METplus

The Long and Winding Road to Unified Verification

Tara Jensen

NCAR/RAL and DTC

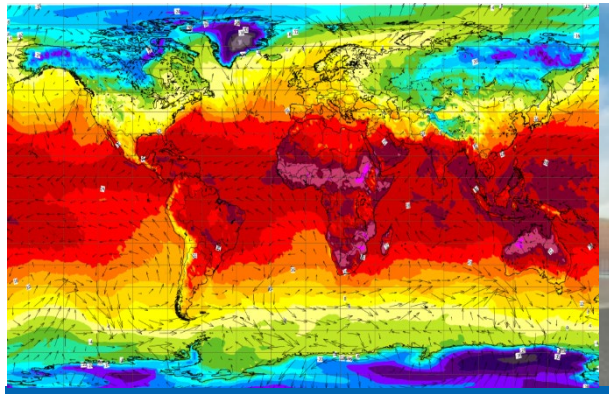
9 Nov 2023

Workshop on Correctness and Reproducibility for Climate and Weather Software

DTC Developmental Testbed Center

Why Unified Verification?

Forecasters



Operational Centers

Universities and National Laboratories

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

METplus

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

METplus Team and Core Collaborators

- Management:
  - Tara Jensen[1], Molly Smith[2], Bonny Strong[2], Matt Wandishin[2]
- MET Engineering:
  - John Halley Gotway[1], Howard Soh[1], Dave Albo[1] , Randy Bullock[1], Seth Linden[1],
- METplus Engineering:
  - George McCabe[1], Julie Prestopnik[1]
- METplus Analysis Suite Engineering:
  METviewer, METexpress, METdataio, METcalcpy, METplotpy
  - Tatiana Burek[1], Minna Win-Gildenmeister[1], Hank Fisher[1], Molly Smith[2], Randy Pierce[2]
- Atmospheric Science:
  - Tara Jensen[1], John Opatz[1], Dan Adriaansen[1], Tina Kalb[1], Jonathan Vigh[1], Jason English[2], Jeff Hamilton[2], Mrinal Biswas[1],
- Statistics:
  - Eric Gilleland[1], Barb Brown[1]

- EMC
  - Jason Levit, Alicia Bently, Mallory Row, Perry Shafran, ***and the rest of VPPPG Branch***
- Met Office
- Air Force
- Naval Research Lab
- Community
  - **UFS Verification and Validation Cross Cutting Team**
  - Other NCEP Centers: WPC, CPC, SWPC, SPC, OPC, NCO
  - NOAA Labs: GSL, PSL, MDL, ARL
  - NCAR and UCAR: RAL, MMM, CGD, ACOM, COMET
  - Universities and Cooperative Institutes: UW CIMMS, CSU CIRA, CU CIRES, George Mason University, SUNY Albany, SUNY Stony Brook, Embry Riddle U, University of Illinois Urbana Champagne, University of Miami
  - Private: AER, SPIRE

1. NCAR/RAL and DTC 2. NOAA/GSL and DTC

METplus History

Goals

- Develop a model/forecast verification package that can be used across the community
- Replicate core capability of EMC VSDB package. This was completed in 2015

2004 – MET idea formed
2008 - First Release of MET

2009 - METviewer dev started

2015 - Selected as verification package for NOAA Unified Forecast System

2016 – METplus Wrappers dev started

2017 – EMC starts developing Global workflow using METplus on WCOSS

2019 – METplus Analysis and Diagnostic Tools dev started

2021 – METplus wrappers accepted for install on WCOSS

2023 – All components accepted for install on NOAA WCOSS2

Challenge: Extending core capability in a way that is useful to scientists without refactoring every 5 years

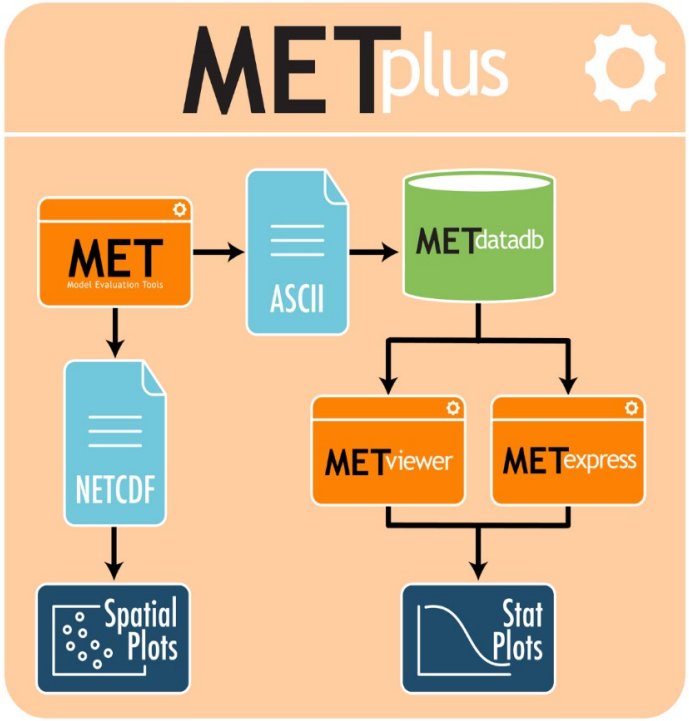
Current METplus Code Base
C++
Fortran
Python – limited libraries

What is METplus?

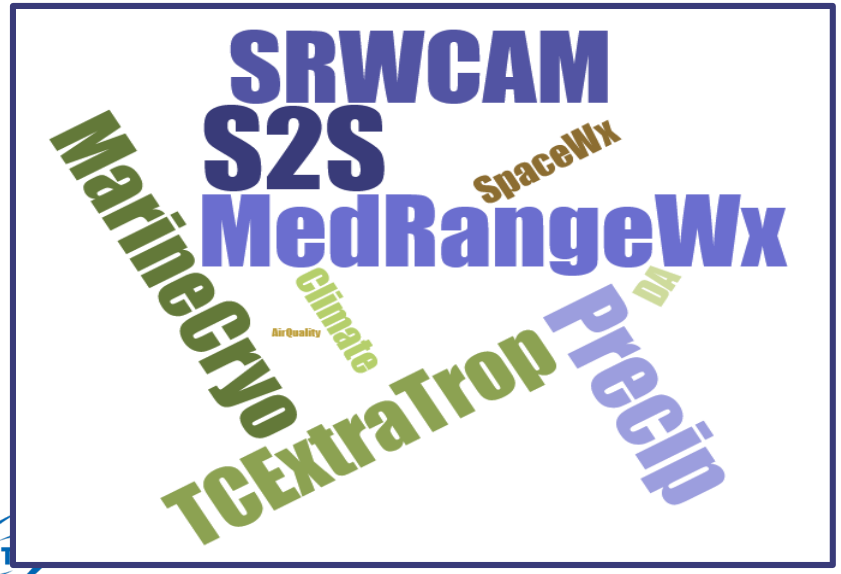
Suite of Python wrappers around

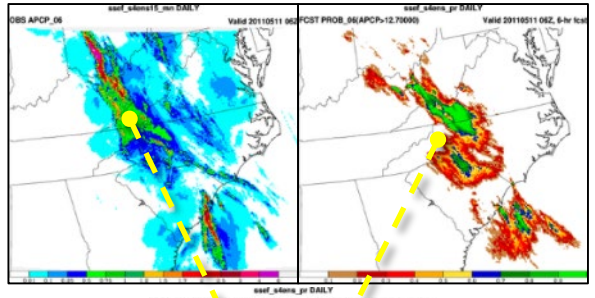
- MET (core)
- Analysis Tools
  - METviewer/METexpress User Interface
  - METviewer Batch Engine
  - Python-based Diagnostics and Plotting
- Communication between MET & python algorithms
- Using manage_externals to connect repos

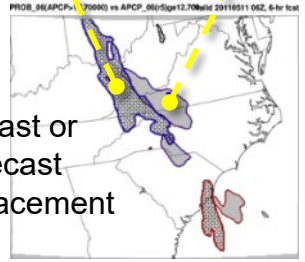
- Over 150 traditional statistics and diagnostic methods for both point and gridded datasets
- 15 interpolation methods
- Mix of C++, Fortran, Python – language driven by operational reqs
- Developed to allow for easy sharing of config files for reproducible results
- 3500+ users; US and Int'l



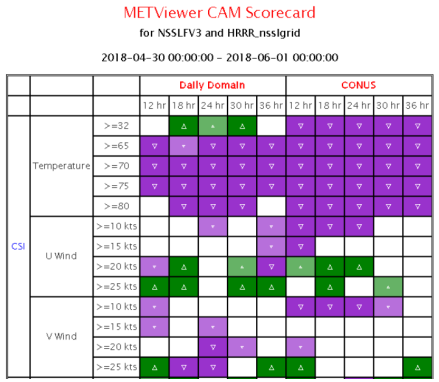
METplus Examples/Use-Case In Development

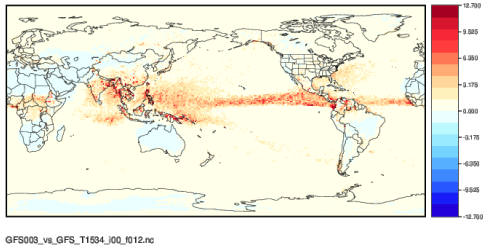


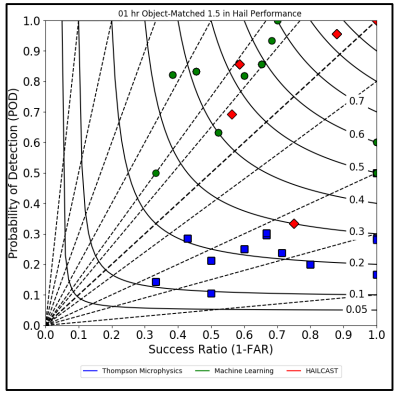




Bad forecast or Good forecast with displacement error?

