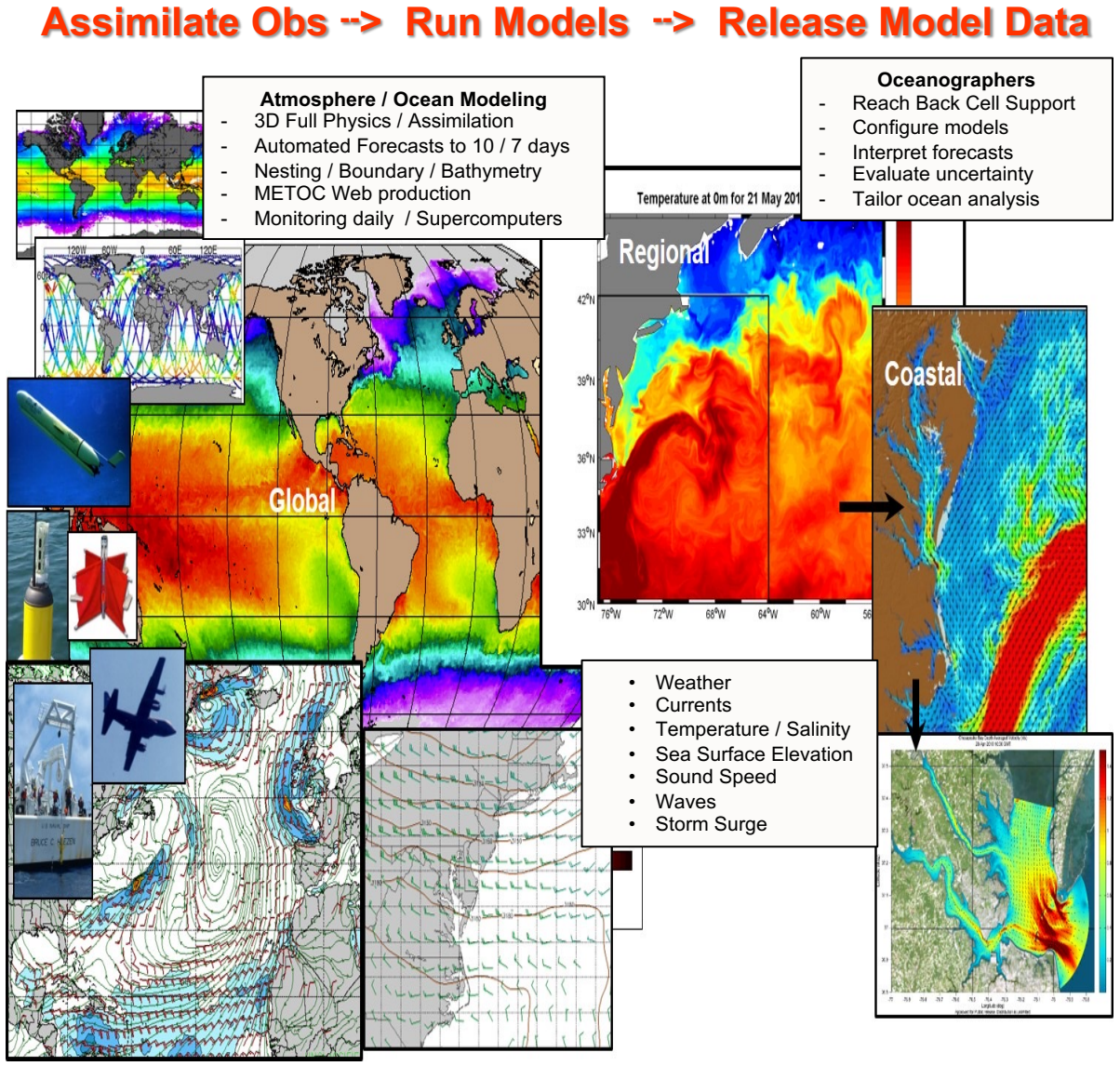
Fleet Numerical Meteorology & Oceanography Center Verification Status Overview

Raymond C. Lee
Regional Modeling Division – COAMPS
Modeling Department Verification Lead

