Recent COAMPS-TC Development and Future Plans

James D. Doyle, Jon Moskaitis, Rich Hodur[1], Sue Chen, Hao Jin, Yi Jin, Will Komaromi, Alex Reinecke, David Ryglicki, Dan Stern[2], Shouping Wang

Naval Research Laboratory, Monterey, CA
[1]SAIC, [2]UCAR

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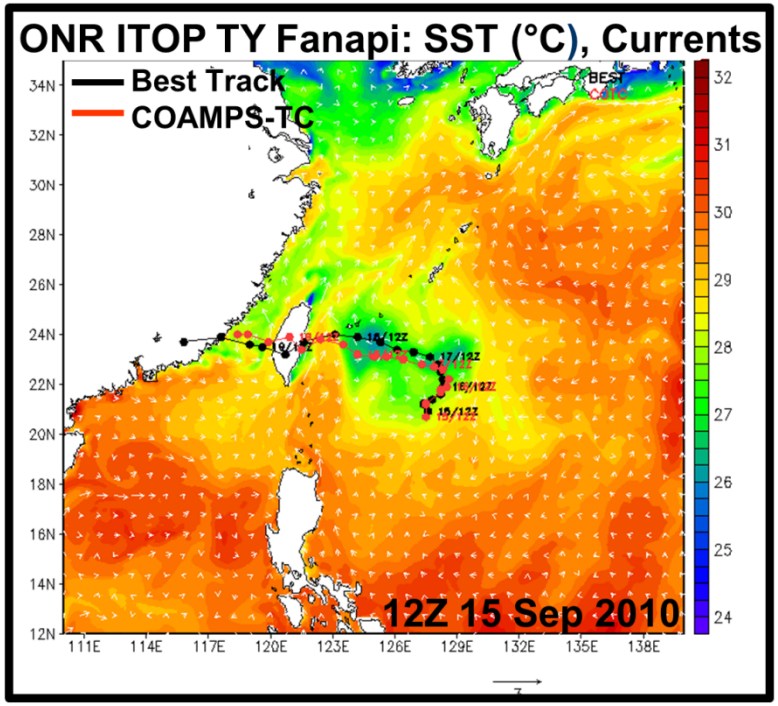
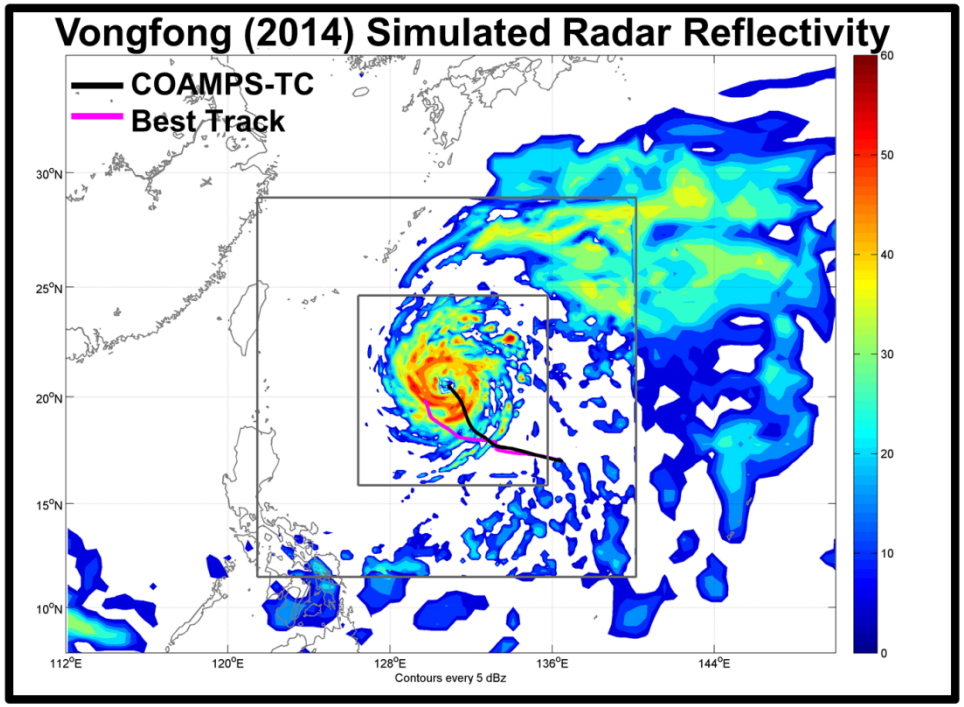
Sept. 13, 2016 0510 UTC, MODIS image of Super Typhoon Meranti (NASA)

COAMPS-TC System Overview

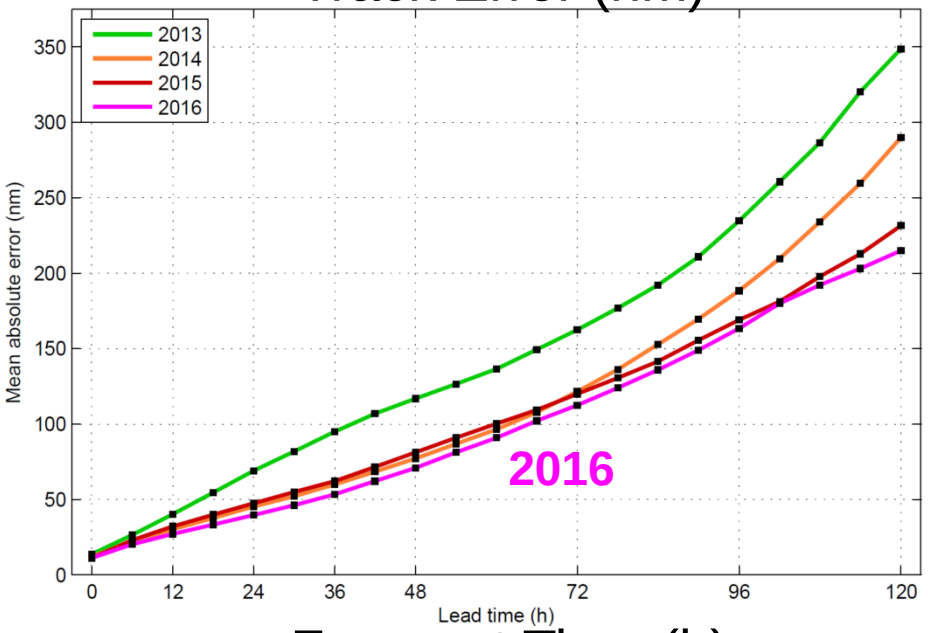
- Analysis: **No cycling or Cycling: 3D-Var (NAVDAS), 4D-Var, EnKF DART**
- Atmos.: **Nonhydrostatic, moving nests, TC physics**
- Ocean: **3D-Var (NCODA), ocean (NCOM), wave options (SWAN, WWIII)**
- Ops.: **45-15-5km (2016); 36-12-4km (2017) COTC (NAVGEM) & CTCX (GFS)**
- Ensemble: **45-15-5km (2016); 36-12-4km (2017) 11 member CTCX ensemble**





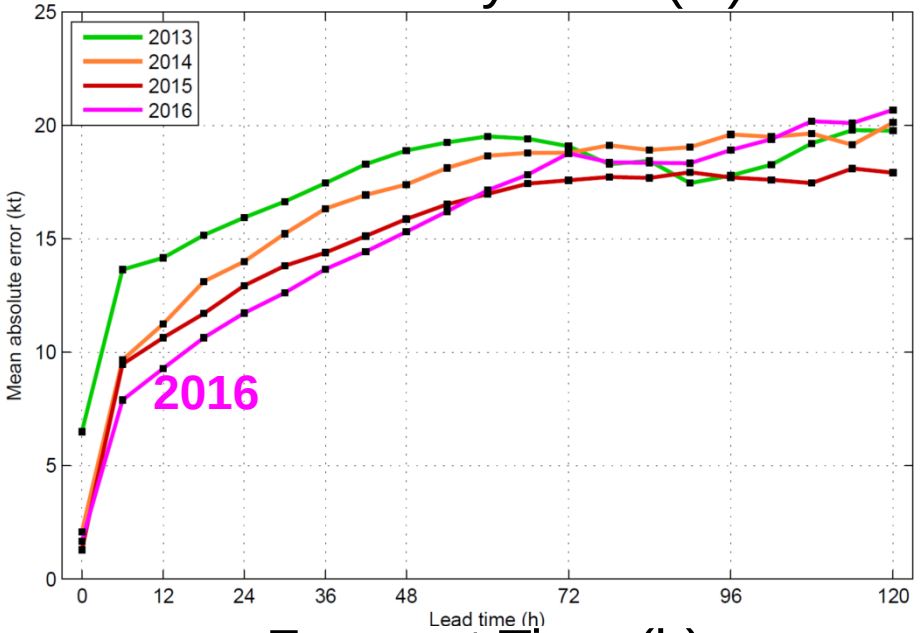
COAMPS Performance History
2013-2016 (AL/EP/CP/WP)

Track Error (nm)



Forecast Time (h)

Intensity Error (kt)

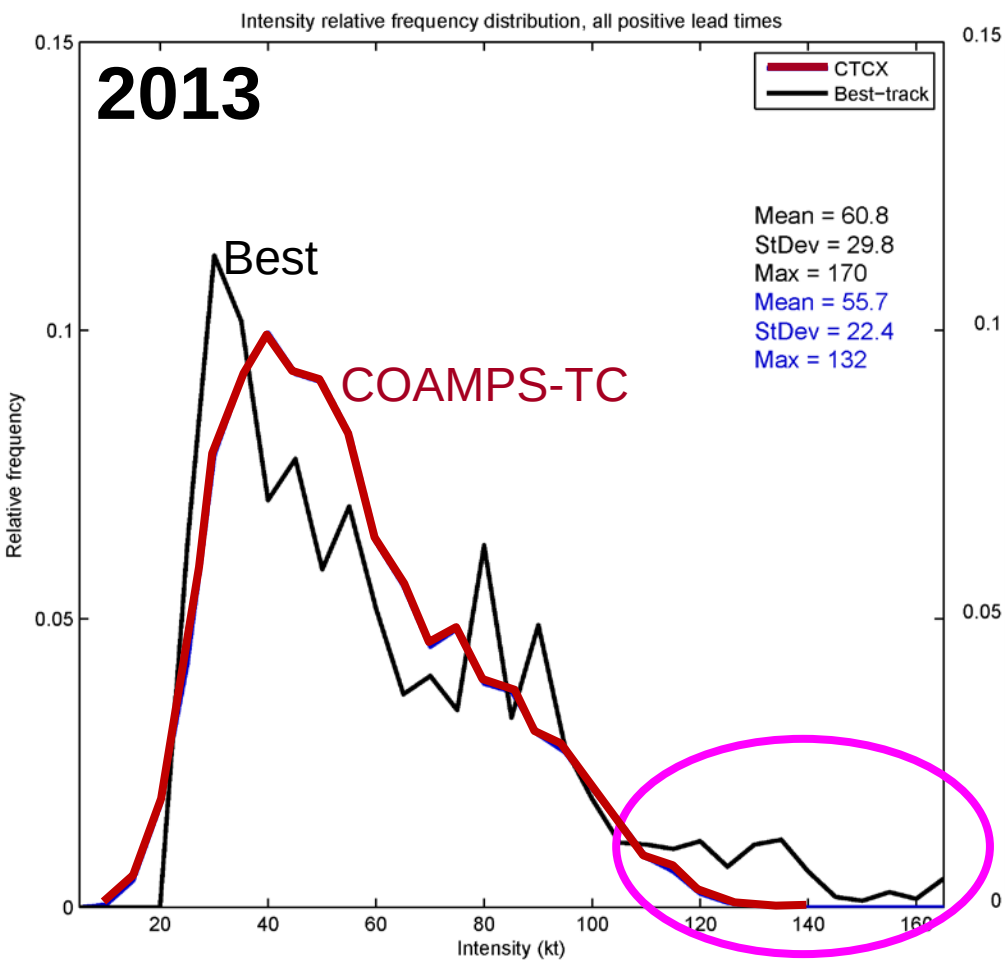


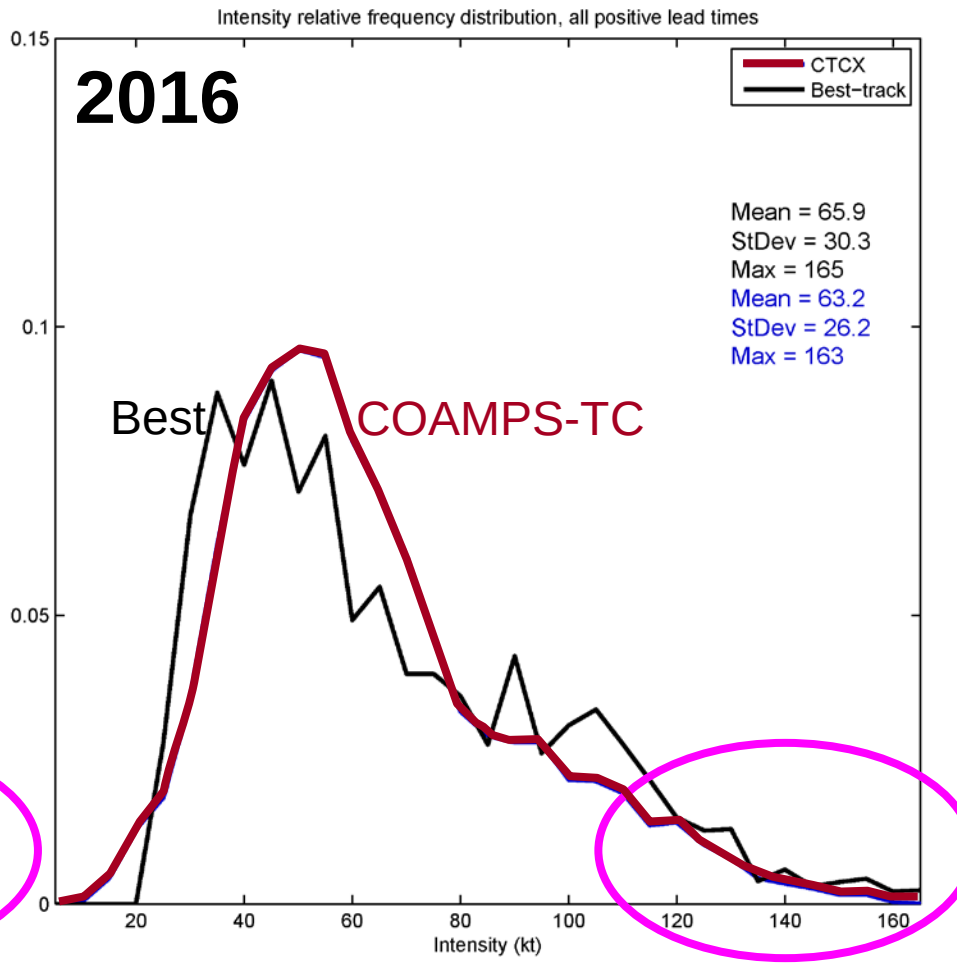
Forecast Time (h)

