**F I N A L   R E P O R T**

# Texas High School Coastal Monitoring Program: 2012–2013

Tiffany L. Caudle


## Bureau of Economic Geology

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**Austin, Texas 78713-8924**


**June 2013**

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# Texas High School Coastal Monitoring Program: 2012–2013

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

**Tiffany L. Caudle**

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Coastal Studies Group

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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 there. 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 2012–2013 academic year. During this time, Ball High School on Galveston Island completed its fifteenth year in the program, and Port Aransas and Port Isabel High Schools completed their fourteenth year (Fig. 1). Through collaboration with the Lower Colorado River Authority, the program works with three schools in the Bay City, Texas, region. Tidehaven and Van Vleck Middle Schools completed their ninth year in the program, and Palacios High School completed its seventh year. Cunningham Middle School in the Corpus Christi Independent School District participated in its first field trip in late spring of 2009. The 2012–2013 academic year marked its fifth year in the program. All of the schools anticipate continuing with the program during the 2013–2014 academic year. Discussions of data collected by the students are included in this report. A manual with detailed field procedures, field forms, classroom exercises, and teaching materials was prepared during the first year of the project at Ball High School in 1997–1998. The manual was updated with the addition of the Bay City region schools in 2005. The program is also enhanced by a continuously updated website (http://www.beg.utexas.edu/coastal/thscmp/).

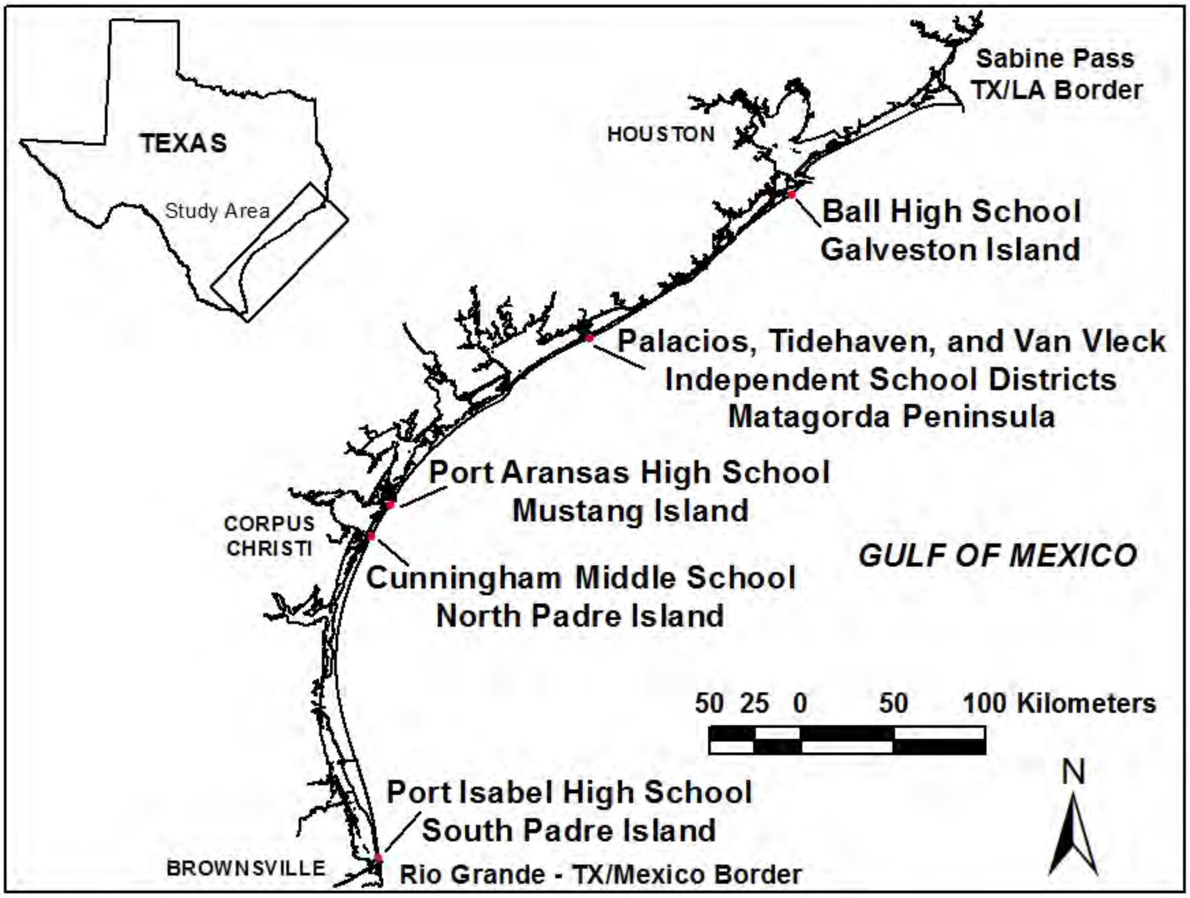

Figure 1. Participating schools.

## PROGRAM DESCRIPTION

### Goals

The coastal monitoring program has three major goals:

*(1) Provide high school 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 Winter 2006 and Winter 2009 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. A website (http://www.beg.utexas.edu/coastal/thscmp/) containing the latest information is central to the community outreach part of the project. If coastal residents wish to view the effects of a storm that strikes the upper coast, they are able to do so by accessing the THSCMP website to view maps, graphs, and photographs collected by Ball High School. Curiosity may drive this inquiry at first, but eventually awareness and appreciation of coastal processes and how future storms could affect a community will increase.

*(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 quasi-periodic 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 presented in detail in a manual and on the website, which also includes field forms. Following is a general discussion of the field measurements.

*(1) Beach profile*. 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 (Fig. 2). 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.

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

*(2) Shoreline and vegetation-line mapping.* Using a differential Global Positioning System (GPS) receiver, students walk along the vegetation line and shoreline mapping these features for display on Geographic Information System software. The GPS mapping provides measurements of the rate of change.

*(3) Sediment sampling.* Students occasionally take sediment samples along the beach profile at the foredune crest, berm top, and beach face. They then sieve the samples, weigh the grain-size fractions, and inspect the grains using a microscope. These samples show the dependence of sand characteristics on the various processes acting on the beach.

*(4) Beach processes* (Fig. 3). 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, stop watch, and tape measure. They also take readings of shoreline and foredune orientation. From these measurements, students 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.

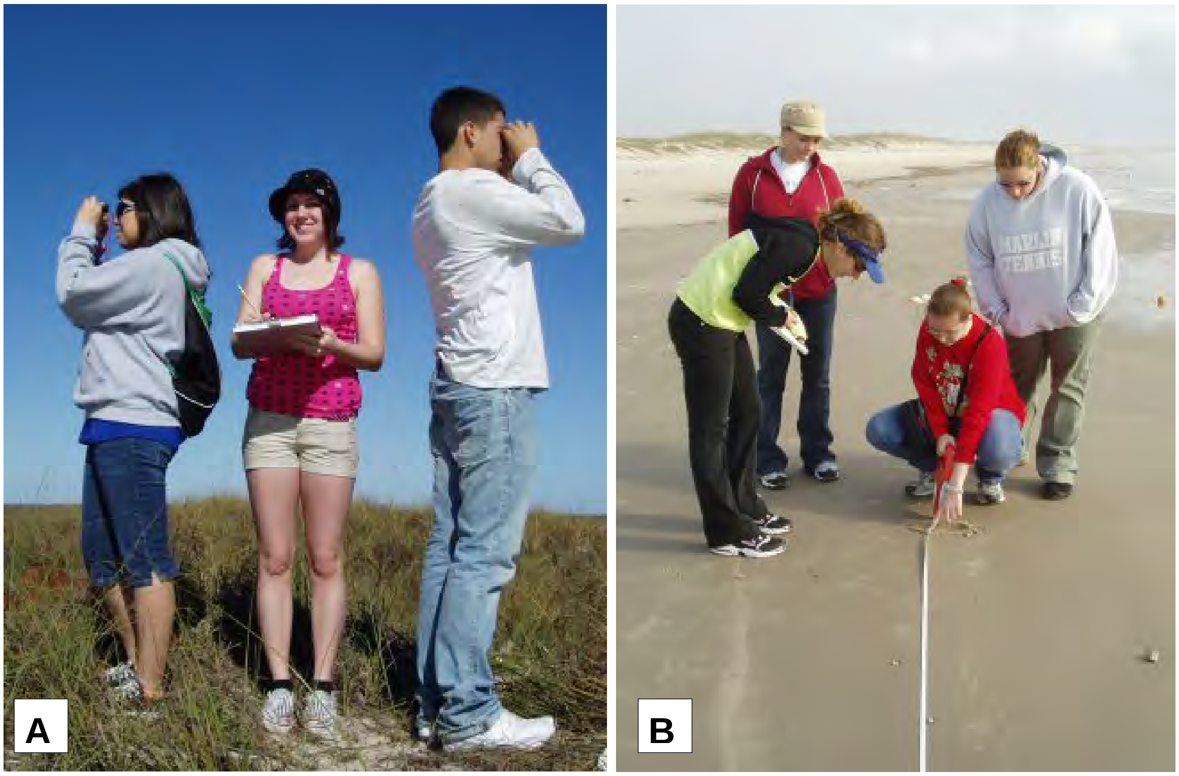

Figure 3. Students (A) using a sighting compass to measure dune orientation and (B) measuring how far along the shoreline the float (an orange) drifted to determine longshore current.

## Training

Bureau scientists provide teachers 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 the 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 website (http://www.beg.utexas.edu/coastal/thscmp/), which resides on a UT server, was implemented toward the end of the 1998–1999 academic year. The website 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 photos taken by an electronic camera. Bureau scientists manage the data in an electronic database and make them available to the public. Bureau scientists also evaluate the data in light of coastal management problems.

## STUDENT, TEACHER, AND SCIENTIST INTERACTIONS DURING THE 2012–2013 ACADEMIC YEAR

Bureau scientist Ms. Tiffany Caudle worked with teachers Ms. Sara Black of Ball High School, Mr. Ryan Piwetz of Port Aransas High School, and Dr. Michelle Zacher of Port Isabel High School. Ms. Black chose her Advanced Placement Environmental Science classes to participate in the program. Mr. Piwetz chose his Aquatic Sciences classes to participate in the program. Port Isabel High School biology teacher, Dr. Zacher, tapped juniors and seniors taking Dual Enrollment Biology for participation.

The Bureau is working together with the Lower Colorado River Authority (LCRA) at Matagorda Bay Nature Park. This collaboration has allowed the Bureau to expand the THSCMP to three schools in the Bay City, Texas, region. Expansion of the program not only increased the number of schools, but now includes younger students, who are making the same field measurements as the high school students, but who are visiting only one profile site per field trip.

Ms. Caudle worked with teachers Mr. Warren Morris of Palacios High School, Mr. Robert Hutto and Mr. Duane Schroedter from Tidehaven Middle School, and Ms. Meredith Keelan of Van Vleck Middle School during the first field trip of the 2012–2013 academic year. Representatives from LCRA worked with teachers and students during the winter and spring field trips.

After a workshop held at TAMUCC in November 2008, the Innovation Academy for Engineering, Environmental and Marine Science, at Cunningham Middle School (Corpus Christi Independent School District) expressed interest in joining the program. Ms. Caudle and Ms. Diana Del Angel (TAMUCC) worked with Mr. Johnnie Darnell and Ms. Rebekah Sutton at Cunningham Middle School during the 2012–2013 academic year.

A Bureau scientist visited with each school at least once, letting the visits coincide with the first field trip of the academic year. During the course of the field trips, the scientist discussed coastal issues pertaining to the area of the coast that the students are visiting, coastal issues concerning the entire state of Texas, and careers in science. These visits served not only to enhance scientific instruction, but they also gave 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 profile while the other team collected data on weather and waves and conducted a GPS survey of the shoreline and vegetation line. Team members had specific tasks, and students took turns performing them. 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 two four- to seven-member teams works well. One team conducts the beach profile, and the other measures processes and the shoreline. Extra 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 Advanced Placement students at Ball, Port Aransas, and Port Isabel High Schools. Adding middle-school students to the program has changed our approach to working with students, but only slightly. For example, Bay City regional schools, which collect data on Matagorda Peninsula, collect data from only one monitoring site. Because of the distance from the schools to the beach (~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, etc.). 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 (seine, cast nets, etc.) 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 the 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. Following are details on activities at each school.

## Ball High School

Hurricane Ike struck the Texas coast near Galveston Island at the beginning of the 2008–2009 academic year. Because of the catastrophic impact that Galveston Island received from the hurricane, Ball High School was closed for several weeks. In early October 2008, after inspection of the island by Bureau and Texas A&M University Corpus Christi (TAMUCC) scientists, it was determined that the monitoring site at Galveston Island State Park (BEG02) was unsafe for students to visit until debris was removed and the park was reopened. Profile BEG08 on Follets

Island was inaccessible to buses because the Blue Water Highway (FM 3005) had been severely damaged during the storm surge. Although the highway is now reopened, Ball High students have not resumed monitoring this location. The original datum point for BEG08 was unrecoverable following Hurricane Ike. A new datum point was set on the landward side of the Blue Water Highway, which would require students to cross the highway on foot while conducting the profile. Students from Ball High School did not participate in the program during the 2008–2009 academic year, although data were collected at these sites by Bureau and TAMUCC scientists. Ball High School rejoined the program for the 2009–2010 academic year with a new teacher and a new monitoring site.

Ms. Sara Black's AP Environmental Science classes at Ball High School participated in field trips on September 27, 2012; January 24, 2013; and May 22, 2013. They conducted surveys at two locations in Galveston Island State Park—BEG02 and GLO06 (Fig. 4)—profiles that the Bureau has been measuring since the 1980's. Ms. Caudle accompanied the class on all three trips and provided further training and background information to the students.


Figure 4. Location map of Ball High School monitoring sites.

## Port Aransas High School

Port Aransas students participated in field trips on October 25, 2012; January 31, 2013; and May 2, 2013. Mr. Piwetz' class collected data at three profile locations on Mustang Island: MUI01 near Horace Caldwell Pier, MUI02 in Mustang Island State Park, and MUI03 (Fig. 5). Port Aransas High School has been measuring these profiles since 1999. Ms. Caudle accompanied the class on all three field trips.

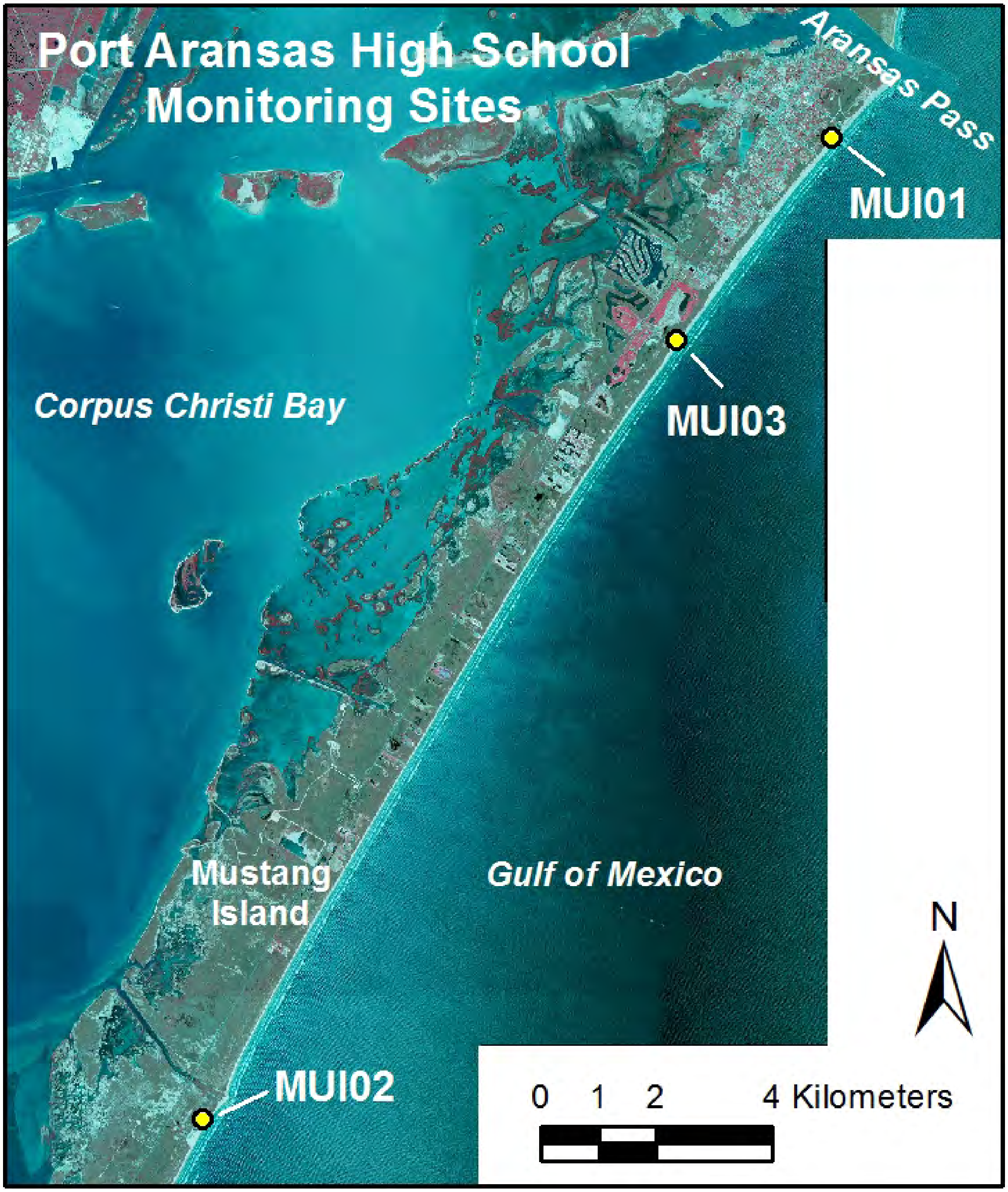


Figure 5. Location map of Port Aransas High School monitoring sites.

Port Isabel High School

Port Isabel students participated in field trips on September 26, 2012; January 23, 2013; and May 21, 2013. Students from Dr. 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 the newest site, SPI08, at the Tiki Condominiums (E. Whitesands Street) (Fig. 6). Port Isabel High School has been measuring SPI01 and SPI02 since 1999, and SPI08 since 2007. Ms. Caudle was able to accompany the class on all three trips to provide further training and background information to the students.

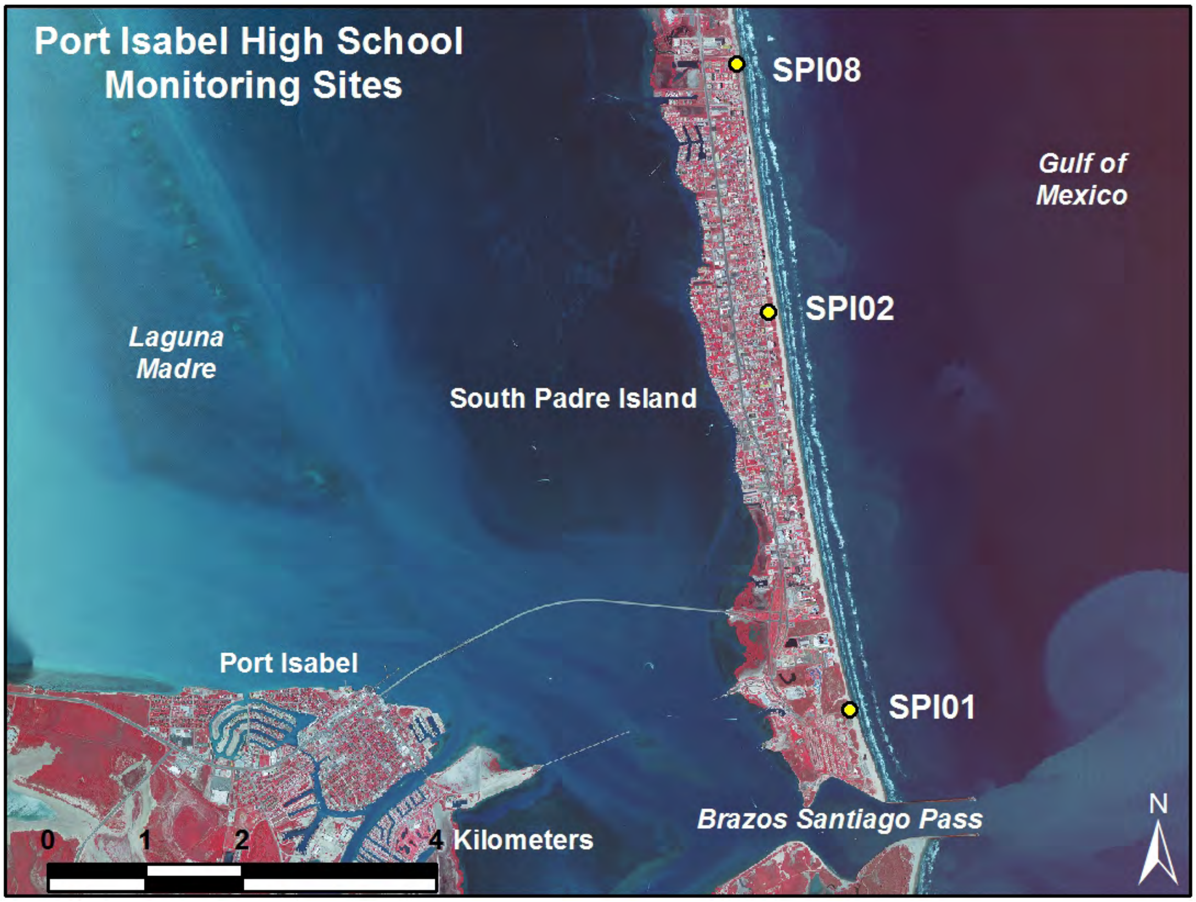

Figure 6. Location map of Port Isabel High School monitoring sites.

Matagorda Area Schools

Van Vleck Middle School students participated in field trips on September 20, 2012; January 31, 2013; and May 8, 2013. Ms. Keelen's class collected data at MAT01 (Fig. 7). Physics students from Palacios High School participated in field trips on September 21, 2012; January 24, 2013; and April 8, 2013. Mr. Morris's students collected data at MAT02 (Fig. 7). Tidehaven Middle School participated in field trips on September 22, 2012; January 31, 2013; and April 20, 2013. The students from Tidehaven collected data at MAT03 (Fig. 7).

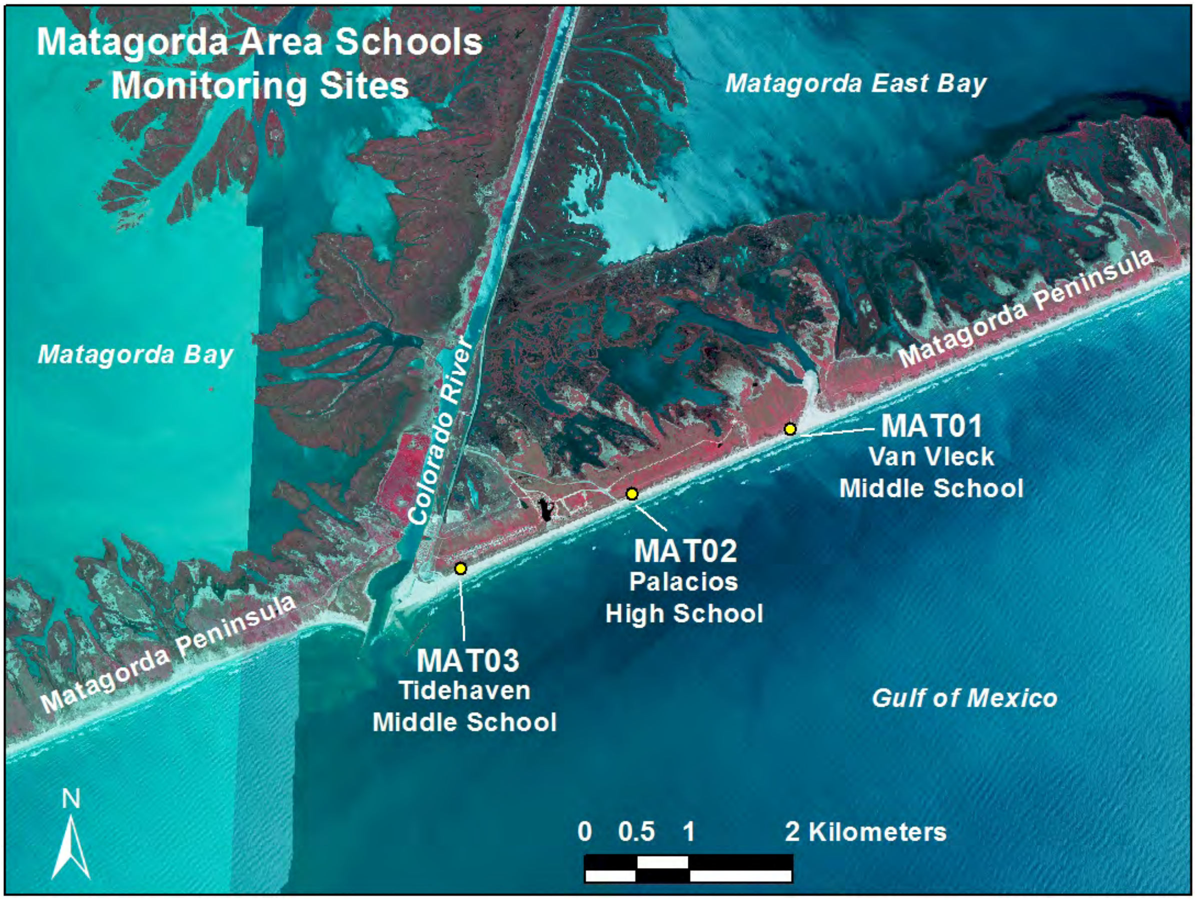

Figure 7. Location map of Matagorda area schools' monitoring sites.

Cunningham Middle School

The Innovation Academy at Cunningham Middle School asked to join the program after participating in a workshop at TAMUCC in November 2008. The teachers at Cunningham Middle School expressed a desire to include all 8th grade students (~75 students) in the field trips. During the first few years participating in the program, the 8th grade class was divided into 3 groups of approximately 25 students each. A different group participated in each of the three field trips so that the entire class could be accommodated. The students were further split into two groups during the field trip. One group worked on the topographic profile while the second made wind, waves, and current observations. The groups then switched in order for every student to experience collecting all types of data. Trying to accommodate the entire grade in three field trips, however, proved to be a bit taxing for both the teachers and the field-trip leaders. Including 25 or more students on each field trip simply became too many to keep engaged in the data-collection process. For the 2012–2013 academic year, therefore, 15 to 20 students participated in each field trip (a different group of students for each trip) during the year. The Bureau collaborates with graduate students and staff at TAMUCC to conduct field trips with Cunningham Middle School, owing to the number of students that participate in the program. Cunningham students participated in field trips on October 26, 2012, and February 1, 2013, collecting data at NPI08 on North Padre Island (Fig. 8). Cunningham students and teachers and Bureau and TAMUCC staff met for a third field trip on May 3, 2013. Owing to an extremely strong, late-season cold front that had arrived the previous day, the group was unable to collect data. A strong north wind—gusts were measuring over 60 kph on the students' wind gauges—made it impossible to collect data accurately. The students would have been unable to hear the instructor, keep the Emery rods straight, or focus on collecting accurate measurements. Also, the teachers and staff did not want to risk students getting sand in their eyes.

Figure 8. Location map of Cunningham Middle School monitoring site.

## EFFECTS ON SCIENCE CURRICULUM

The THSCMP addresses several requirements of Texas Essential Knowledge and Skills (TEKS) for science, and the program was relevant in these 2012–2013 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 in these courses 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 an excellent fit with the program. TEKS and Standards, which require students to use critical thinking and scientific problem solving to make informed decisions, are also well served. Teachers and scientists can use the program to illustrate to students the role science could, should, or does play in developing public policy. A case study of a local erosion problem could be used to illustrate.

## EFFECTS ON SCIENTIFIC RESEARCH, COASTAL MANAGEMENT, AND PUBLIC AWARENESS

During the 2012–2013 academic year, Ball High School students measured a profile location in Galveston Island State Park (BEG02, Fig. 4). Ball High School students had measured this same location in previous years, and the Bureau had conducted quarterly surveys at these locations 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 Galveston Island State Park profile has increased in importance because it served as a control site for comparing profiles measured in front of geotextile-tube projects along the Pirates Beach subdivision to the northeast of the park. Results of a study utilizing data collected by Ball High School students were published in *Shore & Beach*, the journal of the American Shore & Beach Preservation Association. The data have increased scientific understanding of recovery of beaches and dunes following storms (Hurricane Alicia, Tropical Storm Frances, Hurricane Claudette, Hurricane Rita, Hurricane Ike) that have impacted the area.

Palacios, Port Aransas, and Port Isabel High Schools and Cunningham, Van Vleck, and Tidehaven Middle Schools 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 the 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. The program has also increased public awareness through the students. Given the number of inquiries from people wishing to enter their school or group in THSCMP, the program seems to be reaching the public. Television reports, presentations at conferences, and newspaper articles have also helped. The website will continue to be instrumental in extending the reach of the program and increasing public awareness of coastal processes.

We emphasize to the students that they are collecting critical scientific data that will help scientists address coastal issues affecting their community. All data collected by THSCMP are integrated into past and ongoing coastal research programs at the Bureau. THSCMP-collected data played a large role in two important Bureau studies. First, Galveston Island State Park served as a control site in a study looking at the effects of geotextile tubes. Most recently, data collected by THSCMP students were invaluable in verifying shoreline position for an update of Texas' long-term shoreline-change rates, which are widely used by public officials, corporations, and private citizens.

BEG02, one of the Ball High monitoring sites, has been used by Bureau scientists in a study on the effects of geotextile tubes that have been 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, Galveston Island State Park. Beach width in the natural beach area was wider, owing to the lack of restriction caused by placement of the geotextile tubes (Gibeaut et al., 2003) (Fig. 9).

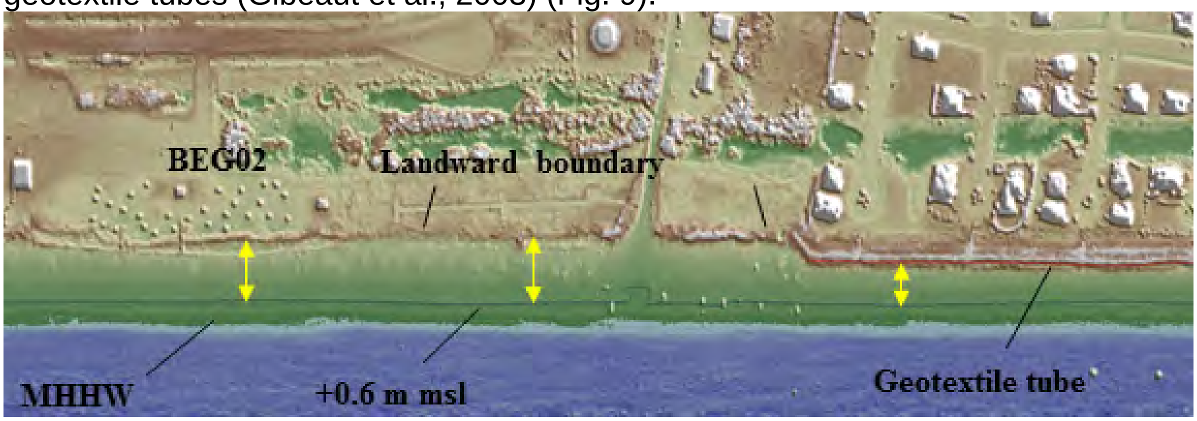


Figure 9. Lidar topographic-relief image of Galveston Island State Park and Pirates Beach subdivision. Note the difference in beach width between the natural beach and the area in front of the subdivision. From Gibeaut et al. (2003).

A recent Bureau project updated the 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 invaluable in validating interpretation of the shoreline position on Galveston Island, Follets Island, Matagorda Peninsula, Mustang Island, and South Padre Island. The georeferencing of the 2007 photographs and interpretation of the position of the wet beach/dry beach boundary were 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 to be used for change-rate calculations (Paine et al., 2011). At Galveston Island State Park (Fig. 10), 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).

