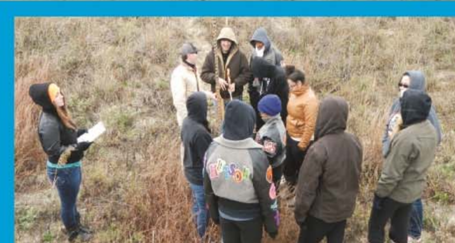
FINAL REPORT

Texas High School Coastal Monitoring Program: 2014–2015

Tiffany L. Caudle



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F I N A L R E P O R T

Texas High School Coastal Monitoring Program: 2014–2015

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

Tiffany L. Caudle

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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 2014–2015 academic year. During this time, Ball High School on Galveston Island completed its seventeenth year in the program, and Port Aransas and Port Isabel High Schools completed their sixteenth year (**fig. 1**). Through collaboration with the Lower Colorado River Authority, the program works with three schools in the Matagorda area: Tidehaven Middle School and Van Vleck High Schools completed their eleventh year in the program and Palacios High School completed its ninth year. Cunningham Middle School in the Corpus Christi Independent School District participated in its first field trip in late spring of 2009. The 2014–2015 academic year marked its seventh year in the program. All of the schools anticipate continuing with the program during the 2015–2016 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/).

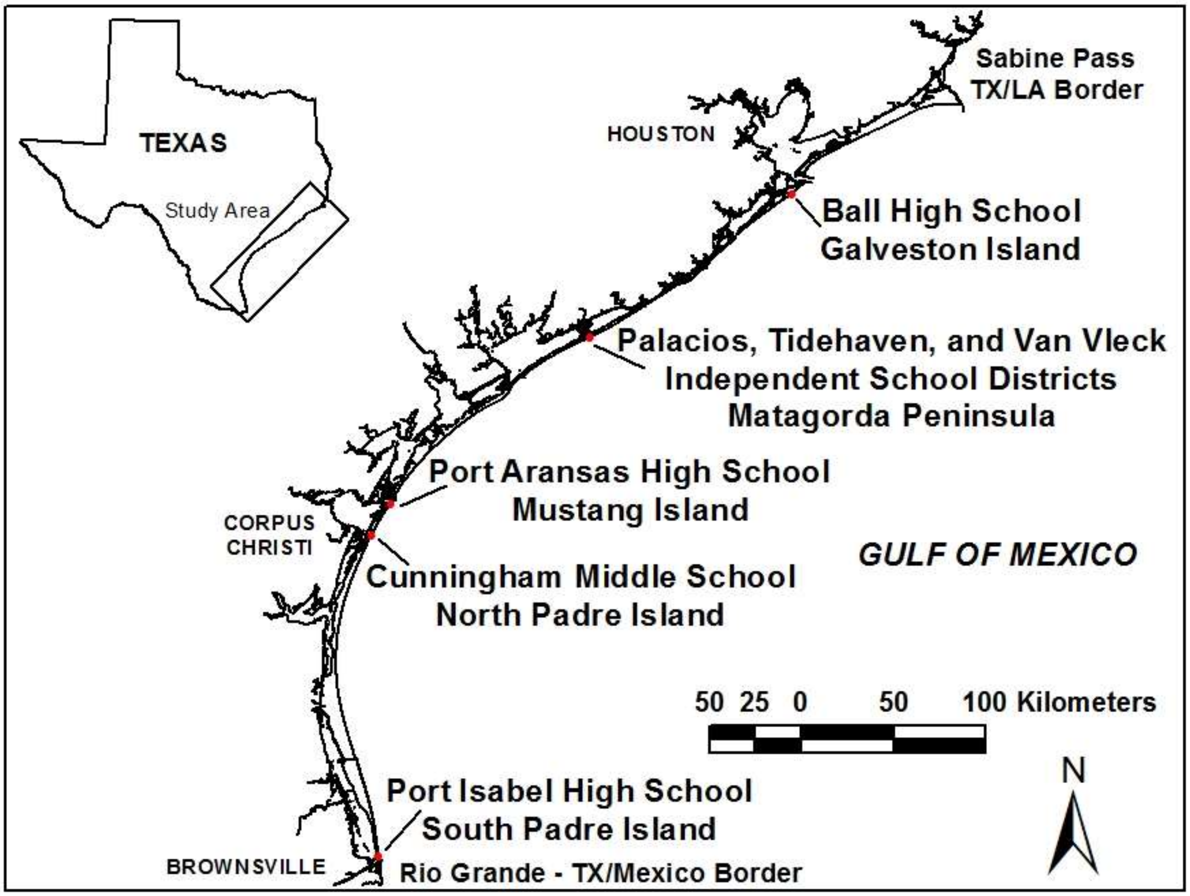

Figure 1. Participating schools.

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 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 and at the 2013 American Shore and Beach Preservation Association national coastal conference. 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 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. 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.

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

(3) Sediment samples. Sediment samples show the dependence of sand characteristics on the various processes acting on the beach. 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.

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

(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, 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.

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.

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.

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 2014–2015 ACADEMIC YEAR

Bureau scientists Tiffany Caudle and Lucie Costard worked with teachers Tessie Howard of Ball High School, Ryan Piwetz of Port Aransas High School, and Dr. Michelle Zacher of Port Isabel High School. Ms. Howard's Advanced Placement Environmental Science classes, Mr. Piwetz's Environmental Science classes, and Dr. Zacher's juniors and seniors taking Dual Enrollment Biology participated in the program.

A collaboration between the Lower Colorado River Authority (LCRA) and the Bureau at Matagorda Bay Nature Park has allowed the Bureau to expand the THSCMP to three schools in the Matagorda Bay area. Expansion of the program has not only increased the number of schools but also included younger students, who visit only one profile site per field trip but make the same field measurements as the high school students. Ms. Caudle worked with teachers Warren Morris of Palacios High School, Robert Hutto and Duane Schroedter of Tidehaven Middle School, and Sherry Martinez of Van Vleck High School during the first field trip of the 2014–2015 academic year. Representatives from the LCRA worked with teachers and students during the winter and spring field trips.

After a workshop held at Texas A&M University–Corpus Christi (TAMUCC) in November 2008, the Innovation Academy for Engineering, Environmental and Marine Science at Cunningham Middle School (Corpus Christi ISD) expressed interest in joining the program. Tiffany Caudle and Lucie Costard worked with Jennifer Welch at Cunningham during the 2014–2015 academic year.

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 four- to seven-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.

Ball High School

Tessie Howard’s AP Environmental Science classes at Ball High School participated in field trips on October 8, 2014; January 28, 2015; and May 19, 2015. Students 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. Bureau scientist Tiffany Caudle accompanied the class on all field trips and provided further training and background information to students.

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

Port Aransas High School

Port Aransas students participated in field trips on October 7, 2014; January 29, 2015; and April 30, 2015. Ryan Piwetz's 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. Tiffany Caudle accompanied the class on all three field trips.

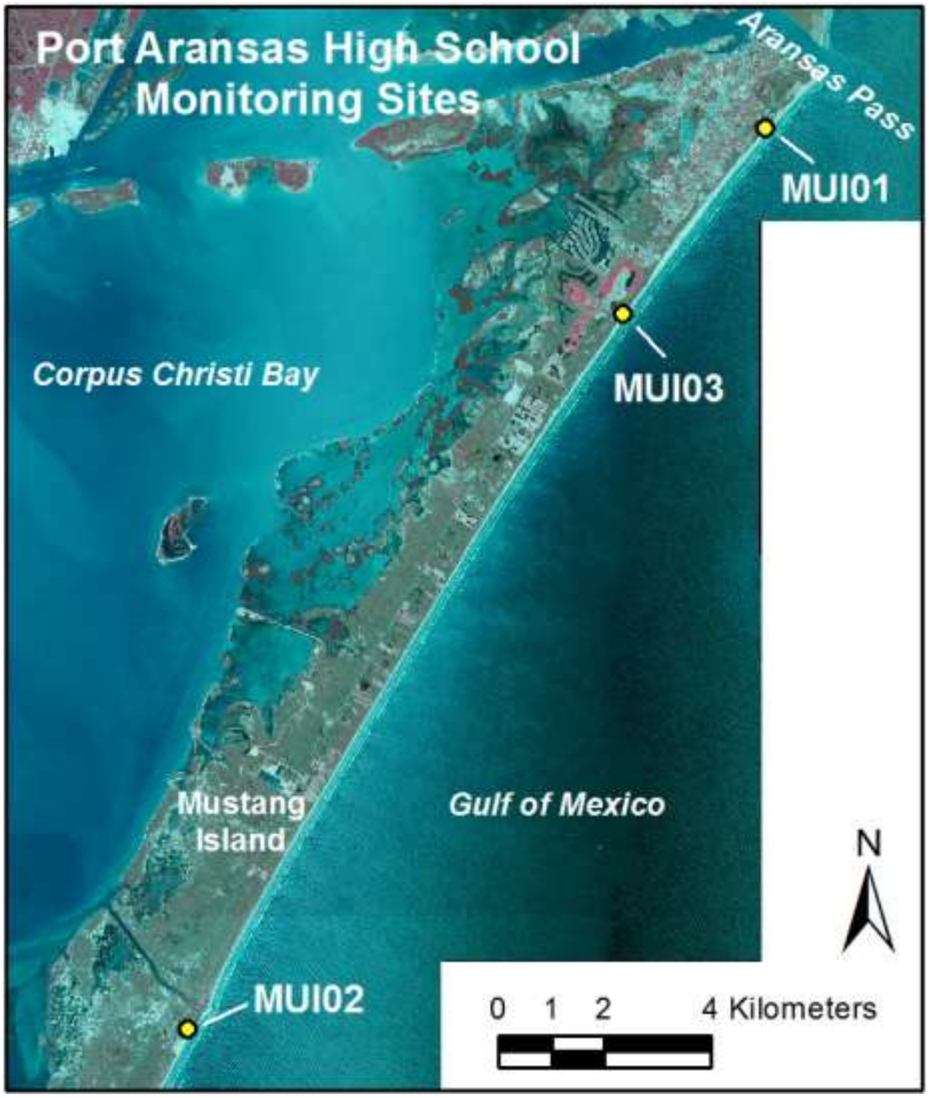

Figure 5. Location map of Port Aransas High School monitoring sites.

Port Isabel High School

Port Isabel students participated in field trips on September 17, 2014; February 4, 2015; and April 22, 2015. 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. Tiffany Caudle was able to accompany the class on all three trips to provide further training and background information to the students.

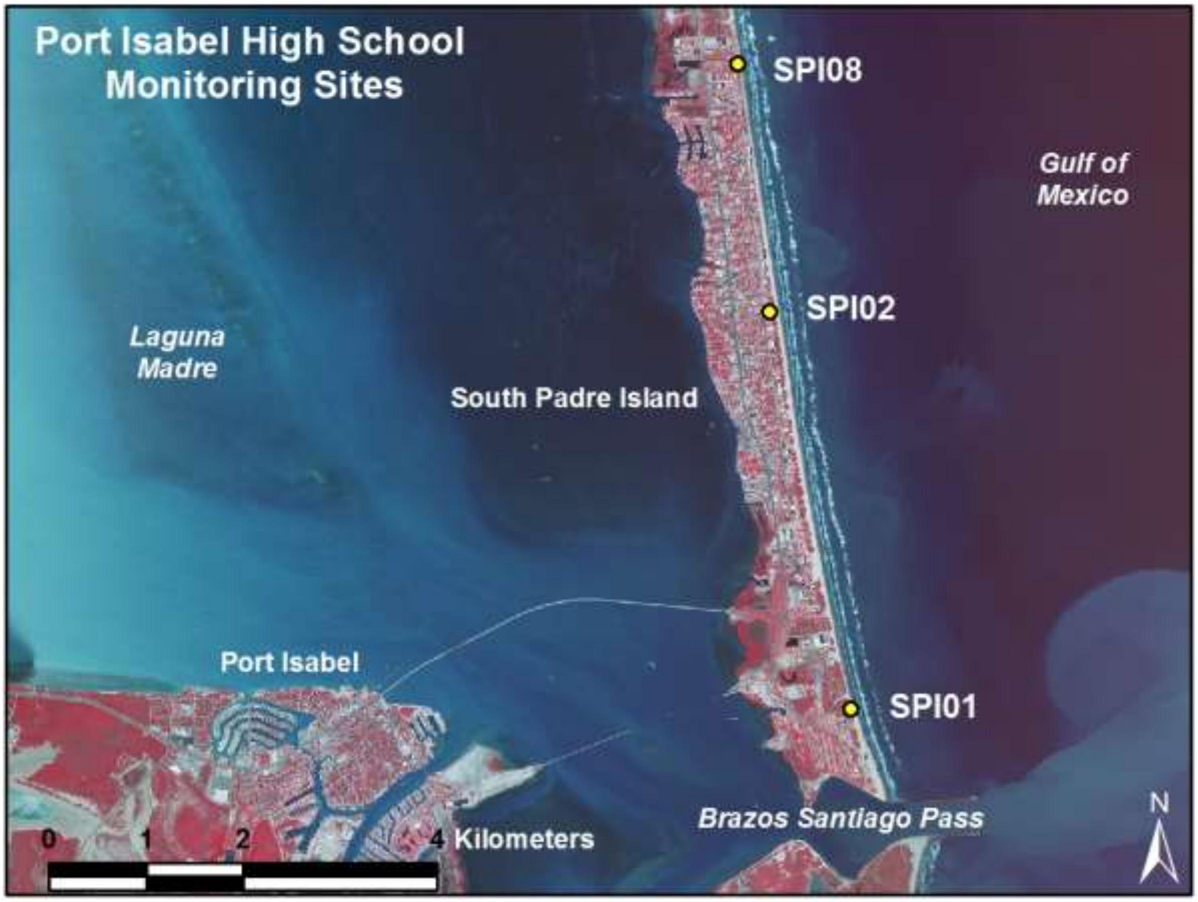

Figure 6. Location map of Port Isabel High School monitoring sites.

Matagorda Area Schools

Van Vleck High School environmental science students participated in field trips on January 23, 2015, and May 1, 2015. Sherry Martinez's class collected data at MAT01 (**fig. 7**). (A fall field trip was canceled because of a teacher issue. Bureau scientist Caudle met with Van Vleck ISD staff to confirm that the program would continue to take place with a new teacher.) Physics students from Palacios High School participated in field trips on September 25, 2014; February 12, 2015; and April 30, 2015. Warren Morris's students collected data at MAT01 (September field trip only) and MAT02 (**fig. 7**). Tidehaven Middle School participated in field trips on

September 27, 2014, and January 24, 2015. The students from Tidehaven collected data at MAT03 (**fig. 7**). Tidehaven's September field trip was scheduled to coincide with the fall Beach Clean-Up at Matagorda Bay Nature Park. (Tidehaven's spring field trip was canceled because of a teacher's prolonged illness.) LCRA staff collected data at MAT03 on May 14, 2015.

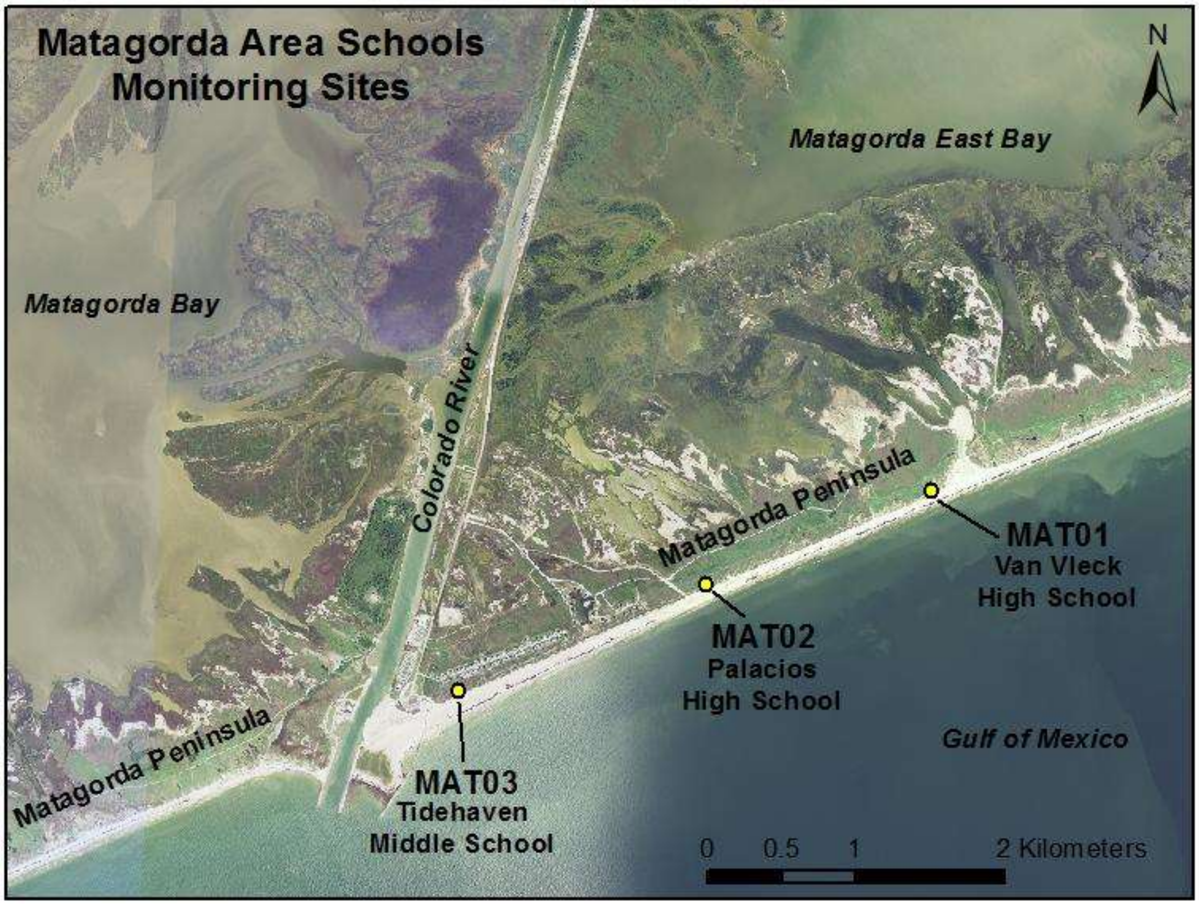

Figure 7. Location map of Matagorda area schools monitoring sites.

Cunningham Middle School

The Bureau collaborates with graduate students and staff at TAMUCC to conduct field trips with Cunningham Middle School because of the number of students that participate in the program.

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 the school expressed a desire to include all 8th-grade students (around 75 students) in the field trips. During the first few years of participation 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 each field trip. One group worked on the topographic profile while the second made observations on wind, waves, and currents. The groups rotated so that every student had the experience of collecting all types of data. Because of the difficulty in trying to keep 25 or so students engaged in the data-collection process, for the 2012–2013 academic year, only 15 to 20 students participated in each field trip (a different group of students for each trip).

Cunningham Middle School STEM 8th graders were scheduled for their first two field trips on November 13, 2014 and January 30, 2015. Unfortunately, these trips were canceled by school administration because of students' low test scores. Cunningham students participated in a field trip on May 1, 2015, once academic testing had been completed. They collected data at NPI08 on North Padre Island (**fig. 8**). With satisfactory test scores, Cunningham MS students will return to a normal field trip schedule for the 2015–2016 academic year.

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. The program was relevant in these 2014–2015 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 2014–2015 academic year, Ball High School students measured a profile location in Galveston Island State Park (BEG02, **fig. 4**). 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. Results of a study utilizing data collected by Ball High School students were published in *Shore & Beach*, the journal of the American Shore and Beach Preservation Association. 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.

Palacios, Port Aransas, Port Isabel, and Van Vleck High Schools and Cunningham 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 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 two important Bureau studies.

In one study, BEG02, one of the Ball High School monitoring sites, 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, Galveston Island State Park. Beach width in the natural beach area was wider because of the lack of restriction caused by placement of the geotextile tubes (Gibeaut and others, 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 and others (2003).

More 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. A recent Bureau 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 2007 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 to be used for change-rate calculations (Paine and others, 2011). At Galveston Island State Park (**fig. 10**), 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).

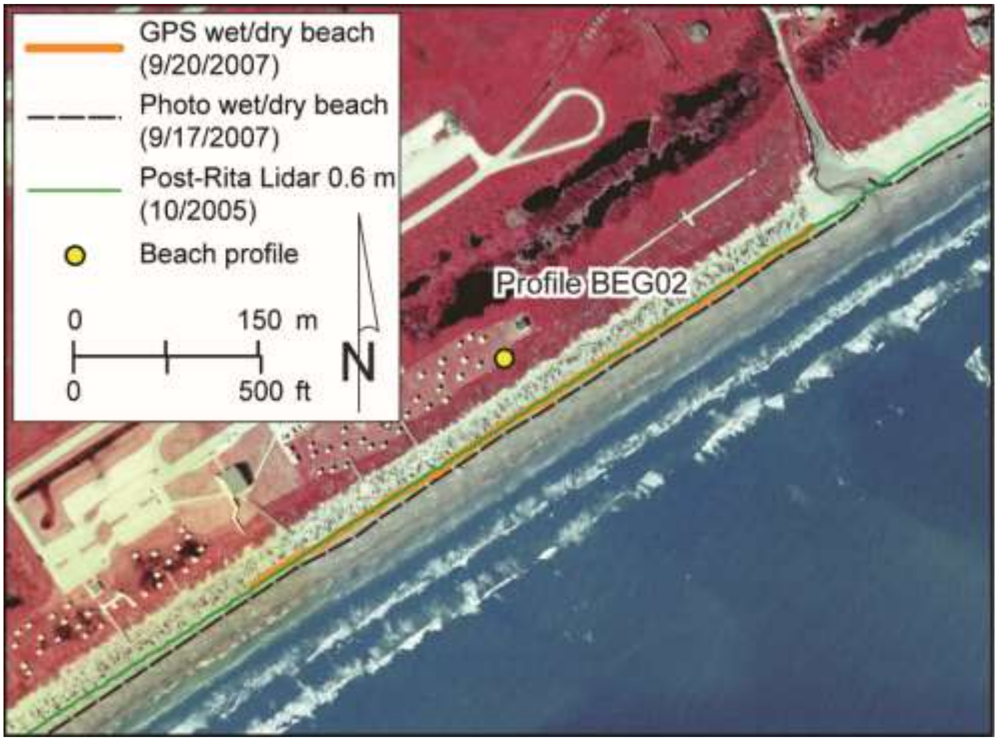

Figure 10. Shoreline position comparison at Galveston Island State Park site BEG02. Shorelines include the 2007 wet beach/dry beach boundary mapped on aerial photographs taken September 17, 2007; the wet beach/dry beach boundary mapped on September 20, 2007, by THSCMP students and staff using ground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

The THSCMP has increased public awareness of coastal issues through the students themselves, as well as through media reports and presentations at conferences. At a symposium held in March of this year, 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 Corpus Christi, Texas. The website, too, continues to be instrumental in extending the reach of the program and increasing public awareness. Given the number of inquiries from people wishing to enter their school or group in THSCMP, information on the program and on the results it generates certainly seems to be reaching the public.

SCIENTIFIC RESULTS OF 1997–2015 STUDIES

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 field notes made by students and scientists. 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 THSCMP since 1997. During this time frame, 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 this storm, which caused significant damage to beaches along the southeast coast of Texas, comparable to damage caused by Category 3 Hurricane Alicia in 1983 (Hepner and Gibeaut, 2004). Several other severe storms have also impacted the study area. Tropical Storm Allison (June 2001), Tropical Storm 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 pre-storm 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 did in 1998. **Figure 12** is a plot of pre- and post-storm beach profiles measured at Galveston

Island State Park. The pre-storm 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 and others, 2008).

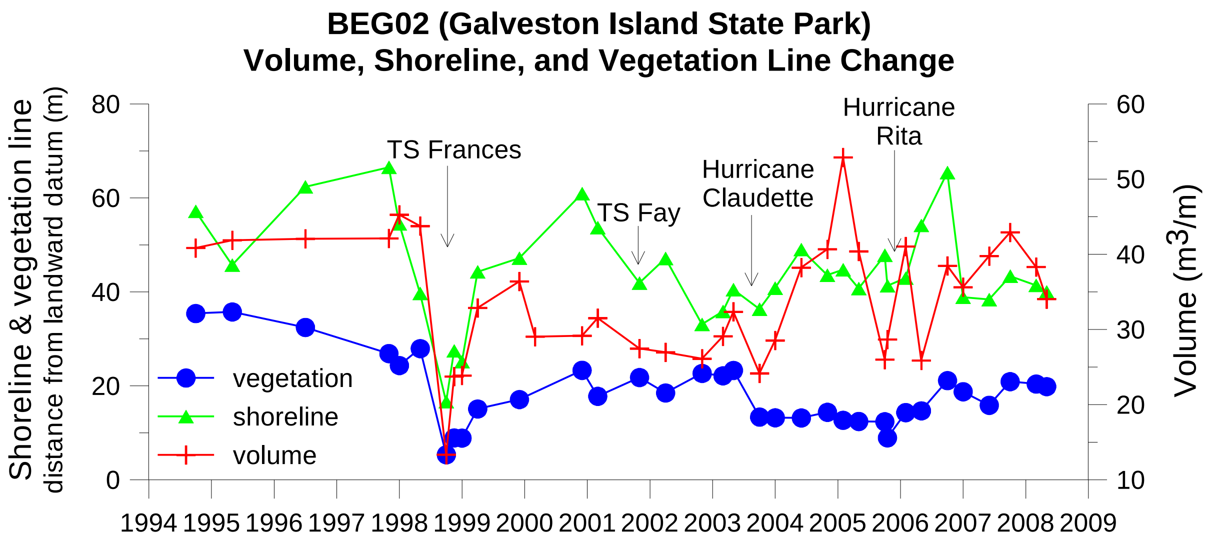

Figure 11. Profile volume, shoreline, and vegetation-line changes at Galveston Island State Park, September 1994–April 2008.

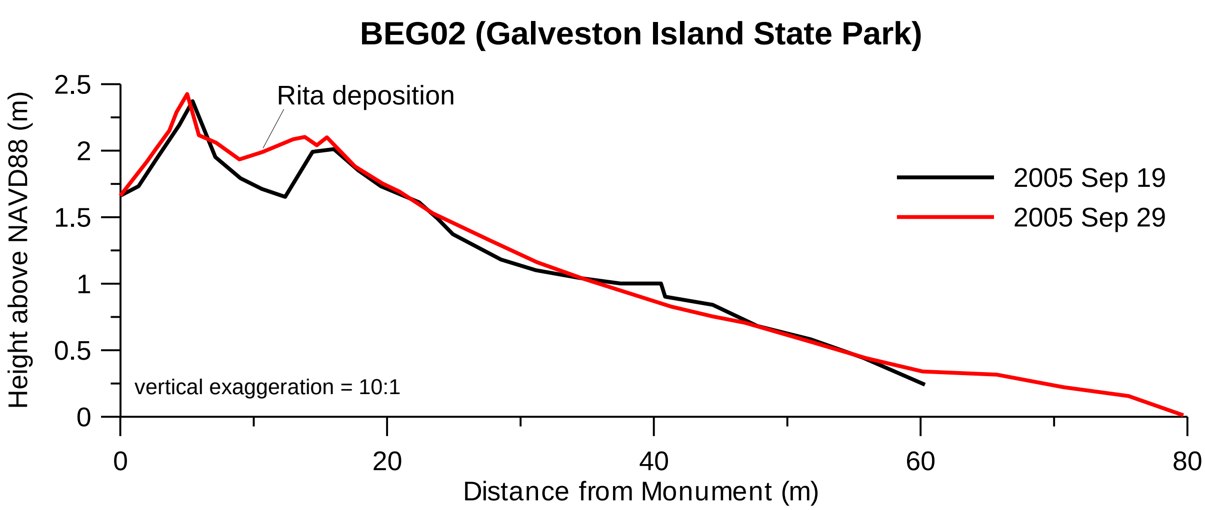

Figure 12. Plot of pre- and post-Rita beach profiles measured at Galveston Island State Park.

