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Houston Ship Channel Expansion Channel Improvement Project (ECIP) Numerical Modeling Report: BABUS Cell and Bird Island Analysis

Jennifer McAlpin and Cassandra Ross

August 2021

Coastal and Hydraulics Laboratory

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Jennifer McAlpin and Cassandra Ross

Coastal and Hydraulics Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

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Abstract

The Houston Ship Channel (HSC) is one of the busiest deep-draft navigation channels in the United States and must be able to accommodate increasing vessel sizes. The US Army Engineer District, Galveston (SWG), requested the Engineer Research and Development Center, Coastal and Hydraulics Laboratory, perform hydrodynamic and sediment modeling of proposed modifications in Galveston and Trinity Bays and along the HSC. The modeling results are necessary to provide data for hydrodynamic, salinity, and sediment transport analysis.

SWG provided three project alternatives that include closing Rollover Pass, Bay Aquatic Beneficial Use System cells, Bird Islands, and HSC modifications. These alternatives and a Base (existing condition) will be simulated for present (2029) and future (2079) conditions. The results of these alternatives/conditions as compared to the Base are presented in this report.

The model shows that the mean salinity varies by 2–3 ppt due to the HSC channel modifications and by approximately 5 ppt in the area of East Bay due to the closure of Rollover Pass. The tidal prism increases by 2.5% to 5% in the alternatives. The tidal amplitudes change by less than 0.01 m. The residual velocity vectors vary in and around areas where project modifications are made.

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Preface

The model investigation was conducted for the US Army Corps of Engineers, Galveston District, and was authorized and funded by the Port of Houston Authority through Services Agreement SA-2020-CHL-3562, under Funding Account Code U4374255; AMSCO Code 451902.

The work was performed at the Coastal and Hydraulics Laboratory, US Army Engineer Research and Development Center (ERDC-CHL), Vicksburg, MS, under the general direction of Dr. Ty V. Wamsley, Director, and Mr. Keith Flowers, Deputy Director, ERDC-CHL. Direct supervision was provided by Dr. Cary A. Talbot, Chief, Flood and Storm Protection Division, and Mr. David May, Chief, River and Estuarine Engineering Branch.

COL Teresa A. Schlosser was Commander of ERDC, and the Director was Dr. David W. Pittman.

1 Introduction

1.1 Background

Since the early 1800s, vessels have transited Galveston Bay both to and from Galveston and Houston (Galveston Bay Estuary Program 2002). Galveston Bay is a tidal estuary such that the effect of the tide on the water surface elevation is observed from the Gulf of Mexico to locations near Houston, TX. The Houston Ship Channel (HSC) is a deep-draft navigation channel that allows for vessel passage from the Gulf to the City of Houston, approximately 53 mi[1] upstream. Since 1903, Operations and Maintenance dredging has been conducted in the bay portion to maintain authorized channel dimensions. Figure 1 shows the HSC as it passes through Galveston Bay from its entrance at Bolivar Roads to the Port of Houston.

Figure 1. HSC area map.

[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

In 2005, The US Army Corps of Engineers (USACE), Galveston District (SWG), enlarged the HSC from a 40 ft depth by 400 ft width to a 45 ft depth by 530 ft width. A three-dimensional (3D) numerical model study was implemented at the US Army Engineer Research and Development Center, (ERDC) Coastal and Hydraulics Laboratory (CHL), to evaluate the salinity and circulation impact of this enlargement. In Berger et al. (1995a), the model was shown to represent the salinity and circulation in the earlier channel configuration. Berger et al. (1995b) used the model to predict the impact of the enlarged channel. Carrillo et al. (2002) used the model to evaluate the addition of barge lanes along the ship channel flanks. Tate and Berger (2006) looked into possible reasons for increased shoaling in the ship channel by analyzing vessel effects and sediment properties in the area. In Tate et al. (2008), the sediment model was validated using the same hydrodynamic model, and the results included the effects of vessel transport on the sedimentation patterns. The model was utilized again to investigate proposed changes to the Bayport Flare (Tate and Ross 2012).

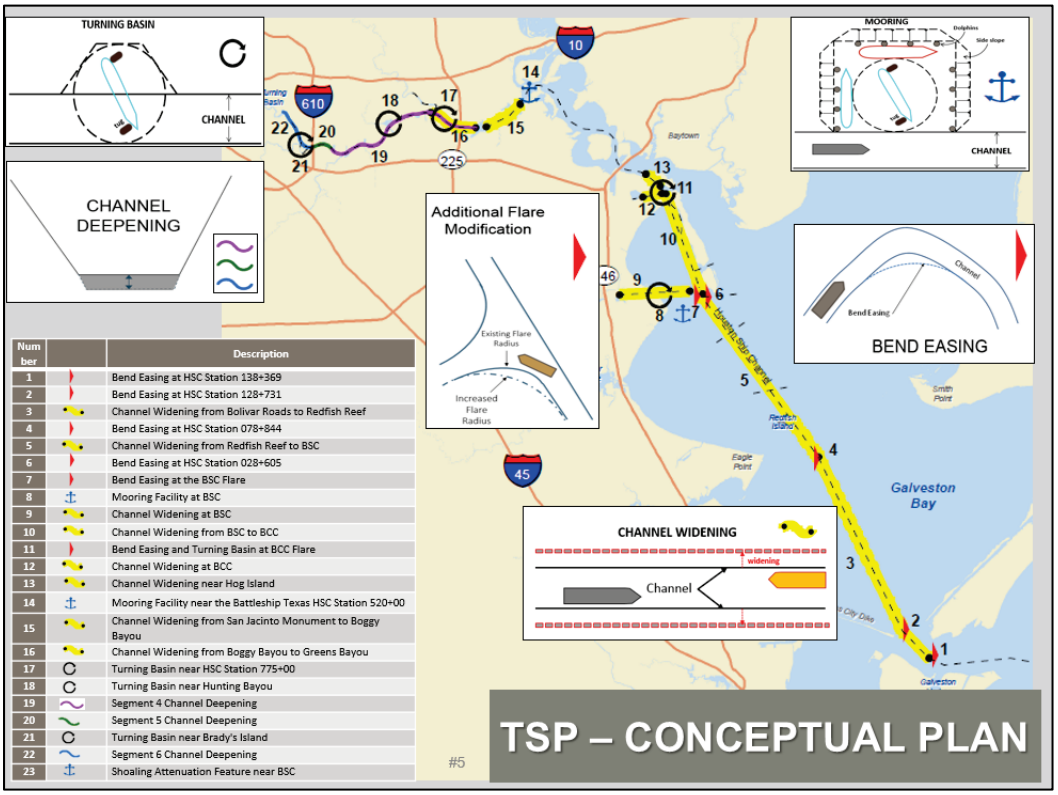
The deep navigation channel acts as a natural pathway for salinity to travel upstream since high-saline water is denser than fresh water and tends to flow up-channel along the channel bottom. The residual velocity, or net drift, is flood in much of the channel (Tate and Berger 2006) (i.e., the tendency is for suspended material to move upstream into Galveston Bay.) The velocity magnitudes drop in the Atkinson Island reach due to tidal reflections from the bay boundaries. More stratification occurs as a result in this reach, and material from farther downstream in the estuary will tend to collect near Atkinson Island.

The behavior of the salinity and hydrodynamics in Galveston Bay during May through June is different than the remainder of the year due to a salinity drop in the northern Gulf of Mexico as the Mississippi, Sabine-Neches, Atchafalaya, and other northern Gulf river systems provide a significant influx of fresh water. When the salinity in the Gulf of Mexico drops, the salt water tends to evacuate from the bays (Berger et al. 1995a). A reduction in bay salinity is hypothesized to result in different suspended concentrations. Therefore, fresh deposit characteristics may change during this time period when compared to data collected at other times during the year. If this is the case, sediment would tend to collect farther down the channel toward Red Fish Reef during this late springtime period.

1.2 Objective

In 2016, the SWG requested ERDC-CHL perform hydrodynamic and sediment transport modeling of proposed modifications along the HSC from its connection at the Gulf of Mexico to the Port of Houston (Figure 2). The modeling results are necessary to provide data for salinity and sediment transport analysis as well as ship simulation studies in which pilots test the navigation effects of the modifications. The model results of project year zero (2029) and project year 50 (2079) with and without project results were documented in McAlpin et al. 2019b.

Figure 2. Proposed modifications to the HSC (figure from SWG).



Number		Description
1		Bend Easing at HSC Station 138+369
2		Bend Easing at HSC Station 128+731
3		Channel Widening from Bolivar Roads to Redfish Reef
4		Bend Easing at HSC Station 078+844
5		Channel Widening from Redfish Reef to BSC
6		Bend Easing at HSC Station 028+605
7		Bend Easing at the BSC Flare
8		Mooring Facility at BSC
9		Channel Widening at BSC
10		Channel Widening from BSC to BCC
11		Bend Easing and Turning Basin at BCC Flare
12		Channel Widening at BCC
13		Channel Widening near Hog Island
14		Mooring Facility near the Battleship Texas HSC Station 520+00
15		Channel Widening from San Jacinto Monument to Boggy Bayou
16		Channel Widening from Boggy Bayou to Greens Bayou
17		Turning Basin near HSC Station 775+00
18		Turning Basin near Hunting Bayou
19		Segment 4 Channel Deepening
20		Segment 5 Channel Deepening
21		Turning Basin near Brady's Island
22		Segment 6 Channel Deepening
23		Shoaling Attenuation Feature near BSC

In early 2020, the Port of Houston Authority (PHA) requested modeling for two additional channel widths in the bay portion of the HSC (HSC Stations 138+000 to 0+000; labeled from 1 to 13 in Figure 2). These widths are necessary for ship simulation such that an adequate channel width can be determined for safe navigation. Previously, a 650 ft channel width was simulated. McAlpin and Ross (2020) include the analysis for channel widths of 700 ft and 750 ft.

SWG requested additional simulations to analyze impacts on hydrodynamics, salinity, and sediment transport due to the closure of Rollover Pass (which remained opened in all previous model simulations), the addition of Bay Aquatic Beneficial Use System (BABUS) sites and proposed Bird Islands, as well as the combined impact of these additions with the Expansion Channel Improvement Project (ECIP) Project 11 (P11) modifications. These three alternatives will be documented in this report.

1.3 Approach

Previously, a 3D Adaptive Hydraulics (AdH) model was developed and validated for simulation of hydrodynamics, salinity, and sediment transport (Savant and Berger 2015). The AdH code solves the shallow water equations to compute depth and velocity at node points defining the domain. AdH includes a linkage to the SEDLIB sediment transport library that computes cohesive and non-cohesive erosion and deposition, which is then transported by the AdH code. Flocculation of sediment is not included in AdH but is somewhat accounted for by manipulation of sediment grain size and settling velocity. All models are limited by the data used to define them, and uncertainty in model boundary conditions must be considered when reviewing the model results and determining their applicability to the specific project.

The model was validated to available field data for all parameters (McAlpin et al. 2019a) and then utilized to test project alternatives for present and future conditions (McAlpin et al. 2019b). For all simulations, the model was set up to run for 2 yr — the first year being a spin-up period to obtain an accurate initial salinity field as well as an accurate sediment bed, and the second year was used for all analyses. The same method is used for simulation of these three alternatives.

The model development and boundary condition specification for the hydrodynamic, salinity, and sediment transport model as well as the model to field data comparisons, including water surface elevation, velocity, salinity, and HSC dredge volumes were documented in McAlpin et al. 2019a. This document focuses on the model results for the three additional alternatives that include the closure of Rollover Pass, the addition of four BABUS cells between Atkinson Island and Mid Bay Marsh, and the PHA Project 11 ship channel modifications. These simulations are made for both the present and future boundary conditions.

2 Plan Alternatives

Documentation of the plan alternatives includes the geometric modifications to the system as well as the input conditions for the "present" project year zero (2029) and "future" project year (2079). Therefore, there will be eight alternatives – four geometries, each with two simulation years.

- Base or Existing Without Project (Base)
- Closure of Rollover Pass (CloseRollover)
- Closure of Rollover Pass and Babus Cells (CloseRollover-BABUS)
- Closure of Rollover Pass, Babus Cells, PHA modifications and Bird Islands (CloseRollover-BABUS-P11).

Although the Base condition was simulated during the initial project (McAlpin et al. 2019b), it was re-run and will be presented here with the additional alternatives for purpose of consistency in comparison.

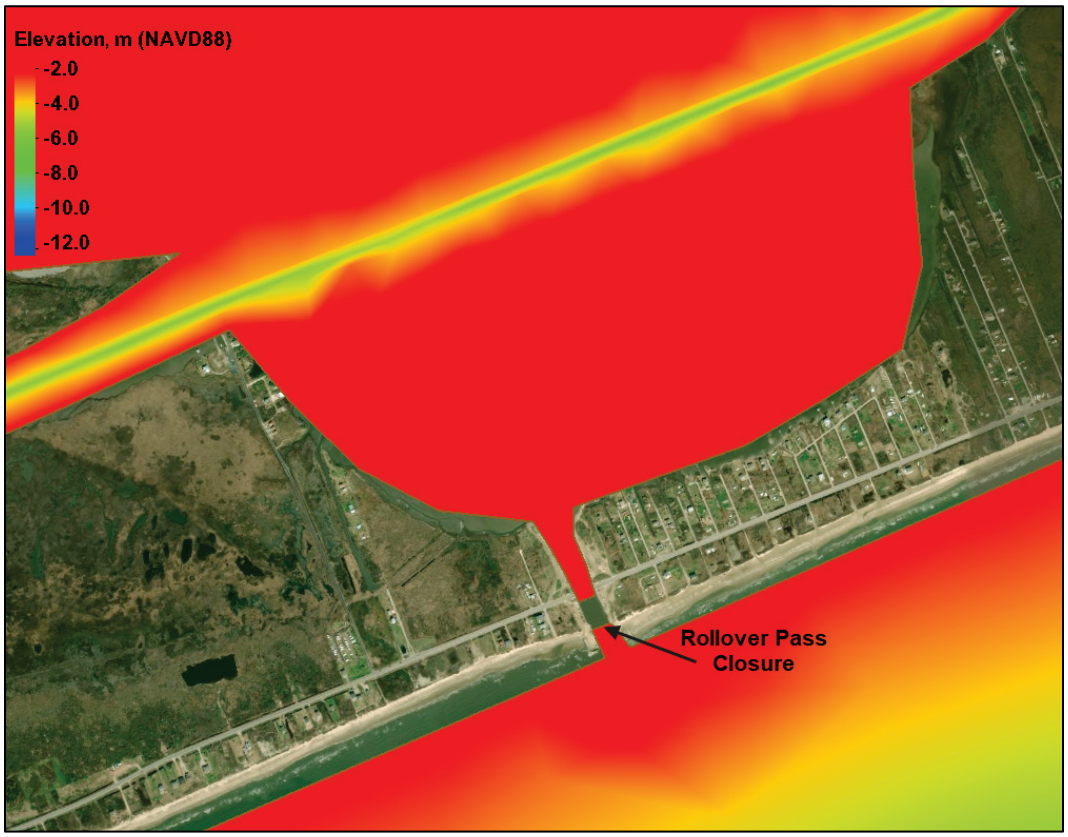
2.1 Project modifications

The Base condition is taken from the numerical model definition used for the model validation, detailed in the model calibration/validation report (McAlpin et al. 2019a).

2.1.1 Rollover Pass closure

The closure of Rollover Pass to protect residents from potential storm surge and flooding has been discussed for many years. The pass connects East Bay to the Gulf of Mexico and was created by the Texas Game and Fish Commission (now Texas Parks and Wildlife) in 1955 (Texas General Land Office 2020). Authorization to close Rollover Pass was given in December 2011, and the closure process began in September 2019. All previous modeling performed with this 3D AdH model did not include closing Rollover Pass. This alternative simulates the closure by placing a simple gap in the model domain, thereby disconnecting the Gulf of Mexico from East Bay at this location. Figure 3 shows the AdH model domain with the closure of Rollover Pass.

Figure 3. Rollover Pass closure as defined in the numerical model mesh.



2.1.2 Rollover Pass closure and BABUS cells

In addition to the closure at Rollover Pass, SWG proposes to place four BABUS cells in Trinity Bay south of Atkinson Island. These areas are intended to be for dredge disposal and beneficial use habitat. SWG provided drawing files of the size and placement of these cells. The planned elevation on the inside of the cells is +2 ft Mean Lower Low Water (MLLW), which is equal to the current average water surface elevation in this area. Although there is an entrance channel into each cell, at this internal bed elevation these cells will not wet with every tidal cycle. These cells are modeled as completely closed structures given that this 3D AdH model is unable to simulate dry nodes/elements. Although the openings into the cell will allow some exchange, that volume of water will be extremely small due to the internal design elevation of the cells and yield a negligible impact on the bay-wide flow and salinity results. Figure 4 shows the size and placement of the four BABUS cells as specified by SWG. The red line inside the green cells is the dike crest center line and used to reference all mesh distances. SWG also provided a drawing file with side slope specifications that was used to determine where to place the mesh

boundary and at what elevation such that all nodes remain wet throughout the simulations. These details are provided in Figure 5. Figure 6 shows the domain bathymetry with the BABUS cells along with an inset illustrating the mesh elements around the cells.

Figure 4. BABUS cell Google Earth file provided by SWG giving cell placement and size.

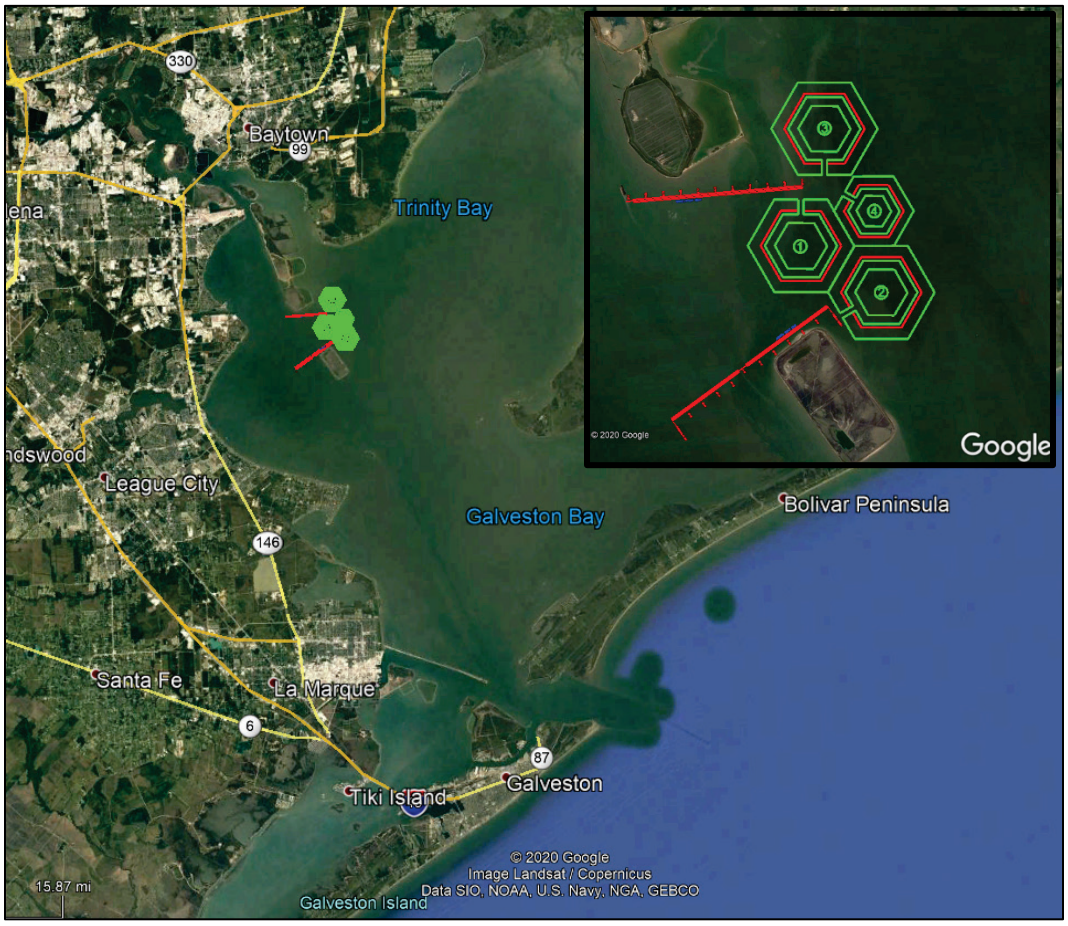


Figure 5. Side slope and elevation definition for BABUS mesh (not to scale).

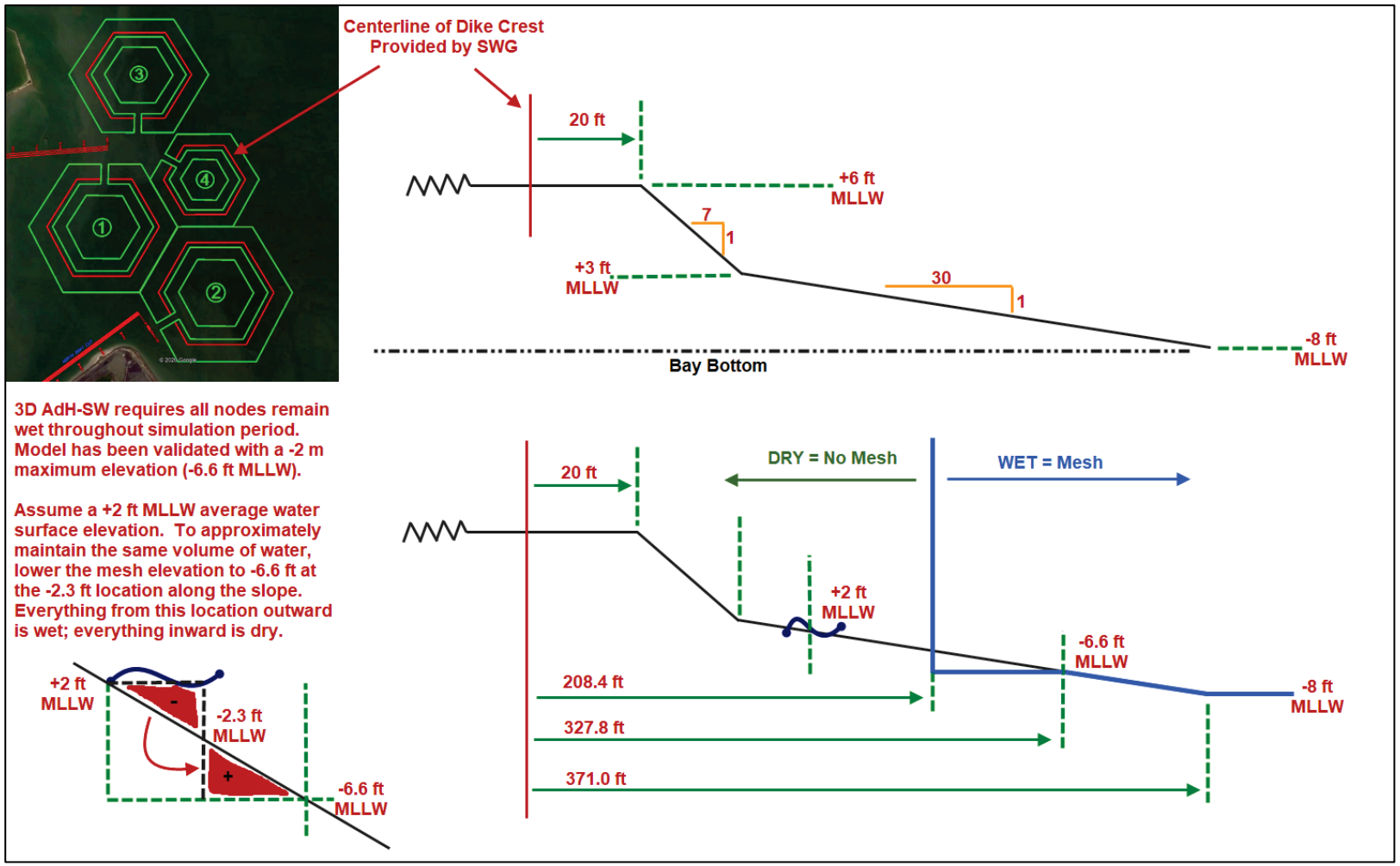
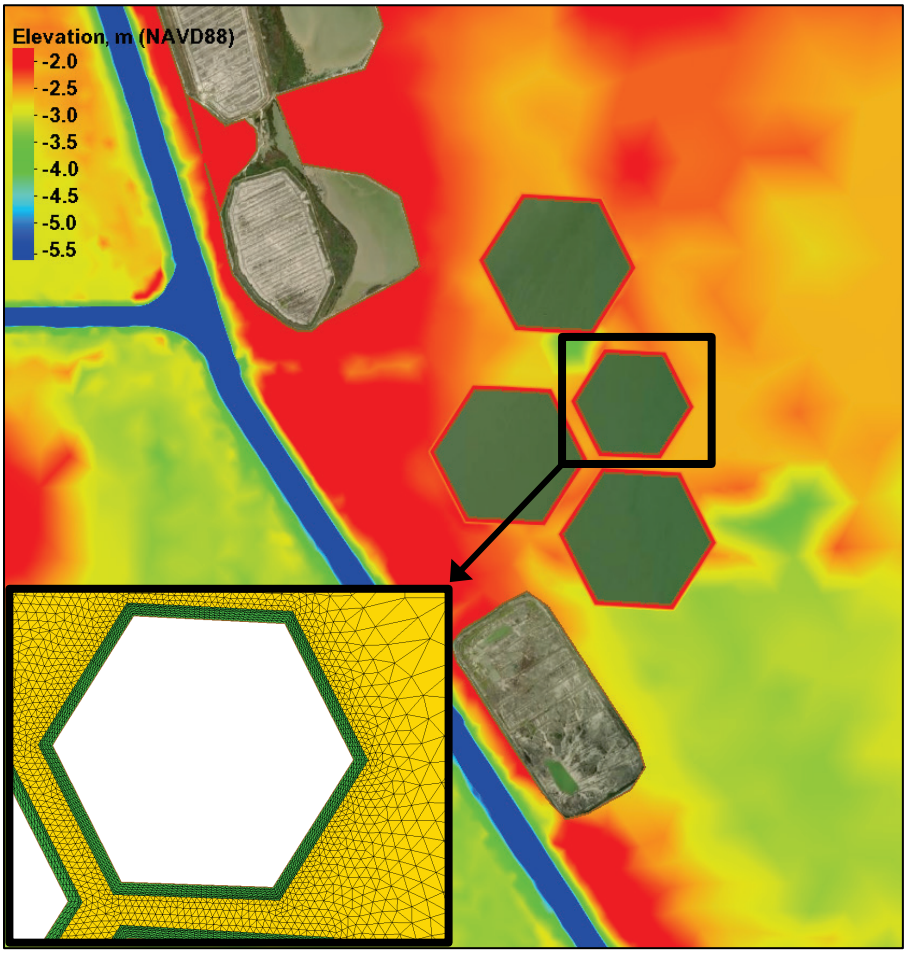


Figure 6. AdH model mesh with BABUS cells and mesh element inset.



2.1.3 Rollover Pass closure, BABUS cells, and PHA modifications and Bird Islands

The closure of Rollover Pass and the BABUS cells are then included with the PHA proposed HSC modification plan (P11). Several potential channel modification plans were analyzed for cost/benefit based on labor for dredging, mitigation for habitat adjustment, and other factors. The final tentatively selected plan (TSP) was alternative 8, otherwise known as the "everything plan." This plan includes widening the bay portion of the HSC to a width between 650 ft to 820 ft, widening and deepening several sections of the bayou portion of the HSC, as well as bend easings, mooring facilities, and turning basins. Figure 2 is a schematic of this alternative.

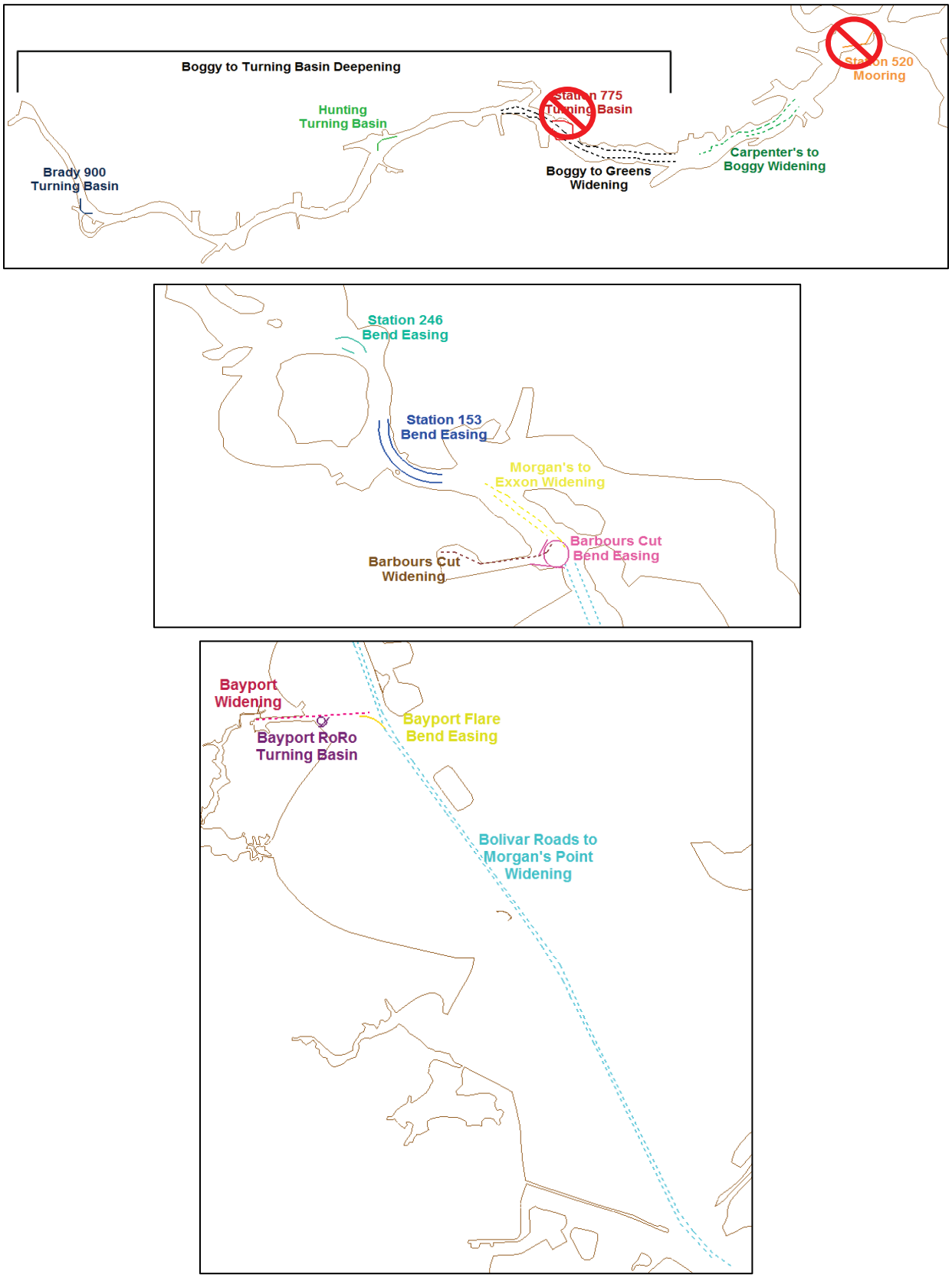
Details of the TSP, or project, are provided in Table 1 and Figure 7. Deepening segments are not included in Figure 7. All depths given in the table are based on MLLW and include advanced maintenance (AM) and

Allowable Overdepth (AO) where specified. The width of the bay portion of the HSC from Bolivar Roads to Morgan's Point was modeled initially at 650 ft as requested by SWG. The Bolivar-to-Morgan's Point widening was later modeled at the two additional channel widths – 700 ft and 750 ft. The TSP in the alternatives presented here is updated to current plans such that the channel width from Bolivar to Morgan's Point is 700 ft and does not include the mooring facility at Station 520 or the turning basin at Station 775. Additionally, a larger disposal area is planned for the eastern side of Atkinson Island and three avian habitat areas, or Bird Islands. All other plan features remain unchanged in the project alternative.

Table 1. Details of TSP. Dimensions in feet. Updated October 2020.

HSC Segment	Widening	Deepening	Bend Easing	Mooring Facility	Turning Basin
Bolivar Roads to Red Fish Light 1	700				
Redfish Light 1 to Beacon 76	700				
Beacon 76 to Lower End Morgan's Point Cut	700				
Morgan's Point to Exxon	600		Station 153+06 Station 246+54		
Exxon to Carpenter's Bayou					
Carpenter's Bayou to Boggy Bayou	530			~~Station 520+00~~ 41.5	
Bayport Ship Channel	455		Flare		RoRo 46.5
Barbours Cut Ship Channel	455		Flare		
Boggy Bayou to Greens Bayou	530	46.5 +2 AM +1 AO			~~Station 775+00~~ 46.5
Greens Bayou to Sims Bayou		46.5 +2 AM +1 AO			Hunting 46.5
Sims Bayou to I-610 Bridge		41.5 +2 AM +1 AO			
I-610 Bridge to End Main Turning Basin		41.5 +2 AM +1 AO			Brady 900 46.5

Figure 7. TSP location map.



The three Bird Island sites lie along the east side of the HSC from near Bolivar Roads to just south of Atkinson Island. The two southernmost dredge disposal areas on the eastern side of Atkinson Island are to be connected in the updated PHA modifications. Figure 8 shows the location of these areas in the model domain.

Figure 8. Model domain boundary (red line) including Bird Islands and added dredge disposal.

2.2 Input conditions

Most USACE design projects require a 50 yr project life span; therefore, analysis at some year zero and year 50 is required. For this project, the 2010 validation year was determined suitable by SWG as a base or starting point for the year zero (present, 2029) and year 50 (future, 2079) model inputs. The 2010 sea level was adjusted to account for sea level change to arrive at the 2029 and 2079 sea level values. All other forcings were equivalent to 2010. For details of the 2010 model boundary conditions, see McAlpin et al. 2019a. The tidal water surface elevation, freshwater inputs, and sediment loads (because they are based on the freshwater input) are the only model inputs that will vary from the 2010 base condition. All

simulations will be made for a 2 yr period with the first year-long simulation serving to generate an accurate initial salinity field and initial sediment bed. Data availability for each input parameter determines if consecutive years of data are used for the 2 yr simulations or if a single year of data is repeated in the spin-up and analysis years.

Given the variability in several input parameters for the present and future conditions, great care should be taken when reviewing the model results. Changes from present to future must be understood with no project in place to understand the project impacts. In other words, comparison of with and without project should be done on the present conditions and the future conditions separately and only mixed when well understood.

2.2.1 Sea level rise

The tidal boundary condition at the Gulf of Mexico is based on harmonics and measured data from National Oceanic and Atmospheric Administration gages at Freeport (8772447) and Sabine Pass (8770822), Texas. To account for potential sea level rise at year zero (2029), guidance defined in USACE Engineering Circular 1165-2-212, *Sea-Level Change Considerations for Civil Works Programs*, was used. The 2010 data for the model validation was adjusted to 2017 utilizing the low sea level rise curve to obtain present conditions. The intermediate sea level rise projection curve was then applied to the 2017 adjusted elevations. Table 2 provides the elevation shift applied to the 2010 tide elevation for the year 2029 (present) and year 2079 (future) model scenarios. The elevation shift was constant over the length of the model boundary and the time of the model simulation for each year.

Table 2. Sea level rise adjustment for model tidal boundary conditions.

Adjustment Period	Sea Level Rise Curve	Elevation Shift
2010 to 2017	Low	0.148 ft (0.045 m)
2017 to 2029	Intermediate	0.322 ft (0.098 m)
2017 t0 2079	Intermediate	1.914 ft (0.583 m)

2.2.2 Freshwater inflow

Freshwater inflow into the model domain was applied at the two major rivers – Trinity River and San Jacinto River – and at seven ungaged flow locations. These flow values were obtained from the Texas Water Development Board (TWDB) hydrology model, which computes flows for the area from the 1970s to present (Schoenbaechler and Guthrie 2012). SWG determined that years 1985 and 1986 were typical flow conditions for the region and would be a good estimate of future flow patterns. Based on findings by SWG in coordination with TWDB, the freshwater flow into the Trinity and Galveston Bay system will decline by approximately 12% over the 50 yr project life. This reduction is primarily due to projections of increased water needs for the surrounding municipalities, meaning that more volume will be diverted for local water supply and less will be available to enter the bay system.

For the 2029 spin up and 2029 (present) conditions simulations, 2009 (spin-up year) and 2010 (analysis year) inflows are used for all freshwater inflow locations. Figure 9 shows the year 2029 (2009/2010) inflows. For year 2079, spin up and 2079 (future) conditions, 88% of the 1985 (spin-up year) and 1986 (analysis year) freshwater inflows are used for the Trinity River and San Jacinto River, and 88% of the 2009 and 2010 inflows are used at the ungaged locations. Figure 10 shows the 2079 inflows.

Figure 9. Year 2029 (present) freshwater inflows (first 365 days were spin up and remaining 365 days were 2029 inflows).

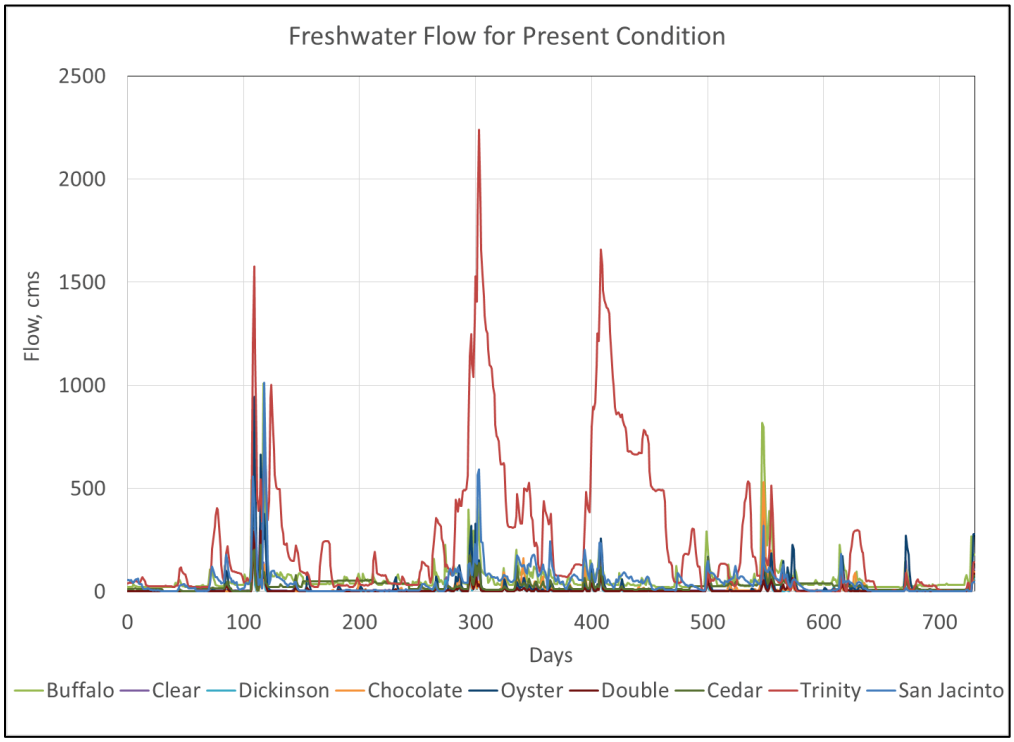
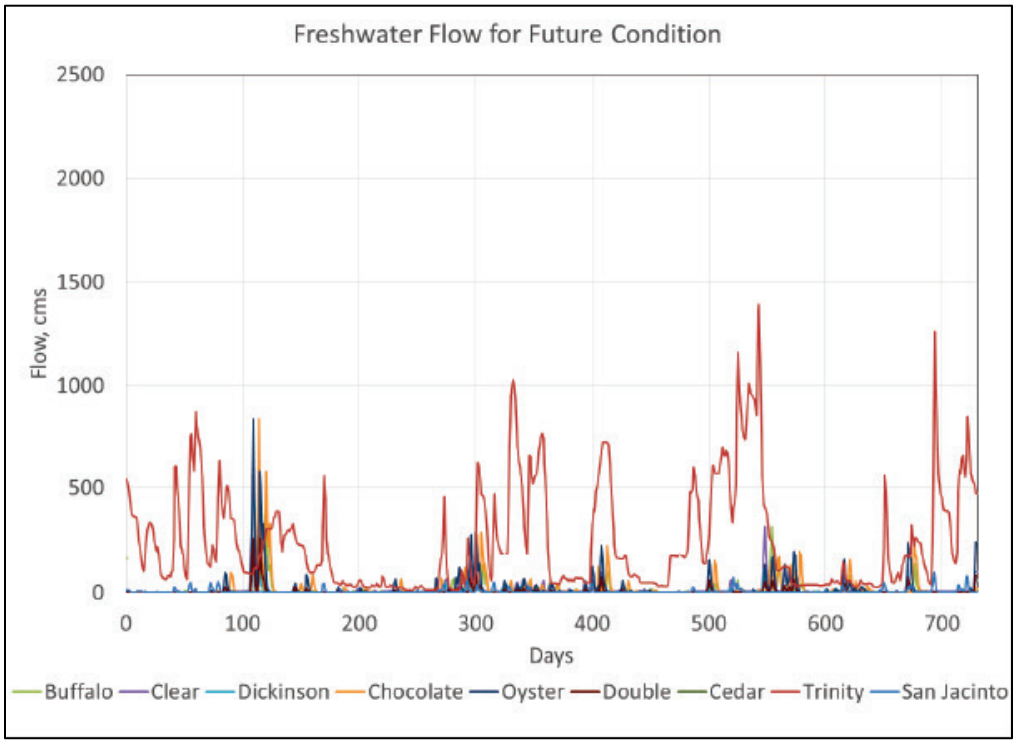


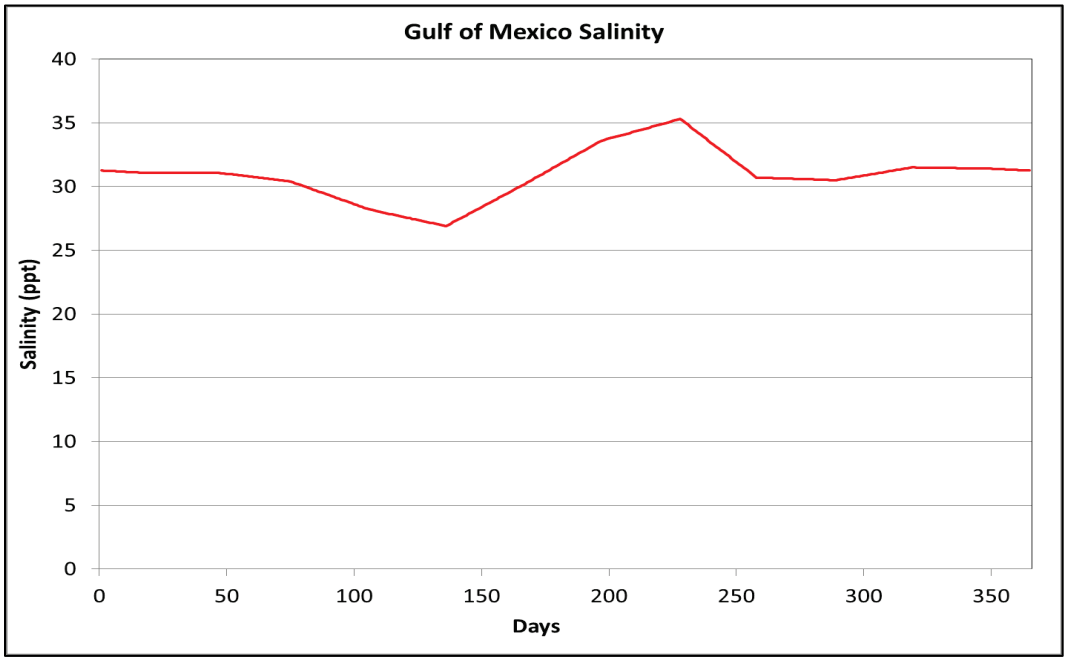
Figure 10. Year 2079 (future) freshwater inflows (first 365 days were spin up, and remaining 365 days were 2029 inflows).



2.2.3 Salinity

The salinity input at the model's ocean boundary is unchanged from the model validation and shown in Figure 11 (McAlpin et al. 2019a). The time-varying boundary condition is based on monthly averages over a 15 yr period. The single year of data was repeated such that the same input was applied for the spin up-year and the analysis year for both the present and future conditions.

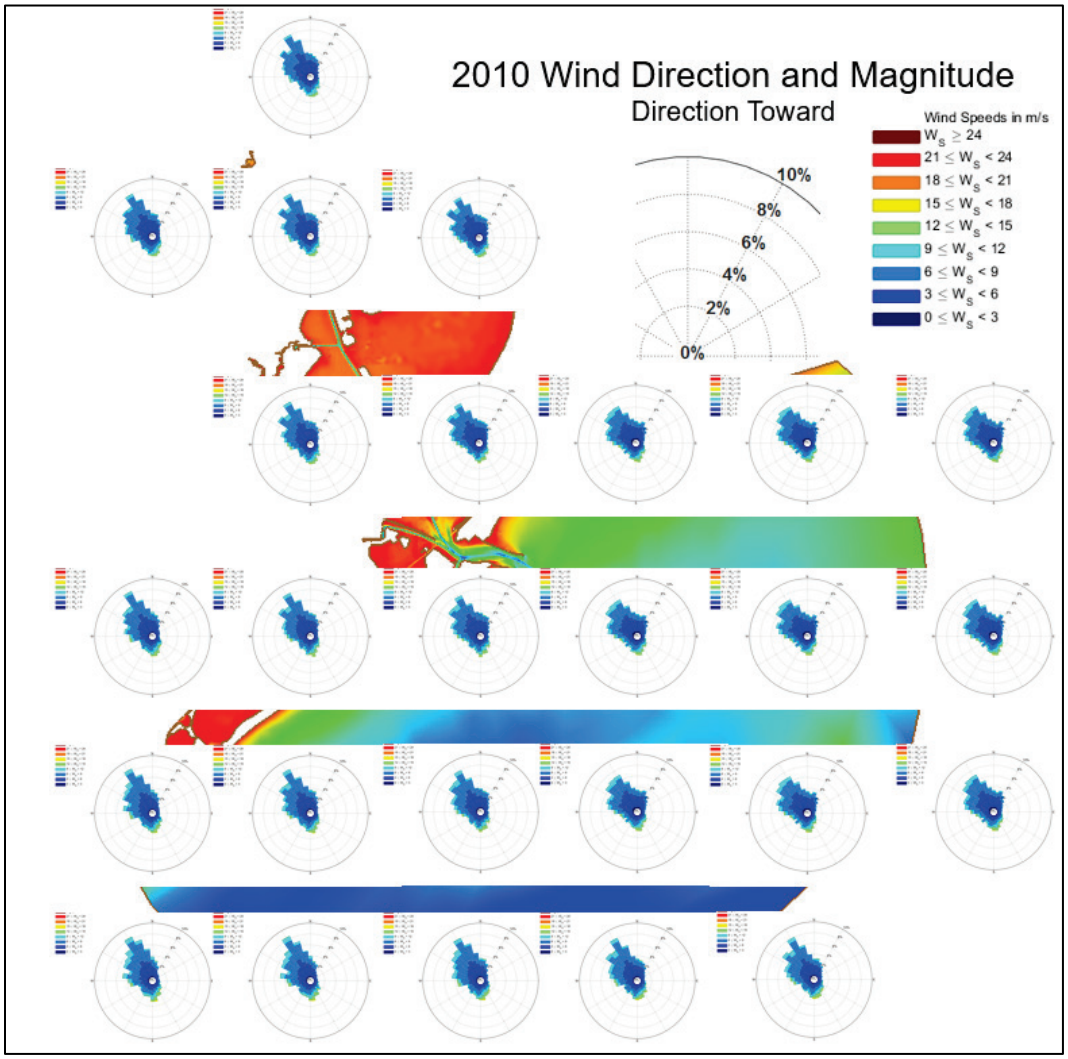
Figure 11. Salinity boundary condition for 2029 (present) and 2079 (future) conditions.



2.2.4 Wind

The 2010 wind data set was obtained from the Wave Information Studies computed wind field at 26 points in the vicinity of the model domain. This data set was maintained from the model validation (McAlpin et al. 2019a). This wind data set was unchanged and repeated for the spin-up and analysis years for both the present and future conditions. Figure 12 shows the 2010 wind rose at all 26 computed wind series locations.

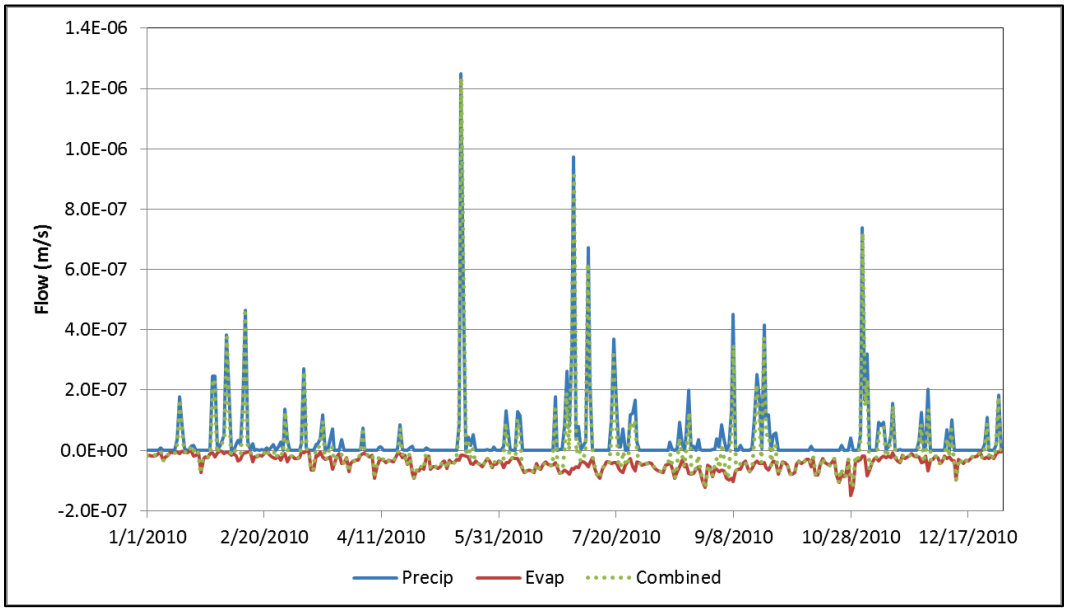
Figure 12. 2010 wind rose at all sites for 2029 (present) and 2079 (future) conditions.



2.2.5 Meteorological conditions

Precipitation and evaporation were included in the model validation and alternative conditions simulations (McAlpin et al. 2019a). The 2010 data from the TWDB were applied equally over the model domain. The data were unchanged and repeated for the spin-up and analysis years for both the present and future conditions. Figure 13 shows the time series of the meteorological data.

Figure 13. 2010 meteorological conditions for 2029 (present) and 2079 (future) conditions.



2.2.6 Sediment

The sediment grain and initial bed parameters were equivalent to the validation effort (McAlpin et al. 2019a). The loads are applied to the two major rivers by applying a rating curve that correlates river discharge with the total concentration in the same manner as in the model validation. Figure 14 shows the 2029 sediment loads, which are based on 2009 (2029 spin up) and 2010 (2029 simulations) inflow data. Figure 15 shows the 2079 loads, which are based on the reduced 1985 (2079 spin up) and 1986 (2079 simulations) inflow data. These total loads are divided equally among the five simulated grain classes when applied in the model. No sediment is applied at the ungaged inflow locations similar to the model validation.

The model validation (McAlpin et al. 2019a) details sediment loads that are not included in this model. These include unaccounted sediment loads from

the ungaged freshwater inflows, from wind-generated wave erosion along the shallows, and from vessel-induced erosion in the bays. A historical scaling method for each channel segment was determined to be the best option to account for the combined effect of the various unknown loads.

Figure 14. Year 2029 (present) total sediment load (first 365 days were spin up and remaining 365 days were 2029 sediment concentrations).

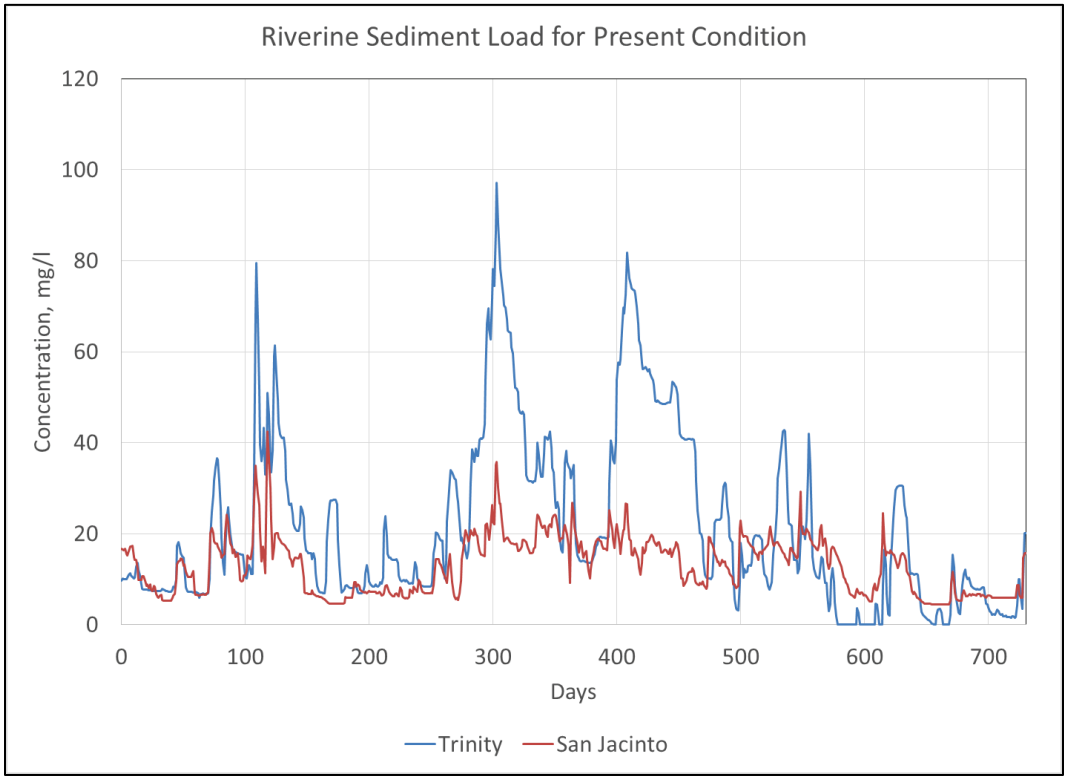
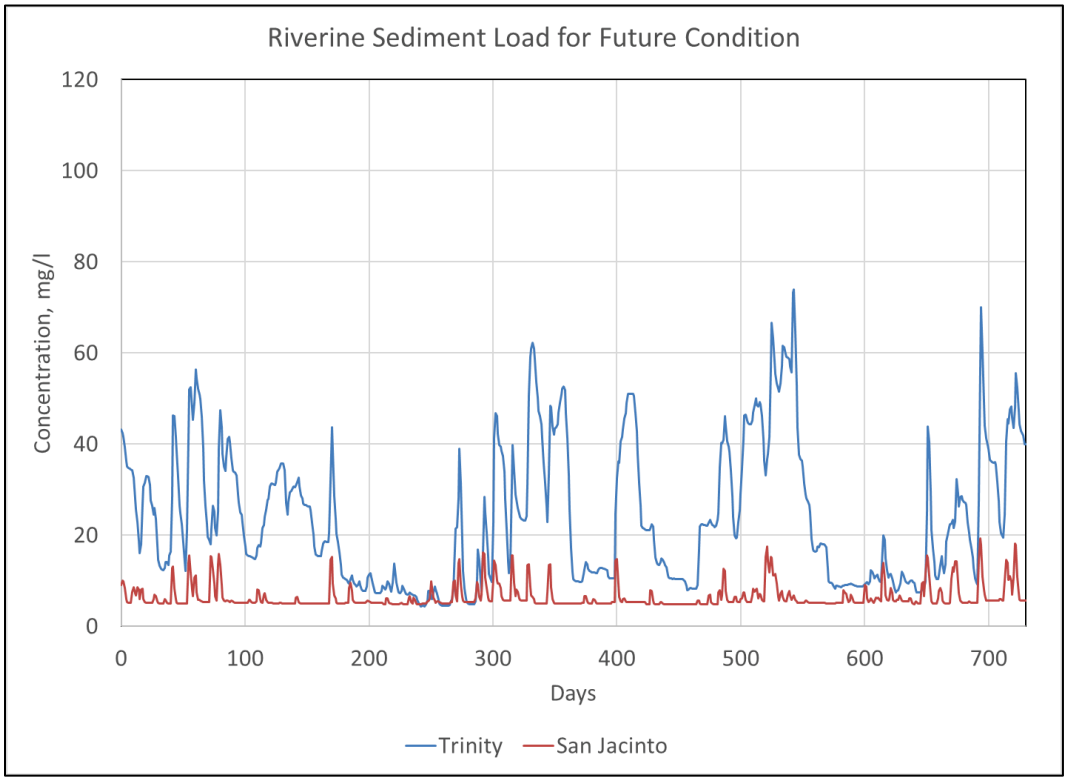


Figure 15 . Year 2079 (future) total sediment load (first 365 days were spin up and remaining 365 days were 2079 sediment concentrations).



3 Model Results and Discussion

The eight alternatives include present (2029) and future (2079) conditions for the following:

- Base or Existing Without Project (Base)
- Closure of Rollover Pass (CloseRollover)
- Closure of Rollover Pass and BABUS Cells (CloseRollover-BABUS)
- Closure of Rollover Pass, BABUS Cells, HSC ECIP Improvements, and Bird Island (CloseRollover-BABUS-P11).

These alternatives were simulated using 3D AdH as stated in the previous chapters. “Present” is considered the projected project completion in year 2029 and “future” is 2079 assuming a 50 yr project lifespan. The results will include changes in salinity and velocity throughout the model domain under the various alternative conditions. Additionally, changes to the shoaling in the HSC will be analyzed from the model results.

3.1 Salinity

3.1.1 Salinity point analysis

Several locations were identified for specific analysis such as time history, percent less than, and maximum/minimum/average computations of salinity. These locations are shown by the points in Figure 16 and labeled in Table 3. A subset of these locations, circled in red in Figure 16 and the shaded rows in Table 3, will be included and discussed in the text. All analysis plots and images will be included in the appendix.

Figure 16. Point analysis locations. Circled locations discussed in this section. The placement of BABUS cells and Bird Islands are shown as brown circles.

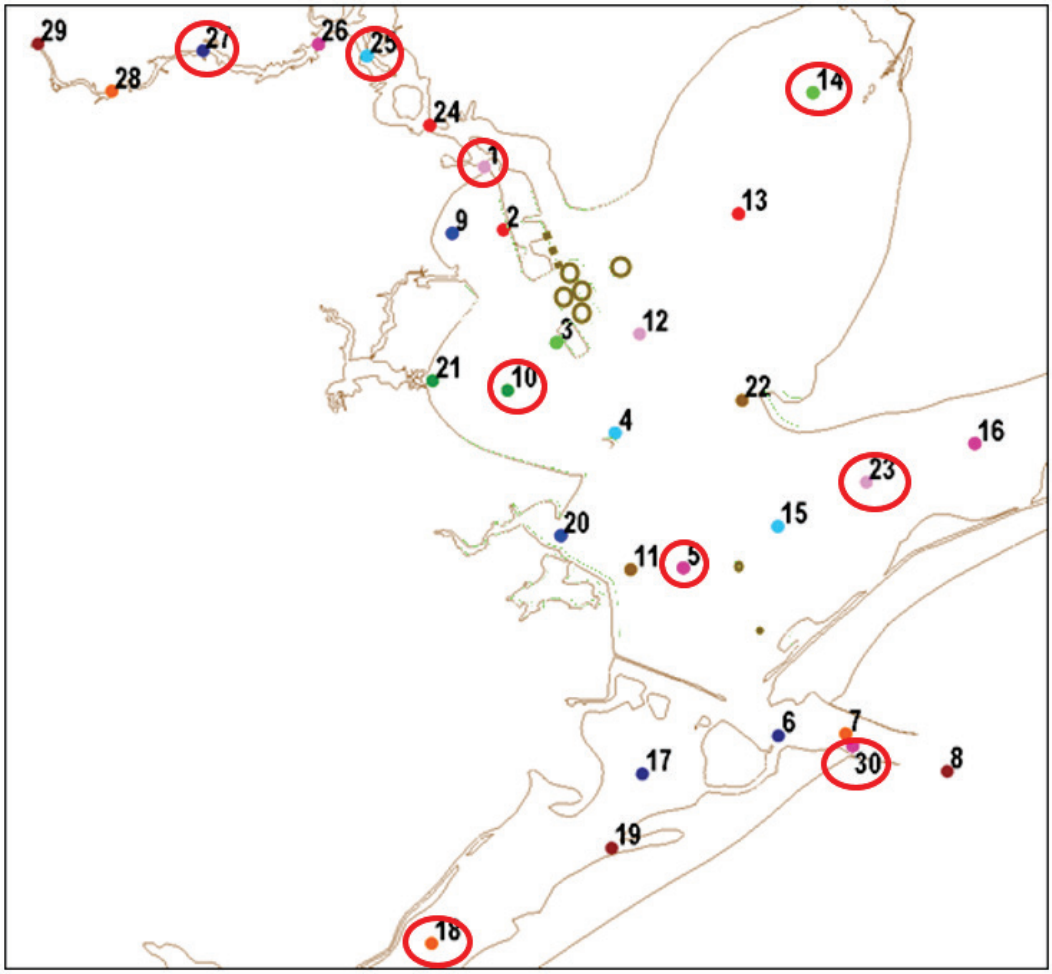


Table 3. Point analysis location names. Highlighted locations discussed in this section.

Point #	Name
1	HSC at Morgan's Point
2	HSC at Atkinson Island
3	HSC at Mid Bay Marsh
4	HSC at Red Fish Reef
5	HSC at Lower Galveston Bay
6	HSC at Bolivar Roads
7	HSC at Entrance
8	HSC at Gulf
9	Upper Galveston Bay 1

Point #	Name
16	Eastern East Bay
17	Eastern West Bay
18	Mid West Bay
19	Offatts Bayou
20	Dickinson
21	Clear Creek
22	Smith Point
23	Mid East Bay
24	HSC at Fred Hartman Bridge

Point #	Name
10	Upper Galveston Bay 2
11	Lower Galveston Bay
12	Lower Trinity Bay
13	Mid Trinity Bay
14	Upper Trinity Bay
15	Western East Bay

Point #	Name
25	HSC at Goat Island
26	HSC at Carpenters Bayou
27	HSC at Greens Bayou
28	HSC at Sims Bayou
29	HSC at Turning Basin
30	Apfell Park

Time history of salinity is shown for several points within the HSC and several in the bays. Also provided are plots showing the maximum, average, and minimum salinity at each location for the year-long analysis period. The salinity shown in the time series plots are bottom values that will be larger than or equal in magnitude to the surface values due to the density stratification of salt water. For all plots of salinity, Base is blue, CloseRollover is red, CloseRollover-BABUS is yellow, and CloseRollover-BABUS-P11 is purple.

Additionally, percent-less-than plots are provided to show how the salinity varies over the analysis period. The maximum salinity value is given at 100% and the minimum value at 0%. The 50% salinity value indicates that the salinity is less than this value for 50% of the analysis time and greater than this value for 50% of the time. Figure 17 through Figure 40 show the point salinity analysis at the nine selected locations for the present condition. The results (surface and bottom, present and future) for all 30 locations are provided in the appendix.

The variation in salinity between present and future conditions is significant as expected. The rise in water surface elevation due to sea level changes as well as a reduction in freshwater inflow for future conditions generates very different salinity magnitudes throughout the analysis year. In most locations, the mean salinity is larger for the future conditions. The variation in salinity between with and without project alternatives is quite small for most locations – generally less than 2 ppt. The closure of Rollover Pass generates an approximate 5 ppt reduction in East Bay salinity on average. The variation in salinity between with and without BABUS cells is quite small overall. The HSC modifications (P11) show the largest variation in salinity between Base and project results in the upstream locations of the HSC. The salinities are almost identical near the entrance but begin to diverge farther into the system at Mid Bay Marsh,

Morgan's Point, and locations farther up the HSC. However, the change in the mean salinity between with and without project remains within 2 to 3 ppt. This behavior is visible in the point analysis as well as in the cross-sectional analysis to be discussed in the next section. The time history of salinity includes dotted lines at 10 ppt and 15 ppt thresholds – values requested by SWG due to various environmental considerations.

Figure 17. Bottom salinity time history at HSC at Greens Bayou (Point 27).

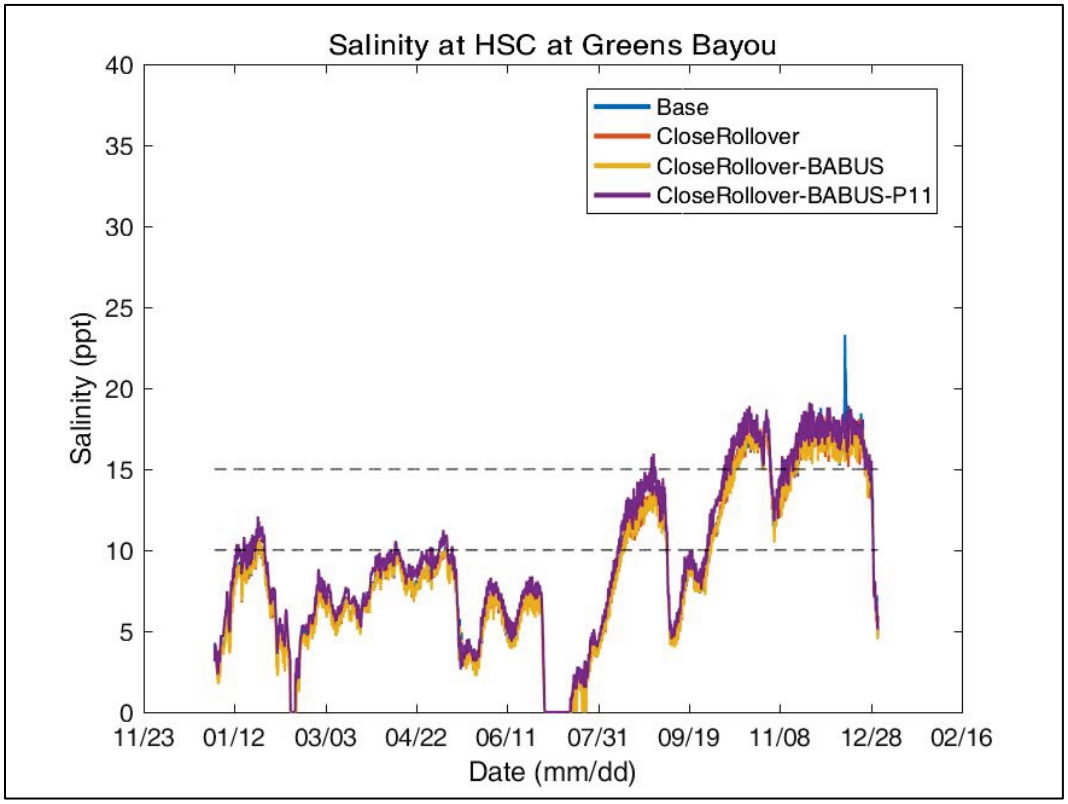


Figure 18. Maximum, minimum, and mean bottom salinity at HSC at Greens Bayou (Point 27).

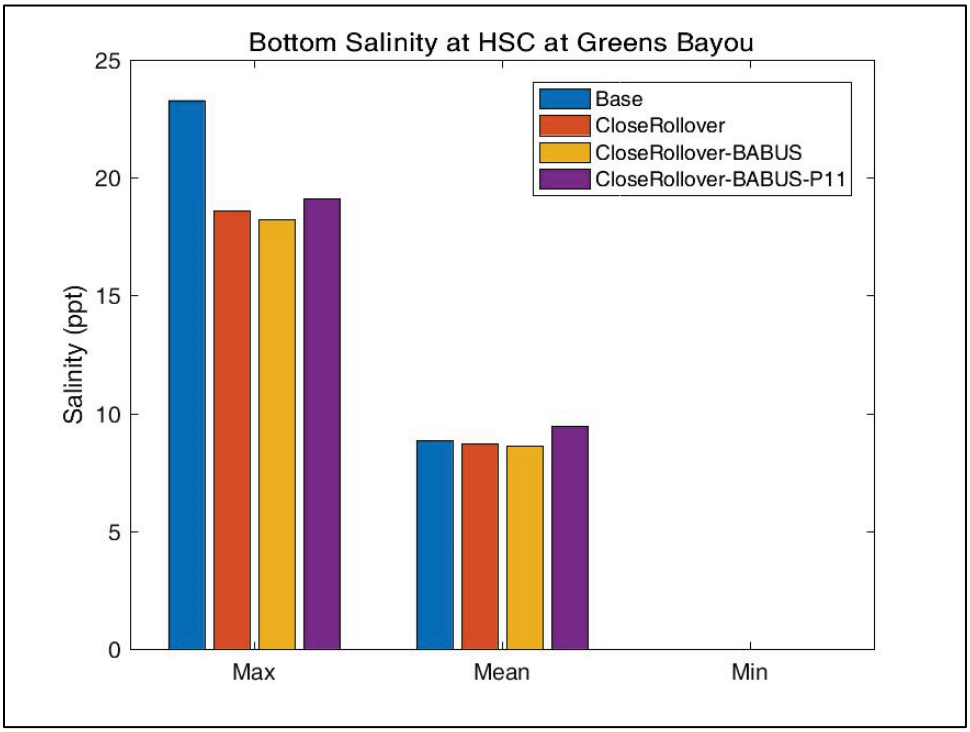


Figure 19. Percent-less-than bottom salinity at HSC at Greens Bayou (Point 27).

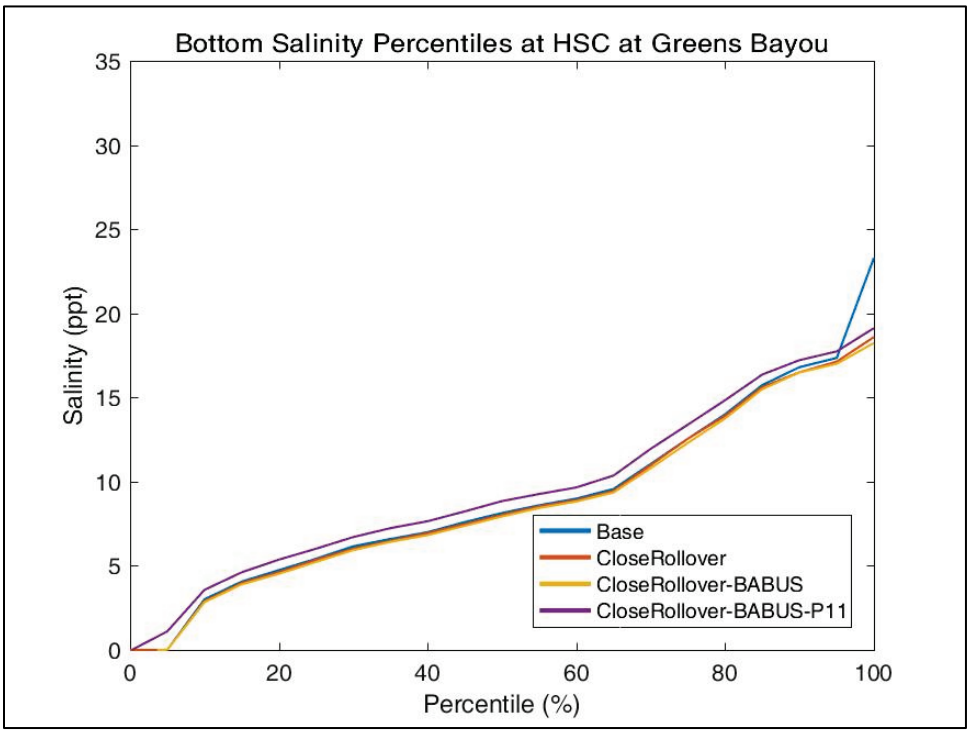


Figure 20. Bottom salinity time history at HSC at Goat Island (Point 25).

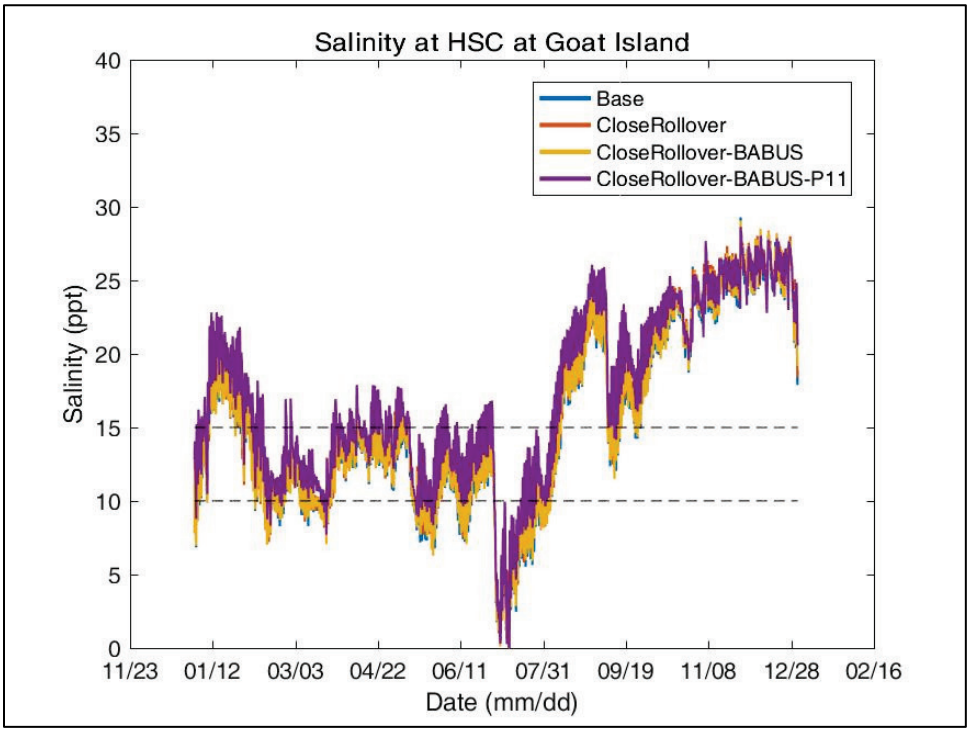


Figure 21. Maximum, minimum, and mean bottom salinity at HSC at Goat Island (Point 25).

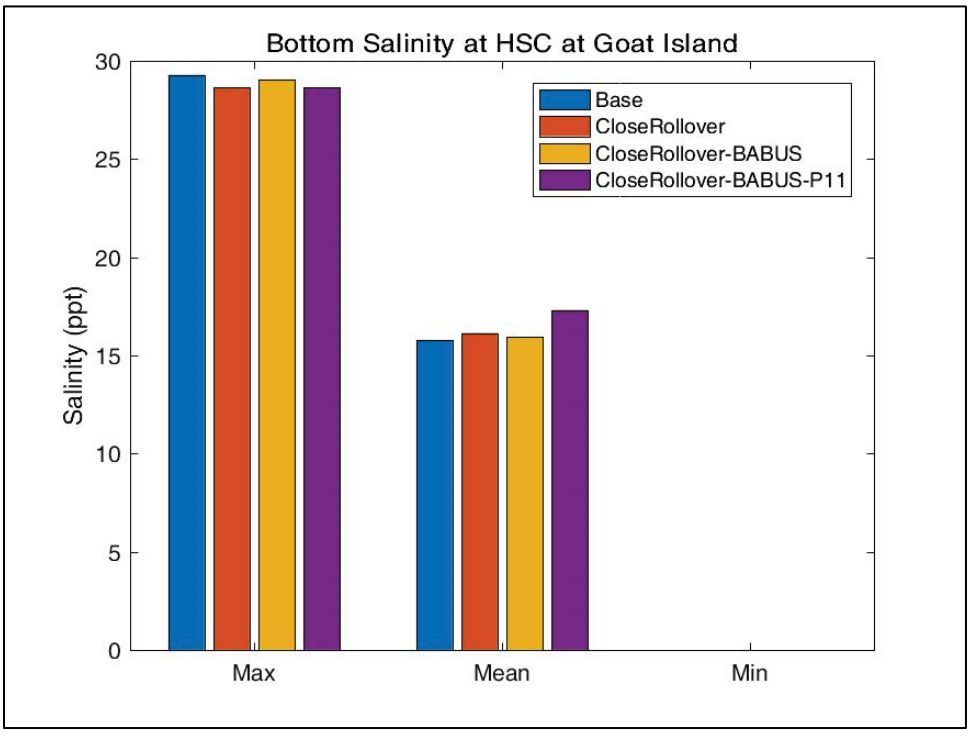


Figure 22. Percent-less-than bottom salinity at HSC at Goat Island (Point 25).

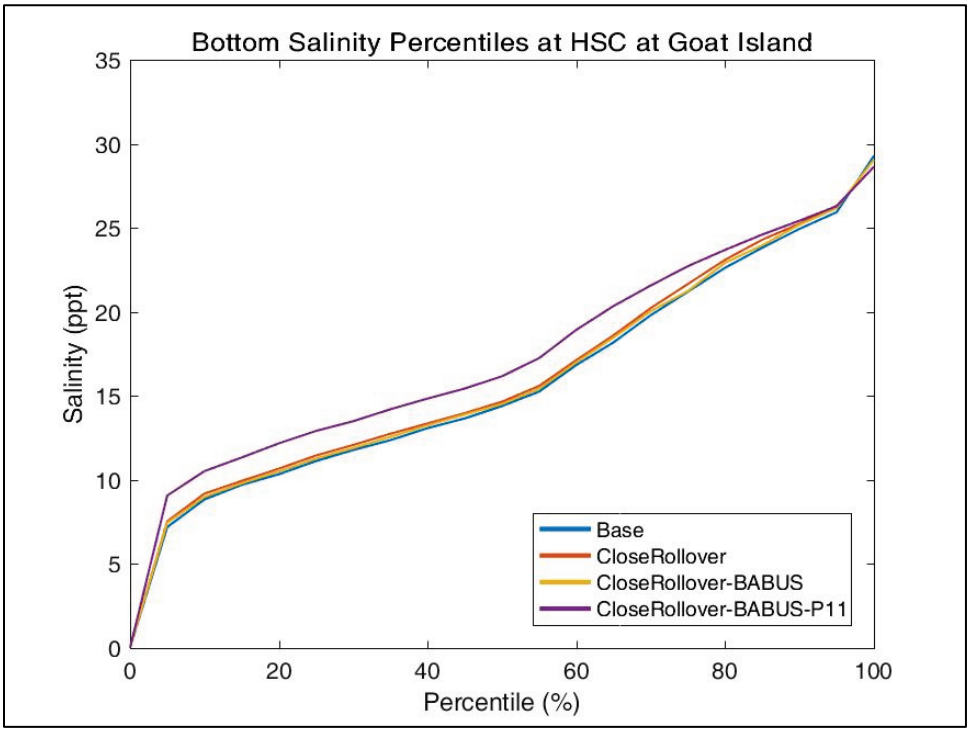


Figure 23. Bottom salinity time history at HSC at Morgan's Point (Point 1).

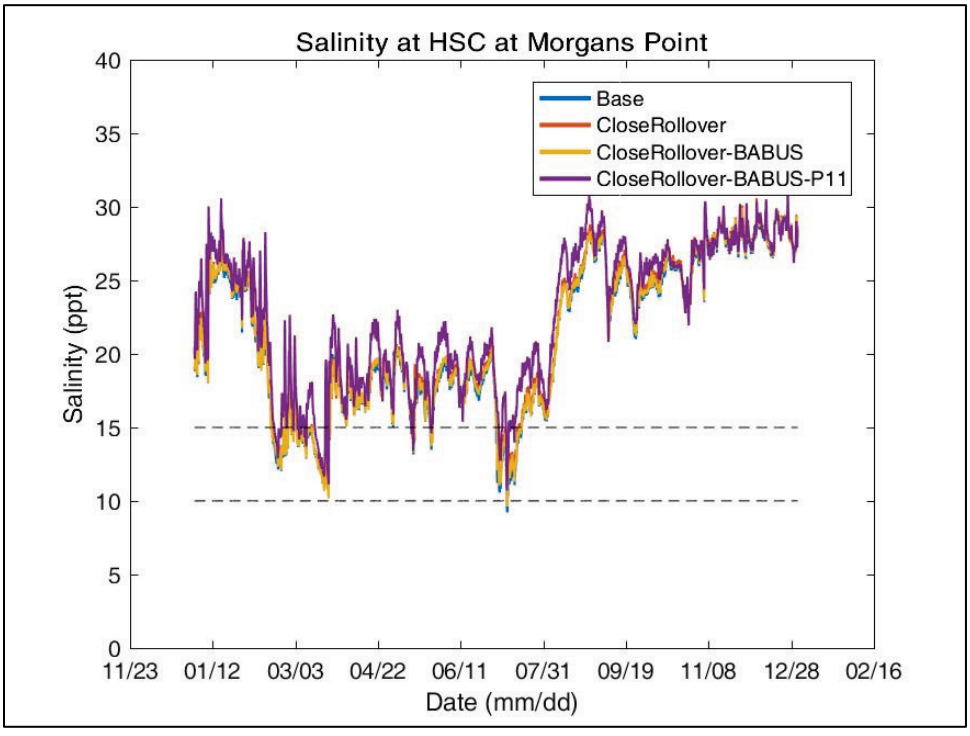


Figure 24. Maximum, minimum, and mean bottom salinity at HSC at Morgan's Point (Point 1).

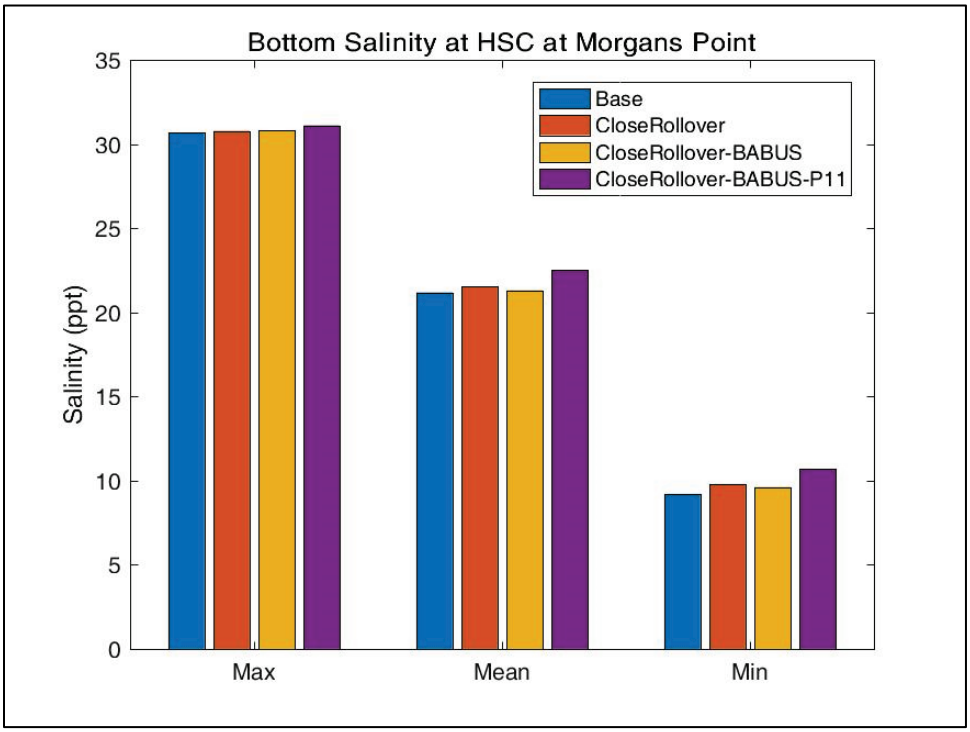


Figure 25. Percent-less-than bottom salinity at HSC at Morgan's Point (Point 1).

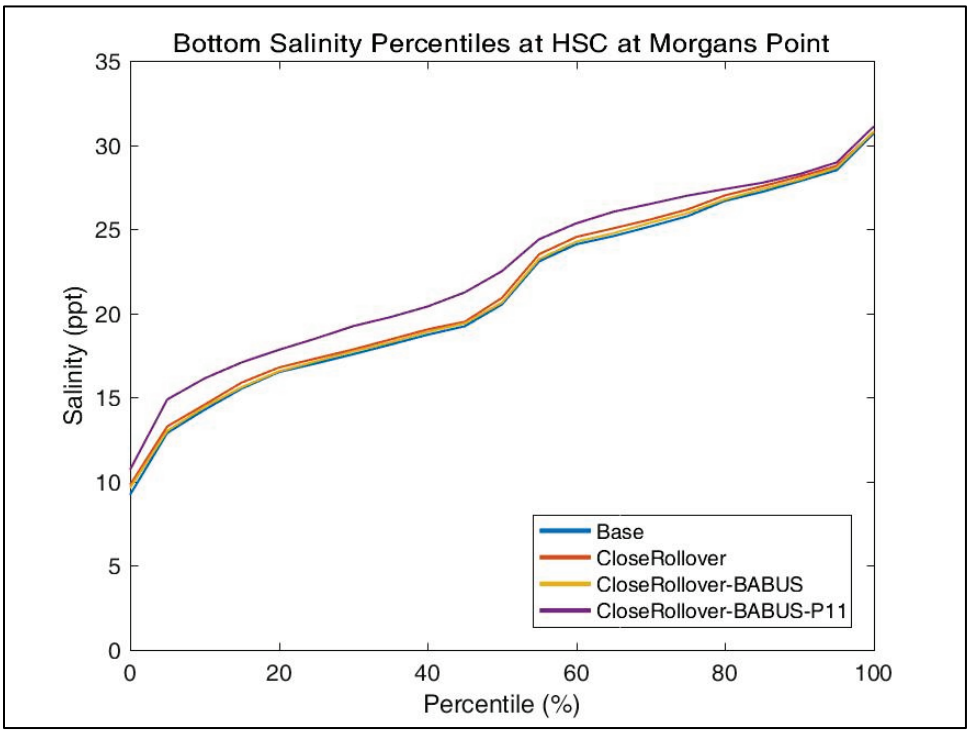


Figure 26. Bottom salinity time history at HSC at Lower Galveston Bay (Point 5).

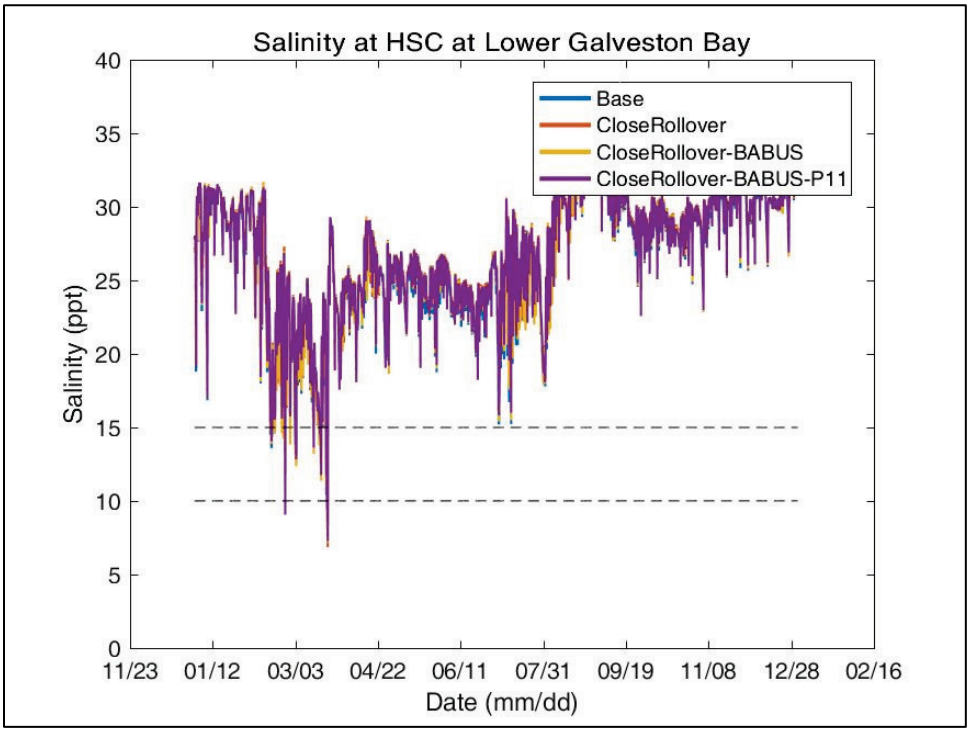


Figure 27. Maximum, minimum, and mean bottom salinity at HSC at Lower Galveston Bay (Point 5).

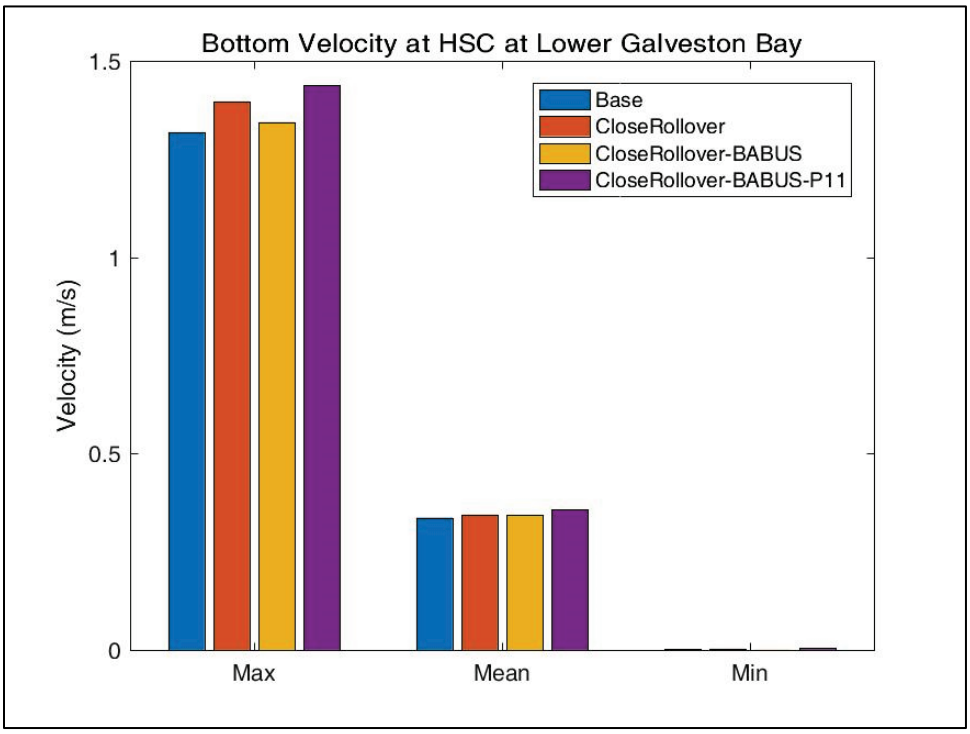


Figure 28. Percent-less-than bottom salinity at HSC at Lower Galveston Bay (Point 5).

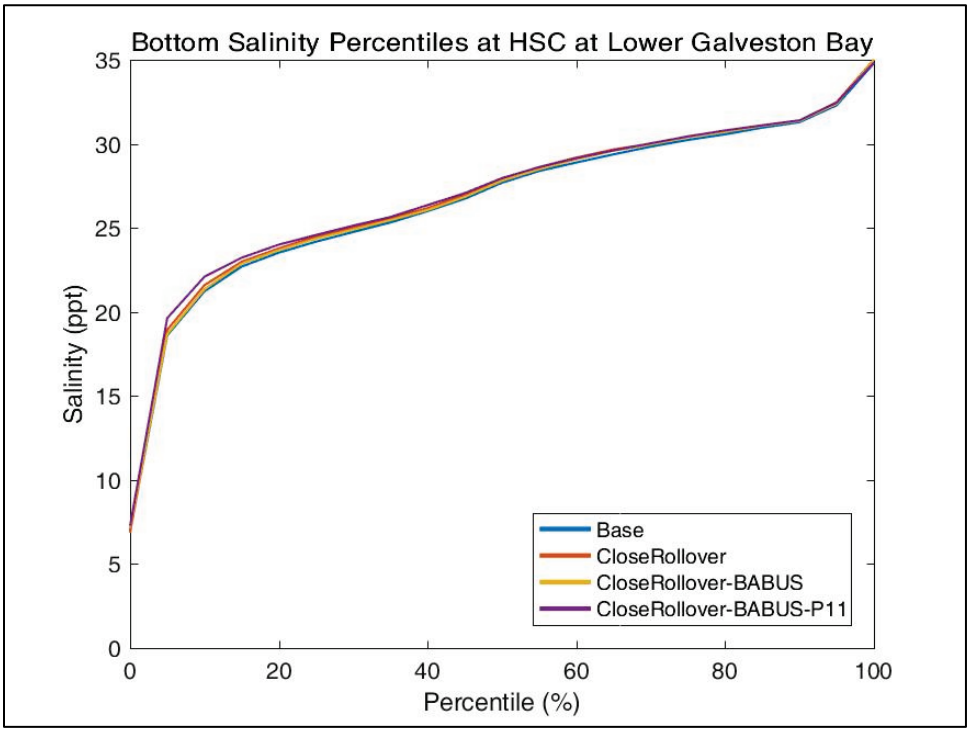


Figure 29. Bottom salinity time history at Upper Galveston Bay 2 (Point 10).

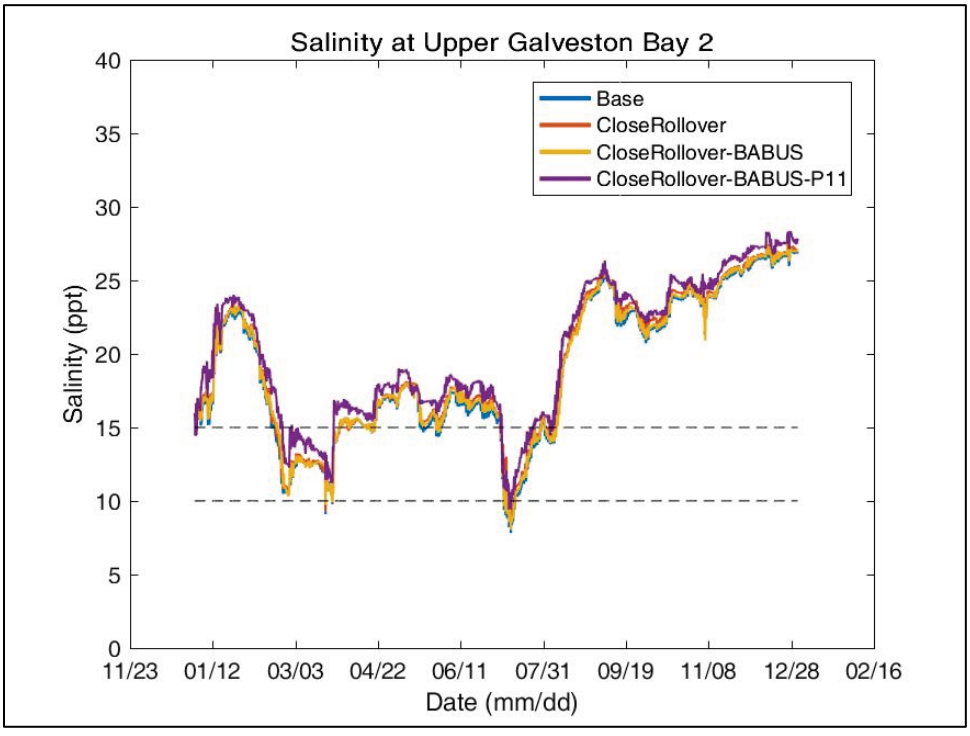


Figure 30. Maximum, minimum, and mean bottom salinity at Upper Galveston Bay 2 (Point 10).

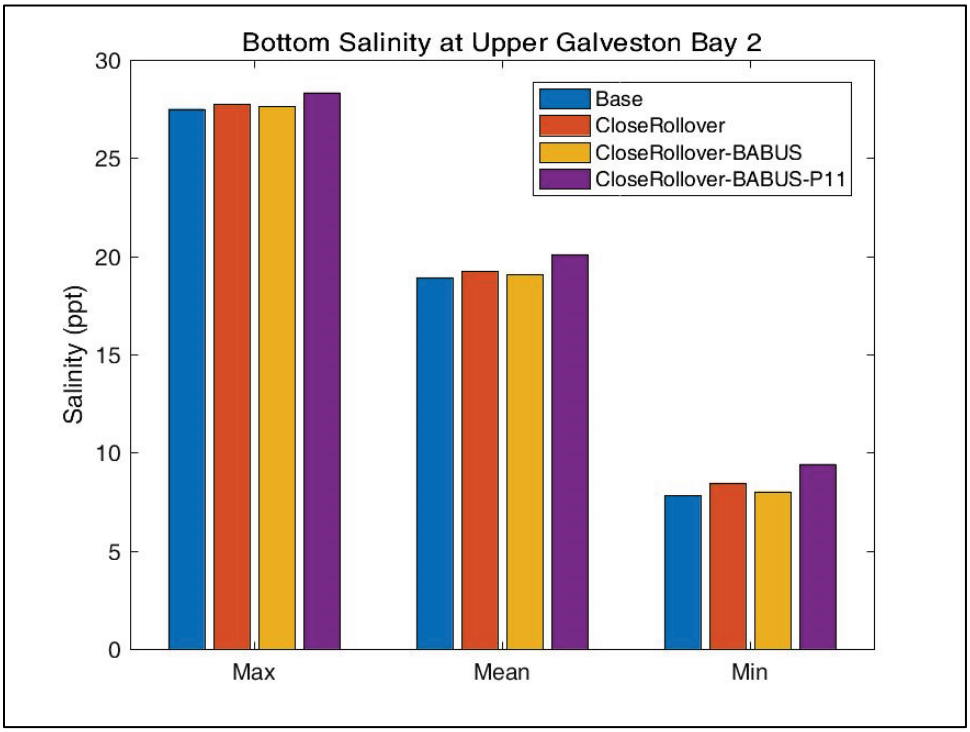


Figure 31. Percent-less-than bottom salinity at Upper Galveston Bay 2 (Point 10).

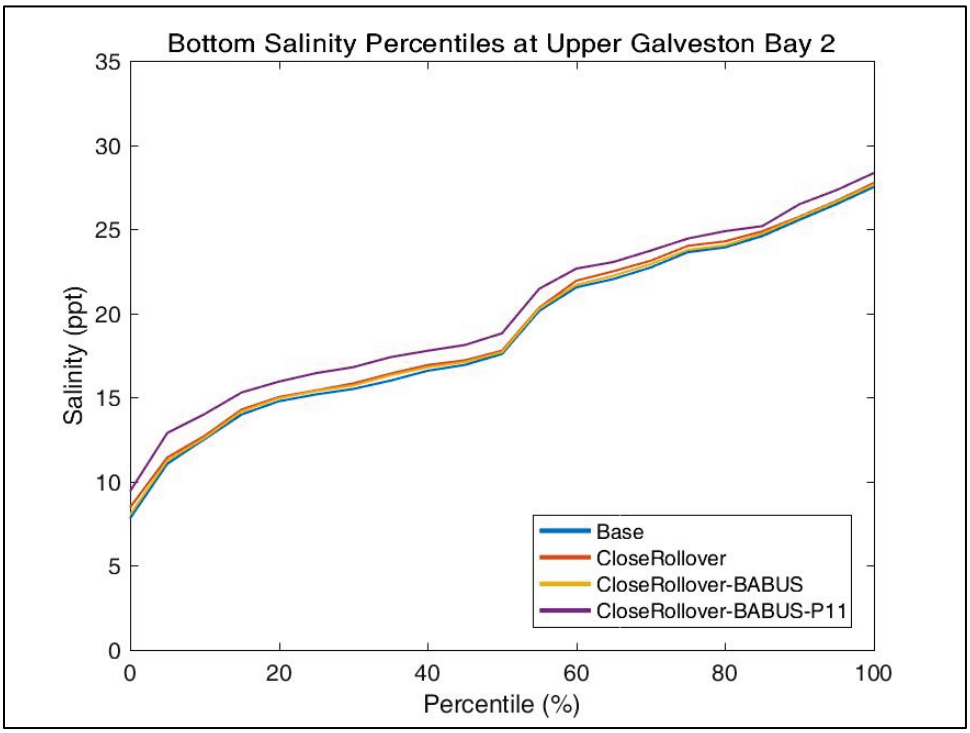


Figure 32. Bottom salinity time history at Upper Trinity Bay (Point 14).

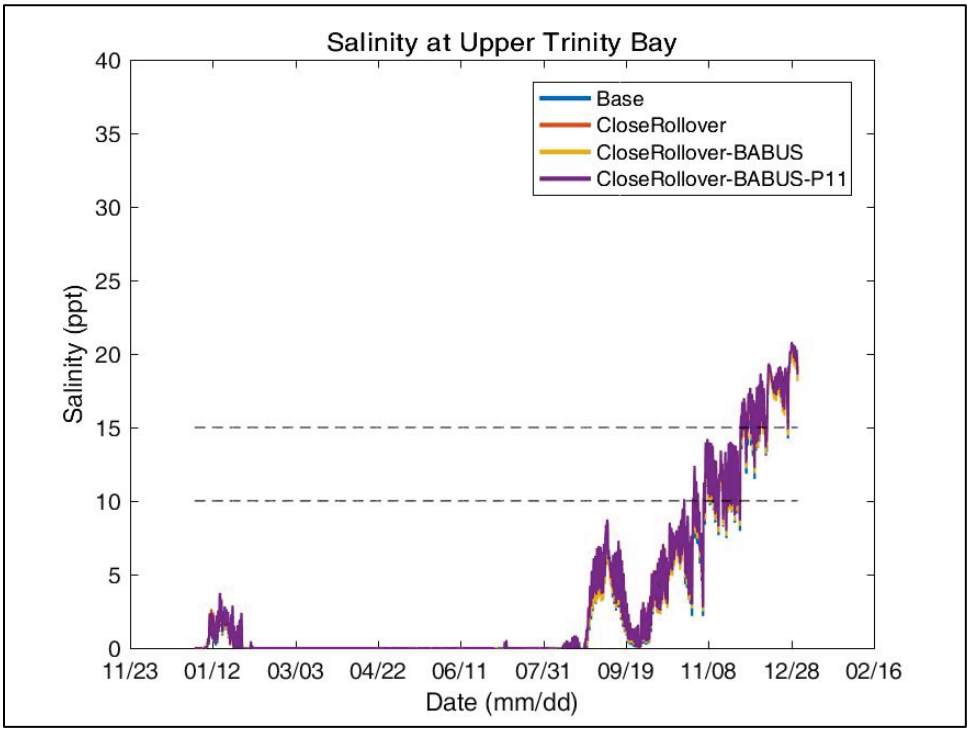


Figure 33. Maximum, minimum, and mean bottom salinity at Upper Trinity Bay (Point 14).

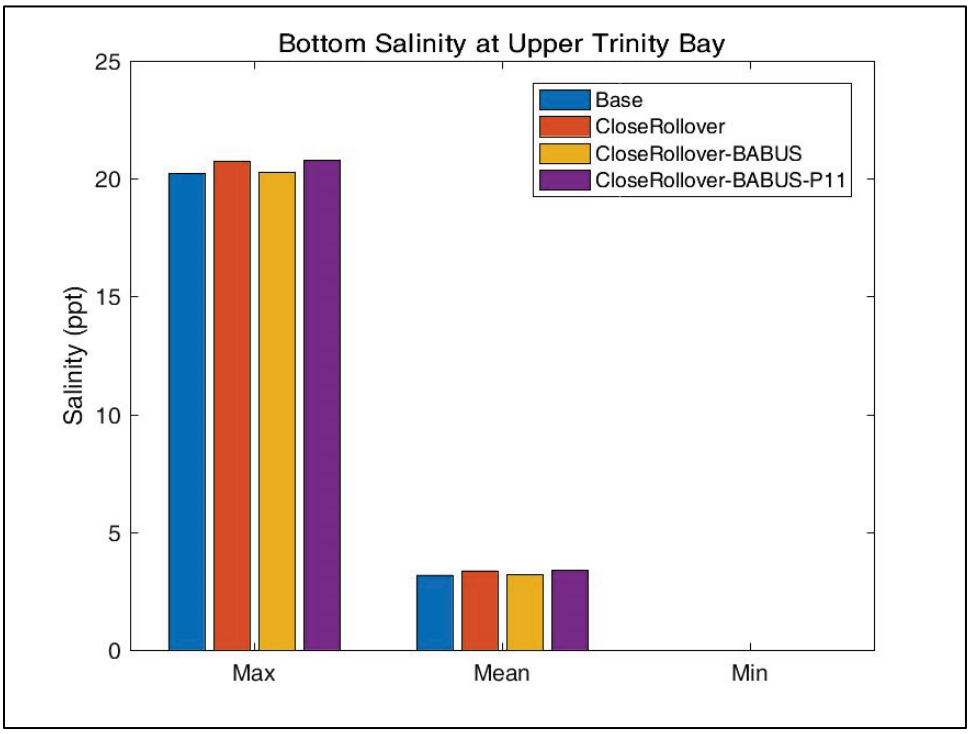


Figure 34. Percent-less-than bottom salinity at Upper Trinity Bay (Point 14).

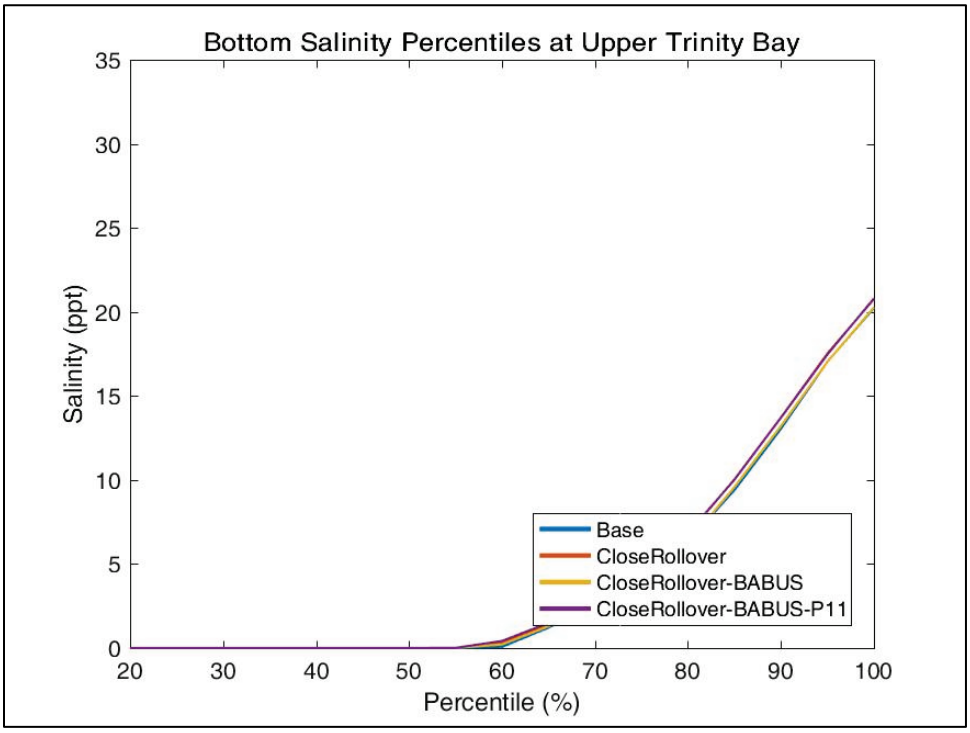


Figure 35. Bottom salinity time history at Mid West Bay (Point 18).

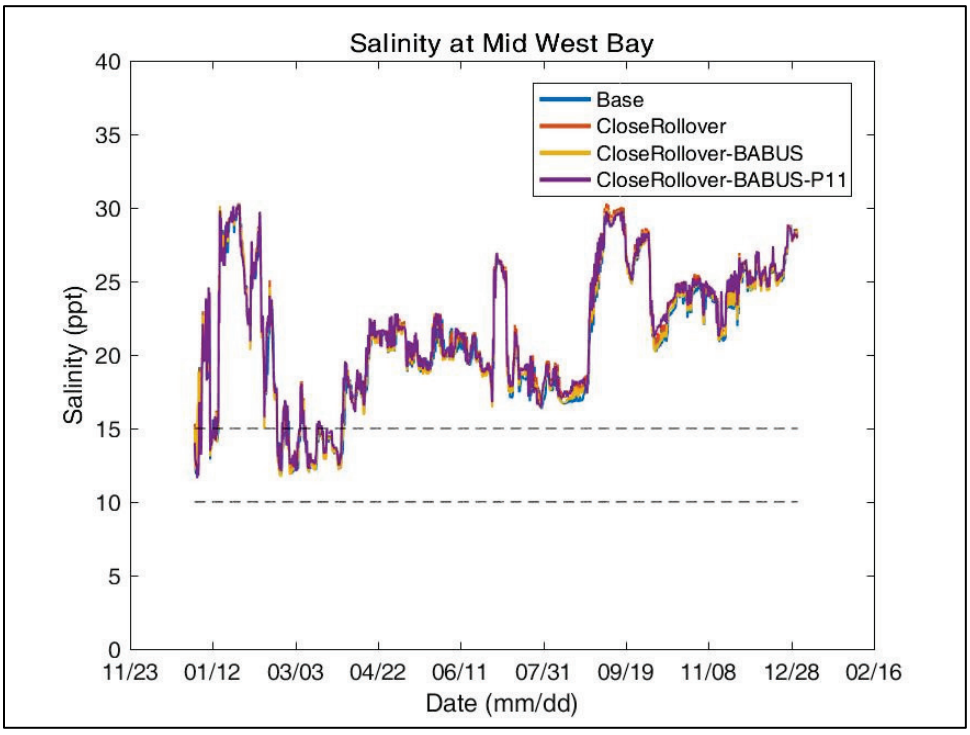


Figure 36. Maximum, minimum, and mean bottom salinity at Mid West Bay (Point 18).

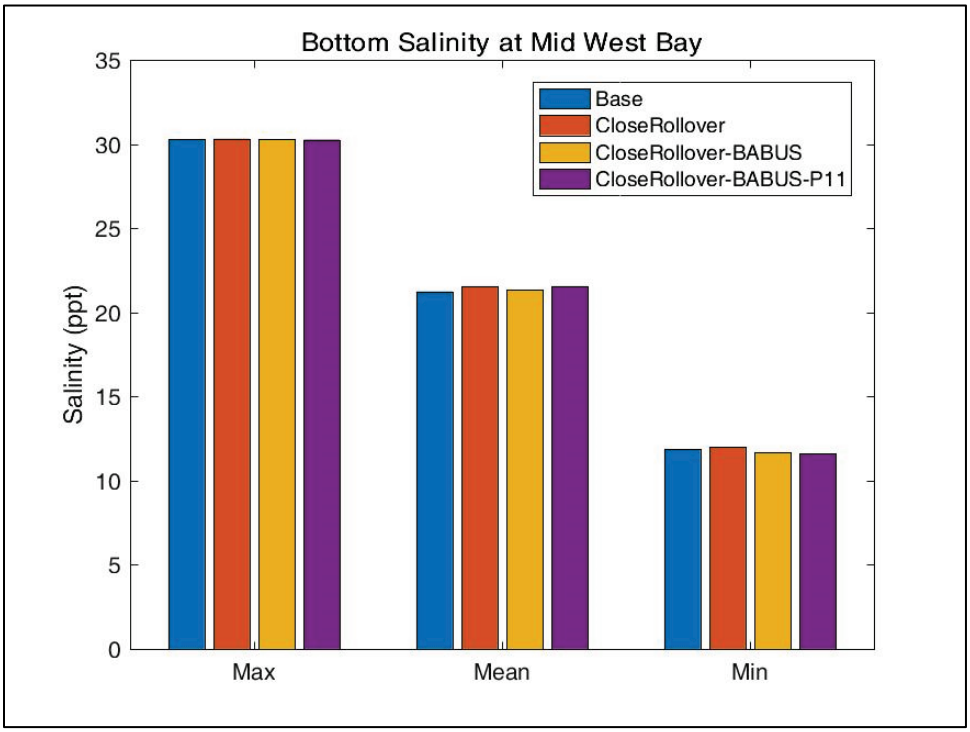


Figure 37. Percent-less-than bottom salinity at Mid West Bay (Point 18).

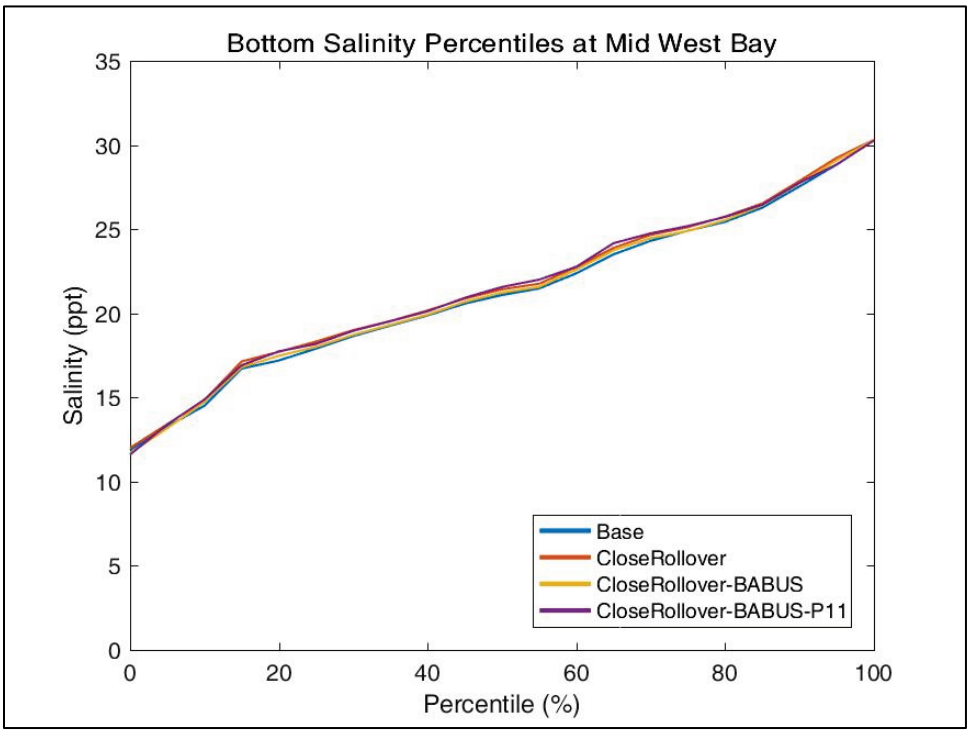


Figure 38. Bottom salinity time history at Mid East Bay (Point 23).

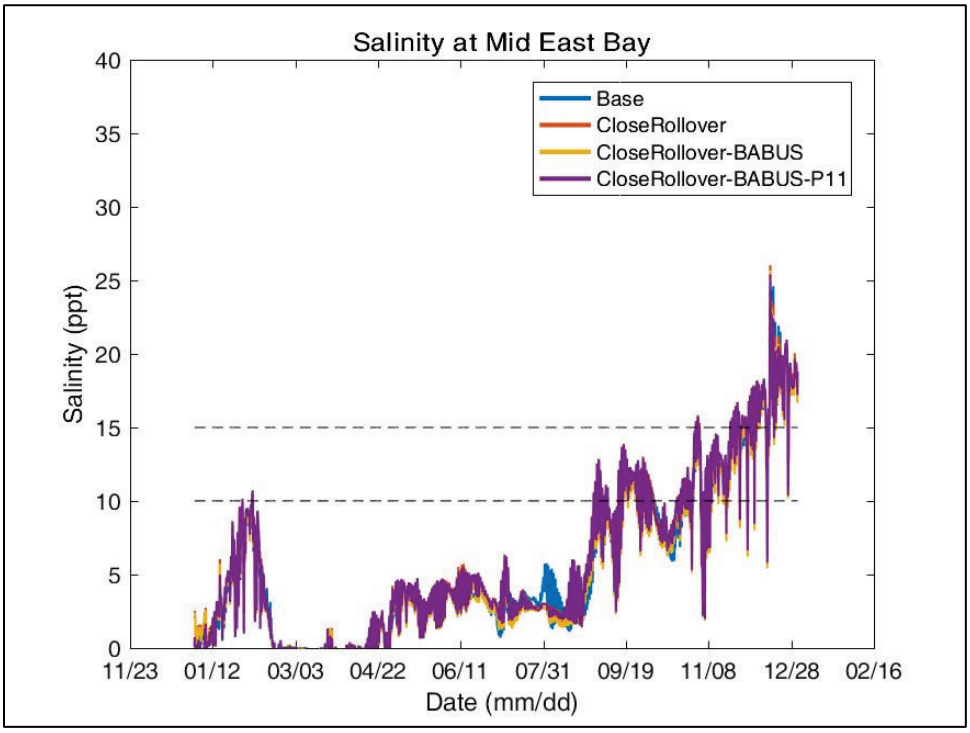


Figure 39. Maximum, minimum, and mean bottom salinity at Mid East Bay (Point 23).

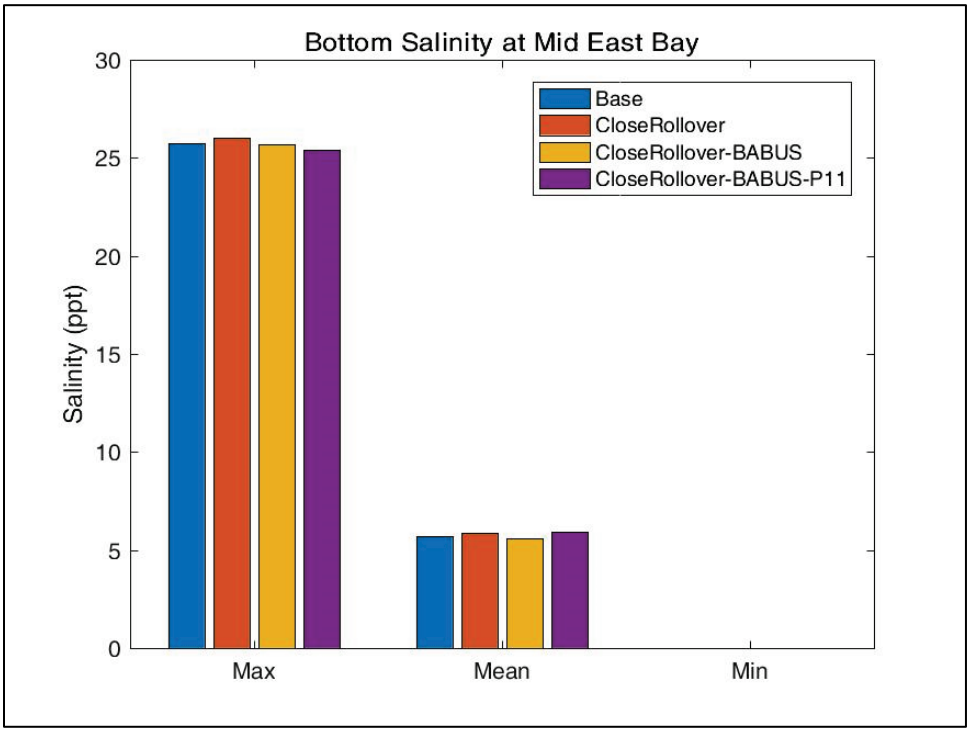
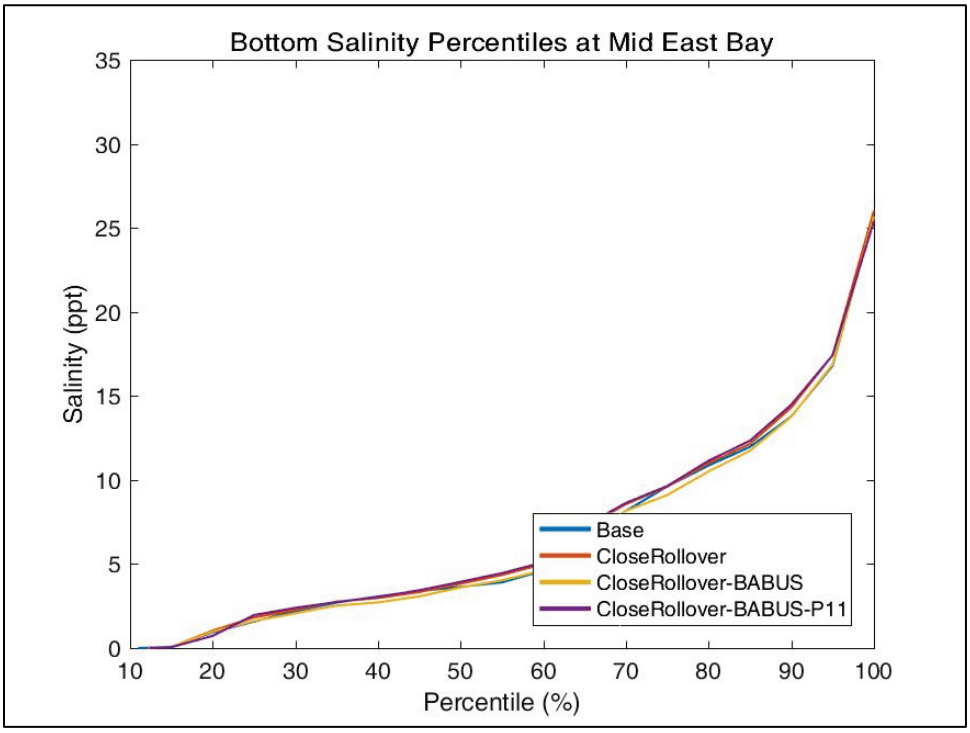


Figure 40. Percent-less-than bottom salinity at Mid East Bay (Point 23).



3.1.2 Spatial salinity analysis

The mean salinity for the analysis year over the entire domain is shown for the present conditions in Figure 41 and Figure 42 and for future conditions in Figure 43 and Figure 44. These results show that the salinity moves upstream along the bottom of the ship channel. The closure of Rollover Pass creates a drop in salinity in East Bay by nearly 5 ppt in places. The addition of the BABUS cells does not appear to create a change in the salinity in excess of 1 to 2 ppt in the area of their placement. From these mean salinity results, the most significant changes in salinity in the domain are due to closing Rollover Pass and enlarging the HSC in width and/or depth.

3.1.2.1 Present, 2029

Figure 41. Present condition bottom salinity mean, (a) Base, (b) CloseRollover, (c) CloseRollover-BABUS, (d) CloseRollover-BABUS-P11.

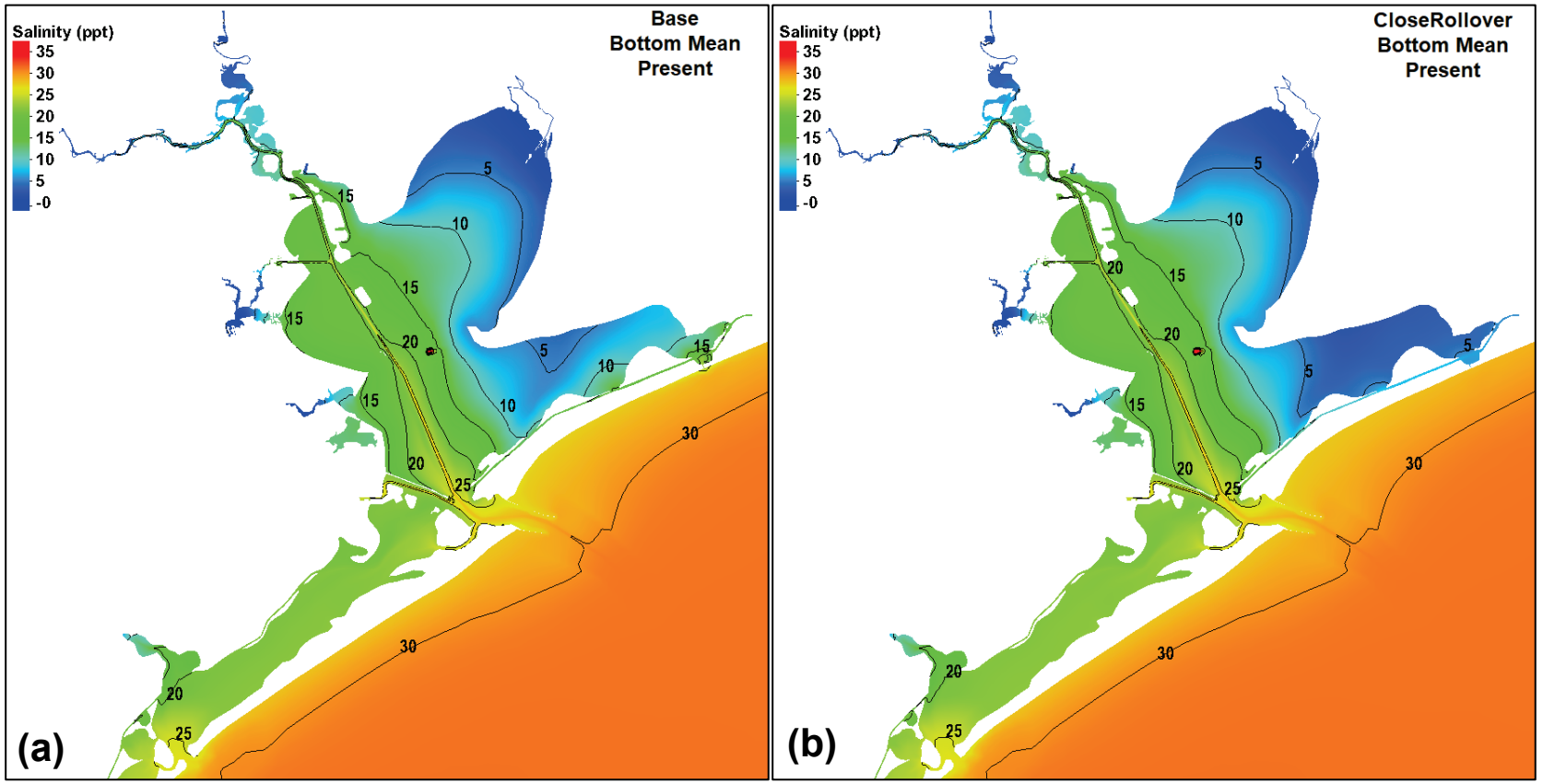


Figure 41. Continued.

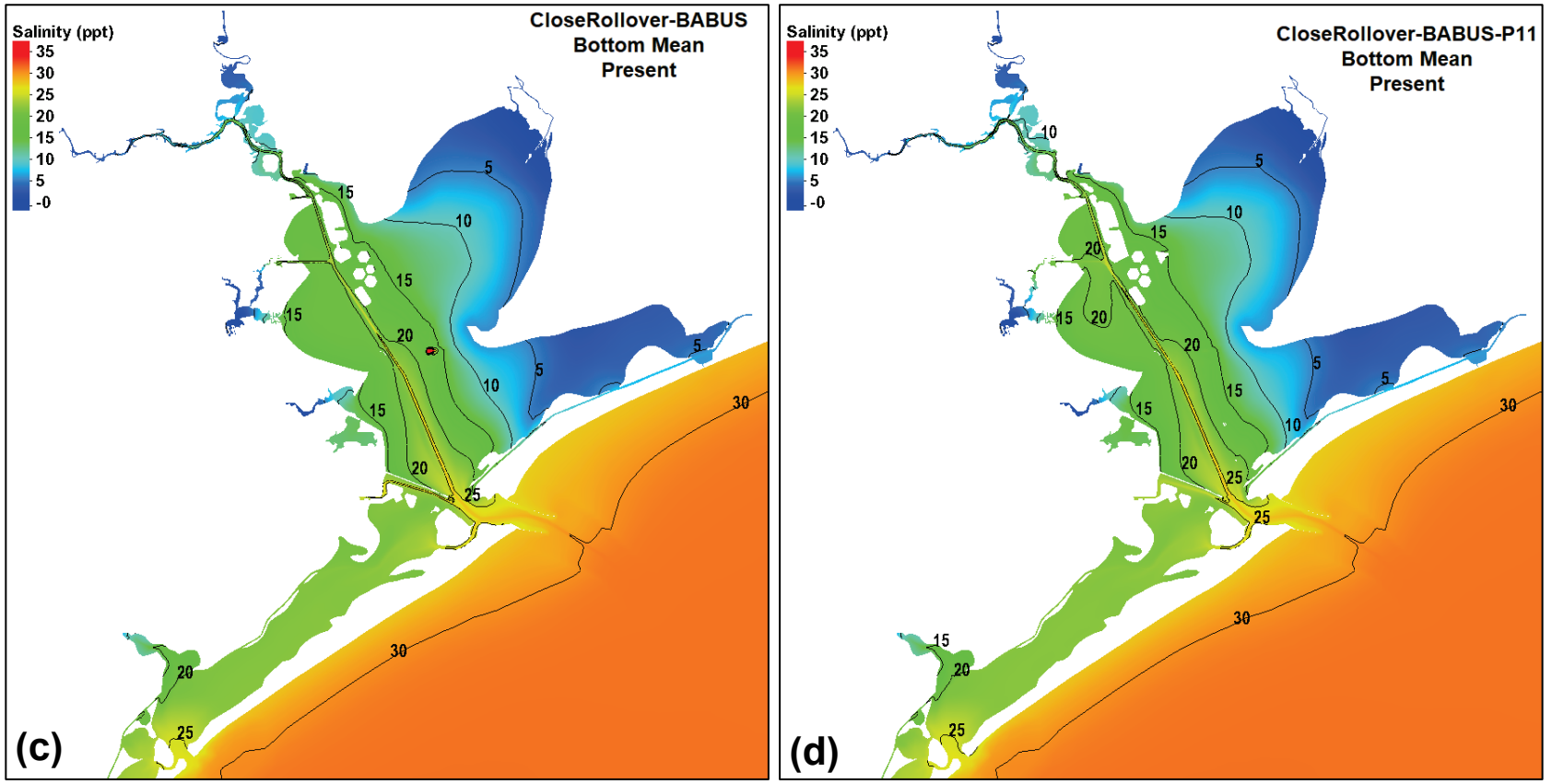


Figure 42. Present condition surface salinity mean, (a) Base, (b) CloseRollover, (c) CloseRollover-BABUS, (d) CloseRollover-BABUS-P11.

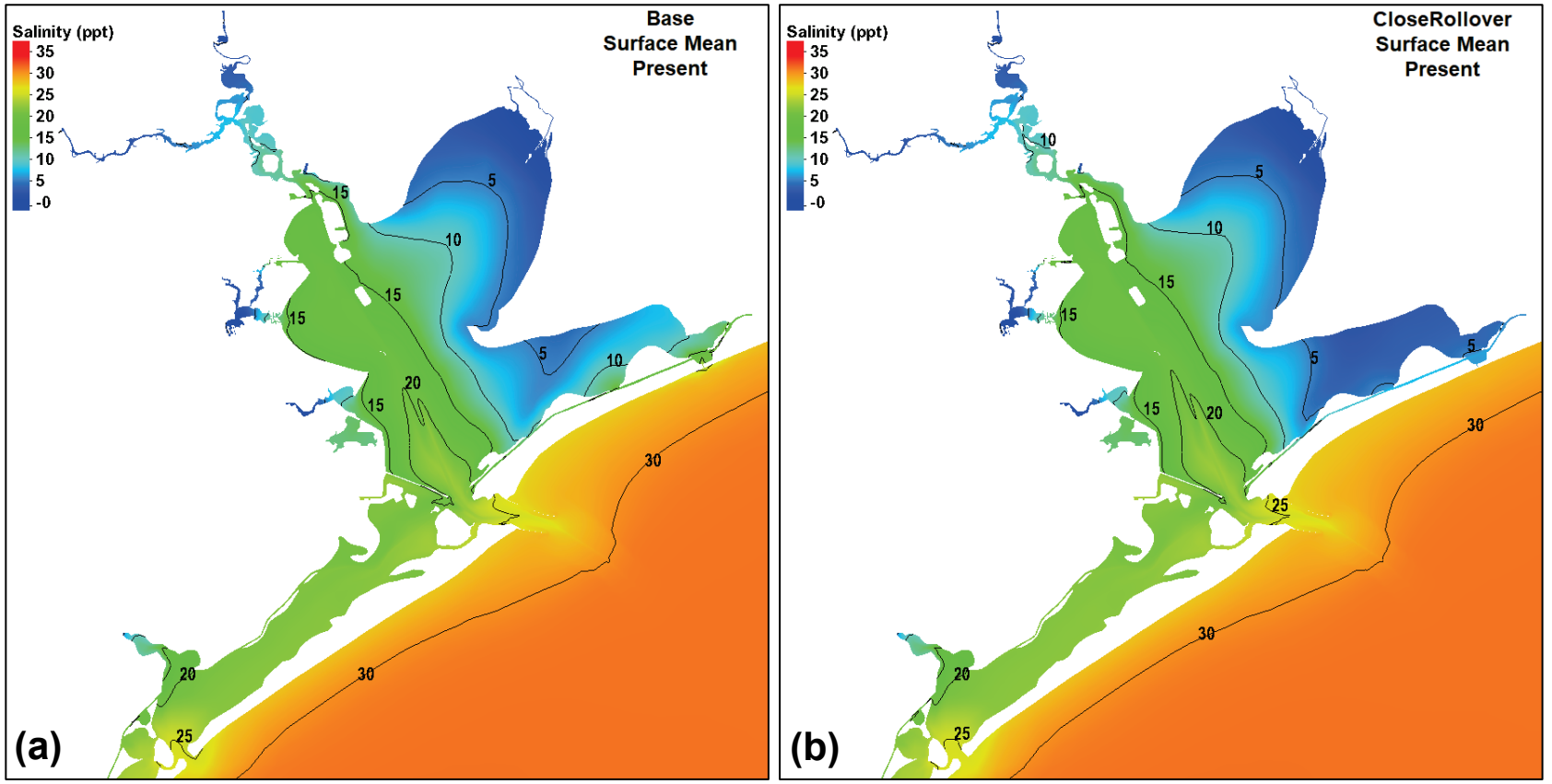
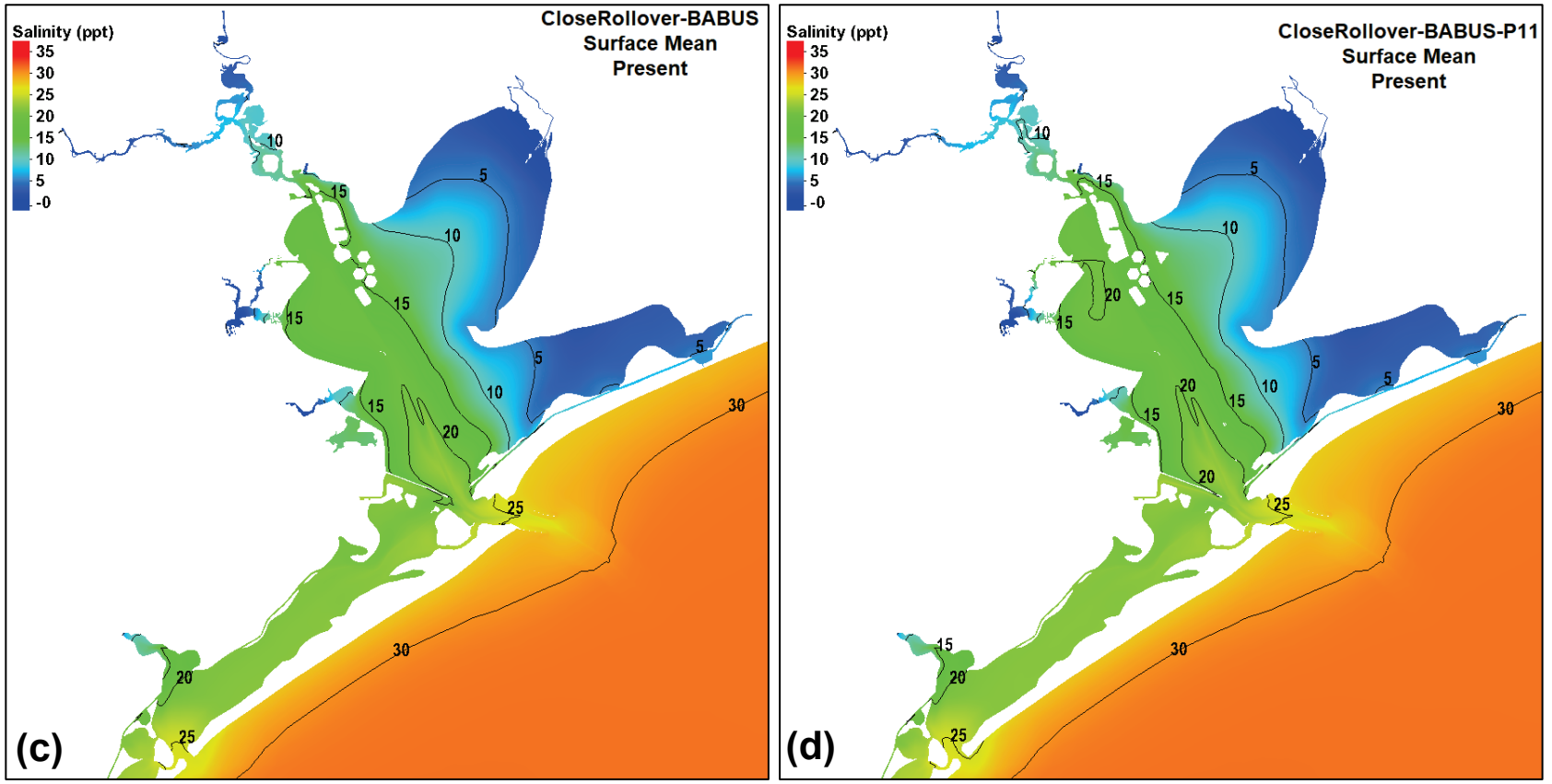


Figure 42. Continued.



3.1.2.2 Future, 2079

Figure 43. Future condition bottom salinity mean, (a) Base, (b) CloseRollover, (c) CloseRollover-BABUS, (d) CloseRollover-BABUS-P11.

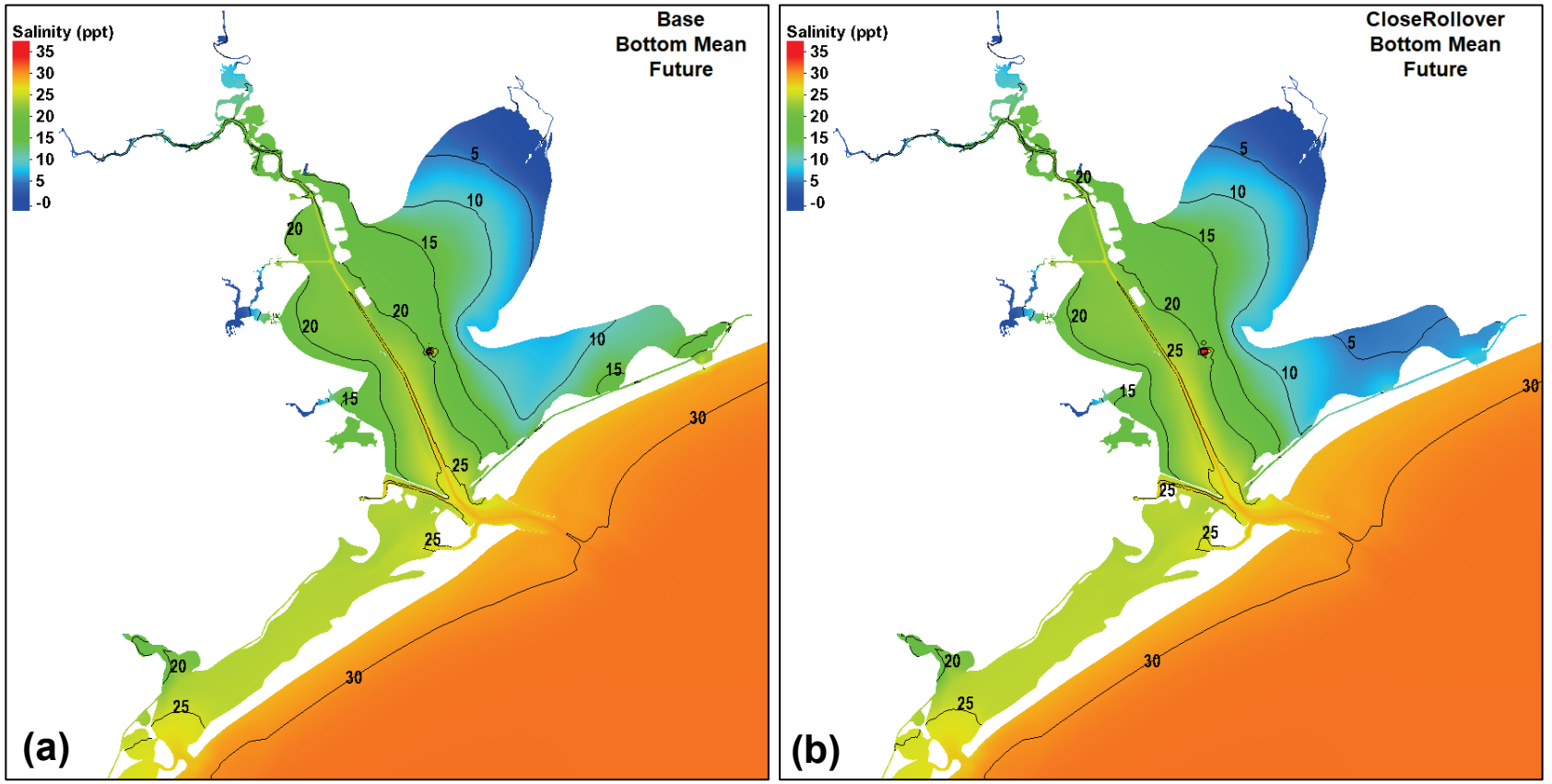


Figure 43. Continued.

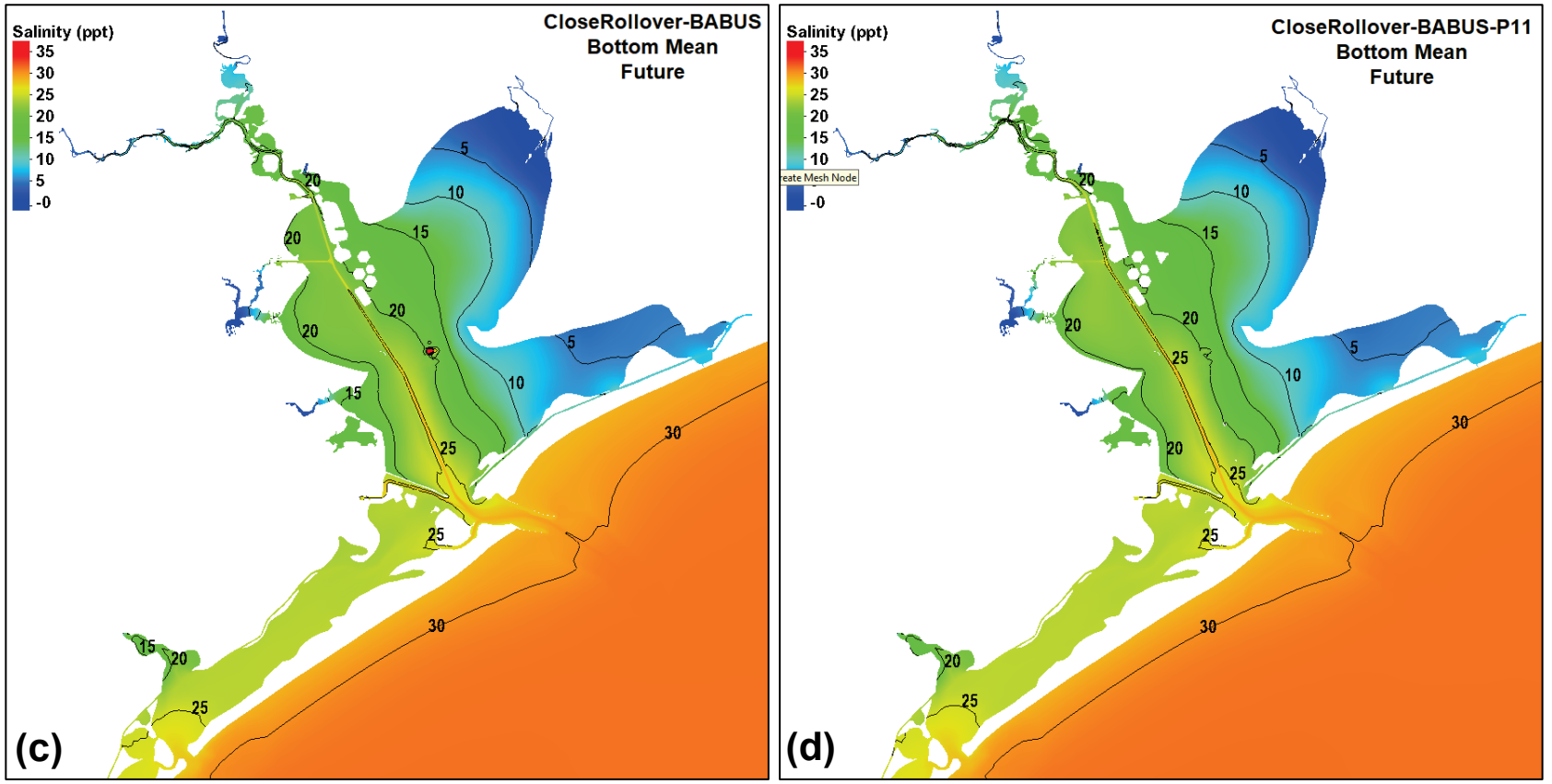


Figure 44. Future condition surface salinity mean, (a) Base, (b) CloseRollover, (c) CloseRollover-BABUS, (d) CloseRollover-BABUS-P11.