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

COAMPS Performance History

Intensity Distribution: 2013-2016

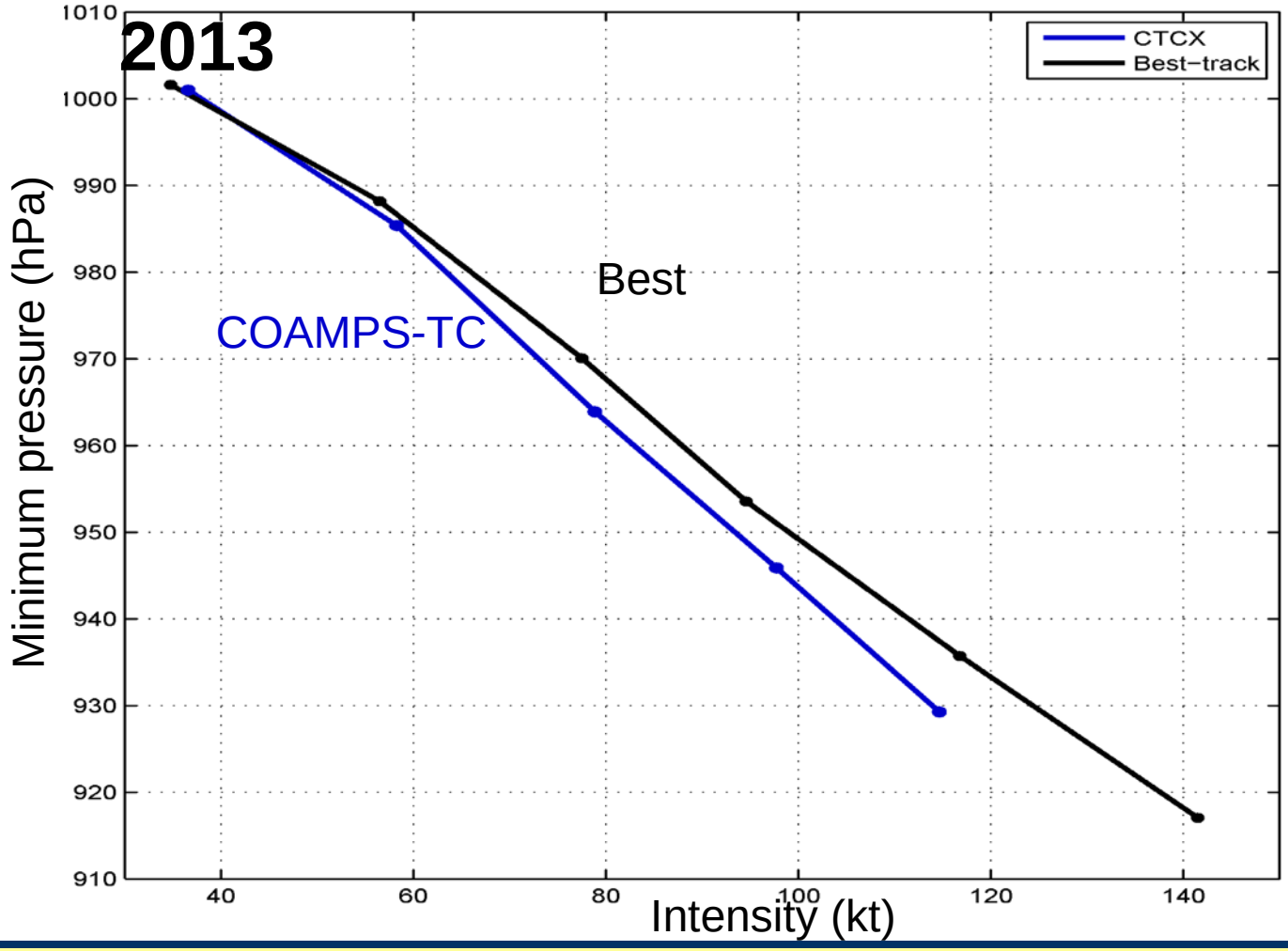




Much Improved Intensity Distribution for Strong Storms (above 120 kts)

COAMPS Performance History

Pressure-Wind Relationship: 2013-2016



Improved Pressure-Wind Relationship Primarily Due to New Formulation of Surface Drag Coefficient and Coupled Air-Ocean Interaction

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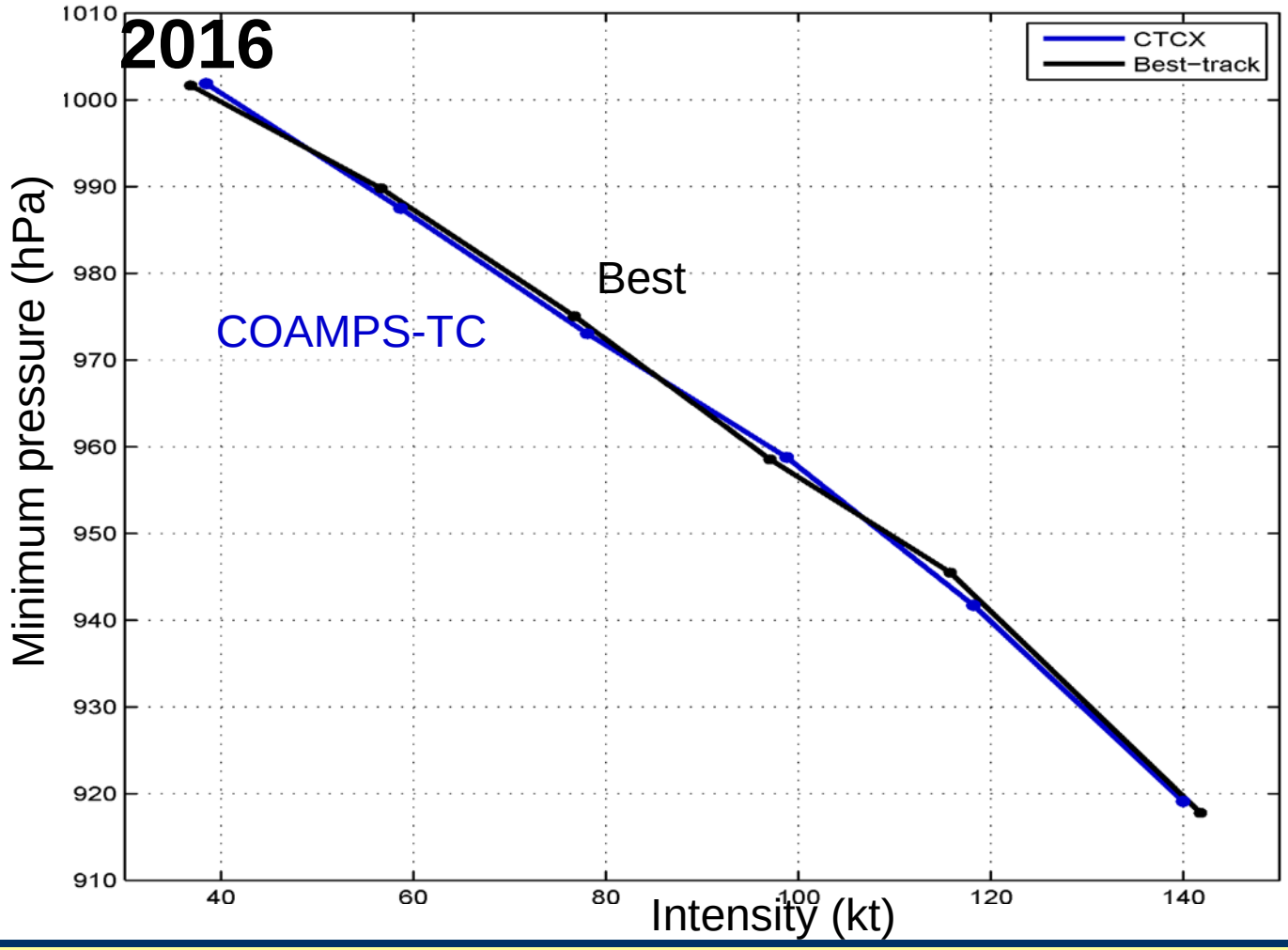

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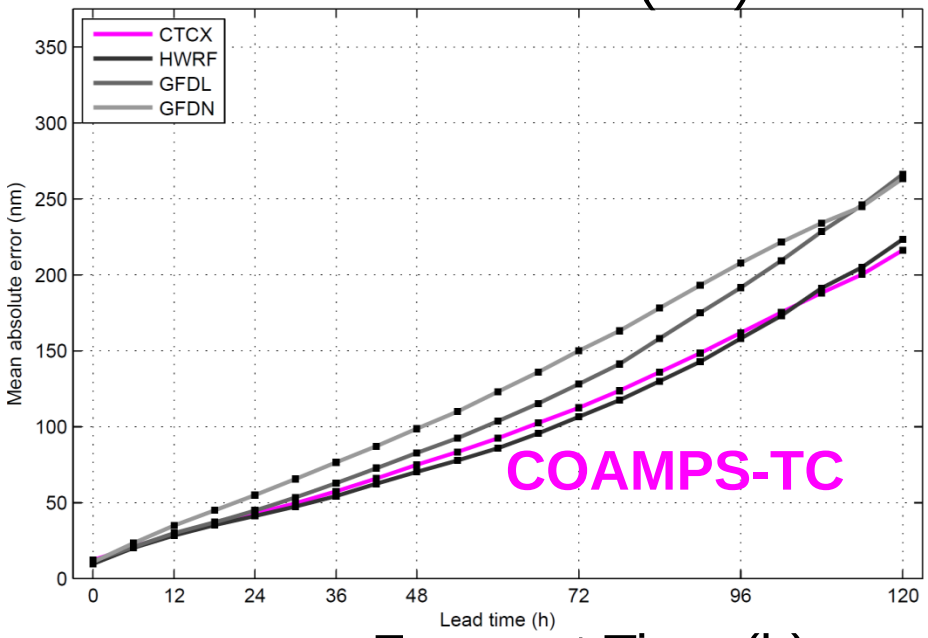
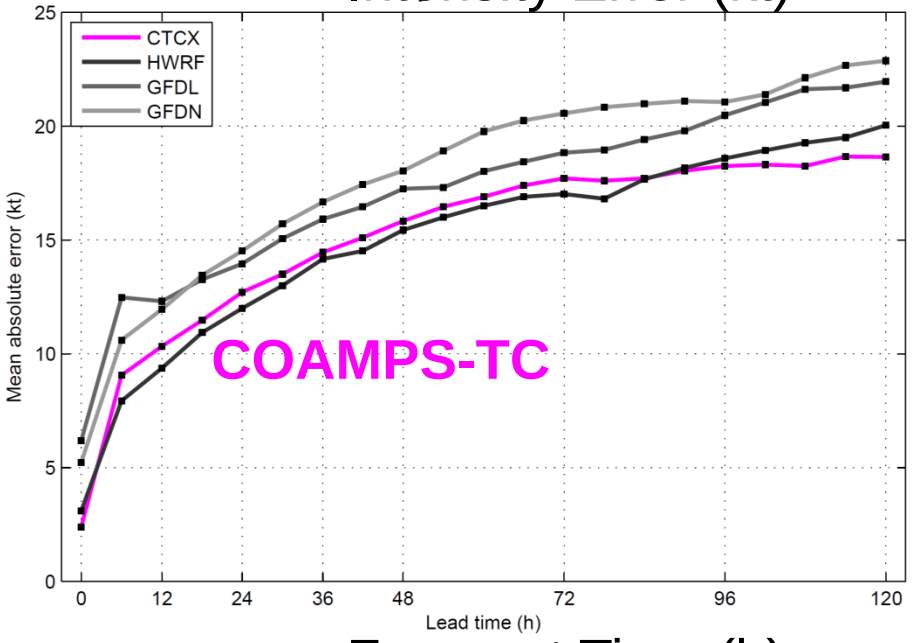
COAMPS Operational Statistics
2015-2016

Track Error (nm)



Forecast Time (h)

Intensity Error (kt)



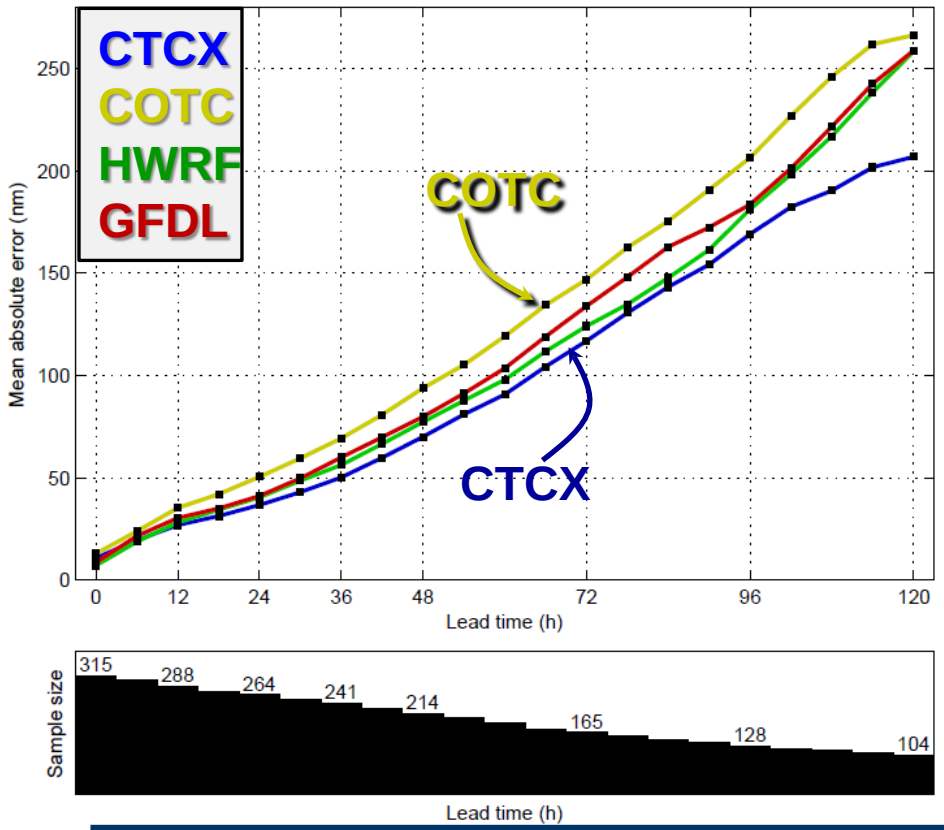
Forecast Time (h)

COAMPS-TC (CTCX) has performed very well compared with other leading models for the 2015-2016 time period (AL/EP/CP/WP)

