous** statistics for raw fields.
 - **Single and Multi-Category** counts and statistics for thresholded fields.
 - Parametric and non-parametric **confidence intervals** for statistics.
 - Compute **partial sums** for raw fields and/or the raw matched pair values.
 - Methods for **probabilistic** forecasts.
 - **HiRA** spatial verification method.

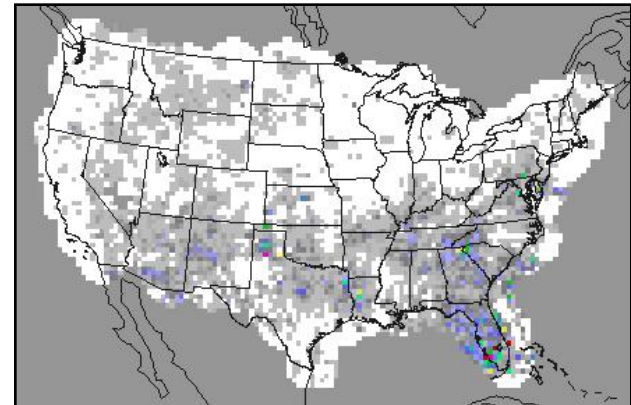


Grid-Stat: Overview



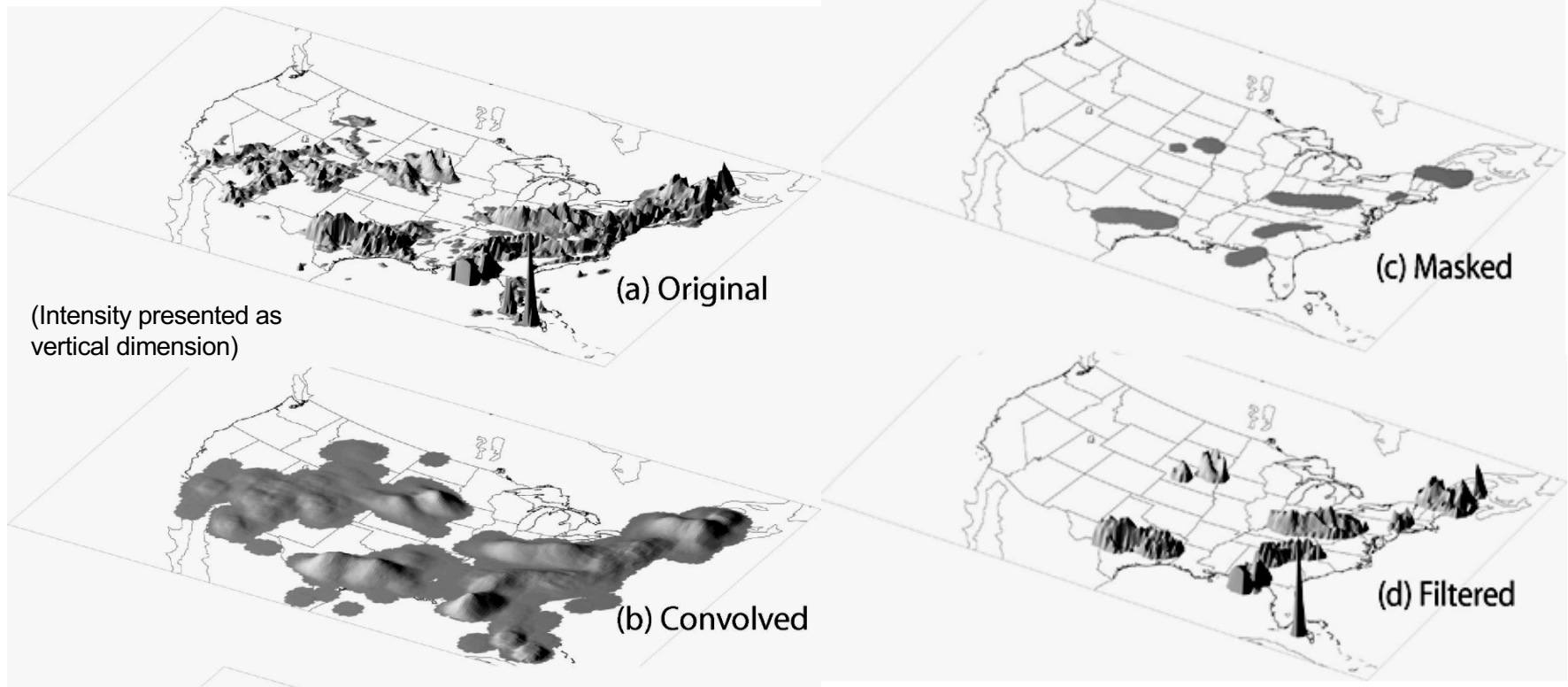
- Compare **gridded forecasts** to **gridded observations** on the **same grid**.
- Accumulate matched pairs over a defined area at a **single** point in time.
- Verify one or more variables/levels.
- Analysis tool provided to aggregate through time.

- Verification methods:
 - **Continuous** statistics for raw fields.
 - **Single and Multi-Category** counts and statistics for thresholded fields.
 - Parametric and non-parametric **confidence intervals** for statistics.
 - Compute **partial sums** for raw fields.
 - Methods for **probabilistic** forecasts.
 - Continuous statistics and categorical counts/statistics using **neighborhood** verification method and **gradients**.



MODE: Object Identification

Source: Davis 2006

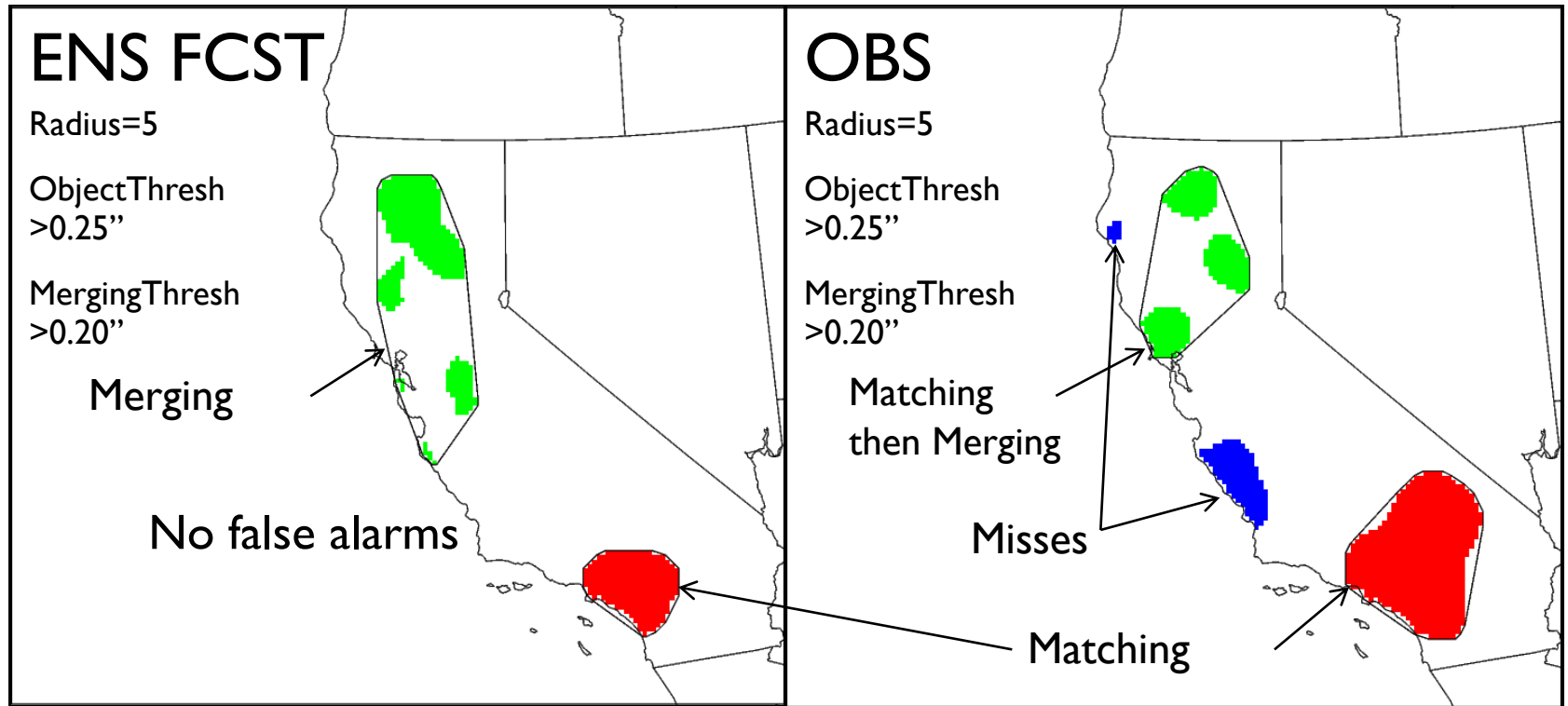
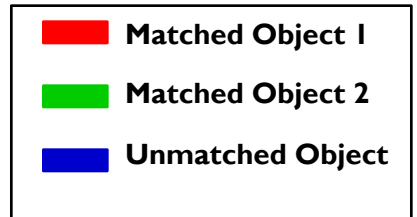


Smoothing radius
(in grid squares)

Accumulation threshold
(in mm)

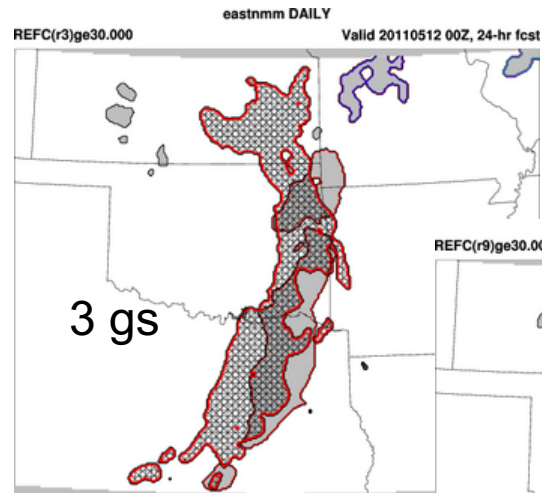
* User-defined parameters in configuration file

MODE: Precip Example

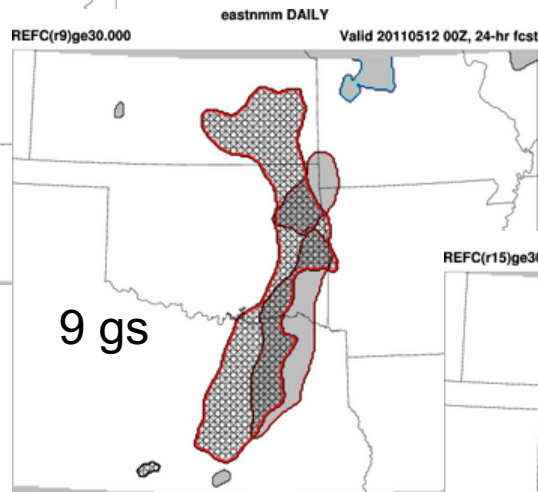


MODE: REFC > 30 Example

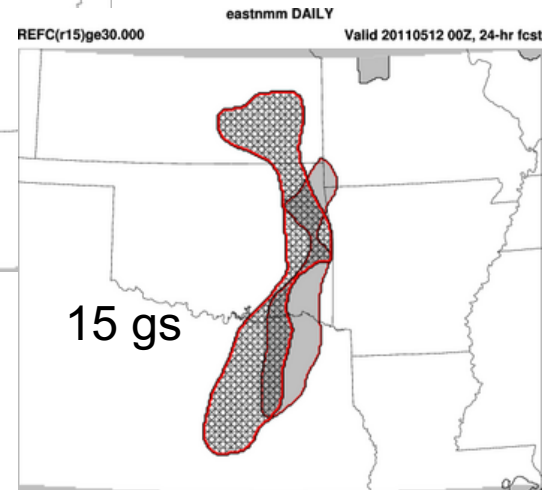
Impact of Smoothing Radius



Total Interest: 0.96
Area Ratio: 0.57
Centroid Distance: 95km
P90 Intensity Ratio: 1.00



Total Interest: 0.96
Area Ratio: 0.57
Centroid Distance: 94km
P90 Intensity Ratio: 1.02



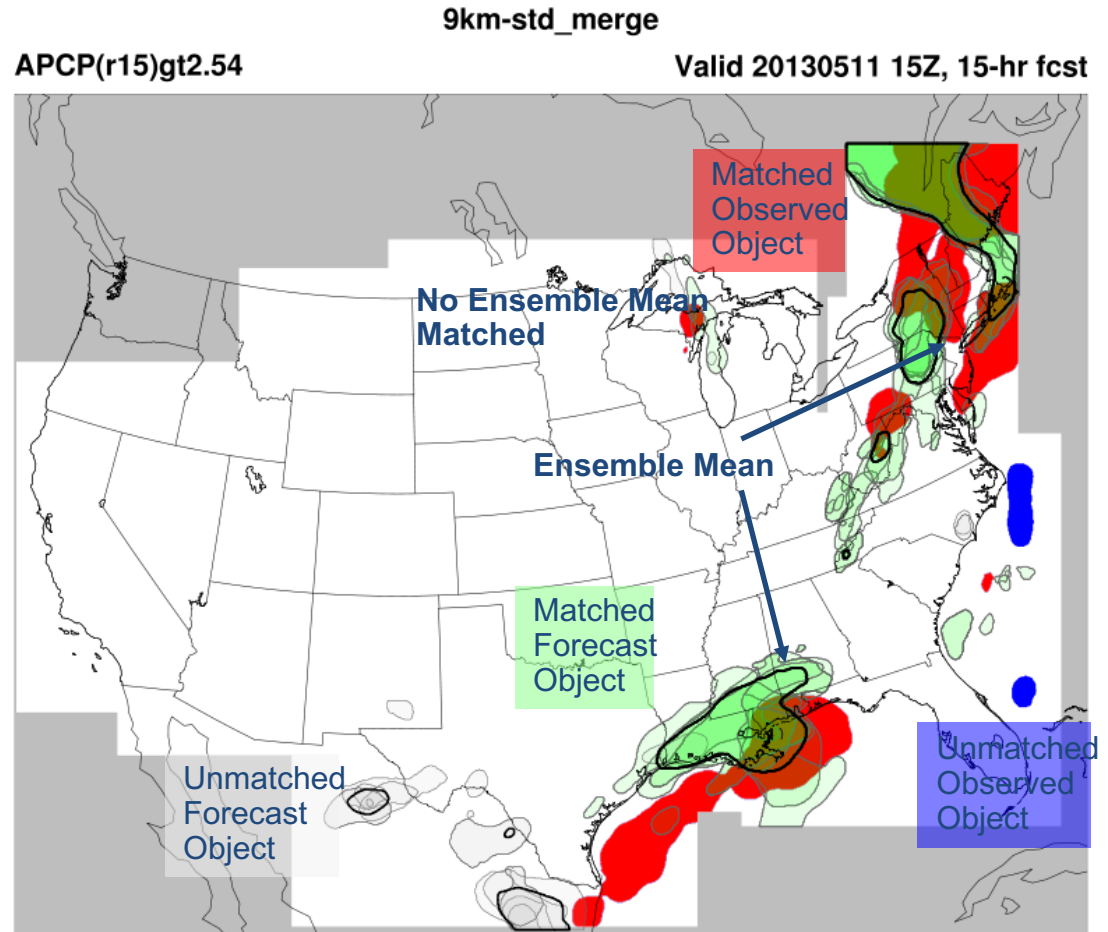
Convolution
Radius Increases

Total Interest: 0.96
Area Ratio: 0.53
Centroid Distance: 92km
P90 Intensity Ratio: 1.04

MODE: Ensemble Precip Example

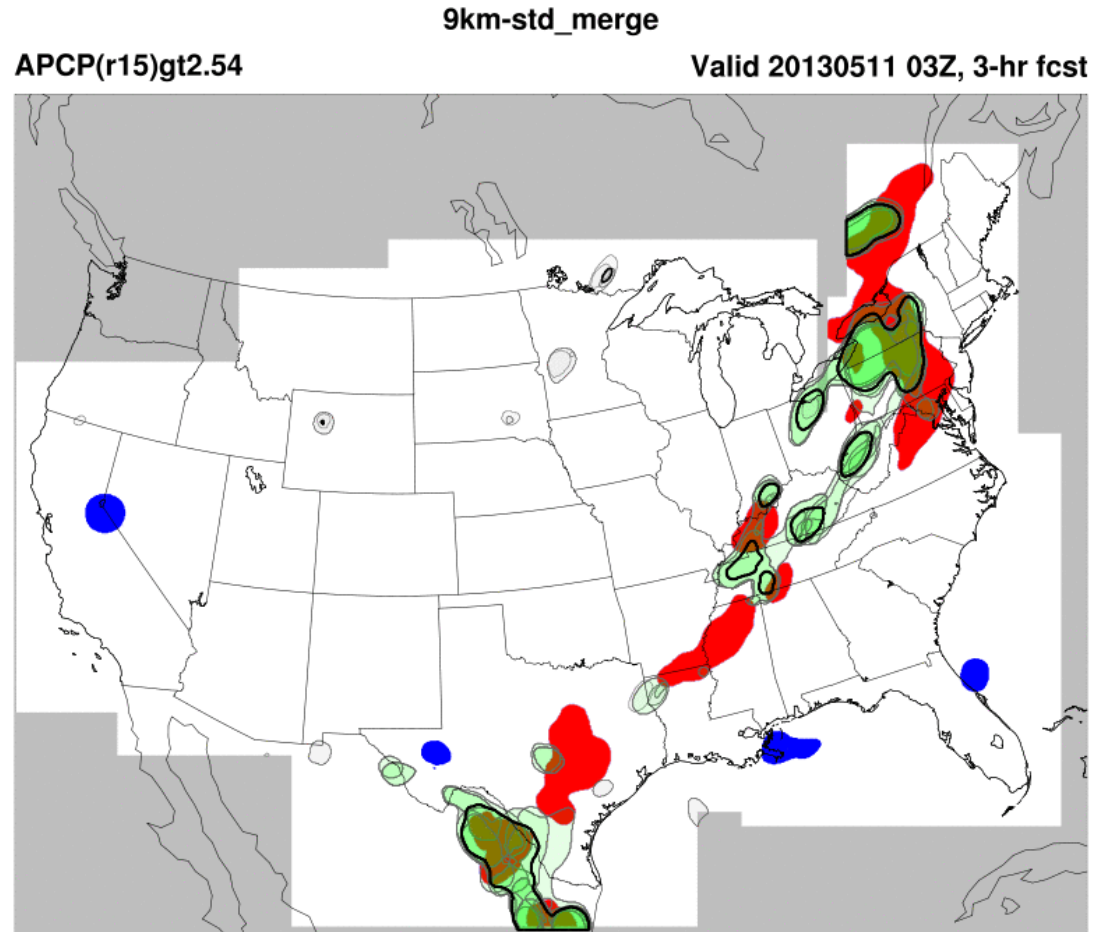
Example
May 11,
2013

DTC SREF
Tests – ARW
Members



MODE: Ensemble Precip Example

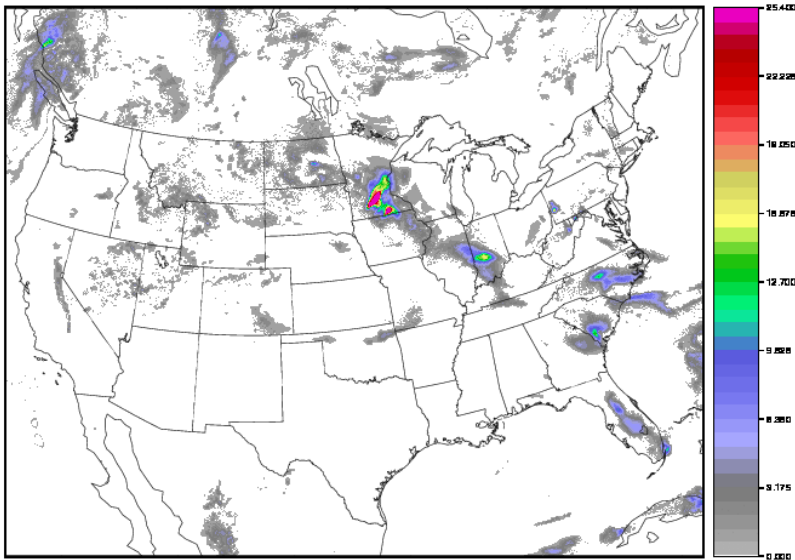
Spread
increases
With Time



Series-Analysis: Example

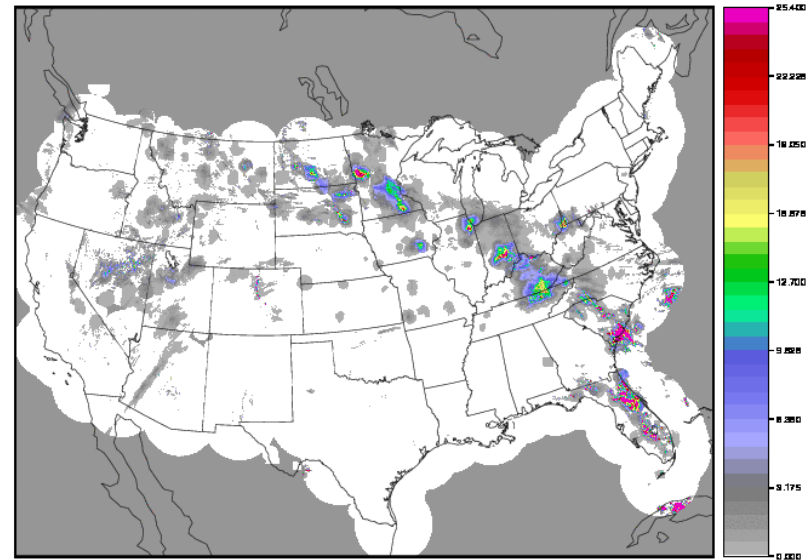
- Define series as:
 - Same field from multiple files.
 - Different fields from the same file.
 - Example: 24hr NAM fcst of 3hr APCP vs StageII

