The 4-Dimension Ocean Cube Training Test and Evaluation Area

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Abstract

Over the next decade there will be an increase in the development and use of unmanned maritime technologies by the Navy, NOAA, and other commercial and educational entities. There is a need for a cost effective training, test, and evaluation (TT&E) area that can support the demonstration and evaluation of these emerging unmanned maritime systems. The University of Southern Mississippi (USM) has developed the environmental and oceanographic measurement tools, modeling framework, data processing, and visualization products required for the testing and performance evaluation of these maritime systems. Since the performance of these systems and their advanced technologies are coupled to changing ocean and atmospheric environments, their capabilities must be demonstrated, tested, and evaluated in an area with a broad range of oceanographic, acoustic propagation, and environmental variabilities. Mississippi's coastal waters provide these wide range of oceanographic variabilities that are not collectively available in other test areas. Data analysis, modeling, acoustic channel propagation characteristics, and visualization products have been developed to support TT&E activities for both private and academic research partners. Both underwater and atmospheric sensor systems provide data on the controlling environmental processes and their variabilities in the 4-D Ocean Cube test area. Nowcasts and forecasts using high-resolution Navy and NOAA operational models have been integrated into visualization and interactive tools to describe the 4-D Ocean Cube's operational environment.

I. Introduction

Over the next several decades there will be an increase in the development and use of unmanned maritime technologies by the Navy, NOAA, and other commercial and educational and entities. Thus, there is a need for cost effective methods and instrumentation systems that can support the demonstration and evaluation of these emerging unmanned maritime systems and their supporting advanced technologies.

Since the performance of these emerging advanced technologies and unmanned maritime systems are coupled to a changing ocean environment, their capabilities must be tested, demonstrated, and evaluated over a broad range of oceanographic, environmental, and acoustic channel propagation variabilities. These environments include deep-and shallow-water areas and areas that are controlled by numerus coastal forcing functions such as river discharges and high-current channels.

These types of test and evaluation areas are found in the Gulf of Mexico and along the Mississippi Gulf coast. Mississippi's Gulf coast is characterized by a unique shallow-water shelf that extends offshore for approximately 150 km with depths less than 30 m. A set barrier islands approximately 11 km offshore separates the offshore waters from the coast and creates high-current areas between the islands. These currents generate a highly-variable oceanographic and acoustic propagation environment south and north of these barrier islands. There are also large river run offs that influence theses near shore coastal-waters. Offshore, the Gulf of Mexico waters are controlled by the dynamic loop current and warm core rings that impact the local weather and bring periodic fluxes of salty-water across the shelf and into the sound enhancing the variabilities of both the oceanographic and the acoustic environment.

These wide-ranging variabilities in Mississippi's offshore and shallow-coastal waters form an ideal testing ground for the evaluation of unmanned maritime systems including their sensor systems and sensor data fusion concepts. These areas are also ideal for the evaluation of new underwater navigation advances that can be used to test innovative image processing approaches for new feature detection and classification algorithms. Each of these systems will have different surveillance and environmental measuring objectives all of which can be evaluated and demonstrated in these areas.

II. The 4-D Ocean Cube

The University of Southern Mississippi (USM) in collaboration with its research partners has developed the environmental measurement framework, data processing, the visualization and modeling environment, and vessel support required for the testing, performance, and evaluation of these new and emerging unmanned maritime systems. This training, test, and evaluation (TT&E) area is a 775 square kilometer area just south of the Mississippi barrier islands. The water depths range from 3 m to approximately 25 m. A schematic of the area with its measurement system nodes is shown in figure 1. The deployed measurement nodes consist of a wave rider buoy system, an ocean meteorological buoy, and a subsurface ambient noise and CTD mooring. The data from the wave rider and ocean meteorological buoy nodes are transmitted via iridium to USM's data fusion center at 1 hour intervals. The data from the moored ambient noise and CTD systems are stored internally.

