Coupled Wave-Circulation-Sedimentation Dynamics

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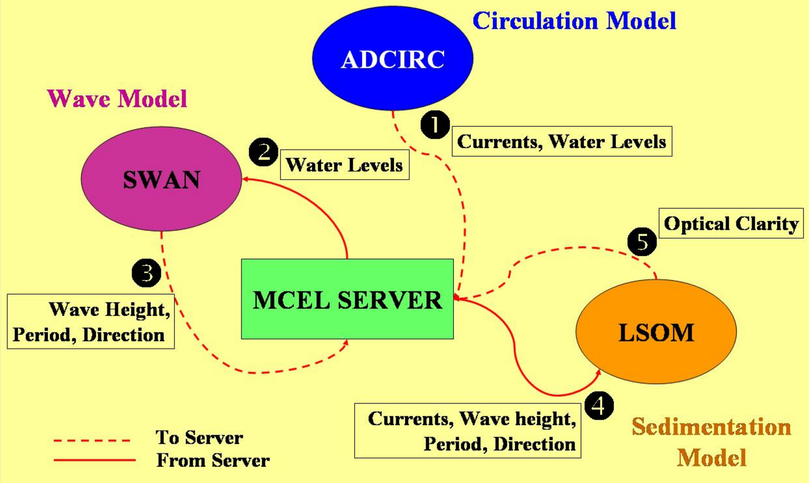
ABSTRACT

State-of-the-art coastal models have advanced such that the nonlinear feedback between physical processes associated with surface waves, marine currents, and sediment dynamics can no longer be ignored but must be considered as a coupled system. Typical file-based coupling schemes must address model differences in computational grids (type and resolution) and file I/O structures resulting in large computational and user overheads. For the applications presented, a distributed framework designed to facilitate model coupling (MCEL) is demonstrated by coupling numerical models representing coastal wave, circulation, and sedimentation dynamics. Coupling involves sharing the following quantities: surface wave radiation stress gradients, wave orbital velocities, currents, and sea surface heights to capture important nonlinear processes such as the impact of sea level variations on wave breaking location, the wave/current blocking of currents/waves, the effect of wave-current interaction in the marine boundary layer on sediment re-suspension, and sediment transport under a variable current field. The coupled system is applied in two diverse geographic regions, the Mississippi Bight and the Persian Gulf. Relevant observations are utilized for validation of each model component.

COUPLED MODEL SYSTEM



- The wave module is comprised of the shelf-scale wave generation and transformation model, SWAN [Booij et al, 1999].
- Coastal circulation and sea level changes are represented by the shallow water hydrodynamics of the Advanced Circulation model, ADCIRC [Luettich et al., 1992; Luettich and Westerink, 2003].
- Sedimentation processes are simulated by the Littoral Sedimentation and Optics Model, LSOM [Keen and Glenn (1998);Keen and Stavn (2000)].

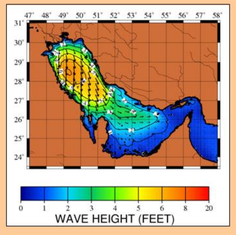
DYNAMICAL MODEL DESCRIPTIONS

- **SWAN** wave model computes realistic estimates of wave parameters in coastal regions, lakes and estuaries given wind, bottom, and current conditions.
  - non-stationary (time dependent) and stationary modes
  - full plane (waves traveling from any direction)
  - provides sig. wave height, period, and direction
- **ADCIRC** 2-D and 3-D nonlinear, barotropic circulation model that simulates tidal dynamics, shoreline inundation, storm surge, nearshore wave-driven flow, and river influx.
  - mesh flexibility due to finite element formulation
  - provides sea surface heights and 2-D or 3-D currents
- **LSOM** bottom boundary layer component calculates the combined shear stresses resulting from wave and current interaction in the marine bottom boundary layer given waves, currents, bathymetry and sediment type
  - includes re-suspension and optical properties of sand and silt
  - provides derived estimates of diver visibility and backscatter

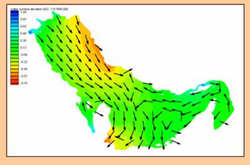
PERSIAN GULF

Forcing: ADCIRC: Tides from 8 constituents (Q_1,O_1, K_1, N_2, M_2, S_2, K_2, P_1)
ADCIRC & SWAN: 10-m winds from the Navy 27-km COAMPS model
SWAN: WAM wave spectra at 4 offshore locations

