What's Available in MET+

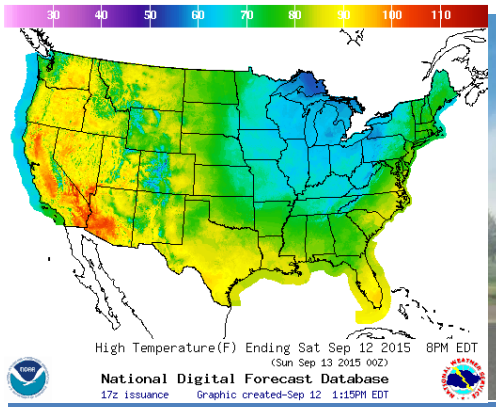
Tara Jensen

DTC Community UFS Test Plan and Metrics Workshop

July 30-Aug 1 2018

Why Unification

Forecasters



Government Centers

University and National Lab Researchers

Comprehensive and unified verification tool - Make R20 more efficient - Provide a consistent set of metrics

Allows Researchers and Operational Scientists to speak a "common verification" language

MET
Model Evaluation Tools

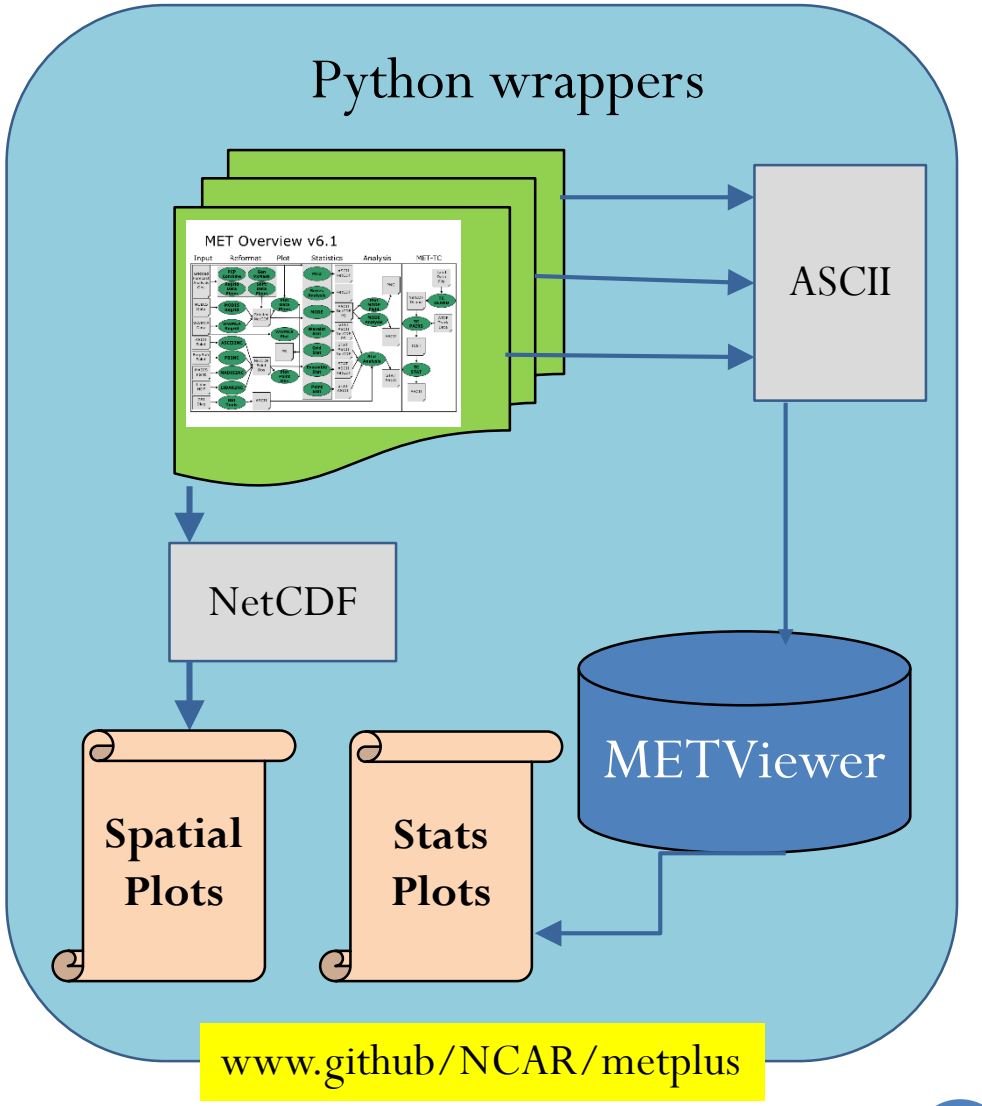
User Support of unified package provides greater opportunity to train all on verification best practices

MET+

Python wrappers around:

- MET (core)
- METViewer (core)
- Plotting
  - METViewer User Interface
  - METViewer Batch Engine
  - Python plotting scripts
- Communication between MET & python algorithms

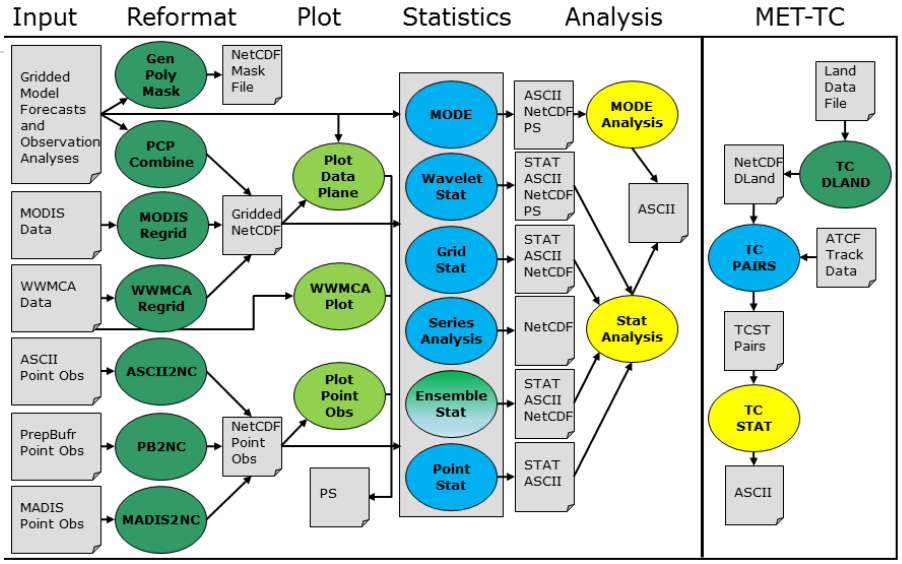
***Near Term:** After Global - CAM, Ensembles and Aerosols / Air Qual*
***Longer Term:** Earth System "Components"*



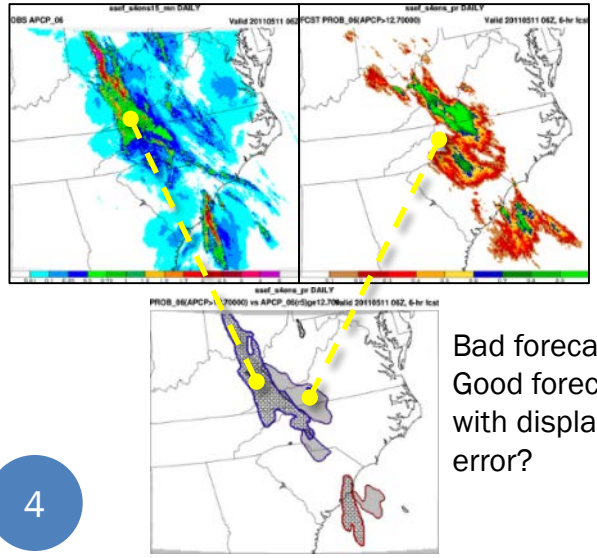
A Verification Toolkit Designed for Flexible Yet Systematic Evaluation
(supported to the community via the DTC)

