

# Sebastian Inlet District Oceanographic and Meteorological Monitoring Program

2021 – 2022

Prepared for:



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## **Executive Summary**

Current, wave and weather data are presented in this report. The oceanographic sensors are described in terms of maintenance along with a view of data from the sensors in a series of plots. Overall, the sensors performed well but were impacted by two hurricanes that crossed central Florida in late 2022. Statistics of the time series record are present as far back as 1997, when observation began at Sebastian Inlet. Among the themes addressed are variability and impacts of coastal sea level by variations in Gulf Stream flow. The combined impacts of hurricane storm surge on top of the annual highstand of sea level in the fall months are addressed.

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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 situated 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 data includes wind direction, wind speed, barometric pressure, air temperature, sea surface temperature and water level. The water level gauge is referenced to a known vertical datum. These data are used to calibrate the ongoing coastal processes model used in regional sediment management of the central Florida coast by the Sebastian Inlet District. Real time data for the ADCPs was established in 2012 and provide a resource for the navigation through the narrow throat of the Inlet which can be difficult under certain wave conditions. In combination with the National Oceanic and Atmospheric Administration (NOAA) / National Weather Service funded 48-hour forecast model maintained by Florida Tech and NOAA nearshore buoys 41113 and 41114, the real-time ADCP data provide regional coverage of the directional wave field not found in most other areas of US coastal waters. The measured and model data are being used to support shore protection projects by Federal, State, and local agencies. This report presents the ADCP collected from August , 2021, to December 2022. and weather station data collected from August 2021 to December 2022.

## 2.0 Equipment Maintenance

The real time ADCP wave gauge functioned well over the past year having minimal down time. Returned wave statistics covered about 99% of the time using a combination of the gauges connected to the shore station by a communications cable and the co-located remote sensor used as a back up. With respect to wave monitoring, the only major maintenance issue was replacement of the microwave transceiver that provides high speed internet connection between the electronics shed at Sebastian Inlet and the Florida Tech Coastal Processes Laboratory. Wave data are available for the two Hurricanes that impacted Florida in 2022.

The weather station located on the Sebastian Inlet north jetty (Figure 1) required significant attention during this reporting period, particularly after being impacted by Hurricane Nicole in early November. The barometer, water temperature and water sensors became misaligned by strong winds. In addition the Verizon cell modem that provides an internet link between the weather station and Florida tech Coastal Processes Lab was compromised by the storm. The sensors were re-aligned and the cellular modem replaced.

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

- Florida Institute of Technology webpage

<http://research.fit.edu/wave-data/index.php>.

South East Coastal Ocean Observing Regional Association's webpage (SECOORA)

<https://portal.secoora.org/#metadata/111457/station/data>

NOAA's National Data Buoy Center (NDBC) website

[http://www.ndbc.noaa.gov/station\\_page.php?station=sipfl](http://www.ndbc.noaa.gov/station_page.php?station=sipfl).

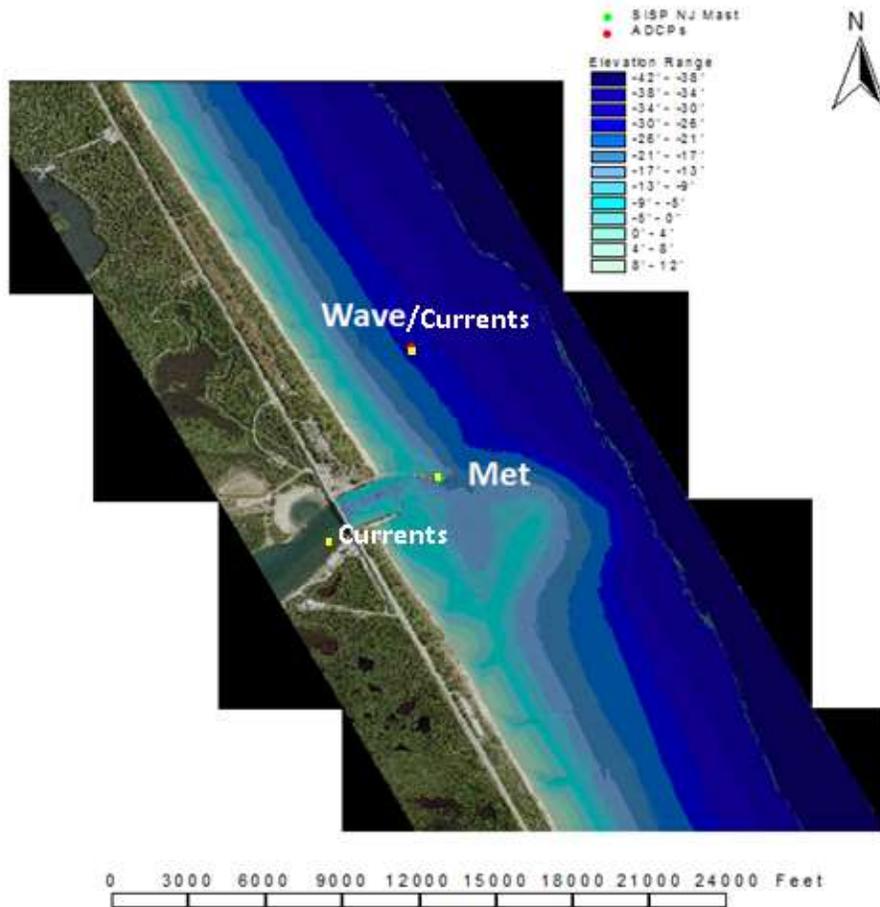


Figure 1. Location of Sebastian Inlet State Park oceanographic and meteorological instrumentation sites. Aerial photo and bottom topography are courtesy of the Sebastian Inlet District.

## 2.0 Instrumentation

### 2.1 ADCPs

Two ADCPs are co-located at the study site; one real time and a second for redundancy. Teledyne R.D.I Instruments (RDI) 1200kHz Workhorse Sentinels ADCP are continuously co-deployed at the site offshore of SISP. Figure 2 shows a side scan sonar record of the sensor field. 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 is 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.

