Modeling the Potential Impact of Dredging the Corpus Christi Ship Channel On Passive Particle Transport

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Abstract

We present a study of the potential impact of deepening the Corpus Christi Ship Channel through Aransas Pass; in particular, we study the effect on the transport of red drum fish larvae due to the change in channel depth. The study is conducted by high resolution simulation of the circulation of the seawater entering and exiting the pass for the current and proposed Ship Channel depths. The computer model incorporates tides and meteorological forcing and includes the entire Gulf of Mexico and the North American Atlantic coast. The corresponding transport of larvae modeled as passive particles due to the sea water circulation is established by releasing particles in the nearshore region outside Aransas Pass and subsequently tracking their trajectories. Both models are implemented in supercomputers at the Texas Advanced Computing Center (TACC). Accuracy of the circulation model computations is validated through comparisons to data collected from tidal gauges in the fall of 2020. We compare the difference in the number of larvae that successfully reach appropriate nursery grounds inside Aransas Pass for four distinctive initial larvae positions in the nearshore region. Our results indicate that the change in channel depth does not significantly alter the number of red drum larvae that reach suitable see a net increase of 0.5%.

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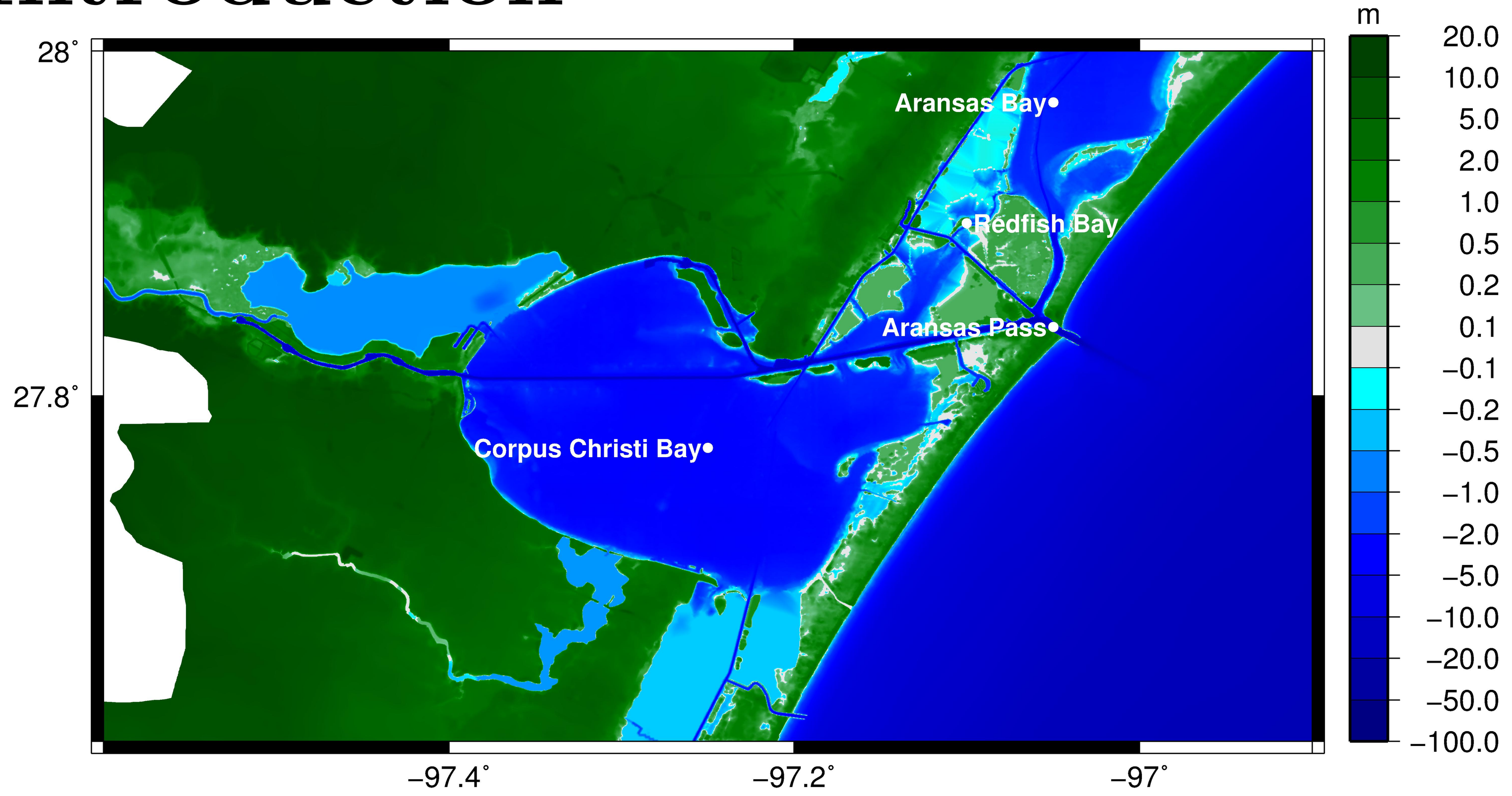
Introduction

