

A WAVCIS Based Ocean Observing Station to Provide Hydrodynamic Data off Eglin Air Force Base, Fort Walton, Florida, USA

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Abstract: A new coastal ocean observing station has been established for the west Florida shelf, off Eglin Air Force Base, with an upward looking ADCP deployed at the approximate 11 m isobath for measuring the coastal currents, waves and tide. Hourly processed data were communicated to the WAVCIS station, through secured cellular communication. Vertical profiles of current speed and direction were continuously monitored until summer 2008. Also, directional wave spectra, bulk wave parameters and spectral evolution were computed from the ADCP measurements. These data are critical in monitoring wave and current transformation over the innershelf, associated with the passage of tropical cyclones and winter storms. NRL is using the data to enhance understanding of the nearshore/beach morphodynamics. The entire automated operation was executed by software developed in-house, taking advantage of interface-drivers for the data-loggers. The user-developed software controls the sampling scheme and the operational control of all of the sensors and the onsite computer.

I. INTRODUCTION

The Wave-Current-Surge Information System (WAVCIS) is a near real-time ocean observing program implemented for the northern Gulf of Mexico [1-3]. WAVCIS measures met-ocean processes and sea state information for offshore Louisiana, Mississippi and the Florida Panhandle. The information measured includes waves, currents, water depth, surge, salinity, water temperature and meteorological conditions. The data measured from offshore stations are transmitted on a near real time basis, through cellular communication, to the WAVCIS Laboratory and are published online (www.wavcis.lsu.edu). As of August 2009, there are six operational stations (Fig. 1) and more stations have been planned for future deployments, particularly off western Louisiana coast. Archived data are also available for some of the stations which are no longer active (yellow dots in Fig. 1).

For this project, the CSI FTW station (see Fig. 2) was deployed offshore, off a 91.4 m tall meteorological tower at Eglin Air Force Base, along the Florida Panhandle coast. The system was originally deployed during summer 2005 and was severely damaged when Hurricane Dennis made landfall on 10th July, 2005, which came ashore slightly west of Fort Walton Beach [4]. The station was re-deployed shortly thereafter and remained operational until early summer 2008[5]; the station location was 86° 45.797' W and 30° 23.057' N. The oceanographic data collected from the station along with meteorological data from a nearby NOAA station, are discussed in this paper. The Florida observation station (CSI FTW) consisted of an upward looking 1200 KHz Teledyne RDI Acoustic Doppler Current Profiler (ADCP) deployed at the ~11 m isobaths. The ADCP was tethered to a surface buoy (see Fig. 2) in order to facilitate real time transmission of the data back to the ground station. The on-site data were stored in a Campbell CR23X Data logger which was housed inside the surface buoy. Field measurements from the CSI FTW station included wave height, wave period, wave direction, directional wave spectra, current speed & direction profiles and water depth. Meteorological data were collected from a nearby station PCLF1, operated and maintained by NOAA's National Ocean Service.

The broad objective of this coastal program is to establish monitoring stations along the northern Gulf of Mexico, capable of providing near-real time met-ocean data, in support of an effort to understand the coupled dynamics of waves, currents, and sediments in heterogeneous environments. The station location of CSI FTW, in a tectonically stable and sandy West Florida coast [6-7], as opposed to the muddy/fine sand shelf environment off Louisiana, provides ample opportunity to compare and contrast wave and current transformation across different shelf environments along the northern Gulf of Mexico. Also, these diverse coastal settings provide a natural laboratory for calibrating and validating wave and hydrodynamic models, as many of the 3rd generation hydrodynamic models are rarely being tested in contrasting bottom friction conditions.

