Validation of Significant Weather Features and Processes in Operational Models Using a Cyclone Relative Approach

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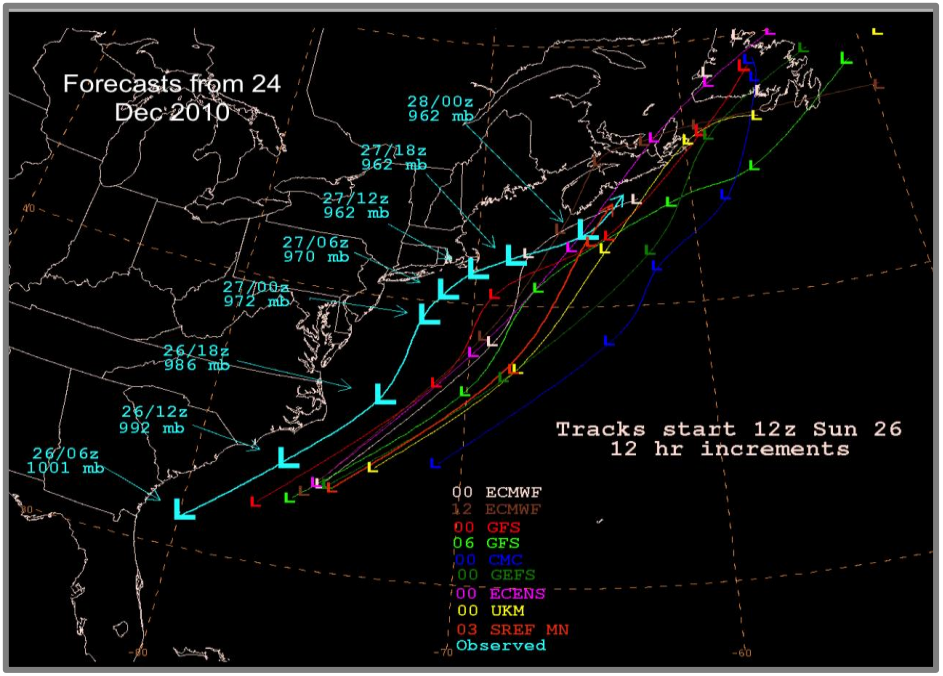
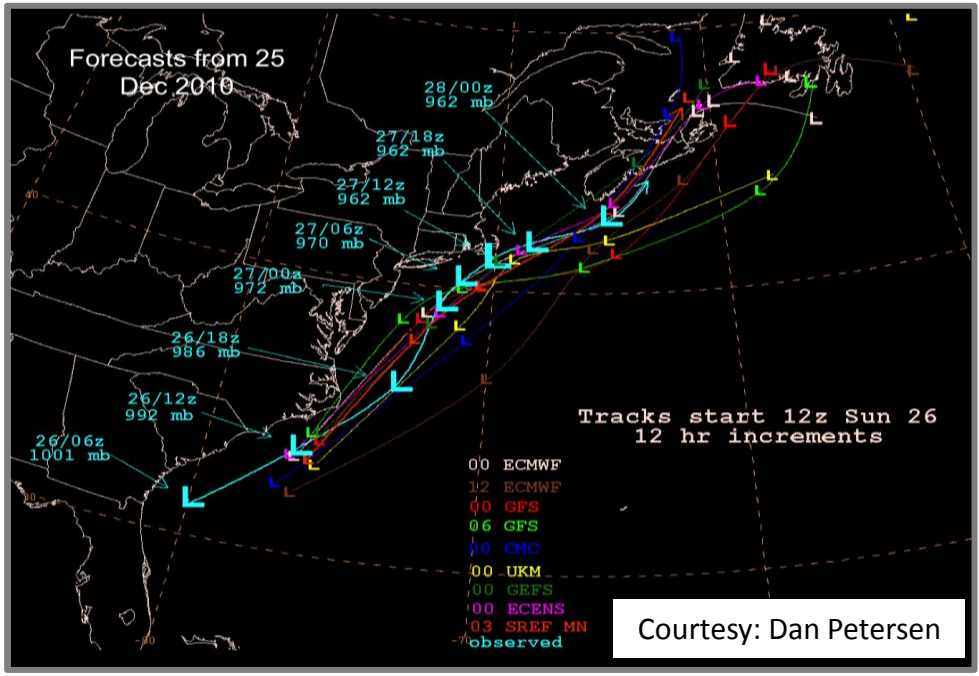
***Partners**:*

NCAR and Developmental Testbed Center, Environmental Modeling Center, Weather Prediction Center, Ocean Prediction Center, and Aviation Weather Center)

Motivation

- Extratropical cyclones can have large predictability issues, especially in the medium range.
- There has no comprehensive evaluation of NCEP, Canadian, and ECMWF ensemble systems for U.S. East Coast storms.
- More community tools are needed to evaluate the next generation model using a feature-based approach, with more focus on the physical processes.





Courtesy: Dan Petersen

Project Goals

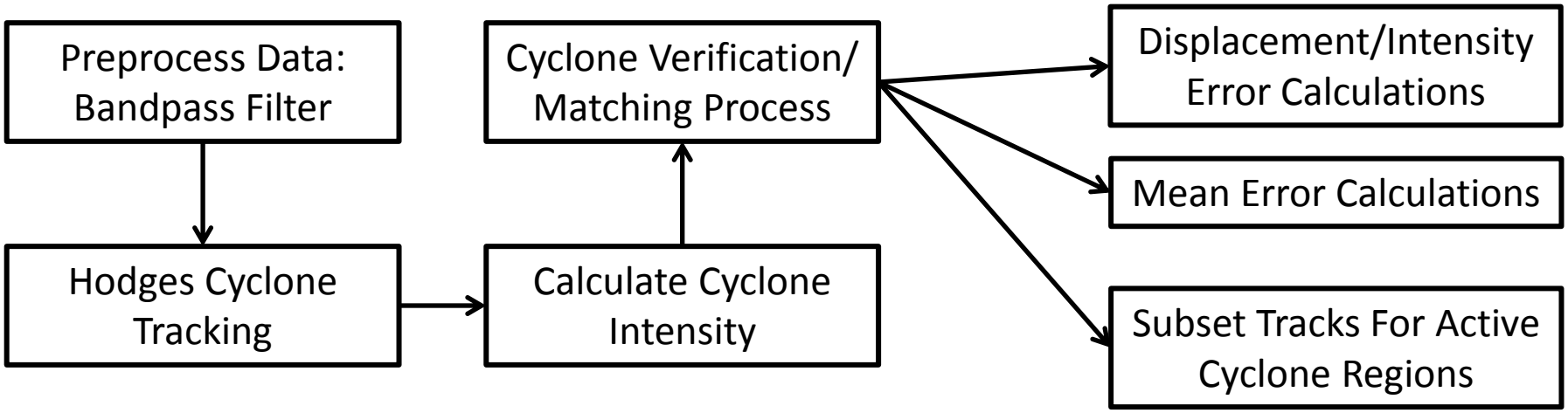
- Cyclone tracking, matching, and verification. Compare GEFS, CMC, and EC for days 0-7.
- Use cyclone relative approach to investigate some of the relevant processes associated with various cyclone biases (moisture, precipitation, surface fluxes, stability, etc…).
- Develop Cyclone-relative verification and diagnostic software within NCAR MET (Model Evaluation Tools).
- Port the cyclone-relative software in MET to our Operational Center partners and iterate on parameters relevant to operations and Testbeds (e.g., WPC Winter Weather Experiment).

Extratropical Cyclone Data/Tracking

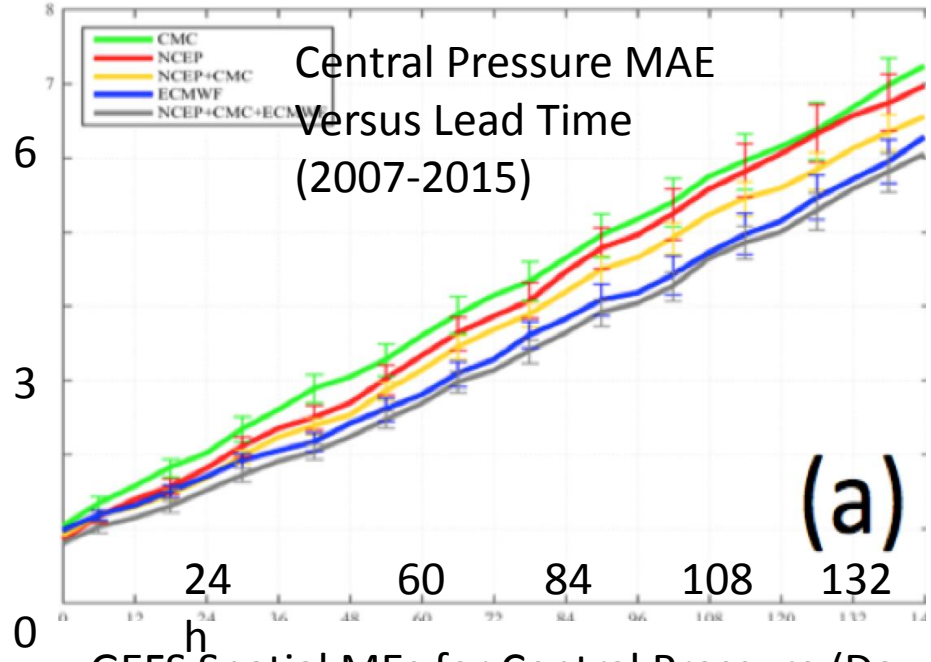
- TIGGE: THORPEX Interactive Grand Global Ensemble (Oct-March 2007-2015)
  - 20 member NCEP - GEFS: Global Ensemble Forecast System
  - 50 member ECMWF: European Center for Medium-Range Weather Forecasts
  - 20 member CMC: Canadian Meteorological Center Ensemble
  - Control Members are included for statistical comparison