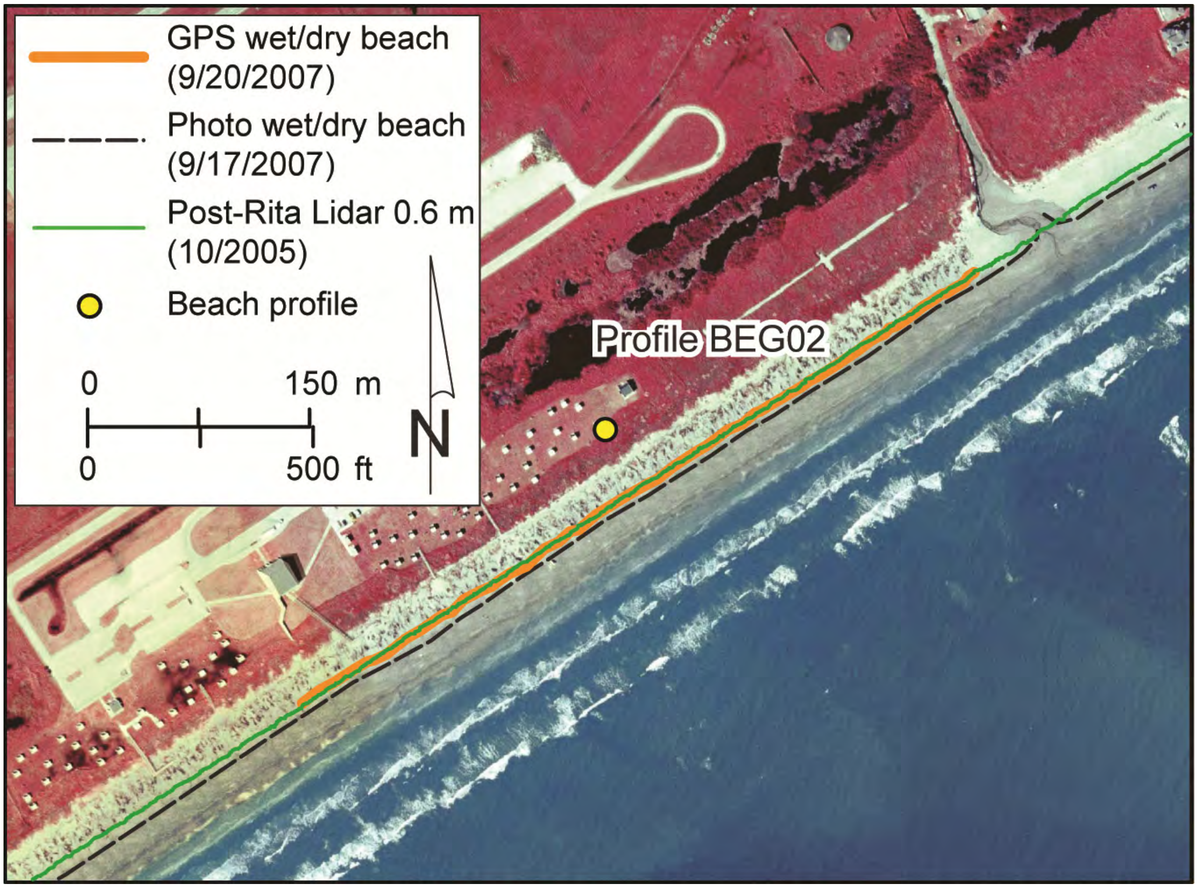


Figure 10. Shoreline position comparison at Galveston Island State Park site BEG02. Shorelines include the 2007 wet beach/dry beach boundary mapped on aerial photographs taken September 17, 2007; the wet beach/dry beach boundary mapped on September 20, 2007, by THSCMP students and staff using ground GPS; and the 0.6-m msl shoreline proxy extracted from airborne lidar data acquired after Hurricane Rita in October 2005. From Paine et al. (2011).

## SCIENTIFIC RESULTS OF 1997–2013 STUDIES

The first goal of the Texas High School Coastal Monitoring Program is to provide high school students with an inquiry-based learning experience, which is achieved by involving students in a real-world research project. 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/.

Profile data 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 notes made by students and scientists while in the field collecting data. The shoreline is designated by the wet/dry line or a berm crest. Volume, shoreline, and vegetation-line plots for each monitoring site are found in Appendix B, and profile plots are in Appendix C.

Students from Ball High School have been collecting data for the coastal monitoring program since 1997. During this timeframe, Tropical Storm Frances (September 1998) played a major role in reshaping the beaches in Galveston County. Data collected by Ball High School students on Galveston Island have been used by scientists at the Bureau to track beach and dune recovery stages following Tropical Storm Frances. The storm caused significant damage to beaches along the southeast coast of Texas that was comparable to damage caused by category-3 Hurricane Alicia in 1983 (Hepner and Gibeaut, 2004). Several other severe storms have impacted the study area. Allison (June 2001), Fay (September 2002), Hurricane Claudette (July 2003), and Hurricane Rita (September 2005) have each caused varying degrees of damage to beaches and dunes along the Texas coast (Fig. 11). Ball High School students provided important prestorm beach topography data from their field trips during the 2004–2005 and 2007–2008 academic years.

Hurricane Rita made landfall at Sabine Pass on the Texas–Louisiana border at 7:30 UTC on September 24, 2005. Rita was a category 3 hurricane, with maximum sustained winds of about 105 knots. Overall, Rita did not cause the kind of episodic beach or dune erosion on Galveston or Follets Islands that Frances had in 1998. Figure 12 is a plot of pre- and post-storm beach profiles measured at Galveston Island State Park. The prestorm profile was measured by Ball High School science students, and the post-storm profile was measured by scientists from the Bureau. 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. 11) (Gibeaut, 2005).

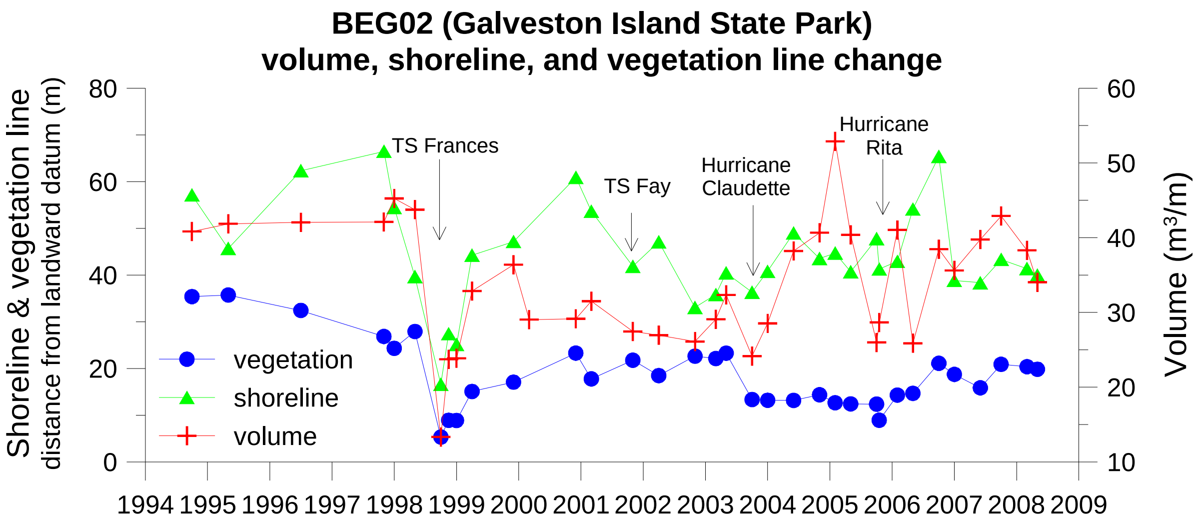


Figure 11. Profile volume, shoreline, and vegetation-line changes at Galveston Island State Park, September 1994–April 2008.

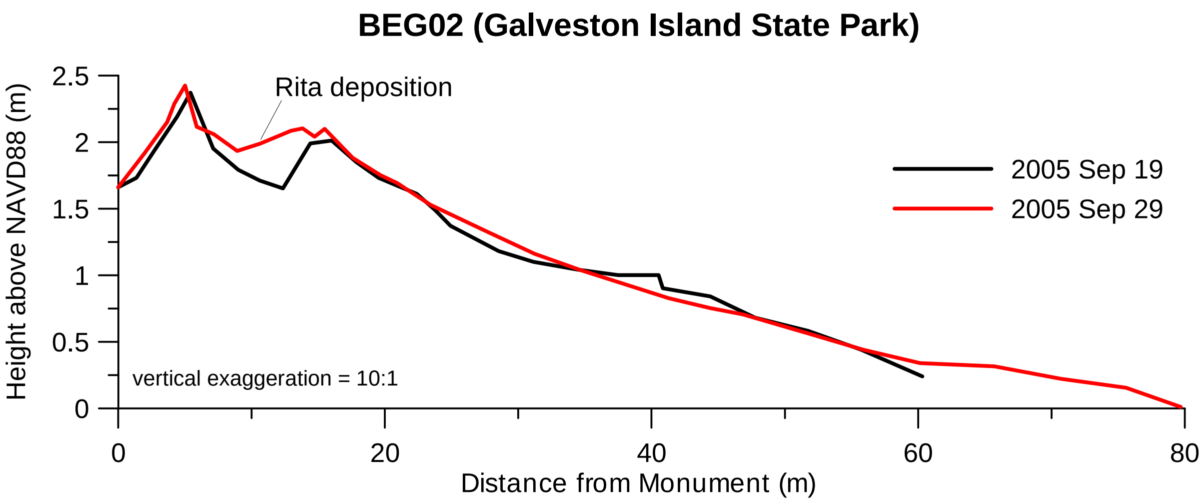


Figure 12. Plot of pre- and post-Rita beach profiles measured at Galveston Island State Park.

The 2008–2009 academic year was severely affected by the landfall of Hurricane Ike on Galveston Island September 13, 2008. Palacios, Port Aransas, Tidehaven, and Van Vleck school field trips were postponed because of school closings in preparation for the hurricane. Owing to the shear size of the storm, impacts from this hurricane were seen along the entire Texas coast, despite Ike's being only a category 2 storm at the time of landfall. Dune erosion was also documented at Matagorda Peninsula and Mustang Island (see Appendix C).

Galveston Island experienced significant beach and dune erosion, as well as extensive damage to property and infrastructure because of Hurricane Ike. Ball High School students were unable to participate in the program during the 2008–2009 academic year owing to safety concerns about accessing their monitoring sites. Bureau and TAMUCC scientists visited Galveston Island in early October to conduct ground surveys—beach profiles, photography, and observations of beach and dune conditions—of the area impacted by the hurricane. Profile location BEG02 in Galveston Island State Park was visited during this reconnaissance trip, and it was found that the datum marker at BEG02 had been destroyed by the storm. GPS techniques were used to navigate to the horizontal location of the datum marker, which post-storm was on the open beach. The marker had been the corner of a concrete picnic pavilion landward of the foredunes. BEG02 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. A topographic profile was conducted at this time. GLO06, at the southwest corner of Galveston Island State Park, was also lost as a result of Hurricane Ike. GLO06 was reset approximately 60 m landward of the old datum marker along the same azimuth line. The new marker is landward of the foredunes and adjacent to a wetland feature.

Ball High School students from the 2007–2008 academic year provided extremely valuable prestorm 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 13 is a profile plot at BEG02 comparing Ball High prestorm profiles (February and 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. The dune system at Galveston Island State Park was completely destroyed, and the shoreline (wet–dry line) moved 53 m landward between April 23, 2008, and October 7, 2008 (Fig. 13). The vegetation line moved 56 m landward. The old datum point was 1.14 m above the current surface of the beach.

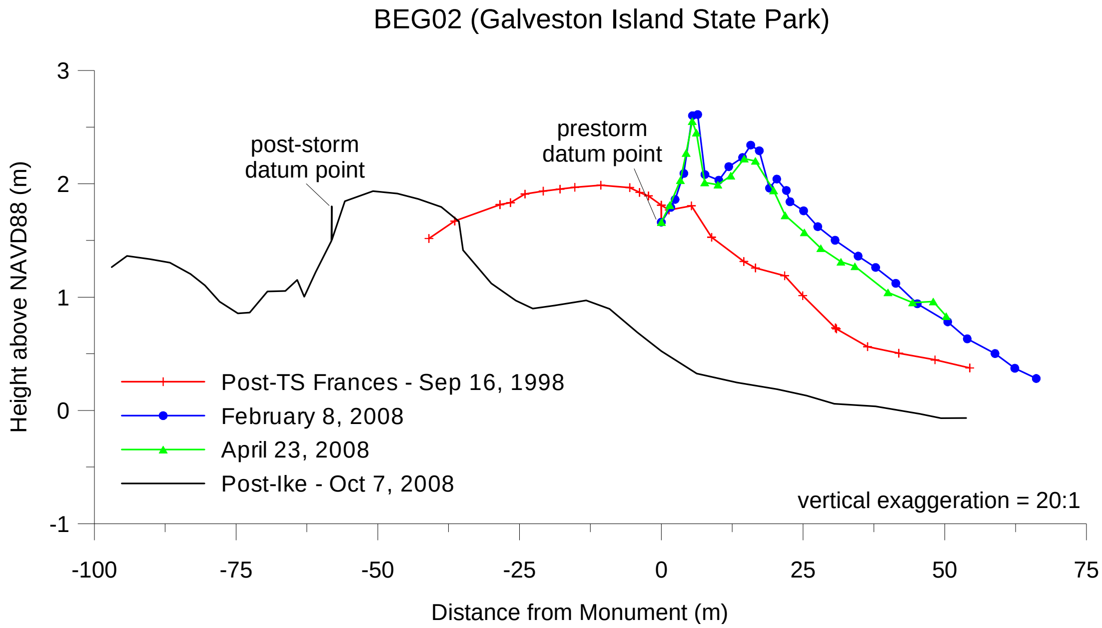


Figure 13. Beach-profile plots from BEG02 in Galveston Island State Park comparing the post-Hurricane Ike profile with two prestorm profiles from early 2008 and the post-Tropical Storm Frances profile from September 1998. The old datum point is 0.

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 both BEG02 (Fig. 14) and GLO06, beaches and dunes had continued to recover post-Hurricane Ike. Between September 2009 and January 2010, the foredunes at BEG02 had begun to grow. Whether growth of the foredune is due to natural recovery processes or human intervention is unclear.

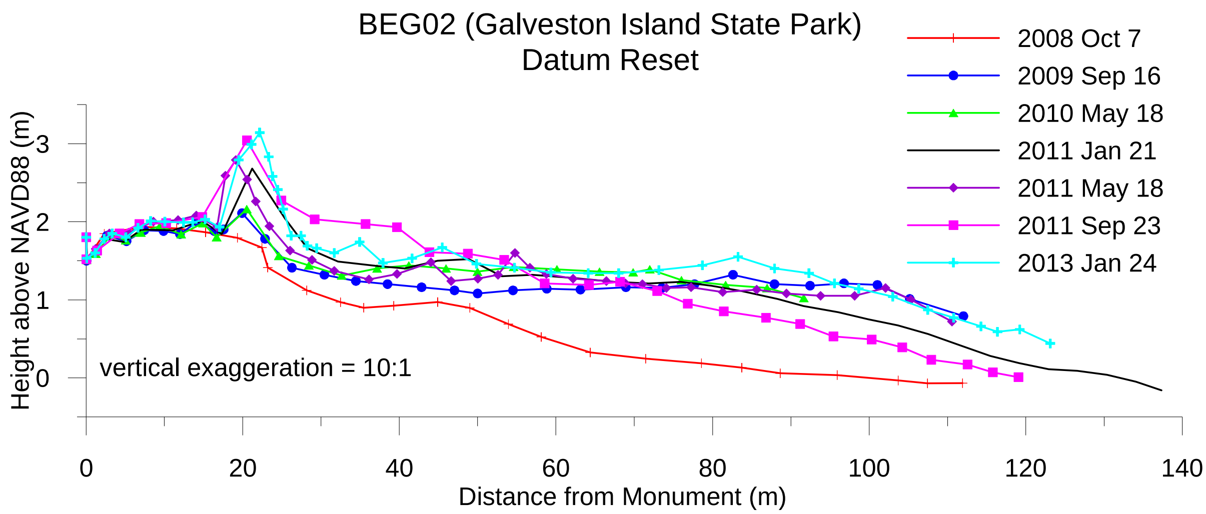


Figure 14. BEG02 datum reset post-storm profile plus data collected by Ball High School students. Students are monitoring recovery of the beaches and dunes at this site.

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, the 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. Dredged material is placed on beaches of South Padre Island, and the three sites monitored by Port Isabel High School students are within the nourishment areas. The SPI02 monitoring site has also been used by students and scientists to monitor the growth of dunes. When SPI02 was established in August 2000, there were no dunes between the seawall and the waterline at this location. Since that time, sand fences have been installed, and vegetation has been planted. Profile data have been quantifying the effects of these actions (Fig. 15). Whereas the vegetation line has remained in a similar position throughout the study period, beach volume at this location has been increasing owing to a slowly accreting shoreline and entrapment of sand in the dune area. Hurricane Dolly made landfall on South Padre Island near Port Mansfield on

July 23, 2008. Impacts to beaches and dunes in the Port Isabel students' study area were not measured because of the arrival of Hurricane Ike before their first field trip. The storm surge due to Hurricane Ike deposited sand in the dune area at SPI02 and covered the vegetation, essentially flattening the profile. Although shoreline position and beach volume appear steady at this site, the vegetation line moved seaward during the 2012–2013 academic year. Port Isabel students will continue to monitor dune changes and shoreline advancement at this location.

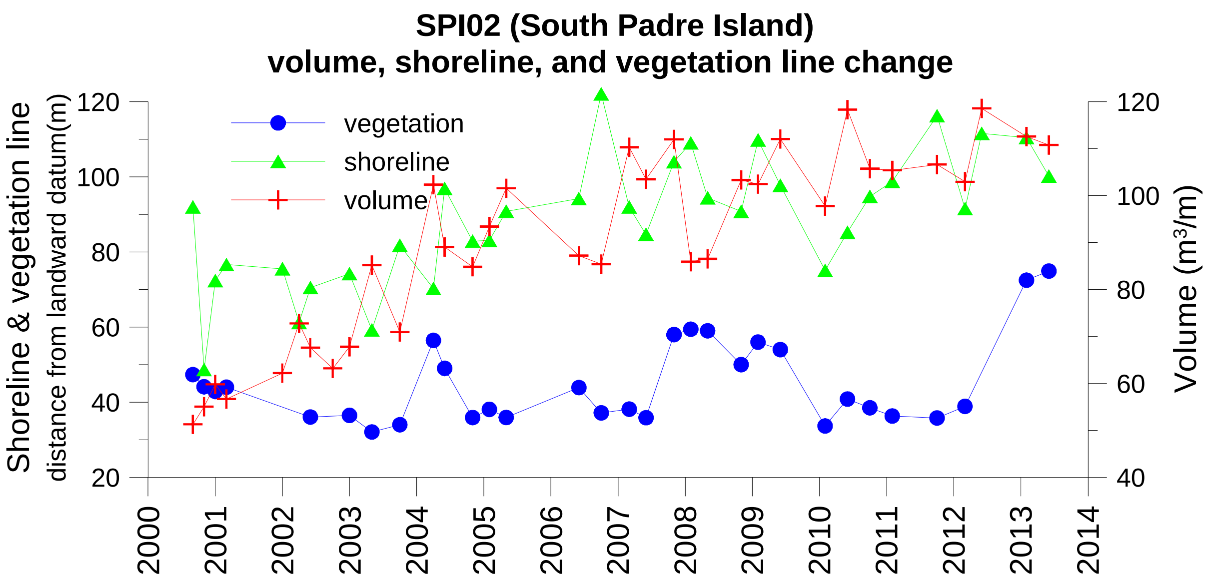

Figure 15. Changes at SPI02 on South Padre Island due to beach-nourishment projects and the installation of sand fences.

Starting in the 2007–2008 academic year, students at Port Isabel High School began gathering data at an additional monitoring site at a chronically eroding location in front of the Tiki Condominiums near the north end of the city, SPI08 (Fig. 6). This site has a narrow beach backed by a seawall (see Appendix B for profile plots) that periodically receives nourishment sand from road maintenance north of the City of South Padre Island. 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 seawall. When the students returned to the site on September 28, 2010, the sand fence had been removed, 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 larger beach-nourishment project using sand dredged 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 are still no dunes or vegetation in front of the seawall (Fig. 16). On the May 13, 2011, field trip, students observed that a 0.5-m scarp had formed at the shoreline. Port Isabel students continued to monitor this site during the 2011–2012 academic year to determine whether the nourished beach would reach equilibrium. The shoreline position has returned to the prenourishment position. After an initial, significant decrease in beach volume (to prenourishment levels), volume on the backbeach has increased steadily owing to installation of sand fences. As of May 2013, the sand fences remained in place, serving to trap sand in front of the seawall at this site, and vegetation has been planted on the incipient dunes.

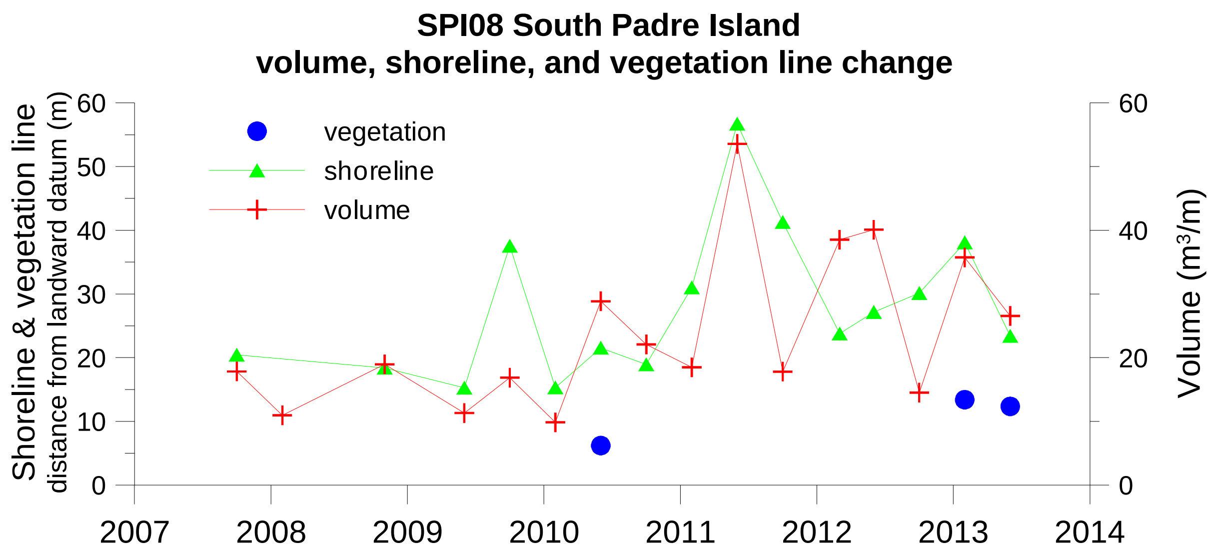

Figure 16. Volume and shoreline changes at SPI08 on South Padre Island due to beach-nourishment projects and the installation of sand fences.

The beach-monitoring activities of Port Aransas High School students have also provided beneficial information regarding 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. The sand and seaweed removed from the berm and forebeach are regularly placed at the seaward base of the foredunes. 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 17 is an example of expansion of the foredune at MUI01 near Horace Caldwell Pier in Port Aransas. Note that the width of the dune increased between 2001 and early 2012, although the shoreline remained in a relatively stable position. When students arrived to collect profile data in October 2012, a large part of the dune face had been excavated (Figs. 17, 18). We are unsure why sand had been removed from the foredune, and, as of May 2013, it remained open. Port Aransas students will continue to monitor this situation.

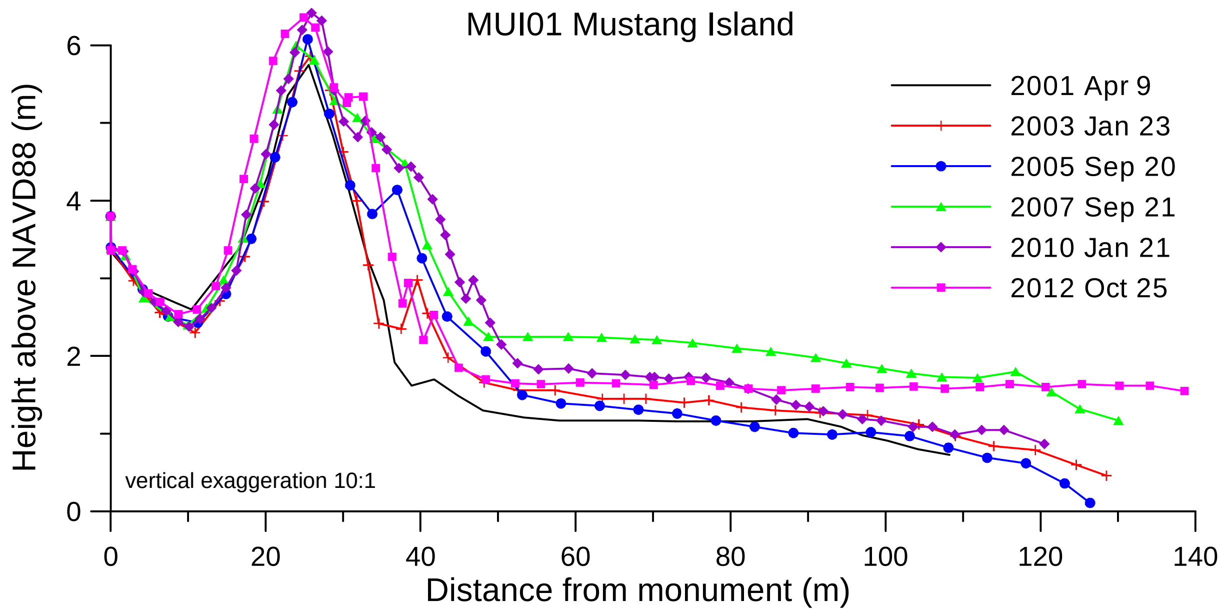


Figure 17. Foredune expansion at MUI01 on Mustang Island.

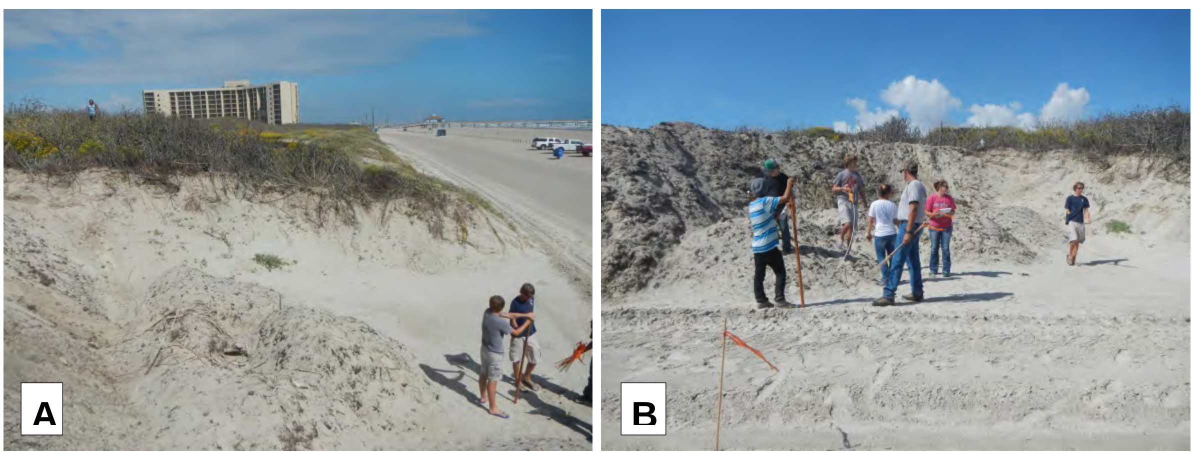


Figure 18. Excavated dune at MUI01 on Mustang Island looking (A) north toward Horace Caldwell Pier and (B) landward.

Palacios, Van Vleck, and Tidehaven students have continued their beach measurements at Matagorda Bay Nature Park. The park has two special circumstances that make this monitoring especially informative and important. Monitoring sites have been established on the up-drift side of the jetty at the mouth of the Colorado River and at sites that allow students to compare (1) a beach/dune system where vehicular traffic on the beach will be strictly prohibited (MAT03) with (2) an adjacent area where vehicular traffic will continue to be permitted (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 pedestrian beach at the Nature Park until 2007. There is now a call to reopen this section of beach to vehicular traffic because of a perceived lack of use by pedestrian-only beachgoers. Data collected between 2005 and 2007 will serve as a baseline for the study on vehicular impact on beaches if the beach remains closed to vehicles. Because it is still too early in the study to compare the beaches, in the interest of scientific study, we hope that the beach remains a pedestrian beach. Also during the 2009–2010 academic year, the U.S. Army Corps of Engineers began constructing a new north jetty at the mouth of the Colorado River. GPS-mapped shorelines from September 2006 and September 2012 show a 90-m seaward movement of shoreline position at MAT03 immediately north of the new jetty (Fig. 19). Student data at MAT03 will be used to continue monitoring the effects of the jetty on east Matagorda Peninsula.

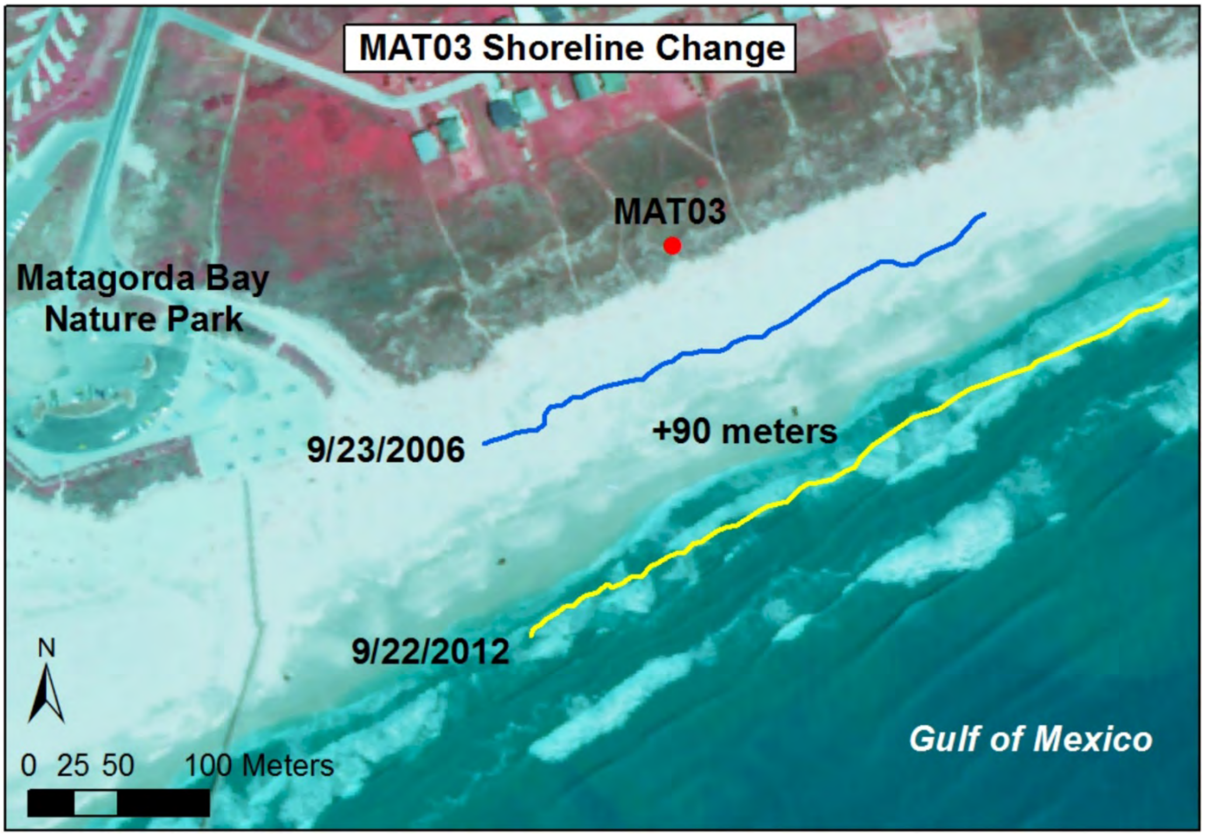

Figure 19. Shoreline position change at Matagorda Peninsula.

Cunningham Middle School students have already witnessed a remarkable change in their profile location after 5 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. Owing to the sparse vegetation on the foredune, sand is constantly being rearranged by prevailing winds. Sand has been moved 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 new 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.

Future measurements by all schools involved in THSCMP will show not only change through time at each location, but also spatial variation along the Texas coast. Through time, data collected from 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.

## WEBSITE UPGRADES

The program's website (http://www.beg.utexas.edu/coastal/thscmp/index.html) was redesigned and evolved during the 2006–2007 academic year. The color scheme was changed to make it more appealing, and several exercises were developed as part of a National Science Foundation grant that were meant to utilize data collected by participants in the program and that were added to the new site. Field guides for Mustang and Galveston Islands were added in 2007. The photo gallery is updated to include all photos since the program began. Data collected by the students are also posted on this site.

An exciting upgrade to the website during the 2008–2009 academic year was an interactive virtual barrier island. The Bureau, along with TAMUCC, has developed a 3-D virtual model of the Gulf of Mexico and Texas coastal environments for use in the classroom and for the general public to explore how relative sea-level change, caused by climate change and other things, may impact the coastal zone. The virtual barrier island can be downloaded from the website to run on users' computers. A lesson plan titled *Sea-Level Changes and the Texas Coastal Environment* has also been created for use in the classroom. This lesson encourages students to consider the impacts of increased greenhouse gases in the atmosphere and how they may affect climate change, sea level, and, eventually, coastal environments. A PowerPoint presentation offers teachers the opportunity to introduce the lesson in their classrooms, and a 10-minute video explains how to navigate and manipulate the data within the model. In 2011–2012, updates were made to the model to include data that compare pre- and post-Hurricane Ike beaches in Galveston Island State Park.

The 3-D model was presented to teachers and educators at two conferences during the 2009–2010 academic year. The first was a short course at the Conference for the Advancement of Science Teaching (CAST), which is the annual meeting for the Science Teachers Association of Texas (STAT), in Galveston on November 5, 2009. The second presentation was during an Educator Workshop at the International Conference on Sea-Level Rise in the Gulf of Mexico in Corpus Christi in early March 2010. Both presentations were met with enthusiastic response from educators who attended the programs. In addition, the model was part of a June 2011 teacher workshop, "Groundwater to the Gulf," at Matagorda Bay Nature Park.

# CONCLUSIONS

The Texas High School Coastal Monitoring Program provides high school students with a real-world learning experience outside the everyday classroom. The program not only provides hands-on education, but it also complies with many TEKS requirements. The 2012–2013 academic year was productive, with Ball, Palacios, Port Aransas, and Port Isabel High Schools and Cunningham, Tidehaven, and Van Vleck Middle Schools collecting data on several field trips. Another exciting addition to the program has been an update of the virtual-barrier-island program.