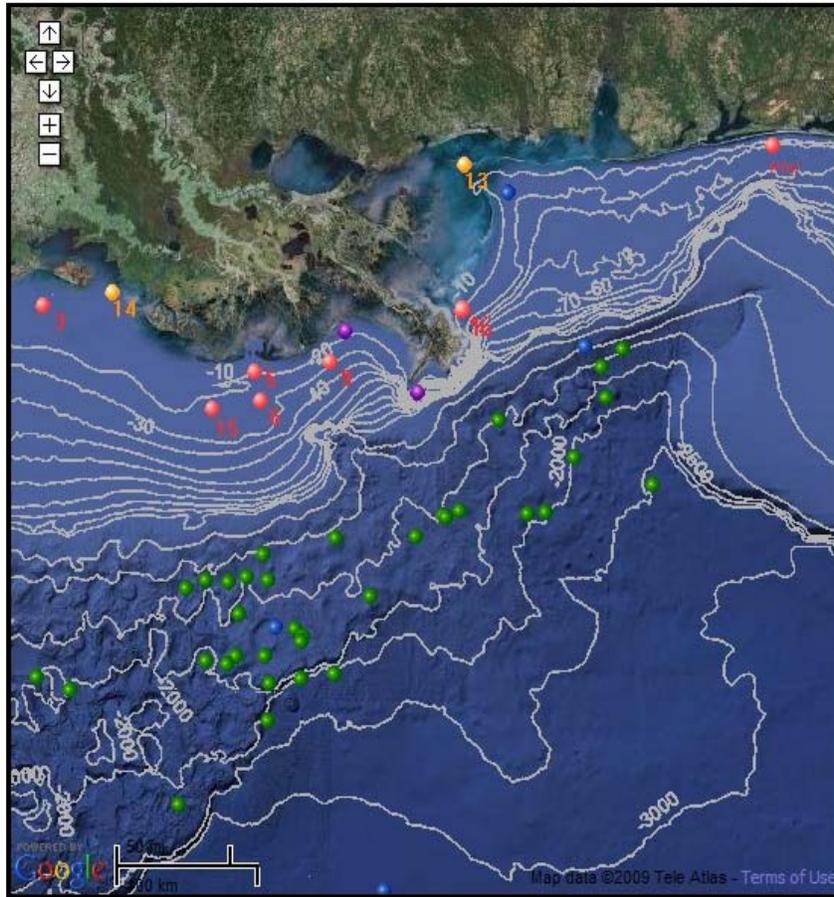


Fig. 1 Location map of WAVCIS stations and the MMS mandated ADCP platforms along northern Gulf of Mexico

As part of the expansion of our ocean observing program, we have also implemented a suite of third generation wind, wave and hydrodynamic models for the northern Gulf of Mexico. MIKE 21, SWAN, WAVEWATCH-III and WAM models are currently operational and provide eighty-four (84) hours of wave forecasts. The wave models are forced using the North American meso-scale (NAM) model wind data, provided by the National Center for Environmental Prediction (NCEP/NOAA). Near real-time skill assessment of the simulated bulk wave parameters are also implemented and the results are available online.

II. STATION LOGISTICS AND SENSOR PACKAGE

Much of the hardware and software components for the WAVCIS program have been designed and fabricated at the Coastal Studies Institute, Louisiana State University (CSI/LSU). The hardware consists of three components, viz., measurement module, communication module and power supply. The software includes the remote control and communication module as well as the data processing module. Instead of setting up the station on an oil platform facility, as has been the practice along the Louisiana and Mississippi coasts, the CSI FTW station was based on a moored surface buoy (see Fig. 2), which was tethered to an upward looking ADCP, deployed on a trawl resistant platform at the 11 m isobath. The data communication between the buoy and the ADCP was effected through cable connection. This type of deployment necessitated more frequent attention as the chances of vandalism, and the logistical challenges in near-real time data communication created issues. Unlike Louisiana, fixed platforms were unavailable for sensor mounting.

The hydrodynamic sensor package for the CSI FTW station comprised a *Teledyne RDI* ADCP (1200 KHz), which provided measurements of current profiles, directional waves and water level. The on-site data were stored in a Campbell CR23X Data-Logger, embedded in the surface Buoy (Fig. 2). The CR23X also functioned as the central control of the remote station. The entire automated operation of data collection, initial on-site processing and data communication were executed by the software developed by Coastal Studies Institute personnel, upon the operation-platform and interface-drivers provided by Campbell Scientific Inc[®]. The user-developed software controls the sampling scheme and the operational control of all of the sensors in addition to the computer.



Fig. 2 Surface Buoy at the Fort Walton WAVCIS station (CSI FTW)

The ADCP was operated in burst mode and the data measured offshore were stored in the Campbell data logger on-site and transferred to the WAVCIS data processing laboratory via cellular telecommunication. A router was set-up on the meteorological tower, located on Santa Rosa Island, to facilitate secured and rapid communication with Data Servers located in the WAVCIS Laboratory. Downloaded data were processed by a post-processing program. This program reads the semi-processed data, which had been initially processed on-board for the wave and current components. The post-processing program also read each time, related settings of the ADCP prior to processing them. After QA/QC, the processed real-time data were archived in an SQL database which was viewed and queried by users using the web interface. For the WAVCIS stations, in general, hourly communications of met-ocean data were accomplished through a dedicated telephone line at the receiving station. The automated communication is controlled by Symantec's[®] PC Anywhere[®] software with the capability of regular data downloading and remote control of the station computer and sensors from the base station. The data sampling and communication schemes can be modified remotely from the land station. The remote access capability also allowed quality checks of the various sensor packages as well as the station power supply.

