Sebastian Inlet District Oceanographic and Meteorological Monitoring Program

Annual Report for 2025

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Executive Summary

Currents, waves, and weather data recorded during 2025 are presented in this report. The real time wave gauge system was services following an extended outage due to cable failure and came back online 22 January 2025. Seawater intrusion in the plug had corroded a single conductor. The system has been performing well since, with two planned interruptions to data acquisition to back up the data files stored in the unit. Spectrum internet was installed in the electronics shed to replace Florida High Speed that had no connectivity due to line-of-sight obstruction, likely caused by the nearby sea grapes. Monitoring data from the Sebastian Inlet State Park ADCPs and weather station serves a wide and diverse audience and is incorporated in data reported by SECOORA and NOAA at the station designated as Station SIPF1 under the National Data Buoy System. Data collected by the weather station and Acoustic Doppler Current Profiler (ADCP) from 2025 are presented in this report.

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Acknowledgments

We would like to thank the Sebastian Inlet District for their support of long-term monitoring.

1.0 Introduction

The monitoring network at the Sebastian Inlet includes a meteorological station on the north jetty and two nearshore acoustic Doppler current profiler (ADCPs) gauges located approximately 0.5 km north of the inlet in approximately 8 m of water depth. Data from this network serves a diverse audience. Data collected via the ADCPs includes information about currents, waves, water temperature and water level. The real-time meteorological station located on the Sebastian Inlet north jetty records wind direction, wind speed, barometric pressure, air temperature, sea surface temperature, and water level. The water level gauge is referenced to the mean lower low water (MLLW) vertical datum, which can be related to other vertical datums such as NAVD88. These data are used to calibrate the ongoing coastal processes model and applied to analysis of regional sediment management of the central Florida coast that includes the Sebastian Inlet. Real-time data for the ADCPs was established in 2012 and provides a resource for the navigation through the narrow throat of the Inlet and is combined with real-time forecast of water level, currents, and directional wave data proved by the Delft3D model of the central Florida coast. Data from the Sebastian Inlet Weather Station updates the project web page and are automatically sent to the National Oceanic and Atmospheric Administration (NOAA) and posted to the NOAA NBDC Station SIPF1. Data provided by the Delft3D forecast model, NOAA nearshore buoys 41113 and 41114, and the real-time wave data provide regional coverage of the directional wave field not found in most other areas of US coastal waters. The measured and modeled data are used to support shore protection projects by Federal, State, and local agencies.

2.0 Equipment Maintenance

The real-time wave gauge system was rehabilitated during the 2025 period and has been performing well since. The communications cable connecting to the offshore wave gauge was repaired at the seaward end after being compromised by saltwater intrusion. In the data receiving electronics shed located on the north side of Sebastain Inlet, an upgraded a power supply system provides power down the cable to the wave gauge. Multiple repairs and sensor replacements were made to the weather station on the seaward end of the Sebastian Inlet north jetty. During this process, the wind anemometer was replaced and calibrated. This resulted in a minor loss of wind velocity data. Figure 1 shows the locations of the monitoring system components.

The Sebastian Inlet data is made available in the following sources:

- Florida Institute of Technology webpage
  - https://coastal.fit.edu
- South East Coastal Ocean Observing Regional Association's webpage (SECOORA)
  - https://portal.secoora.org/#map
- NOAA's National Data Buoy Center (NDBC) website
  - https://www.ndbc.noaa.gov/station_page.php?station=sipf1.

- Delft3D coastal processes forecast model
  - https://realtimefl.github.io/Sebastian_Inlet

Figure 1. Location of Sebastian Inlet State Park oceanographic and meteorological instrumentation sites. The aerial photo and bottom topography are courtesy of the Sebastian Inlet District.

3.1 Instrumentation

3.1 ADCPs

Two ADCPs are co-located at the study site; one is real-time, and the second is for redundancy. Teledyne R.D.I Instruments (RDI) 1200kHz Workhorse Sentinels ADCP are continuously co-deployed at the site offshore of SISP (Figure 2). Both instruments collect wave height, wave direction, current magnitude, current direction, water level and water temperature. The RDI has been cabled and powered from a shore station since early 2012. The second autonomous ADCP has a deployment time of approximately six months limited by battery life and biofouling. Routine maintenance of each gauge for biofouling occurs multiple times during the deployment. Each gauge measures the data by using the Doppler Effect of a transmitted signal from three or four transducer heads. Pressure is measured via an internal pressure sensor and water temperature from a thermistor. Data is stored in an internal memory card; each instrument's propriety software is used to download and process the raw data once the instruments are recovered. The cabled ADCP data are also stored on an internal memory card and sent along the cable to a computer onshore and automatically sent to Florida Tech for processing, archiving, and posting on the webpage. The mounting pole for the remote ADCP site was replaced in 2018. The gauge at this site is autonomous and is replaced at 6-month intervals.

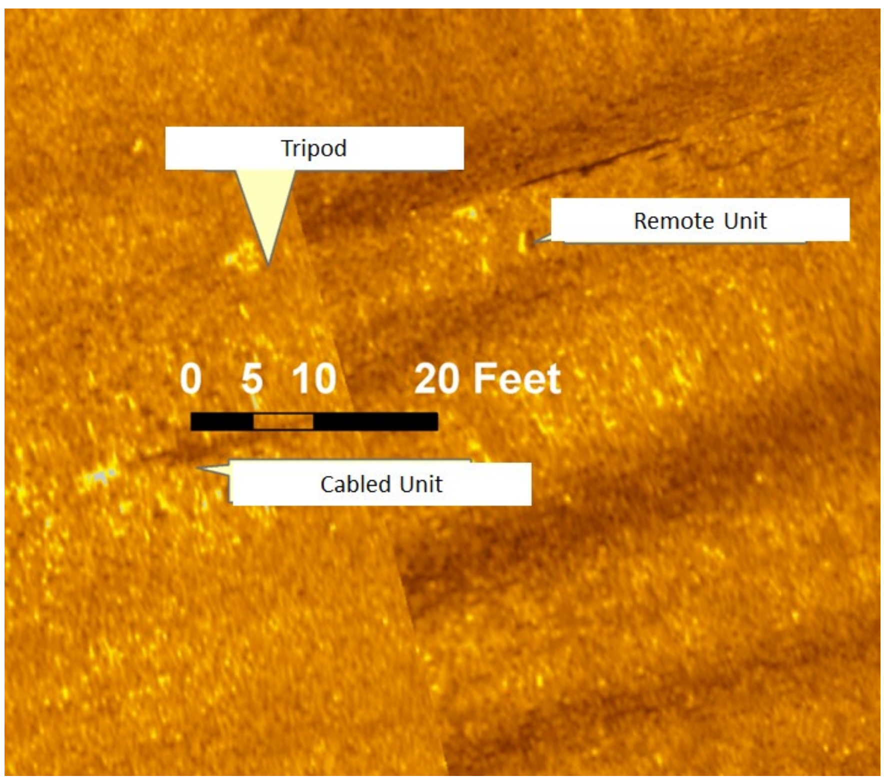

Figure 2. Deployment configuration of the ADCP instruments as seen in a side-scan sonar record.

3.2 Weather Station

The Meteorological station is located atop the mast at the seaward end of the SISP north jetty 10 meters (30 feet) above the water. This is the standard reference height for wind data collection. This system includes an anemometer for measuring wind speed and direction, barometric pressure sensor, air temperature sensor, radar water level gauge. Other components of this station include a data logger with cellular communication and a solar panel which provides power to the station.

A Campbell Scientific Radar Water Level sensor was first installed in early September 2015 and is replaced at an approximate 2-year cycle due to the harsh conditions and wave attack on the north jetty of Sebastain Inlet. The water level sensor is mounted to the north jetty cap and sends a radar signal to the water to measure the water level. This is a remote sensing approach to recording water elevation which minimizes the effects of biofouling. A stainless-steel housing was constructed and installed to help protect the instrument from damage from fishing equipment entanglement. This housing is occasionally lost during storms and a replacement is occasionally fabricated and reinstalled. A cable runs from the radar water level gauge along the north jetty cap enclosed in a protective schedule 40 conduit. The cable continues underneath the cap and runs to the top of the Meteorological station inside the tower mast. Both the cable and PVC conduit were replaced in early 2024 after a lifespan of about 10 years for the original installation

4.0 On-Site Operations

A new connection and power supply was installed in the electronics shed in 2018 and refurbished as described under Section 2. This new connection is contained within a weather resistant box, which houses both the real-time cable connection and power supply. As an interim remedy to potential cable failure, the communications protocol has been reverted to RS232 over an RS485 converter to utilize two wires for transmission and receiving over the shore cable instead of the four wires required for the previously utilized RS422 communications protocol. In 2024, the power supply system was upgraded with new circuit boards that process the two-way communications between the ADCP and computer (In 2025, Spectrum Internet replaced the Florida High Speed service. Figure 3 shows the cable route to the electronics shed from A1A

