



Recent Enhancements to METplus for Weeks 3-4 Evaluation and Diagnostics

Tara Jensen on behalf of the METplus Team

NCAR/RAL

and

Developmental Testbed Center

Week 3-4/S2S Webinar

2 May 2022

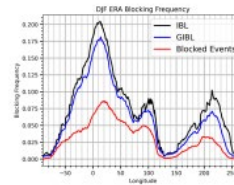


Overview

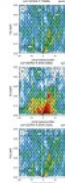
- **New process-based metrics in METplus (v4.1)**
 - Real-time Multivariate MJO Index (RMM)
 - OLR Based MJO Index (OMI)
 - Atmospheric Blocking
 - Weather Regime Analysis
 - Zonal/Meridional Means
 - Marine and Cryosphere Metrics
- **A twist on standard statistics**
- **Upcoming development**

5.2.8. Subseasonal to Seasonal

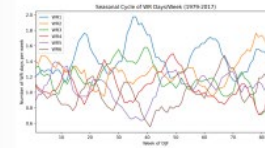
Subseasonal-to-Seasonal model configurations; Lower resolution model configurations (>4km) usually producing forecasts out beyond 14 days and up 1 year



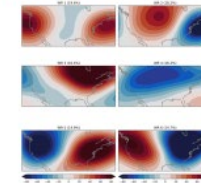
Blocking Calculation:
RegridDataPlane,
PcpCombine, and
Blocking dvthon



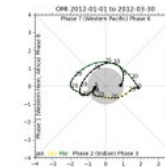
UserScript: Make a
Cross Spectra plot



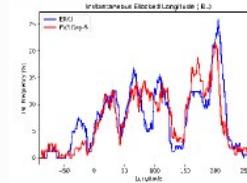
WeatherRegime
Calculation:
RegridDataPlane,
PcpCombine, and



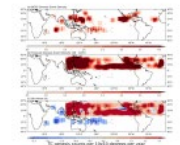
WeatherRegime
Calculation:
RegridDataPlane,
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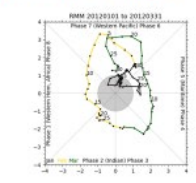
UserScript: Make
OMI plot from
calculated MJO
indices



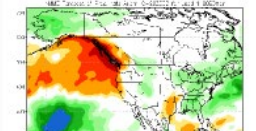
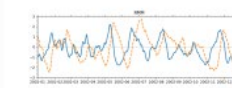
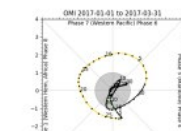
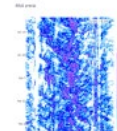
Blocking Calculation:
RegridDataPlane,
PcpCombine, and
Blocking dvthon