In the 16 years since the inception of the Texas High School Coastal Monitoring Program, work by students at Ball, Palacios, Port Aransas, and Port Isabel High Schools and Cunningham, Tidehaven, and Van Vleck Middle Schools has been beneficial to Bureau researchers and coastal managers in several Bureau research projects. Availability of data through the program's website allows access to coastal managers and the public. Scientists, students, and the public will continue to gain a better understanding of coastal processes and shoreline change along the Texas coast through this successful student research program.

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Gibeaut, J. C., Hepner, T. L., Waldinger, R. L., Andrews, J. R., Smyth, R. C., and Gutierrez, R., 2003. Geotextile Tubes along the Upper Texas Gulf Coast: May 2000 to March 2003. The University of Texas at Austin, Bureau of Economic Geology. Report prepared for Texas General Land Office, 37 pages plus appendices.

Hepner, T. L., and Gibeaut, J. C., 2004. Tracking post-storm beach recovery using data collected by Texas high school students. *Shore and Beach*. Volume 72, Number 4. Pages 5 to 9.

Paine, J. G., Mathew, S., and Caudle, T., 2011. Gulf Shoreline Change Rates through 2007. The University of Texas at Austin, Bureau of Economic Geology. Report prepared for Texas General Land Office, 38 pages.

# 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 Geiod99 Ellipsoid Model.

| Profile | Latitude (deg min) | Longitude (deg min) | Easting (m) | Northing (m) | HAE (m) | NAVD88 (m) | Azimuth (M) |
|---|---|---|---|---|---|---|---|
| **BEG02** | 29 11.64 | 94 57.09 | 310255.20 | 3231059.16 | -24.75 | 1.66 | 139 |
| **BEG02R**[1] | 29 11.67 | 94 57.11 | 310228.82 | 3231110.58 | -24.61 | 1.80 | 139 |
| **BEG08**[2] | 29 3.22 | 95 8.90 | 290838.52 | 3215830.51 | -24.21 | 2.09 | 145 |
| **GLO06** | 29 11.12 | 94 58.05 | 308696.85 | 3230117.35 | -24.32 | 2.08 | 138 |
| **MAT01** | 28 36.67 | 95 56.55 | 212269.73 | 3168453.74 | -22.77 | 3.69 | 148 |
| **MAT02** | 28 36.31 | 95 57.47 | 210751.39 | 3167825.80 | -23.25 | 3.22 | 148 |
| **MAT03** | 28 35.91 | 95 58.48 | 309090.26 | 3167112.23 | -21.81 | 4.68 | 148 |
| **MUI01** | 27 49.53 | 97 03.40 | 691396.24 | 3079393.46 | -22.29 | 3.79 | 123 |
| **MUI02** | 27 40.42 | 97 10.19 | 680502.58 | 3062387.97 | -24.22 | 1.61 | 120 |
| **MUI03** | 27 47.66 | 97 05.08 | 688697.42 | 3075882.39 | -22.24 | 3.79 | 125 |
| **NPI08** | 27 35.86 | 97 12.78 | 676359.73 | 3053901.89 | -23.32 | 2.35 | 110 |
| **NPI08R**[3] | 27 35.85 | 97 12.77 | 676381.84 | 3053893.52 | -22.70 | 2.97 | 110 |
| **SPI01** | 26 4.57 | 97 9.46 | 684274.71 | 2885422.83 | -18.48 | 2.75 | 70 |
| **SPI02** | 26 6.79 | 97 9.93 | 683438.99 | 2889509.24 | -18.11 | 3.19 | 78 |
| **SPI08** | 26 8.17 | 97 10.10 | 683116.29 | 2892056.38 | -18.32 | 3.01 | 75 |

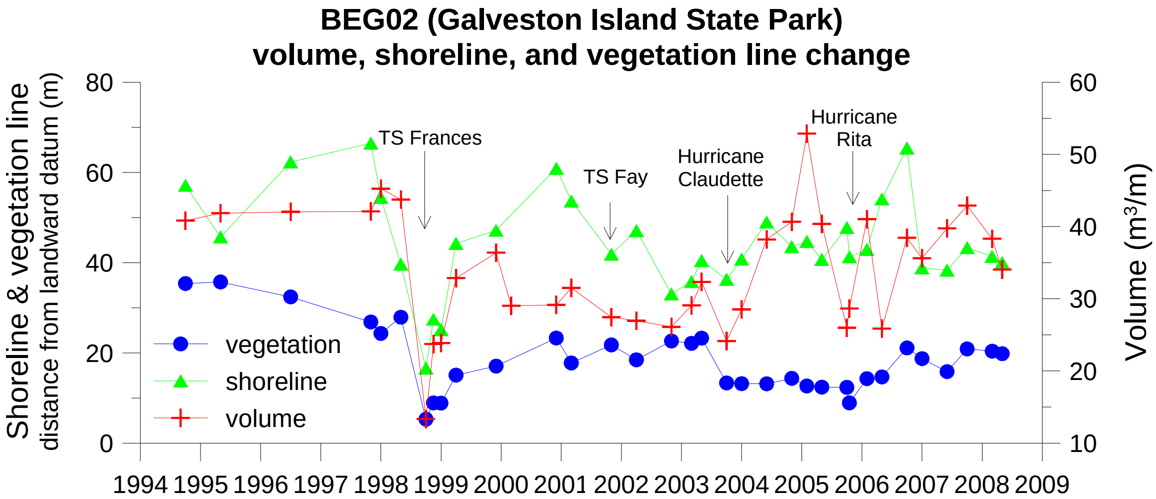
[1]BEG02 reset in October 2008 after Hurricane Ike.

[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.

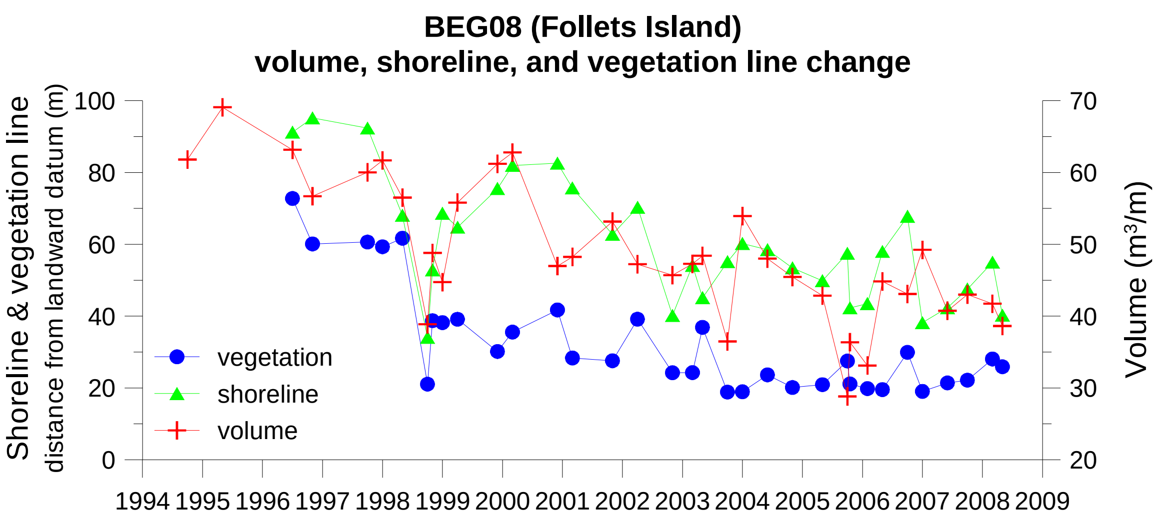
[3]NPI08 reset closer to foredune in April 2009 for easier access by Cunningham Middle School students. New datum marker was buried by landward toe of dune between March and May 2010. Students have used the original marker since the May 2010 survey.

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

BEG02 volumes were calculated from datum to 0.75 m below datum. Profiles that did not extend to –0.75 m were extrapolated.

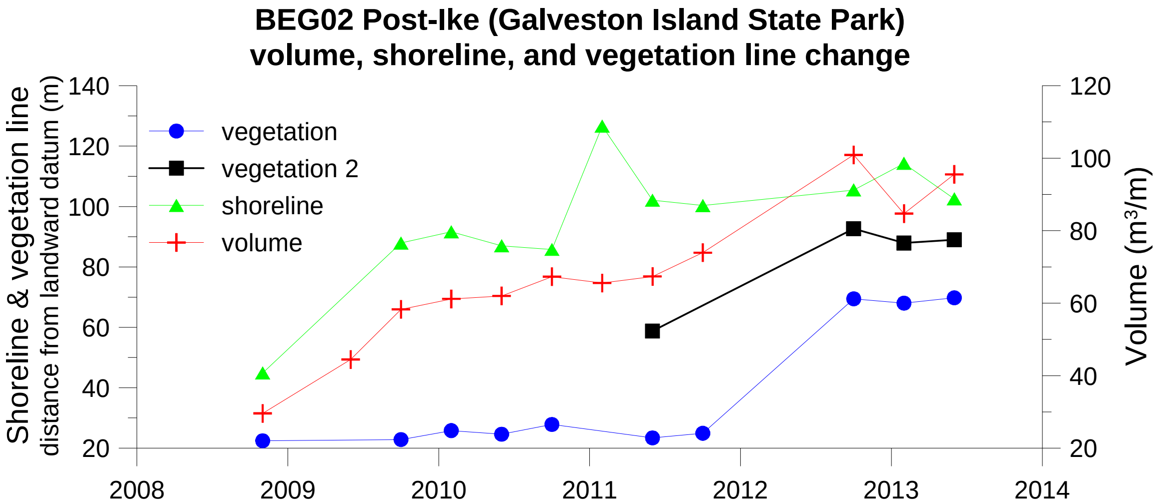



BEG08 volumes were calculated from datum to 1 m below datum. Profiles that did not extend to –1 m were extrapolated.

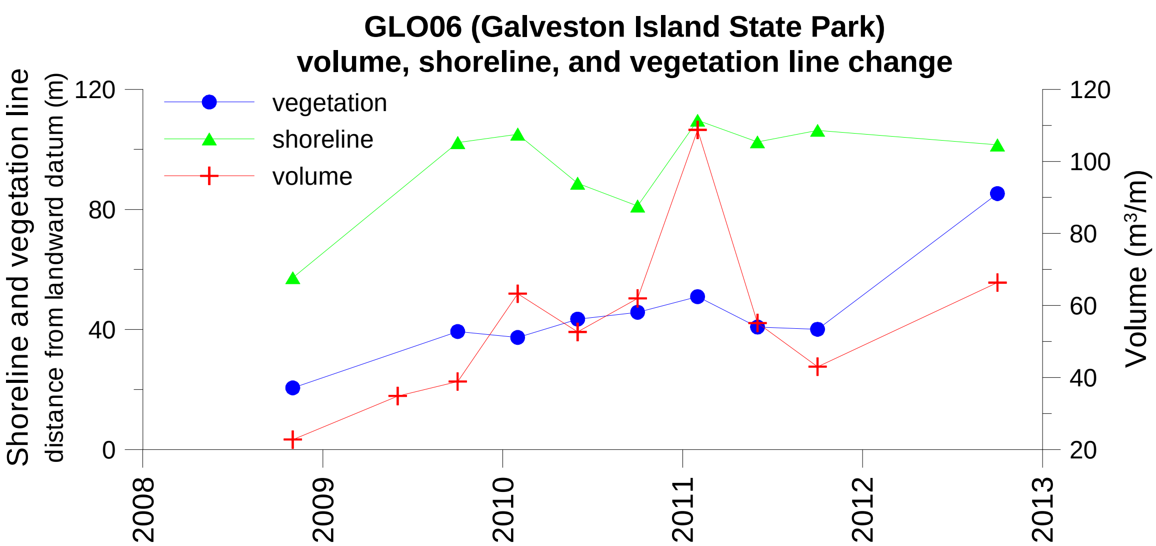



BEG02 and BEG08 have data from 1994 through the spring of 2008. Ball High School did not participate in the program because of Hurricane Ike's impact on Galveston Island.

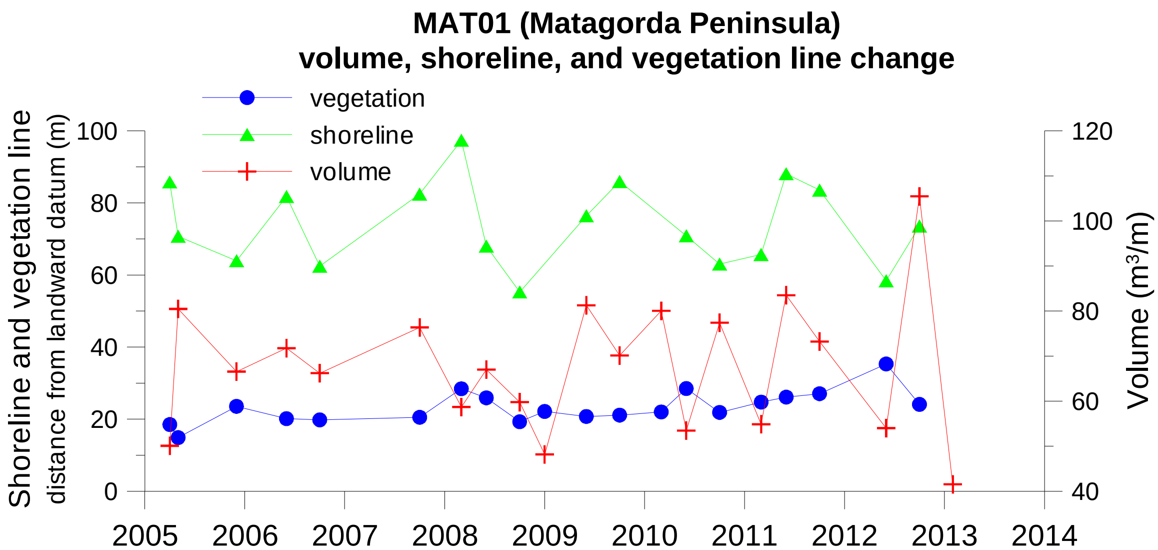
BEG02R volumes were calculated from datum to 1 m below datum. Profiles that did not extend to –1 m were extrapolated.



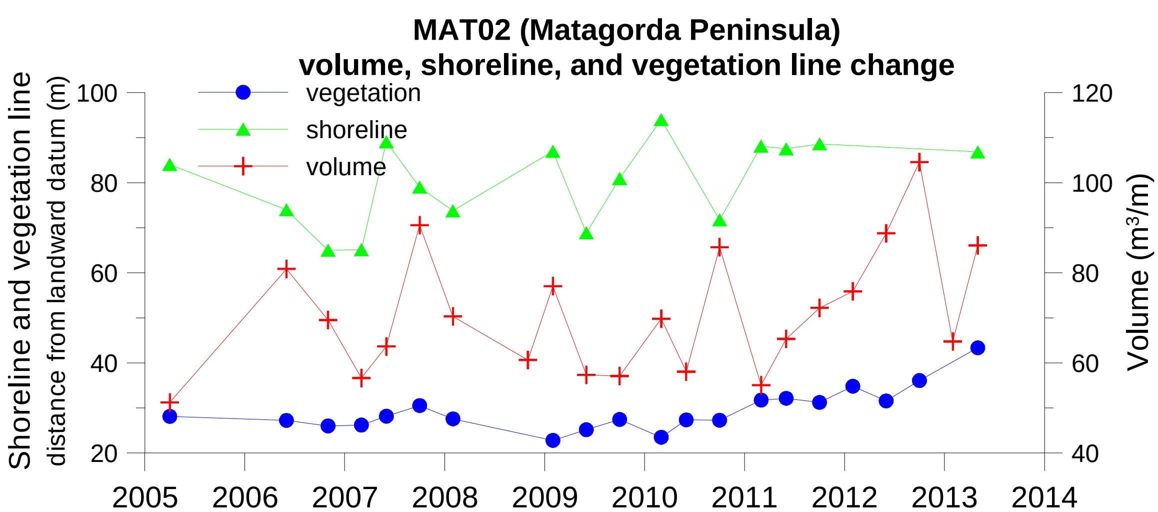

GLO06 volumes were calculated from datum to 1 m below datum. Profiles that did not extend to –1 m were extrapolated.



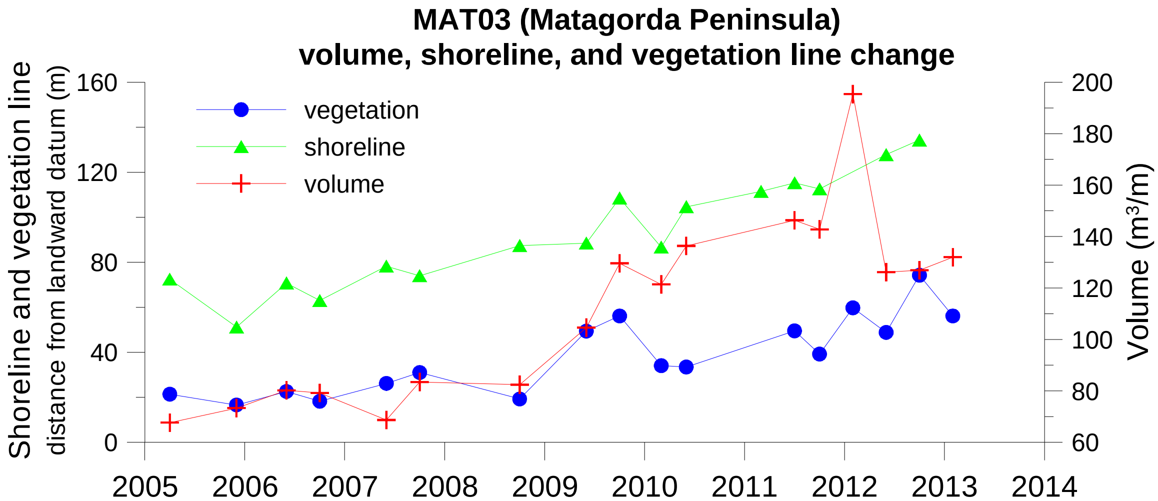
MAT01 volumes were calculated from datum to 2.5 m below datum. Profiles that did not extend to –2.5 m were extrapolated.



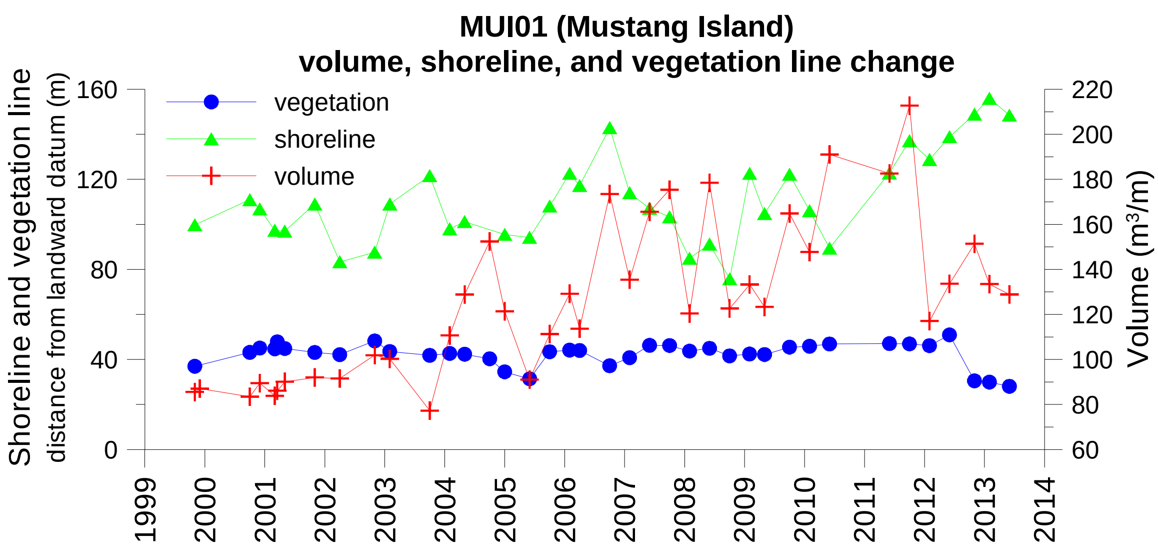

MAT02 volumes were calculated from datum to 2 m below datum. Profiles that did not extend to –2 m were extrapolated.



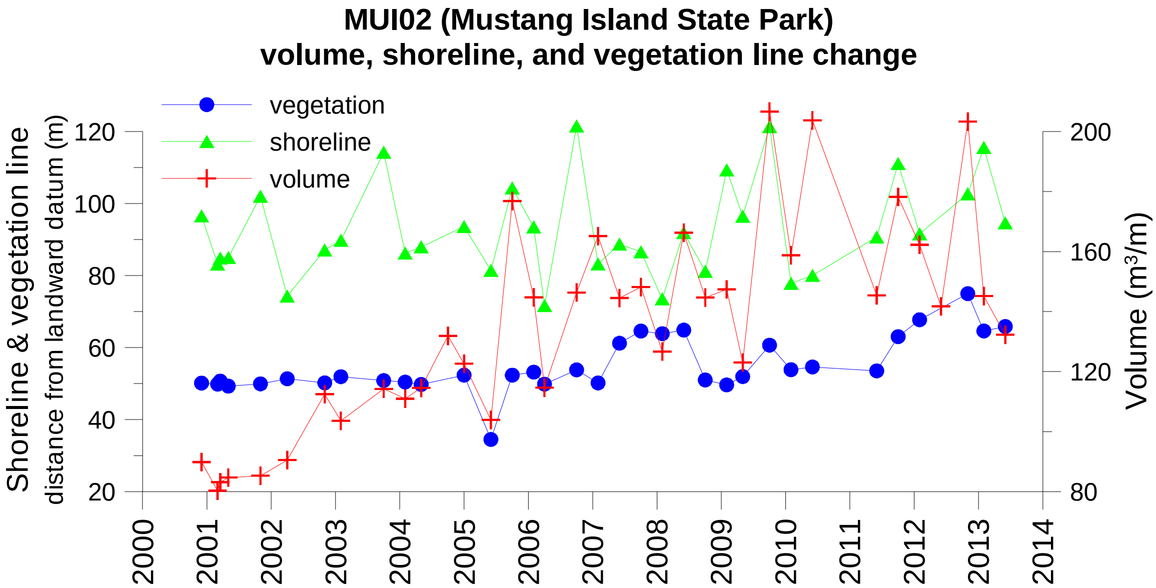
MAT03 volumes were calculated from datum to 3.75 m below datum. Profiles that did not extend to –3.75 m were extrapolated.



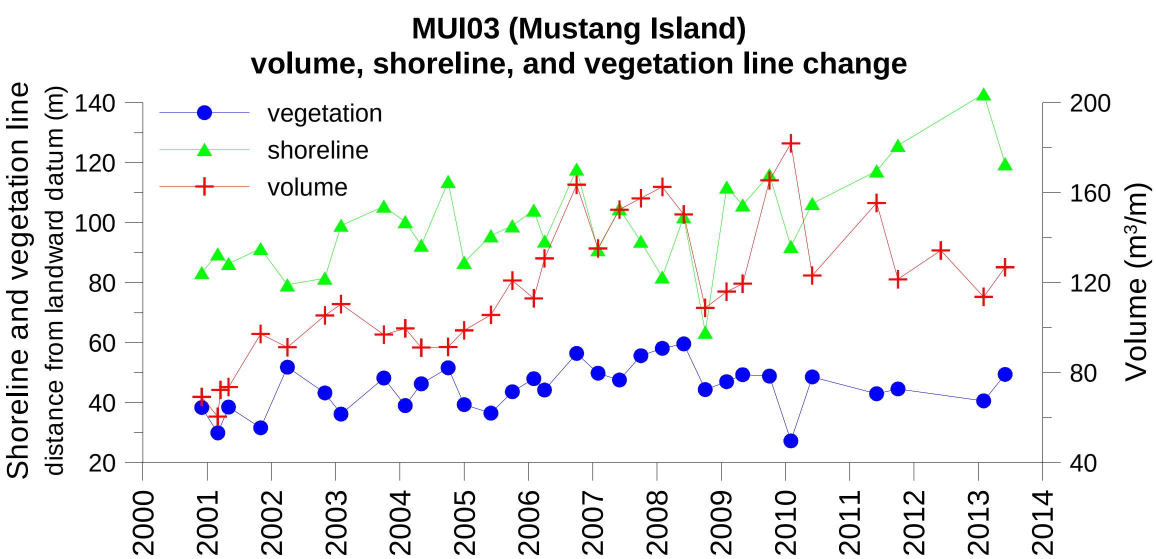

MUI01 volumes were calculated from datum to 2.5 m below datum. Profiles that did not extend to –2.5 m were extrapolated.



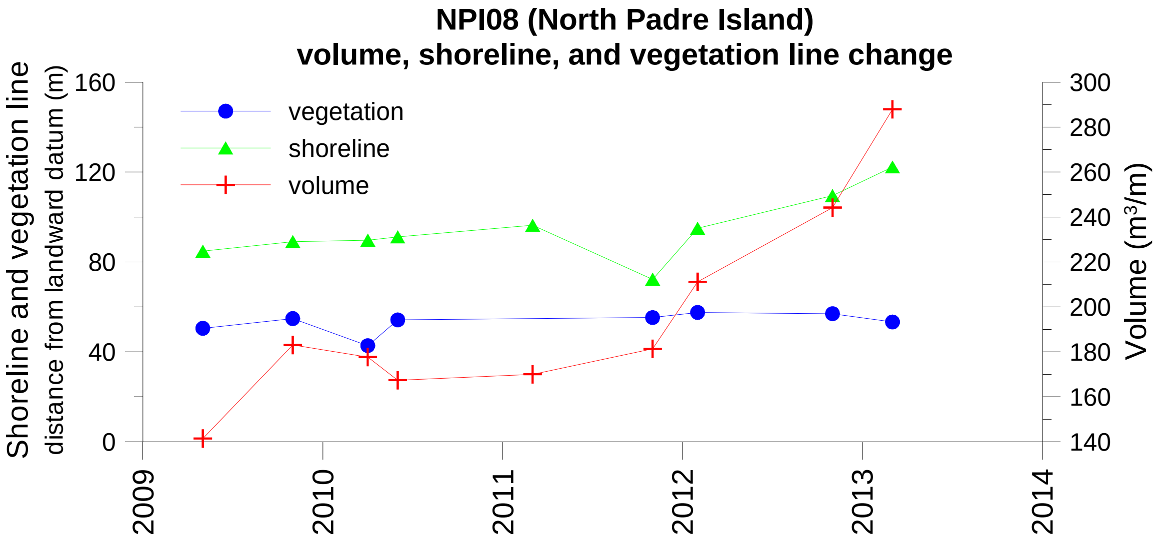
MUI02 volumes were calculated from datum to 0.5 m below datum. Profiles that did not extend to –0. 5 m were extrapolated.



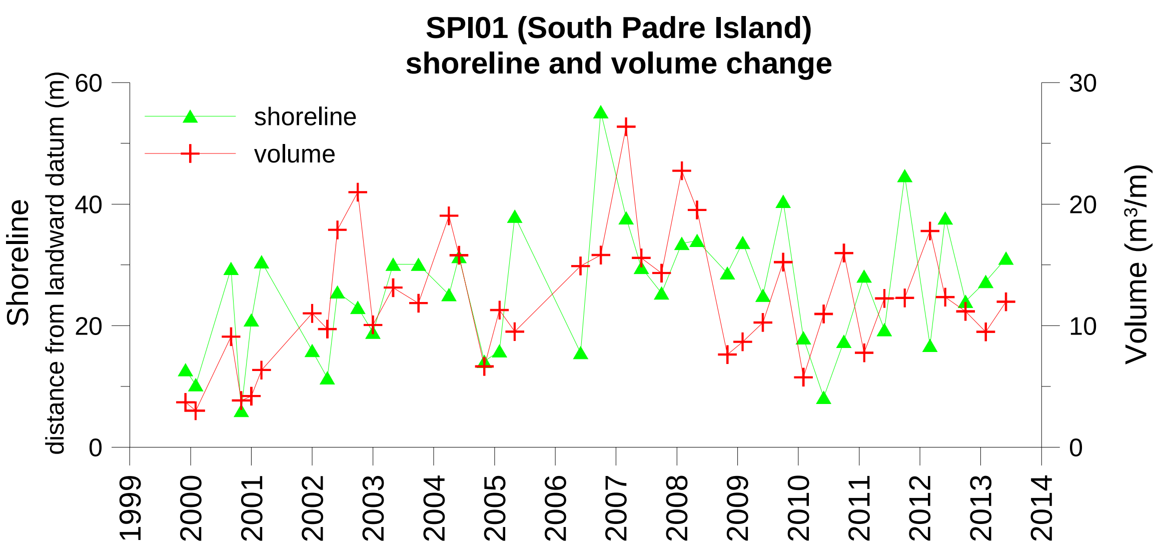

MUI03 volumes were calculated from datum to 2.5 m below datum. Profiles that did not extend to –2.5 m were extrapolated.



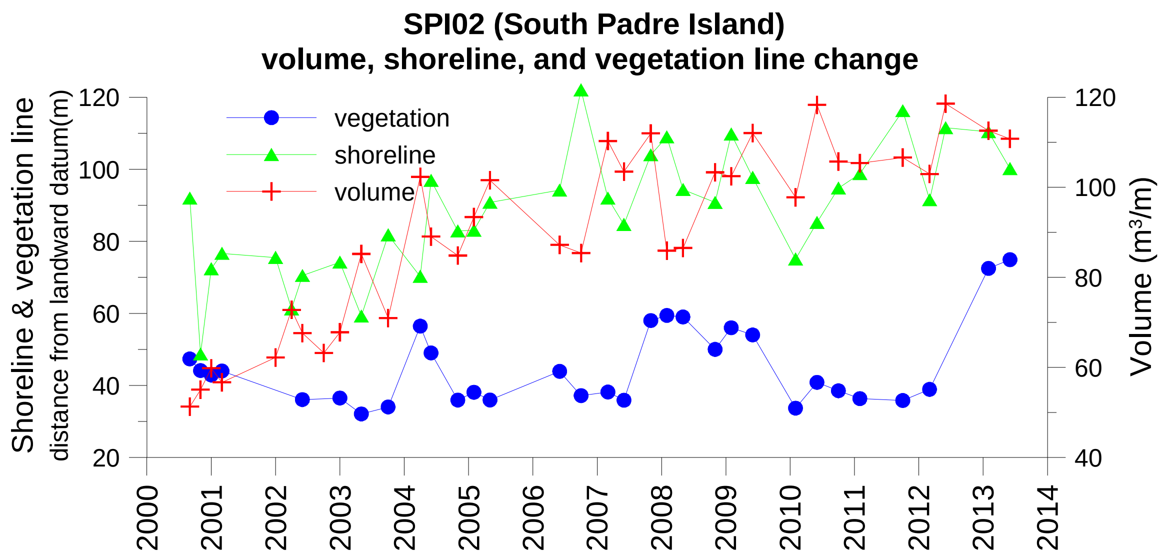
NPI08 volumes were calculated from datum to 1.25 m below datum. Profiles that did not extend to –1.25 m were extrapolated.



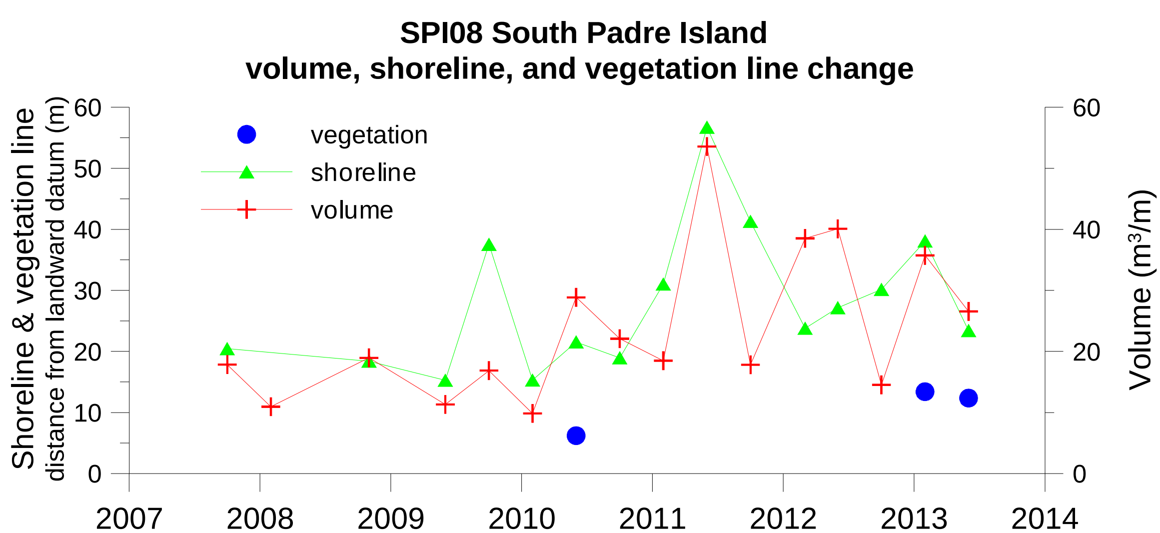

SPI01 volumes were calculated from datum to 2 m below datum. Profiles that did not extend to –2 m were extrapolated.