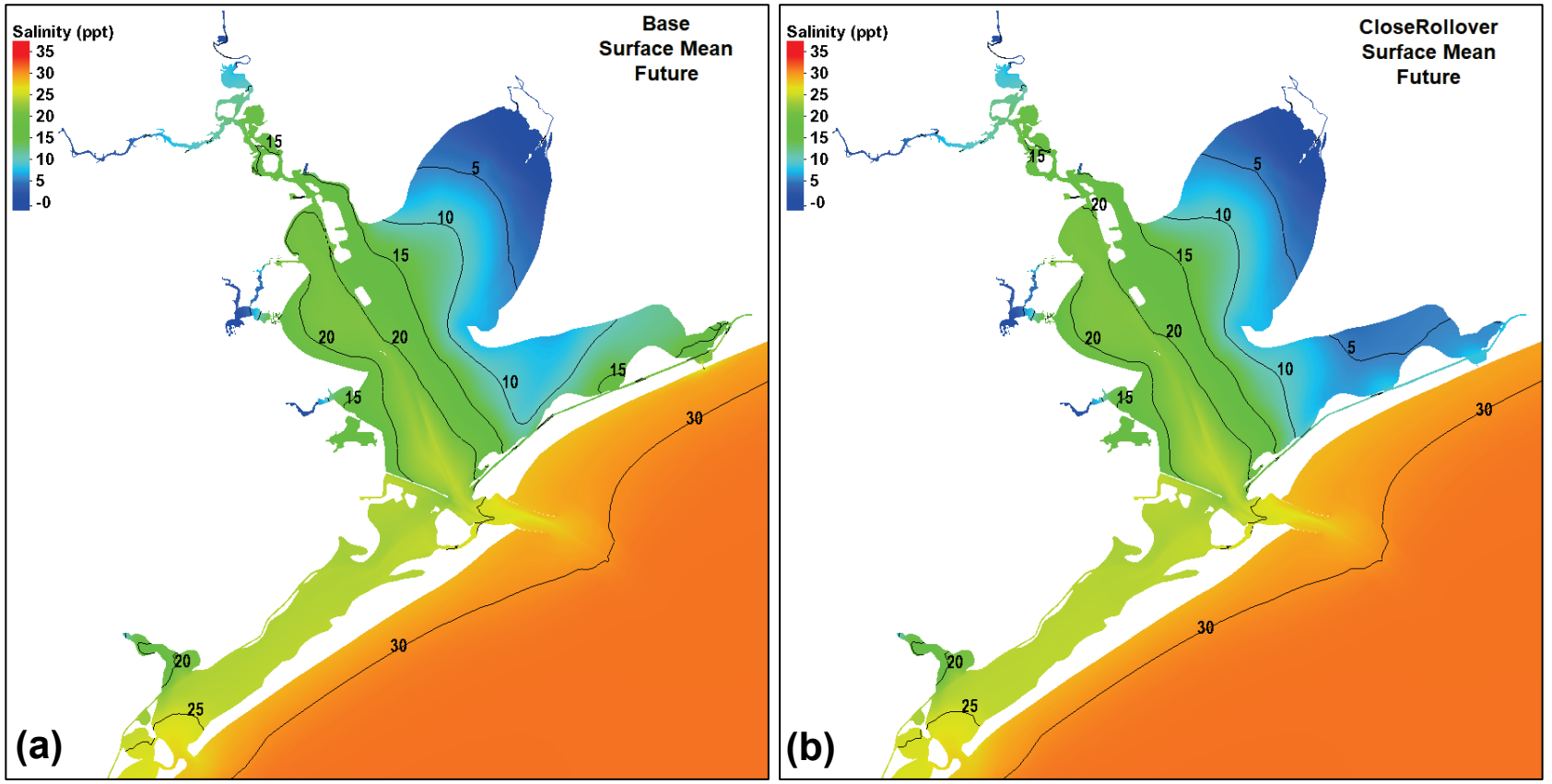
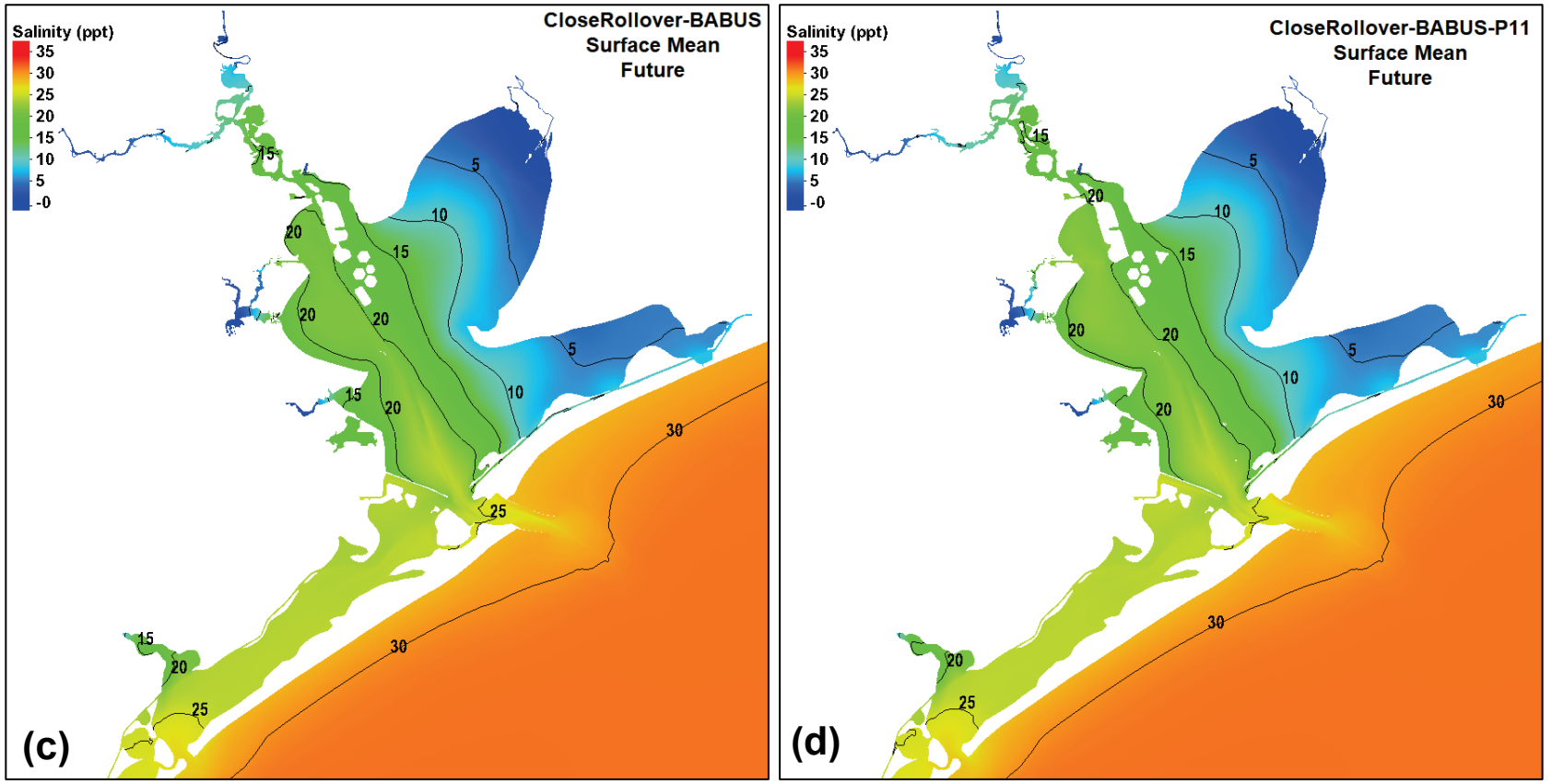


Figure 44. Continued.



3.1.3 Salinity HSC slice analysis

A slice along the center of the HSC from the Gulf of Mexico to the HSC Turning Basin allows for the comparison of the salinity wedge migration along the ship channel. These results are for mean salinity over the year-long analysis period, both present and future conditions. Figure 45 shows the location of key features along the HSC for reference (contours are irrelevant). Figure 46 shows the present condition mean salinity along the HSC for all four alternatives and Figure 47 for the future condition. The distance of salinity migration along the bottom of the ship channel is shown in Table 4. There is little variation in the salinity wedge migration from the Base for the CloseRollover and CloseRollover-BABUS alternatives. The salinity does migrate farther upstream for the wider channel alternative, CloseRollover-BABUS-P11. The salinity wedge migration is between 2 and 5 mi, depending on the contour, but greatest in the upper bay portion of the domain (Bayport and Atkinson Island area). The wider ship channel allows the high saline ocean water to push farther upstream until it is compressed in the along-channel direction due to the fresh water entering the ship channel from the San Jacinto River and the Buffalo River. The mid-depth salinity actually increases in some locations due to this along channel compression, making the salinity wedge thicker and more stair-stepped in shape.

Figure 45. HSC slice analysis reference map (contours are irrelevant).

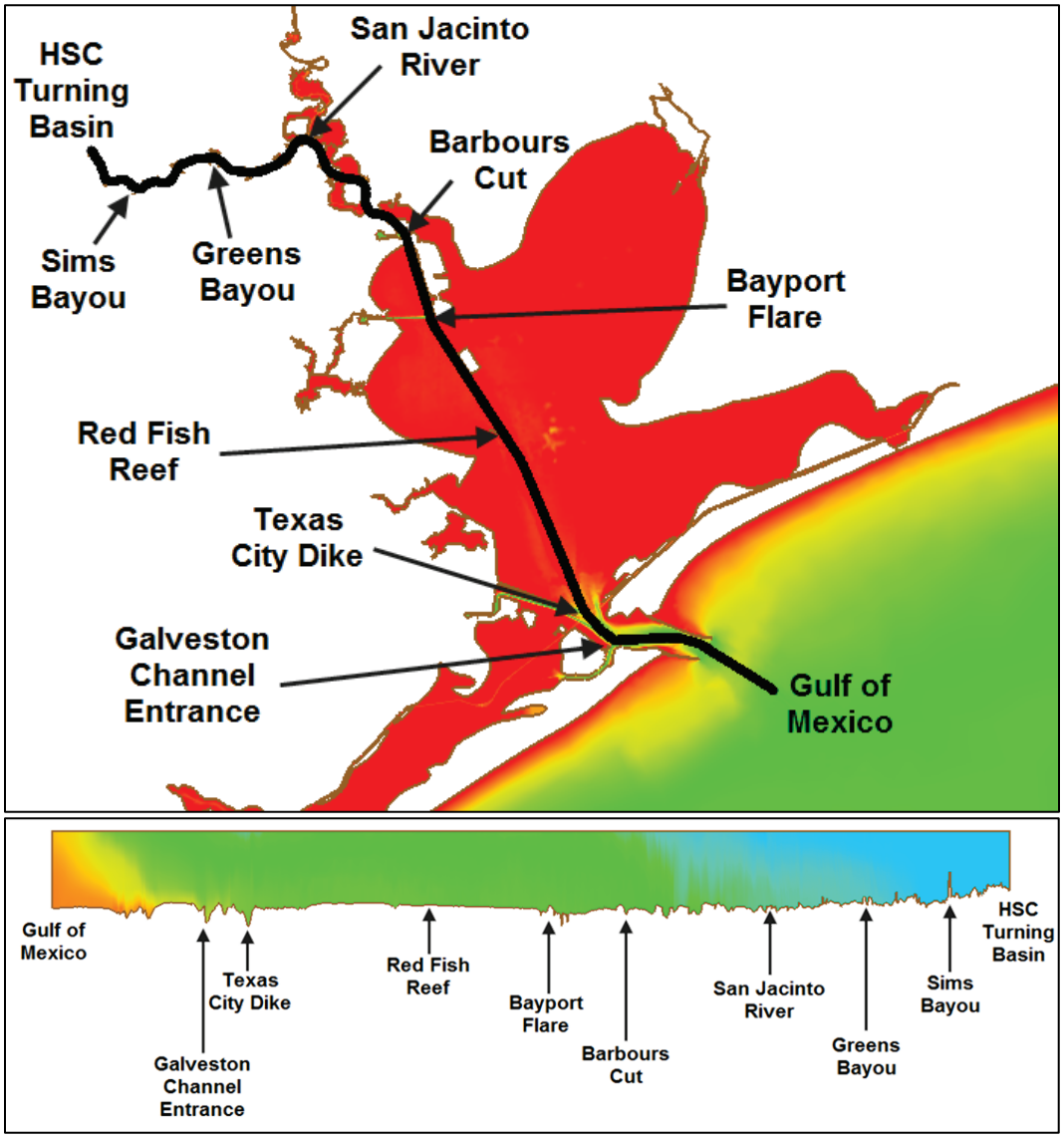


Figure 46. Present HSC average salinity slice results.

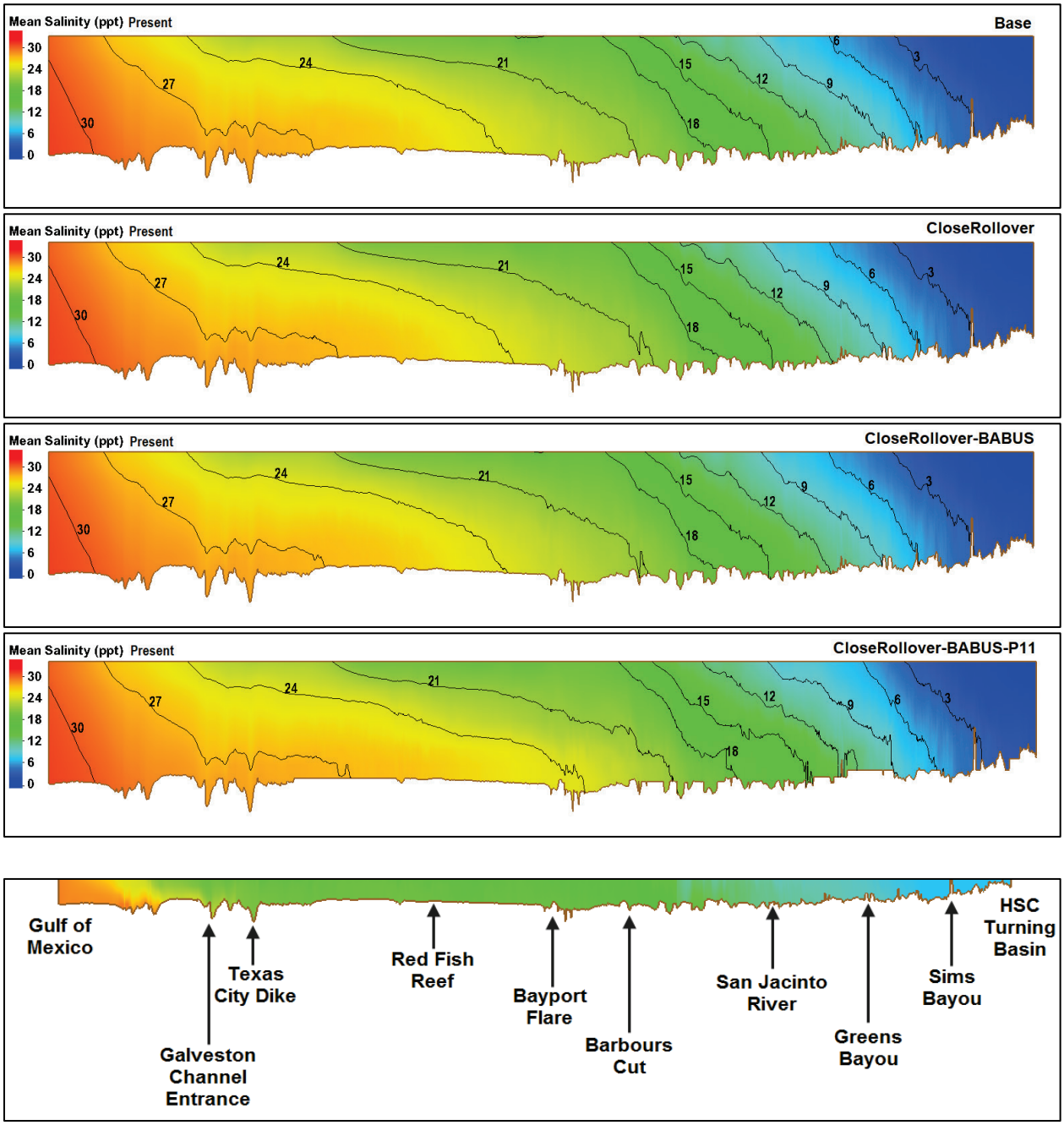


Figure 47. Future HSC average salinity slice results.

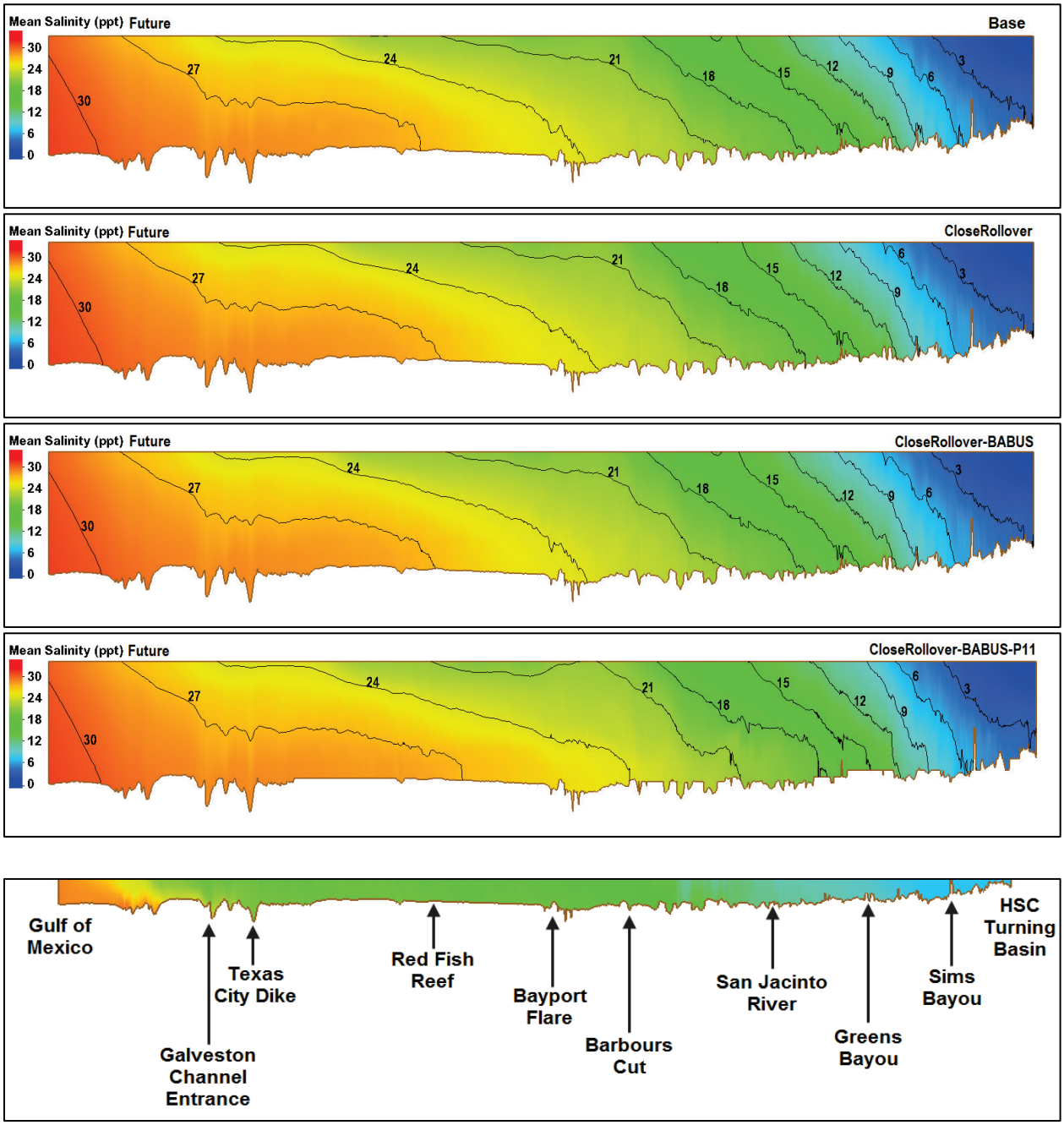


Table 4. Salinity wedge migration from Base to with project alternatives.

Salinity contour (ppt)	Present (2029)			Future (2079)		
	Close Rollover upstream shift (m) / (mi)	Close Rollover + BABUS Cells upstream shift (m) / (mi)	Close Rollover + BABUS Cells + P11 (m) / (mi)	Close Rollover upstream shift (m) / (mi)	Close Rollover + BABUS Cells upstream shift (m) / (mi)	Close Rollover + BABUS Cells + P11 (m) / (mi)
24	835/0.52	250/0.16	8000/4.97	1340/0.83	230/0.14	4380/2.73
21	1700/1.06	1150/0.71	4140/2.57	725/0.45	315/0.20	2250/1.40
15	275/0.17	85/0.05	4375/2.72	0/0	0/0	1020/0.63
9	0/0	0/0	960/0.60	0/0	0/0	540/0.34
3	0/0	0/0	740/0.46	0/0	0/0	505/0.31

3.2 Tidal prism and amplitude

Changes to the system geometry can impact the tidal exchange into a bay environment such as Galveston and Trinity Bays. Closing Rollover Pass eliminates one location of tidal exchange into the system. In addition, the HSC channel depth and width are modified in CloseRollover-BABUS-P11 and will allow for changes in the volume of flow being exchanged through the inlets. The tidal prism is a calculation of the volume of water that enters and leaves through the inlets with each tide. This volume is computed for all tides over the analysis year, present and future, and the average tidal prism is determined. Table 5 shows the volume of the average tidal prism for each alternative as well as the percentage change in the with project alternative as compared to the Base alternative. The greatest increase (3.6 % for present conditions and 5.4% for future conditions) in tidal prism occurs for the CloseRollover condition. It is possible that more water is entering the system from the Gulf to make up for the closure of Rollover Pass. Additional modifications to the system then provide a drop in the tidal prism change such that the BABUS cells and Bird Islands remove some of the wetted area within the system. All three alternatives generate an increase in the average tidal exchange. The future conditions show a much larger tidal prism change than present conditions, but this is due to the higher water level, therefore automatically increasing the volume of water entering/exiting the system.

Table 5. Average tidal prism volume for analysis year and percent change of the with project alternatives from the Base alternative for present and future conditions.

	Present (2029)				Future (2079)			
	Base (1000 m³)	Close Rollover % change from Base	Close Rollover + BABUS Cells % change from Base	Close Rollover + BABUS Cells + P11 % change from Base	Base (1000 m³)	Close Rollover % change from Base	Close Rollover + BABUS Cells % change from Base	Close Rollover + BABUS Cells + P11 % change from Base
Average	278,962	3.61	3.07	2.86	281,784	5.36	4.47	4.85

The tidal amplitude is the change in the water level from low tide to high tide and vice versa. The tidal prism gives an overall impact on the water exchange whereas the tidal amplitude may vary at locations depending on where the system modifications are made and changes in the flow patterns within the system. Table 6 shows the Base alternative tidal amplitude and the percentage change between Base and with project alternatives for the locations shown in Figure 16. All locations see a 2% or less change in the tidal amplitude when the alternative modifications are included. The largest variation in tidal amplitude is generally seen in the CloseRollover-BABUS-P11 alternative, but this change is still less than 2%. For reference, a 2% change on an amplitude of 0.4 m is 0.008 m (8 mm).

Table 6. Percent change in tidal amplitude of the with project alternatives from the Base.

	Present (2029)				Future (2079)			
	Base Amplitude (m)	Close Rollover % change from Base	Close Rollover + BABUS Cells % change from Base	Close Rollover + BABUS Cells + P11 % change from Base	Base Amplitude (m)	Close Rollover % change from Base	Close Rollover + BABUS Cells % change from Base	Close Rollover + BABUS Cells + P11 % change from Base
HSC at Morgans Point	0.39	0.16	0.61	1.43	0.44	0.26	0.51	1.01
HSC at Atkinson Island	0.39	0.12	0.53	1.35	0.43	0.26	0.65	1.00
HSC at Mid Bay Marsh	0.37	0.15	0.98	1.81	0.42	0.81	1.69	1.65
HSC at Red Fish Reef	0.37	0.14	0.80	0.92	0.41	0.55	0.44	0.23
HSC at Lower Galveston Bay	0.34	0.10	0.54	1.24	0.39	0.07	0.45	1.08

	Present (2029)				Future (2079)			
	Base Amplitude (m)	Close Rollover % change from Base	Close Rollover + BABUS Cells % change from Base	Close Rollover + BABUS Cells + P11 % change from Base	Base Amplitude (m)	Close Rollover % change from Base	Close Rollover + BABUS Cells % change from Base	Close Rollover + BABUS Cells + P11 % change from Base
HSC at Bolivar Roads	0.35	-0.31	0.32	0.15	0.37	-0.37	-0.10	0.24
HSC at Entrance	0.36	0.15	0.53	0.73	0.37	-0.10	0.69	0.54
HSC at Gulf	0.42	0.21	0.38	0.20	0.42	0.27	0.06	-0.35
Upper Galveston Bay 1	0.39	0.10	0.59	1.33	0.43	0.01	0.67	1.05
Upper Galveston Bay 2	0.38	0.15	0.81	1.69	0.43	0.51	0.60	1.31
Lower Galveston Bay	0.35	0.04	0.47	0.59	0.39	0.21	0.62	1.40
Lower Trinity Bay	0.37	0.37	0.37	1.48	0.42	0.26	0.52	1.40
Mid Trinity Bay	0.39	0.34	0.75	1.58	0.44	1.21	1.15	1.60
Upper Trinity Bay	0.40	0.11	0.47	1.12	0.45	0.22	0.65	1.31
Western East Bay	0.35	0.03	0.46	1.39	0.39	0.53	0.70	1.33
Eastern East Bay	0.36	0.77	0.73	1.30	0.41	-0.37	0.06	0.80
Eastern West Bay	0.38	0.14	0.47	0.26	0.39	0.28	0.63	1.22
Mid West Bay	0.39	0.92	0.80	0.75	0.39	0.14	0.81	0.82
Offatts Bayou	0.38	1.35	1.25	1.02	0.39	0.55	0.89	0.78
Dickinson	0.36	-0.35	0.80	1.11	0.40	0.52	0.94	1.39
Clear Creek	0.38	0.35	0.53	1.30	0.43	0.24	0.40	1.42
Smith Point	0.37	0.37	0.77	1.63	0.41	0.24	0.61	1.54
Mid East Bay	0.36	0.46	1.20	2.00	0.40	0.23	0.93	1.64
HSC at Fred Hartman Bridge	0.39	1.29	2.65	3.37	0.44	0.85	0.63	0.98

	Present (2029)				Future (2079)			
	Base Amplitude (m)	Close Rollover % change from Base	Close Rollover + BABUS Cells % change from Base	Close Rollover + BABUS Cells + P11 % change from Base	Base Amplitude (m)	Close Rollover % change from Base	Close Rollover + BABUS Cells % change from Base	Close Rollover + BABUS Cells + P11 % change from Base
HSC at Goat Island	0.41	-0.70	0.04	0.72	0.45	0.24	0.43	0.61
HSC at Carpenters Bayou	0.41	0.11	0.95	1.02	0.46	-0.30	0.29	0.52
HSC at Greens Bayou	0.42	-0.16	0.22	0.89	0.46	0.23	0.56	1.07
HSC at Sims Bayou	0.42	0.04	0.47	1.26	0.47	-0.08	0.72	1.28
HSC at Turning Basin	0.43	-0.40	0.15	0.83	0.47	0.15	0.54	0.65
Apfell Park	0.38	-0.29	-0.08	0.03	0.38	-0.20	0.42	-0.40

3.3 Velocity

The velocity comparisons among the alternatives will focus on residual velocity vectors. Residual velocity is the velocity that remains when the tidally varying velocity has been averaged out. This vector defines the predominant flow direction and speed of a particle of water. Although the tide will cause the particle to move back and forth, there is generally a flow direction that is dominant, allowing for a particle to migrate along a certain path. Typically, in a tidally driven environment with a deep navigation channel such as the HSC, the predominant flow direction is upstream along the channel bottom and downstream along the channel surface. The present condition surface and bottom velocity comparisons for the alternatives are shown in Figure 48 through Figure 53. The red vectors indicate the direction of the alternative residual velocity and the black vectors, the Base. The contours represent the difference in the velocity magnitudes – alternative minus Base such that positive values (reds/yellows) indicate the alternative residual velocity magnitude is greater and negative values (blues) indicate that the Base residual velocity magnitude is greater. The bottom velocity is a near-bed velocity and can be assumed to be at 5% of the depth above the bed.

The comparisons show that the residual vector directions vary greatly in the vicinity of the Rollover Pass closure and the BABUS cell locations. The comparisons farther away from these geometric modifications are very similar for the alternatives, especially in Trinity Bay. The area with the most variation for the HSC modification alternative (CloseRollover-BABUS-P11) is primarily between Red Fish Reef and Morgan's Point, as well as along the eastern side of Atkinson Island. There is widening of the HSC, bend easing, turning basins, and additional dredge disposal added to this area, so the variation is not unexpected. The same variations are shown in both the surface and bottom residual velocities. The change in the residual velocity magnitudes from the Base is generally less than 0.05 m/s.

Figure 48. Bottom average residual velocity comparison for CloseRollover, present conditions. (Red vectors – with project, Black vectors – Base)

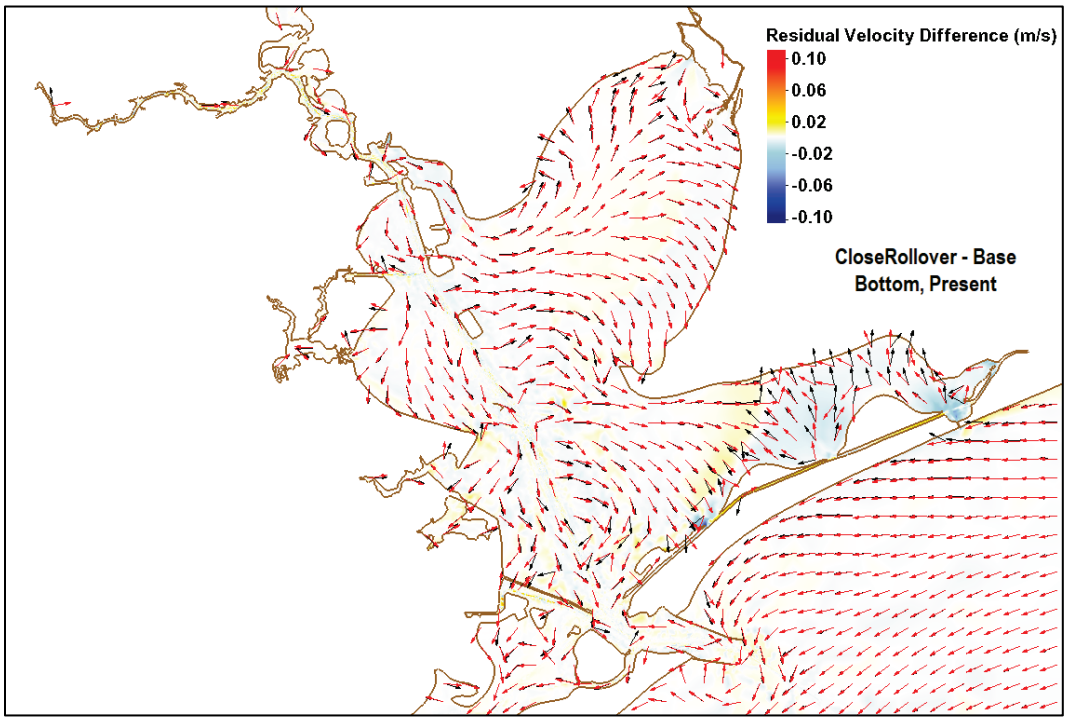


Figure 49. Surface average residual velocity comparison for CloseRollover, present conditions. (Red vectors – with project, Black vectors – Base)

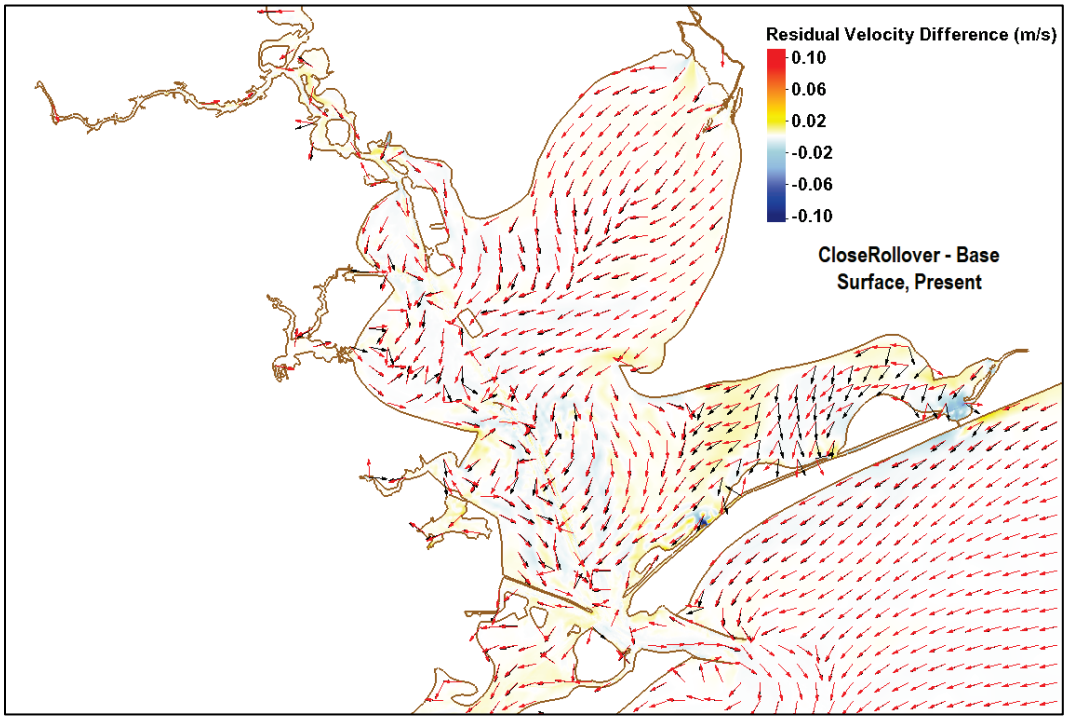


Figure 50. Bottom average residual velocity comparison for CloseRollover-BABUS, present conditions. (Red vectors – with project, Black vectors – Base)

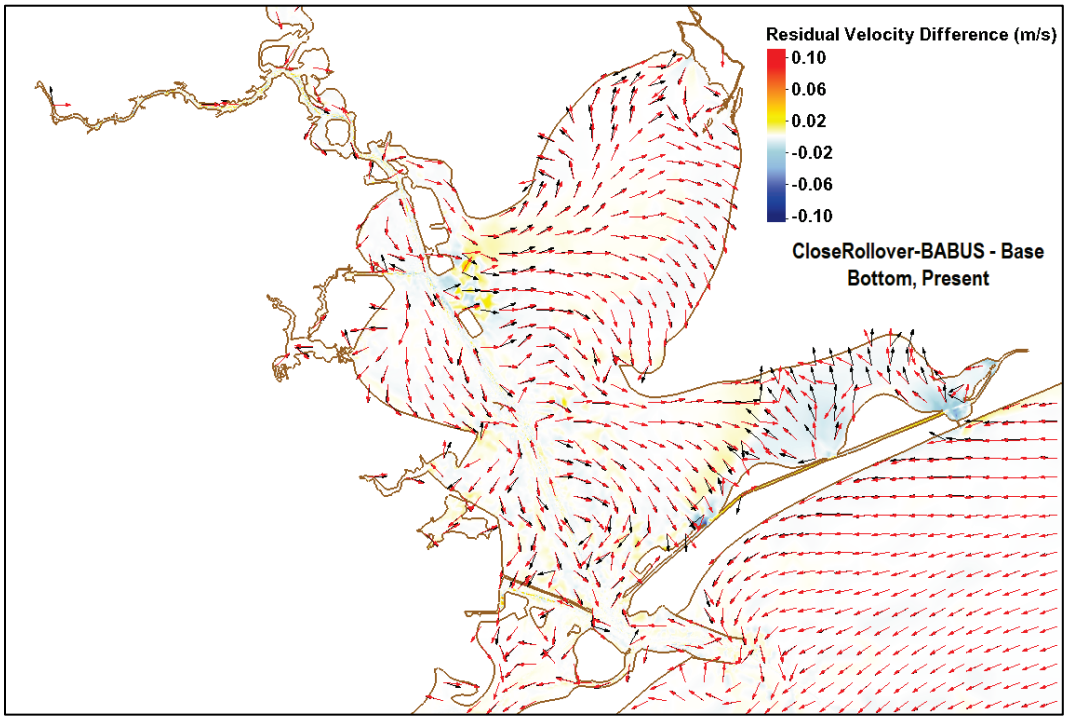


Figure 51. Surface average residual velocity comparison for CloseRollover-BABUS, present conditions. (Red vectors – with project, Black vectors – Base)

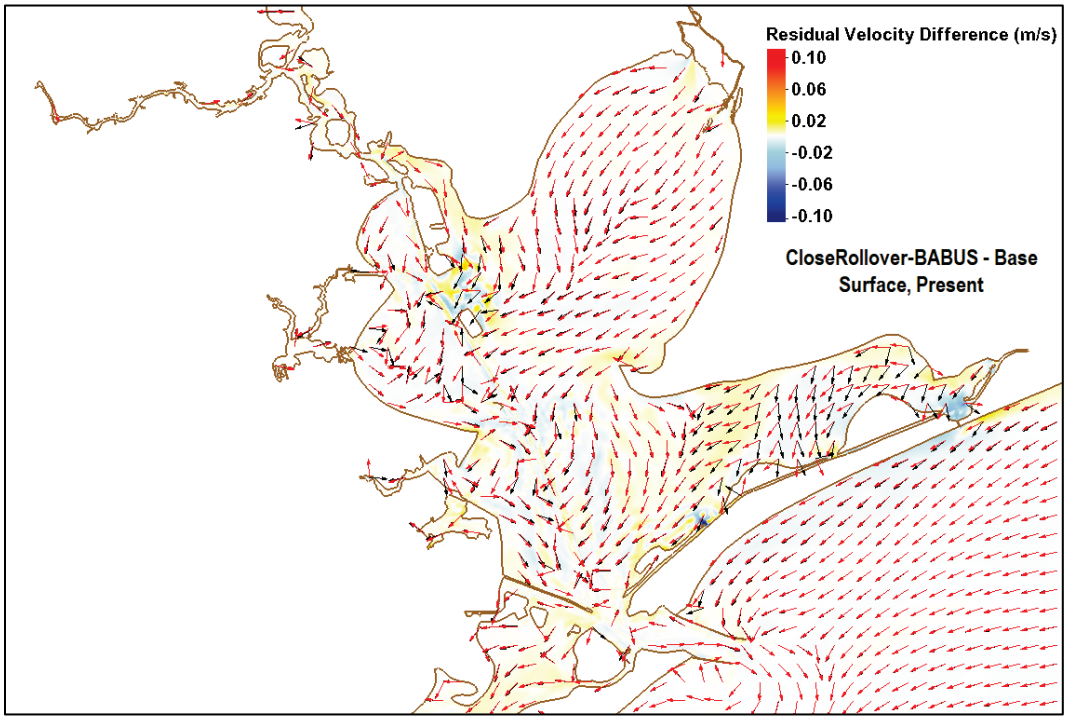


Figure 52. Bottom average residual velocity comparison for CloseRollover-BABUS-P11, present conditions. (Red vectors – with project, Black vectors – Base)

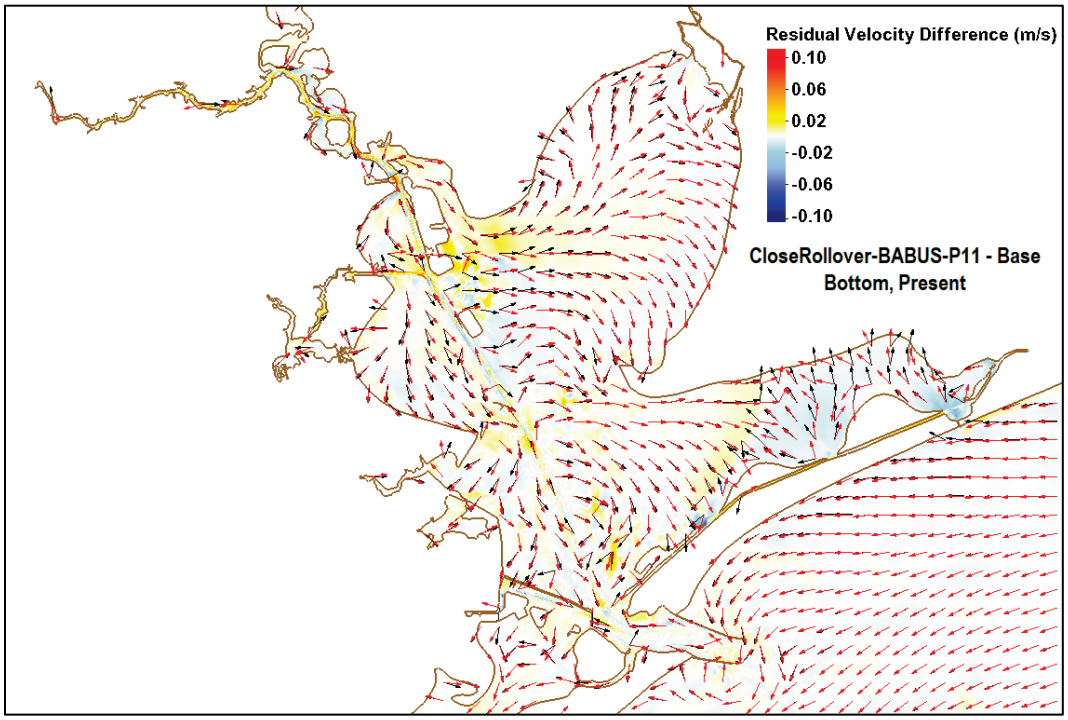
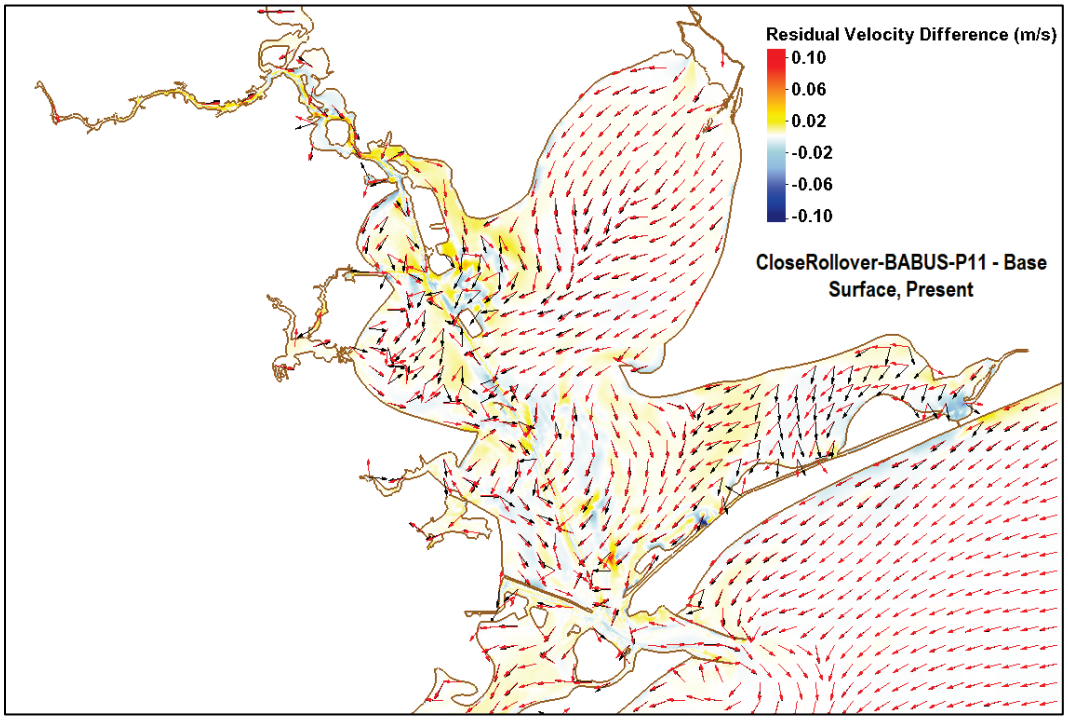


Figure 53. Surface average residual velocity comparison for CloseRollover-BABUS-P11, present conditions. (Red vectors – with project, Black vectors – Base)



3.3.1 Average velocity in vicinity of BABUS cells

The arrangement of the BABUS cells allows for flow between the structures. These narrow channels can generate high velocity that in turn can bring about additional bed erosion. Figure 54 and Figure 55 show the present condition, average bottom velocity magnitude for the Base and CloseRollover-BABUS-P11 alternatives. The alternative modifications are visible in the Base figure by the pink outline. The increase in velocity magnitude is easily visible around the BABUS cells and Bird Island. Bed armoring should be included with the addition of the BABUS cells given that the mean velocity increases approximately three times from the Base condition (velocity on the order of 0.05 m/s is now 0.15 m/s, in places). Present condition mean velocity figures for all alternatives, bottom and surface, are provided in the appendix.

Figure 54. Average bottom velocity for Base, present conditions. (alternative modifications shown by pink outline)

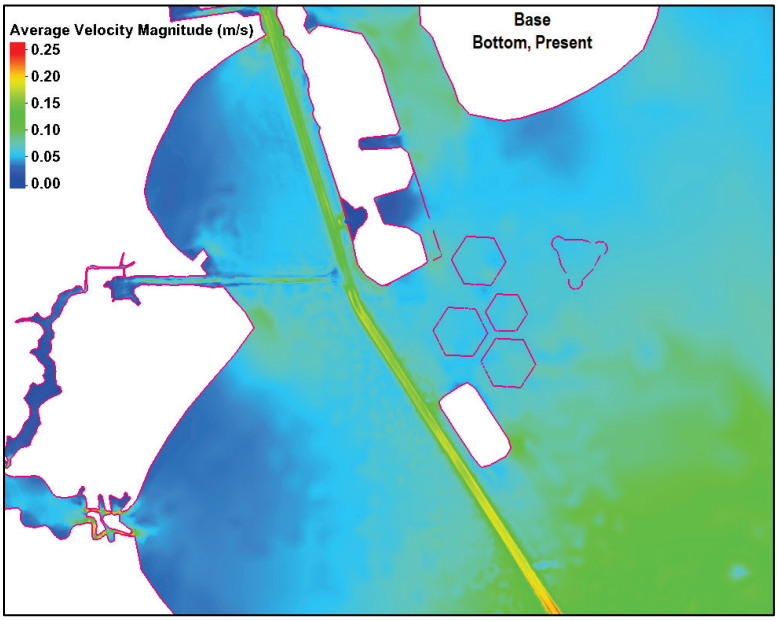
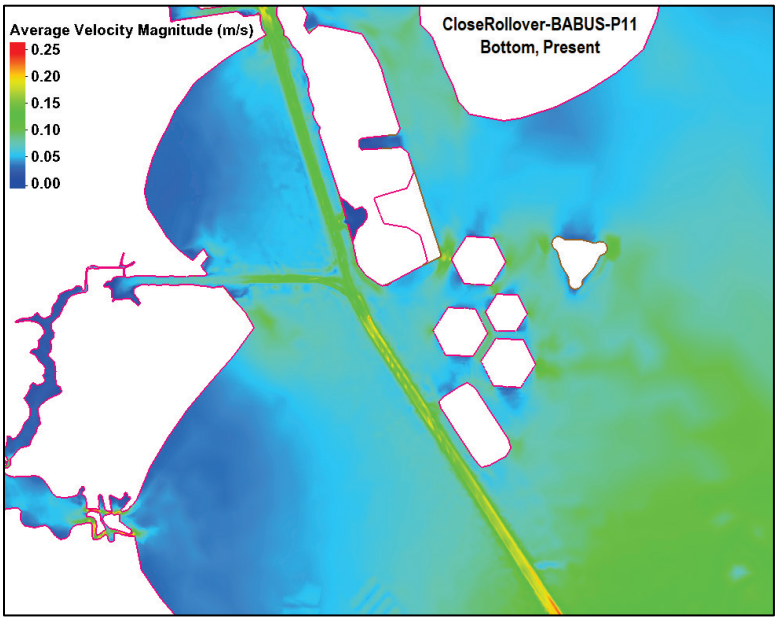


Figure 55. Average bottom velocity for CloseRollover-BABUS-P11, present conditions.



3.3.2 Velocity in vicinity of Apfell Park (Big Reef)

The Big Reef, or Apfell Park, area is located at the eastern tip of Galveston Island, between the south jetty and the HSC entrance (Figure 56). This area is significant due to the critical habitat that resides here. It is necessary to ensure that the proposed modifications tested in this study do not adversely impact this area in terms of velocity and/or shoaling.

Figure 56. Location of Apfell Park (Big Reef).

The ability for sediment to erode or deposit is based on the critical shear stress of the grains as well as the shear stress generated by the flow velocity. When the shear stress due to the flow exceeds the critical shear stress necessary for grain movement, material will erode from the bed. When the opposite is true, material will deposit or slowly settle as it moves within the flow. Velocity magnitude changes are, therefore, a reasonable indicator of shoaling changes. Table 7 shows the average bottom velocity and the maximum bottom velocity over the analysis year at Apfell Park for all alternatives (present condition). There is no change in average bottom velocity among the alternatives. There is a small change in maximum bottom velocity, but this value is 0.03 cm/s or less. Figure 57 shows the residual velocity magnitude and direction in the Apfell Park area. Again, there is almost no change in the residual velocity magnitude or direction among the alternatives. Therefore, there is no indication that the modifications analyzed in this study will generate changes in the erosion or deposition at Apfell Park.

Table 7. Average and maximum bottom velocity magnitudes for all alternatives at Apfell Park.

	Base	CloseRollover	CloseRollover-BABUS	CloseRollover-BABUS-P11
Average Bottom Velocity Magnitude (m/s)	0.19	0.19	0.19	0.19
Maximum Bottom Velocity Magnitude (m/s)	0.55	0.57	0.57	0.58

Figure 57. Residual velocity magnitude (colored contours) and direction (fixed length arrows) at HSC Entrance Channel for a) Base, b) CloseRollover, c) CloseRollover-BABUS and d) CloseRollover-BABUS-P11 for present conditions.

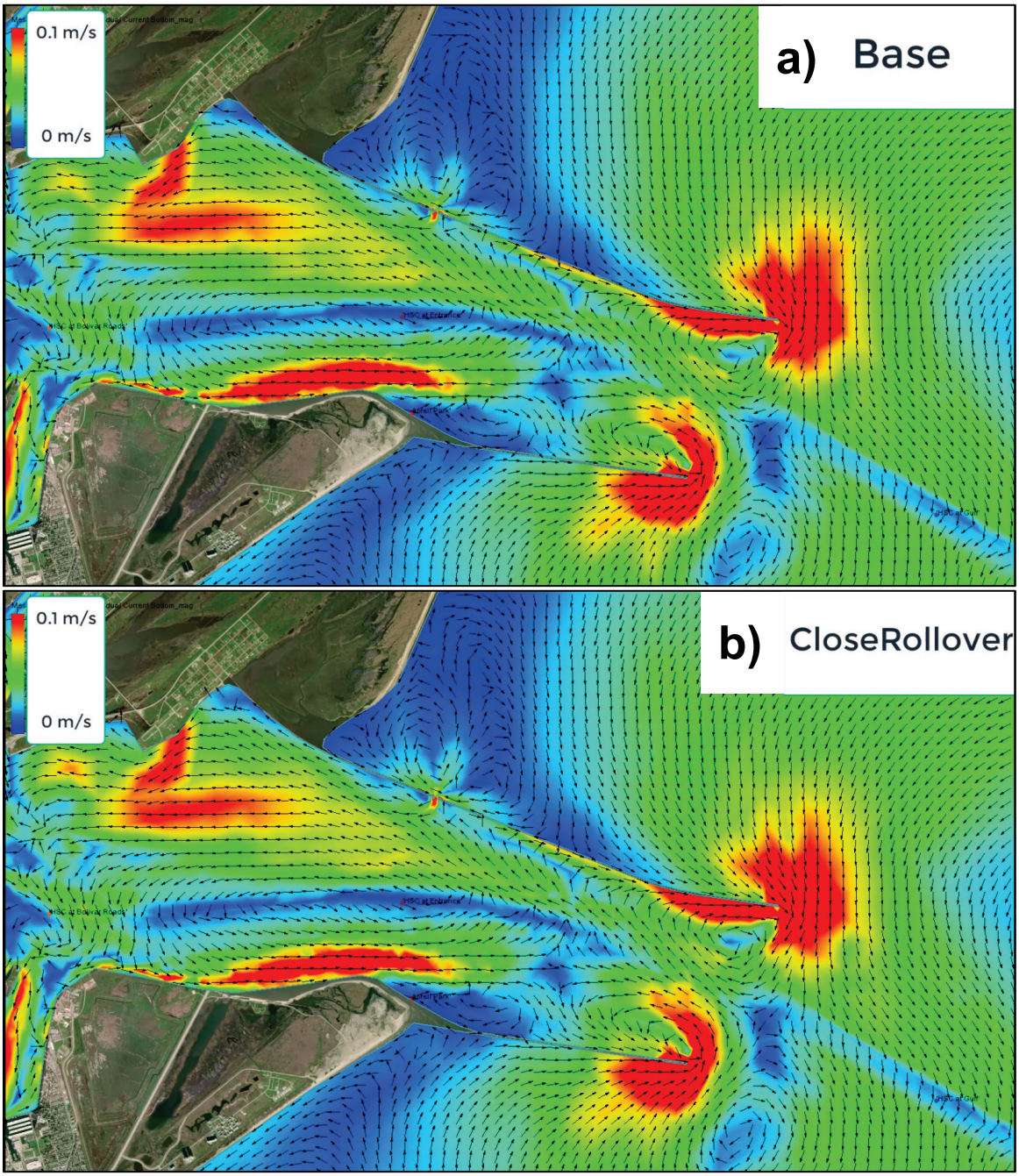
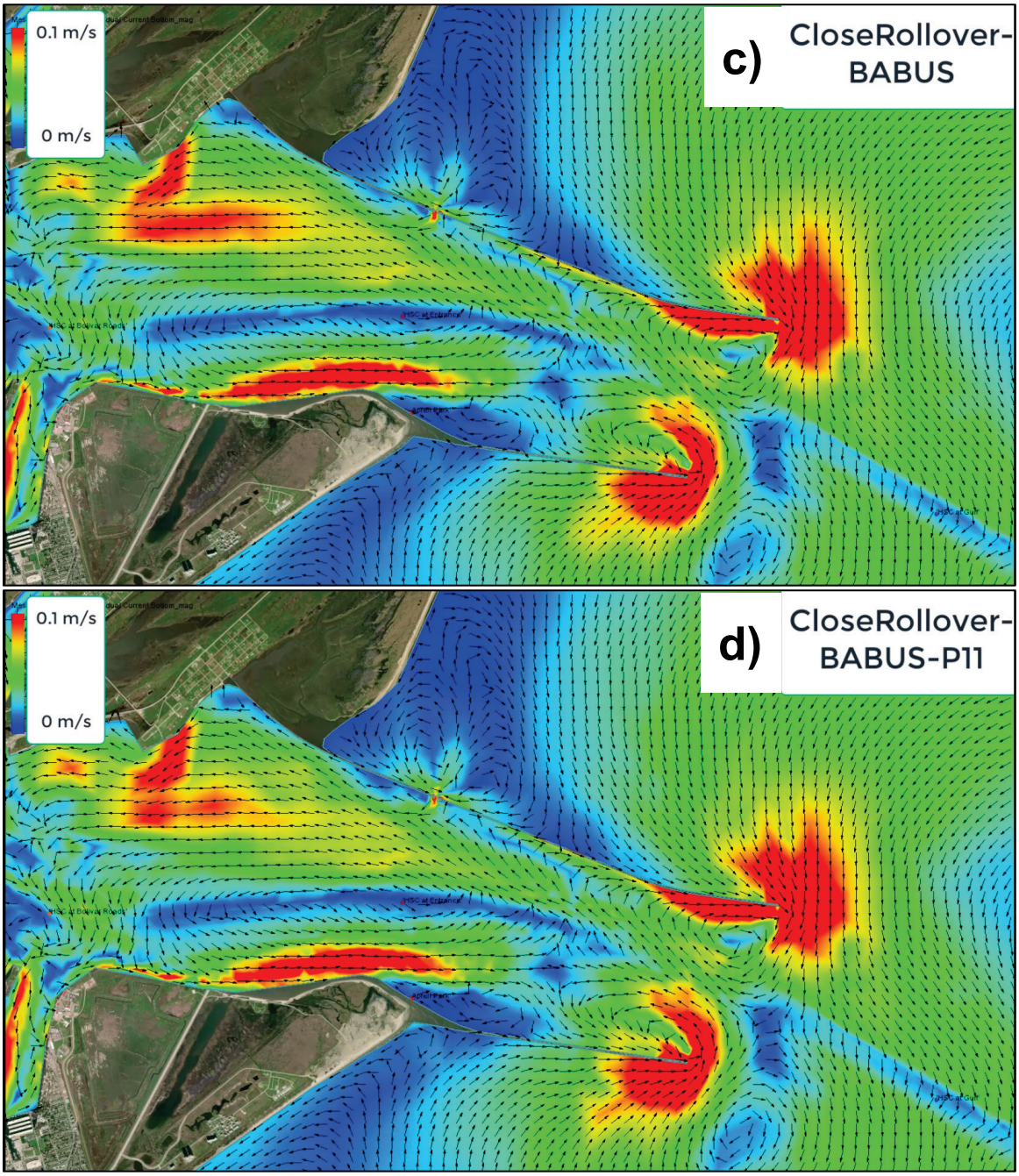


Figure 57. Continued.



3.4 Shoaling

The sediment analysis is based on the historical dredge records from the USACE annual reports as done in the model validation (McAlpin et al. 2019a). These volumes are provided for several reaches of the HSC as noted in the dredge template shown in Figure 58. This template is used to show how the alternative shoaling estimates from the numerical model compare to each other for different channel reaches.

Figure 58. HSC dredge template for shoaling analysis.

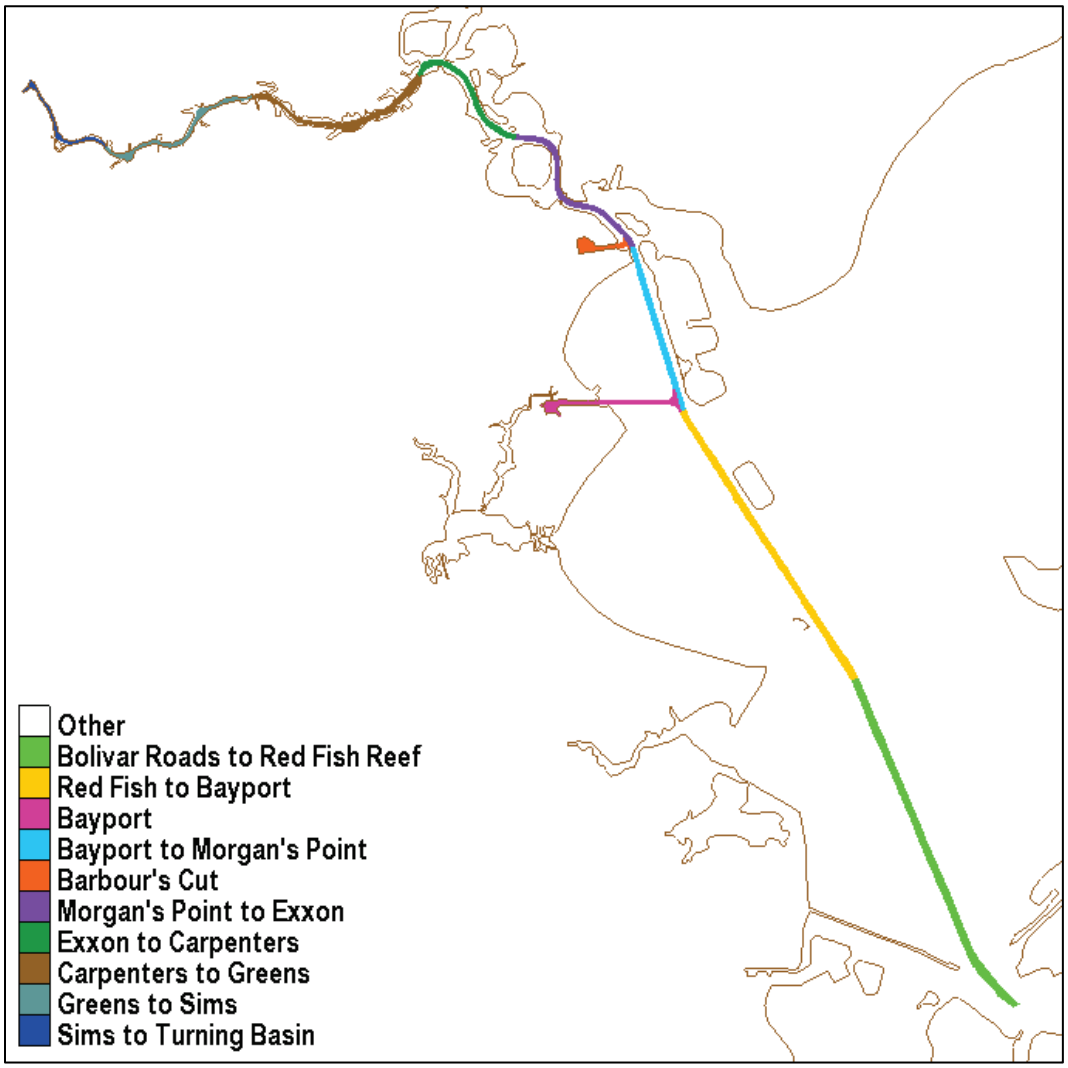


Figure 59 and Figure 60 show the scaled shoaling volume (McAlpin et al. 2019a) within each segment for the 2010 base condition and all four alternatives – Base, CloseRollover, CloseRollover-BABUS, CloseRollover-BABUS-P11 – for present and future conditions, respectively. In general, the largest increase in the HSC shoaling is due to the HSC modifications included in CloseRollover-BABUS-P11. Although the other alternatives do show an increase in shoaling for most reaches, the magnitude of the increase is less. Both present and future conditions indicate that the largest shoaling and the greatest increase from Base occurs in the Bayport area, which has always experienced large amounts of shoaling. The P11 modifications create a much larger increase in HSC shoaling than the other alternatives due to this condition including several modifications (deepening, widening, etc.) to the HSC.

Figure 59. Shoaling results by reach over the present condition analysis year.

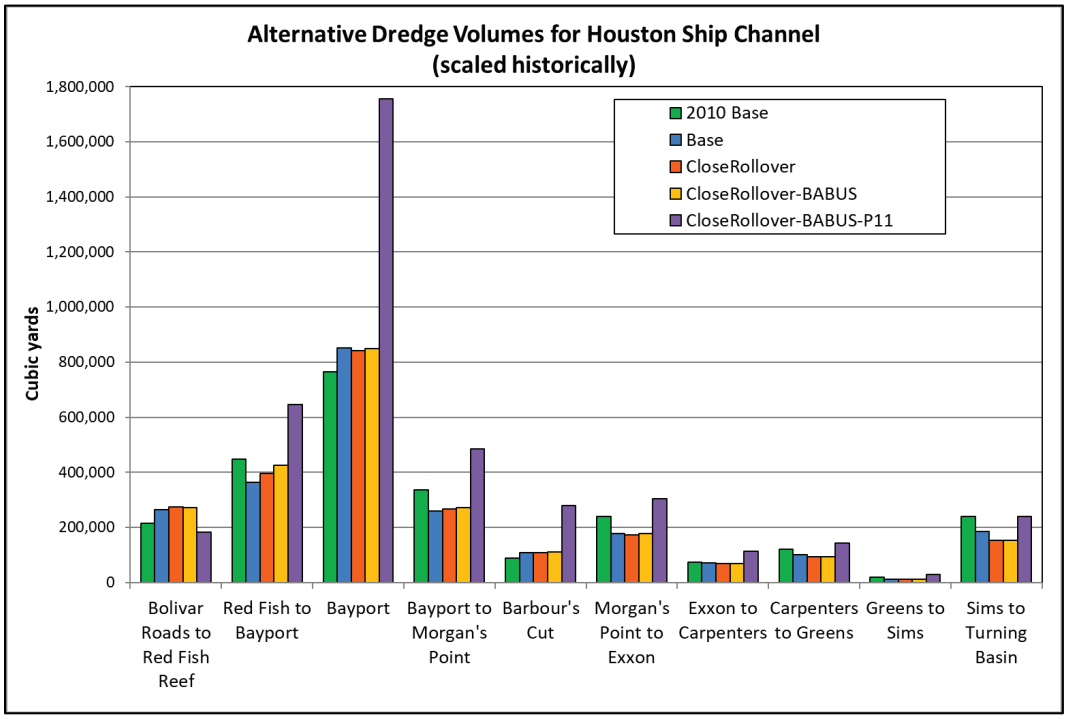


Figure 60. Shoaling results by reach over the future condition analysis year.

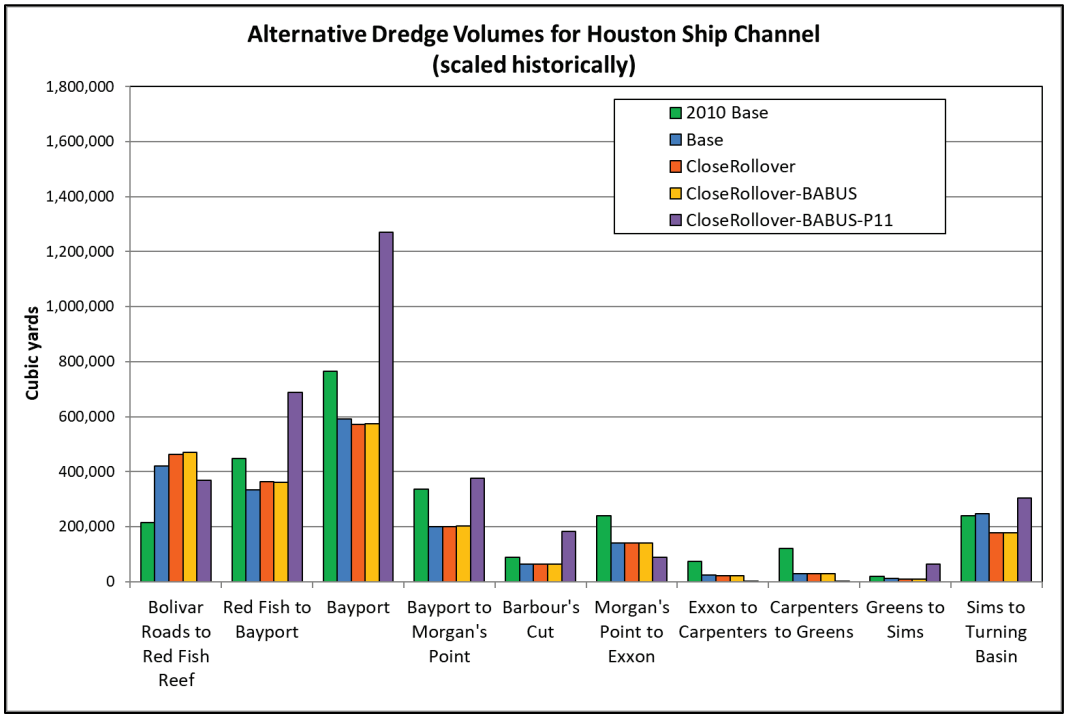


Figure 61 and Figure 62 show the model-computed, unscaled bed displacement along the HSC from the Texas City Dike to the Houston Turning Basin for the present and future conditions, respectively. The reduction in shoaling magnitude for the future condition is expected since that condition includes reduced freshwater inflows and reduced sediment loads. These results show a similar pattern to those in Figure 59 and Figure 60, although no scaling has been done to ensure a correlation to historical data as in the shoaling volume plot. However, the comparison between with and without project will remain if scaled to replicate actual shoaling volumes/depths. The plot does show that the alternatives increase the deposition along most of the HSC, but that increase is very small for the CloseRollover and CloseRollover-BABUS alternatives. The increased shoaling is primarily due to the enlargement of the HSC that is included in the CloseRollover-BABUS-P11 alternative. These figures also indicate a potential shift of the peak shoaling locations to areas upstream of Red Fish Reef and upstream of Bayport for the CloseRollover-BABUS-P11 alternative. It is not uncommon for channel modifications to change the flow patterns such that the turbidity maximum (the location where the sediment tends to collect and often tied to the location of the salinity wedge) moves upstream, especially in the case of channel deepening.

Figure 61. Present condition modeled bed displacement along HSC (non-scaled, focus on the change).

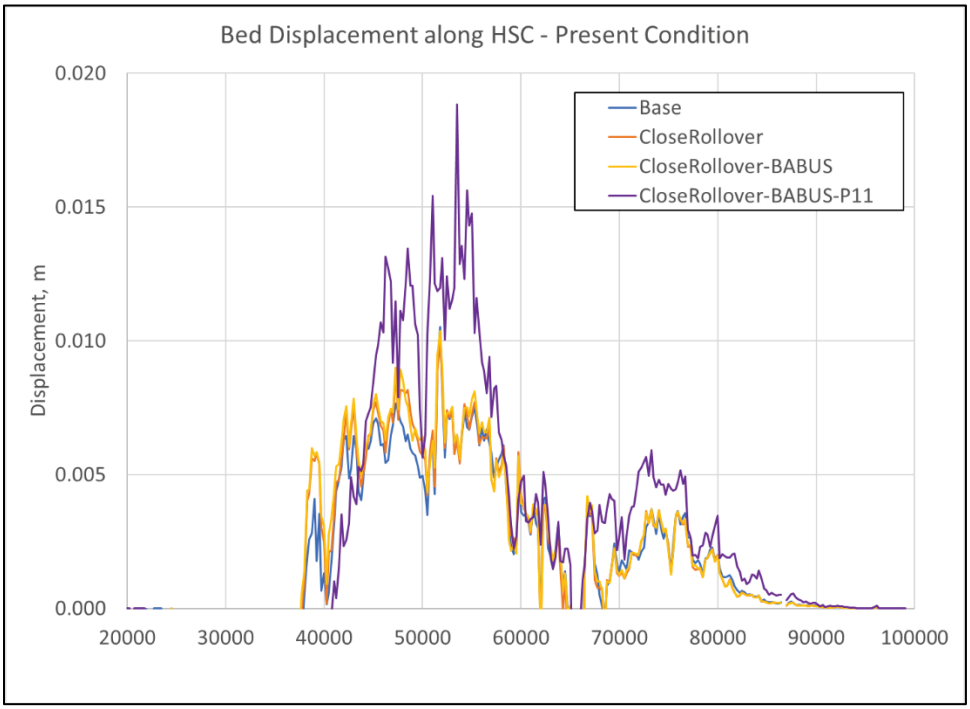
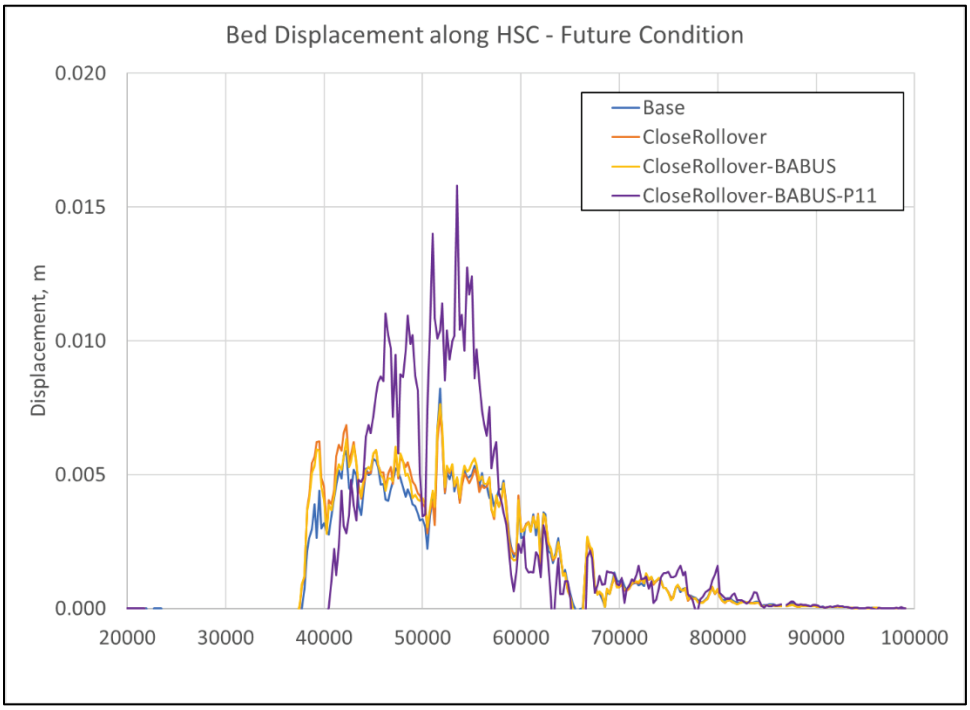


Figure 62. Future condition modeled bed displacement along HSC (non-scaled, focus on the change).



The widened ship channel in the bay section shows definite increases in shoaling volume as well as shoaling depth (bed displacement) along the HSC, especially in the Bayport Flare area. Based on survey data, vessel traffic will continuously erode the navigation channel centerline and may actually reduce these modeled shoaling depth projections (vessel impacts are included in the historical shoaling factor applied to the modeled reach volumes). However, vessels can transit at higher speeds in wider channels, which, in turn, can cause more erosion in the bays, providing a sediment source easily transported into the channel.

The deepened portion of the HSC in the CloseRollover-BABUS-P11 alternative is located upstream of the San Jacinto River. Sediment loads from the bayous entering the HSC in the area of the deepening may have a tendency to migrate upstream due to the salinity wedge moving further upstream along the channel bottom, although the salinity change is less than 1 ppt for most of this area. This model does not include these bayou sediment loads because they are unknown and therefore is unable to predict this potential upstream sediment migration.

4 Conclusions

Overall, the proposed alternatives impact salinity, and they do generate larger HSC shoaling and localized changes in velocity patterns. Closing Rollover Pass reduces the salinity in East Bay, and the change in salinity pattern can migrate to other areas depending on the strength of the tide and freshwater inflows. Velocity magnitudes and directions vary in the area of Rollover Pass and the location of the BABUS cells and Bird Islands as these structures create non-wetted areas within the system. The HSC modifications create a larger channel width and, therefore, an increase in channel shoaling potential.

The salinity was analyzed at 30 locations along the HSC and in the surrounding bays and on average did not vary in the alternatives by more than 2 to 3 ppt from the Base at any location. At some locations, the maximum or minimum salinity values varied by more, but these are extreme values and likely only occur a couple of times throughout the simulation year. The percent-less-than plots of salinity show the range of salinity values for all locations over the simulation period and, again, show little variation between with and without project results. Locations near Rollover Pass show the largest impact on salinity due to its disconnection from the Gulf of Mexico. The salinity wedge does tend to migrate farther upstream due to the channel widening and deepening alternative (CloseRollover-BABUS-P11). That distance is on the order of 0 to almost 5 mi depending on the salinity value being tracked. However, once upstream of Morgan's Point, the salinity contours compress together, and the upstream migration due to the geometry changes in the ship channel lessens. Although the distance of the salinity wedge migration is several miles at the bed, the variation in the salinity in most locations remains on the order of 2 to 3 ppt for the alternatives, except in East Bay where the variation can be as much as 5 ppt.

The average tidal prism change for the alternatives ranges between 2.8% and 5% depending on alternative and condition. The future conditions produce larger tidal prism impacts than present conditions. Including the HSC modifications actually negates some of the tidal prism increase produced with the closure of Rollover Pass. The average tidal amplitudes varied by less than 0.01 m at any of the 30 locations for all alternatives and conditions.

The residual velocity indicates the predominant flow direction and magnitude when the tide is removed from the velocity throughout the model domain. The residual velocity change from the Base is limited to areas in and immediately around where the modifications are made. Significant differences in residual velocity direction and magnitude are visible in East Bay due to the closure of Rollover Pass and in the location of the BABUS cells and Bird Islands. There are also differences around Bayport as well as in the upper HSC area where widening and deepening occur, but these changes are generally less than 0.05 m/s.

The alternatives do indicate an increase in the shoaling along the HSC when compared to the Base results. The CloseRollover and CloseRollover-BABUS alternatives produce very small increases compared to the CloseRollover-BABUS-P11 alternative. The largest increases are in the Bayport channel and flare. This is not unexpected since this area is presently a sediment trap due to its large, deep footprint and the alternative condition increases the channel width at the location of the flare. Additionally, it is in this area where the salinity wedge shows the largest migration (on average), which will also impact the tendency for sediment to fall to the bed in the area of the flare. It should be expected that the shoaling volume at the Bayport Flare will exceed the volume change due to the increased channel dimensions. Upstream of Morgan's Point, the shoaling increase is on the order of the increase in channel size. However, as noted previously, sediment loads from bayous entering the ship channel in this area are not included in the model. The shoaling volume results should be reviewed in connection with shoal height to determine the overall impacts of the channel shoaling analysis and how they relate to the proposed modifications. A widened channel with an increased shoal volume may mean that although more volume must be removed when dredged, the number of dredging occurrences may be reduced if shoal height is reduced. In addition, a deeper/wider channel tends to result in increased sizes and speeds for the ships navigating the channel. In general, this will result in larger resuspension of sediment and could result in increased deposition in the ship channel beyond those predicted in this model study.

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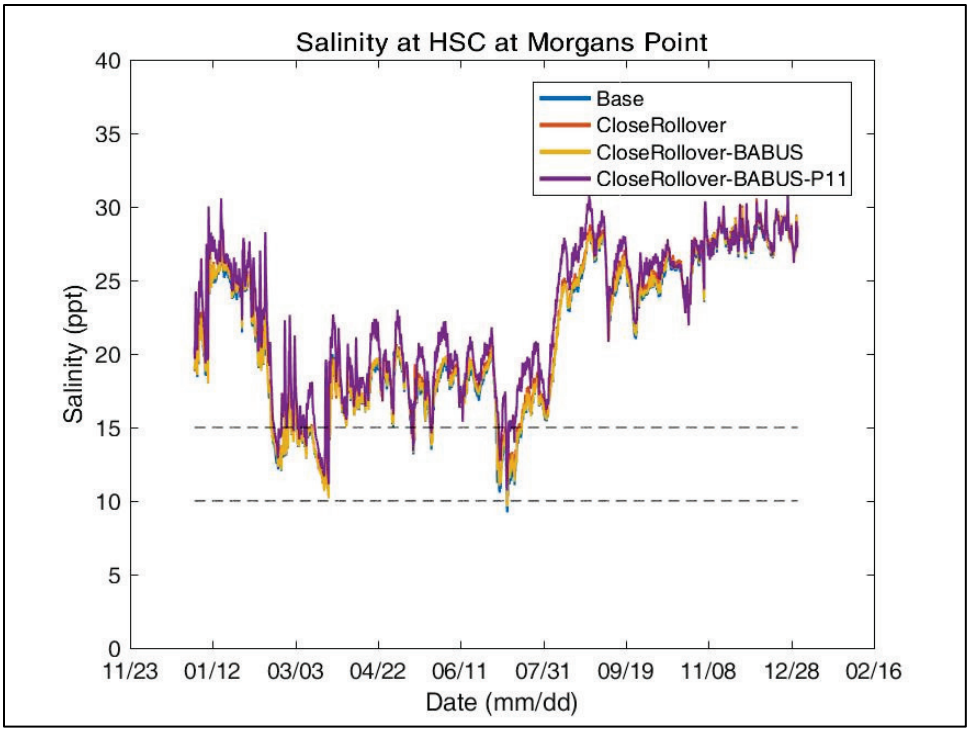
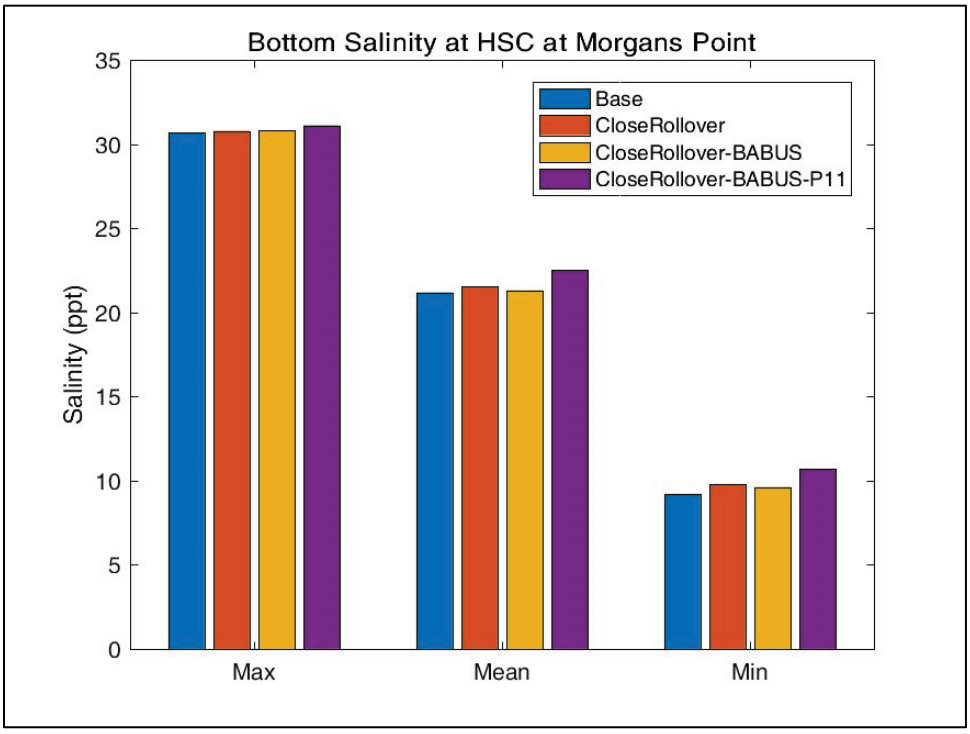
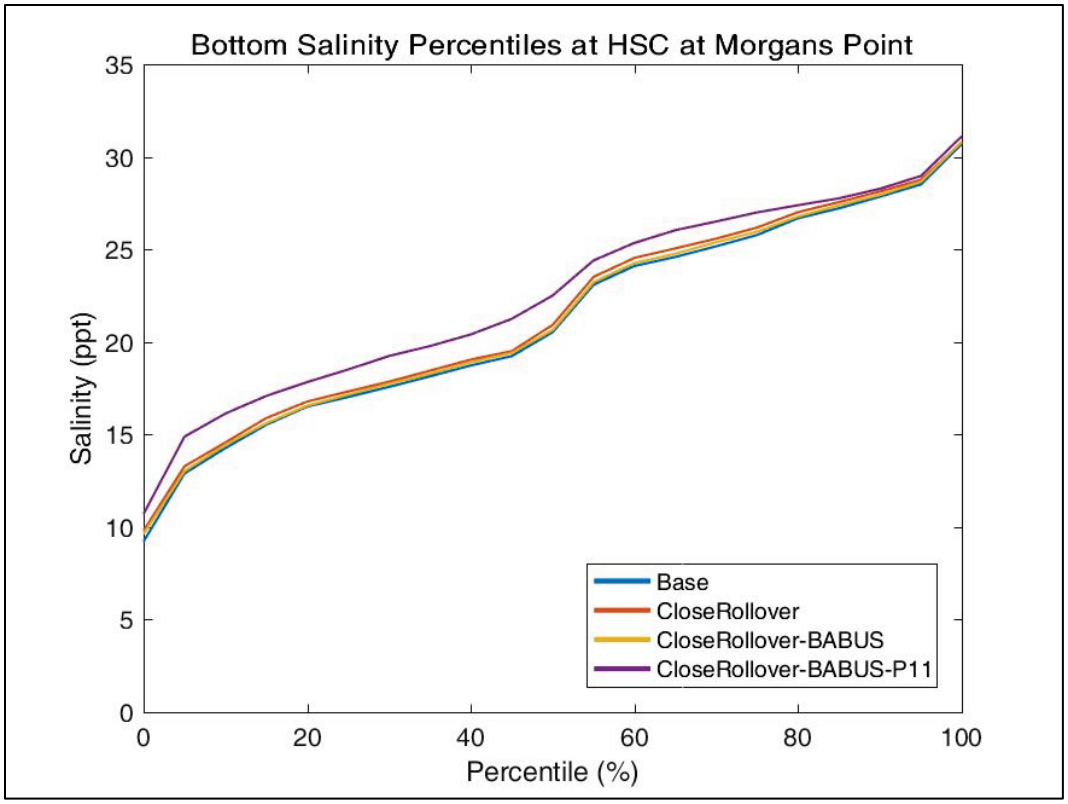
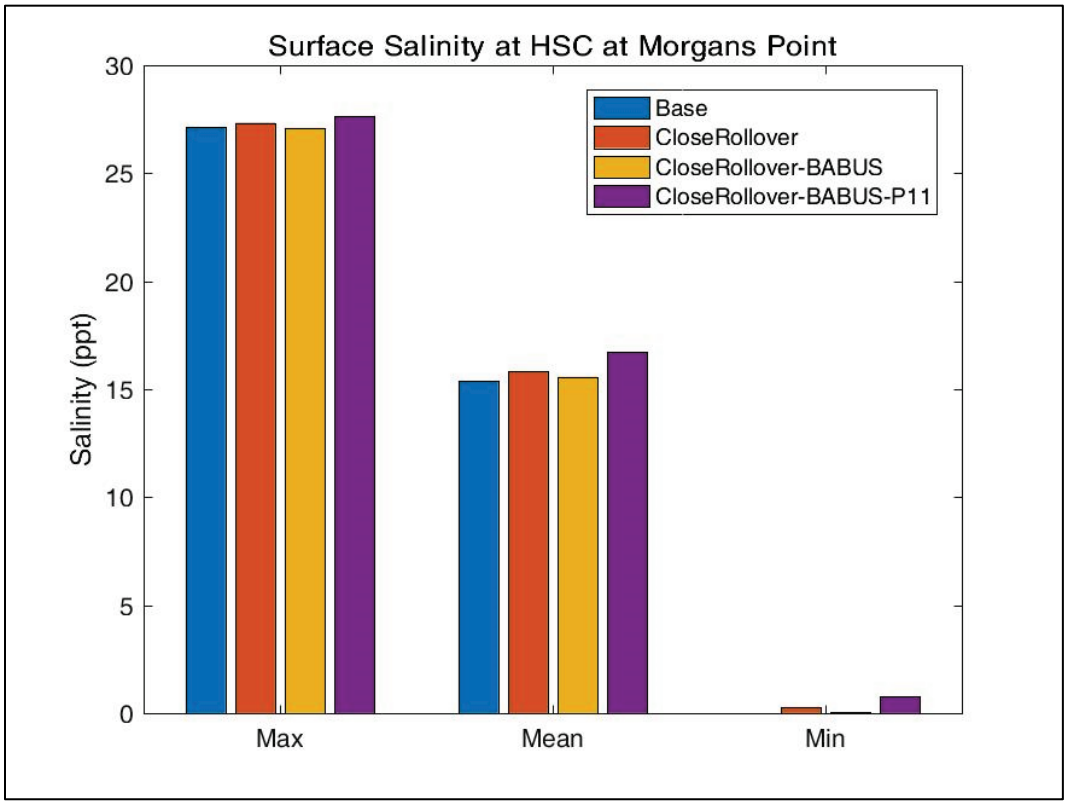
Appendix

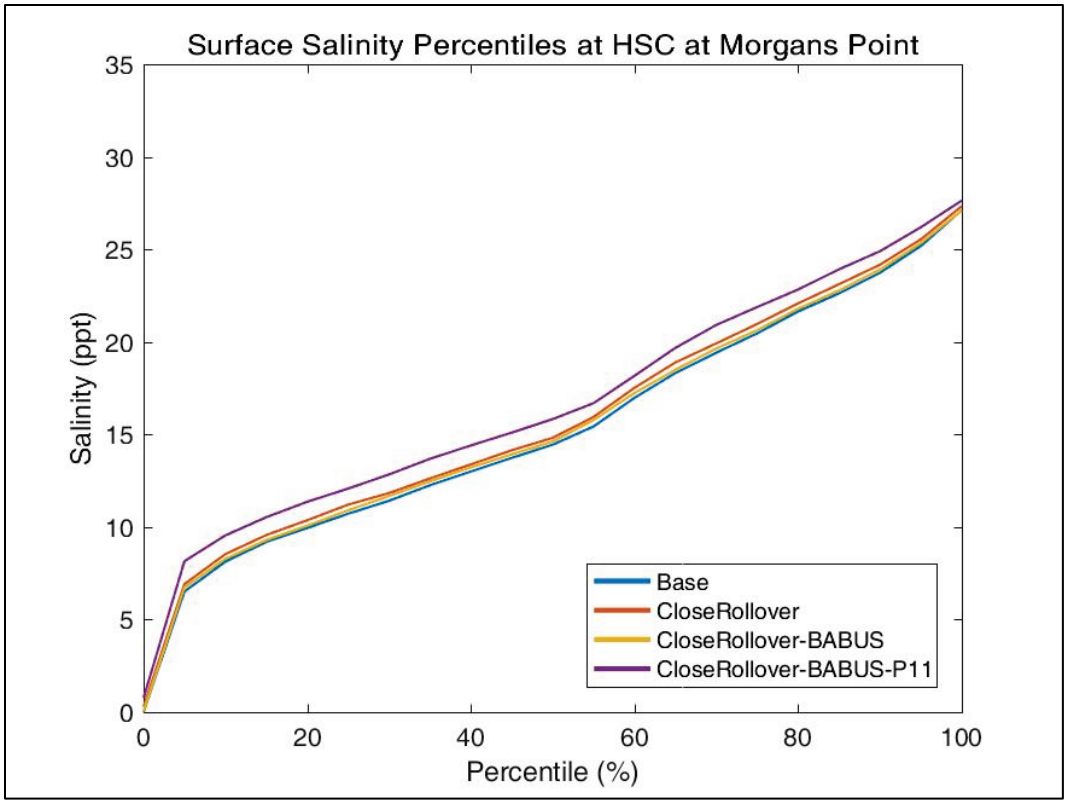
Point salinity analysis (Present)

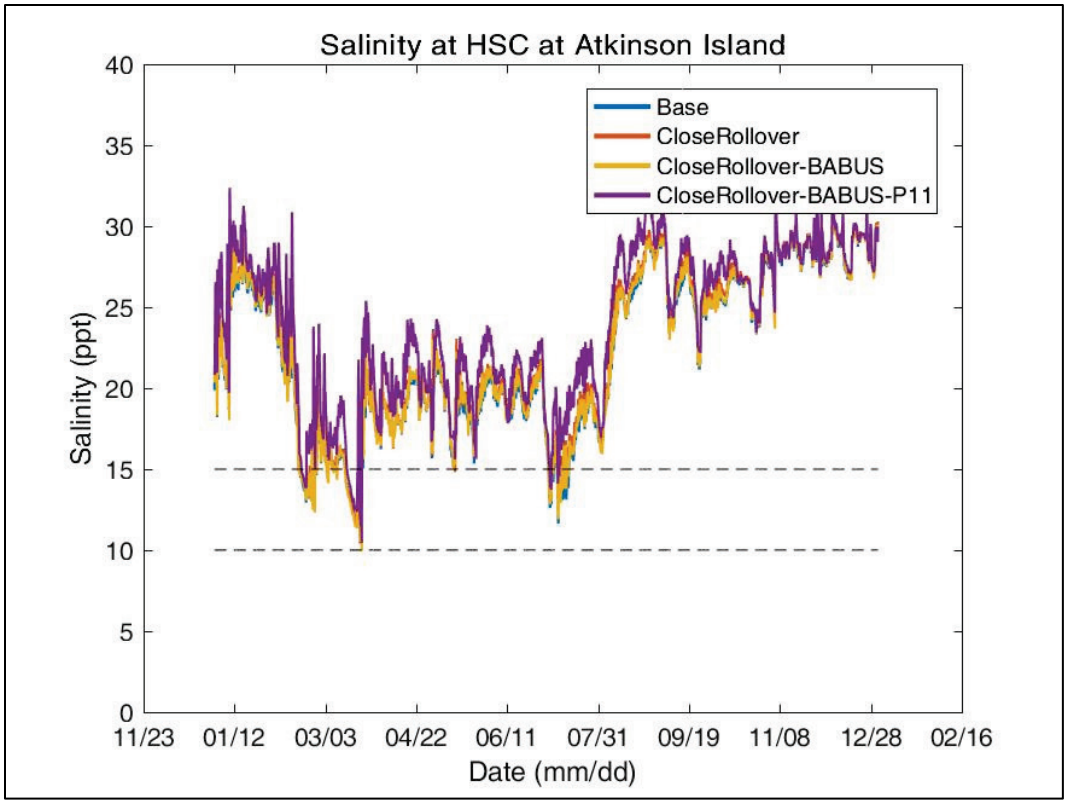


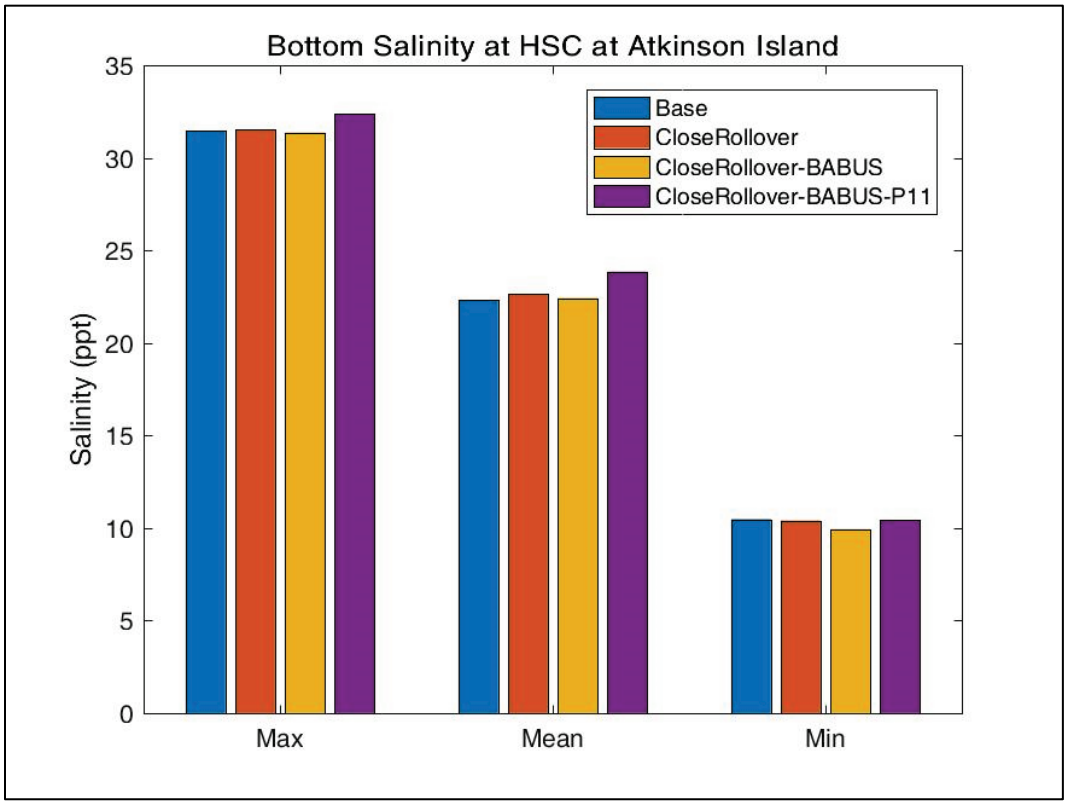


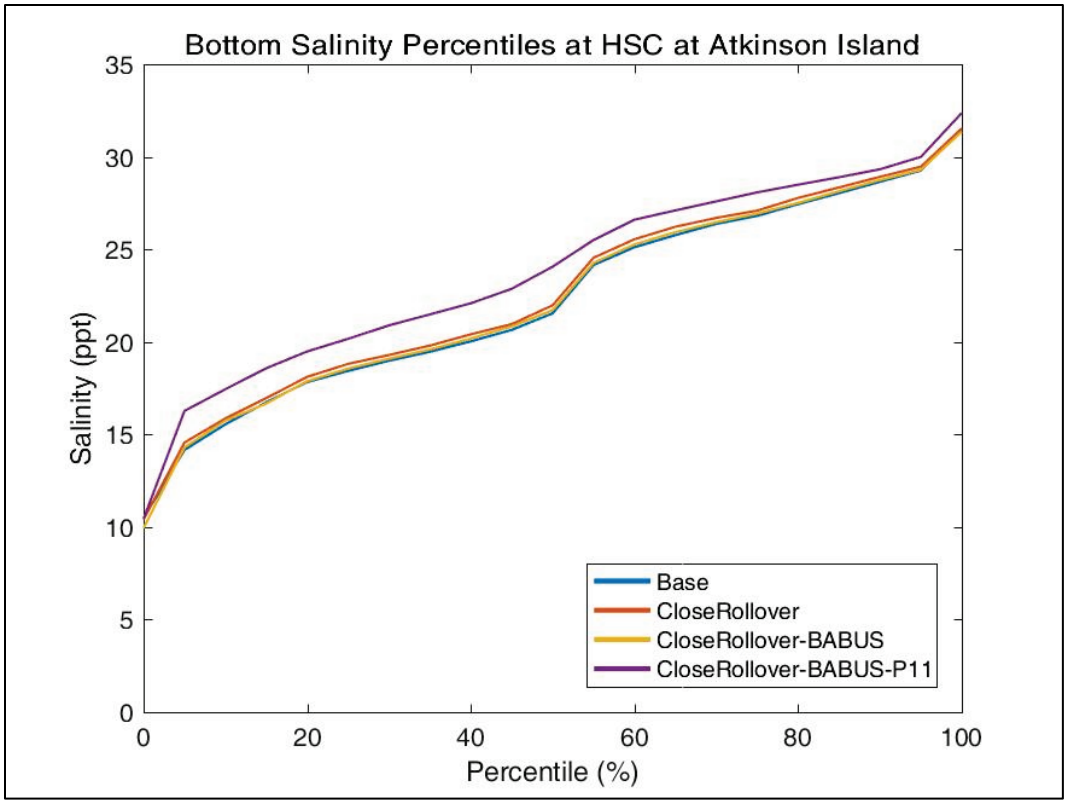

Bottom Salinity Percentiles at HSC at Morgans Point
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

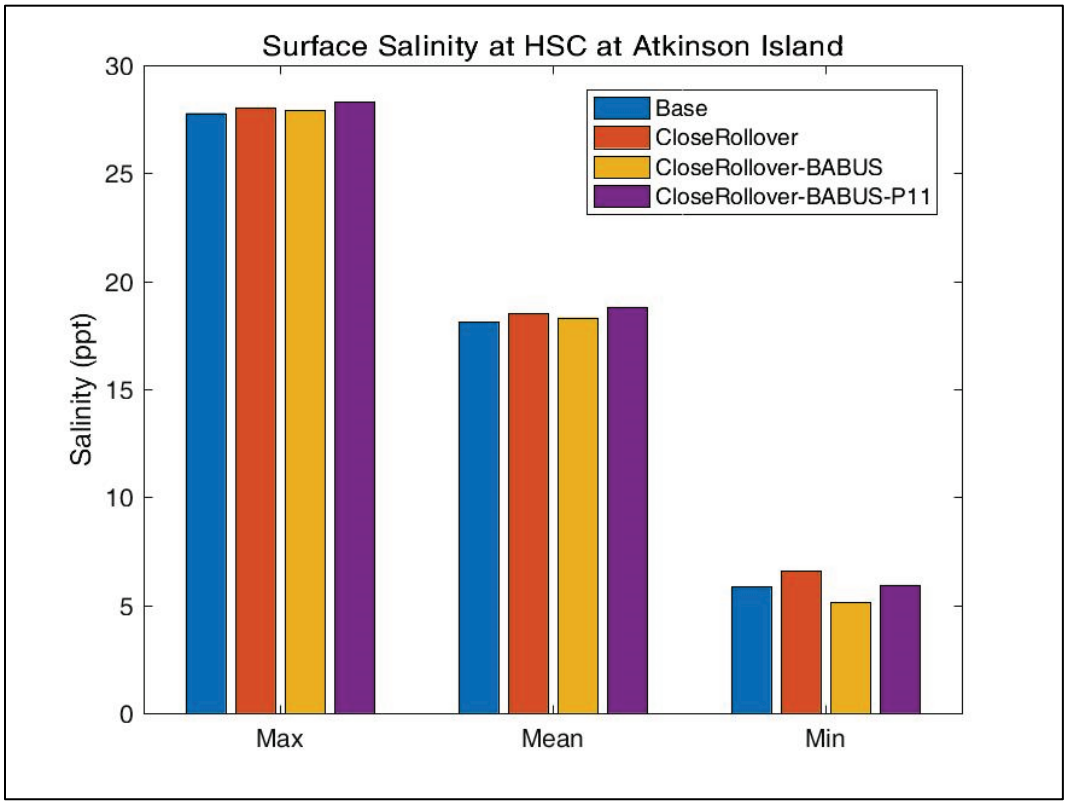

Surface Salinity at HSC at Morgans Point
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

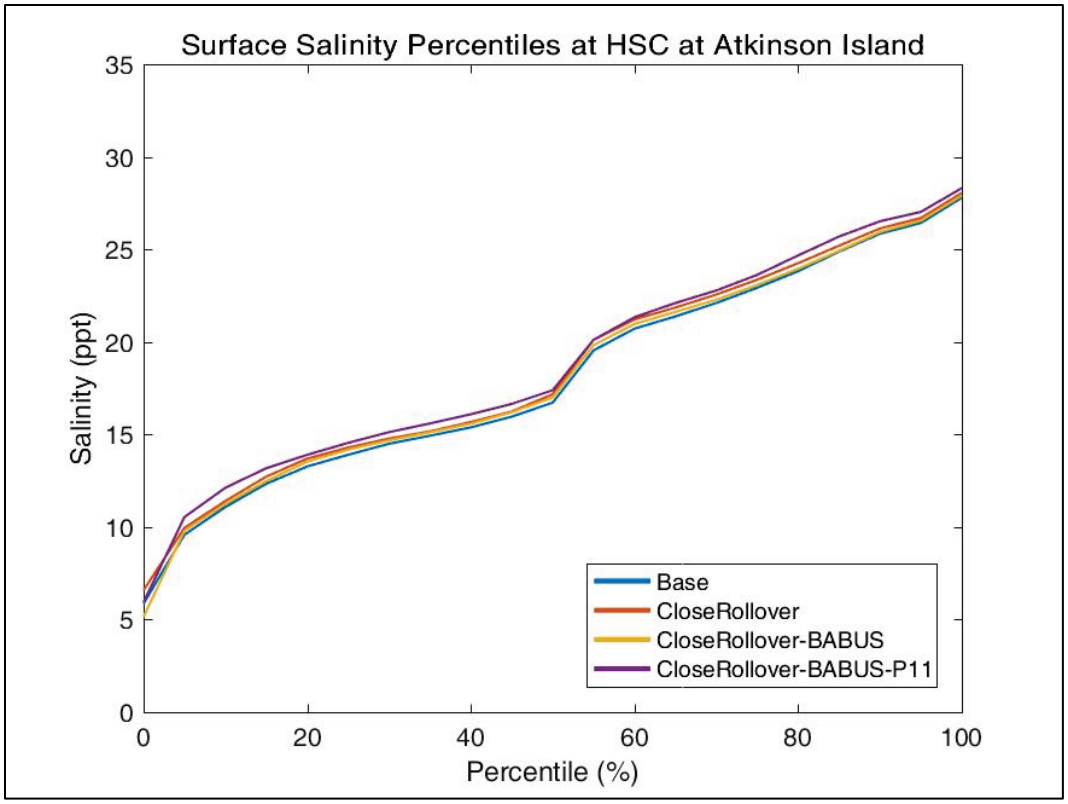

Surface Salinity Percentiles at HSC at Morgans Point
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

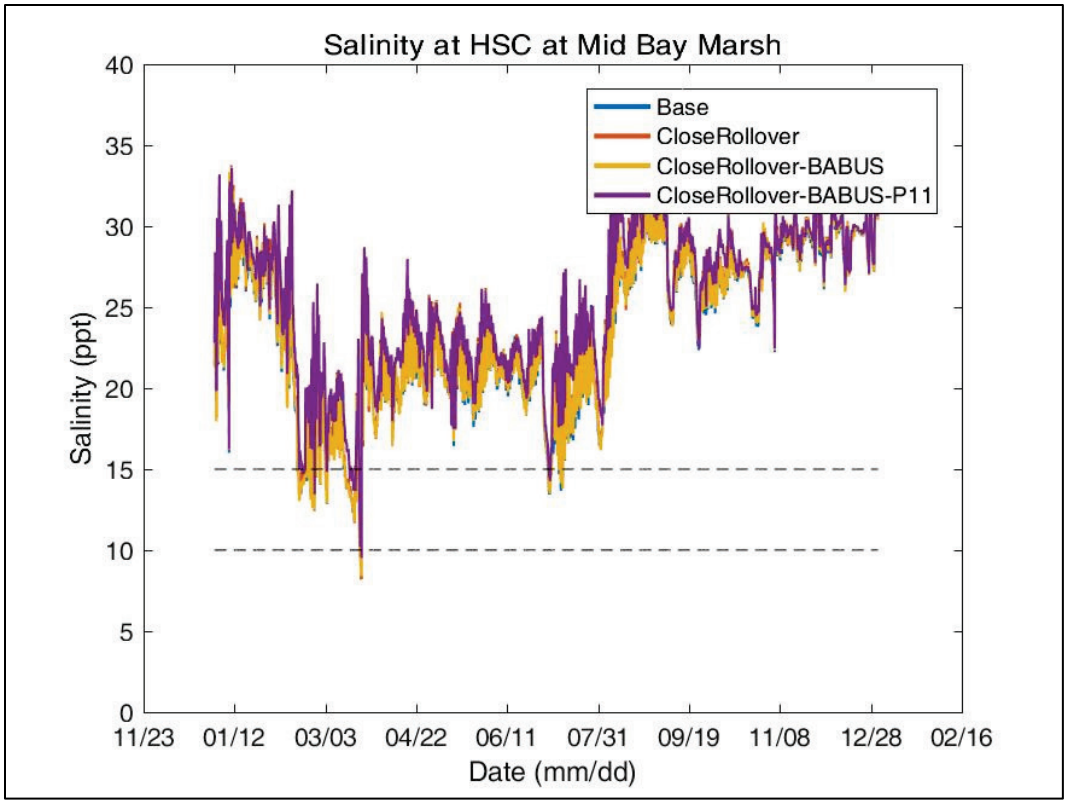

Salinity at HSC at Atkinson Island
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

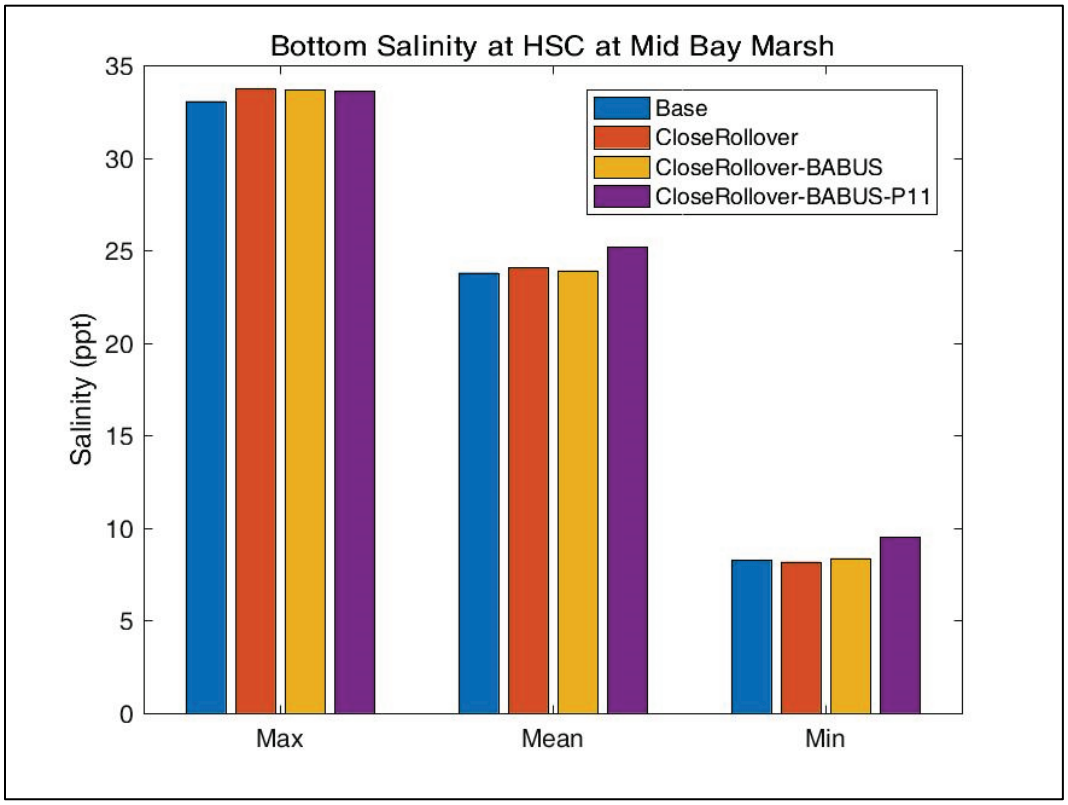

Bottom Salinity at HSC at Atkinson Island
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

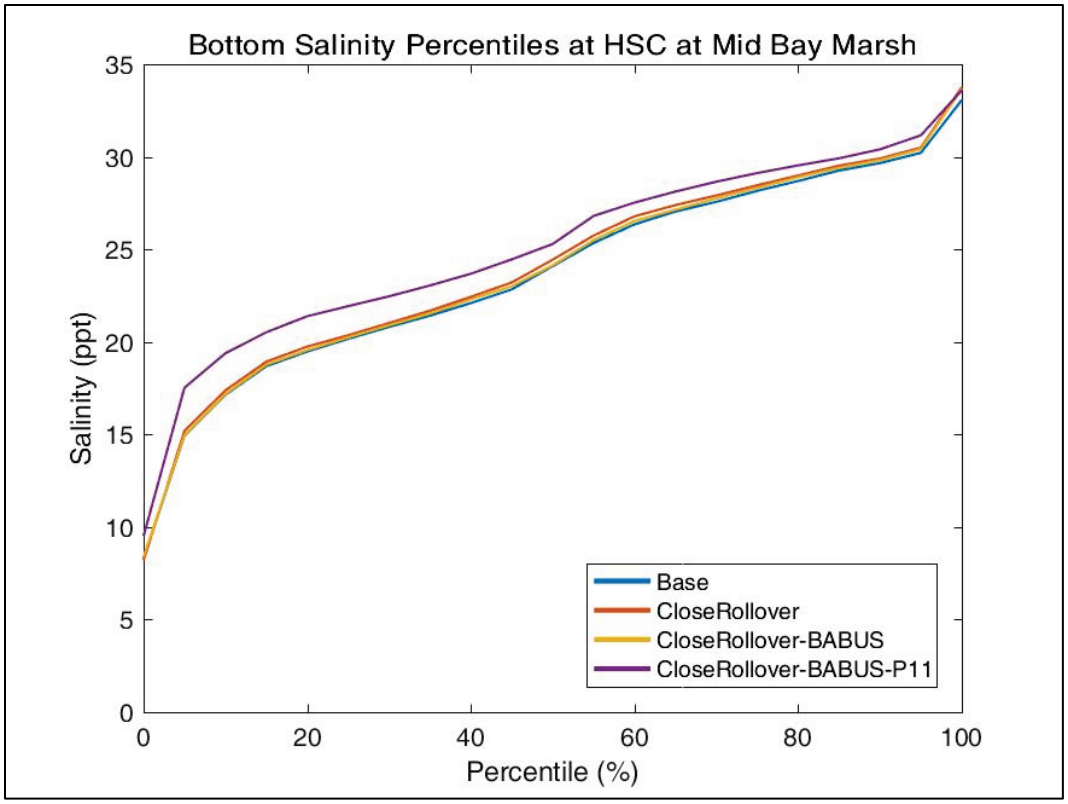

Bottom Salinity Percentiles at HSC at Atkinson Island
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

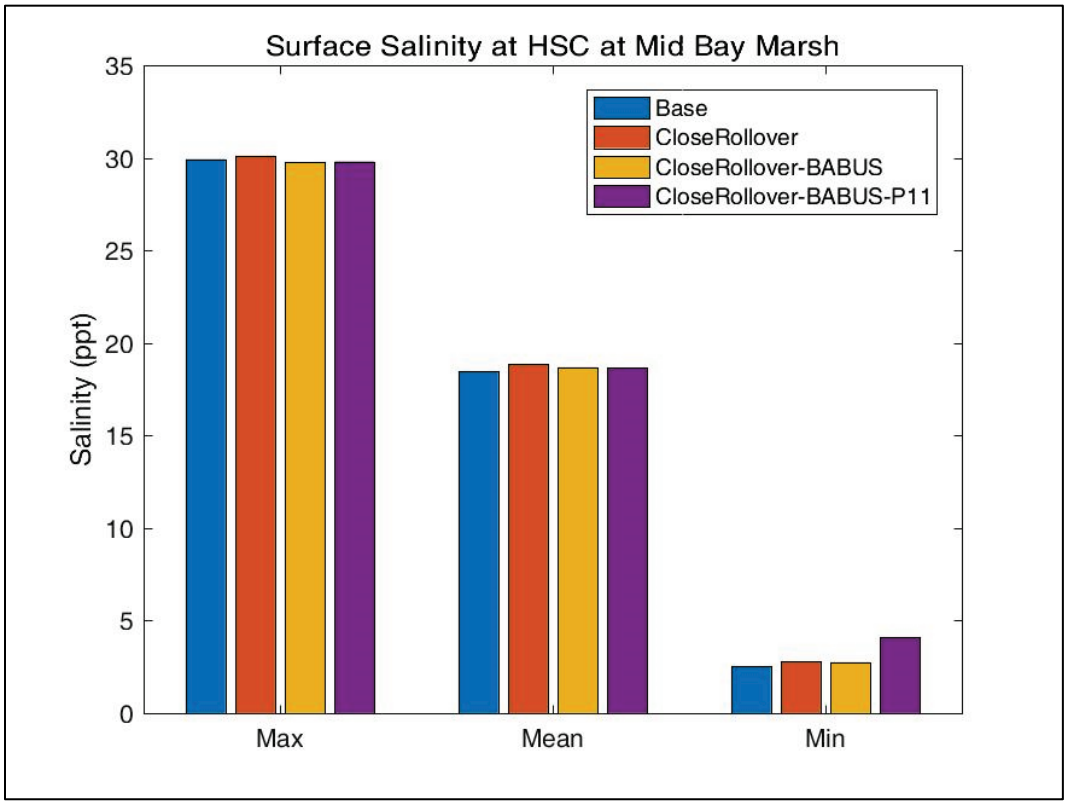

Surface Salinity at HSC at Atkinson Island
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

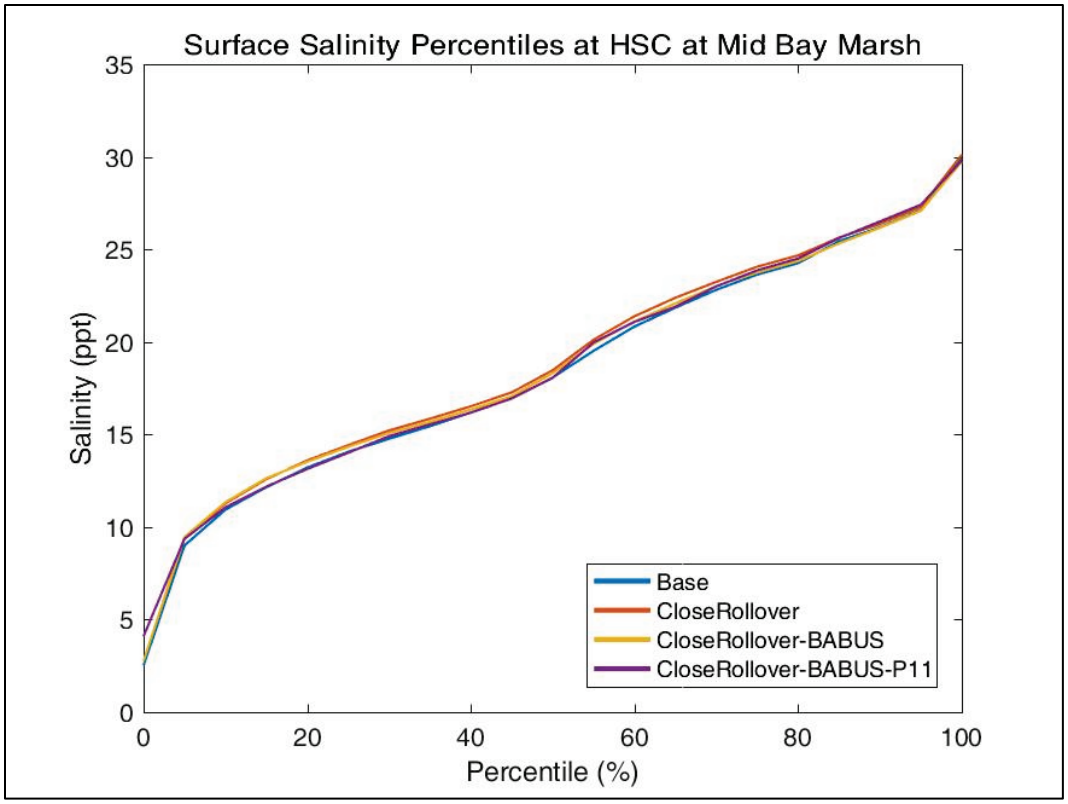

Surface Salinity Percentiles at HSC at Atkinson Island
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

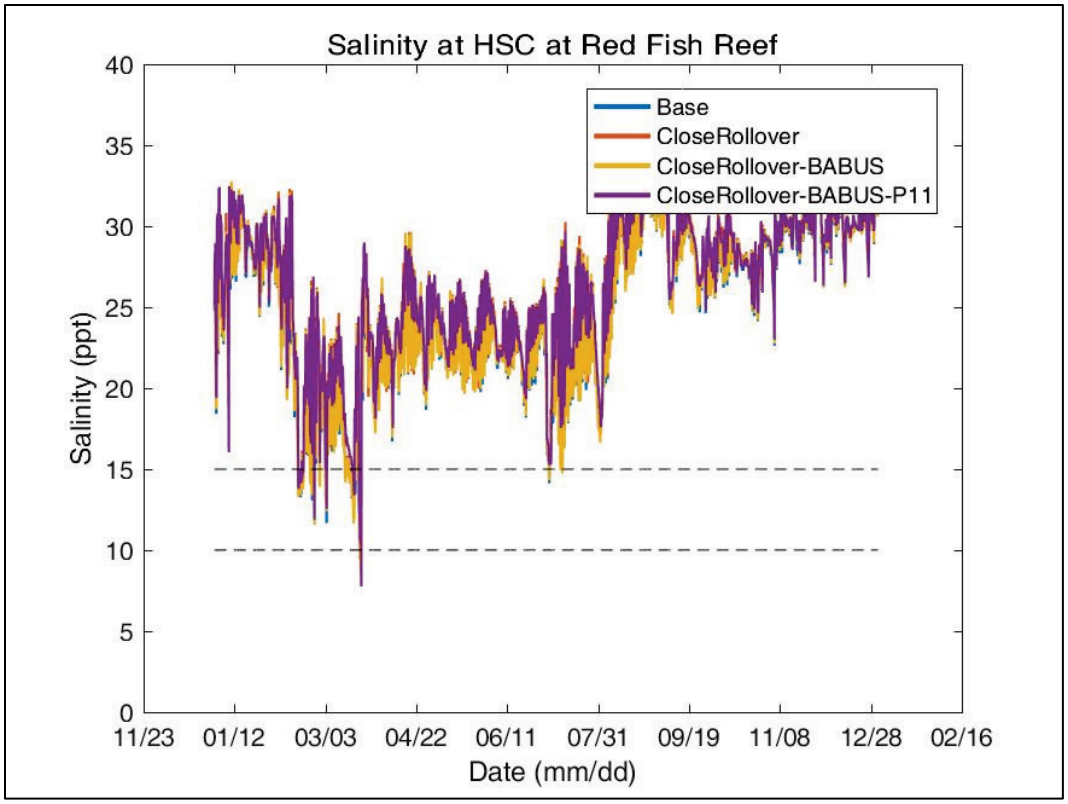

Salinity at HSC at Mid Bay Marsh
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

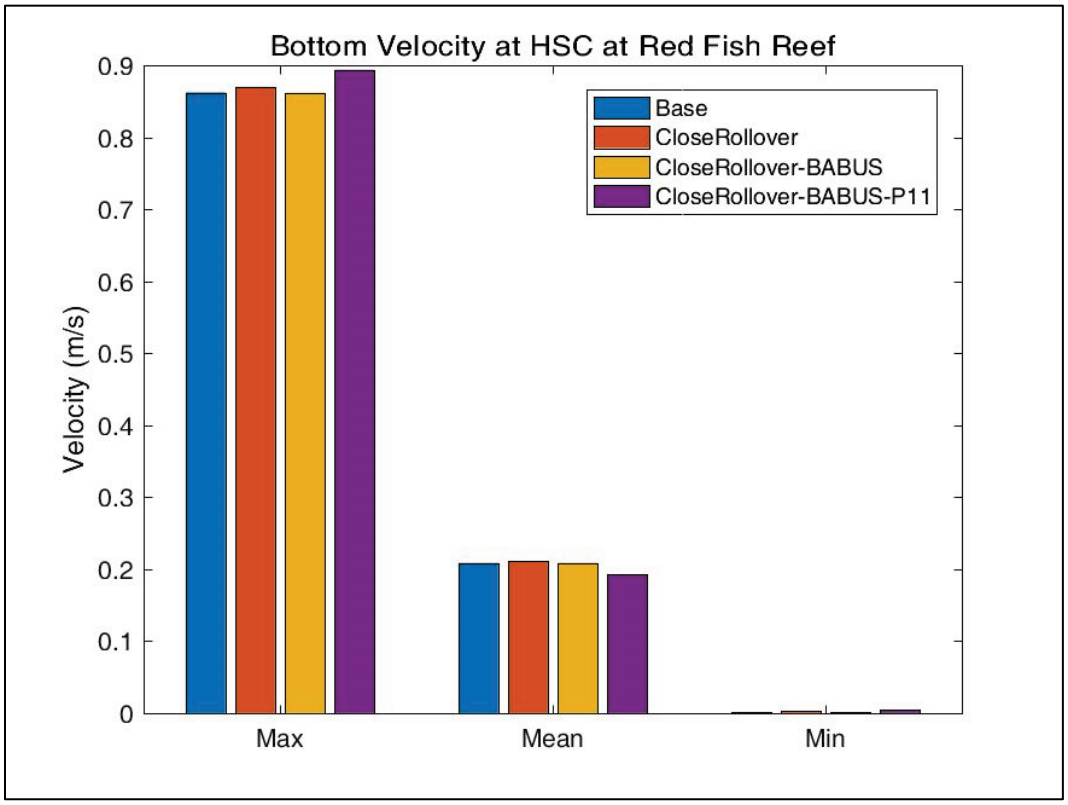

Bottom Salinity at HSC at Mid Bay Marsh
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

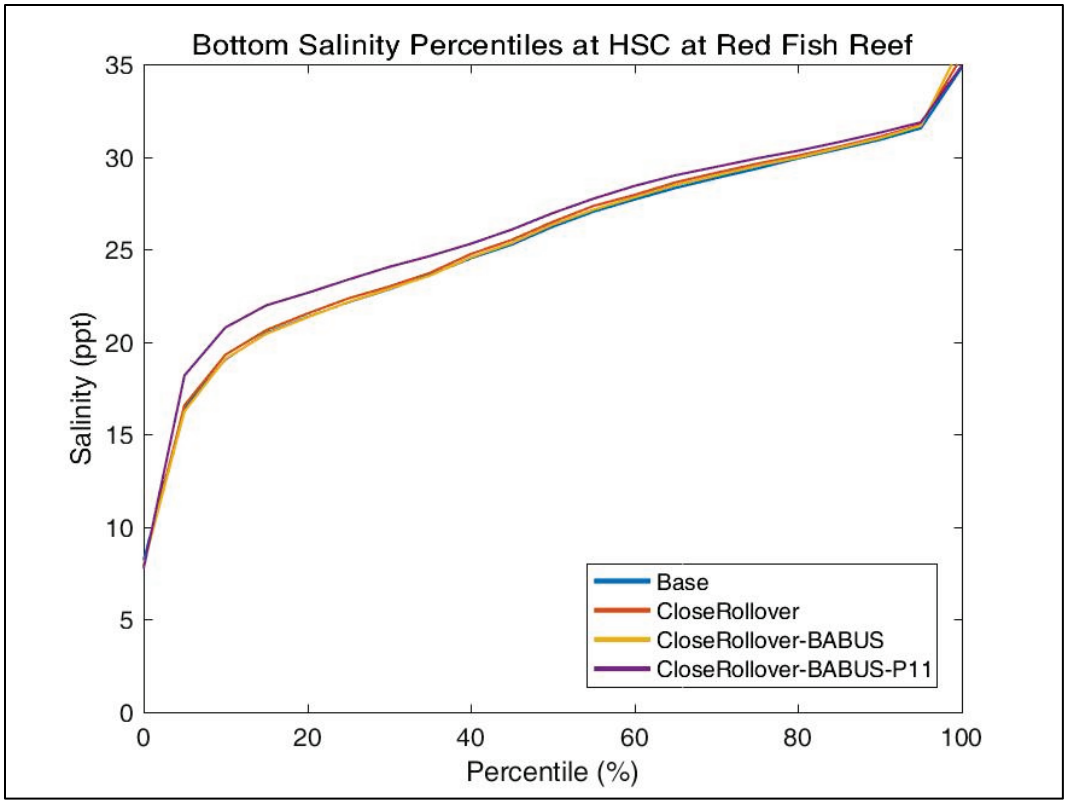

Bottom Salinity Percentiles at HSC at Mid Bay Marsh
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

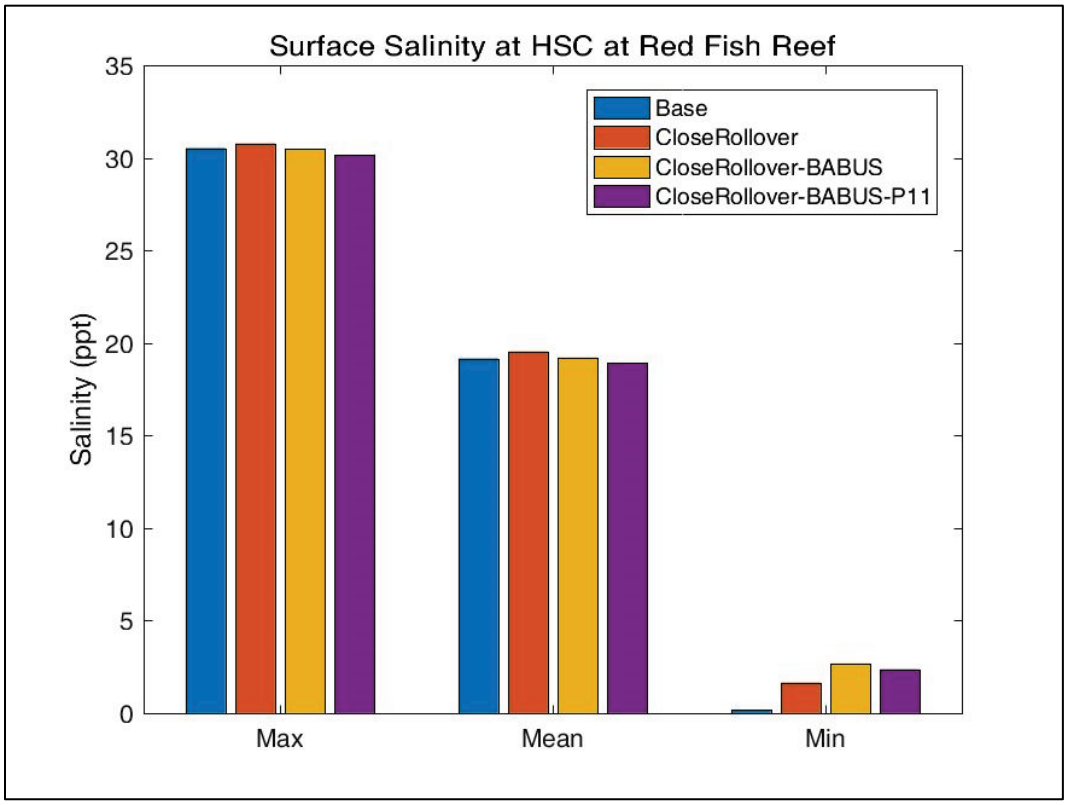

Surface Salinity at HSC at Mid Bay Marsh
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

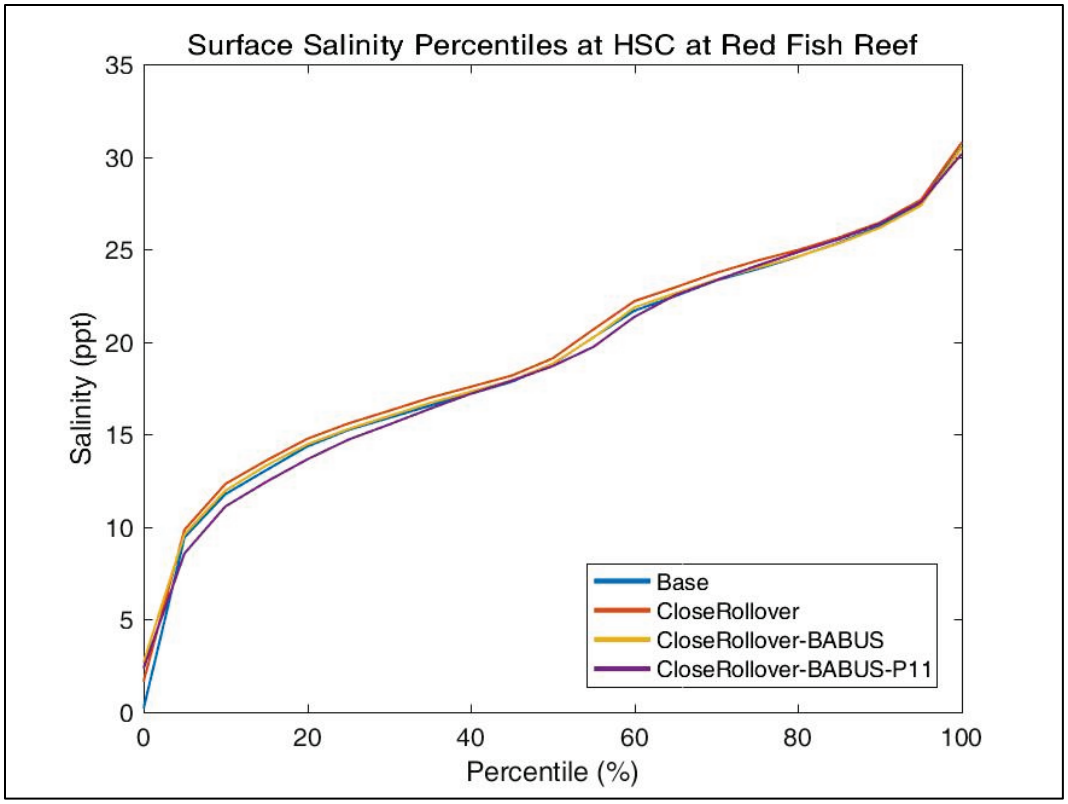

Surface Salinity Percentiles at HSC at Mid Bay Marsh
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

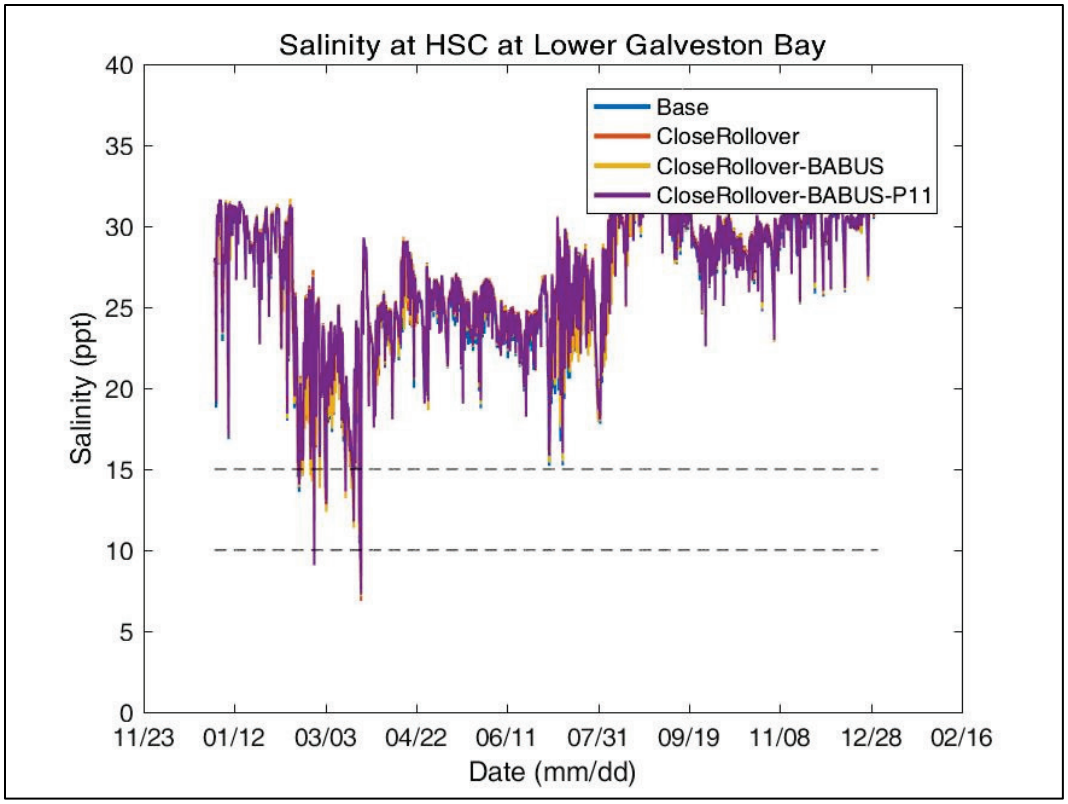

Salinity at HSC at Red Fish Reef
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

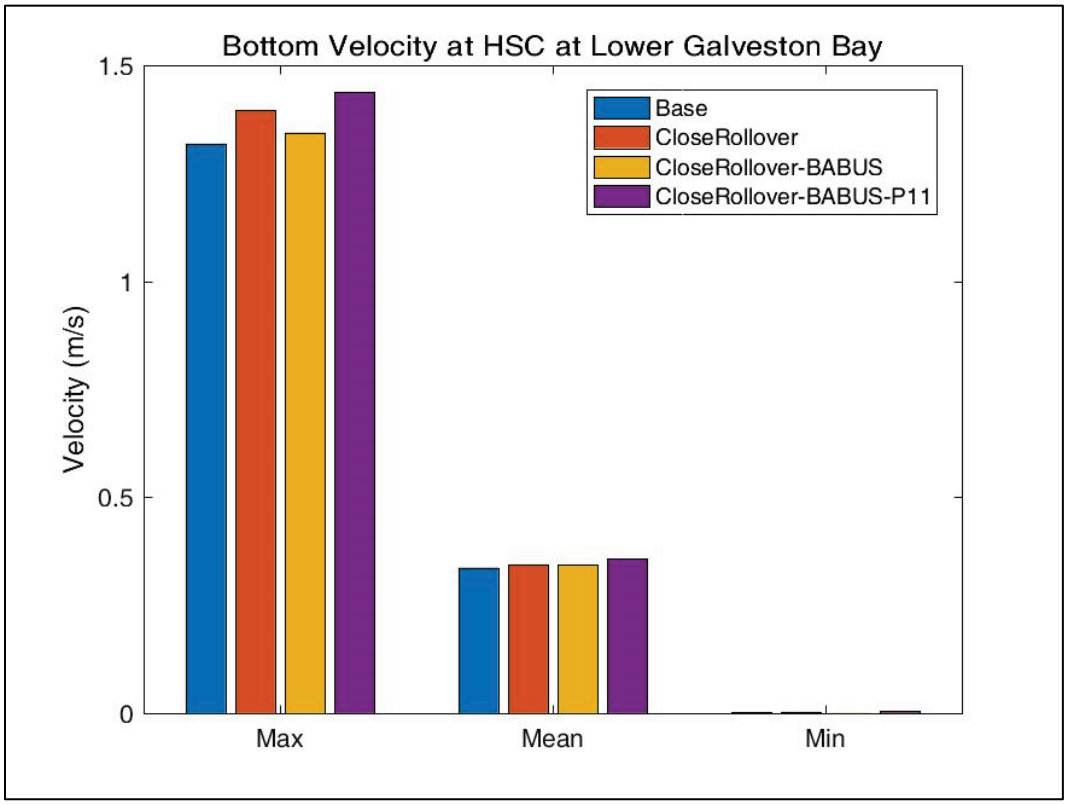

Bottom Velocity at HSC at Red Fish Reef
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Velocity (m/s)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Max
Mean
Min

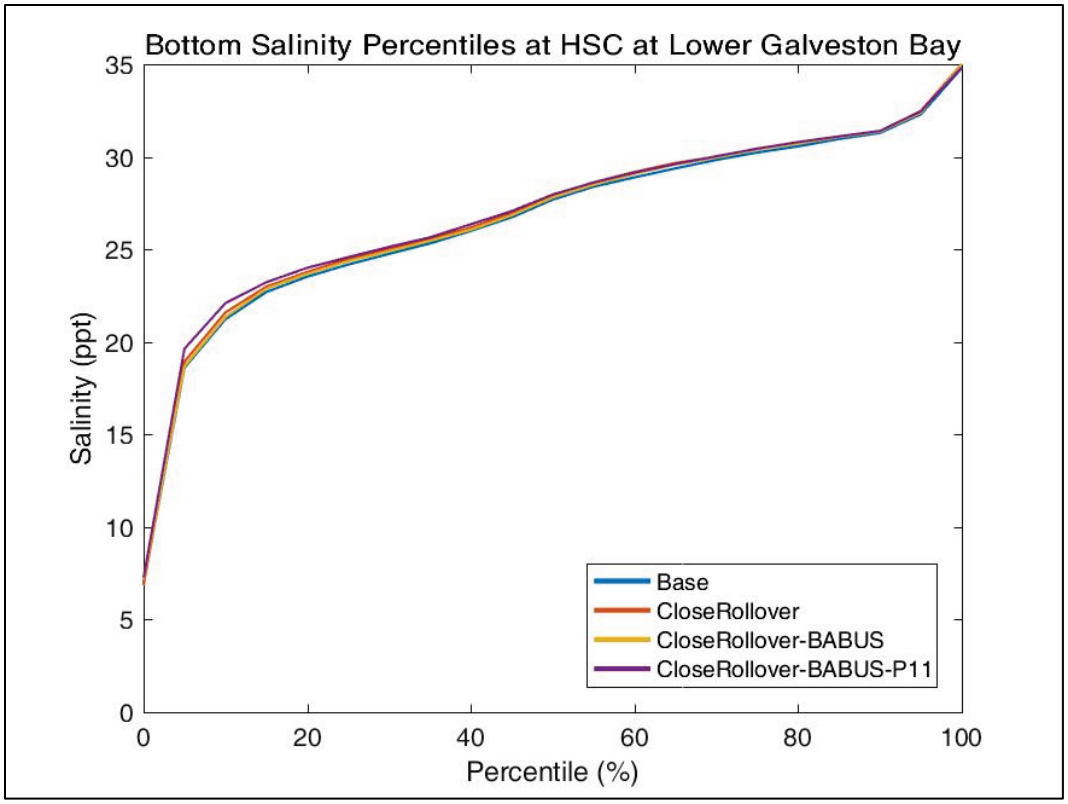

Bottom Salinity Percentiles at HSC at Red Fish Reef
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

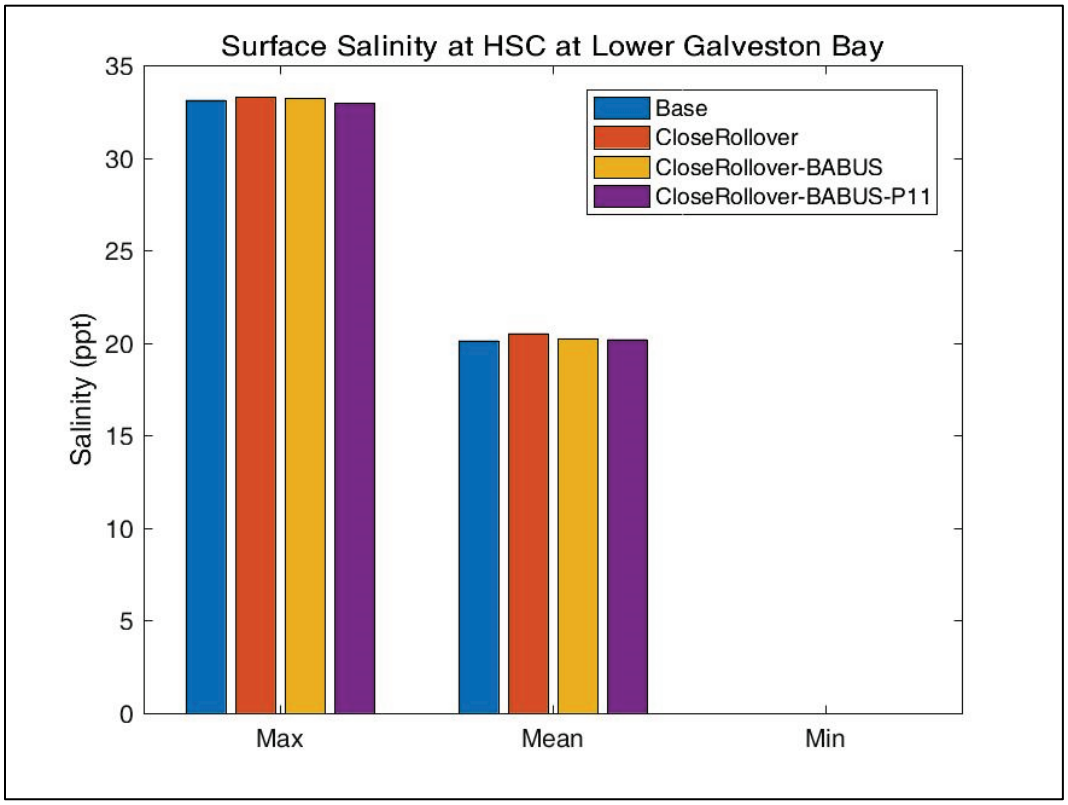

Surface Salinity at HSC at Red Fish Reef
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

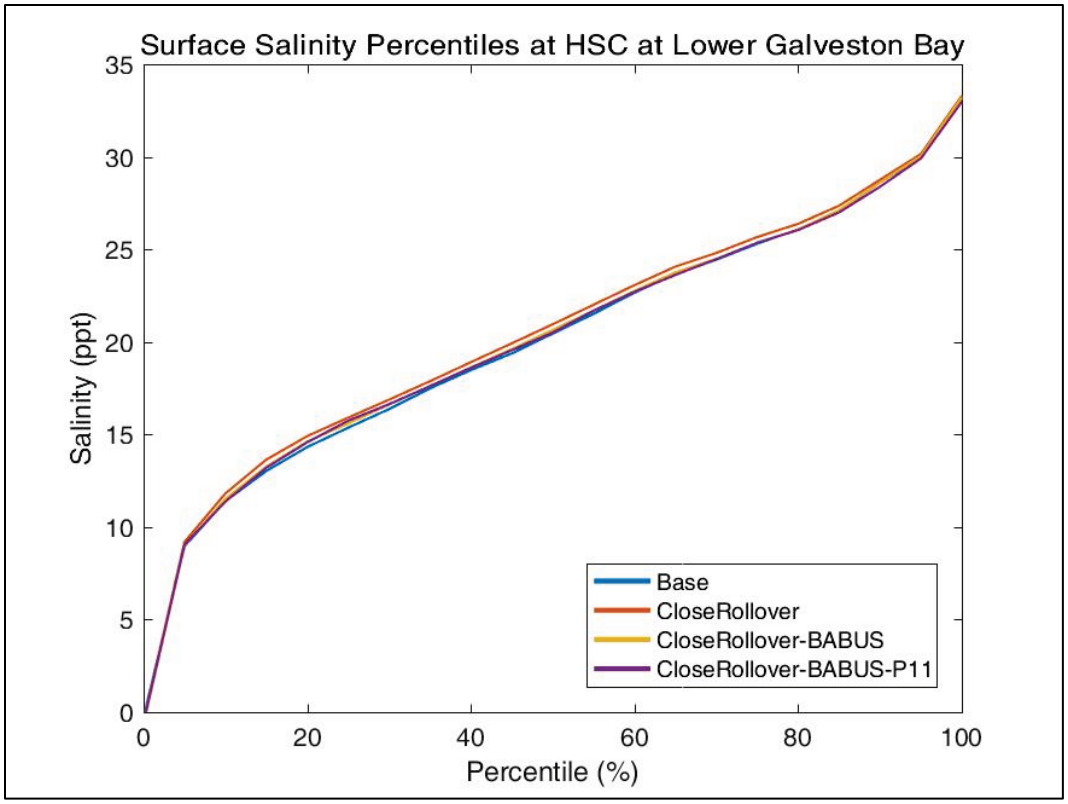

Surface Salinity Percentiles at HSC at Red Fish Reef
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

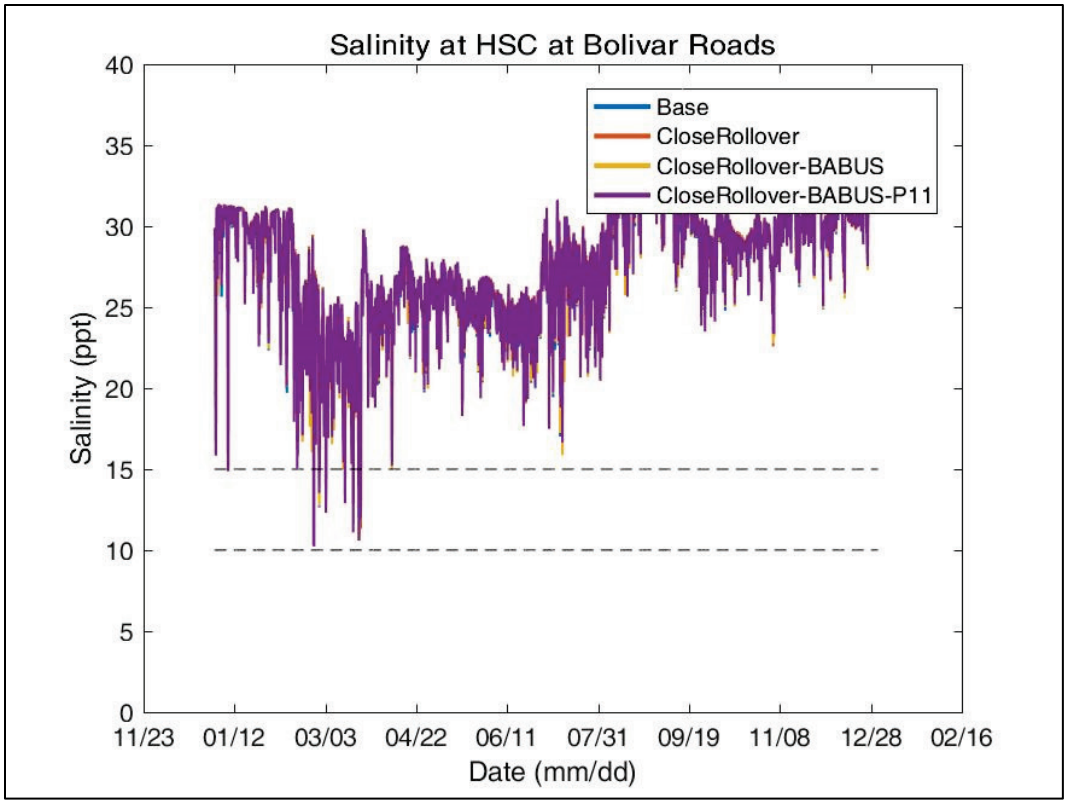

Salinity at HSC at Lower Galveston Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