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

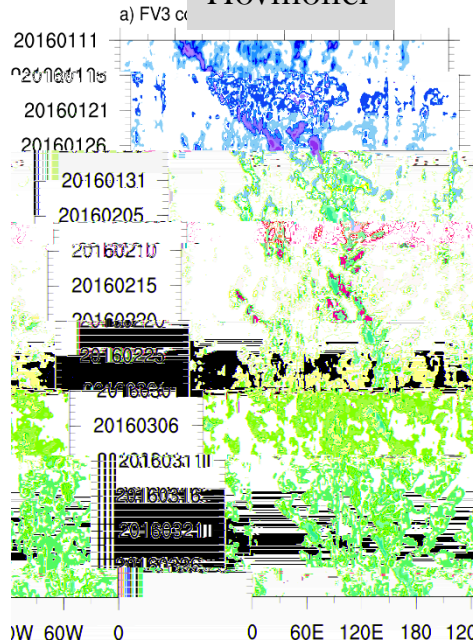


UserScript: Make a
Phase Diagram plot
from input RMM or
OMI

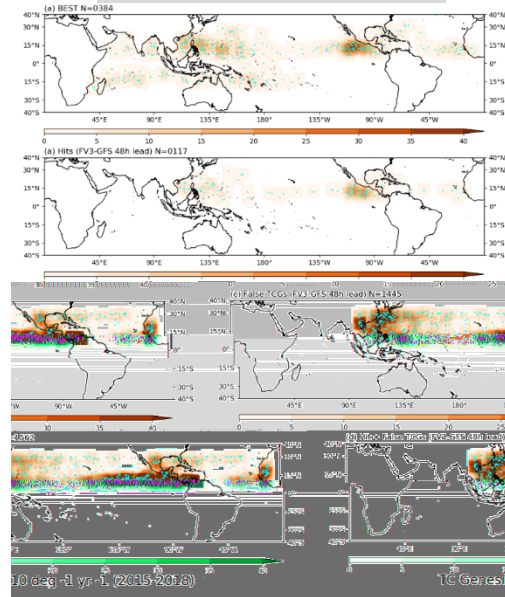


Covered in Previous Presentations

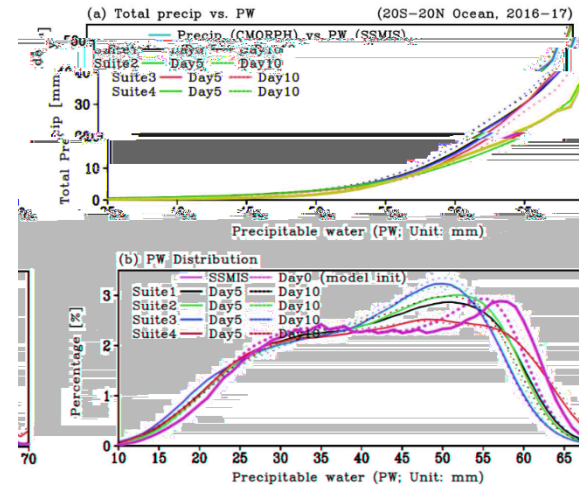
Hovmoller



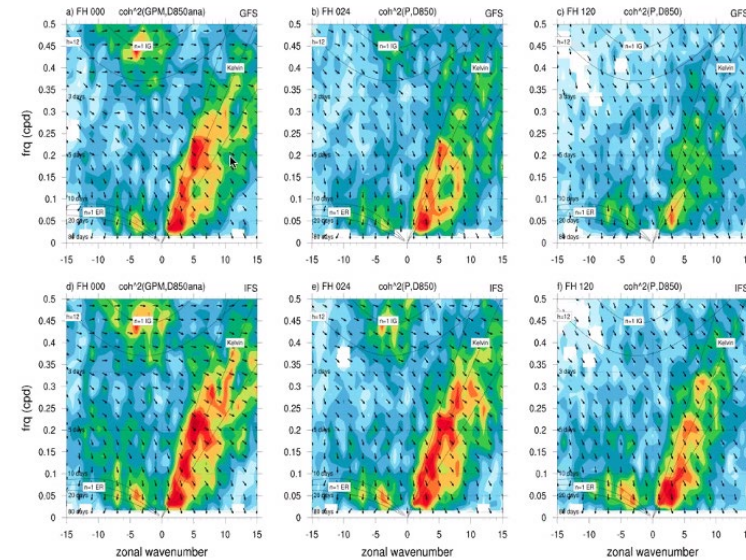
TC Genesis Density



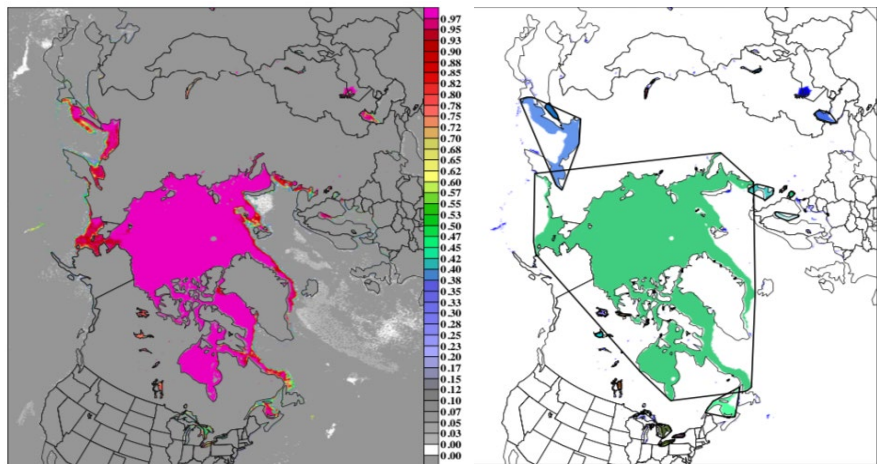
Moisture – Precip Relationship



Space-Time Coherence Spectra

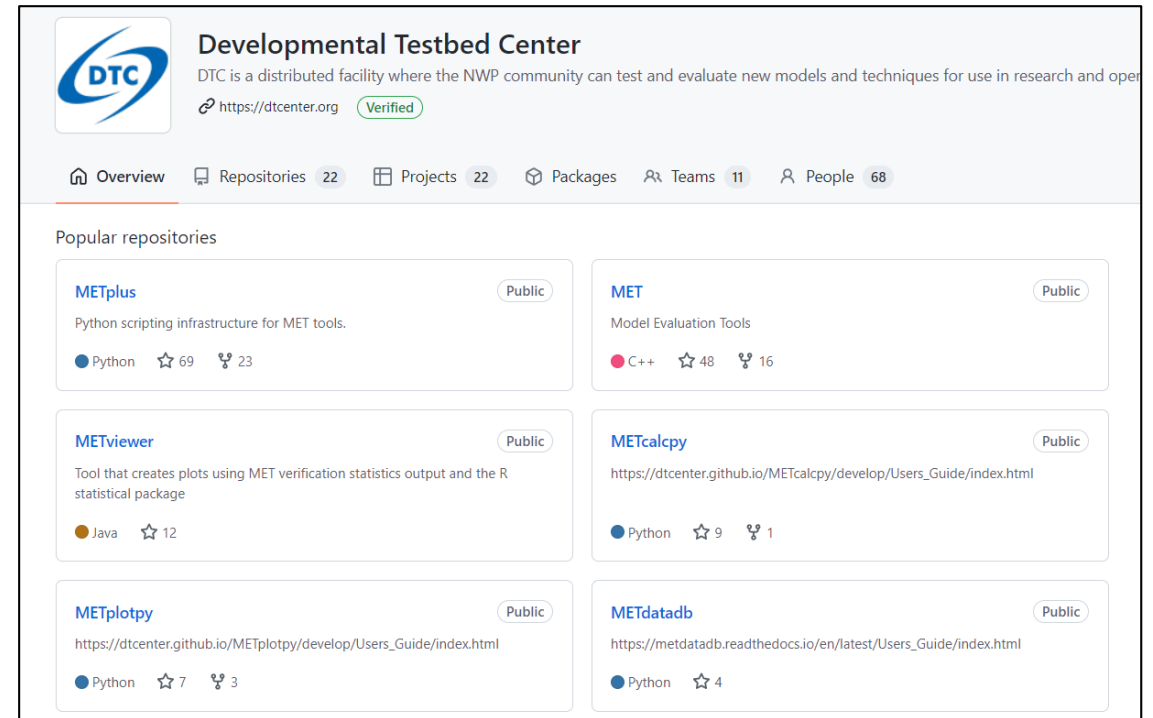


Sea Ice Objects



Process Oriented Diagnostics – General Approach

- **Run scripts from multiple repositories**
 - MET, METcalcpy, METplotpy, METdatadb
- **Specifically: include combinations of the following:**
 - Pre-processing steps
 - MET tools (like pcp_combine, regrid_data_plane)
 - python scripts (METcalcpy)
 - Indices and diagnostics calculated in python (METcalcpy)
 - Graphics (METplotpy)
 - Statistics computed on the output (stat_analysis, etc.)
- **Use multiple input files**
 - Similar to MODE-TD, Series-Analysis
- **Indices and diagnostics computed separately for model and observations**
- **Run using a driver script and called in METplus with UserScript**

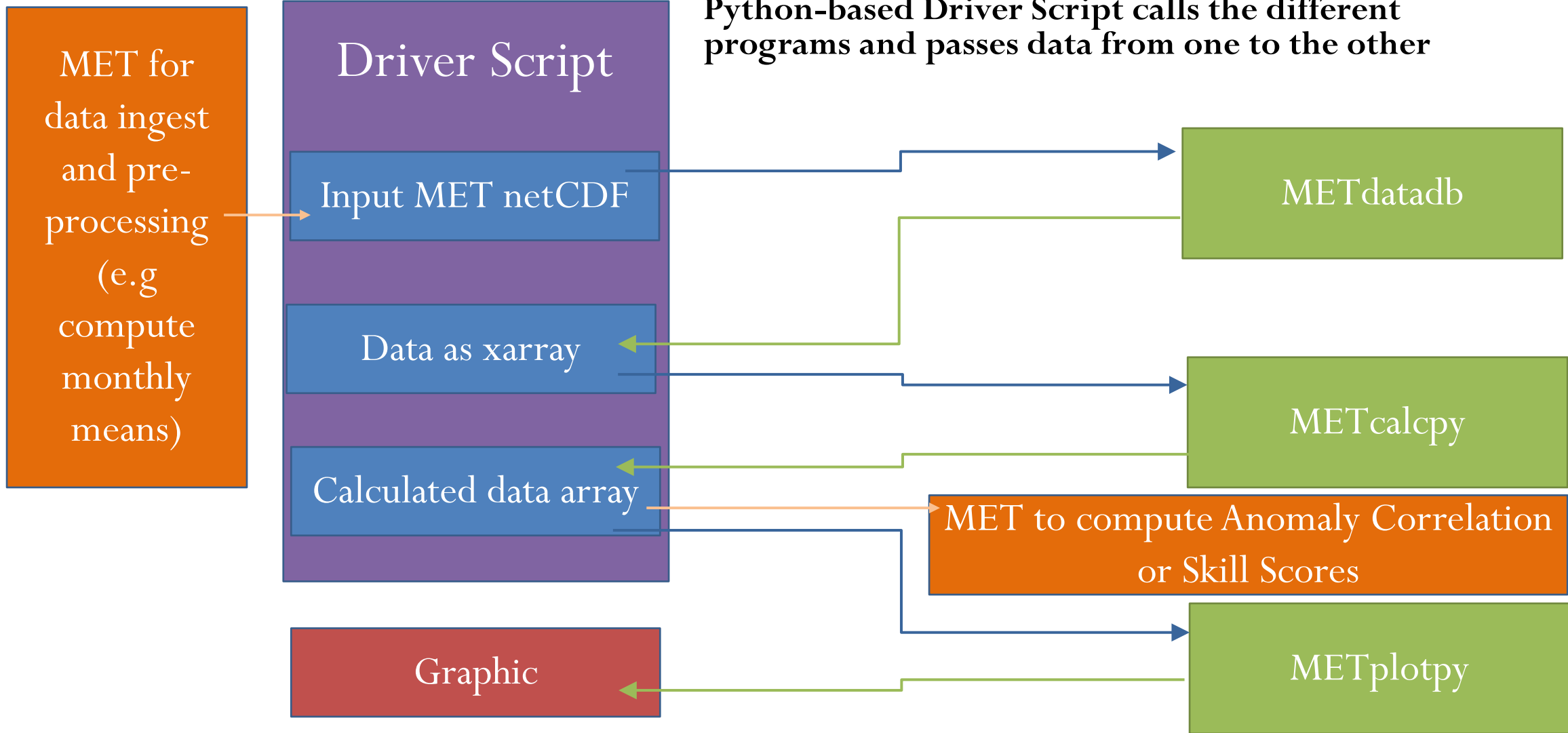


The screenshot displays the GitHub profile for the Developmental Testbed Center (DTC). The profile includes a logo, the name 'Developmental Testbed Center', a description, a verified badge, and a link to the website. Below the profile information, there are navigation tabs for Overview, Repositories (22), Projects (22), Packages, Teams (11), and People (68). The main content area is titled 'Popular repositories' and lists six repositories:

- METplus**: Python scripting infrastructure for MET tools. 69 stars, 23 forks.
- MET**: Model Evaluation Tools. 48 stars, 16 forks.
- METviewer**: Tool that creates plots using MET verification statistics output and the R statistical package. 12 stars.
- METcalcpy**: https://dtcenter.github.io/METcalcpy/develop/Users_Guide/index.html. 9 stars, 1 fork.
- METplotpy**: https://dtcenter.github.io/METplotpy/develop/Users_Guide/index.html. 7 stars, 3 forks.
- METdatadb**: https://metdatadb.readthedocs.io/en/latest/Users_Guide/index.html. 4 stars.

Driver Script Simple Example

Python-based Driver Script calls the different programs and passes data from one to the other

