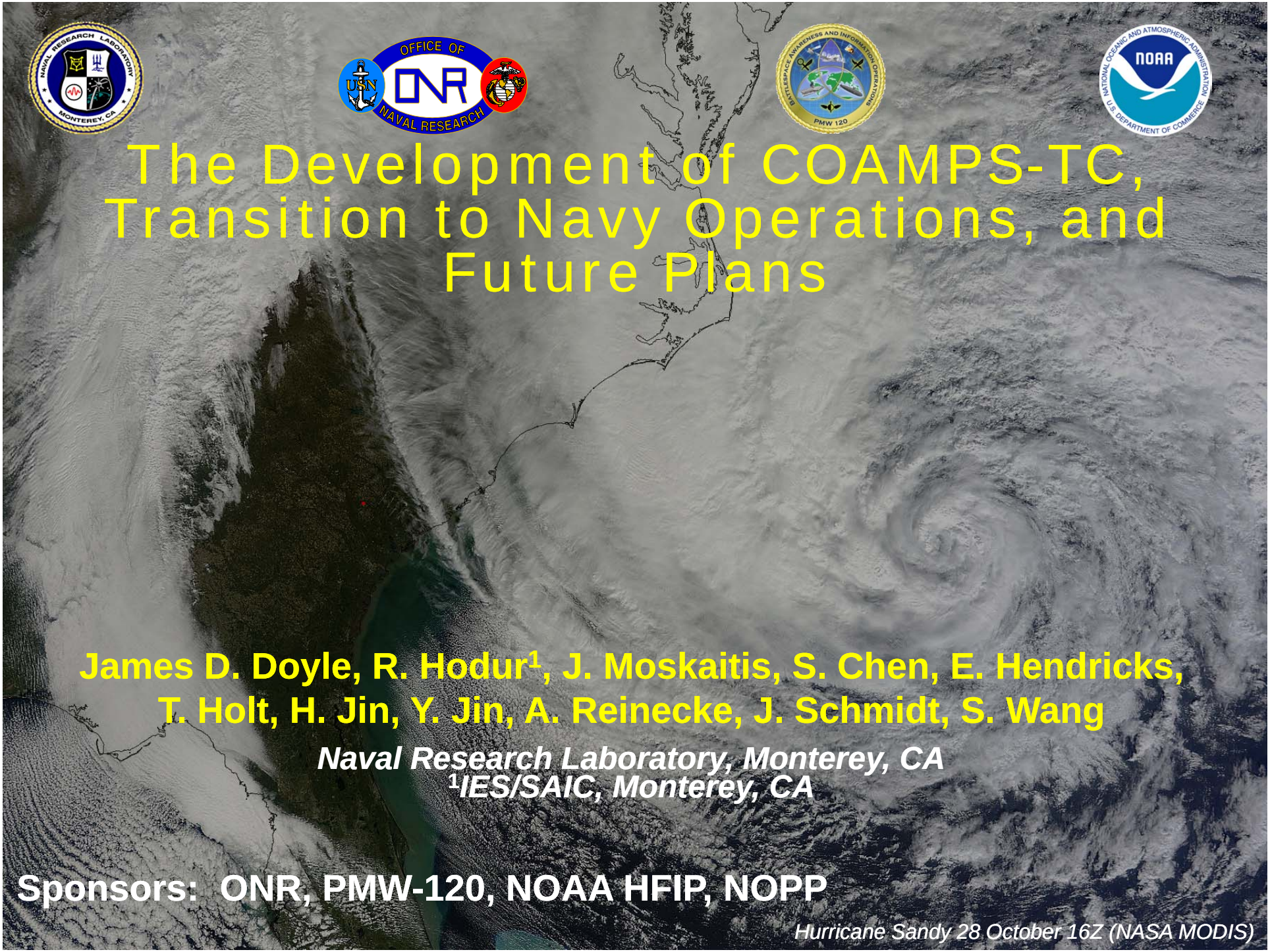

The Development of COAMPS-TC, Transition to Navy Operations, and Future Plans

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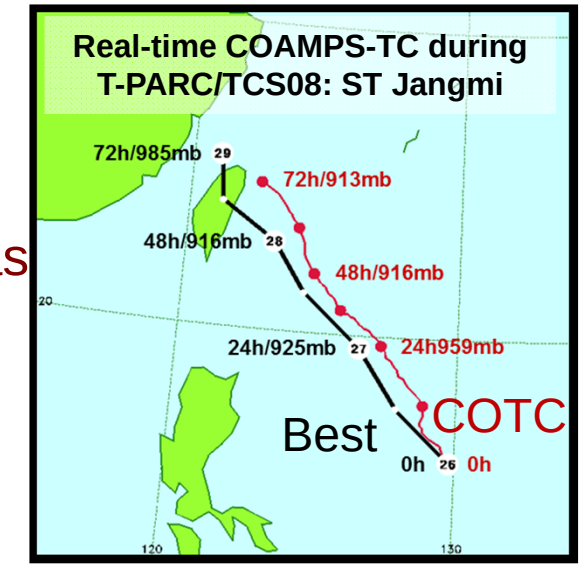
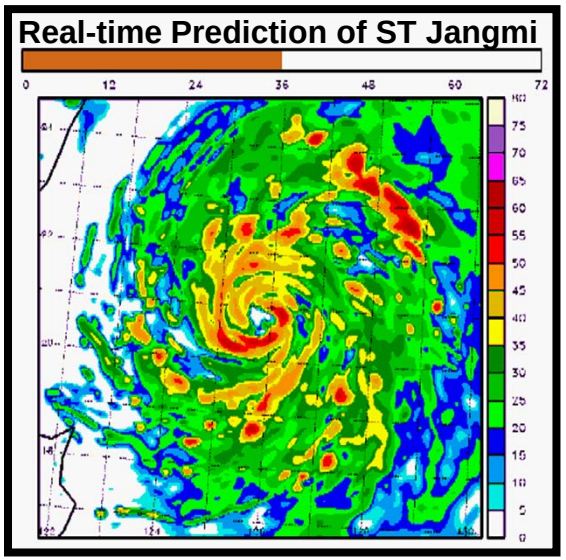
Sponsors: ONR, PMW-120, NOAA HFIP, NOPP

Hurricane Sandy 28 October 16Z (NASA MODIS)

COAMPS-TC System Development

- COAMPS-TC development began in FY2008 and greatly benefited from building on the operational COAMPS system, which is robust and run worldwide in operations at FNMOC (70+ areas).
- NRL used *rapid prototyping* to accelerate development and transition.
  - Real-time demonstration in the first year of development for T-PARC/TCS-08 to support field operations.
  - Subsequent real-time prototyping for JTWC 2009-2012.
  - As skill was established, JTWC used COAMPS-TC for consensus tools, forecasting.
  - Stream 1.5 testing as part of HFIP; feedback from NHC.
- Coordinated with JTWC and NOAA HFIP - received valuable feedback.
- A cost effective transition was accomplished using this strategy.