MET
Model Evaluation Tools

- Originally developed to replicated the EMC mesoscale verification system
- **Over 85 traditional statistics** using both point and gridded datasets
- 15 interpolation methods
- Computation of confidence intervals
- Able to read in GRIB1, GRIB2 and CF-compliant NetCDF
- **Applied to many spatial and temporal scales**
- 3500+ users, both US & Int'l

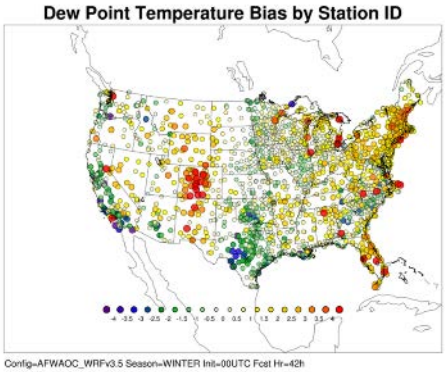


Object Based and Spatial Methods

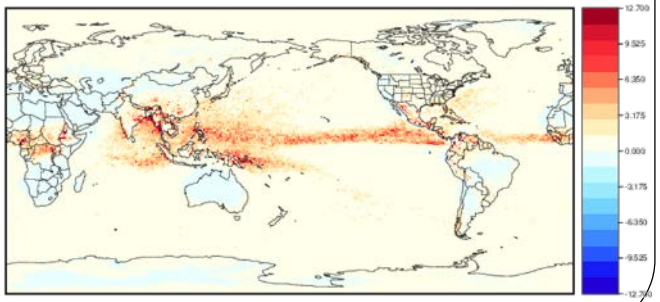


Bad forecast or Good forecast with displacement error?

Geographical Representation of Errors



90th Percentile of difference between two models



Laundry List of Statistics

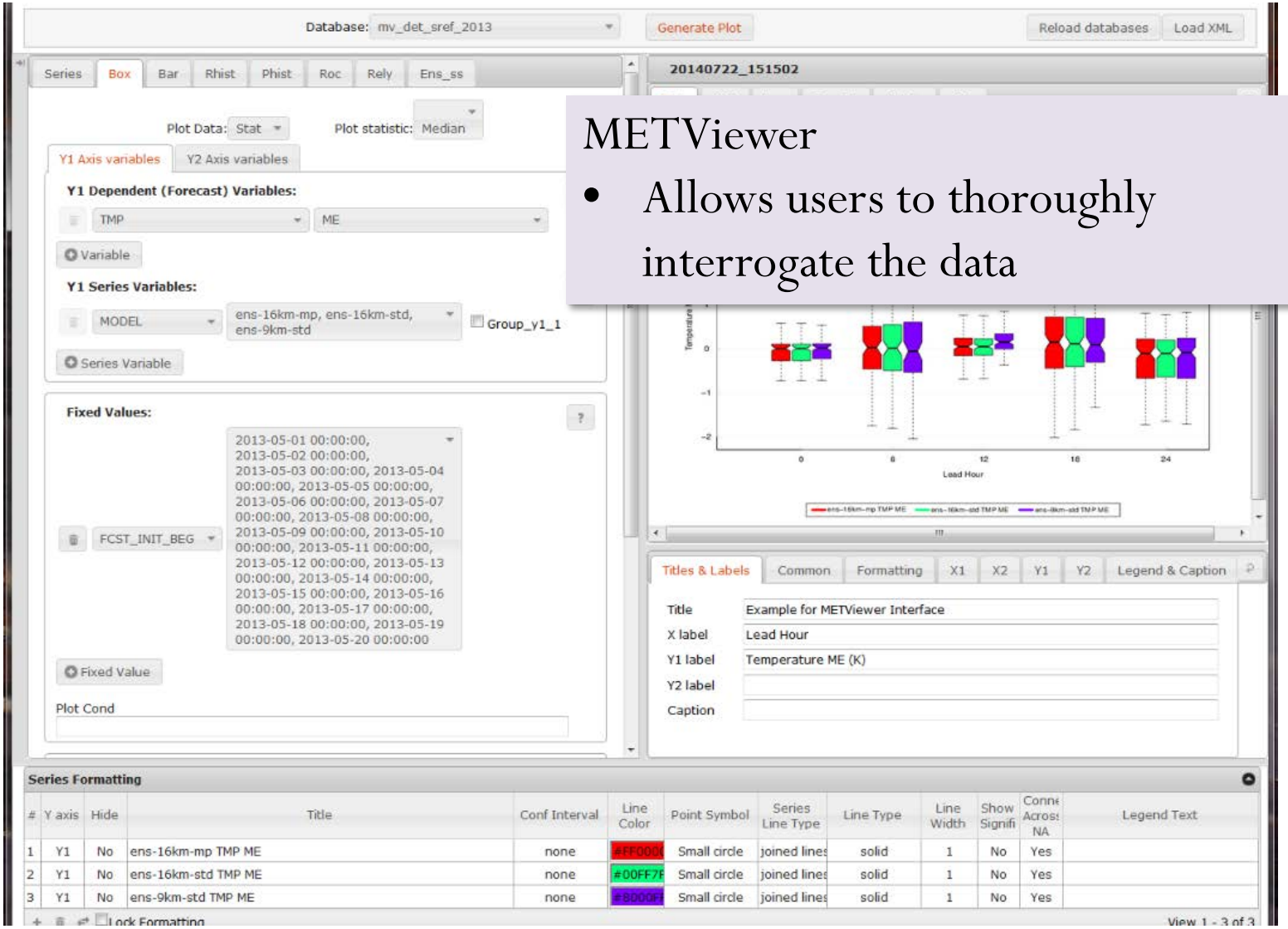
Type	Statistics
Continuous	Forecast and Observation mean, Standard deviation of the forecast and observations, Mean error (F-O), Standard deviation of the error, Anomaly Correlation, Pearson correlation coefficient, Spearman's rank correlation coefficient, Kendall's tau statistic, Multiplicative bias, Mean absolute error, Mean squared error, Bias-corrected mean squared error, Root mean squared error, 10th, 25th, 50th, 75th, and 90th percentiles of the error, Interquartile Range, Median Absolute Deviation, Square of the mean error, Mean squared error skill score, Root mean squared forecast anomaly, Root mean squared observation anomaly, Mean of absolute value of forecast and observed gradients, Mean of maximum of absolute values of forecast and observed gradients, Mean of absolute value of forecast minus observed gradients, S1 score, S1 score with respect to observed gradient, Ratio of forecast and observed gradients, Scalar Partial Sums, Vector Partial Sums, Anomaly Partial Sums
Categorical	Base rate, Forecast mean, Accuracy, Frequency Bias, Probability of detecting yes, Probability of detecting no, Probability of false detection, False alarm ratio, Critical Success Index, Gilbert Skill Score, Hanssen-Kuipers Discriminant, Heidke Skill Score, Odds Ratio, Logarithm of the Odds Ratio, Odds Ratio Skill Score, Extreme Dependency Score, Symmetric Extreme Dependency Score, Extreme Dependency Index, Symmetric Extremal Dependency Index, Bias Adjusted Gilbert Skill Score, Gerrity Score for multi-categorical statistics

