



Recent Advancements in METplus: A Verification and Diagnostics Framework

Tara Jensen and METplus Team

National Center for Atmospheric Research and
Developmental Testbed Center

ICAP Meeting

18-20 October 2022

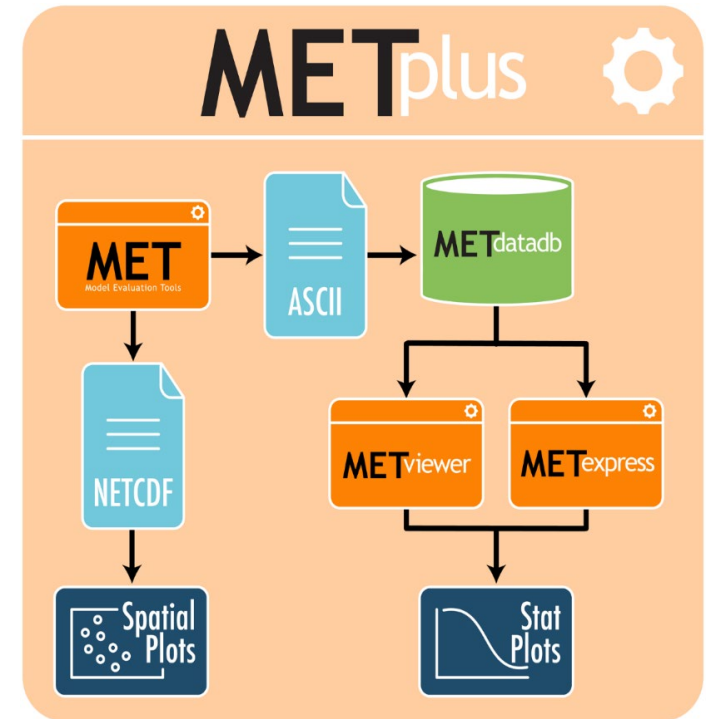


What is METplus?

Suite of Python wrappers around

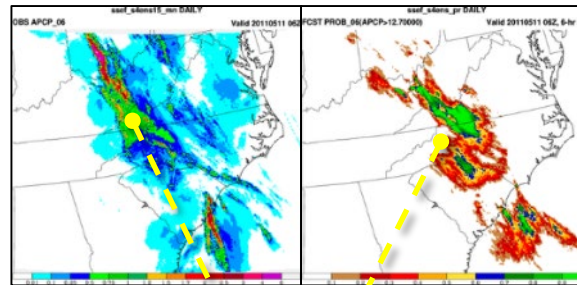
- MET (core)
- Analysis Tools
 - METviewer/METexpress User Interface
 - METviewer Batch Engine
 - Python-based Diagnostics and Plotting
- Communication between MET & python algorithms
- Using manage_externals to connect repos

- Over 150 traditional statistics and diagnostic methods for both point and gridded datasets
- 15 interpolation methods
- Applied to many spatial and temporal scales
- Developed to allow for easy sharing of config files for reproducible results

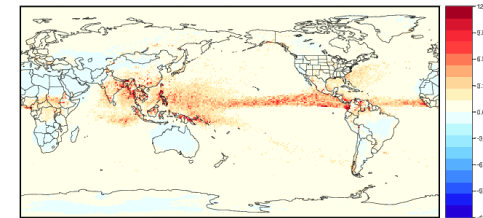
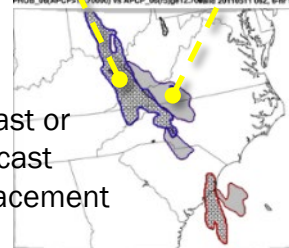


METplus Examples/Use-Case In Development

SRWCAM
S2S
MedRangeWx
MarineCryo
SpaceWx
TCExtraTrop
Climate
Air Quality
Precip



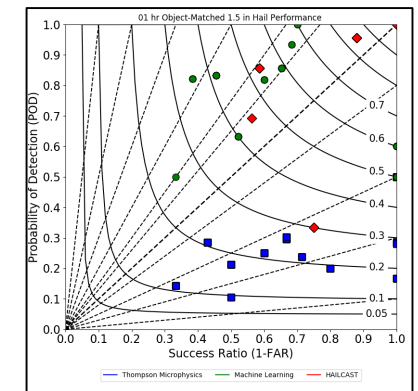
Bad forecast or Good forecast with displacement error?



METviewer CAM Scorecard for NSSLFV3 and HRRR_nsslgrid

2018-04-30 00:00:00 - 2018-06-01 00:00:00

		Daily Domain					CONUS				
		12 hr	18 hr	24 hr	30 hr	36 hr	12 hr	18 hr	24 hr	30 hr	36 hr
Temperature	>=32		Δ	Δ	Δ		▽	▽	▽	▽	▽
	>=65	▽	▽	▽	▽	▽	▽	▽	▽	▽	
	>=70	▽	▽	▽	▽	▽	▽	▽	▽	▽	
	>=75	▽	▽	▽	▽	▽	▽	▽	▽	▽	
	>=80		▽	▽	▽	▽		▽	▽	▽	
U Wind	>=10 kts										
	>=15 kts										
	>=20 kts										
V Wind	>=10 kts	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	
	>=15 kts	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	
	>=20 kts	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	

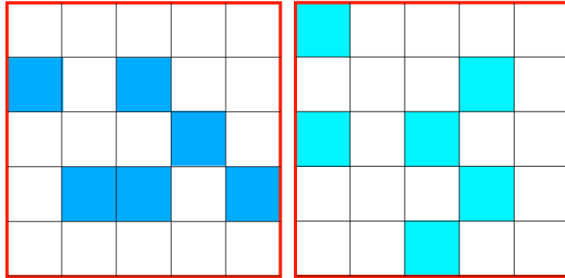


Overview of What's in METplus

Traditional	
<p>Grid-Stat, Point-Stat, Series-Analysis</p> <p>Contingency table statistics (CTS) Continuous statistics Probability forecast statistics Confidence intervals</p>	<p>Ensemble-Stat</p> <p>CRPS, CRPSS Rank prob., Prob. Integral Transform (PIT), and Relative Position histograms Spread/Skill Ignorance Confidence intervals</p>
Spatial	
<p>MODE</p> <p>Location differences Geometric attribute differences Intersection area Intensity distributions & differences CTS measures</p>	<p>MODE-TD</p> <p>Time and location differences Volume differences Velocity differences Intersection volume Intensity distributions & differences</p>
<p>Wavelet-Stat</p> <p>MSE by scale Energy by scale Intensity-scale skill score</p>	<p>Grid-Stat and Point-Stat</p> <p>FSS, <u>HiRA</u> Distance Measures: MED, Baddeley, <u>Hausdorff</u>, Zhu, etc.</p>
Tropical Cyclones and Diagnostics	
<p>MET-TC</p> <p>Track error (along, cross, total) Intensity errors (pressure, wind) Rapid intensification/weakening errors CTS measures of TC genesis</p> <p>TC-GEN</p> <p>CTS measures of TC genesis</p>	<p>Grid-Diag</p> <p>Distributions of fields for use in contour plots</p> <p>TC-RMW</p> <p>Radius of maximum wind errors and metrics</p>

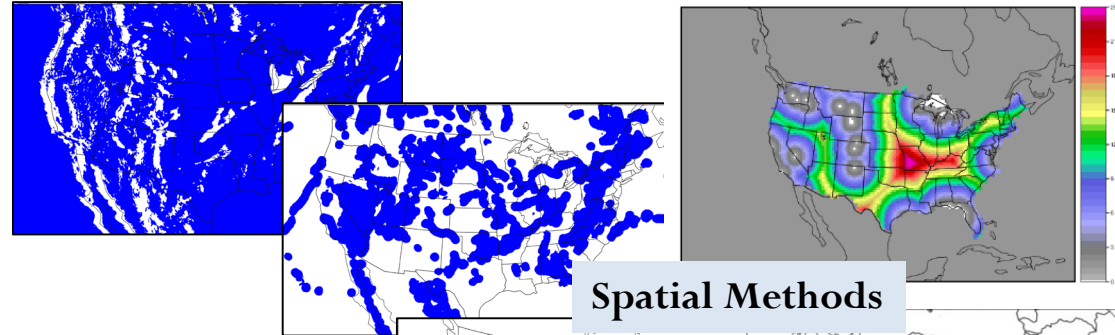
Tools That Support Diagnostics

Neighborhood Methods

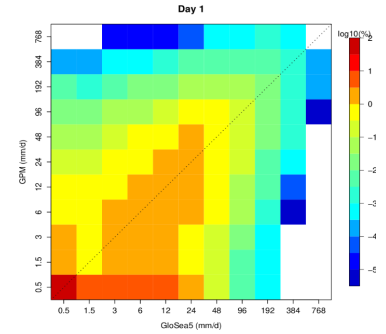


Fraction = 6/25 = 0.24

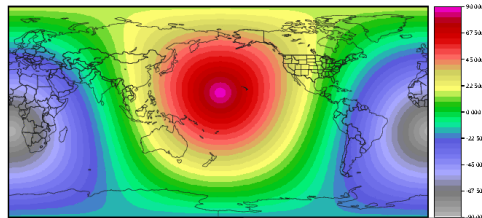
Fraction = 6/25 = 0.24



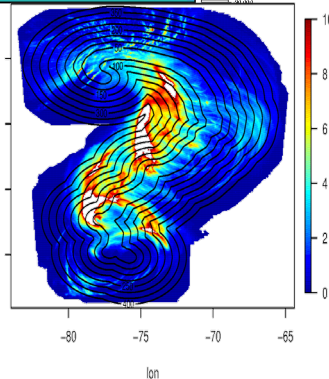
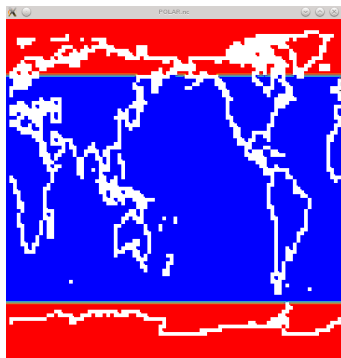
Spatial Methods