The overall classification of this brief is: UNCLASSIFIED

FNMOC Overview

- US Navy's premier environmental modeling center
- Responsible for numerical weather and oceanographic predictions to the fleet
- ~20 military officers
- ~120 civilians and contractors
- Approximately 35 modelers in the Modeling Department
- 5 of the 35 have limited time (<15%) to work on verification code improvements



FNMOC's Current Model Inventory

Global:
ESPC EFS
NAVGEM
NAVGEM EFS
GOFS (ocean)
NAAPS (aerosol)
Wave Watch 3
WW3 Ensemble
Derived Products

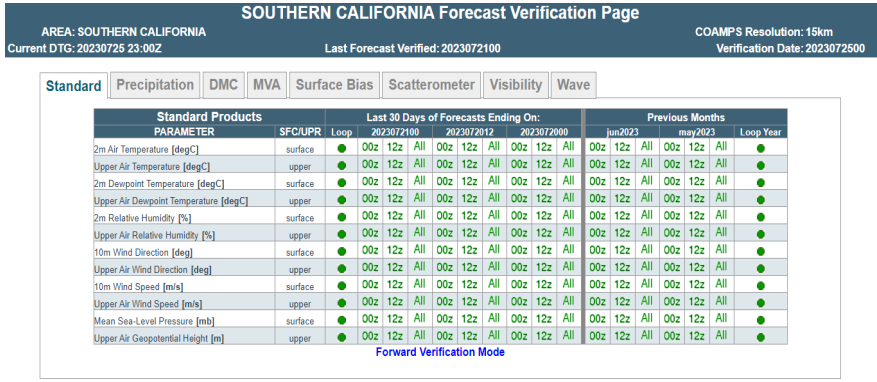
Regional:
'Static' COAMPS-ATM (x120)
'Moving' COAMPS-ATM
COAMPS-NCOM (ocean, x30)
WW3 Regional (x100 areas)
WW3 TC-OFCL
SWAN (coastal, x200 areas)
DELFT3D (x100 areas)

Specialized:
COAMPS TC (x7 storm)
REA COAMPS
AAP (acoustic)
CSIPS (surge)
FST (synthetic)
Drift / SAR prediction
Standard Ocean Area Assessments (x15)
Water Sampling Plan

FNMOC has ~35 modelers and ~10 forecasters in the Modeling Department to support all of these models and products when fully staffed…
We need verification that is flexible and low maintenance

Model Verification

- **Deterministic Model Verification**
  - How have the models been performing? Which is best? On which model should a sailor base their forecast? Does this model accurately predict what will happen at the ship's location?
  - How can the Naval Research Laboratory (NRL) best leverage these results to improve future versions of the models?
  - Near Real-time Ocean Verification is developed
    - FNMOC is evaluating the optimal distribution mechanism for releasing these results
  - Near Real-time Atmosphere and Wave Verification available
  - Verification results released at multiple classification levels



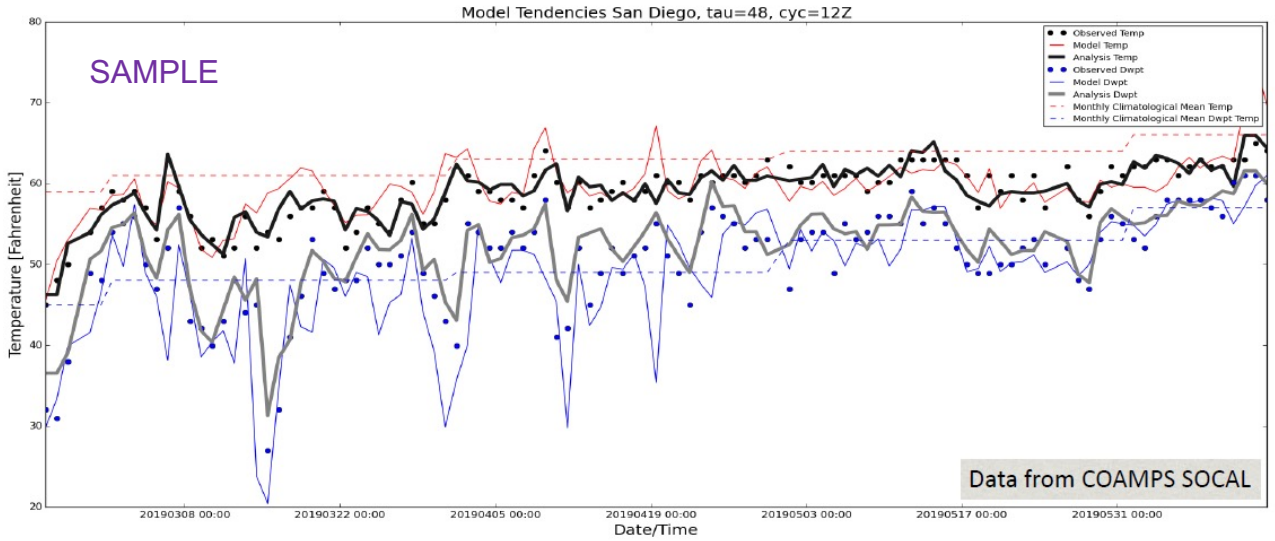
- **Ensemble Model Verification**
  - Verification of the probabilities of occurrence for Ensemble model forecasts

