

Recent Progress and Challenges in Tropical Cyclone Intensity and Track Prediction Using COAMPS-TC

James D. Doyle¹, Jon Moskaitis¹, Sue Chen¹, Pete Finocchio¹, Hao Jin¹, Yi Jin¹,
Will Komaromi¹, Alex Reinecke¹, David Ryglicki¹, Dan Stern², Allen Zhao¹

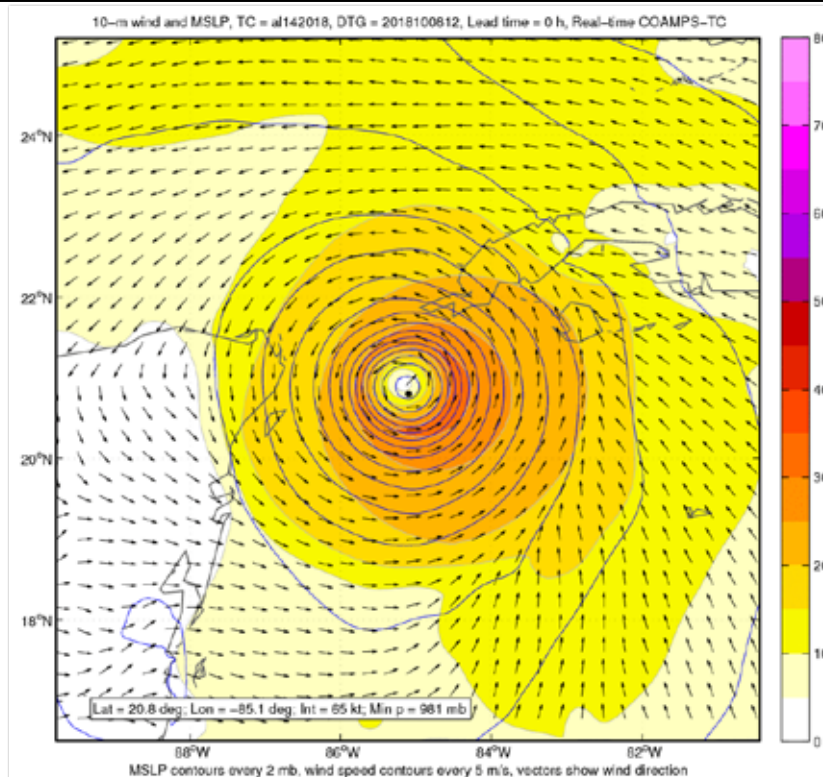
¹Naval Research Laboratory, Monterey, CA, ²UCAR

COAMPS-TC

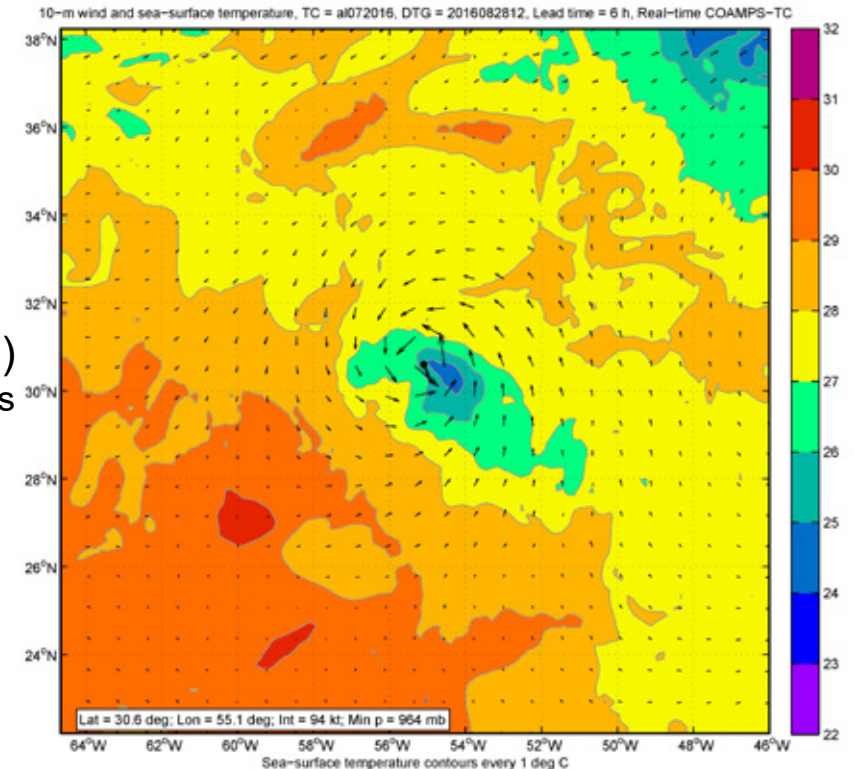
System overview

- COAMPS-TC is a specialized version of COAMPS designed to predict tropical cyclone (TC) track, intensity and structure (wind radii)
- Features: TC-following nested grid meshes (4 km on inner mesh, 40L)
Specialized TC PBL physics (C_D and PBL); Vortex initialization
Coupled with NRL Coastal Ocean Model, NCOM
- Operational at Navy FNMOC: i) deterministic NAVGEM BCs (**COTC**) and GFS BCs (**CTCX**)
ii) COAMPS-TC ensemble (11 member, 4 km resolution)

Michael (14L)
(12Z 8 Oct
2018)
Sea Level
Pressure and
10-m Winds



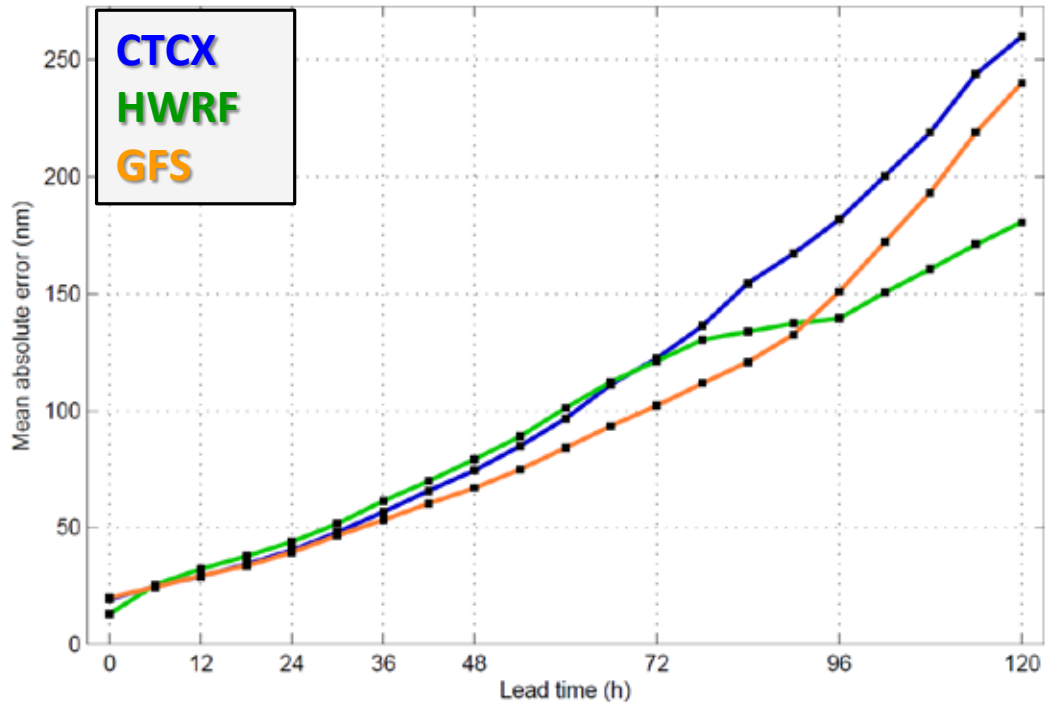
Gaston (07L)
(12Z 28 Aug 2016)
SSTs and 10-m Winds