Deployment configuration of the ADCP wave and current sensors

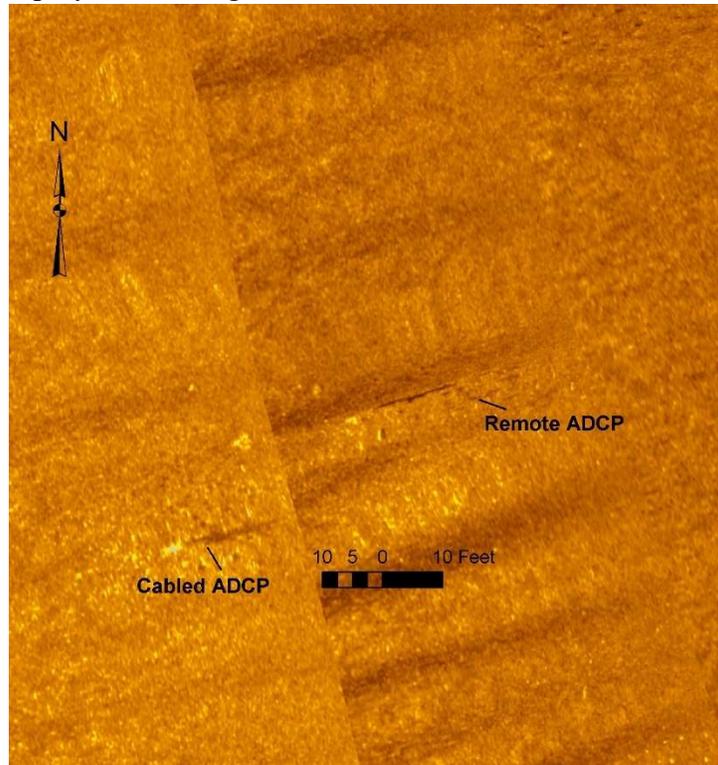


Figure 2. Deployment configuration of the ADCP wave and current sensors

### 2.2 Meteorological Station

The Meteorological station is located atop of the mast at the seaward end of the SISP north jetty 10 meters (30 feet) above the water as shown in Figure 3. 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.

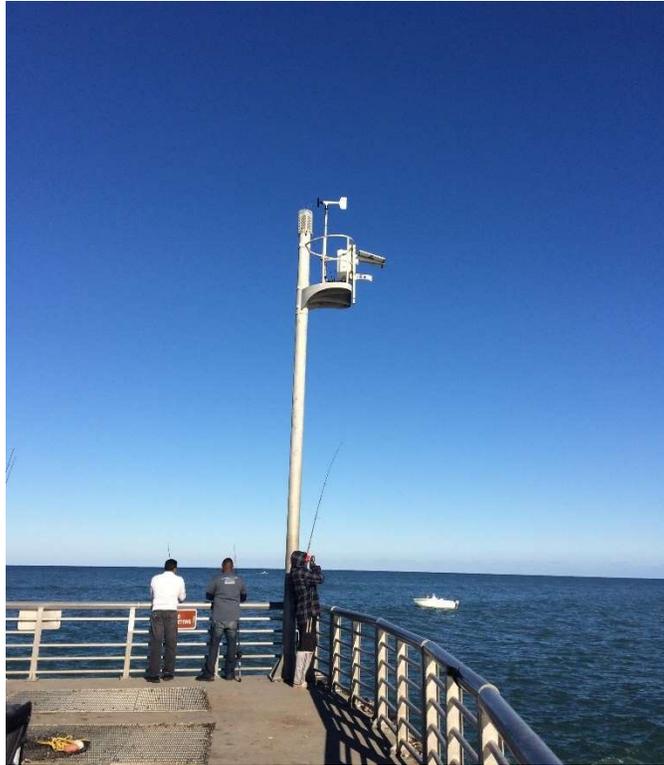


Figure 3. Meteorological tower at the east end of the Sebastian Inlet north jetty

A Campbell Scientific Radar Water Level sensor (Figure 4) was first installed in early September, 2015, which replaced the Yellow Springs Instruments (YSI) water level sonde. This Radar based gauge 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 protect the instrument from damage from fishing equipment entanglement and vandalism. 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 Metrologic station inside the tower mast.



Figure 4. Looking down at the Radar water level sensor mounted to the side of the north jetty concrete cap.

An additional ADCP unit was deployed within the interior of Sebastian Inlet in October 2021 under a permit issued by the US Army Corps of Engineers. Figure 5 shows the location of the unit within the inlet conveyance channel. At this time the unit is still deployed after several efforts to retrieve it to process the data. The challenge is the limited time during inlet slack tide to locate and retrieve the unit. The next effort to retrieve the inlet ADCP will be on February 17<sup>th</sup>, 2022 when slack tide will be at approximately 12 Noon.

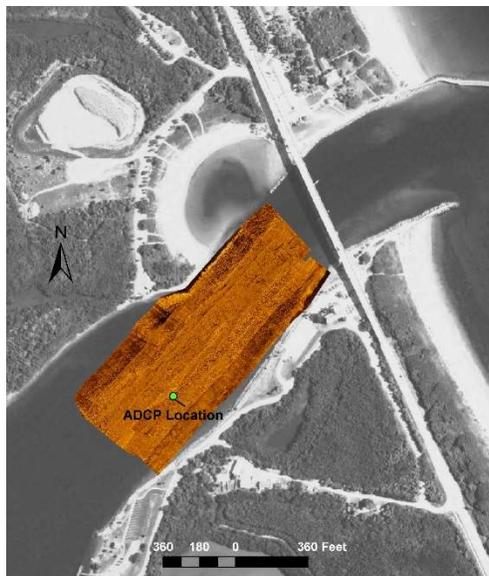


Figure 5. Location of the “Inlet ADCP” unit within the interior channel.

## 4.0 Data Presentation

Figure 6 shows a flow chart of data handling among the various sensors maintained by Florida Tech on behalf of the Sebastian district. The data handling system is scheduled to undergo an upgrade in the next monitoring cycle by porting the data flow into the cloud and restructuring the data archiving system and web resources.

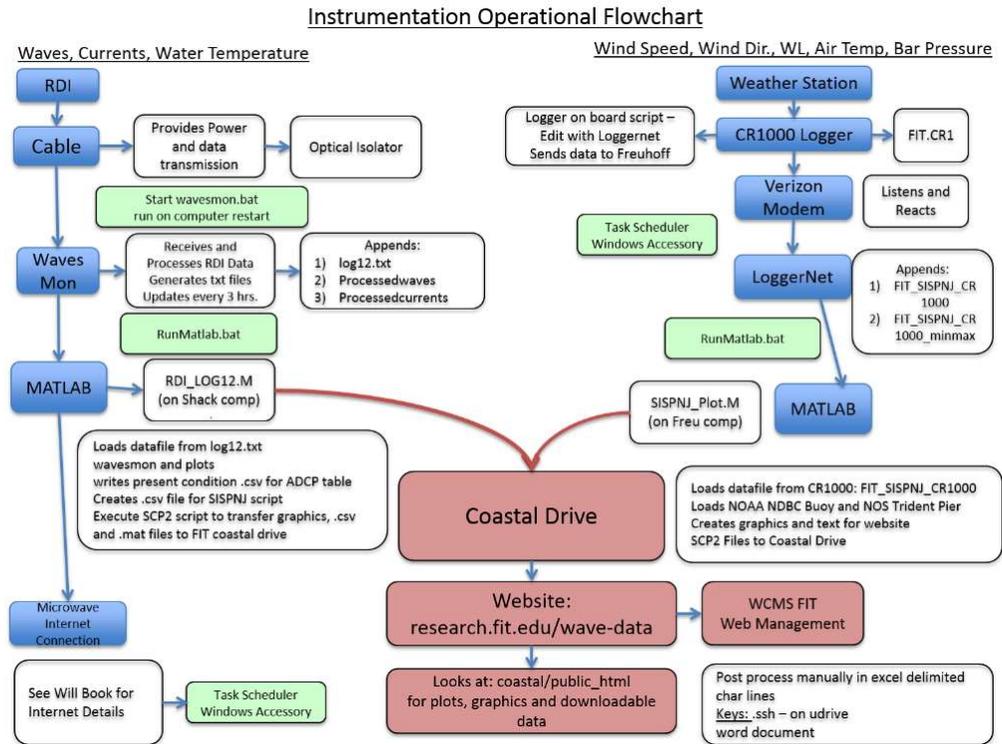


Figure 6. Data processing flow chart.