Valid Area:

- **Tropical Cyclone (TC) Model Forecast Verification**
  - Primarily for Joint Typhoon Warning Center (JTWC) forecasters to see how various TC forecast aids have been performing in near-real-time
  - Forecasters can know which model has been handling a storm well while the storm is still active

Trends & Tendencies

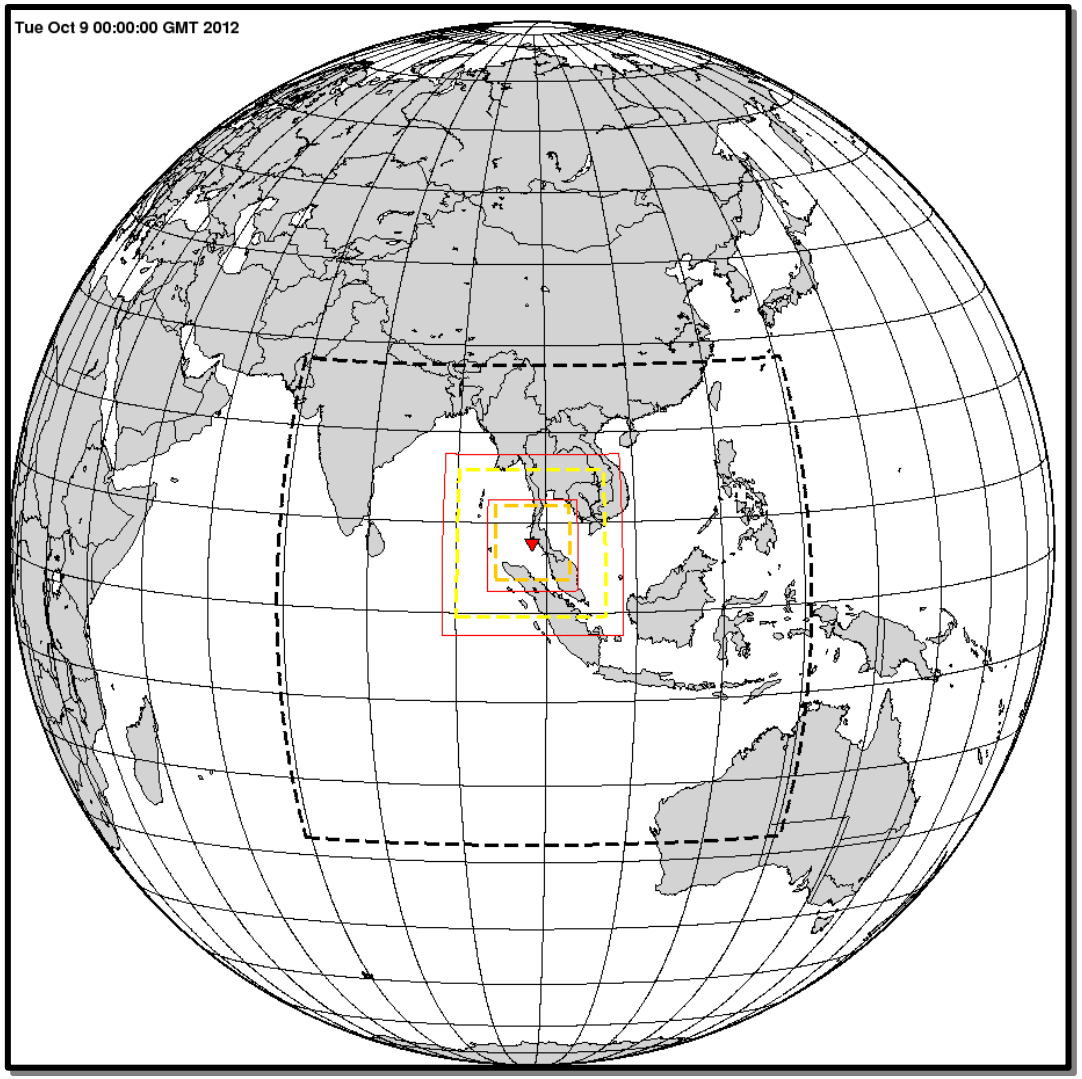
- Model Trends and Tendencies can help forecasters know typical model departures from observed values in specific situations
  - With FNMOC's Climatology Division
  - In development
  - Continual staffing issues mean this long-term work continually gets pushed to the side
- We want feedback and forecaster knowledge as we develop this resource but getting these responses is difficult



