Numerical Modeling of hydrodynamics and sediment transport of New River Inlet (NC) using NearCoM-TVD

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1. Introduction

A new version of the Nearshore Community Model System (NearCoM-TVD) is utilized in this study to investigate hydrodynamics, sediment transport and morphological evolution of New River Inlet, NC. In this poster, we focus on how the interaction between waves and strong tidal current near the inlet can change the pattern of wave and current fields and the resulting sediment transport. The advantages of using NearCoM-TVD for the study are:

a) The coupling of SHORECIRC and SWAN is able to capture the important feature of the nonlinear wave-current interaction in nearshore region.

b) the parallelized quasi-3D model is computationally efficient and allows modeling sediment transport and long term morphological evolution.

2. Numerical Model - NearCoM-TVD

NearCoM integrates the wave model SWAN [Booij et al., 1999] and the quasi-3D nearshore circulation model SHORECIRC. The quasi-3D circulation model incorporates the effect of wave on the vertical structure of current [Svendsen et al. 1994].

1) A new code of SHORECIRC applies a hybrid method combining the finite-volume and finite-difference — TVD-type scheme [Toro, 2009]. The TVD-type scheme has been demonstrated to be stable and robust in modeling wave breaking and moving shorelines in the most recent development of the fully-nonlinear Boussinesq model [FUNWAVE-TVD, Shi et al., 2011, 2012].

2) SWAN is a spectral wave model which solves the wave action balance equation. The wave model SWAN was integrated with SHORECIRC and expand its applicability to inner shelf and river/inlet [Shi et al. 2011].

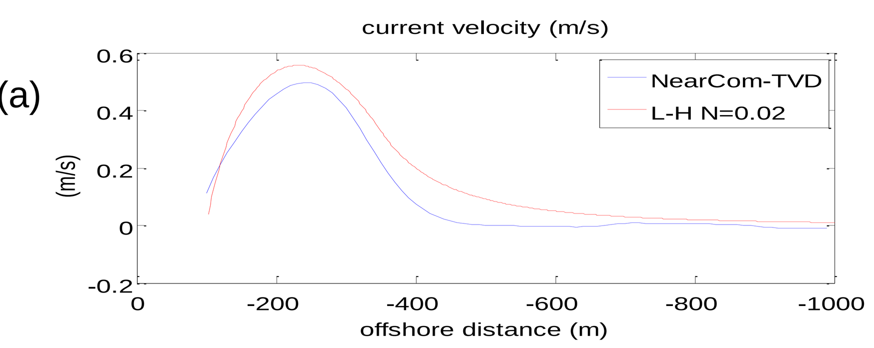
2.1 Model Validation

We validate NearCoM-TVD with two classic test cases, (1) shelf tidally driven circulation [Leendertse1967] and (2) wave driven longshore current [Longuet-Higgins 1970]

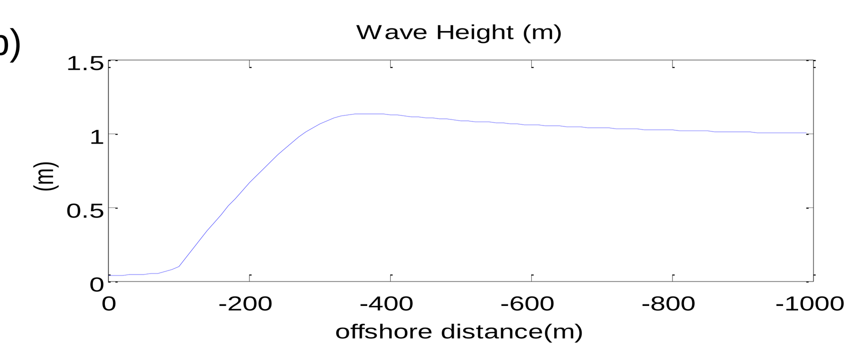
1) Shelf tidally driven circulation:
Model tidal amplitude rectangular domain representing a simple estuary open in the right and closed at the others with depth D wave length of tide L.

2) Wave driven longshore current:
figure (a) Model current velocity profile
figure (b) wave height distribution profile of longshore current as function of distance from the breaking line.