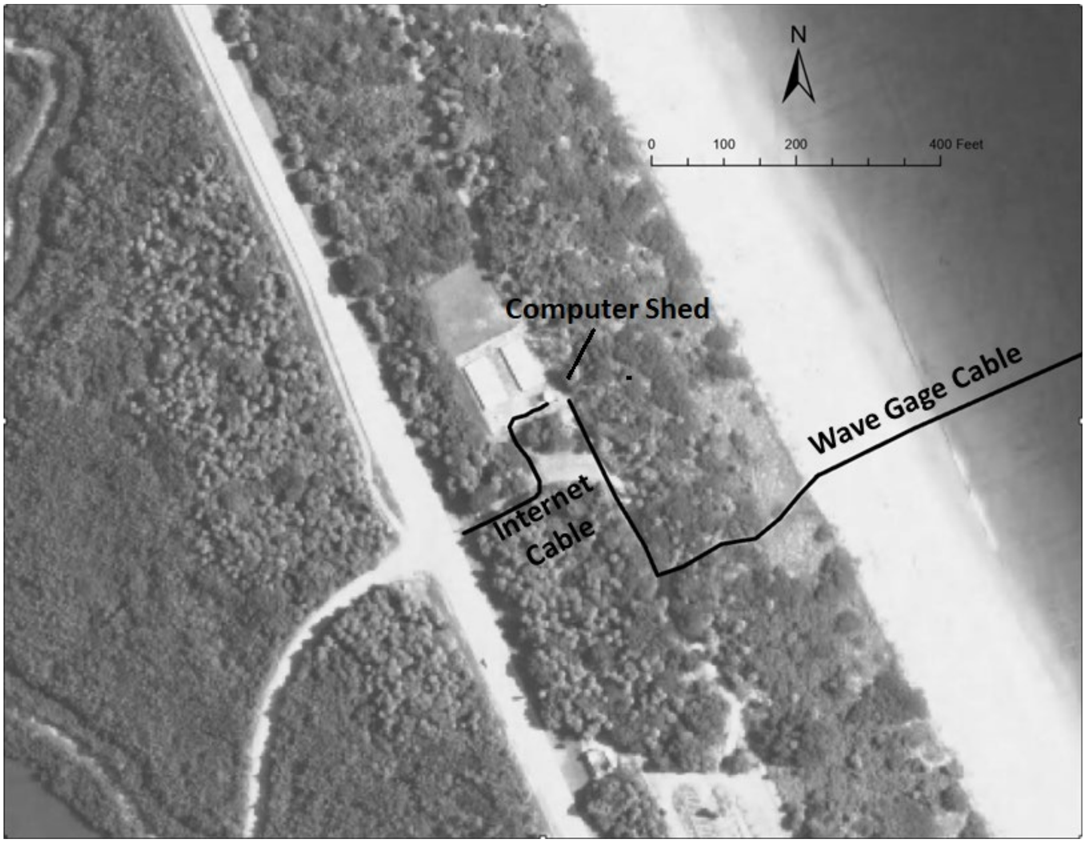

Figure 3. Internet and wave gage cable routes

5.0 Data Presentation

Figure 4 shows a flow chart of data handling among the various sensors maintained by Florida Tech on behalf of the Sebastian district. This data flow stream has been in place since 2012. The data handling system is now being revised and moved over to processing in the cloud using Amazon Web Services (AWS) before final storage on the Sebastian Inlet service provider (SISP) server. Figure 5 shows the flow of data collection and post processing in the AWS environment before final storage on the SISP. The AWS will accumulate data streams into the cloud and distribute to the project web site and provide transfer of all data to the SISP server.

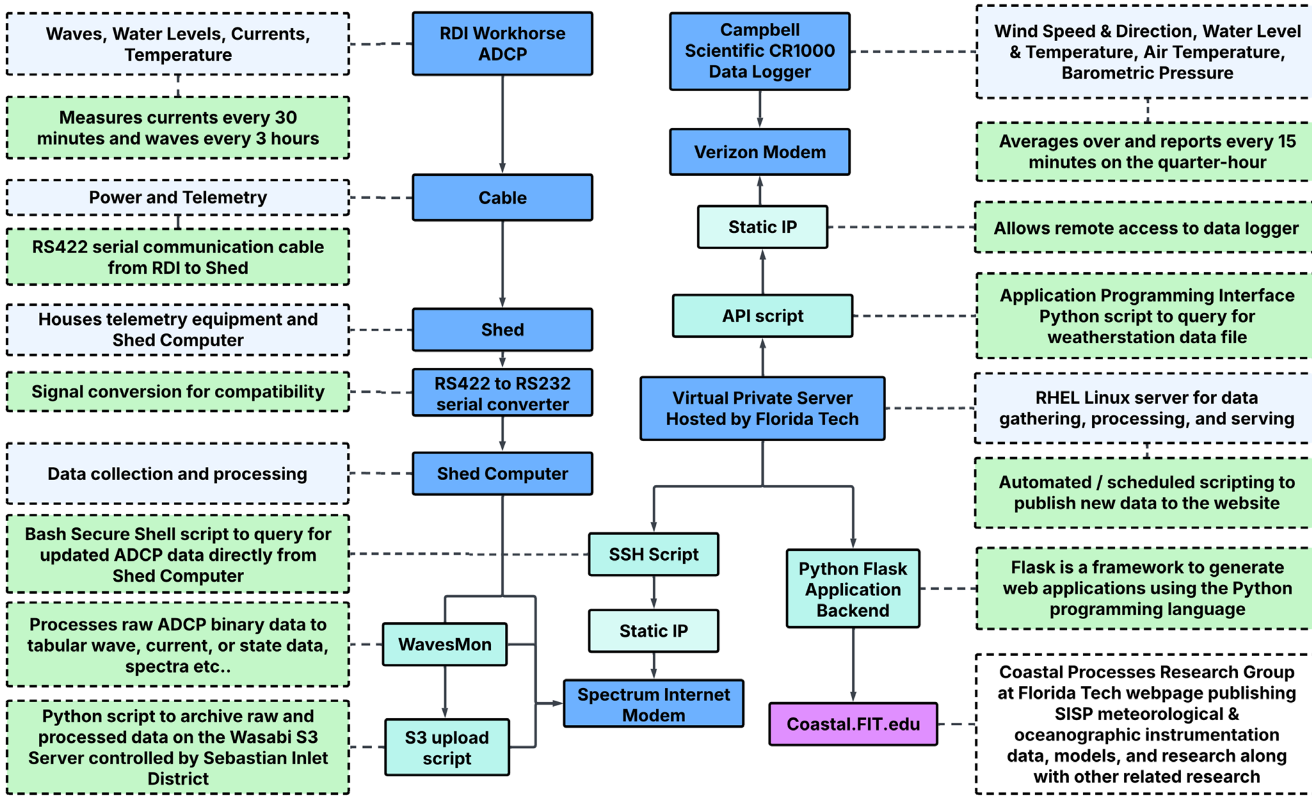

Figure 4. Flow diagram of the present data handling and processing system.

5.1 Statistics

Table 1 through 6 summarize basic statistics from the field gauges spanning the 2025 period. Longer term statistics at the 10, 15, and 23-year timescales are also provided for wave parameters. The longest time available for currents is 19 years since the years 2002 through 2004 are not available. The median depth averaged current direction is toward the south; nearly shore parallel. The median wave direction is from the northeast. The range of depth-averaged current speed at the ADCP site over the past year was from near zero to a maximum of approximately 0.54 m/s. The average speed was about 0.12 m/s in the southerly flow. Wave height ranged from 0.23 m to a maximum of about 3.5 m, which occurred on December 12th, 2025. The average for significant wave height for 2025 was 1 m. The average wave period was about 8.8s from the east-northeast Table 5 Summarizes 2024 meteorological parameters. Wind speeds range from near calm to about 23 m/s (51 mph). Other metrological parameters are discussed in comparison with water level and Gulf Stream flux data later in this report. Directional distributions of waves, currents and winds are presented in a series of rose diagrams in the concluding section of this report. Table 6 summarizes metrological statistics over the period of record, 1996 to 2024.

Table 1. Wave Statistics 2025

	Wave Height (m)	Wave Period (s)	Wave Direction (°TN)
Minimum	0.19	2.56	
Maximum	2.69	16.9	
Average	0.78	8.50	60.23

Table 2 Wave Statisitcs: 10,15,29 years [1996 – 2025].

	Wave Height (m)			Wave Period (s)			Wave Direction (°TN)		
	10yr.	15yr.	29yr.	10yr.	15yr.	29yr.	10yr.	15yr.	29yr.
Minimum	0.12	0.11	0.01	2.2	1.70	1.70			
Maximum	4.86	5.10	5.10	21.0	21.0	21.0			
Average	0.85	0.84	0.80	8.9	8.8	8.7	63.27	64.55	64.66

Table 3 Annual Current Statisitcs: 2025.

	Current Speed (m/s)	Current Direction (°TN)
	1 year	1 year
Minimum	0.03	
Maximum	0.68	
Average	0.20	170.91

Table 4. Current Statistics: 10, 15 and 29 Years [1996 – 2025]

	Current Speed (m/s)			Current Direction (°TN)		
	10yr.	15yr.	29yr.	10yr.	15yr.	29yr.
Minimum	0.00	0.00	0.00			
Maximum	1.52	1.60	1.96			
Average	0.14	0.10	0.12	162.45	159.22	158.34

Table 5. Statistics for 2025 meteorological data .