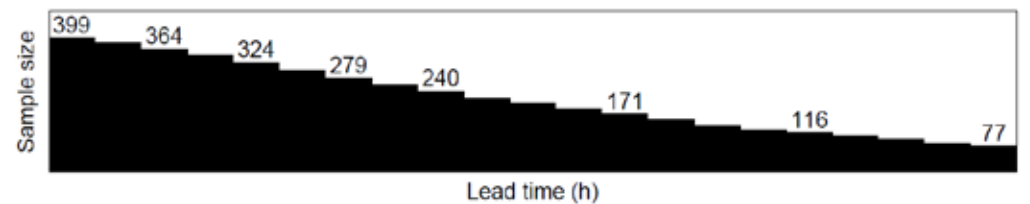
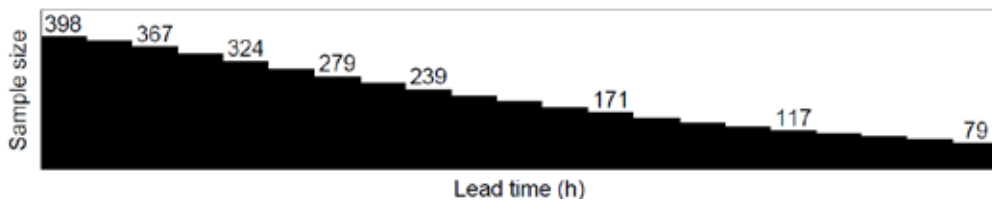
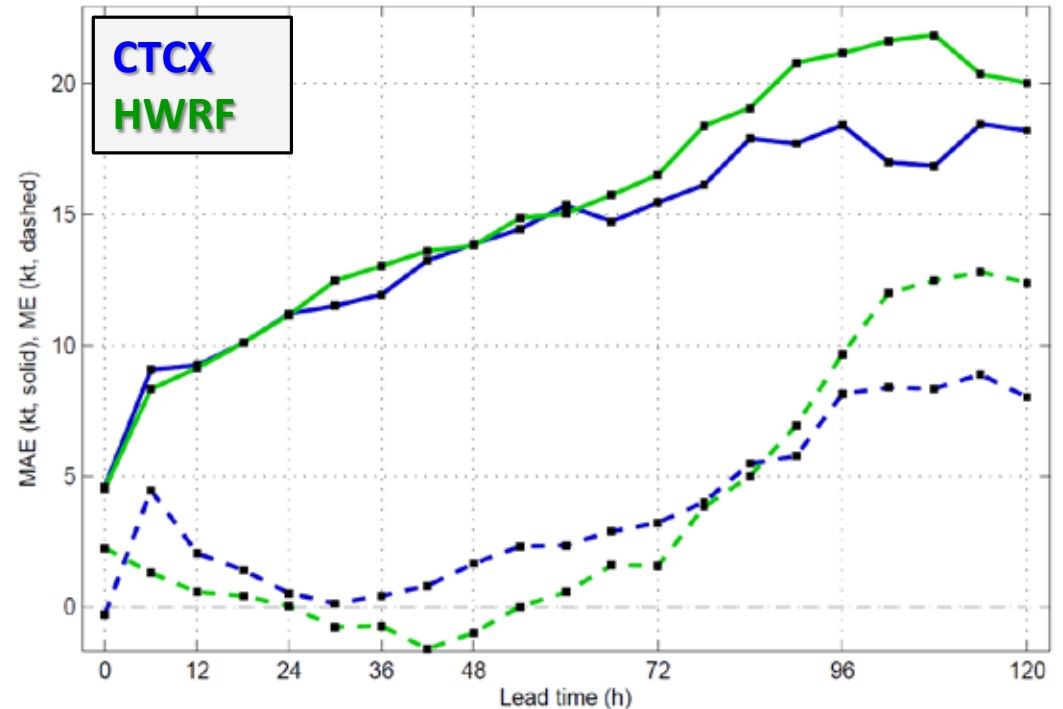
COAMPS-TC Performance

Western North Pacific Basin 2020

Track Mean Absolute Error (nm)



Intensity MAE (solid) and ME (dashed)

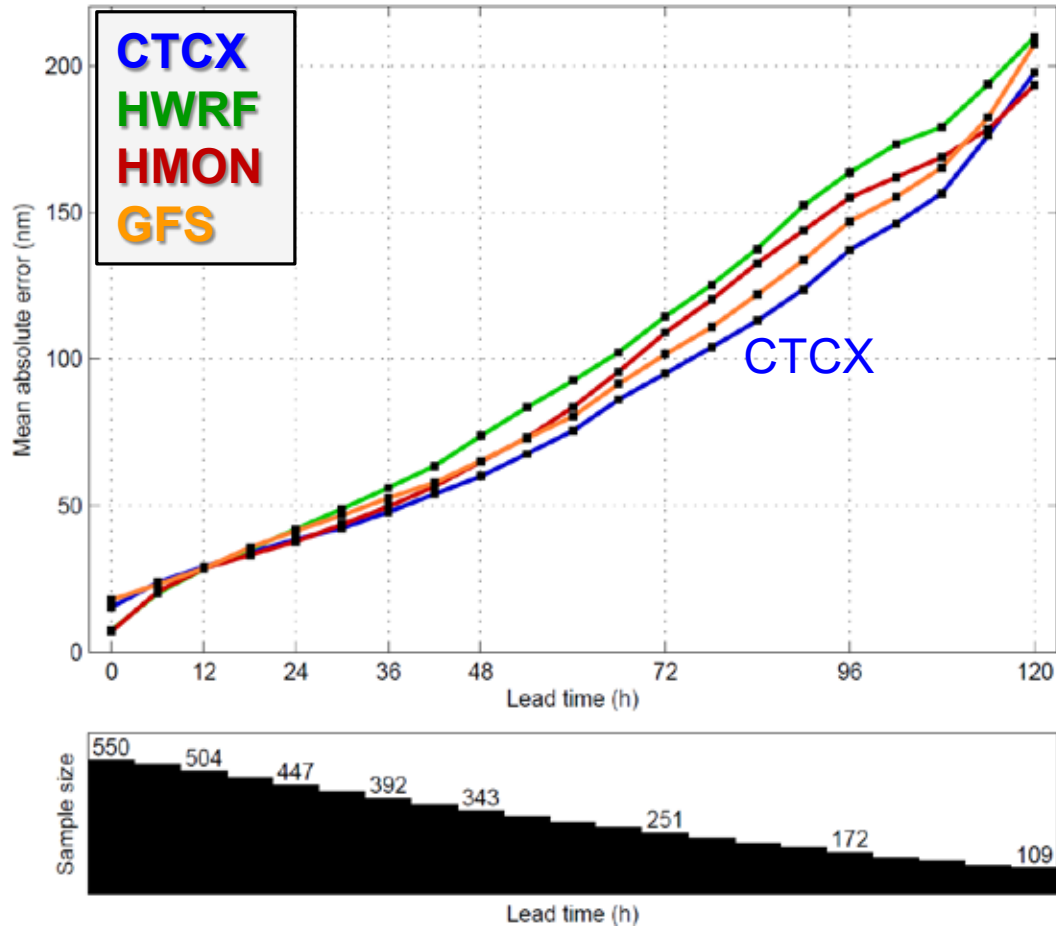


- CTCX track error is excellent through 72h in W. Pacific (improvements in 2021 to come!)
- CTCX intensity MAE is generally better than HWRF at most lead times

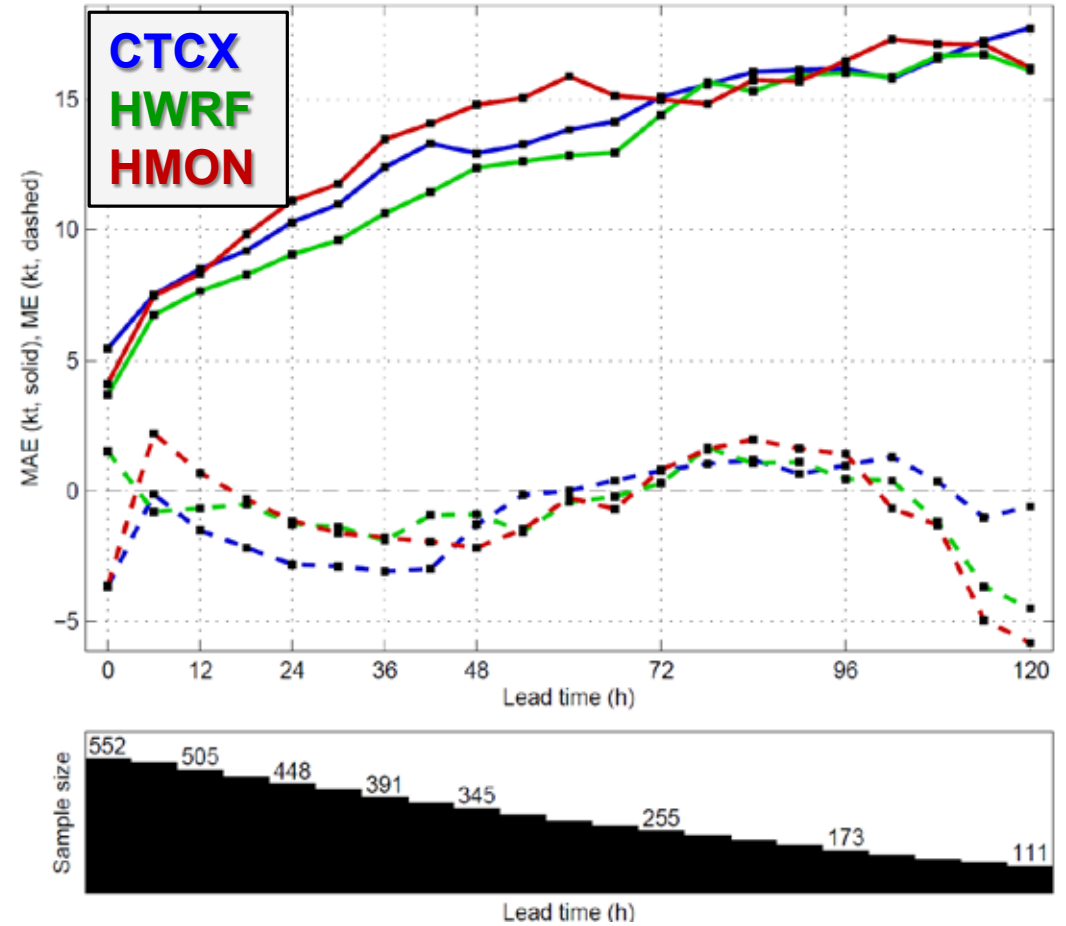
COAMPS-TC Performance

Atlantic Basin 2020

Track Mean Absolute Error (nm)



