Texas Automated Buoy System

Sustainable Ocean Observations to Help Protect the Environment

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Abstract*-The Deepwater Horizon oil spill off the coast of Louisiana in 2010 woke the country once again to the inherent risks involved in offshore drilling operations. The final overall cost of this spill will not only be measured in dollars, but also in the tragic loss of life, environmental damage to coastal wetlands and damage to the psyche of many of the local residents who once regarded the oil industry simply as a means to prosperity. Although the environment will likely eventually recover, the outrage, hardship and economic impact on local communities cannot be overlooked. Fortunately spills of this nature and magnitude are rare occurrences. Companies involved in the oil industry mitigate the chance for accidents by requiring proper personnel training, daily regular safety and toolbox meetings and regular equipment maintenance. There are standard operating procedures that must be followed for most operations on drilling platforms, tankers and fueling depots which are designed specifically to prevent the accidental discharge of oil. Still, regardless of the quality of training, equipment and procedures, some accidents will still occasionally occur. Some of these accidents will rarely, but inevitably, result in oil being discharged into the environment. Working at sea is a challenging and potentially dangerous occupation where the at sea environment can make even simple tasks difficult and hazardous. Being prepared to act on an oil spill is critical in being able to mitigate the potential impacts. Many of the people who were working on the Deepwater Horizon platform were not yet born in 1979 when the last big blowout occurred in Mexico's Bay of Campeche in the Gulf of Mexico. Some were too young to remember the Exxon Valdez disaster in 1989 and the enormity of the costs involved in cleaning it up. Events such as these led the United States government to pass the 1990 Federal Oil Pollution Act, which allowed the government and its agencies to take control of cleanup operations during an oil spill and recoup all expenses from the responsible party. This in turn led to the Texas government passing the Texas Oil Spill Prevention and Response Act in 1991. Because of the potentially large environmental and socioeconomic impact of any size spill that reaches the coast, there is a great need for timely knowledge and understanding about the environment in which the spill occurred. This is why in 1994, the Texas General Land Office (TGLO) contracted the Geochemical and Environmental Research Group (GERG) of Texas A&M University (TAMU) to develop the Texas Automated Buoy System (TABS). It is the only state funded ocean observation system in the country whose primary mandate is to provide oceanographic and meteorological data for the purpose of modeling oil spill trajectories. With nine permanent locations on the Texas shelf, the TABS system provides spill response managers in Texas with the real time data necessary to accurately predict the trajectory of an offshore oil spill so the environmental and economic impacts of the spill can be minimized. In sixteen years of operation, TABS has been used for decision making purposes in over forty events. The first few minutes after a spill has been detected are critical to determine how to treat the spill, how and where to intercept it and to determine what resources are required. The TABS system provides that vital information to allow response managers to act and mitigate the potential impact from an oil spill.

I. INTRODUCTION

The United States has approximately 12,853 miles of coastline bordering on 4 oceans from the Arctic to the Gulf of Mexico [1]. Preservation and protection of the coastal land and water environments is critical to the economic and social welfare of the people who inhabit these coastal areas and make use of the resources that the regions support. The contributions to the country's gross domestic product (GDP), individual state GDP's and socioeconomic wellbeing of the coastal population cannot be overstated. In 2007, coastal ocean communities of the United States were responsible for providing over 48,560,000 jobs in the US and contributing over 5.3 trillion dollars to the US economy[2].

One of the greatest threats to the continued wellbeing of the coastal regions in many parts of the United States is the potential for damage due to accidents in the offshore oil and transportation industries. This was highlighted recently by the 2010 Deepwater Horizon oil spill in the Gulf of Mexico and the subsequent loss of jobs and income of the locally affected populations. Long term damage to the coastal wetlands and nursing grounds are still being assessed and may not be known until after several breeding seasons. The 1989 accident involving the Exxon Valdez in Prince William Sound, Alaska highlighted the need for a national policy on oil spill prevention and response. At the time of the Exxon Valdez oil spill there was no cohesive spill response plan in effect in Prince William Sound. There was no federal, state or industry entity that had the resources or institutional mission to provide an effective response in Prince William Sound for a spill of this magnitude [3]. There was a single oil spill response barge which was out of service and unavailable at the time that 11 million gallons

(257,000 barrels) of oil were spilled. With industry self regulating tanker operations in the sound and the lack of a clear policy of who was in overall command of the response, there was insufficient scientific equipment to monitor the advance of the spill and insufficient resources to clean up and disperse the oil [3]. The lack of a comprehensive plan and preparedness for reacting to an event such as this resulted in nearly 1300 miles of coastline being impacted at a cost of over 2.8 billion dollars to Exxon.