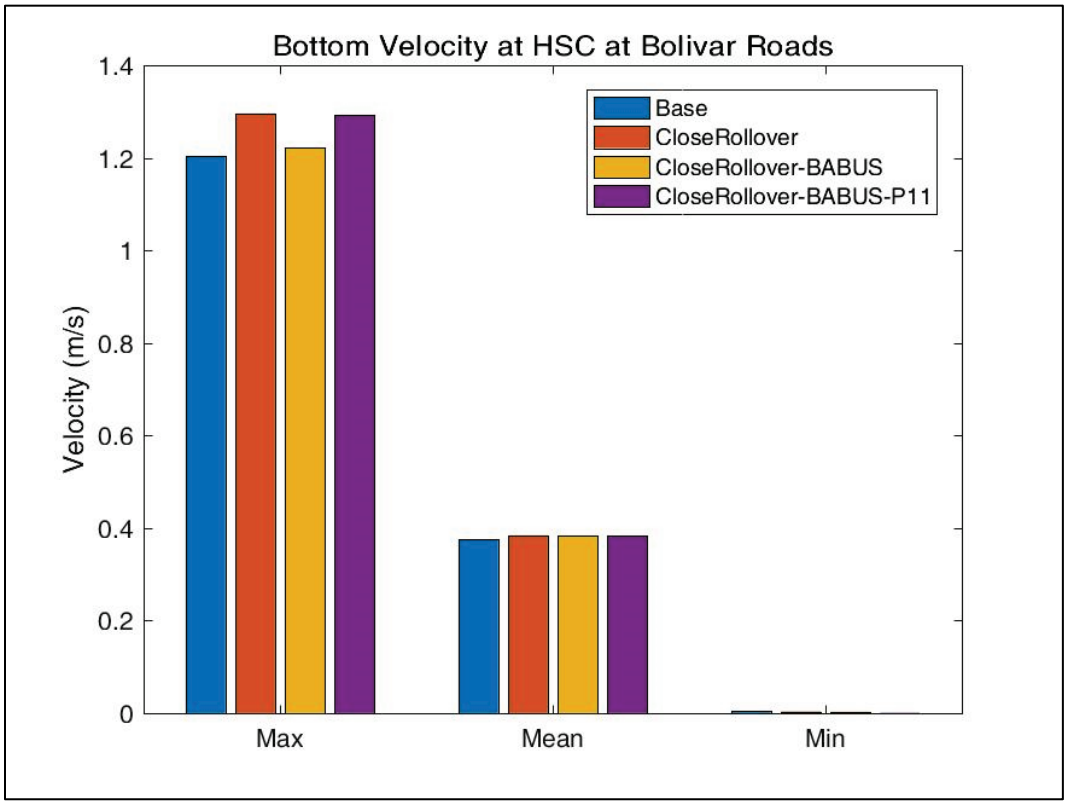

Bottom Velocity at HSC at Lower Galveston Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Velocity (m/s)
0
0.5
1
1.5
Max
Mean
Min

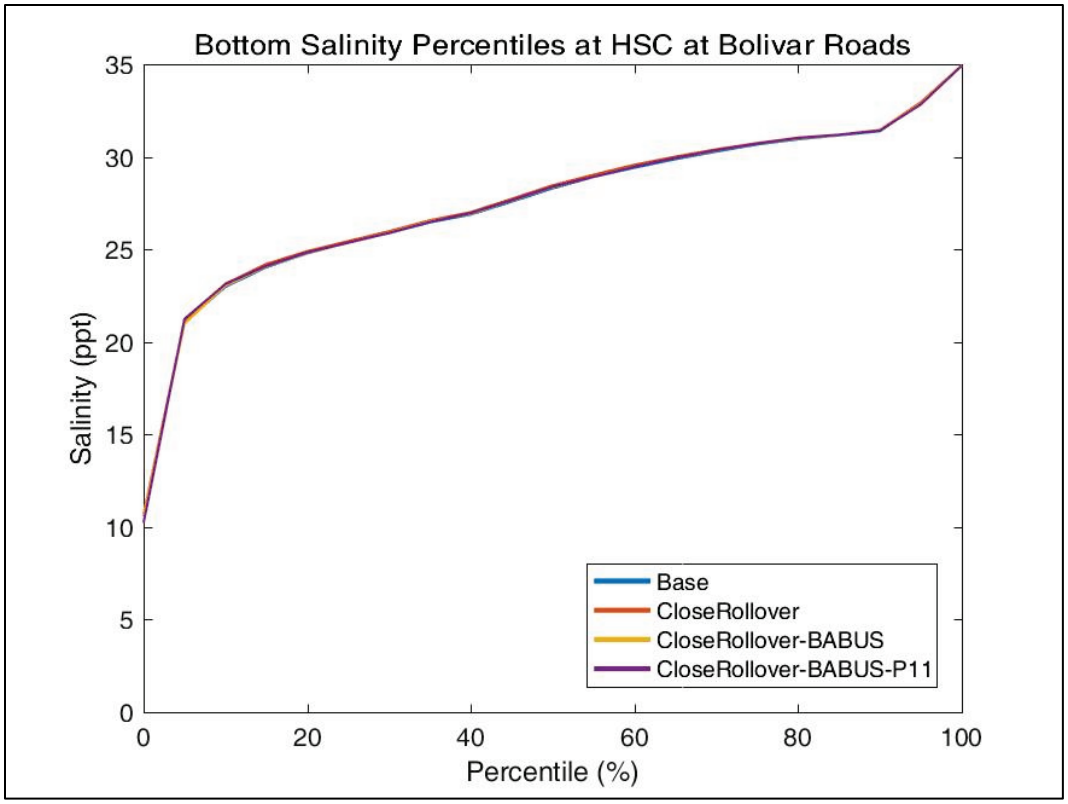

Bottom Salinity Percentiles at HSC at Lower Galveston Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

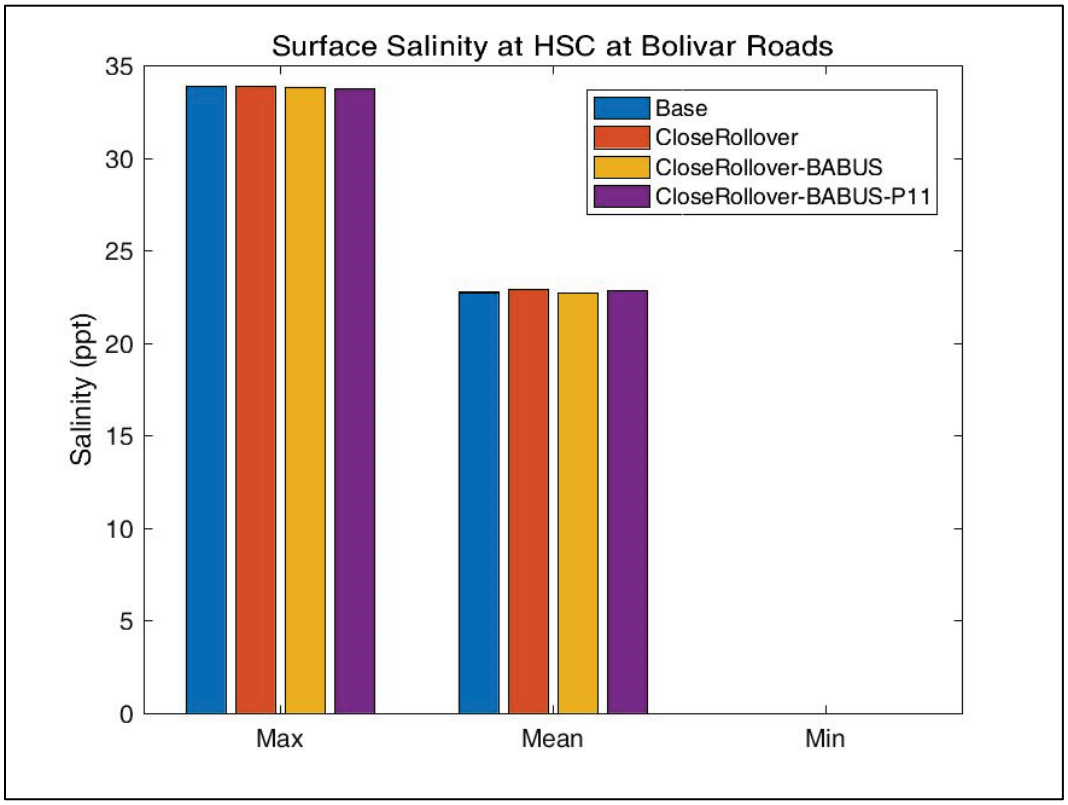

Surface Salinity at HSC at Lower Galveston Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

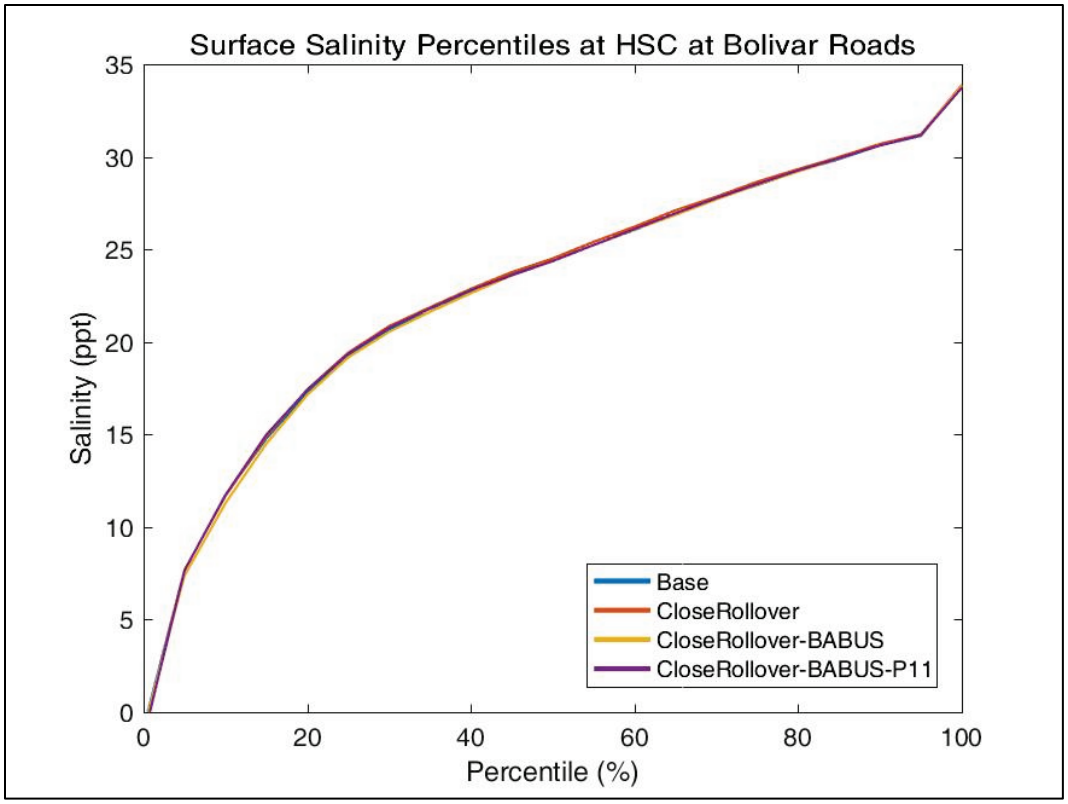

Surface Salinity Percentiles at HSC at Lower Galveston Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

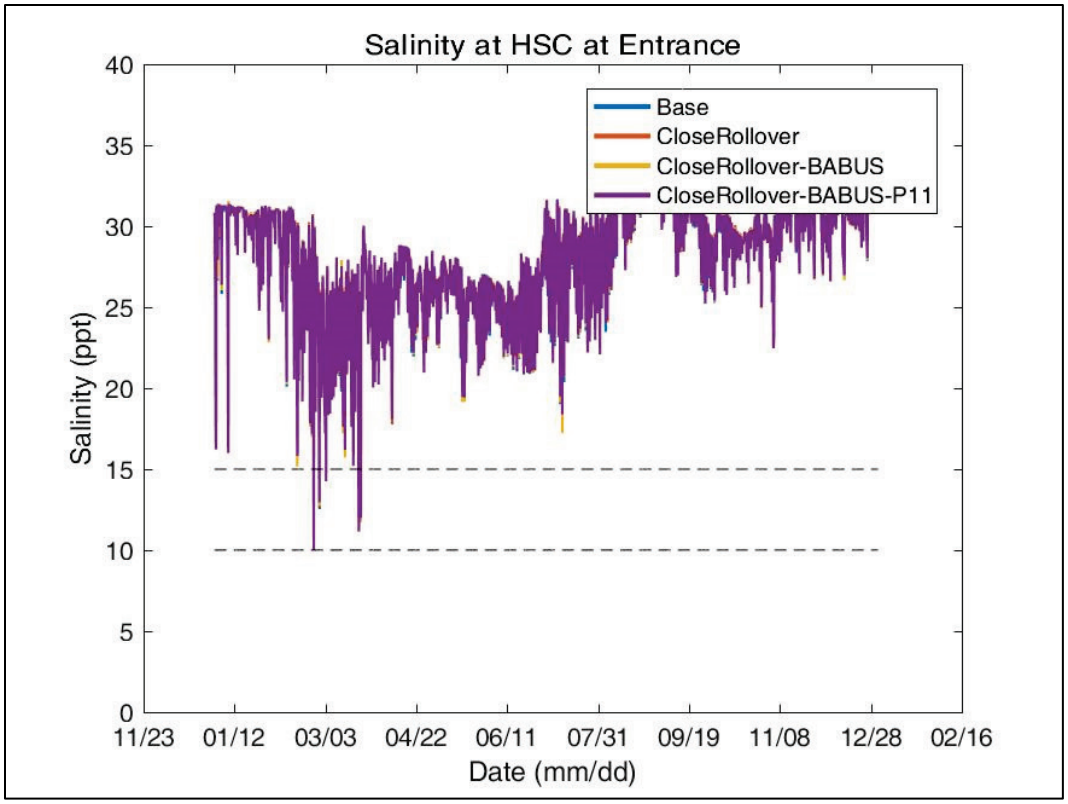

Salinity at HSC at Bolivar Roads
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

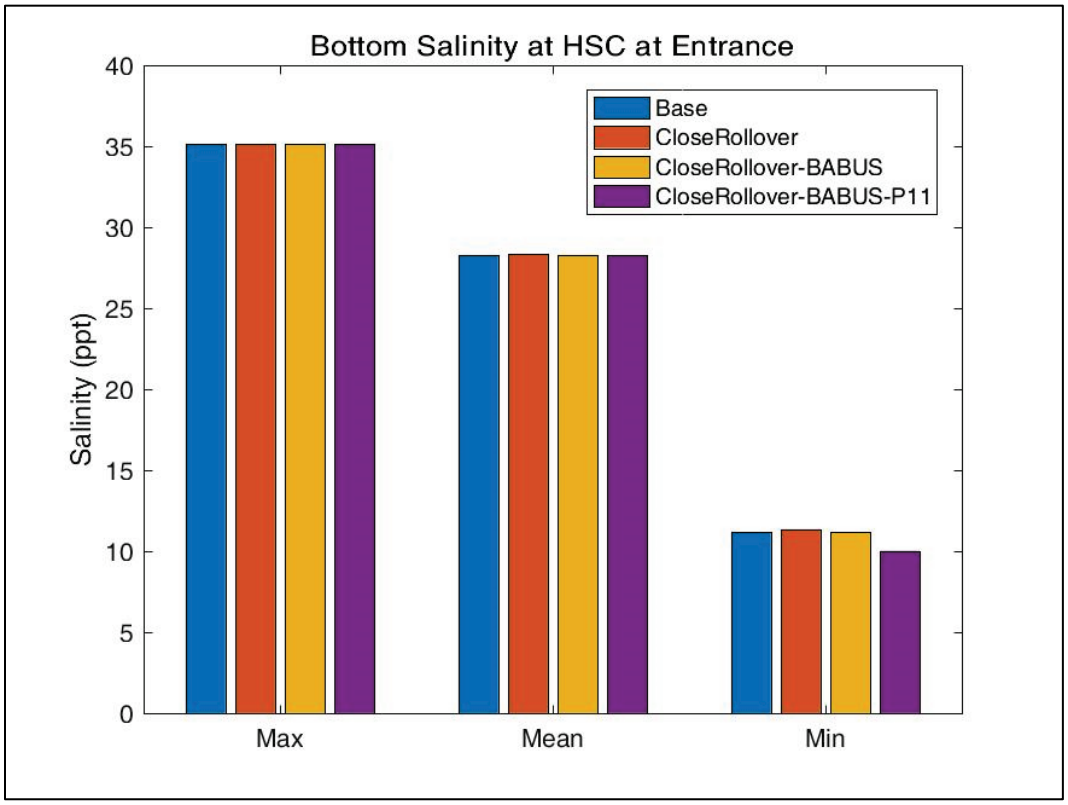

Bottom Velocity at HSC at Bolivar Roads
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Velocity (m/s)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Max
Mean
Min

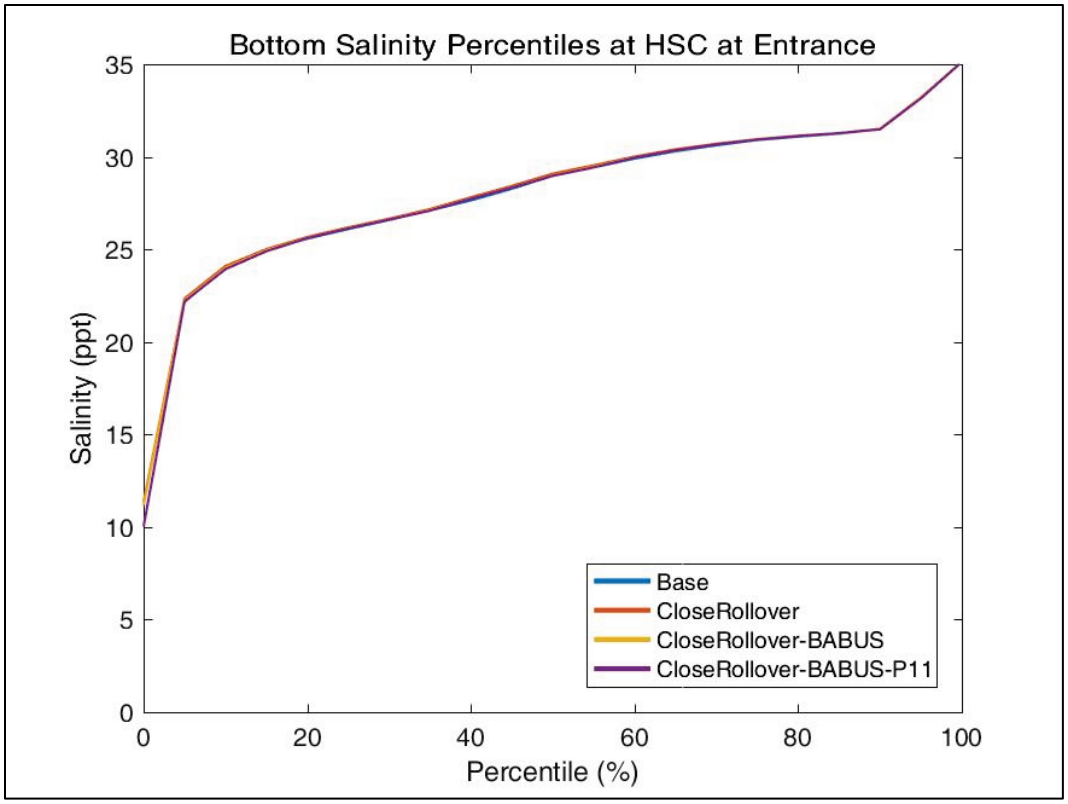

Bottom Salinity Percentiles at HSC at Bolivar Roads
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

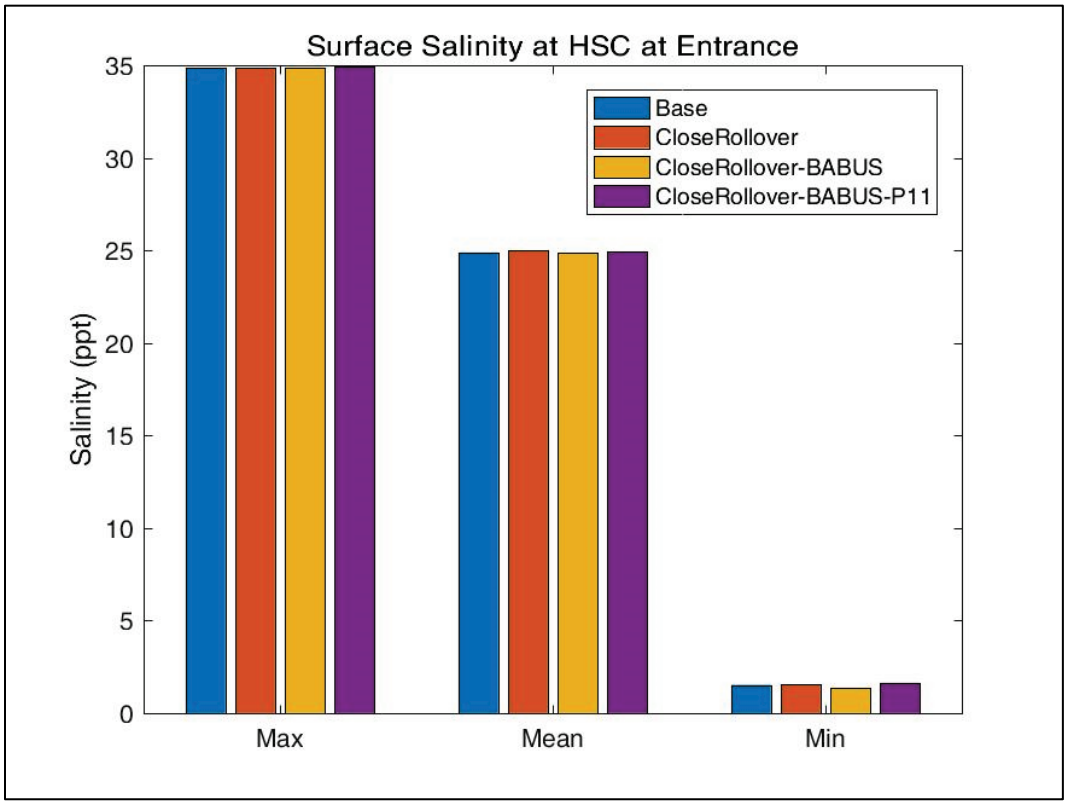

Surface Salinity at HSC at Bolivar Roads
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

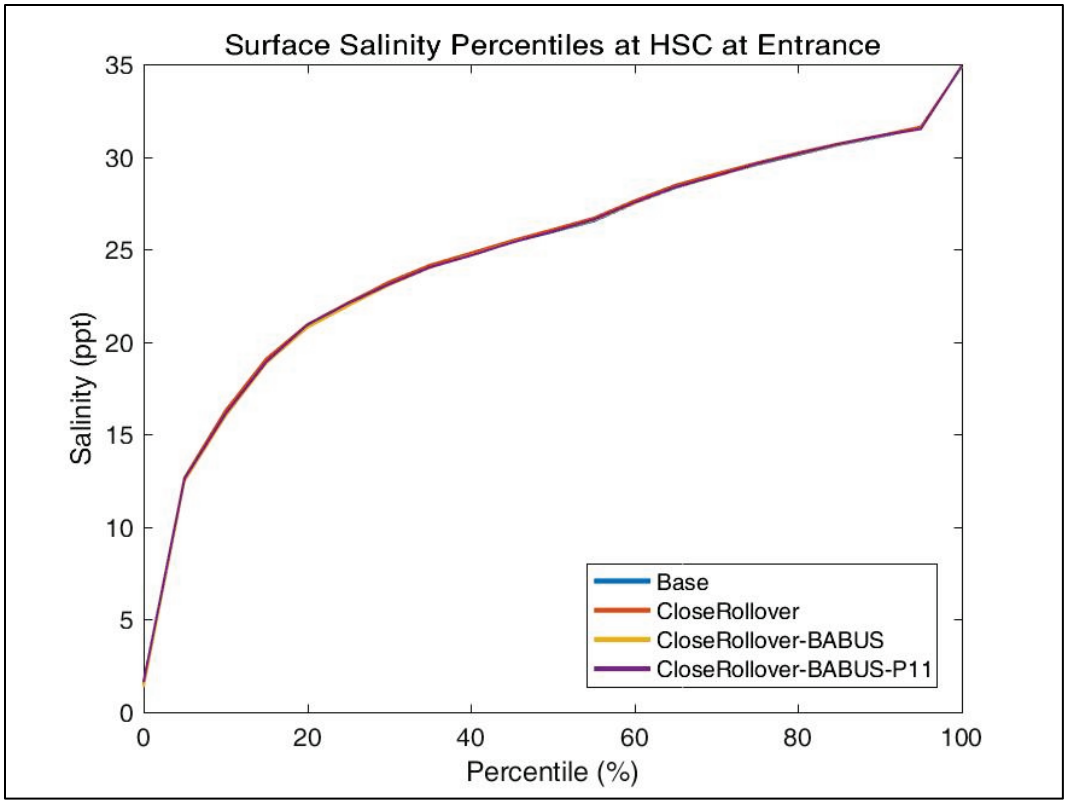

Surface Salinity Percentiles at HSC at Bolivar Roads
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

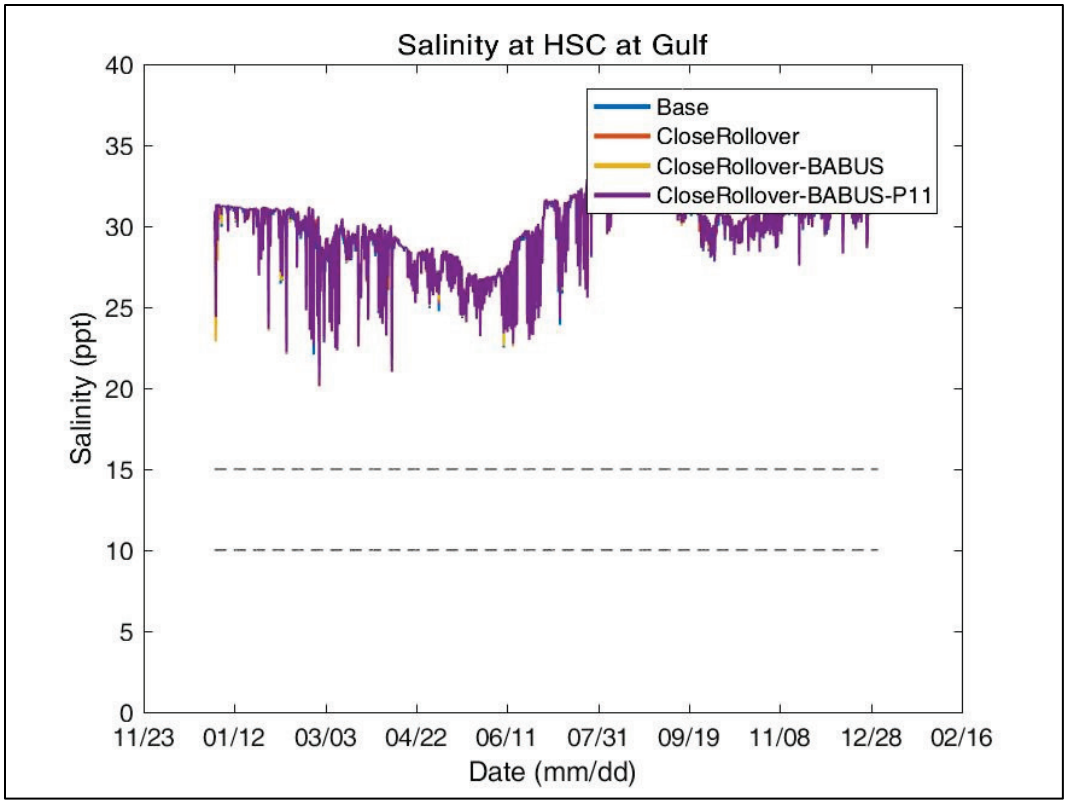

Salinity at HSC at Entrance
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

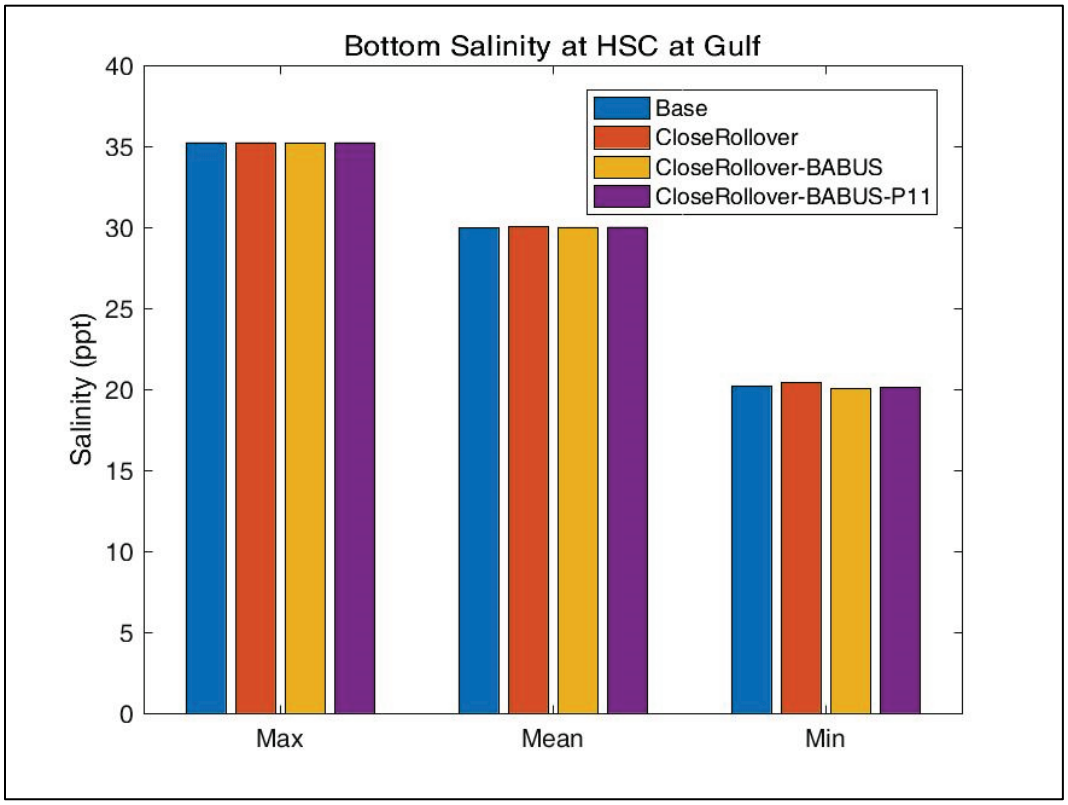

Bottom Salinity at HSC at Entrance
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
Max
Mean
Min

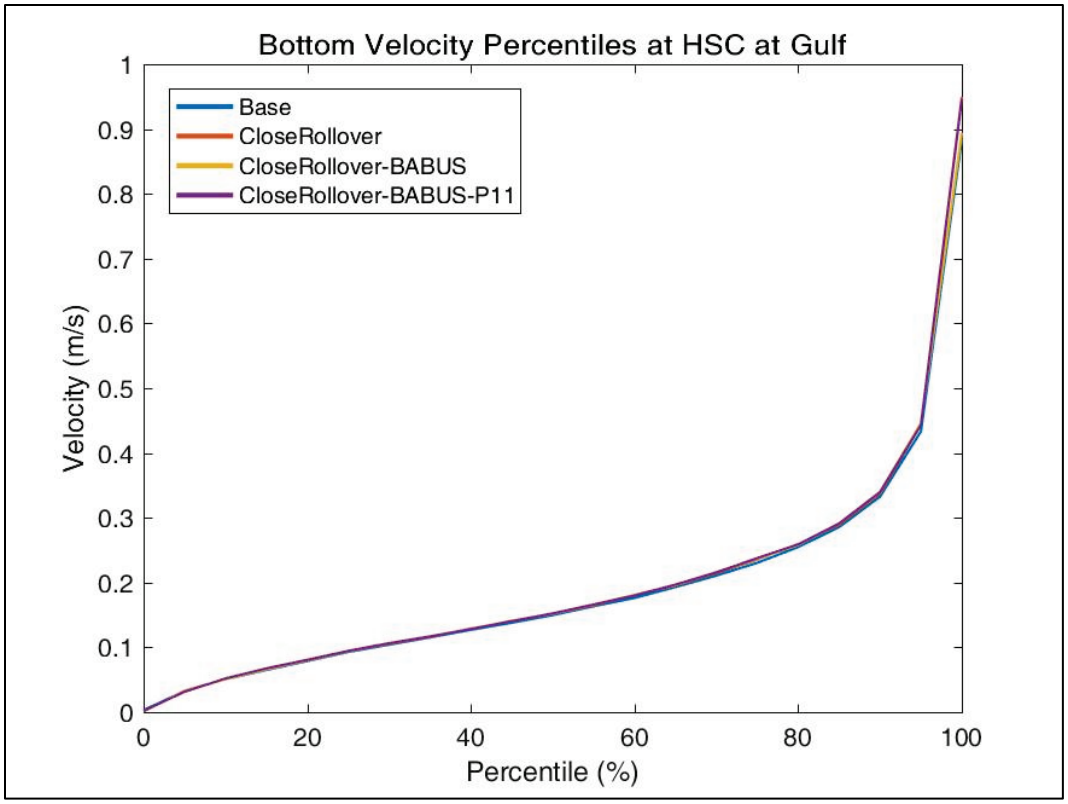

Bottom Salinity Percentiles at HSC at Entrance
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

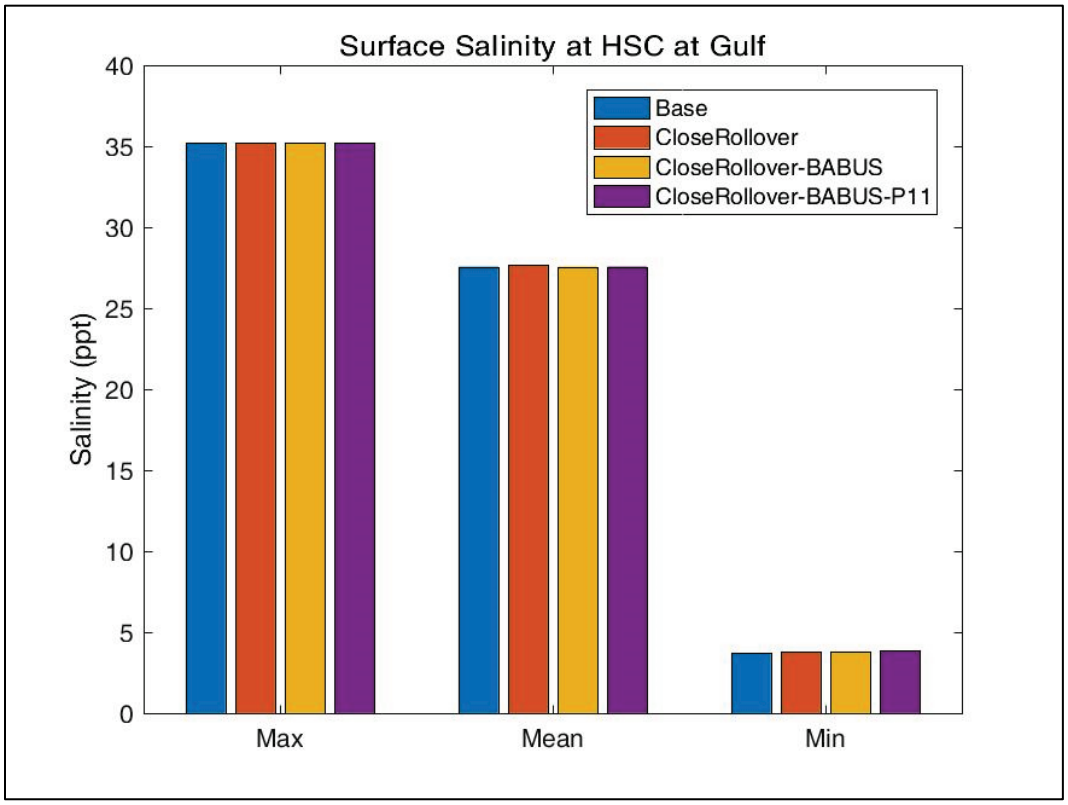

Surface Salinity at HSC at Entrance
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

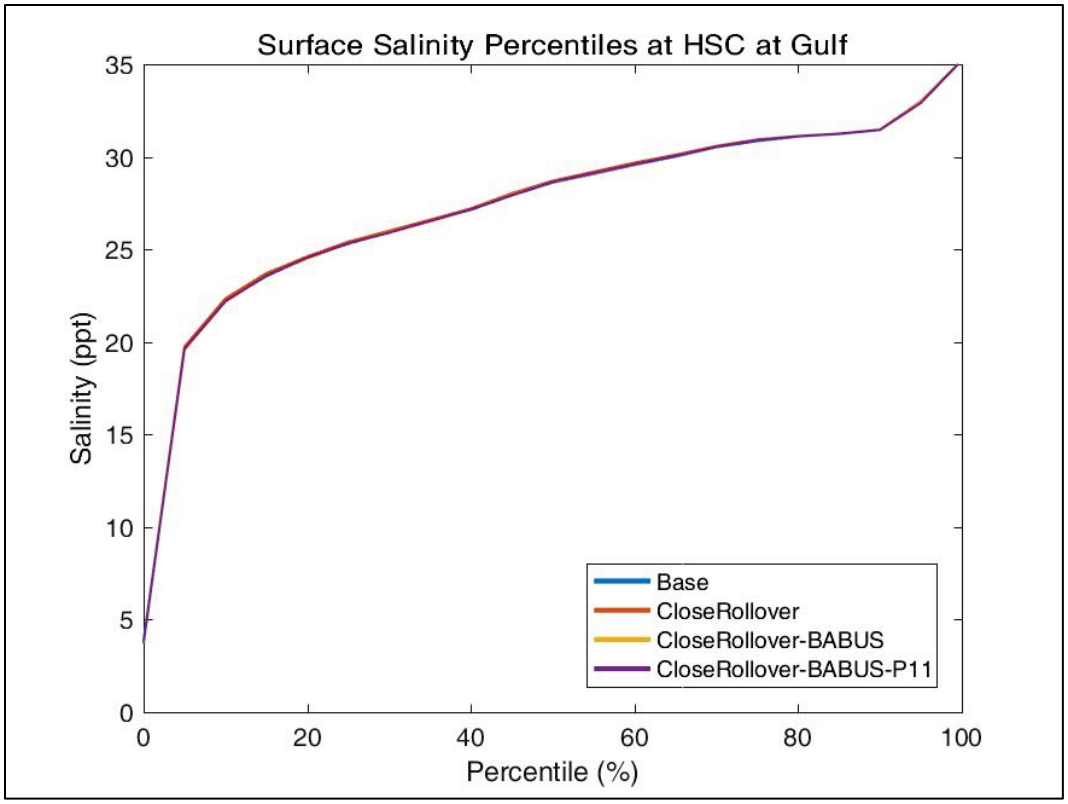

Surface Salinity Percentiles at HSC at Entrance
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

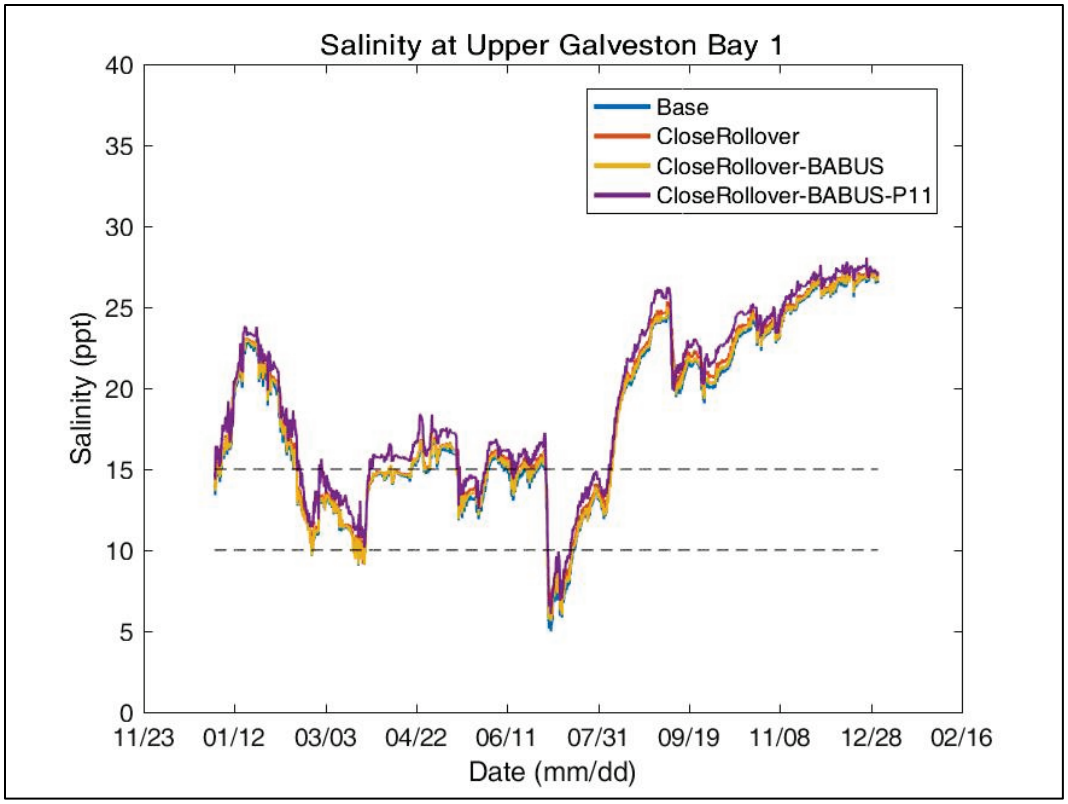

Salinity at HSC at Gulf
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

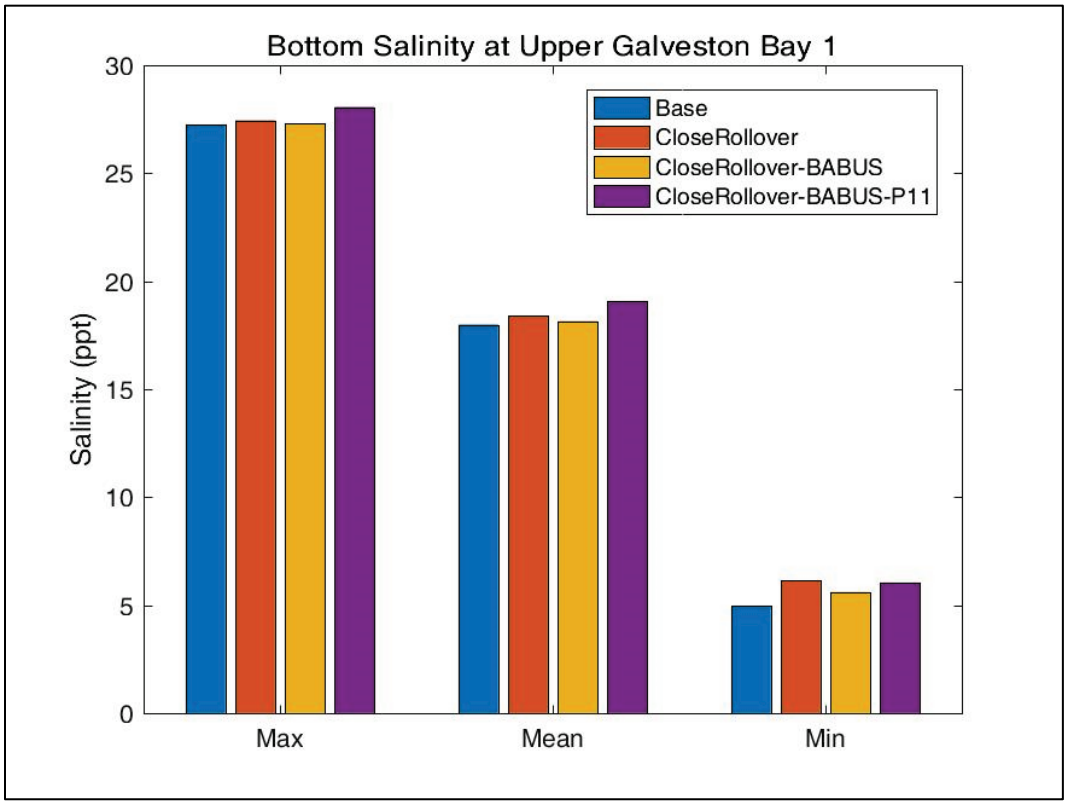

Bottom Salinity at HSC at Gulf
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
Max
Mean
Min

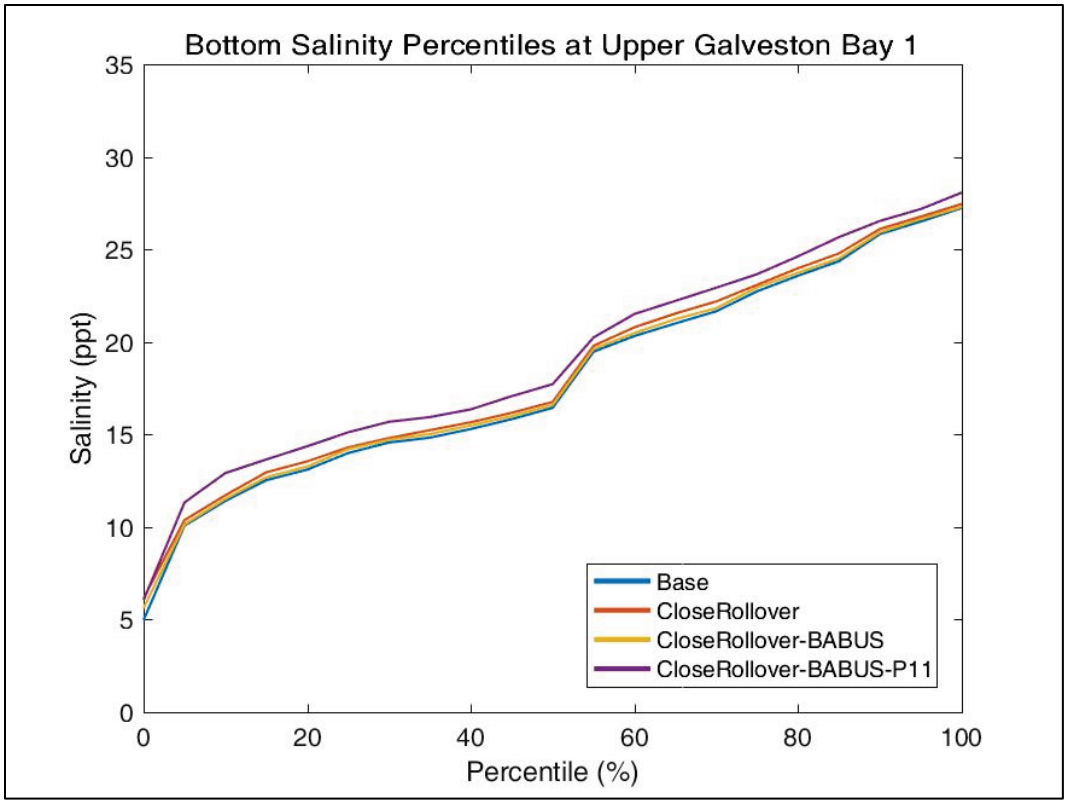

Bottom Velocity Percentiles at HSC at Gulf
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Velocity (m/s)
Percentile (%)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100

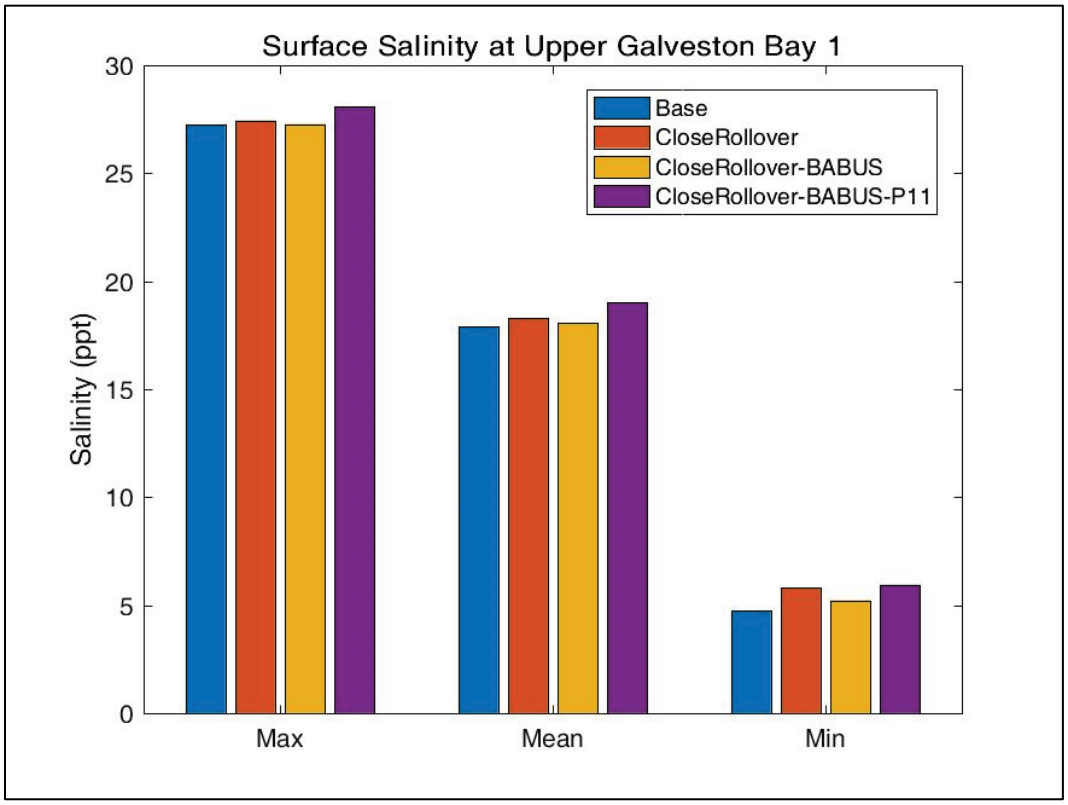

Surface Salinity at HSC at Gulf
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
Max
Mean
Min

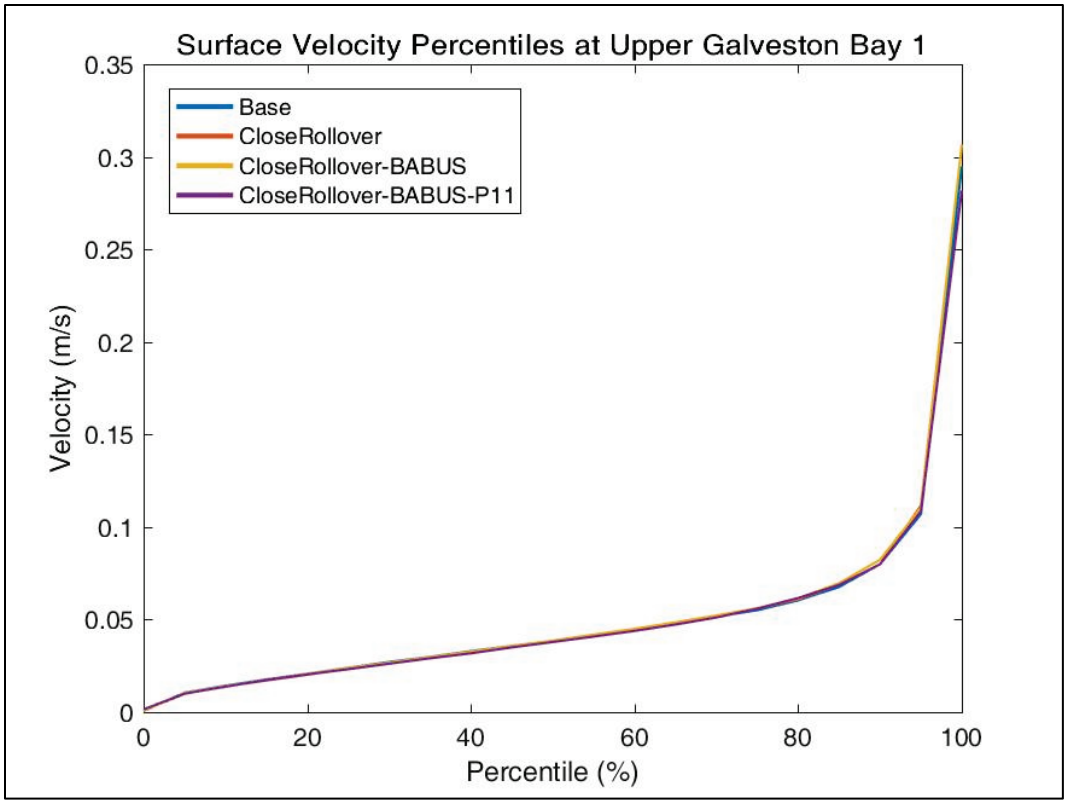

Surface Salinity Percentiles at HSC at Gulf
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

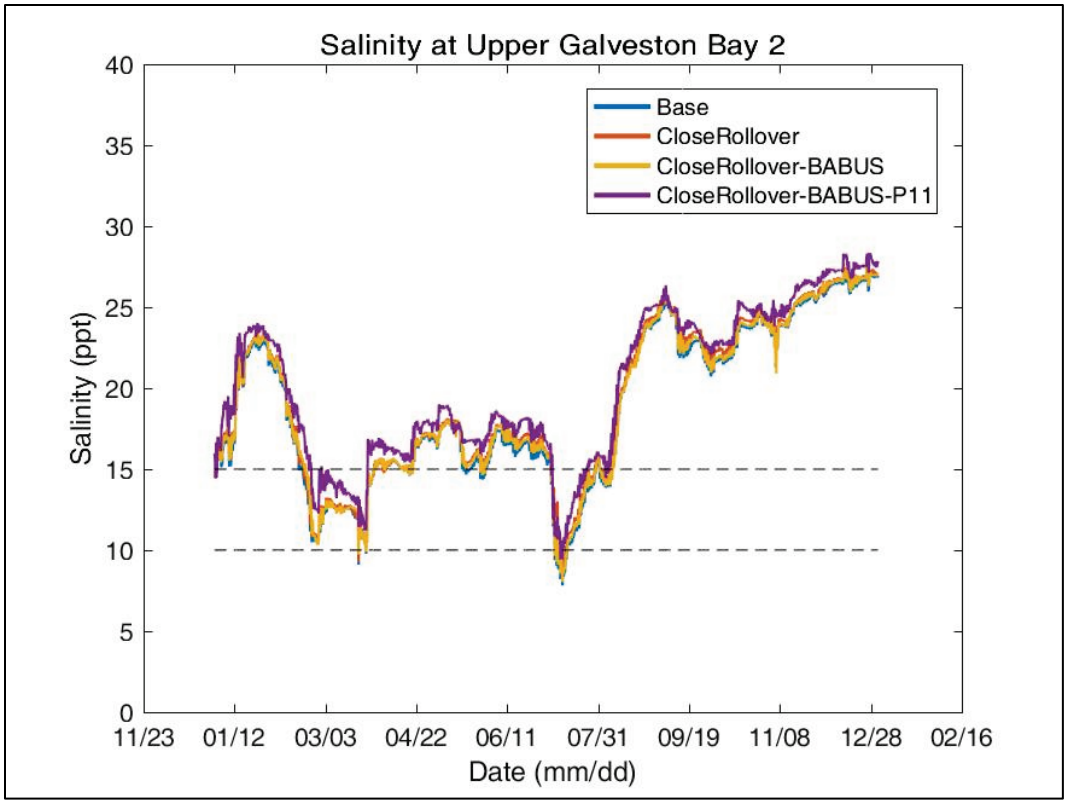

Salinity at Upper Galveston Bay 1
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

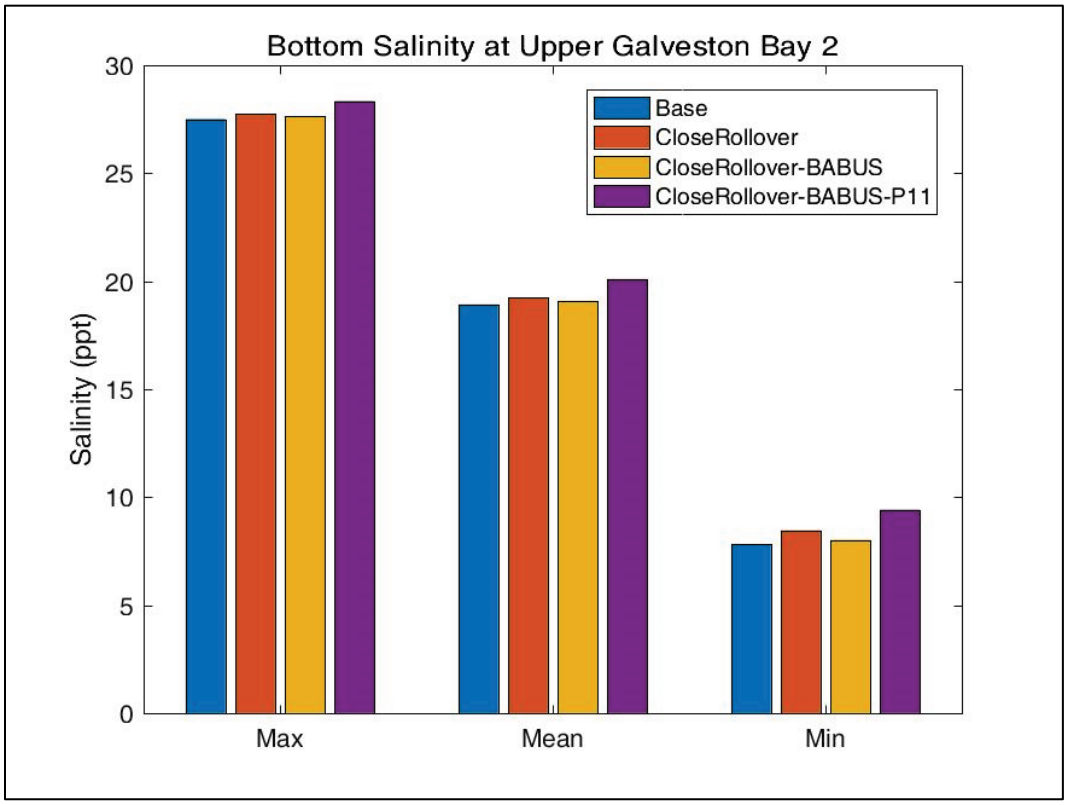

Bottom Salinity at Upper Galveston Bay 1
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

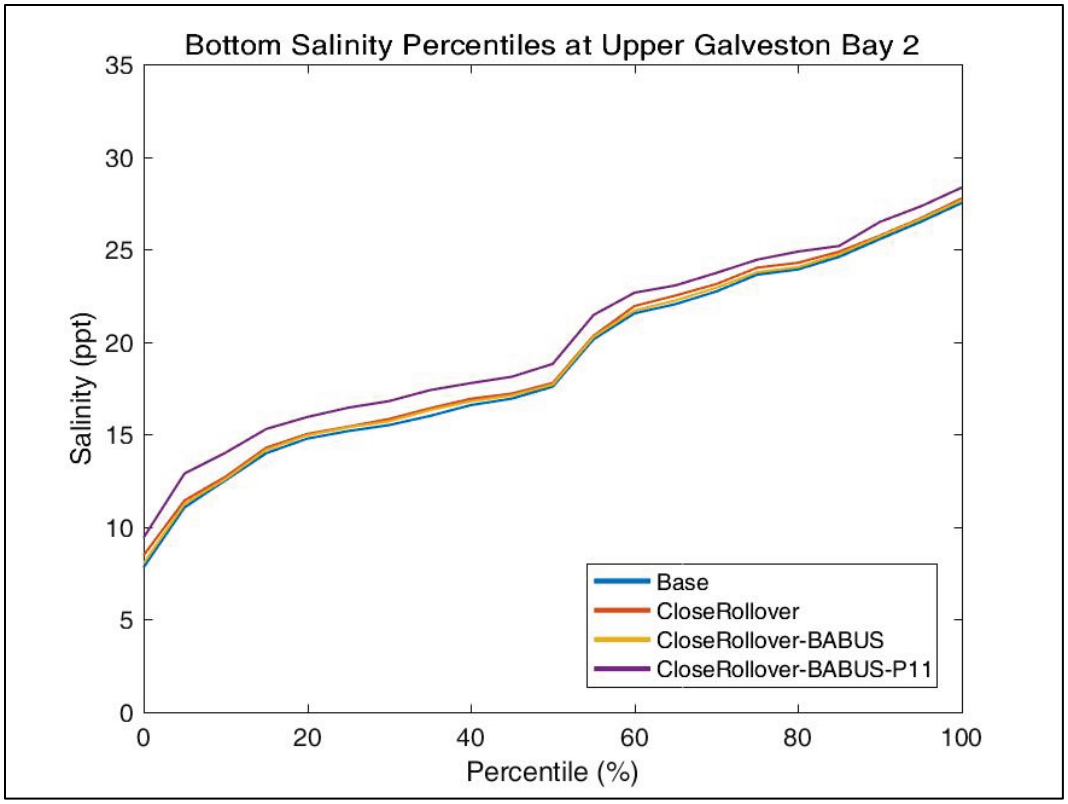

Bottom Salinity Percentiles at Upper Galveston Bay 1
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

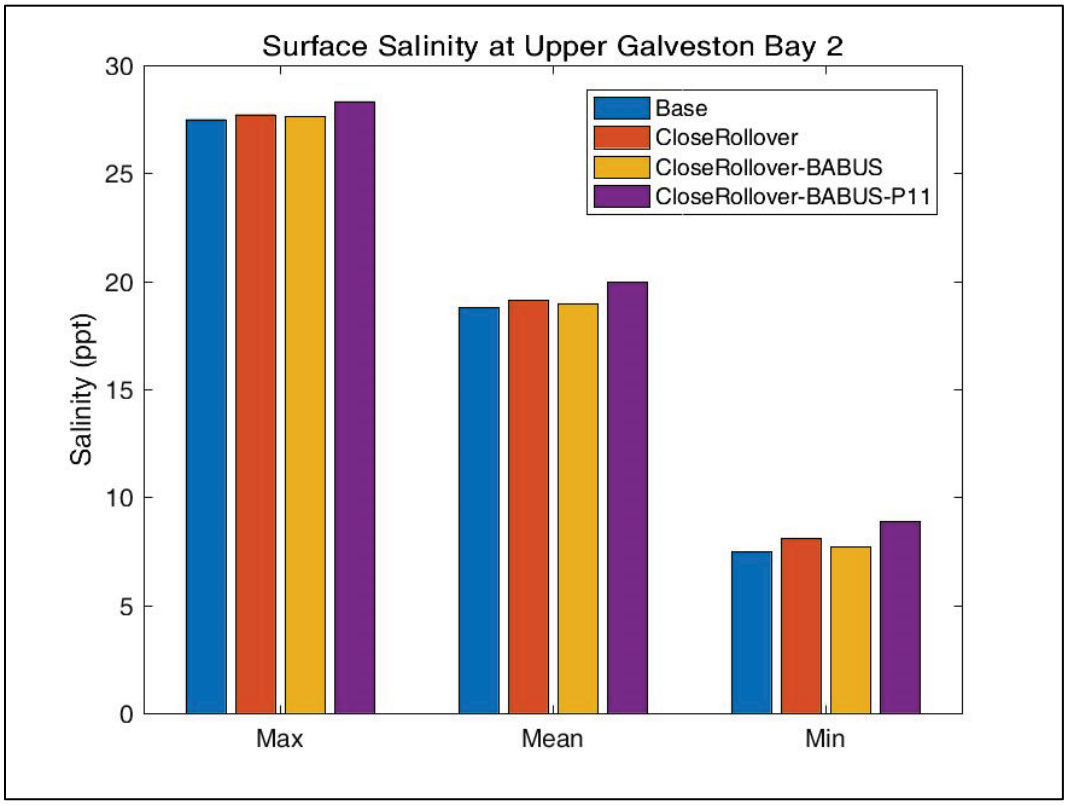

Surface Salinity at Upper Galveston Bay 1
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

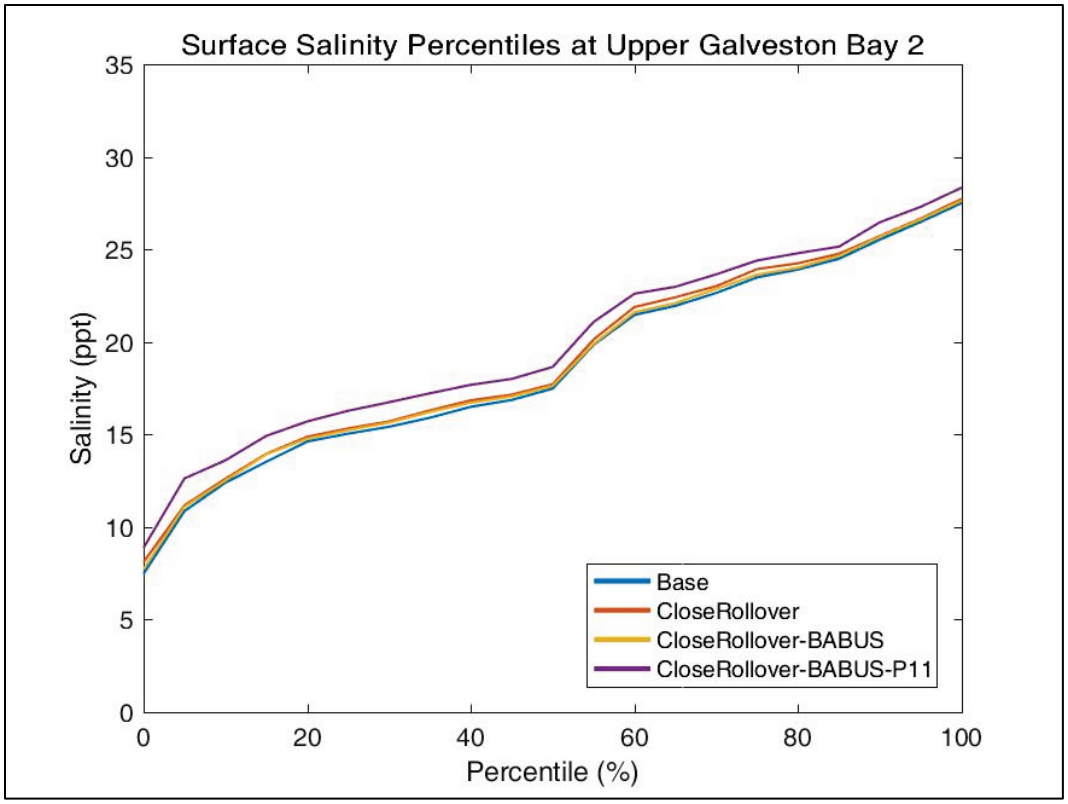

Surface Velocity Percentiles at Upper Galveston Bay 1
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Velocity (m/s)
Percentile (%)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0
20
40
60
80
100

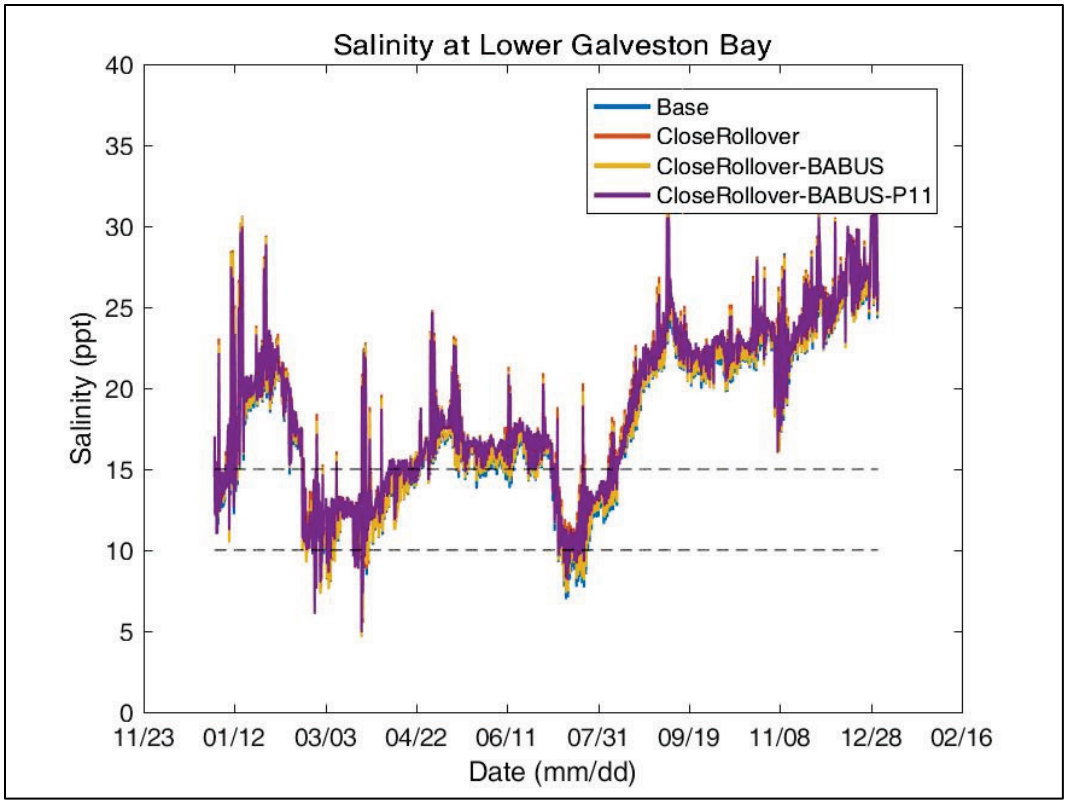

Salinity at Upper Galveston Bay 2
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

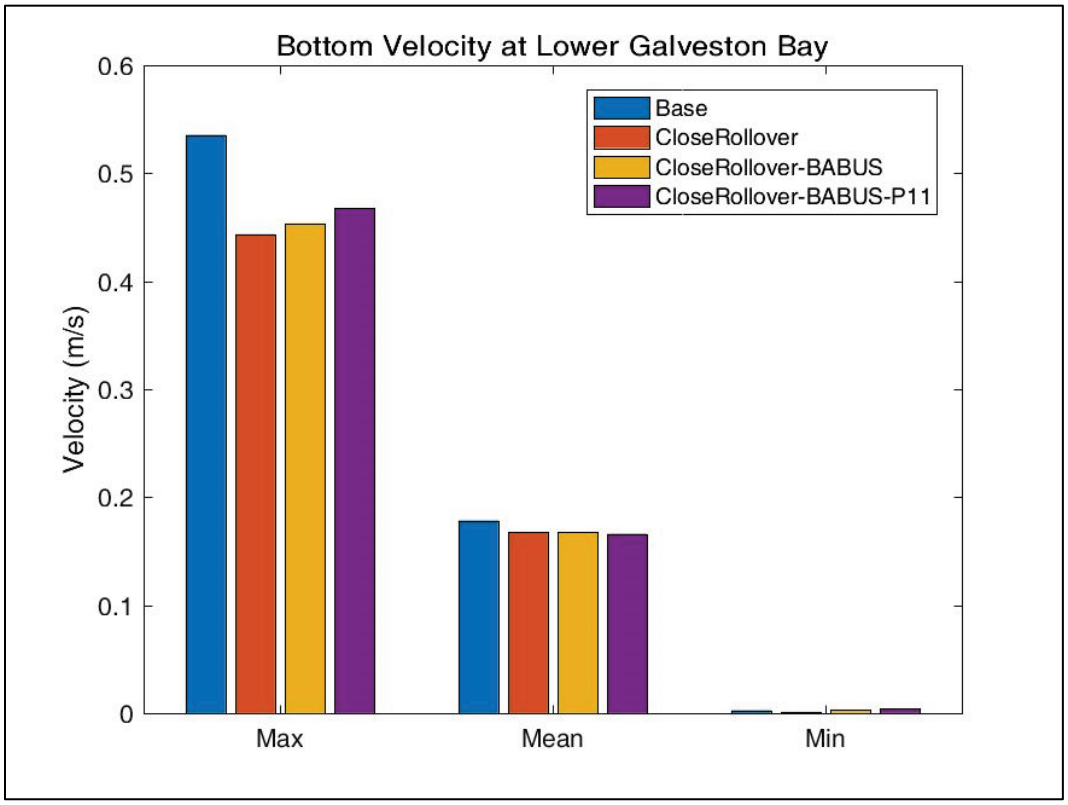

Bottom Salinity at Upper Galveston Bay 2
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

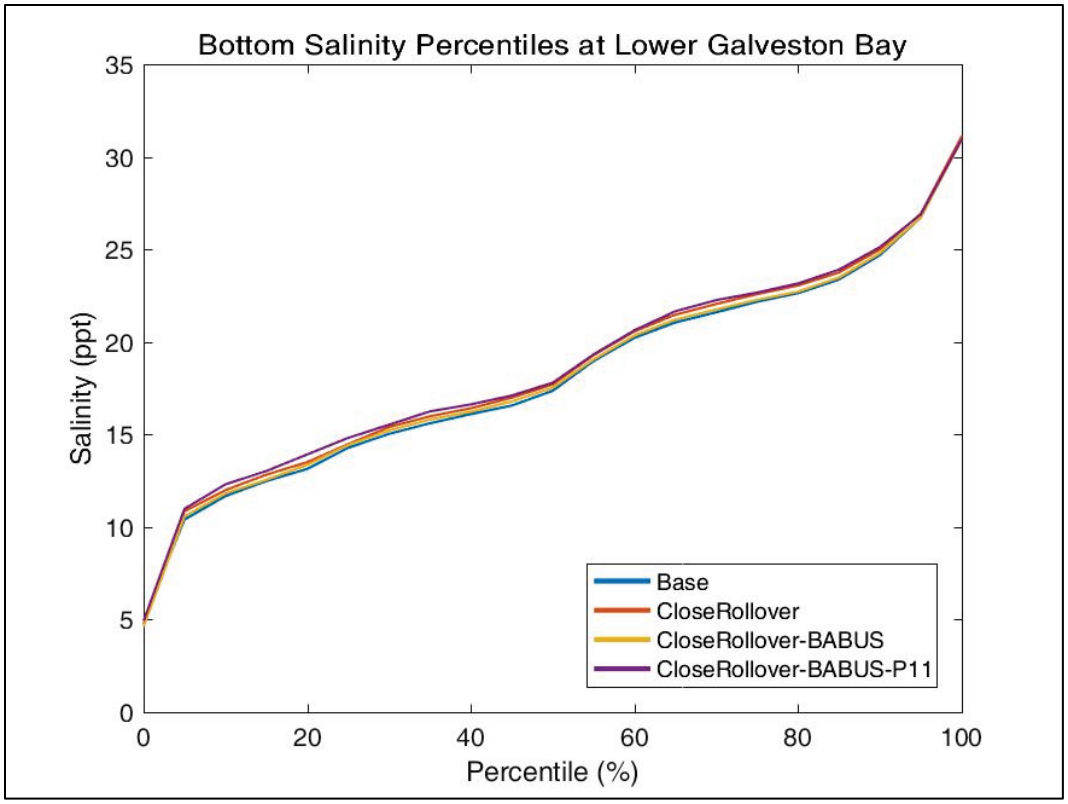

Bottom Salinity Percentiles at Upper Galveston Bay 2
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

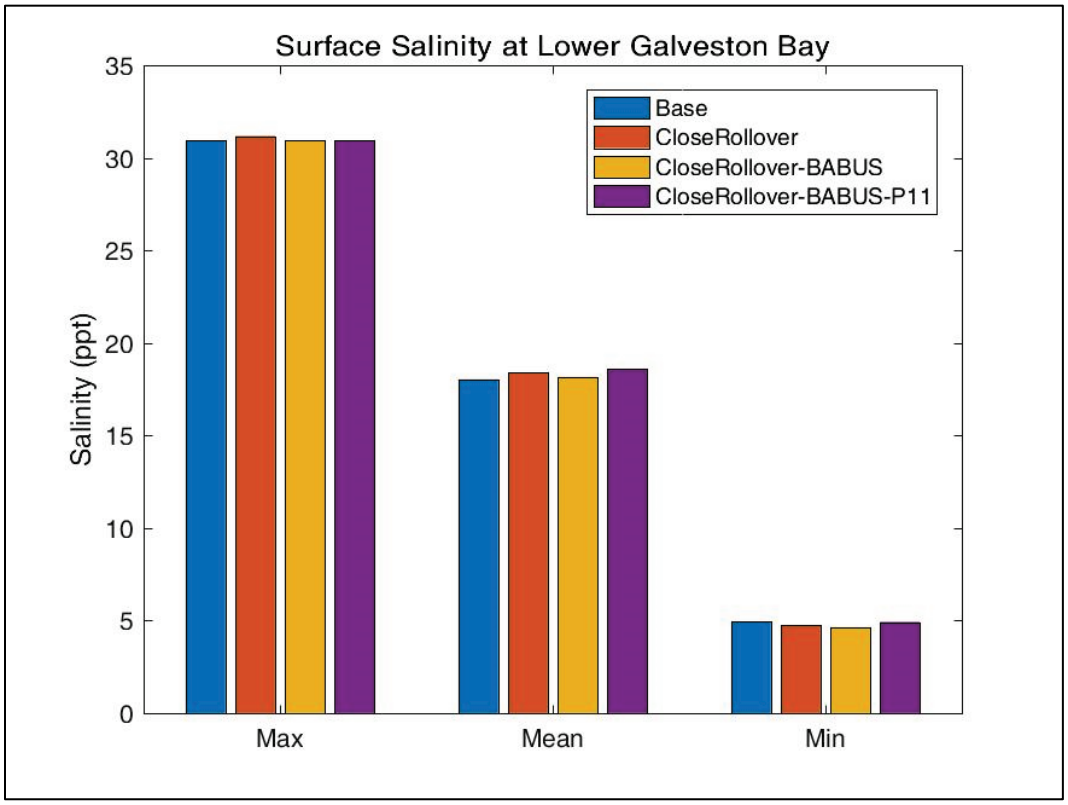

Surface Salinity at Upper Galveston Bay 2
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

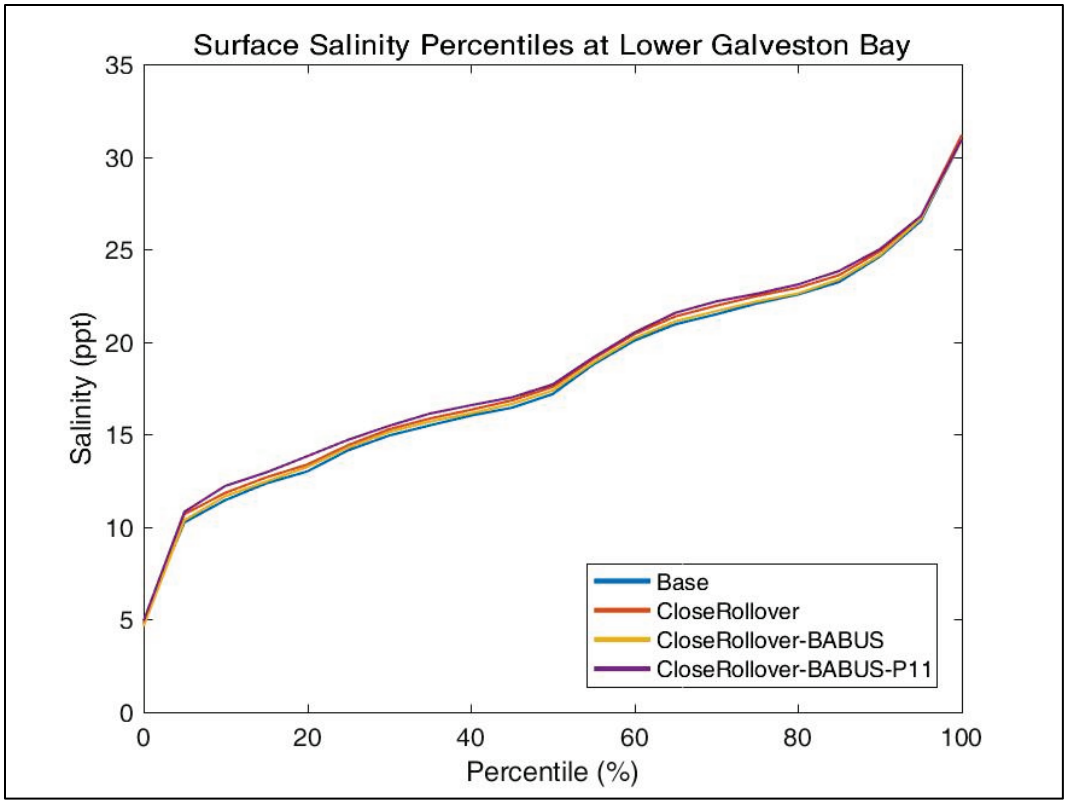

Surface Salinity Percentiles at Upper Galveston Bay 2
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

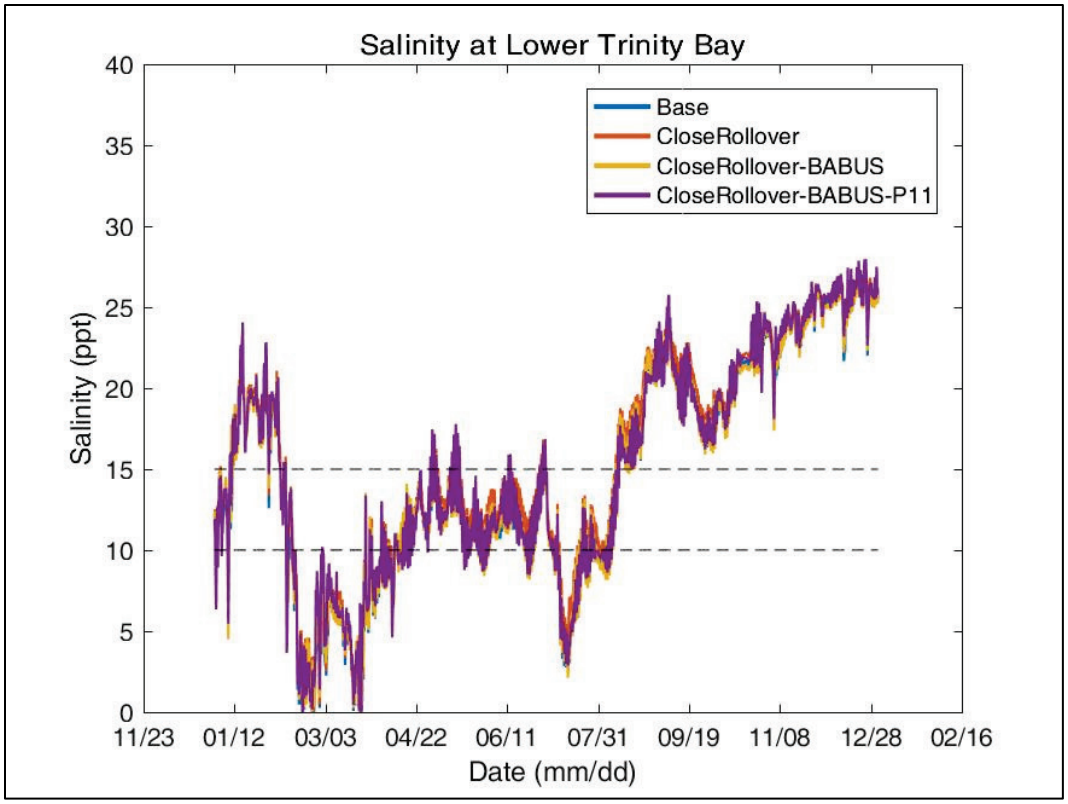

Salinity at Lower Galveston Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

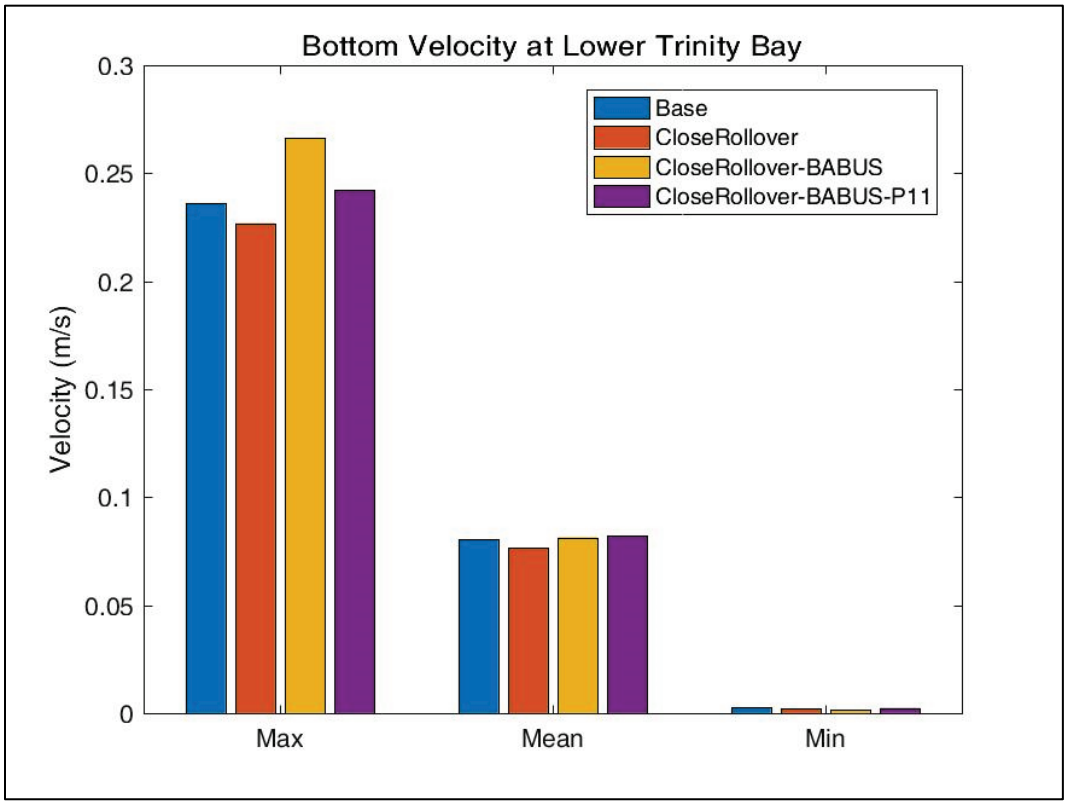

Bottom Velocity at Lower Galveston Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Velocity (m/s)
0
0.1
0.2
0.3
0.4
0.5
0.6
Max
Mean
Min

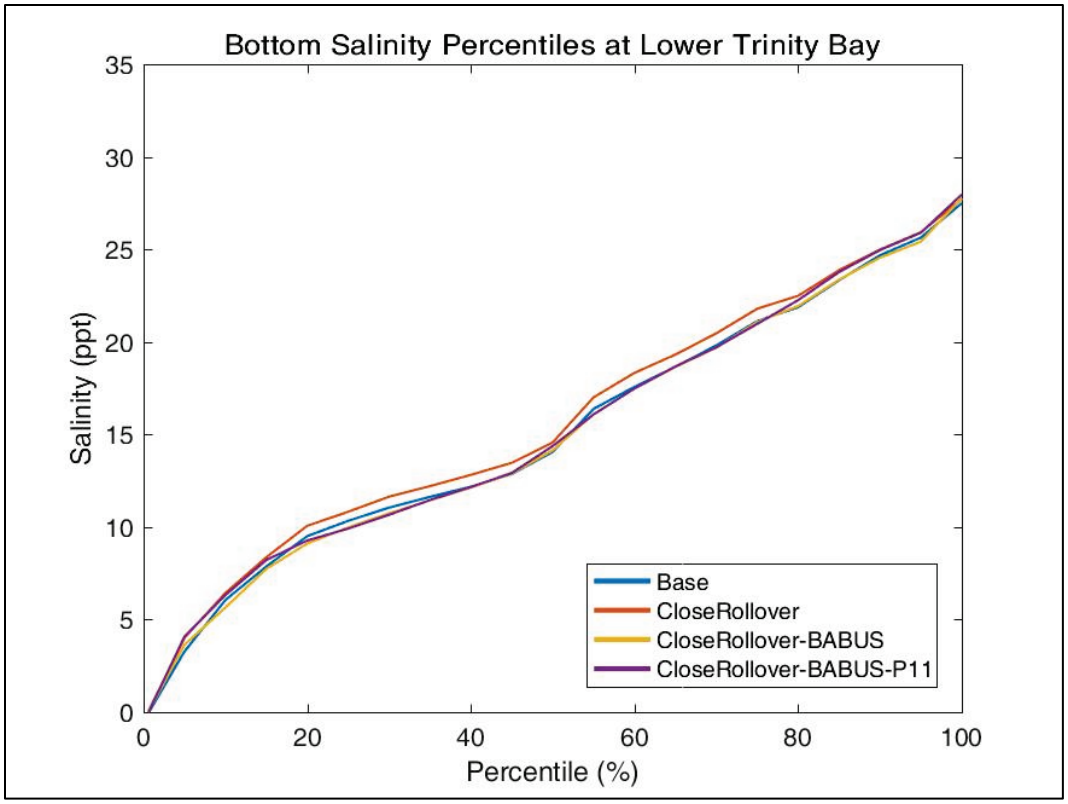

Bottom Salinity Percentiles at Lower Galveston Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

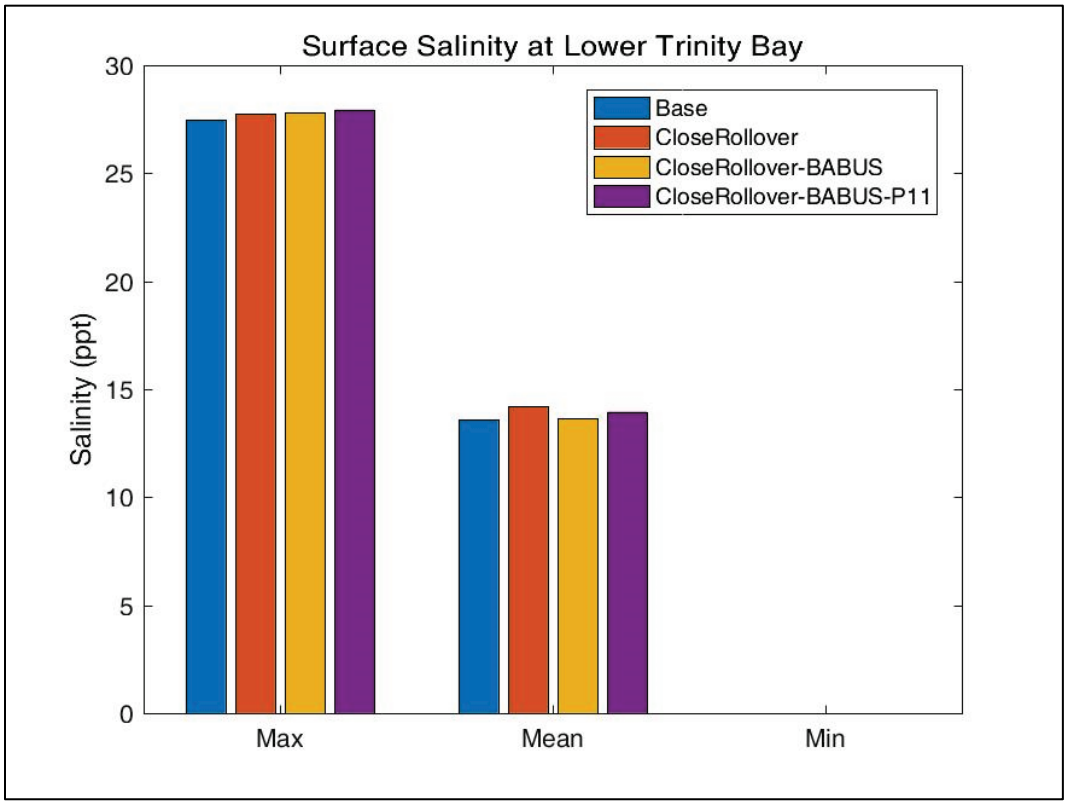

Surface Salinity at Lower Galveston Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

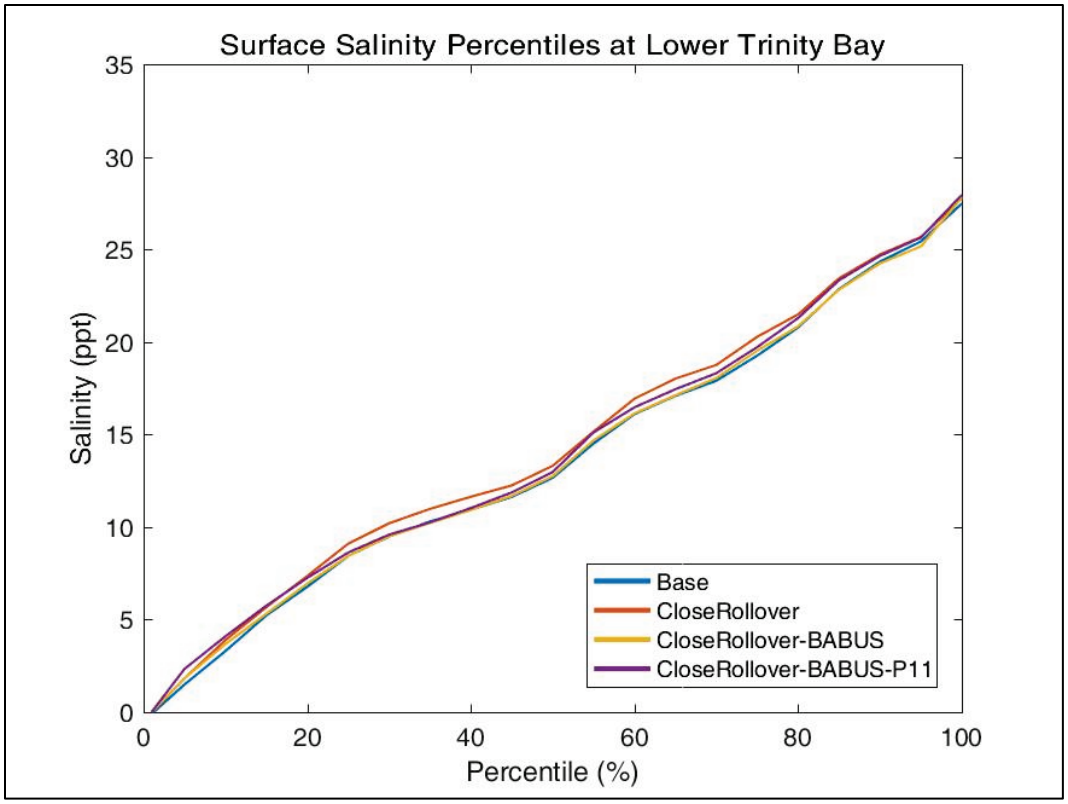

Surface Salinity Percentiles at Lower Galveston Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

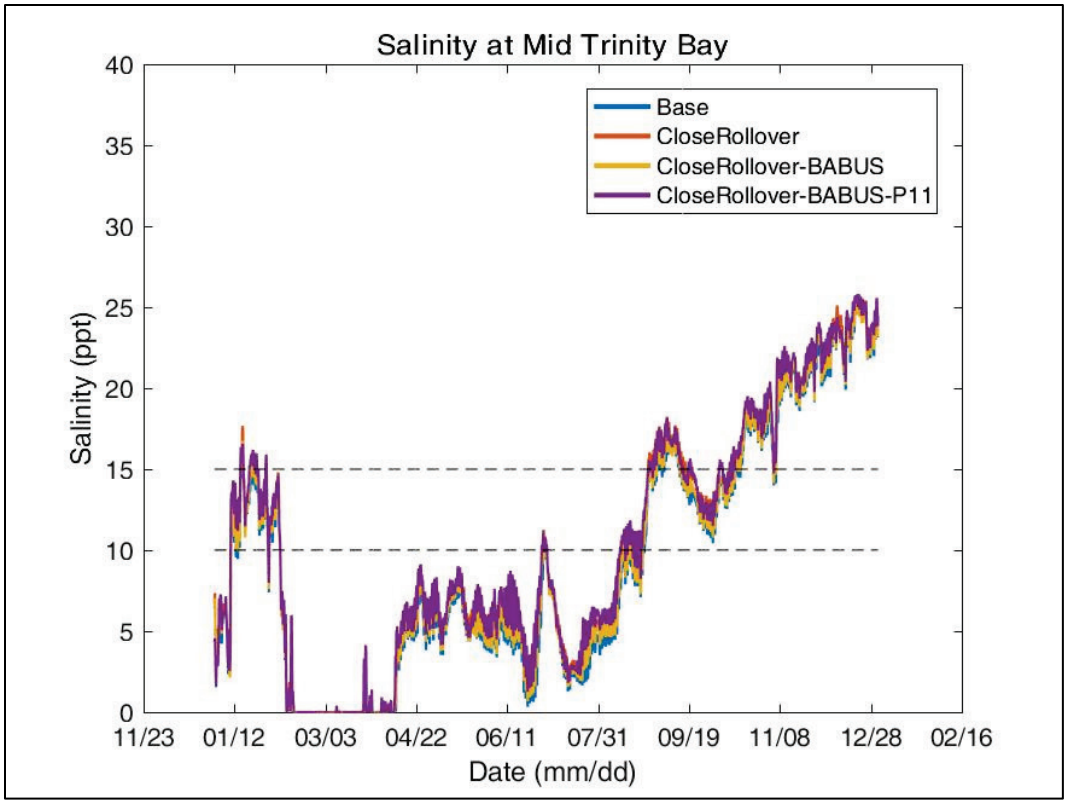

Salinity at Lower Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

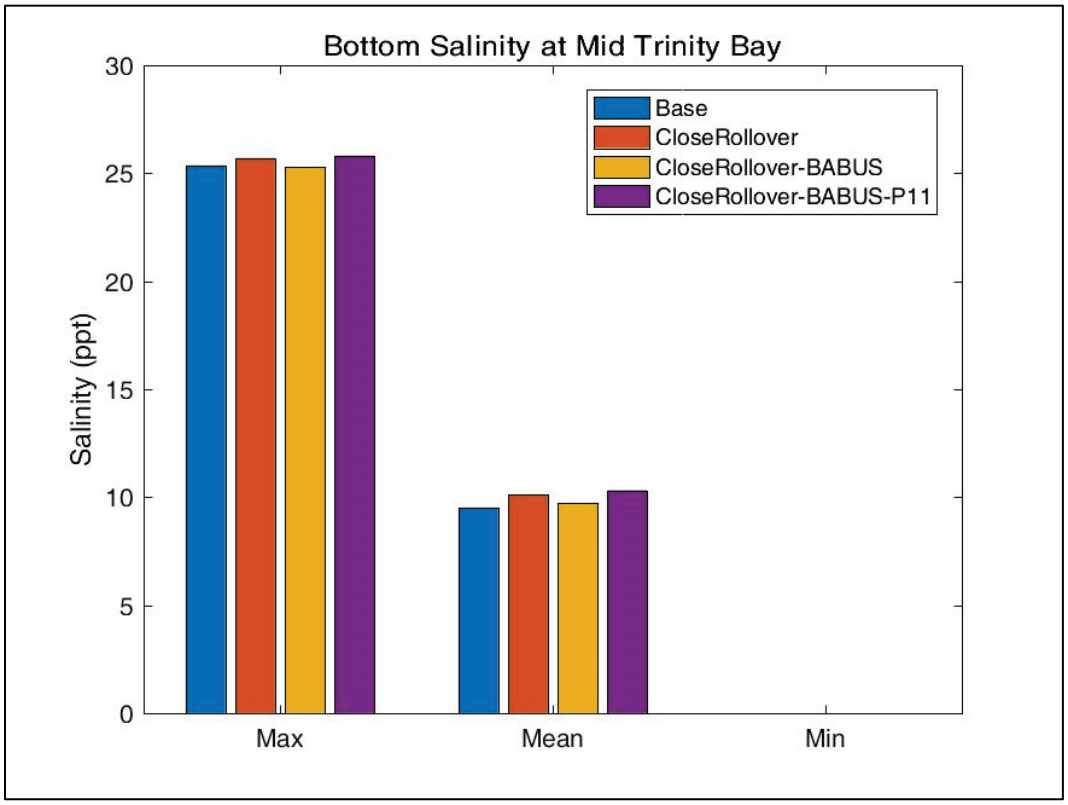

Bottom Velocity at Lower Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Velocity (m/s)
0
0.05
0.1
0.15
0.2
0.25
0.3
Max
Mean
Min

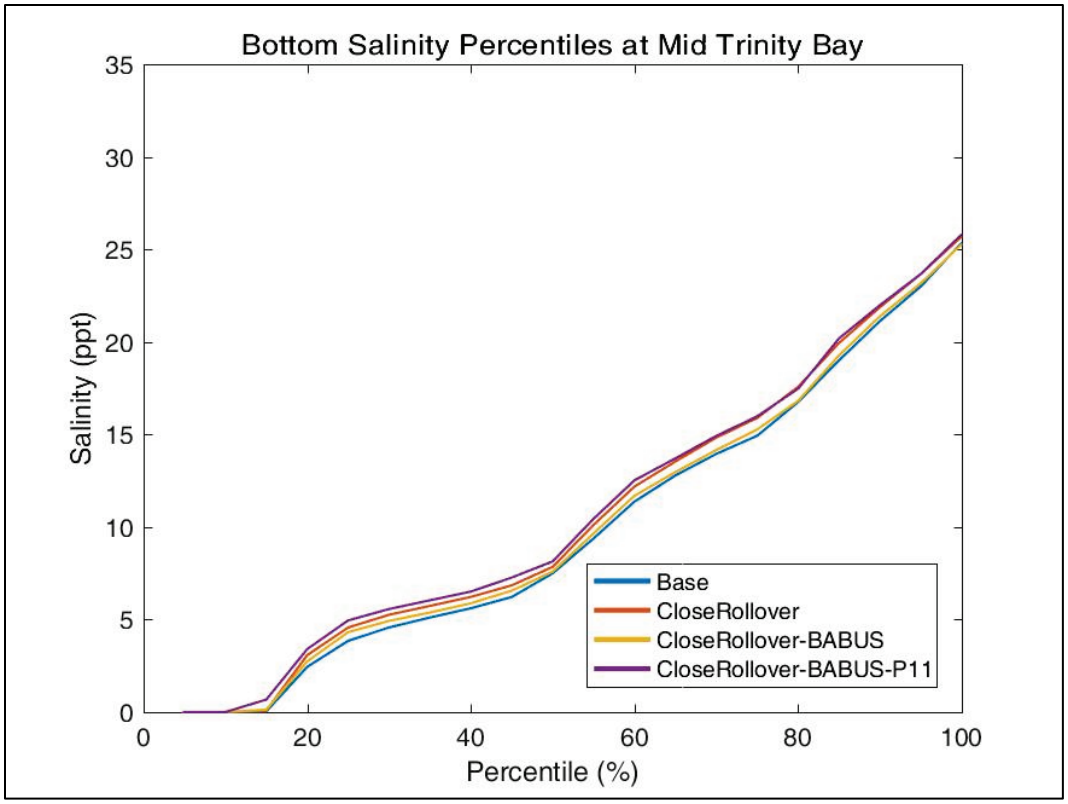

Bottom Salinity Percentiles at Lower Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

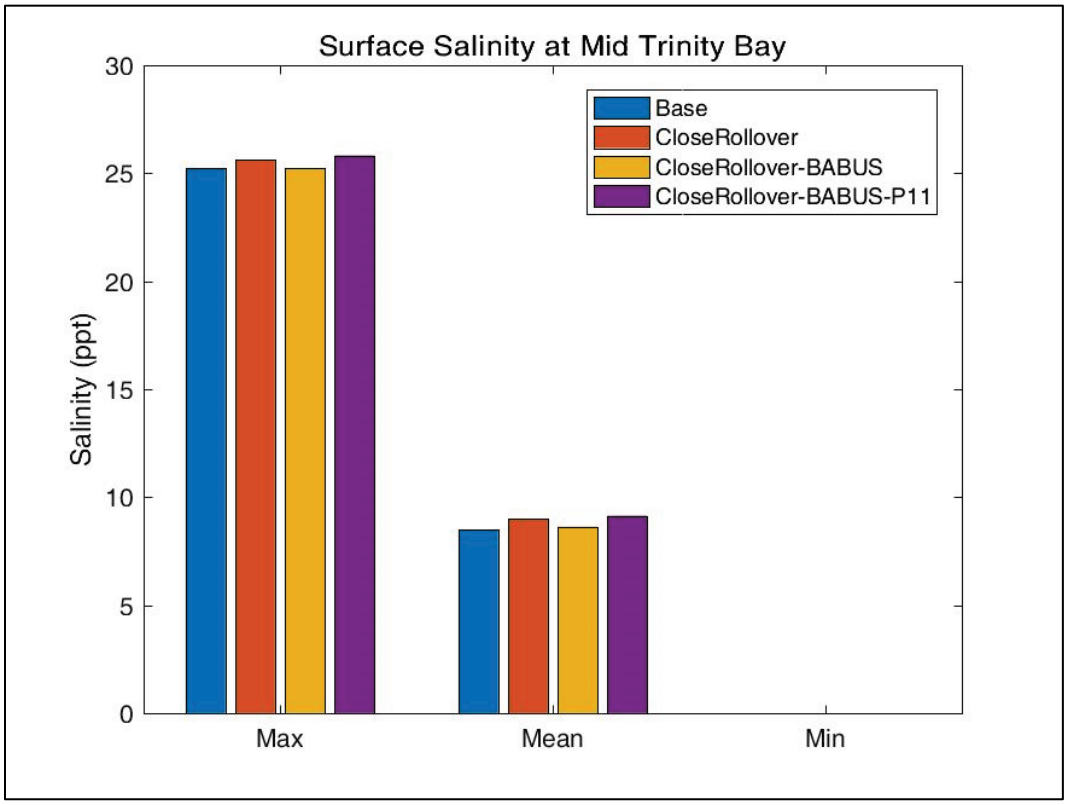

Surface Salinity at Lower Trinity Bay
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

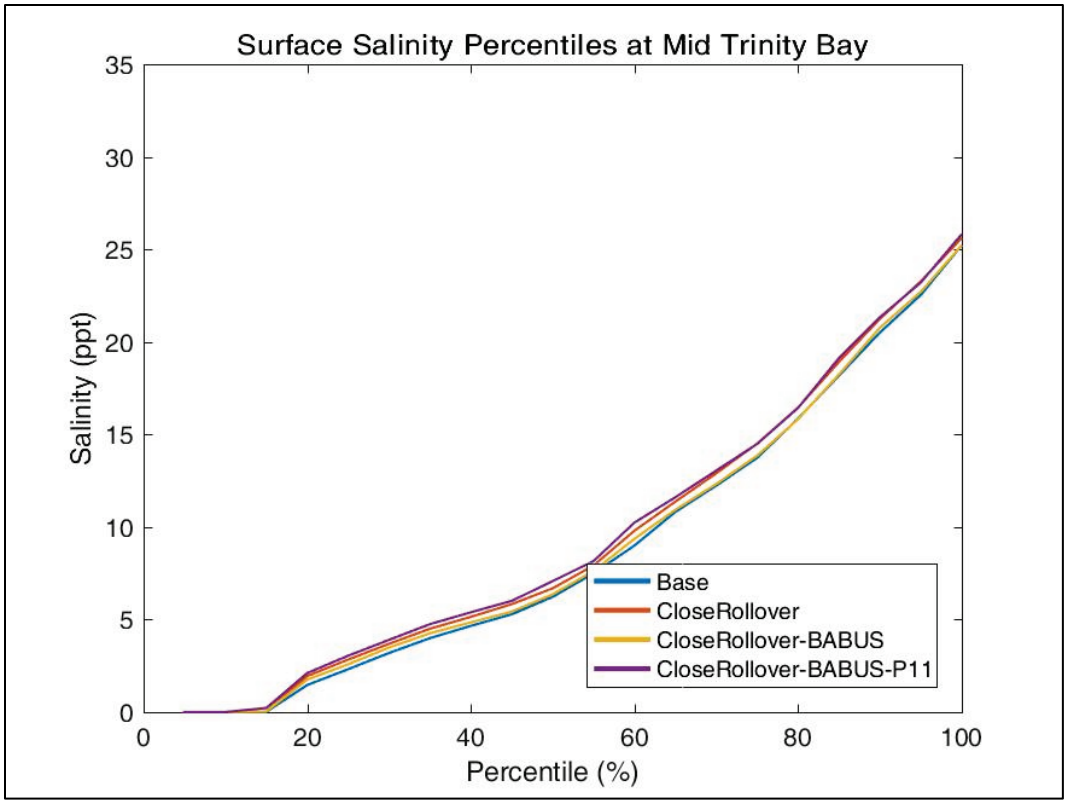

Surface Salinity Percentiles at Lower Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

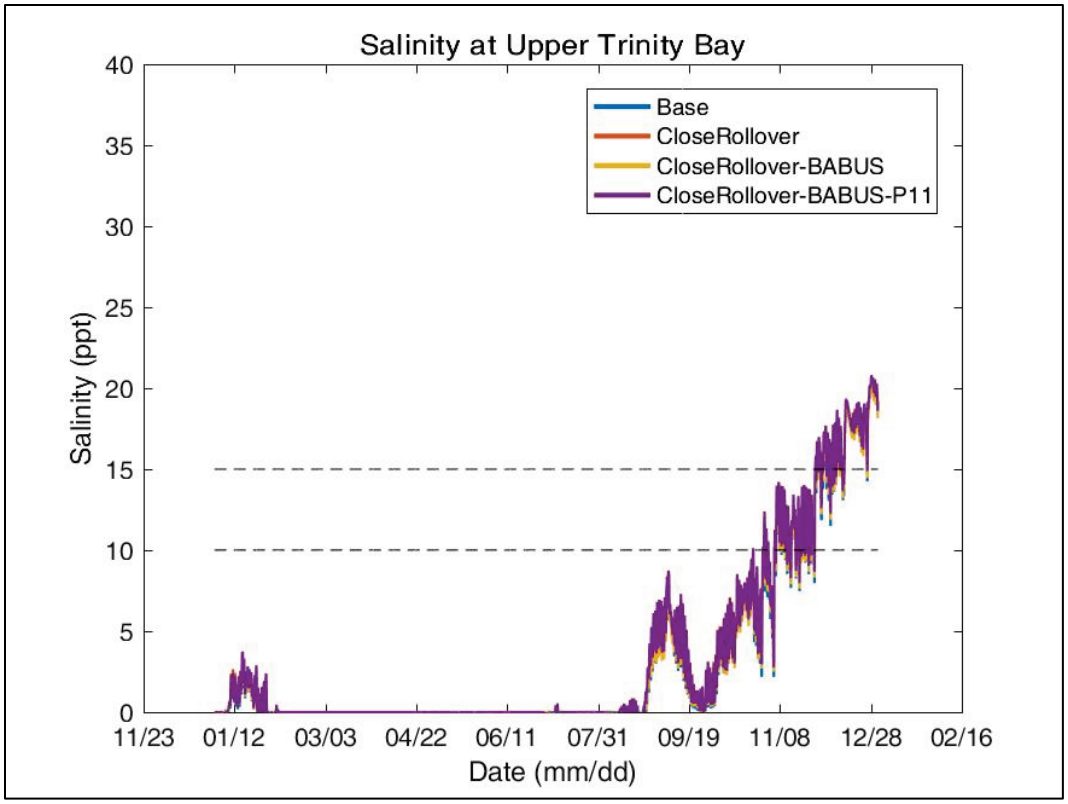

Salinity at Mid Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

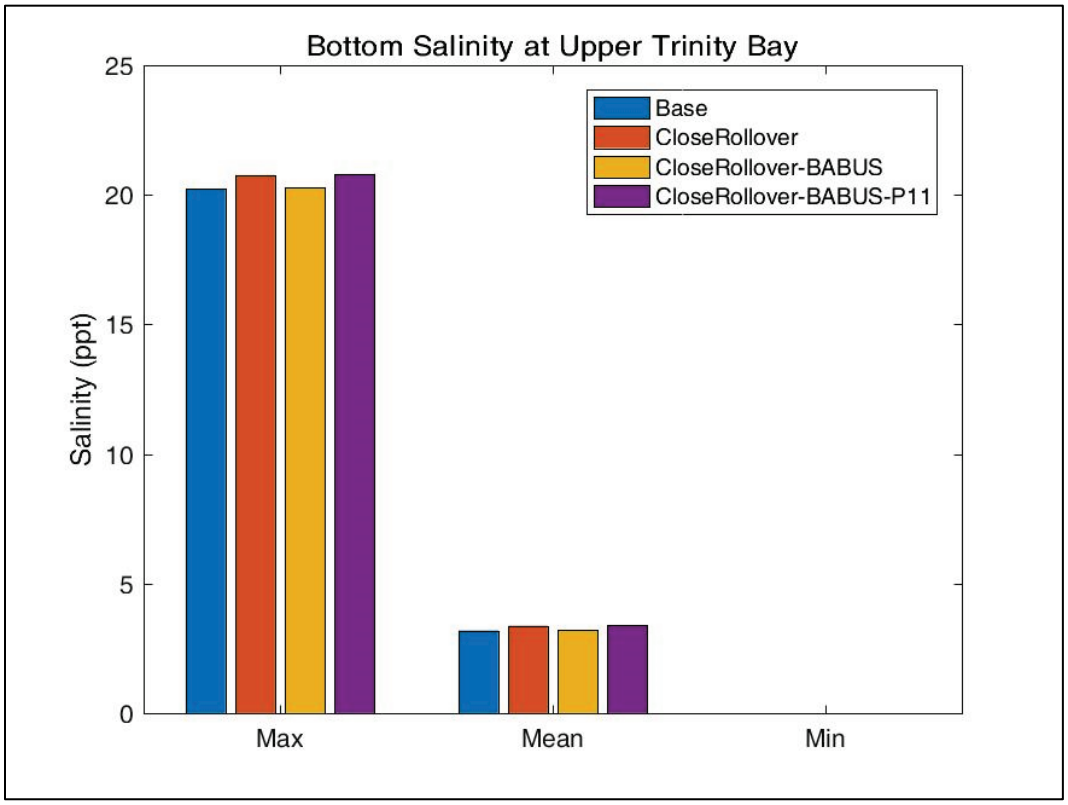

Bottom Salinity at Mid Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

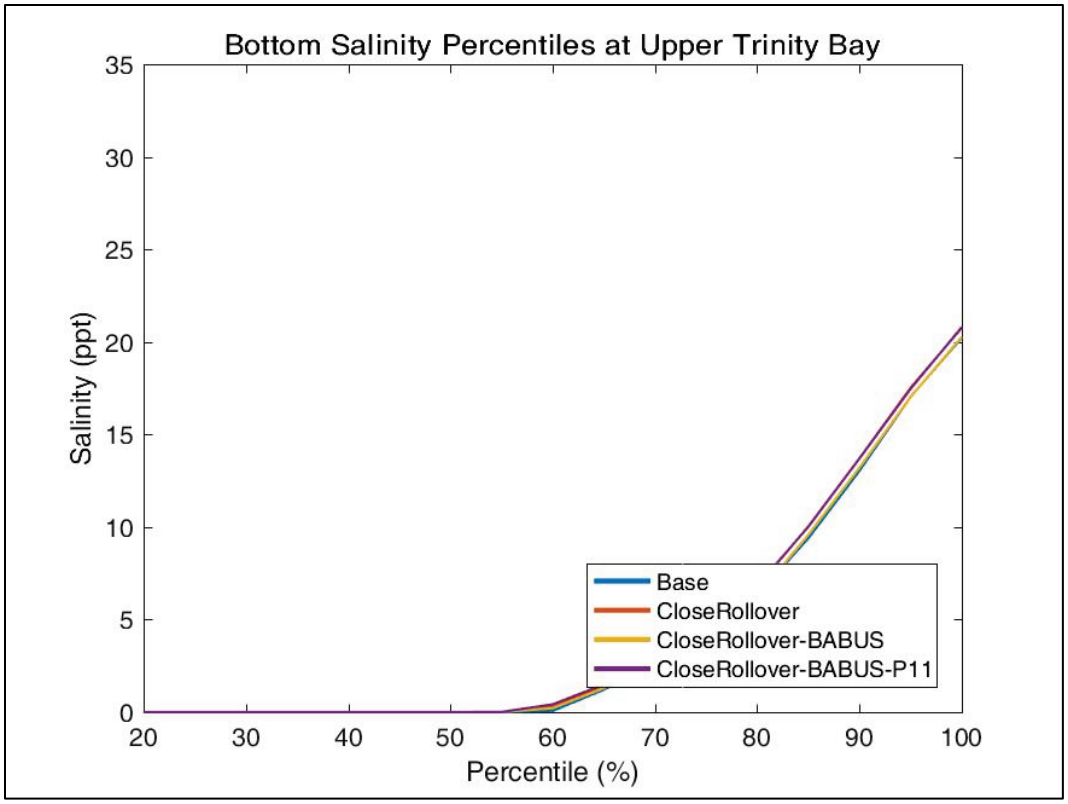

Bottom Salinity Percentiles at Mid Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

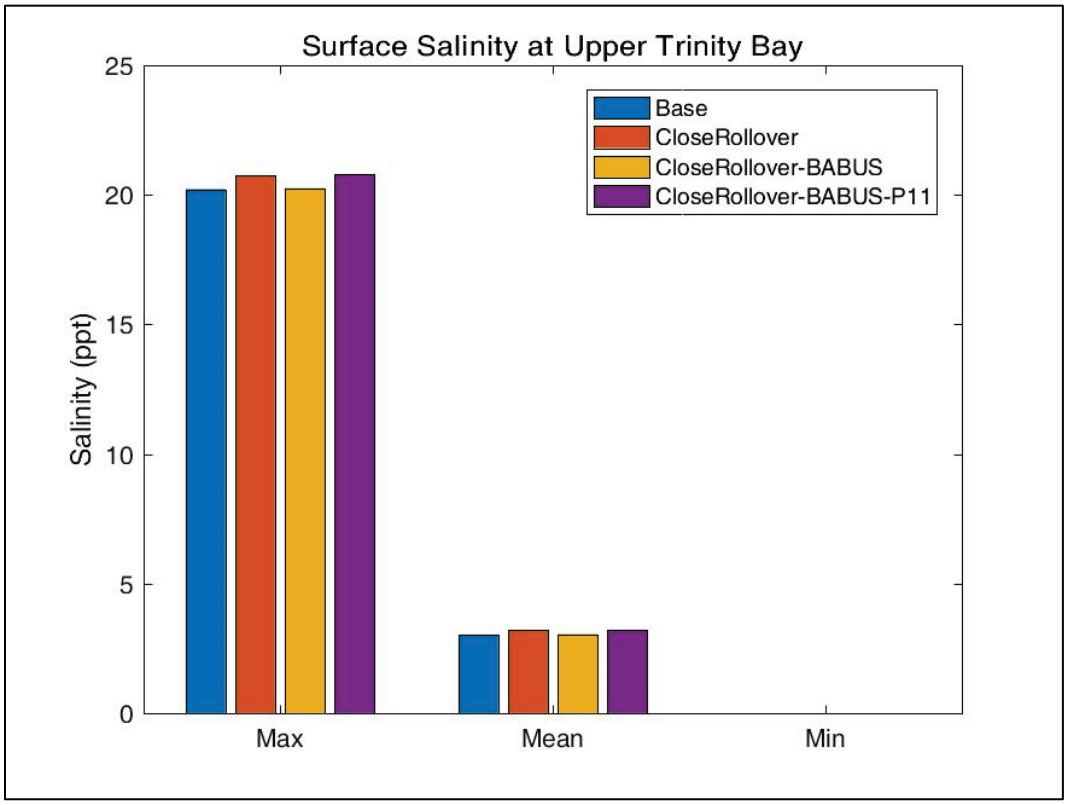

Surface Salinity at Mid Trinity Bay
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

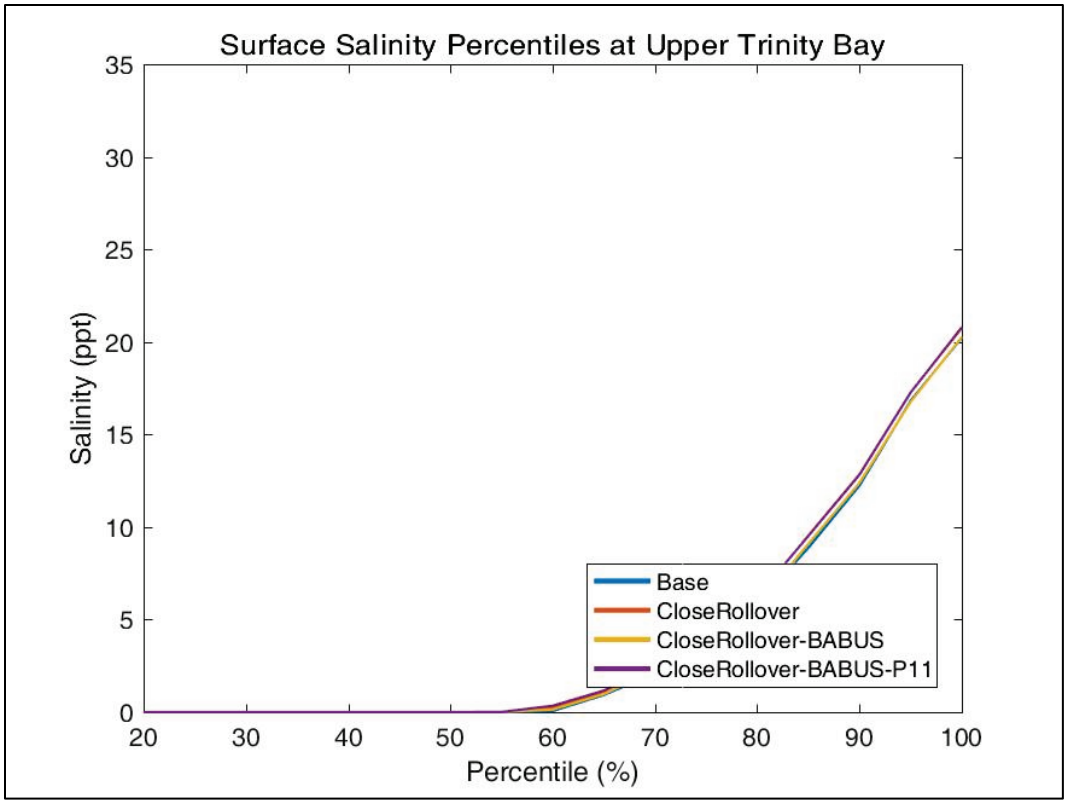

Surface Salinity Percentiles at Mid Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

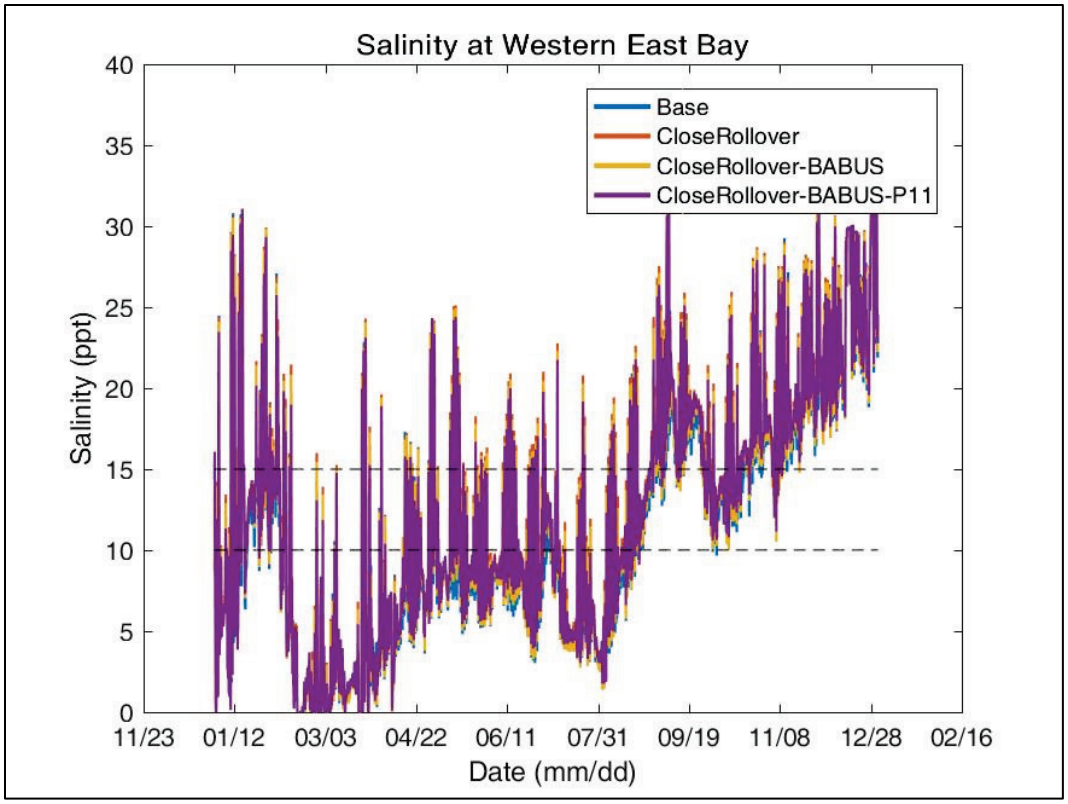

Salinity at Upper Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

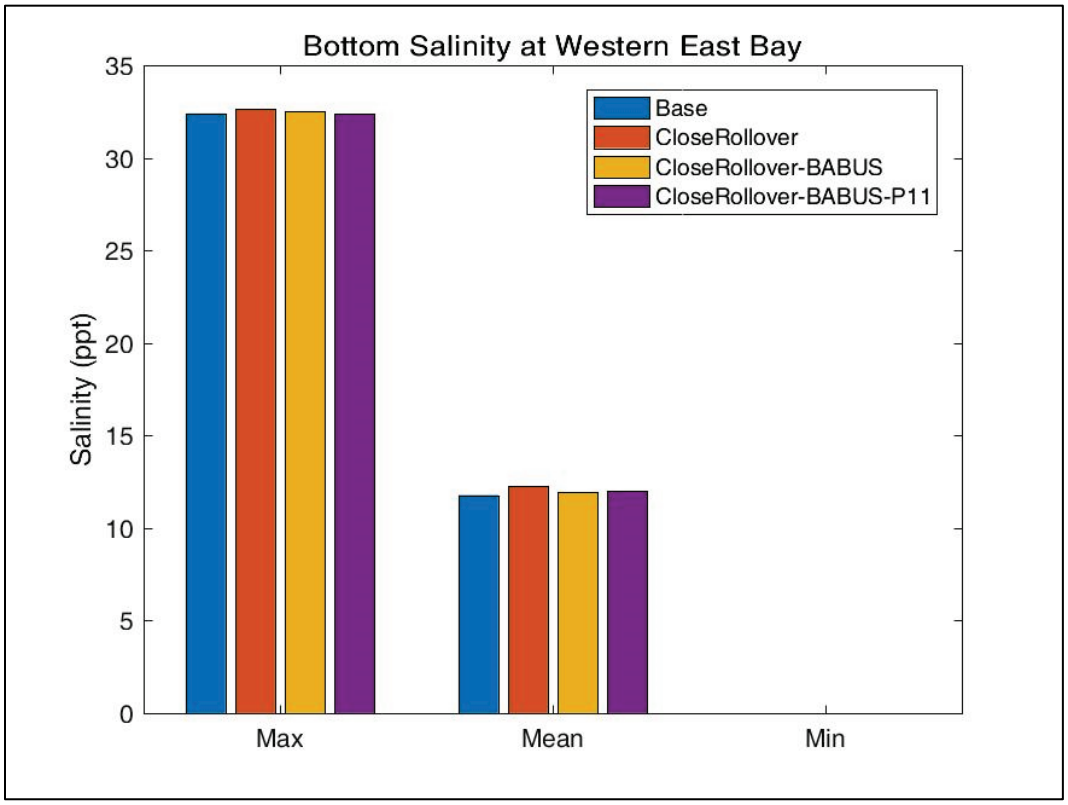

Bottom Salinity at Upper Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min

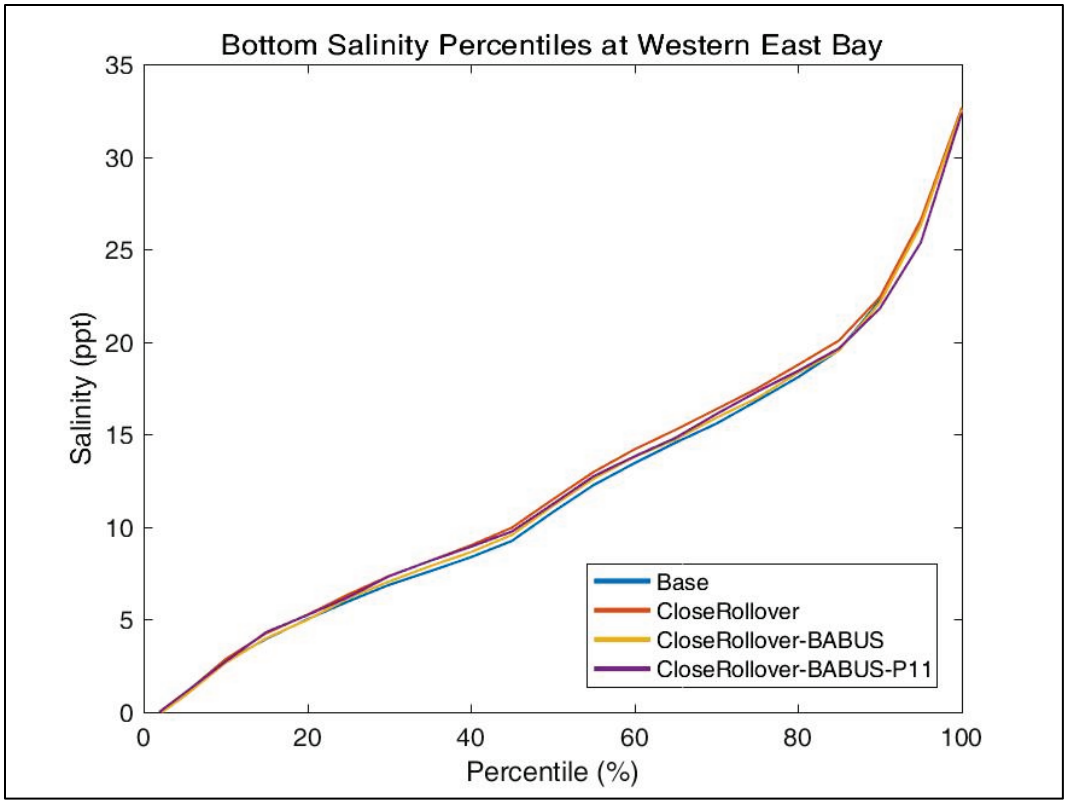

Bottom Salinity Percentiles at Upper Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
20
30
40
50
60
70
80
90
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

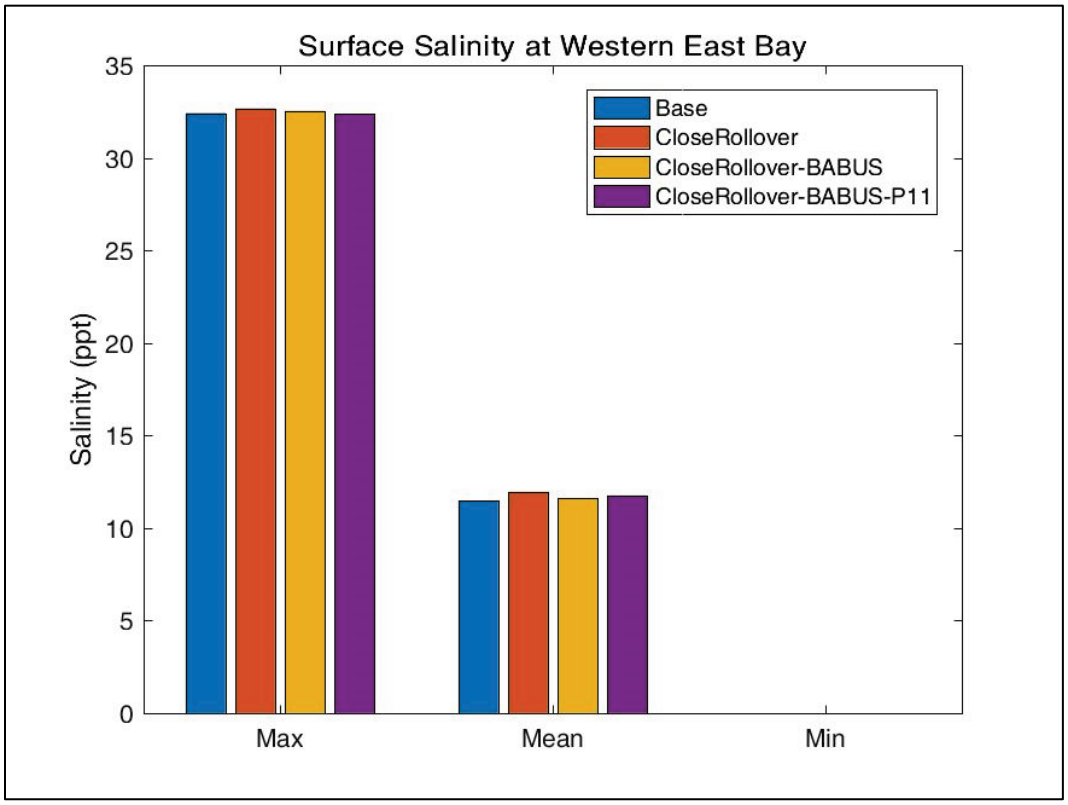

Surface Salinity at Upper Trinity Bay
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

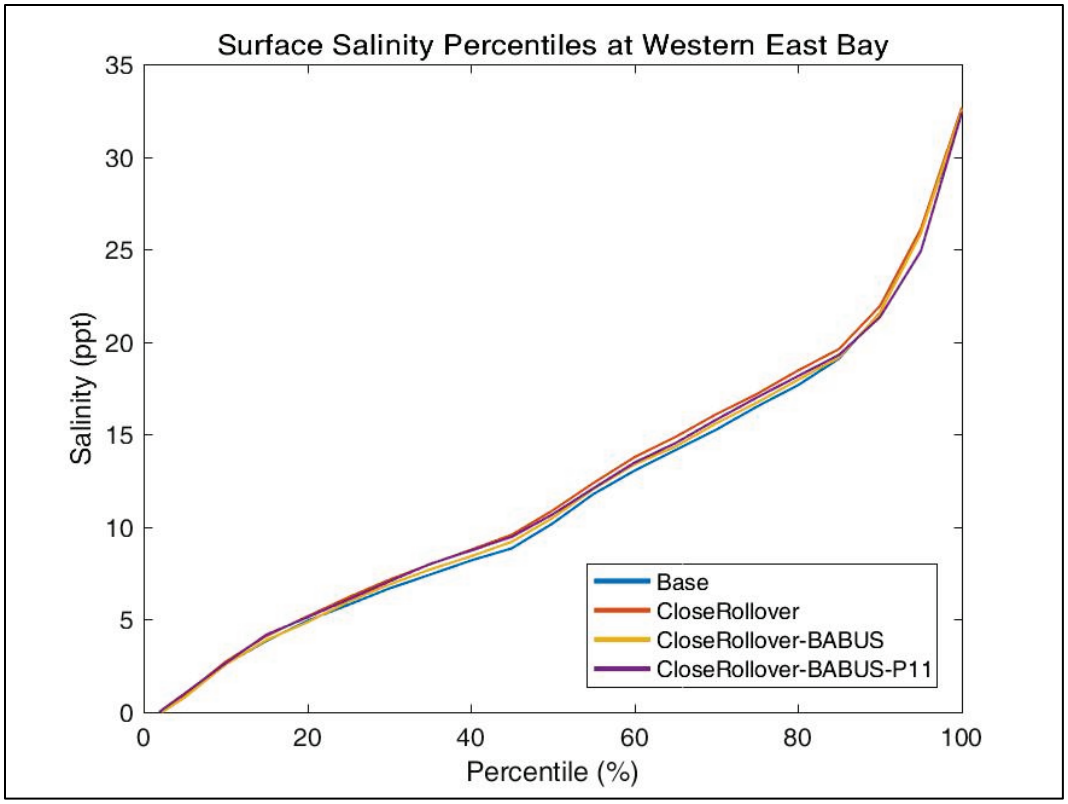

Surface Salinity Percentiles at Upper Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
20
30
40
50
60
70
80
90
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

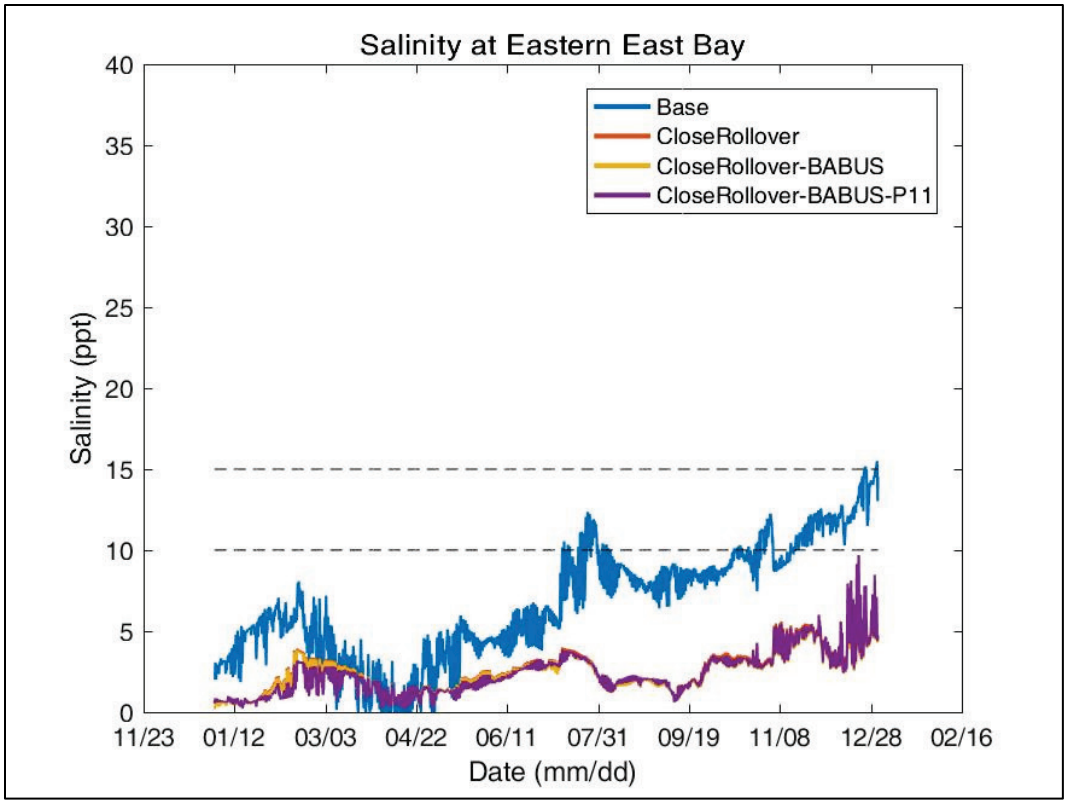

Salinity at Western East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

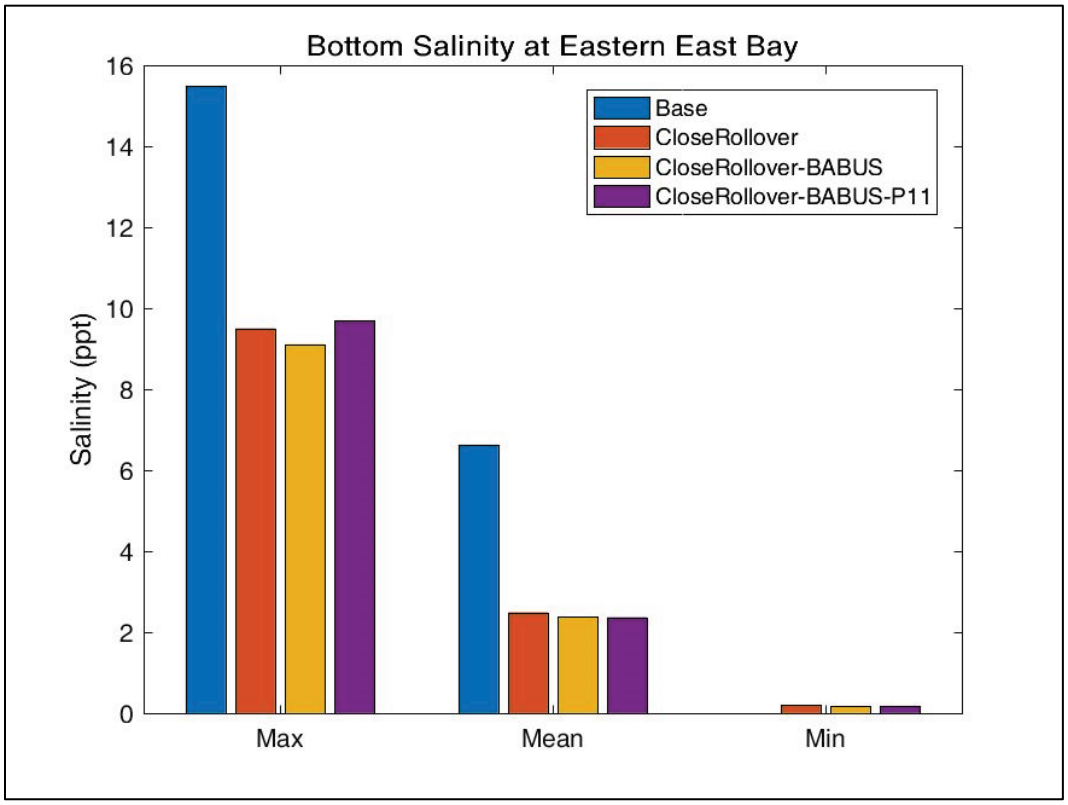

Bottom Salinity at Western East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

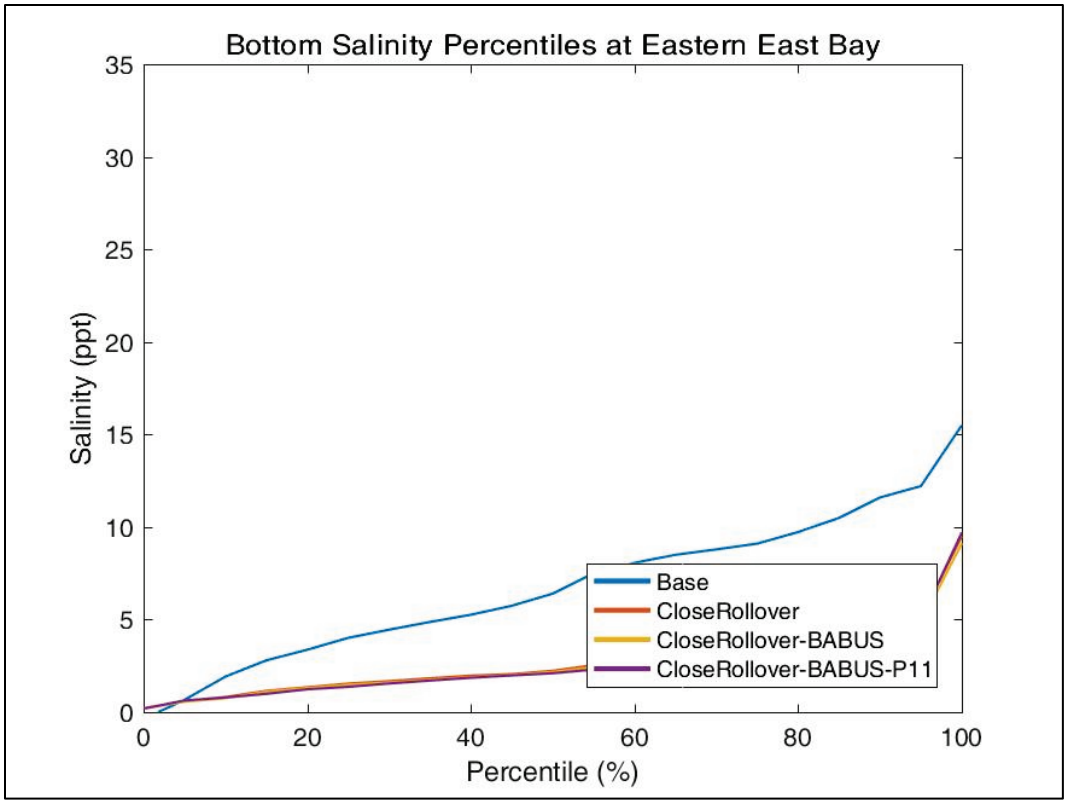

Bottom Salinity Percentiles at Western East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

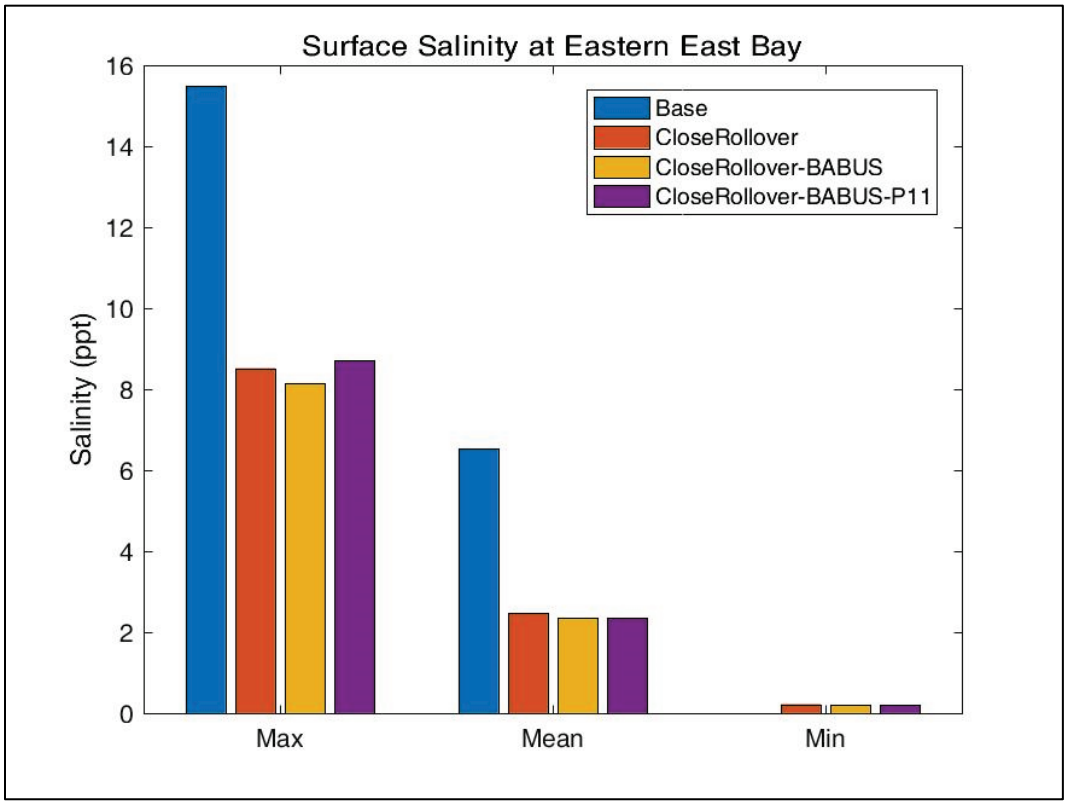

Surface Salinity at Western East Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