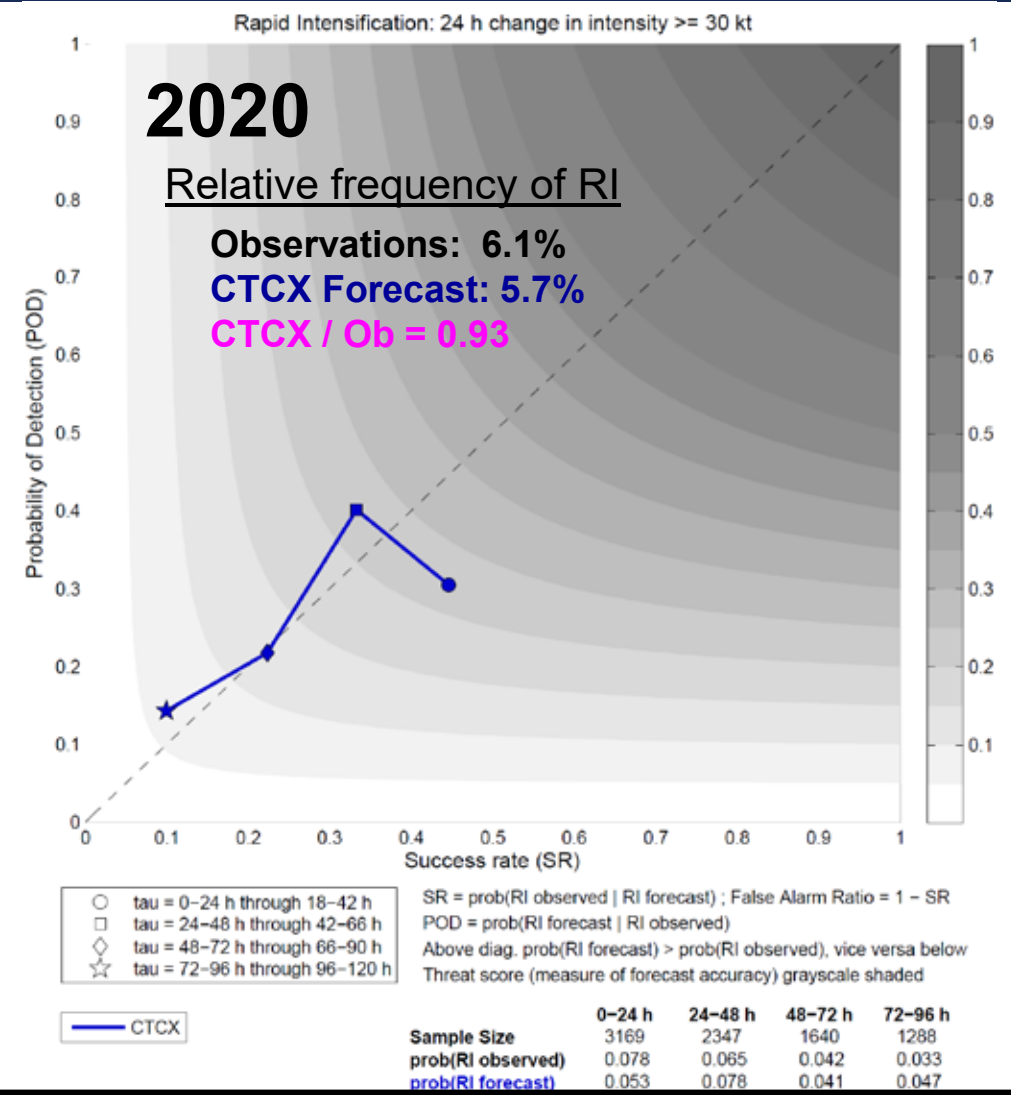
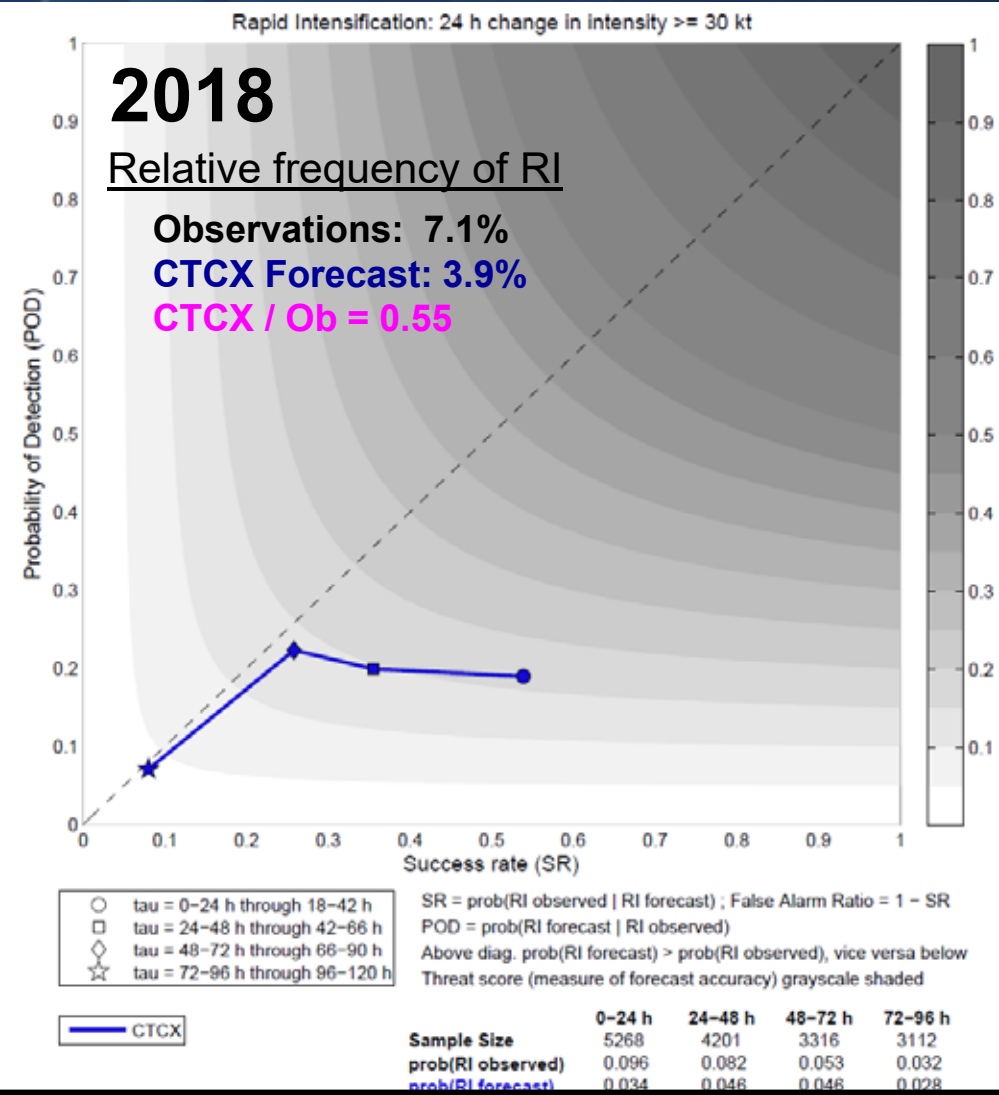
Intensity MAE (solid) and ME (dashed)



- CTCX track error was very good with lower errors than GFS, HWRF, HMON
- CTCX intensity trailed HWRF by ~0.5-1 kt (0-72h) (CTCX was top intensity model in 2019)

COAMPS-TC Performance

Rapid Intensification



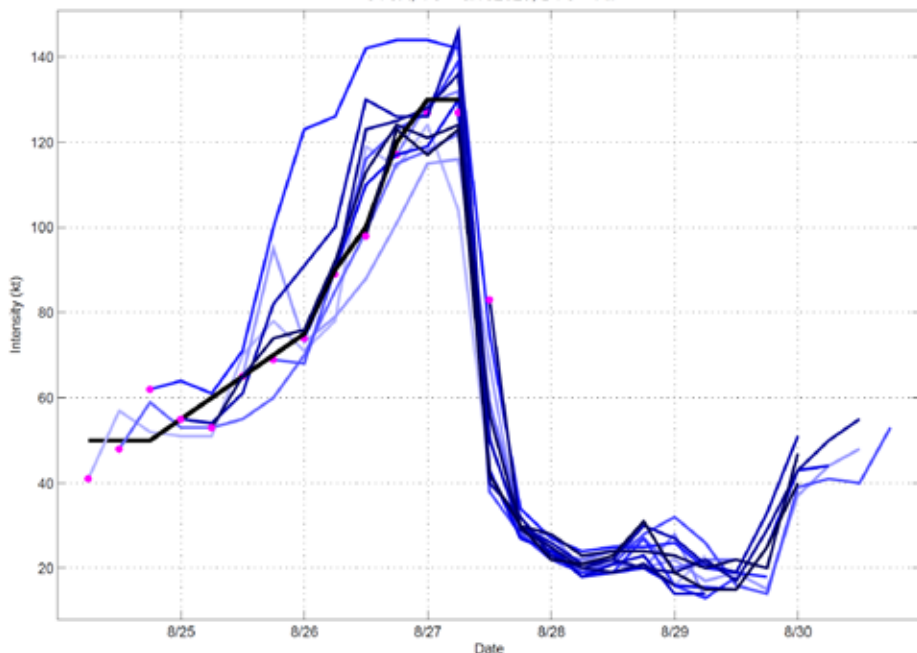
- CTCX Rapid Intensification forecasts improved markedly over last several years, especially in 2020
- Improvements in threat score, relative frequency – first time ever RI Forecast/Obs ~ 1