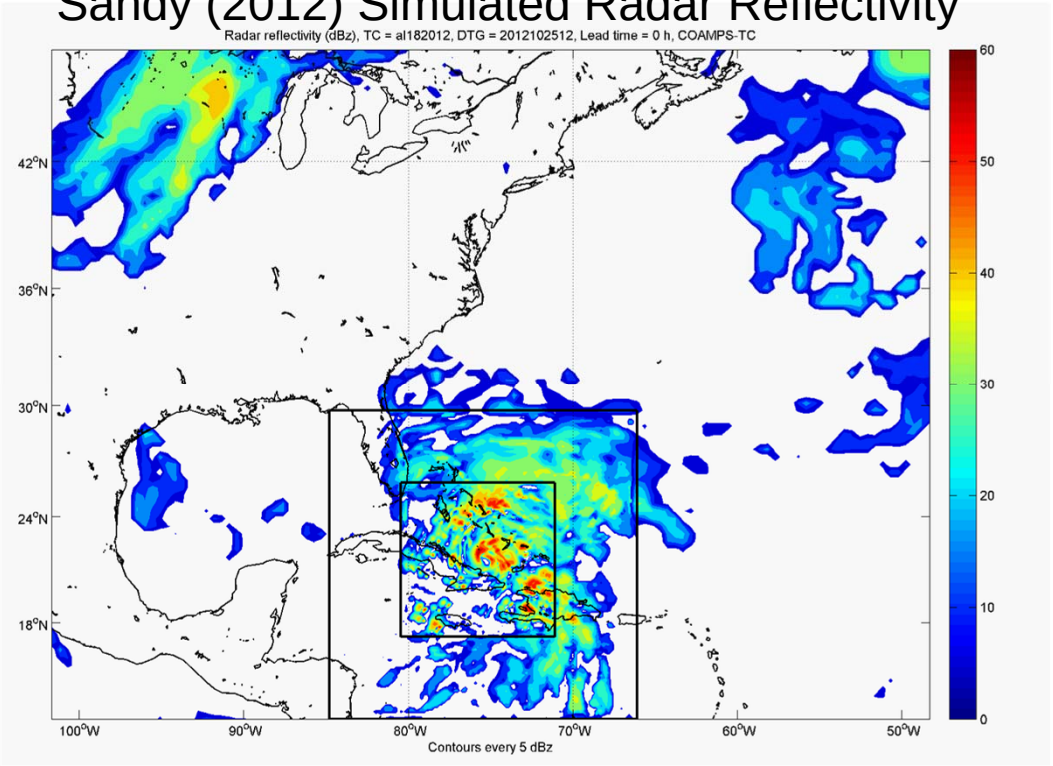


COAMPS-TC System Overview

- Analysis: **3D-Var (NAVDAS), synthetic observations**
- Atmosphere: **Nonhydrostatic, moving nests, TC physics**
- Ocean: **3D-Var (NCODA), ocean (NCOM), wave (SWAN, Wave Watch III)**
- Ensemble: **COAMPS-TC EnKF DART, Coupled Ensemble Transform**
- Real-Time **Navy & NOAA HFIP prototyping activities**

Ops, Testing: **45-15-5 km, GFS/NAVGEM BCs, cycling DA, uncoupled/coupled**

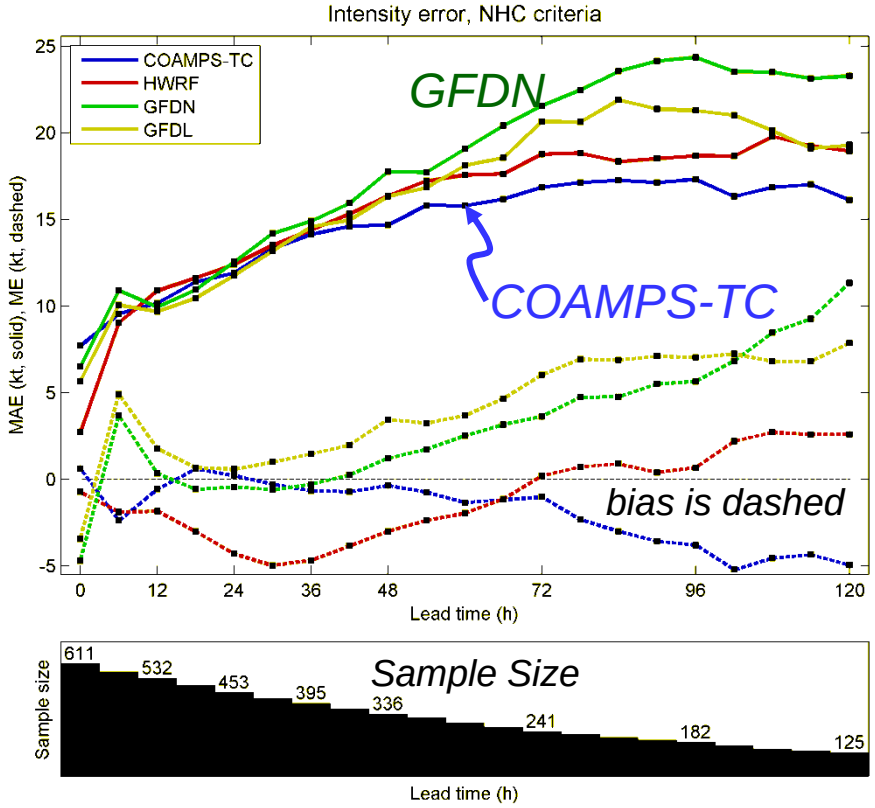
Sandy (2012) Simulated Radar Reflectivity



