COAMPS-TC:
Recent Progress and Future Plans

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COAMPS-TC Outline

• Background
• COAMPS-TC Description
• Real-Time COAMPS-TC Runs during T-PARC/TCS08
  • System configuration
  • Results
  • Prototype coupled model tests
  • Improvements following TCS08/T-PARC
• Real-Time Sensitivity & Targeting during T-PARC
• Conclusions/Future Research
COAMPS-TC
Background

• COAMPS-TC: New version of COAMPS® developed for tropical cyclone track, intensity, and structure prediction:
  • Improved TC analysis, microphysics, air-sea fluxes and boundary layer

• THORPEX Pacific Asian Regional Campaign (T-PARC) Tropical Cyclone Structure ‘08 (TCS08) Experiment
  • Objectives:
    - Observe TCs and environment from genesis to extratropical transition.
    - Targeted Observing: Additional observations in regions where they are most likely to improve forecasts.

• COAMPS-TC real-time forecasts for T-PARC/TCS08
  • Assess the skill of the COAMPS-TC predictions
  • Perform follow-on research to improve the prediction of the TC track, structure, and intensity
### Atmospheric Analysis
- Complex Data Quality Control
- Relocation of TC in background
- NAVDAS 3DVAR: $u$, $v$, $T$, $q$, TC option
- Initialization: **Hydrostatic Constraint on Analysis Increments, and/or Digital Filter**
- TC Balance Step: underway

### Ocean Analysis
- Navy Coupled Ocean Data Assimilation (NCODA) System
- 2D OI: SST
- 3D MVOI: $T$, $S$, SSH, Sea Ice, Currents
- Complex Data Quality Control
- Initialization: **Stability check**

### Atmospheric Model
- Numerics: **Nonhydrostatic, Scheme C**, Nested Grids, Sigma-z, Flexible Lateral BCs
- Physics: PBL, Convection, Explicit Moist Physics, Radiation, Surface Layer
- TC Tools: Moving nests, dissipative heating, spray parameterization, shallow convection

### Ocean Models
- NRL Coastal Ocean Model (NCOM)
- Numerics: **Hydrostatic, Scheme C**, Nested Grids, Hybrid Sigma/z
- Physics: **Mellor-Yamada 2.5**
- Wave Models (WWIII and SWAN)
- Generalized Flux Coupler (ESMF)
# COAMPS-TC Configuration for T-PARC/TCS08

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- Relocation of TC in background
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*Ocean Model was not used in TCS-08 runs*
COAMPS-TC
Real-Time Modeling for T-PARC/TCS08

**Inputs**
- **T-PARC/TCS08 Input**
  - T-PARC Invest
  - Targeting Alert
  - JTWC Warning Message

- **Routine Observations**
  - Satellite
  - Radiosondes
  - Surface
  - Commercial Aircraft

- **T-PARC/TCS08 Observations**
  - Drop/Driftsondes
  - Satellite
  - Aircraft
  - AXBTs

**Models**
- **COAMPS-TC**
  - Track, Structure, Intensity
  - 45/15/5 km nests
  - Uncoupled

- **Invest COAMPS-TC**
  - Genesis
  - 45/15/5 km
  - 5 km relocated on demand

- **Adjoint COAMPS-TC**
  - Targeting Genesis
  - First time ever
  - Response function relocated each fcst

**Computers**
- AFRL SGI Altix 4700
- NAVO IBM PS
- NRL LINUX Cluster

**Products**
- Digital
- NRL www
- T-PARC catalog

**Field Campaign**
- **Products**
  - Digital
  - NRL www
  - T-PARC catalog

- **Decision Making**
  - Forecast Discussions
  - Mission Planning
  - Adaptive nests, adjoint areas

- **Missions**
  - Real-time observations
  - Evaluation
  - Targeting

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USPACOM Tropical Cyclone Conference 2009
45/15/5 km grids set up for WPAC (TCS-08) basin
45 km grid fixed for all storms
Inner 2 grids move with the TC
Automatically submitted based on “ngt” file from FNMOC (JTWC warning message)

45/15/5 km grids also set up for WATL, EPAC, and CPAC basins
These forecasts were run using the same configuration as the WPAC basin, except for the grid location

Sample contents of ngt file:

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<th>Longitude</th>
<th>Latitude</th>
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<th>V</th>
<th>S</th>
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<th>P2</th>
<th>P3</th>
<th>P4</th>
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COAMPS-TC
Real-Time Modeling for T-PARC/TCS08

Typhoon Sinlaku (15W) (0000 UTC 9 August 2008)

• Synthetic Observations Built From:
  • Modified Rankine Vortex
  • JTWC Warning Message w/Satellite Data
  • NOGAPS T20/L15 truncated fields
• Blend Synthetics w/all other observations in 3DVAR

Issues/Comments
• For warm-starts, TC circulation is relocated to warning position
• Some influence of NOGAPS TC circulation seen in COAMPS analysis fields (cold starts)
• 3DVAR leads to small-scale “spokes” in horizontal wind distribution
• Imbalances apparent in the initial state
COAMPS-TC

COAMPS-TC Track Forecasts for T-PARC/TCS08

Homogeneous Sample Compared to all Models for TC

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<th>#Cases</th>
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</tbody>
</table>

COAMPS-TC slightly underperforms in TC track early in the forecast, but does well at later forecast times outperforming GFDN and competitive with other models.
COAMPS-TC forecasted rapid intensification of Super Typhoon Jangmi, however the system stronger than observed by 72 h since the predicted TC did not make landfall.

Convection was spotty and disorganized early in forecasts (esp. cold starts).

Basic intensity metrics were encouraging for the first 36-48h of forecasts.