TABLE 1:
Gulf state coastal region contributions to GDP by industry in 2004 [2]

State	Jobs - Coastal Areas	Wages/ Salaries ($ millions)	Fisheries ($ millions)	Tourism ($ millions)	Offshore Minerals ($ millions)
Alabama	22,091	453	48.4	354.5	601.6
Florida	312,190	6,800	174.8	10,721	67.3
Louisiana	112,680	3,200	287	2,164.6	6,405
Miss.	30,235	880.7	577	209.7	Not avail.
Texas	112,885	3,100	174	1,913.4	3,057.1

In response to this tragedy, in 1990 the United States federal government passed the Federal Oil Pollution Act (OPA) [4]. The legislation provides that the federal government and its agencies take charge of the oil spill response and cleanup efforts while the party responsible for the discharge of oil is accountable for all costs incurred related to the cleanup, lost income and revenue as well as damaged property.

There were two major incidents which occurred off the Texas coast in 1990 that spurred Texas legislators to enact its own Oil Spill Prevention and Response Act [6]. The first incident was a large lightering accident southeast of Galveston involving the super tanker Mega Borg in which over 5.1 million gallons of Angolan crude were spilled into the Gulf of Mexico. The second incident was the Apex barge incident in which 694,000 gallons of fuel oil were spilled into the Houston ship channel. The resulting legislation which passed in March of 1991 was called the Oil Spill Prevention and Response Act (OSPRA) [5]. In this legislation, the Texas General Land Office was named as the lead agency in responding to and mitigating the potential damage of an oil spill. It is the intent of OSPRA to support and compliment the OPA of 1990 particularly as it applies to the national contingency plan for cleaning up spills and discharges including provisions relating to the responsibilities of state agencies [5]. Historical data from the Gulf of Mexico that had traditionally been used for oil spill response planning and execution was inadequate for accurately predicting oil trajectories. Both these spill incidents in 1990, highlighted the need for local, on site command, prepared and ready to respond as soon as a spill takes place. Also highlighted was the need for timely accurate environmental information so that resources could be deployed in the proper areas to intercept, clean and prevent or minimize coastal impact from the oil [6][7][8]. The latter need became a reality in 1994 following a request from the TGLO that the Geochemical and Environmental Research Group (GERG) of Texas A&M University develop a near real time system to report near surface currents, winds and other environmental parameters to aid in spill response planning and modeling. GERG worked with the Woods Hole Group (W. Falmouth, MA) and Urethane Technologies (Denham Springs, LA.) to develop the first buoys. The Texas Automated Buoy System (TABS) became operational in April, 1995 and remains the only state sponsored ocean observing system in the United States dedicated to protecting the coastal environment from oil spills. With a principle mandate of supplying spill response managers with data to feed trajectory models, TABS provides managers with essential information, necessary to intercept spills at the earliest possible moment after occurrence and mitigate potential coastal impact and environmental damage.

II. Texas Automated Buoy System

Seven permanent deployment locations along the Texas coast (Fig. 1) between Sabine pass near the Texas-Louisiana border, and Port Isabelle near the US-Mexico border were chosen based on their proximity to population centers and ports, drilling and lightering activity, and general oceanography. Most of the TABS buoys are located within 12 NMI of the coast and one, site F, is located in the vicinity of a lightering area approximately 40 NMI SE of Galveston, where oil tankers offload their cargo to smaller tankers for delivery to Texas ports. An additional two TABS locations (sites N and V) were added in 2001 at the Flower Garden Banks National Marine Sanctuary (FGBNMS) and are supported by a consortium of oil companies through the Texas A&M Research Foundation and operated as part of the TABS program. All the buoys use solar energy to charge internal batteries which power the buoy controllers, sensors and telemetry systems. The limiting factor in deployment duration is marine fouling and mooring abrasion and erosion at the seafloor interface. TABS buoys transmit their data every 30 minutes over the Globalstar satellite network to GERG where data are passed through an initial level 1 quality control then processed and displayed on the TABS web page at http://tabs.gerg.tamu.edu/tglo. Each buoy in the TABS network is registered with the US Coast Guard as a private aid to navigation and has been given a letter designation as a site identifier.