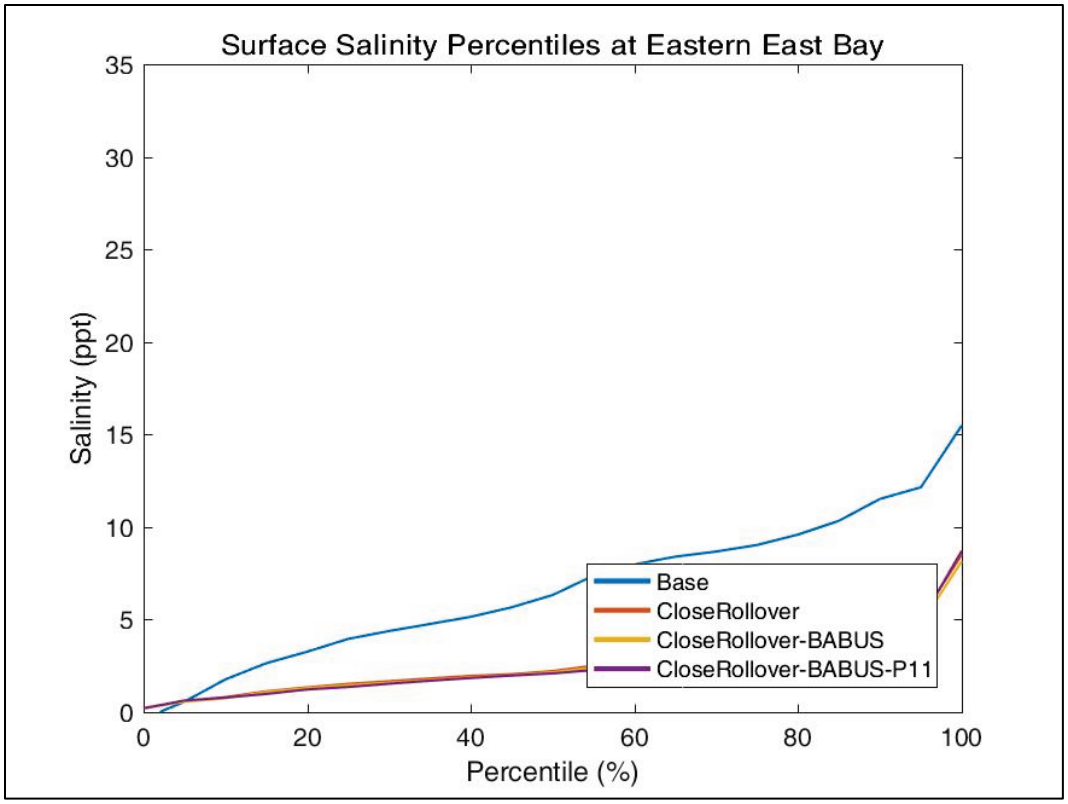

Surface Salinity Percentiles at Western East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

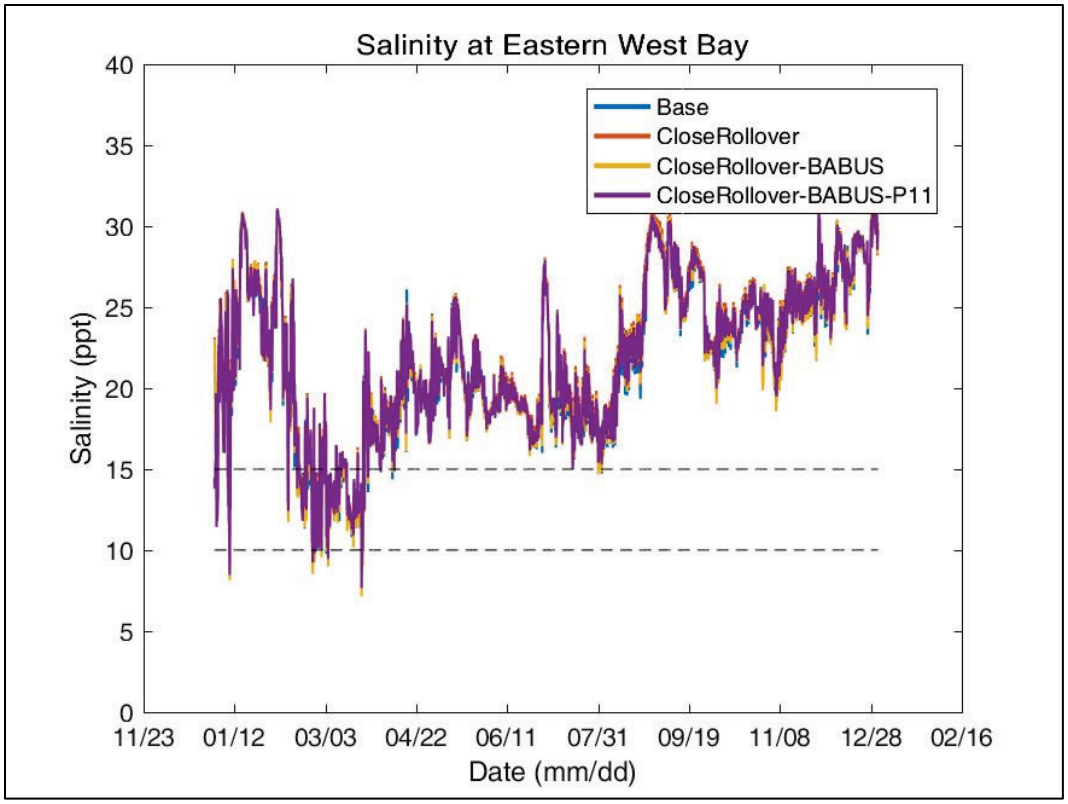

Salinity at Eastern East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

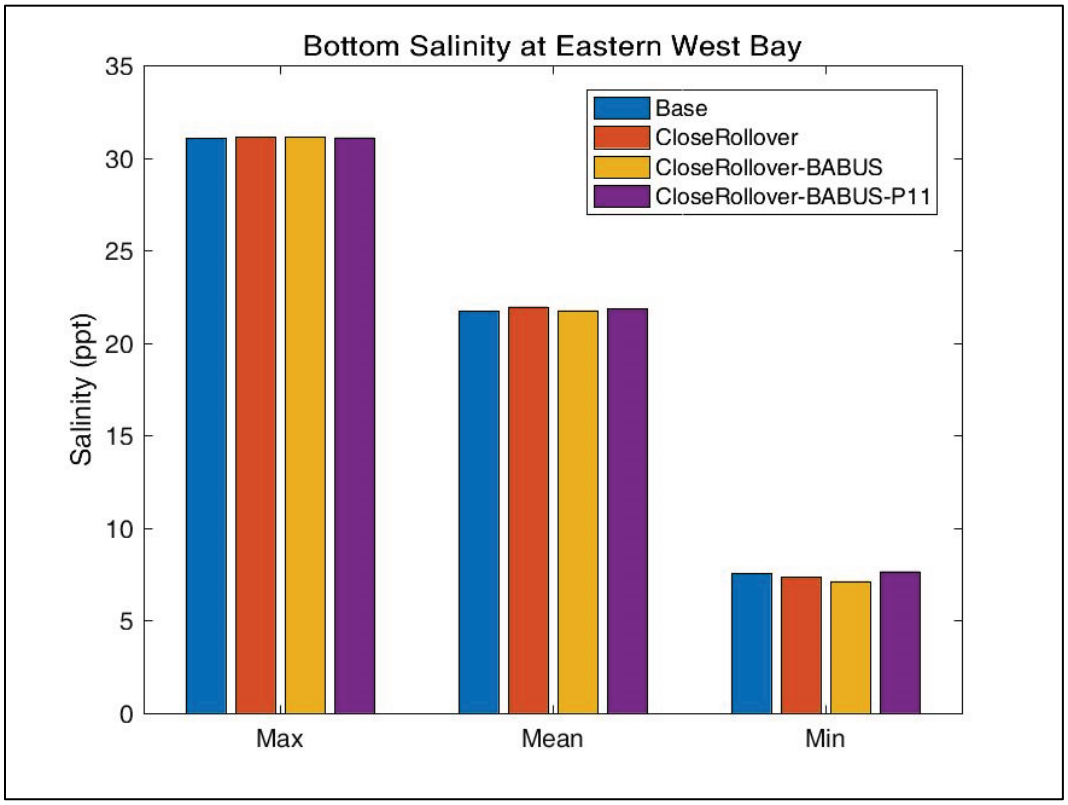

Bottom Salinity at Eastern East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
2
4
6
8
10
12
14
16
Max
Mean
Min

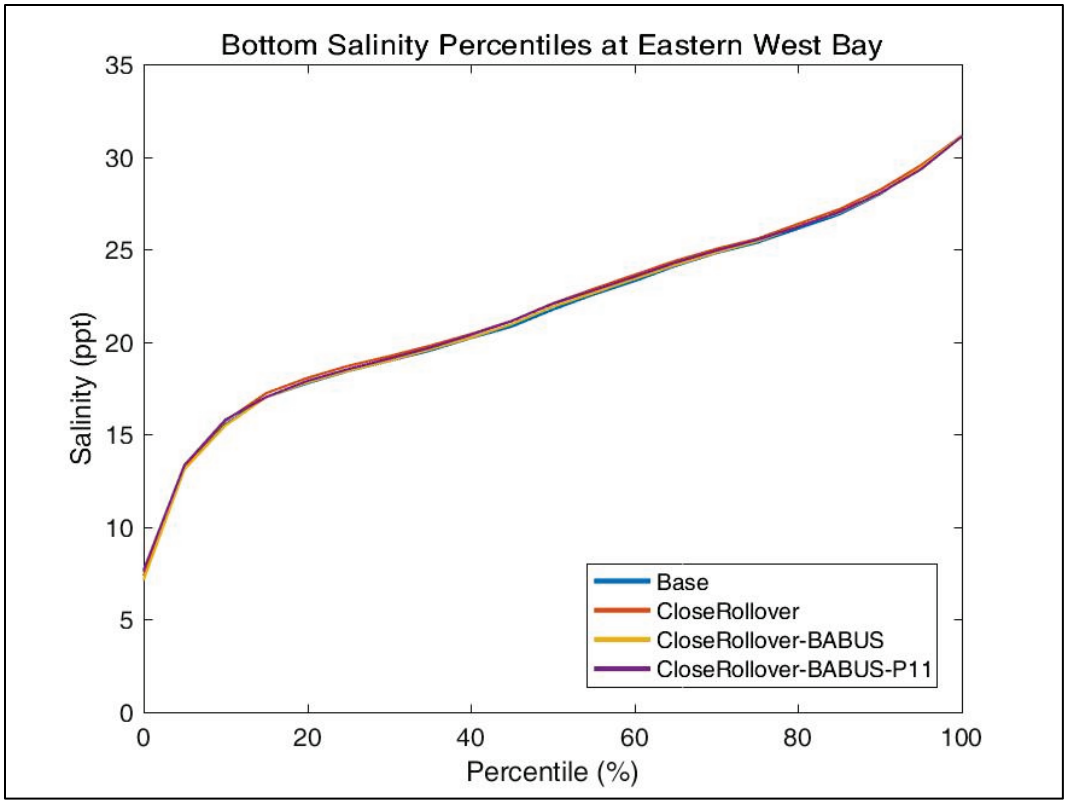

Bottom Salinity Percentiles at Eastern East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

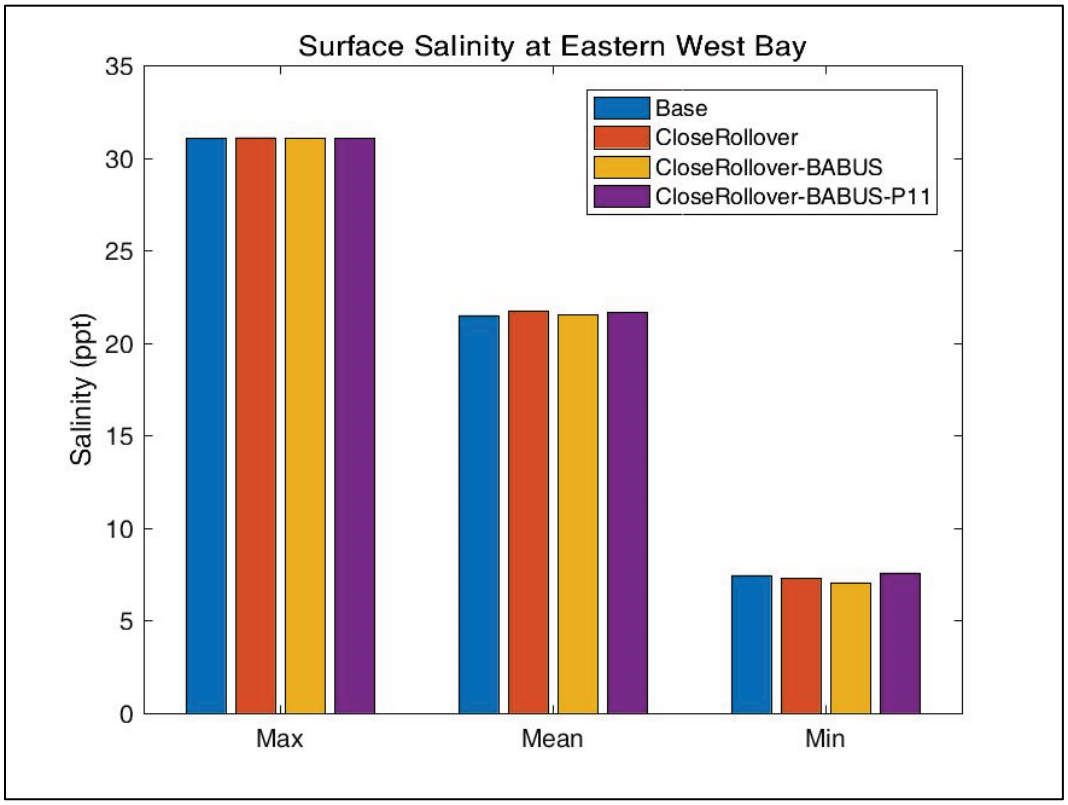

Surface Salinity at Eastern East Bay
Salinity (ppt)
0
2
4
6
8
10
12
14
16
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

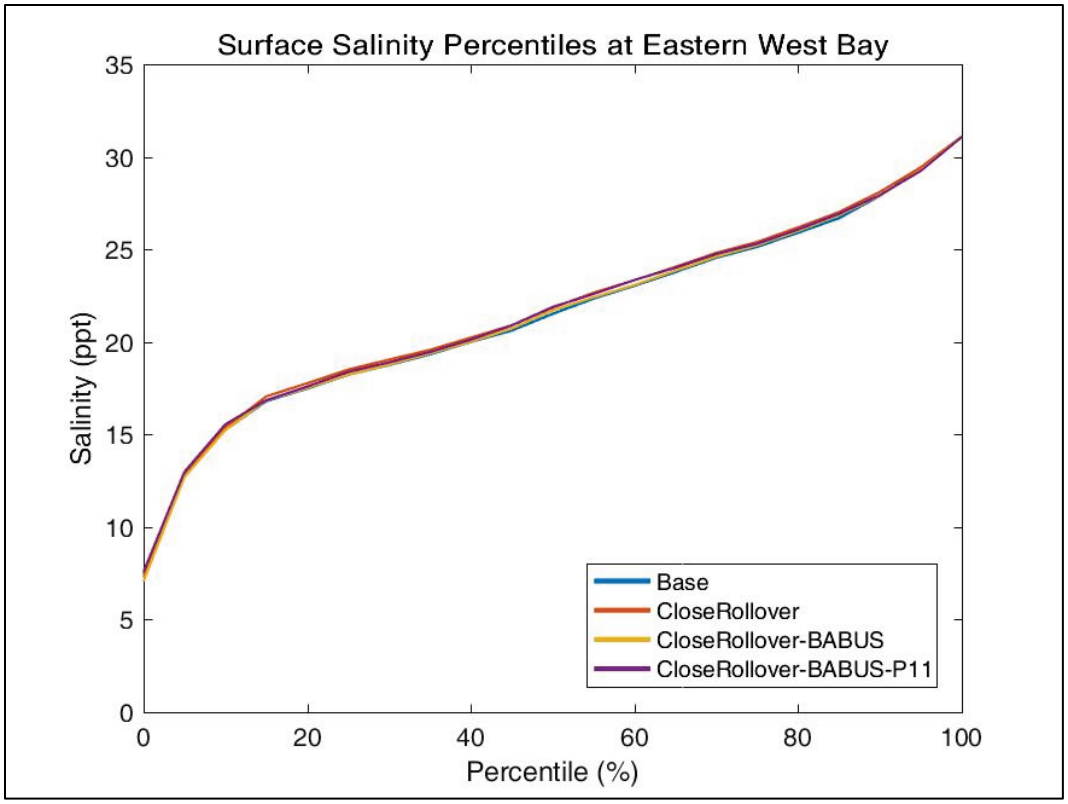

Surface Salinity Percentiles at Eastern East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

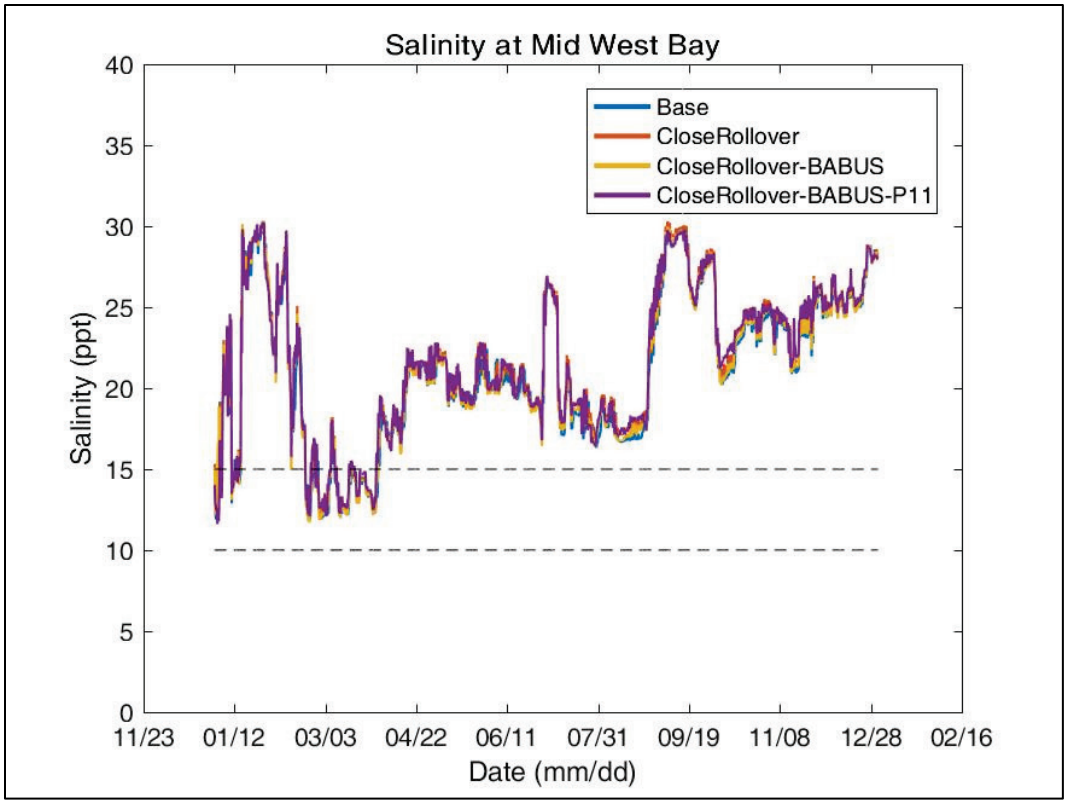

Salinity at Eastern West Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

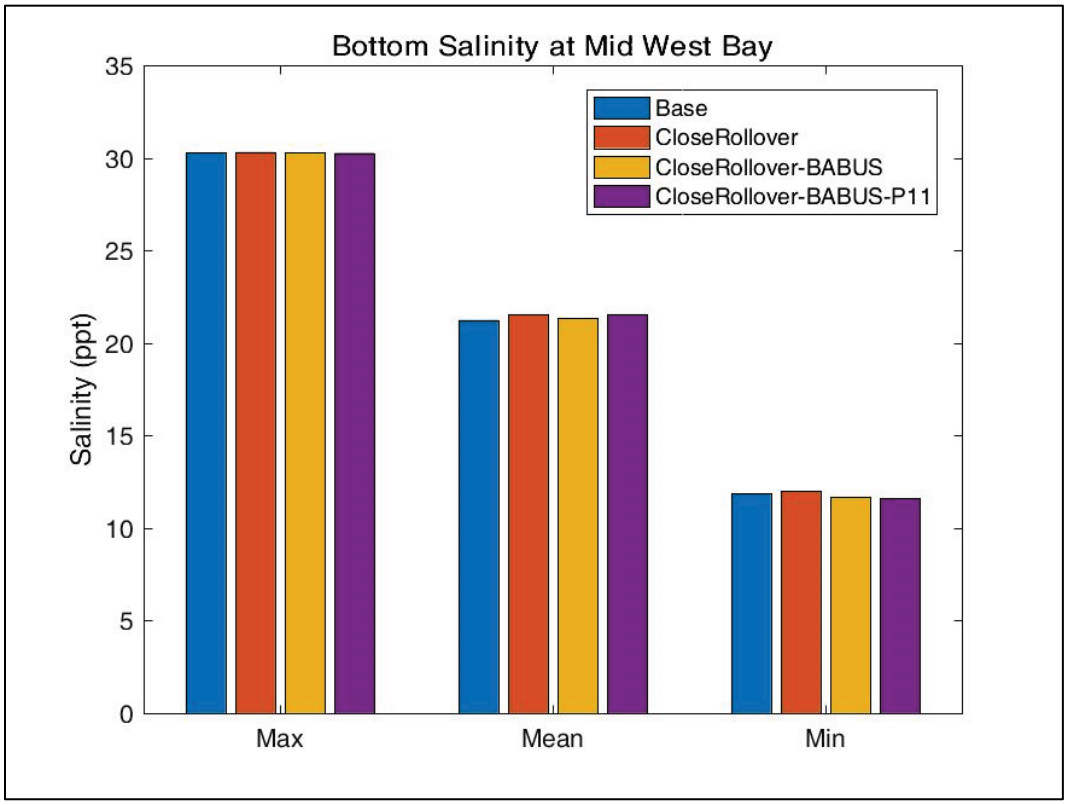

Bottom Salinity at Eastern West Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

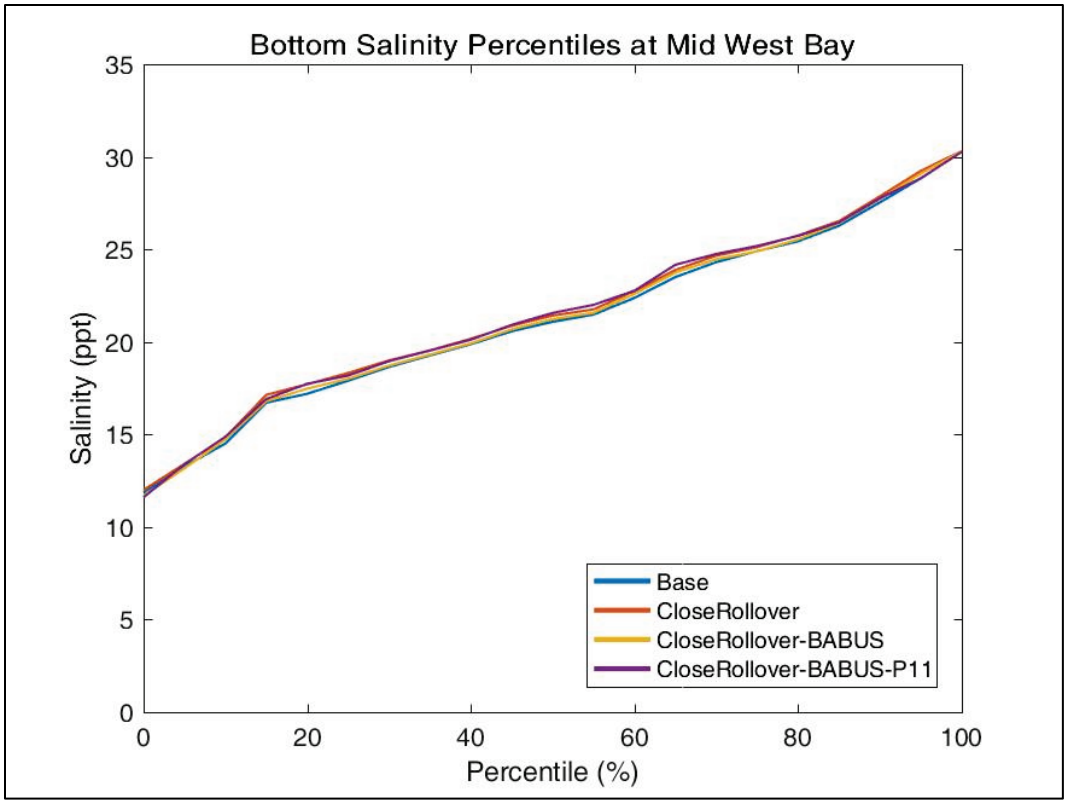

Bottom Salinity Percentiles at Eastern West Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

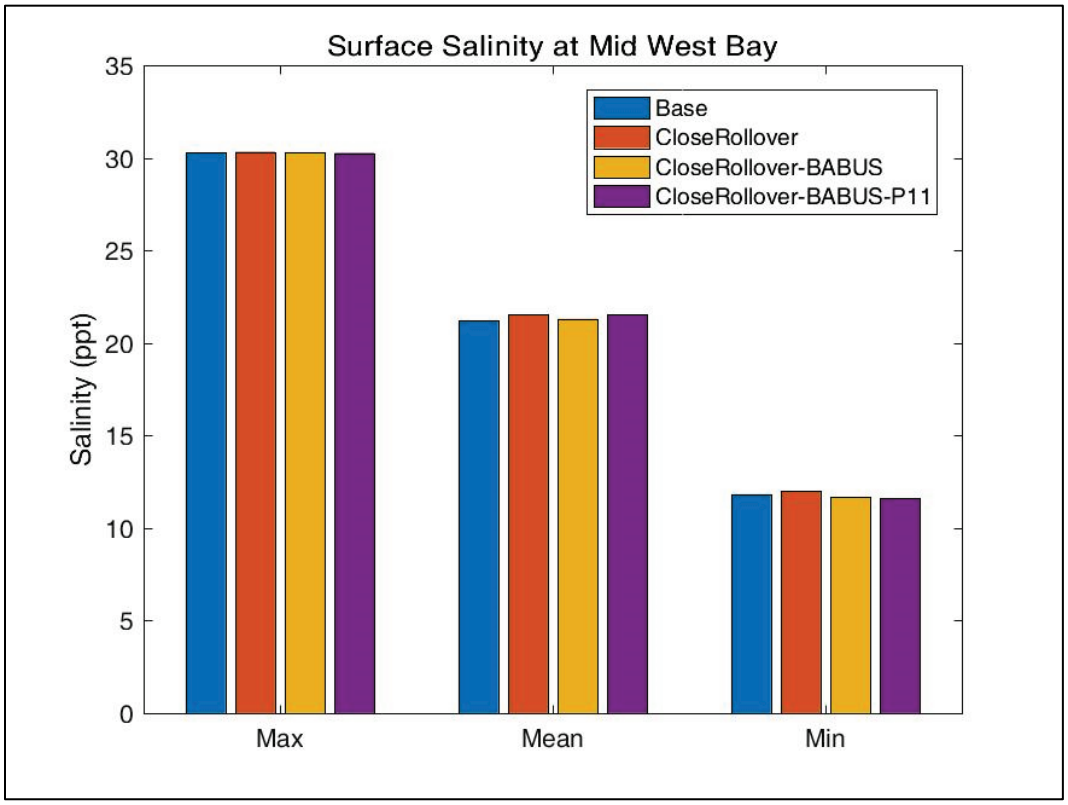

Surface Salinity at Eastern West Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

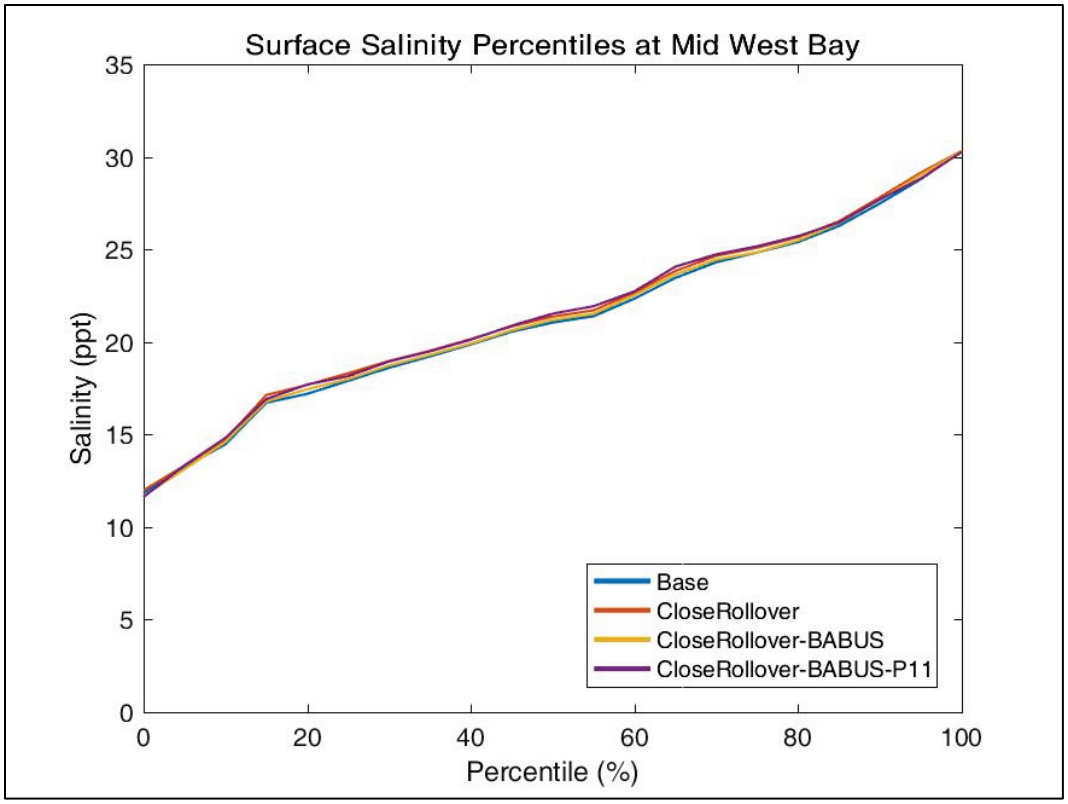

Surface Salinity Percentiles at Eastern West Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

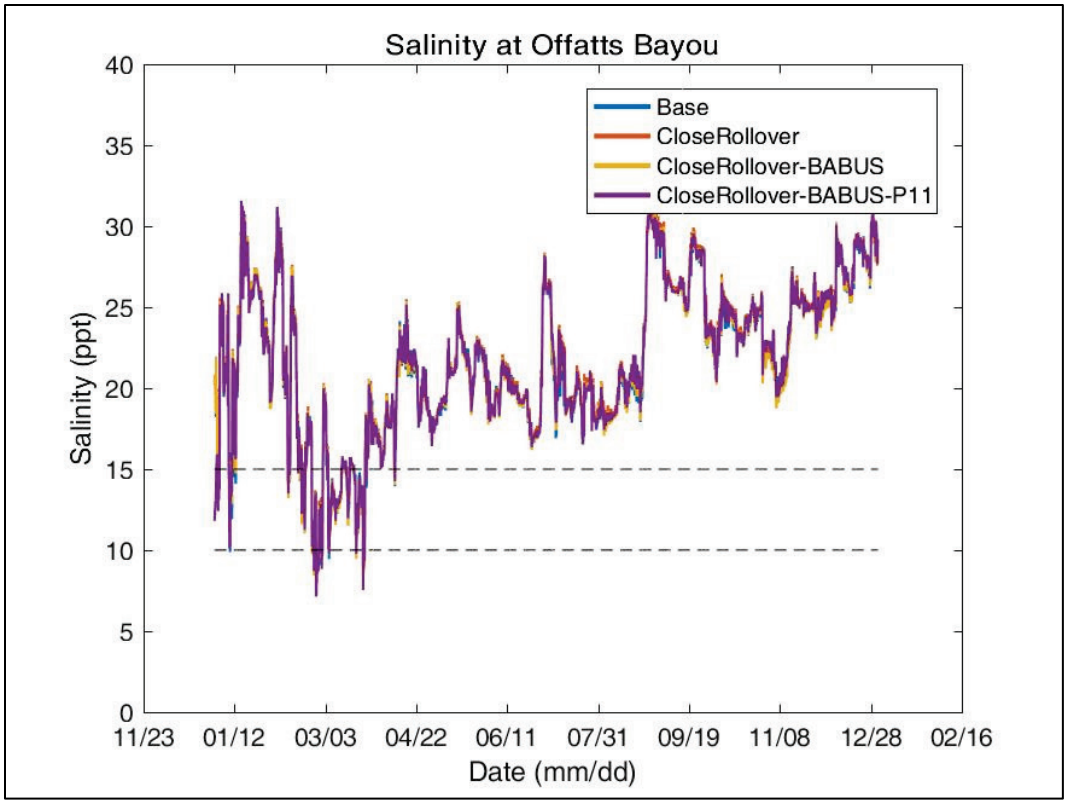

Salinity at Mid West Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

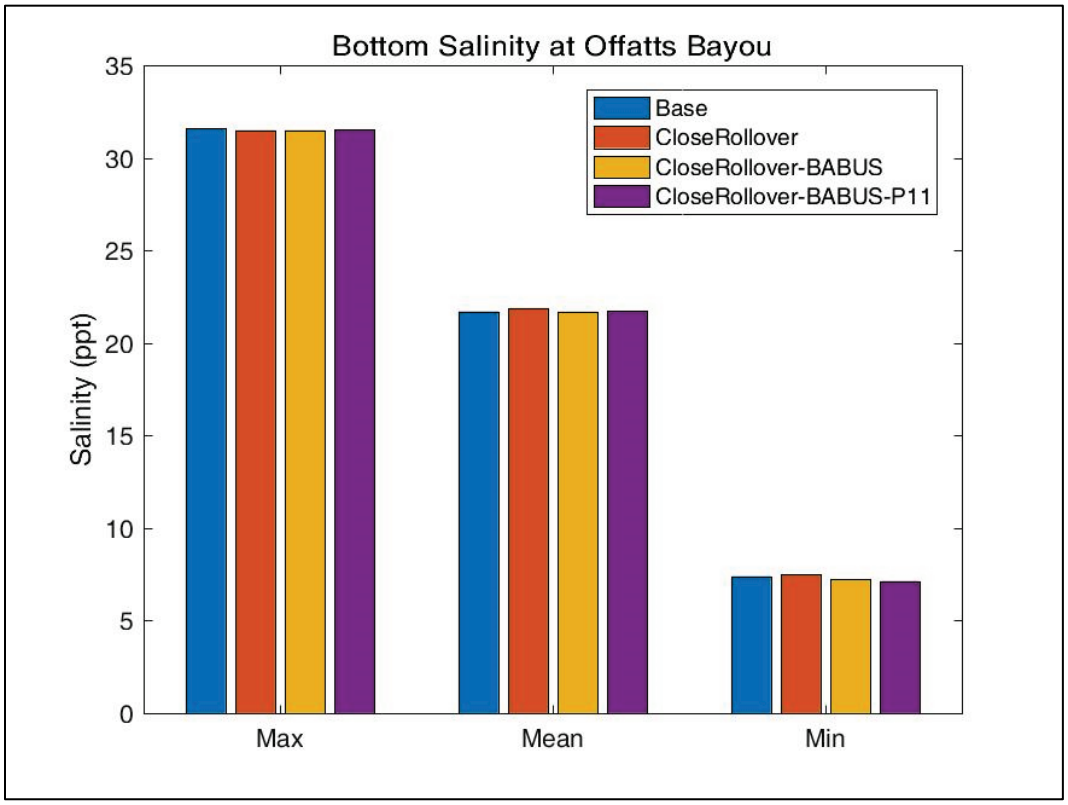

Bottom Salinity at Mid West Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

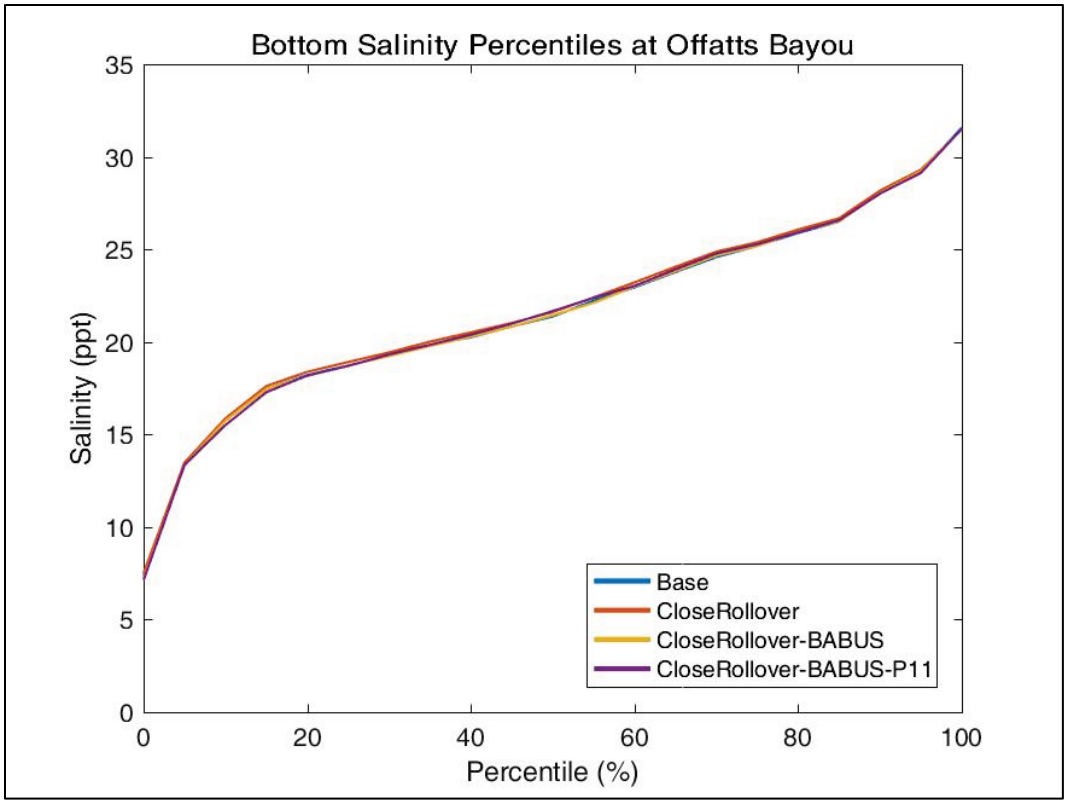

Bottom Salinity Percentiles at Mid West Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

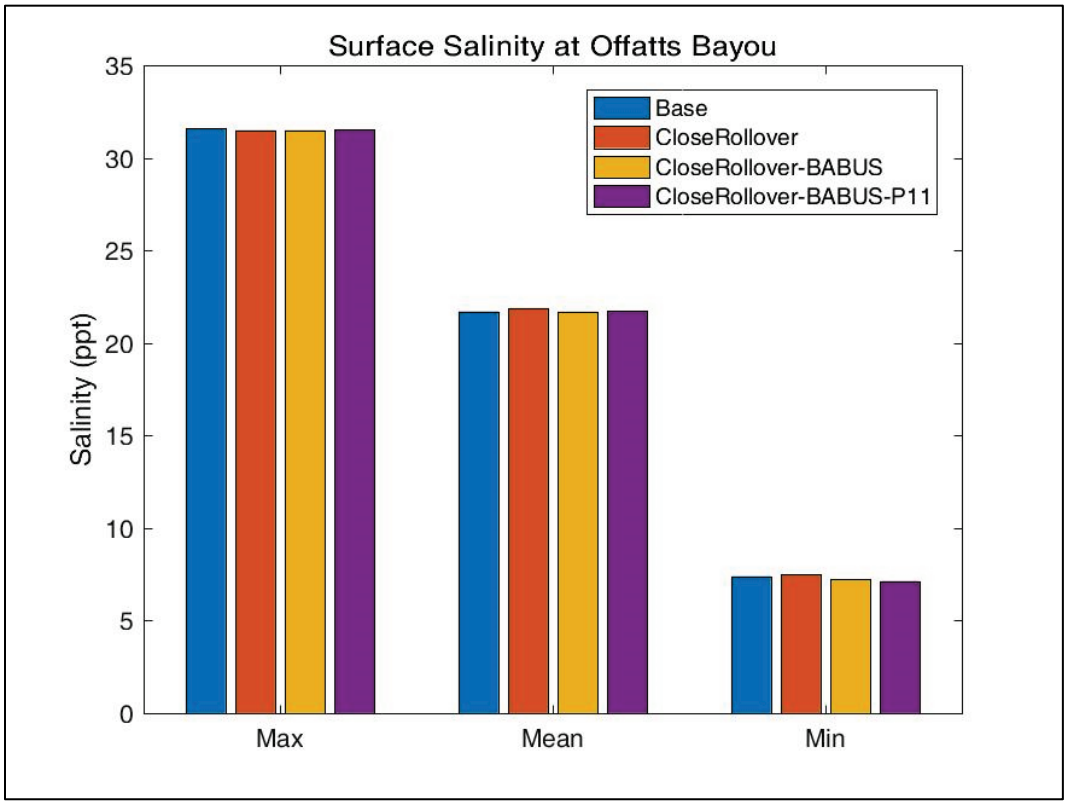

Surface Salinity at Mid West Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

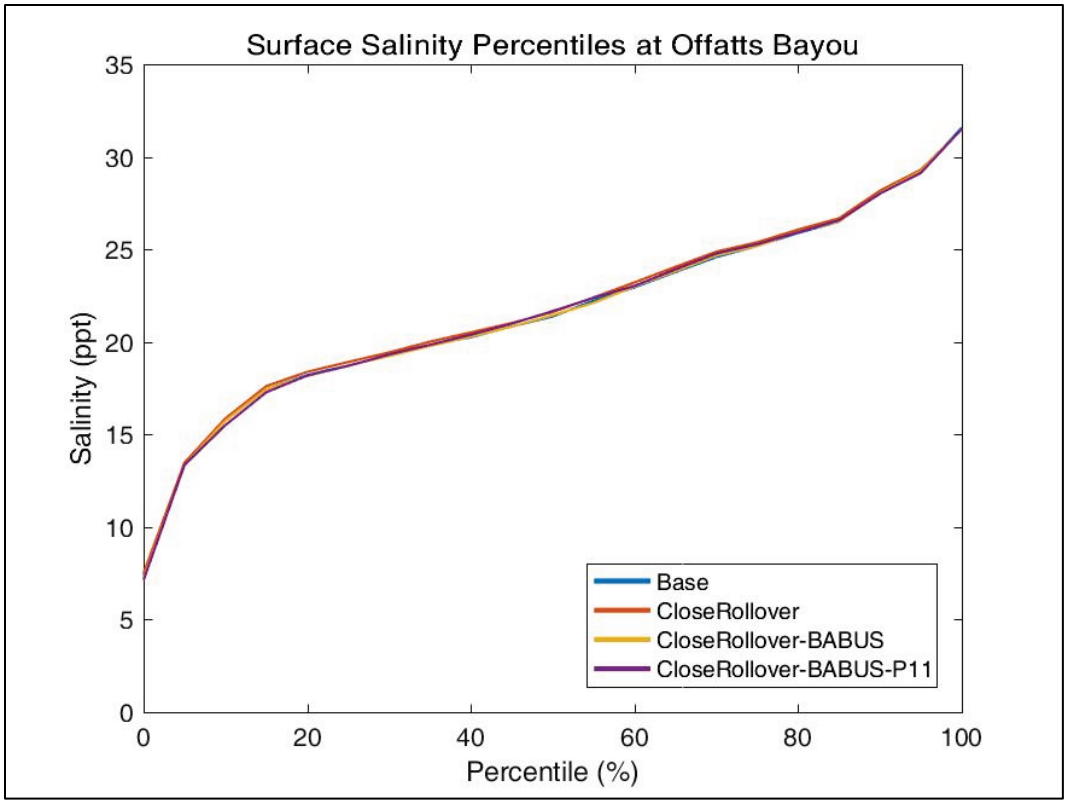

Surface Salinity Percentiles at Mid West Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

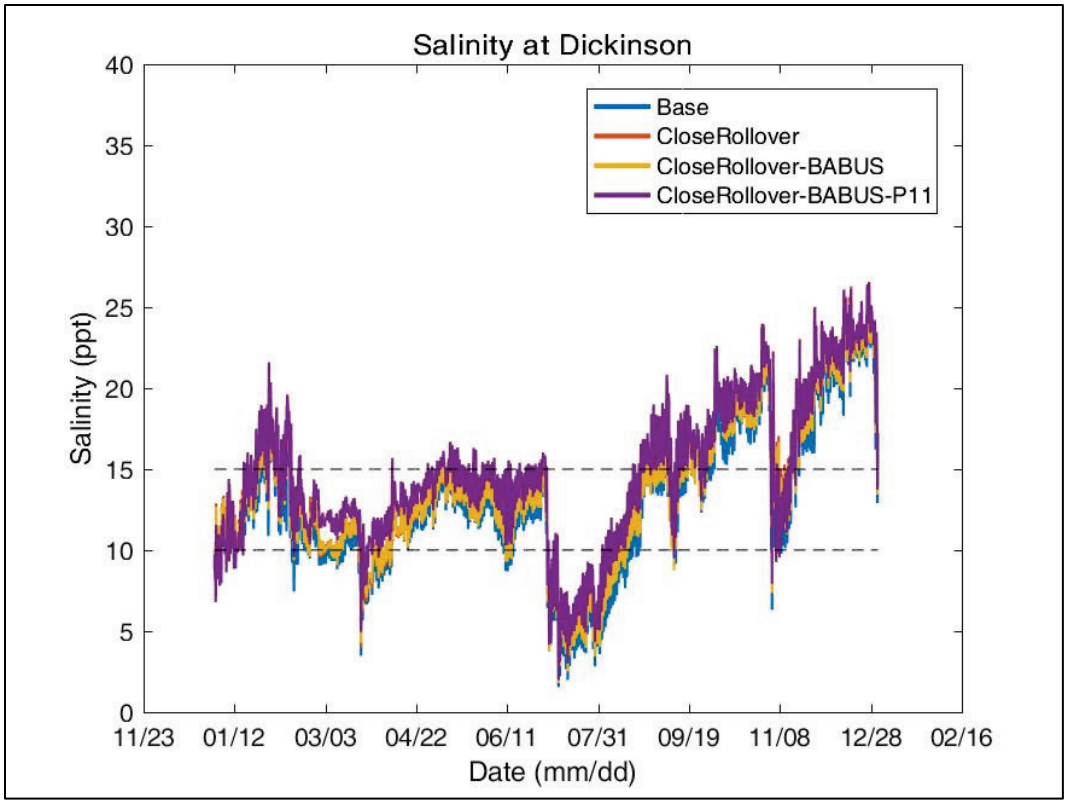

Salinity at Offatts Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

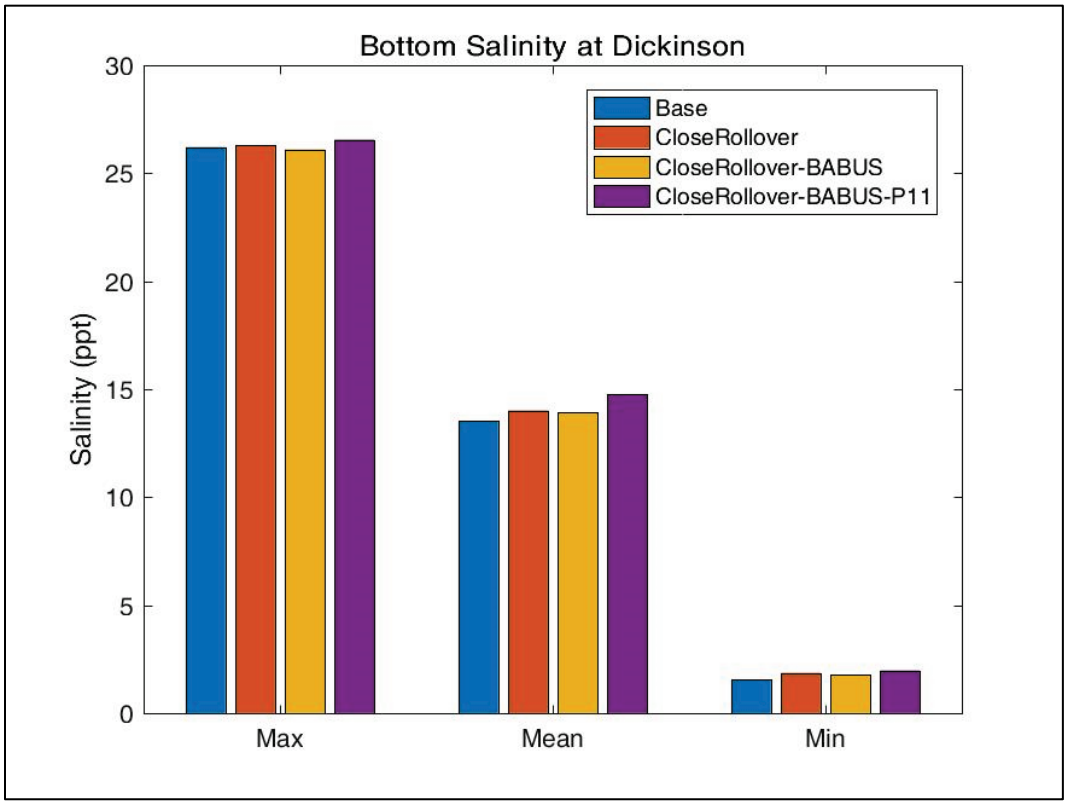

Bottom Salinity at Offatts Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

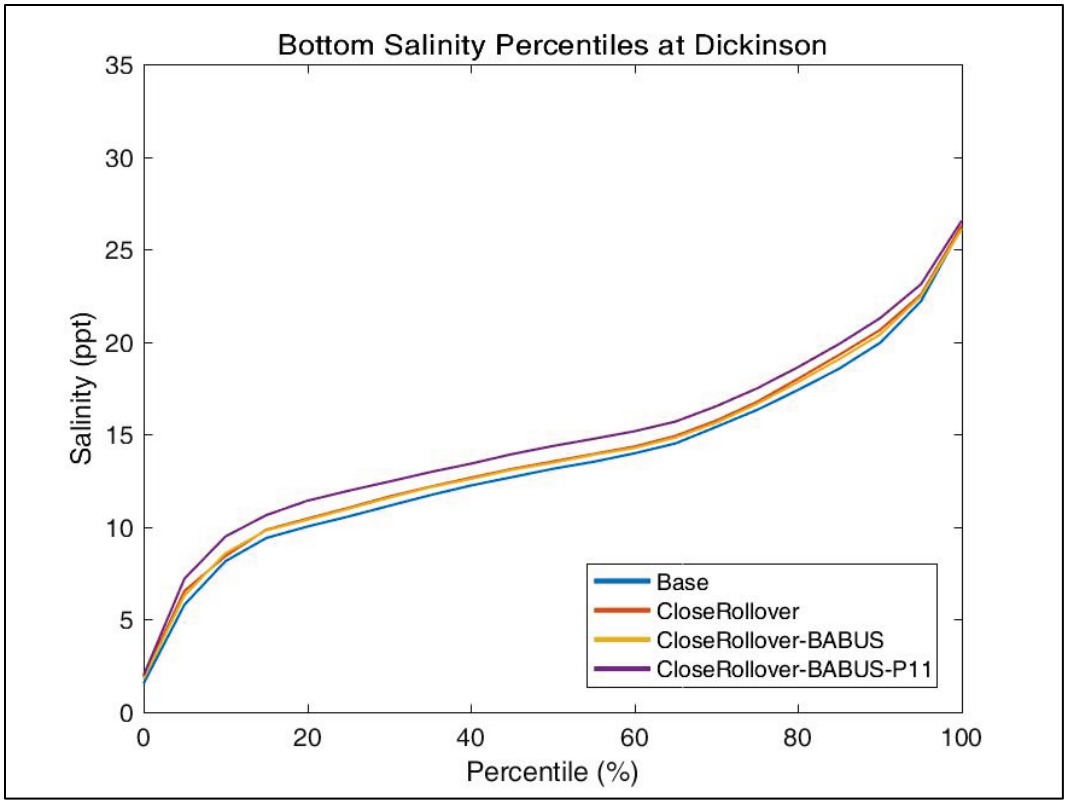

Bottom Salinity Percentiles at Offatts Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

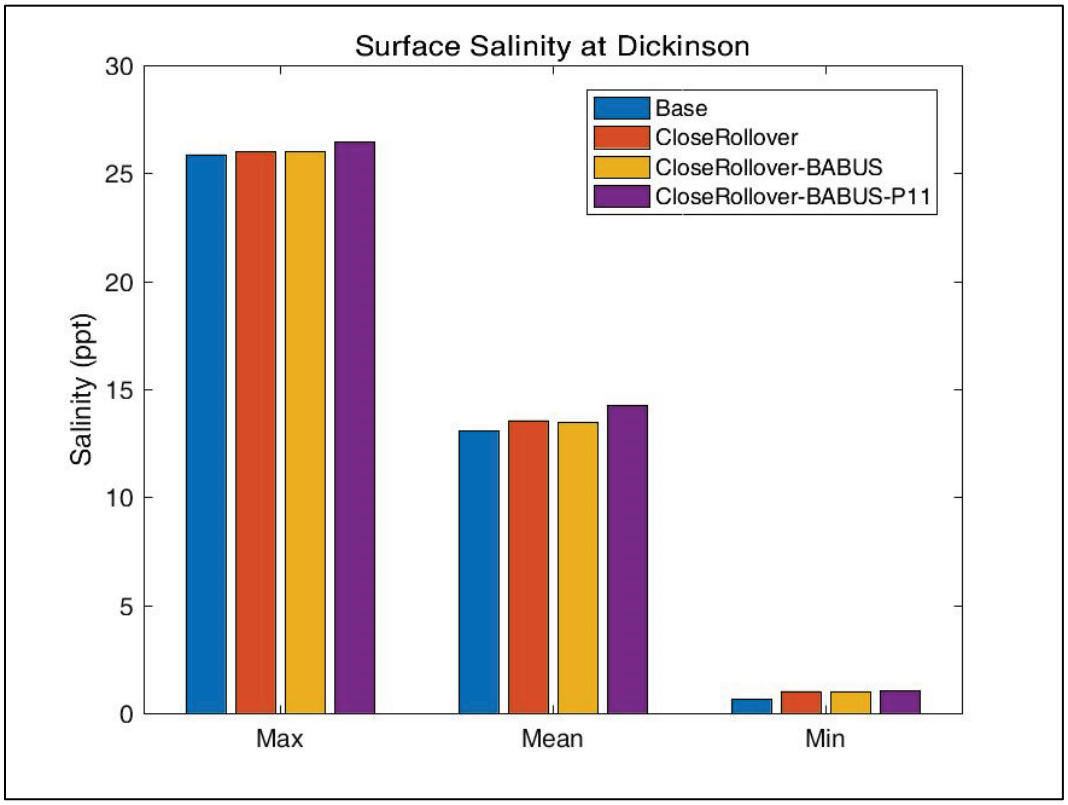

Surface Salinity at Offatts Bayou
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

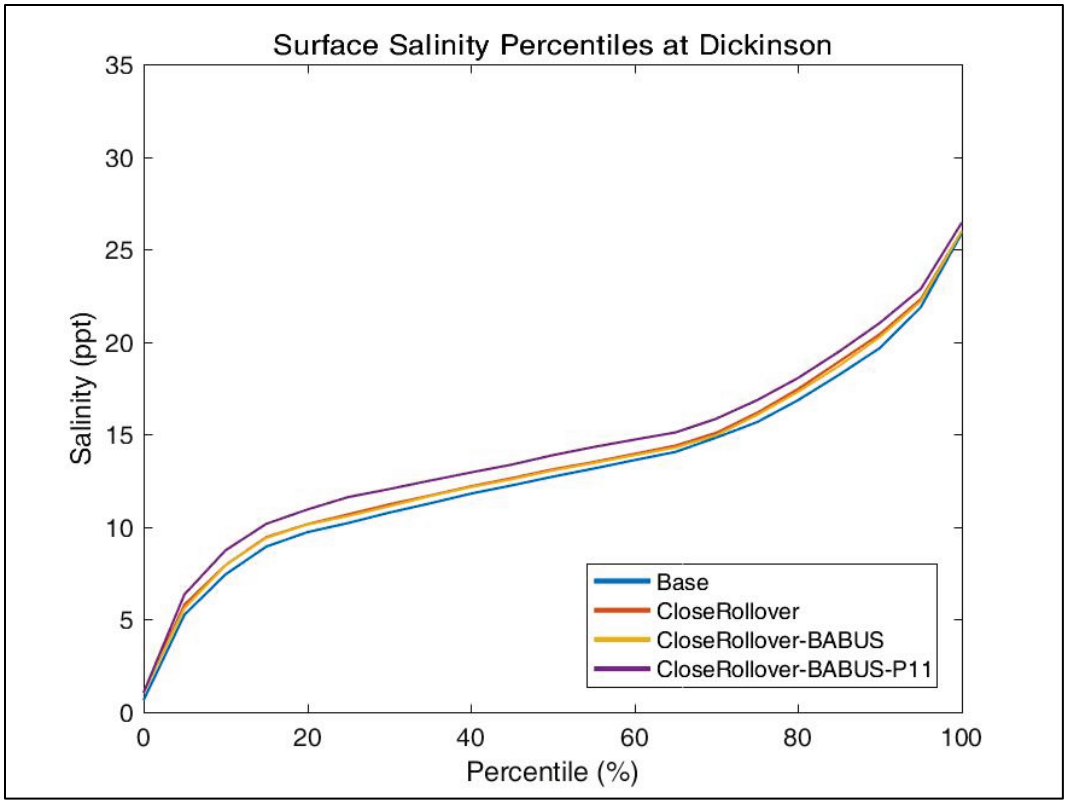

Surface Salinity Percentiles at Offatts Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

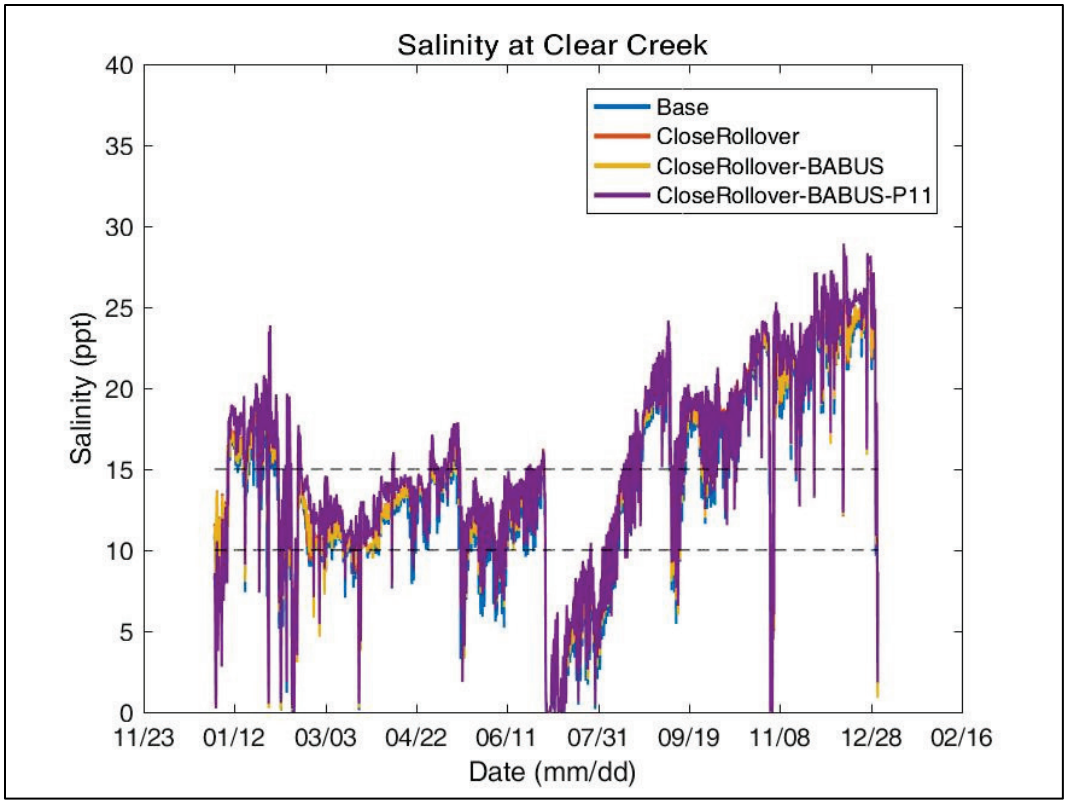

Salinity at Dickinson
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

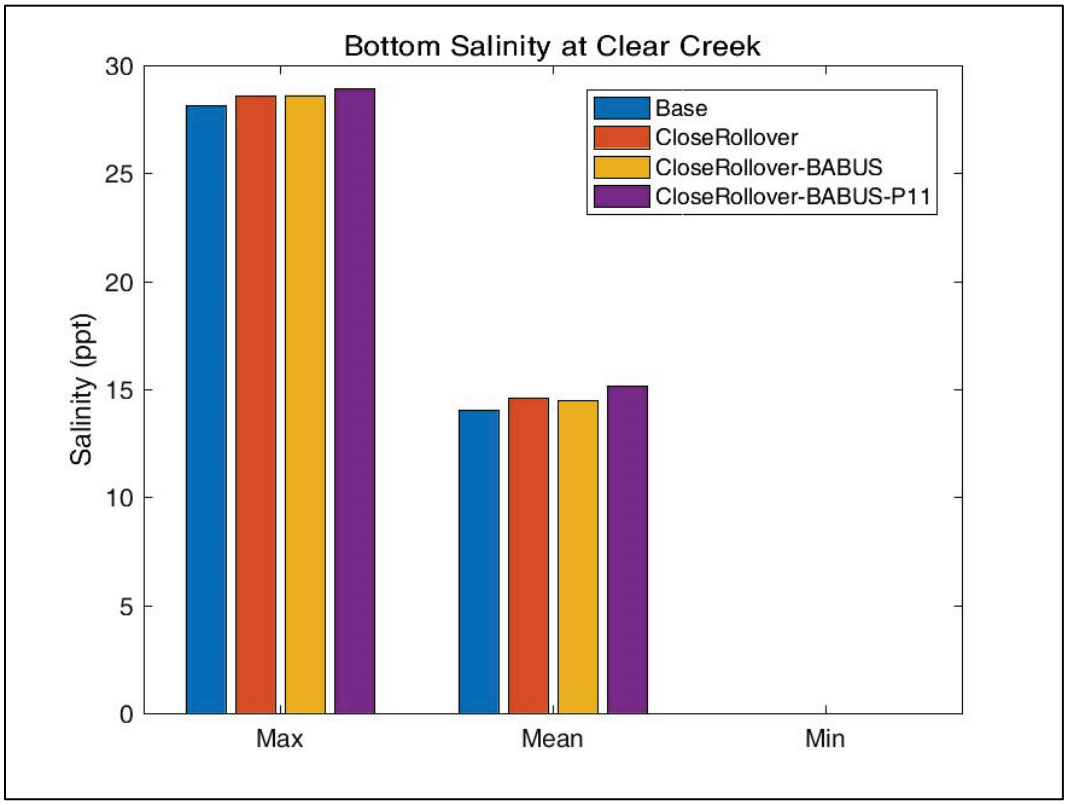

Bottom Salinity at Dickinson
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

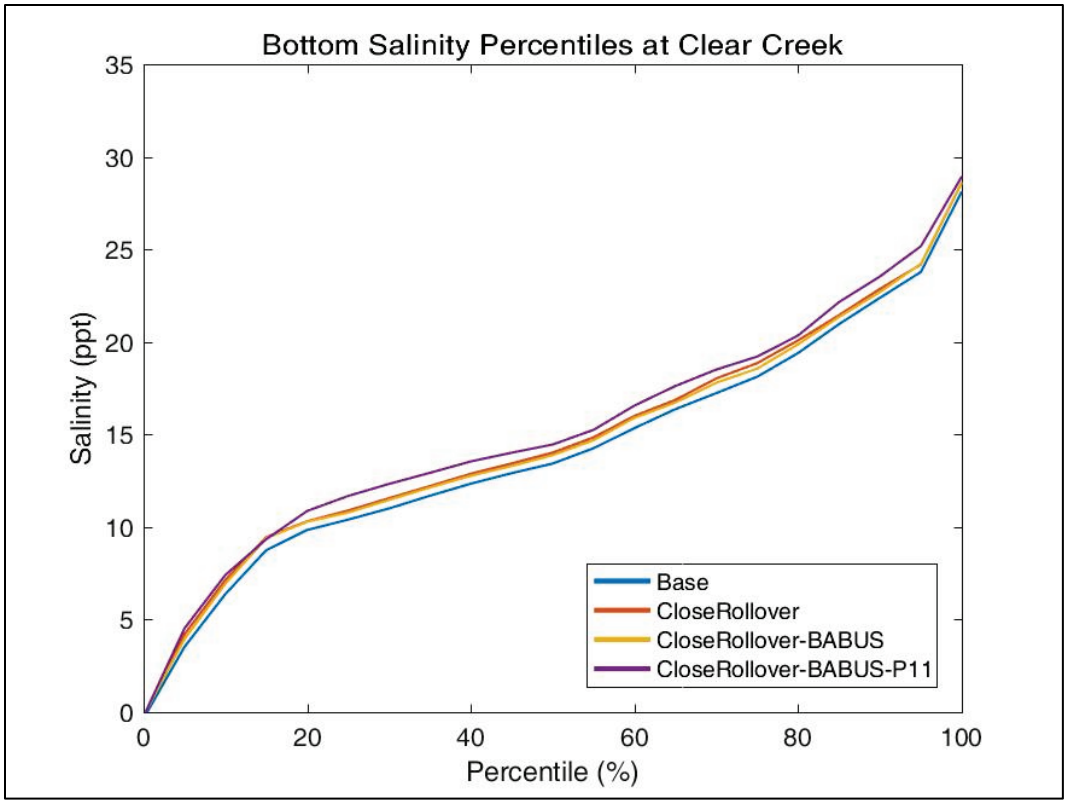

Bottom Salinity Percentiles at Dickinson
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

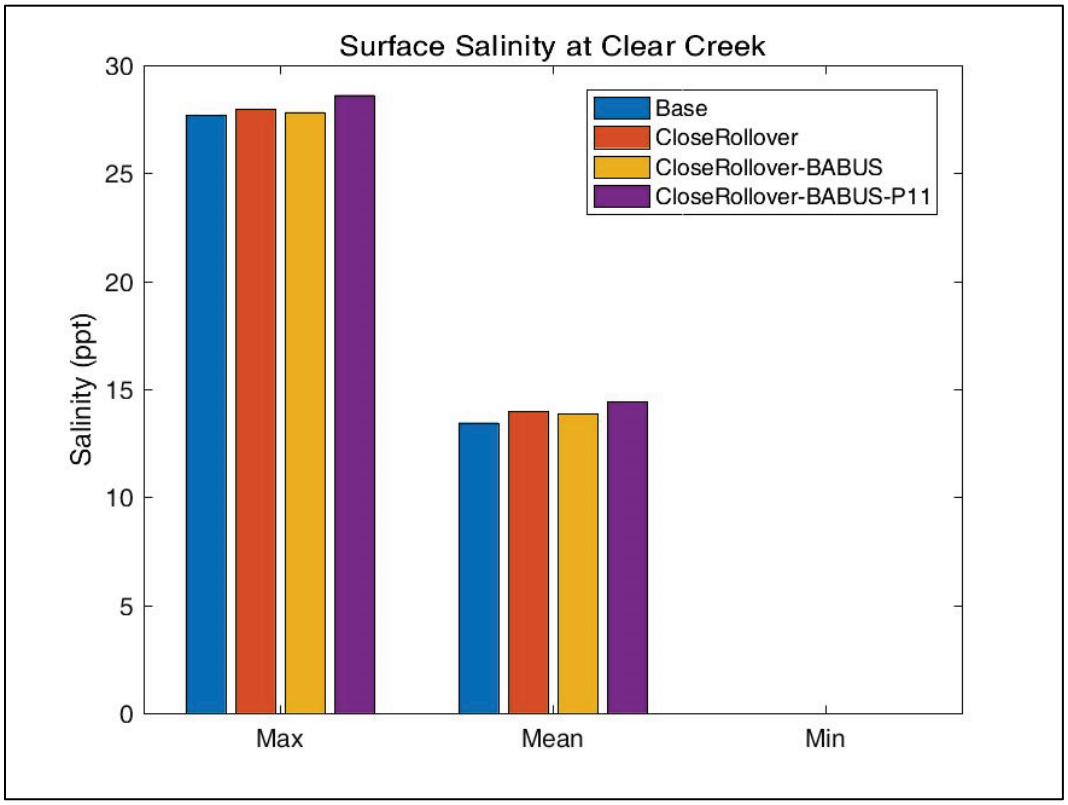

Surface Salinity at Dickinson
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

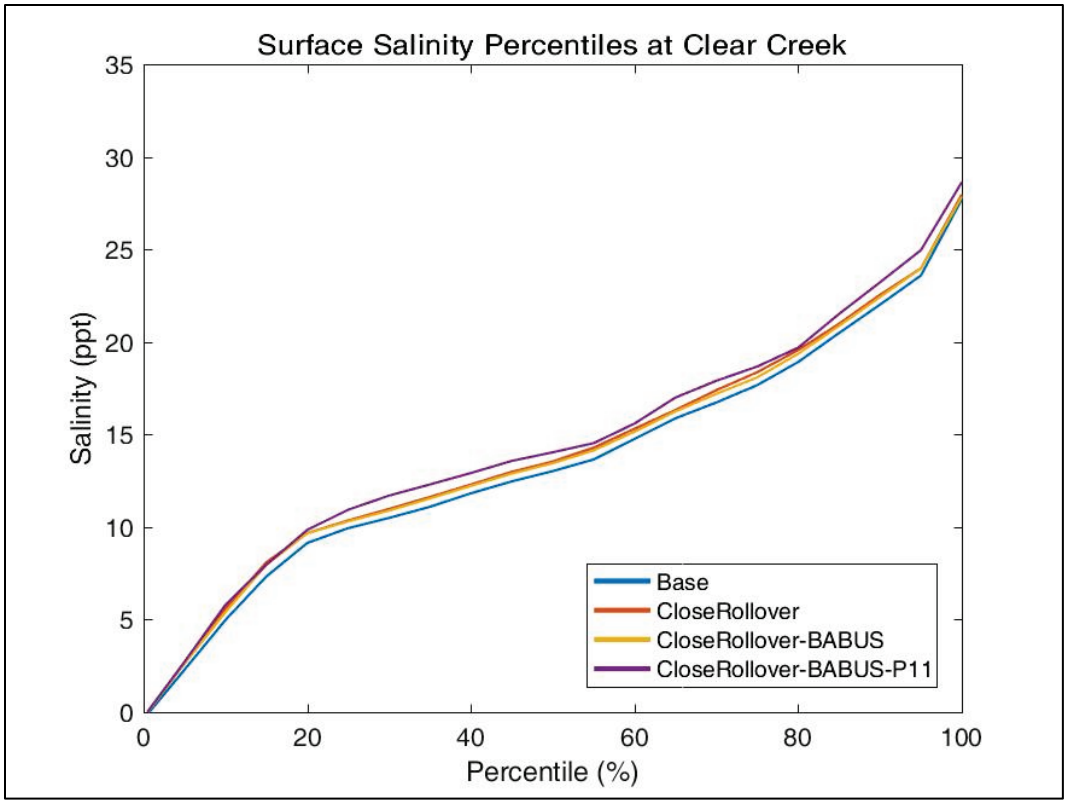

Surface Salinity Percentiles at Dickinson
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

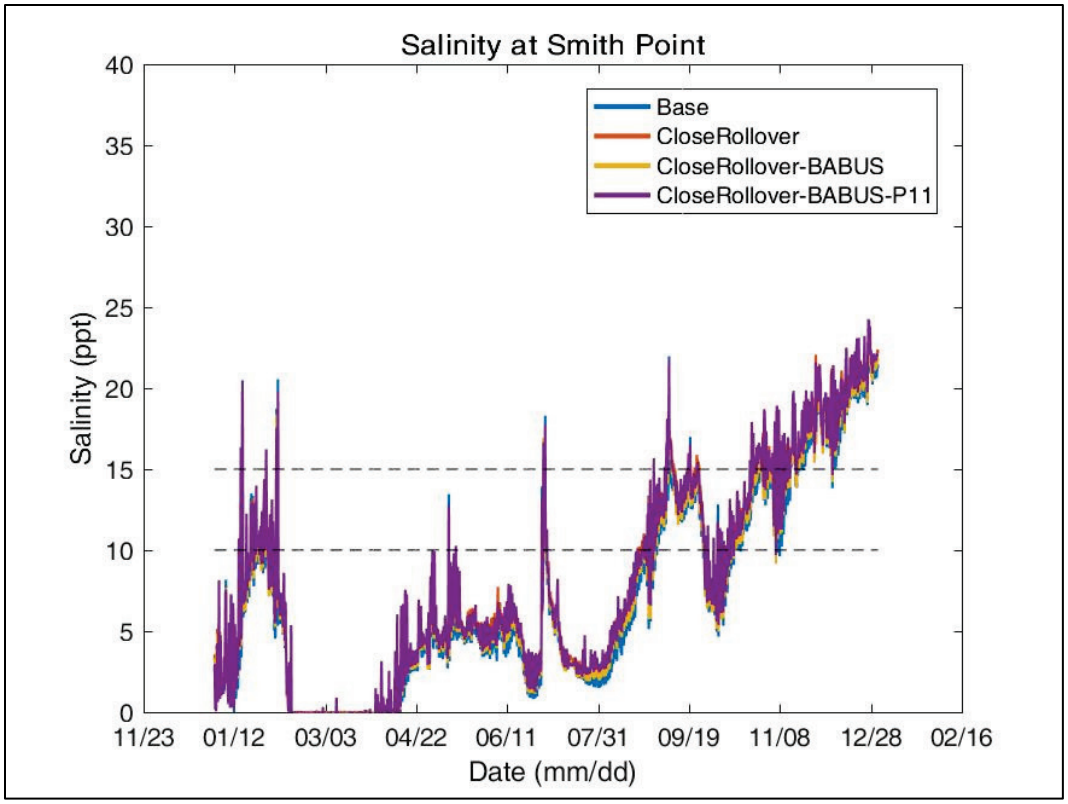

Salinity at Clear Creek
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

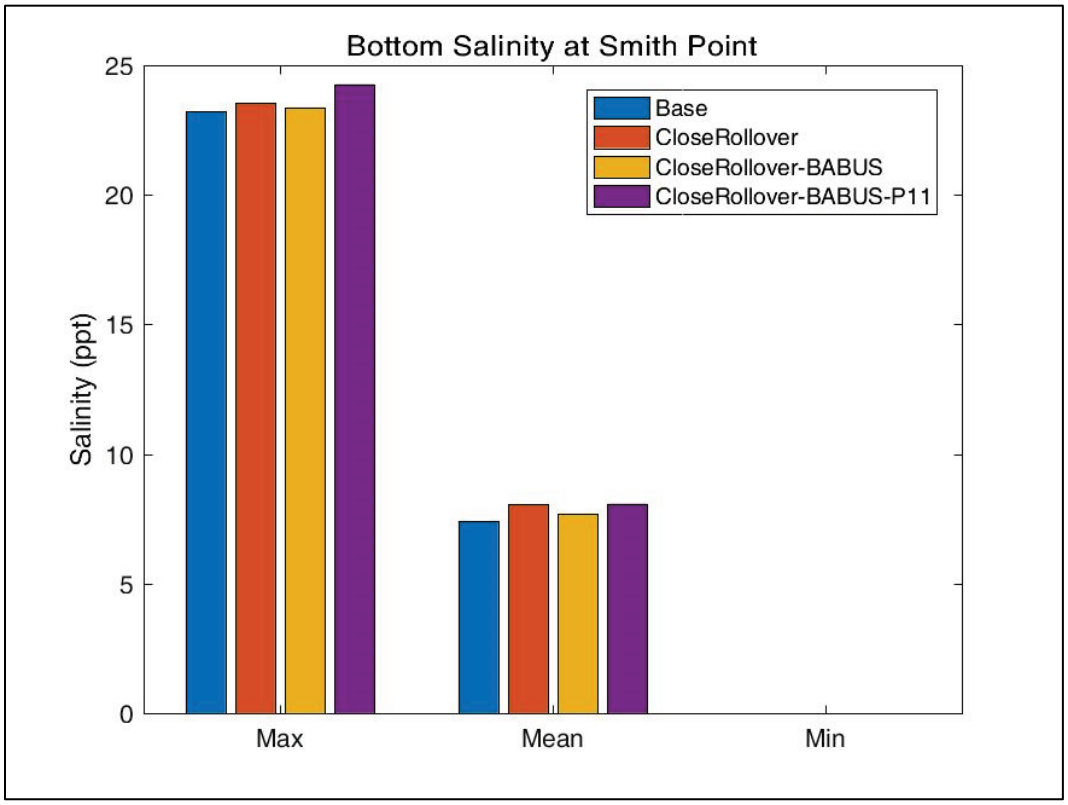

Bottom Salinity at Clear Creek
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

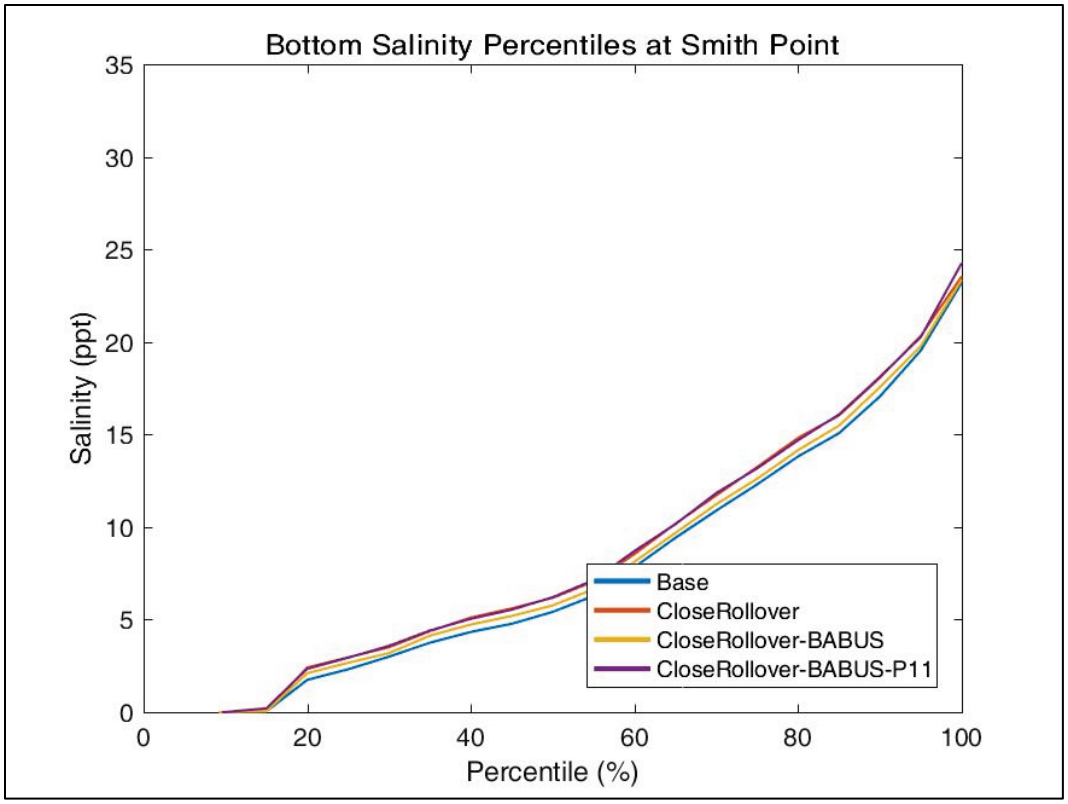

Bottom Salinity Percentiles at Clear Creek
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

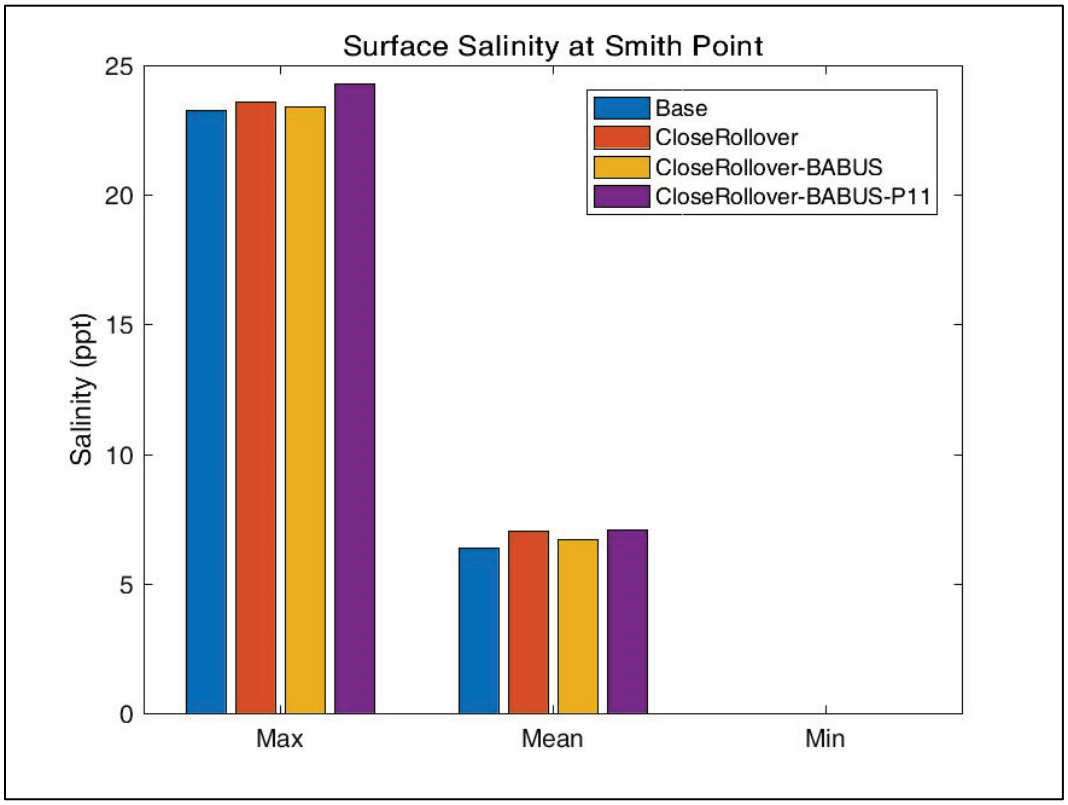

Surface Salinity at Clear Creek
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

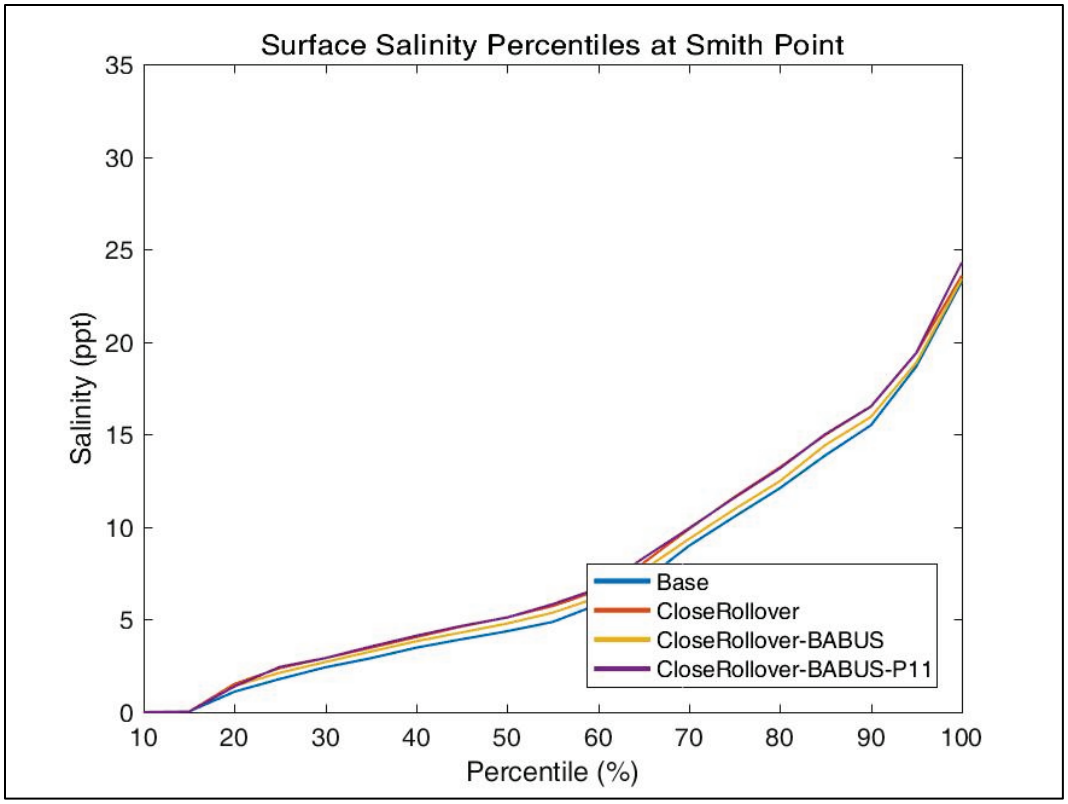

Surface Salinity Percentiles at Clear Creek
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

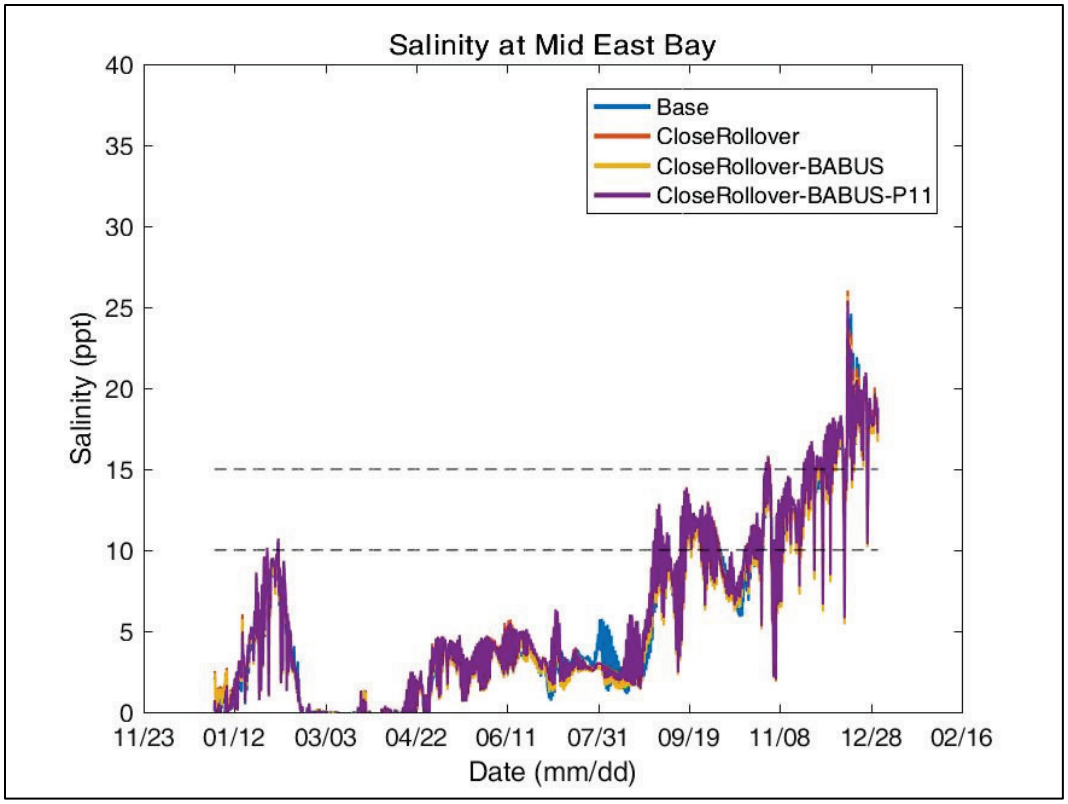

Salinity at Smith Point
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

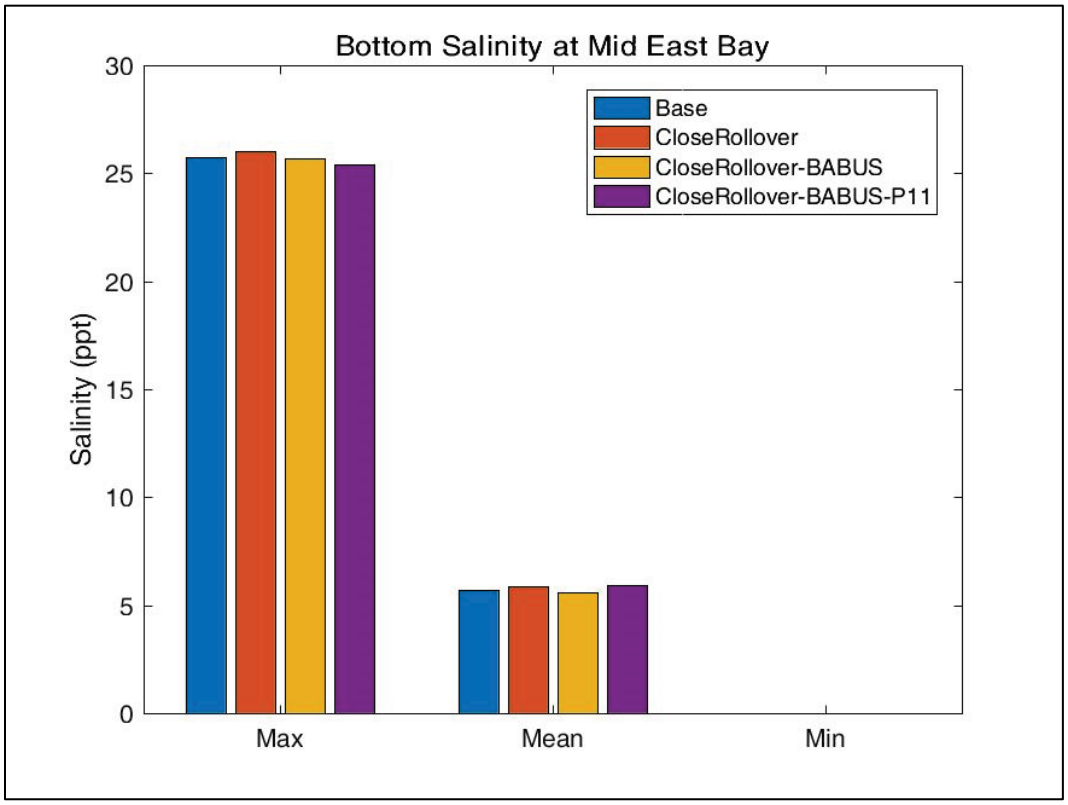

Bottom Salinity at Smith Point
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min

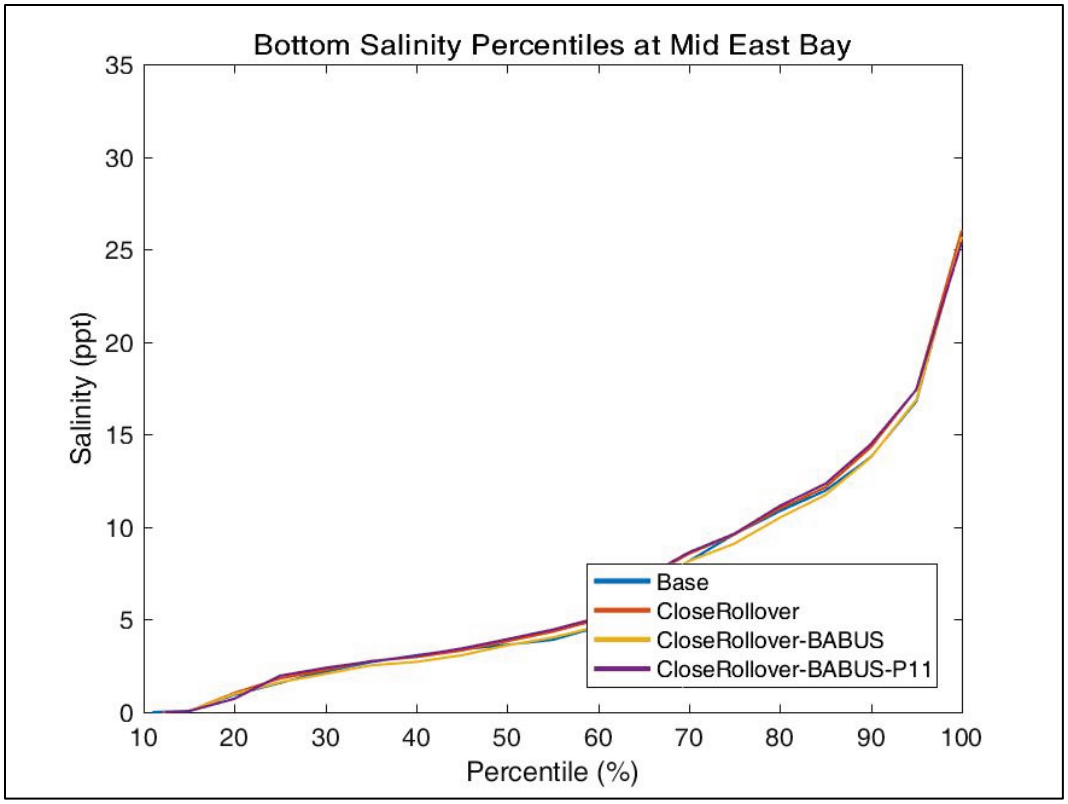

Bottom Salinity Percentiles at Smith Point
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

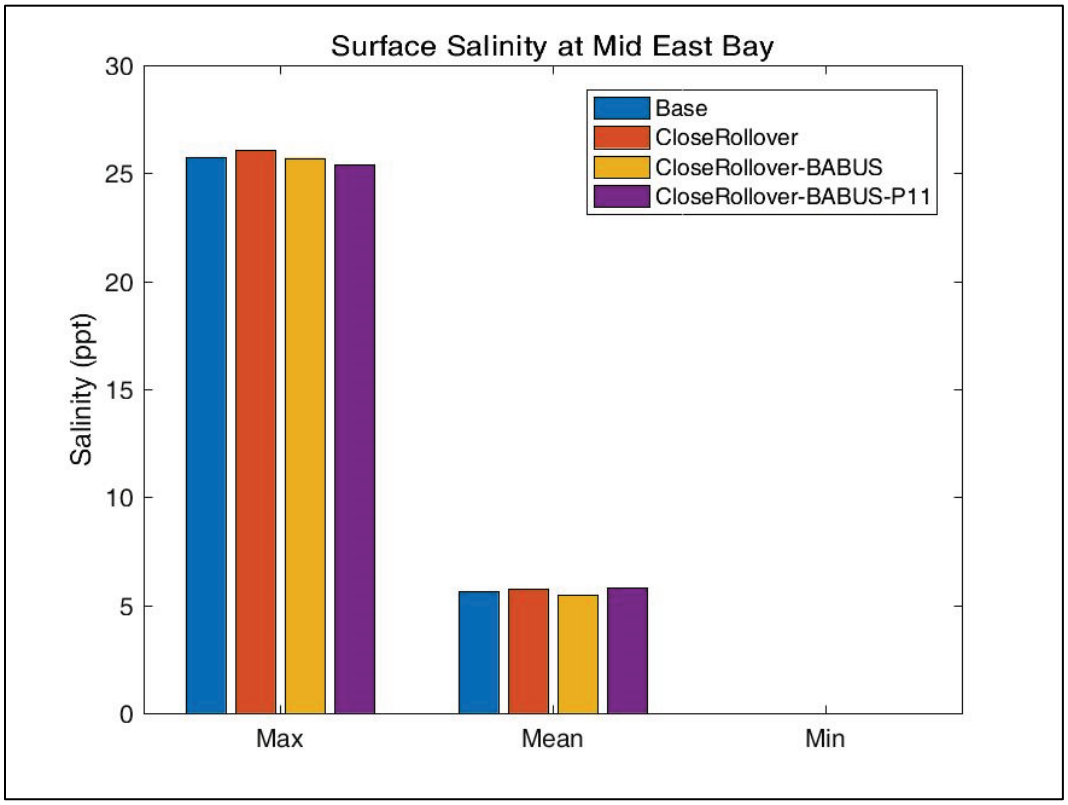

Surface Salinity at Smith Point
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

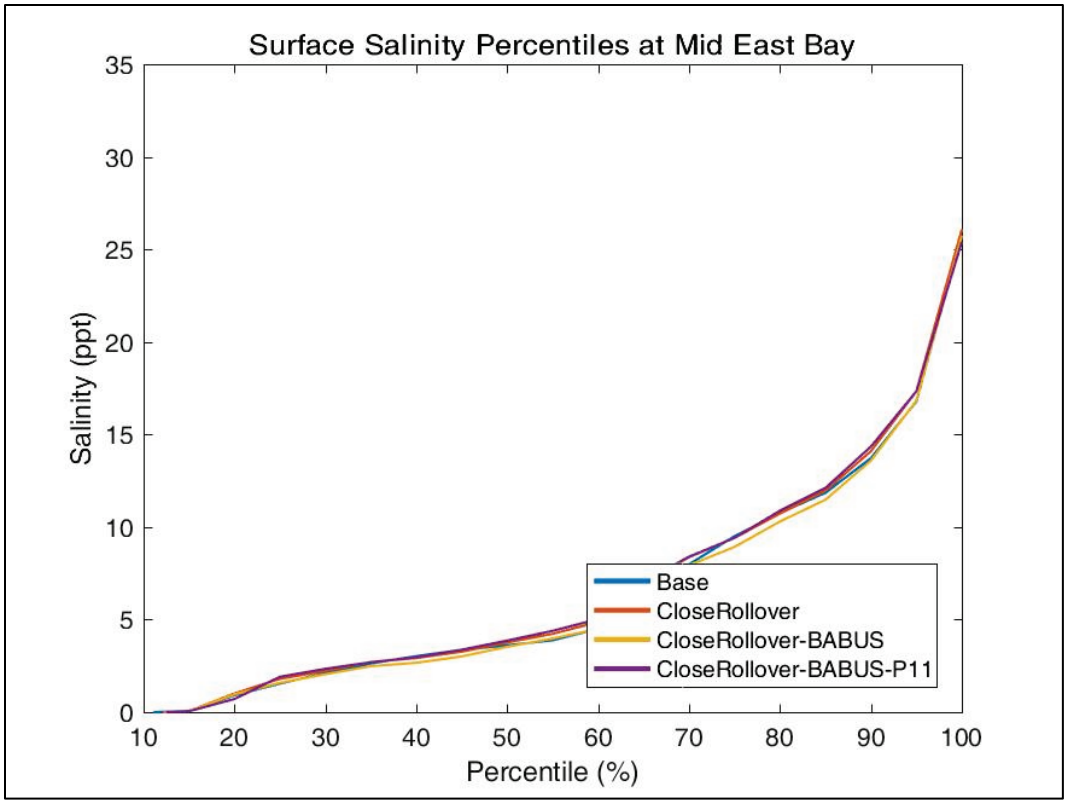

Surface Salinity Percentiles at Smith Point
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
10
20
30
40
50
60
70
80
90
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

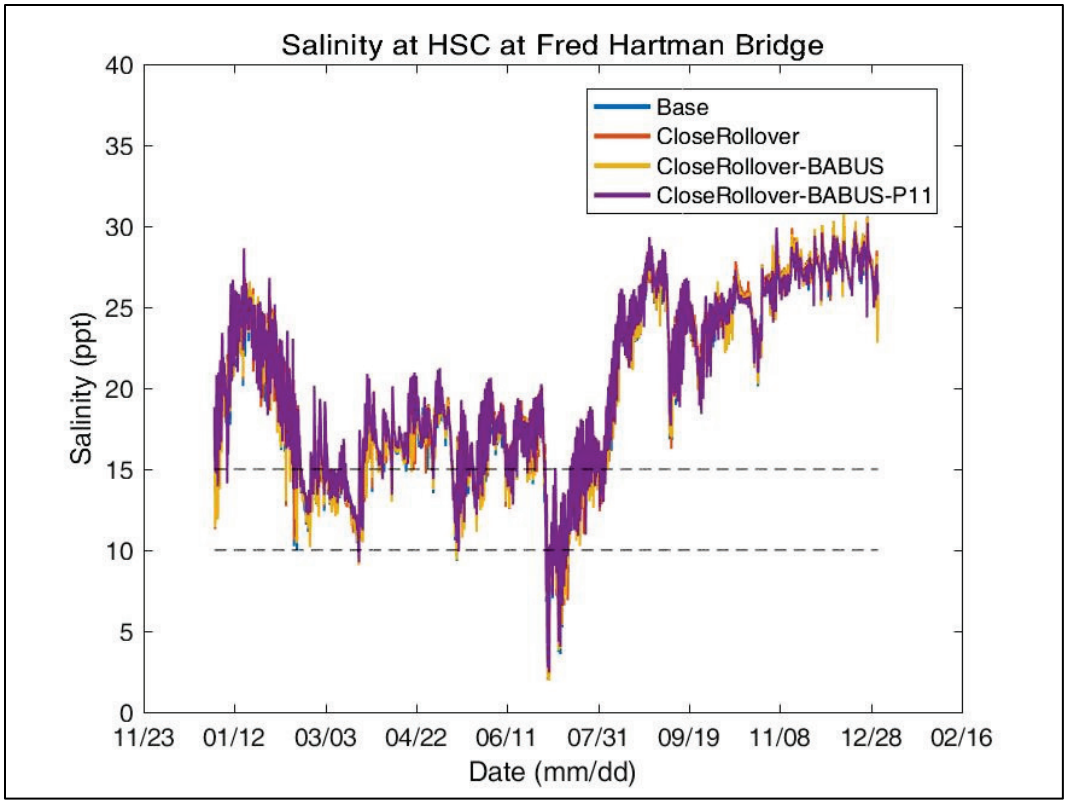

Salinity at Mid East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

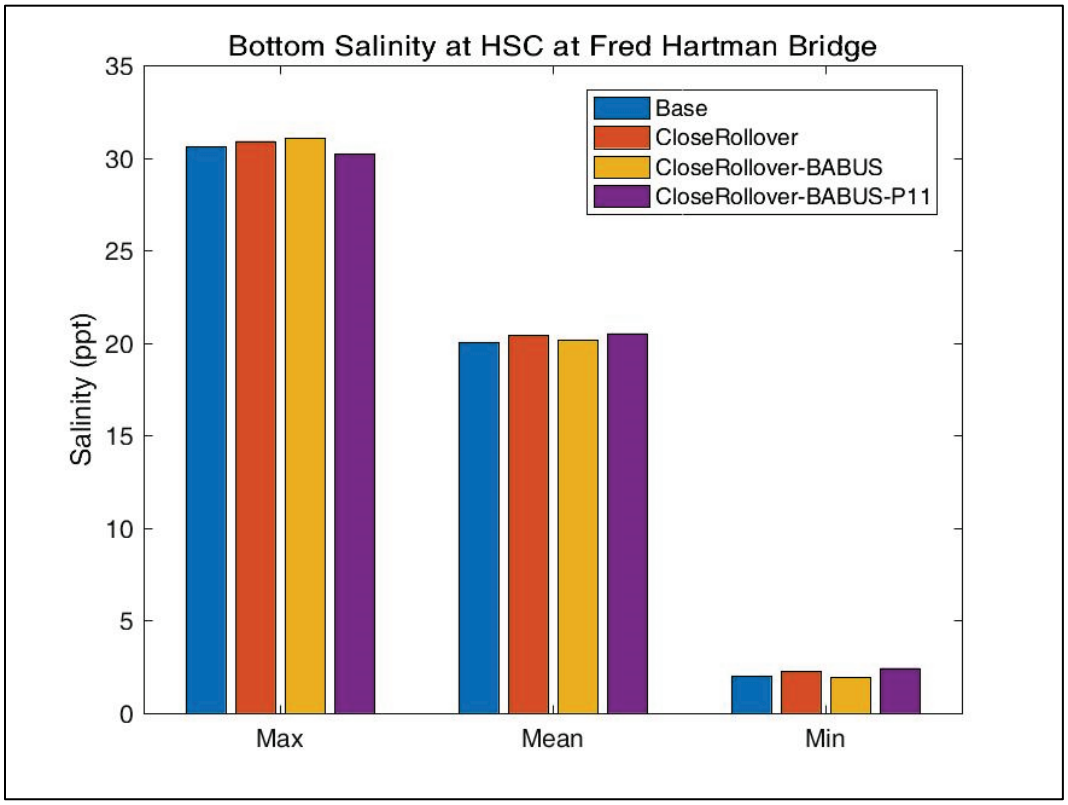

Bottom Salinity at Mid East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

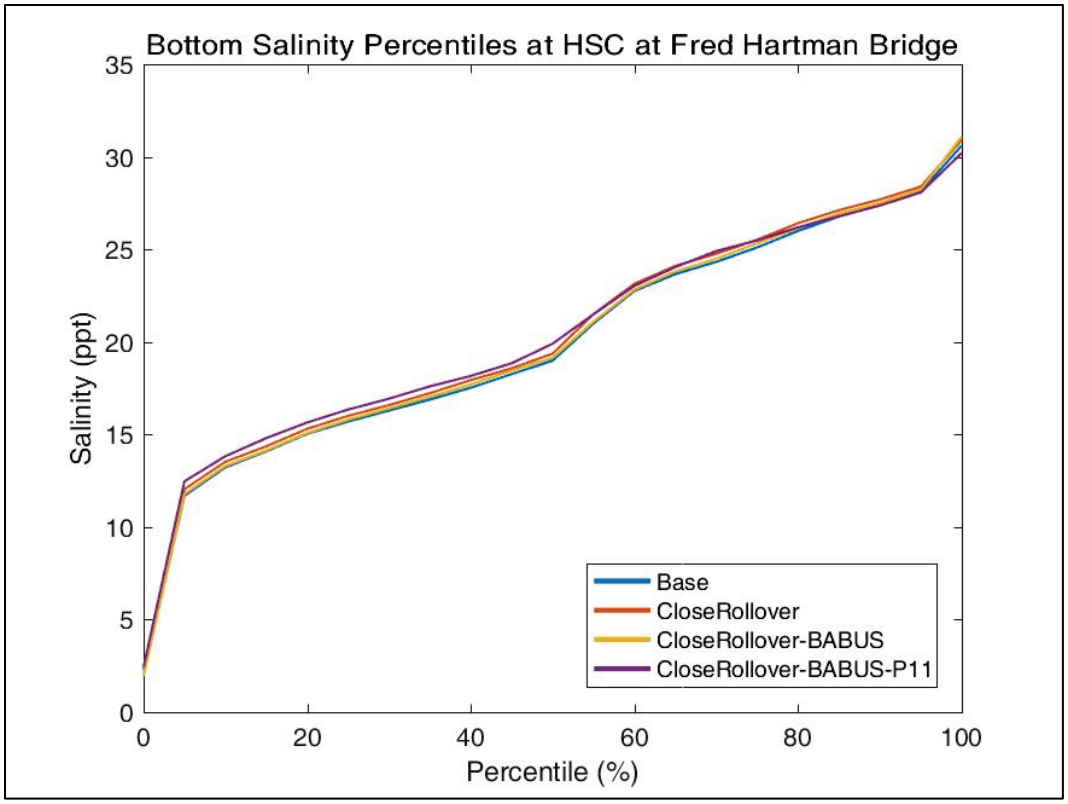

Bottom Salinity Percentiles at Mid East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
10
20
30
40
50
60
70
80
90
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

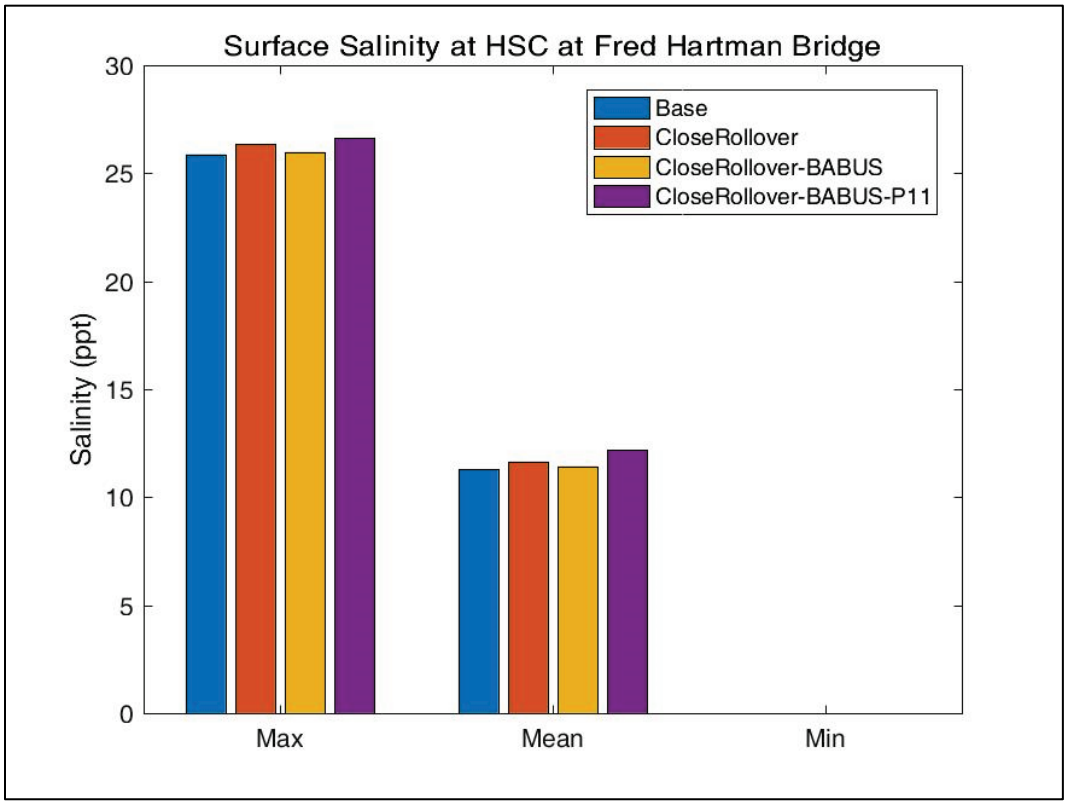

Surface Salinity at Mid East Bay
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

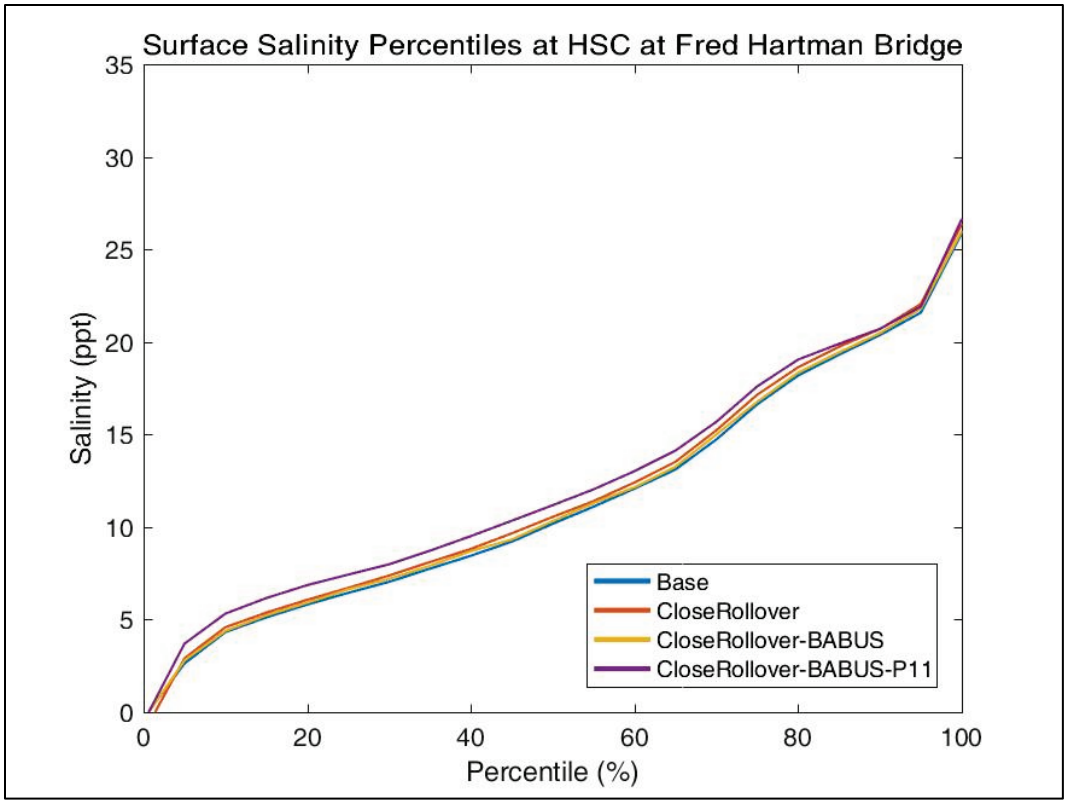

Surface Salinity Percentiles at Mid East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
10
20
30
40
50
60
70
80
90
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

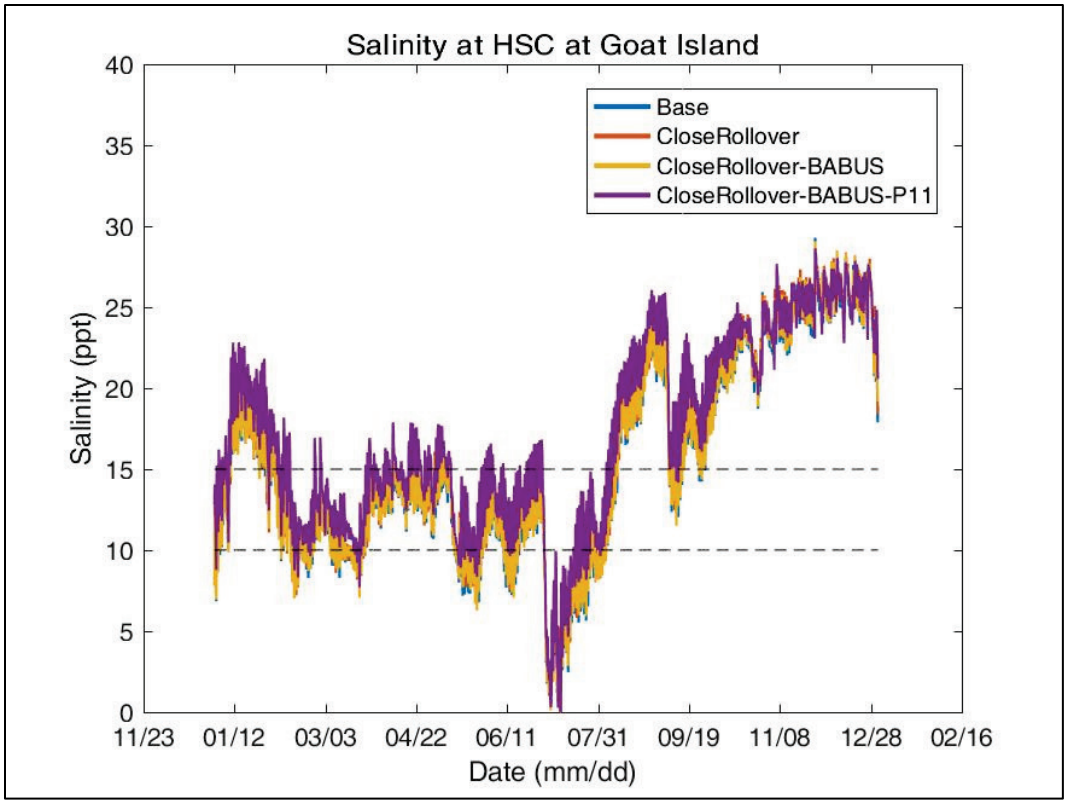

Salinity at HSC at Fred Hartman Bridge
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

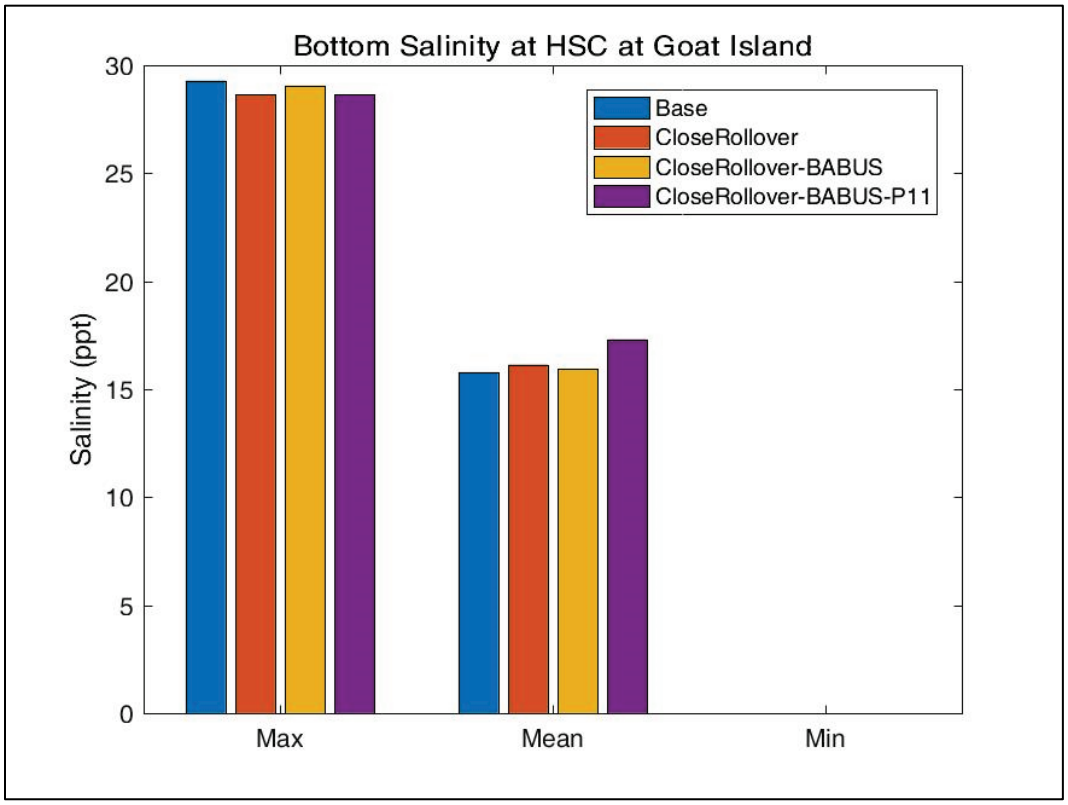

Bottom Salinity at HSC at Fred Hartman Bridge
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

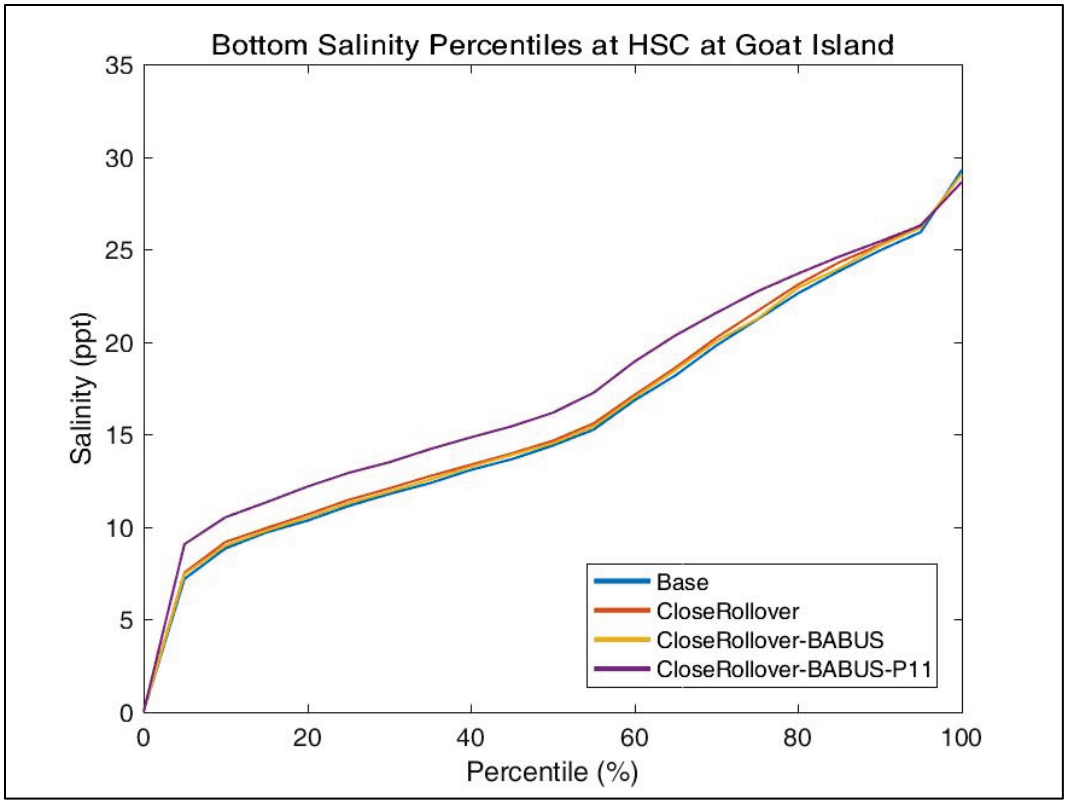

Bottom Salinity Percentiles at HSC at Fred Hartman Bridge
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

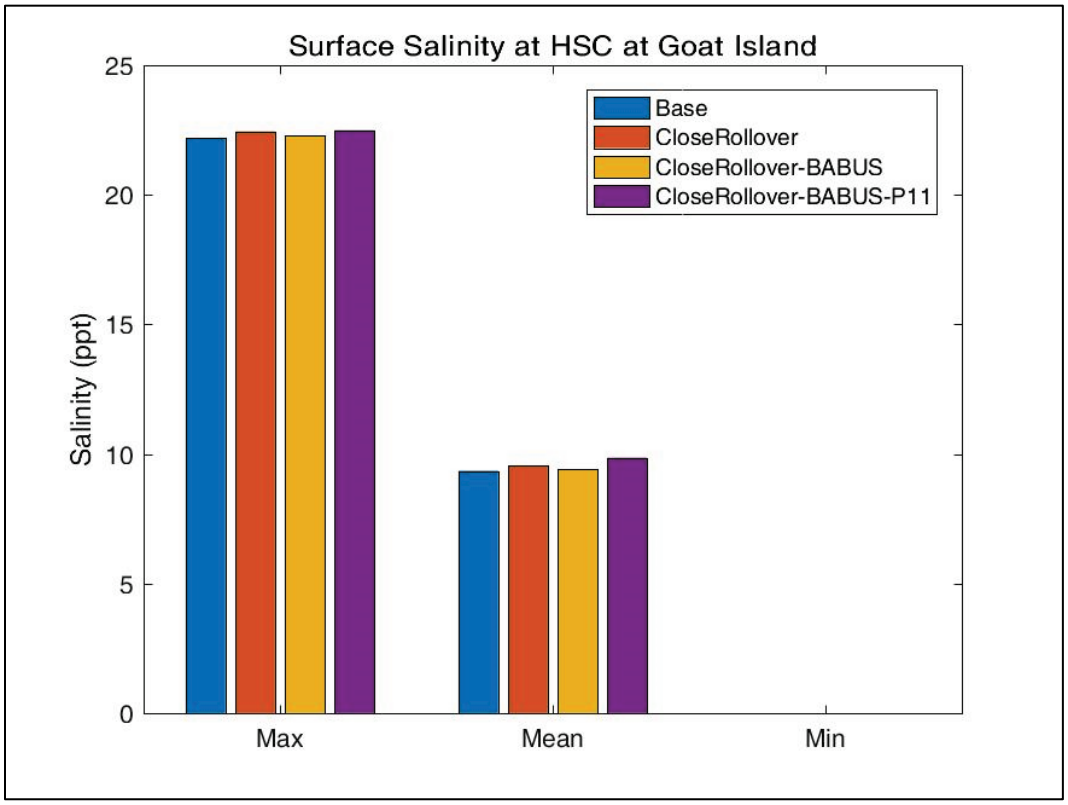

Surface Salinity at HSC at Fred Hartman Bridge
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

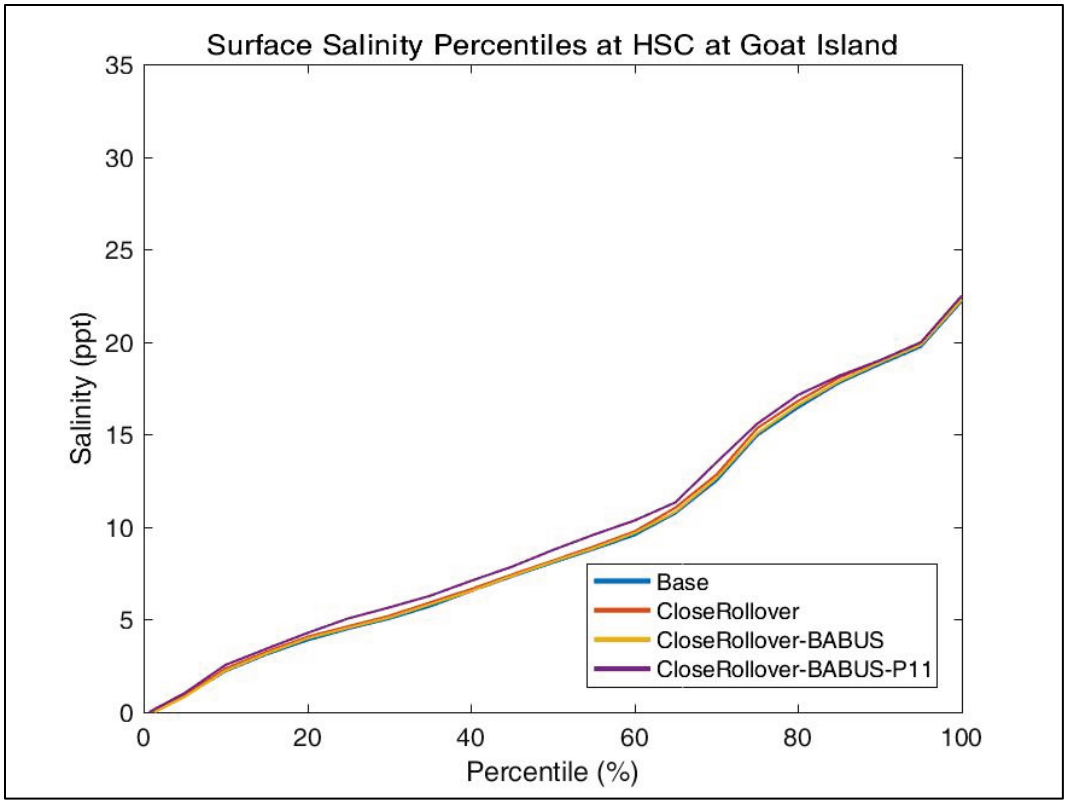

Surface Salinity Percentiles at HSC at Fred Hartman Bridge
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

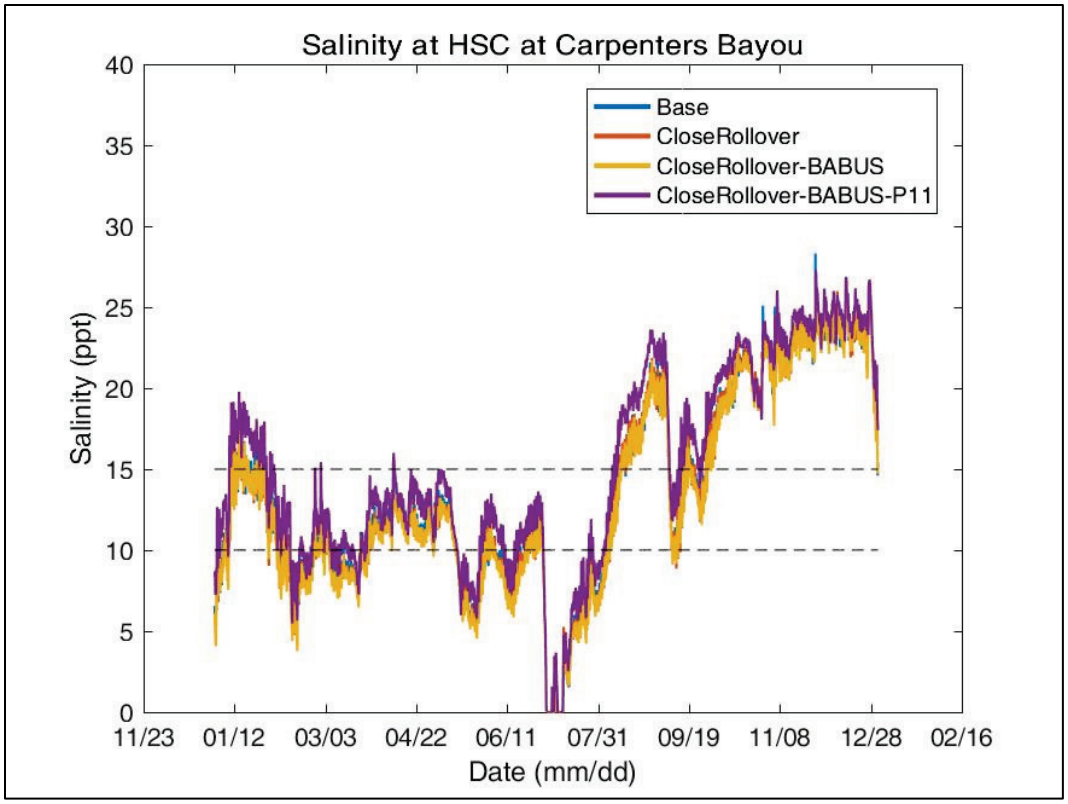

Salinity at HSC at Goat Island
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

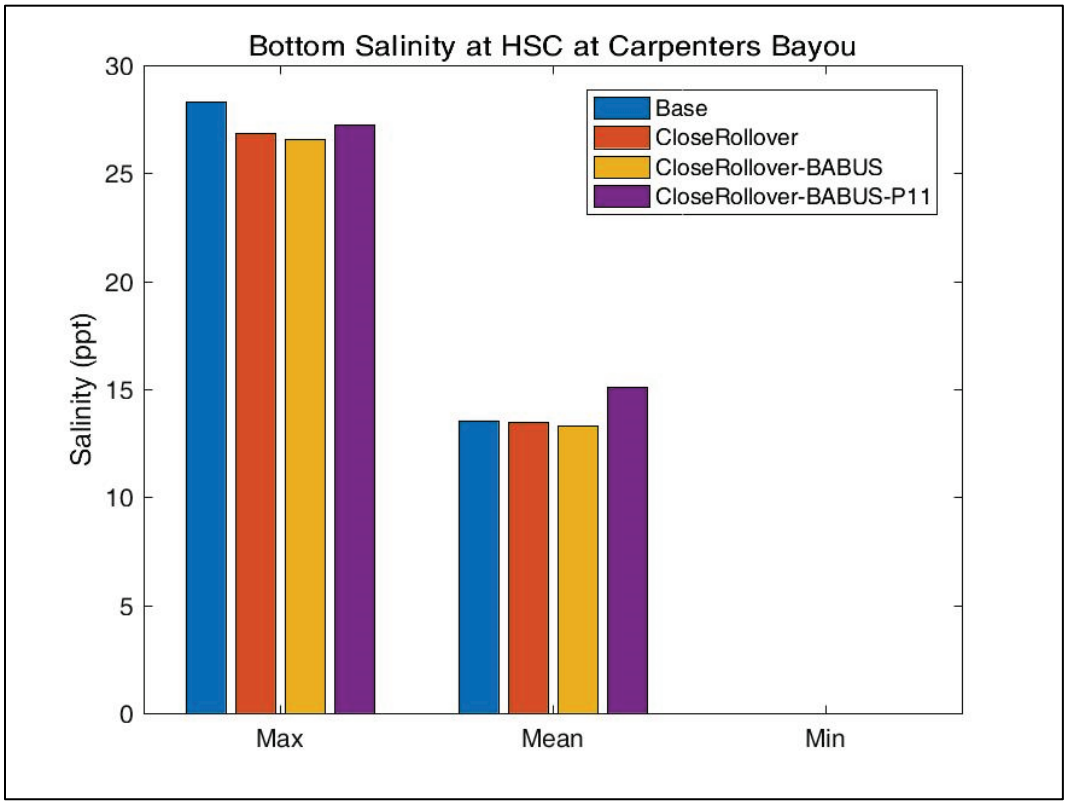

Bottom Salinity at HSC at Goat Island
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

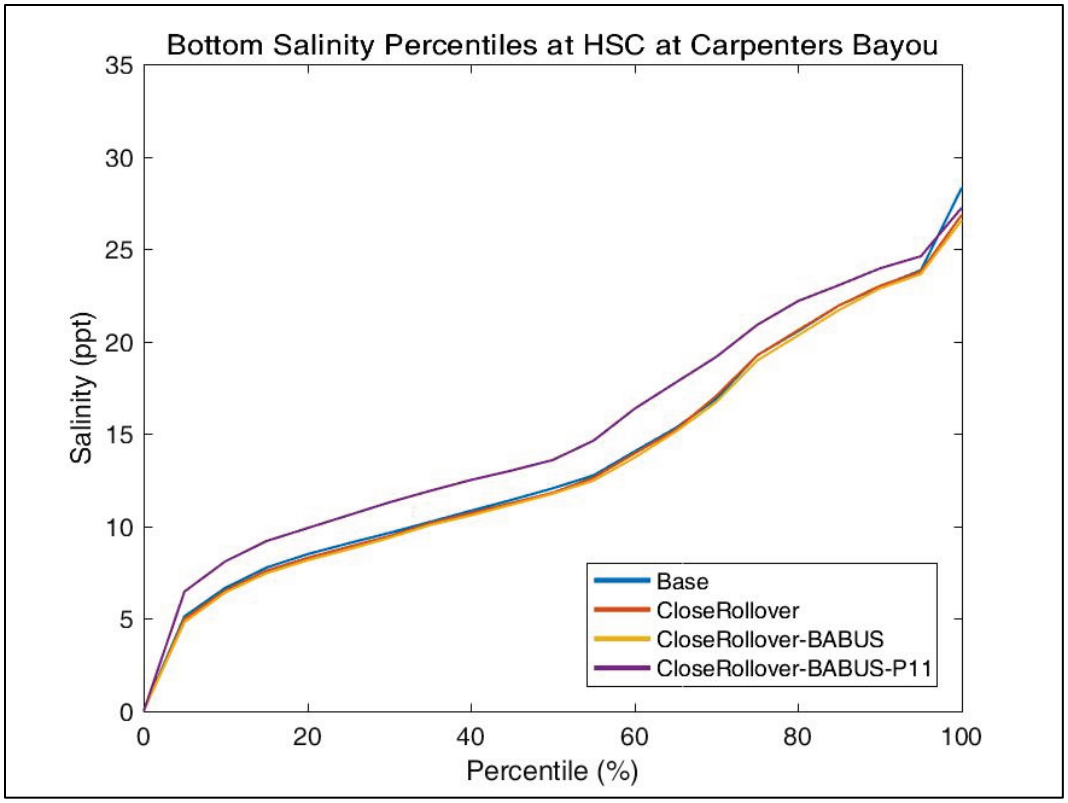

Bottom Salinity Percentiles at HSC at Goat Island
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

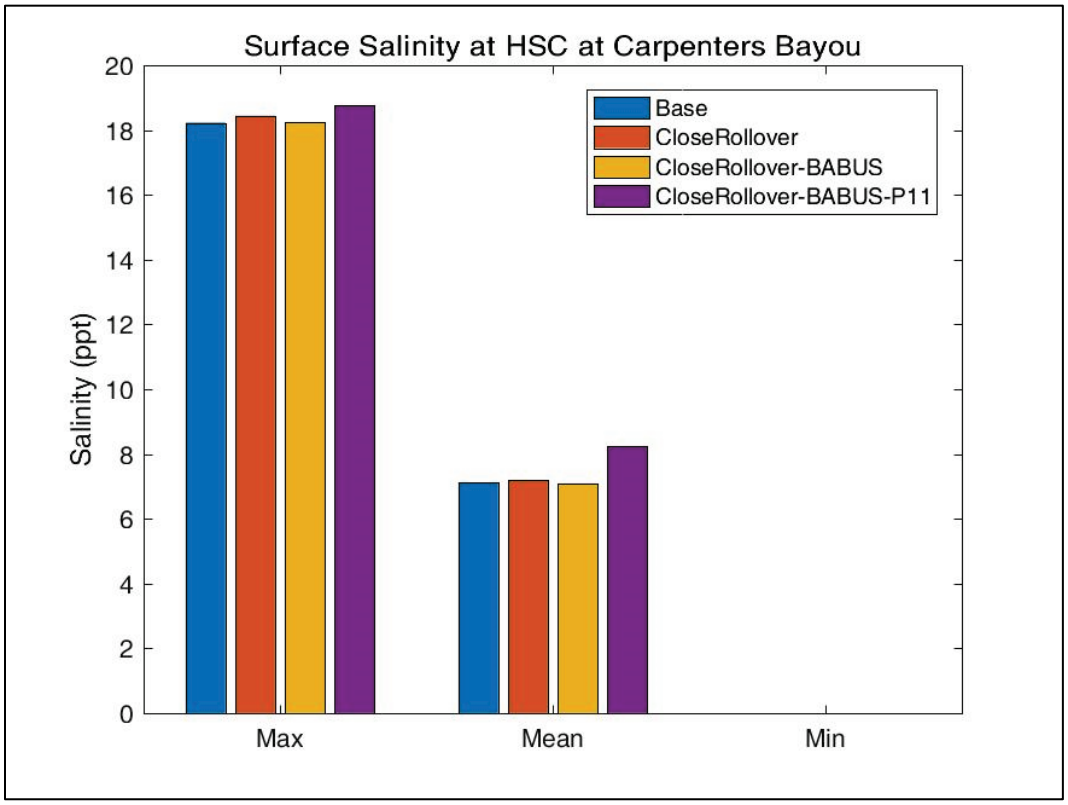

Surface Salinity at HSC at Goat Island
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

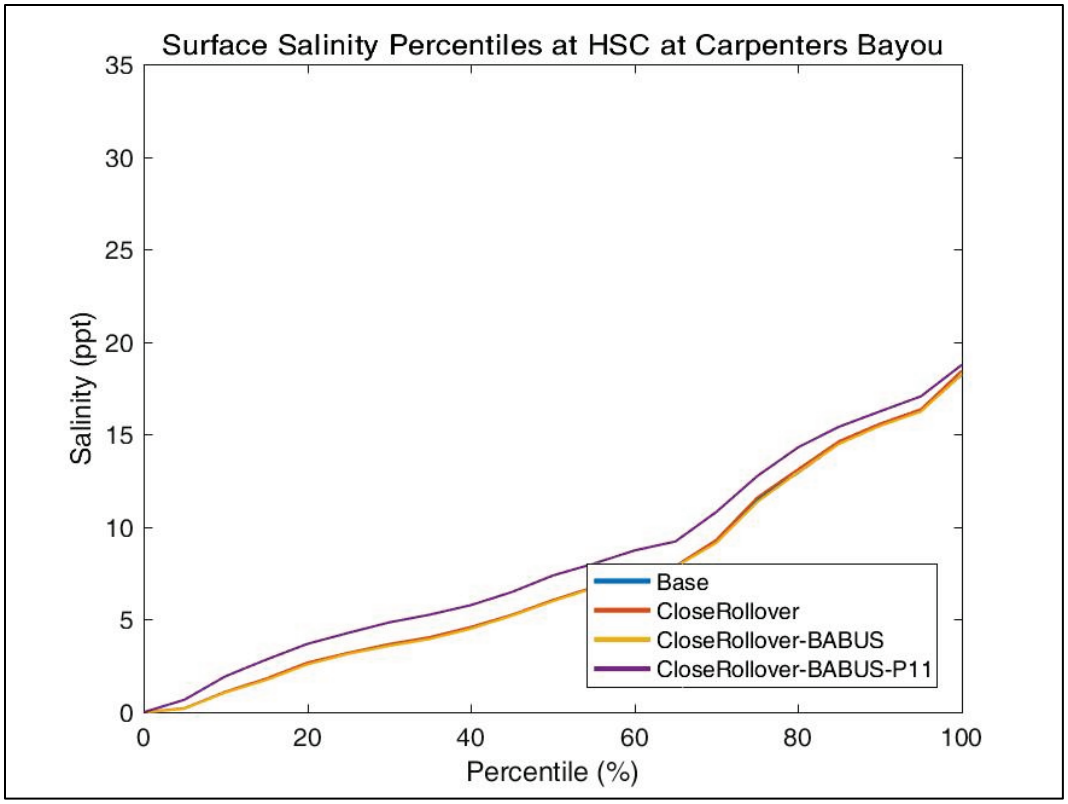

Surface Salinity Percentiles at HSC at Goat Island
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

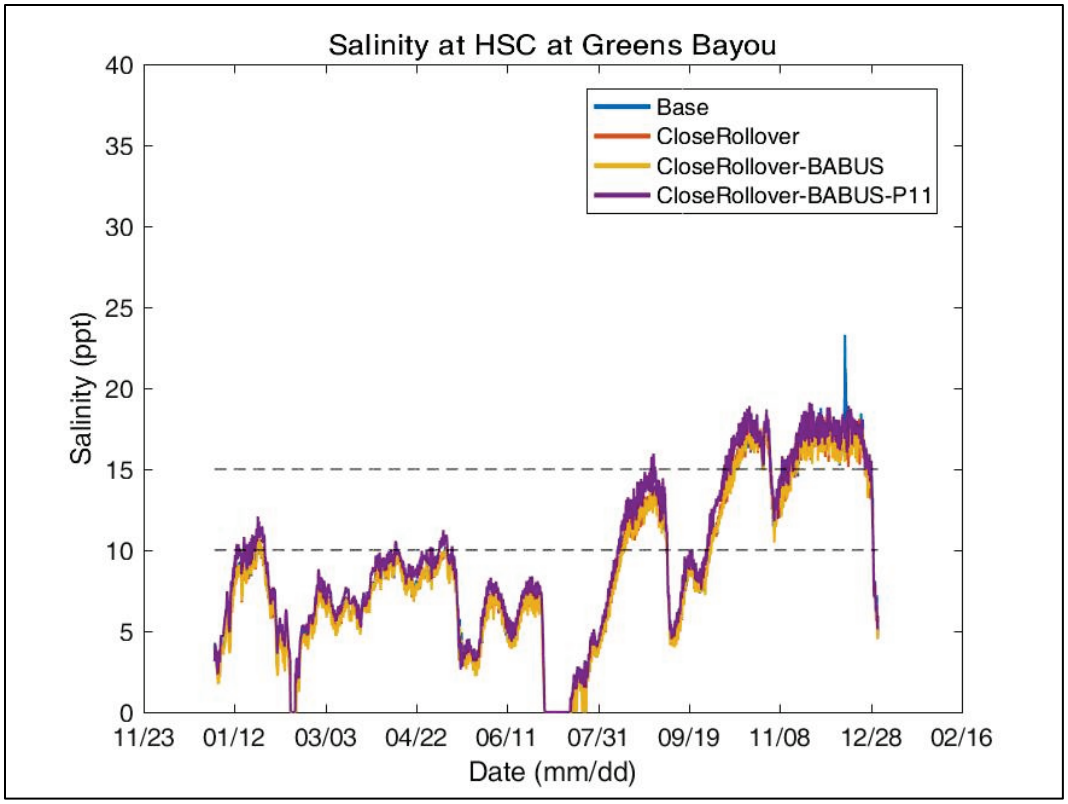

Salinity at HSC at Carpenters Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

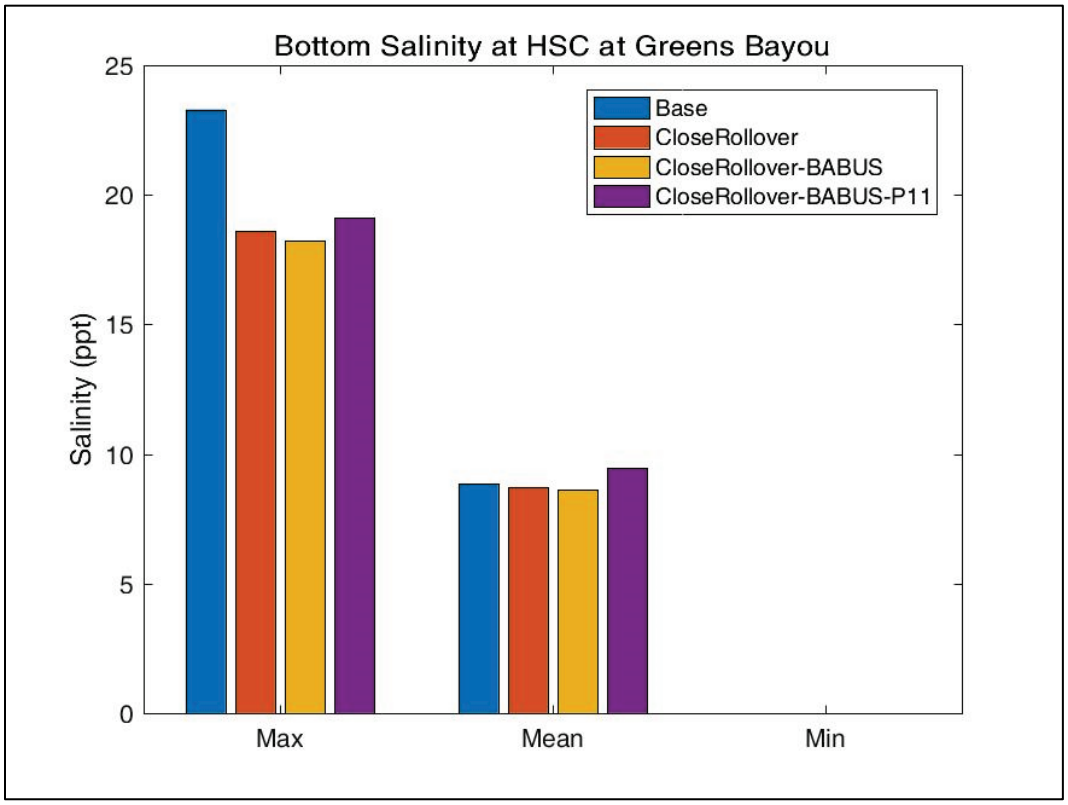

Bottom Salinity at HSC at Carpenters Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