Unique Challenge: 'Moving' COAMPS

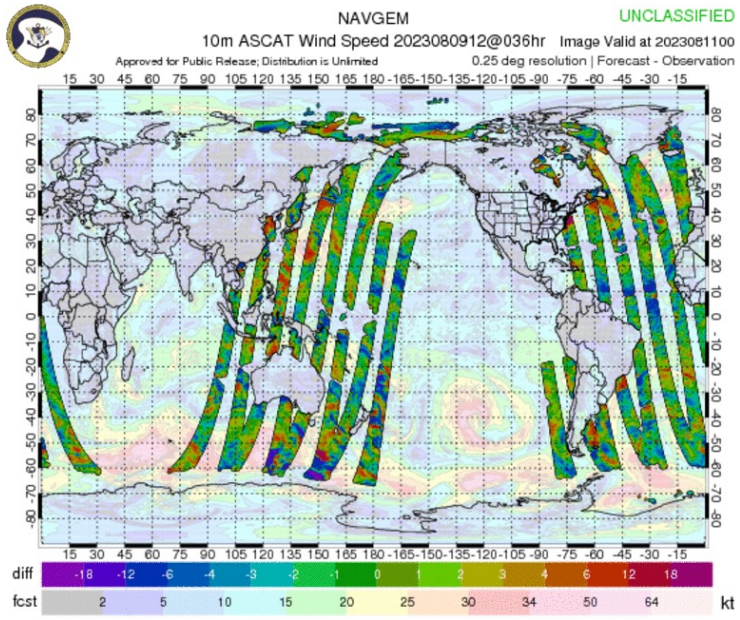
- Automated moving boxes for atmospheric and oceanographic wave support for ships at sea

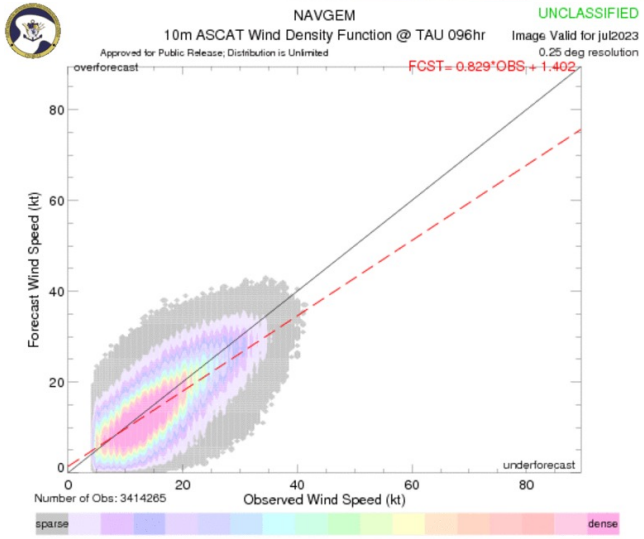
- The problem is how do we produce near-real-time verification results that are meaningful for the ship when it moves to & through different climatic situations
- Classification levels can mean multiple input datasets of the same data type needing to be leveraged by the verification processes