3-hour Accumulated Precipitation



nam_2009061600_021_024.nc

3-hour Accumulated Precipitation



ST2ml2009061700.03h.nc

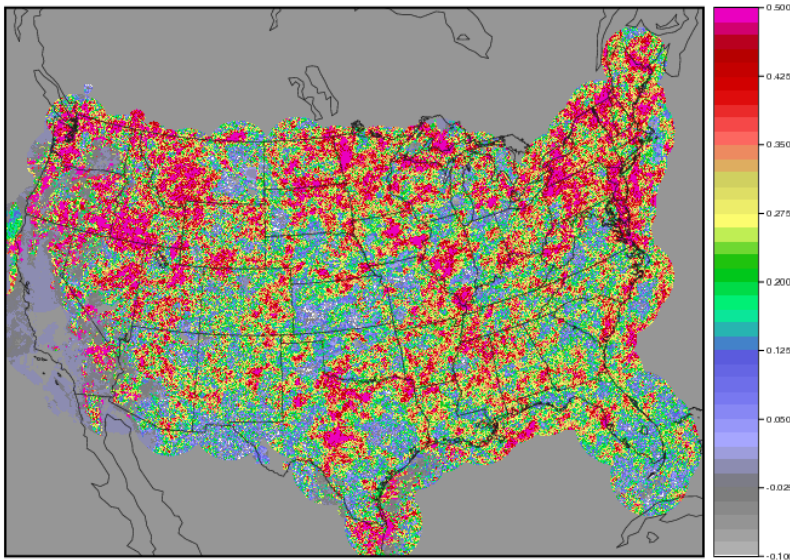
Series-Analysis: Example

Writes Gridded Output Statistics

3hr APCP > 0.254 mm
(0.01 in)

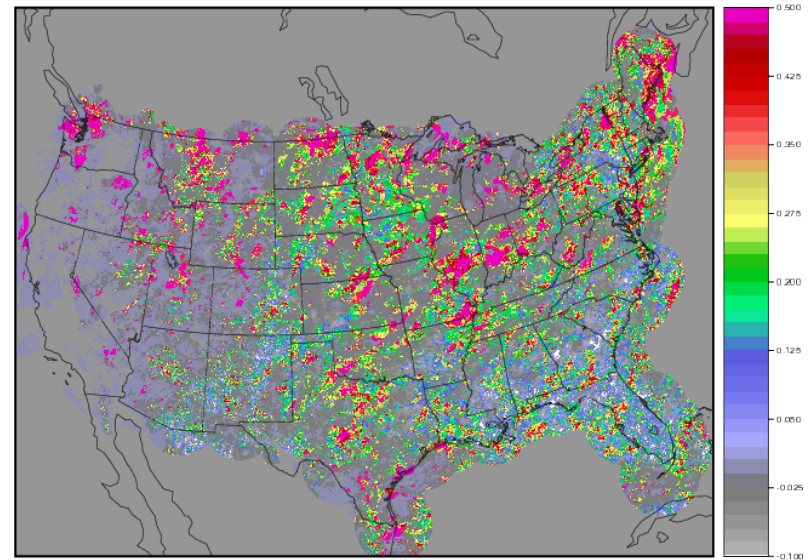
3hr APCP > 2.54 mm
(0.1 in)

series_cts_HSS_gt0.254



series_nam_st2_24hr_fcst_summer.nc

series_cts_HSS_gt2.540



series_nam_st2_24hr_fcst_summer.nc

MODE Time-Domain

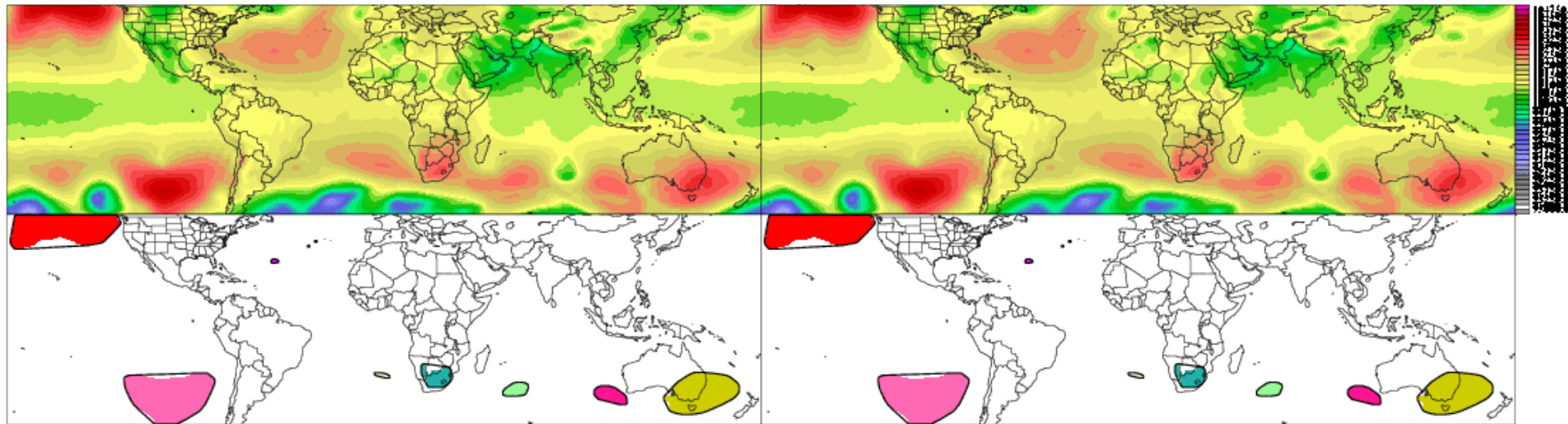
GFS vs Analysis

f000 to f240 every 6 hours

Objects $\geq 1025\text{mb}$

Forecast

Analysis

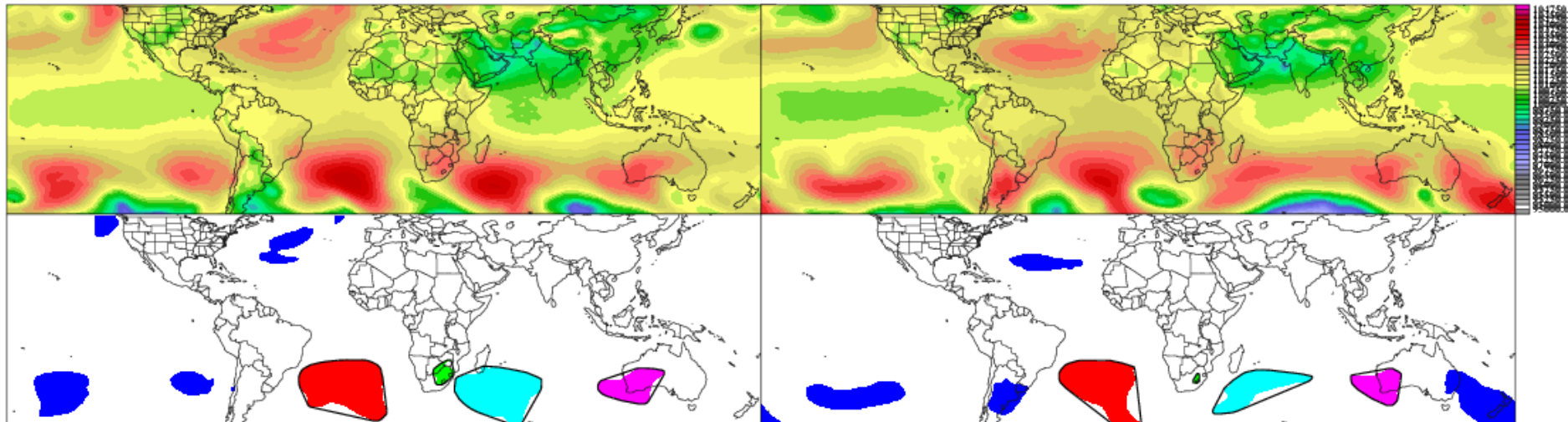


MODE Time-Domain

f240	Pair 1	Pair 2	Pair 3	Pair 4
Centroid Distance	4.62	10.31	10.12	11.22
Fcst Area	13983	1097	12146	5132
Obs Area	11584	133	6713	4225
Intersection	10857	133	5723	3610

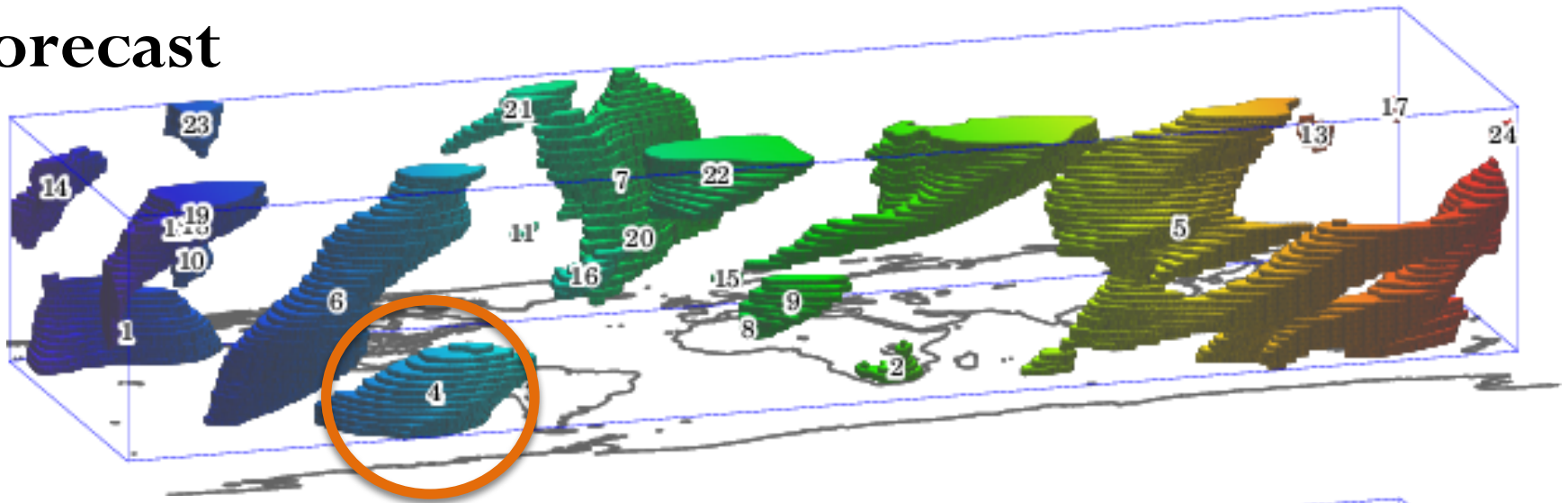
Forecast

Analysis

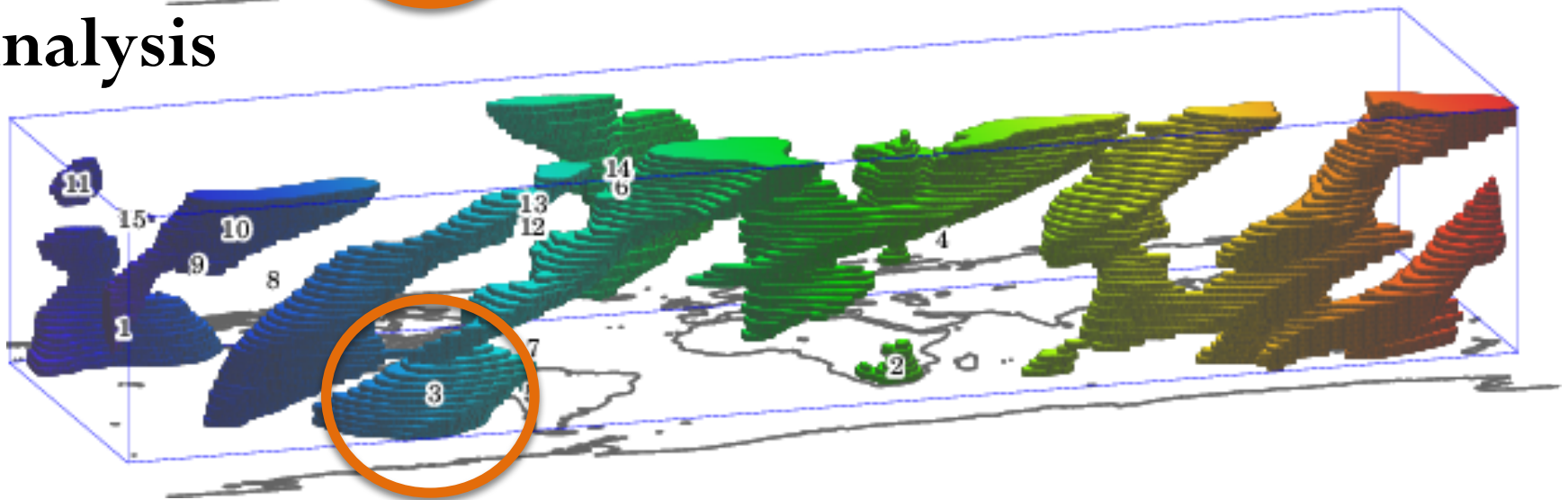


MODE Time-Domain

Forecast

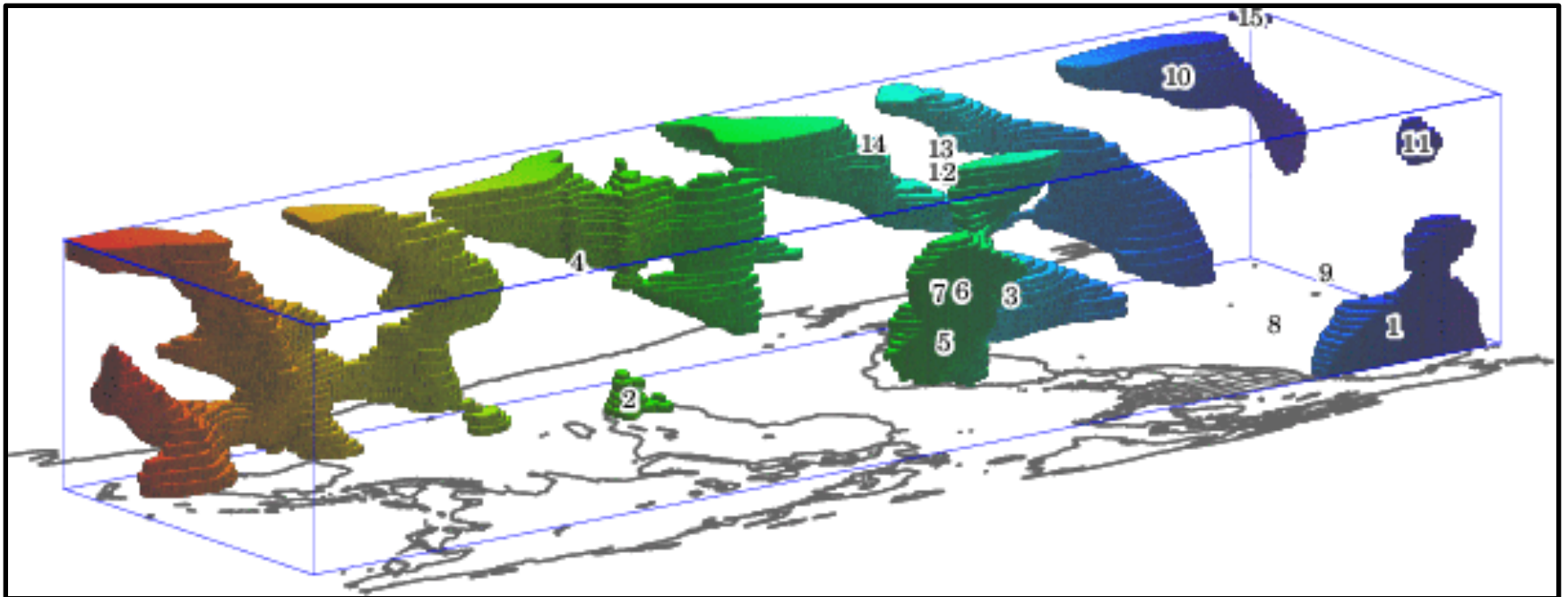


Analysis



MODE Time-Domain

f000 – f240	Max Inten	Volume	Centroid(x,y,t)	Velocity
Fcst Object 4	103927	111493	336, 57, 4.19	2.85
Analysis Object 3	103914	113692	335, 59, 4.27	2.79



MET Config Entries

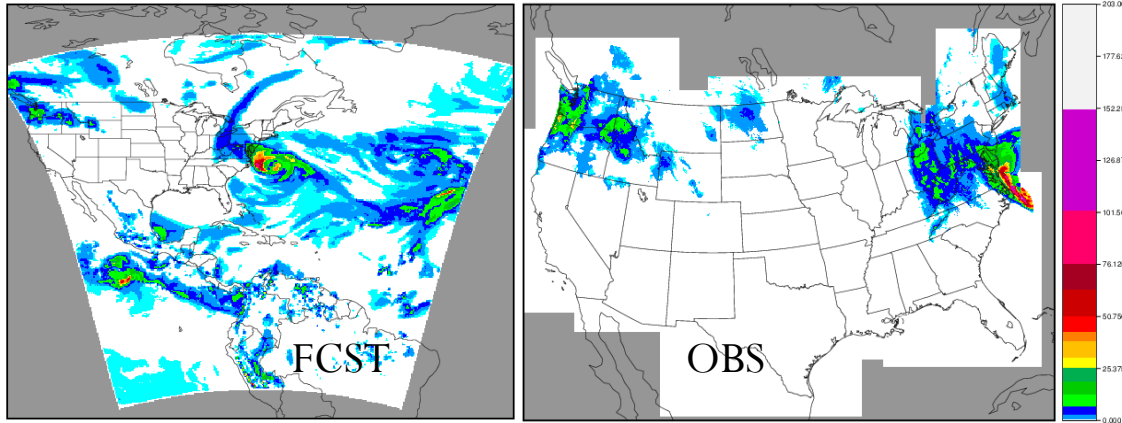
```
//  
// Output model name to be written  
//  
model = "WRF";  
//  
// Output description to be written  
// May be set separately in each "obs.field" entry  
//  
desc = "NA";  
//  
// Output observation type to be written  
//  
obtype = "ANALYS";  
//  
// Verification grid  
//  
regrid = {  
    to_grid   = OBS;  
    method    = BUDGET;  
    width     = 2;  
    vld_thresh = 0.5;  
    shape     = SQUARE;  
}
```

```
//  
// May be set separately for each task  
//  
sensor_thresh = [ <0 ];  
sensor_val    = [ 0 ];  
//  
// Fields to be verified  
//  
fcst = {  
    field = [  
        {  
            name     = "APCP";  
            level    = [ "A03" ];  
            cat_thresh = [ >0.0, >=5.0 ];  
        }  
    ];  
}  
obs = fcst;
```

Automated Regridding in MET

Config

file: grid to verify on:
FCST, OBS,
or USER
DEFINED



Old method: Regrid outside MET

Regrid to FCST or OBS - requires at least 1 more file

Regrid to USER DEFINED - requires 2 more files

Impact #1 – Decreased complexity & storage requirements

Automated regridding could save **0.5 to 7.5 GB per operational cycle**

Equates to **60 GB – 1 TB per month** of storage

Impact #2 – Less complexity for using climatologies

Climatologies may not be on same grid as forecasts.

