METplus

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

Tara Jensen on behalf of the METplus Team

NCAR/RAL

and

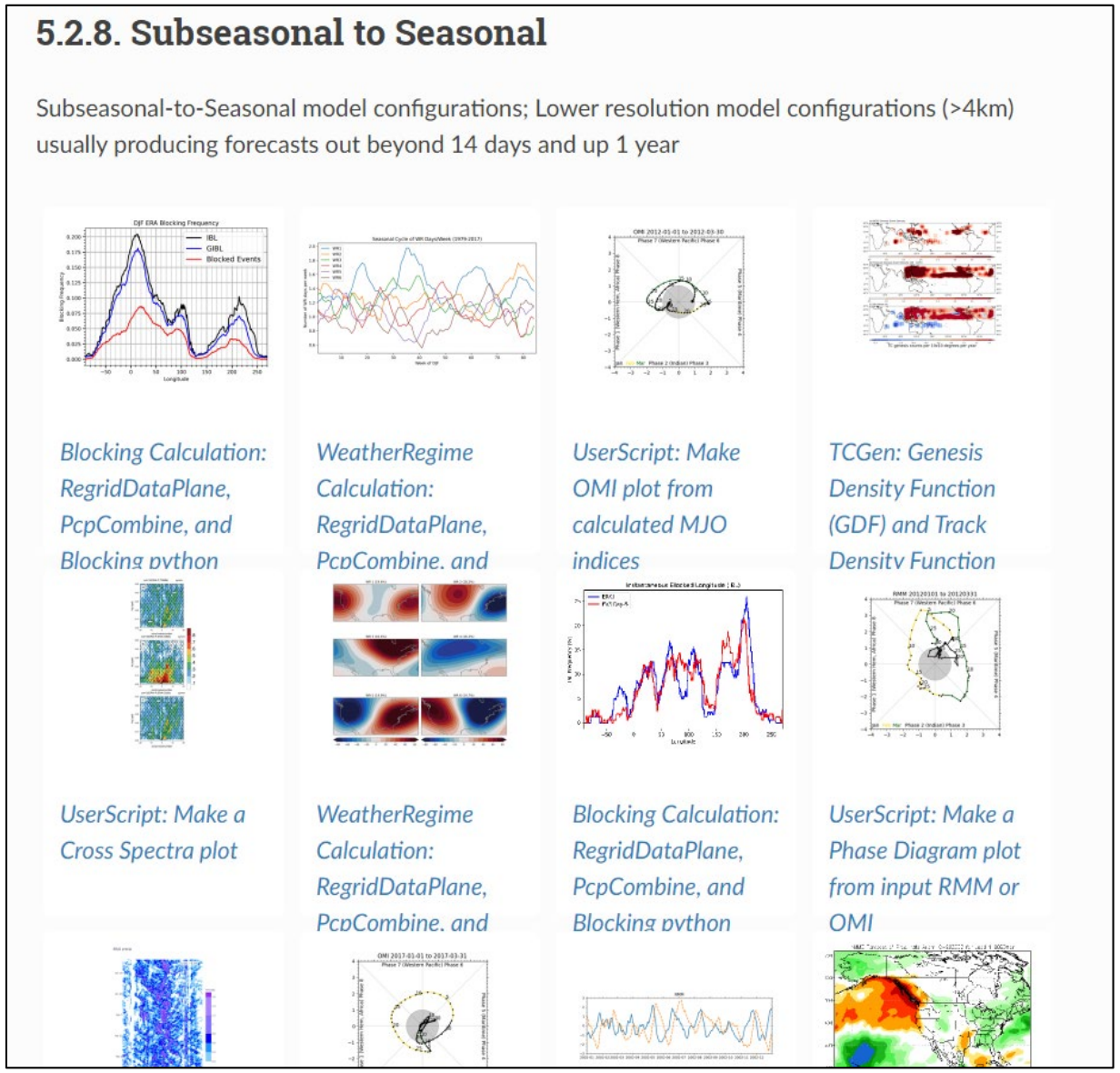
Developmental Testbed Center

Week 3-4/S2S Webinar

2 May 2022

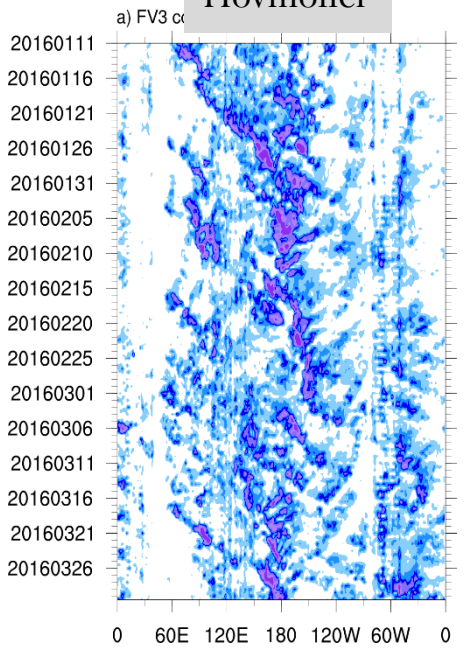
Overview

- **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**

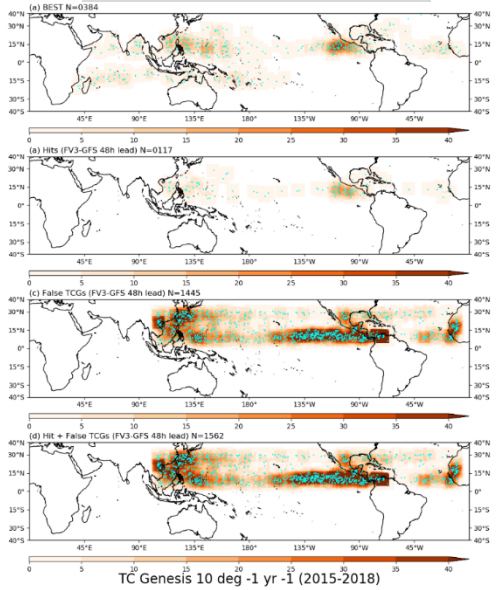


Covered in Previous Presentations

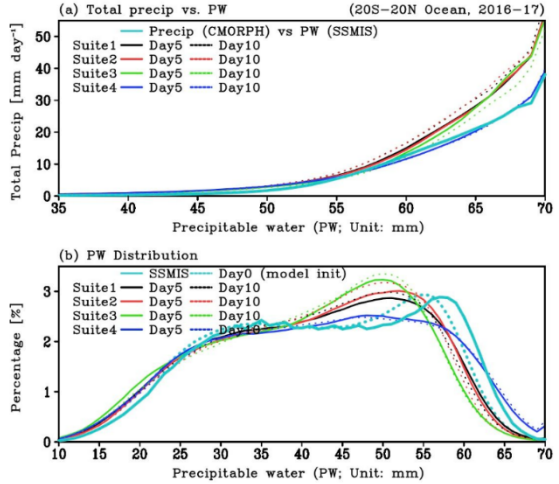
Hovmoller



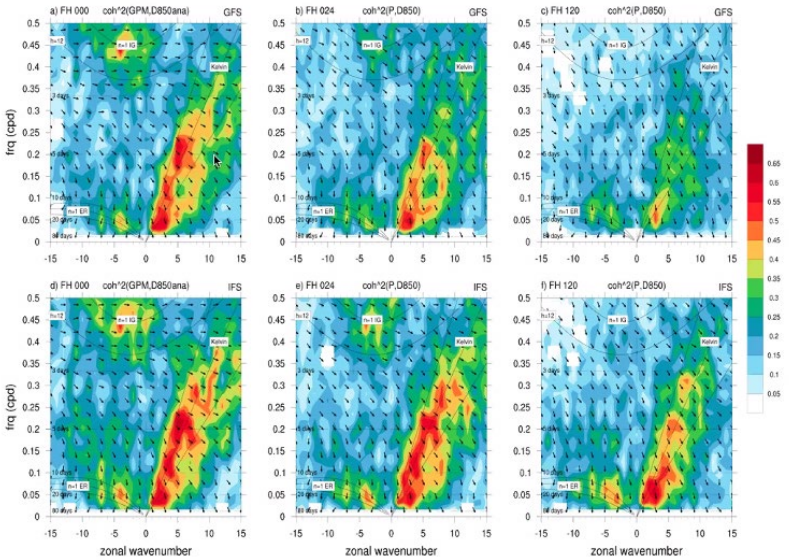
TC Genesis Density



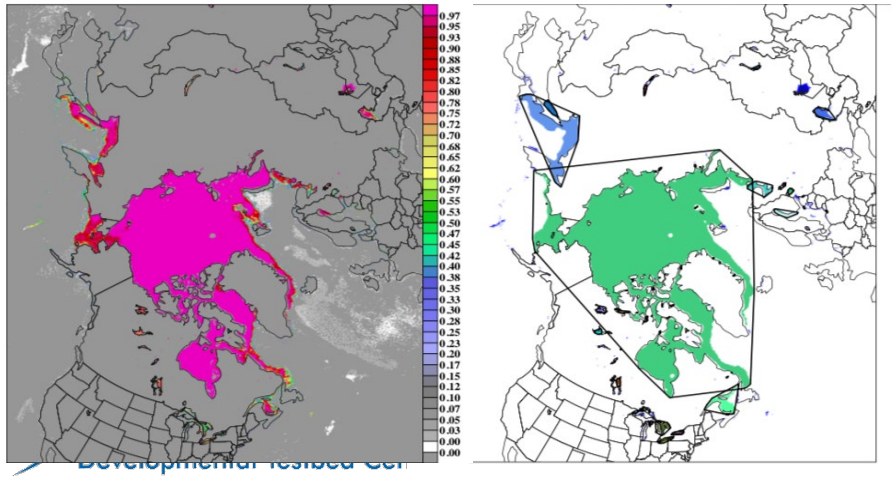
Moisture – Precip Relationship