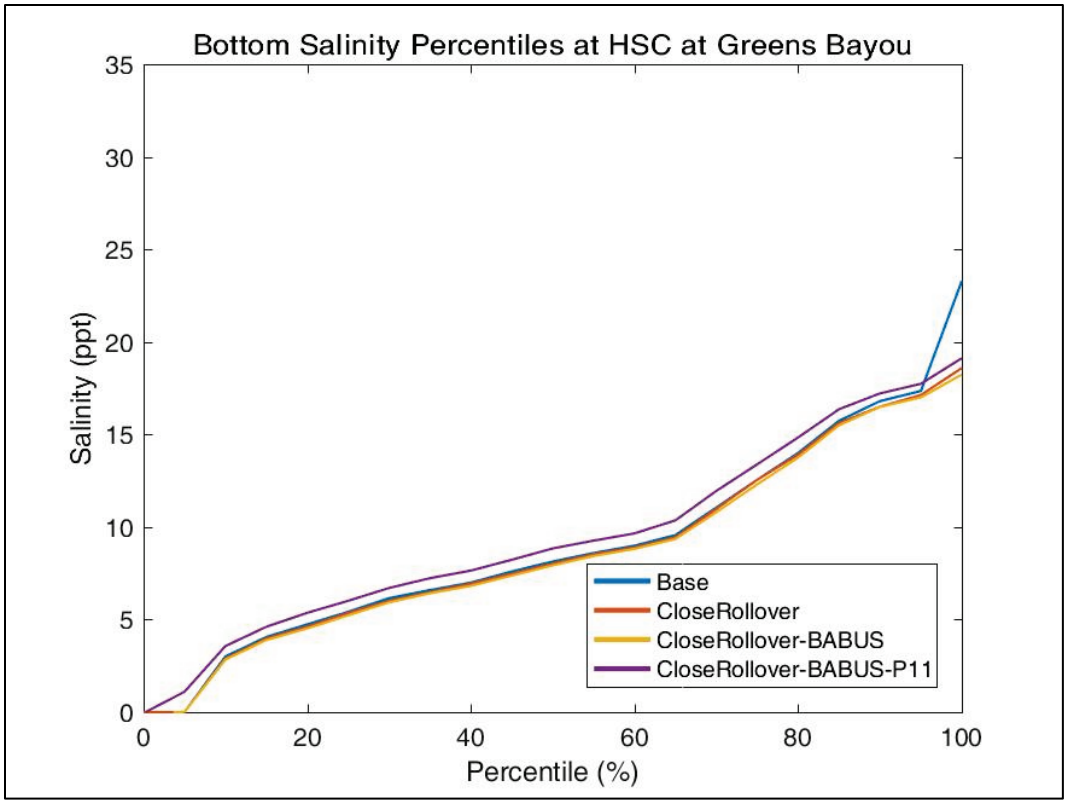

Bottom Salinity Percentiles at HSC at Carpenters Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

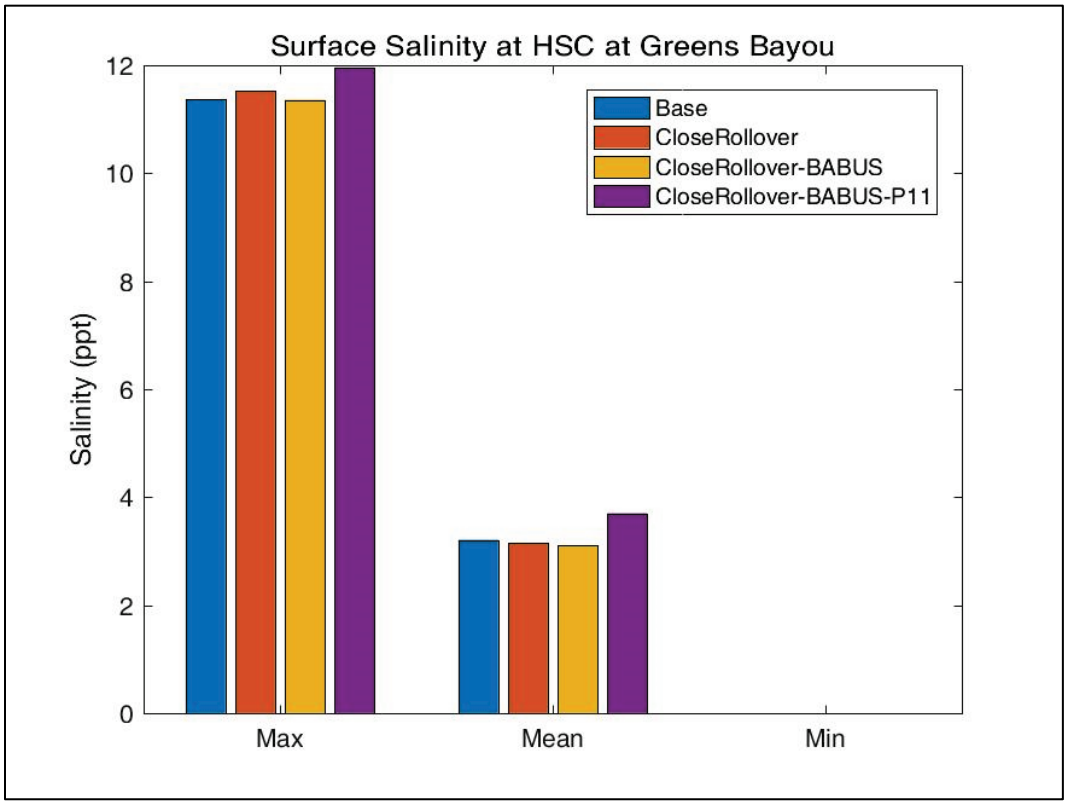

Surface Salinity at HSC at Carpenters Bayou
Salinity (ppt)
0
2
4
6
8
10
12
14
16
18
20
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

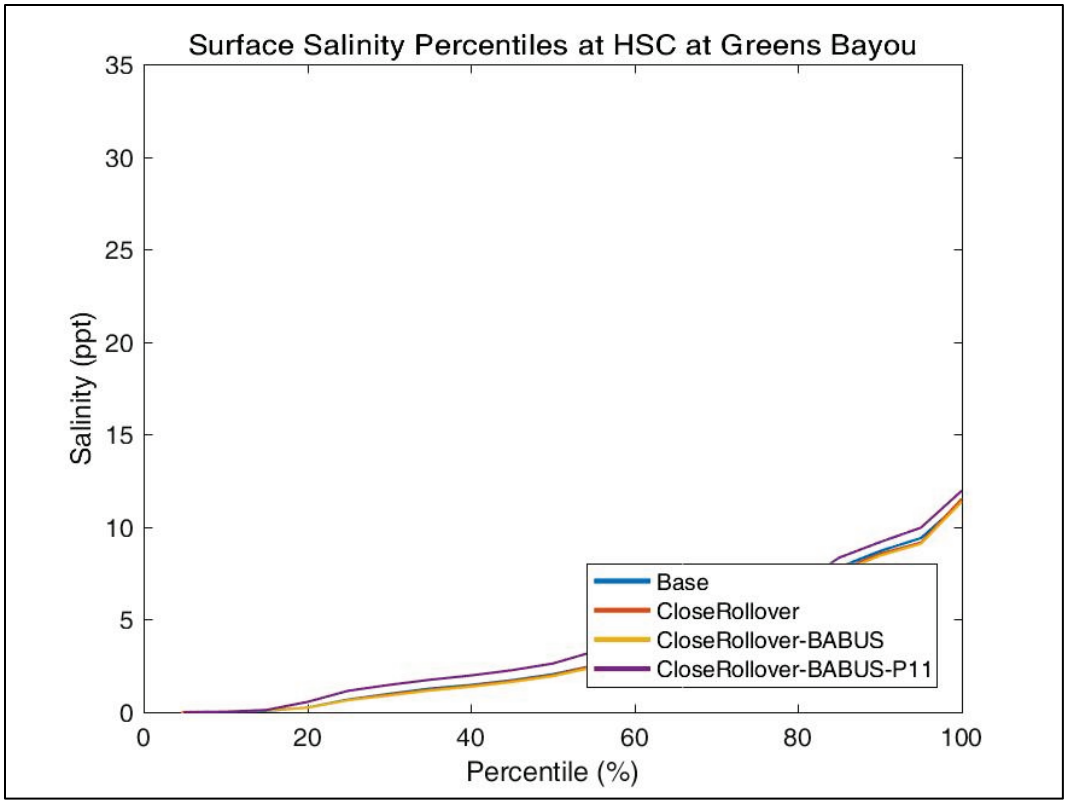

Surface Salinity Percentiles at HSC at Carpenters Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

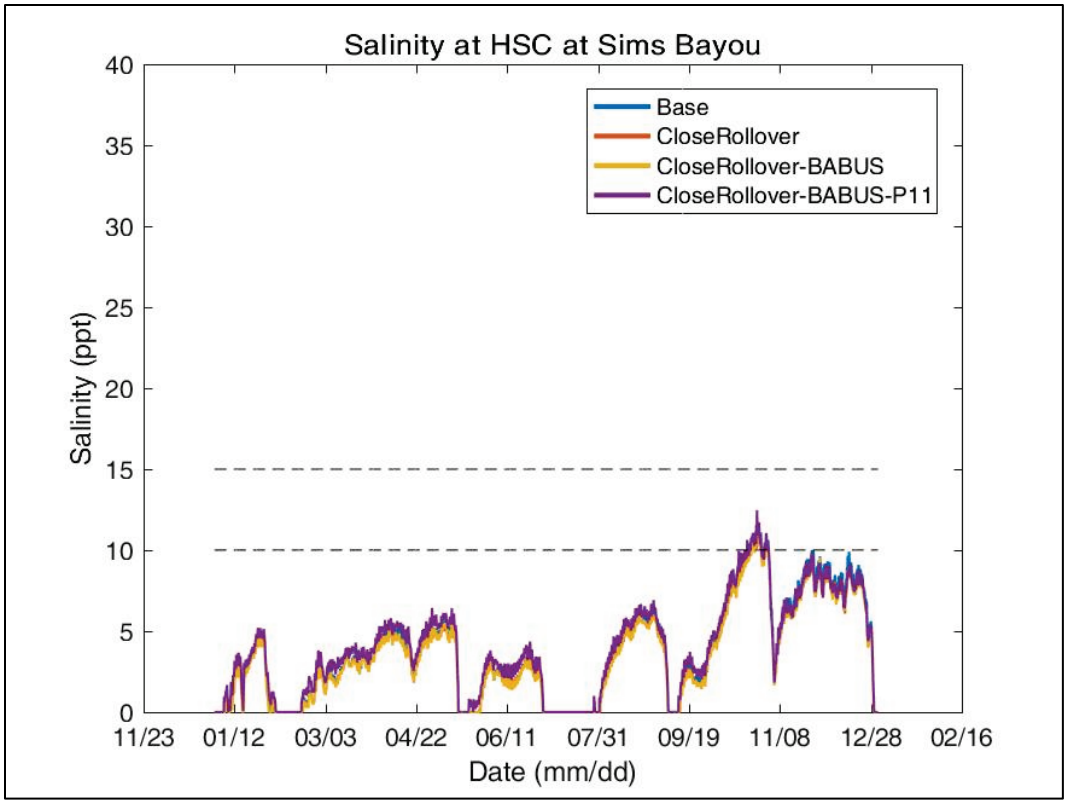

Salinity at HSC at Greens Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

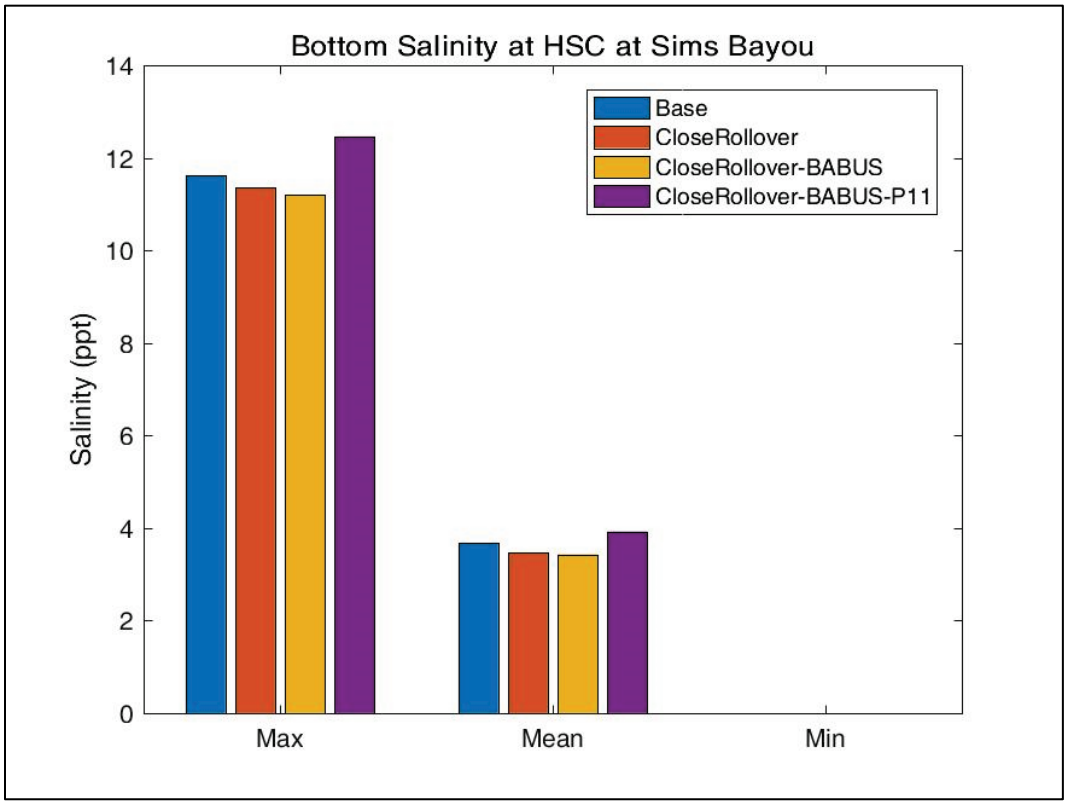

Bottom Salinity at HSC at Greens Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min

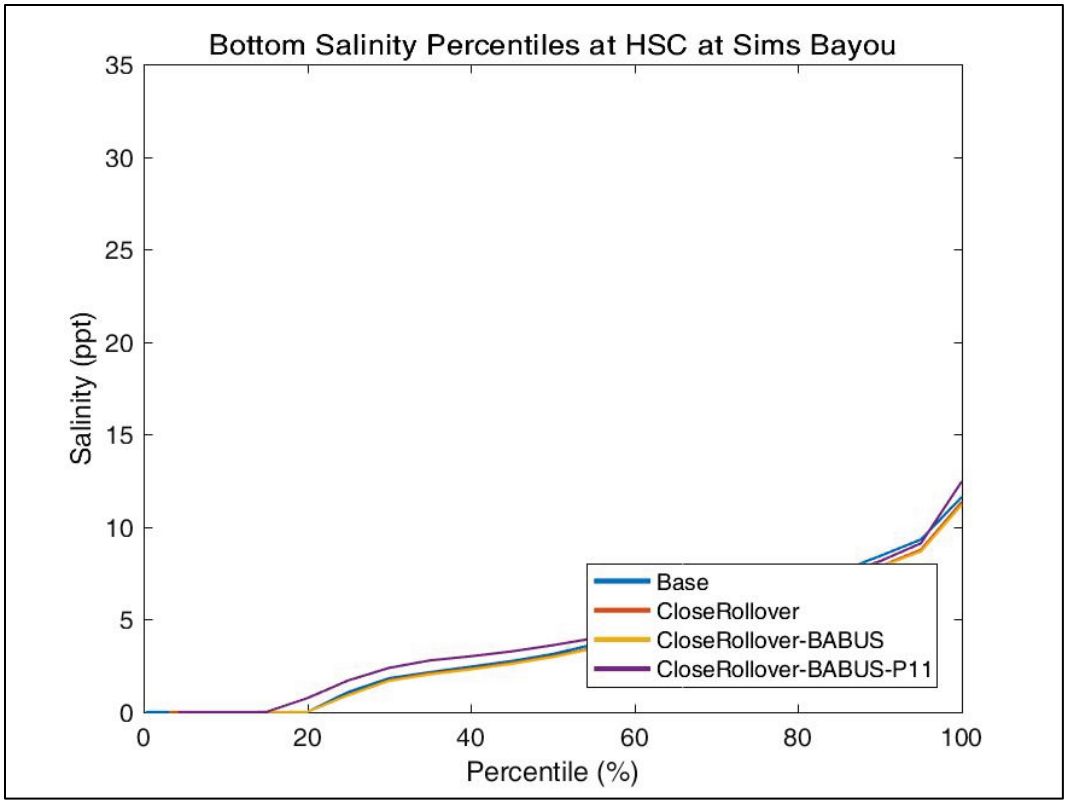

Bottom Salinity Percentiles at HSC at Greens Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

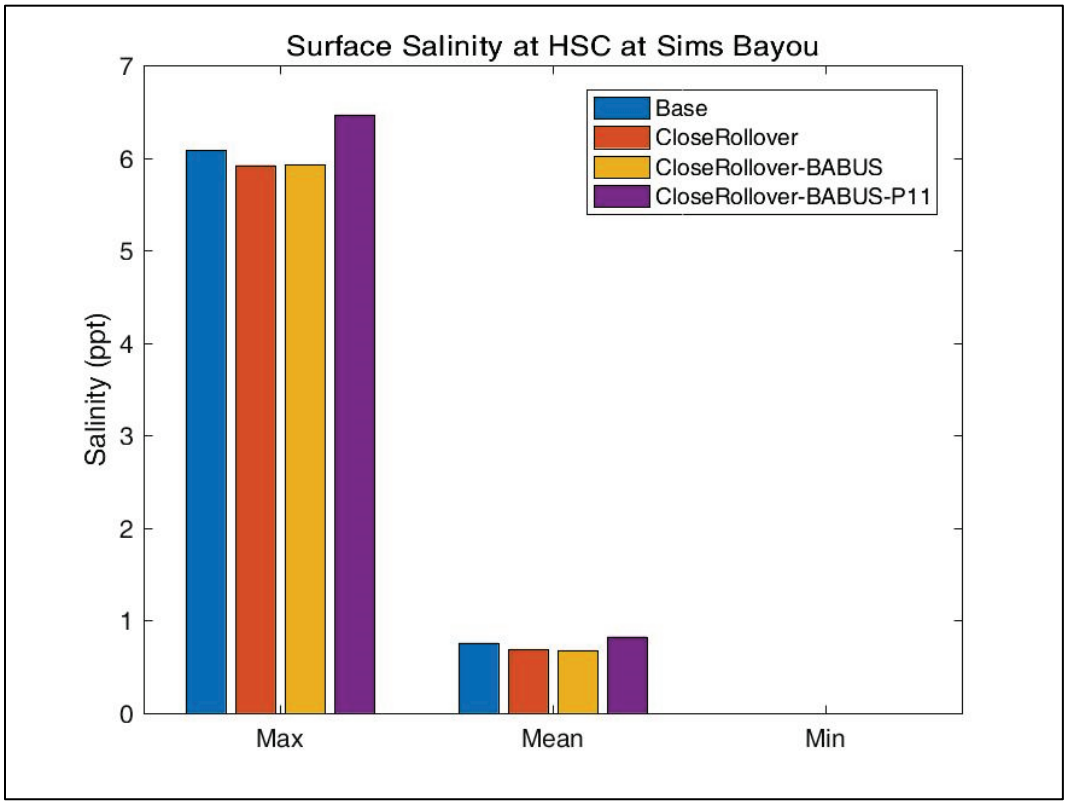

Surface Salinity at HSC at Greens Bayou
Salinity (ppt)
0
2
4
6
8
10
12
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

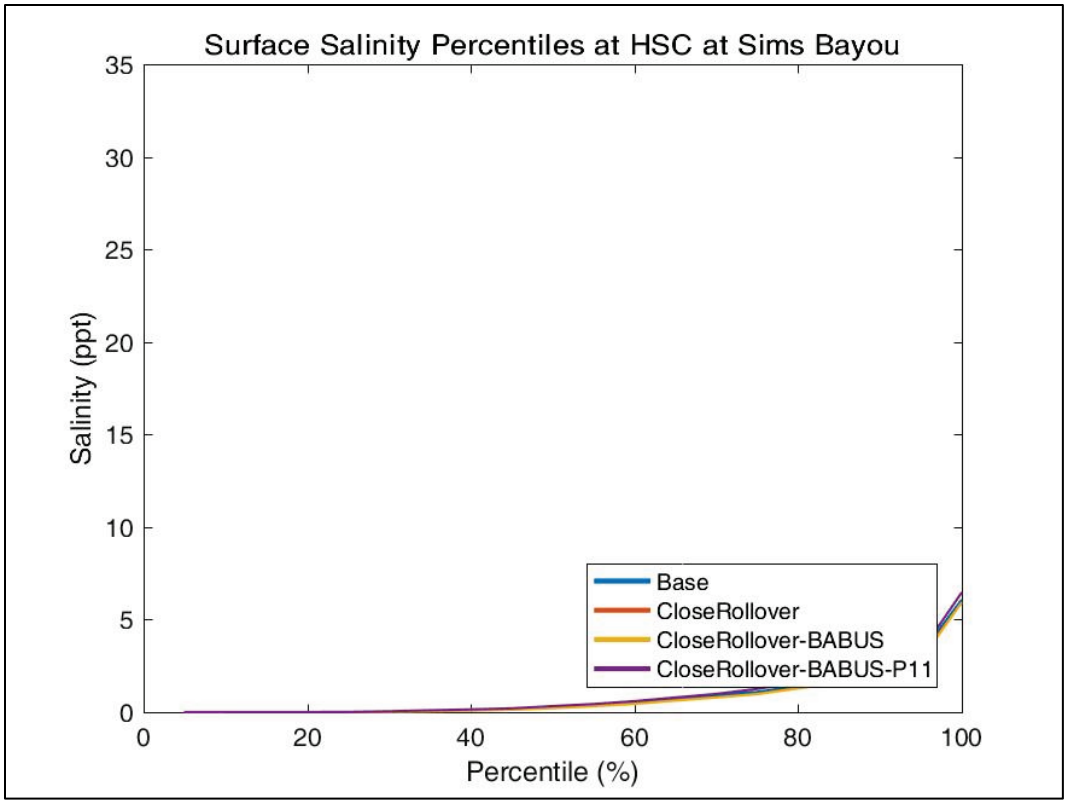

Surface Salinity Percentiles at HSC at Greens Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

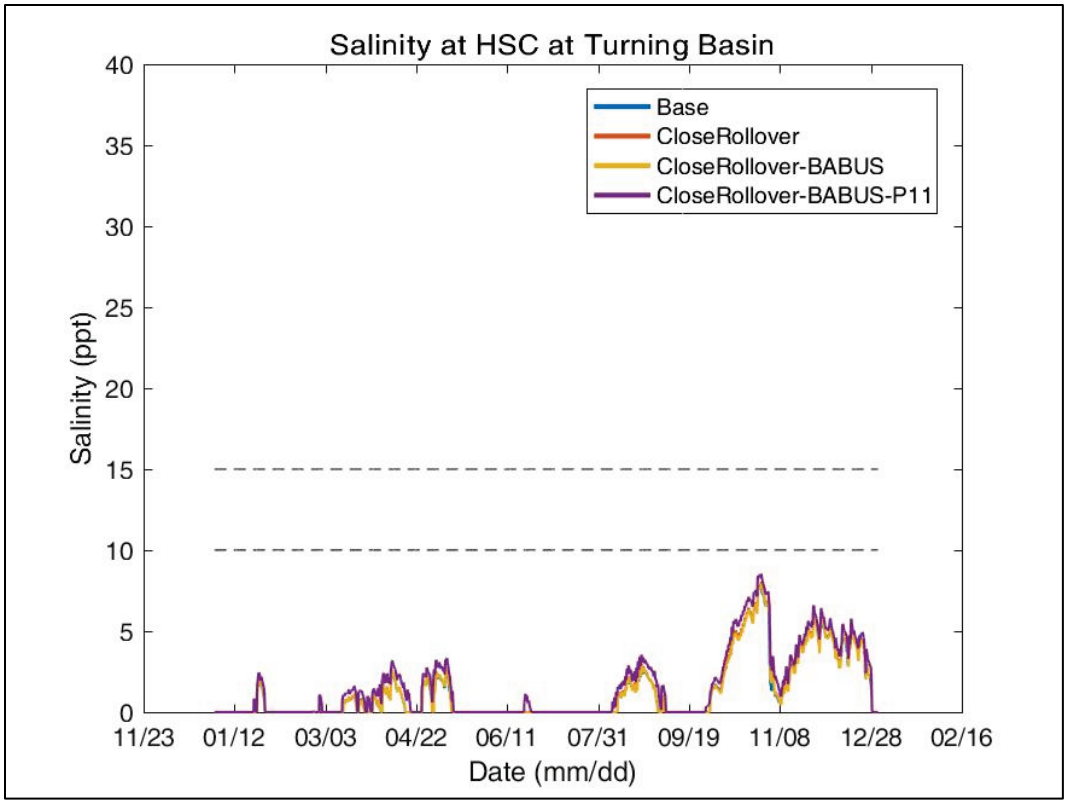

Salinity at HSC at Sims Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

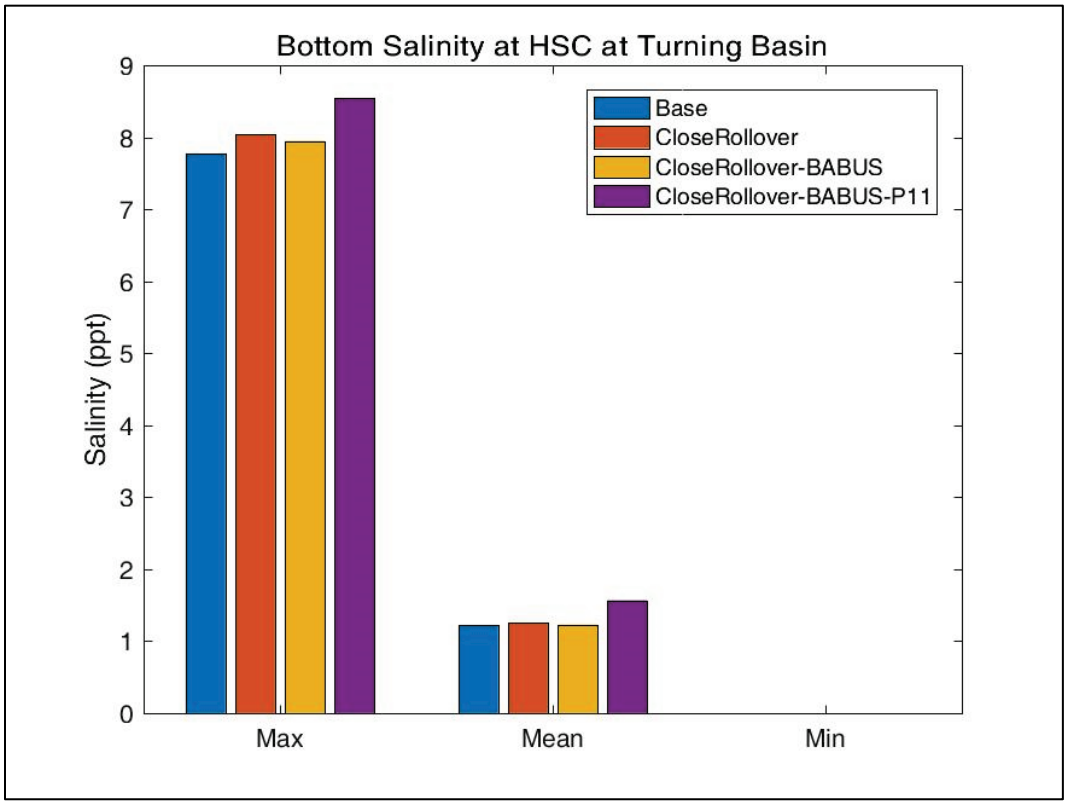

Bottom Salinity at HSC at Sims Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
2
4
6
8
10
12
14
Max
Mean
Min

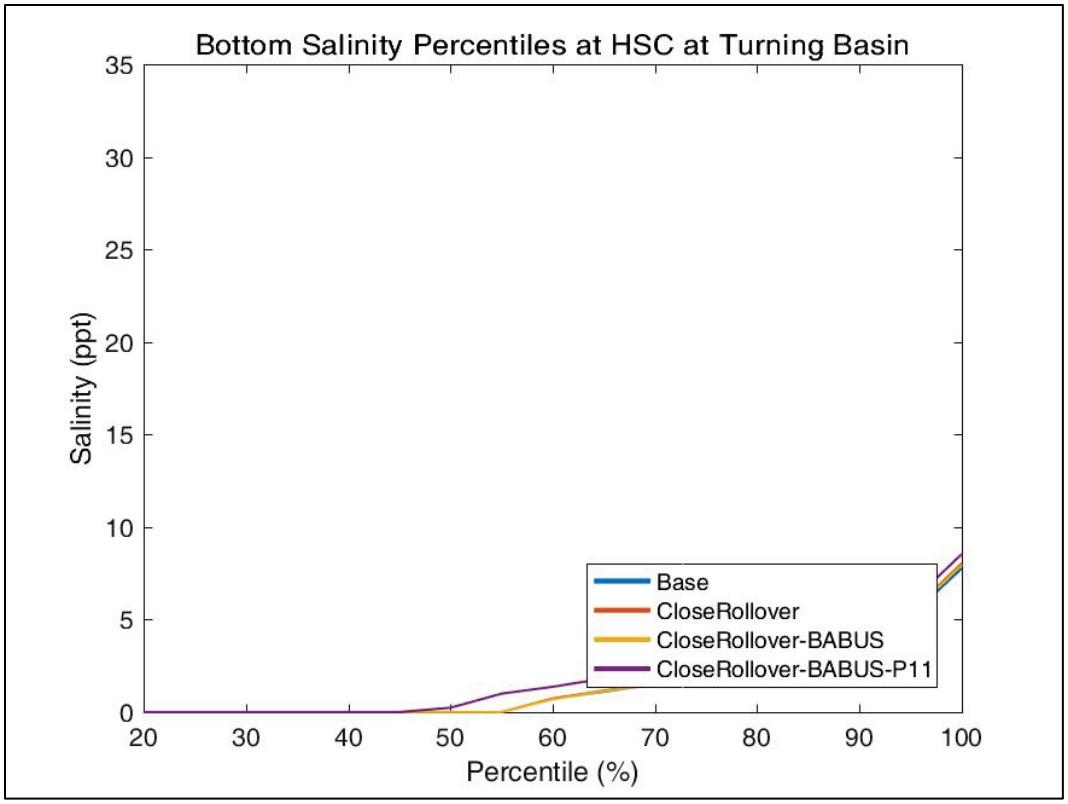

Bottom Salinity Percentiles at HSC at Sims Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

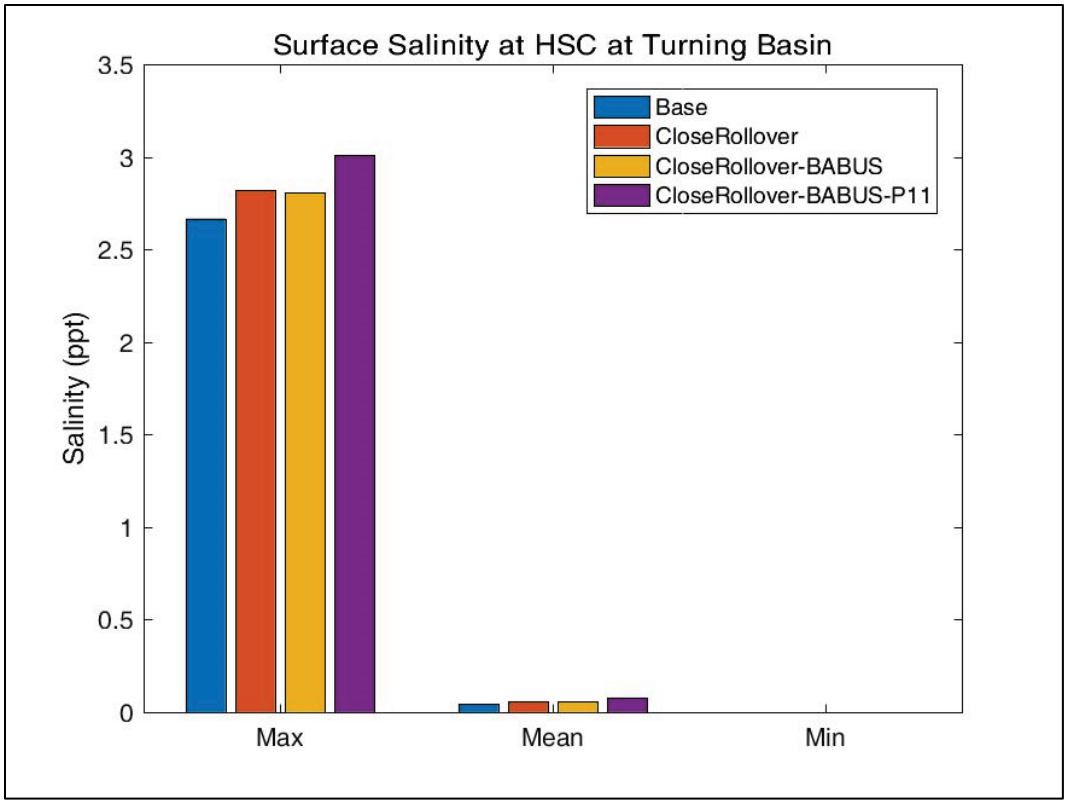

Surface Salinity at HSC at Sims Bayou
Salinity (ppt)
0
1
2
3
4
5
6
7
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

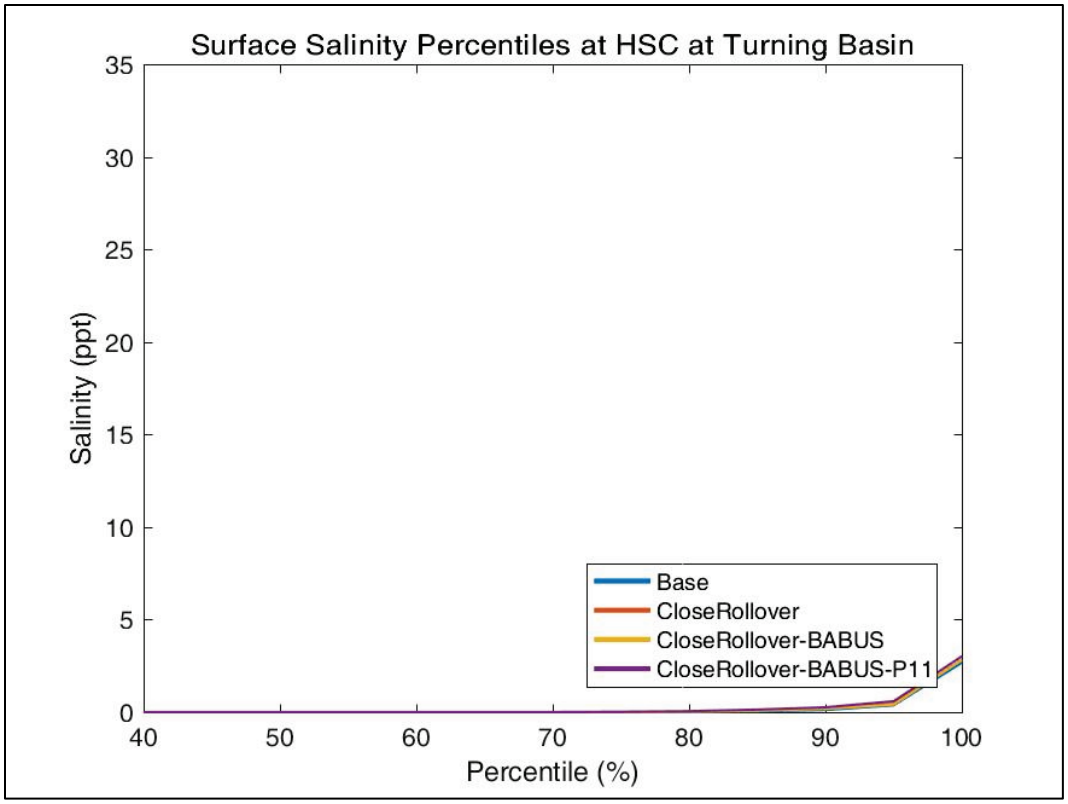

Surface Salinity Percentiles at HSC at Sims Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

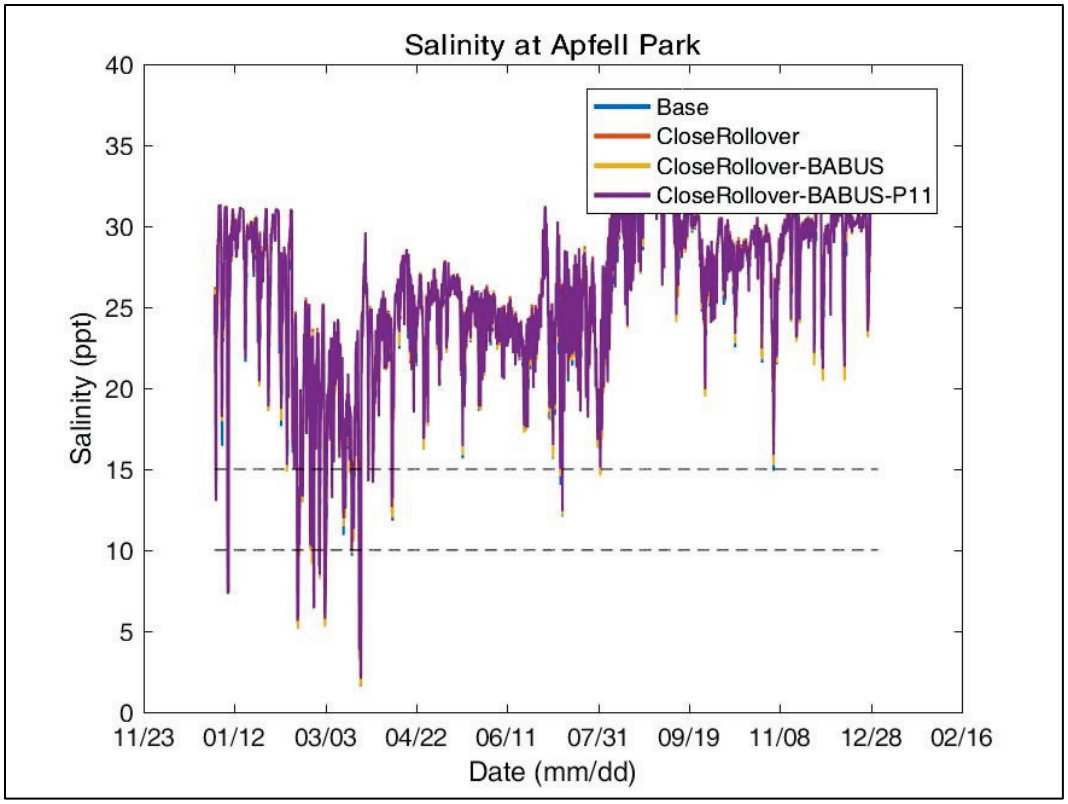

Salinity at HSC at Turning Basin
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

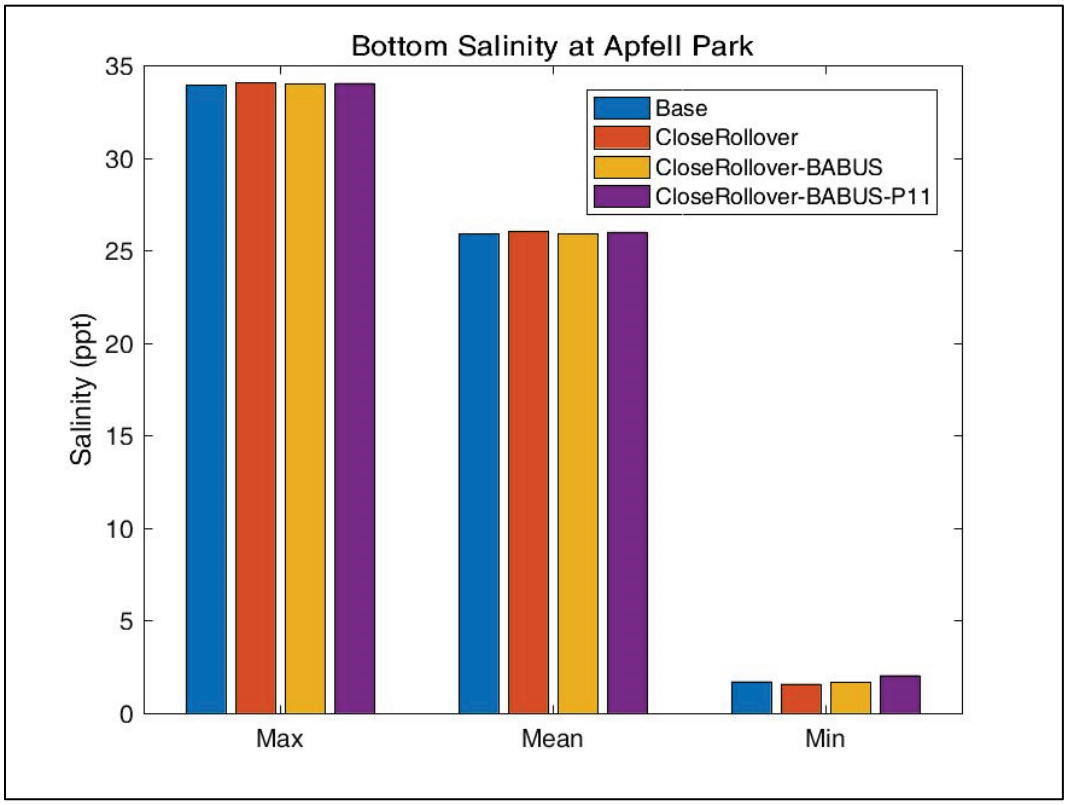

Bottom Salinity at HSC at Turning Basin
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
1
2
3
4
5
6
7
8
9
Max
Mean
Min

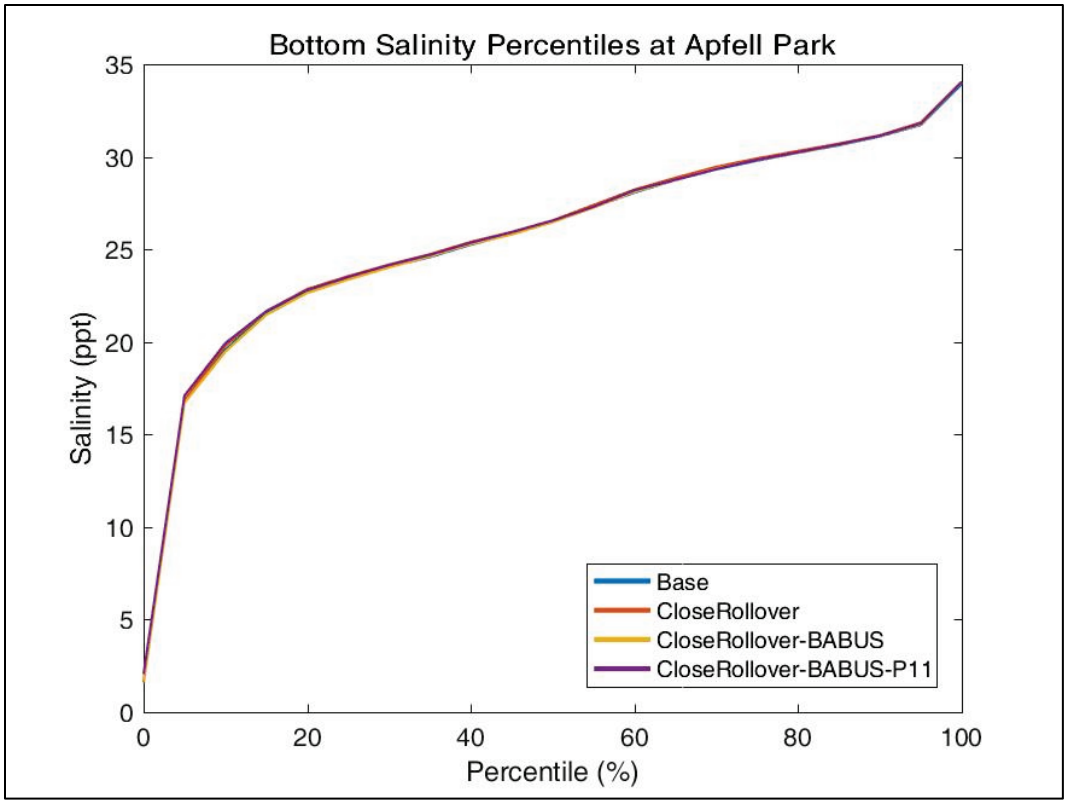

Bottom Salinity Percentiles at HSC at Turning Basin
Salinity (ppt)
Percentile (%)
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

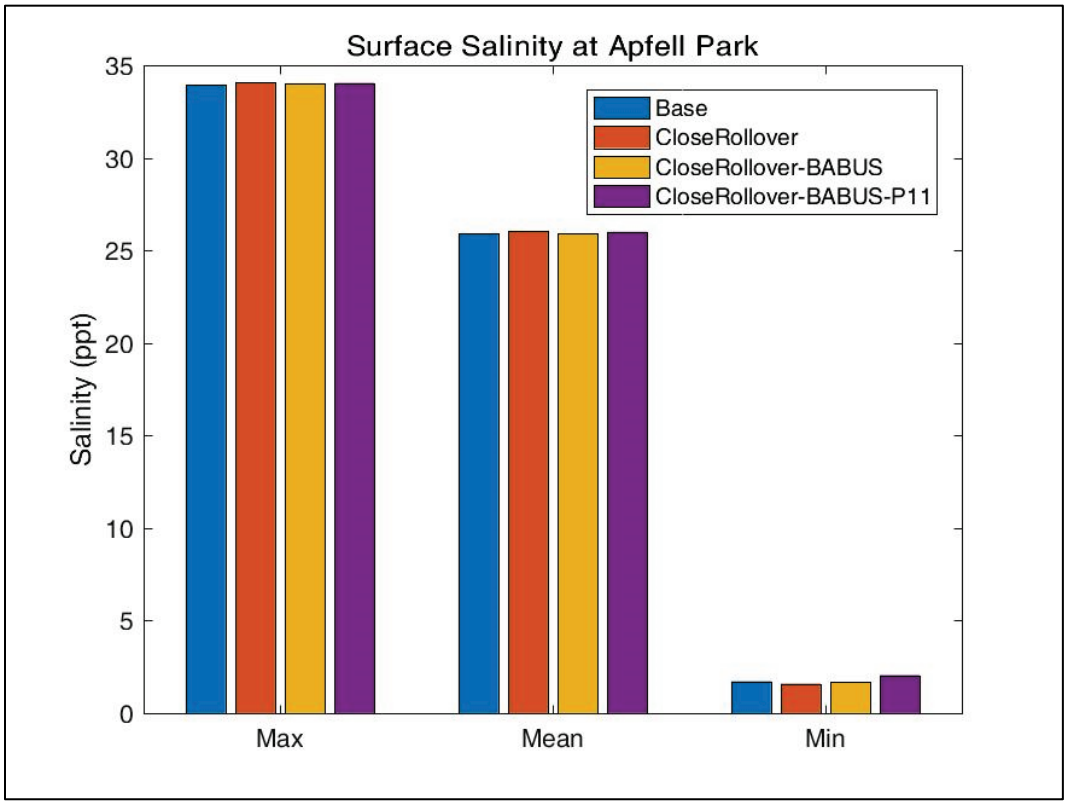

Surface Salinity at HSC at Turning Basin
Salinity (ppt)
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

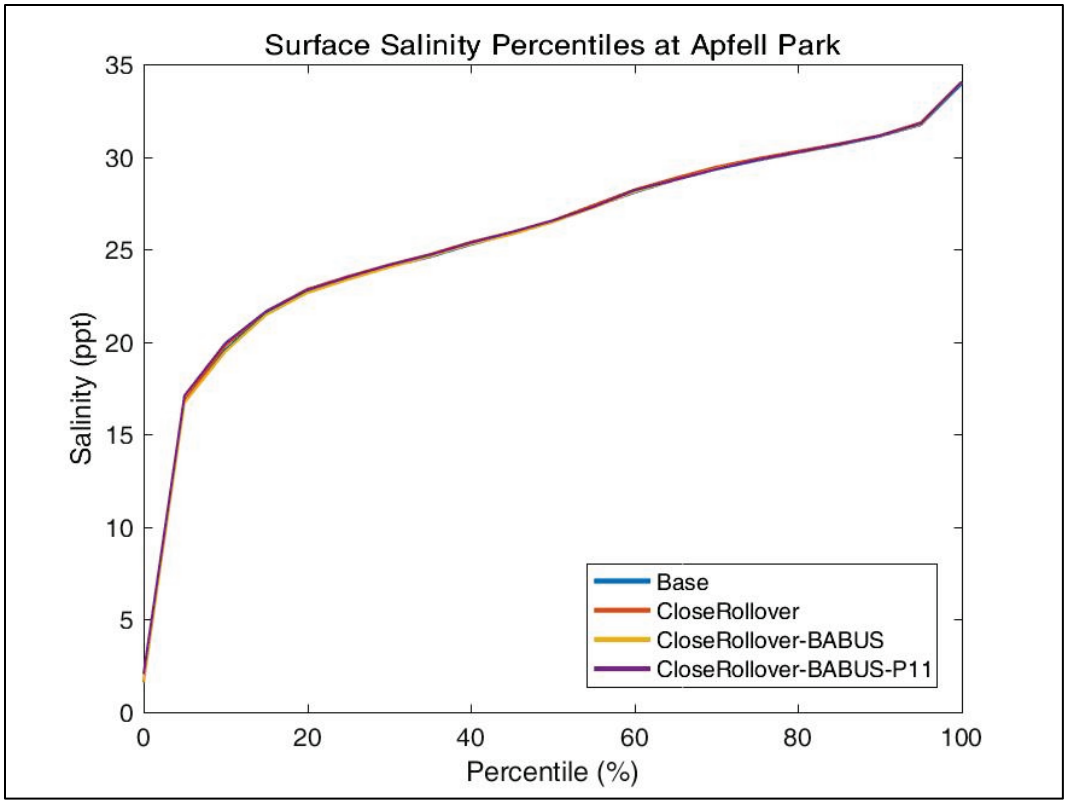

Surface Salinity Percentiles at HSC at Turning Basin
Salinity (ppt)
Percentile (%)
35
30
25
20
15
10
5
0
40
50
60
70
80
90
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11


Salinity at Apfell Park
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

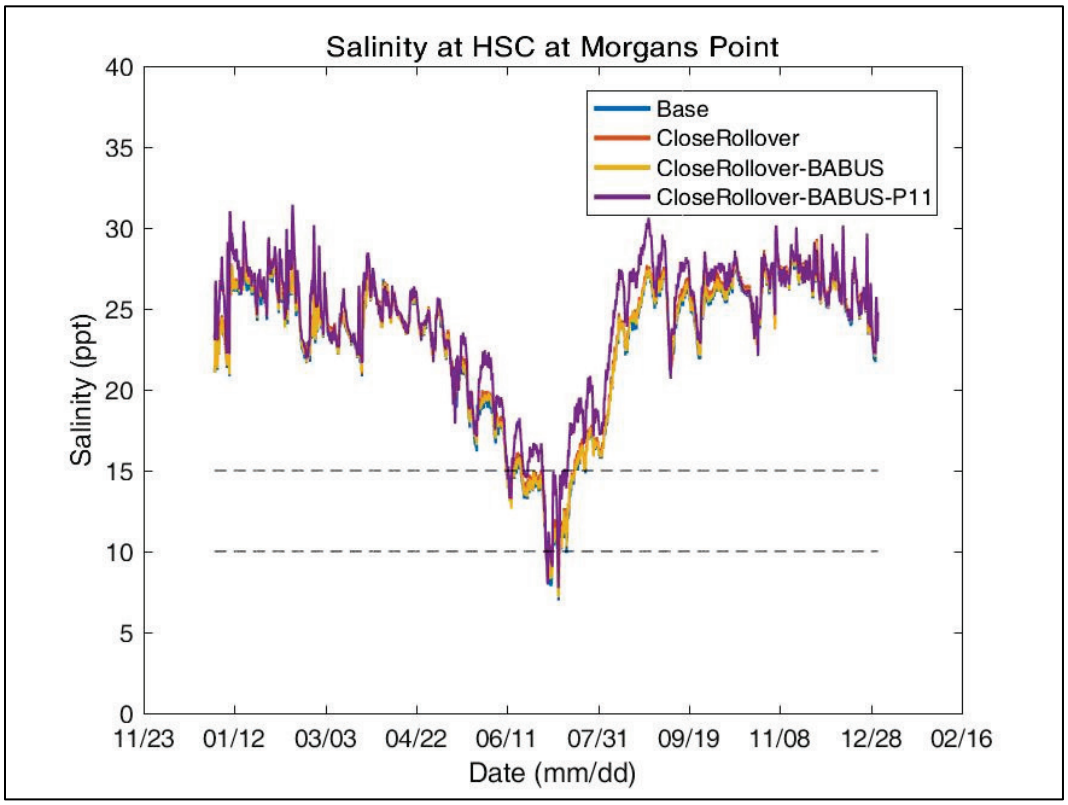

Bottom Salinity at Apfell Park
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

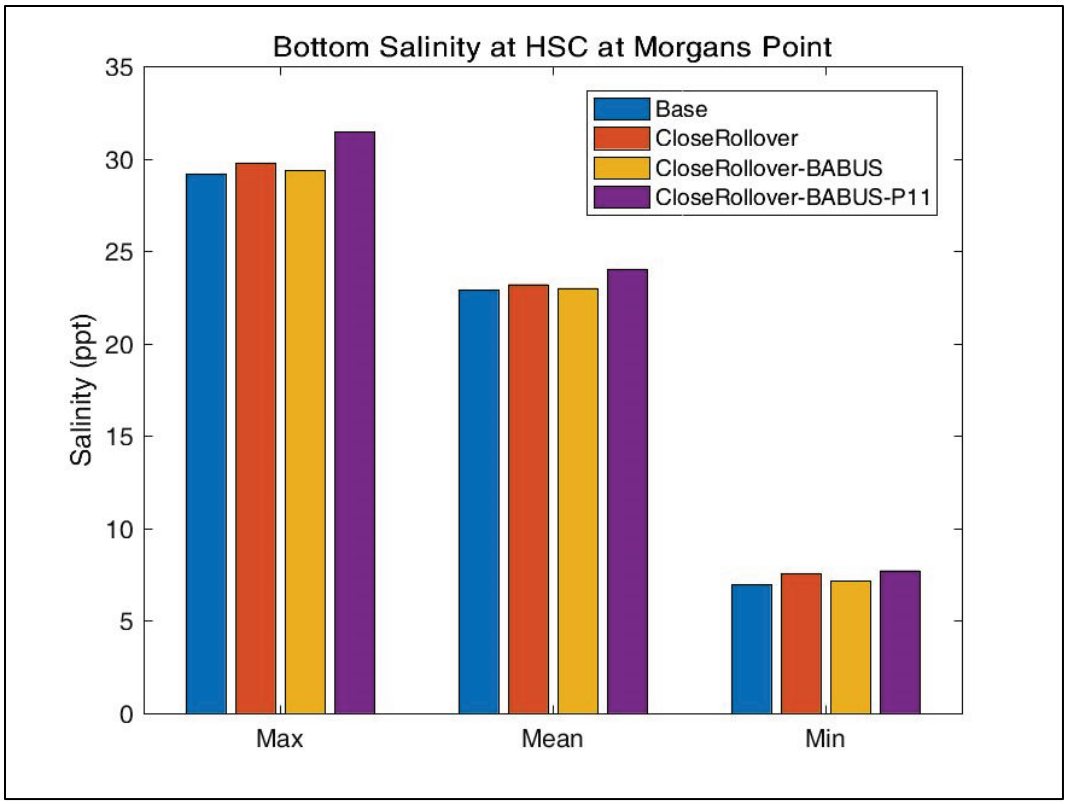

Bottom Salinity Percentiles at Apfell Park
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

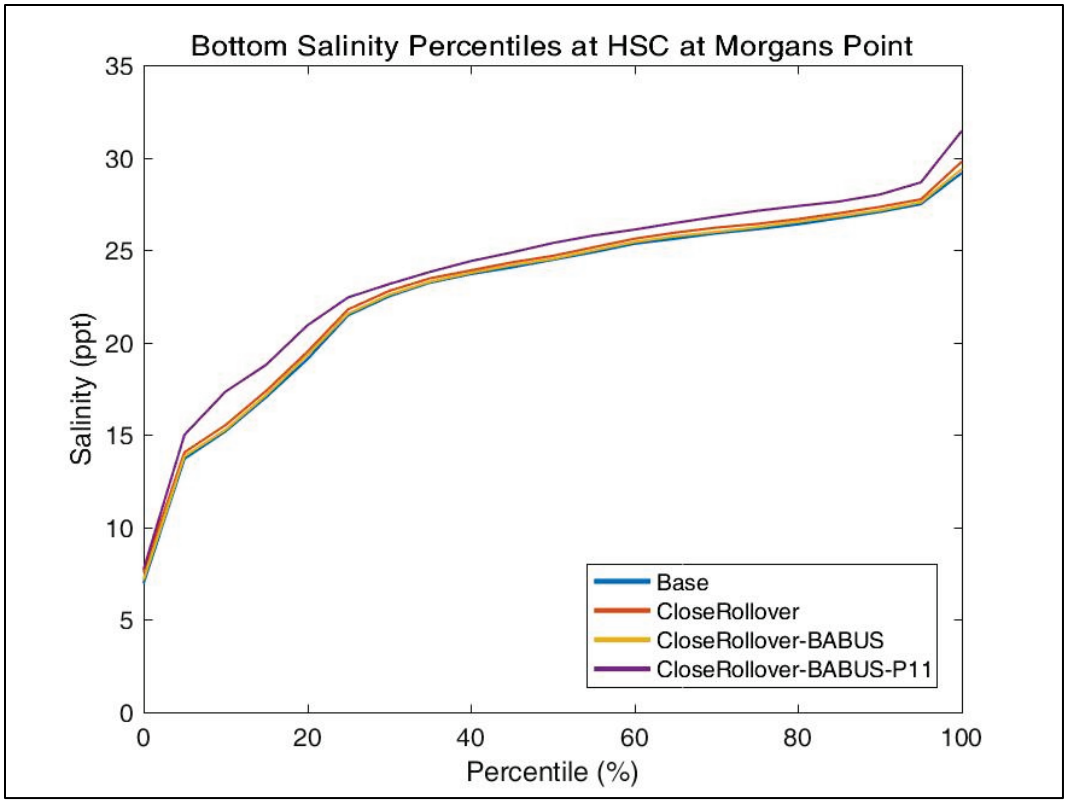

Surface Salinity at Apfell Park
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

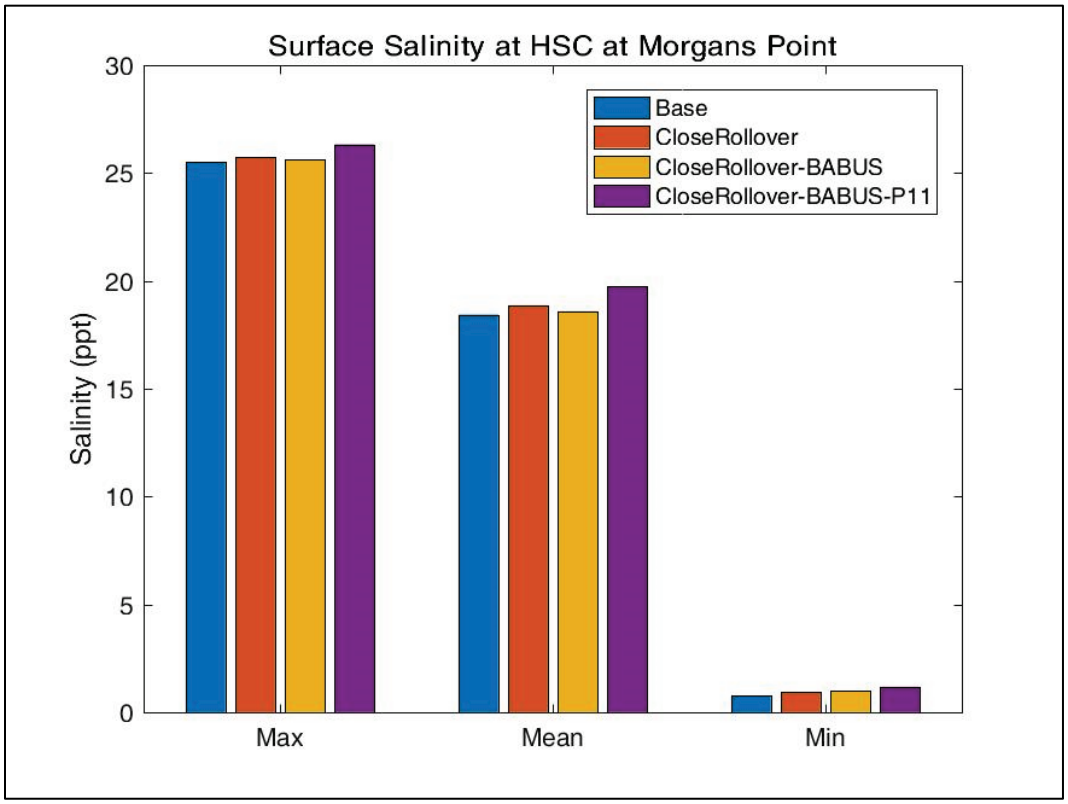

Surface Salinity Percentiles at Apfell Park
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

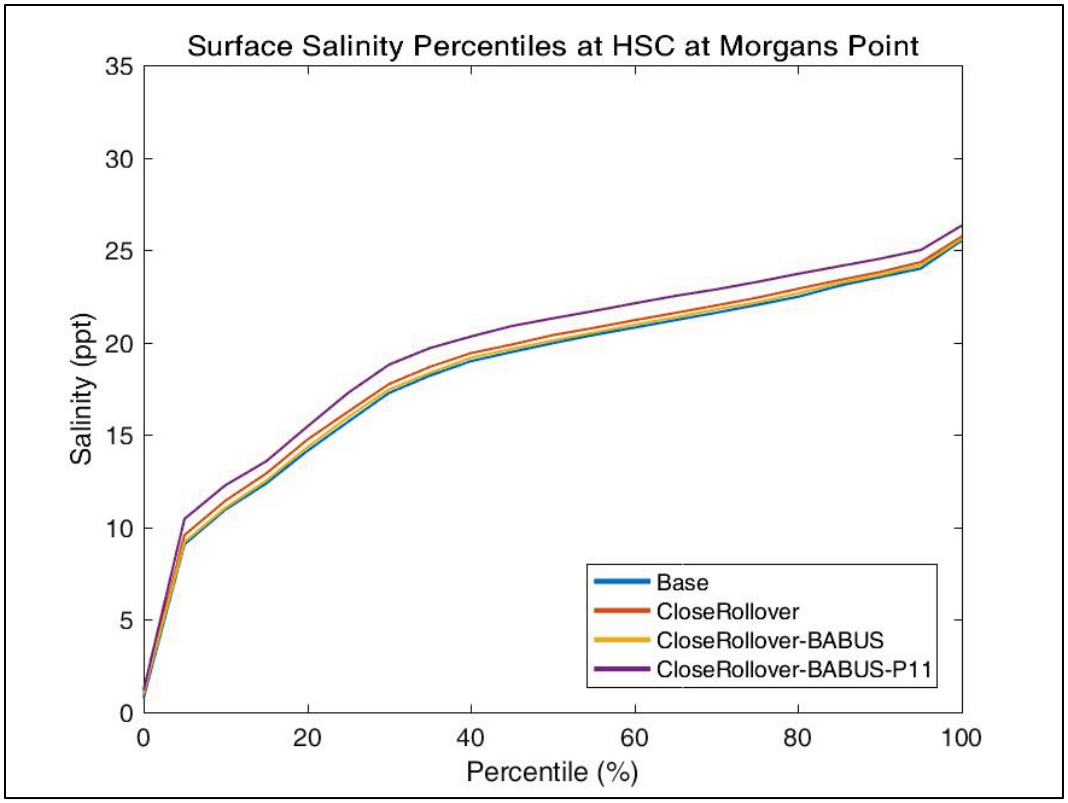
Point salinity analysis (Future)

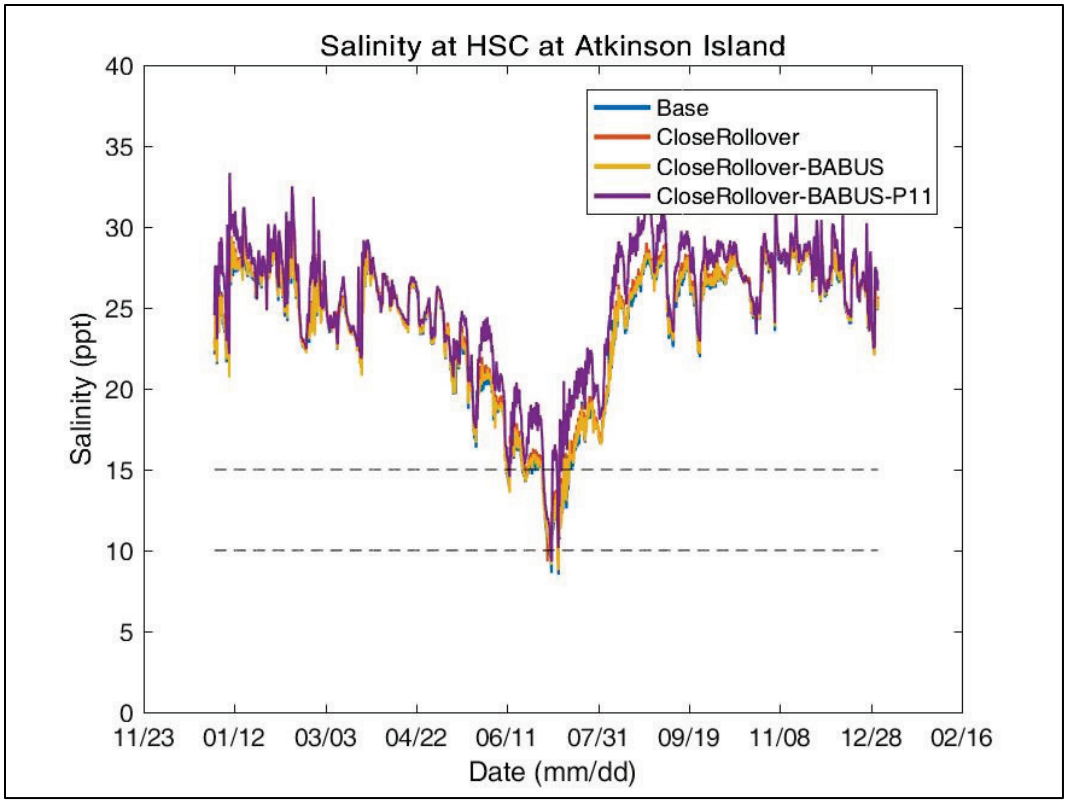


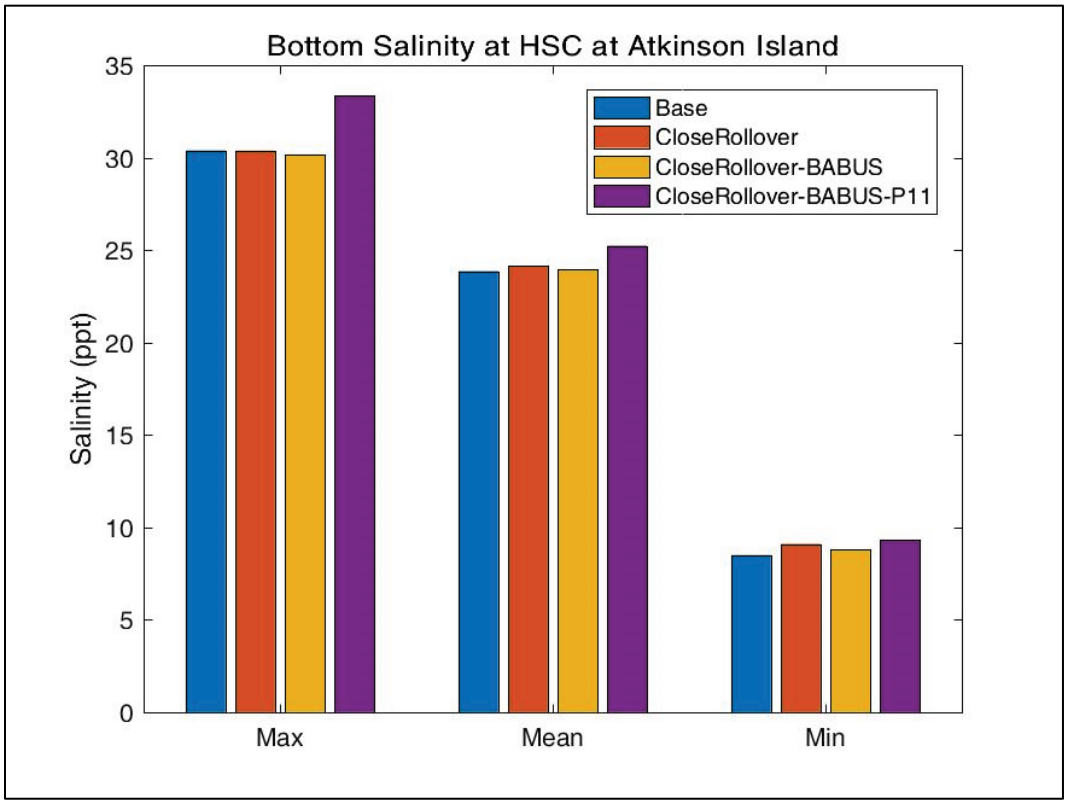


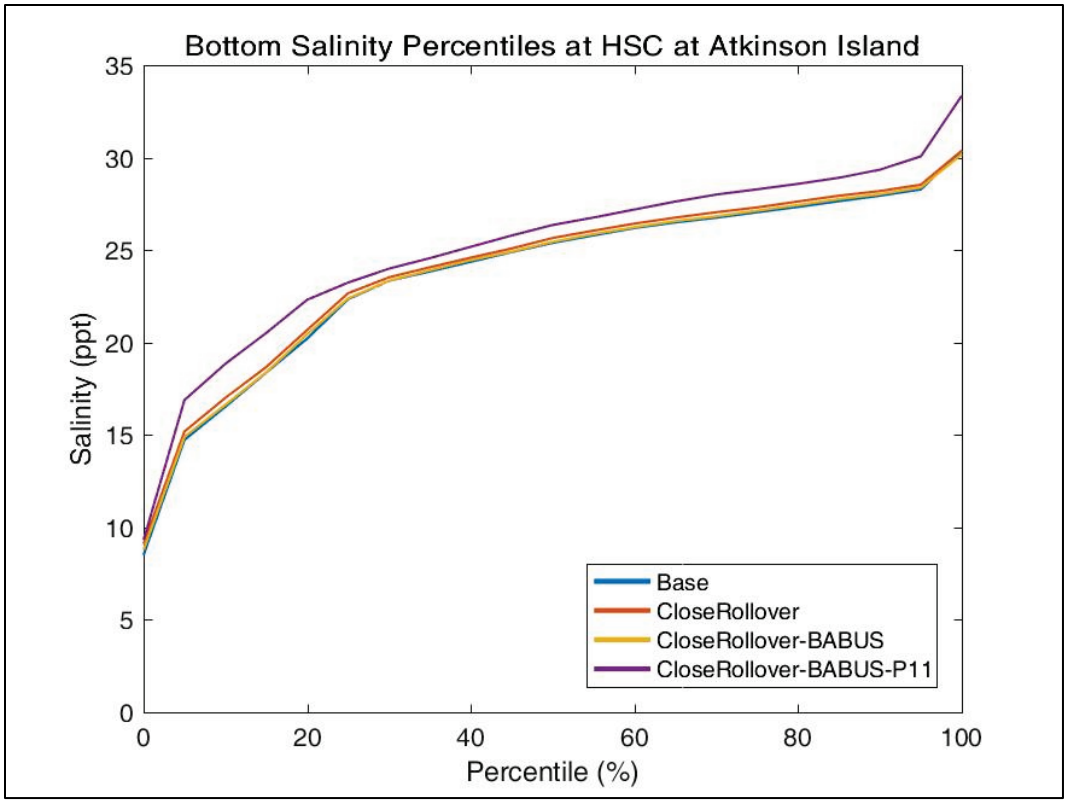

Bottom Salinity Percentiles at HSC at Morgans Point
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

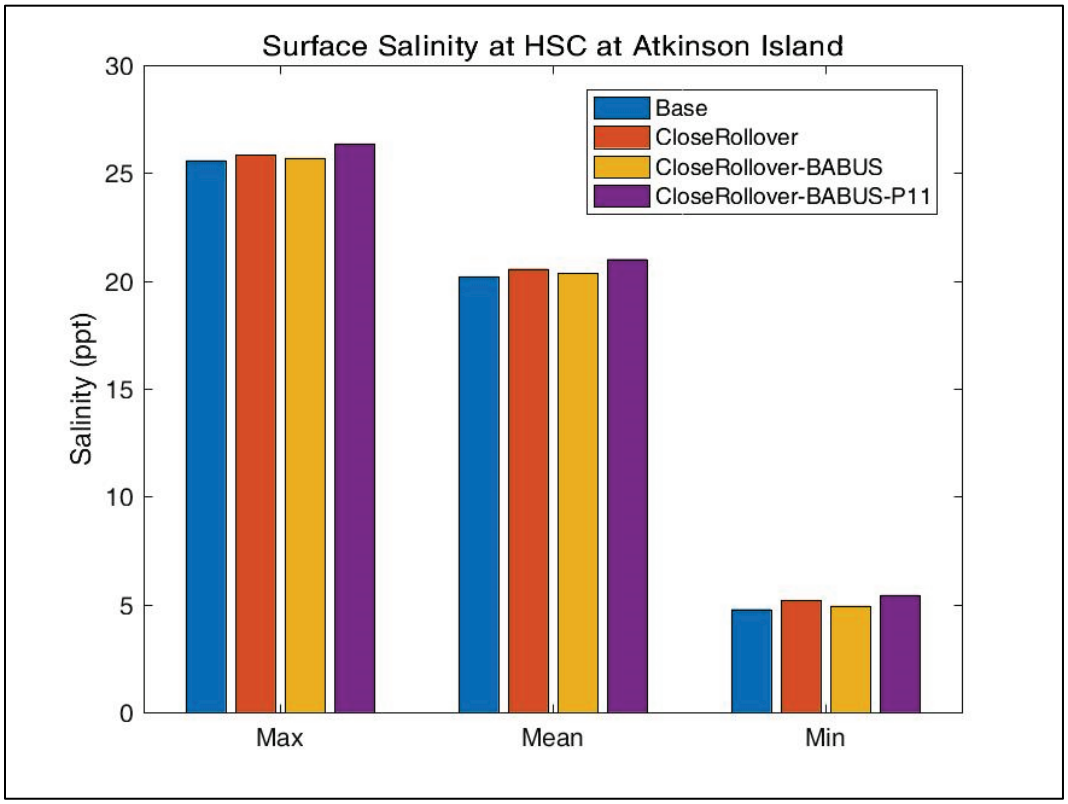

Surface Salinity at HSC at Morgans Point
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

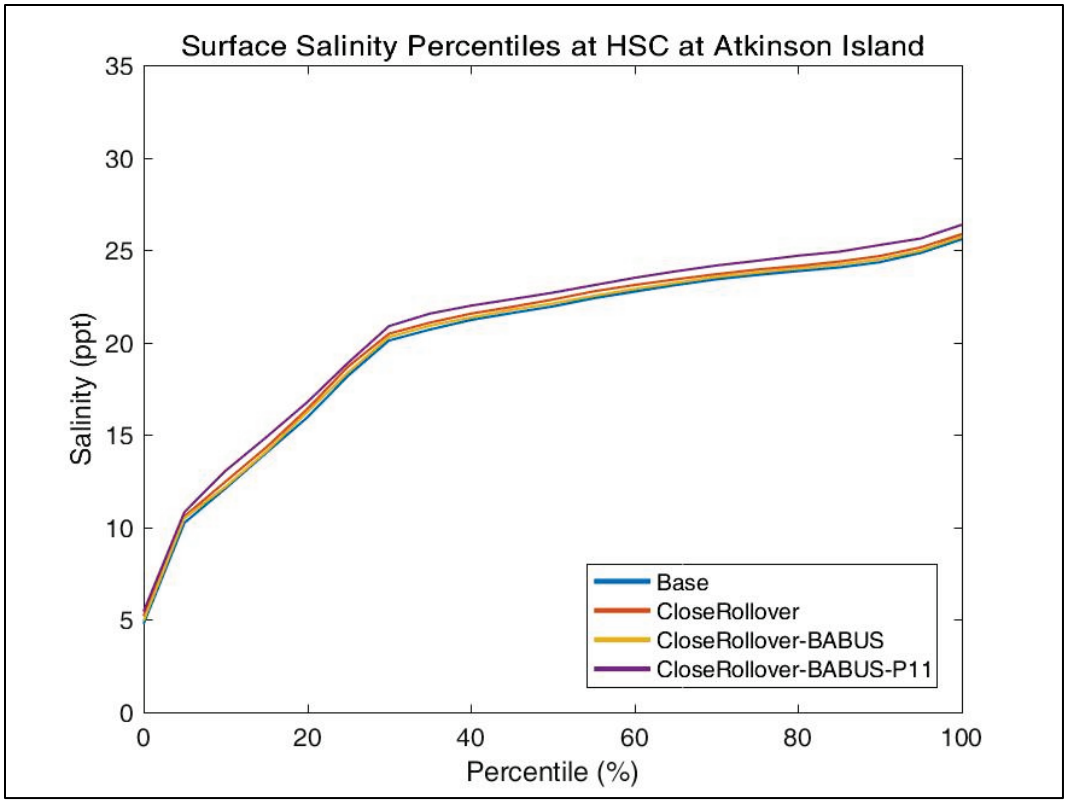

Surface Salinity Percentiles at HSC at Morgans Point
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

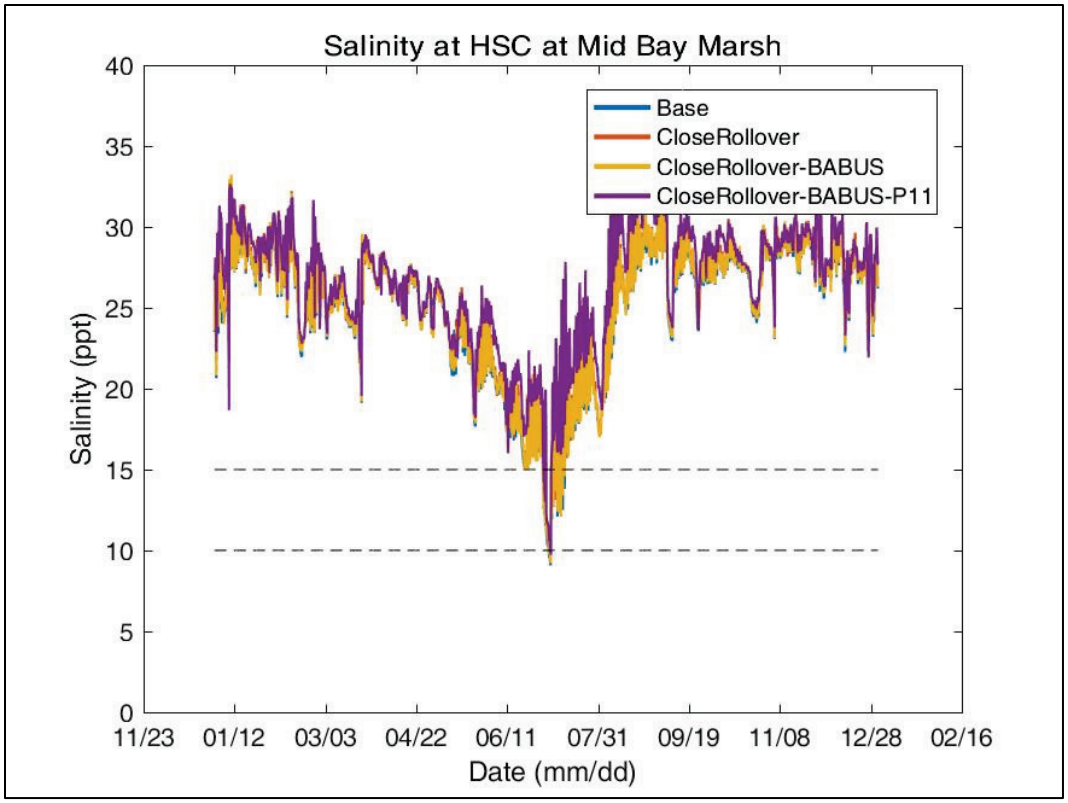

Salinity at HSC at Atkinson Island
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

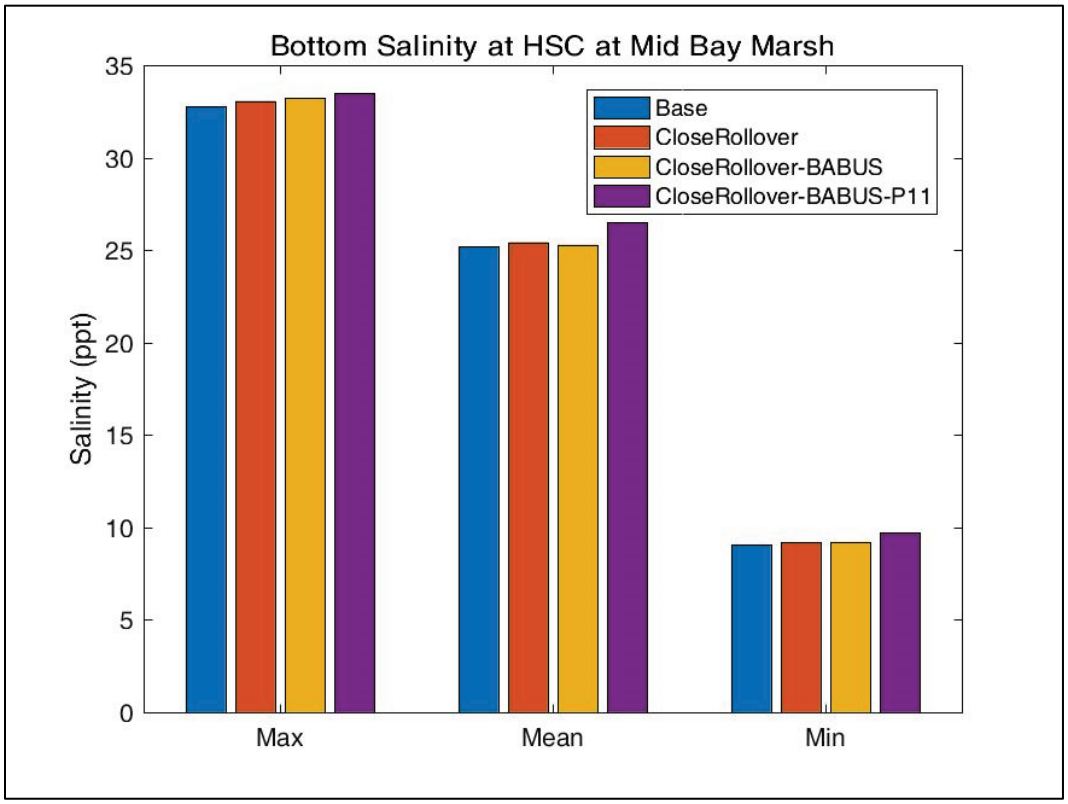

Bottom Salinity at HSC at Atkinson Island
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

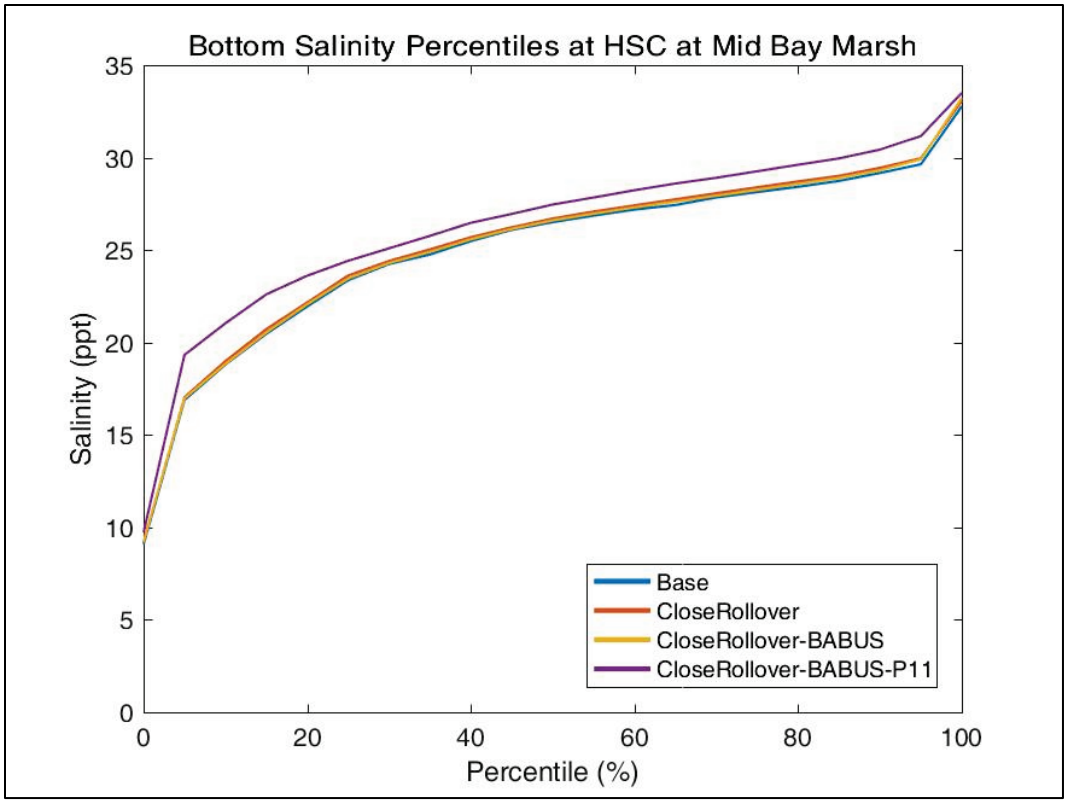

Bottom Salinity Percentiles at HSC at Atkinson Island
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

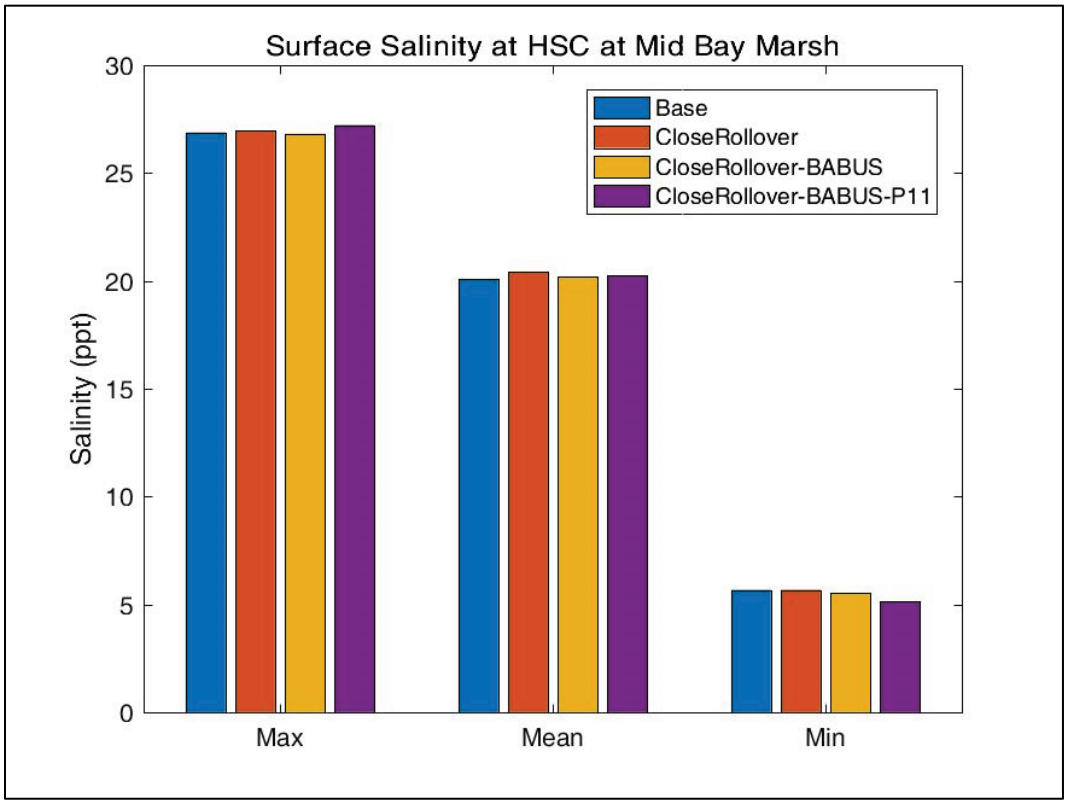

Surface Salinity at HSC at Atkinson Island
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

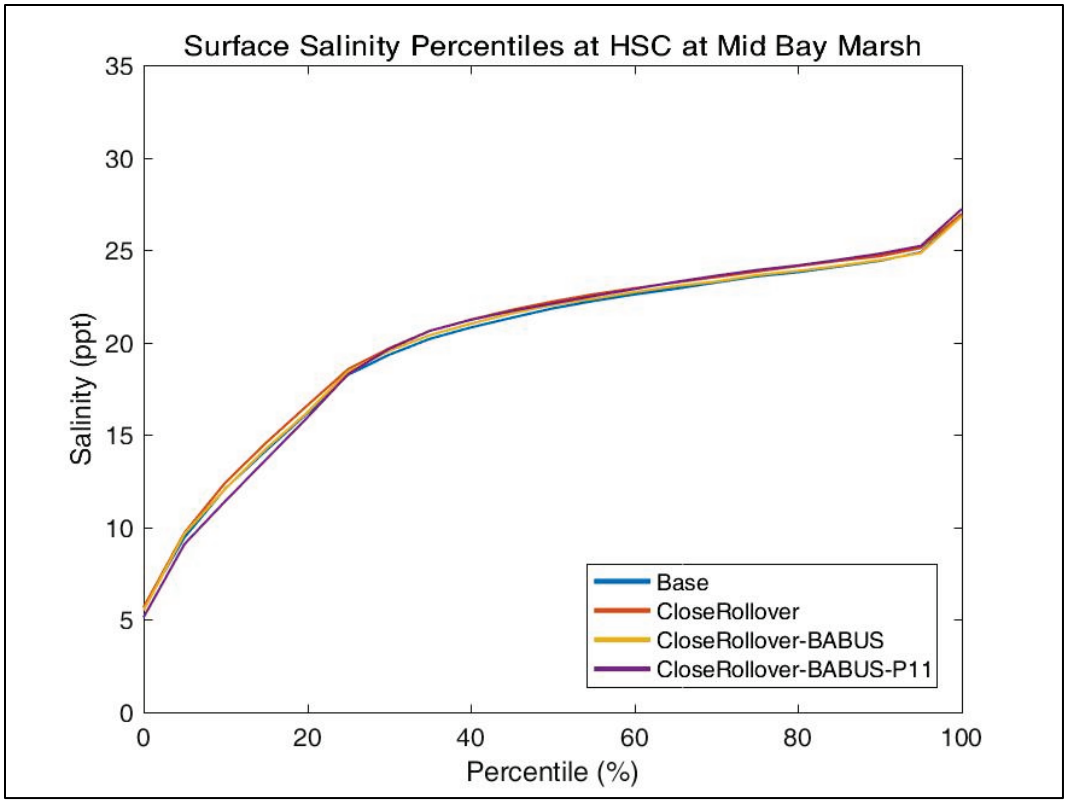

Surface Salinity Percentiles at HSC at Atkinson Island
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

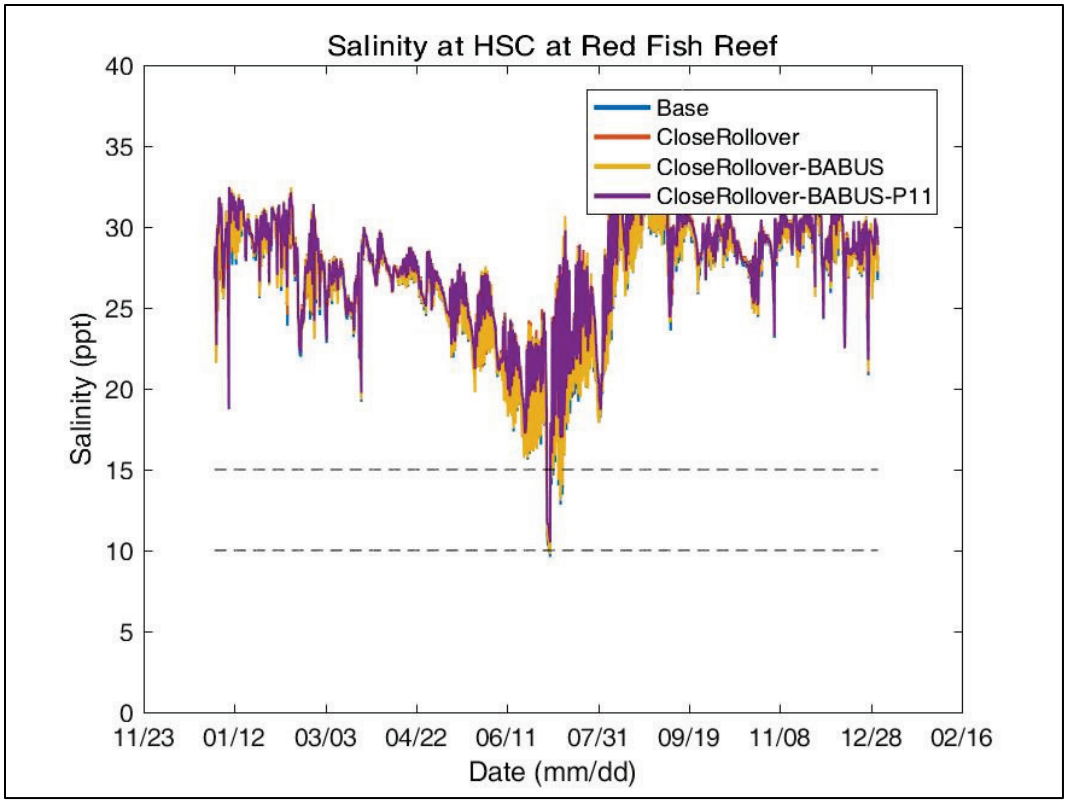

Salinity at HSC at Mid Bay Marsh
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

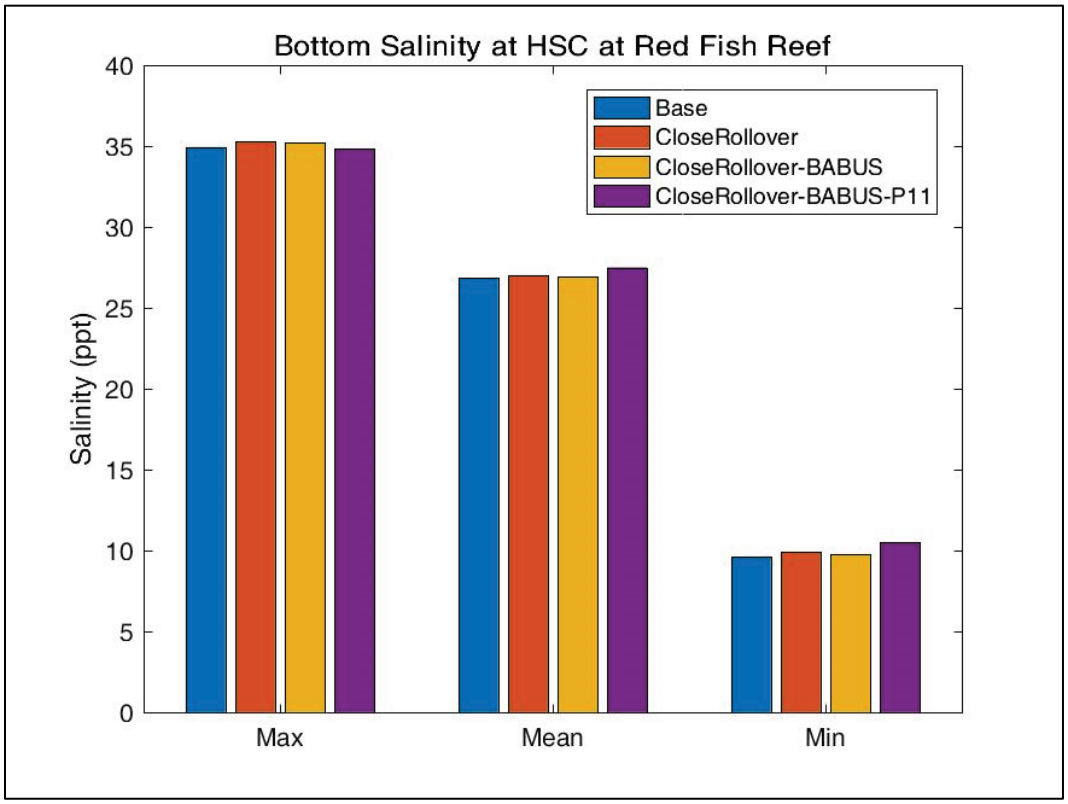

Bottom Salinity at HSC at Mid Bay Marsh
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

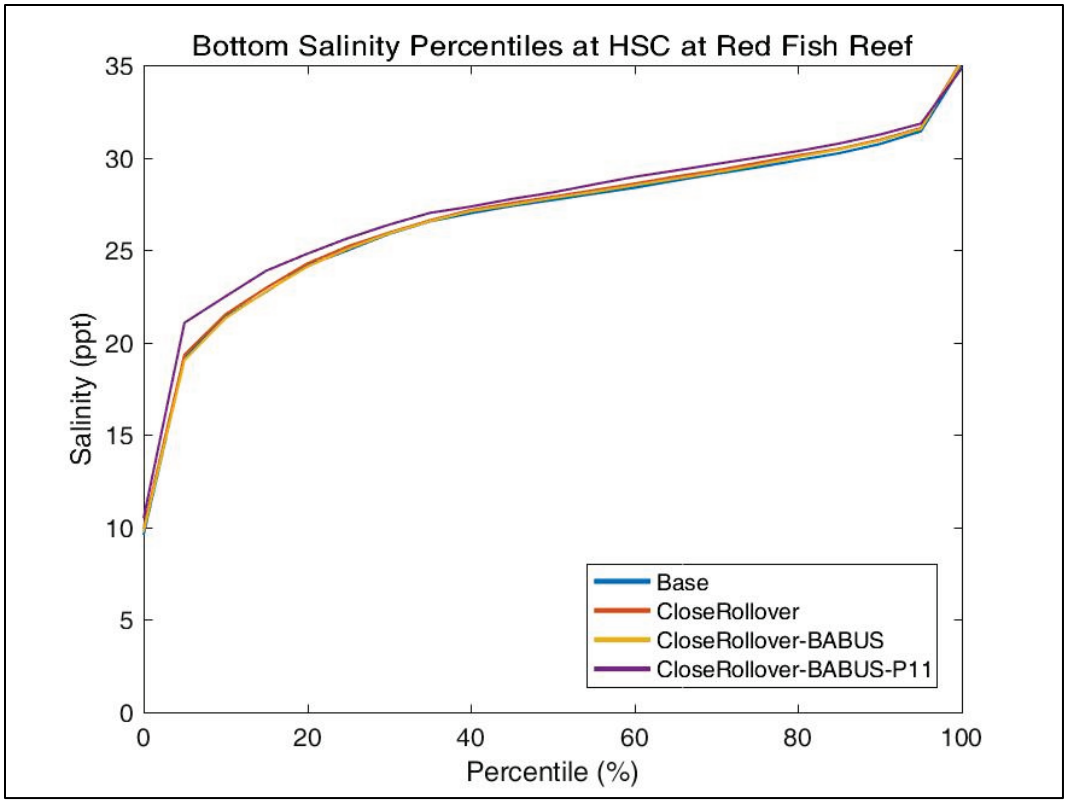

Bottom Salinity Percentiles at HSC at Mid Bay Marsh
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

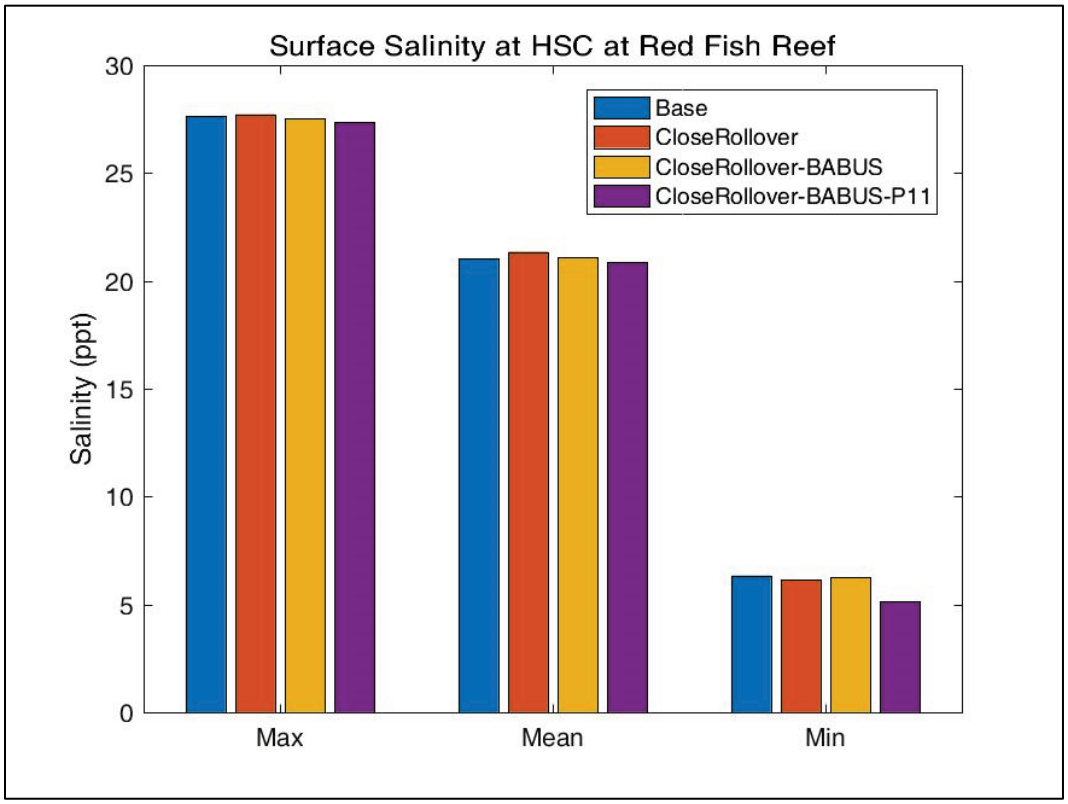

Surface Salinity at HSC at Mid Bay Marsh
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

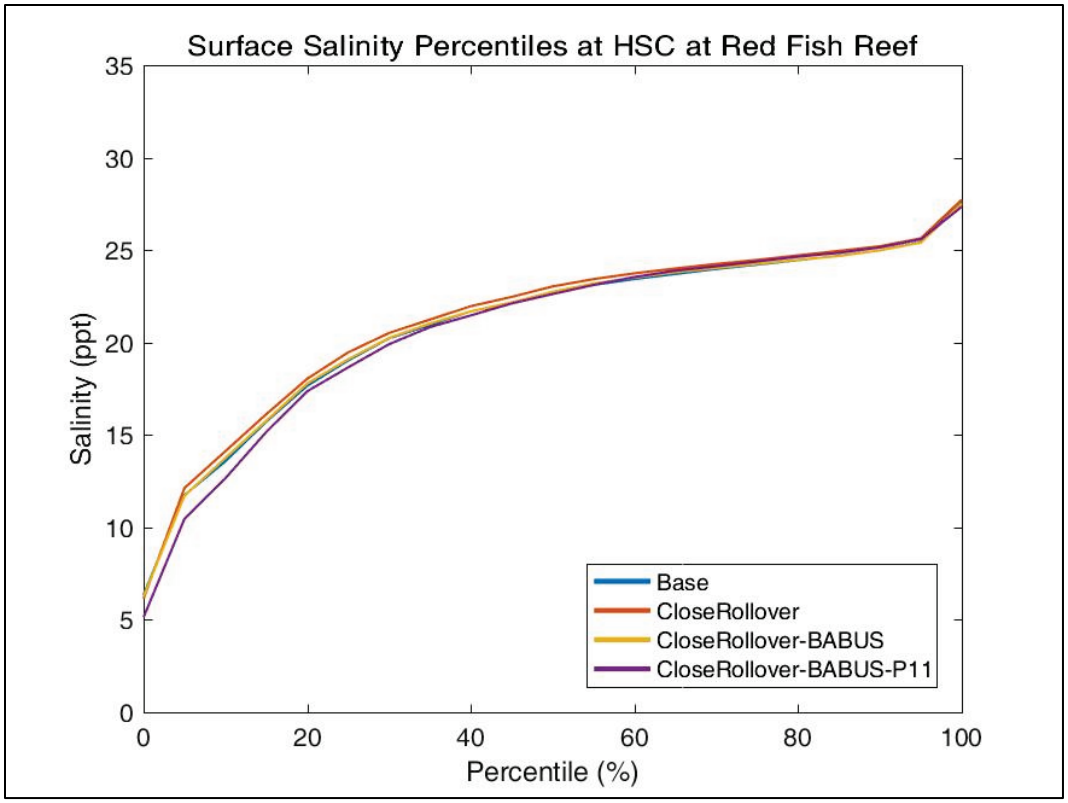

Surface Salinity Percentiles at HSC at Mid Bay Marsh
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

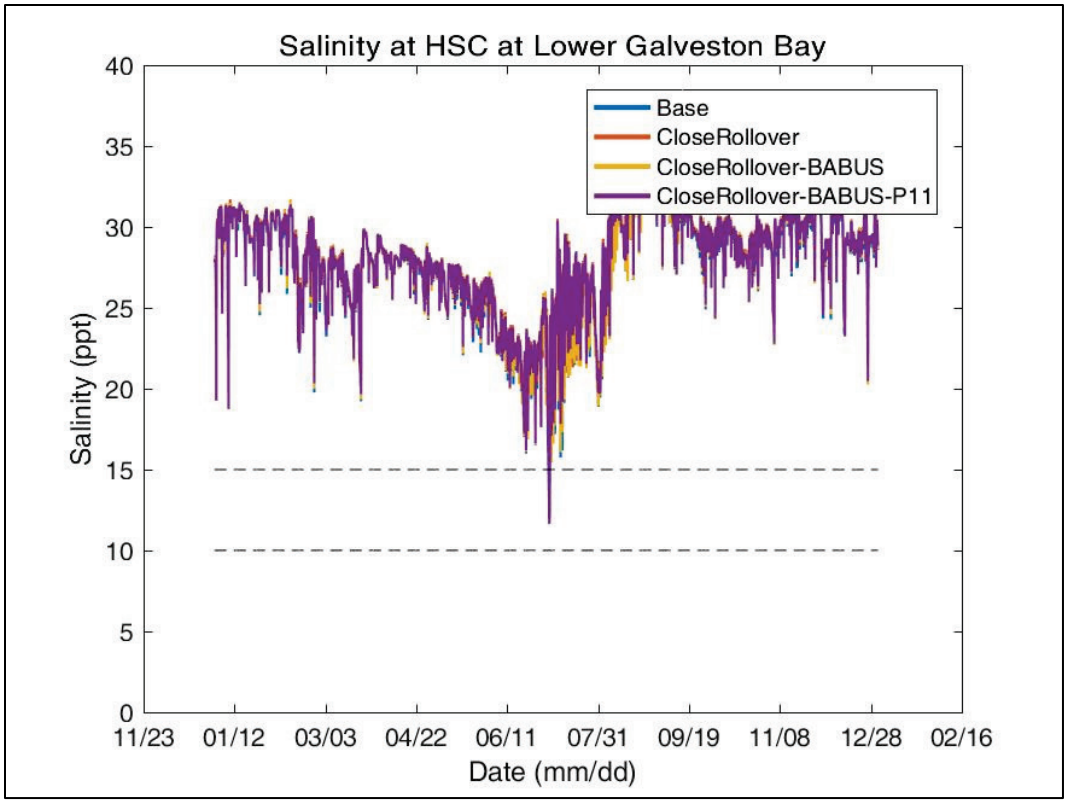

Salinity at HSC at Red Fish Reef
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

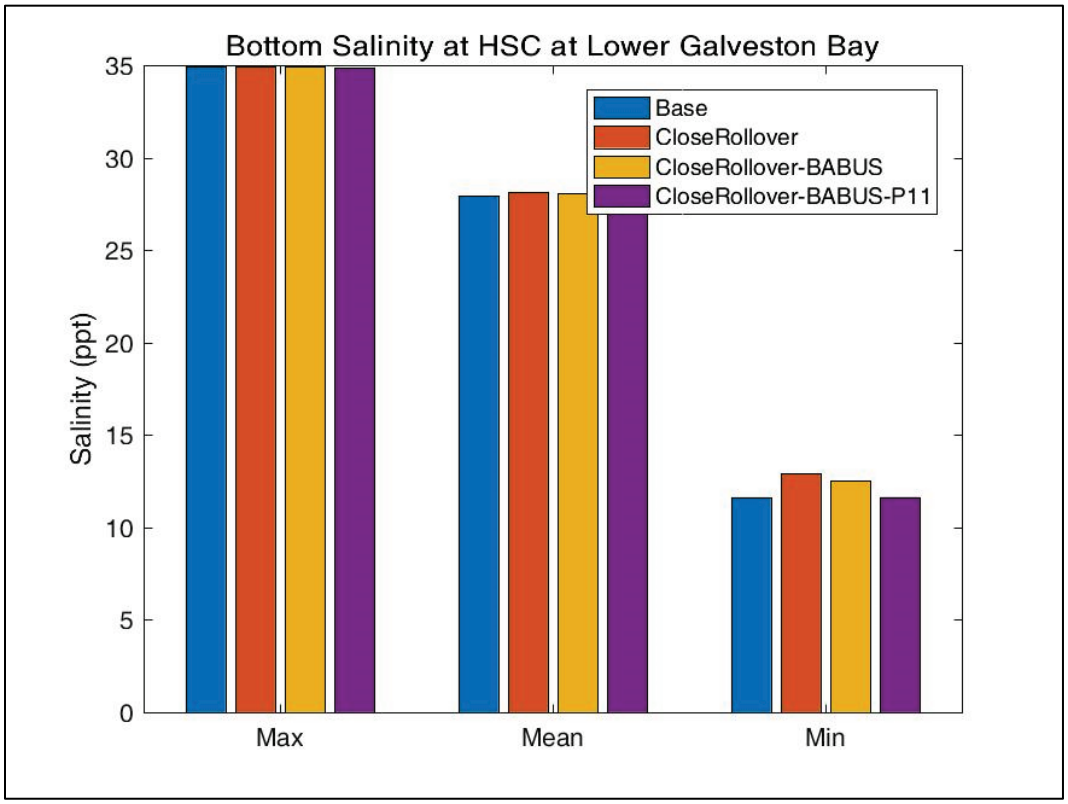

Bottom Salinity at HSC at Red Fish Reef
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
Max
Mean
Min

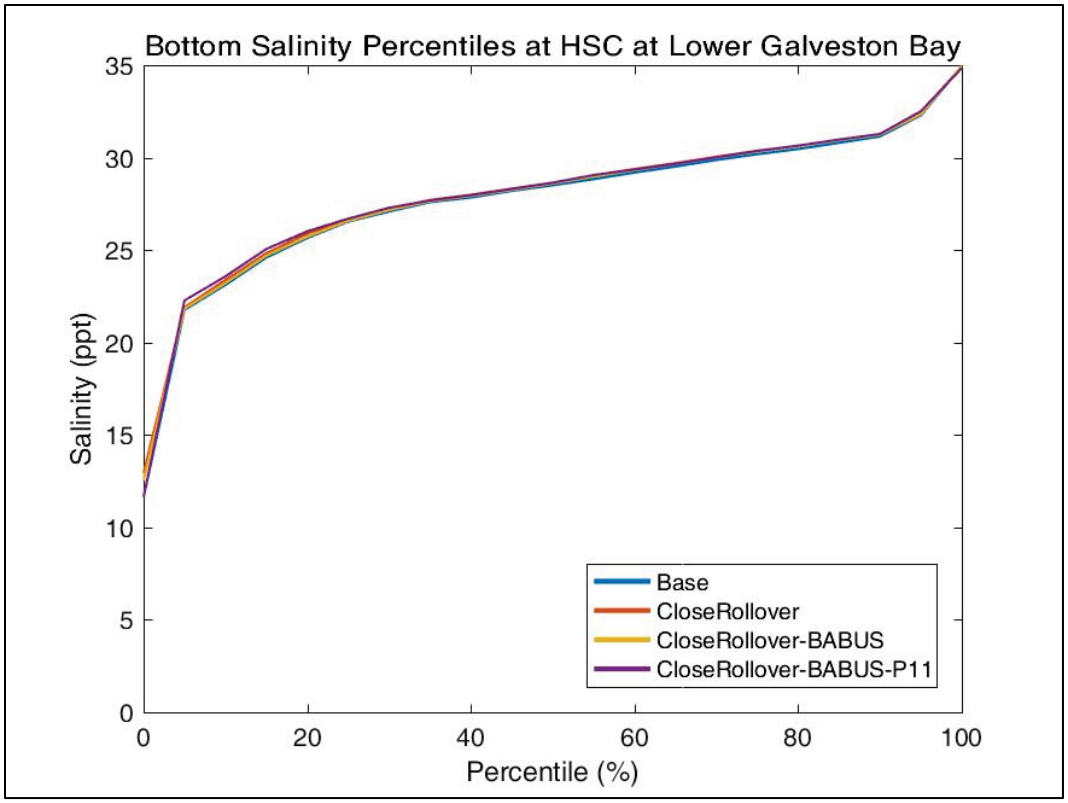

Bottom Salinity Percentiles at HSC at Red Fish Reef
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

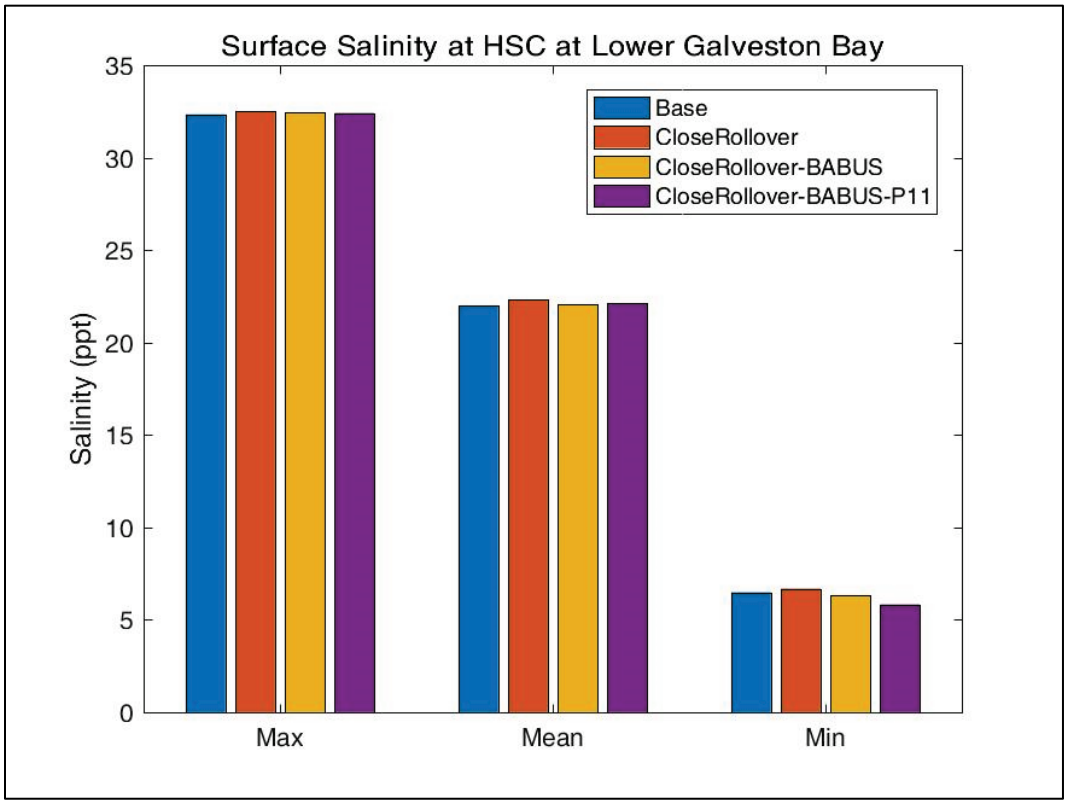

Surface Salinity at HSC at Red Fish Reef
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

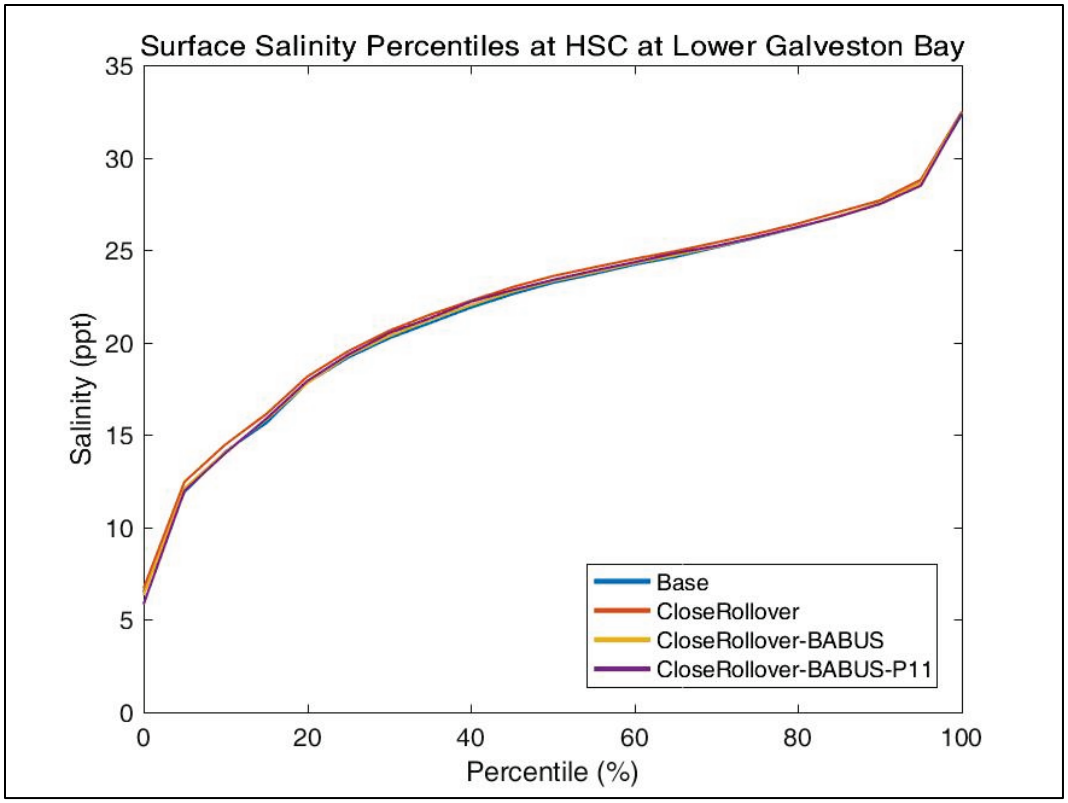

Surface Salinity Percentiles at HSC at Red Fish Reef
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

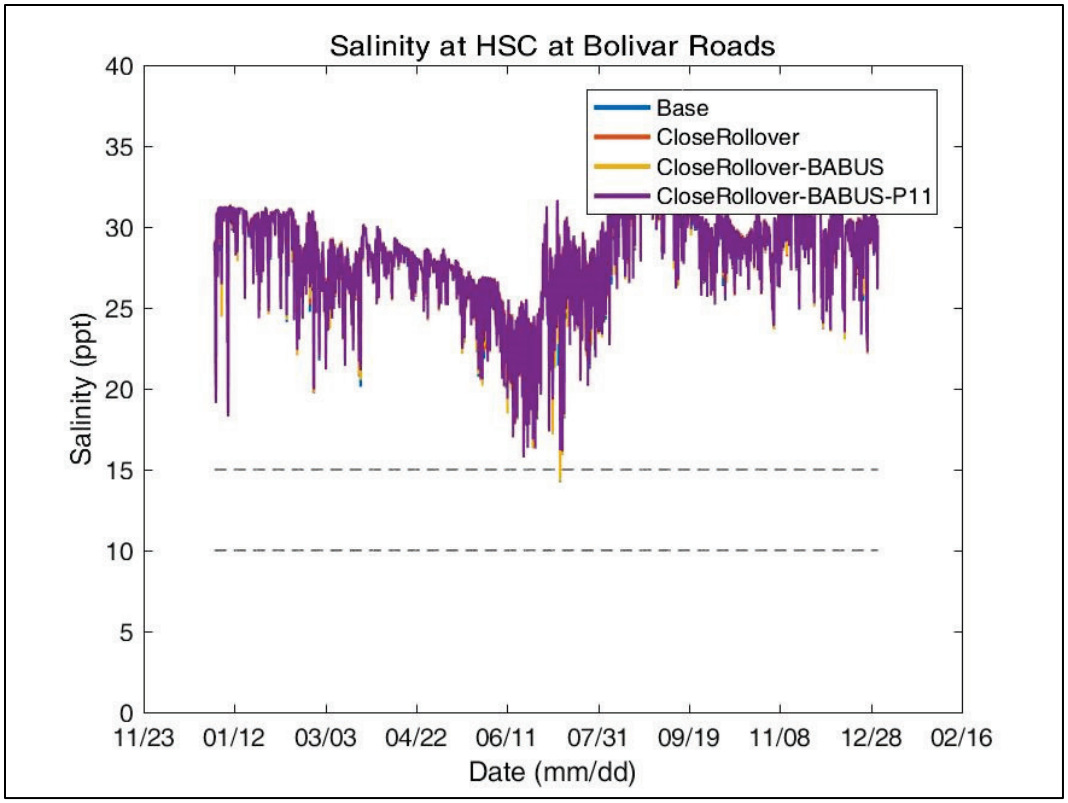

Salinity at HSC at Lower Galveston Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

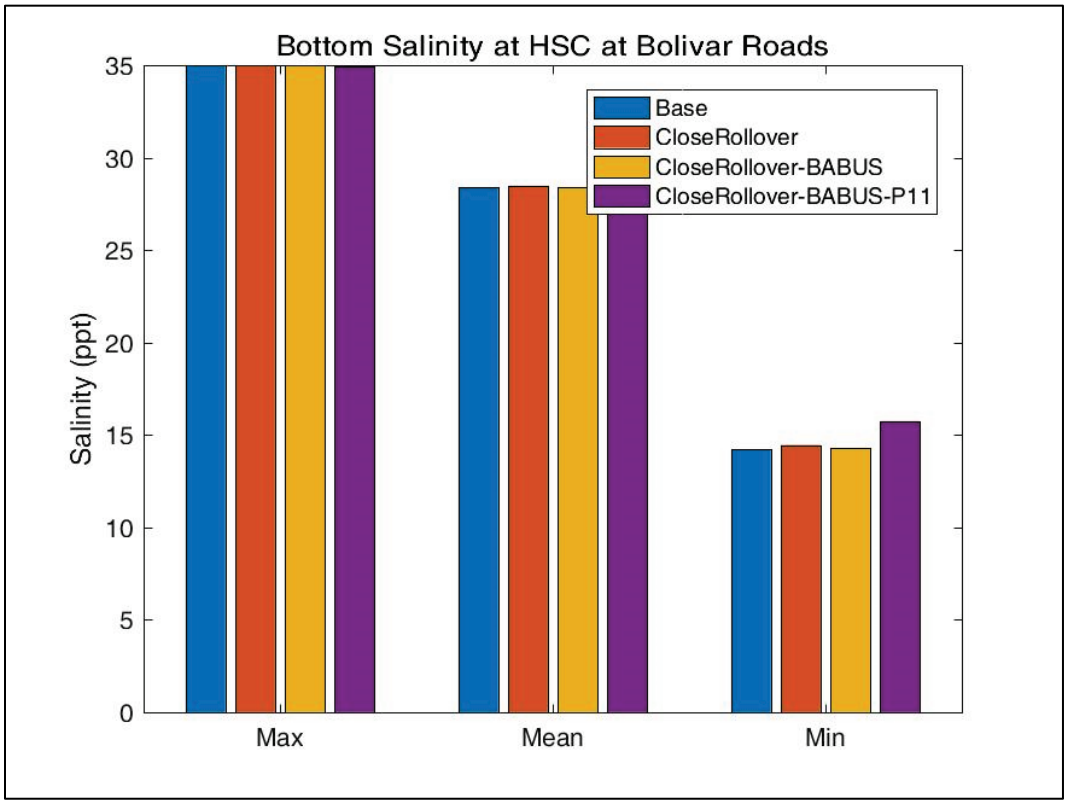

Bottom Salinity at HSC at Lower Galveston Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

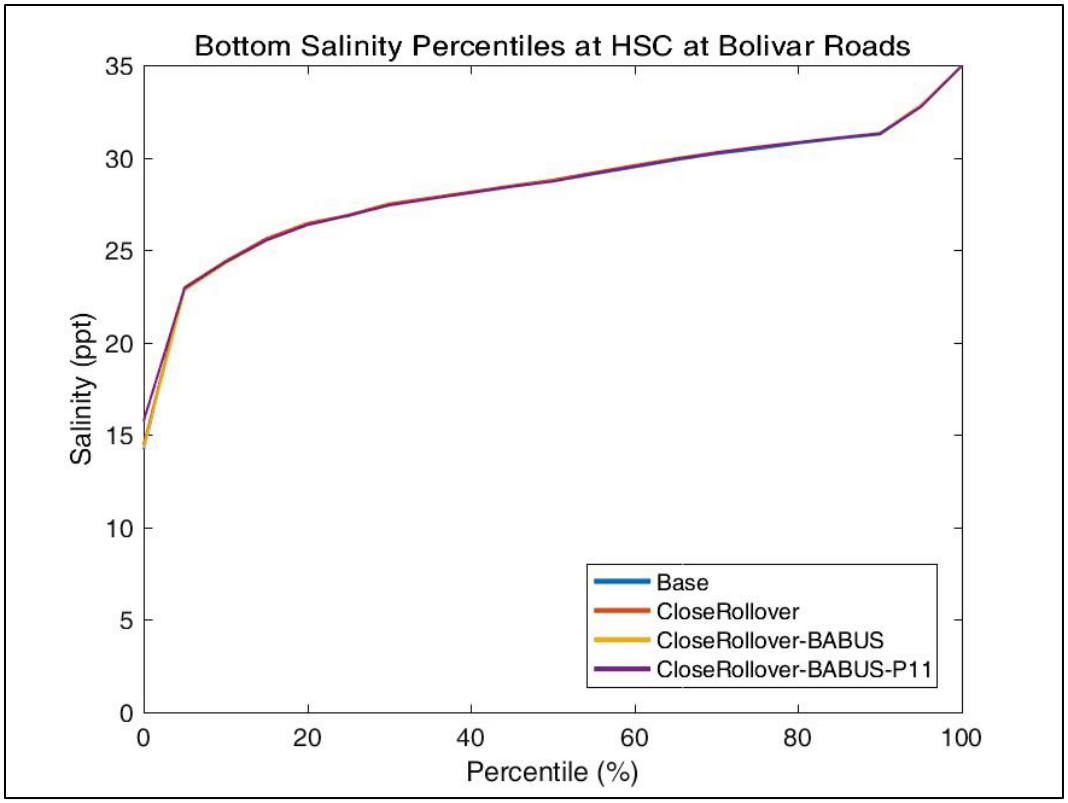

Bottom Salinity Percentiles at HSC at Lower Galveston Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

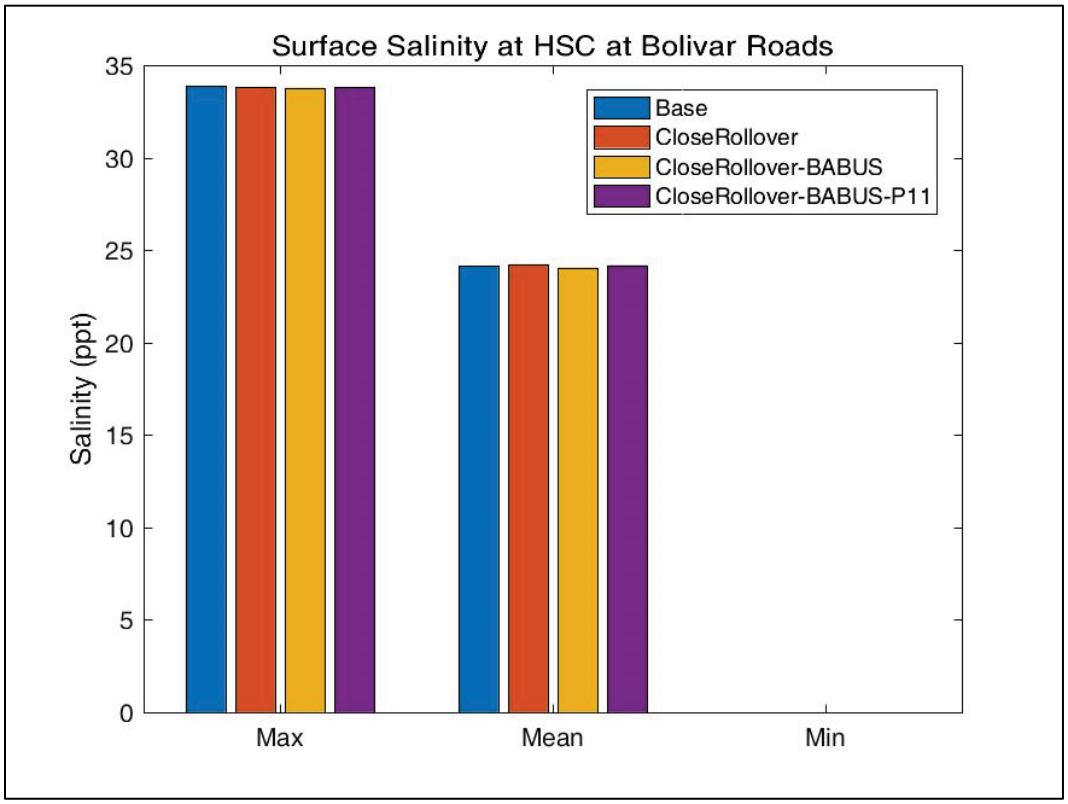

Surface Salinity at HSC at Lower Galveston Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

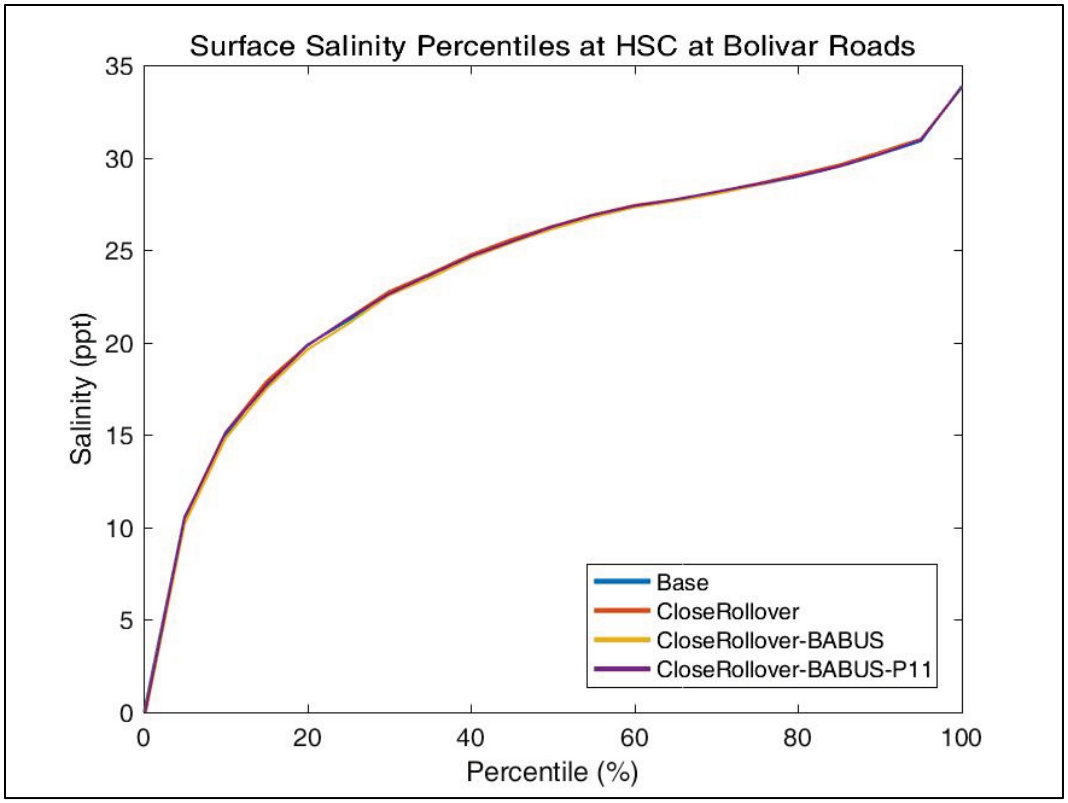

Surface Salinity Percentiles at HSC at Lower Galveston Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

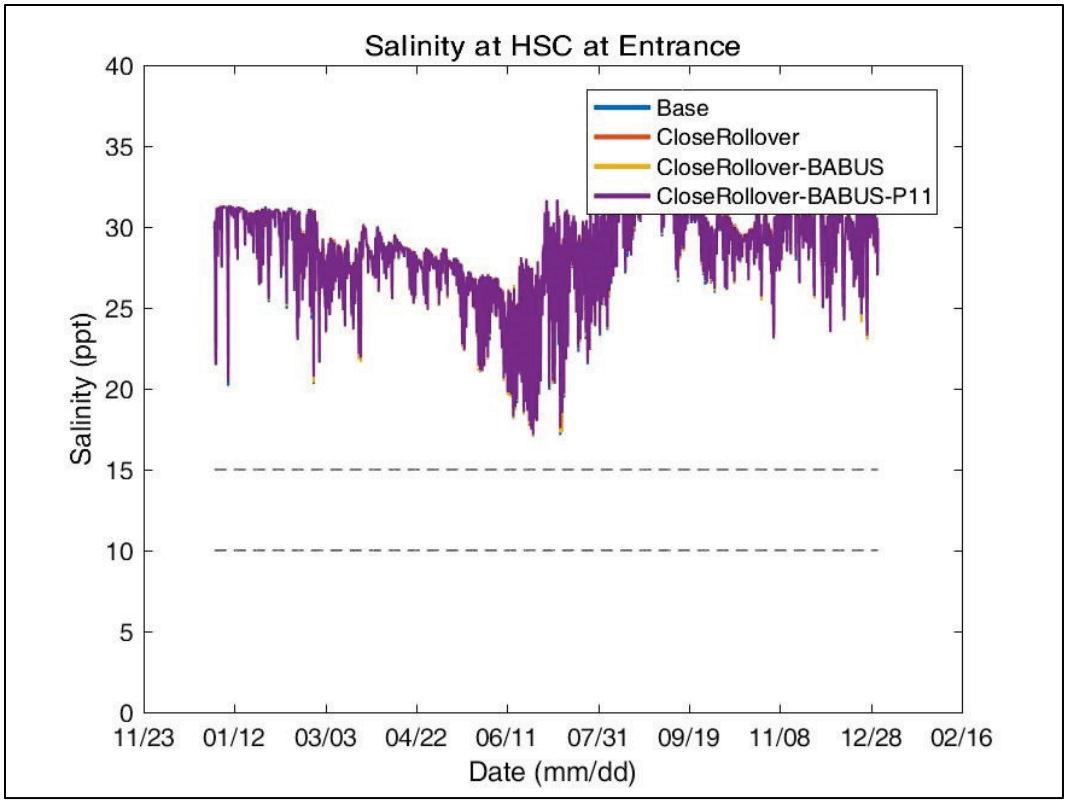

Salinity at HSC at Bolivar Roads
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

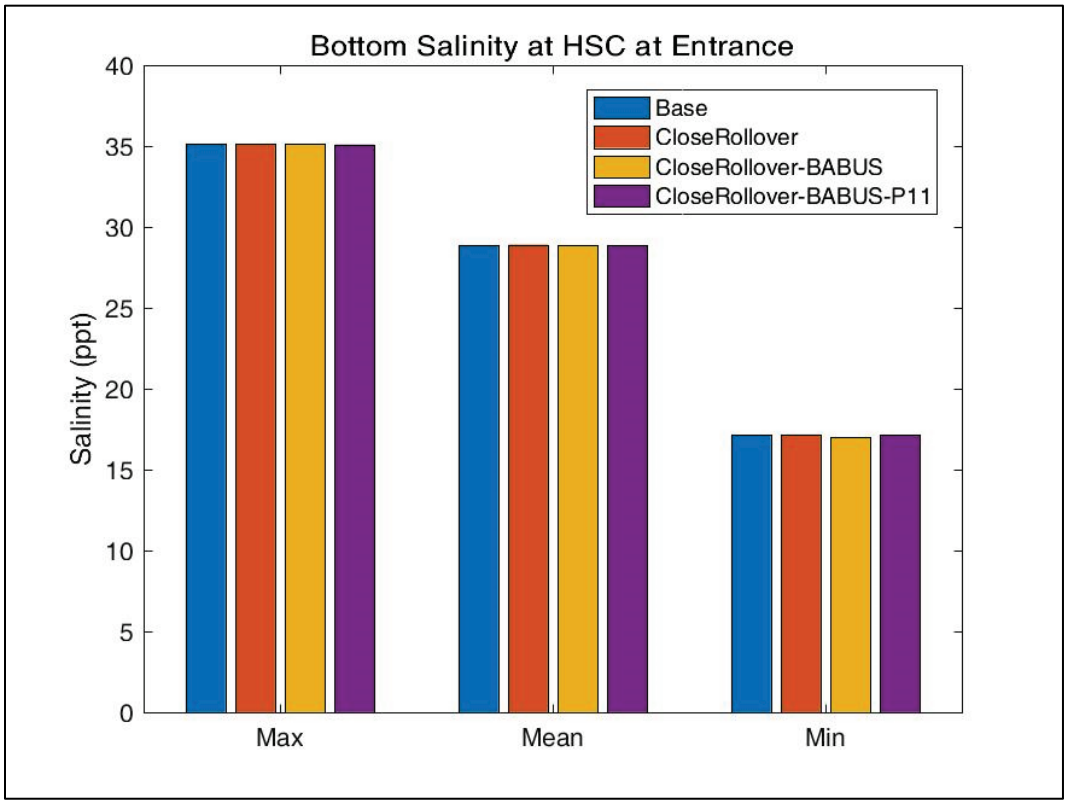

Bottom Salinity at HSC at Bolivar Roads
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

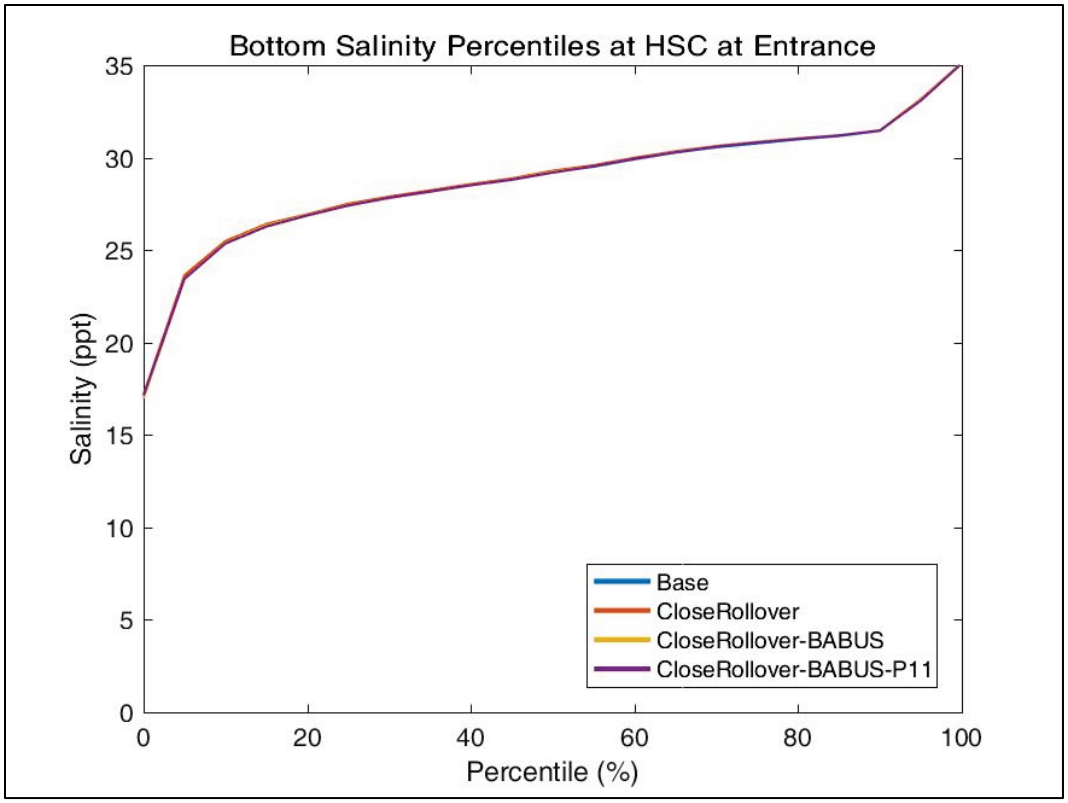

Bottom Salinity Percentiles at HSC at Bolivar Roads
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

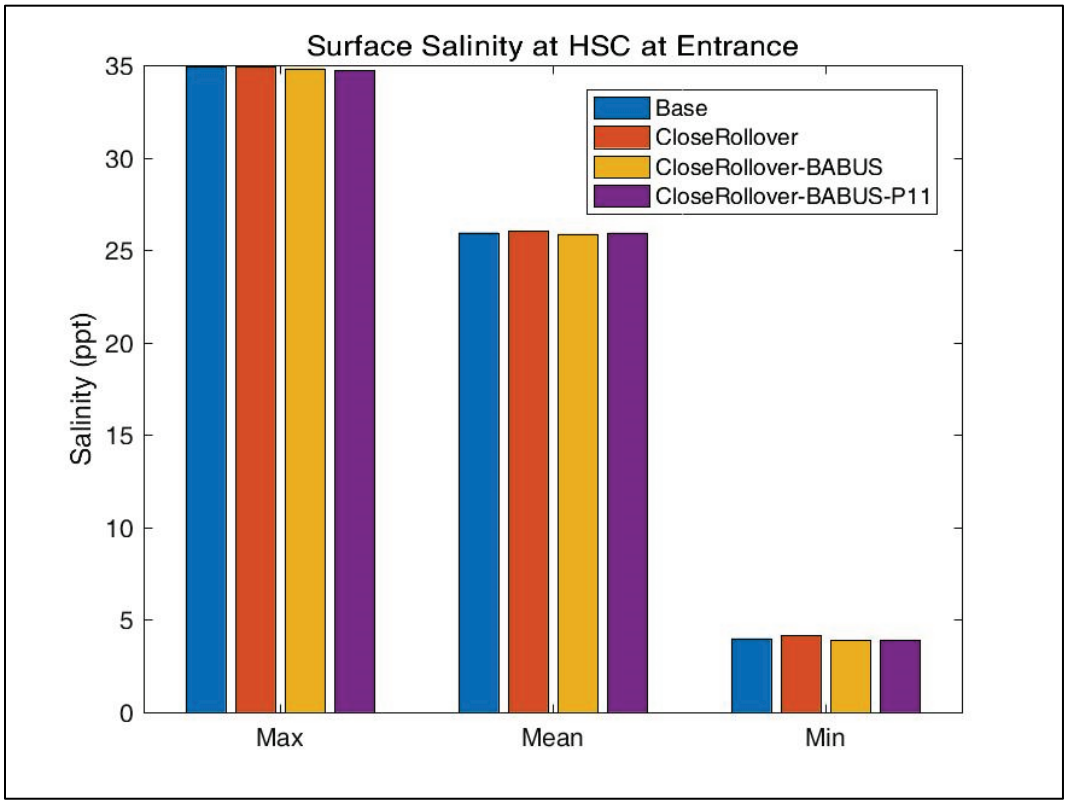

Surface Salinity at HSC at Bolivar Roads
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

