COAMPS-TC 2015 Version, Performance, and Future Plans

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Sponsors: ONR, NOAA HFIP, NRL, PMW-120

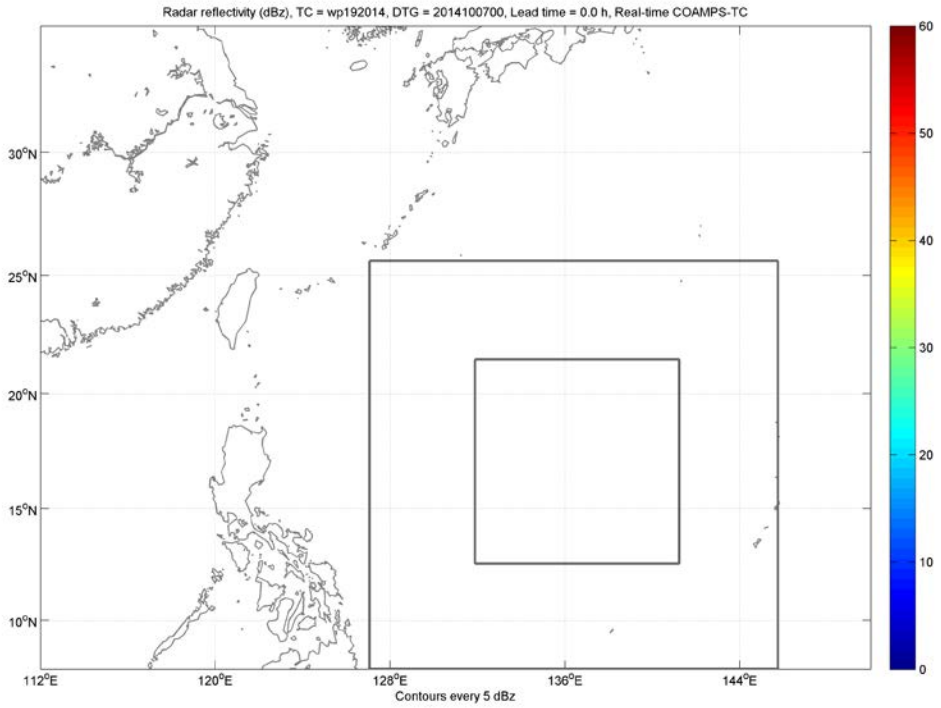
Hurricane Patricia from the International Space Station (Scott Kelly, NASA)

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), 1D, 3D ocean (NCOM), wave (SWAN, WWIII)**
- **Ensemble:** **ICs, BCs, & vortex perturbations; EnKF & ETKF options**
- **Operations:** **45-15-5km for COTC (NAVGEM ICs BCs) & CTCX (GFS ICs BCs)**

Real Time: **i) Fully coupled (NCOM), ii) 27-9-3 km 11 member ensemble**

Vongfong (2014) Simulated Radar Reflectivity



COAMPS-TC 2015 System Overview

New Surface Drag Parameterization

Issue

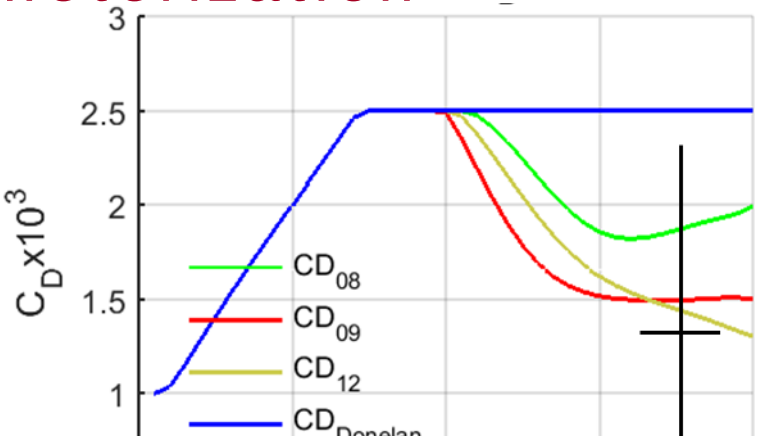
- Negative intensity bias for strong storms.
- Large uncertainties in Cd in high wind regime.

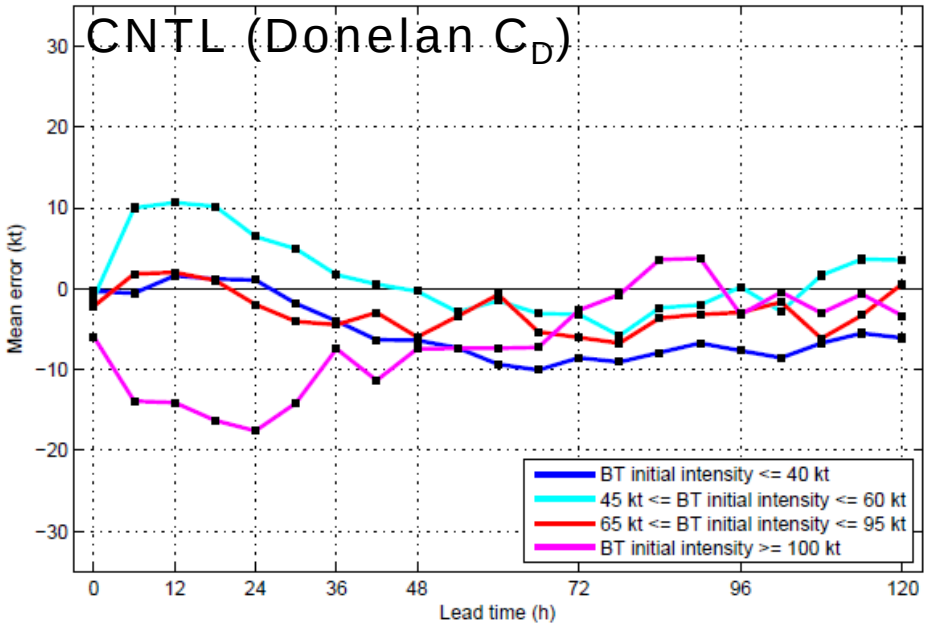
Solution

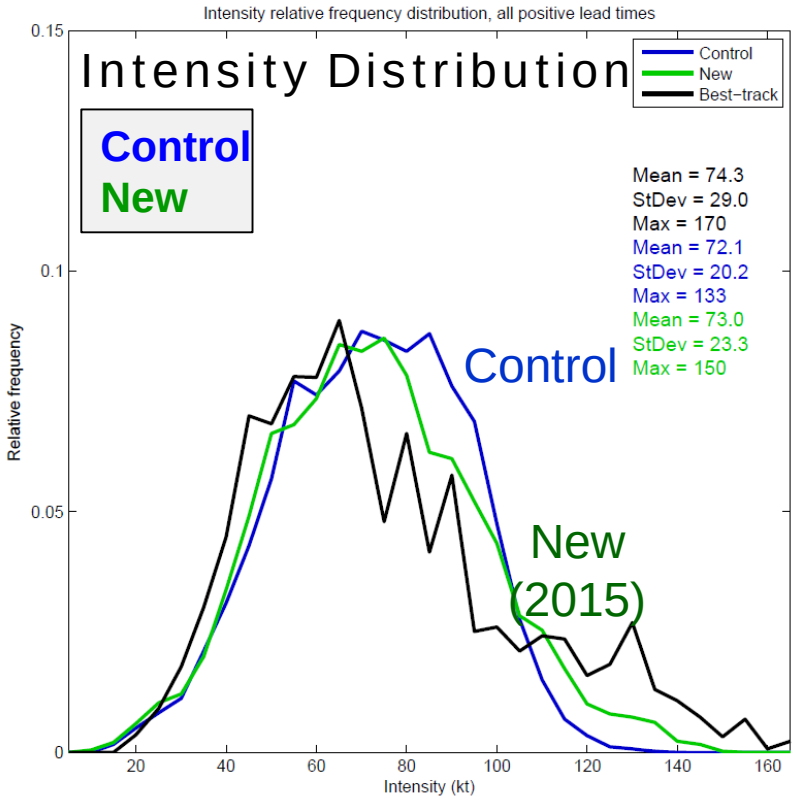
- New Cd parameterization for high wind regime (partially based on CBLAST, Bell, Soloviev)

Key Findings

- Intensity bias for strong storms reduced
- Pressure-wind relationship much improved