Laundry List of Statistics

Type	Statistics
Probability	Base Rate, Reliability, Brier Score, Resolution, Uncertainty, Climatological Brier Score, Brier Skill Score, Receiver Operating Characteristic (ROC) Curve, Area under the ROC curve, Reliability Diagram points, Economic Cost/Loss Relative Value Diagram points), Calibration, Refinement, Likelihood
Ensemble	Continuous Ranked Probability Skill Score, Ignorance Score, Rank Histogram, Probability Integral Transform, Relative Position
Skill by Spatial Scale	Fourier Decomposition of fields prior to computation of scores or use Wavelet_Stat tool which computes for each scale: Mean squared error, Intensity scale skill score, Forecast energy squared, Observed energy squared, Frequency Bias. Not scale dependent: Base rate
Neighborhood	Same as categorical statistics plus Fractions Brier Score, Fractions Skill Score, Asymptotic Fractions Skill Score, Uniform Fractions Skill ScorTCe
Tropical Cyclones	Mean, Standard deviation, Minimum Value, Percentiles, Maximum Value, Interquartile Range, Range, Sum, Independence time, Frequency of superior performance, contingency tables counts for Rapid Intensification and Rapid Weakening, contingency tables counts for Probability of Rapid Intensification and Rapid Weakening

Type	Statistics
2D Objects	For each object: Location of the centroid in grid units, Location of the centroid in lat/lon degrees, Axis angle, Length of the enclosing rectangle, Width of the enclosing rectangle, Object area, Radius of curvature of the object defined in terms of third order moments, Center of curvature, Ratio of the difference between the area of an object and the area of its convex hull divided by the area of the complex hull, percentiles of intensity of the raw field within the object, Percentile of intensity chosen for use in the percentile intensity ratio, Sum of the intensities of the raw field within the object, For paired objects: Distance between two objects centroids, Minimum distance between the boundaries of two objects, Minimum distance between the convex hulls of two objects, Difference between the axis angles of two objects, Ratio of the areas of two objects, Intersection area of two objects, Union area of two objects, Symmetric difference of two objects, Ratio of intersection areas, Ratio of complexities, Ratio of the nth percentile of intensity, Total interest value computed for a pair of simple objects, NetCDF files with the objects and raw data for further processing
Objects through time	For 3D objects: x,y and t coordinates of centroid, Latitude and Longitude of centroid, x, y component of object velocity, Angle that the axis plane of an object makes with the grid x direction, Integer count of the number of 3D "cells" in an object, Object start time, Object end time, Total great circle distance travelled by the 2D spatial centroid over the lifetime of the 3D object, percentiles of intensity of the raw field within the object For 3D object pairs: Spatial distance between coordinates of object space-time centroid, Difference in index of object spacetime centroid, Difference in spatial axis plane angles, Difference in object speeds, Difference in object direction of movement, Ratio of object volumes, Difference in object start times, Difference in object end times, "Volume" of object intersection, Difference in the lifetimes of the two objects, Total interest for this object pair, NetCDF files with the objects and raw data for further processing