	Wind Speed (m/s)	Wind Direction (°TN)	Barometric Pressure (mb)	Air Temperature (°C)	Water Temp at Surface (°C)	Water Temp at Depth (°C)
Minimum	0.00		1002.42	5.25	3.48	13.62
Maximum	17.91		1027.74	32.03	31.22	31.19
Average	4.72	70.33	1015.39	23.14	21.41	23.97

Table 6. Meteorological data statistic 1996-2025.

	Wind Speed (m/s)	Wind Direction (°TN)	Barometric Pressure (mb)	Air Temperature (°C)	Water Temp at Surface (°C)	Water Temp at Depth (°C)
Minimum	0		931	-0.46	2.77	12.22
Maximum	44.2		1036	36.80	44.33	31.75
Average	4.84	96.15	1017.15	23.32	23.76	23.59

5.2 Time Series

5.2.1 Wave Height and Water Level Data

Wave height time series for 2025 observation period is shown in Figure 6. The seasonal variation in the record is observed as shown by an increase in average and maximum wave heights from October to March. Lower waves are observed in May through late August. This quiescent period is normal for this area during the summer months. Wave heights did not exceed 3 meters this year. However, significant wave heights approached and exceeded 2 meters in early October 2025, followed by four more short-term occurrences of wave heights between 1.5 and 2 meters for the remainder of the year. Figure 6 displays the direction height of wave energy for 2025, which is from the northeast.

Figure 7 Shows joint probability plots among wave height, wave direction and wave period. This allows a perspective view of the concentration of sea-state observations across the parameter space.

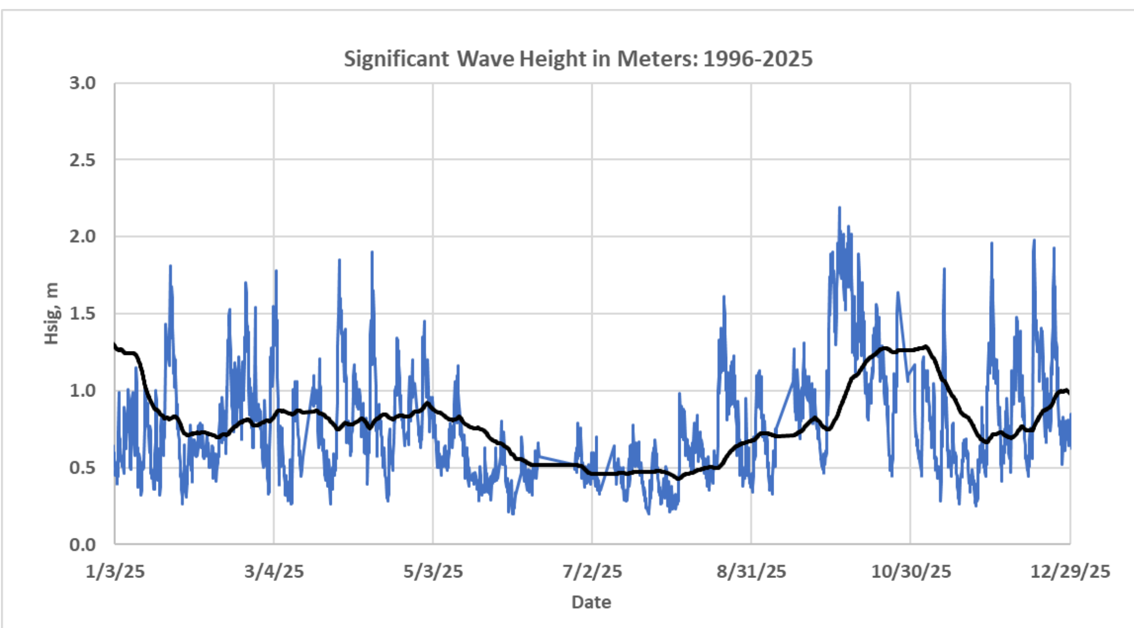

Figure 5. Wave Height time series January 2025 to December 2025

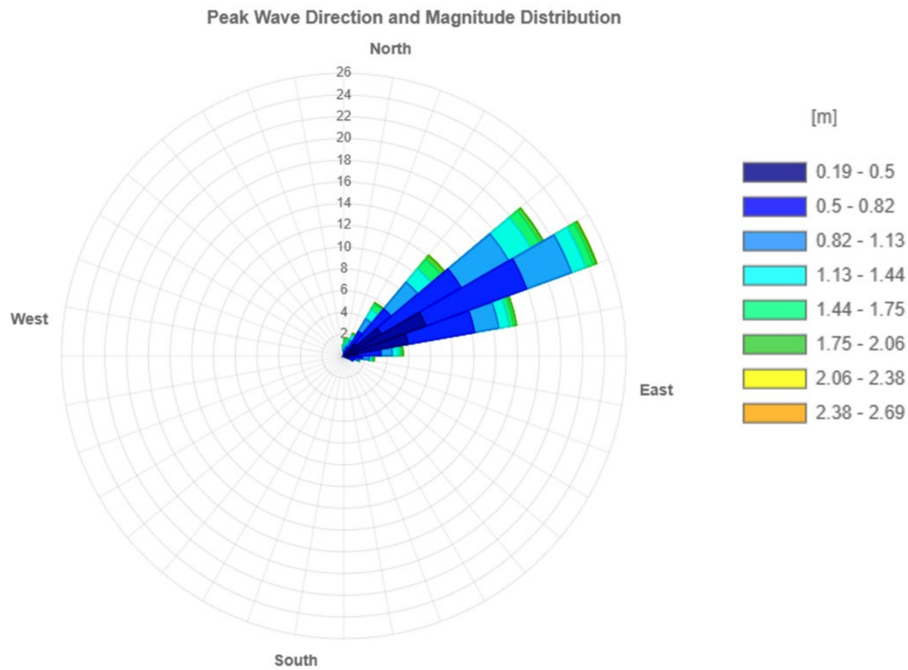

Figure 6. Wave Direction and Height from January 2025 to December 2025

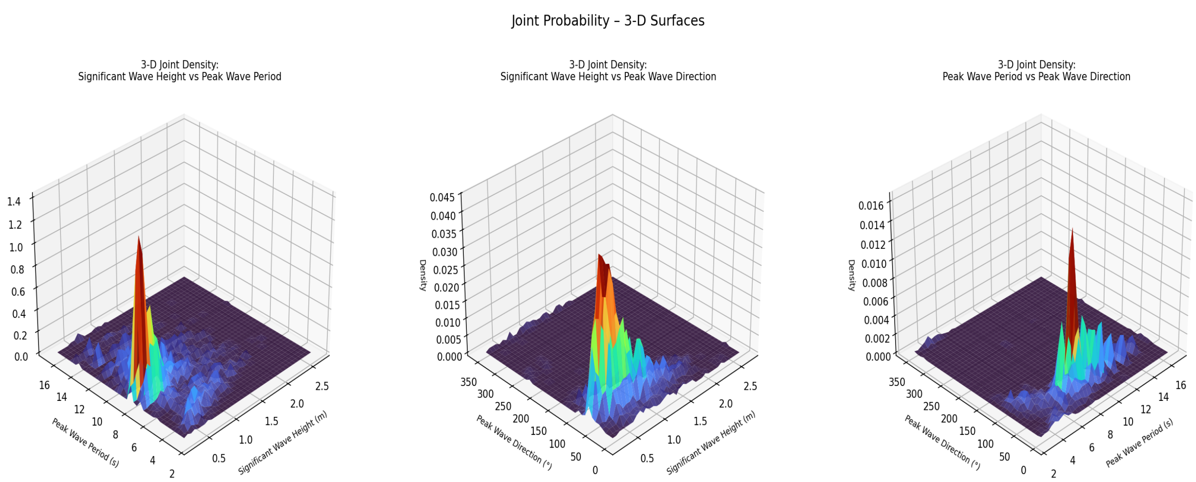

Figure 7. Three-dimensional surface representations of the joint probability density for each parameter pair. The vertical axis represents probability density, offering a perspective view of the concentration of sea-state observations across the parameter space.

Figure 8 plots the historical record of significant wave height just offshore of Sebastian Inlet. The record shows the strong seasonal variation is wave height according to monthly averages of the BLR center line. All the large, recorded wave heights above 5m (16ft) can be attributed to hurricane events, either striking the Florida coast or approaching Florida from hurricanes passing by Florida offshore, like Hurricane Sandy in 2012.