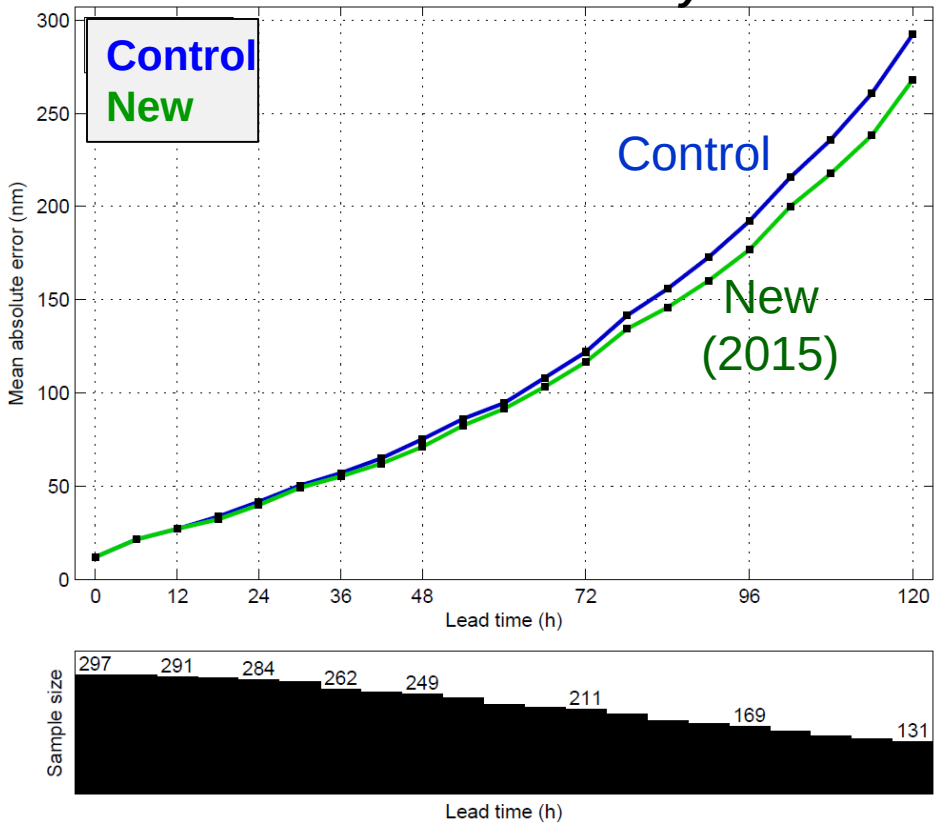




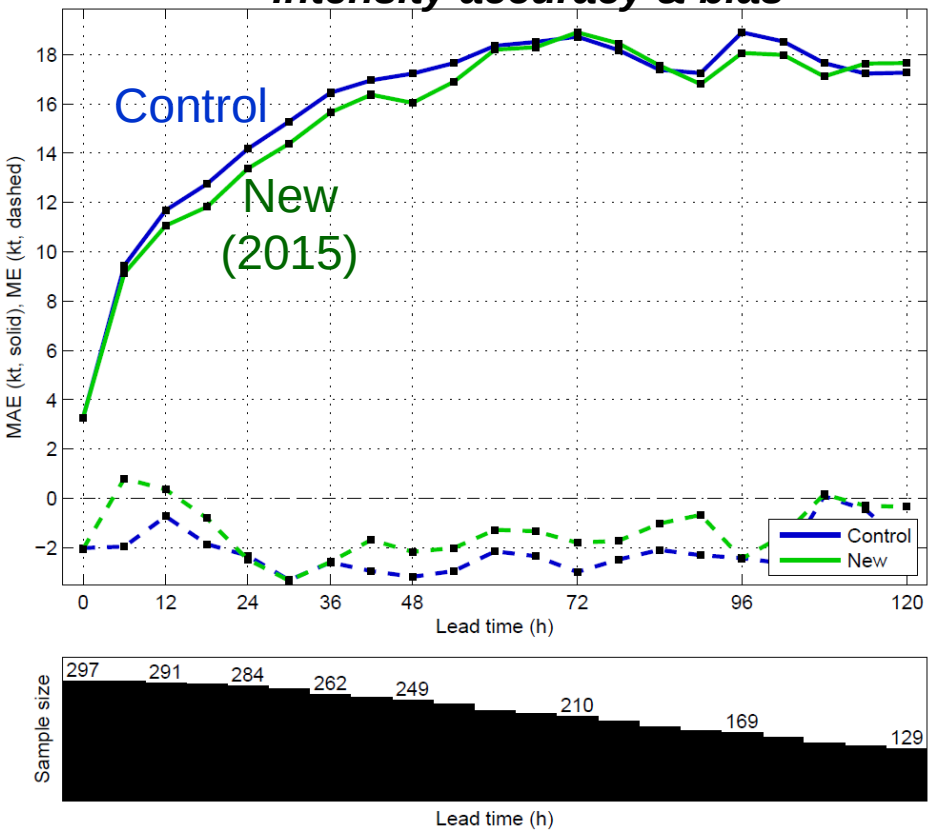
COAMPS-TC 2015 Pre-Season Tests

Control: 2014 version
New: 2015 config

Track accuracy



Intensity accuracy & bias

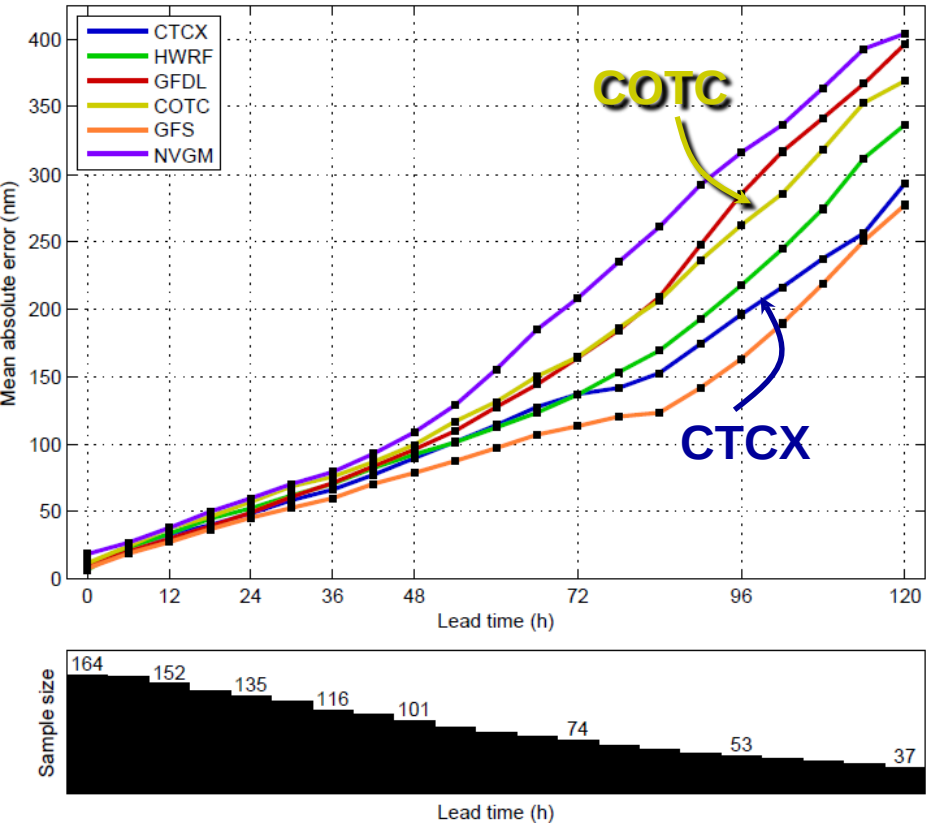


- **New 2015 COAMPS-TC Version: i) improved vortex initialization, ii) new CD param., iii) new terrain treatment, iv) "unified" TC and COAMPS code**
- **Results of a large sample of retrospective tests (from 2013-2014) demonstrate that the New (2015 Version) provides considerably improved track and intensity forecast performance relative to the 2014 version (Control).**

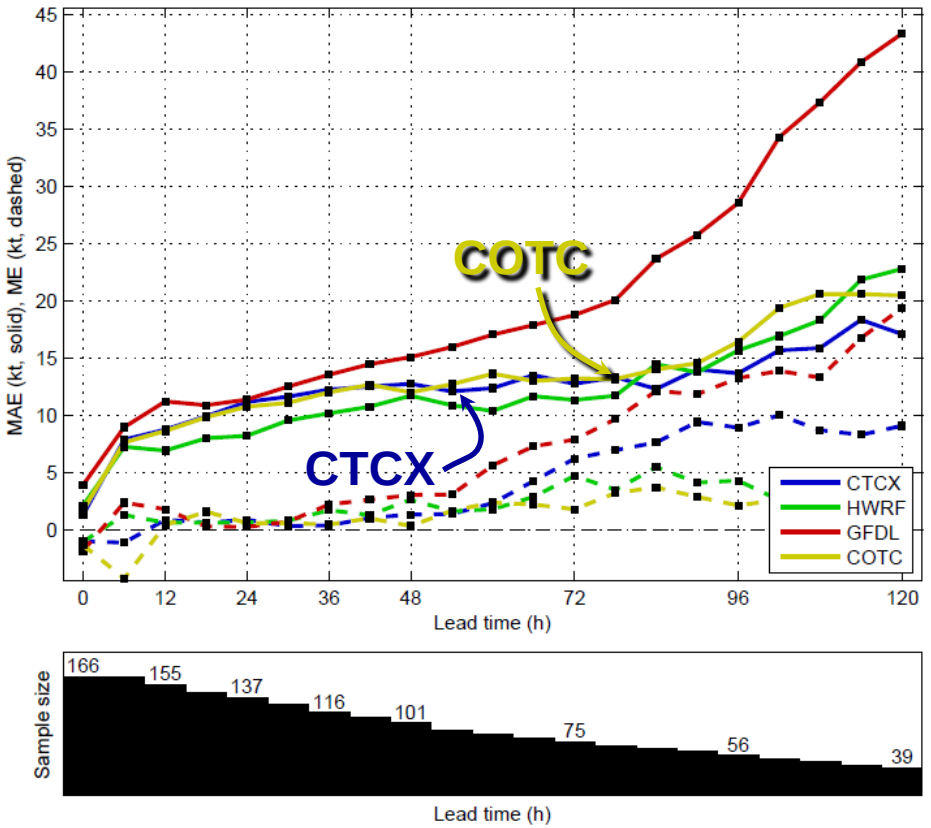
COAMPS-TC 2015 Operational Statistics

W. Atlantic: 01-11L

Track MAE



Intensity MAE & ME



CTCX
HWRF
GFDL
COTC
GFS
NVGM

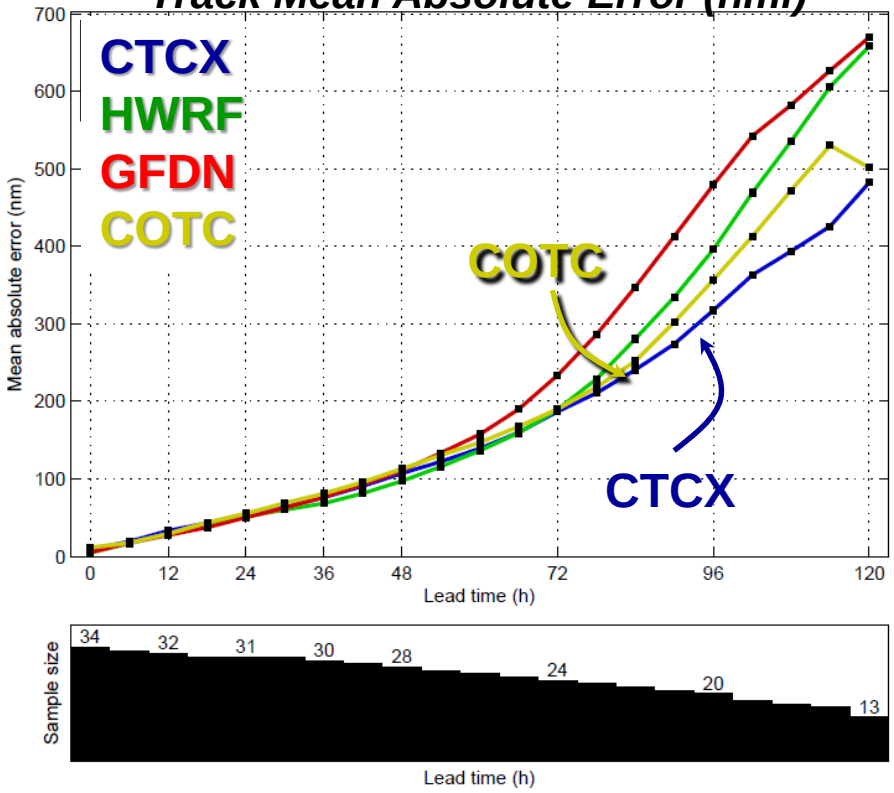
- **Track errors closely follow parent model**
  - ➢ **CTCX errors smaller than COTC**
- **Intensity errors for CTCX and COTC relatively small – bias for CTCX greater than COTC (>60h)**