### 4.1 Statistics

Table 1 through Table 5 summarize basic statistics from the field gauges spanning August 1, 2021 through December 31st, 2022. Longer term statistics at the 10, 15, and 23-year timescales are also provided for wave parameters. The longest time period available for currents is 19 years since 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 two years was from near zero to a maximum of approximately 1.17 m/s. The average speed was about 0.011 m/s in a southerly flow. Wave height ranged from 0.12 m to a maximum of about 3.83 m at the ADCP location during Hurricane Nicole. The average for the 2021-2022 observation period was consistent with previous years at about 0.82 m. The average Wave period was about 9.0 s from the east-northeast which also compares well to previous year. Table 5 summarizes meteorological parameters. Wind speeds range from near calm to wind gusts of 23.57 m/s (52.7 mph) which corresponds to Hurricane Nicole. Other meteorological 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 final section of this report.

Table 1. Wave Statistics: August 1 2021 - December 31st 2022.

	Wave Height (m)	Wave Period (s)	Wave Direction (°TN)
Minimum	0.12	2.3	
Maximum	3.83	21.0	
Average	0.82	9.0	54.16

Table 2. Wave Statistics: 10,15,26 years [1996 – 2022].

	Wave Height (m)			Wave Period (s)			Wave Direction (°TN)		
	10yr.	15yr.	26yr.	10yr.	15yr.	26yr.	10yr.	15yr.	26yr.
Minimum	0.14	0.11	0.01	1.70	1.70	1.70			
Maximum	4.67	5.10	5.10	21.0	21.0	21.0			
Average	0.83	0.82	0.77	8.71	8.77	8.69	67.56	68.81	69.67

Table 3. Annual Current Statistics: August 1 2021 - December 31st 2022.

	Current Speed (m/s)	Current Direction (°TN)
	1 year	1 year
Minimum	0.00	
Maximum	0.55	
Average	0.11	160.35

Table 4. Current Statistics: 10, 15 and 26 Years [1996 – 2022]

	Current Speed (m/s)			Current Direction (°TN)		
	10yr.	15yr.	24yr.	10yr.	15yr.	26yr.
Minimum	0.00	0.00	0.00			
Maximum	0.76	1.60	1.60			
Average	0.10	0.10	0.10	183.01	180.60	179.44

Table 5. Statistics derived from meteorologic data Aug 1 2021 – December 31st, 2022.

	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		672	4.03	3.52	16.56
Maximum	23.57		1032	32.71	36.31	30.71
Average	3.99	139.89	1017	24.01	24.09	24.30

## 4.2 Time Series

### 4.2.1 Wave Height and Water Level Data

Wave height time series for the 2021– 2022 observation period is shown in Figure 7. The seasonal variation in the record is observed as shown by an increase in average and maximum wave heights from October to March. The extreme waves heights occurring in November are related to passing of Hurricane Nicole and are not considered part of the seasonal variation in wave height since the generation of these waves is tropical in nature. Lower waves are observed in the months May through late This quiescent period is normal for this area during the summer months.

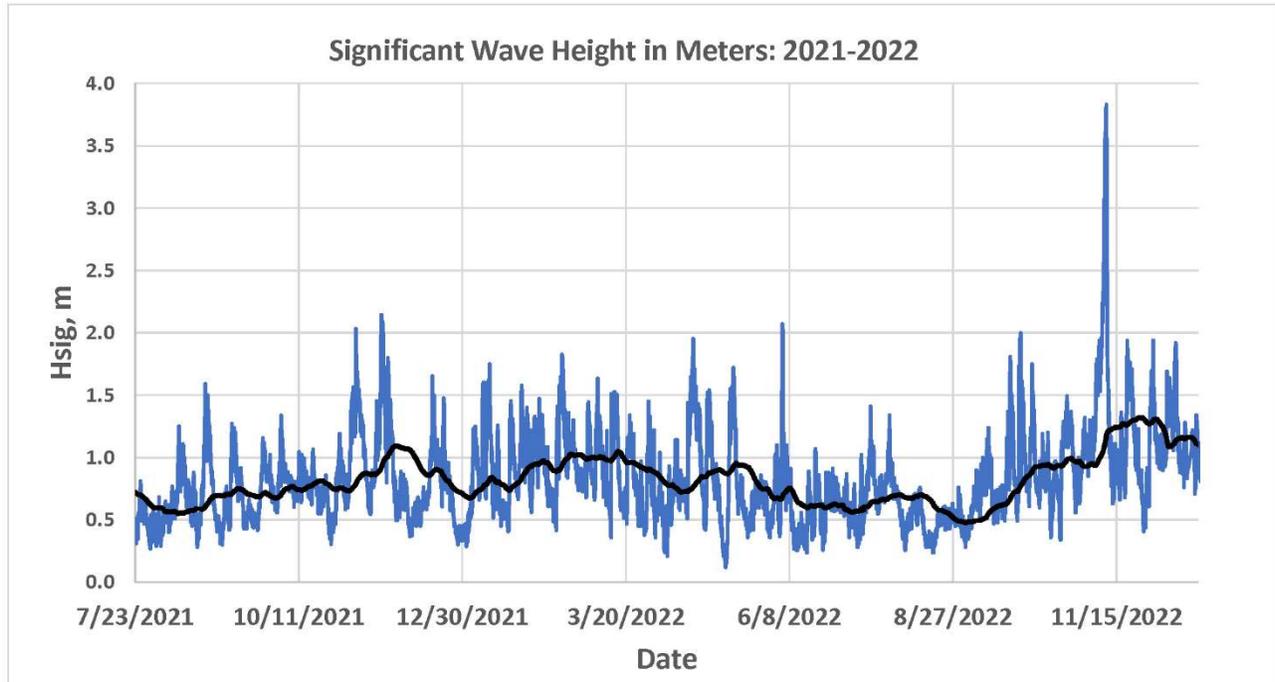


Figure 7. Wave Height time series August 1, 2021 through December 31st, 2022.

The combined directional and wave height rose plots shown in Figure 8 is consistent with the wave direction statistics listed in Table 2 and Table 3. Wave energy arrives mostly from east-northeast directions. The entire wave height record recorded from 1997 to 2022 is shown in Figure 9. Major named storms are indicated on the plot.