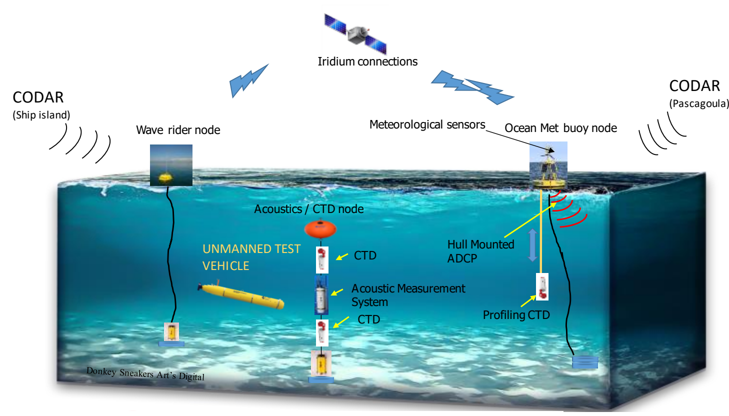

Figure 1. The 4-D Ocean Cube

A. Modeling and Visualization Environment

USM's 4-D Cube also has web accessible interactive marine modeling and visualization tools tailored for this Mississippi Sound test area. The tools provide parameter fields and vertical profiles from hydrodynamic models, and satellite and field observations. The Cube web tools display vertical profiles of current speed, temperature, salinity. These visualization tool also display surface chlorophyll, bottom depth contours, and ocean surface elevation.

The models used in the 4-D Cube environment are: 1) HYCOM (Hybrid Coordinate Ocean Model) which is the Naval Oceanographic Office's operational ocean model. 2) NCOM (Navy Coastal Ocean Model) this model was the operational global ocean model for the Navy prior to HYCOM. 3) The Northern Gulf of Mexico Operational Forecast System (NGOFS) and 4) The Northeastern Gulf of Mexico Operational Forecast System (NEGOFS).

Model resolutions, time steps and forecasting times are given in Table I. The horizontal resolutions of the different models range from 3.5 km to 0.4 km. The model vertical resolutions are determined by the number of layers that are calculated by each model and range from 13 to 36 depending on the model. These models can also forecast the currents, salinity, temperature profiles, and calculate the sound velocity profiles out to 144 hrs depending on the model. The visualization tools also have the capability to continuously step through these parameters in an hourly time frame. The along track sound velocity profile data are also inputted in to the Bellhop propagation model. This model uses these sound velocity profiles to calculated and display the propagation environment along that path.

Table I

Name	Source	Horizontal Resolution	Vertical Resolution	Time Step	Forecast
HYCOM	hycom.org experiment 90.1m000	3.5 km	36 z, sigma and isopycnal layers	3-hour	120 hours
NCOM	NRL-Stennis	1 km	13 z and sigma layers	3-hour	144 hours
NGOFS	tidesandcurrents.noaa.gov	1 km calculated at 150 m – 11 km	41 sigma layers	1-hour	72 hours
NEGOFS	tidesandcurrents.noaa.gov	0.5 km calculated at 45 m – 2.2 km	20 sigma layers	1-hour	72 hours

Figure 2 is an example of the layered interactive display of the currents calculated from the HYCOM model anywhere in the selected area off the MS coast. The arrows show the current directions at the surface. An example of the salinity, current, and temperatures profiles at the selected model layer depths calculated at point A are also shown in figure 2. The along track model outputs visualizations show the current speed and directions along the line B-C as a function of lat-long positions along the track. The visualization display also generates a 4-D display of the various parameters as a function of depth, spatial position, and time. These visualization and modeling tools are critical for vehicle tests, mission planning, and post mission performance analysis.