The registered location of each TABS buoy is displayed on NOAA's nautical charts as an aid to navigation in order to inform mariners of their presence. TABS buoys have also been given number designations by the National Data

Buoy Center (NDBC) and data are provided to NDBC for inclusion in their database and distribution to the National Weather Service. Currently there are five types of buoys in the TABS fleet (Fig. 2). Each buoy measures, at a minimum, near surface currents, water temperature and salinity. Data from the buoy network are collected every 30 minutes via Globalstar satellite, processed at GERG and distributed to the TGLO, GCOOS (Gulf of Mexico Coastal Ocean Observing System), NDBC and to the general public through the internet. The TABS I buoy is a spar buoy designed to measure high quality near surface currents, salinity and water temperature in depths of 30m or less. These are typically used near shore at sites too shallow for the TABS II buoy. The TABS II buoys are a larger spar design with greater payload capacity and sensor capability.

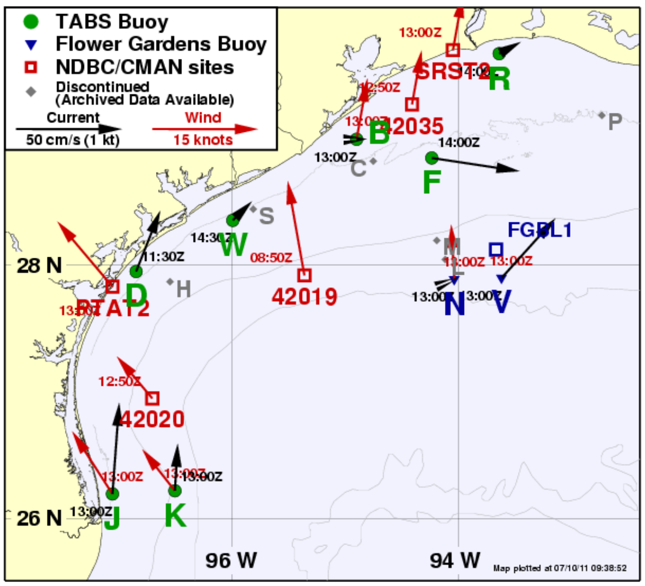

Figure 1: Map of TABS locations in the Gulf of Mexico on the TABS web page

TABS II buoys typically measure near surface currents and/or current profiles, water temperature, salinity, GPS position and time, as well as meteorological data such as wind speed and direction, air temperature, humidity and barometric pressure in water depths of up to 100 meters. The TABS II also has the capability of accepting additional subsurface sensors such as flourometers, transmissometers or turbidity sensors. One of the many lessons learned over the years is that because of their limited reserve buoyancy, small spar buoys with traditional moorings do not do well in hurricane conditions when deployed in water depths that approach 100 meters. Such is the case at TABS sites N, V and K. The type of mooring typically used to enable a TABS spar buoy to ride vertically in the water column is a heavy chain and wire catenary type mooring with scope (up to 2:1) provided by surplus light chain on the seafloor. Because of the weight required to properly ballast the buoy, the amount of reserve buoyancy is reduced, while at the same time increasing drag in the water column. It is the heavily damped motion imparted by the traditional chain catenary mooring that limits motion allowing high quality, low noise currents to be measured. While the additional chain on the seafloor does provide required scope for the mooring, it does not provide the necessary compliance or elasticity useful during storm conditions. Once the chain is stretched out, it does not rebound like nylon rope or other more compliant materials. By trading off reserve buoyancy and compliance, the buoy is susceptible to being forced underwater in heavy storms such as hurricanes. If the buoy is forced deep enough, the polyurethane foam floatation will compress to the point where the overall displacement is less than the weight of the mooring. In an effort to increase the compliance of the mooring, in May 2011, GERG remodeled the traditional catenary mooring to one based on an inverse catenary design where all the weight required for the spar motion is carried in the top portion of the mooring above the seafloor. Some measure of compliance is provided by nylon rope which makes up a significant portion of the remaining mooring. Mooring models indicate that the new mooring design with similar scope but greater compliance should provide increased survivability during hurricane conditions. The TABS II spar buoys are fabricated from closed cell 4 lb. polyurethane foam over an aluminum skeleton that houses the electronics and power supply [7]. The foam is covered with a woven Spectra 900© fabric and then covered with a rubber like Samthane coating to give the buoys a very tough resilient exterior resistant to cuts and scrapes from barnacles and being dragged over the deck of a ship. The TABS fleet of buoys has continued to grow and develop over the years and now includes a 2.25m discus buoy, which along with all the other oceanographic and meteorological parameters, also measures directional wave data and can be deployed in much greater water depths than the TABS II buoy. The buoy was developed at GERG in 2006 in part because of the poor performance of the TABS II buoy in extremely rough conditions. Since 2006, GERG has fabricated six of these buoys; one for TABS, two for the Flower Garden Banks (FGB) program, one for the University of Southern Mississippi (USM), and two for private industry.