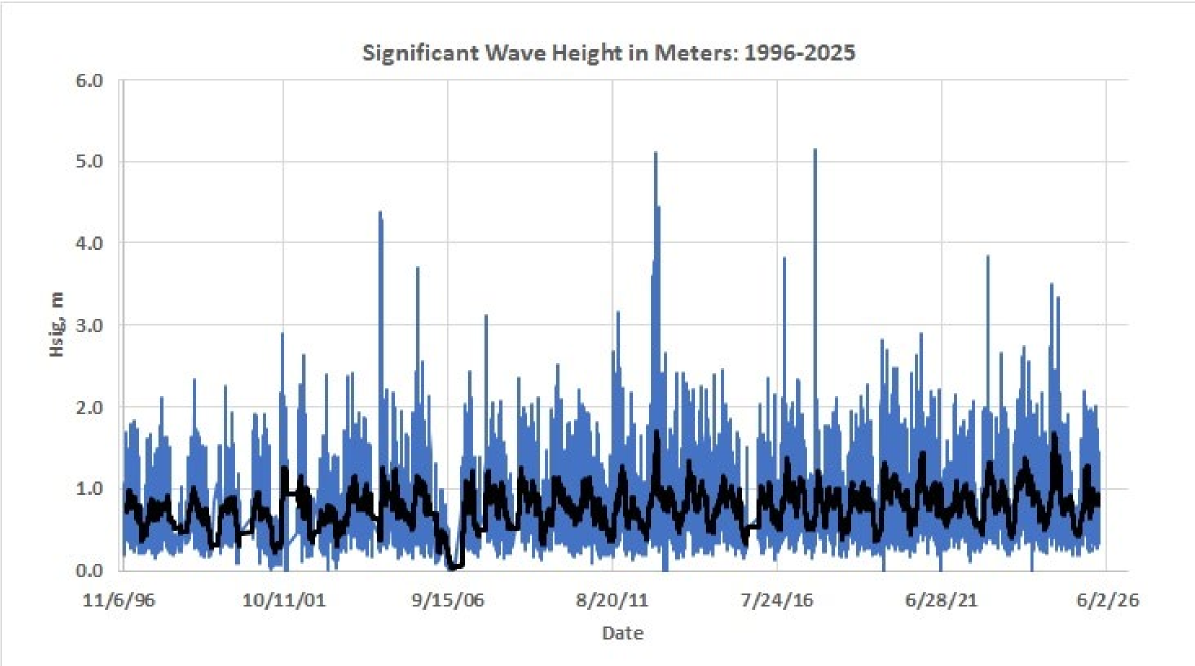

Figure 8. Historical wave height record at Sebastian Inlet

Water level data from January 2025 through December 2025 is shown in Figure 9. The plot includes a trendline used to filter out the tide signal to show sea level changes over the past year. The seasonal shift in water level from an annual low stand in late July to an annual high stand in late October is linked to variations in the Gulf Stream flow (Zarillo, 2023). High rates of Gulf Stream flow lower coastal ocean levels. Conversely, the slowing down the GS flow results in higher sea levels at the coast. Figure 10 exemplifies this inverse relationship between January 2022 and December 2025.

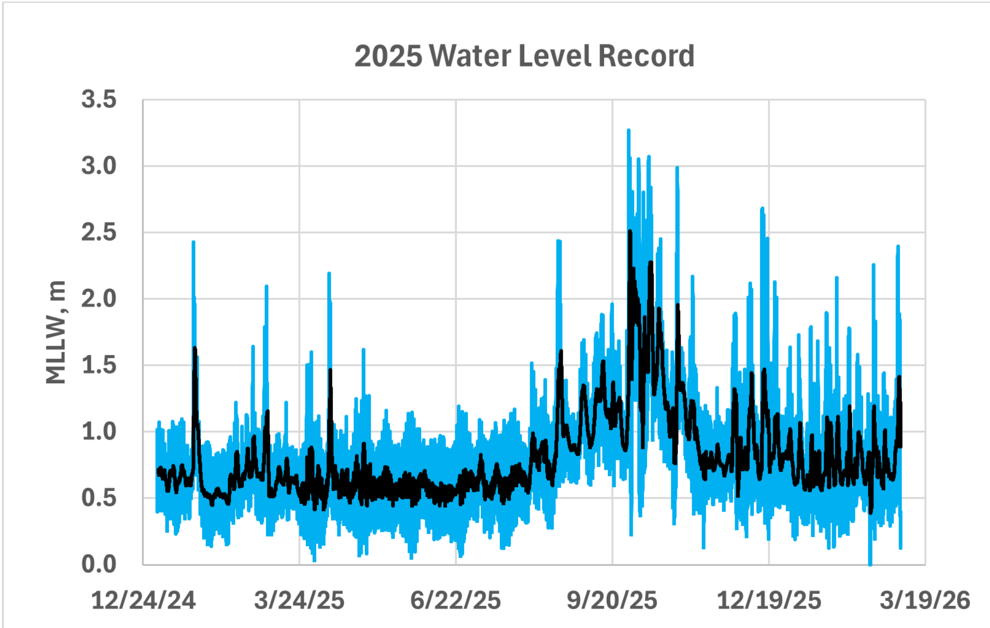

Figure 9. Water level data at Sebastian Inlet 2025

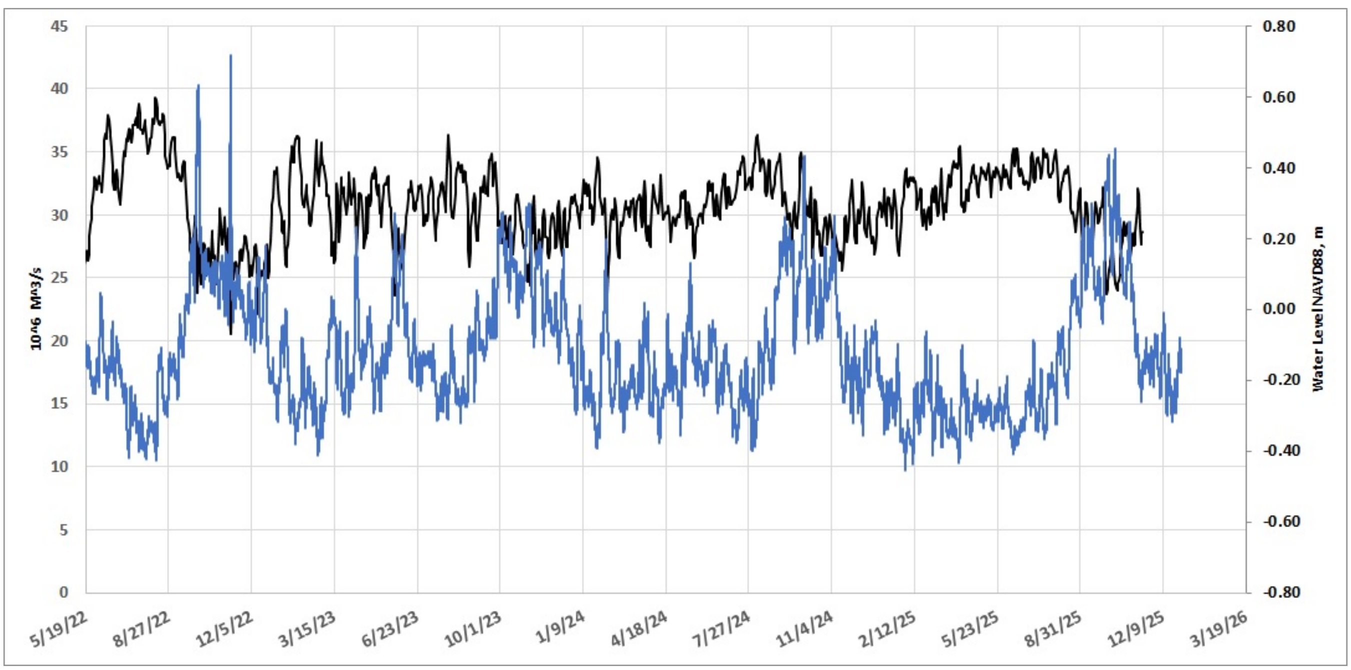

Figure 10. Comparison of Gulf Stream flow and sea level from May 2022 to December 2025.

The sea level record from 2006 through January of 2025 is plotted in Figure 11. Nontidal and the trend of rising sea levels are superimposed on the blue line dominated by tide levels. The annualized sea level from the record is plotted in Figure 13 and shows a net sea level rise of about 20 cm (0.6 ft.) within this record. Interannual increases and declines in sea level of up10 cm can be seen.

