A 50-Year History of Coastal Studies Institute Contributions to Science

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Abstract

The Coastal Studies Institute (CSI), Louisiana State University was established as an interdisciplinary and field-oriented research organization in 1952. Initial funding for CSI research was established to address Navy needs through institutional support from Geography Programs of the Office of Naval Research. Coastal geomorphology and sedimentology were the themes of early studies of the Louisiana coast. However, studies of biology, marsh ecology, and soils chemistry were included in the investigations of deltaic coasts where soon extended into other parts of United States including the Arctic as well as Europe, Asia, and South America. The institute grew from a single investigator and founder Dr. Richard L. Russell, in the early 1950s to 25 full-time personnel, numerous graduate students, and undergraduate student workers in the late 1960s. By this time, the institute's programs had expanded beyond the simple physical, biological, and cultural aspects of coasts to include physical oceanography, coastal meteorology, geochemistry and beach dynamics. During this era and through the 1970s fundamental science contributions were made in understanding worldwide delta variability, process sedimentology, lithification along tropical coasts, physical processes of reef environments, air-sea-land interactions of subtropical coasts, and wave dynamics/rhythmic changes of sandy beaches. At this time CSI was recognized as one of the world's most important and productive coastal research programs. By the mid-1970s CSI researchers had worked on every continent except Antarctica and research programs were expanding beyond the coast to continental shelves.

In the mid-1980s ONR changed its funding format and institutional funding which sustained CSI for ~ 30 years was gone. To function, the institute's research had to be funded project-by-project by a variety of national and state funding agencies. The CSI Field Support Group expanded to meet the challenge of new technology utilized on a variety of new problems in both shallow and deep water. Capabilities in high resolution seismic and side-scan sonar were developed in parallel with use of cutting edge oceanographic sensors. During this period scientific

achievements were made in shelf circulation and the dynamics of sea straits as well as the sedimentology of muddy coasts and the marine geology of mixed siliciclastic-carbonate shelves. In 1987, the Earth Scan Laboratory (ESL) was established within CSI to become the first NOAA AVHRR satellite receiving station in the Gulf Coast. Since then, the ESL has steadily improved remote sensing capability at LSU. Now, ESL acquires SeaWifs, MODIS, GOES-8, and RADARSAT data in addition to NOAA AVHRR. Programs in numerical modeling of waves and currents are currently developing for application to both shallow and deep water research problems. Most recently a number of real time ocean observing stations under the program name WAVCIS (Wave-Current Surge Information System) have been deployed along the Louisiana coast. Data from these stations have already provided insight into the oceanographic response to various types of storms, data critical for evaluating potential impacts to Louisiana's coast. Critical problems of land loss and coastal change in Louisiana need the attention of well-trained coastal scientists now and in the future. The Coastal Studies Institute at LSU remains a repository of experienced personnel for addressing these and other basic and applied science problems.

Introduction

The Coastal Studies Institute (CSI) of Louisiana State University is celebrating it's official 50th anniversary. The Institute's origin began as a result of a national study to evaluate the environmental problems faced by the defense department during World War II. Dr. Richard Russell, the founder of the Institute, served on this panel. One of the major findings was that a lack of coastal environmental data that could be used for accurate prediction of coastal conditions was the cause of major failures in wartime operations. Dr. Russell met with the newly appointed director, of the Coastal Geography Programs of the Office of Naval Research, Dr. Evelyn Pruitt, and convinced her that a long-term systematic research program should be oriented towards understanding the geomorphology and coastal processes that occur along the world's coastlines (Fig. 1). As a result of this relationship, a long-term contract between the Office of Naval Research and Louisiana State University was established. With the initial contract, Dr. Russell immediately enlisted several graduate students to begin studies of the Louisiana coast. They quickly became known as the "marsh rats" (Fig. 2). The initial projects concentrated on trafficability and stability of the Louisiana coastline and the effects of coastal changes caused by hurricanes. Although Dr. Russell coined the name for the Coastal Studies Institute in 1952, the Institute was not formally recognized by the Louisiana State University Board of Supervisors until 1954 when it became an independent unit under the School of Geoscience.