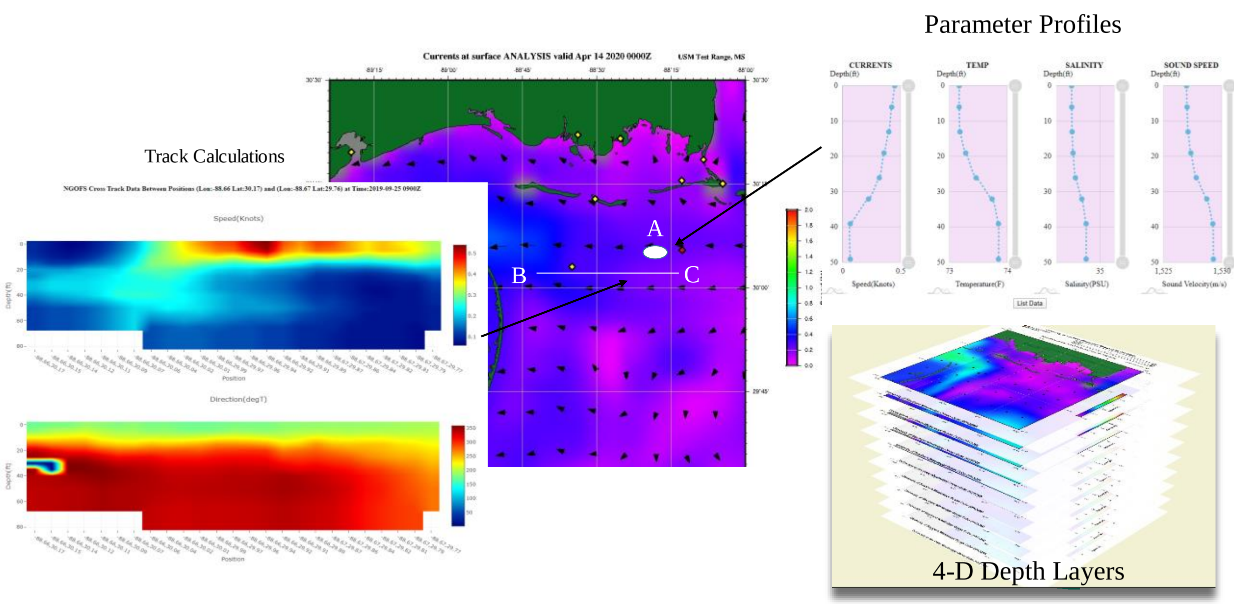

Figure 2. Visualization products generated using the HYCOM model

B. Data Environment

As shown in figure 1, the Ocean Cube is also instrumented with a number of high-resolution measurements nodes. A wave rider buoy measurement system was deployed in the 4-D Ocean Cube. The system was moored in about 12 m of water just south of Ship Island. The raw data continuously taken by this sensor system is stored on a 1GB compact flash card. Every hour segments of these data is transmitted via Iridium to USM's data fusion center for analysis. The wave rider buoy's configuration is also controlled via an Iridium link. Shown in figure 3 are examples of the available data analysis products. These include wave heights, various types of spectrum analysis, and spectral statistics. Numerous other types of analysis are available.

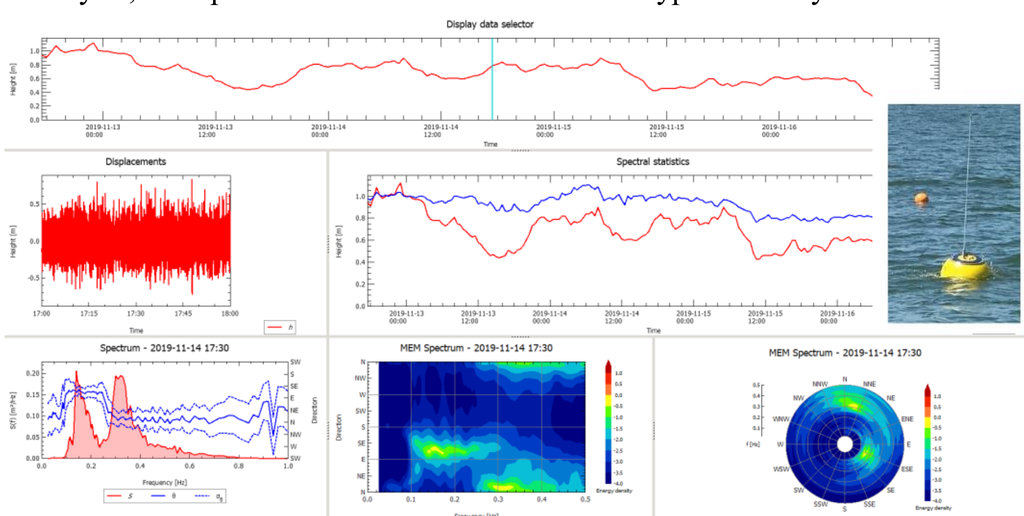

Figure 3. Wave rider data analysis

A 2-m diameter Ocean Meteorological is also deployed in 21 m of water at the south eastern side of the 4-D Cube. On this buoy are numerous high-resolution sensor systems that measure surface wind speeds, directions, atmospheric pressure, relative humidity, and surface wave characteristics. Subsets of these data are transmitted back to the data fusion center every hour via an Iridium connection.