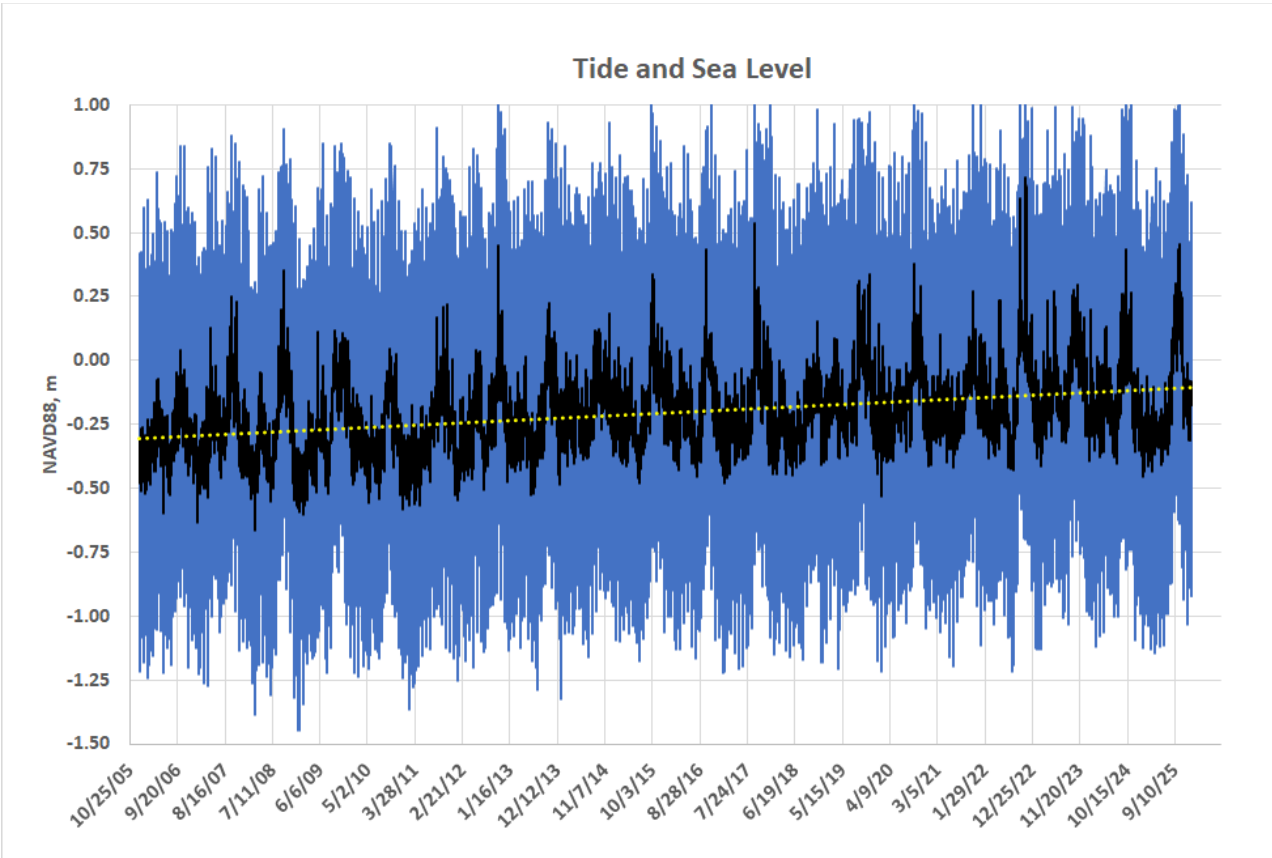

Figure 11. Tide and sea level record at Sebastian Inlet 2006-2024. Blue = tidal level, black = daily non tidal sea level and yellow = trend.

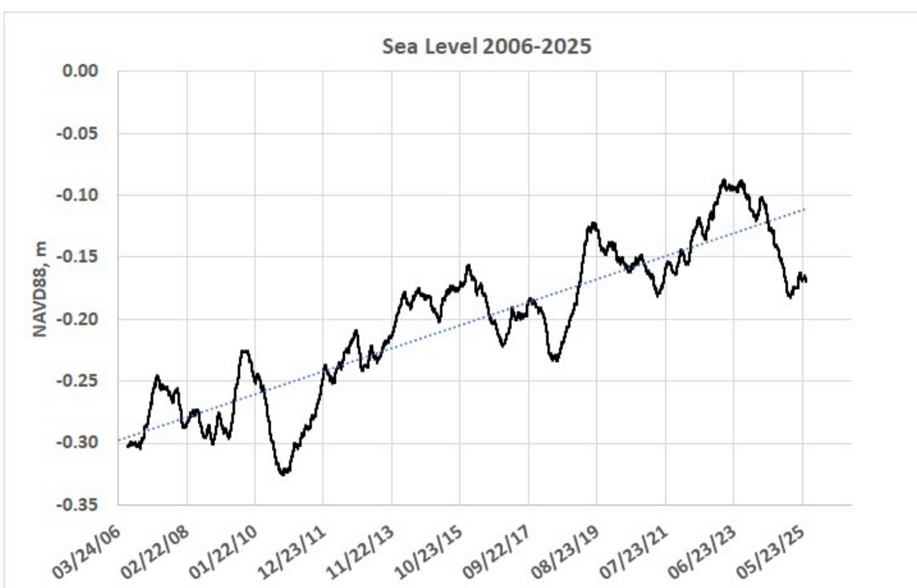

Figure 12. Annual average sea level at Sebastian Inlet 2006-2025.

5.2.2 Weather Station

The wind speed record from the north jetty weather station is shown in Figure 10 . The seasonal variation in wind speed is apparent in the higher speeds occurring in the winter months and lower speed occurring in the summer months. Figure 14 shows the direction and magnitude recorded by the North Jetty weather station during the same period.

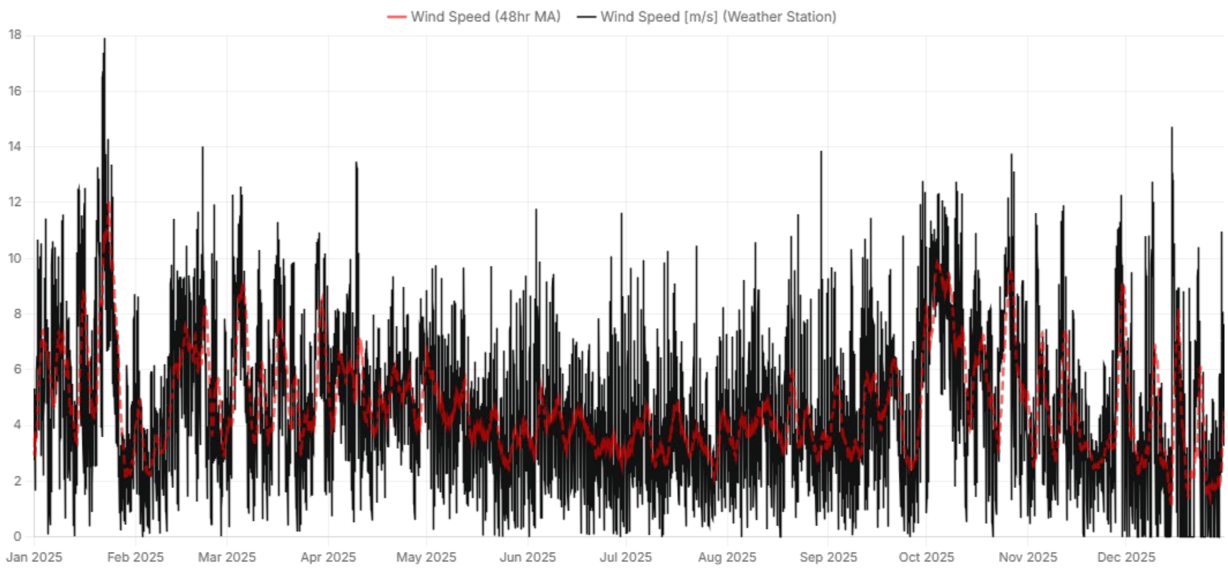

Figure 13. Wind speed time series January 2025 to December 2025.

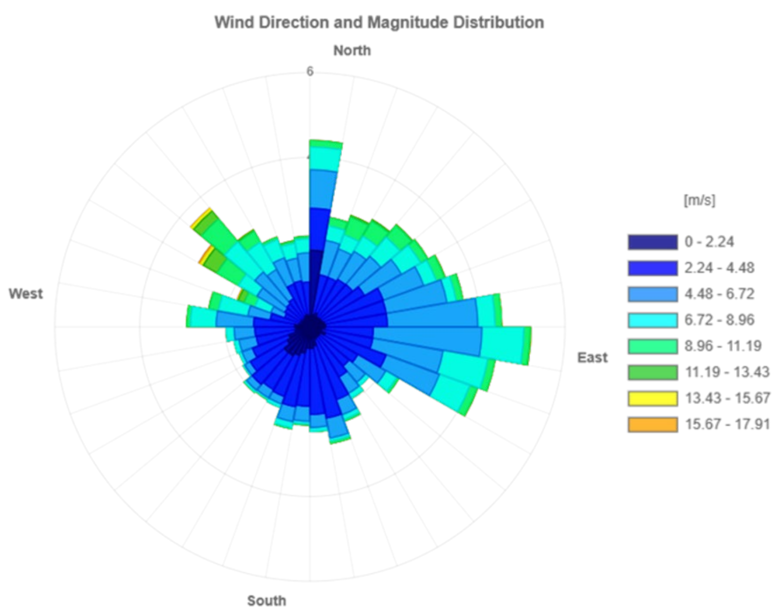

Figure 14. Wind Speed and Velocity magnitude for SISP North Jetty from January 2025 to December 2025

Sea surface water temperature (SST) from the SISP weather station shown in Figure 15. For 2025. Water temperature records both show mid-winter decline in temperatures starting in November lasting through April when temperatures begin to rise. It should be noted that this water temperature is sea surface temperature as measured from the weather station using an infrared (IR) water temperature sensor. Figure 17 presents a comparison between the water temperature measured by the infrared sensor mounted at 10 m above the water surface and the ADCP recorded temperature located in approximately 6m water depth. Air Temperature is also provided on this plot. The temperatures recorded by these 3 methods correlate in seasonal variation, with subsea temperatures maintaining more excellent stability compared to the fluctuations in air and sea-surface temperatures.