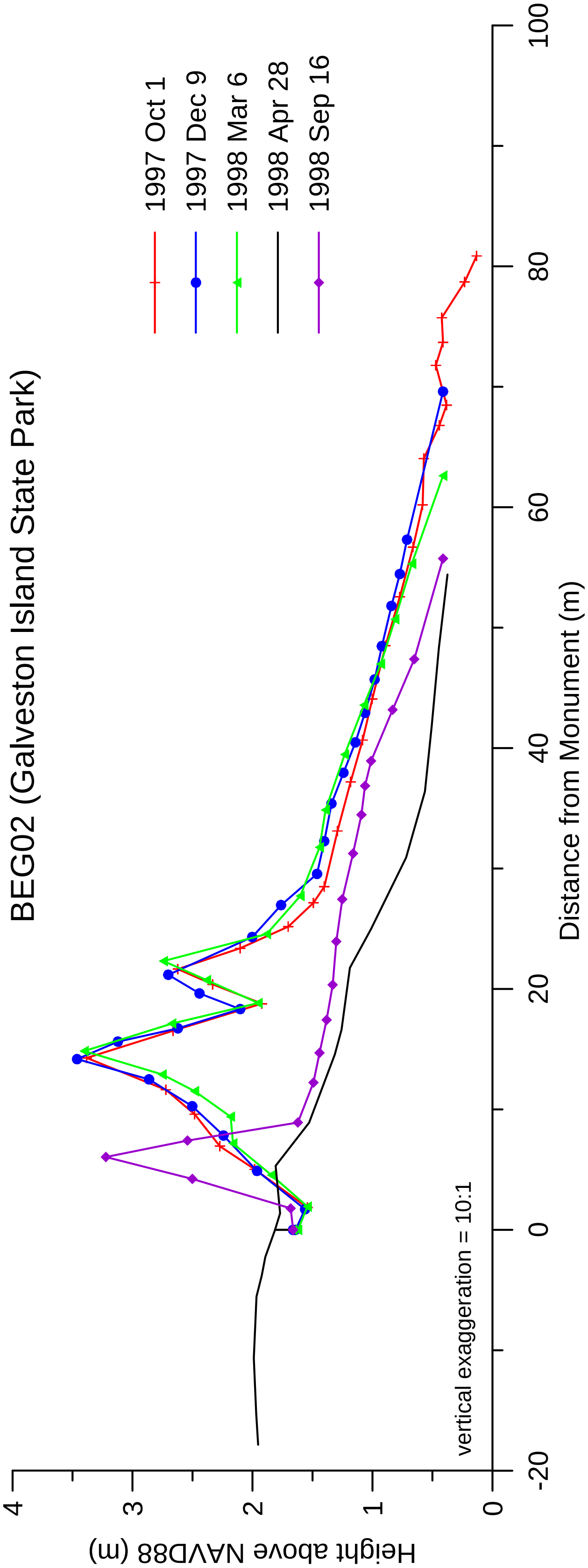
SPI02 volumes were calculated from datum to 2.25 m below datum. Profiles that did not extend to –2.25 m were extrapolated.

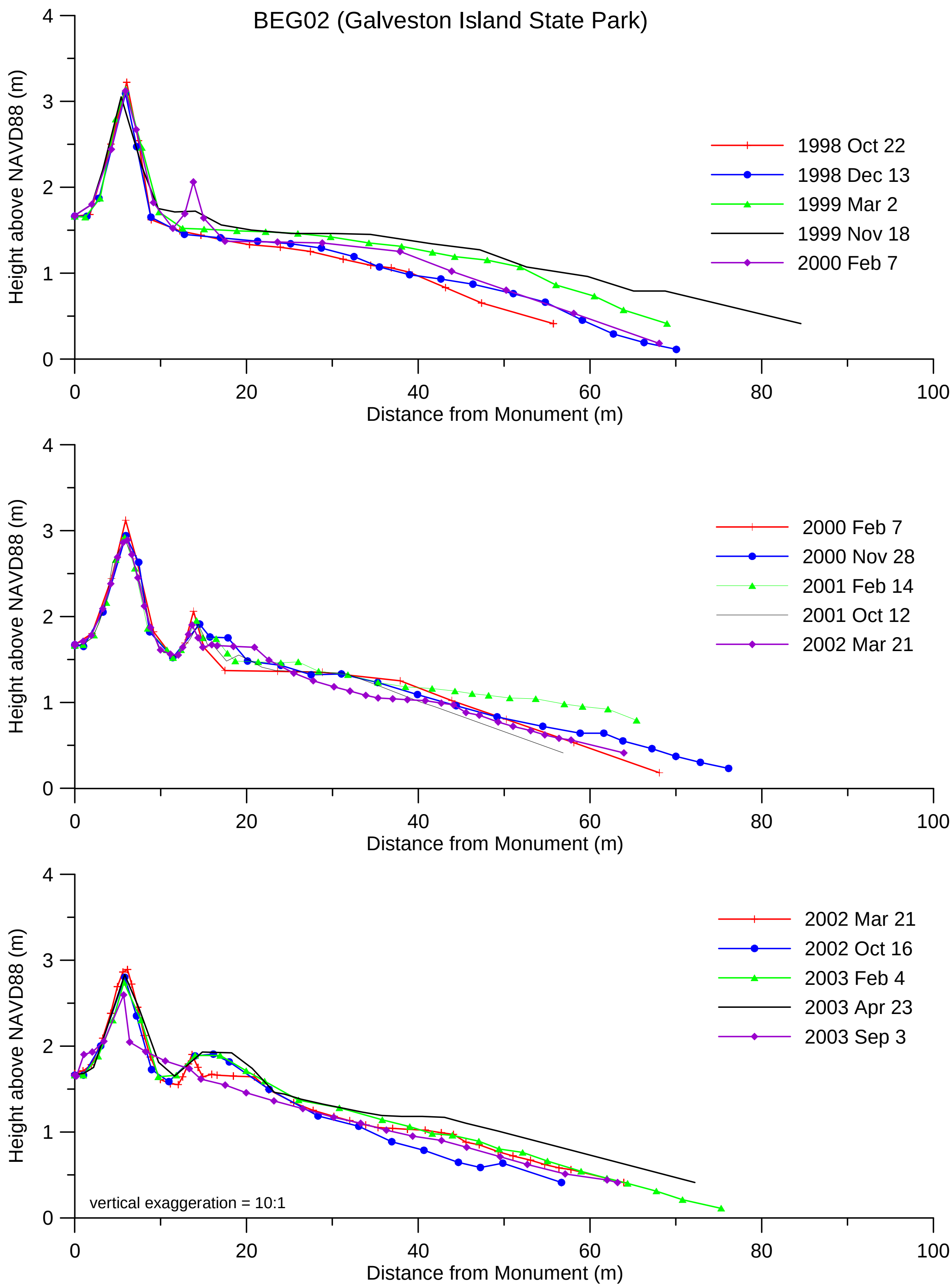


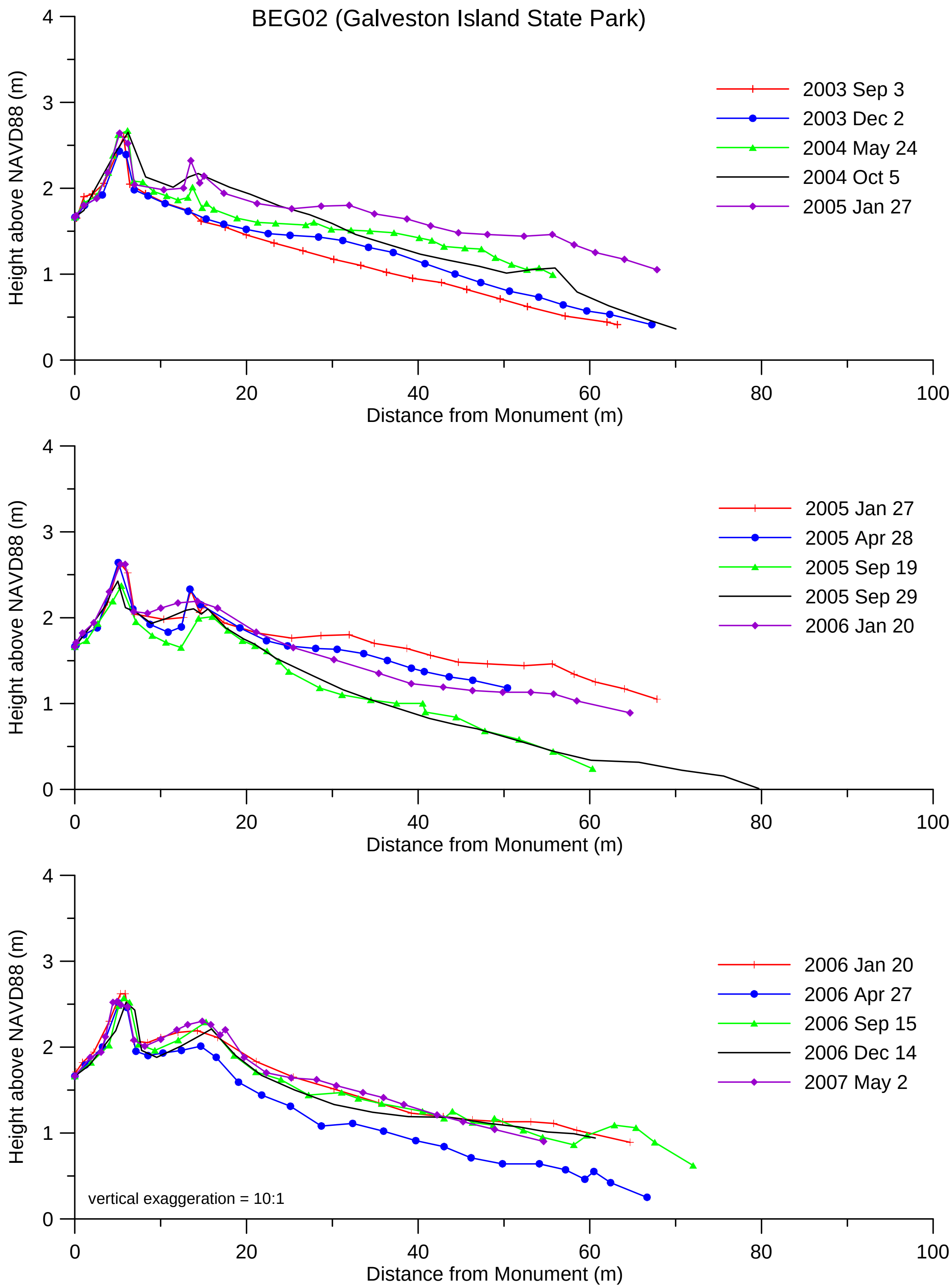

SPI08 volumes were calculated from datum to 2.5 m below datum. Profiles that did not extend to –2.5 m were extrapolated.

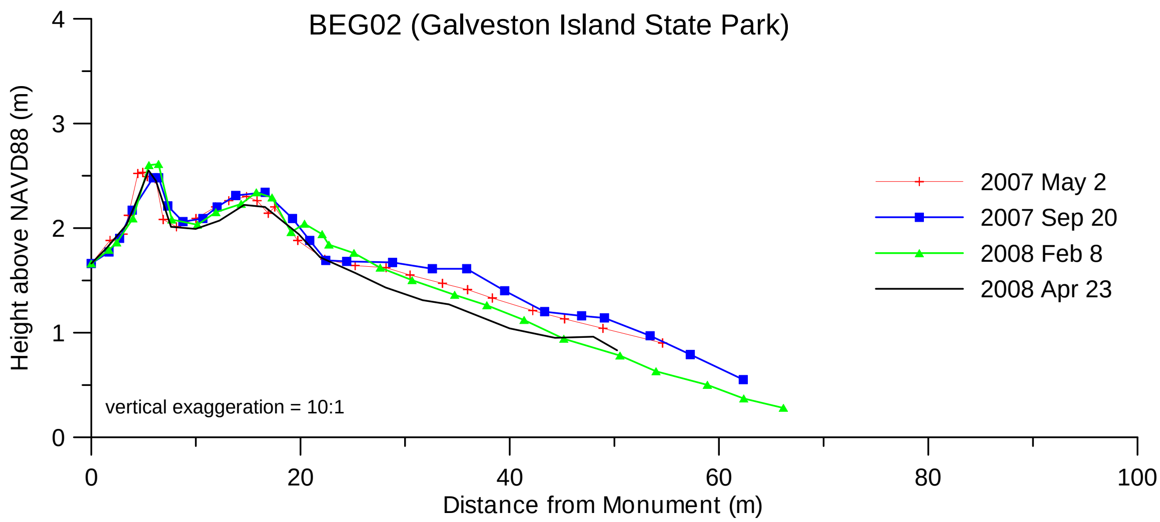


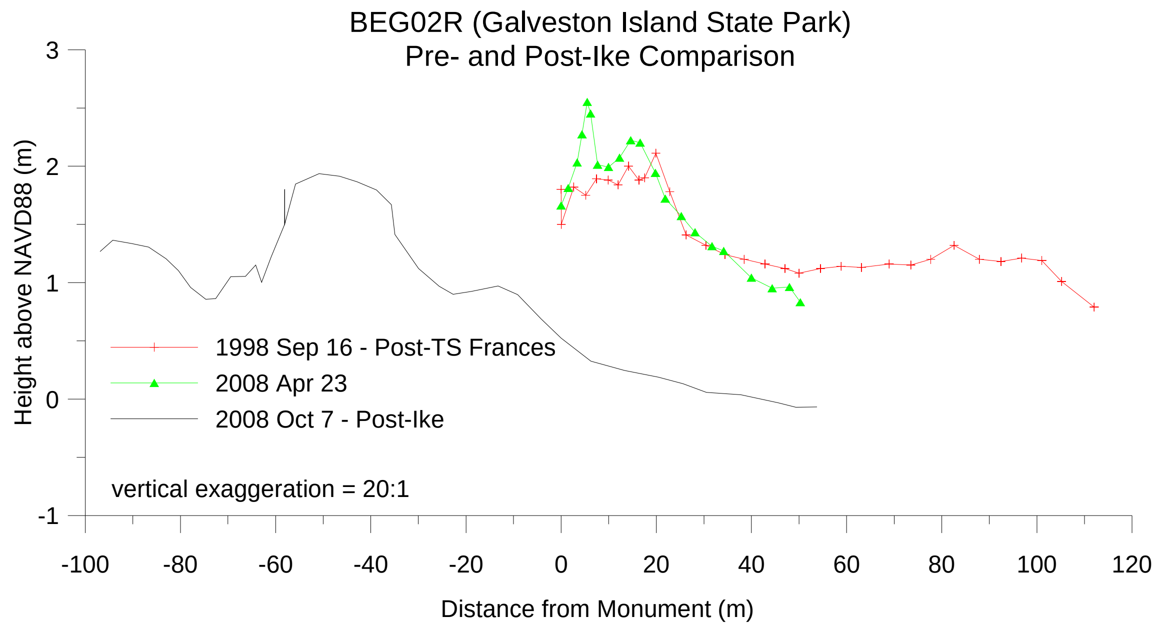
# APPENDIX C: GRAPHS OF BEACH PROFILES


BEG02 (Galveston Island State Park)
1997 Oct 1
1997 Dec 9
1998 Mar 6
1998 Apr 28
1998 Sep 16
vertical exaggeration = 10:1
Distance from Monument (m)
Height above NAVD88 (m)
-20
0
20
40
60
80
100
0
1
2
3
4

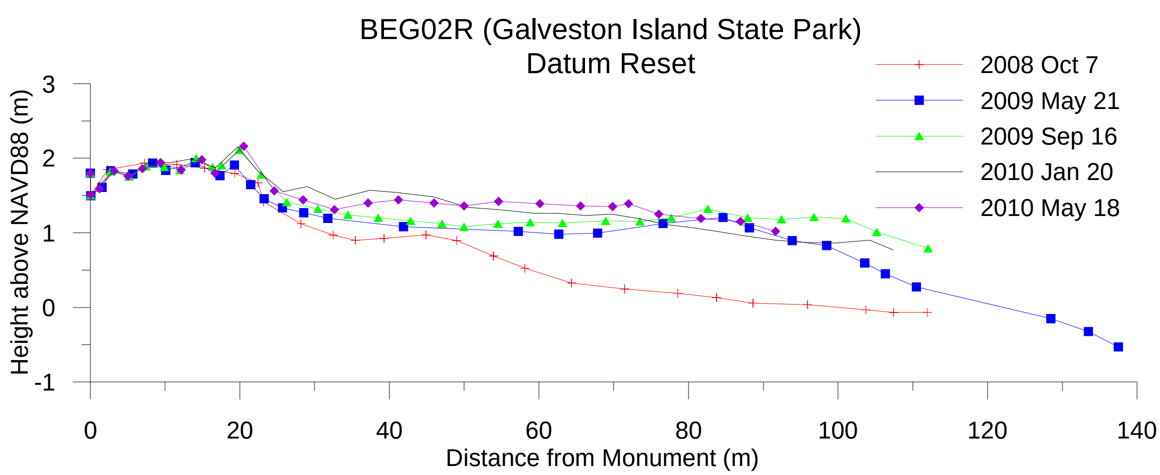

BEG02 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
1998 Oct 22
1998 Dec 13
1999 Mar 2
1999 Nov 18
2000 Feb 7
2000 Feb 7
2000 Nov 28
2001 Feb 14
2001 Oct 12
2002 Mar 21
2002 Mar 21
2002 Oct 16
2003 Feb 4
2003 Apr 23
2003 Sep 3
vertical exaggeration = 10:1


BEG02 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2003 Sep 3
2003 Dec 2
2004 May 24
2004 Oct 5
2005 Jan 27
Height above NAVD88 (m)
Distance from Monument (m)
2005 Jan 27
2005 Apr 28
2005 Sep 19
2005 Sep 29
2006 Jan 20
Height above NAVD88 (m)
Distance from Monument (m)
2006 Jan 20
2006 Apr 27
2006 Sep 15
2006 Dec 14
2007 May 2
vertical exaggeration = 10:1

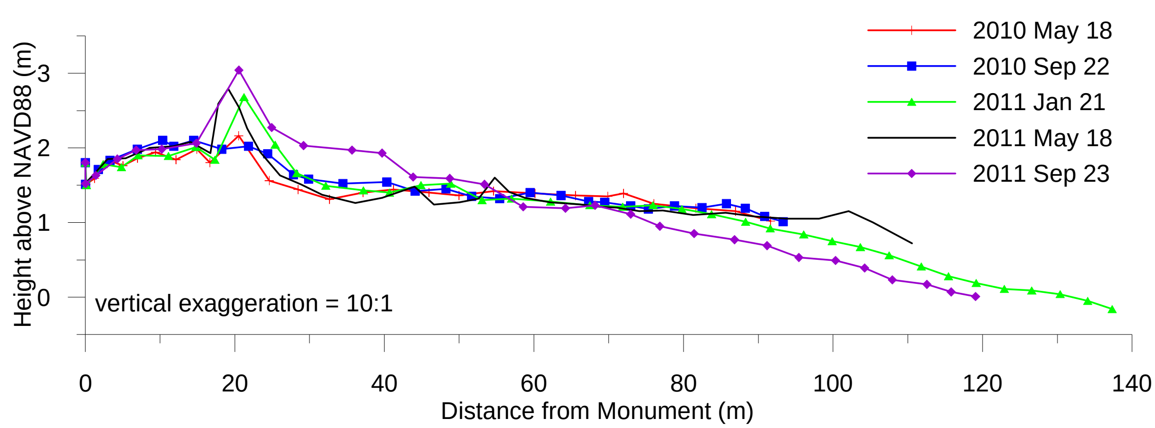

BEG02 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2007 May 2
2007 Sep 20
2008 Feb 8
2008 Apr 23
vertical exaggeration = 10:1
0
1
2
3
4
0
20
40
60
80
100



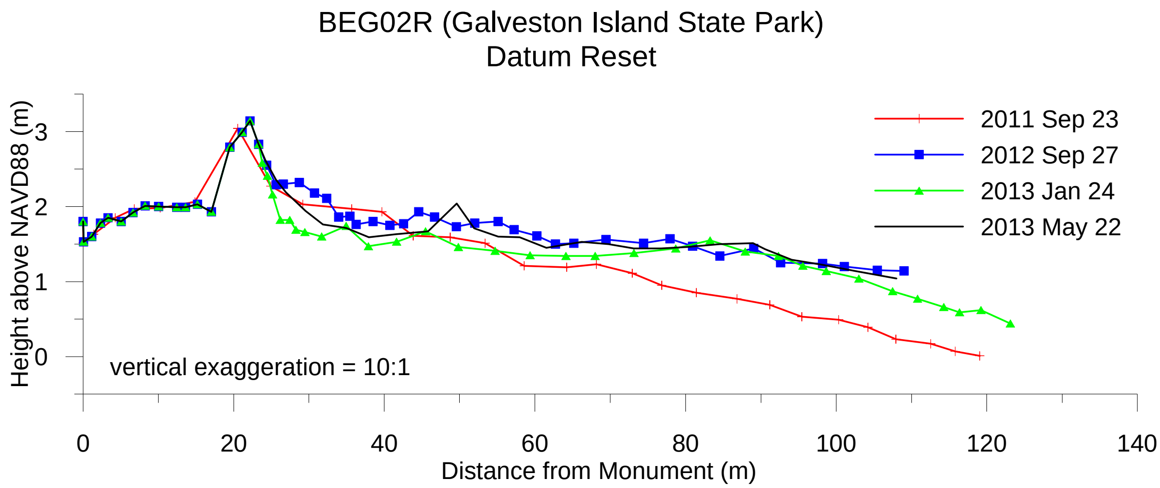
BEG02R (Galveston Island State Park)
Pre- and Post-Ike Comparison
Height above NAVD88 (m)
Distance from Monument (m)
1998 Sep 16 - Post-TS Frances
2008 Apr 23
2008 Oct 7 - Post-Ike
vertical exaggeration = 20:1

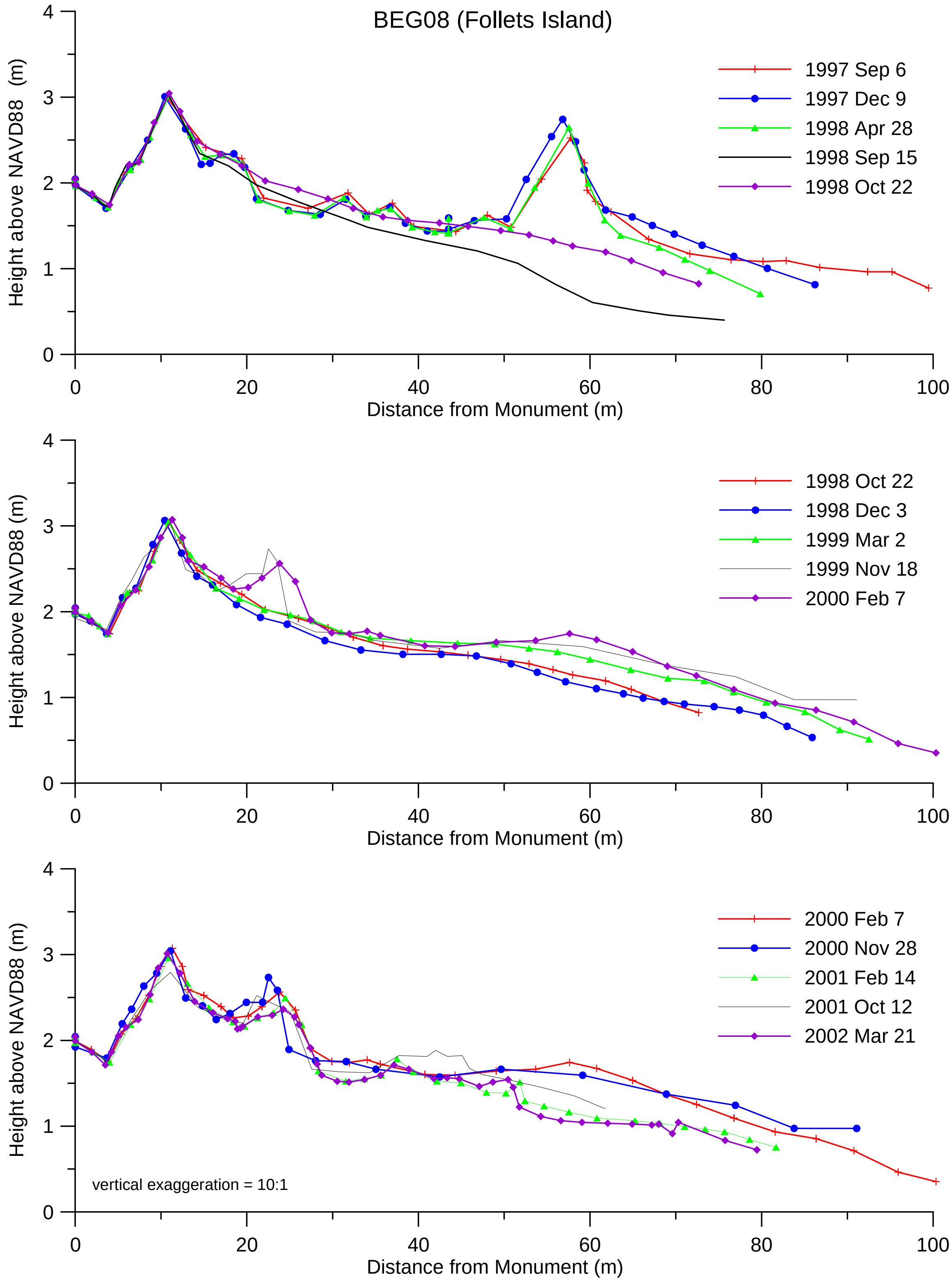



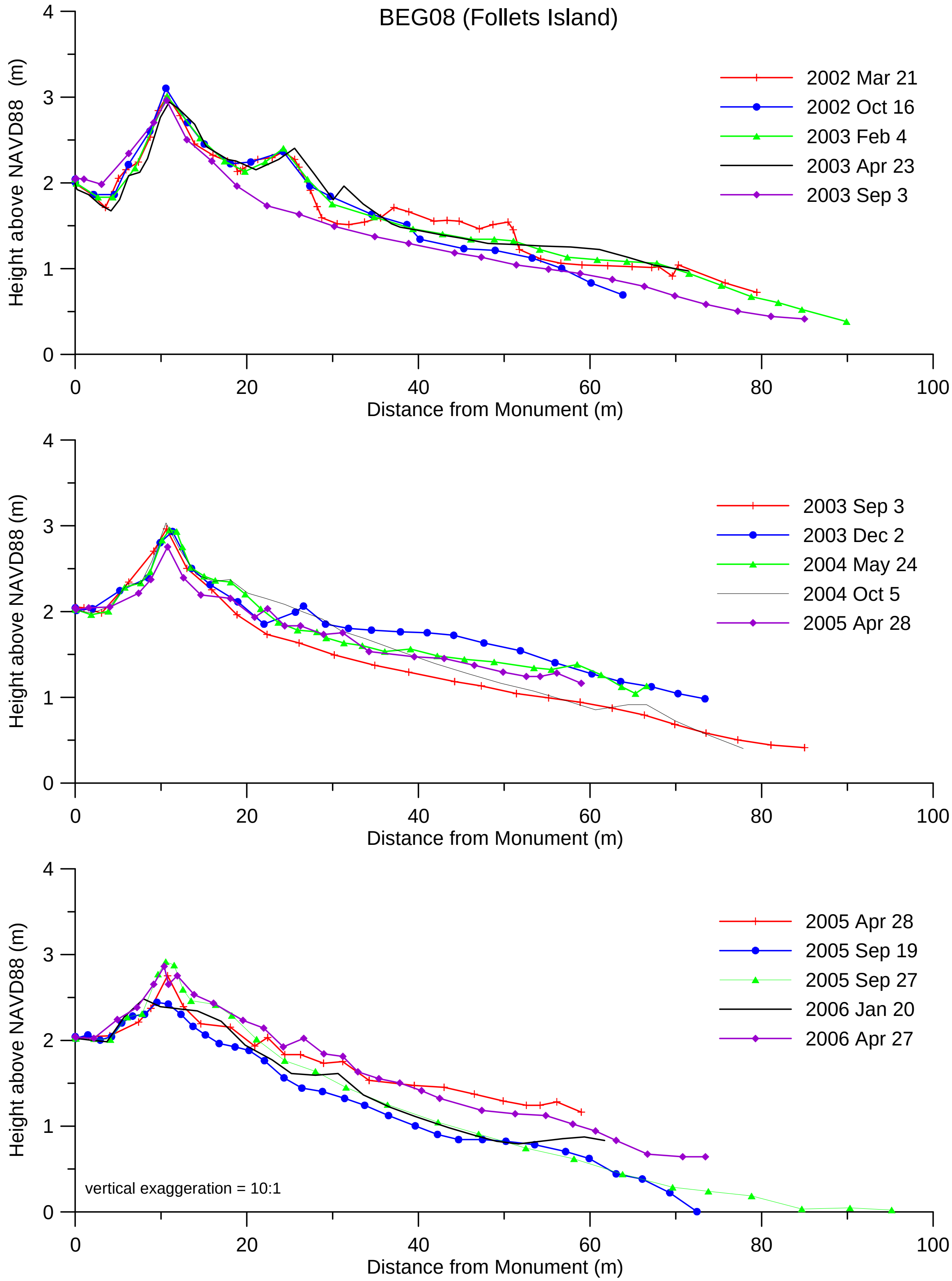
BEG02R (Galveston Island State Park)
Datum Reset
2008 Oct 7
2009 May 21
2009 Sep 16
2010 Jan 20
2010 May 18
Height above NAVD88 (m)
Distance from Monument (m)

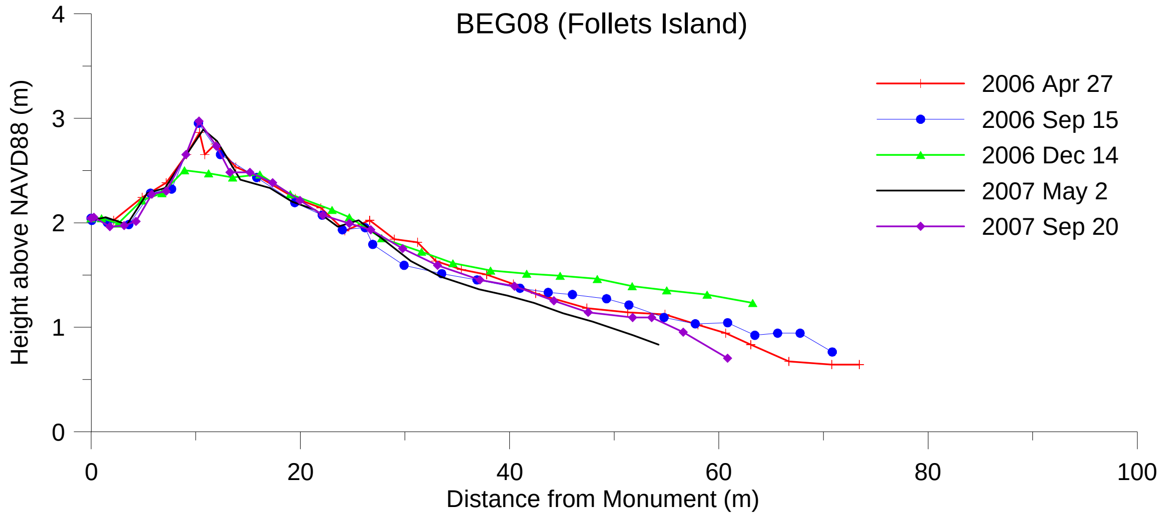



2010 May 18
2010 Sep 22
2011 Jan 21
2011 May 18
2011 Sep 23
Height above NAVD88 (m)
vertical exaggeration = 10:1
Distance from Monument (m)

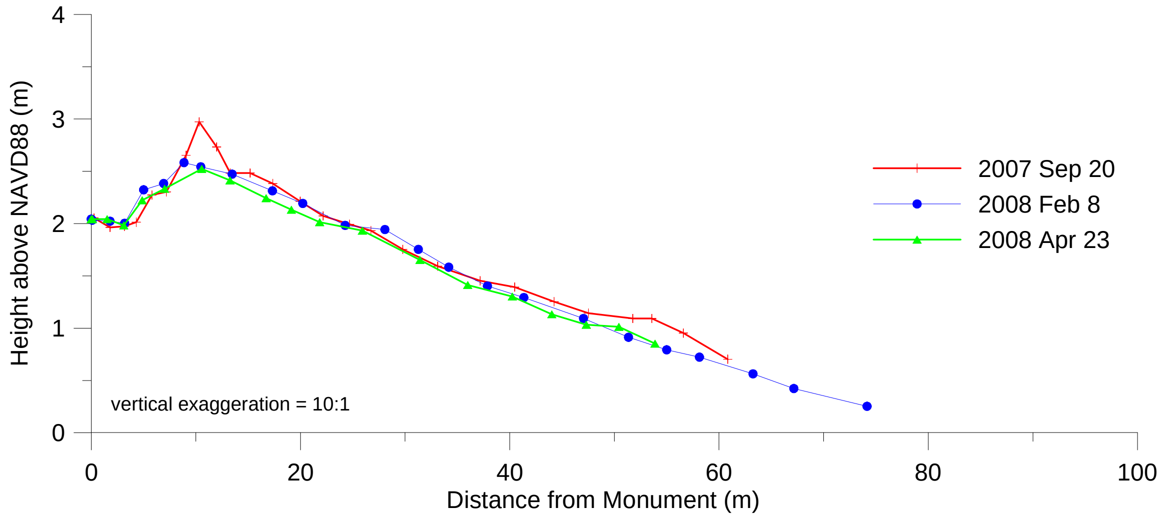

BEG02R (Galveston Island State Park)
Datum Reset
Height above NAVD88 (m)
0
1
2
3
vertical exaggeration = 10:1
2011 Sep 23
2012 Sep 27
2013 Jan 24
2013 May 22
0
20
40
60
80
100
120
140
Distance from Monument (m)


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
1998 Oct 22
1998 Dec 3
1999 Mar 2
1999 Nov 18
2000 Feb 7
2000 Feb 7
2000 Nov 28
2001 Feb 14
2001 Oct 12
2002 Mar 21
vertical exaggeration = 10:1