COAMPS-TC: Laura Performance

2020 Atlantic Storm 13L (LA direct hit)

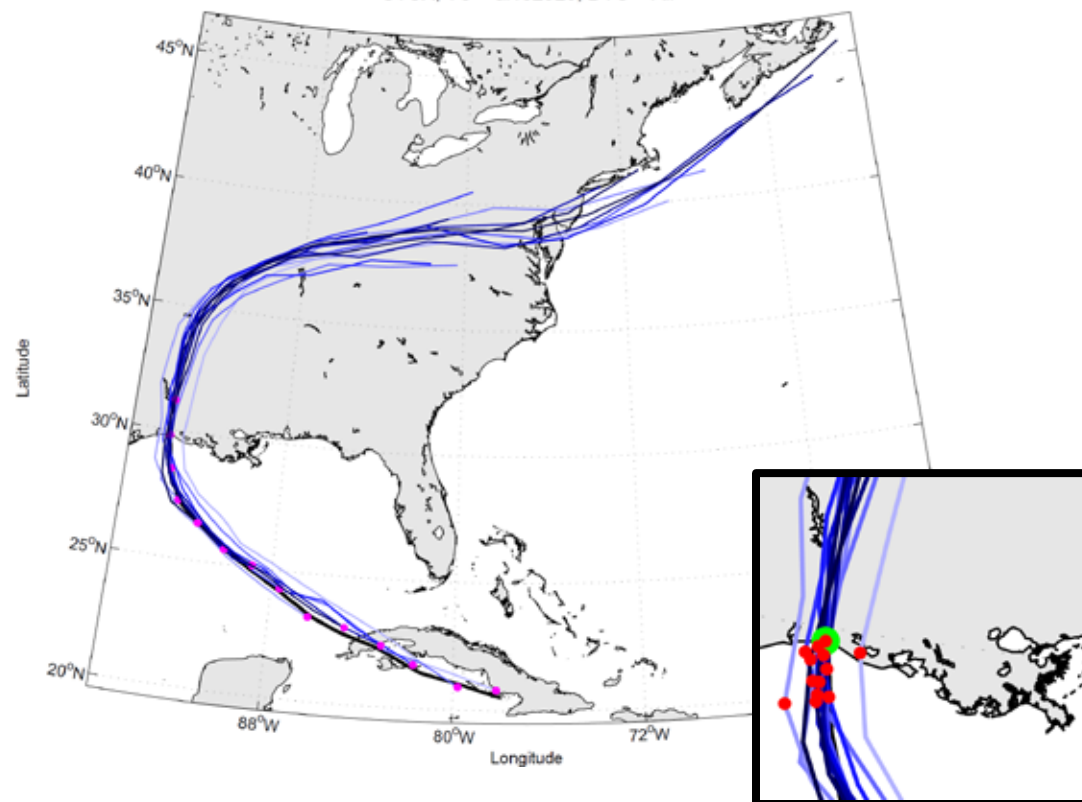
Intensity (kt)

CTCX, TC = al132020, DTG = All



Track

CTCX, TC = al132020, DTG = All



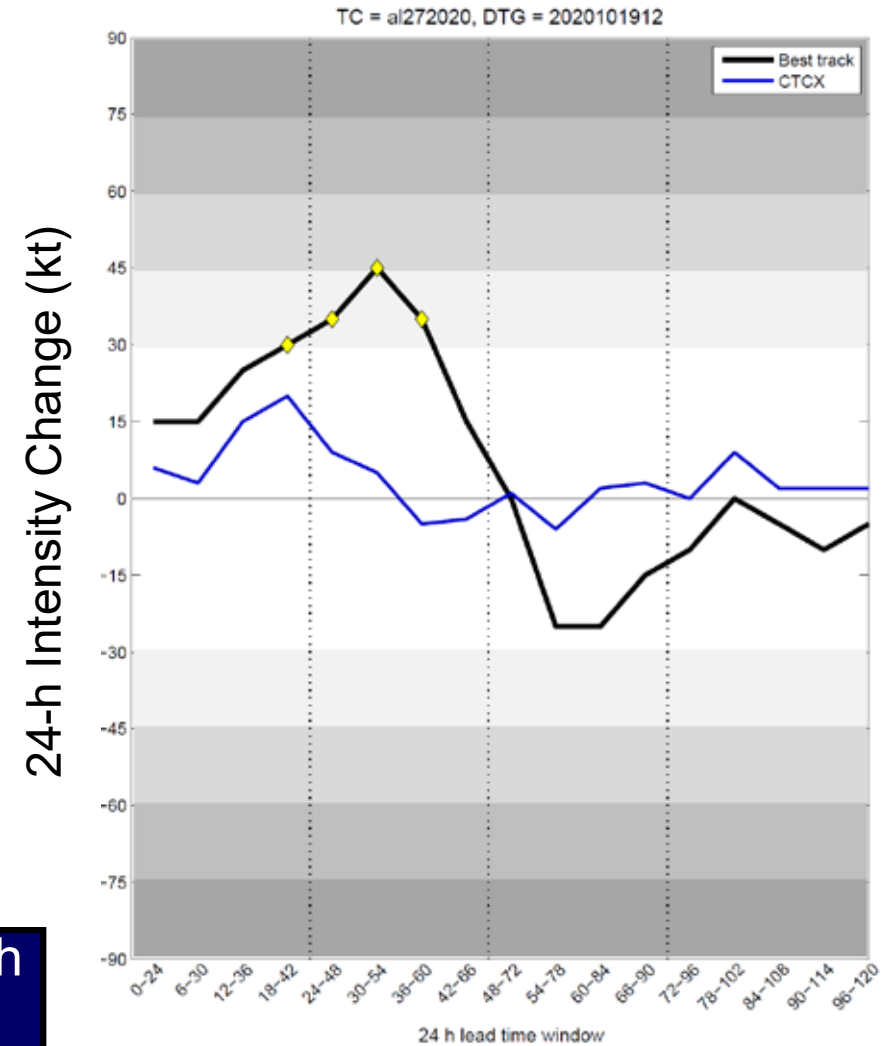
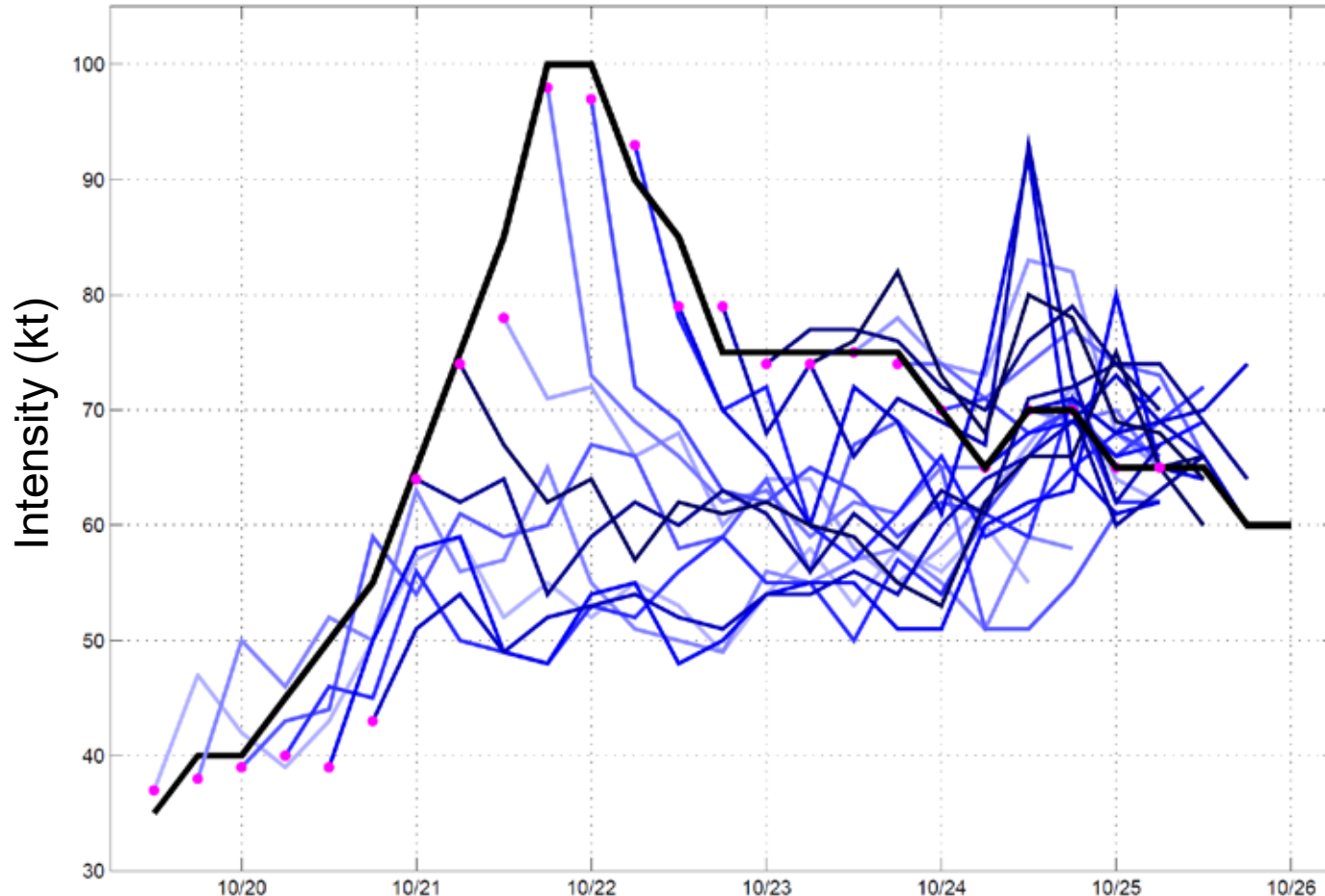
Time	Init. Intensity (kt)	Forecast Peak Intensity (kt)				
		CTCX	HWRF	HMON	DSHP	LGEM
2020082406	55	124	131	115	75	73
2020082412	50	122	130	96	76	71
2020082418	50	144	129	62	76	74
2020082500	55	146	117	102	89	87
2020082506	55	124	117	107	86	85
2020082512	65	116	111	102	86	88
2020082518	70	144	108	107	90	93
2020082600	75	130	123	131	90	90
2020082606	90	136	122	137	99	102
2020082612	100	123	122	129	106	110
2020082618	120	132	119	119	120	125
2020082700	130	139	134	118	130	130
		131.7	121.9	110.4	93.6	94.0

