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Recent COAMPS-TC Development and Future Plans

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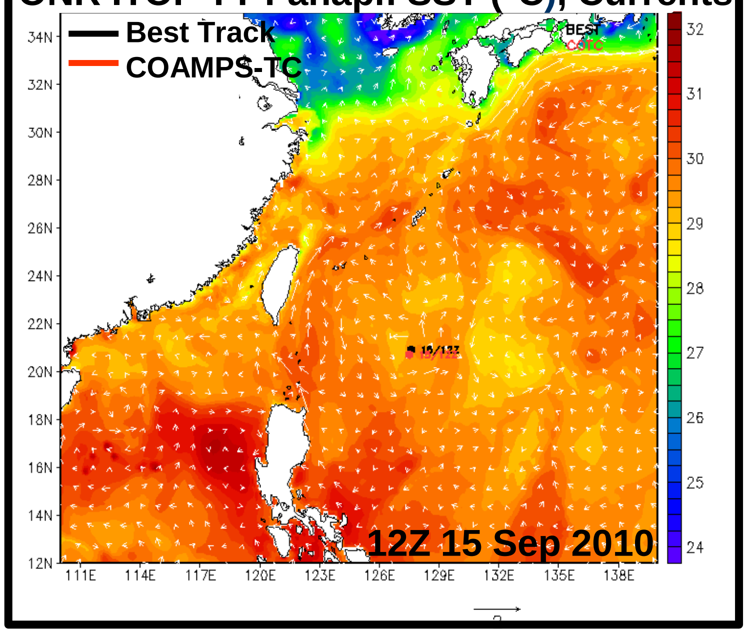
Sept. 13, 2016 0510 UTC, MODIS image of Super Typhoon Meranti (NASA)

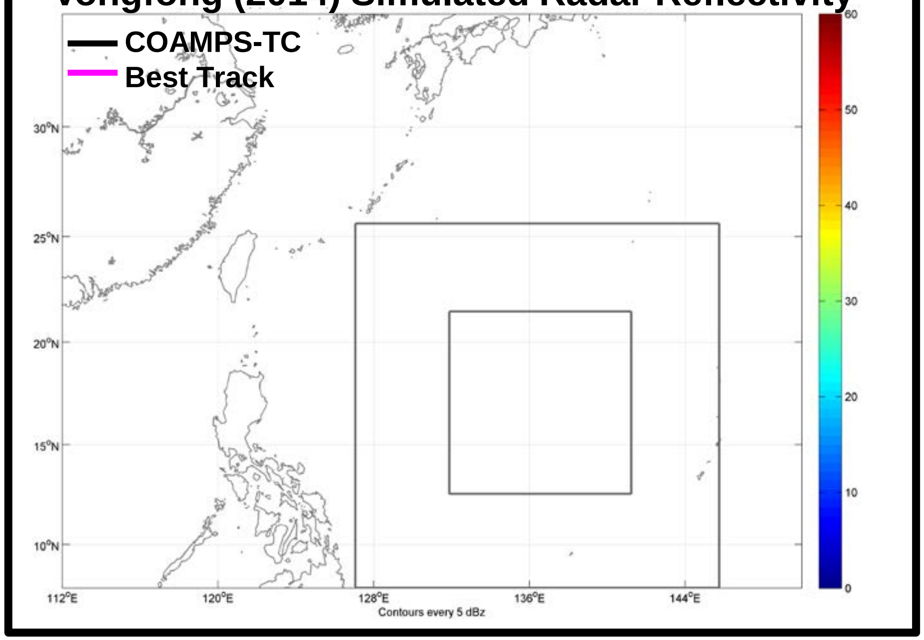
COAMPS-TC System Overview

- **Analysis:** No cycling or Cycling: 3D-Var (NAVDAS), 4D-Var, EnKF DART
- **Atmosphere:** Nonhydrostatic, moving nests, TC physics
- **Ocean:** 3D-Var (NCODA), ocean (NCOM), wave options (SWAN, WWIII)
- **Ensemble:** ICs, BCs, & vortex perturbations; EnKF & ETKF options
- **2016 Ops:** 45-15-5km for COTC (NAVGEM ICs BCs) & CTCX (GFS ICs BCs)
- **Real Time:** 27-9-3 km 11 member CTCX ensemble

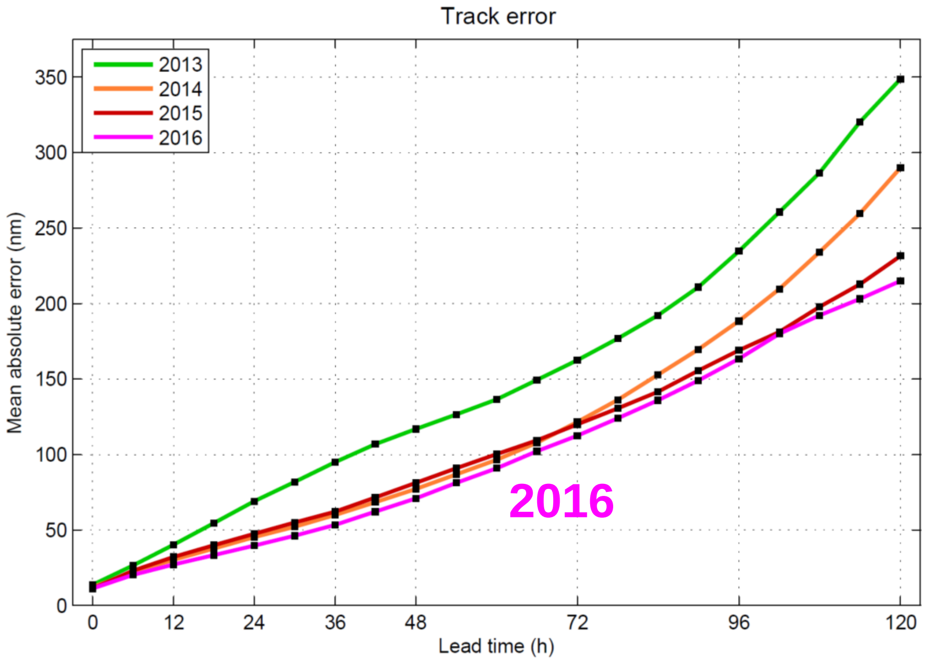
ONR ITOP TY Fanapi: SST (°C), Currents

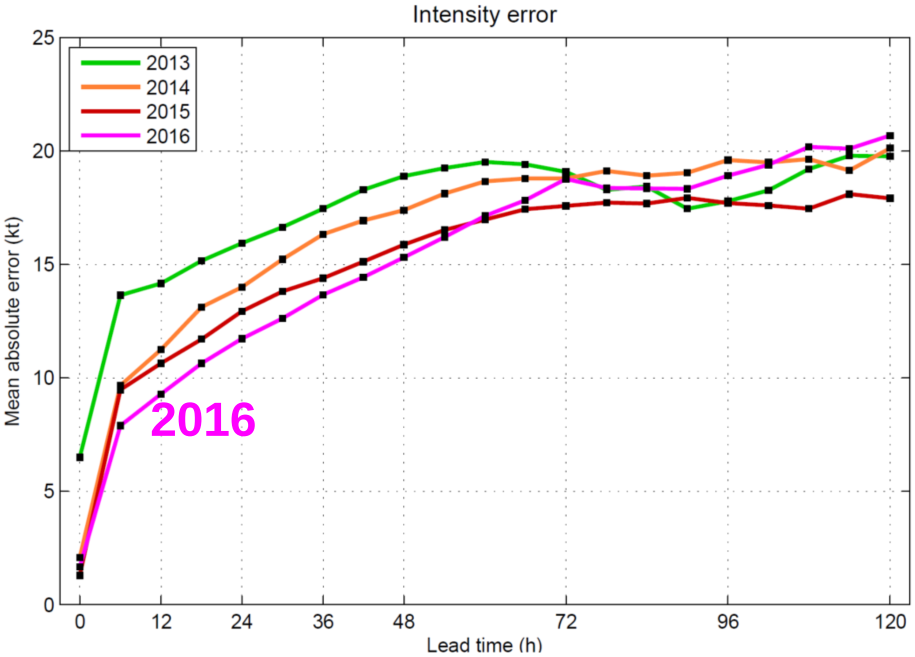


Vongfong (2014) Simulated Radar Reflectivity



COAMPS Performance History
2013-2016





Marked improvement in COAMPS-TC (CTCX) track and intensity forecasts over time (non-homogeneous sample)

2016 Operational Statistics

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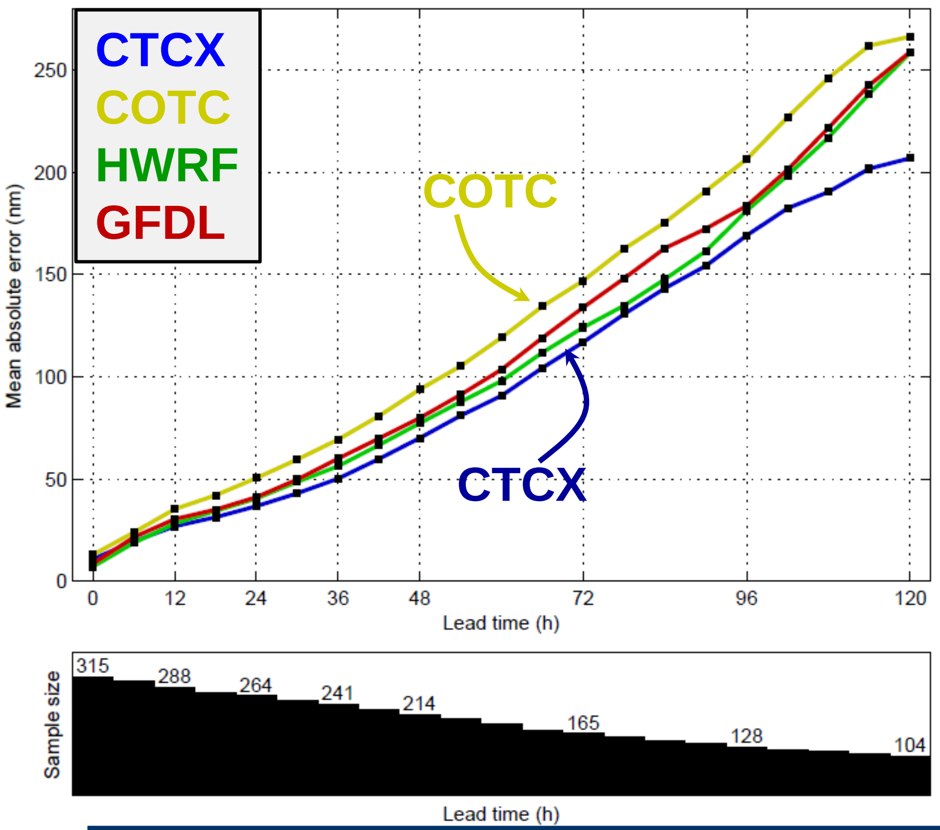
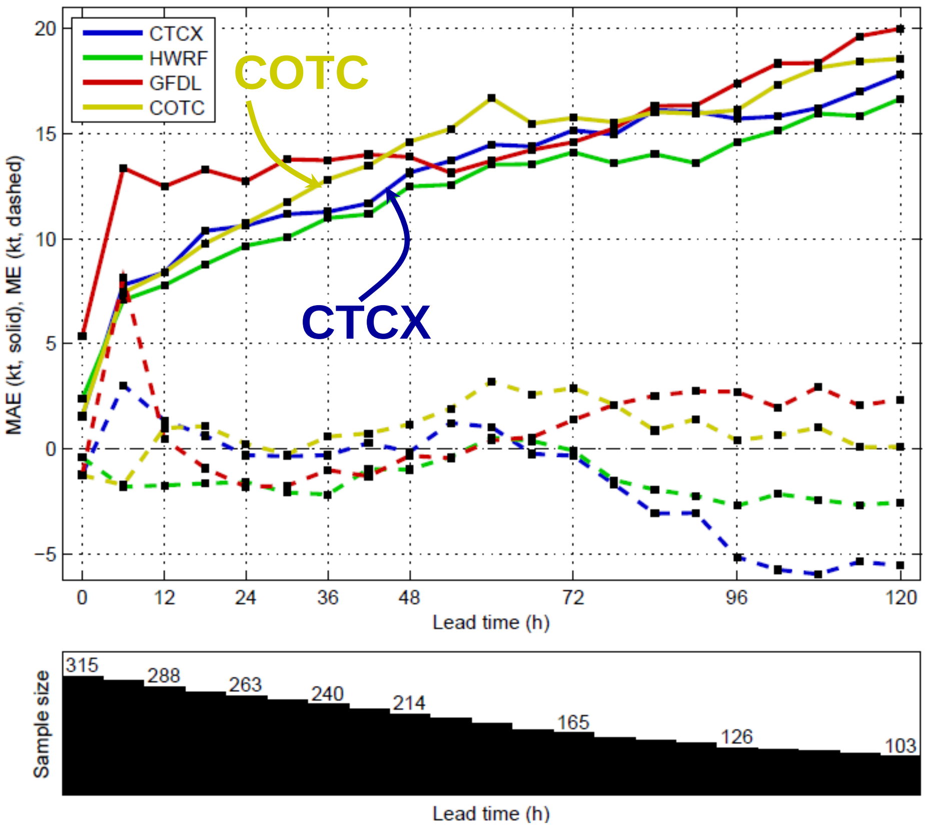
Atlantic Basin