The initial studies of the Louisiana shoreline lasted from 1951 through 1958 and resulted in the first major understanding of coastal change and processes that affected a deltaic coastline. Later, additional graduate students continued to study the Louisiana coast and conducted studies on the botanical and archaeological aspects of the coastal marshes. These systematic scientific studies were the first to be conducted on coastal processes. With a promise of continuing funding, research activity expanded from the Louisiana coast to various foreign coastal areas. Research on one of the world's largest deltas, that of the Ganges-Brahmaputra River system in Bangladesh, was one of the first of many studies of foreign deltas (Morgan and McIntire, 1959). Additional research was carried out along the coasts of Brazil and Baluchistan. The 1960s saw the beginning of the study of carbon-

Figure 1. Dr. Evelyn Pruitt and Dr. R.J. Russell, the co-founders of Coastal Studies Institute. Dr. Pruitt provided support through Geography Programs at the Office of Naval Research while R.J. Russell directed science project activities.

Figure 2. The "marsh rats" who worked on the initial projects funded by ONR. From left to right they are: Lewis Nichols, Bob Treadwell, Jack Van Lopik, and Frank Welder.

ate coasts of tropical islands, environments that were not well-studied by the scientific community. This type of environment was the site of numerous failed beach landings during WWII and this research was aimed at a better understanding of carbonate beaches and the formation of beach rock. Studies were conducted in many of the Caribbean Islands.

In 1956, legal questions concerning the Louisiana coast, generally referred to as the Tidelands Issue, became the first CSI studies to be funded from sources other than the Office of Naval Research. The State of Louisiana contracted with the Institute to conduct studies of the changes in the Louisiana shoreline and the mudlumps at the mouth of the Mississippi River (Morgan, et al, 1968). Private industry (Gulf Oil Corporation), entangled in legal issues in the Mississippi River delta, contracted with the CSI to conduct investigations on those processes and sedimentological characteristics of the river's subdeltas (Coleman et al., 1969), specifically West Bay (Fig. 3). It was at this time that two full-time researchers were hired, James Coleman and Sherwood Gagliano. With the increase in grants and contracts, Dr. James P. Morgan, a professor of Geology at LSU, was appointed as Managing Director of the Institute (Fig. 4). These two contracts and with continuing support from ONR launched the Coastal Studies Institute on a 50 year program of continuous research on coastal and deltaic regions on a world-wide scale. It also marked the beginning of the "form-process" investigations in which geomorphic form is intimately associated with those processes responsible for the creation of the coastal landscape. Realizing the importance of coastal research, the Institute with the support of the University requested NSF funding for permanent housing of this newly created institute. In 1964, funds were made available to convert and upgrade three former military buildings on the LSU campus to permanent offices and laboratories.

Figure 3. Taking a rest from the West Bay project. From left to right are Dr. James Morgan, Dr. Marcus Hanna, graduate student Sherwood Gagliano.

River Deltas and Muddy Coasts

Early in the history of the Institute, studies were conducted on the arctic Colville delta (Walker, 1974, Walker, 1970). In the early 1960s a four-year project, referred to as the Coastal Information Program, was initiated. The objective of this research project was to acquire data from a large number of sources on approximately 200 variables on fifty world deltas (Wright, et al., 1974; Coleman and Wright, 1975; Coleman and Wright, 1977). This data-base then formed the basis for detailed field work on modern world deltas. Field work was conducted in the Burdekin (Australia), Klang (Malasia) (Fig. 5), Ord (Australia), Ebro (Spain), Sao Francisco (Brazil), Ganges-Brahmaputra (Bangladesh), Senegal (Africa), Nile (Egypt), and Yellow (China) river delta systems (Coleman and Wright, 1973). Associated field-work commenced in the early 1960s and lasted for some fifteen

Figure 4. Dr. James Morgan, managing director of Coastal Studies Institute during the pioneering work in the modern Mississippi River delta. Graduate student Frank Welder is in the background.