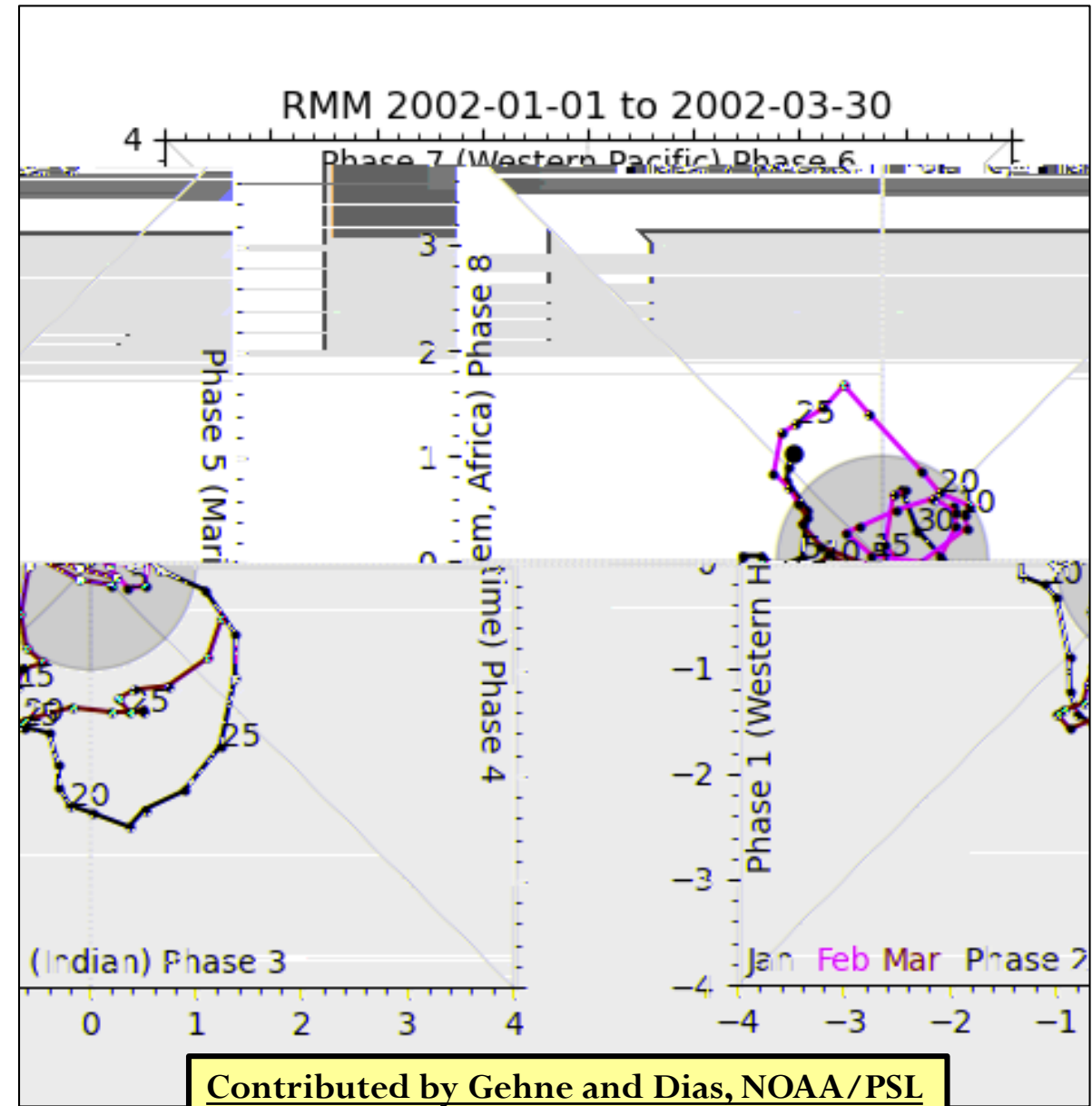


Why so complicated?

- Standardization
 - Data ingest
 - Computation of statistics (e.g. Anomaly Correlation and Skill Scores)
 - Plotting
- Operational constraints
 - Need to limit Python-packages (as per NCO requirements)
- Flexibility and Re-usability
 - Remove hard-wiring from contributed code (e.g. field names, sample size, thresholds)
 - Compute similar derived fields for different inputs (e.g. monthly mean of temperature, winds, heights, pressures at different levels) for different metrics

Real Time Multivariate MJO Index Use Case

- **UserScript_obsERA_obsOnly_RMM.conf:**
 - RMM_driver.py
- **Data:**
 - OLR, 850 mb wind, 200 mb wind anomalies
 - EOFs1 and 2 for OLR, u850, u200
 - Text files from BoM Australia
- **4 optional pre-processing step (optional)**
 - Pcp_combine: mean daily annual cycle and daily means
 - Regrid_data_plane: cut the domain to -15 – 15 latitude
 - Compute anomalies (3 variables)
 - harmonic analysis in METCalcpy (UserScript)
- **1 Calculation, RMM**
 - METcalcpy (contributed/rmm_omi):
compute_mjo_indices.py
- **3 Plots: time series, EOFs, phase diagram**
 - METplotpy (contributed/mjo_rmm_omi):
plot_mjo_indices.py
- **Output 3 plots, separate for model/obs**



RMM Setup

- Calculation includes
 - Removes 120 day mean
 - Normalize by square root of variance
 - Regress data onto EOF patterns
 - Normalize principal components by standard deviation
- Configuration Options
 - Run forecast, obs, or both
 - RMM calculated separately
 - Number of Observations per day
 - EOF filenames (not a template)
 - Normalization Factors
 - Plotting specific variables (start/end times, output file names and format)
 - Input directories and templates (UserScript section)

```
[user_env_vars]
# Whether to Run the model or obs
RUN_OBS = True
RUN_FORECAST = False

# Make OUTPUT_BASE Available to the script
SCRIPT_OUTPUT_BASE = {OUTPUT_BASE}

# Number of obs per day
OBS_PER_DAY = 1

# Variable names for OLR, U850, U200
OBS_OLR_VAR_NAME = OLR_anom
OBS_U850_VAR_NAME = U_P850_anom
OBS_U200_VAR_NAME = U_P200_anom

# EOF Filename
_RMM/EOF/rmm_olr_eofs.txt OLR_EOF_INPUT_TEXTFILE = {INPUT_BASE}/model_applications/s2s/UserScript_obsERA_obsOnly
_y_RMM/EOF/rmm_u850_eofs.txt U850_EOF_INPUT_TEXTFILE = {INPUT_BASE}/model_applications/s2s/UserScript_obsERA_obsOnly
_y_RMM/EOF/rmm_u200_eofs.txt U200_EOF_INPUT_TEXTFILE = {INPUT_BASE}/model_applications/s2s/UserScript_obsERA_obsOnly

# Normalization factors for RMM
RMM_OLR_NORM = 15.11623
RMM_U850_NORM = 1.81355
RMM_U200_NORM = 4.80978
PC1_NORM = 8.41935591459724
PC2_NORM = 8.40736449709697

# Output Directory for the plots
# If not set, it this will default to {OUTPUT_BASE}/plots
RMM_PLOT_OUTPUT_DIR = {OUTPUT_BASE}/s2s/UserScript_obsERA_obsOnly_RMM/plots

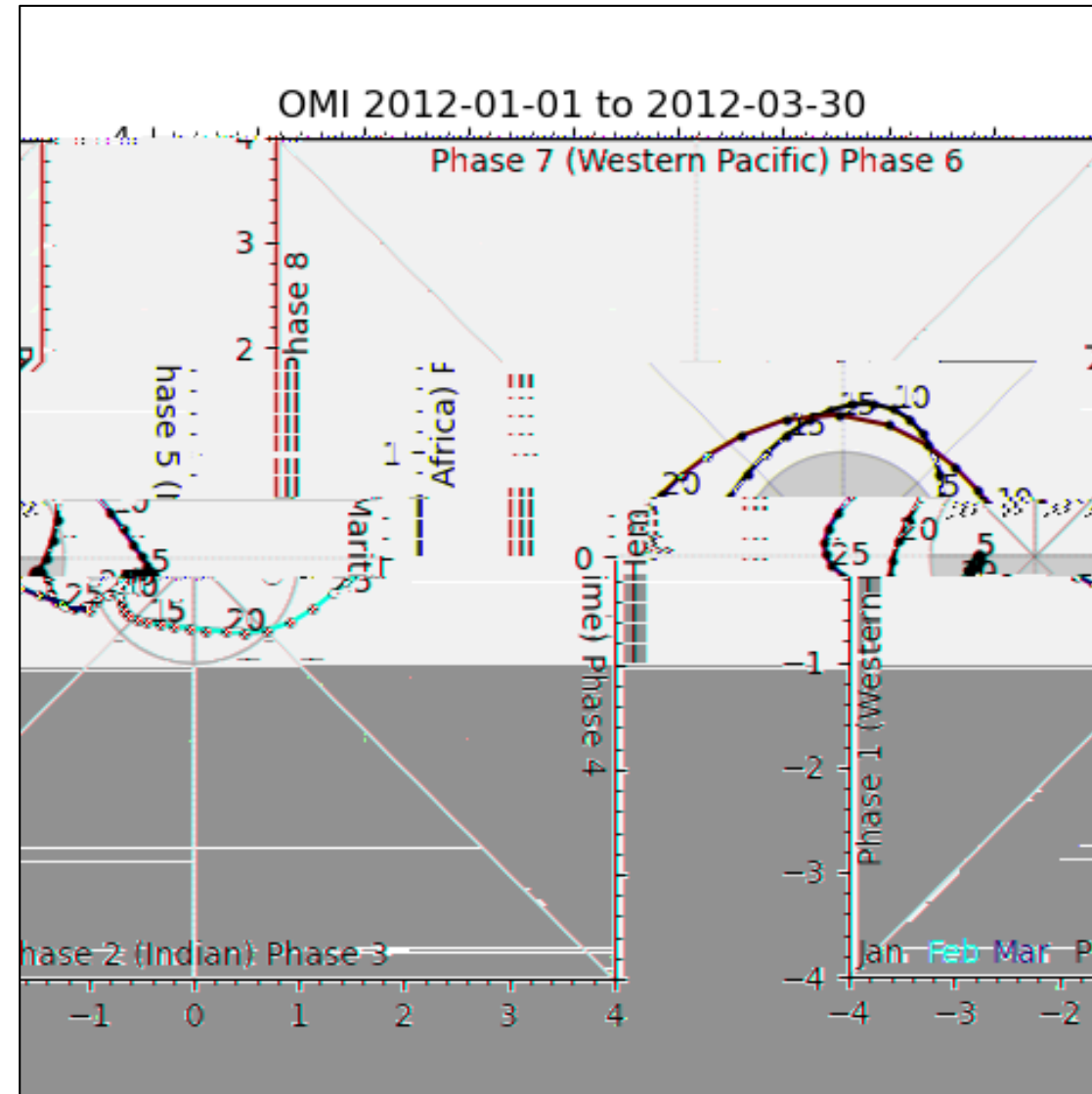
# EOF plot information
EOF_PLOT_OUTPUT_NAME = RMM_EOFs
EOF_PLOT_OUTPUT_FORMAT = png

# Phase Plot start date, end date, output name, and format
PHASE_PLOT_TIME_BEG = 2002123000
PHASE_PLOT_TIME_END = 2002123000
PHASE_PLOT_TIME_FMT = %Y%m%d%H%M
OBS_PHASE_PLOT_OUTPUT_NAME = obs_RMM_comp_phase
OBS_PHASE_PLOT_OUTPUT_FORMAT = png

# Time Series Plot start date, end date, output name, and format
TIMESERIES_PLOT_TIME_BEG = 2002121000
TIMESERIES_PLOT_TIME_END = 2002123000
TIMESERIES_PLOT_TIME_FMT = {VALID_TIME_FMT}
OBS_TIMESERIES_PLOT_OUTPUT_NAME = obs_RMM_time_series
OBS_TIMESERIES_PLOT_OUTPUT_FORMAT = png
```


