FINAL REPORT

Texas High School Coastal Monitoring Program: 2016–2017

Tiffany L. Caudle







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Ball, High Island, Palacios, Port Aransas, Port Isabel, Tidehaven, Van Vleck High Schools and Cunningham Middle School

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INTRODUCTION

The Texas High School Coastal Monitoring Program (THSCMP) engages people who live along the Texas coast in the study of their natural environment. High school students, teachers, and scientists work together to gain a better understanding of dune and beach dynamics in their own locales. Scientists from The University of Texas at Austin (UT) provide the tools and training needed for scientific investigation. Students and teachers learn how to measure the topography, map the vegetation line and shoreline, and observe weather and wave conditions. By participating in an actual research project, the students obtain an enhanced science education. Public awareness of coastal processes and the Texas Coastal Management Program is heightened through this program. The students' efforts also provide coastal communities with valuable data on their changing shoreline.

This report describes the program and our experiences during the 2016–2017 academic year. During this time, Ball High School on Galveston Island completed its nineteenth year in the program, and Port Aransas and Port Isabel High Schools completed their eighteenth year (**fig**. **1**). Through collaboration with the Lower Colorado River Authority, the program works with three schools in the Matagorda area: Tidehaven and Van Vleck High Schools completed their thirteenth year in the program and Palacios High School completed its eleventh year. Cunningham Middle School in the Corpus Christi Independent School District marked its ninth year in the program. High Island High School on Bolivar Peninsula joined THSCMP during the 2015–2016 academic year. All of the schools anticipate continuing with the program during the 2017–2018 academic year. Discussions of data collected by the students are included in this report. The program is also enhanced by a continuously updated website (http://www.beg.utexas.edu/coastal/thscmp/).

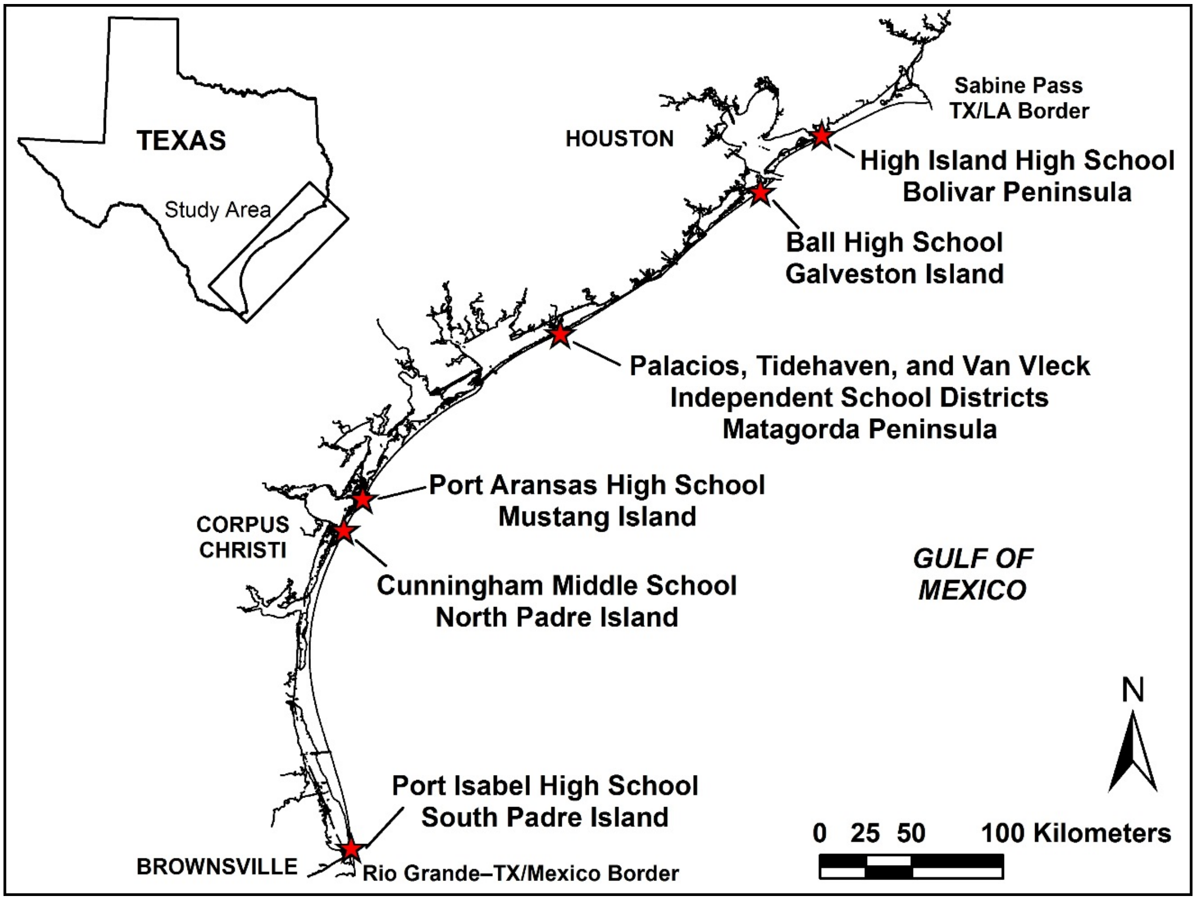

Figure 1. Location map of participating schools.

PROGRAM DESCRIPTION

Goals

The coastal monitoring program has three major goals:

(1) Provide students with an inquiry-based learning experience. Students make several field trips to their study sites during the school year. Working in teams, they conduct topographic surveys (beach profiles) of the foredune and beach, map the vegetation line and shoreline, collect sediment samples, and observe weather and wave conditions. Back in the classroom, students analyze their data and look for relationships among the observed phenomena. UT scientists provide background information and guide inquiries about the data, but students

are encouraged to form and test their own hypotheses. Through their collaboration with working scientists on an actual research project, the students gain an enhanced science education.

(2) Increase public awareness and understanding of coastal processes and hazards. We expect that participating students will discuss the program with their parents, classmates, and neighbors, further expanding the reach of the program. We also expect the program to attract media attention, as it has in the past. The program was featured in the 2006 and 2009 winter issues of *On the Coast*, a coastal-issues newsletter from the Texas General Land Office. A paper featuring the program and data collected by the high school students was published in the fall 2004 issue of *Shore & Beach* (Vol. 72, No. 4), the journal of the American Shore & Beach Preservation Association. A paper was written and presented at the 2012 Gulf Coast Association of Geological Societies annual meeting. THSCMP was presented at the 2013 American Shore and Beach Preservation Association national coastal conference in South Padre Island, the 2015 Texas Chapter of the American Shore and Beach Preservation Association Symposium in Corpus Christi, in a panel discussion on coastal outreach activities at the Texas Beach and Dune Forum in September 2015 in Corpus Christi, and the 2017 Texas Chapter of the American Shore and Beach Preservation Association Symposium in Port Aransas. An article based upon the data THSCMP students collect was published May 2017 in the Journal of Coastal Research (Caudle and Paine, 2017). A website (http://www.beg.utexas.edu/coastal/thscmp/) containing the latest information is central to the community outreach part of the project. Coastal residents can view the effects of a storm that strikes the upper coast by accessing the THSCMP website to view maps, graphs, and photographs collected by Ball High School.

(3) Achieve a better understanding of the relationship between coastal processes, beach morphology, and shoreline change and make data and findings available for solving coastal management problems. The Bureau of Economic Geology (Bureau) at UT has conducted a 40-year research program to monitor shorelines and investigate coastal processes. An important part of this program is the

repeated mapping of the shoreline and measurement of beach profiles. Over time, these data are used to determine the rate of shoreline change. A problem we face is the limited temporal resolution in our shoreline data. The beach is a dynamic environment where significant changes in shape and sand volume can occur over periods of days or even hours. Tides, storms, and seasonal wind patterns cause large, periodic or quasiperiodic changes in the shape of the beach. If coastal data are not collected often enough, periodic variations in beach morphology could be misinterpreted as secular changes. The THSCMP helps address this problem by providing scientific data at key locations along the Texas coast. These data are integrated into the ongoing coastal research program at the Bureau and are made available to other researchers and coastal managers.

Methods

The central element in the high school monitoring program is at least three class field trips during the academic year, weather permitting. During each trip, students visit several locations and apply scientific procedures to measuring beach morphology and making observations on beach, weather, and wave conditions. These procedures were developed during the program's pilot year (1997–1998) and are available on our website, which also includes field forms. The following is a general discussion of the field measurements.

(1) Beach profile (**fig. 2**). Students use a pair of Emery rods, a metric tape, and a hand level to accurately survey a shore-normal beach profile from behind the foredunes to the waterline (Emery, 1961; Krause, 2005; O'Connell, 2001). The students begin the profile at a presurveyed datum stake so that they can compare each new profile with earlier profiles. Consistently oriented photographs are taken with a digital camera. The beach profiles provide detailed data on the volume of sand and the shape of the beach.

(2) Shoreline and vegetation-line mapping (**fig. 3**). GPS mapping provides measurements of the rate of change. Using handheld GPS units, students walk along the shoreline and vegetation line mapping these features for

display on Geographic Information System software. A comparison of positions determined through GPS mapping over time allows students to visual shoreline and vegetation line changes.

Figure 2. Students using (A) a sighting level to determine vertical offset between Emery rods, and (B) a metric tape to measure horizontal distance.

Figure 3. Students mapping (A) the vegetation line and (B) shoreline (wet/dry line) using handheld GPS units.

(3) Beach processes (**fig. 4**). Students measure wind speed and direction, estimate the width of the surf zone, and observe breaker type. They note wave direction, height, and period and estimate longshore current speed and direction using a float, stopwatch, and tape measure. Students also take

readings of shoreline and foredune orientation. From these measurements, they can infer relationships between physical processes and beach changes in time and space. Students also learn to obtain weather and oceanographic data from resources on the Internet.

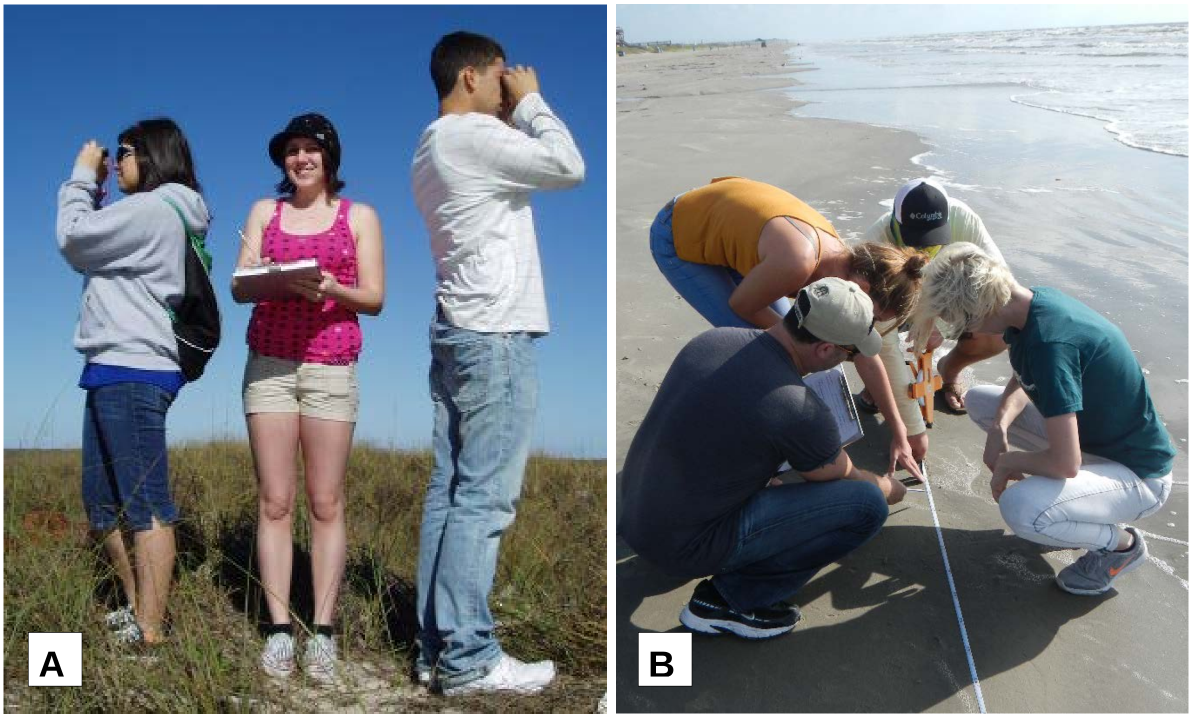

Figure 4. Students (A) using a sighting compass to measure dune orientation, and (B) measuring how far along the shoreline the float (an orange) drifted to determine longshore current.

Training

Bureau scientists provide teachers and students with all the training, information, field forms, and equipment needed to conduct field and lab measurements. During the school year, Bureau scientists accompany students on at least one field trip. The scientists discuss with students general and theoretical issues regarding scientific research, as well as specific techniques and issues related to coastal research. The visits also provide scientists with an opportunity to ensure quality of the data.

Data Management, Data Analysis, and Dissemination of Information

The web is central to the dissemination of data collected for this program. A UT-based website (http://www.beg.utexas.edu/coastal/thscmp/), implemented toward the end of the 1998–1999 academic year, provides all the information needed to begin a beach-monitoring program, as well as curriculum materials for high school teachers. Each school in the program has an area on the website for posting its data and observations, including digital photos. After Bureau scientists manage the data in an electronic database and evaluate it in light of coastal management problems, they then make it available to the public.

STUDENT, TEACHER, AND SCIENTIST INTERACTIONS DURING THE 2016–2017 ACADEMIC YEAR

In 1997, BEG researchers developed a pilot beach-monitoring program with Ball High School on Galveston Island (Caudle and Paine, 2012; Hepner and Gibeaut, 2004). THSCMP has since expanded several times to now include a total of eight schools (Table 1). Expansion of the program has not only increased the number of high schools in THSCMP but also introduced middle school students, who make the same field measurements and observations as the high school students. Students in the program are enrolled in classes such as physics, environmental science, biology, aquatic science, and general science.

Table 1. Schools involved in THSCMP.

School	Location	Year Started
Ball HS	Galveston Island	1997
Cunningham MS	North Padre Island	2009
High Island HS	Bolivar Peninsula	2016
Palacios HS	Matagorda Peninsula	2006
Port Aransas HS	Mustang Island	1999
Port Isabel HS	South Padre Island	1999
Tidehaven HS	Matagorda Peninsula	2005
Van Vleck HS	Matagorda Peninsula	2005

BEG researchers work with the same teachers each academic year. Researchers communicate directly with teachers to schedule field trips in the fall (September or October), winter (January or February), and spring (April or May). The teacher arranges transportation to the study sites (bus or SUV, depending on class size) and a substitute teacher to cover his or her classroom for the day. In order to encourage school districts to continue participation in THSCMP, project support provides funding to cover the cost of student transportation and substitute teachers. A stipend is also provided to the participating teachers.

The most heavily used segments of the Texas coast are now monitored two or three times a year (**fig. 1**). Students monitor beaches, dunes, and vegetation lines from the following sandy barrier islands and peninsulas: Bolivar Peninsula, Galveston Island, Matagorda Peninsula, Mustang Island, and North and South Padre Islands. Staff from the Lower Colorado River Authority (LCRA) at Matagorda Bay Nature Park help facilitate field trips on Matagorda Peninsula and graduate students from the Harte Research Institute, Texas A&M University Corpus Christi help with the Cunningham Middle School field trips.

A Bureau scientist visited each school at least once, coinciding with the first field trip of the academic year. During field trips, scientists discussed coastal issues pertaining to the area that the students were visiting, coastal issues concerning the entire State of Texas, and careers in science. These visits served not only to enhance scientific instruction but also to give students insight into science as a career and the chance to discuss coastal community concerns.

During field trips, students were divided into two or three teams, according to the size of the class. One team measured the beach profile while the others collected data on weather and waves or conducted a GPS survey of the shoreline and vegetation line. Team members had specific tasks; after each team completed its tasks at the first location, the teams switched roles so that everyone had an opportunity to conduct all measurements.

Dividing students into five- to eight-member teams works well. Aside from conducting the beach profile and measuring processes and the shoreline, additional tasks can be assigned to the team that finishes first. It is important to assign each student a job to keep him or her focused and interested, although time for a little fun is also allowed. People normally think of the beach as a place of recreation, and participation in this project should not change that. In fact, it is hoped that program participants will enjoy going to the beach even more because of their newly acquired knowledge and observation skills.

The method of breaking students into teams and collecting data works well for high school students. Adding middle-school students to the program has changed our approach to working with students only slightly. For example, Matagorda area schools, which collect data on Matagorda Peninsula, collect data from only one monitoring site. Because of the distance from the schools to the beach (around 45 minutes to 1 hour each way), time does not always allow data collection from multiple sites. Instead of breaking into groups to collect the data, we attempt to keep the students active by constantly rotating them through the different positions. The last student to conduct a measurement teaches the next student.

The day of the field trip, students meet in the teacher's classroom to organize equipment and gather additional materials that they may need for the day (coolers with ice and water, lunches, and so on). Throughout the day, data and samples are collected from one to three locations, with sufficient time allotted for lunch and breaks. On some trips, there is time for additional scientific inquiry. Port Isabel students have visited the Laguna Madre Nature Trail on South Padre Island or used a seine net in Laguna Madre. Ball High School students have observed the wetlands at Galveston Island State Park; used different types of nets (such as seine and cast nets) to observe shrimp, crabs, and small fish that live in the waters at the edge of the wetlands; and tested water quality. Port Aransas High School students have visited the University of Texas Fisheries and Mariculture Laboratory or the Marine Science Institute. All trips allow ample time for careful data collection, while ensuring that students are back at school about 1 hour before the end of the day. During this hour, equipment is stored and data are filed or transferred to the computer.

The following sections detail specific activities at each school.

High Island High School

High Island High School joined THSCMP during the 2015–2016 academic year. Ms. Caudle worked with High Island High School science teacher Maria Skewis to start the Program in the High Island Independent School District. Tenth grade biology students collected data from three sites on Bolivar Peninsula on October 5, 2016; February 1, 2017; and May 10, 2017. Two of the monitoring sites are adjacent to Rollover Pass, BOL02 to the west and BOL03 to the east of the Pass (**fig. 5**). The third site (HIB01) is seaward of High Island just past the eastern end of Highway 87 (**fig. 5**).

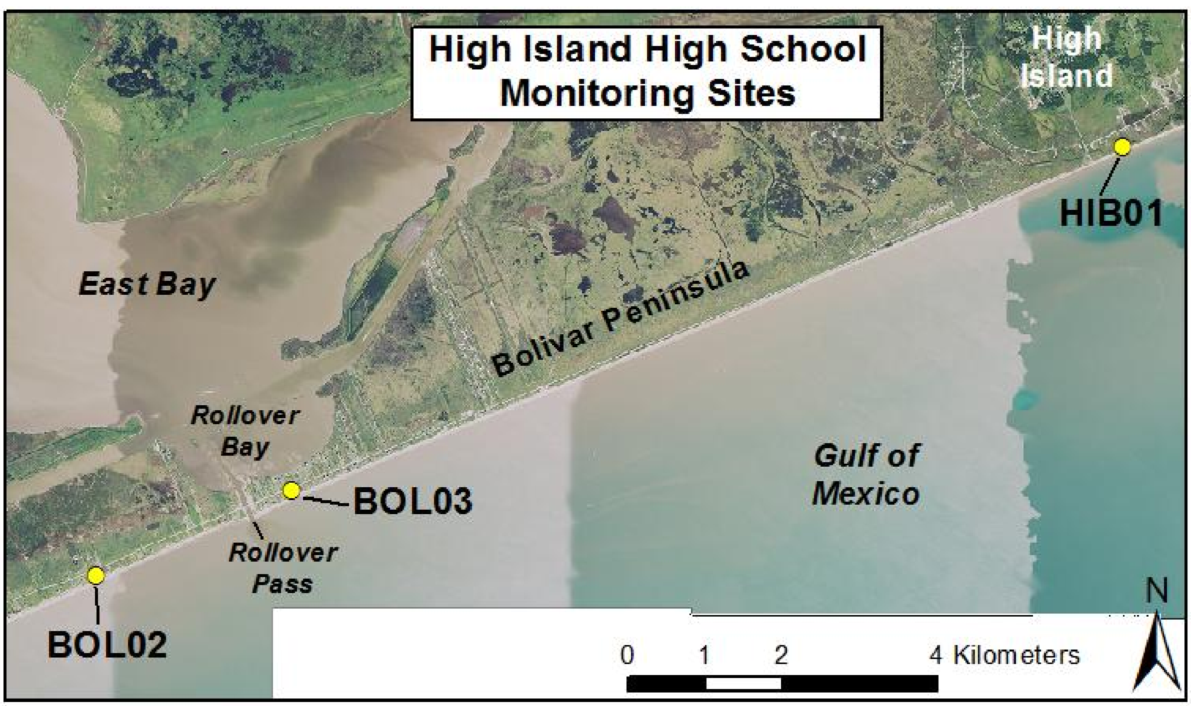

Figure 5. Location map of High Island High School monitoring sites.

Ball High School

Dr. Daniel Hochman's AP Environmental Science classes at Ball High School participated in field trips on October 6, 2016; February 2, 2017; and May 11, 2017. Students conducted surveys at Galveston Island State Park, BEG02 (**fig. 6**)—a profile that the Bureau has been measuring since the 1980's. Ball High School students also started collected data at two new locations, JAM02 in Jamaica Beach and DEL01 at the Dellanera RV Park (**fig. 6**). Both of these sites will monitor beach nourishment and Coastal Erosion Planning and Response Act (CEPRA) beach and dune restoration activities.

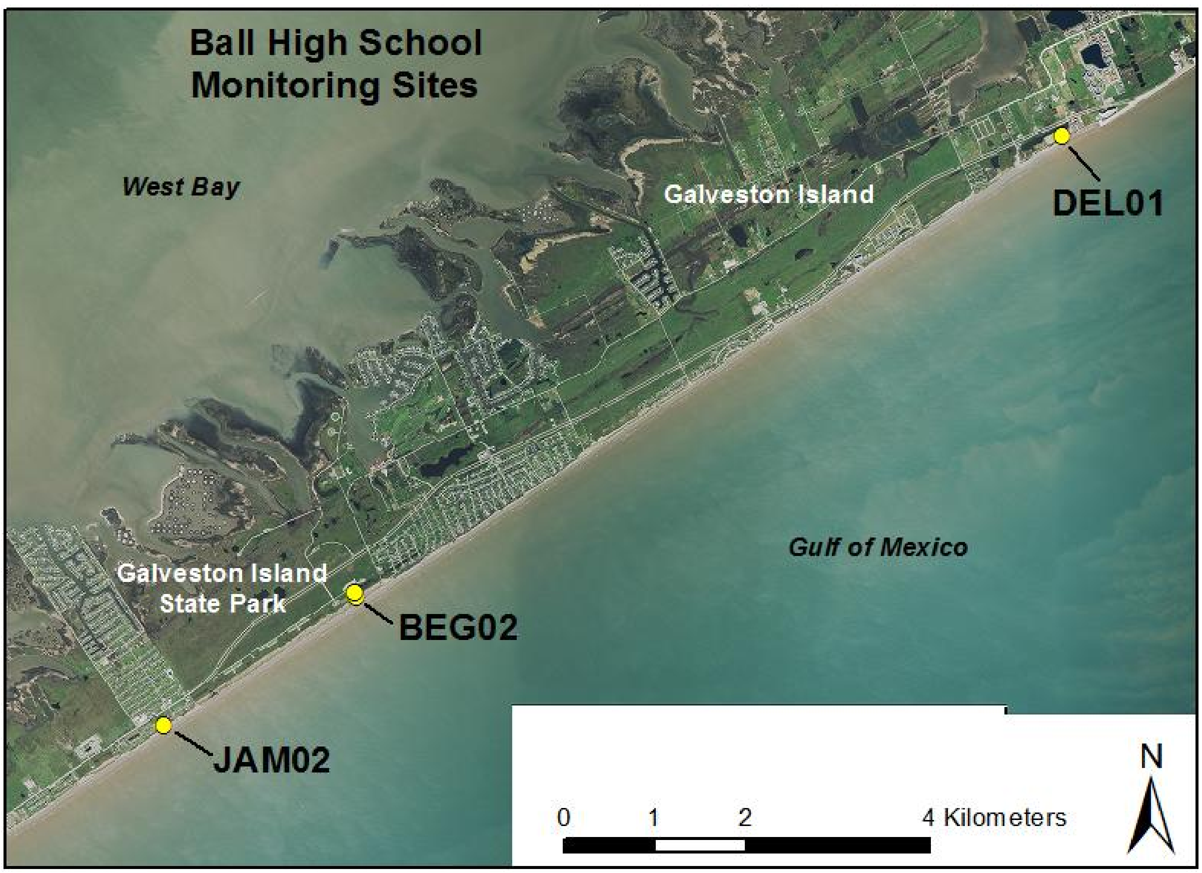

Figure 6. Location map of Ball High School monitoring sites.

Matagorda Area Schools

Van Vleck High School environmental science students participated in field trips on September 23, 2016; January 12, 2017; and May 11, 2017. Sherry Martinez's class collected data at MAT01 (**fig. 7**). Physics students from Palacios High School participated in field trips September 22, 2016; January 11, 2017; and April 26, 2017. Richard Davis' students collected data at MAT02 (**fig. 7**). Tidehaven High School participated in field trips on September 21, 2016; January 26, 2017; and May 6, 2017. The students from Tidehaven collected data at MAT03 (**fig. 7**).

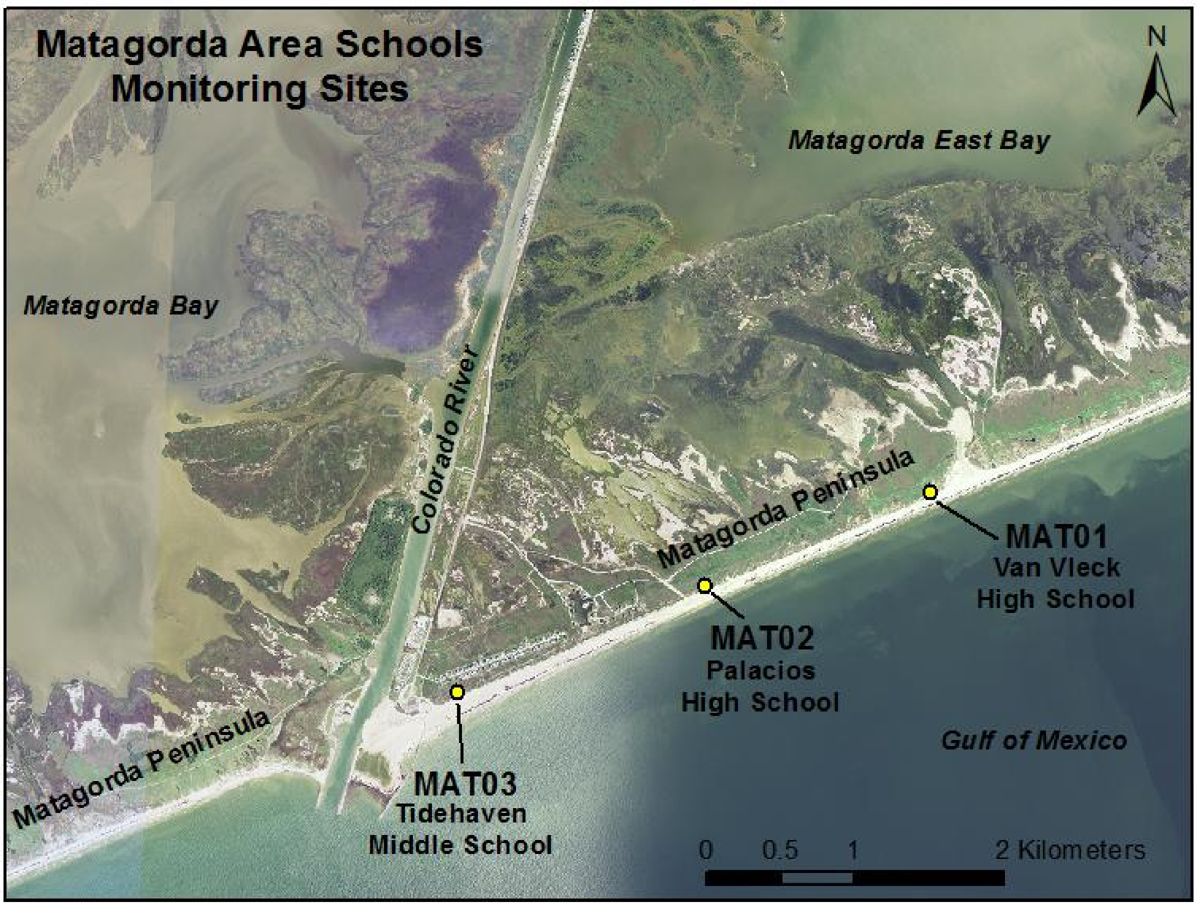

Figure 7. Location map of Matagorda area schools monitoring sites.

Port Aransas High School

Port Aransas students participated in field trips on September 28, 2016; January 19, 2017; and May 4, 2017. Ryan Piwetz's Aquatic Science class collected data at three profile locations on Mustang Island: MUI01 near Horace Caldwell Pier, MUI02 in Mustang Island State Park, and MUI03 (**fig. 8**). Port Aransas High School has been measuring these profiles since 1999.

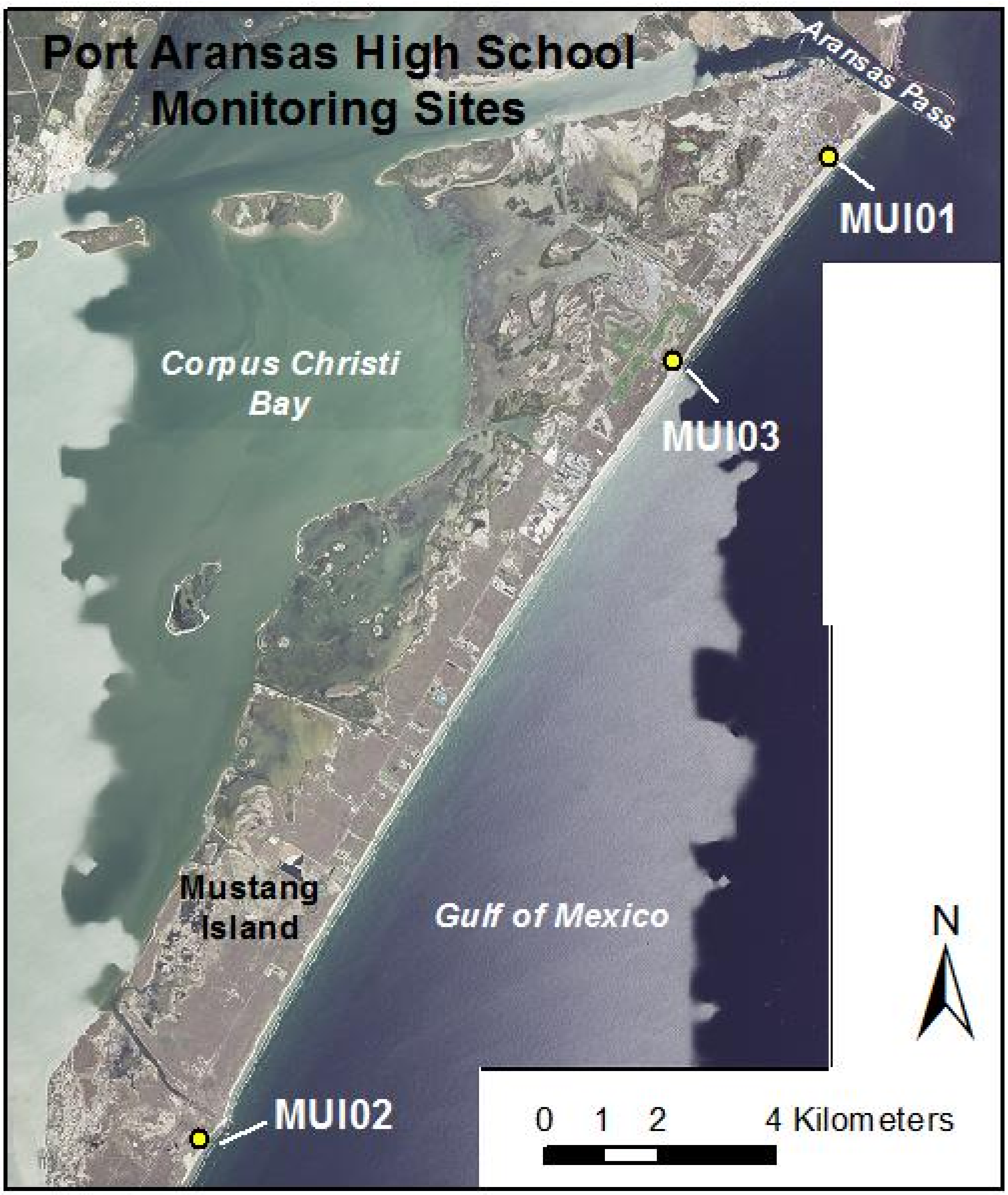

Figure 8. Location map of Port Aransas High School monitoring sites.

Cunningham Middle School

The Bureau collaborates with graduate students and staff at TAMUCC to conduct field trips with students from the Innovation Academy at Cunningham Middle School. The students are split into two groups during each field trip. One group works on the topographic profile while the second makes observations on wind, waves, currents and collects GPS shoreline and vegetation line data. The groups rotate for the second monitoring site. Cunningham Middle School 8th graders participated in field trips on September 29, 2016; January 20, 2017, and April 26, 2017. Eunice Silva's students collected data at NPI08 on North Padre Island (**fig. 9**). A new site on the North Padre Island seawall (NPC06) was added for the 2015–2016 academic year (**fig. 9**) that will monitor beach restoration activities seaward of the seawall.

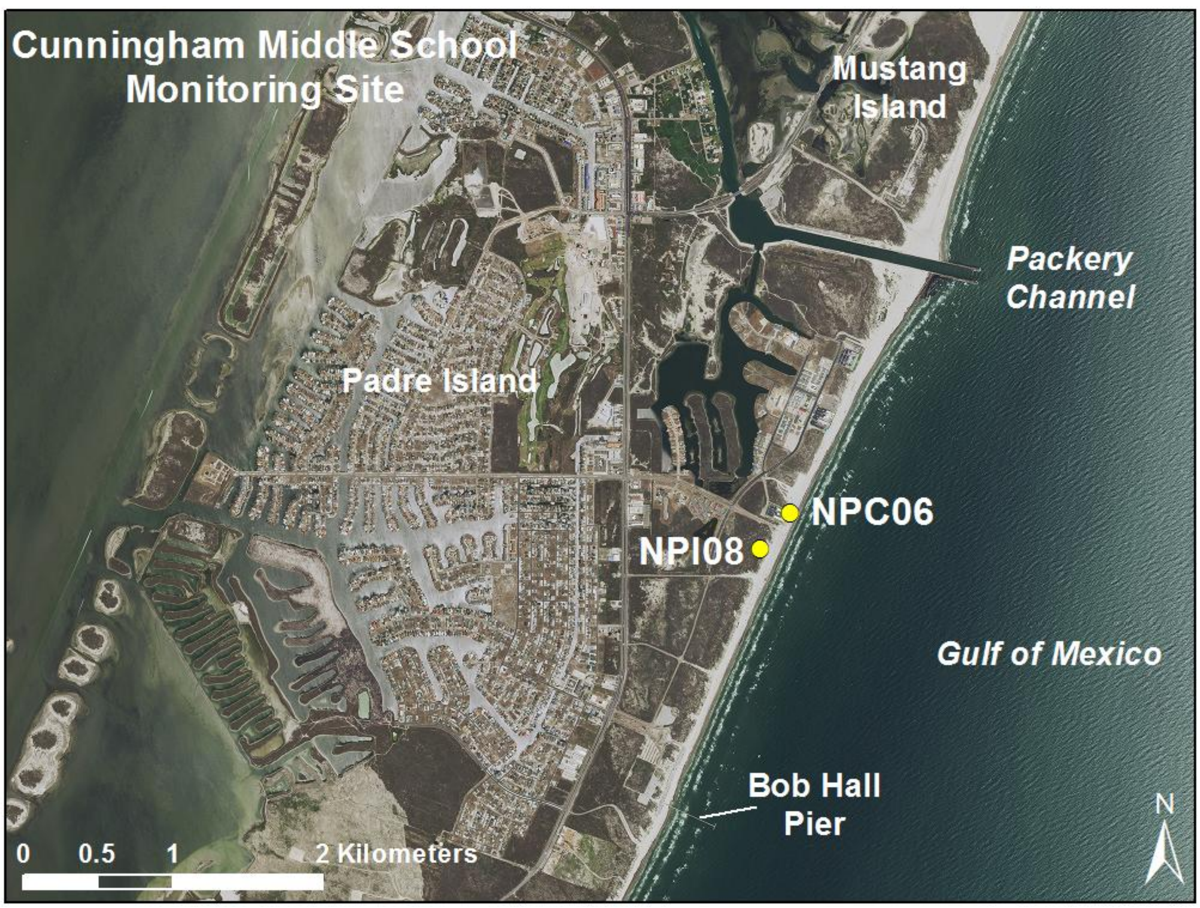

Figure 9. Location map of Cunningham Middle School monitoring sites.

Port Isabel High School

Port Isabel students participated in field trips on September 27, 2016; January 18, 2017; and April 19, 2017. Students from Dr. Michelle Zacher's Dual Enrollment Biology class collected data at three profile locations on South Padre Island: SPI01 in Isla Blanca Park, SPI02 at Beach Access #13, and SPI08 at the Tiki Condominiums (E. White Sands Street) (**fig. 10**). Port Isabel High School has been measuring SPI01 and SPI02 since 1999, and SPI08 since 2007.

Figure 10. Location map of Port Isabel High School monitoring sites.

EFFECTS ON SCIENCE CURRICULUM

The THSCMP addresses several requirements of Texas Essential Knowledge and Skills (TEKS) for Science. The program was relevant in these 2016–2017 Texas high school courses: (1) Environmental Systems; (2) Aquatic Sciences; and (3) Geology, Meteorology, and Oceanography. The program also addresses several National Science Education Standards: (1) unifying concepts and processes in science, (2) science as inquiry, (3) physical science, (4) Earth and space science, (5) science and technology, and (6) science in personal and social perspectives.

TEKS and Standards related to applying scientific methods in field and laboratory investigations are well covered in the coastal-monitoring program. Specific requirements such as (1) collecting data and making measurements with precision, (2) analyzing data using mathematical methods, (3) evaluating data and identifying trends, and (4) planning and implementing investigative procedures are also an excellent fit with the program, as are standards requiring students to use critical thinking and scientific problem solving to make informed decisions. In addition, teachers and scientists can use the program (such as in a case study of a local erosion problem) to illustrate to students the role science could, should, or does play in developing public policy.

EFFECTS ON SCIENTIFIC RESEARCH, COASTAL MANAGEMENT, AND PUBLIC AWARENESS

The first goal of the THSCMP is to provide high school students with an inquiry-based learning experience, which is achieved by involving students in real-world research projects. The student-collected beach data can be and have been used by researchers at the Bureau to help respond to several beach-related issues. Data are available to coastal managers and the public online at http://www.beg.utexas.edu/coastal/thscmp/.

During the 2016–2017 academic year, Ball High School students measured a profile location in Galveston Island State Park (BEG02, **fig. 6**). The students had measured this same location in previous years, and the Bureau had conducted quarterly surveys here from 1983 through 1985 after Hurricane Alicia. Since 1985, however, the beaches had been surveyed on an irregular schedule, about once a year, and only when specific projects were funded to do so or when Bureau personnel were in the area conducting other work. The THSCMP helps ensure that time series at these key locations are continued. The data have increased scientific understanding of recovery of beaches and dunes following recent storms (Hurricane Alicia, Tropical Storm Frances, Hurricane Claudette, Hurricane Rita, Hurricane Ike) that have impacted the area.

High Island, Palacios, Port Aransas, Port Isabel, Tidehaven, and Van Vleck High Schools and Cunningham Middle School continued the beach-profile time series at their established locations. Profile and process data that the students collected have been incorporated into the beach-profile database at the Bureau, and scientists are using these data to investigate beach-erosion patterns.

In support of coastal-management issues, data collected by students are clearly useful in explaining beach cycles and defining short-term versus long-term trends. Defining these trends is important in decision-making regarding coastal development and beach nourishment.

We emphasize to students that they are collecting critical scientific data that will help scientists address coastal issues affecting their community. All data collected by the THSCMP are integrated into past and ongoing coastal research programs at the Bureau. THSCMP-collected data played a large role in three important Bureau studies.

In one study, BEG02, has been used by Bureau scientists to investigate the effects of geotextile tubes installed along the upper Texas coast. BEG02, located in

Galveston Island State Park, is adjacent to a subdivision where these erosion-control devices have been installed. One of the observations made during this study involved beach width (distance from the vegetation line or base of dune to the waterline) in front of the geotextile tubes versus a natural beach area in the adjacent state park. Beach width in the natural beach area was wider than in the subdivision—average width of 45.7 m compared to 20.4 m in the subdivision (Gibeaut and others, 2003; **fig. 11**). The natural area allowed for the landward migration of the dunes as the shoreline retreated while the geotextile tube created a fixed dune line (Caudle and Paine, 2017).

Figure 11. Lidar topographic-relief image of Galveston Island State Park and Pirates Beach subdivision. Note the difference in beach width between the natural beach and the area in front of the subdivision. From Gibeaut and others (2003).

More recently, data collected by THSCMP students were invaluable in verifying shoreline position for two updates of Texas' long-term shoreline-change rates, which are widely used by public officials, corporations, and private citizens. The first project updated long-term rates of shoreline change along the entire Texas coast on the basis of mapping of the shoreline position on 2007 aerial photography. Beach profiles and GPS-mapped shorelines (wet beach/dry beach boundary) collected by THSCMP students were used to confirm the shoreline position digitized on the 2007 aerial photography. The student-collected data proved vital in validating interpretation of the shoreline position on Galveston Island, Follets Island, Matagorda Peninsula, Mustang Island, and South Padre Island. The georeferencing of the photographs and interpretation of the position of the wet beach/dry beach boundary was checked by superimposing GPS-based beach profiles and wet beach/dry beach boundary data acquired in 2007 by THSCMP and the photo-interpreted 2007 wet beach/dry beach boundary used for change-rate calculations (Paine and others, 2011). At Galveston Island State Park (**fig. 12,** Paine and others, 2011, 2012), the GPS-based wet beach/dry beach boundary mapped on September 20, 2007, at BEG02 lies generally a few feet landward of the same boundary mapped on a 2007 aerial photograph acquired 3 days earlier (September 17, 2007).

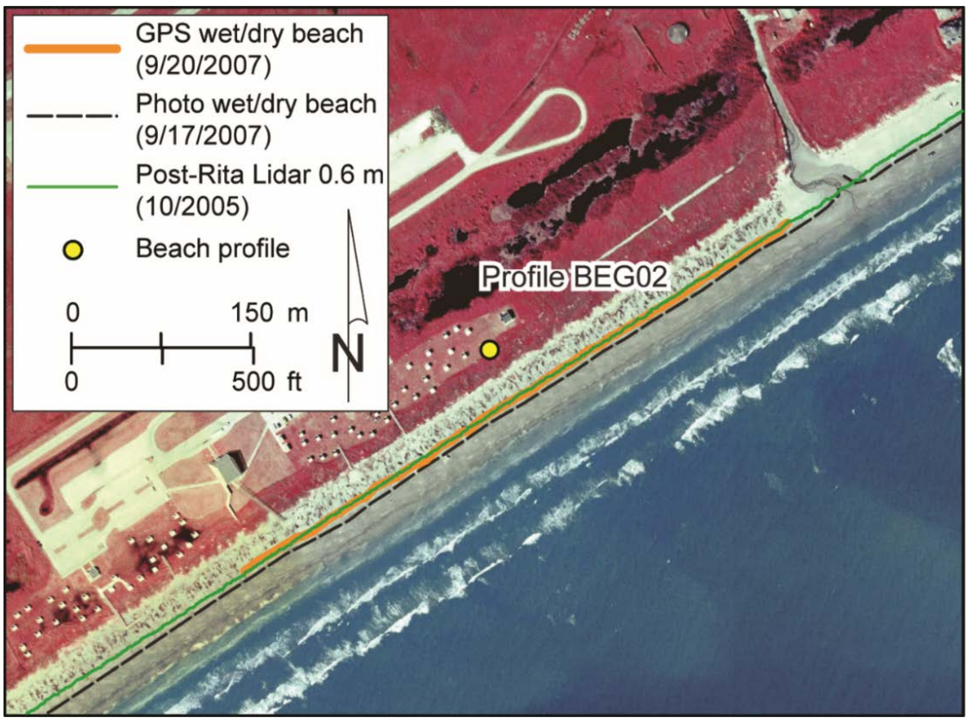

Figure 12. Shoreline position comparison at Galveston Island State Park site BEG02. Shorelines include the 2007 wet beach/dry beach boundary mapped on aerial photographs taken September 17, 2007; the wet beach/dry beach boundary mapped on September 20, 2007, by THSCMP students using ground GPS; and the 0.6-m msl shoreline proxy extracted from airborne lidar data acquired after Hurricane Rita in October 2005. From Paine and others (2011, 2012).

The second project updated long-term rates of shoreline change on the Texas Gulf coast based upon extraction of the shoreline position from aerial lidar data collected in 2012 (Paine and others, 2014). A 0.6 m (2.0 ft) msl elevation contour was extracted from lidar derived digital elevation models (DEMs). GPS-mapped shorelines collected by THSCMP students were used to confirm the elevation of the 2012 shoreline position that was used for shoreline change calculations. On South Padre Island (**fig. 13**, Paine and others, 2014), there is positional agreement between the 2012 lidar-extracted shoreline; the wet beach/dry beach boundary as interpreted on NAIP aerial imagery acquired April 23, 2012; and the wet beach/dry beach boundary surveyed using GPS by THSCMP students on September 26, 2012.

Figure 13. Shoreline position comparison at South Padre Island site SPI08. Shorelines include the wet beach/dry beach boundary mapped on September 27, 2011 and September 26, 2012 by THSCMP students using GPS and the 0.6 m (2.0 ft) msl shoreline proxy extracted from airborne lidar data acquired in February 2012. Shorelines are superimposed on NAIP imagery acquired on April 23, 2012.

The THSCMP has increased public awareness of coastal issues through the students themselves, as well as through media reports and presentations at conferences. Port Isabel High School students presented THSCMP to coastal visitors at the Winter Outdoor Wildlife Expo (WOWE) in January 2017, at the South Padre Island Birding Center. One student gave an overview of the Program to the entire group while the rest of the students created teams to demonstrate the data collection activities. Tiffany Caudle presented a talk on the scientific impacts of the THSCMP at the Texas Chapter of the American Shore and Beach Preservation Association Symposium in Port Aransas, Texas in April 2017. A technical communication paper was published May 2017 in the Journal of Coastal Research describing the critical scientific data collected by THSMP students that helps scientists and coastal managers address coastal issues and understanding of dune and beach dynamics on the Texas coast (Caudle and Paine, 2017). The website, too, continues to be instrumental in extending the reach of the program and increasing public awareness.

SCIENTIFIC RESULTS OF 1997–2017 STUDIES

Profile data collected by the students are entered into BMAP (Beach Morphology and Analysis Package) in CEDAS (Coastal Engineering Design & Analysis System) version 4.0. BMAP, originally developed by the U.S. Army Corp of Engineers, is commonly used by coastal engineers and scientists in beach-profile analysis. Beach-volume calculations are then made using BMAP, and shoreline and vegetation-line positions are determined from field notes made by students and scientists. The shoreline is designated by the wet beach/dry beach boundary or a berm crest (a prominent break in slope between the forebeach and backbeach) for consistency with historical measurements (Gibeaut and Caudle, 2009). Volume, shoreline, and vegetation-line plots for each monitoring site are found in Appendix B.Profile plots that contain all student collected data for each monitoring site are found in Appendix C. GPS mapped shoreline and vegetation line data for each monitoring site are found in Appendix D.

Students participating in THSCMP have been collecting critical data since 1997 that is used by scientists at the Bureau to increase understanding of beach and dune recovery stages following major storms. Storm damage to beaches and dunes are indicated by the landward movement of shoreline and vegetation line positions and a decrease in sediment volume in the beach profile immediately after storms (**fig. 14**).

The gradual seaward migration of the shore and vegetation lines plus sediment volume increases, tracks beach and dune recovery in the years following storms.

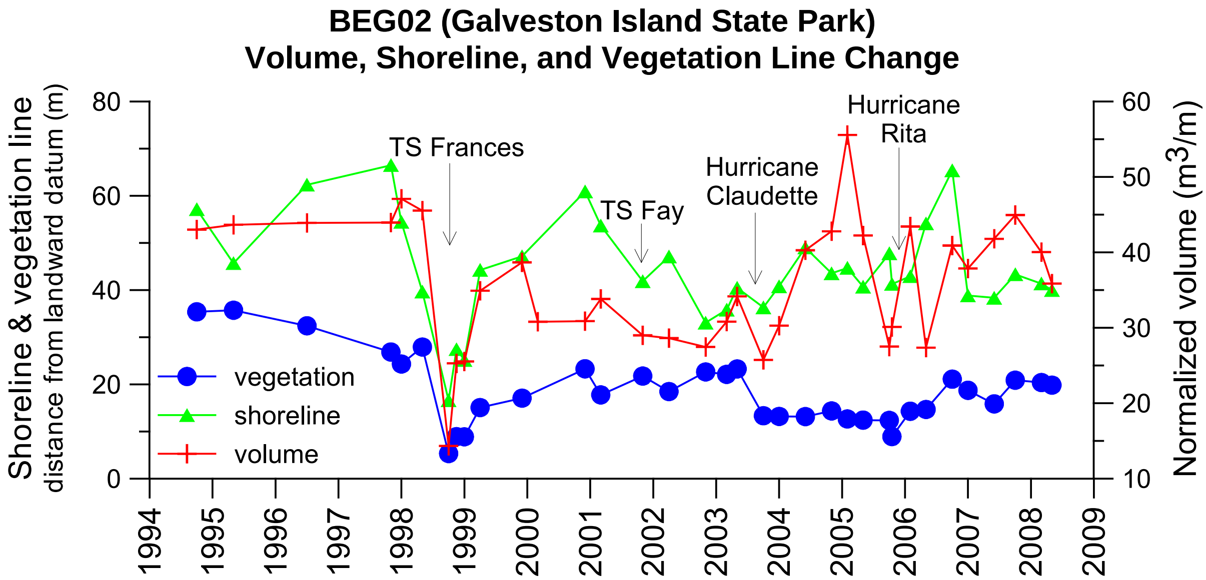

Figure 14. Profile volume, shoreline, and vegetation-line changes at Galveston Island State Park, September 1994–April 2008.

Tropical Storm Frances (September 1998) played a major role in reshaping the beaches on the upper Texas coast. Data collected by Ball High School students on Galveston and Follets Islands documented that Frances caused significant damage to beaches along the southeast coast of Texas comparable to damage caused by Hurricane Alicia in 1983 (Gibueat and others, 2002; Hepner and Gibeaut, 2004; Morton and Paine, 1985), a category 3 hurricane on the Saffir/Simpson scale (Simpson and Riehl, 1981). Several other severe storms have also impacted the Galveston study area. Tropical Storms Allison (June 2001) and Fay (September 2002) and Hurricanes Claudette (July 2003) and Rita (September 2005) have each caused varying degrees of damage to beaches and dunes along the Texas coast (**fig. 14**). Ball High School students provided important pre-storm beach topography data from their field trips during the 2004–2005 and 2007–2008 academic years.

Hurricane Rita, a category 3 hurricane (Simpson and Riehl, 1981), made landfall at Sabine Pass on the Texas–Louisiana border in September 2005. Overall, Rita did not cause the kind of episodic beach or dune erosion on Galveston or Follets Islands that Frances did in 1998. **Figure 15** is a plot of pre- and post-storm beach profiles measured at BEG02 in Galveston Island State Park (**fig. 6**). Rita flattened the profile and caused a small amount of overwash deposition, but positions of the vegetation line and shoreline were not greatly affected (**fig. 14**; Gibeaut and others, 2008).

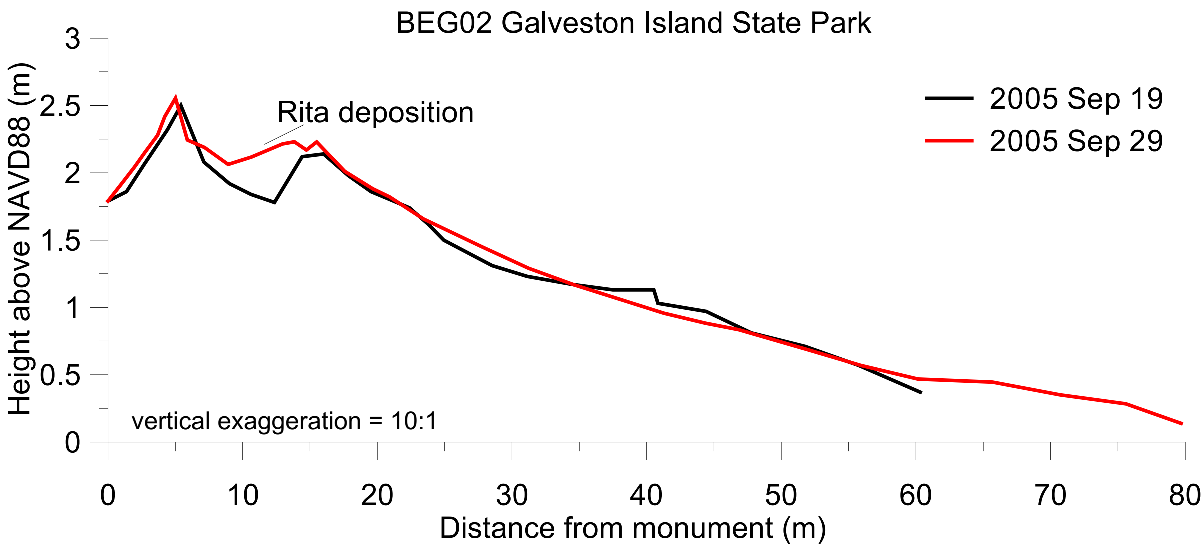

Figure 15. Plot of pre- and post-Rita beach profiles measured at Galveston Island State Park.

The upper Texas coast was severely affected by the landfall of Hurricane Ike in September 2008. Galveston Island experienced significant beach and dune erosion, as well as extensive damage to property and infrastructure. Ball High School students were unable to participate in the THSCMP during the 2008–2009 academic year because of safety concerns while accessing their monitoring sites. Bureau and TAMUCC scientists visited Galveston Island in early October 2008 to conduct ground surveys—beach profiles, photography, and observations of beach and dune conditions—of the area impacted by the hurricane. During this reconnaissance trip, scientists visited profile location BEG02 in Galveston Island State Park, where they discovered that the datum marker at BEG02 had been destroyed by the storm. Scientists used GPS techniques to navigate to the horizontal location of the datum marker, which post-storm was on the open beach. (Before the storm, the marker had been at the corner of a concrete picnic pavilion landward of the foredunes.) BEG02 (**fig. 6**) was reset approximately 60 m landward of the old datum marker along the same azimuth line. The new marker (a buried metal pipe) is landward of a washover feature. Reestablishing the marker allowed students to continue to monitor activities and storm recovery, and continue to compare pre- and post-storm profiles, at this location.

Ball High School students from the 2007–2008 academic year provided extremely valuable pre-storm profile data on February 8, 2008, and April 23, 2008. These data have been used to determine how much the beach and dunes changed after Hurricane Ike. **Figure 16** is a profile plot at BEG02 comparing the Ball High School pre-storm profile (April 2008) with the post–Hurricane Ike profile measured on October 7, 2008. The post–Tropical Storm Frances profile from September 16, 1998, is also plotted for comparison. At Galveston Island State Park the dune system was completely destroyed; the shoreline (wet beach/dry beach boundary) moved 53 m landward between April 23, 2008, and October 7, 2008; the vegetation line moved 56 m landward; and the old datum point was 1.14 m above the post-storm surface of the beach (**fig. 16,** Caudle and Paine, 2017). Data from one year post-storm is also included. This profile shows that the elevation of the beach had been restored, the beach width (dunes to waterline) has increased, and incipient dunes are beginning to form (**fig. 16**).

Ball High School students resumed monitoring beaches as part of the THSCMP at the start of the 2009 academic year. Students measured beach profiles at two sites within Galveston Island State Park. At BEG02 (**fig. 17**), beaches and dunes had continued to recover post–Hurricane Ike. Between September 2009 and January 2011, the foredunes at BEG02 had begun to grow. Whether initial growth of the foredunes is due to natural recovery processes or human intervention is unclear. The foredune ridge has continued to grow in the intervening years. A wide vegetated zone with expanding coppice dunes has developed between the seaward base of the foredunes and the landward extent of wave run-up (**fig. 17**).

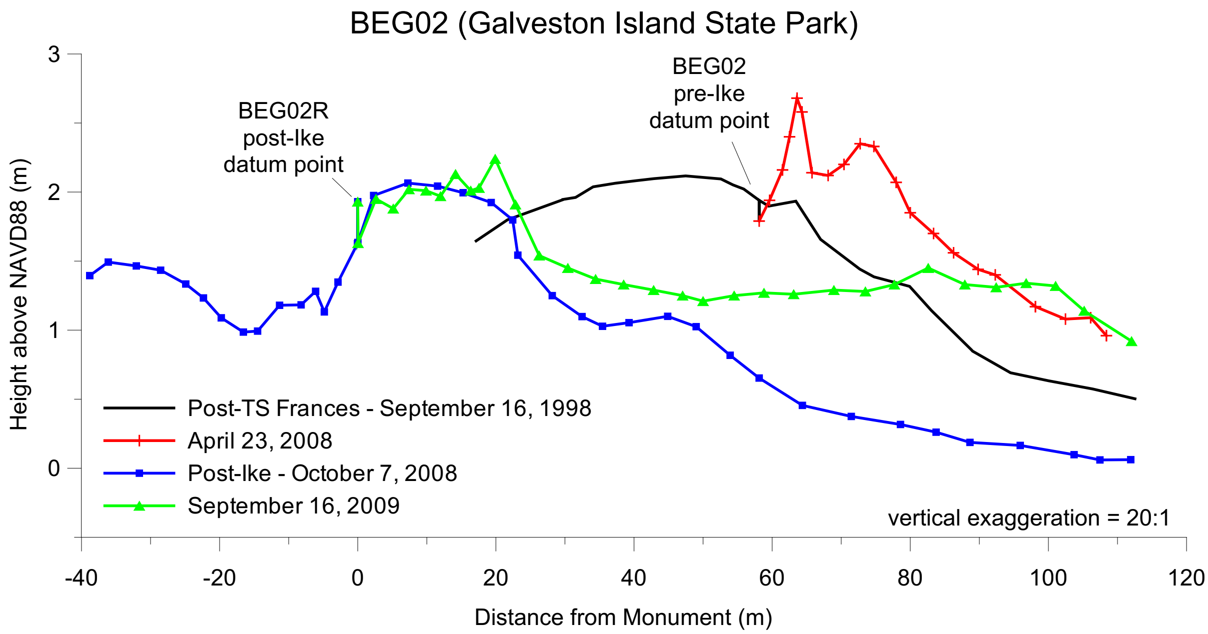

Figure 16. Beach-profile plots from BEG02 in Galveston Island State Park comparing the post–Hurricane Ike profile with a pre-storm profile from early 2008 and the post–Tropical Storm Frances profile from September 1998. Data from September 2009 (one year post-storm) is also included.