Figure 5. James Coleman and Gill Smith in the Klang River delta, one of the many CSI foreign delta projects.

years. These research efforts resulted in documenting the variability of modern world deltas, as well as gathering some of the best scientific information on delta processes and delta forms. This body of work formed the basis for delta studies by scientists in other domestic and foreign institutions. Later in the history of the Institute, an extensive study was conducted on the Mahakam delta in Indonesia (Roberts, 1996; Roberts and Sydow, 2003). Shelf-edge deltas became of interest to the petroleum industry in the 1990s, but little information was available on the details of their sedimentary architecture. A detailed research project funded by the petroleum industry was conducted on a late Pleistocene shelf edge delta slightly east of the modern Mississippi delta. This study added considerable knowledge to our understanding of late Quaternary shelf edge deltas (Sydow and Roberts, 1994).

Delta studies continued on the Mississippi River delta, investigating such topics as dynamic changes in the deltas (Coleman, 1988), sediment instability (Prior and Coleman, 1978; Prior and Coleman, 1982), river mouth processes (Wright and Coleman, 1971; Wright and Coleman, 1974), and sedimentary structures in deltaic environments (Coleman, and Gagliano, 1965), and the emerging new Atchafalaya-Wax Lake delta complex (Rouse et al., 1978; Roberts et al., 1980; Adams et al., 1982). The studies on sediment instability were some of the first studies to document submarine landslides on low angle slopes and the research on sedimentary structures in modern coastal environments formed the basis for interpretation of ancient deltaic deposits.

Since many shorelines adjacent to deltas are mud-rich, research studies on processes associated with muddy coasts were researched not only along the Louisiana coast (Wells and Roberts, 1981; Kemp and Wells, 1987), but in Pakistan (Wells, and Coleman, 1984), Surinam (Wells and Coleman, 1981), and Korea (Wells et al., 1990; Adams et al., 1998). These studies were some of the first investigations ever initiated on processes associated with muddy shorelines, which make up a major portion of the world's coasts. In more recent years, ONR has funded a new initiative to investigate the effects of muddy coasts on wave processes along western Louisiana, and to develop new numerical modeling schemes that will strengthen wave models used over seabeds characterized by cohesive sediments (Sheremet and Stone, in press; Stone and Sheremet, 2003).

As technology developed, more research was focused offshore and a larger Institute field support staff was needed. Institute investigators began to concentrate their research on the continental shelves that lie seaward of the shoreline. An extensive geologic study of the continental shelf offshore of Louisiana was based on one of the most extensive core-hole data sets ever assembled (foundation core holes for offshore drilling platforms) and resulted in a better understanding of the geologic framework and chronology of depositional events that helped build the Louisiana shelf (Coleman and Roberts, 1988a and 1988b). It was but a short jump to began research on the continental slope and research began on the sedimentary characteristics of the recent sediments deposited on the Louisiana continental slope (Roberts and Coleman, 1988), the history and formation of the Mississippi Canyon (Coleman, et al., 1983), and the geologic and biologic impacts of fluid-gas expulsion in deep water (Roberts et al., 1990; Roberts and Carney, 1997). This latter research formed some of the initial investigations into a potentially important energy source for the future, gas hydrates. In the early 1980s, an opportunity to participate in the Deep Sea Drilling Project aboard the last cruise of the Glomar Challenger resulted in one of the first detailed investigations of the processes and sedimentary characteristics of a deep sea fan, the Mississippi Fan in the Gulf of Mexico (Bouma, et al, 1986). Thus in a short period of time, roughly 20 years, investigations by Institute researchers had literally progressed from sedimentary processes at the shoreline to the deep waters of the Gulf of Mexico basin.

Beaches and Nearshore Processes

Some of the earliest research by Institute scientists was concentrated on beaches and the nearshore zone. Studies by Morgan and Larimore (1957) documented the changes along the Louisiana shoreline and showed that coastal erosion was prevalent along most of its length. In the 1960s little was known concerning the processes responsible for causing beach changes. Studies at the

Figure 6. Norwood Rector dyeing sand for a sediment tracer experiment on Fort Walton Beach, Florida.