OMI Use Case

- **UserScript_fcstGFS_obsERA_OMI.conf, UserScript_obsERA_obsOnly_OMI.conf:**
 - OMI_driver.py
- **OLR, EOFs1 and 2 (text from PSL, one file for each day of the year)**
- **2 optional pre-processing step (turned off)**
 - Pcp_combine: daily means
 - Regrid_data_plane: cut the domain to -20 – 20 latitude
 - Both model and observation
- **1 Calculation, OMI**
 - METcalcpy (contributed/rmm_omi): compute_mjo_indices.py
- **1 Plot: phase diagram**
 - METplotpy (contributed/mjo_rmm_omi): plot_mjo_indices.py
- **Output plots separate for model/obs**



Contributed by Gehne and Dias, NOAA/PSL

Blocking Overview

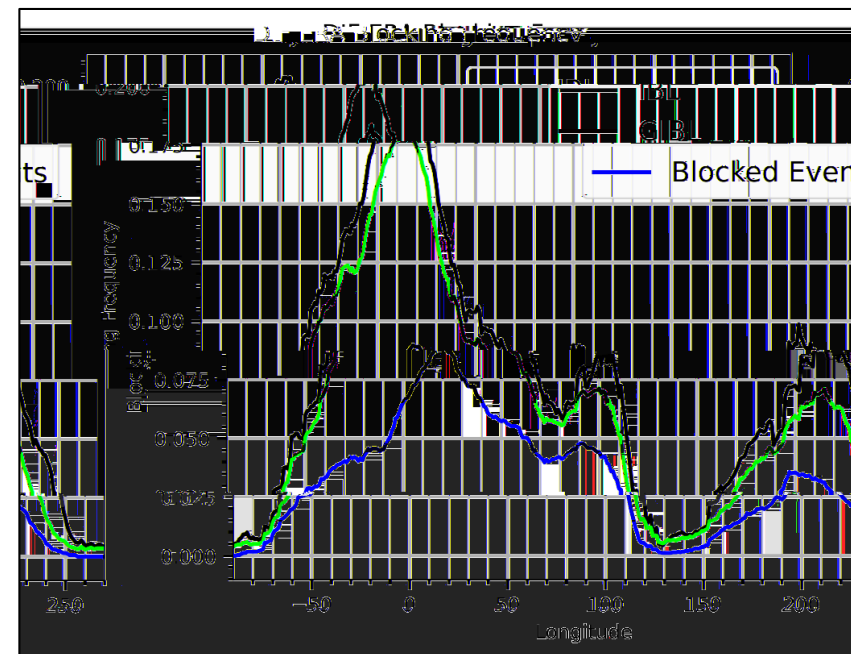
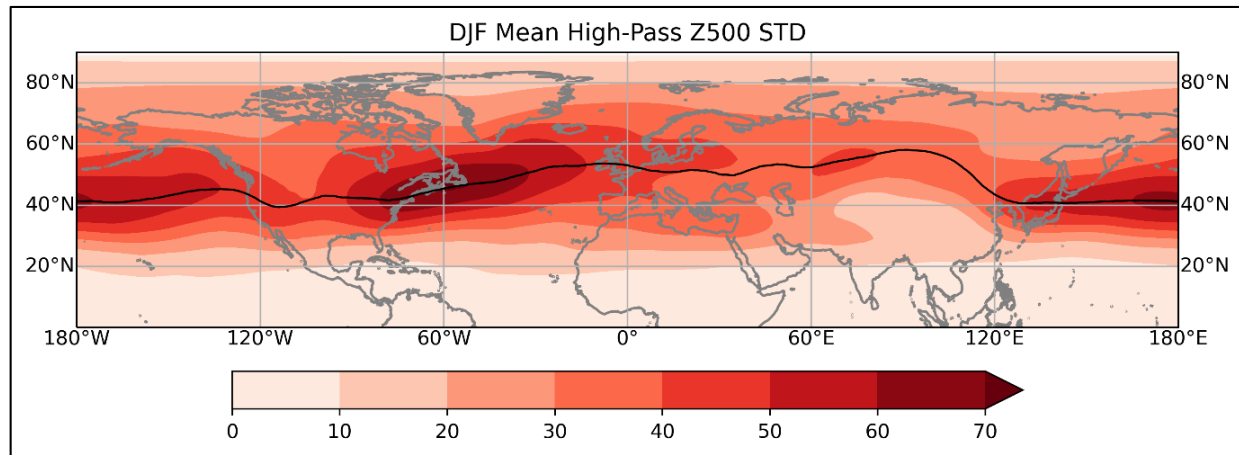
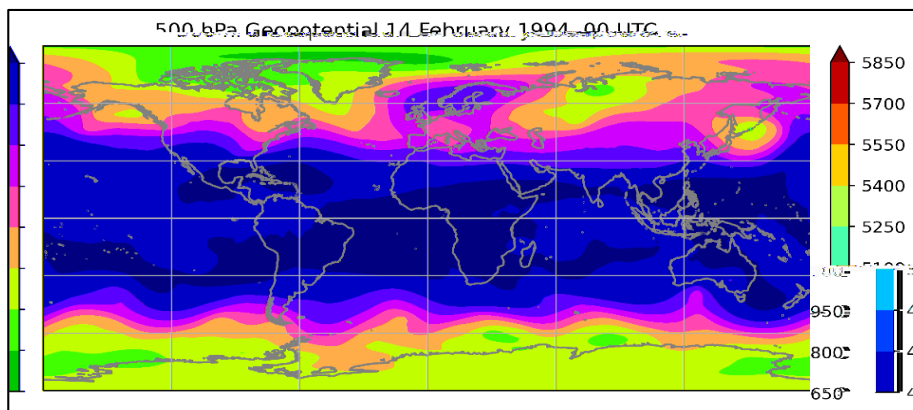
- **UserScript_fcstGFS_obsERA_Blocking.conf, UserScript_obsERA_obsOnly_Blocking.conf**
 - Blocking_driver.py
- **Daily mean and anomaly 500 mb height, preferably 20 – 30 years**
- **4 pre-processing steps (turned off)**
 - Regrid_data_plane: Regrid to 1 degree
 - Pcp_combine: daily mean/forecast lead mean, running means, computing anomalies
- **4 Blocking calculation steps (METcalcpy), run in order**
 - CBL (Central Blocking Latitude), IBL (Instantaneously Blocked Longitudes), GIBL (Group IBLs), Blocking Frequency
 - IBLs and Blocks written to MET's matched pair (MPR) format if both run
 - METcalcpy (contributed/blocking_weather_regime): Blocking.py, Blocking_WeatherRegime_util.py
- **3 optional plots**
 - CBL, IBL, Blocking Frequency
 - METplotpy (contributed/blocking_s2s): plot_blocking.py, CBL_plot.py

Blocking Overview Continued

- **2 Stat-Analysis runs (if both model and obs run)**
 - Contingency Table statistics for IBLs and Blocks
- **Output Notes:**
 - **Central Blocking Latitudes (CBLs)** and blocks plotted separately for model and observations
 - **Instantaneous Blocking Latitudes (IBLs)** on same plot

Example Blocking Output

- **Central Blocking Latitude** - Latitude maximum of high pass filtered geopotential height variance, weighted by cosine
- **IBL: Computes IBLs using Pelly-Hoskins method (Barnes et al. 2012)** - Looks for reversals in Geopotential Height gradient
 - Easterly flow equatorward of block
- **GIBL** - Groups IBLs by applying spatial thresholds
- **Required: daily 500 mb height files, number seasons, days per season**



Blocking Stat-Analysis

- **IBL and Blocking output to matched pair format**
 - 0/1 Binary
 - File for each day
 - Line for each longitude
 - CBL output for latitude

Statistic	IBL	Blocks
CSI	0.558	0.559
FBIAS	1.01	1.01
PODY	0.717	0.721
PODN	0.976	0.990
FAR	0.285	0.288