CTCX
HWRF
GFDL
COTC

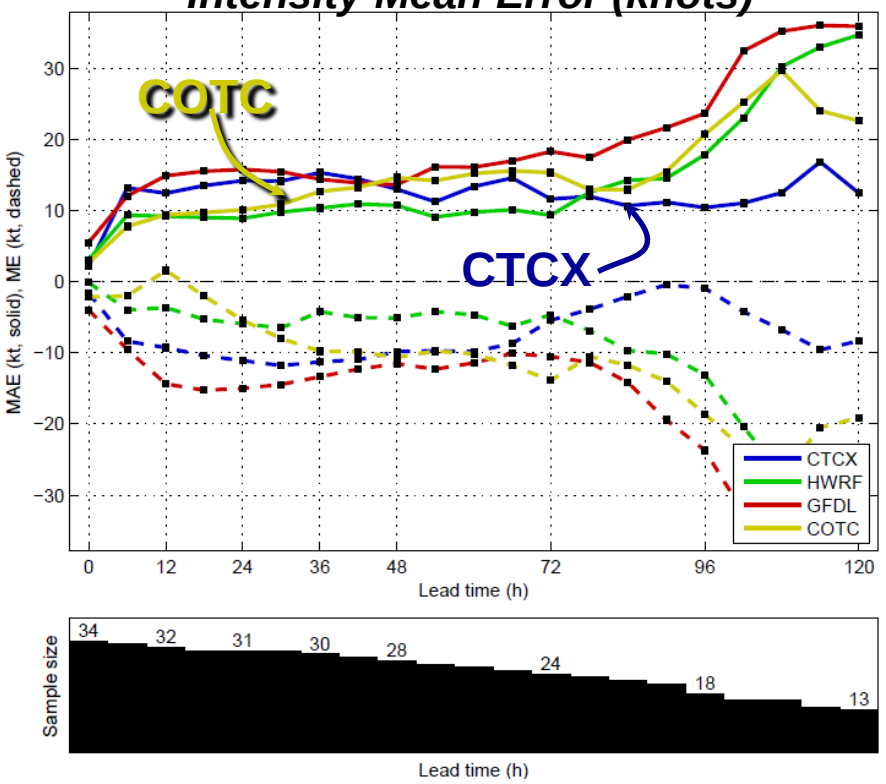
COAMPS-TC 2015 Operational Statistics

Joaquin (11L)

Track Mean Absolute Error (nmi)



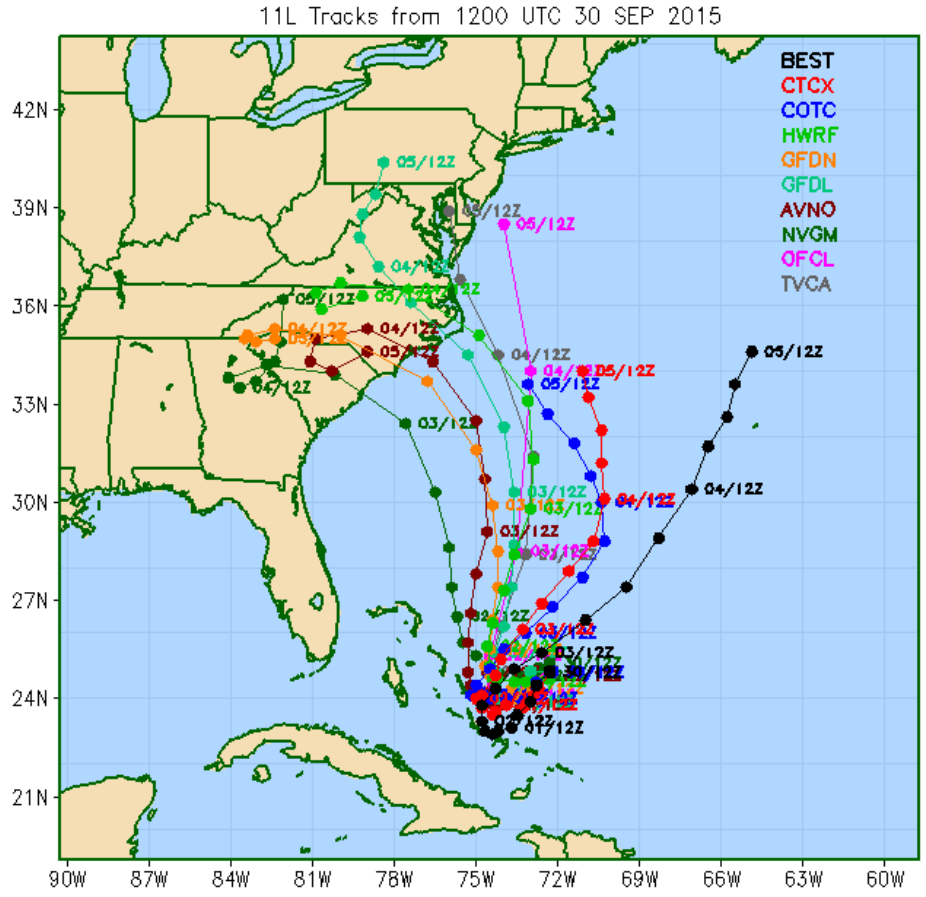
Intensity Mean Error (knots)

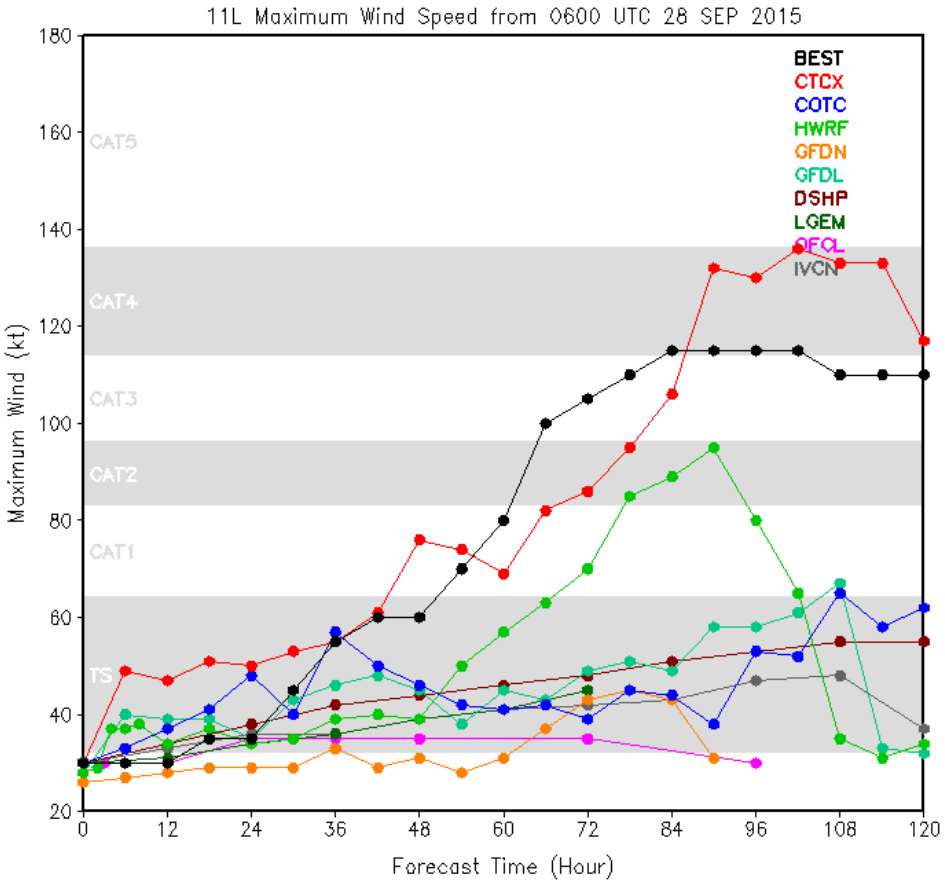


- **COAMPS-TC shows very good performance for intensity and track prediction for Joaquin**
- **Track prediction was generally to the right of other high-resolution deterministic models to the east of the US Atlantic coast.**

COAMPS-TC 2015 Operational Statistics

Joaquin (11L) Example Forecasts



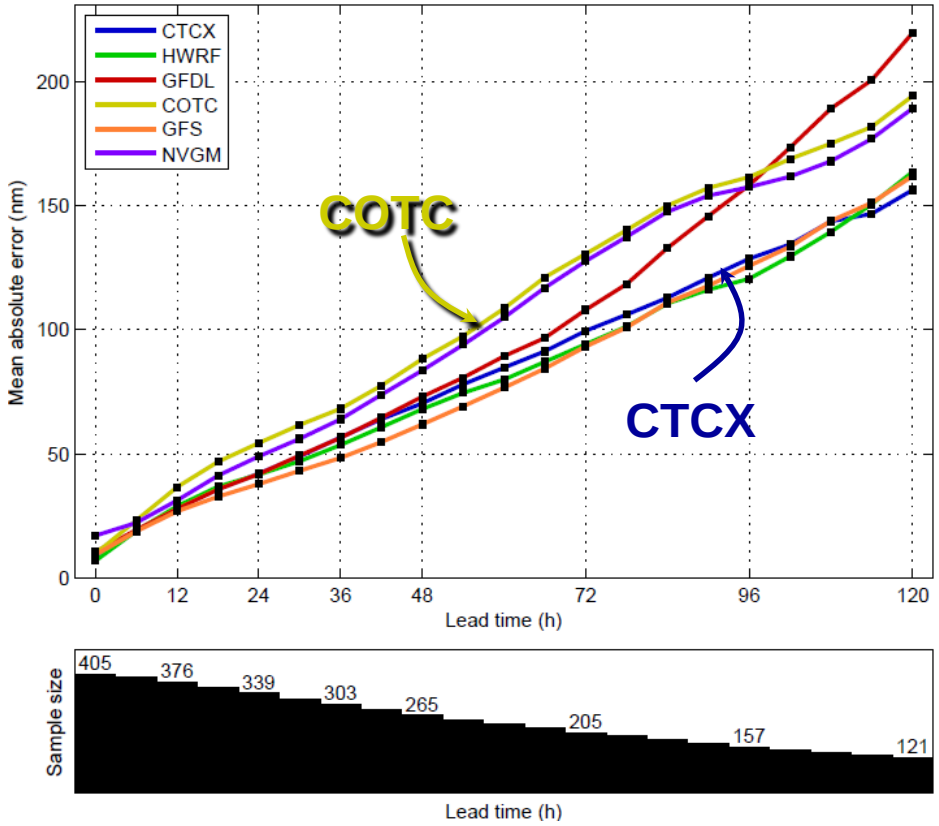


- **COTC and CTCX track was generally right of other ops models.**
- **CTCX gave early indications of rapid intensification.**
  - **Basis for ONR TCI shifting ops from EPAC (Marty) to W. Atlantic**