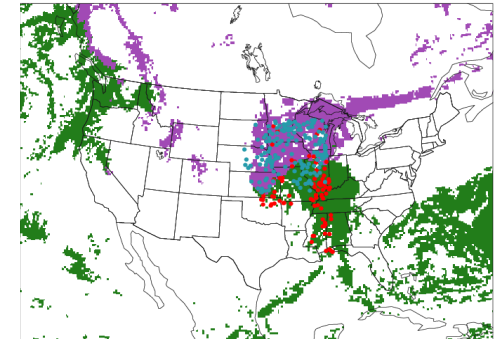
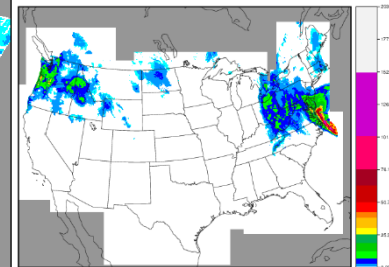
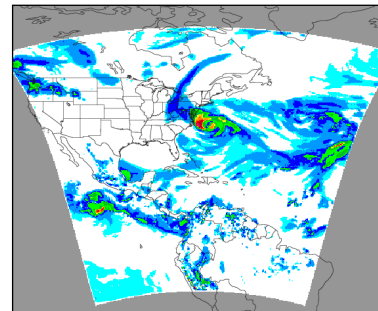
Multivariate PDFs For Climo and Percentiles



Masking

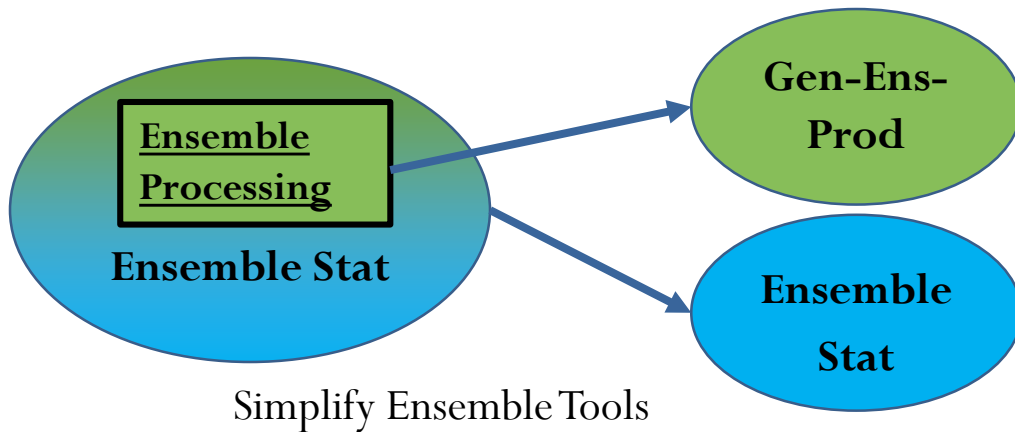
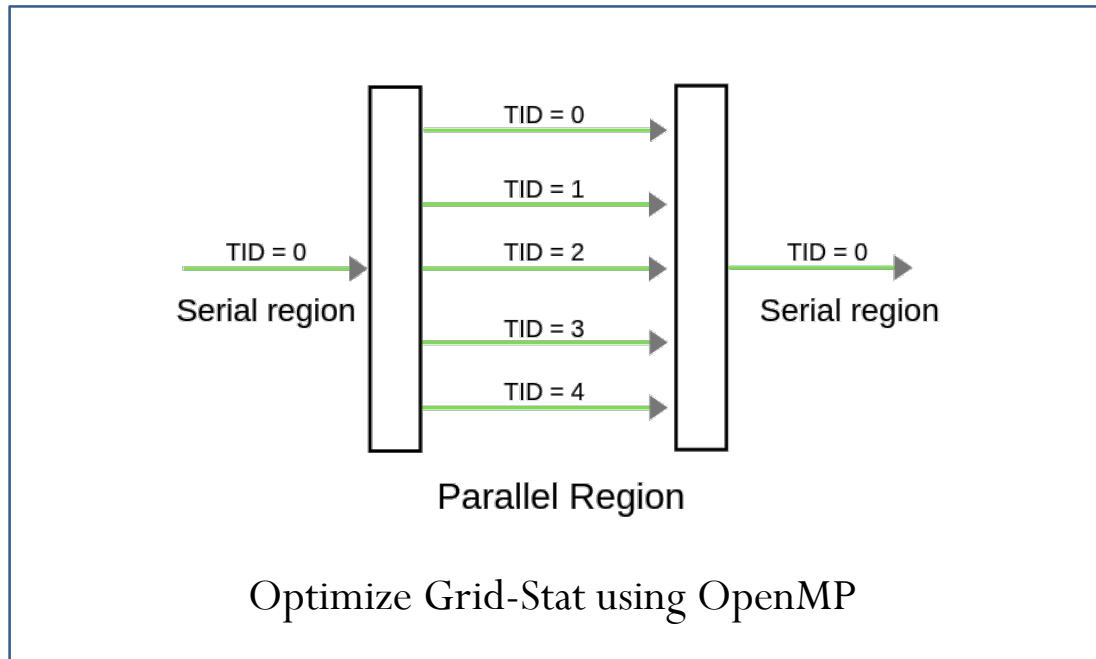
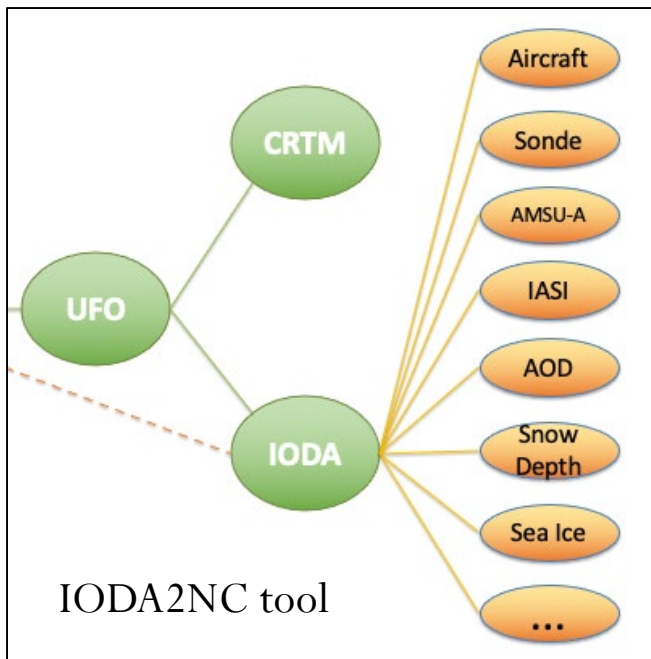