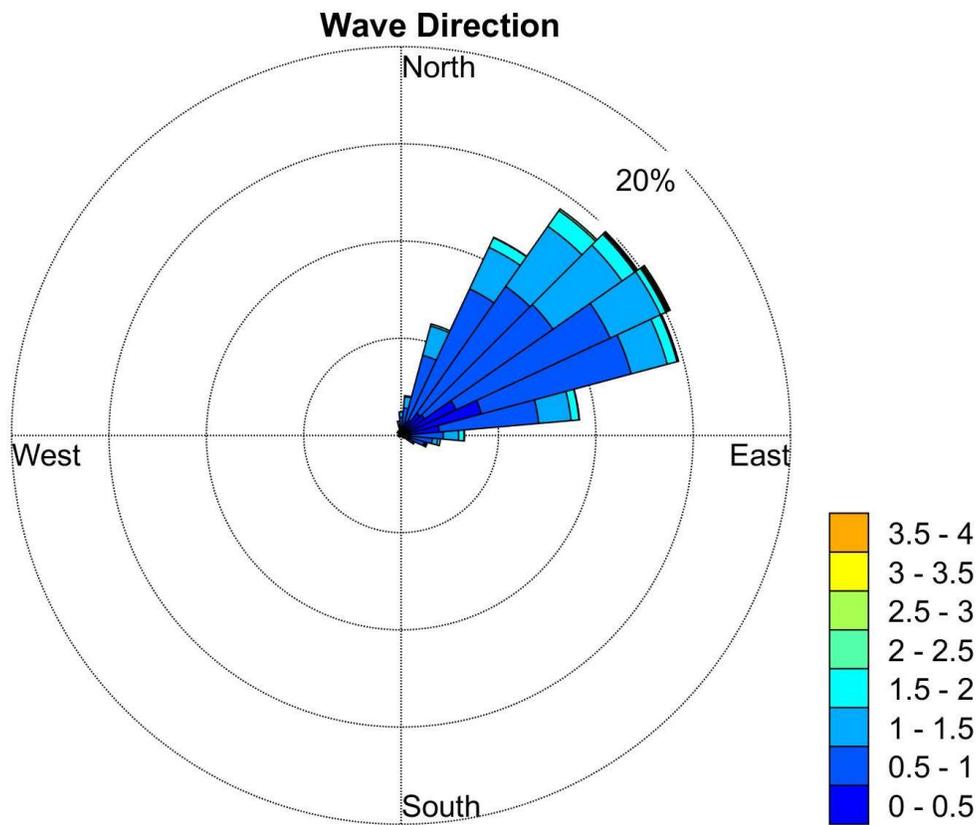


Figure 8. Wave Direction and Height from August 2021 through December 2021

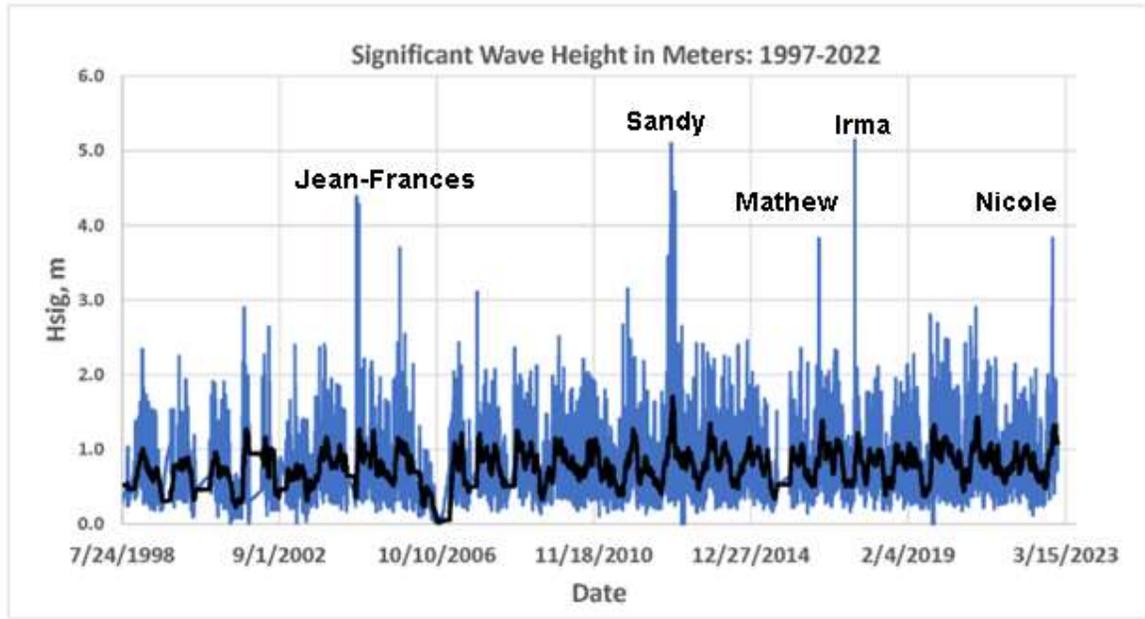


Figure 9, Record of significant wave height a Sebastian Inlet 1997 - 2022

Water level data from August 2021 through December 2022 is shown in Figure 10. Included in the plot is a trendline used to filter out the tide signal to show sea level changes over the past year. The filtered record reveals the magnitude of the storm surge at the central Florida Coast generated by Hurricanes Ian and Nicole, which was about 3 to 4 feet.

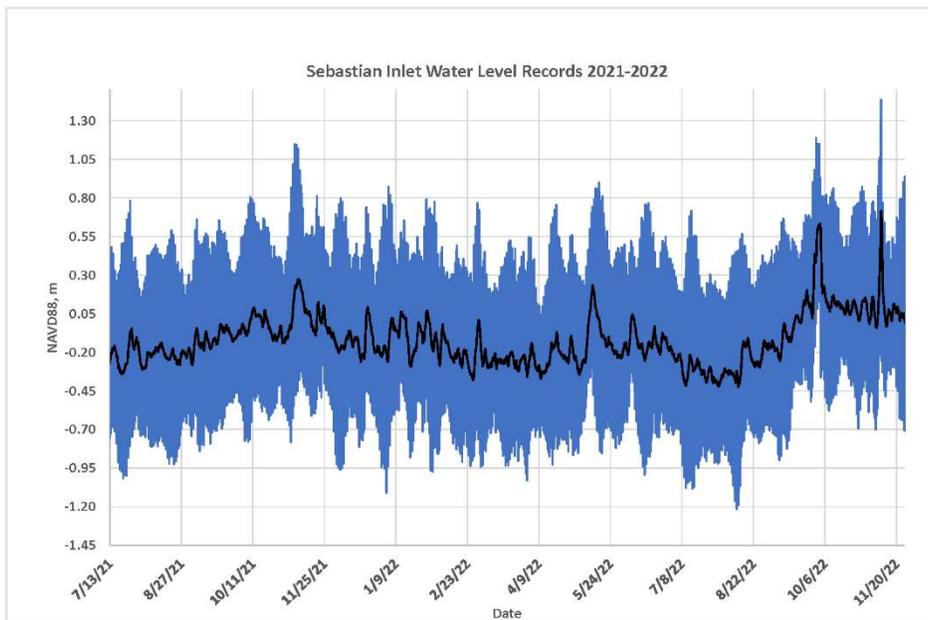


Figure 10. Water level data from July, 2021 through December 31<sup>st</sup> 2022

#### 4.2.2 Meteorological data

The wind speed record from the SISP north jetty weather station is shown in Figure 11. 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. The maximum wind speed recorded in the 2018-2019 observation period occurred during Hurricane Nicole when recorded winds at the weather station exceeded 17 m/s. Figure 12 shows the direction and magnitude recorded by the North Jetty weather station during the same period.