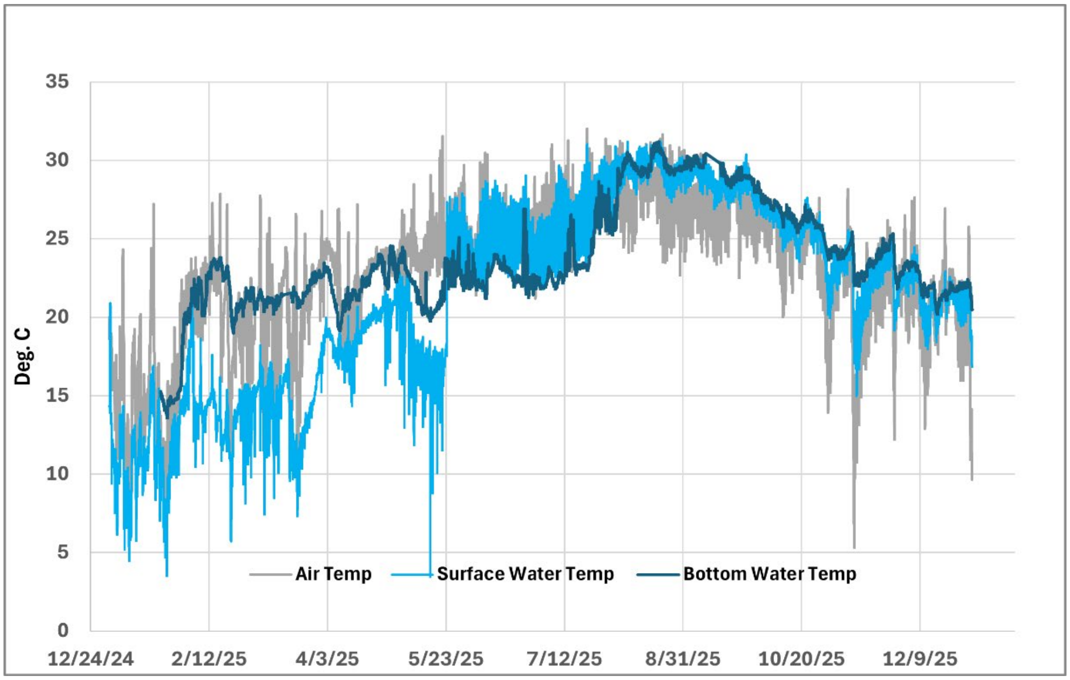

Figure 15. Air, Sea Surface, and Sub- Sea Temperature measured at the SISP North Jetty and ADCP locations.

Figure 16 compares water temperature with Gulf Stream flow over 6 years from late 2022 through November 2025. Possible ocean upwelling events occurred in the summer of 2022, fall of 2023, and summer of 2024, corresponding to a high GS flow that can produce subsurface cross-shore flows, compensating by bringing deep cold water to near the surface of the coastal ocean on the west side of the GS. Upwelling is most easily identified during the summer months when water temperatures are above 25 ^{0}C

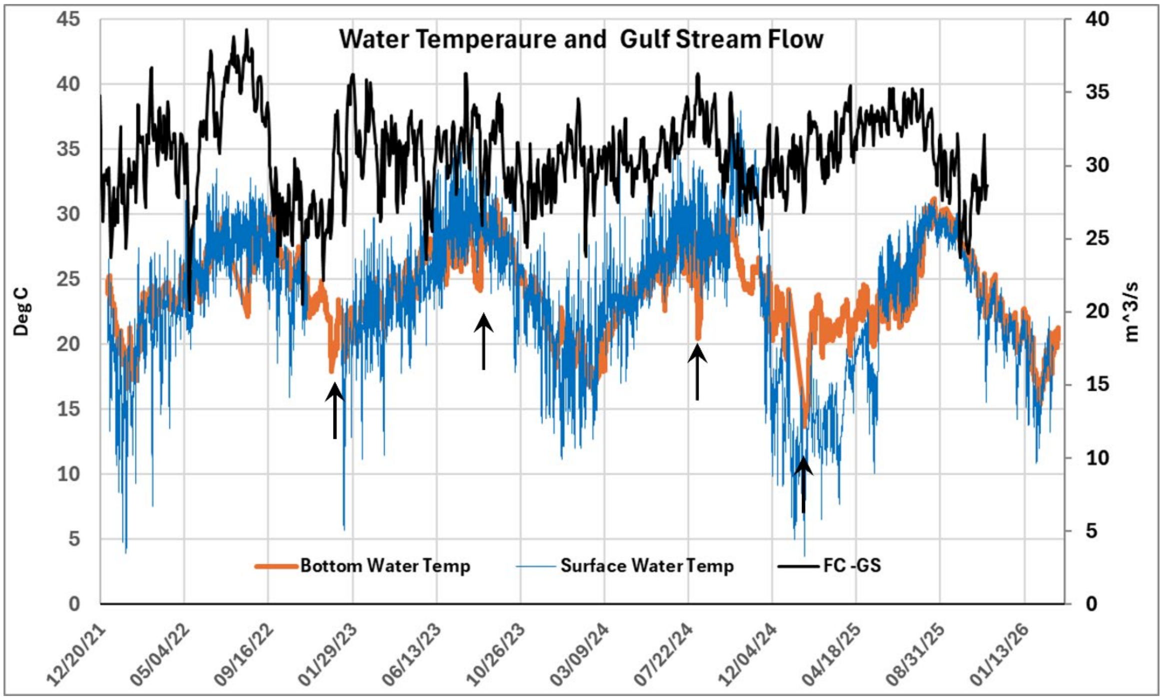

Figure 16. Comparison of water temperature and Gulf Stream flow showing possible upwelling in summer of 2022, fall of 2023, and summer of 2024.

Current magnitude and direction are measured at the bottom-mounted ADCP. Depth depth-averaged current velocity recorded every 30 minutes is shown on Figure 17 as well as a 24-hour moving average to add clarity. Figure 15 shows the depth-averaged current direction and associated velocity magnitudes.

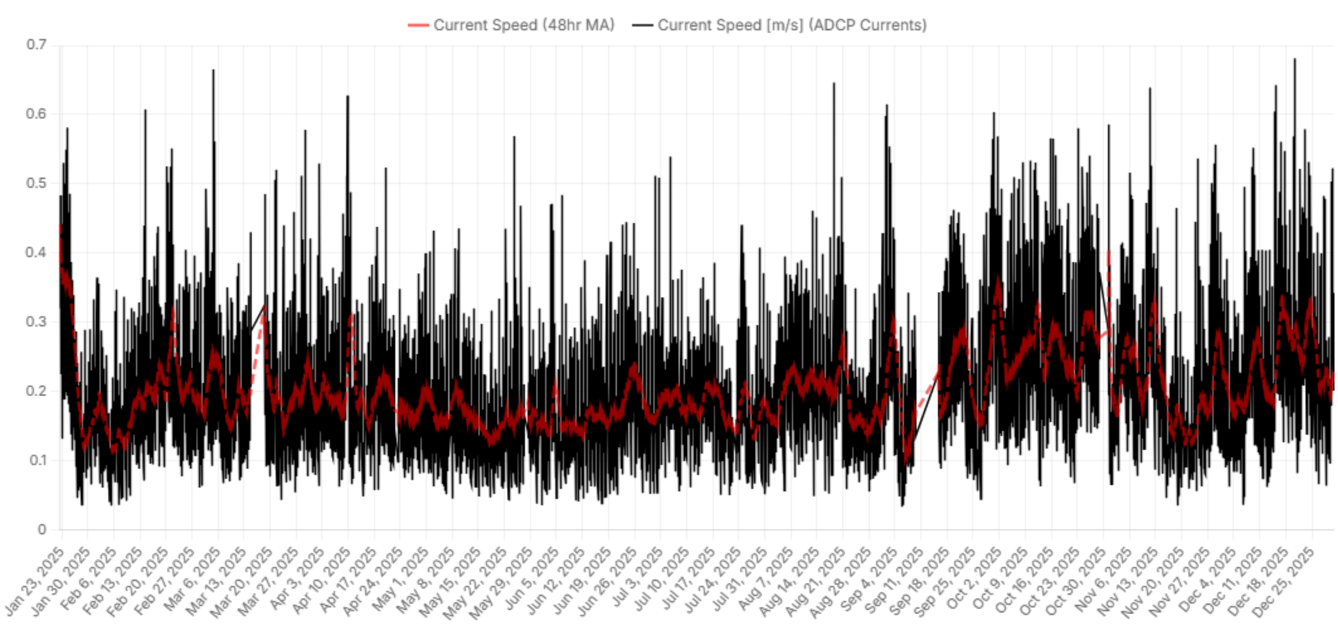

Figure 17. Depth-averaged current magnitude from January 2025 to December 2025.