- TS: 33-63 kt
- Cat 1: 64-82 kt
- Cat 2: 83-95 kt
- Cat 3: 96-112 kt
- Cat 4: 113-136 kt
- Cat 5: 137+ kt

CTCX RI forecasts for Hurricane Laura (13L) were amazingly accurate, as was the track and landfall location

COAMPS-TC: Epsilon Performance

2020 Atlantic Storm 27L



- Epsilon had 4 overlapping observed RI intervals, max 45 kt / 24 h
- For forecasts of the 0-24 through 66-90 h windows:
 - 0 hits, 22 misses, 0 false alarms
- Epsilon developed in a very challenging environment

24-h Lead Time Window

COAMPS-TC Ensemble

Operational and Demonstration Systems

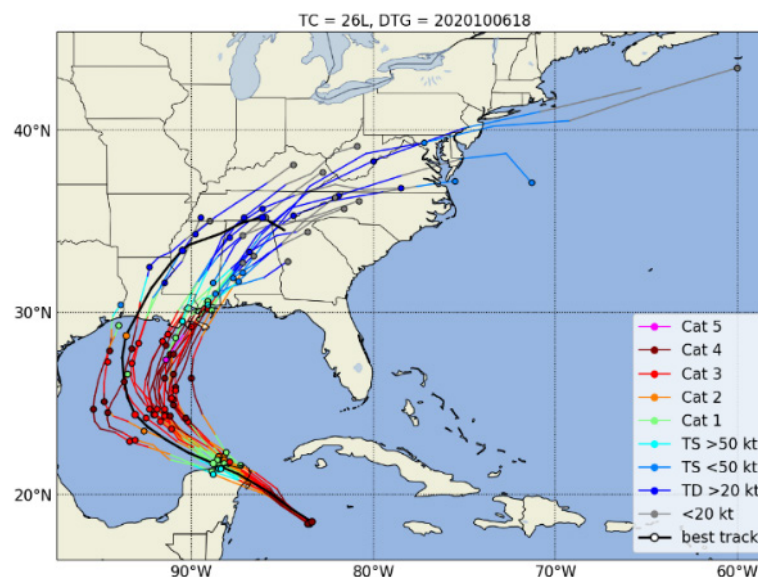
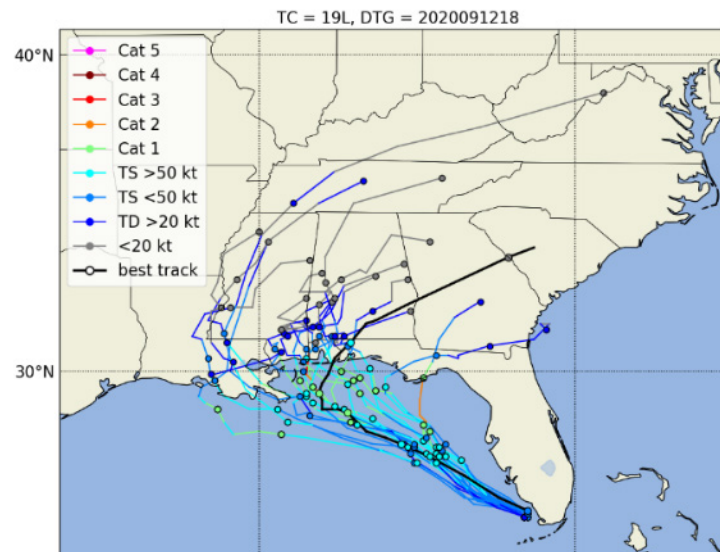
Operational ensemble at FNMOC

- The first fully-operational high-resolution tropical cyclone ensemble system
- GFS initial and boundary conditions
- 36/12/4-km resolution
- 11 members
- Available in ATCF

Demonstration ensemble at NRL

- 21 members
- Tuned IC/BC perturbation parameters
- Improved graphics suite
- Available online at:

<https://www.nrlmry.navy.mil/coamps-web/web/ens>



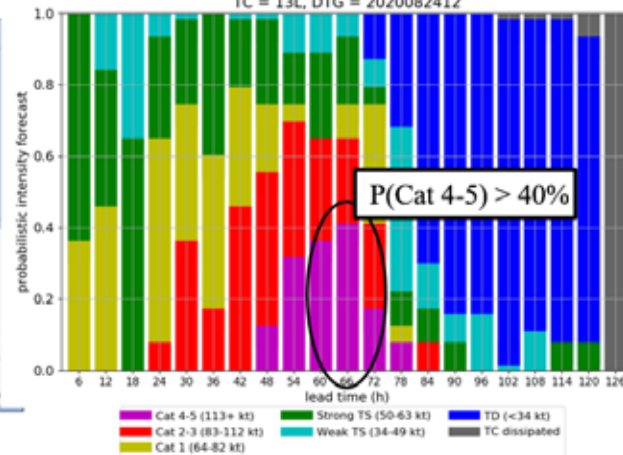
Both operational and experimental versions of COAMPS-TC Ensemble had strong performance for both track and intensity for U.S.-landfalling TCs in 2020, including Laura, Sally and Delta

COAMPS-TC Ensemble Graphical Products

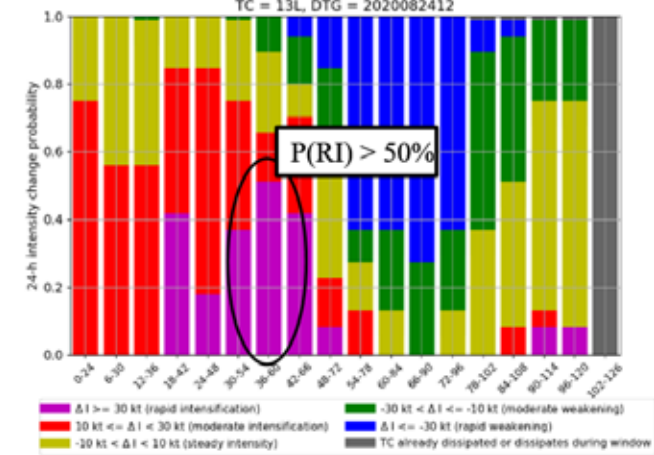
Tracks colored by intensity



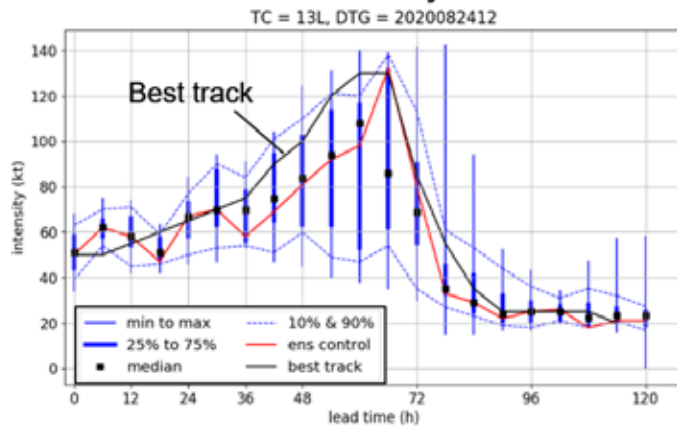
Probabilistic intensity forecast



Probabilistic intensity change forecast

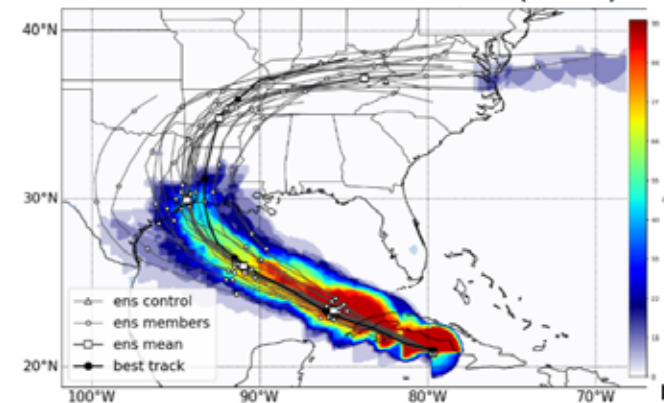


Intensity



Graphical forecast products have been developed to depict probabilistic track, intensity, chances of RI, and various wind thresholds