III. DATA PROCESSING

A. Meteorological Data

Wind and other meteorological data from the region were analyzed using *in-situ* data from the weather station PCLF1, located at Pensacola Bay, owned and maintained by NOAA's National Ocean Service. This station was located well inside the Bay and was far away from the CSI FTW station. Unfortunately, another coastal station, located at Panama City, farther east, was not operational during the study period. Annual met-ocean conditions in Pensacola Bay, based on data from PCLF1, are provided in Fig. 3. The data correspond to 2007 and no major hurricanes or tropical storms impacted the coast during this period. Wind-climate for the study area was characterized by a low-energy regime, except during the cold front season, when wind speed increased and the direction changed from south-easterly/southerly to north-westerly/northerly, as the storm crossed the coast. This has been well documented in [8-10]. The *in-situ* data from the station for 2007 (2007/01/01-2007/12/31) indicated that approximately 60% of the duration of this study, wind speed was less than or equal to 3 m s^{-1} and for 30% of the time, between 3 and 6 m s^{-1} . Because no major hurricanes or tropical storms came ashore during 2007, the maximum wind speed recorded was approximately 15 m/s. Winds predominantly blew from the north to southwest, although the direction was highly variable (Fig. 3). Atmospheric pressure annual statistics shows a normal distribution with almost 40% of the time surface pressure was in the range 1015-1020 hPa. Sea Surface temperature also shows warm trends with 25-30°C prevailing for almost 30% of the year.

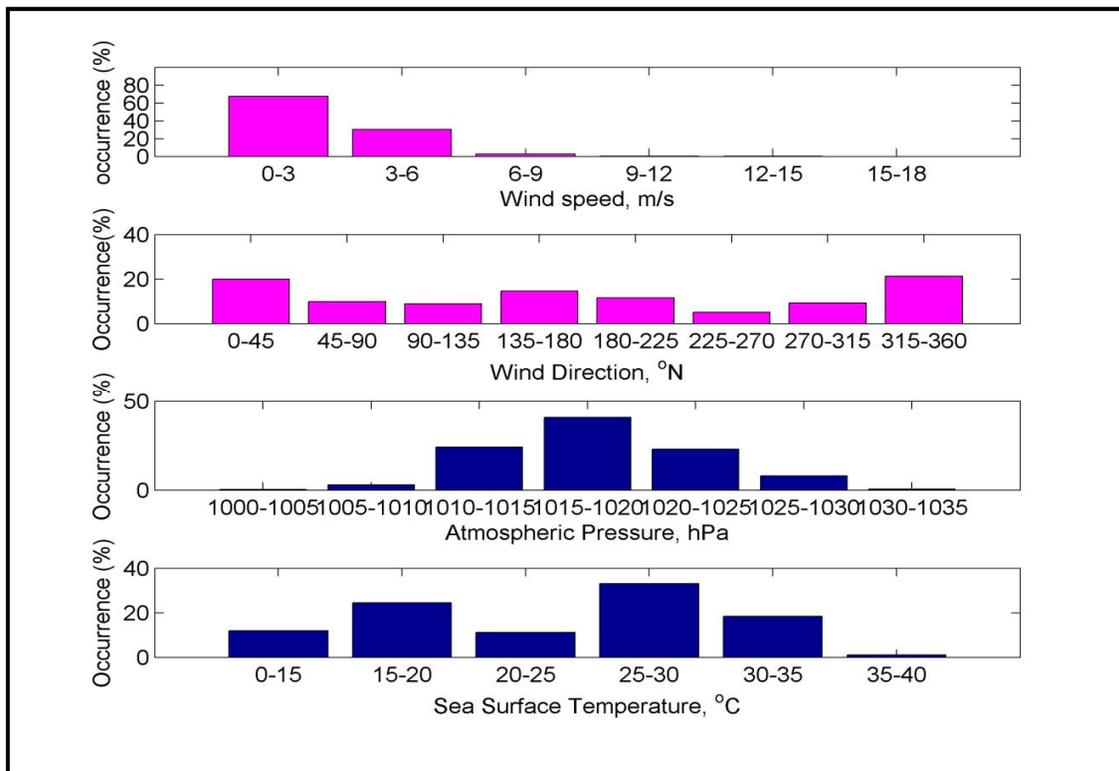


Fig. 3 Annual met-ocean statistics for 2007, compiled from weather station PCLF1. The coastal station was located at Pensacola Bay, western Florida