Position Error



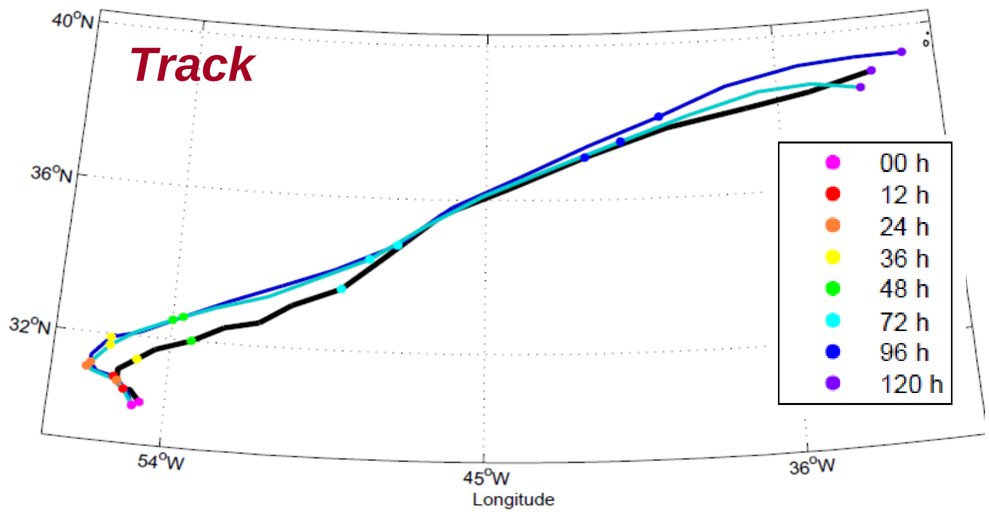
Intensity Error & Bias



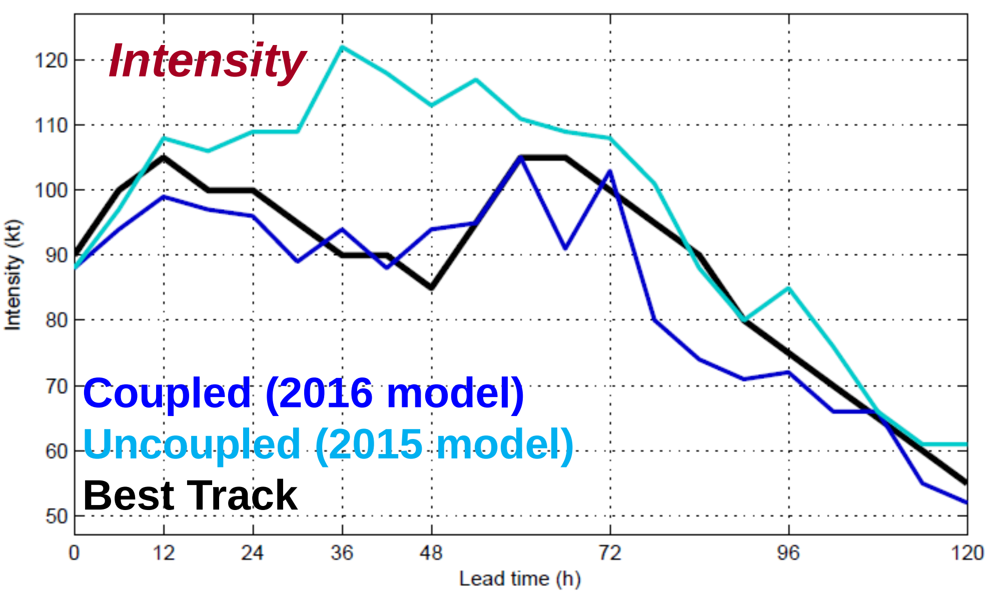
- Significant improvements in 2016 for CTCX and COTC in both track & intensity
    - ➢ Two-way coupling with NCOM
    - ➢ Improvements to vortex initialization, physics (new C_D param.)
- CTCX (GFS) and COTC (NAVGEM) fairly close together in terms of overall performance, although CTCX better by 1-3 kt (moisture?) and in track too

Atmosphere-Ocean Coupling

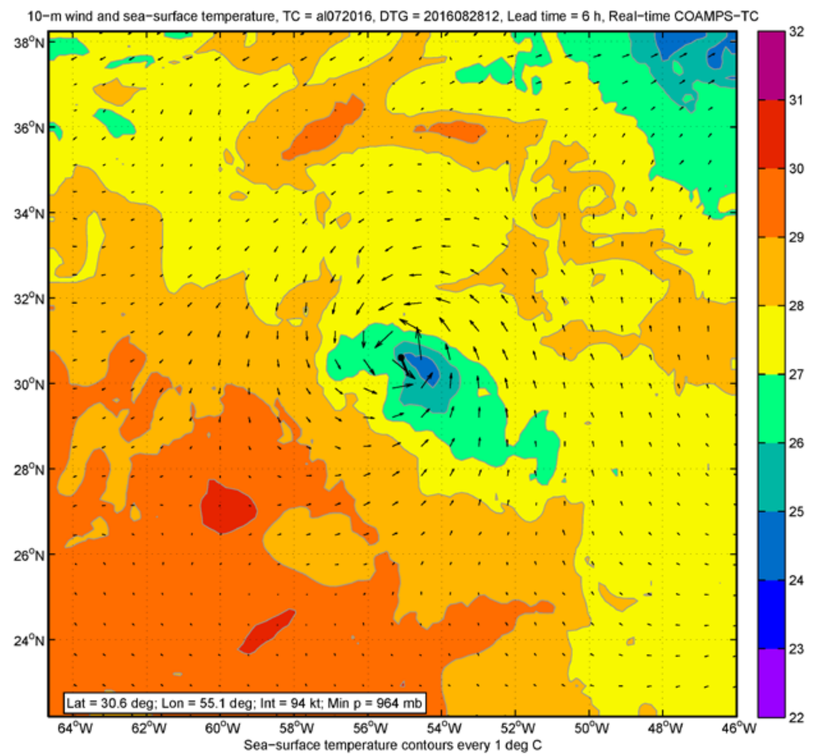
Example from Gaston (07L) (12Z 28 Aug 2016)



- Both track forecasts are accurate; note slow motion of TC through 48h
- Coupled: Intensity decreases after 12 h; recovers after 48 h (similar to obs)
- Uncoupled: Intensity is too high



Coupled model SSTs and 10 m winds



COAMPS-TC 2017 Version

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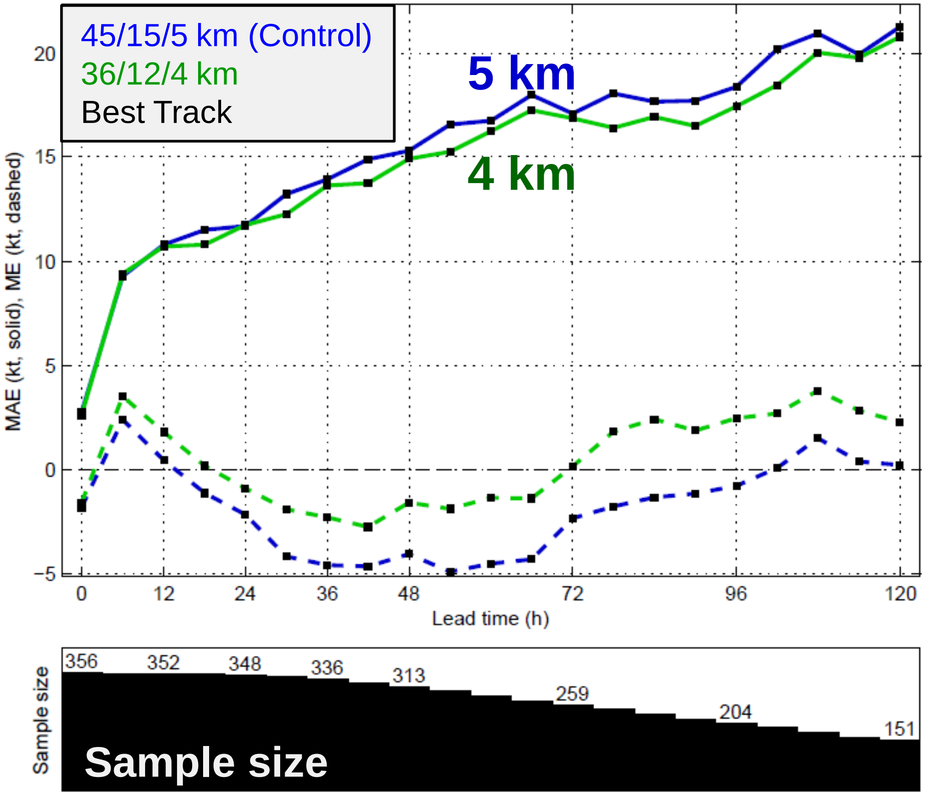
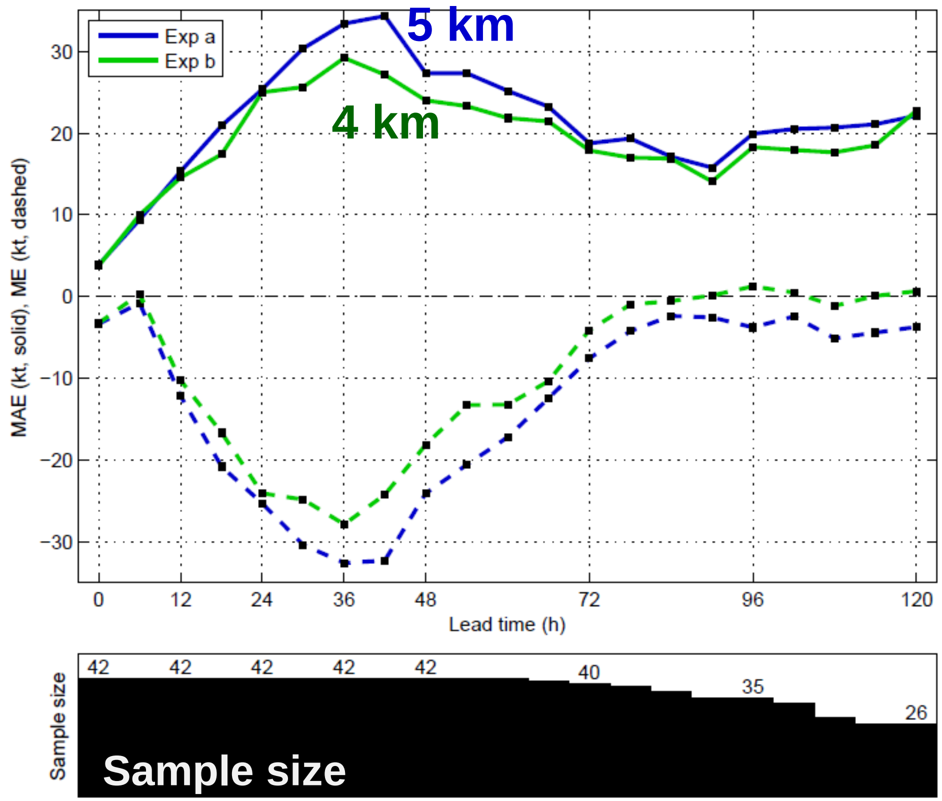
Atlantic/EastPac/WestPac

