Attachment 5
PPBEP COMMUNITY GRANT FINAL RESEARCH REPORT FORM

Agreement No.:	FY2023-08		
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Project Title:	Understanding and Improving Water Quality in Backwater Areas of Perdido-Pensacola System Under Changing Climate		
Please submit any high-resolution photos related to the project (include photo credit for possible use by PPBEP for use in our e-newsletter, annual report, social media, or website) with your report as image files to lmcdonald@ppbep.org.			

ABSTRACT: Limit to 250 words. The abstract should include background and a statement of the problem or issue, followed by a description of the research method(s) and design, the major findings, and the conclusions reached.

Small-scale but ecologically significant backwater regions encompass dead-end bayous, isolated embayments, and other areas with restricted circulation. The drivers of poor flushing in the present and future due to impacts of climate change, e.g., sea level rise, warming, and changing freshwater inflows remain unknown. To fill these gaps, we applied a three-dimensional high-resolution hydrodynamic model to examine these scenarios. Based on model outputs, water residence time was estimated in 9 backwater areas under current and future sea level conditions utilizing the Lagrangian particle tracking methos. In bayous with narrow inlets, the residence time increases dramatically from 5 days near the inlet to more than 20 days toward the head. 20 ~ 50% particle remain in the system after 30 days. These particles stop horizontal movement and only oscillate vertically due to the standing wave effect. An increase of 0.5 m in sea level increases 6 ~ 8% particles outgoing and decrease mean residence time by 1 day in bayous along western coast of Pensacola Bay. Opposite responses occurred in bayous along eastern coast, where 20% more particles remain in the system and mean residence time increase by 2 days. The potential reasons might be the opposite wind driven flow patterns across these systems.

INTRODUCTION: Provide necessary background information, describe the purpose of the project, and state the key objectives.

This project investigated flushing characteristics and their responses to climate change and sea level rise in backwater areas in Perdido-Pensacola Bays system. Toward this goal, the major objectives are: (1) development and verification of a high-resolution cross-scale model for Perdido-Pensacola- Choctawhatchee Bays system based on SCHISM; (2) application of virtual particle tracking to quantitative determine the residence time in backwater areas, (3) condition of scenario studies to understand the influence of sea level rise on residence time in backwater areas.

METHODS: Provide sufficient detail for how the project was conducted and data were collected, including specific materials and methodologies/protocols.

A numerical model that highly resolves all backwater areas was developed for the Perdido-Pensacola-Choctawhatchee Bays system based on SCHISM (Semi-implicit Cross-scale Hydroscience Integrated System Model). In the model, rivers and creeks in the upstream delta and local water shed were resolved. Narrow inlets and jetties are all resolved to capture flow rectification near these features. The mesh has 70,214 nodes and 104,510 elements. The bathymetry data is composed of data products at 1 arcsecond (30 m) and 1/9 arcsecond (3 m) resolutions. In rivers and creeks, where bathymetry is missing, data from https://usa.fishermap.org/depth-map/ were used as a supplement. Freshwater discharge from 11 rivers were input to drive the model.