B. Ocean Data

Sampling Scheme and Data Processing

The RD Instrument's ADCP was remotely controlled and initiated by the on-site computer via the PC208 Software. The "WAVESMON" program controls the ADCP and provides for the storage of the raw data as well as initial processing. Current speed and direction were provided as profiles, extending from near bottom to near water surface in successive bins of 35cm bin-width. Significant wave height, peak wave height, average period, peak period, peak wave direction and the directional wave spectra were the parameters computed on-site (Spectral analysis procedure) and were transferred to the WAVCIS Lab via the PC Anywhere software.

The data were processed automatically following successive data downloading every hour. The data were archived in a relational database, and posted to the web simultaneously. The interactive web page is designed not only for users to acquire the latest updated information, but also to provide an interface for users to access our online database. All information in the database can be retrieved, queried, and graphically viewed on the web page. The Raw ADCP data were retrieved periodically from the site and archived for further research and model validation studies. Also, raw data were periodically transferred to the project sponsor at the Naval Research Laboratory (NRL), who has been using the data to enhance the understanding of the nearshore/beach morphodynamics. Due to the classified nature of the data, access to the hydrodynamic observations from the CSI FTW station has been restricted. The following figures (Fig. 4-8) provide a representative illustration of the met-ocean data collected and processed from the CSI FTW station.

Directional Spectrum

The directional spectrum provides the distribution of wave energy in the frequency-direction domain. Given the complex interaction of swells propagating from offshore and locally generated seas along the coastal waters, this analysis offers a better understanding of sea state at any given time. Especially, during the approaching phase of Tropical Cyclones and other extra tropical storms, the bimodal distribution of wave energy could be studied from this analysis. From the given plot of the directional spectra (Fig. 9 left) it is shown that southerly waves, approaching from a broad window, $110^{\circ} - 250^{\circ}$, with a wider band width (mix of sea and swell waves), dominated the study area. This corresponds to a pre-frontal wave climate for the coast. The wave spectrum after 10 hours, on 1st January 2007, is provided in Fig. 9 right. The bimodal distribution of wave energy, long period swells propagate from the south along with higher frequency westerly waves, indicates the passage of an extra-tropical storm in the study area. This is a typical spectral evolution pattern associated with a frontal passage along the northern Gulf of Mexico on the upper shoreface (fetch-limited condition), during winter and early spring season and has been discussed in [9, 11].