Intensity MAE (solid) and ME (dashed)



TCs observed to rapidly intensify (0-24 h)

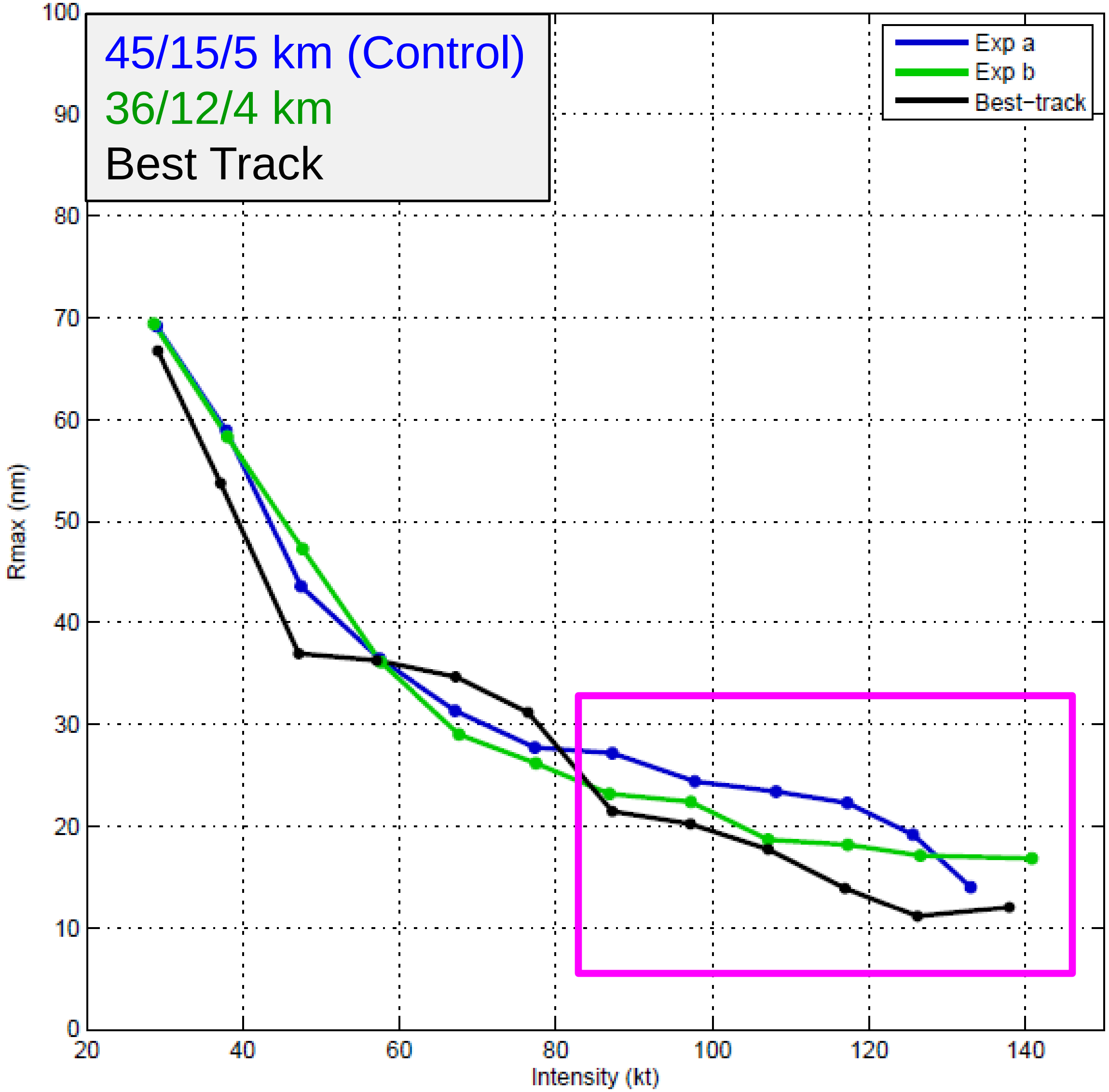
Intensity MAE (solid) and ME (dashed)



- 2017 version of COAMPS-TC with 4 km horizontal resolution.
- Intensity MAE is improved at all lead times for the full sample
- Forecasts are particularly improved for TCs with observed RI
- Currently testing physics improvements (EDMF and cumulus).

COAMPS-TC 2017 Version

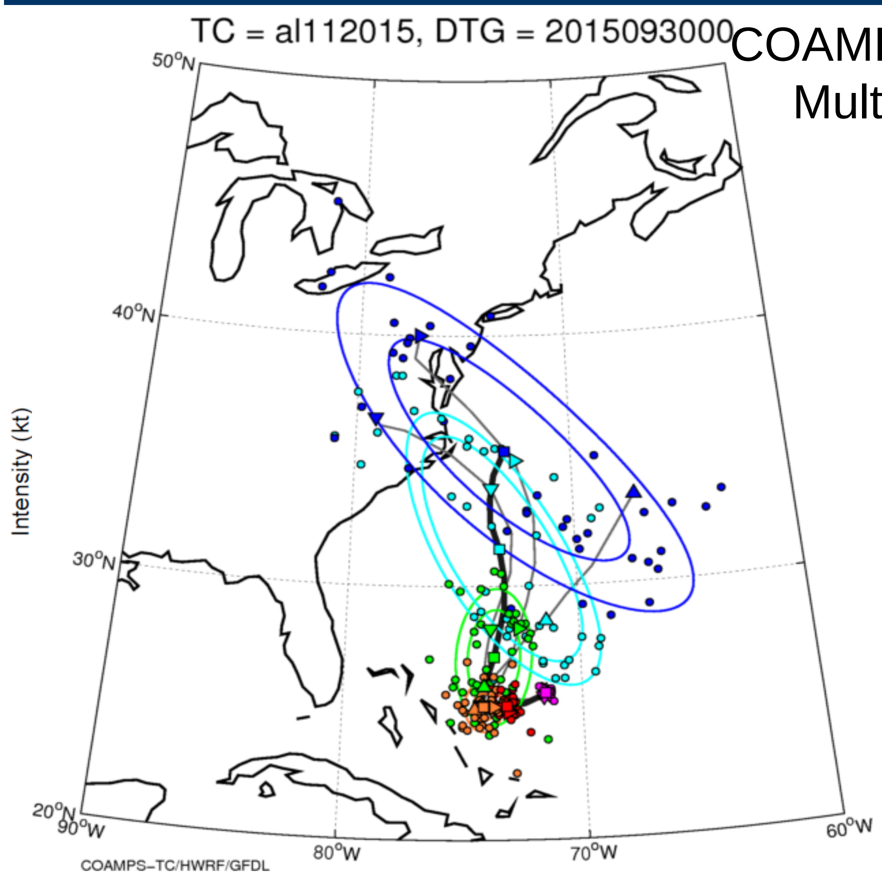
Rmax conditional (on intensity) mean



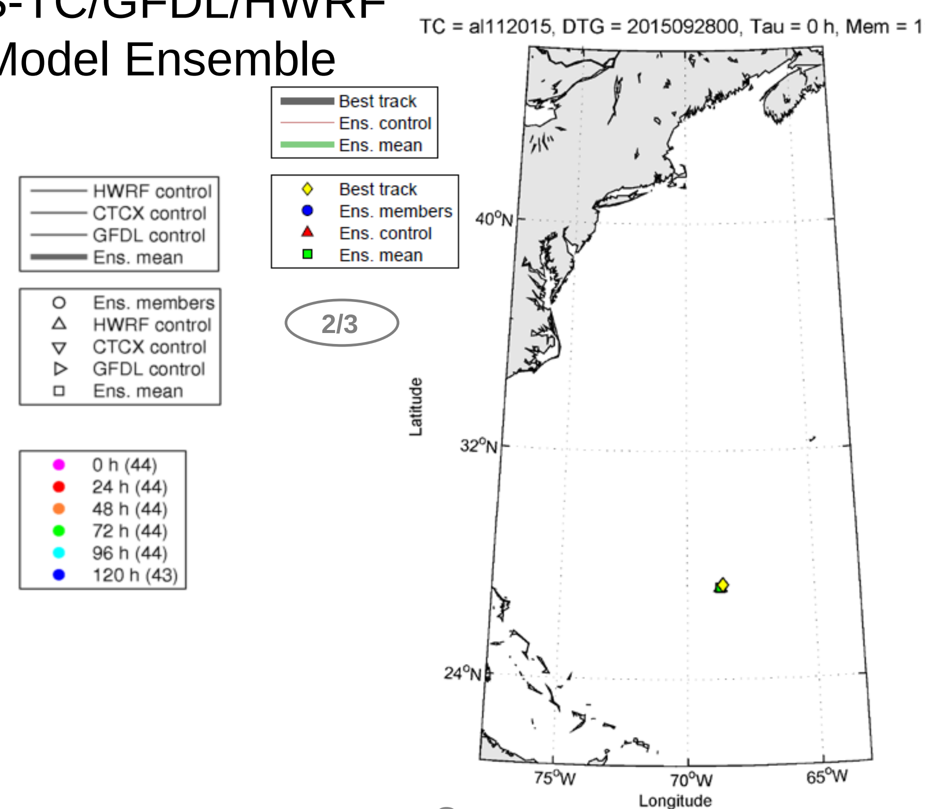
- Observed Rmax decreases w/ intensity
- For intensity > 80 kt, 4-km forecasts have smaller mean Rmax than 5-km forecasts; similar to best track
- Higher resolution model can more realistically simulate intense storms with small inner cores

High-Resolution Ensemble

- Intensity changes (RI) may not be predictable in a deterministic sense.
- Multi-model ensembles are more capable of accounting for forecast uncertainty due to model & IC errors, than a single-model ensemble.
- Real-time HFIP ensemble: COAMPS-TC (3km), HWRF (3km), GFDL (6km)
- COAMPS-TC & HWRF control consensus and ensemble mean outperform their single-model counterparts in deterministic validation