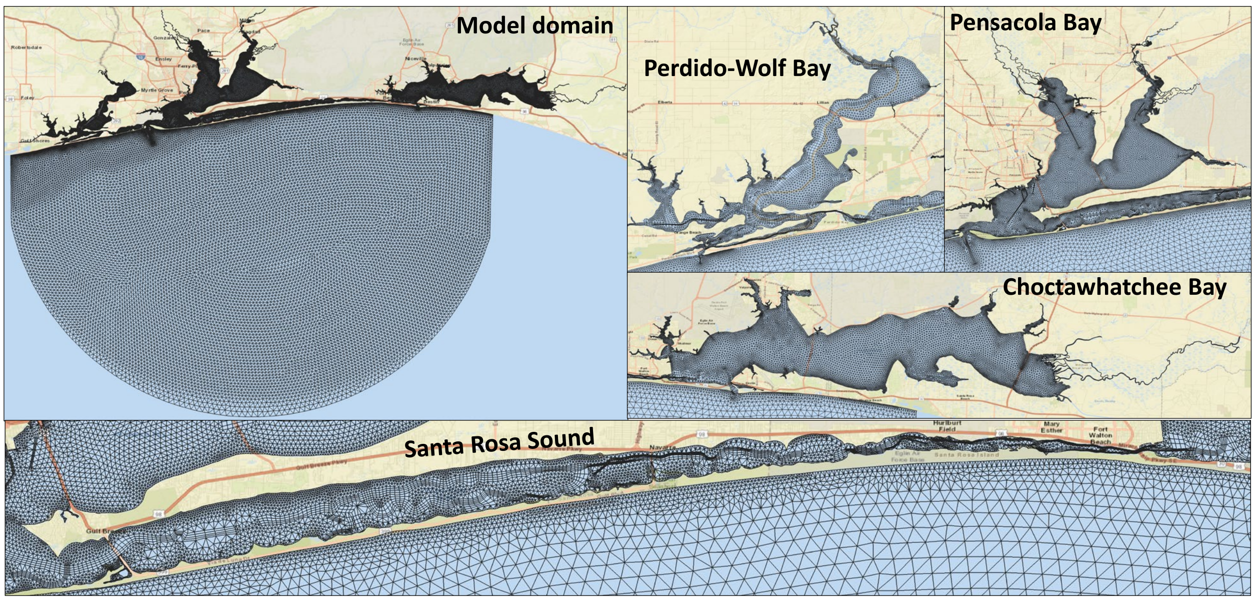

Figure. 1 SCHISM model of Perdido-Pensacola- Choctawhatchee Bay system.

Based on a hydrodynamic simulation in January 2019, residence time in Bayou Texar, Bayou Chico and Bayou Grande was estimated based on offline Lagrangian particle tracking. Particles were released over 48 hours (i.e., 2 tidal cycles) at an interval of 2 hours. There were 3 repetitions with a gap of 10 days. In the vertical direction, the particles were released at every 1m depth level measuring from the surface. The mean residence time is defined as the averaged time taken by the particles released at same location to leave the system. Each release lasted for 30 days. The particles that didn't leave the system after 30 days were defined as "dead particles", of which the resident time was set to 30 days. Particles that could leave the system within 30 days were named "survival particles". Both the spatial distribution of residence time and the ratio of dead particles reveal the flushing characteristics of backwater areas.

RESULTS: Present and describe key results from your research project. This section should accurately describe all data collected, including data summaries, significant observations, and trends (if applicable). Please attach a separate file with map(s), tables, and figures.

In backwater areas with narrow inlets such as Bayou Texar, Bayou Chico, and Bayou Grande, the residence time increased dramatically from inlet to head areas. The residence time is around 5 days around the inlet, and it quickly increased up to 20 days toward the head (Figures 2 - 4). Unlike Bayou Garcon, where particles can escape through the wide connection to the estuary, all other bayous have 20 ~50% particles that get stuck (Table 1).

Different backwater areas demonstrate various responses to sea level rise. Residence time in bayous with narrow inlets such as Bayou Texar, Bayou Chico, and Bayou Grande decreased when sea level increases by 0.5 m. The ratio of dead particles decreased by 6 ~ 8%, the mean residence time decreased almost by 1 day. Thus, more particles can escape from the backwater area with sea level rise. Meanwhile, regions with lower residence time (<10 days) extended toward upstream indicating sea level rise promote exchange between backwater areas and main estuary.

However, residence time in East Bay River demonstrates opposite responses to sea level rise. The dead particle ratios increased by 18% and mean residence time increased by 2 days (Table 1, Figure 6).

Table 1 Mean residence time and ratio of dead particles

Backwater area	Sea Level	Total no. of particles	Dead particle ratio	Mean residence time (day)
Bayou Texar	Current	53,136	50.19%	21.99
	+ 0.5 m	61,056	41.64%	21.13
Bayou Chico	Current	67,464	28.83%	13.70
	+ 0.5 m	72,720	22.16%	12.04
Bayou Grande	Current	143,784	57.59%	23.18
	+ 0.5 m	170,712	51.05%	22.06
East Bay River	Current	33,048	18.88%	12.40
	+ 0.5 m	39,744	24.69%	14.49
Bayou Garcon	Current	17,136	2.99%	3.51
	+ 0.5 m	17,136	1.66%	3.06
Catfish Basin	Current	16,488	14.12%	8.37
	+ 0.5 m	18,504	10.33%	4.29
Palmetto Creek	Current	27,648	30.89%	14.42
	+ 0.5 m	31,464	32.83%	15.84
Soldier Creek	Current	38,664	67.04%	23.00
	+ 0.5 m	44,496	49.23%	19.64
Tarkiln Bayou	Current	8,208	16.59%	12.04
	+ 0.5 m	10,440	18.38%	11.84