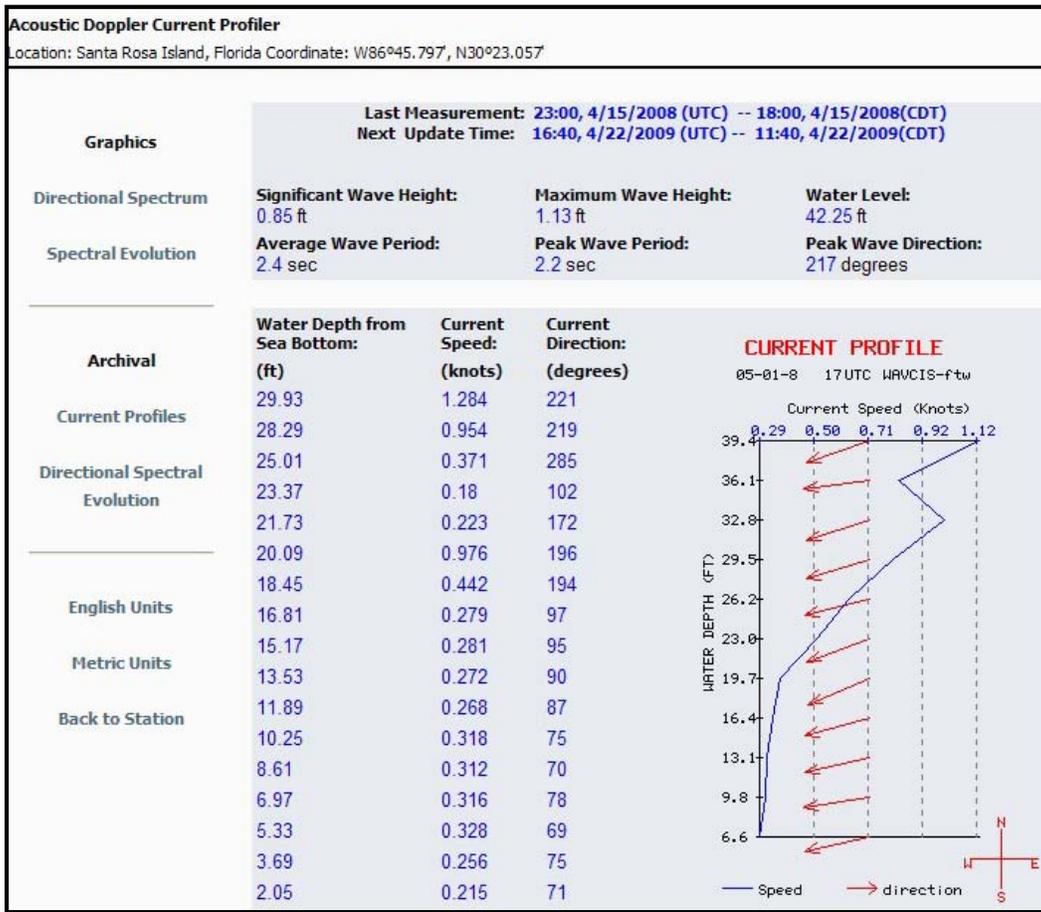


Fig. 4 Coastal current profile measured using a 1200 KHz ADCP off the Eglin Air Force Base at Fort Walton (CSI FTW), on 15th April 2008

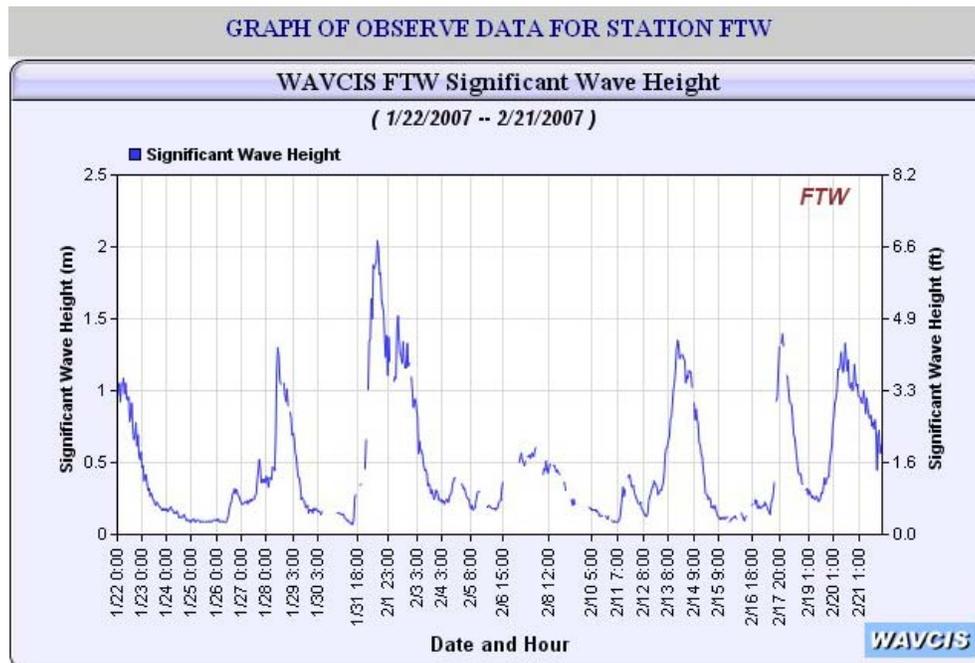


Fig. 5 Time series (one month) of significant wave height distribution from 1/22/2007- 2/21/2007. The peaks in wave height are correlated to the passage of winter storms. Significant wave height shows a maximum of 2 m