Outer Banks of North Carolina by Dolan (1965, 1966) began to document the summer and winter processes causing changes in beach and nearshore topography. Using photographic techniques, the high frequency changes in beach morphology was documented (Dolan, 1967). Later, Sonu and van Beek (1971) instrumented the beach and nearshore area and documented the wave-induced currents that were responsible for short-term beach changes. More detailed research projects were conducted on a beach site in Fort Walton, Florida from the late 1960s through the early 1970s (Sonu, 1972; 1973), Figure 6. These studies documented beach response to a large number of forcing functions. Using a tethered balloon (Sonu, 1969) and a well-instrumented zone of the beach, documentation of the meandering currents and formation of rhythmic nearshore topography was established. During the period from 1971 to 1973, Institute researchers conducted a study of the temporal and spatial variability of the physical processes and environment of the Alaskan arctic coast. These studies were divided into four major themes: atmospheric processes; coastal hydrodynamic processes; coastal geomorphological characteristics; and beach processes and responses (Short, et al, 1974), Figure 7.

In the 1950s Morgan, et al. (1958) carried out the first comprehensive evaluation of hurricane impacts along the Louisiana coast after Hurricane Audrey made landfall in Cameron Parish in 1957. This study marked the beginning of a research thrust focused on the effects of storms on coasts. Most storm studies concentrated on the Gulf of Mexico, but did extend into the Caribbean (Stoddart, 1962b). Since these early CSI researchers have evaluated the morphological impacts of very powerful hurricanes land falling along the northern Gulf including impacts of hurricanes Camille (1969) along the Chandeleur Islands and Mississippi coast (Wright, et al., 1970); Andrew (1992) along the Isles Dernieres and Timbalier islands (Stone et al., 1993; 1995; Stone and Finkl, 1995); Opal (1995) along the Florida Panhandle (Stone, et al., 1996); Georges (1998) along south-central Louisiana (Stone et al., 1999) and more recently Isidore and Lili (2002) along the same area (Stone et al., 2003). A considerable amount of work has also been carried out by CSI researchers on winter storms associated with cold fronts (Huh et al., 2000, Armbruster and Stone, 2001; Pepper and Stone, 2002; Sheremet and Stone, 2003; in press).

Figure 7. A CSI research team preparing for a project on the north slope of Alaska. From left to right these researchers are: Walker Winans, Bill Wiseman, John Harper, Larry Rouse, the pilot, and student worker.

Tropical Carbonate Coasts and Shelves

Reconnaissance-level research started on tropical carbonate coasts early in CSI's history. These studies were initiated by R.J. Russell in the mid-to-late 1950s with an emphasis on determining the variability and origin of beach rock. Russell traveled throughout the Caribbean region making observations related to lithification of carbonate beaches and is credited with originating the term beach rock to describe the products of carbonate beach cementation. His research papers in Russell (1958), Russell (1959), Russell (1962), and Russell and McIntire (1965), chart progress on this subject and represent the first comprehensive appraisal of beach rock formation. It is interesting that his final field project was at Cape Sable at the southern tip of the Florida peninsula with a focus on ground water and beach rock (Russell, 1971).