See Impact #1

MTD

Series
Analysis

MODE

Wavelet
Stat

Grid
Stat

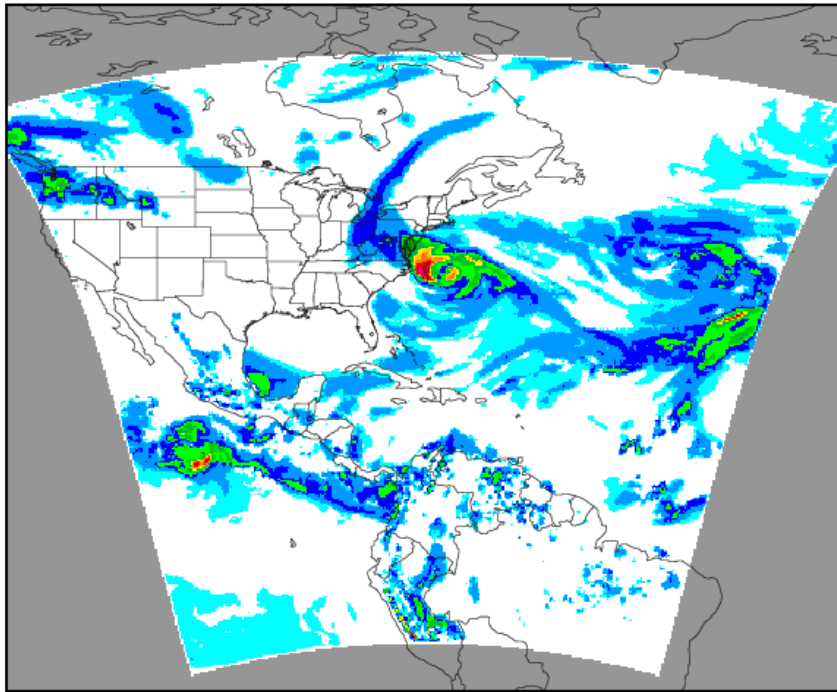
Ensemble-
Stat

Point
Stat

Automated Regridding

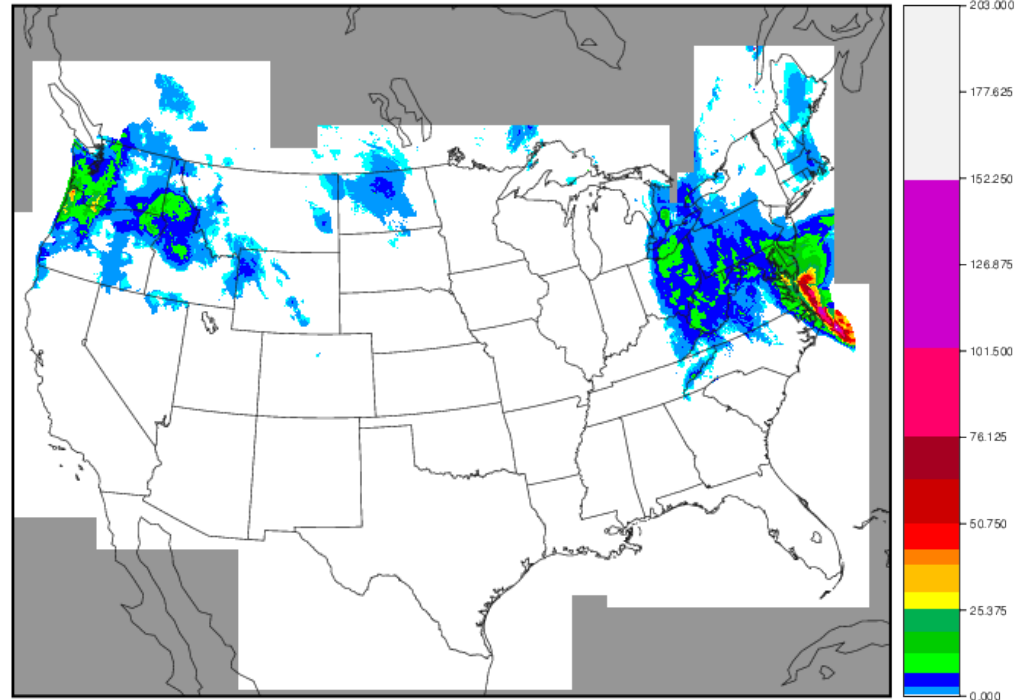
0.25° HWRF

Sandy 6-hour APCP



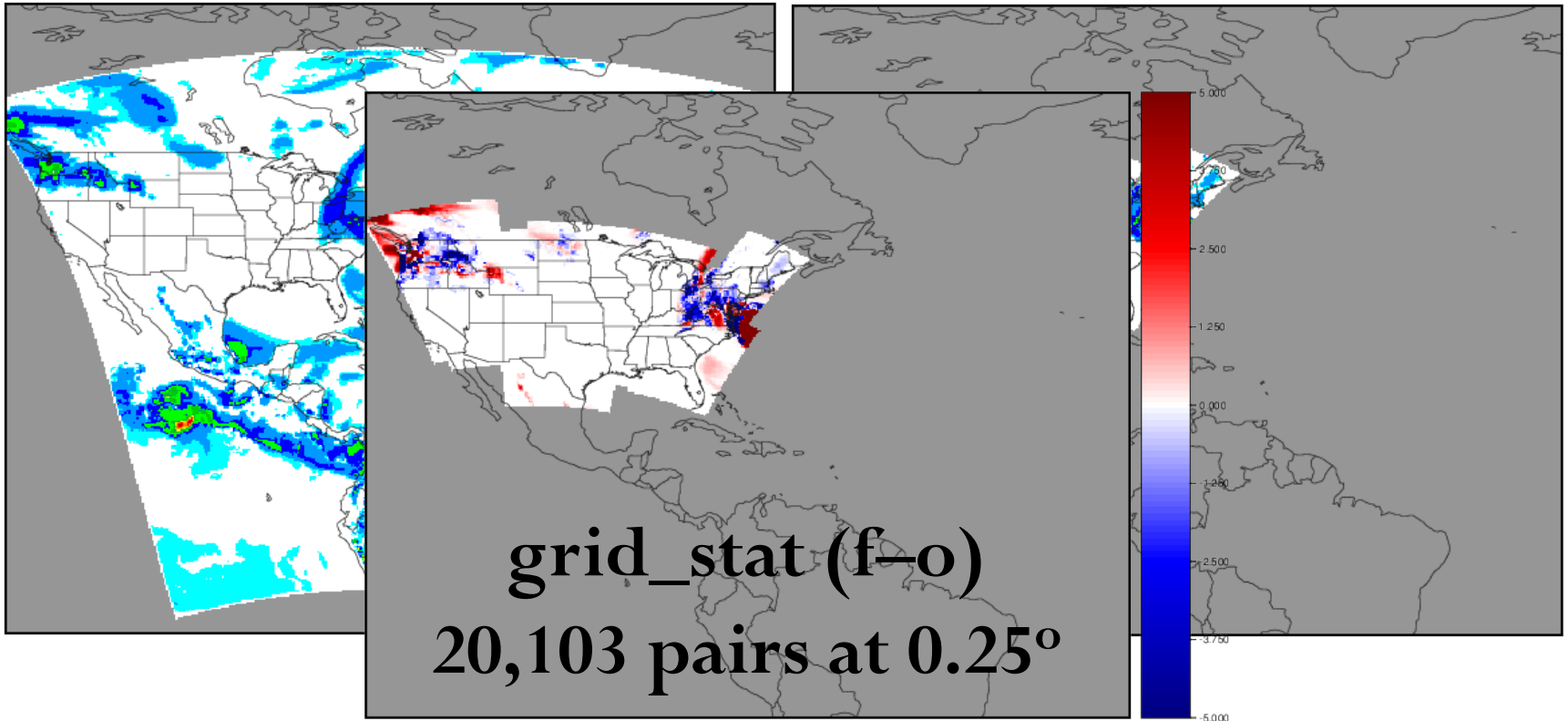
4km StageIV

6-hour APCP



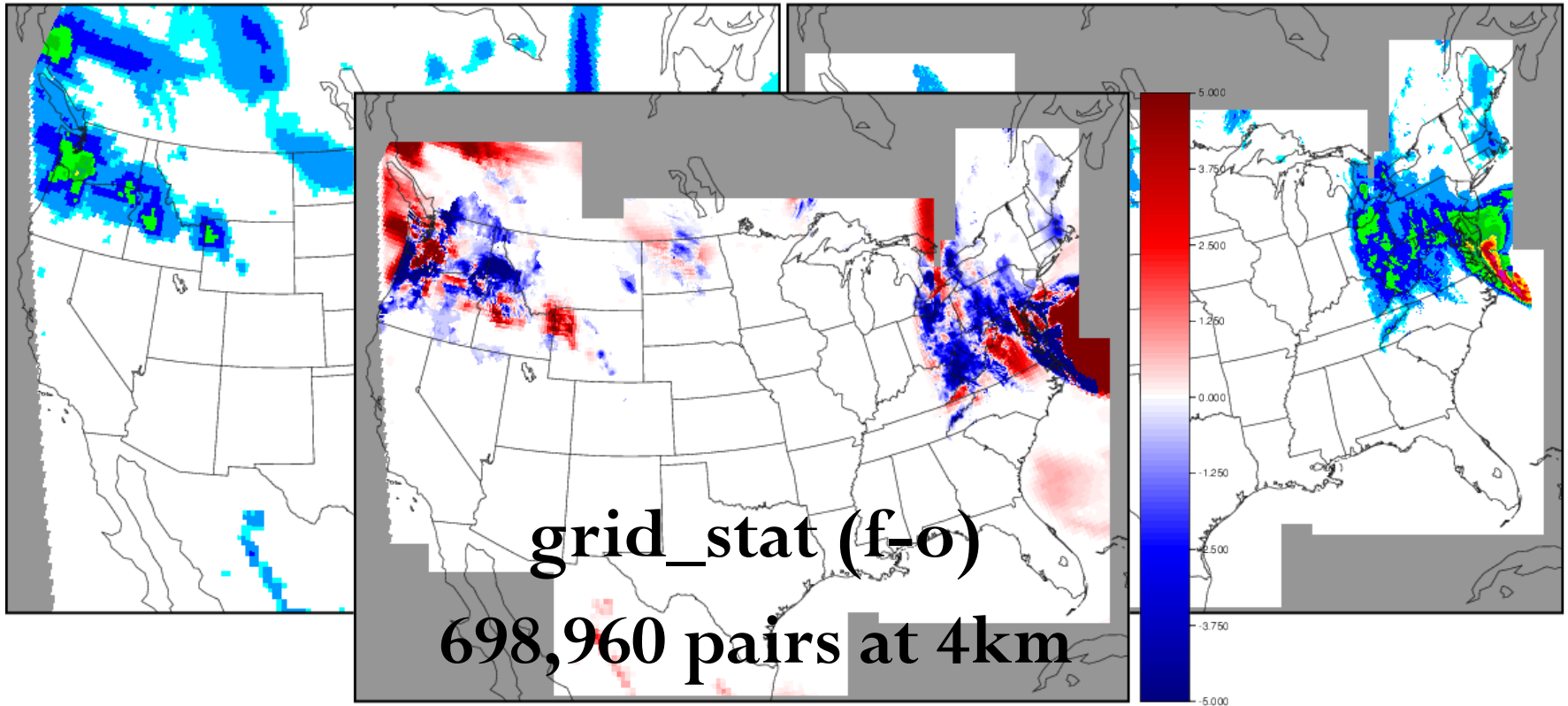
Automated Regridding

to_grid = FCST;



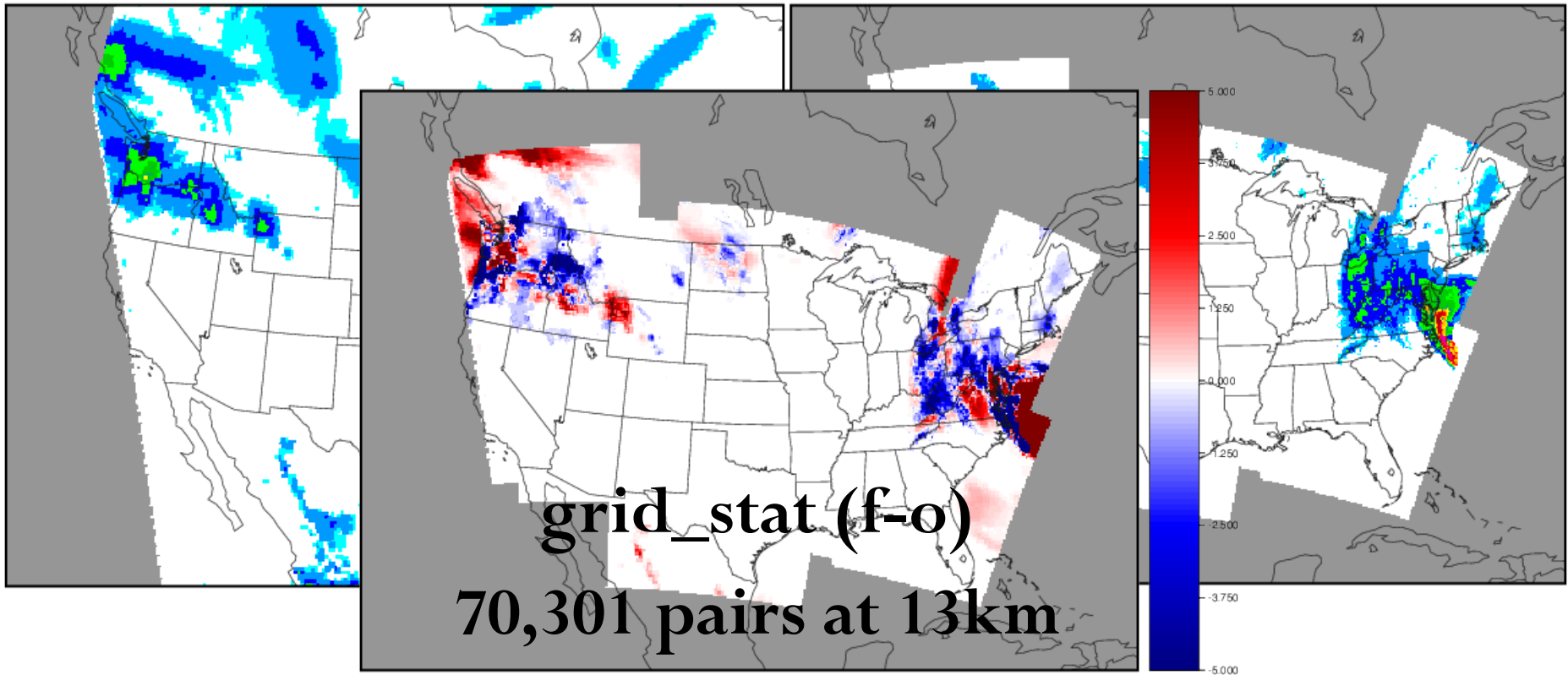
Automated Regridding

`to_grid = OBS;`



Automated Regridding

`to_grid = "G130";`



- Named grid, gridded data file, or grid definition string

Output from Point and Grid-Stat

```
output_flag = {
```

```
  fho    = STAT;
```

```
  ctc    = STAT;
```

```
  cts    = STAT; CATEGORICAL
```

```
  mctc   = STAT;
```

```
  mcts   = STAT;
```

```
  cnt    = STAT;
```

```
  l12    = STAT; CONTINUOUS
```

```
  sal112 = STAT;
```

```
  vl112  = STAT; VECTOR
```

```
  val112 = STAT;
```

```
  vcnt   = STAT; WINDS
```

```
  pct    = NONE;
```

```
  pstd   = NONE;
```

```
  ppc    = NONE; PROBABILISTIC
```

```
  prc    = NONE;
```

```
  eclv   = NONE;
```

```
  nbrctc = STAT; (*GS)
```

```
  nbrcts = STAT; (*GS)
```

```
  nbrcnt = STAT; (*GS) NEIGHBORHOOD
```

```
  grad   = STAT; (*GS)
```

```
  npr    = STAT; (*PS) MATCHED PAIRS
```

```
}
```

CTC Output Line Type

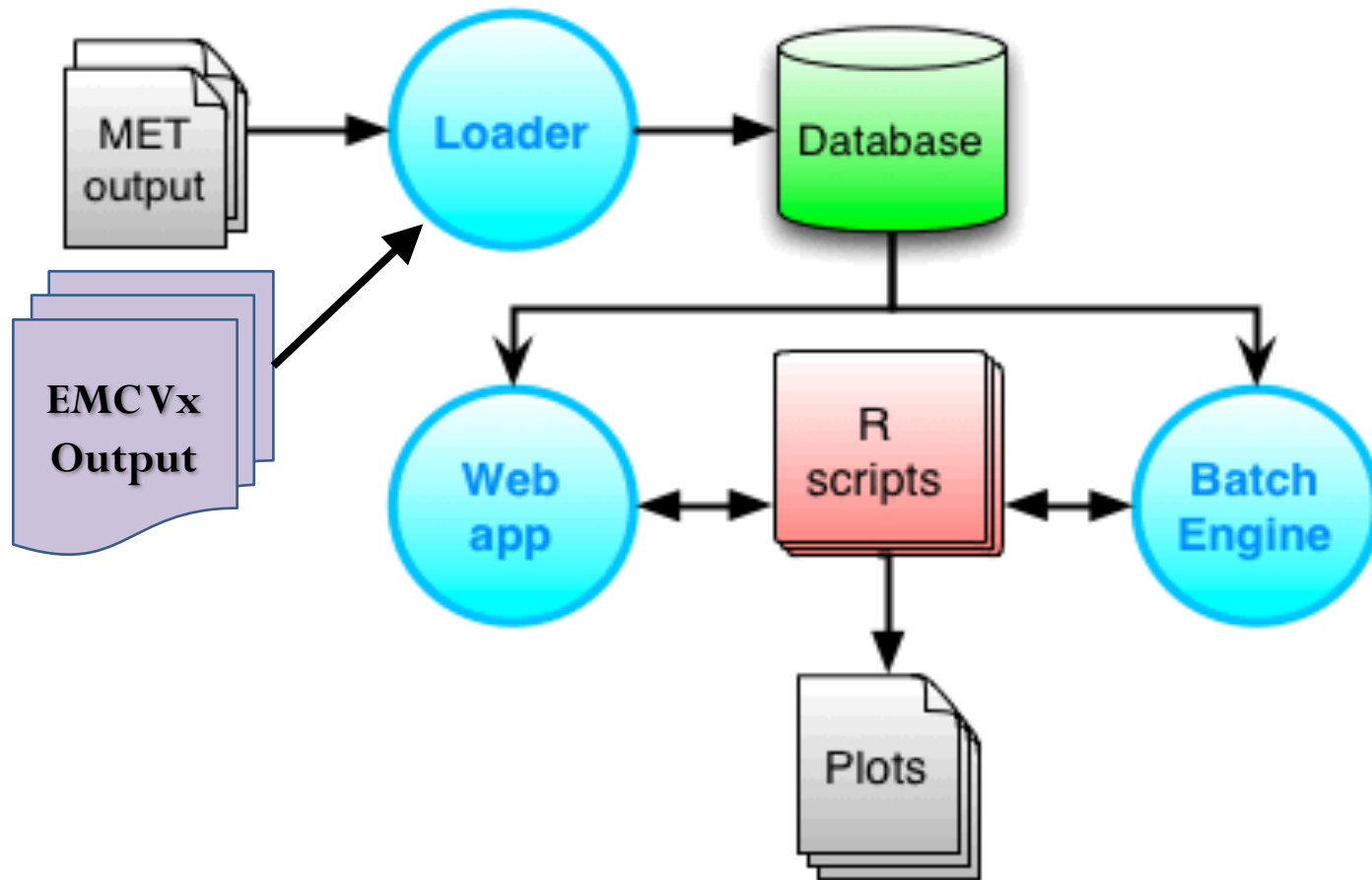
VERSION	V7.0
MODEL	WRF
DESC	NA
FCST_LEAD	360000
FCST_VALID_BEG	20070331_120000
FCST_VALID_END	20070331_120000
OBS_LEAD	000000
OBS_VALID_BEG	20070331_103000
OBS_VALID_END	20070331_133000
FCST_VAR	TMP
FCST_LEV	Z2
OBS_VAR	TMP
OBS_LEV	Z2
OBTYPE	ADPSFC

VX_MASK	FULL
INTERP_MTHD	UW_MEAN
INTERP_PNTS	1
FCST_THRESH	>273.000
OBS_THRESH	>273.000
COV_THRESH	NA
ALPHA	NA
LINE_TYPE	CTC
TOTAL	4003
FY_OY (hits)	3111
FY_ON (f.a.)	78
FN_OY (miss)	215
FN_ON (c.n.)	599

METViewer

METViewer components

Packages: Java, Apache/Tomcat, MySQL, R statistics



Database and Display analysis tool

METViewer: GUI Options

<http://www.dtcenter.org/met/metviewer/metviewer1.jsp>

Save plot, XML, R script, R data, SQL, Y1 Points, Y2 Points, Load Existing XMLs data

The screenshot shows the METViewer 2.5 interface with several key components highlighted by red boxes and arrows:

- Database:** A dropdown menu showing 'mv_gmtb_gftest_da' with an arrow pointing to it labeled 'Select database'.
- Generate Plot:** A button with an arrow pointing to it labeled 'Generate Plot'.
- Save/Export:** Buttons for 'Reload databases' and 'Load XMLs' with arrows pointing to them labeled 'Save plot, XML, R script, R data, SQL, Y1 Points, Y2 Points, Load Existing XMLs data'.
- Series:** A row of tabs including 'Box', 'Bar', 'Roc', 'Rely', 'Ens_ss', 'Perf', 'Taylor', 'Hist', 'Eclv', and 'Contour' with an arrow pointing to it labeled 'Select plot template'.
- Plot Data:** A dropdown menu set to 'Stat' with an arrow pointing to it labeled 'Select plot template'.
- Y1 Axis variables:** A section with a dropdown for 'APCP_06' and a 'Select attribute stat' dropdown with an arrow pointing to it labeled 'Select variable and statistic'.
- MODEL:** A dropdown menu with an arrow pointing to it labeled 'Select variable and statistic'.
- Fixed Values:** A section with 'Fixed Value' and 'Event Equalizer' options with an arrow pointing to it labeled 'Select plot stratifications'.
- Independent Variable:** A section with 'FCST_LEAD' and 'Equalize' options with an arrow pointing to it labeled 'Select Y-axis series variable(s) calculating the statistic'.
- Titles & Labels:** A section with tabs for 'Titles & Labels', 'Common', 'Formatting', 'X1', 'X2', 'Y1', 'Y2', and 'Legend & Caption'. The 'Titles & Labels' tab is active, showing fields for Title, X label, Y1 label, Y2 label, and Caption. An arrow points to it labeled 'Select series formatting'.
- Series Formatting:** A table at the bottom with columns for '#', 'Y axis', 'Hide', 'Title', 'Conf Interval', 'Line Color', 'Point Symbol', 'Series Line Type', 'Line Type', 'Line Width', 'Show Significant', 'Connec Across NA', and 'Legend Text'. It also includes buttons for '+ Add Derived Curve', '- Remove Derived Curve', 'Apply defaults', and 'Lock Formatting'.