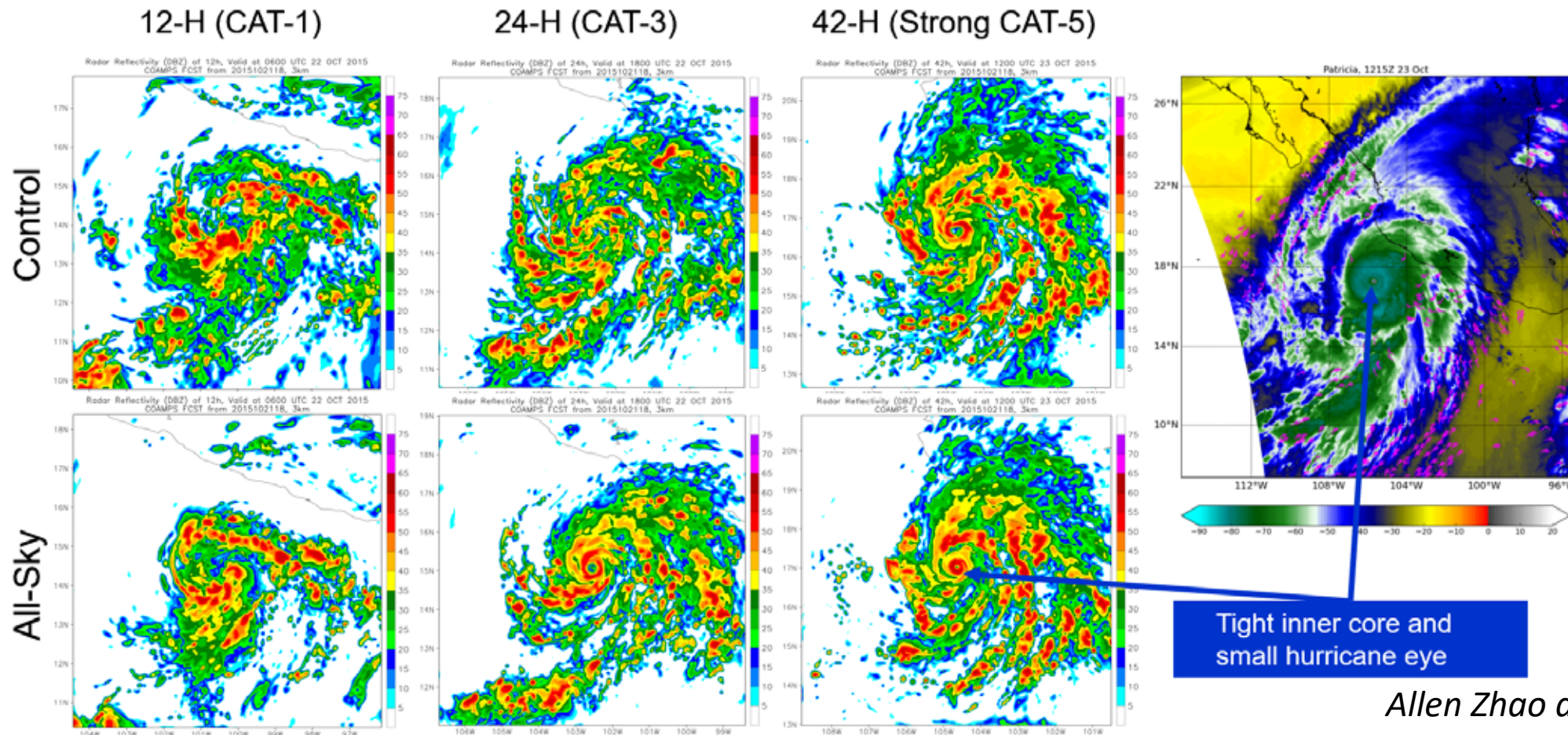
Probabilistic wind swath (34-kt)



High-resolution ensembles have the capability to increase the RI forecast accuracy and better capture uncertainties of track and intensity forecasts for developing TCs

COAMPS-TC Data Assimilation

All Sky Radiance Assimilation

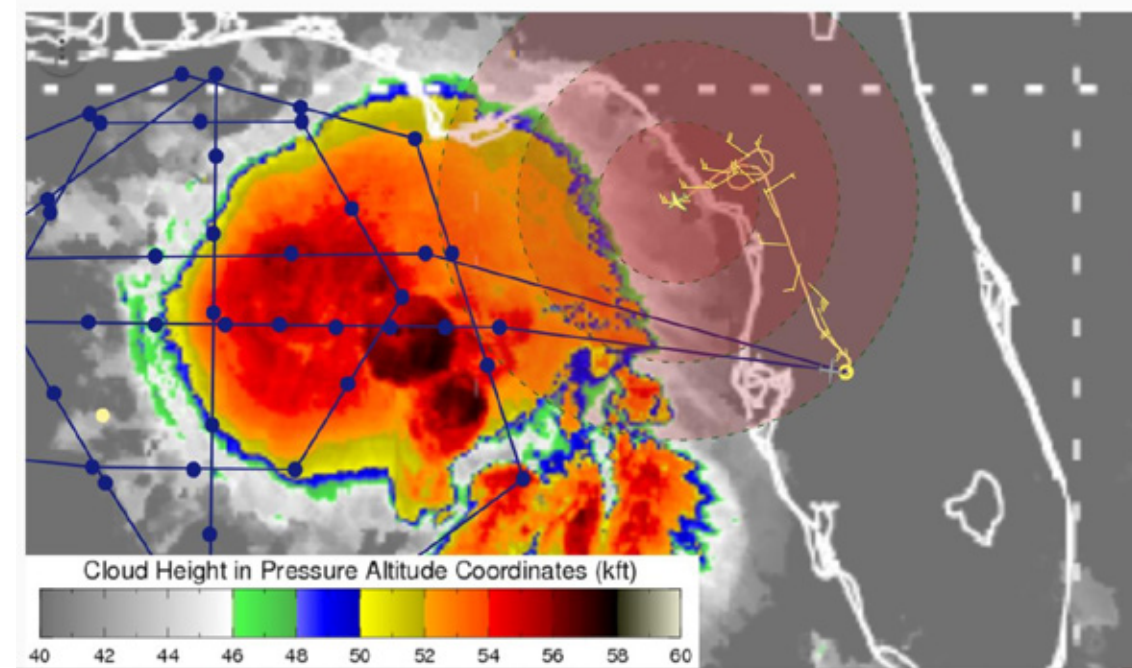
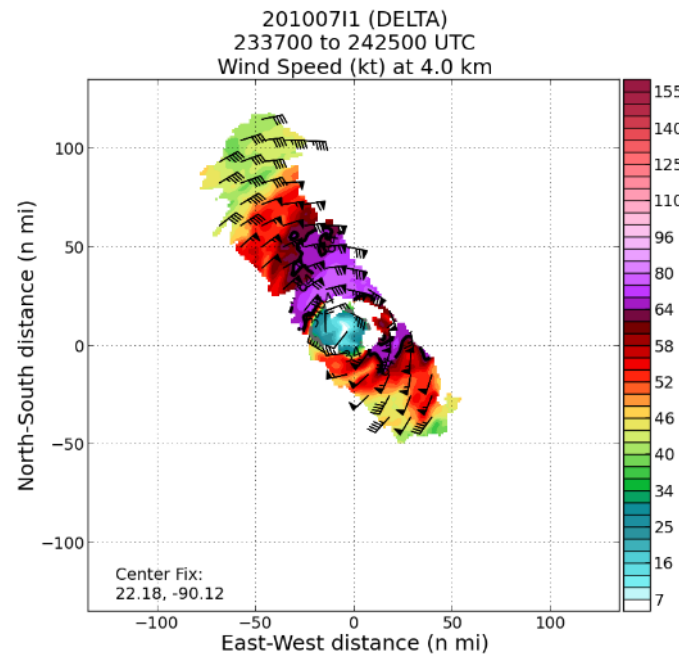
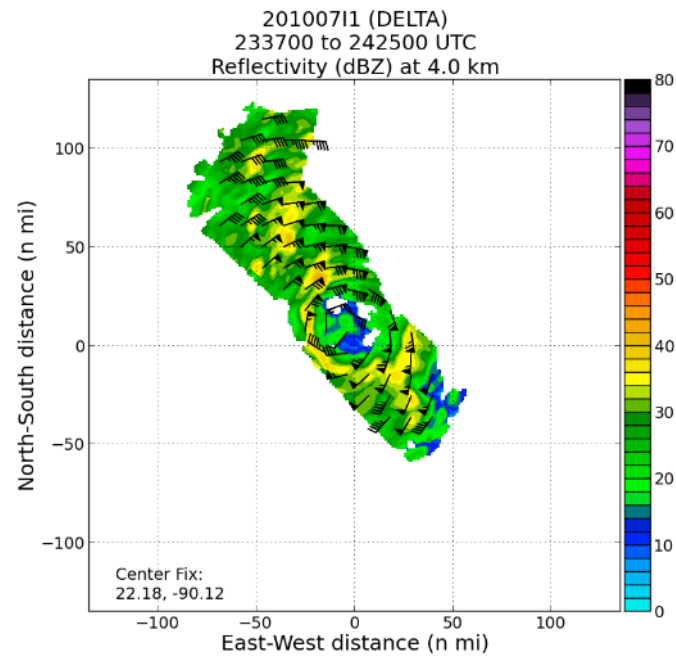