Auto Regridding



Quick-Look Plotting

Recent Additions



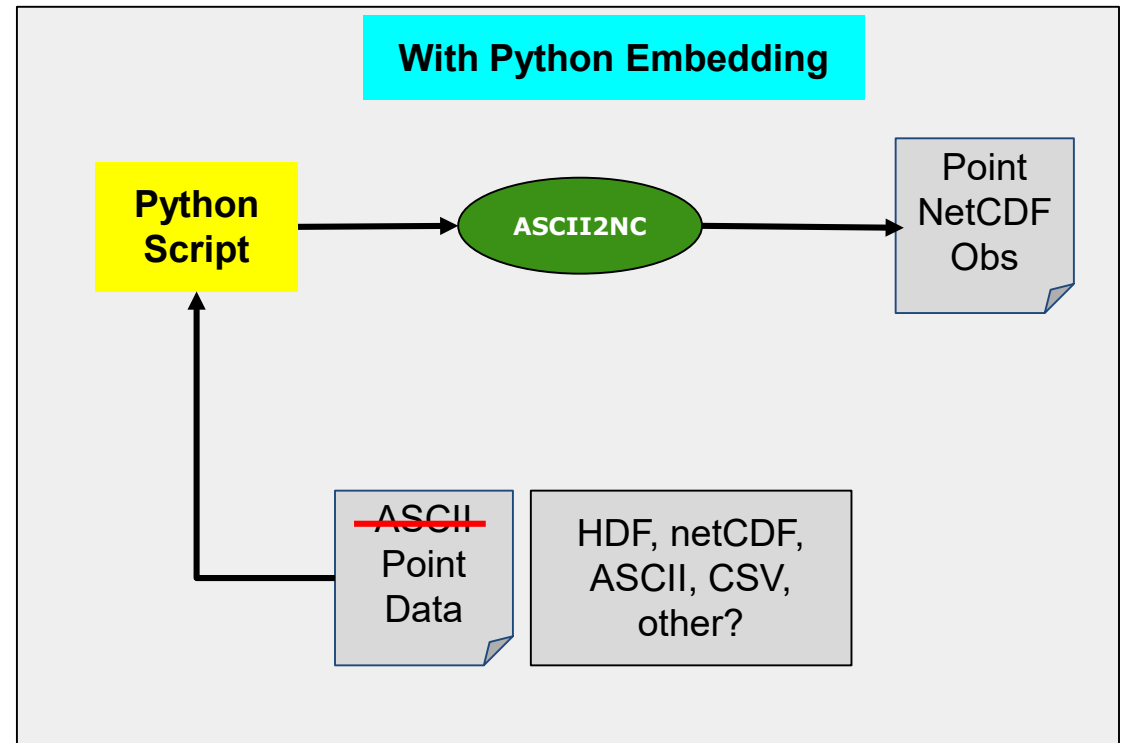
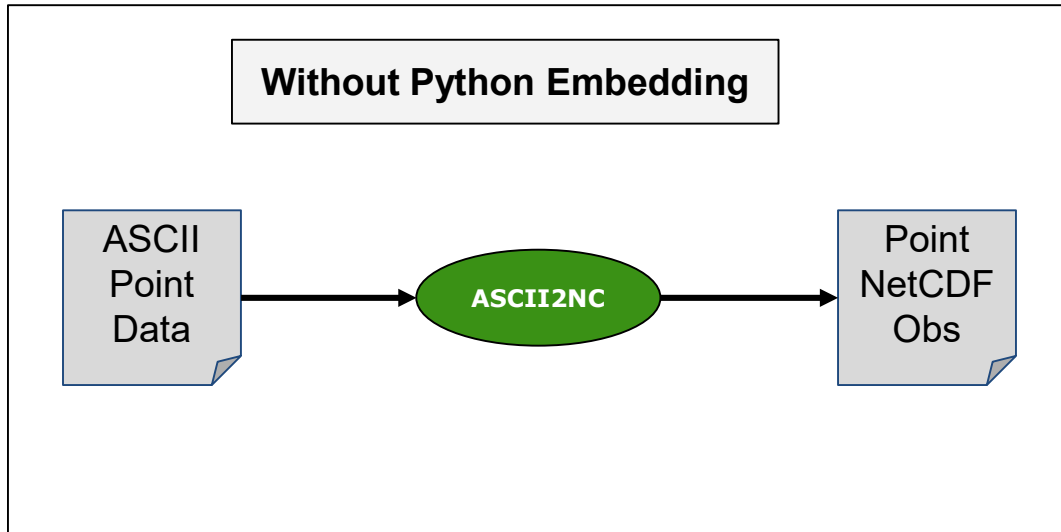
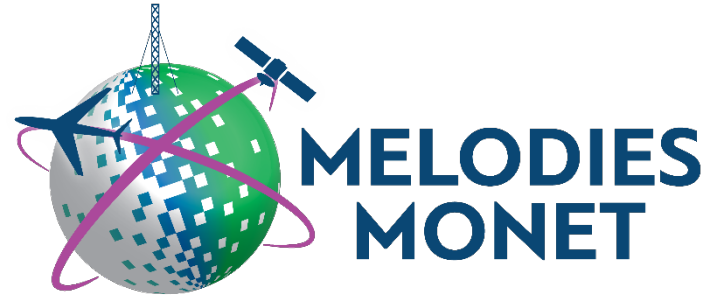
Support for AirNow ASCII data



It's All About Wrangling the Data – Python Embedding



Example: Using MONET IO to read in data and pass to METplus

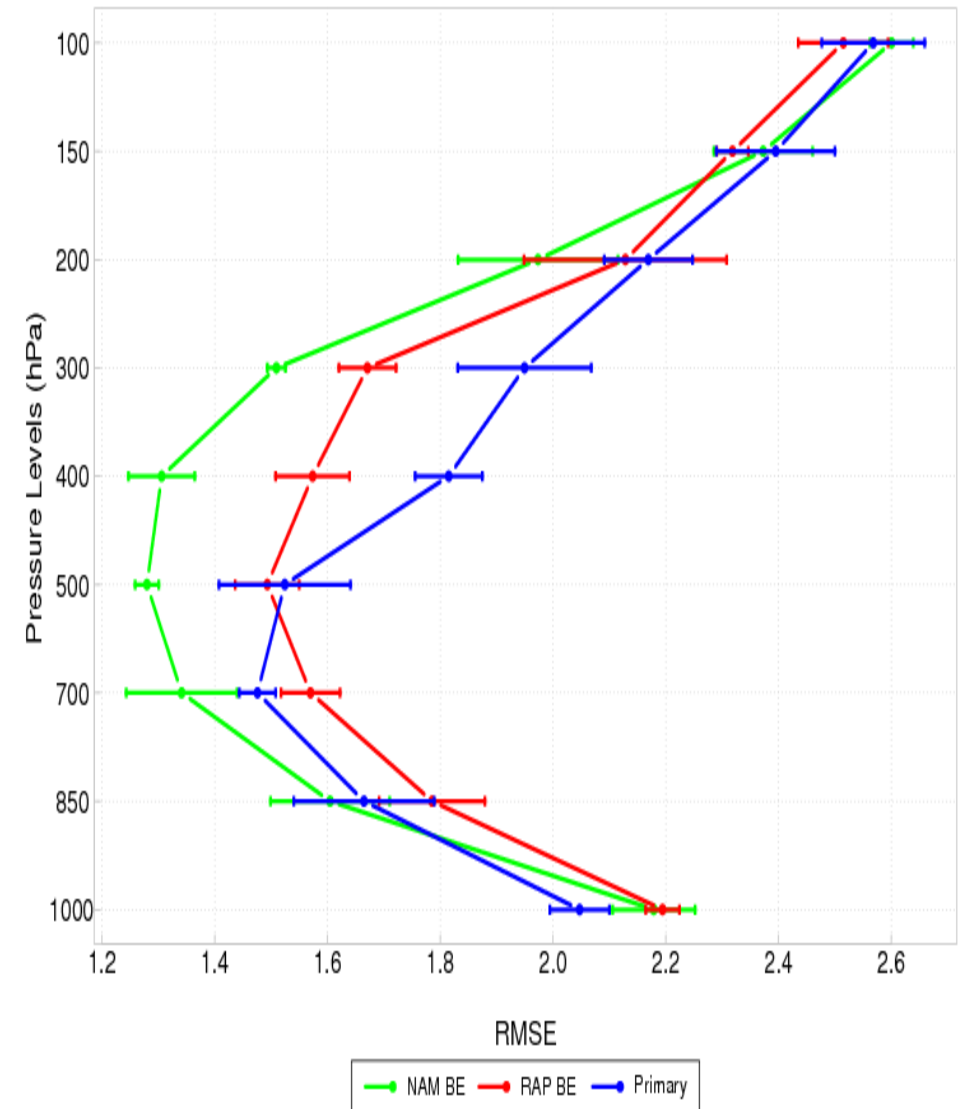


Traditional Evaluation

Profiles/Sondes

- **Tools applied: Point-Stat** to pair up gridded forecast with point observations and computed statistics; **METviewer** to compute over many forecasts and compute confidence intervals
- **Vertical Interpolation:** Linear interpolation height (depth) levels and natural log of pressure for pressure levels
- **Horizontal Interpolation:** choose from 1 of 15 methods including nearest neighbor, distance weighted mean, mass conserving, “best”
- **Fields supported:** Can be any field(s) that can be passed into METplus; observation name and scale does not need to match forecast name