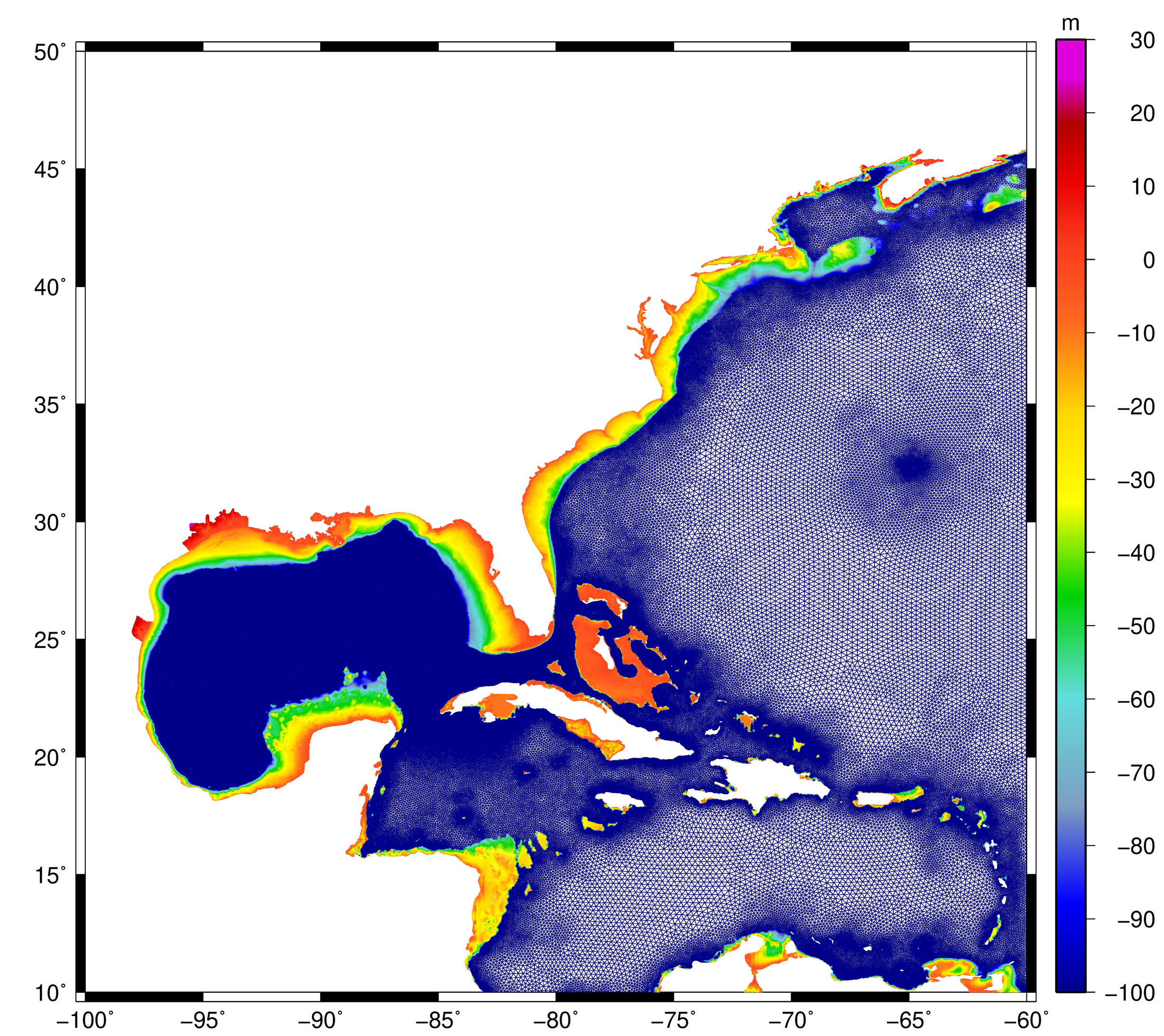


Study Area

A proposed deepening of the Corpus Christi Ship Channel, which connects the Gulf of Mexico and the Port of Corpus Christi, from an average depth of 14.33m to 21.33m to accommodate larger ships. In the nearshore region outside the ship channel, there are breeding grounds of multiple commercially and recreationally important fish species, including the Red drum fish (Sciaenops ocellatus). The reproduction of Red drum relies on the transport of larvae from the Gulf into shallow seagrass beds within Corpus Christi Bay via the Aransas Pass. In order to analyze the potential impact of the deepening, a numerical model that describes ocean circulation is developed for the case with the current and proposed channel configurations. The model is run using the stampede2 supercomputer at the Texas Advanced Computing Center (TACC) which allows the model to be highly detailed in the region of interest and executed for simulated time scales of months. This is also necessary to resolve the flow fields in the Aransas Pass while also maintaining the model size necessary to accurately simulate the winds and tides that drive the circulation in the open ocean. Subsequently, a Lagrangian particle tracker is used to ascertain the trajectories of the larvae modeled as passive Lagrangian particles using the outputs from the ocean model. Compared to similar studies done previously, the use of the TACC supercomputers