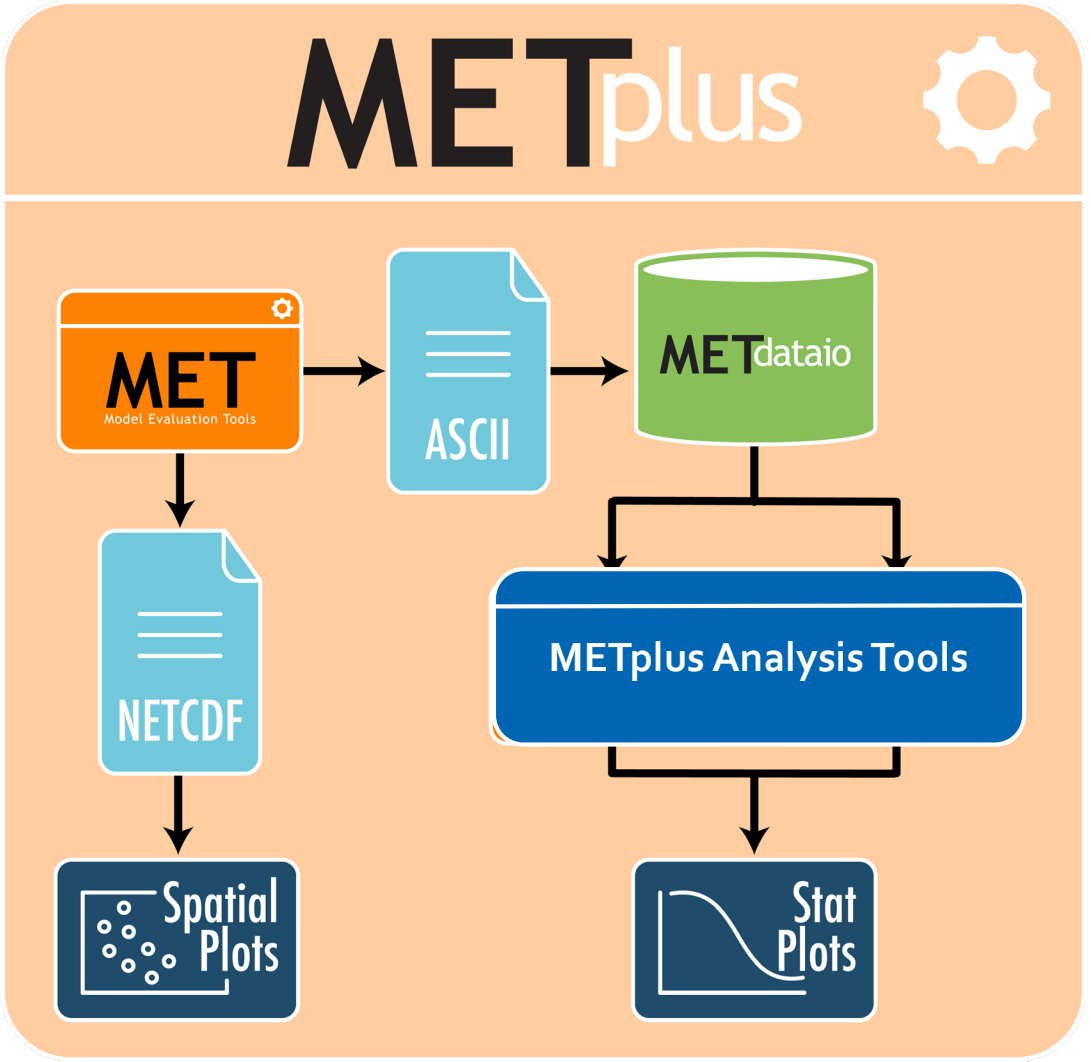






METplus – A Layered System

- **Wrappers** – around core MET statistics tools - represented by black arrows – low level workflow
- **MET** – suite of statistical and diagnostic tools
- **Analysis Tools** – available for advanced analysis includes
  - METviewer user interface
  - METexpress user interface
  - METdataio, METcalcpy, METplotpy Python components

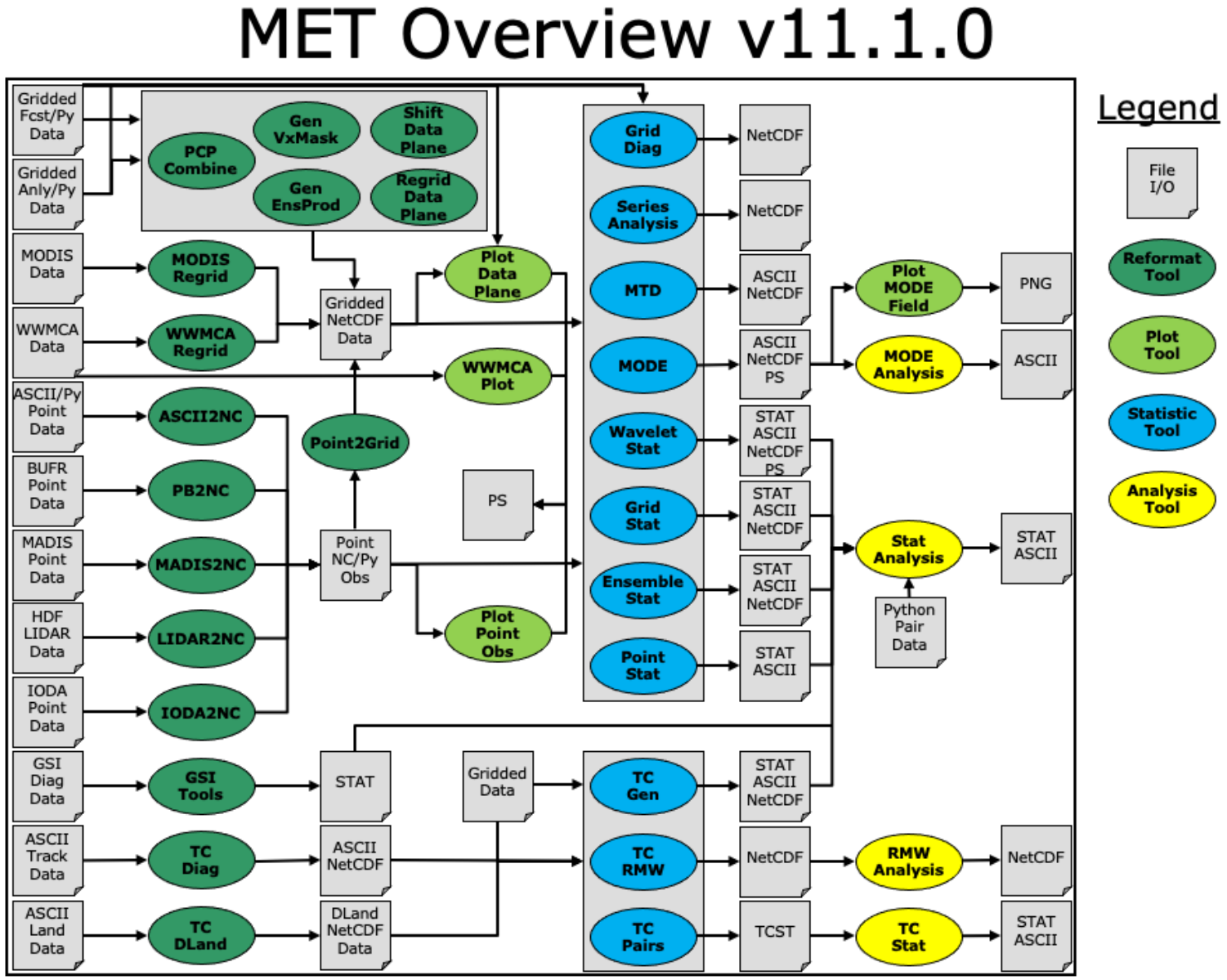


- Version 5.1 released Aug 1st

Core MET Tools

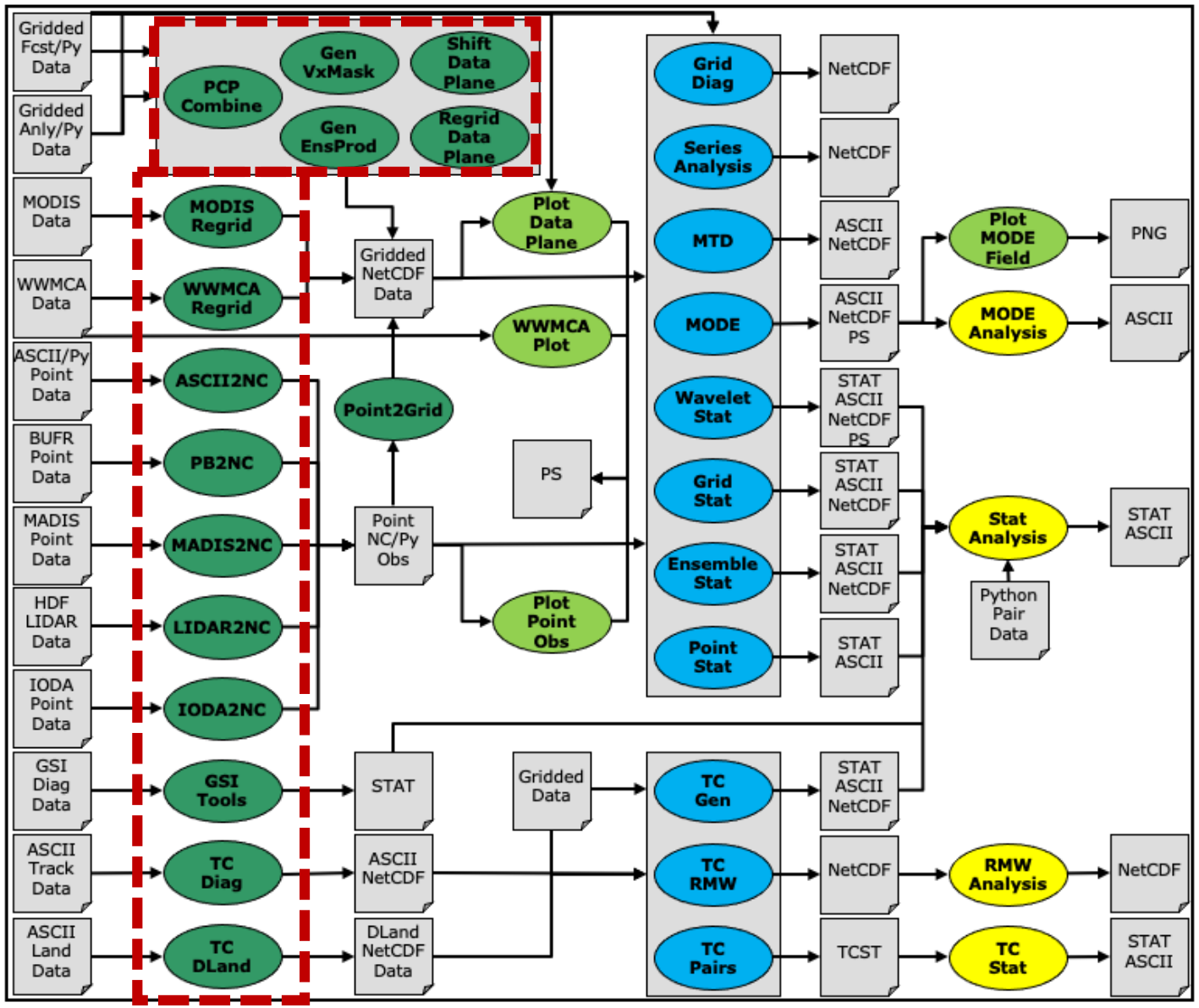
- **MET** – suite of statistical and diagnostic tools
- Reformatting tools
- Data Inspection tools
- Statistical tools
- Analysis tools

- Traditional grid-to-grid and grid-to-point statistics
- Ensemble statistics
- Spatial methods
- TC methods

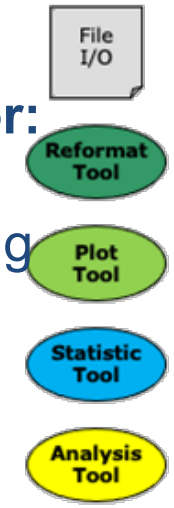


Tools for **Preprocessing**

MET Overview v11.1.0



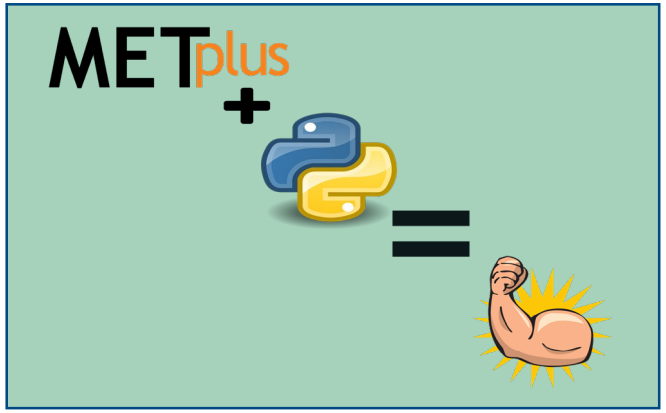
Legend



Includes tools for:

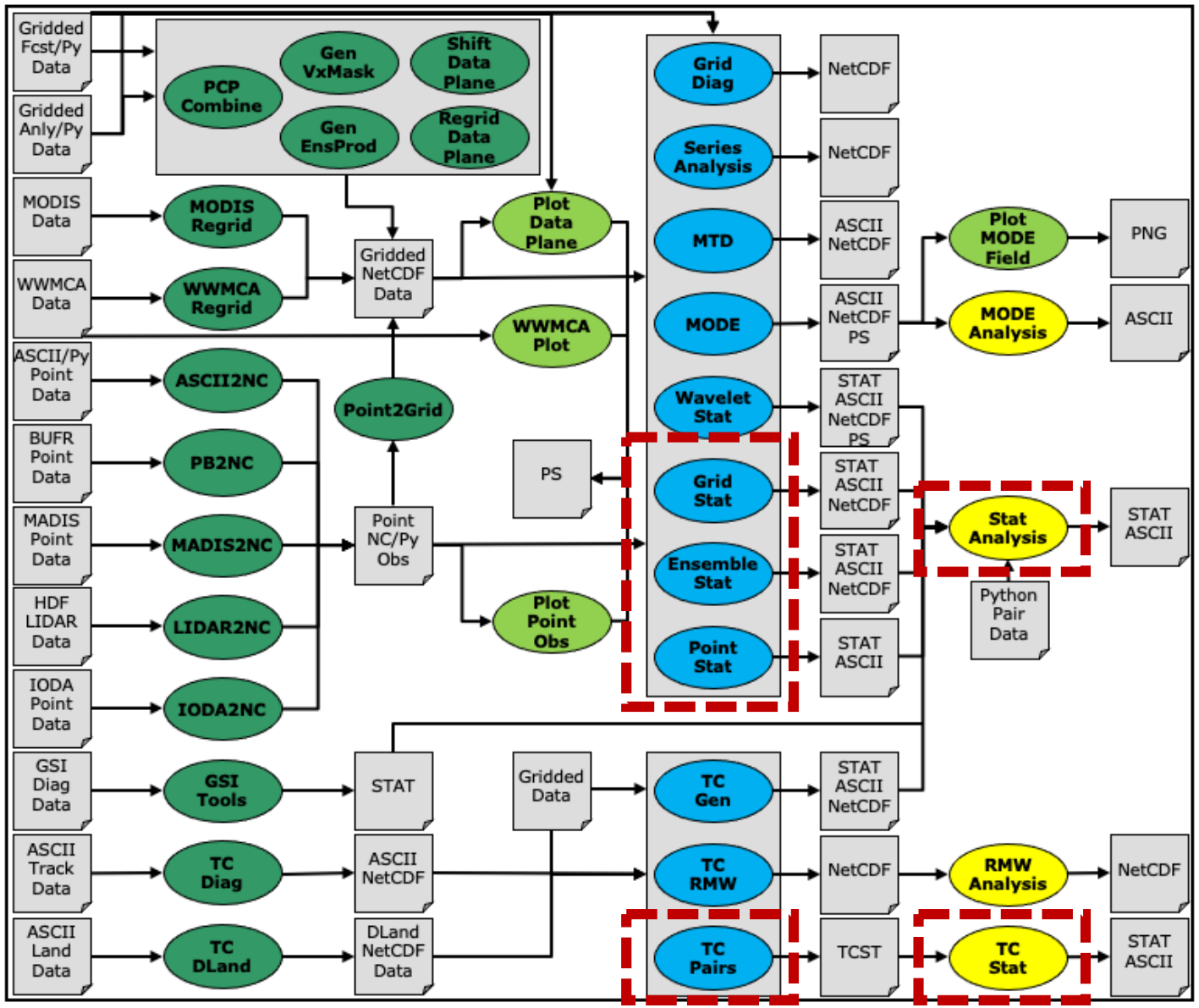
- Reformatting
- Quick look plotting
- Statistics computation
- Analysis

PythonEmbedding



Tools for **Standard Statistics**

MET Overview v11.1.0



Legend

- File I/O
- Reformat Tool
- Plot Tool
- Statistic Tool
- Analysis Tool

Includes tools for:

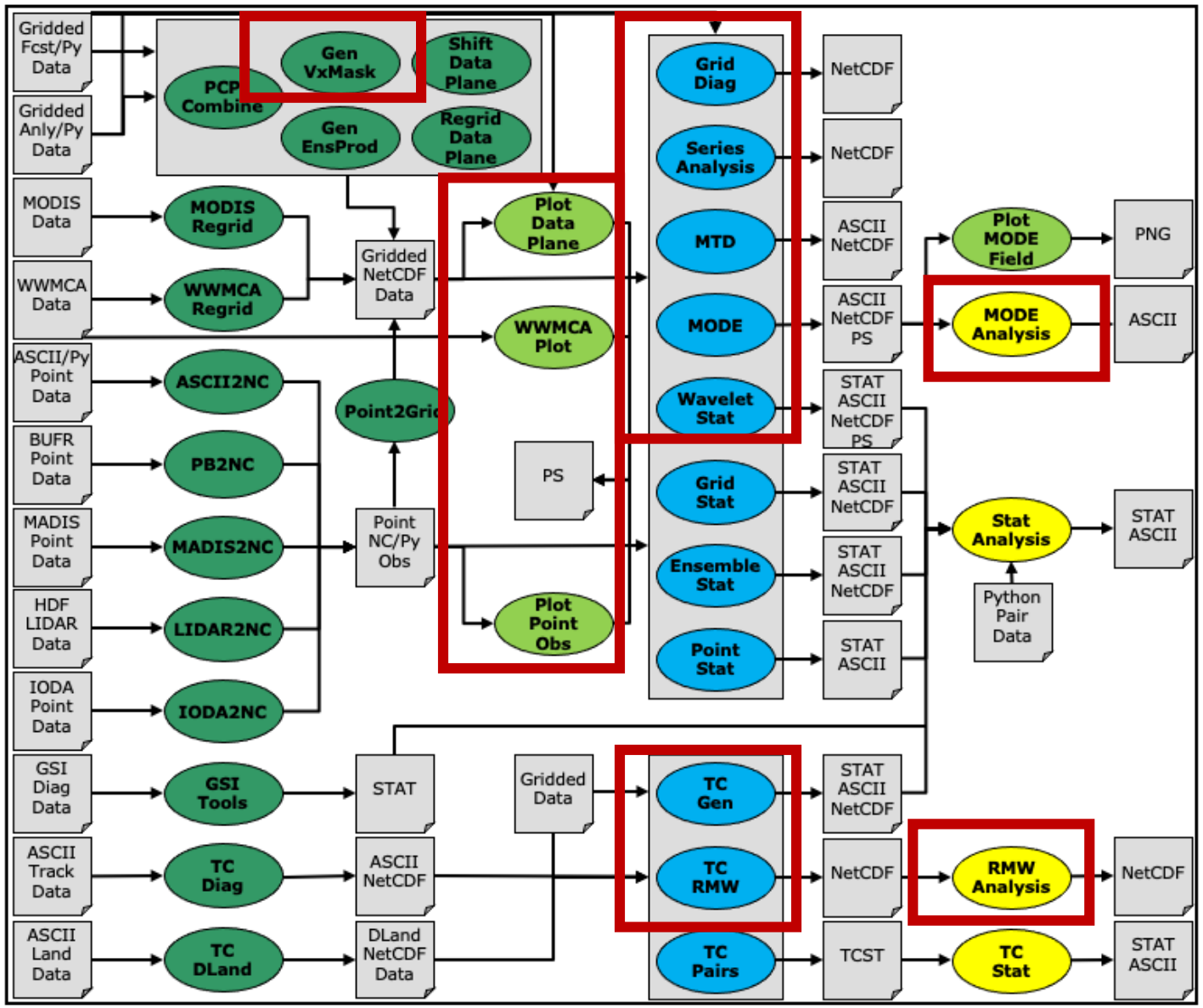
- Reformatting
- Quick look plotting
- Statistics computation
- Analysis

METviewer

METexpress

Tools for **Diagnostics**

MET Overview v11.1.0



Legend

File I/O

Reformat Tool

Plot Tool

Statistic Tool

Analysis Tool

Includes tools for:

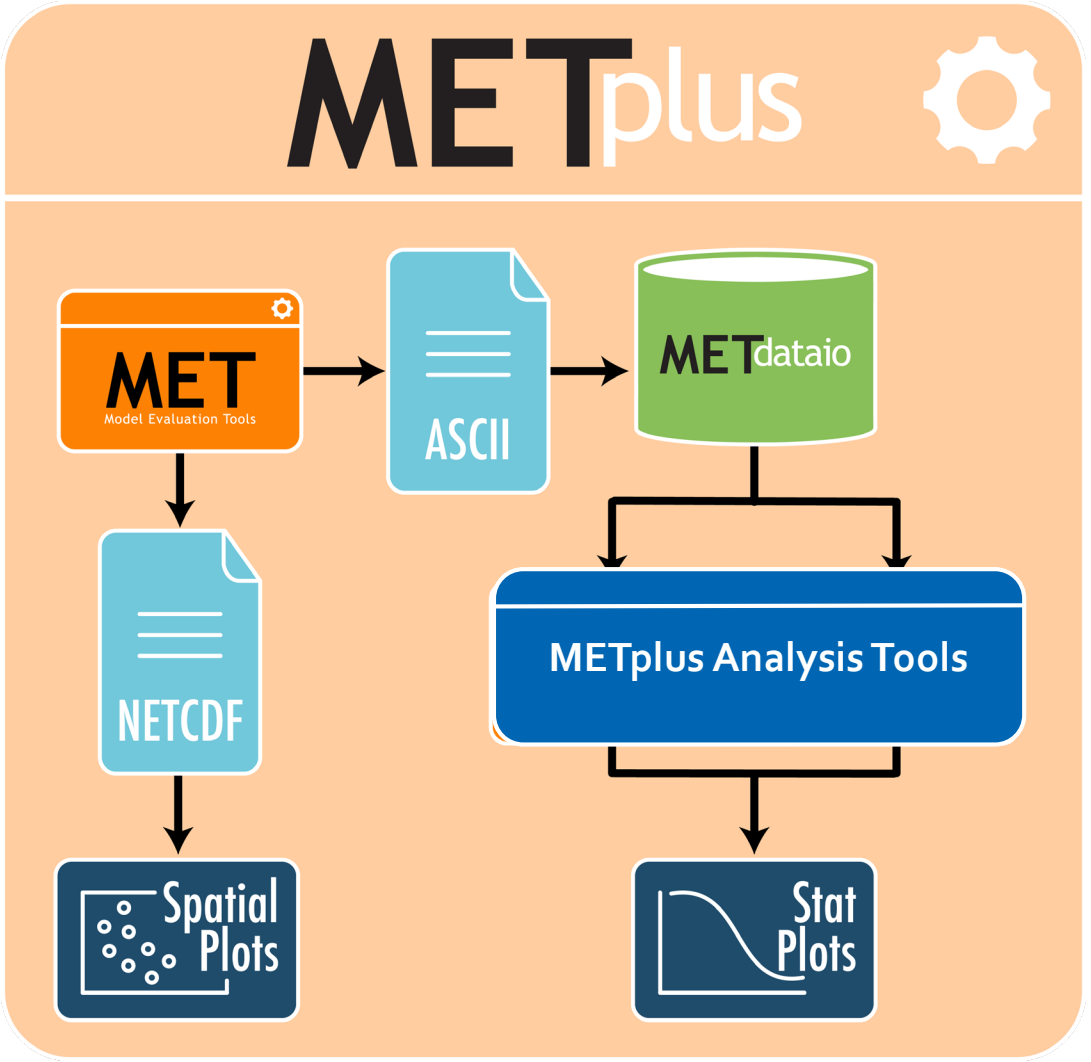
- Reformatting
- Quick look plotting
- Statistics computation
- Analysis