The 2008–2009 academic year was severely affected by the landfall of Hurricane Ike on Galveston Island on September 13, 2008. Palacios, Port Aransas, Tidehaven, and Van Vleck school field trips were postponed because of school closings in preparation for the hurricane. Because of the sheer size of the storm, impacts from this hurricane were seen along the entire Texas coast, despite Ike being only a Category 2 storm at the time of landfall. Dune erosion from Hurricane Ike was 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 THSCMP during the 2008–2009 academic year because of safety concerns about 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 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. GLO06, at the southwest corner of Galveston Island State Park, was also lost as a result of Hurricane Ike and 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 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 13** 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. 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. 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.

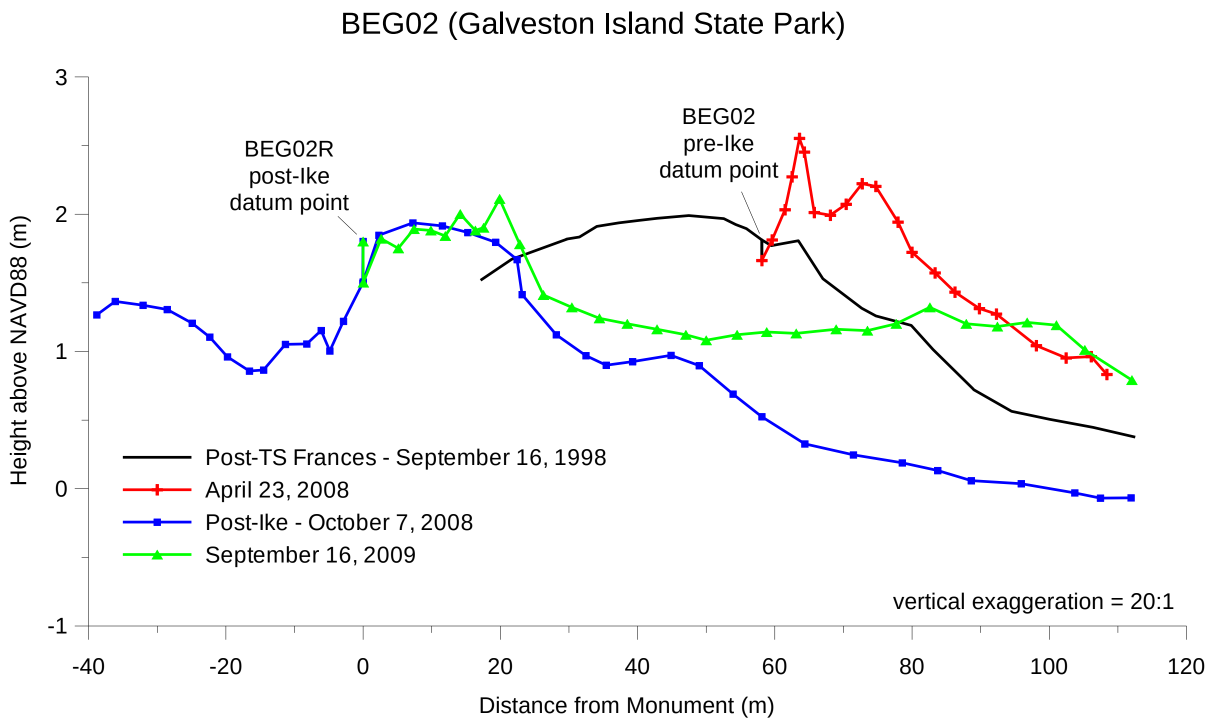

Figure 13. Beach-profile plots from BEG02 in Galveston Island State Park comparing the post–Hurricane Ike profile with a pre-storm profile from early 2008 and the post–Tropical Storm Frances profile from September 1998. Data from September 2009 (one year post-storm) is also included.

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 foredunes is due to natural recovery processes or human intervention is unclear.

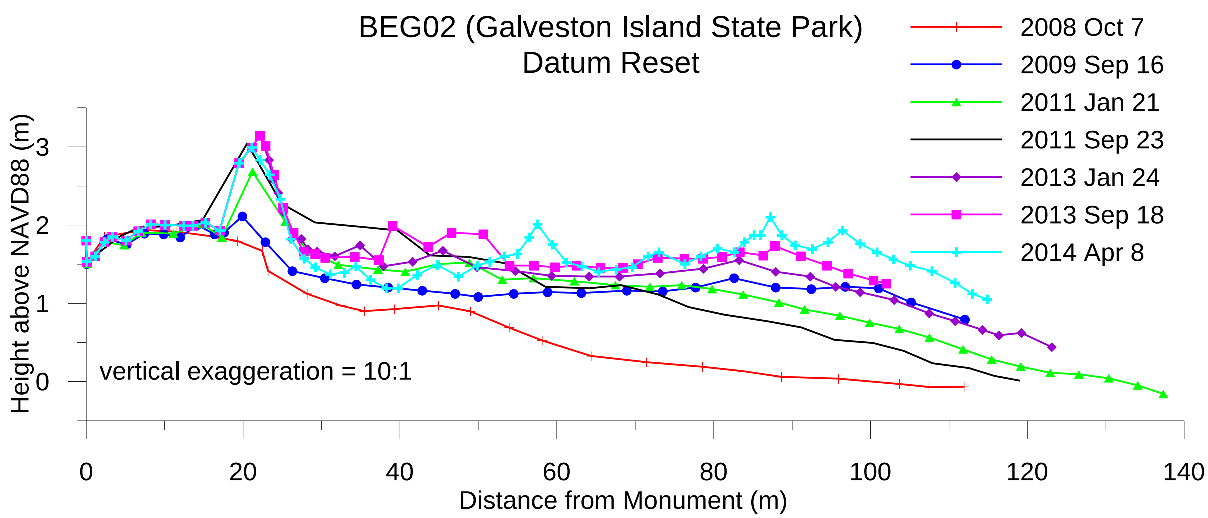

Figure 14. BEG02 datum reset post-storm profile plus data collected by Ball High School students. Students are monitoring recovery of the beaches and dunes at this site.

Dune erosion due to Hurricane Ike was also documented on the middle Texas coast at Matagorda Peninsula and to a lesser extent on Mustang Island (**fig. 1**). Van Vleck Middle School (site MAT01) and Palacios High School (site MAT02) students have been monitoring the recovery of the dunes (**fig. 15**) and the seaward movement of the vegetation line post–Hurricane Ike on Matagorda Peninsula.

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.

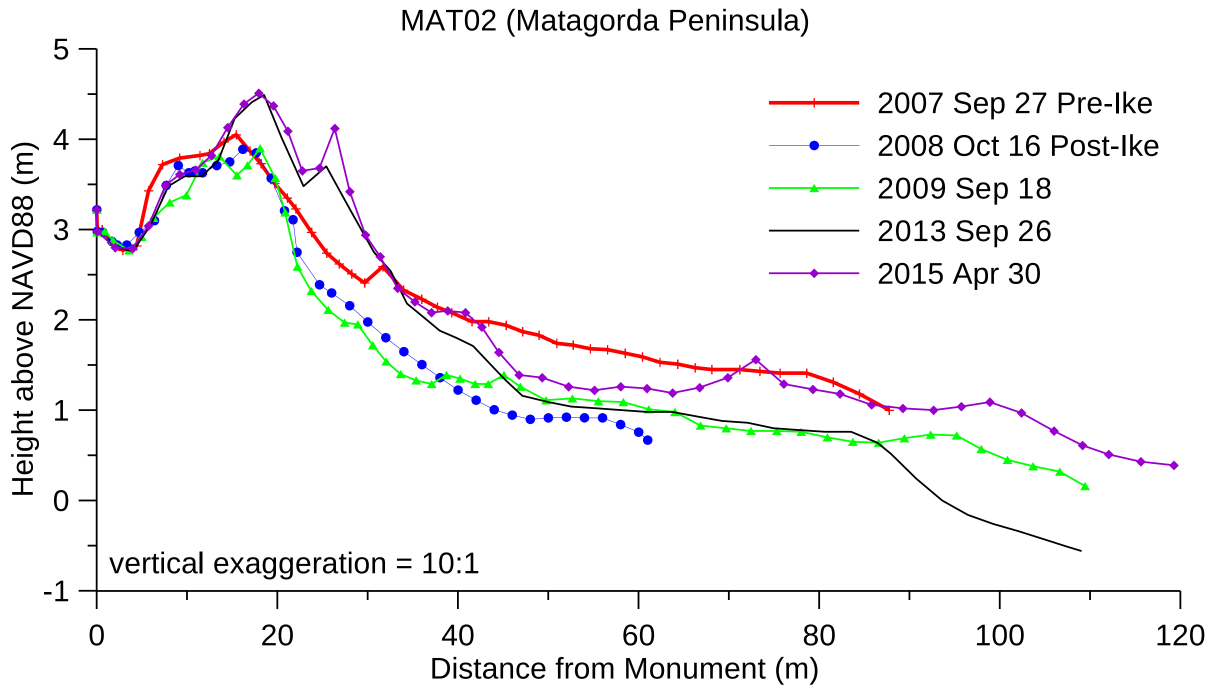

Figure 15. MAT03 pre- and post-storm profile data collected by Palacios High School students. Students are monitoring recovery of the foredune at this site.

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 placed on the beaches of South Padre Island and the three sites monitored by Port Isabel High School students are within beach-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, vegetation has been planted, and numerous beach-nourishment projects have been completed. Profile data have been quantifying the effects of these actions (**fig. 16**). Beach volume at this location has been increasing because of a slowly accreting shoreline and entrapment of sand in the dune area. The vegetation line had remained in a relatively stable position prior to 2012. A large push-up dune, seaward of the vegetation line, has been created by beach-maintenance practices (beach scraping to remove seaweed) and accounts for the increase in beach volume at

SPI02, the seaward movement of the vegetation line, and the change in the beach profile shape (**fig. 16**).

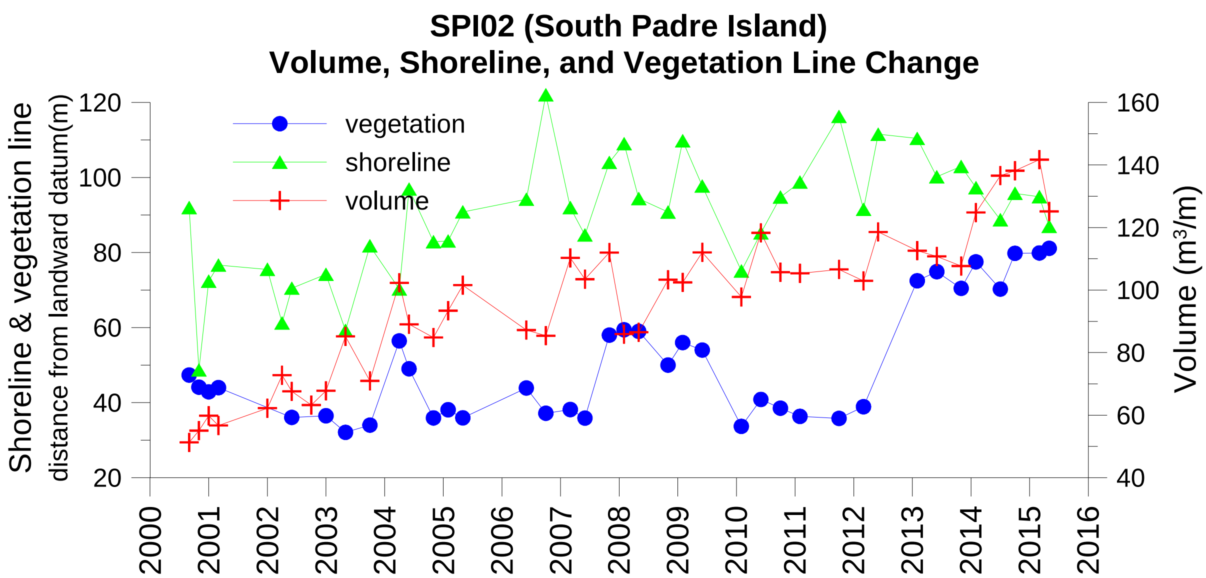

Figure 16. Changes at SPI02 on South Padre Island due to beach-nourishment projects and the installation of sand fences.

Starting in the 2007–2008 academic year, students at Port Isabel High School began gathering data at 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 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 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. 17**). 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 has since returned to the prenourishment position. After an initial significant decrease in beach volume (to prenourishment levels), volume on the back beach has increased steadily because of the 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. 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 has remained stable. Port Isabel students will continue to monitor this rapidly changing and chronically eroding location.

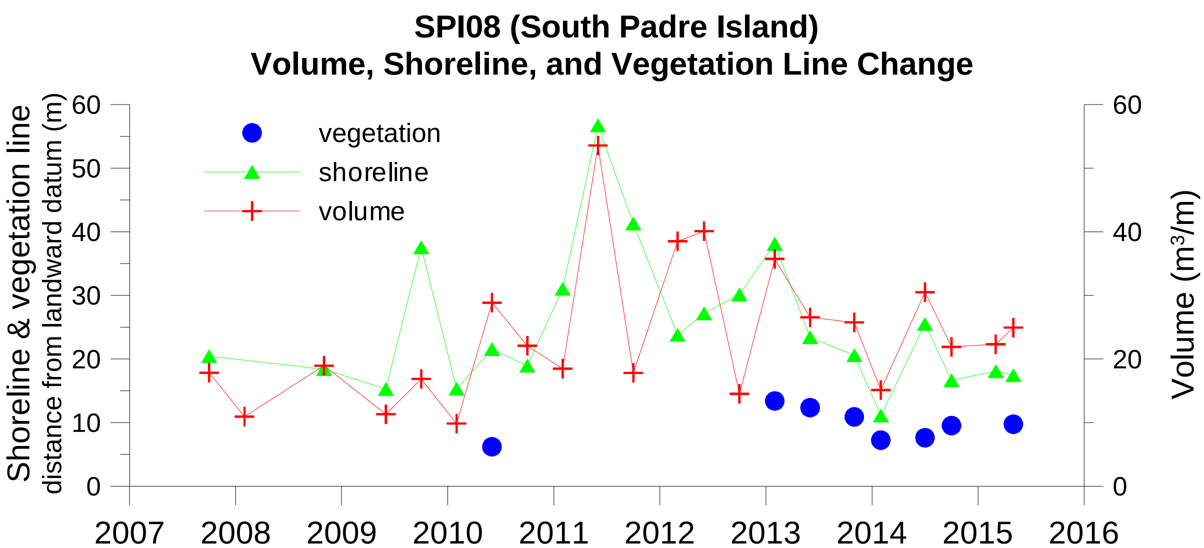

Figure 17. Volume and shoreline changes at SPI08 on South Padre Island due to beach-nourishment projects and the installation of sand fences.

The beach-monitoring activities of Port Aransas High School students have also provided beneficial information 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 are 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 18** 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.

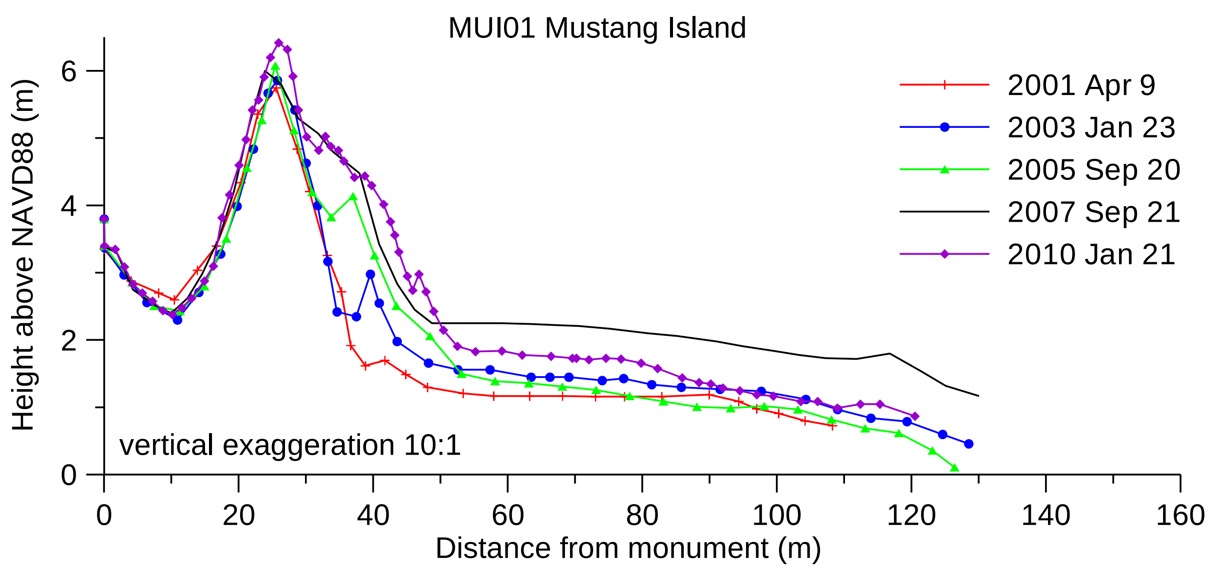

Figure 18. Foredune expansion at MUI01 on Mustang Island.

When Port Aransas students arrived to collect profile data in October 2012, a large part of the dune face had been excavated (**figs. 19, 20**) 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 throughout the 2014–2015 academic year. The current width of the foredune is narrower and the volume of sand in the profile is less than when the THSCMP began monitoring in 1999 (see change plot in Appendix A).

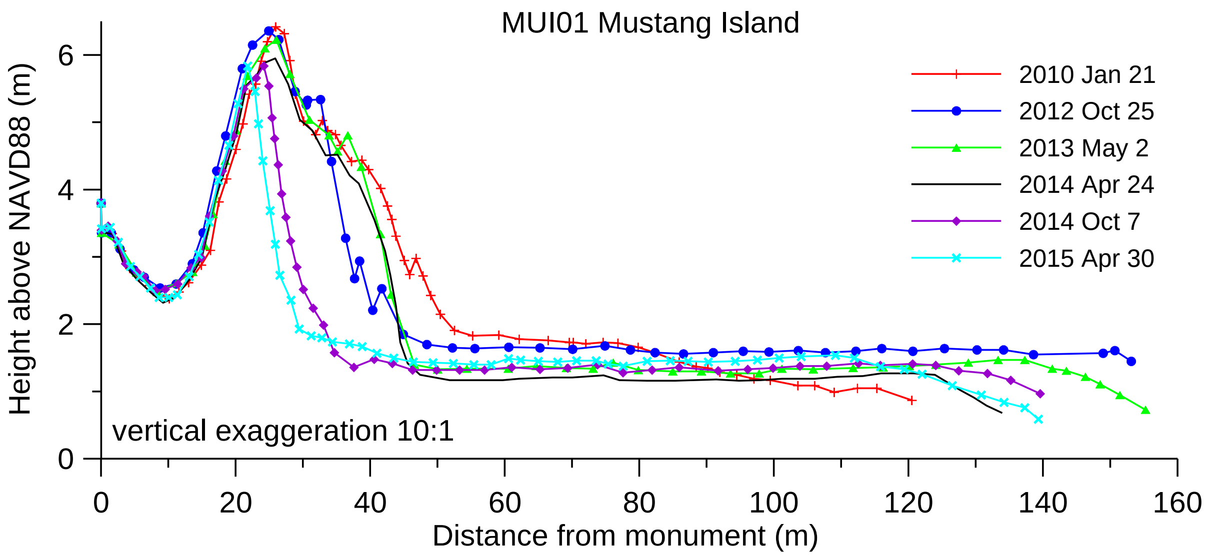

Figure 19. Excavated dune profile at MUI01 on Mustang Island.

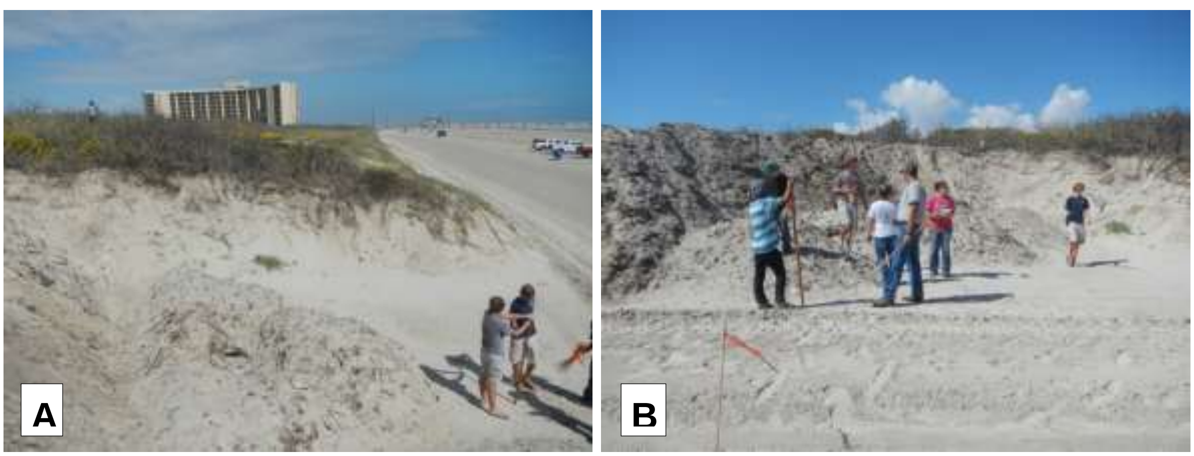

Figure 20. Excavated dune at MUI01 on Mustang Island looking (A) north toward Horace Caldwell Pier, and (B) landward.

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. (1) Monitoring sites have been established on the updrift side of the jetty at the mouth of the Colorado River and 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. Data collected between 2005 and 2007 will served as a baseline for the study on vehicular impact on beaches if the beach remains closed to vehicles.

(2) 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 an 80-m seaward movement of shoreline position at MAT03 immediately north of the new jetty (**fig. 21**). Student data at MAT03 has shown that the new jetty on east Matagorda Peninsula has caused the shoreline to move seaward at a rate of 11 m per year between 2006 and 2014.

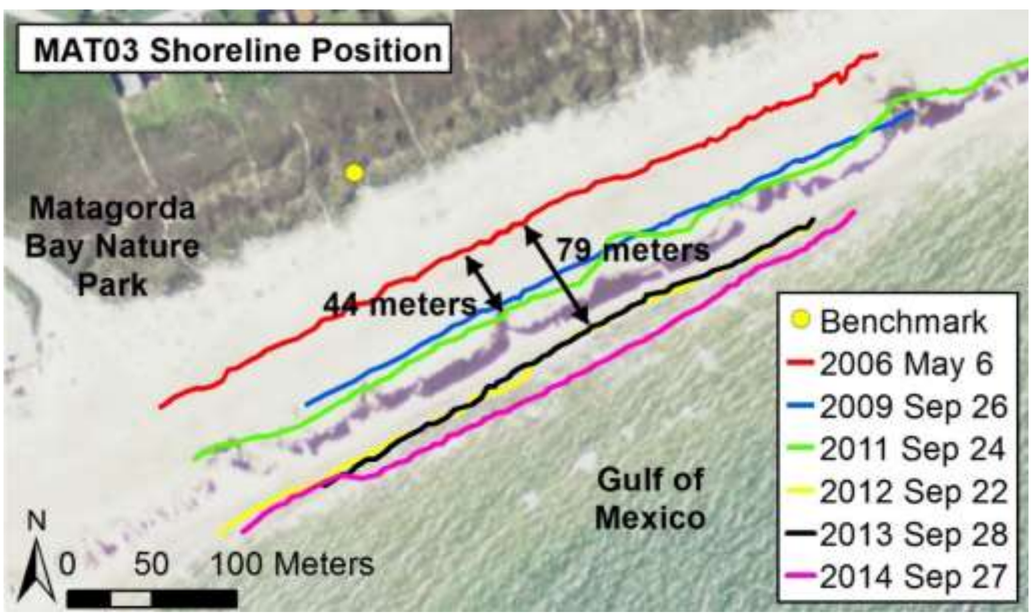

Figure 21. Shoreline position change at Matagorda Peninsula.

The shoreline and vegetation line position have been continuously moving seaward and volume has been increasing at this site throughout the study period (**fig. 22**). 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. Tidehaven Middle School students will continue to monitor this site to determine if the shoreline, vegetation line, and sand volume will continue advancing or eventually stabilize.

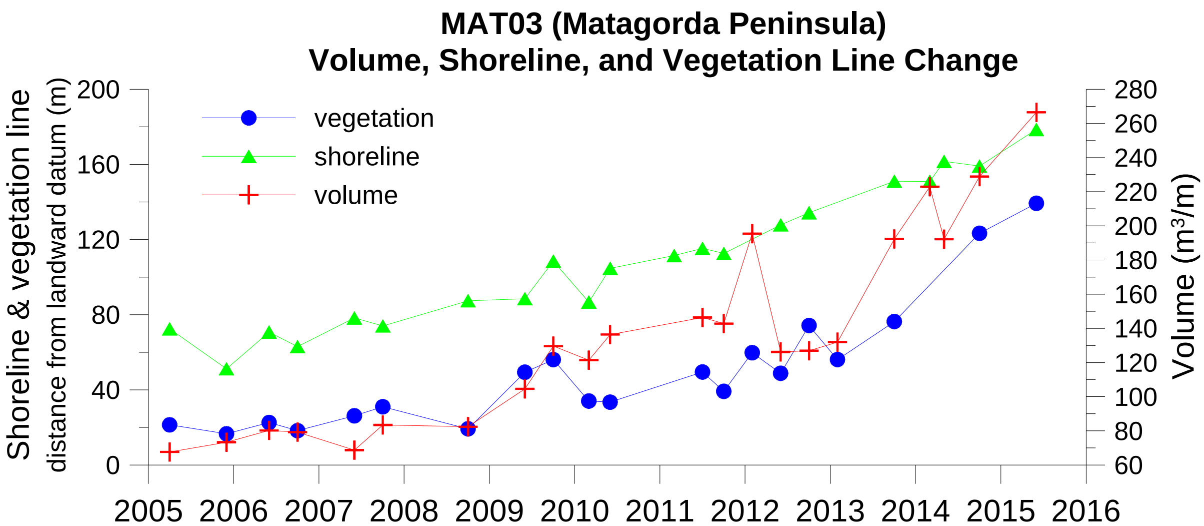

Figure 22. Changes in beach and dune volume, shoreline position, and vegetation line position at MAT03 on Matagorda Peninsula.

Cunningham Middle School students have already witnessed a remarkable change in their profile location after 6 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 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. The 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 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 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.

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 complies with many TEKS and NSES requirements. The 2014–2015 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 several field trips.

In the 16 years since the inception of the THSCMP, work by students at Ball, Palacios, Port Aransas, Port Isabel, and Van Vleck High Schools and Cunningham and Tidehaven 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. Through this successful student research program, scientists, students, and the public will continue to gain a better understanding of processes and shoreline change along the Texas coast.

ACKNOWLEDGMENTS

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Austin. Tiffany Caudle served as the Principal Investigator. The project was funded under a Coastal Management Program (Cycle 18) grant made available to the State of Texas by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, pursuant to the Federal Coastal Zone Management Act of 1972, NOAA Award Number NA13NOS4190113. Additional funds to support the project came from the Trull Foundation, Schlumberger, and The Jackson School of Geosciences. Field trip support was provided by staff at Matagorda Bay Nature Park, Lower Colorado River Authority.

REFERENCES

Gibeaut, J. C., Hepner, T., Andrews, J., Gutierrez, R., and Smyth, R., 2008, Hurricane Rita impacts on the Texas shoreline: a summary report: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas General Land Office under GLO contract number 02-267 C, 26 p.

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 the Texas General Land Office under GLO contract number 02-493 R, 37 p. plus appendices.

Hepner, T. L., and Gibeaut, J. C., 2004, Tracking post-storm beach recovery using data collected by Texas high school students: Shore & Beach, v. 72, no. 4, p. 5–9.

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 the Texas General Land Office under GLO contract number 10-041-000-3737, 38 p.