Summary – scores computed per each combination of fixed values and independent variable, then mean or median taken

Aggregate – accumulates SL1L2 lines or Y-axis series variable(s) calculating the statistic

Select series formatting

METViewer: GUI Plot

METViewer 2.5 Database: mv_gmtb_gftest_da Generate Plot Reload databases Load XML

Series Box Bar Roc Rely Ens_ss Perf Taylor Hist Eclv Contour Plot Data: Stat

Y1 Axis variables Y2 Axis variables

Y1 Dependent (Forecast) Variables:
 TMP ME

Y1 Series Variables:
 MODEL gfda_op25_G218, sasda_op25_G218 Group_y1_1

Fixed Values:
 VX_MASK CONUS Equalize
 INIT_HOUR 00
 OBTYPE ADPSFC

Plot Cond

20180607_162216
 Plot XML Log R script R data SQL Y1 Points Y2 Points

**2-m Temperature Bias over the CONUS
 20160601 - 20160615**

Titles & Labels Common Formatting X1 X2 Y1 Y2 Legend & Caption

Synch Y1 and Y2 Ranges Variance Inflation Factor
 Print Y1 Series Values Print Y2 Series Values
 Y1 Stagger Points Y2 Stagger Points
 Conf Interval Alpha 0.05

Series Formatting

#	Y axis	Hide	Title	Conf Interval	Line Color	Point Symbol	Series Line Type	Line Type	Line Width	Show Significant	Connec Across NA	Legend Text
1	Y1	No	gfda_op25_G218 TMP ME	std	0000ff	Small circle	joined lines	solid	2	No	Yes	GF DA
2	Y1	No	sasda_op25_G218 TMP ME	std	ff0000	Small circle	joined lines	solid	2	No	Yes	SAS DA

+ Add Derived Curve Remove Derived Curve Apply defaults Lock Formatting View 1 - 2 of 2

METViewer: Plot Templates

Click on tab to pick plot type

Series Box Bar Roc Rely Ens_ss Perf Taylor Hist Edv

Y1 Axis variables Y2 Axis variables

Y1 Dependent (Forecast) Variables:

APCP_03 CSI

Y1 Series Variables:

MODEL GFS_27km_WRFv3.6.1, GFS_3km_WRFv3.6.1, GFS_9km_WRFv3.6.1 Group_y1_1

Fixed Values:

Fixed Value

Event Equalizer

Plot Cond

Independent Variable:

FCST_LEAD Select value Equalize

Statistics:

Series Formatting

#	Y axis	Hide	Title	Conf Interval	Line Color	Point Symbol	Series Line Type	Line Type	Line Width	Show Significant	Connect Across NA	Legend Text
1	Y1	No	GFS_27km_WRFv3.6.1 APCP_03 CSI	none	#F0000	Small circle	joined lines	solid	1	No	Yes	
2	Y1	No	GFS_3km_WRFv3.6.1 APCP_03 CSI	none	#8000F	Small circle	joined lines	solid	1	No	Yes	
3	Y1	No	GFS_9km_WRFv3.6.1 APCP_03 CSI	none	#00FF7F	Small circle	joined lines	solid	1	No	Yes	

+ Add Derived Curve - Remove Derived Curve Apply defaults Lock Formatting

View 1 - 3 of 3

Series
Box
Bar
ROC
Reliability
Ensemble Spread-Skill
Performance Diagram
Taylor Diagram
Hist (RHIST, PHIST, RELP)
ECLV
Contour

METViewer: Statistically Significant Differences

Database: mv_ncep_meso_sl12 Generate Plot Reload databases Load XML

Series Box Bar Rhist Phist Roc Rely Ens_ss Perf

Plot Data: Stat

Y1 Axis variables Y2 Axis variables

Y1 Dependent (Forecast) Variables: RH RMSE

Y1 Series Variables: MODEL GFS/212, NAM/212 Group_y1_1

Fixed Values: INIT_HOUR 00 VX_MASK G236 OBTYPE ONLYSF

20160506_031343

Plot XML Log R script R data SQL Y1 Points Y2 Points

test title

Titles & Labels Common Formatting

Series Formatting

#	Y axis	Hide	Title	Conf Interval	Line Color	Point Symbol	Series Line Type	Line Type	Line Width	Show Significant	Connect Across NA	Legend Text
1	Y1	No	GFS/212 RH RMSE	std	#ff0000	Small circle	joined lines	solid	1	No	Yes	GFS
2	Y1	No	NAM/212 RH RMSE	std	#8000ff	Small circle	joined lines	solid	1	No	Yes	NAM
3	Y1	No	DIFF ("GFS/212 RH RMSE"- "NAM/212 RH RMSE")	std	32cd32	Small circle	joined lines	solid	1	Yes	Yes	(GFS-NAM)

+ Add Difference Curve Remove Difference Curve Apply default Lock Formatting

View 1 - 3 of 3

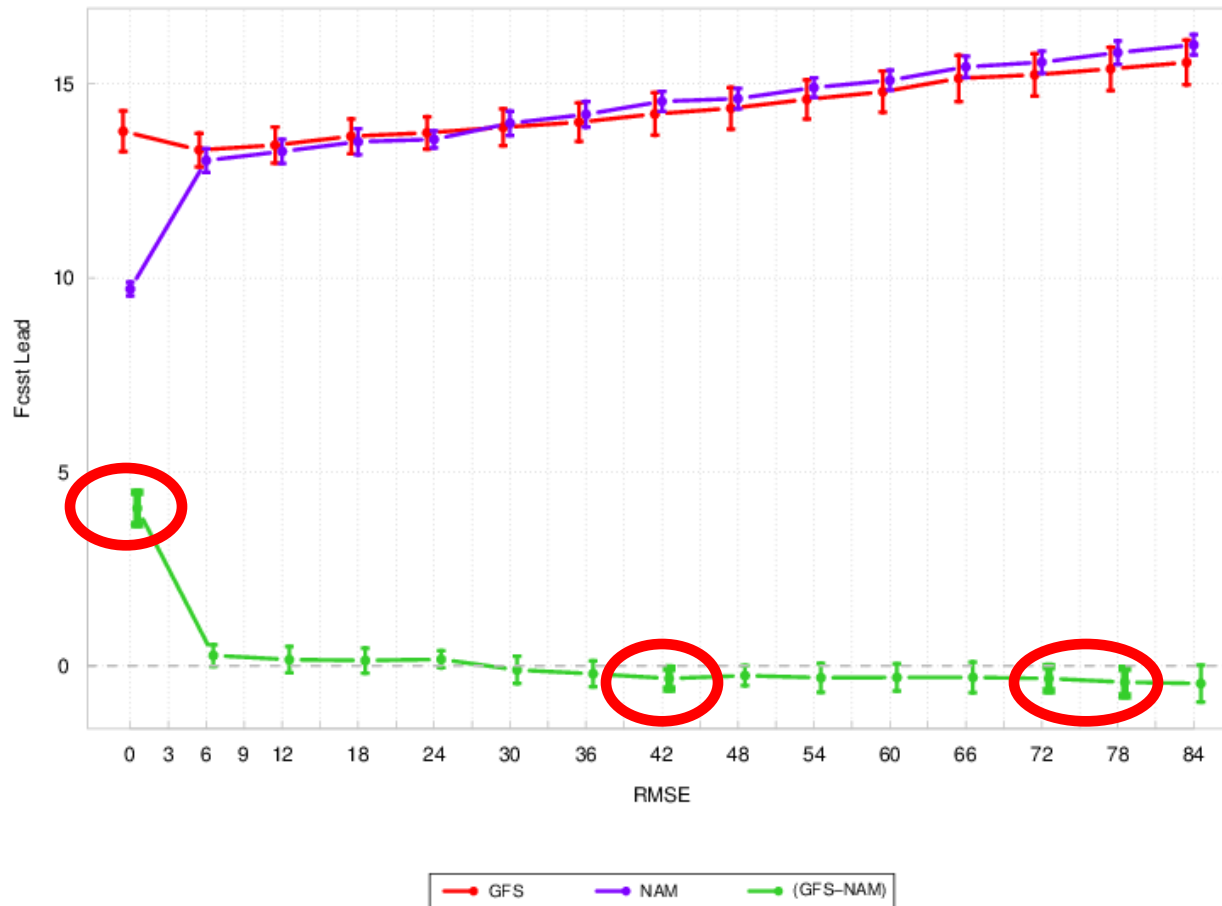
Turn on Show Signif to have Statistically Significant differences highlighted

Add difference curve... Next to it is remove difference curve...

You might want to also turn on confidence intervals

Statistically Significant Plot

GFS vs. NAM



METViewer History

The screenshot displays the METViewer interface with the following components:

- Database:** mv_det_sref_2013
- Series:** Box, Bar, Rhist, Phist, Roc, Rely, Ens_ss
- Plot:** A line plot titled "test title" with "test_x_label" on the x-axis and "test_y_label" on the y-axis. The plot shows several data series with different colors and line styles.
- History Window:** A window titled "20160413_203117" containing XML metadata for the plot specification, including connection details, folders, and plot options.
- Series Formatting Table:** A table at the bottom of the interface listing the series and their formatting options.

History Window XML Content:

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<plot_spec>
  <connection>
    <host>mandan.rap.ucar.edu:3306</host>
    <database>mv_namp_vsdb</database>
    <user>*****</user>
    <password>*****</password>
  </connection>
  <rscrip>/usr/local/bin/Rscript</rscrip>
  <folders>
    <r_tmpl>/opt/vx/www/tomcat/webapps/metviewer/R_tmpl</r_tmpl>
    <r_work>/opt/vx/www/tomcat/webapps/metviewer/R_work</r_work>
    <plots>/d2/www/dtcenter/met/metviewer_output/plots</plots>
    <data>/d2/www/dtcenter/met/metviewer_output/data</data>
    <scrips>/d2/www/dtcenter/met/metviewer_output/scrips</scrips>
  </folders>
  <plot>
    <template>series_plot.R_tmpl</template>
    <dep>
      <dep1>
        <fcst var name="VIS">

```

Series Formatting Table:

#	Y axis	Hide	Title	Conf Interval	Line Color	Point Symbol	Series Line Type	Line Type	Line Width	Show Signif	Conne Across	Legend Text
1	Y1	No	ens-16km-mp TMP ME	none	#FF0000	Small circle	joined lines	solid	1	No	Yes	
2	Y1	No	ens-16km-std TMP ME	none	#00FF7F	Small circle	joined lines	solid	1	No	Yes	
3	Y1	No	ens-9km-std TMP ME	none	#8000FF	Small circle	joined lines	solid	1	No	Yes	



METViewer

Save Plots, XML,
Data, Rscripts, etc

**Based on which tab is selected

Database: mv_det_sref_2013 Generate Plot Reload databases Load XML

Series **Box** Bar Rhist Phist Roc Rely Ens_ss

Plot Data: Stat Plot statistic: Median

Y1 Axis variables Y2 Axis variables

Y1 Dependent (Forecast) Variables:

TMP ME

Variable

Y1 Series Variables:

MODEL ens-16km-mp, ens-16km-std, ens-9km-std Group_y1_1

Series Variable

Fixed Values:

2013-05-01 00:00:00, 2013-05-02 00:00:00, 2013-05-03 00:00:00, 2013-05-04 00:00:00, 2013-05-05 00:00:00, 2013-05-06 00:00:00, 2013-05-07 00:00:00, 2013-05-08 00:00:00, 2013-05-09 00:00:00, 2013-05-10 00:00:00, 2013-05-11 00:00:00, 2013-05-12 00:00:00, 2013-05-13 00:00:00, 2013-05-14 00:00:00, 2013-05-15 00:00:00, 2013-05-16 00:00:00, 2013-05-17 00:00:00, 2013-05-18 00:00:00, 2013-05-19 00:00:00, 2013-05-20 00:00:00

FCST_INIT_BEG

Fixed Value

Plot Cond

20140722_151502

Plot XML Log R script R data SQL

Example for METViewer Interface

Temperature ME (K)

Lead Hour

ens-16km-mp TMP ME ens-16km-std TMP ME ens-9km-std TMP ME

Titles & Labels Common Formatting X1 X2 Y1 Y2 Legend & Caption

Title: Example for METViewer Interface

X label: Lead Hour

Y1 label: Temperature ME (K)

Y2 label:

Caption:

Series Formatting

#	Y axis	Hide	Title	Conf Interval	Line Color	Point Symbol	Series Line Type	Line Type	Line Width	Show Signifi	Connec Across	Legend Text
1	Y1	No	ens-16km-mp TMP ME	none	#FF0000	Small circle	joined lines	solid	1	No	Yes	
2	Y1	No	ens-16km-std TMP ME	none	#00FF7F	Small circle	joined lines	solid	1	No	Yes	
3	Y1	No	ens-9km-std TMP ME	none	#8000FF	Small circle	joined lines	solid	1	No	Yes	

View 1 - 3 of 3

METViewer

Upload XML scripts
from your system

Database: mv_det_sref_2013 Generate Plot Reload databases Load XML

Series: **Box** Bar Rhist Phist Roc Rely Ens_ss

Plot Data: Stat Plot statistic: Median

Y1 Axis variables Y2 Axis variables

Y1 Dependent (Forecast) Variables:

TMP ME

Variable

Y1 Series Variables:

MODEL ens-16km-mp, ens-16km-std, ens-9km-std Group_y1_1

Series Variable

Fixed Values:

2013-05-01 00:00:00, 2013-05-02 00:00:00, 2013-05-03 00:00:00, 2013-05-04 00:00:00, 2013-05-05 00:00:00, 2013-05-06 00:00:00, 2013-05-07 00:00:00, 2013-05-08 00:00:00, 2013-05-09 00:00:00, 2013-05-10 00:00:00, 2013-05-11 00:00:00, 2013-05-12 00:00:00, 2013-05-13 00:00:00, 2013-05-14 00:00:00, 2013-05-15 00:00:00, 2013-05-16 00:00:00, 2013-05-17 00:00:00, 2013-05-18 00:00:00, 2013-05-19 00:00:00, 2013-05-20 00:00:00

FCST_INIT_BEG

Fixed Value

Plot Cond

20140722_151502

Plot XML Log R script R data SQL

Example for METViewer Interface

Temperature ME (K)

Lead Hour

ens-16km-mp TMP ME ens-16km-std TMP ME ens-9km-std TMP ME

Titles & Labels Common Formatting X1 X2 Y1 Y2 Legend & Caption

Title: Example for METViewer Interface

X label: Lead Hour

Y1 label: Temperature ME (K)

Y2 label:

Caption:

Series Formatting

#	Y axis	Hide	Title	Conf Interval	Line Color	Point Symbol	Series Line Type	Line Type	Line Width	Show Signifi	Connec Across	Legend Text
1	Y1	No	ens-16km-mp TMP ME	none	#FF0000	Small circle	joined lines	solid	1	No	Yes	
2	Y1	No	ens-16km-std TMP ME	none	#00FF7F	Small circle	joined lines	solid	1	No	Yes	
3	Y1	No	ens-9km-std TMP ME	none	#8000FF	Small circle	joined lines	solid	1	No	Yes	

View 1 - 3 of 3

METViewer

Database: mv_det_sref_2013 Generate Plot Reload databases Load XML

Series: Box Bar Chart Hist Phist Roc

Plot Data: Stat

Y1 Axis variables: Y2 Axis variables

Y1 Dependent (Forecast) Variables: TMP ME

Y1 Series Variables: MODEL ens-16km-mp, ens-16km-std, ens-9km-std Group_y1_1

Fixed Values: 2013-05-01 00:00:00, 2013-05-02 00:00:00, 2013-05-03 00:00:00, 2013-05-04 00:00:00, 2013-05-05 00:00:00, 2013-05-06 00:00:00, 2013-05-07 00:00:00, 2013-05-08 00:00:00, 2013-05-09 00:00:00, 2013-05-10 00:00:00, 2013-05-11 00:00:00, 2013-05-12 00:00:00, 2013-05-13 00:00:00, 2013-05-14 00:00:00, 2013-05-15 00:00:00, 2013-05-16 00:00:00, 2013-05-17 00:00:00, 2013-05-18 00:00:00, 2013-05-19 00:00:00, 2013-05-20 00:00:00

Plot Cond

Plot Data: Choose between Stat, MODE, and MTD

Titles & Labels: Common Formatting X1 X2 Y1 Y2 Legend & Caption

Title: Example for METViewer Interface

X label: Lead Hour

Y1 label: Temperature ME (K)

Y2 label:

Caption:

Series Formatting

#	Y axis	Hide	Title	Conf Interval	Line Color	Point Symbol	Series Line Type	Line Type	Line Width	Show Signifi	Connec Across	Legend Text
1	Y1	No	ens-16km-mp TMP ME	none	#FF0000	Small circle	joined lines	solid	1	No	Yes	
2	Y1	No	ens-16km-std TMP ME	none	#00FF7F	Small circle	joined lines	solid	1	No	Yes	
3	Y1	No	ens-9km-std TMP ME	none	#8000FF	Small circle	joined lines	solid	1	No	Yes	

View 1 - 3 of 3

MODE Interface

Database: mv_ncep_gfs_mode_extra Generate Plot Reload databases Load XML

History: All Success

Series: Box Bar Rhist Phist Roc Rely Ens_ss Perf

Plot Data: MODE

Y1 Axis variables Y2 Axis variables

Y1 Dependent (Forecast) Variables:

APCP_24 Select ratio stat Fcst Simple Matched
 CNTSUM Diff Obs Cluster Unmatched

Variable

Y1 Series Variables:

MODEL ECMG4, GFS_T1534 Group_y1_1

Series Variable

Fixed Values:

FCST_THR >=20.000

Fixed Value

Plot Cond

Independent Variables:

FCST_LEAD 360000, 600000, 840000, 1080000, 1320000, 1560000, 1800000

Statistics

20160506_042455

Plot XML Log R script R data SQL Y1 Points Y2 Points

MODE Total Objects

Forecast Lead	ECMG4 APCP_24 CNTSUM_AAA	GFS_T1534 APCP_24 CNTSUM_AAA
36	960	960
60	960	950
84	950	940
108	920	950
132	890	940
156	890	850
180	820	860

Titles & Labels: Common Formatting X1 X2 Y1 Y2 Legend & Caption

Title: MODE Total Objects

X label: Forecast Lead

Y1 label: Total Count

Y2 label:

Caption:

Series Formatting

#	Y axis	Hide	Title	Conf Interval	Line Color	Point Symbol	Series Line Type	Line Type	Line Width	Show Significant	Connect Across NA	Legend Text
1	Y1	No	ECMG4 APCP_24 CNTSUM_AAA	none	#FF0000	Small circle	joined lines	solid	1	No	Yes	
2	Y1	No	GFS_T1534 APCP_24 CNTSUM_AAA	none	#8000FF	Small circle	joined lines	solid	1	No	Yes	

+ Add Difference Curve Remove Difference Curve Apply defaults Lock Formatting

View 1 - 2 of 2

METViewer Scorecard

Specify Statistics

Specify Regions

Specify Variables

Specify Aggregations

Specify Levels

Specify Symbol, Values or Both

METViewer Scorecard
for PR4RN_1405 and GFS2016

2014-05-20 00:00:00 - 2014-07-30 00:00:00

		N.American					N.Hemisphere					S.Hemisphere					Tropics														
		Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10						
Anom Corr	Heights	P250	▲				▲						▲												▼						
		P500	▲																							▼		▲			
		P700																								▼		▲			
		P1000																								▼			▲		
Anom Corr	Vector Wind	P250																							▼						
		P500																							▼		▼				
		P850																							▼		▼				
Anom Corr	Temp	P250																							▼		▲	▲	▲	▲	
		P500																							▼						
		P850																							▼		▼				
Anom Corr	MSLP	MSL																						▼							
RMSE	Heights	P10	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
		P20	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲
		P50	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲
		P100	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		P200	▲																							▲		▲	▲	▲	▲
		P500	▲																							▲		▲	▲	▲	▲
		P700	▲																							▲		▲			
		P850	▲																							▲		▲			
P1000	▲																							▲		▲					

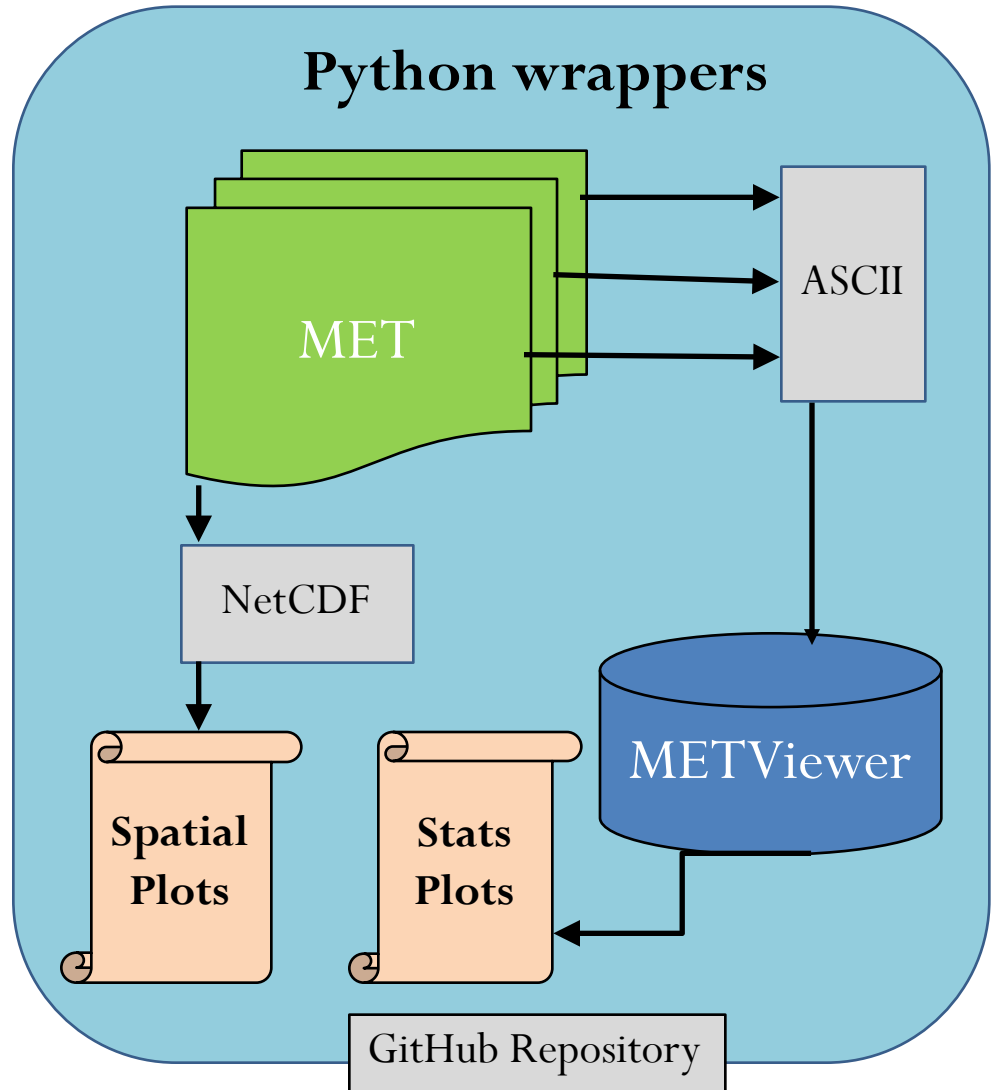
Submit to batch engine of METViewer

MET+

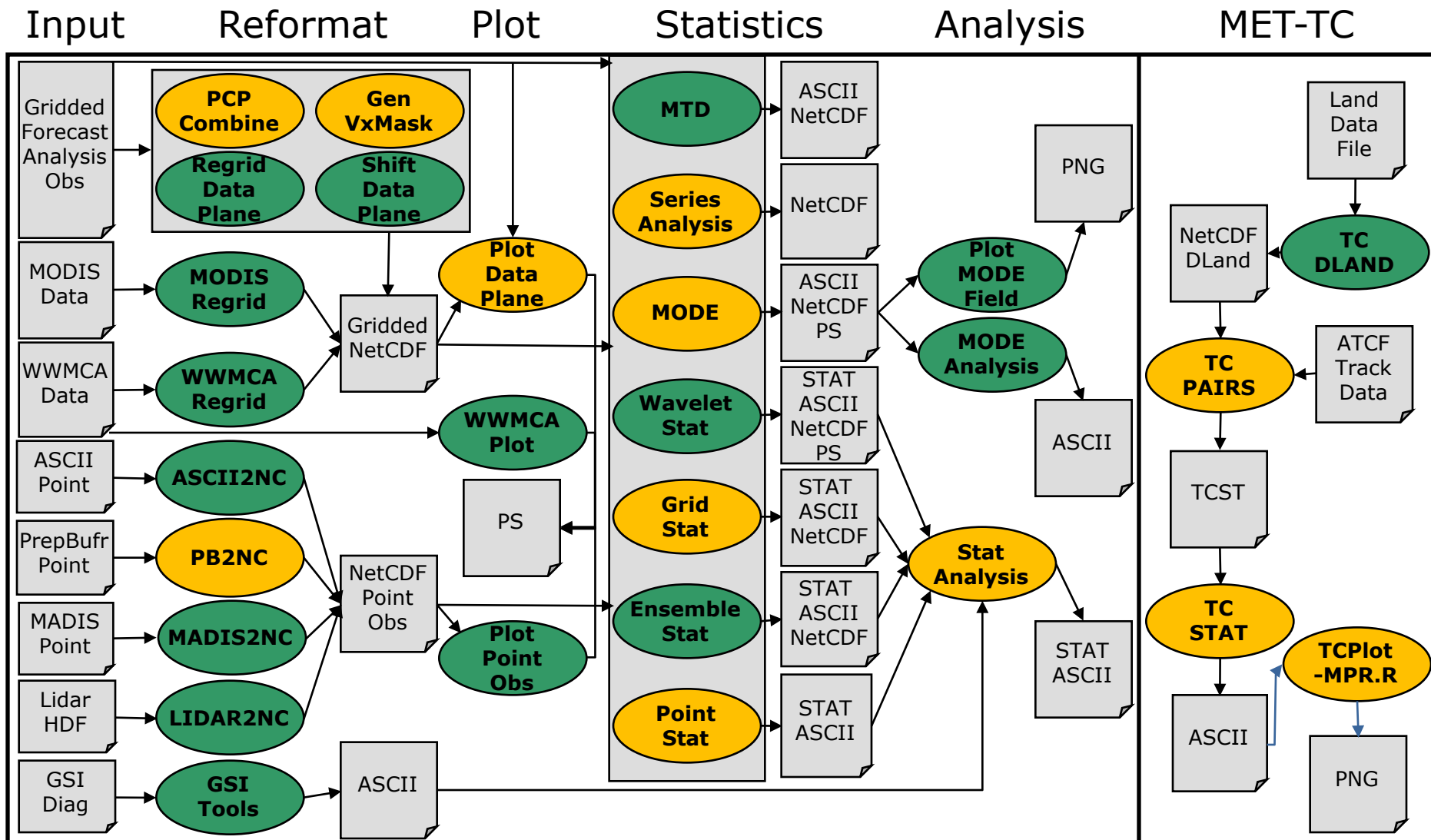
MET+ Unified Package

- Python wrappers around MET and METViewer:
- Simple to set-up and run
- Automated plotting of 2D fields and statistics

Initial system - Global deterministic with plans to generalize across scales when possible to quickly spin-up Ensembles, High Resolution & Global Components



Currently Wrapped by a Use Case



What does wrapped by Python mean?

At <https://github.com/NCAR/METplus/>

NCAR / METplus Private

Unwatch 10 Star 2 Fork 4

Code Issues 32 Pull requests 0 Projects 0 Wiki Insights

Python scripting infrastructure for MET tools.

590 commits 4 branches 7 releases 6 contributors

Branch: master New pull request Create new file Upload files Find file Clone or download

Commit	Message	Time
bikegeek	Include TcStat in process list	Latest commit c8be465 17 minutes ago
doc	Replaced GFS_DIR with MODEL_DATA_DIR, now consistent with metplus_dat...	2 days ago
internal_tests	Merge branch 'master' into merge-qpf-sbu	7 days ago
parm	Include TcStat in process list	17 minutes ago
src	Initial Commit of Doxygen documentation suite.	4 months ago
ush	Fixed incorrect syntax for retrieving the MET_BUILD_BASE from the met...	25 minutes ago
.gitignore	Initial commit	a year ago
README.md	Updated top-level README .	3 months ago

README.md

Control
File and
Config



Python
Scripts



What does wrapped by Python mean?

METplus/parm/use_cases/feature_relative

feature_relative.conf