METcalcpy

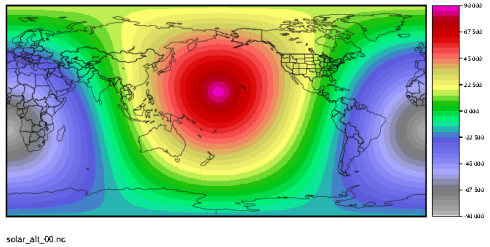
METplotpy

METplus Components

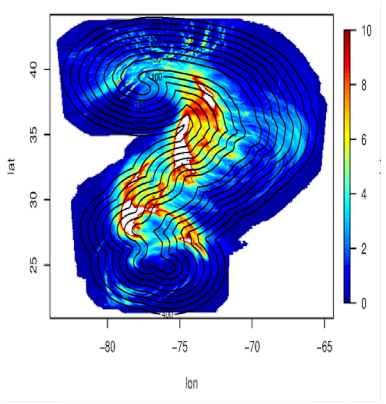
- **Wrappers** - represented by black arrows – low level workflow
- **MET** – suite of statistical and diagnostic tools
- **Analysis Tools** – available for advanced analysis includes
  - METviewer and METexpress user interface
  - METdataio, METcalcpy, METplotpy Python components
- Work in progress to allow for command line use of analysis tools

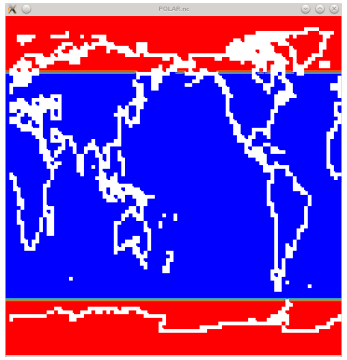


Reproducible Statistics and Methods



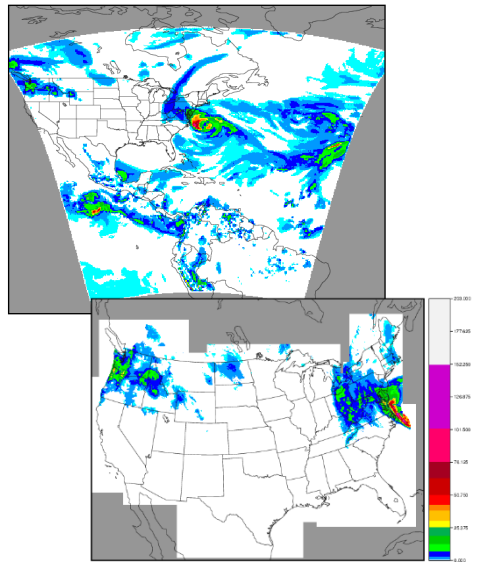
Masking

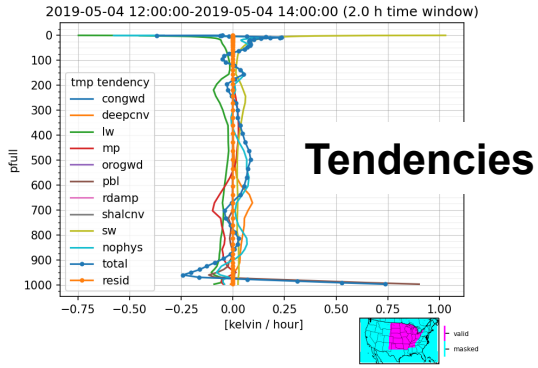




Traditional	
Grid-Stat, Point-Stat, Series-Analysis *Contingency table statistics (CTS)* *Continuous statistics* *Probability forecast statistics* *Confidence intervals*	**Ensemble-Stat** *CRPS, CRPSS* *Rank prob., Prob. Integral Transform (PIT), and Relative Position histograms* *Spread/Skill* *Ignorance*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

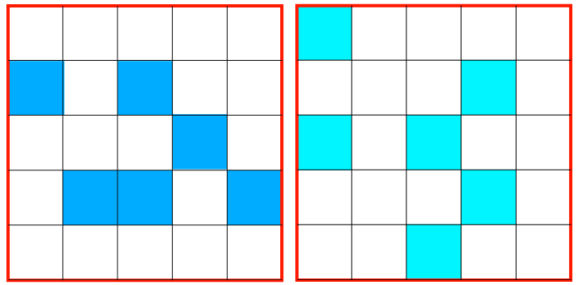
Auto Regridding





Tendencies

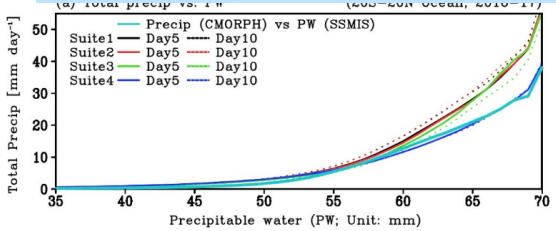
Neighborhood Methods

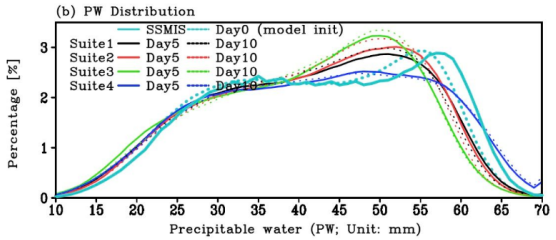


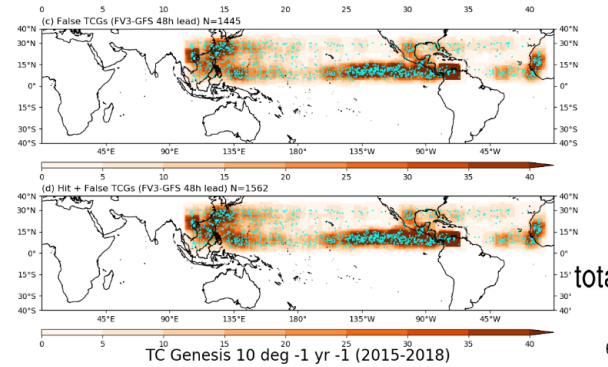
Fraction = 6/25 = 0.24 Fraction = 6/25 = 0.24