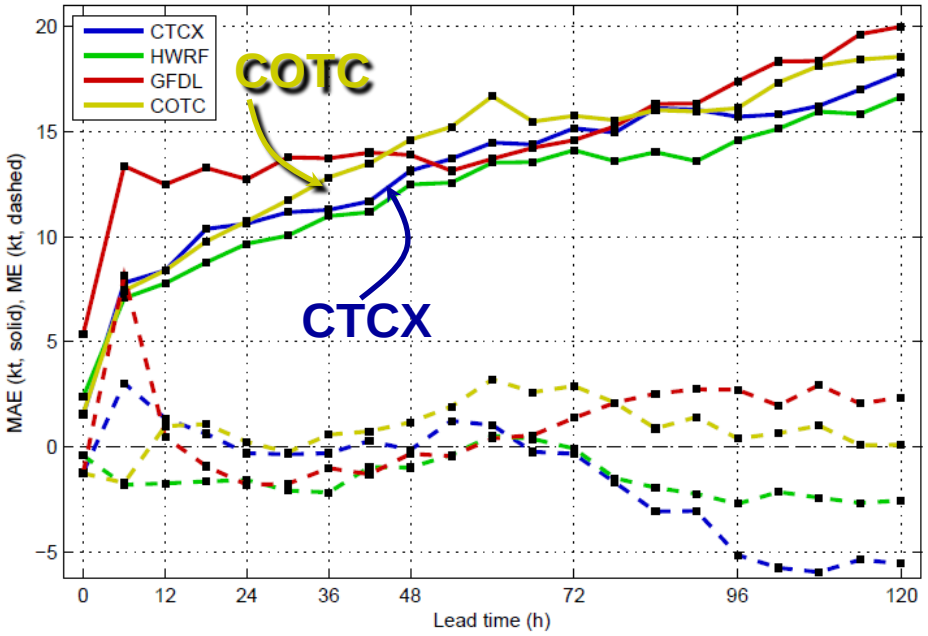
2016 Operational Statistics

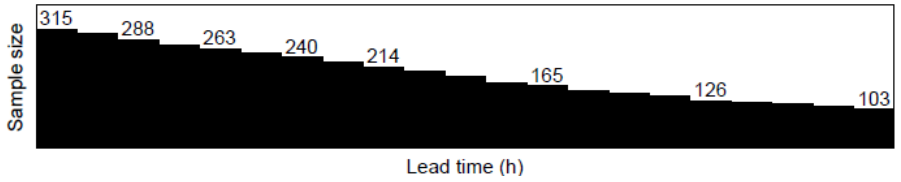
Atlantic Basin

Position Error



Intensity Error & Bias



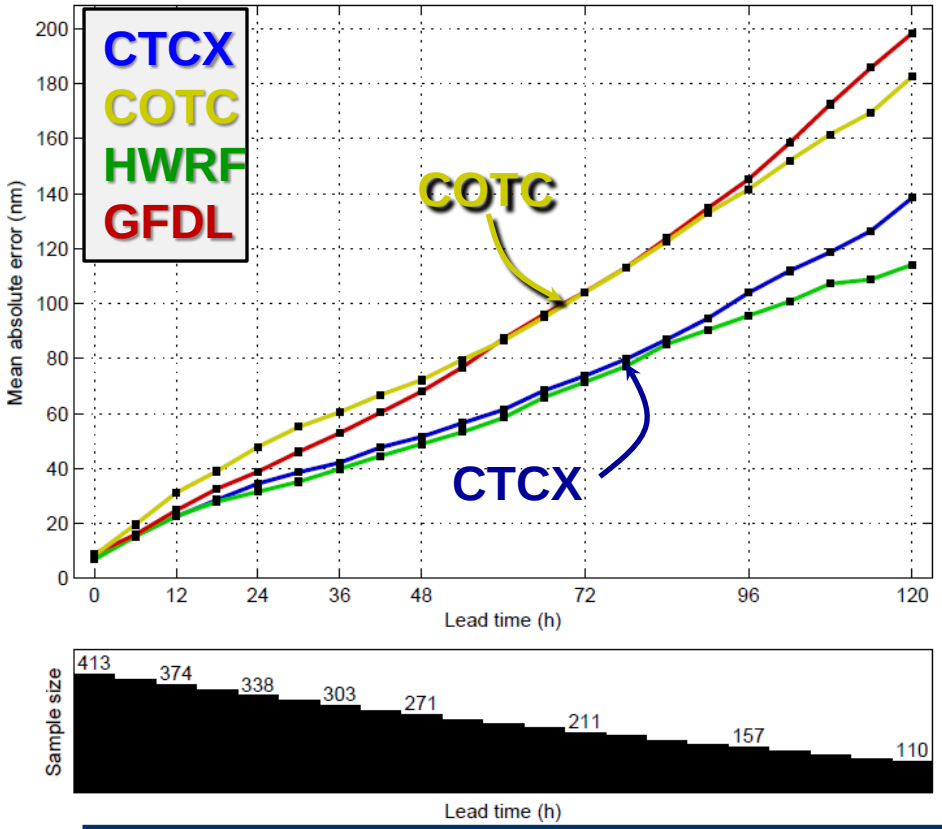


- Significant improvements in 2016 for CTCX and COTC in both track & intensity
  - Two-way coupling with NCOM
  - Improvements to vortex initialization, physics (new C_D param.)
- CTCX (GFS) and COTC (NAVGEM) fairly close together in terms of overall performance, although CTCX better by 1-3 kt and in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

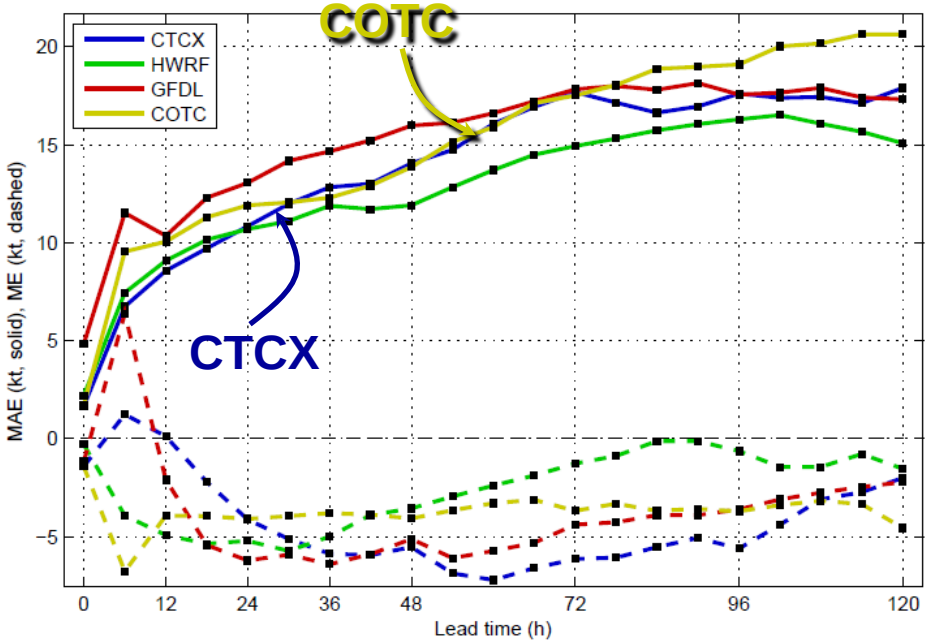
2016 Operational Statistics

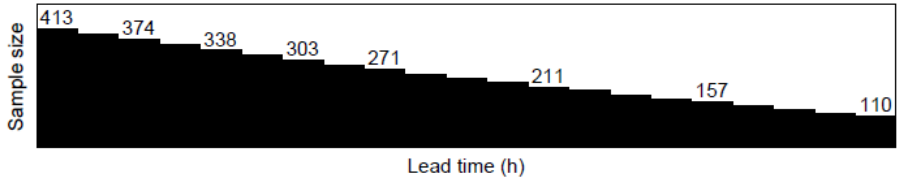
Eastern and Central Pacific Basins

Position Error



Intensity Error & Bias





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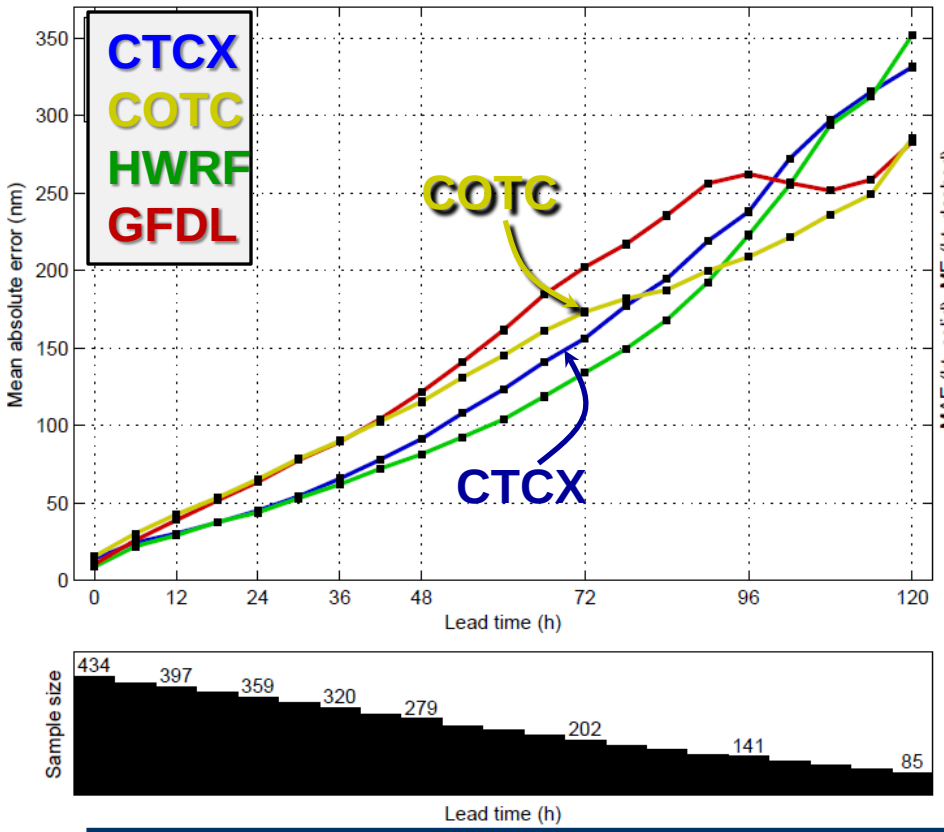
2016 Operational Statistics

W. Pacific Basin

Position Error



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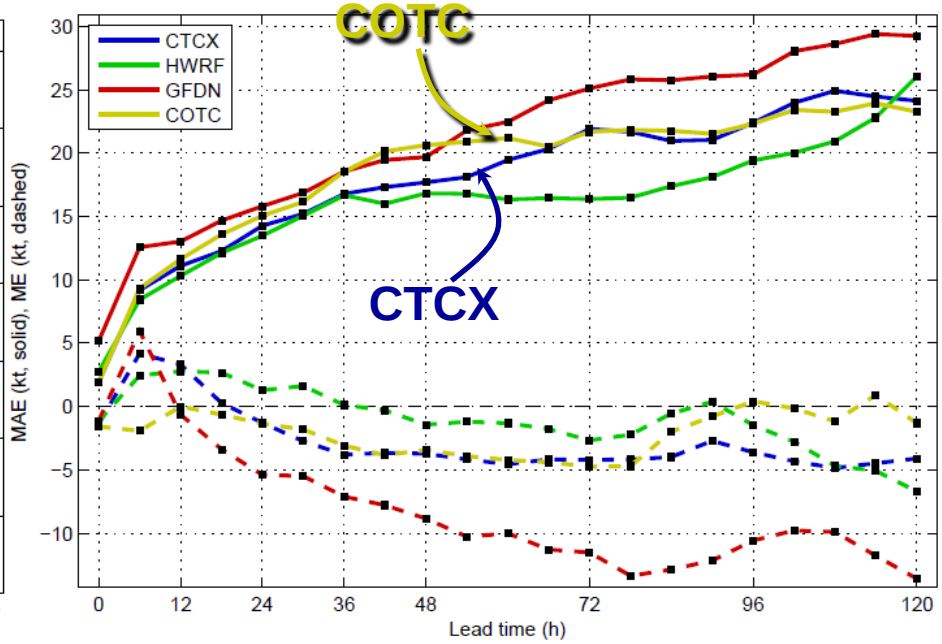

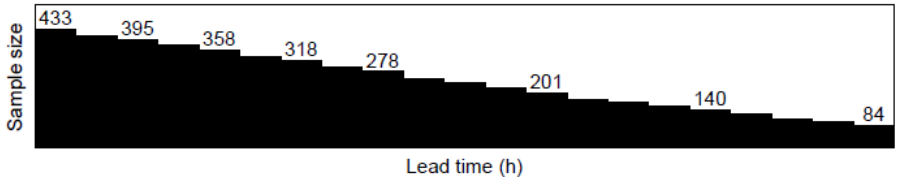

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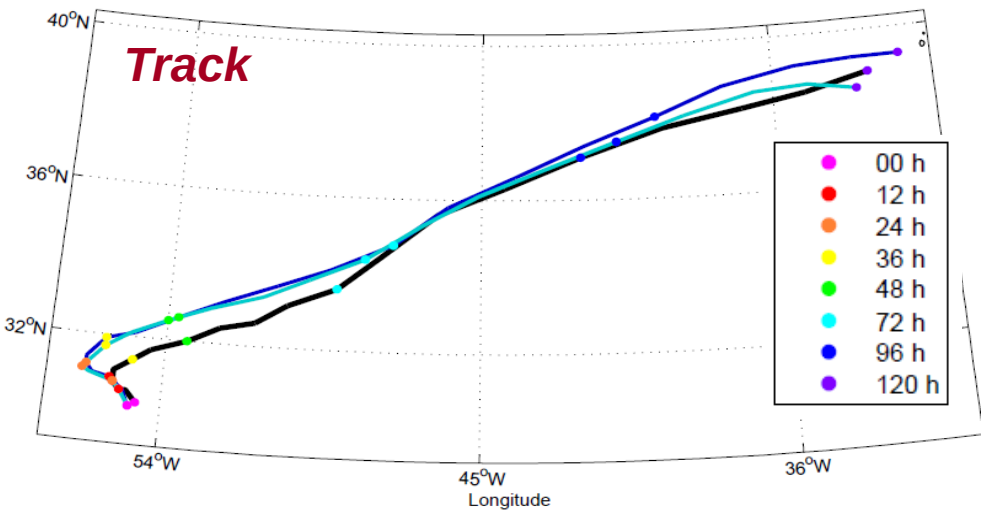
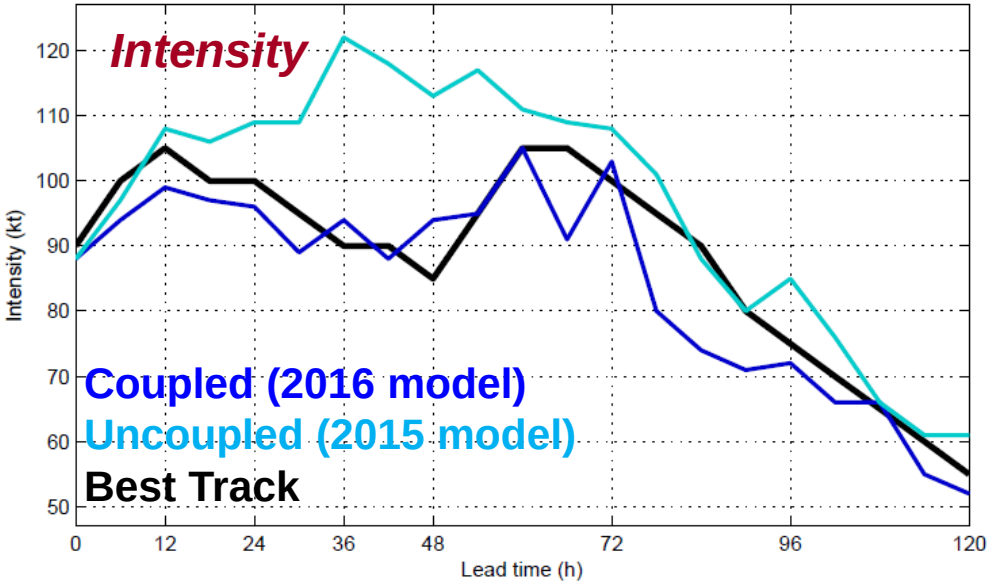
Atmosphere-Ocean Coupling

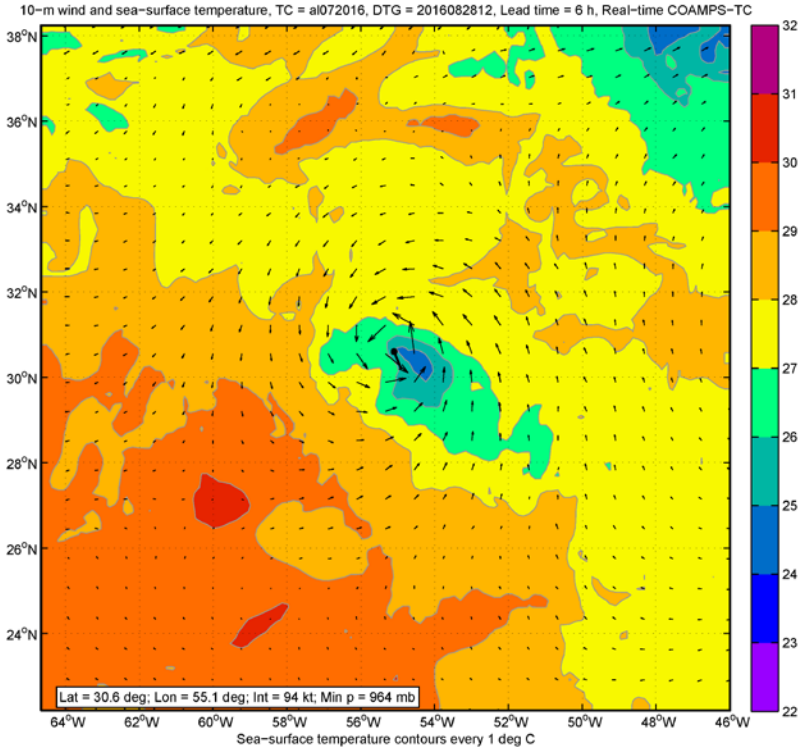
Example from Gaston (07L) (12Z 28 Aug 2016)