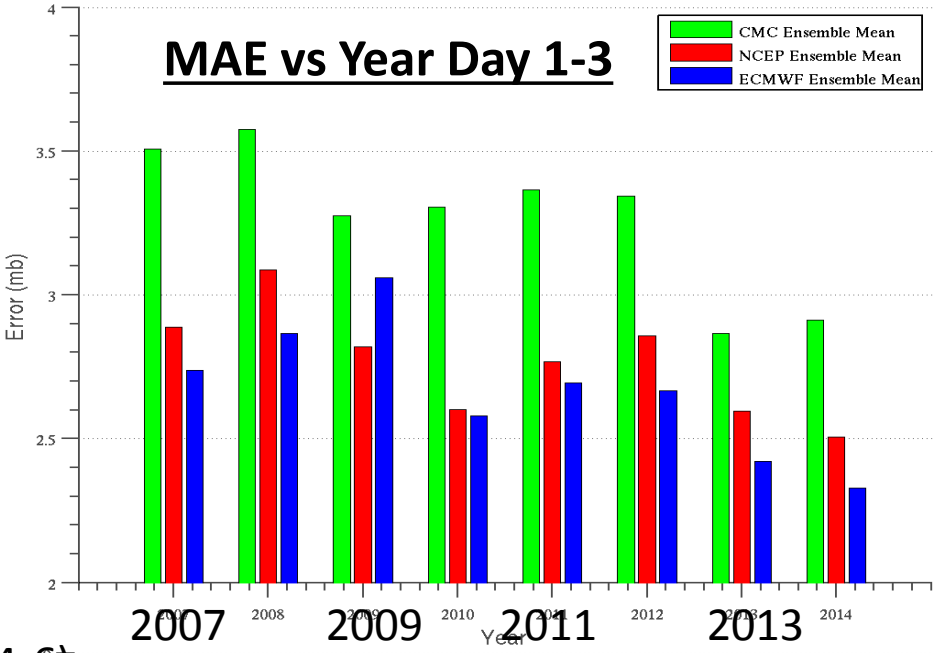
    ***** Most ensemble mean results are calculated using the errors from each of the ensemble members *****

- Track and match ensemble, control, and reanalysis cyclones using Hodges (1995) surface cyclone tracking scheme
  - ECMWF ERA-Interim Re-Analysis is used to verify cyclone properties from October to March
  - All MSLP data is 1˚ x 1˚ resolution
  - Data is filtered to remove planetary scale effects (small wavenumber) and small scale effects (large wavenumber)
  - Cyclone tracking conditions: 24 h lifetime and 1000 km distance traveled (Colle et al. 2013)
  - The pairing distance d of a point in an individual forecast track to a point in the analysis track, which coincides in time with the analysis track, is $< d_{max} = 1500$ km. –> modified (Froude et al. 2007).
  - At least 60% of the points in the forecast track coincided in time with the analysis track and satisfied $d \leq d_{max}$.

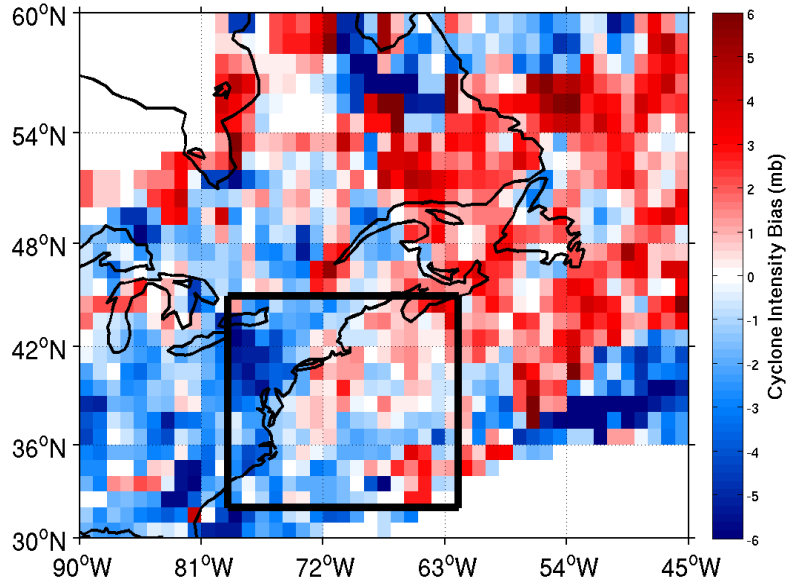


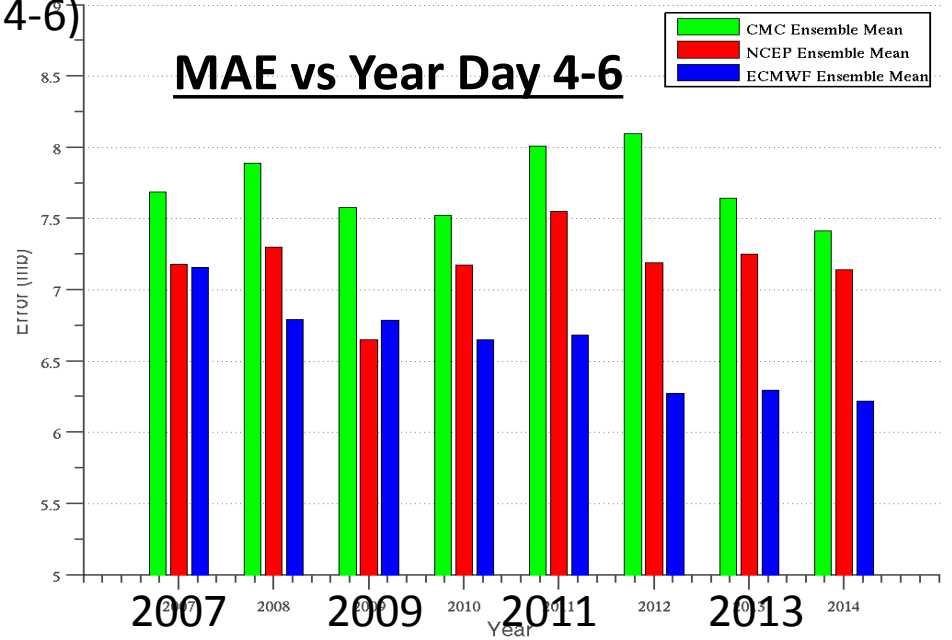
U.S. East Coast/ W Atlantic Cyclone Intensity (Central Pressure) ME and MAE



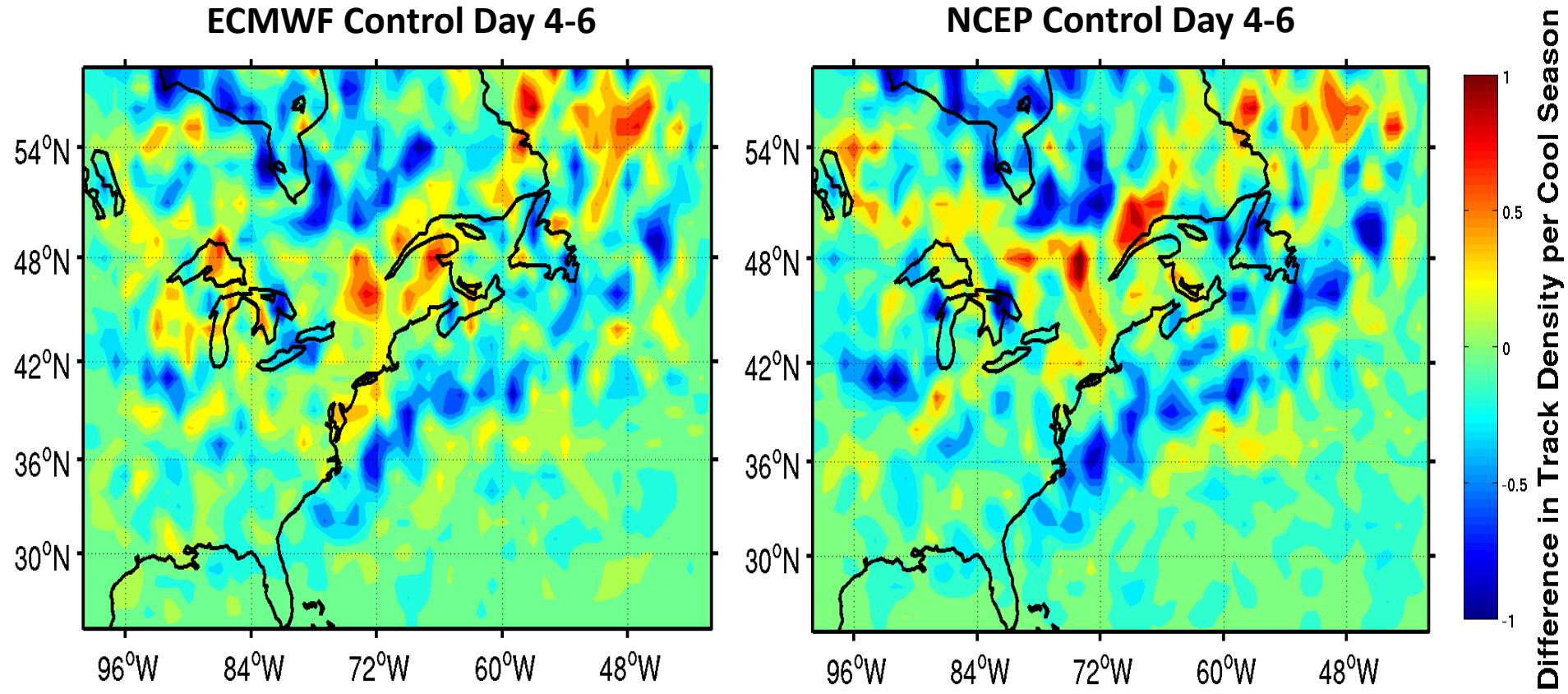


GEFS Spatial MEs for Central Pressure (Day 4-6)