Examples of Community Contributions

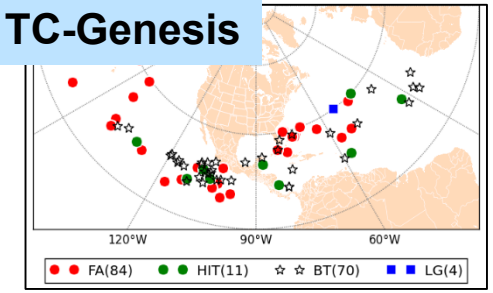
S2S Multivariate Distributions



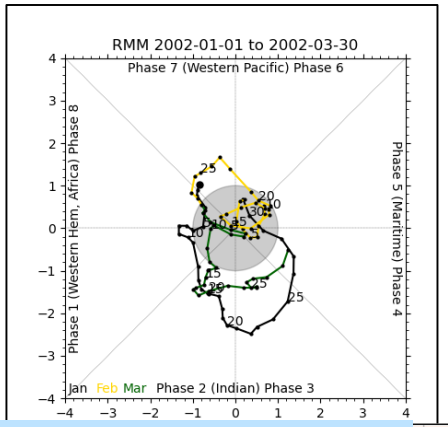


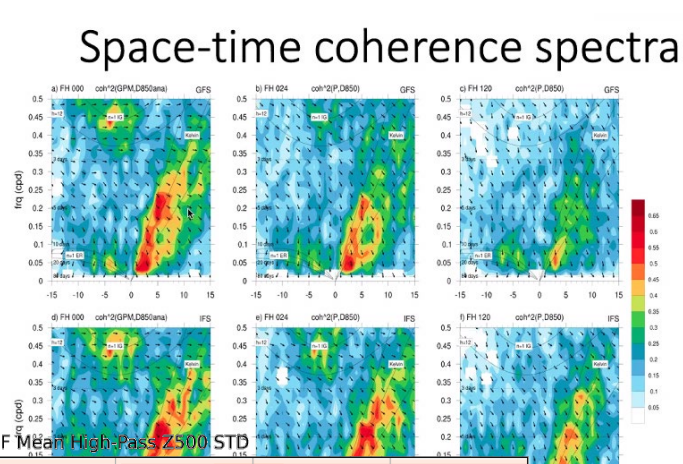


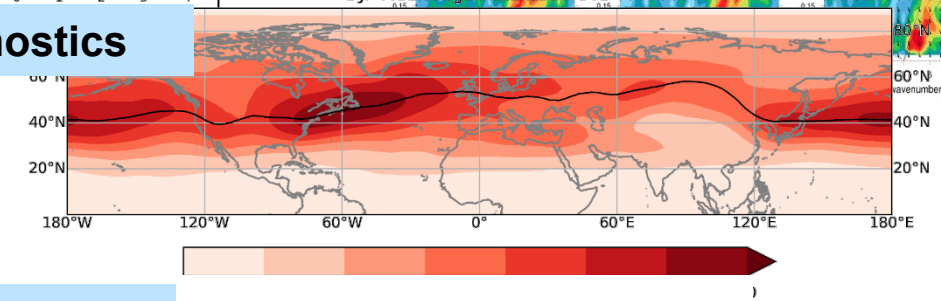
S2S TC-Genesis

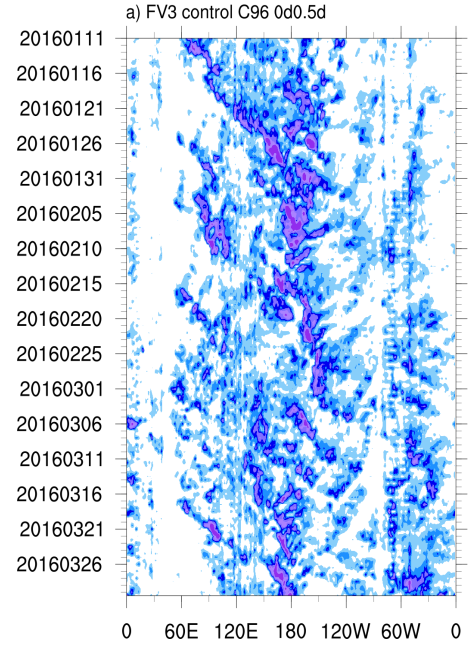


S2S Diagnostics

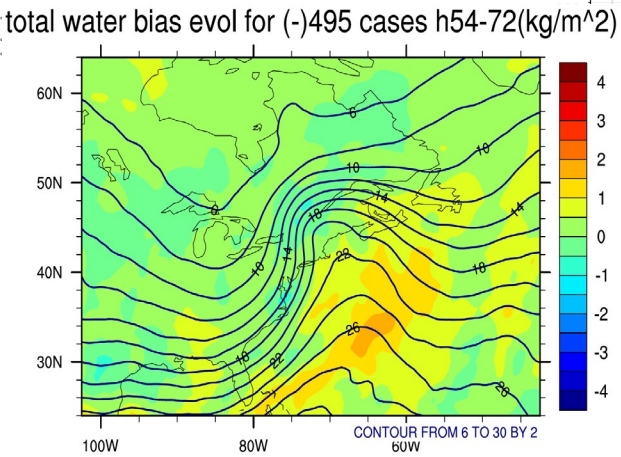


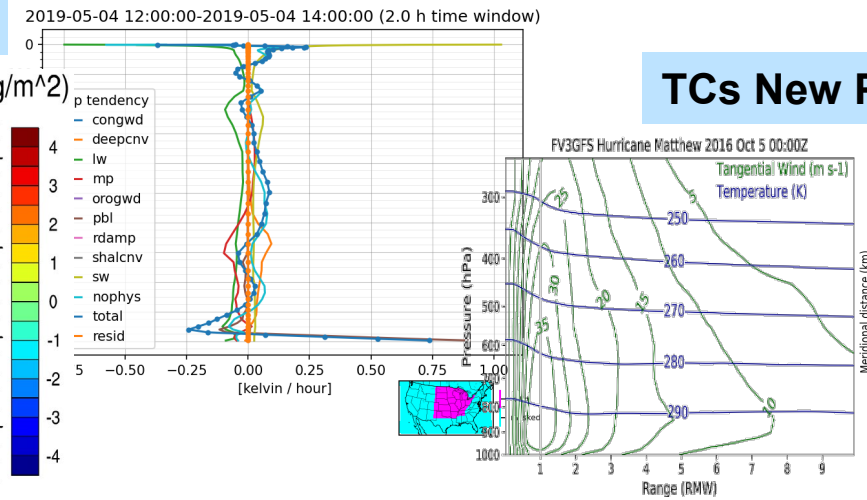




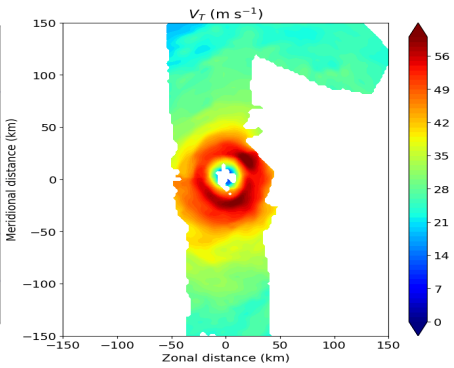


Systematic Errors



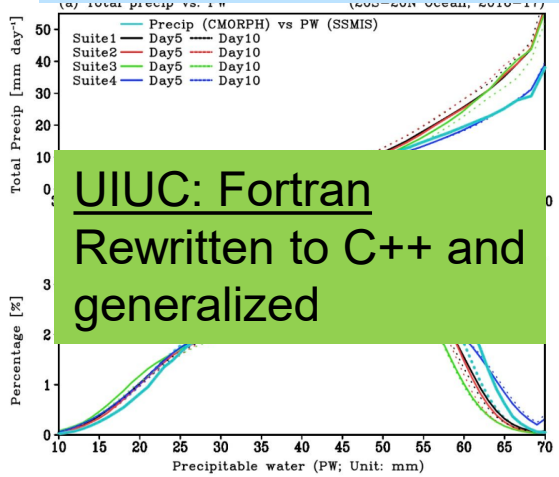


TCs New Projections and Obs

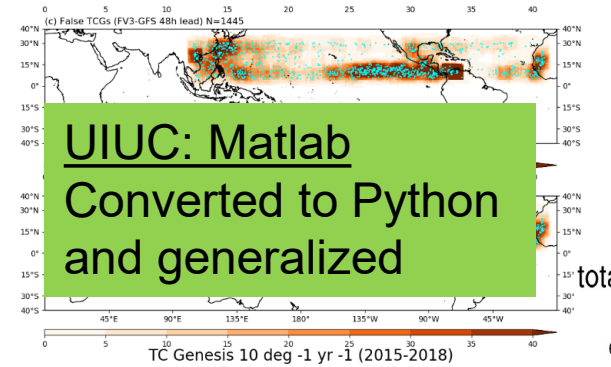


Examples of Community Contributions

S2S Multivariate Distributions

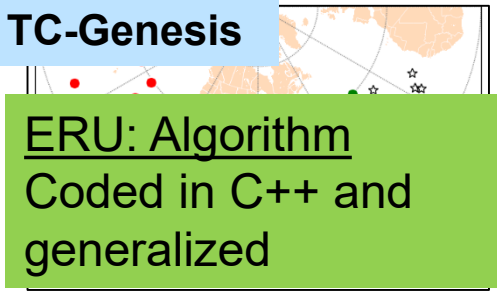


UIUC: Fortran
Rewritten to C++ and generalized



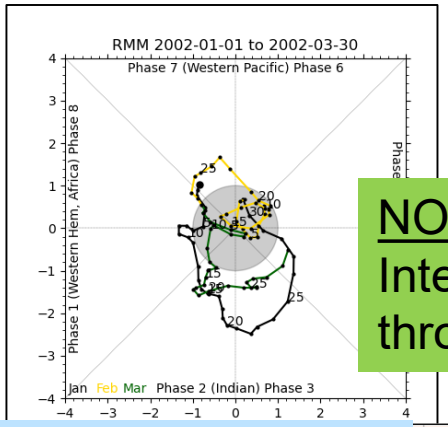
UIUC: Matlab
Converted to Python and generalized

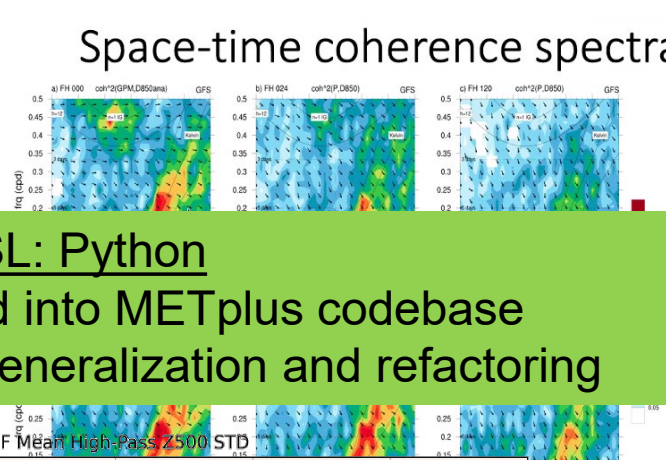
S2S TC-Genesis



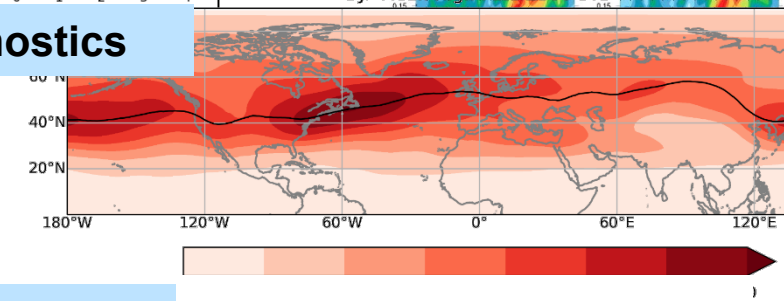
ERU: Algorithm
Coded in C++ and generalized

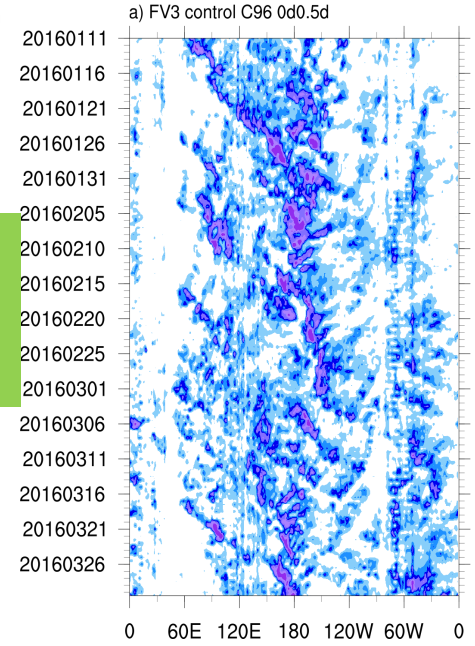
S2S Diagnostics



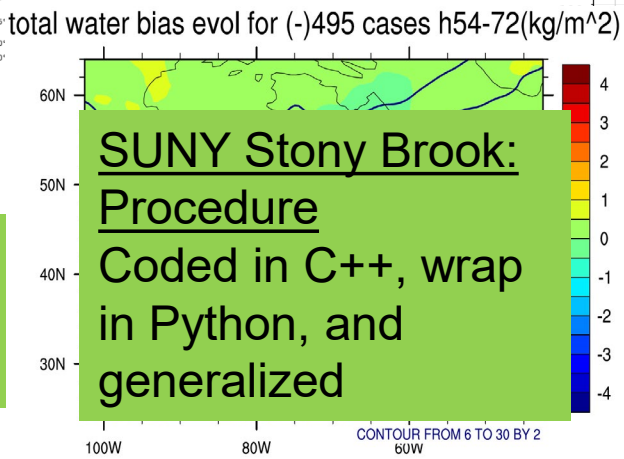


NOAA PSL: Python
Integrated into METplus codebase through generalization and refactoring