- 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

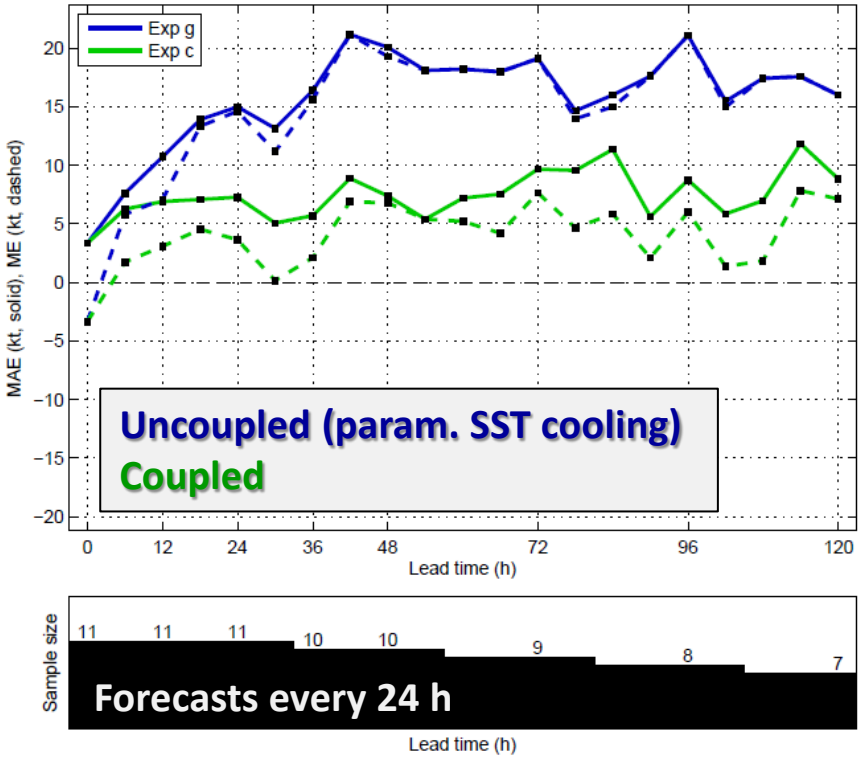
Coupled model SSTs and 10 m winds



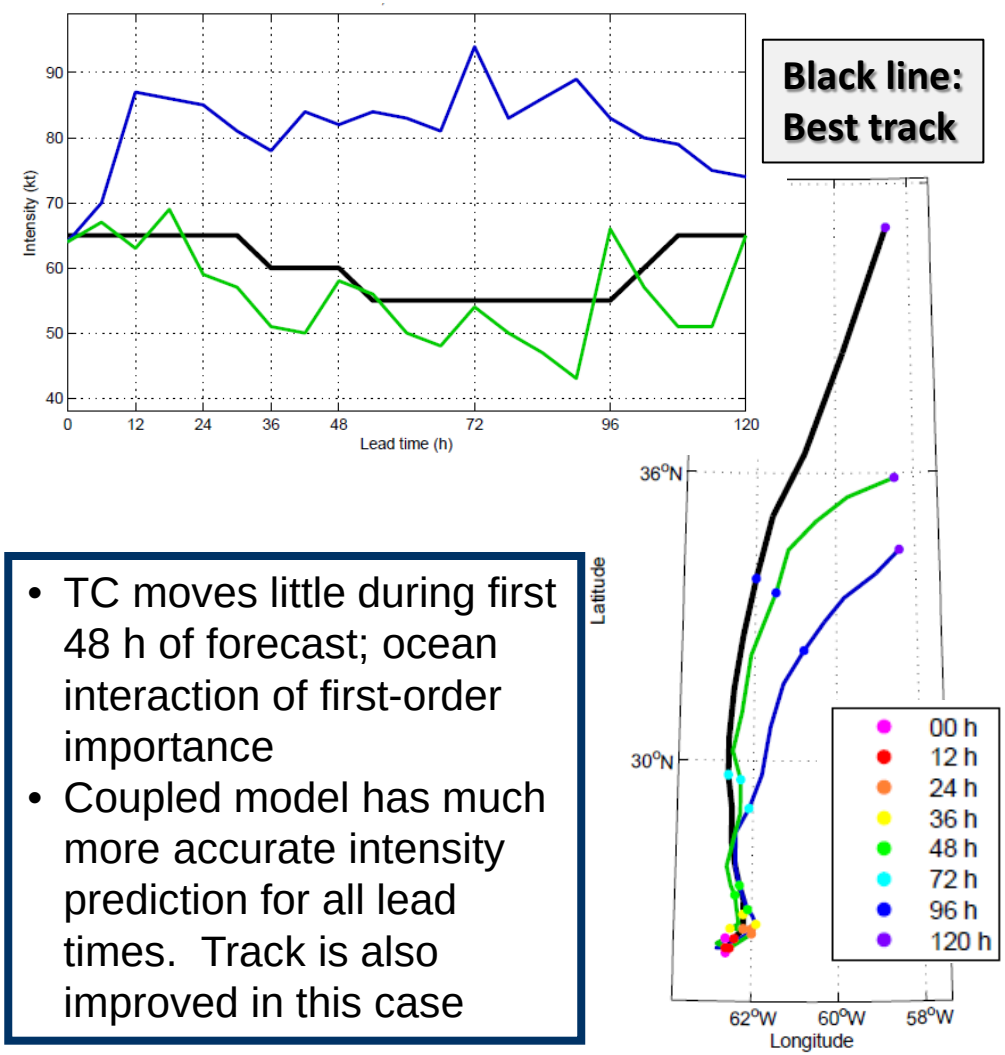
Atmosphere-Ocean Coupling

Benefits of Coupling

Hurricane Leslie (2012): Intensity Error & Bias



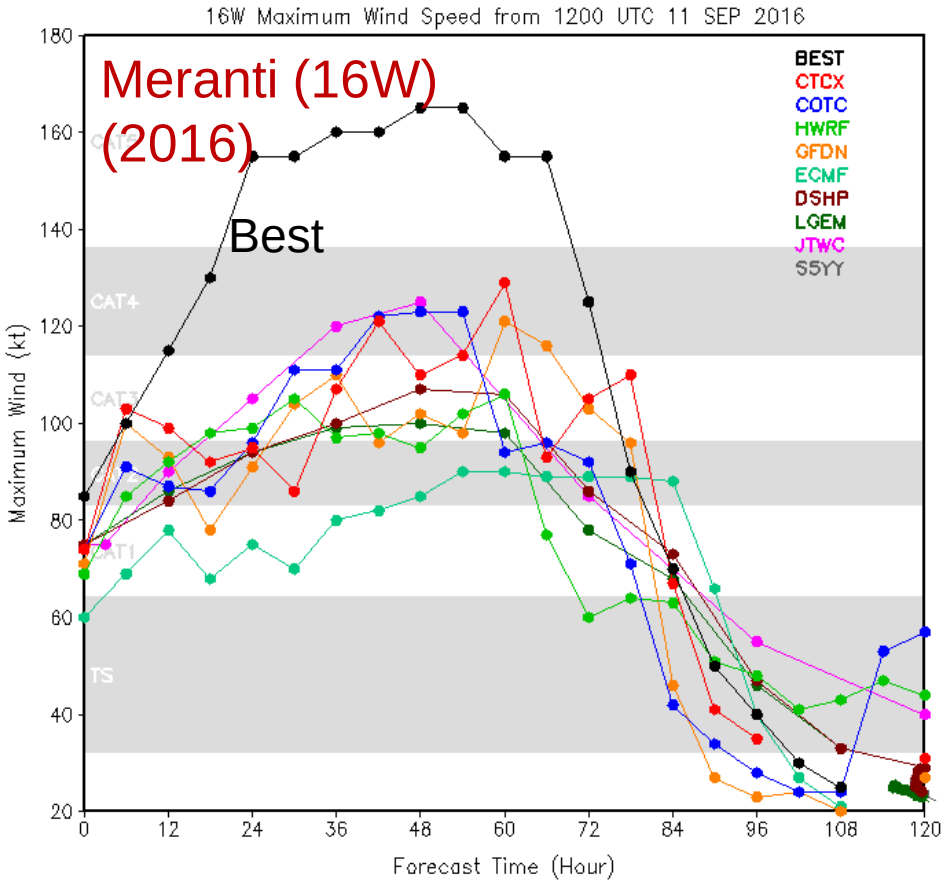
Hurricane Leslie (2012): 2012090600 forecast

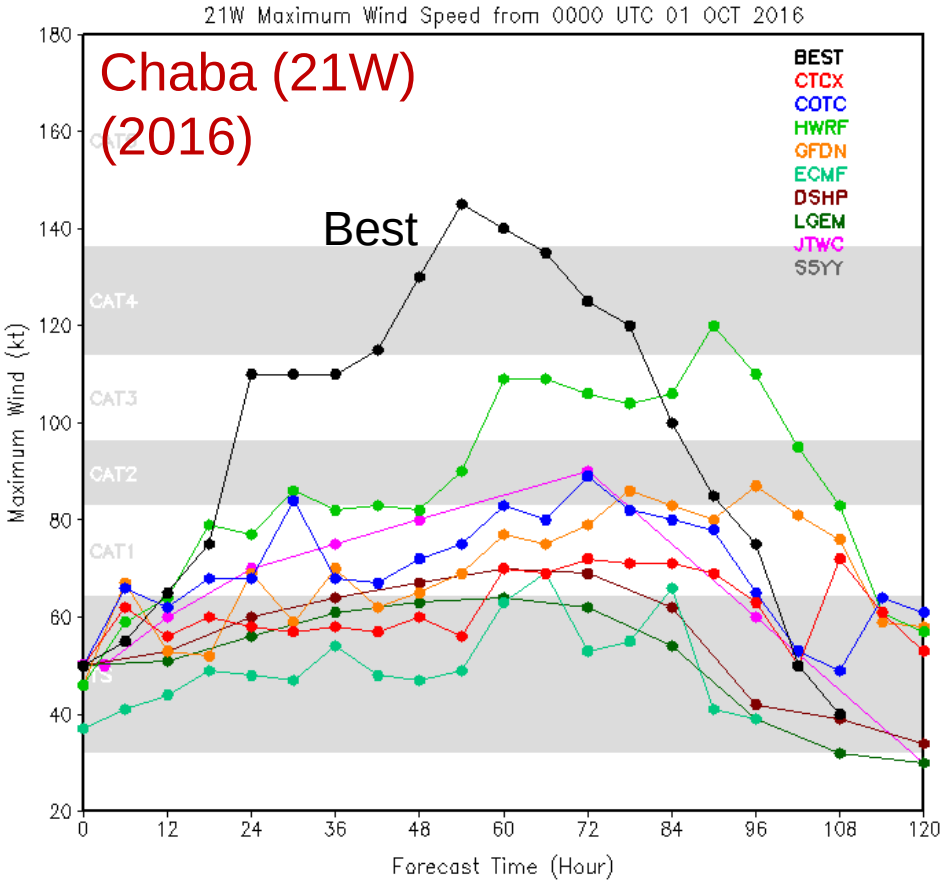


For a very slow-moving TC such as Leslie, the coupled model substantially outperforms uncoupled model in intensity prediction

- 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

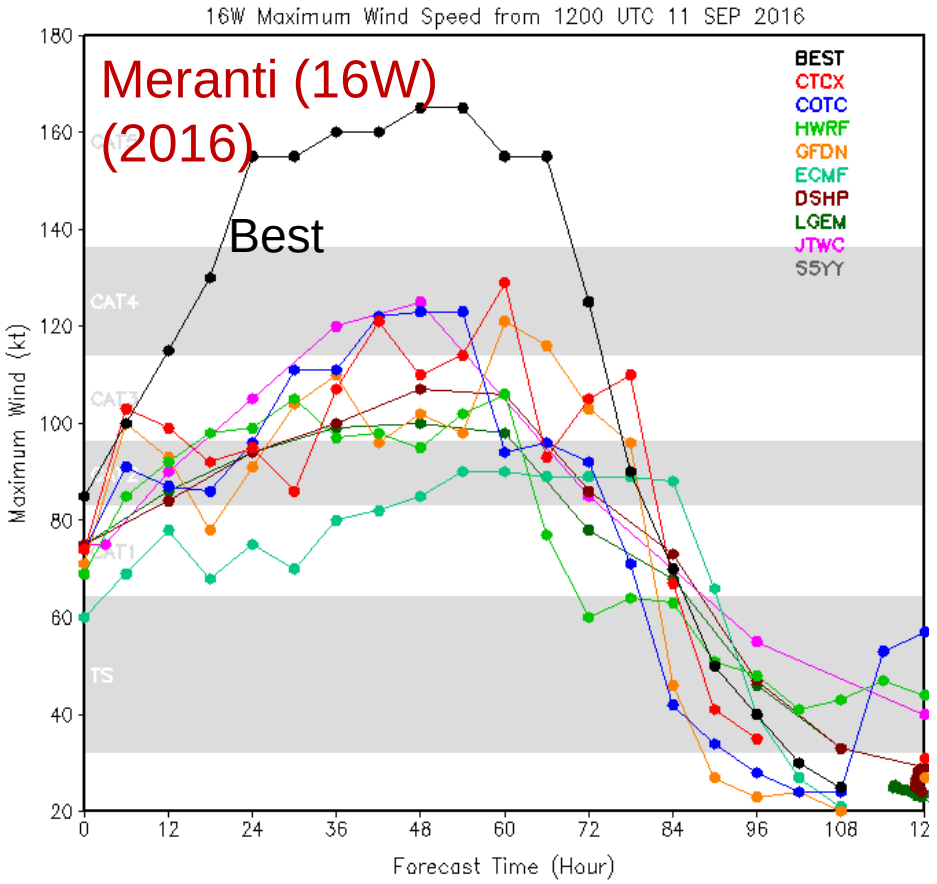
Rapid Intensification

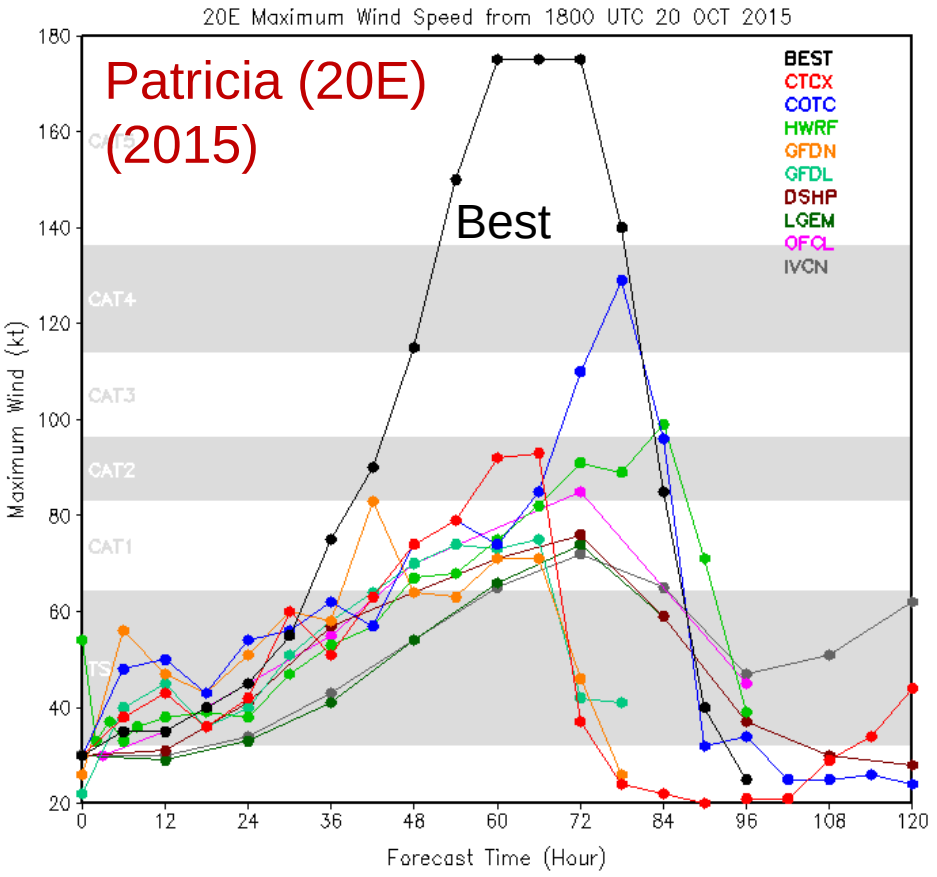




Many challenges remain for RI prediction and it is unclear what the necessary physics, air-sea coupling, data assimilation, resolution needed to predict a Patricia or Meranti and maintain top-flight predictions of weaker storms.

