Recent COAMPS-TC Development and Future Plans

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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), ocean (NCOM), wave options (SWAN, WWIII)
- **Ensemble:** ICs, BCs, & vortex perturbations; EnKF & ETKF options
- **2016 Ops:** 45-15-5km for **COTC** (NAVGEM ICs BCs) & **CTCX** (GFS ICs BCs)
- **Real Time:** 27-9-3 km 11 member **CTCX** ensemble

**ONR ITOP TY Fanapi: SST (°C), Currents**

**Vongfong (2014) Simulated Radar Reflectivity**

12Z 15 Sep 2010
Marked improvement in COAMPS-TC (CTCX) track and intensity forecasts over time (non-homogeneous sample)
2016 Operational Statistics

Position Error

Atlantic Basin

Intensity Error & Bias

CTCX
COTC
HWRF
GFDL

CTCX

COTC

CTCX

COTC

• 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 (moisture?) and in track too
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 12h; recovers after 48h (similar to obs)
- Uncoupled: Intensity is too high

Coupled model SSTs and 10 m winds
• 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
• Currently testing physics improvements (EDMF and cumulus).
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
- Intensity changes (RI) may not be predictable in a deterministic sense.
- Multi-model ensembles are more capable of accounting for forecast uncertainty due to model & IC errors, than a single-model 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
Ensemble control vs Ensemble mean

- 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
Statistics for ATL and EPAC

Ensemble mean error vs Ensemble spread

- 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
COAMPS-TC Ensemble System
New Forecast Products for 2016

Track colored by forecast intensity

**COAMPS-TC**

TC = 07L2016, DTG = 2016082600

**COAMPS-TC / HWRF / GFDL**

TC = 07L2016, DTG = 2016082600
10-m wind threshold exceedance probability

**COAMPS-TC**

TC = 07L2016, DTG = 2016082600, lt = 0 h, prob (%) 34–kt wind

**COAMPS-TC / HWRF**

TC = 07L2016, DTG = 2016082600, lt = 0 h, prob (%) 34–kt wind

Available for 34 kt, 50 kt, and 64 kt thresholds, with both animations as shown above and static images for tau = 120
COAMPS-TC Ensemble System
New Forecast Products for 2016

24 h intensity change probability

COAMPS-TC

Available for $\Delta I \geq 30$ in 0 to 24 h, $\Delta I \geq 55$ in 0 to 48 h, and $\Delta I \geq 65$ in 0 to 72 h (as shown in example above)

COAMPS-TC / HWRF

Colored bars indicate 24 h intensity change probability

$\Delta I \geq 30$ kt (Rapid Intensification)
$10$ kt $\leq \Delta I < 30$ kt (Moderate Intensification)
$-10$ kt $< \Delta I < 10$ kt (Steady Intensity)
$-30$ kt $< \Delta I < -10$ kt (Moderate Weakening)
$\Delta I < -30$ kt (Rapid Weakening)
TC already dissipated or dissipates during window
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)
- 2017 Version: Significant improvements for intensity (RI); physics upgrades for track
- 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 Future Plans:

- 2017+ Priorities
  - TC physics: Emphasis on PBL, clouds
  - Analysis: 4D-Var/EnKF, satellite DA
  - Ensemble: 10-20 members; stochastic
  - 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
- Future: NEPTUNE and adaptive meshes
Next-Generation Models
Navy’s NEPTUNE

- Utilize advanced numerical methods in a global model (e.g., spectral element in Navy’s NEPTUNE) to better resolve TCs and the environment.
- Goal is to achieve global cloud resolving scales (no cu-param. needed) with adaptive mesh refinement capability to better resolve TC and cloud processes.
- Highly scalable on next-generation computer architectures (100K to 1M cores)

Hurricane Sandy
12-h Accumulated Precipitation

Adaptive Mesh Refinement

Hendricks et. al. 2015
Extra Slides
• Significant improvements in 2016 for CTCX and COTC in both track & intensity
  ➢ Two-way coupling with NCOM
  ➢ Smaller (but important) improvements to vortex initialization, physics
• CTCX and COTC fairly close together in terms of overall performance, although CTCX better by 1-3 kt.
Inner Core Data Assimilation

ONR Tropical Cyclone Intensity (TCI) Experiment

- Poor inner core data assimilation in models
- TCI: ~800 sondes deployed in 11 flights
- TCI Testbed for inner core assimilation

Obs: Radar
- HRD radar @ 1km 18Z22
- Base @ 1km 18Z22
- FL @ 1km 18Z22
- CIMSS @ 1km 18Z22

Control

Aircraft Obs
- Aircraft Obs

Sat AMVs

- Sat AMVs

Valarro and Molinari

Xuguang Wang (OU)
Many challenges regarding RI and it is unclear what the necessary physics, air-sea coupling, data assimilation, resolution needed to predict a "Patricia"
COAMPS-TC Ensemble System
New Forecast Products for 2016

Rapid intensification probability

COAMPS-TC

COAMPS-TC / HWRF

Available for $\Delta I \geq 30$ in 0 to 24 h, $\Delta I \geq 55$ in 0 to 48 h, and $\Delta I \geq 65$ in 0 to 72 h (as shown in example above)
Benefits of Coupling

Hurricane Leslie (2012): Intensity Error & Bias

• 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

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