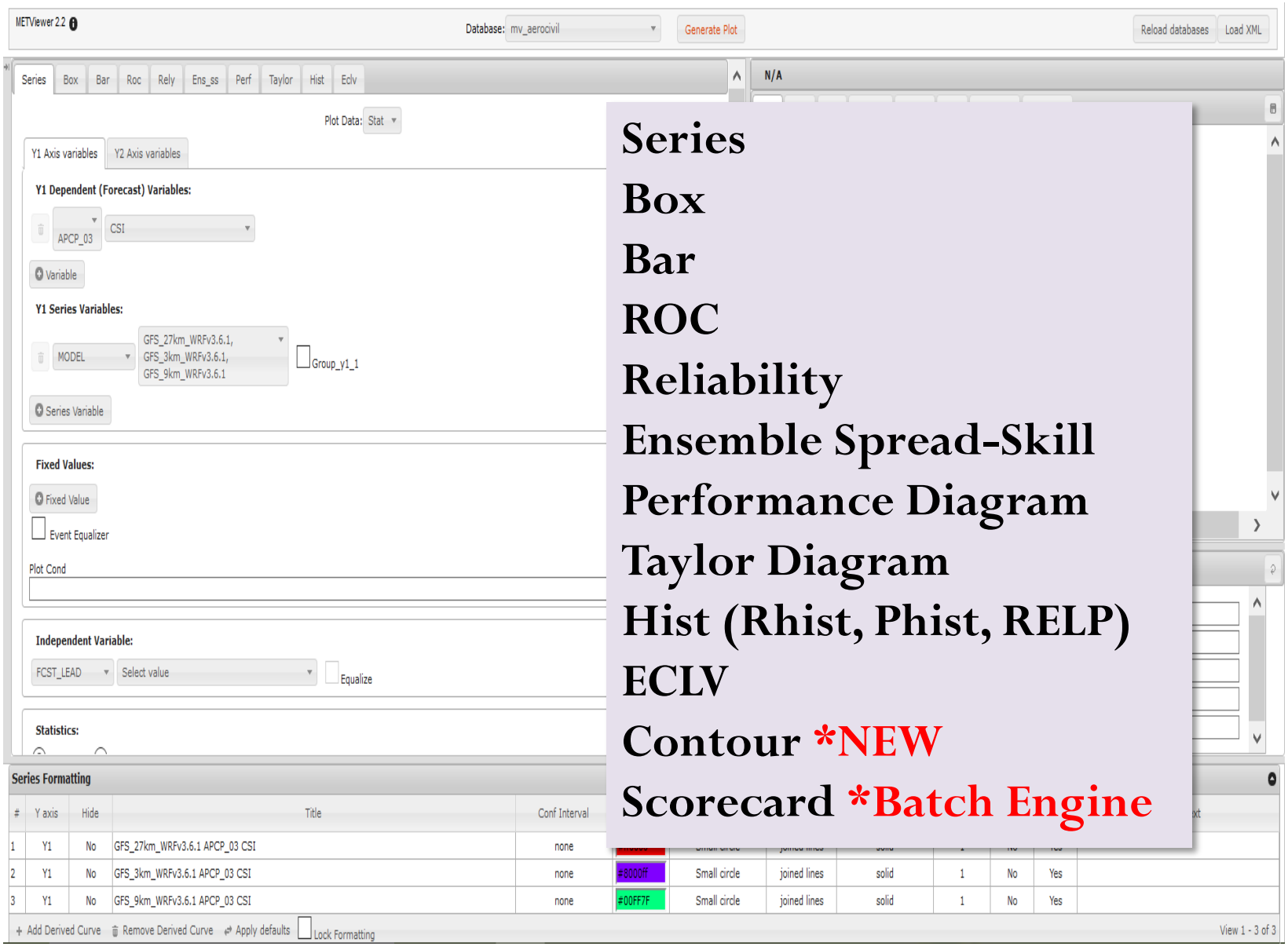
METViewer Database and Display



METViewer

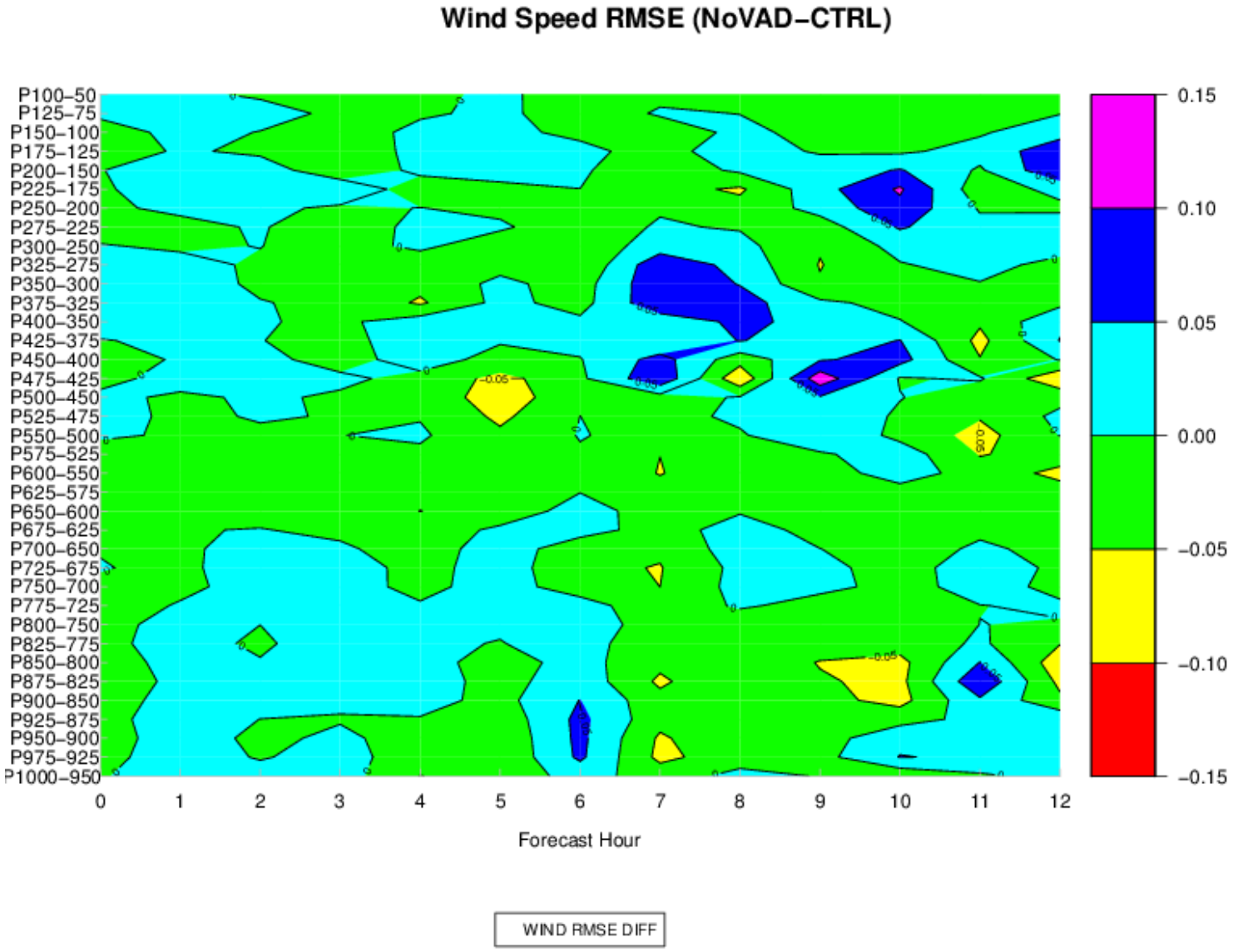
- Allows users to thoroughly interrogate the data

METViewer Plot Templates

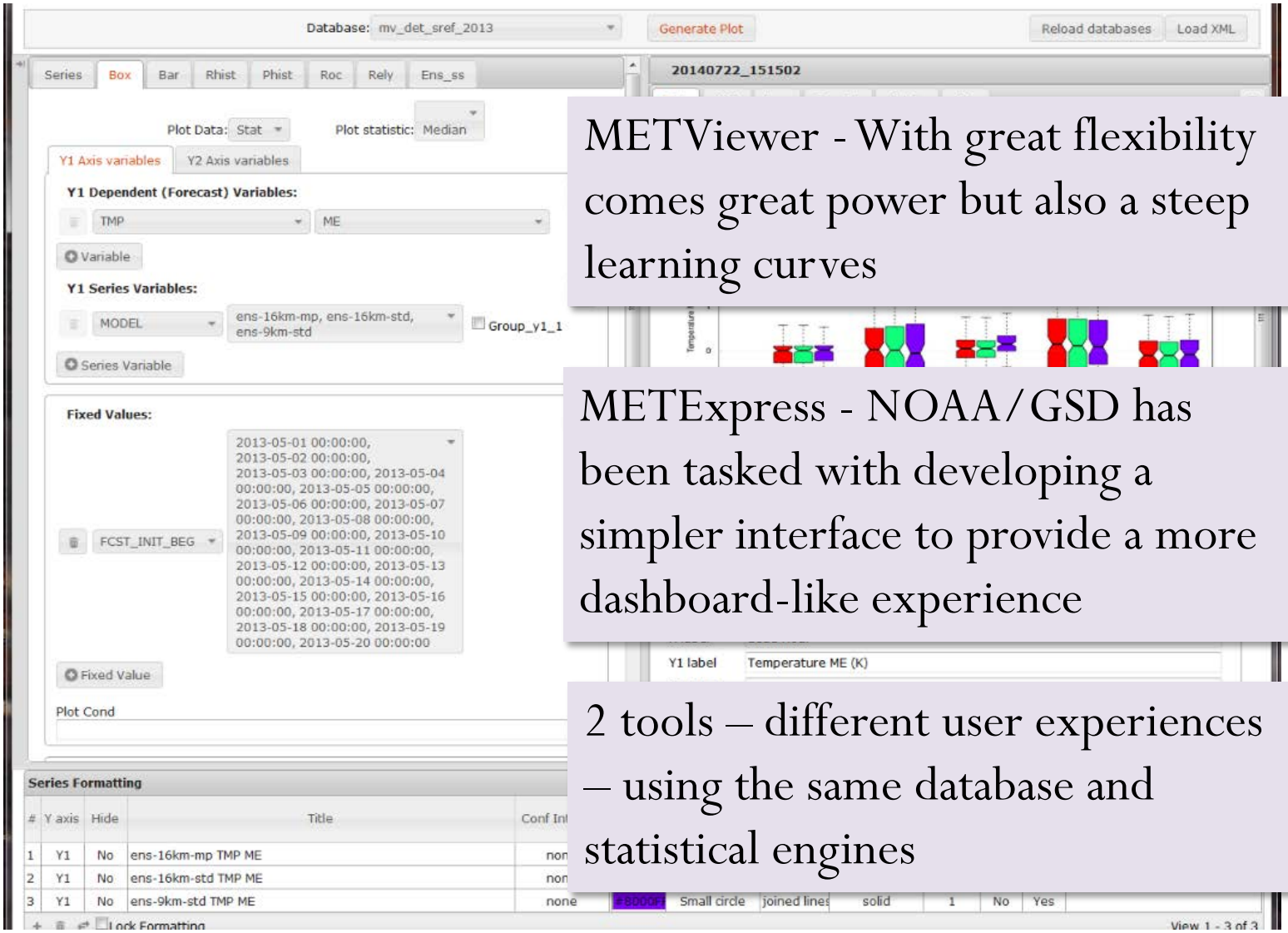


Series
Box
Bar
ROC
Reliability
Ensemble Spread-Skill
Performance Diagram
Taylor Diagram
Hist (Rhist, Phist, RELP)
ECLV
Contour *NEW
Scorecard *Batch Engine