Regional BE Tests vs. Primary Configuration: Wind Analysis



Current Work with NRL

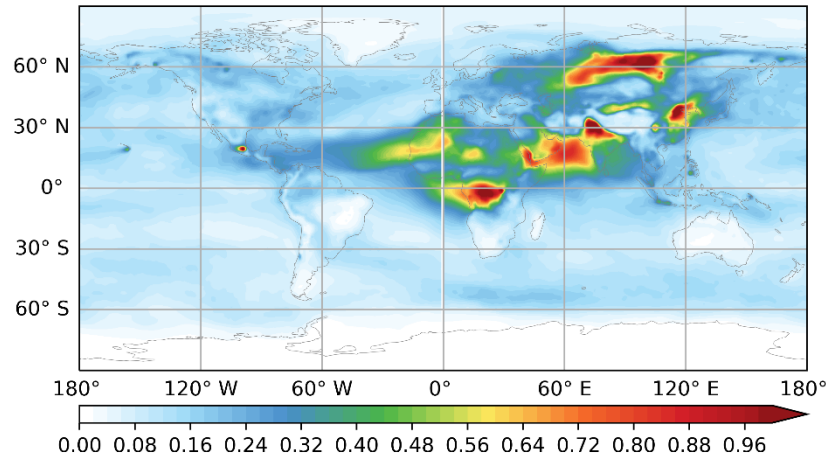


- Focus on the vertical distribution of aerosols, including aircraft sondes and lidar data
- Determine best comparison of coarsely gridded model data against these observations which occur at much higher spatial and temporal resolution and add methods to METplus if needed
- Explore scores based on neighborhood methods such as the High Resolution Analysis (HiRA) method
- Add simple gradient feature identification and define useful gradient object based metrics for comparison of model vertical distribution of aerosol and humidity, beyond bias RMSE.
 - Can we define comparisons of extinction over vertical ranges in METplus? For example, 0-500m, 500-1000m etc.
- Extend vertical evaluations to probability forecast evaluation (probability forecasts need a threshold for comparison).
 - Test probability evaluations using various methods for generating the probability forecasts, including the raw ensemble, neighborhood ensemble probability (NEP) and neighborhood maximum ensemble probability (NMEP) methods which are built into MET.

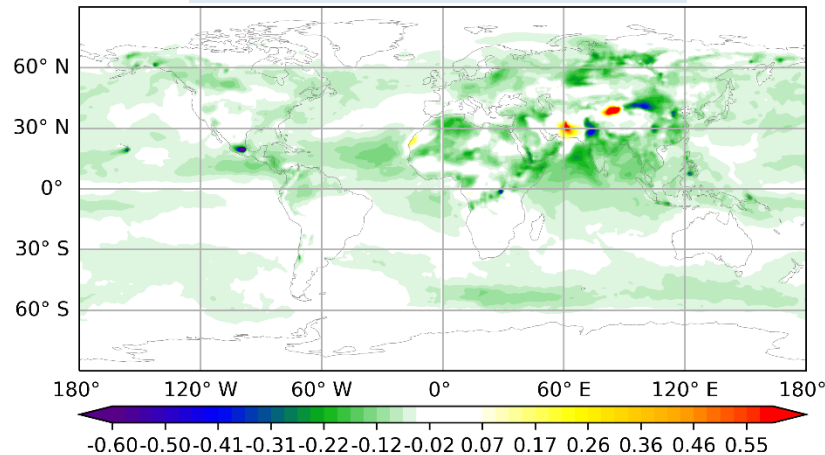
2D Map of statistics

July 2016 monthly mean

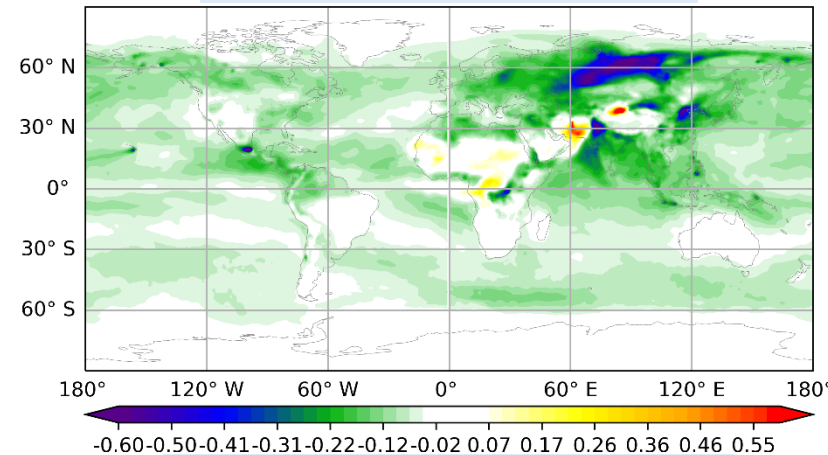
CAMS AOD



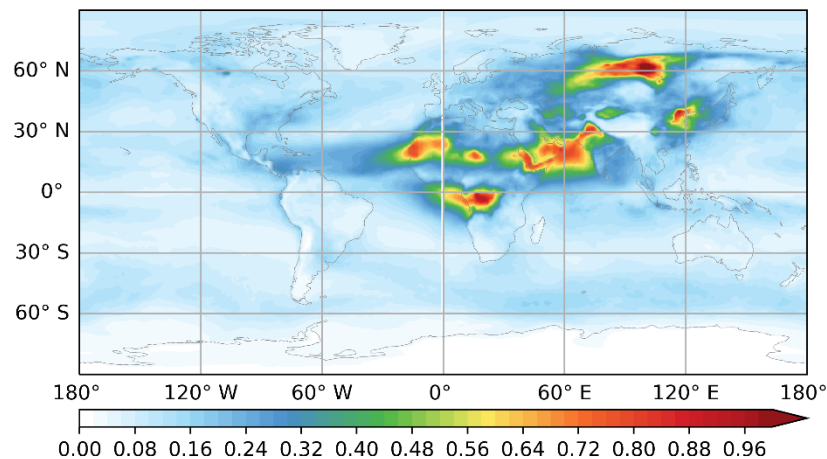
NARA-1 AOD Biases against CAMS



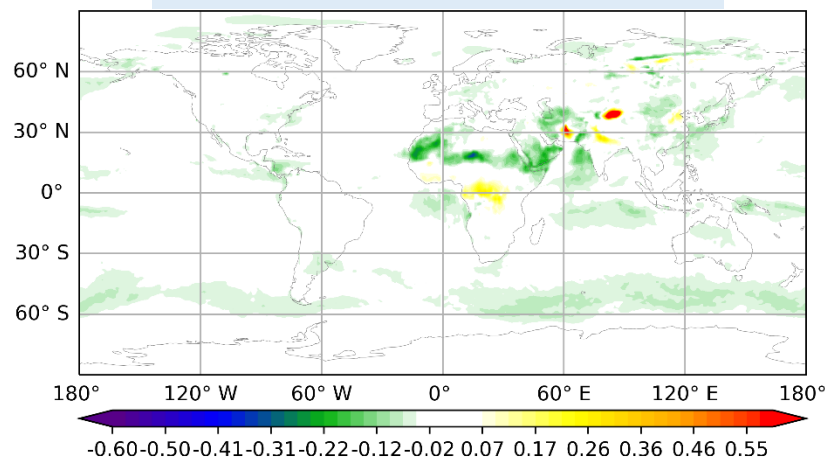
noDA AOD Biases against CAMS



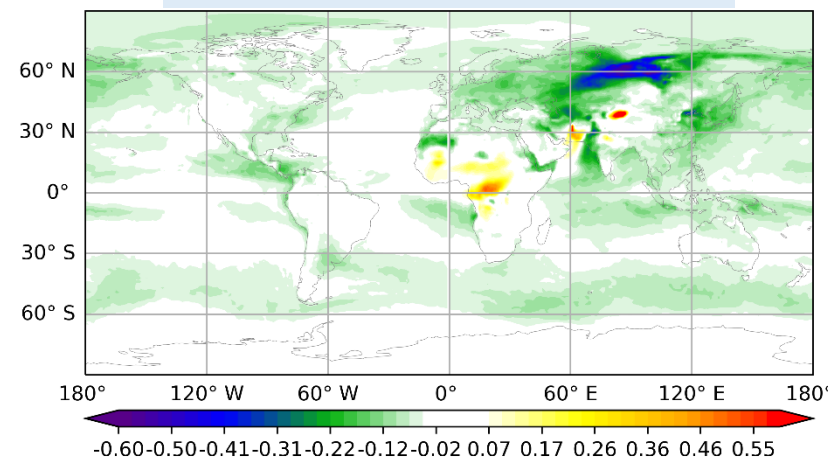
MERRA2 AOD



NARA-1 AOD Biases against MERRA-2



noDA AOD Biases against MERRA-2



To do this, we used NCO tools to split the MERRA-2 file into single-time file then run Series-Analysis.