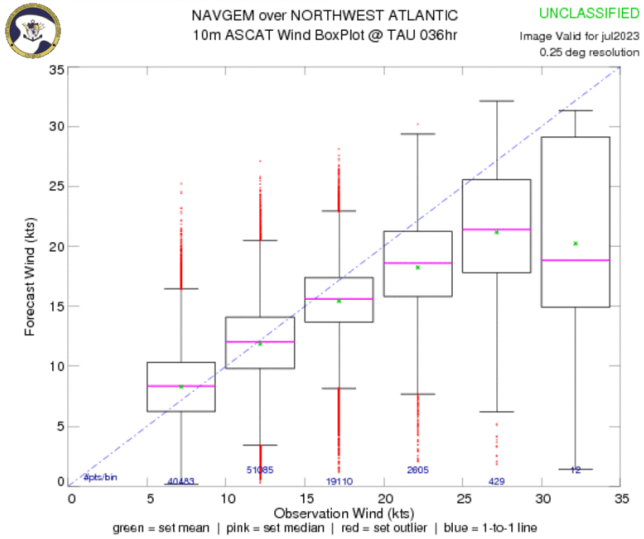


Unique Challenge: Open Ocean Wind Verification

- Naval operations occur away from land-based stations
- How can we verify the 10m winds without surface stations?
- Scatterometer retrievals taken as ‘truth’ and compared to the models
  - Started in early 2015
- Inherent error due to biased observations
  - Look for patterns, not numbers





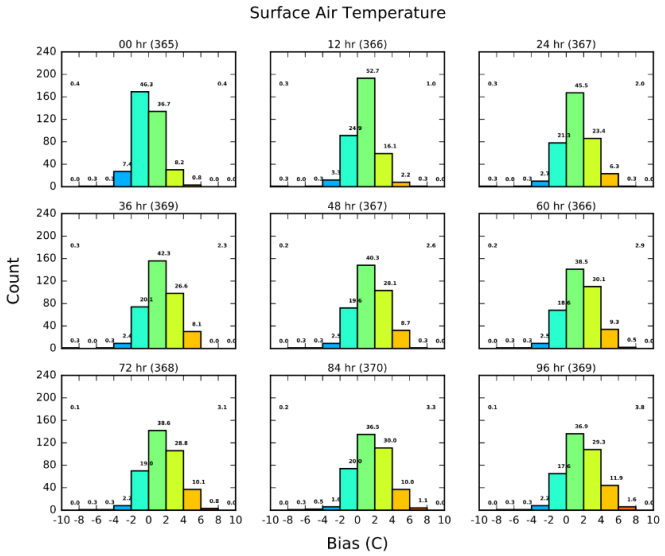


Machine Learning for Automatic Stoplight Results

- Machine Learning approach to automatically determine model reliability and skill
  - Investigating but limited work effort assigned
- Clustering based on RMSE, Bias, and geographic location for pattern identification
- Geo-located clustering gives insight on differences in latitude/longitude, elevation, season, and distance from the coast

- Provides an objective view of results contrasting the more subjective interpretation currently done for the wide variety of results
- Goal is to assign a single stoplight color to describe a region's performance
  - Easy for sailors to understand
  - Easy for leadership to understand