Rapid Intensification



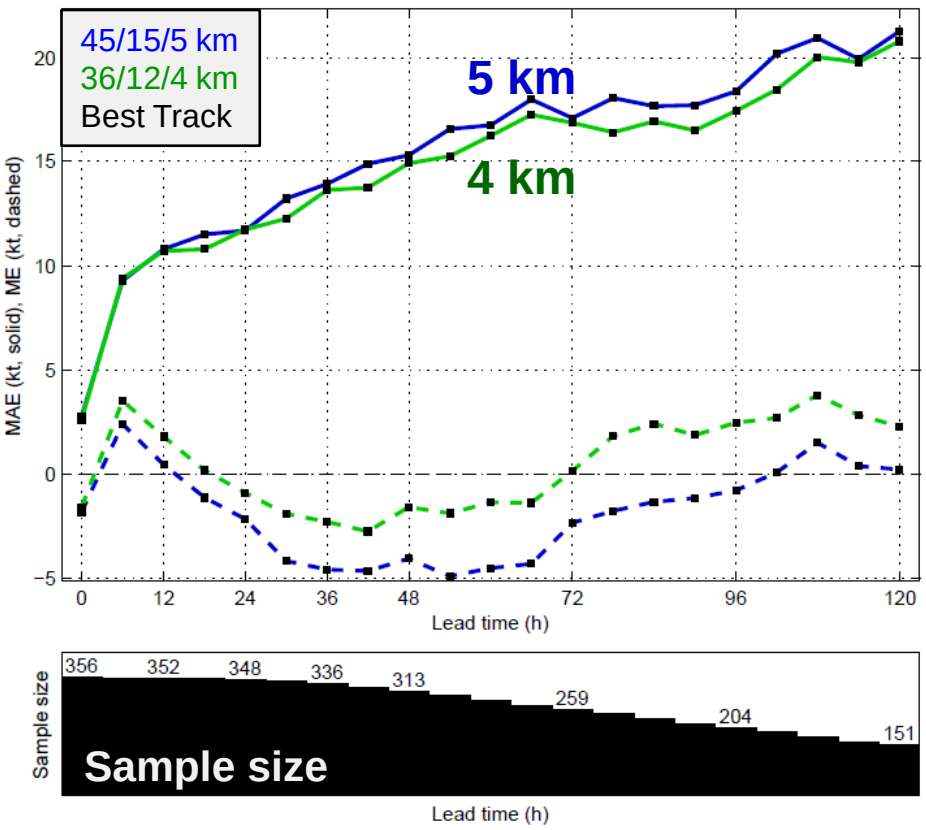


Many challenges remain for RI prediction and it is unclear what the necessary physics, air-sea coupling, data assimilation, resolution needed to predict a Patricia or Meranti and maintain top-flight predictions of weaker storms.

COAMPS-TC 2017 Version

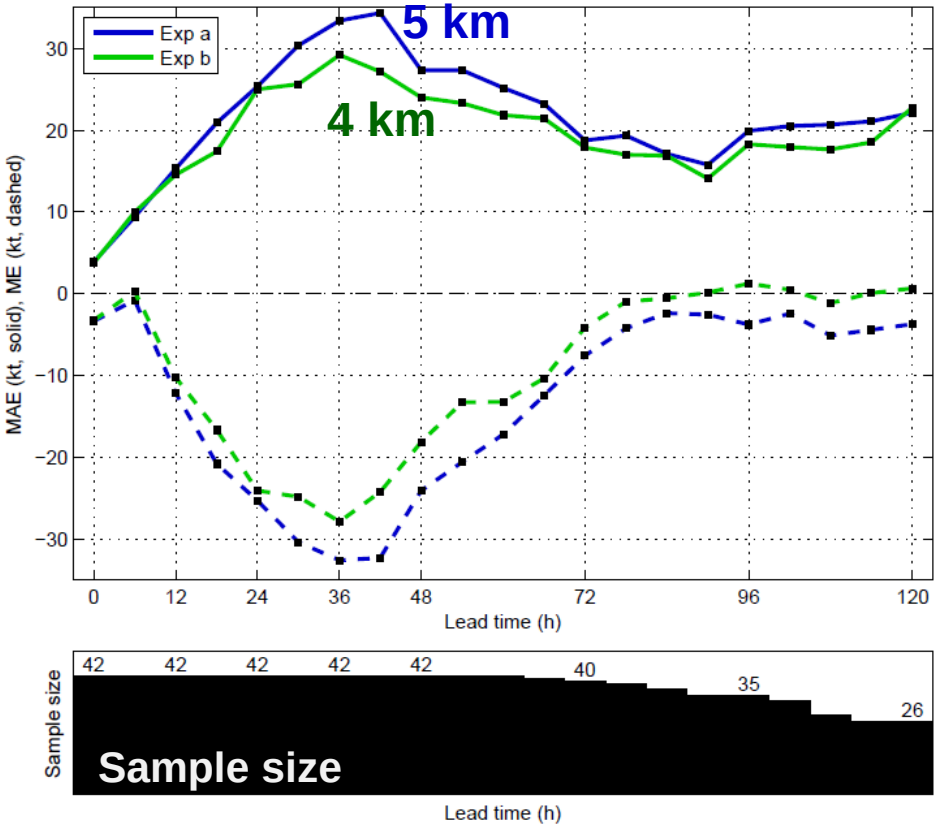
Atlantic/EastPac/WestPac

Intensity MAE (solid) and ME (dashed)



TCs observed to rapidly intensify (0-24 h)

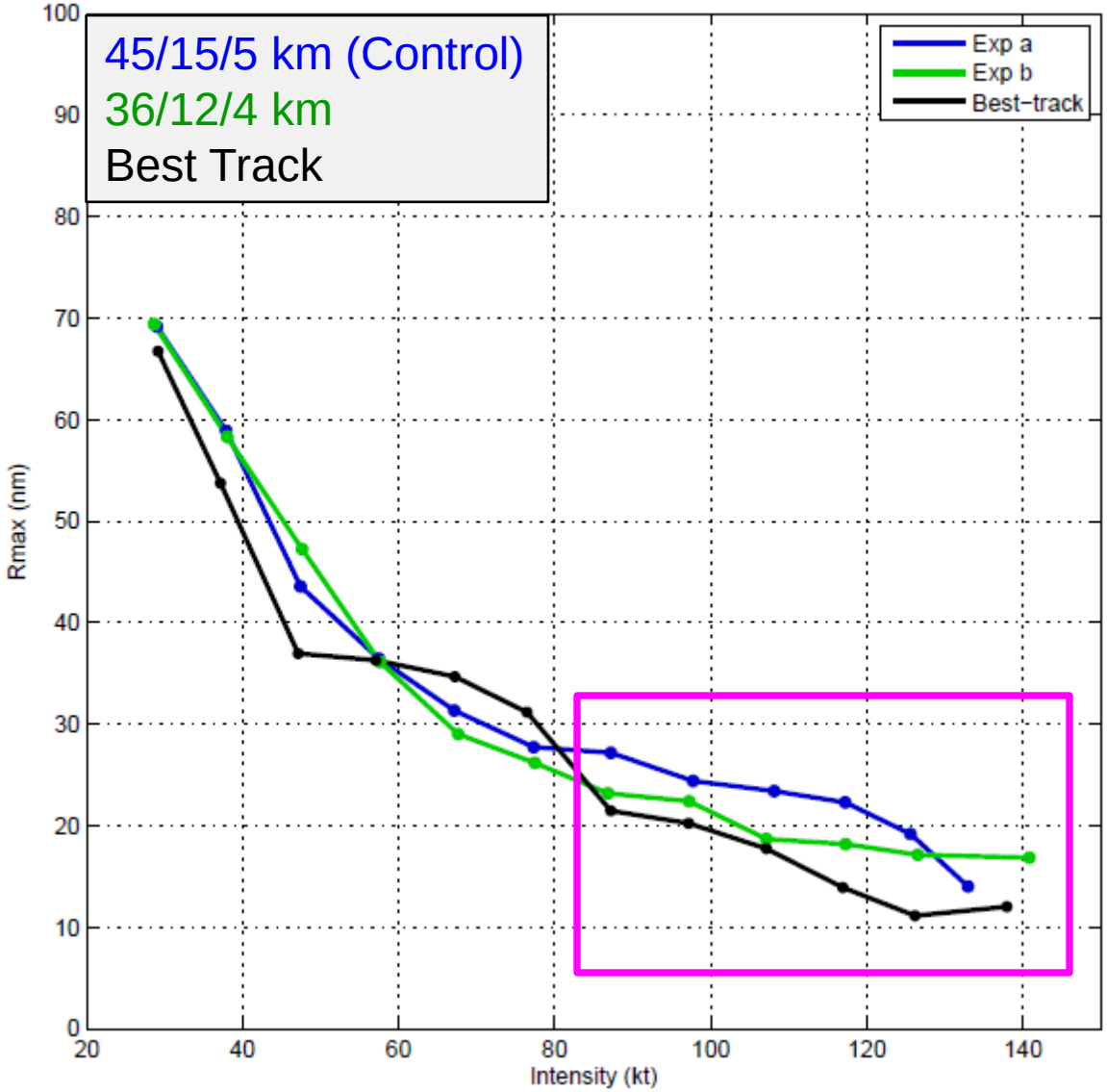
Intensity MAE (solid) and ME (dashed)



- 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

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

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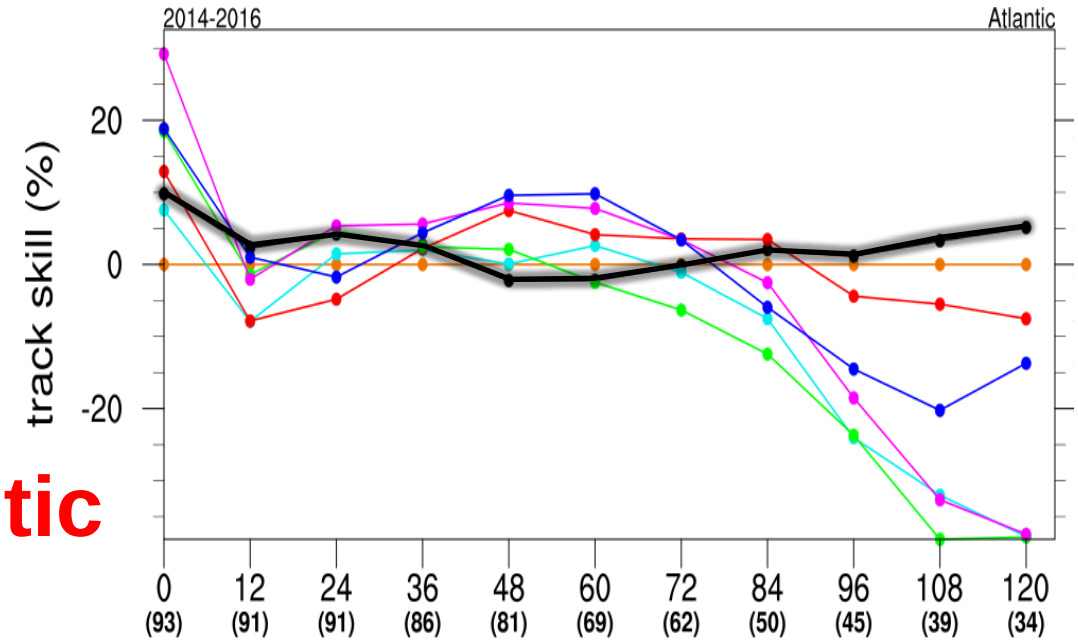
Track Skill (2014-2016)

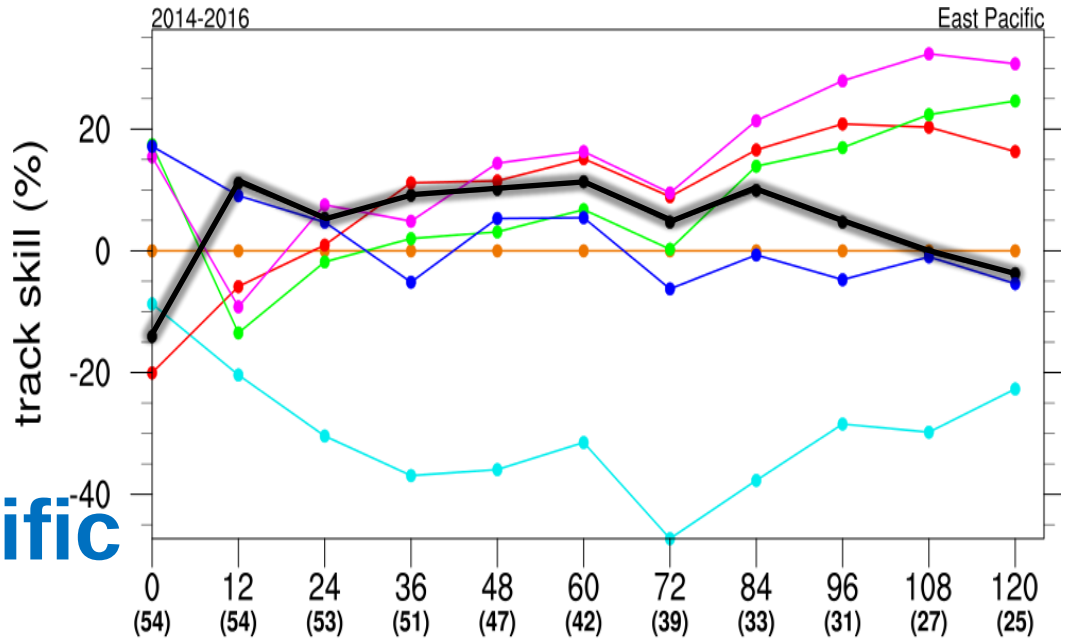
(relative to 2016-CTCX)

- 2017-GFS
- 2016-GFDL
- 2016-HWRF
- 2017-HWRF
- 2017-HMON
- 2016-CTCX
- 2017-CTCX

Atlantic



East Pacific



Courtesy of Andy Penny (NHC)