Other early CSI studies along carbonate coasts and on carbonate islands are represented by McIntire (1961) and Sauer (1962) on the island of Mauritius in the Indian Ocean. David Stoddart from Cambridge worked through CSI to start his long career of studying carbonate islands and reefs with an expedition to the atoll reef platforms off British Honduras (Stoddart, 1962a, b). Other sites of CSI carbonate studies include a reconnaissance of Barbuda (Russell and McIntire, 1966), an appraisal of the coral cap of Barbados (Russell, 1966), a study of Isle de Lobos, Mexico (Rigby and McIntire, 1967), and investigation of the leeward reefs of St. Vincent (Adams, 1968), and initial studies on Grand Cayman Island (Rigby and Roberts, 1976). In the mid-1970s studies of carbonate depositional systems departed from the geomorphological approach of most previous CSI studies and followed the process focus already applied to selected deltas and beaches by CSI researchers. Instrumentation of the forereef shelf of Grand Cayman broke new ground in understanding the interaction of ocean processes and reefs (Roberts et al., 1975). These studies continued in Nicaragua and St. Croix with an emphasis on the processes encountered by shallow reefs that drive sediment transport and backreef lagoon circulation (Roberts and Suhayda, 1983; Roberts et al., 1992, Lugo-Fernandez et al., 1998). Other notable studies in mixed carbonate-siliciclastic systems include the investigation of eastern Nicaragua's coast and shelf (Murray et al., 1982), the carbonate platforms of the northern Red Sea (Roberts and Murray, 1984), the Java Sea shelf margin in Indonesia (Roberts et al., 1987), and the most recent investigation of the carbonate shelf opposite the Mahakam delta of eastern Borneo (Roberts and Sydow, 1997; 2003), Figure 8. These studies and other studies of carbonate coasts and shelves (Walker et al., 1982; Wilson and Roberts, 1992) conducted by CSI researchers indicate a continuing interest in developing a multidisciplinary approach to understanding modern carbonate settings.

Physical Oceanography and Coastal Meteorology Program

By the late 1960s it was apparent that a more comprehensive physical process approach was needed to advanced CSI's research to the next level. Although studies in the 1950s and early 1960s were multidisciplinary, a more quantitative approach toward coastal meteorology and wave-current dynamics was needed in order to expand and refine many of the research fronts initially explored by CSI investigators. To meet this need a program of shallow water physical oceanography was initiated. In 1967 University of Chicago trained Steve Murray was hired to start a program in coastal currents. Soon afterward (1969), a Texas longhorn, S.A. Hsu, was added to direct a research program in coastal meteorology. By 1971 it was clear that at least two additional researchers were needed to create a critical mass in physical oceanography and to meet the needs of a new Arctic research program that was on the horizon. In that year, a physical oceanographer from Johns Hopkins and the Chesapeake Bay Institute, Bill Wiseman, was added to work in the Arctic as well as on general estuarine and shelf circulation problems. With the addition of a Scripps Institute of Oceanography researcher trained in wave dynamics, Joe Suhayda, CSI had its first team of oceanographers to work in parallel with researchers working on sedimentology, beach dynamics, and coastal geomorphology. During this era air-sea-land interaction studies took center stage with the initial study on the sea breeze and its impact on coastal waves, currents, and beach response (Sonu et al., 1973). At the same time, S.A. Hsu established the theoretical foundation for the process of eolian sand transport (Hsu, 1971), a subject he has refined throughout his tenure at CSI, and physical oceanographic work started on the Louisiana coast (Murray, 1972). Hsu continued work on coastal meteorology by investigating shear stress and wind stability over the coastal ocean and at air-coast interfaces (Hsu, 1974 a and b). Fundamental advances in our understanding of the physi-