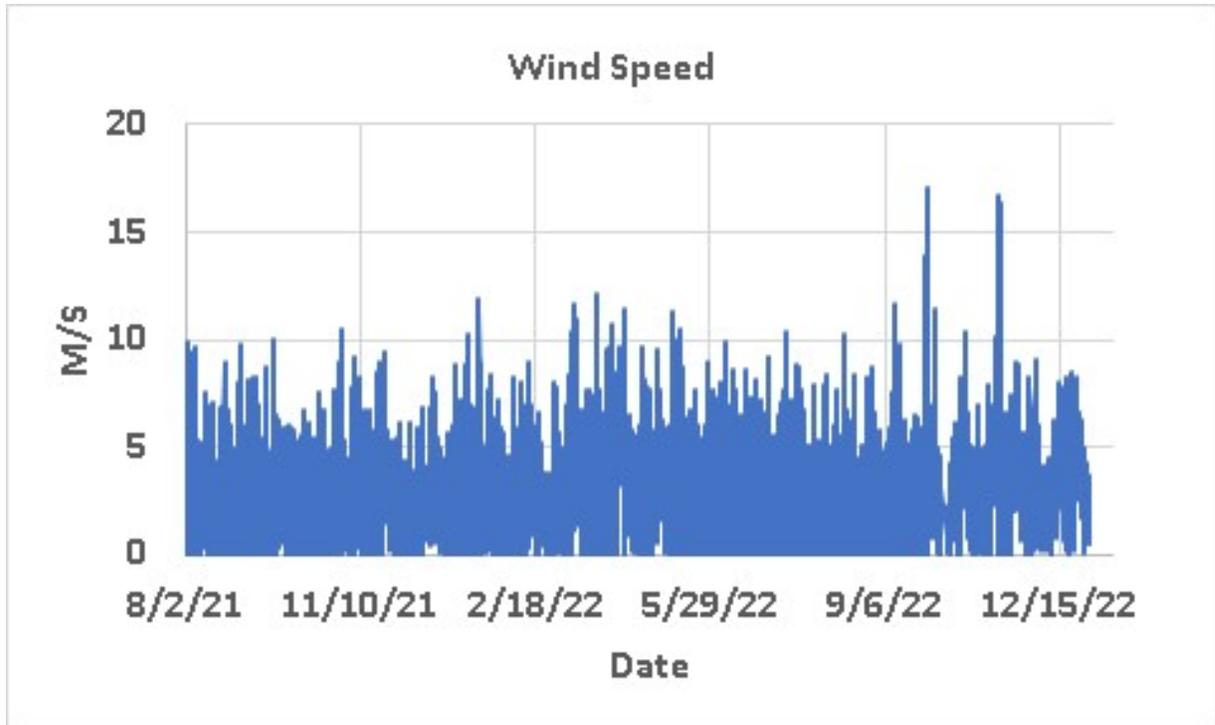


Figure 11. Wind speed time series August 2021 – December 31st, 2022

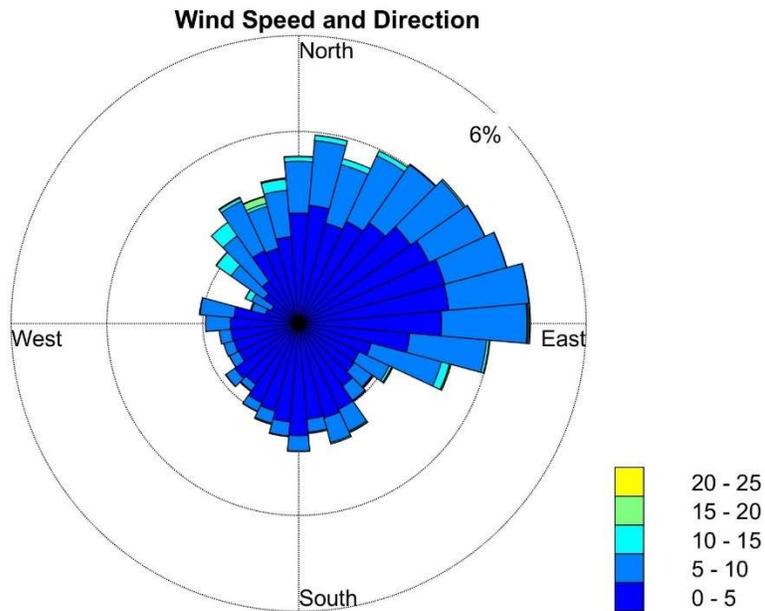


Figure 12. Wind Speed and Velocity magnitude for SISP North Jetty from August 2021 to December 2022

Sea surface water temperature (SST) from the SISP weather station shown in Figure 13. for August 2021 to December 31st 2022. Water temperature records both show mid-winter decline in temperatures starting in November 2021 lasting through April 2022 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 14 presents a comparison between the water temperature measured by the infrared sensor mounted 10 m high on the weather station and the ADCP recorded temperature located in approximately 6m water depth. Air Temperature has also been provided on this plot. The temperatures recorded by these 3 means correlate in seasonal variation, with subsea temperatures maintaining greater stability compared to the fluctuations in air and sea-surface temperatures.