METViewer Contour Plots



METViewer Database and Display



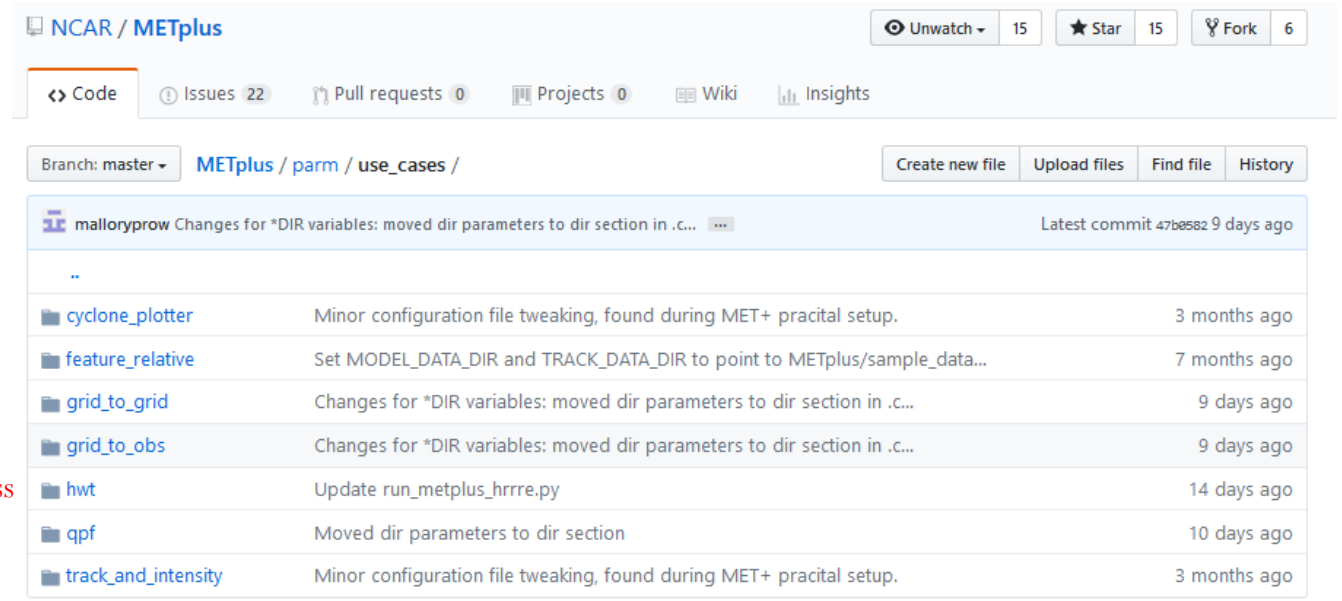
METViewer - With great flexibility comes great power but also a steep learning curves

METExpress - NOAA/GSD has been tasked with developing a simpler interface to provide a more dashboard-like experience

2 tools – different user experiences – using the same database and statistical engines

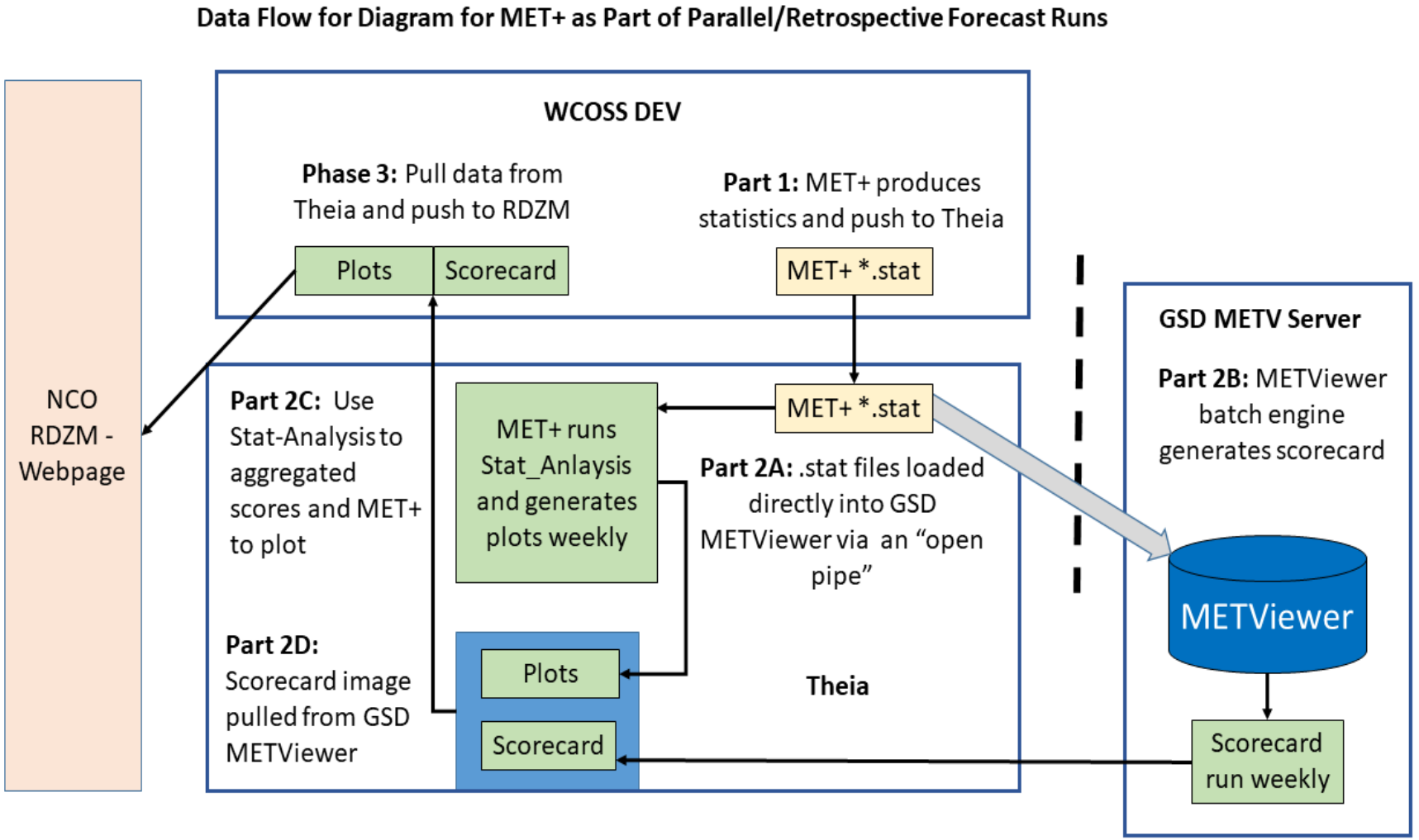
MET+ Use-Cases

- MET+ integrated into FV3GFS parallel workflow
- Grid-to-Grid, Grid-to-Point, QPF/Precip, and TC Track and Intensity verification included
- Python based 2-D Plotting included
- Feature Relative and Extra-Tropical Cyclone examples also available



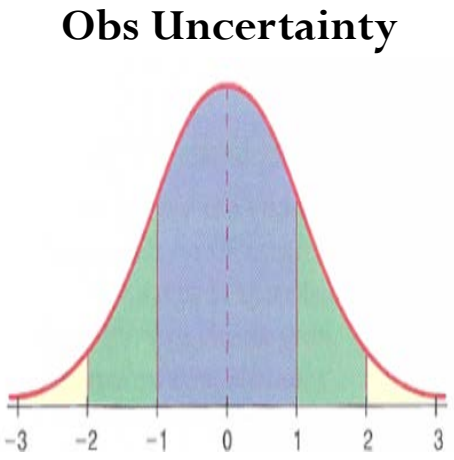
Updated
Updated
Added
Added
In progress
Updated
Updated