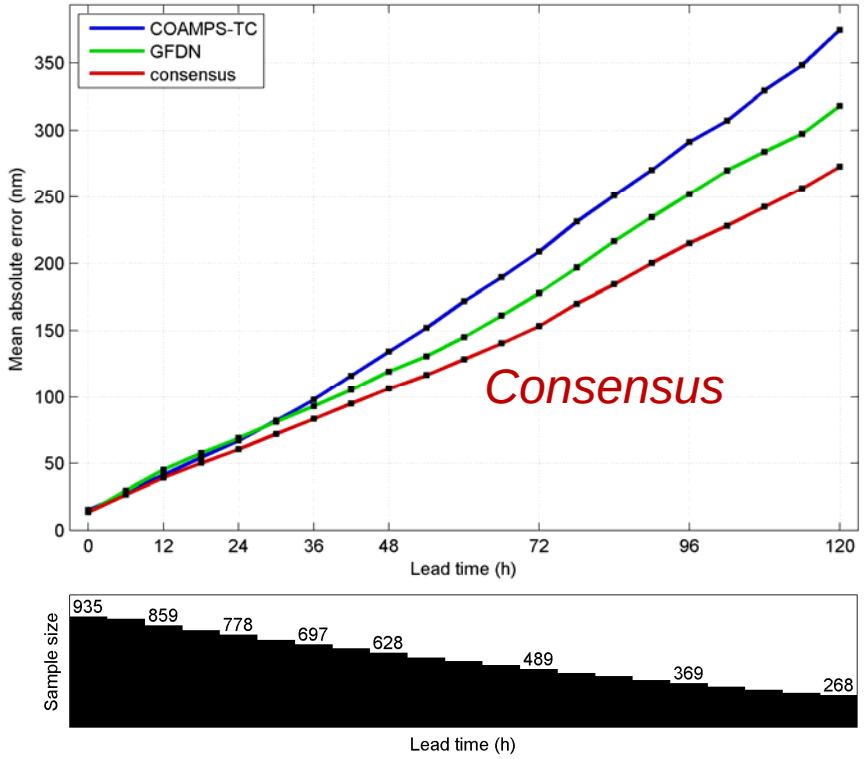
COAMPS-TC Transition to Navy Ops

- **Recommendation by validation test panel for transition to FNMOC in FY2012(2Q) based on TC scorecard (includes intensity and track metrics)**
- **Operational at FNMOC worldwide for all basins in June 2013.**
- **Note benefit of having multiple models (COAMPS-TC, GFDN) as a simple demonstration of the need for a multi-model consensus**

W. ATL Intensity (Wind) Error (Kts)
2010-2011



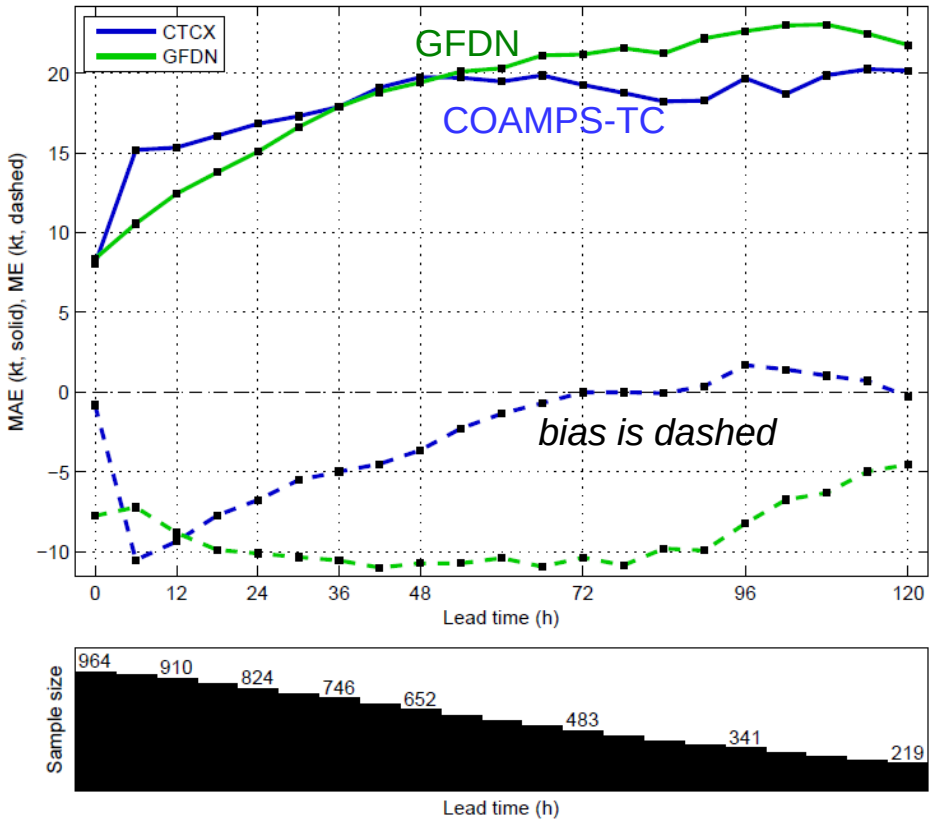
W. PAC Track Error (nmi)
2009-2011



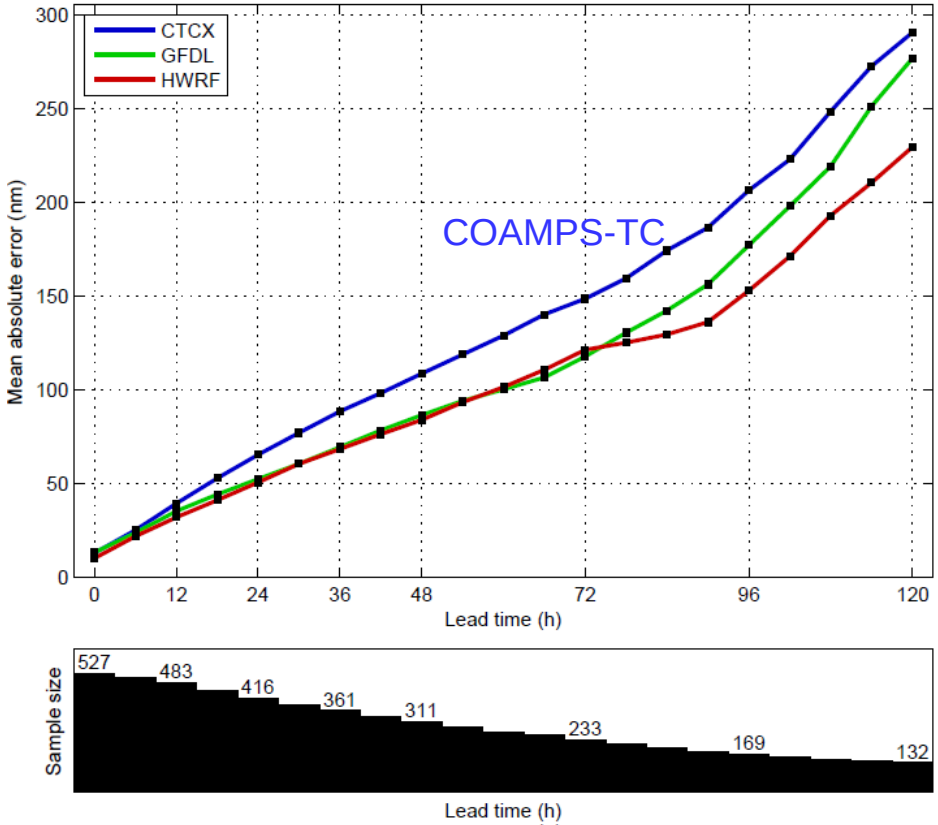
W. Pacific and W. Atlantic Intensity Error