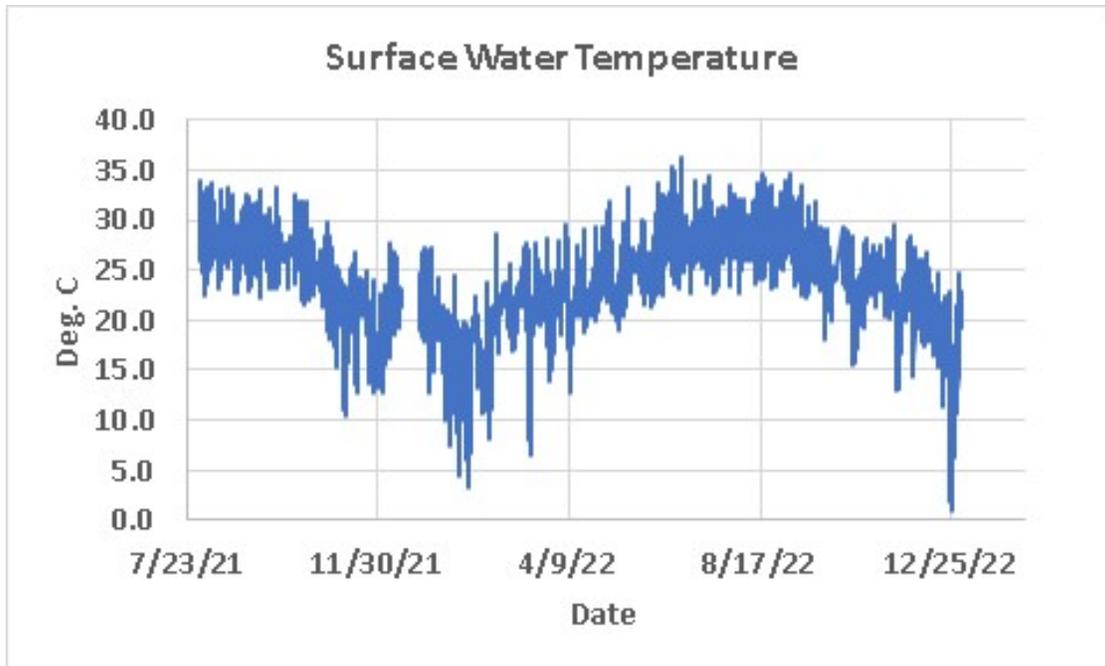


Figure 13. Surface water temperature below the north jetty metrological station

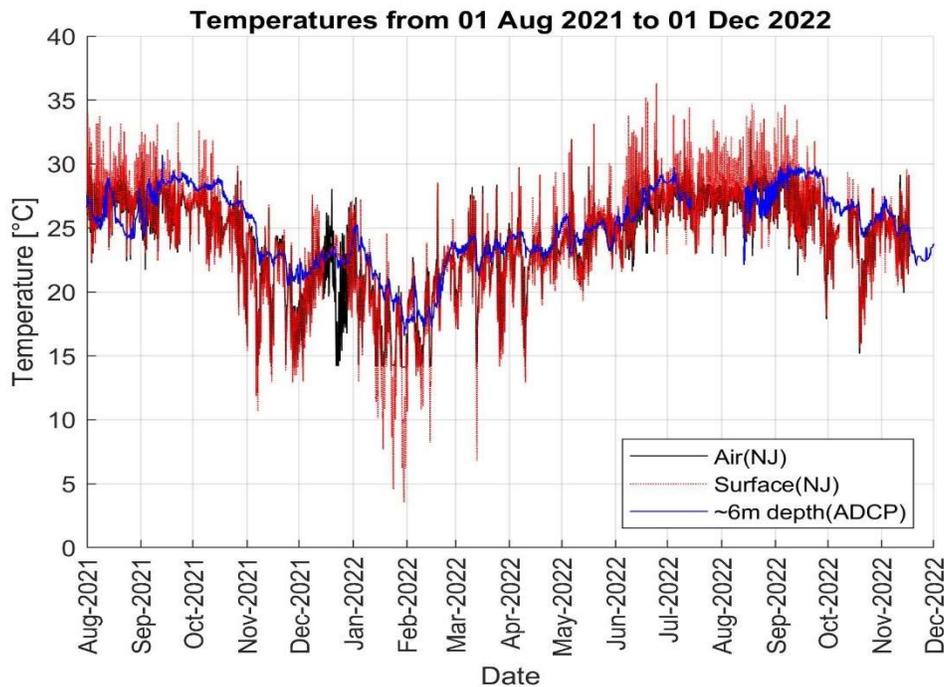


Figure 14. Air, Sea Surface, and Sub-sea Temperature measured at the SISP North Jetty and ADCP locations

Current magnitude and direction are measured at the bottom mounted ADCP. Depth averaged current velocity recorded every 30 minutes is shown on Figure 15 as well as a 24-hour moving

average to add clarity. Figure 16 shows the depth averaged current direction and associated velocity magnitudes.

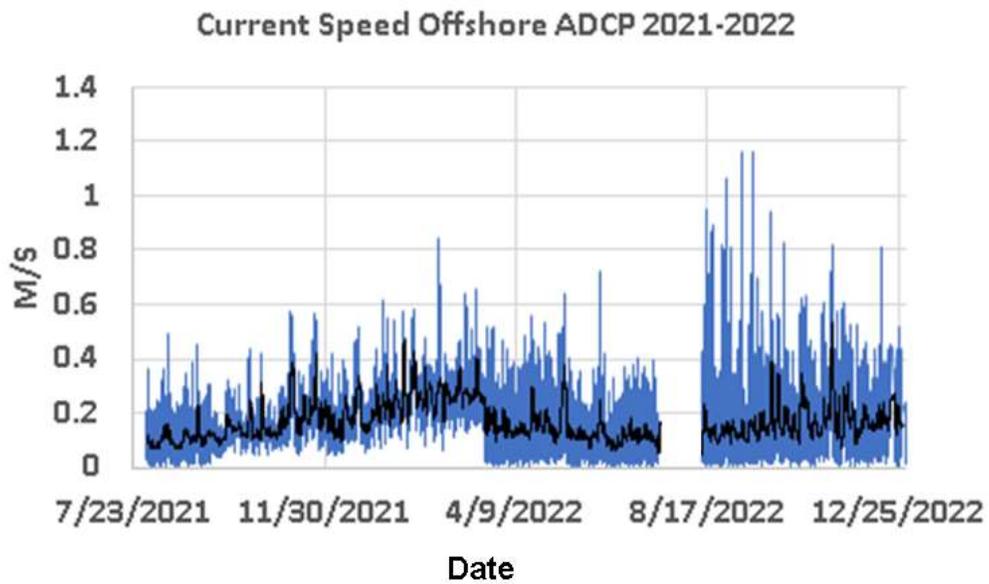


Figure 15. Depth averaged current record at the offshore ADCP 2021-2022.

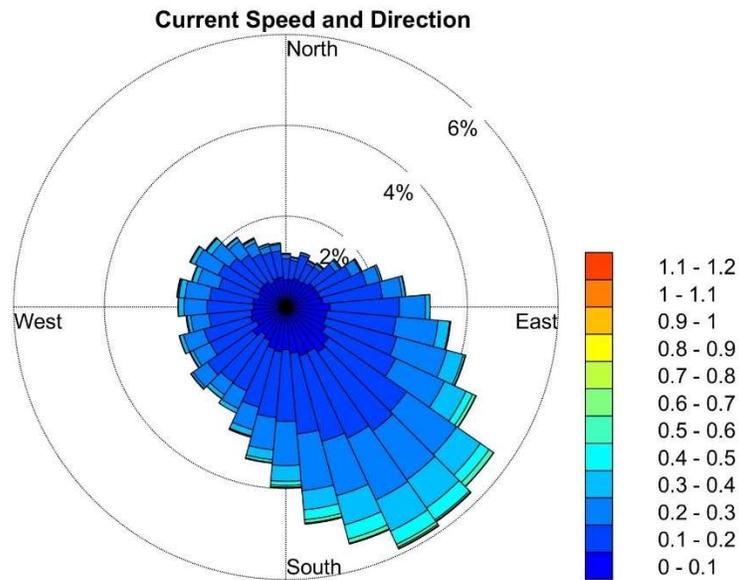


Figure 16. Distribution of current speed, August 2021 to Dec 2022.