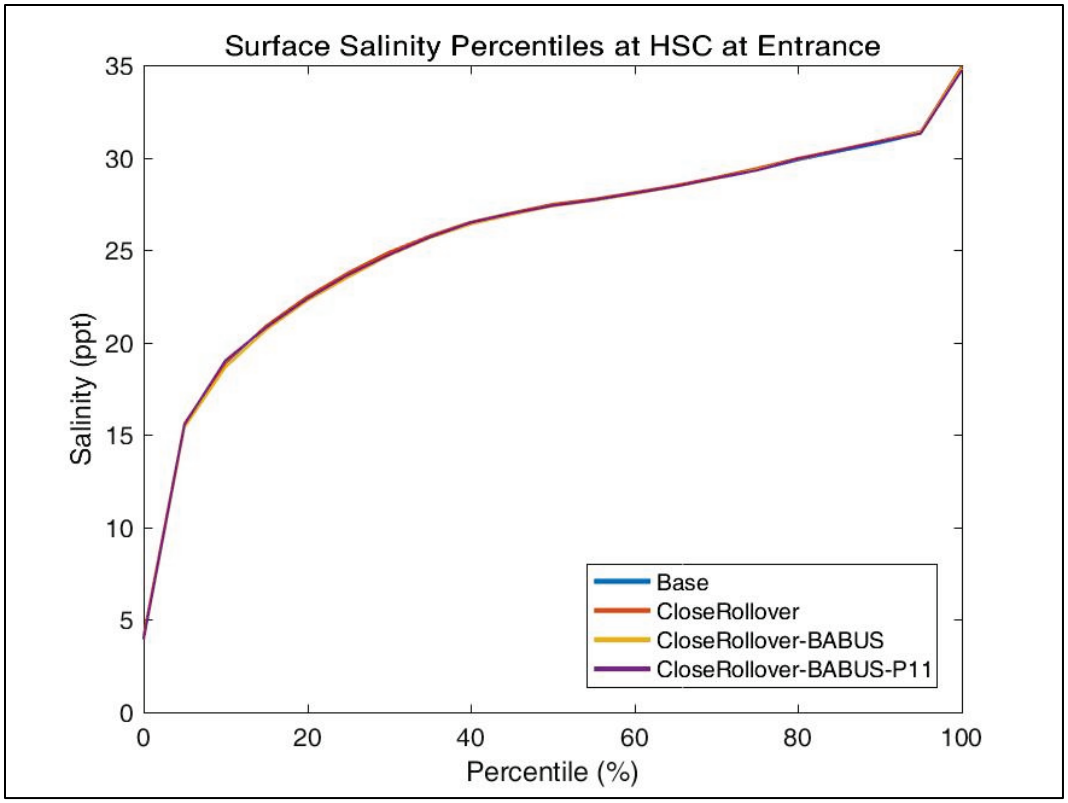

Surface Salinity Percentiles at HSC at Bolivar Roads
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

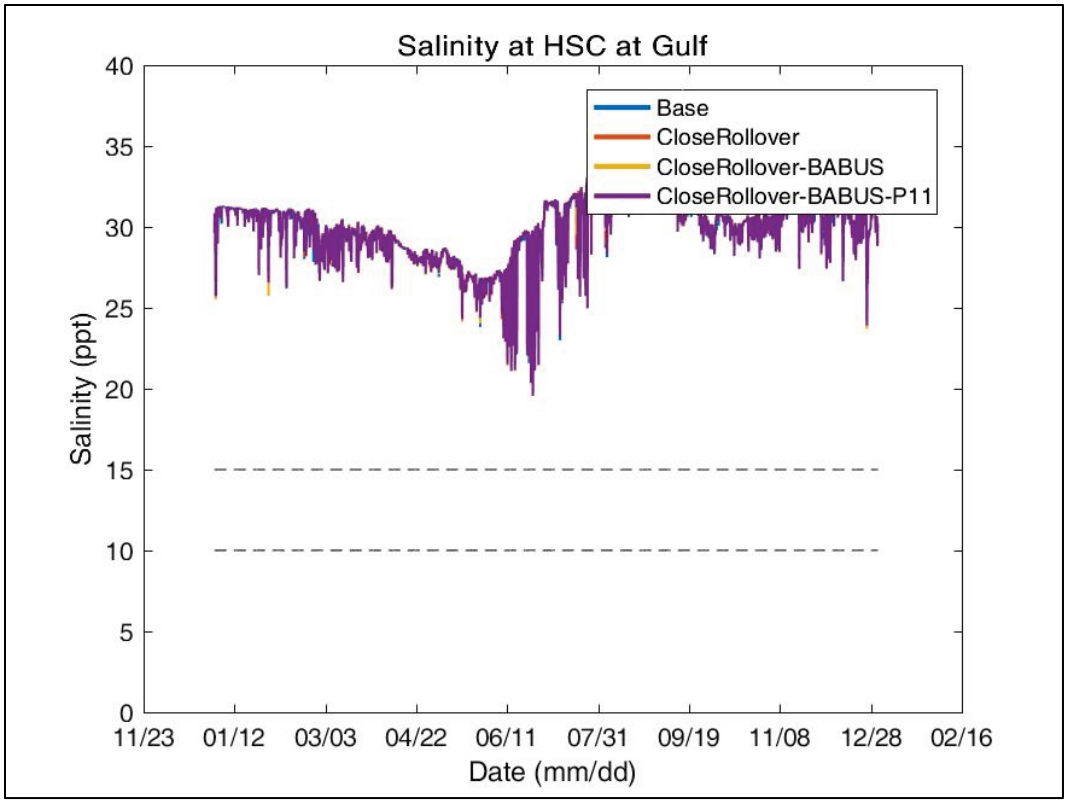

Salinity at HSC at Entrance
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

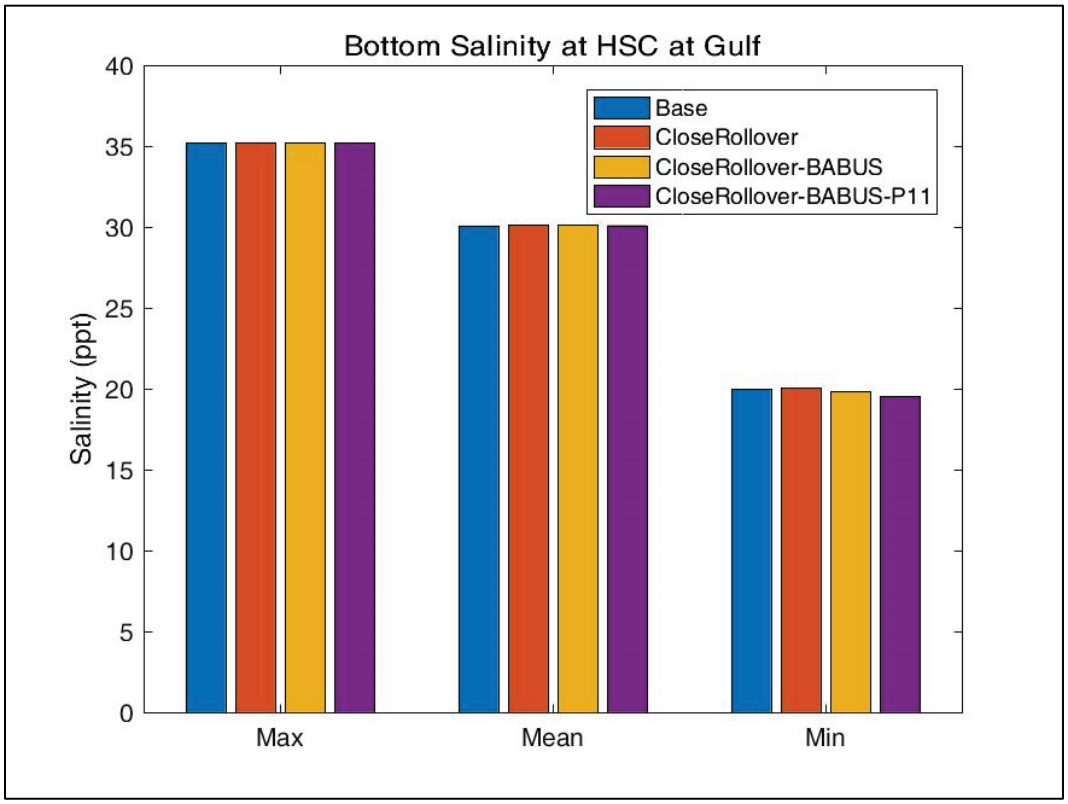

Bottom Salinity at HSC at Entrance
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
Max
Mean
Min

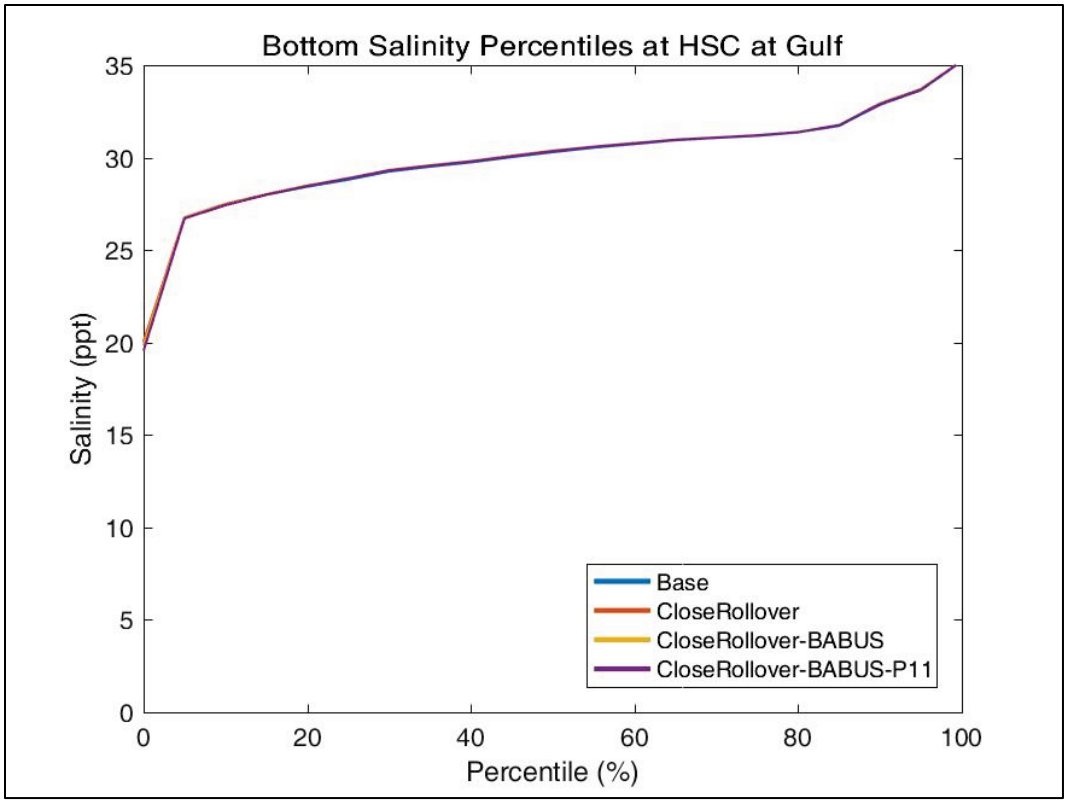

Bottom Salinity Percentiles at HSC at Entrance
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

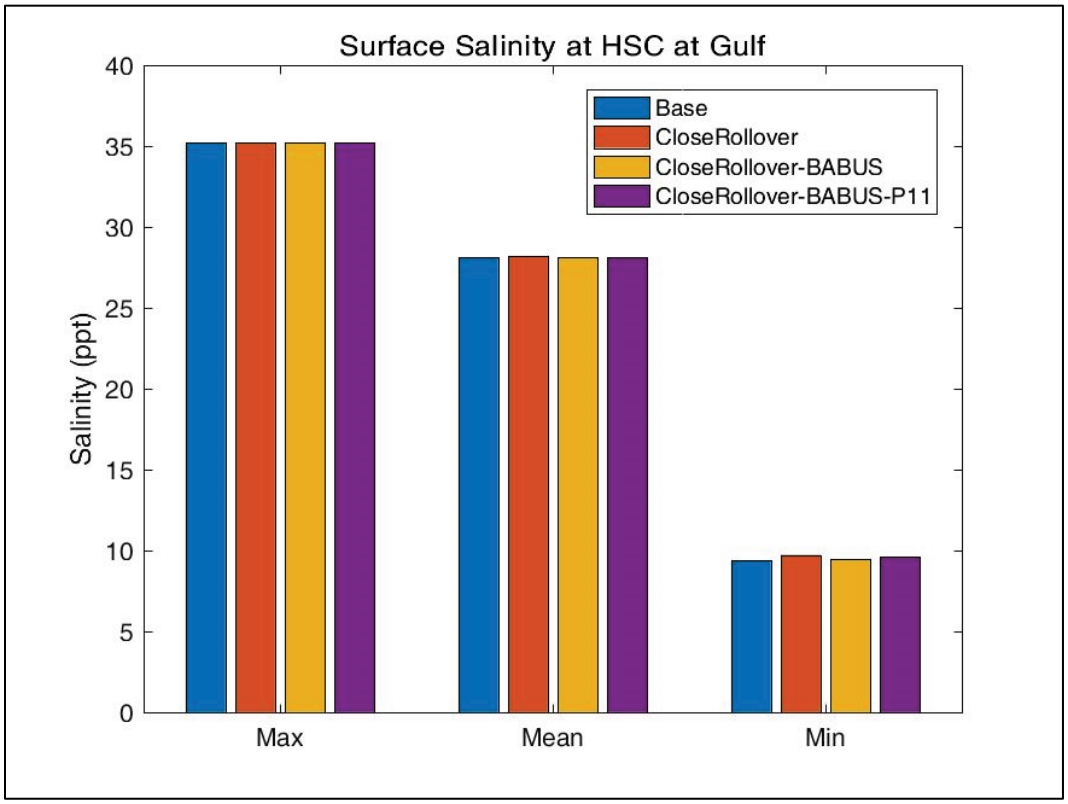

Surface Salinity at HSC at Entrance
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

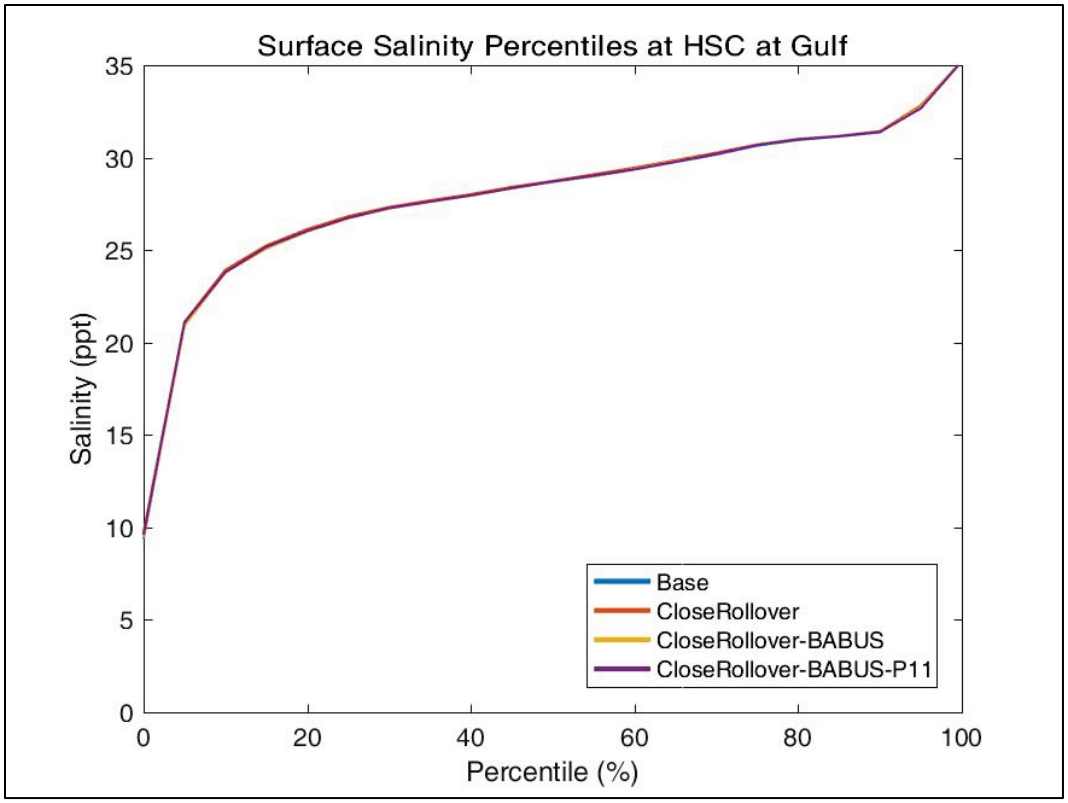

Surface Salinity Percentiles at HSC at Entrance
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

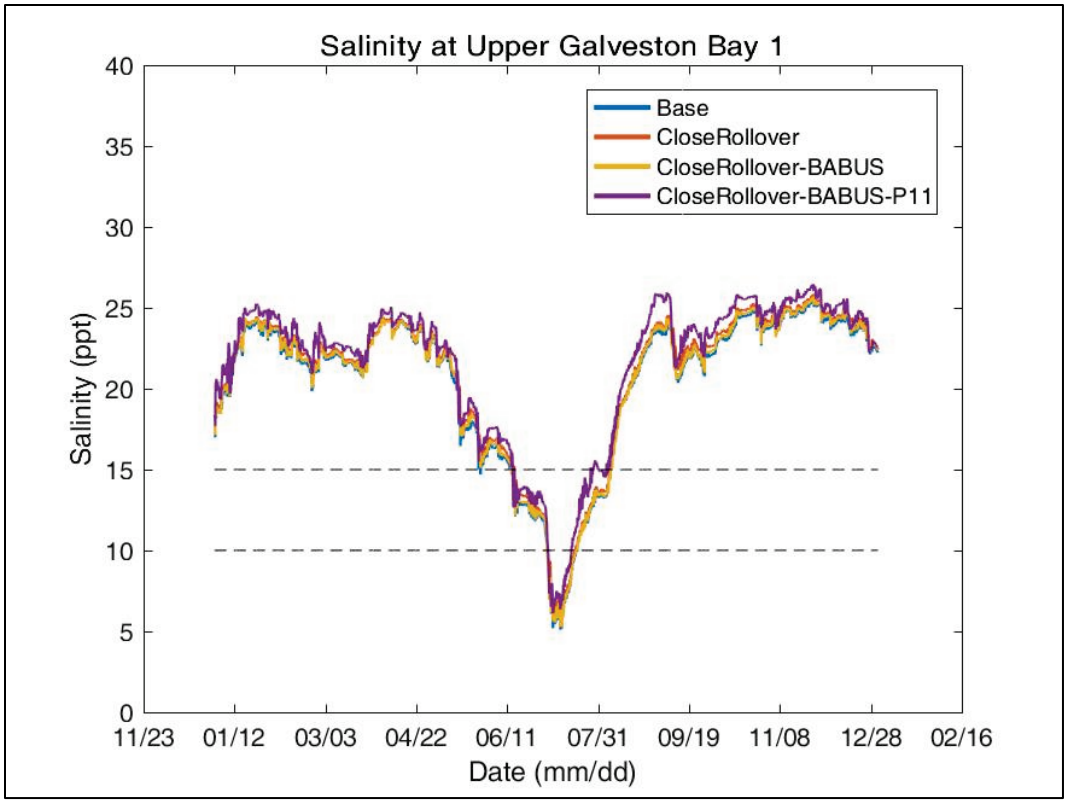

Salinity at HSC at Gulf
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

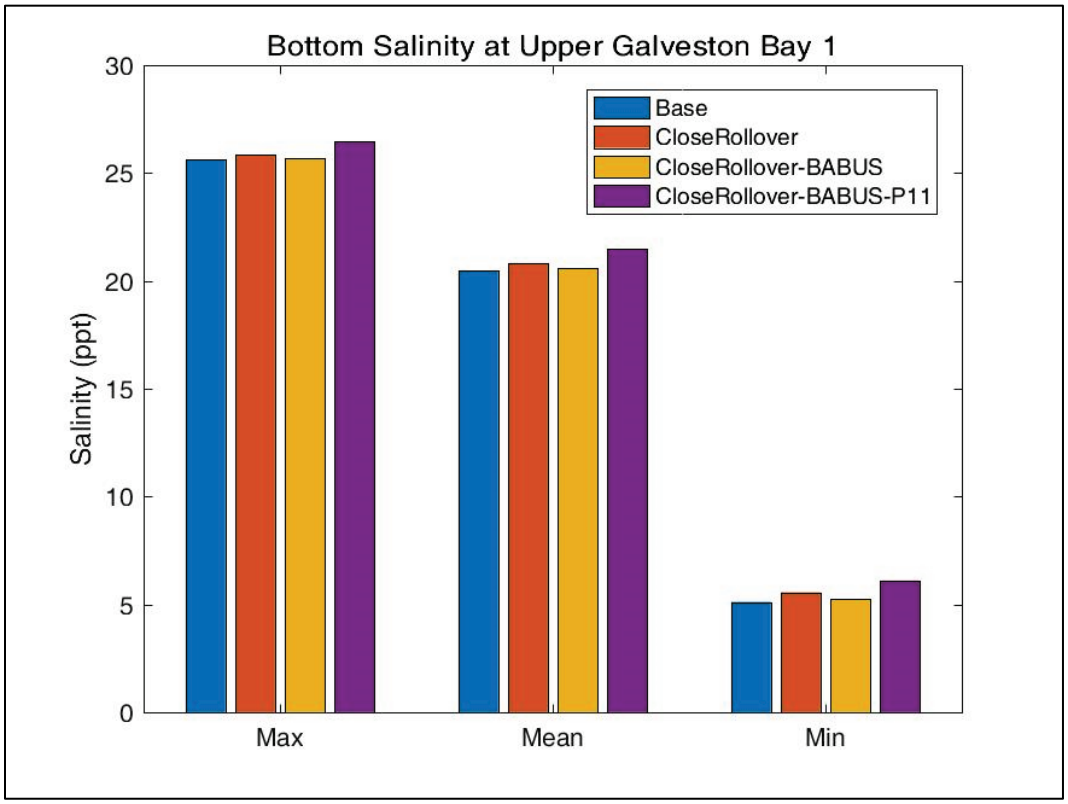

Bottom Salinity at HSC at Gulf
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
Max
Mean
Min

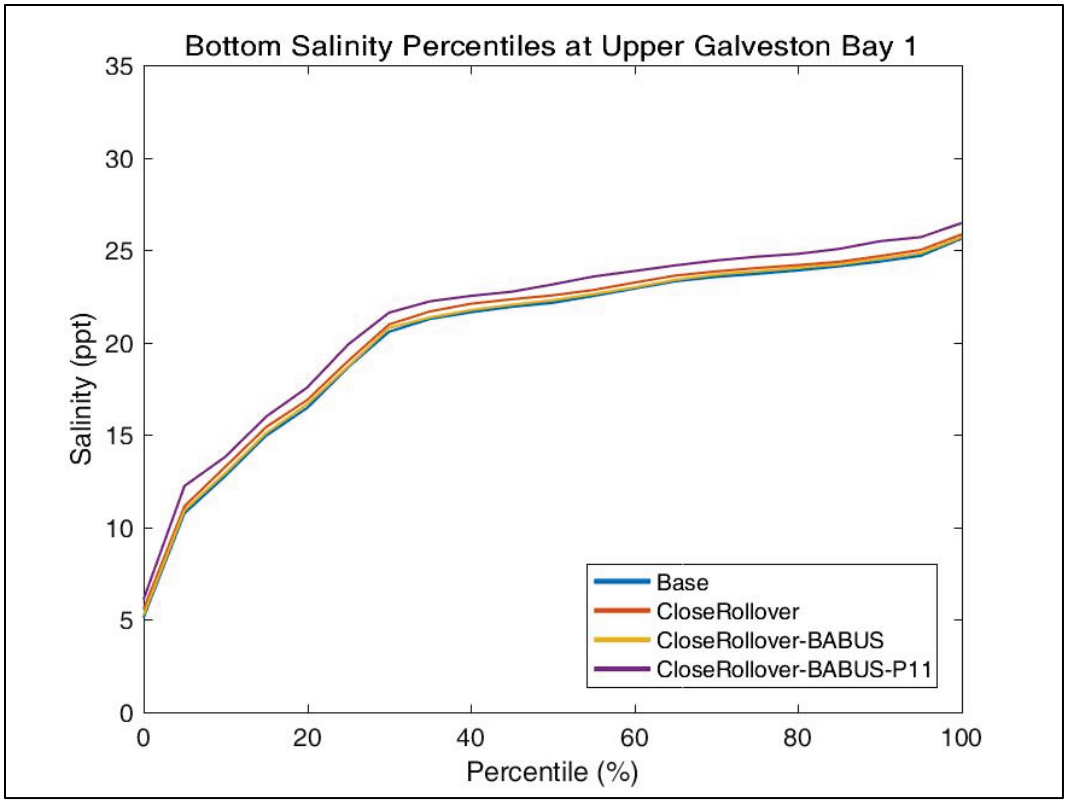

Bottom Salinity Percentiles at HSC at Gulf
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

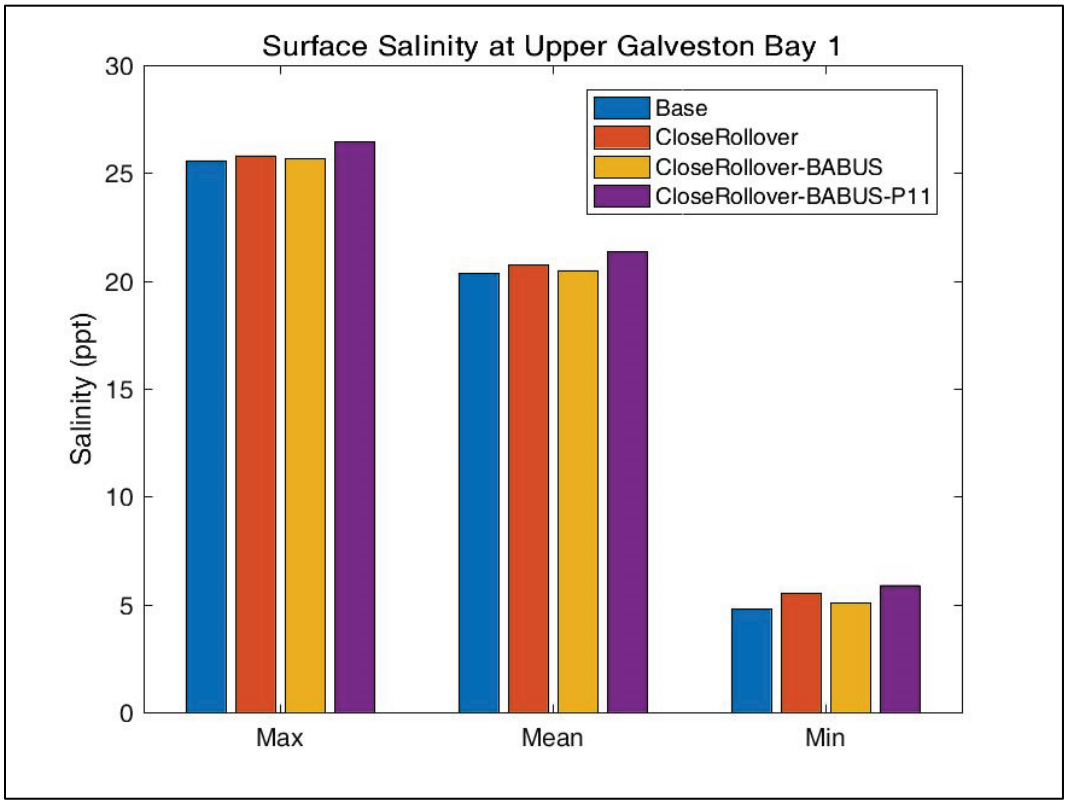

Surface Salinity at HSC at Gulf
Salinity (ppt)
0
5
10
15
20
25
30
35
40
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

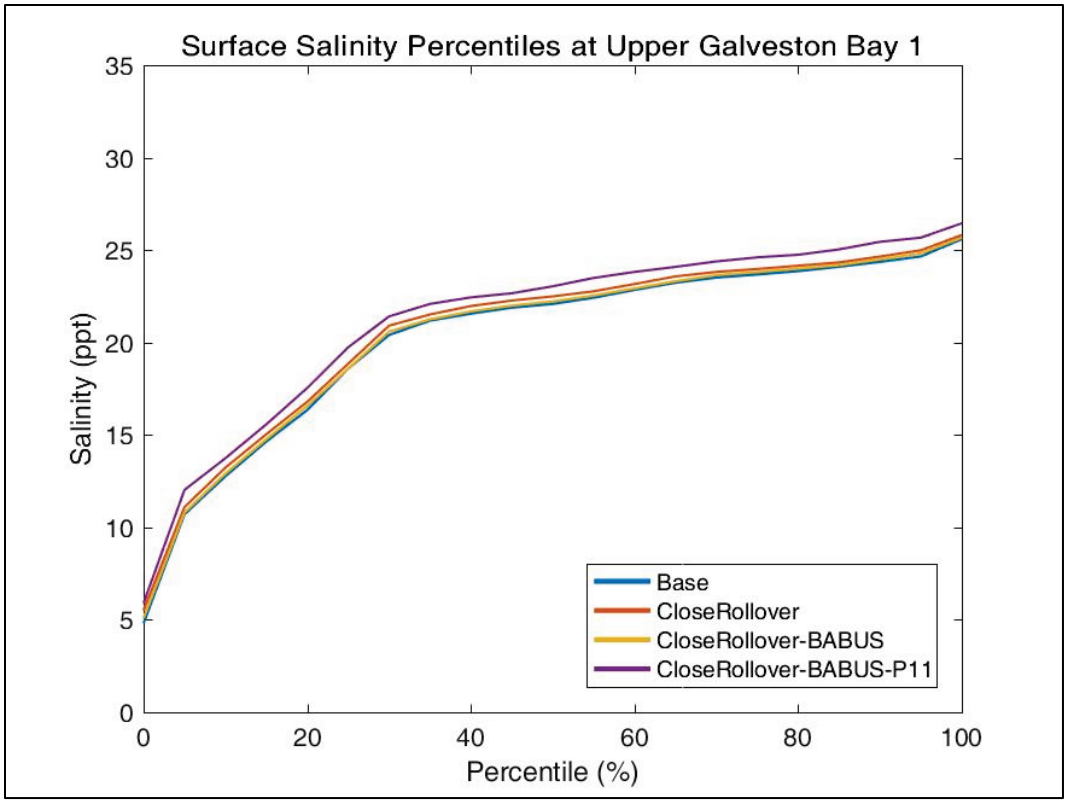

Surface Salinity Percentiles at HSC at Gulf
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

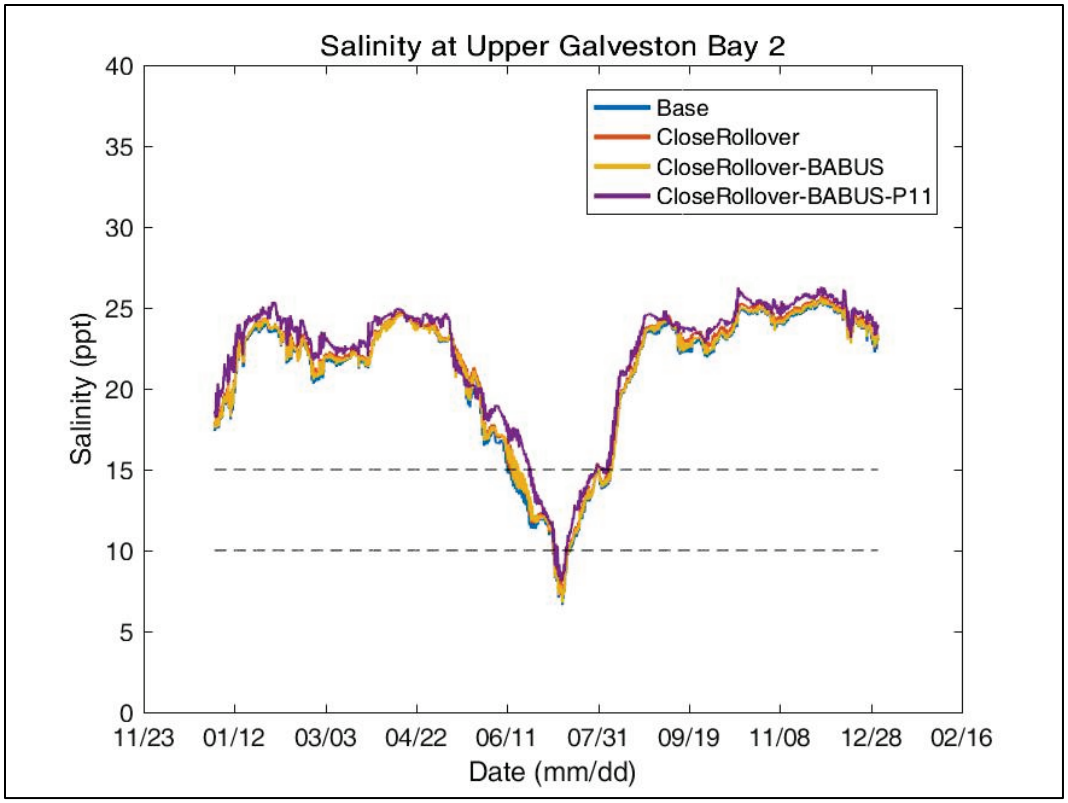

Salinity at Upper Galveston Bay 1
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

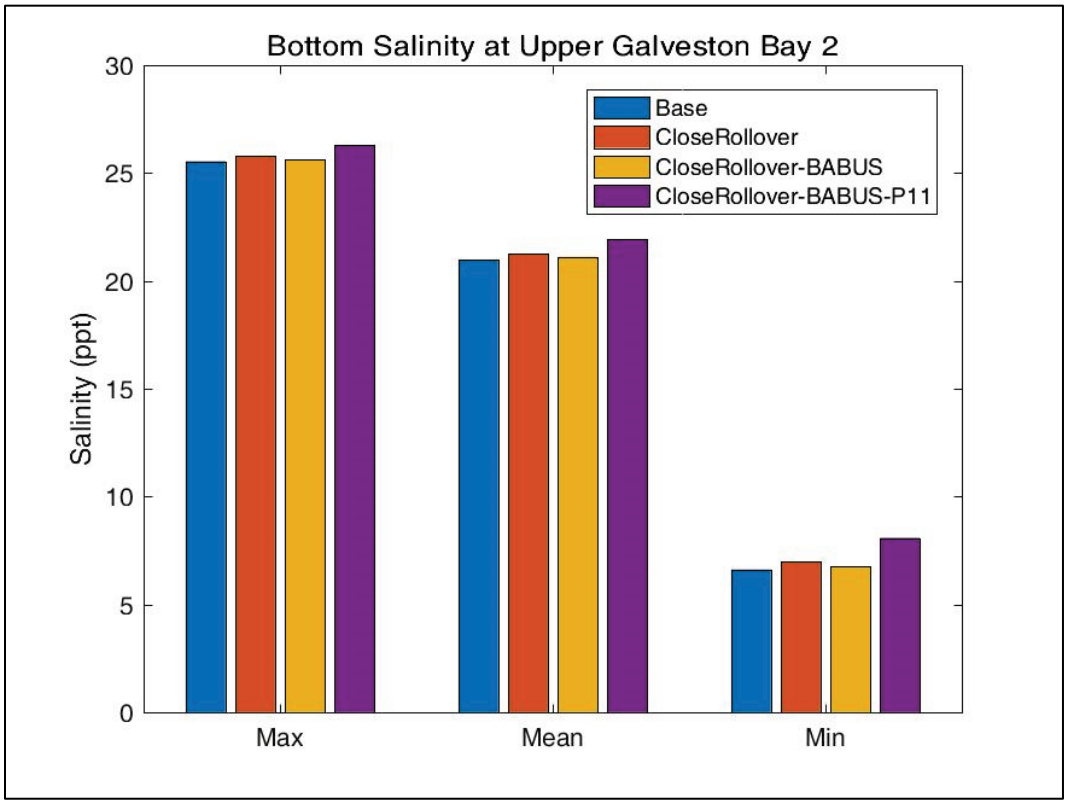

Bottom Salinity at Upper Galveston Bay 1
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

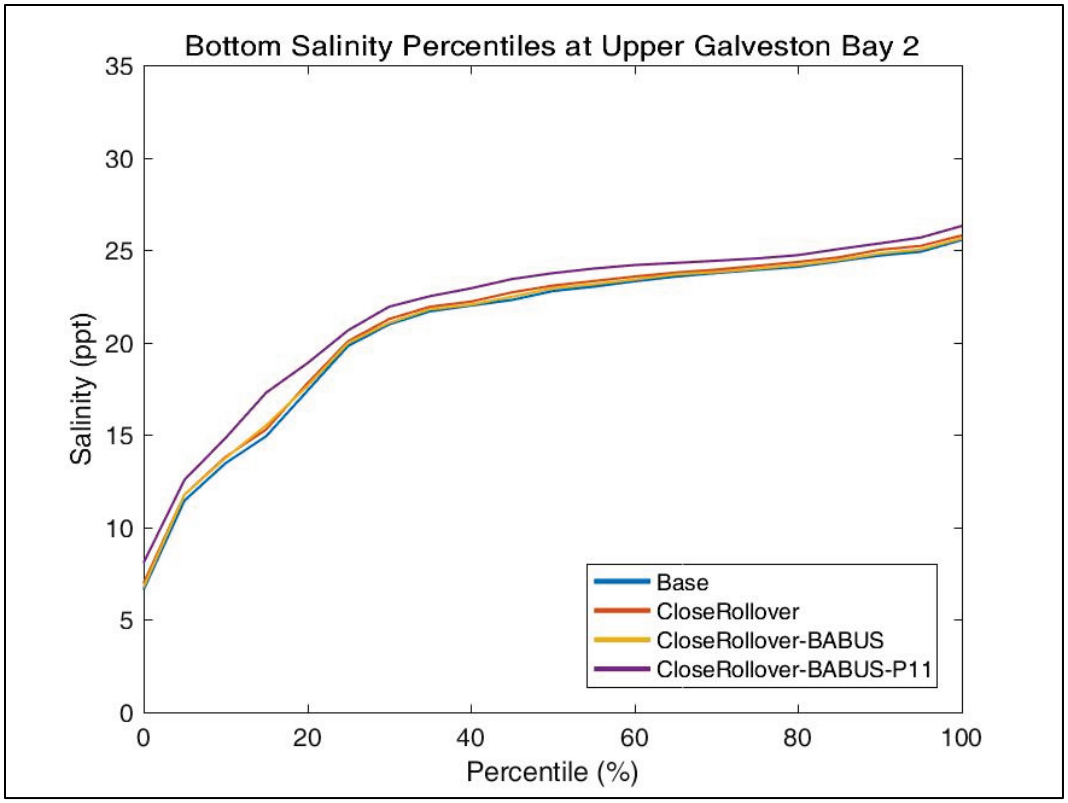

Bottom Salinity Percentiles at Upper Galveston Bay 1
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

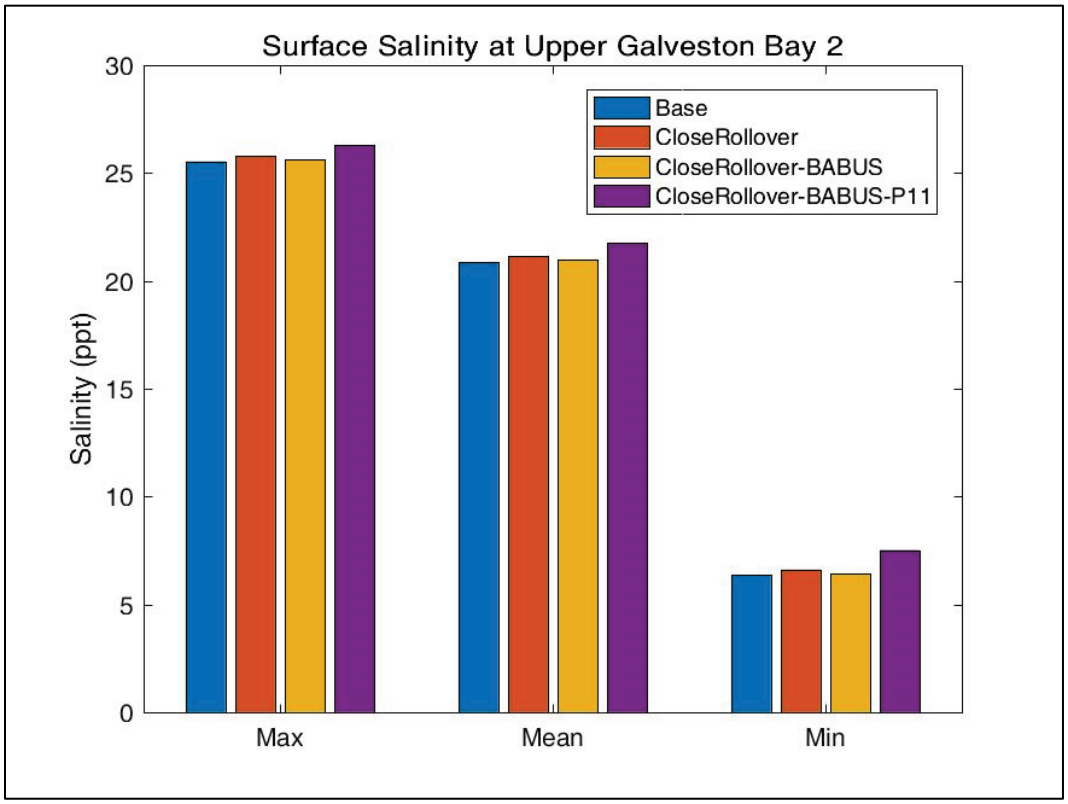

Surface Salinity at Upper Galveston Bay 1
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

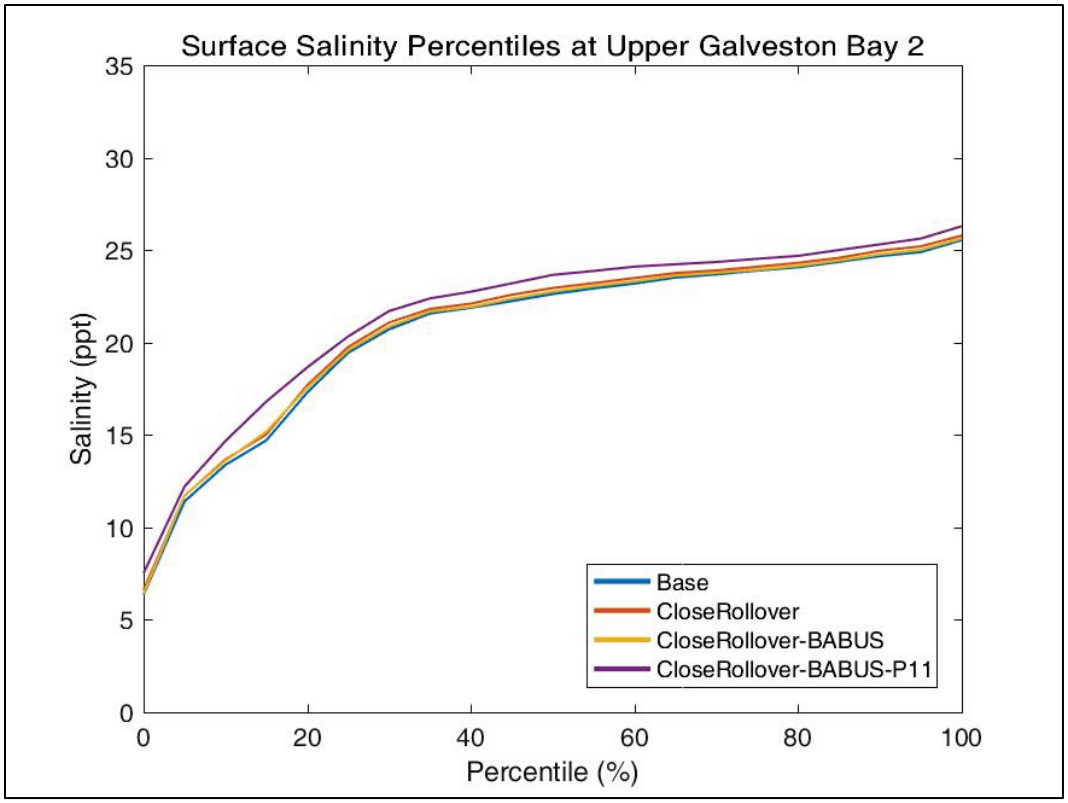

Surface Salinity Percentiles at Upper Galveston Bay 1
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

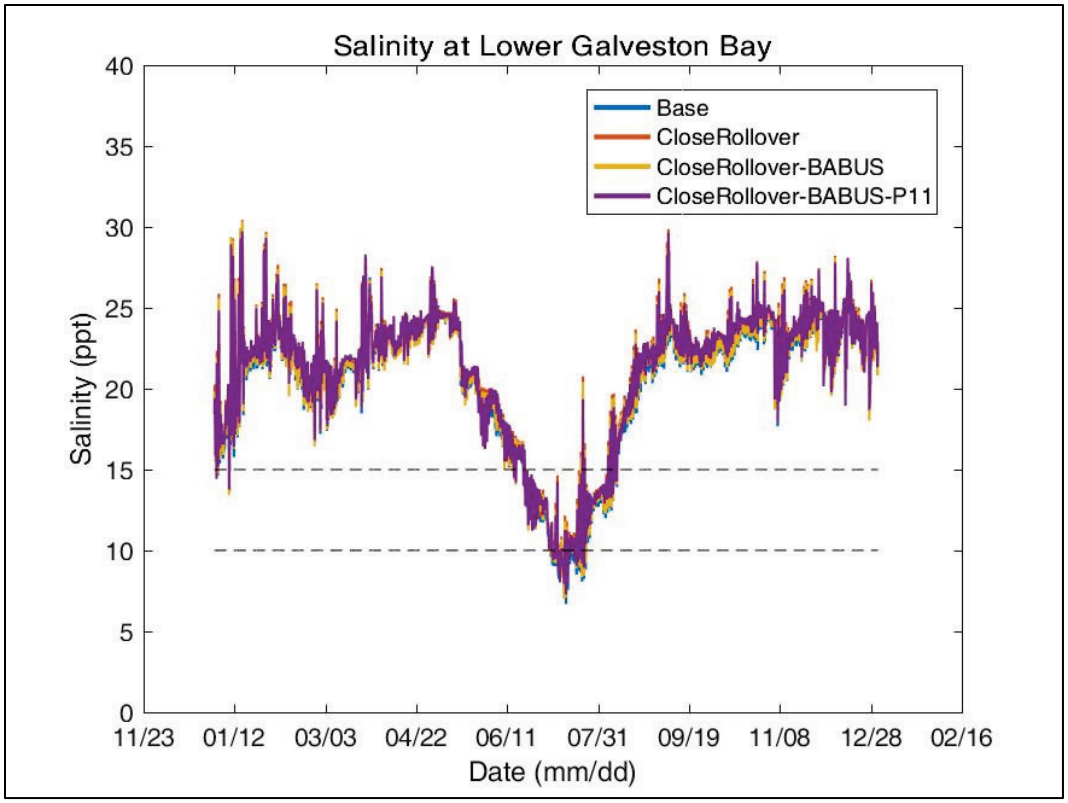

Salinity at Upper Galveston Bay 2
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

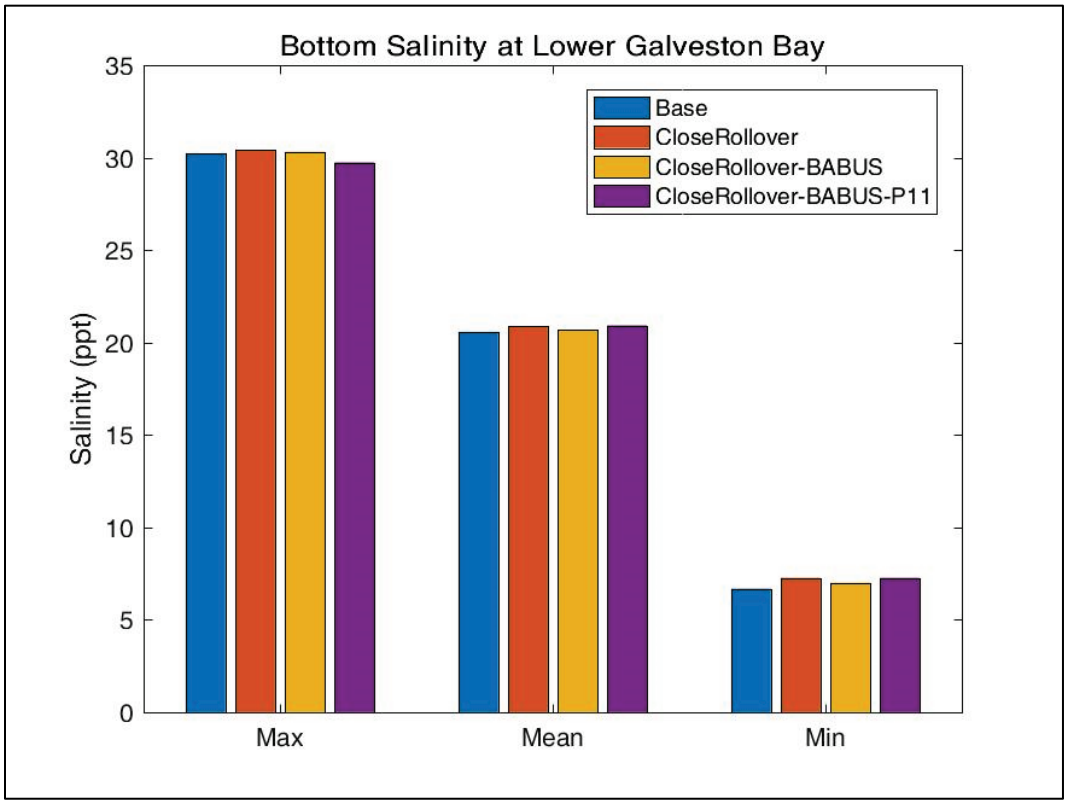

Bottom Salinity at Upper Galveston Bay 2
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

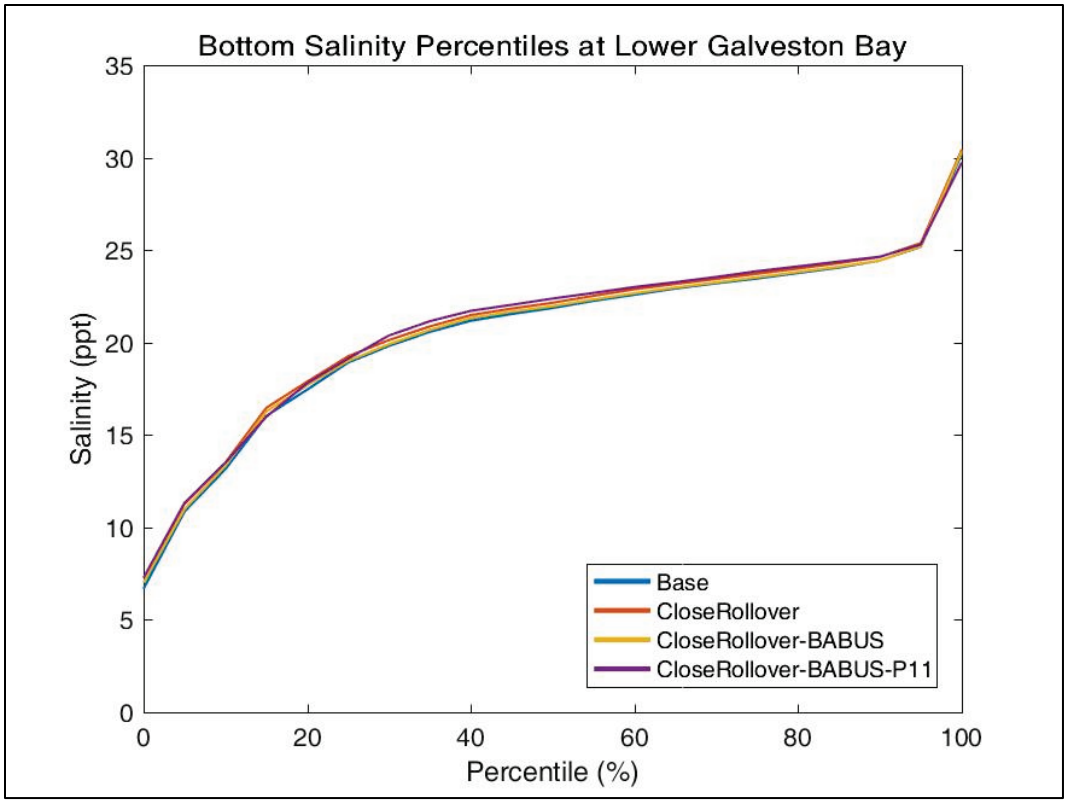

Bottom Salinity Percentiles at Upper Galveston Bay 2
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

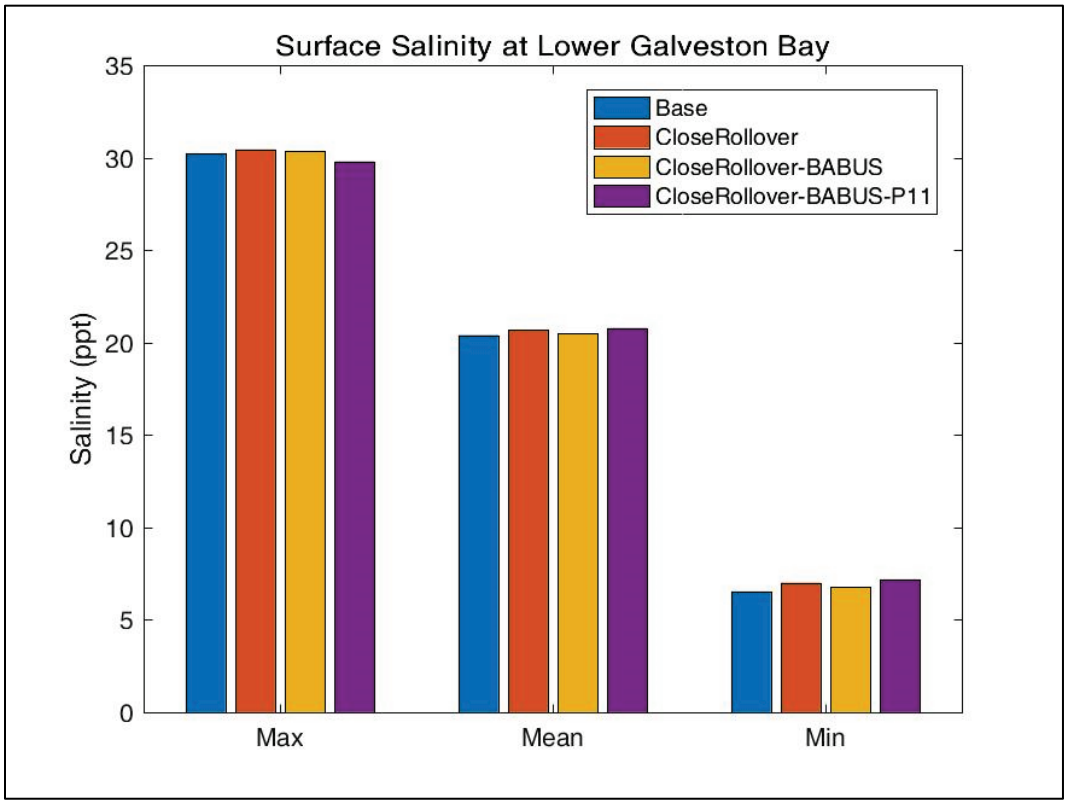

Surface Salinity at Upper Galveston Bay 2
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

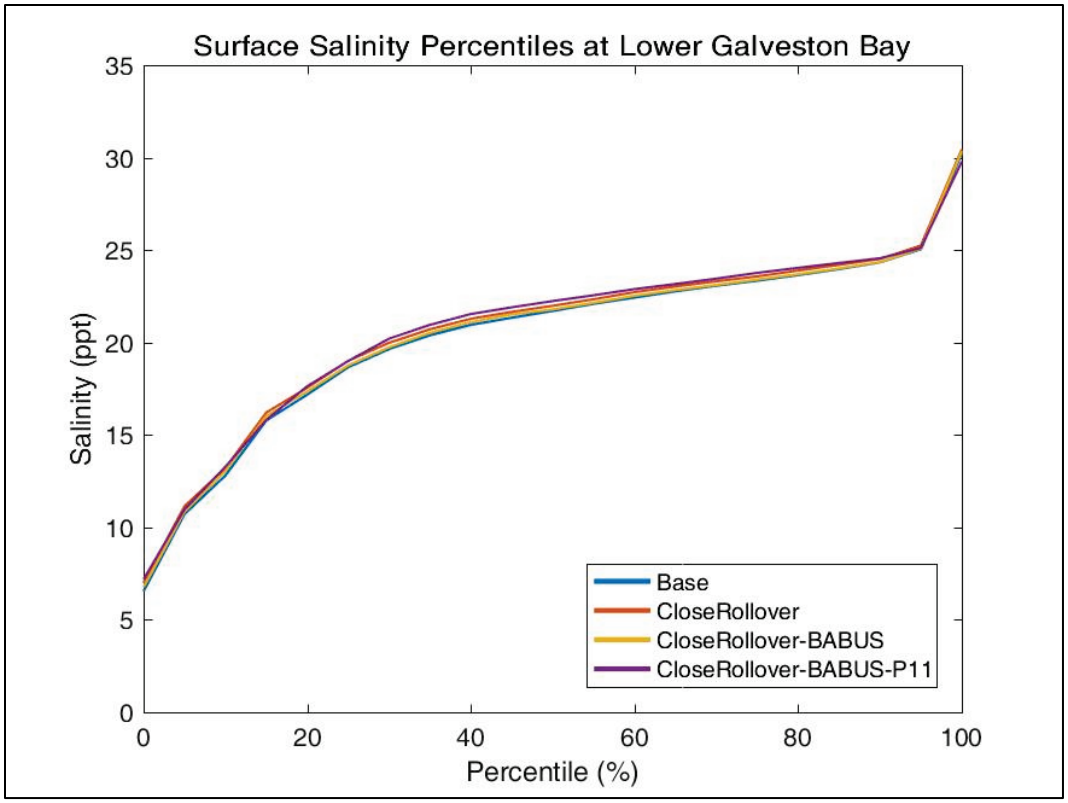

Surface Salinity Percentiles at Upper Galveston Bay 2
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

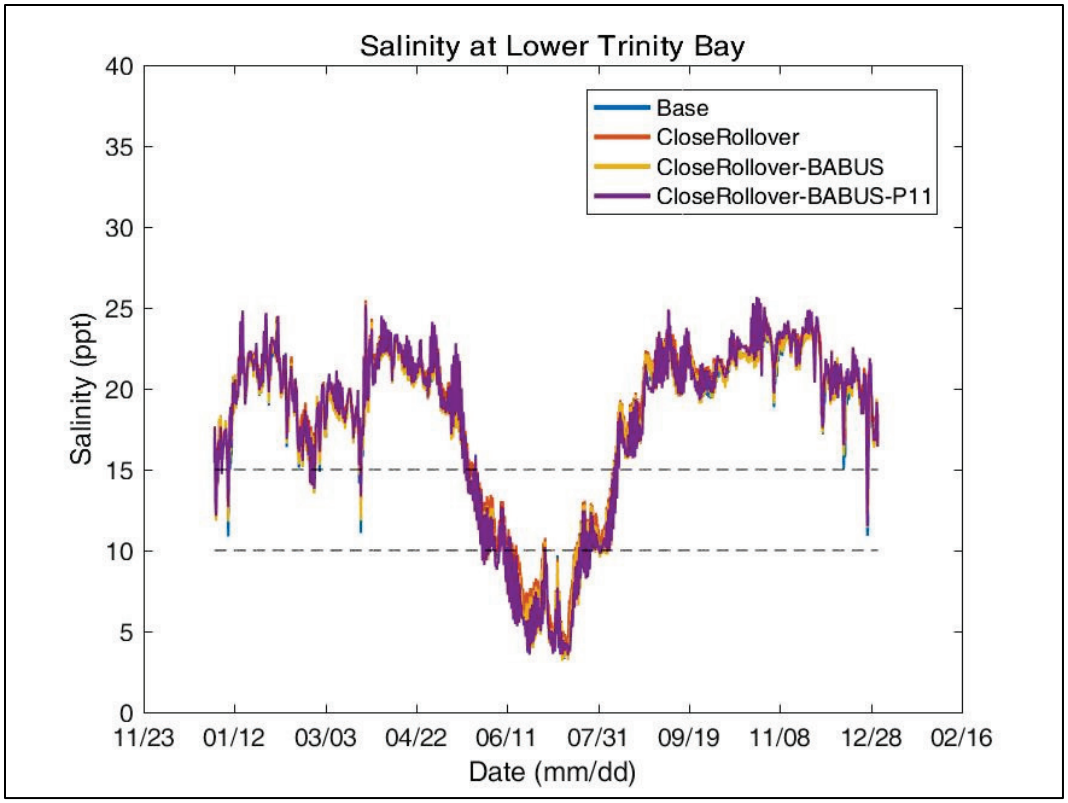

Salinity at Lower Galveston Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

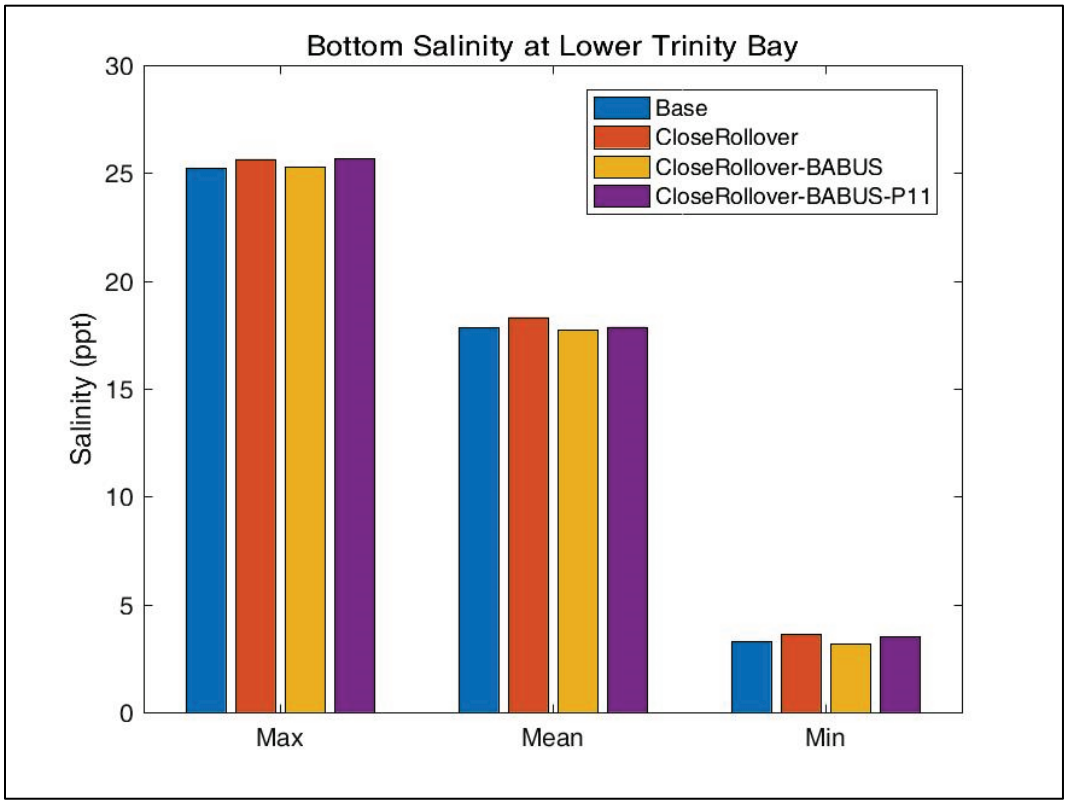

Bottom Salinity at Lower Galveston Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

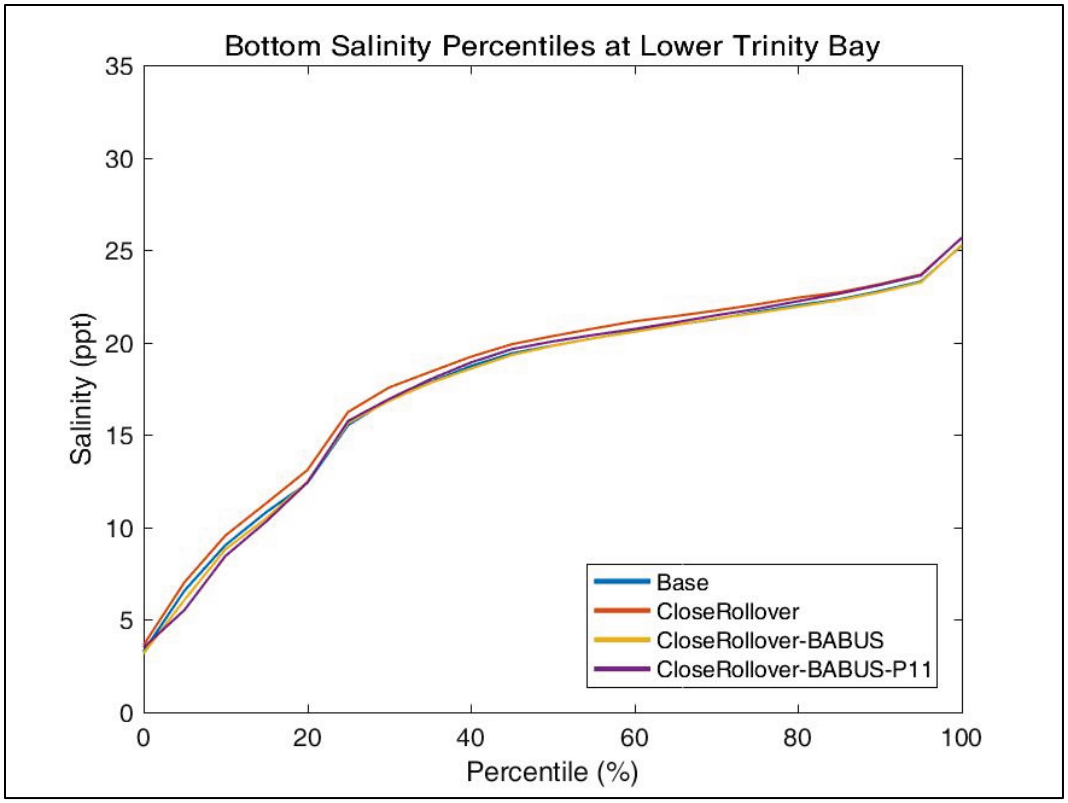

Bottom Salinity Percentiles at Lower Galveston Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

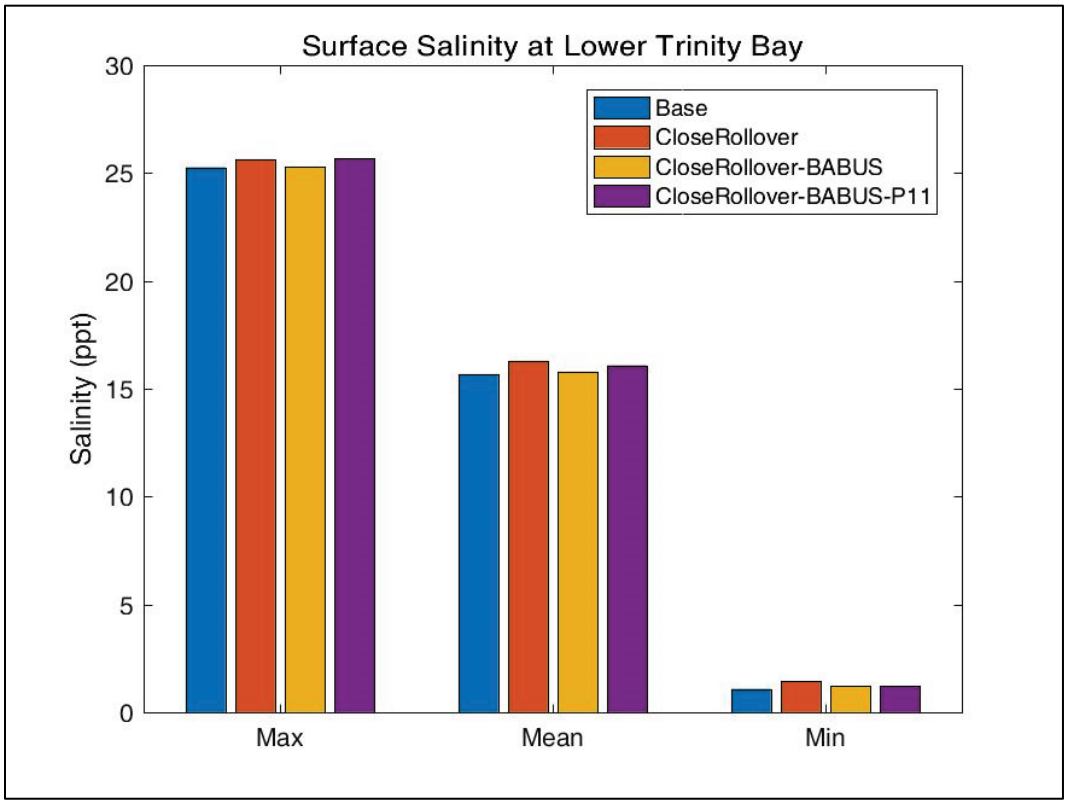

Surface Salinity at Lower Galveston Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

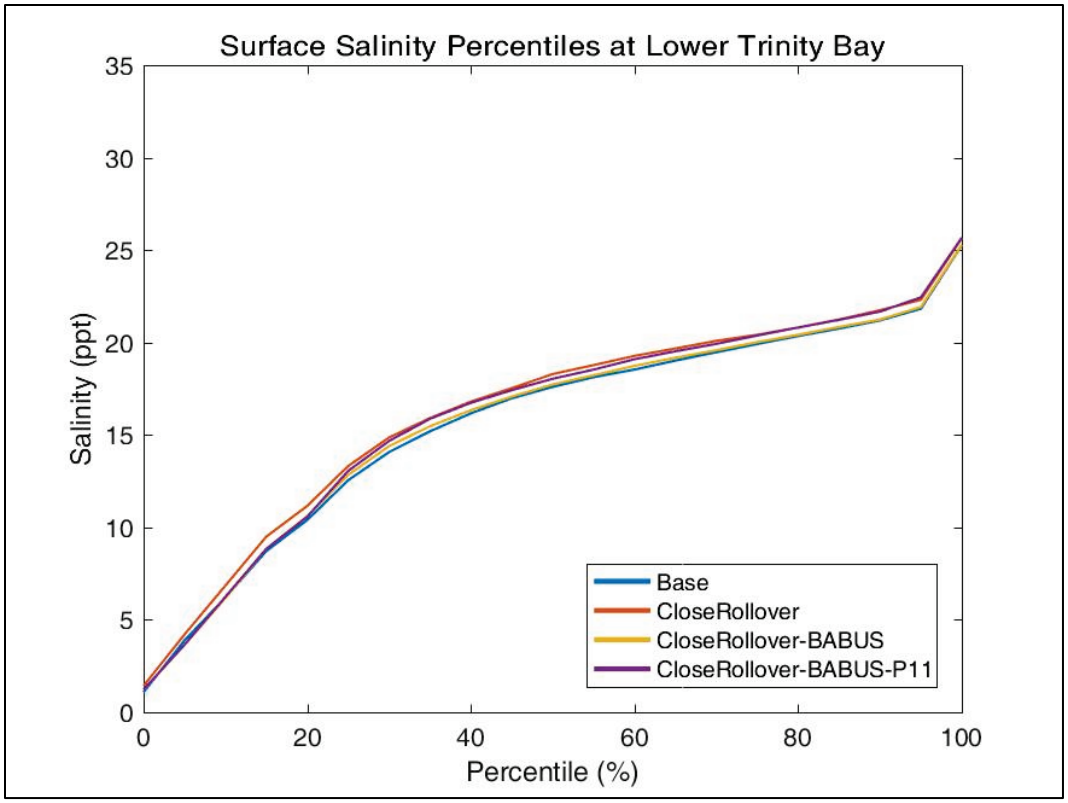

Surface Salinity Percentiles at Lower Galveston Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

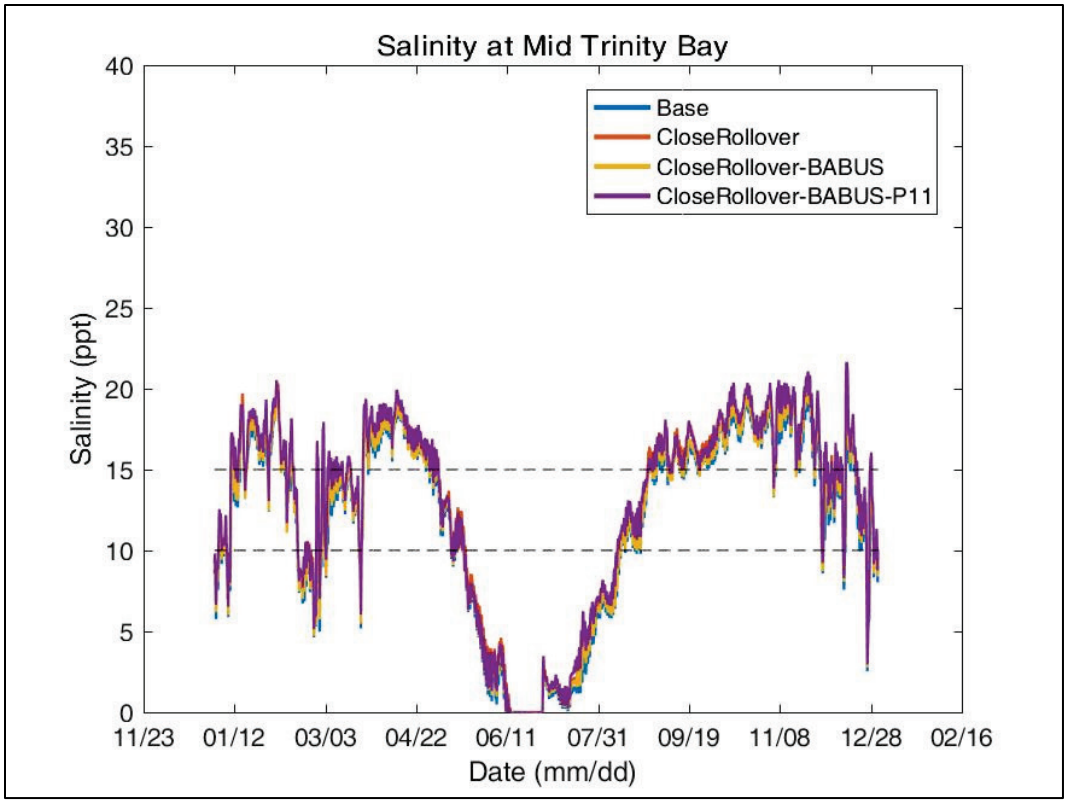

Salinity at Lower Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

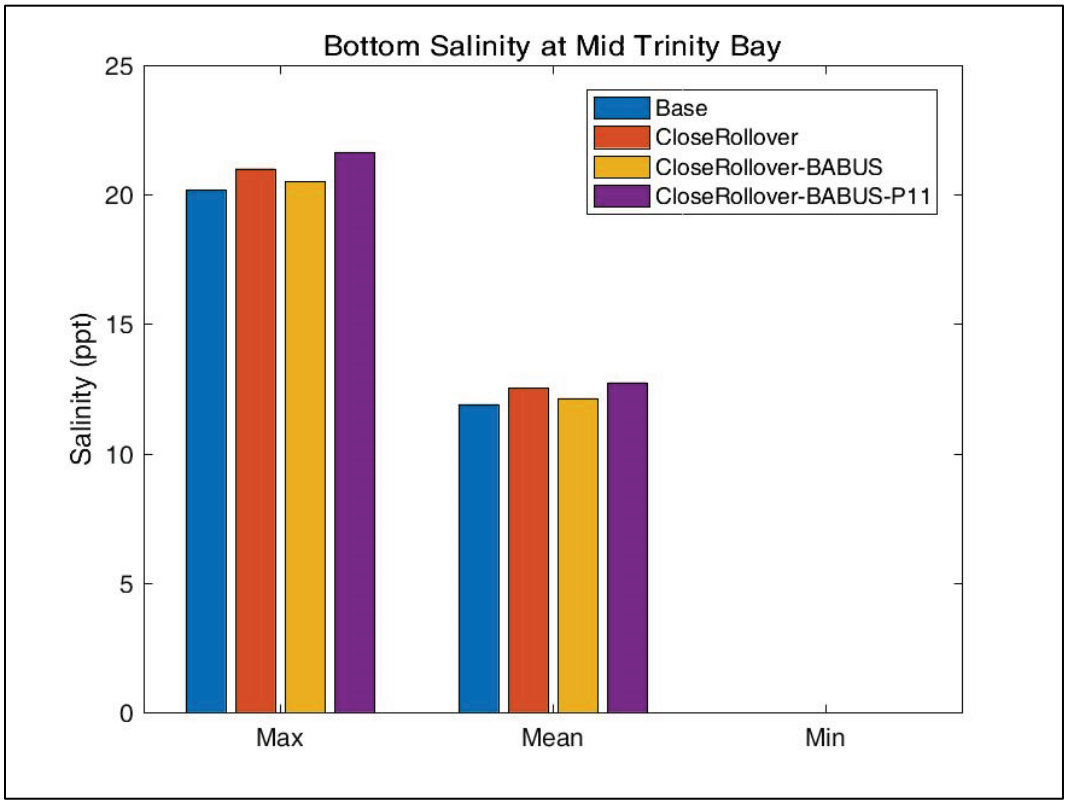

Bottom Salinity at Lower Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

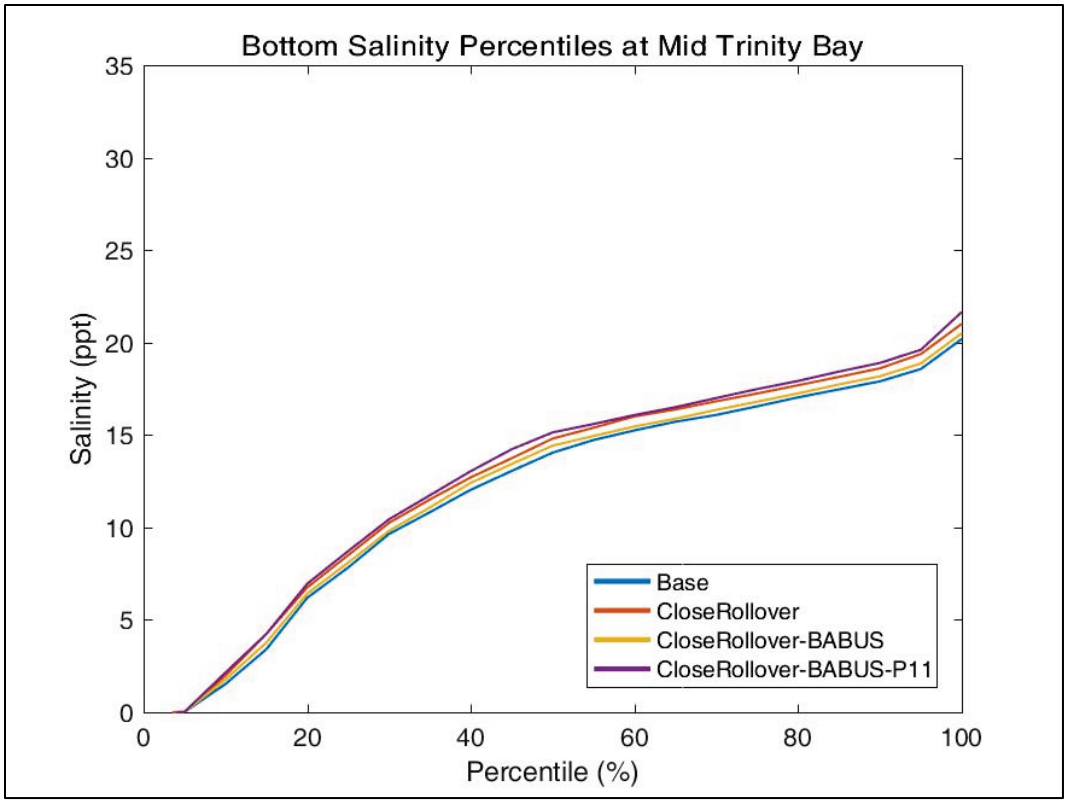

Bottom Salinity Percentiles at Lower Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

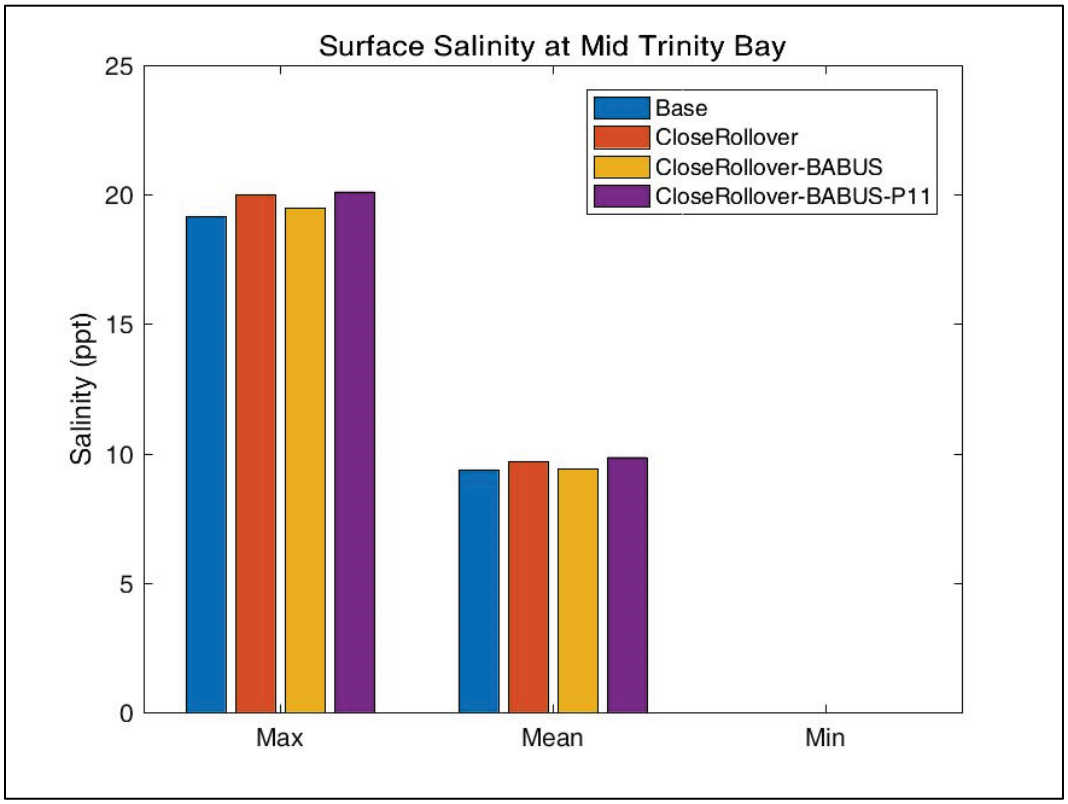

Surface Salinity at Lower Trinity Bay
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

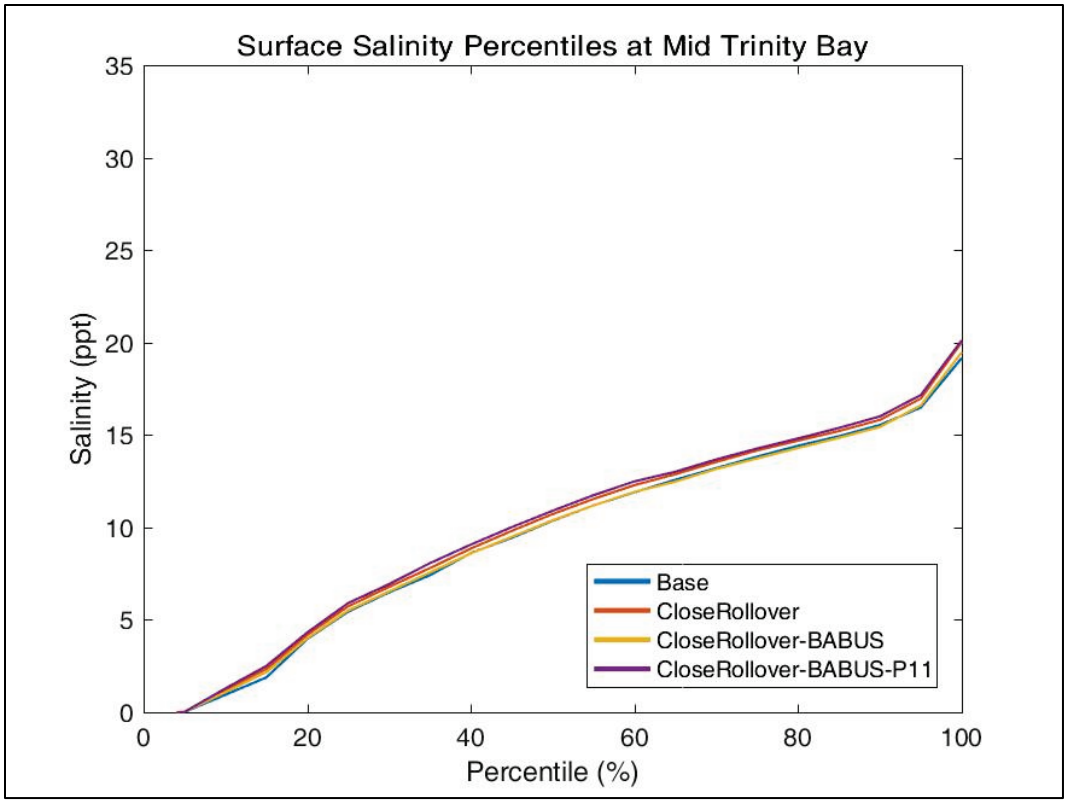

Surface Salinity Percentiles at Lower Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

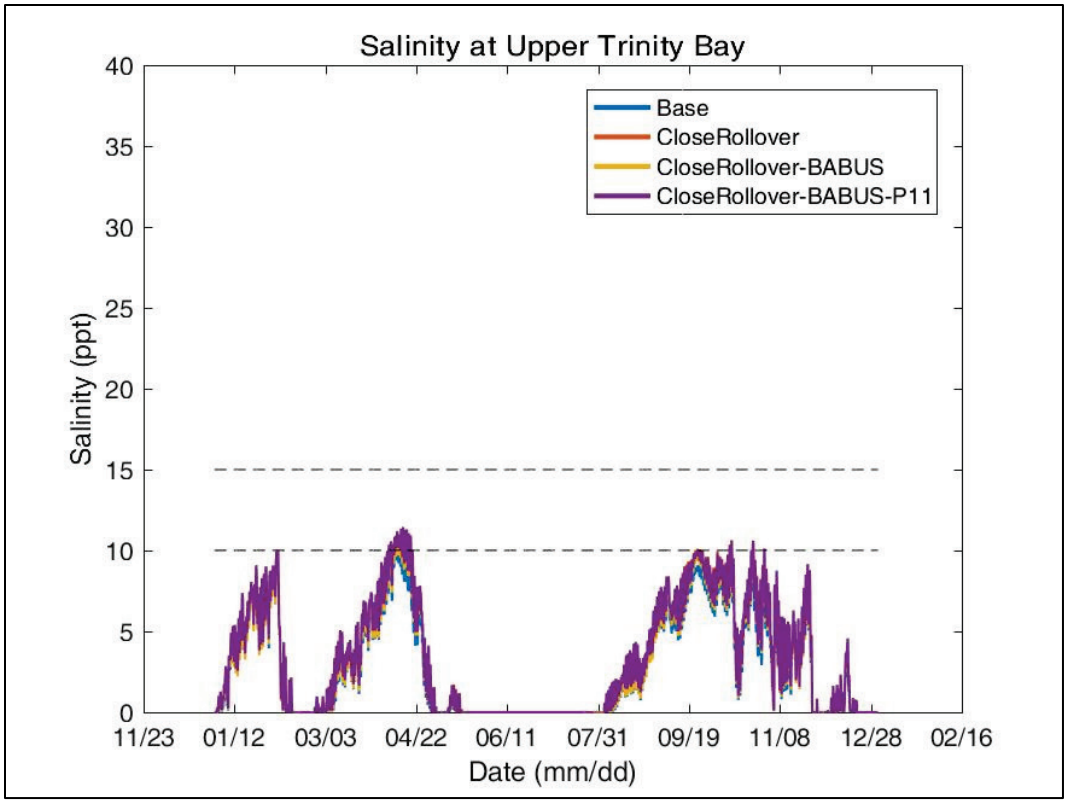

Salinity at Mid Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

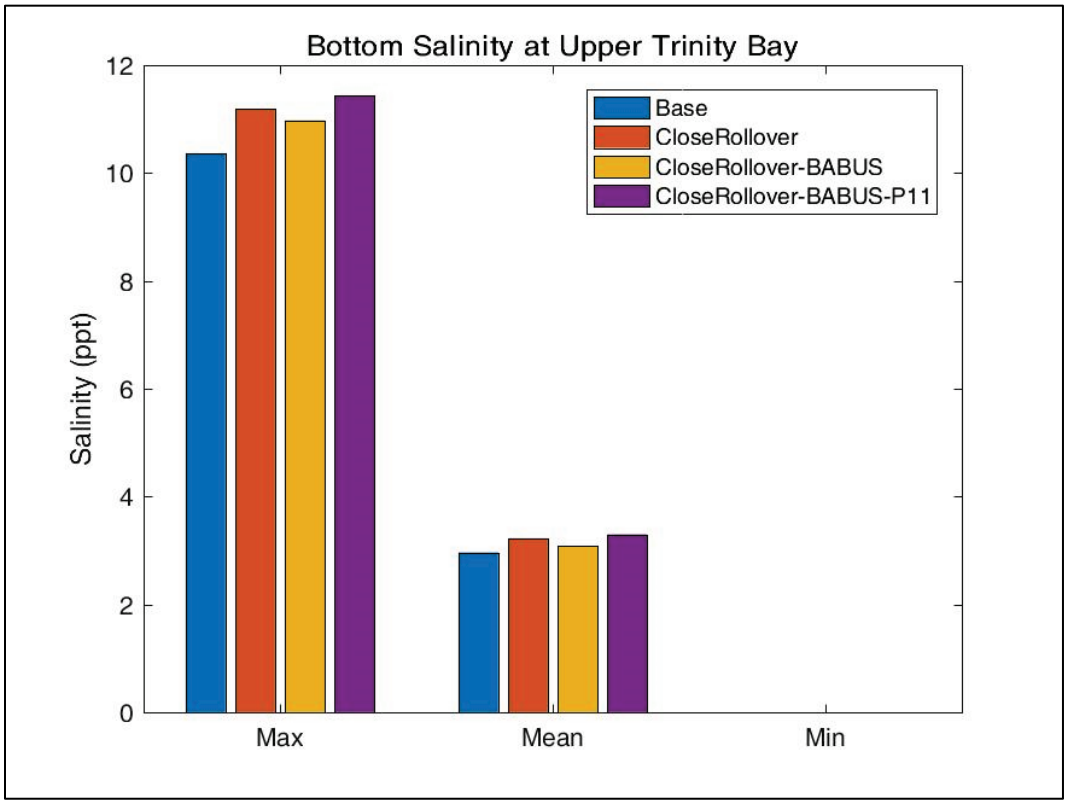

Bottom Salinity at Mid Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min

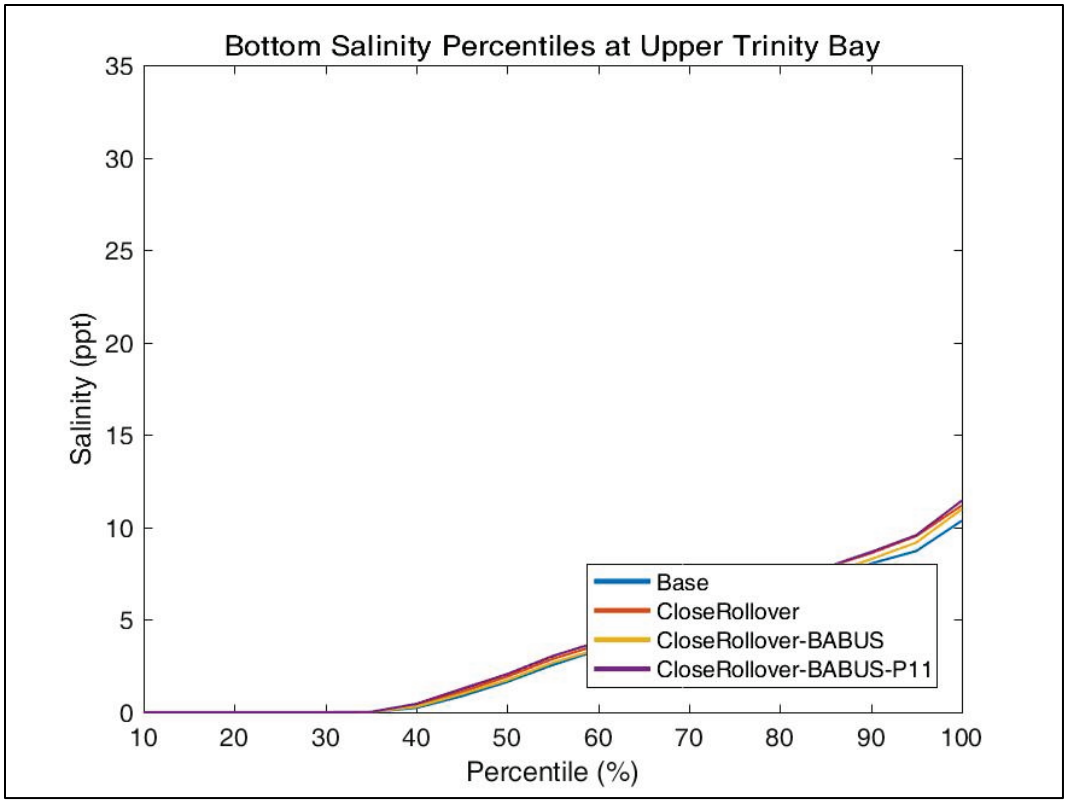

Bottom Salinity Percentiles at Mid Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

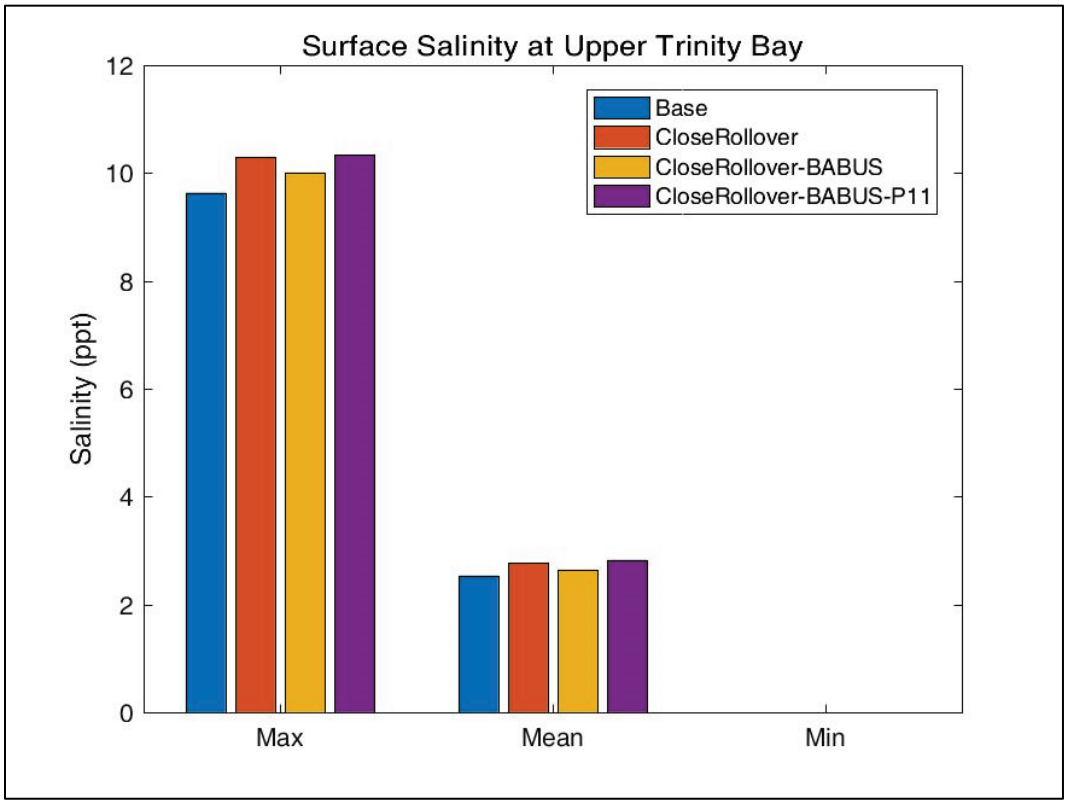

Surface Salinity at Mid Trinity Bay
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

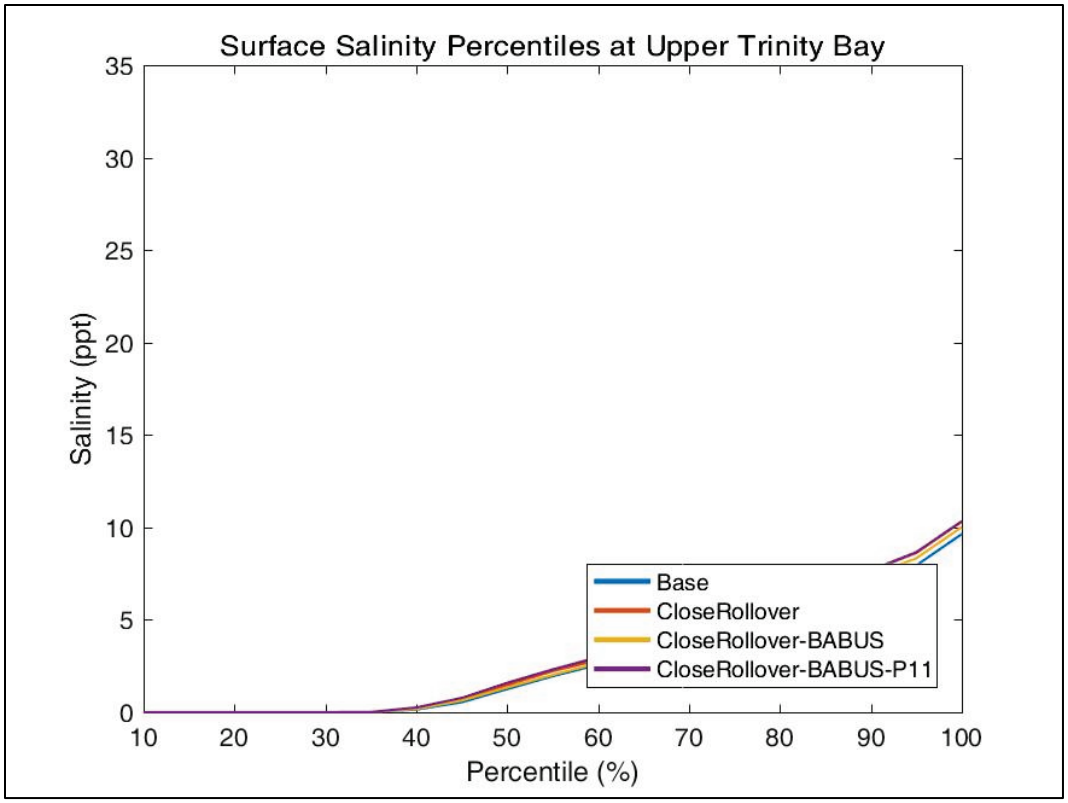

Surface Salinity Percentiles at Mid Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

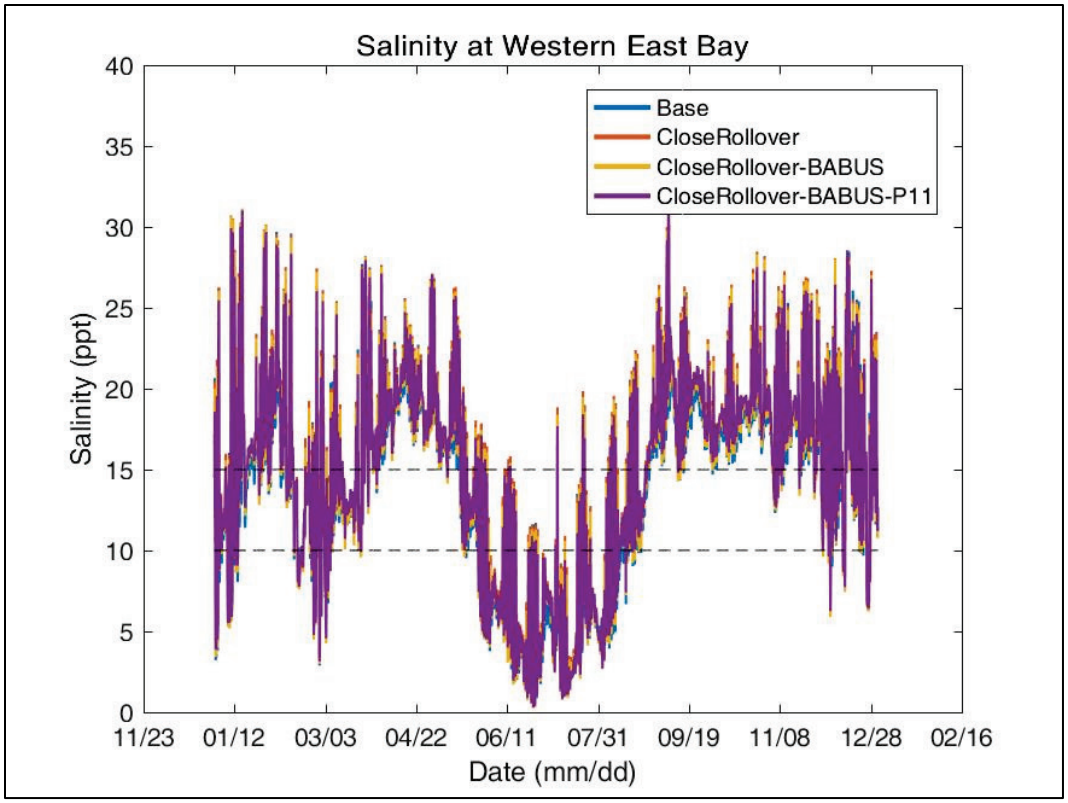

Salinity at Upper Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

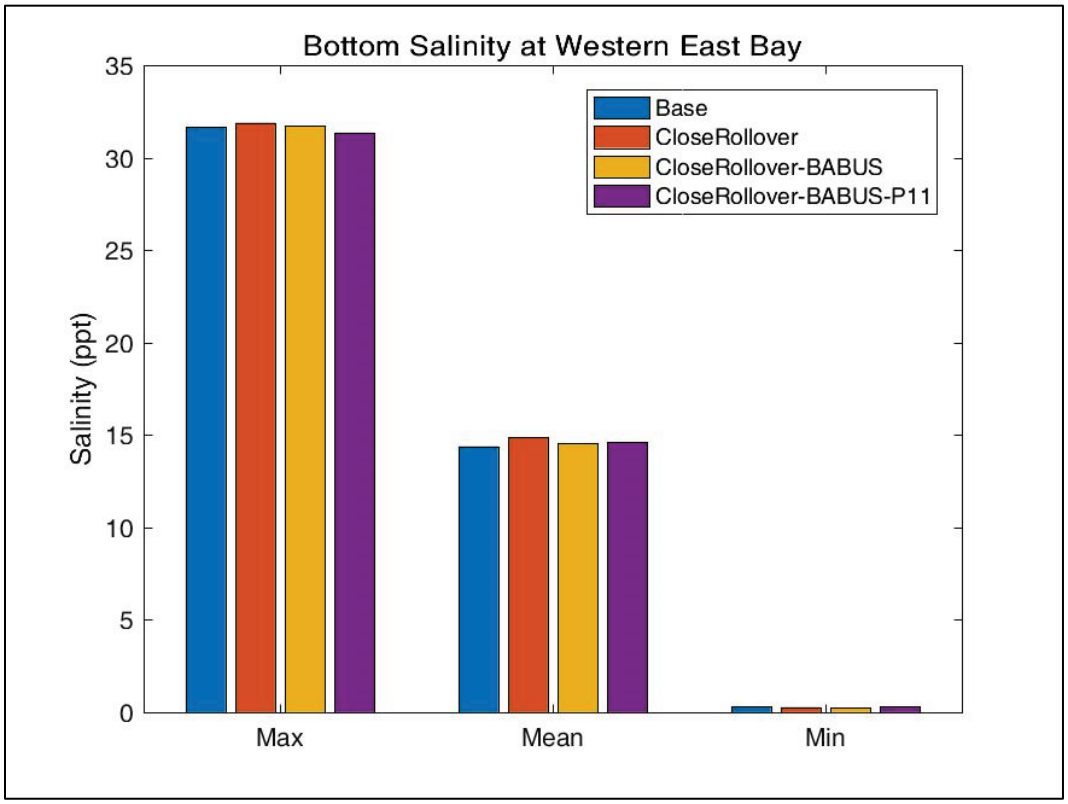

Bottom Salinity at Upper Trinity Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
2
4
6
8
10
12
Max
Mean
Min

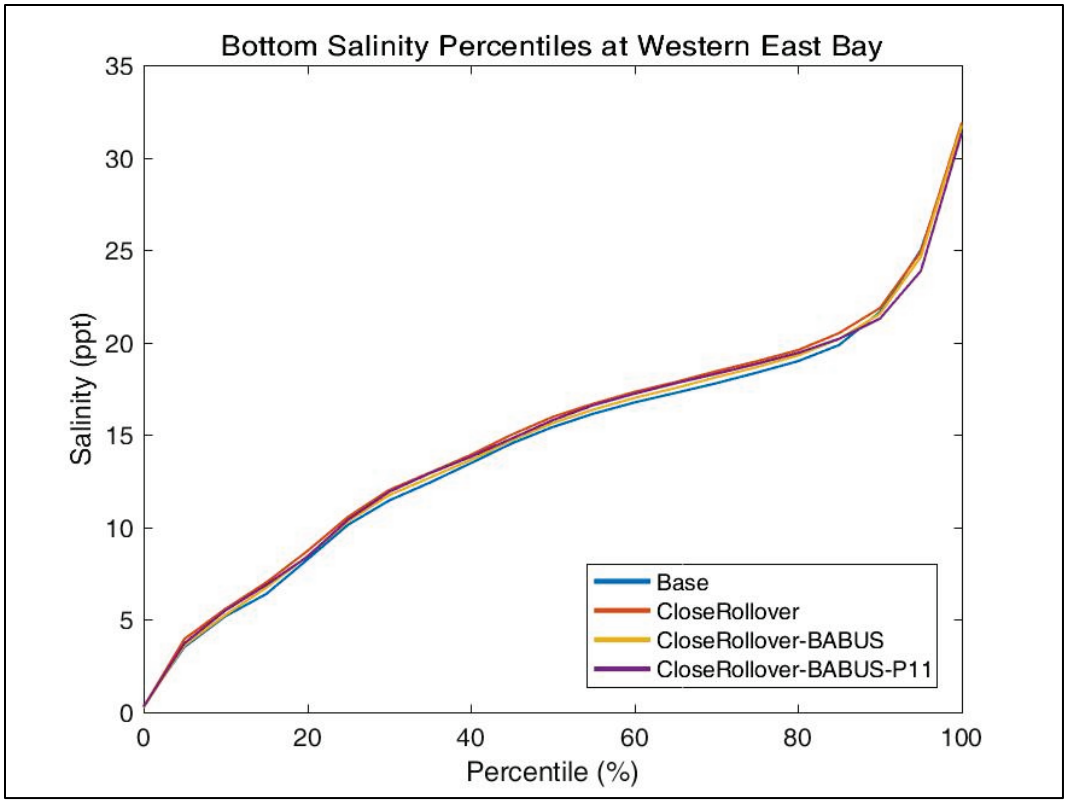

Bottom Salinity Percentiles at Upper Trinity Bay
Salinity (ppt)
Percentile (%)
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

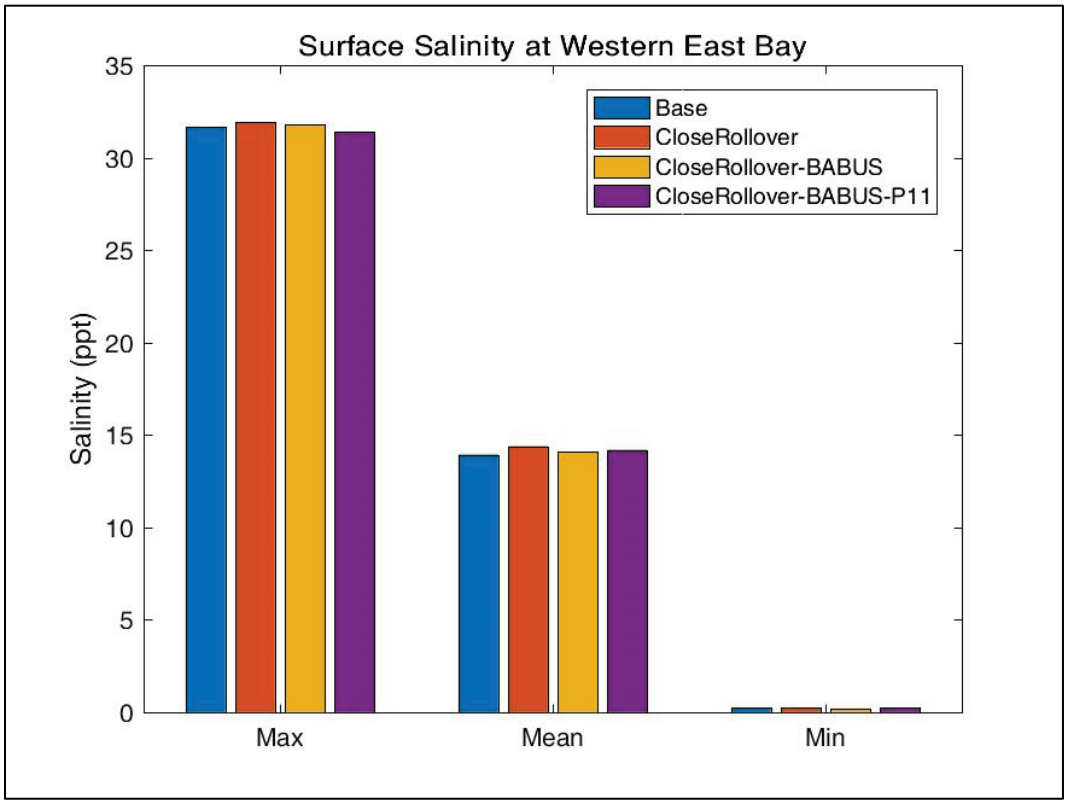

Surface Salinity at Upper Trinity Bay
Salinity (ppt)
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Max
Mean
Min

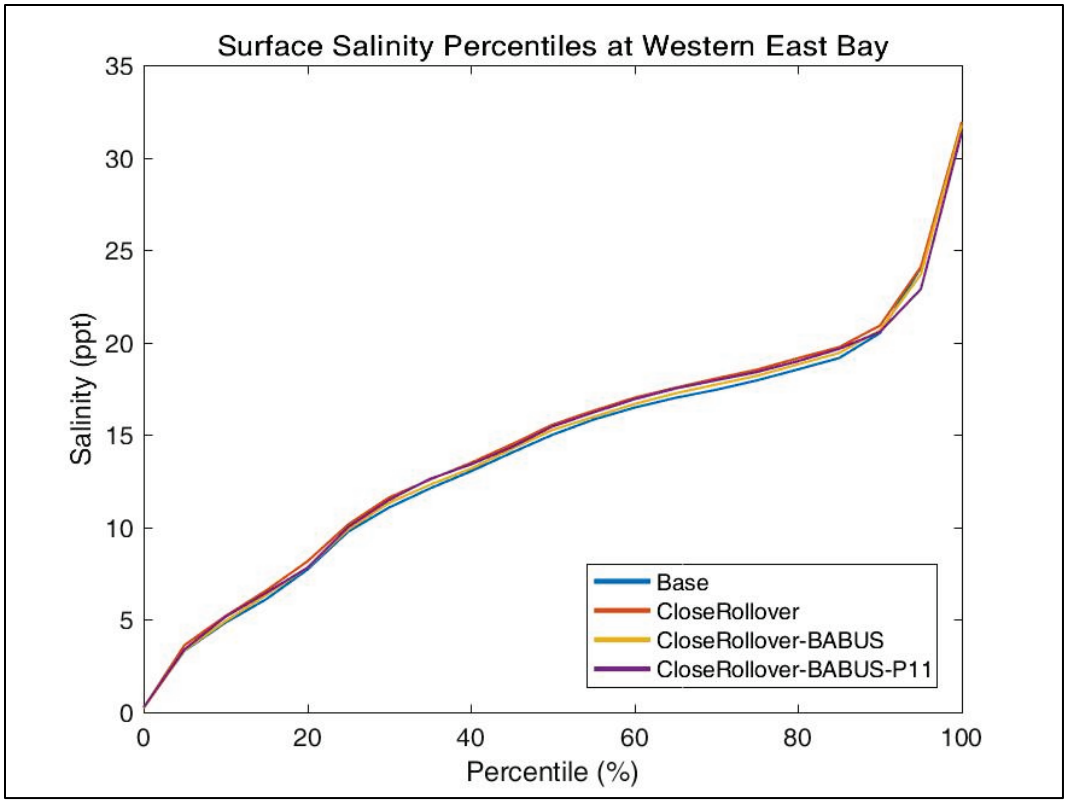

Surface Salinity Percentiles at Upper Trinity Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
10
20
30
40
50
60
70
80
90
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

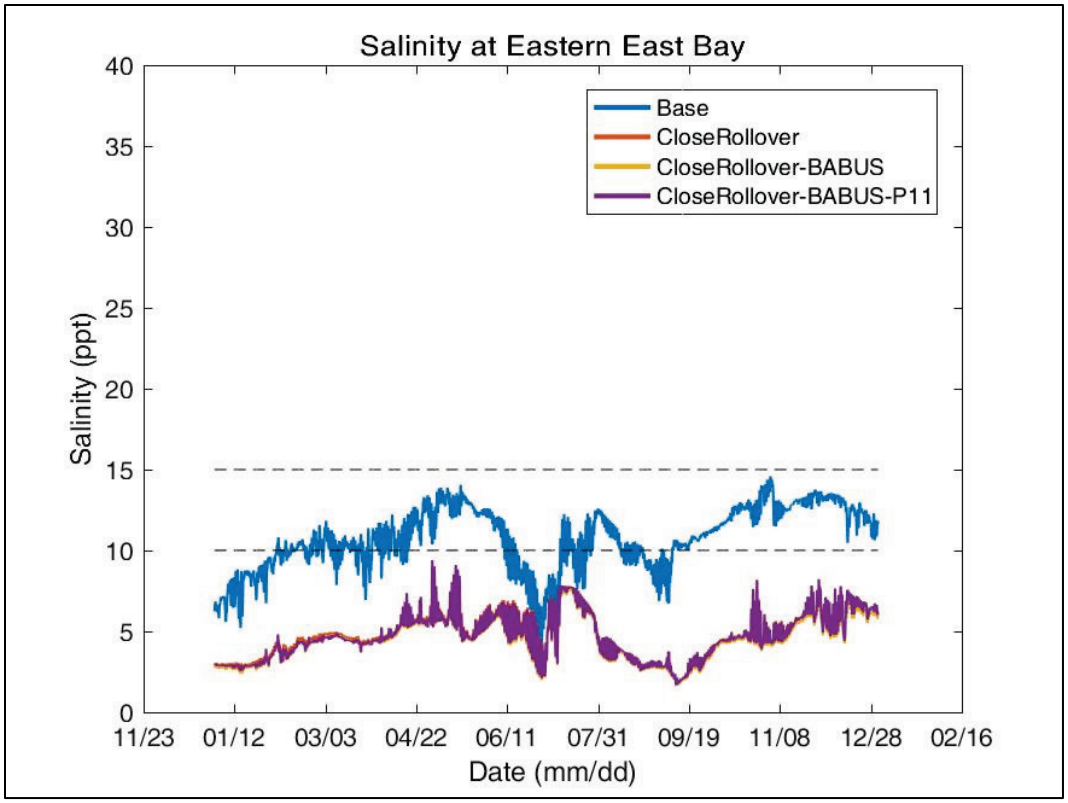

Salinity at Western East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

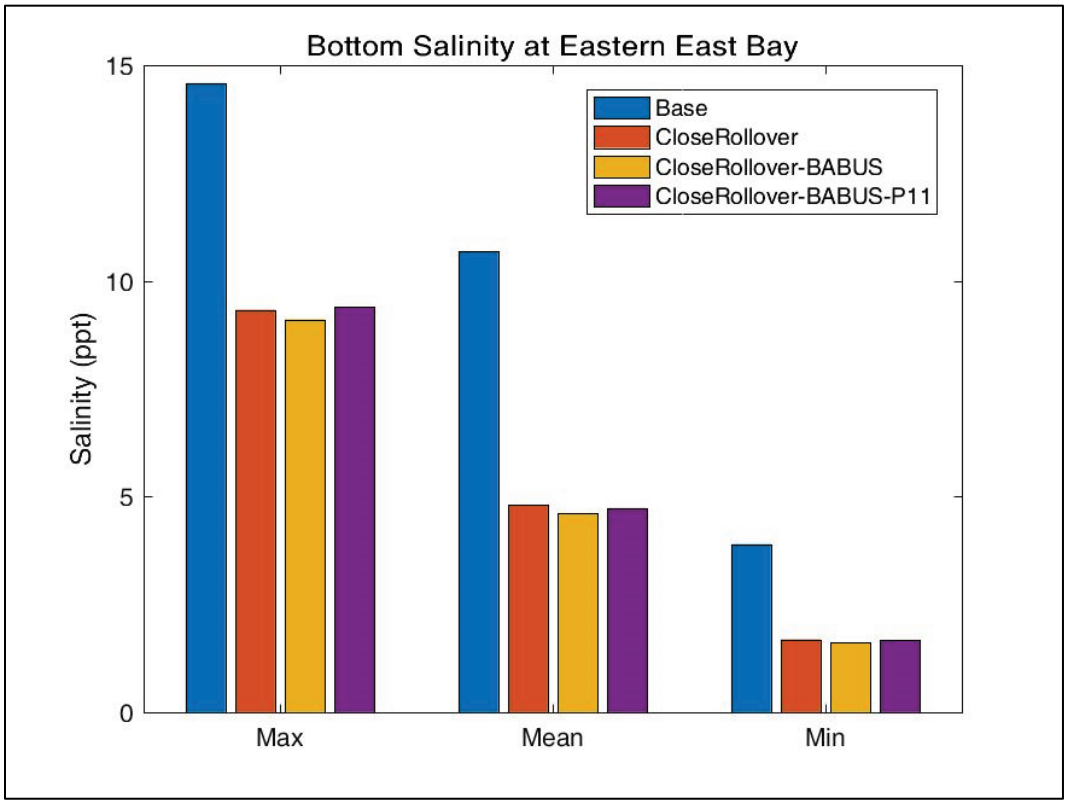

Bottom Salinity at Western East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

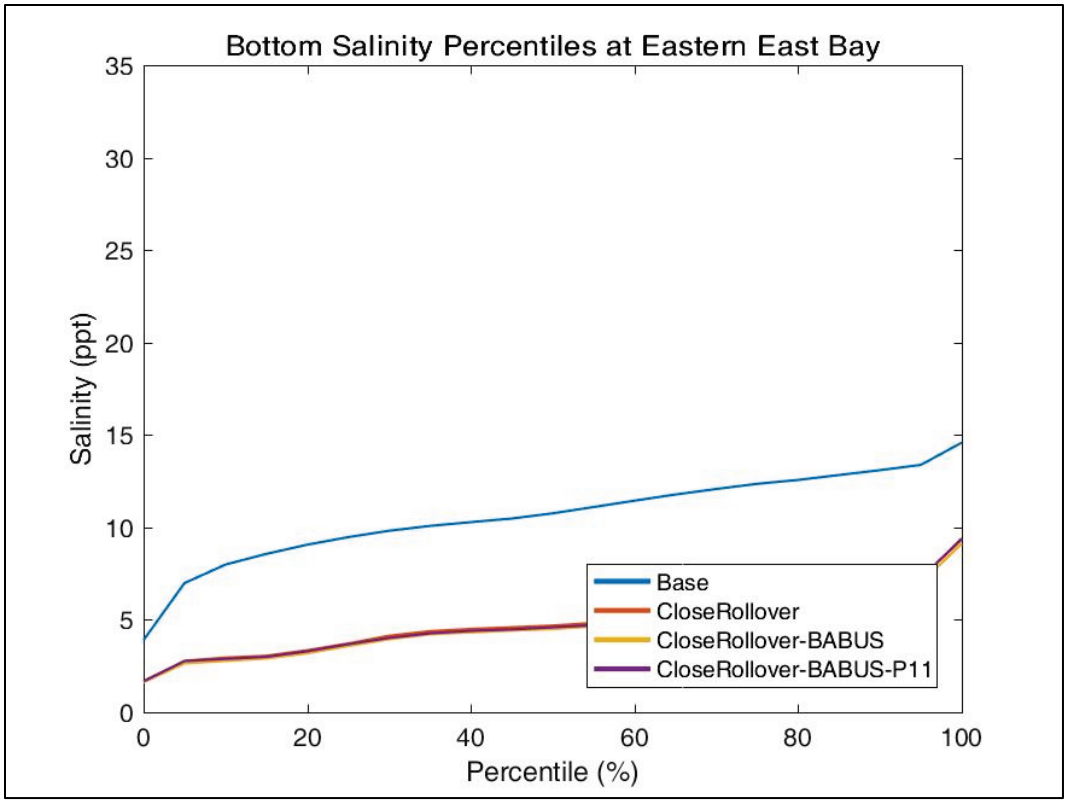

Bottom Salinity Percentiles at Western East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

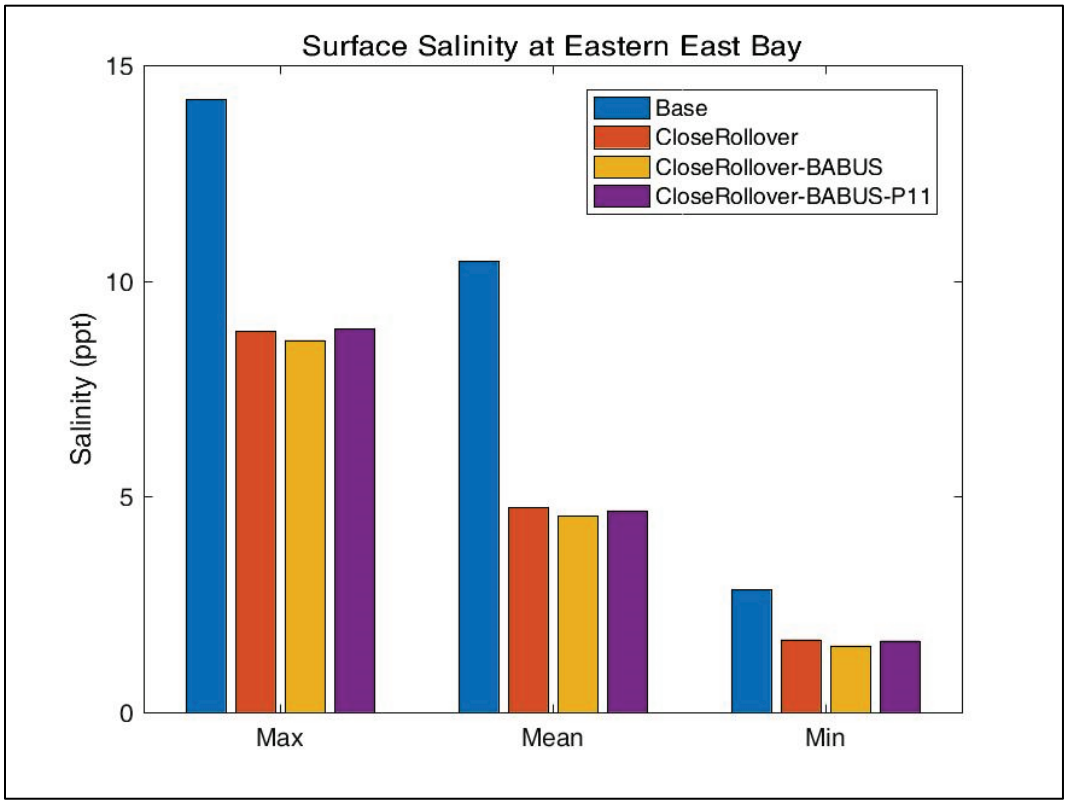

Surface Salinity at Western East Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

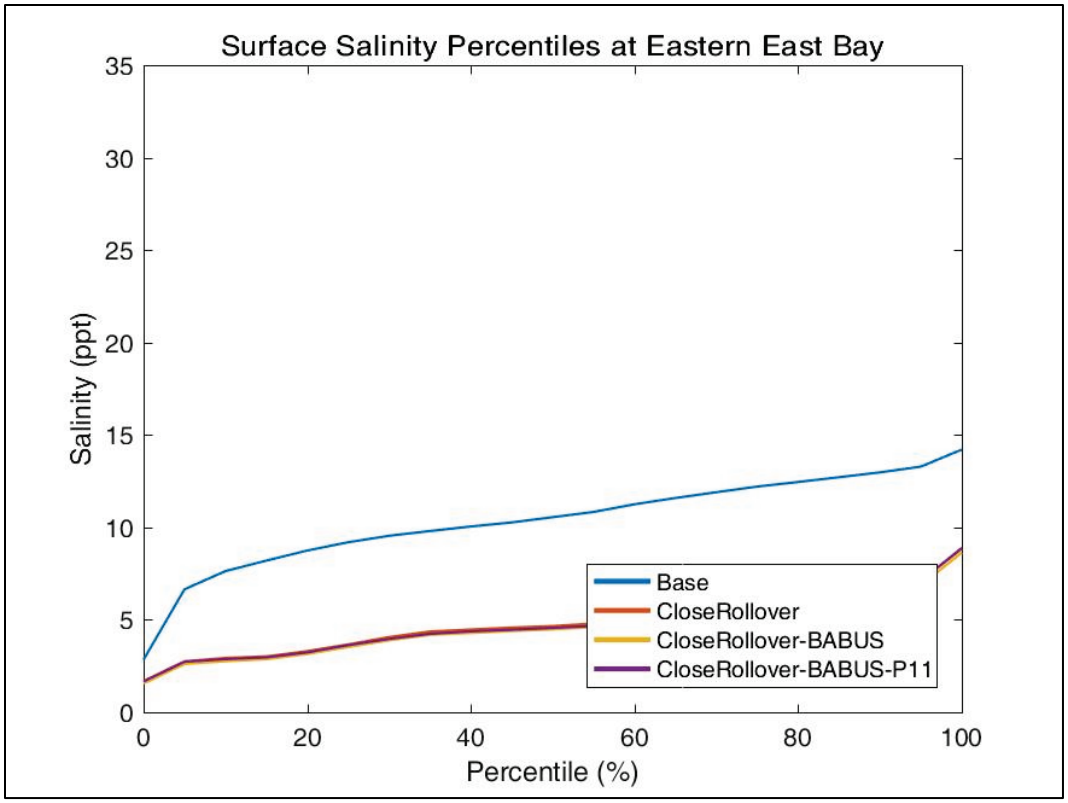

Surface Salinity Percentiles at Western East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

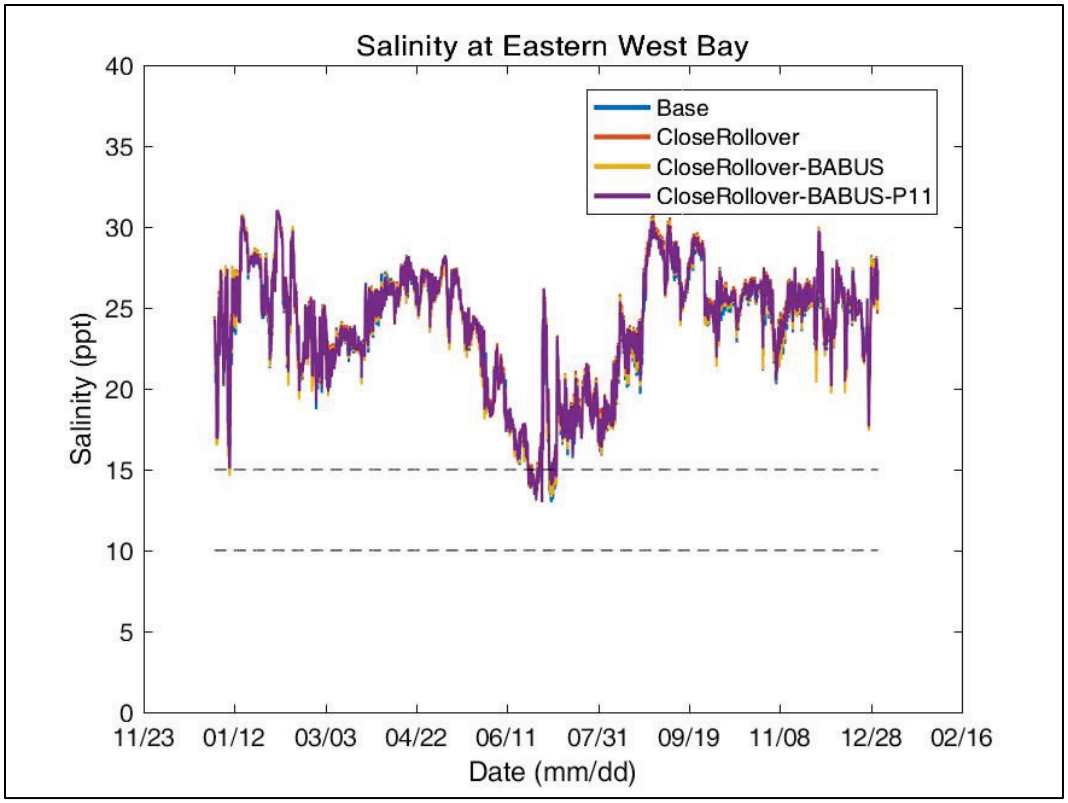

Salinity at Eastern East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

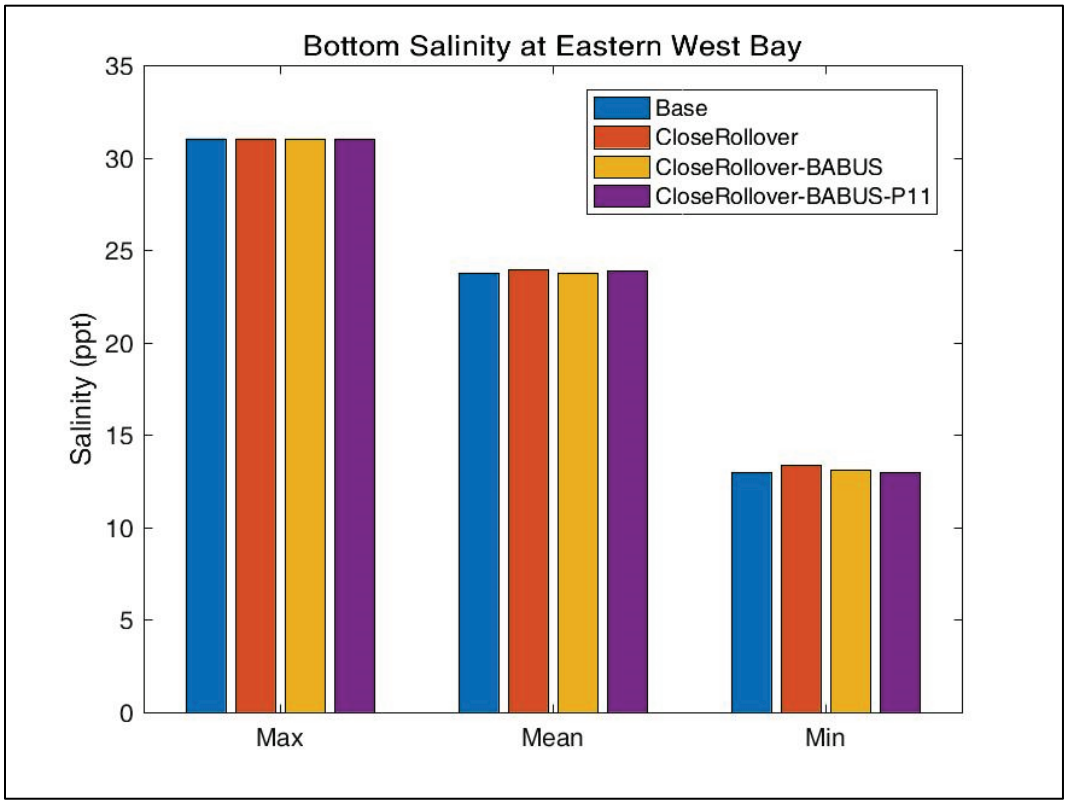

Bottom Salinity at Eastern East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
Max
Mean
Min

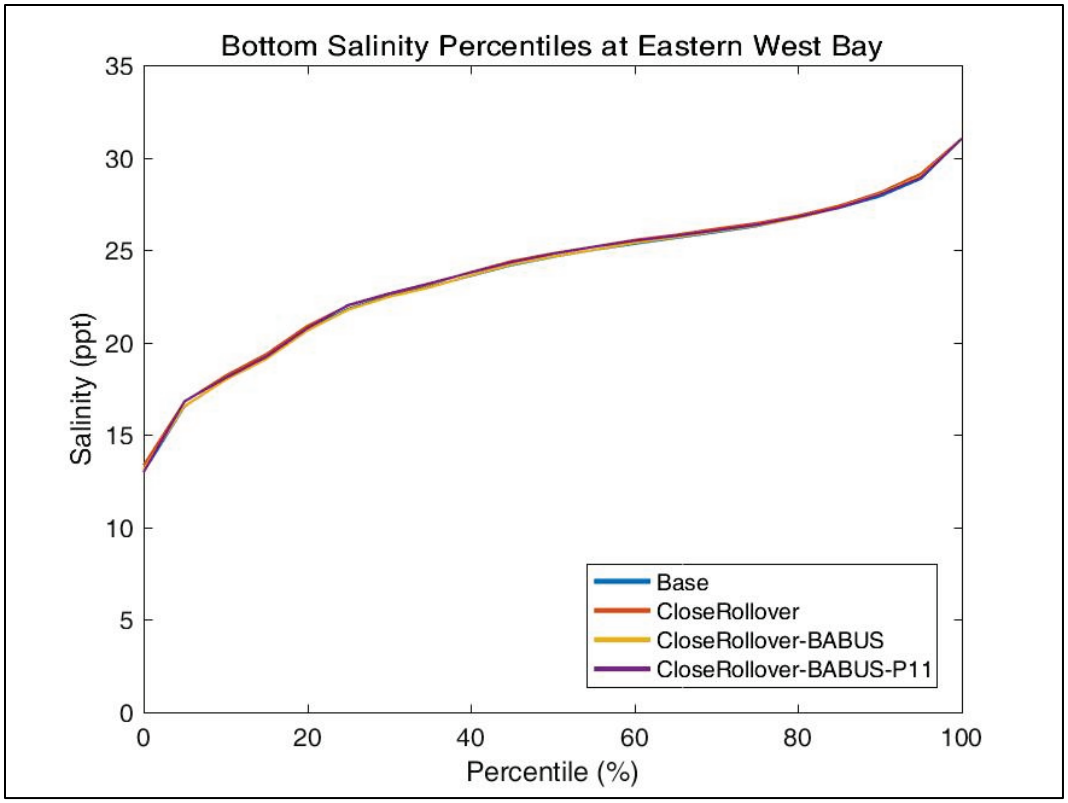

Bottom Salinity Percentiles at Eastern East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

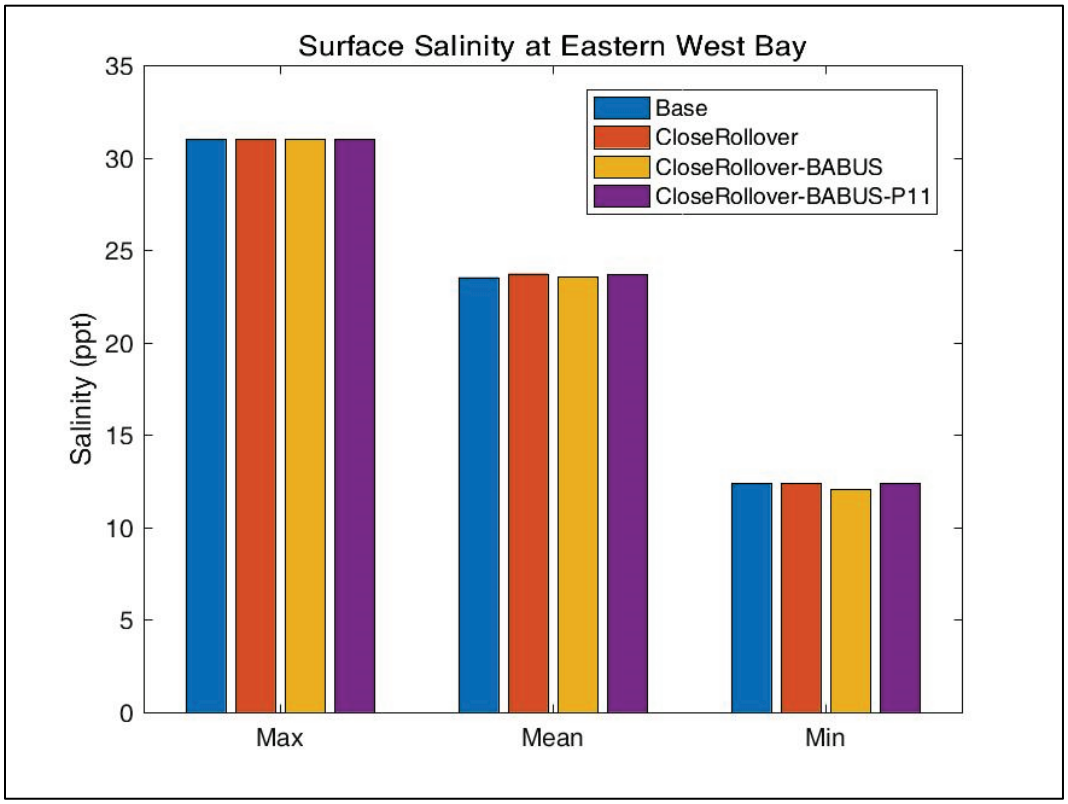

Surface Salinity at Eastern East Bay
Salinity (ppt)
0
5
10
15
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

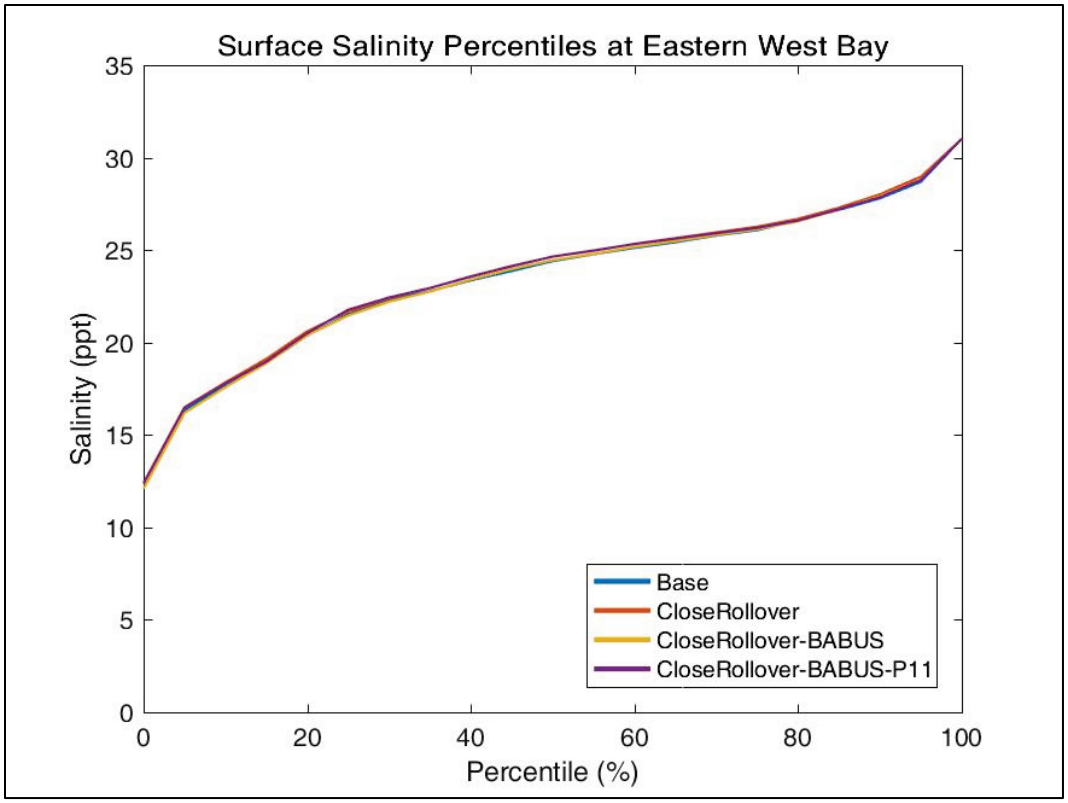

Surface Salinity Percentiles at Eastern East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

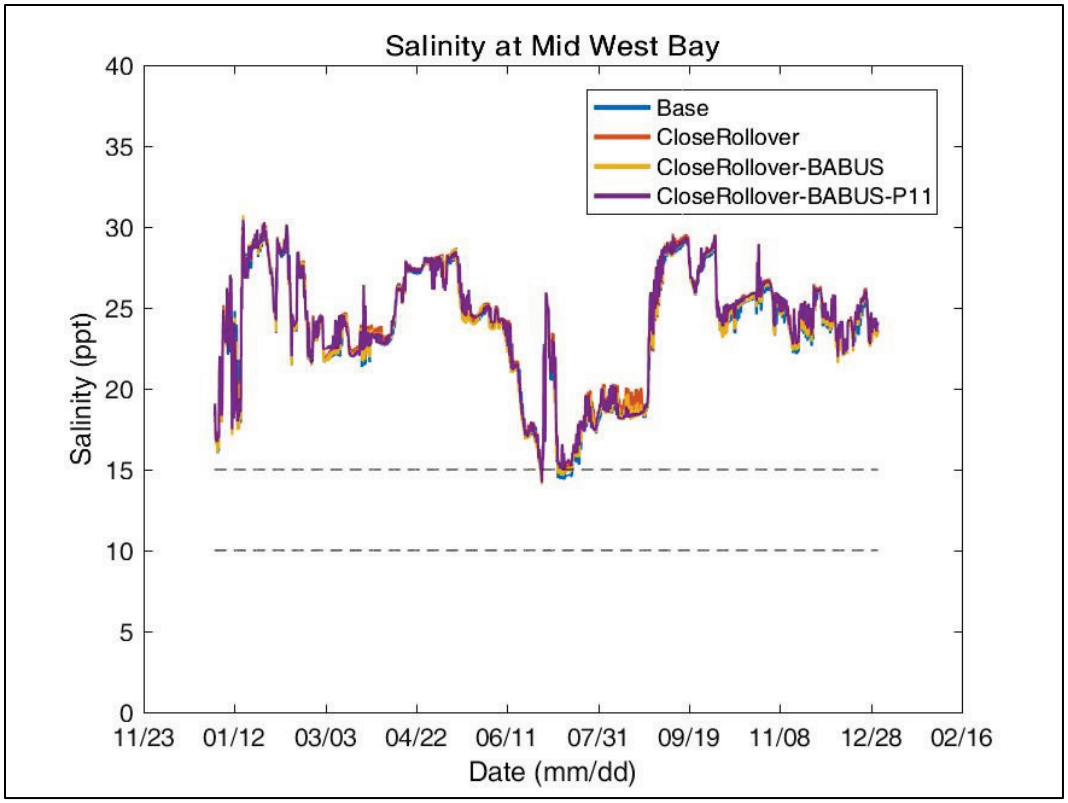

Salinity at Eastern West Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

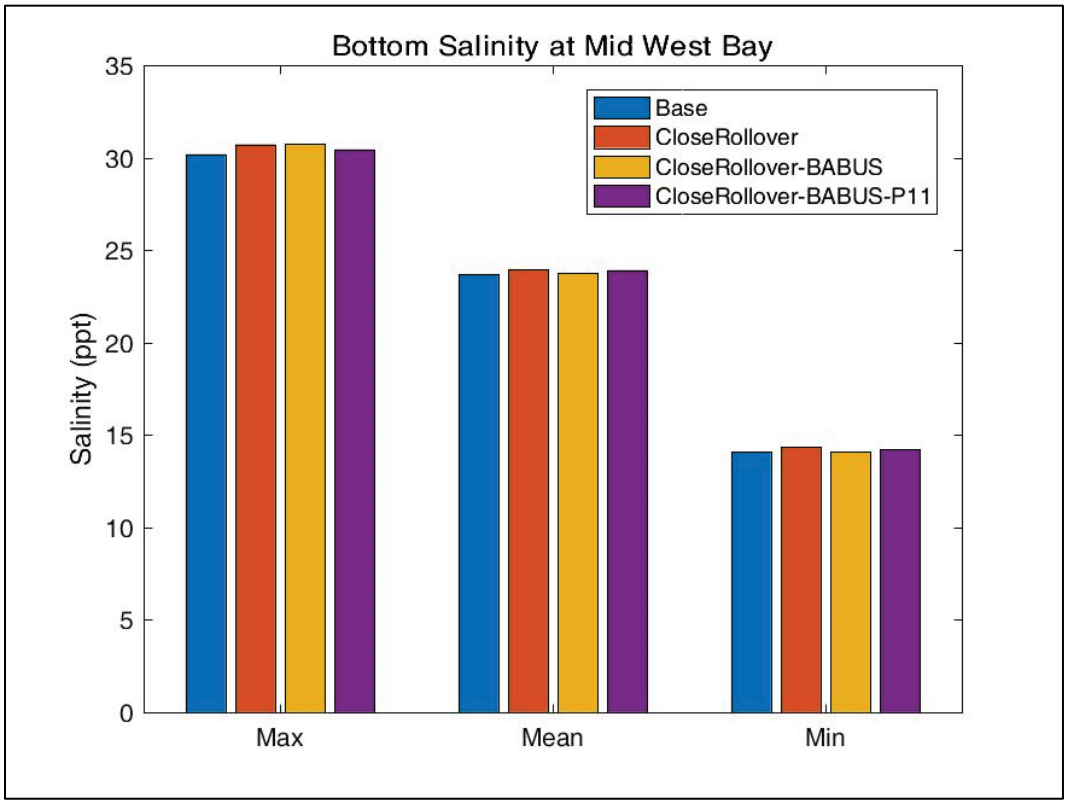

Bottom Salinity at Eastern West Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