U.S. NAVAL RESEARCH LABORATORY

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- 2017-CTCX

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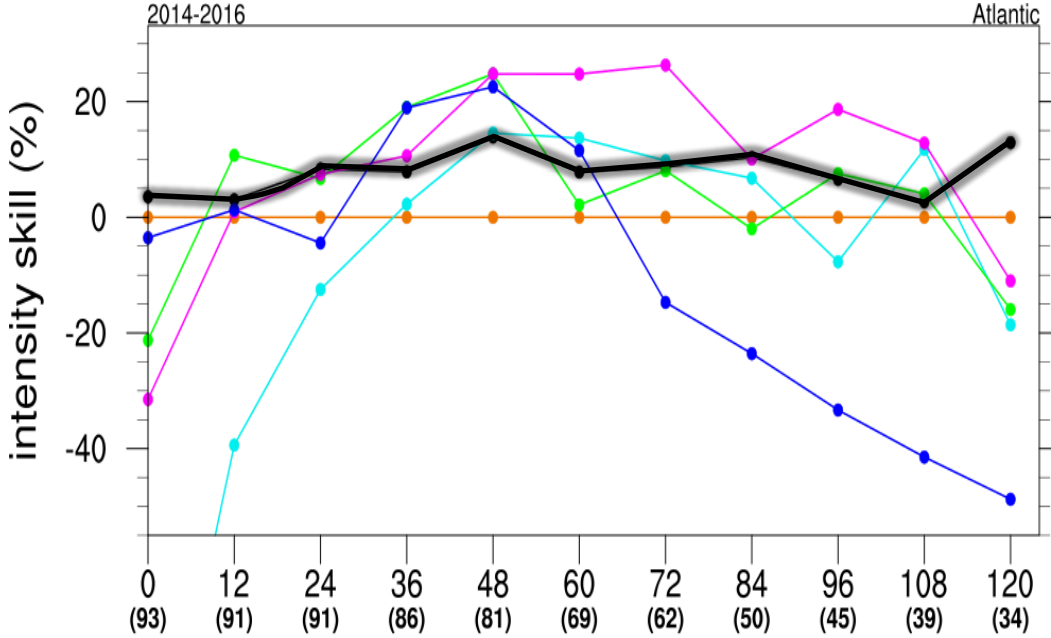

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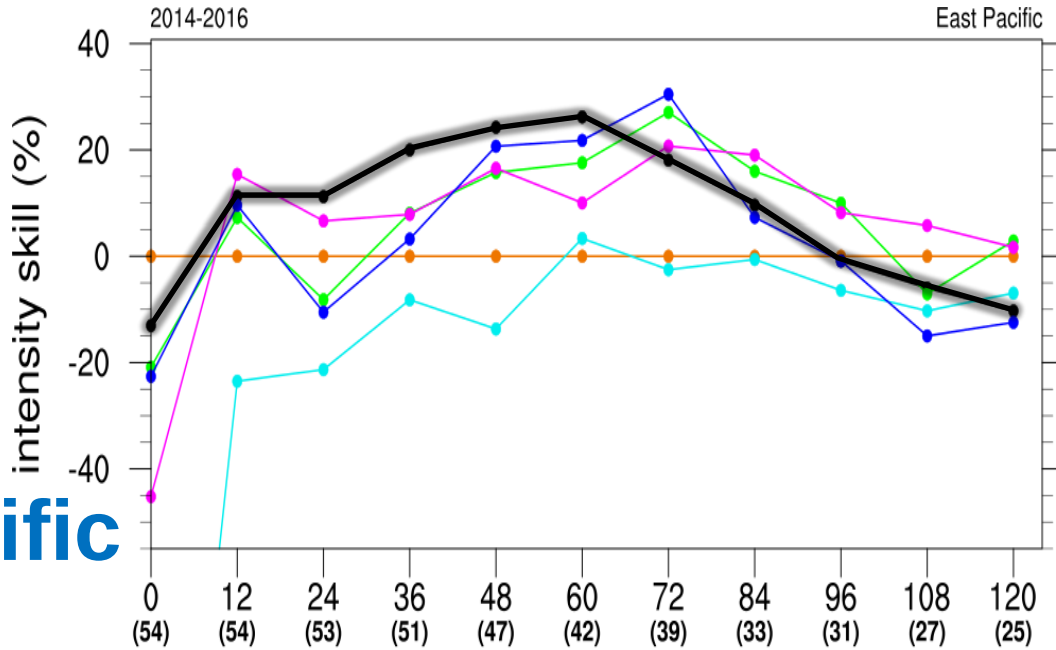


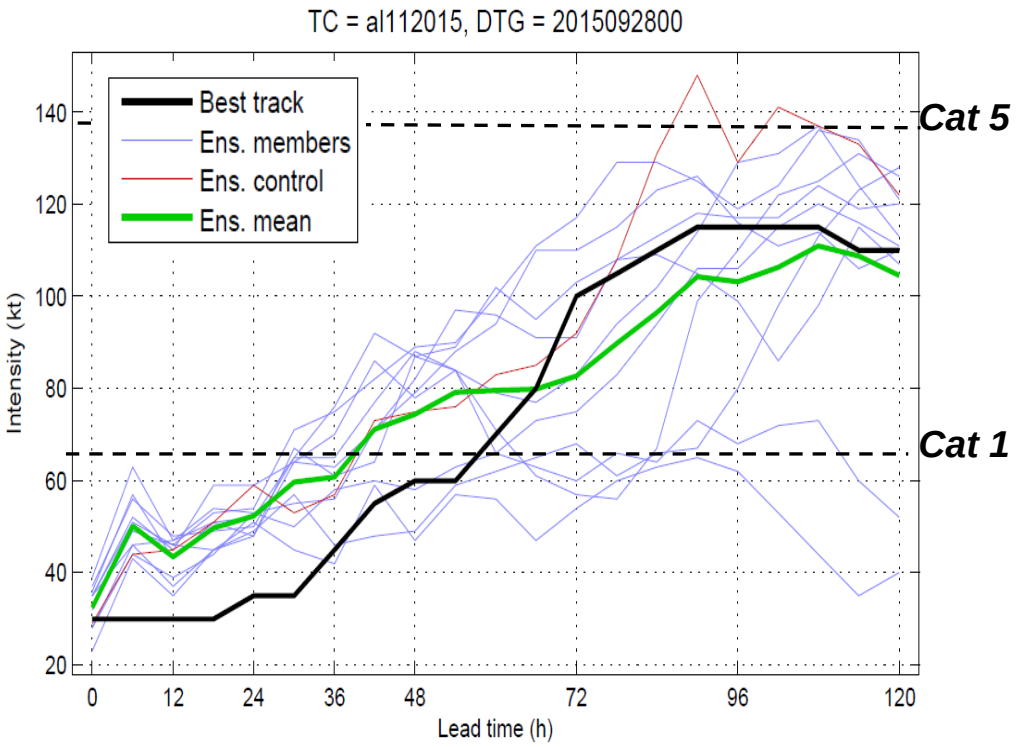
Courtesy of Andy Penny (NHC)

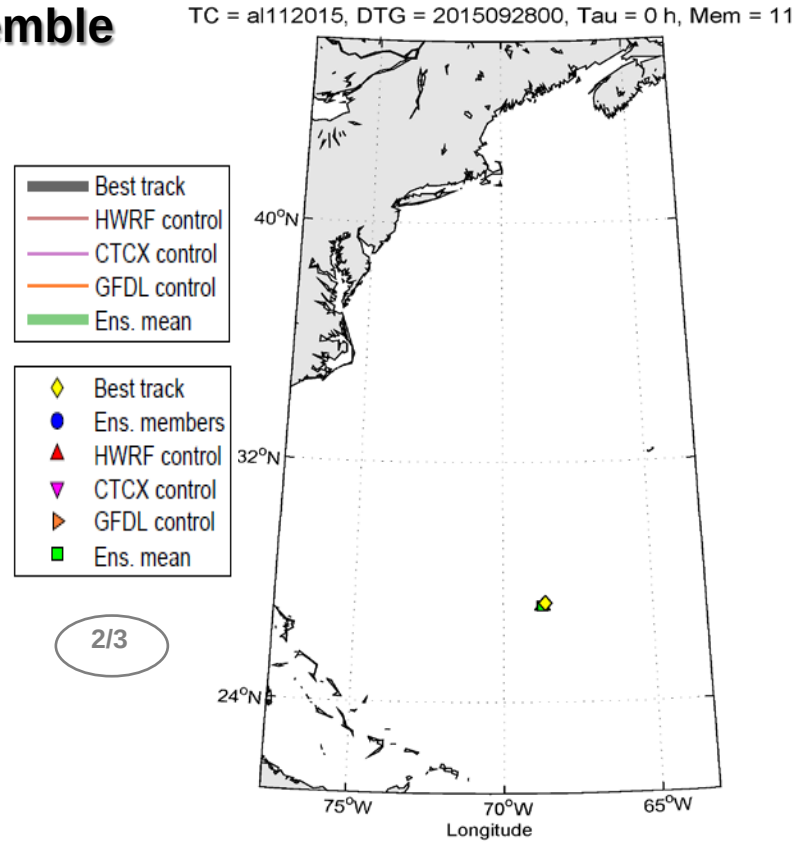
COAMPS-TC and HFIP High-Resolution Ensemble

- 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

Real-time forecast example: Hurricane Joaquin (11L)

COAMPS-TC ensemble





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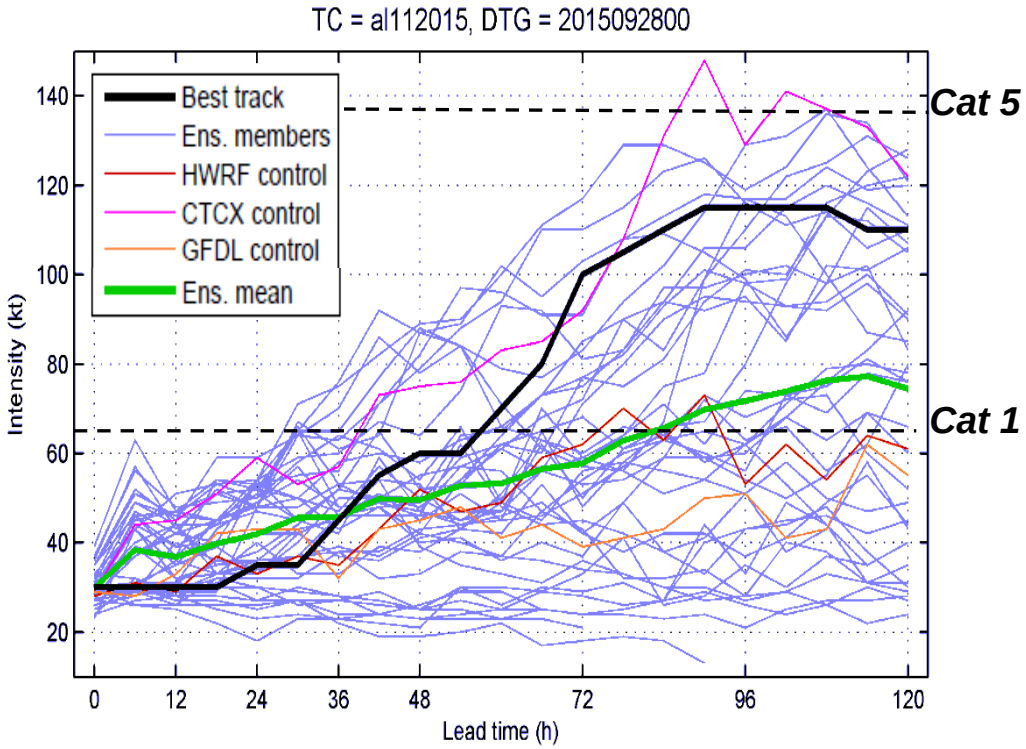
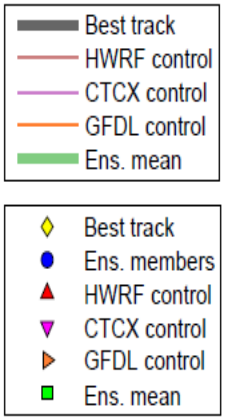
Real-time forecast example: Hurricane Joaquin (11L)

Multi-model ensemble





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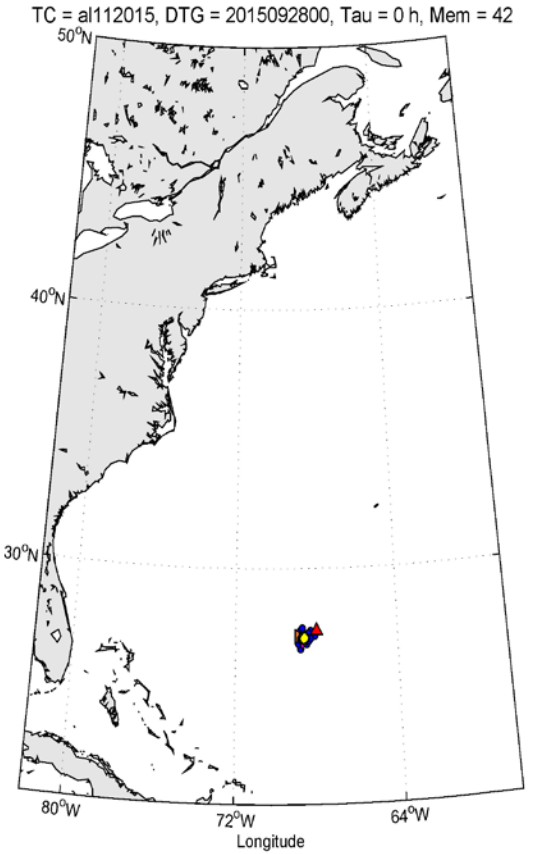
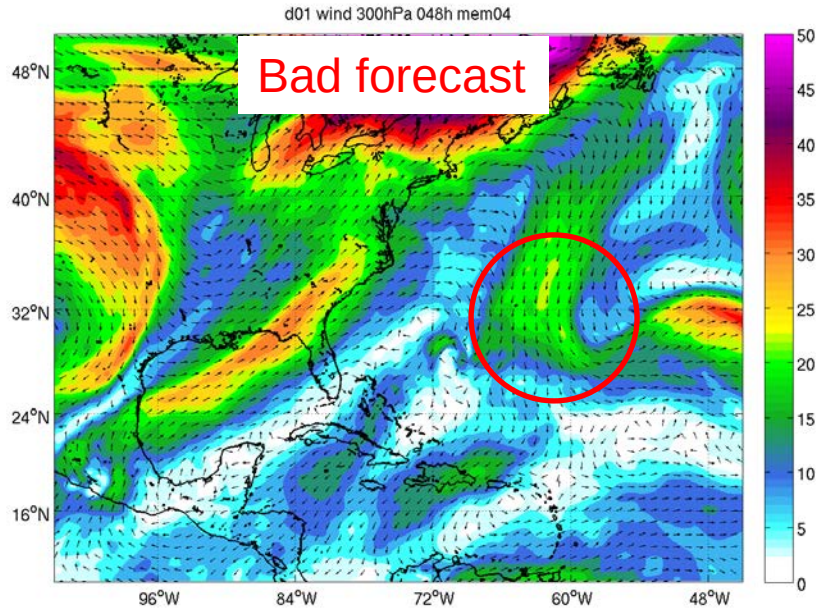
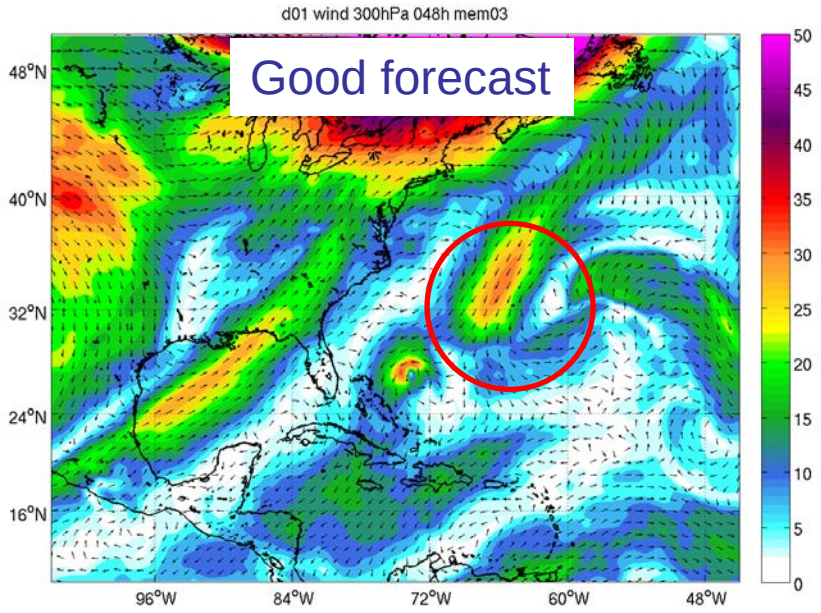