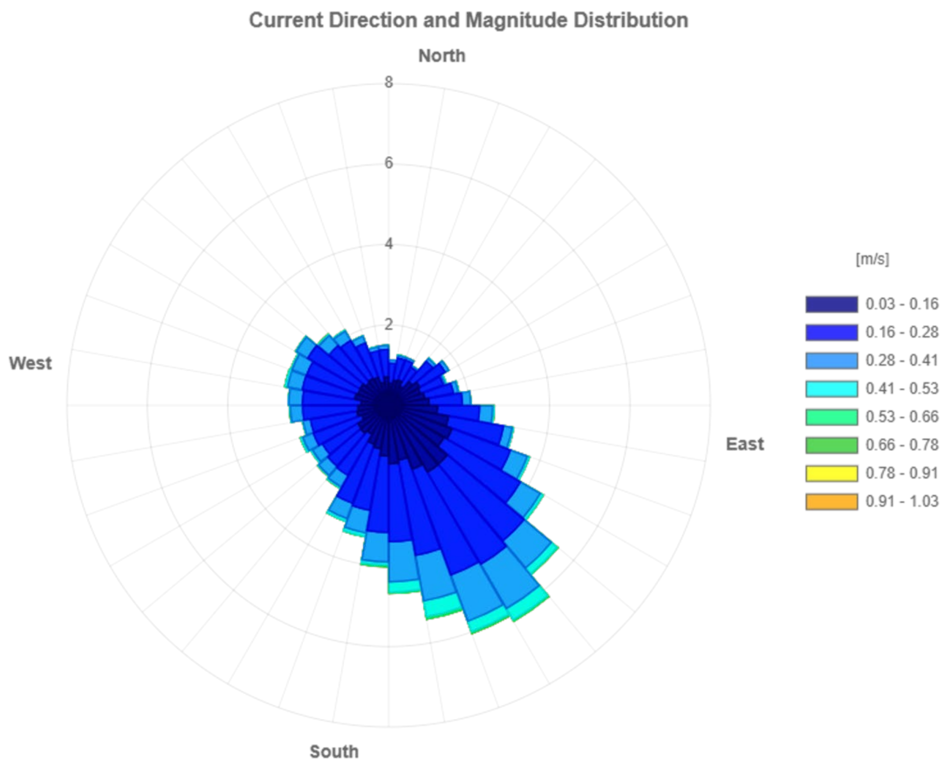

Figure 18. Distribution of current speed, January 2025 to May 2025.

6.0 Sebastian Inlet Current Velocity Data 2021 to 2024

A current profiler was deployed in Sebastian Inlet between October 8th 2012 and May 1st 2024, for a total of 31 months. The ADCP was programed to record data every 30 minutes, includes 19 vertical bins and water depth above sensor. Figure 19 shows the location of the sensor about 1500 feet to the west of the Sebastian Inlet bridge.

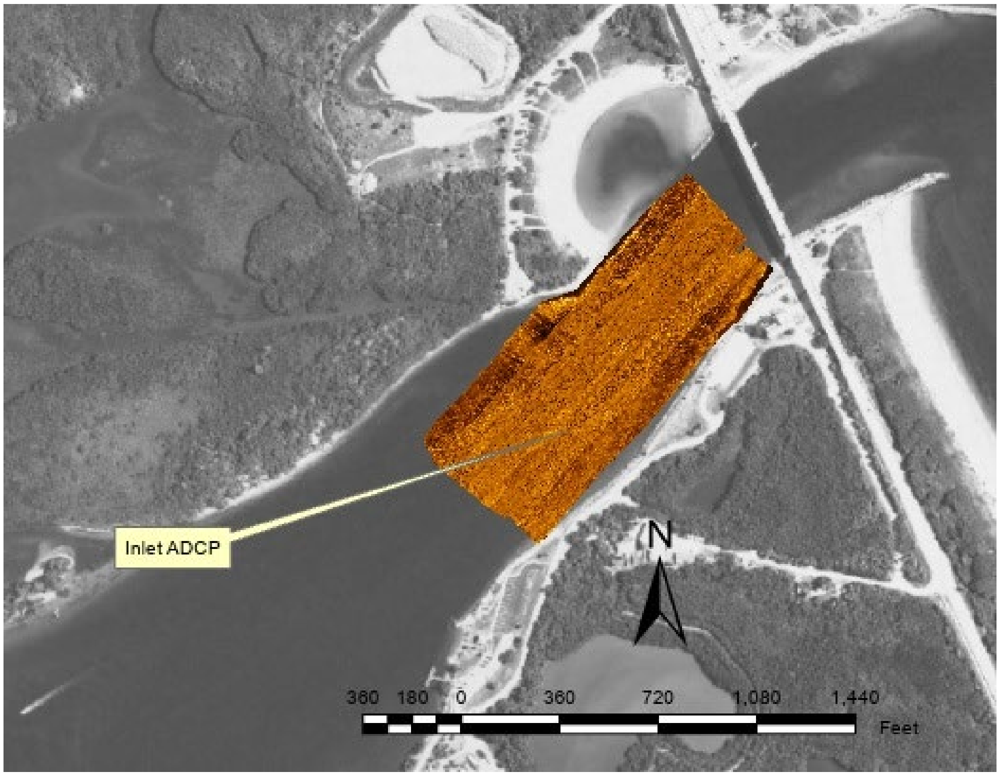

Figure 19. Location of the ADCP sensor within Sebastian Inlet.

Figure 20 presents the complete record of surface flow recorded from October 2021 to May 1st, 2024. In the plot, negative velocity values indicate tidal flow in the flood direction, and positive values indicate flow in the ebb direction toward the ocean. The black center line is a time series of surface currents subjected to a moving average of 25 hours. Figure 21 shows the residual flow without the tidal record/ The flow record in all 19 bins is similar and average over the 25-hour indicate a occasional net, non-tidal residual flow of up to 54 cm per second   Peak velocities during the flood tide (negative values) are higher than the corresponding ebb potion of the tidal cycle in indicating that frictional effects in along the inlet channel is amplifying one of the harmonic overtides in such a way that maximum flood currents are usually higher than ebbing current (Walten, 2002, Aubrey and Speer 1985). Frictional effects on tidal flow producing the overtides also reduce the tidal range in the backwaters of Sebastian Inlet. Figure 22 compares the water level recorded at the entrance of Sebastian Inlet with the tidal record recorded by the ADCP located in the interior of the inlet. The tidal range just 3000 feet from the north jetty entrance is reduced by about 50% when reworking the ADCP location. Inspection of Figure 21 It also reveals the asymmetry of the inlet tidal signal imparted by the nonlinear override in shallow water. The duration of the flooding tide from low tide to high tide can be greater than 7 hours, whereas the water level drops from high tide to low tide in 6 hours or less.

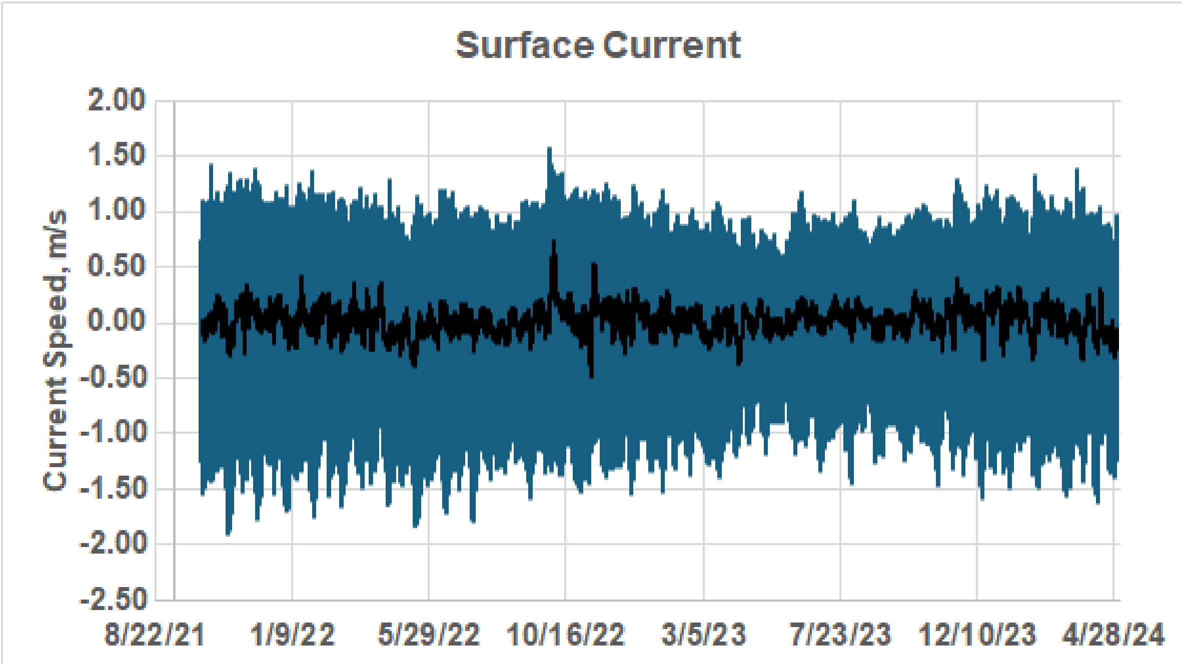

Figure 20. Record of surface layer flow within Sebastian Inlet, October 2021 to May 2024. The black line is the record filtered by a 25-hour moving average.