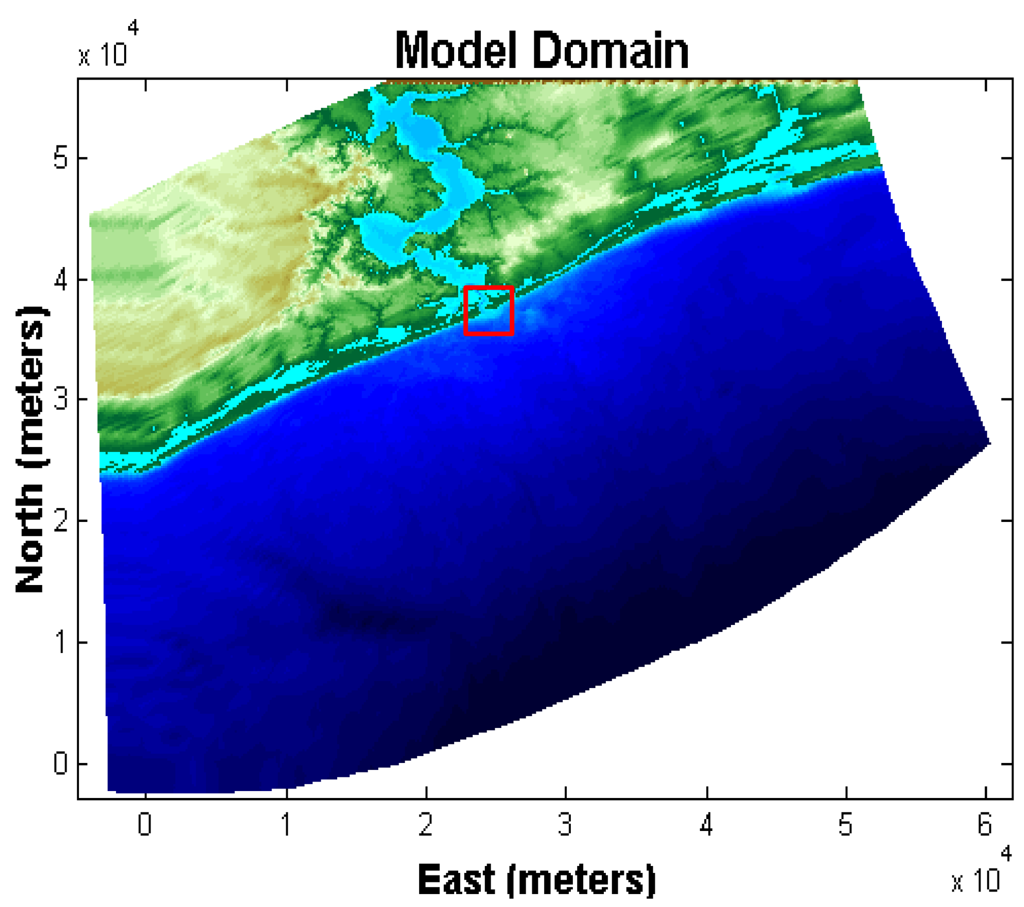
(a)

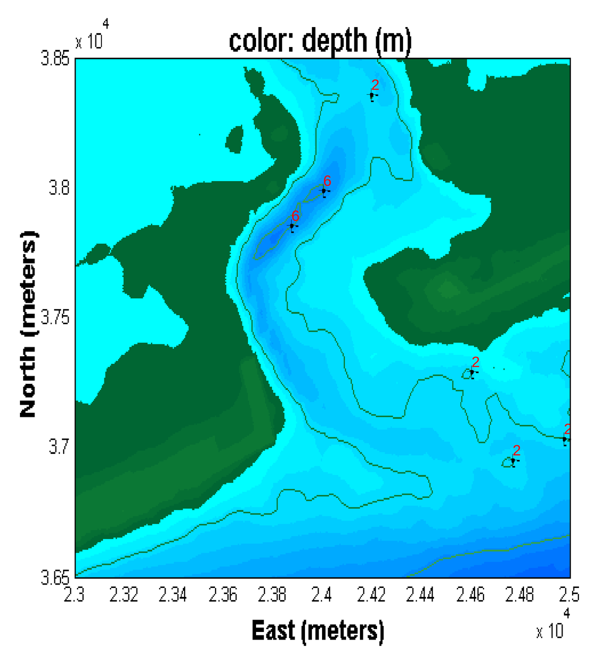


(b)