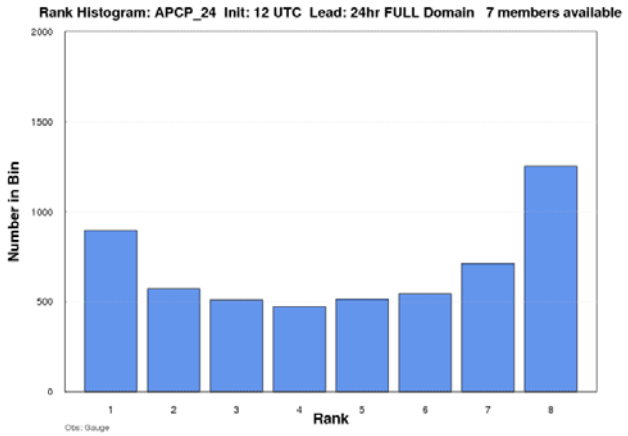
MET+ at EMC



Mallory Row, NOAA/EMC, has become a MET+ developer and set up this workflow

Recent Addition to MET – Obs Uncertainty





Observation error logic is applied only in Ensemble-Stat (currently)

Perturb ensemble member values and/or observation values based on a random draw from obs error information

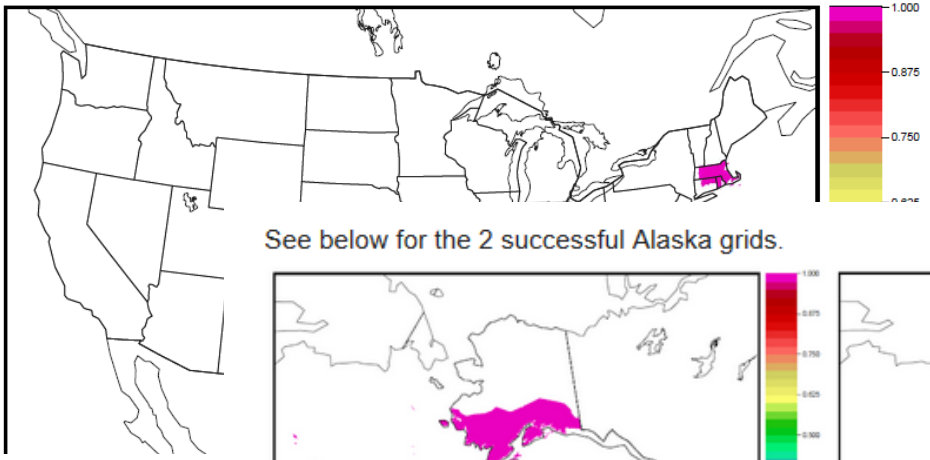
```
obs_error = {
  field          = NONE;    // FCST, OBS, BOTH, or NONE
  dist_type      = NONE;    // Distribution type
  dist_parm      = [];      // Distribution parameters
  inst_bias_scale  = 1.0;   // Instrument bias scale adjustment
  inst_bias_offset = 0.0;   // Instrument bias offset adjustment
```

The default table can be found in the installed share/met/table_files/obs_error_table.txt

Looking at how to include Obs Uncertainty in Point-Stat, Grid-Stat and other tools

Recent Addition to MET – Use of Shapefiles

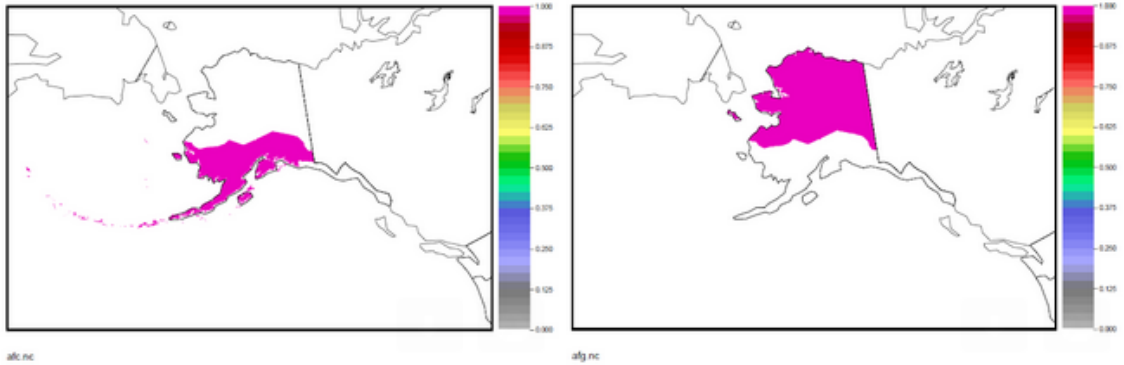
Gen-VX-Mask reads shapefiles and generates a mask that can then be used by other tools



NWS CWA

urma_2p5CO_box.nc

See below for the 2 successful Alaska grids.



If you could increase that buffer size, that would be awesome.

Pretty fantastic utility! Thank you for all of your efforts.

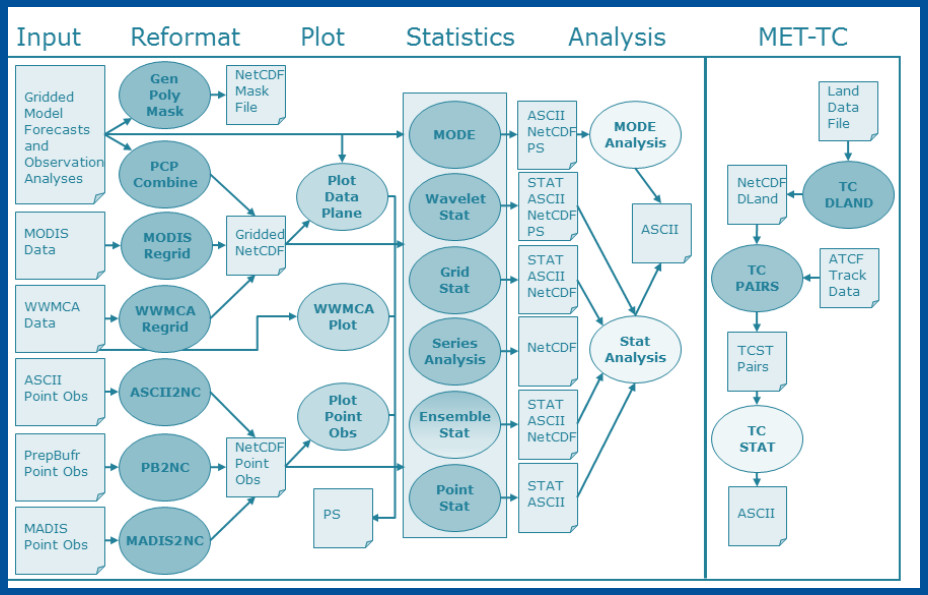
Dana

From Dana Storm (MDL developer)

