Unified Air-Sea Interface in Fully Coupled Atmosphere-Wave-Ocean Models for Storm Predictions

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Chen et al. (2013)
Goals:

- Understand the physical processes that control the air-sea interaction and their impacts on storm prediction
- Develop a physically based and computationally efficient coupling at the air-sea interface for use in a multi-model system that can transition to the next generation of research and operational coupled atmosphere-wave-ocean-land models
Uncoupled Models

Atmosphere Model

Atmosphere surface layer

Surface forcing (wind, rad./latent/sensible fluxes, etc.)

Lower boundary conditions (SST, roughness, etc.)

Ocean surface layer

Ocean Model

From different sources without energetic constrain/consistency

Chen et al. (2013)
New generation coupled models with UNIFIED air-sea interface and need for coupled observations

Chen et al. (2013)
EOMS Based Software Architecture

Atmos
- Internal nested grids
- Atmos exchange grid
- ESMF interface

AirSea
- Wave field module
- Sea spray module
- Surface flux module
- ESMF interface

Wave
- Internal nested grids
- Wave exchange grid
- ESMF interface

Ocean
- Internal nested grids
- Ocean exchange grid
- ESMF interface

Earth System Modeling Framework

Chen et al. (2013)
Building an Information & Interoperability Software Layer

Applications of information layer
- Parallel generation and application of interpolation weights
- Run-time compliance checking of metadata and time behavior
- Fast parallel I/O
- Redistribution and other parallel communications
- Automated documentation of models and simulations
- Ability to run components in workflows and as web services

NUOPC (National Unified Operational Prediction Capability) Layer
Common Model Architecture -- technical rules and associated generic code collection with compliance checking

ESMF
- Standard metadata
- Standard data structures
  - Attributes: CF conventions, ISO standards, METAFORE Common Information Model
  - Component, Field, Grid, Clock

User data is referenced or copied into ESMF structures

Native model data structures
- Modules
- Fields
- Grids
- Timekeeping

Chen et al. (2013)
Chen et al. (2013)
University of Miami Wave Model (UMWM)
Real-time Experiment: **GLAD/CARTHE**

**UMCM** (WRF-UMWM-HYCOM)

Initialized daily at 0000 UTC daily
- Atmosphere (1.3km) initial/LB: GFS
- Wave (4km) initial/LB: WW3 or none
- Ocean (4km) initial/LB: HYCOM global
Tropical Storm Debby (23-28 June 2012)

Chen et al. (2013)
Hurricane Isaac (26-30 Aug 2012)
COAMPS SETUP

- Isaac – Gulf of Mexico (AUG 2012)

- **Horizontal Resolution:**
  - Atmos: 18, 6, and 2 km (child moving)
  - Ocean: 4 km
  - Wave: 8 km

- **Vertical Resolution:**
  - 60 atmospheric levels
  - 50 ocean levels

- **Boundary Conditions:**
  - Atmos: 0.5° NOGAPS
  - Ocean: Global NCOM

- **Data Assimilation:**
  - Atmos: NAVDAS (3DVAR)
  - Ocean: NCODA (3DVAR)
  - 12 hour update cycle for spinup

- **Observation Data:**
  - AXBT (E. Sanabia, USNA)
  - ADOS Drifters (Scripps)
  - Wave Buoy Data (NOAA)
Differing coupling configurations can produce different inner-core convective structures in COAMPS-TC and alter the cyclone’s intensity.
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BEST TRACK
ATMOS ONLY (A ONLY)
ATMOS-OCEAN (AO)
FULLY-COUPLED (AOW)

8/26 12Z

8/27 00Z

8/28 00Z

8/29 00Z

8/29 12Z

Hurricane Isaac Maximum Intensity
2012082612 48-hour forecast

Maximum Intensity (m/s)

Chart Area

A only
A-O
A-O-W
OBS

8/27 00Z

8/28 12Z

8/29 00Z

AF308 (AXBT)

93064 (ADOS)

93065 (ADOS)
Hurricane Isaac

**BEFORE ISAAC PASSAGE**

- Hurricane Isaac (ADOS 93065) 2012082700
  - (27.10N 275.12W)

- Hurricane Isaac (ADOS 93064) 2012082901
  - (27.47N 275.52W)

**AFTER ISAAC PASSAGE**

- Hurricane Isaac (ADOS 93065) 2012082901
  - (27.13N 275.10W)

- Hurricane Isaac (AXBT AF308) 2012082901
  - (28.58N 277.97W)

**ADOS DRIFTER 93065**

**ADOS DRIFTER 93064** (after Isaac)

**AXBT AF308** (after Isaac)
UMCM 5-day Forecast of Hurricane Isaac (initialized at 1200 26 Aug 12): Track and Intensity

Chen et al. (2013)
UMCM Forecasts of Surface Wind Speed and $C_D$ in TS Issac (1200 28 Aug 2012)

Chen et al. (2013)
Uncoupled (deep/sym)

AO (shallow/asym)

AWO (shallow/asym)

Chen et al. (2013)
UMCM verification against NDBC buoy measurements

Near-track buoy

Chen et al. (2013)
UMCM verification against NDBC buoy measurements

Coastal buoy

Chen et al. (2013)
Model verification against sat SST and AXBT data (Sanabia et al. 2013)

Chen et al. (2013)
Sonic Minimet Drifters

L. Centurioni and J. Morzel

Chen et al. (2013)
Model Verification against Drifter Data

Chen et al. (2013)
SUMMARY

- Fully coupled models are a key for building a physically consistent and energetic balanced prediction systems.

- Progress toward development of the unified air-sea interface module using ESMF/NUOPC with interoperability layer that can be transitioned to operations.

- Important to use coupled observations to evaluate/verify coupled model forecasts (e.g., winds, SLP, rain, surface waves, ocean temperature and current, etc.).

- Working toward a data assimilation system using coupled observations in coupled models.

Chen et al. (2013)