COAMPS-TC/GFDL/HWRF
Multi-Model Ensemble

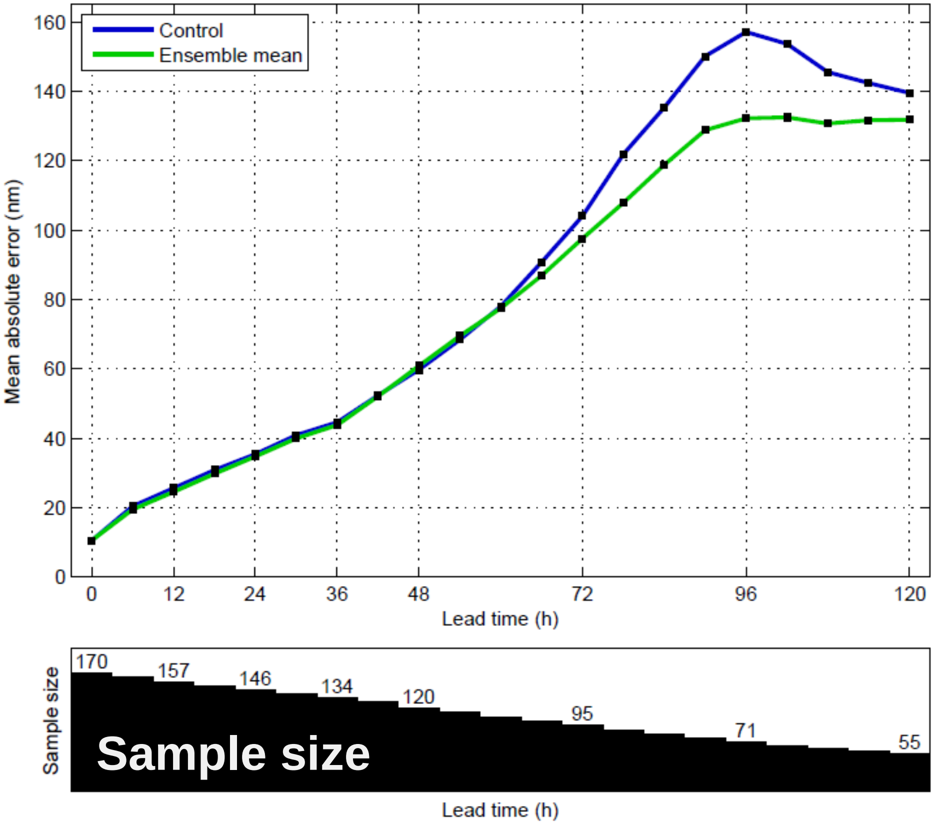


COAMPS-TC Ensemble System

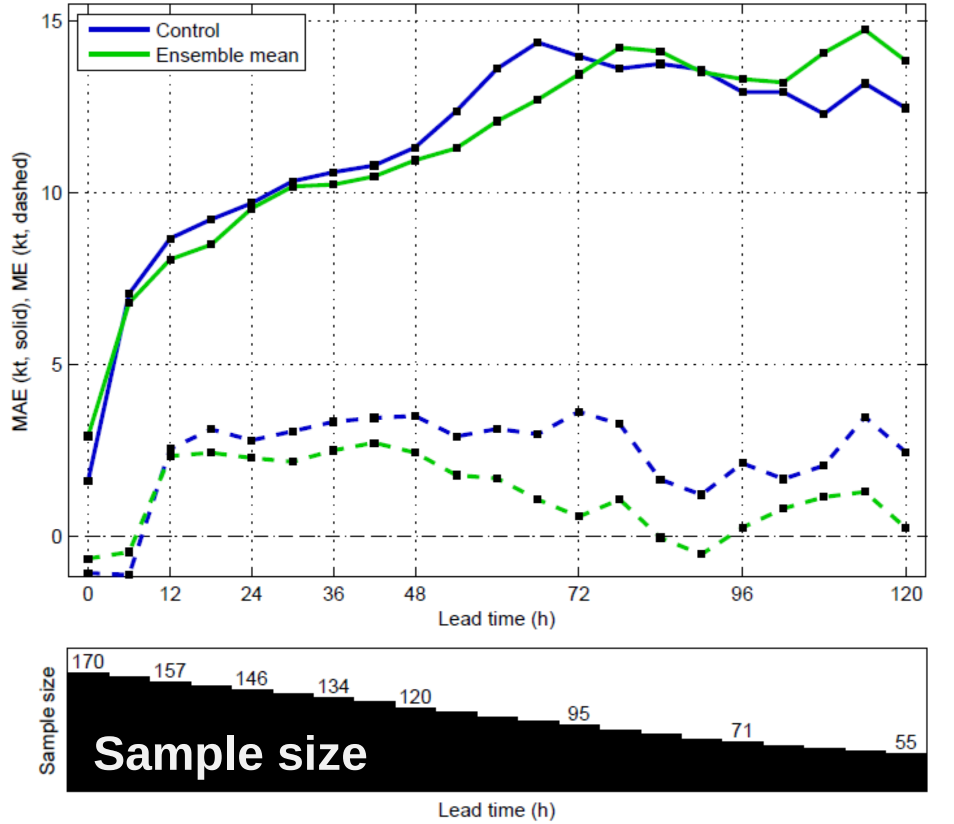
Statistics for ATL and EPAC

Ensemble control vs Ensemble mean

Track MAE



Intensity MAE (solid) and ME (dashed)

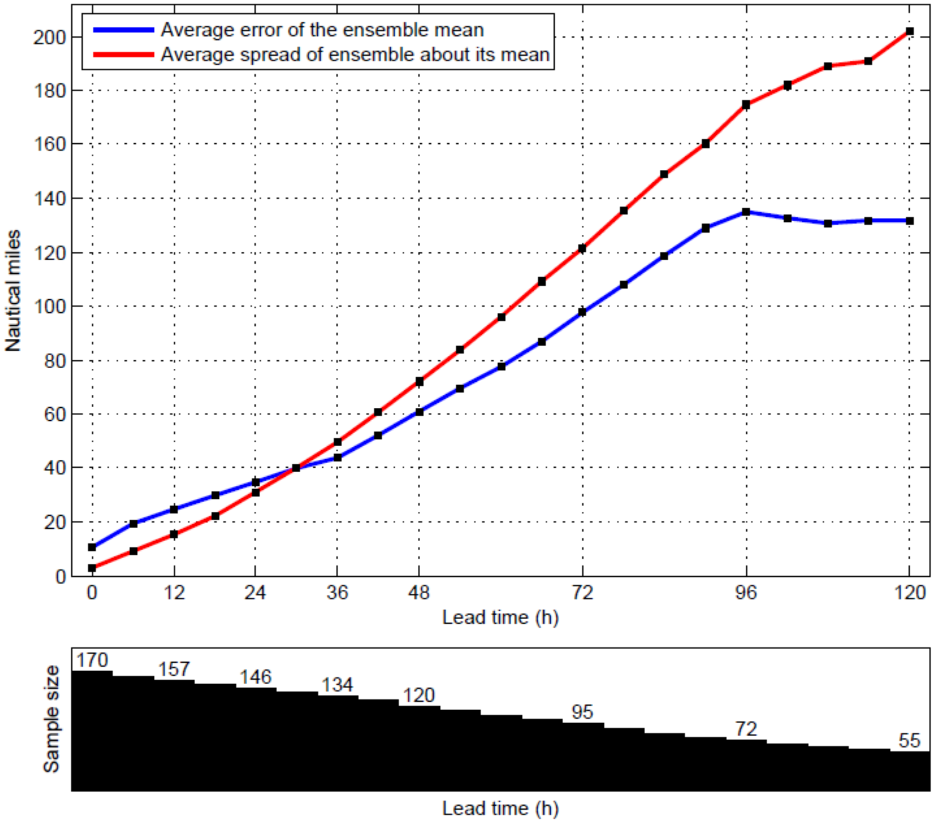


- Ensemble mean outperforms control at long lead times
- Ensemble mean similar or better MAE w.r.t. control for most lead times

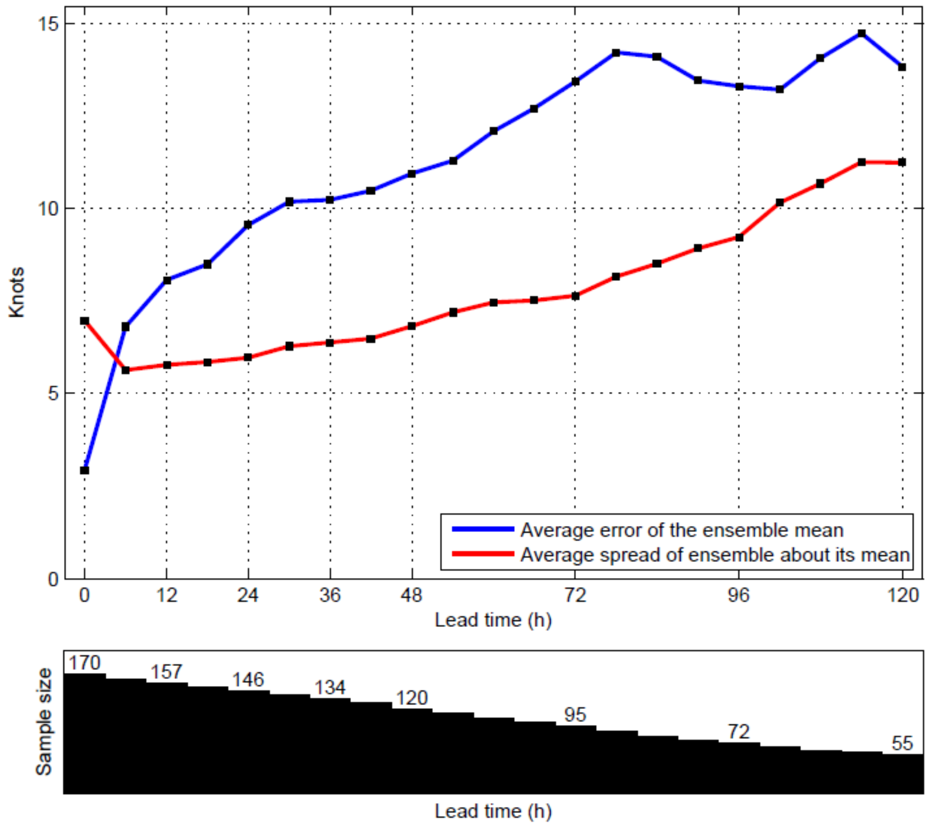
COAMPS-TC Ensemble System
Statistics for ATL and EPAC

Ensemble mean error vs Ensemble spread

Track



Intensity



- Spread is too large for this sample of cases (ensemble mean very accurate)
- As in previous years, intensity spread is lacking relative to intensity skill