ECMWF and NCEP Control Cyclone Density Difference Day 4-6 Forecasts

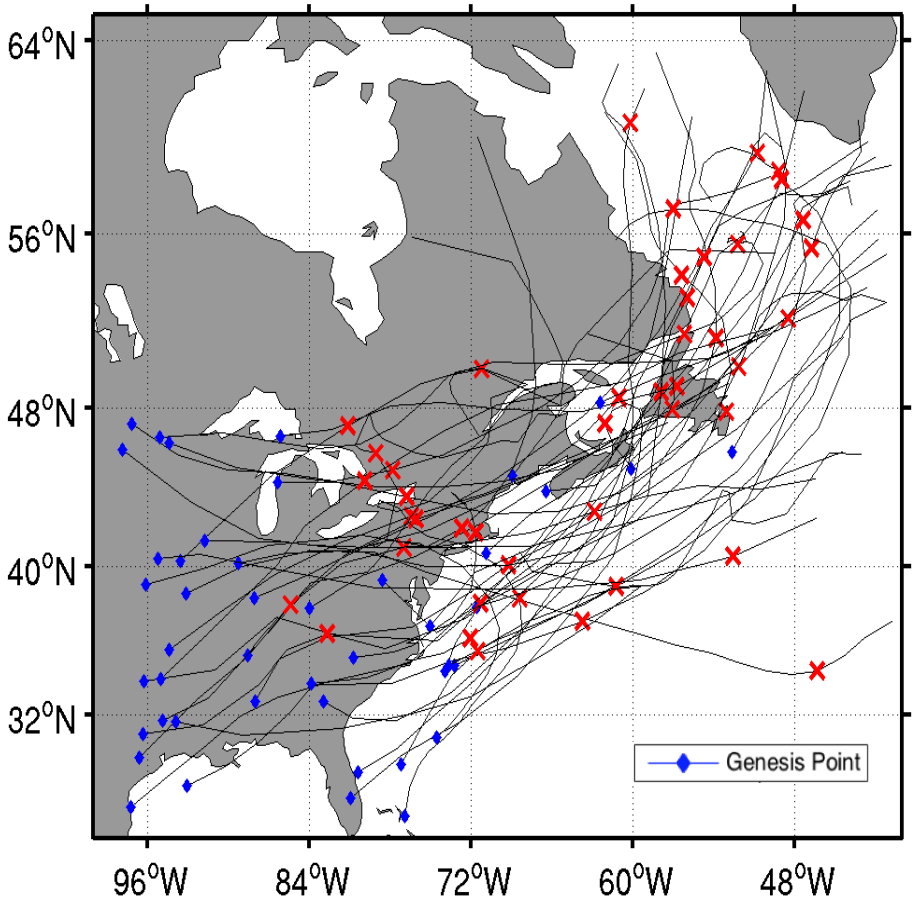


- Difference in track density amounts to 5-10% error where cyclones are underpredicted off the East Coast and near Hudson's Bay
- Both NCEP and ECMWF tend to overpredict over northern New England

NCEP GEFS Control Member Large Error Events – Hour 96

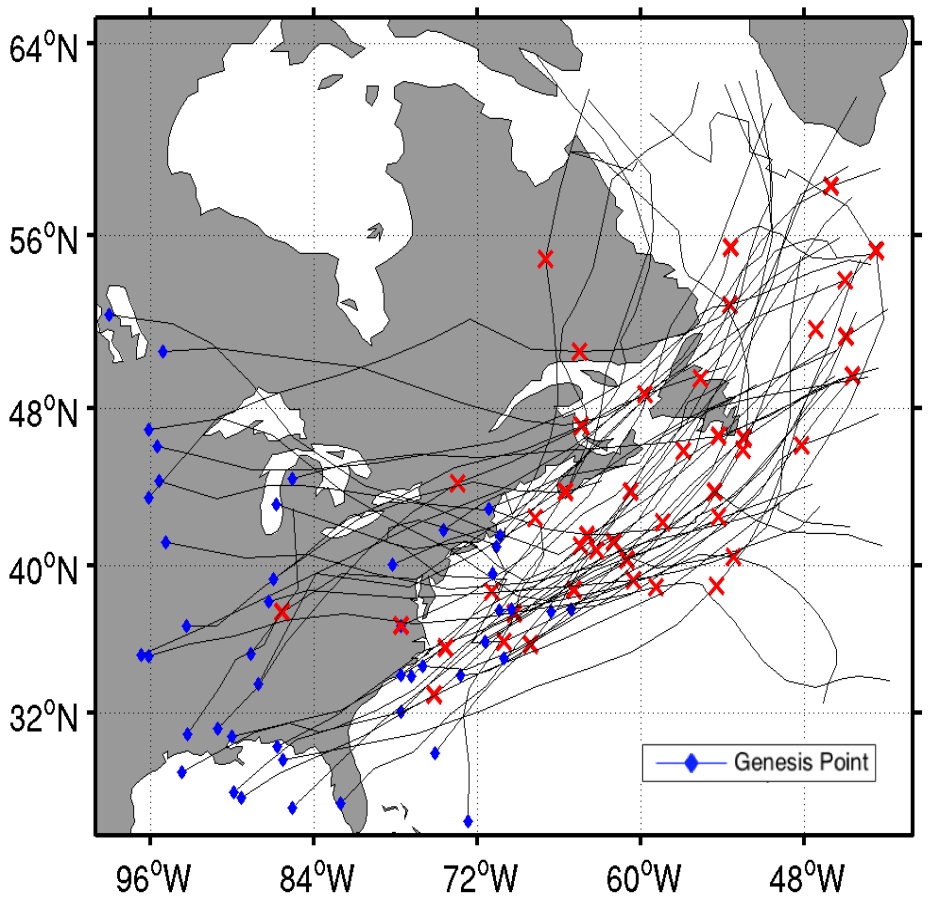
Mean Negative SLP Error:

1.5 std dev (-7.9 mb) < mean error



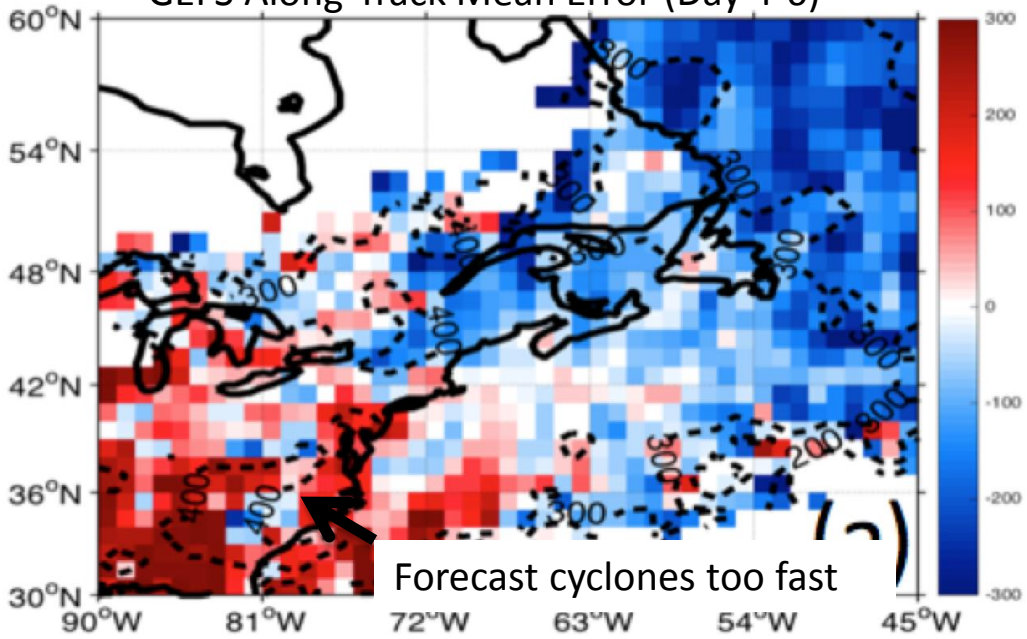
Mean Positive SLP Error:

1.5 std dev (+7.6 mb) > mean error

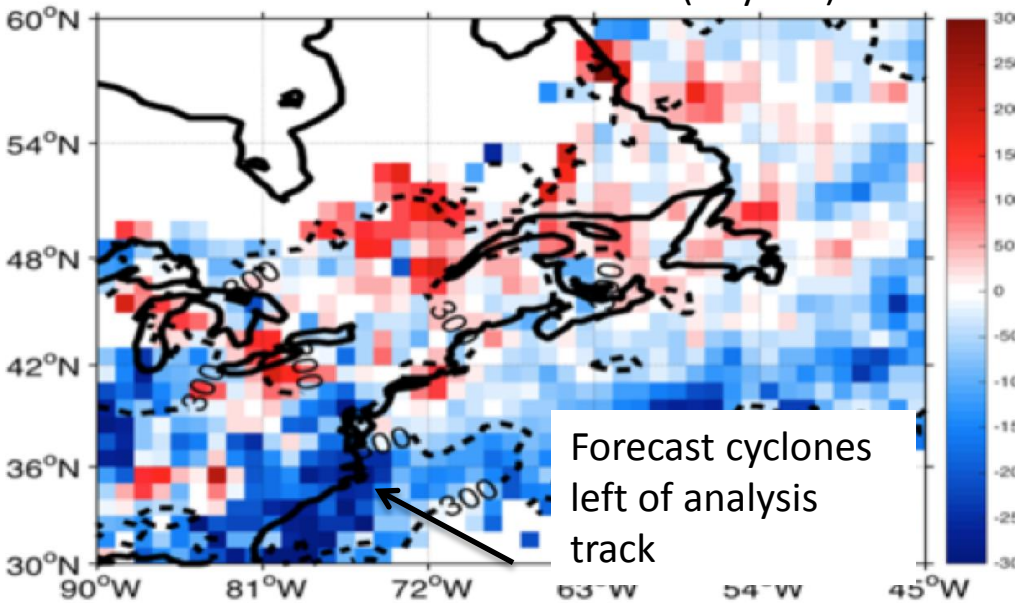


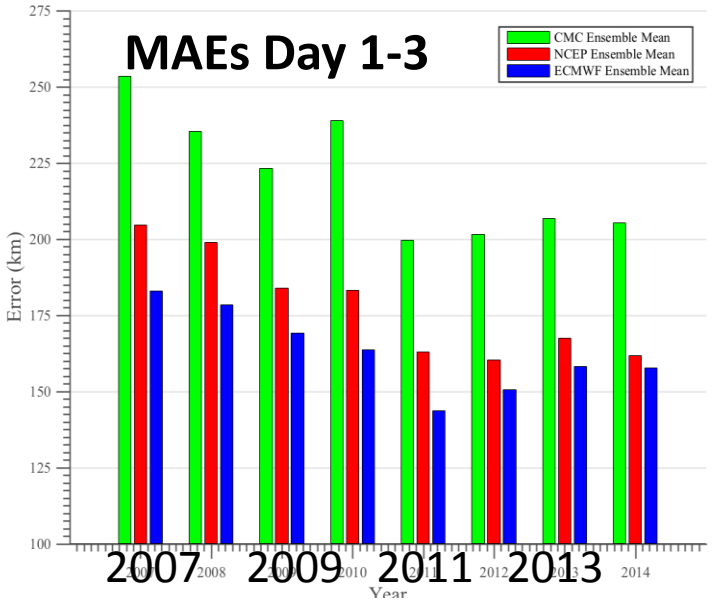
GEFS Medium Range (96-144h) Displacement Errors