```
120 #
121 #   LISTS AND SETTINGS
122 #
123
124 #   Processes to run in master script (master_met_plus.py)
125
126 PROCESS_LIST = ["run_tc_pairs.py", "extract_tiles.py", "series_by_lead.py"]
127
128 #
129 #   NOTE: "TOTAL" is a REQUIRED cnt statistic used by the series analysis scripts
130 #
131
132 STAT_LIST = ["TOTAL", "FBAR", "OBAR", "ME", "MAE", "RMSE", "BCMSE", "E50", "EIQR", "MAD"]
133
134 #   Dates must be in YYYYMMDD format
135 #   INIT_HOUR_INC is the increment in integer format
136 #   INIT_HOUR_END should be a string in HH or HHH format
137
138 INIT_DATE_BEG = "20141201"
139 INIT_DATE_END = "20150331"
140 INIT_HOUR_INC = 6
141 INIT_HOUR_END = "18"
142
143 #   Used by extract_tiles.py to define the records of interest from the grib2 file
144
145 VAR_LIST = ["HGT/P500", "PRMSL/Z0", "TMP/Z2", "PWAT/L0", "HGT/P250", "TMP/P850", "TMP/P500", "UGRD/P250", "VGRD/P250" ]
146 EXTRACT_TILES_VAR_LIST = []
147
148 #   Used for performing series analysis based on lead time
149
```

What does wrapped by Python mean?

At <https://github.com/NCAR/METplus/>

In Configs:
Environment
variables
passed in
from
Constants File

```
30
31 ///////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
32
33 cat_thresh = [ NA ];
34 cnt_thresh = [ NA ];
35 cnt_logic  = UNION;
36
37 //
38 // Forecast and observation fields to be verified
39 //
40 fcst = {
41     field = [
42         {
43             name = "${NAME}";
44             level = [ "${LEVEL}" ];
45         }
46     ];
47 }
48
49 }
50 obs = fcst;
51
52 ///////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
53
54 //
55 // Climatology mean data
```

Series_Analysis_Config

master_metplus.py

proditil

METplus
Launcher
conf

metplus_final.conf

Command
Builder

Process
Script 1

Input

MET Tool
1

Output
1

Process
Script 2

Output
2

Process
Script 3

MET Tool
2

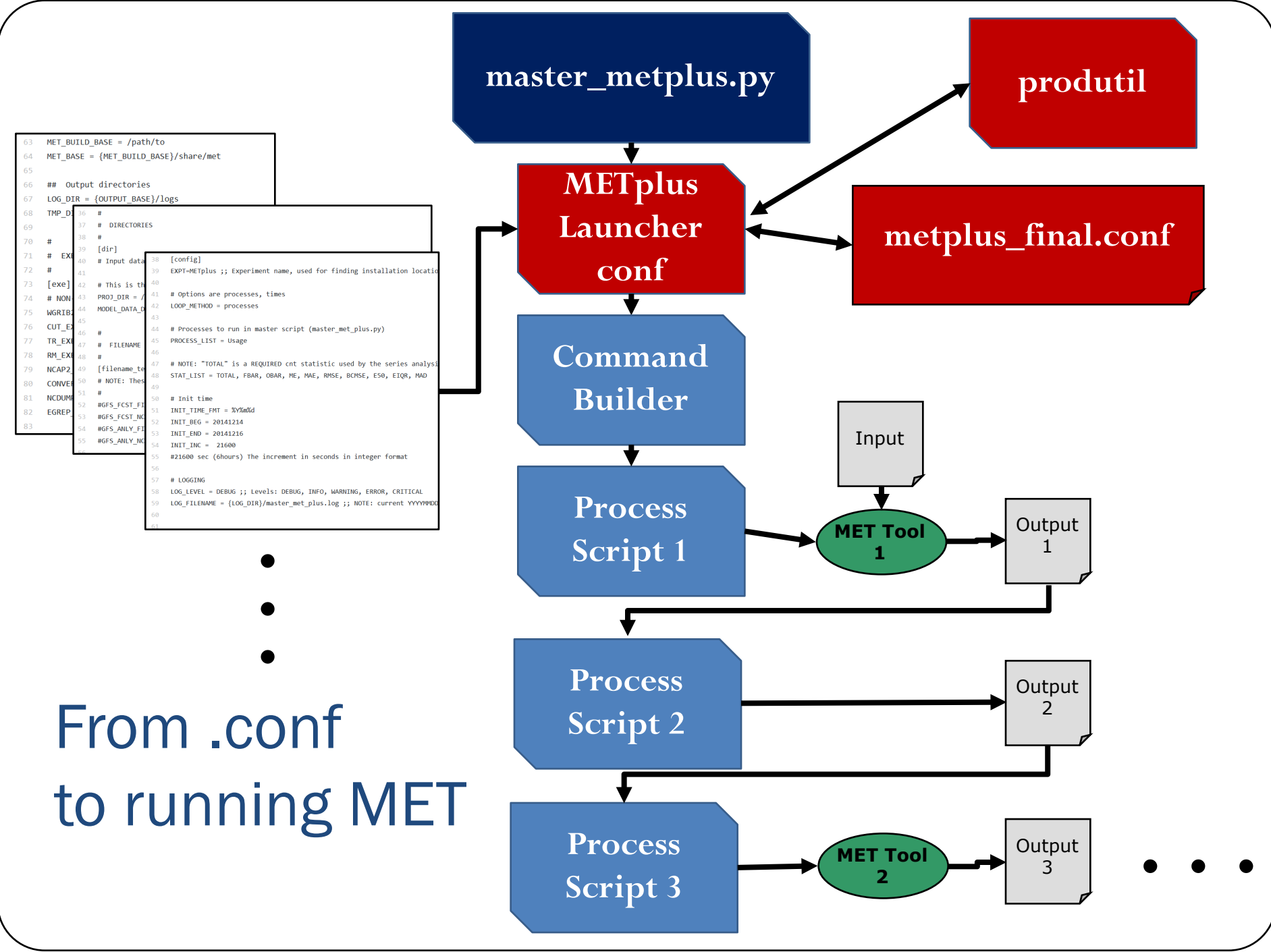
Output
3