- All-sky radiance assimilation (assimilate radiances every 15 mins) in COAMPS-TC looks very promising and should improve initialization for non-classical TC genesis cases
- Builds off of the ideas of Prof. Fuqing Zhang, who was a close collaborator on this project

Tropical Cyclone Rapid Intensity Campaign

ONR Sponsored Program

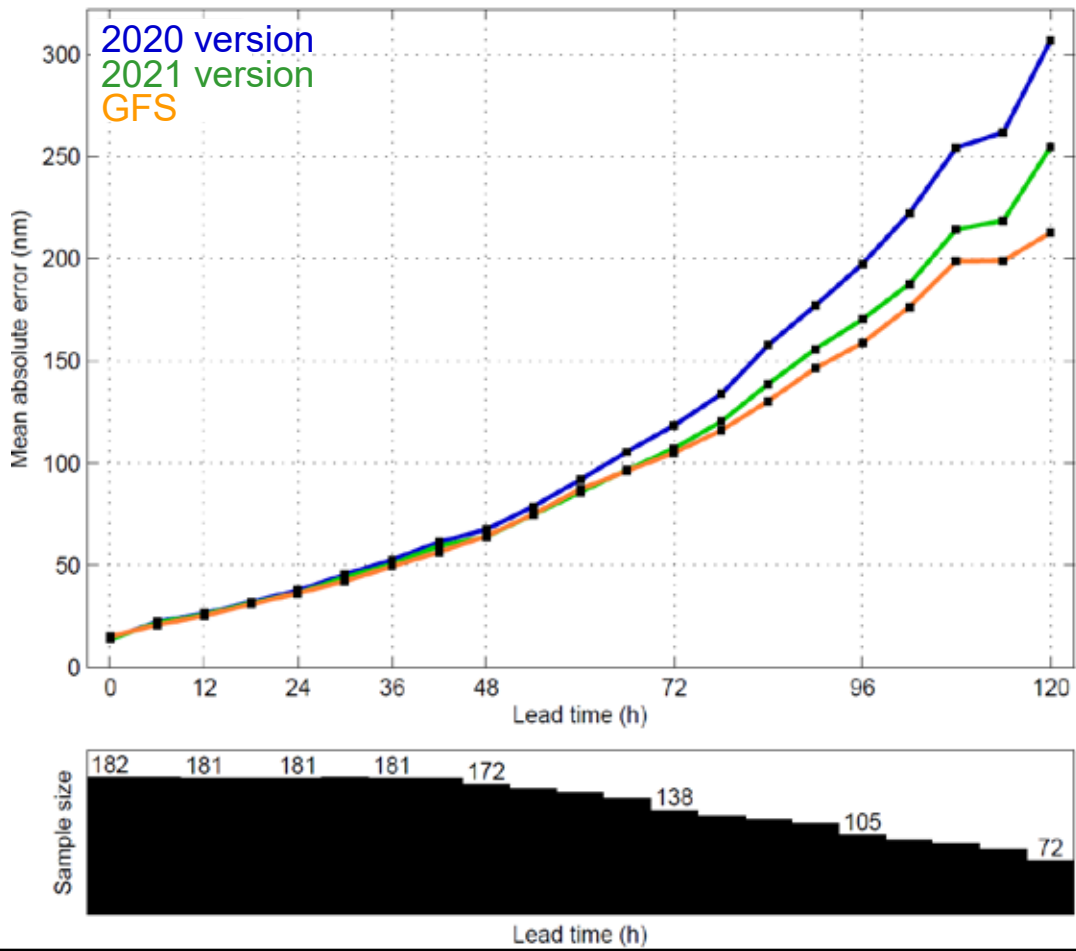
- Conducted in close collaboration with NOAA HRD and IFEX
- 3 P-3 Flights and collaborative G-IV flights during Sally, Teddy, Delta
- Deployed 159 additional dropsondes for TCRI
- Several flights (including Sally) captured the period prior to and during RI
- Plans for 3-4 P-3 Flights and collaborative G-IV flights in 2021



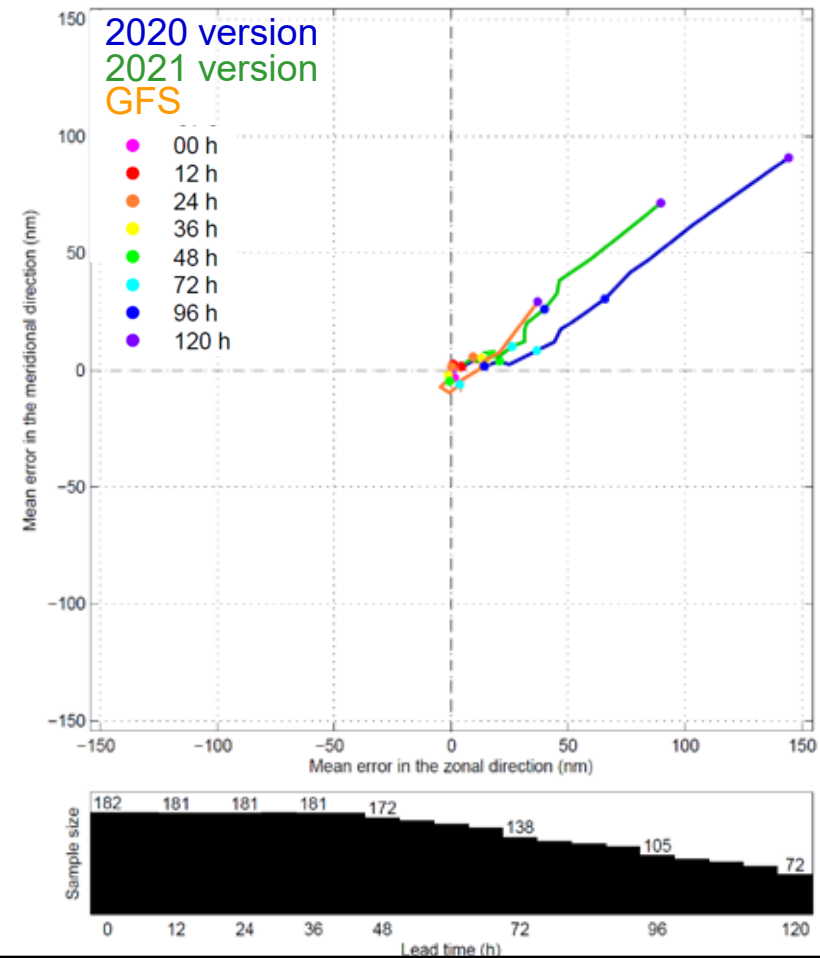
COAMPS-TC 2021 Version

Improved Track Errors in N.W. Pacific

Track Error (nm)



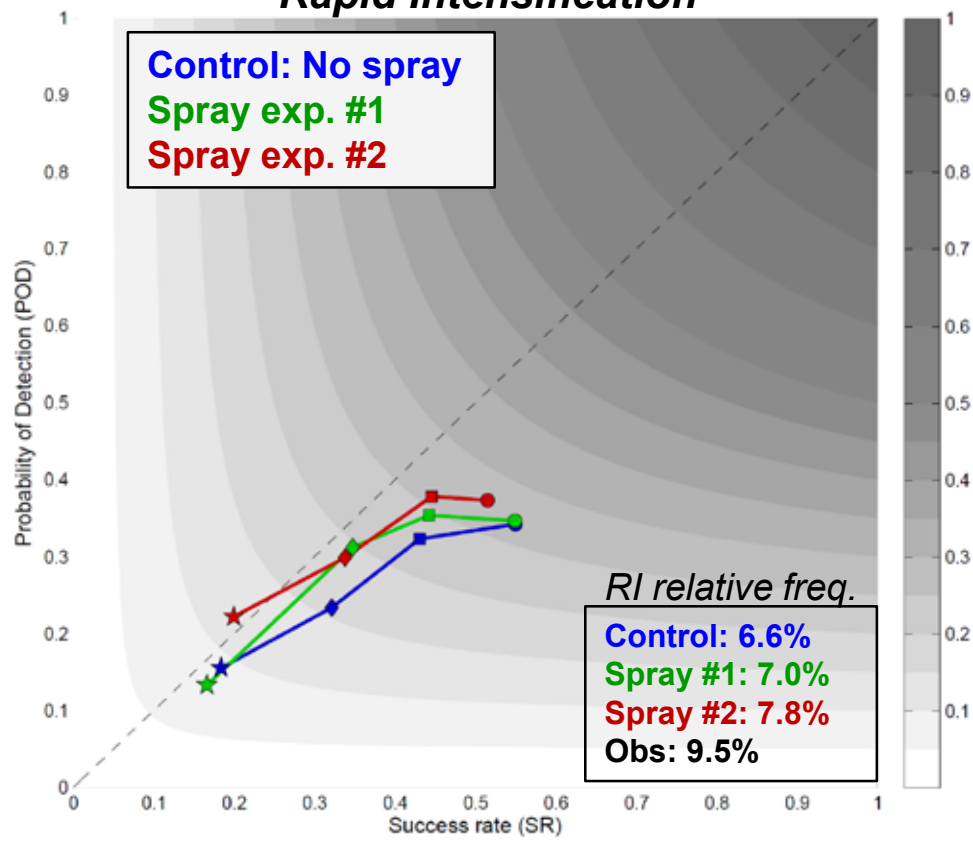
Directional Bias (nm)