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

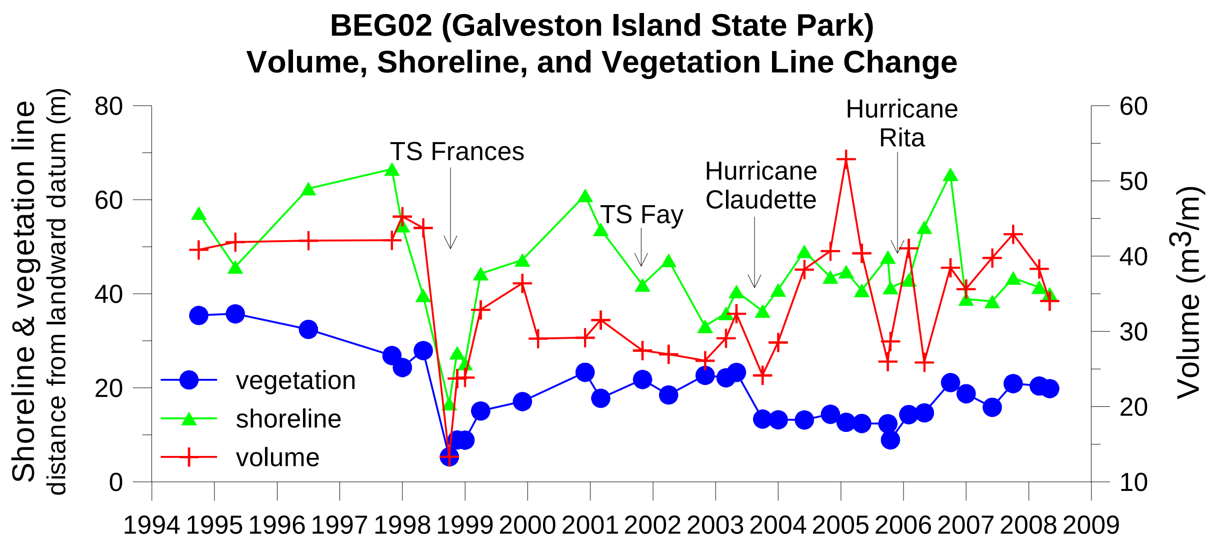
[1]BEG02 reset in October 2008 after Hurricane Ike.

[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.

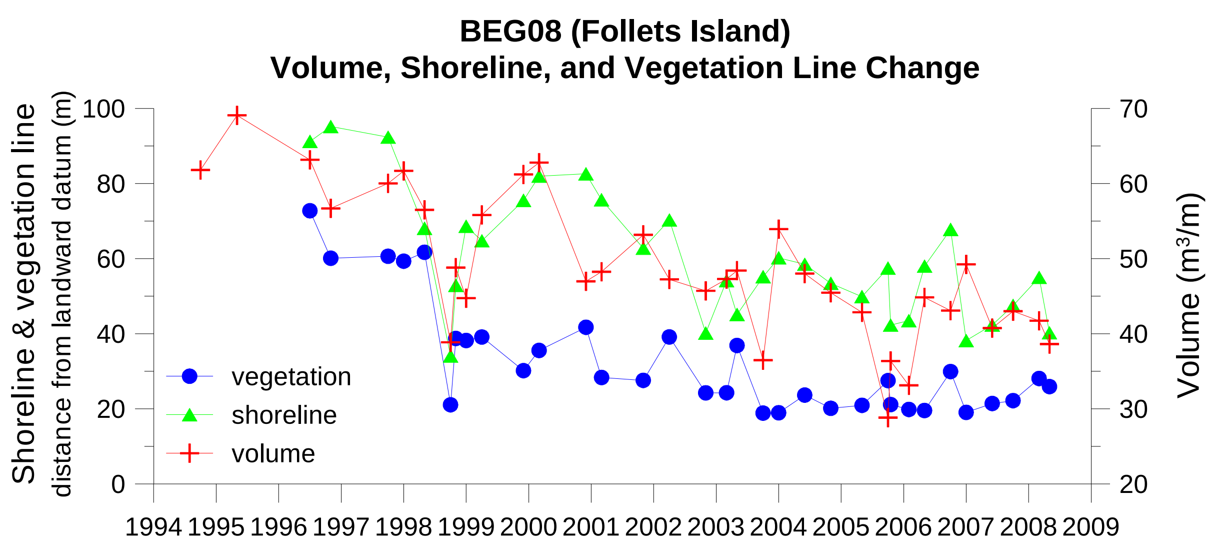
[3]NPI08 reset closer to foredune in April 2009 for easier access by Cunningham Middle School students. New datum marker was buried by landward toe of dune between March and May 2010. Students have used the original marker since the May 2010 survey.

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.

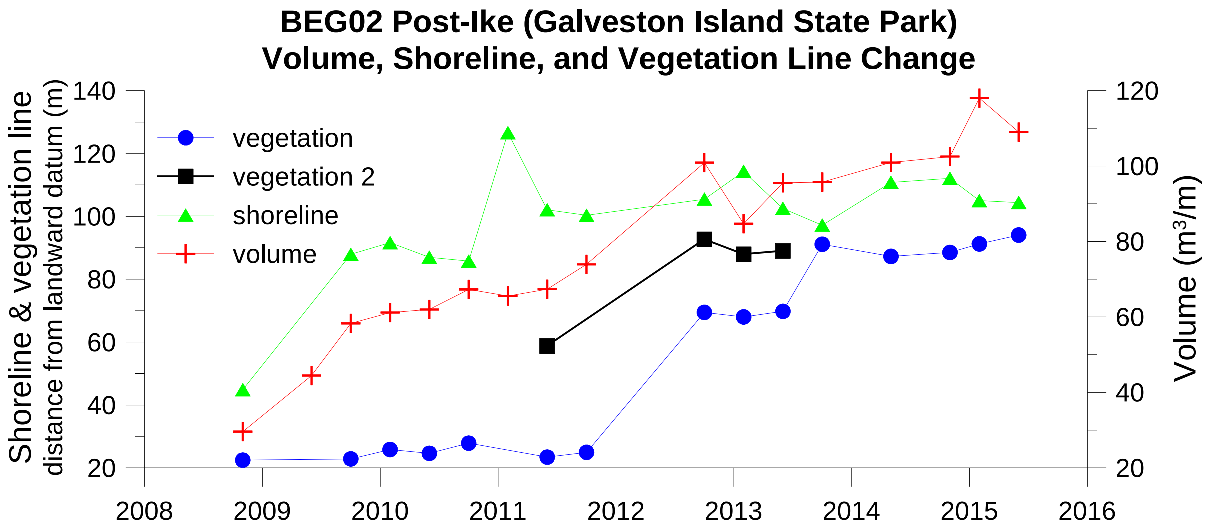


BEG08 volumes were calculated from datum to 1 m below datum. Profiles that did not extend to -1 m were extrapolated.

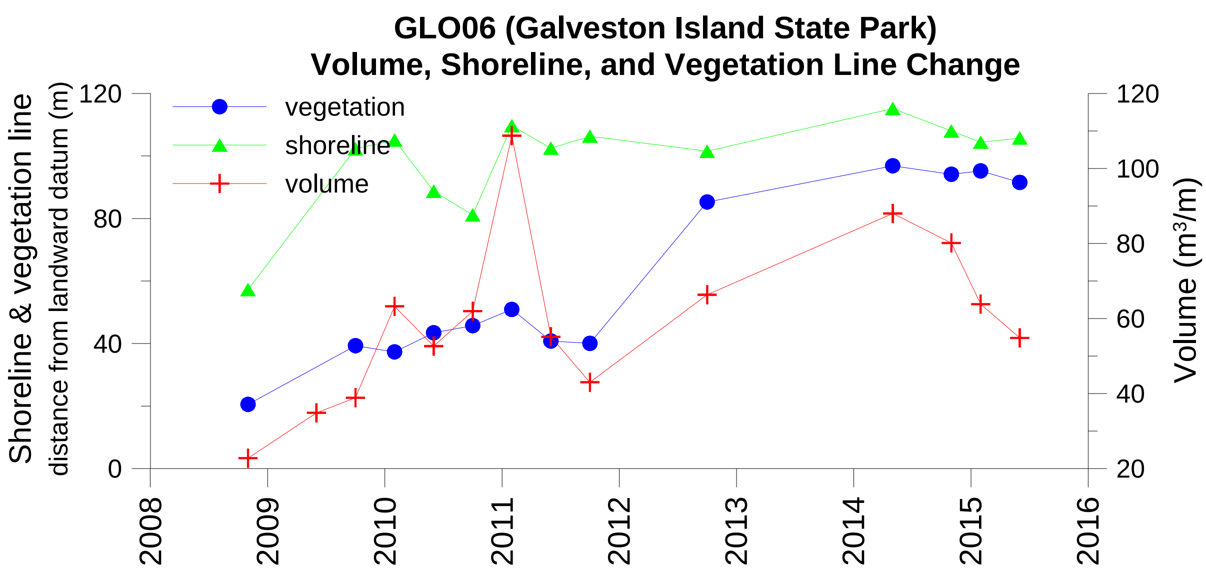


BEG02 and BEG08 have data from 1994 through the spring of 2008. Ball High School did not participate in the program because of Hurricane Ike's impact on Galveston Island.

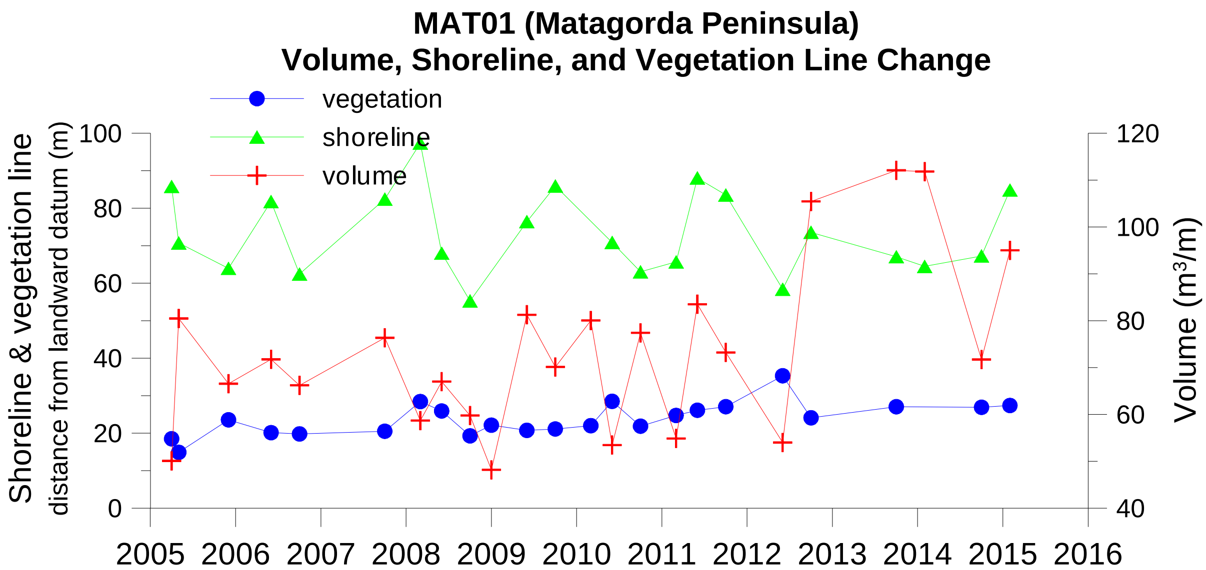
BEG02R volumes were calculated from datum to 1 m below datum. Profiles that did not extend to -1 m were extrapolated.



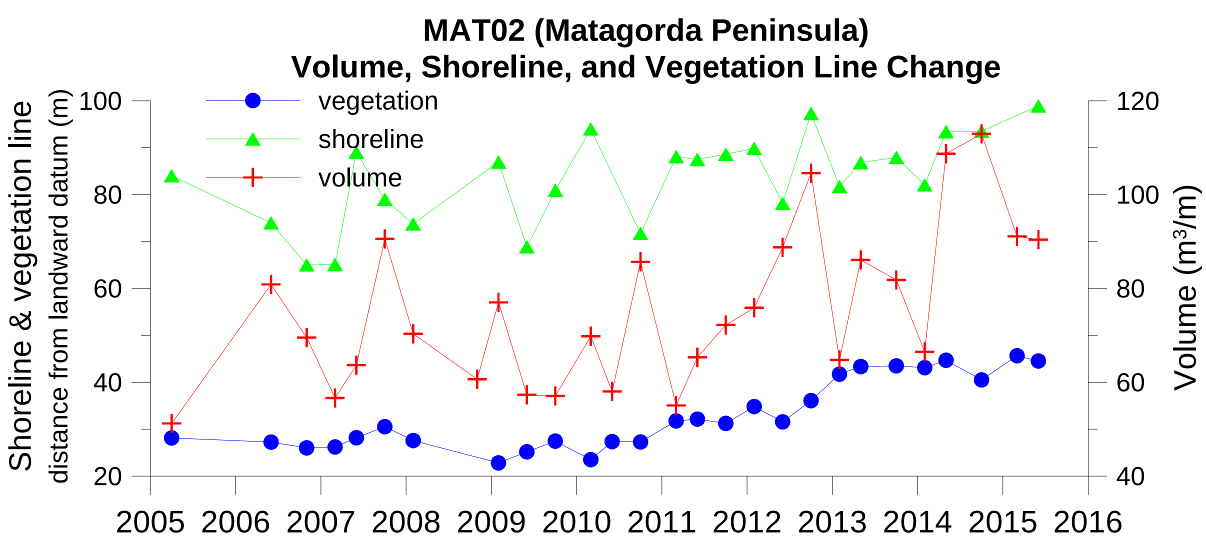
GLO06 volumes were calculated from datum to 1 m below datum. Profiles that did not extend to -1 m were extrapolated.



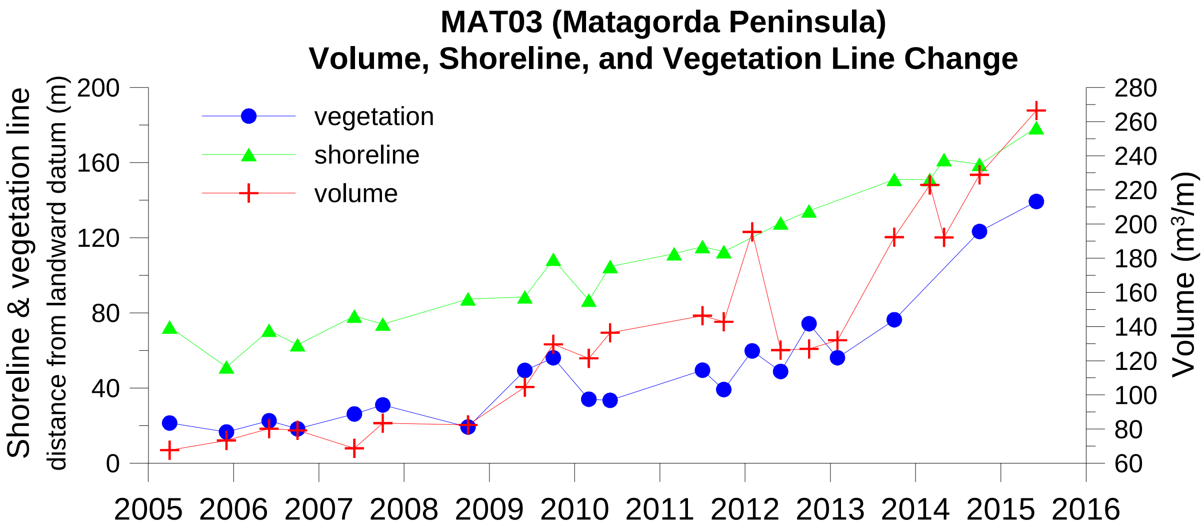
MAT01 volumes were calculated from datum to 2.5 m below datum. Profiles that did not extend to -2.5 m were extrapolated.



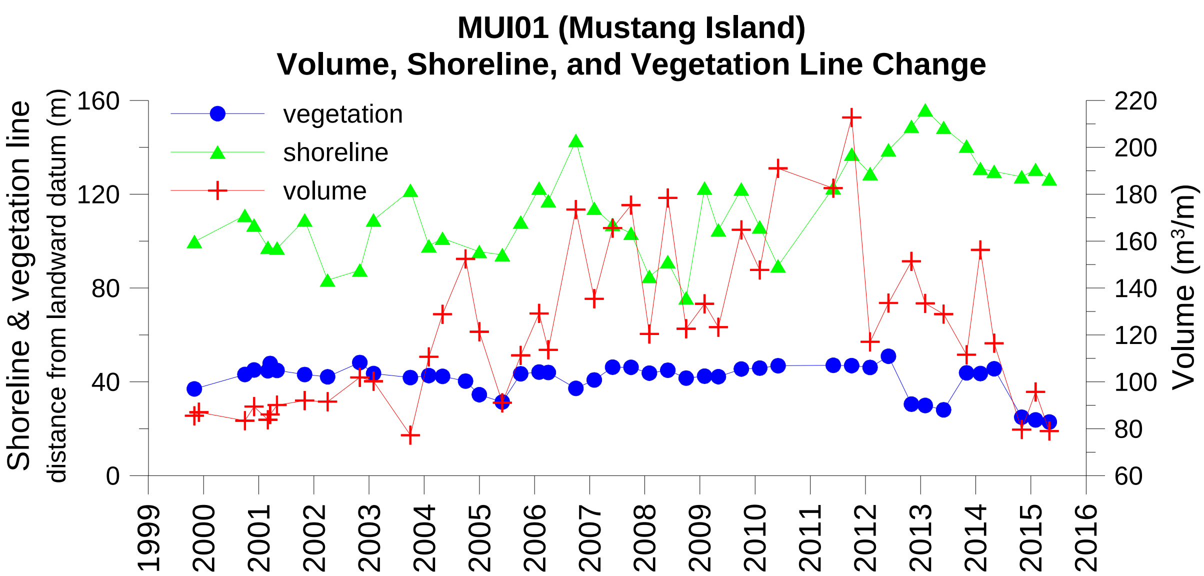
MAT02 volumes were calculated from datum to 2 m below datum. Profiles that did not extend to -2 m were extrapolated.



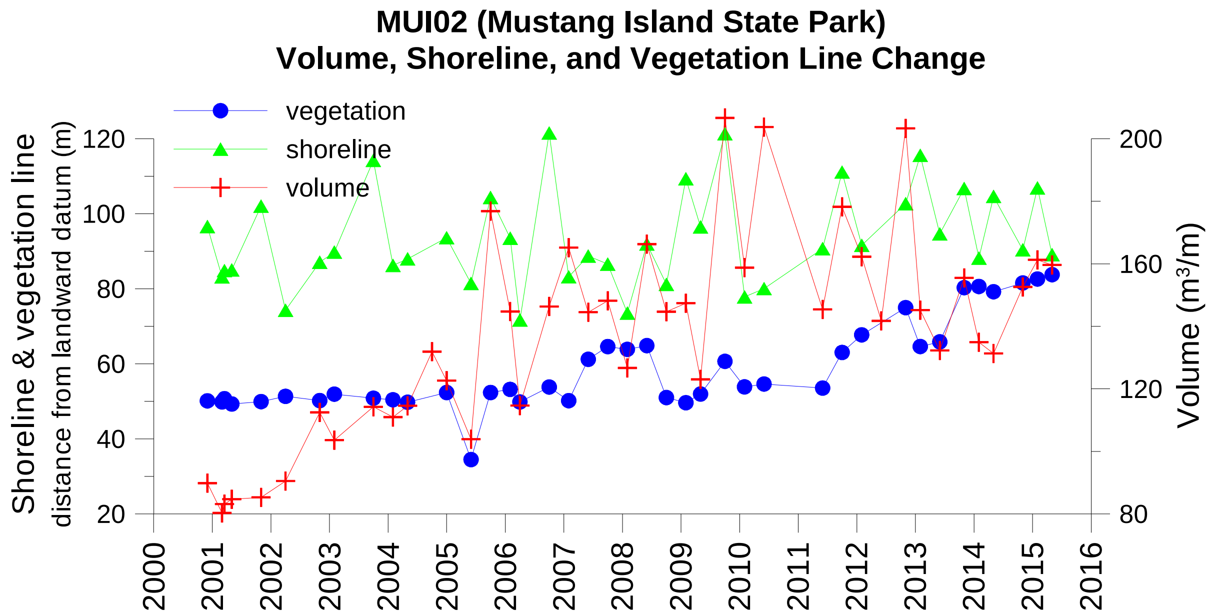
MAT03 volumes were calculated from datum to 3.75 m below datum. Profiles that did not extend to -3.75 m were extrapolated.



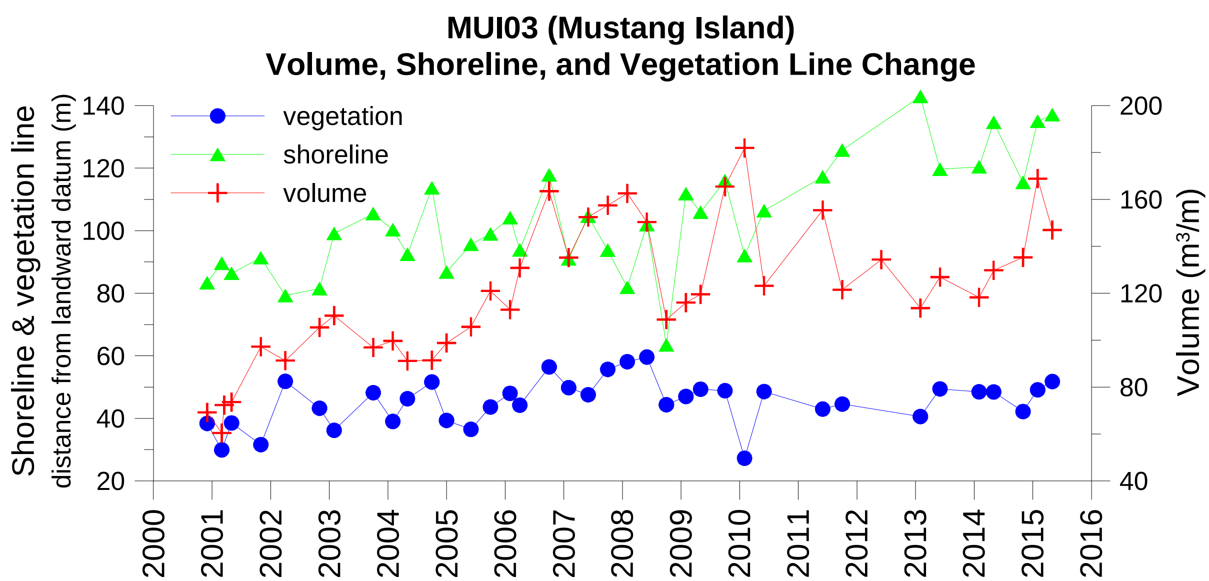
MUI01 volumes were calculated from datum to 2.5 m below datum. Profiles that did not extend to -2.5 m were extrapolated.



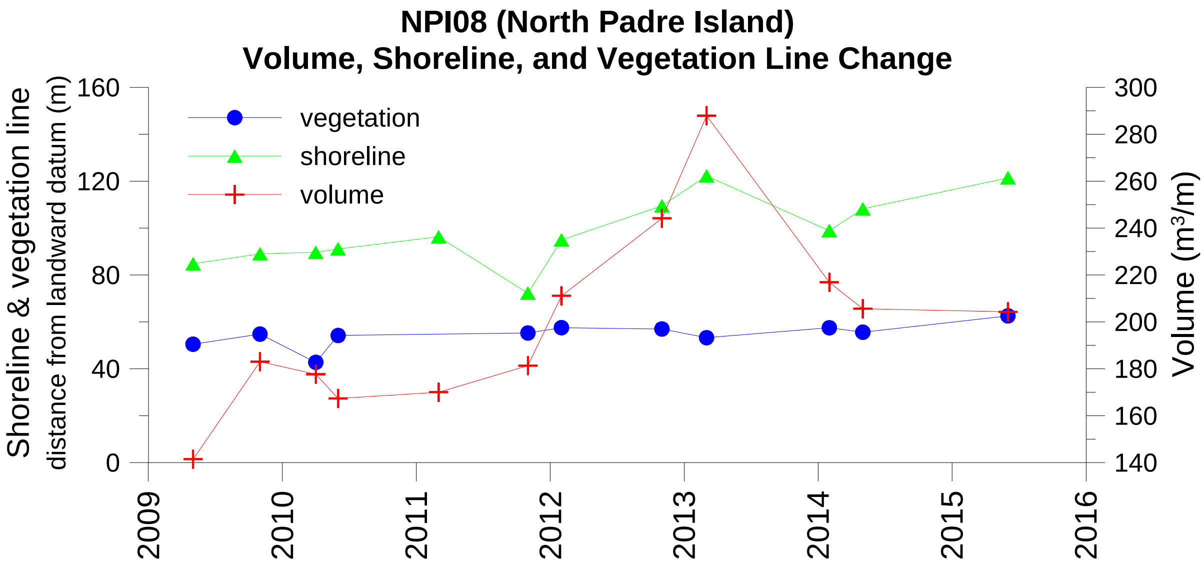
MUI02 volumes were calculated from datum to 0.5 m below datum. Profiles that did not extend to -0.5 m were extrapolated.



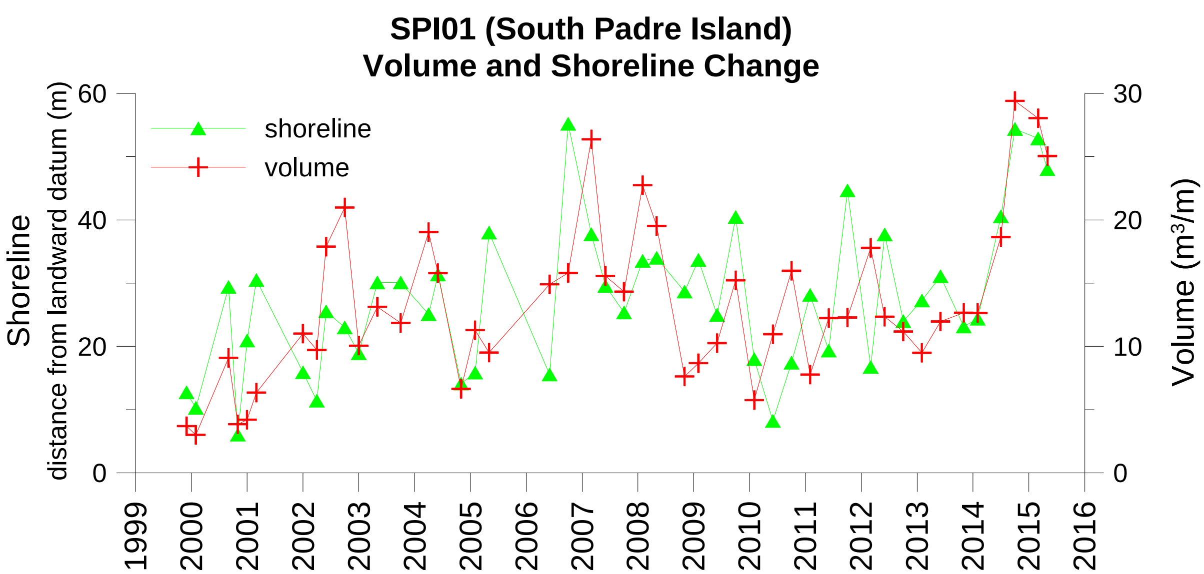
MUI03 volumes were calculated from datum to 2.5 m below datum. Profiles that did not extend to -2.5 m were extrapolated.