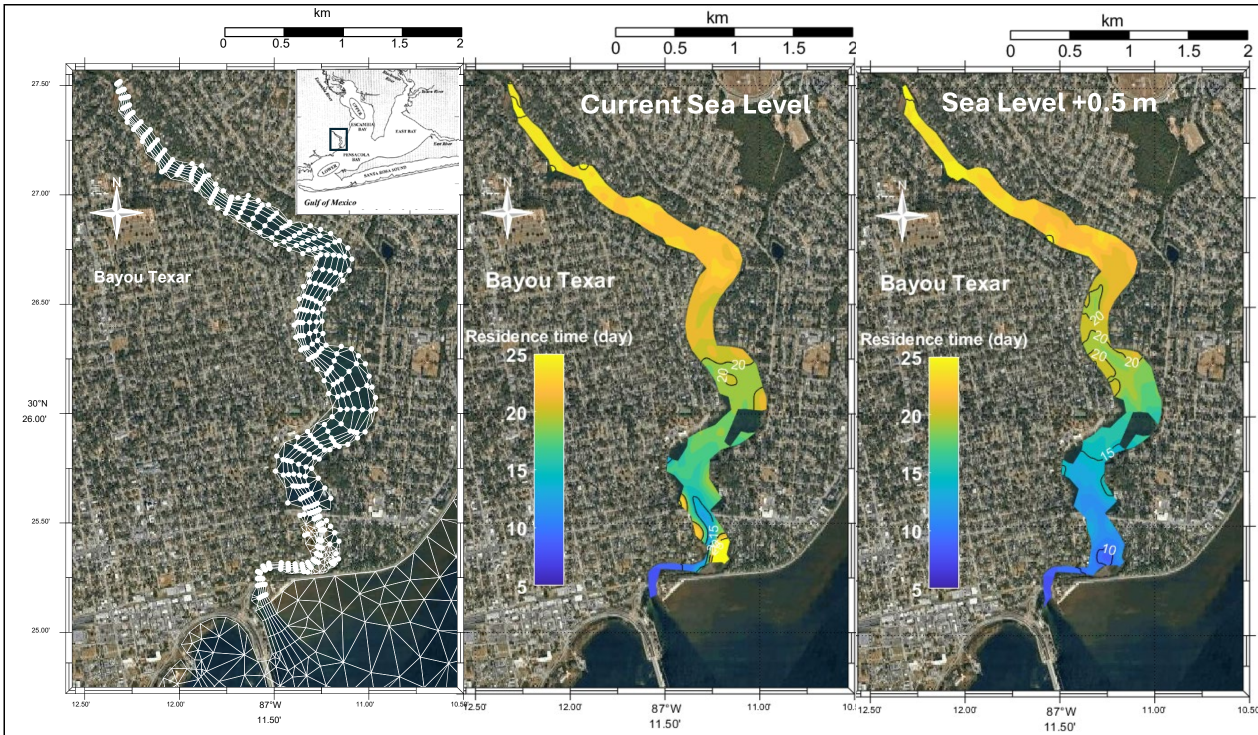

Figure 2 Model mesh and residence time in Bayou Texar. In the left panel, the mesh nodes highlighted by white dots were particle release locations. In the middle and right panels, the contour map demonstrates spatial heterogeneity of residence time.