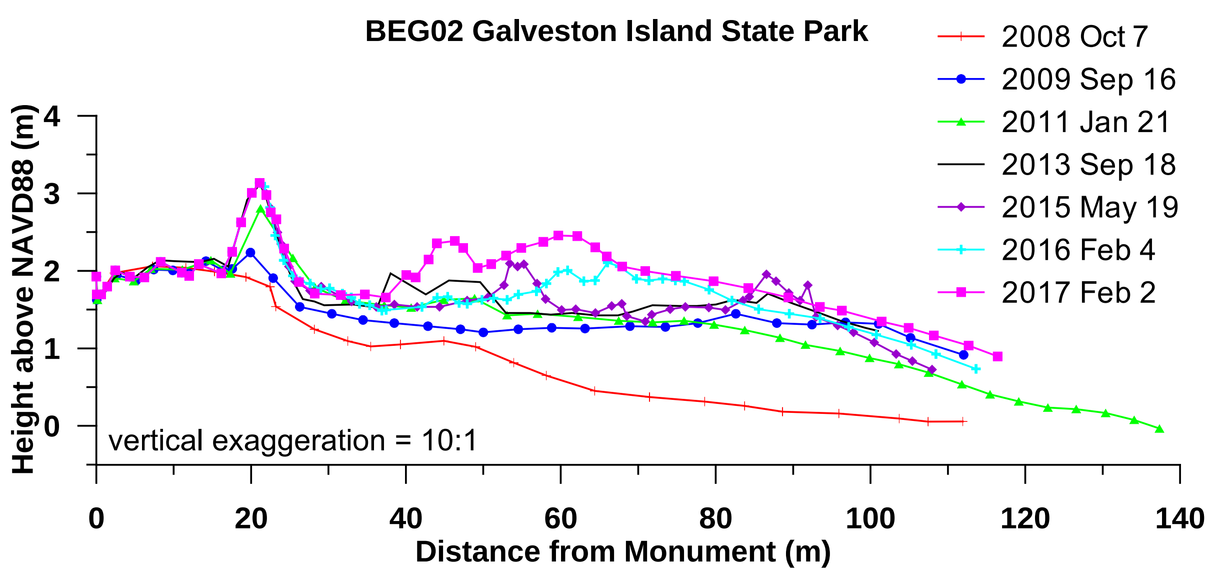

Figure 17. BEG02 datum reset post-storm profile plus data collected by Ball High School students. Students are monitoring recovery of the beaches and dunes at this site.

Despite Ike being only a category 2 storm on the Saffir/Simpson scale (Simpson and Riehl, 1981) at the time of landfall, the sheer size of the hurricane caused impacts along the entire Texas coast. Dune erosion due to Hurricane Ike was documented on the middle Texas coast at Matagorda Peninsula and to a lesser extent on Mustang Island (see Appendix C). Van Vleck and Palacios High Schools students have been monitoring the recovery of the dunes (**fig. 18**) and the seaward movement of the vegetation line post–Hurricane Ike on Matagorda Peninsula (**fig. 7**).

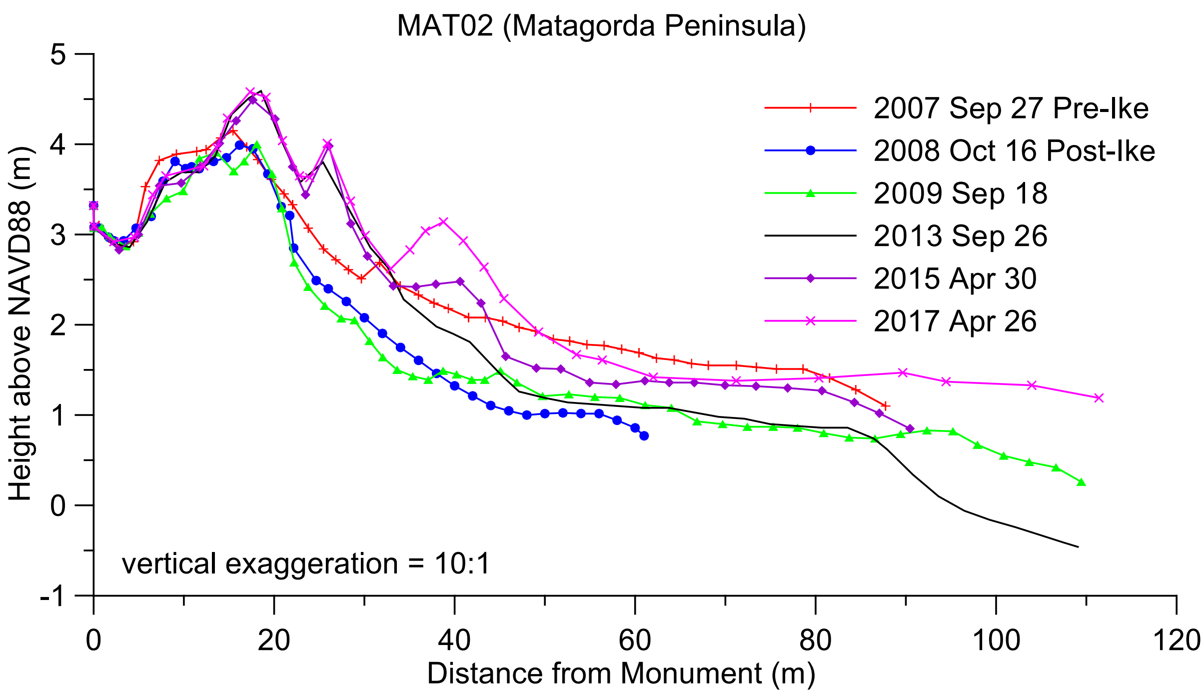

Figure 18. MAT03 pre- and post-storm profile data collected by Palacios High School students. Students are monitoring recovery of the foredune at this site.

Port Aransas and Port Isabel High Schools have been collecting beach-profile data and coastal-process observations since 1999. Although neither Mustang Island nor South Padre Island have experienced the type of dramatic shoreline change due to major storms that Galveston Island has experienced, information gained from the students' work has been beneficial to Bureau researchers' understanding of the dynamics of the Texas coast.

Brazos Santiago Pass, the southern border of South Padre Island, is dredged biannually. The pass serves as the southern Gulf of Mexico access to the Gulf Intracoastal Waterway and the Port of Brownsville. Sediment dredged from the pass is placed on beaches of South Padre Island (beneficial use of dredged material—BUDM) and the three sites monitored by Port Isabel High School students are within these nourishment areas.

The SPI02 (**fig. 10**) monitoring site has been used by students and scientists to monitor the growth of dunes (sand volume) and shoreline movement. When SPI02 was established in August 2000, there were no dunes between the retaining wall and waterline at this location. Since that time, student collected data has been quantifying the effects of the installation of sand fences, planting of vegetation, and numerous BUDM nourishment projects (**fig. 19**). Port Isabel data have documented an overall trend to shoreline advancement and sediment-volume increase throughout the study period (Caudle and others, 2014).

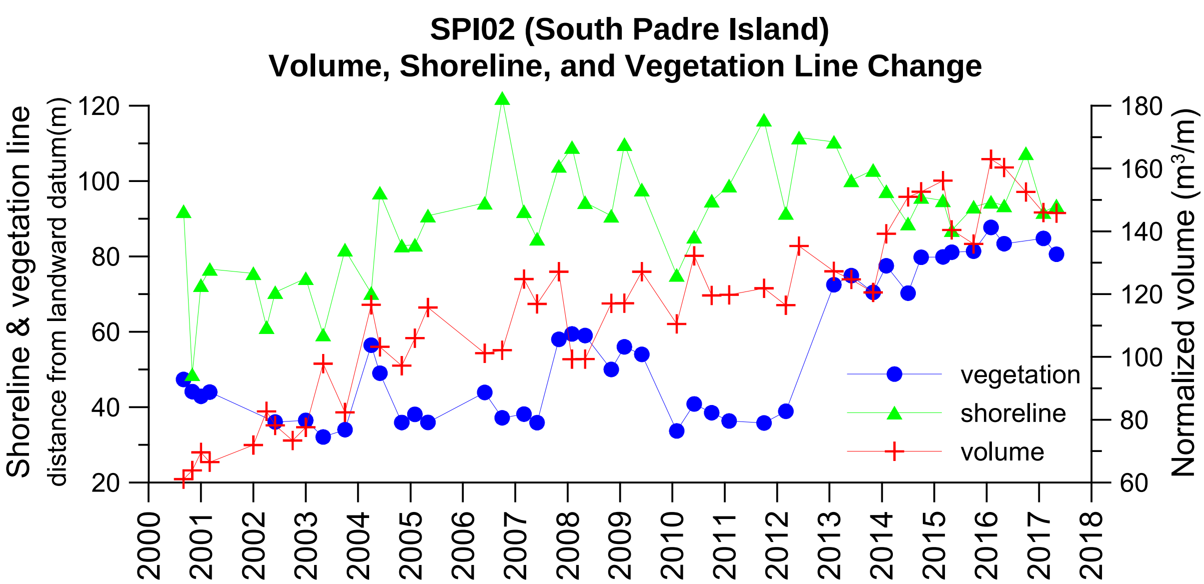

Figure 19. Changes at SPI02 on South Padre Island due to beach-nourishment projects and the installation of sand fences.

The vegetation line had remained in a relatively stable position prior to 2012. Since that time, a push-up dune was created by beach-maintenance practices (beach scraping to remove seaweed). The sand and seaweed scraped from the beach was placed just seaward of the vegetation line, and vegetation has begun to grow on the piled material (**fig. 19**).

Starting in the 2007–2008 academic year, students at Port Isabel High School began gathering data at a chronically eroding location in front of the Tiki Condominiums near the north end of the city, SPI08 (**fig. 10**). This site has a narrow beach backed by a retaining wall (see Appendix B for profile plots) that periodically receives nourishment sand from road maintenance north of the City of South Padre Island and from dredging at Brazos Santiago Pass. The students from Port Isabel have been documenting the cycles between beach nourishment, dune creation by beach maintenance practices, and the long-term shoreline erosion trend.

During the May 14, 2010, field trip, Port Isabel students and UT scientists observed that sand fencing had been installed and vegetation planted adjacent to the retaining wall. When the students returned to the site on September 28, 2010, the sand fence was gone and there was no trace of vegetation in front of the seawall. The narrow beach at this site appeared to be unable to support dune formation.

A large beach-nourishment project using BUDM from Brazos Santiago Pass was completed on South Padre Island in early 2011. The width of the beach and volume of sand significantly increased at the SPI08 location, although there were still no dunes or vegetation in front of the retaining wall (**fig. 20**). On the May 13, 2011, field trip, Port Isabel students observed that a 0.5-m scarp had formed at the shoreline. The students continued to monitor this site during the 2011–2012 academic year to determine whether the nourished beach would reach equilibrium. The shoreline position had returned to the pre-nourishment position. After an initial significant decrease in beach volume (to pre-nourishment levels), volume on the back beach has increased steadily because of the re-installation of sand fences. In May 2013, the sand fences remained in place, serving to trap sand in front of the retaining wall at this site, and vegetation had been planted on the incipient dunes. On the final field trip of the 2013–2014 academic year, a large push-up dune was present seaward of the vegetation line. Throughout the 2014–2015 academic year, this location remained stable. The large spike in beach volume in late 2015 was due to a new push-up dune.

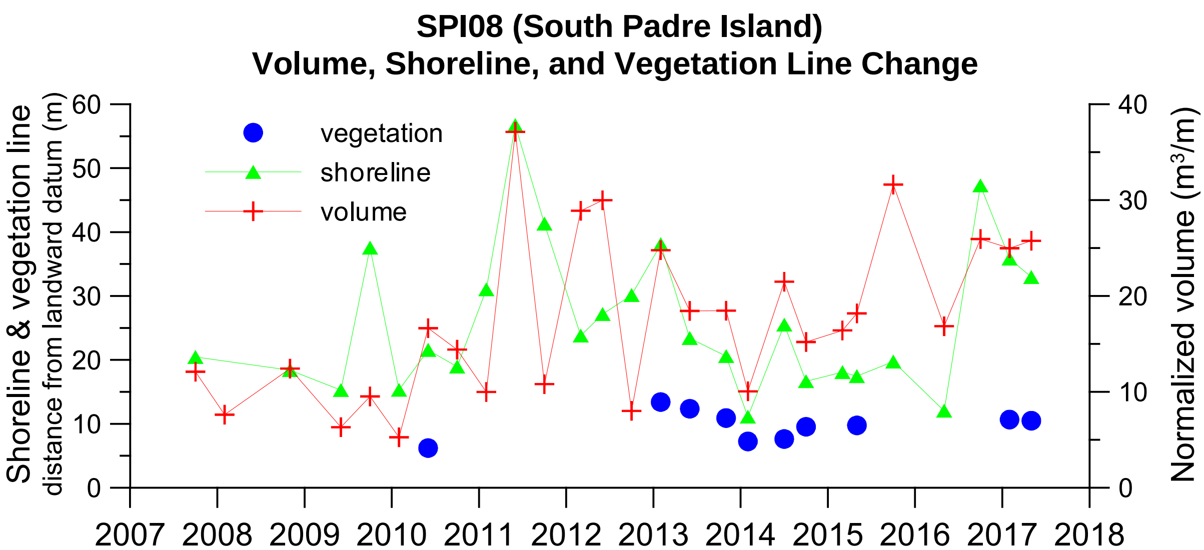

Figure 20. Volume and shoreline changes at SPI08 on South Padre Island due to beach-nourishment projects and the installation of sand fences.

A beach nourishment project using beneficial use material from Brazos Santiago Pass, took place during the winter of 2015–2016. Profile data could not be collected on the January field trip because the area in front of the condominiums was blocked by dredging equipment. The spring 2016 data collection showed that shoreline position and beach volume were similar to the pre-nourishment conditions (**fig. 20**). This profile site benefited from a small nourishment project located just to the south in later 2016. Throughout the 2016—2017 academic year, the shoreline position was stabilized in a more seaward location than it had been in previous years (**fig. 20**). Increased beach volume was also stable due to a vegetated dune. Port Isabel students will continue to monitor this rapidly changing and chronically eroding location.

The beach-monitoring activities of Port Aransas High School students have provided beneficial information about the beach and dune system on Mustang Island. The dune system on Mustang is healthy, with tall (>3 m), wide foredunes along most of the island. The only breaks in the foredune system are at beach-access points and washover features. On Mustang Island, beaches are regularly scraped to remove seaweed from the forebeach. Sand and seaweed removed from the berm and forebeach were regularly placed at the seaward base of the foredune. Since the beginning of the coastal monitoring program, Port Aransas students have been monitoring the growth of the foredune system at their profiling sites. **Figure 21** is an example of expansion of the foredune at MUI01 near Horace Caldwell Pier in Port Aransas. Note that the width of the dunes increased between 2001 and early 2012, although the shoreline remained in a relatively stable position.

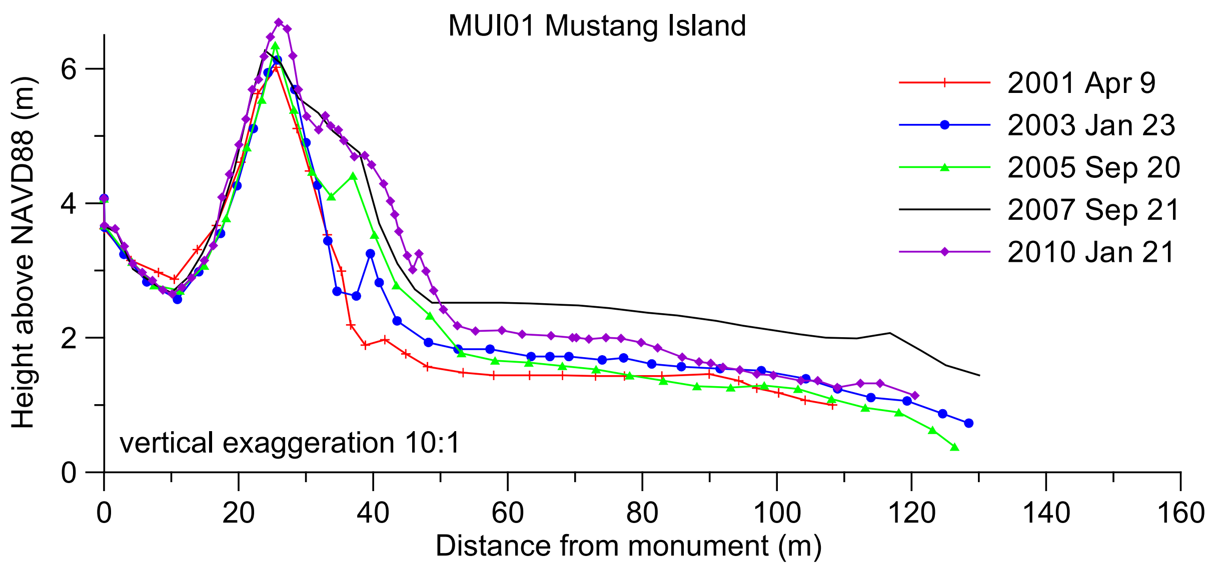

Figure 21. Foredune expansion at MUI01 on Mustang Island.

When Port Aransas students arrived to collect profile data in October 2012, a large part of the dune face had been excavated (**figs. 22, 23**) for beach-maintenance purposes. Students documented that sand was replaced in the foredune by May 2013 and that the vegetation line has been re-established at the toe of the dune. The dune has again been excavated since the 2014–2015academic year. The current width of the foredune is narrower and the volume of sand in the profile is significantly less than when THSCMP began monitoring in 1999 (see change plot in Appendix A). Also the crest of the foredune is lower in elevation because there is no vegetation on the crest. The dune crest is no longer stabilized at this location and sand is being carried away by the wind. The excavated area is slowly being filled in. Notice the increase in sand at the base of the dune face on the latest profile plot (**fig. 22**)

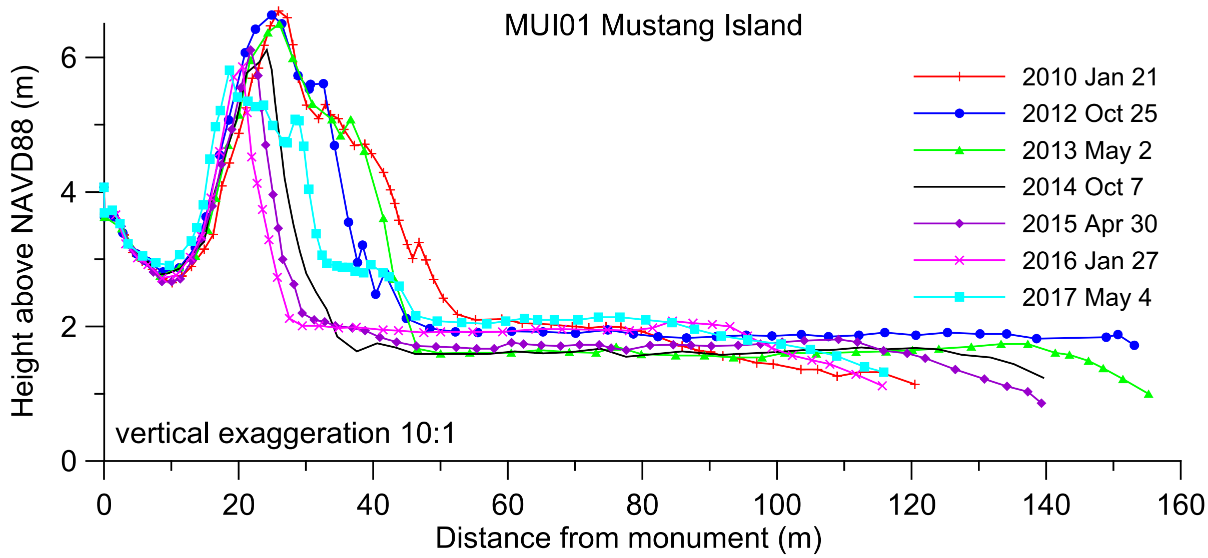

Figure 22. Excavated dune profile at MUI01 on Mustang Island.

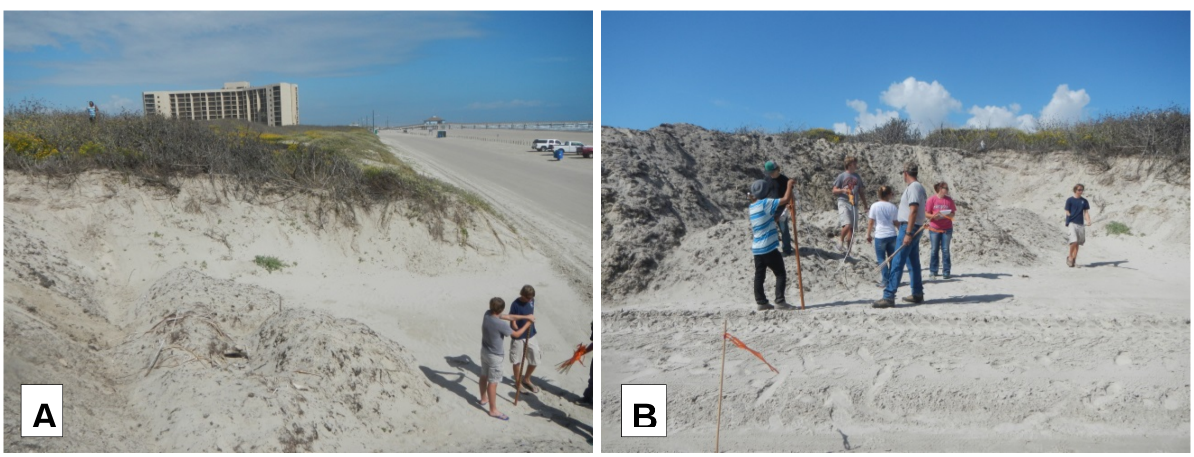

Figure 23. Excavated dune at MUI01 on Mustang Island looking (A) north toward Horace Caldwell Pier, and (B) landward.

Palacios, Van Vleck, and Tidehaven students have continued their beach measurements on the beaches adjacent to Matagorda Bay Nature Park. The park has two special circumstances that make this monitoring especially informative and important. (1) Monitoring sites have been established on the updrift side of the jetty at the mouth of the Colorado River and (2) at sites that allow students to compare a beach/dune system where vehicular traffic on the beach will be limited (MAT03) with an adjacent area where vehicular traffic will continue to be unrestricted (MAT01 and MAT02). Impacts of coastal structures (jetties) are critical to coastal management, and impacts of vehicles on Texas' beaches are not well documented. Vehicular traffic was permitted on the beach adjacent to the Nature Park until 2007. Currently, this section of beach has restricted access for vehicular traffic.

During the 2009–2010 academic year, the U.S. Army Corps of Engineers began constructing a new east jetty at the mouth of the Colorado River. GPS-mapped shorelines from September 2009 and September 2012 show an 45-m seaward movement of shoreline position at MAT03 updrift of the new jetty (**fig. 24**). Student data at MAT03 has shown that the new jetty on east Matagorda Peninsula has caused the shoreline to move seaward at an average rate of 11 m per year between 2009 and 2016.

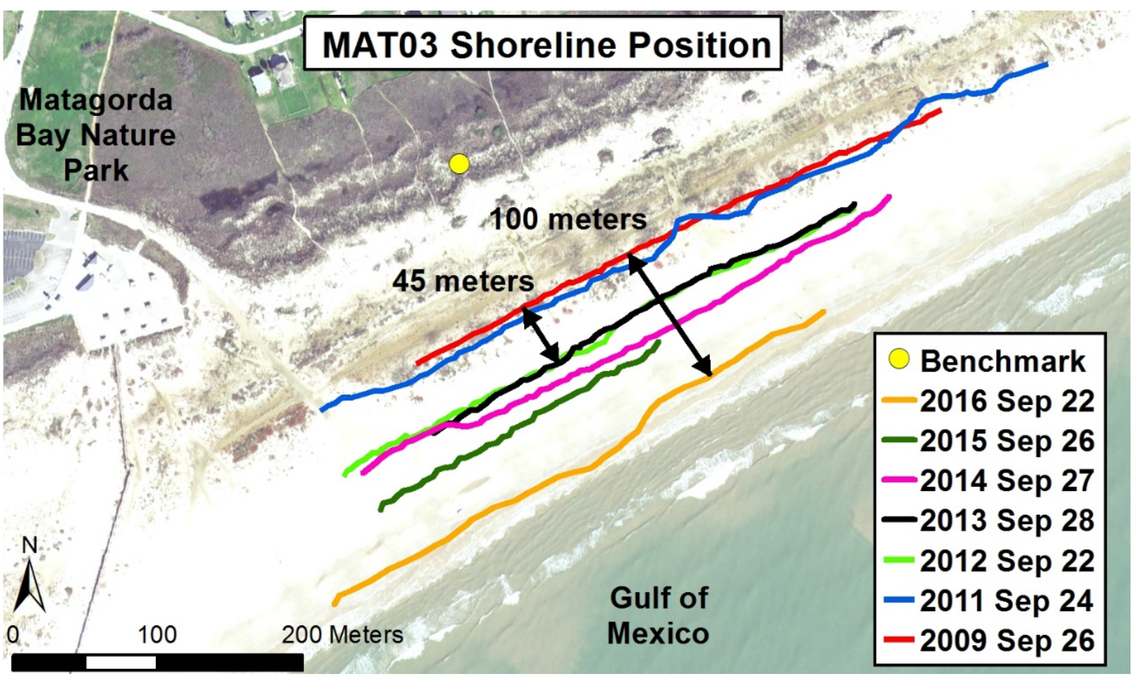

Figure 24. Shoreline position change at Matagorda Peninsula.

The shoreline and vegetation line position have been continuously moving seaward and volume has been increasing at this site throughout the study period (**fig. 25**). The combination of the new jetty impounding sand on the updrift side and the decreased vehicle access at MAT03 has allowed for coppice dune formation to occur on the expanded backbeach area and for new vegetation to develop without being disturbed. On the field trips during the 2015–2016 and 2016—2017 academic years, it was documented that salt marsh plants have become established on the widened backbeach area in the swales between the coppice dunes. Tidehaven students will continue to monitor this site to determine if the shoreline, vegetation line, and sand volume will continue advancing or eventually stabilize. They will also be monitoring the salt marsh plants on the backbeach.

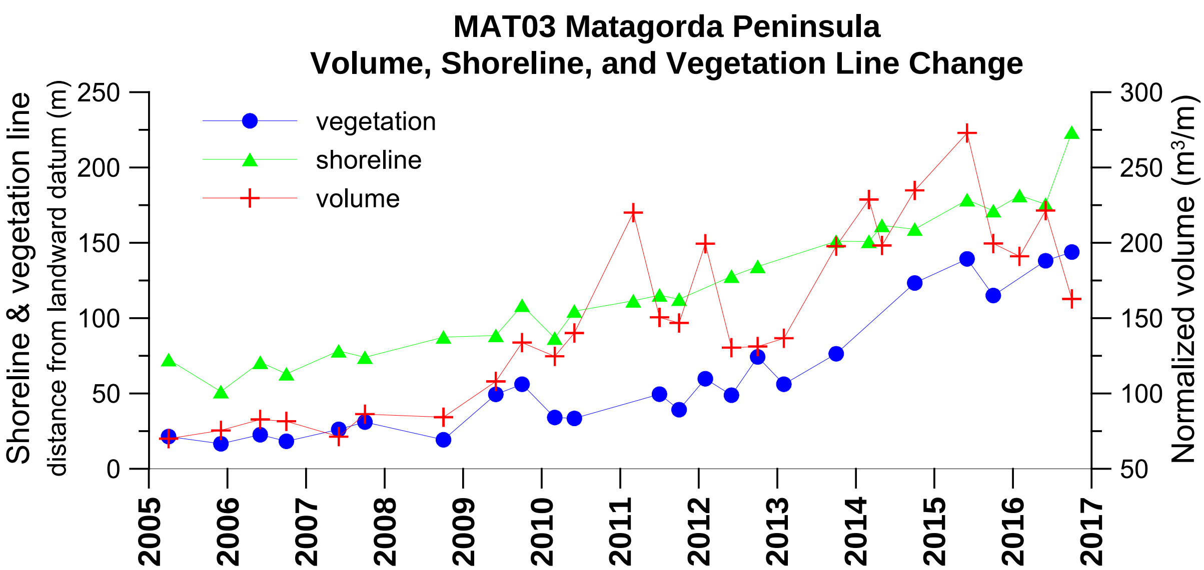

Figure 25. Changes in beach and dune volume, shoreline position, and vegetation line position at MAT03 on Matagorda Peninsula.

Cunningham Middle School students have witnessed remarkable changes at their profile location after 7 years of monitoring. When the program began in 2009, a new profile marker was established along the profile azimuth directly behind the foredune so as to shorten the profile for the middle school students. Because of the sparse vegetation on the foredune, sand is constantly being rearranged by prevailing winds.

Sand has been transported from the top of the foredune down the back slope of the dune so that now the landward toe of the dune has buried the new datum pipe. In addition, the continuous line of vegetation is gradually moving landward. This North Padre Island site has added a highly dynamic foredune location to the THSCMP system that will be interesting to monitor and to compare with the well-vegetated foredunes to the north on Mustang Island.

Six new monitoring sites were added during the 2015–2016 academic year. Cunningham Middle School added a site on the North Padre Island seawall (**fig. 9**). This location will be monitoring the effects of beach nourishment using beneficial use material from Packery Channel and beach maintenance practices seaward of the seawall. Ball High School students added sites at Jamaica Beach and the Dellanera RV Park southwest of the Galveston Seawall (**fig. 6**). The Jamaica Beach site monitors a CEPRA sponsored dune restoration project. The Dellanera site monitors a beach nourishment and dune creation project at this chronically eroding location. With the addition of High Island High School, three new monitoring sites were established on Bolivar Peninsula (**fig. 5**).

CONCLUSIONS

The Texas High School Coastal Monitoring Program provides middle and high school students with a real-world learning experience outside the everyday classroom. The program not only provides hands-on education, but it also valuable data for coastal researchers and decision makers. The 2016–2017 academic year was productive, with Ball, Palacios, Port Aransas, Port Isabel and Van Vleck High Schools and Cunningham and Tidehaven Middle Schools collecting data on three field trips throughout the academic year.

In the 20 years since the inception of the THSCMP, work by students at Ball, High Island, Palacios, Port Aransas, Port Isabel, Tidehaven and Van Vleck High Schools and Cunningham Middle School has been beneficial to Bureau researchers and coastal managers in several research projects. Analysis of the data has been used to investigate storm effects and recovery; impacts to the beach and dune system due to beach nourishment, construction of jetties, and beach maintenance practices; and verify shoreline positions for calculating change rates. Through this successful student research program, scientists, students, and the public continue to gain a better understanding of processes and shoreline change along the Texas coast.

Future measurements by all schools involved in the THSCMP will show not only change through time at each location, but also spatial variation along the Texas coast. Through time, data collected from Bolivar Peninsula, Galveston Island, Matagorda Peninsula, Mustang Island, North Padre Island, and South Padre Island will help scientists better understand the relationship between coastal processes, beach morphology, and shoreline change at these locations.

ACKNOWLEDGMENTS

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APPENDIX A: PROFILE INFORMATION

All profile coordinates are in NAD83. Heights above the GRS80 Ellipsoid were converted to North American Vertical Datum 88 (NAVD88) using the Geiod12B Ellipsoid Model.

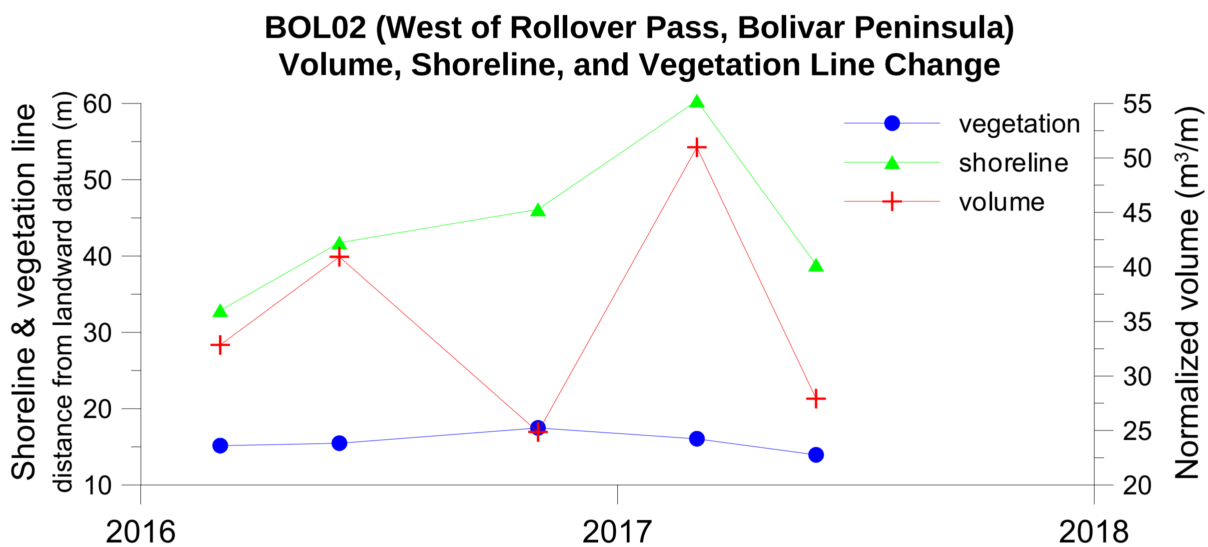
Profile	Latitude (deg min)	Longitude (deg min)	Easting (m)	Northing (m)	HAE (m)	NAVD88 (m)	Azimuth (M)
BOL02	29 30.00	94 31.20	352663.65	3264343.08	-23.62	3.17	150
BOL03	29 30.60	94 29.64	355196.55	3265428.50	-23.26	3.54	150
HIB01	29 33.08	94 23.04	365917.69	3269868.01	-25.18	1.64	150
BEG02[1]	29 11.64	94 57.09	310255.20	3231059.16	-24.75	1.79	139
BEG02R	29 11.67	94 57.11	310228.82	3231110.58	-24.61	1.93	139
BEG08[2]	29 3.22	95 8.90	290838.52	3215830.51	-24.21	2.16	145
GLO06	29 11.12	94 58.05	308696.85	3230117.35	-24.32	2.20	138
DEL01	29 14.44	94 52.38	317984.46	3236109.93	-23.84	2.74	130
JAM02	29 10.86	94 58.38	308140.86	3229662.18	-24.73	1.79	140
MAT01	28 36.67	95 56.55	212269.73	3168453.74	-22.77	3.79	148
MAT02	28 36.31	95 57.47	210751.39	3167825.80	-23.25	3.32	148
MAT03	28 35.91	95 58.48	309090.26	3167112.23	-21.81	4.78	148
MUI01	27 49.53	97 3.40	691396.24	3079393.46	-22.29	4.07	123
MUI02	27 40.42	97 10.19	680502.60	3062387.97	-24.22	1.88	120
MUI03	27 47.66	97 5.08	688697.42	3075882.34	-22.24	4.07	125
NPI08	27 35.86	97 12.78	676359.73	3053901.89	-23.32	2.62	110
NPC06	27 35.99	97 12.66	676557.71	3054150.56	-21.76	4.19	110
SPI01	26 4.57	97 9.46	684274.71	2885422.83	-18.48	2.97	70
SPI02	26 6.79	97 9.93	683438.99	2889509.24	-18.11	3.39	78
SPI08	26 8.17	97 10.10	683116.29	2892056.38	-18.32	3.22	75

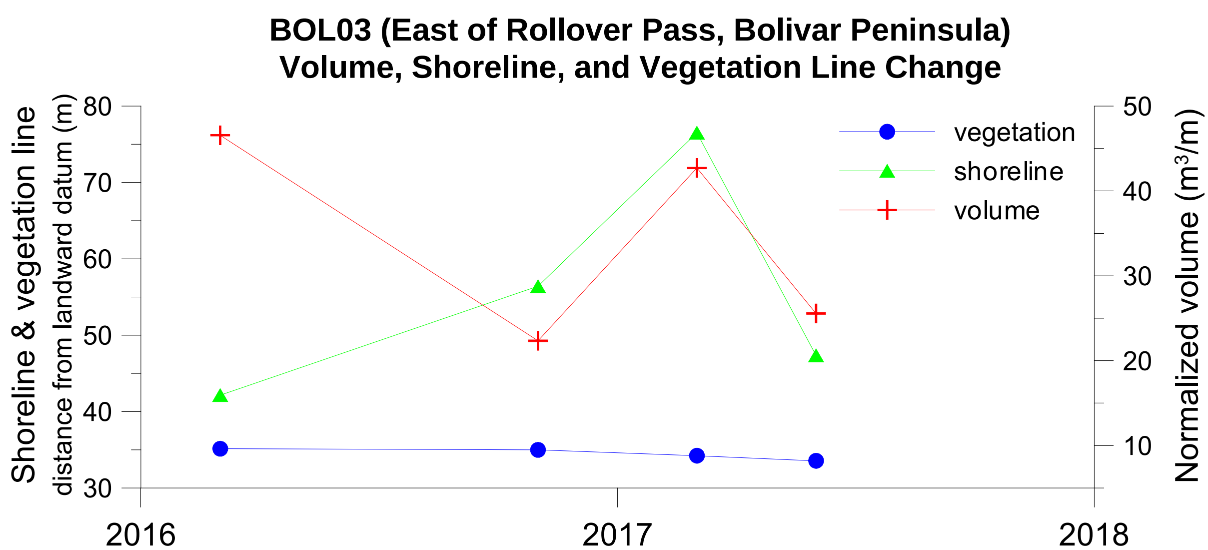
[1]BEG02 reset in October 2008 after Hurricane Ike.

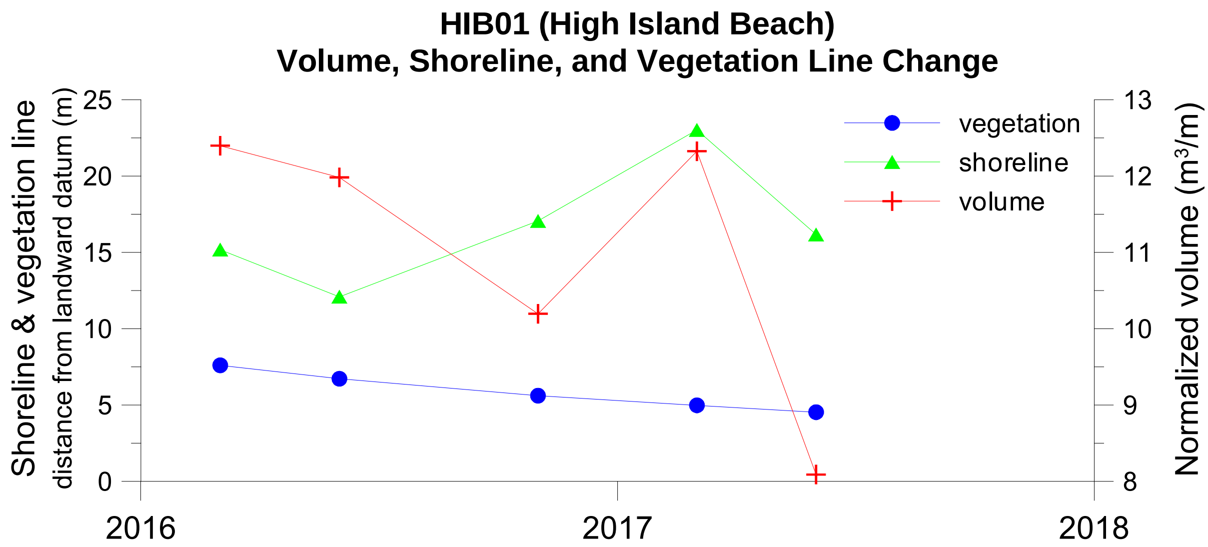
[2]BEG08 cannot be monitored by Ball High School students post–Hurricane Ike. The original datum was lost in the storm. The reset mark is landward of the Bluewater Highway and therefore too dangerous for students to monitor.

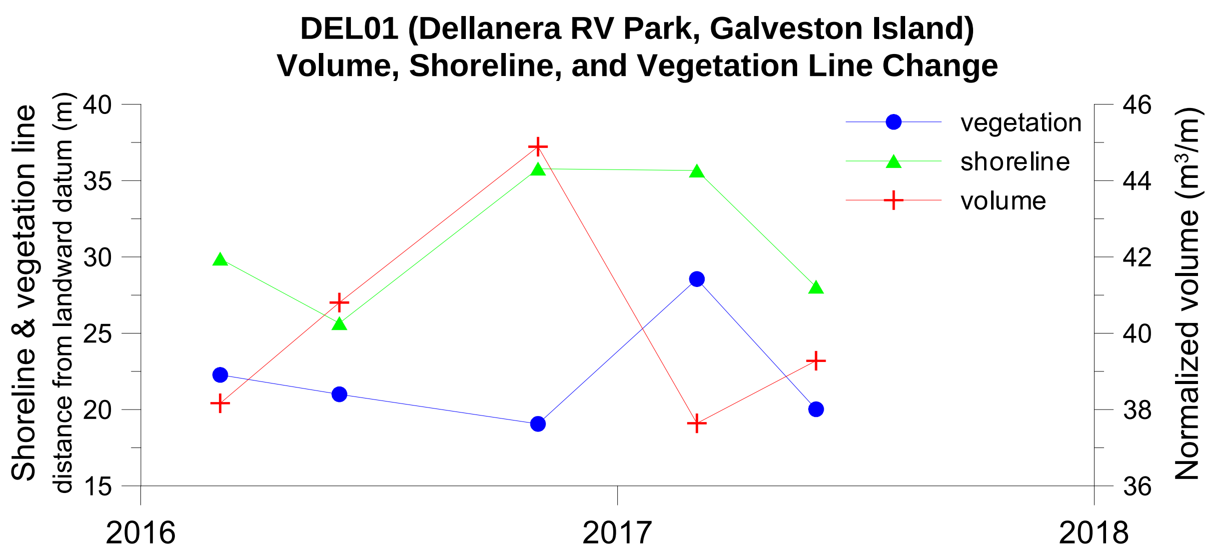
APPENDIX B: GRAPHS OF VOLUME, SHORELINE, AND VEGETATION-LINE CHANGE

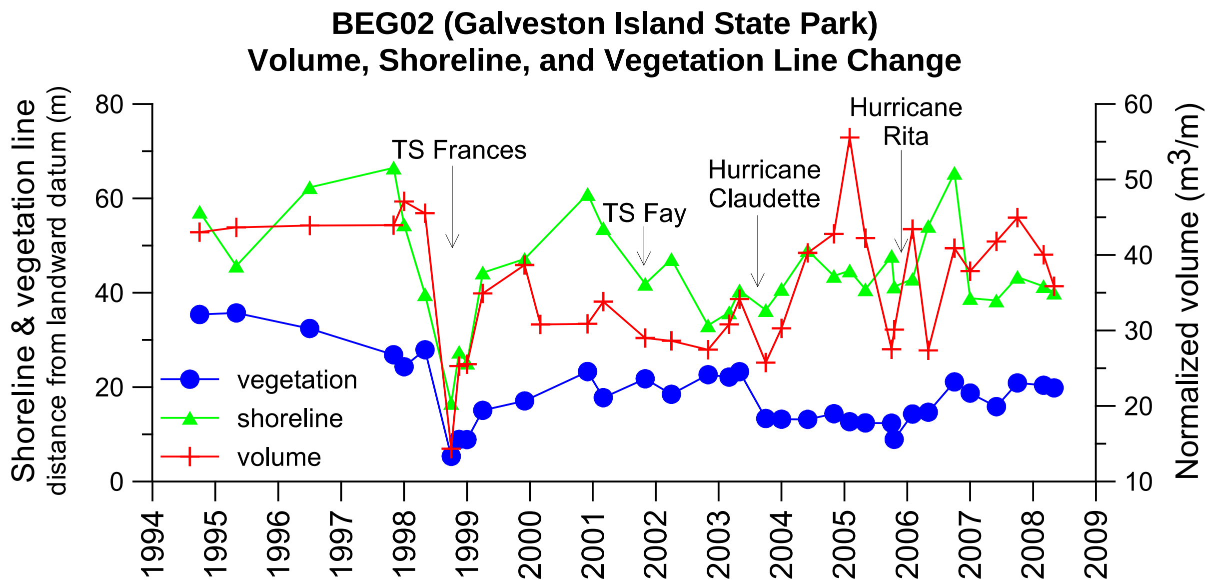
Sediment volume was calculated above 1 meter NAVD88 for all profiles unless otherwise indicated. Profiles that did not extend below the 1 meter NAVD88 elevation were extrapolated.

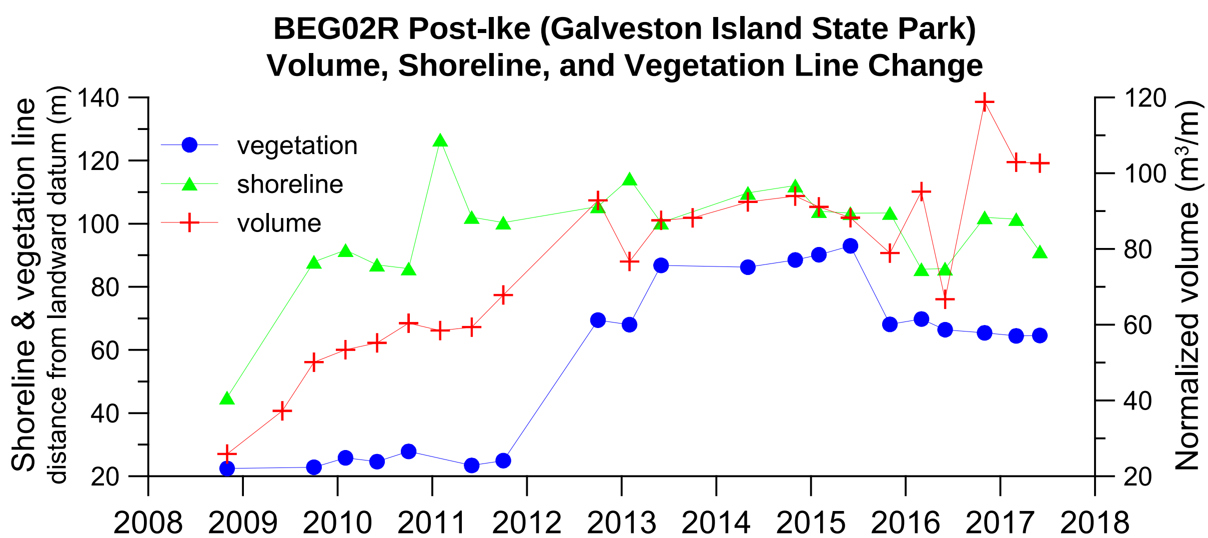


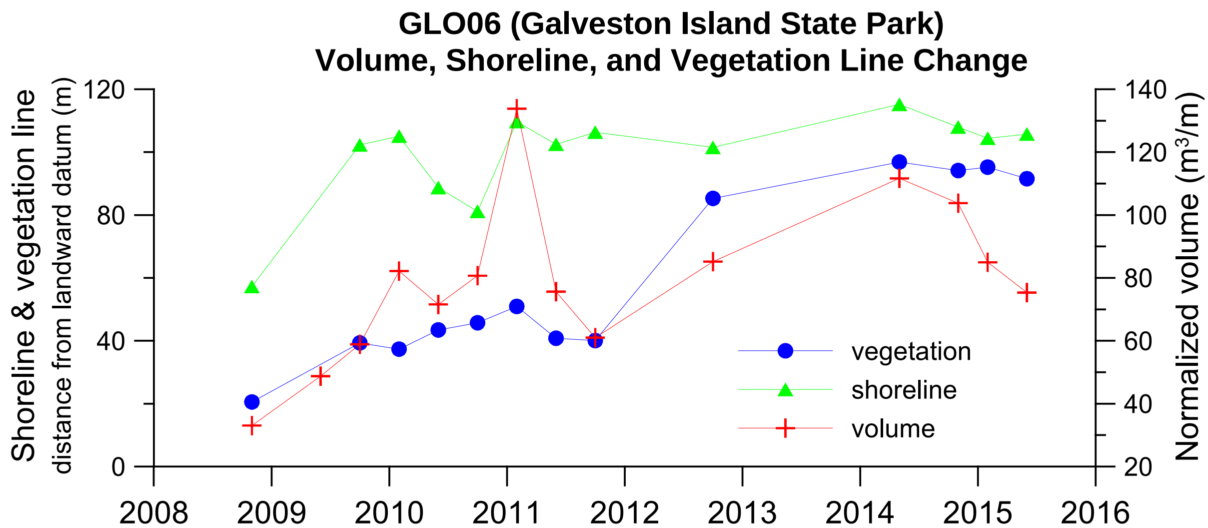


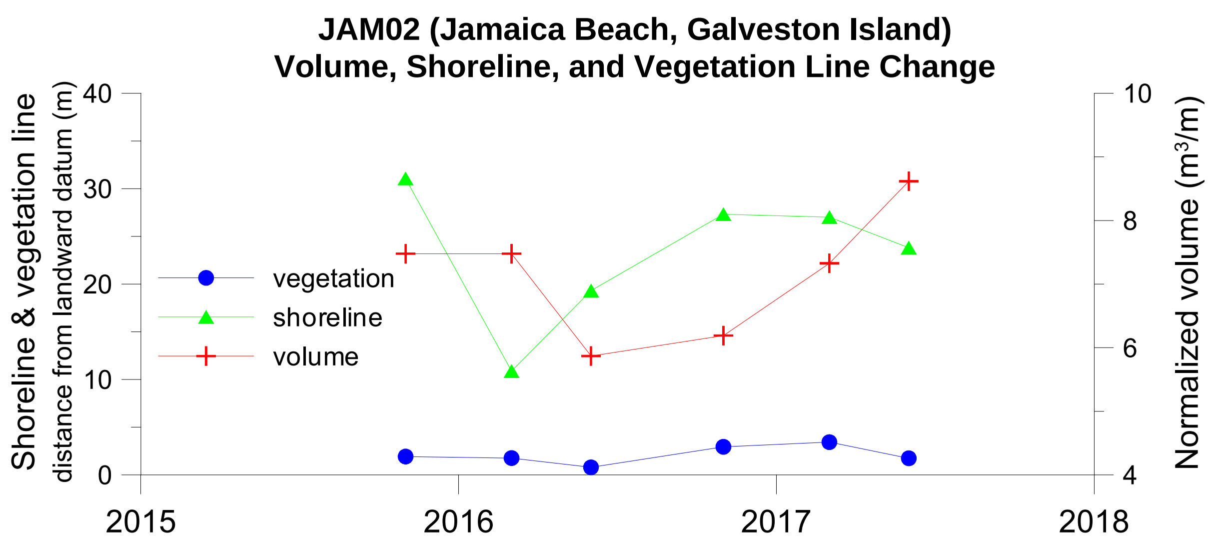

HIB01 (High Island Beach)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m3/m)
vegetation
shoreline
volume
2016
2017
2018

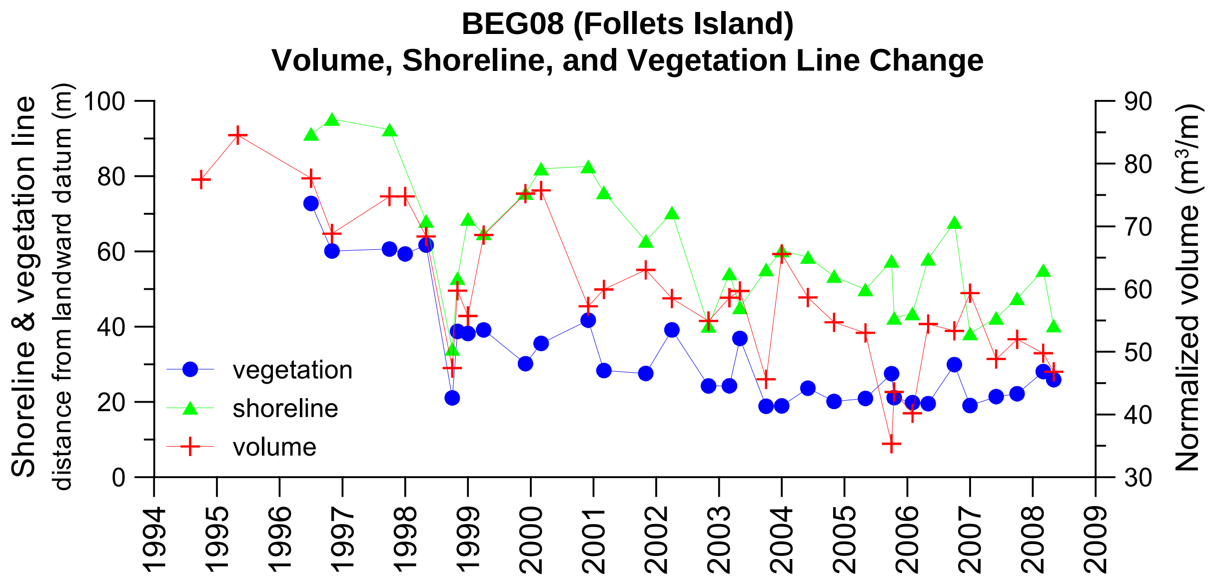

DEL01 (Dellanera RV Park, Galveston Island)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m3/m)
vegetation
shoreline
volume
2016
2017
2018

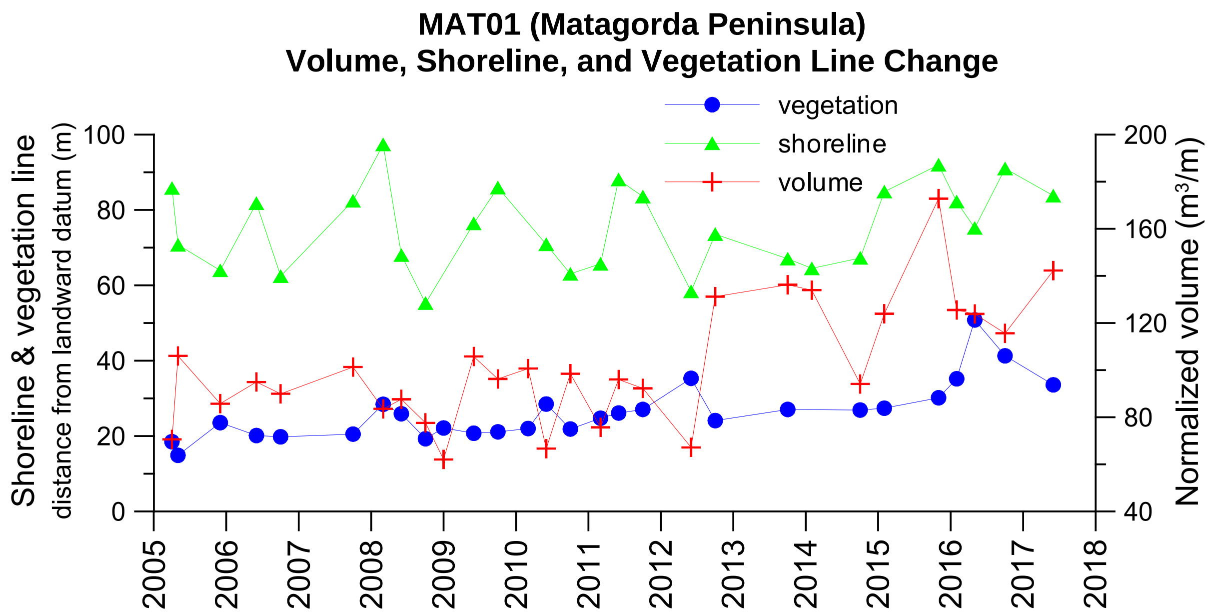

BEG02 (Galveston Island State Park)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m3/m)
TS Frances
TS Fay
Hurricane Claudette
Hurricane Rita
vegetation
shoreline
volume

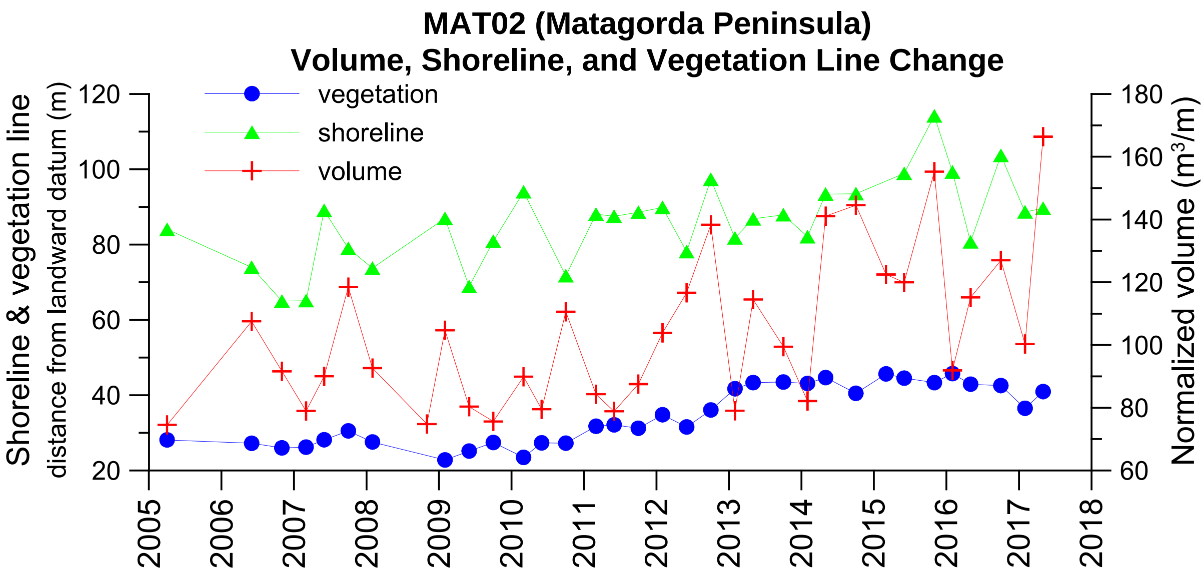

BEG02R Post-Ike (Galveston Island State Park)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m3/m)
vegetation
shoreline
volume

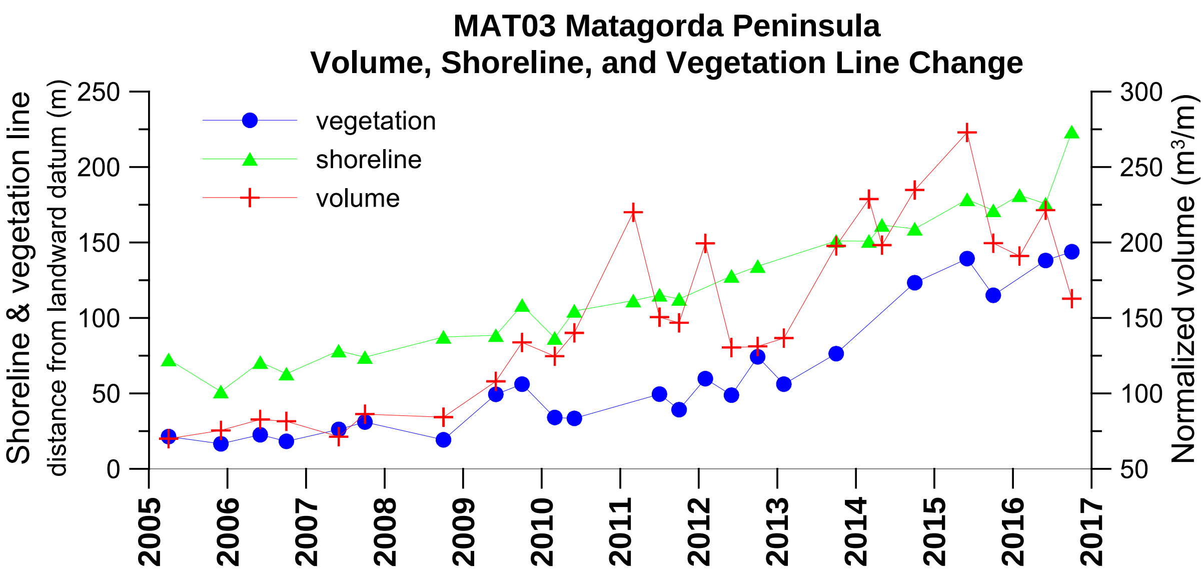

GLO06 (Galveston Island State Park)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m³/m)
0
40
80
120
20
40
60
80
100
120
140
2008
2009
2010
2011
2012
2013
2014
2015
2016
vegetation
shoreline
volume


JAM02 (Jamaica Beach, Galveston Island)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m³/m)
0
10
20
30
40
4
6
8
10
2015
2016
2017
2018
vegetation
shoreline
volume


BEG08 (Follets Island)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m3/m)
vegetation
shoreline
volume
0
20
40
60
80
100
30
40
50
60
70
80
90
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

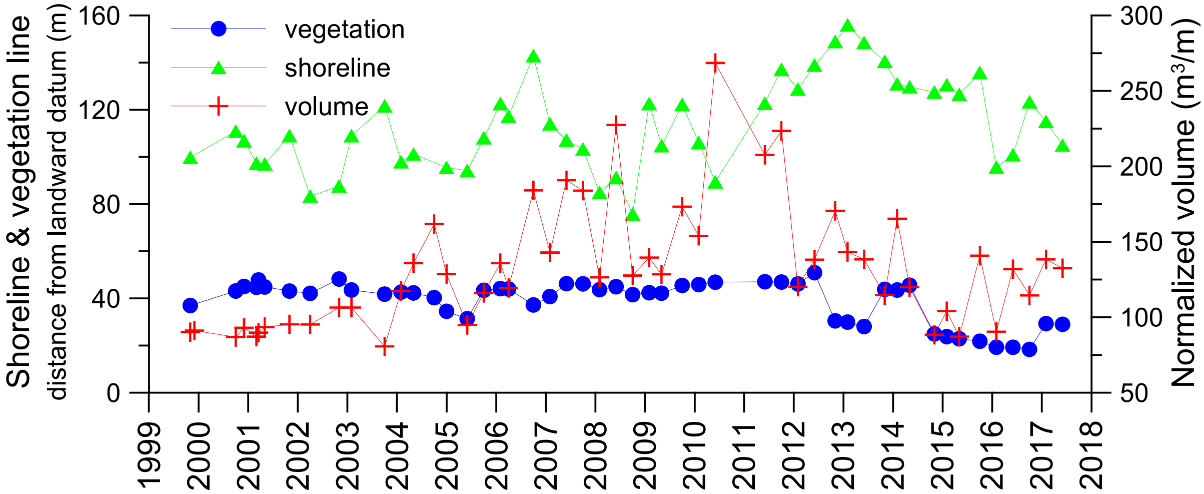

MAT01 (Matagorda Peninsula)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m3/m)
vegetation
shoreline
volume
0
20
40
60
80
100
40
80
120
160
200
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


MAT02 (Matagorda Peninsula)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m³/m)
vegetation
shoreline
volume
120
100
80
60
40
20
180
160
140
120
100
80
60
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


MAT03 Matagorda Peninsula
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m³/m)
vegetation
shoreline
volume
250
200
150
100
50
0
300
250
200
150
100
50
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

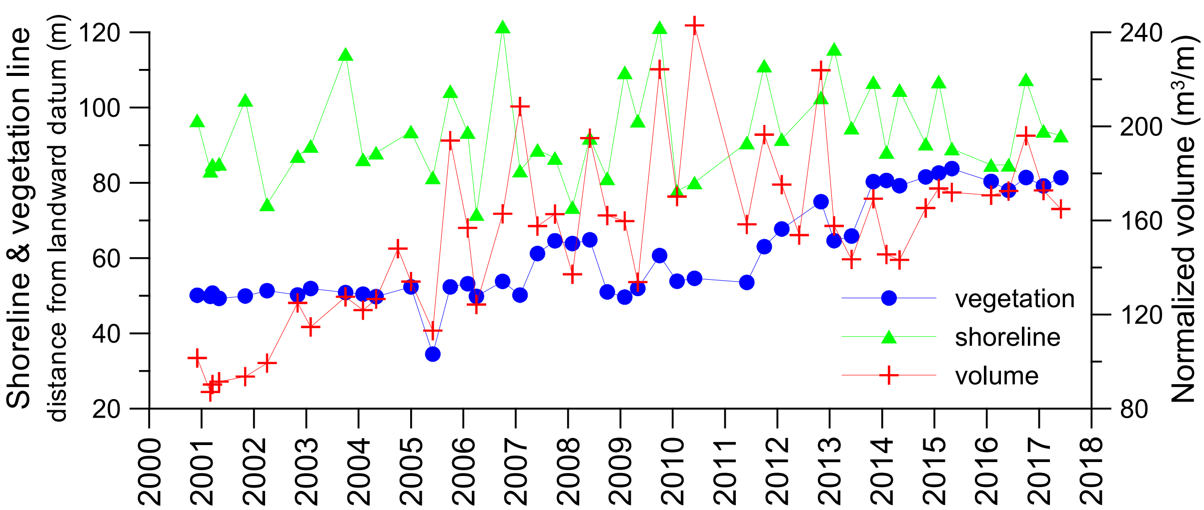
MUI01 volumes were calculated above 1.5 meters NAVD88. Profiles that did not extend below the 1.5 meter NAVD88 elevation were extrapolated.