```

63 MET_BUILD_BASE = /path/to
64 MET_BASE = {MET_BUILD_BASE}/share/met
65
66 ## Output directories
67 LOG_DIR = {OUTPUT_BASE}/logs
68
69 TMP_DIR = #
70 # DIRECTORIES
71 # [dir]
72 # EXE # Input data
73 [exe] # This is the
74 # NON # PROJ_DIR = /
75 WGRIB # MODEL_DATA_D
76 CUT_EX #
77 TR_EX # FILENAME
78 RM_EX #
79 NCAP2 # [filename_t
80 CONVE # NOTE: Thes
81 NCDUM #
82 EGREP #
83
36 #
37 # DIRECTORIES
38 #
39 # [dir]
40 # Input data
41 #
42 # This is th
43 # options are processes, times
44 # LOOP_METHOD = processes
45 #
46 # Processes to run in master script (master_met_plus.py)
47 # PROCESS_LIST = Usage
48 # NOTE: "TOTAL" is a REQUIRED cnt statistic used by the series analysis
49 # STAT_LIST = TOTAL, FBAR, OBAR, ME, MAE, RMSE, BCMSE, E50, EIQR, MAD
50 # NOTE: Thes
51 #
52 # Init time
53 # INIT_TIME_FMT = %Y%m%d
54 # INIT_BEG = 20141214
55 # INIT_END = 20141216
56 # INIT_INC = 21600
57 # #21600 sec (hours) The increment in seconds in integer format
58 #
59 # LOGGING
60 # LOG_LEVEL = DEBUG ;; Levels: DEBUG, INFO, WARNING, ERROR, CRITICAL
61 # LOG_FILENAME = {LOG_DIR}/master_met_plus.log ;; NOTE: current YYYYMMDD

```

From .conf
to running MET

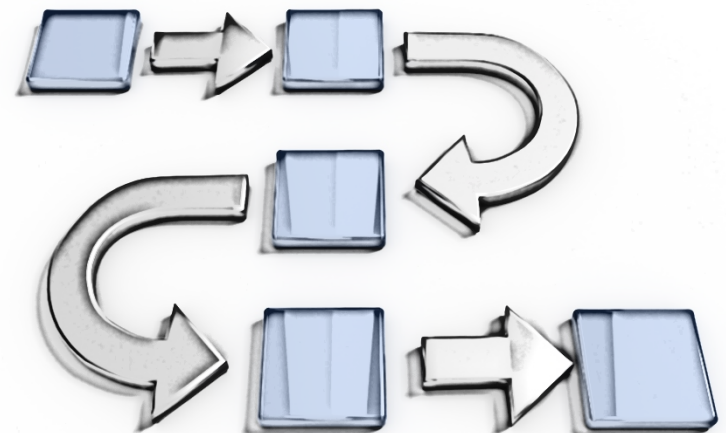


MET+ Coding Standards

- NCEP Coding Standards
- NCO WCOSS Implementation Standards for directory structure and script naming conventions (http://www.nco.ncep.noaa.gov/idsb/implementation_standards/)
- pep8 for Code Style
- Doxygen and Python docstrings for documentation

Aligning with NCEP Workflow

- Discussing and planning to collaborate on new dynamical core (FV3) workflow developers.
- Using PRODUTIL package for logging and constants file parsin plus likely other features
- Plan to use Rocoto workflow management (NOAA tool) for dev environments and make autonomous to also use with ecFlow or Cylc for operations



MET+ Beta - Prerequisites

- Python 2.7 ***When we started this was specified by NCO*
- R version 3.25 *** Only if you are using PlotTCMpr.R tool*
- nco (netCDF operators)
- MET version 6.0 or later installed
*** Tool is designed to sit on-top of MET and should be version insensitive after METv6.0*
- Basic familiarity with MET

- **User:** Access the public release at:
<https://github.com/NCAR/METplus/releases>

-OR-

- Use install on Theia or WCOSS
*** Only on Gyre right now, will populate on Surge, Tide and Luna as access is available*
- **Developer:** Need a github account
<https://github.com/NCAR/METPlus/> then proceed like a User

Grabbing the Release

NCAR / METplus

Unwatch 10

Star 3

Fork 0

Code

Issues 32

Pull requests 0

Projects 0

Wiki

Insights

Releases

Tags

Draft a new release

Latest release

METplus_beta

1aa1573

METplus Beta

Edit

bikegeek released this 20 hours ago · 2 commits to master since this release

METplus_beta

Change name from Alpha-produtil to Beta-METplus.

Downloads

Instructions_METplus_Beta.pdf

164 KB

sample_data.tar.gz

479 MB

Source code (zip)

Source code (tar.gz)

Operational Directory Structure

- doc/ - Doxygen documentation
- internal_tests/ - developer tests
- parm/ - where configs live
- README.md - general README
- src/ - executables
- ush/ - python scripts



3 Use Cases

- Track and Intensity
 - Using MET-TC to pair up ATCF track files
 - PlotTCMPR.R to compute track and intensity errors and plot
- Feature Relative
 - Use MET-TC to pair up ATCF track files
 - Extract 30deg by 30deg tiles from GFS Forecast and Analysis files for comparison
 - Use Series-Analysis to compute statistics for the stack of tiles over CONUS
 - Use Plot-Data-Plane to generate quick look plots
- QPF
 - Use Pcp-Combine to accumulate 1-hr QPE into 3-hr accumulation
 - Use Grid-Stat to compute Categorical statistics

Ensemble Verification Metrics

Tressa Fowler

Acknowledgments: Laurie Wilson, Barbara Brown, Matt Pocerlich, Tom Hamill, CAWCR

Questions to ask before beginning?

- How were the ensembles constructed?
 - Poor man's ensemble (distinct members)
 - Multi-physics (distinct members)
 - Random perturbation of initial conditions (anonymous members)
- How are your forecasts used?
 - Improved point forecast (ensemble mean)
 - Probability of an event
 - Full distribution

Approaches to evaluating ensemble forecasts

- As individual members
 - Use methods for continuous or categorical forecasts
- As probability forecasts
 - Create probabilities by applying thresholds or statistical post-processing
- As a full distribution
 - Use individual members or fit a distributions through post-processing

Approaches to evaluating ensemble forecasts

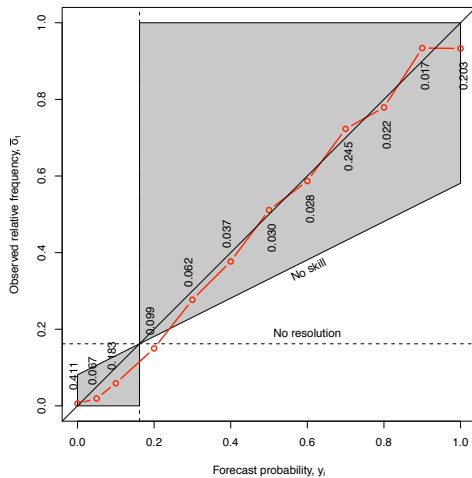
- As individual members
- As probability forecasts
 - Brier Score
 - Reliability diagram
 - ROC diagram
 - Economic Cost Loss Value
- As a full distribution
 - Rank Histograms
 - Spread / Skill comparison
 - Ranked Probability Score / Continuous RPS
 - Ignorance ($\log p$) score

Verifying a probabilistic forecast

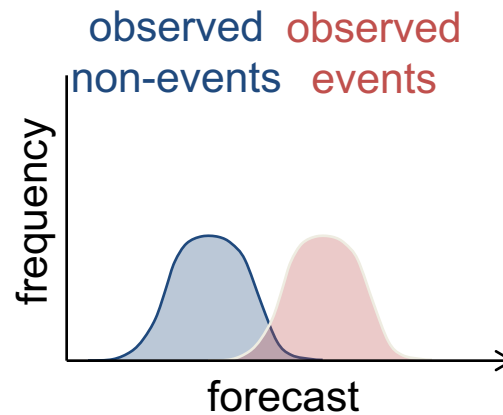
- You cannot verify a probabilistic forecast with a single observation.
- The more data you have for verification, (as with other statistics) the more certain you are.
 - *Evaluation of probability forecasts generally requires larger sample sizes than other types of forecasts*
- Rare events (low probability) require more data to evaluate.
- These comments refer to probabilistic forecasts developed by methods other than ensembles as well.

Properties of a perfect probabilistic forecast of a binary event.

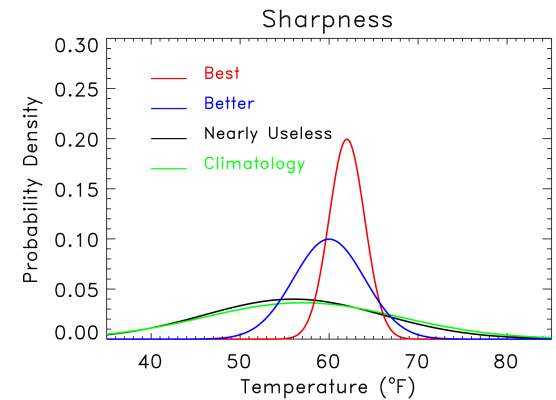
Reliability



Resolution



Sharpness



The Brier Score

- Mean square error of a probability forecast

$$BS = \frac{1}{n} \sum_{i=1}^n (f_i - x_i)^2$$

where n is the number of forecasts

f_i is the forecast prob on occasion i

x_i is the observation (0 or 1) on
occasion i

- Weights larger errors more than smaller ones



Components of the Brier Score

- **Reliability**

Measures how well the conditional relative frequency of events matches the forecast

$$\frac{1}{n} \sum_{i=1}^I N_i (f_i - \bar{x}_i)^2$$

- **Resolution**

Measures how well the forecasts distinguish situations with different frequencies of occurrence

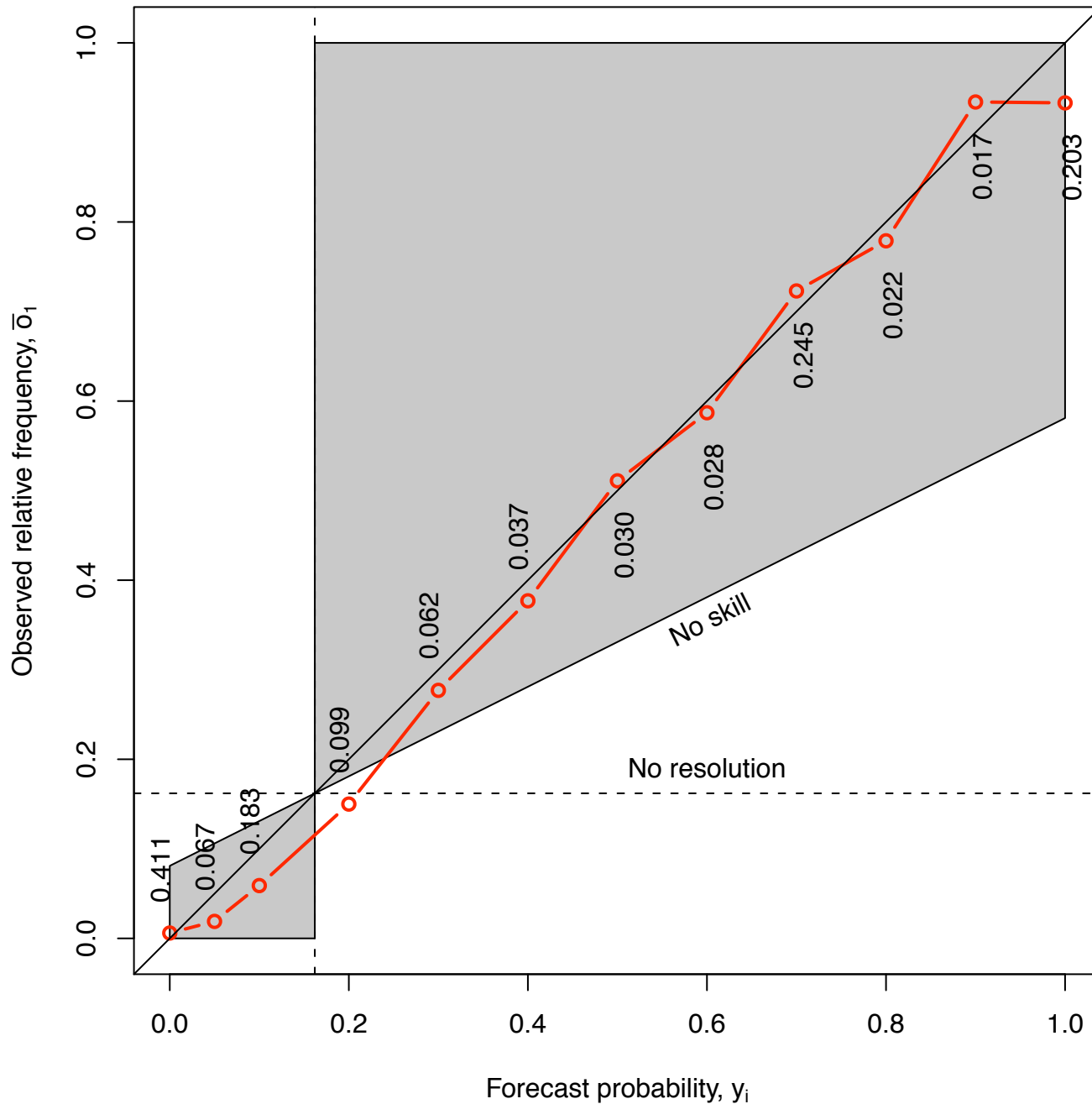
$$\frac{1}{n} \sum_{i=1}^I N_i (\bar{x}_i - \bar{x})^2$$

- **Uncertainty**

Measures the variability in the observations (i.e., the difficulty of the forecast situations)

$$\bar{x}(1 - \bar{x})$$

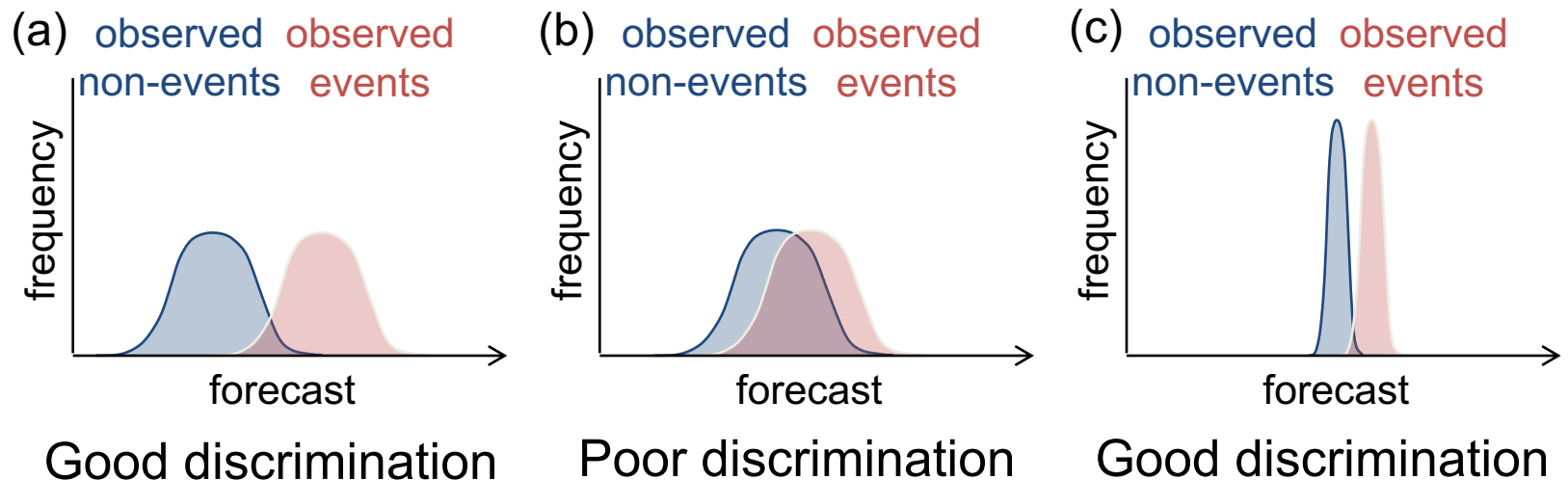
Looking at Brier Score components is critical to understand forecast performance



**Attribute
(Reliability)
diagram**
shows
reliability,
resolution,
skill

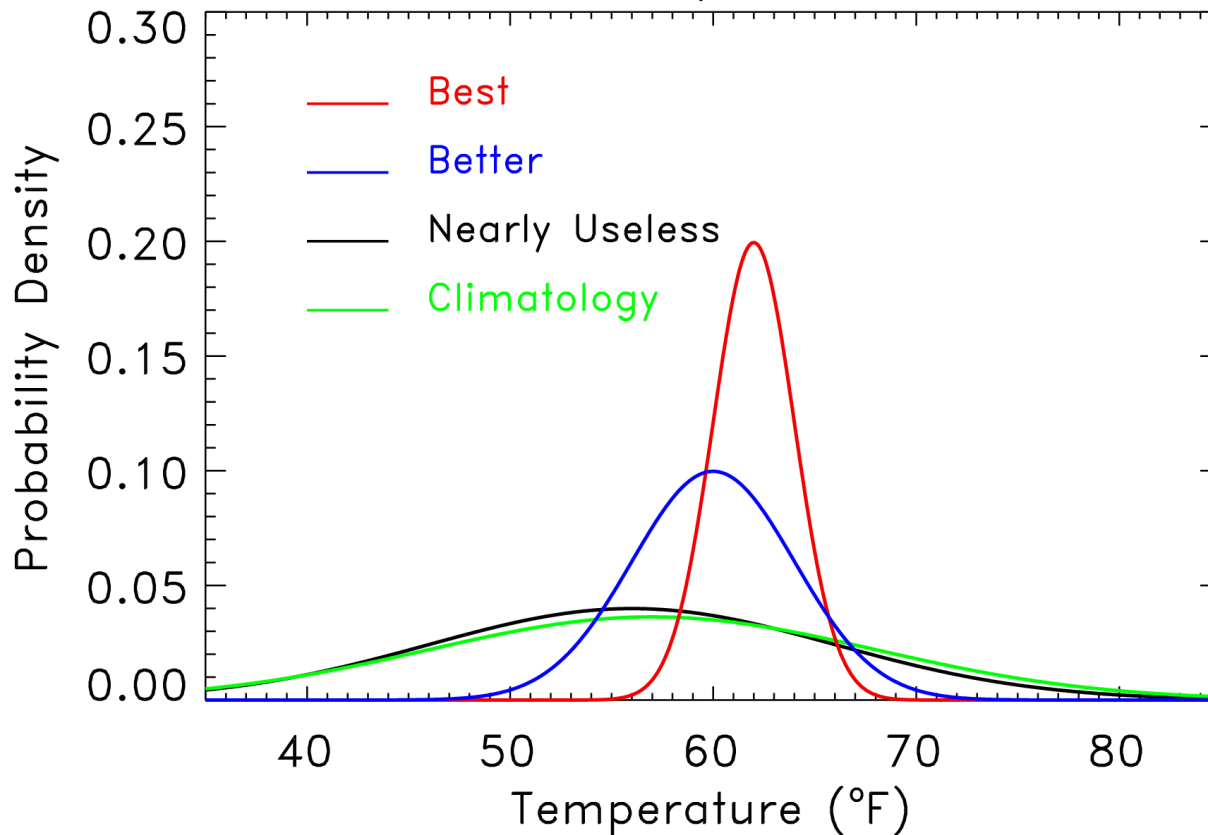
Discrimination

- *Discrimination*: The ability of the forecast system to clearly distinguish situations leading to the occurrence of an event of interest from those leading to the non-occurrence of the event.
- Depends on:
 - Separation of means of conditional distributions
 - Variance within conditional distributions



Sharpness also important

Sharpness

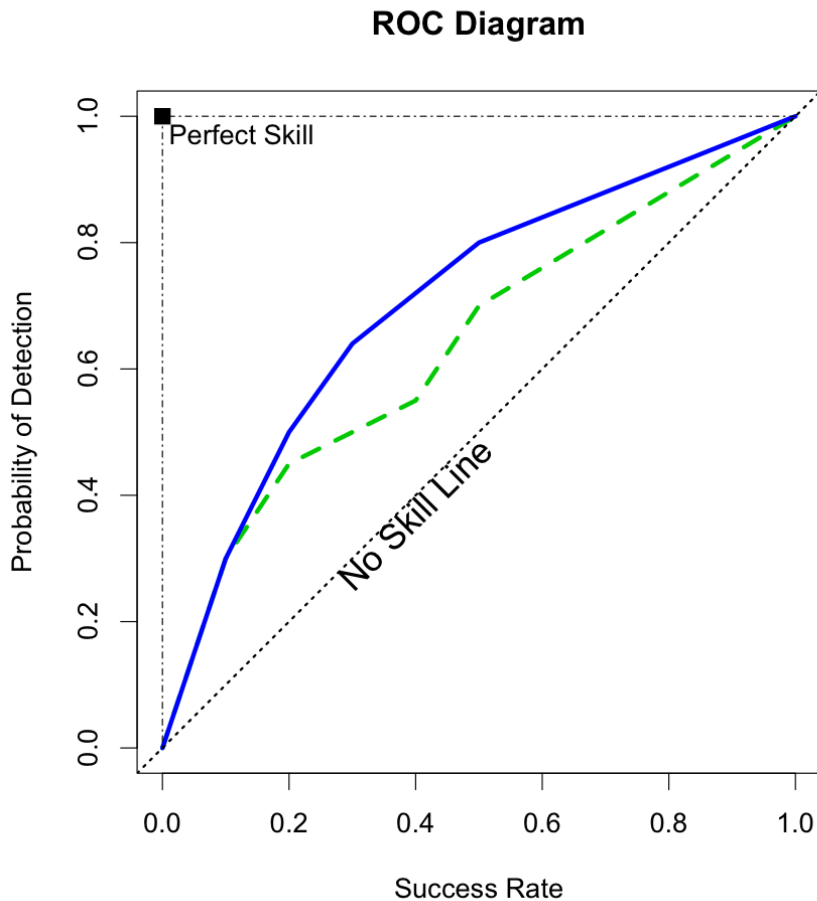


“Sharpness”

measures the specificity of the probabilistic forecast. Given two reliable forecast systems, the one producing the sharper forecasts is preferable.

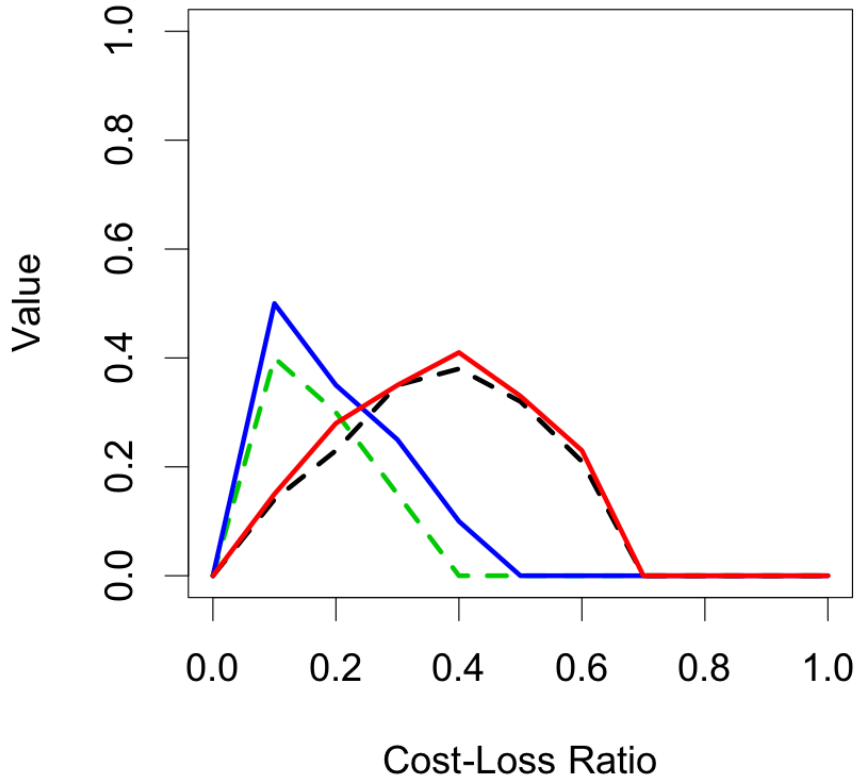
But: don't want sharp if not reliable. Implies unrealistic confidence.

Receiver Operating Characteristic



- Plot POD vs. (1-FAR) for all probability thresholds.
- Upper left corner is perfect.
- Facilitates comparisons even when probabilities are uncalibrated (e.g. conditionally biased).
- Area under ROC also used as a metric.

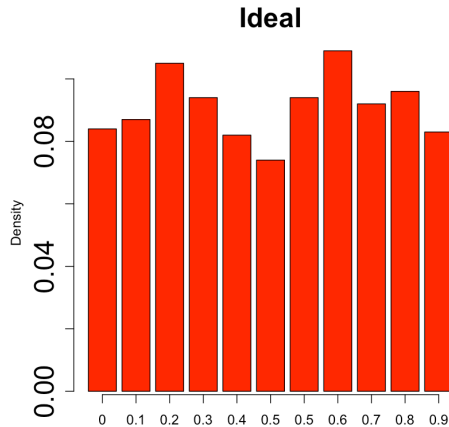
Economic Cost Loss Value Plot



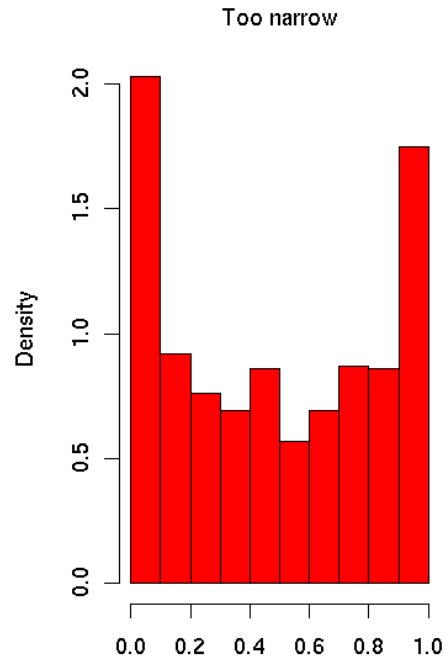
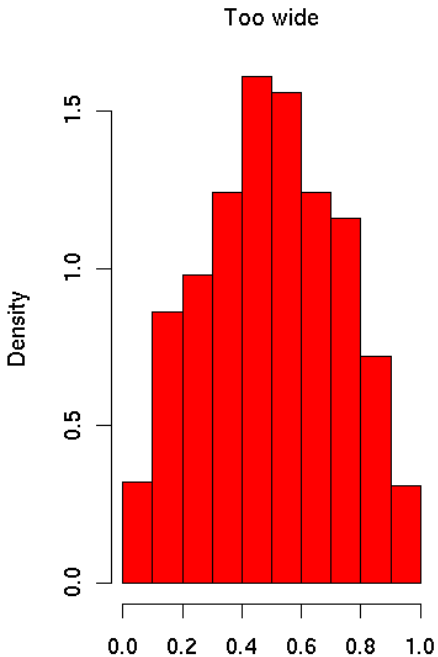
The envelope of relative value curves on the ECLV plot represents the *potential* value since all decision thresholds are possible for probability forecasts.

	Event	No Event
Action	Cost	Cost
No Action	Loss	0

Evaluating ensembles – Rank Histograms



- For a perfect ensemble, the observation comes from the same distribution as the ensemble.

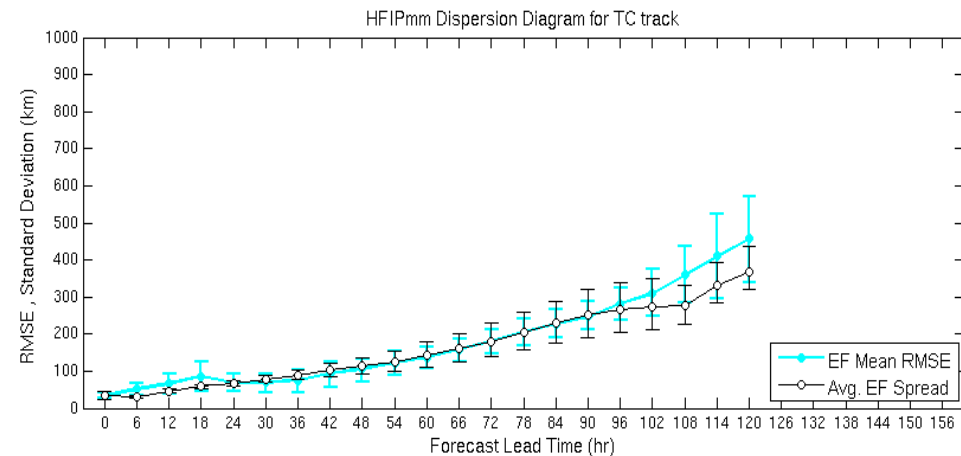
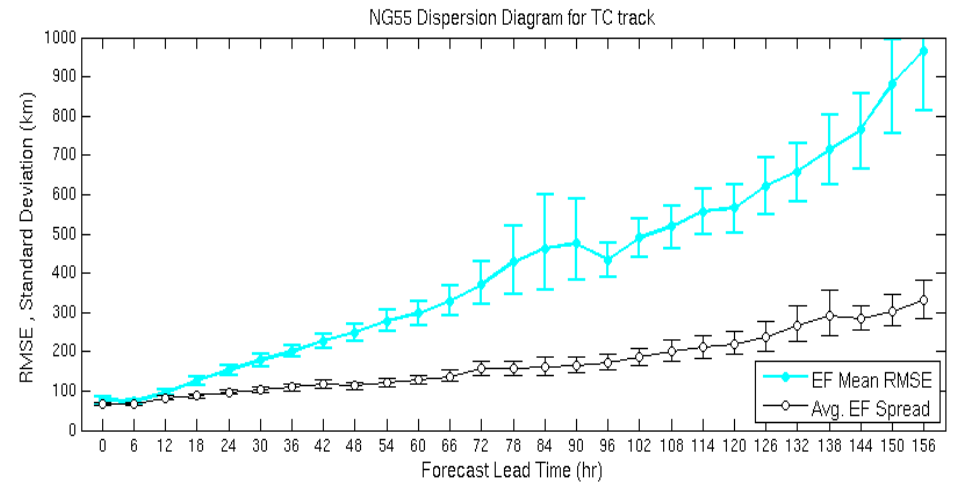


- Thus, ranking the observation among the ensemble member should result in a flat (uniform) distribution.

Evaluating ensembles – Spread Skill diagram

Spread-skill

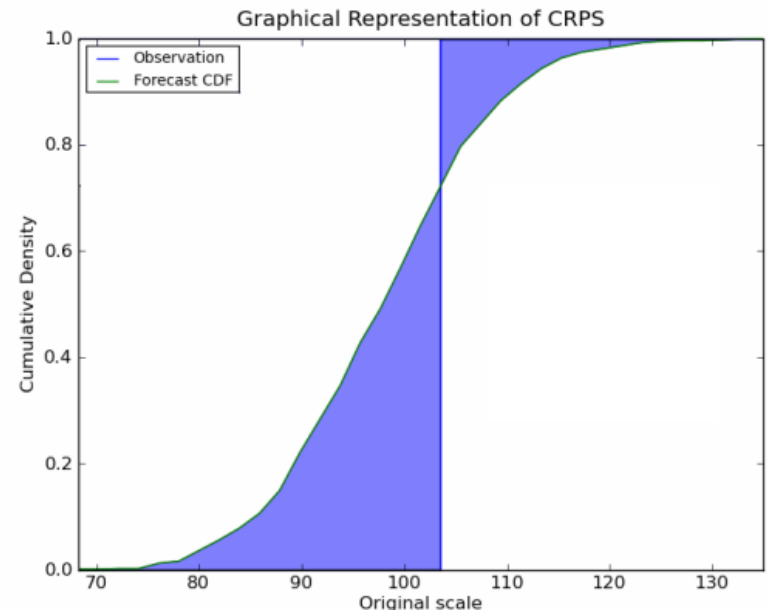
- For a perfect ensemble, the spread of the ensemble represents the error in the forecast.
- We can compare spread (std. dev.) with skill (RMSE) to see if they are close.



Continuous and discrete rank probability scores

- Measures of accuracy for
 - Multiple category forecasts (e.g., precipitation type)
Rank Probability Score (RPS)
 - Continuous distributions (e.g., ensemble distribution)
Continuous Ranked Probability Score (CRPS)

Brier Score, RPS, and CRPS are all MSE-type scores, but with different formats of input data.



Evaluating ensembles – Ignorance ($\log p$) score

The information in a forecast = the reduction of uncertainty due to the forecasts.

$$\text{IGN} = -\log p(a_j)$$

where $p(a_j)$ is the probability of event a_j .

In MET, these are averaged.

Measure	Attribute evaluated	Comments
Probability forecasts		
Brier score	Accuracy	Based on squared error
Resolution	Resolution (resolving different categories)	Compares forecast category climatologies to overall climatology
Reliability	Calibration	
Skill score	Skill	Skill involves <i>comparison</i> of forecasts
Sharpness measure	Sharpness	Only considers distribution of forecasts
Relative Operating Characteristic (ROC)	Discrimination	Ignores calibration
C/L Value	Value	Ignores calibration
Ensemble distribution		
Rank histogram	Calibration	Can be misleading
Spread-skill	Calibration	Difficult to achieve
CRPS	Accuracy	Squared difference between forecast and observed distributions Analogous to MAE in limit
log p score (IGN)	Accuracy	Local score, rewards for correct category; infinite if observed category has 0 density

Useful references

- **Good overall references** for forecast verification:
 - (1) Wilks, D.S., 2011: *Statistical Methods in the Atmospheric Sciences (3rd Ed)*. Elsevier, 704 pp.
 - (2) WMO Verification working group forecast verification web page, <http://www.cawcr.gov.au/projects/verification/>
 - (3) Jolliffe and Stephenson Book: Jolliffe, I.T., and D.B. Stephenson, 2012: *Forecast Verification. A Practitioner's Guide in Atmospheric Science.*, 2nd Edition, Wiley and Sons Ltd.
- **Verification tutorial – Eumetcal** (<http://www.eumetcal.org/-learning-modules->)
- **Rank histograms:** Hamill, T. M., 2001: Interpretation of rank histograms for verifying ensemble forecasts. *Mon. Wea. Rev.*, **129**, 550-560.
- **Spread-skill relationships:** Whitaker, J.S., and A. F. Loughe, 1998: The relationship between ensemble spread and ensemble mean skill. *Mon. Wea. Rev.*, **126**, 3292-3302.
- **Brier score, continuous ranked probability score, reliability diagrams:** Wilks text again.
- **Relative operating characteristic:** Harvey, L. O., Jr, and others, 1992: The application of signal detection theory to weather forecasting behavior. *Mon. Wea. Rev.*, **120**, 863-883.
- **Economic value diagrams:**
 - (1) Richardson, D. S., 2000: Skill and relative economic value of the ECMWF ensemble prediction system. *Quart. J. Royal Meteor. Soc.*, **126**, 649-667.
 - (2) Zhu, Y, and others, 2002: The economic value of ensemble-based weather forecasts. *Bull. Amer. Meteor. Soc.*, **83**, 73-83.
- **Overestimating skill:** Hamill, T. M., and J. Juras, 2006: Measuring forecast skill: is it real skill or is it the varying climatology? *Quart. J. Royal Meteor. Soc.*, Jan 2007 issue. <http://tinyurl.com/kxtct>

Verifying Ensembles & Probability Forecasts with MET

- Ensemble-Stat Tool

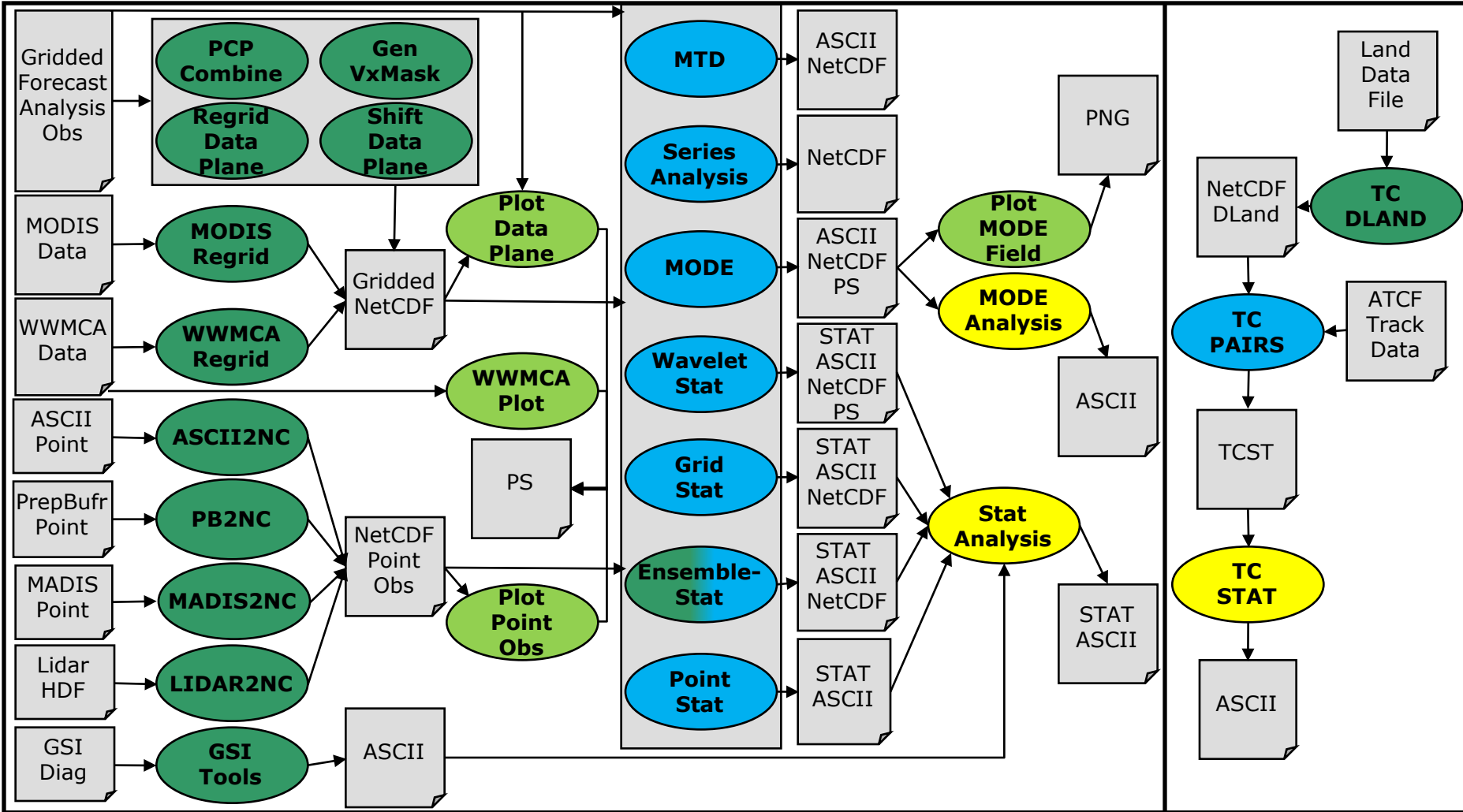
- Ensemble Mean Fields
- Probability Fields
- Ensemble Continuous Statistics
- Rank Histograms, PIT Histograms, Relative Position
- Spread-Skill Calculation

- Point-Stat and Grid-Stat Tool

- Brier Score + Decomposition
- Reliability Diagrams
- Receiver Operating Characteristic Diagram + Area Under the Curve
- Joint/Conditional factorization table

MET Overview v7.0

Input Reformat Plot Statistics Analysis MET-TC



Ensemble-Stat Capabilities

Reads:

- Gridded ensemble member files
- *Gridded AND point* observations files

Calculates:

- Ensemble Mean, Standard Deviations, Mean \pm 1 SD fields
- Ensemble Min, Max, and Range fields
- Ensemble Valid Data Count field
- Ensemble Relative Frequency by threshold fields (i.e. probability)
- Ensemble Continuous Statistics (in met-7.1)
- Rank, Relative Position, and PIT Histograms (if Obs Field Provided)
- Ensemble Spread-Skill (if Obs Field Provided)
- Application of observation error (in met-7.1)

Writes:

- Ensemble products in a NetCDF file
- Stat file with Continuous Ensemble Statistics, Rank Histograms, PIT Histograms, RELP Histograms, Spread-Skill partial sums, and Point Observation Ranks
- Gridded field of Observation Ranks in a NetCDF file

Ensemble Stat Tool: Usage

Usage: ensemble_stat

*n_ens ens_file_1 *
... ens_file_n |
ens_file_list
config_file
[-grid_obs file]
[-point_obs file]
[-ssvar_mean file]
[-obs_valid_beg time]
[-obs_valid_end time]
[-outdir path]
[-log file]
[-v level]

Number of Ensemble members followed by list of ensemble member names OR ens_file_list (the name of an ASCII file with names of members)

Config file name

Name of gridded or point observed file – Required if Rank Histograms desired (optional)

Specify an ensemble mean model data file for use in calculating ensemble spread-skill (optional)

YYYYMMDD[_HH[MMSS]] format to set the beginning and end of the matching observation time window (optional)

Set output directory (optional)

Outputs log messages to the specified file (optional)

Set level of verbosity (optional)

Ensemble-Stat: Configuration

- Many configurable parameters – only set a few:
 - `ens_thresh` - All members must be available; `vld_thresh` – all data in grid must be valid
 - 24hr Accumulated Precip (APCP)
 - Composite Reflectivity (REFC)
 - N-S component of Wind (UGRD)
 - Thresholds used for Ensemble Relative Freq (i.e. probability)
 - `GRIB1_ptv = 129`; Use GRIB Table 129 instead of Table 2