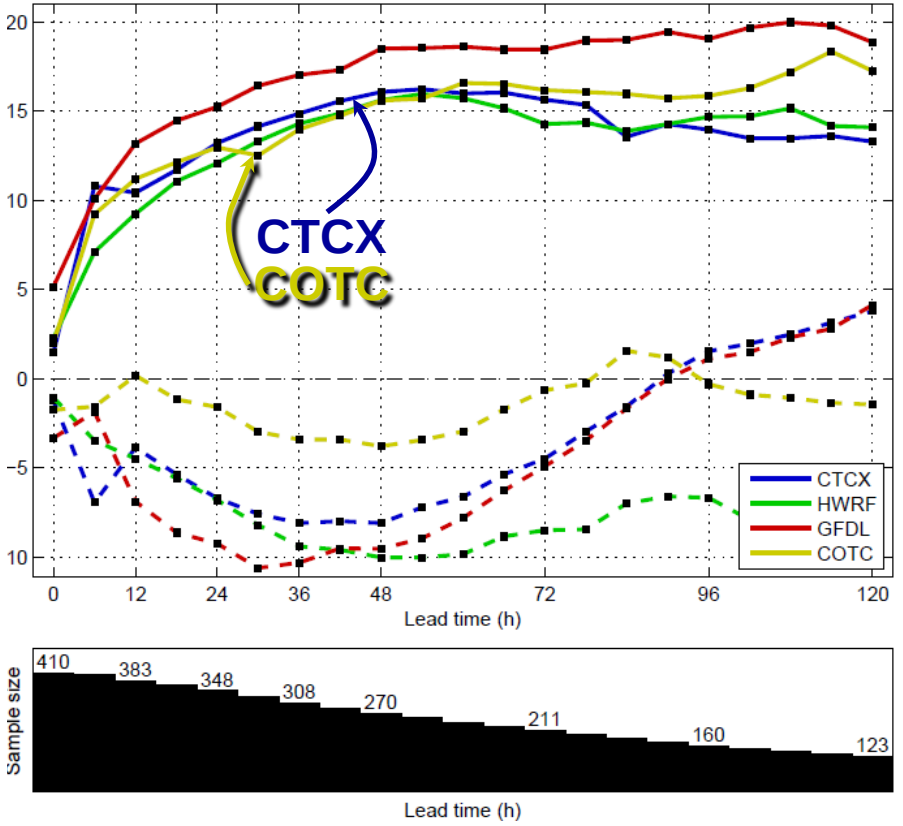
COAMPS-TC 2015 Operational Statistics

E. Pacific: 01-20E

Track MAE



Intensity MAE & ME



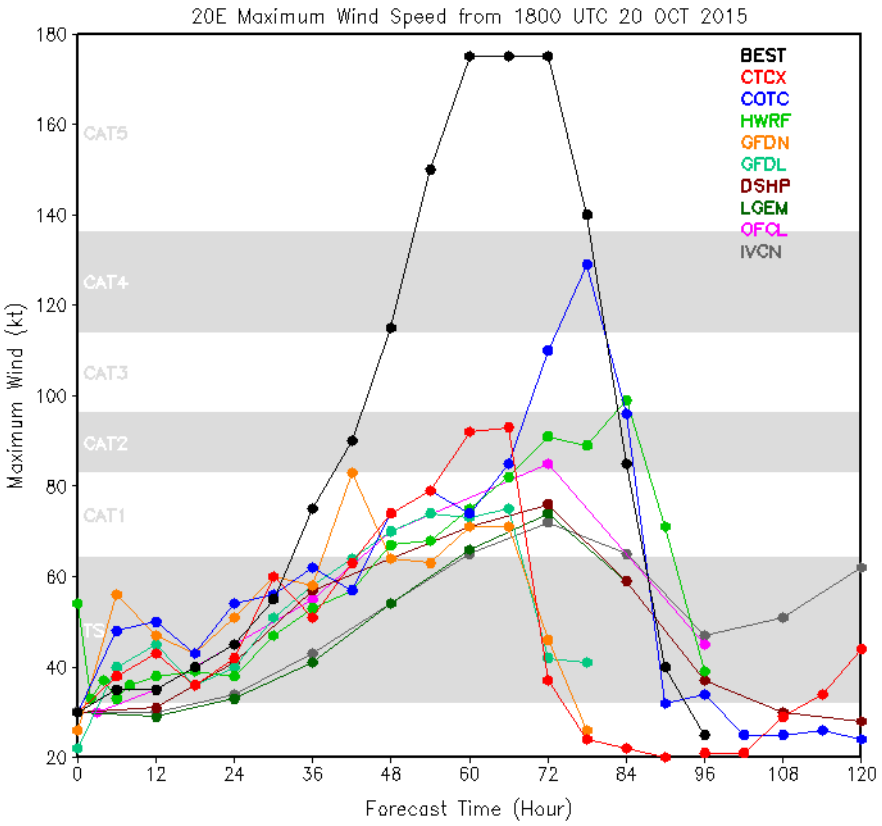
CTCX
HWRF
GFDL
COTC
GFS
NVGM

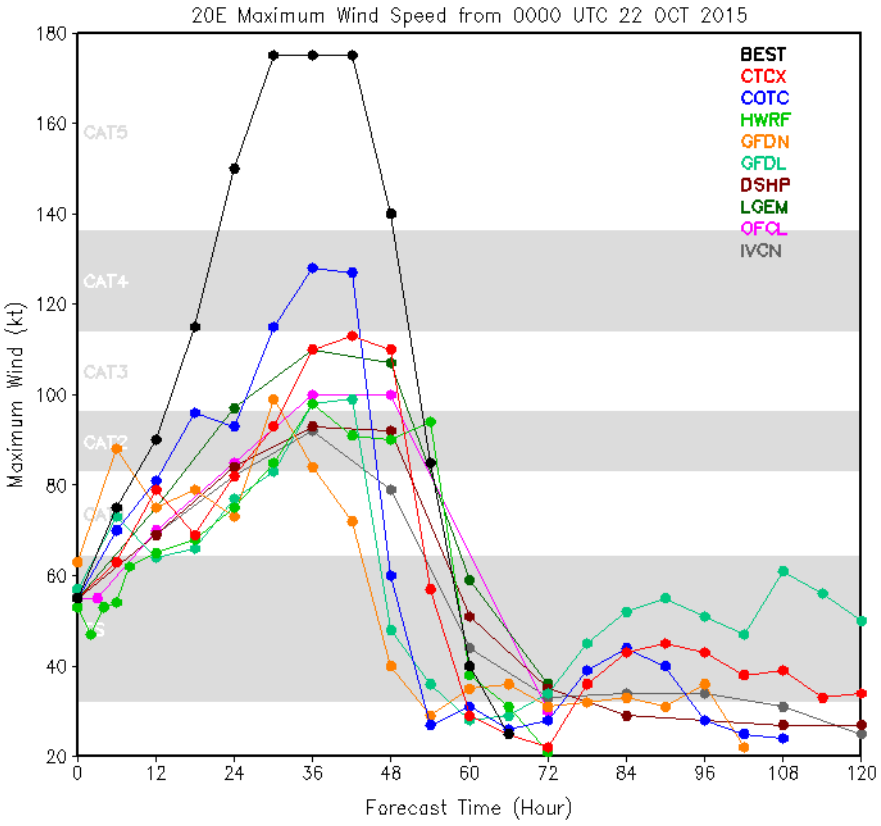
- CTCX track error is very close to GFS & HWRF; COTC track error is very close to NAVGEM
- CTCX intensity error better than COTC (>60h)

CTCX
HWRF
GFDL
COTC

COAMPS-TC 2015 Operational Statistics

E. Pacific Intensity: Patricia (20E)



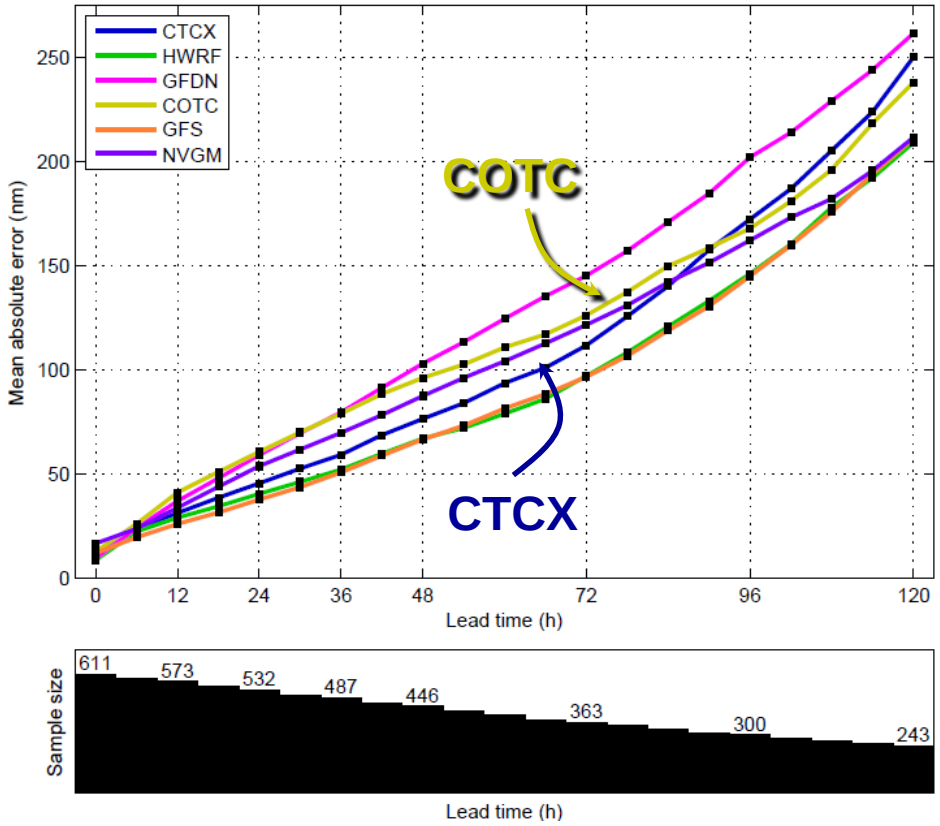


- **Many challenges regarding RI and it is unclear what the necessary physics, air-sea coupling, data assimilation needed to reliably predict a storm such as Hurricane Patricia.**
- **Models were indicating (rapid) intensification (but not rapid enough).**