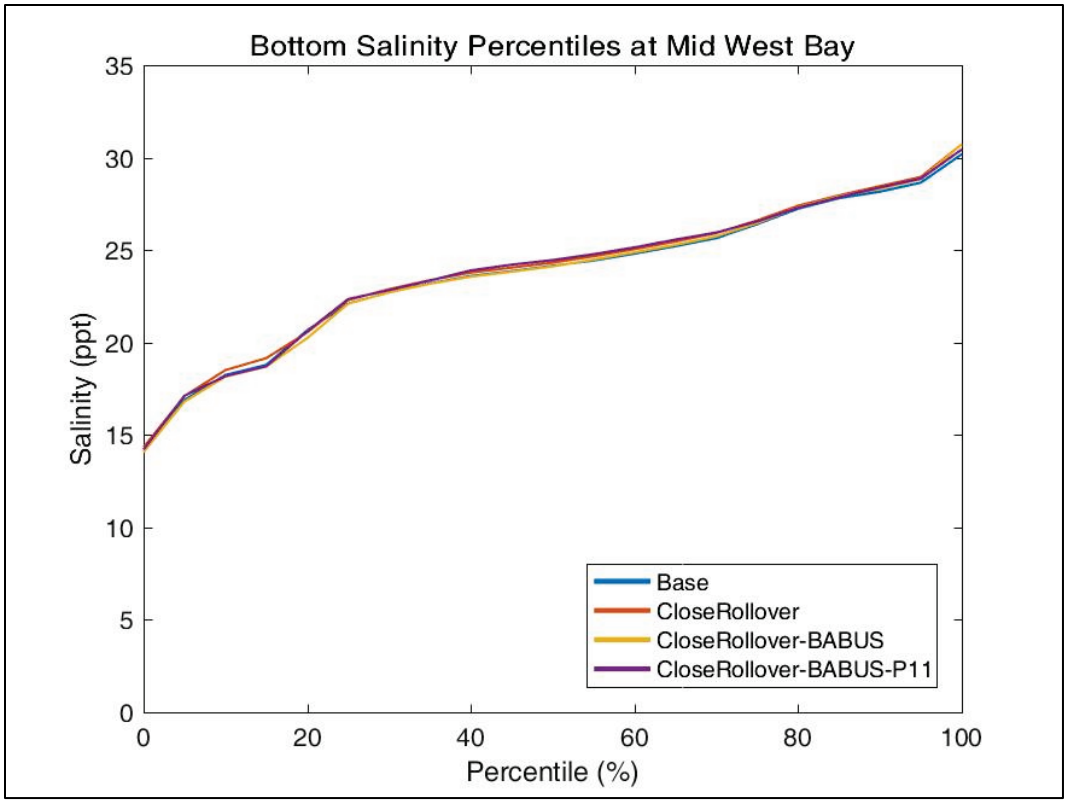

Bottom Salinity Percentiles at Eastern West Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

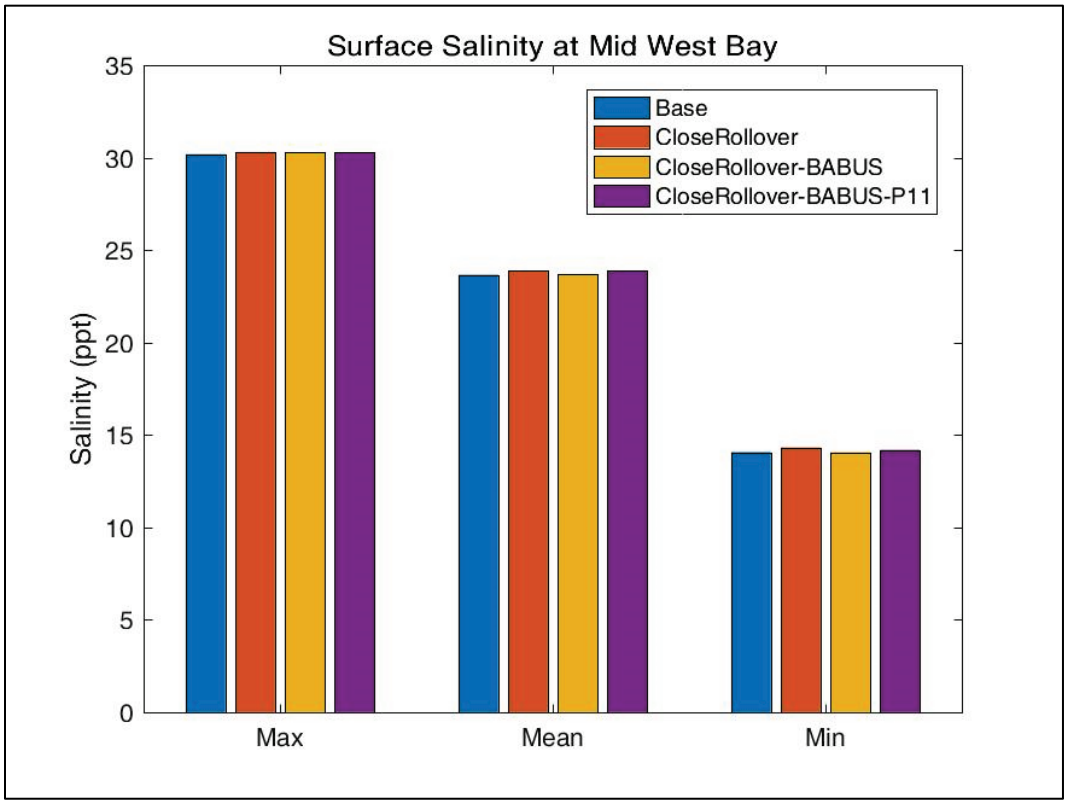

Surface Salinity at Eastern West Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

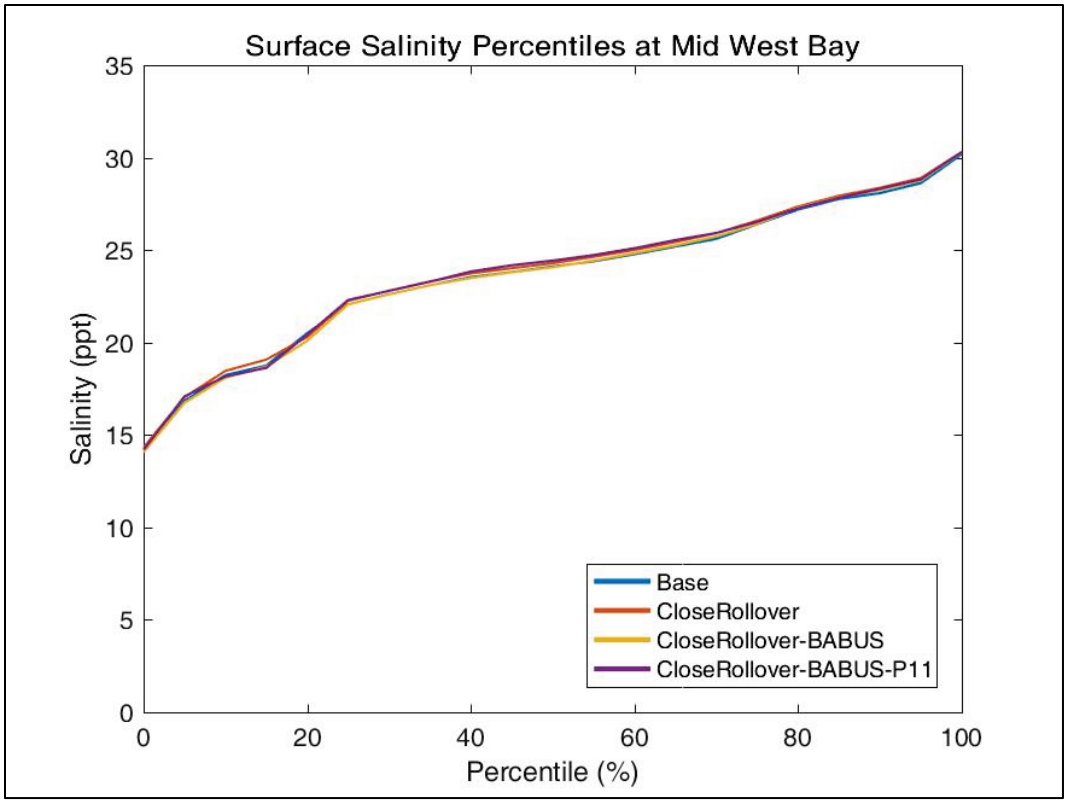

Surface Salinity Percentiles at Eastern West Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

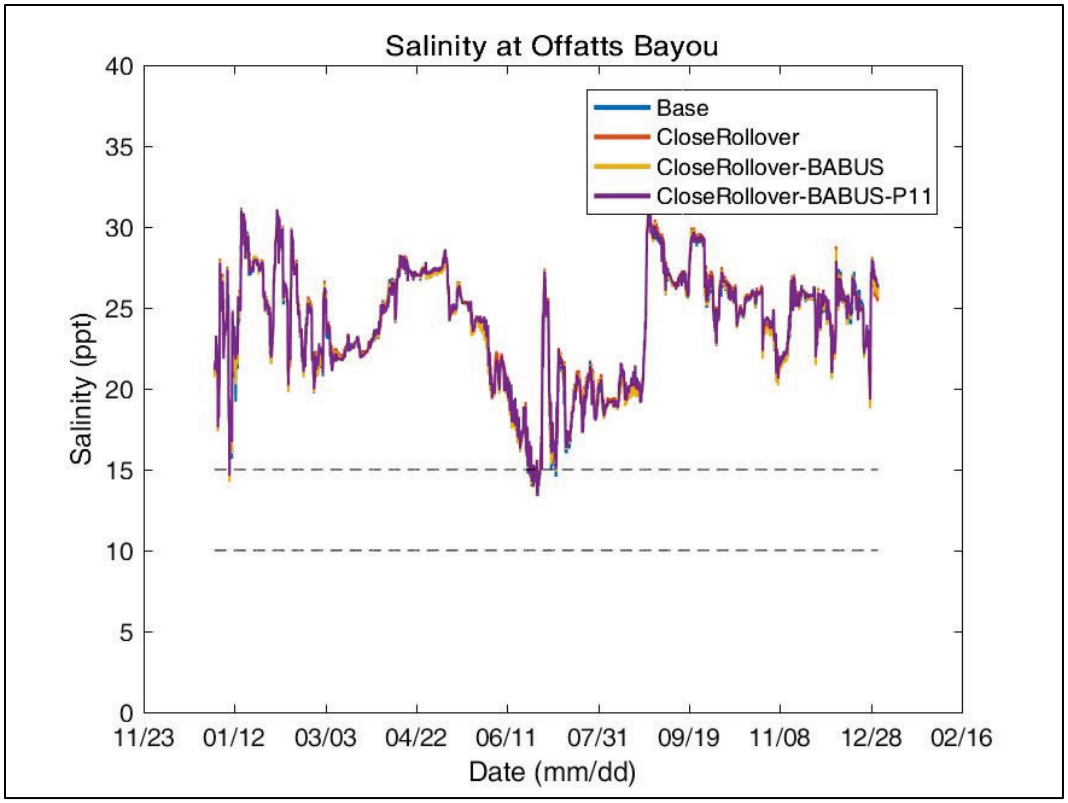

Salinity at Mid West Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

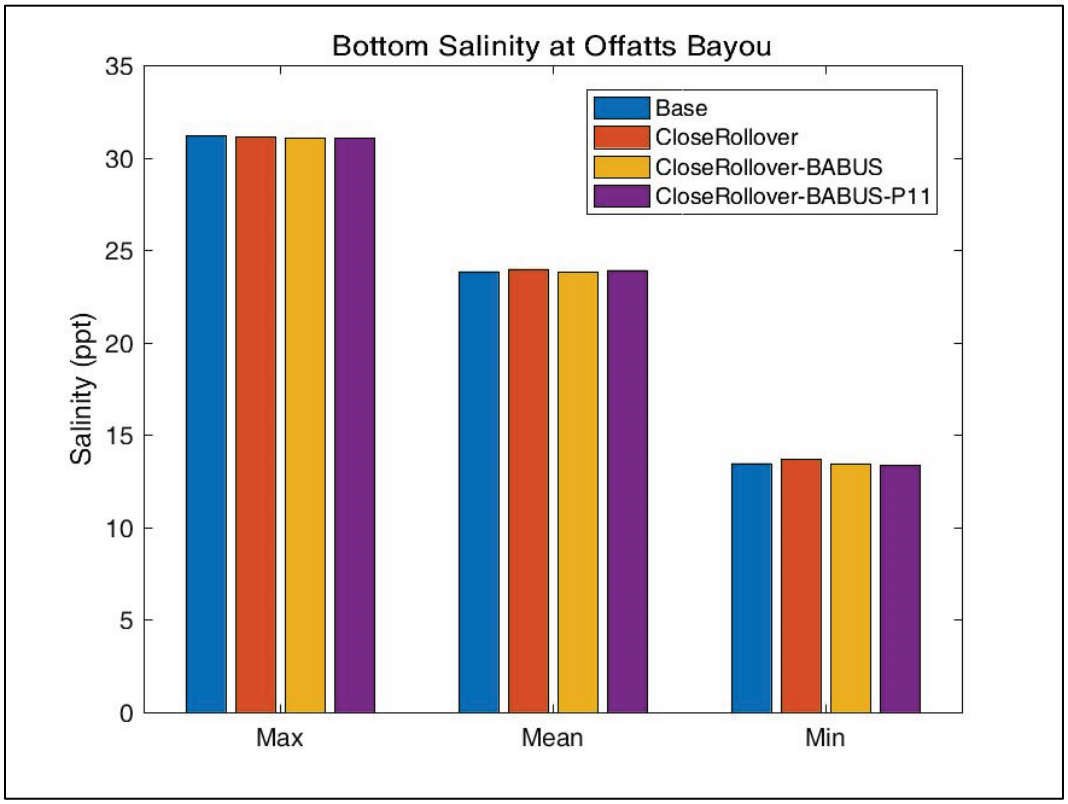

Bottom Salinity at Mid West Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

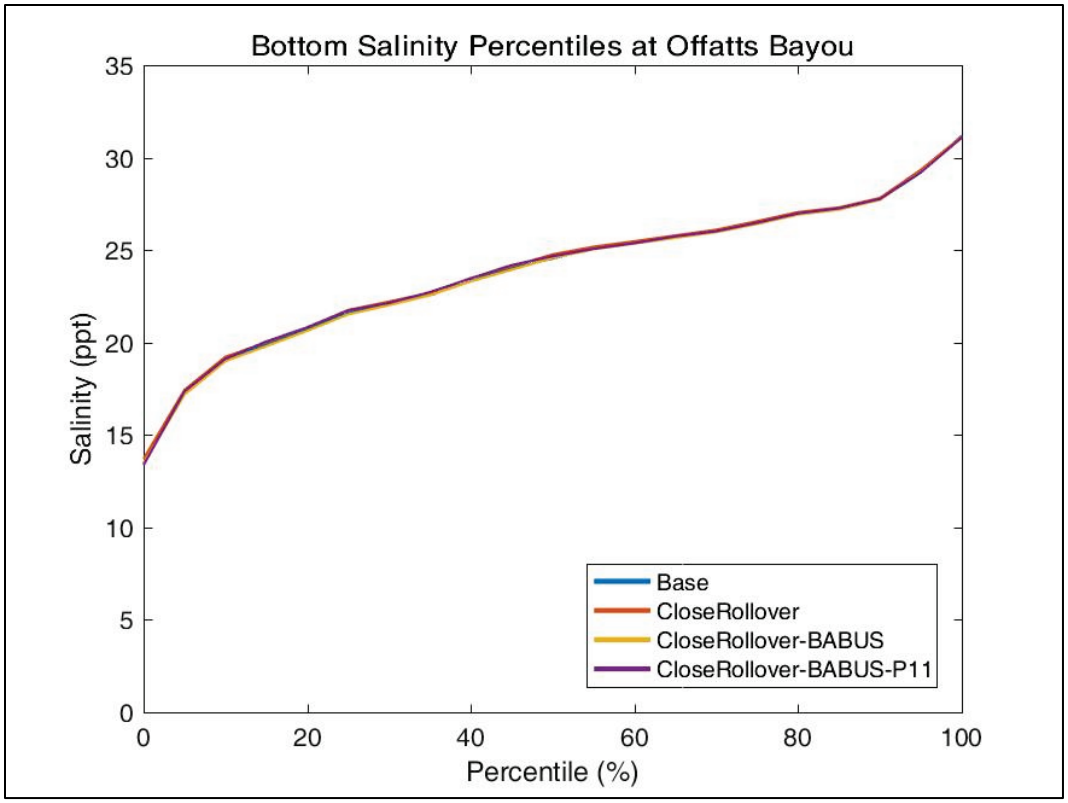

Bottom Salinity Percentiles at Mid West Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

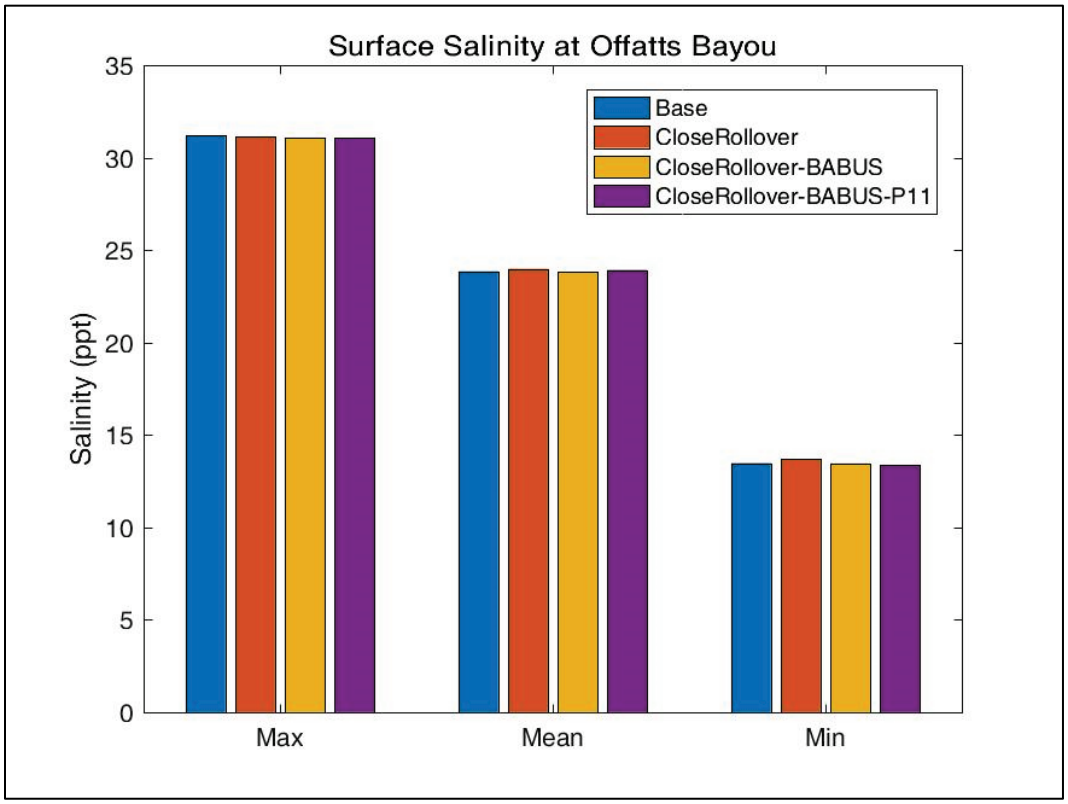

Surface Salinity at Mid West Bay
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

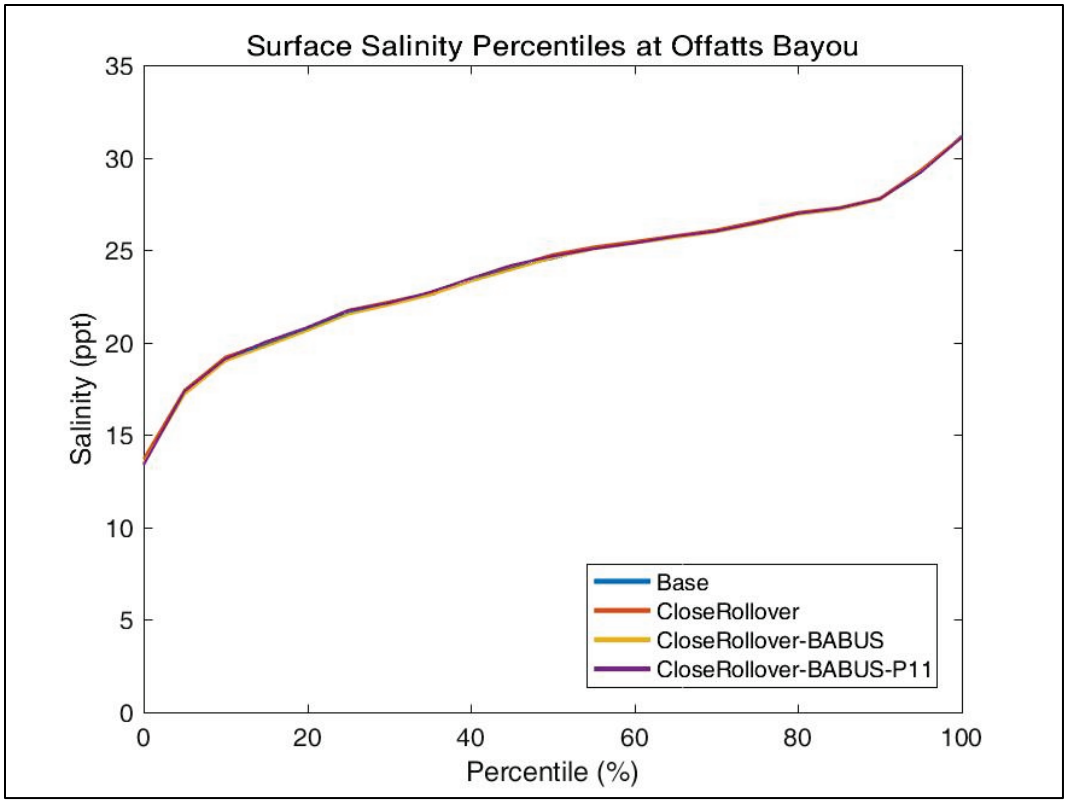

Surface Salinity Percentiles at Mid West Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

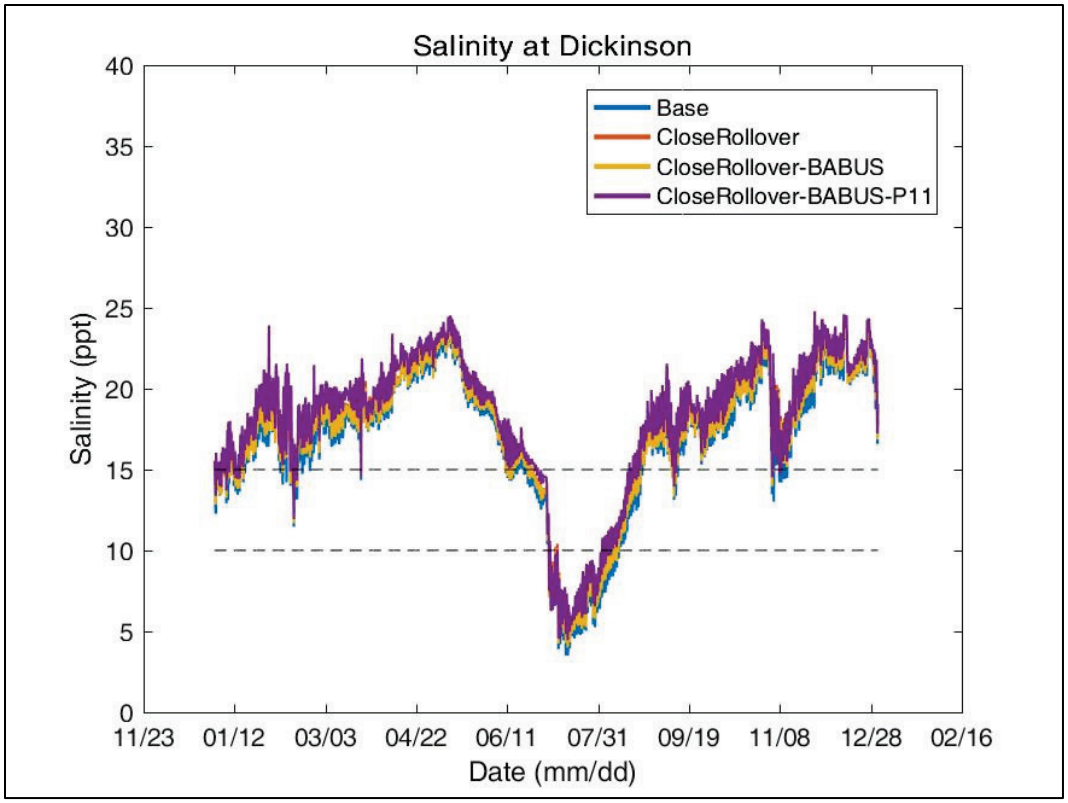

Salinity at Offatts Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

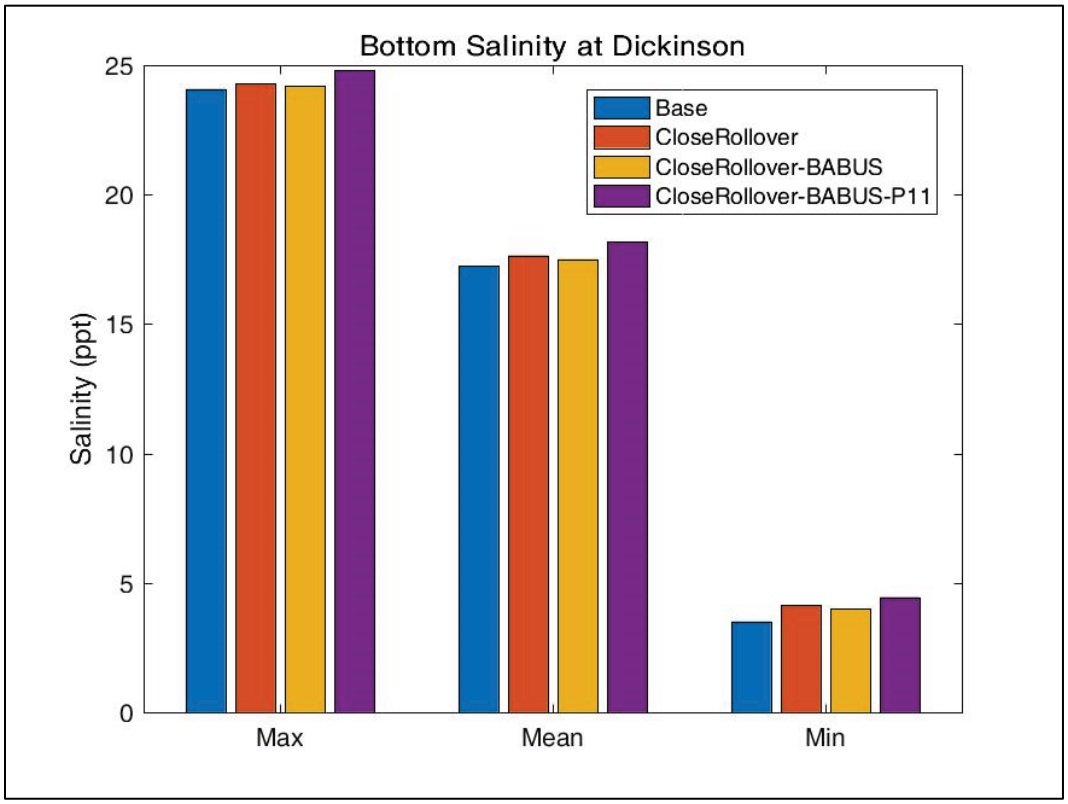

Bottom Salinity at Offatts Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

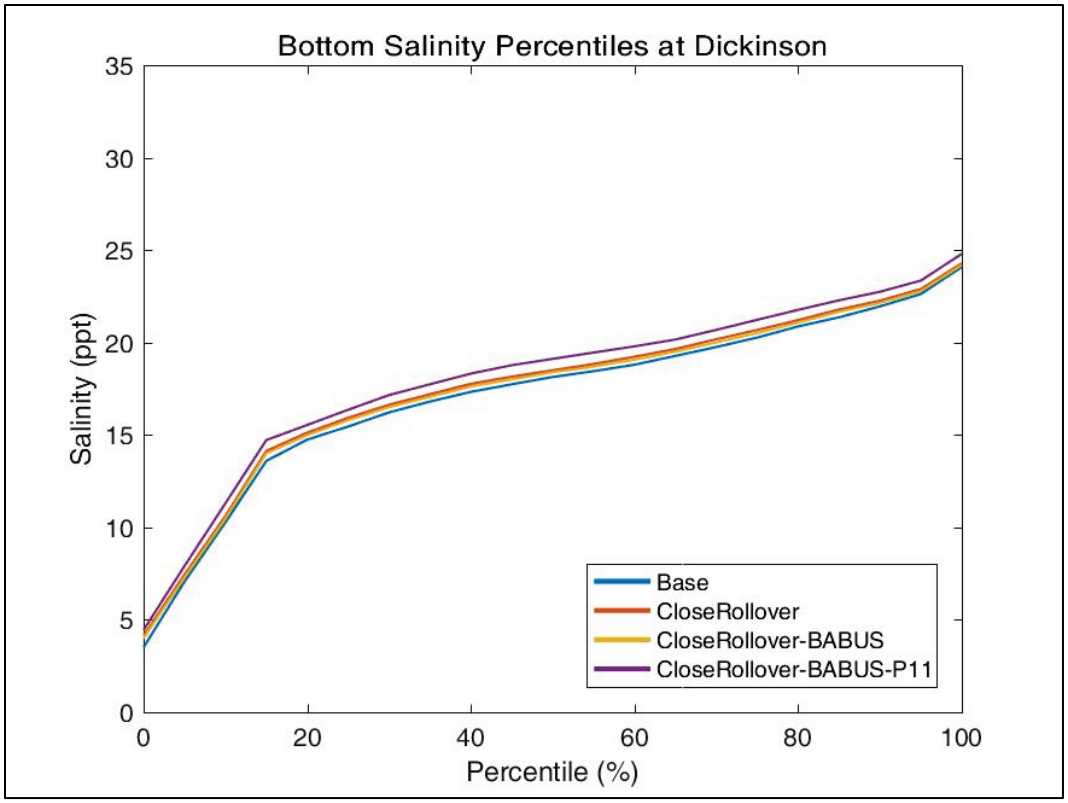

Bottom Salinity Percentiles at Offatts Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

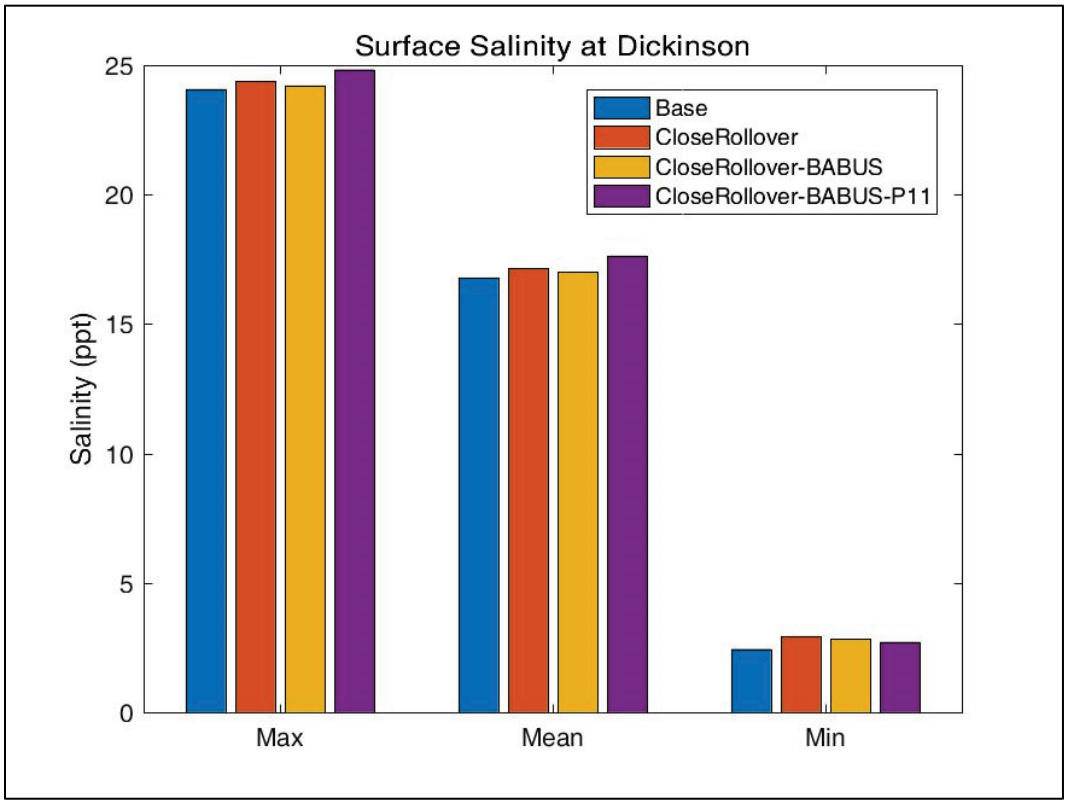

Surface Salinity at Offatts Bayou
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

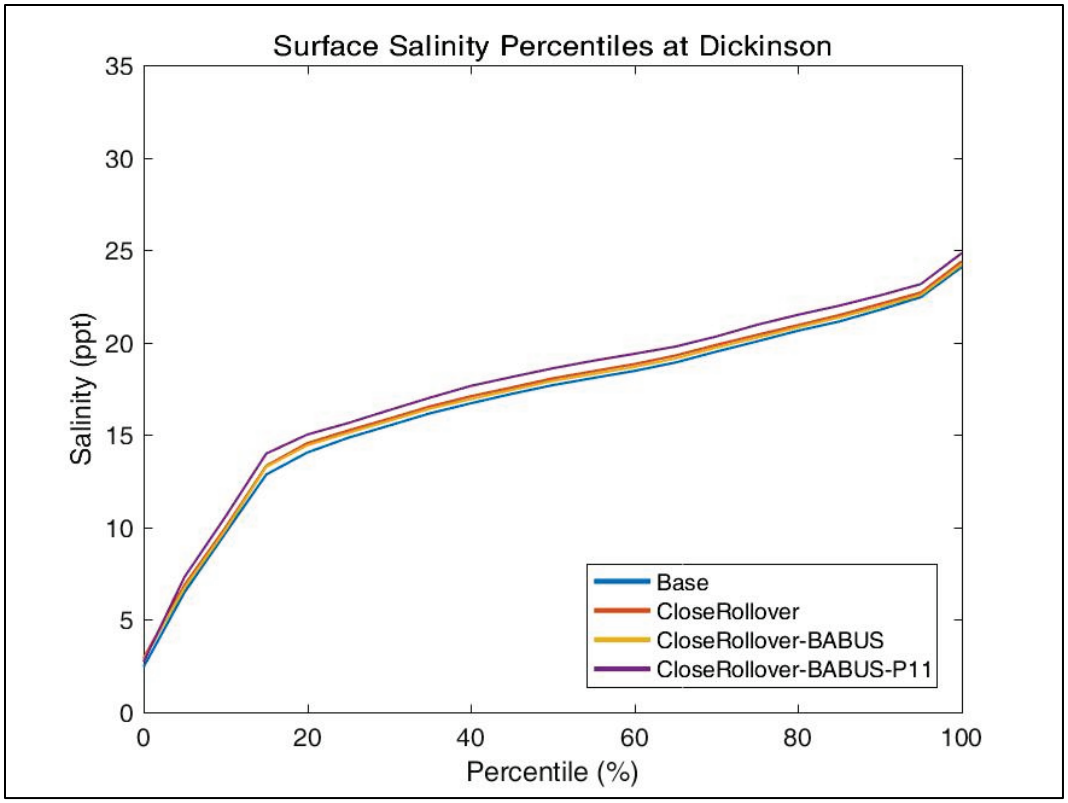

Surface Salinity Percentiles at Offatts Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

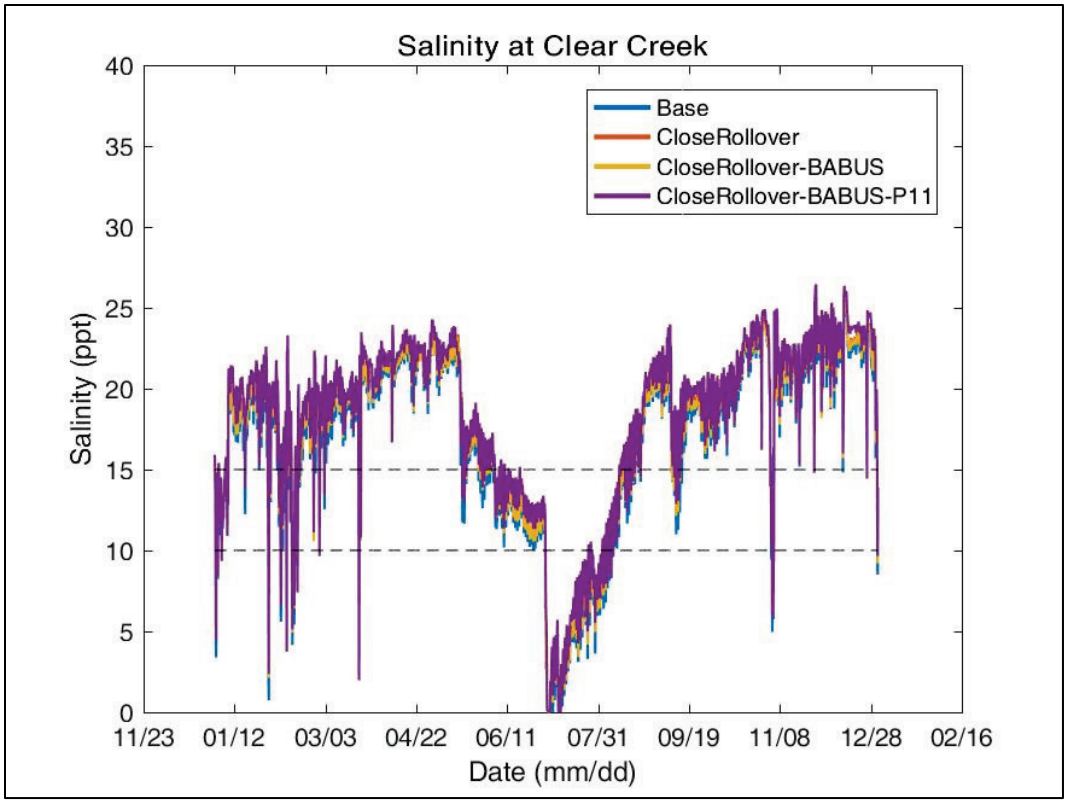

Salinity at Dickinson
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

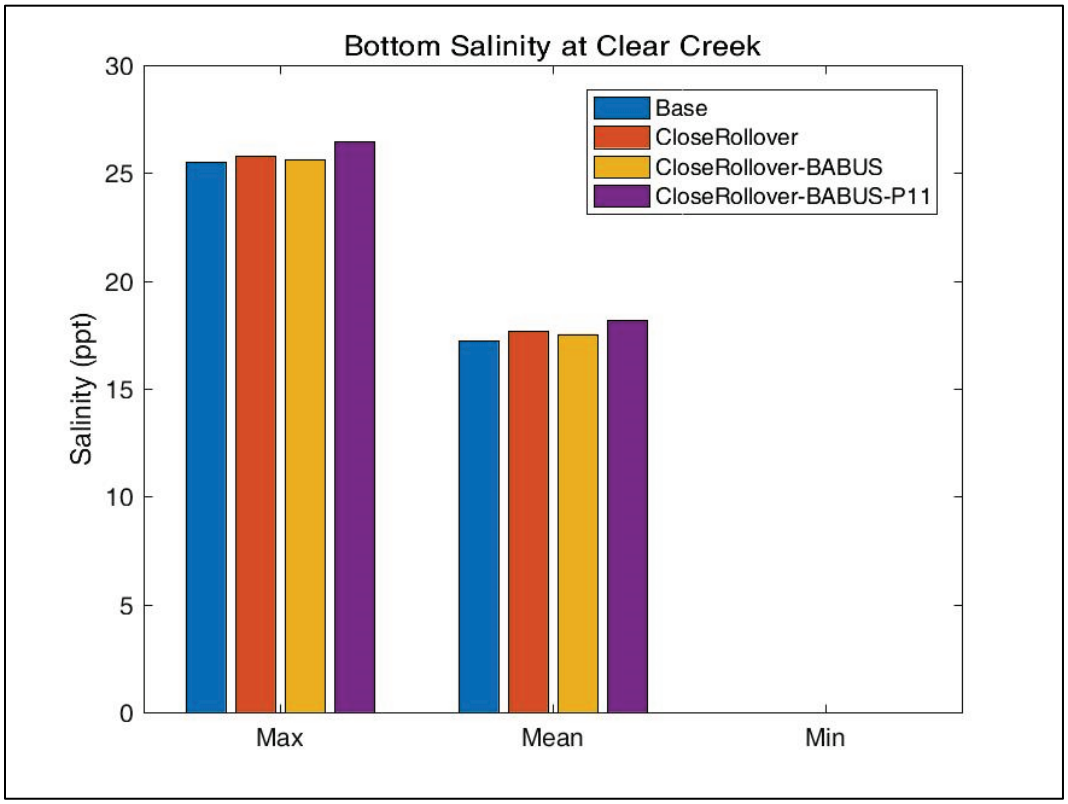

Bottom Salinity at Dickinson
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min

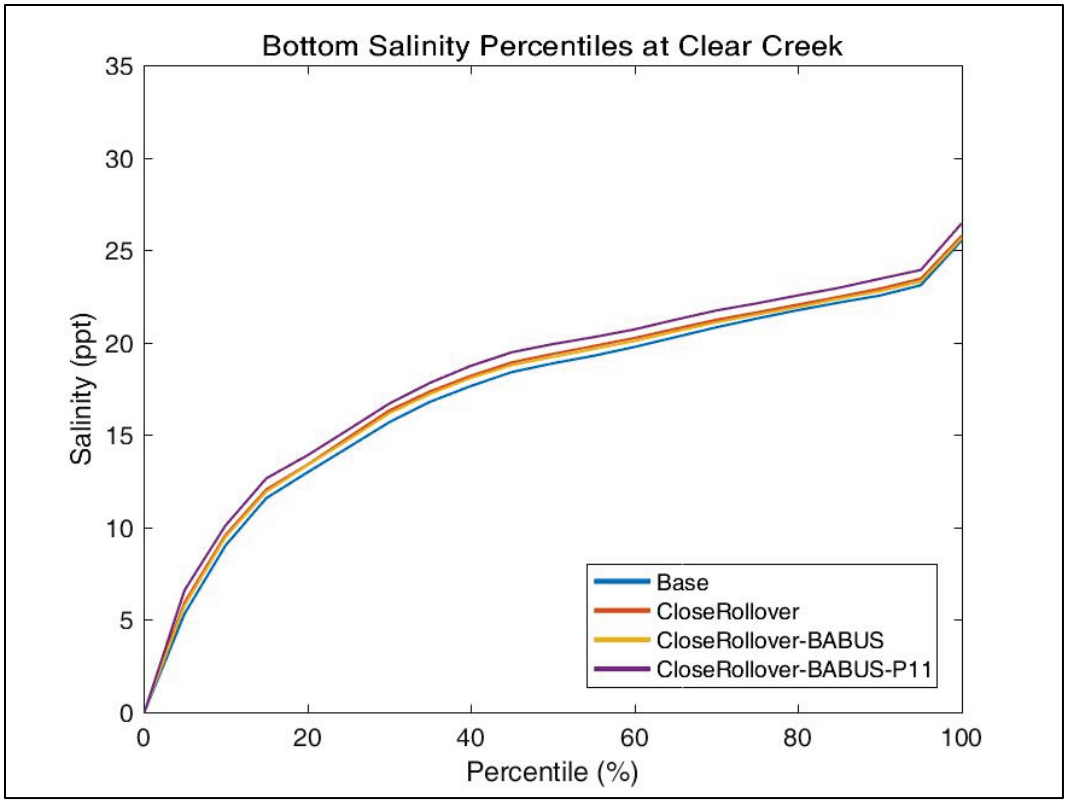

Bottom Salinity Percentiles at Dickinson
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

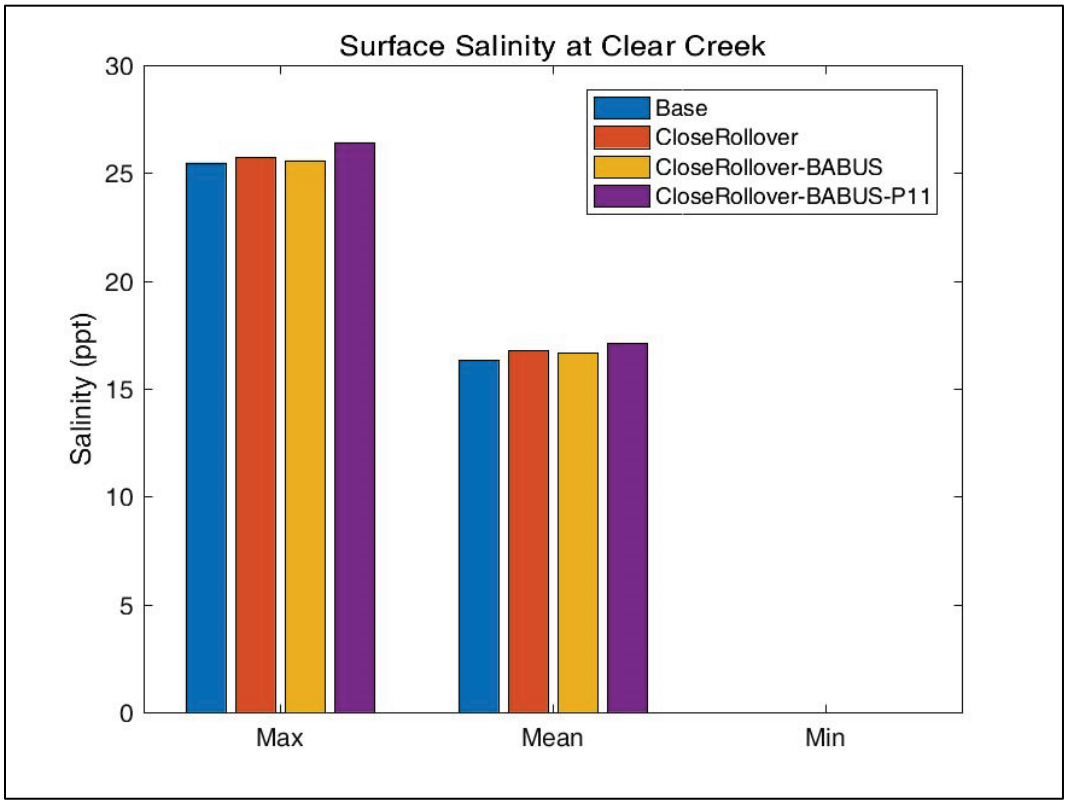

Surface Salinity at Dickinson
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

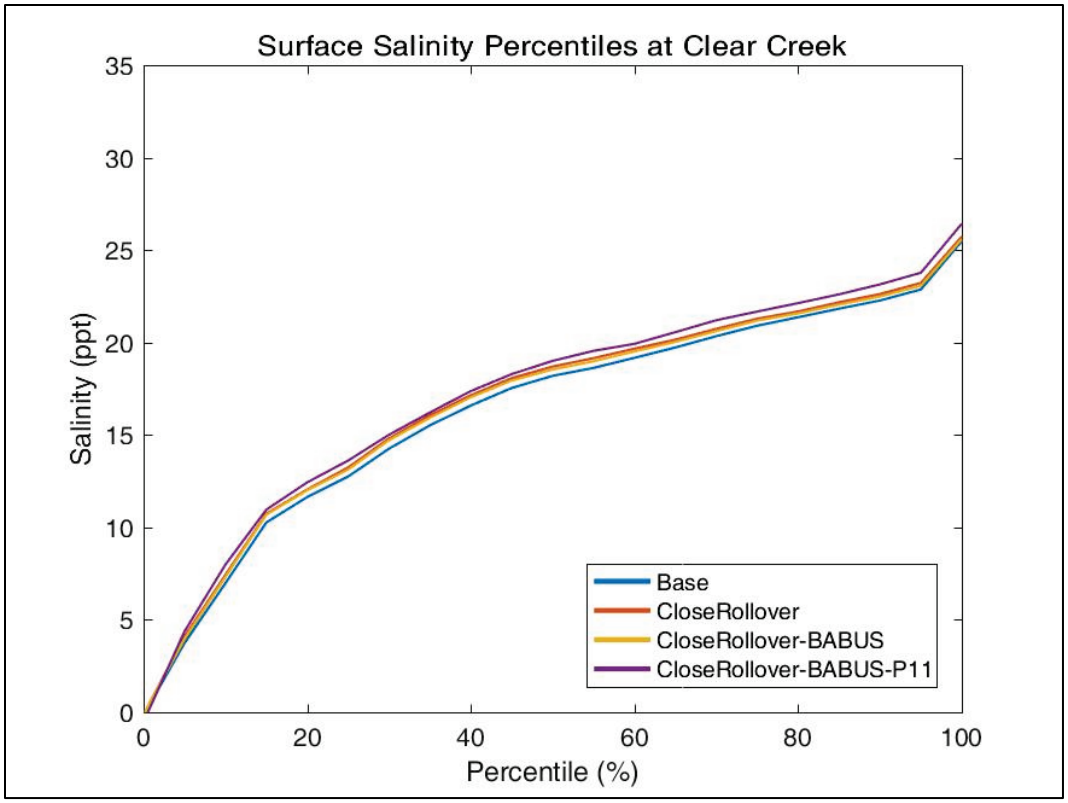

Surface Salinity Percentiles at Dickinson
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

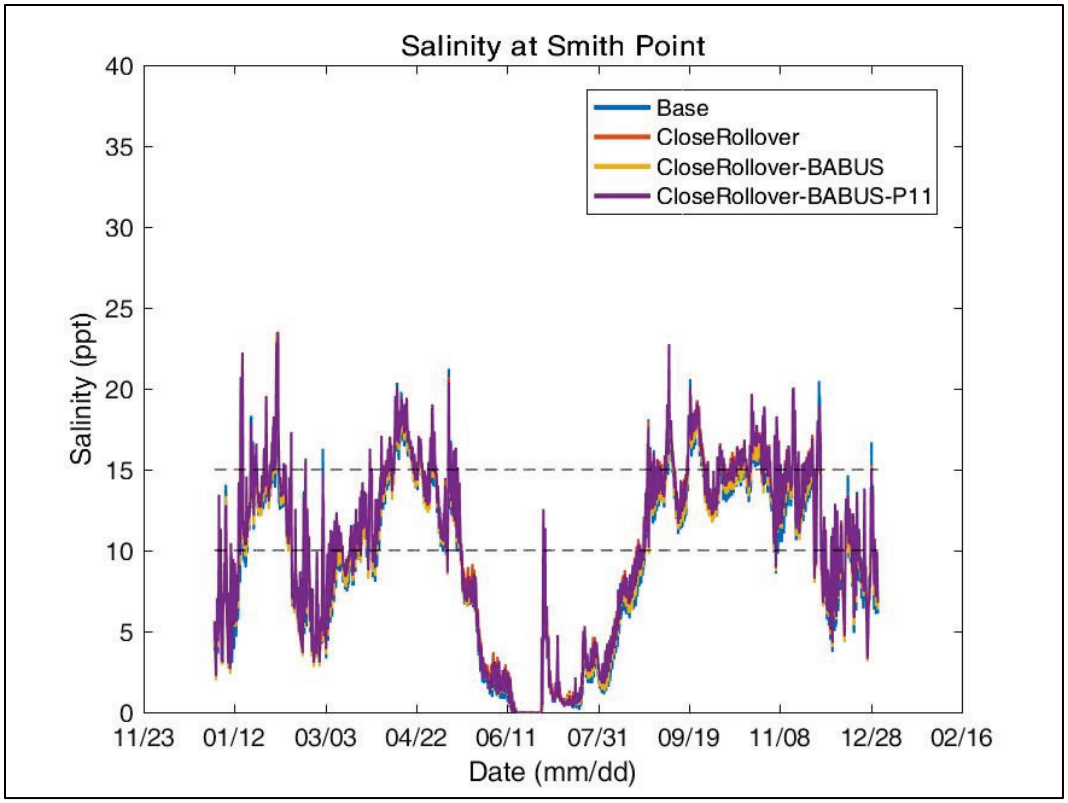

Salinity at Clear Creek
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

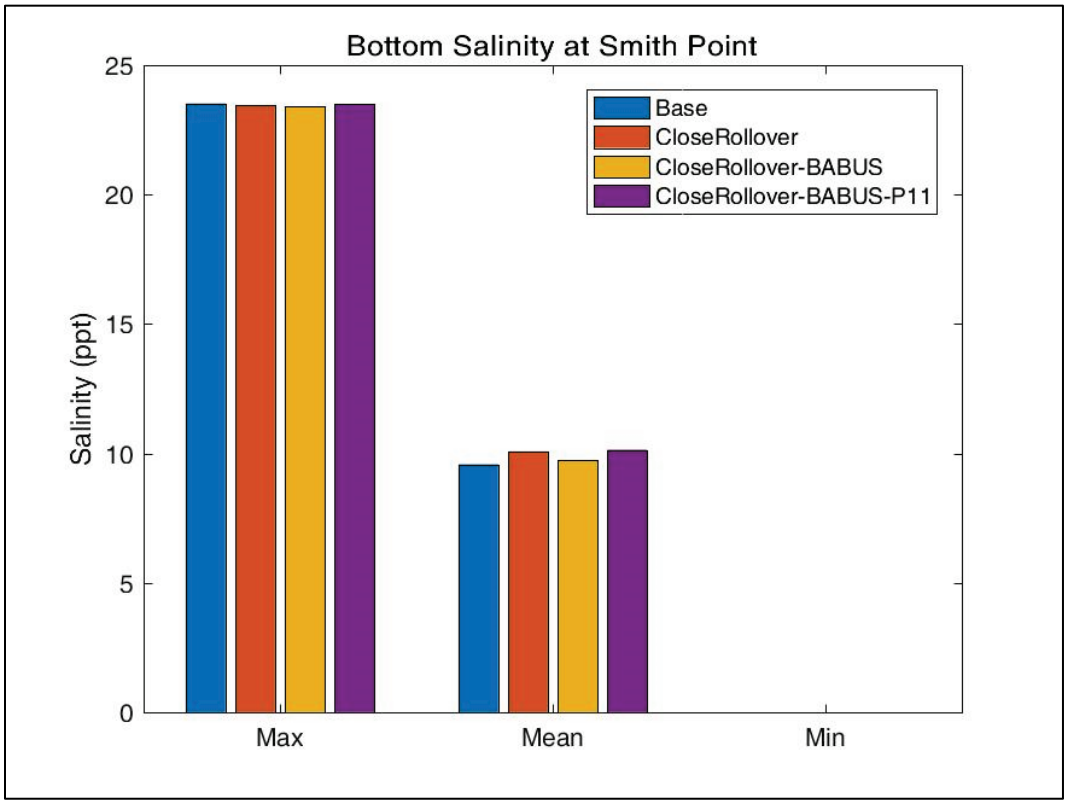

Bottom Salinity at Clear Creek
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

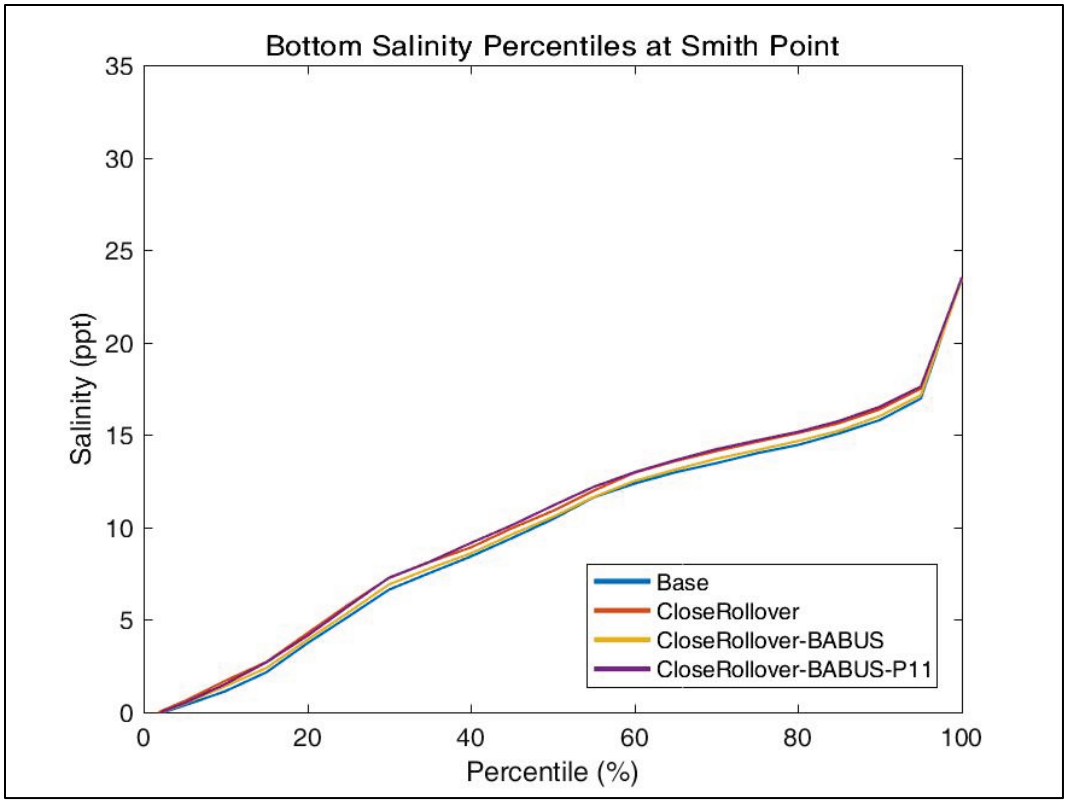

Bottom Salinity Percentiles at Clear Creek
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

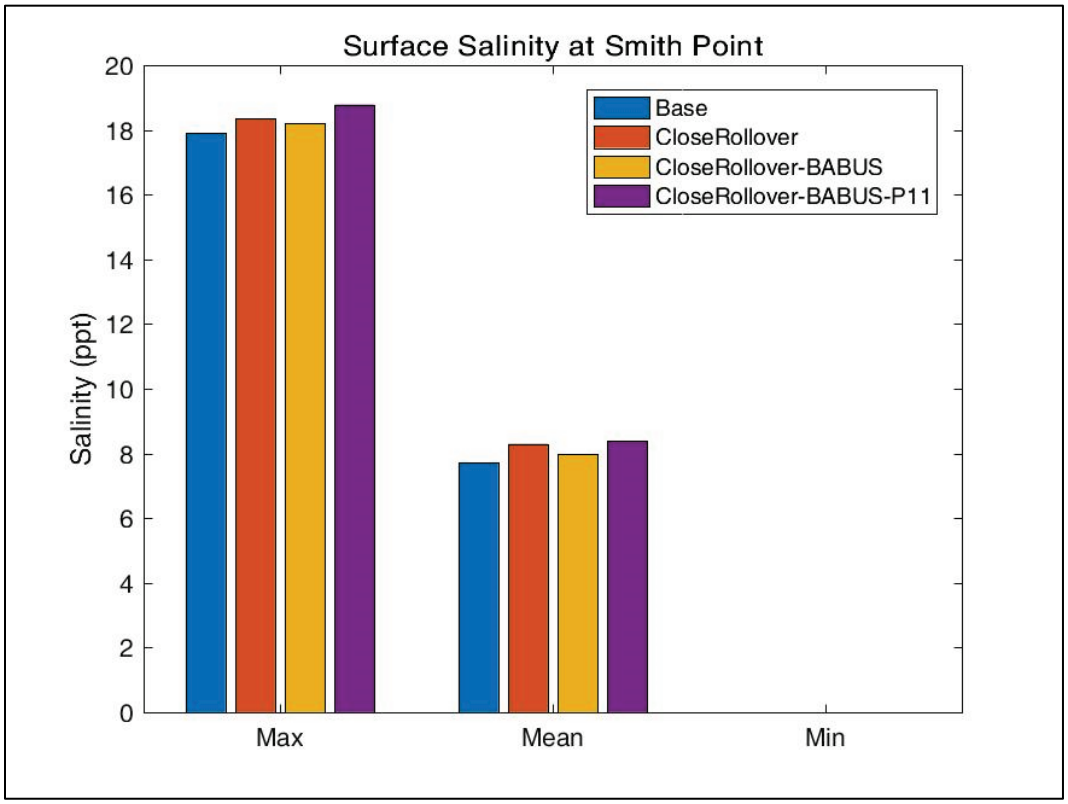

Surface Salinity at Clear Creek
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

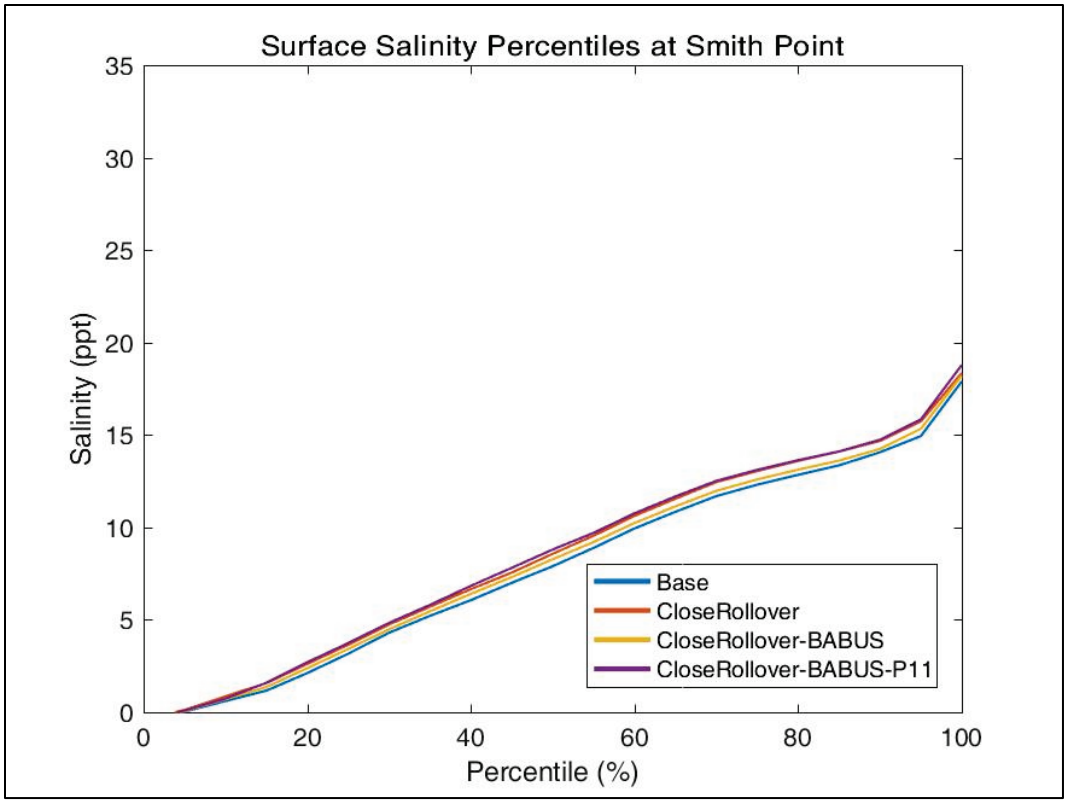

Surface Salinity Percentiles at Clear Creek
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

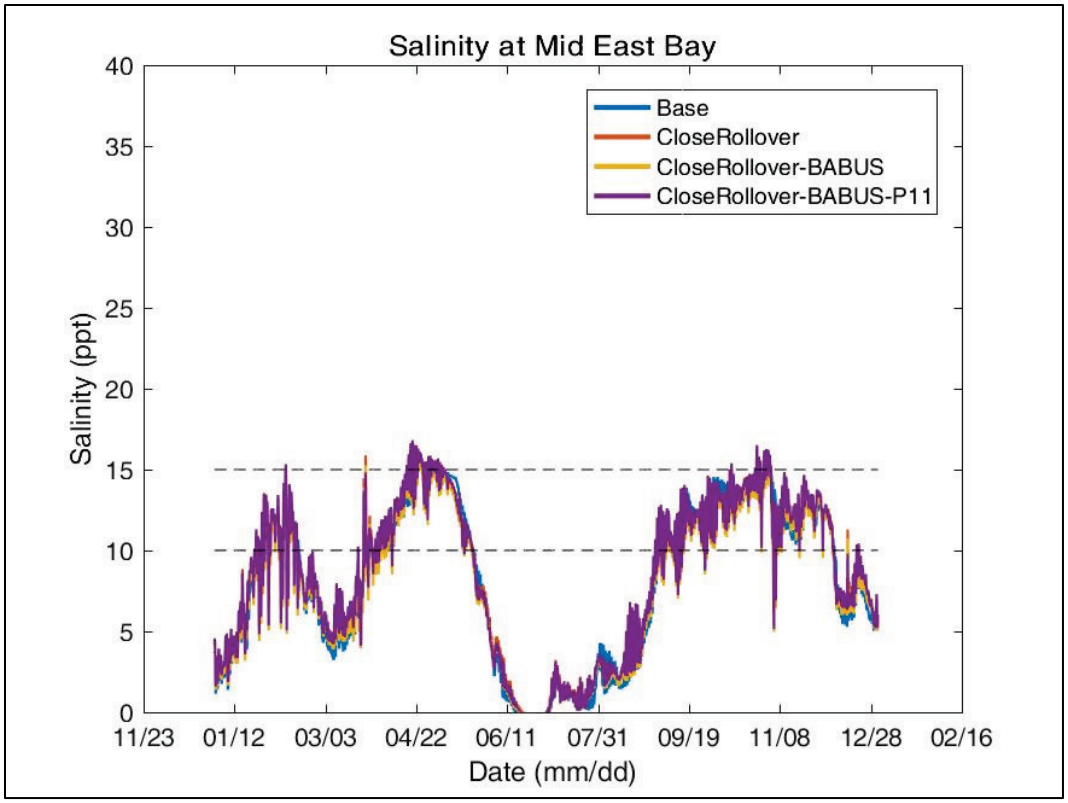

Salinity at Smith Point
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

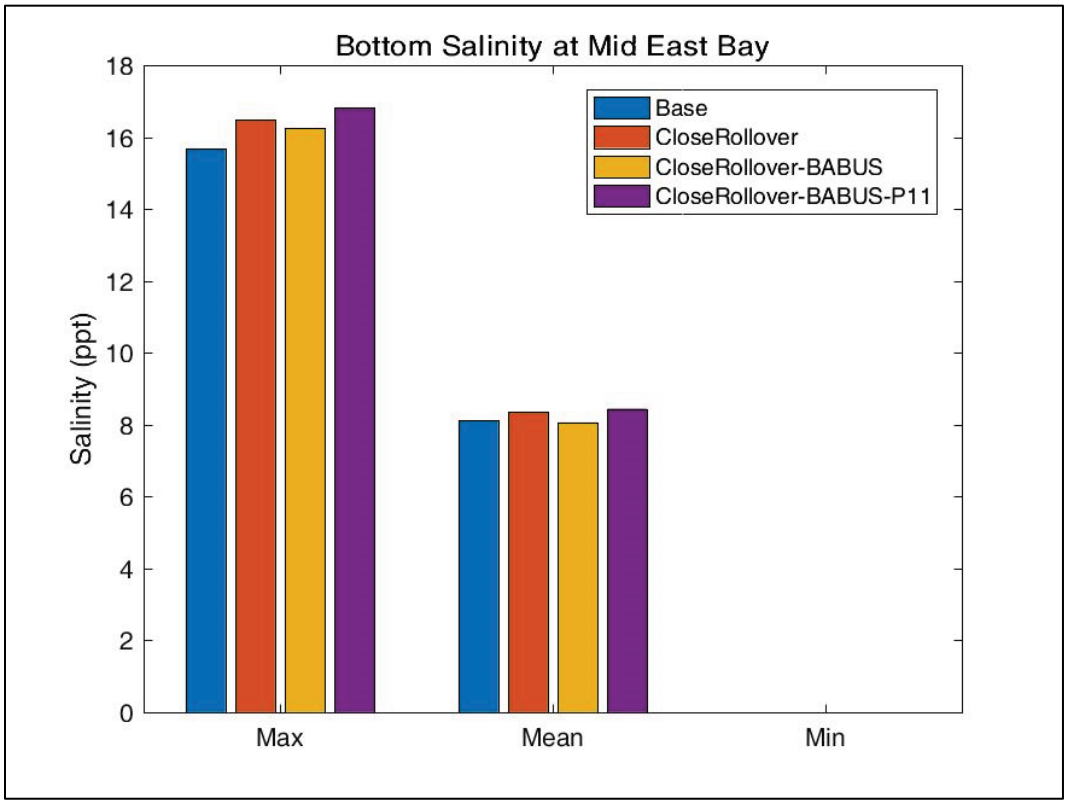

Bottom Salinity at Smith Point
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min

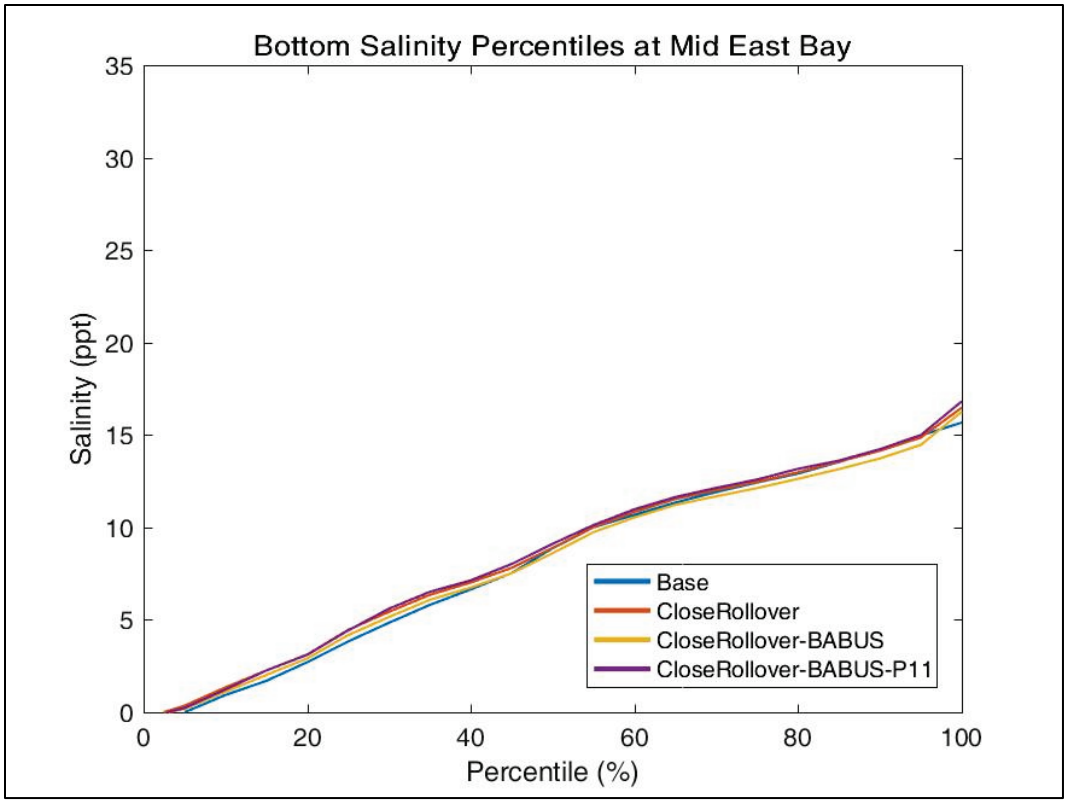

Bottom Salinity Percentiles at Smith Point
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

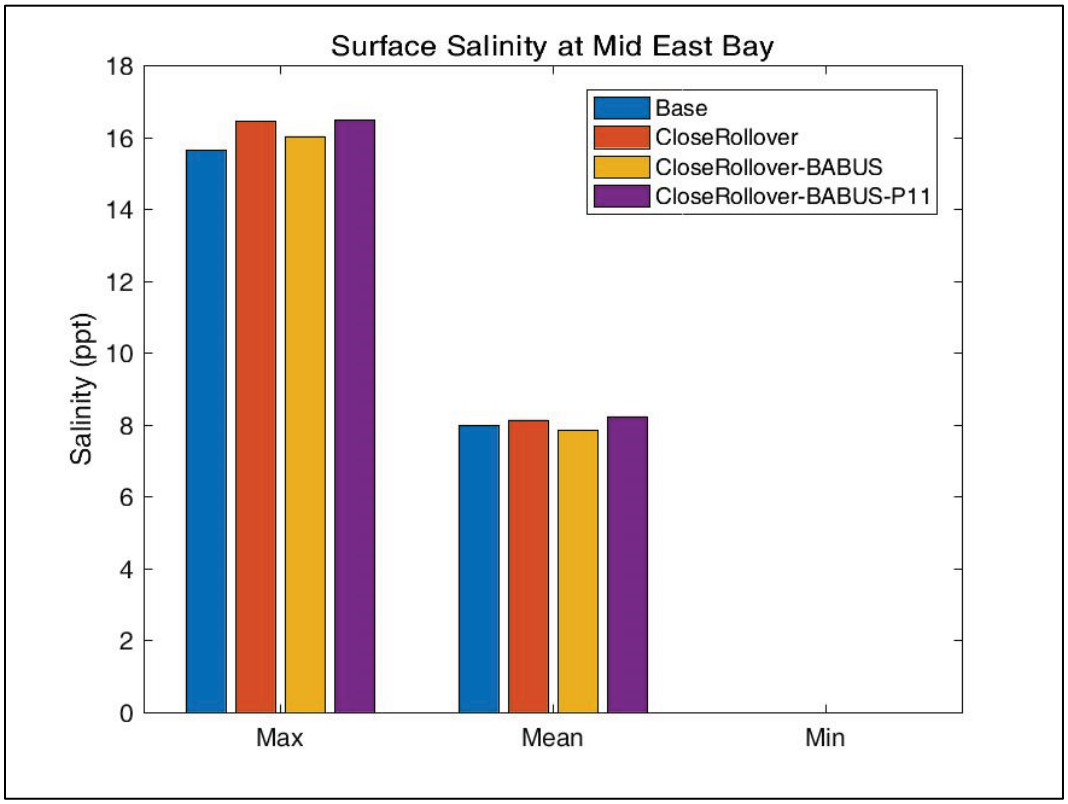

Surface Salinity at Smith Point
Salinity (ppt)
0
2
4
6
8
10
12
14
16
18
20
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

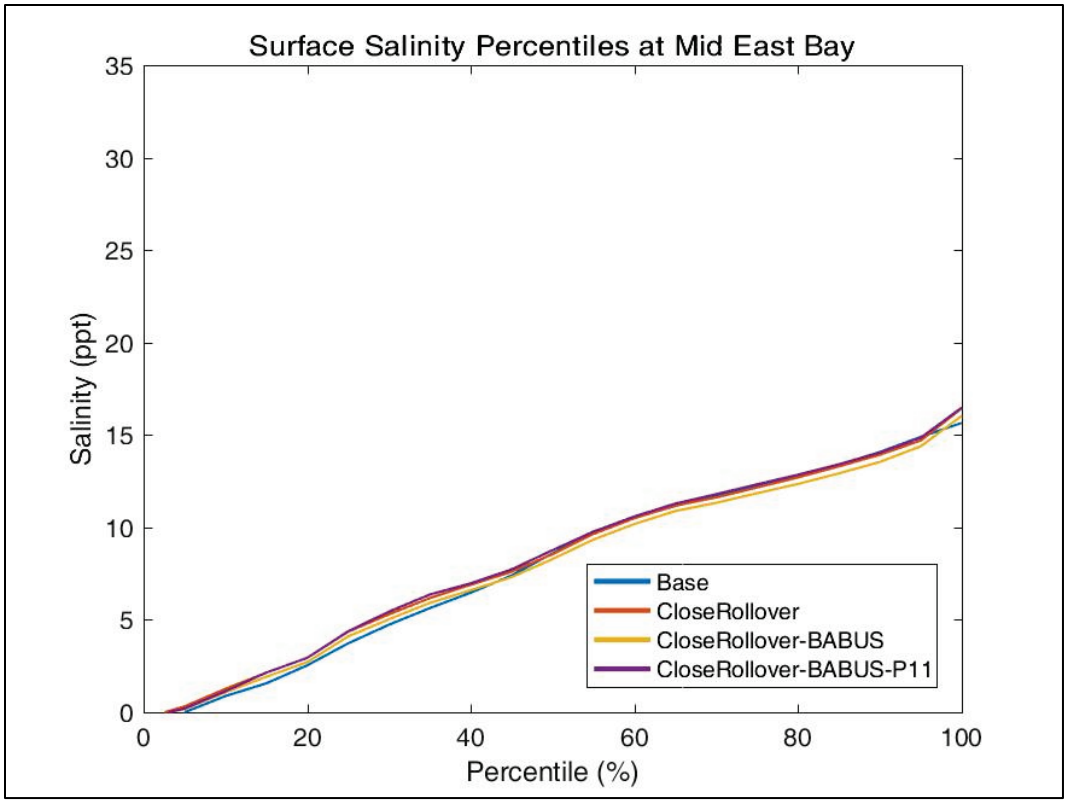

Surface Salinity Percentiles at Smith Point
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

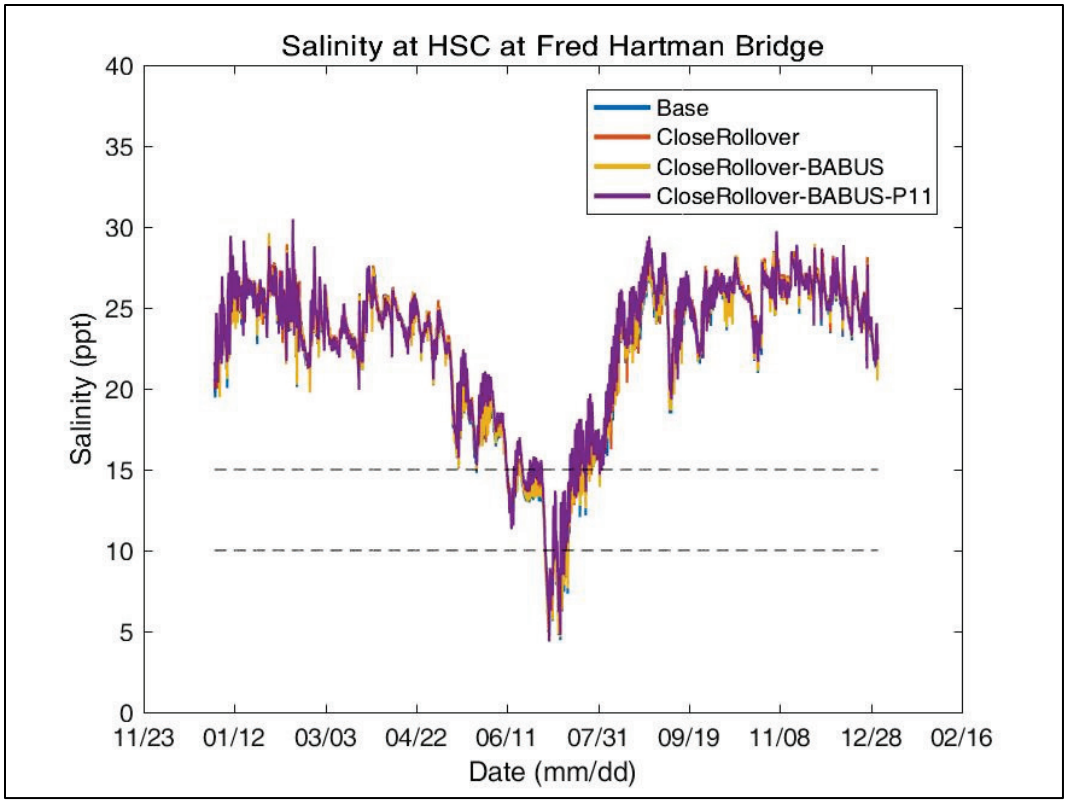

Salinity at Mid East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

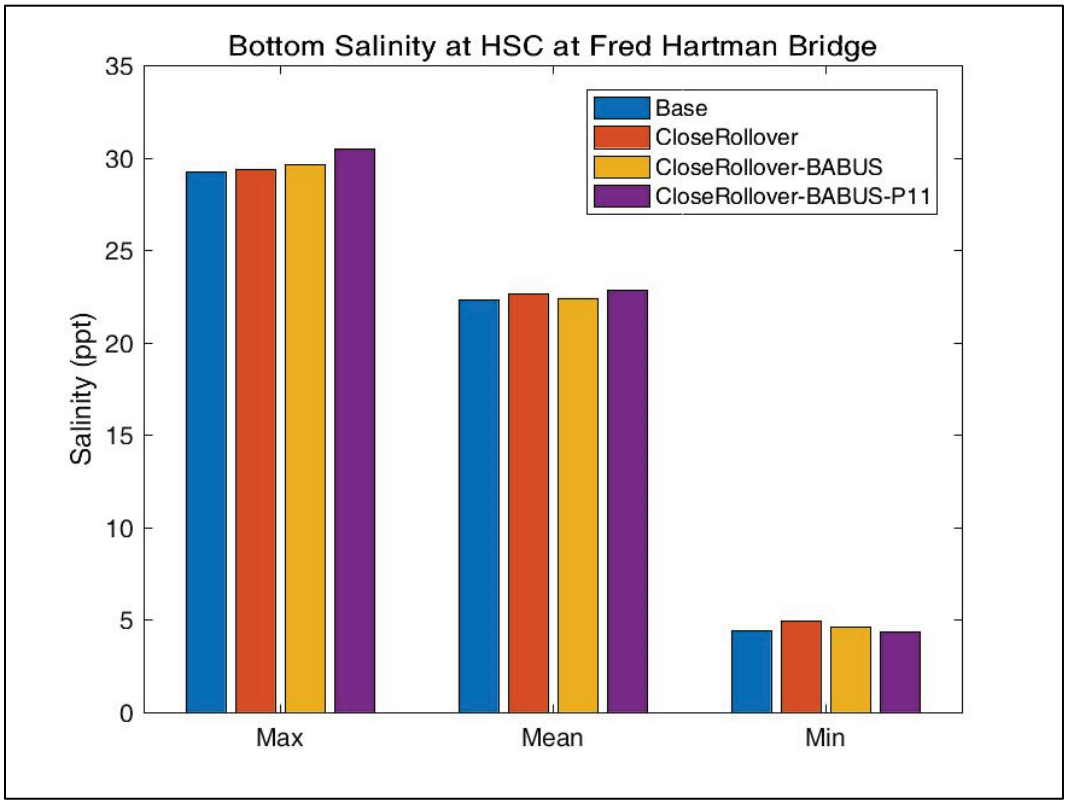

Bottom Salinity at Mid East Bay
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
2
4
6
8
10
12
14
16
18
Max
Mean
Min

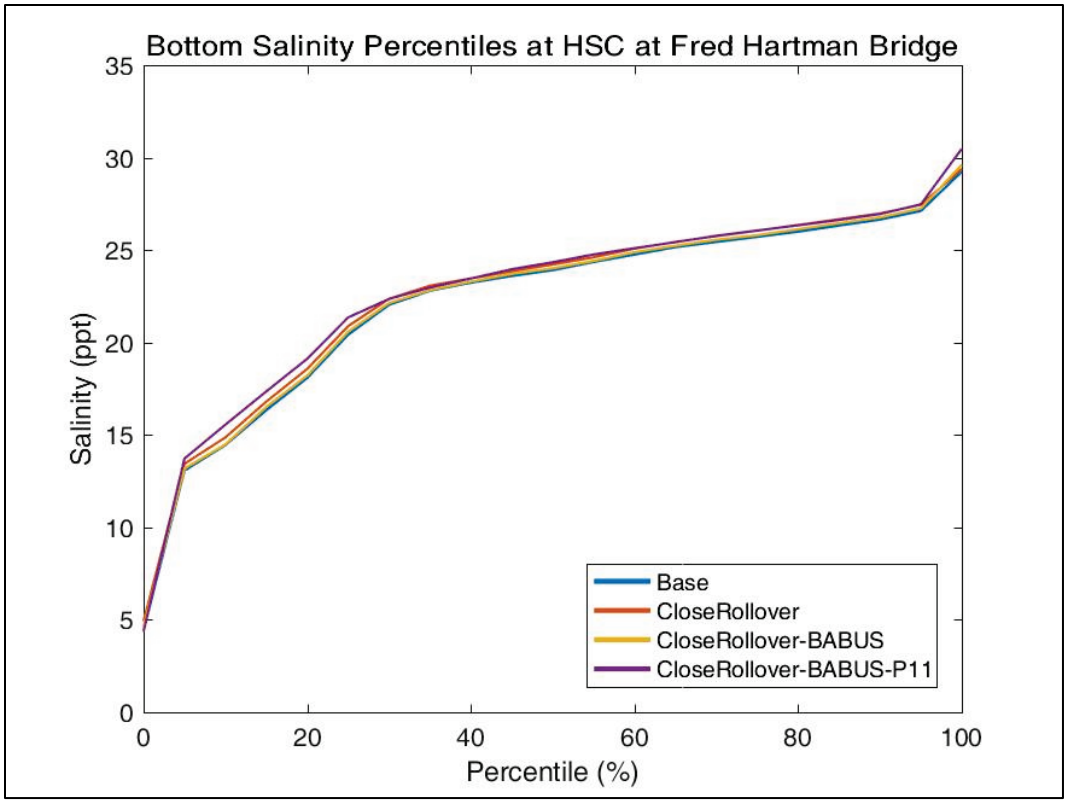

Bottom Salinity Percentiles at Mid East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

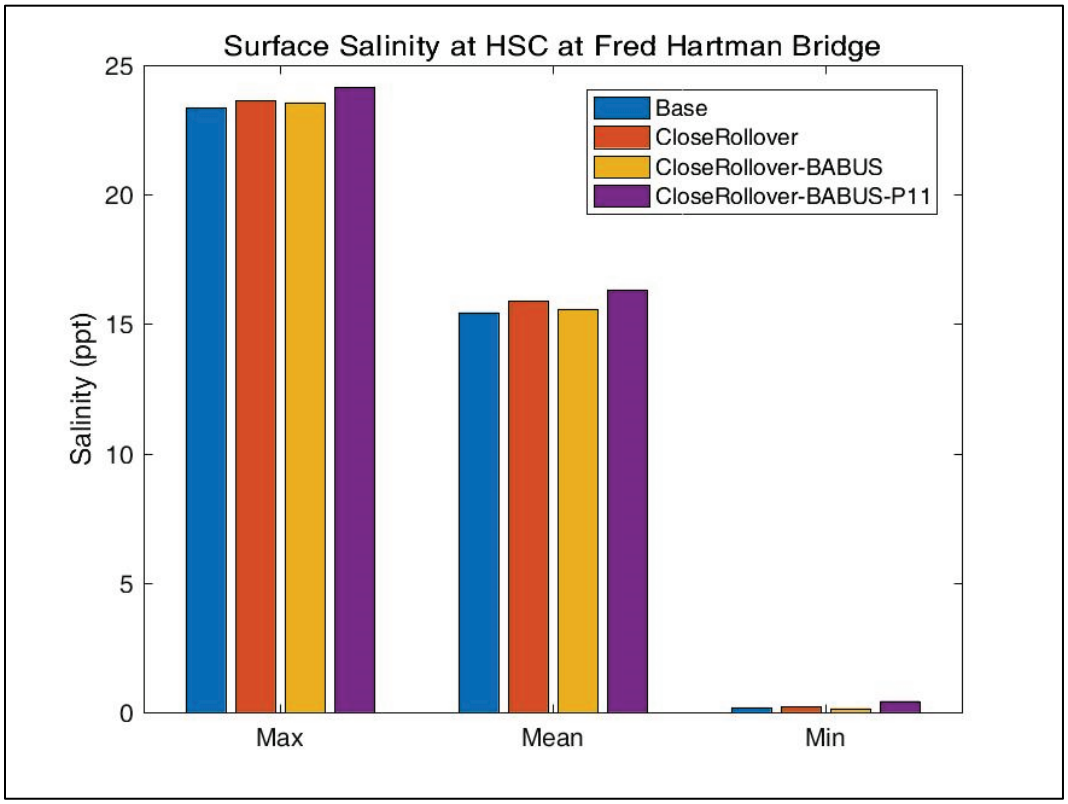

Surface Salinity at Mid East Bay
Salinity (ppt)
0
2
4
6
8
10
12
14
16
18
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

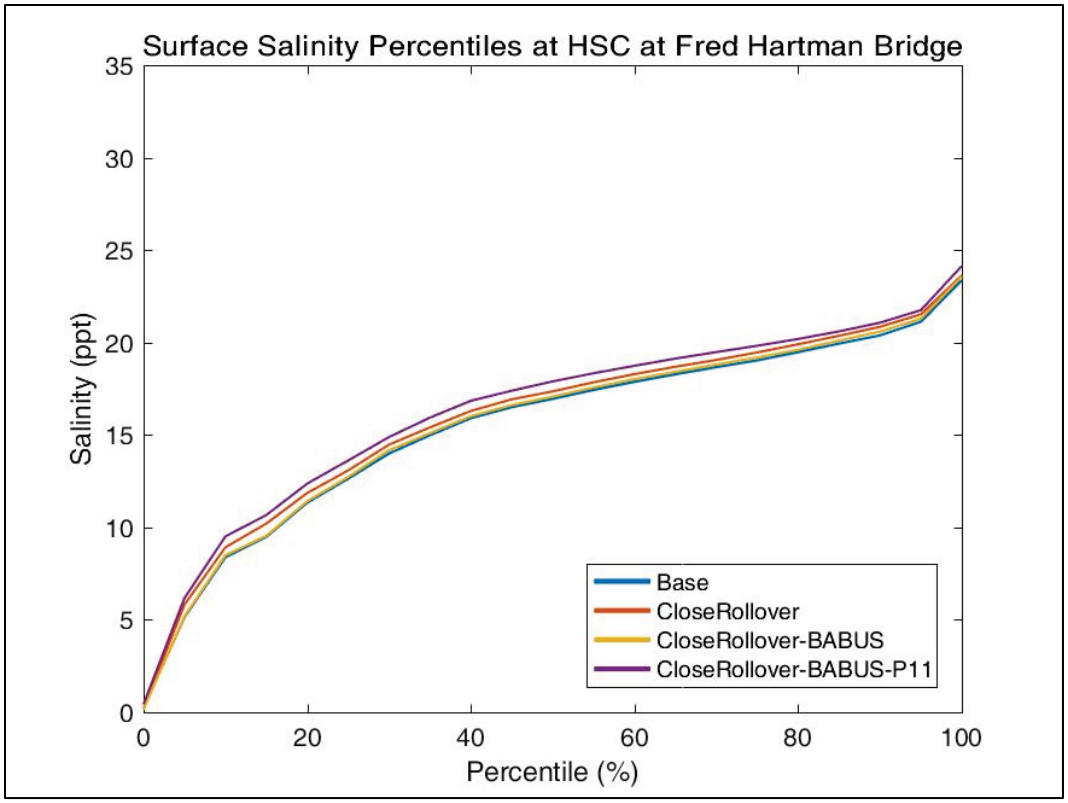

Surface Salinity Percentiles at Mid East Bay
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

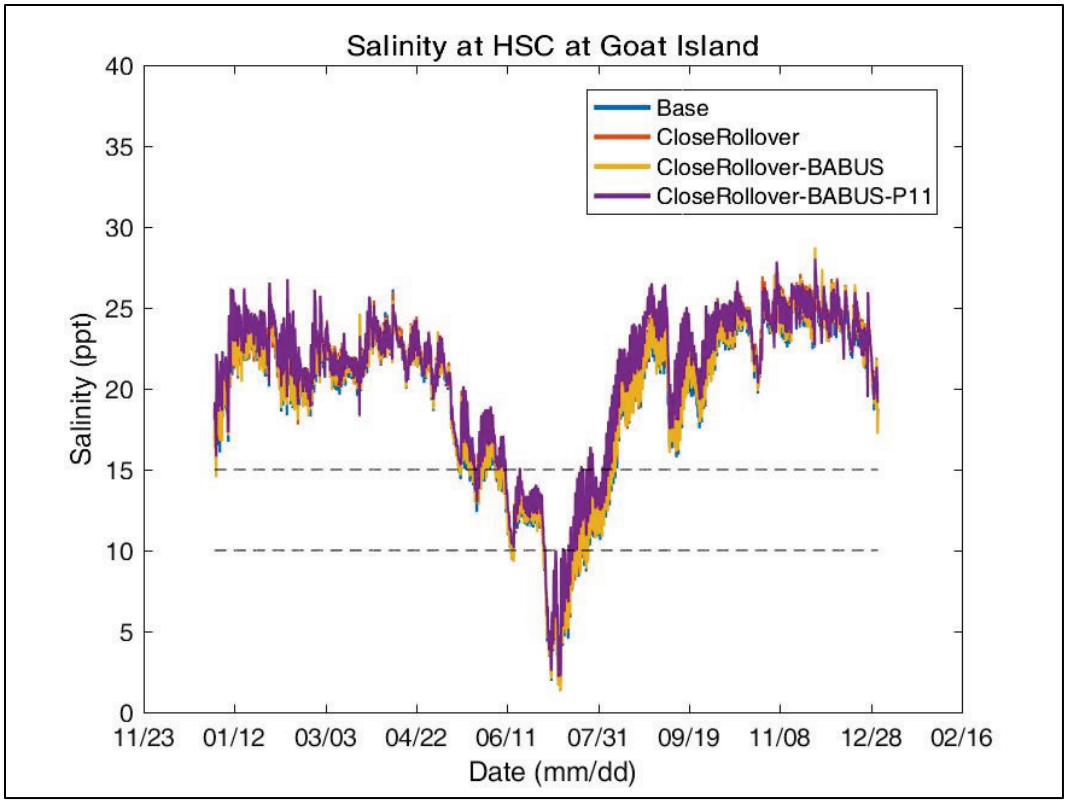

Salinity at HSC at Fred Hartman Bridge
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

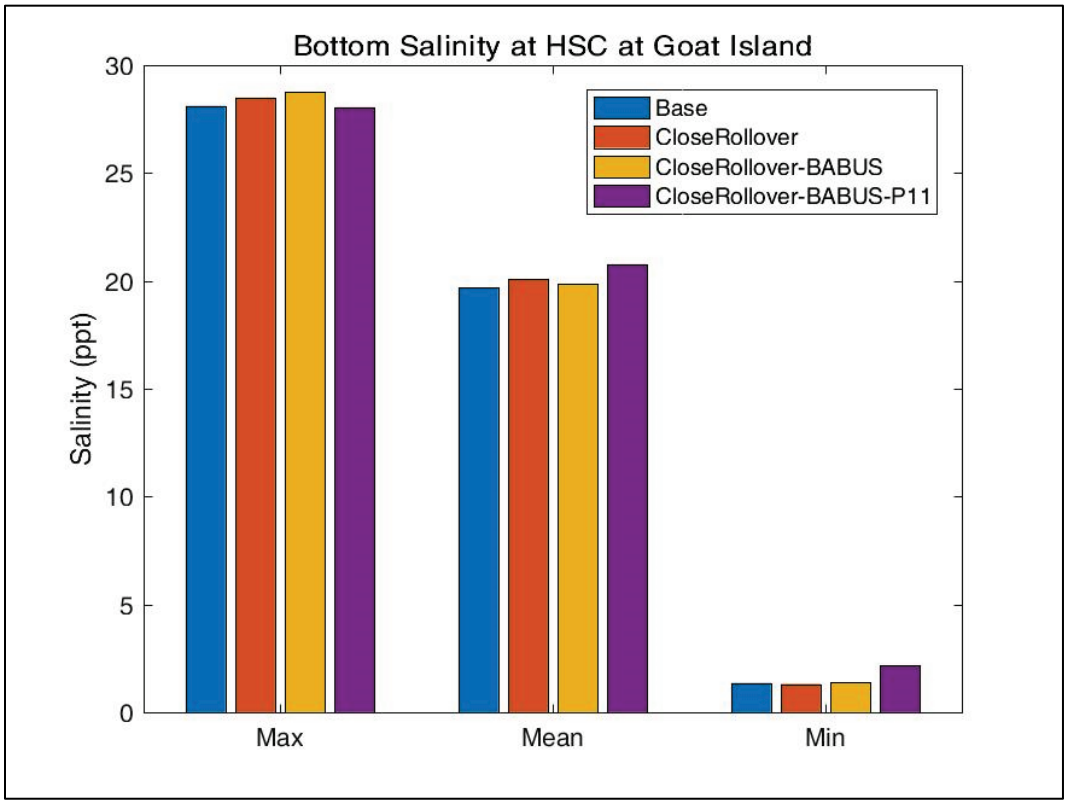

Bottom Salinity at HSC at Fred Hartman Bridge
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

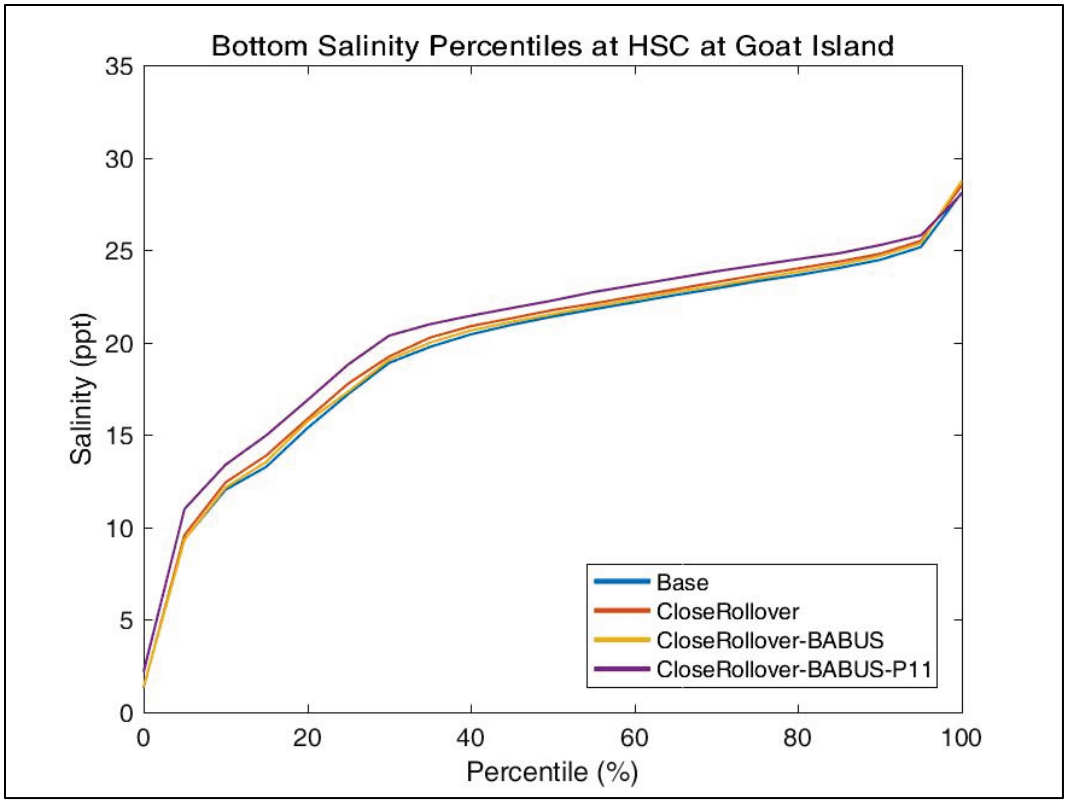

Bottom Salinity Percentiles at HSC at Fred Hartman Bridge
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

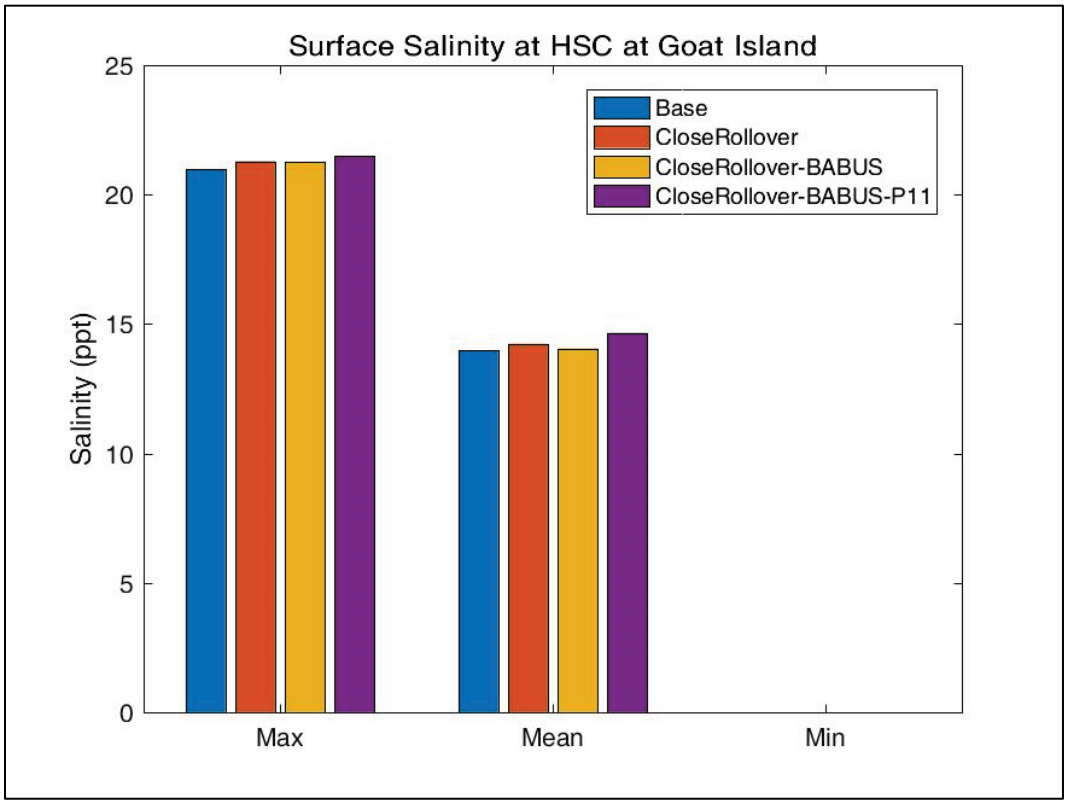

Surface Salinity at HSC at Fred Hartman Bridge
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

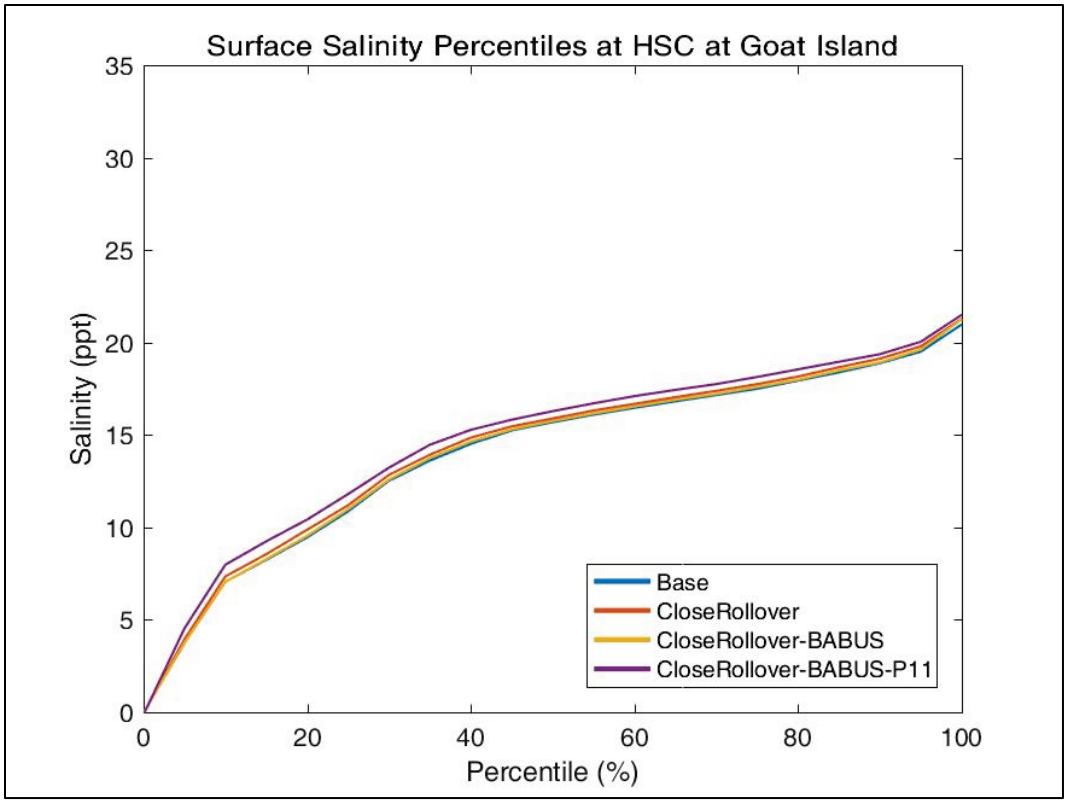

Surface Salinity Percentiles at HSC at Fred Hartman Bridge
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

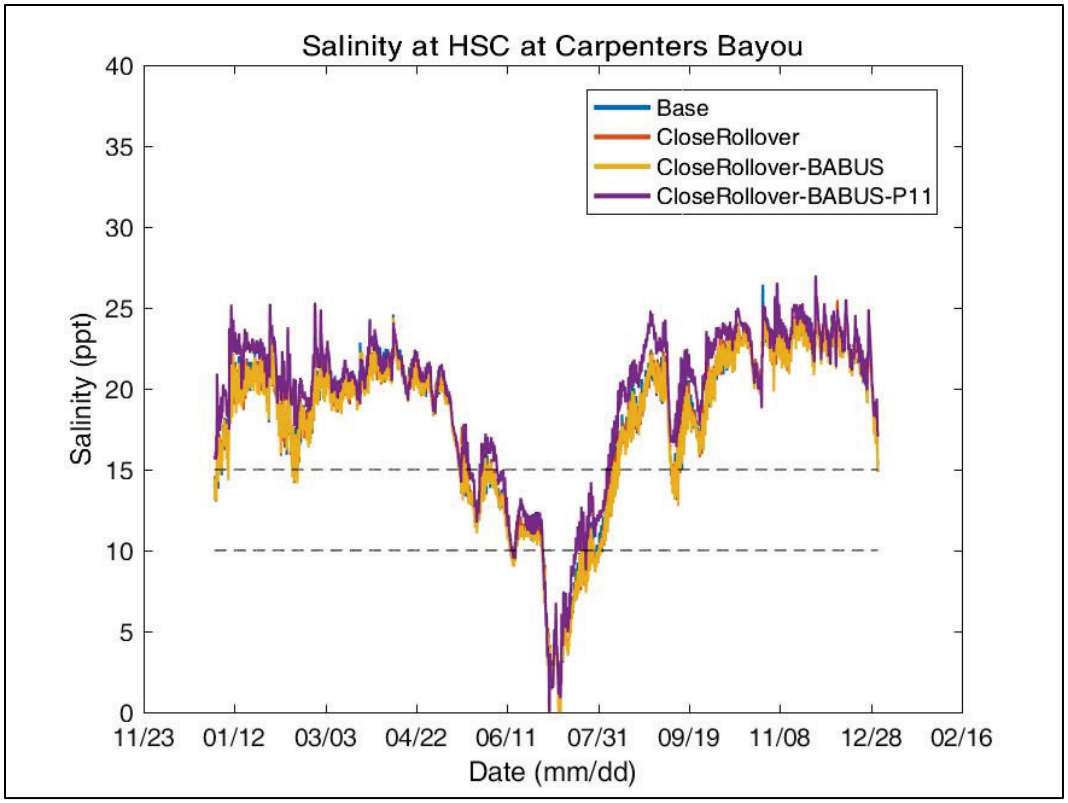

Salinity at HSC at Goat Island
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

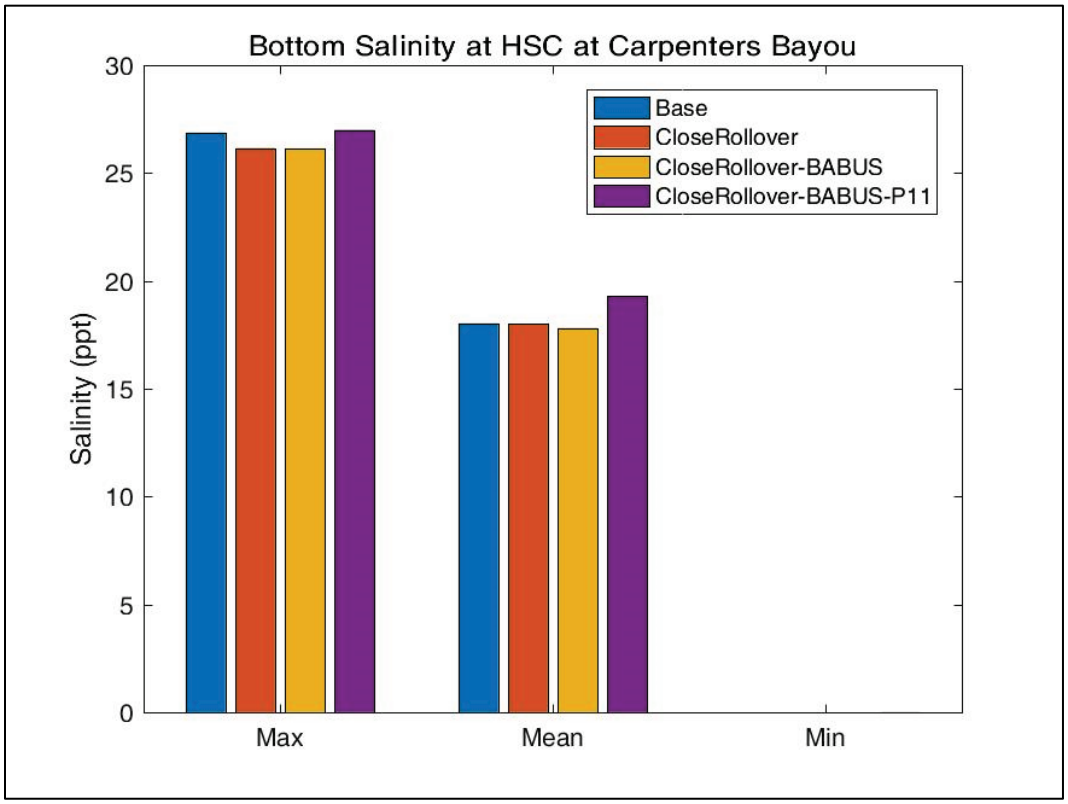

Bottom Salinity at HSC at Goat Island
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

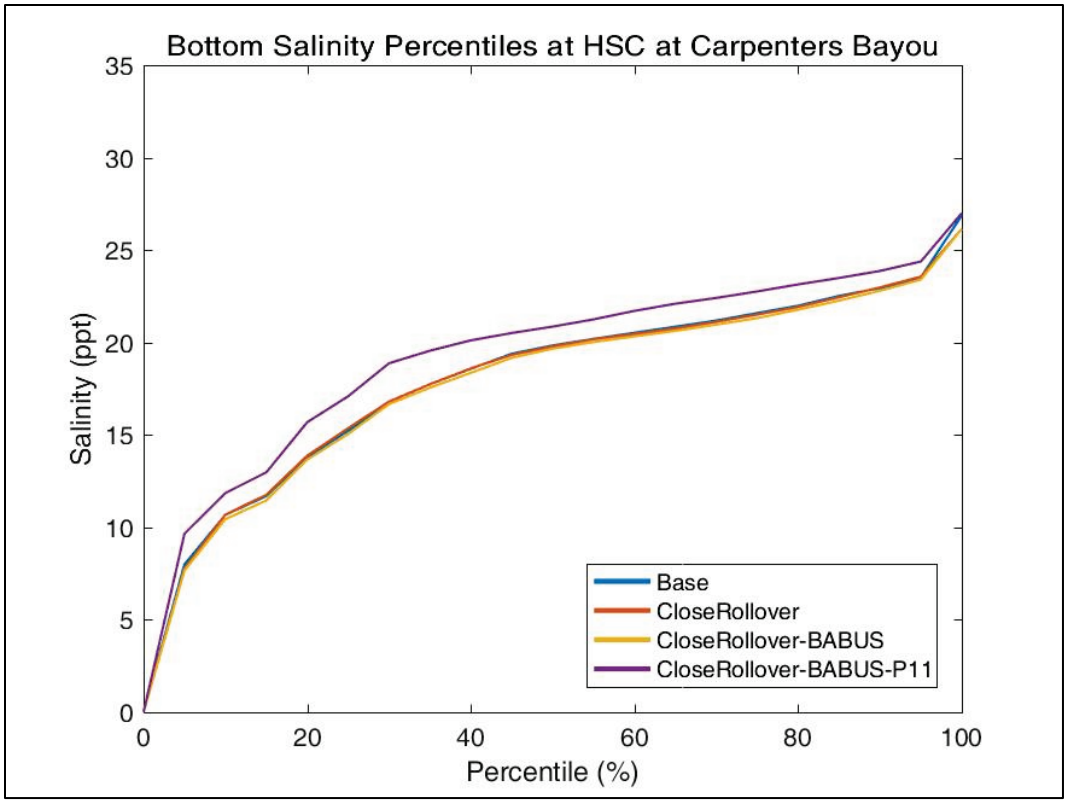

Bottom Salinity Percentiles at HSC at Goat Island
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

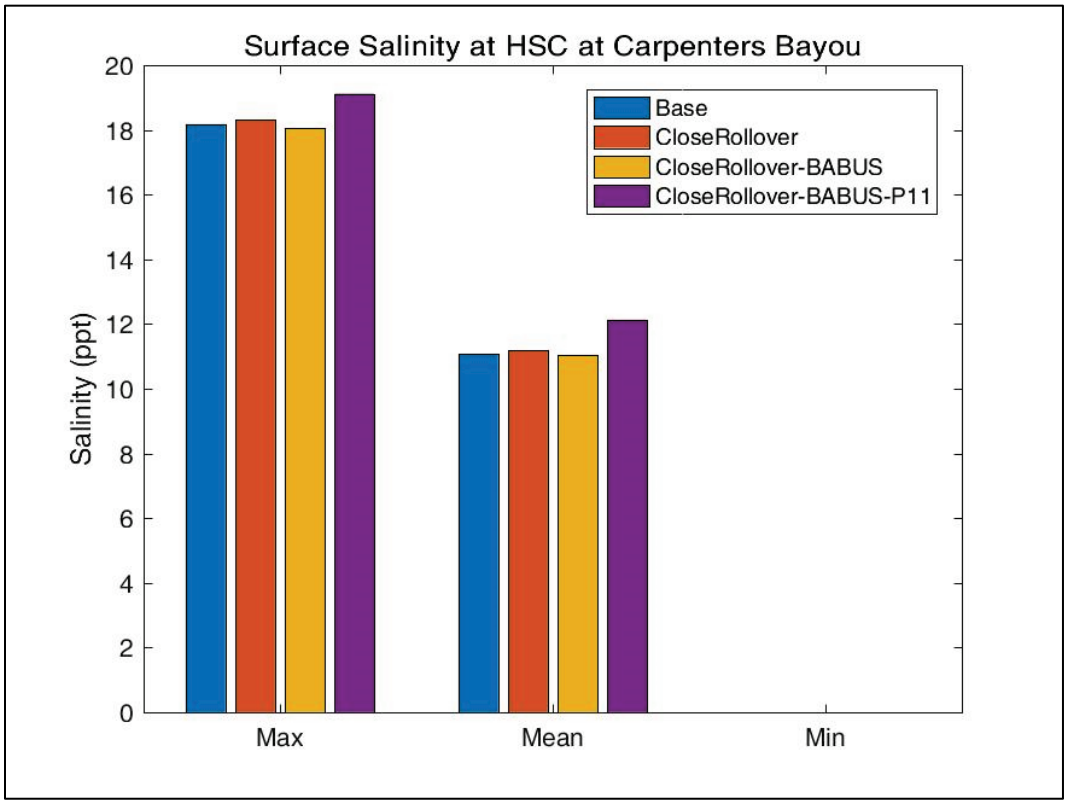

Surface Salinity at HSC at Goat Island
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

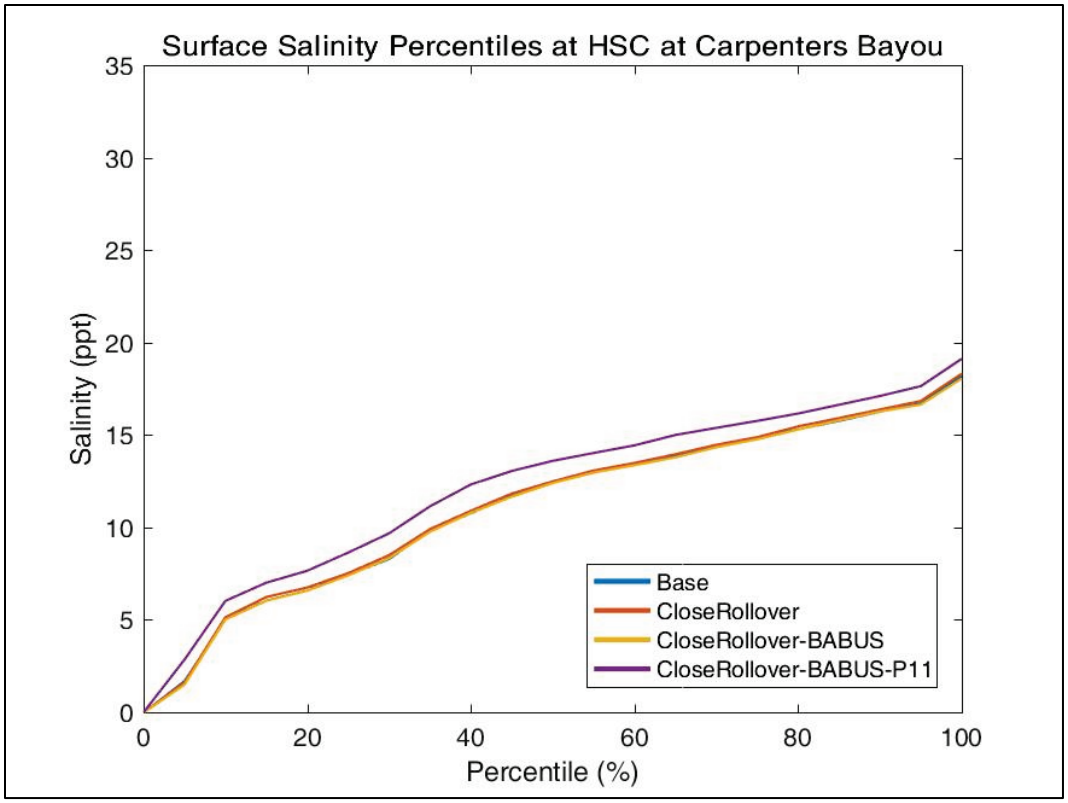

Surface Salinity Percentiles at HSC at Goat Island
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

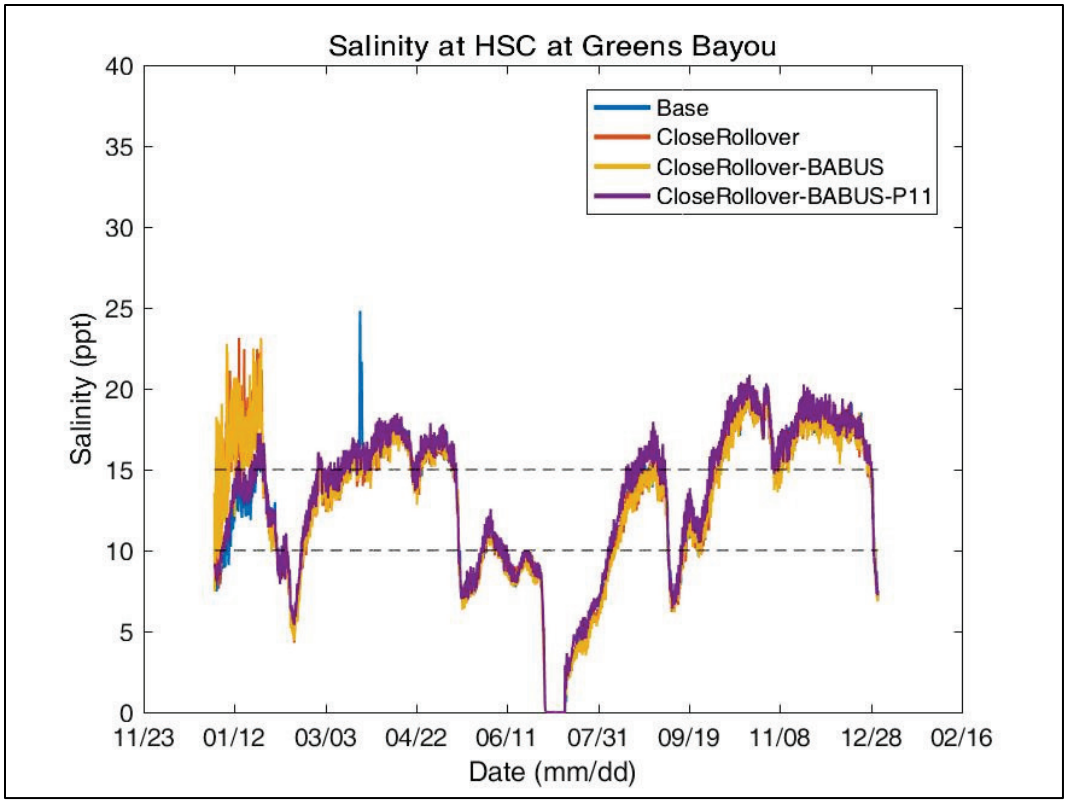

Salinity at HSC at Carpenters Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

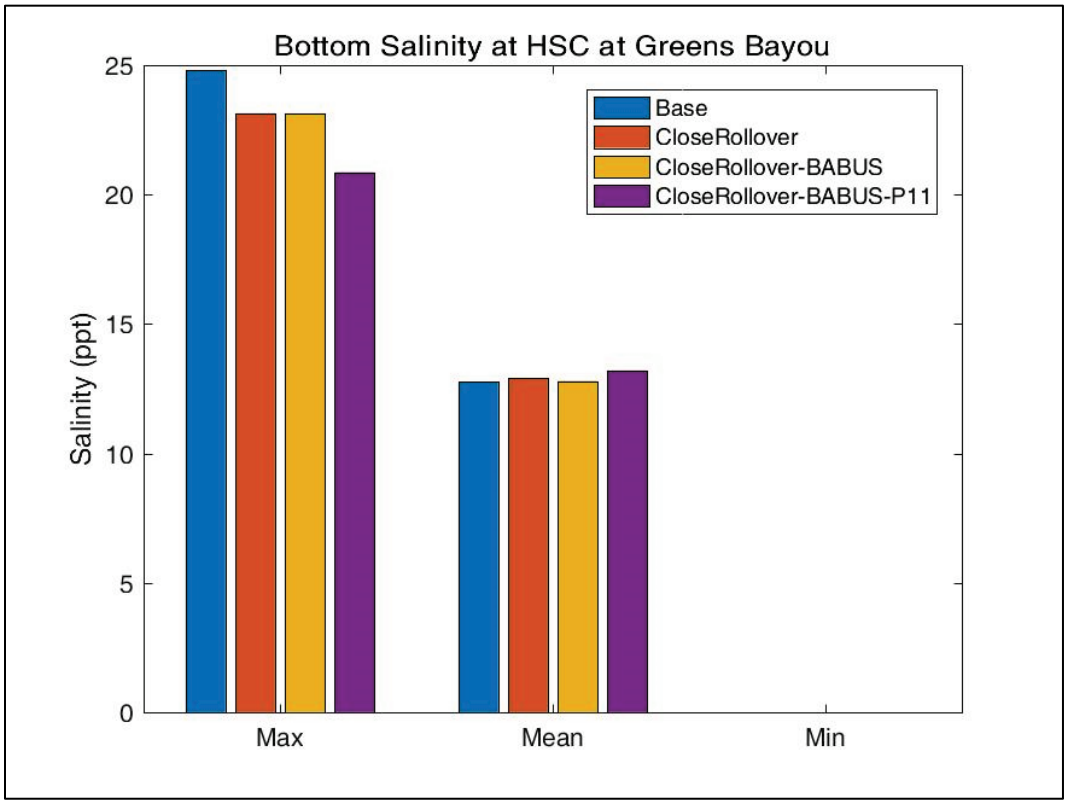

Bottom Salinity at HSC at Carpenters Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
Max
Mean
Min

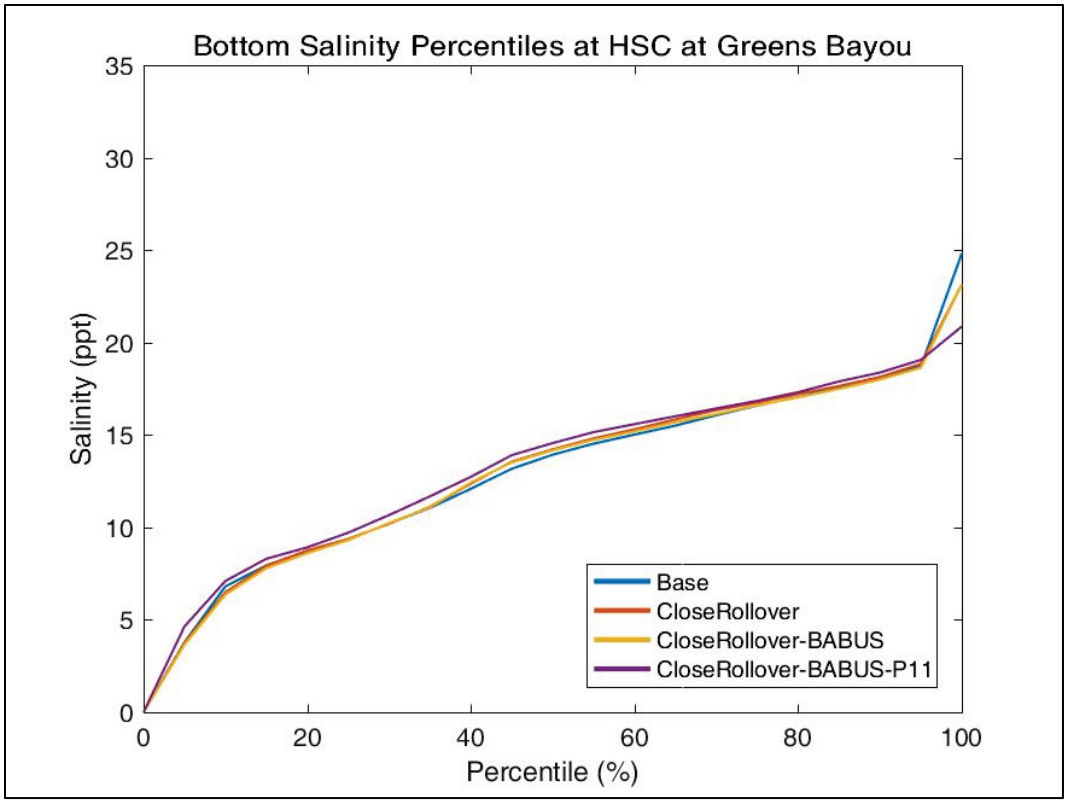

Bottom Salinity Percentiles at HSC at Carpenters Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

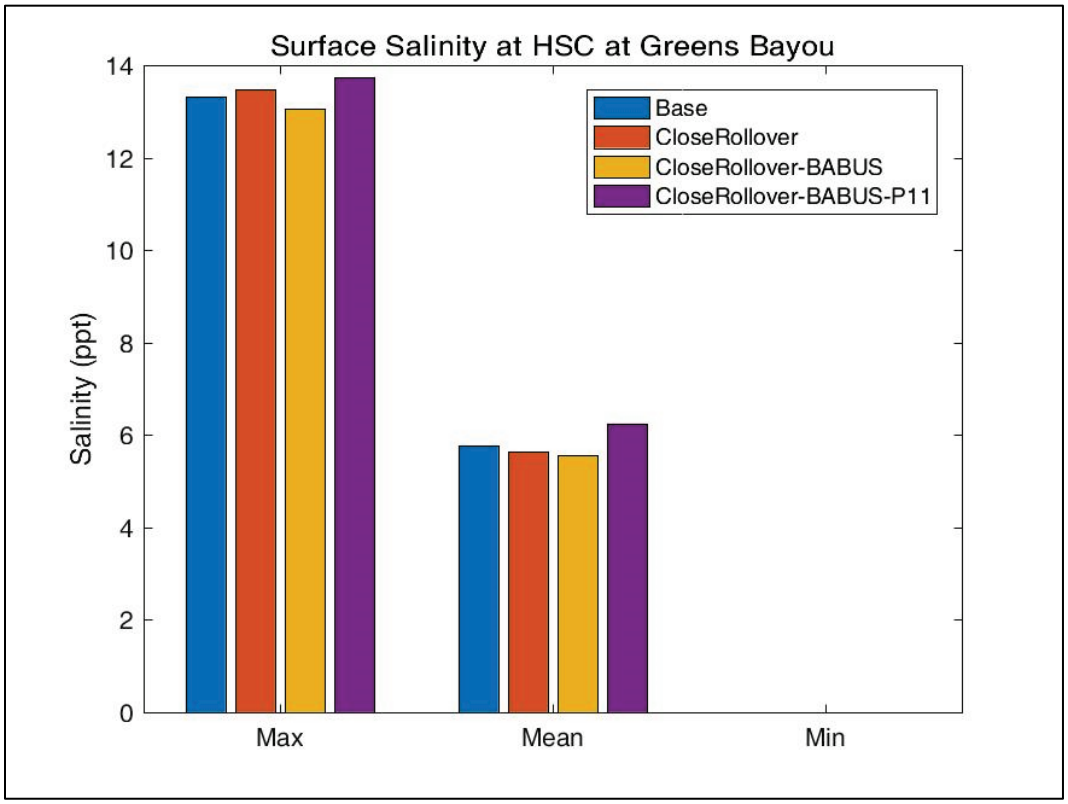

Surface Salinity at HSC at Carpenters Bayou
Salinity (ppt)
0
2
4
6
8
10
12
14
16
18
20
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

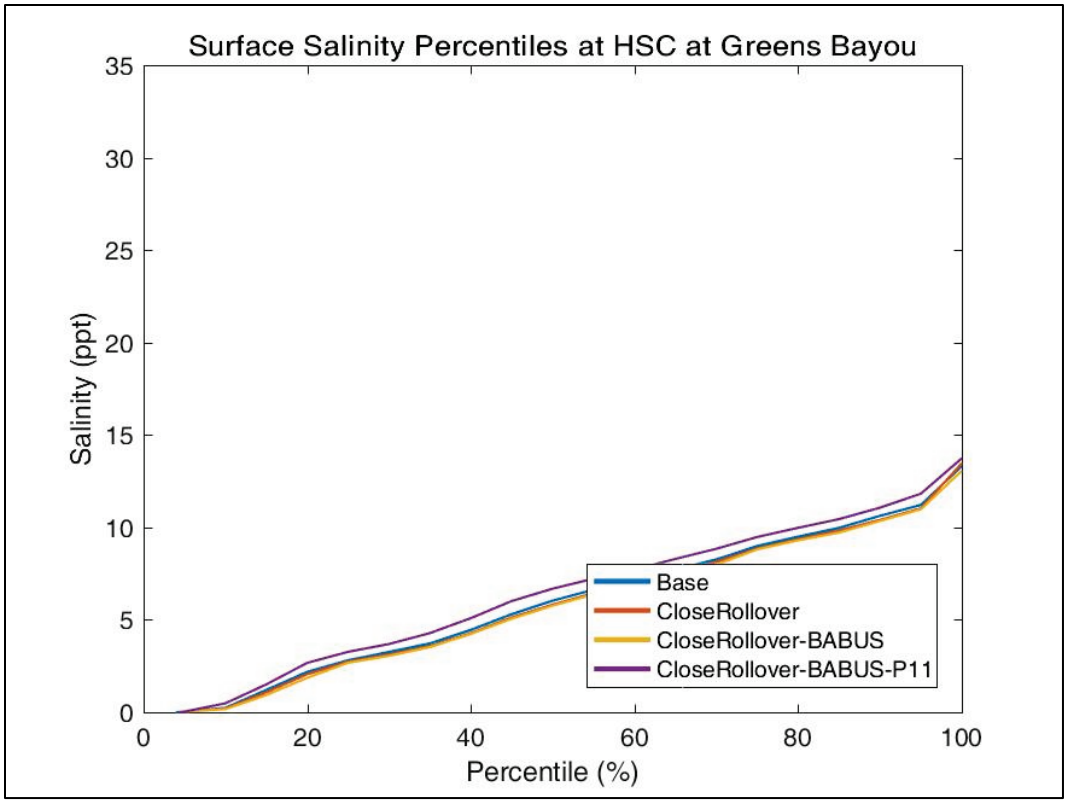

Surface Salinity Percentiles at HSC at Carpenters Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

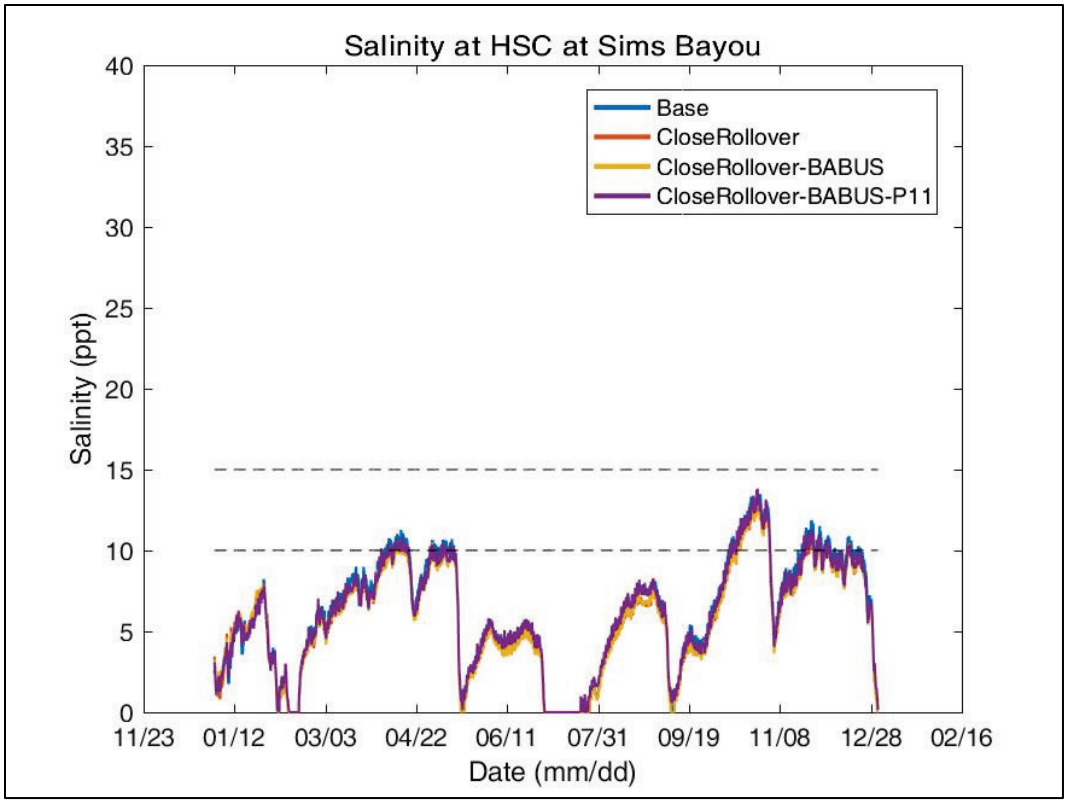

Salinity at HSC at Greens Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

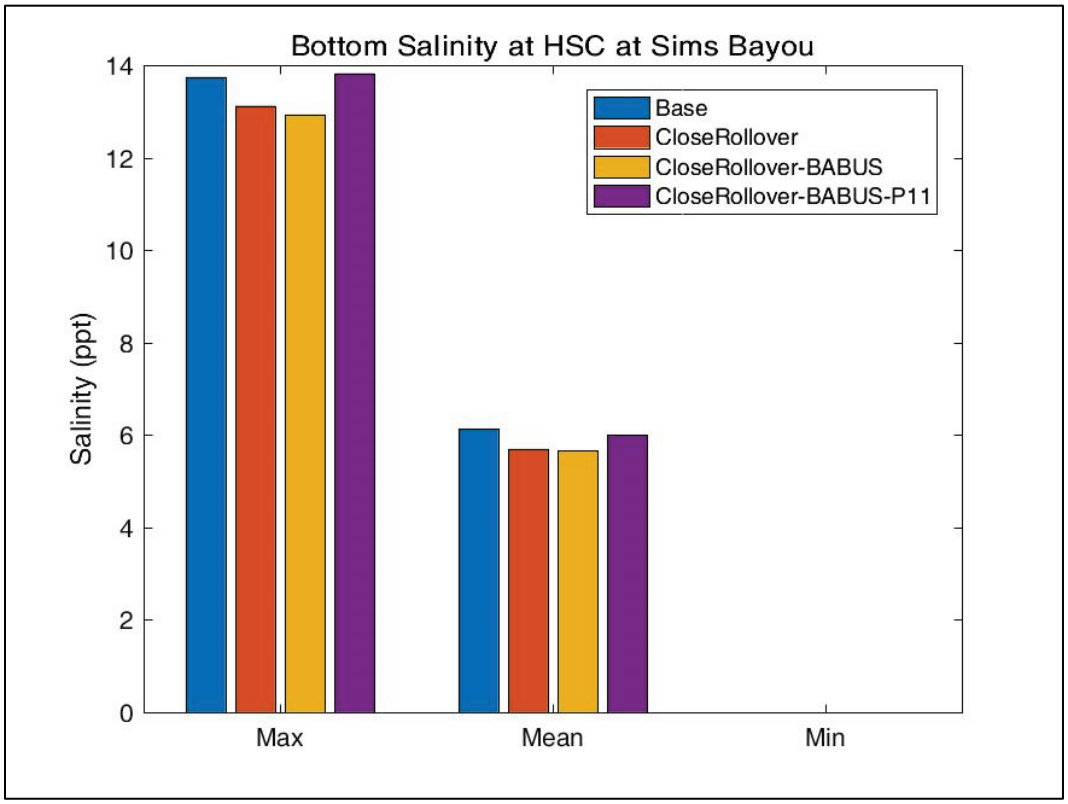

Bottom Salinity at HSC at Greens Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
Max
Mean
Min

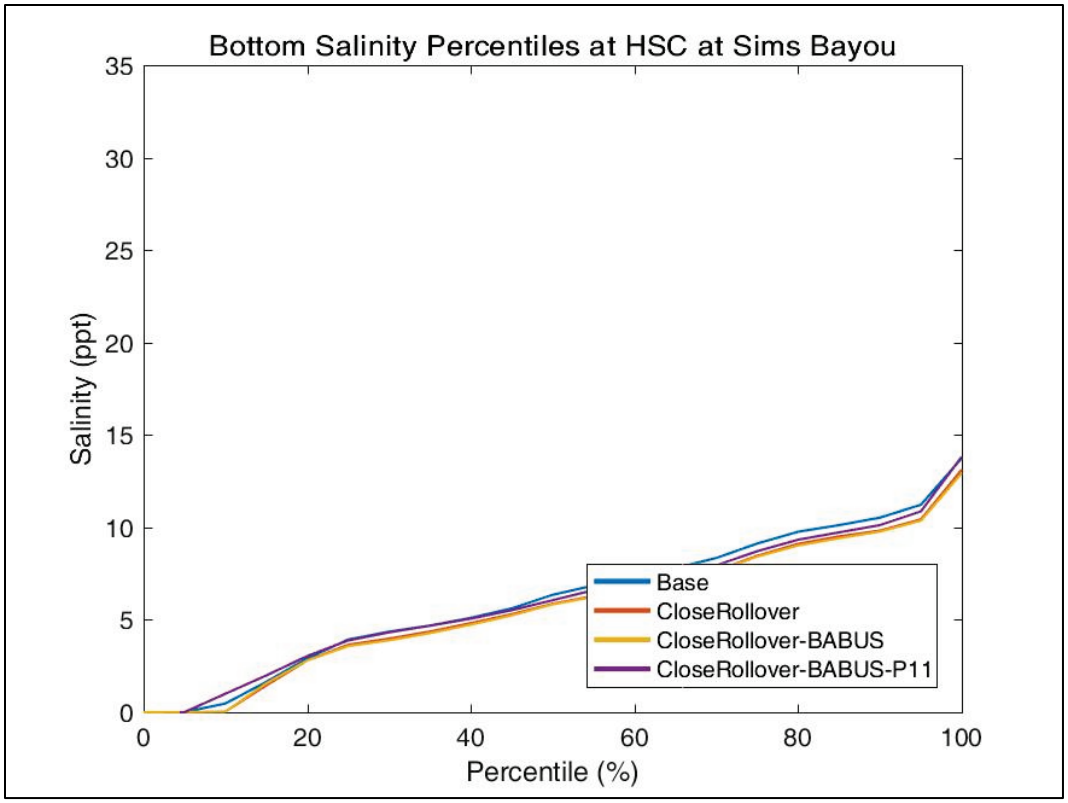

Bottom Salinity Percentiles at HSC at Greens Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

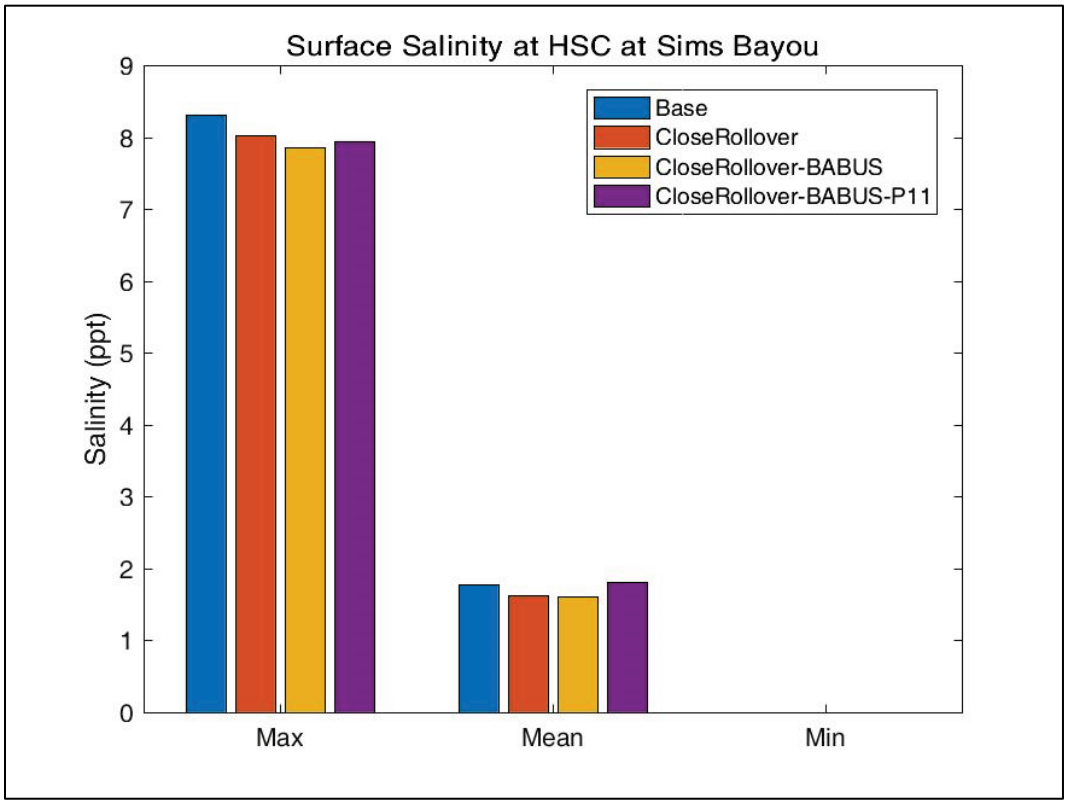

Surface Salinity at HSC at Greens Bayou
Salinity (ppt)
0
2
4
6
8
10
12
14
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

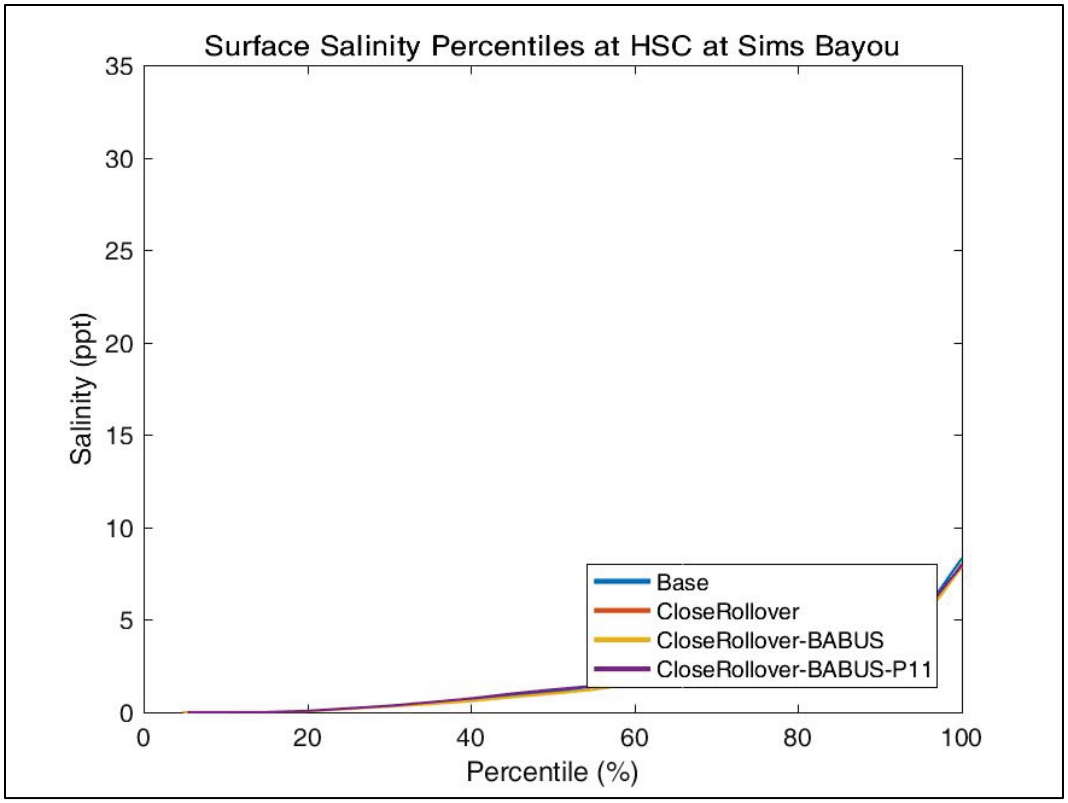

Surface Salinity Percentiles at HSC at Greens Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