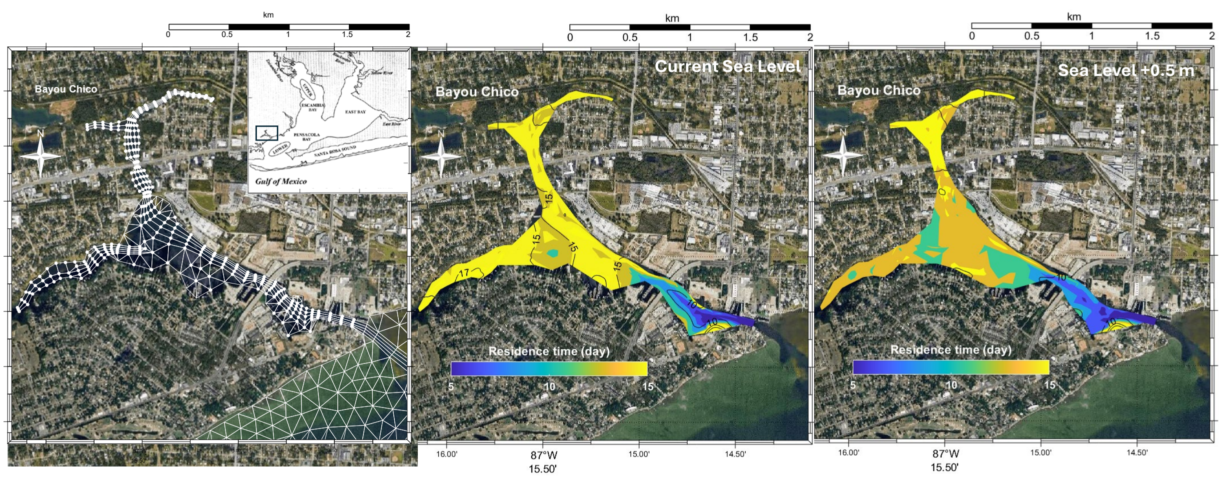

Figure 3 Model mesh and residence time in Bayou Chico. In the left panel, the mesh nodes highlighted by white dots were particle release locations. In the middle and right panels, the contour map demonstrates spatial heterogeneity of residence time.