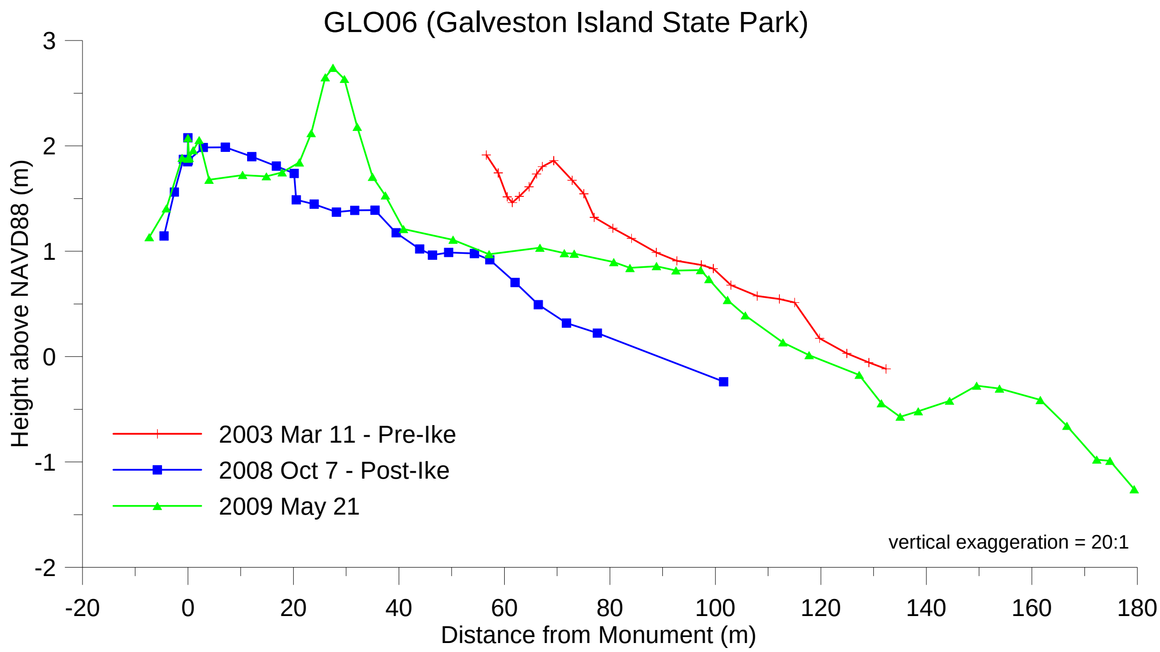

BEG08 (Follets Island)
Height above NAVD88 (m)
Distance from Monument (m)
2002 Mar 21
2002 Oct 16
2003 Feb 4
2003 Apr 23
2003 Sep 3
2003 Sep 3
2003 Dec 2
2004 May 24
2004 Oct 5
2005 Apr 28
2005 Apr 28
2005 Sep 19
2005 Sep 27
2006 Jan 20
2006 Apr 27
vertical exaggeration = 10:1
0
1
2
3
4
0
20
40
60
80
100

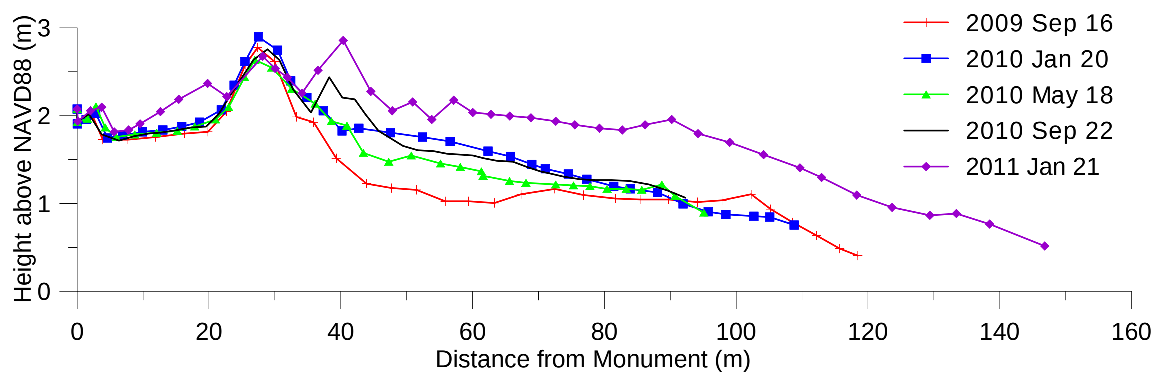


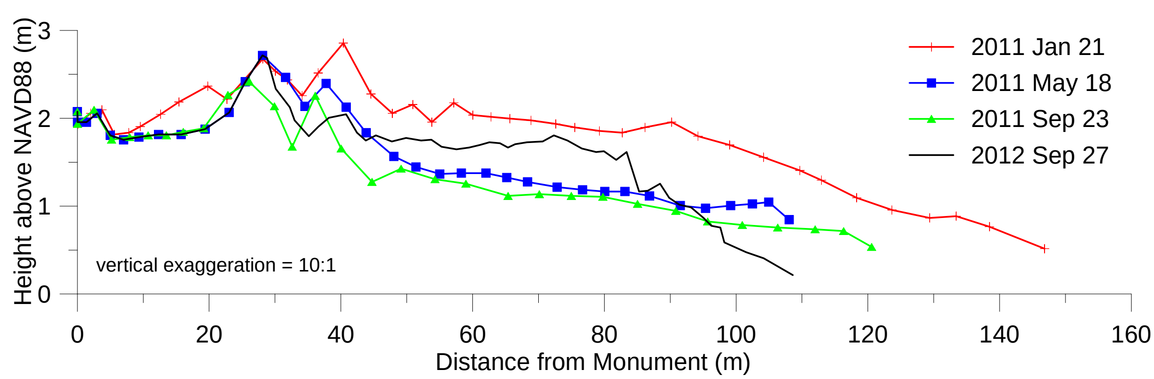
BEG08 (Follets Island)
2006 Apr 27
2006 Sep 15
2006 Dec 14
2007 May 2
2007 Sep 20
Height above NAVD88 (m)
Distance from Monument (m)
0
1
2
3
4
0
20
40
60
80
100

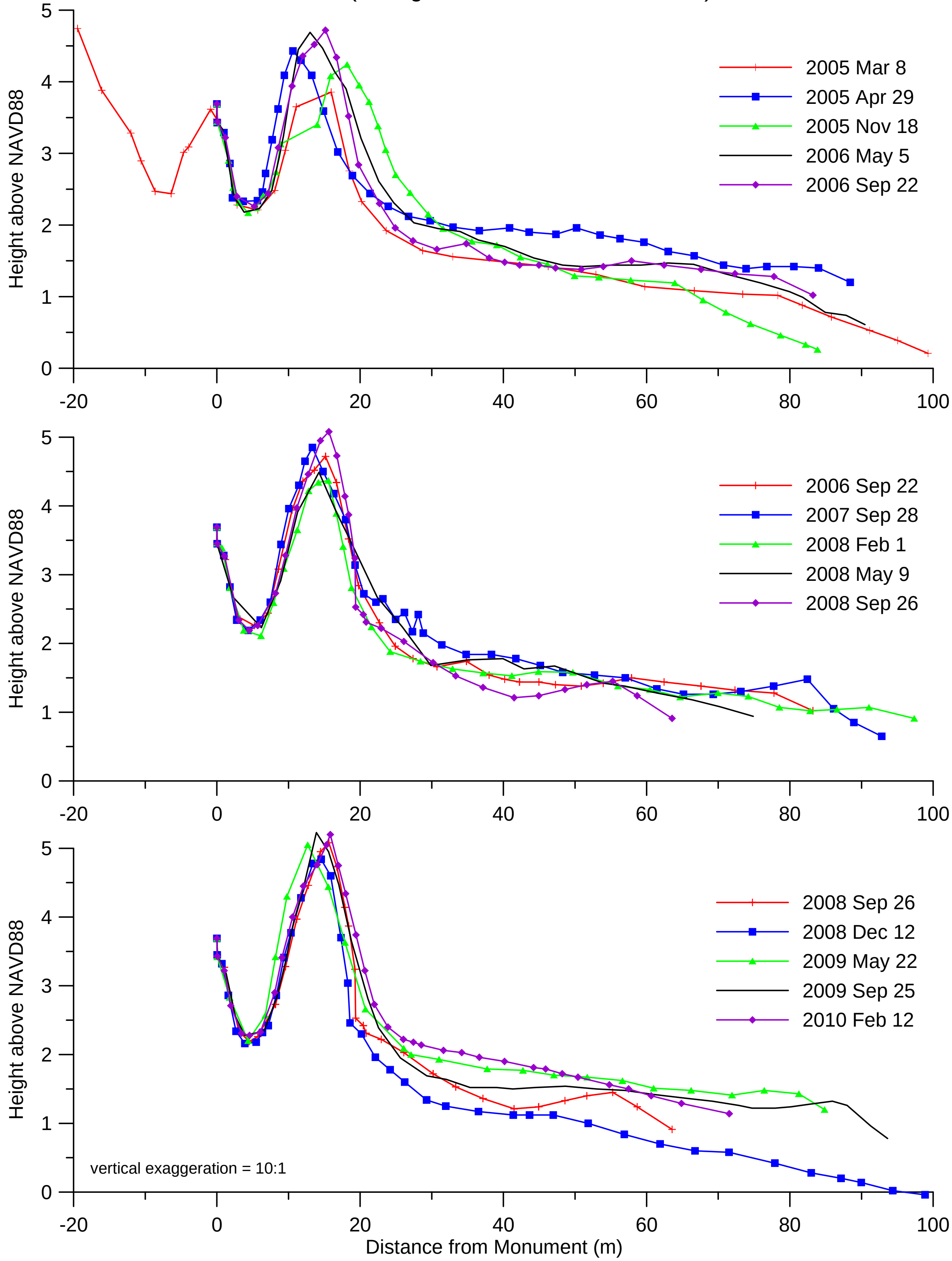
2007 Sep 20
2008 Feb 8
2008 Apr 23
vertical exaggeration = 10:1
Height above NAVD88 (m)
Distance from Monument (m)
0
1
2
3
4
0
20
40
60
80
100

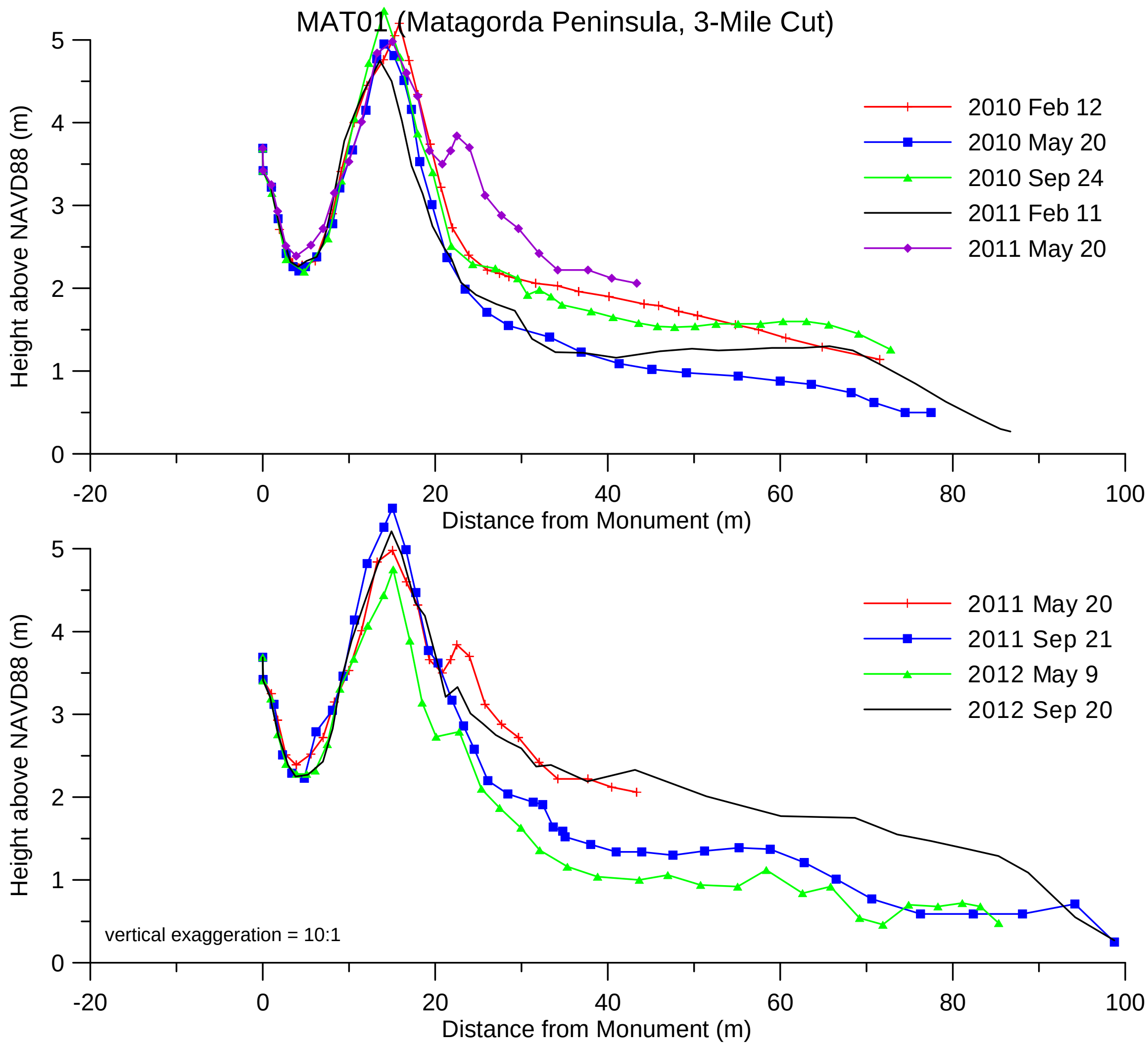

GLO06 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2003 Mar 11 - Pre-Ike
2008 Oct 7 - Post-Ike
2009 May 21
vertical exaggeration = 20:1


Height above NAVD88 (m)
Distance from Monument (m)
2009 Sep 16
2010 Jan 20
2010 May 18
2010 Sep 22
2011 Jan 21

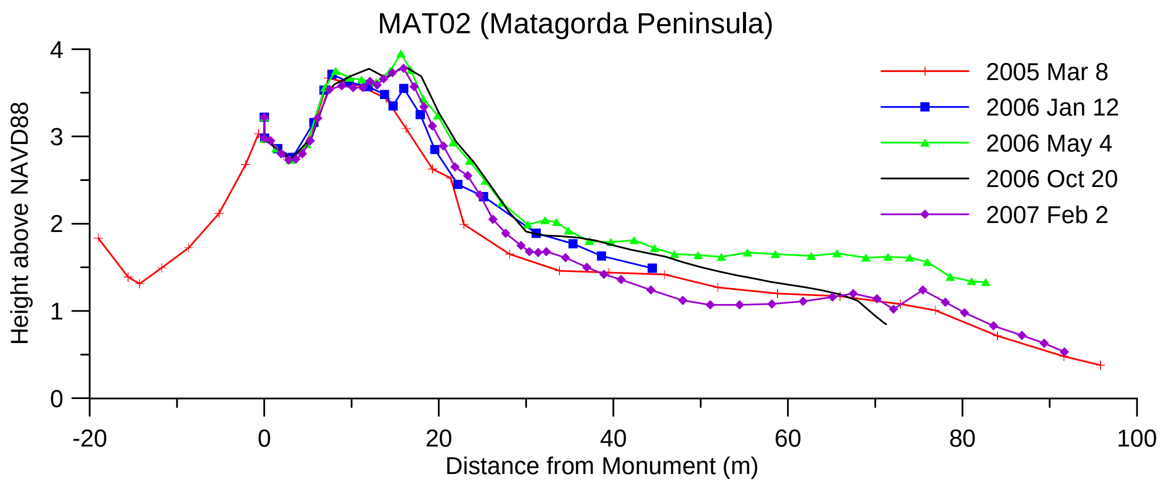

Height above NAVD88 (m)
Distance from Monument (m)
2011 Jan 21
2011 May 18
2011 Sep 23
2012 Sep 27
vertical exaggeration = 10:1

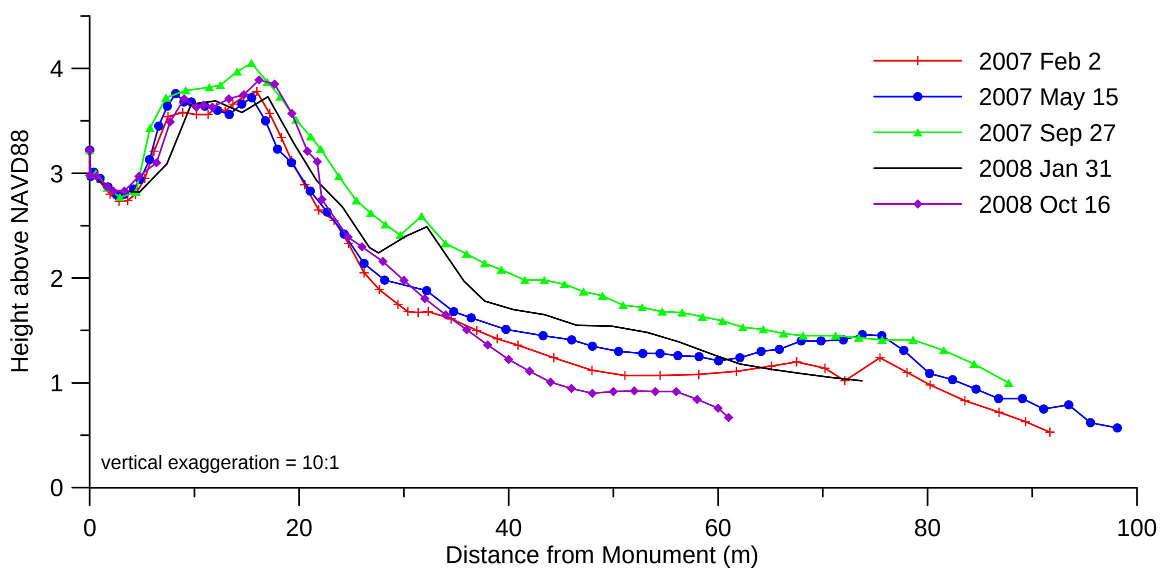
MAT01 (Matagorda Peninsula, 3-Mile Cut)



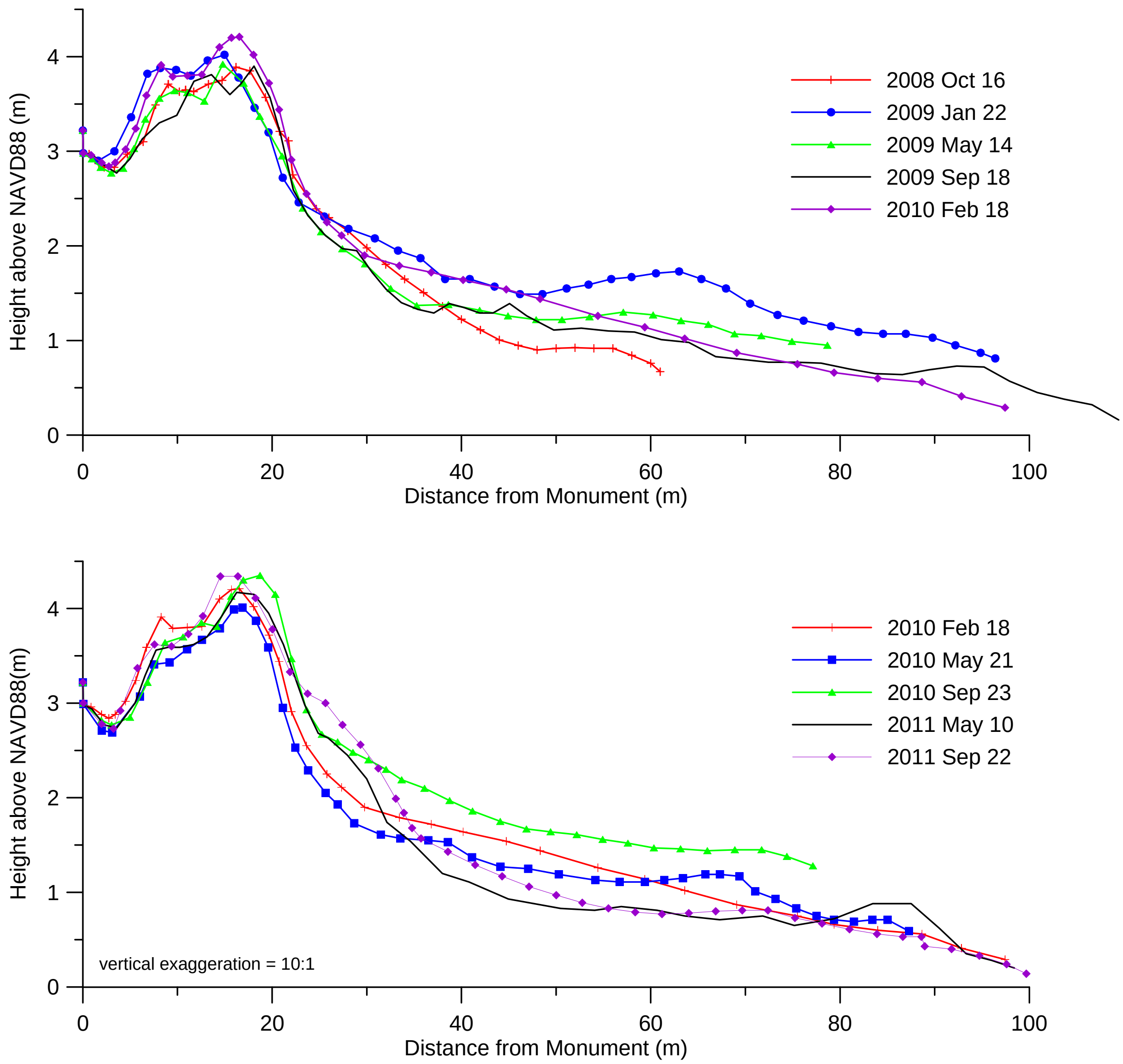


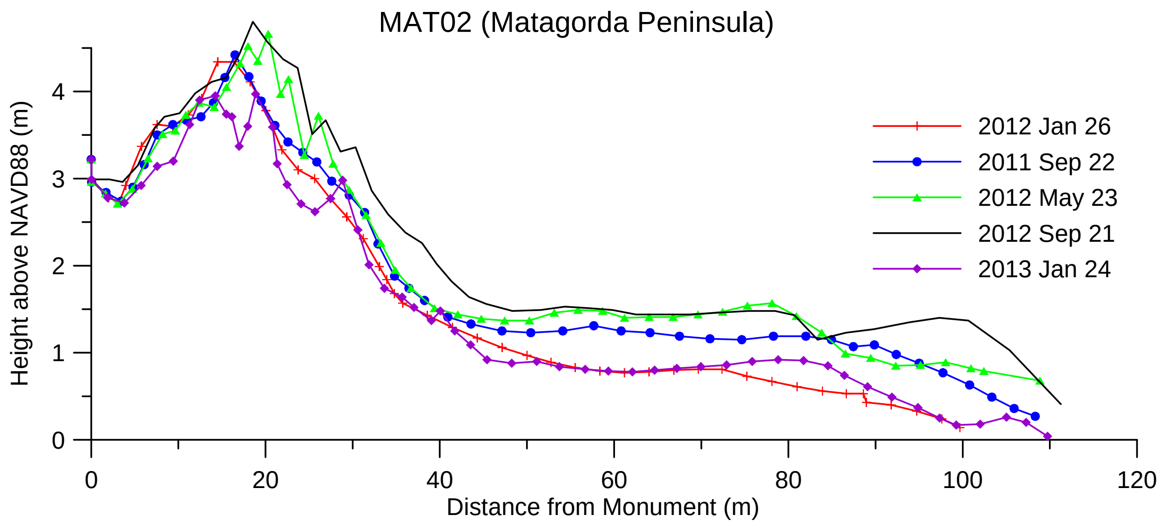
MAT01 (Matagorda Peninsula, 3-Mile Cut)
Height above NAVD88 (m)
Distance from Monument (m)
2010 Feb 12
2010 May 20
2010 Sep 24
2011 Feb 11
2011 May 20
5
4
3
2
1
0
-20
0
20
40
60
80
100
Height above NAVD88 (m)
Distance from Monument (m)
2011 May 20
2011 Sep 21
2012 May 9
2012 Sep 20
vertical exaggeration = 10:1
5
4
3
2
1
0
-20
0
20
40
60
80
100

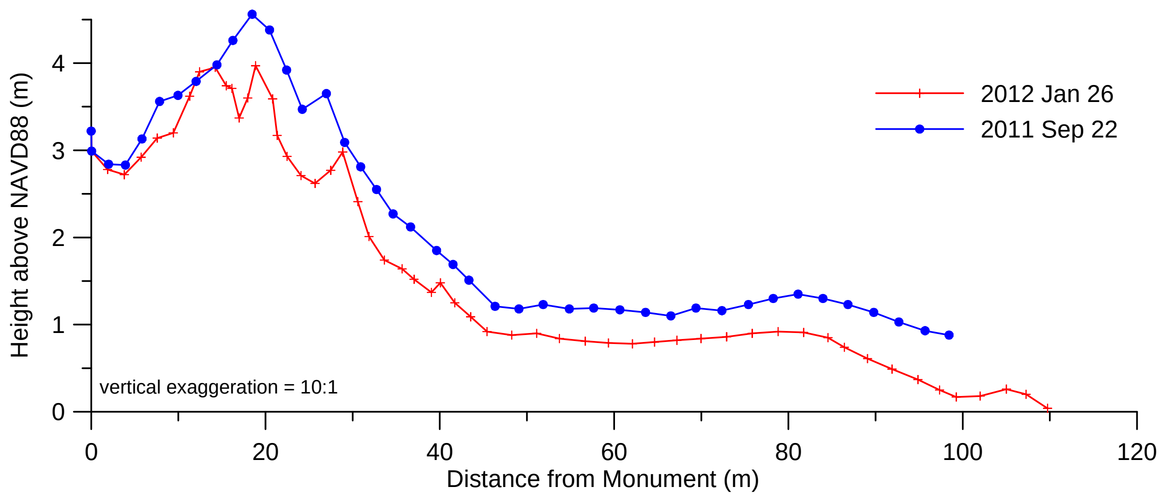

MAT02 (Matagorda Peninsula)
Height above NAVD88
Distance from Monument (m)
2005 Mar 8
2006 Jan 12
2006 May 4
2006 Oct 20
2007 Feb 2
0
1
2
3
4
-20
0
20
40
60
80
100

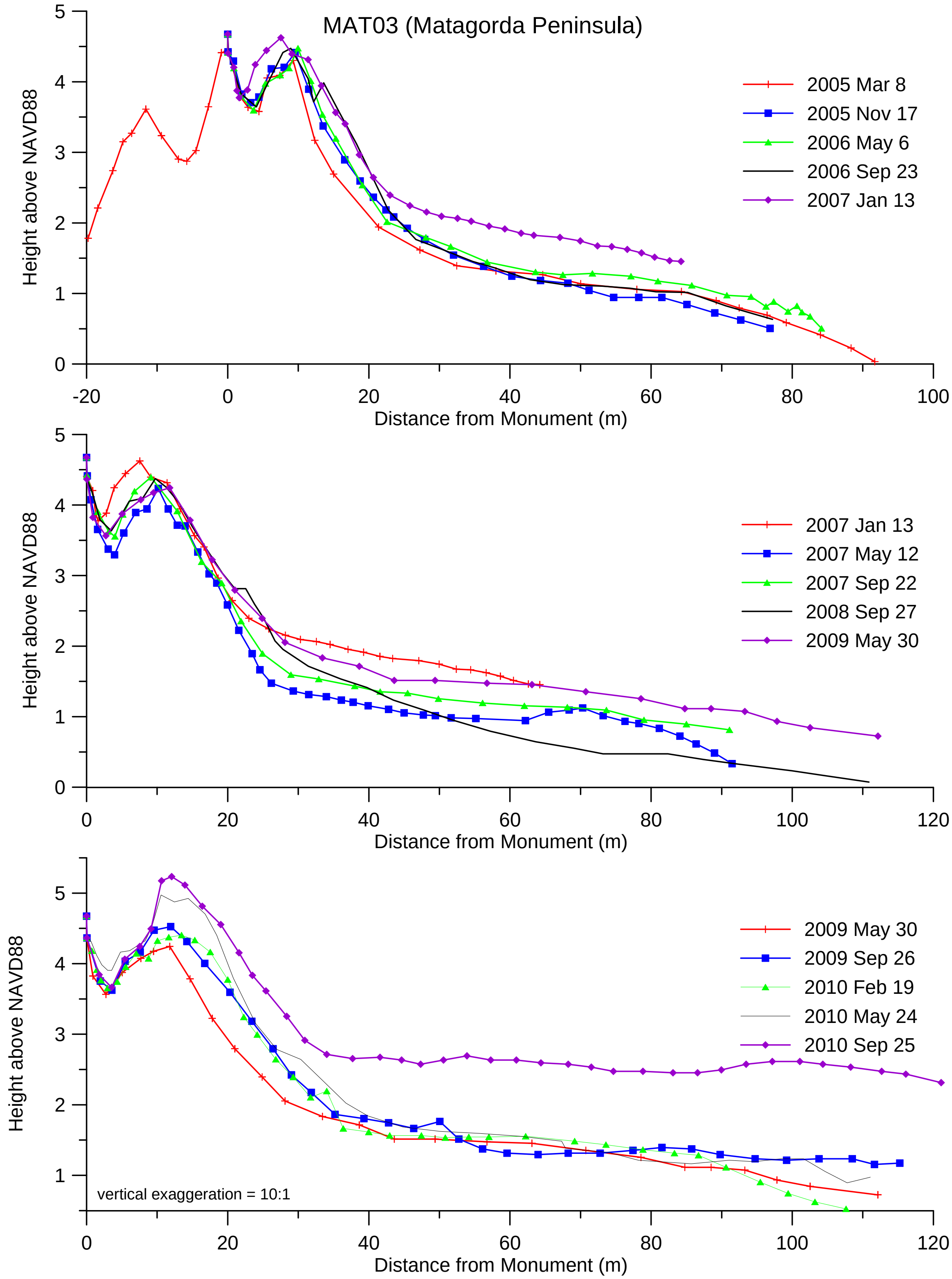

Height above NAVD88
Distance from Monument (m)
2007 Feb 2
2007 May 15
2007 Sep 27
2008 Jan 31
2008 Oct 16
vertical exaggeration = 10:1
0
1
2
3
4
0
20
40
60
80
100

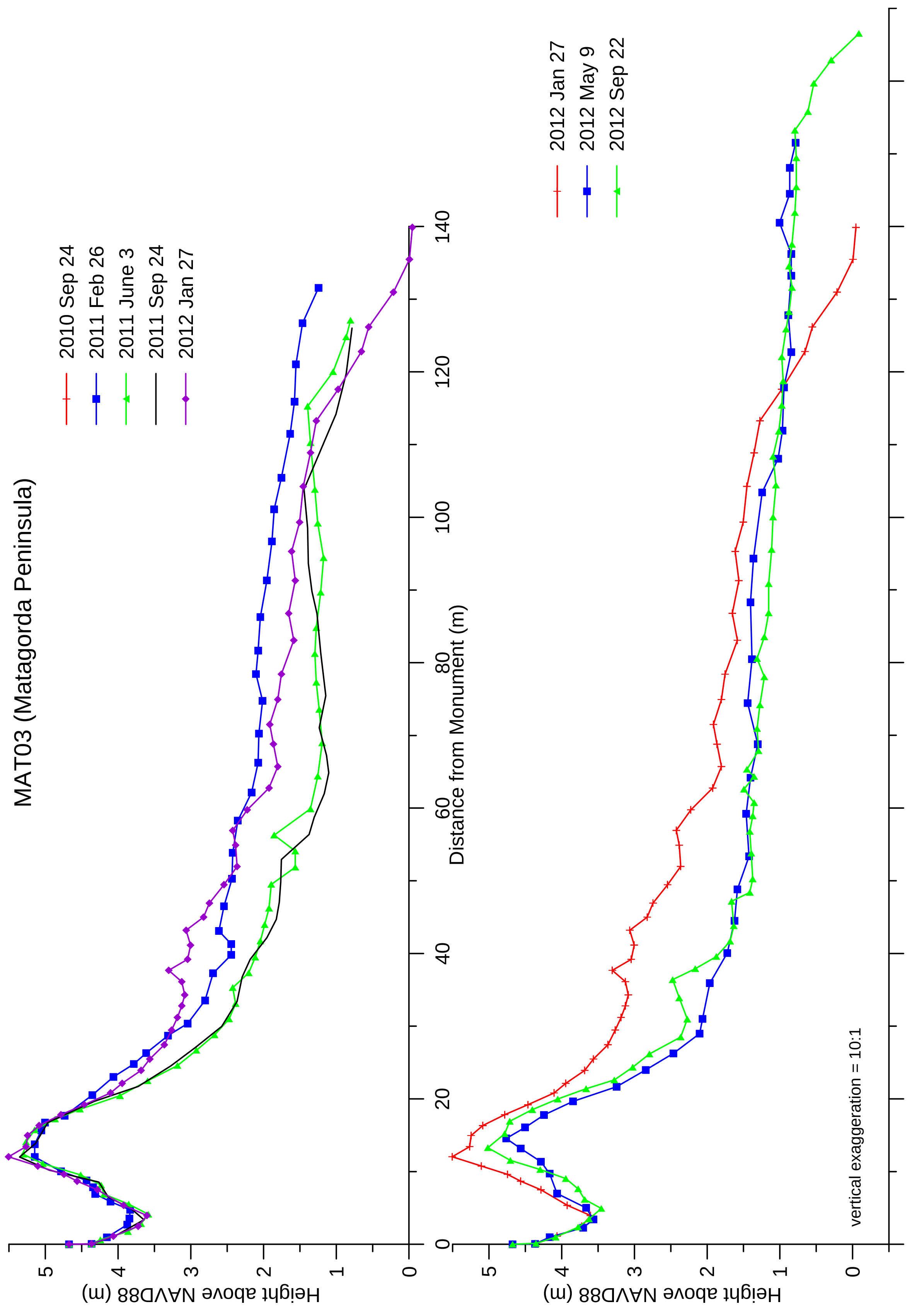
MAT02 (Matagorda Peninsula)