Real-Time Forecasts

W. Pacific Intensity Error (kt) 2012-2013



W. Atlantic Track Error (nmi) 2012-2013



- **COAMPS-TC (CTCX) real-time intensity forecasts in W. Pacific and W. Atlantic are competitive with the other operational models.**
- **Track needs improvement (regional models often lag global models)**

Improved COAMPS-TC Large-Scale Analyses

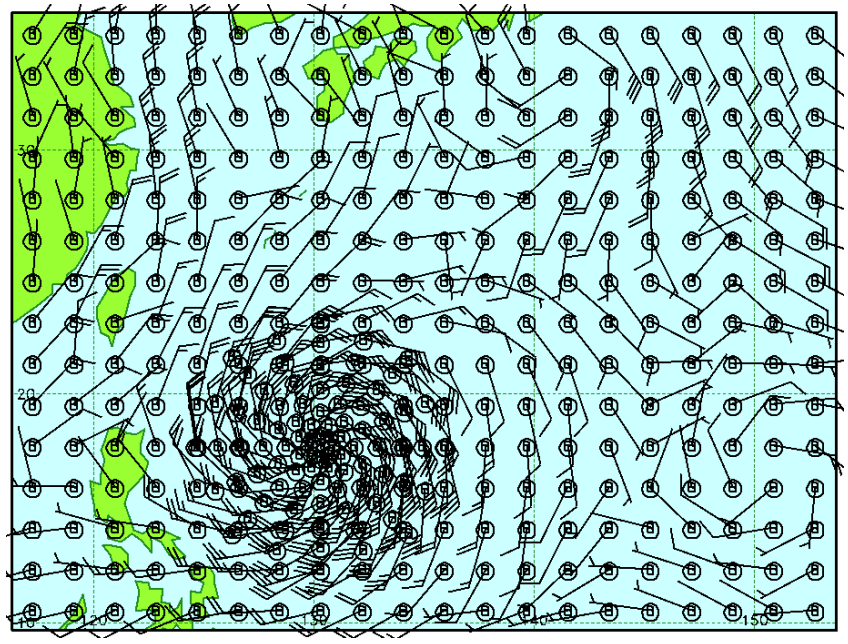
Problem

- Track forecasts in COAMPS-TC are less skillful than other operational models
- Global models assimilate more observations (satellite) than regional models.

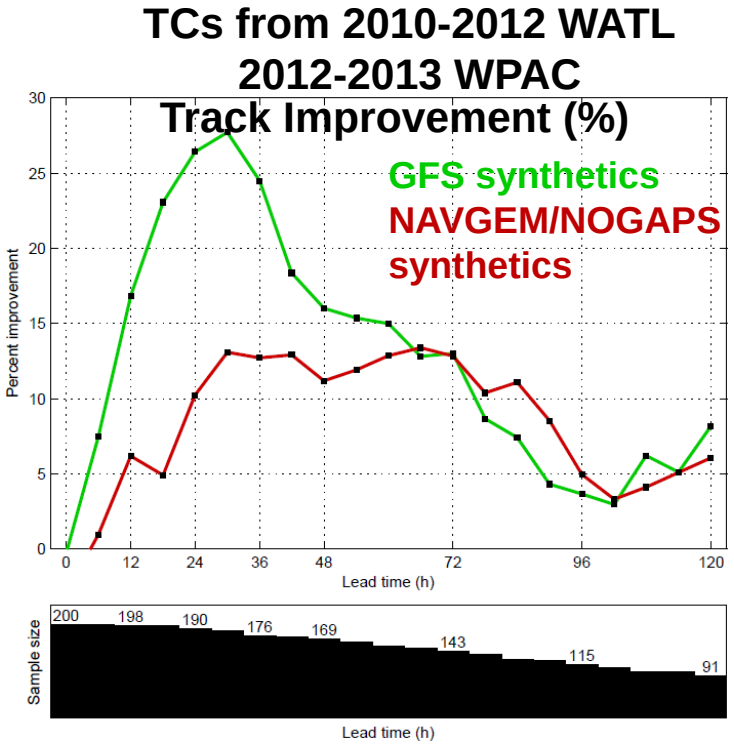
Solution

Create synthetic profiles of u, v, T, and q from NAVGEM & GFS and assimilate

Synthetics are positioned every 4th COAMPS-TC grid point



Sample distribution of global and TC 1000 mb wind synthetics for a portion of the COAMPS-TC coarse mesh



COAMPS-TC track forecasts are improved using either GFS- or NAVDAS-generated synthetics

Improved Initialization of the COAMPS-TC TC Vortex

Problem

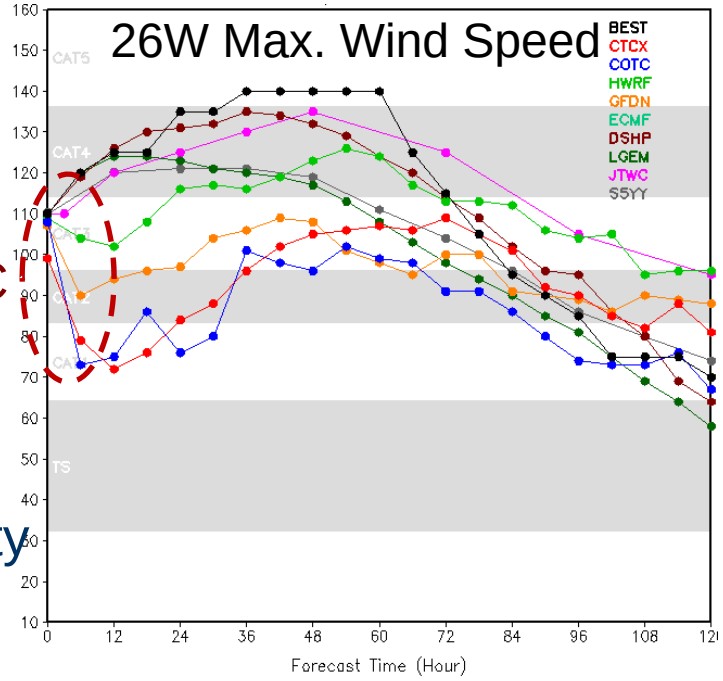
Vortex initialized in models often suffers from a "spin-down" or "spin-up" of intensity in first 12-h

