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


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Sponsors: ONR, PMW-120, NOAA HFIP, NOPP
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 Ops, Testing:** Navy & NOAA HFIP prototyping activities

**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)**

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<td>162</td>
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**W. PAC Track Error (nmi)**

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<td>369</td>
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<tr>
<td>268</td>
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</table>
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.

* TCs from 2010-2012 WATL
* 2012-2013 WPAC

**Track Improvement (%)**

- GFS synthetics
- NAVGEM/NOGAPS 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 $V_{\text{max}}$, 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 $V_{\text{max}}$ for ST Francisco (26W/2013)

26W Max. Wind Speed

V-component for 22W

Balanced
Control

$V_{\text{max}}$ for 22W
Dynamical Initialization in COAMPS-TC

- 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

- 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
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