## 5.0 Storm Impacts

Hurricane Ian impacted southwest Florida in September 2022 moving onshore as a category 4 storm in southwest Florida before weakening as it moved across the Florida Peninsula. Observed storm surge in the central Florida area from the storm was about 1m (3.3 feet) above normal levels. However, the surge continued through several tidal cycles compounding coastal impact. Significant wave height recorded at the Sebastian Inlet wave gauge reached a maximum of only about 2m (about 6.6 feet during the storm. However, at the time of the storm surge caused by Ian, coastal sea level was close to its annual highstand magnifying the impact of storm waves. Hurricane Nicole crossed the south central coast of Florida in early November of 2022. Storm surge recorded at Sebastian Inlet reached about 1m. Surge heights were amplified by the late fall sea level highstand (Figure 17) and significant wave heights riding on top of the surge reached a maximum of about 4 m or about 13 feet (Figure 18).

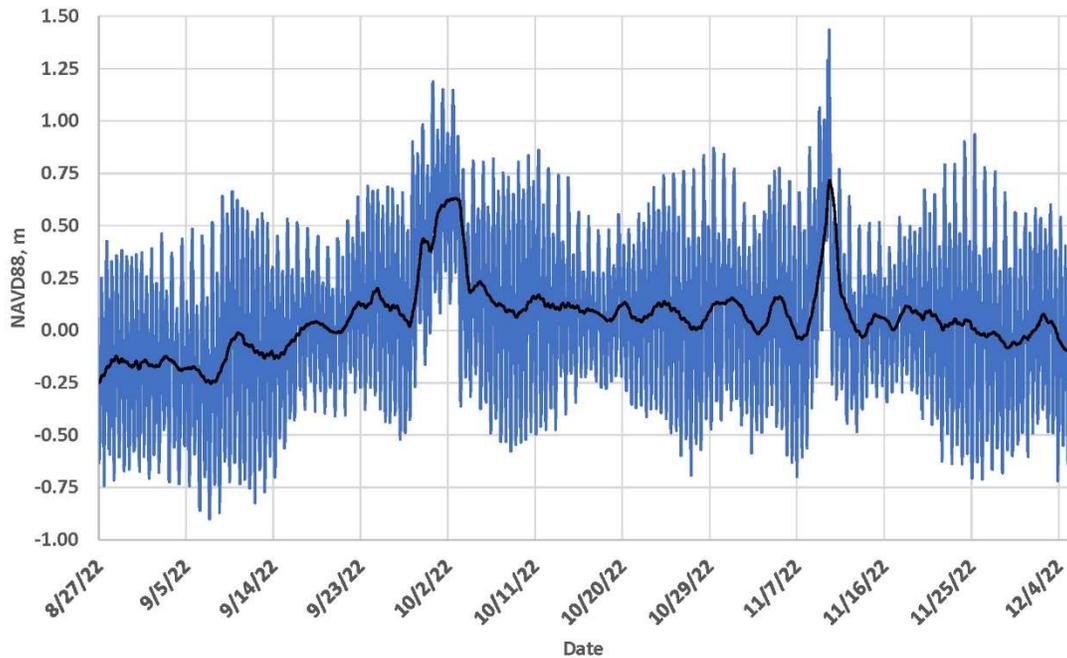


Figure 17. Measured sea level on the central Florida coast during the August to December period illustrating storm surge generated by Hurricanes Ian and Nicole.

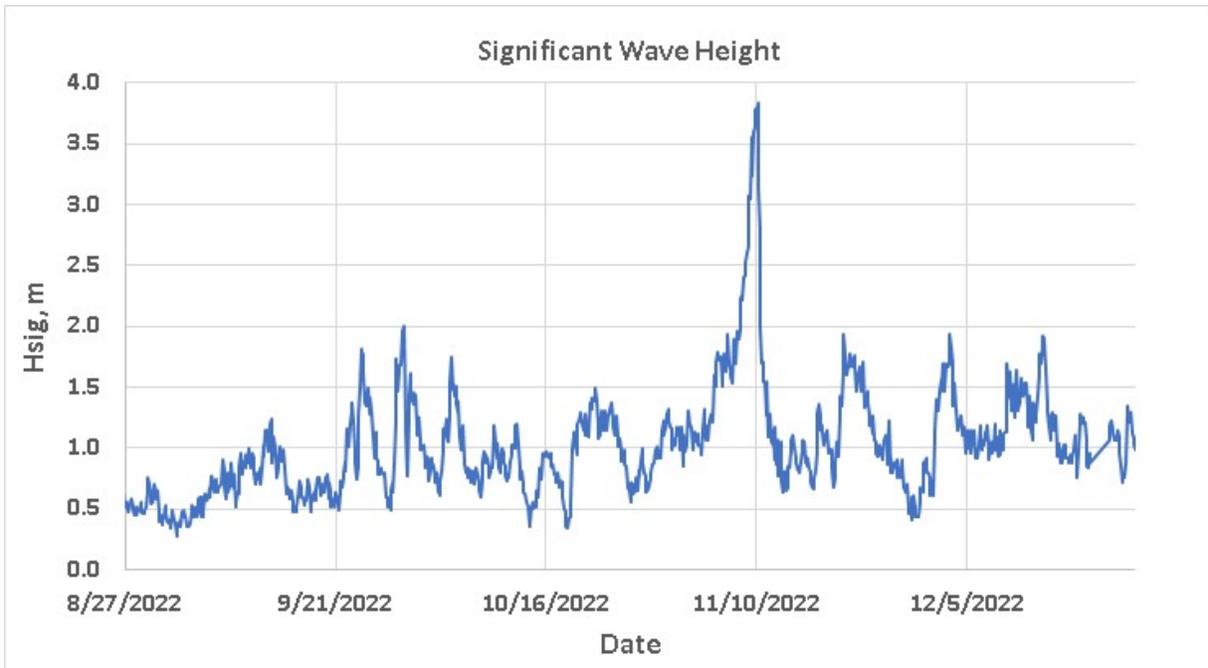


Figure 18. Wave Heights Fall 2022.