Solutions

1. Introduce a 3D balanced vortex in COAMPS-TC
2. Dynamical Initialization (TCDI)

3D-Balanced Vortex

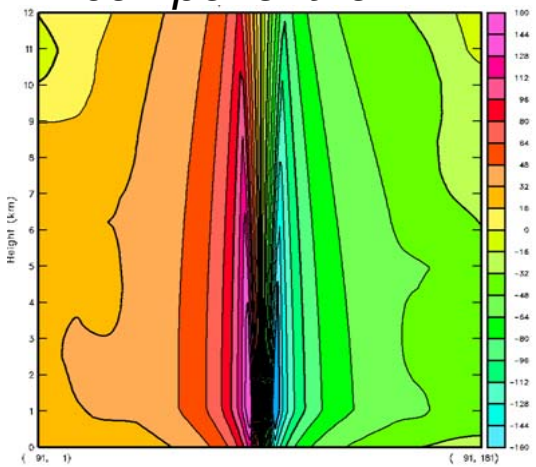
- Use observed V_{max}, RMW, R_{34} to create vortex
- Depth of vortex based on observations or intensity
- Boundary layer theory applied in the lowest 1 km
- Can include sloping eyewall and sheared flow
- Mass field derived using a non-linear balance eqn.

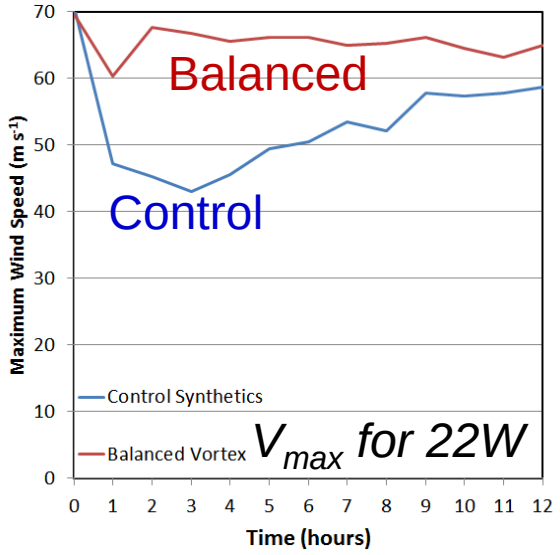


Example

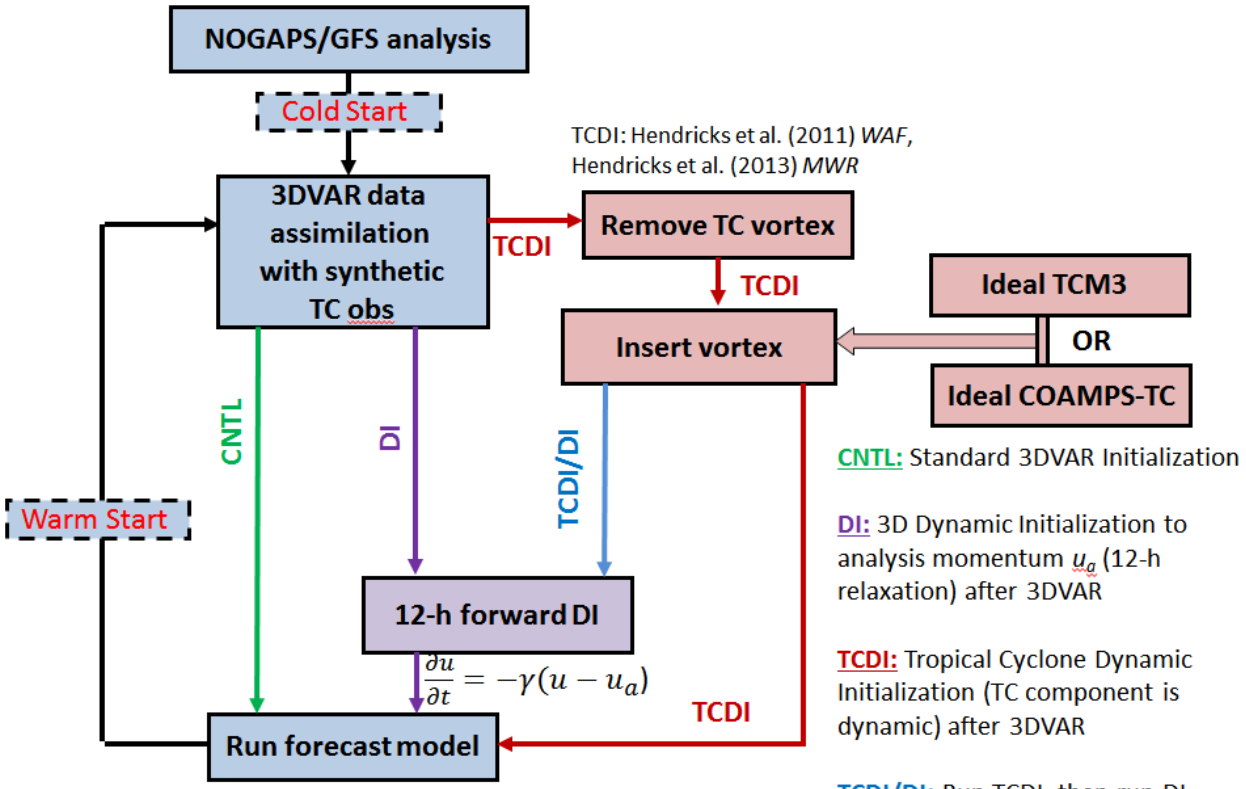
North-south vertical cross-sections of v-wind (left) and time series of V_{max} for ST Francisco (26W/2013)