Space-Time Coherence Spectra

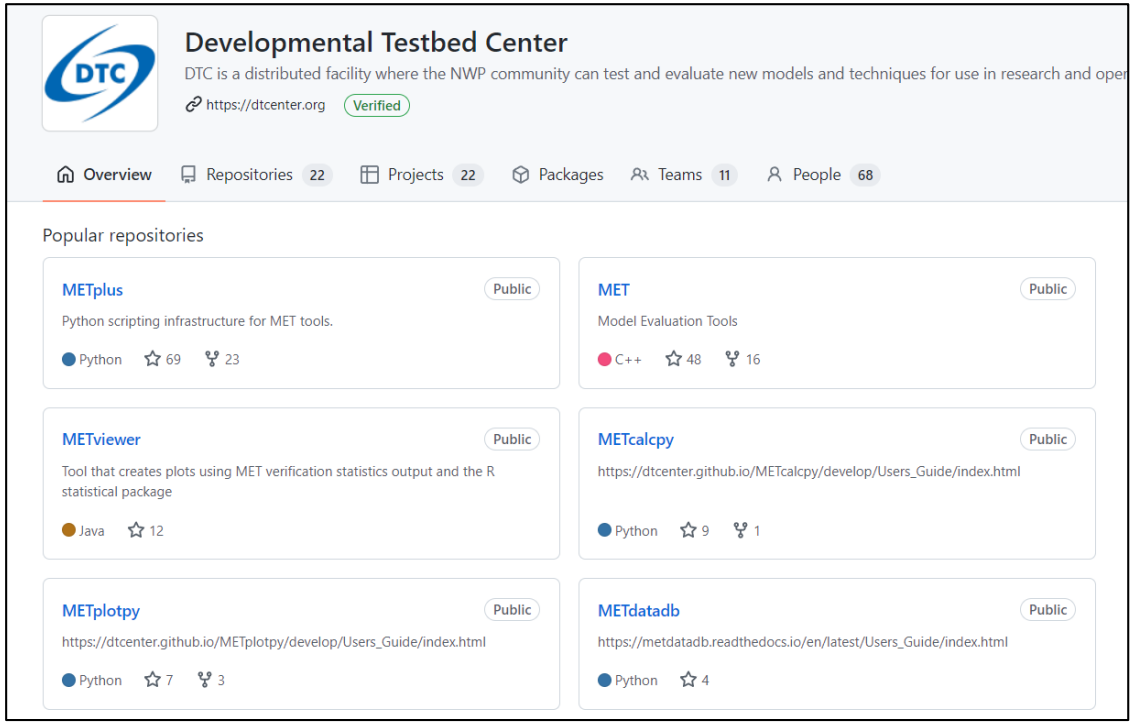


Sea Ice Objects

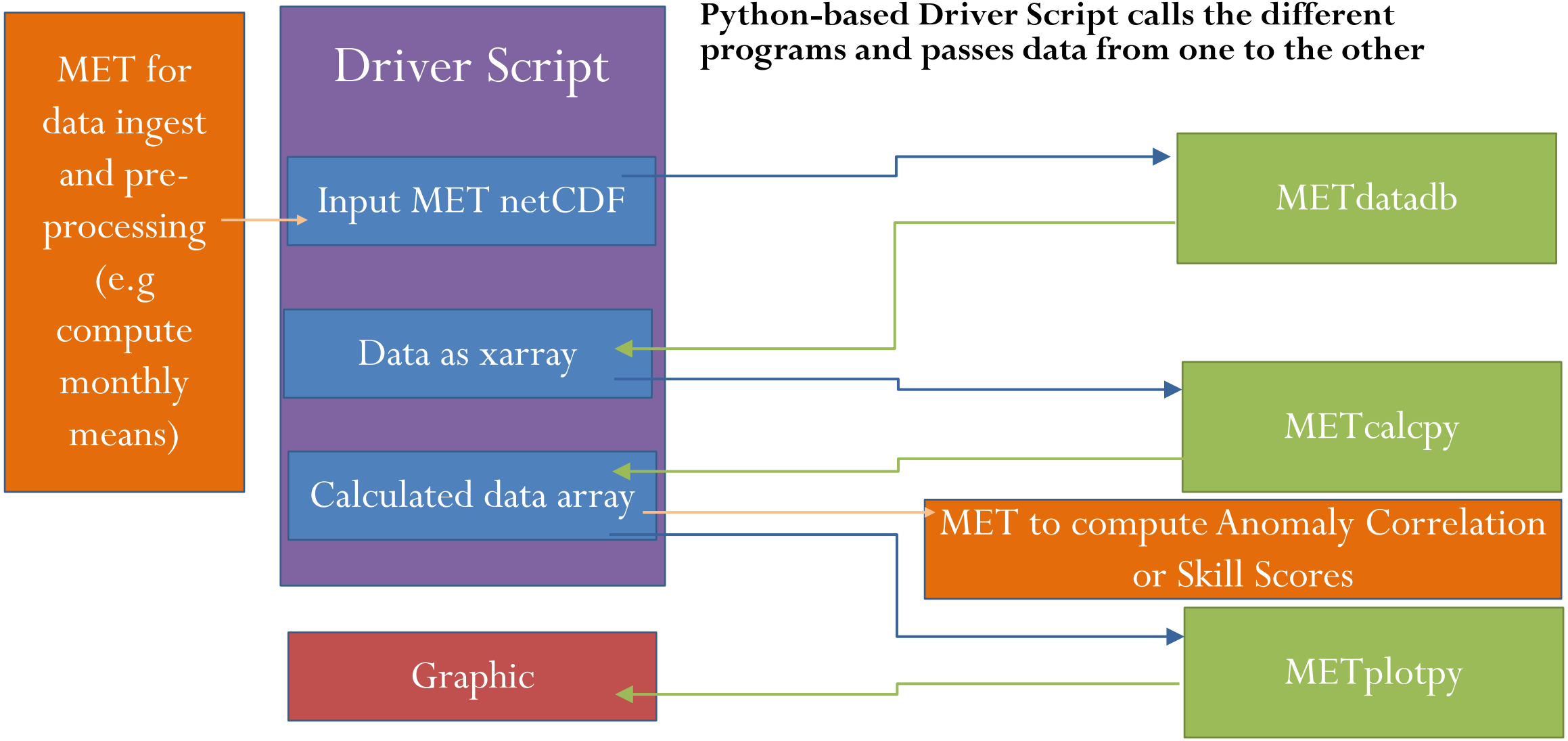


Process Oriented Diagnostics – General Approach

- **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**



Driver Script Simple Example

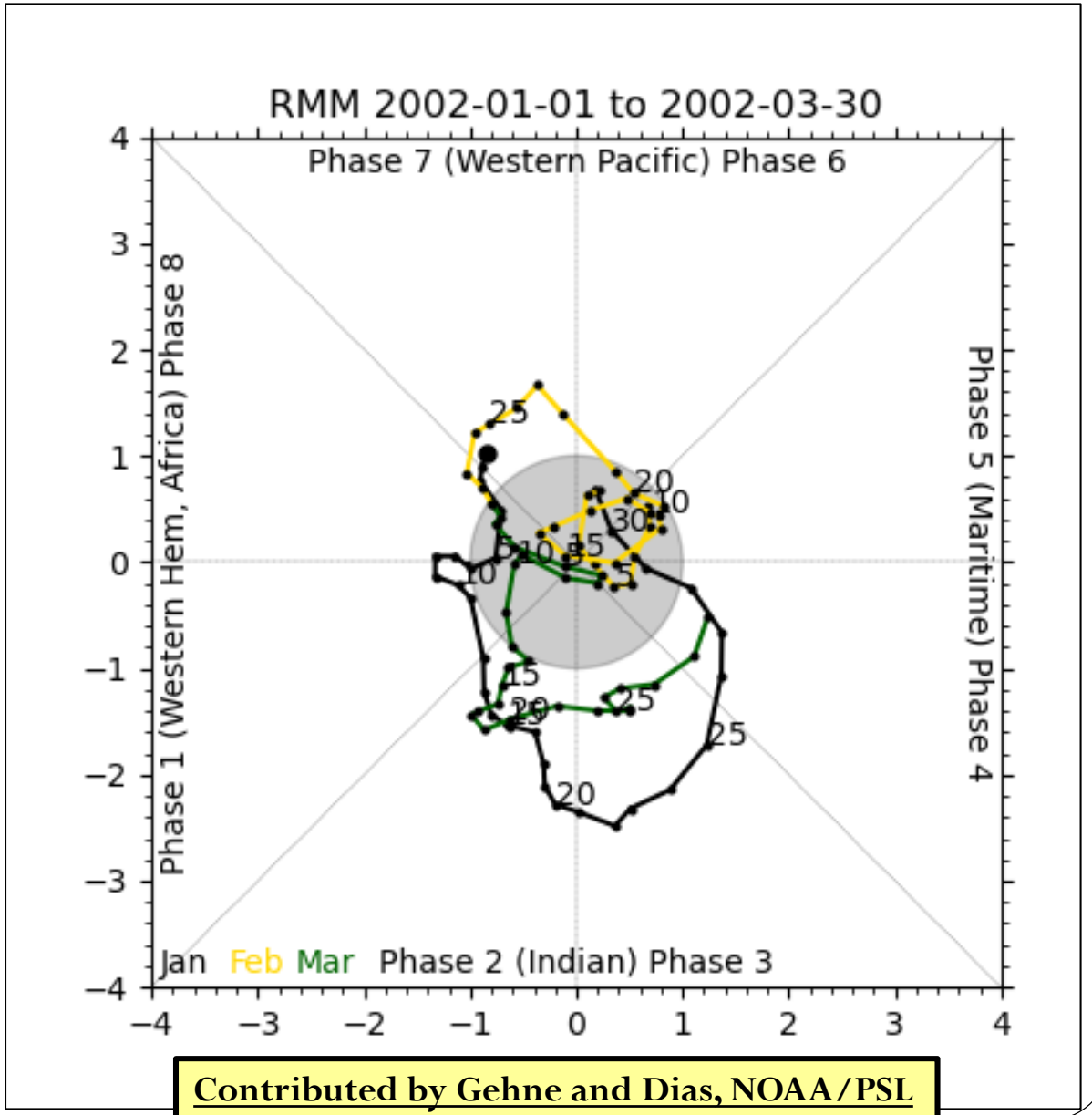


Why so complicated?

- 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**



Contributed by Gehne and Dias, NOAA/PSL

RMM Setup

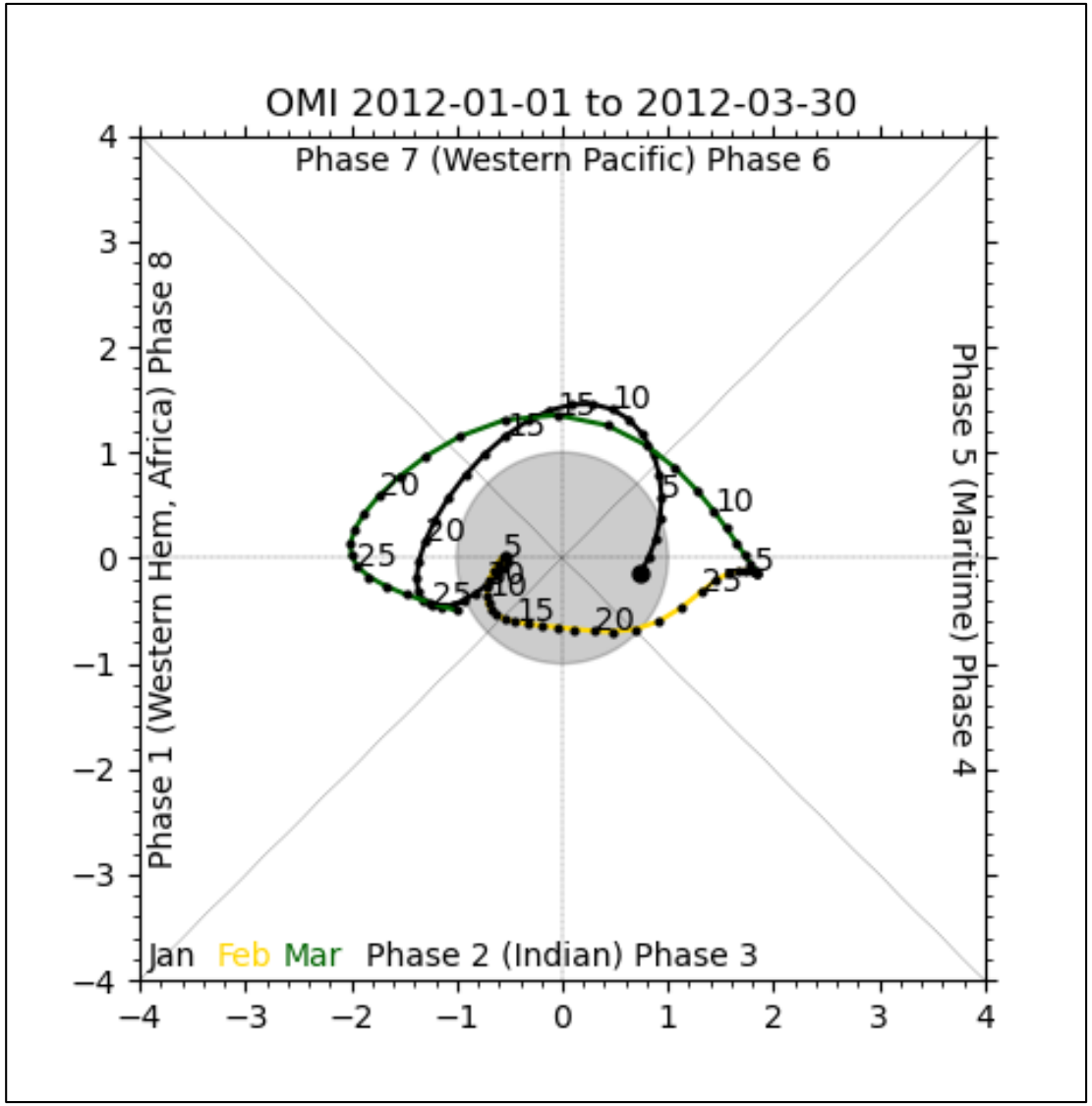
- **Calculation includes**
  - Removes 120 day mean
  - Normalize by square root of variance
  - Regress data onto EOF patterns
  - Normalize principal components by standard deviation
- **Configuration Options**
  - Run forecast, obs, or both
    - RMM calculated separately
  - Number of Observations 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_FCST = 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
OLR_EOF_INPUT_TEXTFILE = {INPUT_BASE}/model_applications/s2s/UserScript_obsERA_obsOnly_RMM/EOF/rmm_olr_eofs.txt
U850_EOF_INPUT_TEXTFILE = {INPUT_BASE}/model_applications/s2s/UserScript_obsERA_obsOnly_RMM/EOF/rmm_u850_eofs.txt
U200_EOF_INPUT_TEXTFILE = {INPUT_BASE}/model_applications/s2s/UserScript_obsERA_obsOnly_RMM/EOF/rmm_u200_eofs.txt