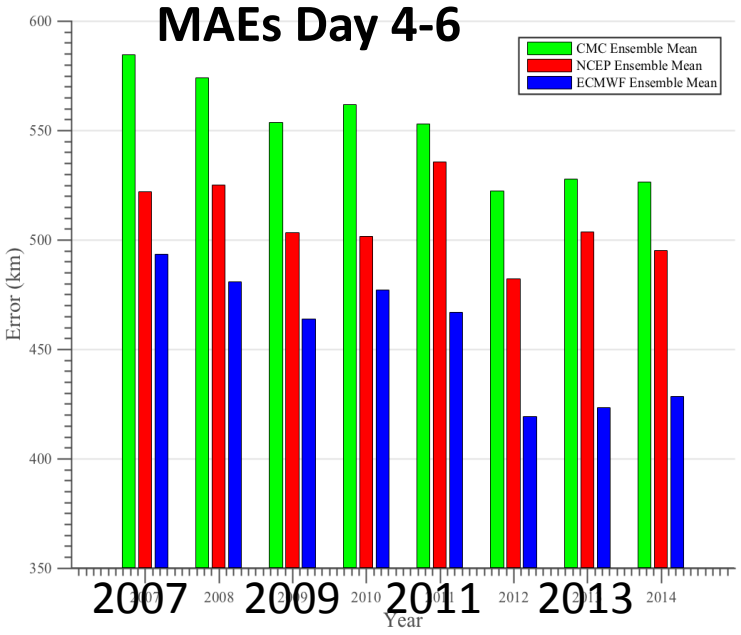
GEFS Along-Track Mean Error (Day 4-6)



GEFS Cross-Track Mean Error (Day 4-6)





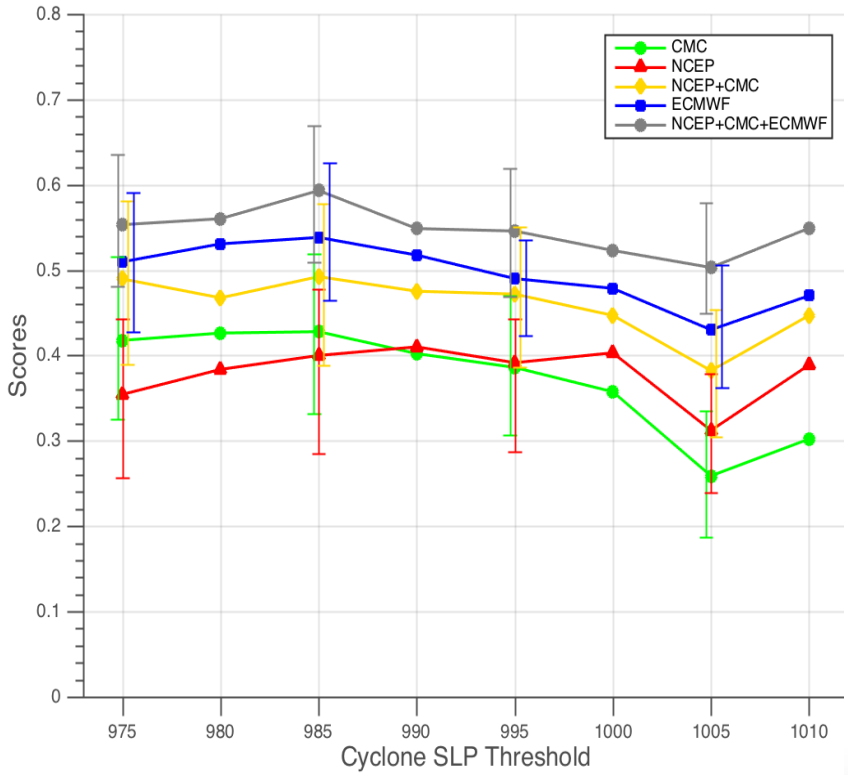


Brier Skill Scores for Central Pressure and Displacement – Day 4-6

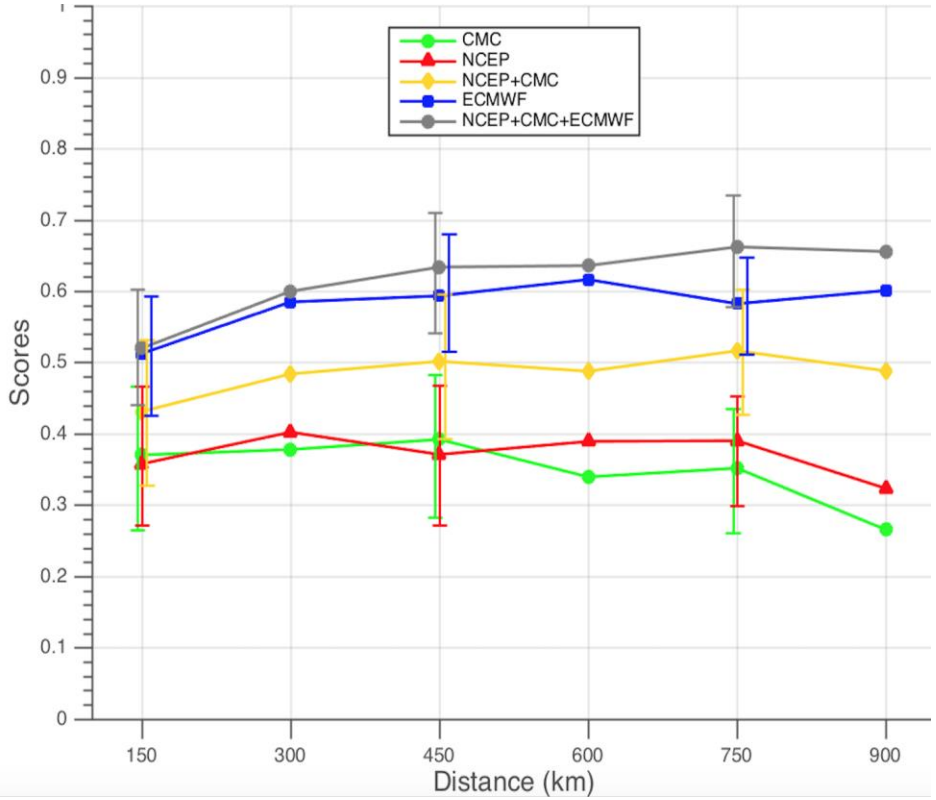
- Only events where model or observed values are below SLP threshold
- The BSS is calculated using the GEFS Control member as reference
  - 1 indicates perfect probabilistic forecast compared with the reference score
  - 0 indicates no improvement over the reference score

$$BSS = 1 - \frac{BS}{BS_{ref}}$$

Central Pressure



Displacement



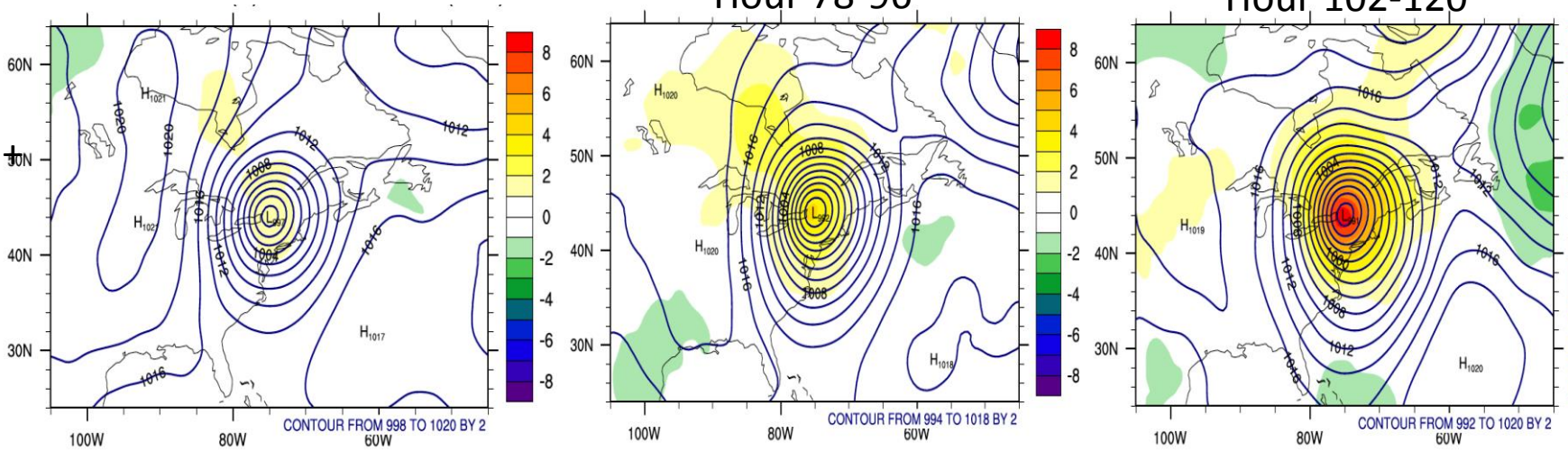
Cyclone Relative Approach –Stony Brook Univ. Software