MUI01 (Mustang Island)
Volume, Shoreline, and Vegetation Line Change

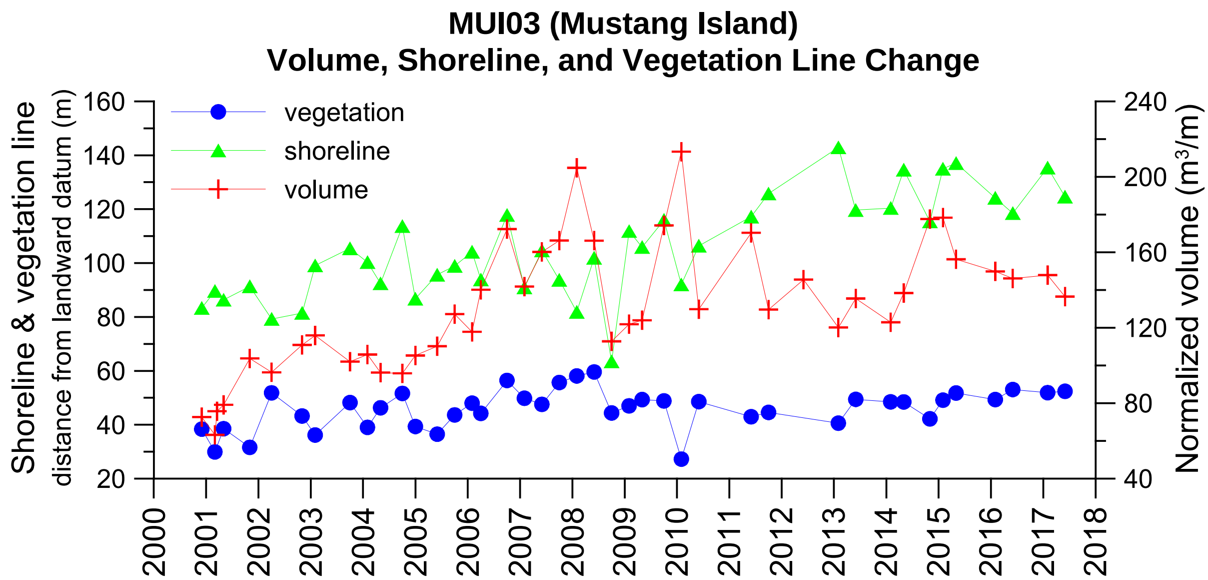


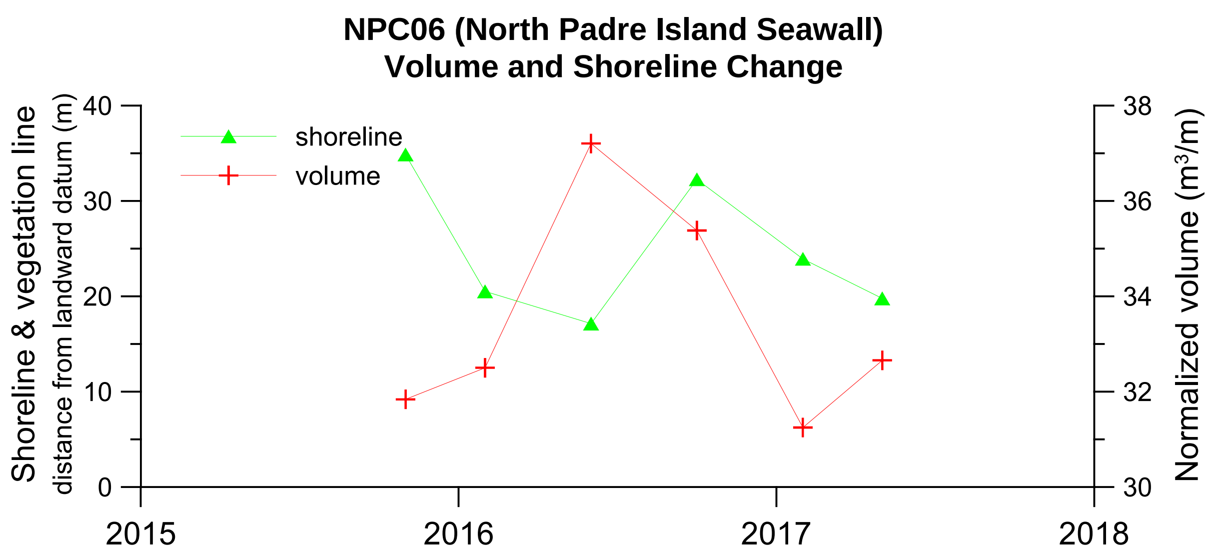
MUI02 volumes were calculated above 1.25 meters NAVD88. Profiles that did not extend below the 1.25 meter NAVD88 elevation were extrapolated.

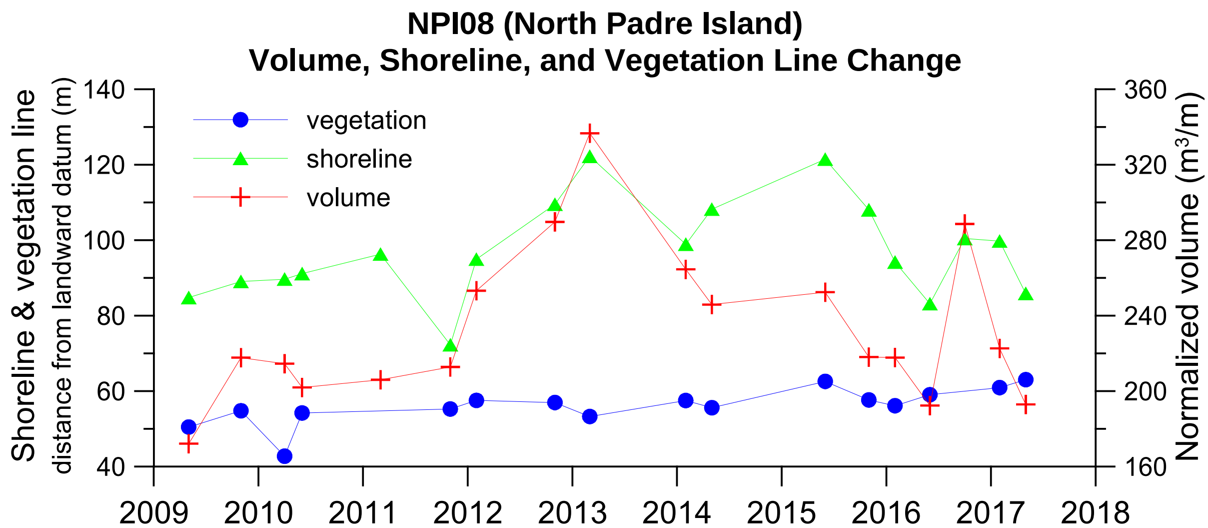
MUI02 (Mustang Island State Park)
Volume, Shoreline, and Vegetation Line Change

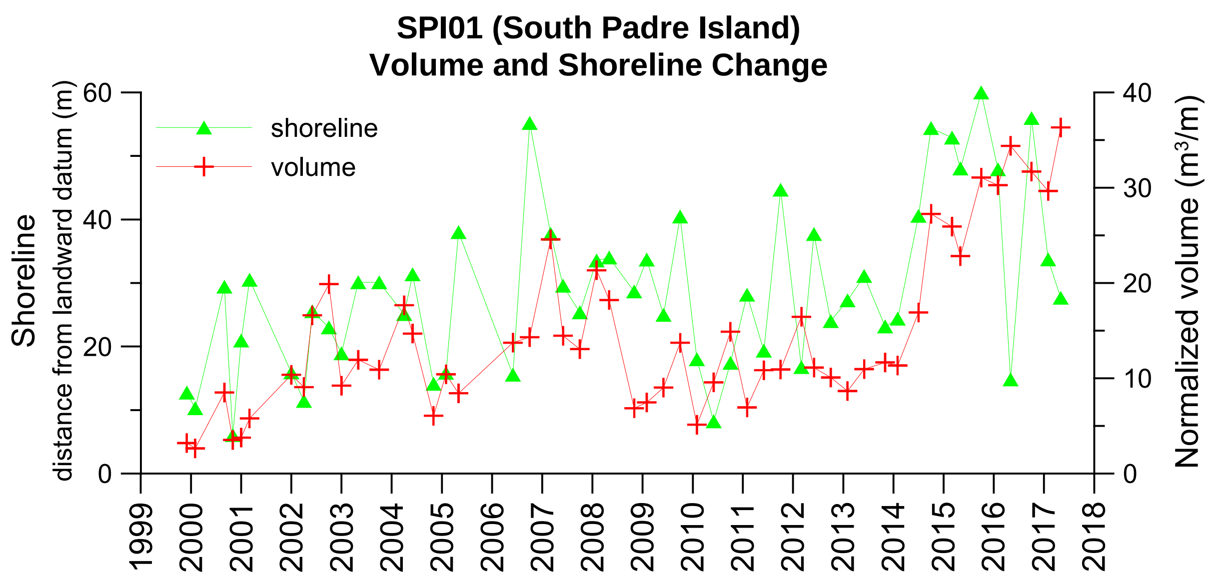


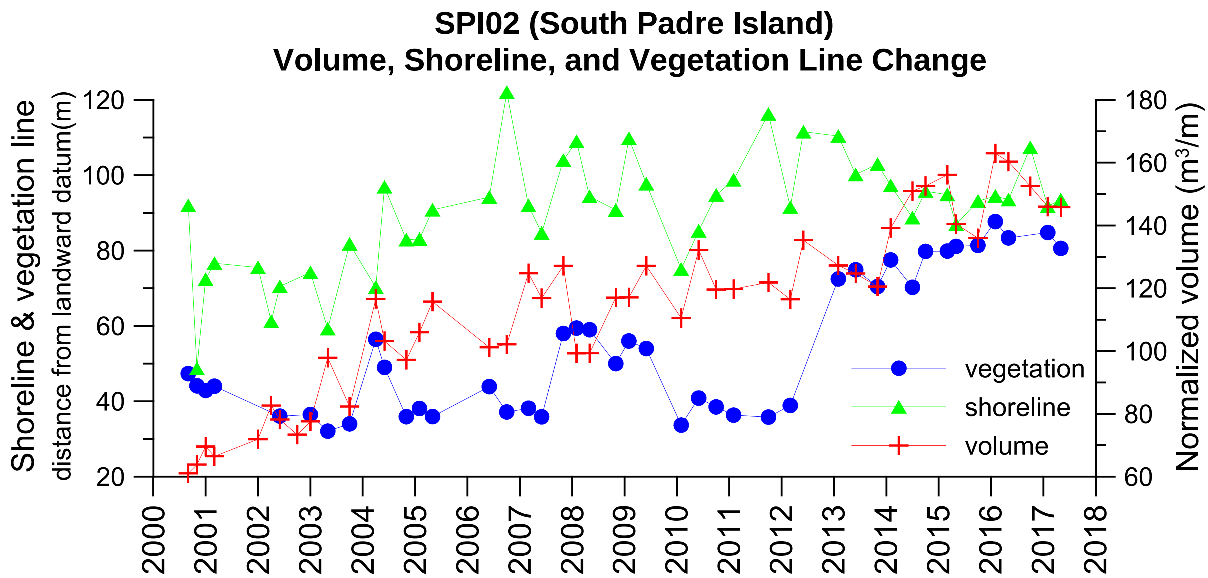
MUI03 volumes were calculated above 1.5 meters NAVD88. Profiles that did not extend below the 1.5 meter NAVD88 elevation were extrapolated.

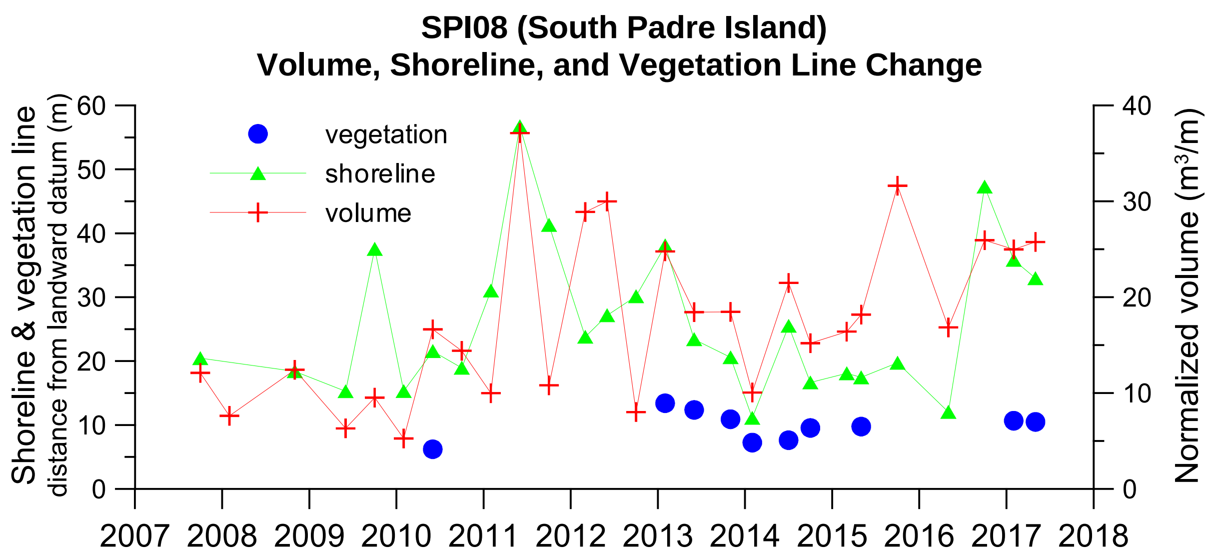





NPI08 (North Padre Island)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m3/m)
vegetation
shoreline
volume
140
120
100
80
60
40
360
320
280
240
200
160
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

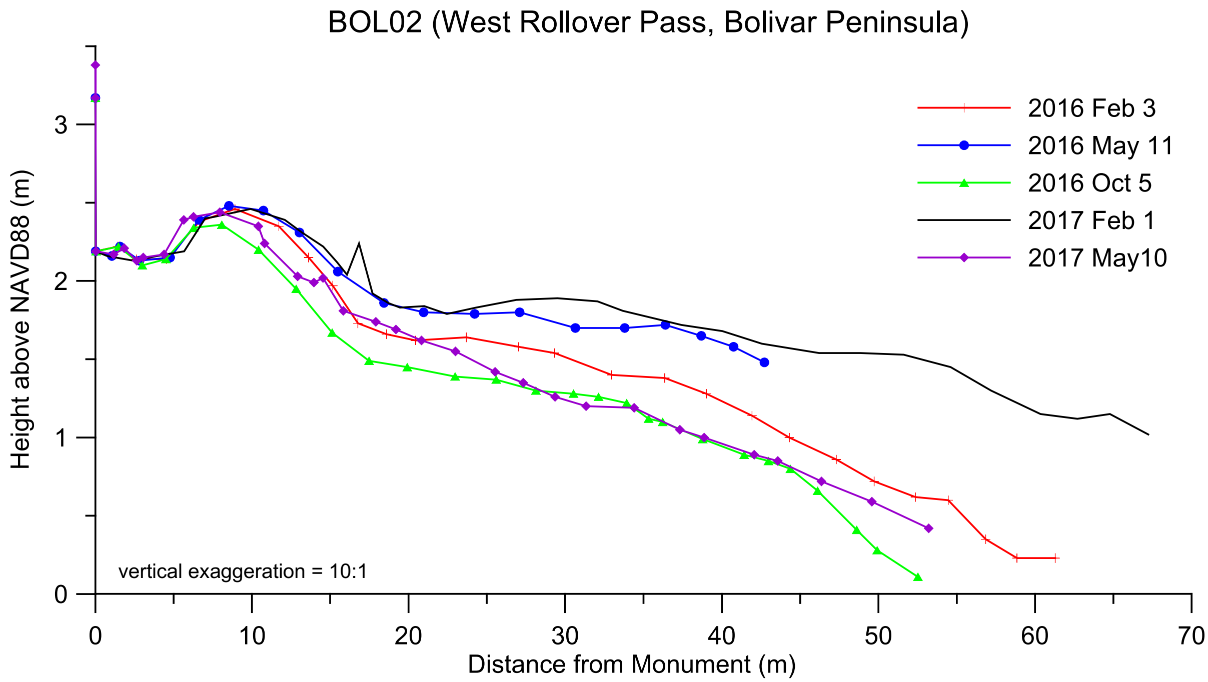

SPI01 (South Padre Island)
Volume and Shoreline Change
Shoreline
distance from landward datum (m)
Normalized volume (m3/m)
shoreline
volume
60
40
20
0
40
30
20
10
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


SPI02 (South Padre Island)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum(m)
Normalized volume (m3/m)
vegetation
shoreline
volume

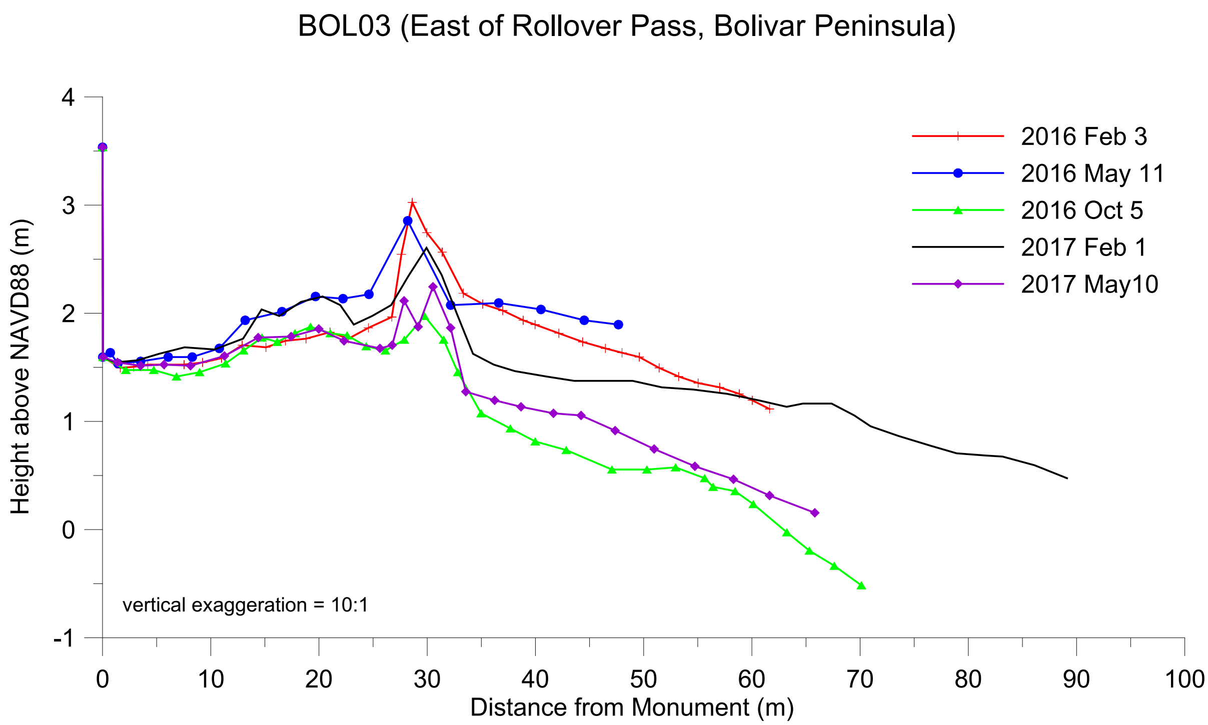

SPI08 (South Padre Island)
Volume, Shoreline, and Vegetation Line Change
Shoreline & vegetation line
distance from landward datum (m)
Normalized volume (m3/m)
vegetation
shoreline
volume

APPENDIX C: GRAPHS OF BEACH PROFILES

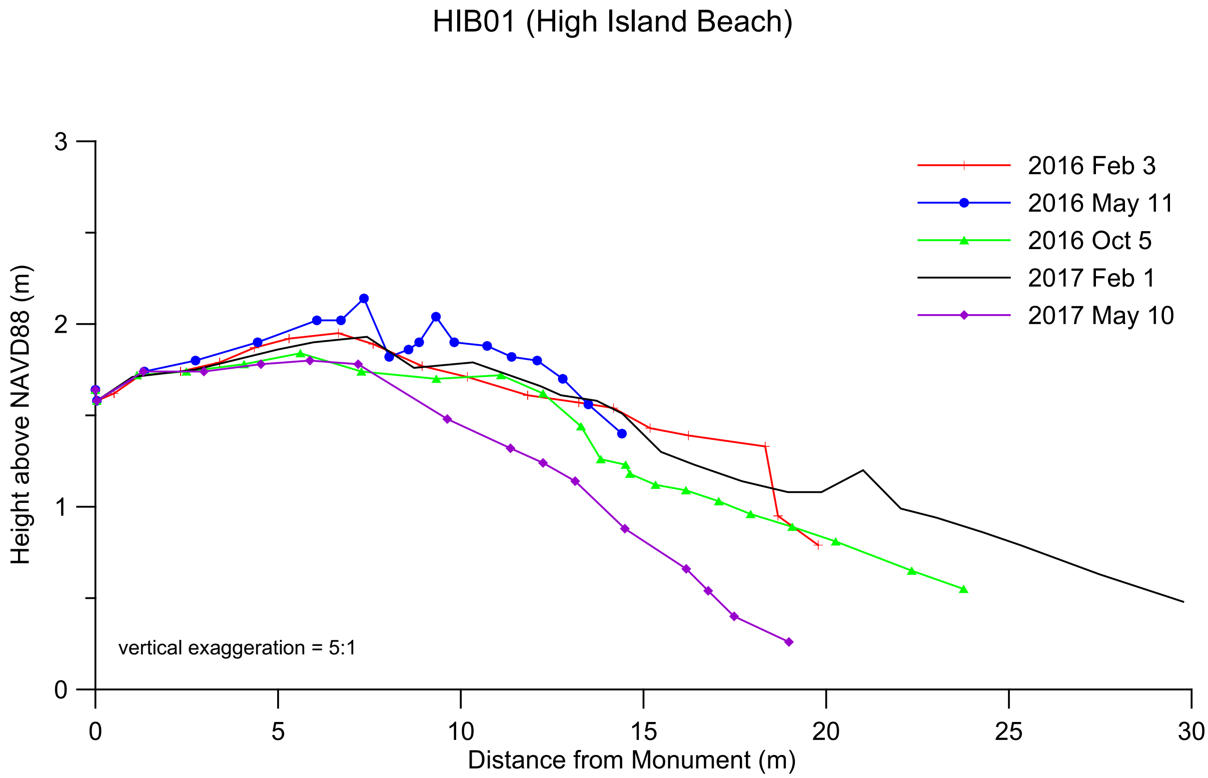
BOL02



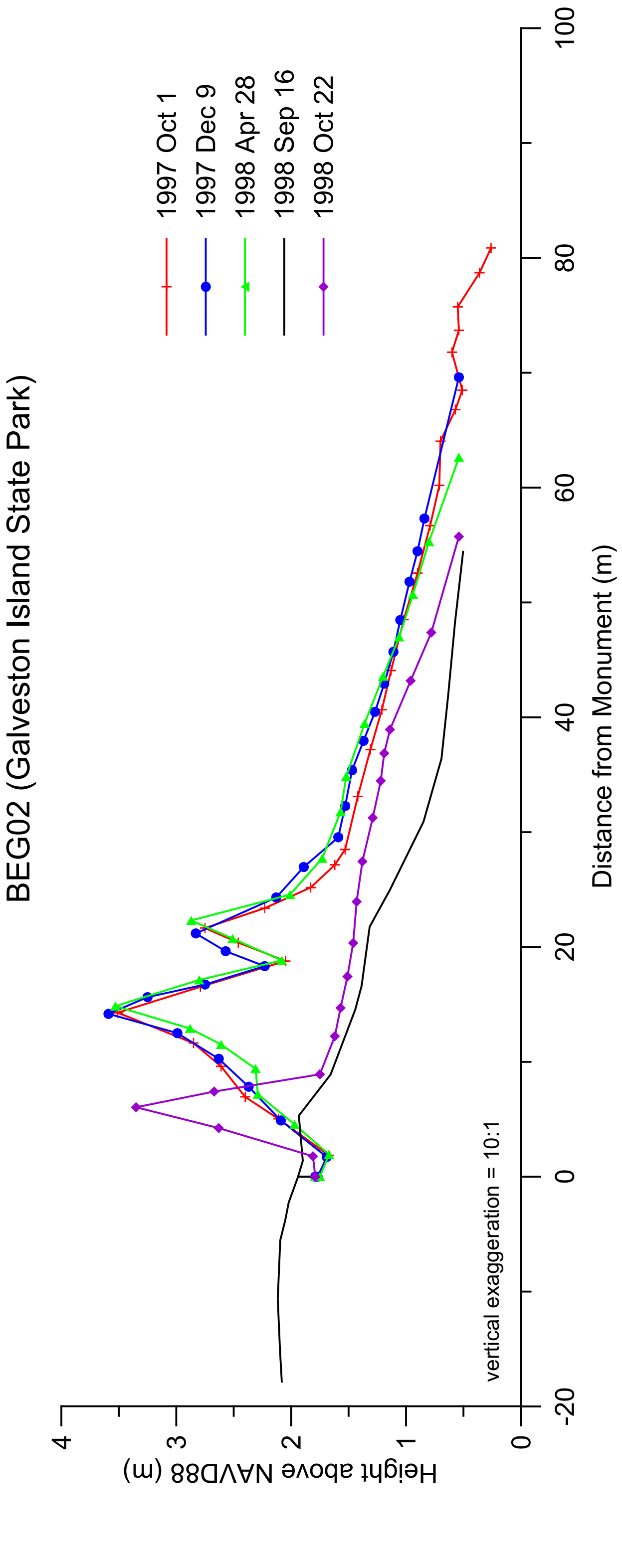
BOL03



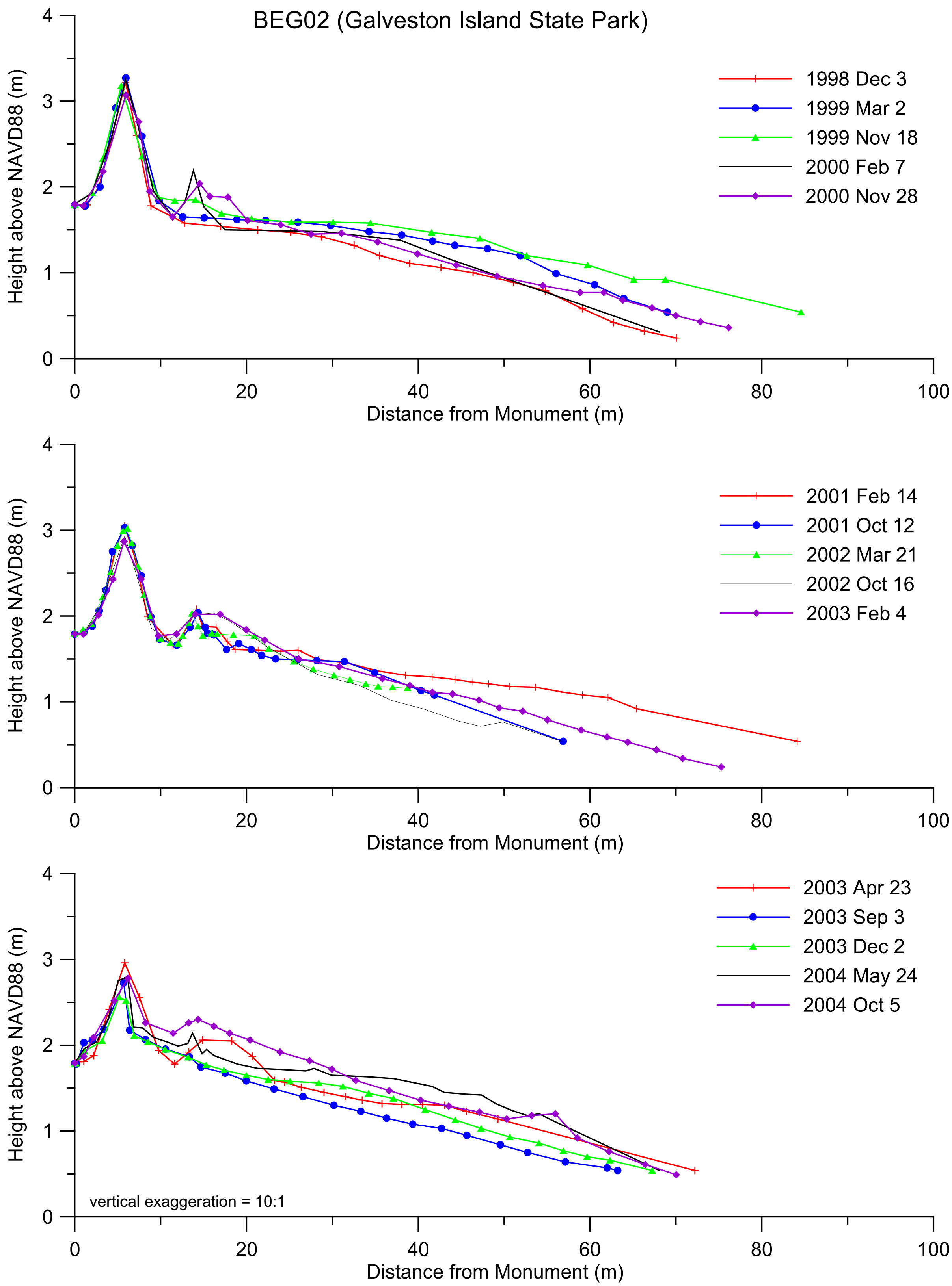
HIB01

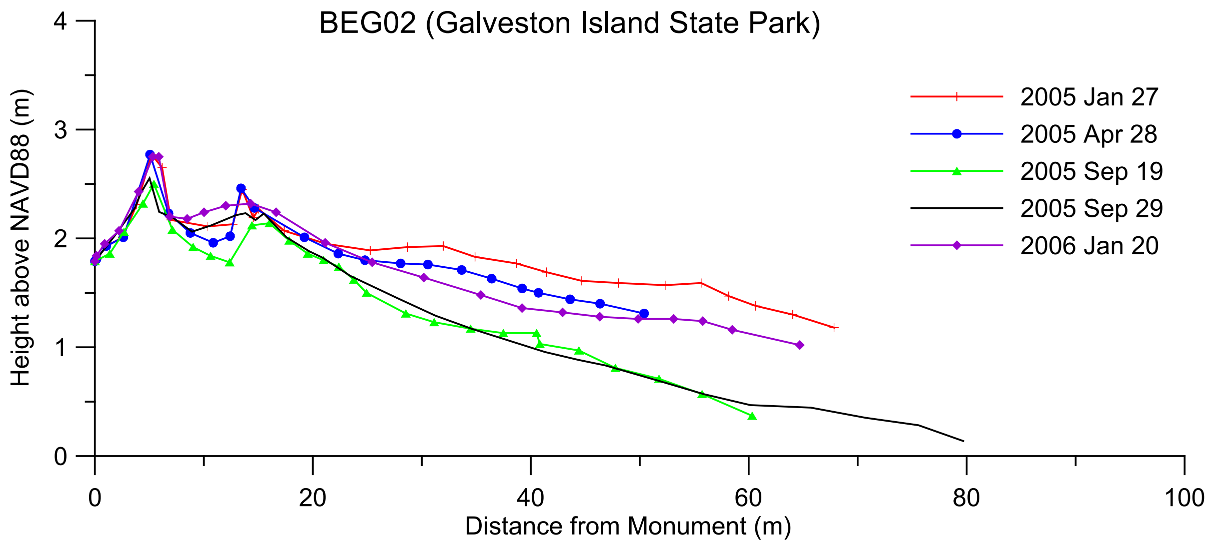

HIB01 (High Island Beach)
2016 Feb 3
2016 May 11
2016 Oct 5
2017 Feb 1
2017 May 10
Height above NAVD88 (m)
Distance from Monument (m)
vertical exaggeration = 5:1
0
1
2
3
0
5
10
15
20
25
30

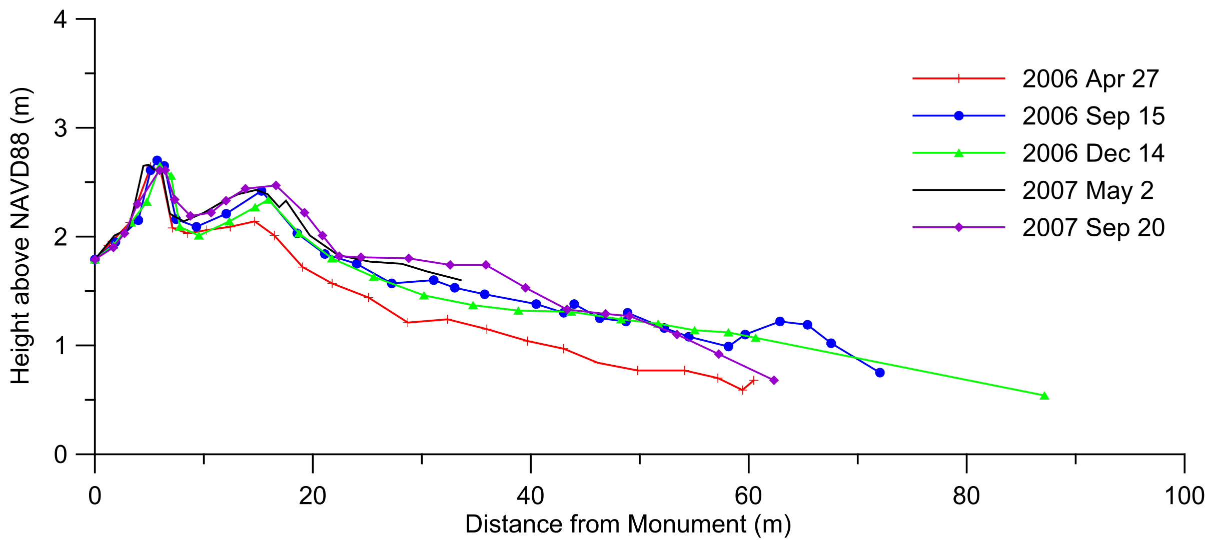
BEG02

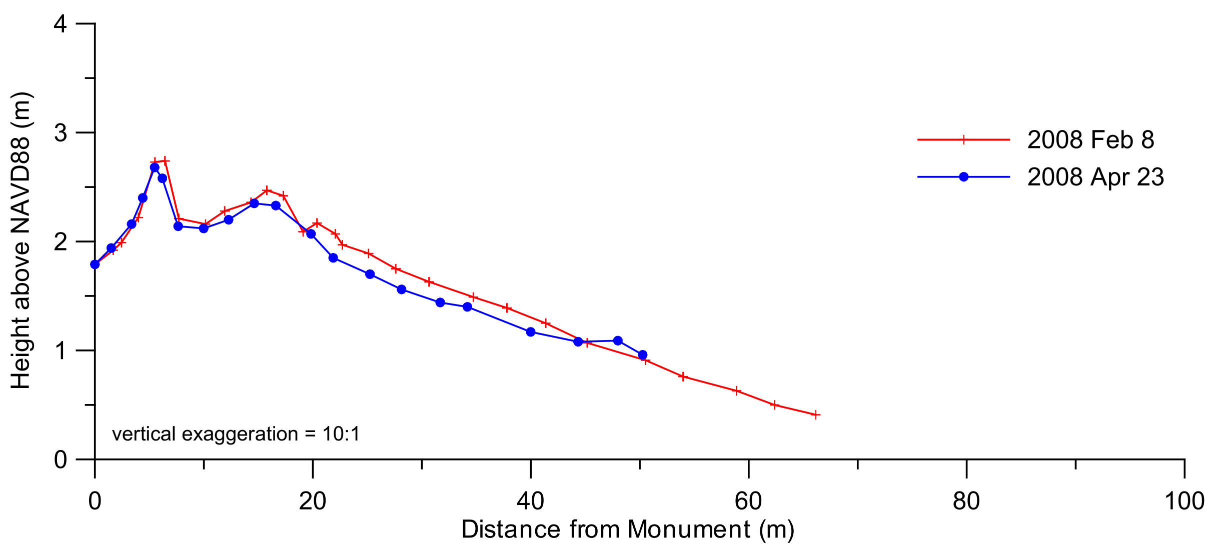


BEG02 (Galveston Island State Park)
1997 Oct 1
1997 Dec 9
1998 Apr 28
1998 Sep 16
1998 Oct 22
vertical exaggeration = 10:1
Distance from Monument (m)
Height above NAVD88 (m)
-20
0
20
40
60
80
100
0
1
2
3
4

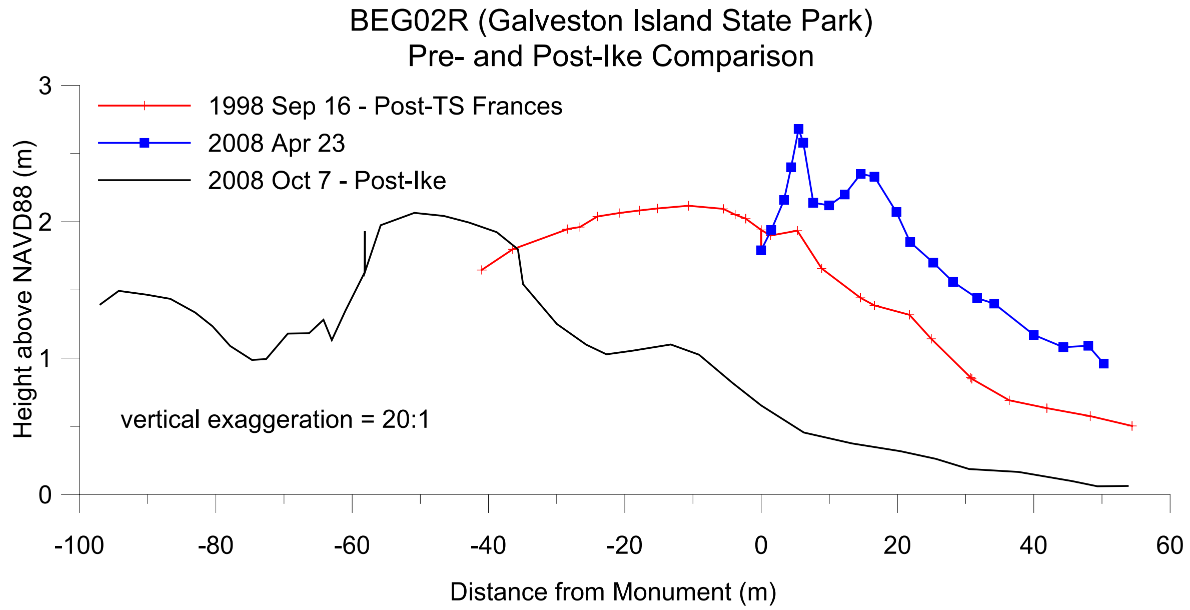

BEG02 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
1998 Dec 3
1999 Mar 2
1999 Nov 18
2000 Feb 7
2000 Nov 28
2001 Feb 14
2001 Oct 12
2002 Mar 21
2002 Oct 16
2003 Feb 4
2003 Apr 23
2003 Sep 3
2003 Dec 2
2004 May 24
2004 Oct 5
vertical exaggeration = 10:1
0
1
2
3
4
0
20
40
60
80
100

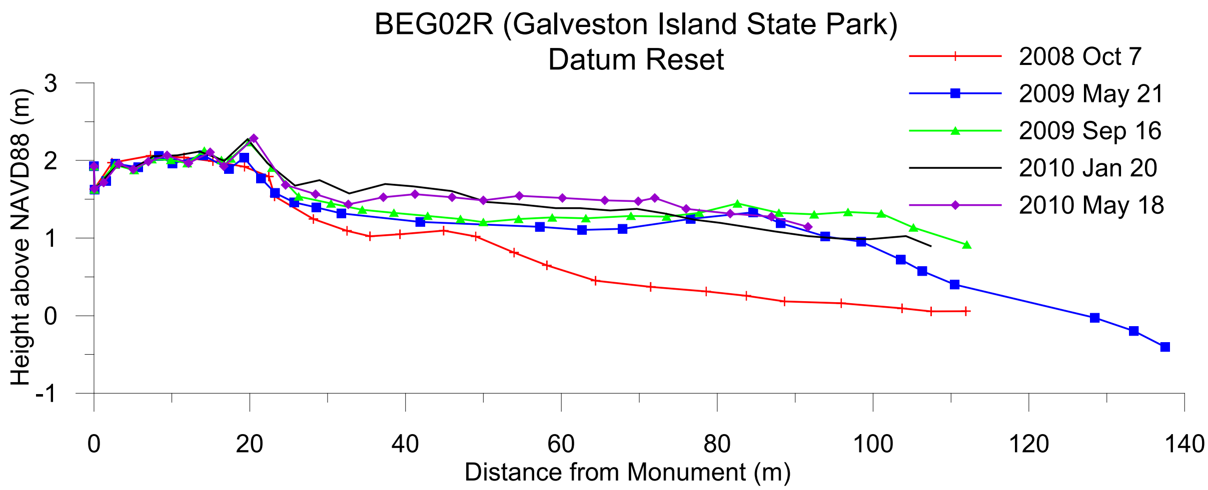

BEG02 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2005 Jan 27
2005 Apr 28
2005 Sep 19
2005 Sep 29
2006 Jan 20
0
1
2
3
4
0
20
40
60
80
100

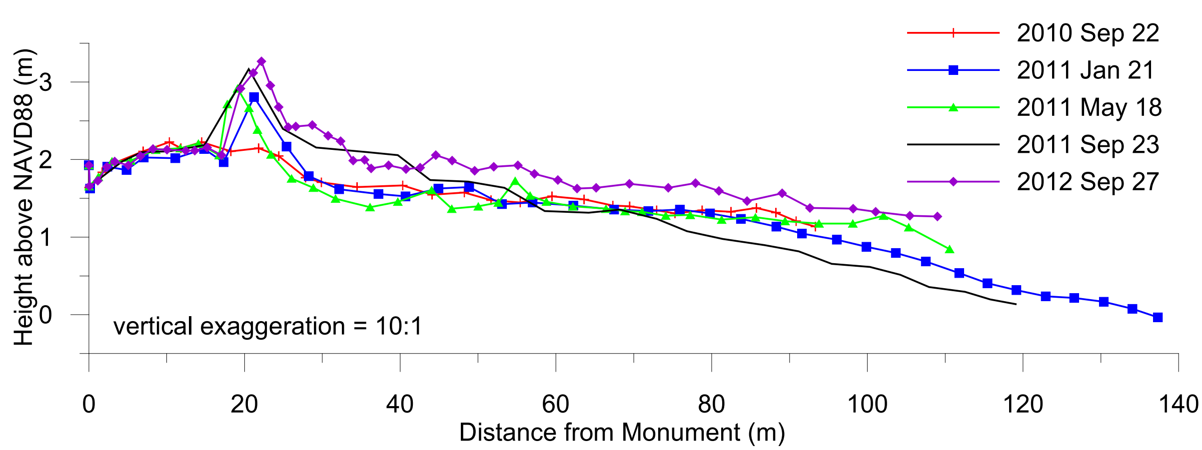

Height above NAVD88 (m)
Distance from Monument (m)
2006 Apr 27
2006 Sep 15
2006 Dec 14
2007 May 2
2007 Sep 20
0
1
2
3
4
0
20
40
60
80
100

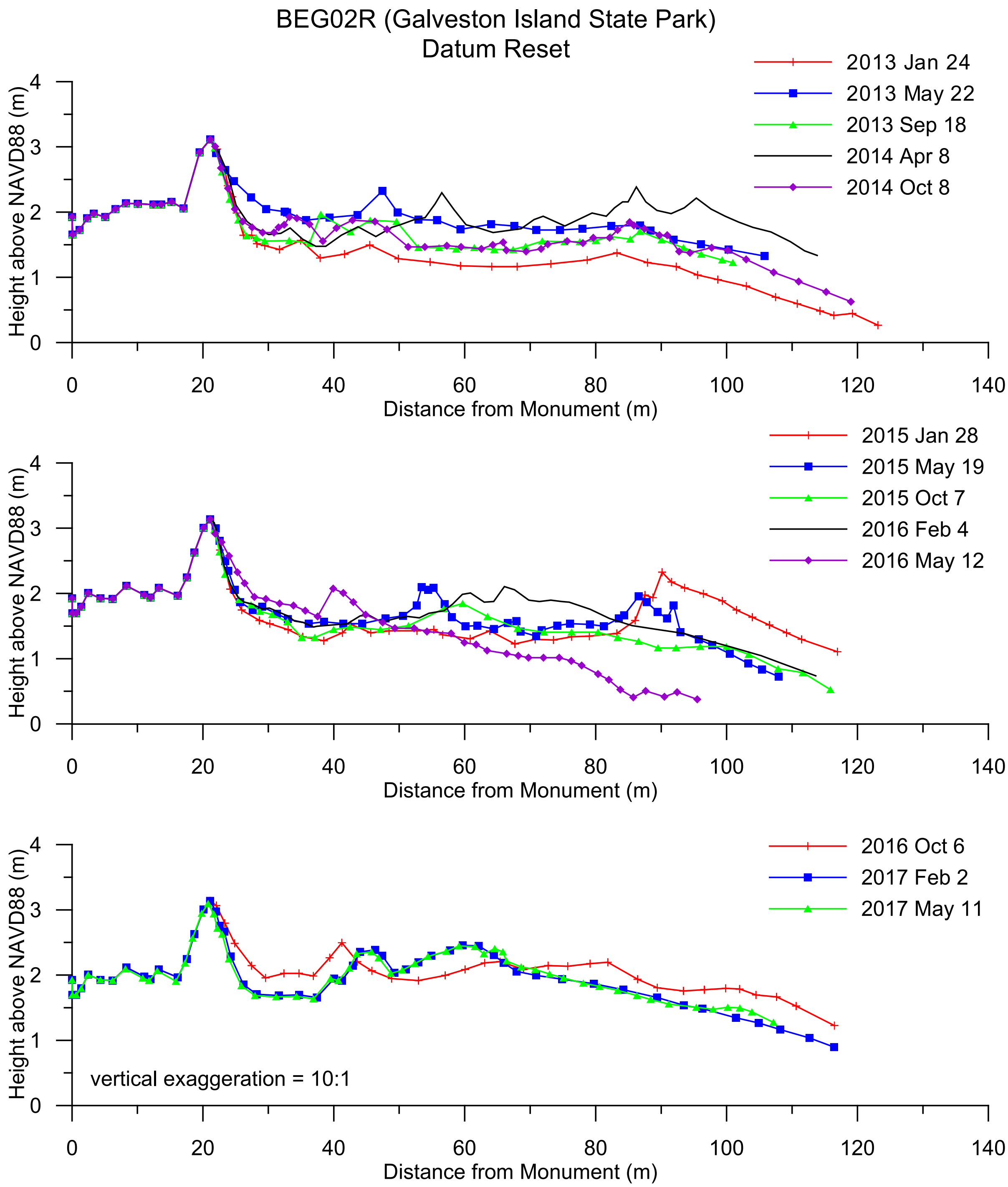

Height above NAVD88 (m)
Distance from Monument (m)
2008 Feb 8
2008 Apr 23
vertical exaggeration = 10:1
0
1
2
3
4
0
20
40
60
80
100

BEG02R

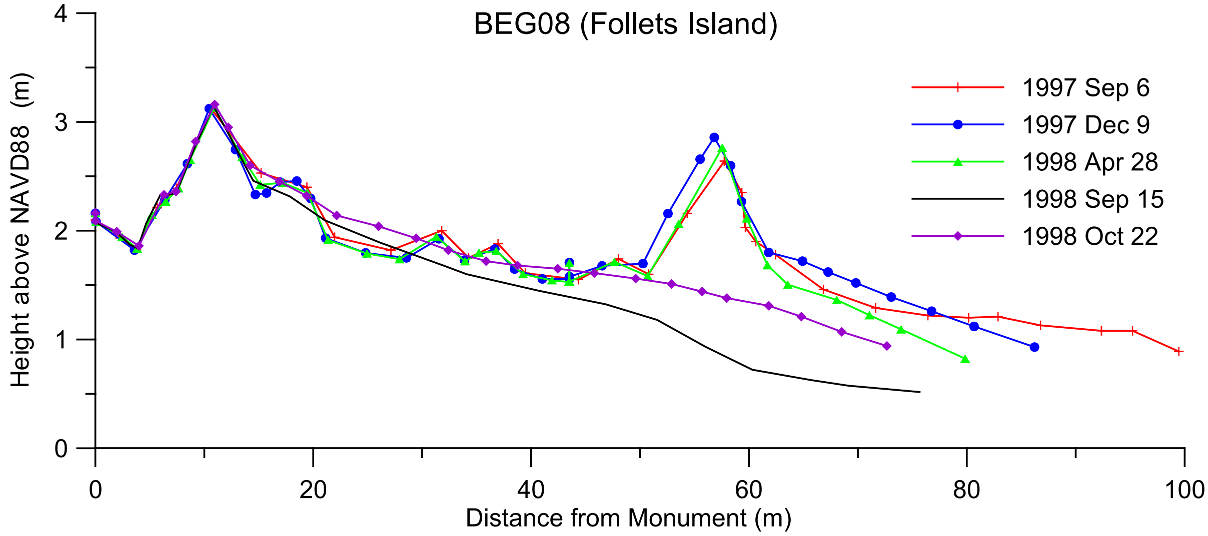

BEG02R (Galveston Island State Park)
Pre- and Post-Ike Comparison
1998 Sep 16 - Post-TS Frances
2008 Apr 23
2008 Oct 7 - Post-Ike
vertical exaggeration = 20:1
Height above NAVD88 (m)
Distance from Monument (m)
3
2
1
0
-100
-80
-60
-40
-20
0
20
40
60


BEG02R (Galveston Island State Park)
Datum Reset
2008 Oct 7
2009 May 21
2009 Sep 16
2010 Jan 20
2010 May 18
Height above NAVD88 (m)
Distance from Monument (m)
3
2
1
0
-1
0
20
40
60
80
100
120
140

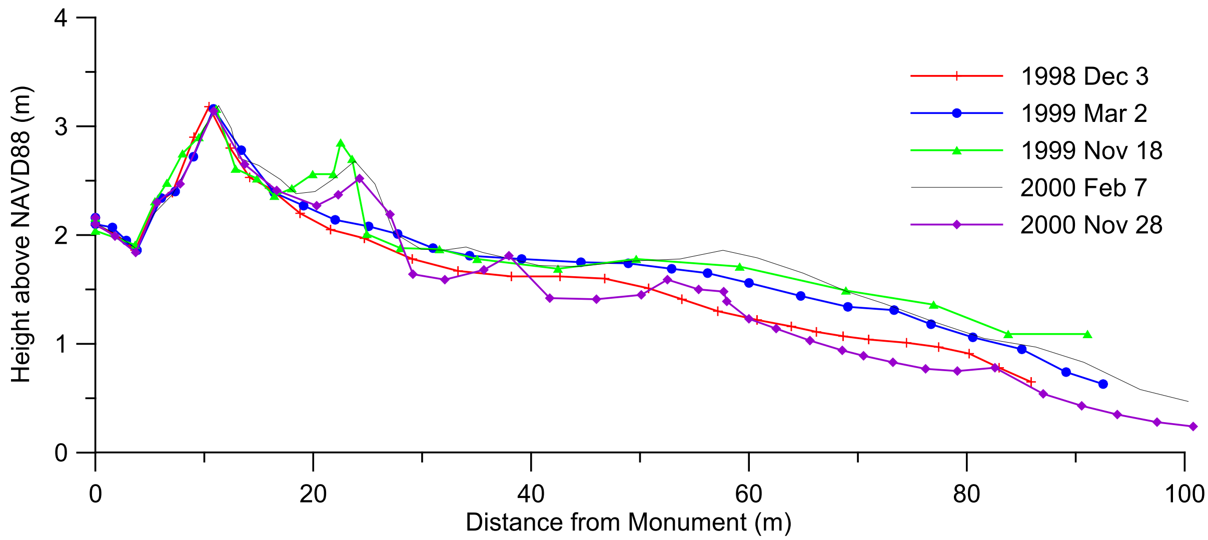

2010 Sep 22
2011 Jan 21
2011 May 18
2011 Sep 23
2012 Sep 27
vertical exaggeration = 10:1
Height above NAVD88 (m)
Distance from Monument (m)
3
2
1
0
0
20
40
60
80
100
120
140


BEG02R (Galveston Island State Park)
Datum Reset
2013 Jan 24
2013 May 22
2013 Sep 18
2014 Apr 8
2014 Oct 8
Height above NAVD88 (m)
Distance from Monument (m)
2015 Jan 28
2015 May 19
2015 Oct 7
2016 Feb 4
2016 May 12
Height above NAVD88 (m)
Distance from Monument (m)
2016 Oct 6
2017 Feb 2
2017 May 11
Height above NAVD88 (m)
vertical exaggeration = 10:1
Distance from Monument (m)

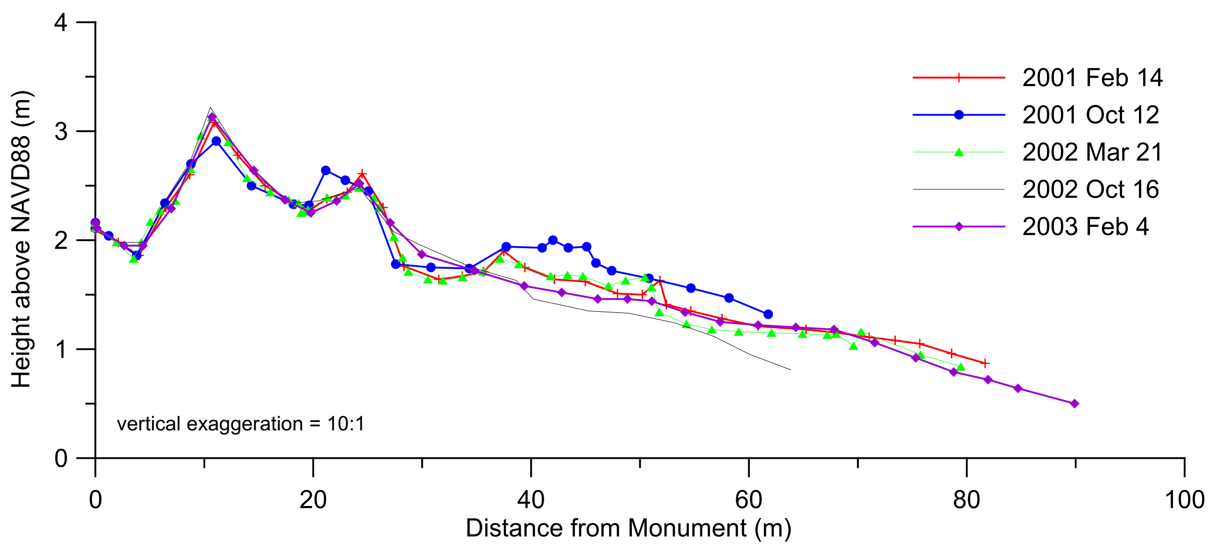
BEG08



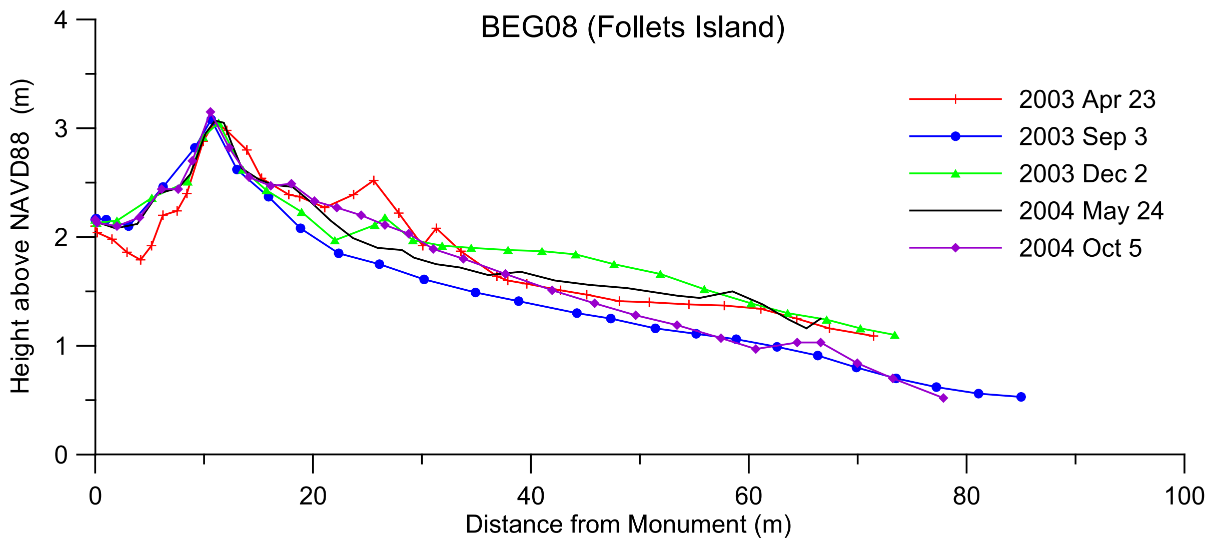
BEG08 (Follets Island)
Height above NAVD88 (m)
Distance from Monument (m)
1997 Sep 6
1997 Dec 9
1998 Apr 28
1998 Sep 15
1998 Oct 22
0
1
2
3
4
0
20
40
60
80
100