Use of METplus for Global Aerosol forecast model (GEFS-Aerosols)

➤ Aerosol Optical Depth (AOD) forecasts from GEFS-Aerosols (at 0.25 deg. and grib2 format) will be verified (using Grid-Stat) against :

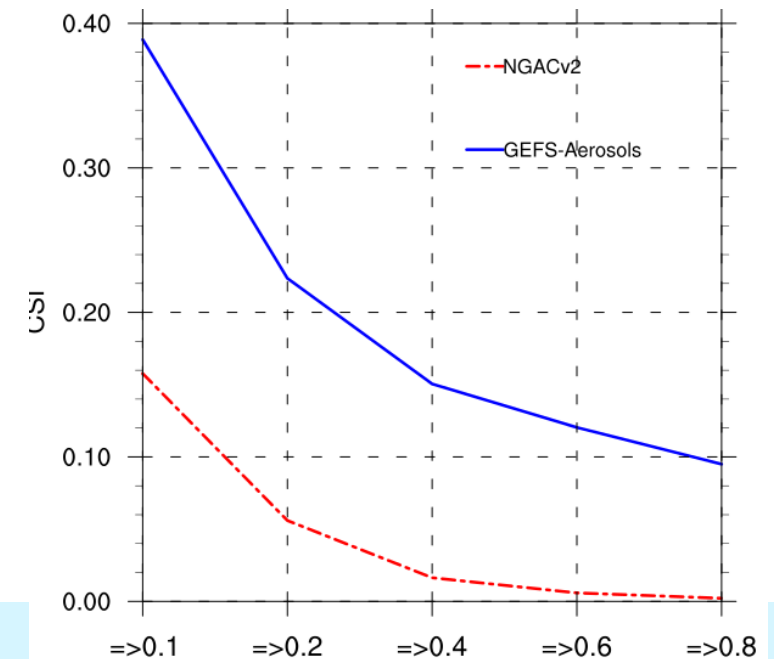
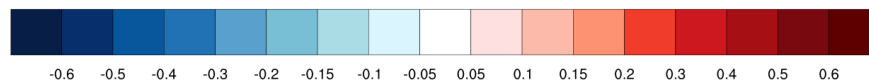
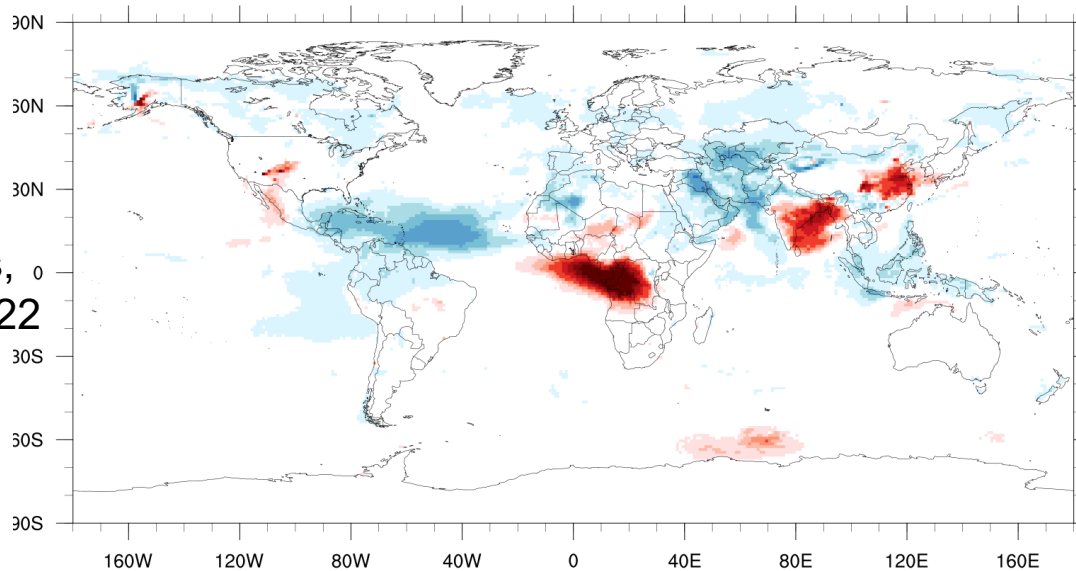
1. International Centers for Aerosol Predictions (ICAP-MME) model forecasts
2. NASA GEOS5 analysis of AOD species
3. Satellite measurement of AOD from NPP/VIIRS

➤ AOD and surface PM2.5 forecasts from GEFS-Aerosols will be verified (using Point-Stat) against :

1. AERONET measured AOD
2. EPA stations over CONUS

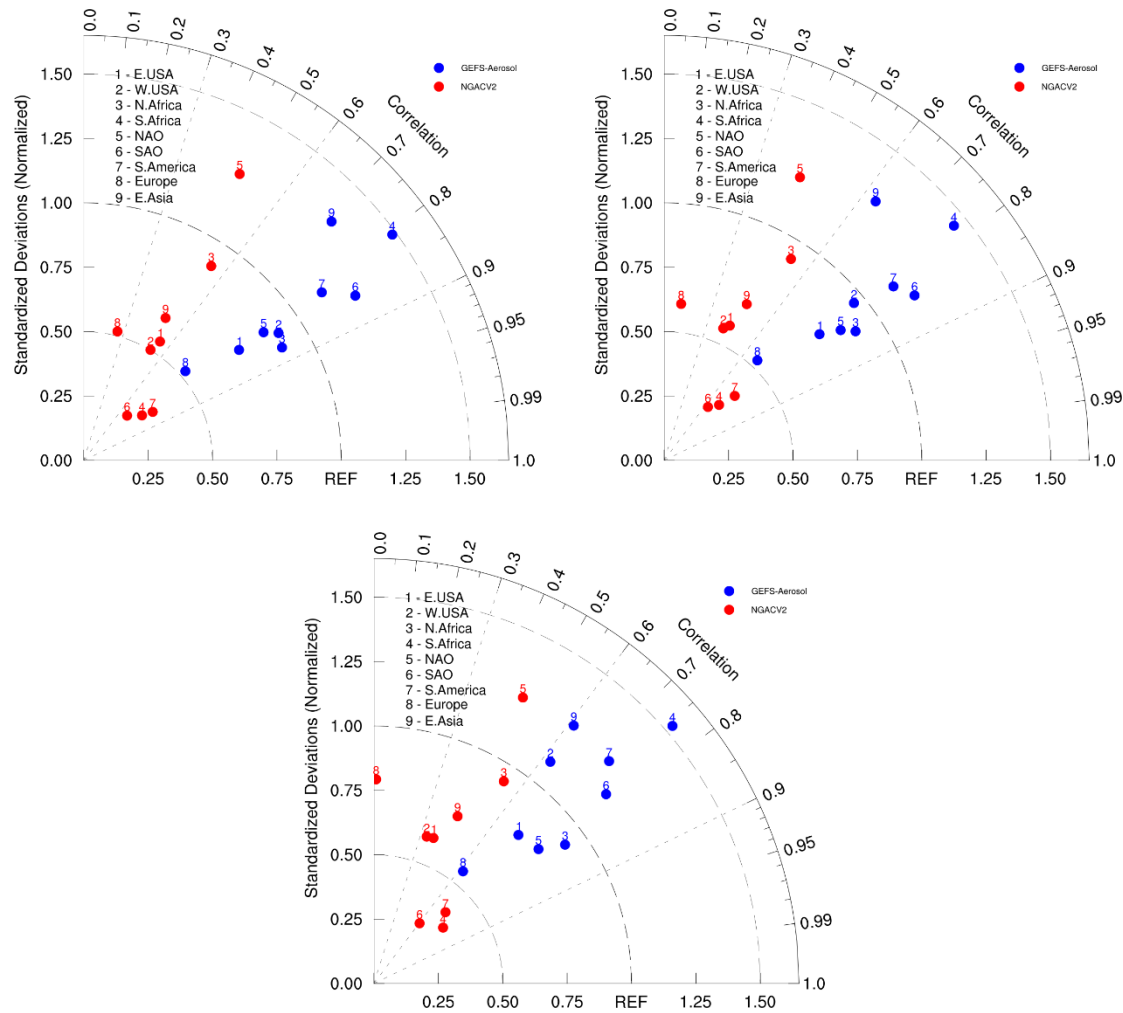
Slide courtesy of [Perry Shafran – EMC - 2022 METplus Users' Workshop](#)