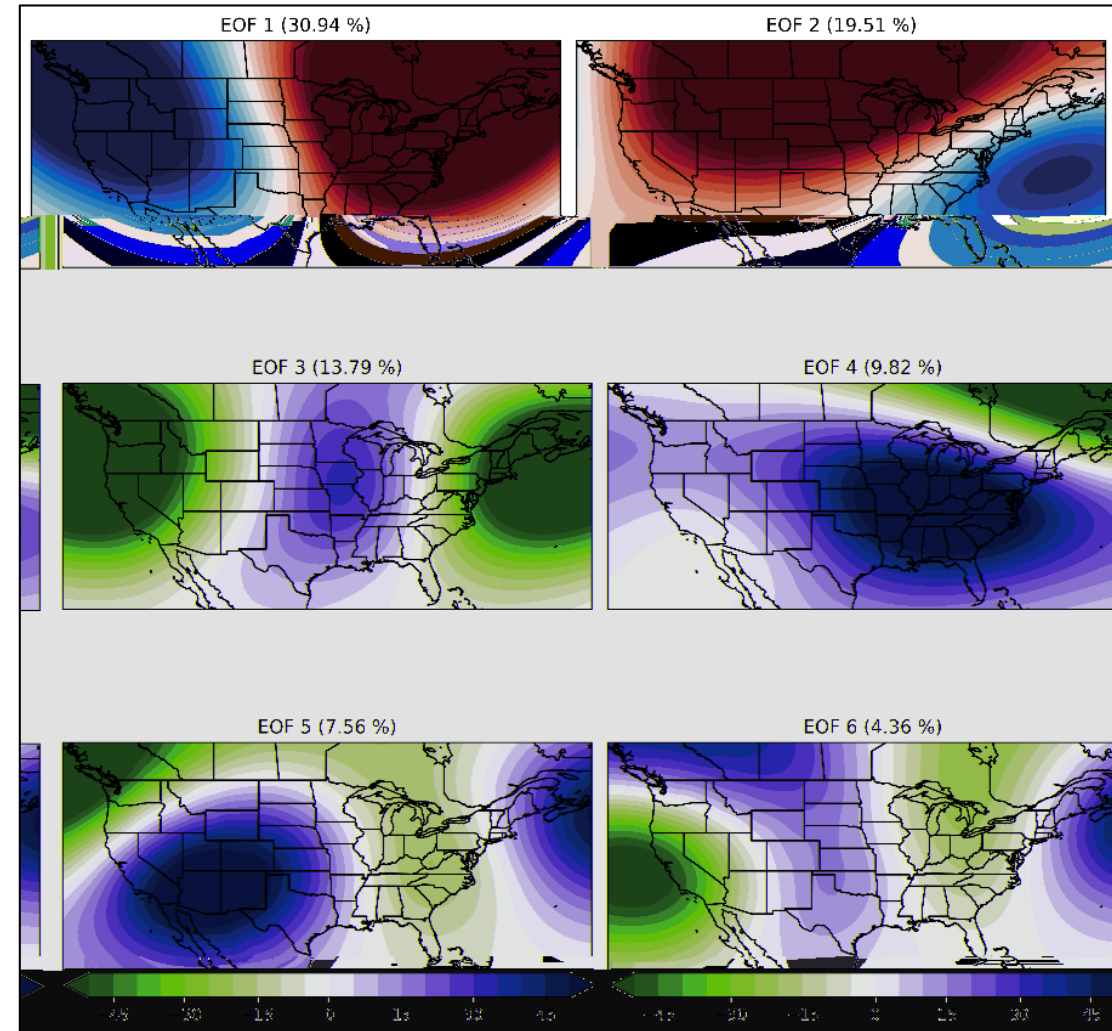
Weather Regime Overview

- **UserScript_fcstGFS_obsERA_WeatherRegime.conf, UserScript_obsERA_obsOnly_WeatherRegime.conf**
 - WeatherRegime_driver.py
- **Daily mean 500 mb height, preferably 20 – 30 years**
- **2 pre-processing steps (turned off)**
 - Regrid_data_plane: Regrid to 1 degree
 - Pcp_combine: daily mean/forecast lead mean
- **4 calculation steps, run any except frequency**
 - Elbow (optimal clusters), EOFs, K-means, Frequency
 - Weather Regime classification and frequency written to MET's MPR format if both run
 - METcalcpy (contributed/blocking_weather_regime): WeatherRegime.py, Blocking_WeatherRegime_util.py
- **4 optional plots**
 - Elbow, EOFs, K-means, Frequency
 - METplotpy (contributed/weather_regime): :plot_weather_regime.py

Weather Regime Overview Continued

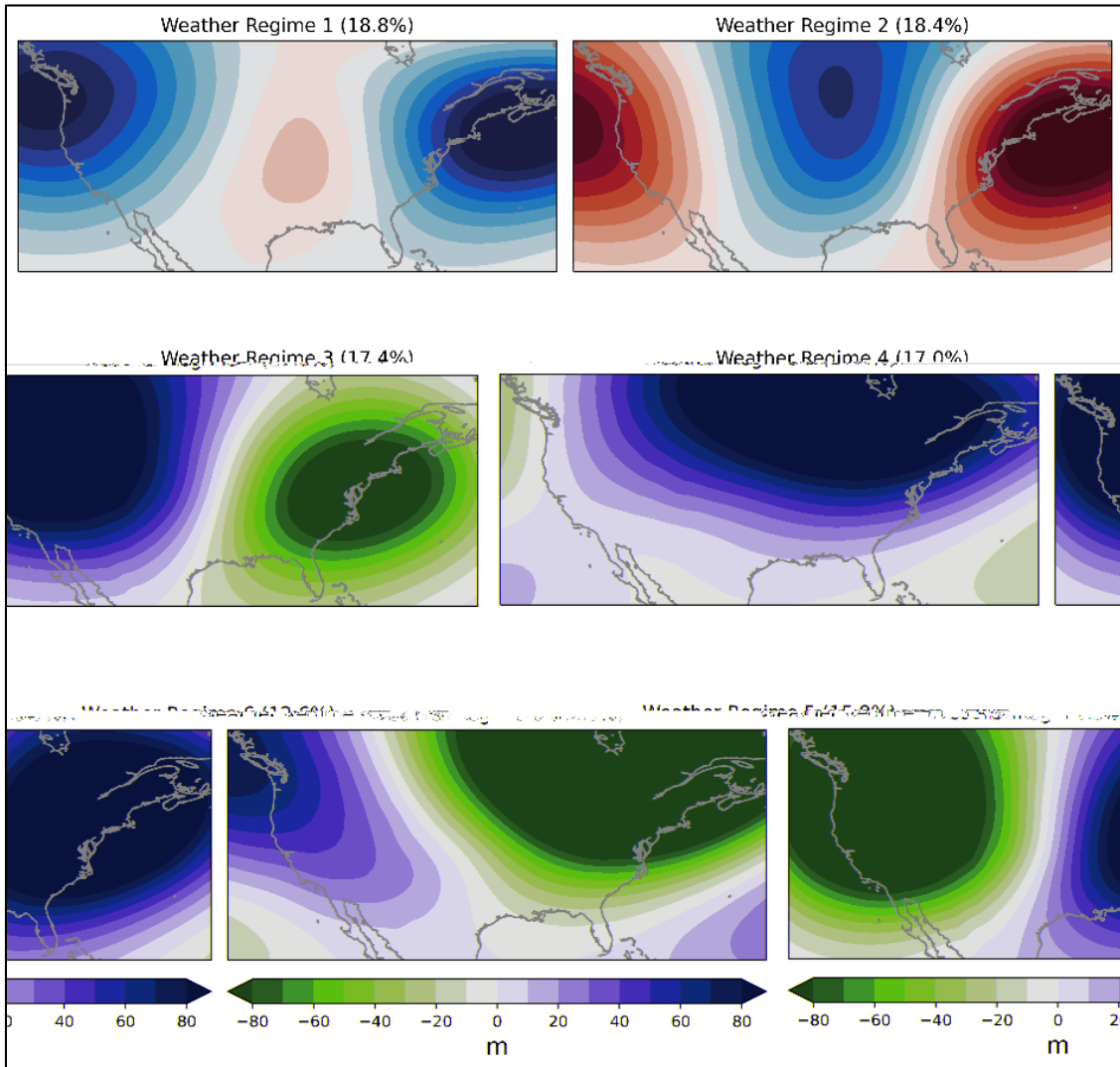
- **2 Stat-Analysis runs (if both model and obs run)**
 - Multi-Category Contingency Table Statistics file for the weather regime classification
 - Continuous Statistics file for the weather regime frequency
- **Additional Output:**
 - Classification file (day and regime) in text or netCDF for model and observations