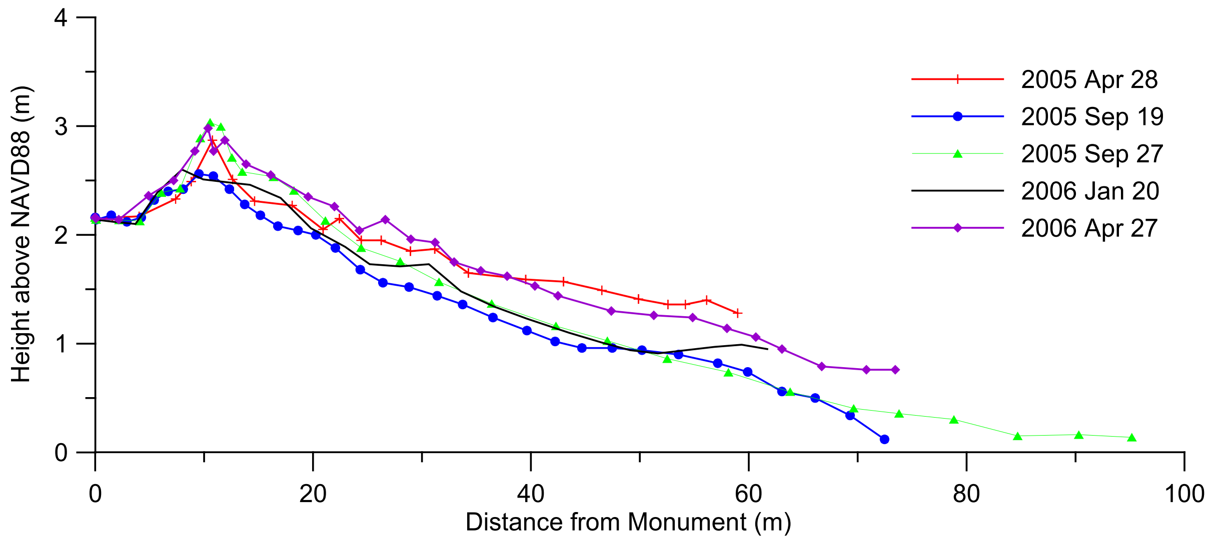


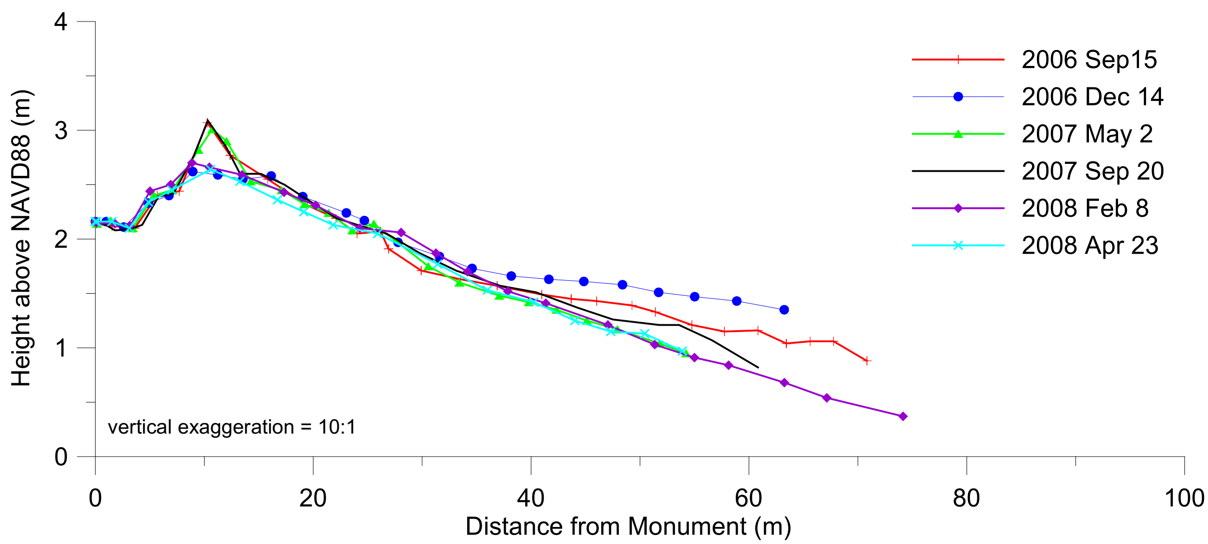
Height above NAVD88 (m)
Distance from Monument (m)
1998 Dec 3
1999 Mar 2
1999 Nov 18
2000 Feb 7
2000 Nov 28
0
1
2
3
4
0
20
40
60
80
100



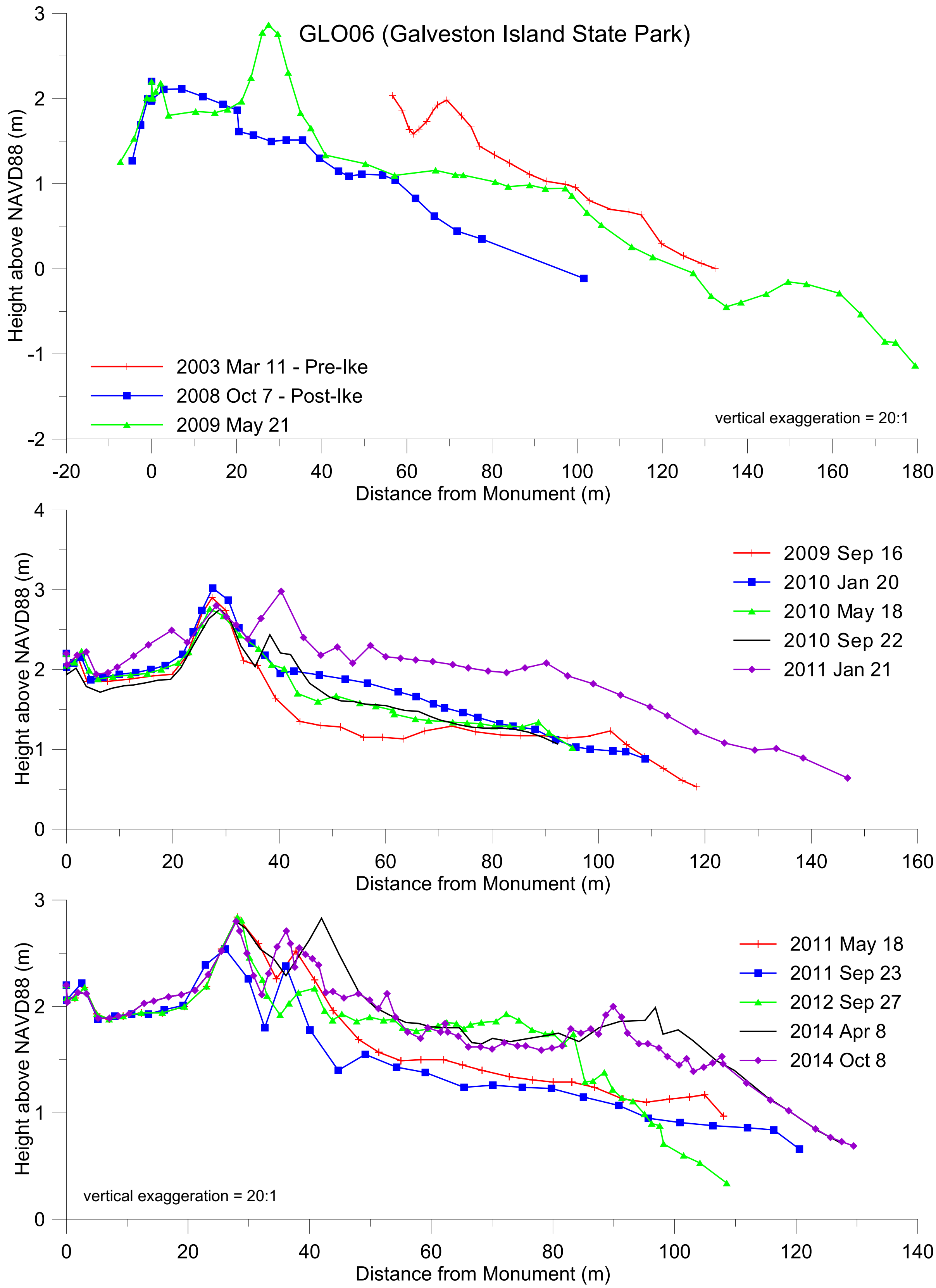
Height above NAVD88 (m)
Distance from Monument (m)
2001 Feb 14
2001 Oct 12
2002 Mar 21
2002 Oct 16
2003 Feb 4
vertical exaggeration = 10:1
0
1
2
3
4
0
20
40
60
80
100


BEG08 (Follets Island)
Height above NAVD88 (m)
Distance from Monument (m)
2003 Apr 23
2003 Sep 3
2003 Dec 2
2004 May 24
2004 Oct 5

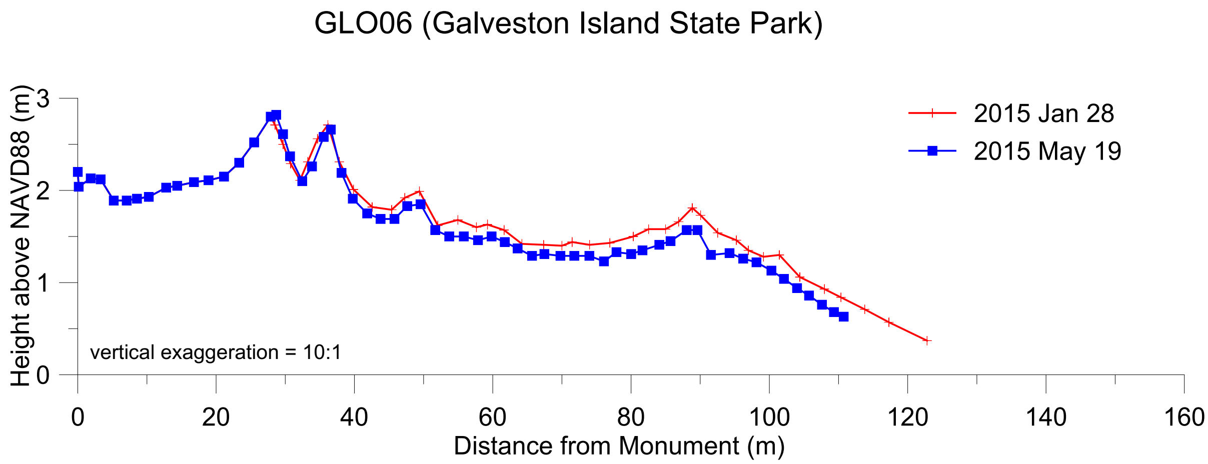

Height above NAVD88 (m)
Distance from Monument (m)
2005 Apr 28
2005 Sep 19
2005 Sep 27
2006 Jan 20
2006 Apr 27


Height above NAVD88 (m)
Distance from Monument (m)
2006 Sep15
2006 Dec 14
2007 May 2
2007 Sep 20
2008 Feb 8
2008 Apr 23
vertical exaggeration = 10:1

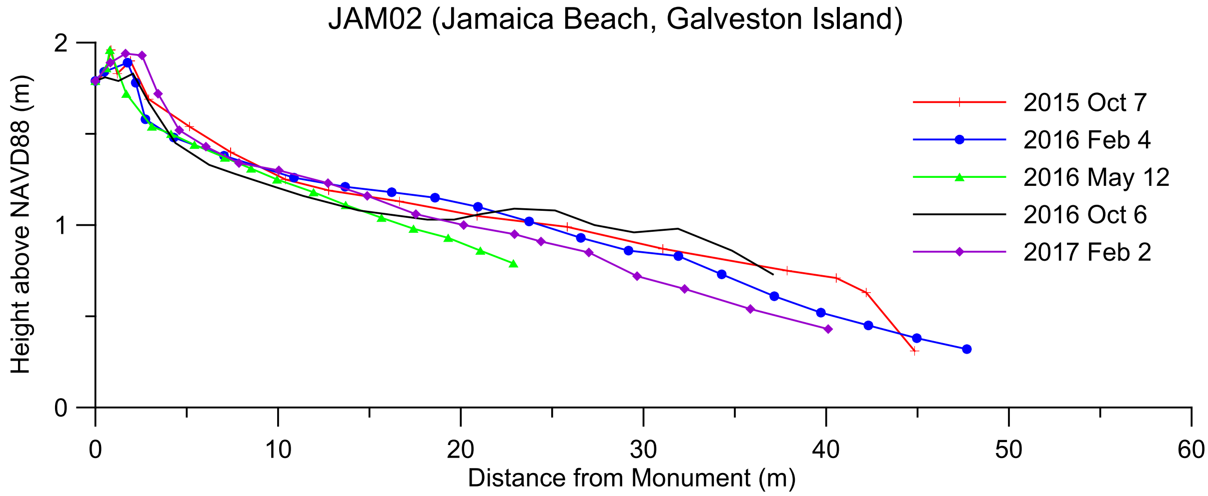
GLO06



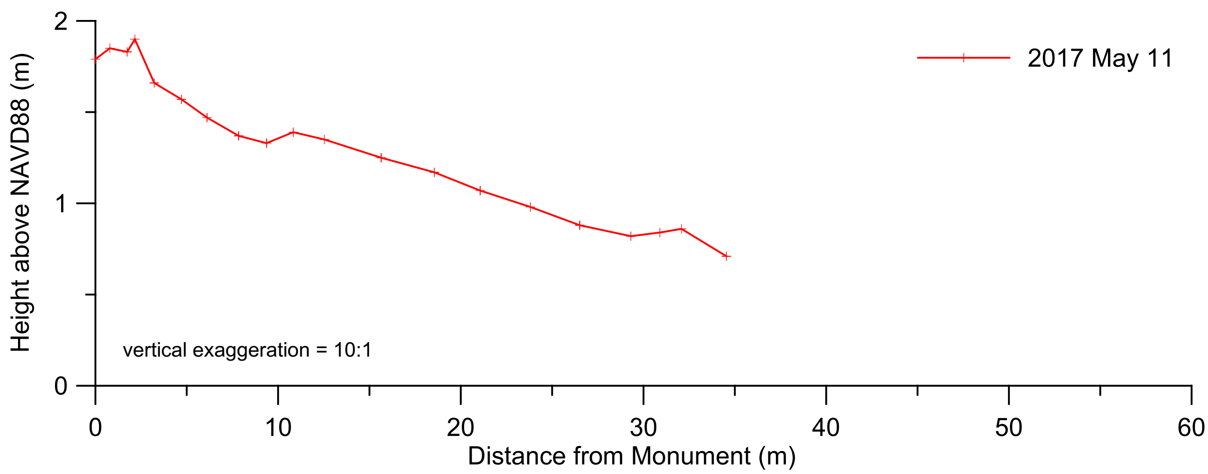
GLO06 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2003 Mar 11 - Pre-Ike
2008 Oct 7 - Post-Ike
2009 May 21
vertical exaggeration = 20:1
2009 Sep 16
2010 Jan 20
2010 May 18
2010 Sep 22
2011 Jan 21
2011 May 18
2011 Sep 23
2012 Sep 27
2014 Apr 8
2014 Oct 8


GLO06 (Galveston Island State Park)
Height above NAVD88 (m)
0
1
2
3
vertical exaggeration = 10:1
0
20
40
60
80
100
120
140
160
Distance from Monument (m)
2015 Jan 28
2015 May 19

JAM02

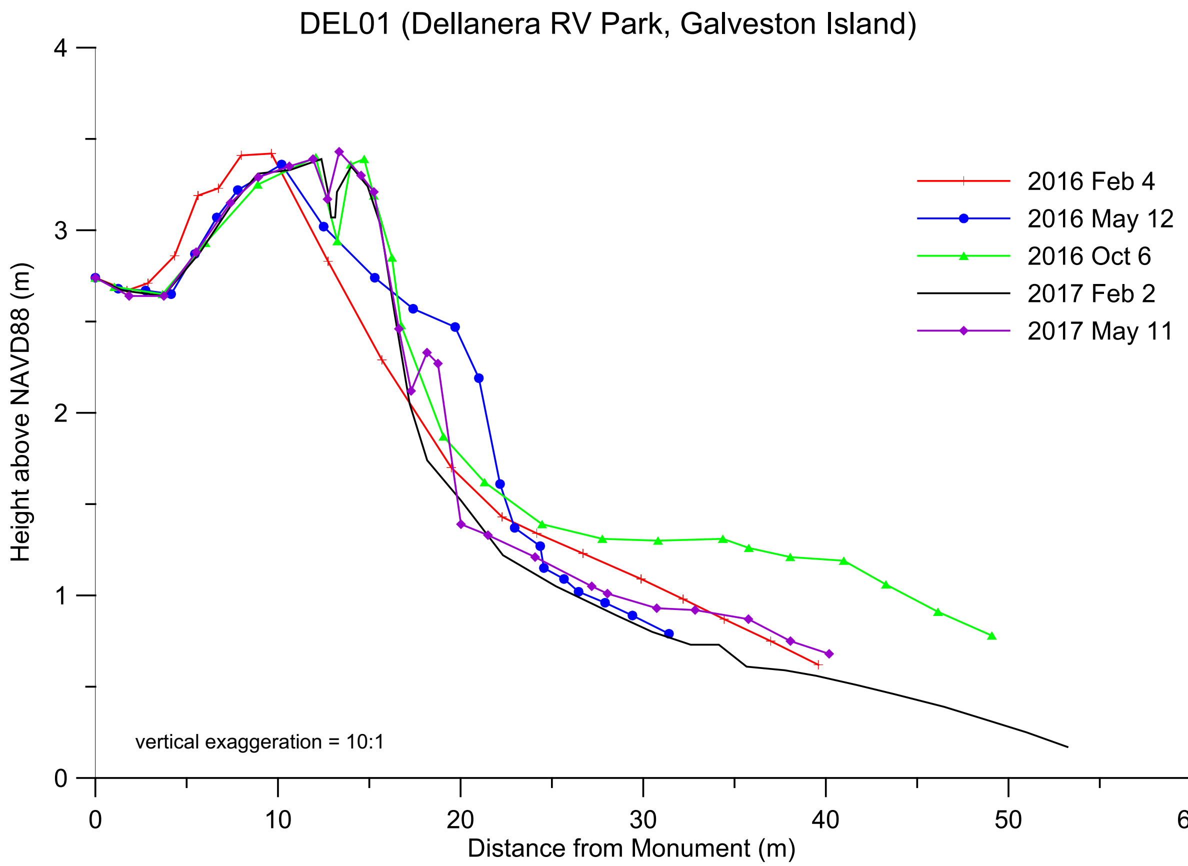


JAM02 (Jamaica Beach, Galveston Island)
Height above NAVD88 (m)
Distance from Monument (m)
2015 Oct 7
2016 Feb 4
2016 May 12
2016 Oct 6
2017 Feb 2



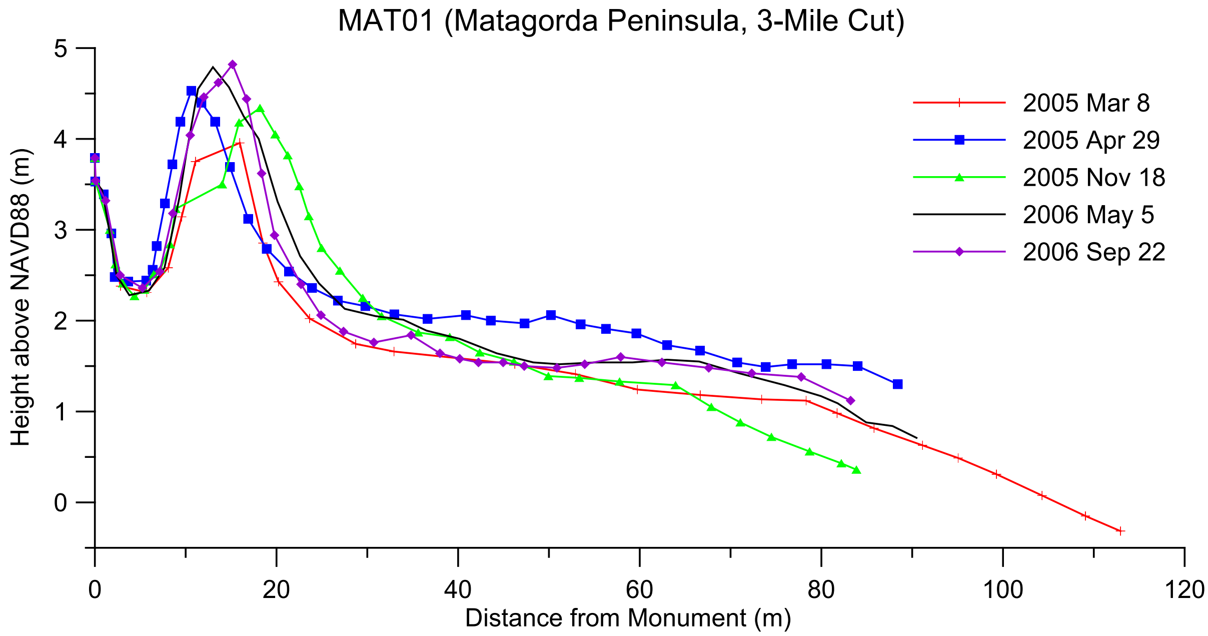
Height above NAVD88 (m)
Distance from Monument (m)
2017 May 11
vertical exaggeration = 10:1

DEL01

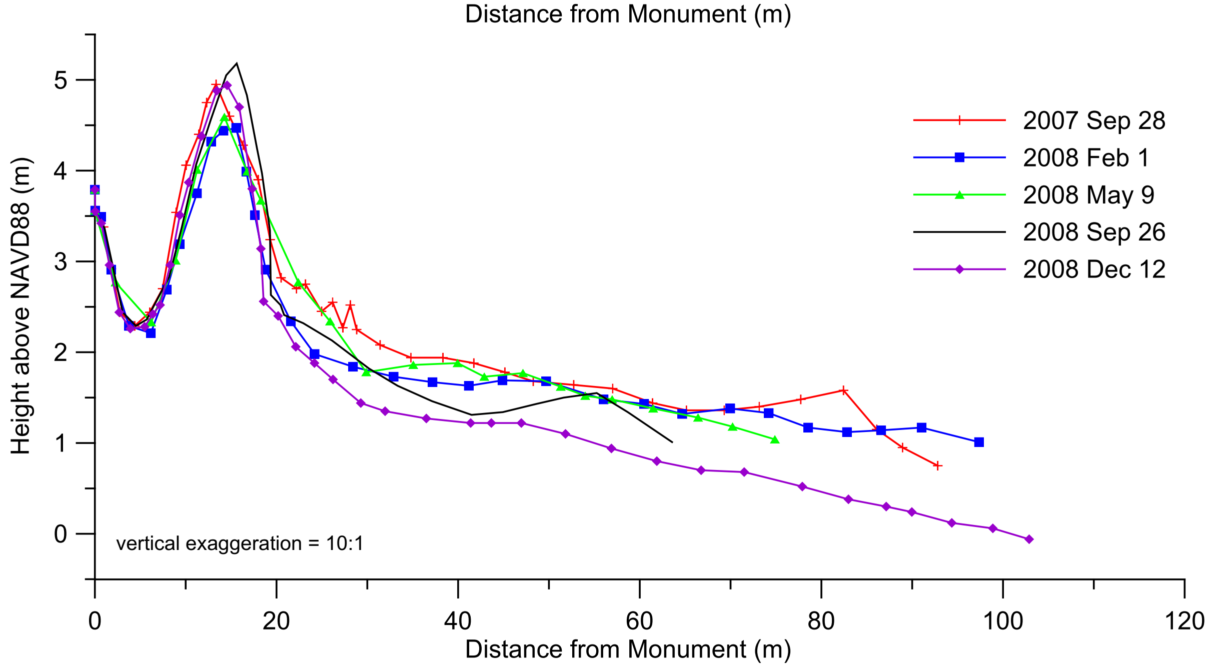


DEL01 (Dellanera RV Park, Galveston Island)
Height above NAVD88 (m)
Distance from Monument (m)
0
1
2
3
4
0
10
20
30
40
50
60
2016 Feb 4
2016 May 12
2016 Oct 6
2017 Feb 2
2017 May 11
vertical exaggeration = 10:1

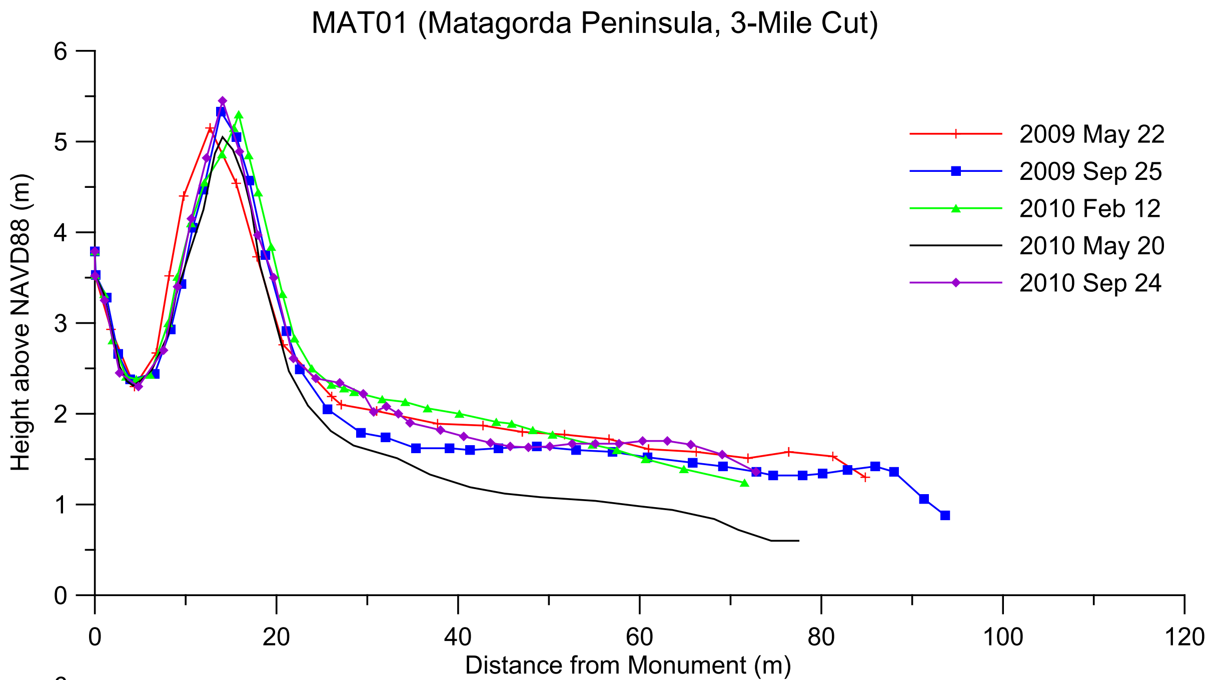
MAT01

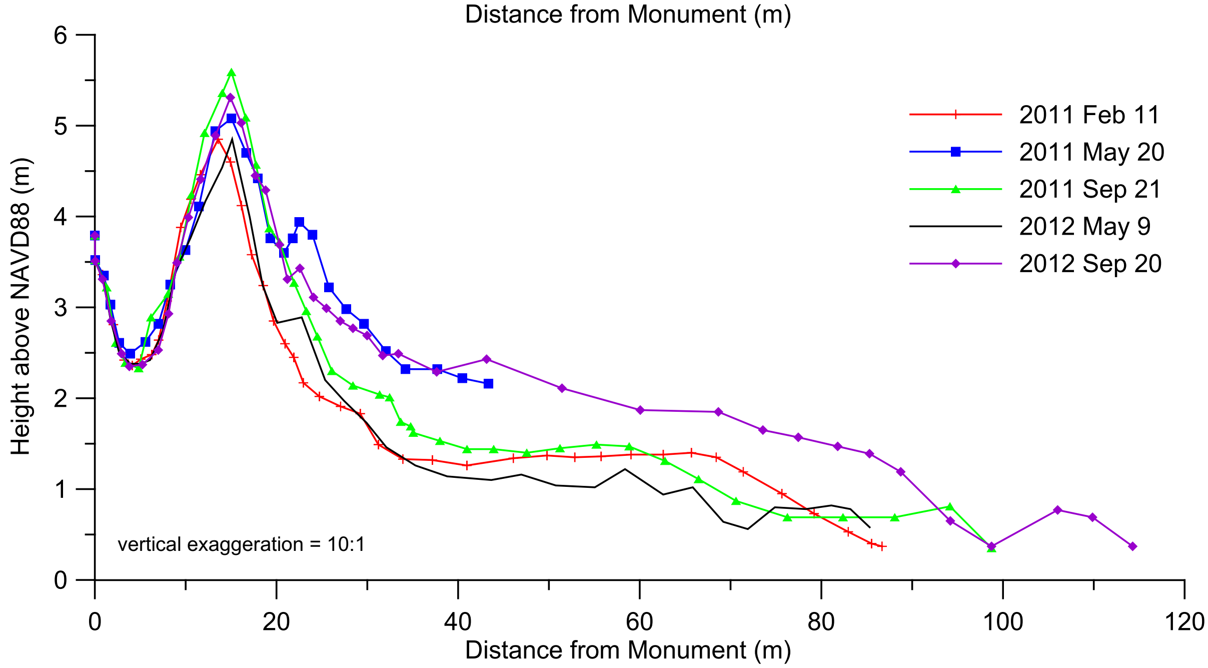


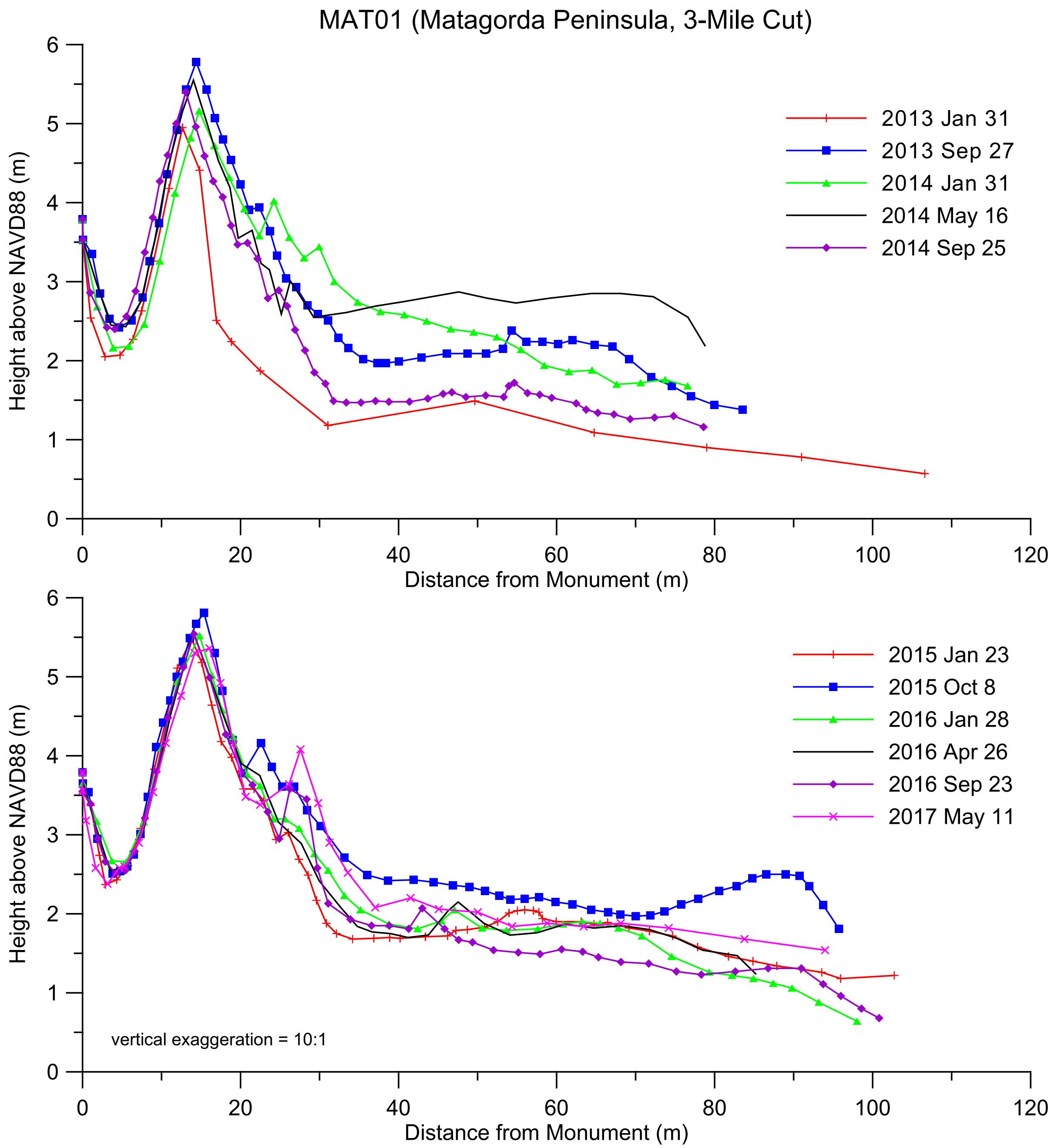
MAT01 (Matagorda Peninsula, 3-Mile Cut)
Height above NAVD88 (m)
Distance from Monument (m)
2005 Mar 8
2005 Apr 29
2005 Nov 18
2006 May 5
2006 Sep 22
5
4
3
2
1
0
0
20
40
60
80
100
120



Height above NAVD88 (m)
Distance from Monument (m)
2007 Sep 28
2008 Feb 1
2008 May 9
2008 Sep 26
2008 Dec 12
vertical exaggeration = 10:1
5
4
3
2
1
0
0
20
40
60
80
100
120

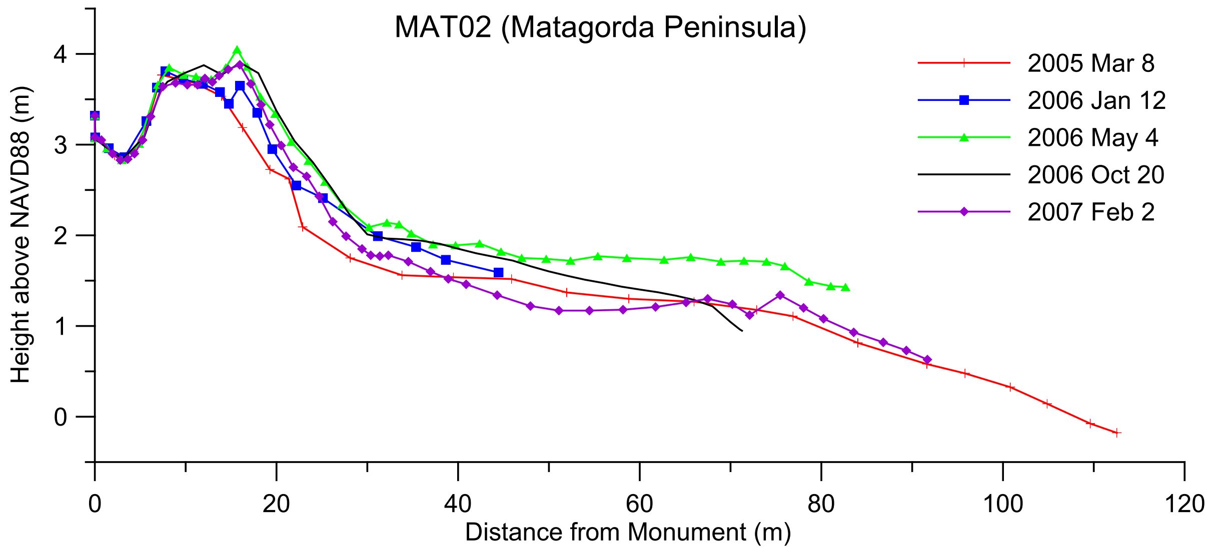

MAT01 (Matagorda Peninsula, 3-Mile Cut)
Height above NAVD88 (m)
Distance from Monument (m)
2009 May 22
2009 Sep 25
2010 Feb 12
2010 May 20
2010 Sep 24


Height above NAVD88 (m)
Distance from Monument (m)
2011 Feb 11
2011 May 20
2011 Sep 21
2012 May 9
2012 Sep 20
vertical exaggeration = 10:1

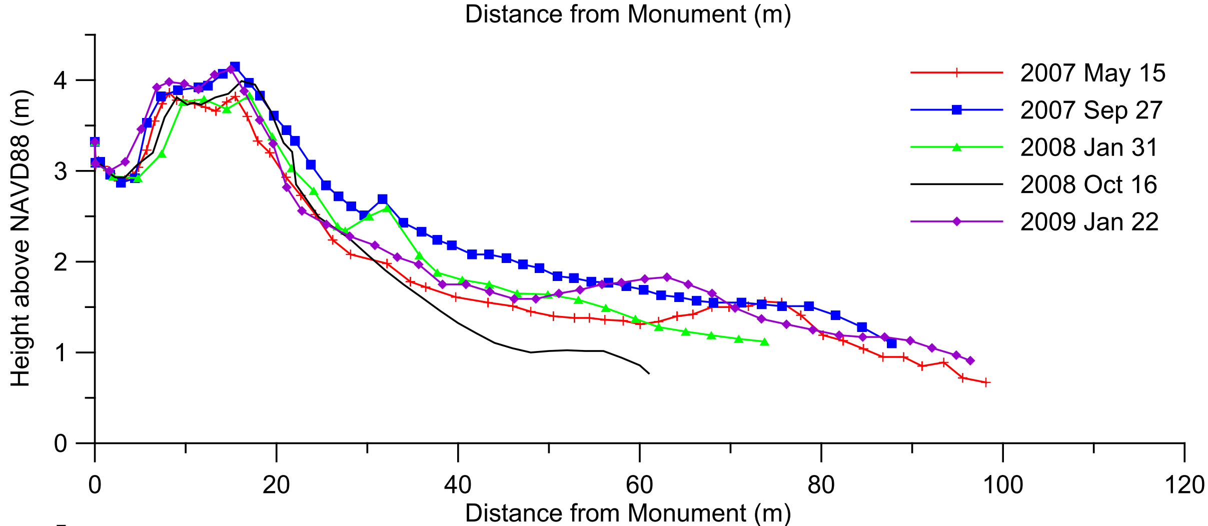


MAT01 (Matagorda Peninsula, 3-Mile Cut)
Height above NAVD88 (m)
Distance from Monument (m)
2013 Jan 31
2013 Sep 27
2014 Jan 31
2014 May 16
2014 Sep 25
2015 Jan 23
2015 Oct 8
2016 Jan 28
2016 Apr 26
2016 Sep 23
2017 May 11
vertical exaggeration = 10:1

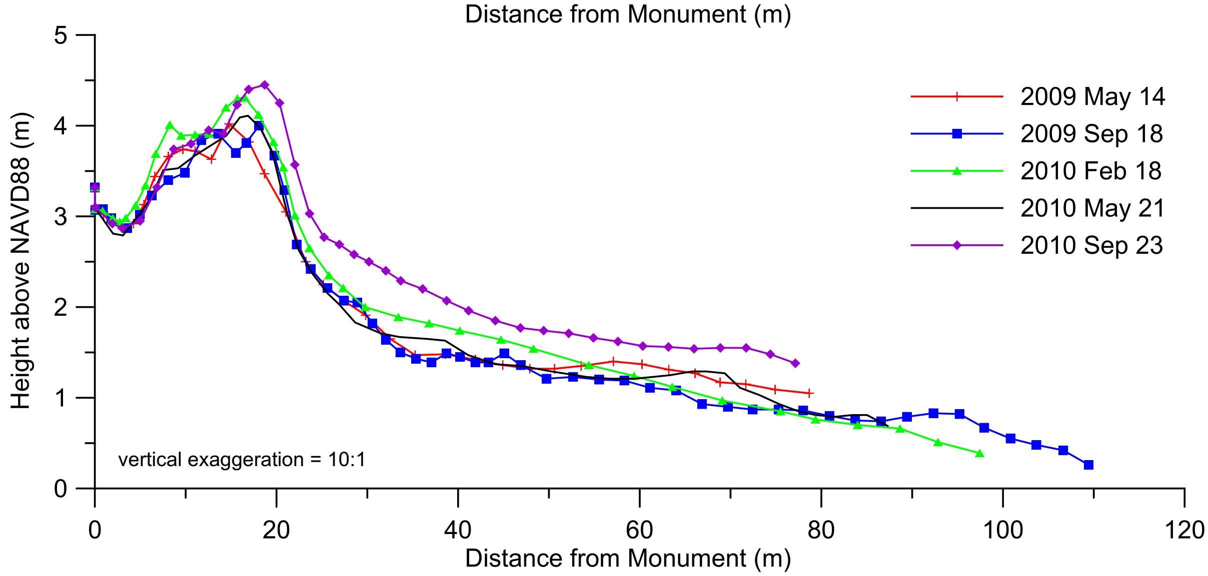
MAT02



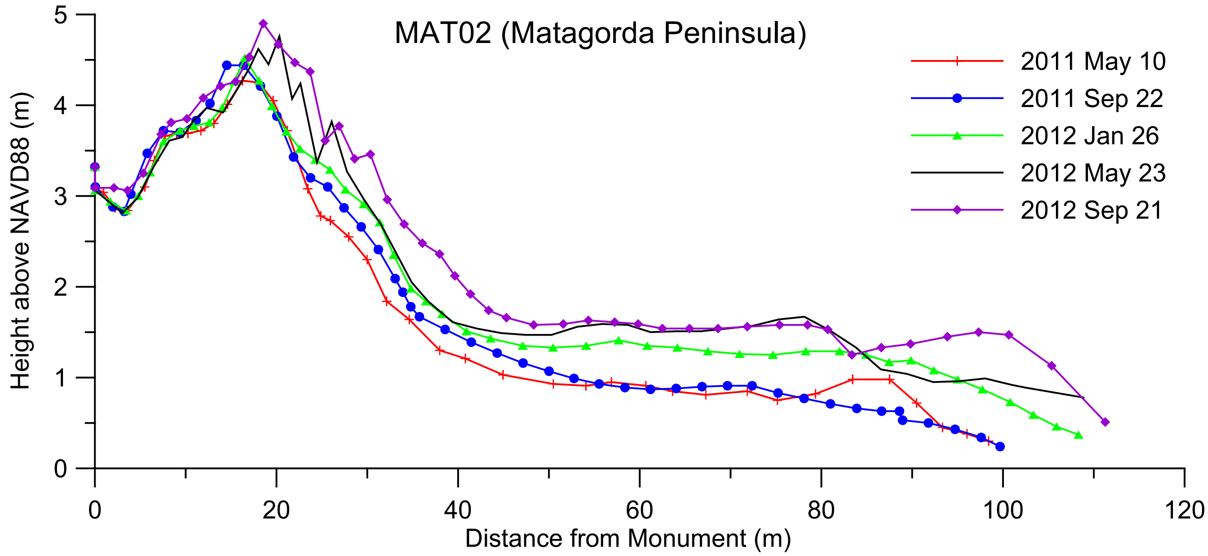
MAT02 (Matagorda Peninsula)
2005 Mar 8
2006 Jan 12
2006 May 4
2006 Oct 20
2007 Feb 2
Height above NAVD88 (m)
Distance from Monument (m)

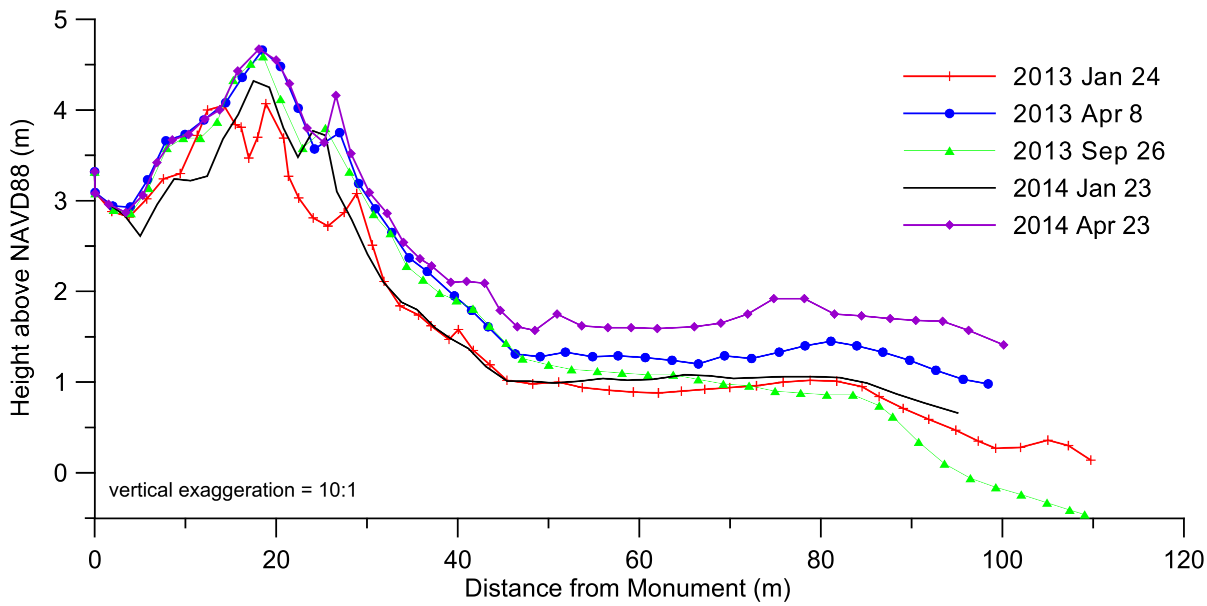


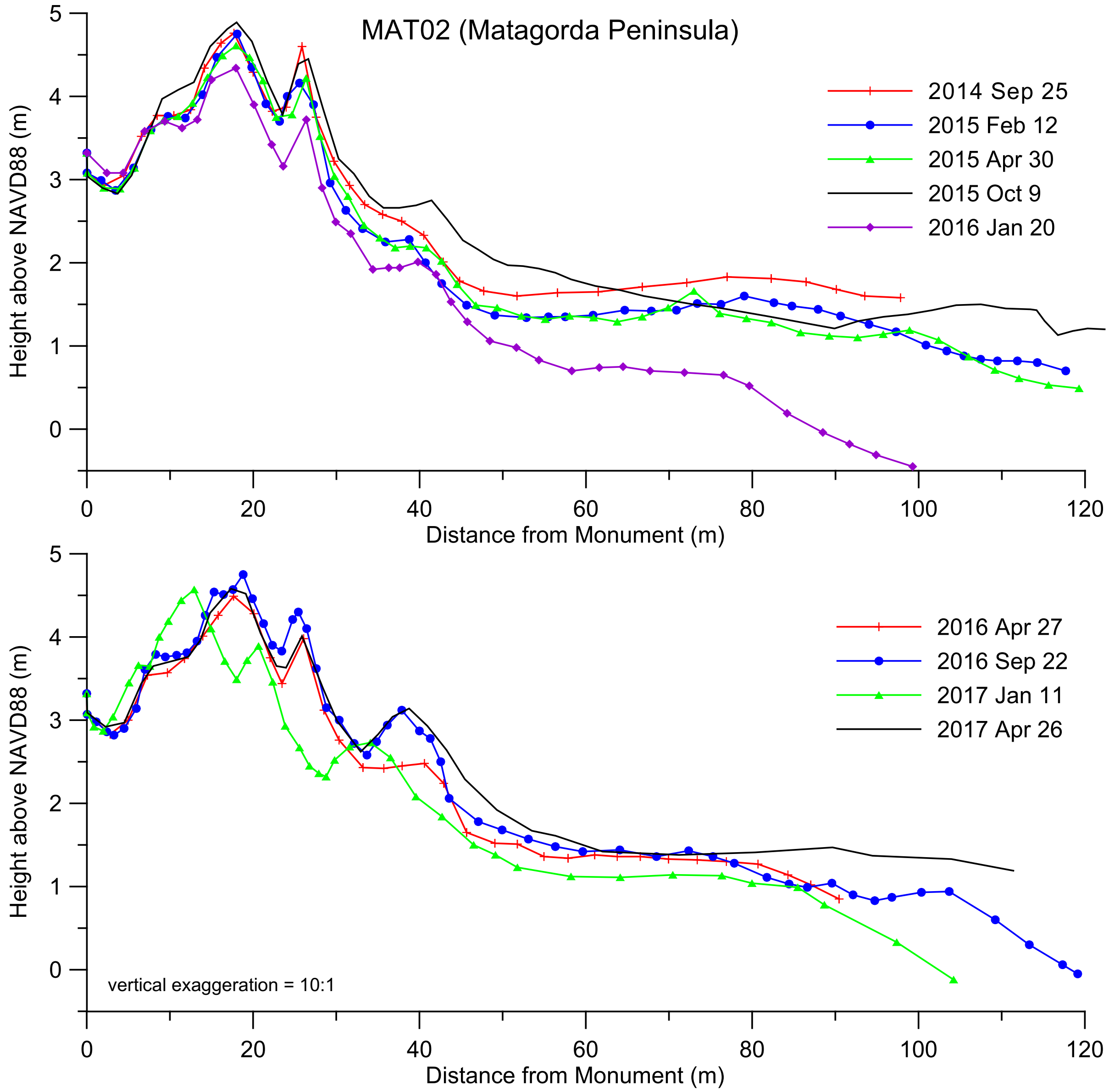
2007 May 15
2007 Sep 27
2008 Jan 31
2008 Oct 16
2009 Jan 22
Height above NAVD88 (m)
Distance from Monument (m)



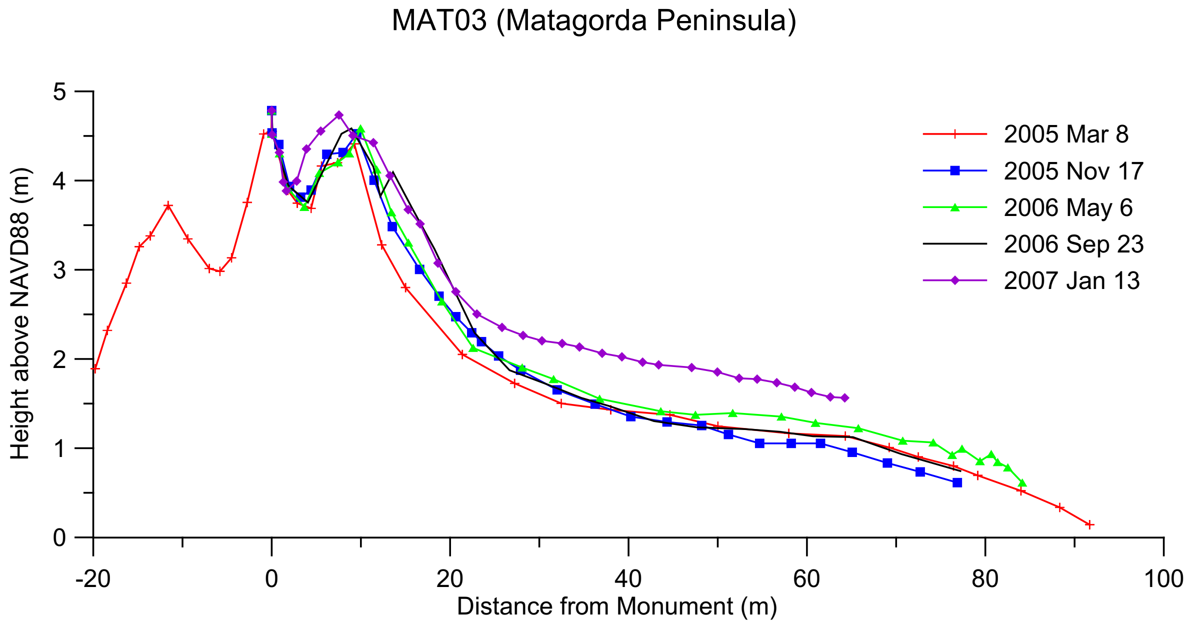
2009 May 14
2009 Sep 18
2010 Feb 18
2010 May 21
2010 Sep 23
vertical exaggeration = 10:1
Height above NAVD88 (m)
Distance from Monument (m)

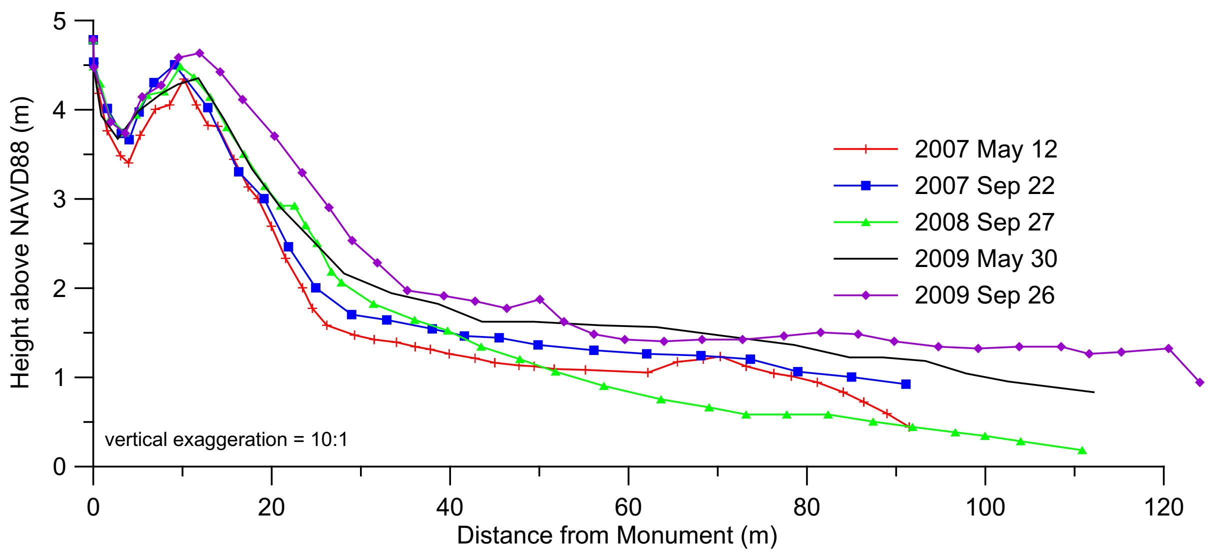

MAT02 (Matagorda Peninsula)
2011 May 10
2011 Sep 22
2012 Jan 26
2012 May 23
2012 Sep 21
Height above NAVD88 (m)
Distance from Monument (m)
0
1
2
3
4
5
0
20
40
60
80
100
120


2013 Jan 24
2013 Apr 8
2013 Sep 26
2014 Jan 23
2014 Apr 23
vertical exaggeration = 10:1
Height above NAVD88 (m)
Distance from Monument (m)
0
1
2
3
4
5
0
20
40
60
80
100
120

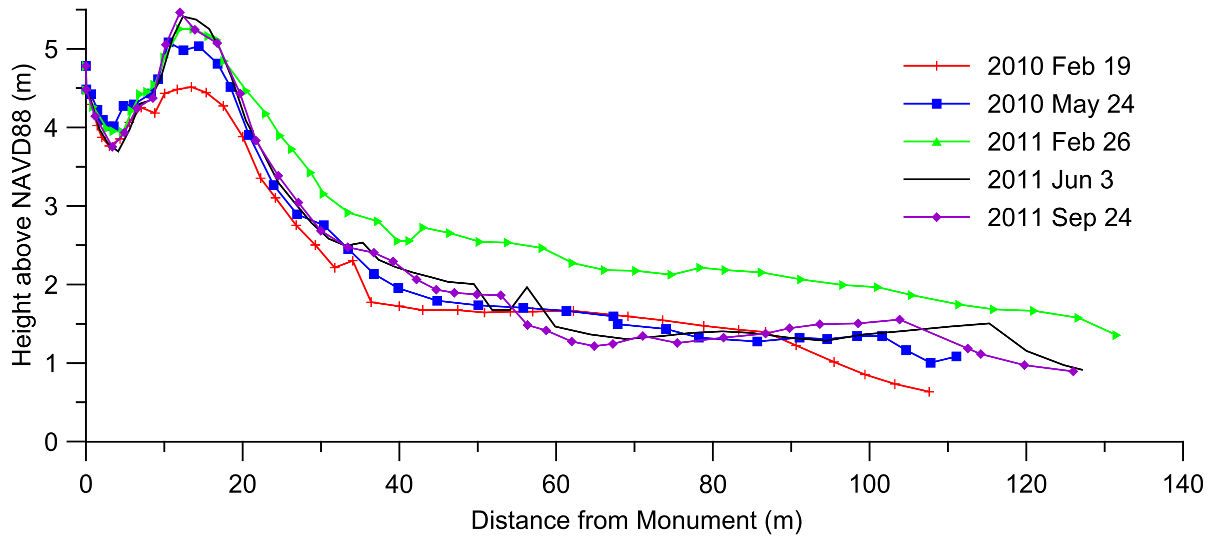

MAT02 (Matagorda Peninsula)
2014 Sep 25
2015 Feb 12
2015 Apr 30
2015 Oct 9
2016 Jan 20
Height above NAVD88 (m)
Distance from Monument (m)
2016 Apr 27
2016 Sep 22
2017 Jan 11
2017 Apr 26
Height above NAVD88 (m)
vertical exaggeration = 10:1
Distance from Monument (m)

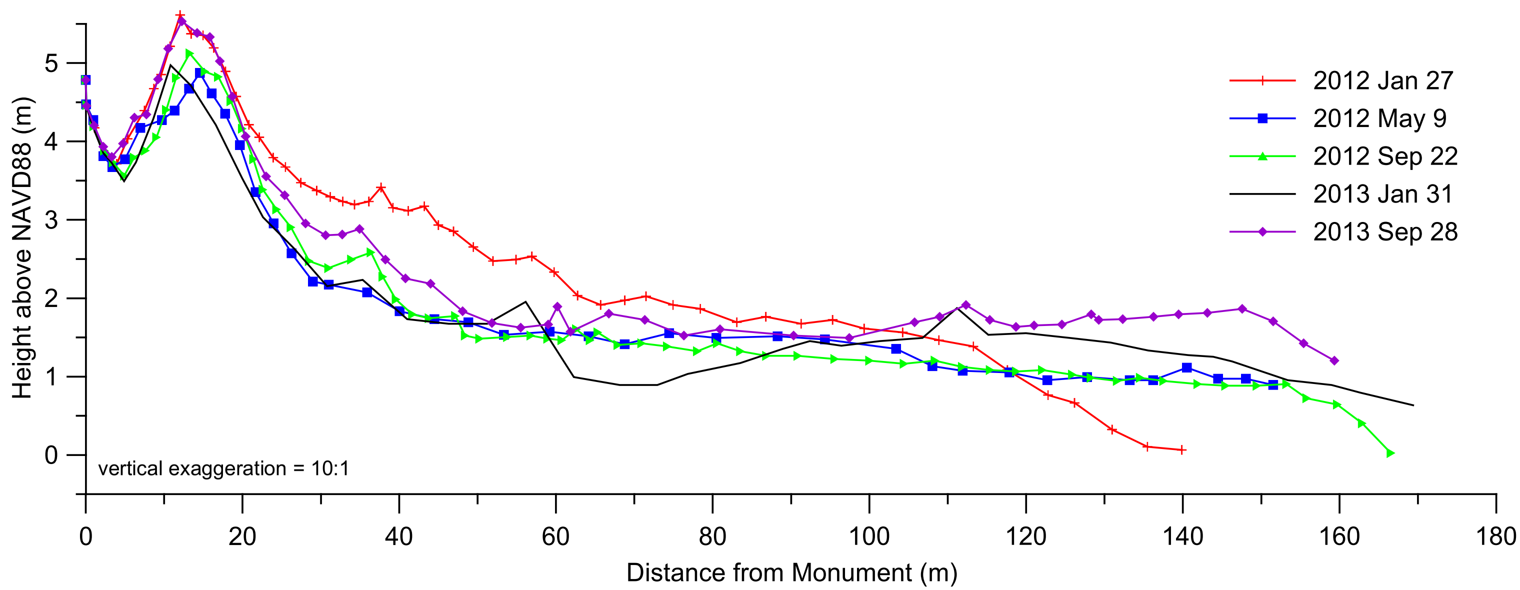
MAT03


MAT03 (Matagorda Peninsula)
Height above NAVD88 (m)
Distance from Monument (m)
5
4
3
2
1
0
-20
0
20
40
60
80
100
2005 Mar 8
2005 Nov 17
2006 May 6
2006 Sep 23
2007 Jan 13