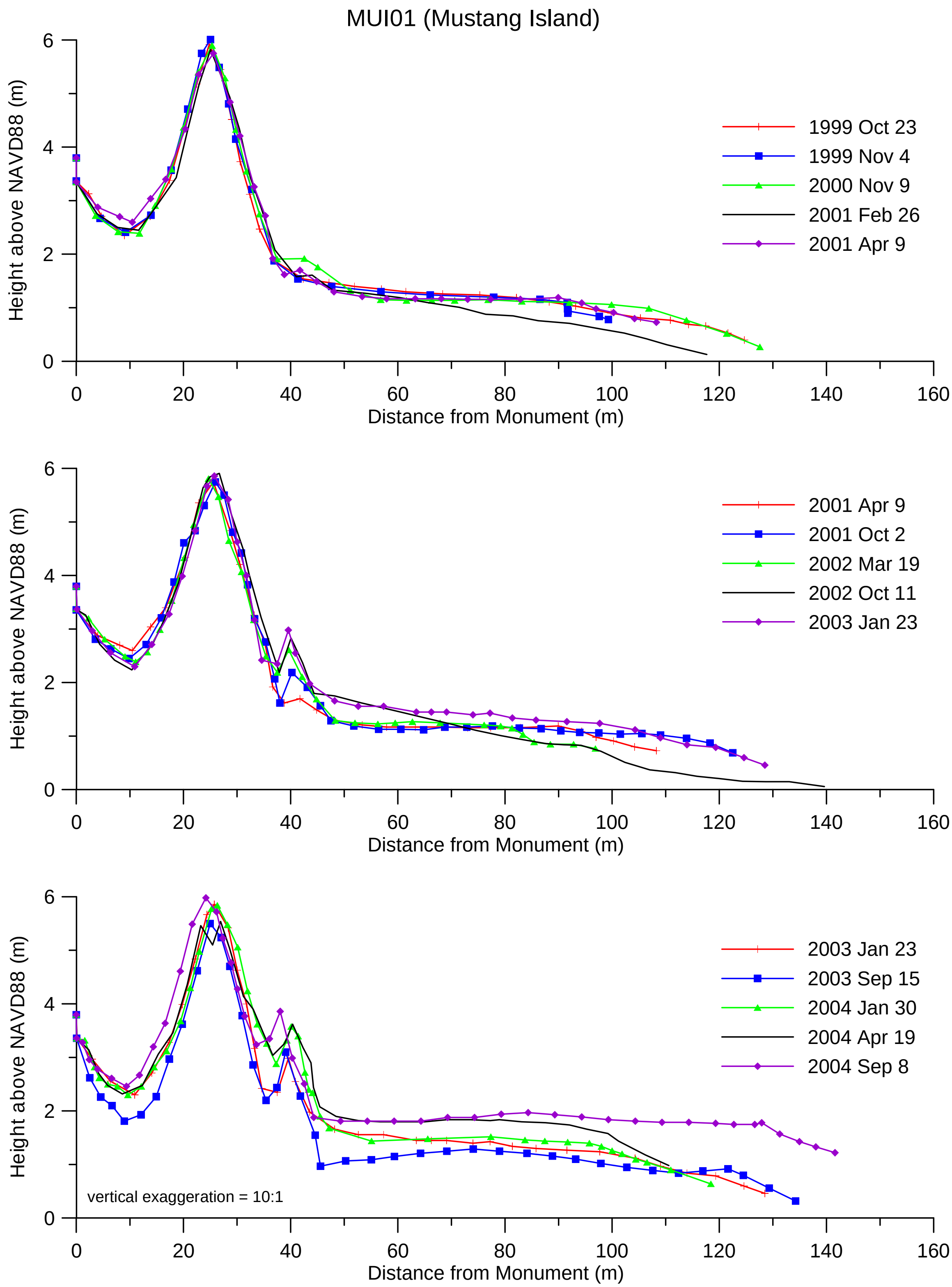


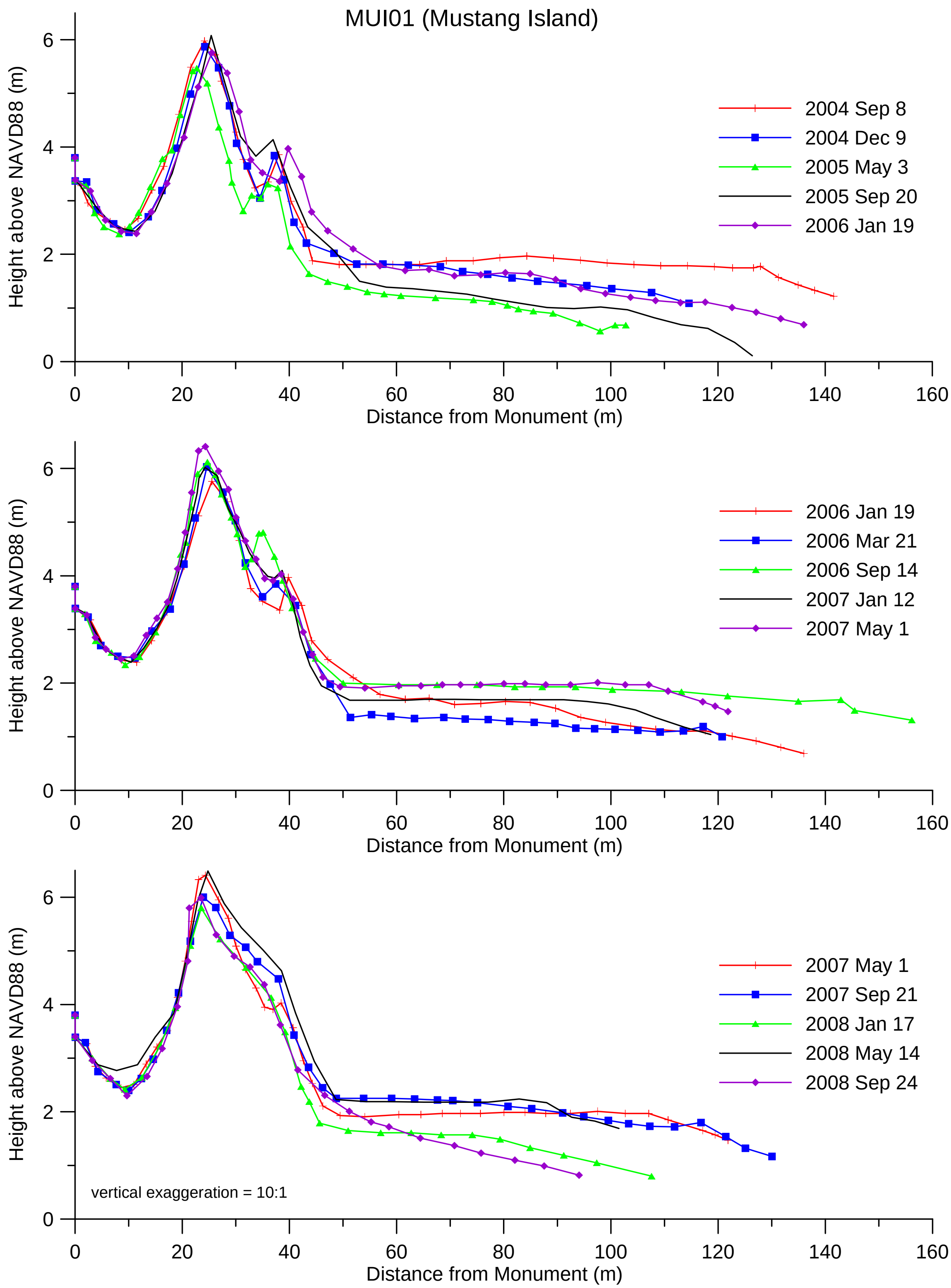

MAT02 (Matagorda Peninsula)
Height above NAVD88 (m)
Distance from Monument (m)
2012 Jan 26
2011 Sep 22
2012 May 23
2012 Sep 21
2013 Jan 24

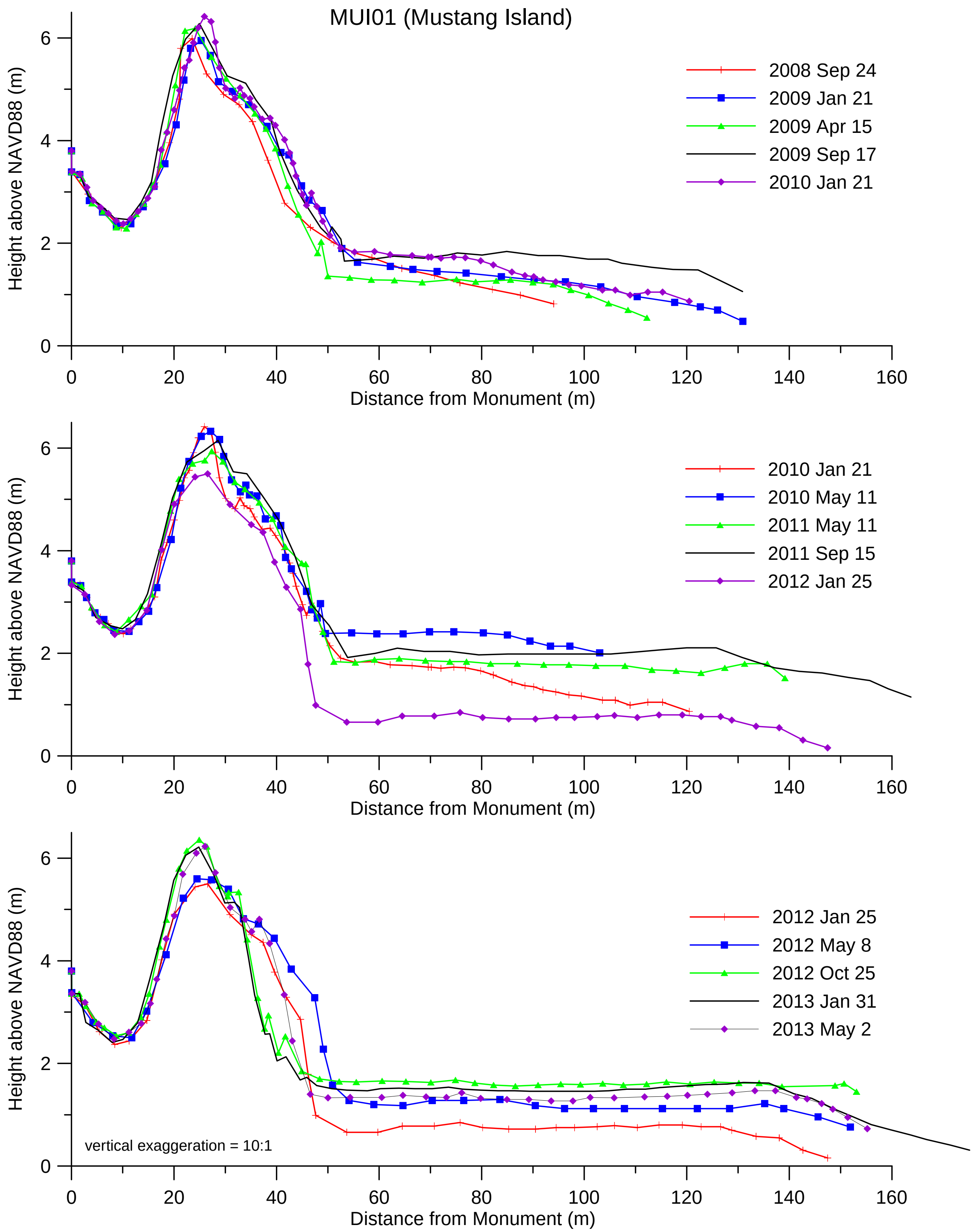

Height above NAVD88 (m)
Distance from Monument (m)
2012 Jan 26
2011 Sep 22
vertical exaggeration = 10:1


MAT03 (Matagorda Peninsula)
Height above NAVD88
Distance from Monument (m)
2005 Mar 8
2005 Nov 17
2006 May 6
2006 Sep 23
2007 Jan 13
2007 May 12
2007 Sep 22
2008 Sep 27
2009 May 30
2009 Sep 26
2010 Feb 19
2010 May 24
2010 Sep 25
vertical exaggeration = 10:1

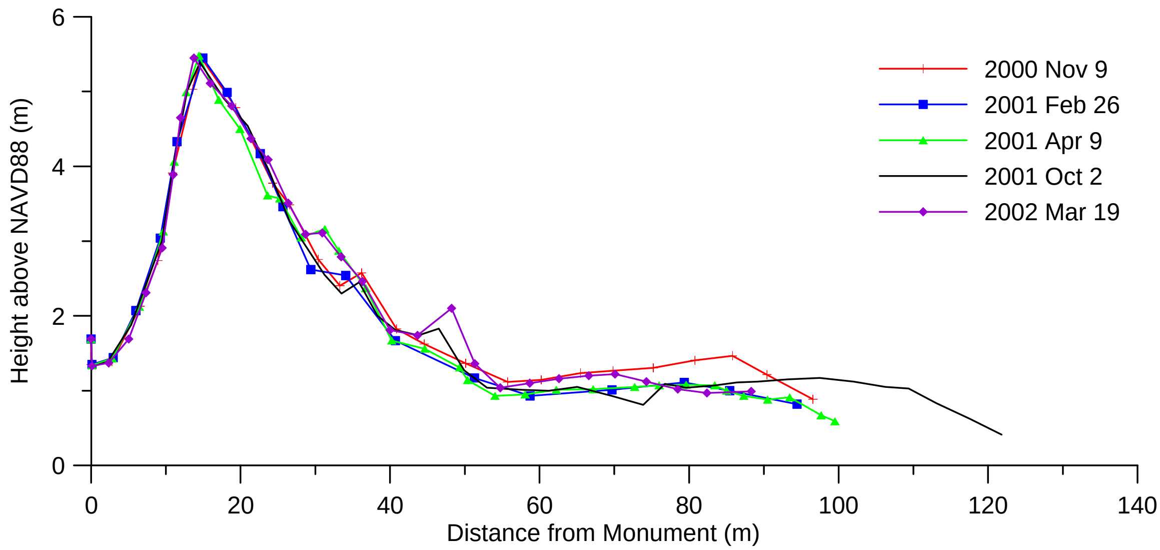

MAT03 (Matagorda Peninsula)
2010 Sep 24
2011 Feb 26
2011 June 3
2011 Sep 24
2012 Jan 27
2012 Jan 27
2012 May 9
2012 Sep 22
Height above NAVD88 (m)
Distance from Monument (m)
vertical exaggeration = 10:1

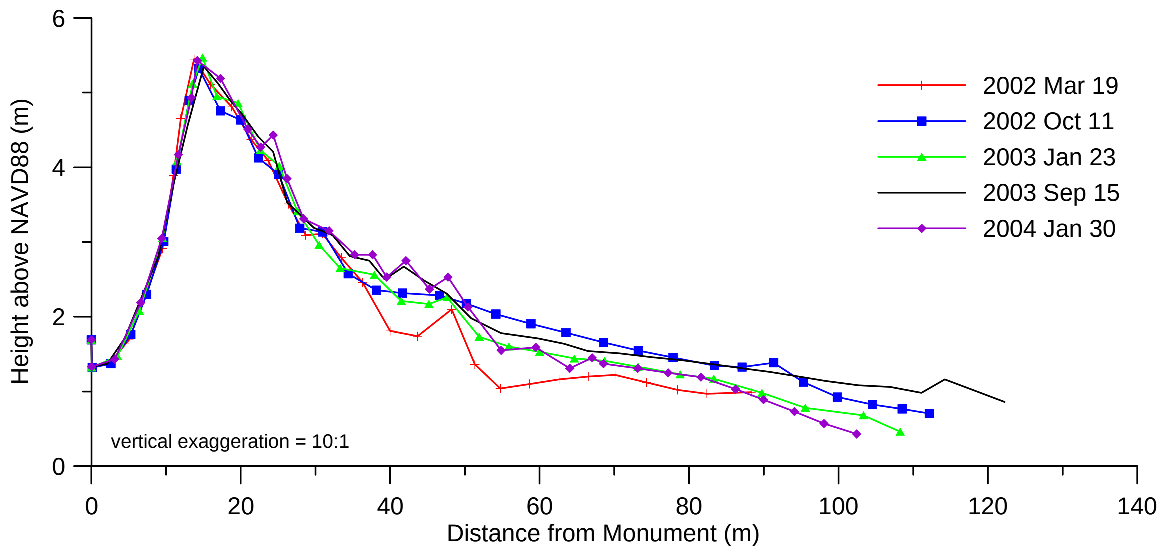

MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
1999 Oct 23
1999 Nov 4
2000 Nov 9
2001 Feb 26
2001 Apr 9
2001 Apr 9
2001 Oct 2
2002 Mar 19
2002 Oct 11
2003 Jan 23
2003 Jan 23
2003 Sep 15
2004 Jan 30
2004 Apr 19
2004 Sep 8
vertical exaggeration = 10:1

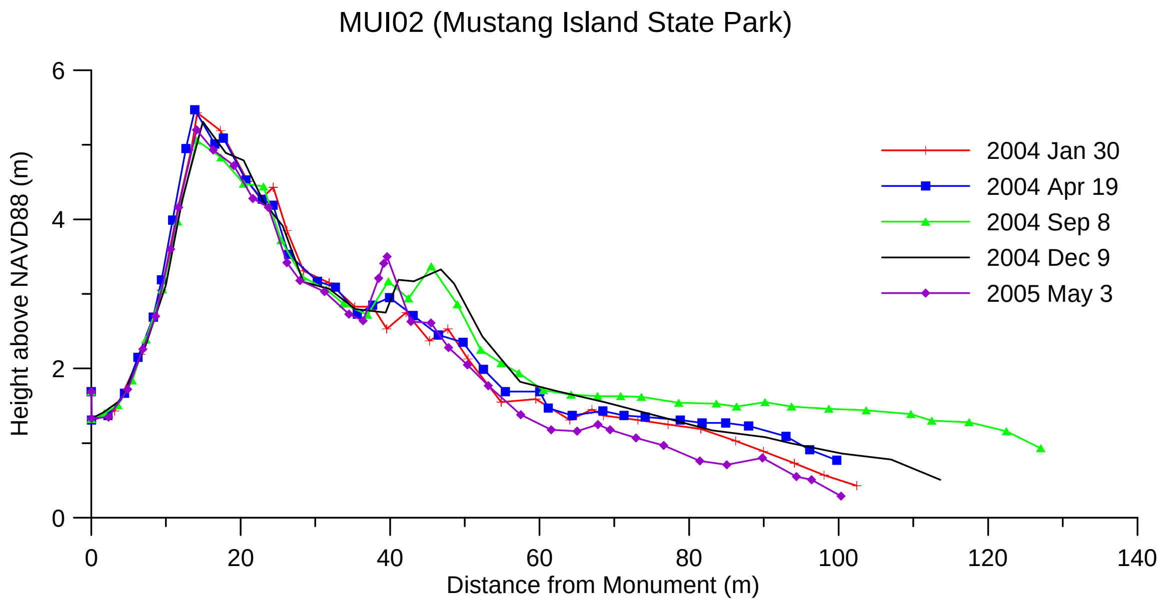

MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2004 Sep 8
2004 Dec 9
2005 May 3
2005 Sep 20
2006 Jan 19
2006 Jan 19
2006 Mar 21
2006 Sep 14
2007 Jan 12
2007 May 1
2007 May 1
2007 Sep 21
2008 Jan 17
2008 May 14
2008 Sep 24
vertical exaggeration = 10:1
0
2
4
6
0
20
40
60
80
100
120
140
160

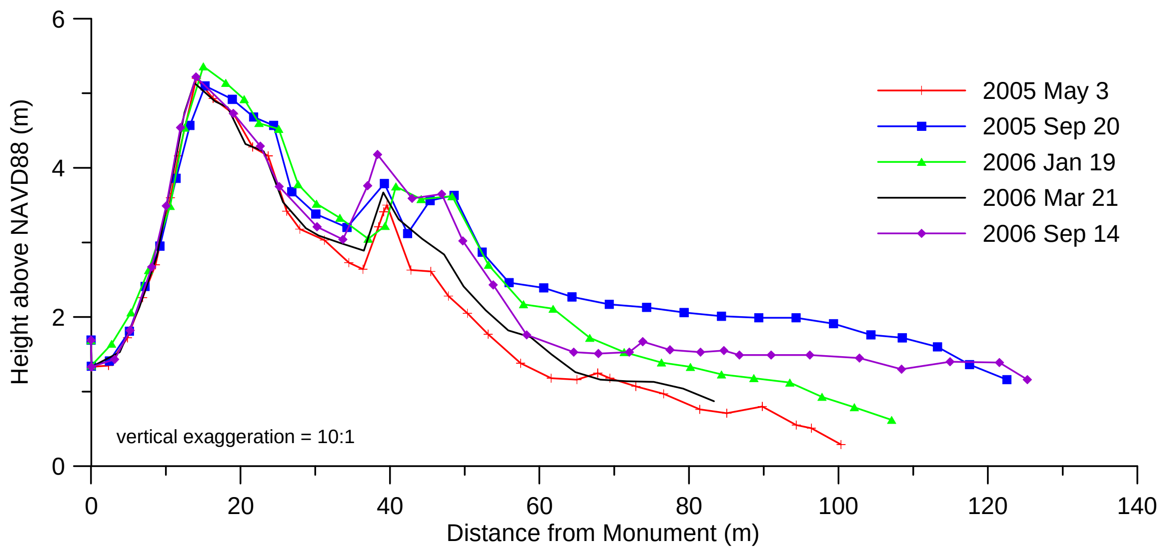

MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2008 Sep 24
2009 Jan 21
2009 Apr 15
2009 Sep 17
2010 Jan 21
2010 Jan 21
2010 May 11
2011 May 11
2011 Sep 15
2012 Jan 25
2012 Jan 25
2012 May 8
2012 Oct 25
2013 Jan 31
2013 May 2
vertical exaggeration = 10:1

MUI02 (Mustang Island State Park)

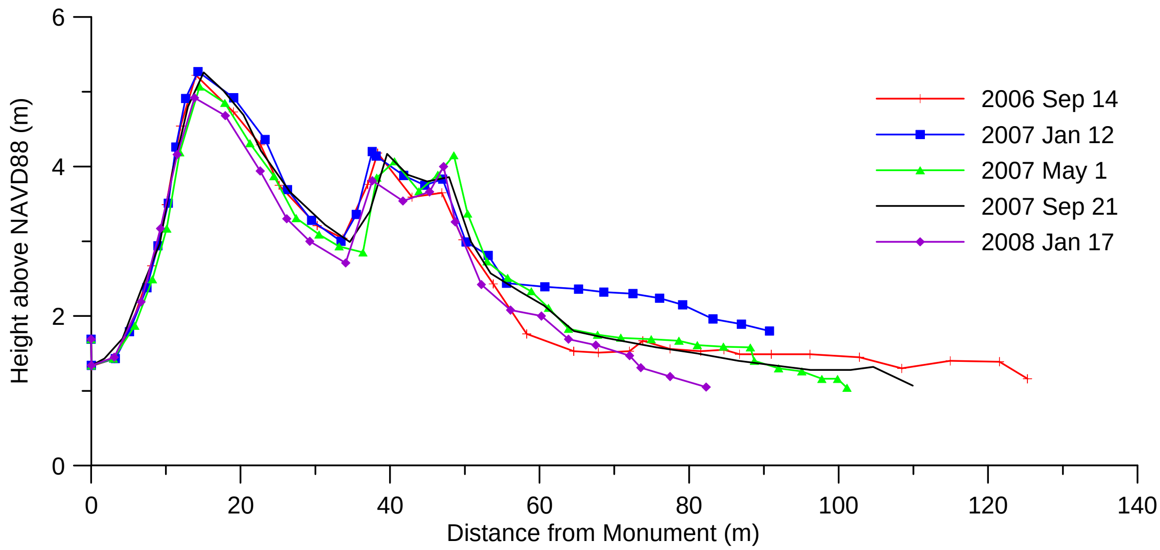


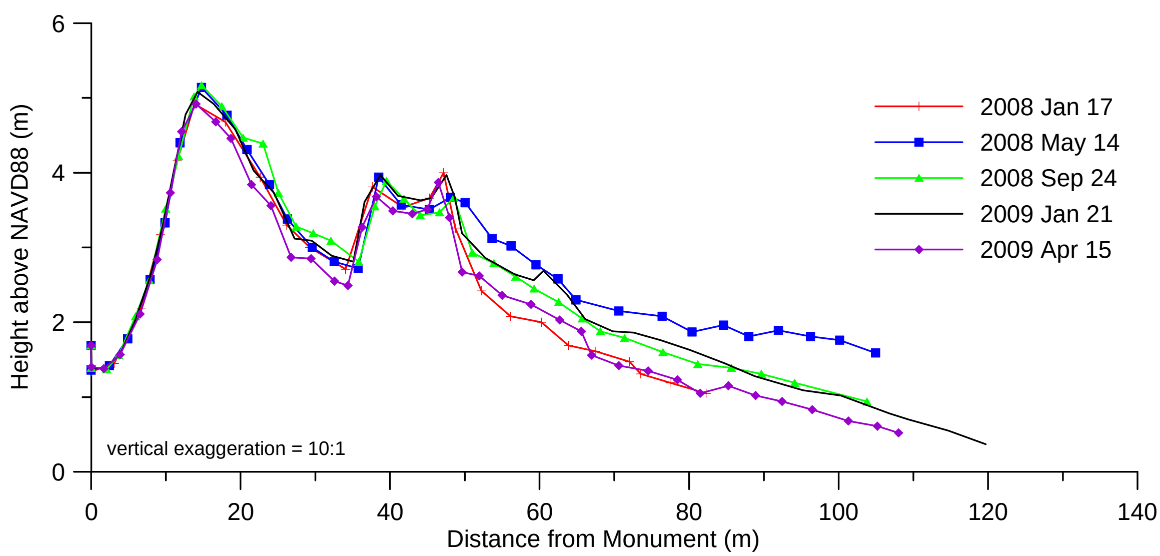




MUI02 (Mustang Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2004 Jan 30
2004 Apr 19
2004 Sep 8
2004 Dec 9
2005 May 3
0
2
4
6
0
20
40
60
80
100
120
140

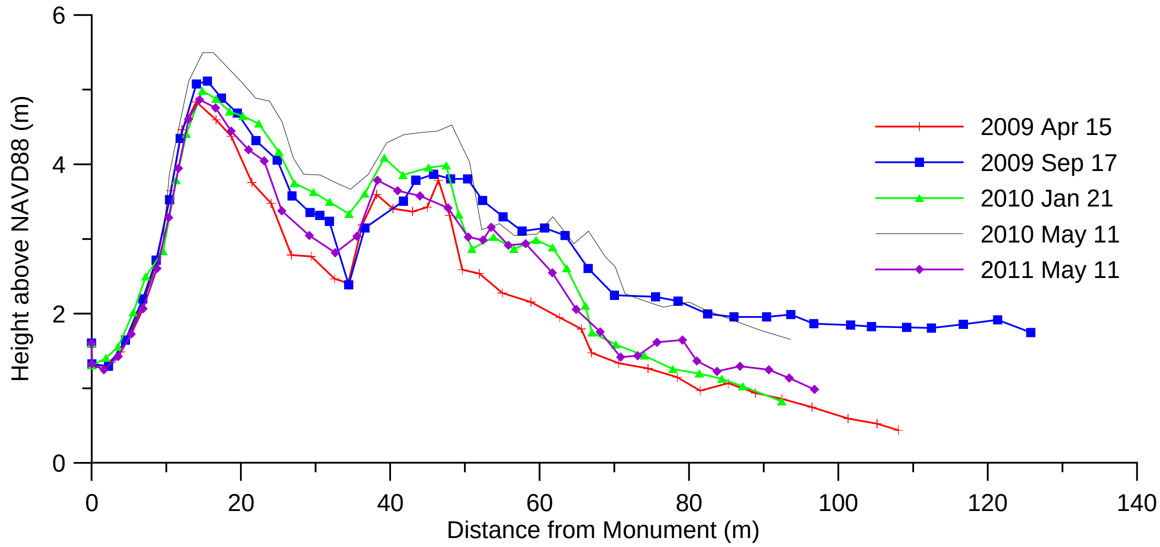

Height above NAVD88 (m)
Distance from Monument (m)
2005 May 3
2005 Sep 20
2006 Jan 19
2006 Mar 21
2006 Sep 14
vertical exaggeration = 10:1
0
2
4
6
0
20
40
60
80
100
120
140

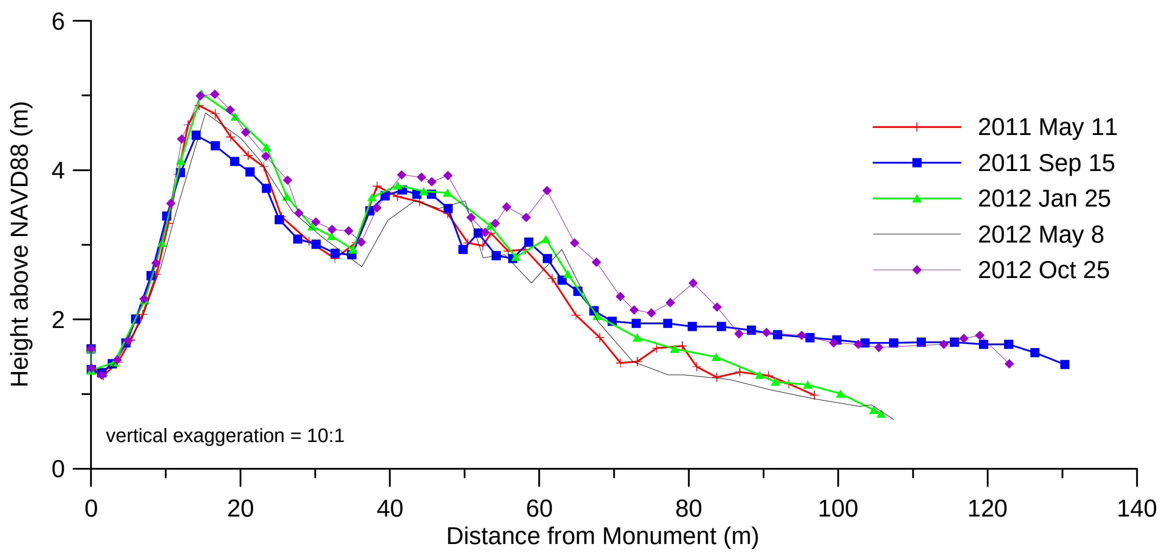
MUI02 (Mustang Island State Park)