Hour 54-72

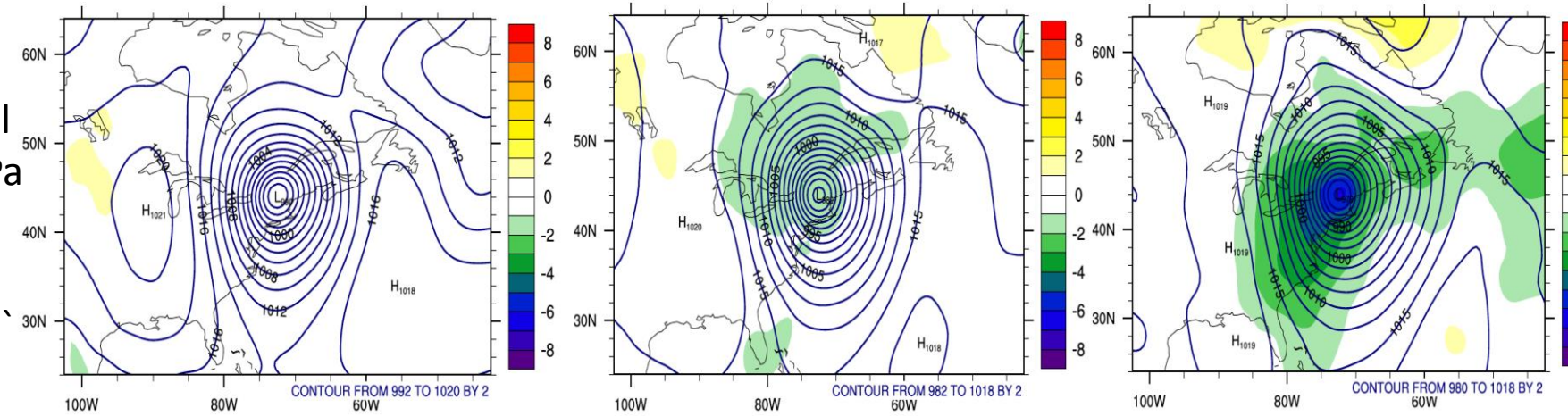
Hour 78-96

Hour 102-120

GEFS Control+ 7.5 hPa Bias 60 storms



GEFS Control -7.5 hPa Bias 52 storms`

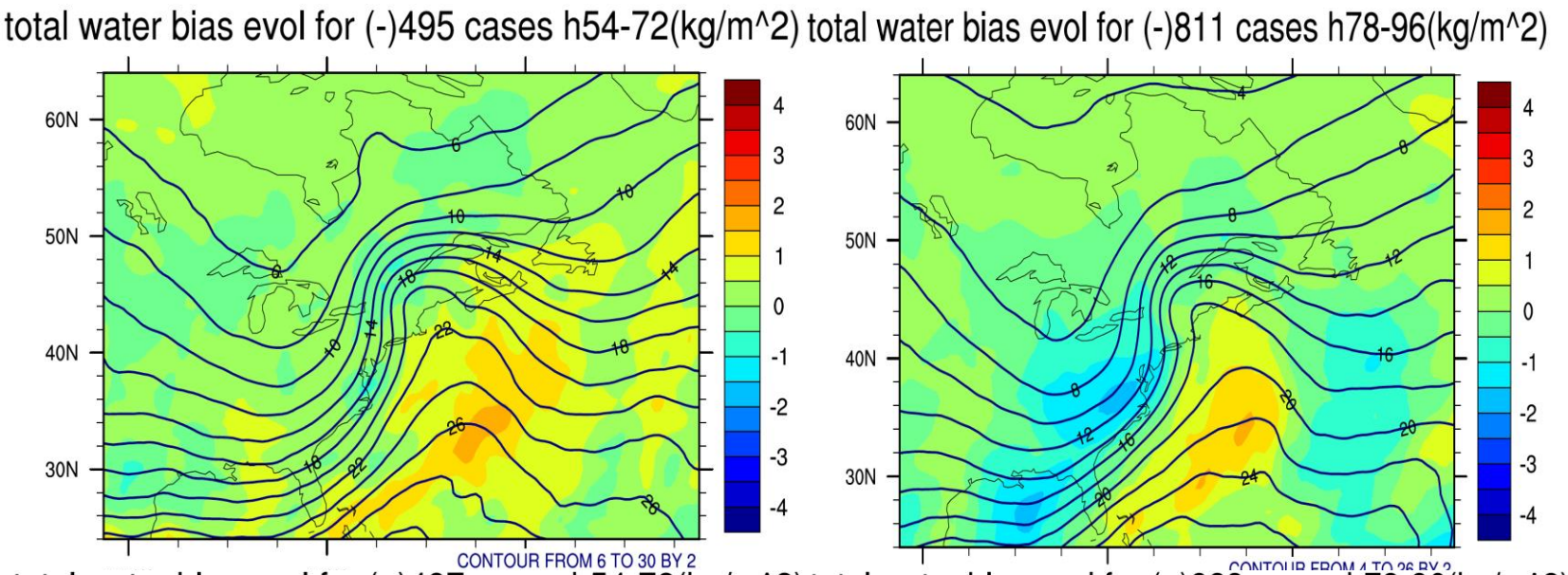


Cyclone Relative Approach: Integrated Moisture Errors for Over- and Under-predicted Storms