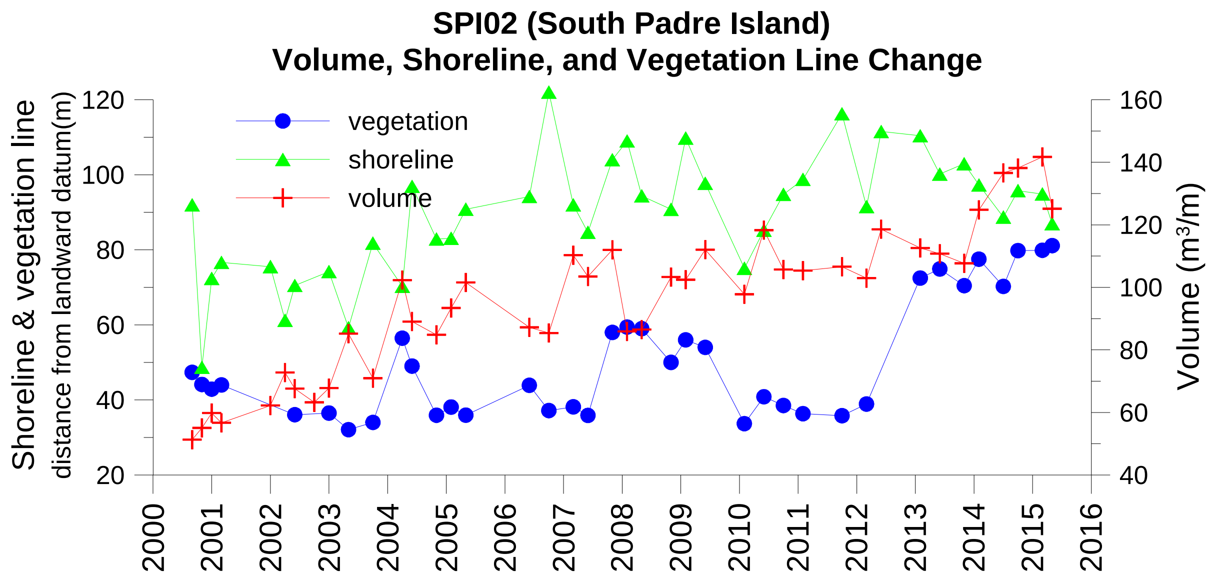
NPI08 volumes were calculated from datum to 1.25 m below datum. Profiles that did not extend to -1.25 m were extrapolated.



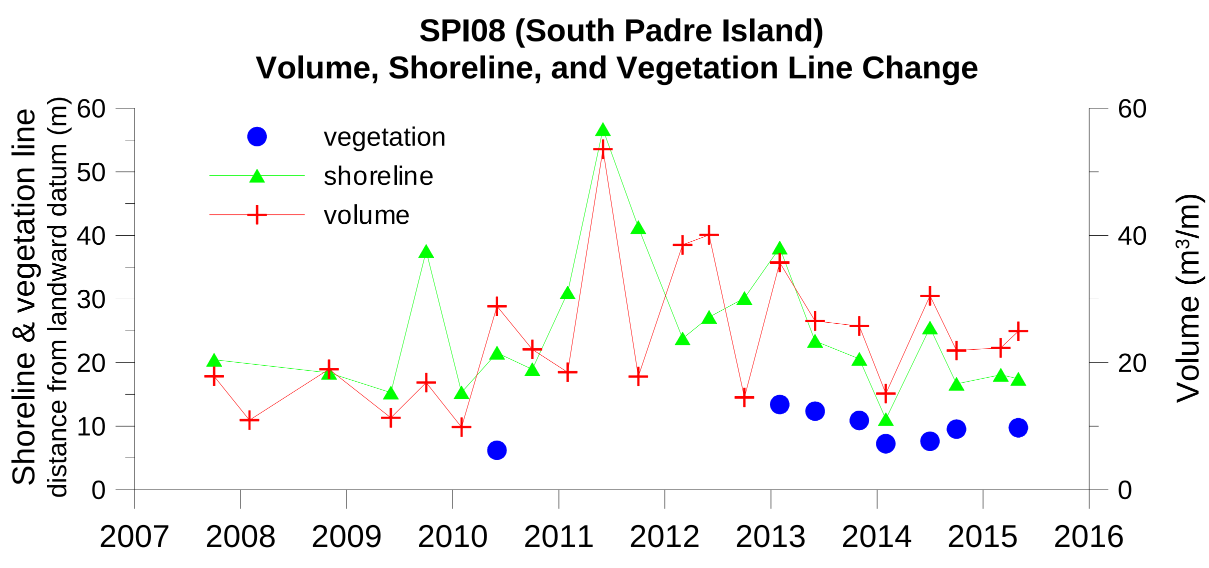
SPI01 volumes were calculated from datum to 2 m below datum. Profiles that did not extend to -2 m were extrapolated.



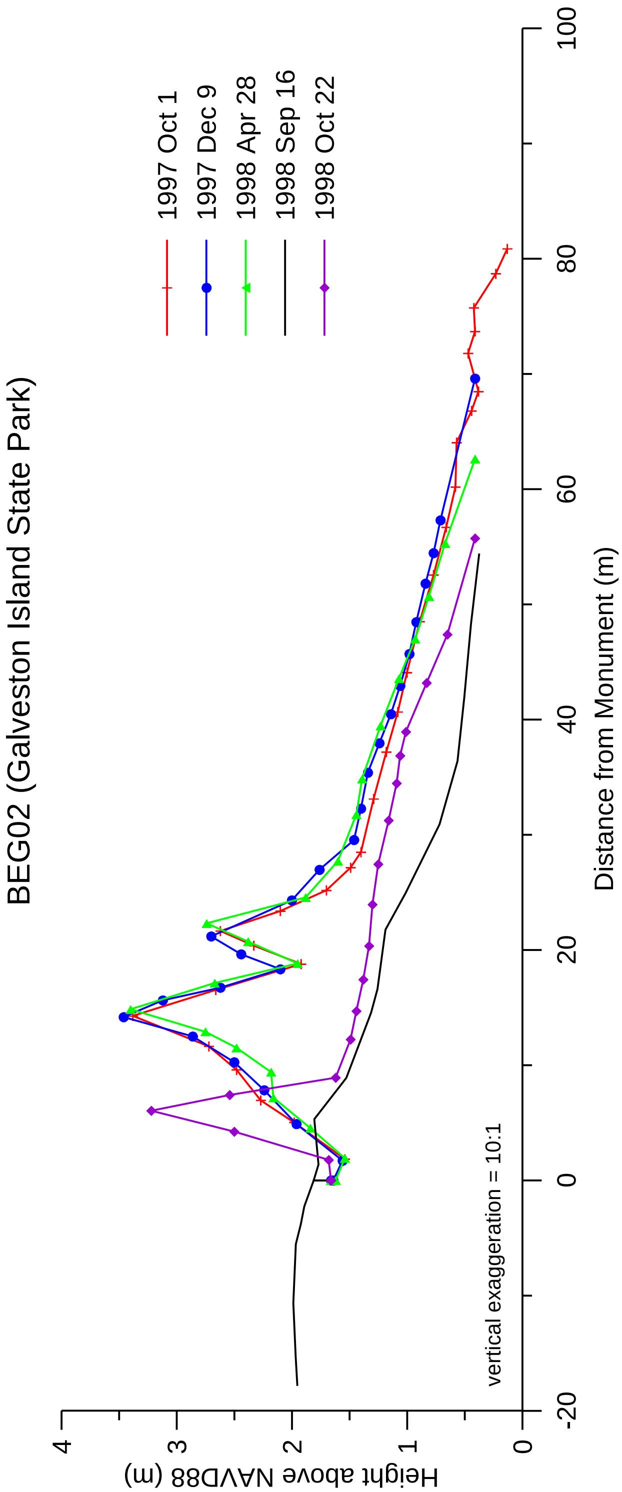
SPI02 volumes were calculated from datum to 2.25 m below datum. Profiles that did not extend to -2.25 m were extrapolated.

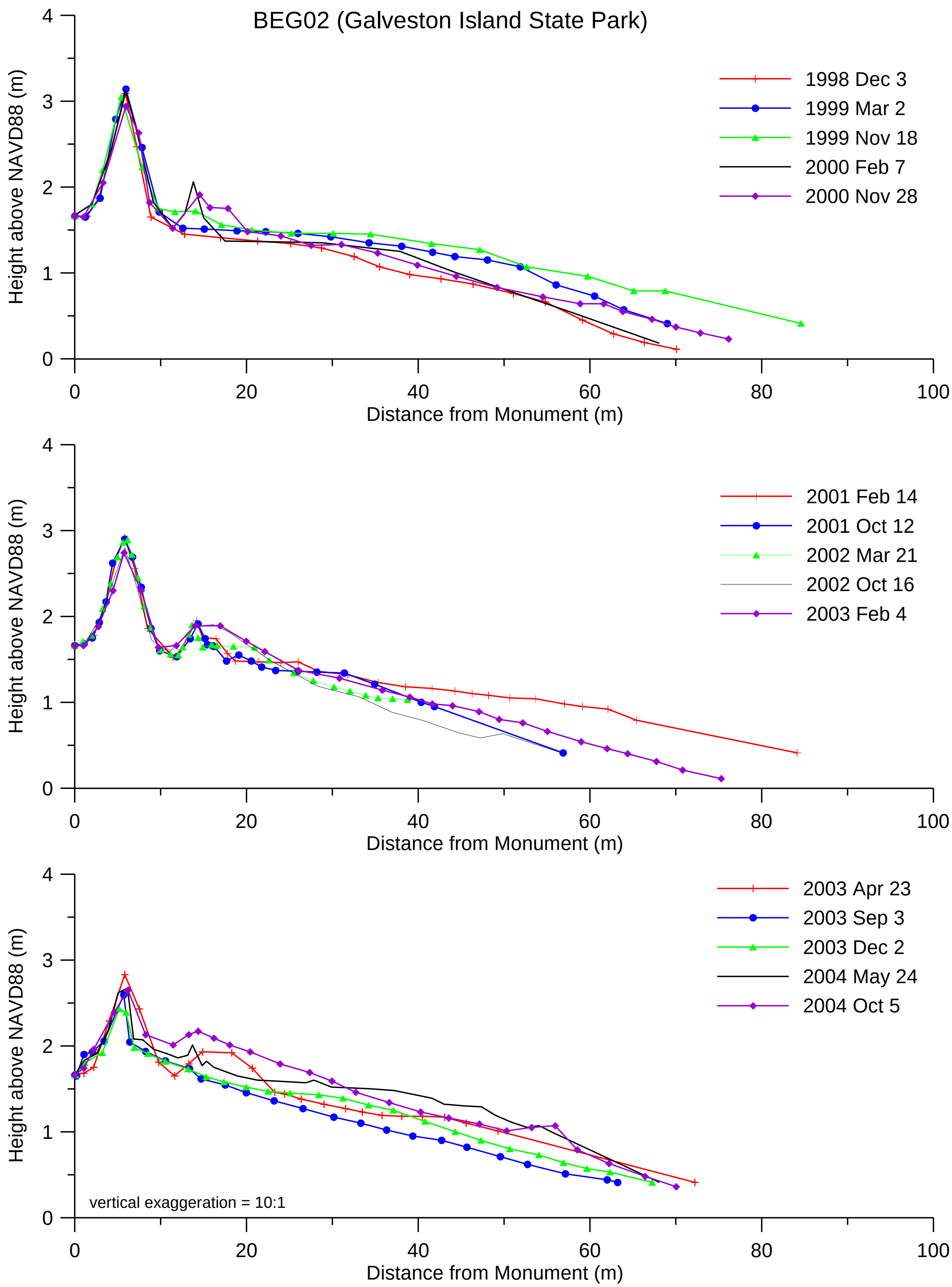


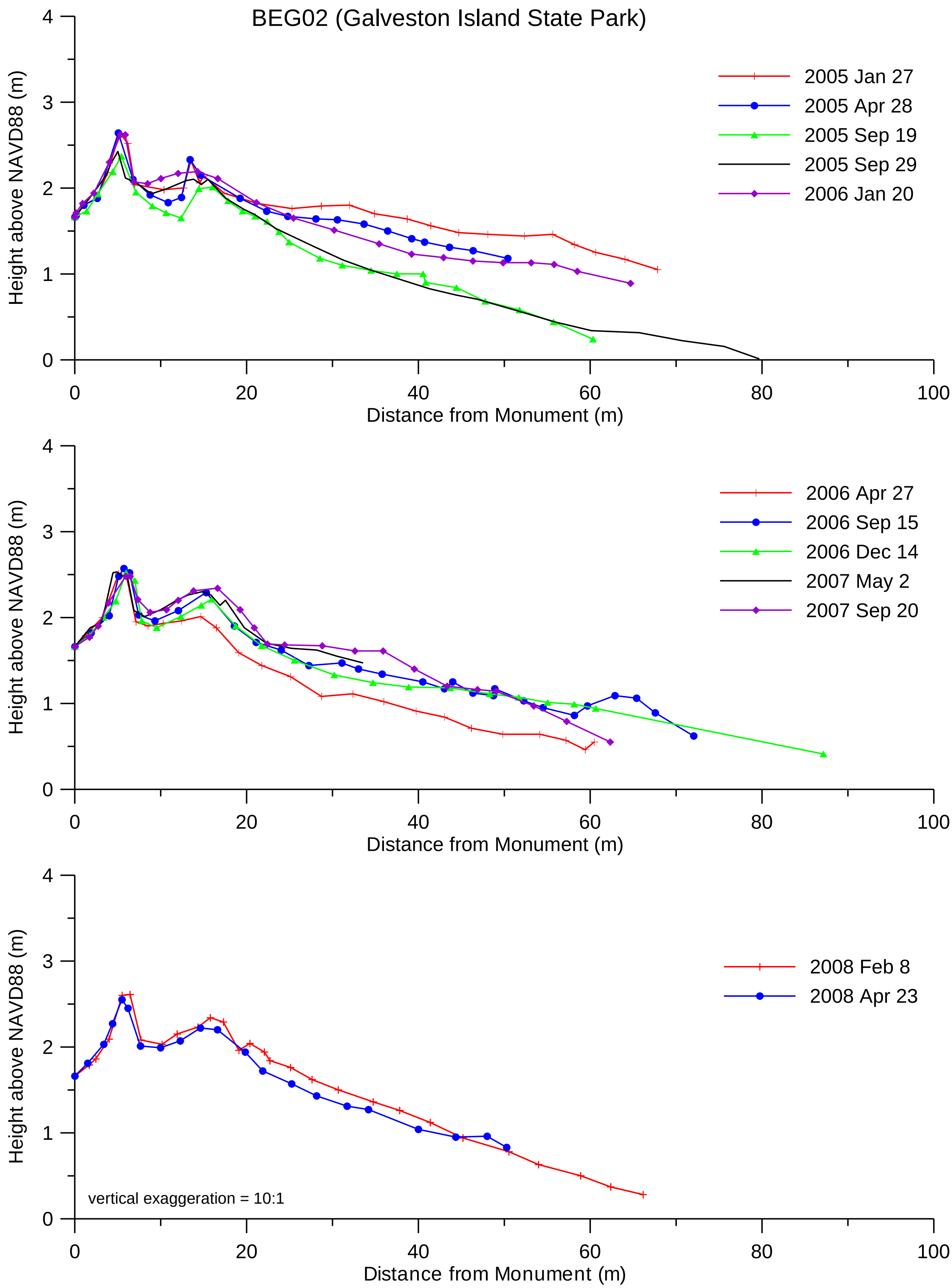
SPI08 volumes were calculated from datum to 2.5 m below datum. Profiles that did not extend to -2.5 m were extrapolated.



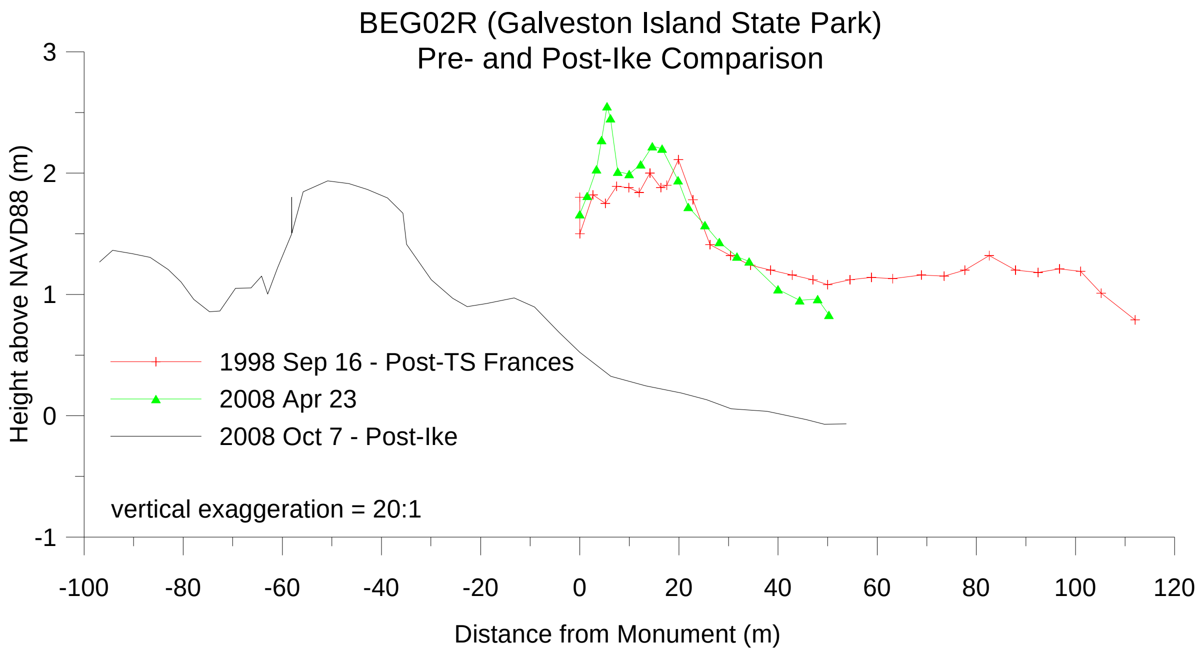
APPENDIX C: GRAPHS OF BEACH PROFILES

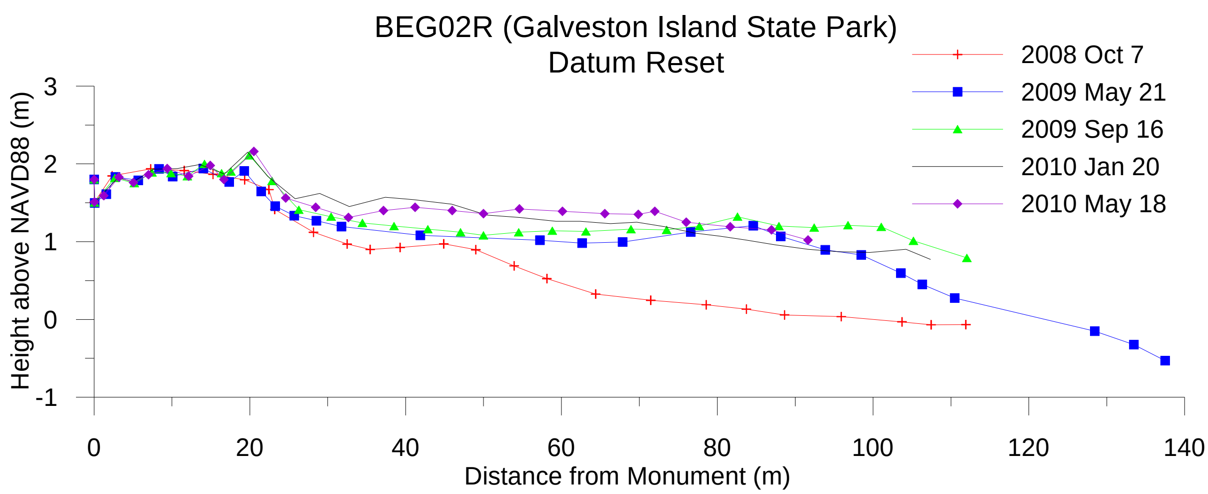


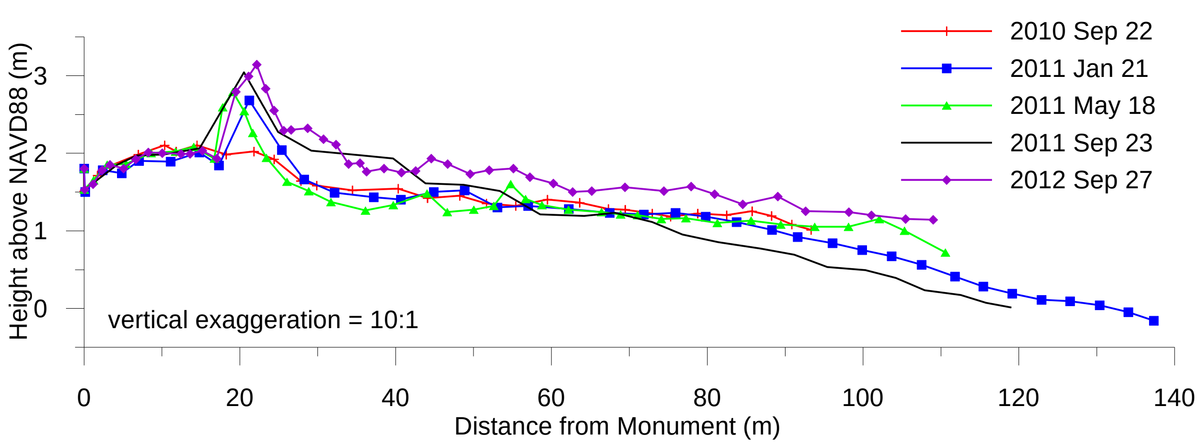

BEG02 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
1998 Dec 3
1999 Mar 2
1999 Nov 18
2000 Feb 7
2000 Nov 28
2001 Feb 14
2001 Oct 12
2002 Mar 21
2002 Oct 16
2003 Feb 4
2003 Apr 23
2003 Sep 3
2003 Dec 2
2004 May 24
2004 Oct 5
vertical exaggeration = 10:1



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
2006 Apr 27
2006 Sep 15
2006 Dec 14
2007 May 2
2007 Sep 20
2008 Feb 8
2008 Apr 23
vertical exaggeration = 10:1


