Numerical Simulation of Tropical Cyclone Intensity Using an Air-Sea-Wave Coupled Prediction System

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The goal of this study is to construct an air-sea-wave coupled modeling system which is appropriate for simulating tropical cyclone activity from hours to a season. The coupled system (Fig. 1) consists of the Weather Research and Forecast (WRF) regional model which is nested in an atmospheric general circulation model (AGCM), a regional ocean circulation model (POM) which is nested in a global ocean circulation model (HYCOM), and a third-generation near-shore ocean surface wave model (SWAN) which is nested in an open water wave model (WWIII).

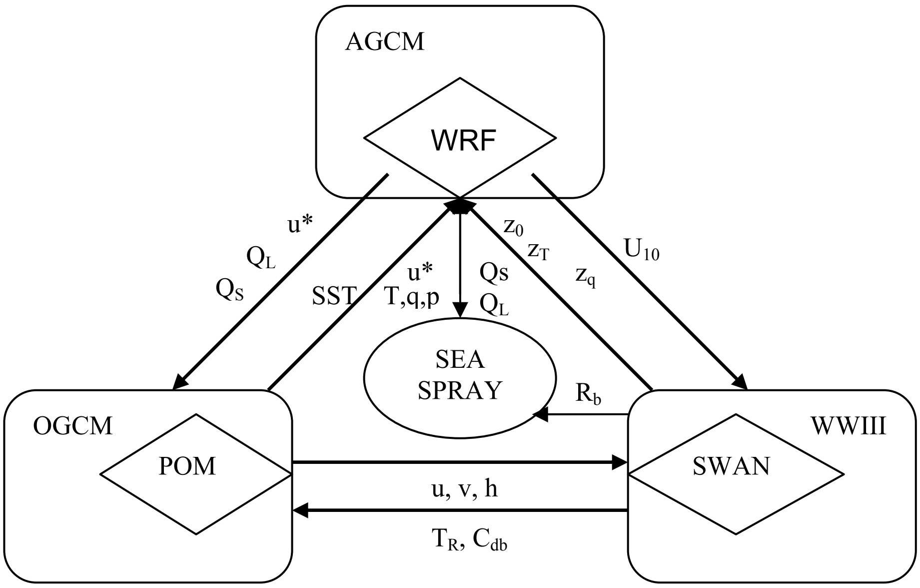

Figure 1. Schematic depiction of air-sea-wave coupling.

The atmospheric models are coupled to the ocean circulation models by receiving sea surface temperature forecast from, and sending air-sea flux estimates to, the ocean models. The atmospheric models are simultaneously coupled to the wave models by providing wind stress to, while receiving roughness parameters from, the wave models. Additionally, the effect of sea spray is included as an additional means of coupling between waves and winds. The ocean circulation models and the wave models are coupled not only through wave and sea spray induced surface flux changes, but also by exchanging radiation stress and bottom stress.

Data assimilation is included in all components of the coupled system. The standard, initial condition optimization procedure is used for “weather forecasting” applications which are characterized by initial value problems. For “climate prediction” applications, a unique “scale filtering” technique is developed to assimilate selected large-scale flow fields in the regional atmospheric model to avoid regional climatic drift.

The model has been tested for both stand-alone and coupled simulations of African waves, Atlantic hurricanes and Pacific typhoons, as well as oceanic responses in terms of surface waves, storm surge and sea surface temperature (SST). A three-window nested simulation was able to reproduce the timing and location of the African wave development and provide much more details of the wind and precipitation structure surrounding the system. In this simulation, the outmost domain has 290×150 grid points using 27km grid size, the intermediate domain has 373×214 horizontal grids using 9km grid size; the innermost domain contains 271×361 horizontal grids using 3km grid size.

Coupled simulations reveal significant contributions from air-sea and wind-wave coupling, as well as sea spray effects to the intensity change of tropical cyclones, storm surge, waves, and SST.

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Acronyms:

WRF: Weather Research and Forecast model – a community regional (limited area) mesoscale atmospheric model

POM: Princeton Ocean Model – a regional ocean circulation model

HYCOM: Hybrid Coordinate Ocean Model – an open source community global ocean model using hybrid depth and density coordinates in the vertical

SWAN: Simulating WAves Near-shore – a third generation wave model suitable for simulating waves near the coast as well as in deep waters

WWIII: WaveWatch III – an operational ocean surface wave forecast model used by U.S. National Oceanic and Atmospheric Administration
AGCM: Atmospheric General Circulation Model