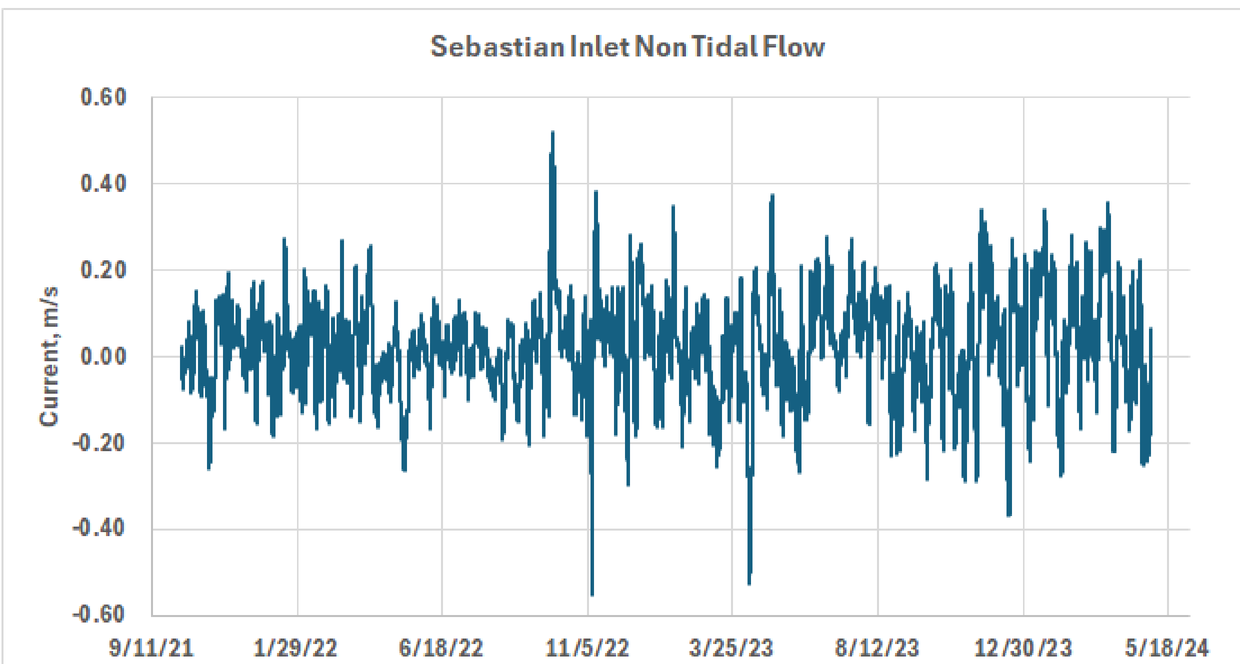

Figure 21. Residual non-tidal flows though Sebastia inlet recorded between 2021 and 2024

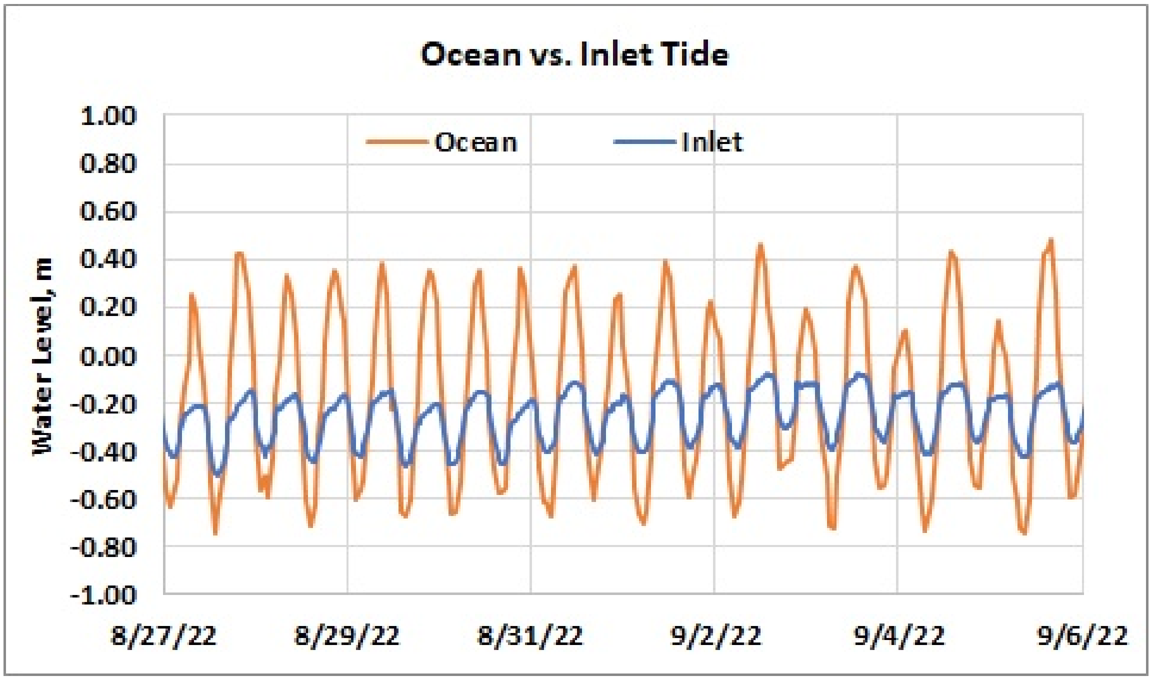

Figure 22. Comparison of tidal record at the ocean entrance of Sebastian Inlet and tides recorded at the interior ADCP location.

Like the water levels of the coastal ocean along the east coast of Florida, the signal of sea level changes due to changes in the flow of the Gulf Stream is also seen in the interior of the Sebastian Inlet system. It propagates throughout the Indian River Lagoon (Zarillo, 2023). Figure 23 The Gulf Stream flow is compared with the water level record from the inlet ADCP, showing an inverse correlation. The sharp drop in water level recorded on August 7th, 2022, is due to the ADCP mooring being dragged into a shallower location by about 2.5 feet. Possibly, an anchor became temporarily caught on the ADCP mooring.

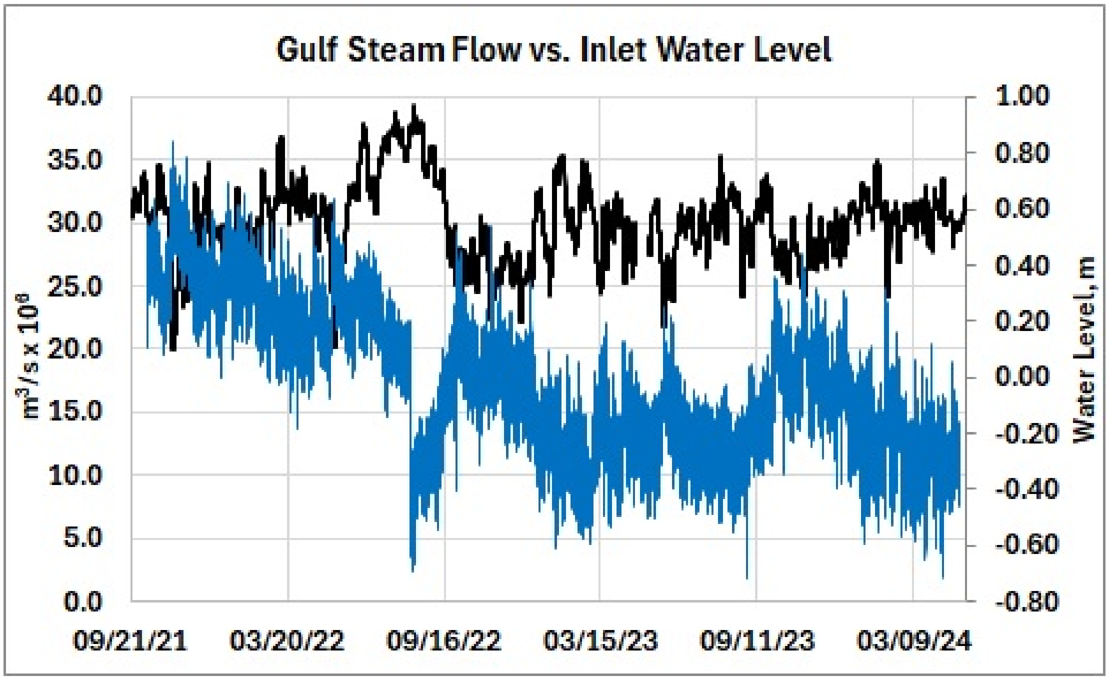

Figure 23. Comparison of Gulf Stream flow and water level recorded by the ADCP located in Sebastian Inlet.

6.0 Summary

Wave, tide, and weather data recorded in 2025 are described in this report. A major activity for the 2025 period was the replacement of microwave Internet Service with a cable connection. Repairs to the wave gauge system included the communication cable. The transition to a new cloud-based data handling and processing system began in 2023 and completed in 2025 and includes the cloud-based AWS, which will process data in the cloud and transfer it to SECOORA and NOAA. There were no extreme weather events or tropical storms in 2025, but significant wave heights exceeded 3 m on two occasions. The seasonal coastal sea level cycle linked to variations in Gulf Stream flow followed the usual pattern of a sea level low stand followed by a sea level high stand in the Fall. Analysis of the 31-month (2.6 years) record from the inlet ADCP provides valuable information about the inlet tidal dynamics and hydrodynamic conditions that determine the inlets' hydraulic features, including the distinct flood-dominated tidal asymmetry.

7.0 References

Aubrey, D. G., and Speer, P. E. (1985). "A study of non-linear tidal propagation in shallow inlet/estuarine systems, Part I: Observations," Estuarine, Coastal and Shelf Science 21, 185-205

Walton, T. L. Jr. (2002). "Tidal velocity asymmetry at inlets," ERDC/CHL CHETN IV-47. U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://chl.wes.army.mil/library/publications/chetn.

Zarillo, G.A. 2023 Inter-Annual Sea Level Change along a Barrier Island Coast. Front. Environ. Sci., 22 Sec. Interdisciplinary Climate Studies Volume 11 https://doi.org/10.3389/fenvs.2023.1107458