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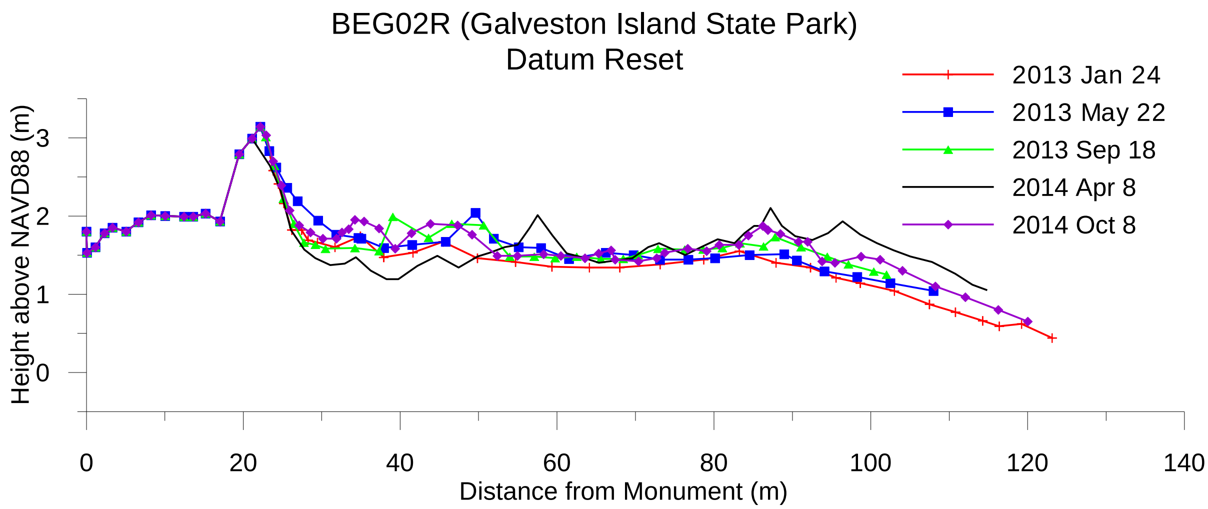
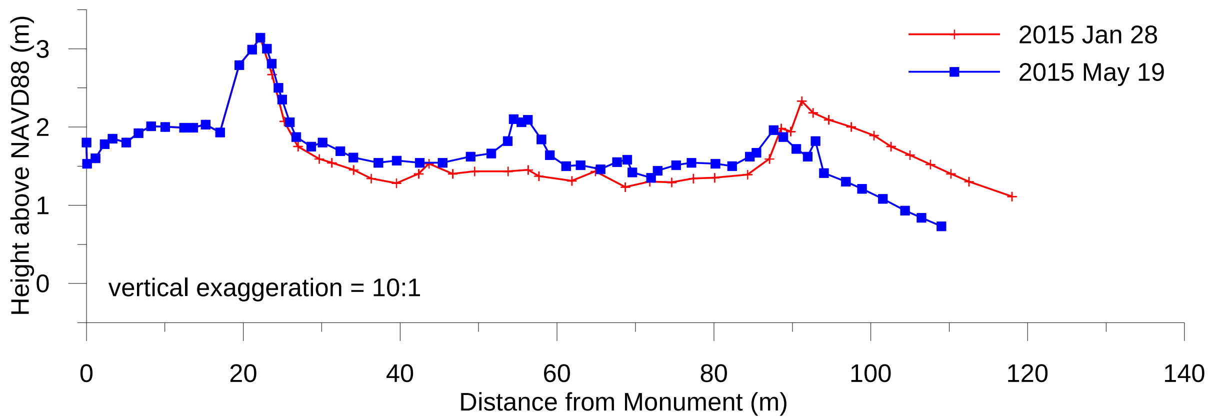
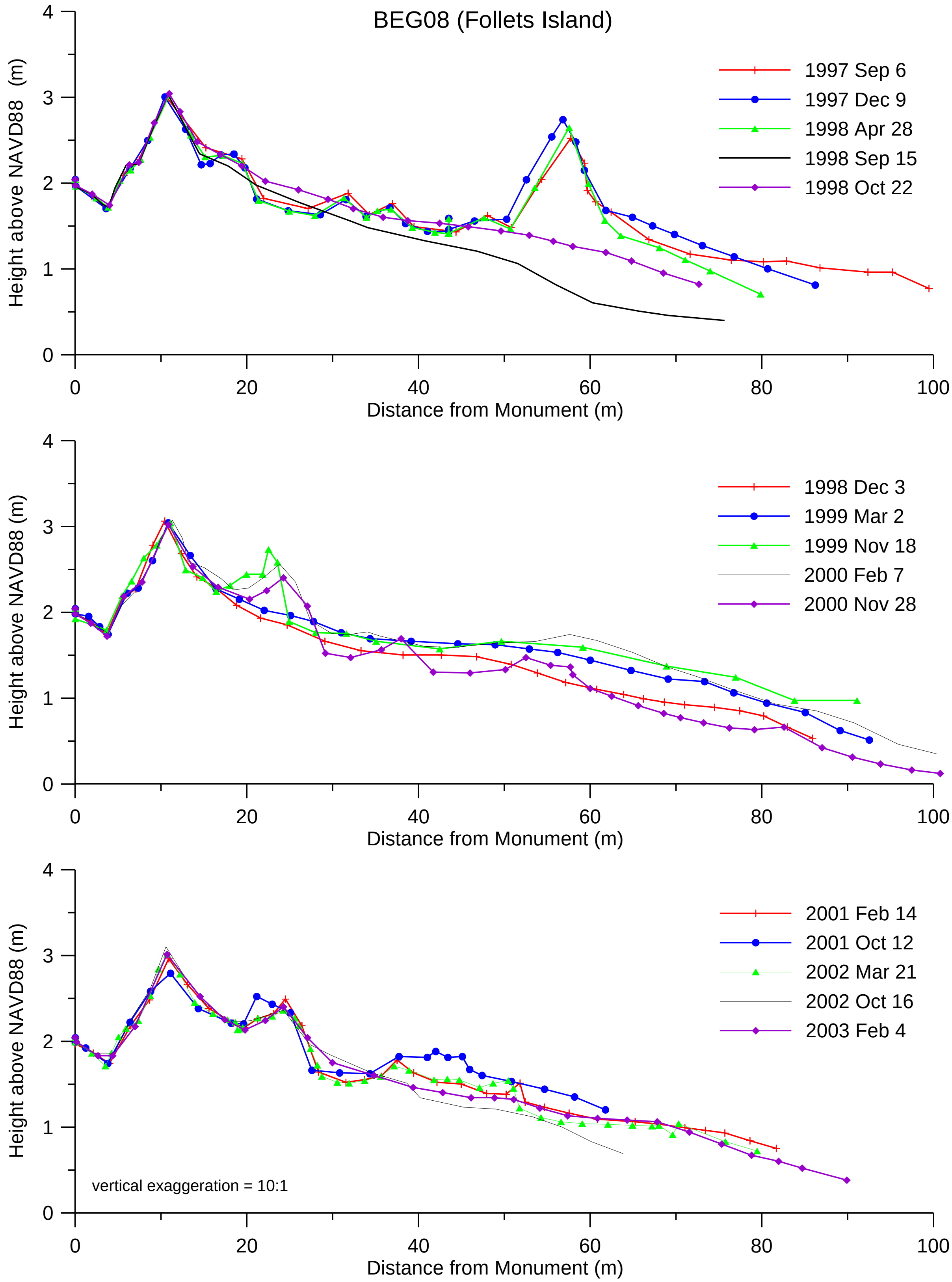
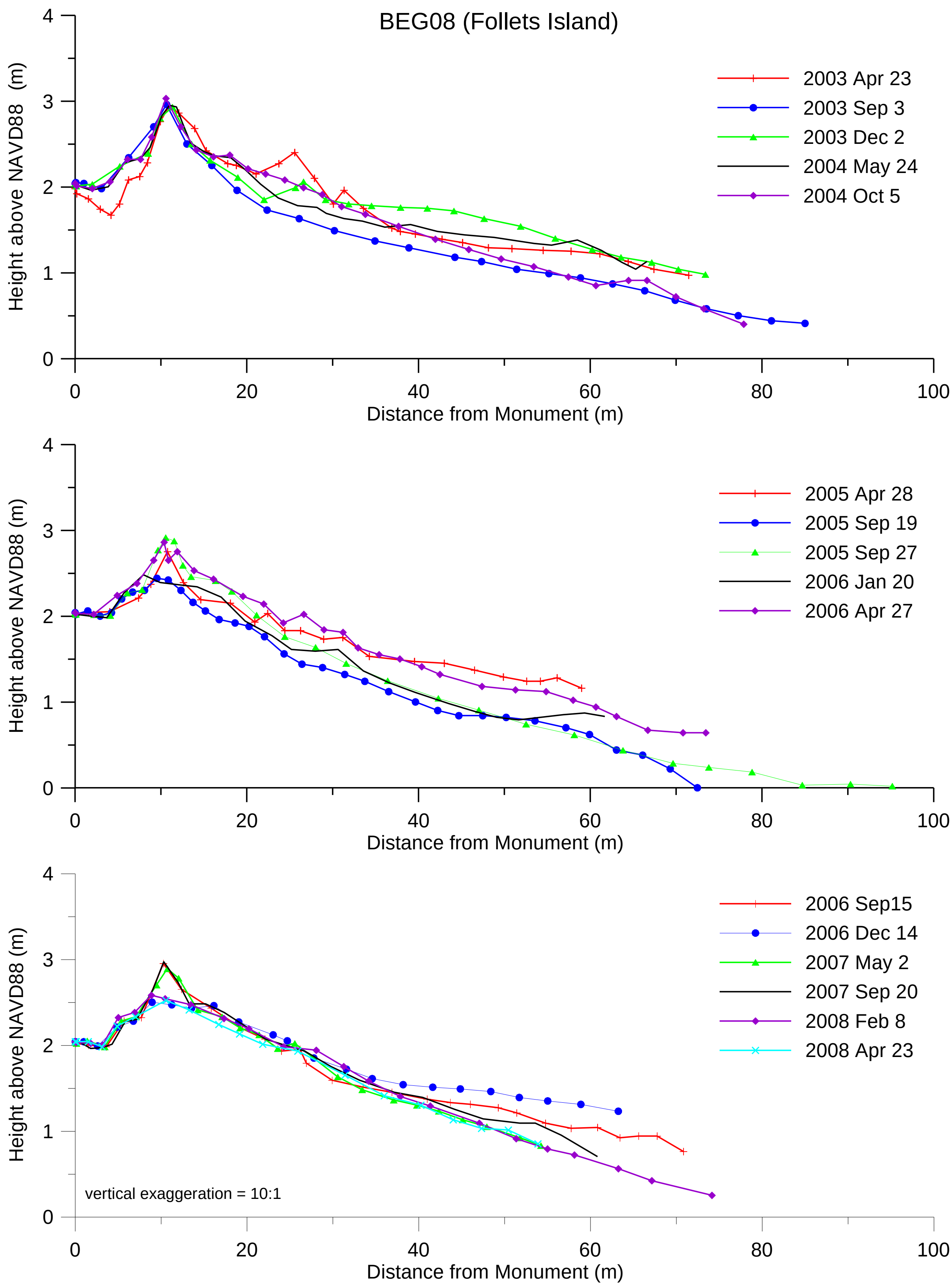
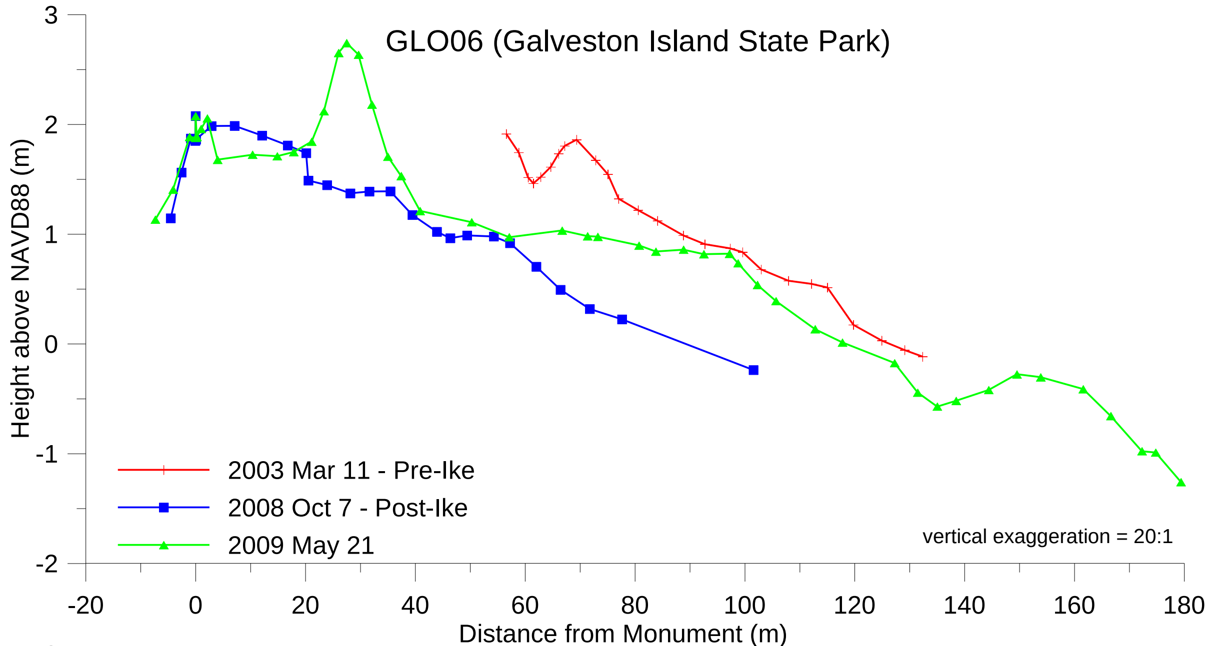
2011 Jan 21
2011 May 18
2011 Sep 23
2012 Sep 27
Height above NAVD88 (m)
vertical exaggeration = 10:1
Distance from Monument (m)

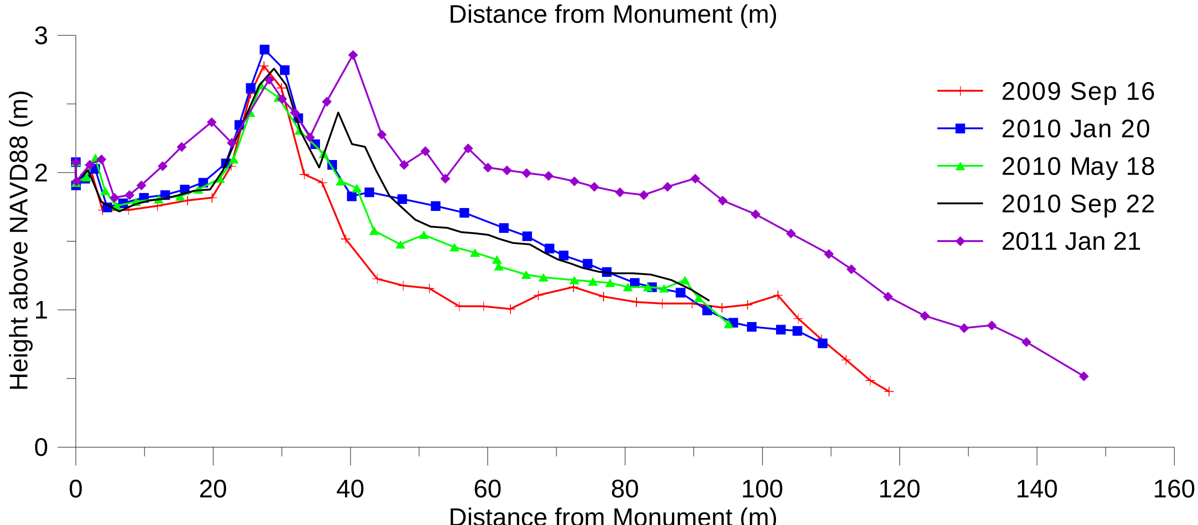

BEG02R (Galveston Island State Park)
Datum Reset
2013 Jan 24
2013 May 22
2013 Sep 18
2014 Apr 8
2014 Oct 8
Height above NAVD88 (m)
Distance from Monument (m)

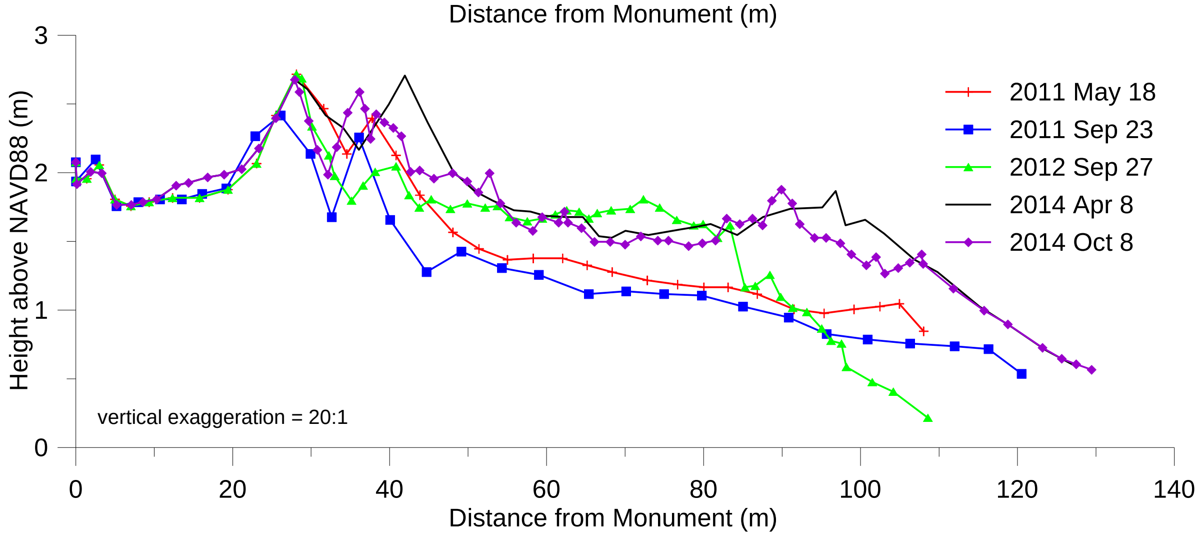

2015 Jan 28
2015 May 19
vertical exaggeration = 10:1
Height above NAVD88 (m)
Distance from Monument (m)

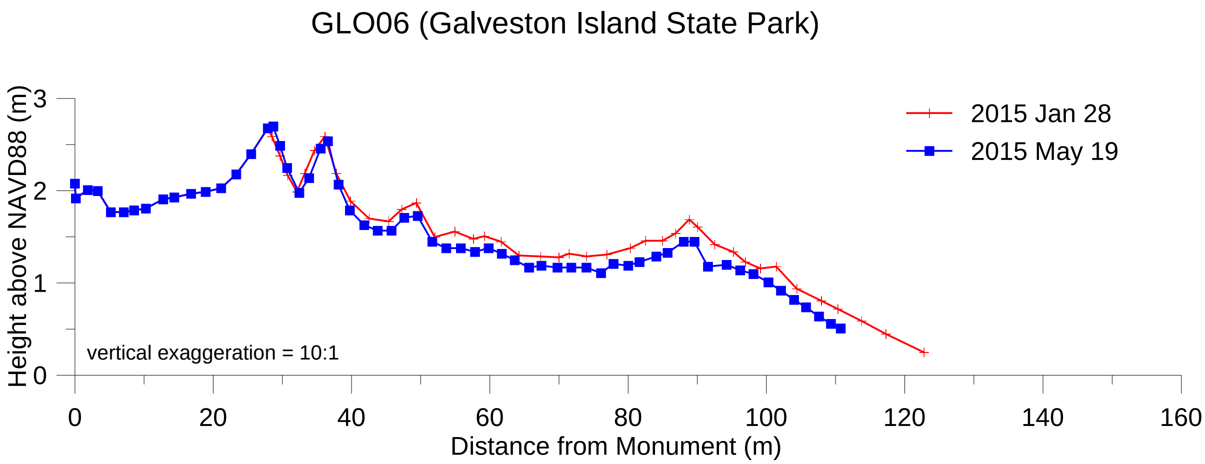

BEG08 (Follets Island)
Height above NAVD88 (m)
Distance from Monument (m)
1997 Sep 6
1997 Dec 9
1998 Apr 28
1998 Sep 15
1998 Oct 22
1998 Dec 3
1999 Mar 2
1999 Nov 18
2000 Feb 7
2000 Nov 28
2001 Feb 14
2001 Oct 12
2002 Mar 21
2002 Oct 16
2003 Feb 4
vertical exaggeration = 10:1
0
1
2
3
4
0
20
40
60
80
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
2005 Apr 28
2005 Sep 19
2005 Sep 27
2006 Jan 20
2006 Apr 27
2006 Sep15
2006 Dec 14
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

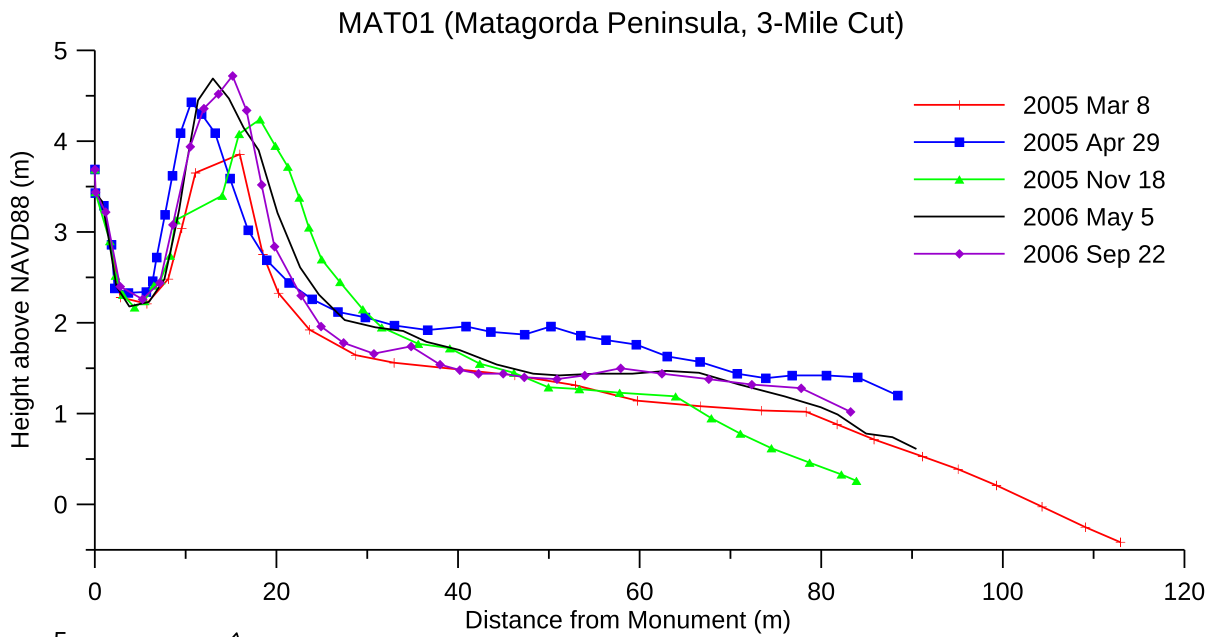

GLO06 (Galveston Island State Park)
Height above NAVD88 (m)
Distance from Monument (m)
2003 Mar 11 - Pre-Ike
2008 Oct 7 - Post-Ike
2009 May 21
vertical exaggeration = 20:1

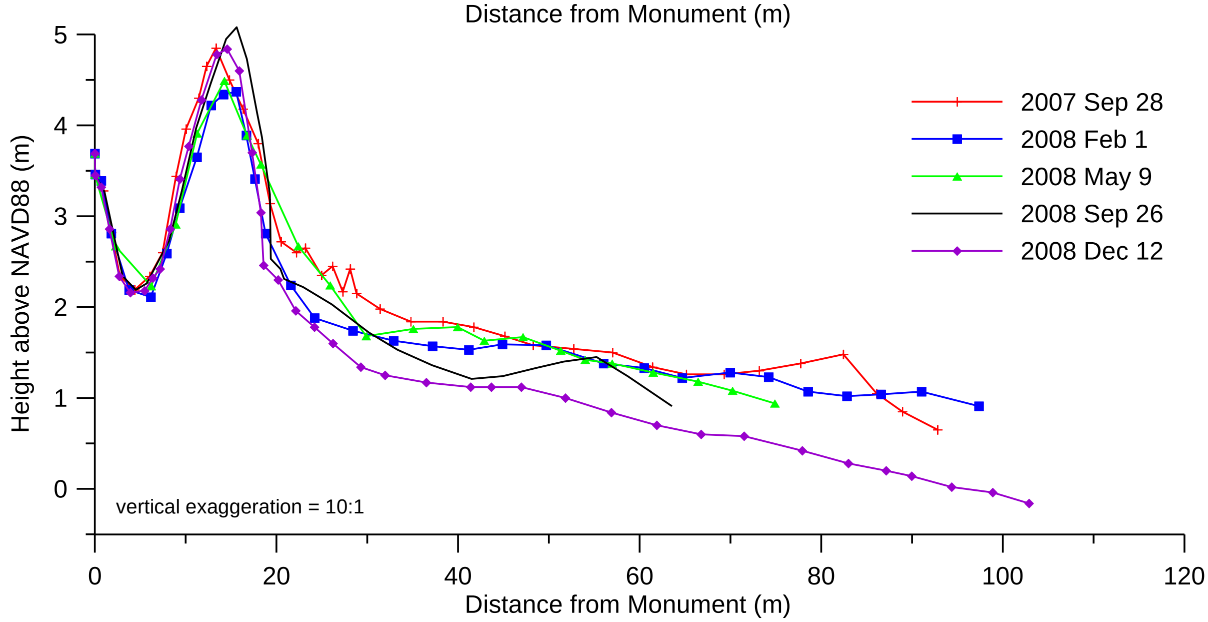

Height above NAVD88 (m)
Distance from Monument (m)
2009 Sep 16
2010 Jan 20
2010 May 18
2010 Sep 22
2011 Jan 21


Height above NAVD88 (m)
Distance from Monument (m)
2011 May 18
2011 Sep 23
2012 Sep 27
2014 Apr 8
2014 Oct 8
vertical exaggeration = 20:1

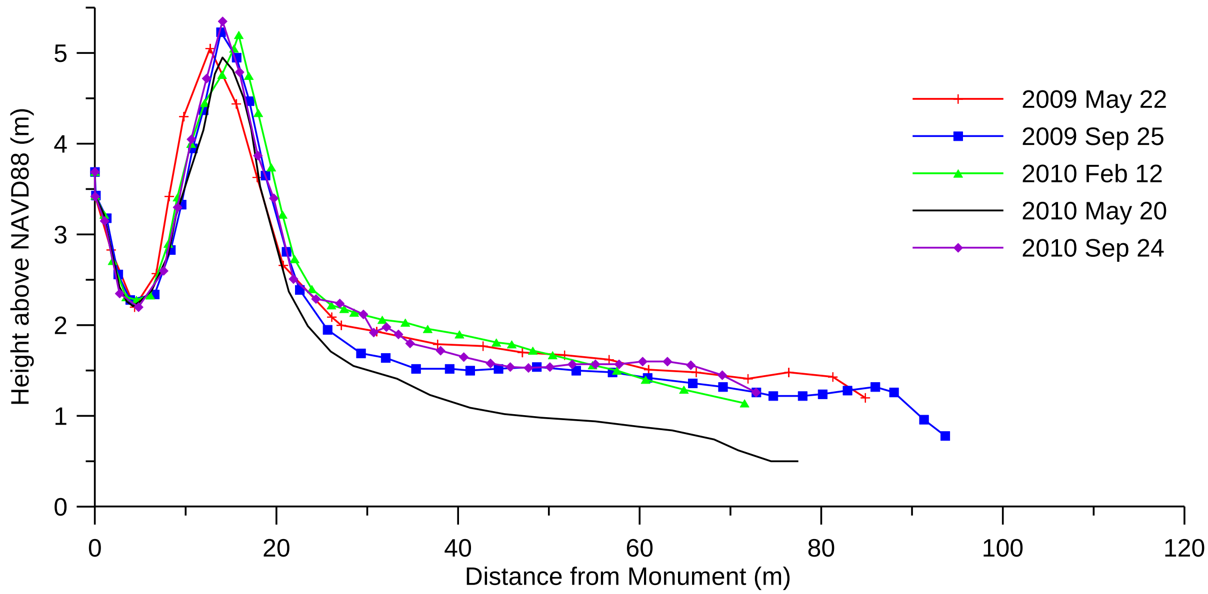


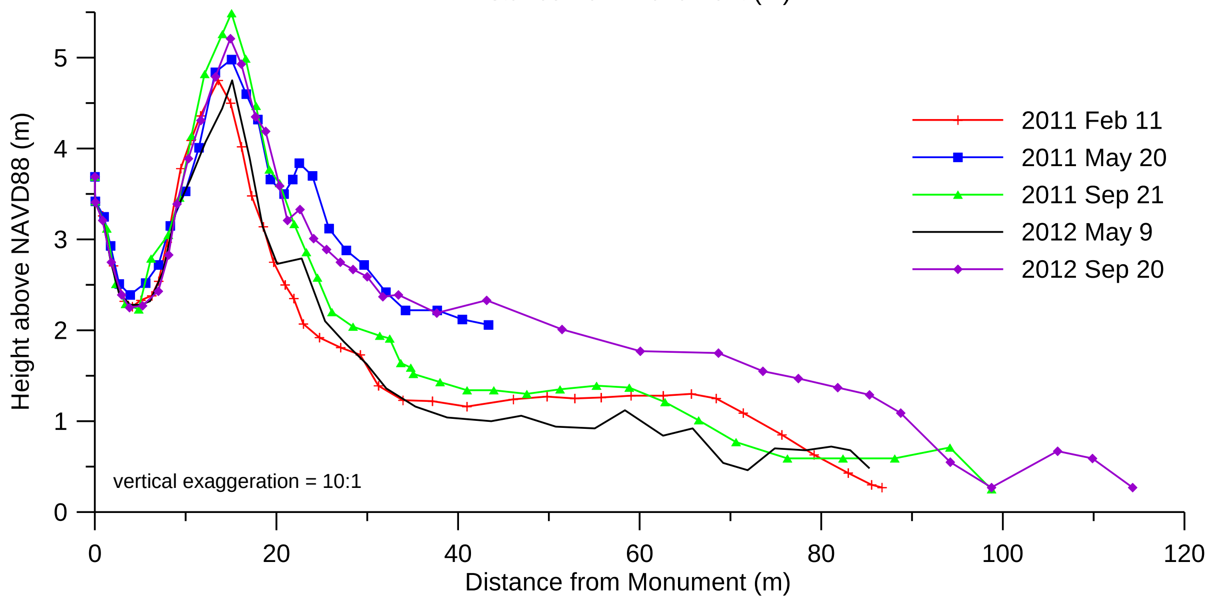
GLO06 (Galveston Island State Park)
2015 Jan 28
2015 May 19
Height above NAVD88 (m)
vertical exaggeration = 10:1
Distance from Monument (m)
0
1
2
3
0
20
40
60
80
100
120
140
160

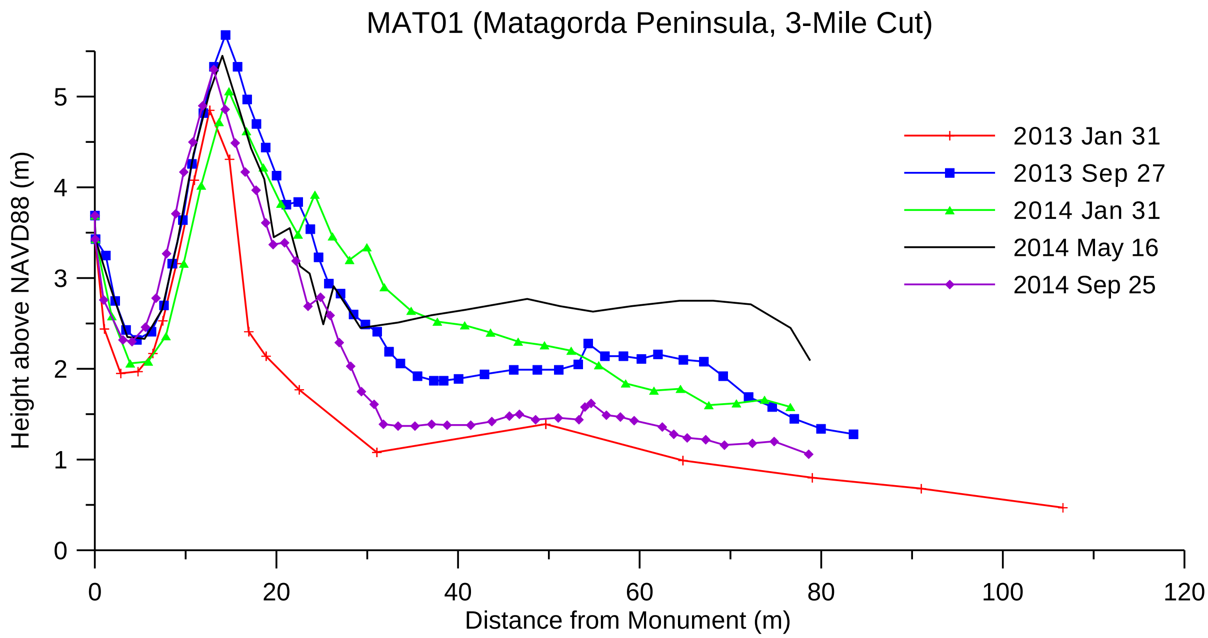

MAT01 (Matagorda Peninsula, 3-Mile Cut)
Height above NAVD88 (m)
Distance from Monument (m)
2005 Mar 8
2005 Apr 29
2005 Nov 18
2006 May 5
2006 Sep 22
0
20
40
60
80
100
120
0
1
2
3
4
5