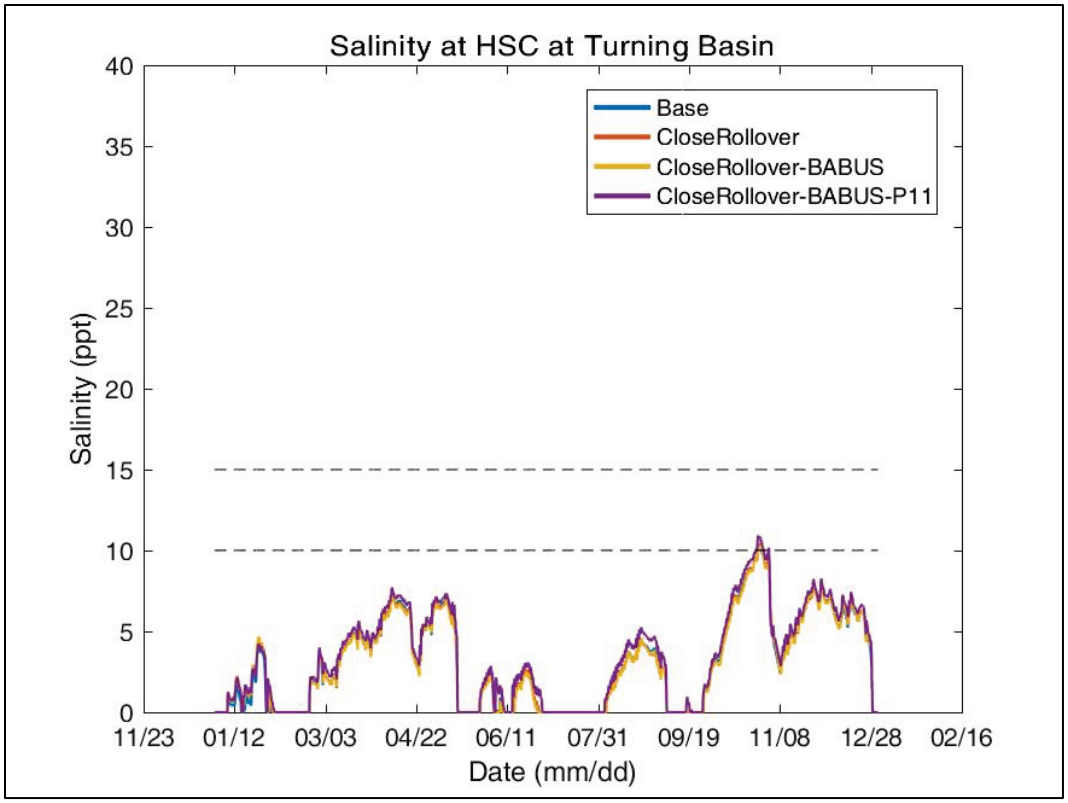

Salinity at HSC at Sims Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

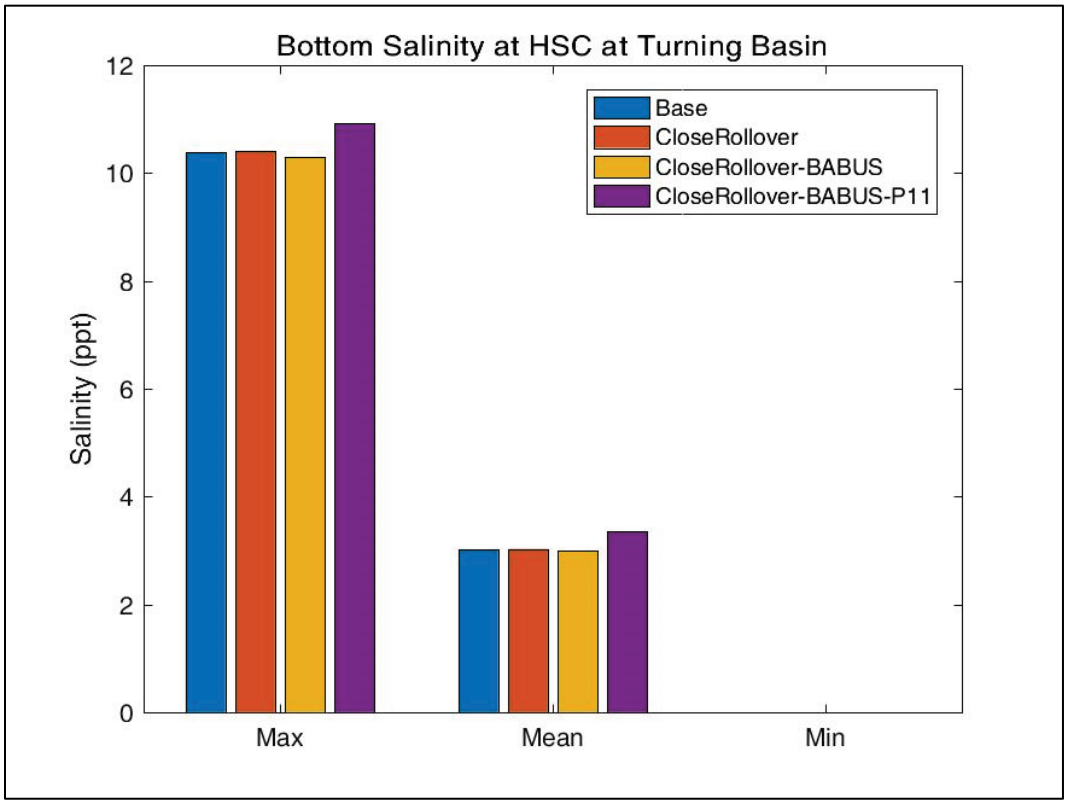

Bottom Salinity at HSC at Sims Bayou
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
2
4
6
8
10
12
14
Max
Mean
Min

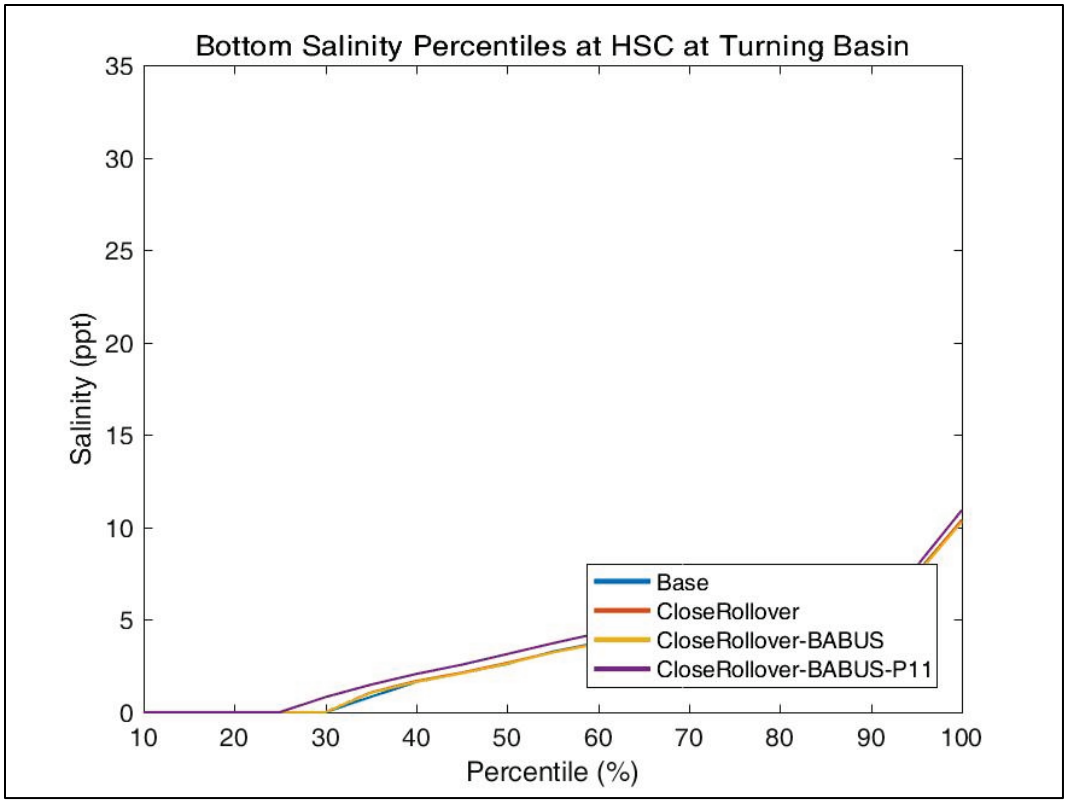

Bottom Salinity Percentiles at HSC at Sims Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

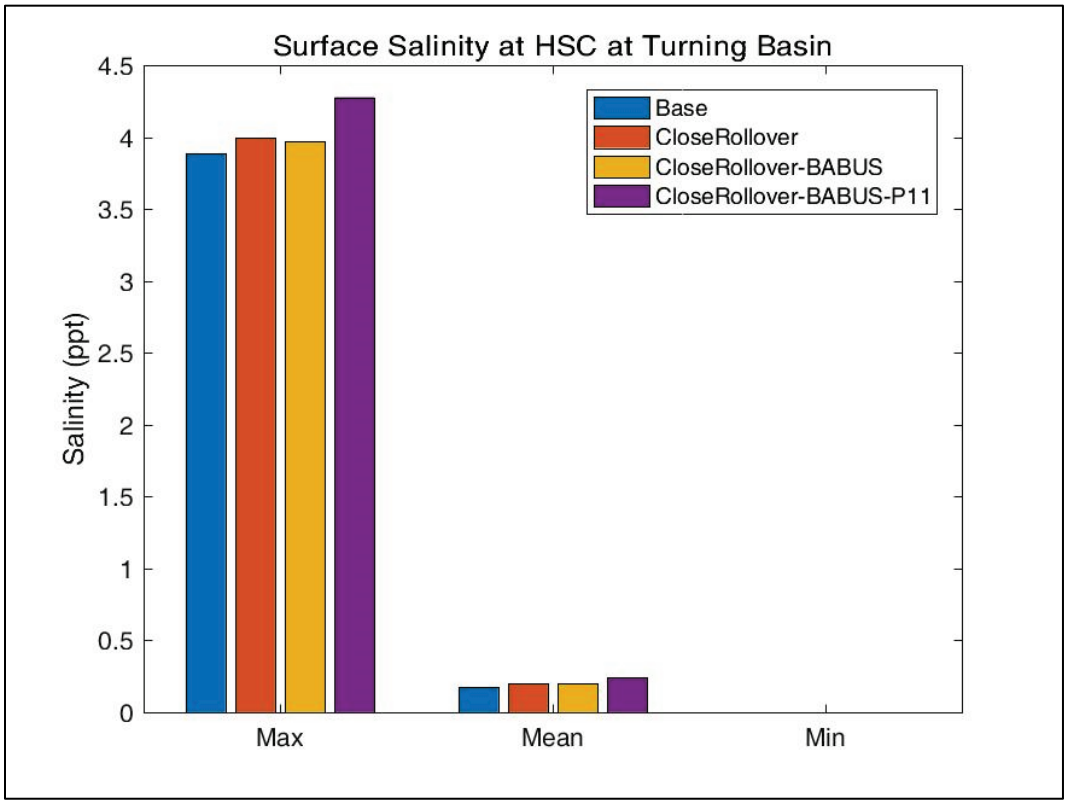

Surface Salinity at HSC at Sims Bayou
Salinity (ppt)
0
1
2
3
4
5
6
7
8
9
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

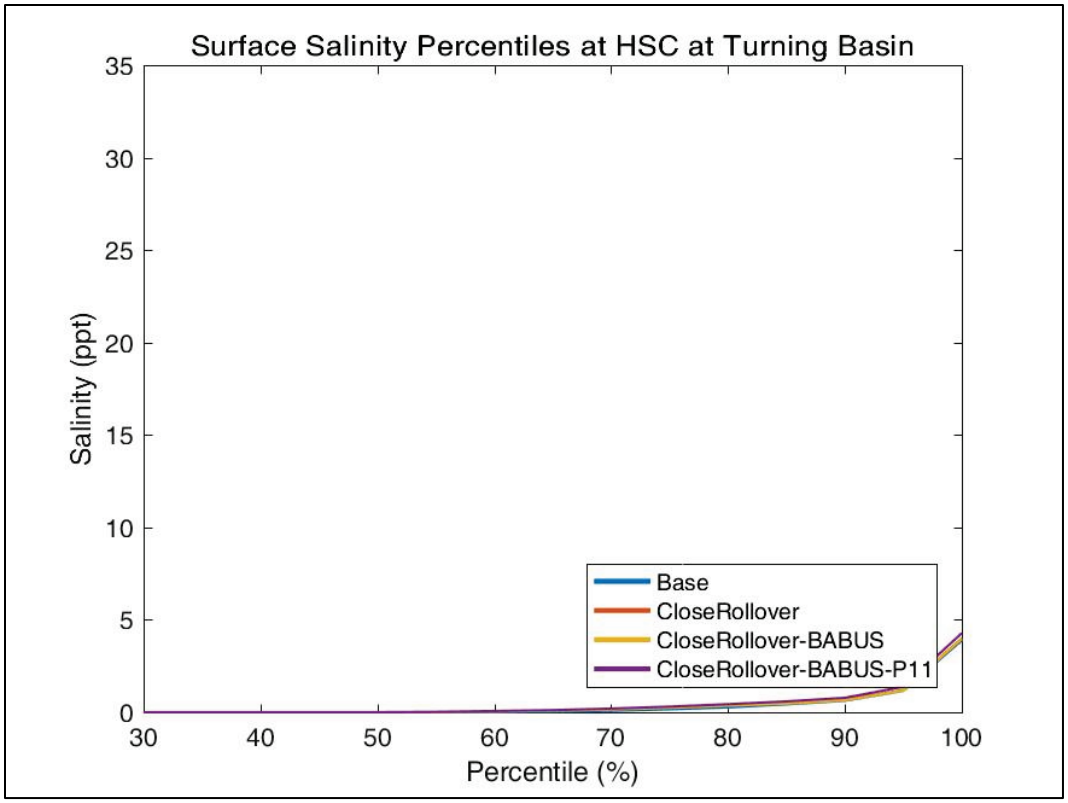

Surface Salinity Percentiles at HSC at Sims Bayou
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

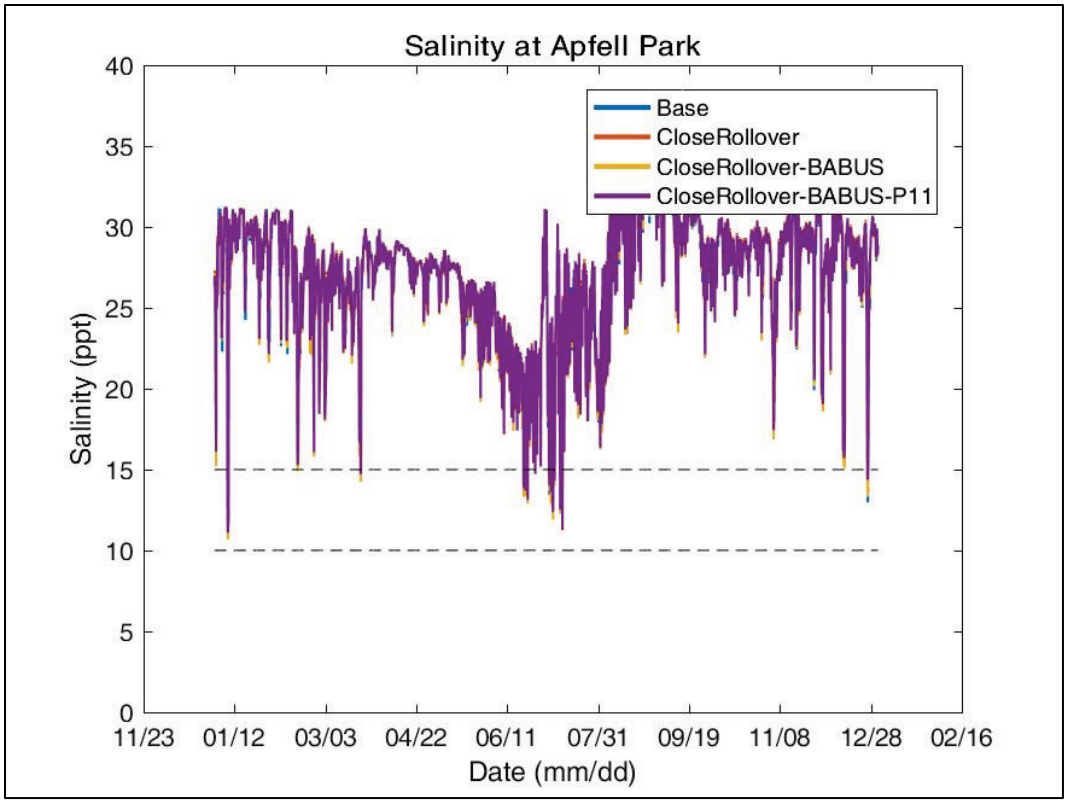

Salinity at HSC at Turning Basin
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

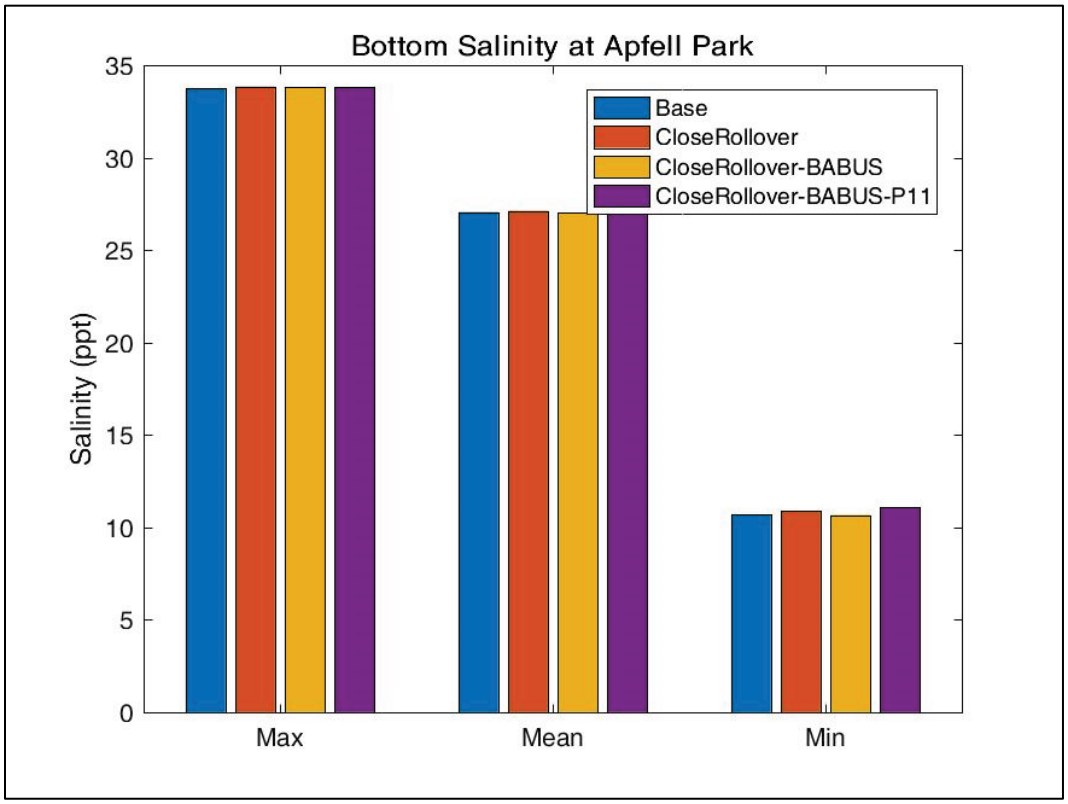

Bottom Salinity at HSC at Turning Basin
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
2
4
6
8
10
12
Max
Mean
Min

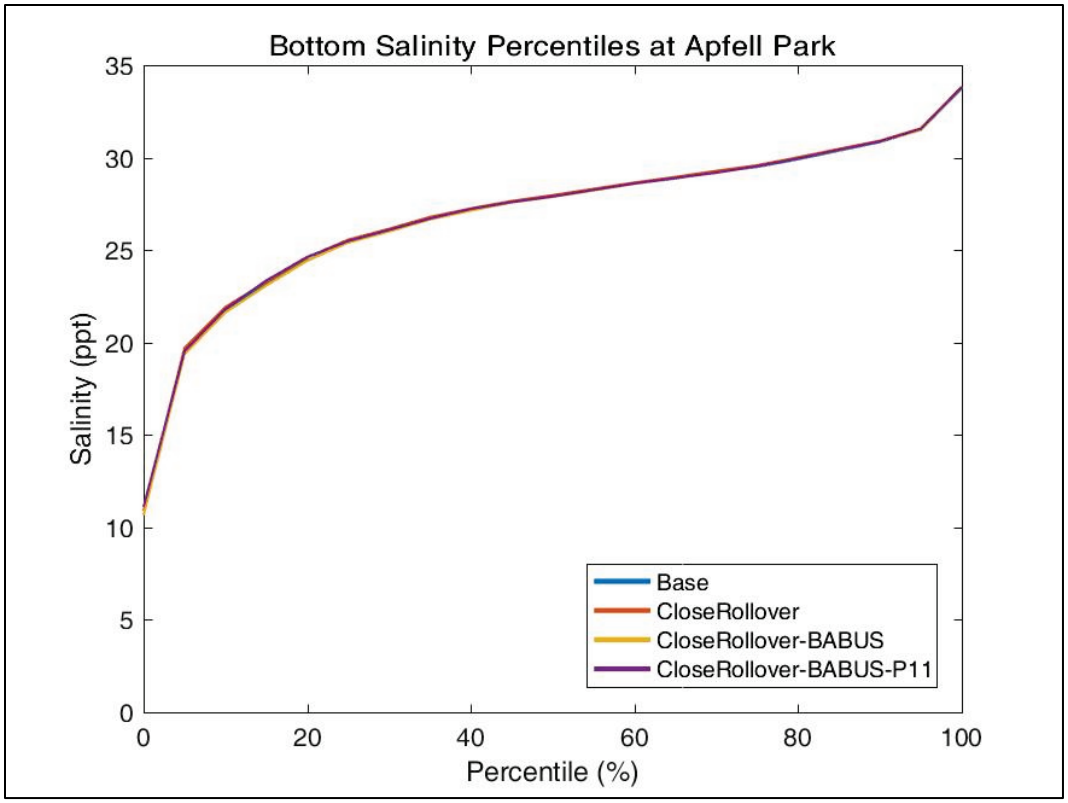

Bottom Salinity Percentiles at HSC at Turning Basin
Salinity (ppt)
Percentile (%)
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

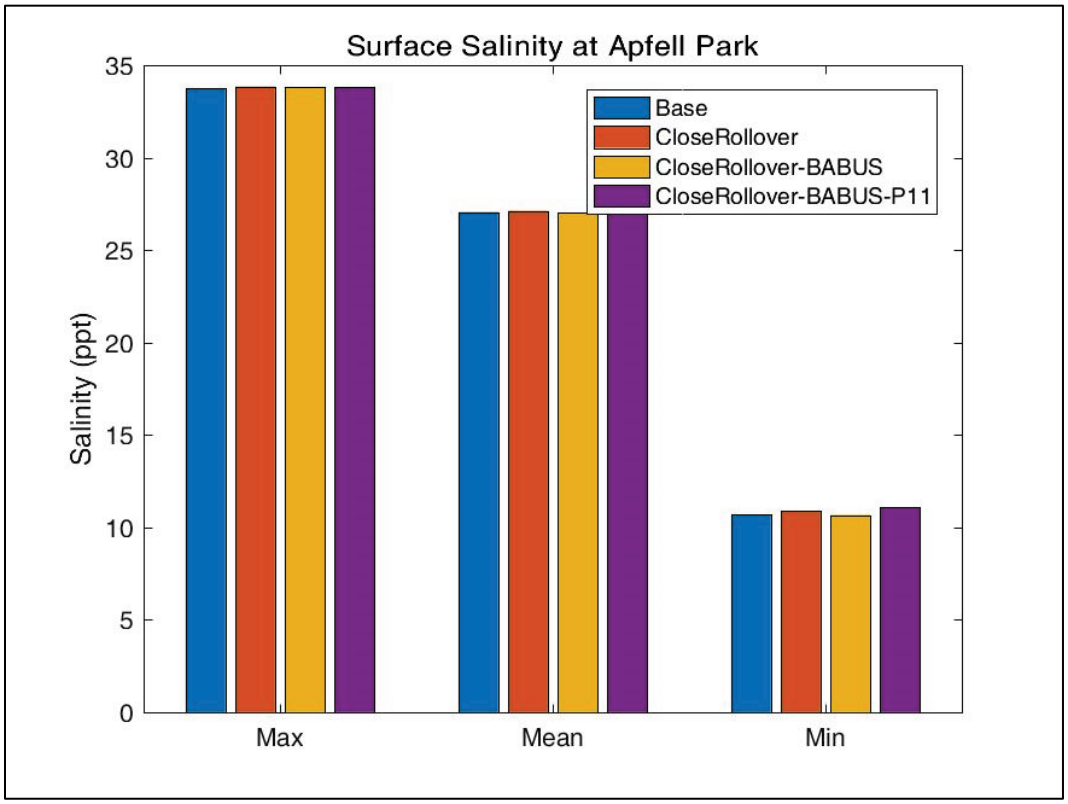

Surface Salinity at HSC at Turning Basin
Salinity (ppt)
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

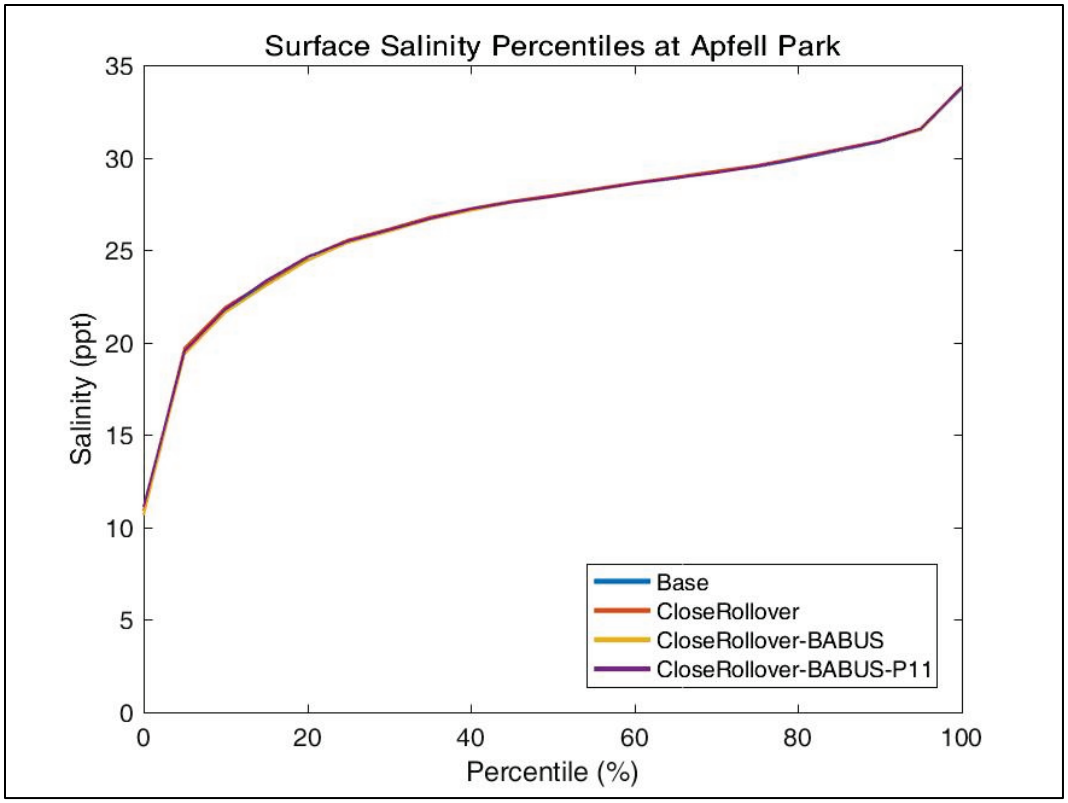

Surface Salinity Percentiles at HSC at Turning Basin
Salinity (ppt)
Percentile (%)
35
30
25
20
15
10
5
0
30
40
50
60
70
80
90
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11


Salinity at Apfell Park
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
40
11/23
01/12
03/03
04/22
06/11
07/31
09/19
11/08
12/28
02/16
Date (mm/dd)

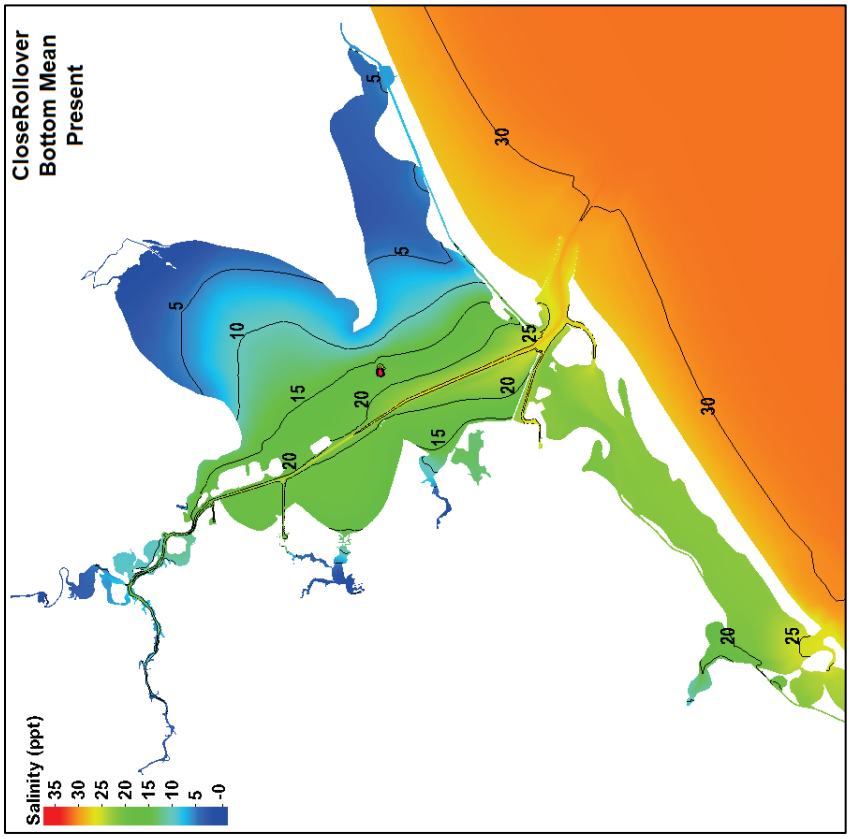

Bottom Salinity at Apfell Park
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min

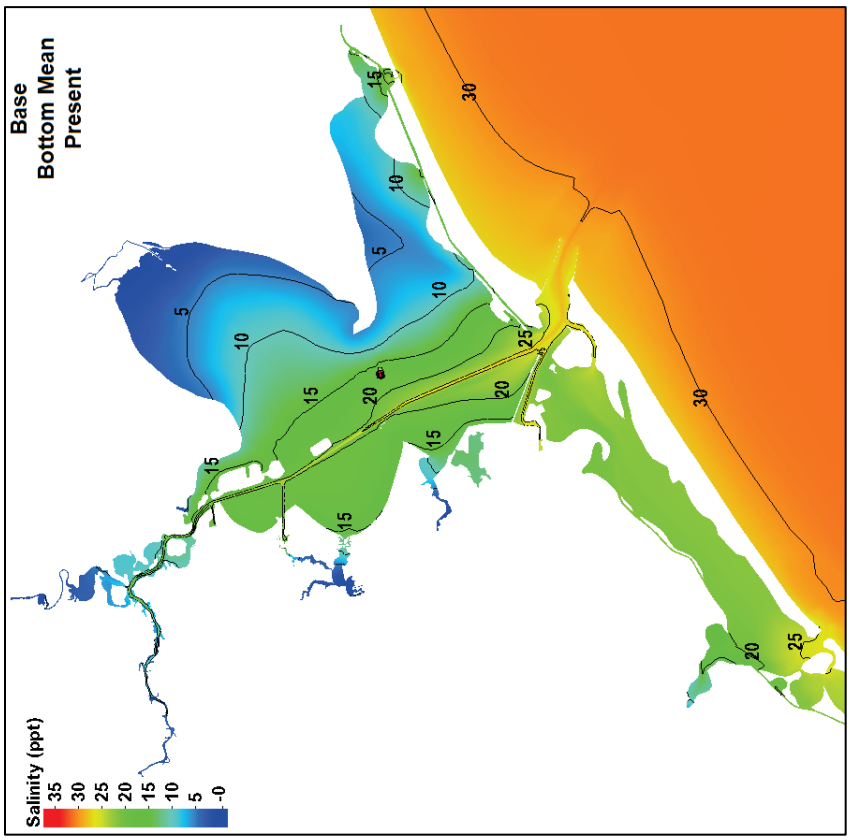

Bottom Salinity Percentiles at Apfell Park
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

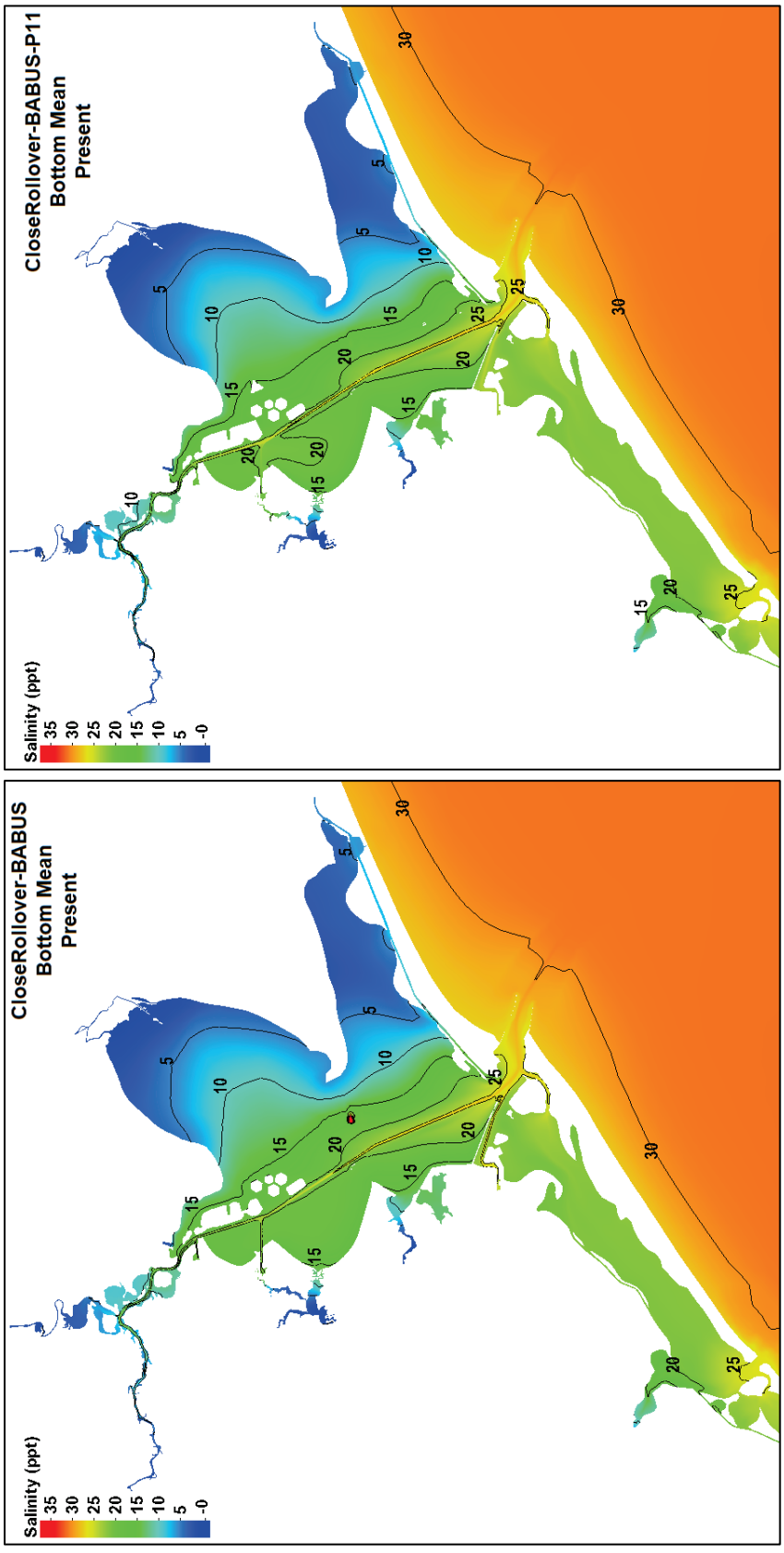

Surface Salinity at Apfell Park
Salinity (ppt)
0
5
10
15
20
25
30
35
Max
Mean
Min
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

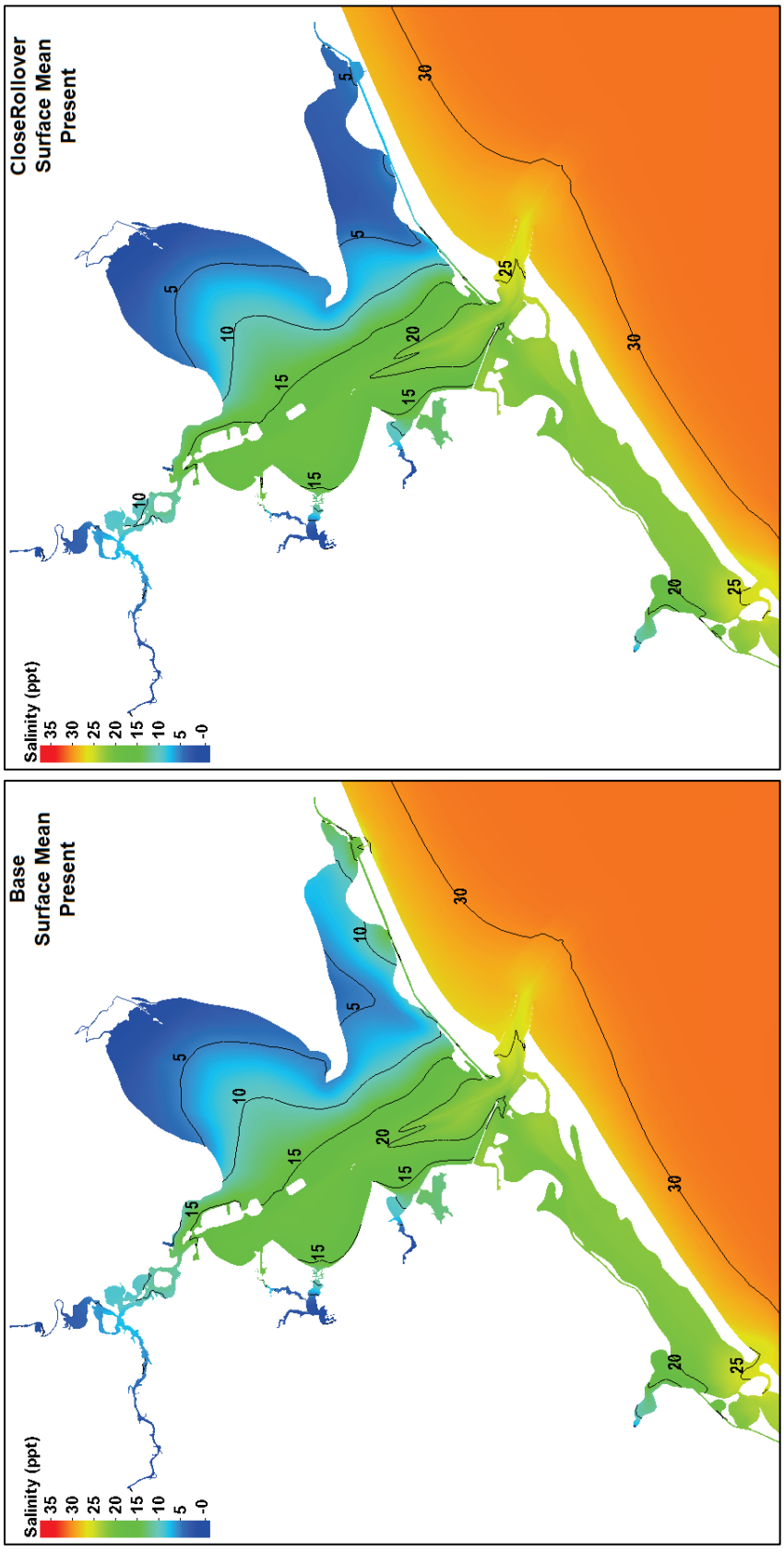

Surface Salinity Percentiles at Apfell Park
Salinity (ppt)
Percentile (%)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
Base
CloseRollover
CloseRollover-BABUS
CloseRollover-BABUS-P11

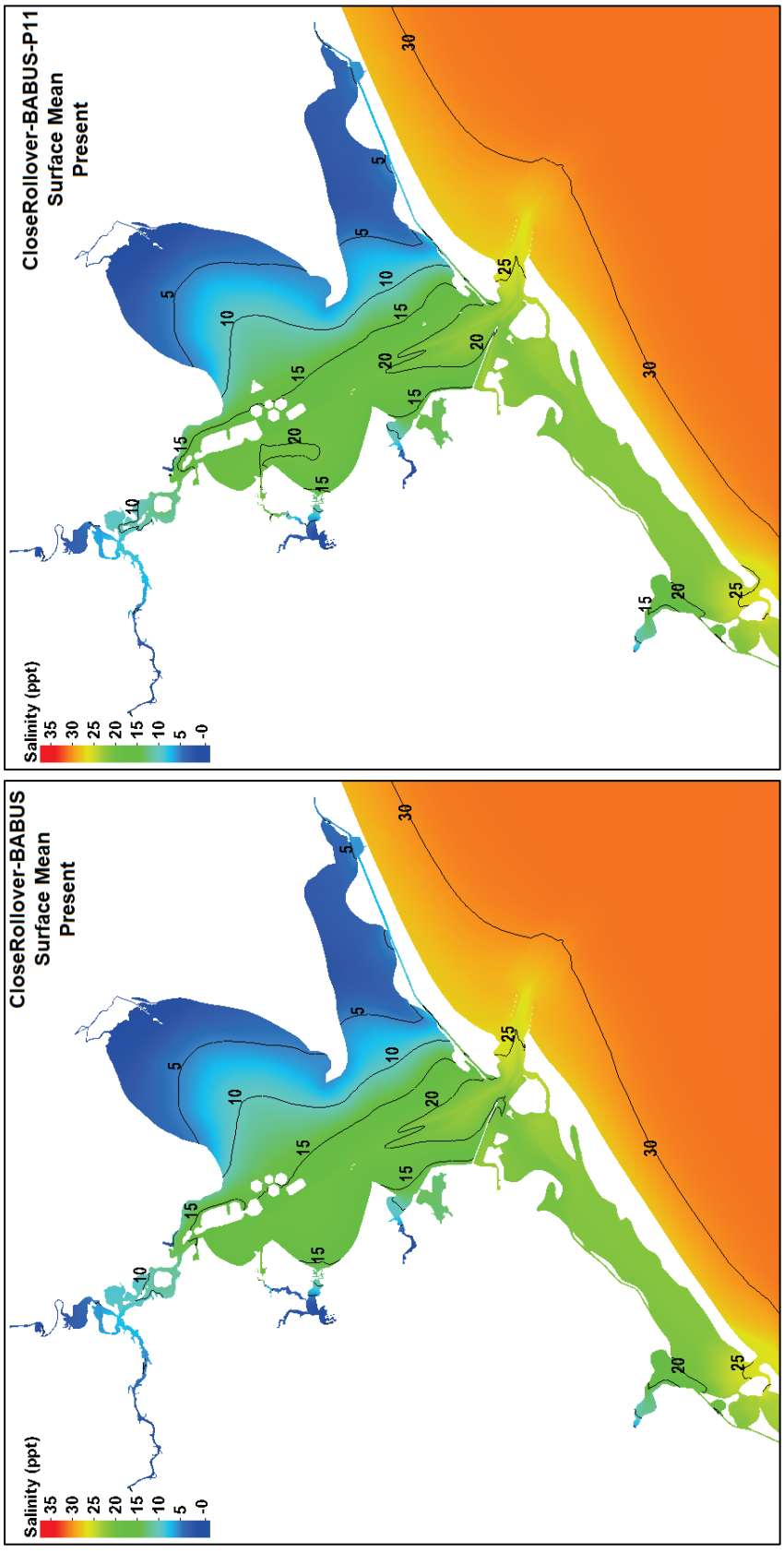
Present spatial salinity analysis (Mean, Max, Min)

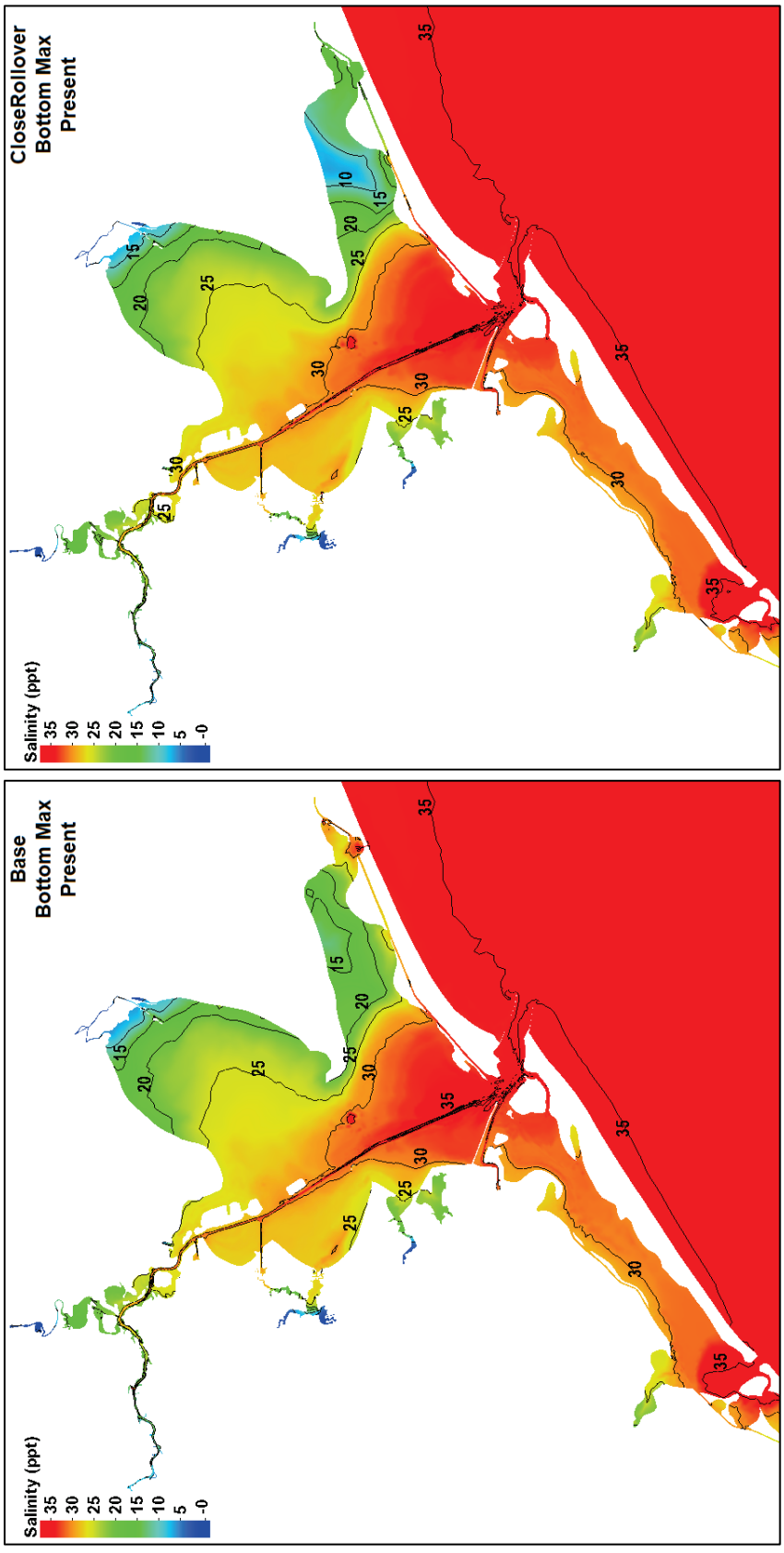


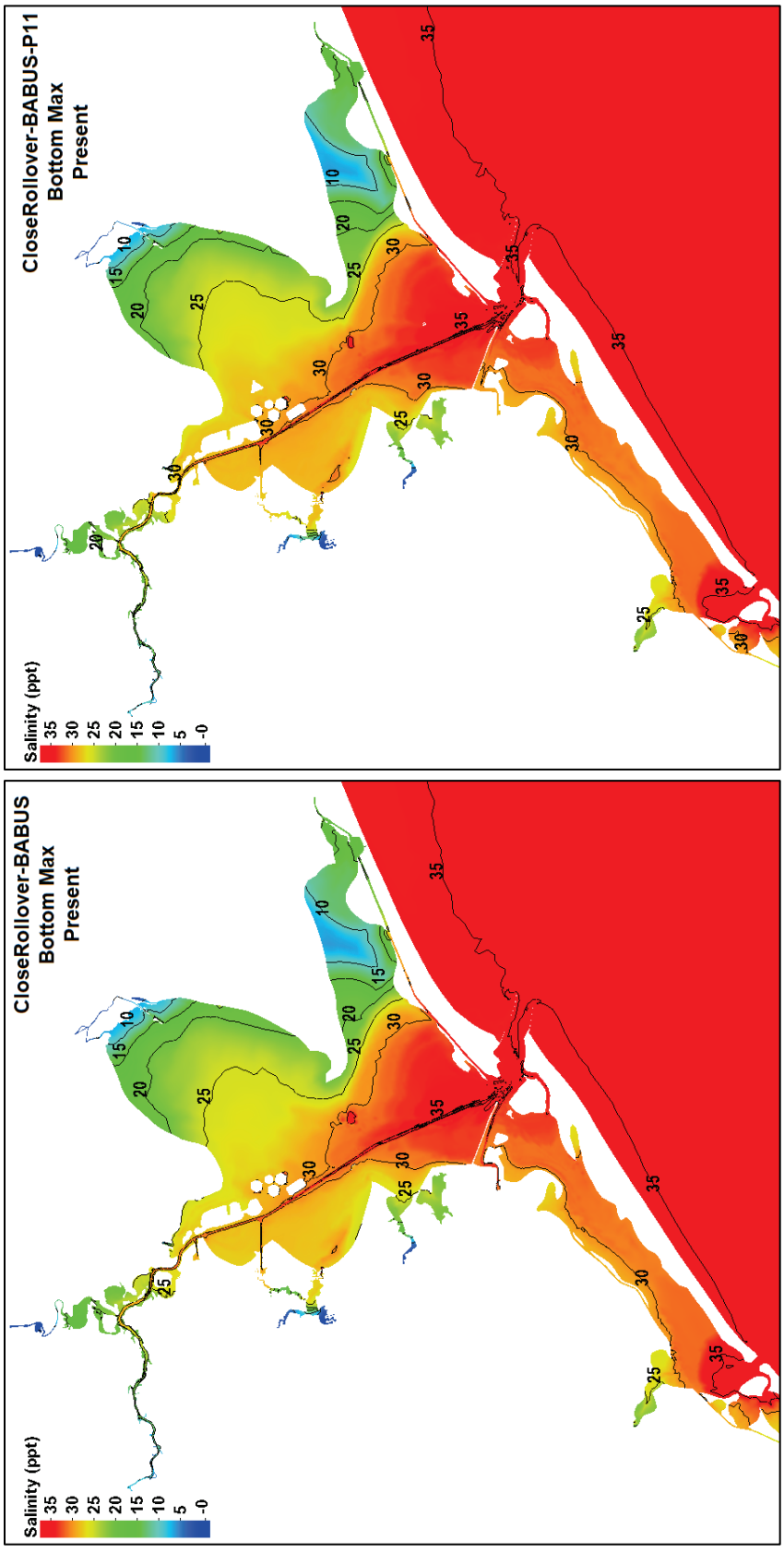


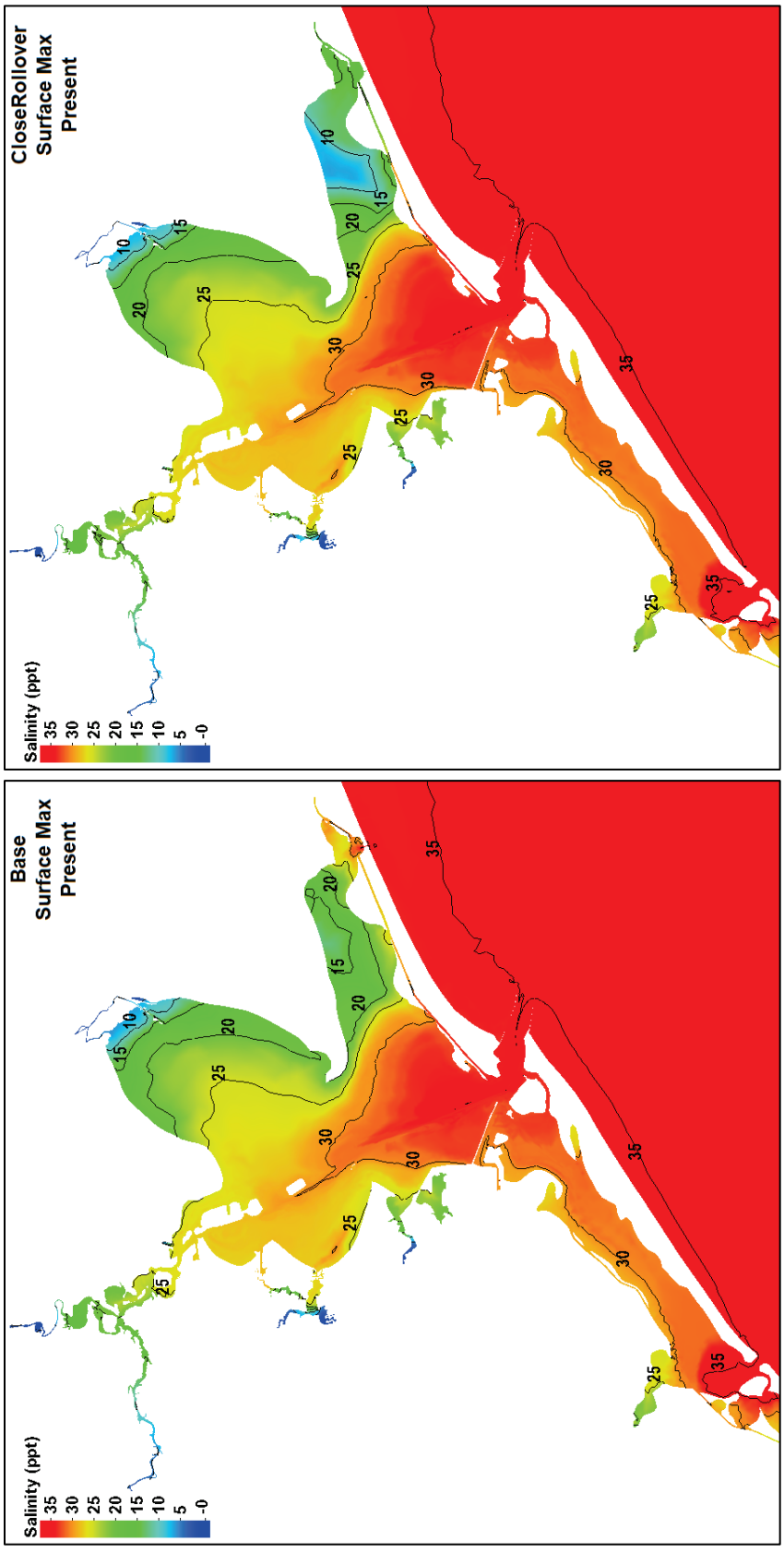

CloseRollover-BABUS-P11
Bottom Mean
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Bottom Mean
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

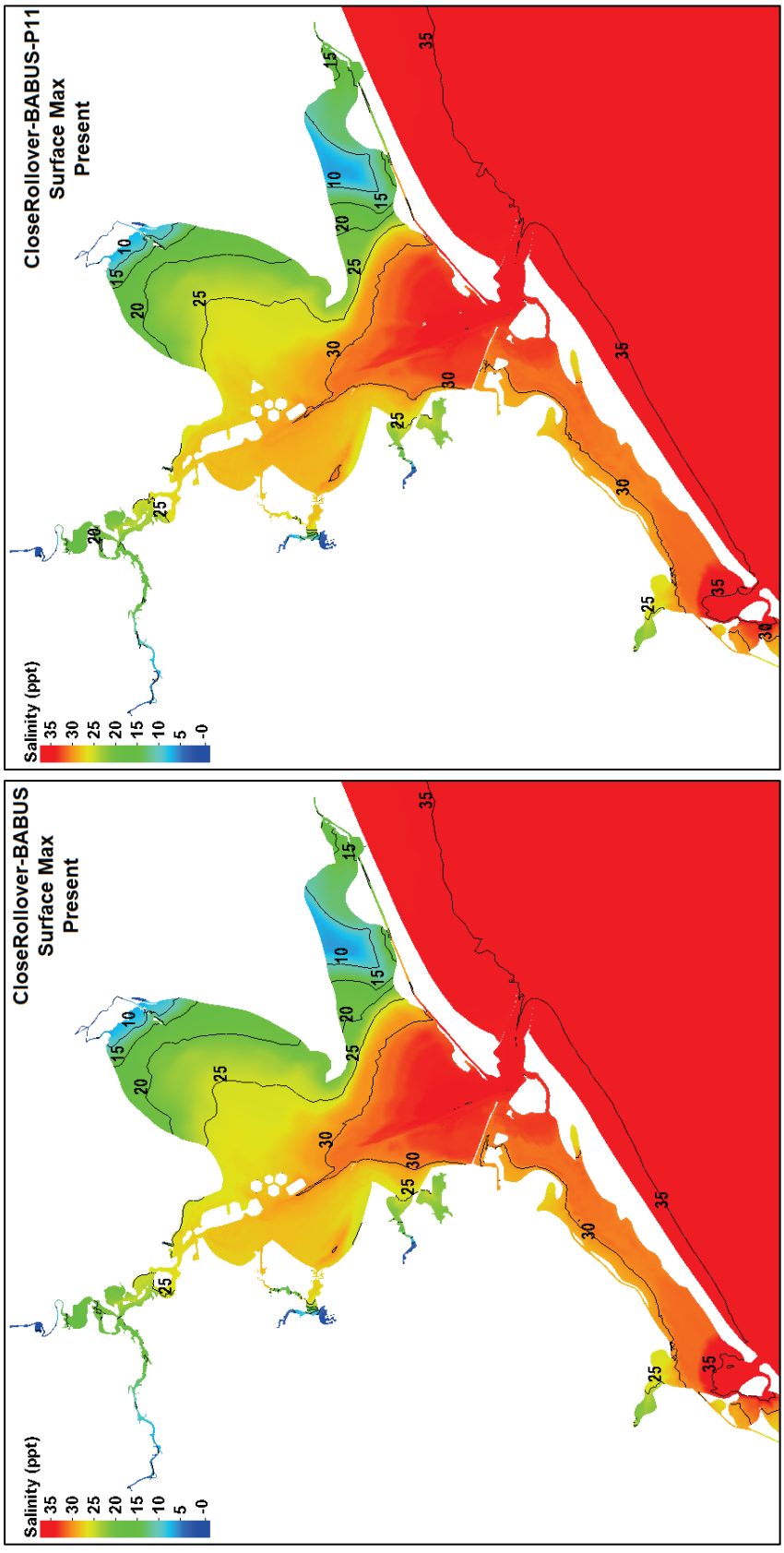

CloseRollover
Surface Mean
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Surface Mean
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

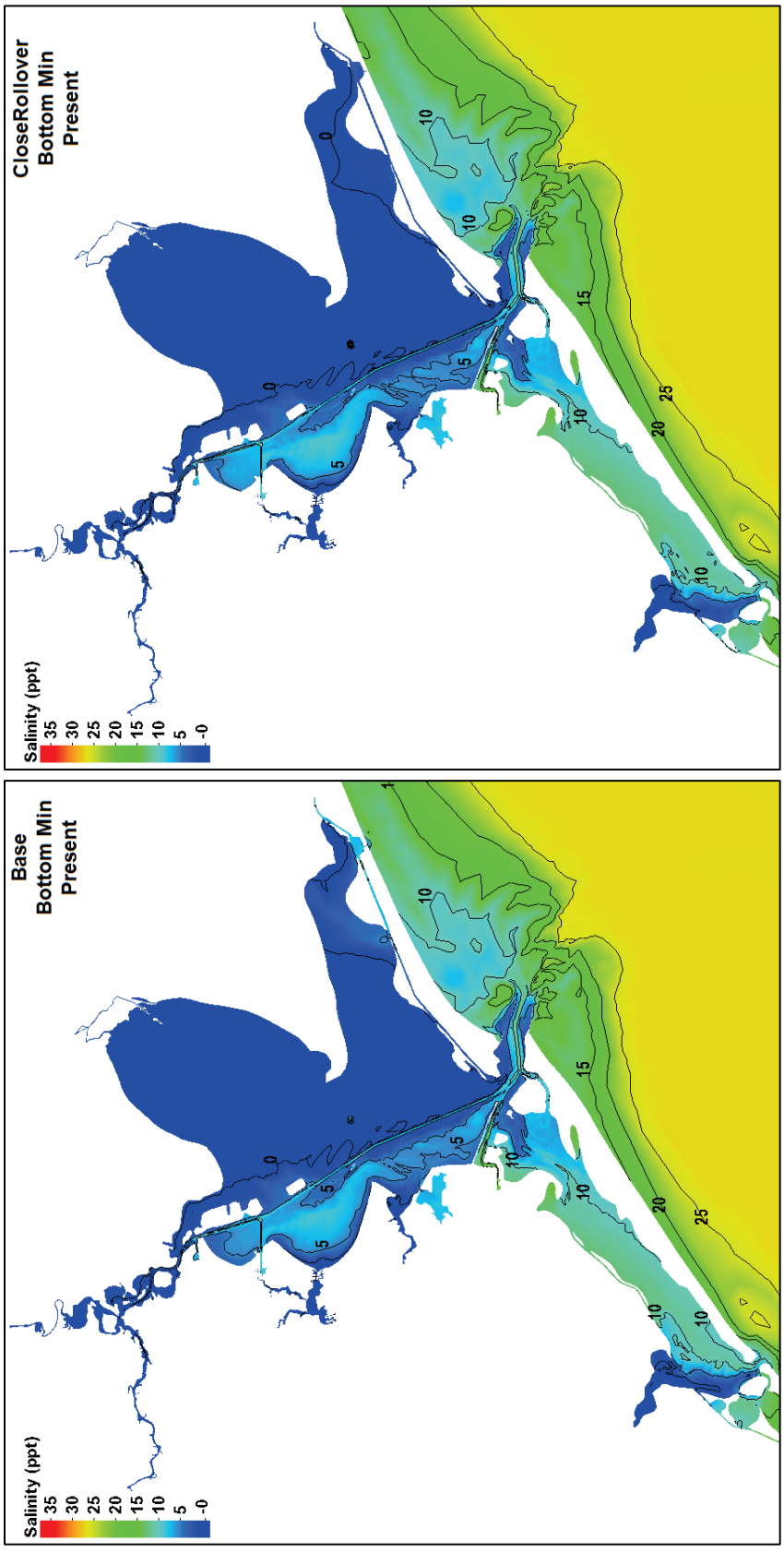

CloseRollover-BABUS-P11
Surface Mean
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Surface Mean
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

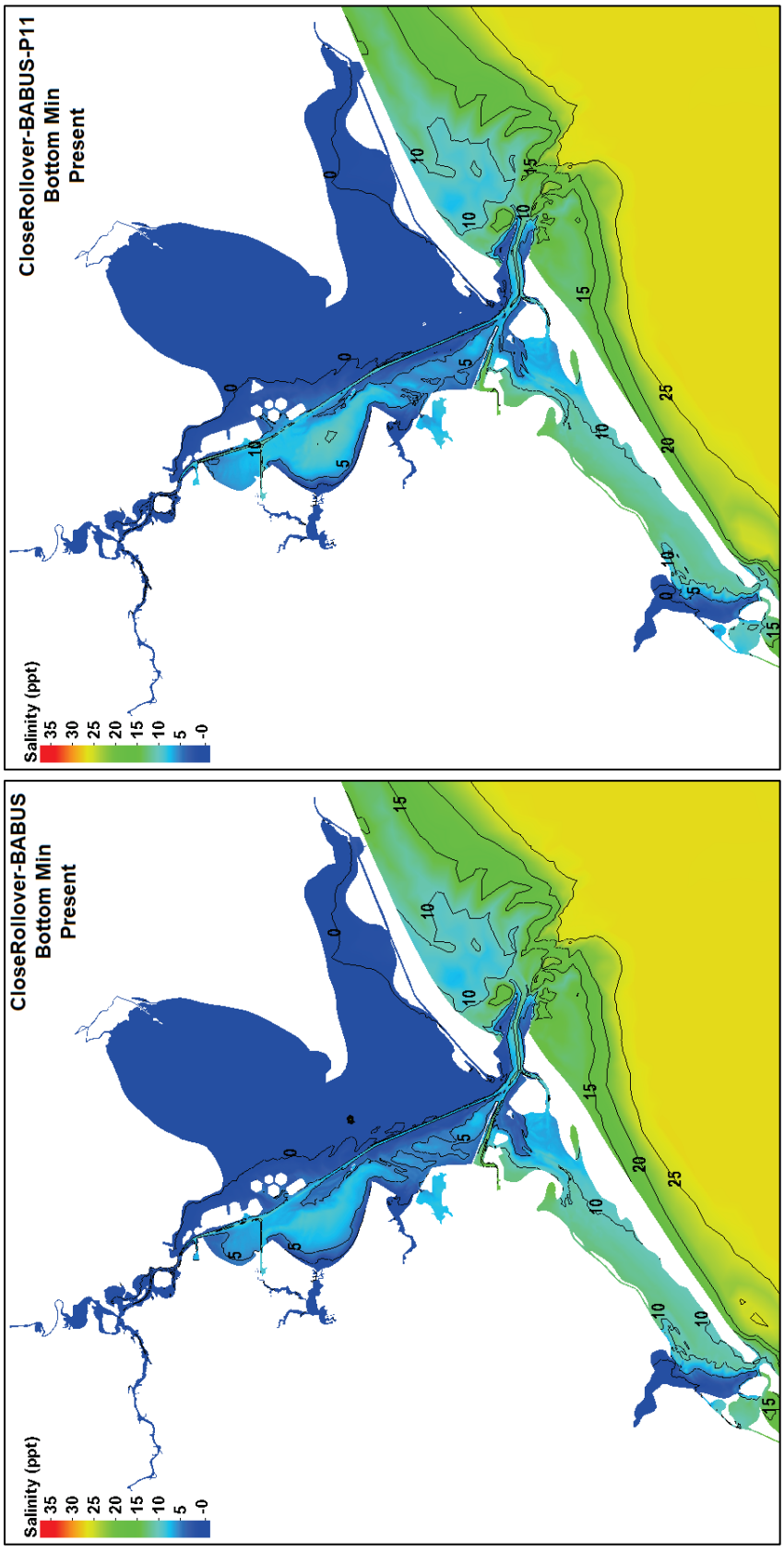

CloseRollover
Bottom Max
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Bottom Max
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

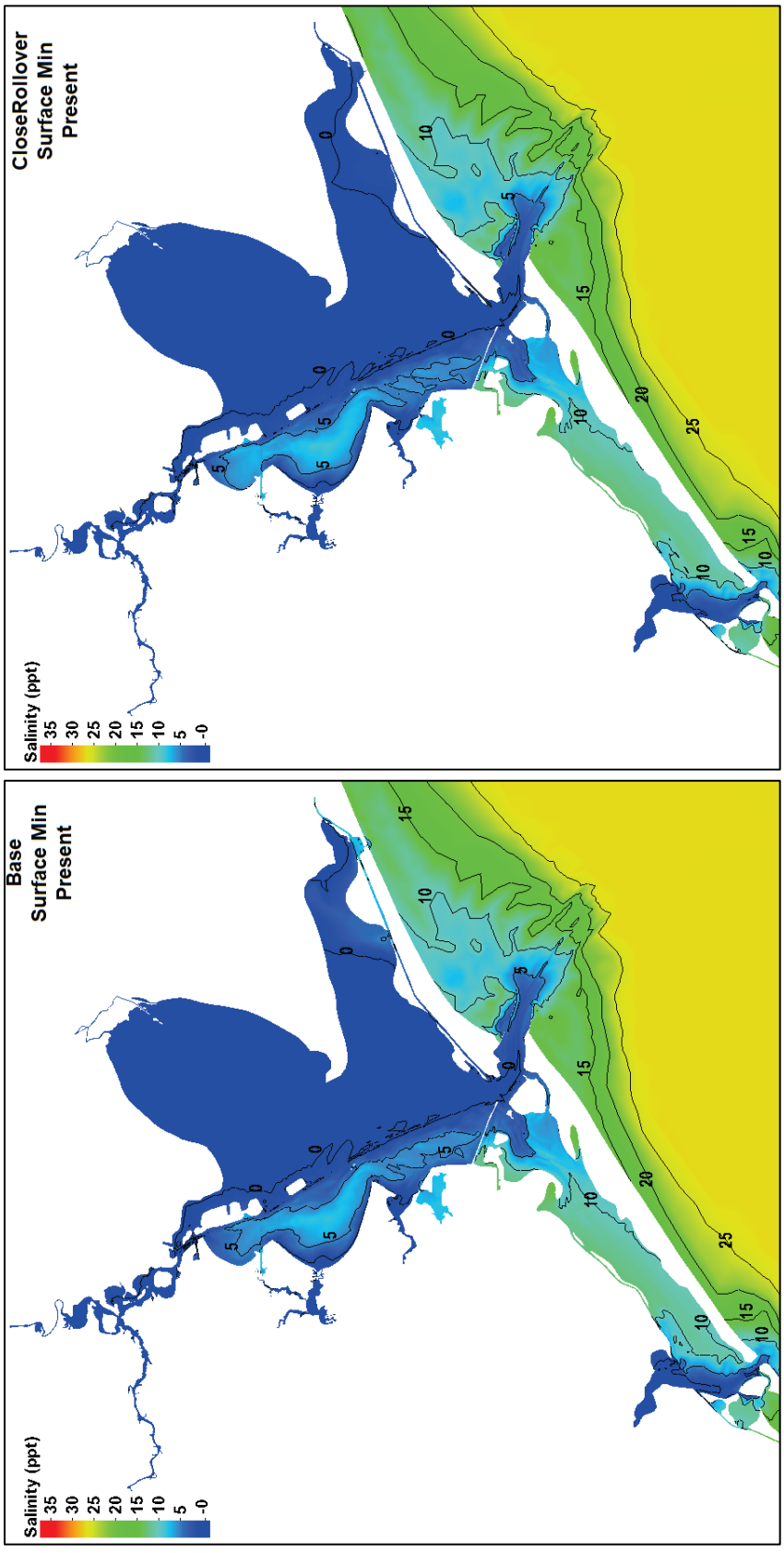

CloseRollover-BABUS-P11
Bottom Max
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Bottom Max
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

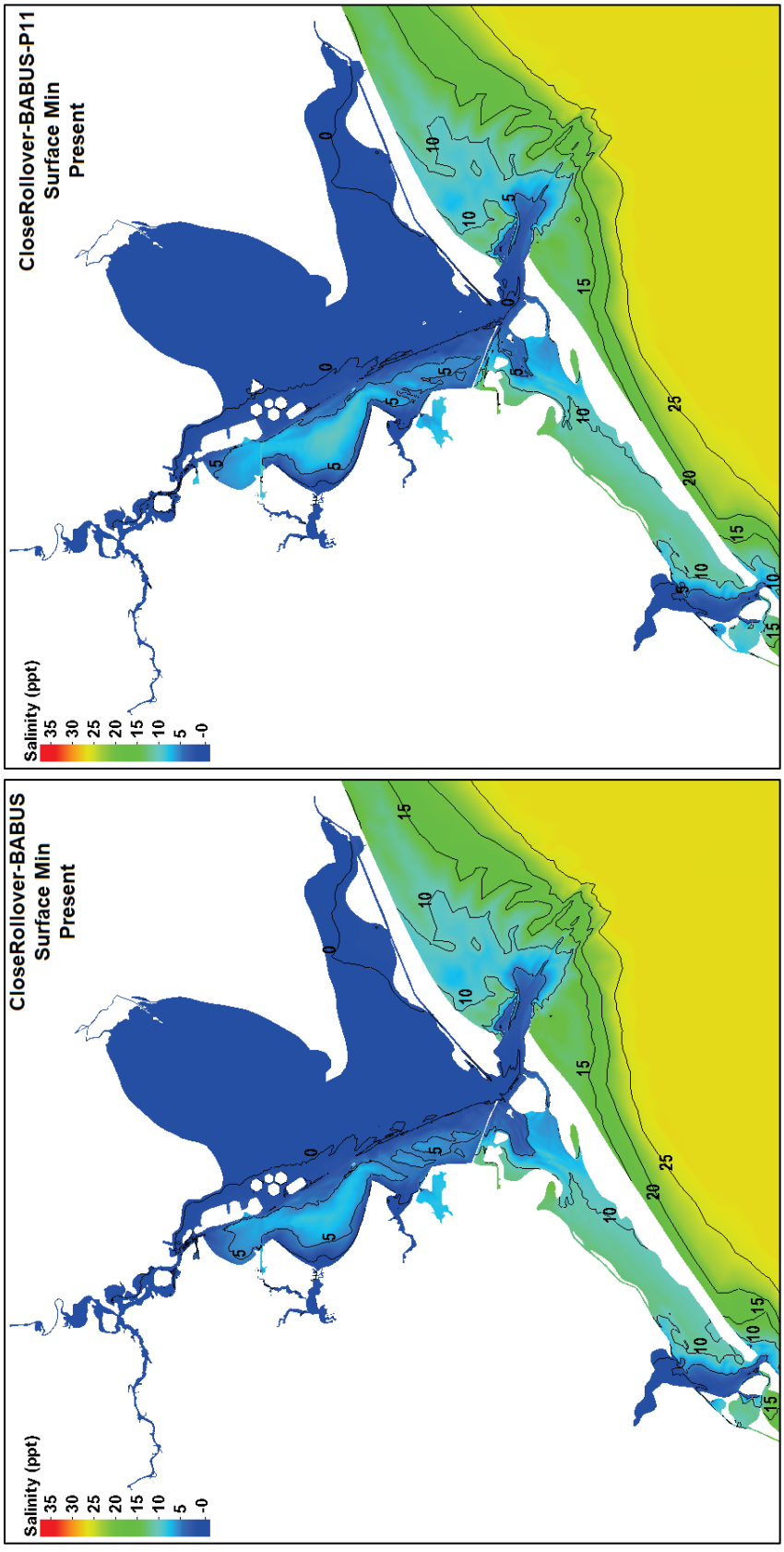

CloseRollover
Surface Max
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Surface Max
Present
Salinity (ppt)
35
30
25
20
15
10
5
0


CloseRollover-BABUS-P11
Surface Max
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Surface Max
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

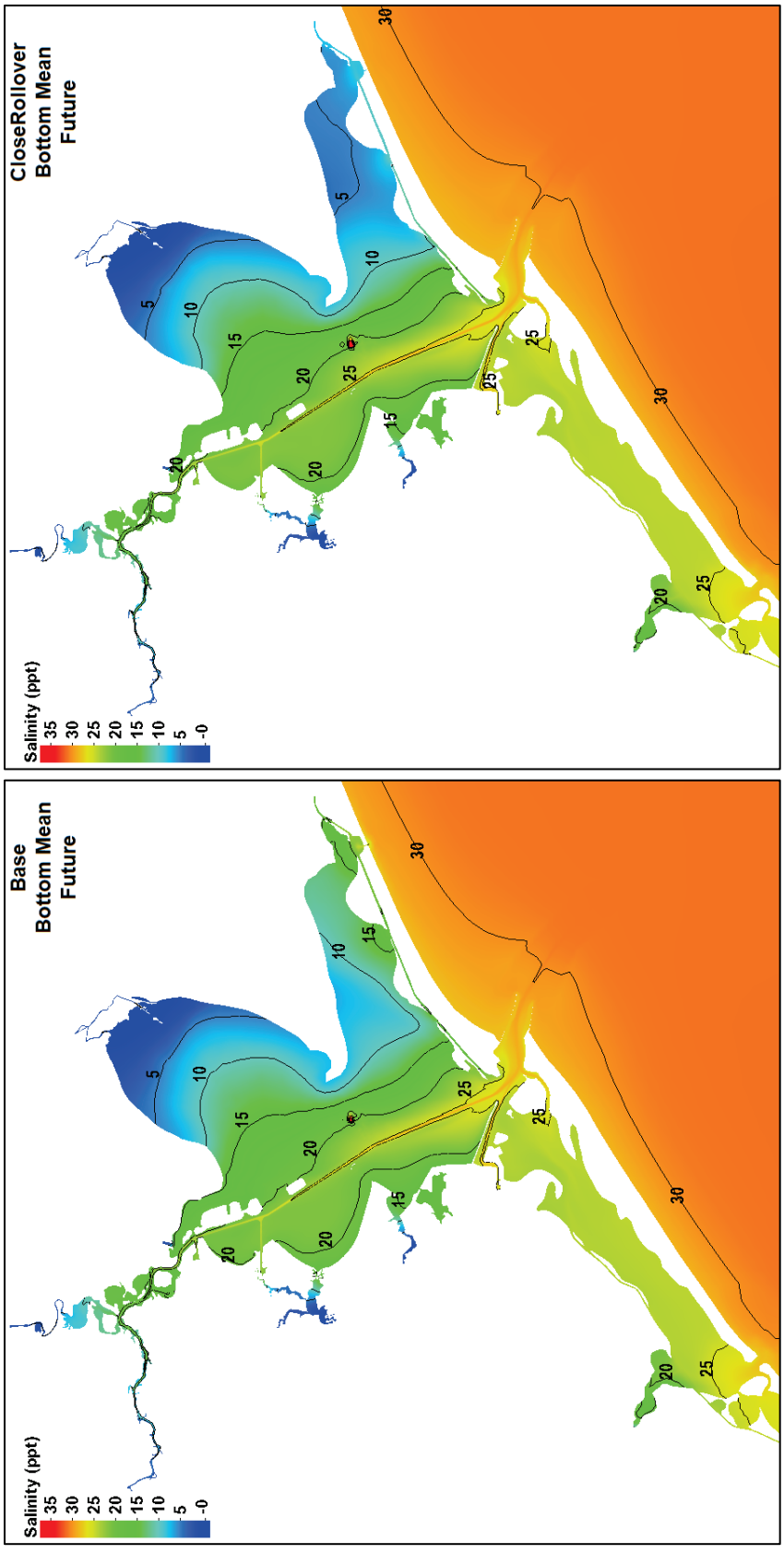

CloseRollover
Bottom Min
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Bottom Min
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

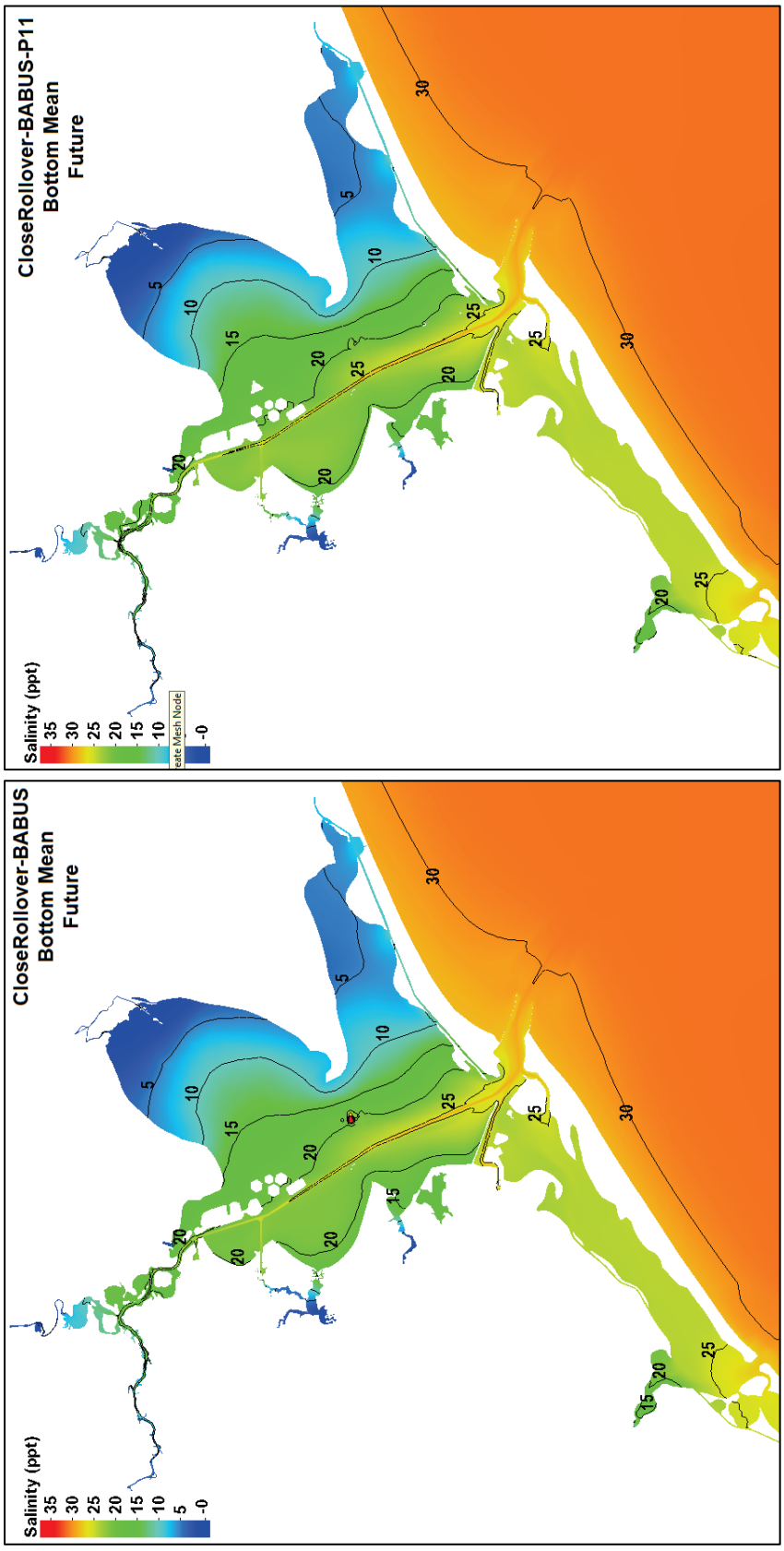

CloseRollover-BABUS-P11
Bottom Min
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Bottom Min
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

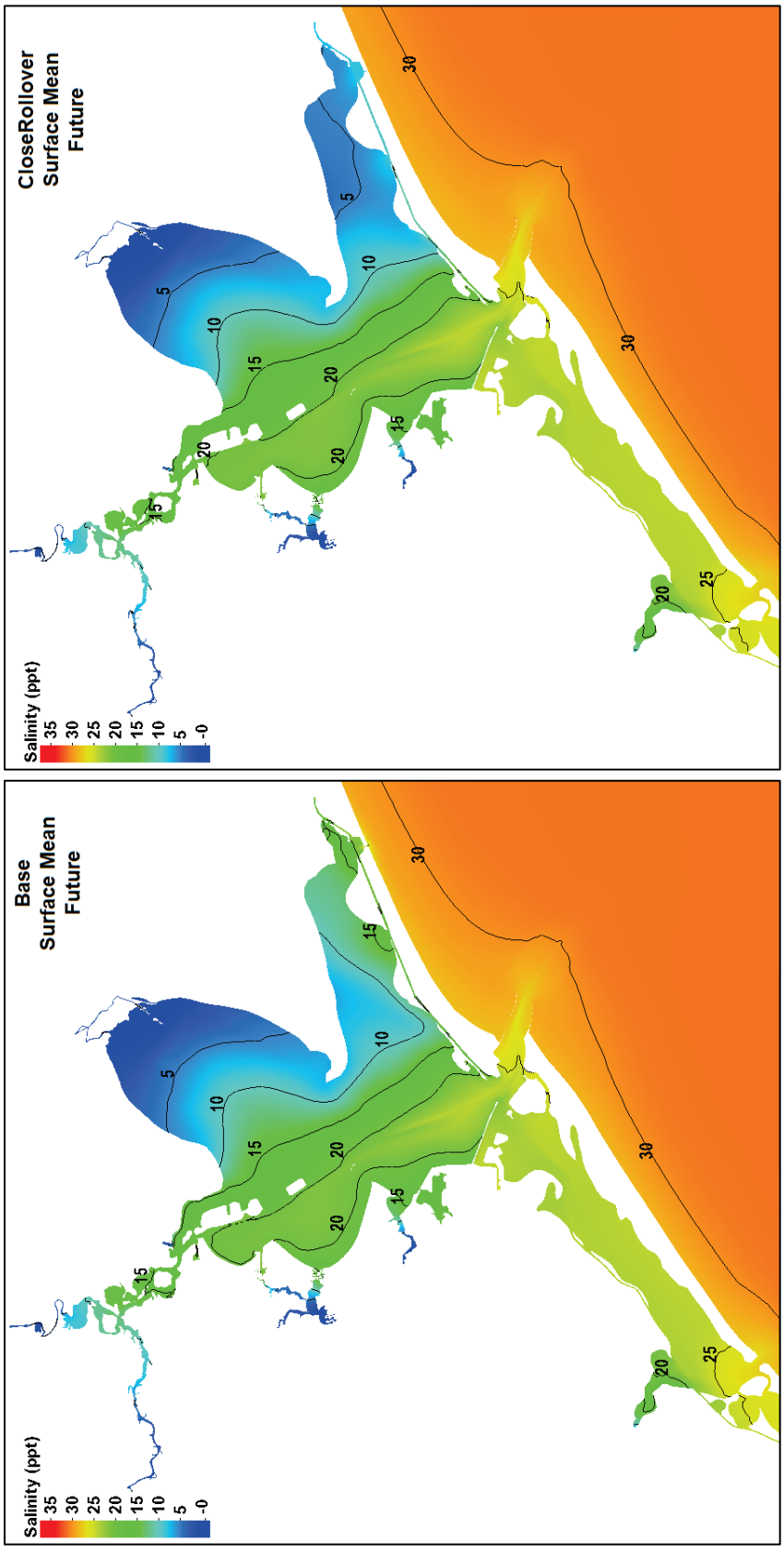

CloseRollover
Surface Min
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Surface Min
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

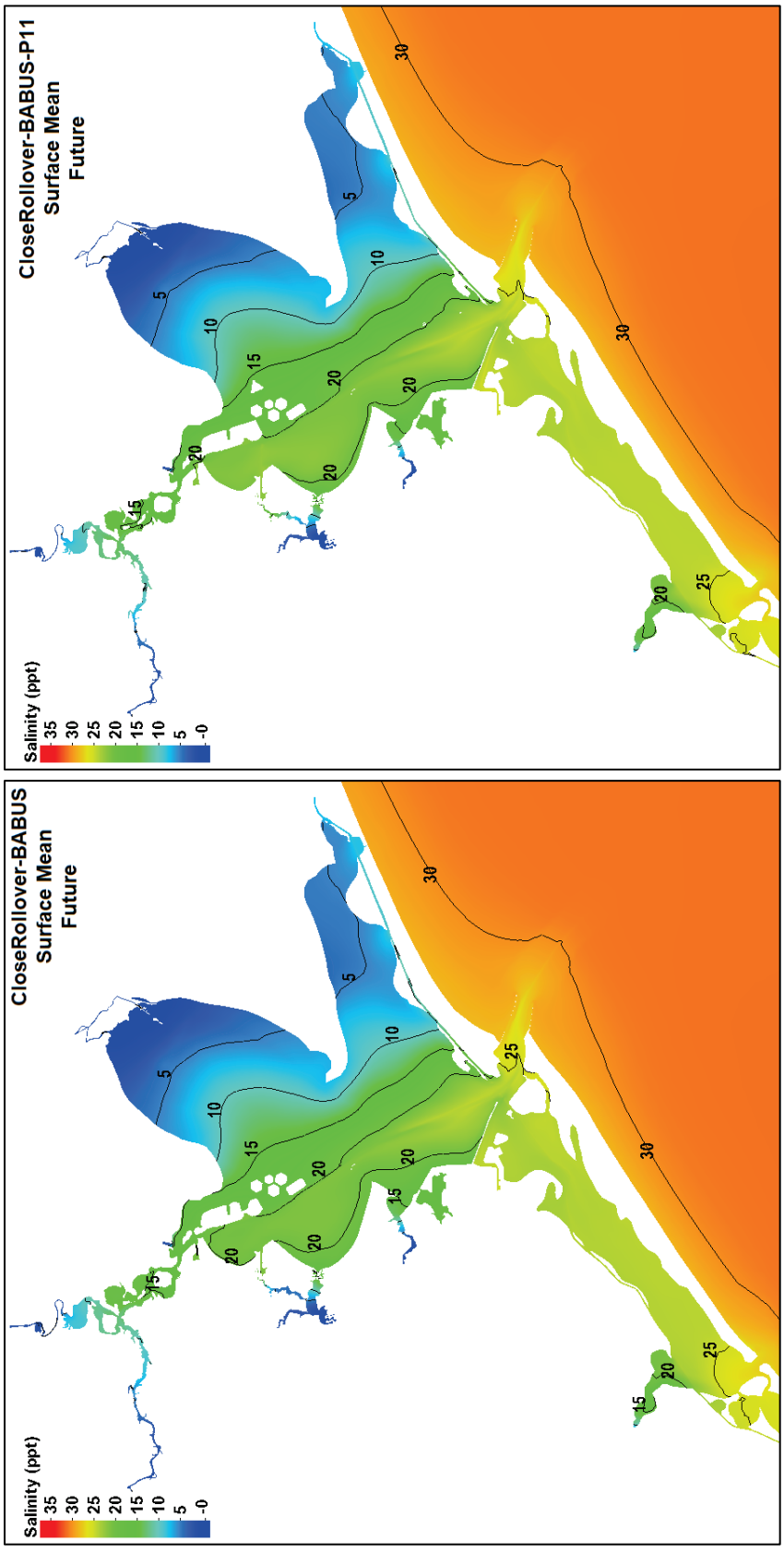

CloseRollover-BABUS-P11
Surface Min
Present
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Surface Min
Present
Salinity (ppt)
35
30
25
20
15
10
5
0

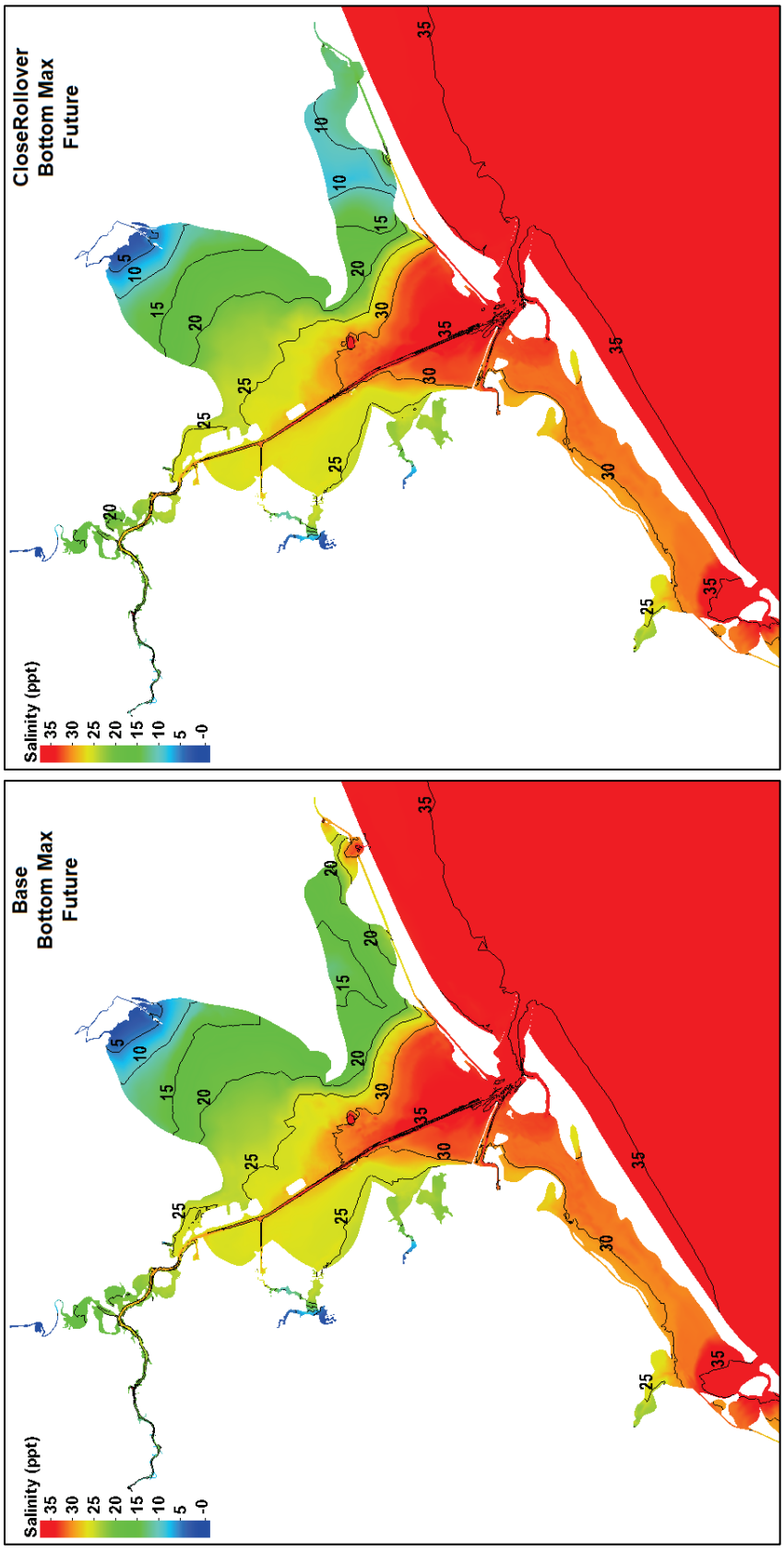
Future spatial salinity analysis (Mean, Max, Min)

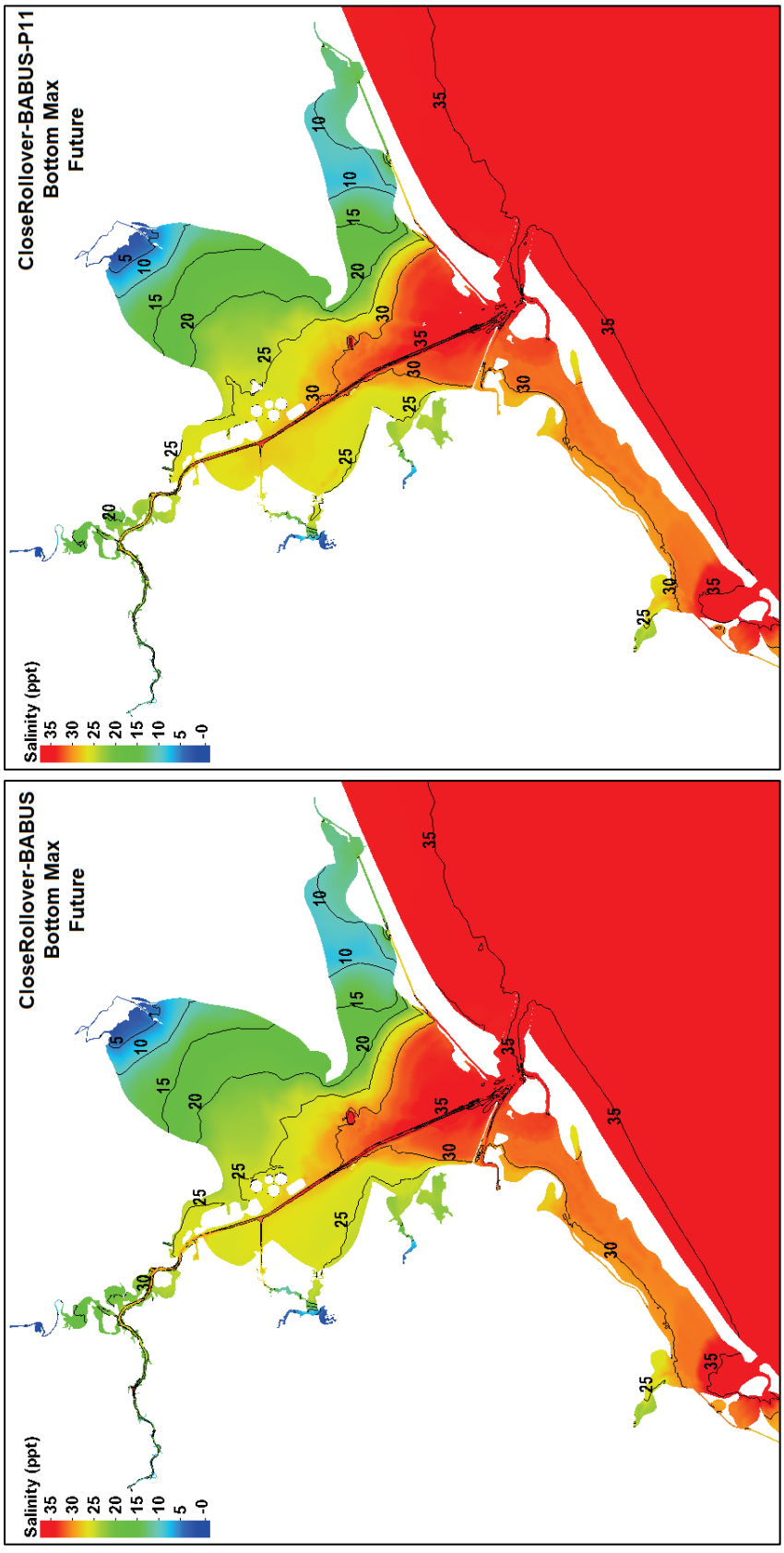


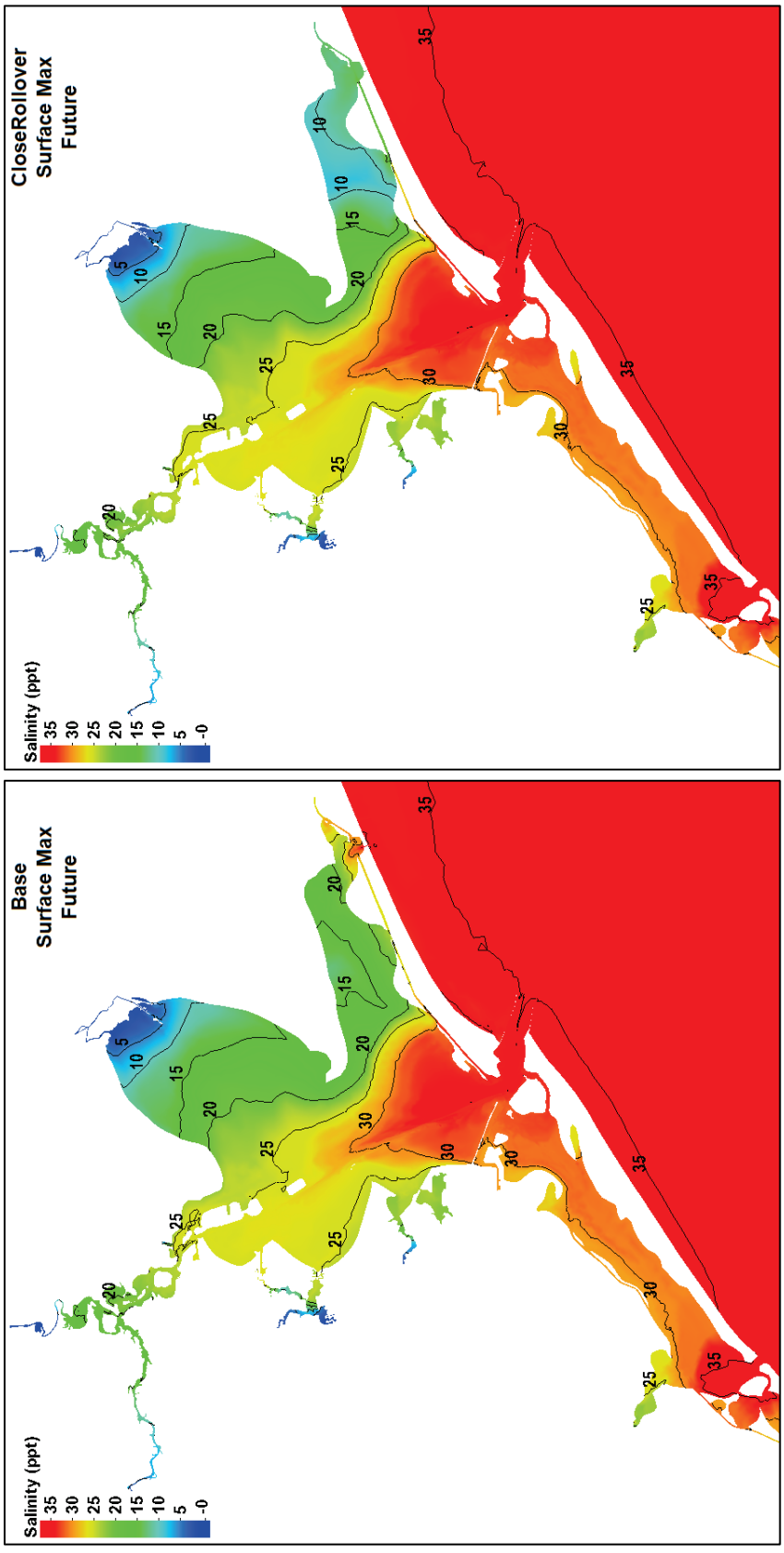

CloseRollover-BABUS-P11
Bottom Mean
Future
Salinity (ppt)
35
30
25
20
15
10
-0
CloseRollover-BABUS
Bottom Mean
Future
Salinity (ppt)
35
30
25
20
15
10
5
-0

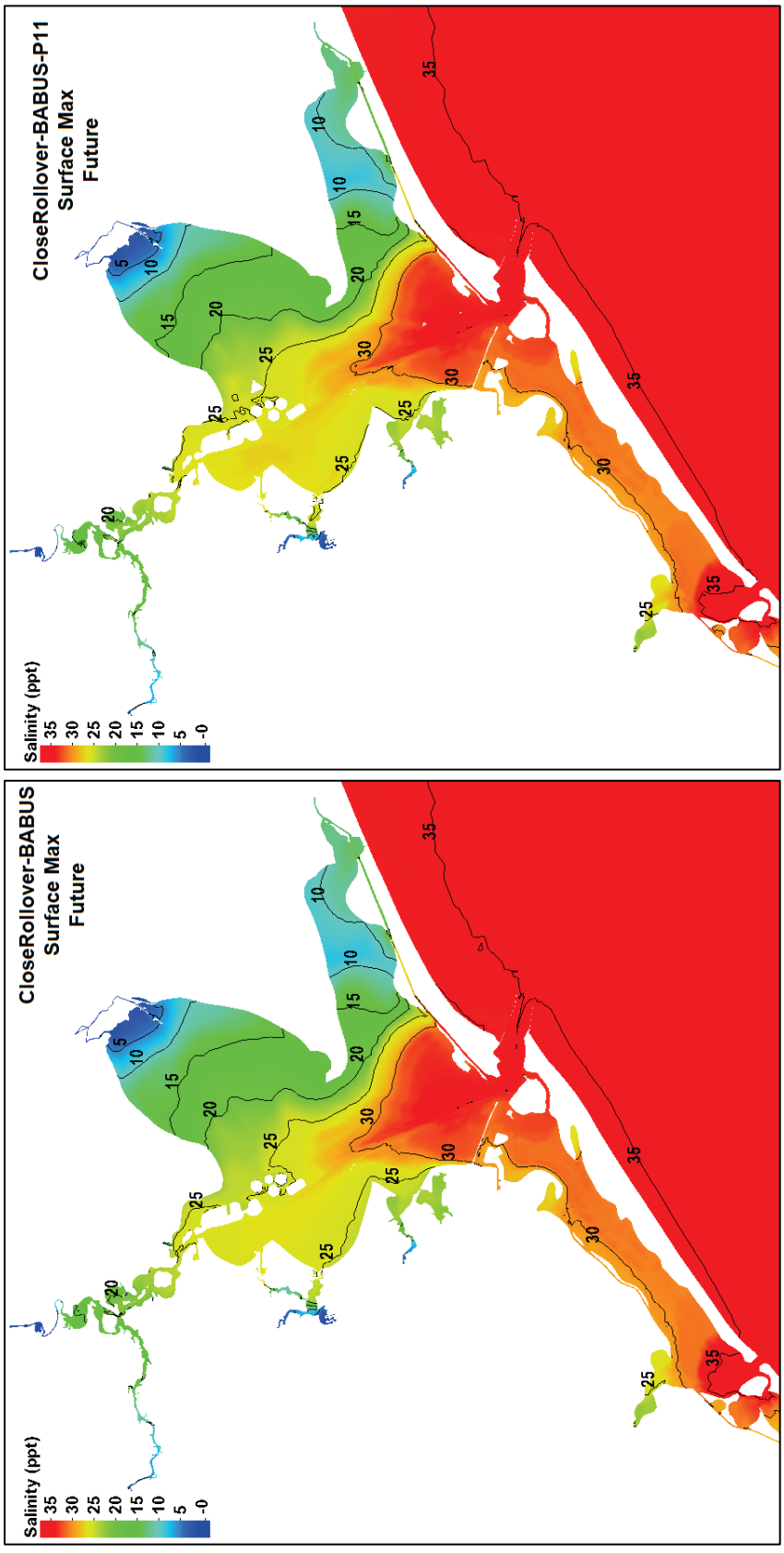

CloseRollover
Surface Mean
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Surface Mean
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

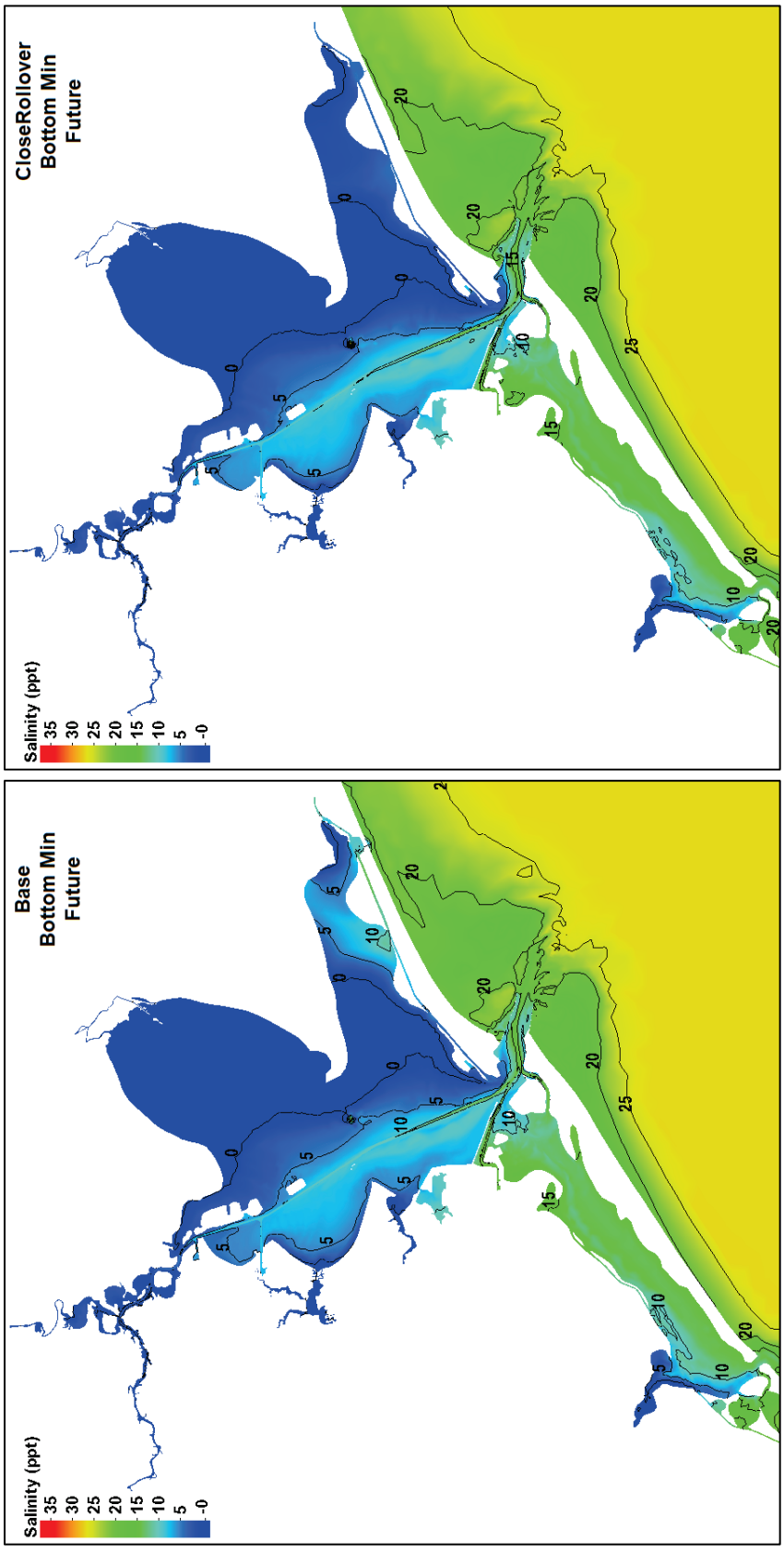

CloseRollover-BABUS-P11
Surface Mean
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Surface Mean
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

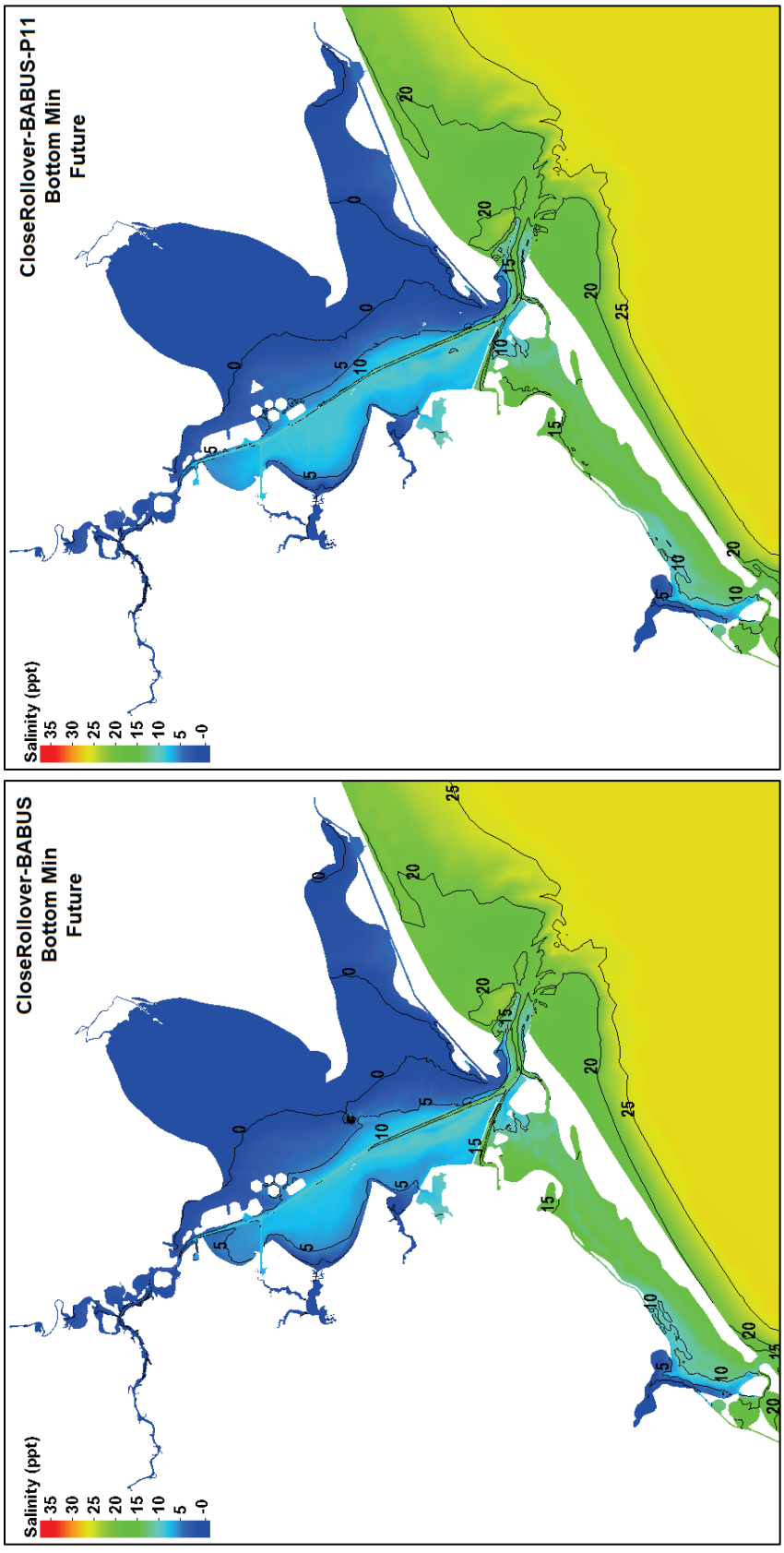

CloseRollover
Bottom Max
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Bottom Max
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

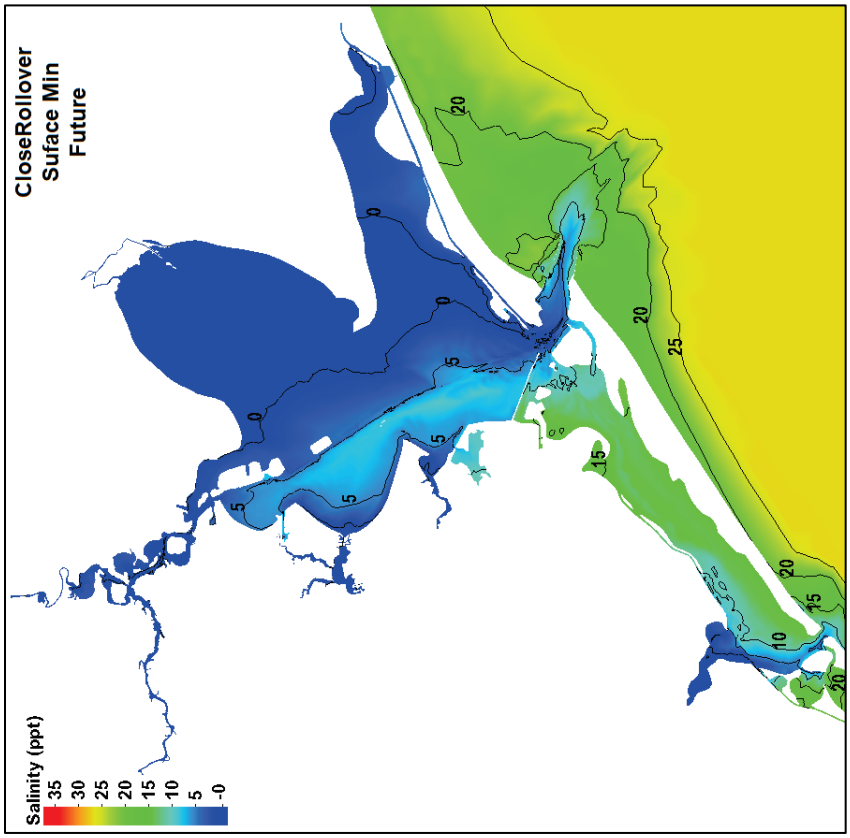

CloseRollover-BABUS-P11
Bottom Max
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Bottom Max
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

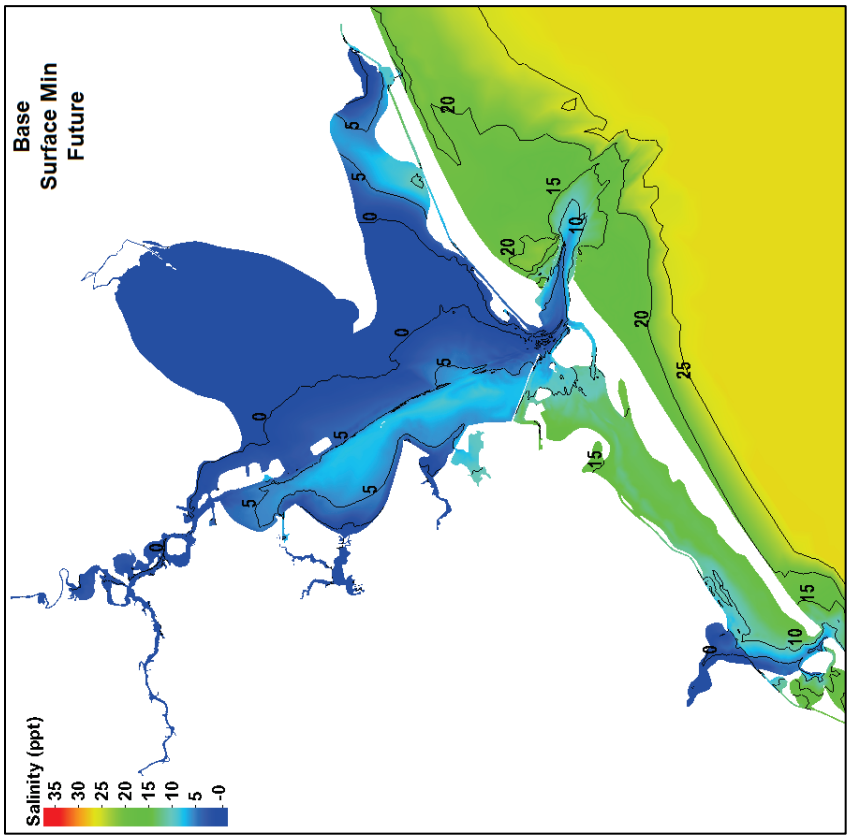

CloseRollover
Surface Max
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Surface Max
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

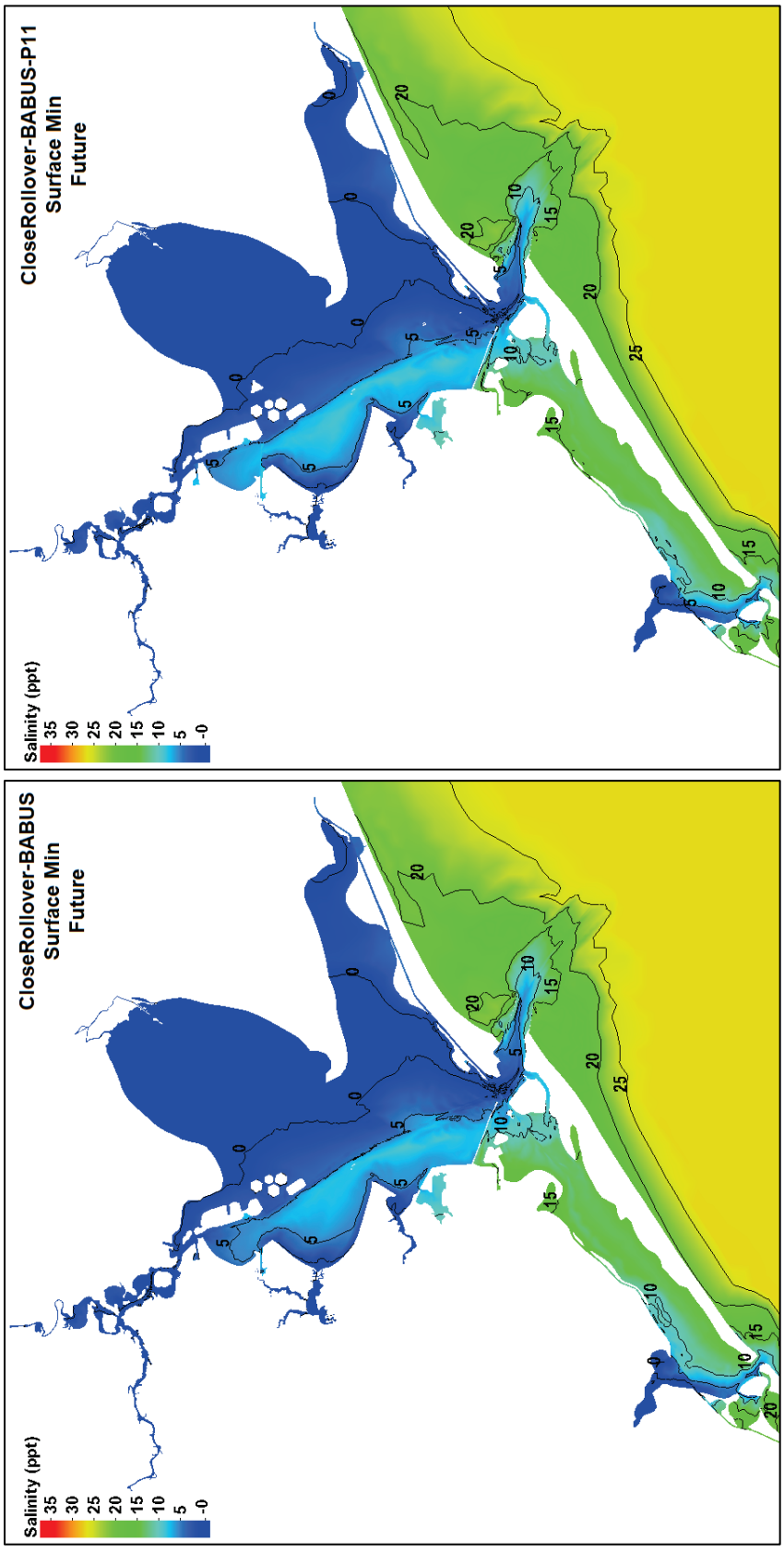

CloseRollover-BABUS-P11
Surface Max
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Surface Max
Future
Salinity (ppt)
35
30
25
20
15
10
5
0


CloseRollover
Bottom Min
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
Base
Bottom Min
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

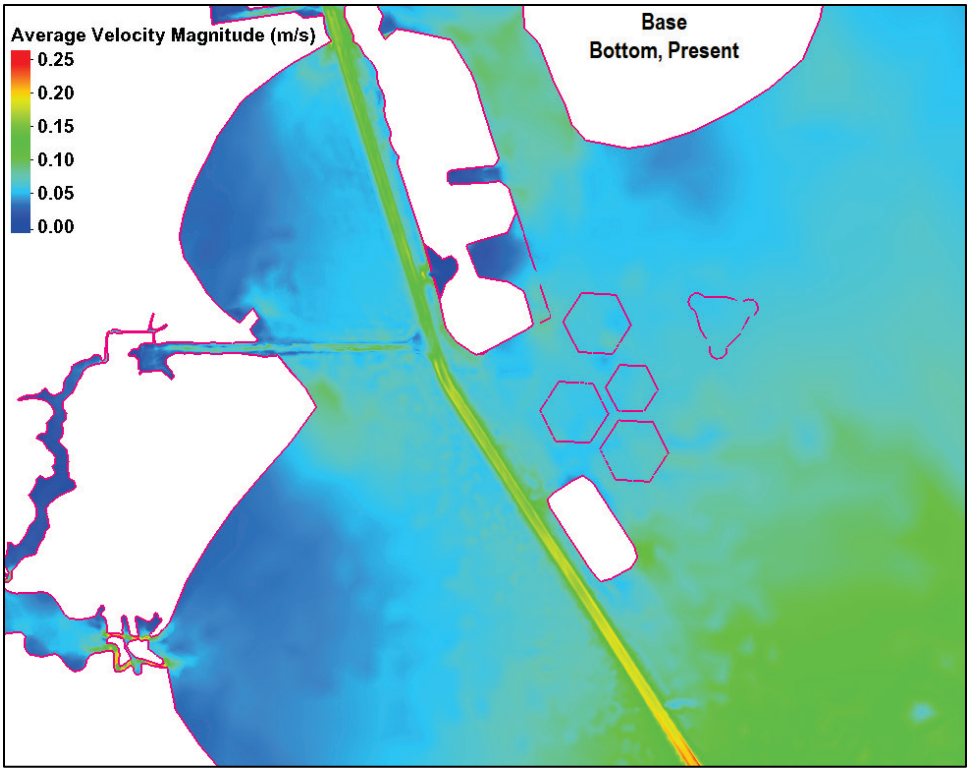

CloseRollover-BABUS-P11
Bottom Min
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Bottom Min
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

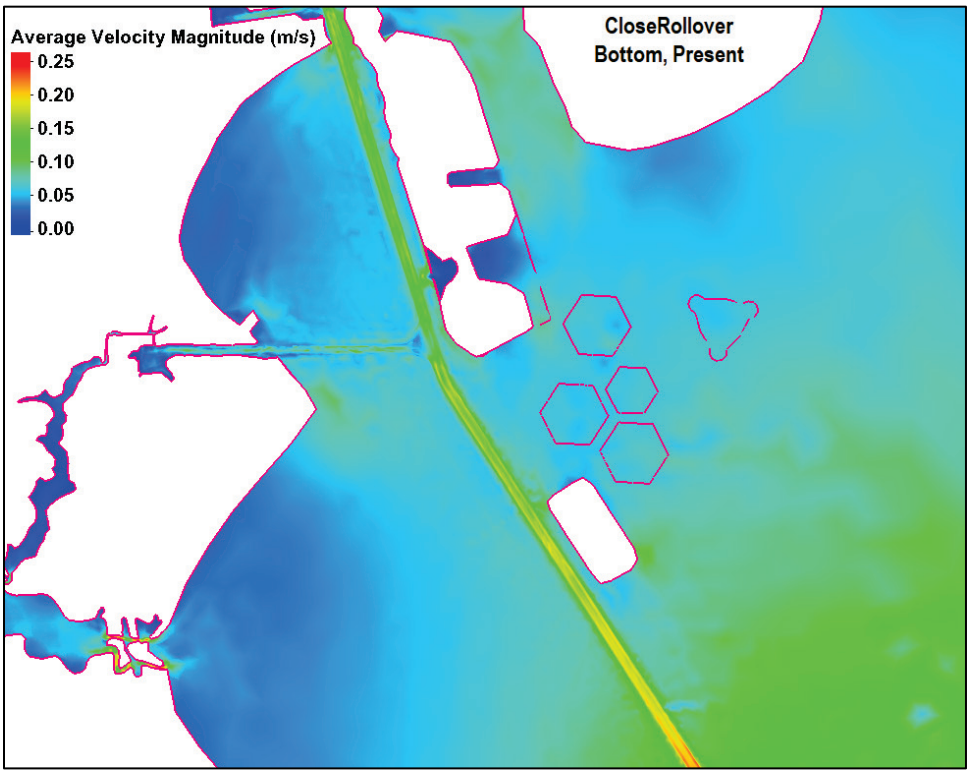

CloseRollover
Suface Min
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

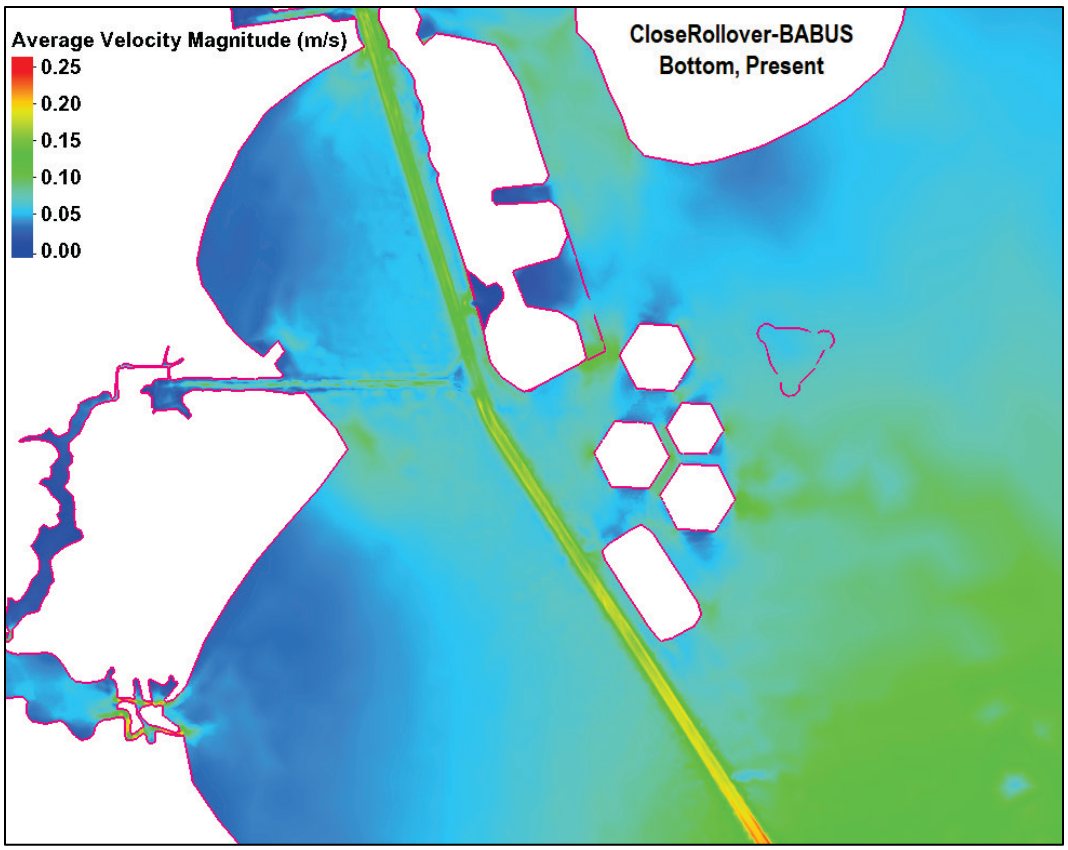

Base
Surface Min
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

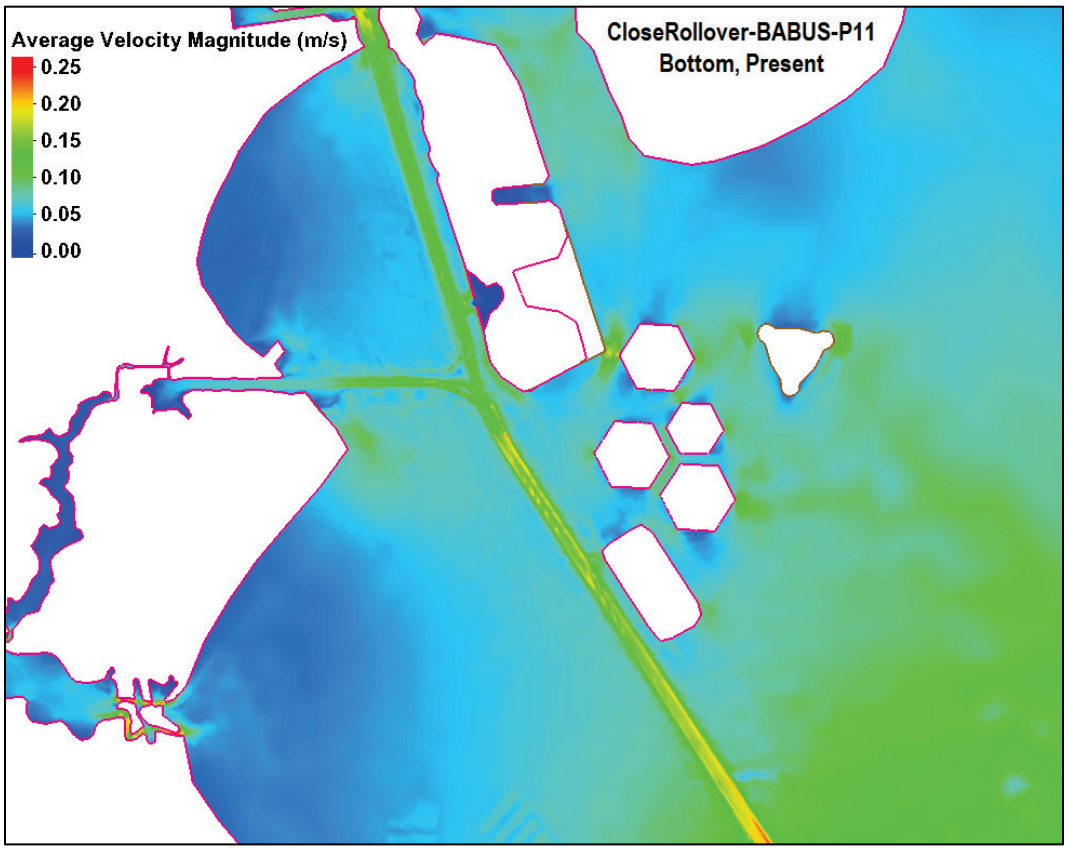

CloseRollover-BABUS-P11
Surface Min
Future
Salinity (ppt)
35
30
25
20
15
10
5
0
CloseRollover-BABUS
Surface Min
Future
Salinity (ppt)
35
30
25
20
15
10
5
0

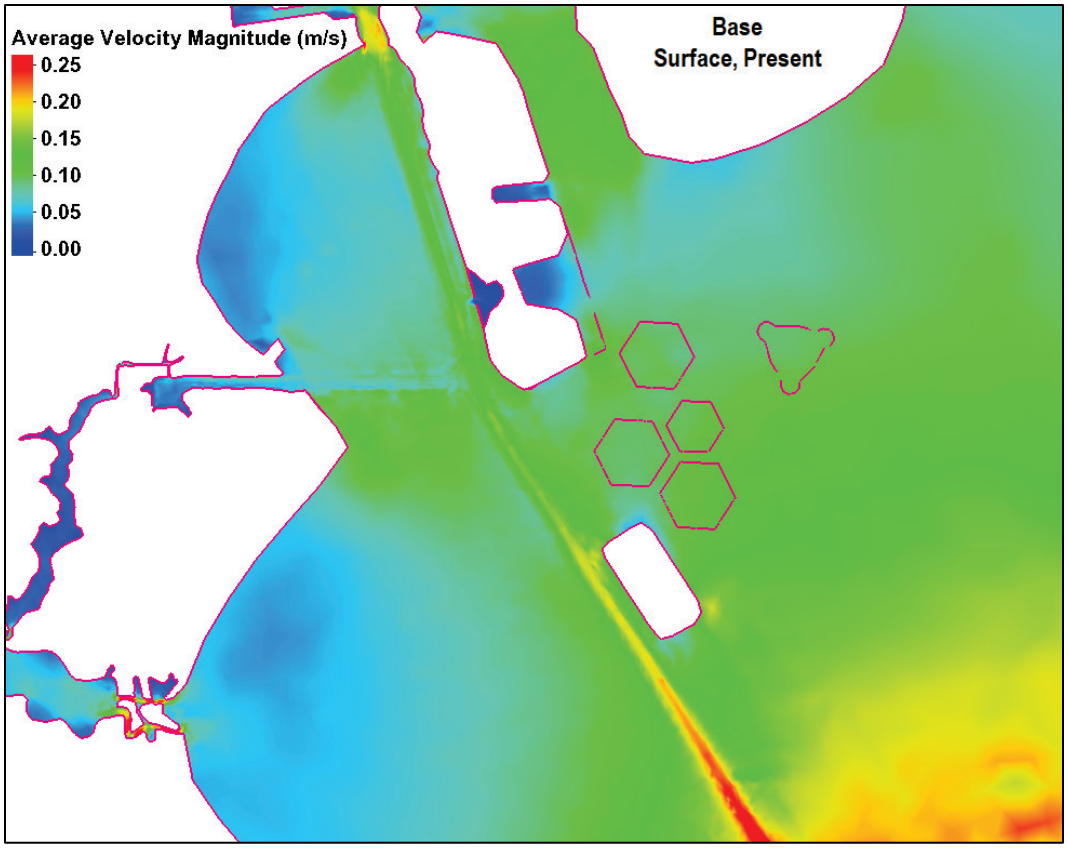
Average velocity magnitude in vicinity of BABUS Cells (Present)

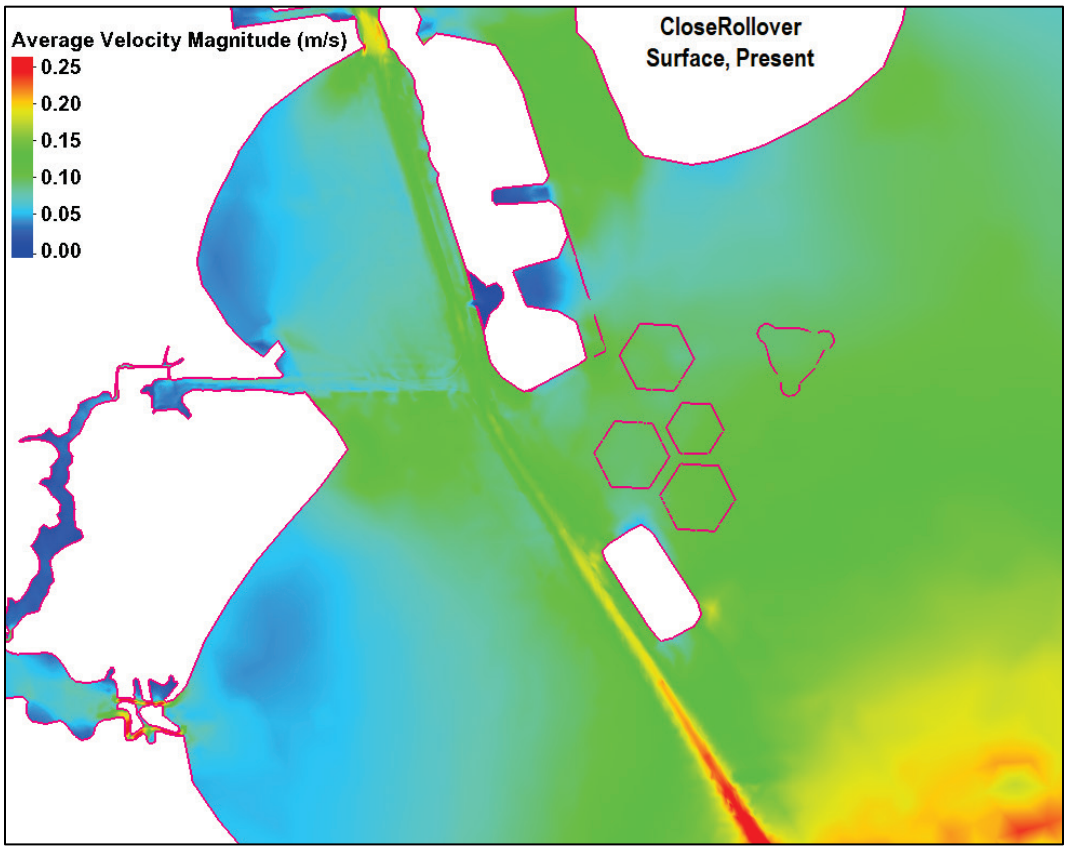


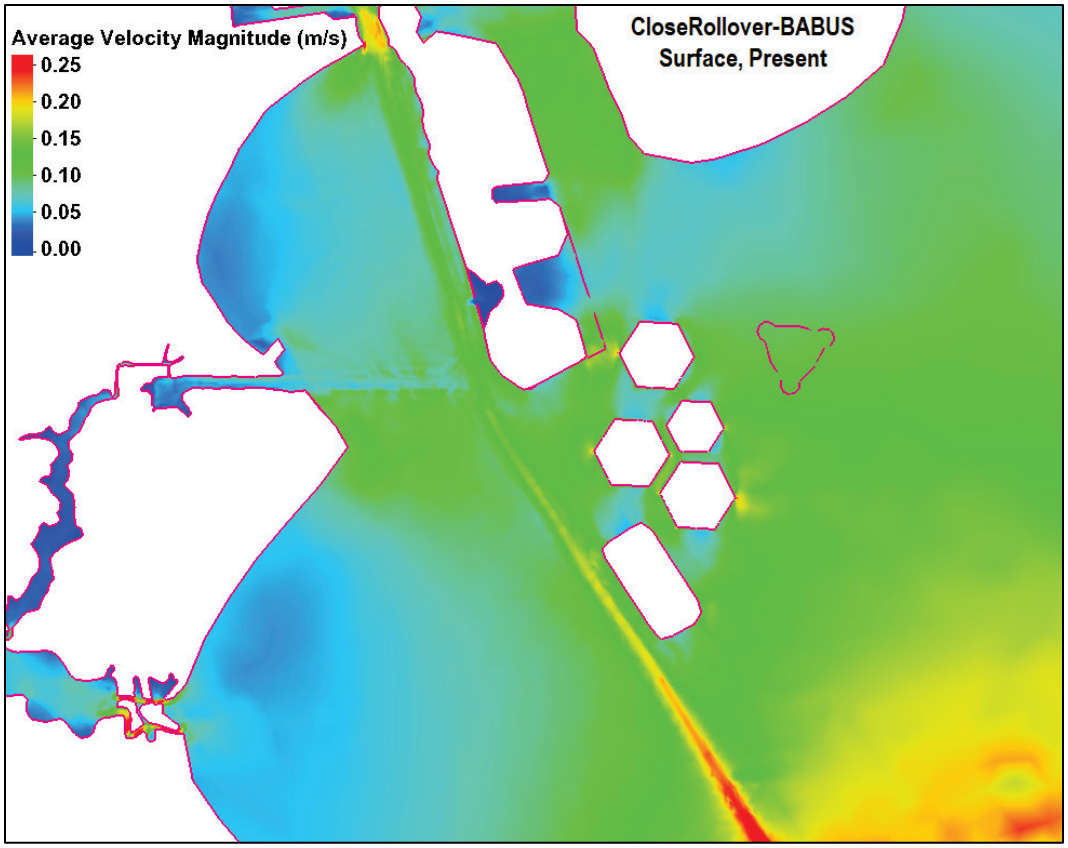


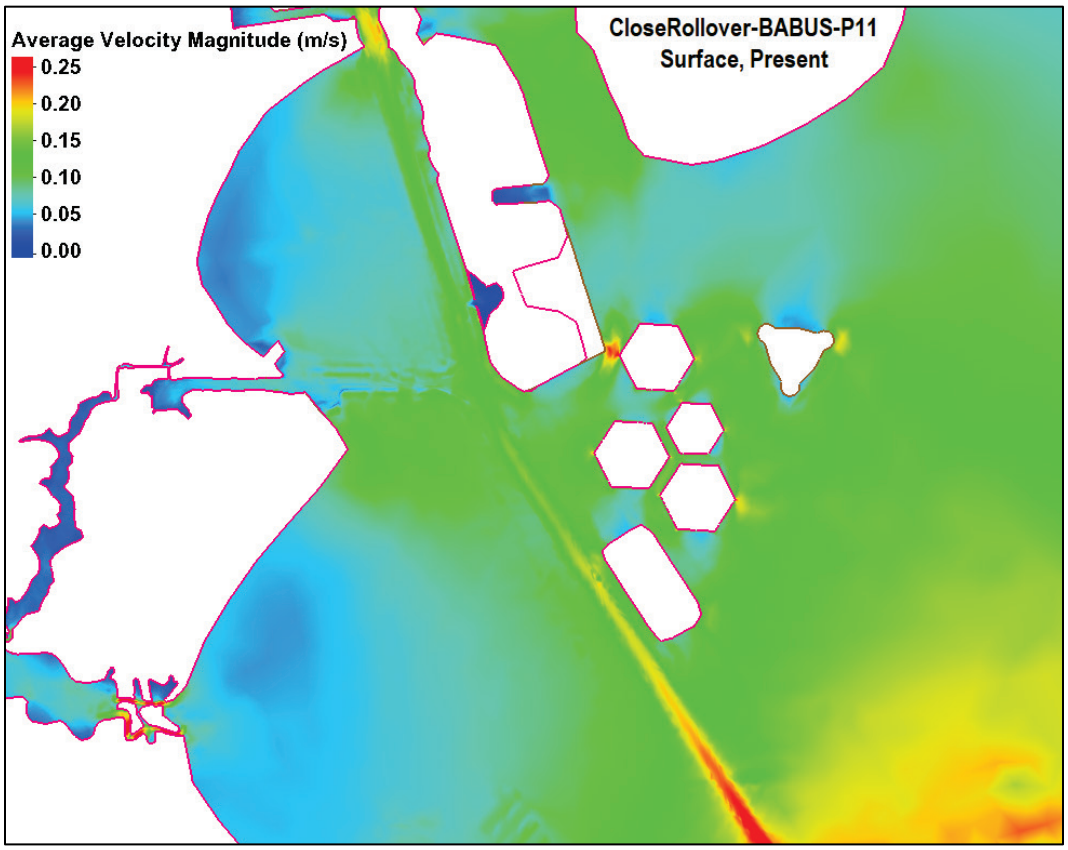

Average Velocity Magnitude (m/s)
0.25
0.20
0.15
0.10
0.05
0.00
CloseRollover-BABUS
Bottom, Present


Average Velocity Magnitude (m/s)
0.25
0.20
0.15
0.10
0.05
0.00
CloseRollover-BABUS-P11
Bottom, Present


Average Velocity Magnitude (m/s)
0.25
0.20
0.15
0.10
0.05
0.00
Base
Surface, Present


Average Velocity Magnitude (m/s)
0.25
0.20
0.15
0.10
0.05
0.00
CloseRollover
Surface, Present


Average Velocity Magnitude (m/s)
0.25
0.20
0.15
0.10
0.05
0.00
CloseRollover-BABUS
Surface, Present


Average Velocity Magnitude (m/s)
0.25
0.20
0.15
0.10
0.05
0.00
CloseRollover-BABUS-P11
Surface, Present

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
cubic feet per second	0.02831685	cubic meters per second
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
inches	0.0254	meters
knots	0.5144444	meters per second
miles (nautical)	1,852	meters
miles (US statute)	1,609.347	meters
square feet	0.09290304	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

Acronyms and Abbreviations

3D	three-dimensional
AdH	Adaptive Hydraulics
AM	advanced maintenance
AO	Allowable Overdepth
BABUS	Bay Aquatic Beneficial Use System
CHL	Coastal and Hydraulics Laboratory
ECIP	Expansion Channel Improvement Project
ERDC	US Army Engineer Research and Development Center
HSC	Houston Ship Channel
MLLW	Mean Lower Low Water
PHA	Port of Houston Authority
SWG	Galveston District
TSP	tentatively selected plan
TWDB	Texas Water Development Board
USACE	US Army Corps of Engineers

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Jennifer McAlpin and Cassandra Ross

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14. ABSTRACT
The Houston Ship Channel (HSC) is one of the busiest deep-draft navigation channels in the United States and must be able to accommodate increasing vessel sizes. The US Army Engineer District, Galveston (SWG), requested the Engineer Research and Development Center, Coastal and Hydraulics Laboratory, perform hydrodynamic and sediment modeling of proposed modifications in Galveston and Trinity Bays and along the HSC. The modeling results are necessary to provide data for hydrodynamic, salinity, and sediment transport analysis.

SWG provided three project alternatives that include closing Rollover Pass, Bay Aquatic Beneficial Use System cells, Bird Islands, and HSC modifications. These alternatives and a Base (existing condition) will be simulated for present (2029) and future (2079) conditions. The results of these alternatives/conditions as compared to the Base are presented in this report.

The model shows that the mean salinity varies by 2–3 ppt due to the HSC channel modifications and by approximately 5 ppt in the area of East Bay due to the closure of Rollover Pass. The tidal prism increases by 2.5% to 5% in the alternatives. The tidal amplitudes change by less than 0.01 m. The residual velocity vectors vary in and around areas where project modifications are made.

15. SUBJECT TERMS
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