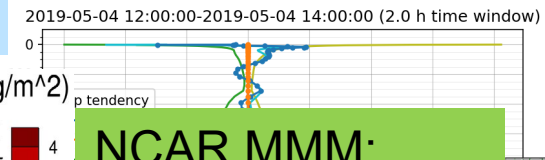




Systematic Errors

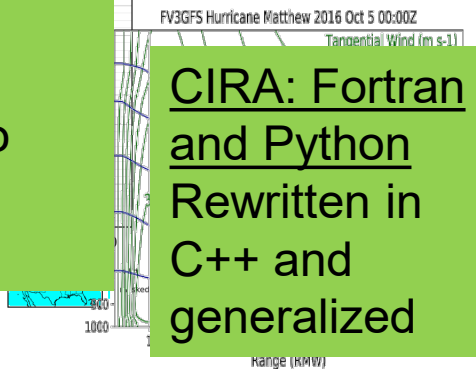


SUNY Stony Brook: Procedure
Coded in C++, wrap in Python, and generalized

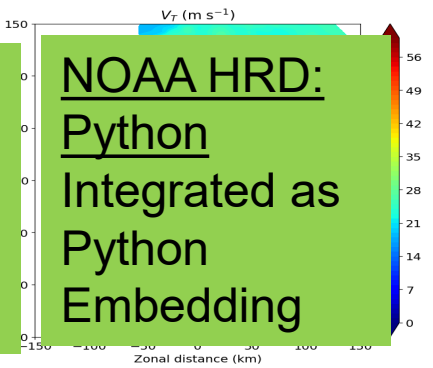


NCAR MMM: Python
Integrated into METplus codebase

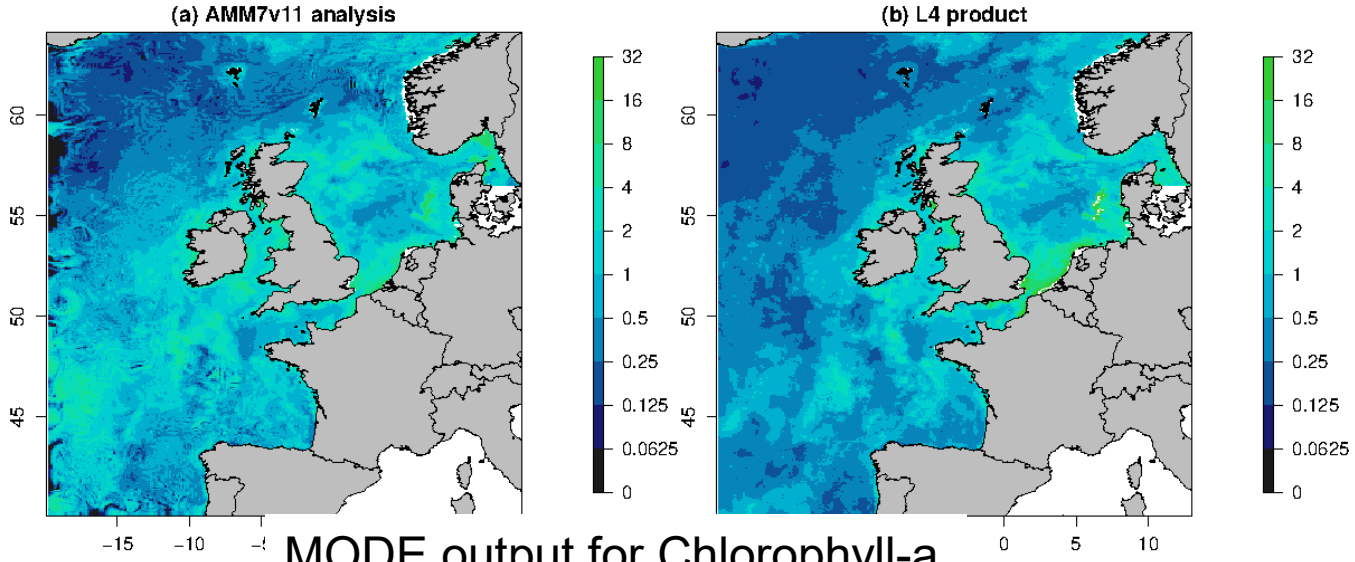
TCs New Projections and Obs



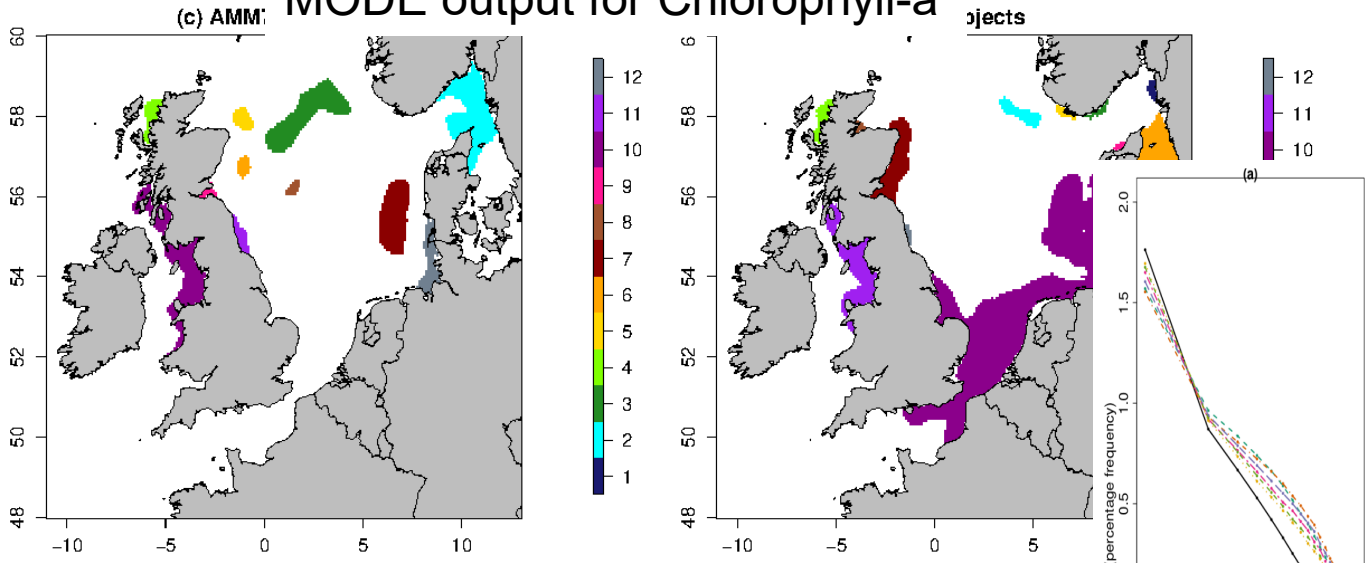
CIRA: Fortran and Python
Rewritten in C++ and generalized



NOAA HRD: Python
Integrated as Python Embedding

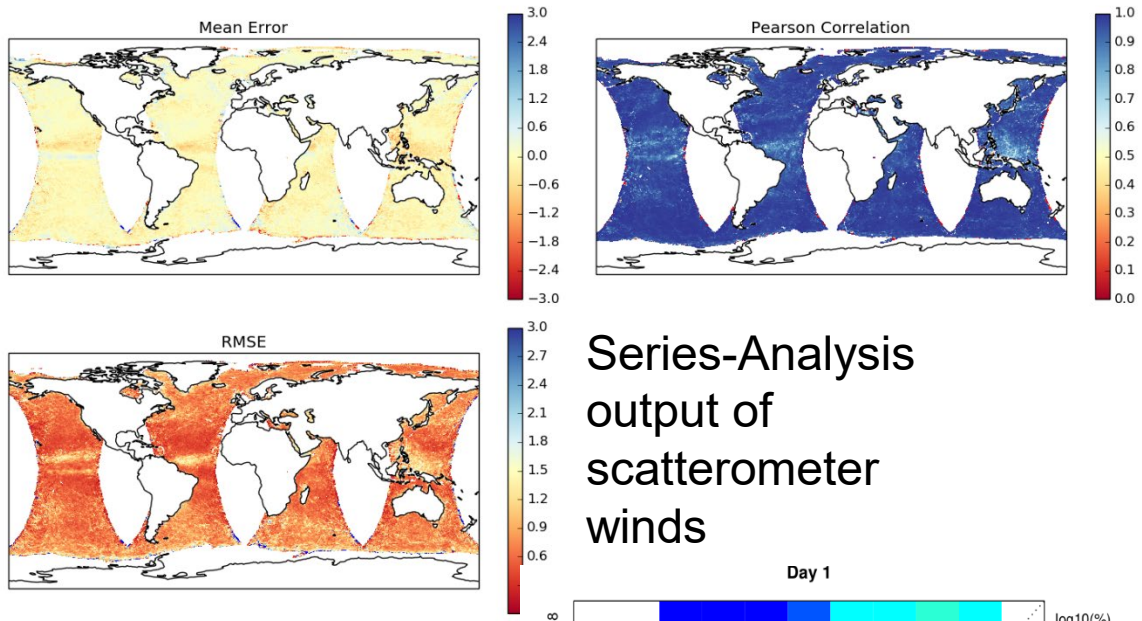


MODE output for Chlorophyll-a



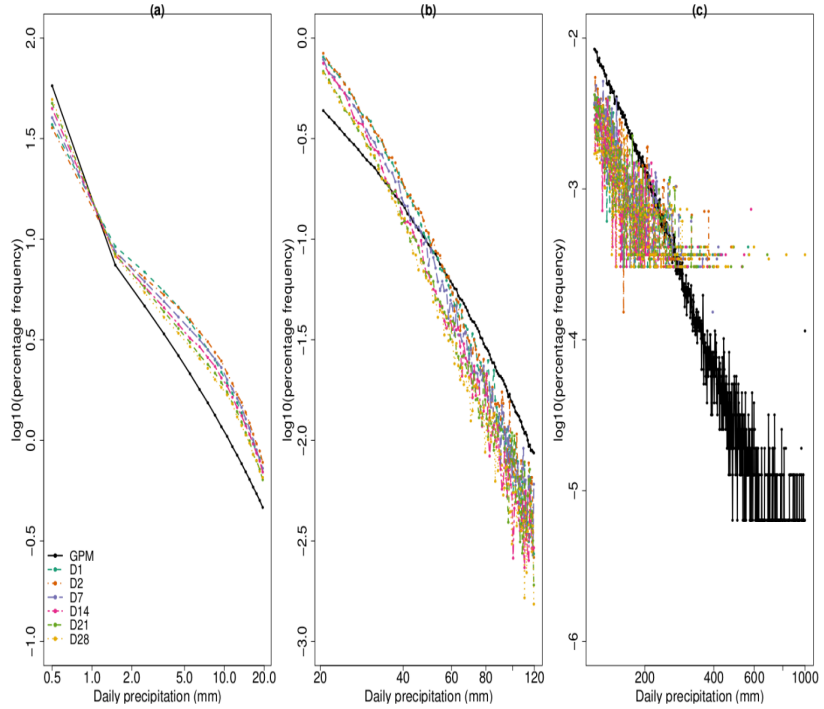
Mittermaier et al. 2021, Ocean Science

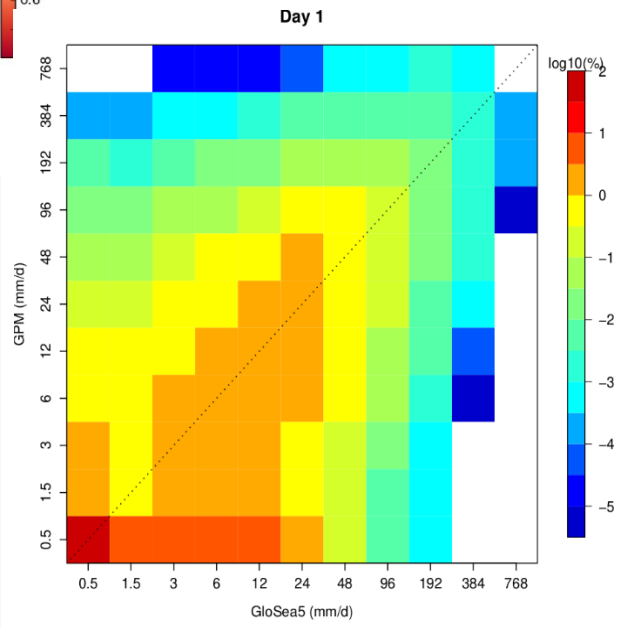
Slide Courtesy of Marion Mittermaier, Met Office



Series-Analysis output of scatterometer winds

Ric Crocker

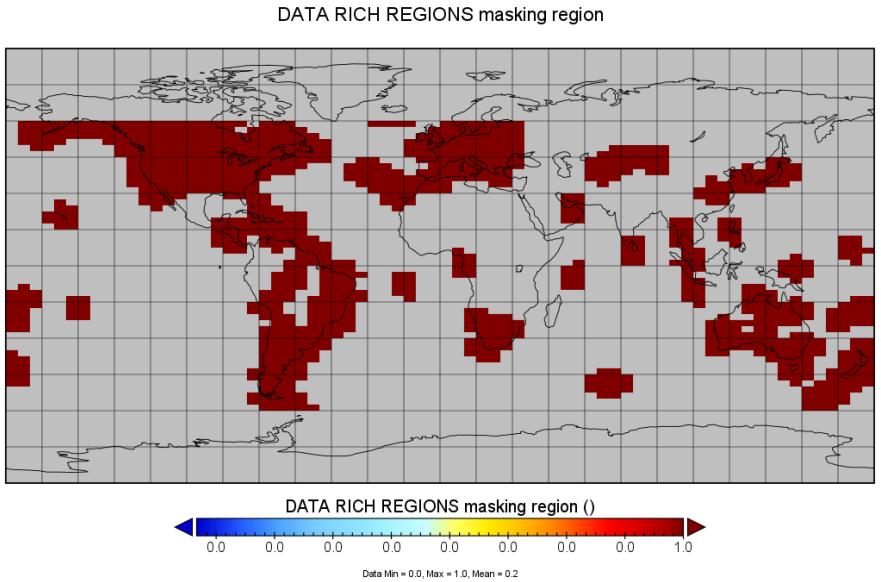




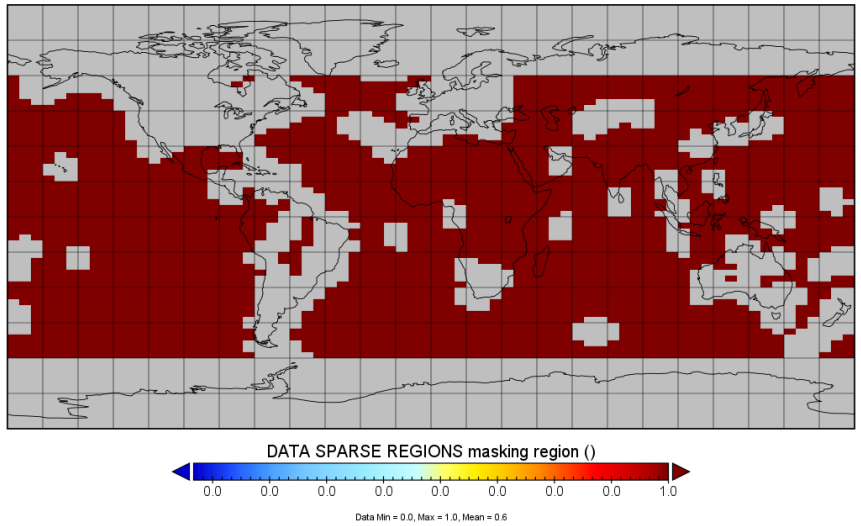
Joint and marginal distributions Grid-Diag