# Normalization factors for RMM
RMM_OLR_NORM = 15.11623
RMM_U850_NORM = 1.81355
RMM_U200_NORM = 4.80978
PC1_NORM = 8.618352504159244
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 = 2002010100
PHASE_PLOT_TIME_END = 2002123000
PHASE_PLOT_TIME_FMT = {VALID_TIME_FMT}
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 = 2002010100
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

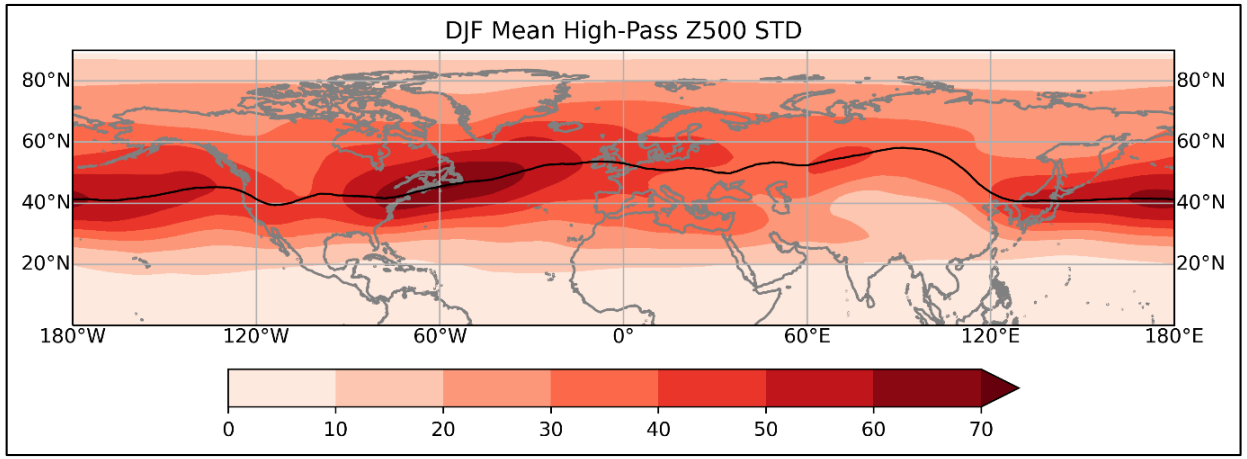
Contributed by Wang and Li, UIUC

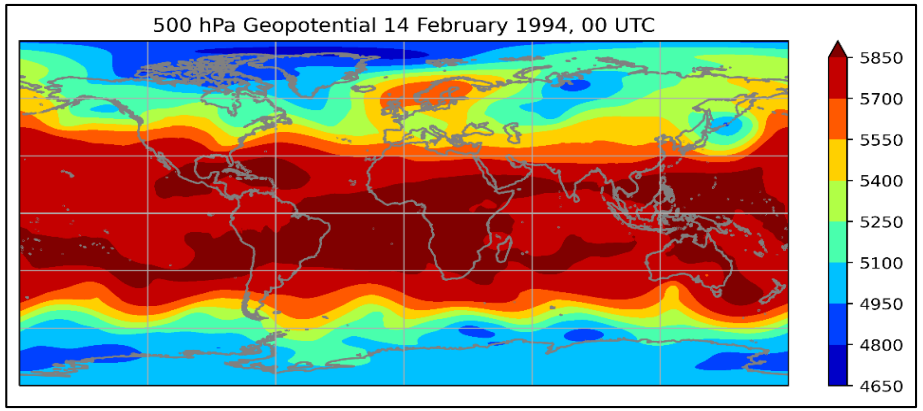
Blocking Overview Continued

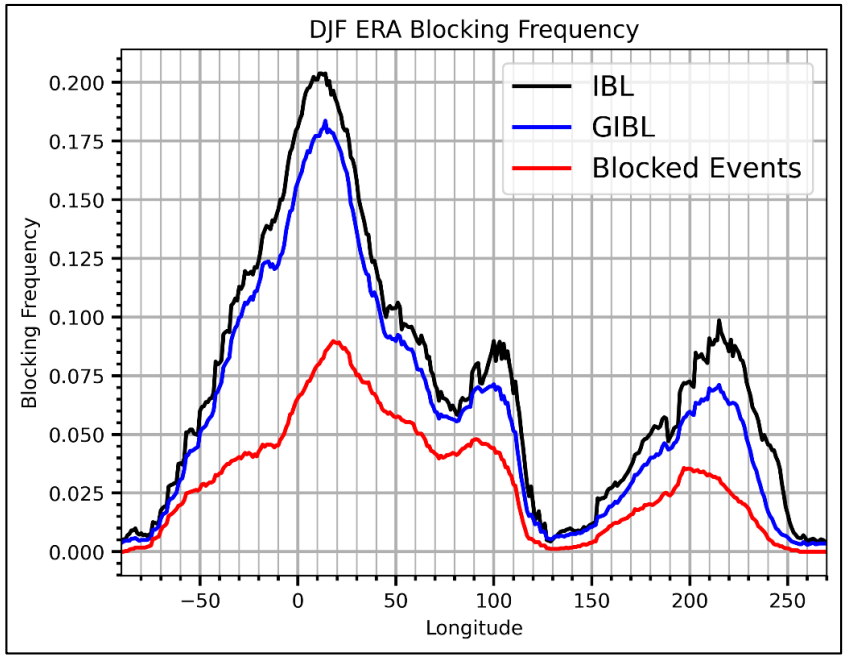
- **2 Stat-Analysis runs (if both model and obs run)**
  - Contingency Table statistics for IBLs and Blocks
- **Output Notes:**
  - **Central Blocking Latitudes** (CBLs) and blocks plotted separately for model and observations
  - **Instantaneous Blocking Latitudes** (IBLs) on same plot