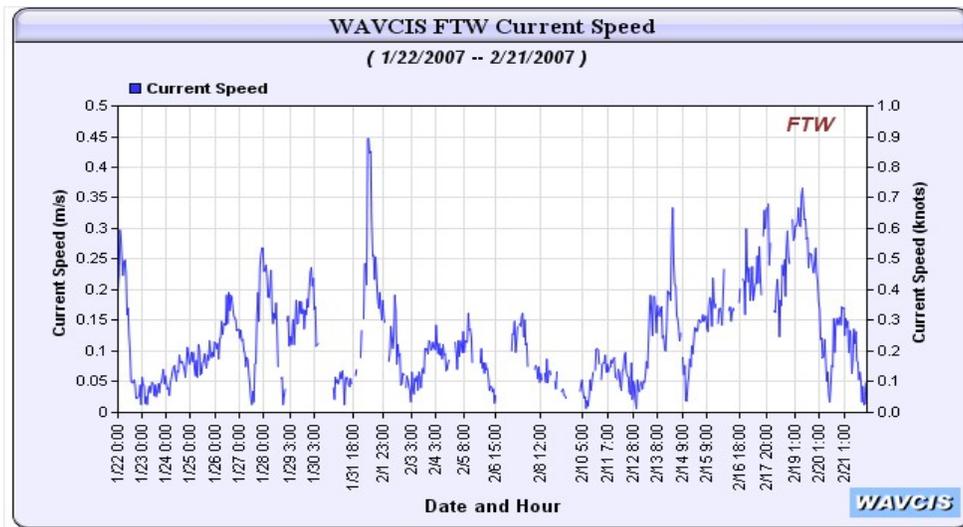


Fig. 6 Surface current speed distributions (one month) from CSI FTW station

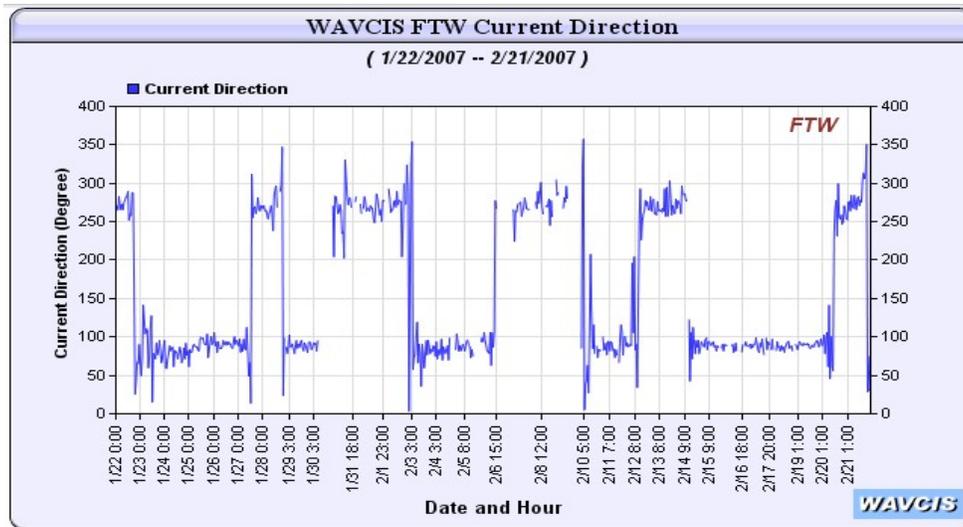


Fig. 7 Surface current direction distribution (one month) from CSI FTW station. Rapid shift in the current direction is attributed to the passage of cold fronts during the winter/spring season

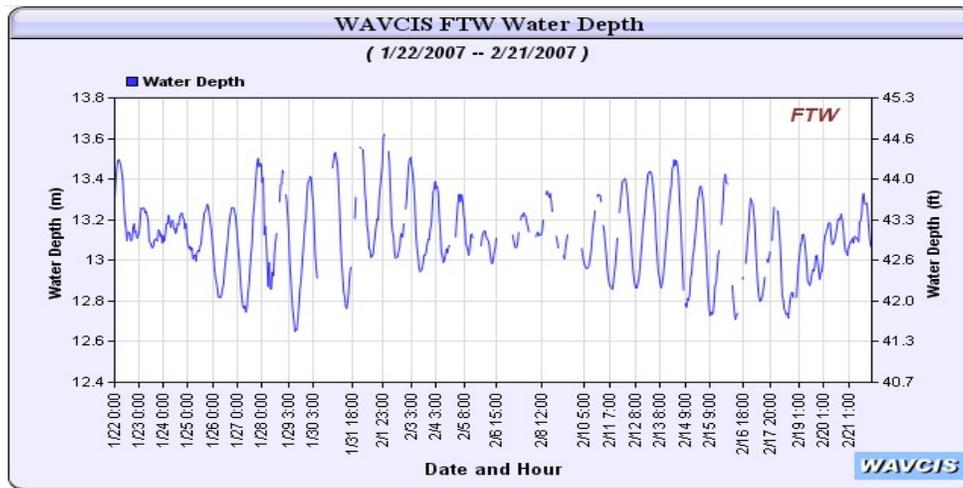


Fig. 8 Times series of water depth from CSI FTW station. The dominance of diurnal tidal components on the signal is evident from the time series