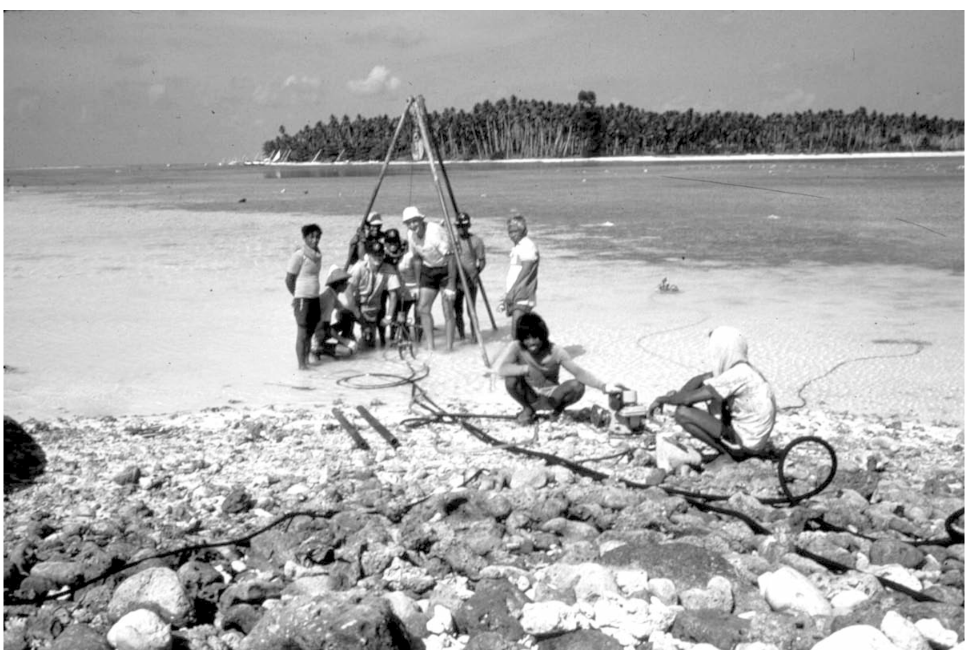

Figure 8. Coring an exposed reef on Toga Toga, a small island along the Sunda shelf margin in Indonesia. Drs. Harry Roberts and Charles Phipps were directing this operations.

cal process and sediment transport dynamics in the coastal zone were made during these years.

During the mid-to-late 1970s shallow water oceanography studies along the Gulf Coast (Murray, 1975; Wiseman et al., 1976) and in the Artic (Wiseman et al., 1974, 1979) expanded. At the same time foreign projects with the focus on coastal oceanography were started. The first was a study of the Guayas estuary of Ecuador (Murray et al., 1976). Later, the first detailed work on the eastern shelf of Nicaragua as conducted by CSI researchers (Murray et al., 1982). During the late 1970s CSI also initiated a program to study sea straits. This program continued for nearly twenty years under the direction of Dr. Murray and is covered in this paper under a separate heading.

Through the 1980s and 1990s much of the Institute's activities in physical oceanography and meteorology shifted toward the Gulf of Mexico. By 1988 S.A. Hsu published his book entitled "Coastal Meteorology" highlighting the results of both foreign and domestic studies conducted through CSI. This book established coastal meteorology as a scientific discipline and brought well-deserved attention to Hsu's research and the work of the Institute. Study of effluent from the Mississippi River, Louisiana estuaries, and flow on the inner shelf of Louisiana and Texas received thorough attention during this period (Wiseman and Dinnel, 1988; Wiseman et al., 1990a; and 1990b). In the early 1990s the Institute also started a serious research thrust in numerical modeling of ocean processes under the direction of Masa Inoue and Susan Welsh (Inoue and Welsh, 1991; Inoue et al., 2002).

Sea Straits Program

In the late 1970s – early 1980s it became clear that ONR had an increasing strategic and scientific interest in sea straits. Dennis Conlon, a graduate student in the Marine Sciences Department working with Dr. Steve Murray of CSI, initiated a long-running study of sea straits by completing a dissertation on the dynamics of flow in the Tsugaru Strait, Sea of Japan (Conlon, 1981). Later, as CSI lost institutional funding from ONR, because they changed their funding format, Dr. Murray was successful in attracting individual ONR support for a sea straits program that started with a study of the Strait of Jubal at the northern end of the Red Sea. Shortly after the field data collection was completed on the Strait of Jubal between the Sinai and the Egyptian mainland, the Strait of Tiran to the east was instrumented (Murray et al., 1984). Following these two landmark studies, funding was again acquired from ONR to extend the straits work into Indonesia to study the little known Lombok Strait between the islands of Bali and Lombok. The surprising volume of flow though the strait from the Pacific to the Indian Ocean provided an important piece in the puzzle related to balancing flow in the world's oceans. Also, low frequency variations in this Indonesian Troughflow were found to be related to storms in the Indian Ocean that caused water level setup along the Indonesian archipelago (Murray and Arief, 1988; Arief and Murray, 1996), Figure 9. Two other straits field measurement programs were conducted before Dr. Murray retired from LSU to take a position in the ONR Physical Oceanography Branch where he is now the director. These two field studies focused on the Vitiaz Strait off Papua New Guinea and the Strait of Bab al Mandab into the Red Sea. Excellent results were obtained in both of these studies (Murray and Johns, 1997). During this era of straits research, the CSI Field Support Group under the direction of Rodney Fredericks gained a reputation as a highly professional group of technical support personnel who could consistently get a high rate of data return from deep water moorings. This technology and experience has paid dividends for other CSI researchers who are working on deep water projects in the Gulf of Mexico.