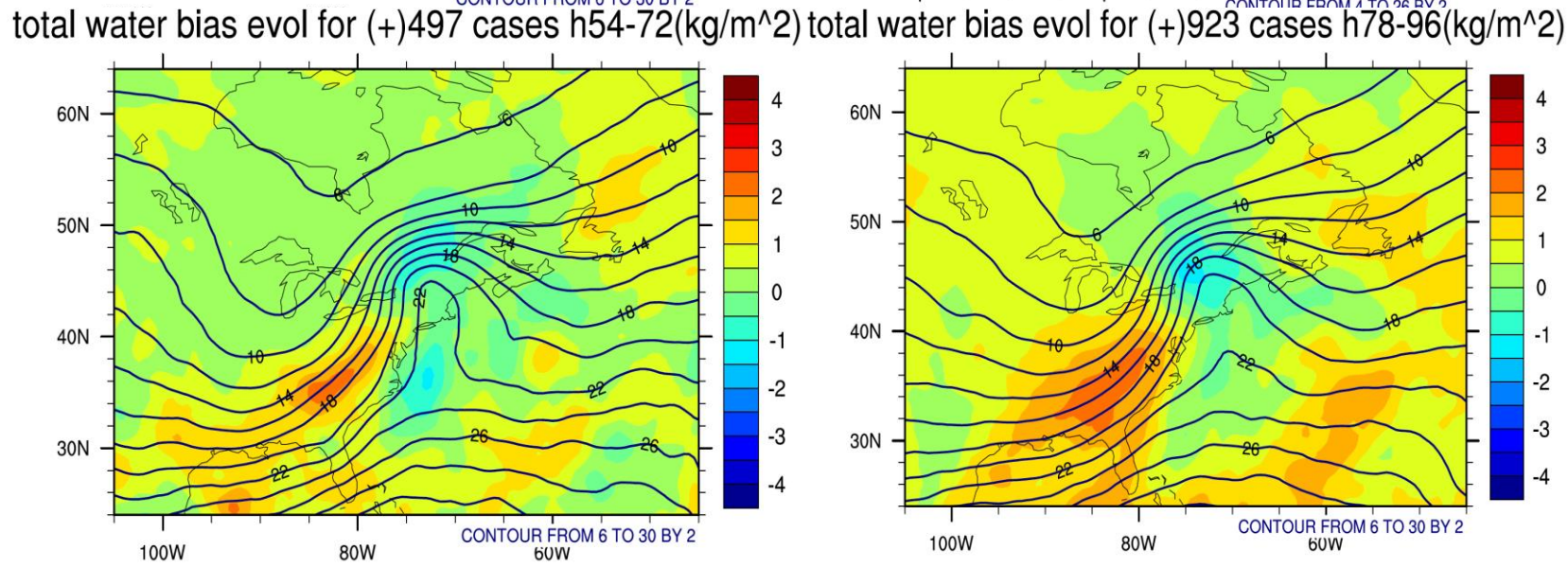
Hour 54-72

Hour 78-96

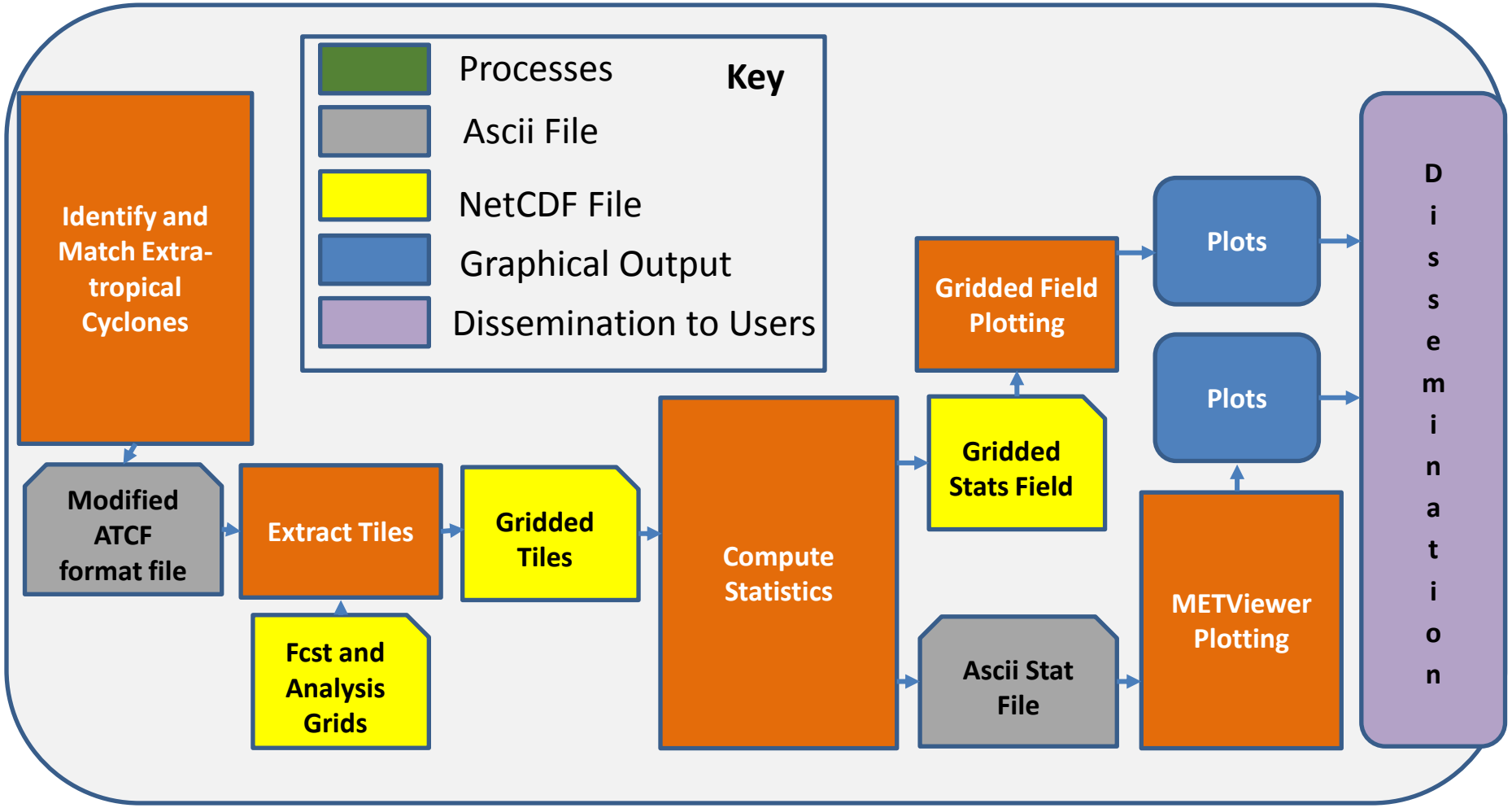
Day 5 GEFS Control -7.5 hPa Bias 52 storms`



Day 5 GEFS Control+ 7.5 hPa Bias 60 storms

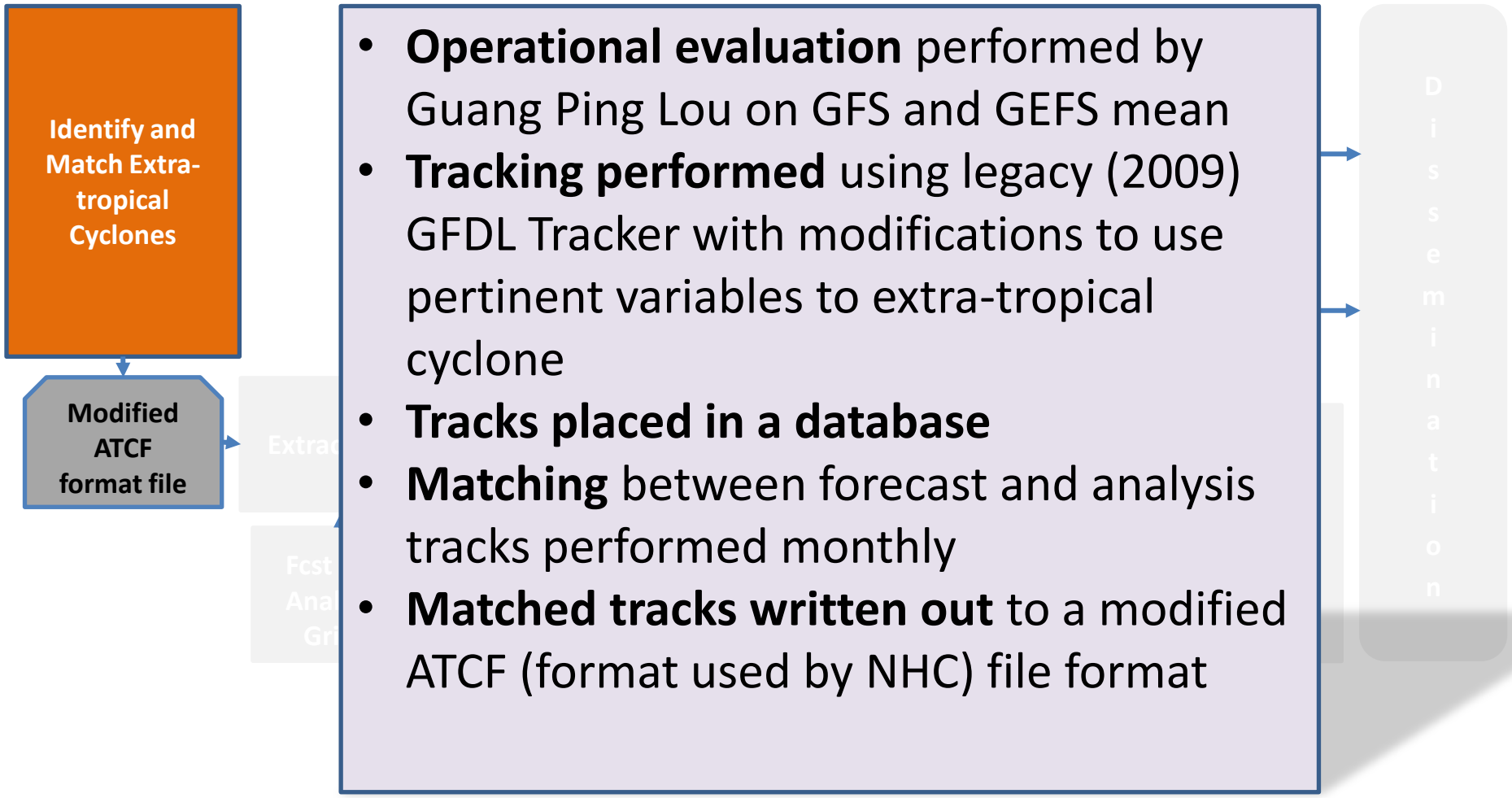


Cyclone Relative Evaluation System within Model Evaluation Tools (MET)



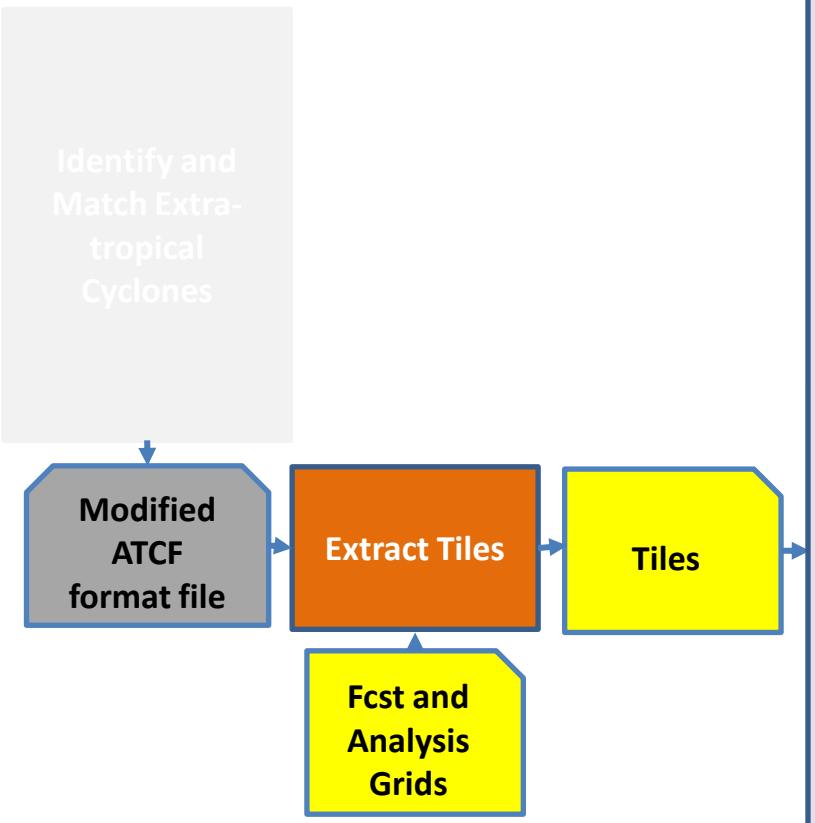
MET Development and Testing: Tara Jensen, Paul Kucera, John Halley-Gotway, and Jamie Wolff
National Center for Atmospheric Research (NCAR) and Developmental Testbed Center (DTC)

Cyclone Relative Evaluation System



- **Operational evaluation** performed by Guang Ping Lou on GFS and GEFS mean
- **Tracking performed** using legacy (2009) GFDL Tracker with modifications to use pertinent variables to extra-tropical cyclone
- **Tracks placed in a database**
- **Matching** between forecast and analysis tracks performed monthly
- **Matched tracks written out** to a modified ATCF (format used by NHC) file format