ERA EOFs Dec 2000 – Feb 2017

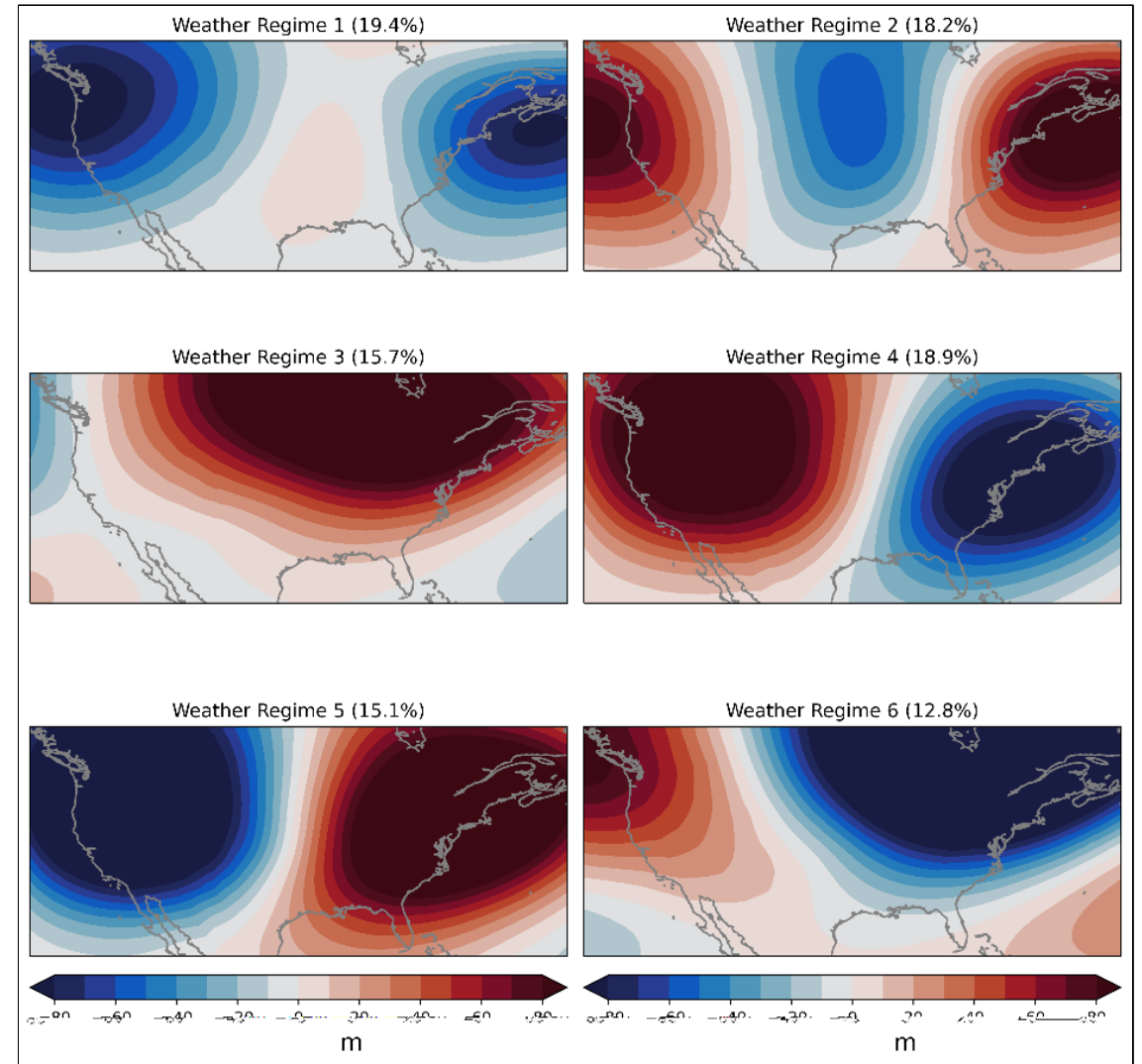


Weather Regime Classification

ERA Dec 2000 – Feb 2017

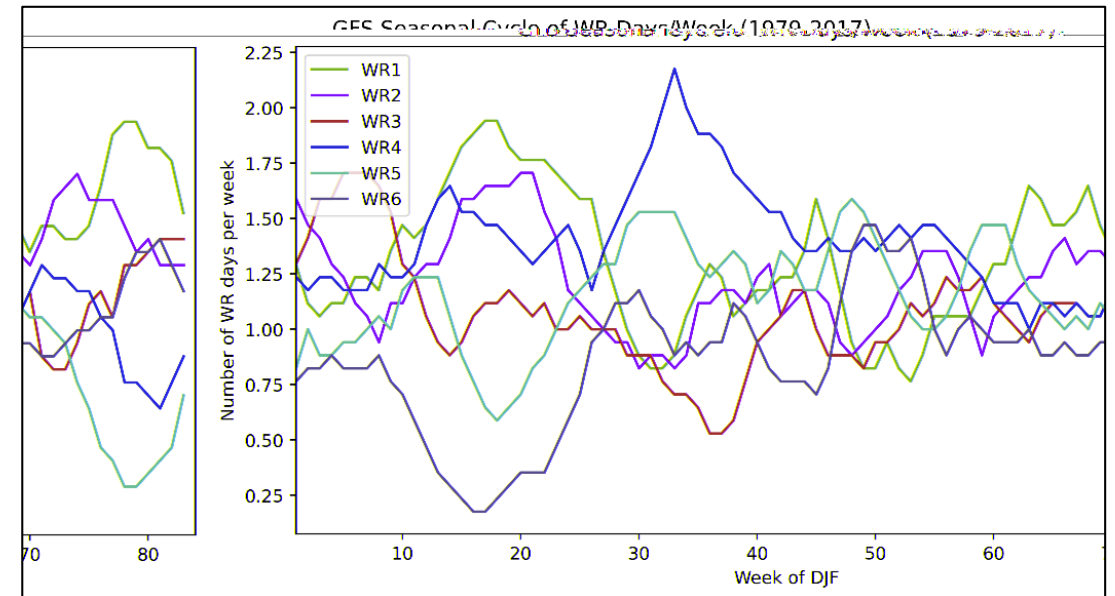
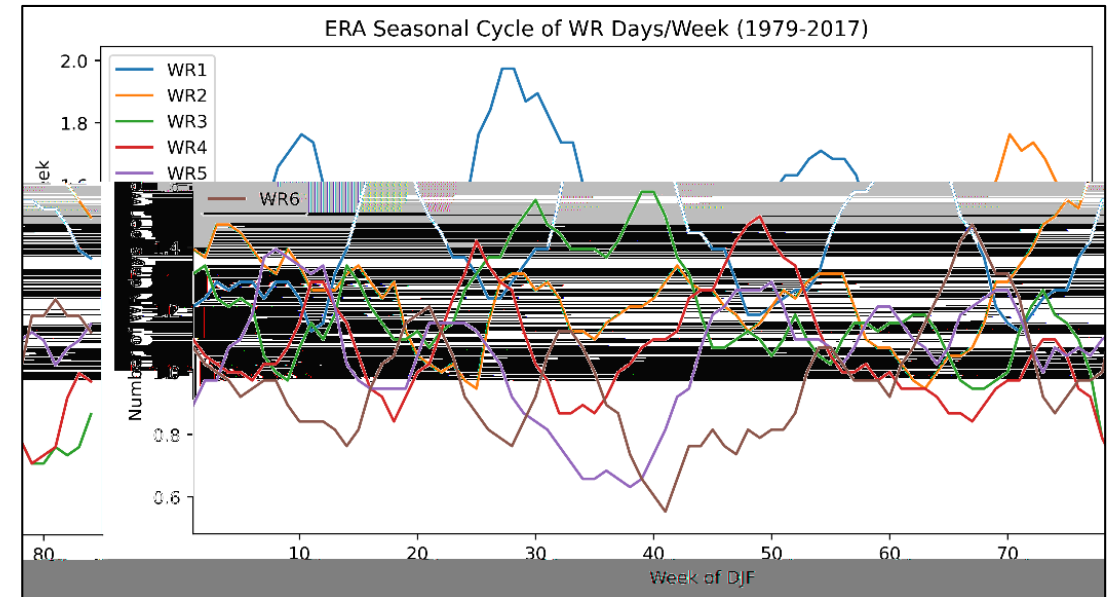


GFS Dec 2000 – Feb 2017



Frequency and PLOTFREQ

- Computes the frequency of each classified weather regime over a time period
- Needs: weather regime classification array
- Optional Input:
 - Number of days to compute the frequency (7 days)
 - Plot title, and output name



Weather Regime Stat-Analysis

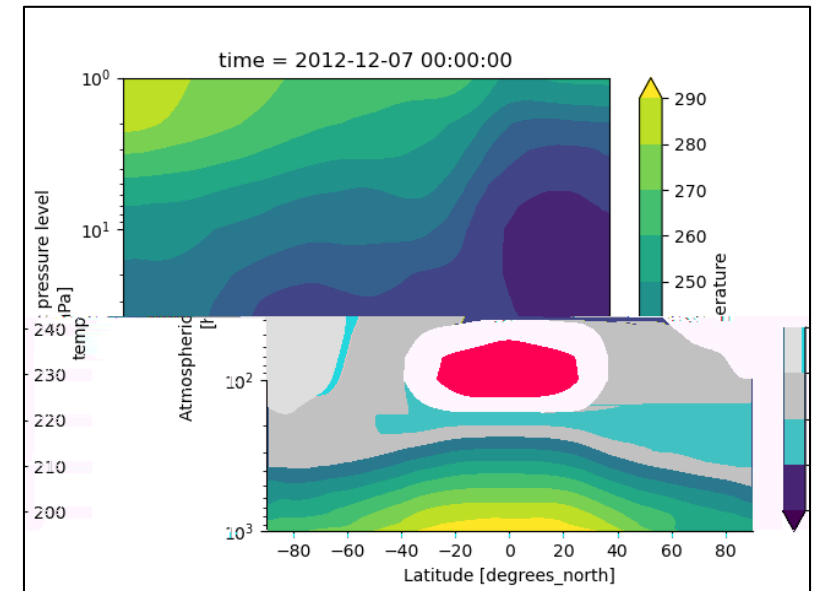
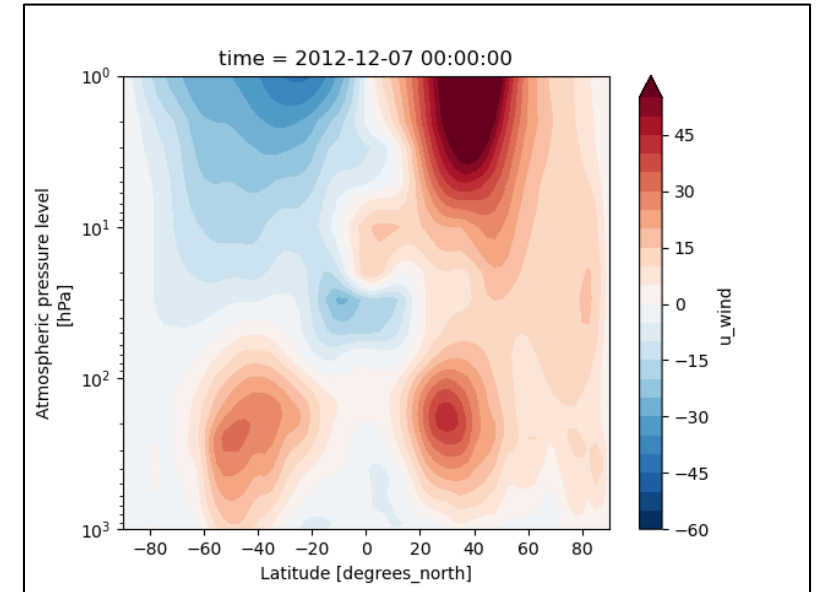
- **Weather Regime Classification and frequency output to matched pair format**
 - File for each day
 - One line per file with classification or frequency