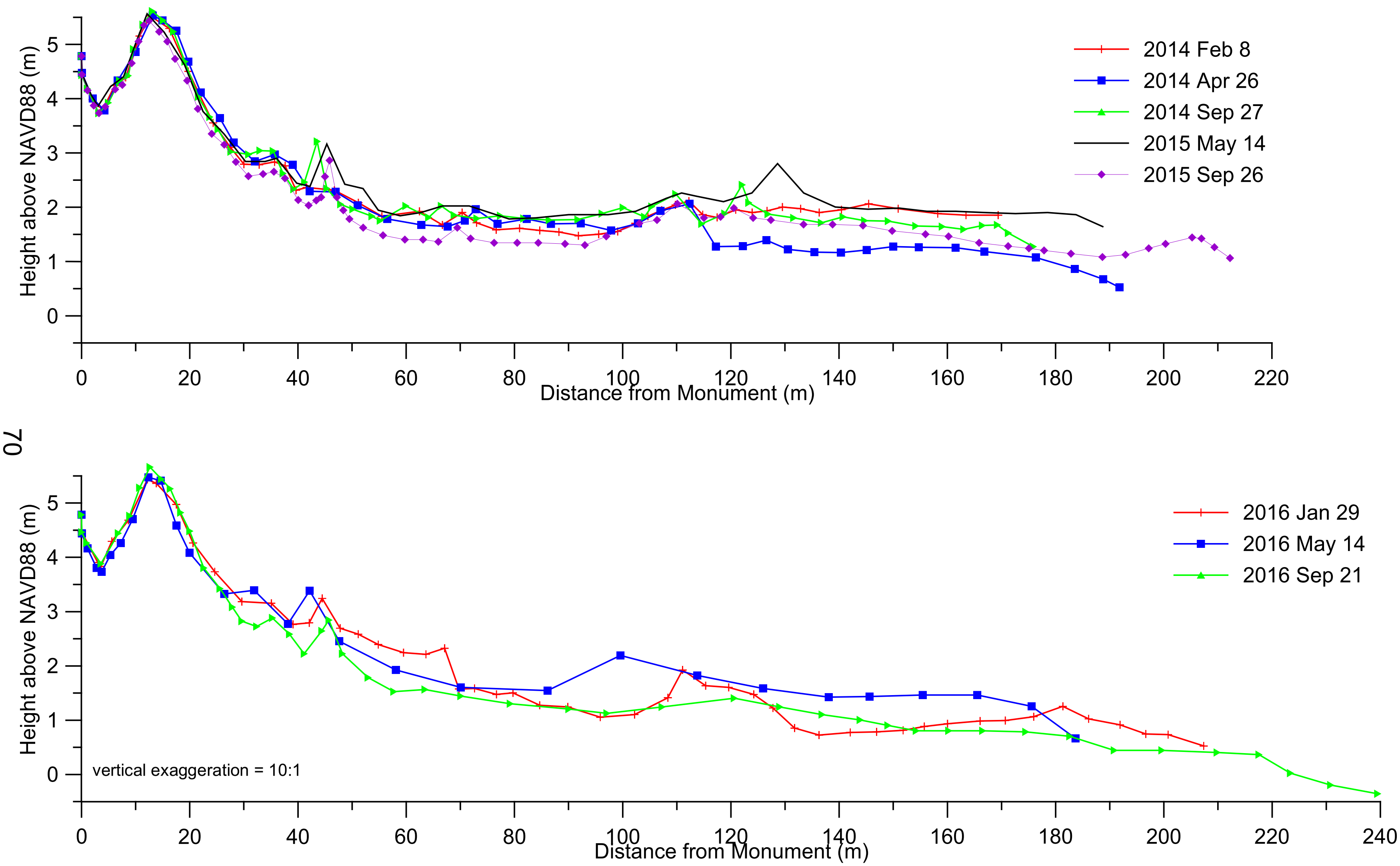

Height above NAVD88 (m)
Distance from Monument (m)
5
4
3
2
1
0
0
20
40
60
80
100
120
2007 May 12
2007 Sep 22
2008 Sep 27
2009 May 30
2009 Sep 26
vertical exaggeration = 10:1

MAT03 (Matagorda Peninsula)

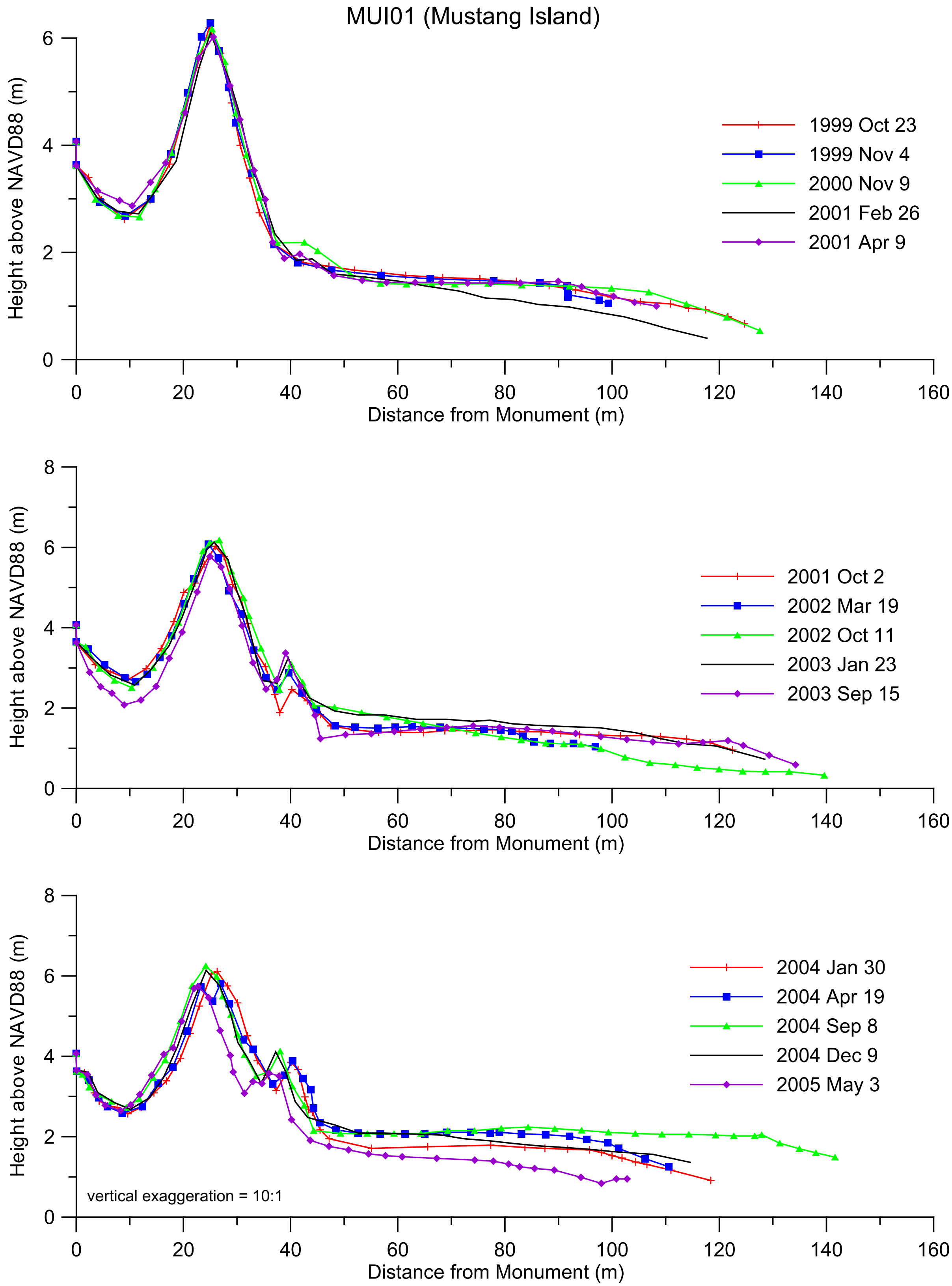


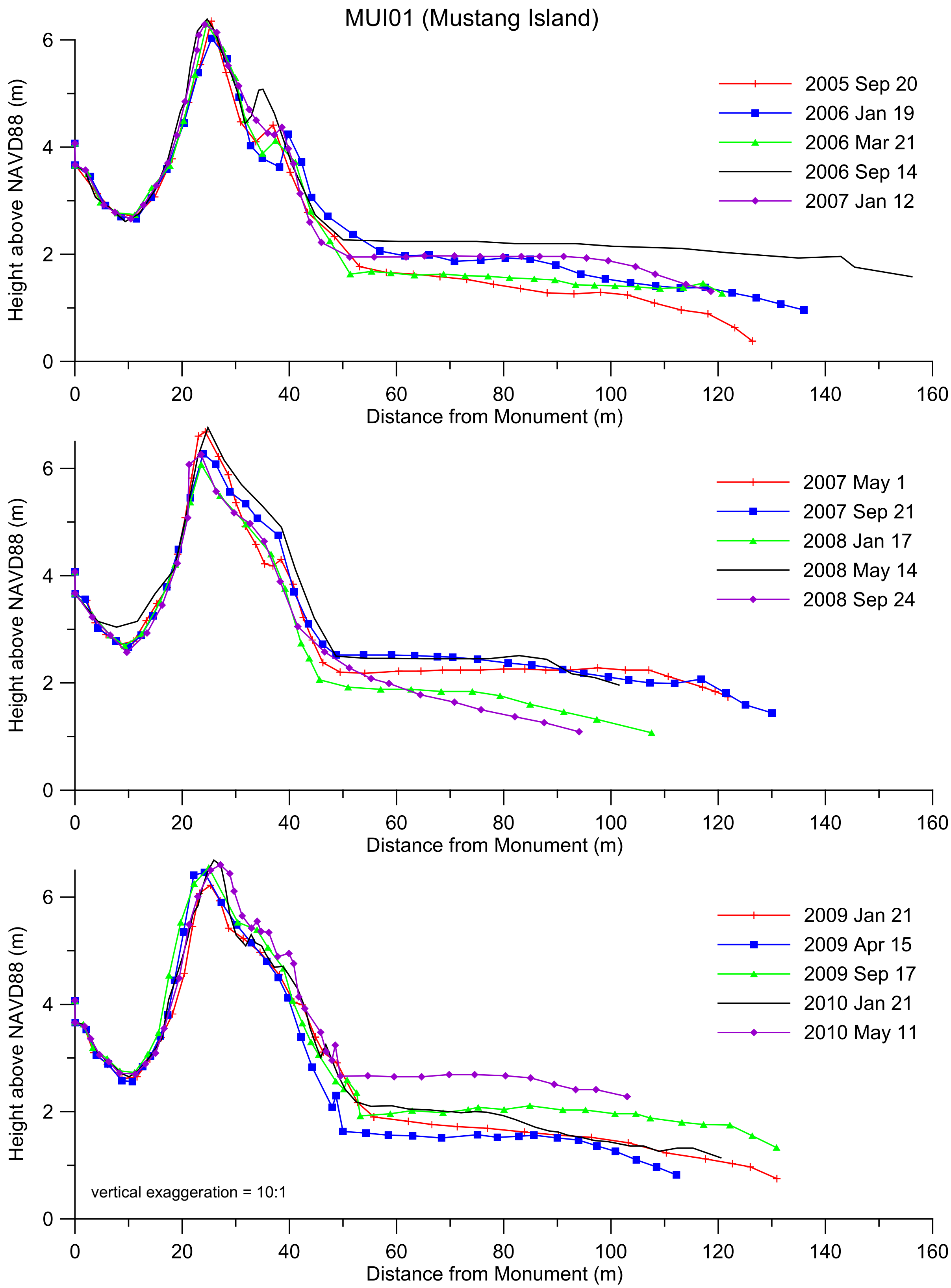


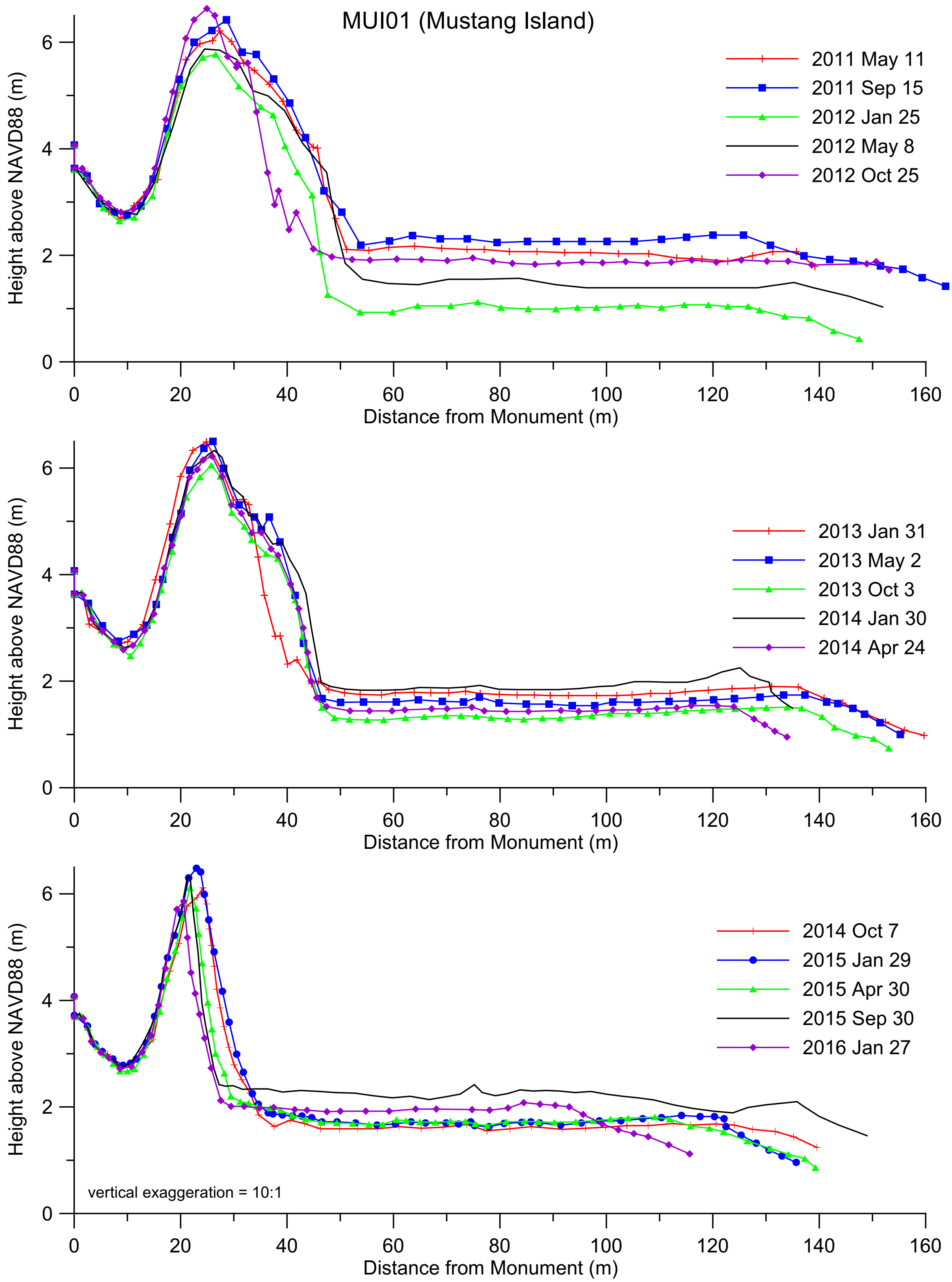
MAT03 (Matagorda Peninsula)

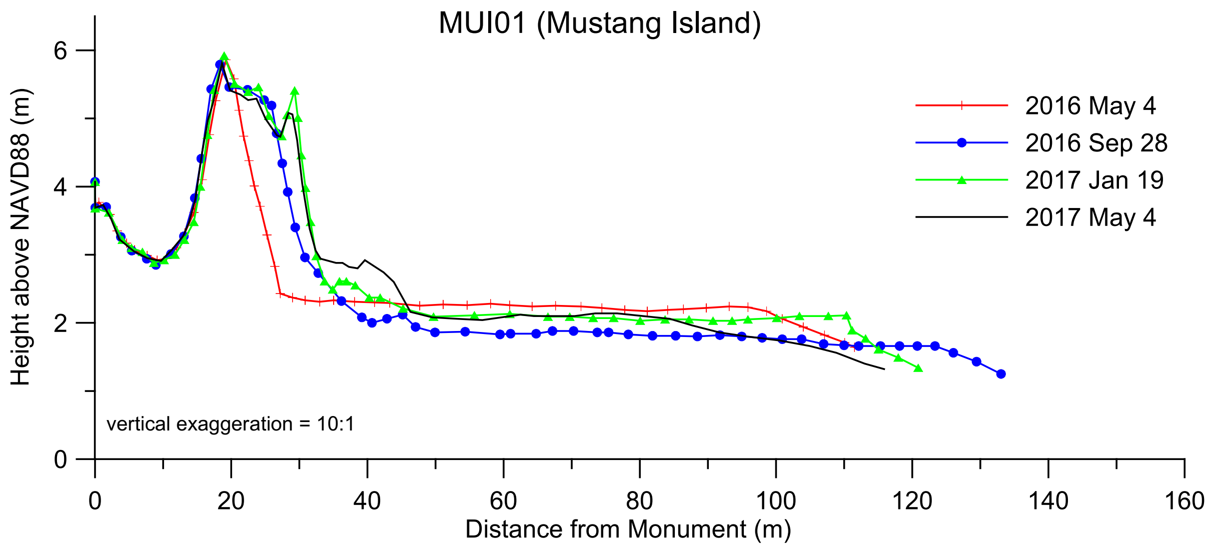


MUI01


MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
1999 Oct 23
1999 Nov 4
2000 Nov 9
2001 Feb 26
2001 Apr 9
2001 Oct 2
2002 Mar 19
2002 Oct 11
2003 Jan 23
2003 Sep 15
2004 Jan 30
2004 Apr 19
2004 Sep 8
2004 Dec 9
2005 May 3
vertical exaggeration = 10:1

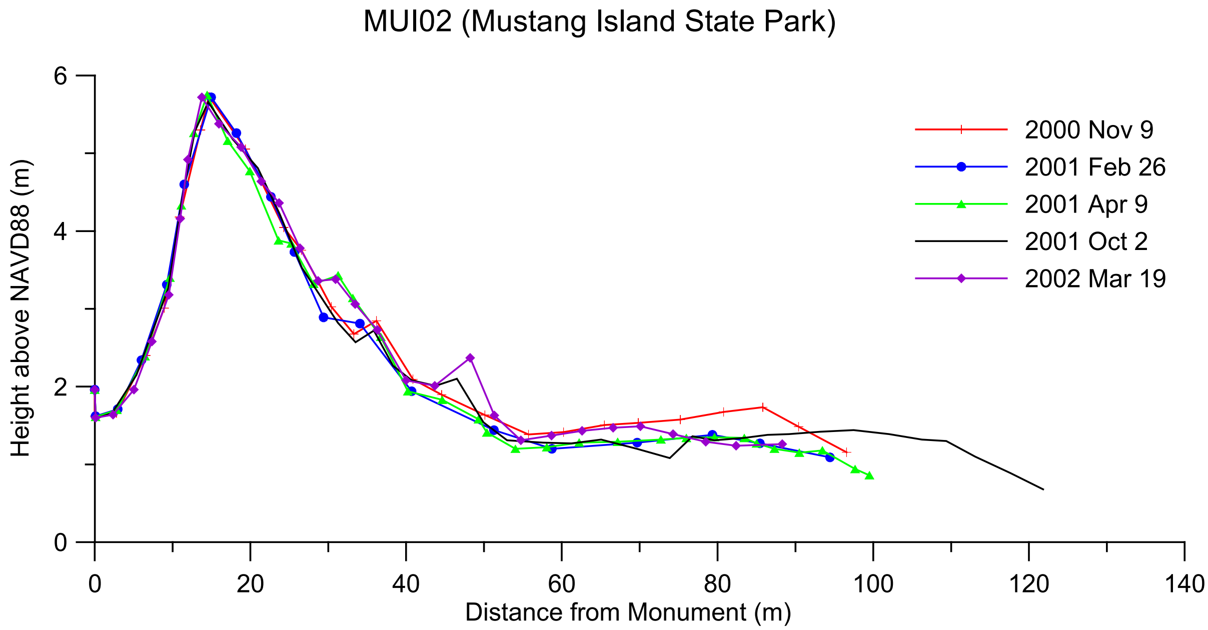

MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2005 Sep 20
2006 Jan 19
2006 Mar 21
2006 Sep 14
2007 Jan 12
2007 May 1
2007 Sep 21
2008 Jan 17
2008 May 14
2008 Sep 24
2009 Jan 21
2009 Apr 15
2009 Sep 17
2010 Jan 21
2010 May 11
vertical exaggeration = 10:1
0
2
4
6
0
20
40
60
80
100
120
140
160

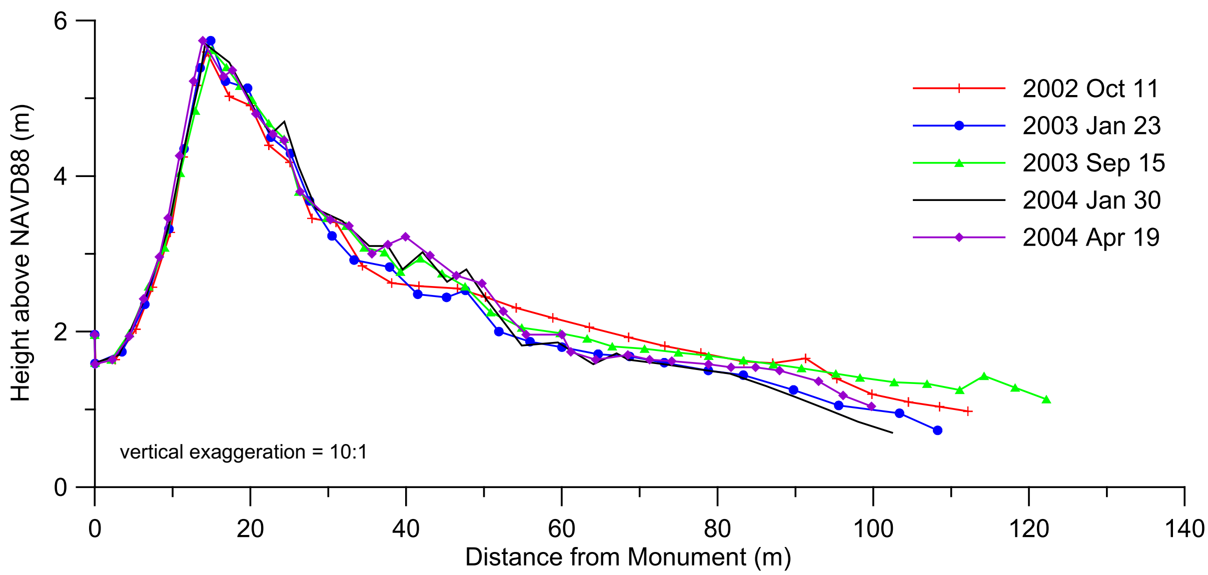

MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2011 May 11
2011 Sep 15
2012 Jan 25
2012 May 8
2012 Oct 25
2013 Jan 31
2013 May 2
2013 Oct 3
2014 Jan 30
2014 Apr 24
2014 Oct 7
2015 Jan 29
2015 Apr 30
2015 Sep 30
2016 Jan 27
vertical exaggeration = 10:1



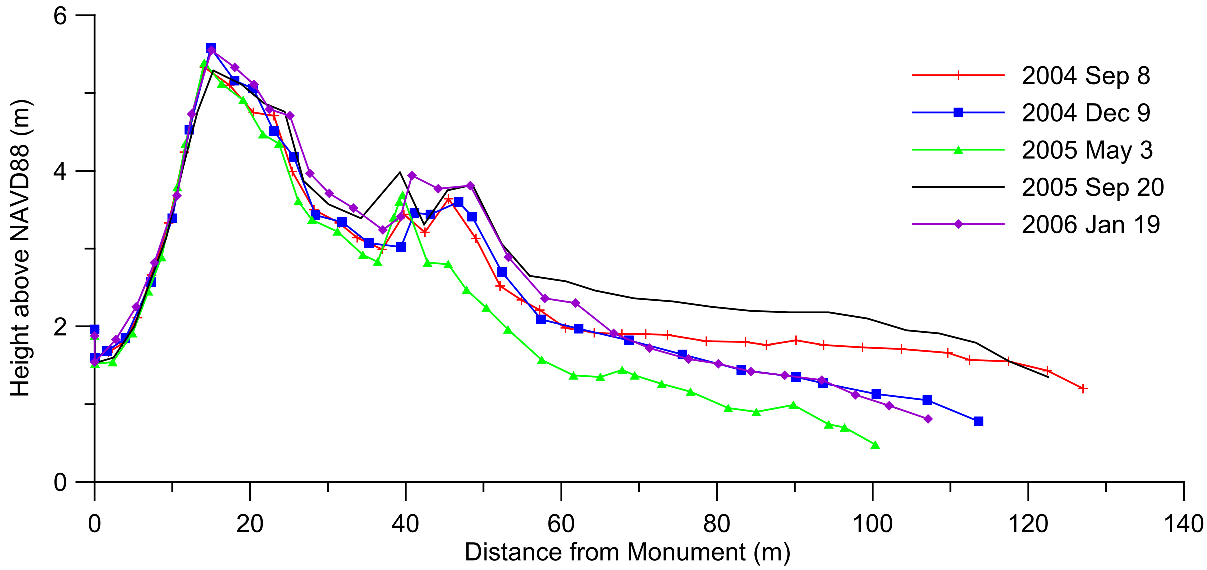
MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2016 May 4
2016 Sep 28
2017 Jan 19
2017 May 4
vertical exaggeration = 10:1
0
2
4
6
0
20
40
60
80
100
120
140
160

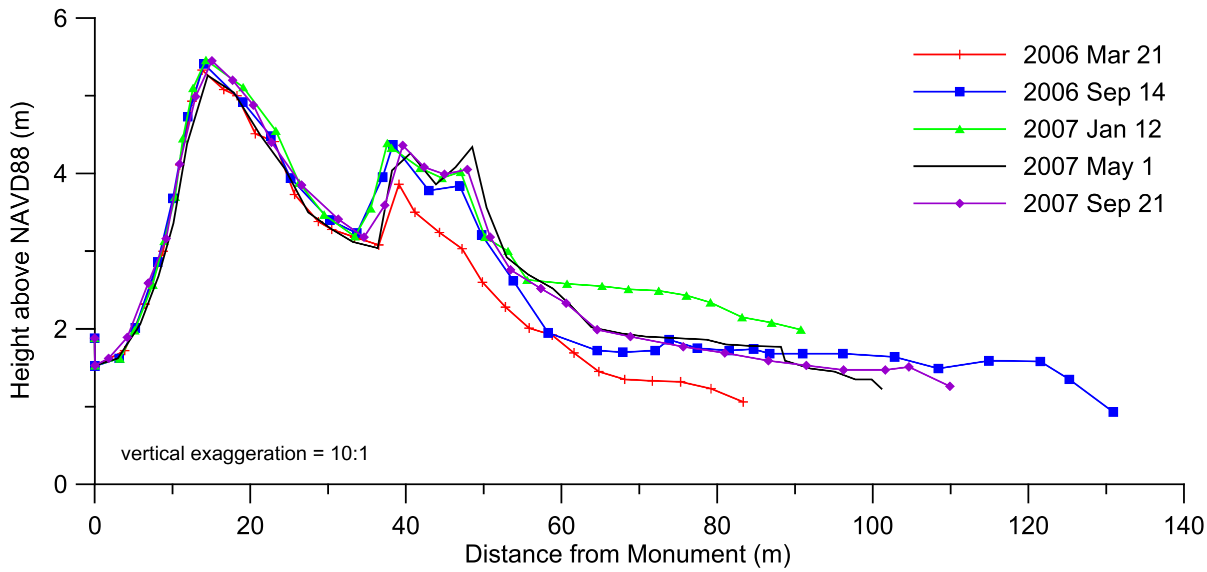
MUI02


MUI02 (Mustang Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2000 Nov 9
2001 Feb 26
2001 Apr 9
2001 Oct 2
2002 Mar 19
0
2
4
6
0
20
40
60
80
100
120
140

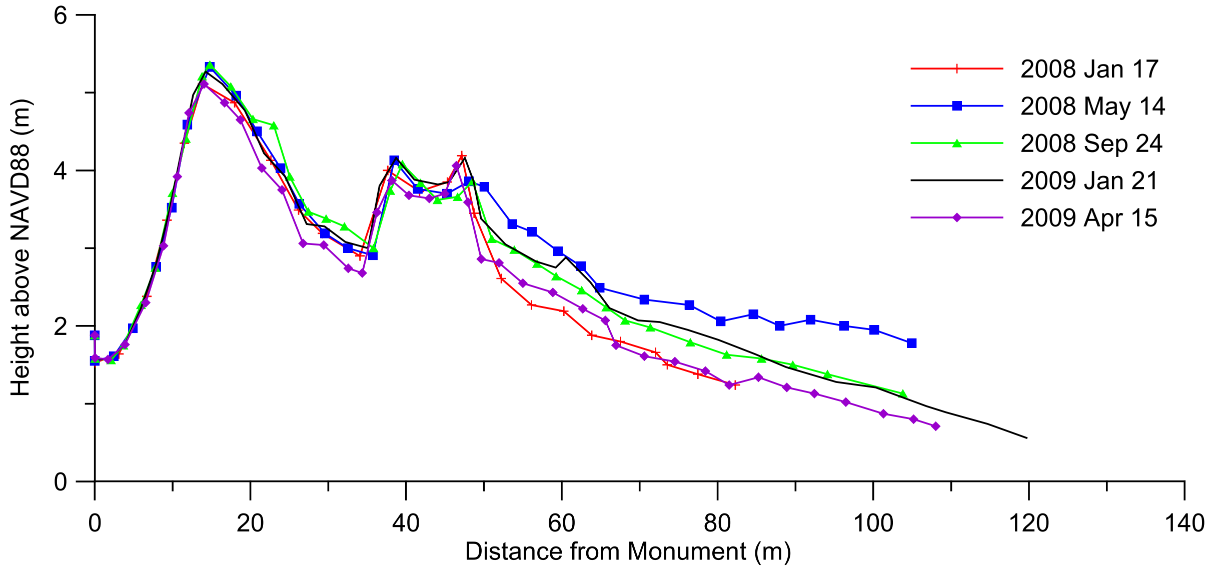

Height above NAVD88 (m)
Distance from Monument (m)
2002 Oct 11
2003 Jan 23
2003 Sep 15
2004 Jan 30
2004 Apr 19
vertical exaggeration = 10:1
0
2
4
6
0
20
40
60
80
100
120
140

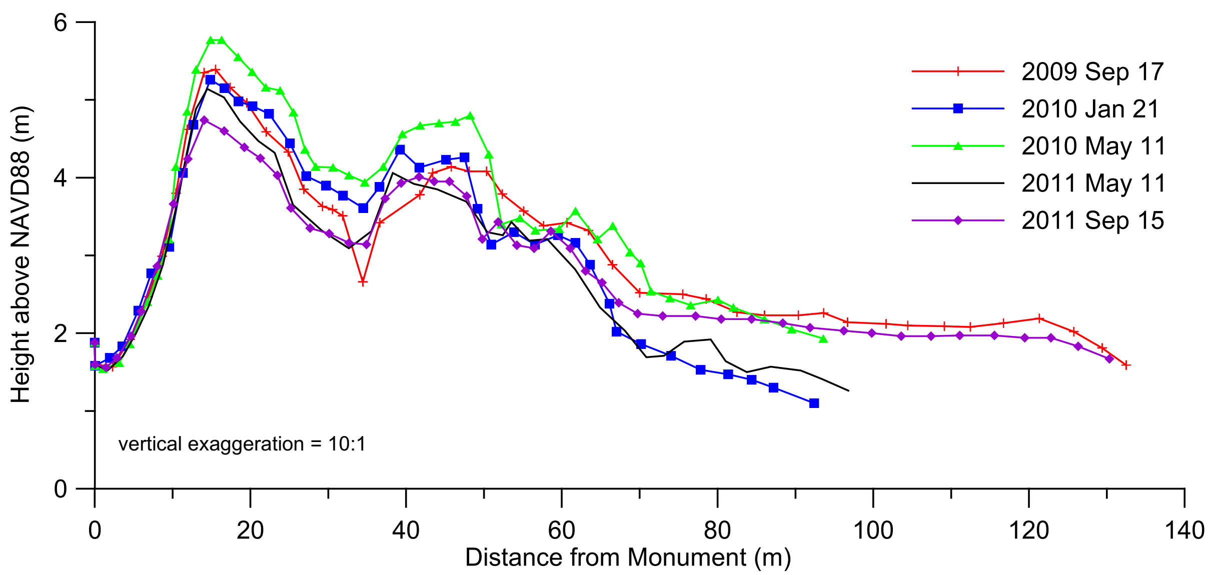
MUI02 (Mustang Island State Park)



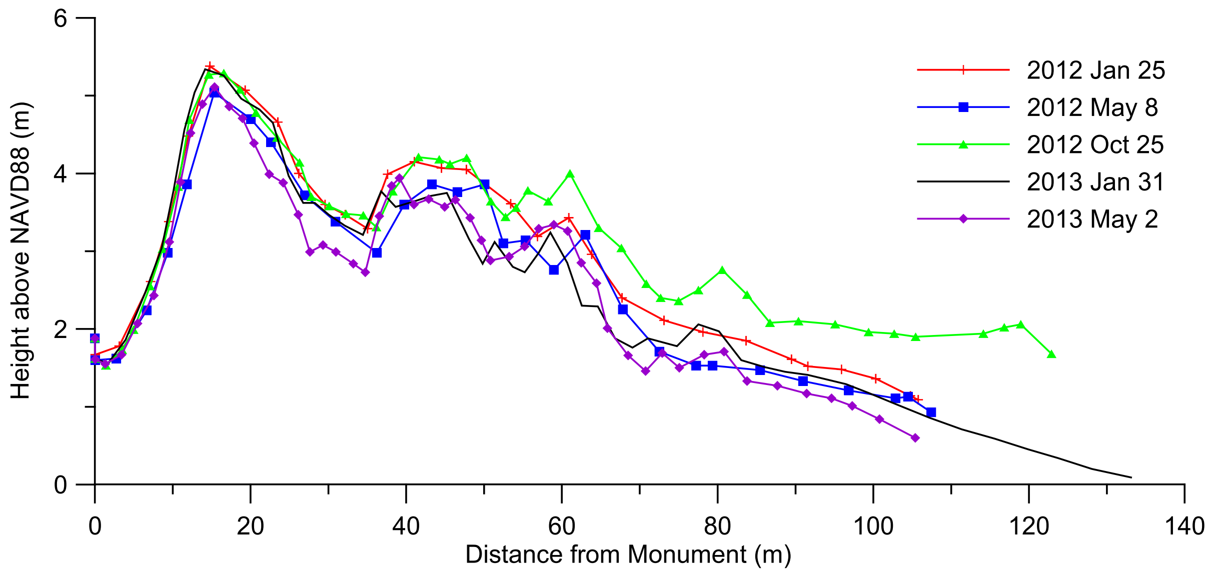


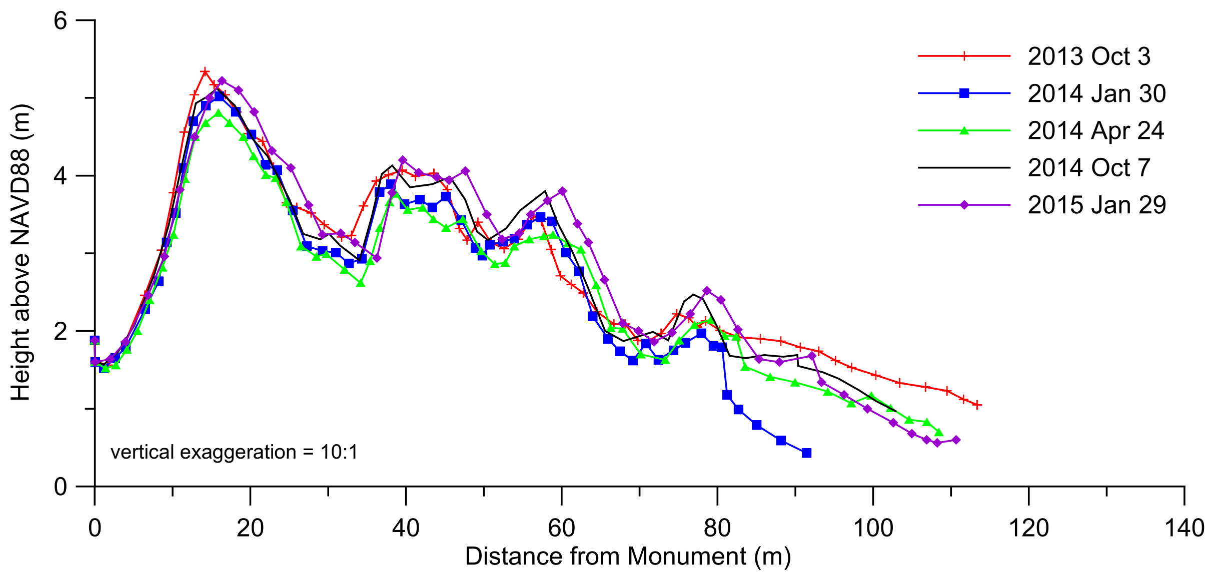
MUI02 (Mustang Island State Park)

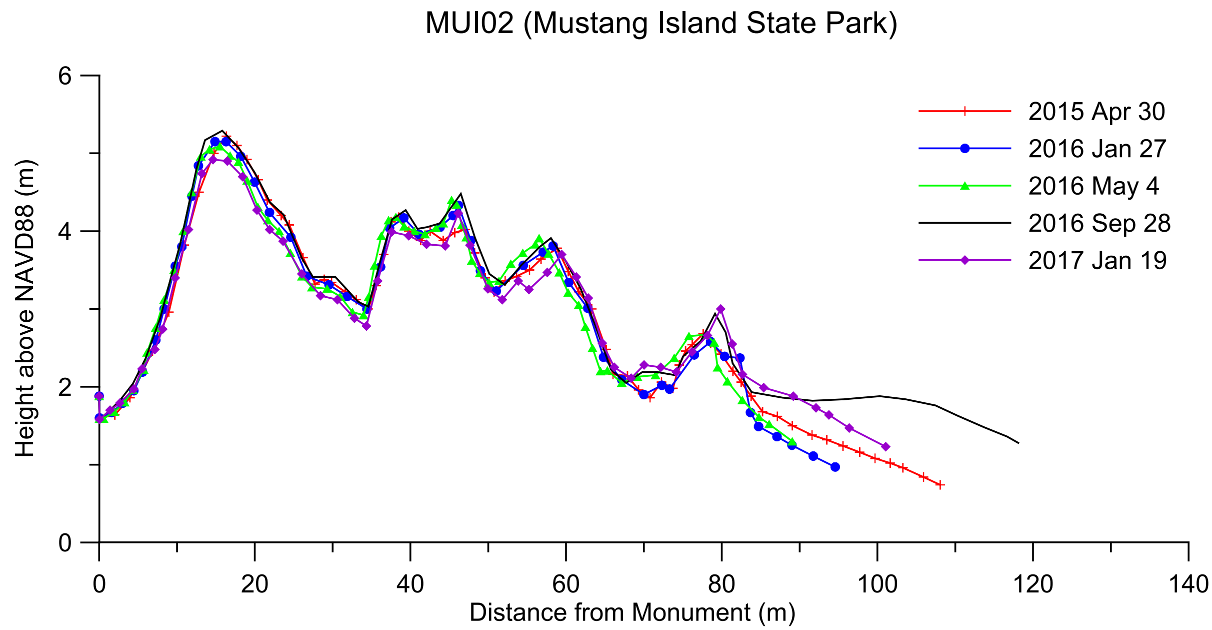


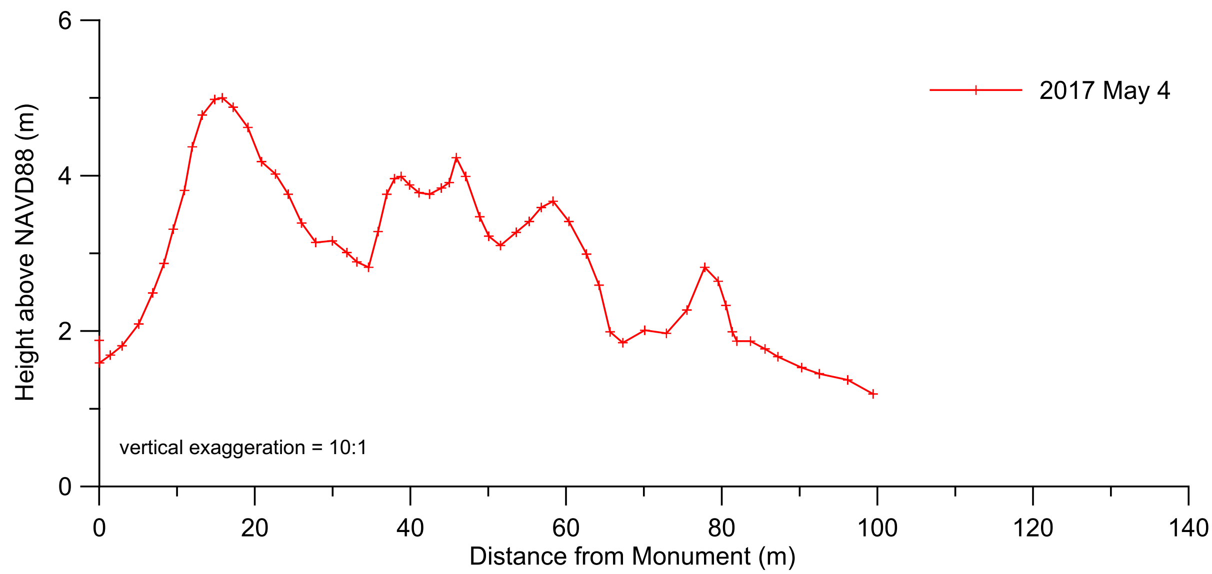


MUI02 (Mustang Island State Park)

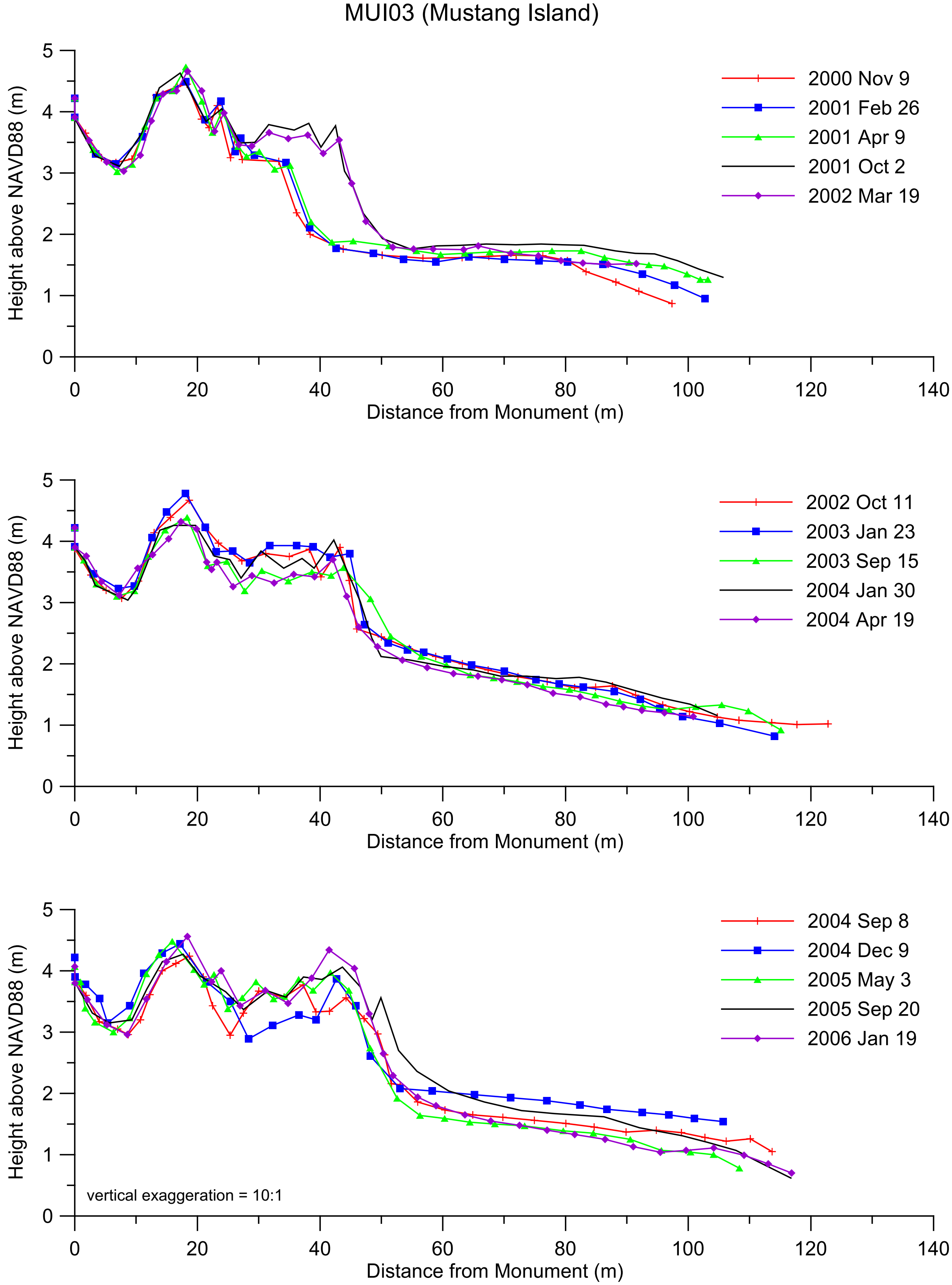




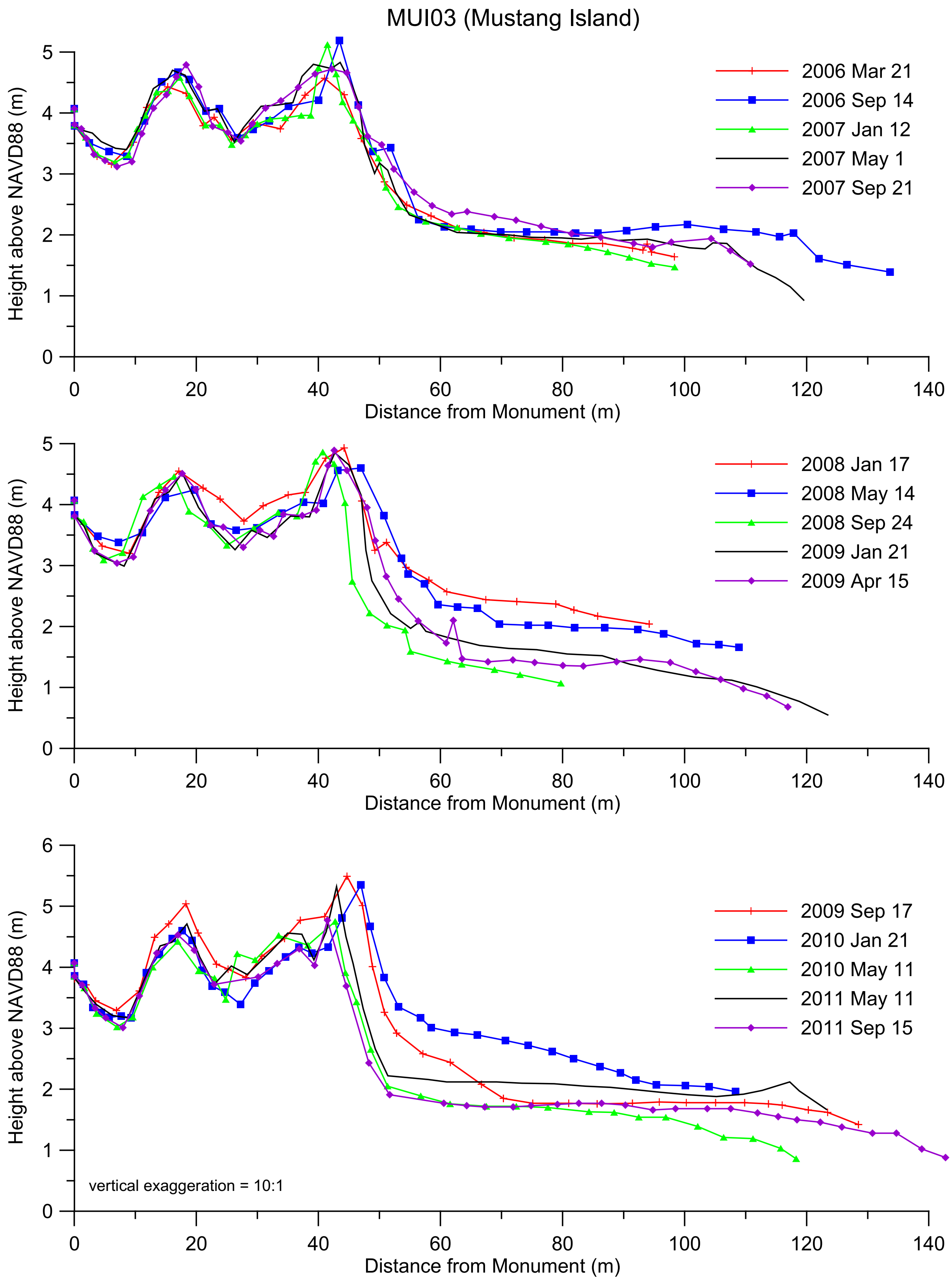

MUI02 (Mustang Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2015 Apr 30
2016 Jan 27
2016 May 4
2016 Sep 28
2017 Jan 19
0
2
4
6
0
20
40
60
80
100
120
140

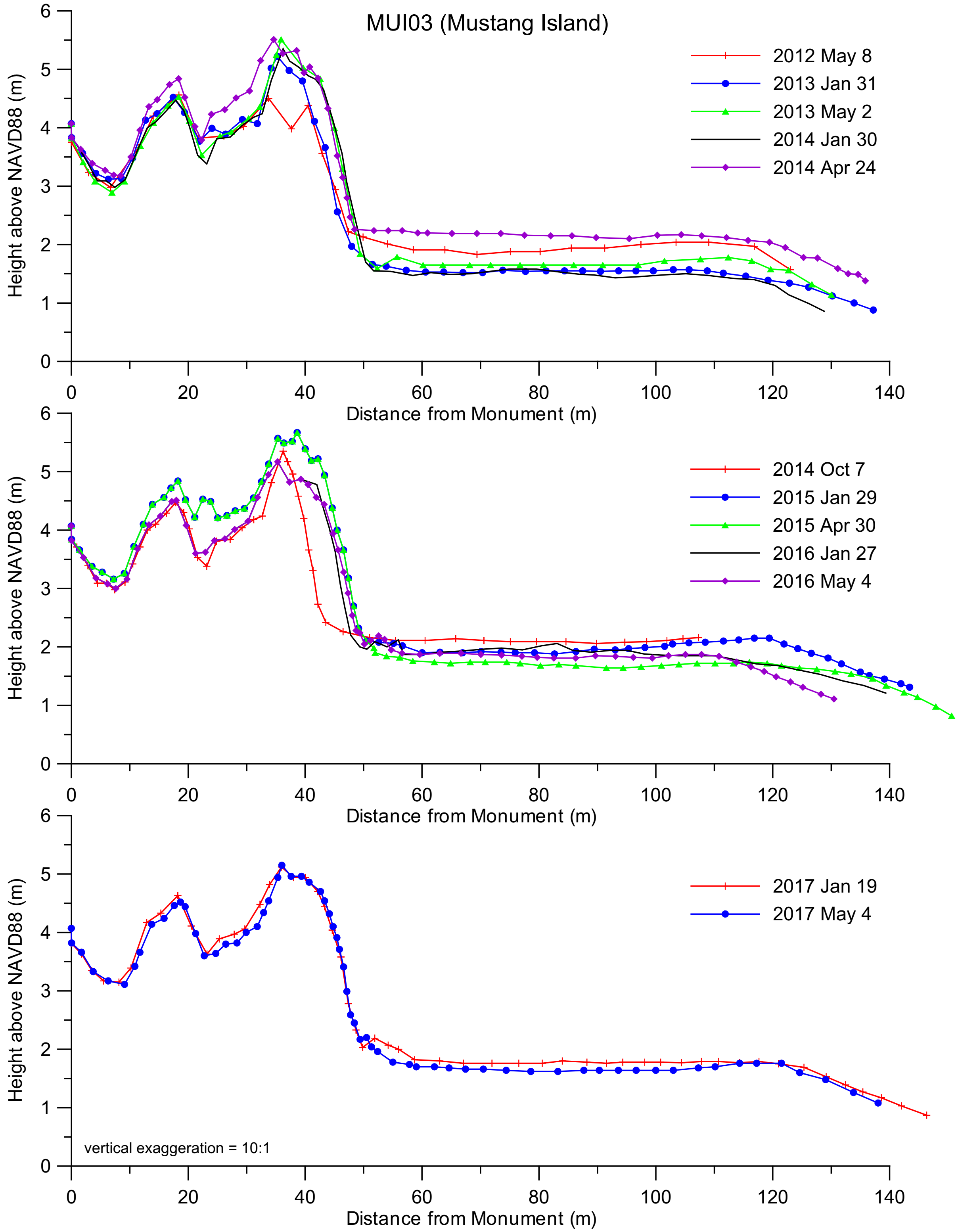

Height above NAVD88 (m)
Distance from Monument (m)
2017 May 4
vertical exaggeration = 10:1
0
2
4
6
0
20
40
60
80
100
120
140

MUI03

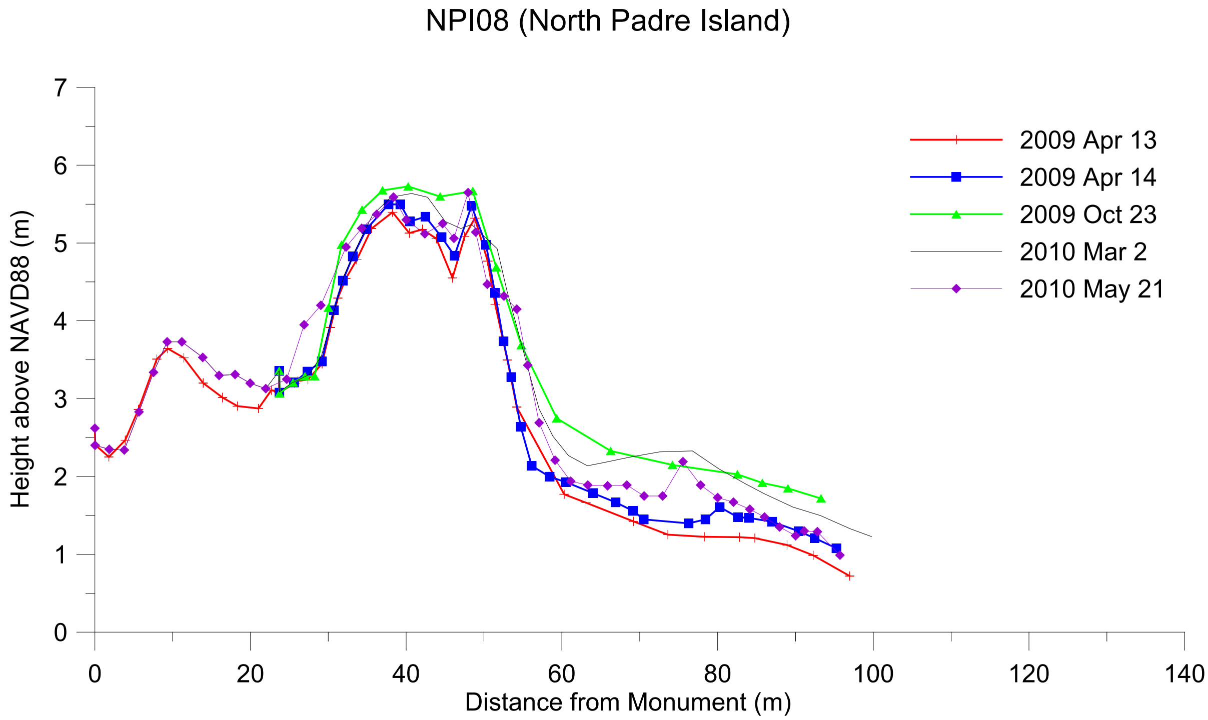


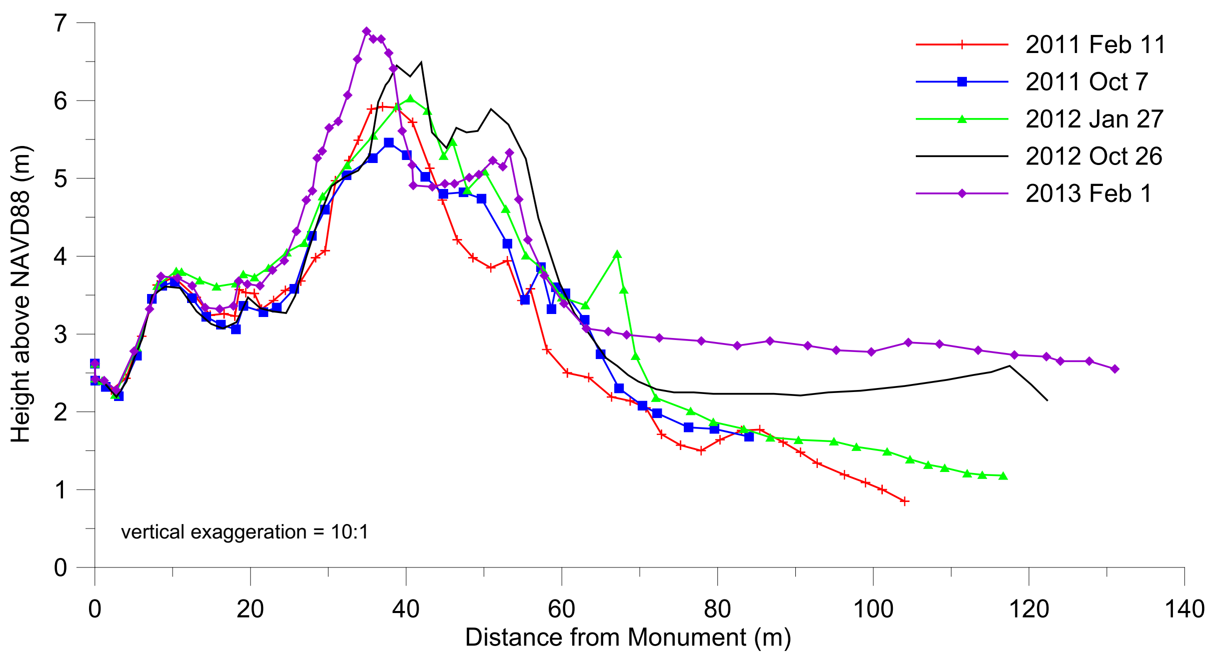
MUI03 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2000 Nov 9
2001 Feb 26
2001 Apr 9
2001 Oct 2
2002 Mar 19
2002 Oct 11
2003 Jan 23
2003 Sep 15
2004 Jan 30
2004 Apr 19
2004 Sep 8
2004 Dec 9
2005 May 3
2005 Sep 20
2006 Jan 19
vertical exaggeration = 10:1


MUI03 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2006 Mar 21
2006 Sep 14
2007 Jan 12
2007 May 1
2007 Sep 21
2008 Jan 17
2008 May 14
2008 Sep 24
2009 Jan 21
2009 Apr 15
2009 Sep 17
2010 Jan 21
2010 May 11
2011 May 11
2011 Sep 15
vertical exaggeration = 10:1