NWS RFC

urma_2p5CO_abrfc.nc

Recent Addition to MET
Communication between MET and Python

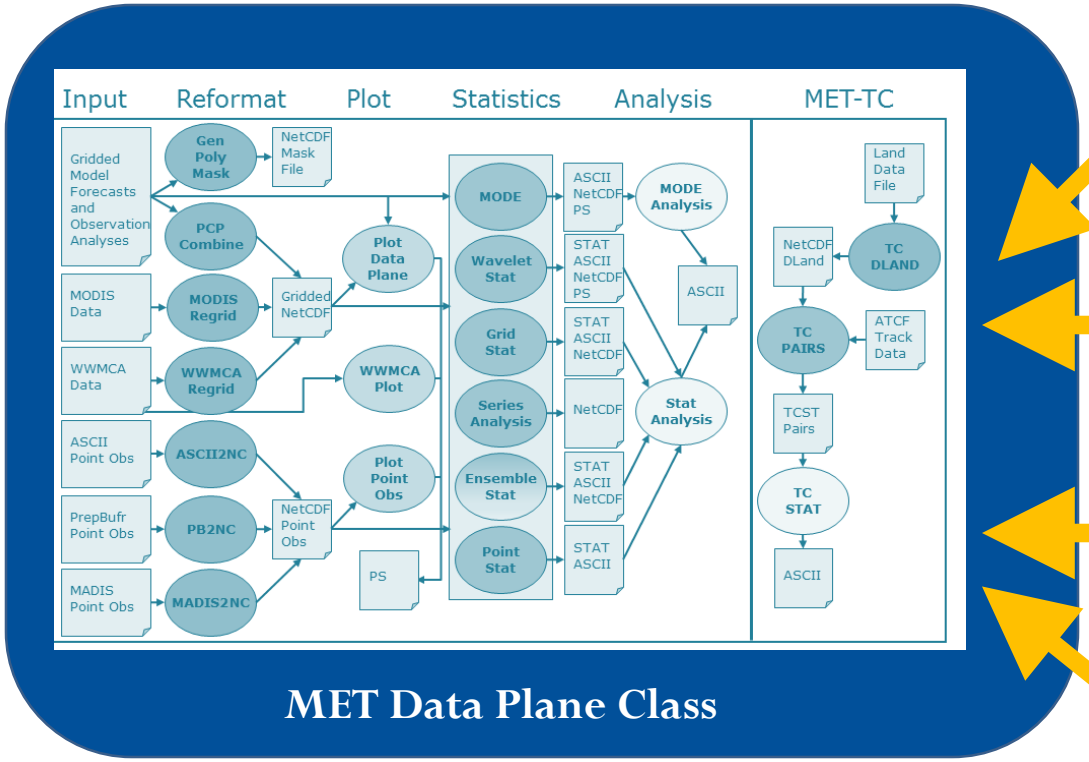


MET Data Plane Class

Python scripts pass data through:
Xarray
NumPy
Pandas

Opens up a world of possibilities

Early Adopters
Communication between MET and Python



MONET: Air Quality

EMC Marine Verification

NSSL CAM Verification

WPC QPF Verification

Opens up a world of possibilities

NGGPS Verification and Validation WG Adding Additional Capability

Already have pre-existing packages which we will link in

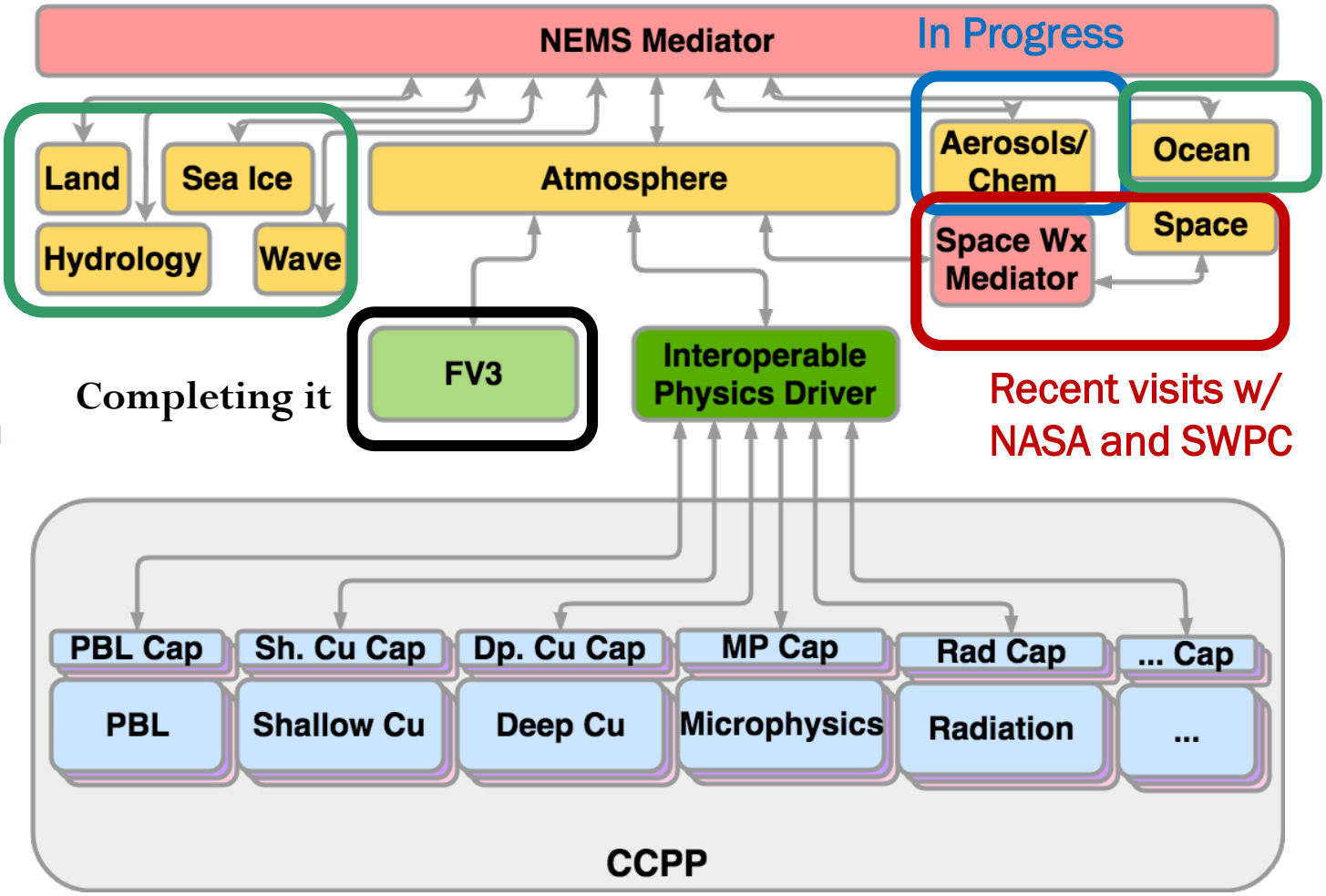


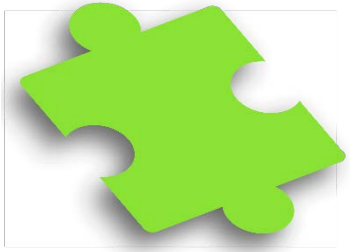
Image courtesy of GMTB

NGGPS V&V Areas of Focus

- ✓Treatment of uncertainty
- ✓Scorecard and weighted performance indices
- ✓Ensemble and probability verification metrics
- Diagnostic tools and S2S (scales at which errors occur, energy spectra)
- Physics-oriented metrics (radiation, fluxes, cloud verification)
- Forecast consistency - extreme weather
- ✓Object-oriented metrics
- Coupled model component performance
- Validation – during development process

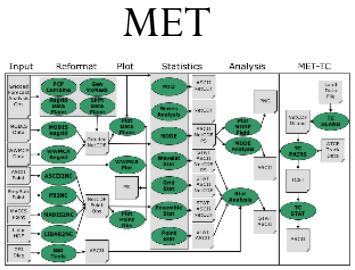
Upcoming MET+ Additions

- **Code clean-up to pass cyber-security software scans (Fortify)** and improve memory handling and speed
- **Process Oriented Diagnostics**
  - Moisture-convection coupling
  - MJO, NAO, and Teleconnection diagnostics
  - TC Genesis diagnostics
  - Extreme Weather related to Blocking
  - Some diagnostics about cloud properties and structure
- **Feature Relative Diagnostics**
  - Extending the MET+ Feature Relative use-case to include multi-variate fields and fluxes



The missing piece is more definition and action on the physics oriented diagnostics

METplus Authoritative Repository



METViewer

METExpress

METplus

Python scripts for low-level workflow

Python scripts for plotting

manage_externals package developed by NCAR CESM team

Connection to Workflow Managers

JEDI

UPP

CROW

Land

Hydro

Space Weather

MONET: Air Quality

EMC Marine

NSSL CAM

NRL

Analogy That Helps Develop Governance?