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
0
20
40
60
80
100
120
0
1
2
3
4
5

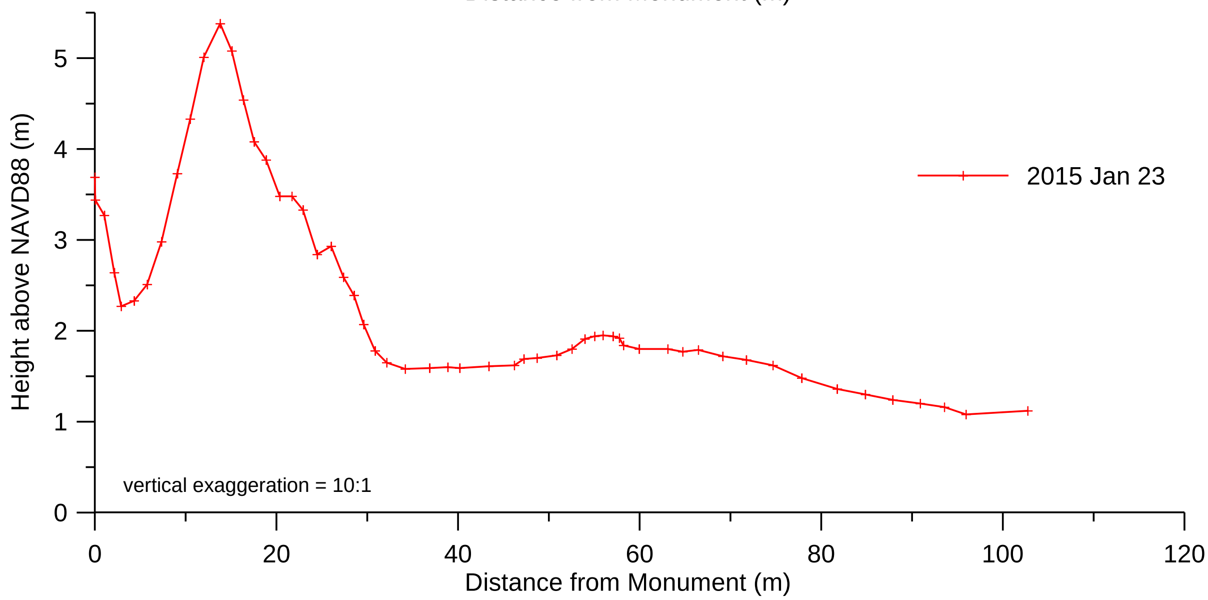
MAT01 (Matagorda Peninsula, 3-Mile Cut)



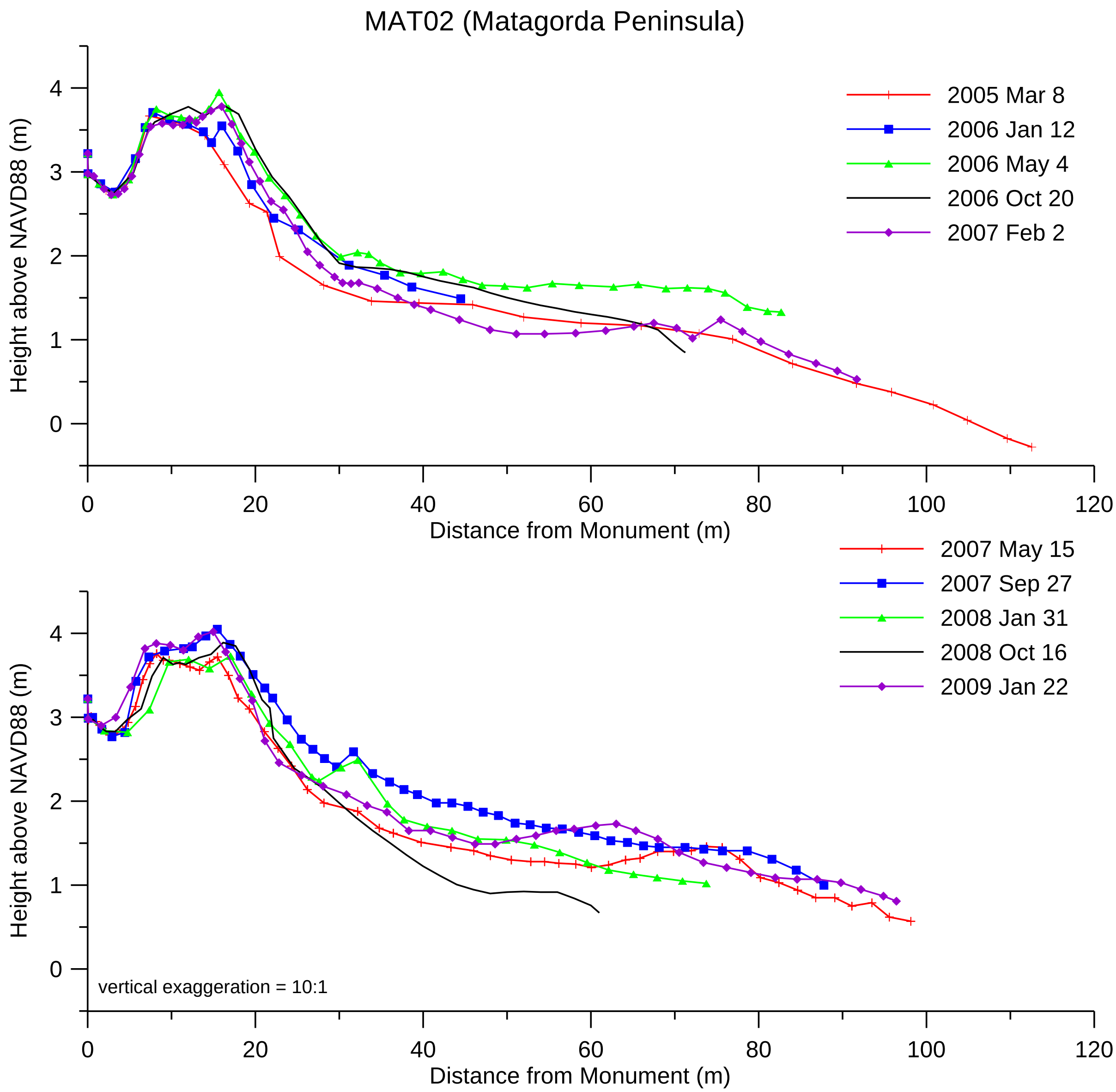




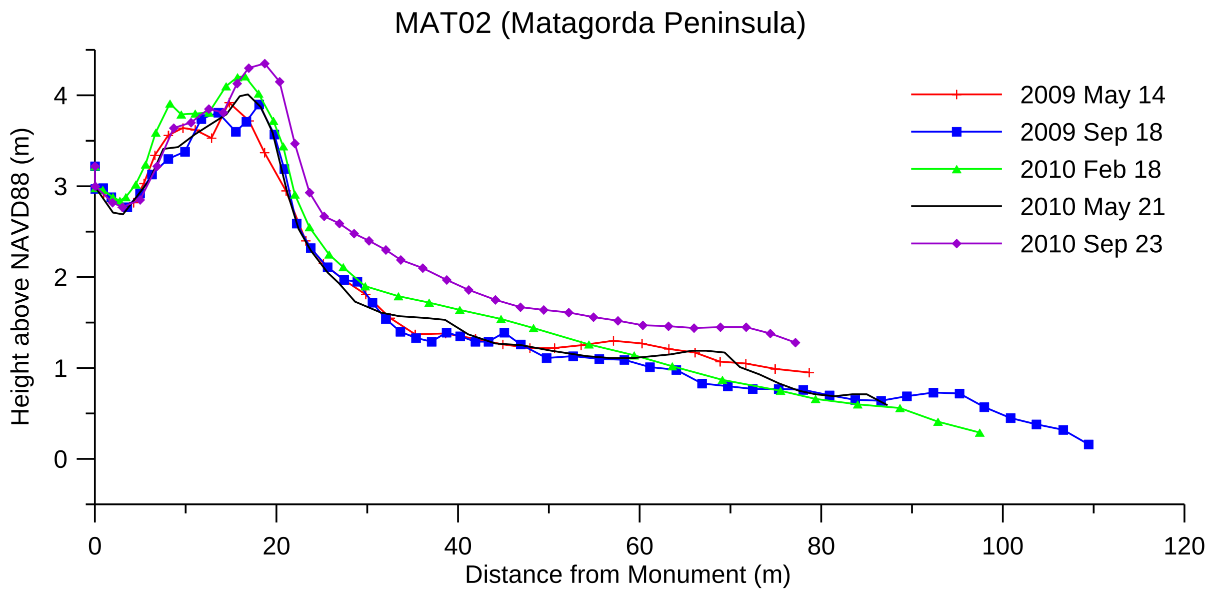
MAT01 (Matagorda Peninsula, 3-Mile Cut)
Height above NAVD88 (m)
Distance from Monument (m)
2013 Jan 31
2013 Sep 27
2014 Jan 31
2014 May 16
2014 Sep 25



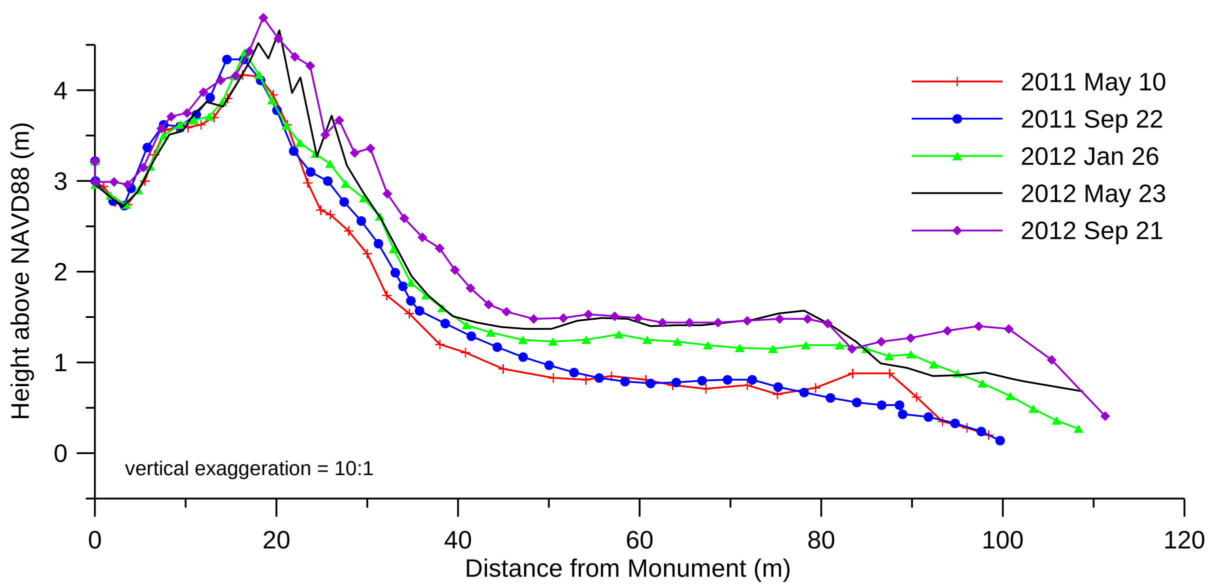
Height above NAVD88 (m)
Distance from Monument (m)
2015 Jan 23
vertical exaggeration = 10:1



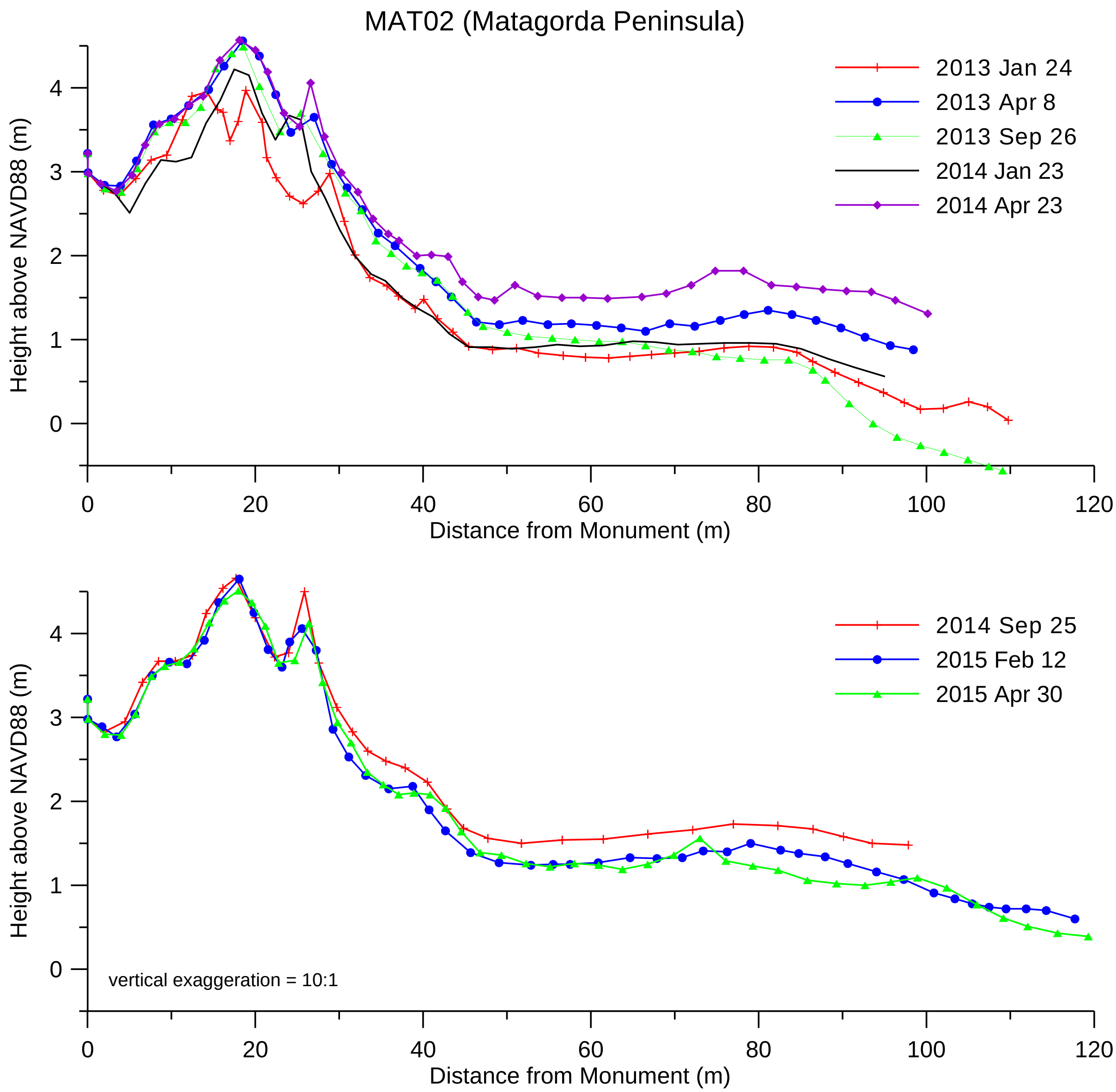
MAT02 (Matagorda Peninsula)
Height above NAVD88 (m)
Distance from Monument (m)
2005 Mar 8
2006 Jan 12
2006 May 4
2006 Oct 20
2007 Feb 2
2007 May 15
2007 Sep 27
2008 Jan 31
2008 Oct 16
2009 Jan 22
vertical exaggeration = 10:1



MAT02 (Matagorda Peninsula)
Height above NAVD88 (m)
Distance from Monument (m)
2009 May 14
2009 Sep 18
2010 Feb 18
2010 May 21
2010 Sep 23
0
1
2
3
4
0
20
40
60
80
100
120

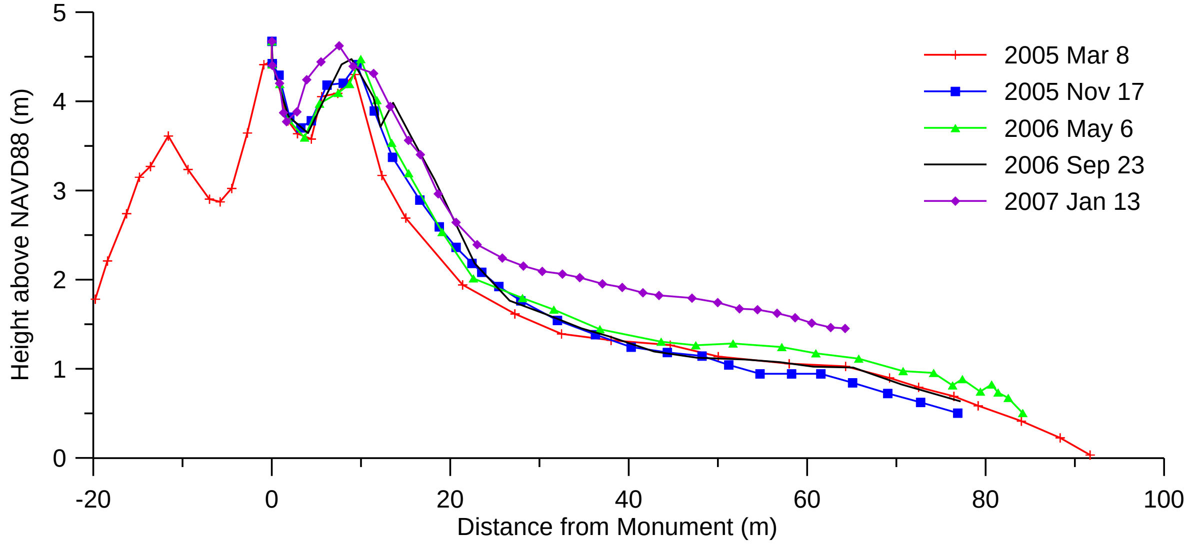


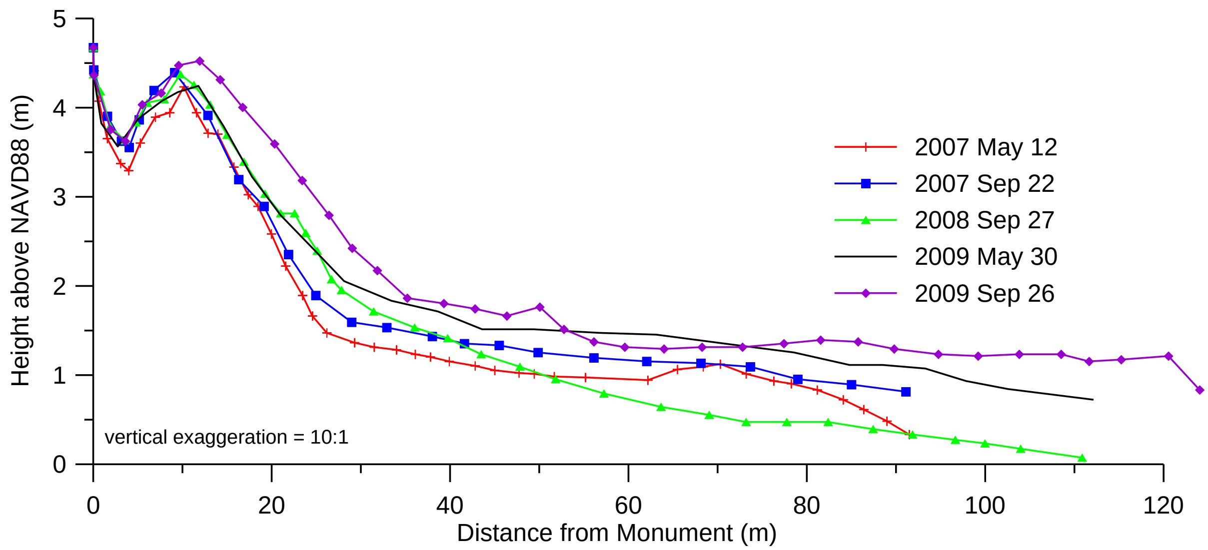
Height above NAVD88 (m)
Distance from Monument (m)
2011 May 10
2011 Sep 22
2012 Jan 26
2012 May 23
2012 Sep 21
vertical exaggeration = 10:1
0
1
2
3
4
0
20
40
60
80
100
120

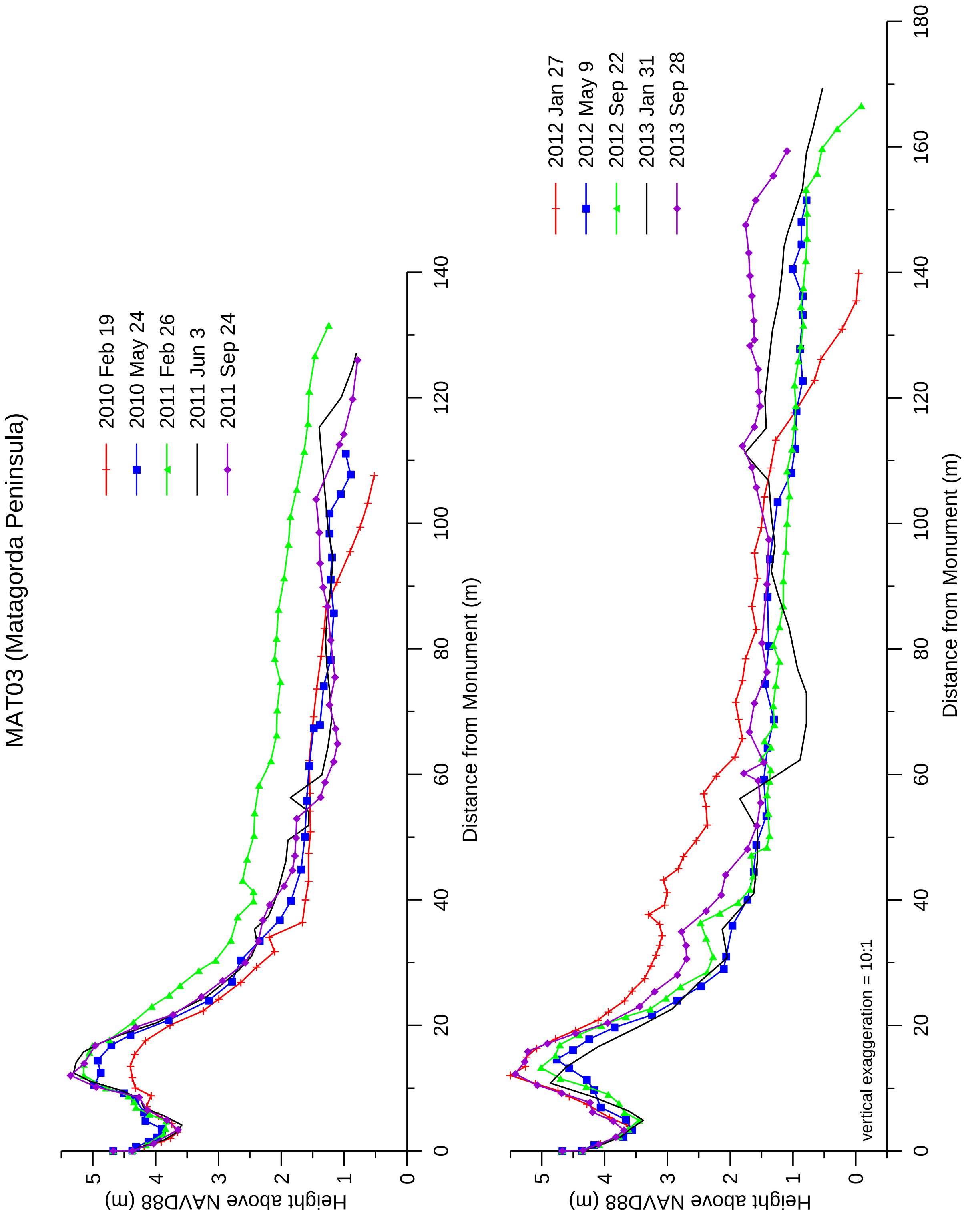


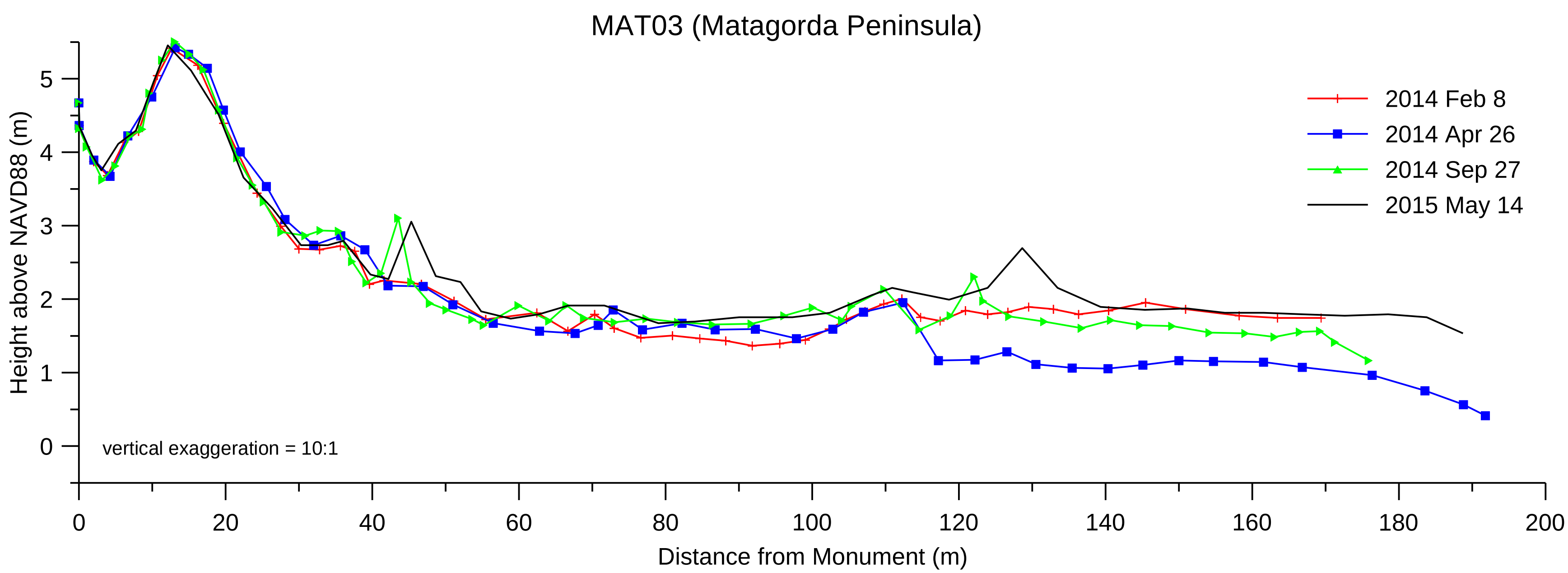
MAT02 (Matagorda Peninsula)
2013 Jan 24
2013 Apr 8
2013 Sep 26
2014 Jan 23
2014 Apr 23
Height above NAVD88 (m)
Distance from Monument (m)
2014 Sep 25
2015 Feb 12
2015 Apr 30
vertical exaggeration = 10:1

MAT03 (Matagorda Peninsula)