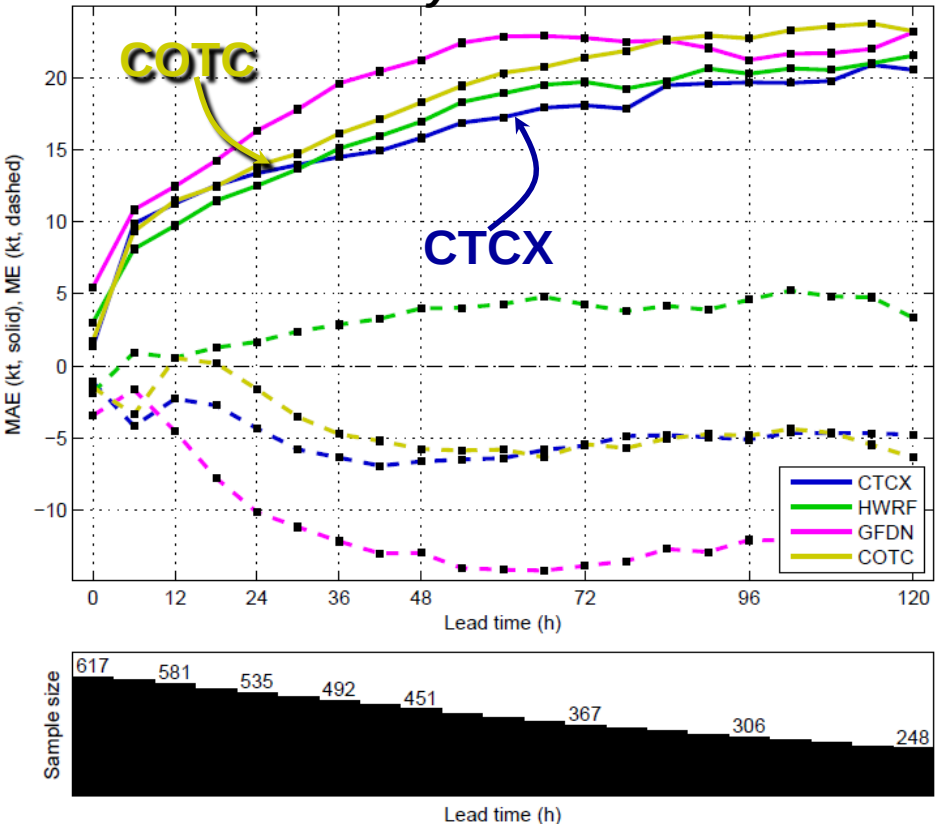
COAMPS-TC 2015 Operational Statistics

W. Pacific: 01-26W

Track MAE



Intensity MAE and ME



CTCX
HWRF
GFDN
COTC
GFS
NVGM

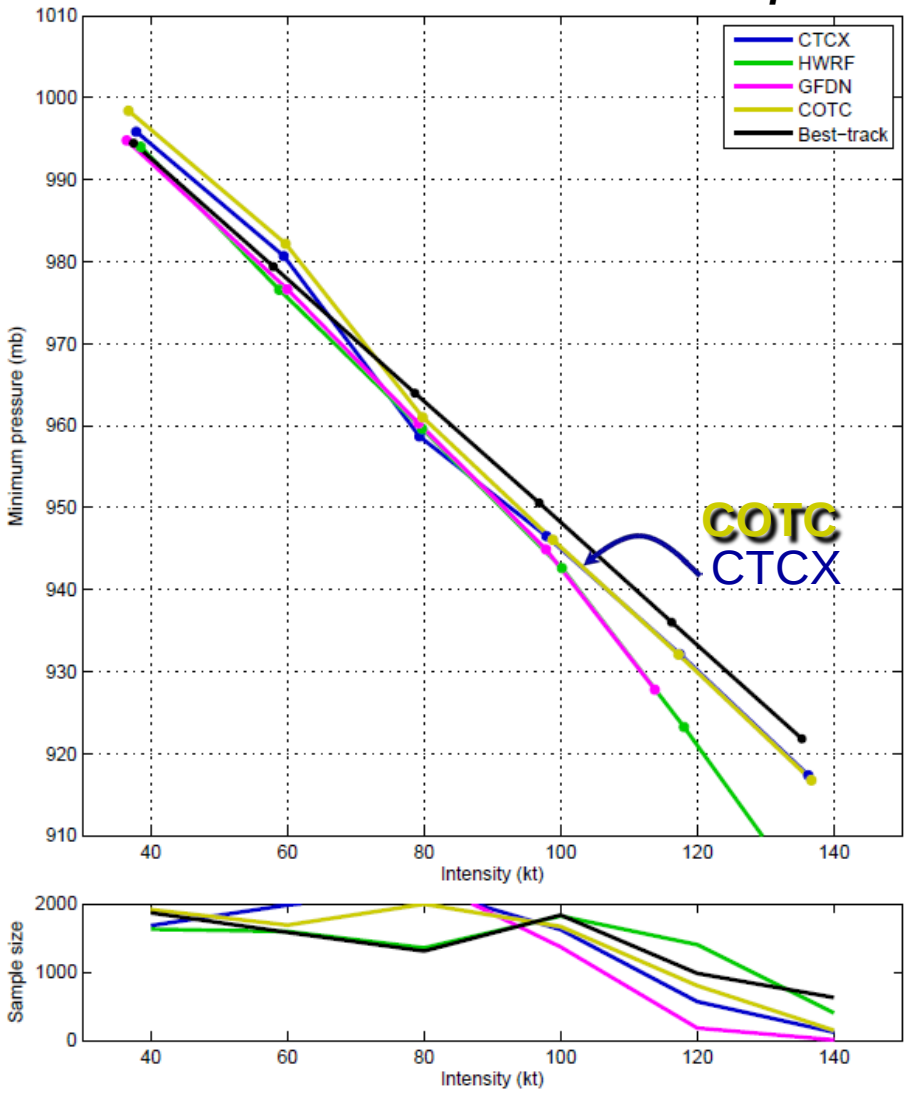
- **CTCX slightly worse track error than GFS; COTC track statistics similar to NAVGEM**
- **CTCX intensity errors are lowest among dynamical models**
- **CTCX and COTC has a low intensity bias**

CTCX
HWRF
GFDN
COTC

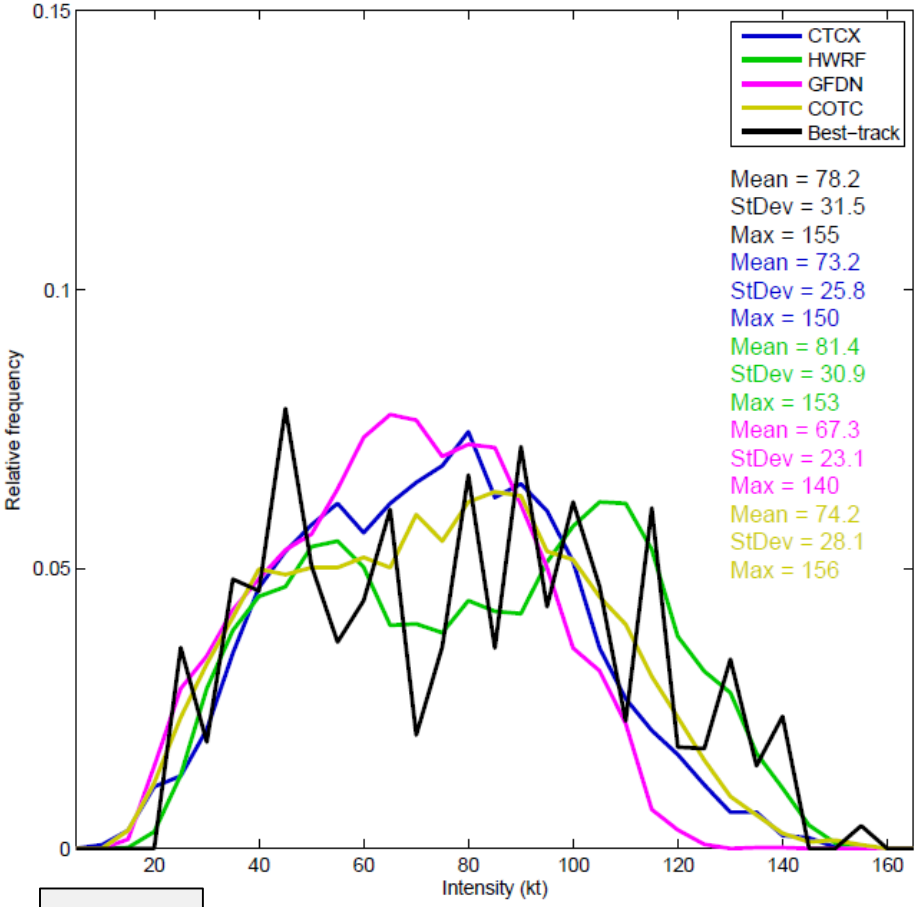
COAMPS-TC 2015 Operational Statistics

W. Pacific: 01-26W

Pressure-wind relationship



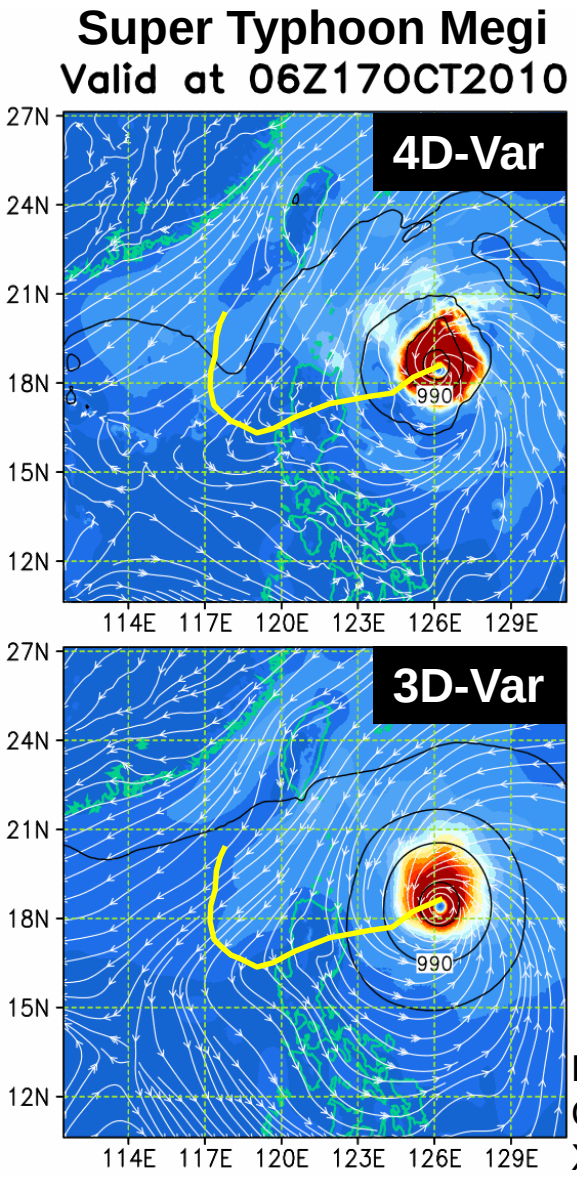
Intensity relative frequency distribution