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

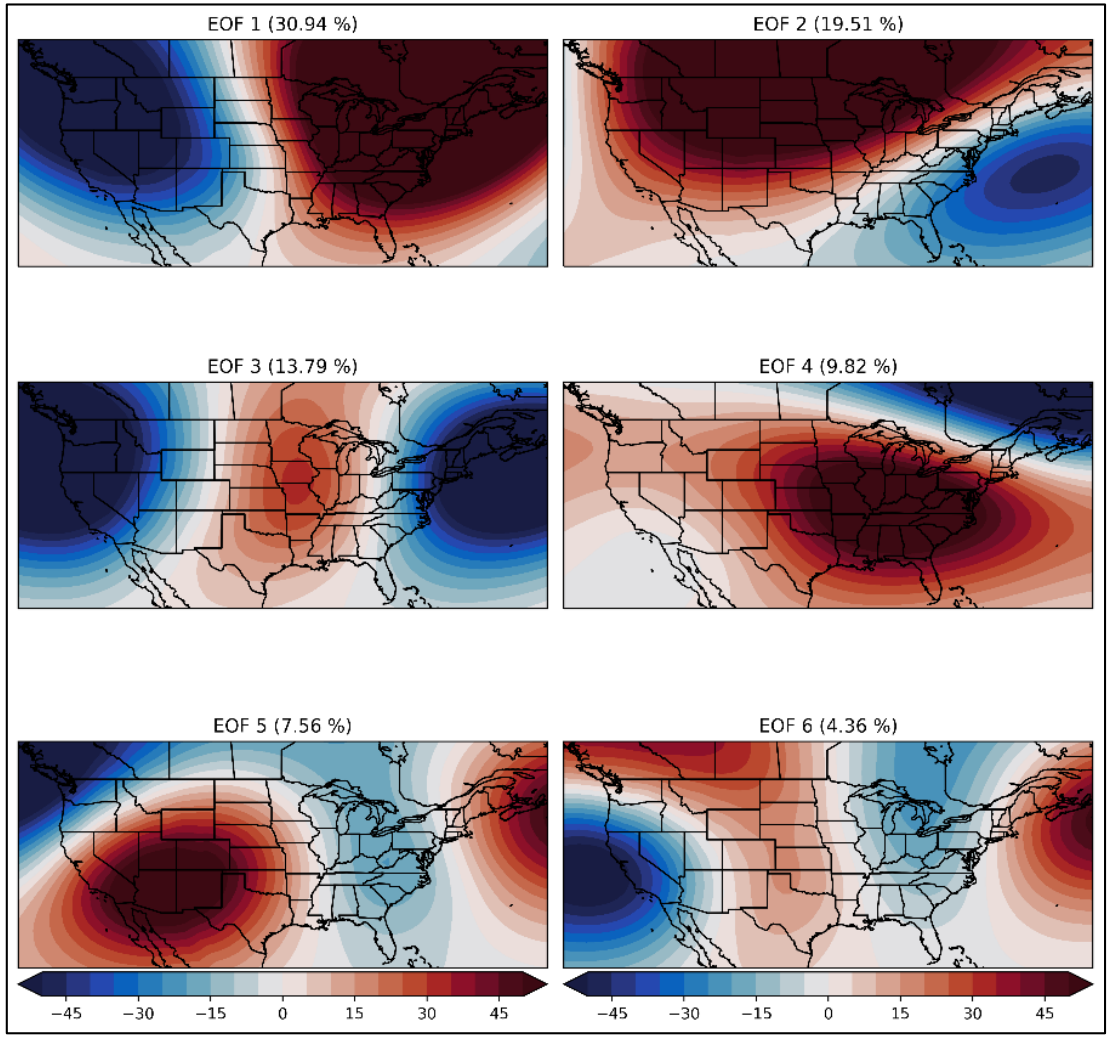
- **UserScript_fcstGFS_obsERA_WeatherRegime.conf, UserScript_obsERA_obsOnly_WeatherRegime.conf**
  - WeatherRegime_driver.py
- **Daily mean 500 mb height, preferably 20 – 30 years**
- **2 pre-processing steps (turned off)**
  - Regrid_data_plane: Regrid to 1 degree
  - Pcp_combine: daily mean/forecast 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

Contributed by Wang and Li, UIUC

Weather Regime Overview Continued

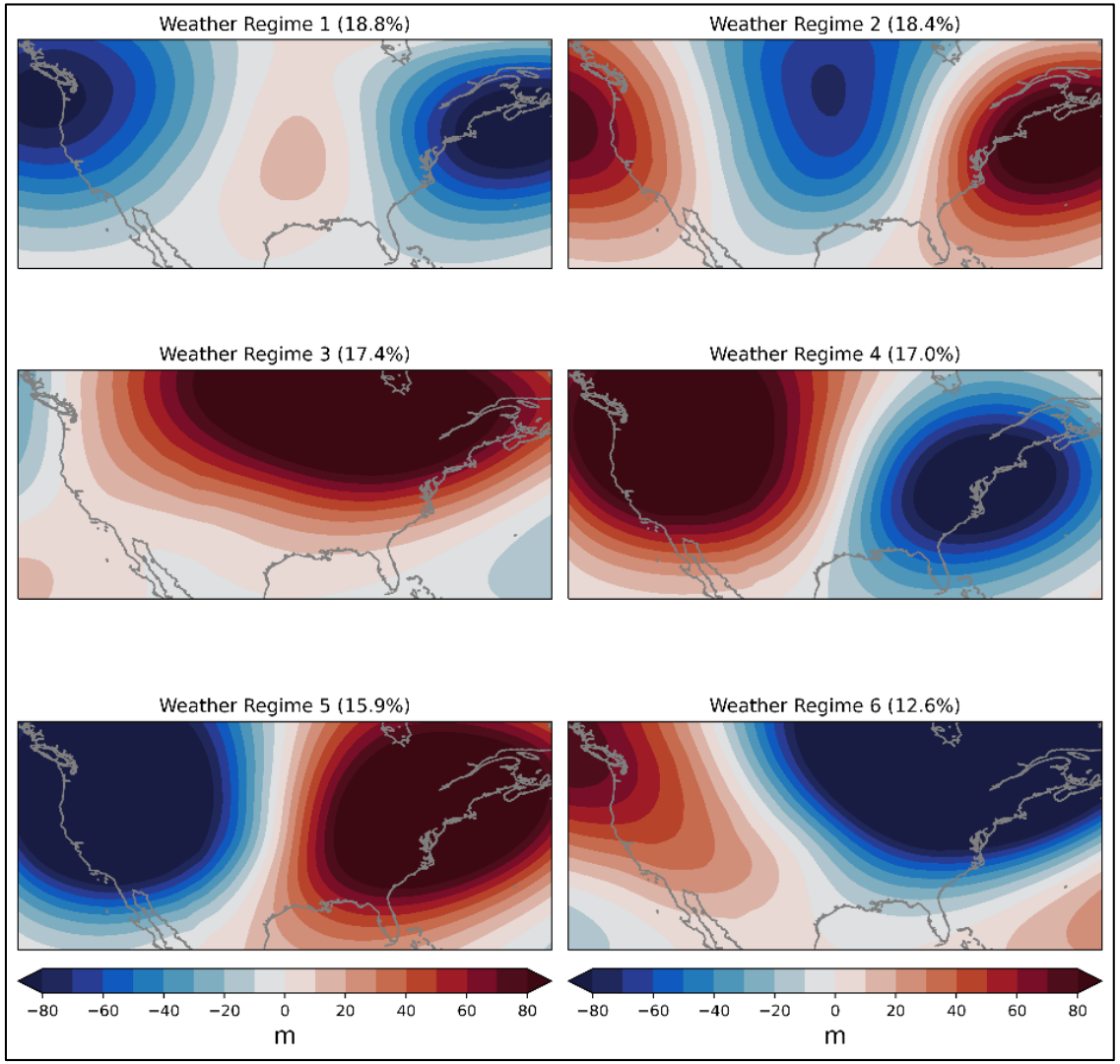
- **2 Stat-Analysis runs (if both model and obs run)**
  - Multi-Category Contingency Table Statistics file for the weather regime classification
  - Continuous Statistics file for the weather regime frequency
- **Additional Output:**
  - Classification file (day and regime) in text or netCDF for model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