## 6.0 Gulf Stream Influence on Sea Level

The impact of variable Gulf Stream flows on coastal sea levels along the east Florida coast is well documented in observation and in theory (Ezer et al, 2013, Zarillo, 2023). An inverse relationship between coastal sea level and Gulf Stream flows is seen in Figure 19. Coastal sea levels are generally lower in the summer months by 70 cm or more ( 2.3 feet ) when GS flows are at a maximum. When Gulf Stream flows decline in the Fall coastal sea level rapidly rebound. In Figure 20 storm surge from Ian and Nicole can be seen on top of the annual coastal highstand of sea level, compounding the storm impacts. The related impacts of this process on the coastal shoreface sand reservoir can be reviewed in Zarillo (2013).

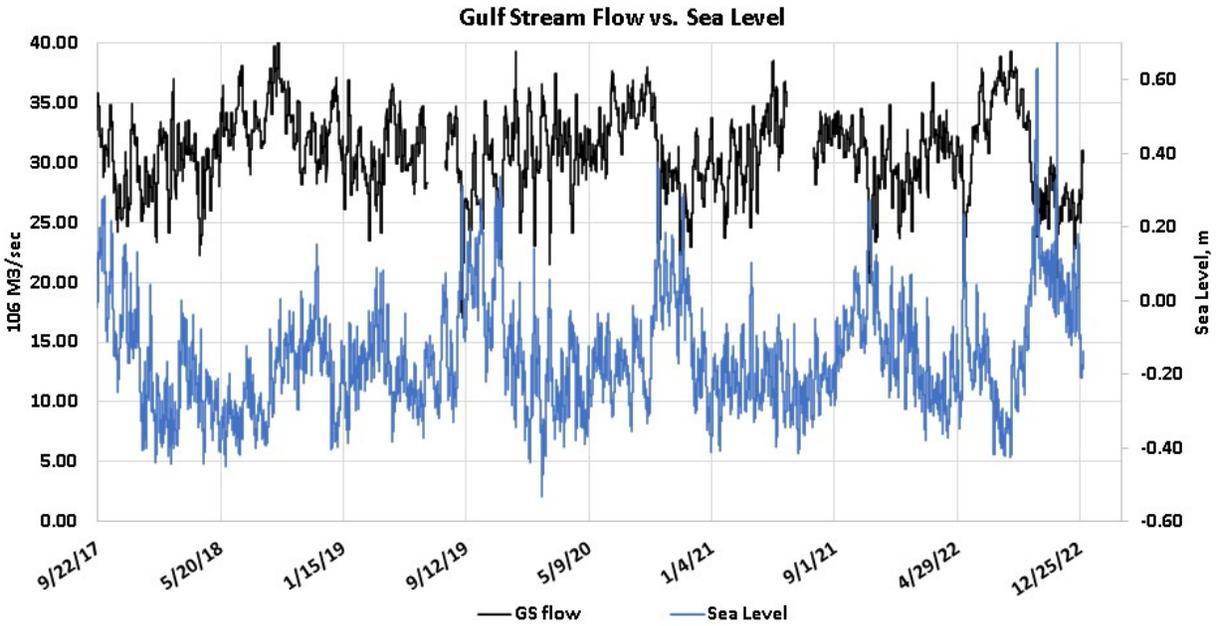


Figure 19 Combination of sea level and Gulf Stream records illustrating an inverse relationship.

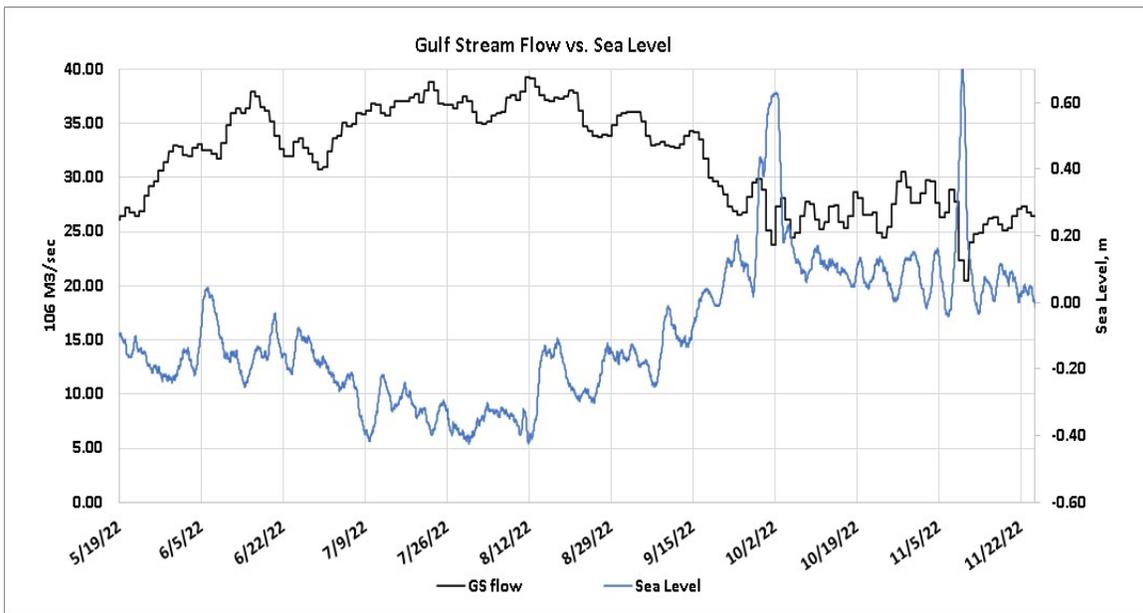


Figure 20. Details of sea level and Gulf Stream flow from May to December of 2022. Storm surges from Hurricanes Ian and Nicole are apparent in the Fall season

## 7.0 Summary

Wave and weather data recorded between August 2021 and December, 2022 are described in this report. Hurricane Ian and Nicole were major meteorological events of this observation period. The seasonal variations in winter-summer southeasterly and northeasterly wind patterns were present as usual. Maximum wave height were recorded at the cabled wave sensor during Hurricane Nicole when significant wave heights reaching nearly 4 meters or about 13 feet at the offshore wave sensor about 460 meters (1500 feet) off the north inlet beach. The maximum coastal water level surge during Hurricane Ian and Hurricane Nicole reached about 1 meter above normal. As seen in Figure 17, the storm surge was compounded by the fact that the surge lasted for 2 or more tidal cycles. Offshore current speeds observed during the storms exceeded 1 m/s.

Gulf Stream flow continues to strongly influence sea level along the central Florida coast as seen in Figure 19. Particular note is made of the fact that both Ian and Nicole occurred during the mid-Fall period of sea level highstand as seen in Figure 19. During the storms coastal sea level along the central Florida coast was more than 2 feet higher compared to the late summer low stand of level just 3-months prior.

## 8.0 References

- Ezer, T. (2013). Sea level rise, spatially uneven and temporally unsteady: Why the US East Coast, the global tide gauge record, and the global altimeter data show different trends. *Geophysical Research Letters*, 40(20), 5439-5444.
- Zarillo., G.A. 2023. Interannual Sea Level Change and Transgression along a Barrier Island Coast. Accepted for Coastal Sediments'23 Conference, April 2023