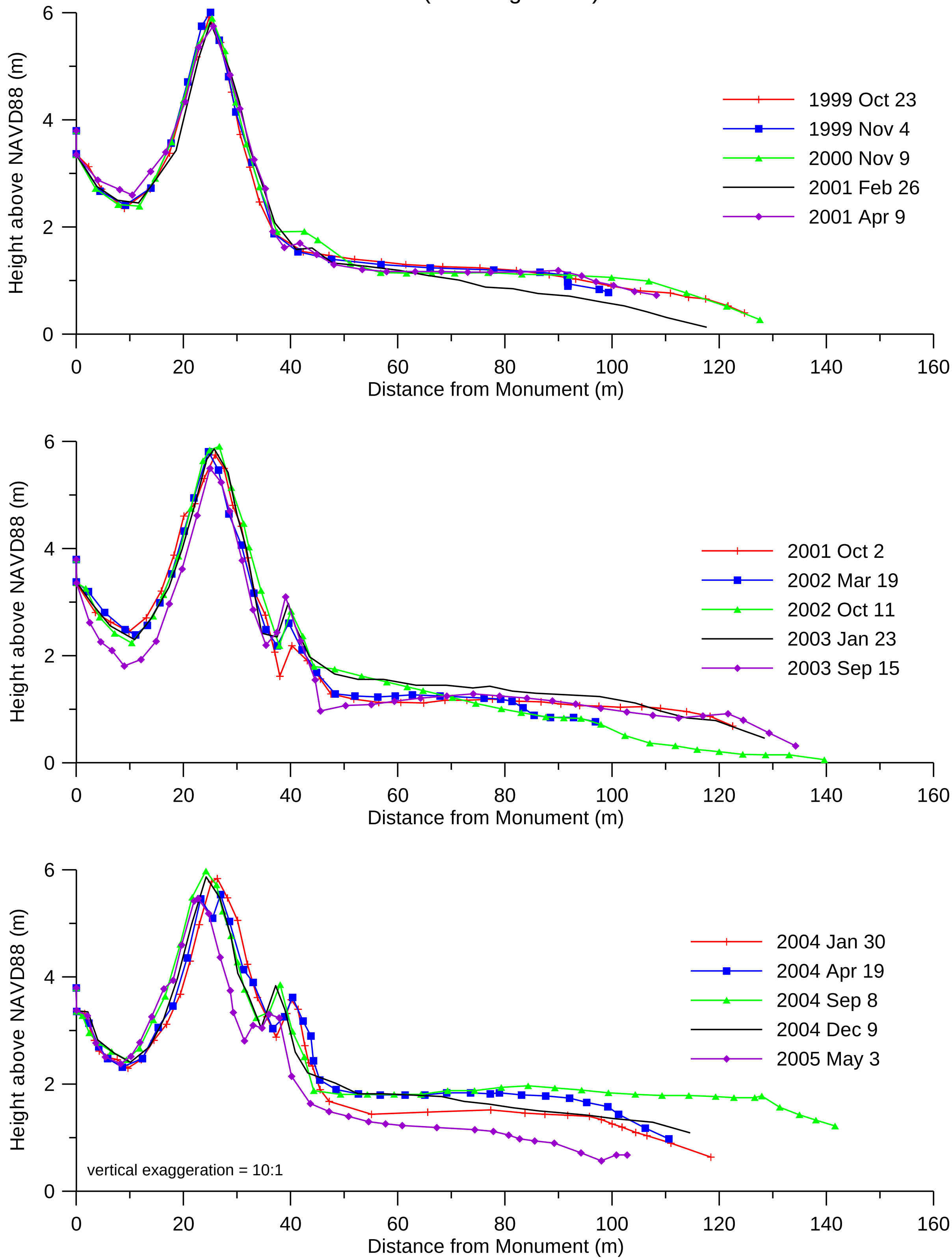


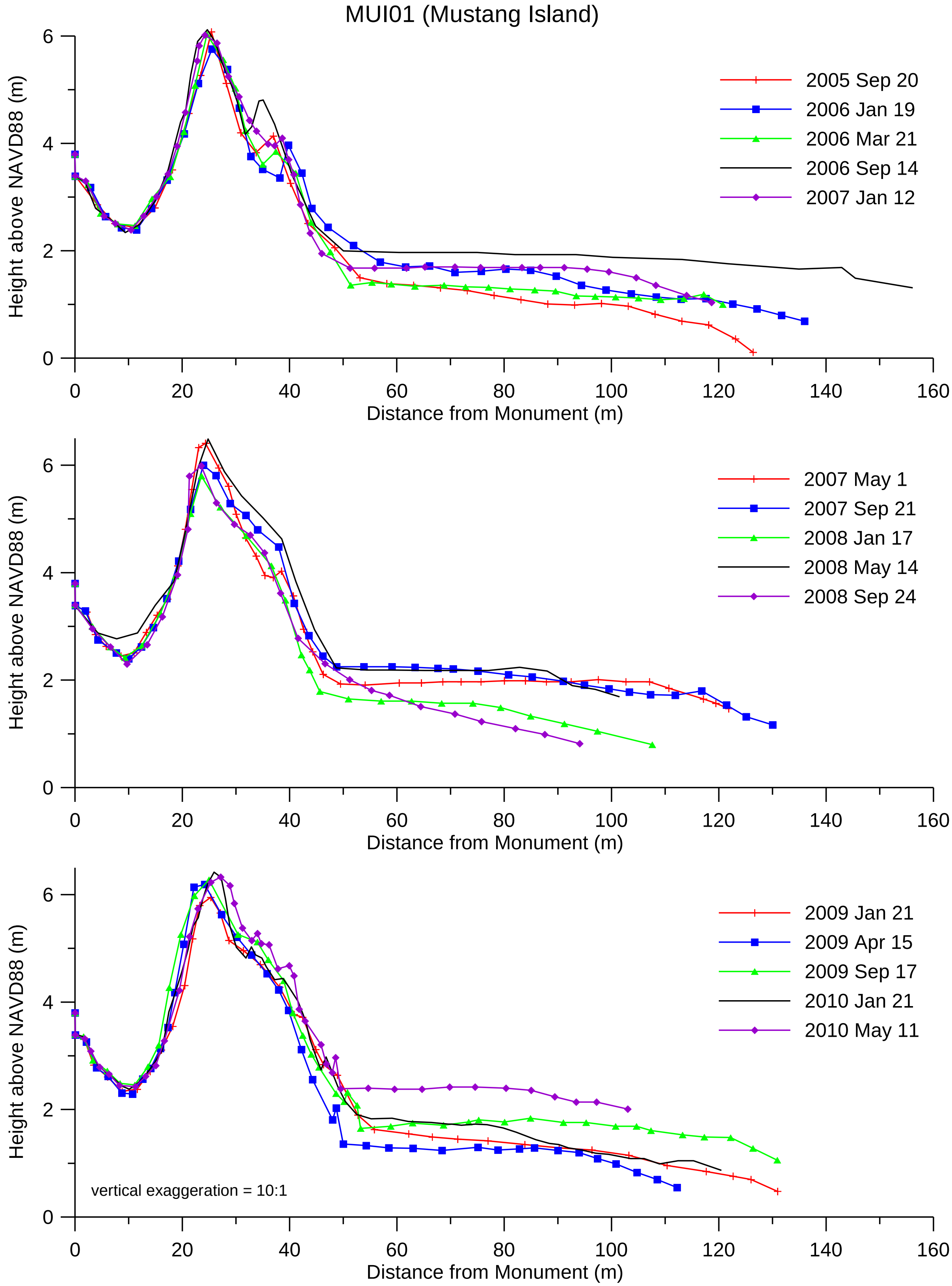

MAT03 (Matagorda Peninsula)
2010 Feb 19
2010 May 24
2011 Feb 26
2011 Jun 3
2011 Sep 24
Height above NAVD88 (m)
Distance from Monument (m)
2012 Jan 27
2012 May 9
2012 Sep 22
2013 Jan 31
2013 Sep 28
vertical exaggeration = 10:1

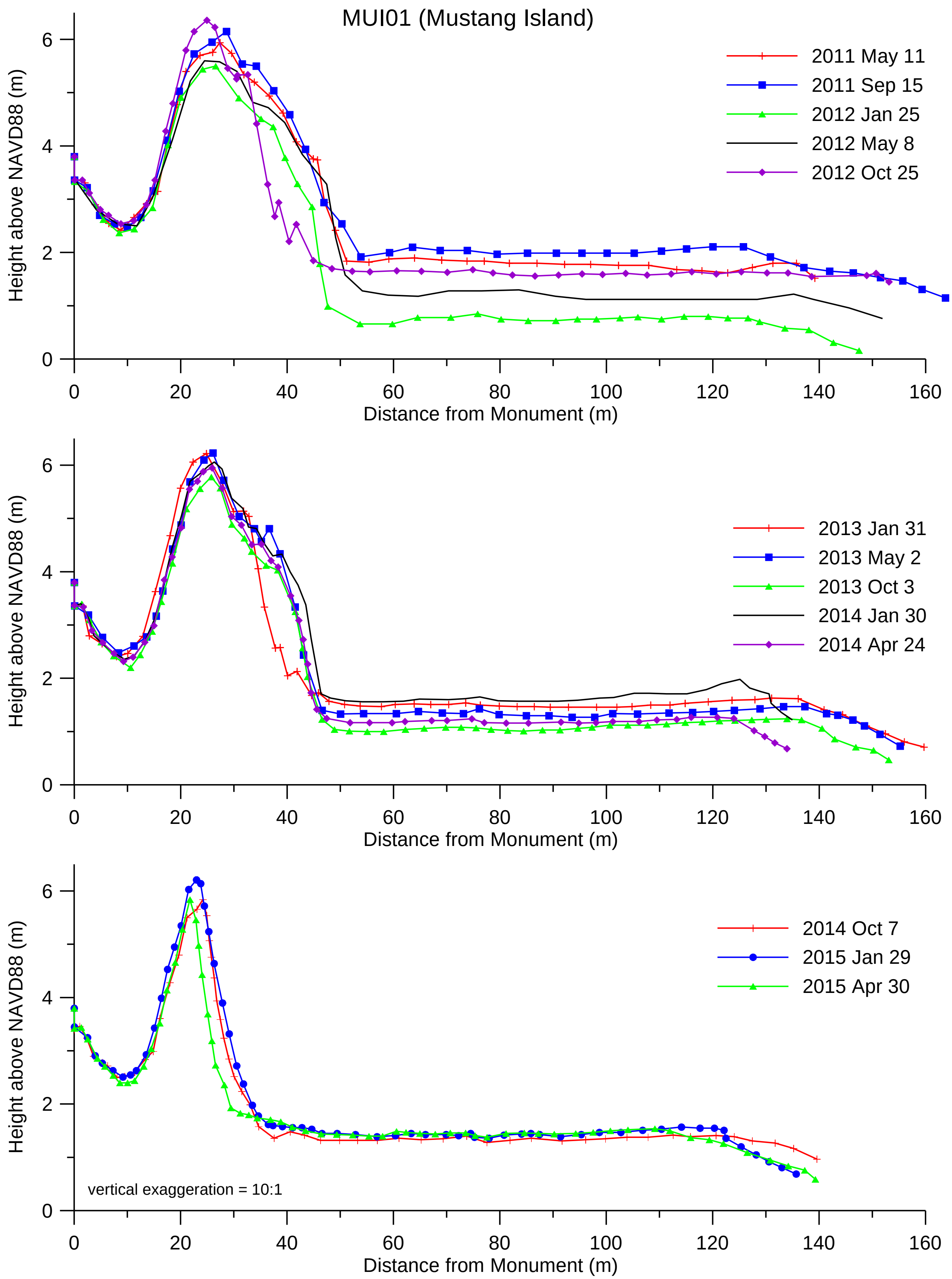


MAT03 (Matagorda Peninsula)
Height above NAVD88 (m)
Distance from Monument (m)
vertical exaggeration = 10:1
2014 Feb 8
2014 Apr 26
2014 Sep 27
2015 May 14

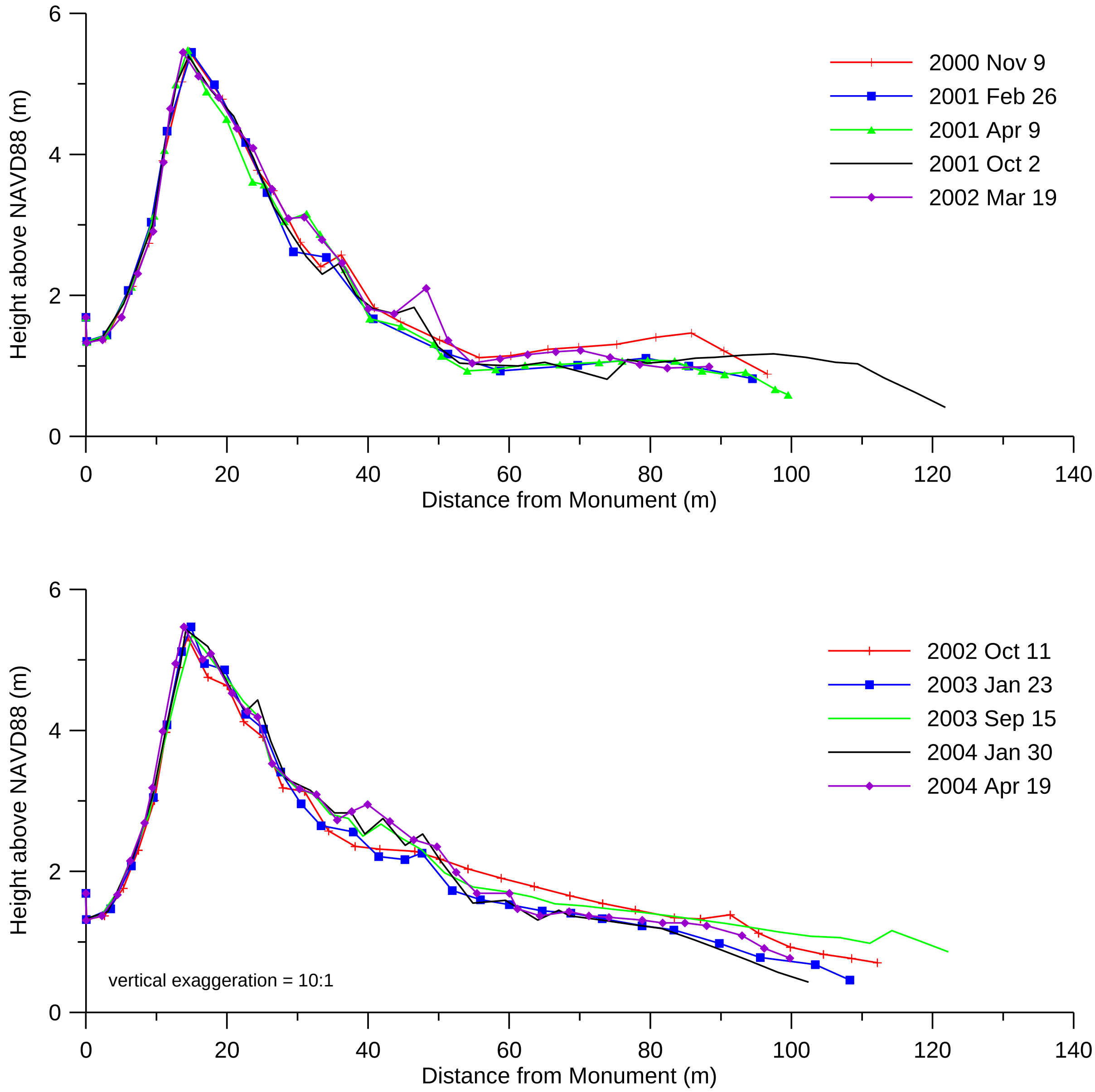
MUI01 (Mustang Island)



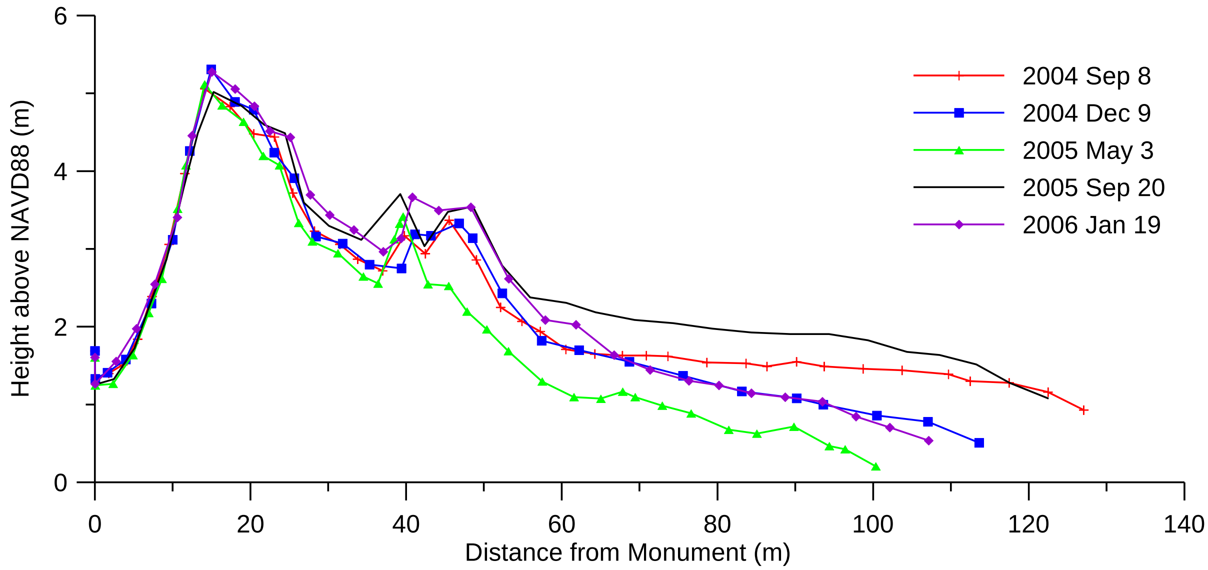

MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2005 Sep 20
2006 Jan 19
2006 Mar 21
2006 Sep 14
2007 Jan 12
2007 May 1
2007 Sep 21
2008 Jan 17
2008 May 14
2008 Sep 24
2009 Jan 21
2009 Apr 15
2009 Sep 17
2010 Jan 21
2010 May 11
vertical exaggeration = 10:1

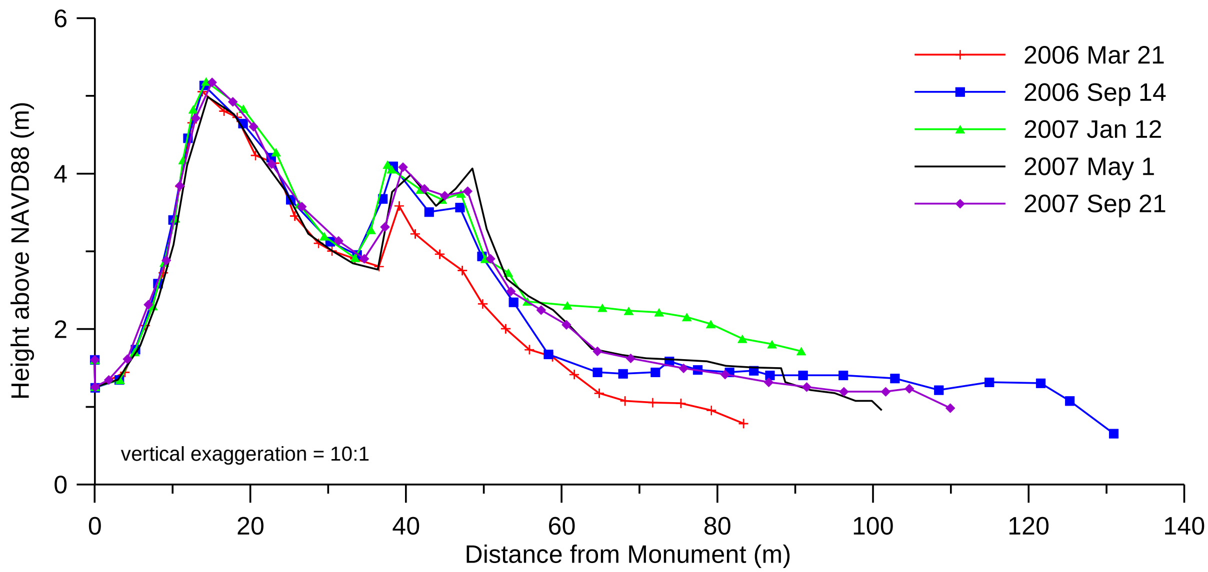

MUI01 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2011 May 11
2011 Sep 15
2012 Jan 25
2012 May 8
2012 Oct 25
2013 Jan 31
2013 May 2
2013 Oct 3
2014 Jan 30
2014 Apr 24
2014 Oct 7
2015 Jan 29
2015 Apr 30
vertical exaggeration = 10:1

MUI02 (Mustang Island State Park)

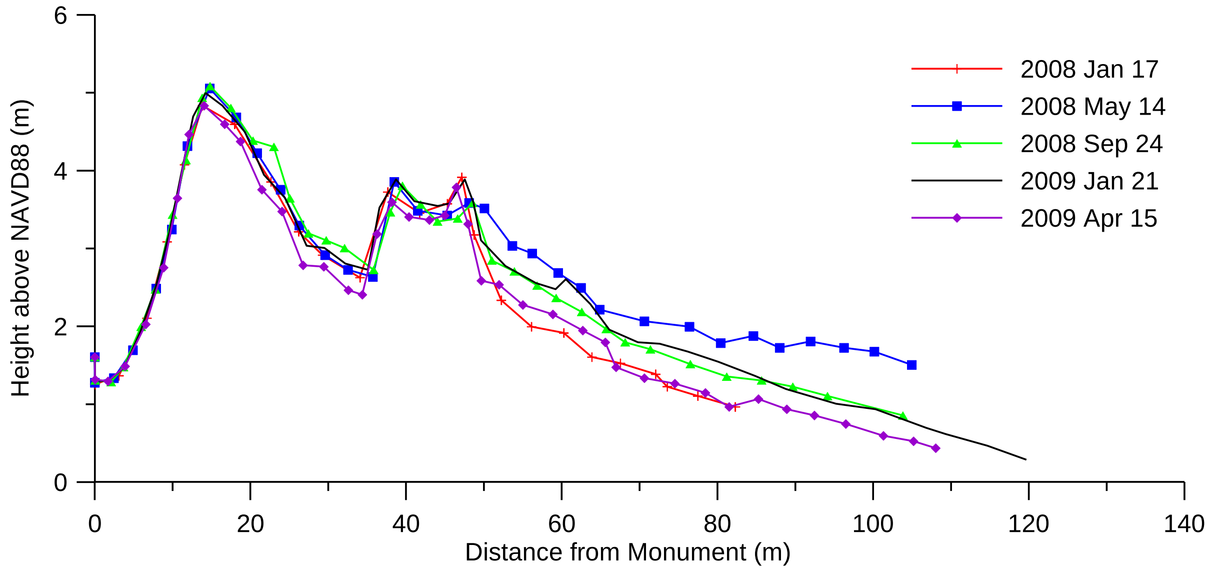


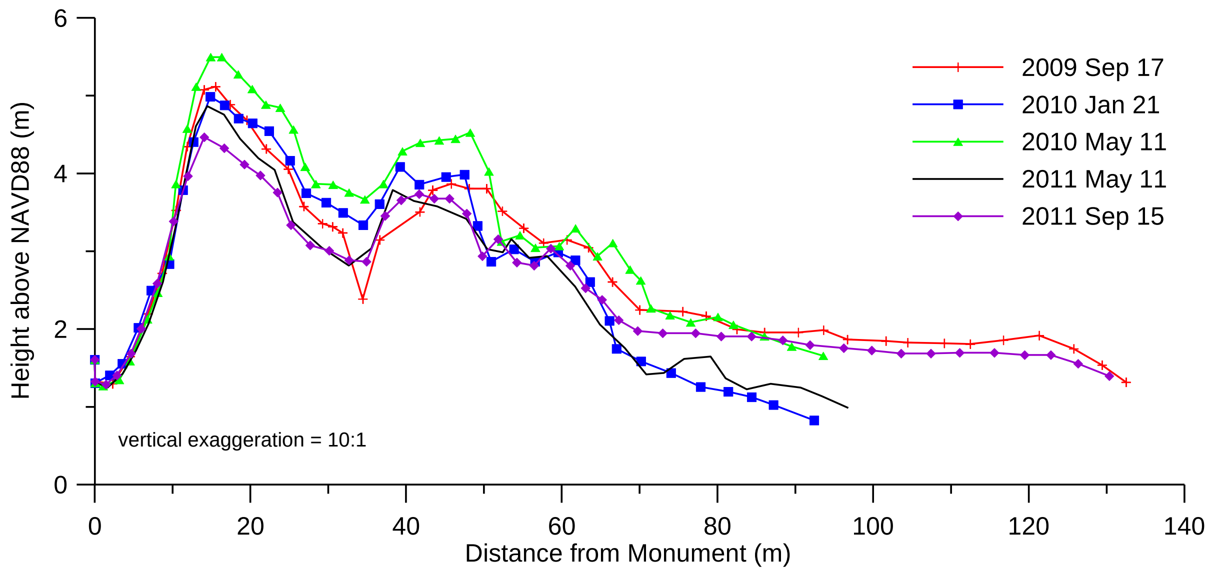
MUI02 (Mustang Island State Park)



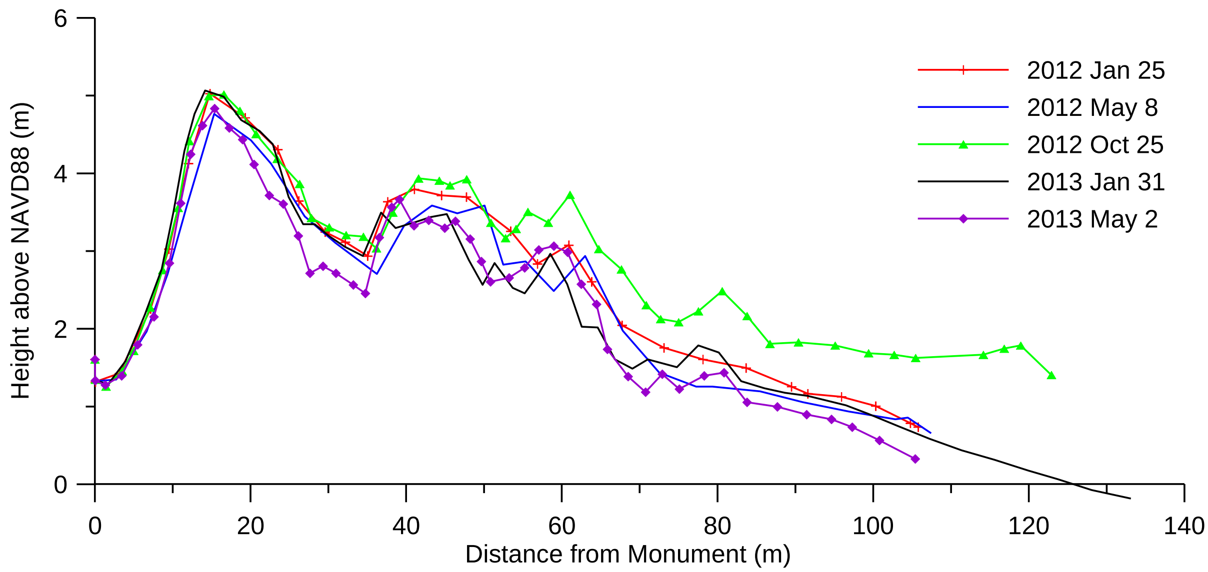


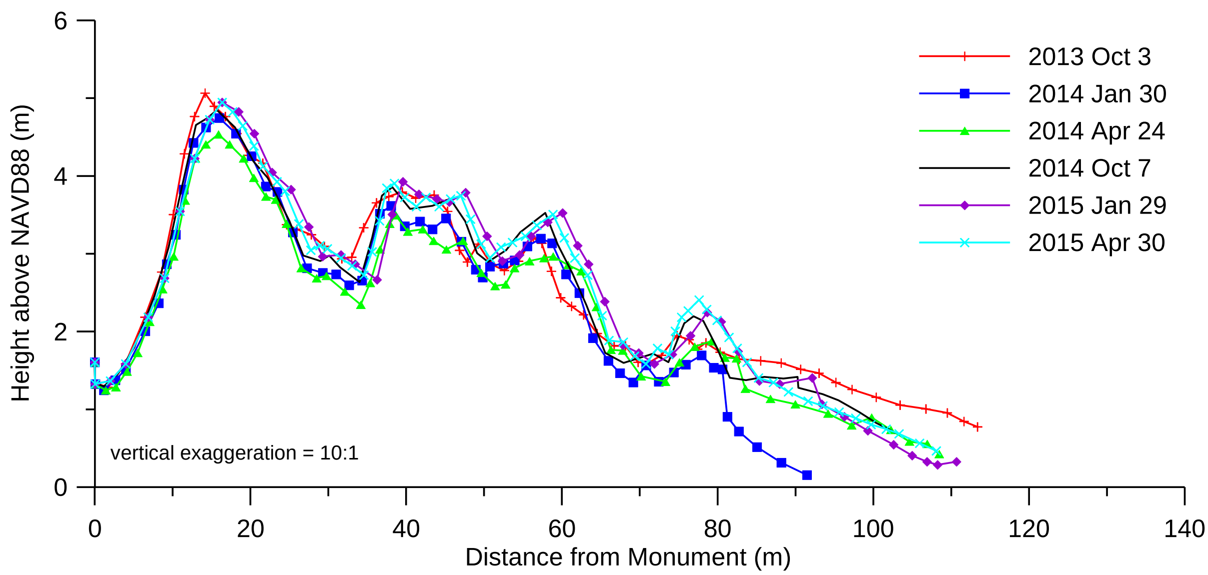
MUI02 (Mustang Island State Park)