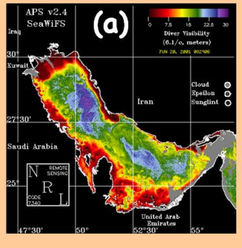
Simulation Period: June 1-30, 2001

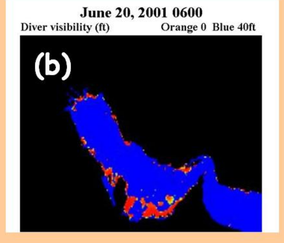


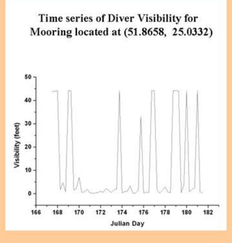
SWAN wave heights (ft) for June 1, 2001 00 GMT. Arrows depict direction waves are moving toward.



ADCIRC computed water levels (color) and currents (arrows indicate current direction) for June 1, 2001, 00 GMT. ADCIRC currents are provided to LSOM every 2 hours of simulation.







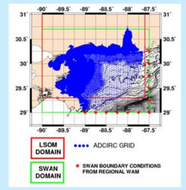
Diver visibility for the Persian Gulf on 20 June 2001: (a) computed from the SeaWiFS sensor and (b) calculated from LSOM using re-suspended sediment and constant chlorophyll.

Diver visibility predicted by LSOM for June 16-30, 2001 east of the Qatar Peninsula.

MISSISSIPPI BIGHT

Forcing: ADCIRC: Tides from 8 constituents (Q_1,O_1, K_1, N_2, M_2, S_2, K_2, P_1)
SWAN: 10-m winds from the Navy's 27-km COAMPS fields
WAM wave spectra at 12 offshore locations

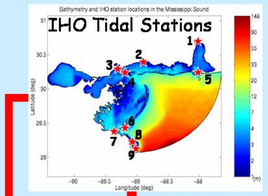
Simulation Period: A 24-hr period November 7-8, 2002



Co-Located Model Domains

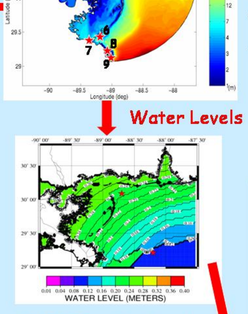
Grid Specifications:	Resolution:
ADCIRC: 28494 elements	167m – 5.2 km
SWAN: 7373 grid points	2.4 km
LSOM: 60060 grid points	777m x 898m, 31 lev.

Validation: ADCIRC Tidal Elevations



- Diurnal tides contain majority of the tidal energy (75%) in the region.
- Diurnal errors reasonable: 10% in amplitude and 10 deg. in phase.

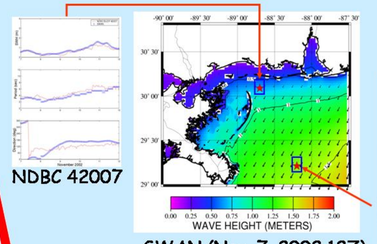
Water Levels



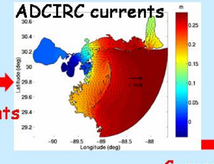
ADCIRC water levels interpolated onto the SWAN grid

Waves

Validation: SWAN Wave Heights

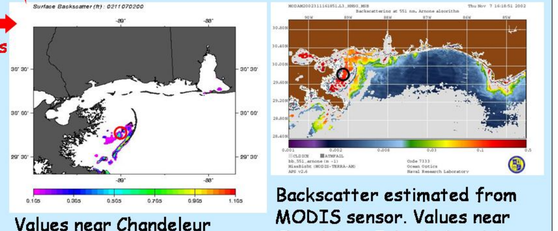


Currents



Currents

Validation: Estimated Backscatter from LSOM Suspended Sediment Concentrations

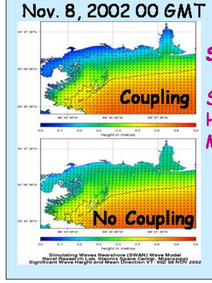


Values near Chandeleur Islands (circle) are approximately 0.1 to 0.7 m^{-1}.

Backscatter estimated from MODIS sensor. Values near Chandeleur Islands (circle) are approximately 0.06 to 0.1 m^{-1}.

Impact of Coupling

Nov. 8, 2002 00 GMT



SWAN Sig. Wave Hts. and Mean Dir.

Dynamic water levels (via coupling) alter the bottom effects on wave propagation especially in shallower water resulting in increased wave heights and changes in direction.