ERA EOFs Dec 2000 – Feb 2017

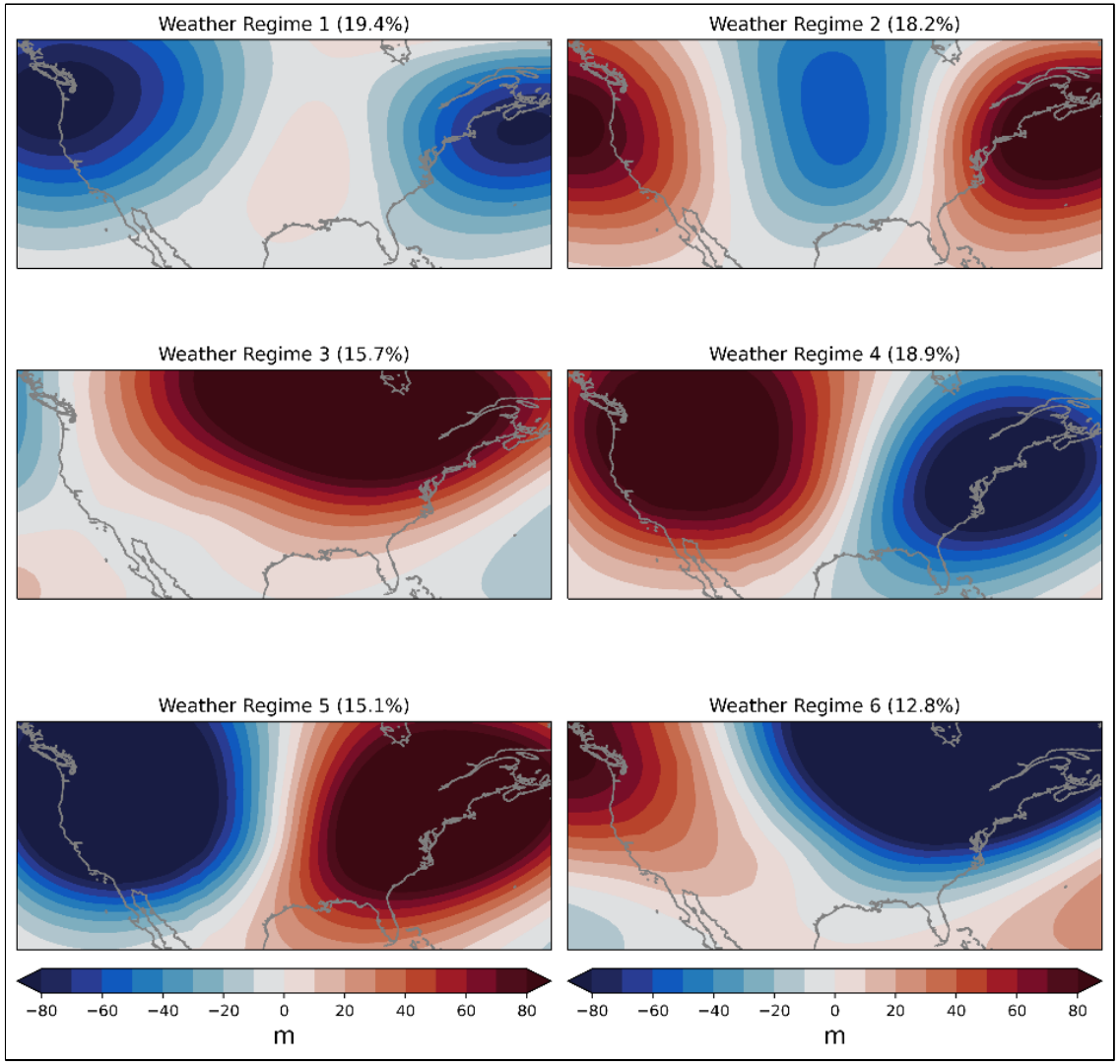


Weather Regime Classification

ERA Dec 2000 – Feb 2017

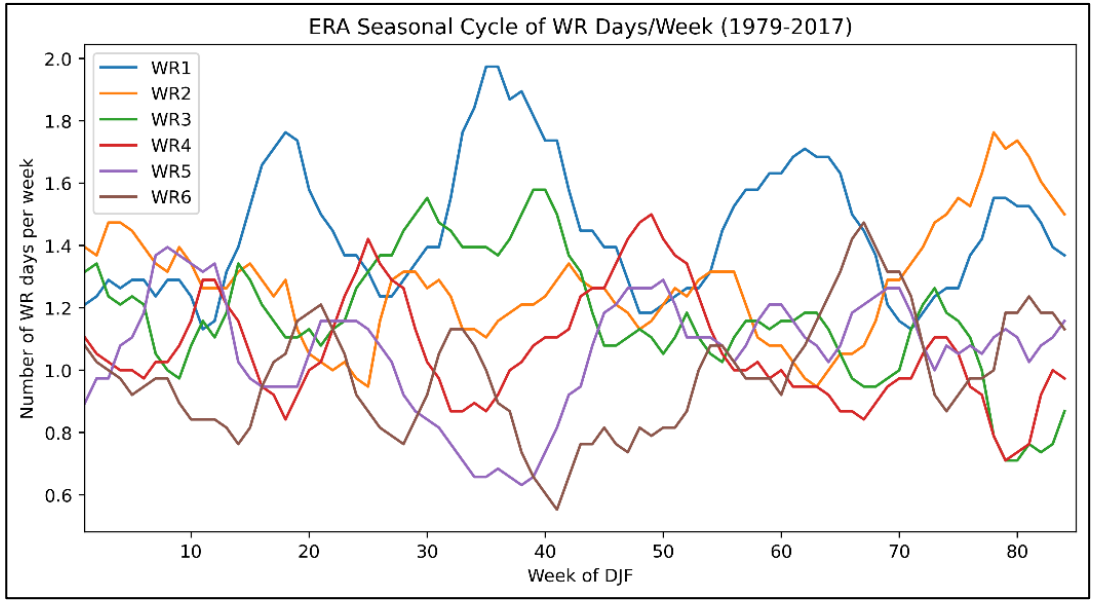


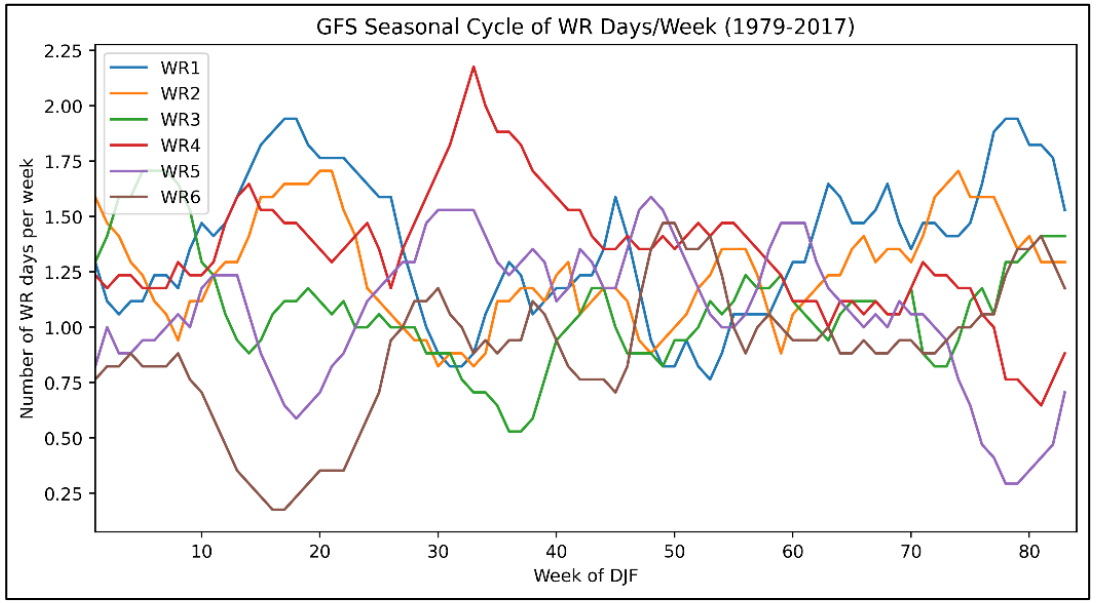
GFS Dec 2000 – Feb 2017



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

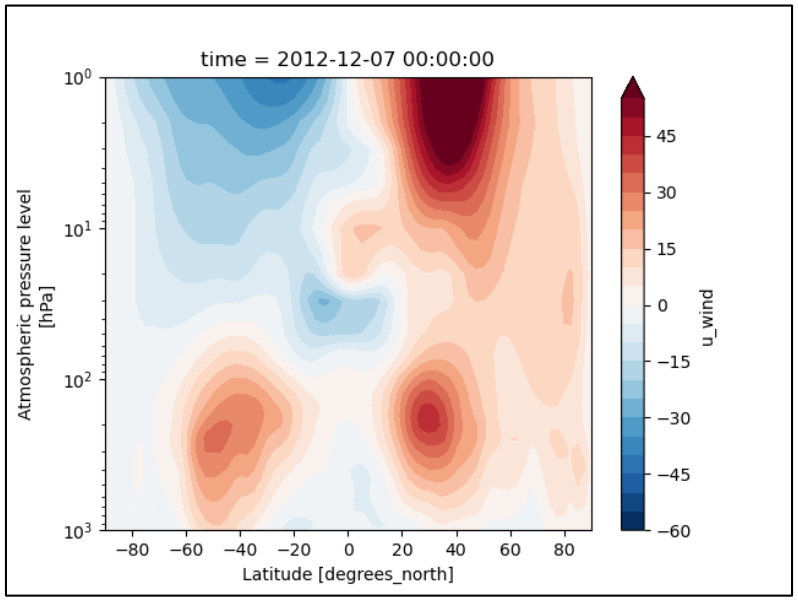
- **Weather Regime Classification and frequency output to matched pair format**
  - File for each day
  - One line per file with classification or frequency

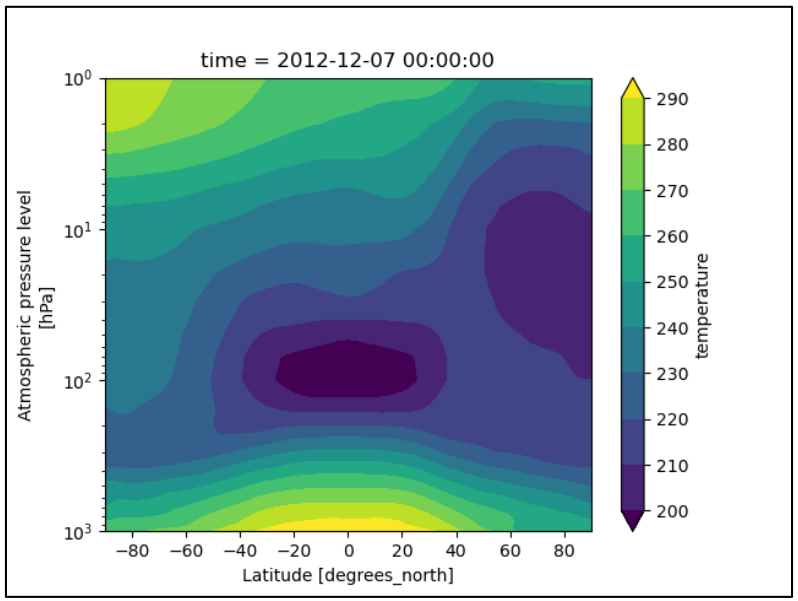
Multi-Category Contingency Table Statistics
HSS: 0.593

