Simulating Wave and Tidally Driven Circulation in a Tidal Inlet Using a Coupled Hydrodynamic-Wave Model

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Objective: To simulate wave and tidally forced circulation in a bay/inlet system using a coupled hydrodynamic-wave model.

Coupled Model Approach to Wave-Current Interaction

Hydrodynamic Model: ADCIRC-2DDI
(Luettich, Westerink, and Scheffner 1992)

- shelf-scale barotropic model
- Solves 2D depth integrated mass and momentum equations
- Finite element model, can employ non-uniform grids
- Capable of simulating wave, wind, tide, and river forced circulation

Wave Model: SWAN wave model (Booji et al. 1999)

- 2D finite difference model
- Phase averaged multi-spectral wave model
- Narrow banded spectrum for this study
- Energy based formulation
- Refraction, shoaling, reflection, and blocking of waves
- No diffraction

Iterative Coupling of ADCIRC and SWAN:

Initial spinup of hydrodynamic model:
Time independent wave forcing is applied until a steady state circulation is obtained.

Coupled Mode: Coupling activated after spinup
iteration interval = 30 minutes (0.02 days)
Decreasing iteration interval to 15 minutes did not significantly alter the results.

SWAN wave model

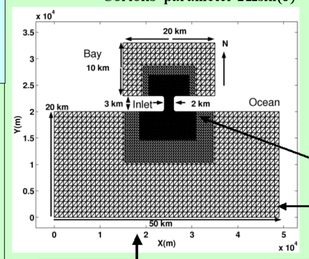
Gradients of surface wave radiation stress calculated from SWAN wave heights and directions

ADCIRC: Currents and Sea surface heights

ADCIRC-2DDI hydrodynamic model

Ideal Inlet Domain

Coriolis parameter $2\Omega\sin(\theta) = 0.00008$



Depth varies linearly from 14 m to 5 m. Constant 5 m depth in the bay and inlet

ADCIRC FE resolution varies from 100 m to 1000 m

SWAN B.C.

ADCIRC B.C.

Normally Incident at southern boundary
Height = 1.0 m
Period = 10 sec

Closed Boundaries except for elevation specified southern B.C.

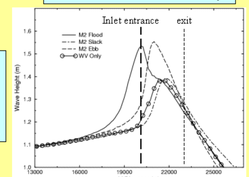
Waves Only: Zero Elevation
Waves and Tides: M_2 tide, Amp = 0.15 m, Phase = 0.0

SWAN resolution = 125 m

Coupled Wave-Tide Driven Circulation
M_2 tidal forcing (amplitude = 0.15 m)

Initial spinup = 6 days
Coupled run = 0.52 days
(approximately M_2 tidal period)

Y-transects at x=25,000 m
simulation time = 6.52 days

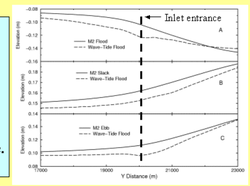


Opposing currents during flood and ebb increase peak wave height.

Slack wave heights are quite similar to those of the coupled wave-driven case.

Wave-induced set-down/up is apparent during all tidal phases of the coupled wave-tide simulation

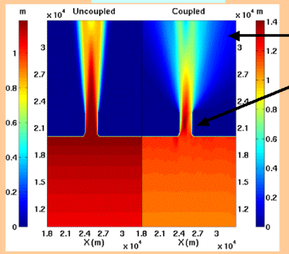
A 0.01 m offset is apparent in the slack sea surface elevation. This is consistent with wave-induced set-down observed in the coupled wave-driven case.



Wave-Driven Circulation

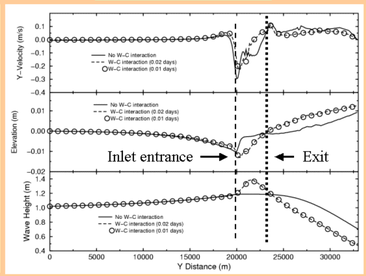
Initial Spinup run = 0.8 days
Coupled run = 0.24 days

Wave Heights

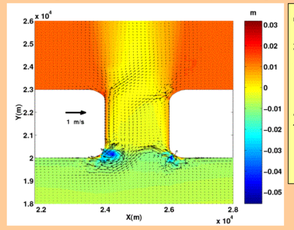


Coupled Case:
1) Current induced refractive spreading of waves in the bay
2) Asymmetric wave heights due to asymmetric current field
3) Increased wave heights due to current induced shoaling
4) Greater wave-induced set-down/ set-up
5) Decreasing iteration interval from 0.02 to 0.01 days does not significantly affect results

Y-transect at x=25,000 m

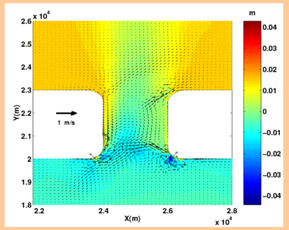


Uncoupled Circulation (0.8 days)