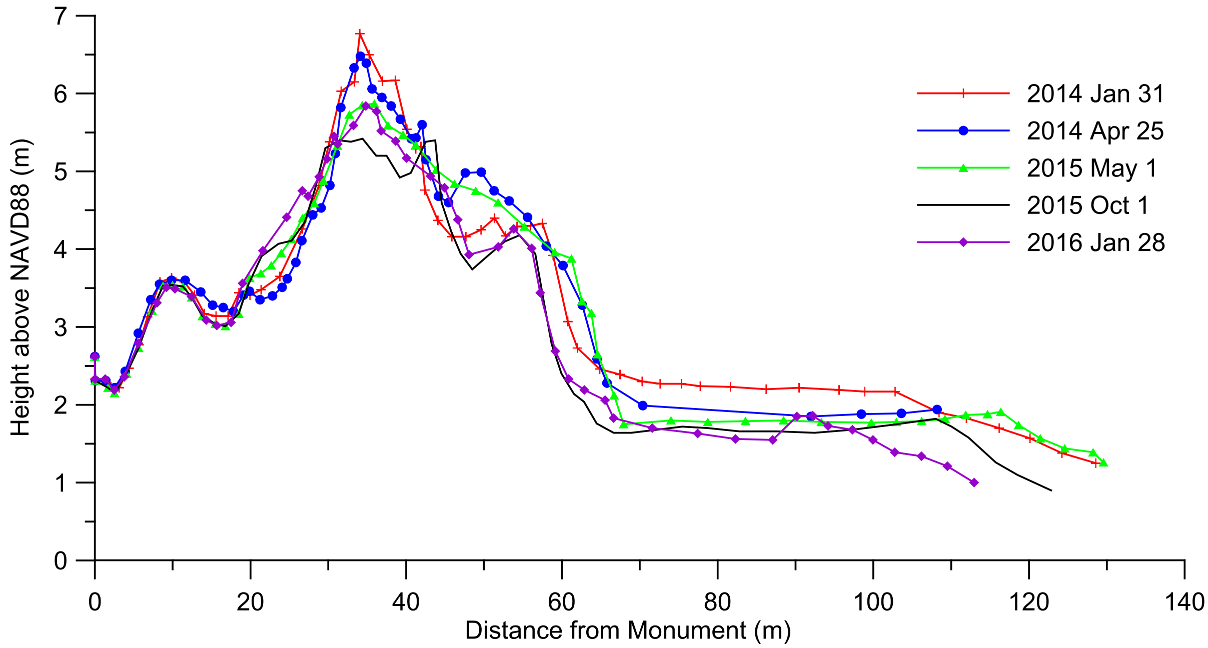

MUI03 (Mustang Island)
2012 May 8
2013 Jan 31
2013 May 2
2014 Jan 30
2014 Apr 24
Height above NAVD88 (m)
Distance from Monument (m)
2014 Oct 7
2015 Jan 29
2015 Apr 30
2016 Jan 27
2016 May 4
Height above NAVD88 (m)
Distance from Monument (m)
2017 Jan 19
2017 May 4
vertical exaggeration = 10:1
Height above NAVD88 (m)
Distance from Monument (m)

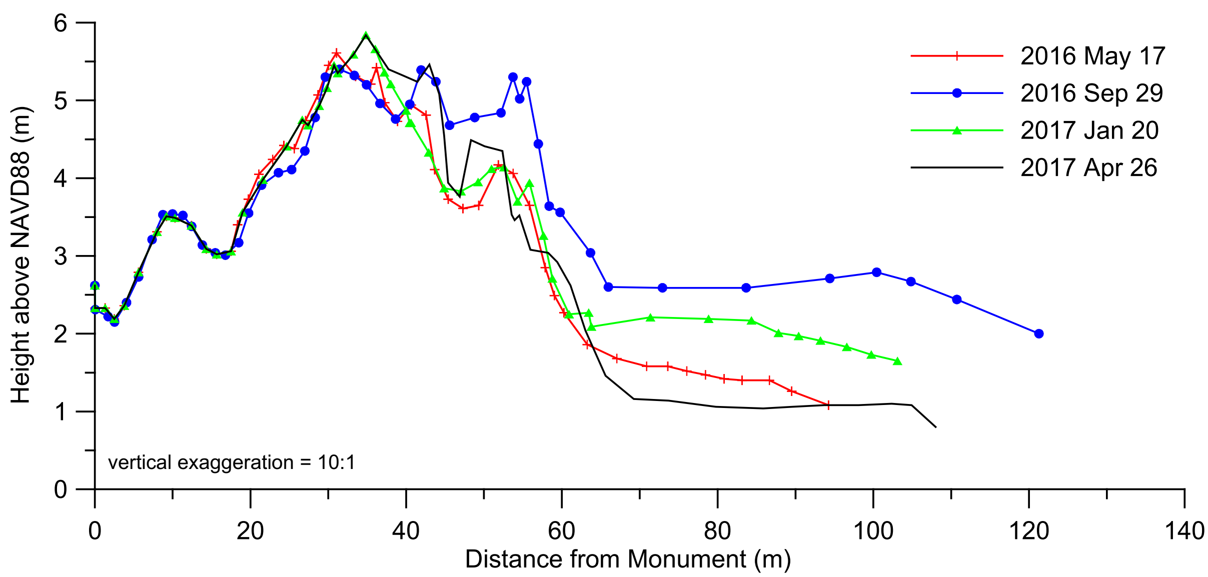
NPI08


NPI08 (North Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2009 Apr 13
2009 Apr 14
2009 Oct 23
2010 Mar 2
2010 May 21

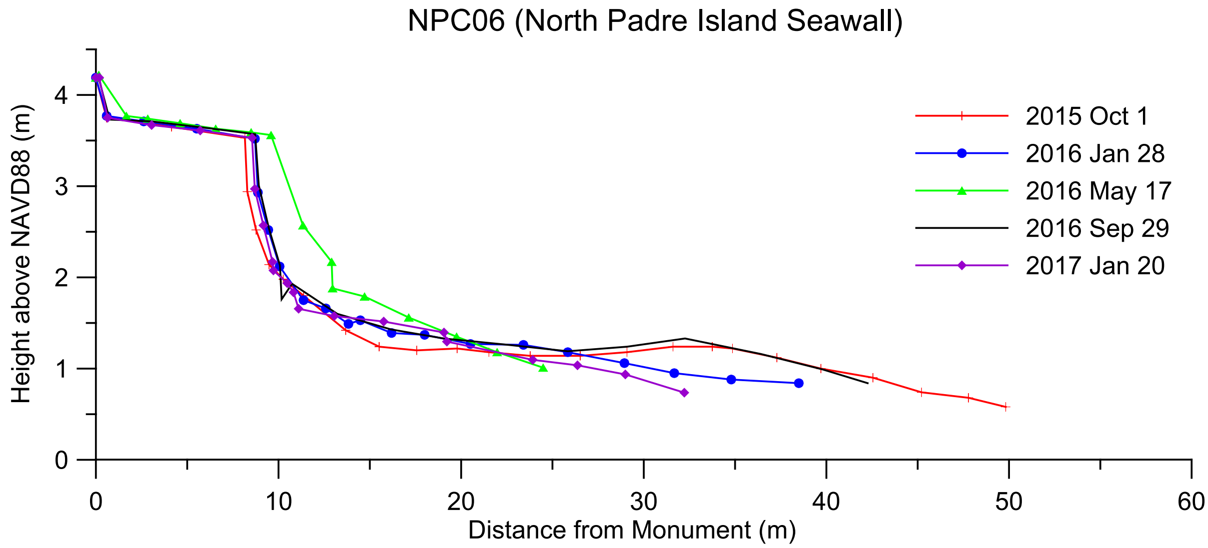

Height above NAVD88 (m)
Distance from Monument (m)
2011 Feb 11
2011 Oct 7
2012 Jan 27
2012 Oct 26
2013 Feb 1
vertical exaggeration = 10:1

NPI08 (North Padre Island)

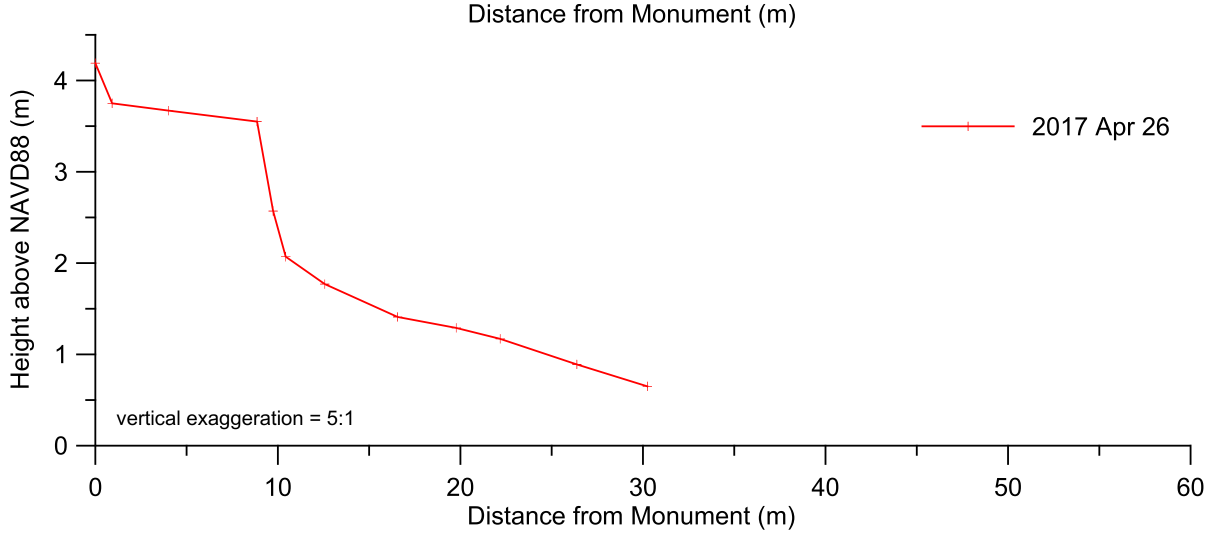




NPC06

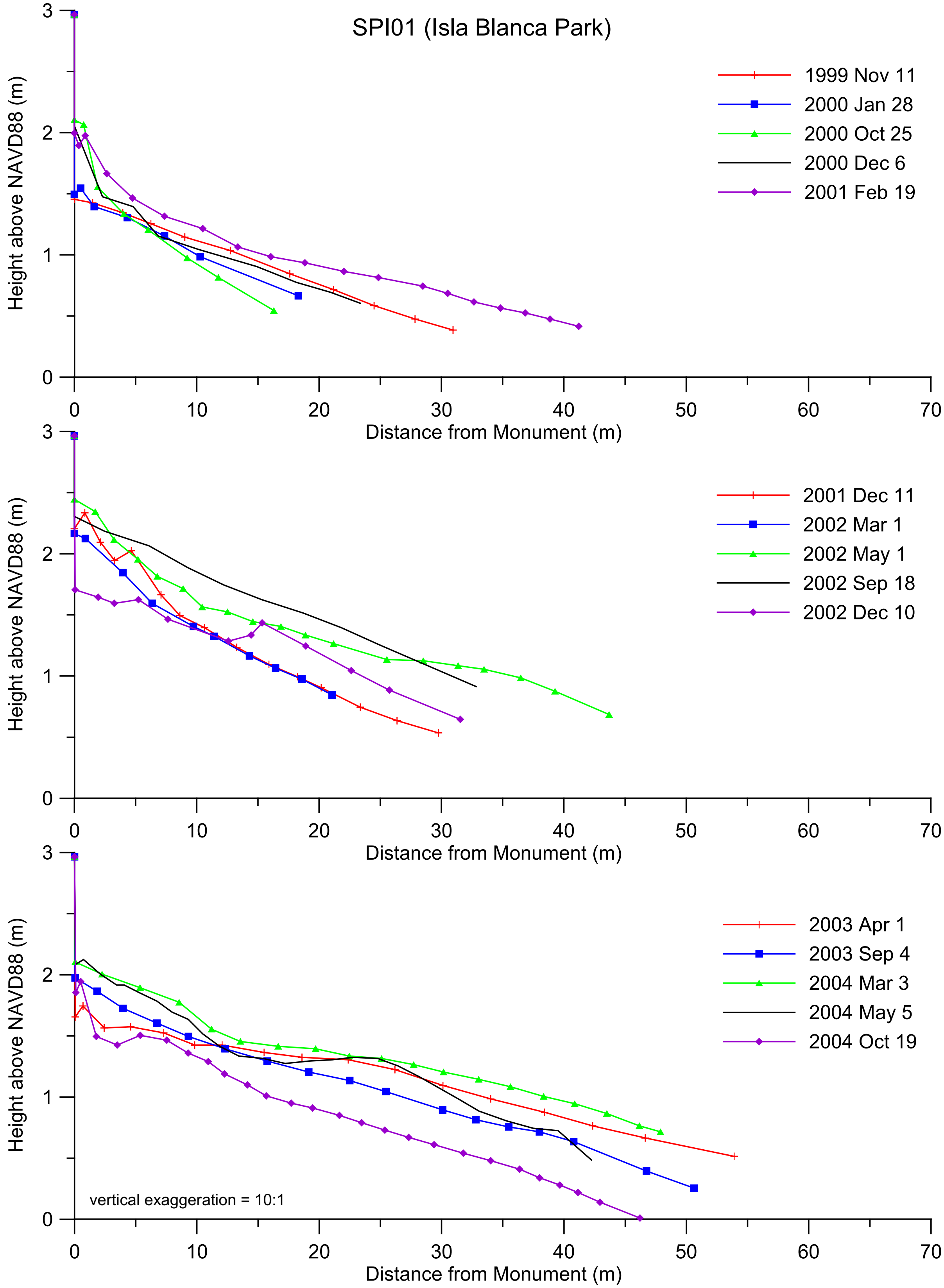


NPC06 (North Padre Island Seawall)
Height above NAVD88 (m)
Distance from Monument (m)
2015 Oct 1
2016 Jan 28
2016 May 17
2016 Sep 29
2017 Jan 20
0
1
2
3
4
0
10
20
30
40
50
60

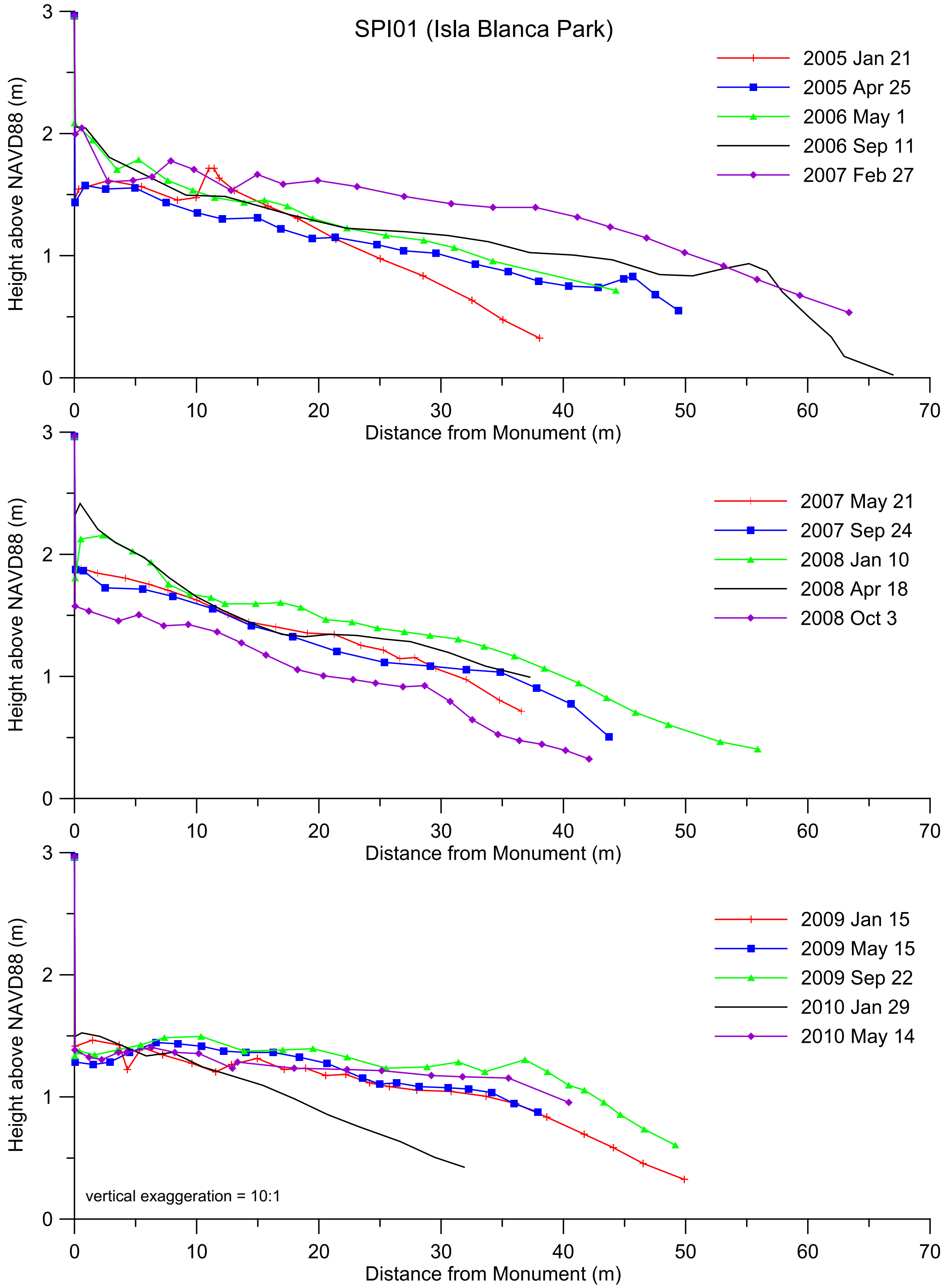


Height above NAVD88 (m)
Distance from Monument (m)
2017 Apr 26
vertical exaggeration = 5:1
0
1
2
3
4
0
10
20
30
40
50
60

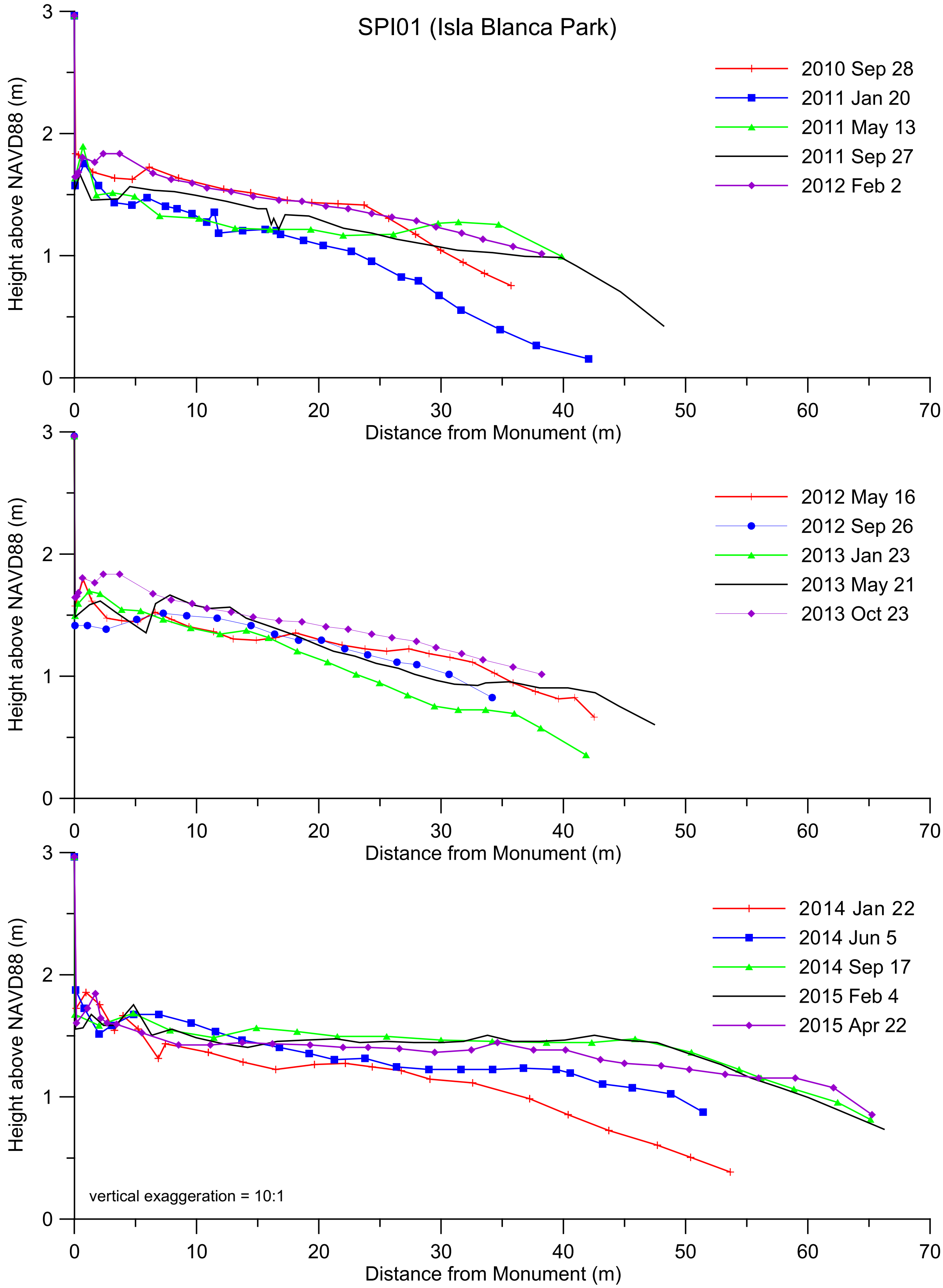
SPI01

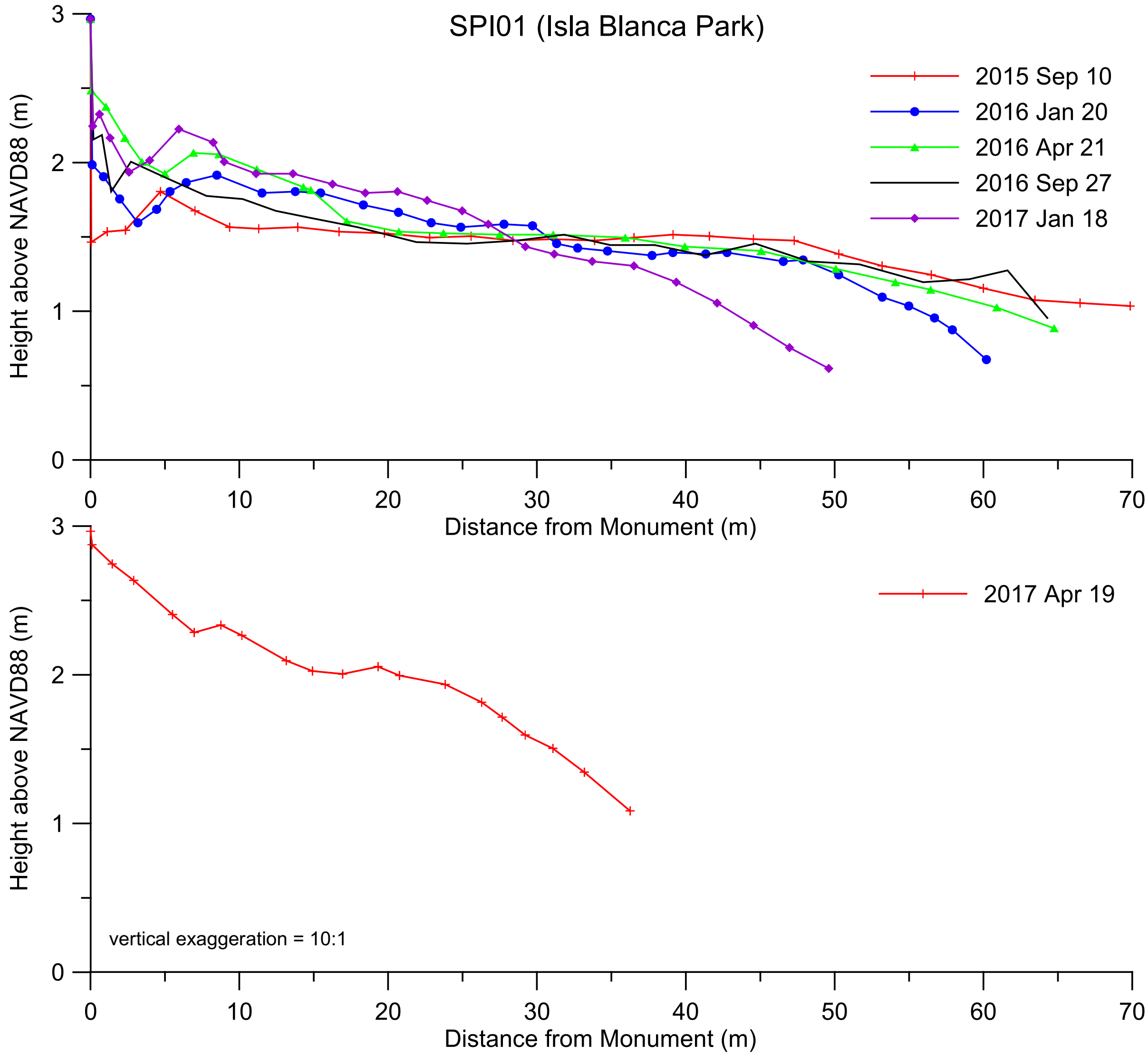


SPI01 (Isla Blanca Park)
1999 Nov 11
2000 Jan 28
2000 Oct 25
2000 Dec 6
2001 Feb 19
2001 Dec 11
2002 Mar 1
2002 May 1
2002 Sep 18
2002 Dec 10
2003 Apr 1
2003 Sep 4
2004 Mar 3
2004 May 5
2004 Oct 19
Height above NAVD88 (m)
Distance from Monument (m)
vertical exaggeration = 10:1
0
1
2
3
0
10
20
30
40
50
60
70

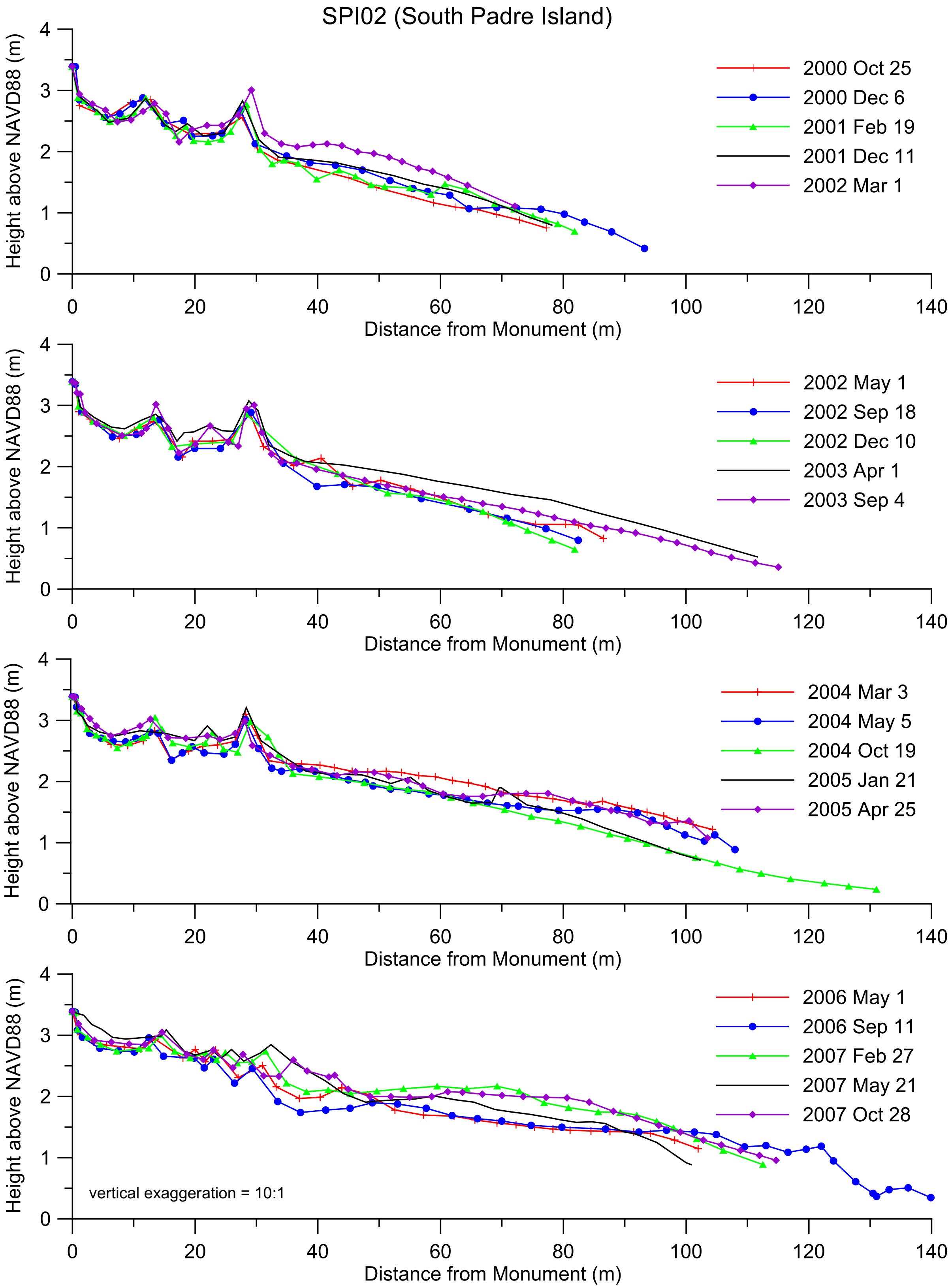


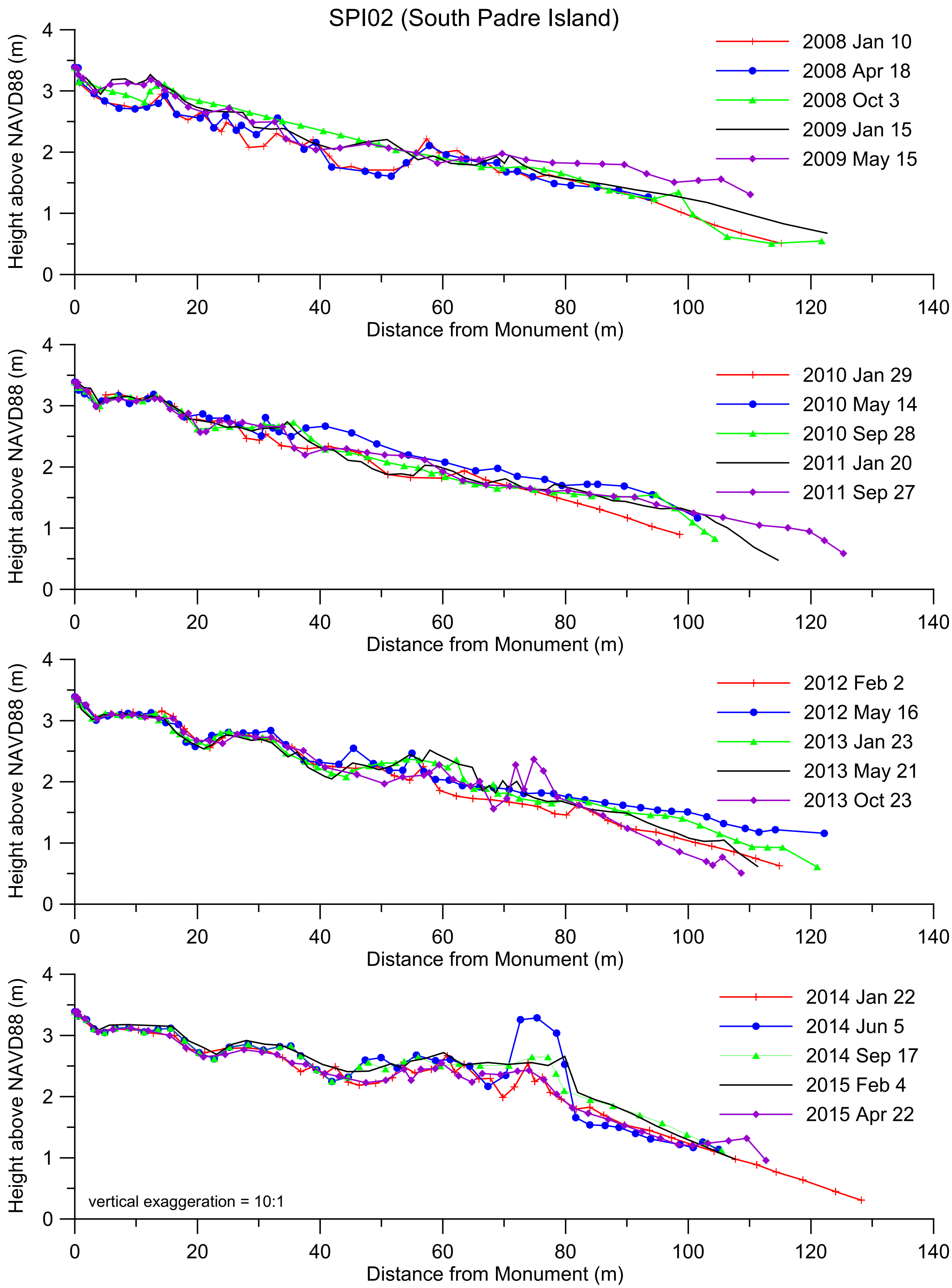
SPI01 (Isla Blanca Park)
2005 Jan 21
2005 Apr 25
2006 May 1
2006 Sep 11
2007 Feb 27
Height above NAVD88 (m)
Distance from Monument (m)
0
1
2
3
0
10
20
30
40
50
60
70
2007 May 21
2007 Sep 24
2008 Jan 10
2008 Apr 18
2008 Oct 3
Height above NAVD88 (m)
Distance from Monument (m)
2009 Jan 15
2009 May 15
2009 Sep 22
2010 Jan 29
2010 May 14
Height above NAVD88 (m)
vertical exaggeration = 10:1
Distance from Monument (m)

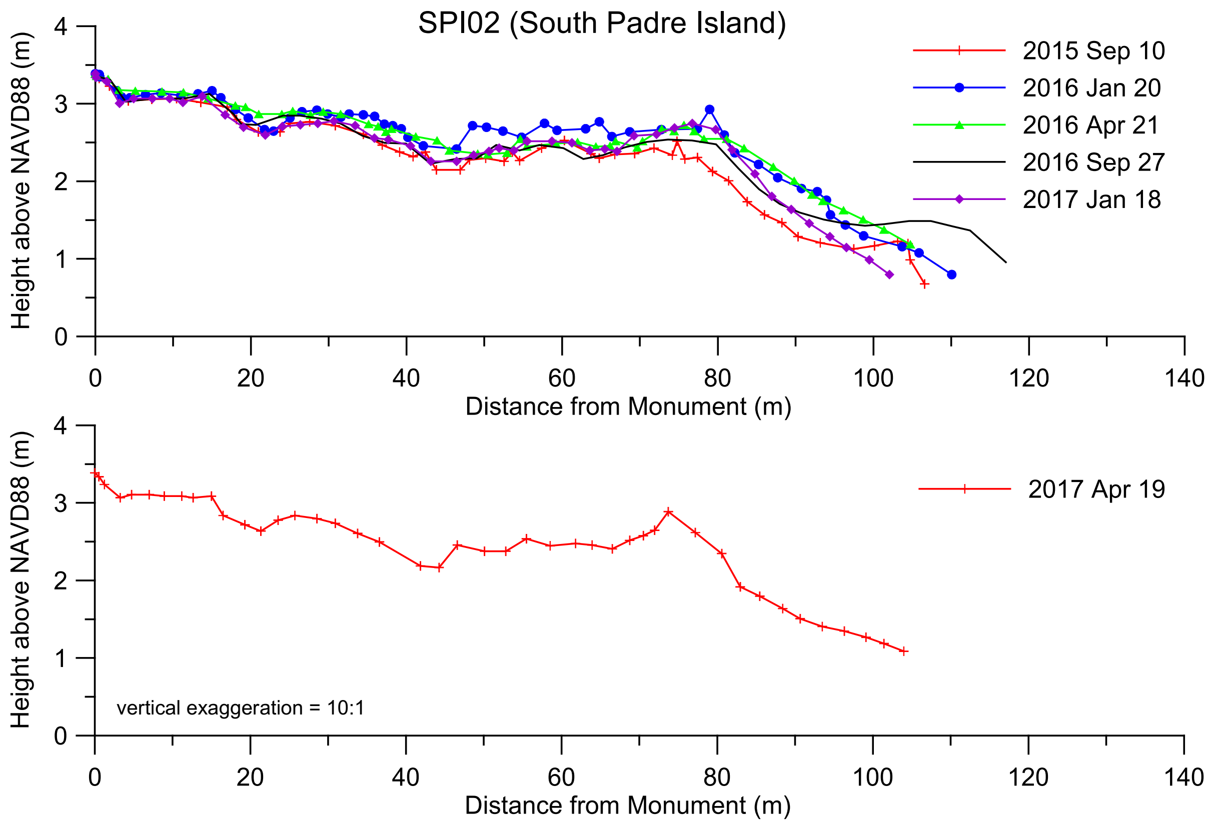

SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
2010 Sep 28
2011 Jan 20
2011 May 13
2011 Sep 27
2012 Feb 2
2012 May 16
2012 Sep 26
2013 Jan 23
2013 May 21
2013 Oct 23
2014 Jan 22
2014 Jun 5
2014 Sep 17
2015 Feb 4
2015 Apr 22
vertical exaggeration = 10:1
0
1
2
3
0
10
20
30
40
50
60
70


SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
2015 Sep 10
2016 Jan 20
2016 Apr 21
2016 Sep 27
2017 Jan 18
2017 Apr 19
vertical exaggeration = 10:1
0
1
2
3
0
10
20
30
40
50
60
70

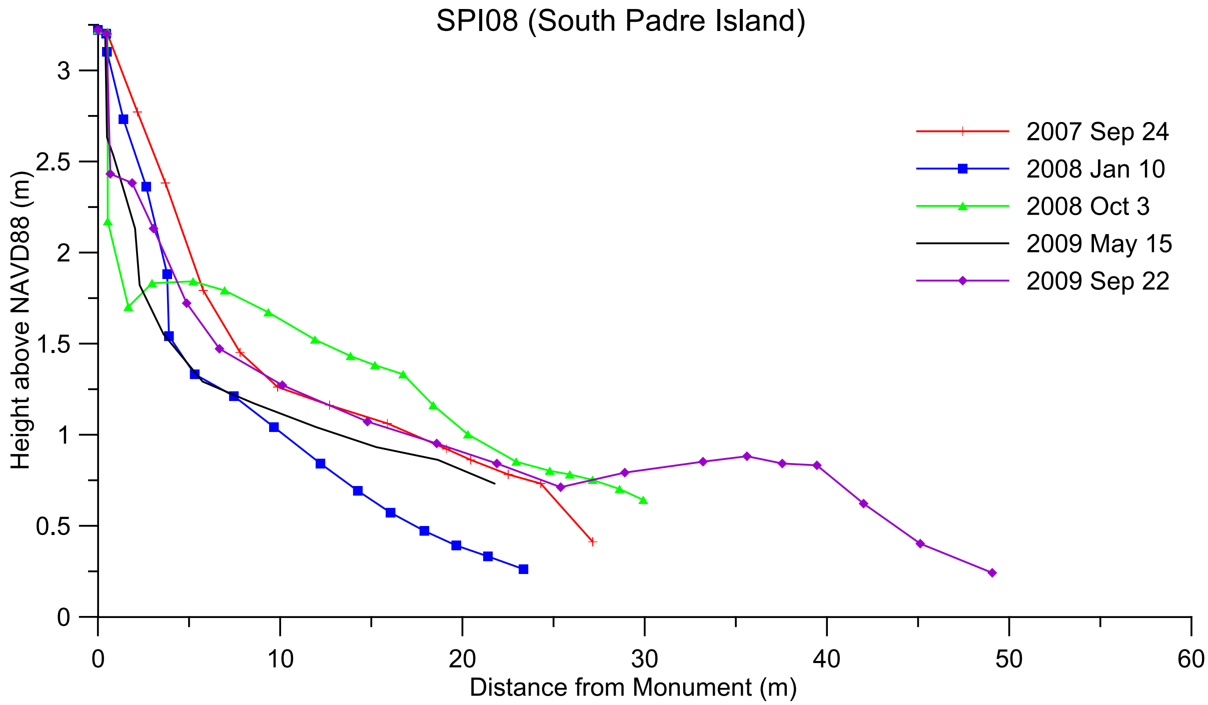
SPI02


SPI02 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
0
20
40
60
80
100
120
140
0
1
2
3
4
2000 Oct 25
2000 Dec 6
2001 Feb 19
2001 Dec 11
2002 Mar 1
2002 May 1
2002 Sep 18
2002 Dec 10
2003 Apr 1
2003 Sep 4
2004 Mar 3
2004 May 5
2004 Oct 19
2005 Jan 21
2005 Apr 25
2006 May 1
2006 Sep 11
2007 Feb 27
2007 May 21
2007 Oct 28
vertical exaggeration = 10:1

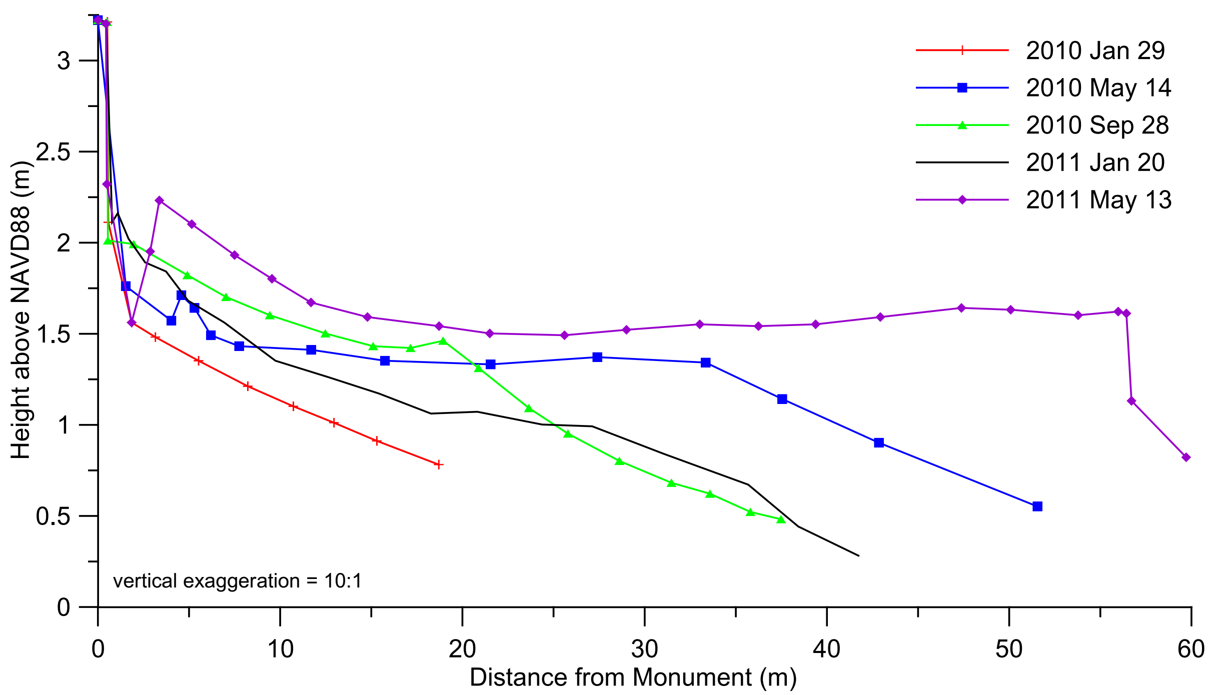

SPI02 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
0
1
2
3
4
0
20
40
60
80
100
120
140
2008 Jan 10
2008 Apr 18
2008 Oct 3
2009 Jan 15
2009 May 15
2010 Jan 29
2010 May 14
2010 Sep 28
2011 Jan 20
2011 Sep 27
2012 Feb 2
2012 May 16
2013 Jan 23
2013 May 21
2013 Oct 23
2014 Jan 22
2014 Jun 5
2014 Sep 17
2015 Feb 4
2015 Apr 22
vertical exaggeration = 10:1


SPI02 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2015 Sep 10
2016 Jan 20
2016 Apr 21
2016 Sep 27
2017 Jan 18
2017 Apr 19
vertical exaggeration = 10:1

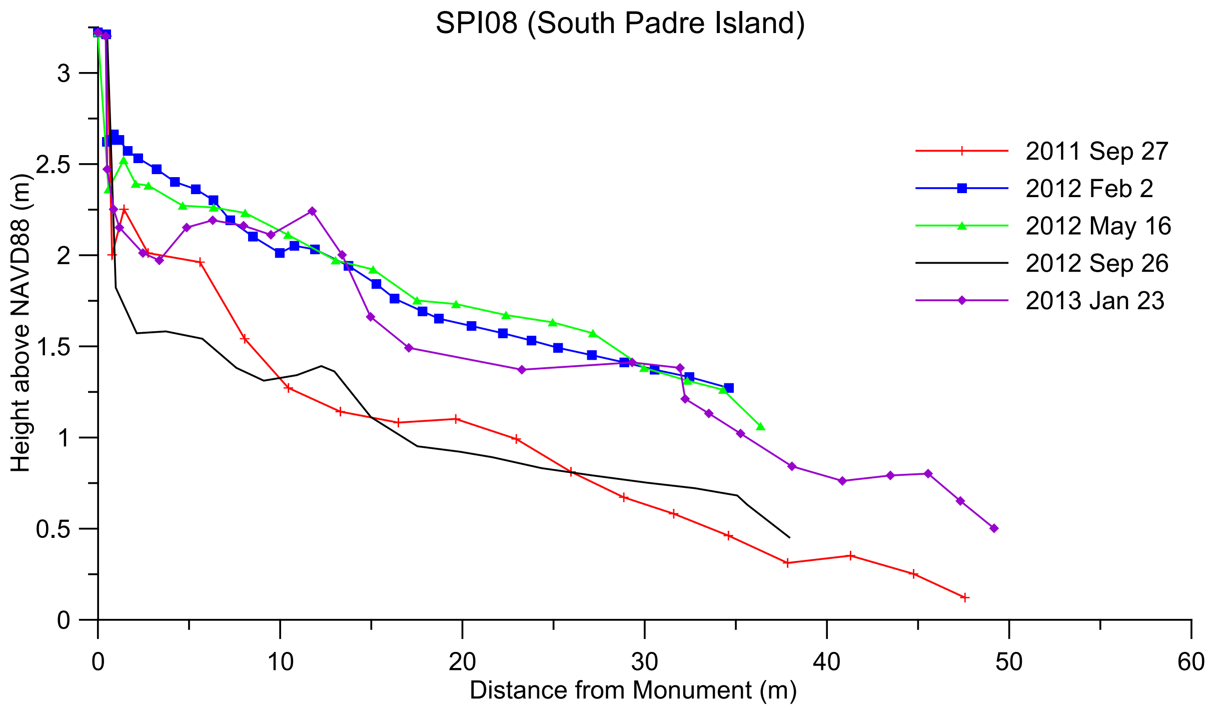
SPI08

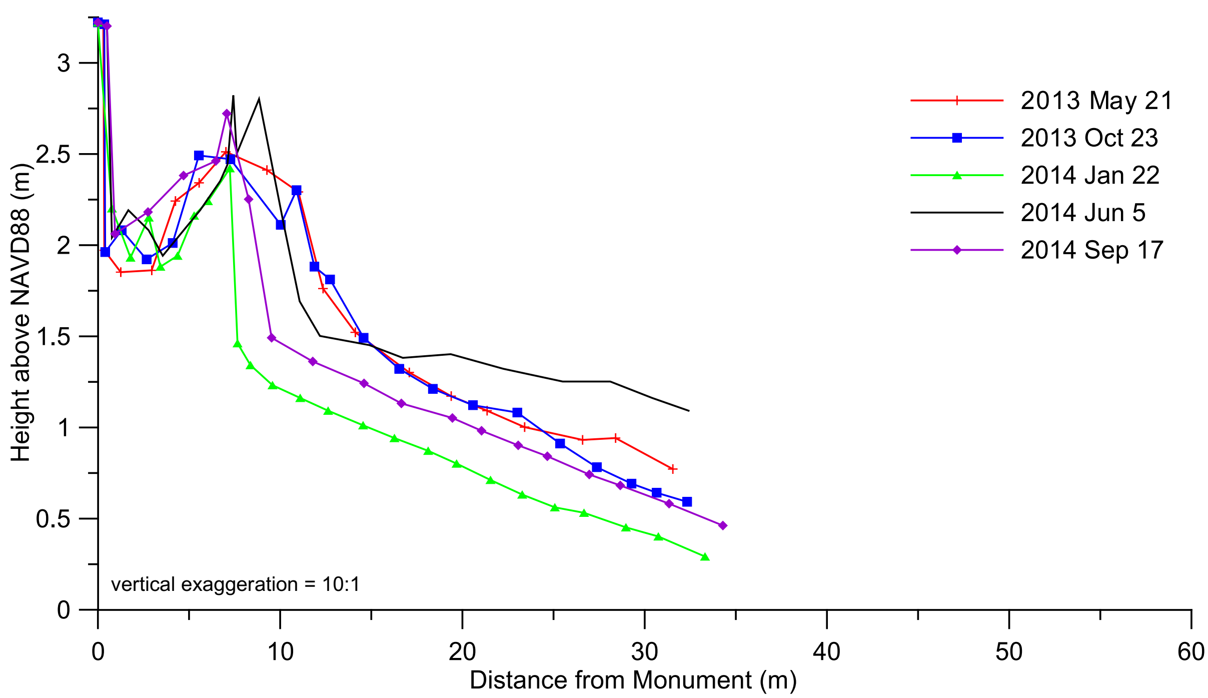


SPI08 (South Padre Island)
2007 Sep 24
2008 Jan 10
2008 Oct 3
2009 May 15
2009 Sep 22
Height above NAVD88 (m)
Distance from Monument (m)
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60

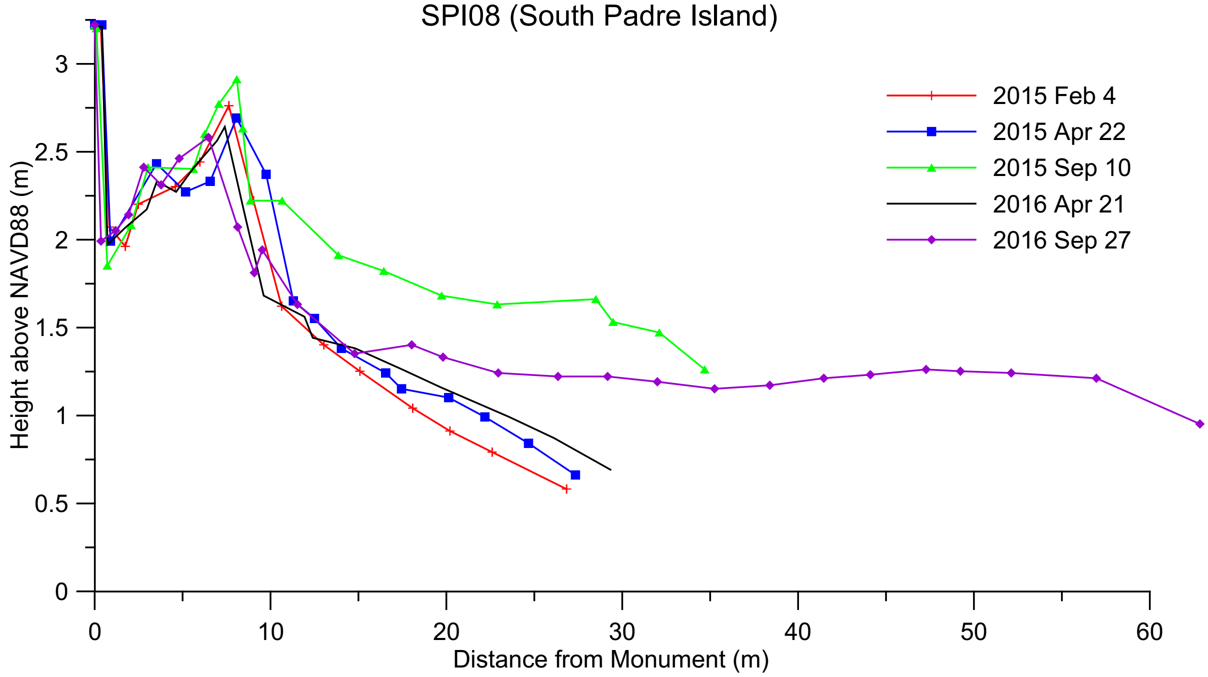


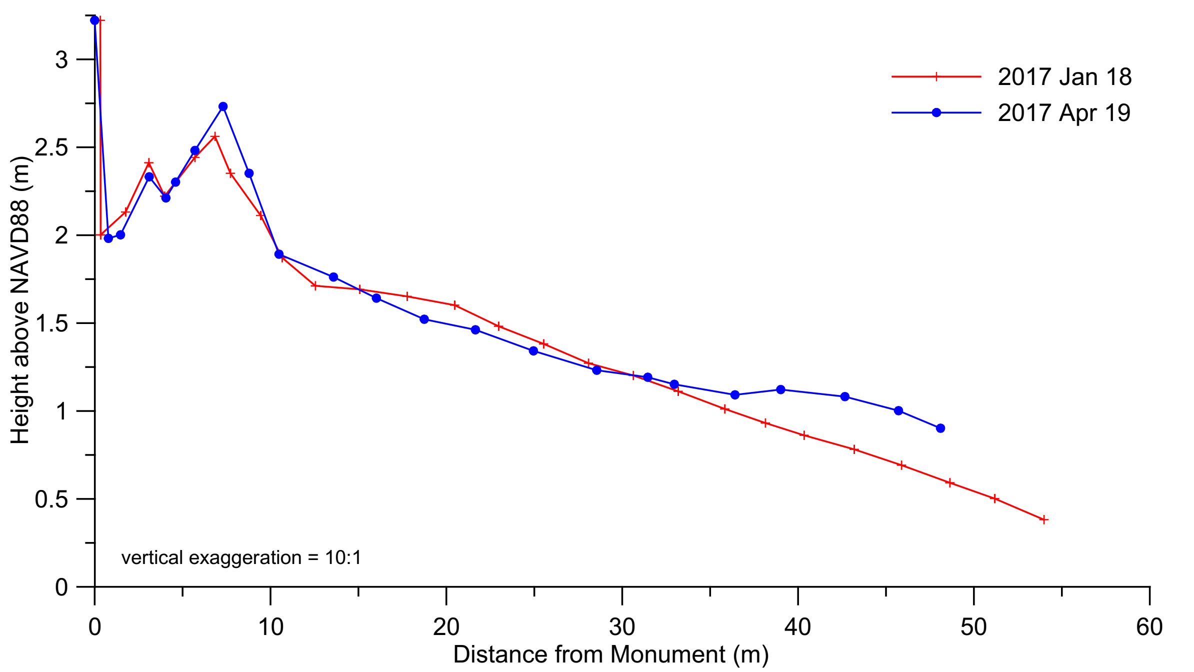
2010 Jan 29
2010 May 14
2010 Sep 28
2011 Jan 20
2011 May 13
vertical exaggeration = 10:1
Height above NAVD88 (m)
Distance from Monument (m)
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60


SPI08 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2011 Sep 27
2012 Feb 2
2012 May 16
2012 Sep 26
2013 Jan 23
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60

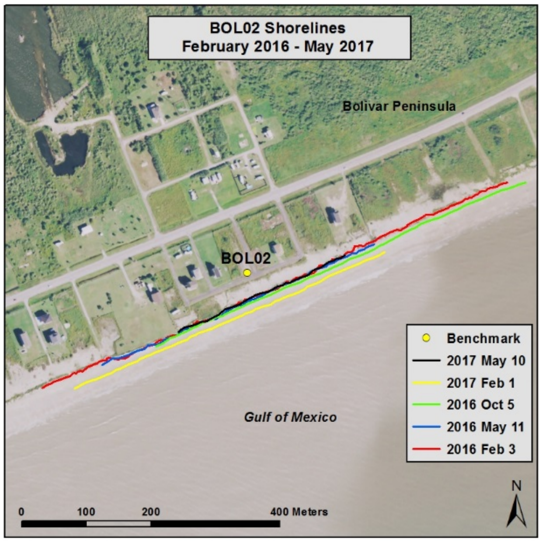

Height above NAVD88 (m)
Distance from Monument (m)
2013 May 21
2013 Oct 23
2014 Jan 22
2014 Jun 5
2014 Sep 17
vertical exaggeration = 10:1
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60

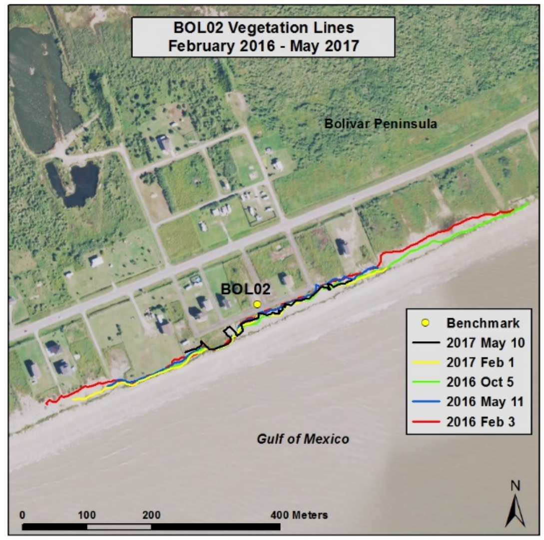
SPI08 (South Padre Island)