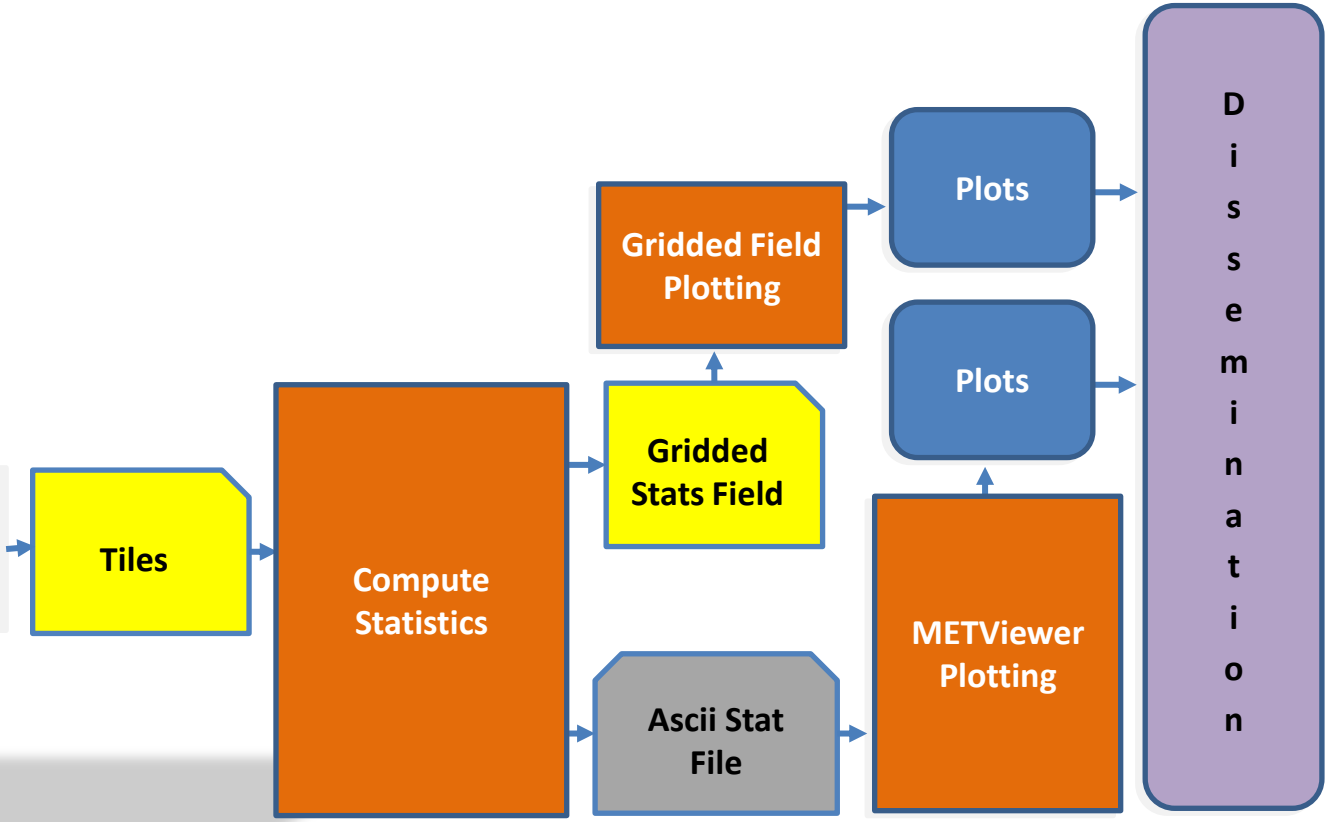
Cyclone Relative Evaluation System



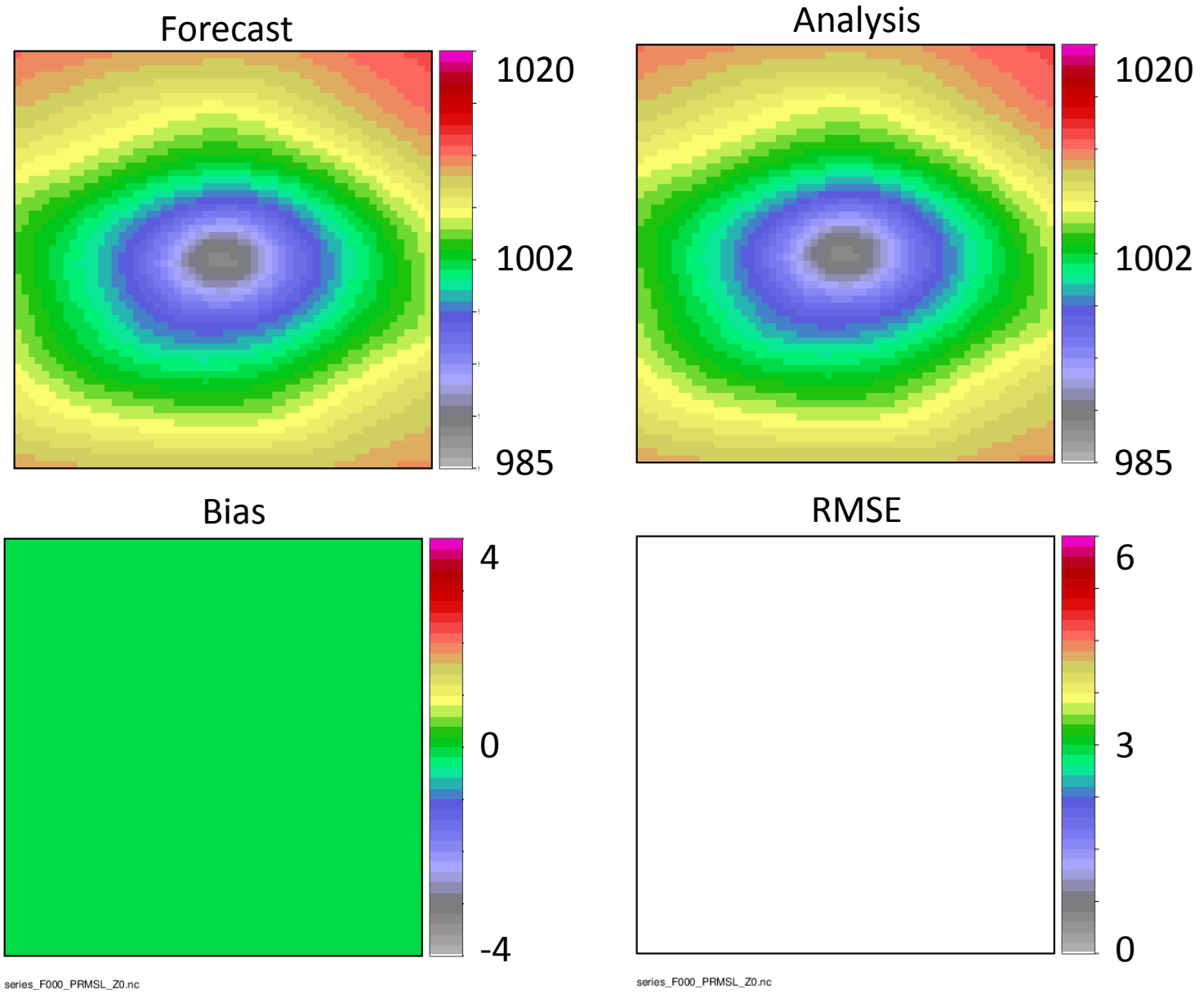
- **Reformat modified ATCF file** into a format MET can read using scripting
- **Extract pertinent Lat/Lon pairs** from track info
- **Extract Tiles – dimensions user defined**
  - **Option 1 -** extract to a separate file and throw away other data (saves space)
  - **Option 2** - Pass Lat/Lon to MET gen_vx_mask tool mask field on the fly (saves complexity)
- **NOTE:** Any field in the gridded files may be used (e.g. state variables and wind speeds, stability indicies, precipitation)

Cyclone Relative Evaluation System

- **Pass a series of tiles or masks into MET** Series_Analysis tool
- **Use new option "-force"** to tell Series_Analysis to disregard displacement errors
- **Compute statistics**
  - **RMSE, Bias, etc…**
  - **CSI, ETS, Freq. Bias etc…**
- **Gridded score fields** and asci output written
- **Scores Plotted** and Disseminated



MET Example –MSLP (U.S. East Coast cyclone from 8 GFS 84 h forecasts 20150126_00 to 20150127_18



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Cyclone Relative Evaluation System