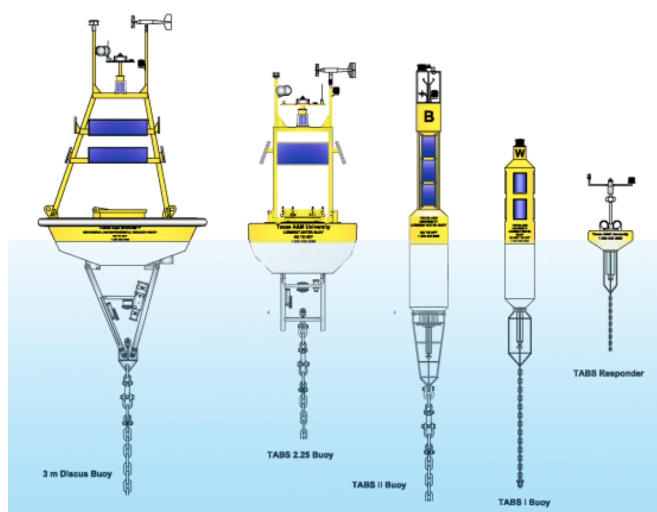

Figure 2: Drawing of different buoy types in the TABS fleet

The 2.25m buoy has 4900 lbs. of reserve buoyancy compared to the 750 lbs. reserve buoyancy of a TABS II buoy. The survivability of the 2.25m buoy was demonstrated during the passage of Hurricane Ike in 2008. Ike passed directly over the 2.25m buoy at site V near the Flower Garden Banks and the buoy continued to collect and transmit data throughout the storm's passage with only minimal damage to the buoy (Fig. 3).

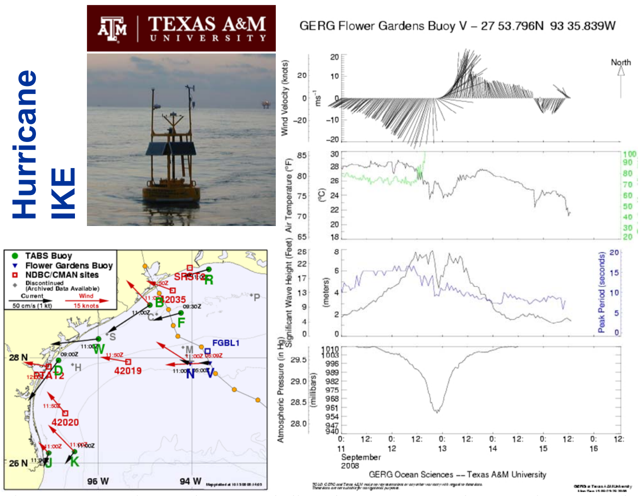

Figure 3: Hurricane Ike passed directly over TABS buoy V in September 2008.