Remote Sensing

With the development of a physical oceanography program at CSI, the need to put site-specific measurements into a larger spatial context became imperative. Satellite-based remote sensing data were beginning to fill that need by the late 1970s (Huh et al., 1978). In 1988 Dr. Oscar Huh started the Earth Scan Laboratory (ESL) within CSI with a grant from Louisiana's Educational Quality

Figure 9. Rod Fredericks is directing the deployment of current meters in the Lombok Strait, Indonesia.

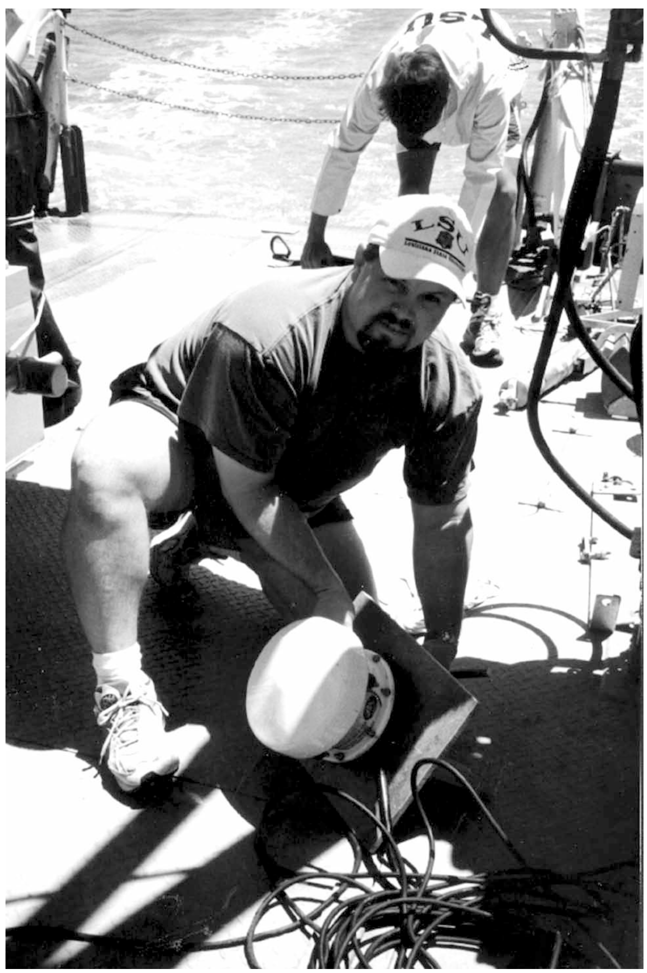

Figure 10. Steve Dartez preparing an ADCP current meter for deployment on a physical oceanography cruise in the Gulf of Mexico.

Figure 11. Mounting the RADARSAT SAR antenna on top of the Howe-Russell Geoscience Building for CSI's Earth Scan Laboratory.