V-component for 22W





Dynamical Initialization in COAMPS-TC



TCDI: Hendricks et al. (2011) *WAF*, Hendricks et al. (2013) *MWR*

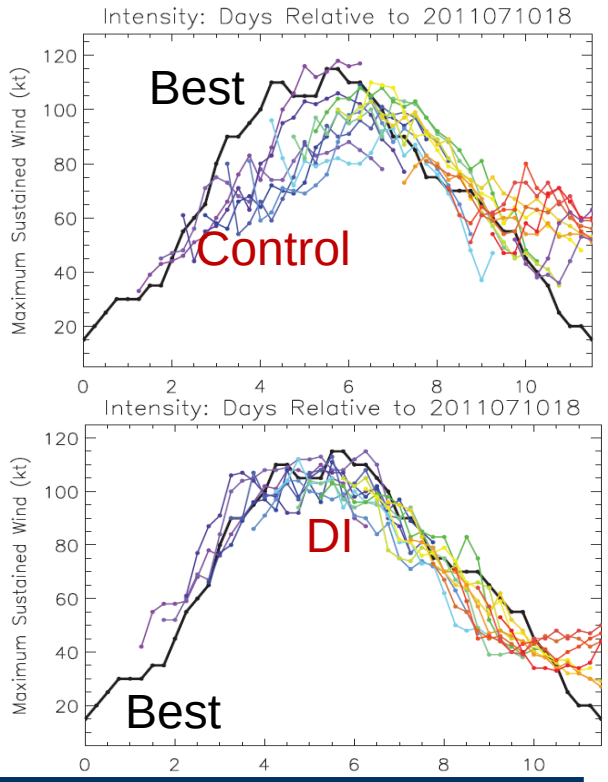
CNTL: Standard 3DVAR Initialization

DI: 3D Dynamic Initialization to analysis momentum u_a (12-h relaxation) after 3DVAR

TCDI: Tropical Cyclone Dynamic Initialization (TC component is dynamic) after 3DVAR

TCDI/DI: Run TCDI, then run DI

Typhoon Ma-On (2011)
Intensity (kts)



- New dynamical initialization algorithm has been developed.
  - Uses a balanced vortex that is consistent with COAMPS-TC (5 km resolution)
  - Correct initial size & intensity, relaxation for secondary circulation to develop.
- Dynamical initialization improves the track & especially intensity (>20%) forecasts.
- Currently under further testing/development with real-time prototyping in 2014.

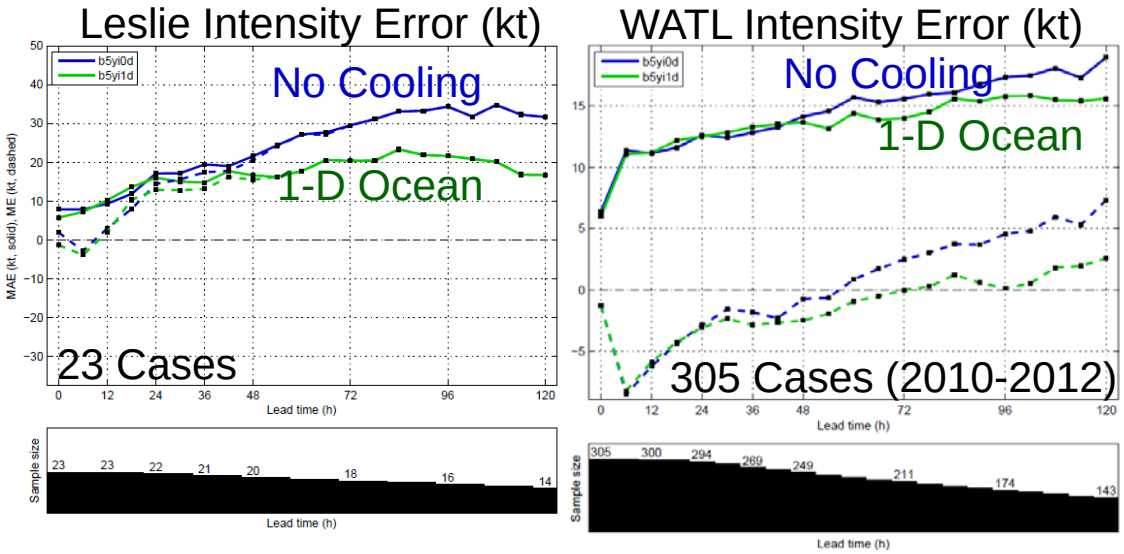
COAMPS-TC Air-Ocean-Wave Coupling

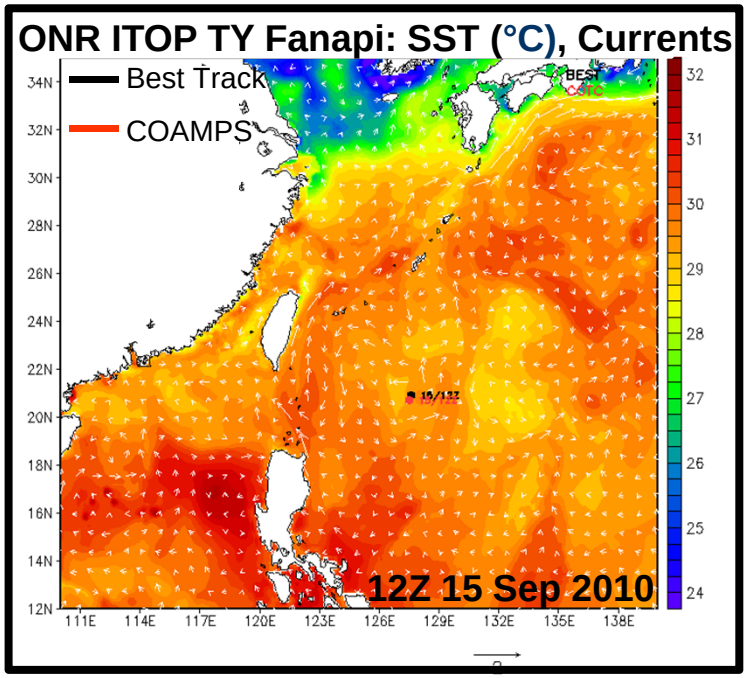
Problem

Air-sea interaction is important for TC intensity

Solutions

1. Introduce 1-D mixed layer cooling (interim)
2. Full air-ocean-wave coupling using ESMF





Coupled Real–Time COAMPS-TC Predicts SST Wake of 2-4°C in Agreement with Observations

- **COAMPS contains a community based (ESMF) coupler to facilitate flexible and generalized exchange between components.**
- **1-D ocean mixed layer model used in the interim prior to 3-D ocean.**
- **Air-Sea (COAMPS-NCOM) coupling testing in FY14.**
- **Air-Sea-Wave (COAMPS-NCOM-WWIII) transition in FY15.**

COAMPS-TC Tropical Cyclone Physics

Problem

Synoptic-scale at days 4-5 is not predicted adequately leading to track errors.
Rapid intensification & intensity of strongest storms (Haiyan) often not captured.