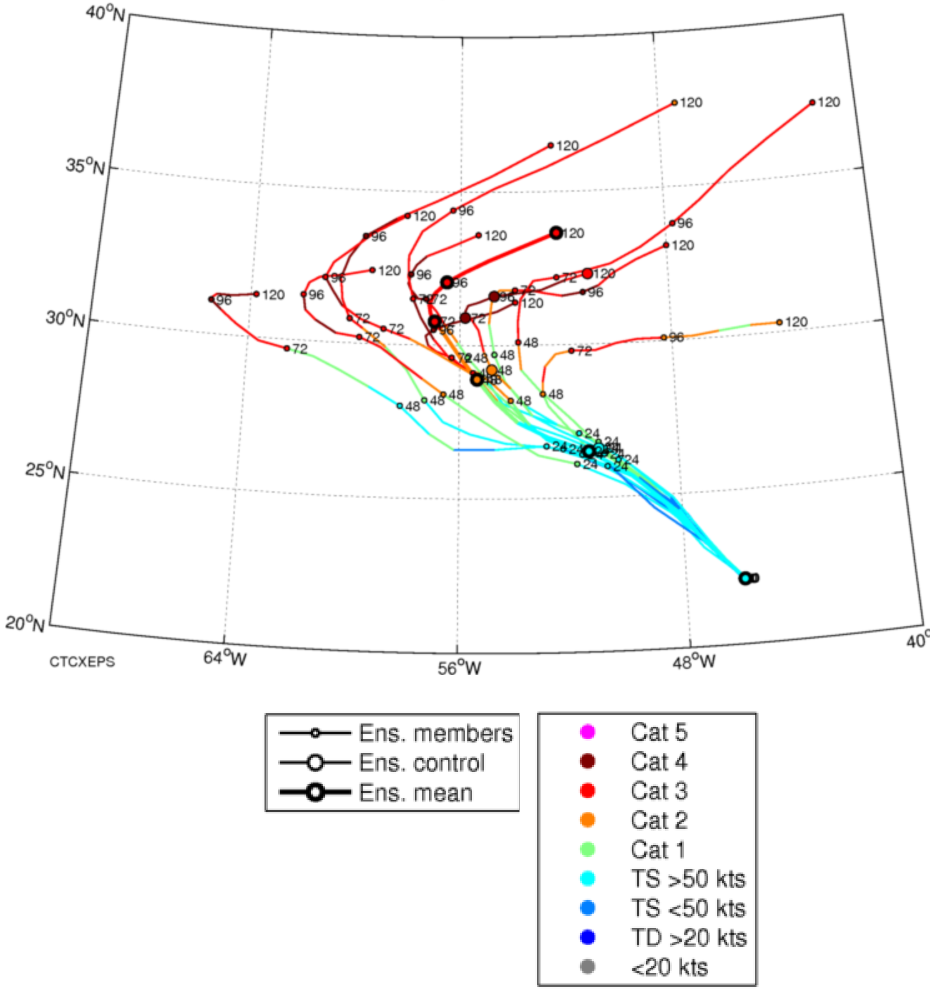
COAMPS-TC Ensemble System

New Forecast Products for 2016

Track colored by forecast intensity

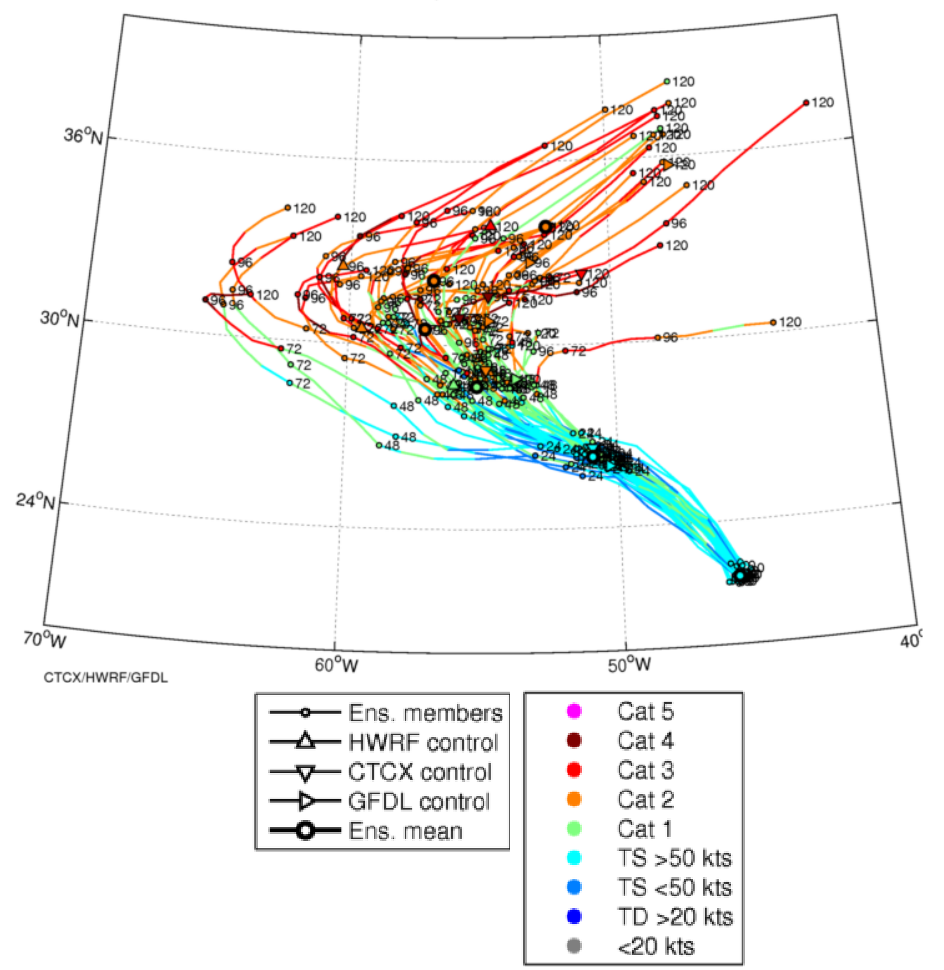
COAMPS-TC

TC = 07L2016, DTG = 2016082600



COAMPS-TC / HWRF / GFDL

TC = 07L2016, DTG = 2016082600

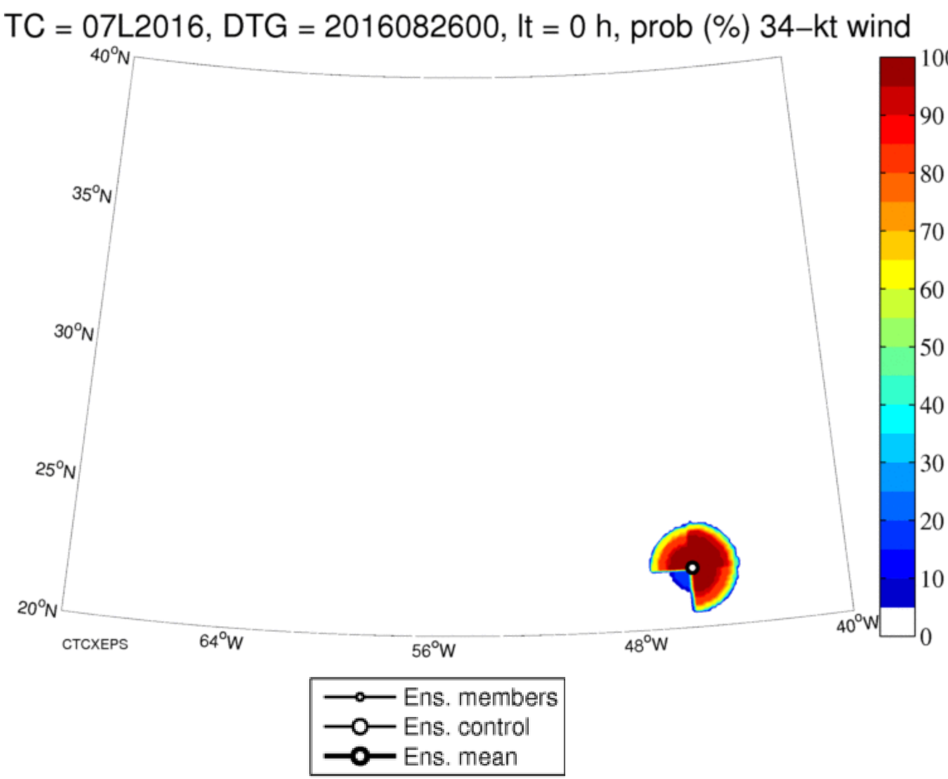


COAMPS-TC Ensemble System

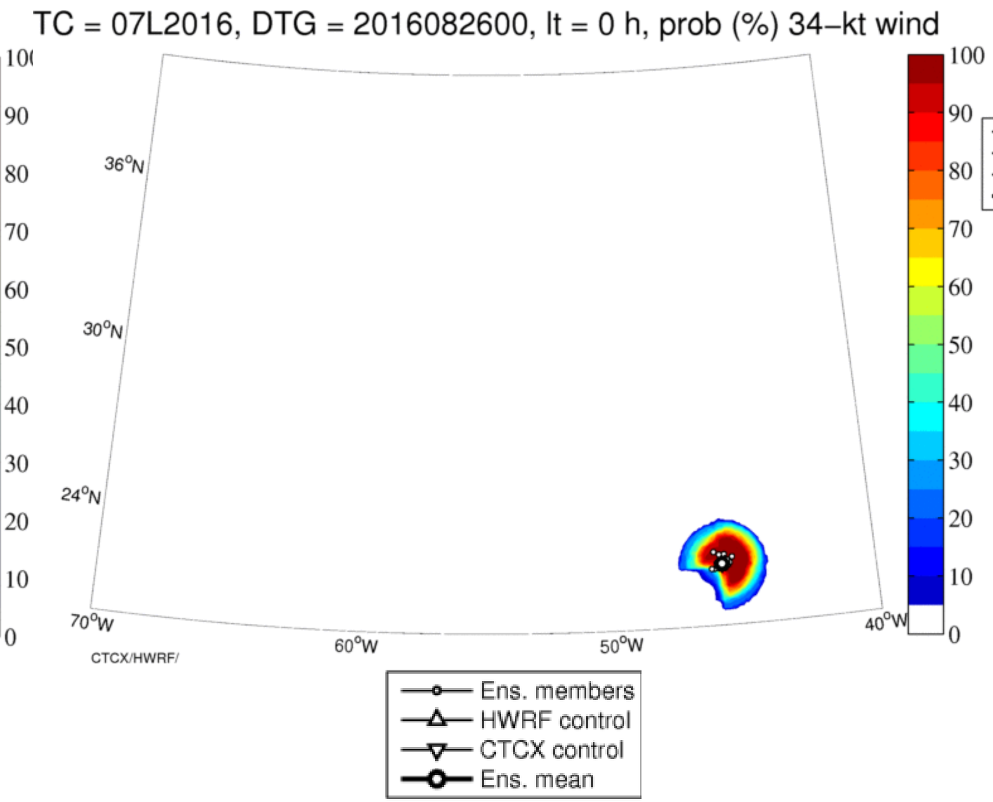
New Forecast Products for 2016

10-m wind threshold exceedance probability

COAMPS-TC



COAMPS-TC / HWRF



Available for 34 kt, 50 kt, and 64 kt thresholds, with both animations as shown above and static images for tau = 120

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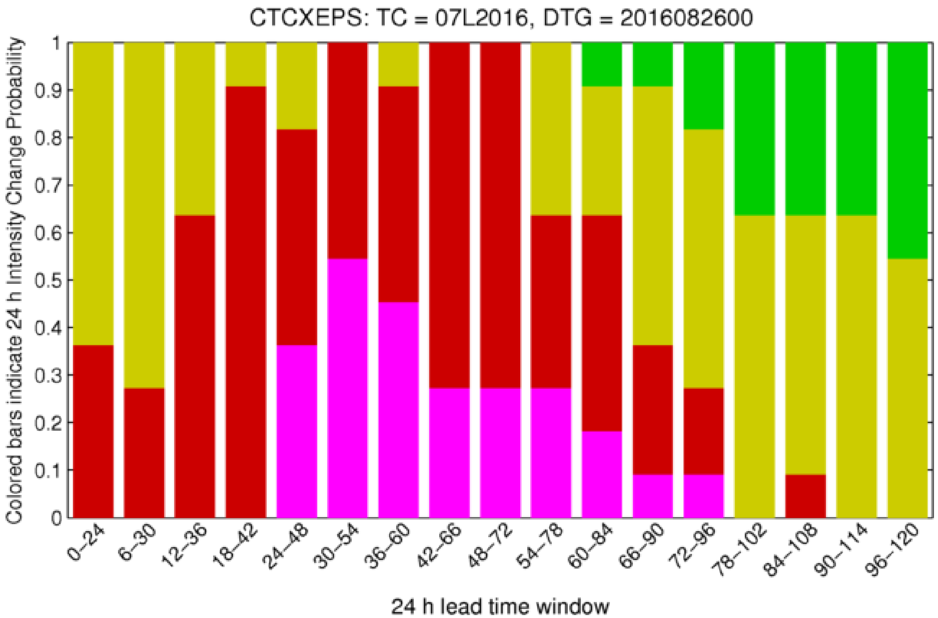
COAMPS-TC Ensemble System
New Forecast Products for 2016