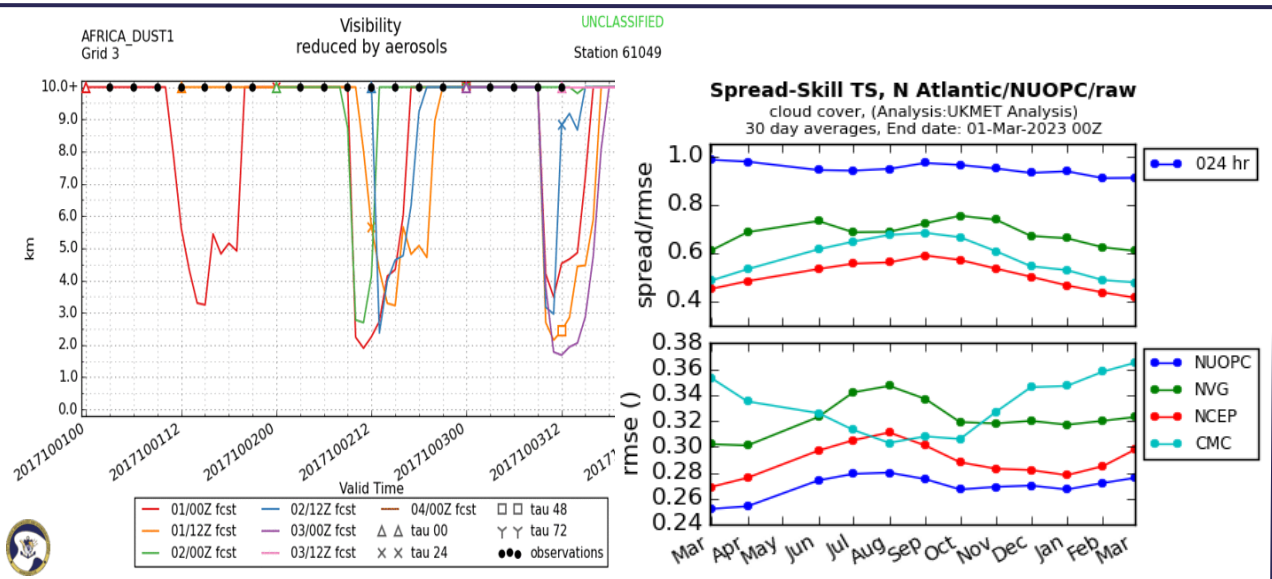
- Automatic Verification Improves
  - Efficiency: Less time and effort needed
  - Frequency: Weekly or Daily verification instead of focusing on Monthly results
- Identify patterns & insights for improvements
- Gaussian Naïve Bayes, Decision Tree, Random Forest methods applied



Code Challenge: Cloud & Visibility Verification

- FNMOC had visibility verification for dust/aerosols, and hydrometeors (2015-2018)
  - It leveraged parts of 5 different code bases making it unmanageable and unmaintainable
  - No direct cloud verification. The hydrometeor visibility was mostly haze/rain detection
- NRL delivered cloud verification but FNMOC wasn't able to run it due to non-IA approved code

- Marine fog is a major problem for mariners (Human error, weather and wave-related accidents top the list for causes of mishaps at sea)
- How to verify marine fog if few to no observations exist in the ocean?



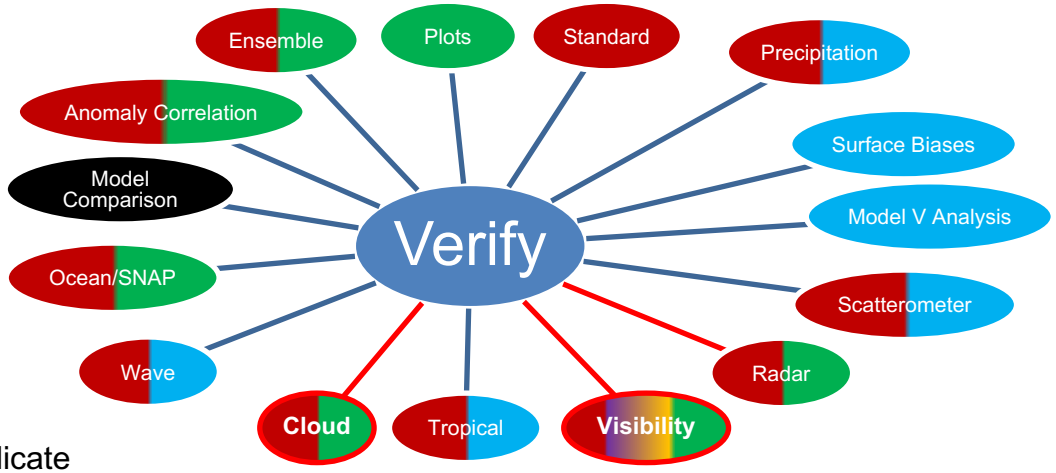
- Ensemble model cloud verification exists but leverages UKMET's analysis of clouds as truth
- Each of these codes exist as completely separate programs coded in different languages for one specific model. This greatly increases the difficulty of making one application serve as a verification tool for the full suite of models at FNMOC