Solutions

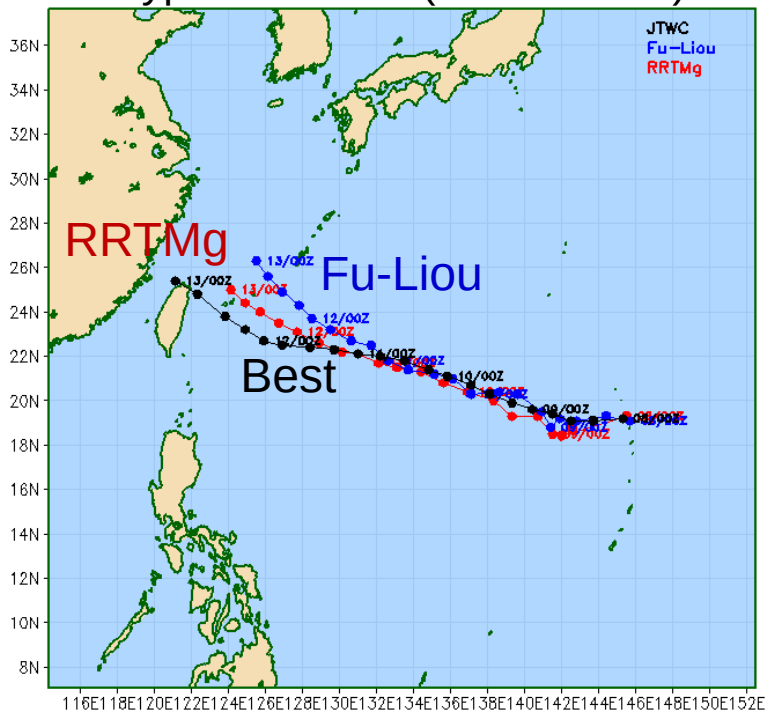
Improve the key TC physical parameterizations in COAMPS-TC.

RRTMg Radiation Testing

- High radiation top at 0.0001 hPa
- Snow-radiation interaction considered
- Initial tests show positive impact on track

- **Upgrade COAMPS-TC physics for both inner-core and synoptic-scales**
  - **RRTMg radiation**
  - **New NRL & Thompson microphysics**
  - **Shallow convection (UW, ED/MF)**
  - **Upgrade to COAMPS-TC PBL**
  - **SAS convection**

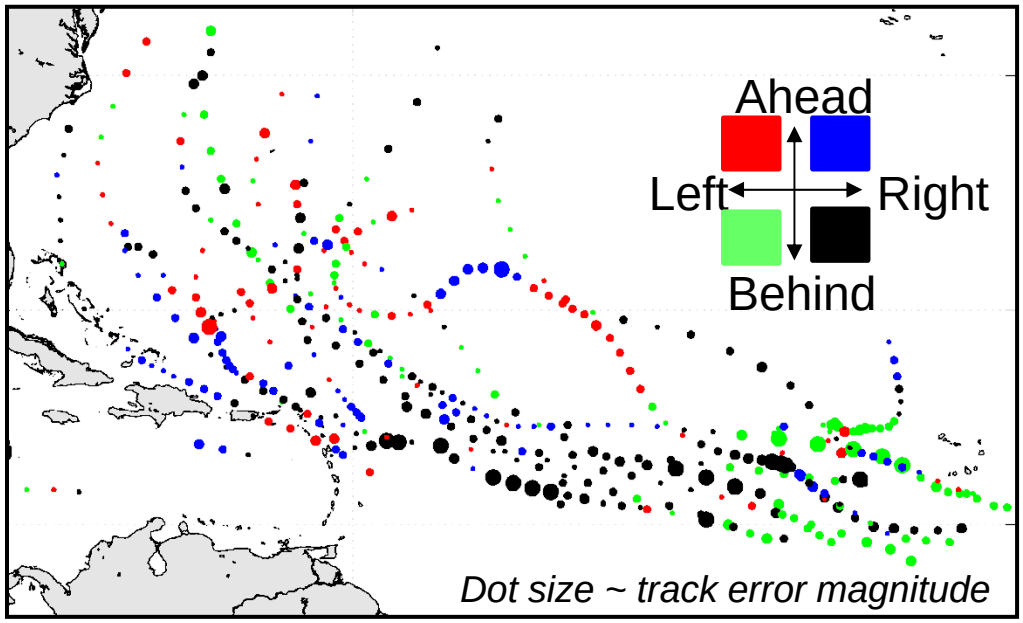
Typhoon Soulik (2013070800)



New COAMPS-TC Diagnostics

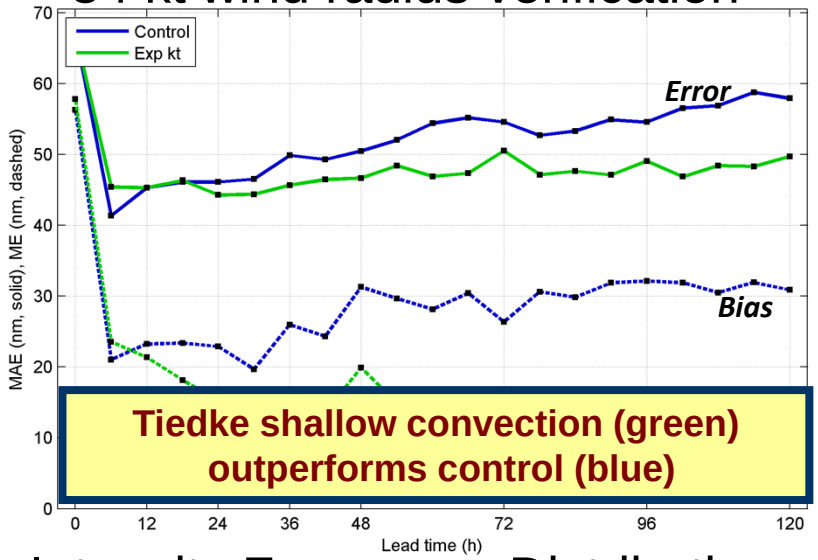
New diagnostics are needed to move beyond the forecast track & intensity