3. Wave current interaction in New river Inlet(NC)





3.1 Model Setup

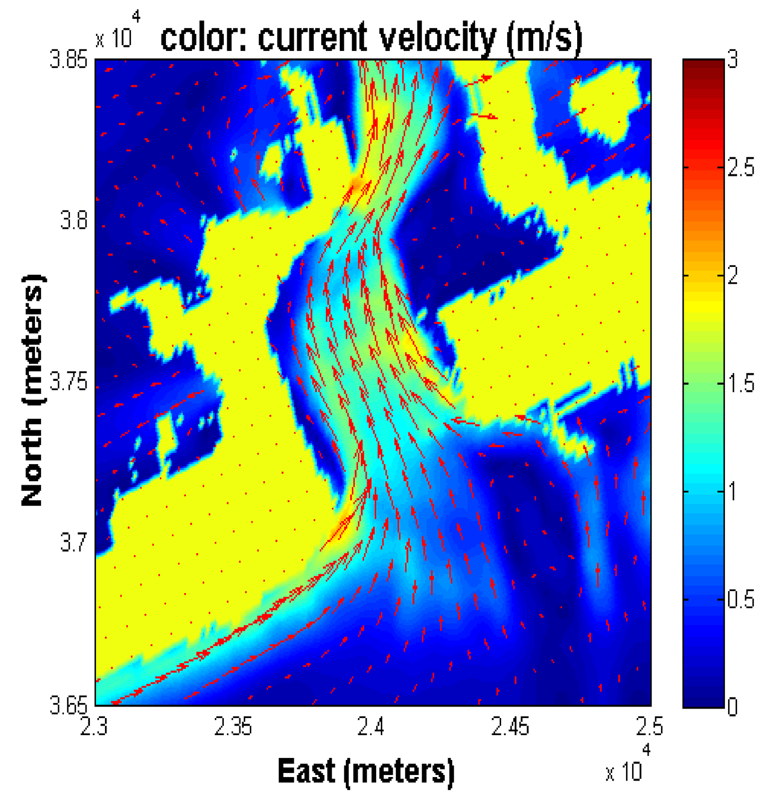
Numerical implementation of the New River Inlet mesh is based on curvilinear grid with minimum grid size 17m.

1) Tidal boundary condition:
M2 tide constitute of station Wilmington, NC. (tidal amplitude 0.623m)
2) Wave boundary condition: 3 m wave in the south boundary, west and east periodic boundary condition.

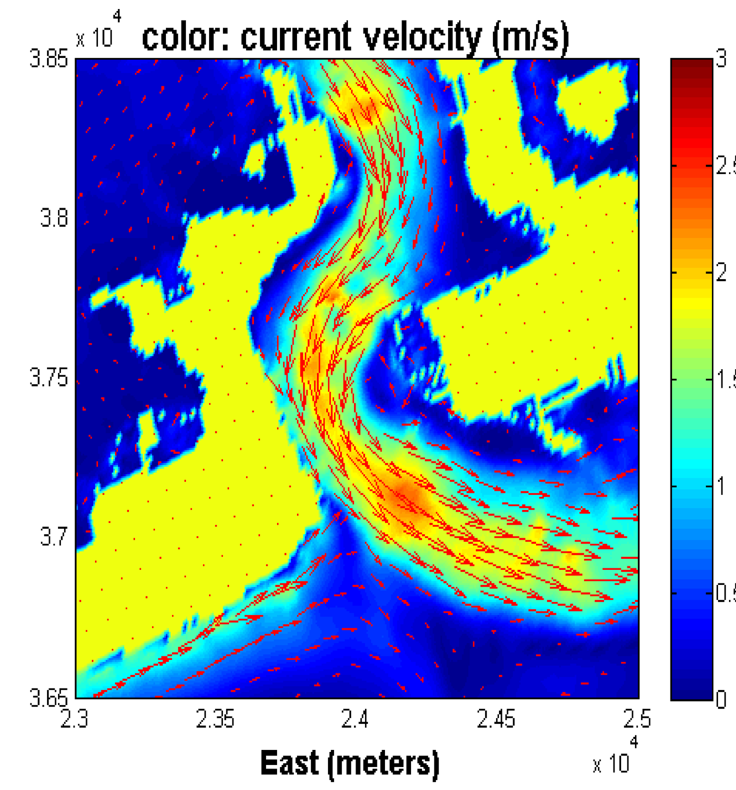
3.2 Simulation Result

(1)Instantaneous flow velocity under the interaction of tidal current and waves:

(a) during flood tide

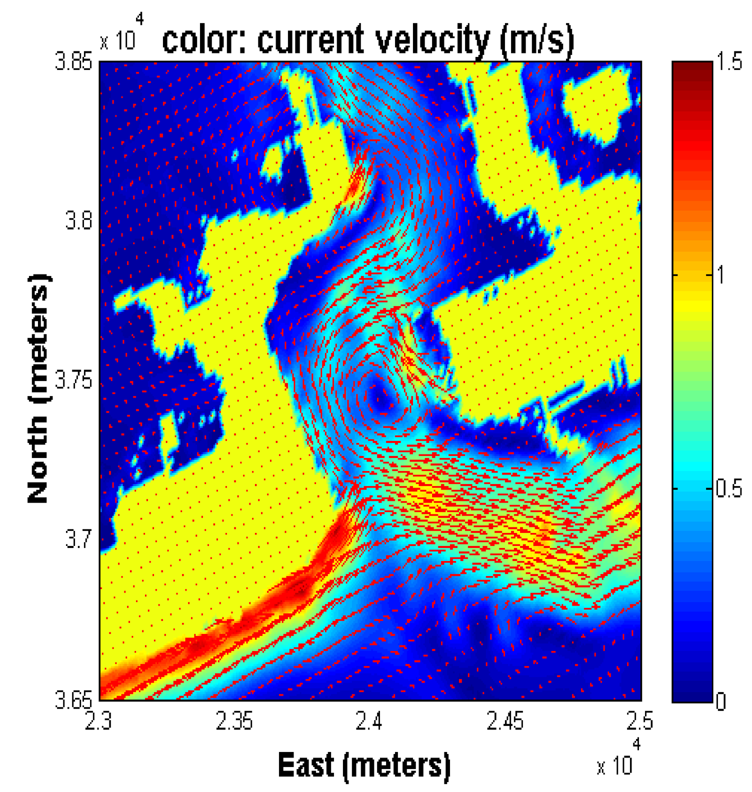


(b) during ebb tide

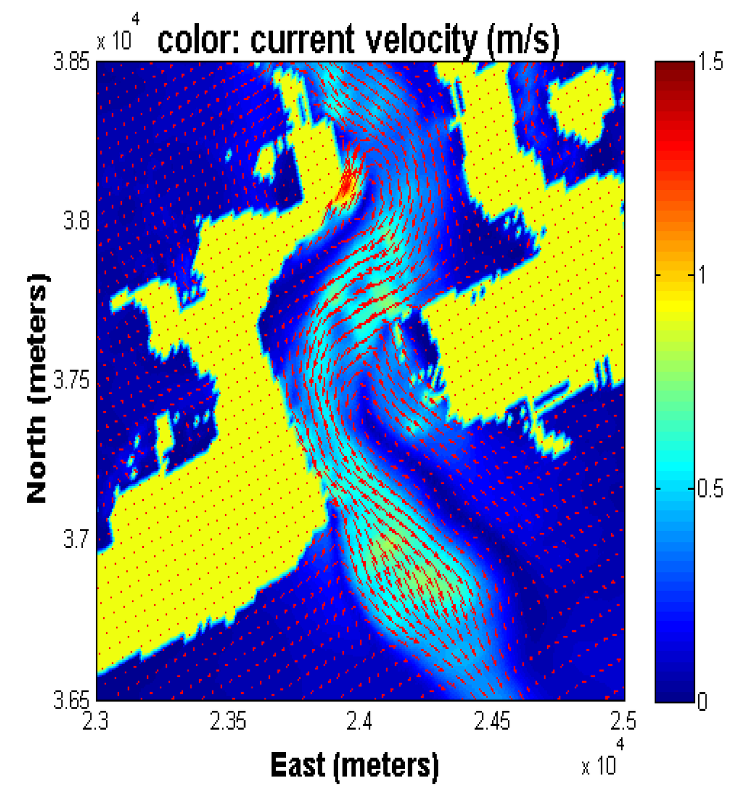


(2)Tidal residual (flow velocity average M2 period):