Multi-Category Contingency Table Statistics
HSS: 0.593

Category	Frequency Correlation
WR1	0.906
WR2	0.859
WR3	0.951
WR4	0.923
WR5	0.952
WR6	0.932

Zonal/Meridional Means

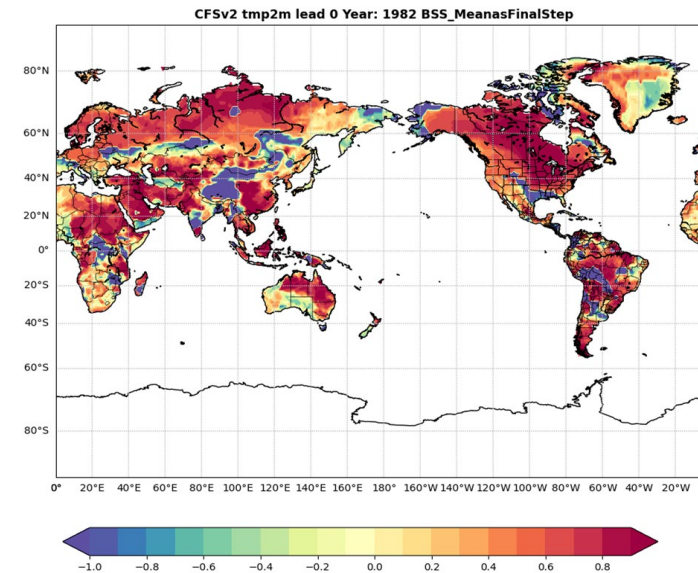
- Work in progress
- UserScript_obsERA_obsOnly_Stratosphere.conf:
 - meridional_mean.py
- Reads u, v, Temperature, Geopotential Height 3D data
- Calculations:
 - zonal mean for u and Temperature
 - Meridional mean on zonal mean Temperature
- 4 calculation steps, run any except frequency
- Separate plots in METplotpy:
 - Zonal mean wind and temperature contour plots
 - Polar zonal mean



CFSv2 Fields and Baselineing with CPC

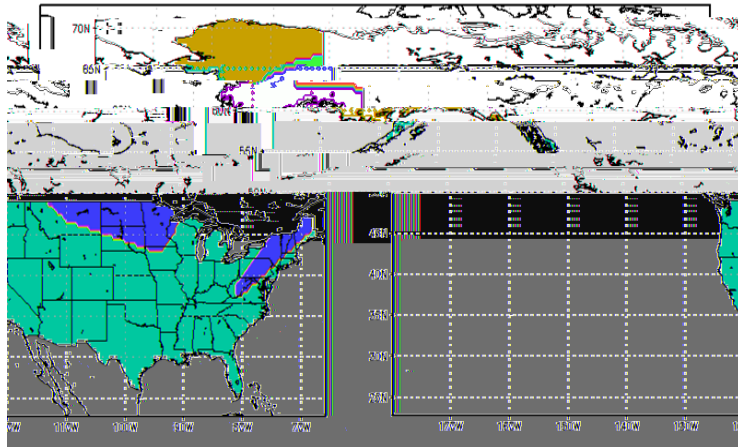
- Discrepancies in Brier Skill Score (BSS) values
 - Rounding differences
- New tool, Gen-Ens-Prod, for standardized anomalies creation
 - Added normalized anomalies from climatology, ensemble data
 - Reference Brier Score (BRIERCL) output
 - Read all ensemble members from 1 file
- METplus replicates Brier Score (BS), BSS values < 0.01 difference
- Recently diagnosed additional capability needed to support how CPC uses Heidke Skill Score (HSS)

```
37 // May be set separately in each "field" entry
38 //
39 censor_thresh = [];
40 censor_val    = [];
41 normalize     = NONE;
42 cat_thresh    = [];
43 nc_var_str    = "";
```

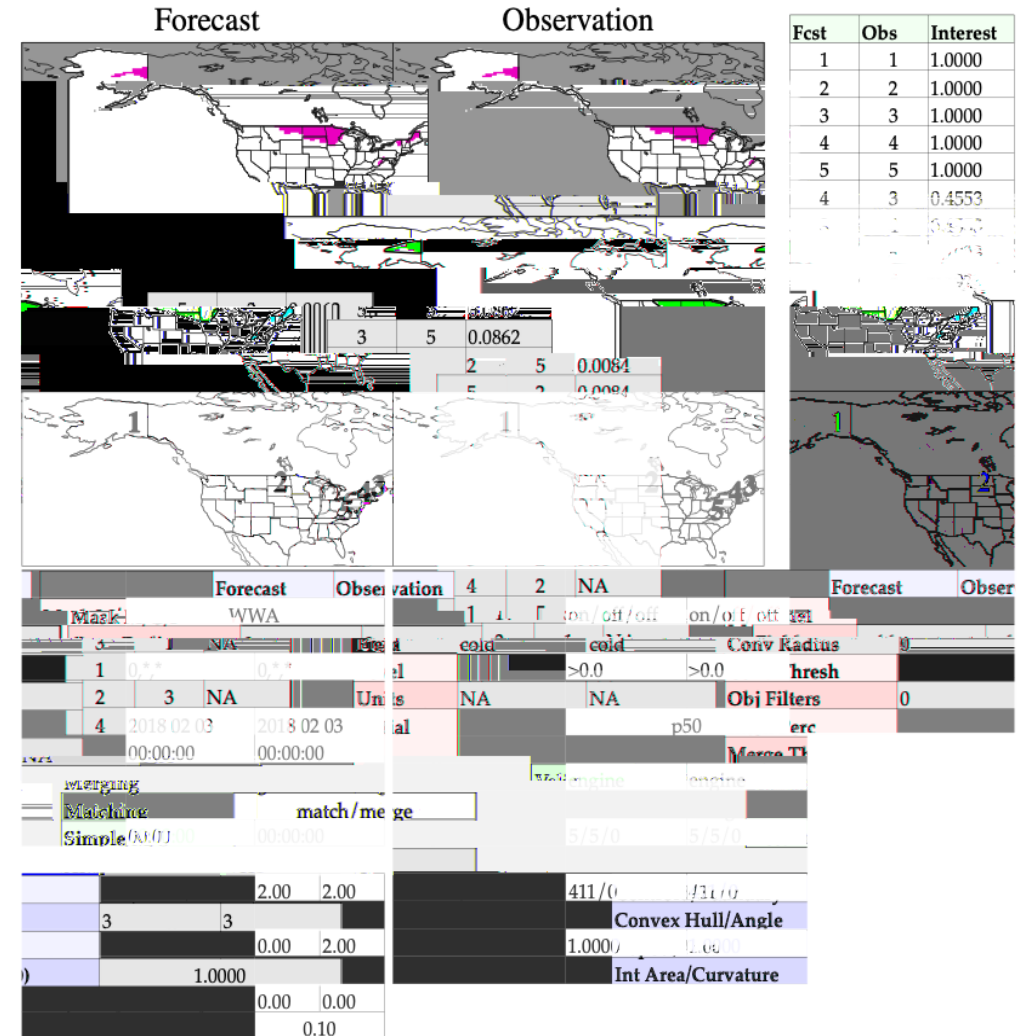


CPC Weather Watch Areas (WWAs)

- Goal: Verify Week-2 hazard forecasts using WWAs
 - Focus on Cold hazards, 8 day
 - Utilized Method for Object-based Diagnostic Evaluation (MODE) tool
 - Investigated beyond binary forecast verification
- Compute Median of Maximum Interest (MMI)
- Garner forecaster input, website development