Scatter of best-track positions at forecast initial time, color/size denotes COAMPS-TC 24 h forecast track error characteristics



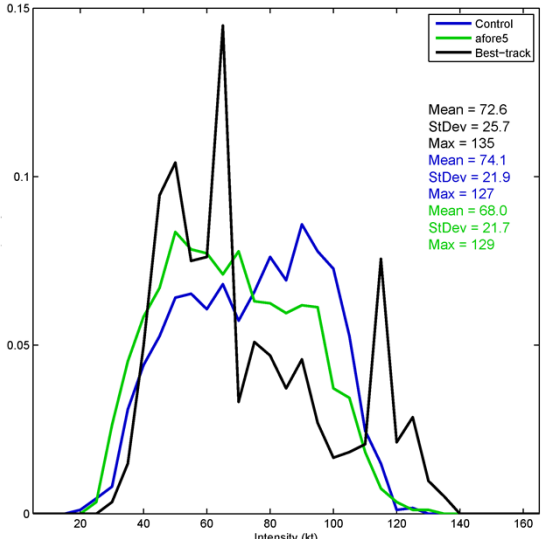
- **COAMPS-TC tracks are consistently slow/left in eastern tropical Atlantic and slow/right in central tropical Atlantic.**
- **These regions also tend to have the largest 24 h track errors.**

34 kt wind radius verification



Tiedke shallow convection (green) outperforms control (blue)

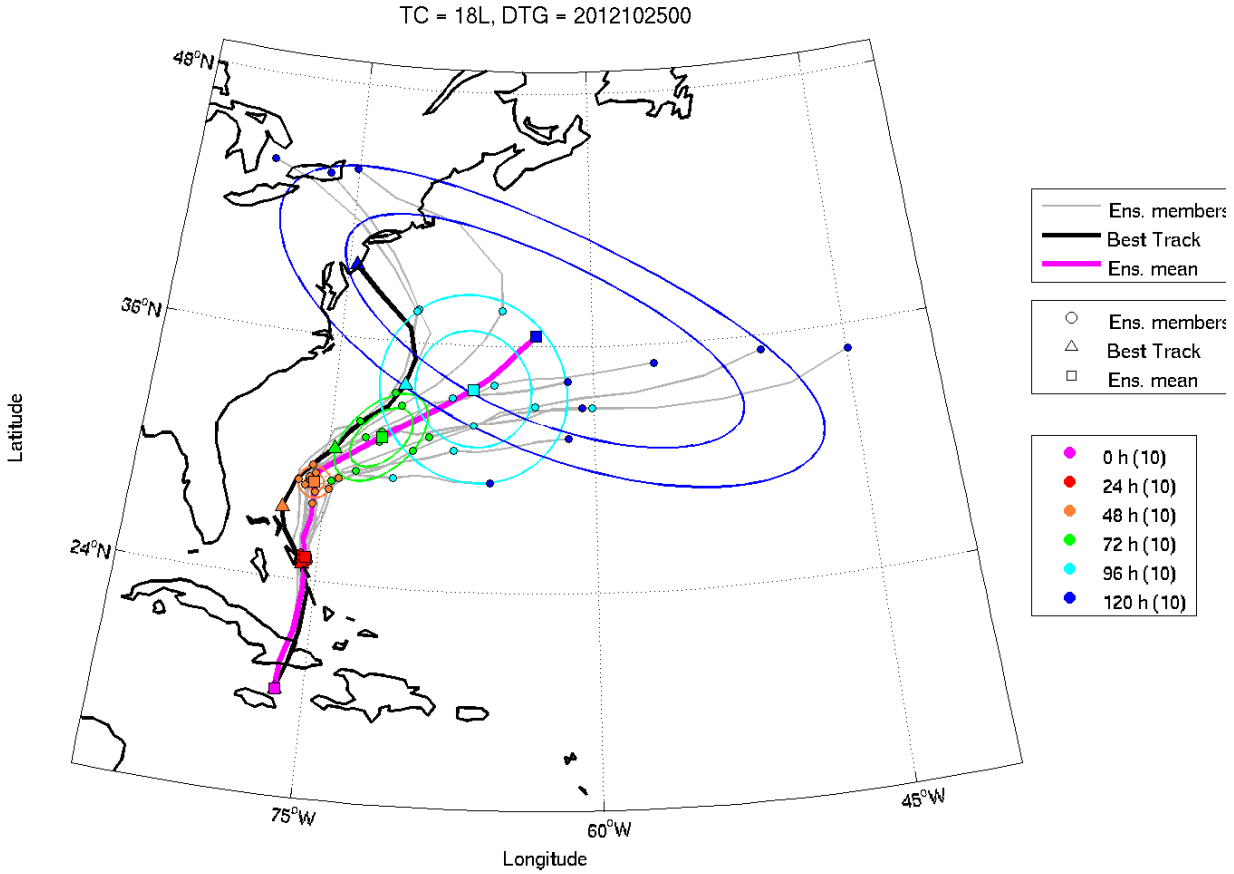
Intensity Frequency Distribution



Intensity forecasts with new PBL (green) better match the observed intensity distribution (black) than the control

COAMPS-TC Ensemble

10-Member 3-km Sandy Ensemble Forecast Initialized 00 UTC 25 October 2012



- **An ensemble Kalman filter data assimilation (80 members) and prediction system has been developed for COAMPS-TC using the community DART system.**
- **Ensemble highlights the uncertainty in Sandy's track forecast (large spread).**
- **Demonstration of a joint HWRF/COAMPS-TC system in real time in 2014 with HFIP.**

COAMPS-TC
Summary and Future Plans

➢COAMPS-TC Shows Promising Skill:

- Transitioned to Navy operations in 2013.
- COAMPS-TC intensity forecasts verified well in 2012-13 in WATL & WPAC
- Addressing TC skill issues (spin-down, RI, track).
- Improved intensity and track in 2014 version (new DA, physics)
- Multi-model high-res. ensemble (Navy/NOAA HFIP) prospects are promising.

➢Future Plans:

- Development of advanced COAMPS-TC (underway)
  - Resolution: 5 km (current) to 3 km to 1 km; 40L to 60L to 80L
  - TC physics: emphasize PBL, air-sea fluxes, microphysics
  - Data assimilation: EnKF, 4D-Var, radiances, radar, HDOB, SFMR
  - Coupling: Ocean (NCOM), waves (WWIII/Swan), coupled DA
- Utilize field observations
  e.g., TS08, HS3, ONR Outflow