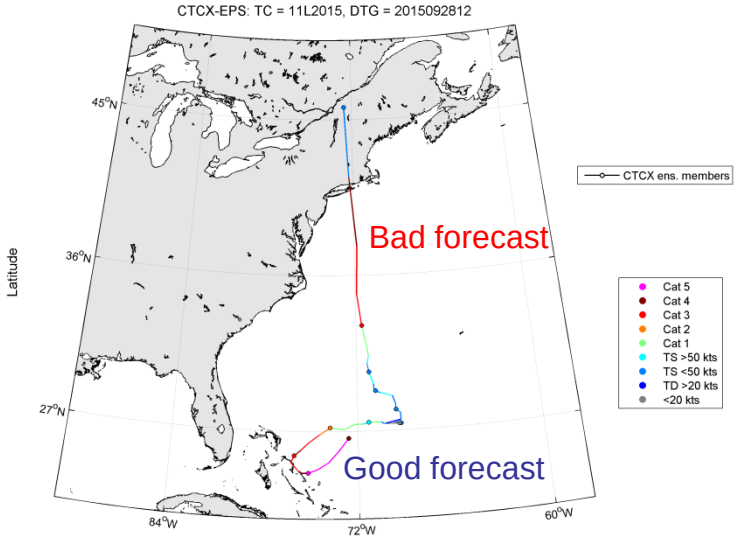
COAMPS-TC Ensemble System

Joaquin (2015)

11L (Joaquin) 2015-09-28 12Z: 300 hPa wind (m/s): D01 t=48h





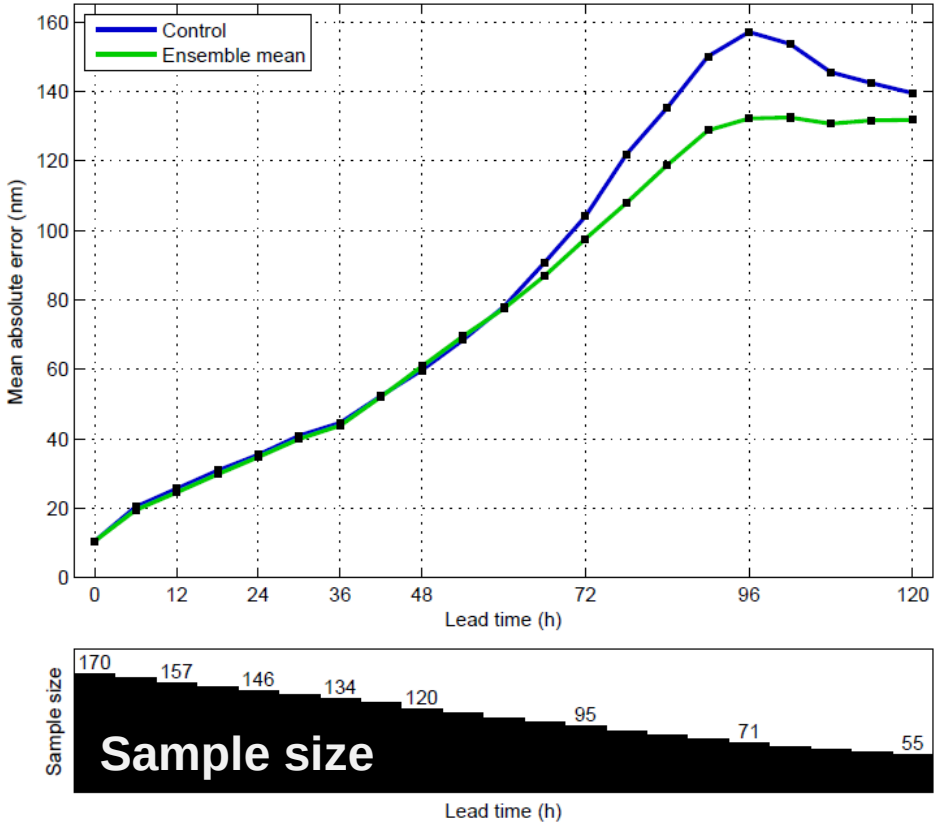


- In all 3 of the members moving SW, the upper-level trough NE of Joaquin propagates further SW and is stronger than it is in any of the other members
- Also, a low-level circulation develops beneath the upper-level low NE of Joaquin in all 3 members
- In most of the other members, this cyclone either develops further from Joaquin or does not develop at all

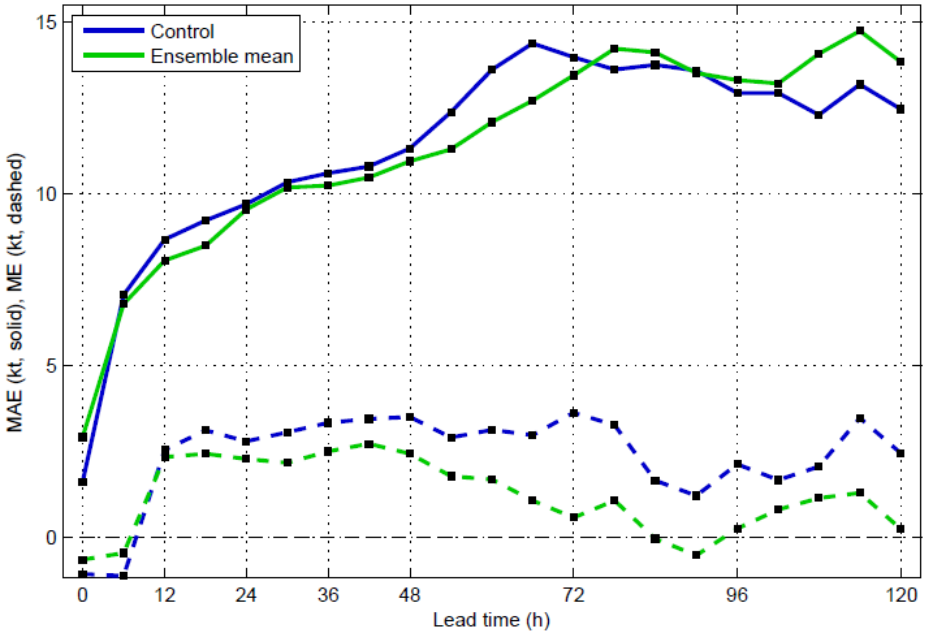
COAMPS-TC Ensemble System
2016 Statistics for ATL and EPAC

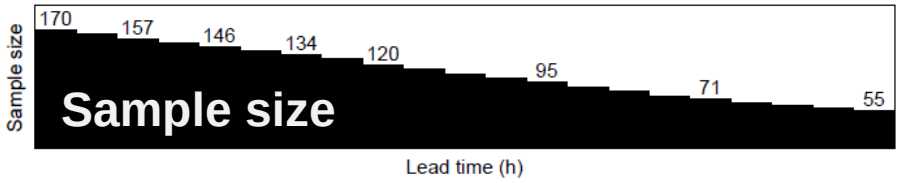
Ensemble control vs Ensemble mean

Track MAE



Intensity MAE (solid) and ME (dashed



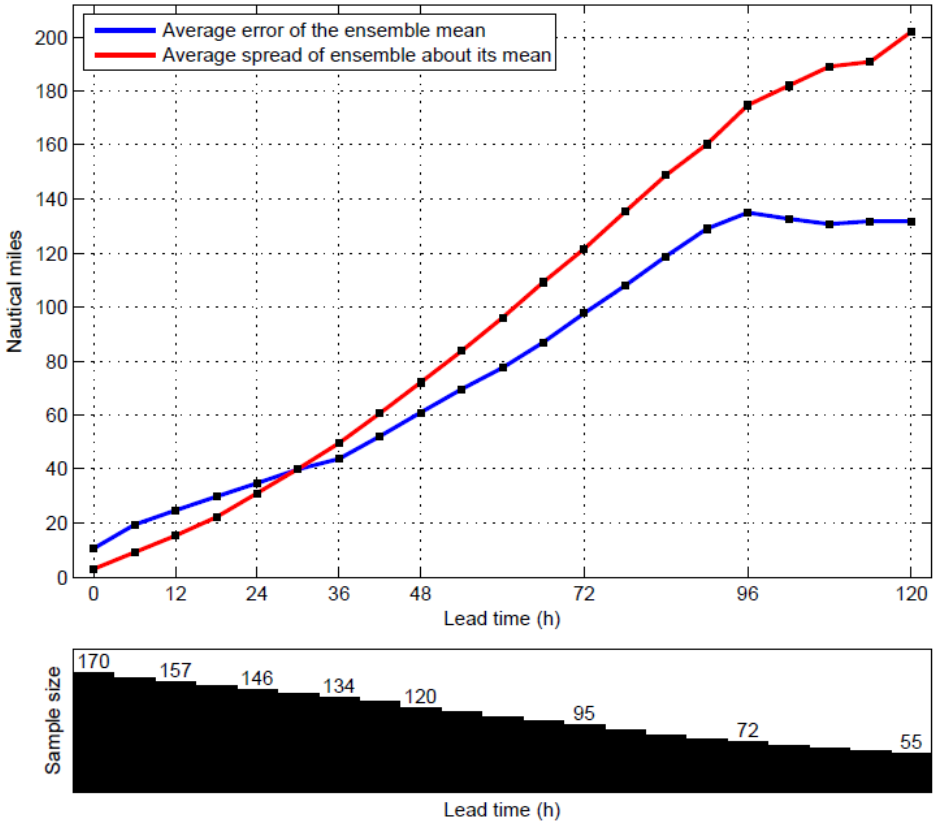


- Ensemble mean outperforms control at long lead times
- Ensemble mean similar or better MAE w.r.t. control for most lead times

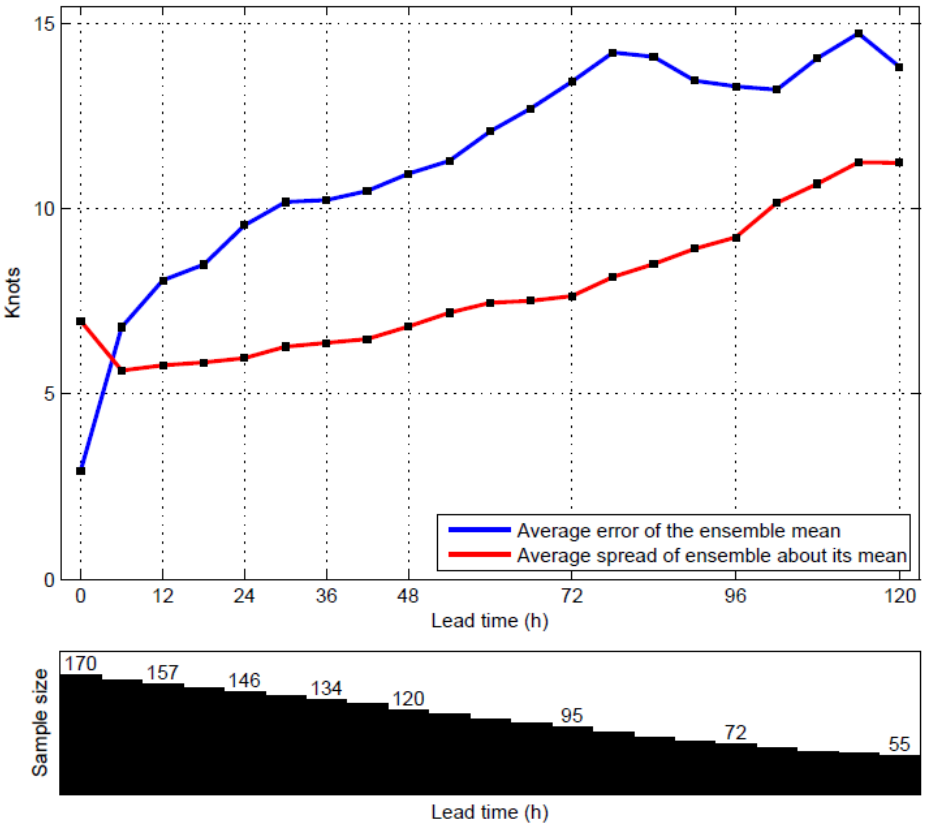
COAMPS-TC Ensemble System
2016 Statistics for ATL and EPAC

Ensemble mean error vs Ensemble spread

Track



Intensity

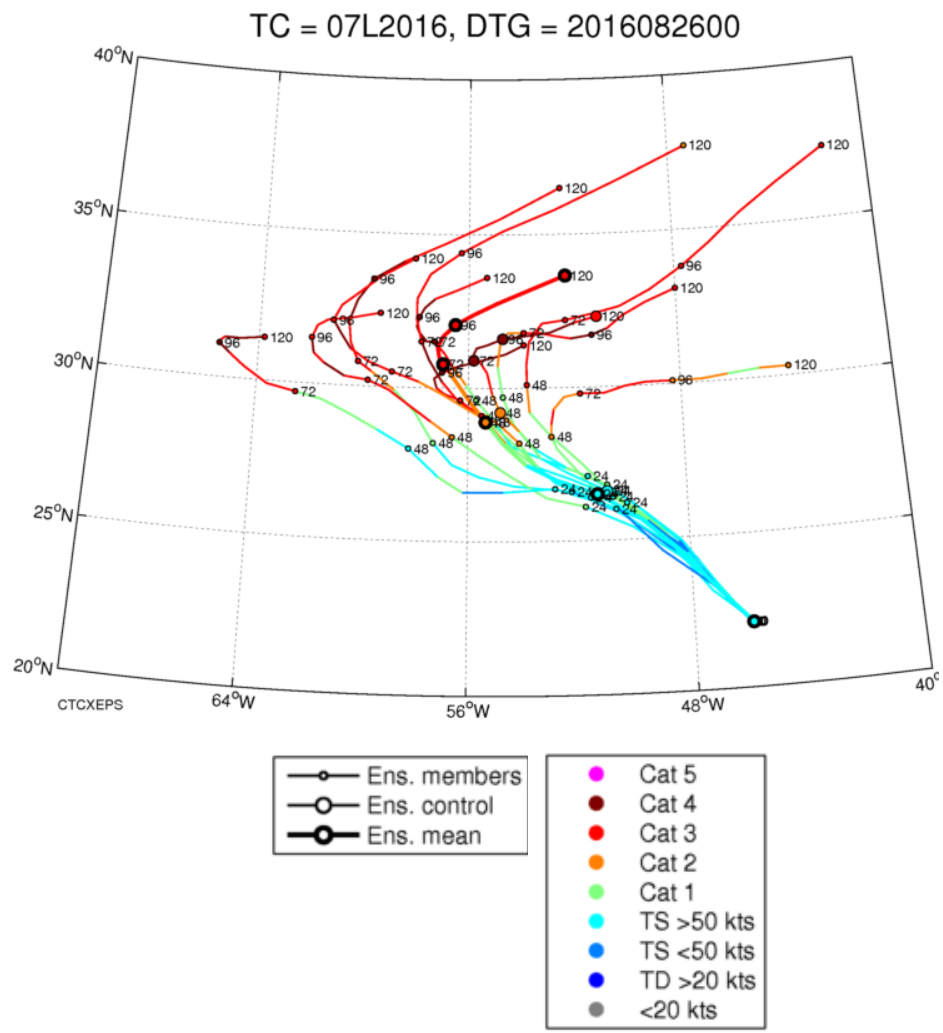


- Spread is too large for this sample of cases (ensemble mean very accurate)
- As in previous years, intensity spread is lacking relative to intensity skill
- Stochastic physics for surface fluxes is in development