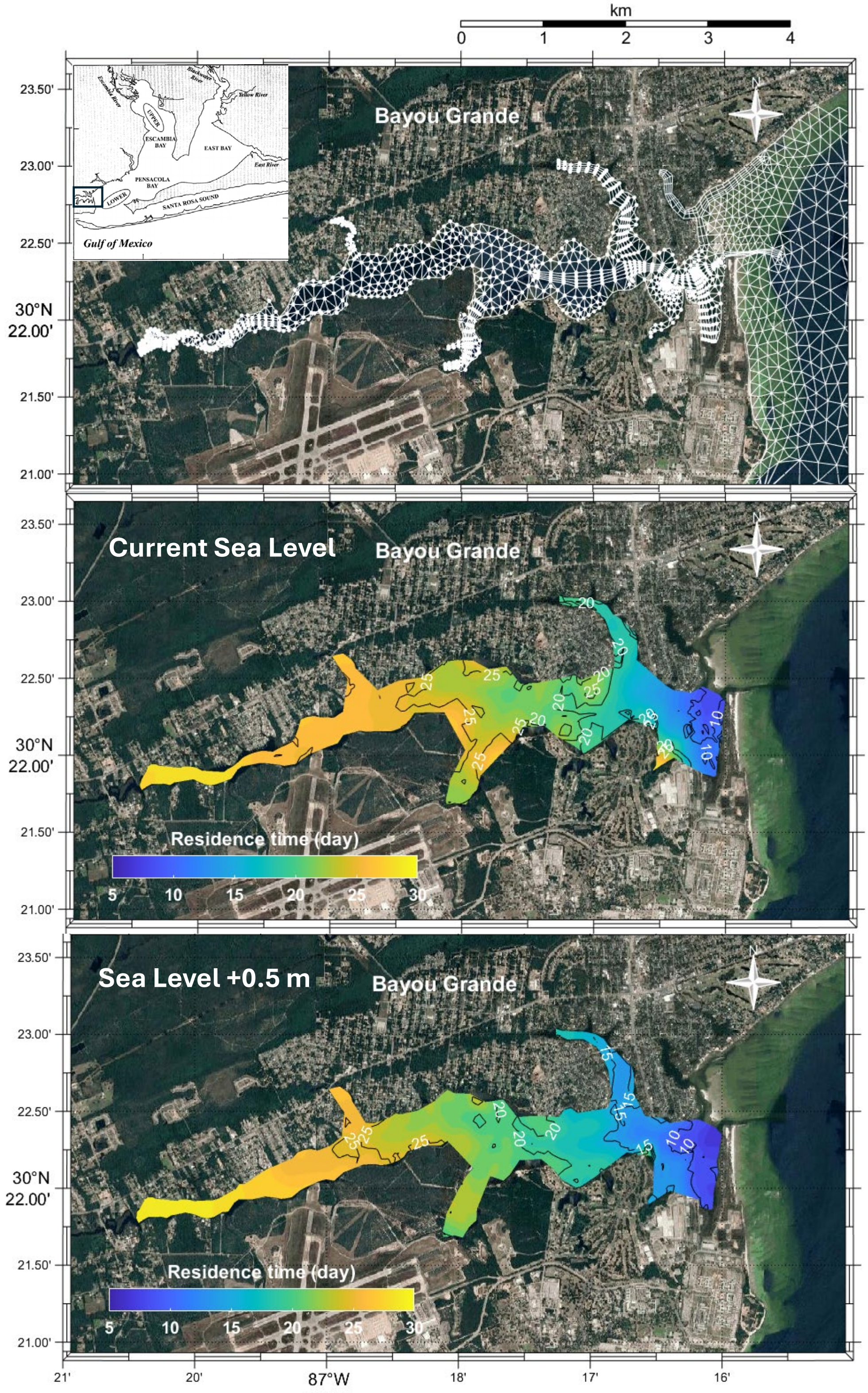

Figure 4 Model mesh and residence time in Bayou Grande. In the upper panel, the mesh nodes highlighted by white dots were particle release locations. In the middle and lower right panel, the contour map demonstrates spatial heterogeneity of residence time.