Space Weather

2. Data Rich vs. Data Sparse Regions

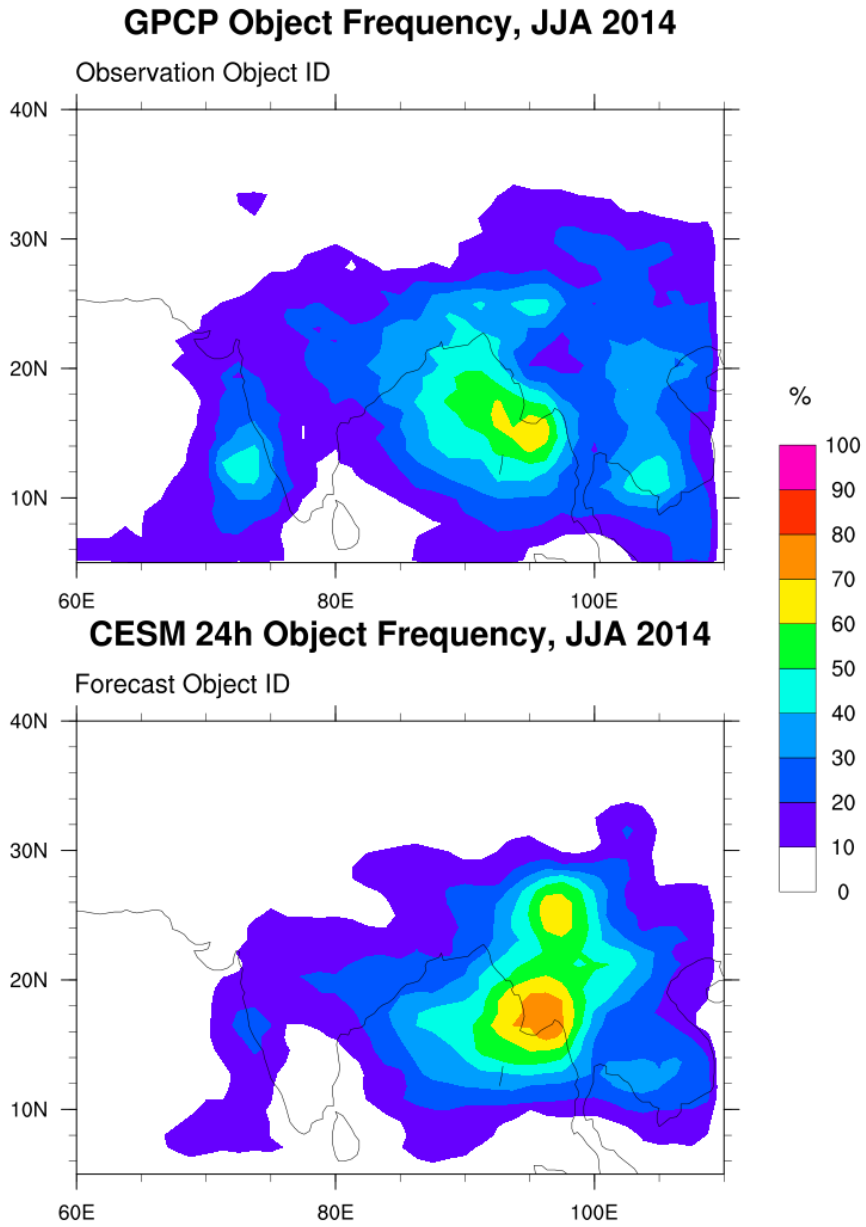


Masking: Near Observing Stations



Masking: Not Near Observing Stations

Climate



Reproducibility and Correctness

How Correctness is Achieved

Feature or Issue development team includes:

- Scientist, Engineer, Documentation Specialist

- Each feature or dev task has Github issue assigned. Feature Branch broken off from dev branch using Github ID when work is being performed
- **Github Actions** used for Continuous Integration testing of new features during each pull request
  - **Container used for GA**
  - **Scientist and/or Engineer are included in pull request phase for quality assurance**
- Beta releases for user and cross-platform testing purposes are published every 6-8 weeks. 4-5 Beta releases per major development cycle

How Reproducibility is Achieved

Configuration files for:

- METplus wrapper allows for most features to be configured
- Reads MET config file and swaps in METplus wrapper environment variables
- METplus Analysis Suite uses a combination of XML and YAML for configuration options

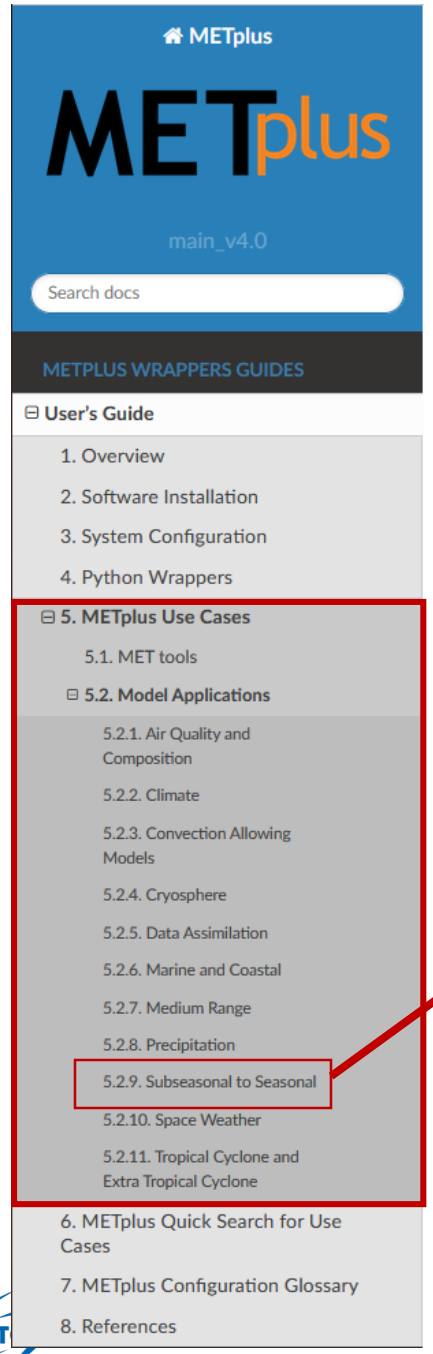
- Examples are published in online documentation as “use-cases” which include METplus .conf, METplus .config, sample data, and documentation on how to run
- Cross platform testing is performed during every beta release