- **From a simplistic perspective…**
  HWRF – a set of scripts to configure and run WRF and to couple with externals, it is the authoritative repository for US tropical cyclone forecasting
- CESM – a set of scripts to configure CAM and other external components, it is the authoritative repository for US climate simulations
- JEDI – a suite of tools that need to couple with externals, it will become the authoritative repository for US data assimilation

MET+ - was a name picked by DTC early in it's development
METplus – is the Github repository name –(because symbols were not allowed) – We propose it becomes the authoritative repository for unified verification

Show of Hands… Moving Forward

MET+

or

METplus

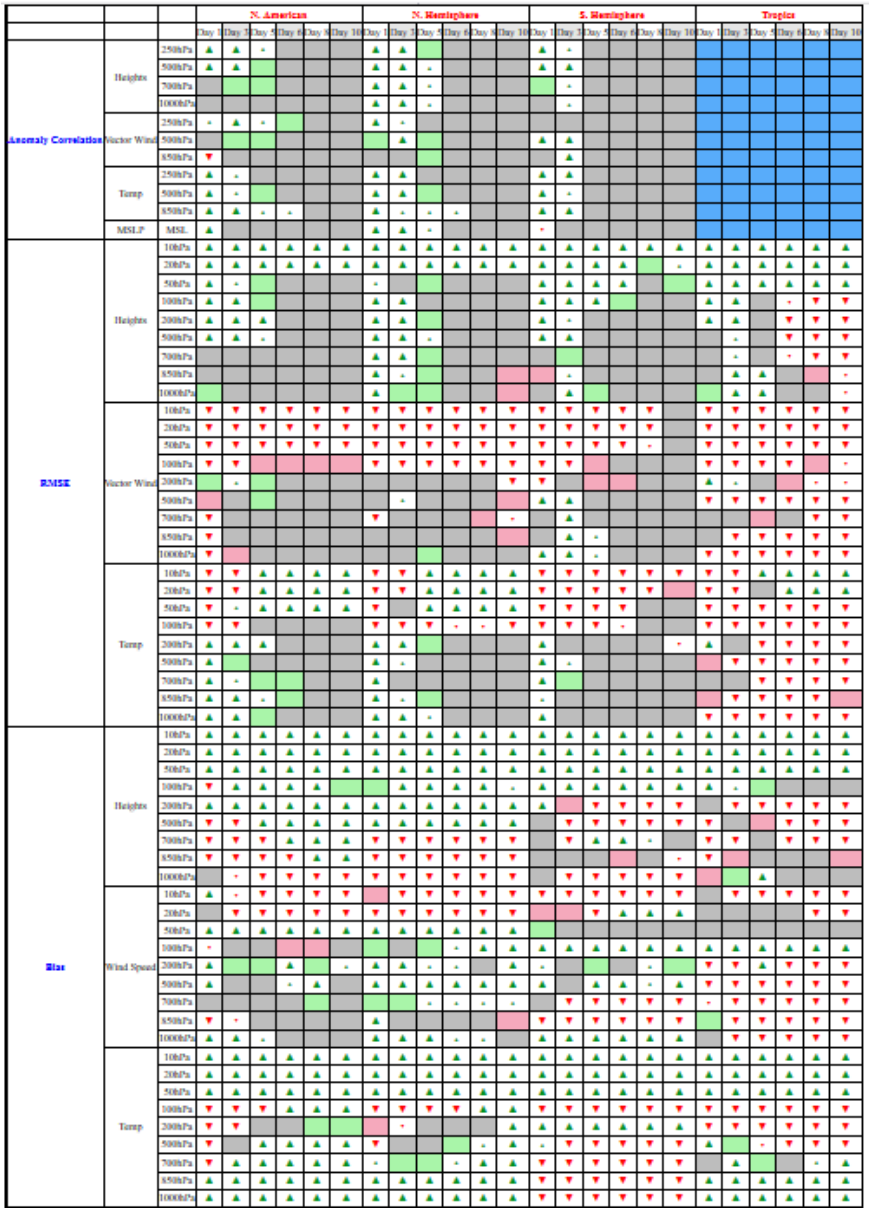
Send your thoughts to me at jensen@ucar.edu or tara.jensen@noaa.gov

Scorecards and the Metrics we choose

Something to think about:

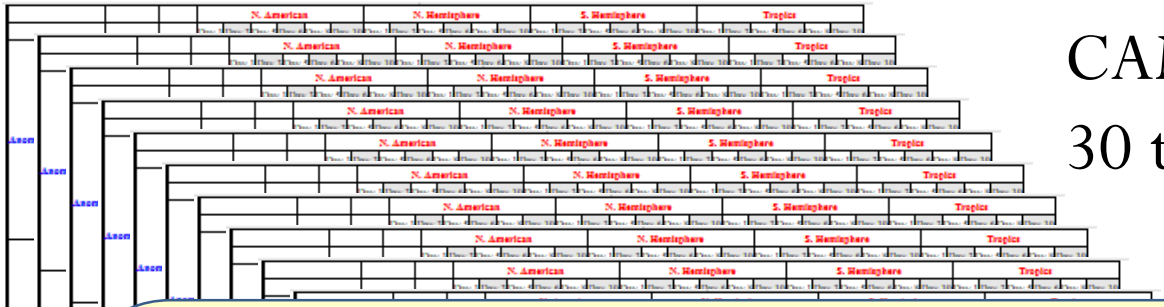
Proposed CAM Metrics with a permutation of all of the fields, statistics, thresholds, regions, and neighborhoods would represent just under 2000 rows

Scorecards and the Metrics we choose



Current EMC Scorecard – 65 rows

Scorecards and the Metrics we choose

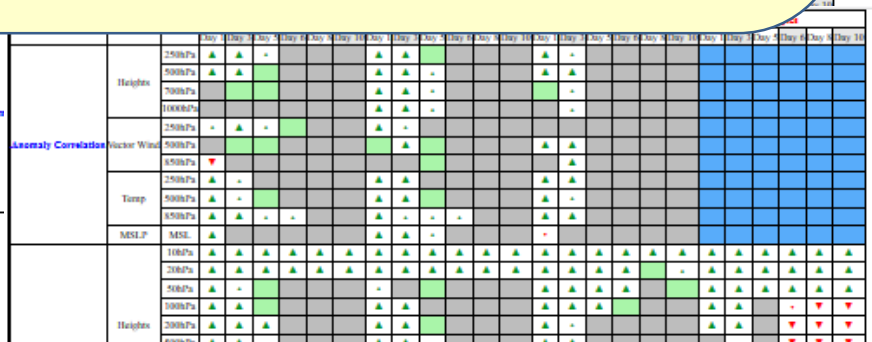


CAM scorecard would be 30 times as large…

We need priorities

1) Important for pre-implementation
2) What should be tested further up the funnel.

Hence the discussion of Hierarchical Testing



Contact: Tara Jensen – jensen@ucar.edu

MET Download:
http://www.dtcenter.org/met/users/downloads/index.php

MET Helpdesk: ***met_help@ucar.edu***

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

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