The 2.25m buoy has now replaced the TABS II buoy as the preferred buoy in deeper water during hurricane season and is the type of buoy now used at sites N, V and K. Because of the limited number of buoys in both programs however, TABS II buoys will still occasionally be deployed at these offshore locations. The redesigned mooring for the TABS II buoy is also the mooring used for the 2.25m discus buoy which allows the buoys to be swapped at sea without the need to change moorings.

A byproduct of the steady increase in the cost of oil over the last ten years has been that it has made it more economical for oil companies to process heavy grades of oils including those with specific gravities greater than 1.02 kg/l. The result is an increase in the danger of oil spills involving submerged oil that does not leave a surface expression. The possibility of submerged spills adds a new dimension to oil spill trajectory modeling and requires subsurface current information as well as surface current information for input into the trajectory models. Local bathymetries, waves and winds can influence the distribution, suspension and movement of the submerged oil making it difficult to track. In November 2005, an oil tank barge in transit between Houston, TX and Tampa, FL struck submerged debris left over from the passage of Hurricane Rita off of Port Arthur, Texas. The debris ripped a 30 foot long gash in the hull of the barge and resulted in over 70,000 barrels of heavy fuel oil being discharged into the Gulf of Mexico. The heavy oil sank leaving no visible surface trace making recovery and tracking very difficult. Although a TABS II buoy with an ADCP was eventually deployed near the recovery site, it took time to mobilize and find a suitable deployment vessel before the system could be deployed. It became clear during the recovery effort that a small quick response buoy that could be quickly deployed on site and provide critical modeling information would be a valuable tool. Lessons learned from that spill resulted in the newest buoy in the TABS fleet called the TABS Responder (Fig.4). The Responder is a very small quick response buoy capable of being deployed by vessels of opportunity and measuring current profiles in water depths of up to 40 meters [9]. It can be deployed inside bays as well as offshore. It is designed to be deployed by ship crews with little or no electronic or computer experience. The Responder requires no input by the user other than turning it on and deploying the buoy with a very simple mooring. It is designed to be deployed at the location of the spill for durations up to two weeks at a time. The buoy was designed to withstand rough handling on deck, is equipped to measure near surface and profiled currents, water temperature, wind speed and direction, air temperature, barometric pressure, GPS position and time, as well as directional wave data. All data are stored on a micro HDSD card and transmitted to shore either by satellite or by Freewave radio every 30 minutes. The buoy weighs only 150 lbs and can be easily handled by two men on deck without the need for cranes or winches. The buoy is designed to be recovered, recharged and moved to whatever area is being occupied by the response crews.

Figure 4: Responder buoy being deployed near Sabine, TX

III. TABS PROGRAM COMPONENTS

The major components of the TABS program are the buoy maintenance/development and field operations, data handling and dissemination, real time analysis and modeling. TABS development is a continuing operation with the goal of maintaining a reliable, sustainable, high quality data network to support the TGLO in its spill response efforts. Although the primary mandate of TABS is to provide data for oil spill response mangers, a secondary goal is to provide relevant scientific information to researchers outside the oil spill community who can use TABS data for other research such as HABS (harmful algal blooms), Hypoxia or general circulation studies. New meteorological and oceanographic sensors are constantly being evaluated to determine if they would be beneficial for TABS in terms of data quality or content. TABS managers are open to the addition of new sensors to the buoys as long as they do not adversely affect the primary mission of supporting spill response. GERG is continually monitoring new solar power components, wind generators and battery technologies as they become available to determine if they can enhance the performance of the TABS buoys. Field operations are generally run two to three times per year with the goal of servicing the spar buoys at six month intervals in shallow water and nine month intervals in deeper water. The deployment duration is generally limited by marine fouling and wear on the mooring chain at the seafloor interface. Because the spar buoys use a chain catenary mooring, the seafloor interface wears the chain down through abrasion caused by picking up and depositing the chain and dragging the chain as the buoy moves around on the surface. The larger 2.25m or 3m buoys use an inverse catenary type of mooring that does not suffer the same wear and only requires changing about every two years. The buoys however still require annual servicing to clean the hulls and replace sensors. When the moorings are changed, GERG makes it a point to recover the entire mooring including the anchor so that no trash is left on the seafloor.