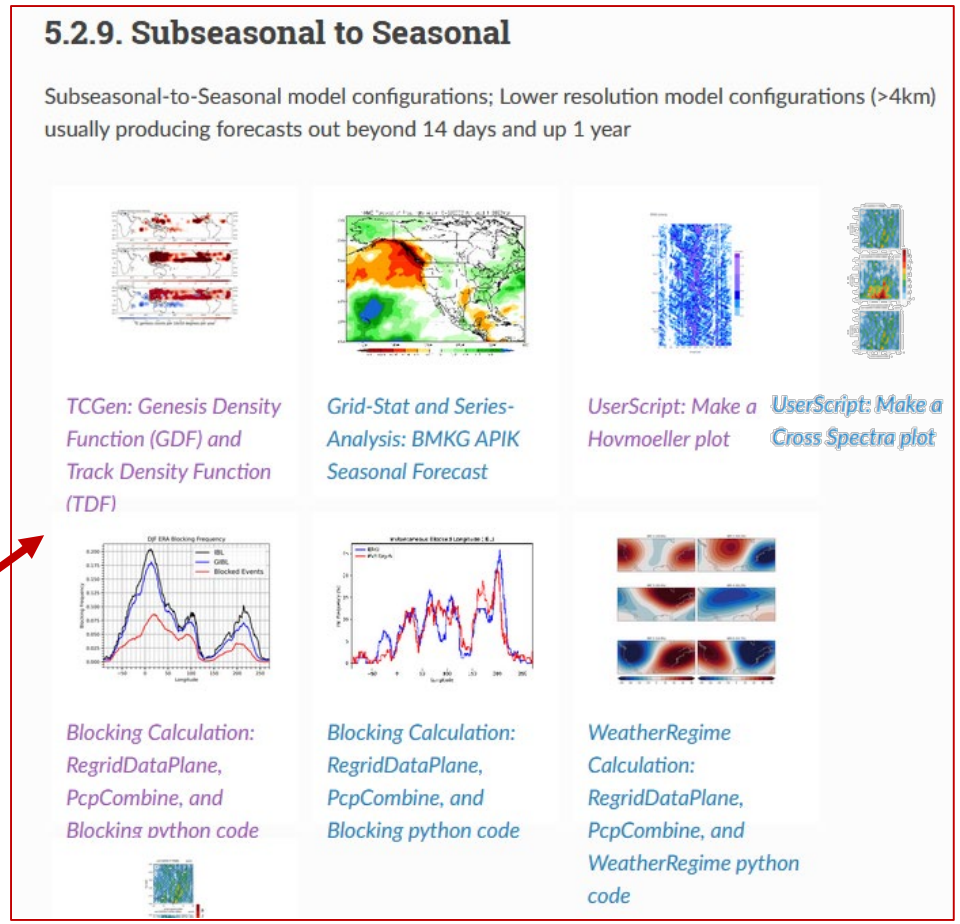
Support and Training

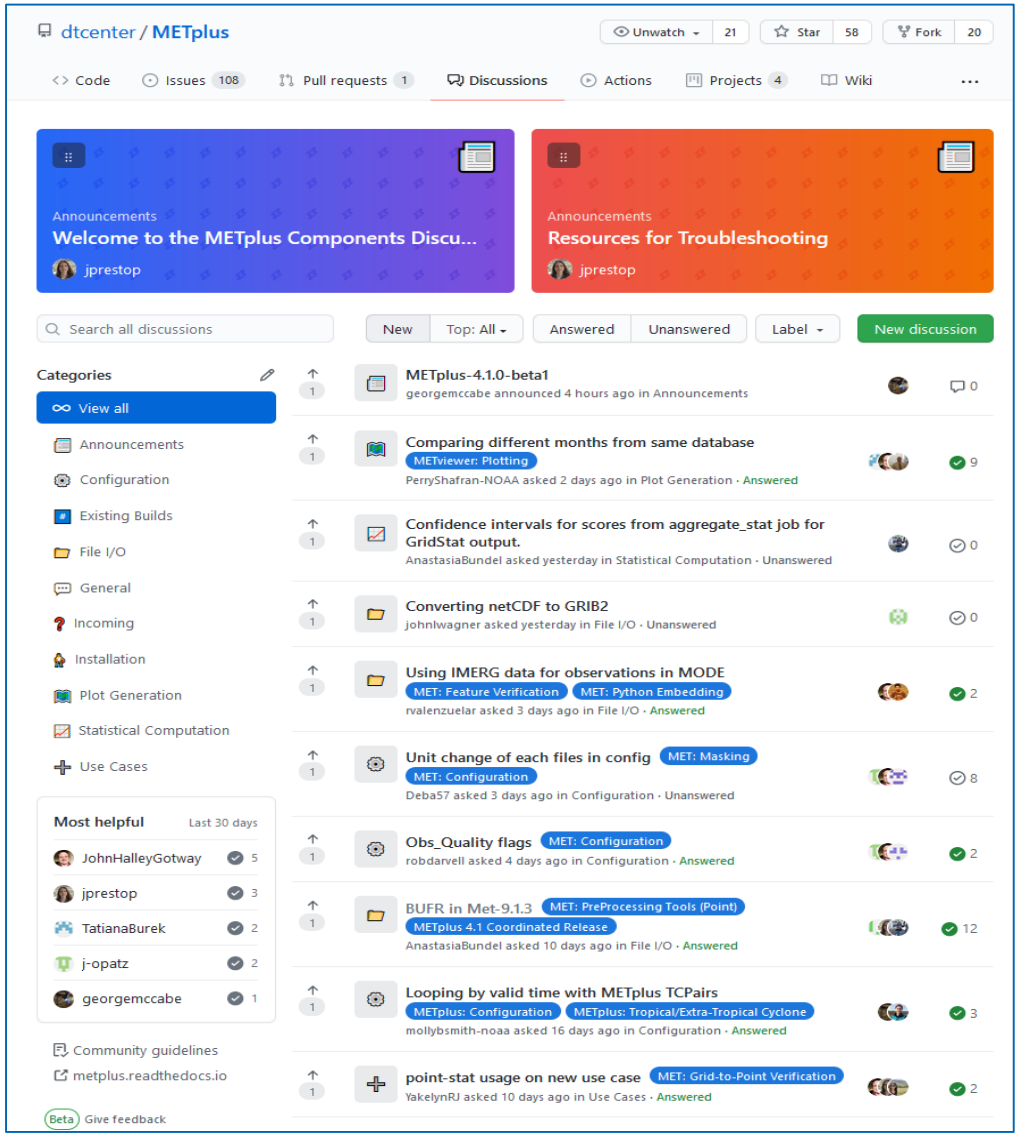
User's Guide and Getting Help

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

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

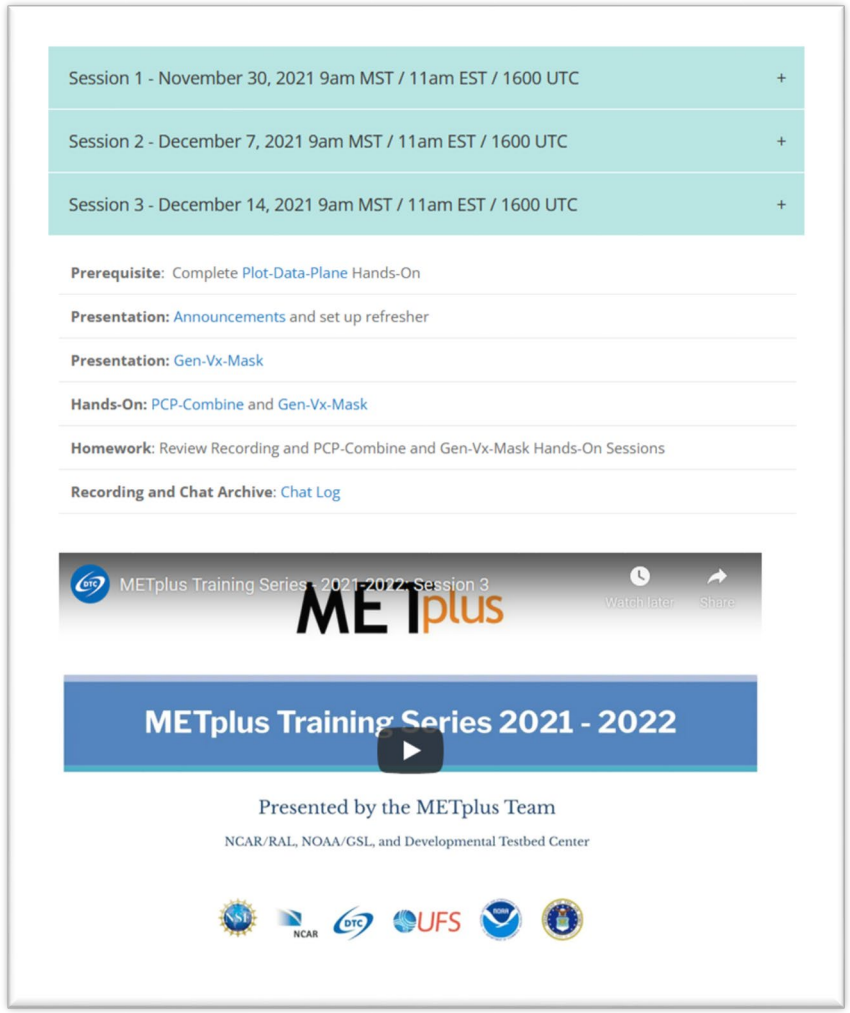




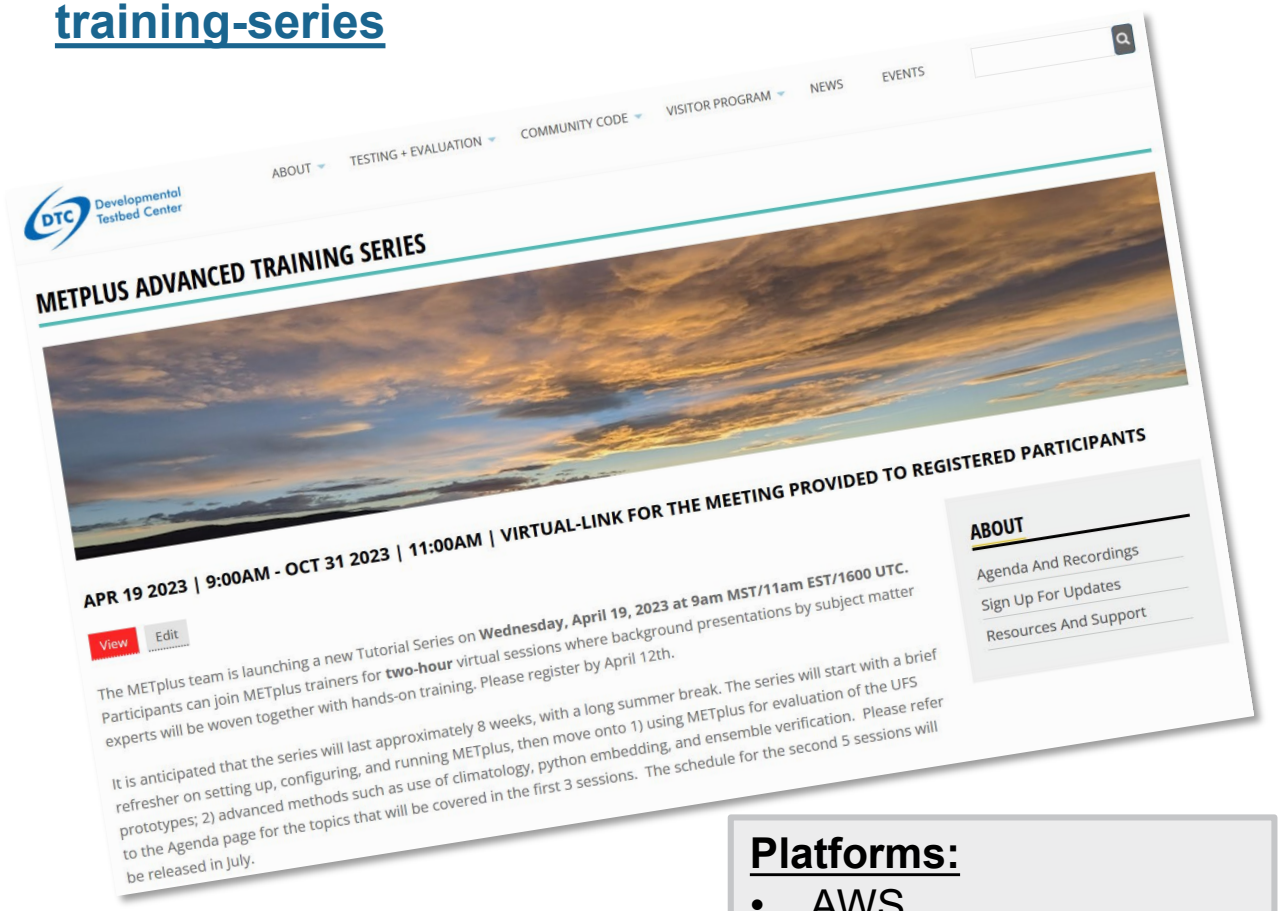


Basic Training To Get You Started

Basic (2021-2022)
https://dtcenter.org/events/2021/metplus-training-series



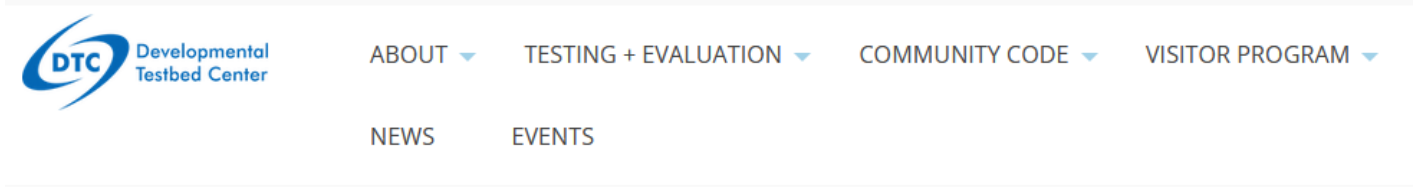
Advanced (2023)
https://dtcenter.org/events/2023/metplus-advanced-training-series



Platforms:

- AWS
- NCAR HPC: Cheyenne
- NOAA HPCs: WCOSS2, Hera, Jet

Online Training



WELCOME TO THE METPLUS PRACTICAL SESSION GUIDE

The METplus v5.0.0 practical consists of 11 sessions. The first six sessions contain instructions for running individual MET tools directly on the command line, followed by instructions for running the same tools as part of a METplus use case. The remaining sessions dive into special applications of METplus and the Analysis tools available in the METplus suite.

https://dtcenter.org/metplus-practical-session-guide-version-5-0

CONTENTS

METplus Use Cases

8. METplus Quick Search for Use Cases

8.1. Use Cases by MET Tool:

ASCII2NC
CyclonePlotter
EnsembleStat
GenVxMask
GenEnsProd
GridStat
GridDiag
IODA2NC
MODE
MTD
PB2NC
PCPCombine
Point2Grid
PlotDataPlane
PlotPointObs
PointStat
RegridDataPlane
SeriesAnalysis
StatAnalysis
TCDiag
TCMPRPlotter
TCGen
TCPairs
TCRMW
TCStat

Use Cases:

- Sample Data
- Sample Configuration Files
- Documentation

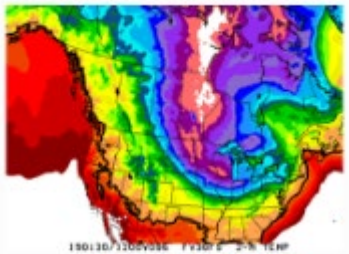
https://metplus.readthedocs.io/en/latest/Users_Guide/usecases.html

8.2. Use Cases by Application:

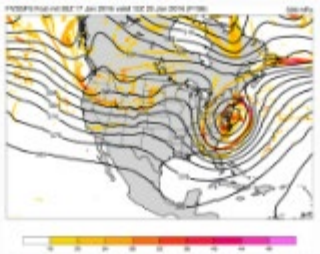
Air Quality and Composition
Climate
Clouds
Short Range
Data Assimilation
Ensemble
Land Surface
Marine and Cryosphere
Medium Range
PBL
Precipitation
Space Weather
Subseasonal to Seasonal
Subseasonal to Seasonal: Madden-Julian Oscillation
Subseasonal to Seasonal: Mid-Latitude
Tropical Cyclone and Extra-Tropical Cyclone

8.3. Use Cases by Organization:

Developmental Testbed Center (DTC)
National Center for Atmospheric Research (NCAR)
NOAA Weather Prediction Center (WPC)
NOAA Space Weather Prediction Center (SWPC)
NOAA Environmental Modeling Center (EMC)
NOAA Global Systems Laboratory (GSL)
NOAA Hydrometeorology Testbed (HMT)
NOAA Hazardous Weather Testbed (HWT)
State University of New York-Stony Brook University (SUNY-SBU)



Grid-Stat: Standard Verification of Surface Fields



Point-Stat: Standard Verification of Global Upper Air

METplus

PyEmbedIngest: Multiple Fields in One File

15 years of reproducible results

METplus

METplus and MET user support discussion forum

METplus website, online tutorial, training series

METplus repository, documentation, releases, Docker, v5.1.0 development

Contact:
Tara Jensen

jensen@ucar.edu, molly.b.smith@noaa.gov

Thank you to our core sponsors

NSF NCAR DTC Developmental Testbed Center NOAA