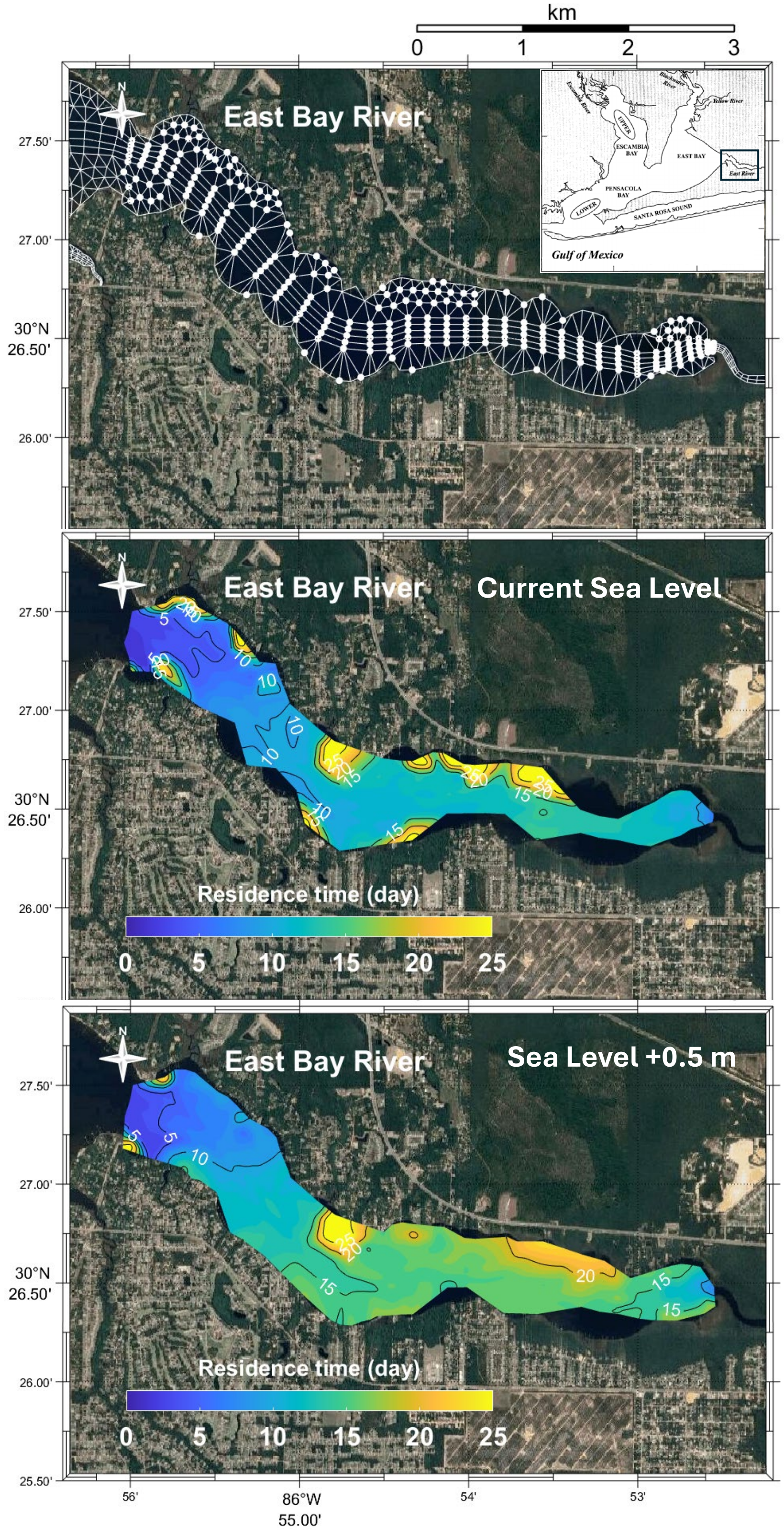

Figure 5 Model mesh and residence time in East Bay River. In the upper panel, the mesh nodes highlighted by white dots were particle release locations. In the middle and lower right panel, the contour map demonstrates spatial heterogeneity of residence time.