allows us to model the circulation of the entire Gulf of Mexico and North American coastline. This is chosen as the impact onto the flow characteristics in the area of interest can be greatly influenced by the meteorological and tidal forcing in the model, due to the nature of hyperbolic wave type problems that are common in weather related phenomena.

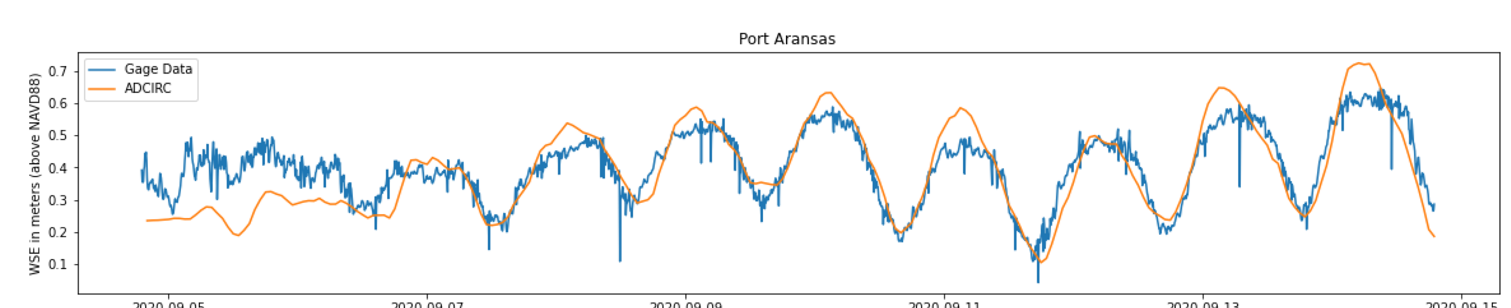
Methods

To estimate the transport of the Red drum larvae, the hydrodynamics are modeled with the highly developed and validated advanced circulation model (ADCIRC). ADCIRC models the ocean circulation by solving the shallow water equations using the finite element method on unstructured triangular meshes. The ADCIRC model needs several inputs in order to run which include a mesh that defines the spatial discretization, tidal forcing, as well as the wind and pressure fields. Two meshes are used which are identical with the exception of the bathymetry in the Ship Channel. Each mesh contains 3,352,598 nodes and 6,675,517 elements with refinement along the coast with resolution near 30m.



ADCIRC mesh

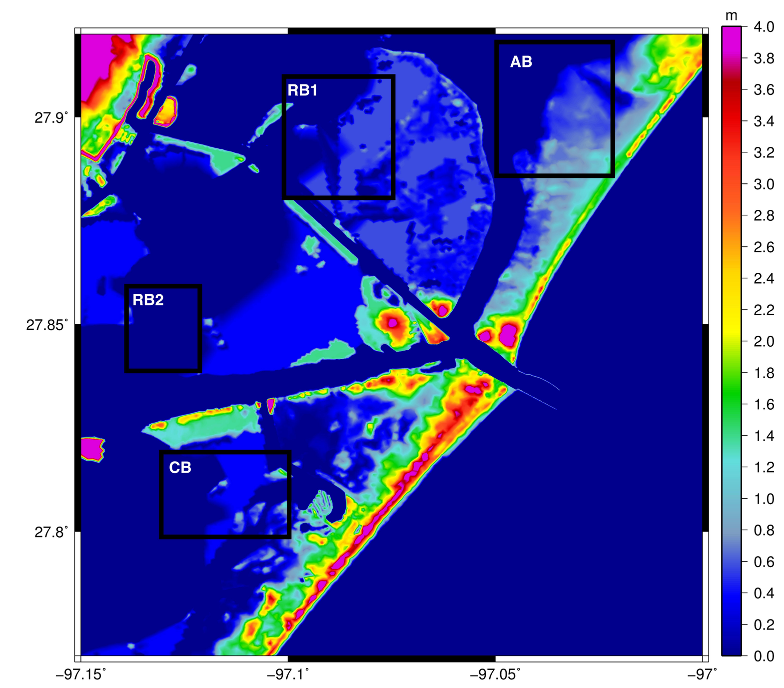
The one mesh that represents the current layout of the Ship Channel has depths of 14.33m while the mesh with the proposed dredging in the channel has a depth of 21.33m. The winds and pressure were obtained from the North American Mesoscale model (NAM), and the tidal forcing input was taken from the TPXO9 model.