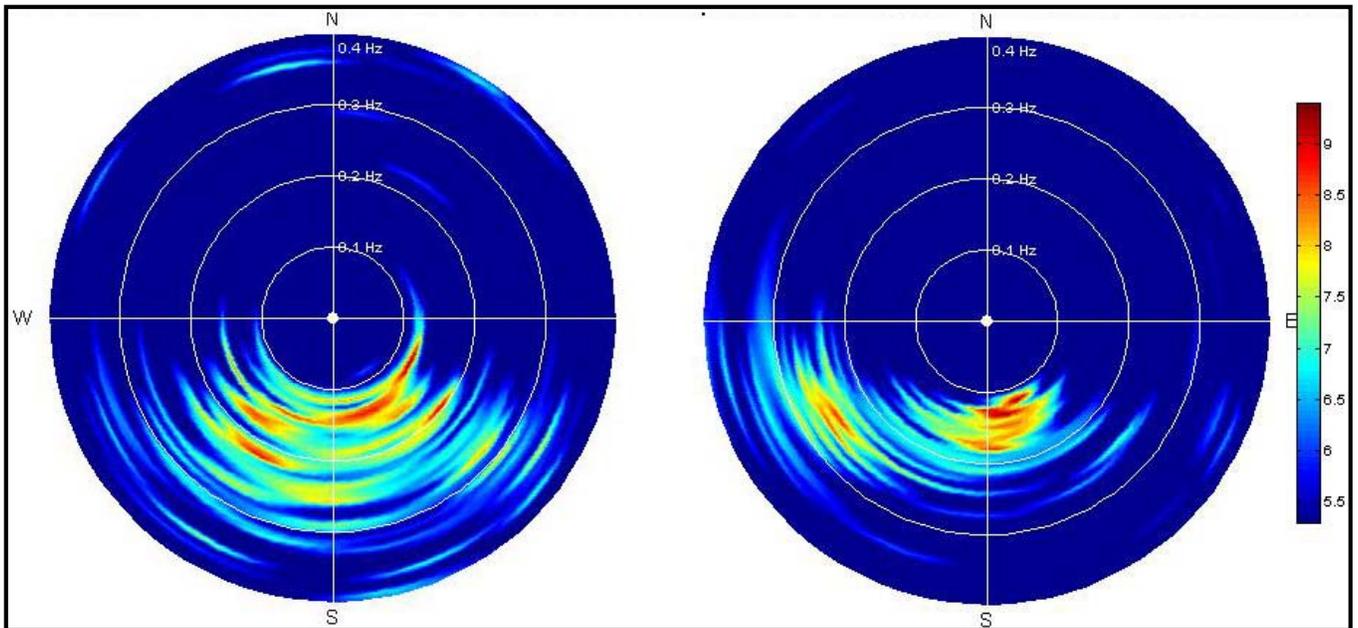


Fig. 9 Directional wave spectra during an extra-tropical winter storm crossing the coast; pre-frontal phase of the storm (left) and when the front approaches the station (right). The evolution in the directional spectra occurred within a time period of 10 hours on 1st January 2007. The spectral density values are magnified for visualization purposes.

IV. DATA QUALITY CONTROL

To ensure a high level of accuracy of WAVCIS data, standardized quality control procedures have been implemented and which consisted of four parts: 1. automatic screening, 2. Visual screening, 3. Field calibration, and 4. Documentation. Automatic screening is designed in the post processing program which checks the range of each parameter to eliminate outliers or other failures. Manual visual screening is performed after every download during working days and at least twice a day during weekends and holiday seasons. Trained personnel inspect the time series graphics for each parameter, compare different parameters with neighboring stations, e.g. wave height, direction vs. wind speed and direction. This procedure can detect problems that the automatic procedure may not find. Field calibration was performed whenever the field crew was deployed to the stations to ensure proper functioning of all sensors of the station. Documentation was kept on all raw data format change, detected errors in previous procedures and might be used for future re-calculation of the raw data.

V. WAVE FORECASTING AND MODEL SKILL ASSESSMENT

As discussed in an earlier section, the vast array of observational data being collected from the WAVCIS stations have been further used for skill assessment and for fine tuning of hydrodynamic models, viz., MIKE 21, WAVEWATCH-III, WAM, and SWAN. As an example, MIKE 21 SW model implementation is discussed in the following section.