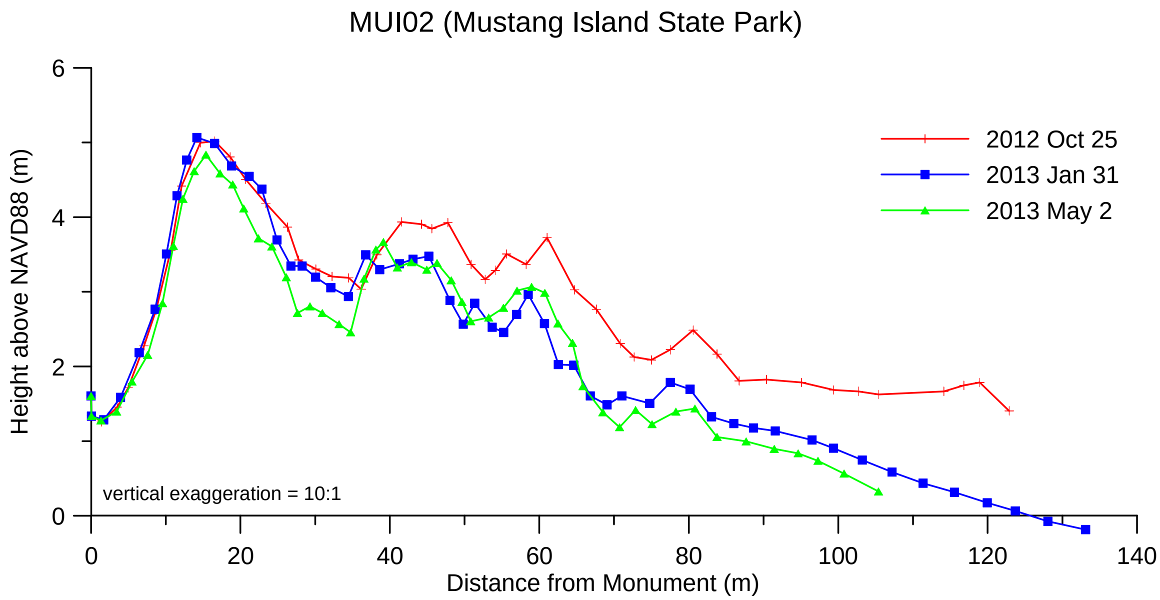


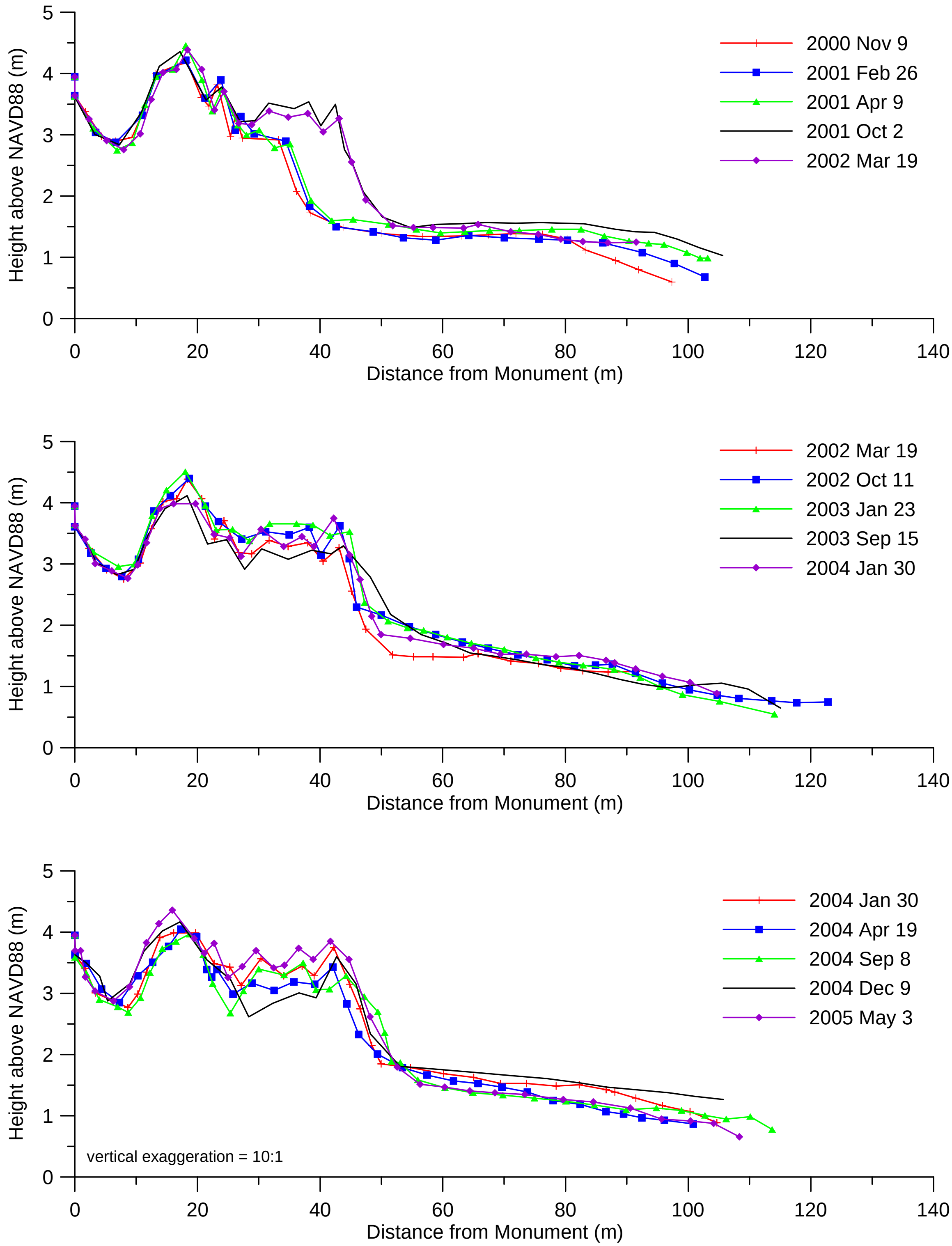
MUI02 (Mustang Island State Park)



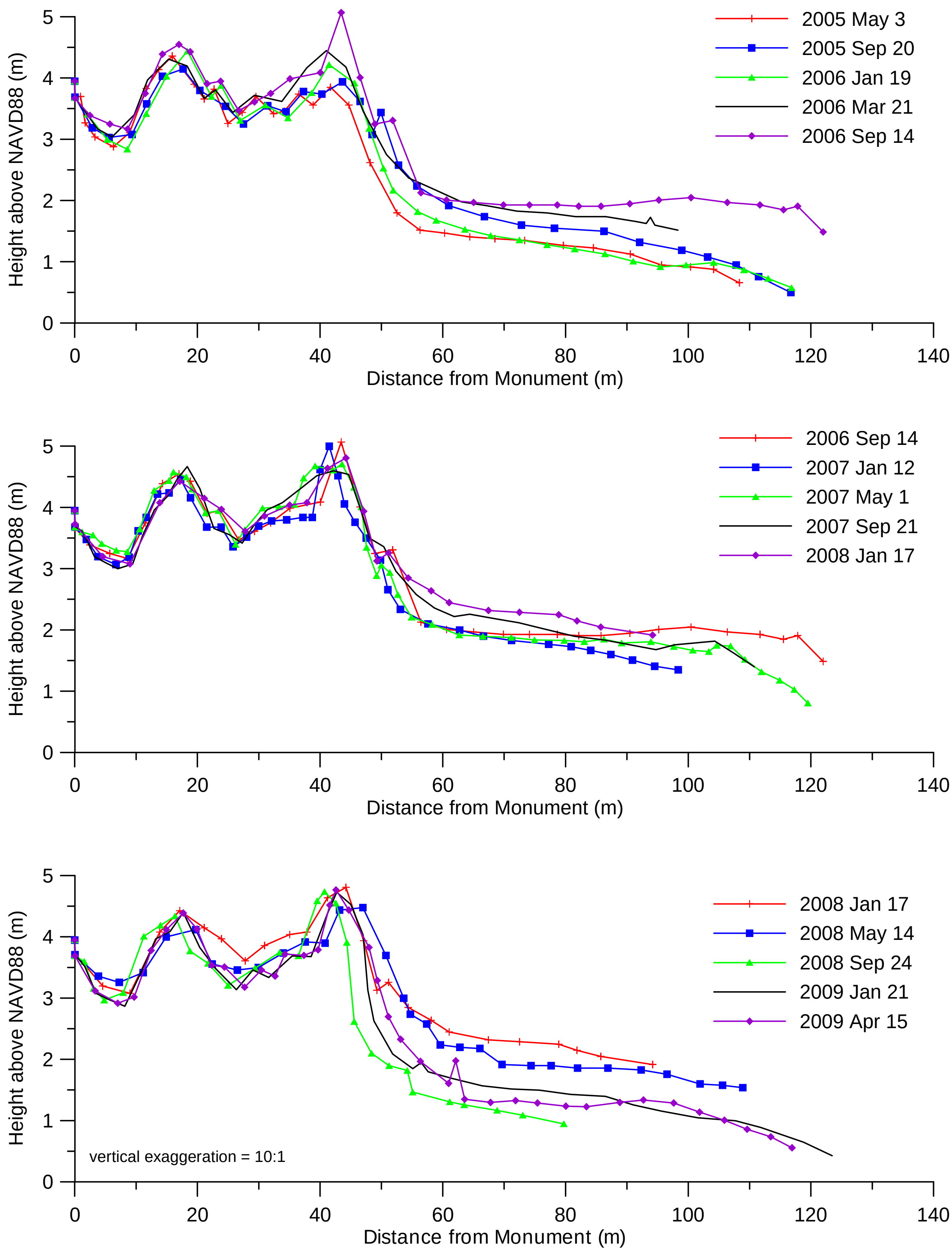




MUI02 (Mustang Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2012 Oct 25
2013 Jan 31
2013 May 2
vertical exaggeration = 10:1
0
2
4
6
0
20
40
60
80
100
120
140

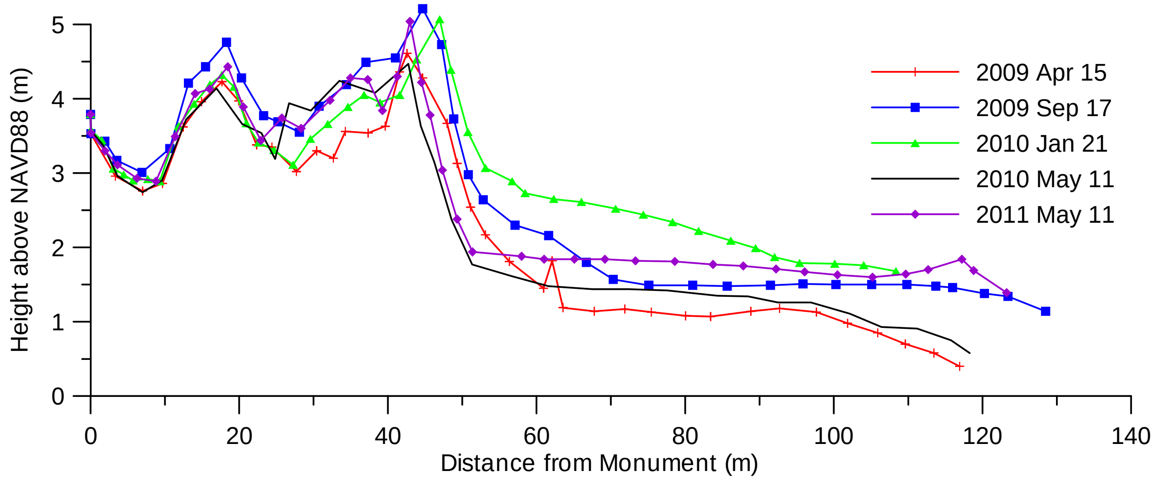
MUI03 (Mustang Island)

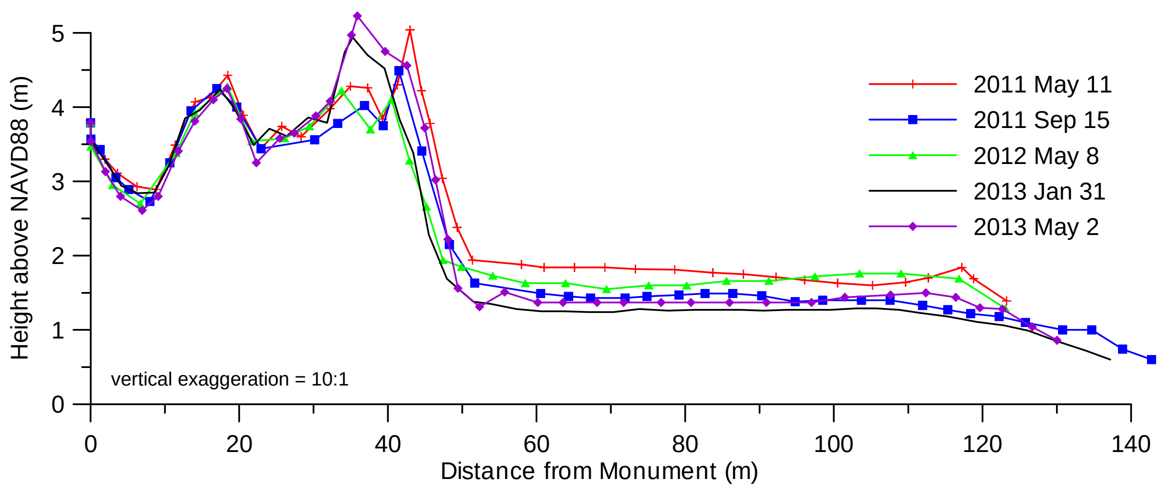


MUI03 (Mustang Island)

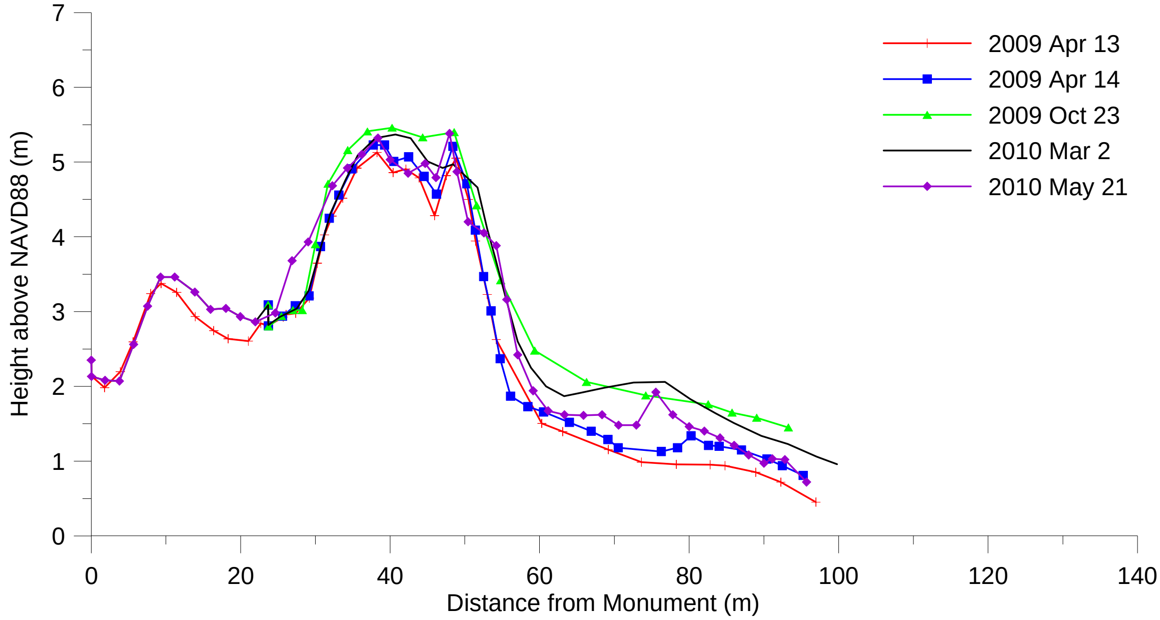


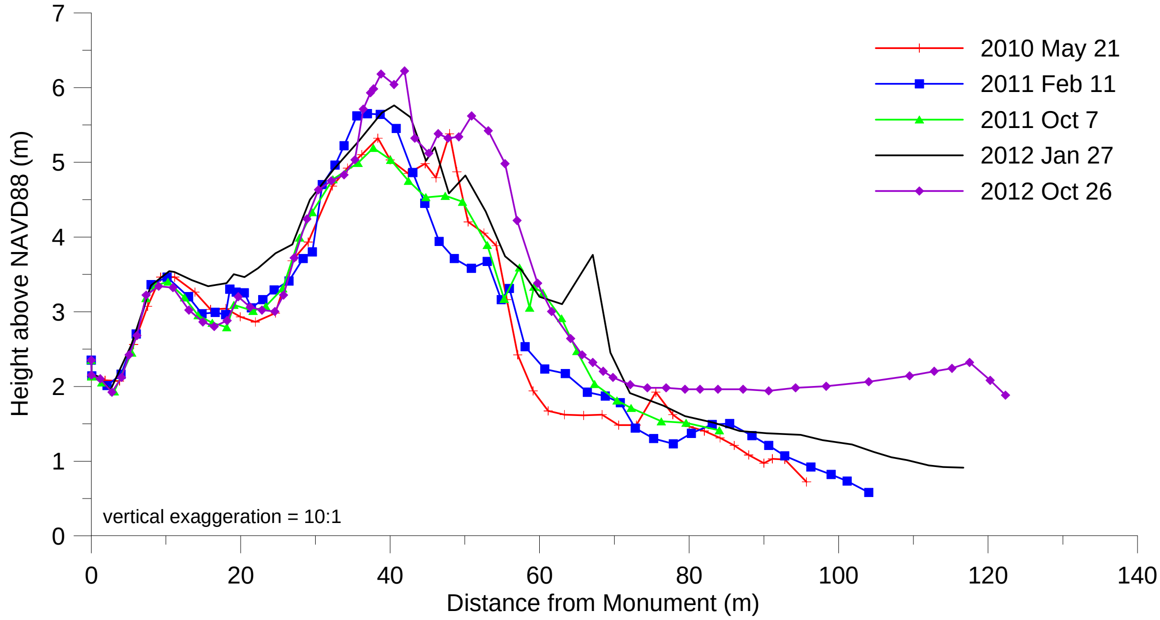
MUI03 (Mustang Island)

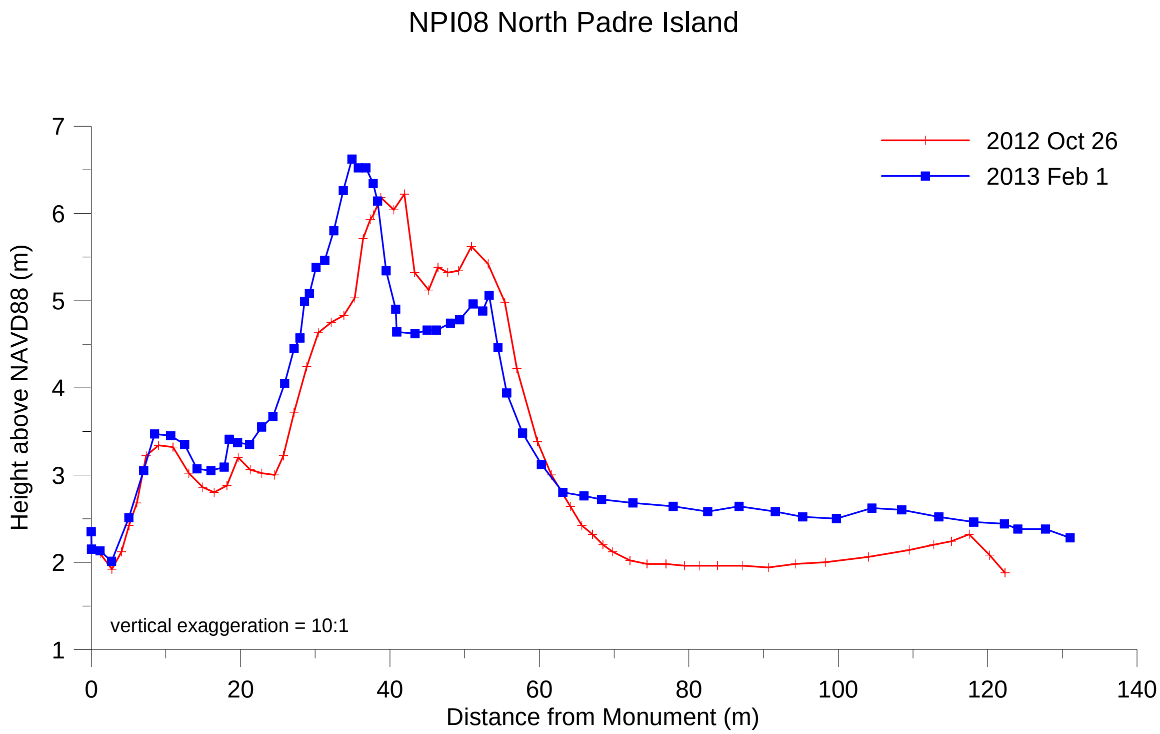


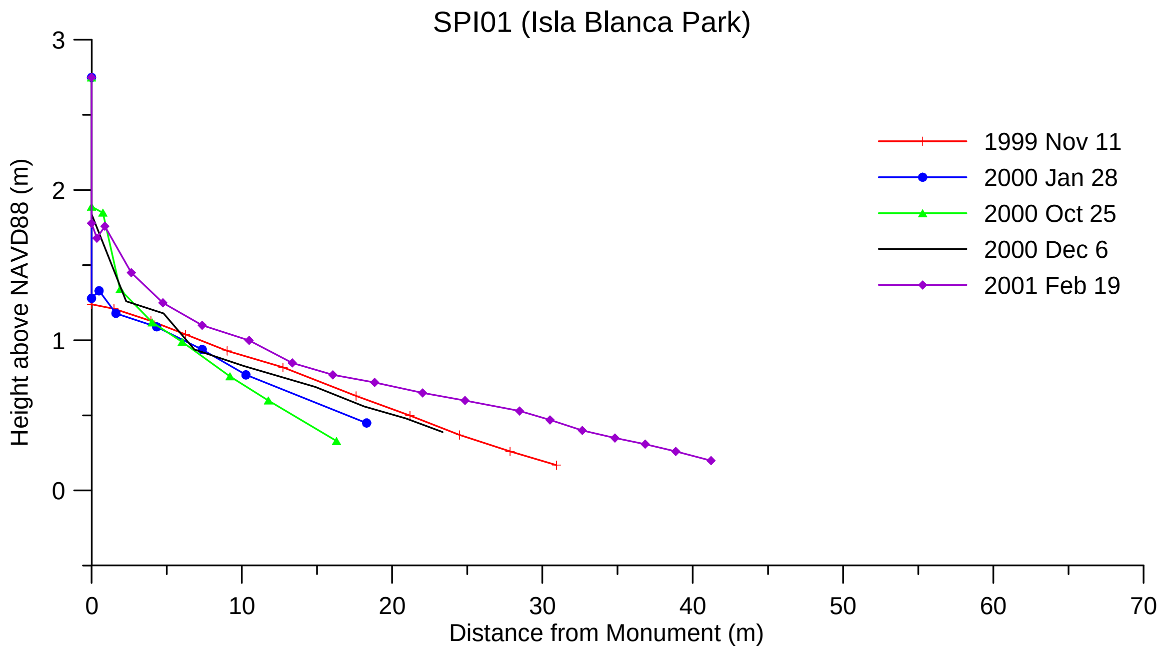
NPI08 North Padre Island

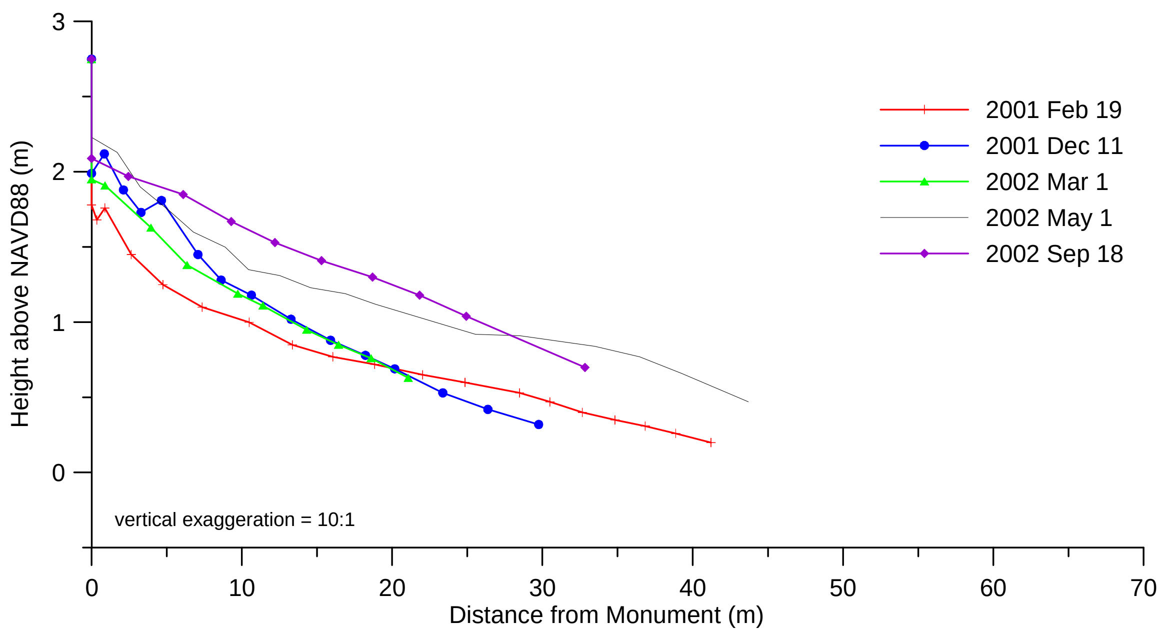


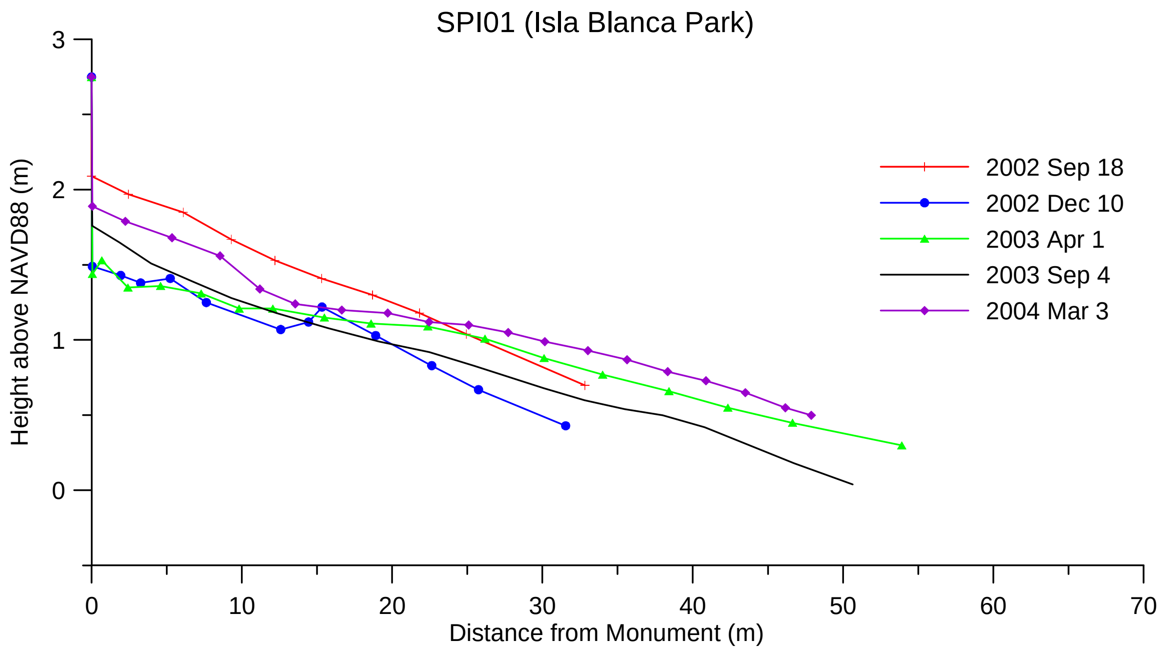



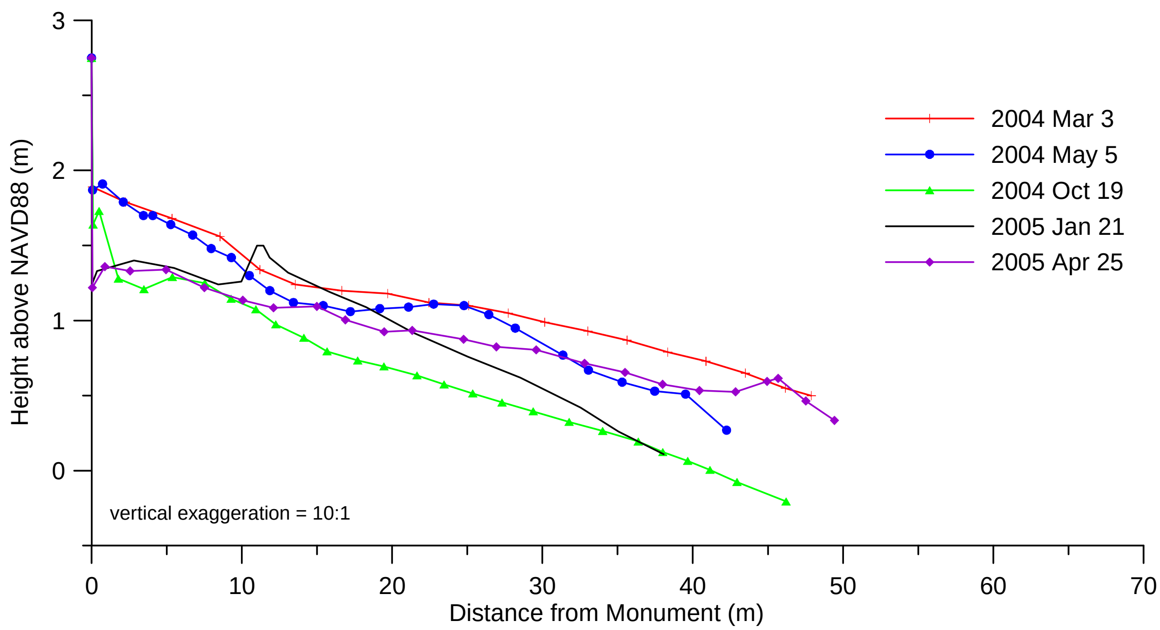


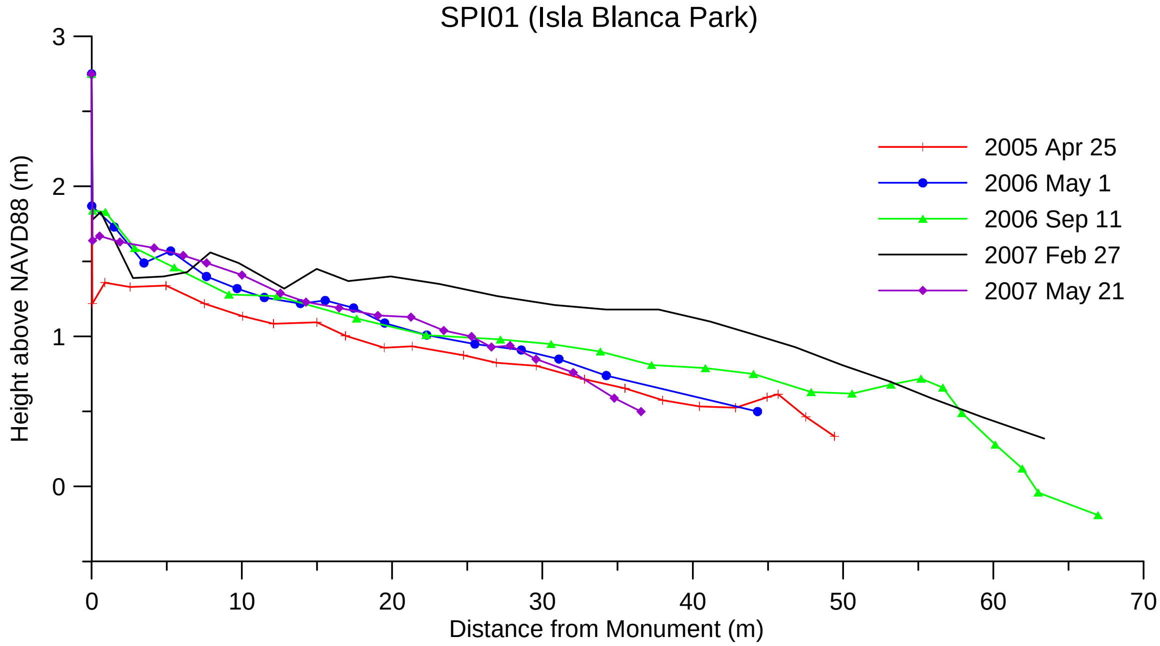
NPI08 North Padre Island
2012 Oct 26
2013 Feb 1
Height above NAVD88 (m)
7
6
5
4
3
2
1
vertical exaggeration = 10:1
0
20
40
60
80
100
120
140
Distance from Monument (m)

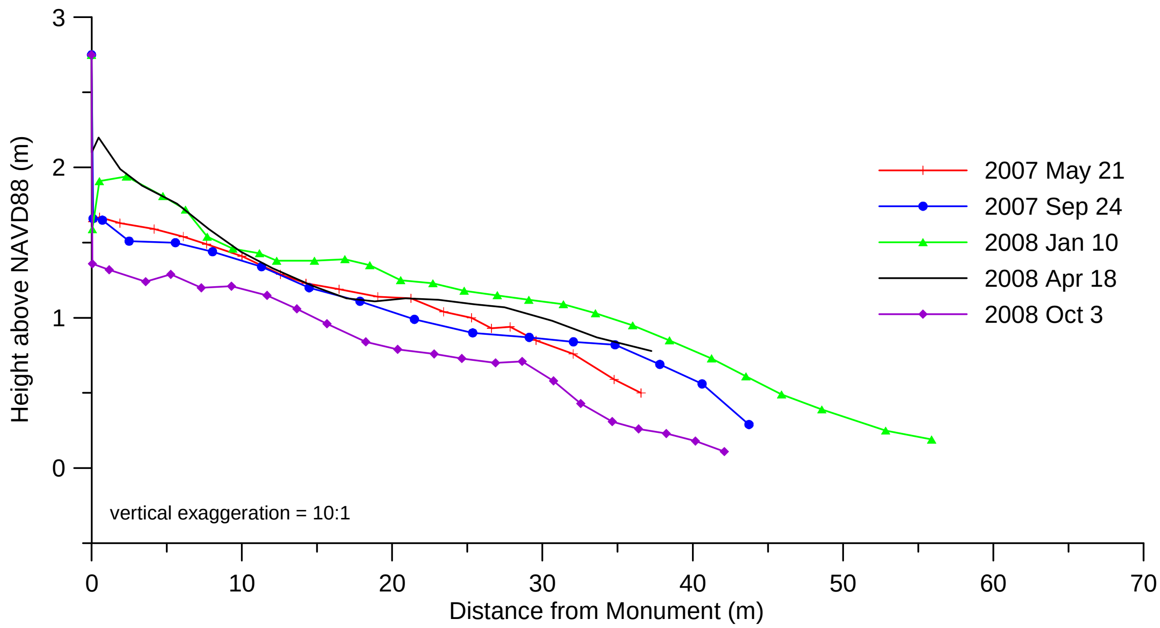

SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
1999 Nov 11
2000 Jan 28
2000 Oct 25
2000 Dec 6
2001 Feb 19