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



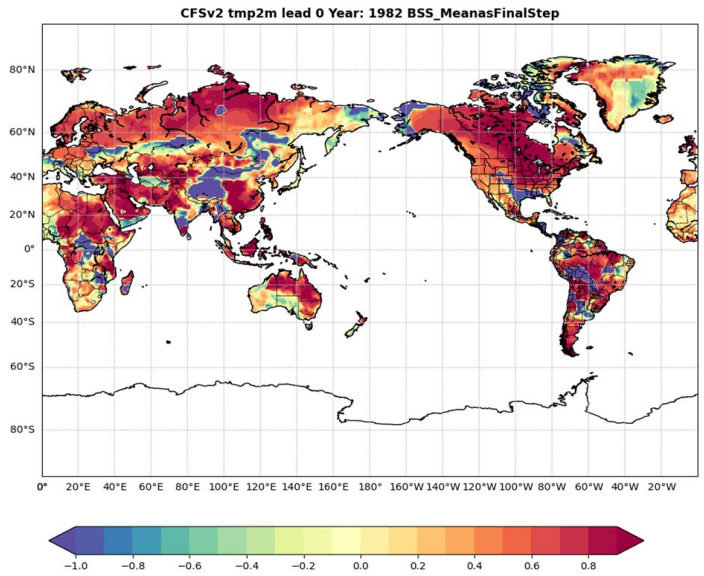


Contributed by Butler and Lawrence, UIUC

CFSv2 Fields and Baselining with CPC

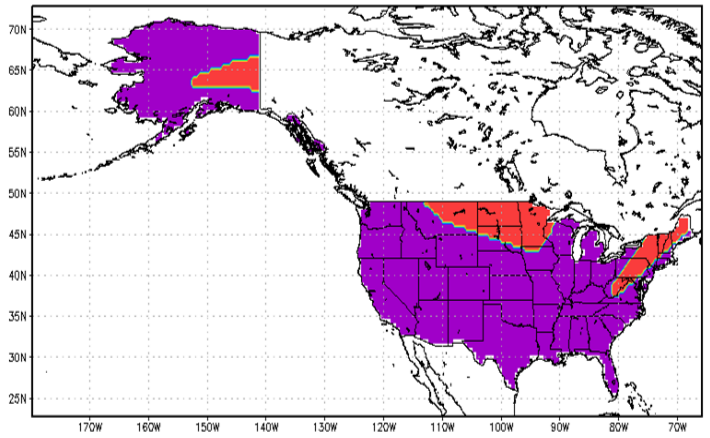
- Discrepancies in Brier Skill Score (BSS) values
  - Rounding differences
- New tool, Gen-Ens-Prod, for standardized anomalies creation
  - Added normalized anomalies from climatology, ensemble data
  - Reference Brier Score (BRIERCL) output
  - Read all ensemble members from 1 file
- METplus replicates 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    = "";
```

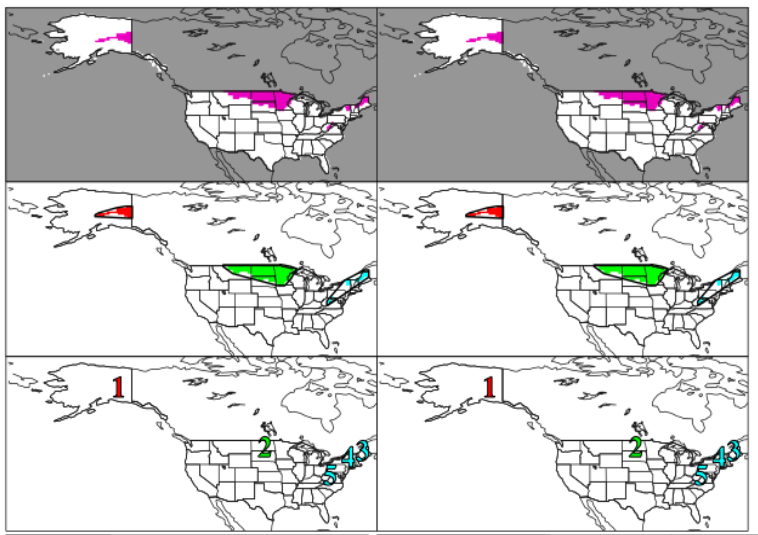


CPC Weather Watch Areas (WWAs)

- 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,*,*



Fcst	Obs	Interest
1	1	1.0000
2	2	1.0000
3	3	1.0000
4	4	1.0000
5	5	1.0000
4	3	0.4553
3	4	0.4553
4	5	0.1923
5	4	0.1923
5	3	0.0862
3	5	0.0862
2	5	0.0084
5	2	0.0084
5	1	NA
1	2	NA
1	4	NA
2	4	NA
2	1	NA
3	2	NA
4	2	NA
1	5	NA
3	1	NA
1	3	NA
2	3	NA
4	1	NA

	Forecast	Observation
Model	WWA	
Field	cold	cold
Level	0,*,*	0,*,*
Units	NA	NA
Initial	2018 02 03 00:00:00	2018 02 03 00:00:00
Valid	2018 02 03 00:00:00	2018 02 03 00:00:00
Accum	00:00:00	00:00:00

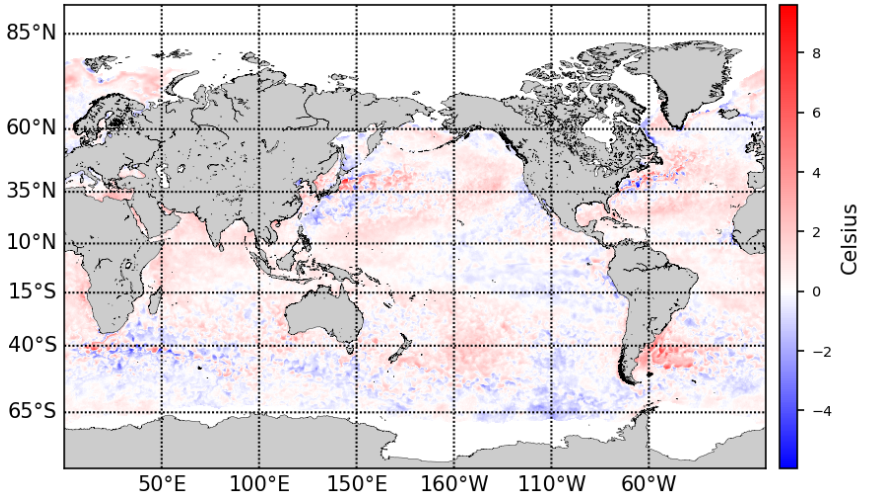
Centroid/Boundary	2.00	2.00
Convex Hull/Angle	2.00	0.00