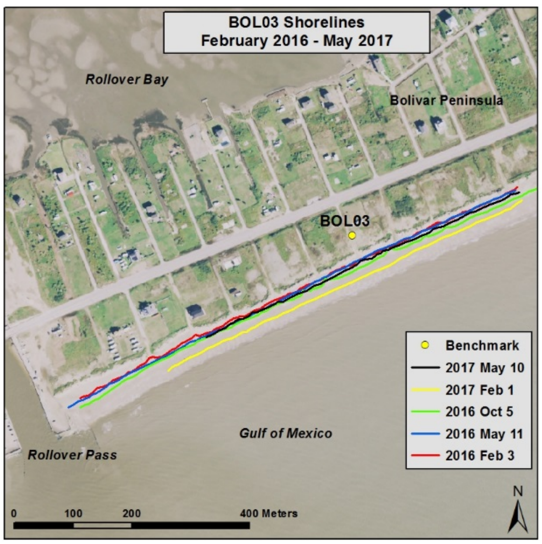


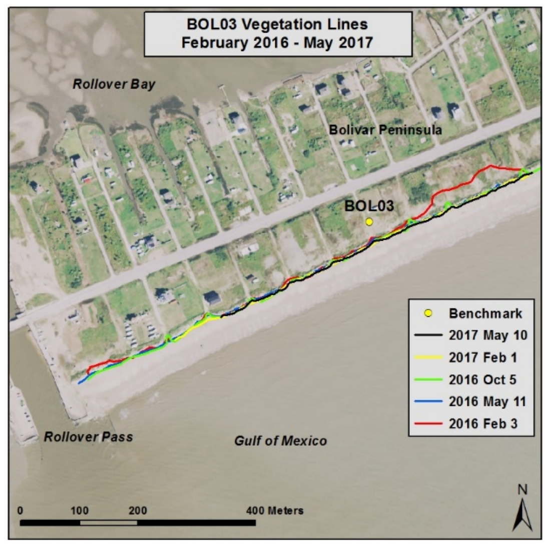


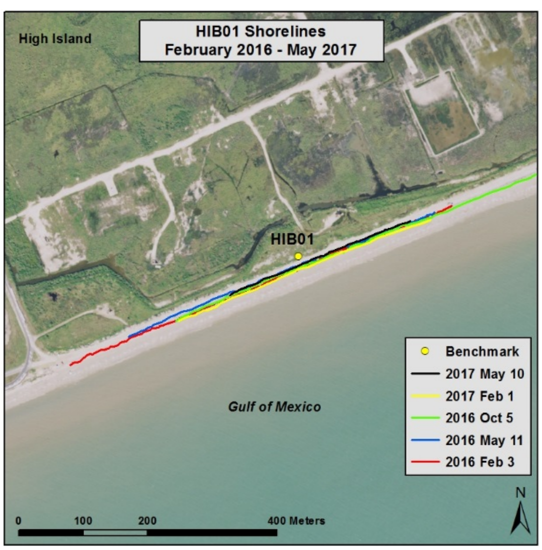
APPENDIX D: MAPS OF GPS SHORELINE AND VEGETATION LINE POSITIONS

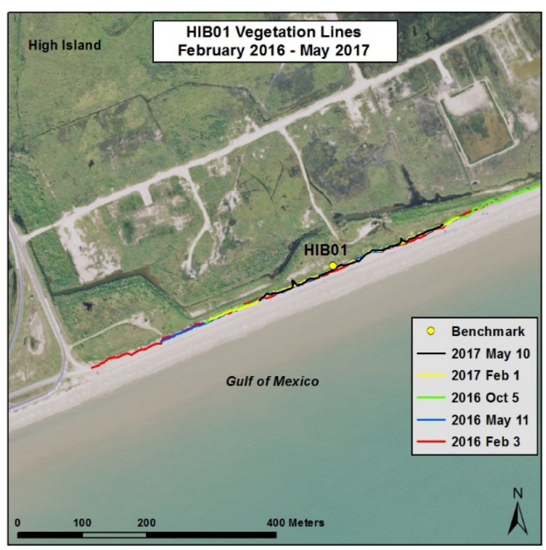


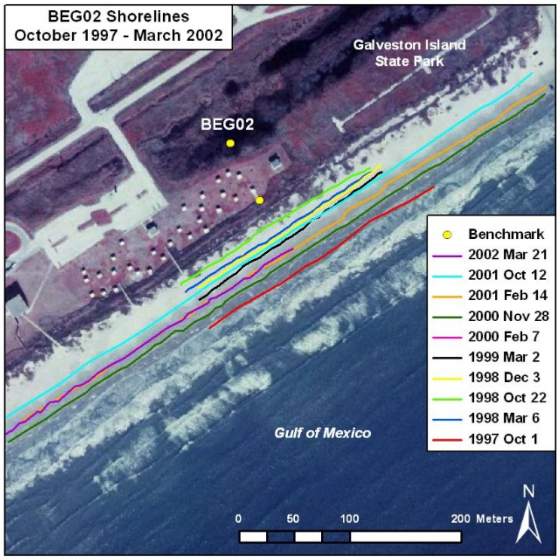








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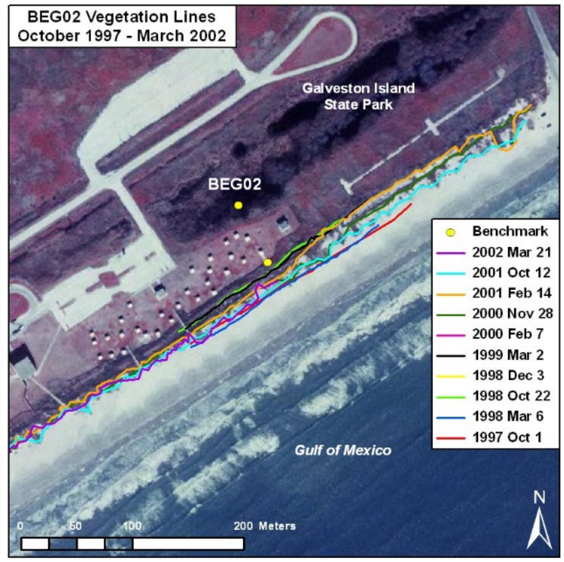
October 1997 - March 2002
Galveston Island
State Park
BEG02
Benchmark
2002 Mar 21
2001 Oct 12
2001 Feb 14
2000 Nov 28
2000 Feb 7
1999 Mar 2
1998 Dec 3
1998 Oct 22
1998 Mar 6
1997 Oct 1
Gulf of Mexico
0 50 100 200 Meters
N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Galveston Island
State Park
BEG02
Benchmark
2002 Mar 21
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2000 Feb 7
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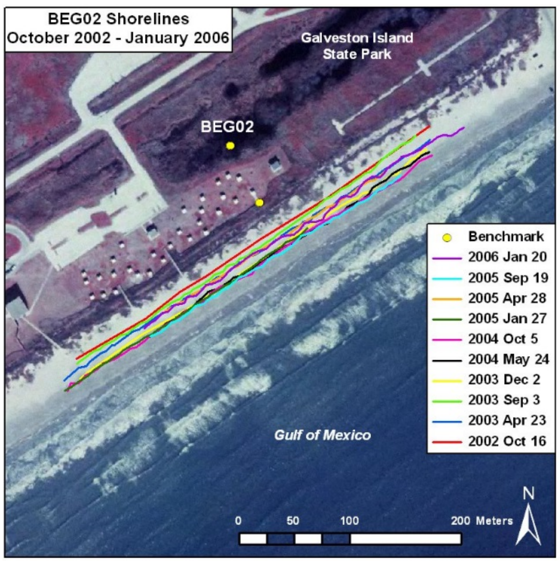
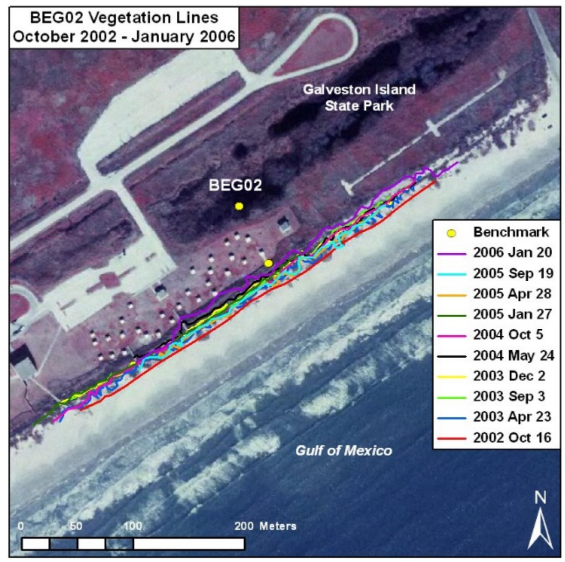
1998 Oct 22
1998 Mar 6
1997 Oct 1
Gulf of Mexico
0 50 100 200 Meters
N


BEG02 Shorelines
October 2002 - January 2006
Galveston Island
State Park
BEG02
Benchmark
2006 Jan 20
2005 Sep 19
2005 Apr 28
2005 Jan 27
2004 Oct 5
2004 May 24
2003 Dec 2
2003 Sep 3
2003 Apr 23
2002 Oct 16
Gulf of Mexico
0 50 100 200 Meters
N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Galveston Island
State Park
BEG02
Benchmark
2006 Jan 20
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2003 Dec 2
2003 Sep 3
2003 Apr 23
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Gulf of Mexico
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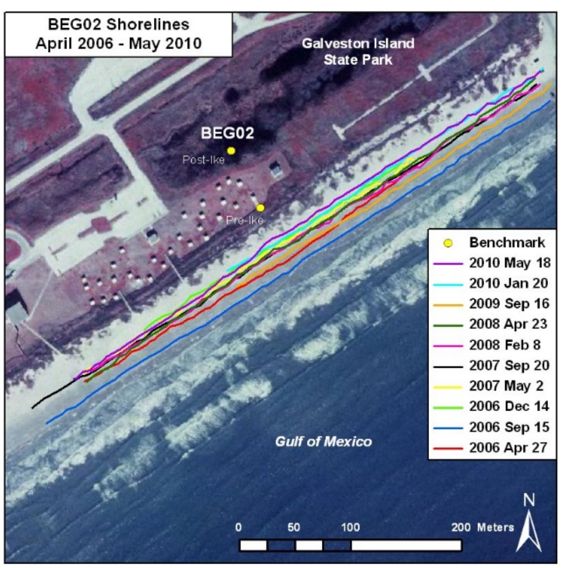
N


BEG02 Shorelines
April 2006 - May 2010
Galveston Island
State Park
BEG02
Post-Ike
Pre-Ike
Benchmark
2010 May 18
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2008 Feb 8
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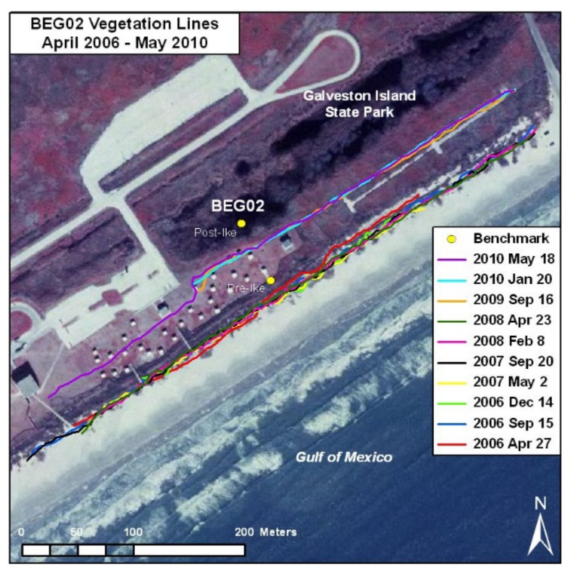
Gulf of Mexico
0 50 100 200 Meters
N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April 2006 - May 2010
Galveston Island
State Park
BEG02
Post-Ike
Pre-Ike
Benchmark
2010 May 18
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2008 Apr 23
2008 Feb 8
2007 Sep 20
2007 May 2
2006 Dec 14
2006 Sep 15
2006 Apr 27
Gulf of Mexico
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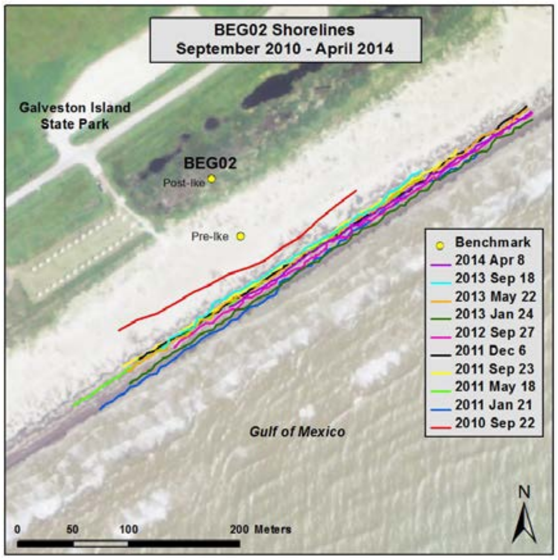
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September 2010 - April 2014
Galveston Island
State Park
BEG02
Post-Ike
Pre-Ike
Benchmark
2014 Apr 8
2013 Sep 18
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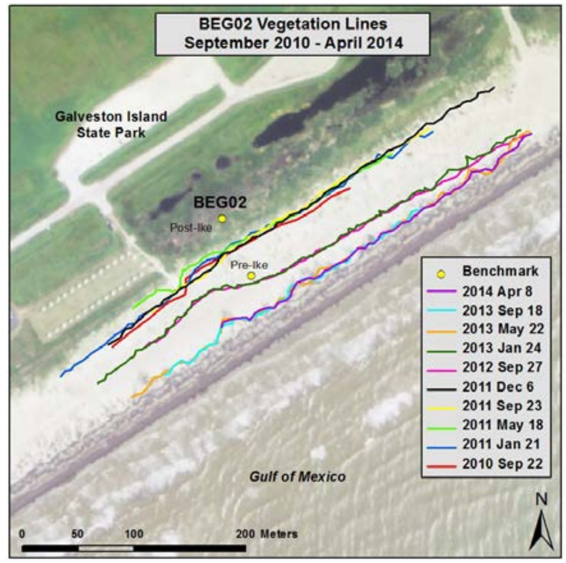
2012 Sep 27
2011 Dec 6
2011 Sep 23
2011 May 18
2011 Jan 21
2010 Sep 22
Gulf of Mexico
0 50 100 200 Meters
N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September 2010 - April 2014
Galveston Island
State Park
BEG02
Post-Ike
Pre-Ike
Benchmark
2014 Apr 8
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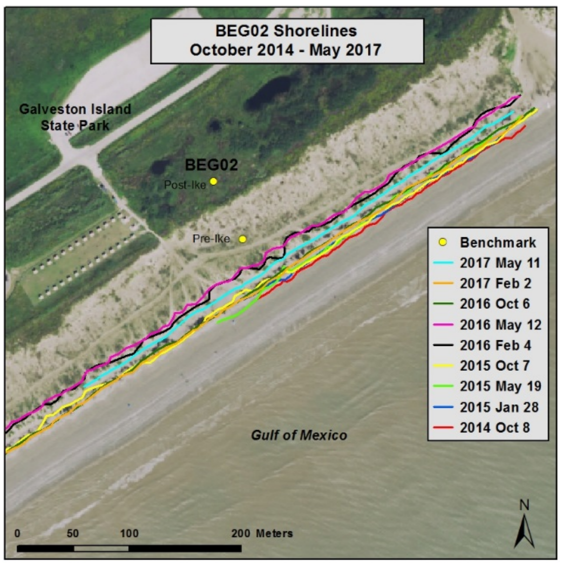
2012 Sep 27
2011 Dec 6
2011 Sep 23
2011 May 18
2011 Jan 21
2010 Sep 22
Gulf of Mexico
0 50 100 200 Meters
N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October 2014 - May 2017
Galveston Island
State Park
BEG02
Post-Ike
Pre-Ike
Benchmark
2017 May 11
2017 Feb 2
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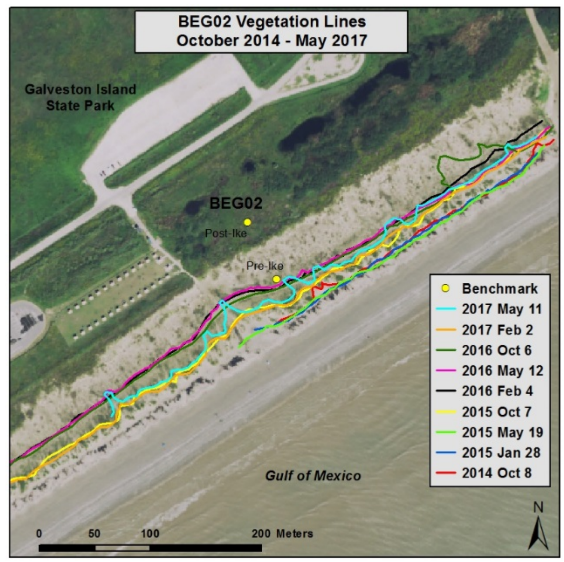
2016 May 12
2016 Feb 4
2015 Oct 7
2015 May 19
2015 Jan 28
2014 Oct 8
Gulf of Mexico
0 50 100 200 Meters
N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October 2014 - May 2017
Galveston Island
State Park
BEG02
Post-Ike
Pre-Ike
Benchmark
2017 May 11
2017 Feb 2
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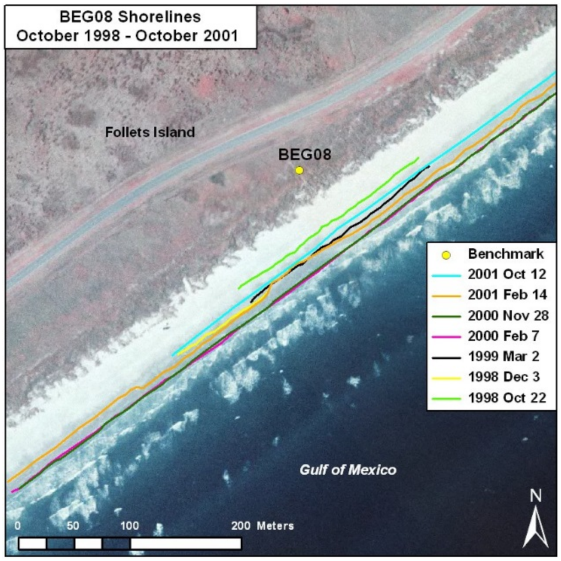
2016 May 12
2016 Feb 4
2015 Oct 7
2015 May 19
2015 Jan 28
2014 Oct 8
Gulf of Mexico
0 50 100 200 Meters
N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October 1998 - October 2001
Follets Island
BEG08
Benchmark
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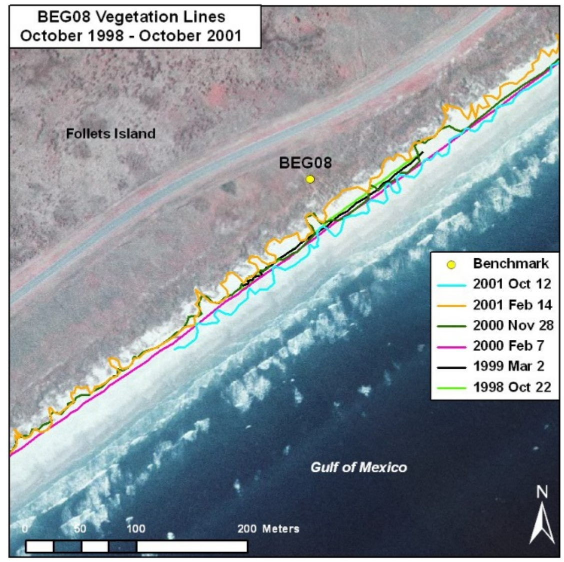
2001 Feb 14
2000 Nov 28
2000 Feb 7
1999 Mar 2
1998 Dec 3
1998 Oct 22
Gulf of Mexico
0 50 100 200 Meters
N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October 1998 - October 2001
Follets Island
BEG08
Benchmark
2001 Oct 12
2001 Feb 14
2000 Nov 28
2000 Feb 7
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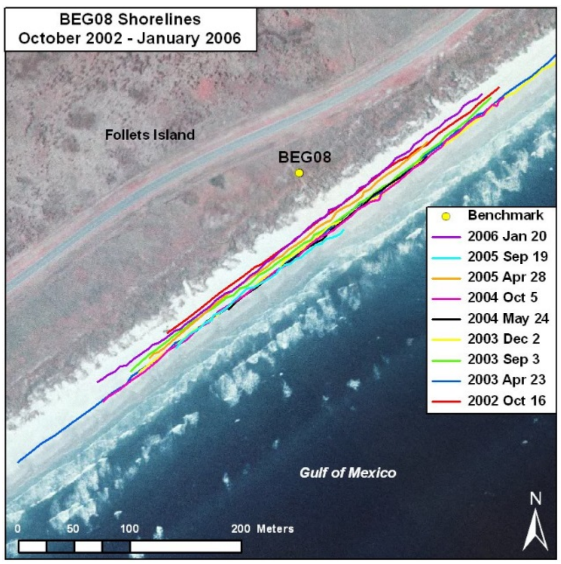
1998 Oct 22
Gulf of Mexico
0 50 100 200 Meters
N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October 2002 - January 2006
Follets Island
BEG08
Benchmark
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2003 Sep 3
2003 Apr 23
2002 Oct 16
Gulf of Mexico
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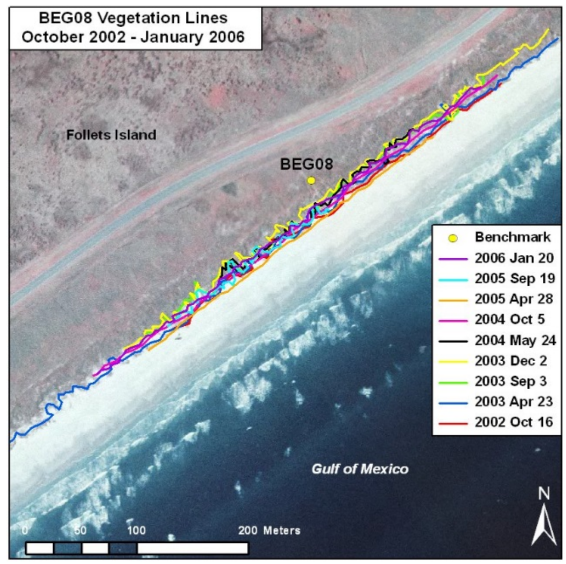
N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Follets Island
BEG08
Benchmark
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Gulf of Mexico
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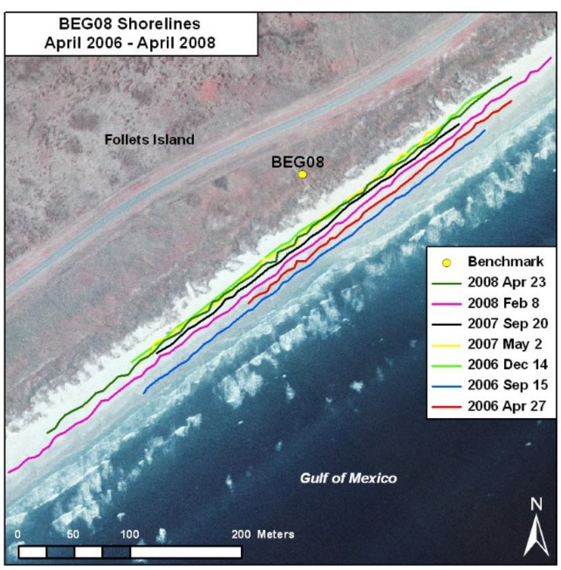
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April 2006 - April 2008
Follets Island
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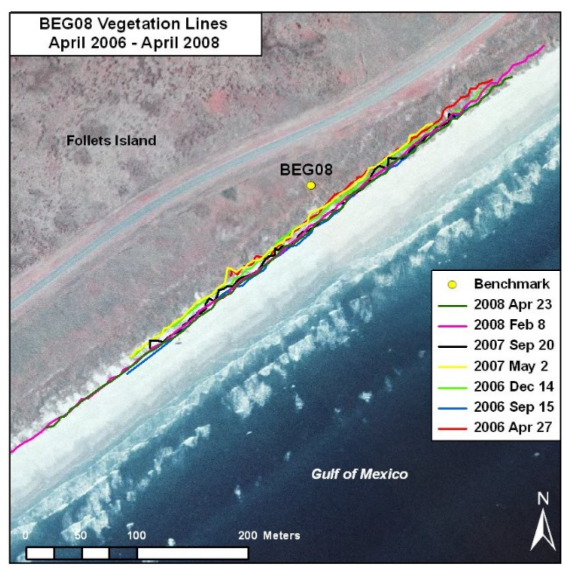
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April 2006 - April 2008
Follets Island
BEG08
Benchmark
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Gulf of Mexico
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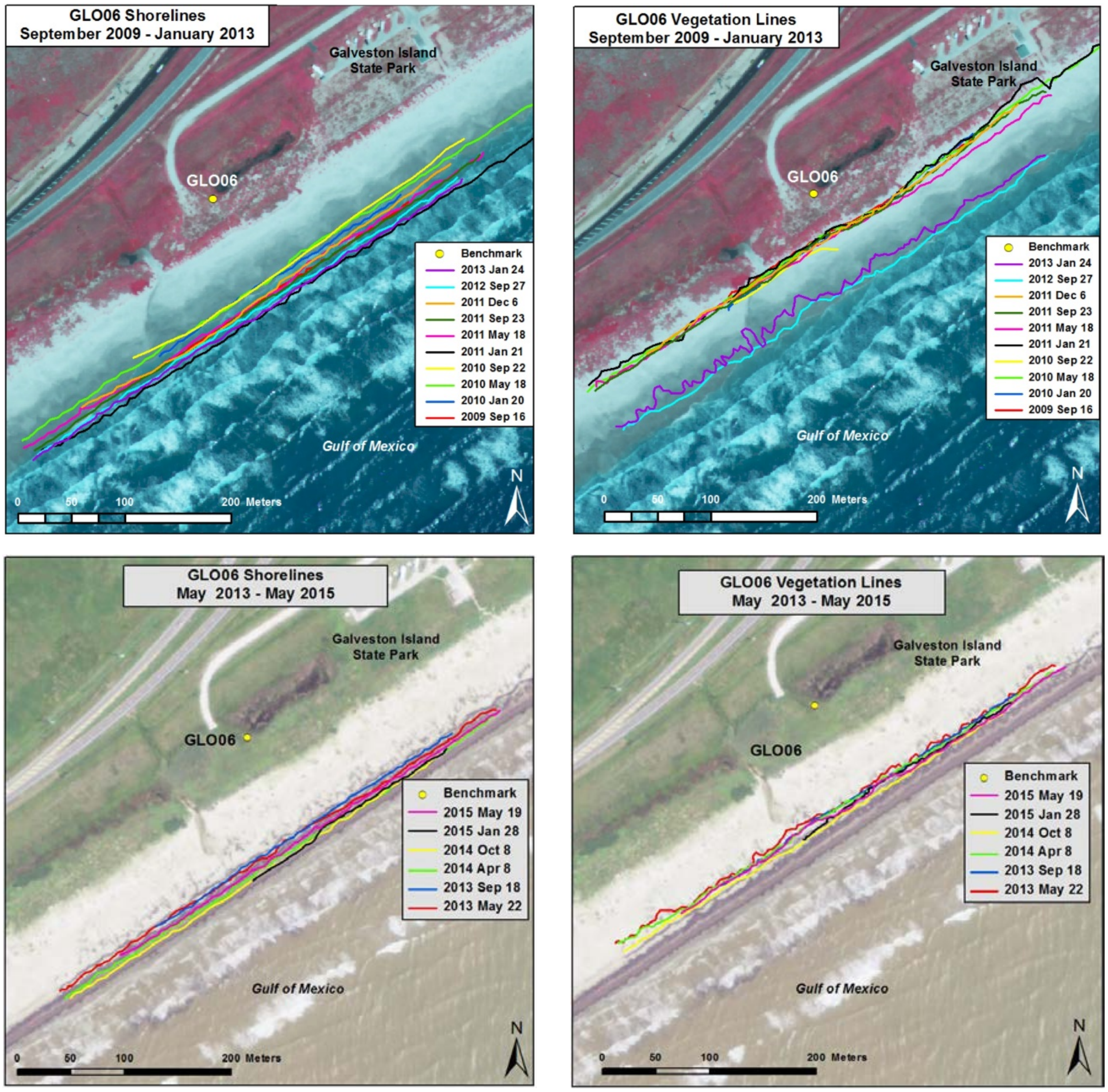
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Galveston Island State Park
GLO06
Benchmark
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2010 Sep 22
2010 May 18
2010 Jan 20
2009 Sep 16
Gulf of Mexico
0 50 100 200 Meters
N
GLO06 Vegetation Lines
September 2009 - January 2013
Galveston Island State Park
GLO06
Benchmark
2013 Jan 24
2012 Sep 27
2011 Dec 6
2011 Sep 23
2011 May 18
2011 Jan 21
2010 Sep 22
2010 May 18
2010 Jan 20
2009 Sep 16
Gulf of Mexico
0 50 100 200 Meters
N
GLO06 Shorelines
May 2013 - May 2015
Galveston Island State Park
GLO06
Benchmark
2015 May 19
2015 Jan 28
2014 Oct 8
2014 Apr 8
2013 Sep 18
2013 May 22
Gulf of Mexico
0 50 100 200 Meters
N
GLO06 Vegetation Lines
May 2013 - May 2015
Galveston Island State Park
GLO06
Benchmark
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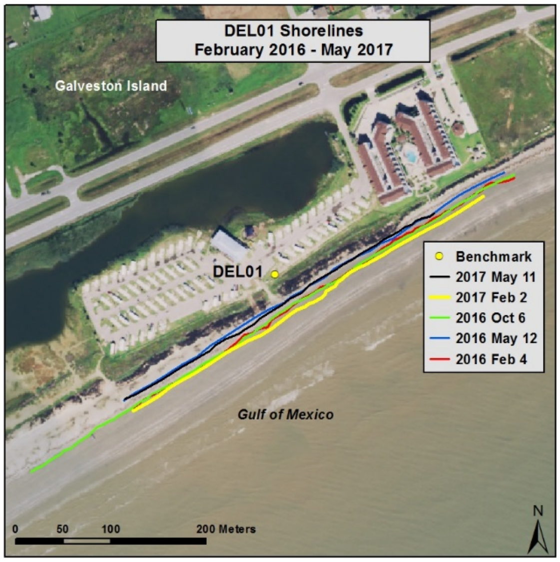
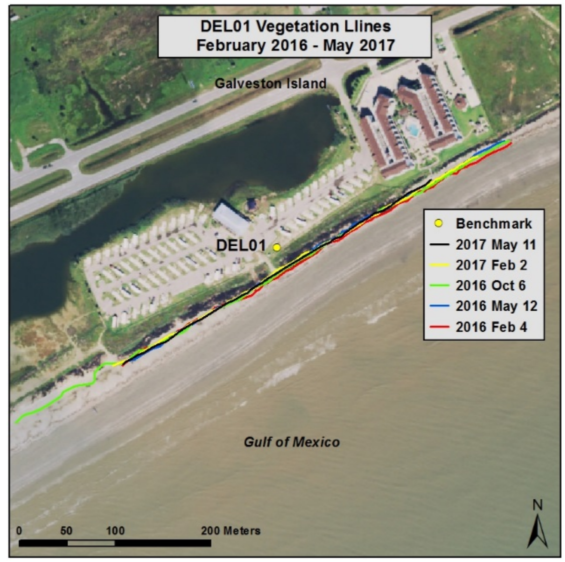
2014 Apr 8
2013 Sep 18
2013 May 22
Gulf of Mexico
0 50 100 200 Meters
N


DEL01 Shorelines
February 2016 - May 2017
Galveston Island
DEL01
Benchmark
2017 May 11
2017 Feb 2
2016 Oct 6
2016 May 12
2016 Feb 4
Gulf of Mexico
0
50
100
200 Meters
N


DEL01 Vegetation Llines
February 2016 - May 2017
Galveston Island
DEL01
Benchmark
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2017 Feb 2
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2016 May 12
2016 Feb 4
Gulf of Mexico
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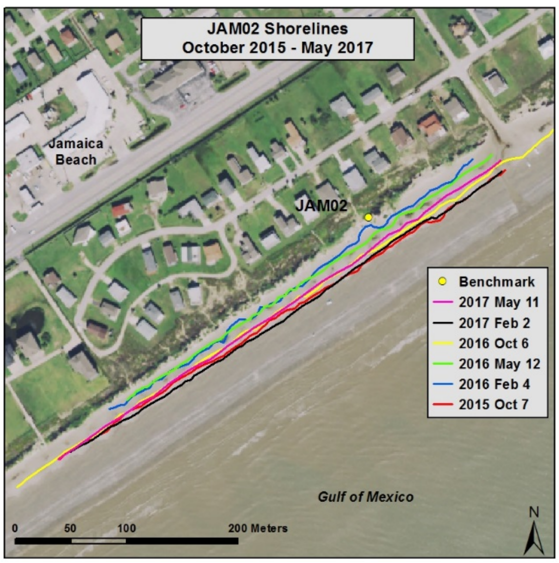
100
200 Meters
N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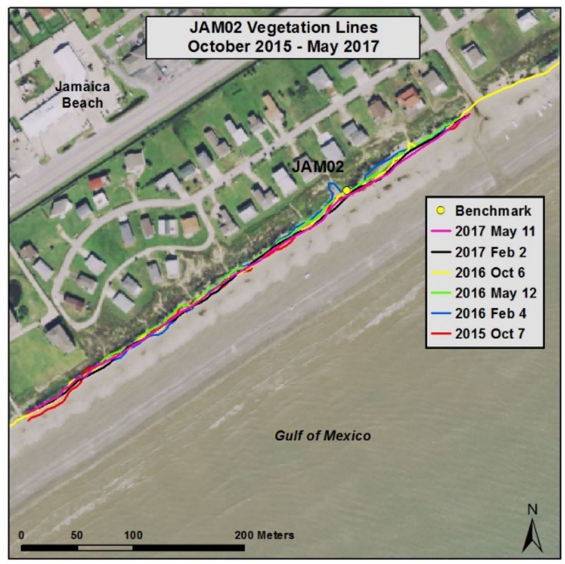
October 2015 - May 2017
Jamaica
Beach
JAM02
Benchmark
2017 May 11
2017 Feb 2
2016 Oct 6
2016 May 12
2016 Feb 4
2015 Oct 7
Gulf of Mexico
0
50
100
200 Meters
N


JAM02 Vegetation Lines
October 2015 - May 2017
Jamaica
Beach
JAM02
Benchmark
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2017 Feb 2
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2016 May 12
2016 Feb 4
2015 Oct 7
Gulf of Mexico
0
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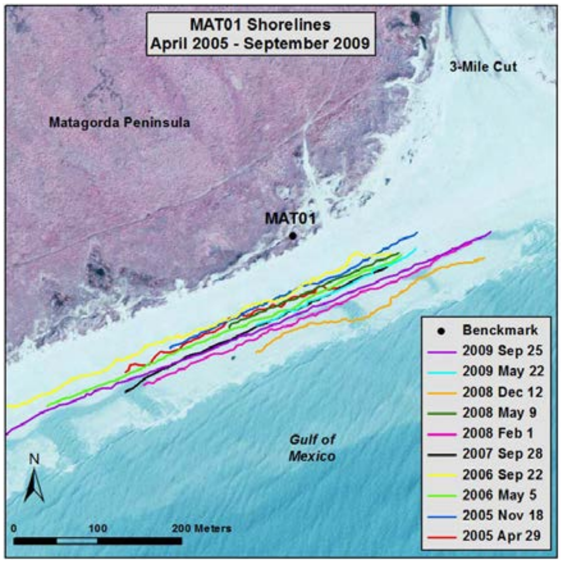
100
200 Meters
N


MAT01 Shorelines
April 2005 - September 2009
3-Mile Cut
Matagorda Peninsula
MAT01
Gulf of Mexico
N
0
100
200 Meters
Benckmark
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2009 May 22
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2008 May 9
2008 Feb 1
2007 Sep 28
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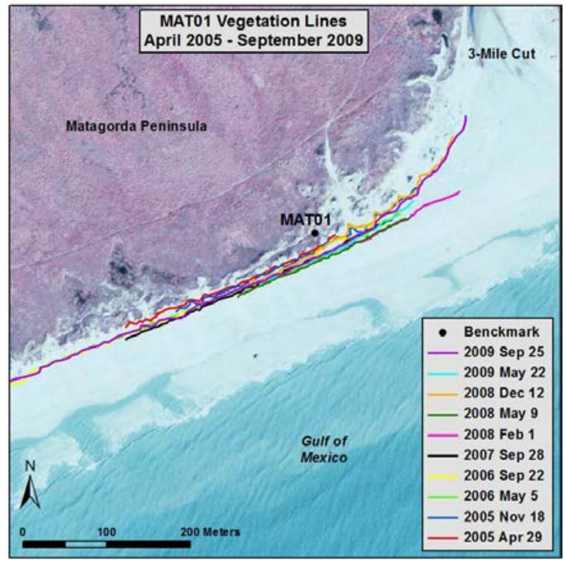
2006 May 5
2005 Nov 18
2005 Apr 29


MAT01 Vegetation Lines
April 2005 - September 2009
3-Mile Cut
Matagorda Peninsula
MAT01
Gulf of Mexico
N
0
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200 Meters
Benckmark
2009 Sep 25
2009 May 22
2008 Dec 12
2008 May 9
2008 Feb 1
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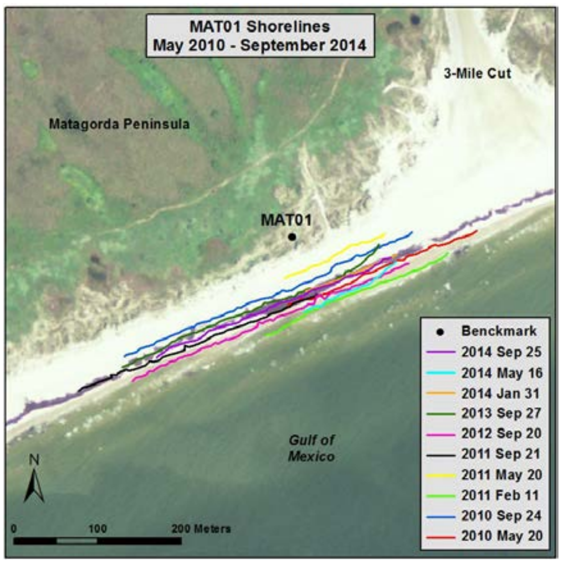
2005 Apr 29


MAT01 Shorelines
May 2010 - September 2014
3-Mile Cut
Matagorda Peninsula
MAT01
Gulf of Mexico
N
0
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200 Meters
Benckmark
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2012 Sep 20
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2011 Feb 11
2010 Sep 24
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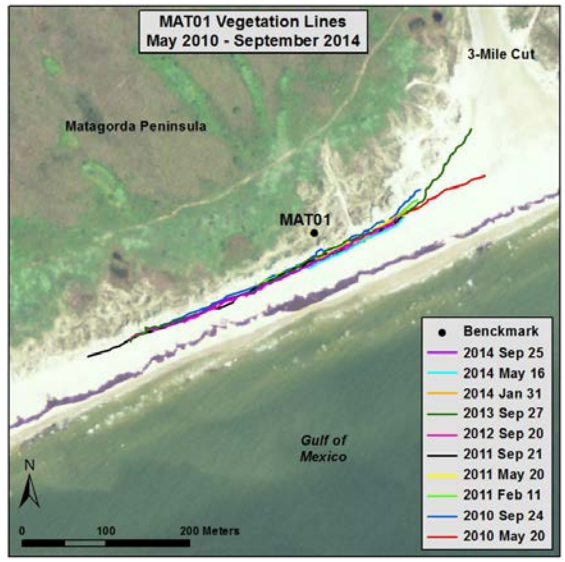
MAT01 Vegetation Lines
May 2010 - September 2014
3-Mile Cut
Matagorda Peninsula
MAT01
Gulf of Mexico
N
0
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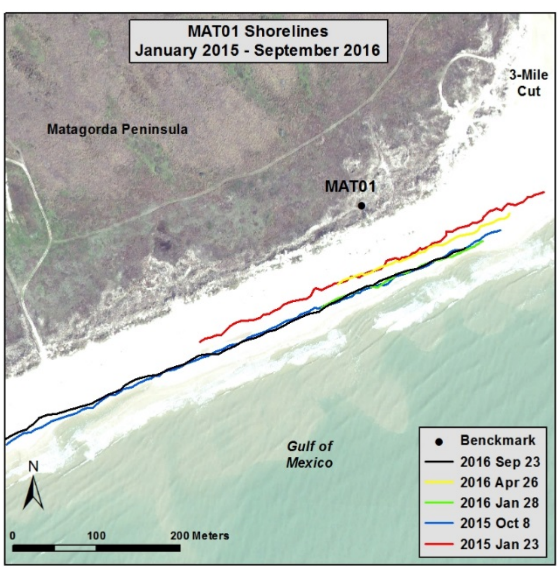
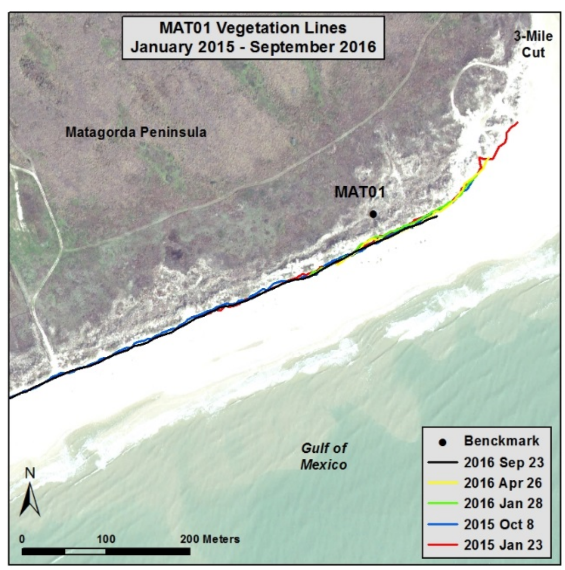
2010 May 20


MAT01 Shorelines
January 2015 - September 2016
3-Mile Cut
Matagorda Peninsula
MAT01
Gulf of Mexico
N
0
100
200 Meters
Benckmark
2016 Sep 23
2016 Apr 26
2016 Jan 28
2015 Oct 8
2015 Jan 23


MAT01 Vegetation Lines
January 2015 - September 2016
3-Mile Cut
Matagorda Peninsula
MAT01
Gulf of Mexico
N
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200 Meters
Benckmark
2016 Sep 23
2016 Apr 26
2016 Jan 28
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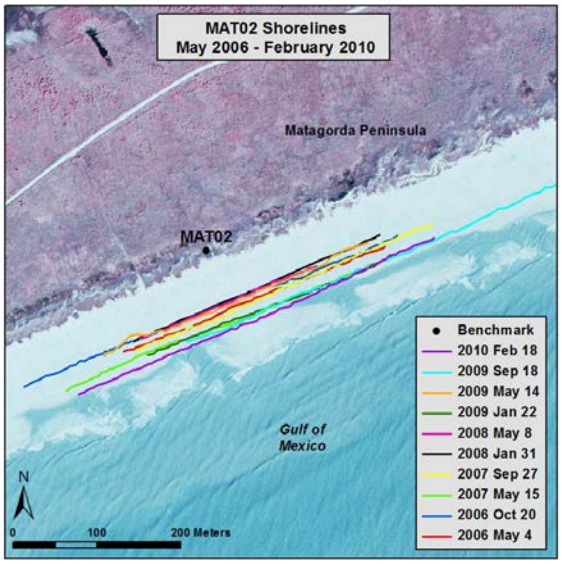
2015 Jan 23


MAT02 Shorelines
May 2006 - February 2010
Matagorda Peninsula
MAT02
Gulf of Mexico
Benchmark
2010 Feb 18
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2008 May 8
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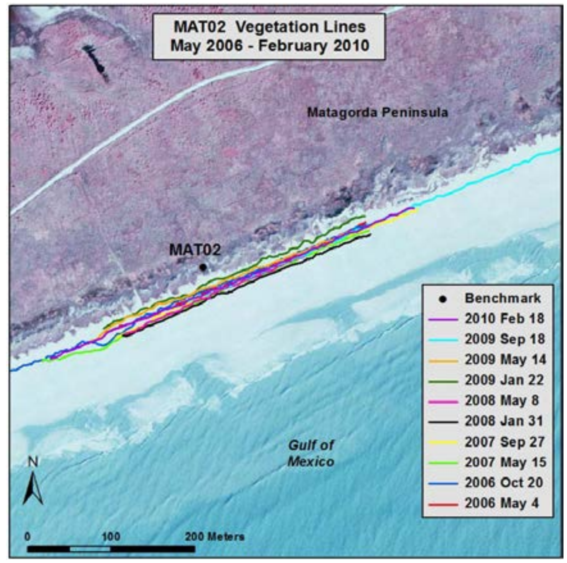
2006 Oct 20
2006 May 4
N
0
100
200 Meters


MAT02 Vegetation Lines
May 2006 - February 2010
Matagorda Peninsula
MAT02
Gulf of Mexico
Benchmark
2010 Feb 18
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2006 Oct 20
2006 May 4
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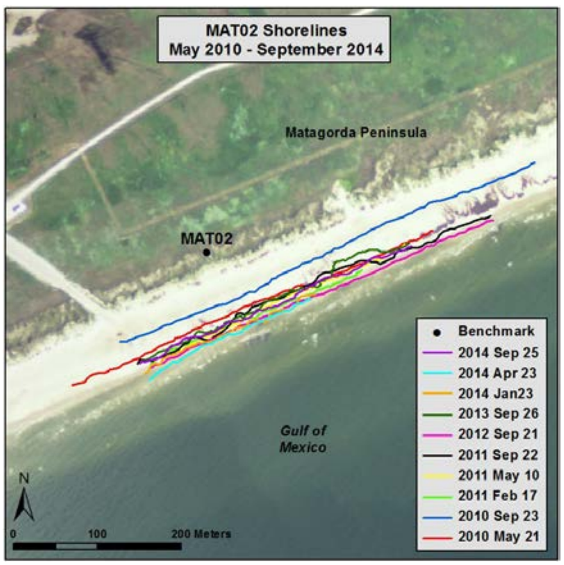
200 Meters


MAT02 Shorelines
May 2010 - September 2014
Matagorda Peninsula
MAT02
Gulf of Mexico
Benchmark
2014 Sep 25
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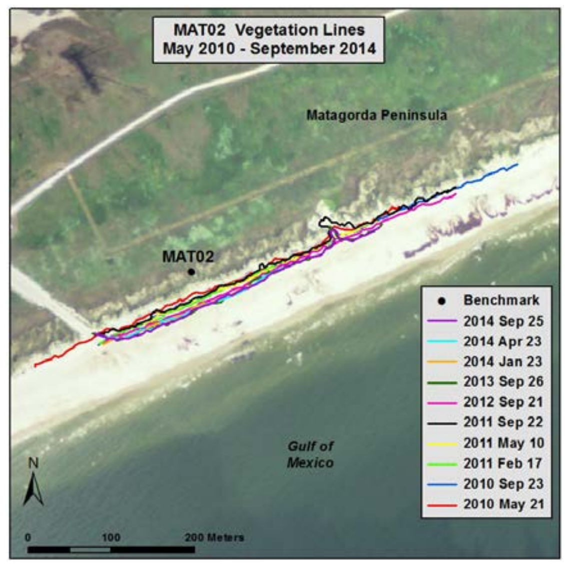
MAT02 Vegetation Lines
May 2010 - September 2014
Matagorda Peninsula
MAT02
Gulf of Mexico
Benchmark
2014 Sep 25
2014 Apr 23
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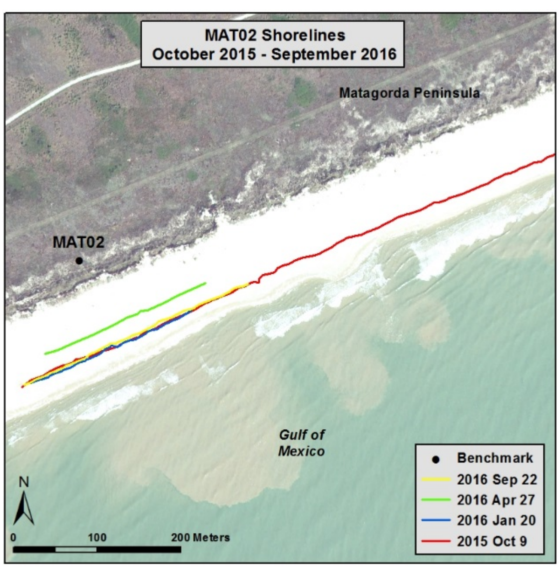
200 Meters


MAT02 Shorelines
October 2015 - September 2016
Matagorda Peninsula
MAT02
Gulf of Mexico
Benchmark
2016 Sep 22
2016 Apr 27
2016 Jan 20
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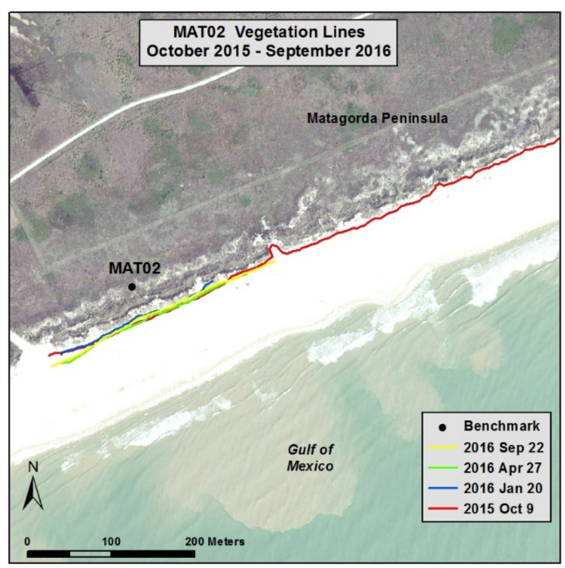
200 Meters


MAT02 Vegetation Lines
October 2015 - September 2016
Matagorda Peninsula
MAT02
Gulf of Mexico
Benchmark
2016 Sep 22
2016 Apr 27
2016 Jan 20
2015 Oct 9
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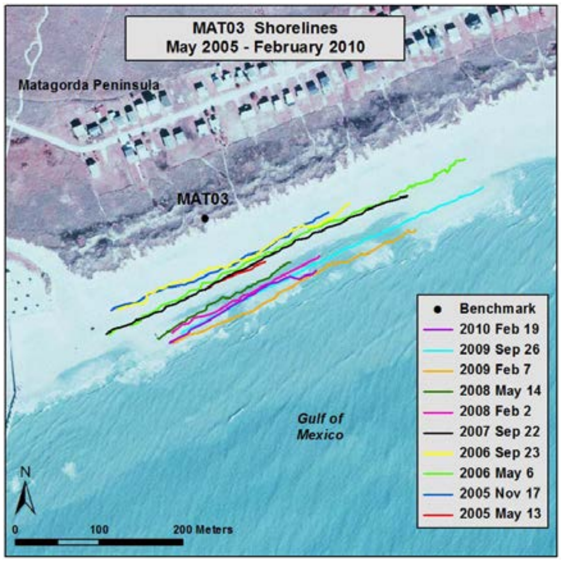
100
200 Meters


MAT03 Shorelines
May 2005 - February 2010
Matagorda Peninsula
MAT03
Gulf of Mexico
Benchmark
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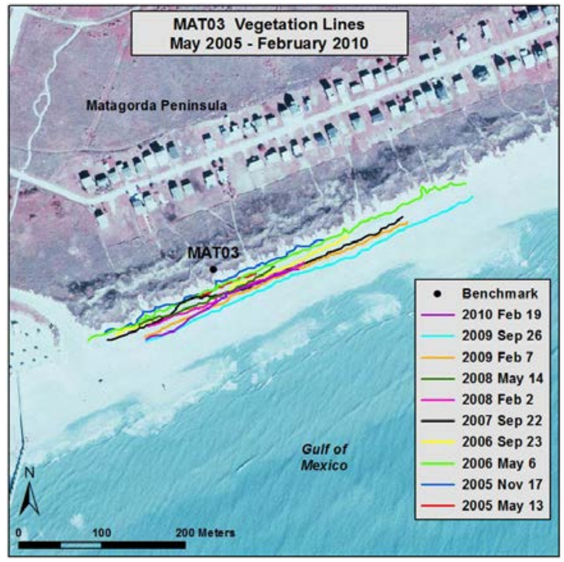
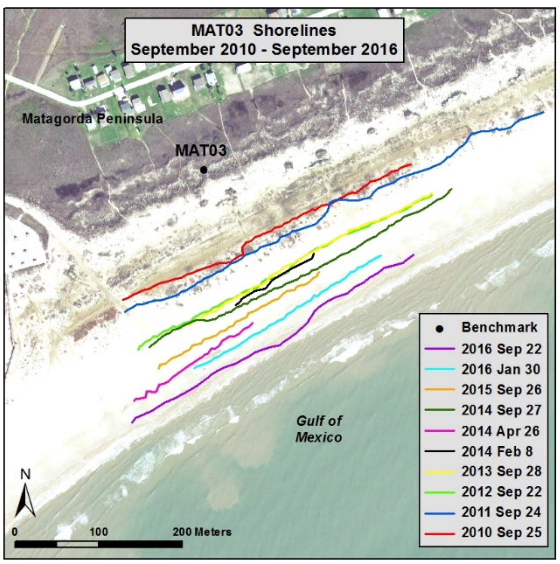
2008 May 14
2008 Feb 2
2007 Sep 22
2006 Sep 23
2006 May 6
2005 Nov 17
2005 May 13
N
0 100 200 Meters


MAT03 Vegetation Lines
May 2005 - February 2010
Matagorda Peninsula
MAT03
Gulf of Mexico
Benchmark
2010 Feb 19
2009 Sep 26
2009 Feb 7
2008 May 14
2008 Feb 2
2007 Sep 22
2006 Sep 23
2006 May 6
2005 Nov 17
2005 May 13
N
0 100 200 Meters