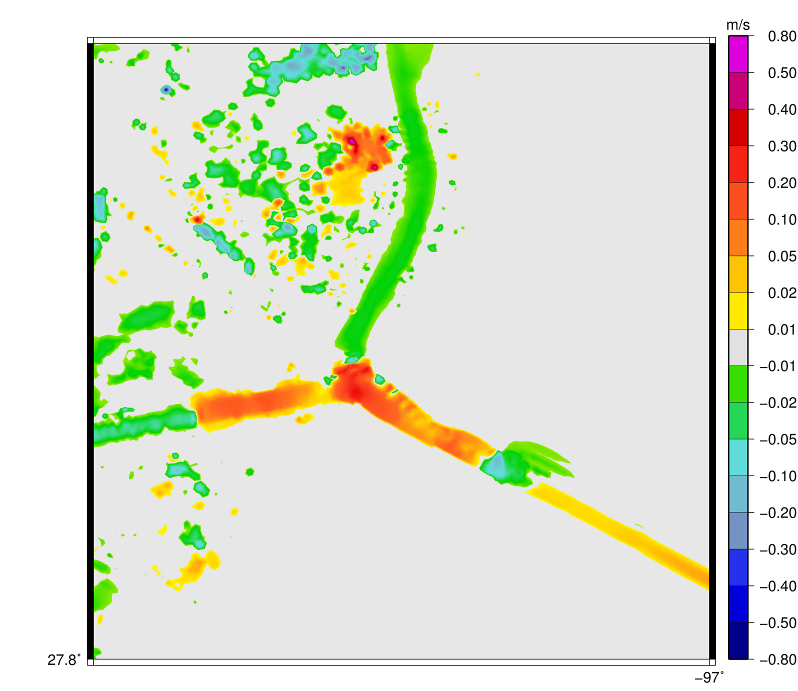
Water surface elevation in ADCIRC compared to gauge data

The ADCIRC model was validated with the current configuration, tides, and winds by comparing to actual gauge data. Once validated, the ADCIRC model was run for both meshes during the most active period of red drum spawning, from 1 September to 31 October. Two different situations were run, one from the year 2012 since that was a year of drought and one from 2019 since that year had average hydrologic conditions. The ADCIRC model produces a velocity field for each case and a separate particle tracking code is used to simulate red drum larvae. Four different conditions for the initial points of the larvae are simulated as seen in [1] and the amount of larvae that fall within the sea grass areas (shown below) are tabulated.

Results and Discussion



Locations of Red drum larvae nursery grounds.



Velocity Change in the Aransas Pass.

The number of larvae that ended up reaching the above bins was shown to be highly dependent on initial condition with the difference in success rates varying as much as 22 percent between any given initial configuration. The number of larvae reaching the grass beds also differed widely between the year with the drought, 2012, and the average year, 2019 with an average difference in success rate of 7% between years. However, at each given initial condition, the differences in success rates for the case with the current channel vs the deeper channel were low with an average increase of 1.0% in success rate across all cases for the deeper channel.

Table 1: 2012 conditions successful larvae count.

Initial condition	Current bathymetry	Proposed bathymetry	% difference
I	442	410	-7.24
II	144	106	-26.39
III	351	381	8.55
IV	1265	1342	6.09
Total	2202	2239	1.54

Table 2: 2019 conditions successful larvae count.

Initial condition	Current bathymetry	Proposed bathymetry	% difference
I	285	294	2.81
II	38	27	-28.95
III	209	216	3.35
IV	959	966	0.73
Total	1491	1503	0.80

References

[1] E. Valseth, M. D. Loveland, C. Dawson **and** E. J. Buskey, ?A study of the potential impact of dredging the corpus christi ship channel on passive particle transport,? *Journal of Marine Science and Engineering*, **jourvol** 9, **number** 9, **page** 935, 2021.