(c) Tidal residual:



(d) Tidal residual flow velocity without wave effect:



(c) and (d) shows **the wave-induced longshore current shifts the direction of ebb tidal jet to the right and also enhances the intensity of ebb tidal jet.**

4. Wave current interaction in Idealized inlet

Tidal residual current in an estuary has been studied in the previous literature [Ye et al. 1998]. However, our simulation results indicate wave-induced longshore current also plays an important role. Because the above flow pattern is simulated in a realistic system with more complex effects such as local bathymetry and Coriolis. it is useful to investigate wave-current interaction under an idealized inlet in order to understand the main effect of wave-current interaction in a tidal inlet system. The idealized bathymetry is set up based on the inlet width, inlet high, beach slope of the New River Inlet. We run the idealize inlet with the scenarios of tide only, wave only, and tide-wave interaction.

4.1 Flow vorticity under wave current interaction

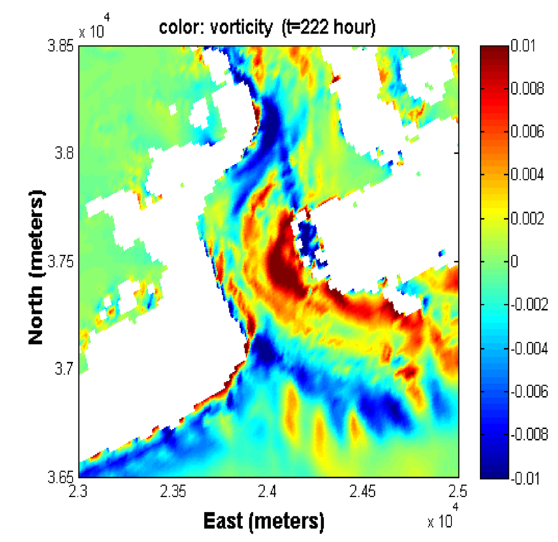
More insights on the wave-current interaction at the New River Inlet can be revealed from the vorticity field (see 1-a): **(1) wave-induced instability in the surf zone** and **(2) tide induced counterclockwise vorticity (red) in the right and clockwise vorticity in the left (blue) of the channel.** The individual run with wave-only (see 2-a) and tide-only (see 3-a) helps us to distinct the effects of tide and waves in New River inlet that instability only appears when waves is considered. Moreover, instabilities disappear in the idealized inlet, suggesting that instabilities are caused by combined effect of wave and bathymetry.

1) Tide+Wave

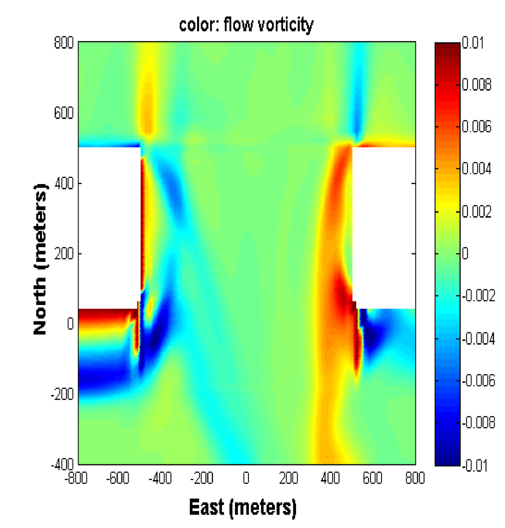
(1-a) Tidal residual vorticity field with both tide and wave incorporated.

(1-b) The idealized case shows that the vorticity distribution near the channel is consistent with realistic case.