Animation of COAMPS predicted radar reflectivity every 30 minutes on 5 km moving grid.
Azimuthally average tangential (shaded) and radial (contour) winds

Hurricane Katrina (72 h valid 00Z Aug 29 2005, $\Delta x=3\,\text{km}$)

COAMPS-TC
Improvements Following T-PARC/TCS08

Physics Tests

- **TCS08 Version**
  - No sea spray

- **New Physics**
  - Bougeault type of mixing (PBL & above)
  - New sfc moisture transfer coefficient
  - New ice nucleation
  - New dissipative heating formulation

- **New Physics Version**
  - Improves the *intensity* forecasts
  - Less tendency to overdevelop
  - Improves the convective structure
  - Good agreement with Doppler obs.
**COAMPS-TC**

Prototype Coupled Model Tests

**COAMPS-TC Air-Ocean Coupled Prediction of Typhoon Jangmi**

*Initial Time: 0000 UTC 2 September 2008*

- COAMPS-TC and 2-way coupled model (COAMPS-NCOM-TC) run for TC 19W
- Significant differences between COAMPS-TC and COAMPS-NCOM: NAVDAS vs. MVOI, 3-nest vs. 2-nest, Different synthetic observations, runs made on different computers, . . .
Animation of COAMPS predicted radar reflectivity every 30 minutes on 5 km moving grid

SST cooling of approximately 1°C-2°C is found to the right of the predicted path of Hurricane Gustav (Initial position is black dot, red dots represent every 12 hours)

COAMPS Forecast Track (red) and Official Warning Positions (black) plotted every 12 hours (dots) in uncoupled run
• Real-time COAMPS adjoint for targeting guidance.
• 40 km resolution for 24-h, 36-h, 48-h lead times.
• Adaptive response function box.

- Vorticity sensitivity bands often anticyclonically curved.
- Strongest sensitivity to low- and mid-level \( \theta \) and \( q_v \).
- C130 often sampled key portions of the sensitivity.

2-km vorticity sensitivity
Total energy sensitivity

Adjoint Targeted Observations (T-PARC/TCS08)

24-h adjoint sensitivity (36-h lead time)
Typhoon Sinlaku (Valid at 12Z 10 Sep 2008)
COAMPS-TC
Conclusions and Future Research

• COAMPS-TC Real-Time Runs for T-PARC/TCS-08:
  • 45/15/5 km nested grids
  • Promising forecasts of intensity and structure in a number of cases
  • Track forecast competitive with other models
  • Tendency to over-deepen TCs
  • Identified inconsistencies, bugs, oversights, . . .
  • Prototype air-ocean coupling tested on limited number of cases
  • Adjoint sensitivity calculations used for target observations

• Future Research:
  • Improve initial mass/wind balance, analysis (recent improvements)
  • Improve handling of convection in 3-5 km regime (recent breakthrough?)
  • Test air-ocean and air-ocean-wave coupling
  • Community interactions with HFIP, ONR/NOAA NOPP, ONR ITOP
  • Real-time demo in 2009 with FNMOC, Coordination with HFIP
COAMPS-TC
Prototype Coupled Model Tests

• Run in Real-Time during latter phase of TCS-08
• COAMPS-NCOM Coupled with ESMF
• Atmosphere:
  • 45/15 km nested grids (181x151, 121x121; 40L)
    • 45 km grid same as in coamps real-time uncoupled runs
    • 15 km grid moves w/TC
    • 15 km grid position set by warning position
  • MVOI used for analysis
• Ocean:
  • Global NCOM fields used for lateral boundary conditions
  • 45 km grid (151x121; 37L)
  • Warm starts after initial cold start (using global NCOM)
• Coupling Frequency: 30 minutes
Results show that COAMPS-TC underestimates TC max wind speed at analysis time, but tends to increase TC max winds relative to the analyzed wind speeds with forecast time.
Contributions from sea spray become important when the storm reach hurricane intensity. Significant amounts of negative surface sensible heat flux occurs in the eyewall due to evaporative cooling of the sea sprays.
COAMPS - TC
Parameterization Evaluation

Vortex-scale fields – winds at 2 km altitude
(72 h forecast valid at 00 Z Aug 29 2005, 3-km)

- New mixing length run simulates most realistic intensity & structure
- Bench version did not intensify the Katrina

The Doppler Observations and the HRS forecasts are provided by R. Rogers of HRD.
Black line: **Warning positions, large white circle with day at 0000 UTC, small white circle at 1200 UTC.**

Colored lines: **COAMPS forecasts starting from different times with a circle every 12 hours.**
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Colored lines: **COAMPS forecasts starting from different times with a circle every 12 hours.**
24-h adjoint sensitivity  
36-h lead time  
Valid at 12Z 10 Sep 2008

- Vorticity sensitivity bands that are anticyclonically curved.
- Strongest sensitivity to low- and mid-level $\theta$ and $q_v$.
- C130 sampled key portions of the sensitivity.
Vorticity sensitivity shows a wave packet pattern.
The $\theta$ and $q_v$ sensitivity have multiple maxima over a broad area.
C130 sampled only a small portion of the sensitivity.
SST Valid at 00Z 25 Sep 2008

Surface temperature (SST) sensitivity

- SST sensitivities were computed in real time.
- The SST sensitivity often showed complex patterns.
- C130 deployed many AXBTs during T-PARC/TCS08.
Comparison of Analyses of TC Jangmi using Old Synthetics and New Synthetics at 1000 mb

Analysis Time: 2008092500
Comparison of Analyses of TC Jangmi using Old Synthetics and New Synthetics at 700 mb

Analysis Time: 2008092500