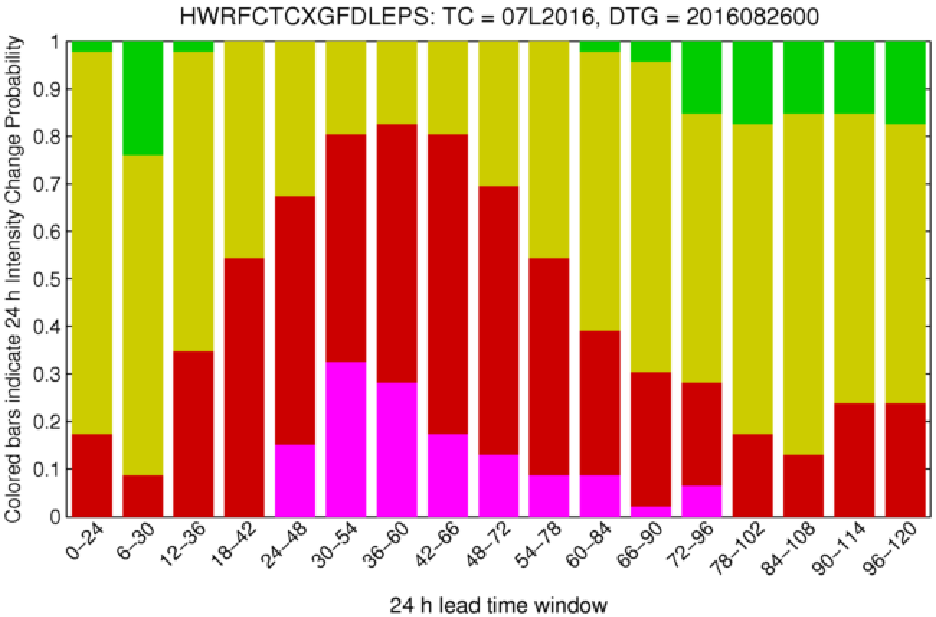
24 h intensity change probability

COAMPS-TC



Δ I >= 30 kt (Rapid Intensification)
10 kt <= Δ I < 30 kt (Moderate Intensification)
−10 kt < Δ I < 10 kt (Steady Intensity)
−30 kt < Δ I <= −10 kt (Moderate Weakening)
Δ I <= −30 kt (Rapid Weakening)
TC already dissipated or dissipates during window

COAMPS-TC / HWRF



Δ I >= 30 kt (Rapid Intensification)
10 kt <= Δ I < 30 kt (Moderate Intensification)
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Δ I <= −30 kt (Rapid Weakening)
TC already dissipated or dissipates during window

Available for ΔI ≥ 30 in 0 to 24 h, ΔI ≥ 55 in 0 to 48 h, and ΔI ≥ 65 in 0 to 72 h
(as shown in example above)

COAMPS-TC
Summary and Future Plans

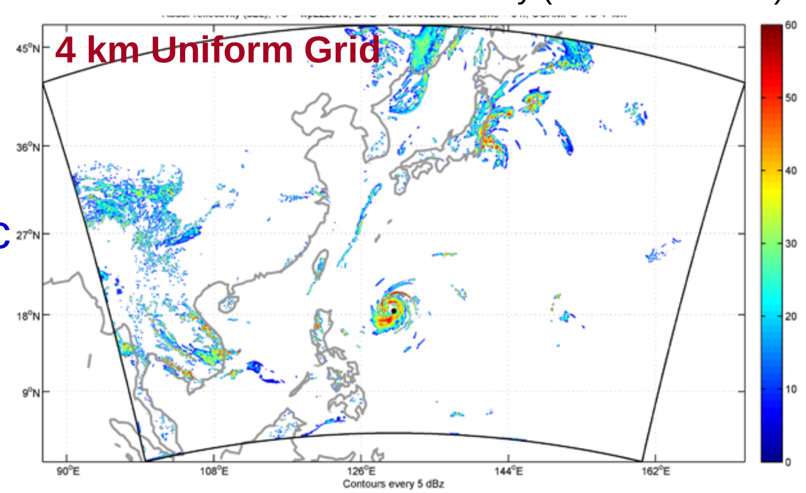
➢COAMPS-TC Much Improved for Track & Intensity in 2015/16:

- Improved intensity error (ocean coupling; new vortex initialization; new C_D param)
- Improved track errors (new initialization; new physics)
- 2017 Version: Significant improvements for intensity (RI); physics upgrades for track
- Multi-model high-res. ensemble (NOAA/Navy) and air-ocean coupling promising
- Challenges: Prediction of rapid intensification; TC physics; inner core data assimilation

➢COAMPS-TC Future Plans:

- 2017+ Priorities
  - TC physics: Emphasis on PBL, clouds
    Analysis: 4D-Var/EnKF, satellite DA
  - Ensemble: 10-20 members; stochastic
  - Coupling: Ocean, waves, coupled DA
  - Resolution: 4 km (2017)
    ~2 km (2019)
    ~4 km basin scale (2021+)

6-120h Simulated Radar Reflectivity (00Z 2 Oct 2013)

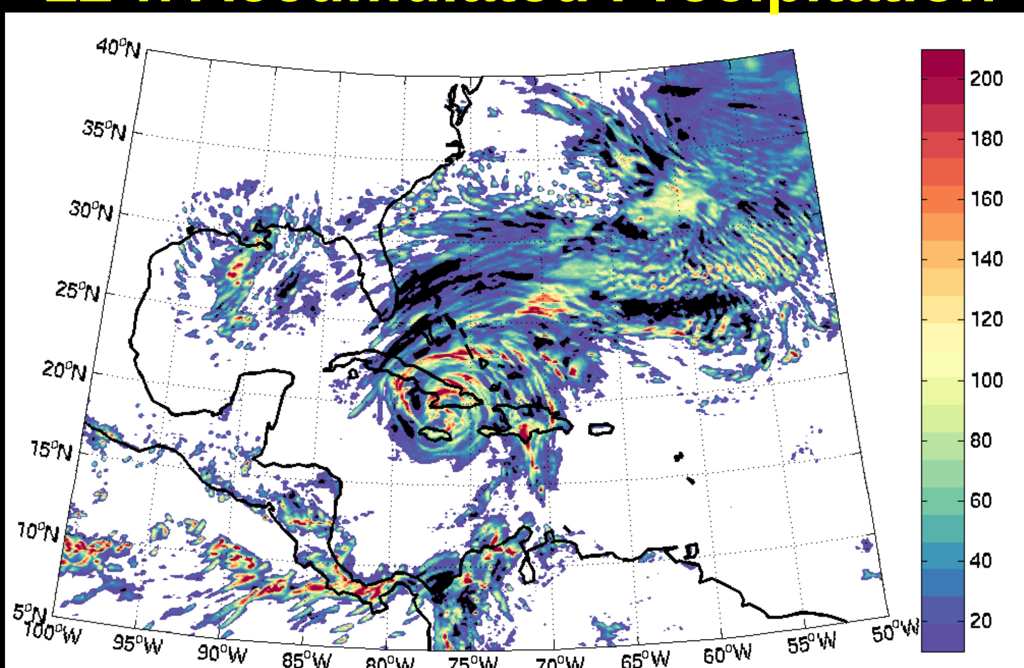


- Utilize field observations: ONR TCI,NASA HS3, SHOUT
- Future: NEPTUNE and adaptive meshes

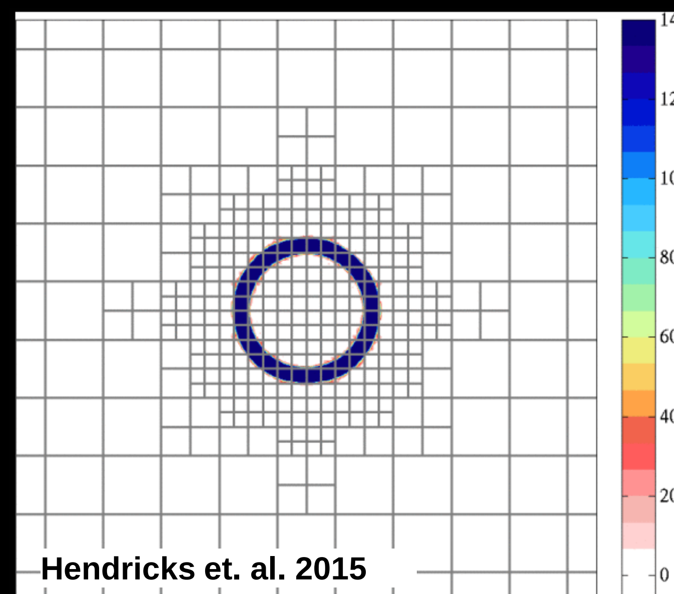
Next-Generation Models
Navy's NEPTUNE

- Utilize advanced numerical methods in a global model (e.g., spectral element in Navy's NEPTUNE) to better resolve TCs and the environment.
- Goal is to achieve global cloud resolving scales (no cu-param. needed) with adaptive mesh refinement capability to better resolve TC and cloud processes.
- Highly scalable on next-generation computer architectures (100K to 1M cores)

Hurricane Sandy
12-h Accumulated Precipitation



Adaptive Mesh Refinement



Extra Slides

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2016 Operational Statistics

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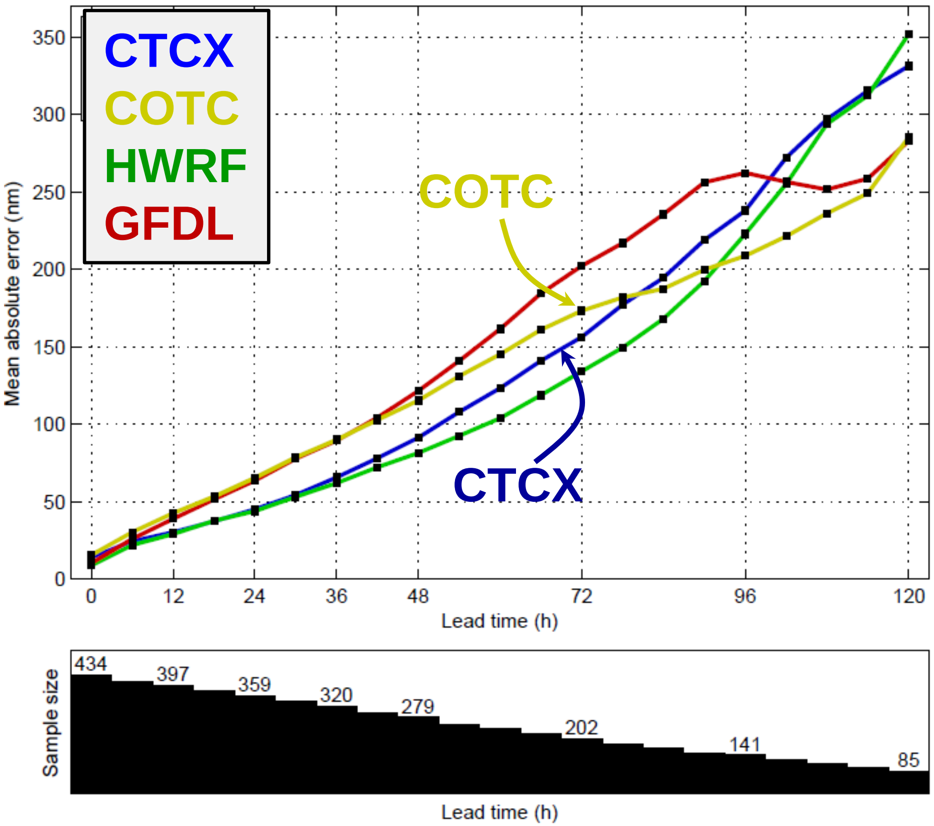
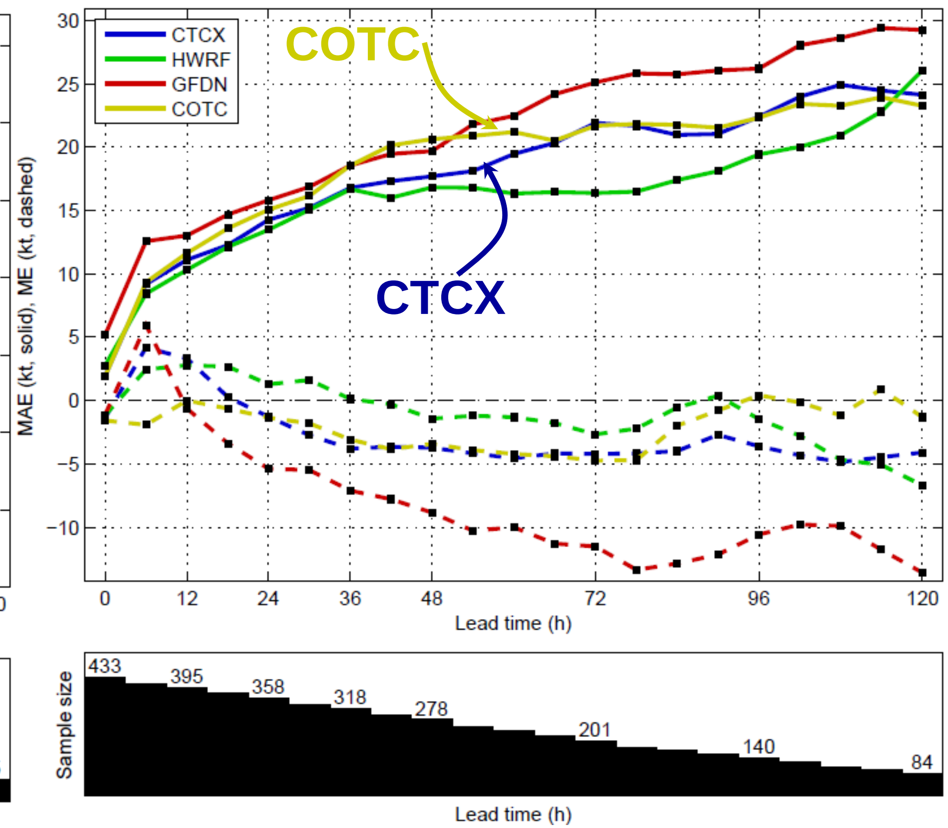
W. Pacific Basin