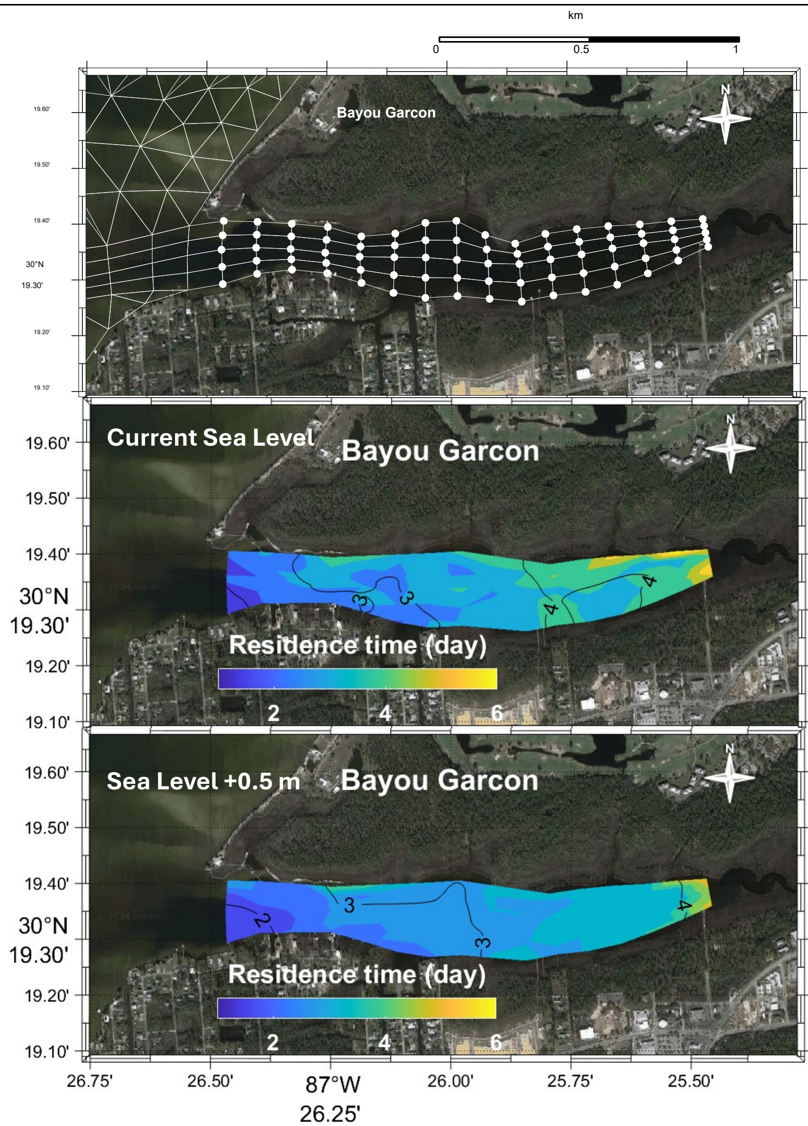

Figure 6 Model mesh and residence time in Bayou Garcon. In the upper panel, the mesh nodes highlighted by white dots were particle release locations. In the middle and lower right panel, the contour map demonstrates spatial heterogeneity of residence time.

DISCUSSION AND CONCLUSION: Present, interpret, and discuss the results, project outcomes, future research needs, and how this research connects back to the CCMP.

The trajectories of "dead" particles only presented vertical oscillation through each tidal cycle without horizontal movement, which seems like the locating in the node of a standing wave, where horizontal transport vanishes. Thus, the mouth region has sufficient flushing due to the impact of tidal excursion. However, shortly away from the mouth region, the standing wave impact prohibits horizontal exchange. Time and effort are required to understand how short-period storm water input influences the standing wave impact in the head zone of backwater areas.

Potential reasons might be that East Bay River is located along the eastern shoal of Pensacola Bay which is opposite Bayou Texar, Bayou Chico, and Bayou Grande. The wind driven flow patterns are opposite along western and eastern shoals, which may cause the major difference in flushing characteristics. Therefore, a universal response of flushing in backwater areas to sea level rise is not expected.

<u>REFERENCES: Please list references cited throughout this report. Additionally, if there are key references that PPBEP needs copies of to fully understand your methods and overall research, please attach references as individual PDFs.</u>

Monsen, N.E., Cloern, J.E., Lucas, L.V. and Monismith, S.G., 2002. A comment on the use of flushing time, residence time, and age as transport time scales. *Limnology and oceanography*, *47*(5), pp.1545-1553.

Zhang, Y.J., Ye, F., Stanev, E.V. and Grashorn, S., 2016. Seamless cross-scale modeling with SCHISM. *Ocean Modelling*, *102*, pp.64-81.

<u>SUCCESSES AND CHALLENGES:</u> **Describe the significant successes and challenges the organization experienced related to the funded grant.**

The successful development, verification and application of the creek-to-ocean cross-scale model promotes our skills and experience in mesh generation and manipulation, high performance computer (HPC) resource management, and heavy data analysis and visualization. The model and associated coding scripts on pre- and post-processing have been well archived and documented for future applications.

The residence time in 9 backwater areas is quantitatively determined to the first time. The model outputs, maps, and images can be provided to local stakeholders as management references. The findings of spatial heterogeneity of residence time and its relation to inlet constraints, bathymetry features, and sea level rise can lead to a peer-review publication.

The most challenging part is the lack of data in creeks and rivers from local watershed including bathymetry and discharge. To have a comprehensive modeling system for backwater areas, we also need high resolution local watershed models besides the hydrodynamic model. The local watershed model can provide accurate input for the hydrodynamic model.

<u>LESSONS LEARNED:</u> **Describe what the organization learned based upon the results, successes, and challenges reported. Address programmatic, evaluative, or organizational changes that will be made based upon these lessons learned.**

The lack of data for setting up and verifying the model pushed us to widely research and contact other institutions. In hindsight, we should have contacted other institutions at the beginning of the project given the limited performance period for the project. In the end, we did build tight connections with other researchers. These connections allow us to access the latest datasets that can benefit our future work. The heavy workload of setting up and running the simulations, data analysis and visualization requires improving our skills in project management and having more well-trained personnel working on the project to share the work.

This report is submitted in accordance with the reporting requirements of Agreement No. FY2023-08 and accurately reflects the activities associated with the project.

Zhilong Liu 06/20/2024

Signature of Grantee's Representative Date

Zhilong Liu Research Assistant Professor

Print Name and Title