GEFS-Aerosol
(Prod)
Vs ICAP
Total AOD Bias,
6-16th June, 2022

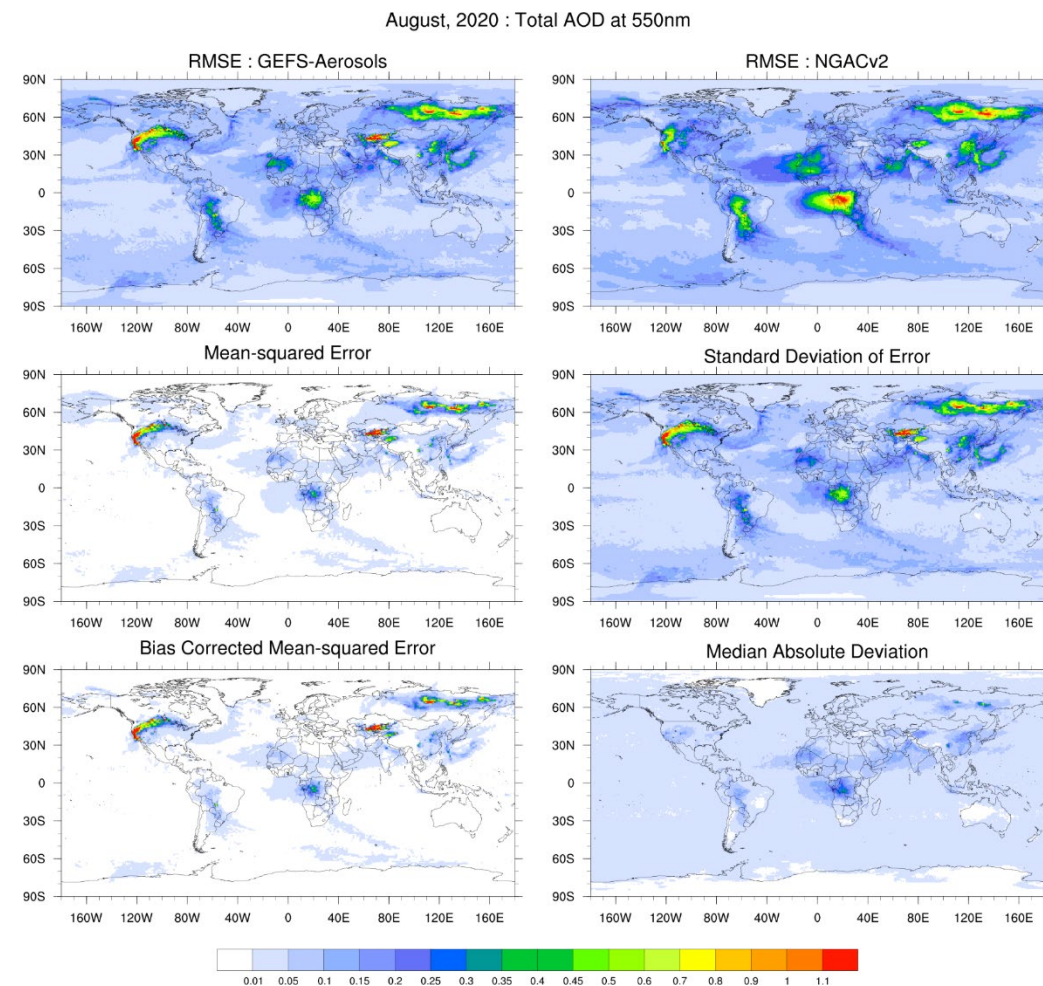


GEFS-Aerosol vs MERRA2 satellite

Taylor Diagrams



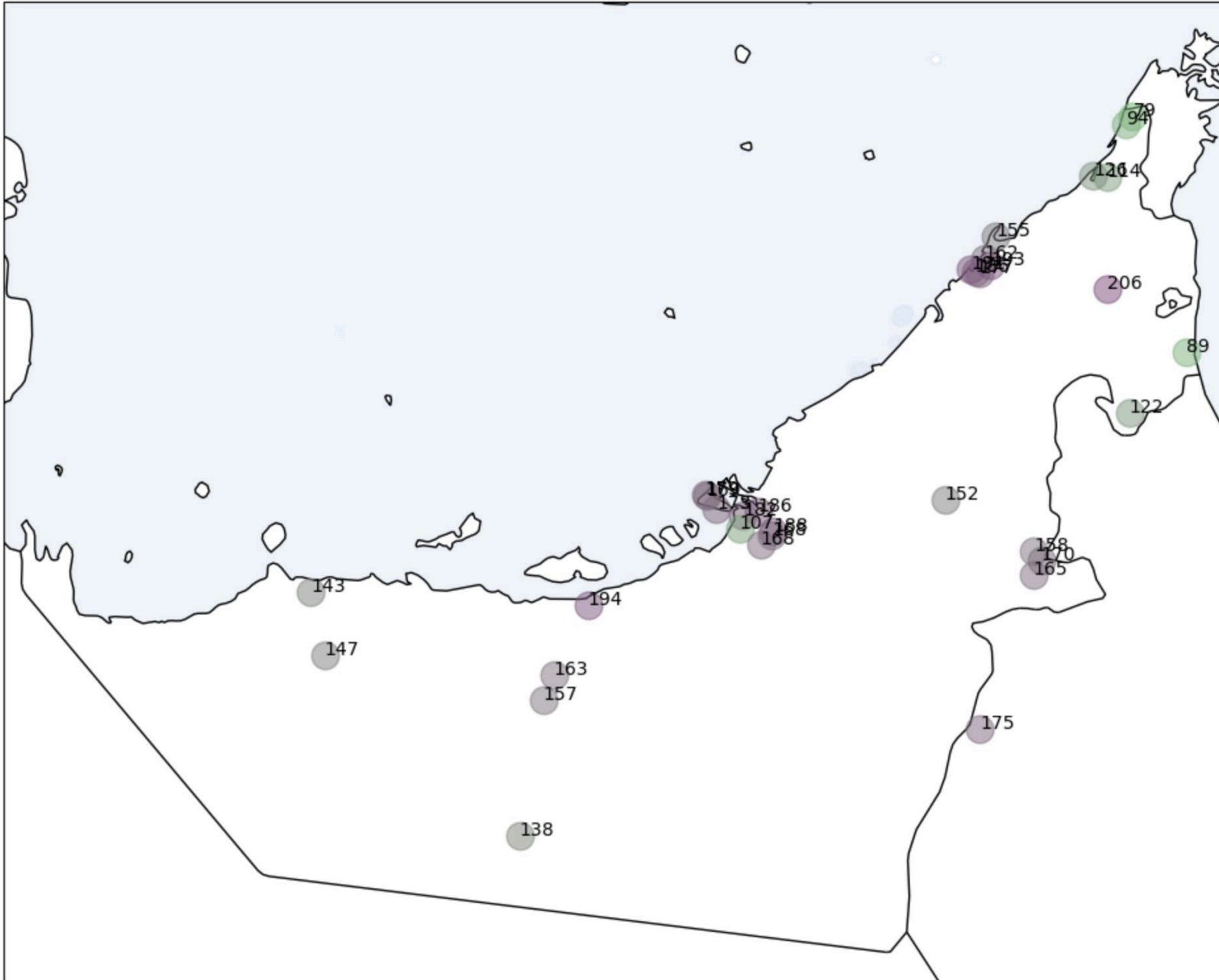
Horizontal error maps using Series-Analysis

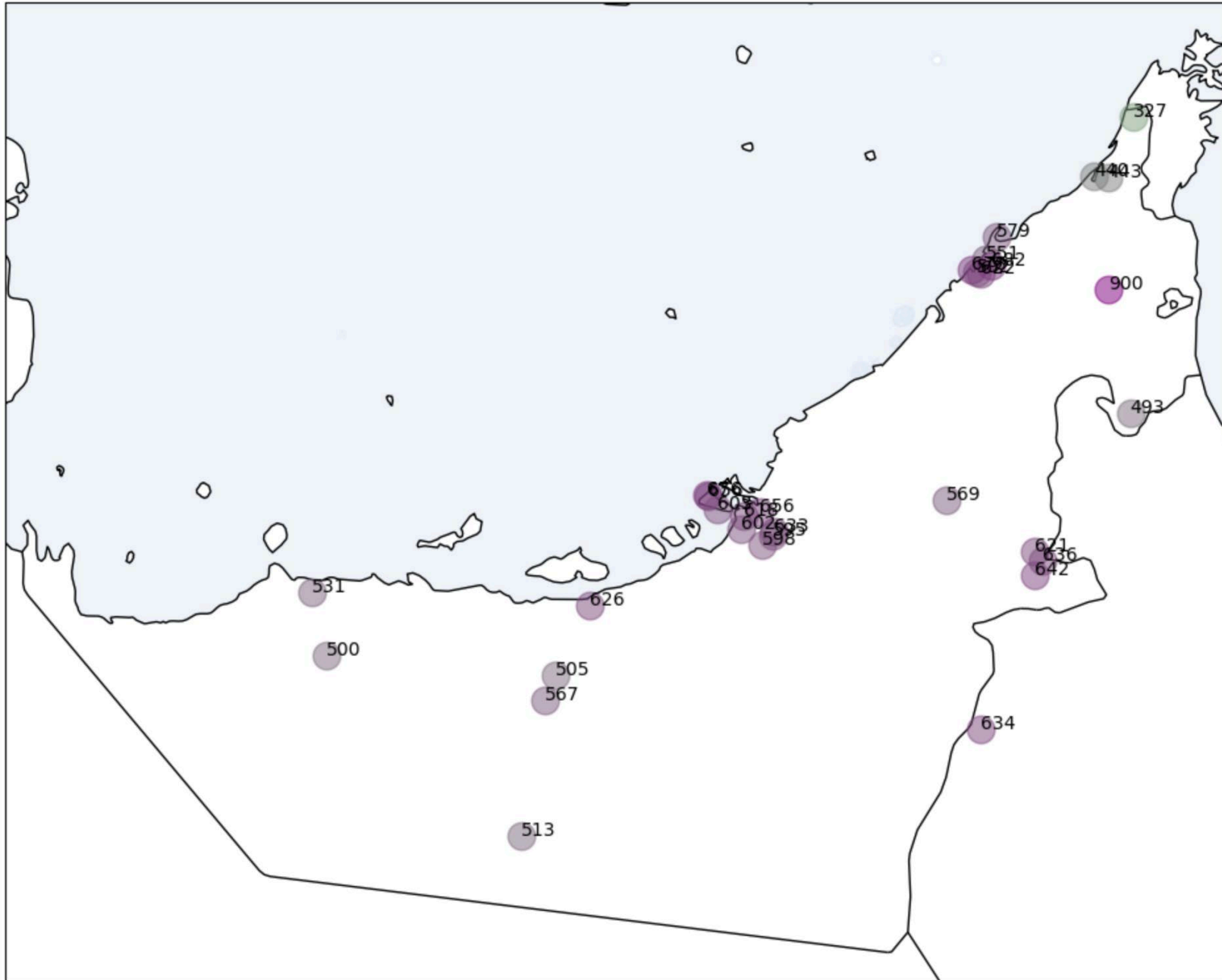


Slide courtesy of [Perry Shafran – EMC - 2022 METplus Users' Workshop](#)