Aspect/Area	0.00	2.00
Int Area/Curvature	2.00	0.00
Complexity/Intensity	0.00	0.00
Total Interest Thresh	0.10	

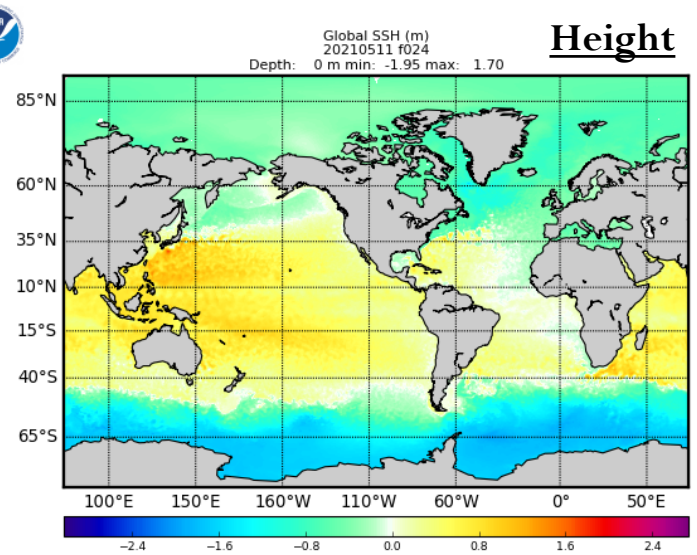
	Forecast	Observation
Mask M/G/P	on/off/off	on/off/off
Conv Radius	0	0
Conv Thresh	>0.0	>0.0
Obj Filters	0	0
Inten Perc	p50	
Merge Thresh	NA	NA
Merging	engine	engine
Matching	match/merge	
Simple/M/U	5/5/0	5/5/0
Area	411	411
Area M/U	411/0	411/0
Cluster	3	3
MMI	1.0000	1.0000
MMI (F+O)	1.0000	

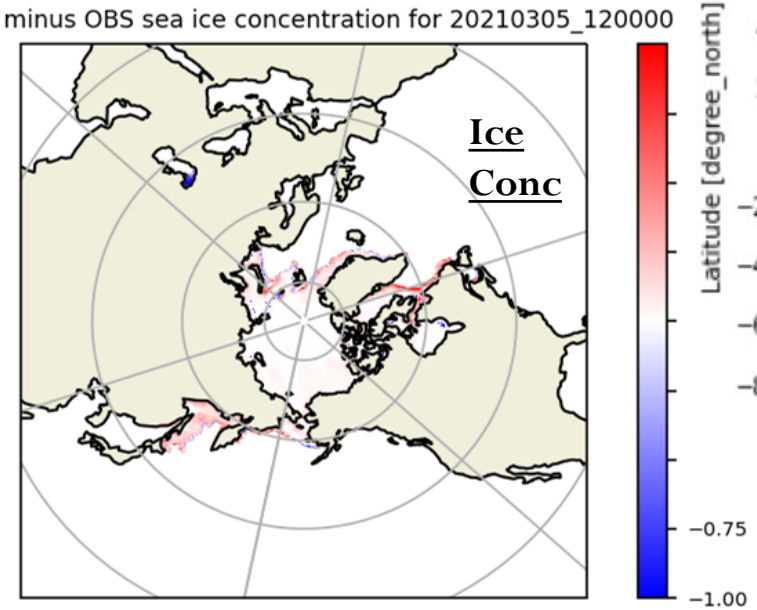
Contributed by Hicks, CPC

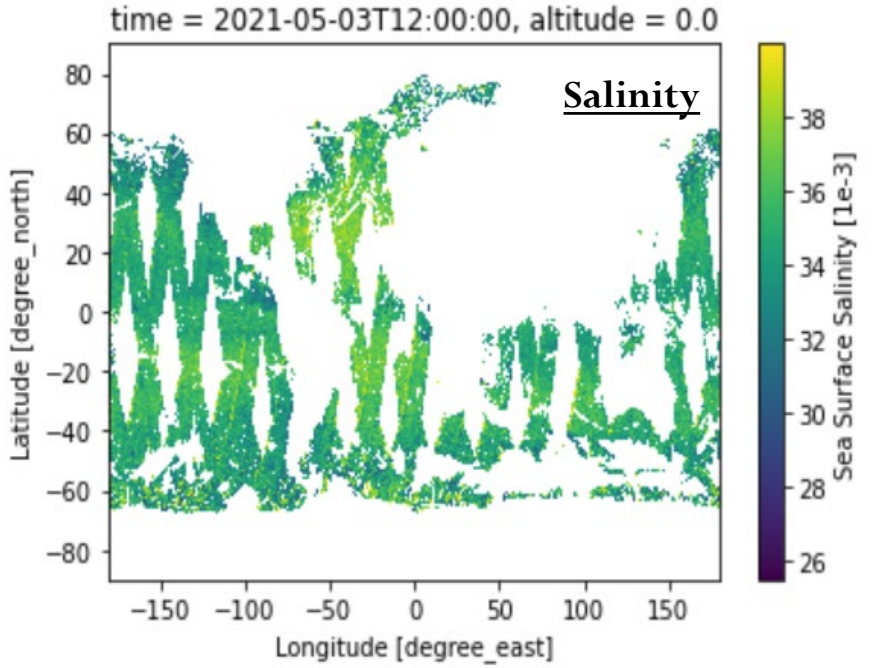
Marine and Cryosphere

- 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	DETERMNISTIC 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, probaility 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 + Mear	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 *Also see Seasonal*	ALEXI satellite data, CPC OLR Analysis, *Also See Marine/Cryo, Hydro, and Land*
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 *Also see Marine/Cryo, Hydro, and Land*

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

2022 DTC METplus Users' Workshop
27-29 June 2022
VIRTUAL
Register and Submit Abstracts at:
https://dtcenter.org/events/2022/2022-dtc-metplus-workshop

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