Where FNMOC is Heading

- FNMOC will be accepting delivery of a version of MetPlus modified by NRL-MRY for IA requirements to begin to unify the multiple different verification codes currently used.
- This will bring FNMOC in alignment with other centers and current verification trends.
- We hope this also allows us to expand the verification support we can provide

FORTRAN
IDL
PYTHON
C+
Grads
Other

Red spoke lines indicate non-operational status



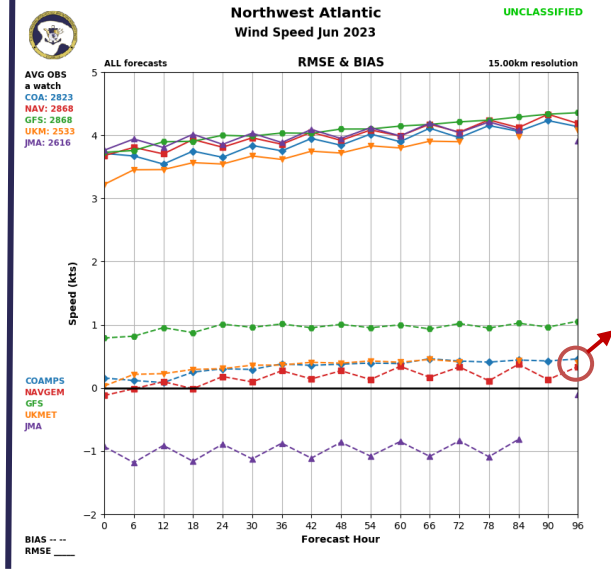
MET
Model Evaluation Tools
METplus

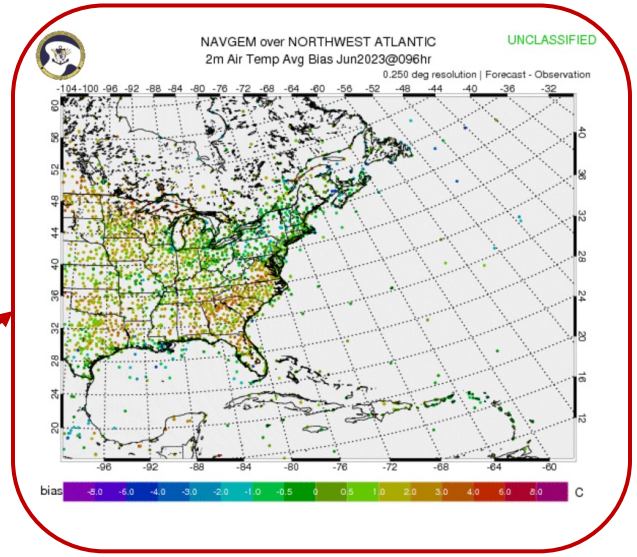
What Does FNMOC Need?

- Simple to understand output images
  - The sailors making the forecasts are mostly high-school grads with 4-5 years of METOC experience
  - They won't use verification if it doesn't make sense to them!
- Low bandwidth images
  - Limited numbers of small file size images that convey all the sailor needs to know

- Simple unified code which is easy to maintain
- Easy to run for many areas
  - Including different nest/resolutions of the same model area.
  - Including model areas which can move
- Ocean, Wave, and Atmospheric models ideally need to be supported

- Highly technical images or results to assist NRL's continuing improvement of the models
  - Yes, this contradicts the 'simple' image the sailors need from above
- Images showing both station and area average results to locate small regional biases
  - The small red dot (circled right) represents all the data in the entire other image (far right)





Thank you

Questions?

The overall classification of this brief is: UNCLASSIFIED