- Improved track error by ~17% at 120h in the N. Western Pacific basin (new northern BC condition)
- Improvements to the nest tracking algorithm to allow the nest to track TCs closer to the boundary

Sea Spray Parameterization

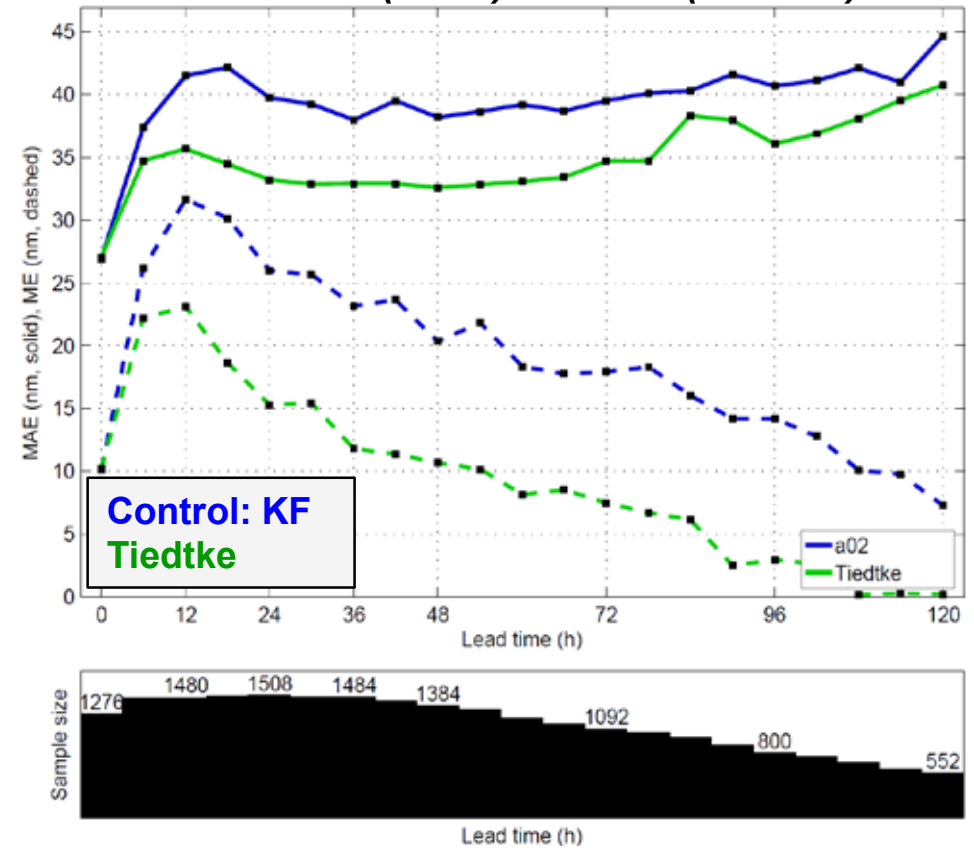
Rapid Intensification



Sea spray improves RI accuracy and relative frequency

New Cumulus Parameterization

R34 MAE (solid) and ME (dashed)



Tiedtke has a drier middle free troposphere than KF, which helps reduce positive bias in outer wind radii

NAVGEM Update

2020 Performance and Future Plans

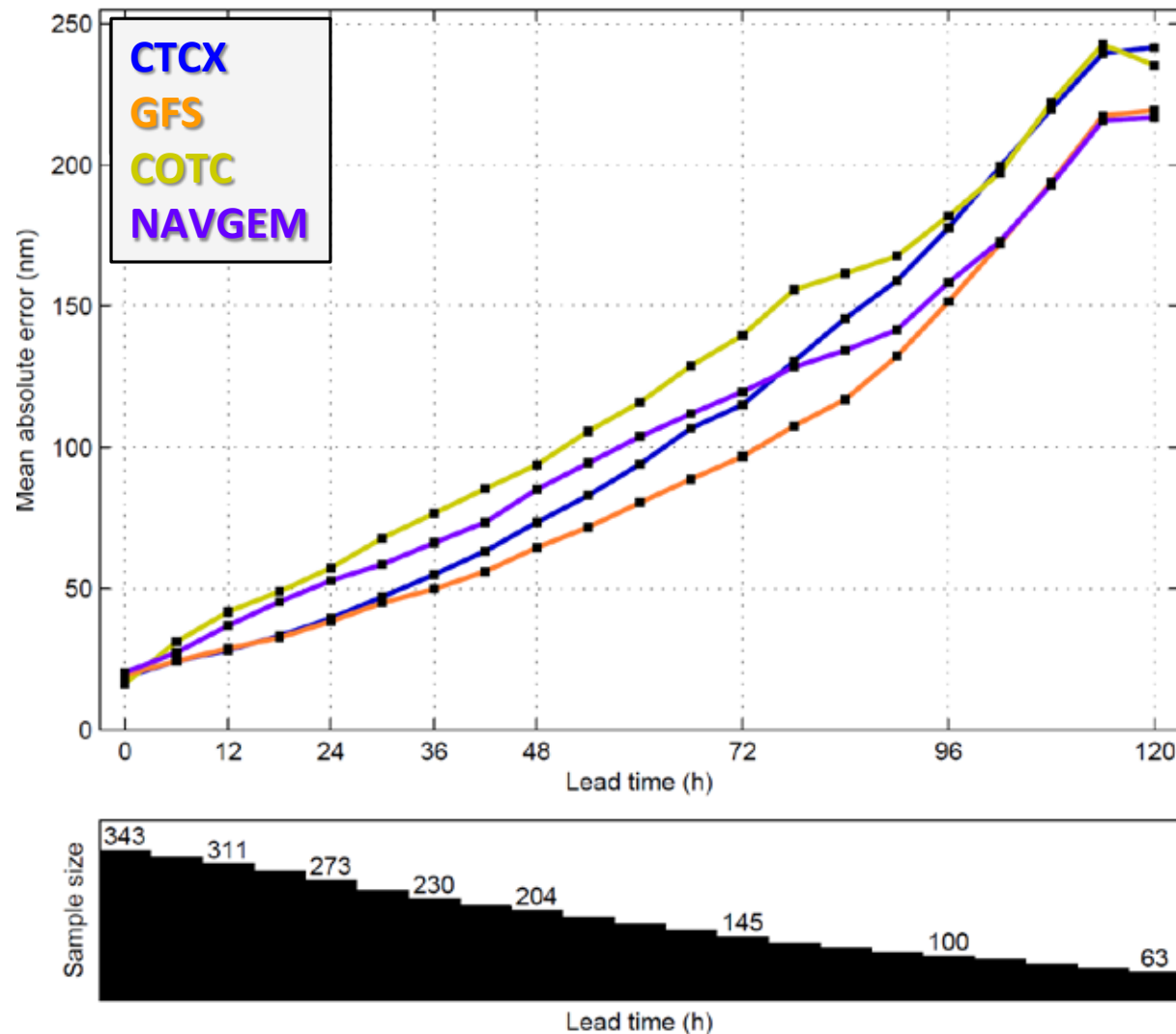
2020 Performance

- Similar to recent years, NAVGEM lags GFS track MAE at most lead times in WP, but is close at days 4-5
- COAMPS-TC track performance parallels that of parent global model

Future Plans

- Upgrade to v2.1 (ops Apr-Jun 2021)
Data assimilation advances, no significant impact on TC forecasts
- Upgrade to v2.2 (ops first half 2022)
100 vertical levels instead of 60 levels, re-tuned physics, TC DA advances, **potential for significant improvement in TC track and structure prediction**

Track MAE: 2020 Western North Pacific



Summary and Key Gaps

- **COAMPS-TC much improved for RI, Intensity and Track over last several years**
 - New upgrades for 2021: Tiedtke cumulus para., improved WPAC tracks, sea spray, smooth spin-up
 - RI challenges remain:
 - Onset, magnitude, timing, environmental shear, PBL and air-sea interaction, microphysics
 - Ensemble design for RI; Predictability horizon
- **Gaps**
 - Need observations during RI onset, RI in moderate shear, and cloud microphysics (focus of TCRI)
 - Improved data assimilation methods in TCs needed (all-sky radiance assimilation is promising)
 - Uncertainties in PBL and microphysics parameterizations
 - Identify predictability sources and barriers for TC rapid intensification (adjoint, ensemble tools)
 - More emphasis on high-resolution ensembles (COAMPS-TC ensemble in ops in 2020)
 - National high-resolution multi-model TC ensemble (COAMPS-TC, HAFS...)