As a state funded program, TABS has always had the requirement to be a public resource. All data collected through the program are available to the general public through the TABS website. The website was developed to make access to the data easy so it can be used by anyone. Ultimately, the main beneficiaries of TABS are the citizens of Texas and all those who make use of the Gulf waters. Organizations and groups who routinely use TABS data include (besides the TGLO), NOAA, GCOOS, NASA, BOEMRE, US Coast Guard as well as pleasure boaters, scientific, recreational and commercial divers, and recreational and commercial fishermen. Because of the importance of the TABS data to the protection of the overall coastal environment, and the fact that it can be required at any time, redundancy is built in throughout the system. The data as well as the WEB products are maintained on two different systems at GERG in two different buildings. Data are maintained on two independent websites in case one site goes down. Each buoy also has a backup system so in the event that one of the receiving stations goes down, the buoy will automatically call a backup number. In addition, should the primary telemetry system fail on a buoy, there is a backup emergency transmitter that will transmit a subset of the data so that responders and other interested parties always have the latest information. Improvements to the original TABS website are currently underway that will eventually provide access to forecast animations, forecast overlays, and provide an up to date graphical interface (Fig. 5). Access to quick look data for each buoy location as well as to graphical data will be available by clicking on the individual buoy sites. Currently data from the TABS buoys are transmitted to GERG in College Station, TX every 30 minutes via the Globalstar satellite network so that the web pages can remain as current as possible.

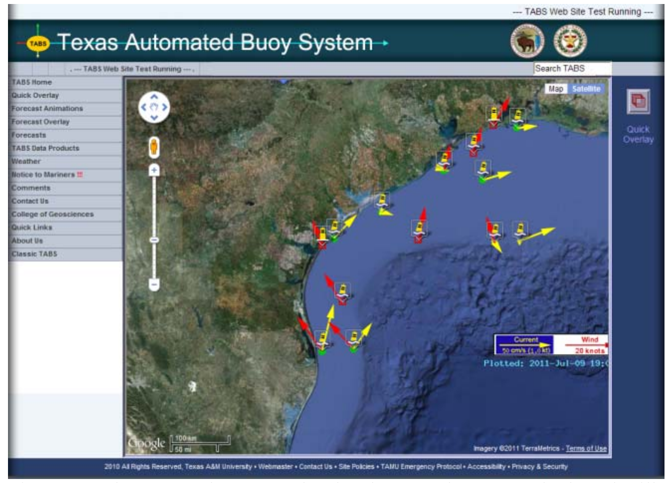

Figure 5: The new web page under development has a new look and will provide circulation forecast overlays and forecast animations

Once received, data are run through a level one quality control (conversion to engineering units and automatic removal of outliers) before being displayed on the web page. Additional, more stringent quality control is carried out once per day and a real time analysis (RTA) procedure is run to produce a number of different data products over time scales which can be chosen by the user. Some of these data products include time series plots, current roses, bivariate histograms, rotary spectra and spectral forecast models. Similar data products are available for both the oceanographic and meteorological data, as well as for Air-Sea interactions (waves, heat flux etc.) Engineering information along with data throughput statistics are also available in graphical format. Data output to the TABS web page are available to the user in graphical or tabular format. All data that has been collected and archived as part of the TABS program are available to the user through the TABS website in either graphical or tabular format. Two hydrodynamic models are maintained by the Department of Oceanography at TAMU, as part of the surface current prediction system [10]. A 3-D version of the Princeton Ocean Model (POM) has been adapted to perform simulations on the Texas shelf. The operational model is a simplified barotropic version that produces a 24 hour surface current simulation from 25^{o} N near the Mexican coast to 85^{o} W at the Florida coast. The second generation TABS modeling system uses the Regional Ocean Modeling System (ROMS) (Fig. 6) as the ocean circulation component. Both models are run on a daily basis by the Oceanography department at Texas A&M, and the output is available through the TABS website