A MIKE 21 SW (Wave forecasting)

The MIKE 21 Spectral Wave (SW) model has been developed by DHI Water and Environment[®] and has been implemented successfully for modeling coastal wave characteristics in the North Sea [12]. The model has been implemented for the Gulf of Mexico [13-14]. Ref. [15] implemented the model for the Florida Panhandle coast to study the bottom shear stress and wave induced sediment re-suspension during Hurricanes Ivan and Dennis. References [16] and unpublished [17] used the model for analyzing the hydrodynamics of Ship Shoal and Sabine Bank, along the Northern Gulf coast. The model is based on unstructured meshes and it simulates the growth, decay and transformation of wind generated waves and swells in offshore and coastal areas. The discretization in geographical and spectral space is performed using a cell-centered finite volume method. In the geographical domain, an unstructured mesh is used. The integration in time is based on a fractional step approach [12].

The model has been implemented for the Gulf of Mexico to forecast bulk wave parameters. Fine resolution synoptic forecast maps of significant wave height and wave direction for the Gulf of Mexico and for all the coastal zones bordering the Gulf of Mexico, including the Gulf coast of United States (see Fig. 10) Cuba and Mexico are accessible from the website. Eighty-four (84) hour forecasts are updated daily on the WAVCIS site at 05:00 (Local Time). The model is skill assessed with observed data from CSI FTW and the remainder of the coastal stations located along the Louisiana coast. Simulated bulk wave parameters (significant wave height, peak wave period and mean wave direction) were plotted against hourly *in*

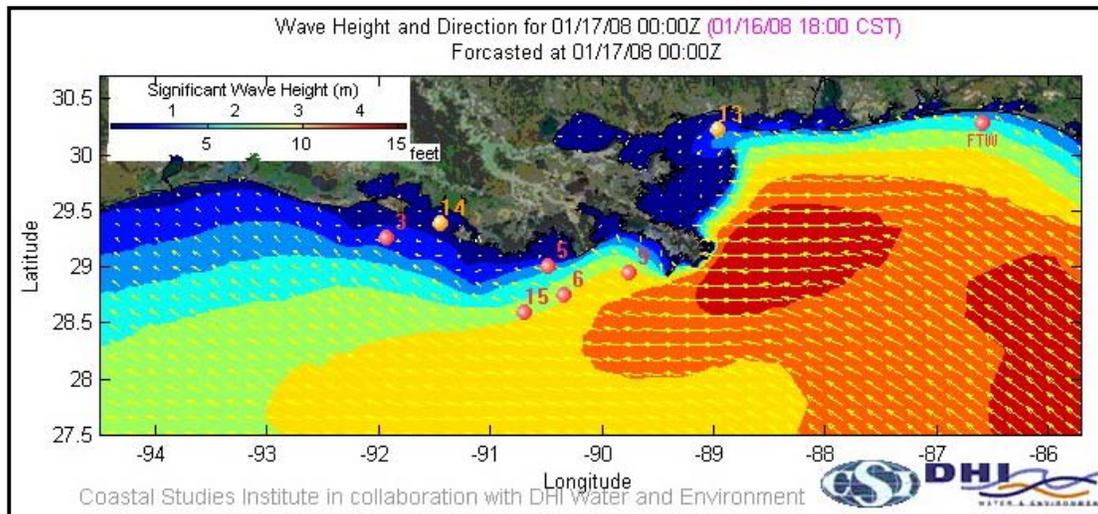


Fig. 10 Forecast of significant wave height and mean wave direction for the northern Gulf of Mexico, using the MIKE 21 Spectral wave model. The red dots on the plot correspond to WAVCIS stations for which near-real time model skill assessment is implemented.

situ observations from WAVCIS stations and the statistical parameters were computed. Results from the skill assessment of the MIKE 21 SW model, using *in situ* data from various WAVCIS stations, are also posted on the web.

VI. CONCLUSIONS

A new WAVCIS station has been set-up for the west Florida shelf, off Eglin Air Force Base, with an upward looking ADCP deployed at ~11 m isobath for measuring the coastal currents, waves and tide. The system was originally deployed during summer 2005 and was severely damaged due to Hurricane Dennis and was re-deployed shortly thereafter and remained operational until early summer 2008. Meteorological data were collected from a nearby station PCLF1, operated and maintained by NOAA's National Ocean Service. *In situ* observations from CSI FTW station include current speed & direction profiles, bulk wave parameters, directional wave spectra and water depth. Hourly processed data were communicated to the WAVCIS station, based at Louisiana State University, through secured cellular communication. The data are critical in monitoring wave and current transformation over the innershelf, associated with the passage of tropical cyclones and winter storms. The user-developed software controls the sampling scheme and the operational control of all of the sensors and even the communication protocol with the land station.

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