Position Error



Intensity Error & Bias

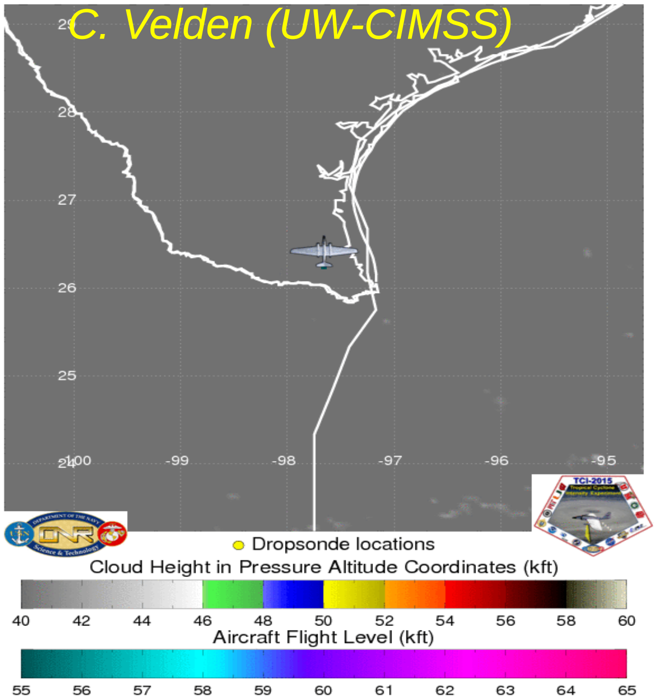


- Significant improvements in 2016 for CTCX and COTC in both track & intensity
  - ➢ Two-way coupling with NCOM
  - ➢ Smaller (but important) improvements to vortex initialization, physics
- CTCX and COTC fairly close together in terms of overall performance, although CTCX better by 1-3 kt.

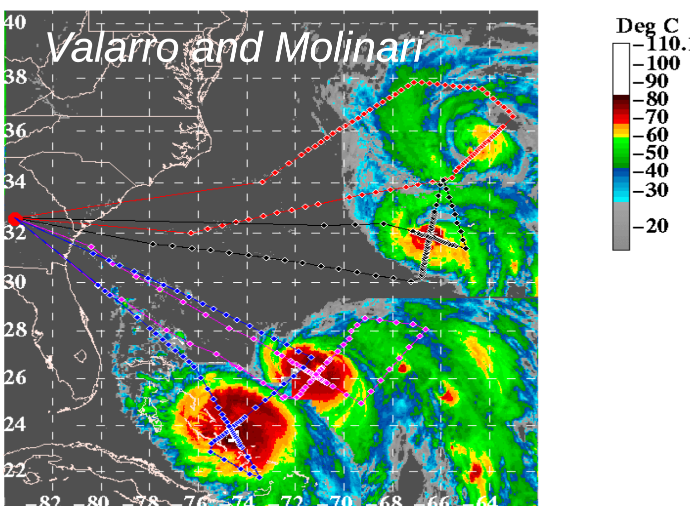
Inner Core Data Assimilation

ONR Tropical Cyclone Intensity (TCI) Experiment

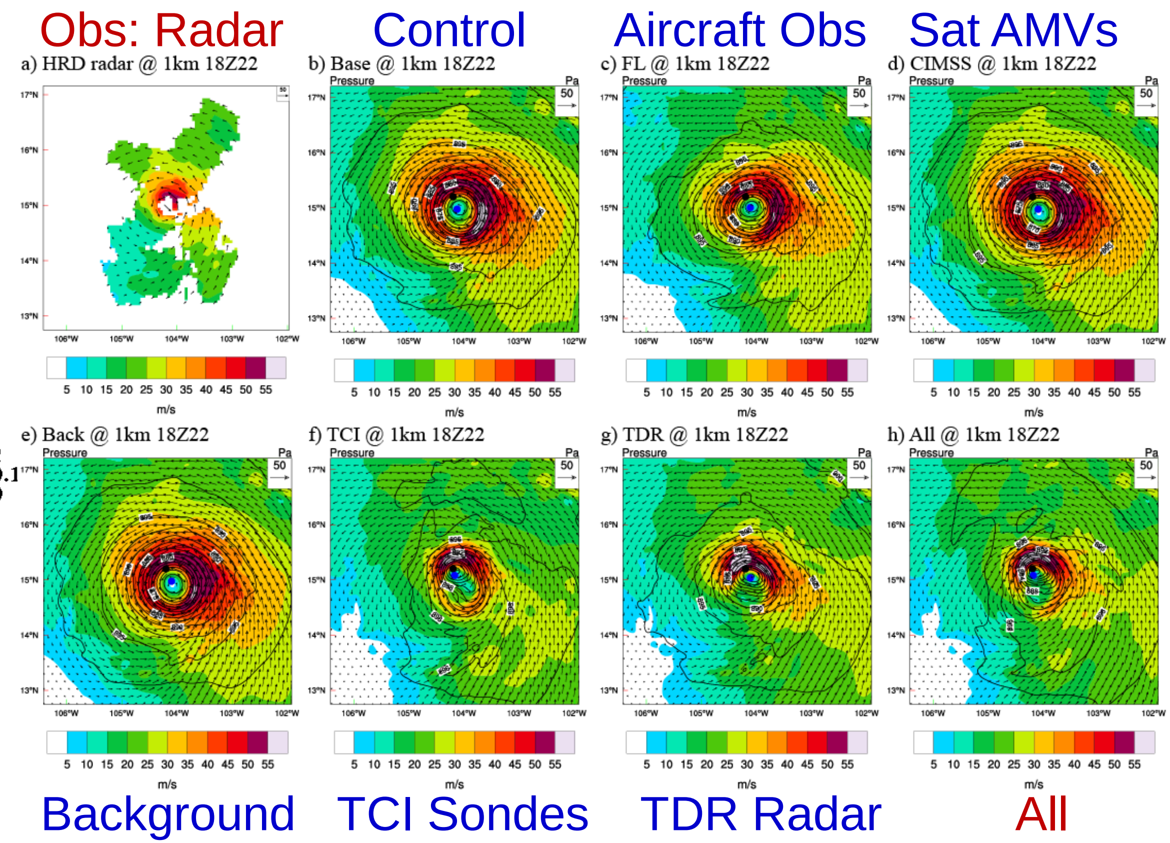
WB-57 flight track and HDSS dropsondes
on October 23, 2015 at 1805 UTC



- **Poor inner core data assimilation in models**
- **TCI: ~800 sondes deployed in 11 flights**
- **TCI Testbed for inner core assimilation**

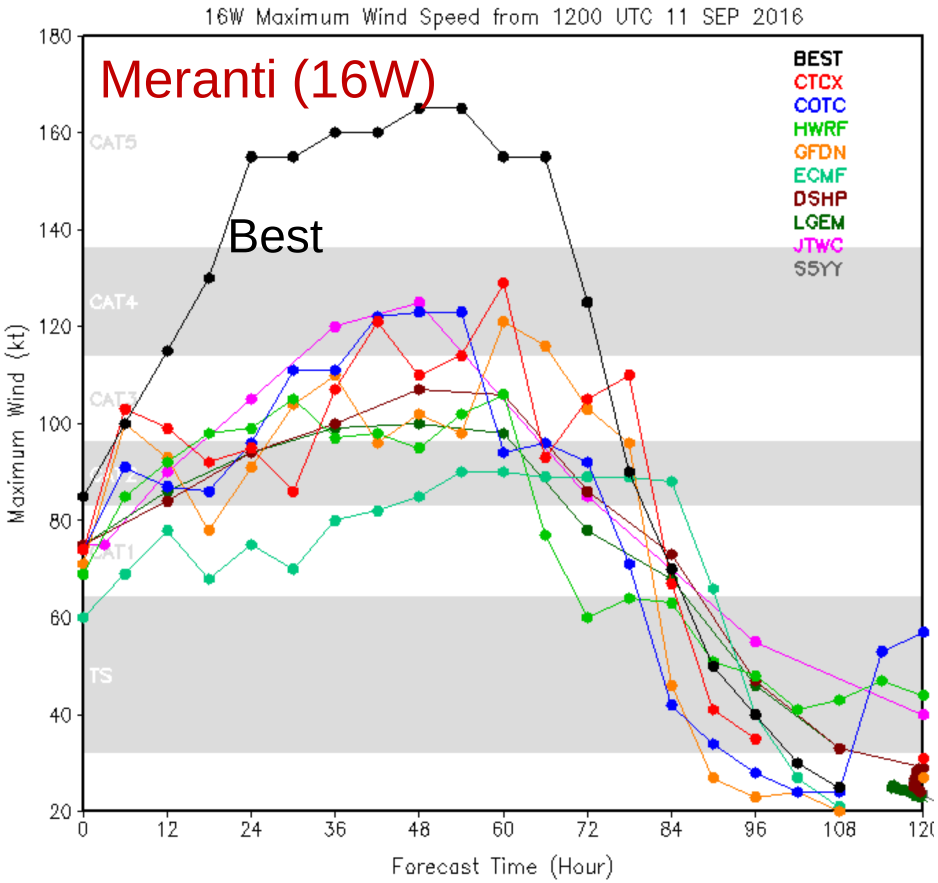


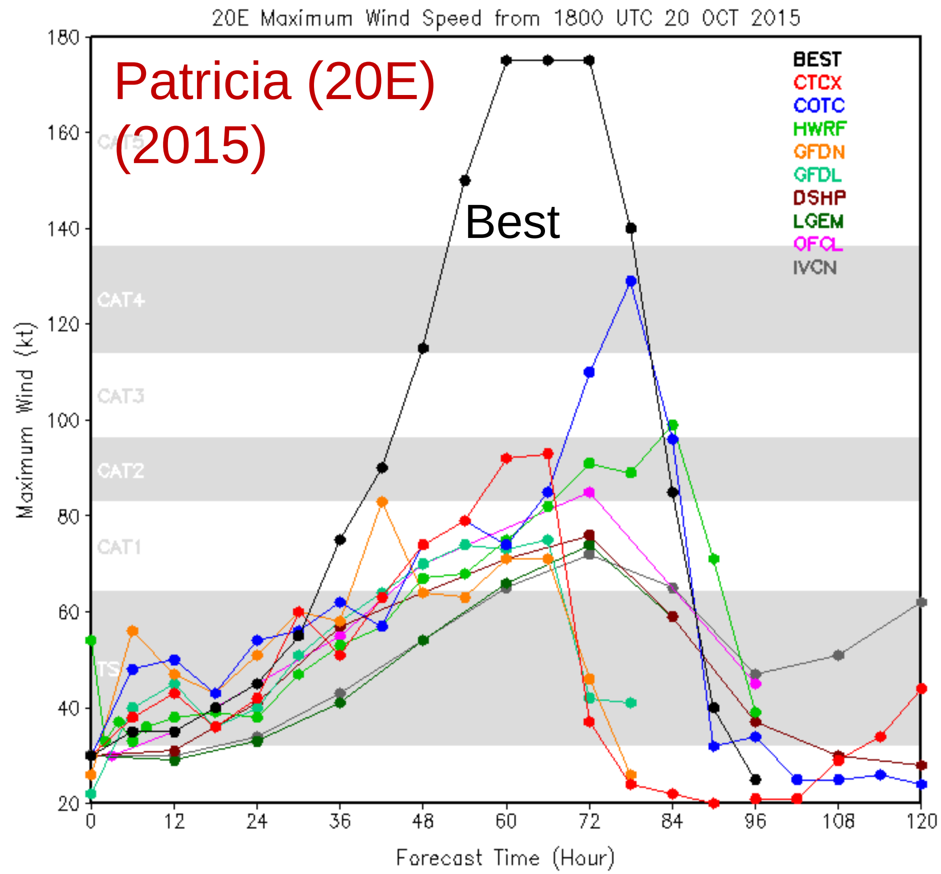
TCI flight montage Hurr Joaquin Oct 2–5 2015