MAT03 Shorelines
September 2010 - September 2016
Matagorda Peninsula
MAT03
Gulf of Mexico
Benchmark
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2014 Feb 8
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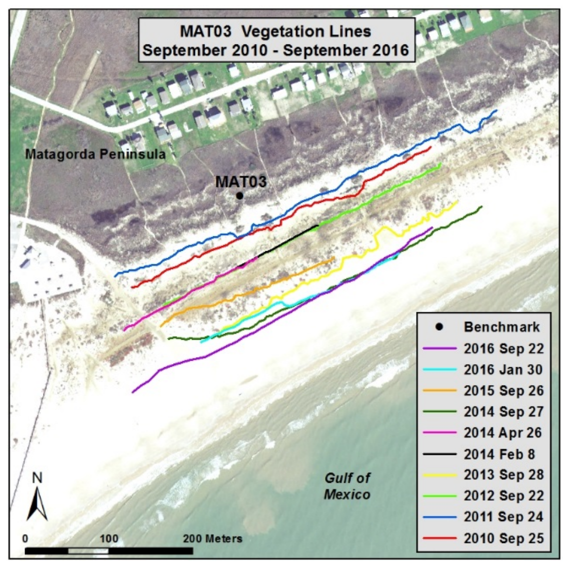
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Matagorda Peninsula
MAT03
Gulf of Mexico
Benchmark
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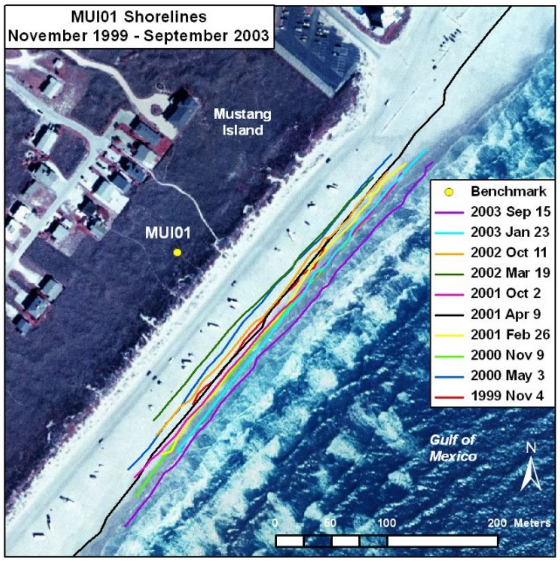
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2000 May 3
1999 Nov 4
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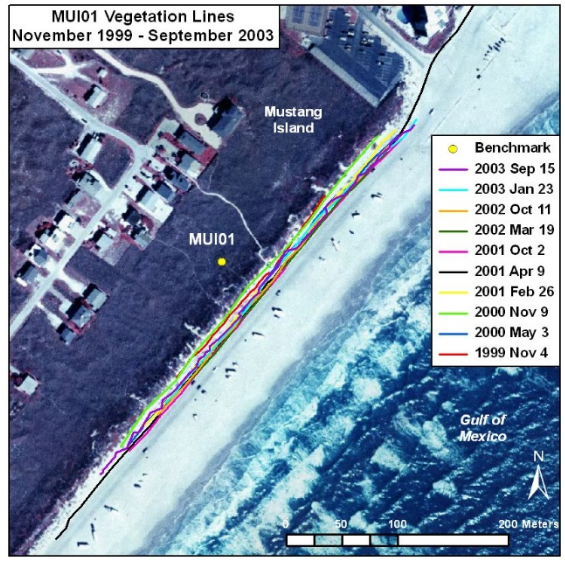
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1999 Nov 4
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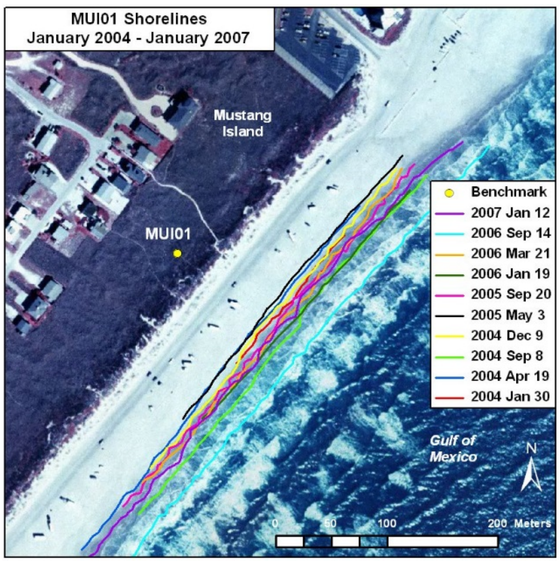
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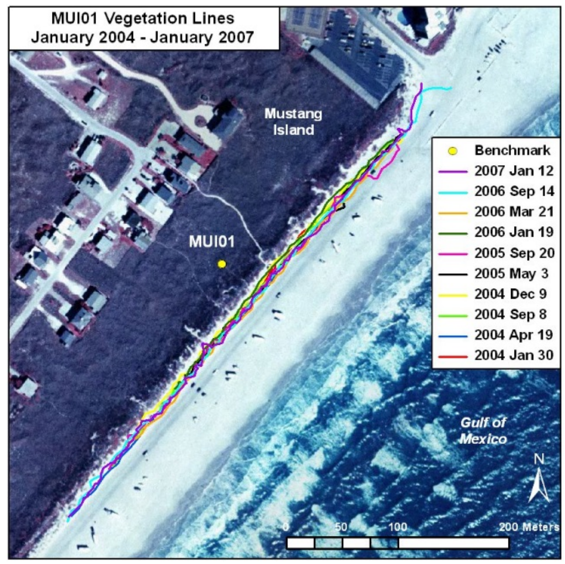
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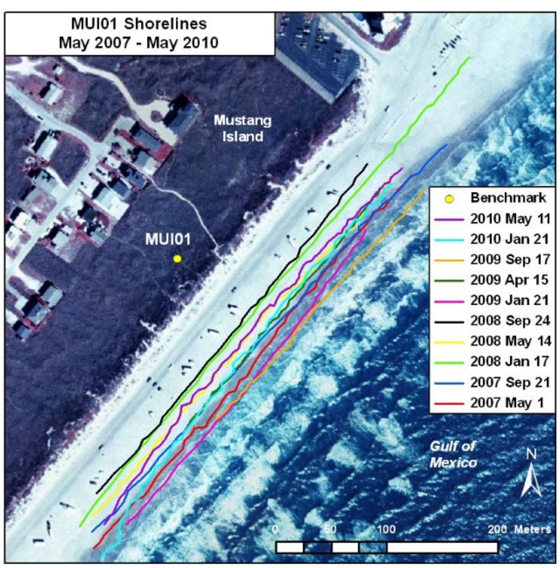
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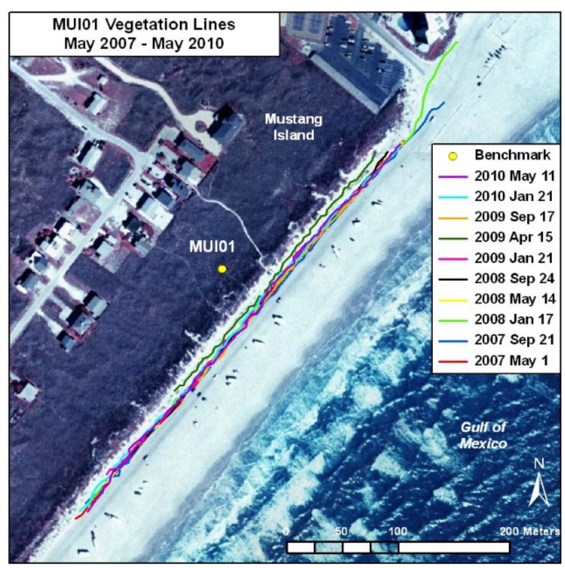
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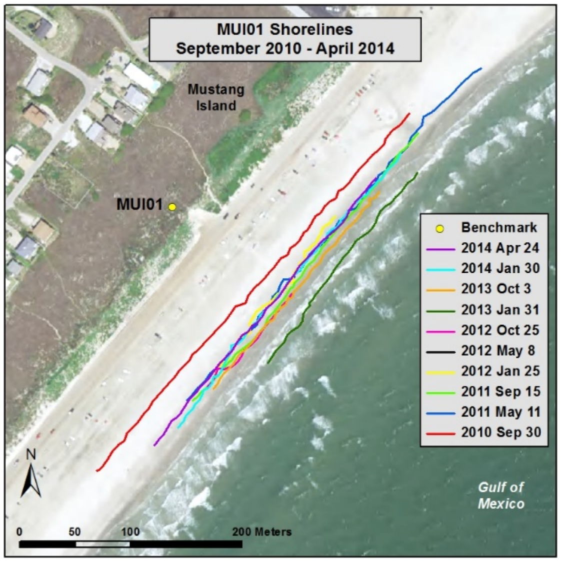
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Benchmark
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2010 Sep 30
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Gulf of Mexico
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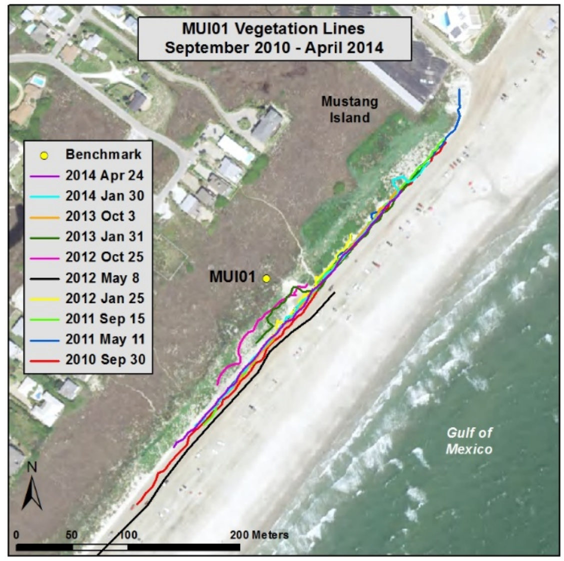
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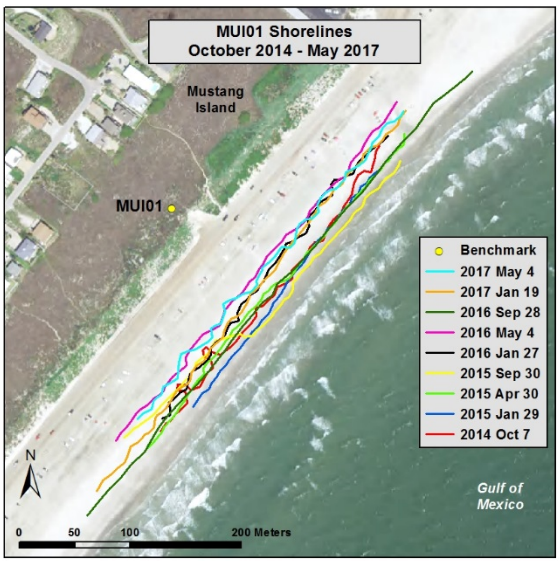
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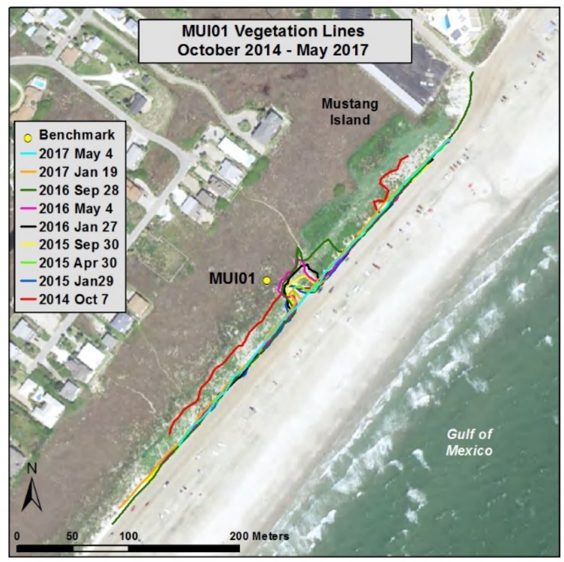
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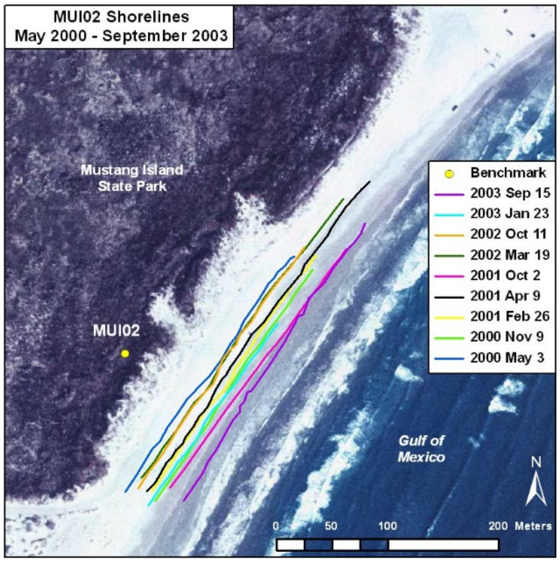
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Mustang Island State Park
MUI02
Benchmark
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2001 Apr 9
2001 Feb 26
2000 Nov 9
2000 May 3
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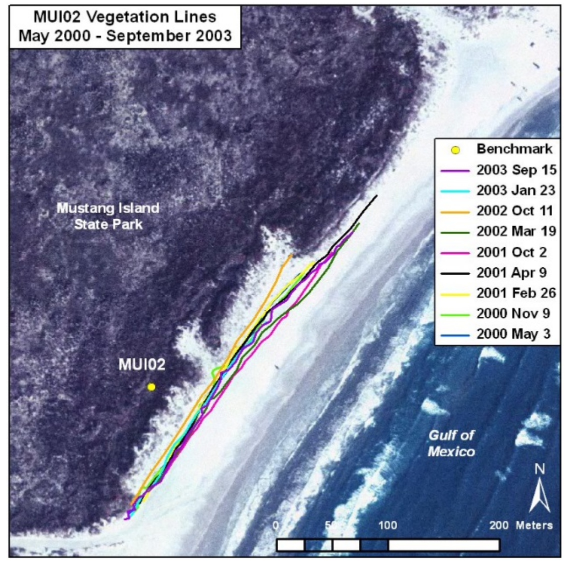
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MUI02
Benchmark
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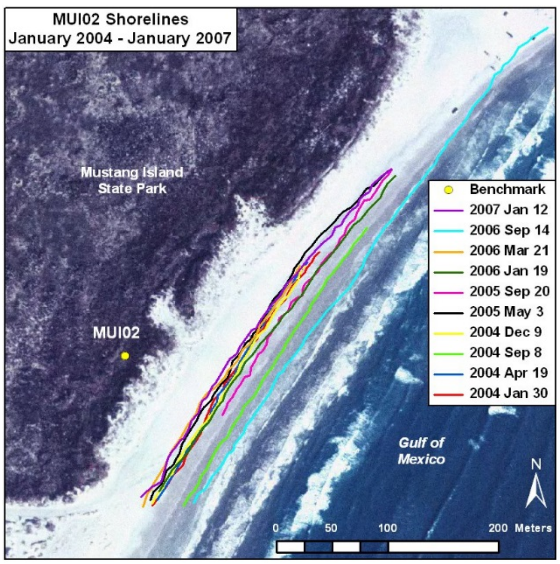
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Benchmark
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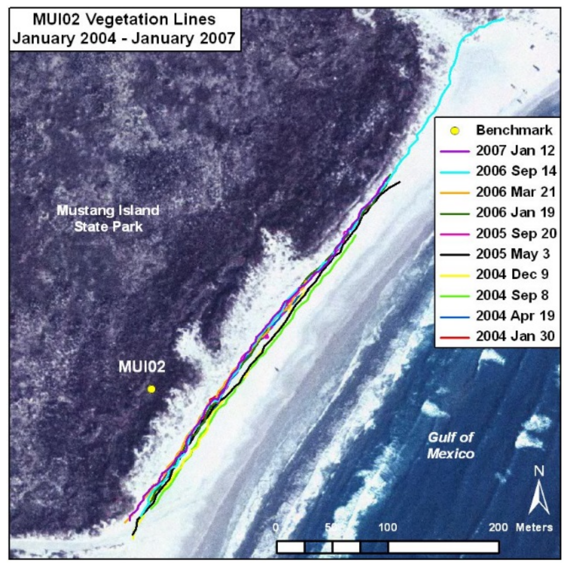
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Benchmark
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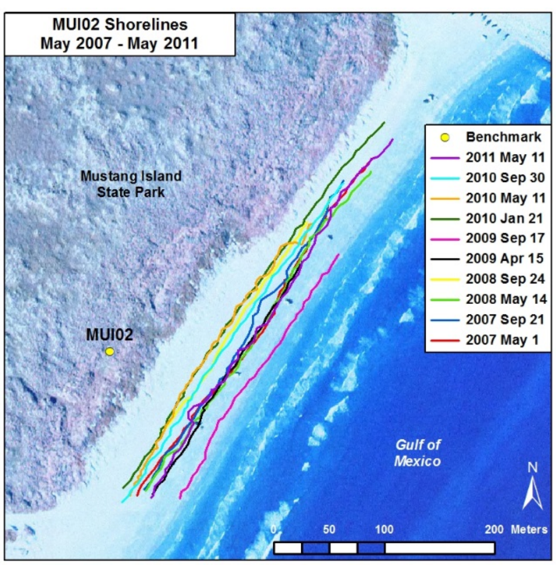
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Benchmark
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2007 May 1
Gulf of Mexico
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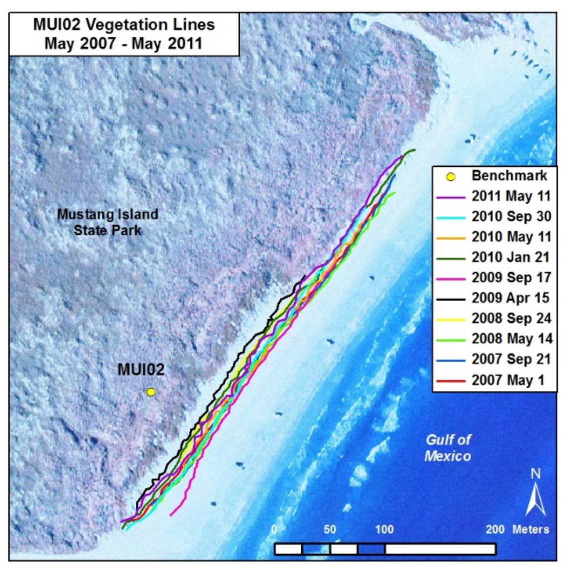
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MUI02
Benchmark
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2007 May 1
Gulf of Mexico
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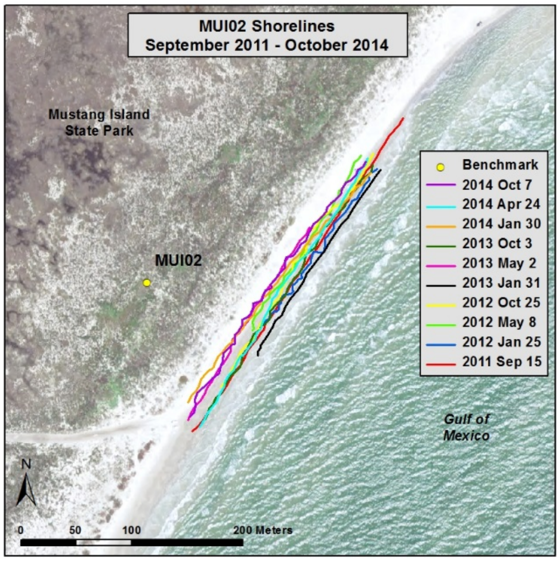
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State Park
MUI02
Benchmark
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2014 Apr 24
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2012 Oct 25
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2012 Jan 25
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Gulf of
Mexico
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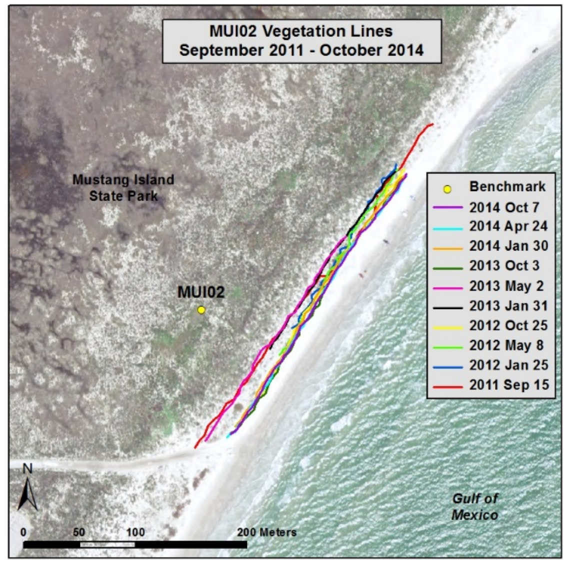
200 Meters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State Park
MUI02
Benchmark
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Gulf of
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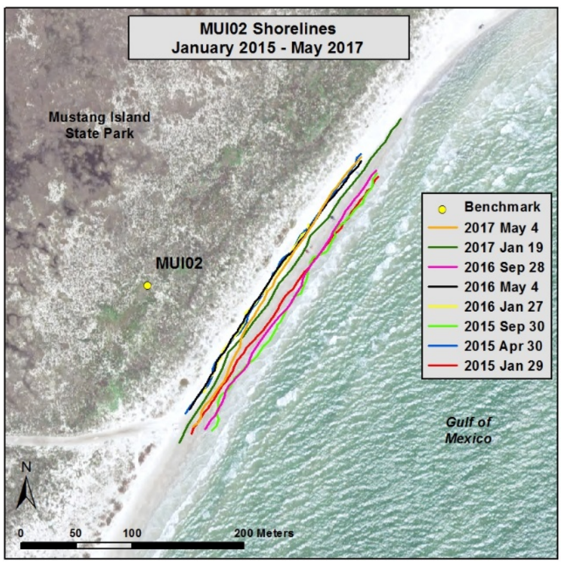
MUI02 Shorelines
January 2015 - May 2017
Mustang Island
State Park
MUI02
Benchmark
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2017 Jan 19
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2016 Jan 27
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2015 Jan 29
Gulf of
Mexico
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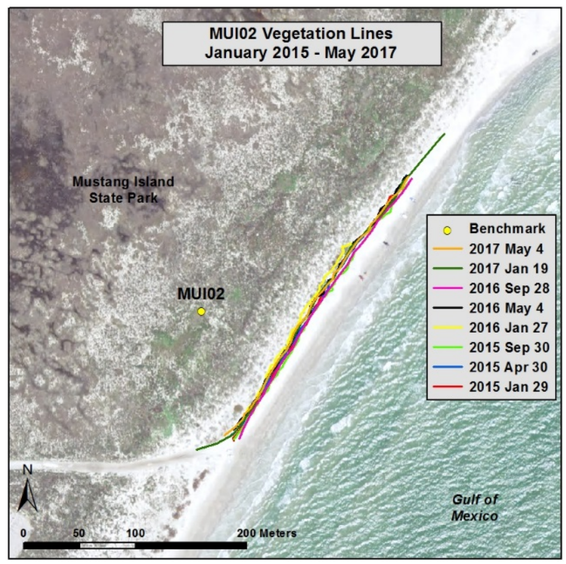
200 Meters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State Park
MUI02
Benchmark
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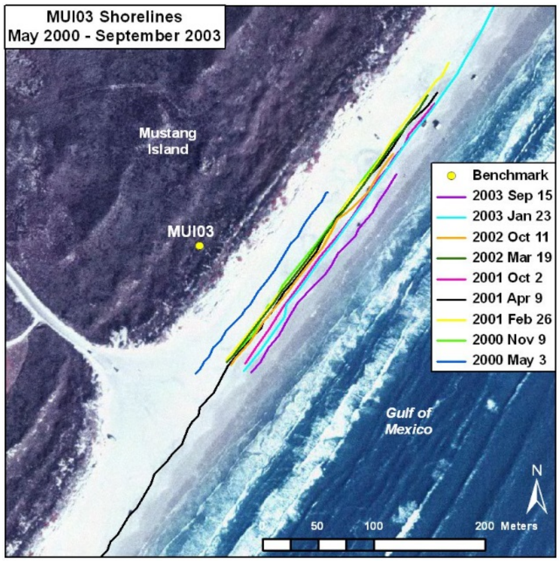
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Mustang Island
MUI03
Benchmark
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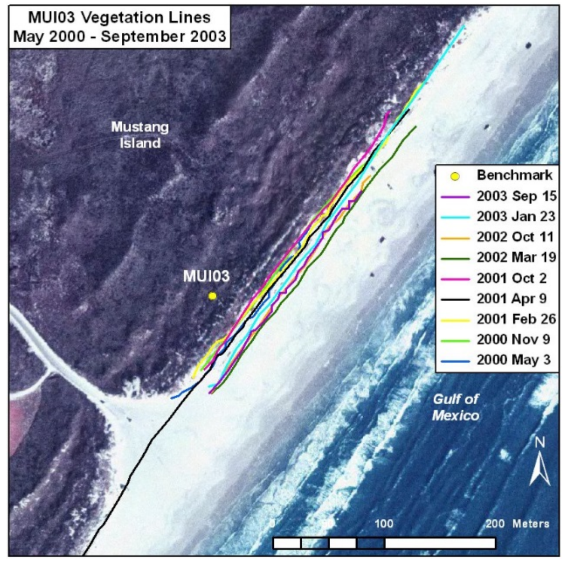
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Mustang Island
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Benchmark
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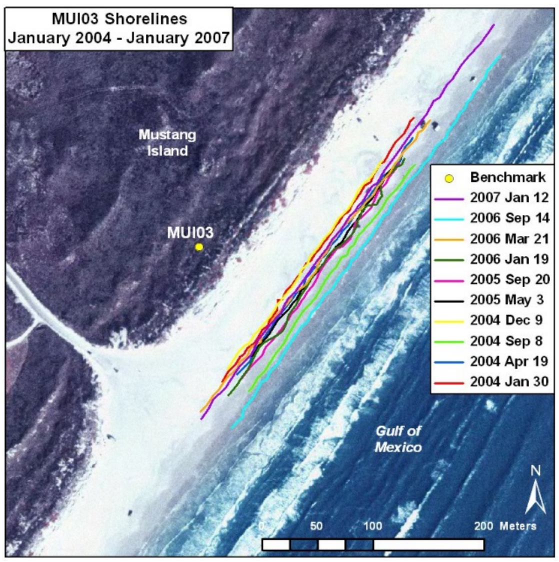
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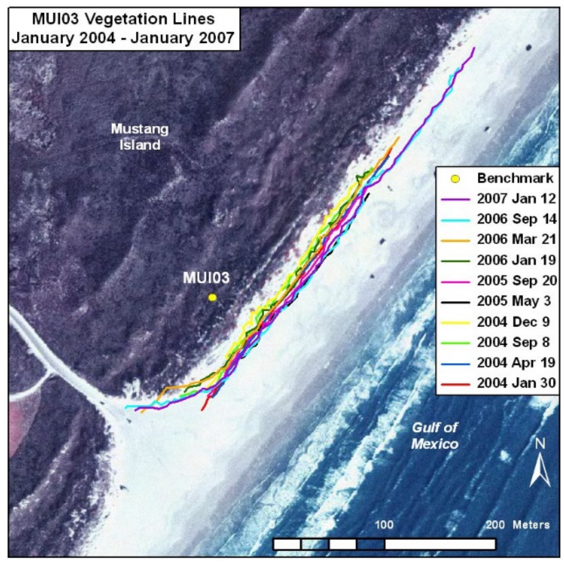
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Gulf of Mexico
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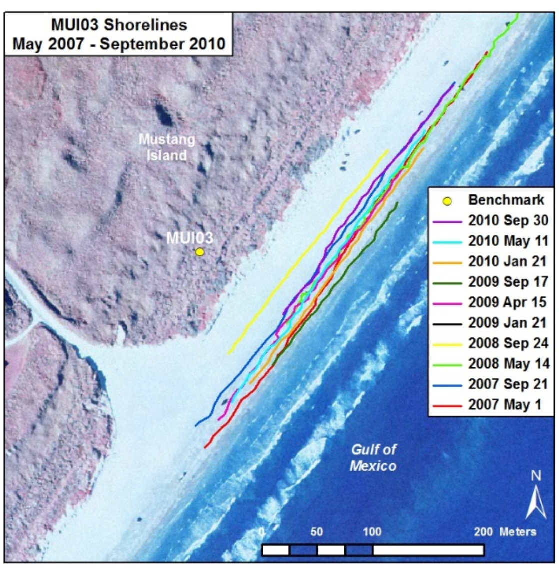
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Gulf of Mexico
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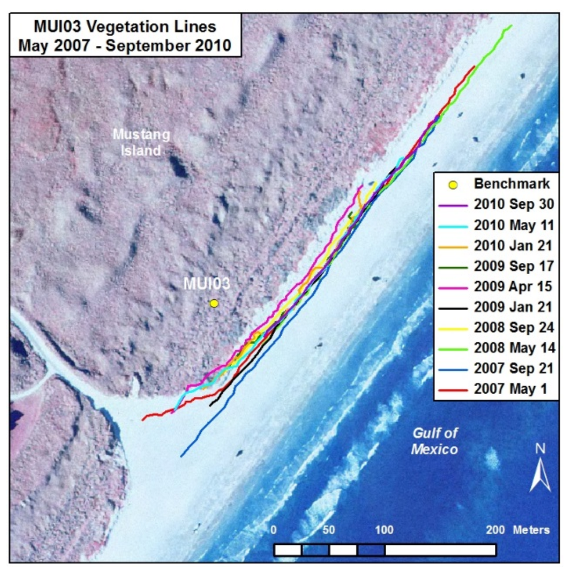
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Benchmark
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Gulf of Mexico
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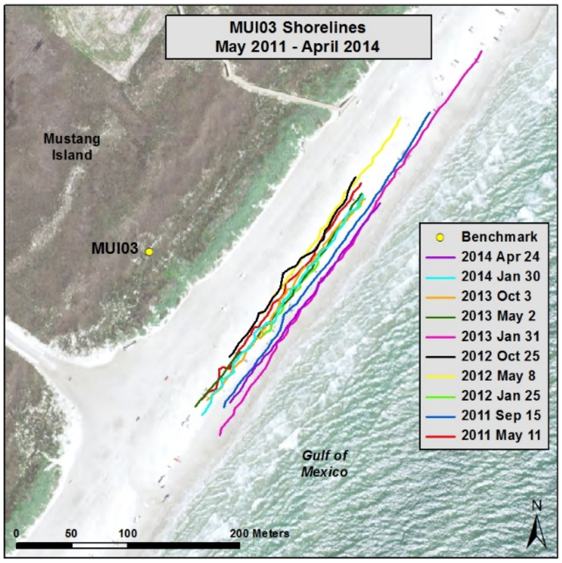

MUI03 Shorelines
May 2011 - April 2014
Mustang Island
MUI03
Benchmark
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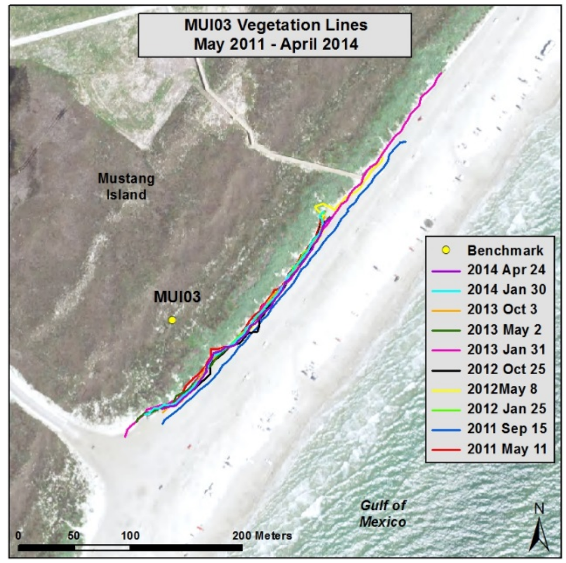

MUI03 Vegetation Lines
May 2011 - April 2014
Mustang Island
MUI03
Benchmark
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200 Meters
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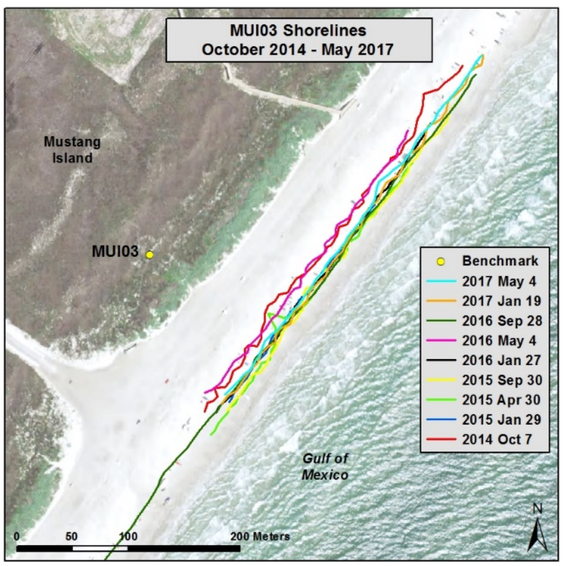

MUI03 Shorelines
October 2014 - May 2017
Mustang Island
MUI03
Benchmark
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200 Meters
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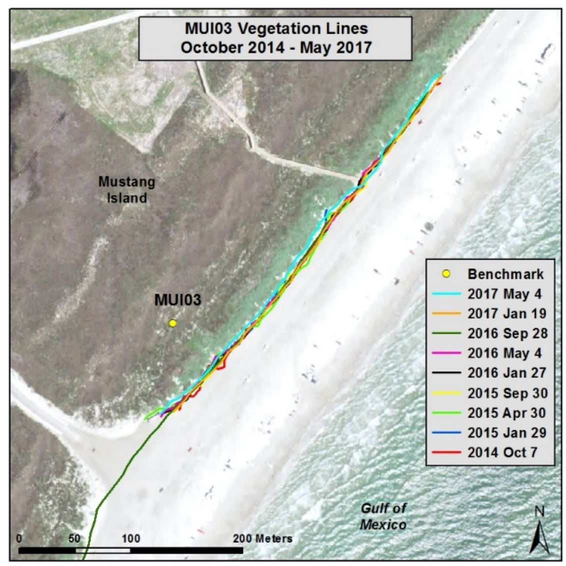

MUI03 Vegetation Lines
October 2014 - May 2017
Mustang Island
MUI03
Benchmark
2017 May 4
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Gulf of Mexico
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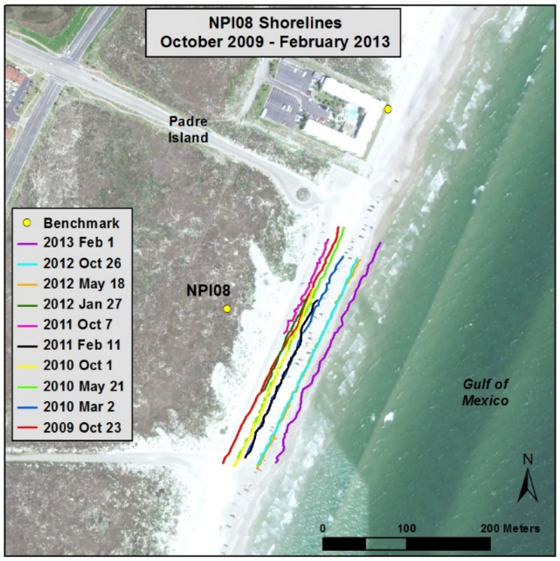
200 Meters
N


NPI08 Shorelines
October 2009 - February 2013
Padre Island
NPI08
Gulf of Mexico
Benchmark
2013 Feb 1
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2011 Oct 7
2011 Feb 11
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2010 May 21
2010 Mar 2
2009 Oct 23
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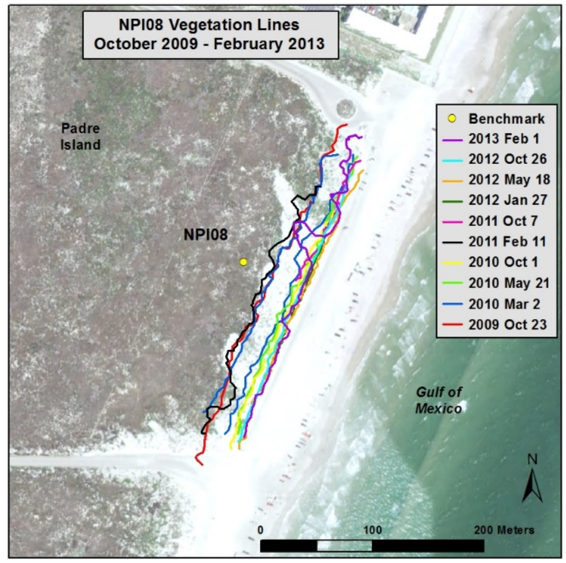
200 Meters


NPI08 Vegetation Lines
October 2009 - February 2013
Padre Island
NPI08
Gulf of Mexico
Benchmark
2013 Feb 1
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2010 Mar 2
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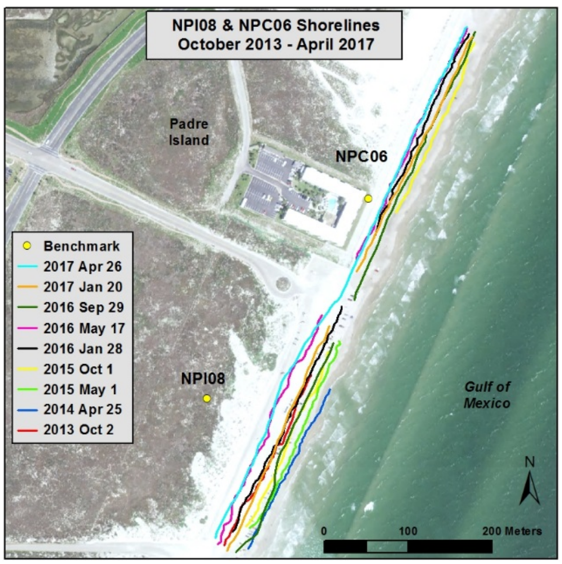
200 Meters


NPI08 & NPC06 Shorelines
October 2013 - April 2017
Padre Island
NPC06
NPI08
Gulf of Mexico
Benchmark
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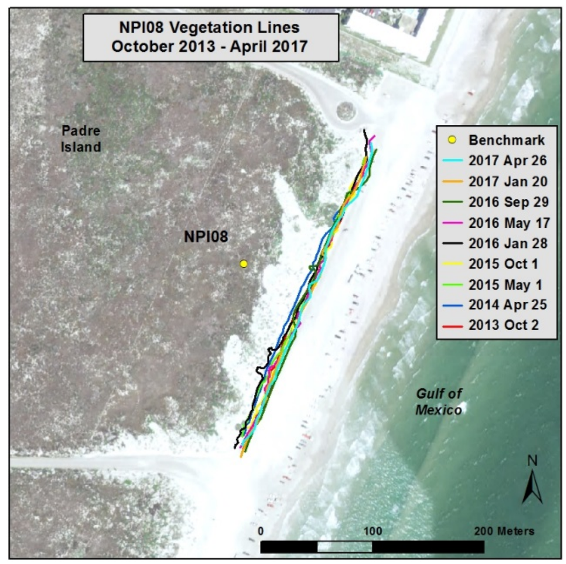
200 Meters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Padre Island
NPI08
Gulf of Mexico
Benchmark
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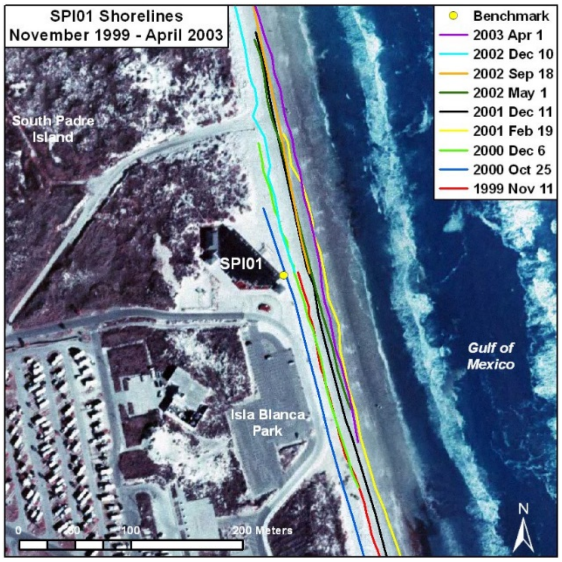
200 Meters


SPI01 Shorelines
November 1999 - April 2003
Benchmark
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South Padre Island
SPI01
Isla Blanca Park
Gulf of Mexico
200 Meters
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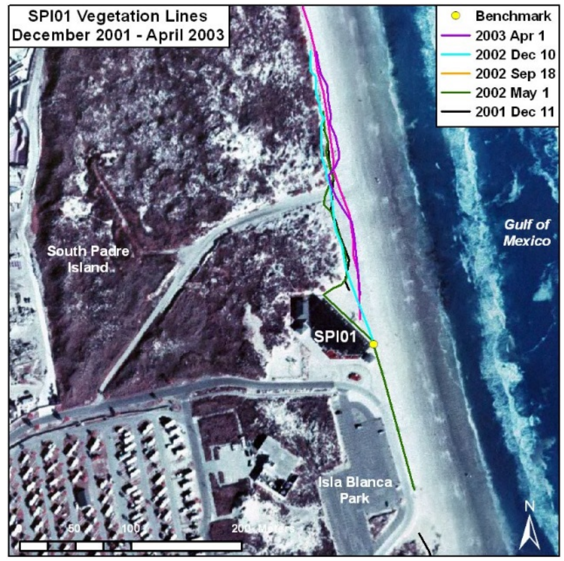
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Benchmark
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South Padre Island
SPI01
Isla Blanca Park
Gulf of Mexico
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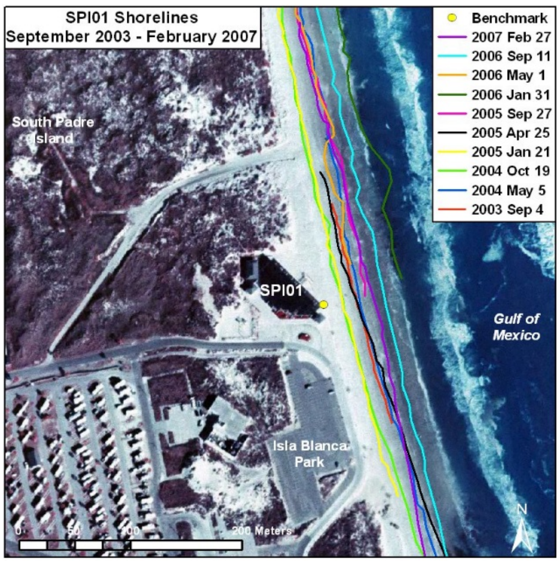
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SPI01
Isla Blanca Park
Gulf of Mexico
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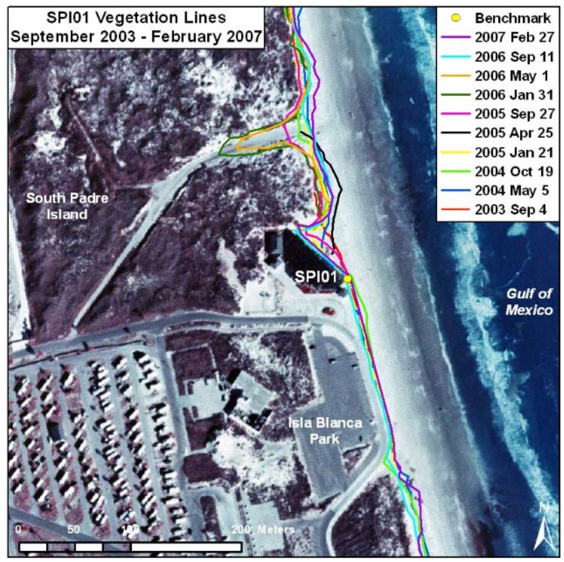
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Isla Blanca Park
Gulf of Mexico
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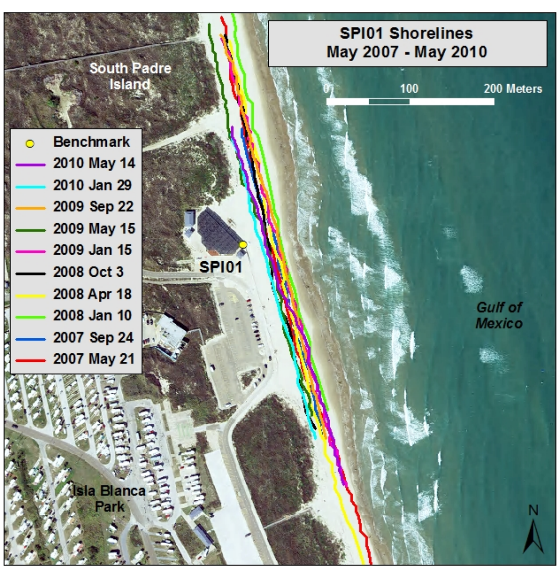
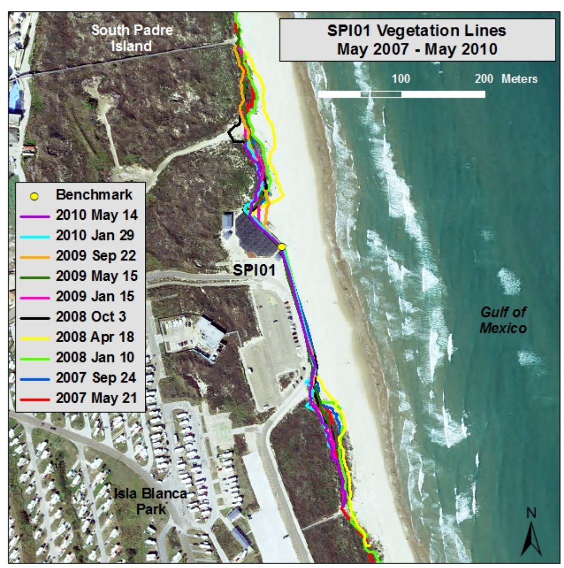

SPI01 Shorelines
May 2007 - May 2010
0 100 200 Meters
South Padre Island
Benchmark
2010 May 14
2010 Jan 29
2009 Sep 22
2009 May 15
2009 Jan 15
2008 Oct 3
2008 Apr 18
2008 Jan 10
2007 Sep 24
2007 May 21
SPI01
Gulf of Mexico
Isla Blanca Park
N


South Padre Island
SPI01 Vegetation Lines
May 2007 - May 2010
0 100 200 Meters
Benchmark
2010 May 14
2010 Jan 29
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2007 May 21
SPI01
Gulf of Mexico
Isla Blanca Park
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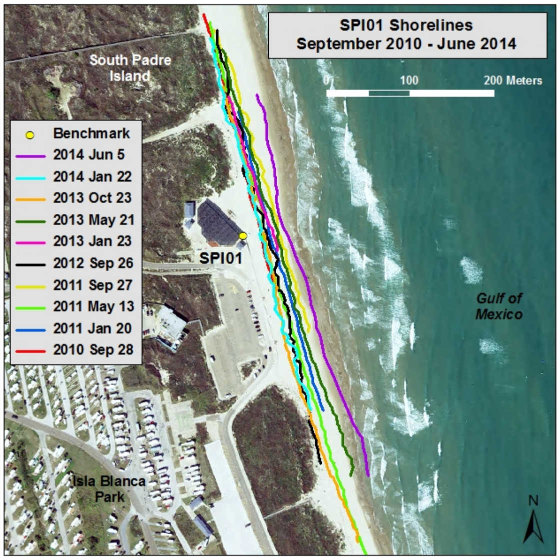
SPI01 Shorelines
September 2010 - June 2014
0
100
200 Meters
South Padre
Island
Benchmark
2014 Jun 5
2014 Jan 22
2013 Oct 23
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2012 Sep 26
2011 Sep 27
2011 May 13
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2010 Sep 28
SPI01
Gulf of
Mexico
Isla Blanca
Park
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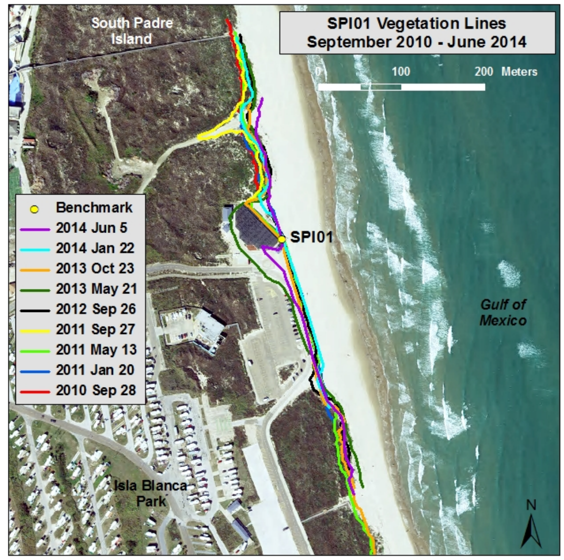
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South Padre
Island
Benchmark
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SPI01
Gulf of
Mexico
Isla Blanca
Park
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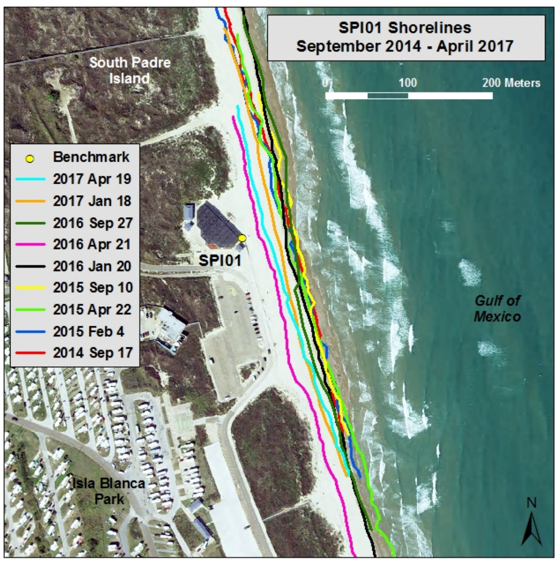
SPI01 Shorelines
September 2014 - April 2017
0
100
200 Meters
South Padre
Island
Benchmark
2017 Apr 19
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2015 Sep 10
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SPI01
Gulf of
Mexico
Isla Blanca
Park
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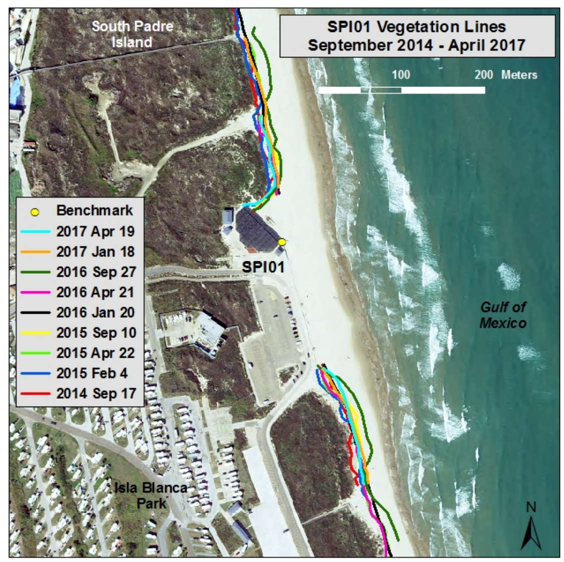
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Benchmark
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SPI01
Gulf of
Mexico
Isla Blanca
Park
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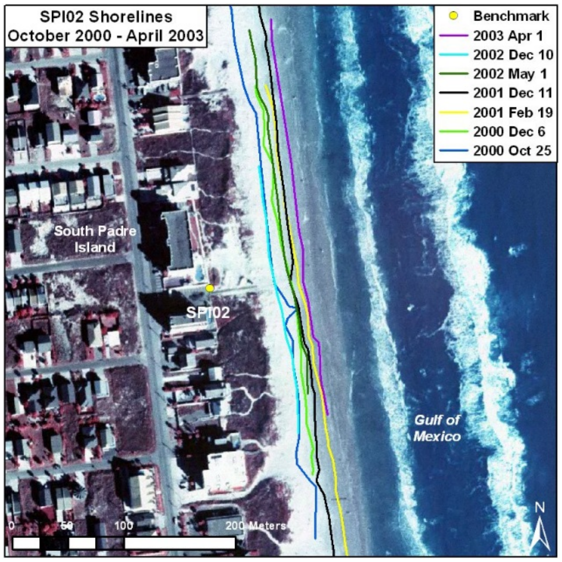
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October 2000 - April 2003
Benchmark
2003 Apr 1
2002 Dec 10
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2001 Dec 11
2001 Feb 19
2000 Dec 6
2000 Oct 25
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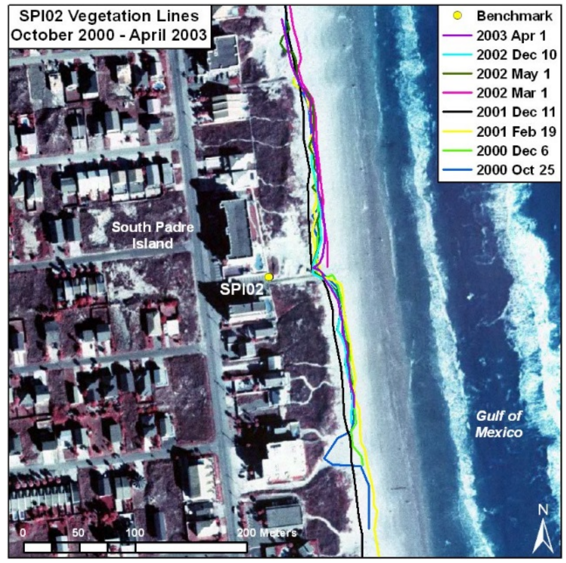
SPI02
Gulf of Mexico
0 50 100 200 Meters
N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Gulf of Mexico
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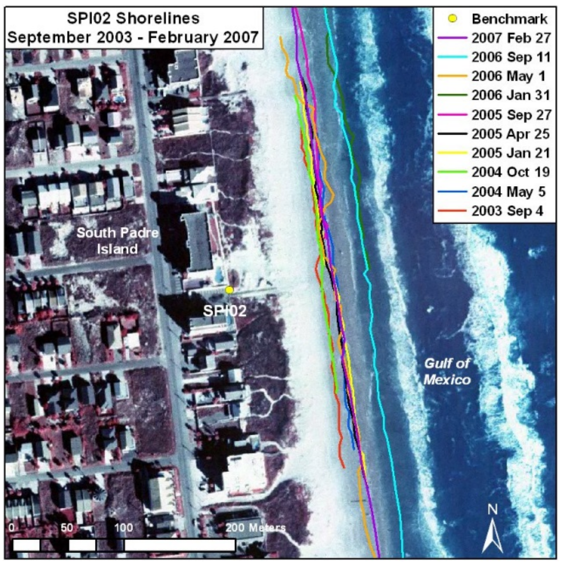
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September 2003 - February 2007
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Gulf of Mexico
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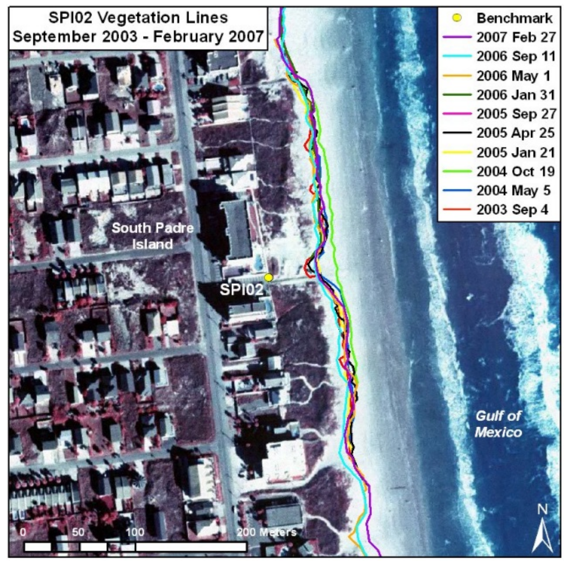
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SPI02
Gulf of Mexico
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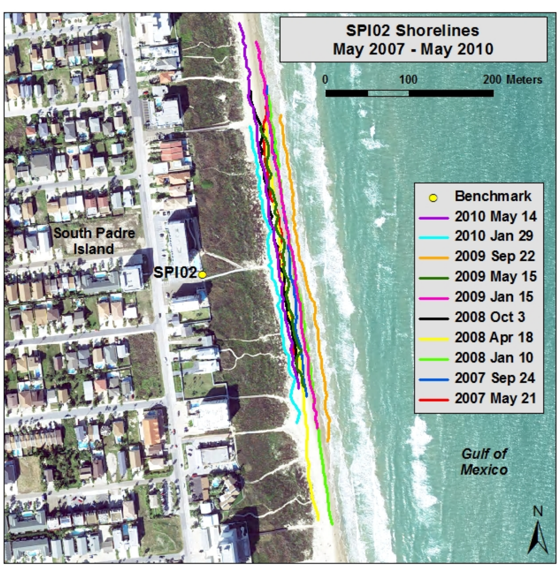
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SPI02
Gulf of Mexico
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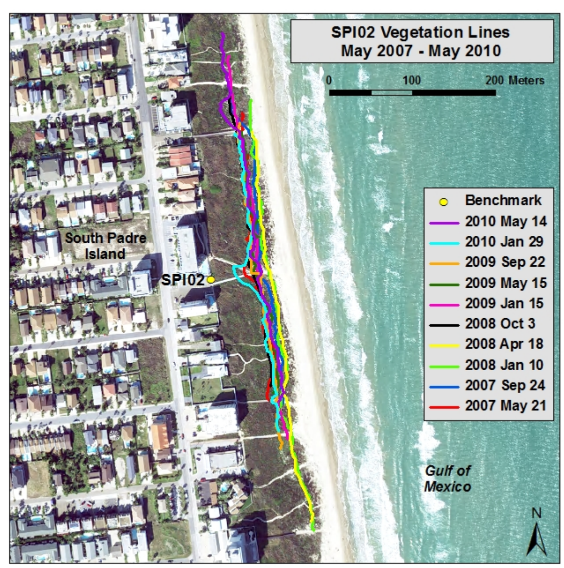
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2007 May 21
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SPI02
Gulf of Mexico
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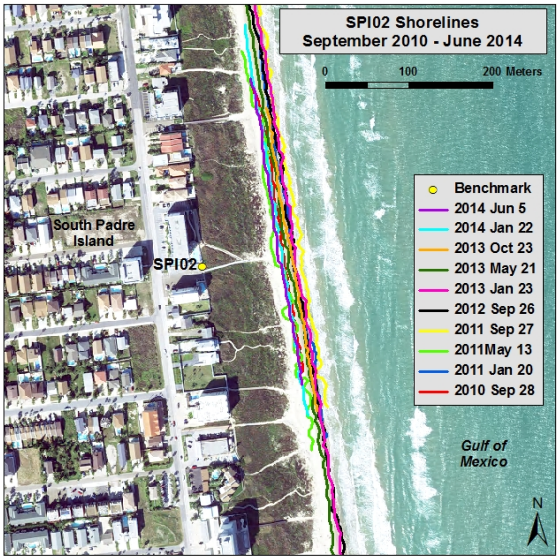
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200 Meters
Benchmark
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South Padre Island
SPI02
Gulf of Mexico
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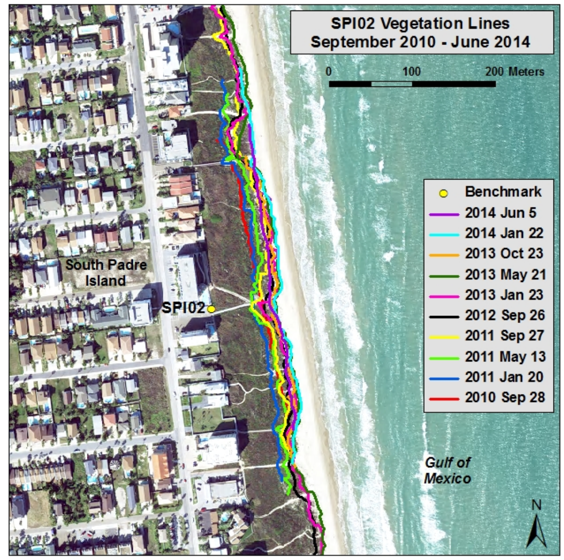
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SPI02
Gulf of Mexico
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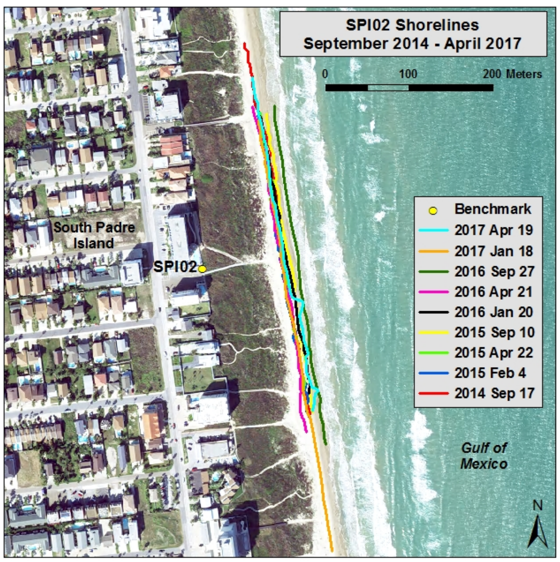
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South Padre Island
SPI02
Gulf of Mexico
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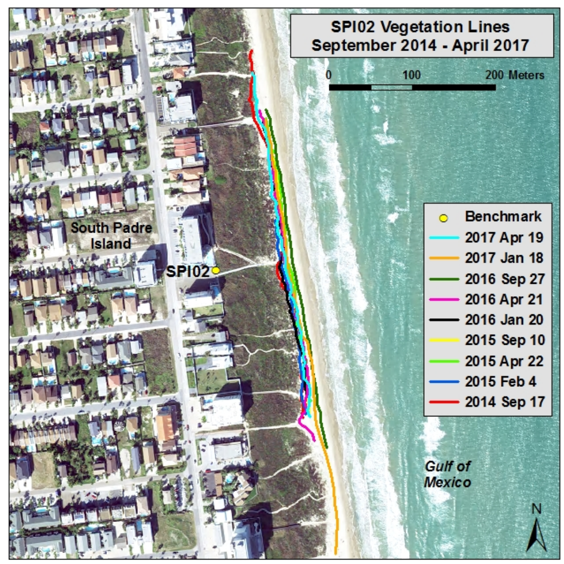
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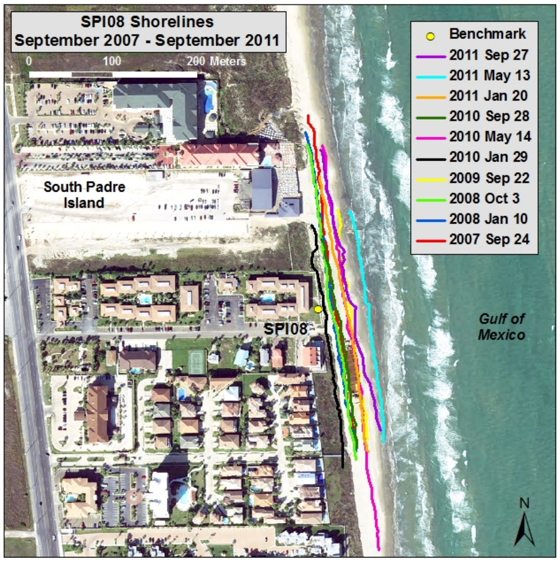
2014 Sep 17
South Padre Island
SPI02
Gulf of Mexico
N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2009 Sep 22
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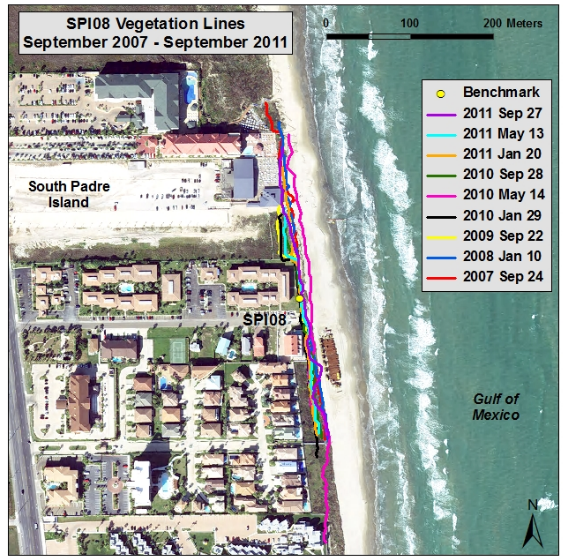
2008 Jan 10
2007 Sep 24
South Padre Island
SPI08
Gulf of Mexico
N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2007 Sep 24
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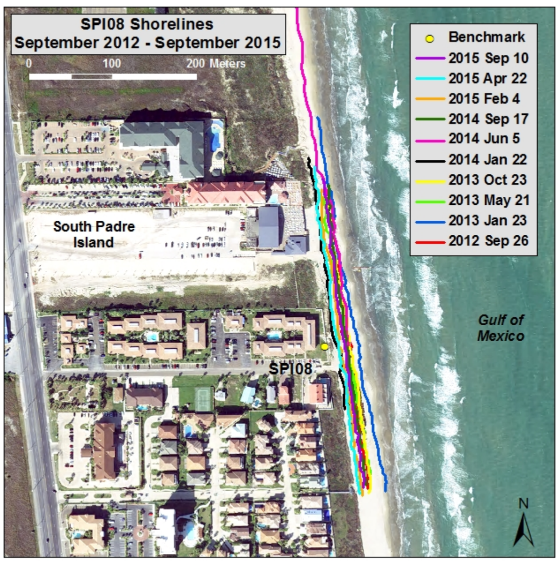
SPI08
Gulf of Mexico
N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South Padre Island
SPI08
Gulf of Mexico
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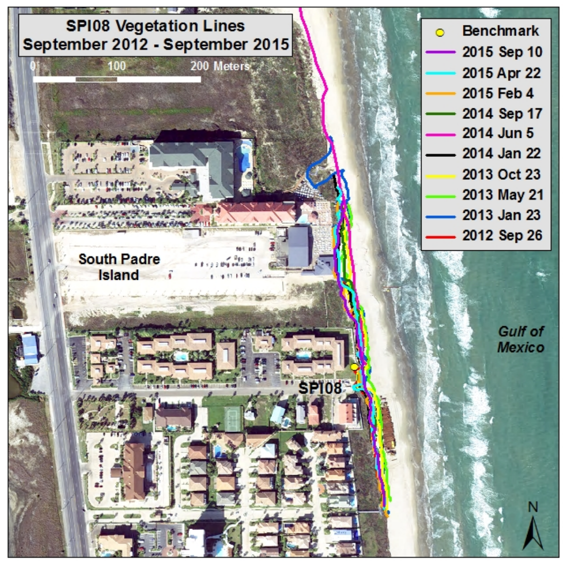
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South Padre Island
SPI08
Gulf of Mexico
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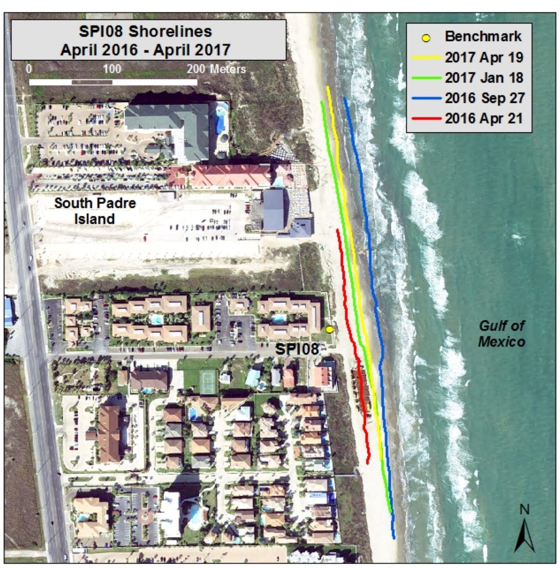
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Gulf of Mexico
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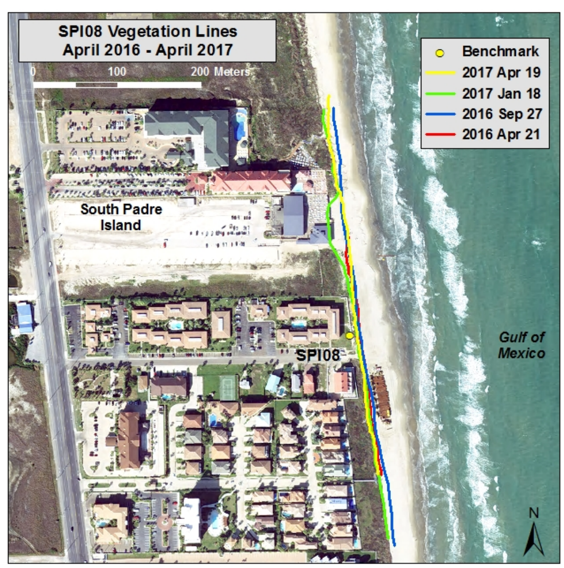
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