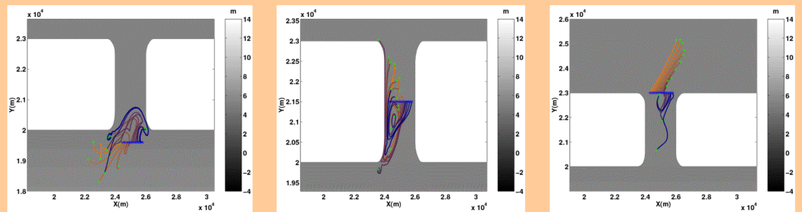


Coupled Circulation: elevation and current velocities
1) Time dependent circulation due to wave-current interaction
2) Significant differences between coupled and uncoupled inlet circulation patterns

Coupled Circulation (1.04 days)



Motion of passive Lagrangian tracers (16 total, * start, * end), duration = 0.24 days, Coupled Mode

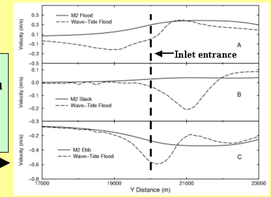


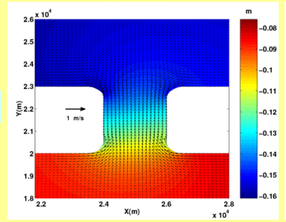
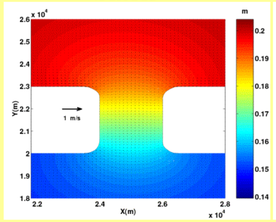
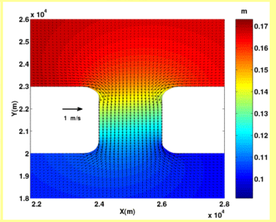
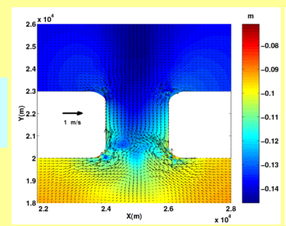
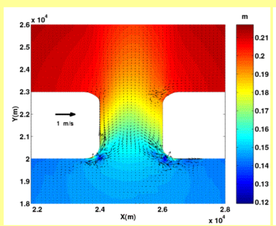
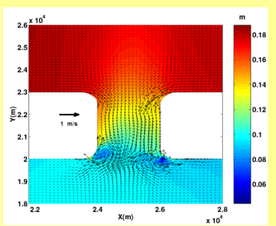
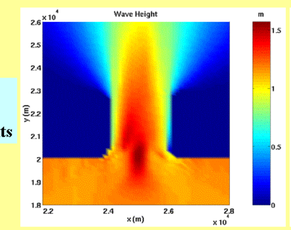
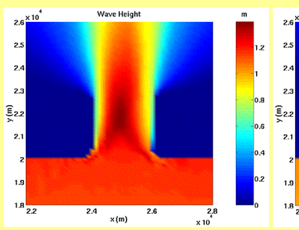
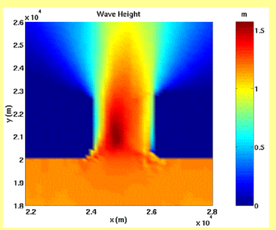
Coupled wave-tide circulation vs. M_2 tidal circulation (at 6.52 days)

1) Overall wave-tide inlet circulation differs significantly from M_2 tidal circulation
2) Wave-induced out-flowing current seen during all phases of tidal cycle
3) Magnitudes of wave-tide induced currents are significantly larger then M_2 tidal currents in the inlet region
4) Wave-induced set-down/up alters M_2 tidal elevations in the the vicinity of the inlet

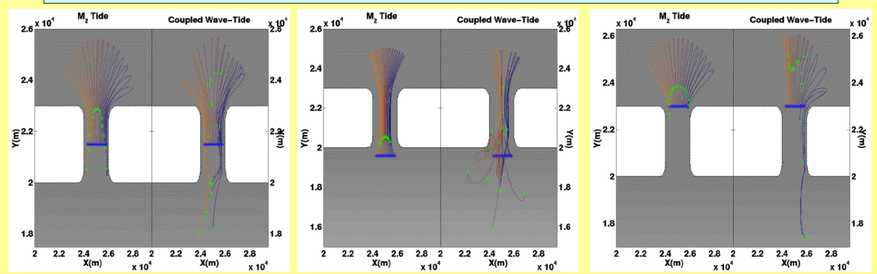
Y-transect at x=25,000 m

Cross-shore Velocity



	Flood	Slack	Ebb
M_2 Tide			
Coupled wave-tide circulation			
Coupled wave-tide wave heights			

Motion of passive Lagrangian tracers (16 total, * start, * end), duration = 0.52 days.
Significant dispersion of tracers by coupled wave-tide circulation.



Conclusion

- Wave-current interaction is necessary for modeling wave- and wave-tide-forced inlet circulation
- Strong inlet currents significantly alter wave heights in both the wave and wave-tide cases
- Overall inlet circulation is noticeably different when wave-current interaction is included
- Motion of Lagrangian tracers in wave-tide case indicates the importance of wave-induced circulation with regard to the transport of sediments, pollutants, and biological organisms in tidal inlets