Xuguang Wang (OU)

Rapid Intensification





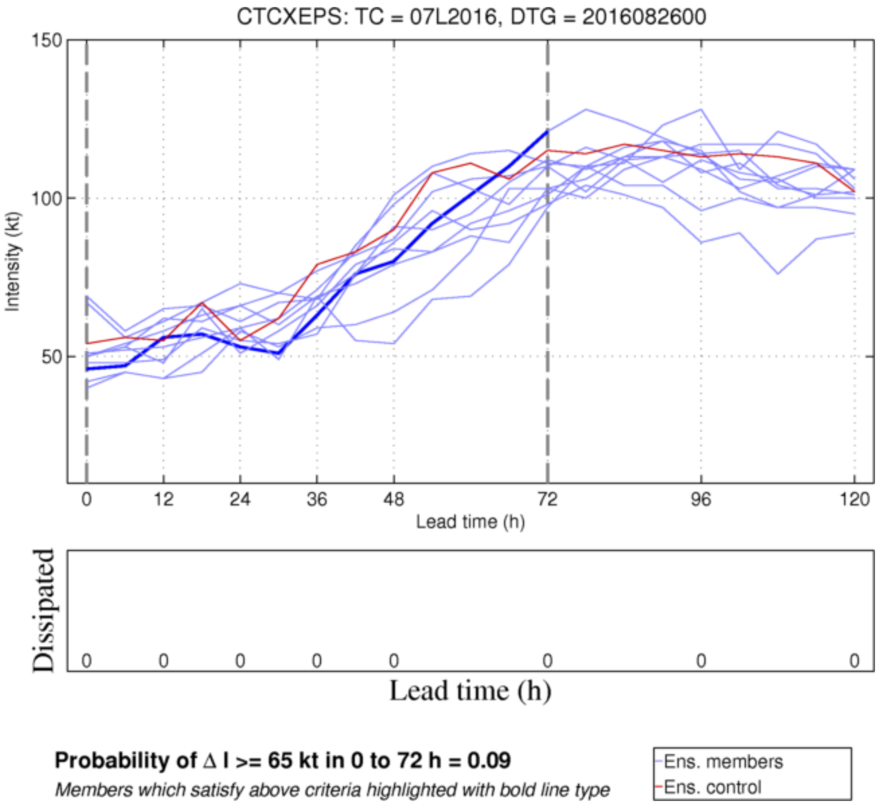
Many challenges regarding RI and it is unclear what the necessary physics, air-sea coupling, data assimilation, resolution needed to predict a "Patricia"

COAMPS-TC Ensemble System

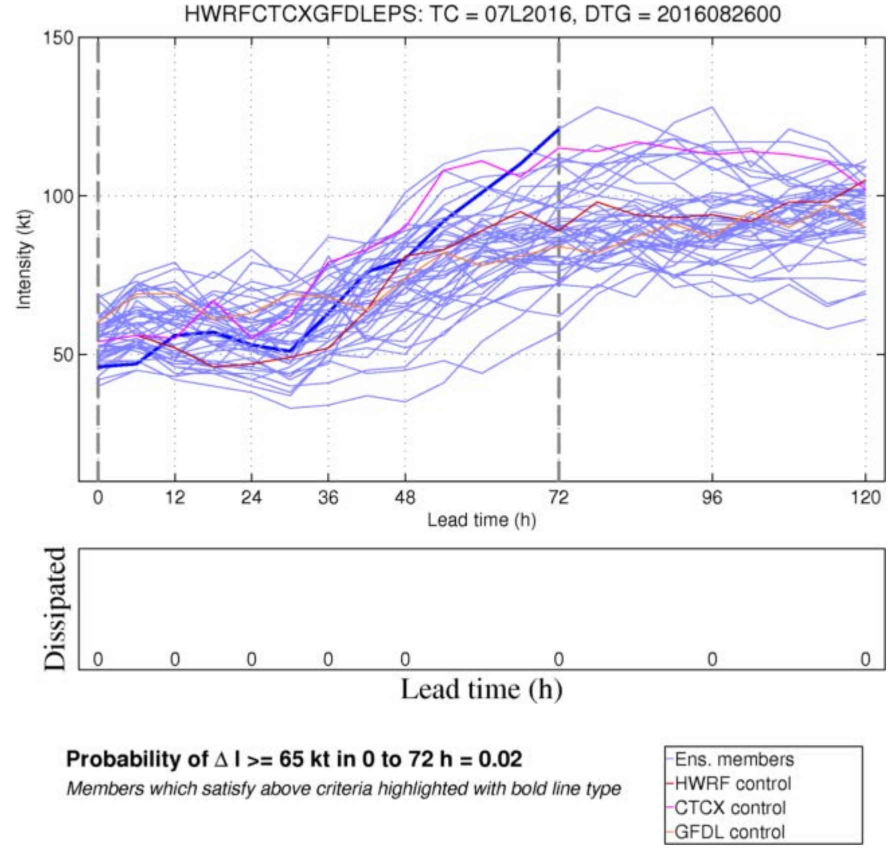
New Forecast Products for 2016

Rapid intensification probability

COAMPS-TC



COAMPS-TC / HWRF

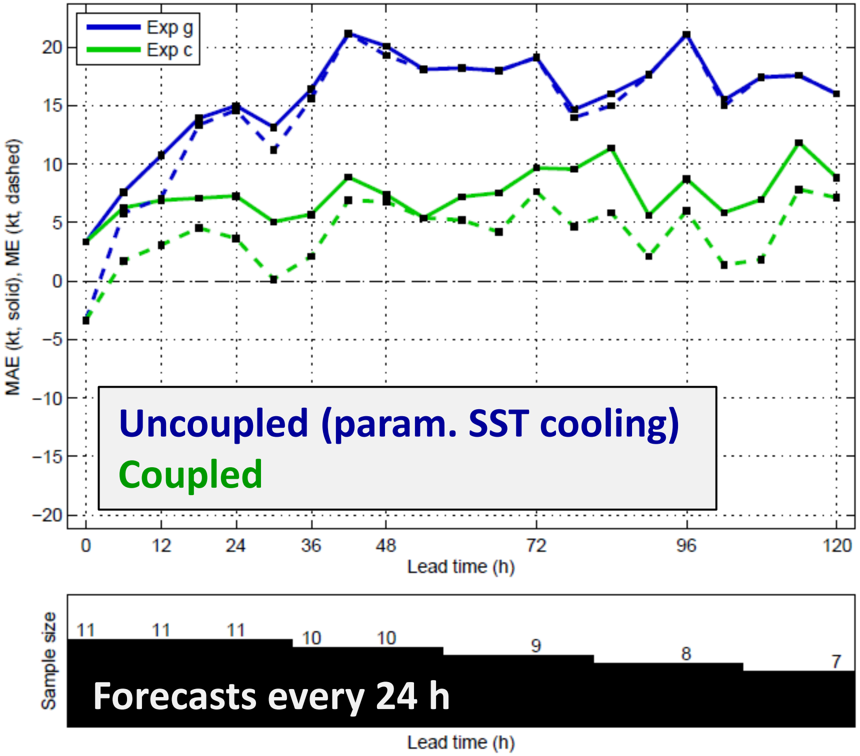


Available for ΔI ≥ 30 in 0 to 24 h, ΔI ≥ 55 in 0 to 48 h, and ΔI ≥ 65 in 0 to 72 h (as shown in example above)

Atmosphere-Ocean Coupling

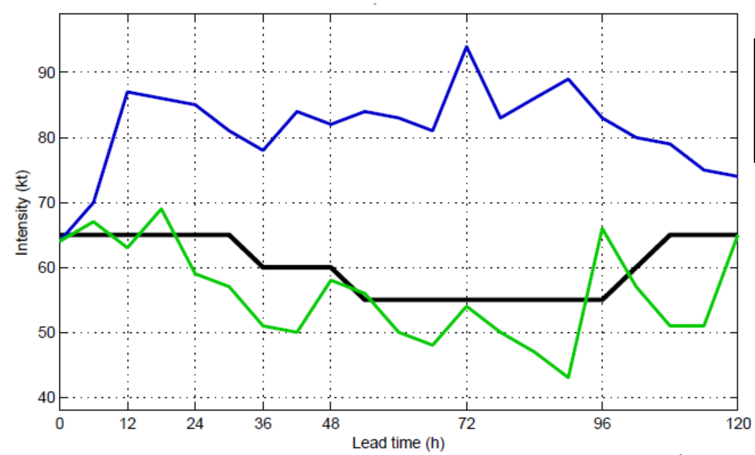
Benefits of Coupling

Hurricane Leslie (2012): Intensity Error & Bias

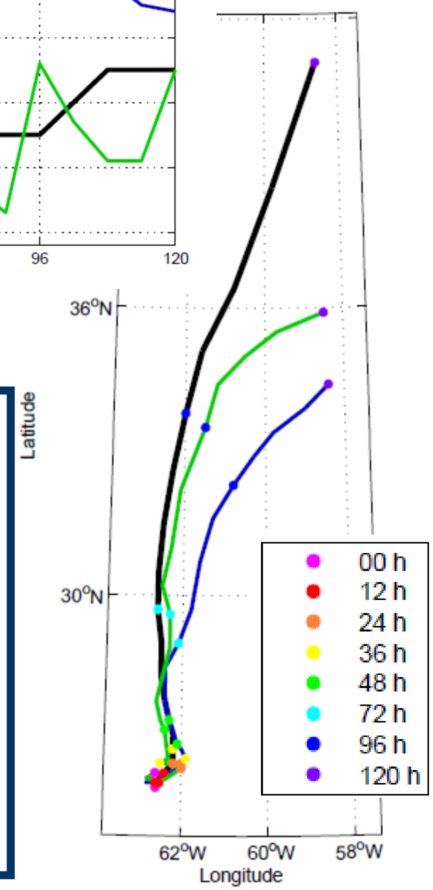


For a very slow-moving TC such as Leslie, the coupled model substantially outperforms uncoupled model in intensity prediction

Hurricane Leslie (2012): 2012090600 forecast



Black line: Best track



- TC moves little during first 48 h of forecast; ocean interaction of first-order importance
- Coupled model has much more accurate intensity prediction for all lead times. Track is also improved in this case