Enhancement Fund. The ESL is a ground station, first on the Gulf coast, which now receives data from six different satellites. The first data sets received by the ESL were NOAA AVHRR images. Now, in addition to data from 4 to 5 NOAA polar orbiting satellites, the ESL receives GOES, Orbview-2 SeaWiFS, Oceansat OCM, MODIS, and most recently SAR (synthetic aperture radar), Figure 11. The archive of satellite data kept by the ESL is invaluable for researchers from many disciplines and for the state of Louisiana emergency response officials. Data from the ESL have been especially useful for (a) studying and predicting the behavior of the Loop Current in the Gulf of Mexico, (b) tracking and predicting the paths of hurricanes (real time data for emergency response planning), (c) tracking oil spills, (d) mapping sediment plume response to various natural forcing events, (e) identifying and tracking phytoplankton blooms, (f) mapping onshore flooded areas, and many other uses. As Louisiana relies on controlled river diversions to help offset the effects of subsidence and land loss, remote sensing products from the ESL will certainly play an important project assessment role. In many areas of research, remotely sensed satellite data have become essential. The ESL will hopefully play an increasingly important role for CSI as well as other research groups as we move into the second half-century of research at the Institute.

Future Directions

In 50 years of research Coastal Studies Institute has contributed to many facets of science including coastal geology-geomorphology, process sedimentology, shallow water oceanography, coastal meteorology, beach dynamics, arctic studies, dynamics of sea straits, worldwide delta variability, physical processes in carbonate settings, marine geology of continental shelves-slopes, numerical modeling of ocean process, remote sensing, and others. During this period CSI researchers worked on all continents except Antarctica and published hundreds of scientific papers. Researchers from CSI have been scientific ambassadors who have traveled the world working with fellow scientists in other countries and presenting scientific results at international professional meetings. The Institute has acquired tens of millions of dollars in grant and contract support and in the process given numerous graduate students an opportunity to work on cutting edge science problems in both domestic and foreign locations.

The multidisciplinary nature of CSI research has been the cornerstone of the Institute's success over the last half century and promises to be an important approach for the future. New technology is making it possible to collect extensive cross-discipline digital data sets from the coastal and marine environment. Ocean observing systems like CSI's WAVCIS (Stone, 2001; Zhang, 2003) and Baywatch (Walker and Hammack, 2000) are becoming more important for studying the effects of physical processes on the marine environment, for example, meteorological events on our coasts and continental shelves. We anticipate that these real time data collection and retrieval systems will provide the long-term quantitative physical process framework for posing more specific science questions about the shallow marine environment. In addition, numerical modeling of both shallow and deep ocean processes will play a larger role in future CSI research. With present and anticipated future computing power, numerical simulations of oceanographic phenomena will become more important (Inoue et al., 2002). Coupled with present and anticipated satellite-based ocean sensors, numerical modeling and remote sensing will be used together to explore a wide range of ocean processes. In situ and shipboard data collection systems for current speed and direction, ocean temperature, salinity, and other ocean chemistry sensors will provide the ground truth data base for calibrating remotely sensed data and numerical model results.

Improved digital high resolution seismic, side-scan, and swath bathymetry systems coupled to highly accurate GPS navigation is making data collection from bays to the deep ocean floor easier and in a format that can be processed and handled by a constantly improving software programs. These basic acoustic sensors as well as geochemical and ocean chemistry sensors are now being carrier on autonomous underwater vehicles (AUV) that have great range and navigational accuracy for collecting data from known depths above the seabed. Coastal Studies Institute has already started using one of these vehicles in marine geology studies of the Gulf of Mexico and it is anticipated that this platform for data collection will be more important in the future. Coupled with improved bottom sampling and sediment processing techniques, studies of ocean floor geology in conjunction with physical oceanographic process data will break new ground in understanding the current seafloor in the context of its physical process environment (Sheremet et al., 2002; Bentley, 2003; Sheremet and Stone, in press).

The state of Louisiana is entering a new era with increased emphasis on understanding of the state's coastal land loss and associated problems by both political and scientific communities. The challenge of dealing with these enormous natural systems problems is to create a solid foundation of science-based understanding so that the best possible solutions can be found. The half-century of research that Coastal Studies Institute has already conducted provides part of the science foundation needed, but we are still in an early stage of addressing Louisiana's substantial coastal problems. In the future, Coastal Studies Institute stands ready with a multidisciplinary research team and Field Support Group to meet Louisiana's scientific challenges and to study the variability of coastal and marine environments throughout the world.

Acknowledgments

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