PM 2.5 Bias ($\mu\text{g m}^3$)





PM 10 Bias ($\mu\text{g m}^{-3}$)

Some Advanced Techniques to Consider

High Resolution Analysis (HiRA)

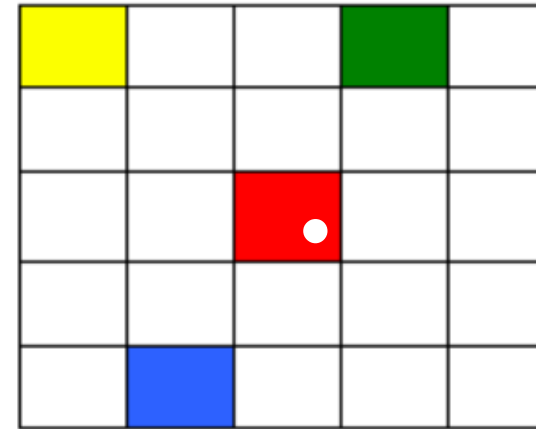


- *Collaboration with Met Office and USAF.*
- Enhance **Point-Stat** to apply the High Resolution Assessment (HiRA) verification logic to deterministic forecasts matched to point observations (Mittermaier, 2014)
- Process neighborhood values as an ensemble forecast (**ECNT** line type).
- Threshold, compute fractional coverage, and verify as a probability forecast (**PCT**, **PSTD**, **PRC**, and **PJC** line types).
- Allows for some spatial / temporal uncertainty by giving credit for being 'close'.
- Allows for comparison of deterministic and ensemble forecasts via the same set of probabilistic statistics.
- Also allows for comparison of models with different grid resolutions via adjustment of neighborhood size.

Model Forecast

White boxes = 0

Colored boxes > 0



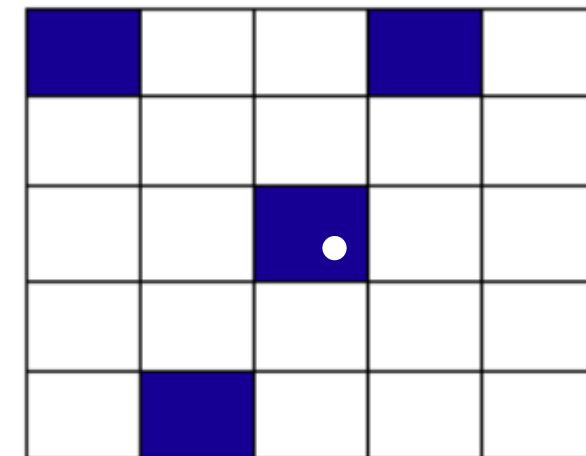
Threshold Forecast

Blue boxes = event

cat_thresh = [>0];

HiRA Probabilities:

- 1x1 NBRHD = 1/1
- 3x3 NBRHD = 1/9
- 5x5 NBRHD = 4/25

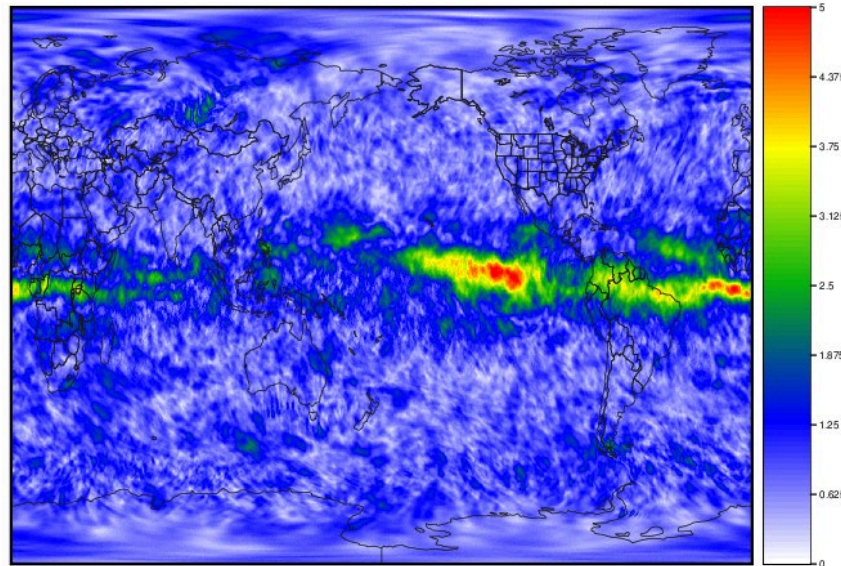


AF: Non-Traditional Validation Methods

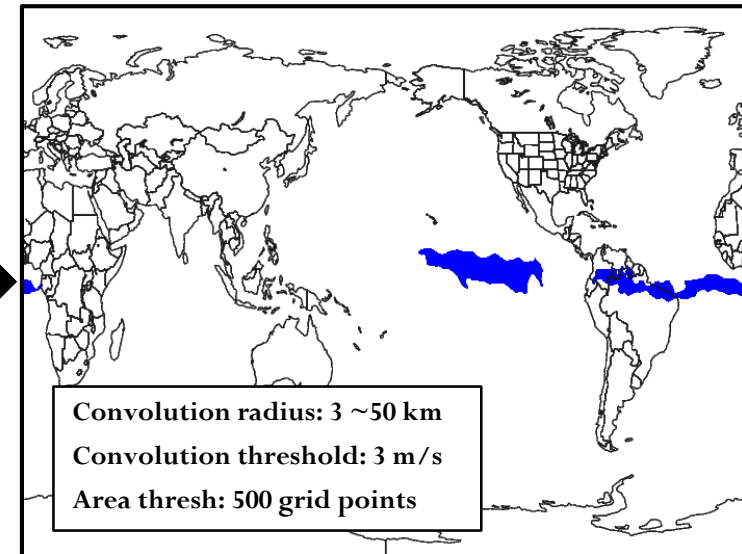


- MODE is used to automate identifying objects in the model difference field, based on user-specified thresholds

Aggregated RMS Differences
U-Wind Component at 10 hPa
18-24 April 2019 00 UTC Inits at F00

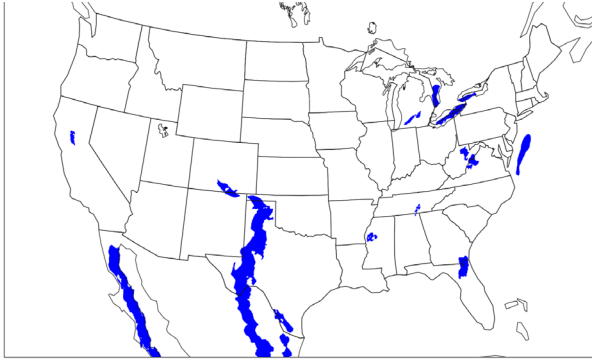


Identified MODE objects (blue)