```
//  
// Ensemble product fields to be processed  
// (i.e. mean, min, max, stdev fields)  
//  
ens = {  
    ens_thresh = 1.0;  
    vld_thresh = 1.0;  
  
    field = [  
        {  
            name      = "APCP";  
            level     = [ "A24" ];  
            cat_thresh = [ >0.0, >=10.0 ];  
        },  
        {  
            name      = "REFC";  
            level     = [ "L0" ];  
            cat_thresh = [ >=35.0 ];  
            GRIB1_ptv = 129;  
        },  
        {  
            name      = "UGRD";  
            level     = [ "Z10" ];  
            cat_thresh = [ >=5.0 ];  
        },  
    ];  
}
```

Ensemble-Stat: Configuration

- Many configurable parameters – only set a few:
 - Use ADPSFC message type for point obs
 - Use 24hr precip for gridded obs field
 - Bin size for spread-skill calculation is 0.1 mm
- Output rank histogram, obs rank, and ssvr calculations
- Output all ensemble products like mean, stdev, etc...

```
//  
// Forecast and observation fields to be  
// verified (i.e. RHIST, PHIST, SSVAR)  
//  
fcst = {  
  
    message_type = [ "ADPSFC" ];  
  
    field = [  
        {  
            name           = "APCP";  
            level          = [ "A24" ];  
            ens_ssvr_bin_size = 0.1;  
        }  
    ];  
}  
obs = fcst;
```

```
output_flag = {  
    ecnt = BOTH;  
    rhist = BOTH;  
    phist = BOTH;  
    orank = BOTH;  
    ssvr = BOTH;  
    relp = BOTH;  
};
```

```
ensemble_flag = {  
    mean      = TRUE;  
    stdev     = TRUE;  
    minus    = TRUE;  
    plus     = TRUE;  
    min      = TRUE;  
    max      = TRUE;  
    range    = TRUE;  
    vld_count = TRUE;  
    frequency = TRUE;  
    rank     = TRUE;  
    weight   = FALSE;  
};
```


Ensemble-Stat Tool: Run

```
ensemble_stat \  
6 sample_fcst/2009123112/*gep*/d01_2009123112_02400.grib \  
config/EnsembleStatConfig \  
-grid_obs sample_obs/ST4/ST4.2010010112.24h \  
-point_obs out/ascii2nc/precip24_2010010112.nc \  
-outdir out/ensemble_stat -v 2
```

NOTE:

You can pass in a path with wildcards to pull out the files you would like to process or you can pass in an ASCII filename that contains a list of ensemble members

Gridded and Obs fields are included for use in calculating Rank Histogram, PIT Histogram, and Spread-Skill

Ensemble-Stat Tool: Run

***** Running Ensemble-Stat on APCP using GRIB forecasts, point observations, and gridded observations *****

DEBUG 1: Default Config File: /d3/projects/MET/MET_releases/met-6.0/data/config/EnsembleStatConfig_default

DEBUG 1: User Config File: config/EnsembleStatConfig

GSL_RNG_TYPE=mt19937

GSL_RNG_SEED=1

DEBUG 1: Ensemble Files[6]:

DEBUG 1: ../data/sample_fcst/2009123112/arw-fer-gep1/d01_2009123112_02400.grib

DEBUG 1: ../data/sample_fcst/2009123112/arw-fer-gep5/d01_2009123112_02400.grib

DEBUG 1: ../data/sample_fcst/2009123112/arw-sch-gep2/d01_2009123112_02400.grib

DEBUG 1: ../data/sample_fcst/2009123112/arw-sch-gep6/d01_2009123112_02400.grib

DEBUG 1: ../data/sample_fcst/2009123112/arw-tom-gep3/d01_2009123112_02400.grib

DEBUG 1: ../data/sample_fcst/2009123112/arw-tom-gep7/d01_2009123112_02400.grib

DEBUG 1: Gridded Observation Files[1]:

DEBUG 1: ../data/sample_obs/ST4/ST4.2010010112.24h

DEBUG 1: Point Observation Files[1]:

DEBUG 1: ../out/ascii2nc/precip24_2010010112.nc

DEBUG 2:

DEBUG 2: -----

DEBUG 2:

DEBUG 2: Processing ensemble field: APCP/A24

DEBUG 2:

DEBUG 2: -----

...

Processing gridded verification APCP_24/A24 versus APCP_24/A24, for observation type MC_PCP, over region FULL, for interpolation method UW_MEAN(1), using 15480 pairs.

DEBUG 1: Output file: out/ensemble_stat/ensemble_stat_20100101_120000V.stat

DEBUG 1: Output file: out/ensemble_stat/ensemble_stat_20100101_120000V_rhist.txt

DEBUG 1: Output file: out/ensemble_stat/ensemble_stat_20100101_120000V_phist.txt

DEBUG 1: Output file: out/ensemble_stat/ensemble_stat_20100101_120000V_orank.txt

DEBUG 1: Output file: out/ensemble_stat/ensemble_stat_20100101_120000V_ssvr.txt

DEBUG 1: Output file: out/ensemble_stat/ensemble_stat_20100101_120000V_ens.nc

DEBUG 1: Output file: out/ensemble_stat/ensemble_stat_20100101_120000V_orank.nc

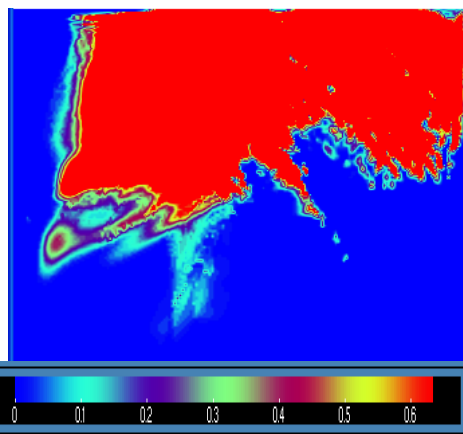
Ensemble-Stat Tool: Output

Output from `out/ensemble_stat/ensemble_stat_20100101_120000V_rhist.txt`

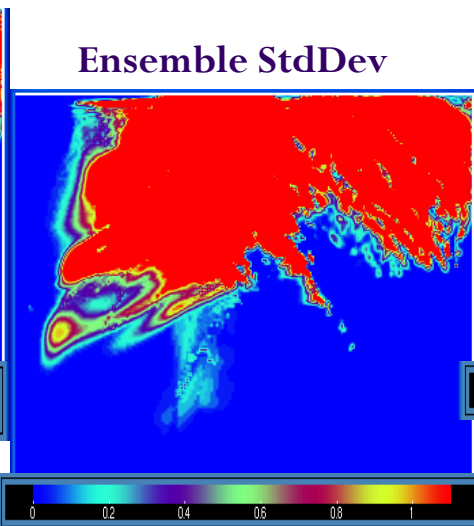
```
VERSION MODEL FCST_LEAD FCST_VALID_BEG FCST_VALID_END OBS_LEAD OBS_VALID_BEG  
OBS_VALID_END FCST_VAR FCST_LEV OBS_VAR OBS_LEV OBTYPEVX_MASK INTERP_MTHD INTERP_PNTS  
FCST_THRESH OBS_THRESH COV_THRESH ALPHA LINE_TYPE TOTAL CRPS IGN N_RANK RANK_1 RANK_2  
RANK_3 RANK_4 RANK_5 RANK_6 RANK_7  
V6.0 WRF 240000 20100101_120000 20100101_120000 000000 20100101_103000 20100101_133000  
APCP_24 A24 APCP_24 A24 ADPSFC FULL UW_MEAN 1 NA NA NA NA  
RHIST 1125 8.21904 6.53721 7 261 160 138 141 149 111 165
```

CRPS IGN RANK HIST

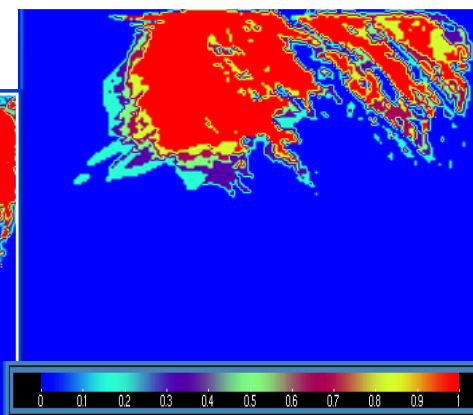
Output from `out/ensemble_stat/ensemble_stat_20100101_120000V_ens.nc` (using `ncview`)



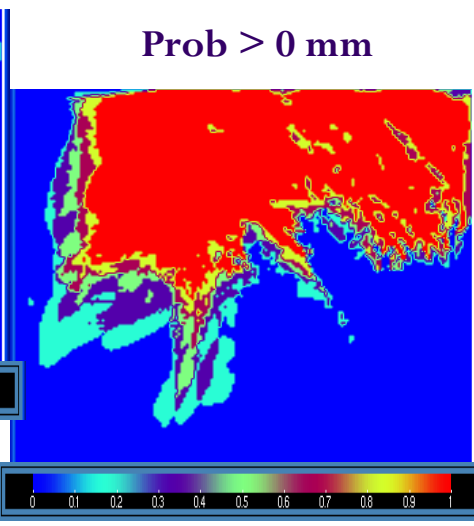
Ensemble Mean



Ensemble StdDev



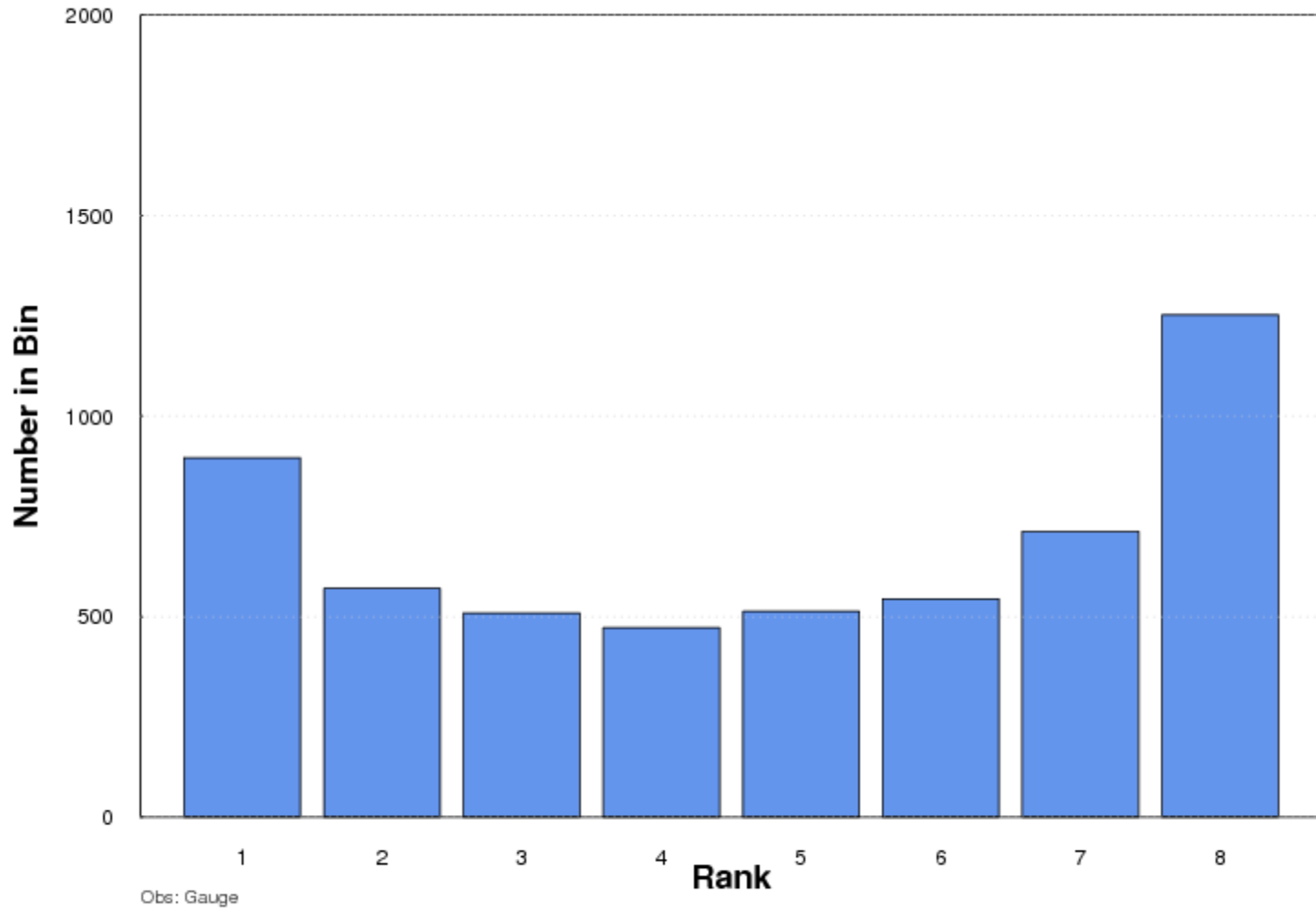
Prob > 5 mm



Prob > 0 mm

Rank Histogram

Rank Histogram: APCP_24 Init: 12 UTC Lead: 24hr FULL Domain 7 members available



RELP Line Type

- Added support to Ensemble-Stat for new relative position (**RELP**) line type.
 - Same as VSDB RELP line type.
 - Similar to the Rank Histogram line type, but no ranking is done.
 - N-th histogram bar indicates how often ensemble member N was closest (in absolute value) to the observation.
 - Ties are assigned equally to all tied members.

Ensemble-Stat Tool: Updates

- **Current met-7.0 release:**

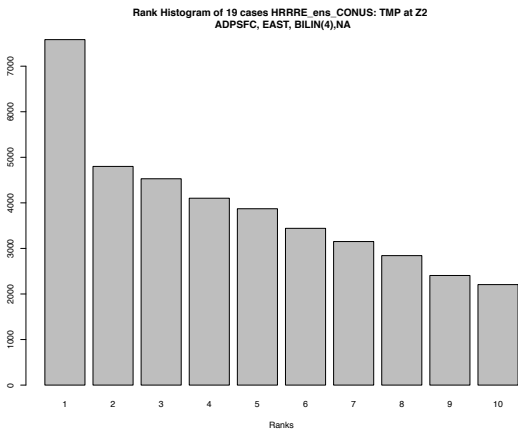
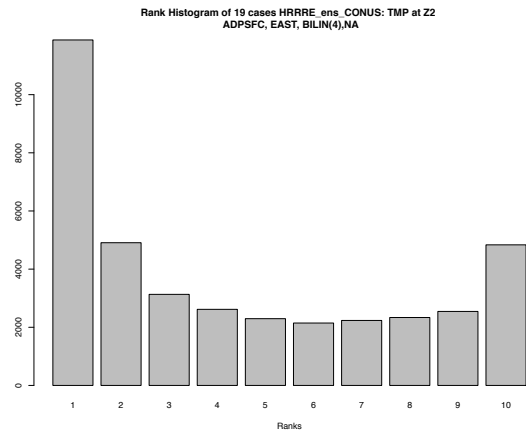
- Config file option to exclude ties (i.e. all ensemble members and observation are identical) ... `skip_const = TRUE;`
- Config file option to filter pairs by the observation values ... `obs_thresh = [>0];` // e.g. only observations of APCP > 0
- Added BSS_SMPL statistic to the PSTD line type, making MET consistent with METViewer.

- **Upcoming met-7.1 release:**

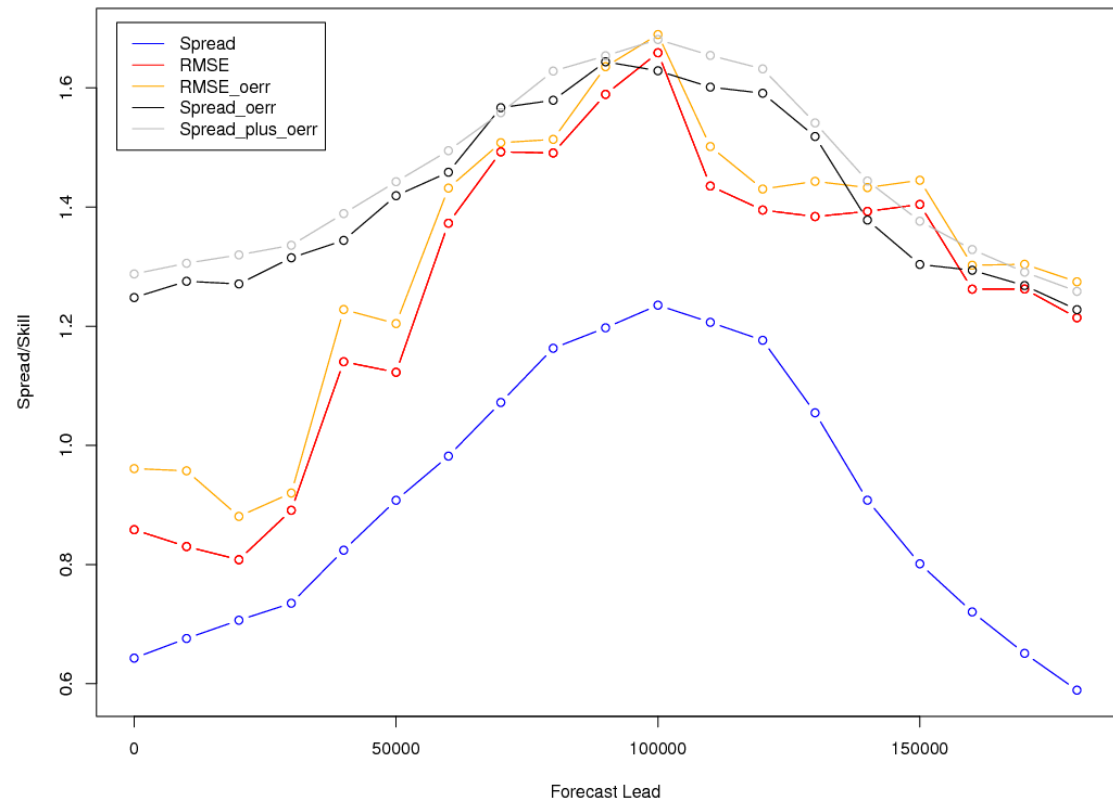
- Read gridded data from user-supplied Python script.
- Read GOES-16 AOD datasets.
- Add new continuous ensemble statistics (ECNT) line type.
- Apply user-configurable observation error in ensemble verification.

Ensemble-Stat: Observation Error

- User has fine control of observation error assumptions.
- Observation error perturbations are applied to the *ensemble member values* ... Counter-intuitive but correct



Ensemble Spread/Skill of 19 cases HRRRE_ens_CONUS: TMP at Z2
ADPSFC, LMV, BILIN(4),NA

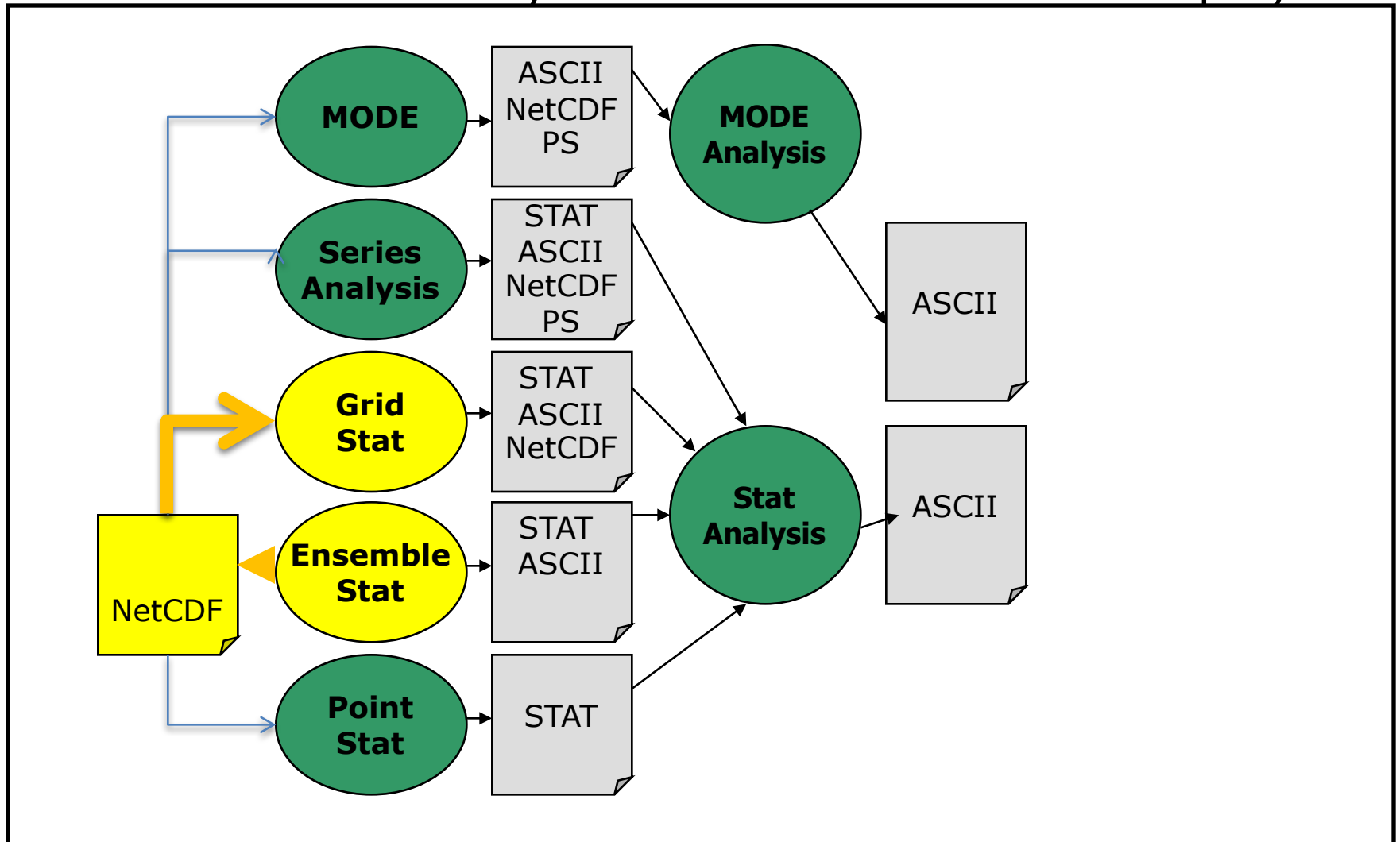


Probability fields

Statistics

Analysis

User Defined Display



Verifying Probabilities

- Probabilistic verification method tools:
 - Grid-Stat, Point-Stat, and Stat-Analysis
- Define Nx2 contingency table using:
 - Multiple forecast probability thresholds
 - One observation threshold

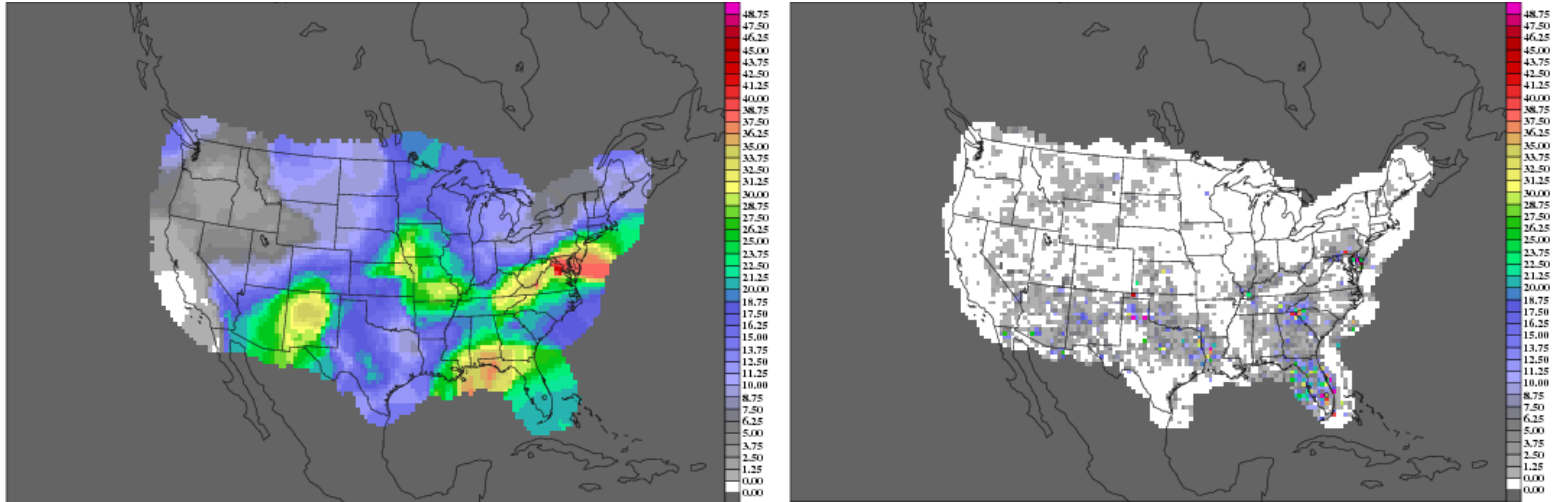
Forecast	Observation		Total
	$o = 1$ (e.g., "Yes")	$o = 0$ (e.g., "No")	
$p_1 = \text{midpoint of } (0 \text{ and threshold1})$	n_{11}	n_{10}	$n_{1.} = n_{11} + n_{10}$
$p_2 = \text{midpoint of (threshold1 and threshold2)}$	n_{21}	n_{20}	$n_{2.} = n_{21} + n_{20}$
⋮	⋮	⋮	⋮
$p_j = \text{midpoint of (threshold } i \text{ and } 1)$	n_{j1}	n_{j0}	$n_{j.} = n_{j1} + n_{j0}$
Total	$n_{.1} = \sum n_{i1}$	$n_{.0} = \sum n_{i0}$	$T = \sum n_i$

Example:

- FCST: Probability of precip
 $[0.00, 0.25, 0.50, 0.75, 1.00]$
 $== 0.25$
- OBS: Accumulated precip
 > 0.00

Verifying Probabilities: Example

- Verify probability of precip with total precip:



- Configuration file settings:

```
fcst = {  
  field = [  
    {  
      name          = "POP";  
      level         = [ "Z0" ];  
      //cat_thresh  = [ >=0.0, >=0.25, >=0.50, >=0.75, >=1.00 ];  
      cat_thresh    = [ ==0.25 ];  
      prob          = TRUE;  
    }  
  ];  
};
```

```
obs = {  
  field = [  
    {  
      name          = "APCP";  
      level         = [ "A12" ];  
      cat_thresh    = [ >0.0 ];  
    }  
  ];  
};
```

Grid-Stat: Probability Config

- Many configurable parameters – only set a few:
 - APCP_24... is name of ens mean in netcdf file
 - prob = True important
 - cat_thresh used for reliability and roc curves
 - Use 24hr Accumulation in grib file threshold at >10 mm
 - Generate probabilistic statistics

```
fcst = {
  wind_thresh = [ NA ];

  field = [
    {
      name      = "APCP_24_A24_ENS_FREQ_ge10.000";
      level     = [ "(*,*)" ];
      prob      = TRUE;
      cat_thresh = [ >=0.0, >=0.1, >=0.2, >=0.3,
                    >=0.4, >=0.5, >=0.6, >=0.8, >=1.0 ];
      //cat_thresh = [ ==0.1 ];
    }
  ];
};

obs = {

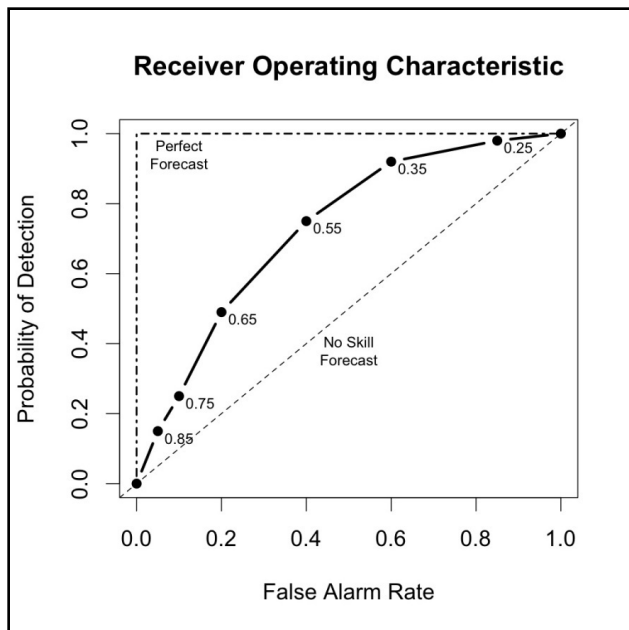
  wind_thresh = [ NA ];

  field = [
    {
      name      = "APCP";
      level     = [ "A24" ];
      cat_thresh = [ >10.000 ];
    }
  ];
};
```

```
output_flag = {
  fho      = NONE;
  ctc      = NONE;
  cts      = NONE;
  mctc     = NONE;
  mcts     = NONE;
  cnt      = NONE;
  sl112    = NONE;
  vl112    = NONE;
  val112   = NONE;
  pct      = BOTH;
  pstd     = BOTH;
  pjc      = BOTH;
  prc      = BOTH;
  eclv     = BOTH;
  nbrctc   = NONE;
  nbrcts   = NONE;
  nbrcnt   = NONE;
  grad     = NONE;
};
```

Grid-Stat: Probability Run

- Output written to .stat file and, if desired, to individual text files:
 - PCT – Probability Contingency Table Counts
 - PSTD – Probability Contingency Table Scores
 - Brier Score, Reliability, Resolution, Uncertainty, Area Under ROC
 - PJC – Joint/Continuous Statistics of Probabilistic Variables
 - Calibration, Refinement, Likelihood, Base Rate, Reliability points
 - PRC – ROC Curve Points for Probabilistic Variables



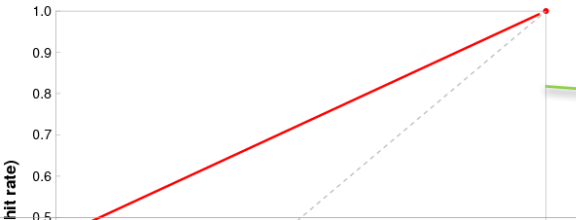
ECLV Line Type

- met-6.1 added support to Grid-Stat and Point-Stat for computation of the Economic Cost-Loss Value (**ECLV**) line type.
- Equivalent to the VSDB ECON line type, except...
 - ECON is only generated when evaluating ensemble probabilities.
 - ECLV from 2x2 contingency table yield a single curve.
 - ECLV from Nx2 probabilistic contingency table yields N curves.
- Configuration file option to specify the cost/loss ratios to be evaluated:
 - `eclv_points = 0.05; // equal spacing`
 - `eclv_points = [0.05, 0.10, 0.15, 0.20, 0.25, 0.50, 0.75]; // non-equal`

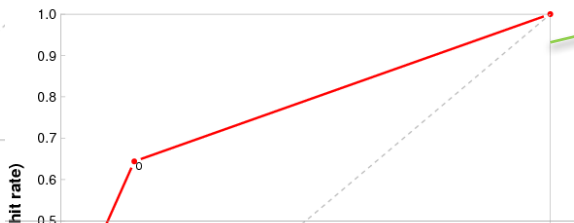
```
// - The "eclv_points" entry specifies the economic cost/loss ratio points
// to be evaluated. For each cost/loss ratio specified, the relative value
// will be computed and written to the ECLV output line. This entry may
// either be specified as an array of numbers between 0 and 1 or as a single
// number. For an array, each array entry will be evaluated. For a single
// number, all evenly spaced points between 0 and 1 will be evaluated, where
// eclv_points defines the spacing. Cost/loss values are omitted for
// ratios of 0.0 and 1.0 since they are undefined.
```

Grid-Stat: Probability Examples

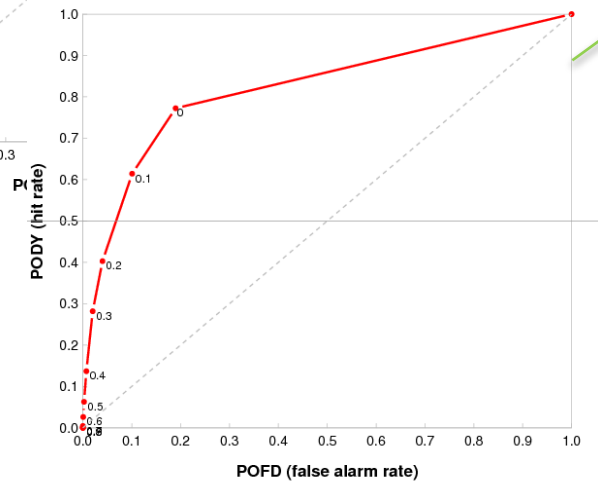
ROC Curve Example – PROB(6hr APCP>12.7 mm) – F18



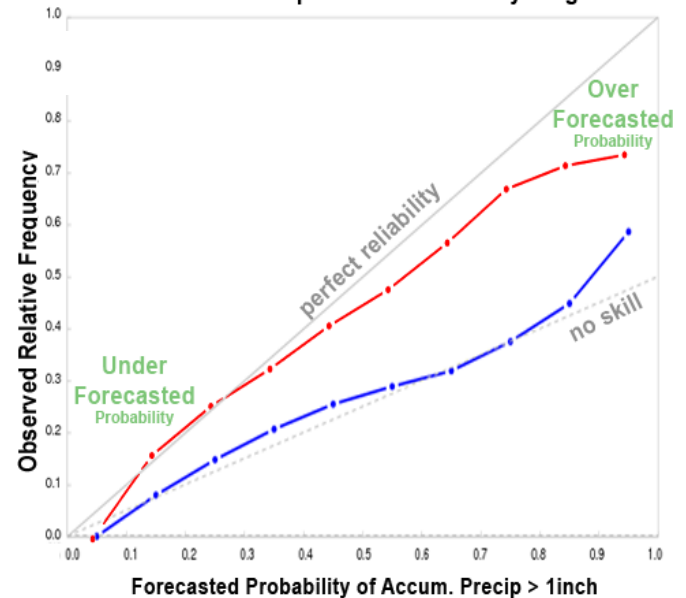
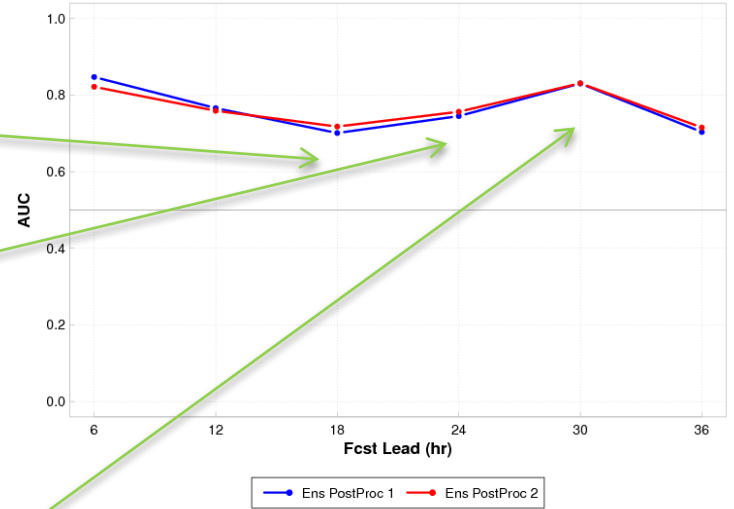
ROC Curve Example – PROB(6hr APCP>12.7 mm) – F24



ROC Curve Example – PROB(6hr APCP>12.7 mm) – F30



Area Under ROC Curve (AUC) Example – PROB(6hr APCP>12.7 mm)



Container NWP Tutorial

https://dtcenter.org/met/docker-nwp/tutorial/container_nwp_tutorial/index.php

END-TO-END NWP CONTAINERS ONLINE TUTORIAL

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END-TO-END NUMERICAL WEATHER PREDICTION (NWP) CONTAINERS

NWP container components

This tutorial provides information on using software containers that have been established for community use to quickly spin up an NWP forecast system [using the Weather Research and Forecasting (WRF) model] that can then be post-processed [using the Unified Post Processor (UPP)] and verified [using the Model Evaluation Tools (MET)].

At the present time, the following components and versions of the code are containerized and detailed in this tutorial:

- WRF Preprocessing System (WPS) version 3.9.1
- Advanced Research Weather Research and Forecasting (WRF-ARW) model version 3.9.1.1
- Unified Post Processor (UPP) version 3.2
- NCAR Command Line (NCL) graphics
- Model Evaluation Tools (MET) version 6.1
- METViewer database and display version 2.3

dtc-nwp

dtc-ncl

dtc-met

dtc-metviewer

This online tutorial describes step-by-step instructions on how to obtain, build, and run each containerized component using Docker.

Thanks and Questions?

Contacts:

John Halley Gotway (Software) – johnhg@ucar.edu

Tressa Fowler (Statistician) – tressa@ucar.edu

Tara Jensen (Project Manager) – jensen@ucar.edu

MET Helpdesk: met_help@ucar.edu

http://www.dtcenter.org/met/users/support/met_help.php