This buoy has a unique CTD profiling system. The CTD is attached to cable-winch profiling system that controls the depths and time intervals of each profile. Currently this system conducts a water column profile every 6 hours. The data is stored on the CDT and subsets of the data are transmitted to the data fusion center via an Iridium connection every hour. The Examples of these temperature salinity profiles are shown in figure 4. A downward looking ADCP measures the spatial distribution of the subsea current field below the buoy. These data are stored on the ADCP and sunsets transmitted every hour back to USM’s data center.

An acoustic ambient noise measurement system is used to measure the ambient ocean noise and acoustic signatures of numerous types of passing ships (figure 1). Attached to this mooring are two CTD’s that measure the time history of the temperature and conductivity at a specific water depth. Since this is a subsea mooring all the data is stored internally on each of the sensor systems.

Examples of the some of the measured parameters are shown in figure 4. The temperature and salinity outputs from the unique profiling system is shown in figure 4. These data are for eighty profiles taken over a 20 day period. These data show the fluctuations of temperature and salinity over time and depth.

Also shown in figure 4 is an example of the measured spectral signature of a small fast boat passing surface mooring. A Labview software algorithm is also used to display segments of the data taken by the sensors on the Ocean Meteorological buoy. All of the buoy sensor data is recorded on the buoy controller memory for future download.

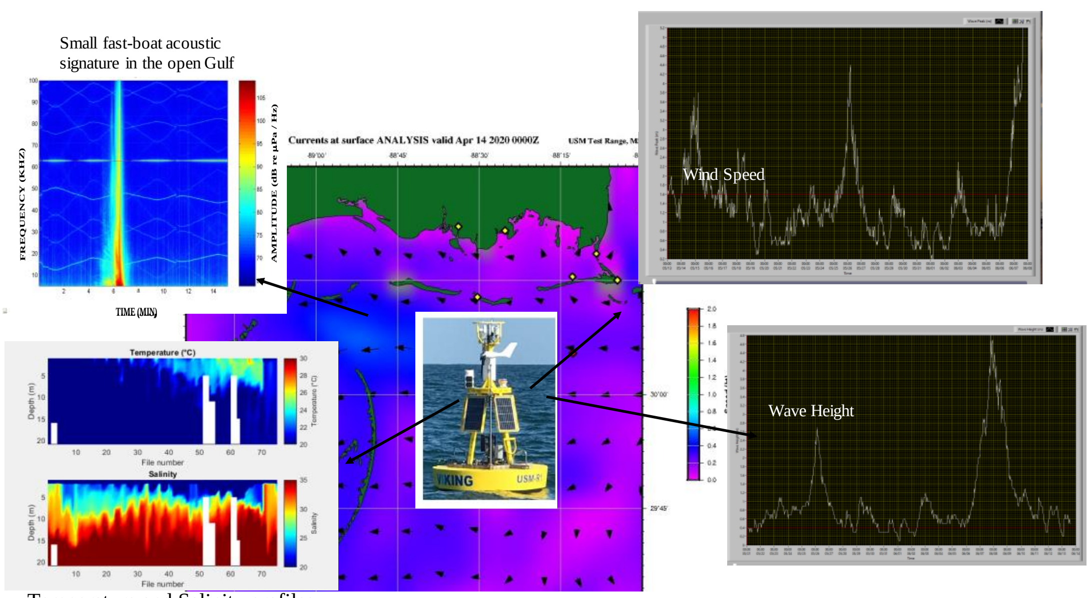

Figure 4. Acoustic and buoy data

III. Summary

Over the next several decades there will be a 100-fold increase in the use of unmanned maritime systems and their associated technologies. There is a requirement to develop a cost effective instrumented long-term test and evaluation area that will provide the conditions needed for their demonstrations, testing, and evaluations. There are currently numerous test and evaluation areas around the US and adjoining coastal areas. However, the Mississippi coastal waters are a unique and highly variable and dynamic area that is influenced by river run offs, highly variable current fields around the offshore islands, and the deep waters of the Gulf of Mexico. These areas provide a wide range of environmental and acoustic channel variabilities for testing and evaluations that are not collectively available at other test and evaluation areas.

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