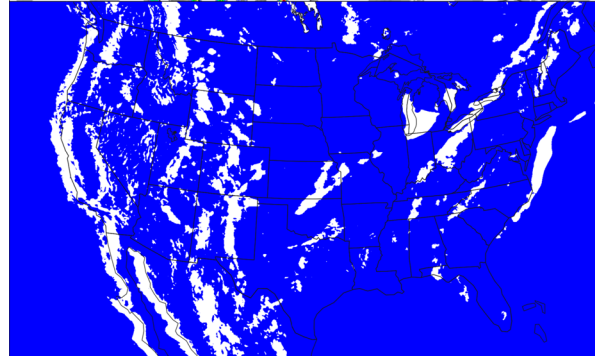


New Research – Multivariate MODE

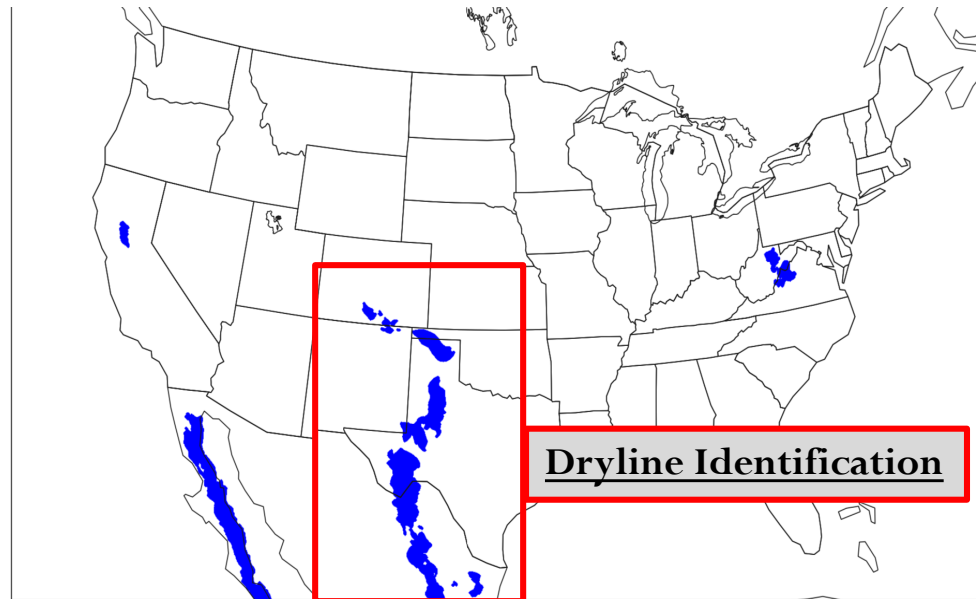
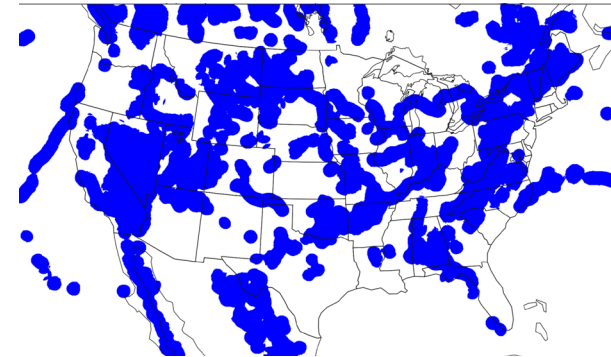
Specific Humidity Gradient



Temperature Gradient



10-m wind direction shift



User's Python Script

Dryline Identification

Contributed by Lindsay Blank

International Collaboration and Resources

- Weekly to Monthly meetings between core contributors: NCAR, NOAA, Met Office, NRL, US Air Force
- Governance meetings every 6 weeks
- Growing online training video library
- Contributors guides for all METplus components
- Open repositories
 - Development Issues in GitHub
 - Pull Requests
 - Continuous Integration
 - Cybersecurity Screening
 - Sample Data



METplus: <https://github.com/dtcenter/METplus>
MET: <https://github.com/dtcenter/MET>
METviewer : <https://github.com/dtcenter/METviewer>
METexpress: <https://github.com/dtcenter/METviewer>
METcalcpy: <https://github.com/dtcenter/METcalcpy>
METplotpy: <https://github.com/dtcenter/METplotpy>

METplus
main_v4.0

Search docs

METPLUS WRAPPERS GUIDES

- User's Guide
 - 1. Overview
 - 2. Software Installation
 - 3. System Configuration
 - 4. Python Wrappers
 - 5. METplus Use Cases**
 - 5.1. MET tools
 - 5.2. Model Applications
 - 5.2.1. Air Quality and Composition
 - 5.2.2. Climate
 - 5.2.3. Convection Allowing Models
 - 5.2.4. Cryosphere
 - 5.2.5. Data Assimilation
 - 5.2.6. Marine and Coastal
 - 5.2.7. Medium Range
 - 5.2.8. Precipitation
 - 5.2.9. Subseasonal to Seasonal**
 - 5.2.10. Space Weather
 - 5.2.11. Tropical Cyclone and Extra Tropical Cyclone
 - 6. METplus Quick Search for Use Cases
 - 7. METplus Configuration Glossary
 - 8. References

User's Guide and Getting Help

https://metplus.readthedocs.io/en/latest/Users_Guide/

5.2.9. Subseasonal to Seasonal

Subseasonal-to-Seasonal model configurations; Lower resolution model configurations (>4km) usually producing forecasts out beyond 14 days and up 1 year

TCGen: Genesis Density Function (GDF) and Track Density Function (TDF)

Grid-Stat and Series-Analysis: BMKG APIK Seasonal Forecast

UserScript: Make a Hovmoeller plot

UserScript: Make a Cross Spectra plot

Blocking Calculation: RegridDataPlane, PcpCombine, and Blocking python code

Blocking Calculation: RegridDataPlane, PcpCombine, and Blocking python code

WeatherRegime Calculation: RegridDataPlane, PcpCombine, and WeatherRegime python code

<https://github.com/dtcenter/METplus/discussions>

dtcenter / METplus

Unwatch 21 Star 58 Fork 20

Code Issues 108 Pull requests 1 Discussions Actions Projects 4 Wiki

Announcements Welcome to the METplus Components Discu... jprestop

Announcements Resources for Troubleshooting jprestop

Search all discussions New Top: All - Answered Unanswered Label - New discussion

Categories View all

- Announcements
- Configuration
- Existing Builds
- File I/O
- General
- Incoming
- Installation
- Plot Generation
- Statistical Computation
- Use Cases

Most helpful Last 30 days

- JohnHalleyGotway 5
- jprestop 3
- TatianaBurek 2
- j-opatz 2
- georgemccabe 1

Community guidelines metplus.readthedocs.io

Beta Give feedback

- METplus-4.1.0-beta1 georgemccabe announced 4 hours ago in Announcements
- Comparing different months from same database METviewer: Plotting PerryShafran-NOAA asked 2 days ago in Plot Generation - Answered 9
- Confidence intervals for scores from aggregate_stat job for GridStat output. AnastasiaBundel asked yesterday in Statistical Computation - Unanswered
- Converting netCDF to GRIB2 JohnWagner asked yesterday in File I/O - Unanswered
- Using IMERG data for observations in MODE MET: Feature Verification MET: Python Embedding rvalenzuelar asked 3 days ago in File I/O - Answered 2
- Unit change of each files in config MET: Configuration MET: Masking Deba57 asked 3 days ago in Configuration - Unanswered 8
- Obs_Quality flags MET: Configuration robdarvell asked 4 days ago in Configuration - Answered 2
- BUFR in Met-9.1.3 MET: PreProcessing Tools (Point) METplus 4.1 Coordinated Release AnastasiaBundel asked 10 days ago in File I/O - Answered 12
- Looping by valid time with METplus TCPairs METplus: Configuration METplus: Tropical/Extra-Tropical Cyclone mollysmith-noaa asked 16 days ago in Configuration - Answered 3
- point-stat usage on new use case MET: Grid-to-Point Verification YakelynRJ asked 10 days ago in Use Cases - Answered 2

METplus Training Series and Workshop

<https://dtcenter.org/events/2021/metplus-training-series>

The image is a collage of three overlapping web pages from the Developmental Testbed Center (DTC) website. The top-left page is titled "METPLUS TRAINING SERIES" and features a sunset background. It includes a navigation menu with "ABOUT", "TESTING + EVALUATION", "COMMUNITY CODE", "VISITOR PROGRAM", "NEWS", and "EVENTS". Below the header, it says "NOV 30 2021 - MAY 1 2022" and has "View" and "Edit" buttons. The text describes a tutorial series starting on Tuesday, November 30, 2021, at 9am MST. The top-middle page is titled "2022 DTC METPLUS WORKSHOP" and also features a sunset background. It includes the same navigation menu and says "JUN 27 2022 | 8:30AM - JUN 29 2022 | 12:30PM" with "View" and "Edit" buttons. The text is titled "Calling All METplus Enthusiasts!" and describes a workshop for building the METplus community. The bottom-right page is a video player for "METplus Training Series - 2021-2022, Session 3". It has a play button and a "Watch Later" button. Below the video, it says "Presented by the METplus Team" and "NCAR/RAL, NOAA/GSL, and Developmental Testbed Center". At the bottom, there are logos for NOAA, NCAR, DTC, UFS, and other partners.

<https://dtcenter.org/events/2022/2022-dtc-metplus-workshop>

Thank You for Your Attention

- Tara Jensen, NCAR, jensen@ucar.edu
- <https://dtcenter.org/community-code/metplus>



Advanced METplus Training Series

Targeting Feb-May 2023

Sign up for more info on DTC Website at:

<https://dtcenter.org/community-code/metplus/sign-metplus-updates>

DTC Visitor Program: <https://dtcenter.org/visitor-program>

METplus