(1-a) realistic



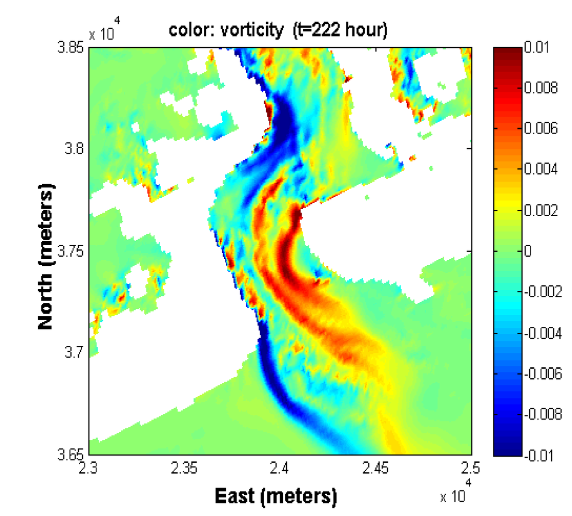
(1-b)idealized



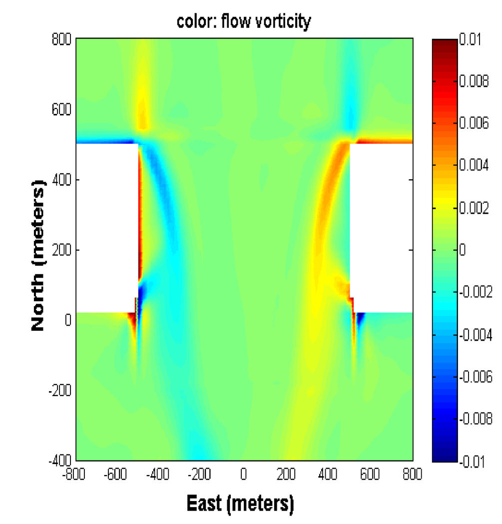
2) Tide Only

Both the realistic and idealized cases show similar pattern: the tide induced counterclockwise (red) vorticity in the right of the channel and clockwise (blue) vorticity in the left of the channel.

(2-a)



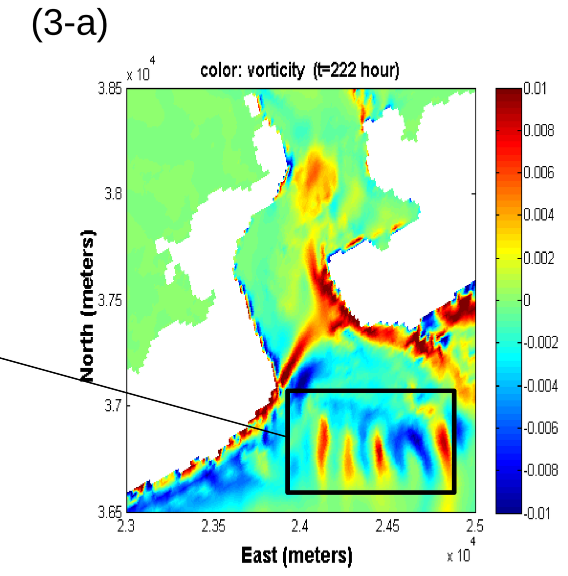
(2-b)



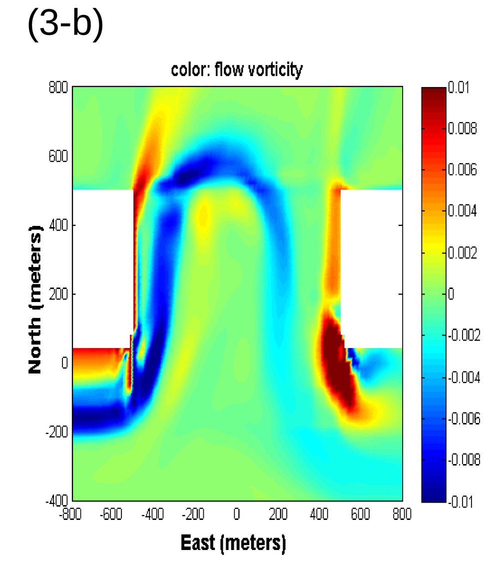
3) Wave Only

Instability only appears in the realistic case, suggesting that wave-induced instability is also due to the effect of bathymetry.

(3-a)



(3-b)



5. Future Work

1) It is expected that the relevant physical quantities can be expressed in terms of non-dimensional parameters so that results from our study can be useful for field applications in other inlet system.
2) The flow pattern studied here is important for modeling sediment transport and morphological evolution. Future study on sediment transport will focus on the influence of wave-current interaction and wave skewness.

6. Acknowledgements/References

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