CTCX
HWRF
GFDN
COTC
BEST

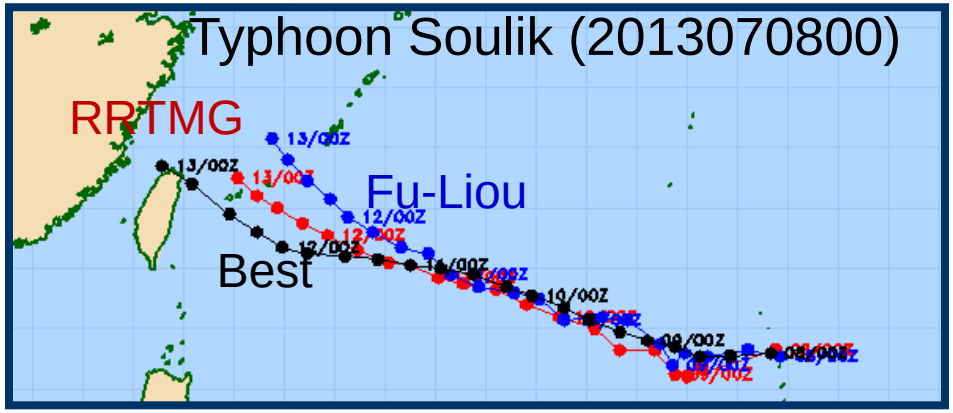
COAMPS-TC for 2016+

Data Assimilation and Physics Advancements



L. Xu
C. Amerault
X. Hong

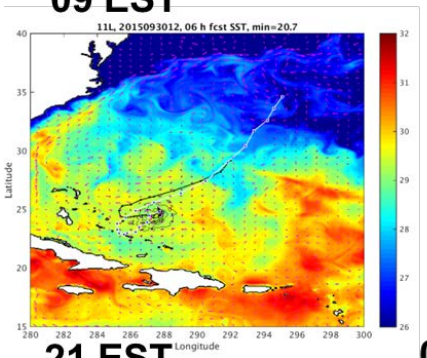
- **Vortex Initialization**
  - Improved vortex initialization
  - Vortex-scale assimilation
- **Data Assimilation**
  - 4D-Var testing is underway
- **New Physics Options Available**
  - New surface drag and PBL
  - RRTMG radiation
  - NRL & Thompson Microphysics
- **Air-Ocean-Wave Coupling**



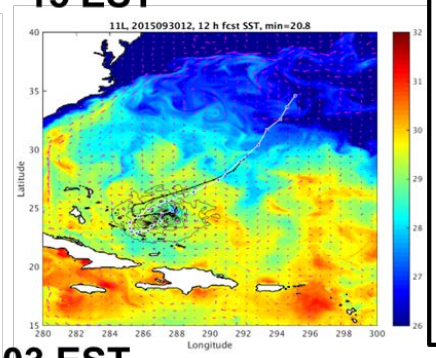
COAMPS-TC Air-Ocean Coupling

Joaquin SST

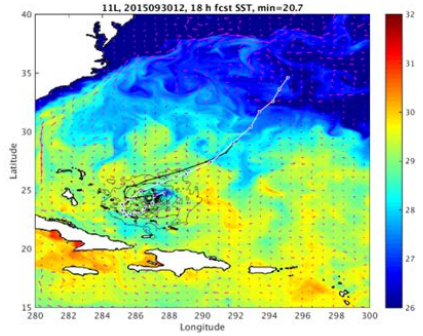
09 EST



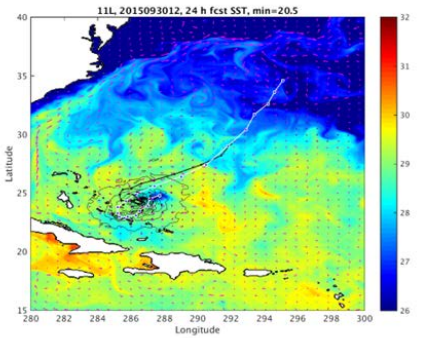
15 EST



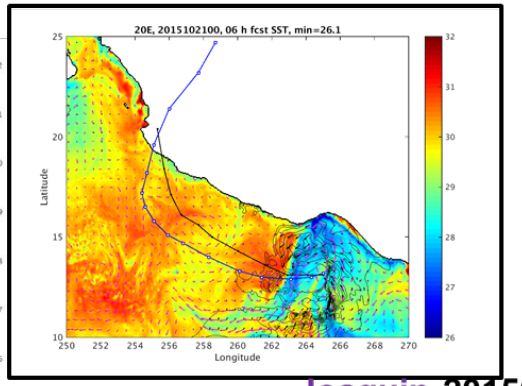
21 EST



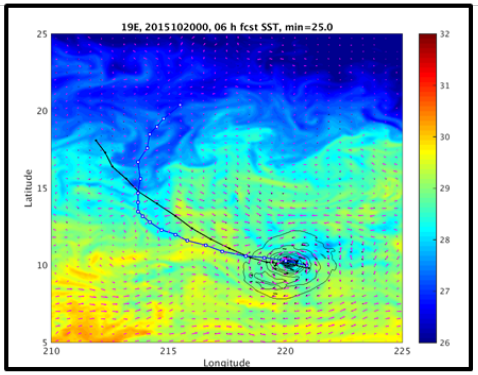
03 EST



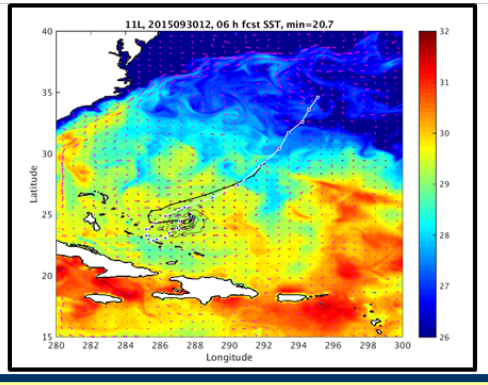
Patricia 2015102100
max wake SST cooling -3.7 °C



Olav 2015102000
max wake SST cooling -7.3 °C



Joaquin 2015093012
max wake SST cooling -3.2°C



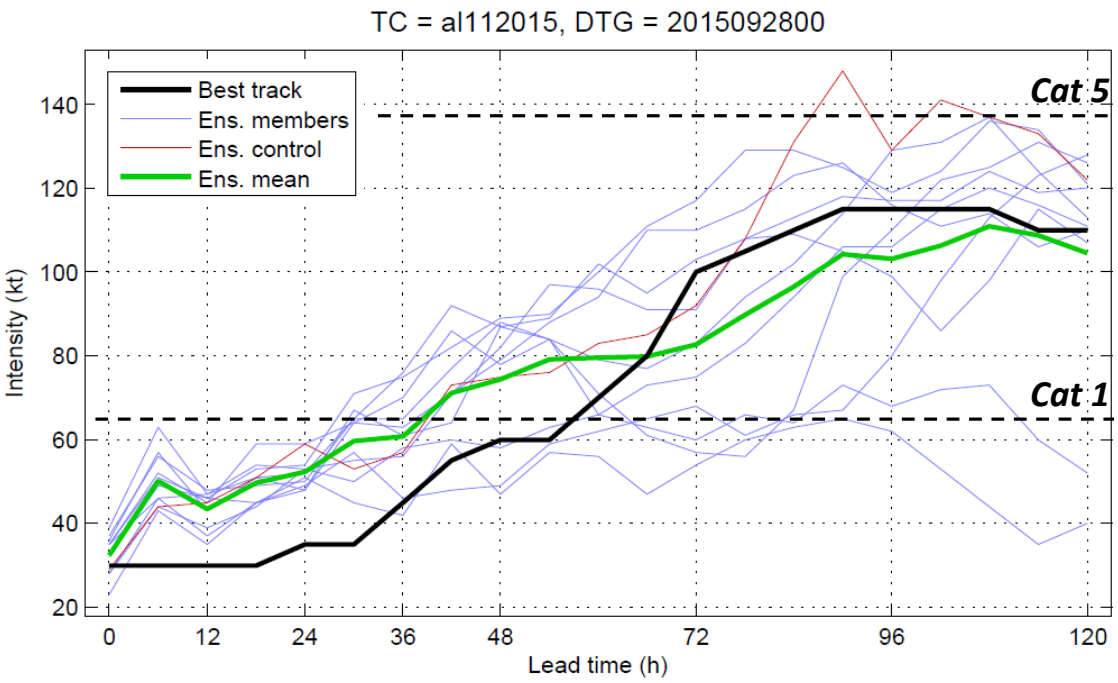
Sue Chen

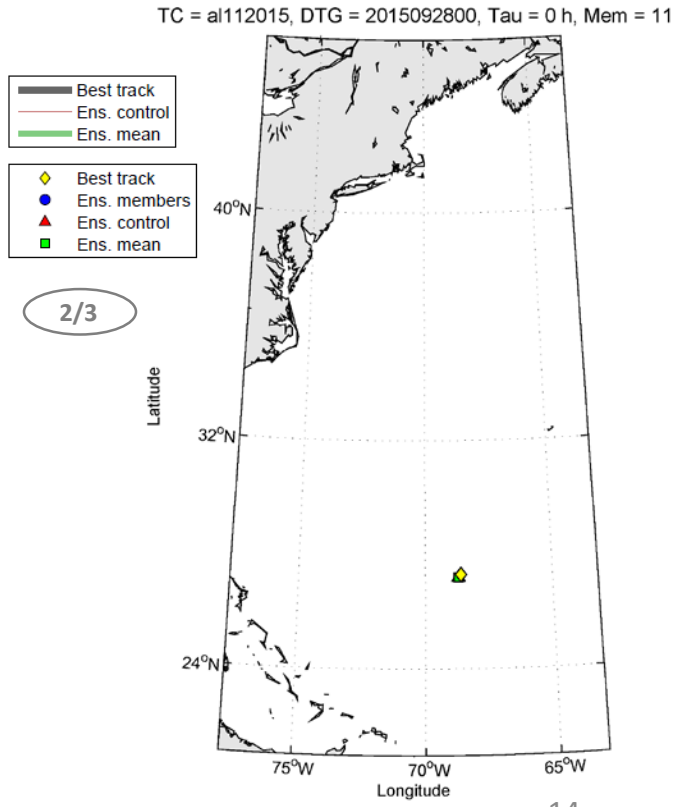
- **Real-time testing in 2015 in WATL and EPAC [Operational in 2016]**
- **Atmosphere: 45,15, 5 km, 40 levels**
  - **Ocean: 5 km, 45 sigma-z levels, 1 m upper layer**
  - **6 h update cycle (atmos & ocean); NAVGEM & HYCOM LBC**
- **Coupled model shows realistic diurnal SST cycle**
- **50% wind stress reduction to ocean; allowed for realistic SST cooling**

COAMPS-TC and HFIP Joint Ensemble
Real Time Demonstration in 2015

- **Real-time COAMPS-TC ensemble (3km) in 2015, joint with HWRF, GFDL**
- **COAMPS-TC & HWRF control consensus and ensemble mean outperform their single-model counterparts in deterministic validation**
- **Demo in 2014-2016; Navy Ops in 2017**