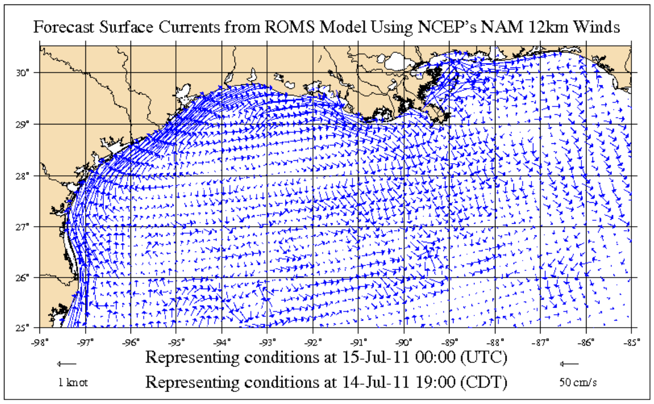

Figure 6: Sample of the ROMS output available through the current TABS website.

IV. Sustainability

Maintaining and developing a system such as TABS requires sustained funding from a source that needs and wants the data. Protecting the coastal waters of Texas was a priority set out in the Texas Oil Spill Prevention and Response Act that was passed by the Texas legislature in March 1991[5]. The government of Texas made a commitment to the people of Texas that it would do its best to ensure the coastal environment was protected from the potential damage of oil spills. The amount of damage and lost income that can potentially result from an oil spill was brought to light most recently by the Deepwater Horizon spill in 2010. The economic, social and environmental impact can be enormous. When the legislature passed the Oil Spill Prevention and Response Act, it also established the Coastal Protection Fund (CPF) to pay for damages, cleanup and expenses incurred during any unauthorized discharge of oil [5]. Money in the fund can only be disbursed for purposes specifically outlined in the legislation. The CPF is maintained by a 1.3 cent per barrel tax on all oil or condensate loaded or unloaded in Texas ports. It is a non lapsing revolving fund that can be depleted and refilled based on need and has a cap set at 20 million dollars. Once the upper limit of the fund has been reached, the tax is no longer collected. When the fund is depleted to below 10 million dollars, the tax collection is resumed. A limited portion of this fund is dedicated to institutions of higher education for the purposes of oil spill research, response technology, prevention and modeling to help mitigate the effects of an oil spill in Texas coastal waters. The core TABS program is funded through this provision. Additional funding is made available through a joint industry project comprised of a consortium of oil companies and is administered by the Texas A&M Research Foundation. Although other states have passed similar Oil Spill Prevention legislation and also administer Coastal Protection Funds, Texas is the only state with a program dedicated to research and prevention through the Texas General Land Office Oil Spill Response Team and programs such as TABS. As a local observing system, TABS is a contributing member to GCOOS and TABS supports the goals of a national Integrated Ocean Observing System (IOOS). GERG supports making the TABS data formats and metadata compatible with data formats being used by other observing systems around the country and is continuing to work towards that end. The interoperability of data systems is one of the primary goals of the IOOS data management committee.

V. Future Goals

The primary goals of TABS are to remain sustainable by providing timely high quality data to help protect the coastal regions of Texas, to maintain and continue to improve its current level of services and to continue to develop new systems that will be able to satisfy the mandate of TABS and also provide a platform on which other researchers can place instrumentation to enhance their research. TABS is paid for by the people of Texas and as such the TABS program has an obligation to provide data to public users in a clear and easy to understand manner which can be used to their benefit in either recreation or business. This is one of the goals for the new website that is currently under development. The new website will be easier to navigate, provide near real time environmental conditions in the Texas Gulf waters and provide overlays and animations of models to aid in spill response, search and rescue and recreation.

One of the downsides to living in such a technologically fast paced world is that electronic systems and components become obsolete much faster than they did in the past. As the TABS fleet of buoys ages, provisions for the future need to be considered. One of the goals for TABS over the next couple of years will be to design a replacement for the TABS I buoy using lessons learned over the last sixteen years of operation and newer technologies that provide greater versatility, reliability and long service life. The TABS I was the first buoy deployed for TABS in 1995. Although it has undergone many changes in terms of electronics and sensors, it is still limited in the type and amount of data it can provide. The goal will be to build a small, versatile, low cost, solar powered coastal buoy to serve the needs of the TGLO, the people of Texas and the overall ocean observing community.

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