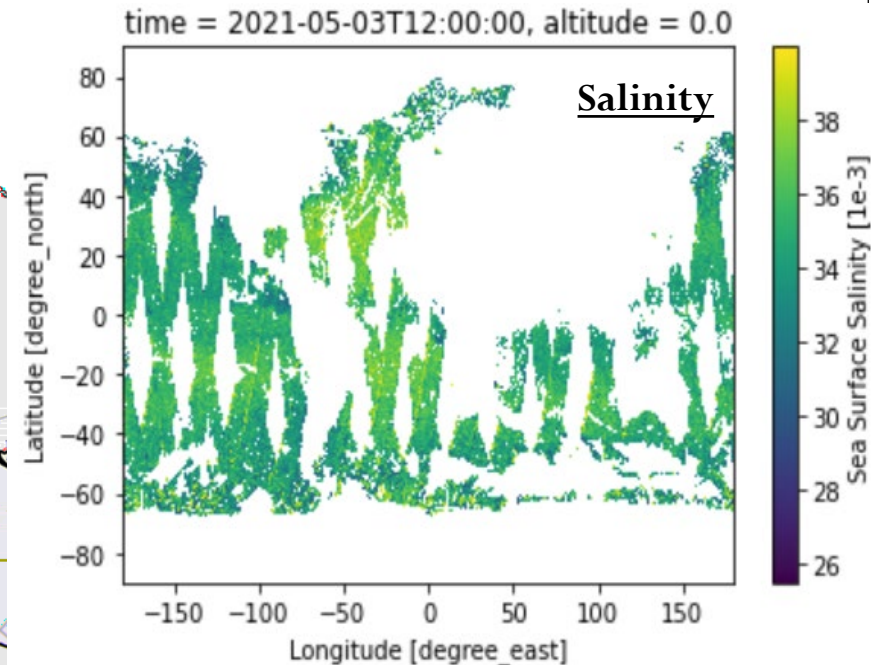
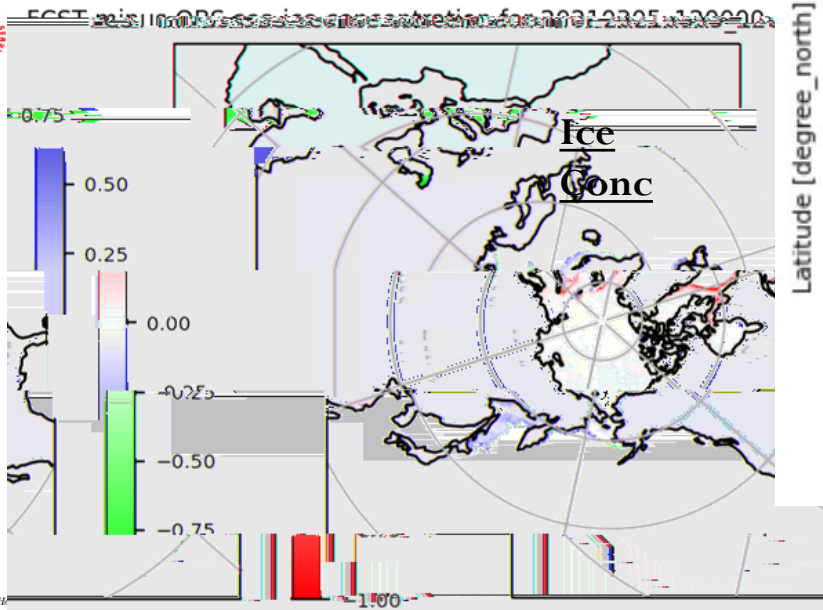
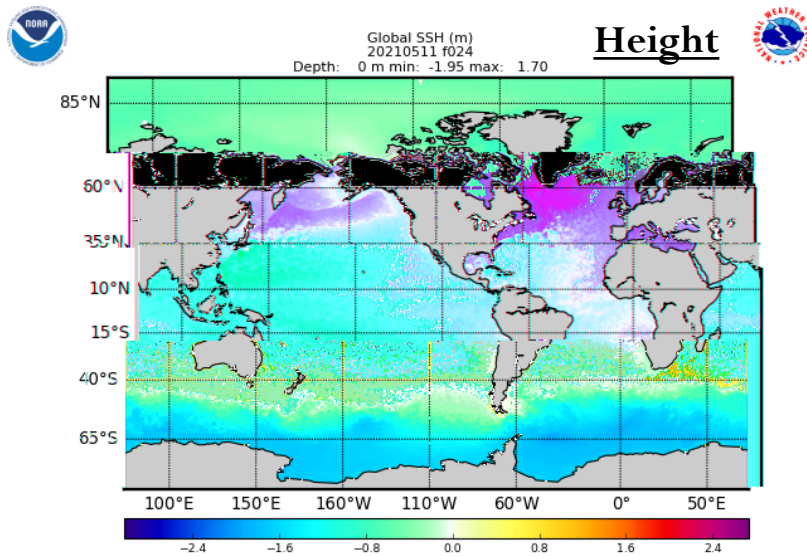
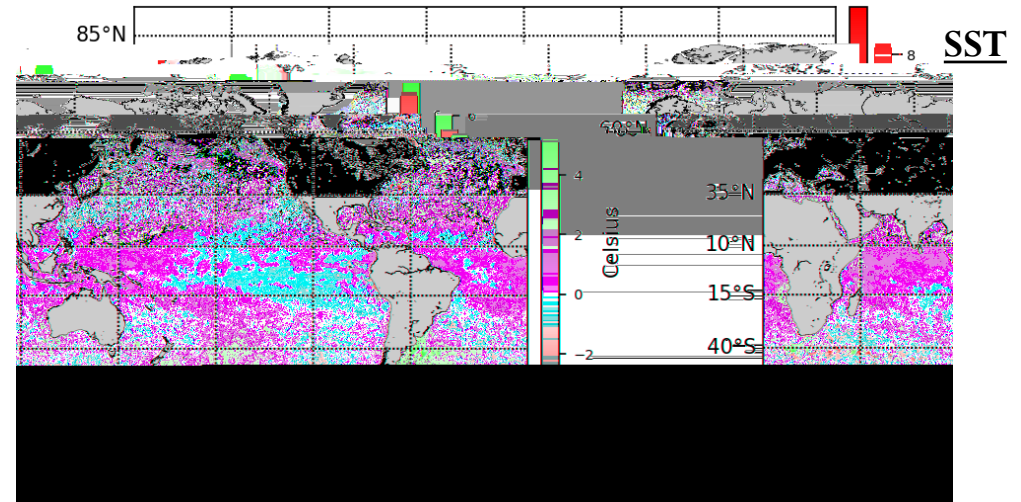


MODE: cold at 0,*,* vs cold at 0,*,*



Marine and Cryosphere

- Satellite verification of
 - Sea Surface Temperature
 - Sea Surface Salinities
 - Sea Surface Height
 - Ice cover/Concentration



Upcoming

- Marine and Cryosphere:
 - Scatterometer Winds
 - Altimeter Wave Heights
- Stratosphere:
 - Sudden Stratospheric Warming
 - Gravity Wave Drag (need expert to help)
- Land Surface Modeling
 - Coupling Index
- ENSO
 - ENSO Indices based on machine-learning derived climos
- Tropical MJO
 - Application of MODE-Time Domain (MTD) to identify zonal and meridional phase speed in precipitation fields.

Final Metrics

Tier 1

<https://dtcenter.org/events/2021/2021-dtc-ufs-evaluation-metrics-workshop/final-metrics-lists>

FIELD	LEVEL	DETERMNSTIC METRIC	ENSEMBLE METRIC
TIER 1			
Temperature Anomaly	2-meter	Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread
RMM1 and RMM2 (MJO)		Anomaly Correlation (climatology); Verification: ECMWF for S2S, observed OLR for OMI, observed OLR and ERA5 winds for RMM, GFS analysis	RMSE of Ensemble Mean + Ensemble Spread
Oceanic Nino Indices (ENSO)		Anomaly Correlation (climatology); Verification: OSTIA, OISST, OISSTv2.1, ERSST, *not* OISST, ERSSTv5	RMSE of Ensemble Mean + Ensemble Spread

Precipitation Anomaly	Surface	Heidke Skill Score	Pattern Anomaly Correlation, ETS and Bias of the Ensemble Mean or Performance Diagram CRPS and Bias.
NAO/PNA Index		Anomaly Correlation (climatology)	RMSE of Ensemble Mean + Ensemble Spread
AO/AAO Index		Anomaly Correlation (climatology)	RMSE of Ensemble Mean + Ensemble Spread
Outgoing Longwave Radiation (MJO)	Top of Atmos	RMS + Mean Error Bias	RMSE of Ensemble Mean + Ensemble Spread

Final Metrics

Tier 2

TIER 2			
Tibaldi-Molteni Index (Blocking)		Anomaly Correlation	RMSE of Ensemble Mean + Ensemble Spread
Standardized Precip Index		Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread
Geopotential Height Anomalies	500-hPa	Anomaly Correlation, Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread
Sudden Stratospheric Warming	10 hPa at 60 N	Zonal Mean Zonal Wind at 60N, 10hPa turning easterly, probability detection or false alarm Zonal wind turns	RMSE of Ensemble Mean + Ensemble Spread, Ranked Probability Skill Score
Basin-Wide TC Counts		ACC	RMSE of Ensemble Mean + Ensemble Spread

Palmer Drought Severity Index		Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread
Sea Ice Concentration	Surface	Heidke Skill Score, Performance Diagram	RMSE of Ensemble Mean + Ensemble Spread

Final Metrics Tiers 3 and 4

TIER 3			
Sea Ice Edge	Surface	Integrated Ice Edge Error, Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread
Fire Danger Index		Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread
Sea-Ice Thickness	Layer depth	RMSE, Bias, Taylor Diagram	RMSE Ens Mean + Spread, Bias
U/V Wind Anomaly	850-hPa	RMS + Mean Error Bias, Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread, ACC
U/V Wind Anomaly	200-hPa	RMS + Mean Error Bias, Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread, ACC
Precipitation	Surface	RMS+Bias	RMSE of Ensemble Mean + Ensemble Spread

TIER 4			
Sea-Ice Drift / Velocity	Surface	error radius, mean velocity difference	error radius and mean velocity difference of ensemble mean
Temperature	Sea Surface	RMS Error + Mean Error Bias	RMSE of Ensemble
Temperature	2-meter	Heidke Skill Score, RMS + Mean Error Bias	RMSE of Ensemble
Geopotential Height	500-hPa	RMSE+Bias	RMSE of Ensemble
U/V Wind	850-hPa	RMS + Mean Error Bias, Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread, ACC
U/V Wind	200-hPa	RMS + Mean Error Bias, Heidke Skill Score	RMSE of Ensemble Mean + Ensemble Spread, ACC

Gaps

S2S	See Seasonal	Fire Danger Index <i>Also see Seasonal</i>	ALEXI satellite data, CPC OLR Analysis, <i>Also See Marine/Cryo, Hydro, and Land</i>
Seasonal	Integrated Ice Edge	AO/AAO Index, NAO/PNA Index, Palmer Drought Severity Index, East Asian Summer Monsoon Index	CPC Precip Analysis, OSI-SAF 10km Analysis <i>Also see Marine/Cryo, Hydro, and Land</i>

<https://dtcenter.org/events/2021/2021-dtc-ufs-evaluation-metrics-workshop/metplus-metrics-gaps>

Thank You for Your Attention

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

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