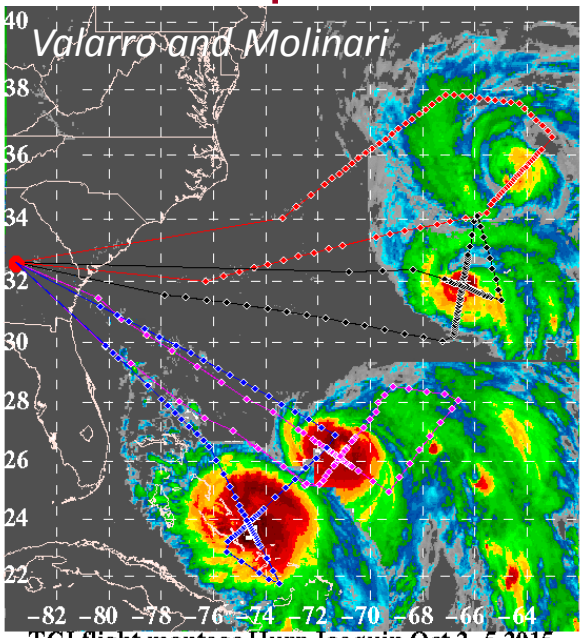
Real-time forecast example: Hurricane Joaquin (11L)





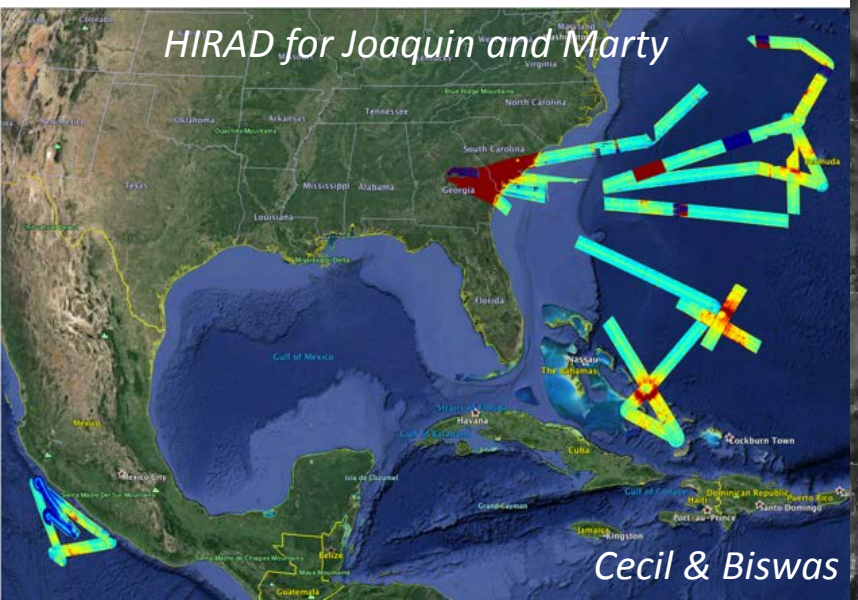
ONR Tropical Cyclone Intensity (TCI) 2015

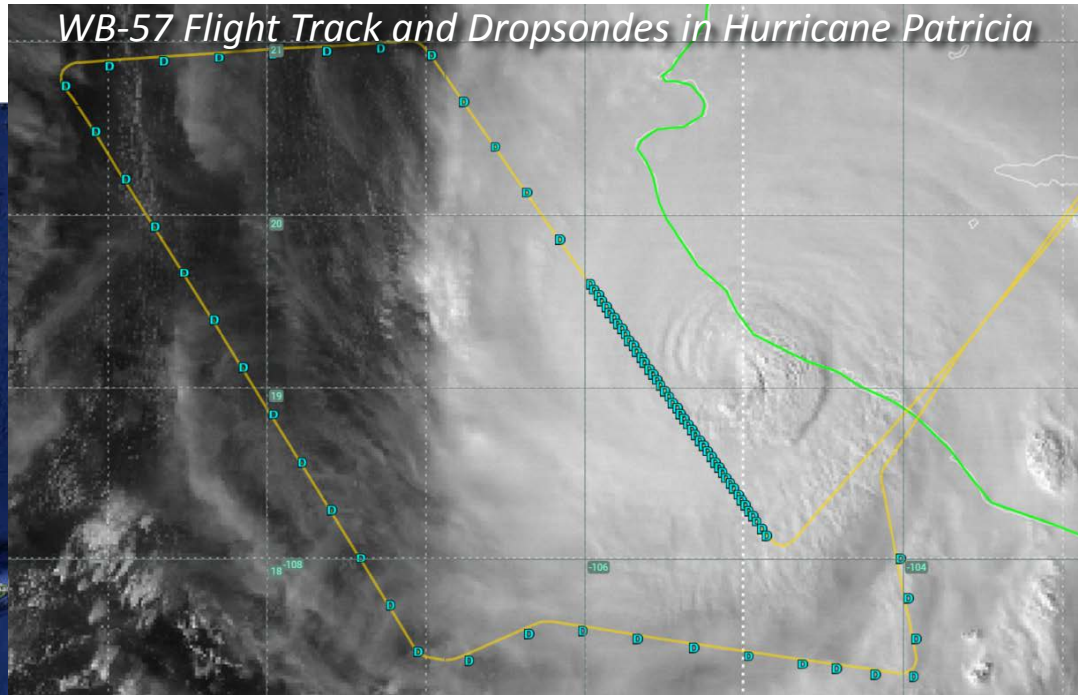
Unique Observations of Marty, Joaquin, Patricia



TCI flight montage Hurr Joaquin Oct 2–5 2015

- **Unprecedented set of dropsonde and HIRAD observations in Hurricanes Marty, Joaquin, Patricia**
- **~800 sondes deployed in 4 TCs in 11 WB-57 flights.**
- **Systematic high-resolution obs of inner core and outflow from 60 kft.**
- **Verification and DA experiments.**





COAMPS-TC
Summary and Future Plans

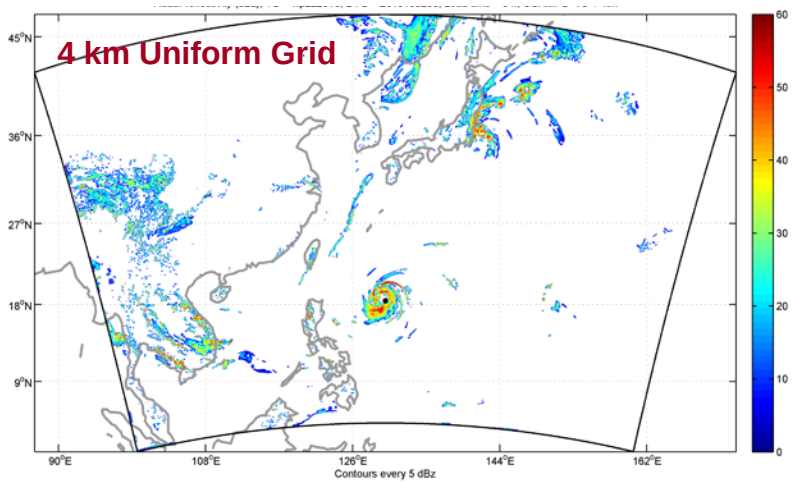
➢COAMPS-TC Much Improved for Track and Intensity in 2015:

- Improved "spin-down" and intensity error (new vortex initialization; new C_D param.)
- Improved track errors (new initialization; new terrain)
- Unified COAMPS-TC and COAMPS codes (one code for operations)
- Multi-model high-res. ensemble (NOAA/Navy) and air-ocean coupling promising.

➢COAMPS-TC Future Plans:

- 2016 Priorities (3-5 km resolution)
  - TC physics: new PBL (EDMF), refinement to C_D parameterization
  - Analysis: Improvements to vortex initialization
  - Coupling: Ocean (NCOM), ocean DA with NCODA
  - Ensemble: 3 km ensemble (w/ HFIP): WATL, EPAC, WPAC (11 member)
- 2017+ Priorities
  - TC physics: Emphasis on PBL, fluxes, microphysics
  - Analysis: 4D-Var/EnKF, satellite DA
  - Ensemble: Stochastic physics
  - Coupling: Ocean, waves, coupled DA
  - Resolution: i) ~1 km (nest following) ii) ~4 km basin scale
- Utilize field observations: ONR TCI,NASA HS3…

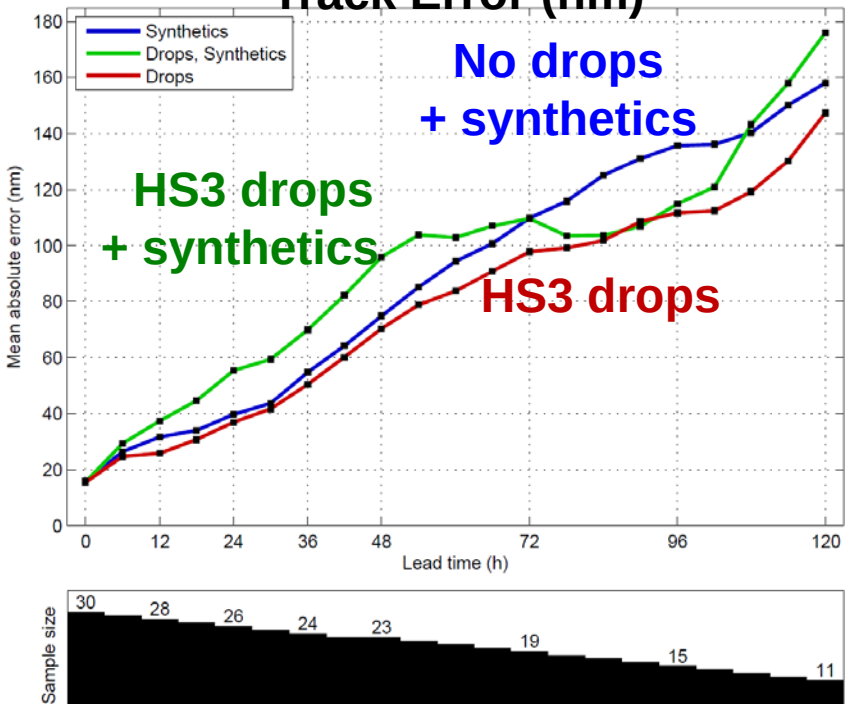
6-120h Simulated Radar Reflectivity (00Z 2 Oct 2013)



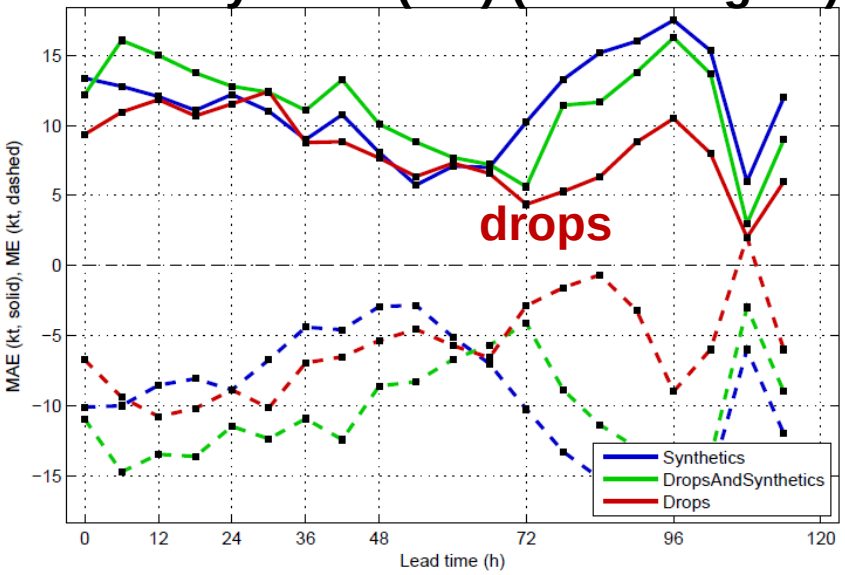
COAMPS-TC Dropsonde Impact

Impact of NASA HS3 Dropsondes (Edouard)