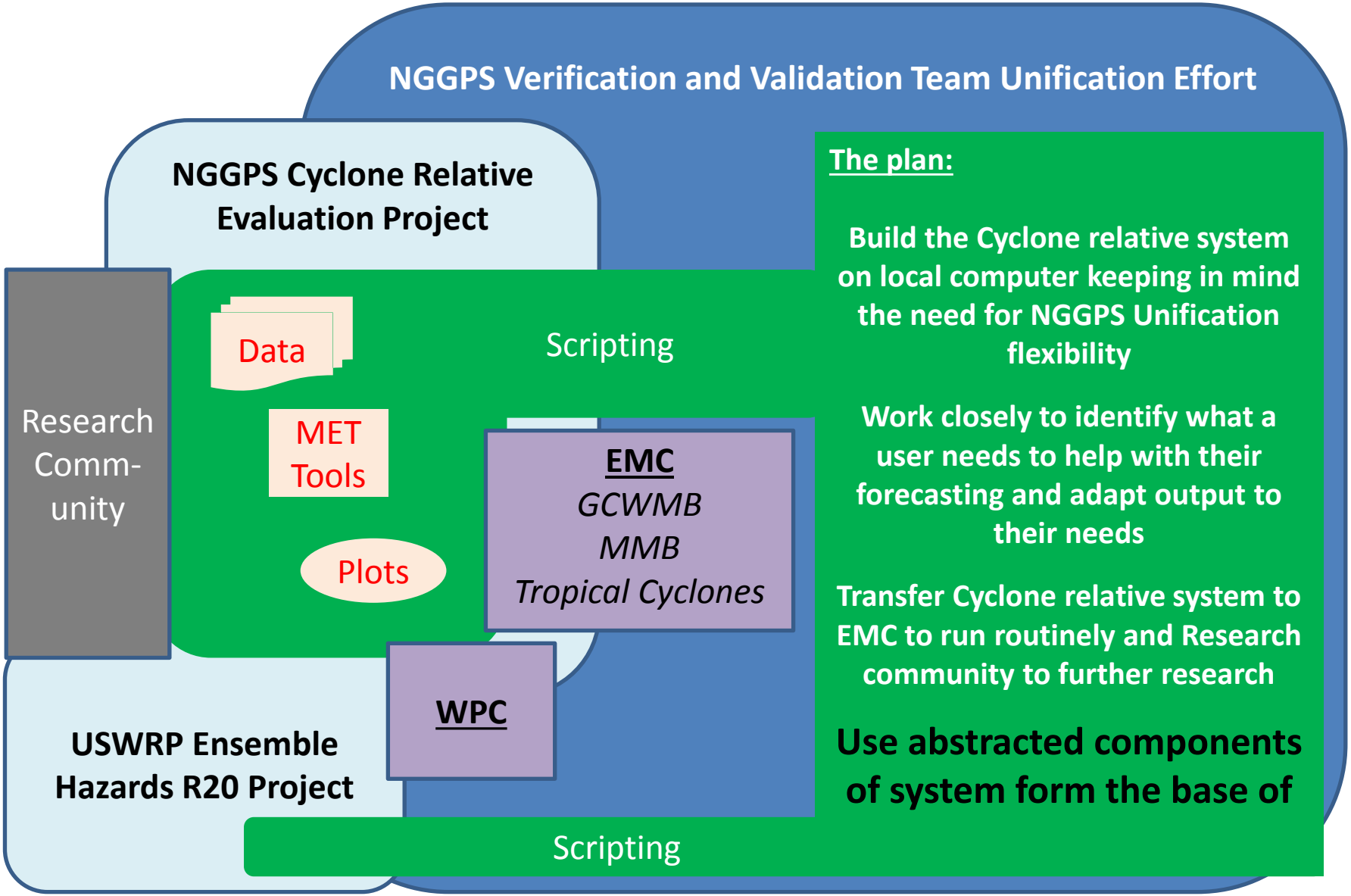
Additional information

- System scripting is being written in python
- System will be ported to NOAA HPCs - Theia or WCOSS (development side) and NCEP IDP (compute network) by mid-Year 2
- This project is the beginning of the unified MET+ (MET/METViewer+scripting) system to be rolled out to EMC in FY17

Other Applications

- Tropical Cyclones
- Feature centric evaluations such as snowbands, extreme precipitation and turbulence
- Storm centric evaluation of MCSs, Convective Lines and other storms

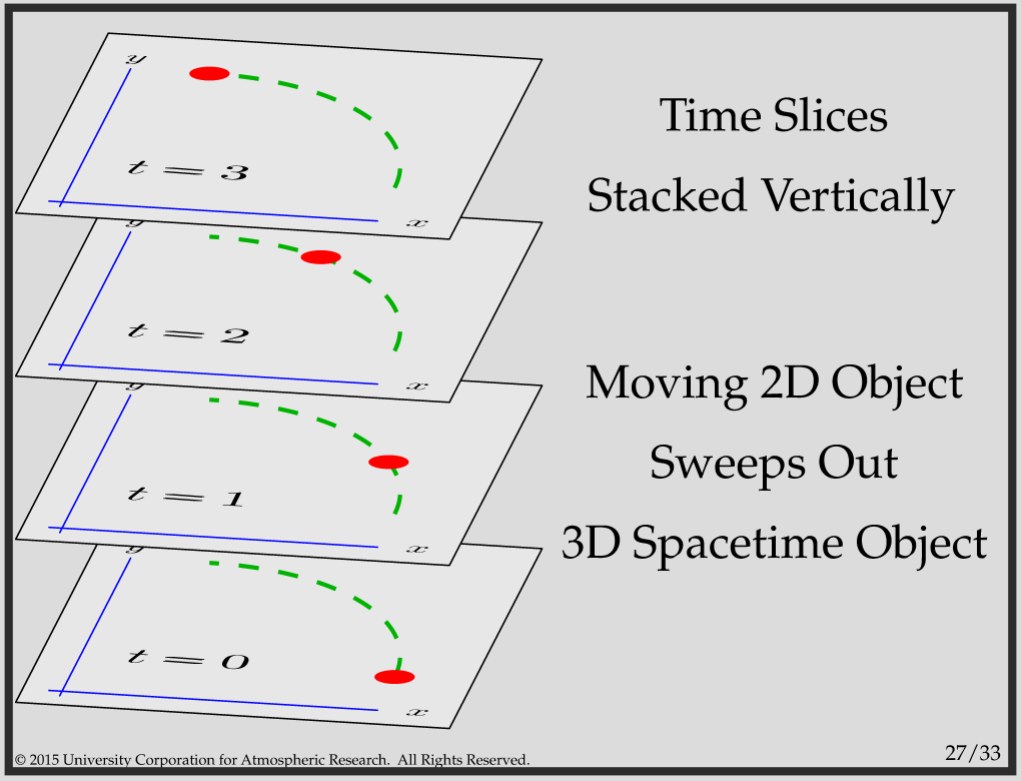
Bigger Picture



Cyclone Relative Evaluation System

Feature tracking using something other cyclone tracker

Use MODE Time-Domain



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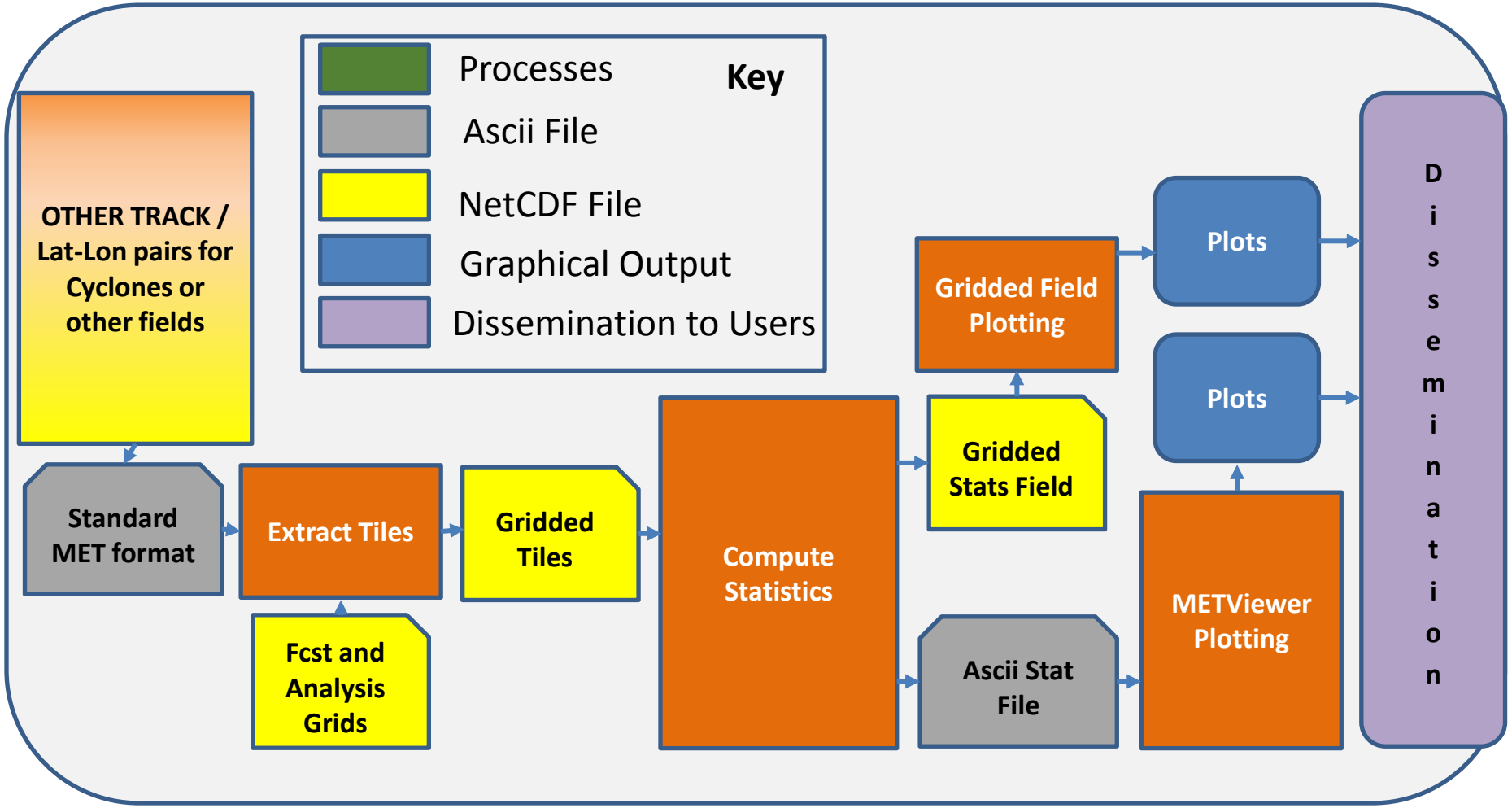

Next Steps

System Next Steps

- Complete system development on local system
- Transition to NCEP system
- Push plots to required dissemination points
- Demonstrate the use of the software for operational evaluation during the WPC Winter Weather Experiment.

Research Next Steps

- Use this feature relative system in MET to better understand cyclone biases and large error events
- Develop framework to generalize the approach for other phenomena (snow bands, TCs, atmospheric rivers, etc…
- Add model and supporting observational data for 2-3 winter weather case studies into Mesoscale Model Eval. Testbed (MMET).

R2O Speed-bumps and Concerns

- CAC card requirements for non-NOAA staff to access to NOAA HPCs may slow down transition to NOAA HPCs
- Working with NCO to assure transition to operational system by conforming to
  - Scripting version
  - Directory structure
  - Interchangeability with work-flow manager
- Extra-tropical cyclone track matching occurs monthly at EMC – if higher frequency evaluation is needed changes to system will likely be required.