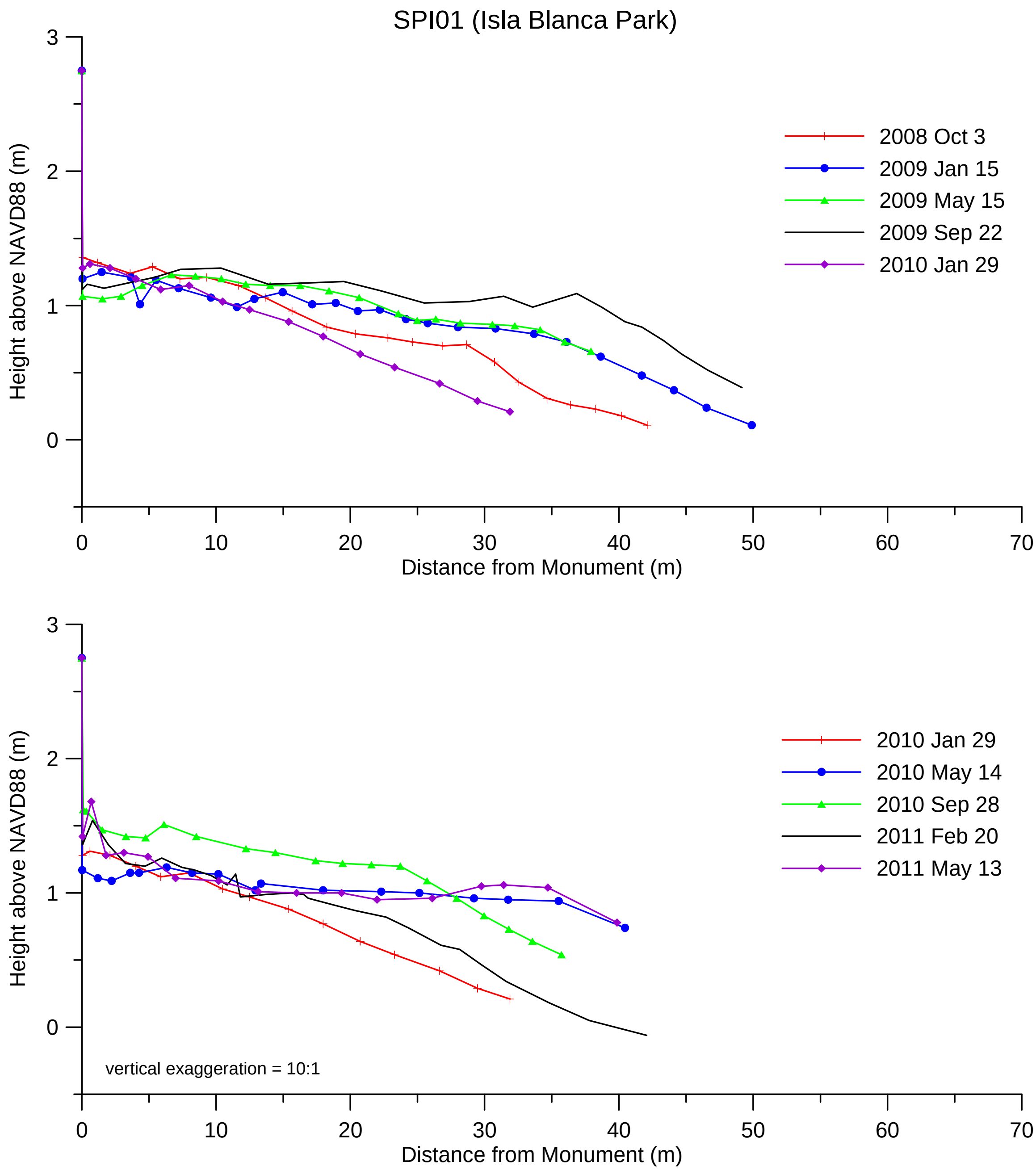

Height above NAVD88 (m)
Distance from Monument (m)
2001 Feb 19
2001 Dec 11
2002 Mar 1
2002 May 1
2002 Sep 18
vertical exaggeration = 10:1


SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
2002 Sep 18
2002 Dec 10
2003 Apr 1
2003 Sep 4
2004 Mar 3
3
2
1
0
0
10
20
30
40
50
60
70

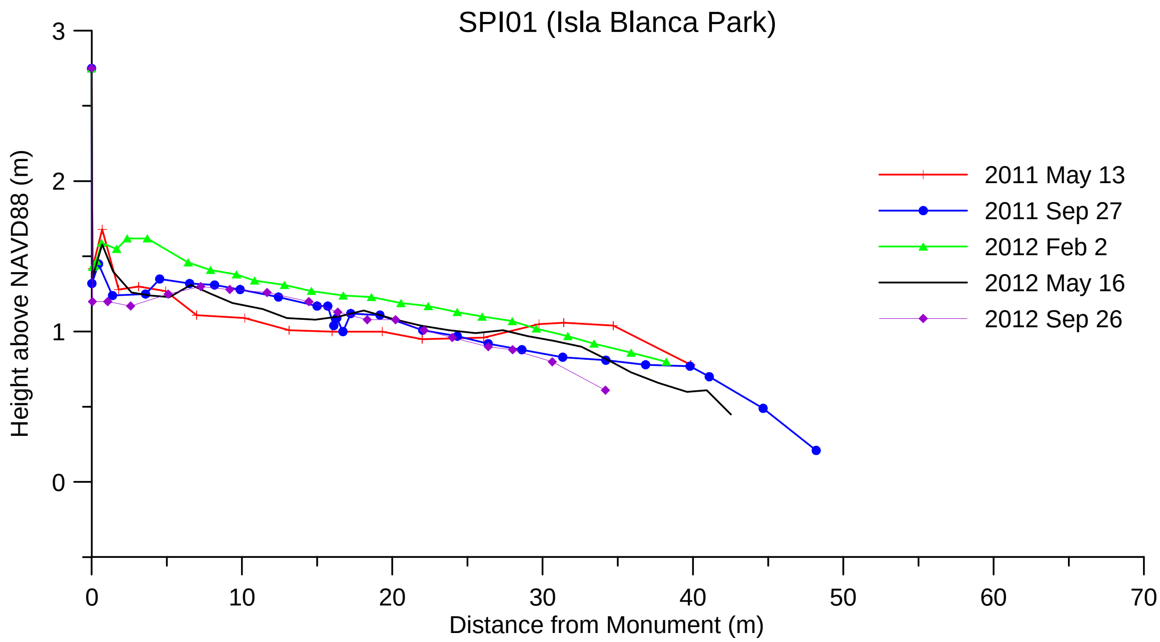

Height above NAVD88 (m)
Distance from Monument (m)
2004 Mar 3
2004 May 5
2004 Oct 19
2005 Jan 21
2005 Apr 25
vertical exaggeration = 10:1
3
2
1
0
0
10
20
30
40
50
60
70

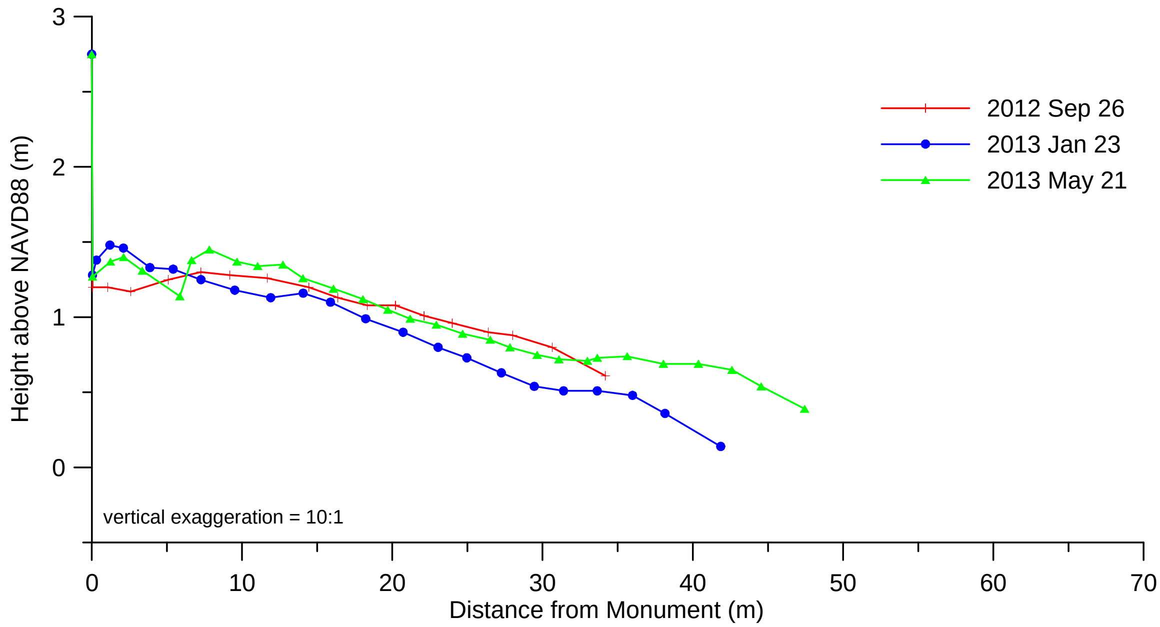

SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
2005 Apr 25
2006 May 1
2006 Sep 11
2007 Feb 27
2007 May 21
3
2
1
0
0
10
20
30
40
50
60
70


Height above NAVD88 (m)
Distance from Monument (m)
2007 May 21
2007 Sep 24
2008 Jan 10
2008 Apr 18
2008 Oct 3
vertical exaggeration = 10:1
3
2
1
0
0
10
20
30
40
50
60
70

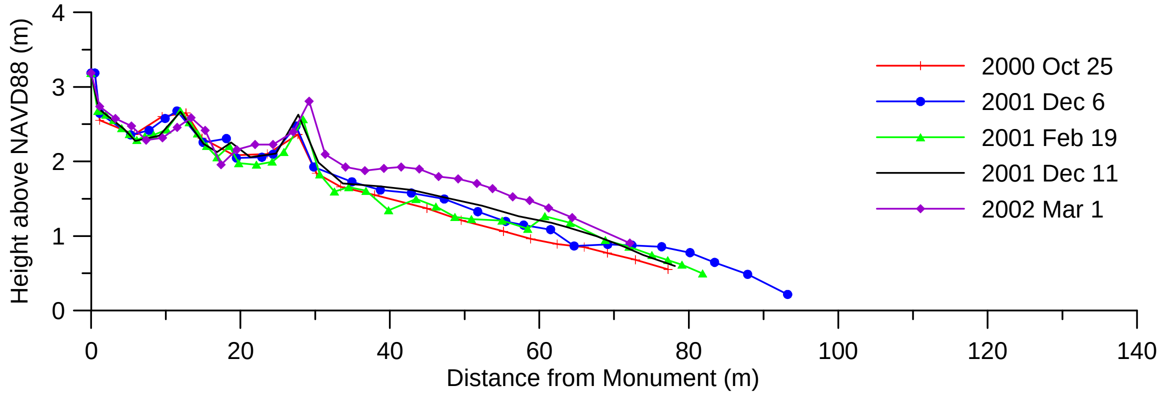


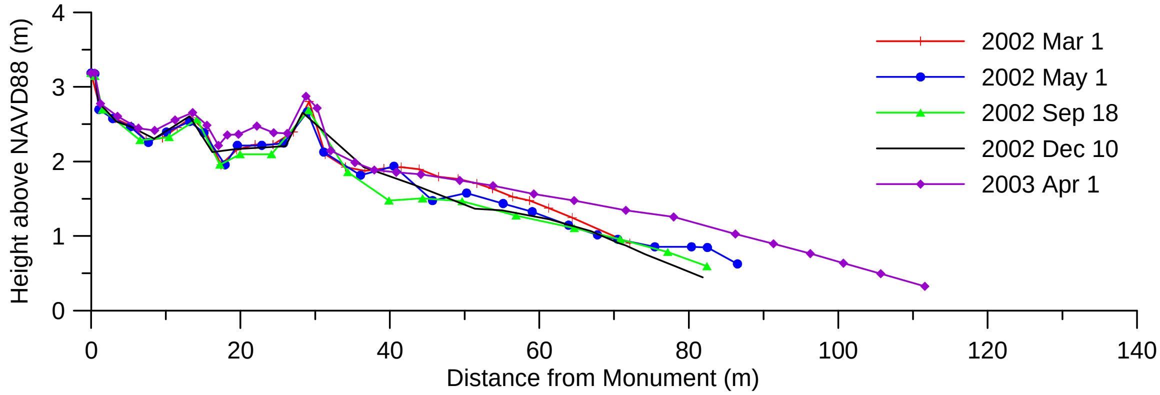
SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
2008 Oct 3
2009 Jan 15
2009 May 15
2009 Sep 22
2010 Jan 29
Height above NAVD88 (m)
Distance from Monument (m)
2010 Jan 29
2010 May 14
2010 Sep 28
2011 Feb 20
2011 May 13
vertical exaggeration = 10:1

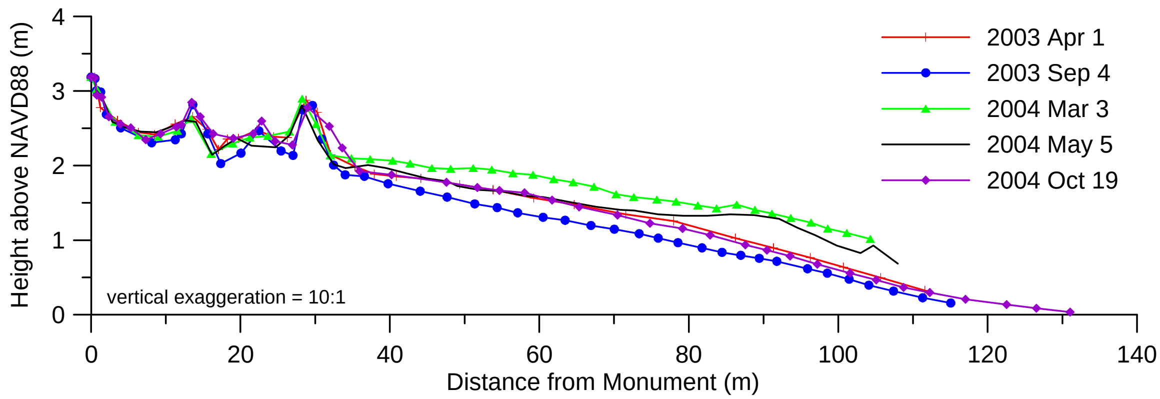

SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
2011 May 13
2011 Sep 27
2012 Feb 2
2012 May 16
2012 Sep 26
0
1
2
3
0
10
20
30
40
50
60
70

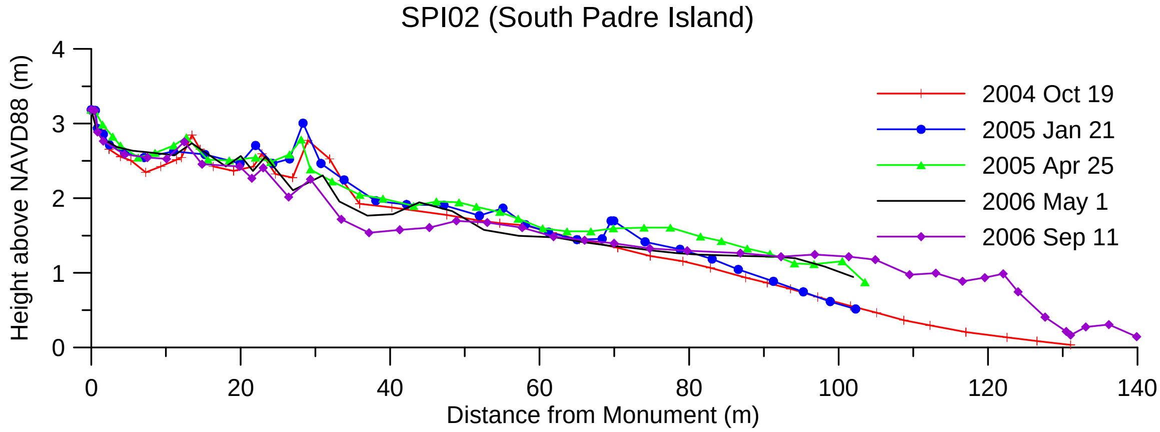

Height above NAVD88 (m)
Distance from Monument (m)
2012 Sep 26
2013 Jan 23
2013 May 21
vertical exaggeration = 10:1
0
1
2
3
0
10
20
30
40
50
60
70

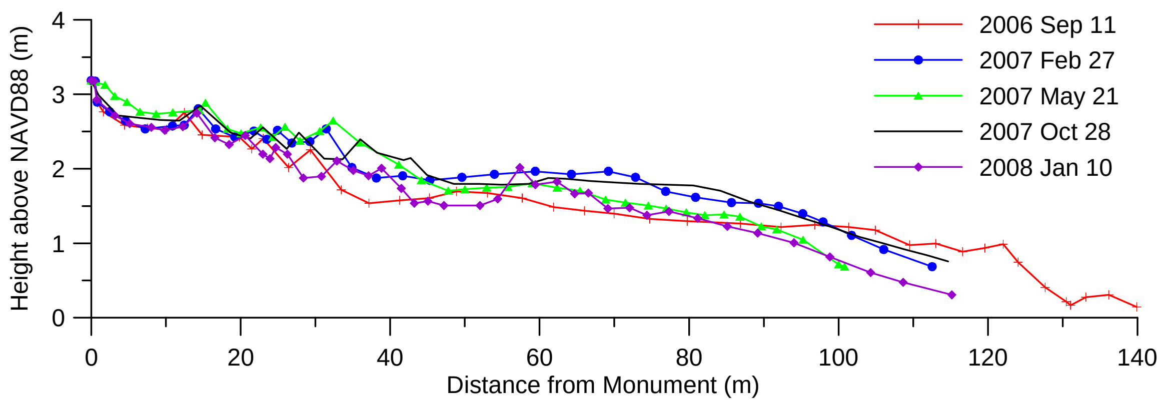
SPI02 (South Padre Island)

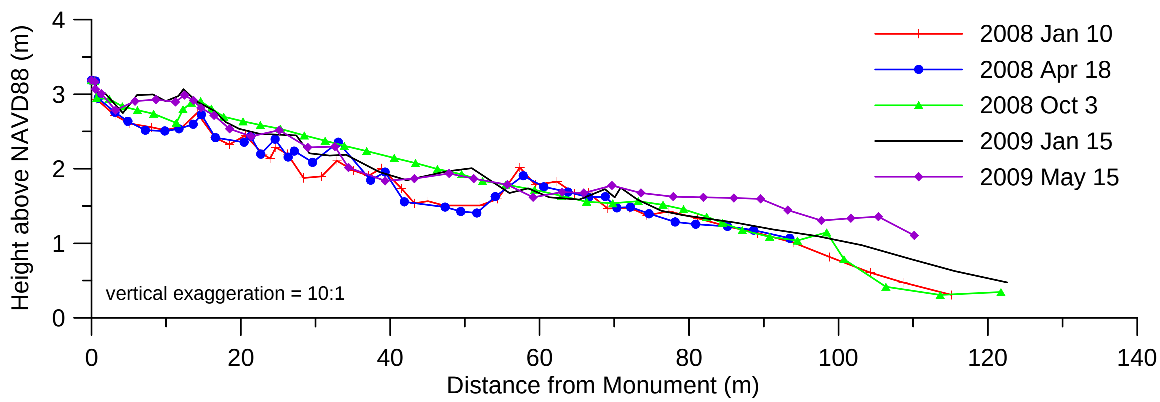


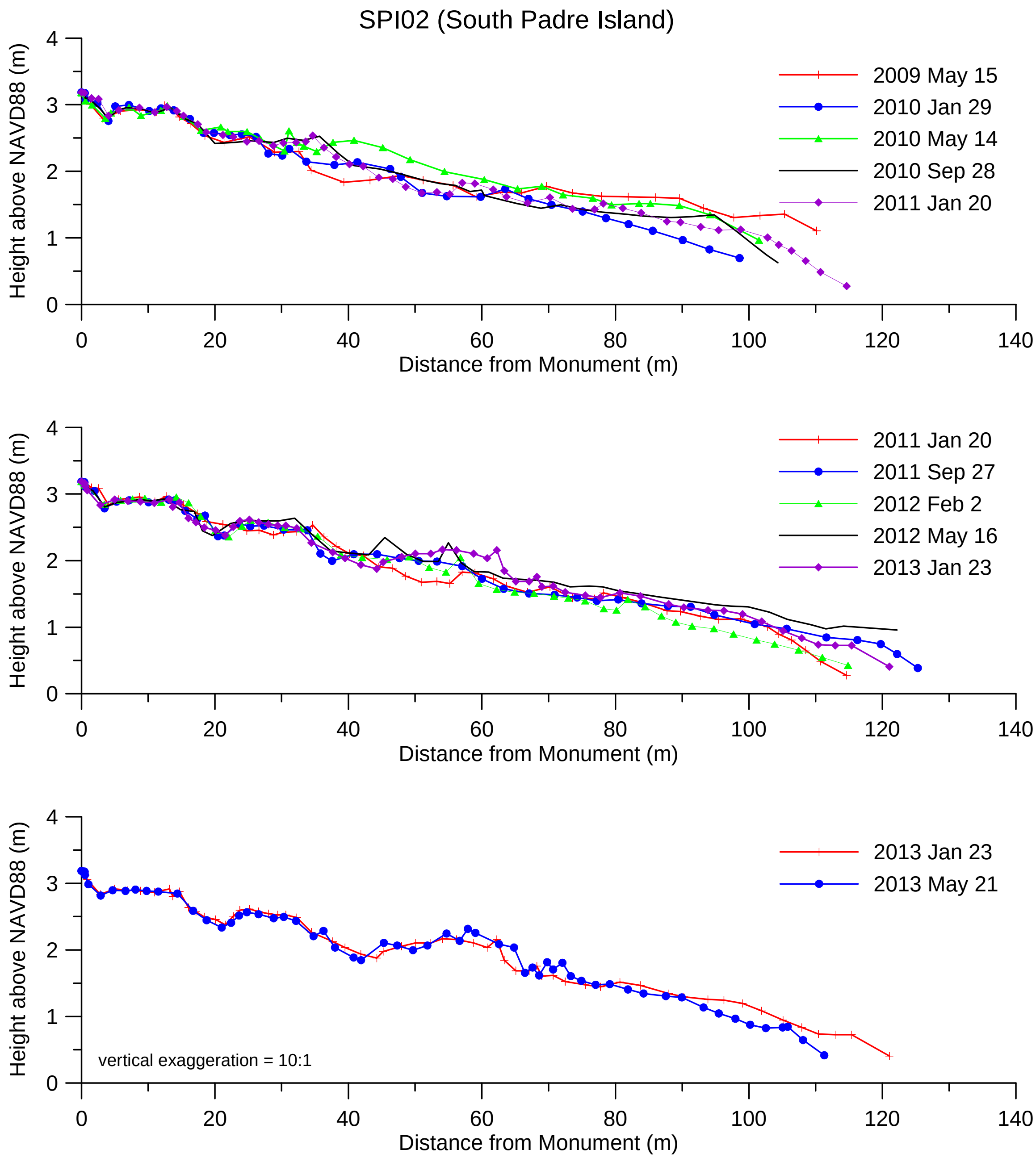



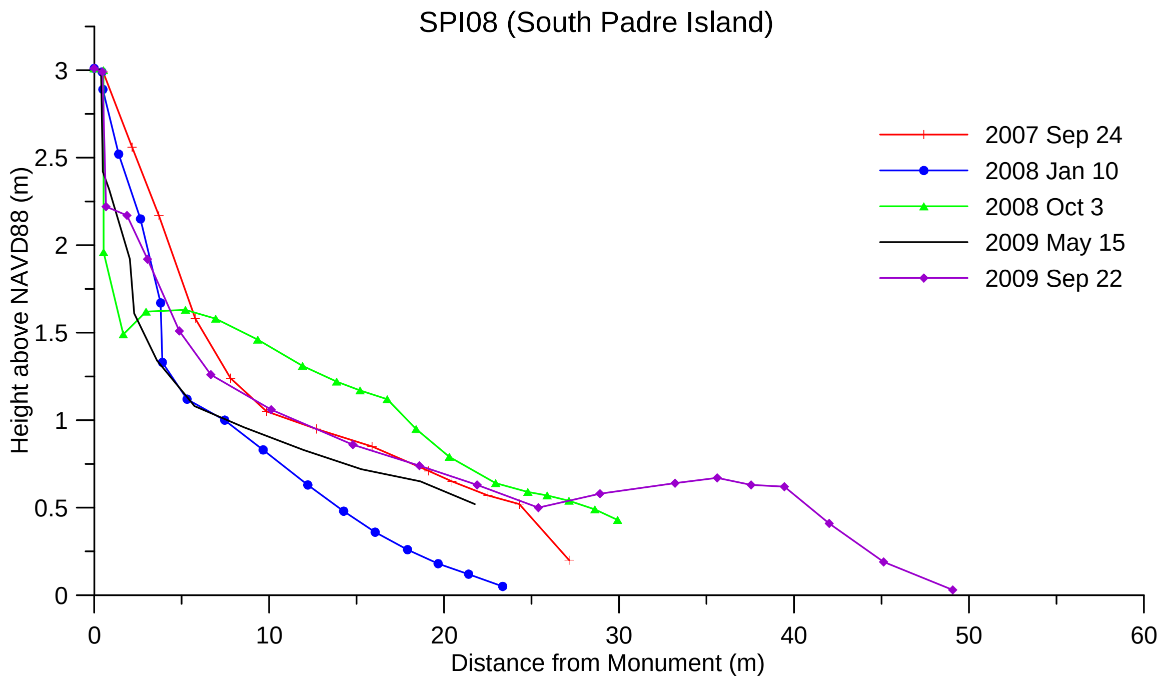



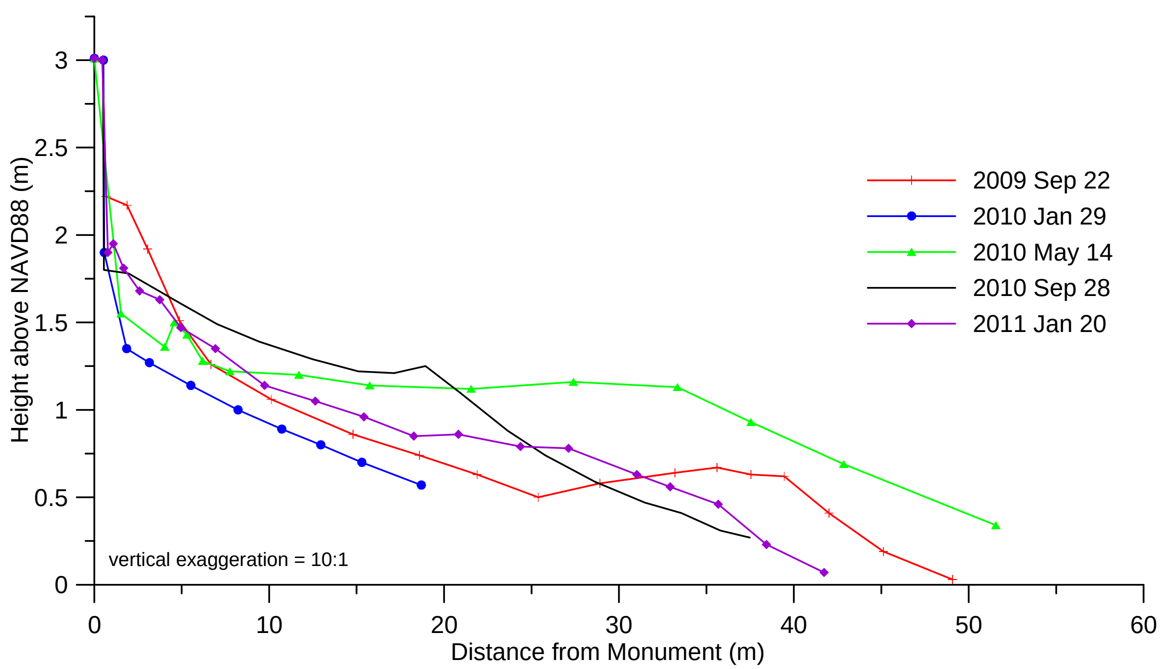

SPI02 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2004 Oct 19
2005 Jan 21
2005 Apr 25
2006 May 1
2006 Sep 11
0
20
40
60
80
100
120
140
4
3
2
1
0

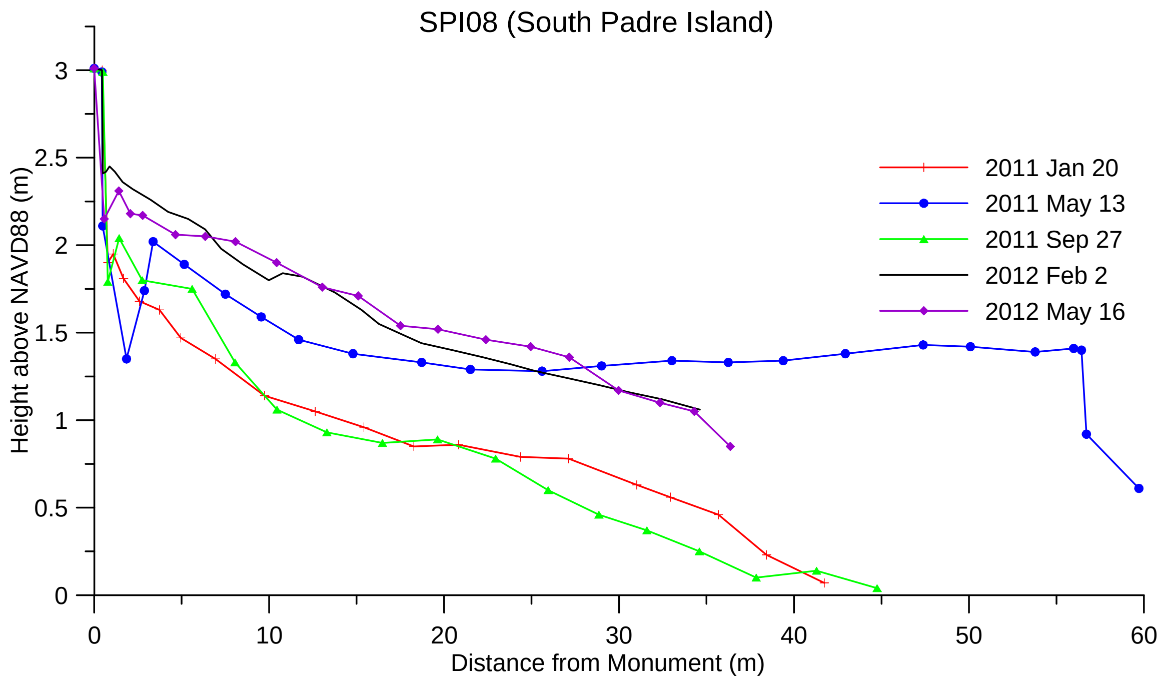

Height above NAVD88 (m)
Distance from Monument (m)
2006 Sep 11
2007 Feb 27
2007 May 21
2007 Oct 28
2008 Jan 10

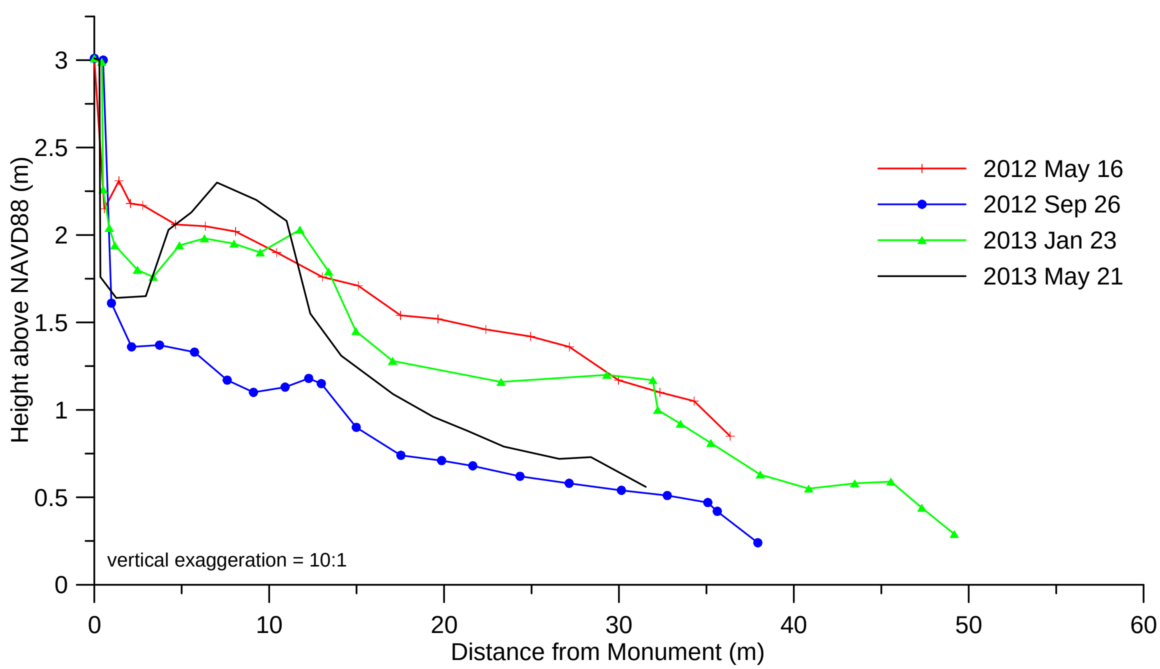

Height above NAVD88 (m)
Distance from Monument (m)
2008 Jan 10
2008 Apr 18
2008 Oct 3
2009 Jan 15
2009 May 15
vertical exaggeration = 10:1


SPI02 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2009 May 15
2010 Jan 29
2010 May 14
2010 Sep 28
2011 Jan 20
2011 Jan 20
2011 Sep 27
2012 Feb 2
2012 May 16
2013 Jan 23
2013 Jan 23
2013 May 21
vertical exaggeration = 10:1


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


2009 Sep 22
2010 Jan 29
2010 May 14
2010 Sep 28
2011 Jan 20
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 Jan 20
2011 May 13
2011 Sep 27
2012 Feb 2
2012 May 16


Height above NAVD88 (m)
Distance from Monument (m)
2012 May 16
2012 Sep 26
2013 Jan 23
2013 May 21
vertical exaggeration = 10:1