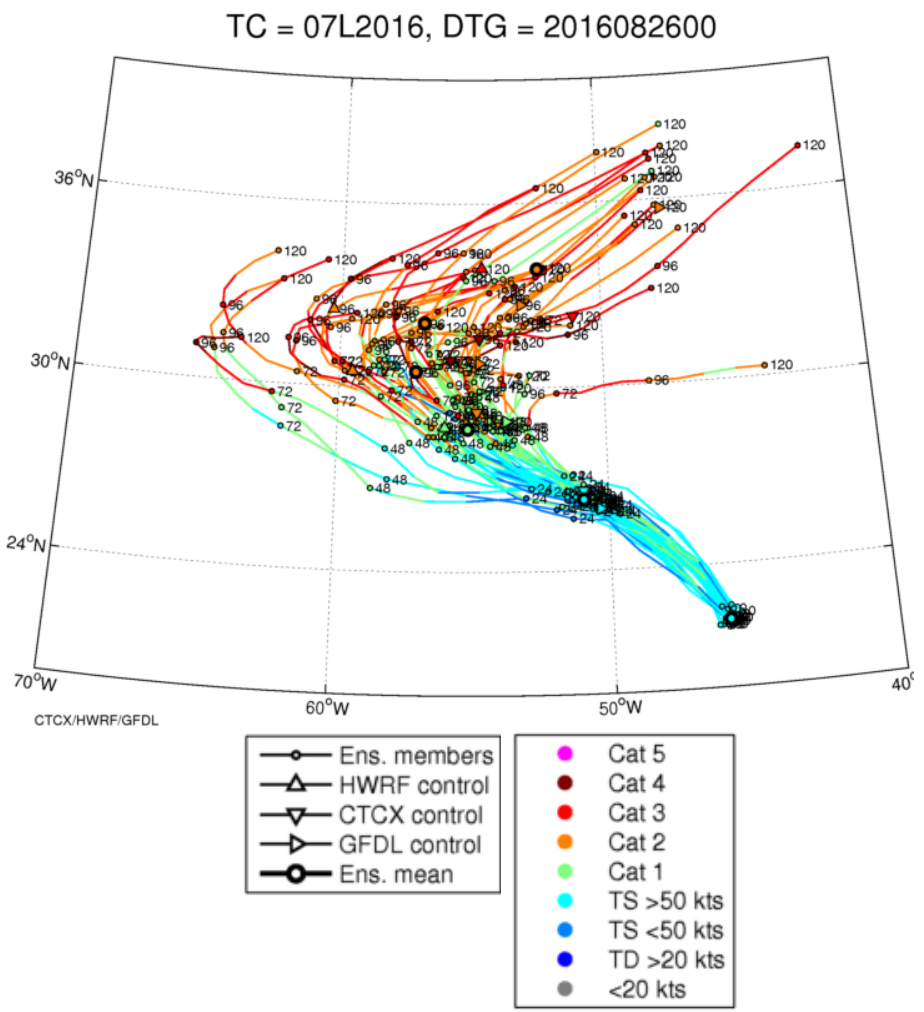
COAMPS-TC Ensemble System
New Forecast Products for 2017

Track colored by forecast intensity

COAMPS-TC



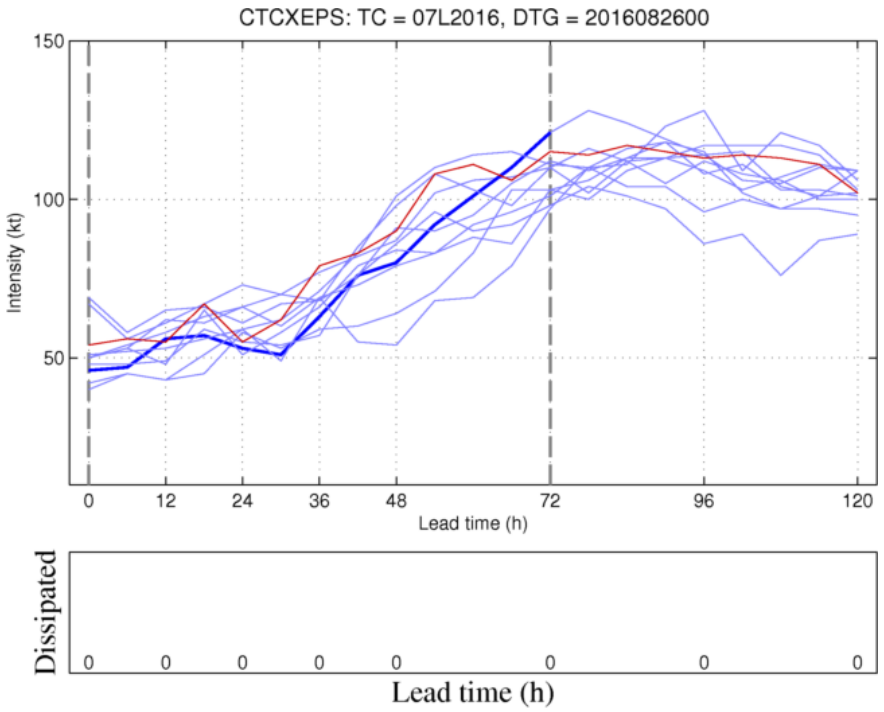
COAMPS-TC / HWRF / GFDL



COAMPS-TC Ensemble System
New Forecast Products for 2017

Rapid intensification probability

COAMPS-TC

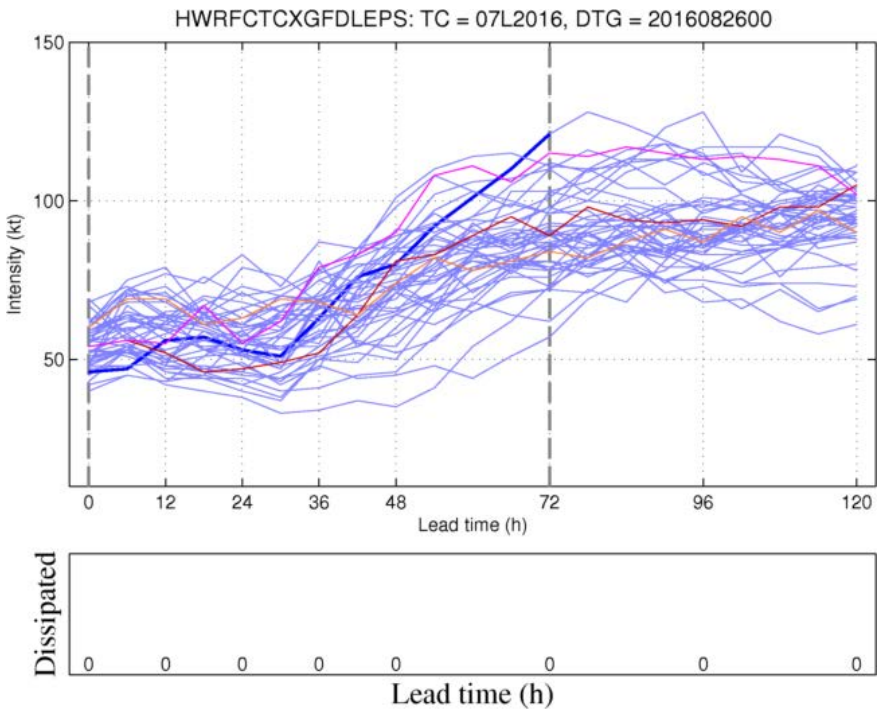


Probability of Δ I >= 65 kt in 0 to 72 h = 0.09

Members which satisfy above criteria highlighted with bold line type

Ens. members
Ens. control

COAMPS-TC / HWRF / GFDL



Probability of Δ I >= 65 kt in 0 to 72 h = 0.02

Members which satisfy above criteria highlighted with bold line type

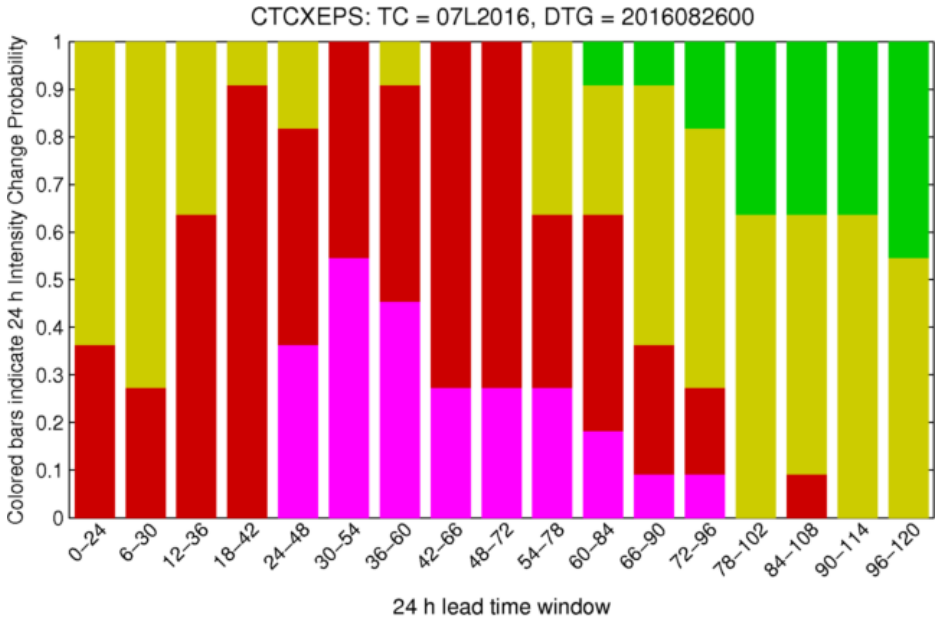
Ens. members
HWRF control
CTCX control
GFDL control

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 Ensemble System
New Forecast Products for 2017

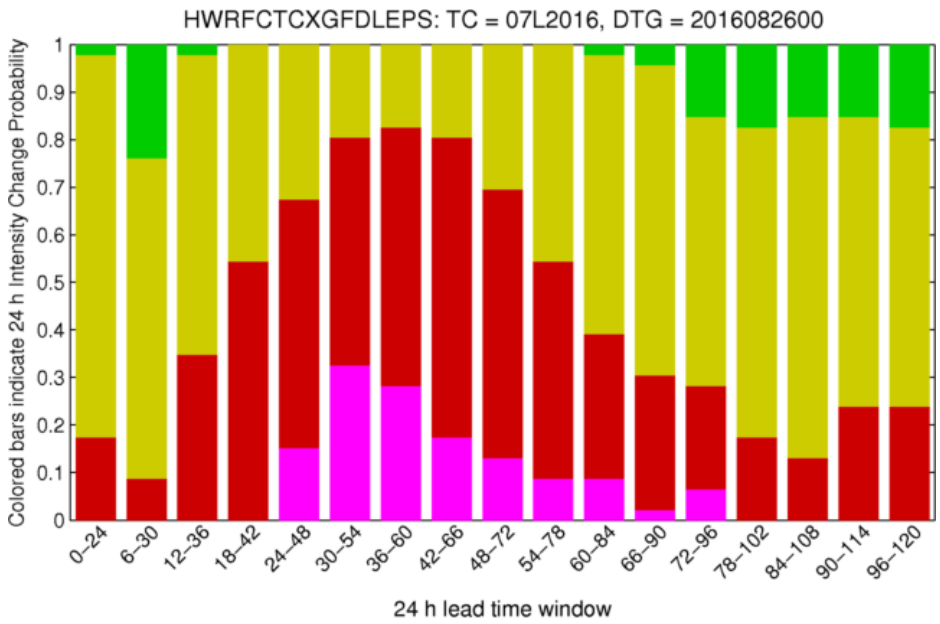
24 h intensity change probability

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

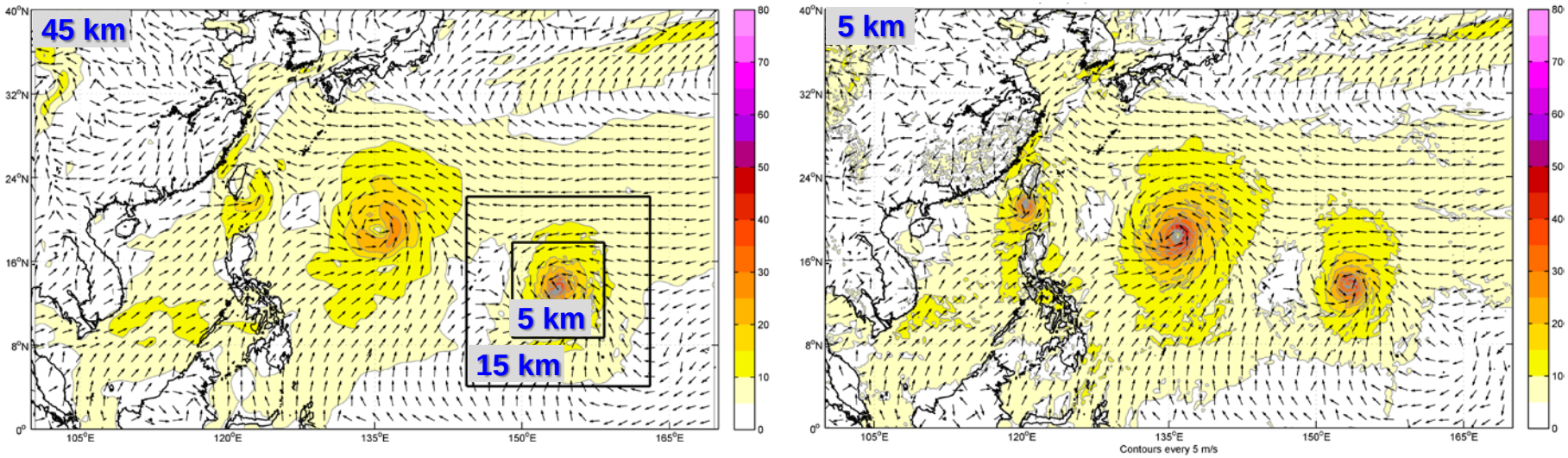


Δ I >= 30 kt (Rapid Intensification)
10 kt <= Δ I < 30 kt (Moderate Intensification)
–10 kt < Δ I < 10 kt (Steady Intensity)
–30 kt < Δ I <= –10 kt (Moderate Weakening)
Δ I <= –30 kt (Rapid Weakening)
TC already dissipated or dissipates during window

Example product for 24-h intensity change probability. Conveys the probability of intensity change as a function of forecast lead time in a compact form.

COAMPS-TC
Basin Scale COAMPS-TC

36-h forecast of 10-m winds
Initial time: 2015070600



- Conventional (triple nested) COAMPS-TC application on left (45-15-5km)
- 5 km basin-scale high-resolution grid (right); entire mesh convective permitting
- Capable of predicting genesis of disturbances that do not exist at initial time
- More expensive (but parallelizes well), step towards hi-res global forecasts

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)
- 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 2017:

- Deterministic: 4 km resolution & various upgrades, ~10-20% improved intensity (& RI)
  CTCX run worldwide
- Ensemble: 4 km resolution, 11 members, initial & boundary condition perturbations
  CTCX run W. Atlantic, E. Pacific, W. Pacific

➢COAMPS-TC Priorities:

TC physics:	Emphasis on PBL, cloud microphysics
Analysis:	4D-Var (2018), emphasis on satellite DA
Ensemble:	10-20 members; stochastic physics
Coupling:	Ocean, waves, coupled DA
Resolution:	4 km (2017), 2 km (2019)
	~4 km basin scale (2021+)

Utilize field observations: ONR TCI,NASA HS3, SHOUT