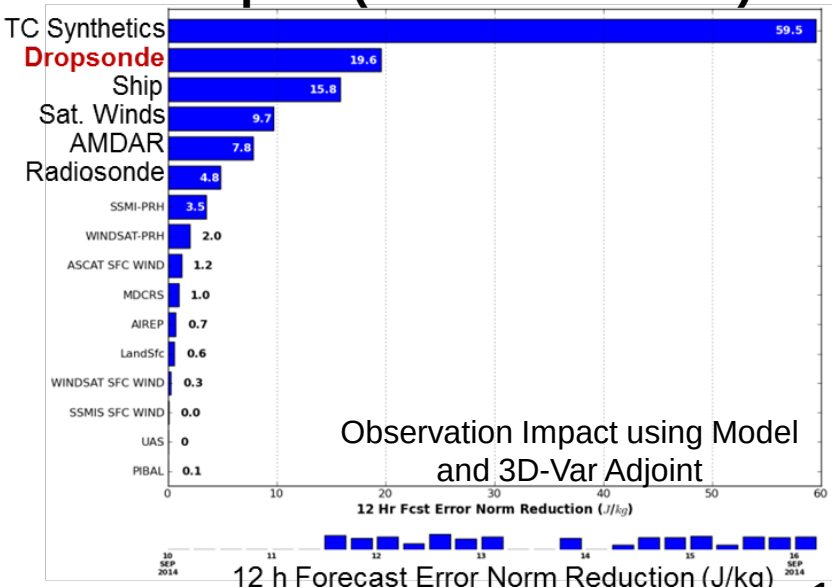
Track Error (nm)



Intensity Error (kts) (2nd-3rd flights)



Impact (Per Observation)

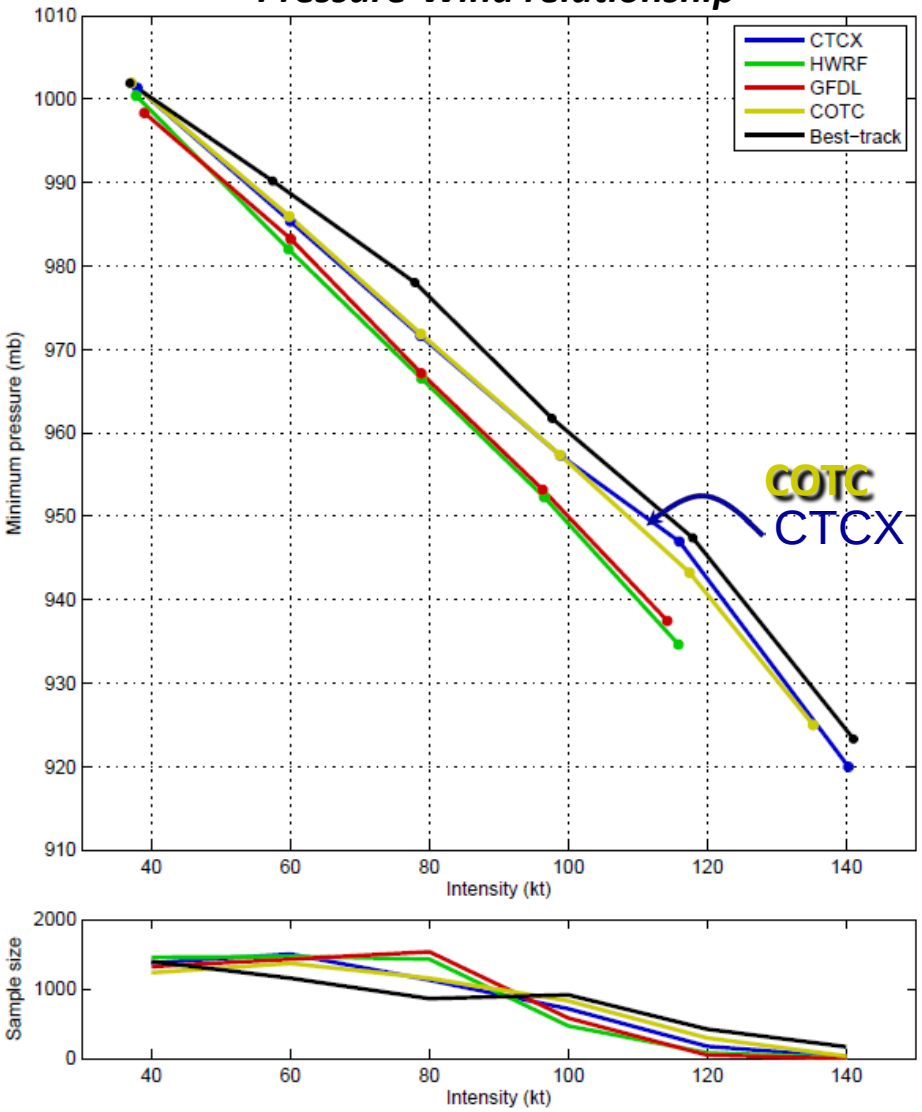


- Improved COAMPS-TC track using drops.
- 2nd & 3rd flights had very good coverage.
- Intensity improved for 2nd 3rd flights.
- Obs impact shows importance of drops.
- ONR TCI & NOAA SHOUT impacts in 2015.
- Other HS3 cases with marked improvement (Nadine, Leslie, etc.)

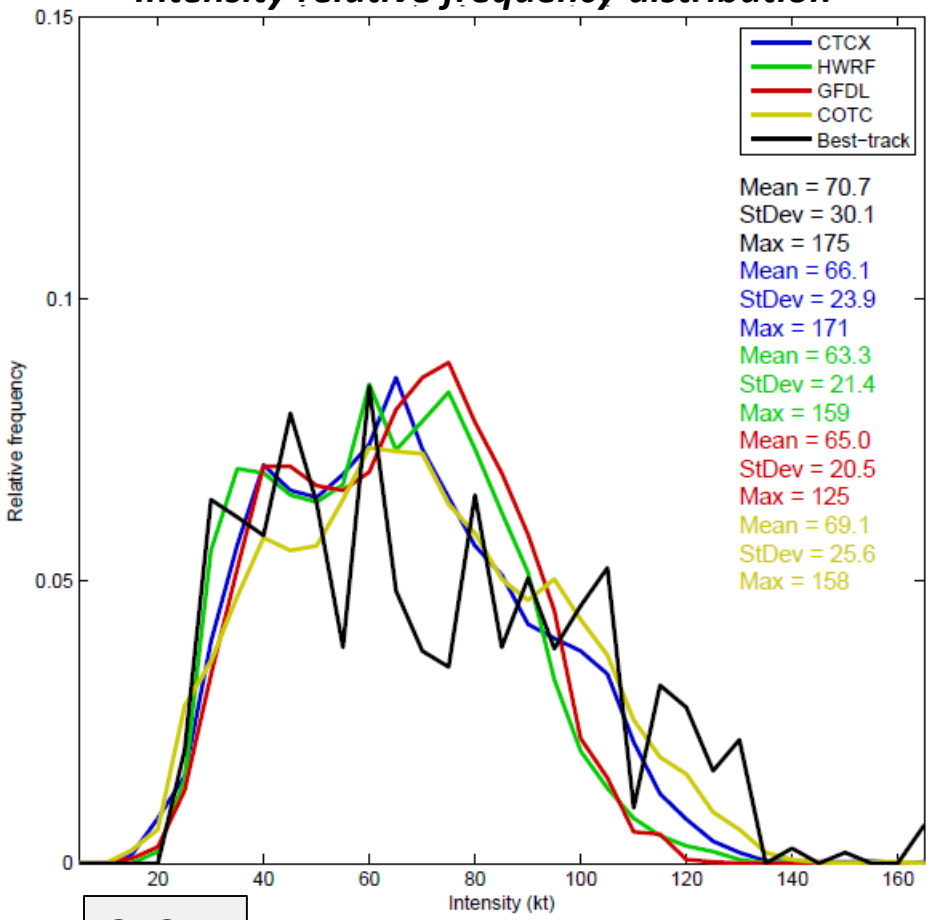
COAMPS-TC 2015 Operational Statistics

E. Pacific: 01-20E

Pressure-Wind relationship



Intensity relative frequency distribution



CTCX
HWRF
GFDL
COTC
BEST

COAMPS-TC 2015 System Overview

Improved Vortex Initialization

Issue

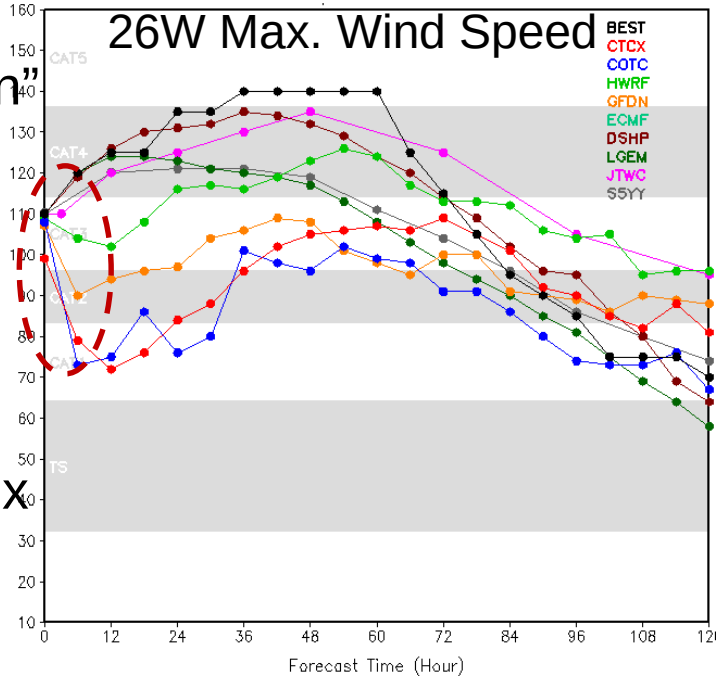
Vortex initialization often suffers from a "spin-down" or "spin-up" of intensity in first 12-h of forecast.

Solution

Introduce a 3D balanced vortex in COAMPS-TC

Key Findings

- V_{max}, RMW, R_{34},depth estimates needed for vortex.
- Non-linear balance eqn. used with BL theory.
- Sloping eyewall & sheared flow can be included.
- Method alleviates the spin-down of intensity.



Example

East-west vertical cross-sections of v-wind (left) and time series of V_{max} for ST Francisco (26W/2013)

V-component for 26W