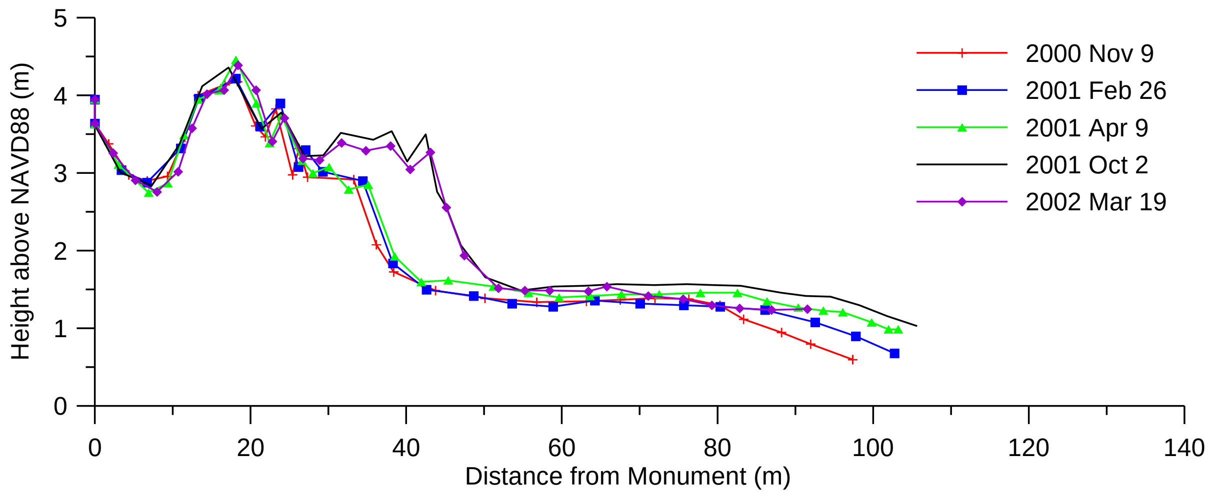


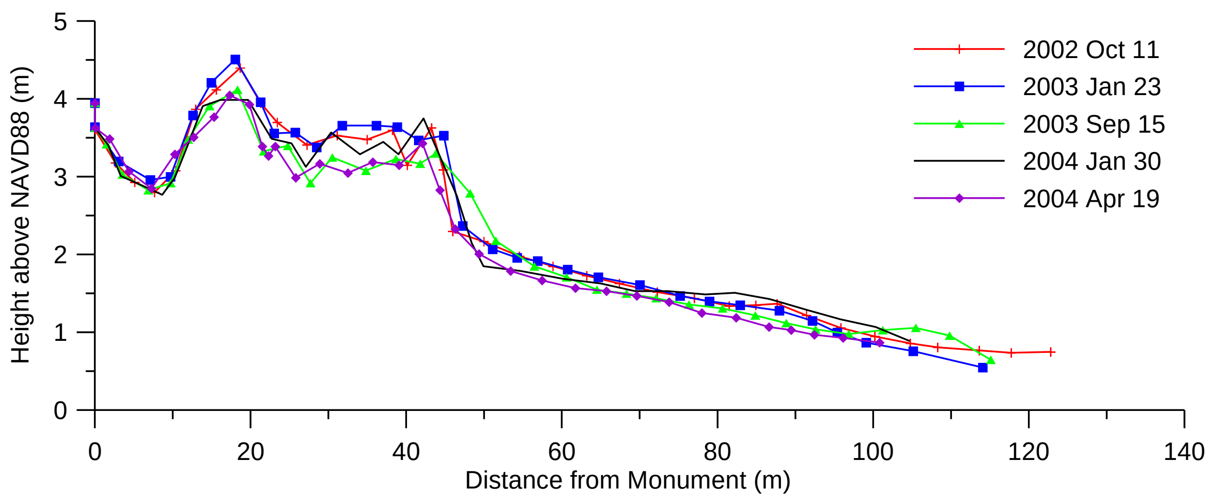
MUI02 (Mustang Island State Park)

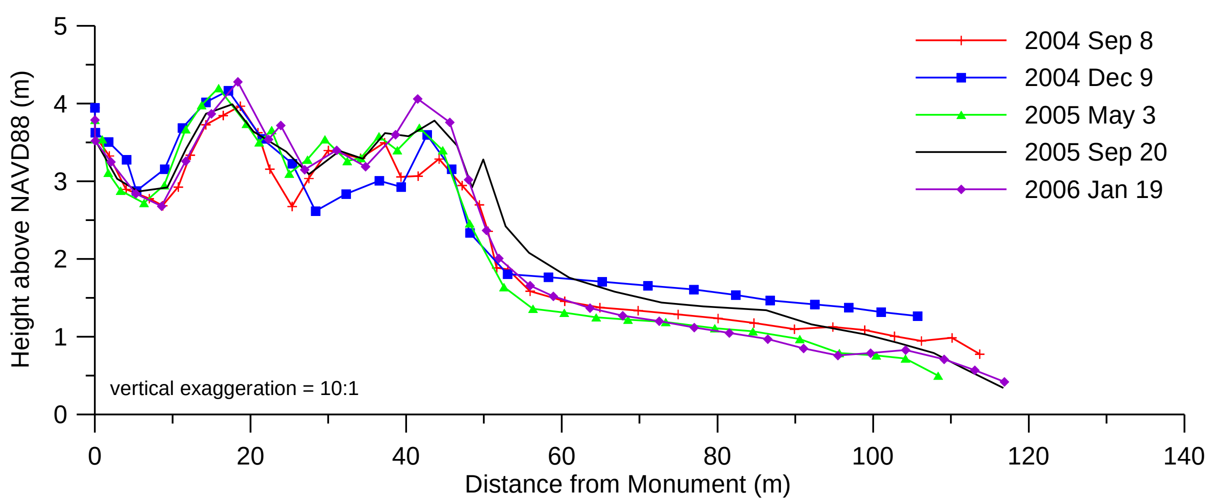




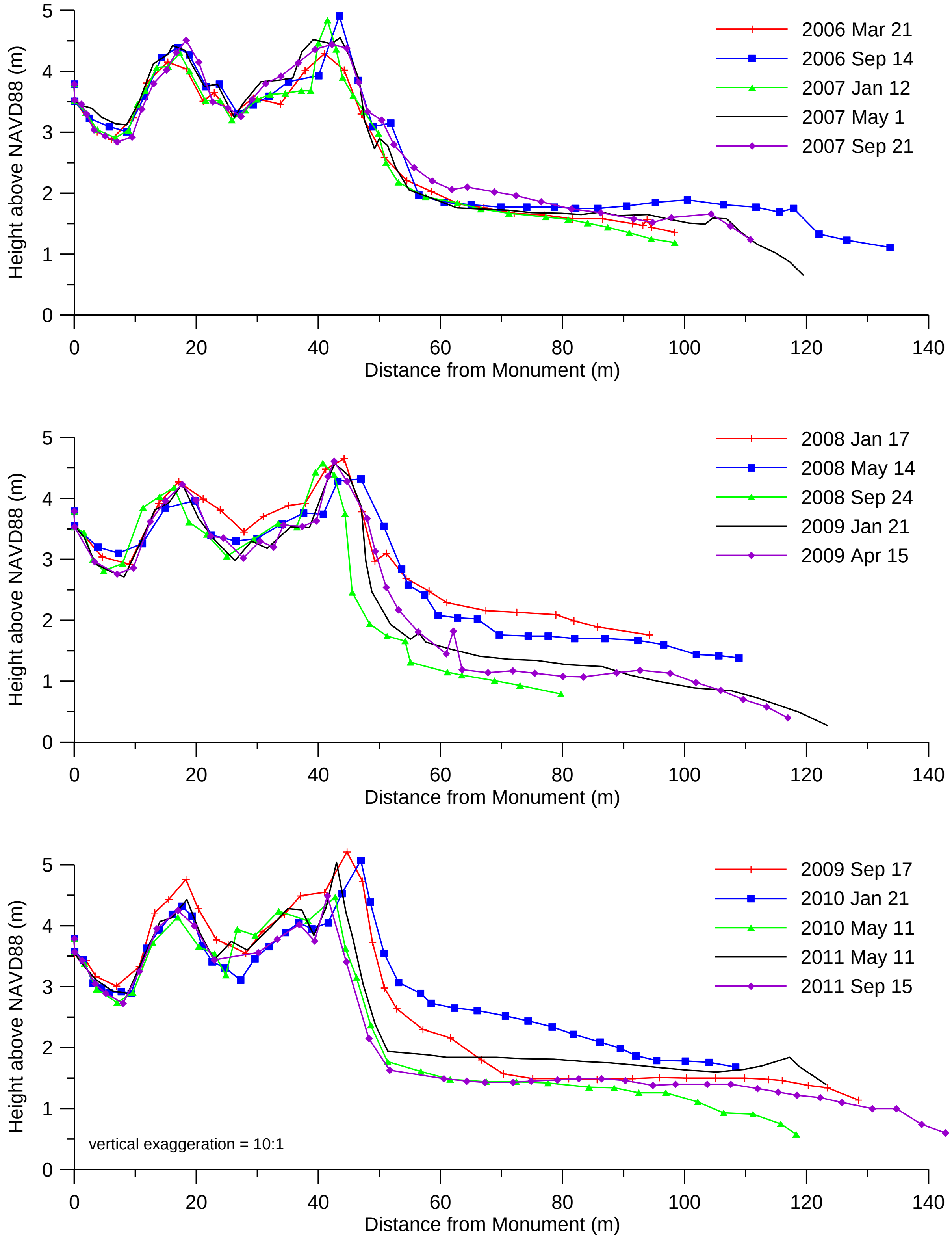
MUI03 (Mustang Island)

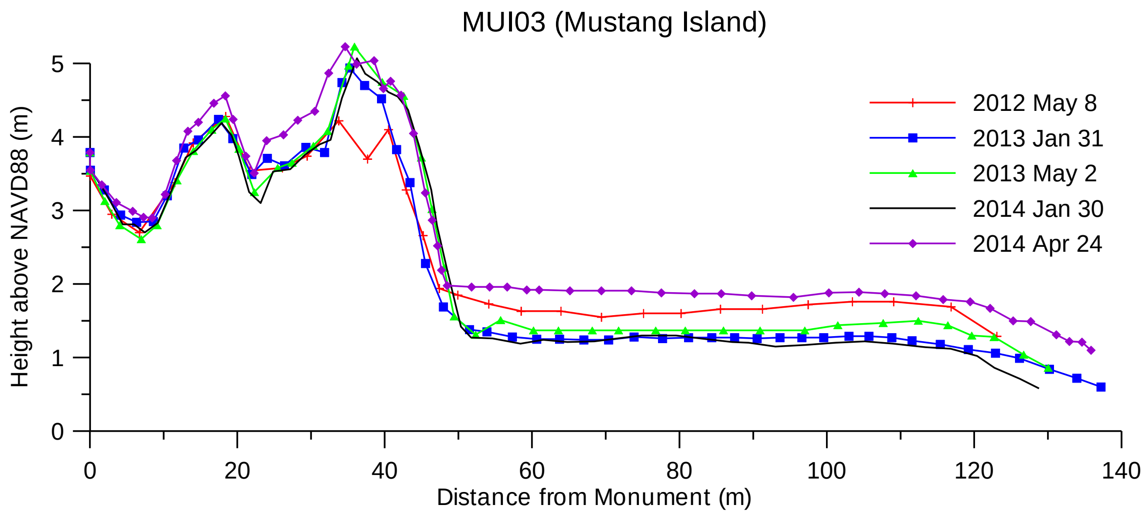


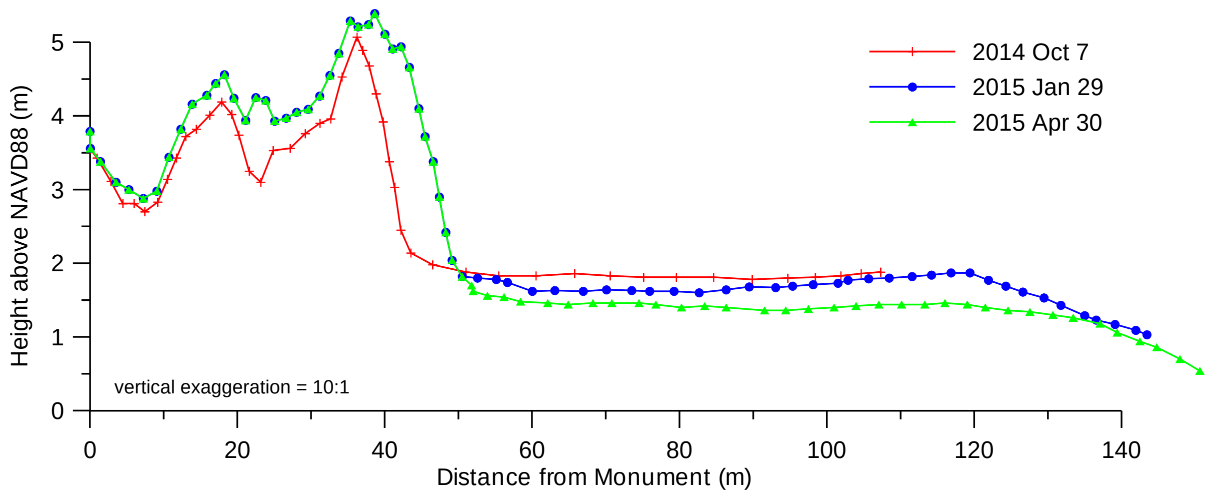




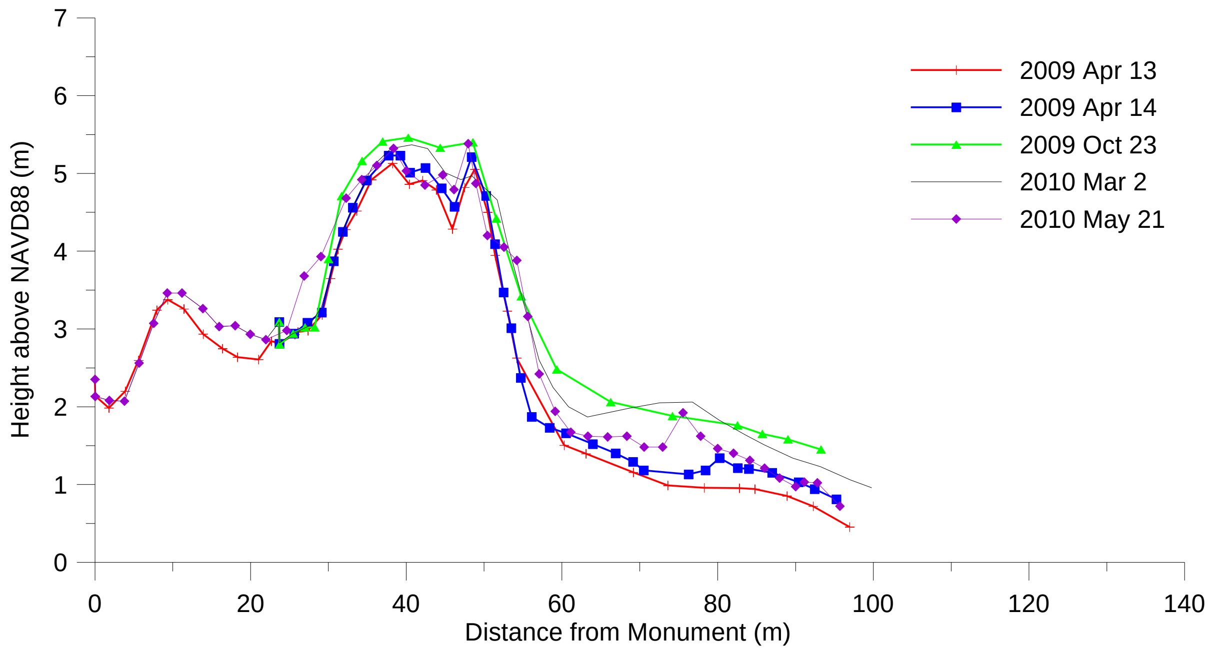
MUI03 (Mustang Island)

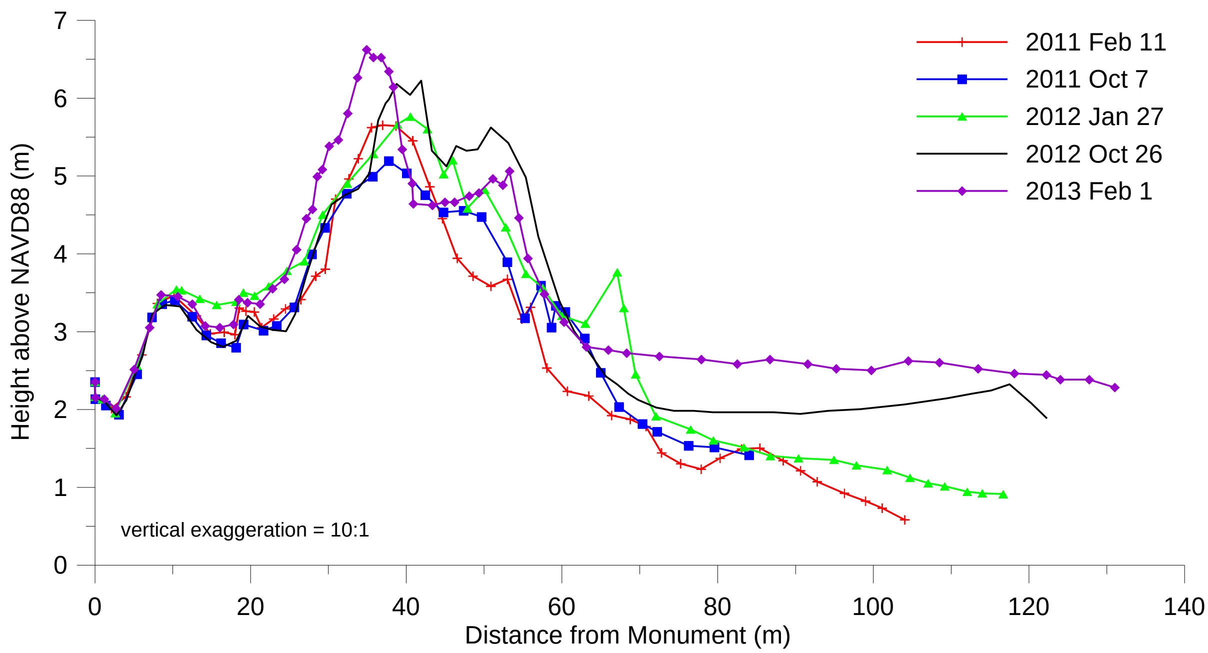


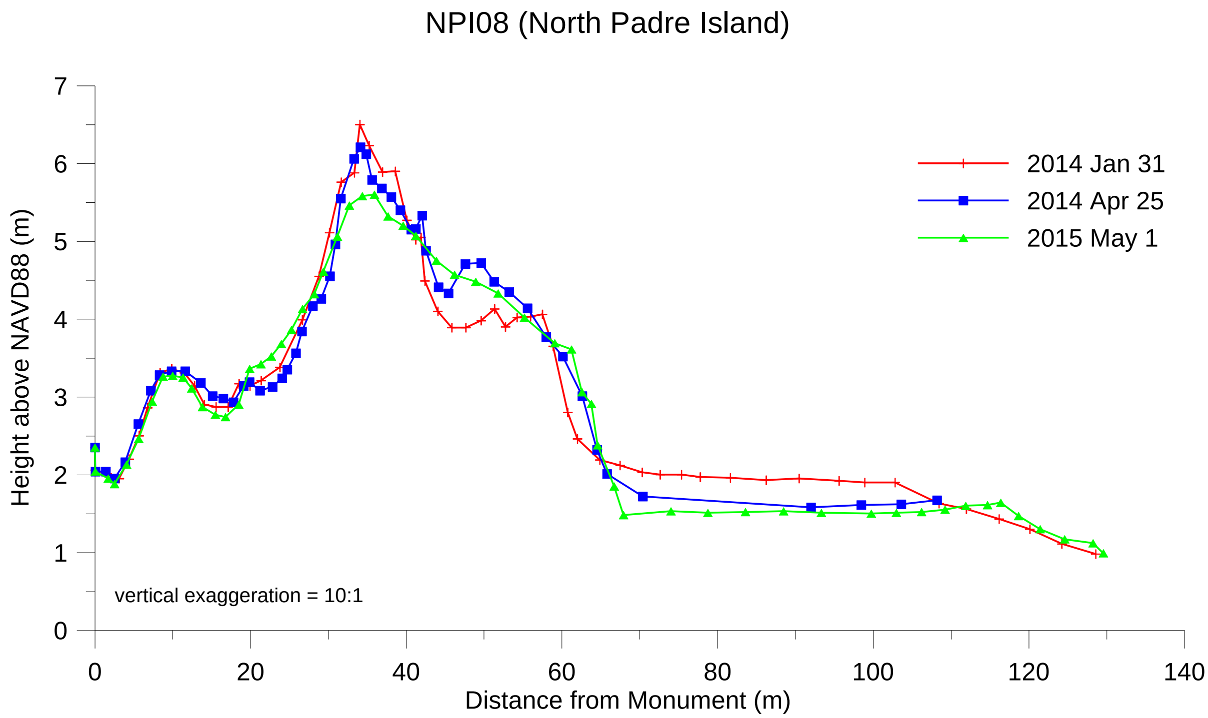

MUI03 (Mustang Island)
Height above NAVD88 (m)
Distance from Monument (m)
2012 May 8
2013 Jan 31
2013 May 2
2014 Jan 30
2014 Apr 24
0
1
2
3
4
5
0
20
40
60
80
100
120
140


Height above NAVD88 (m)
Distance from Monument (m)
2014 Oct 7
2015 Jan 29
2015 Apr 30
vertical exaggeration = 10:1
0
1
2
3
4
5
0
20
40
60
80
100
120
140

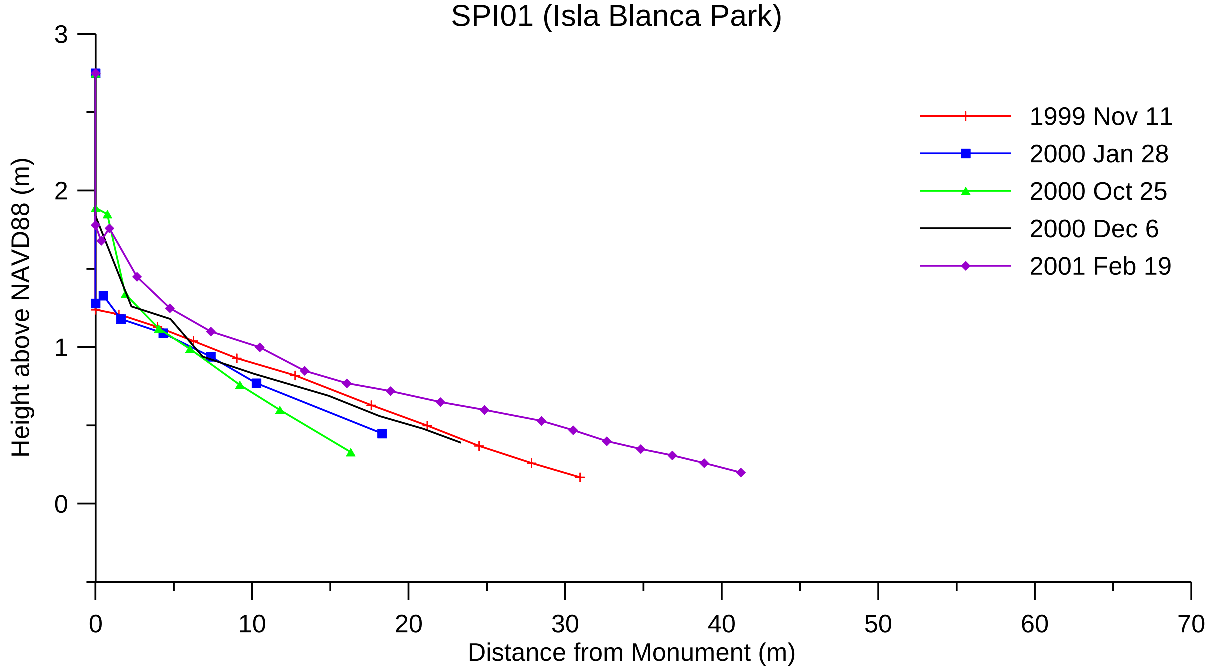
NPI08 (North Padre Island)

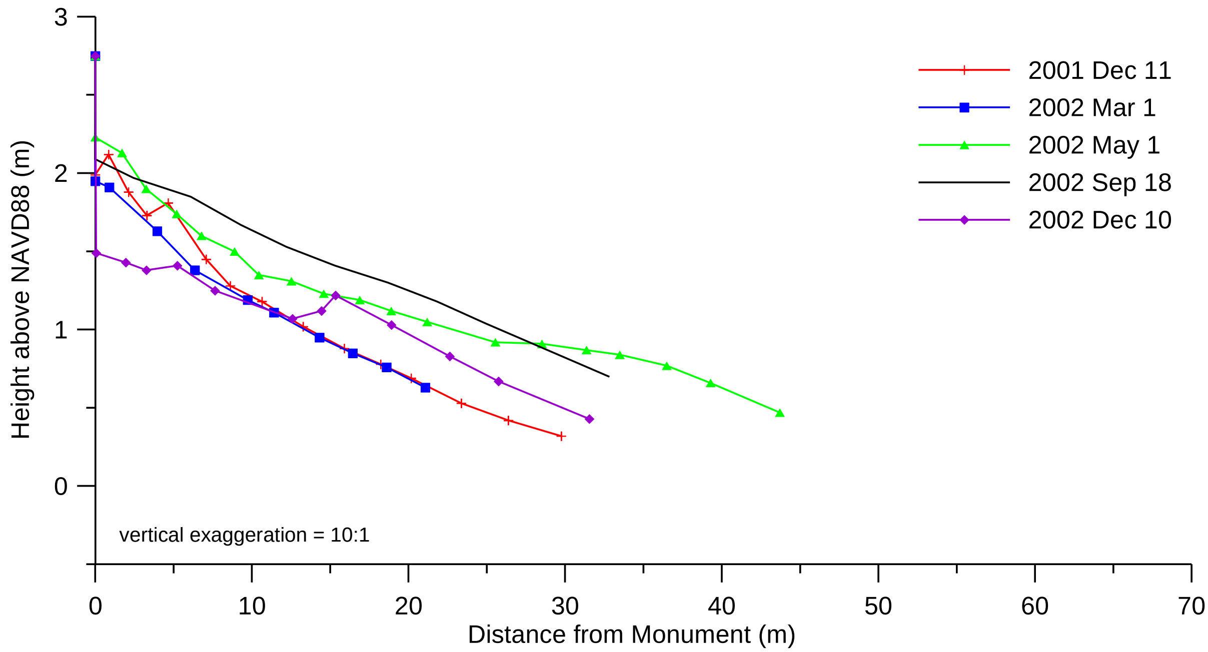


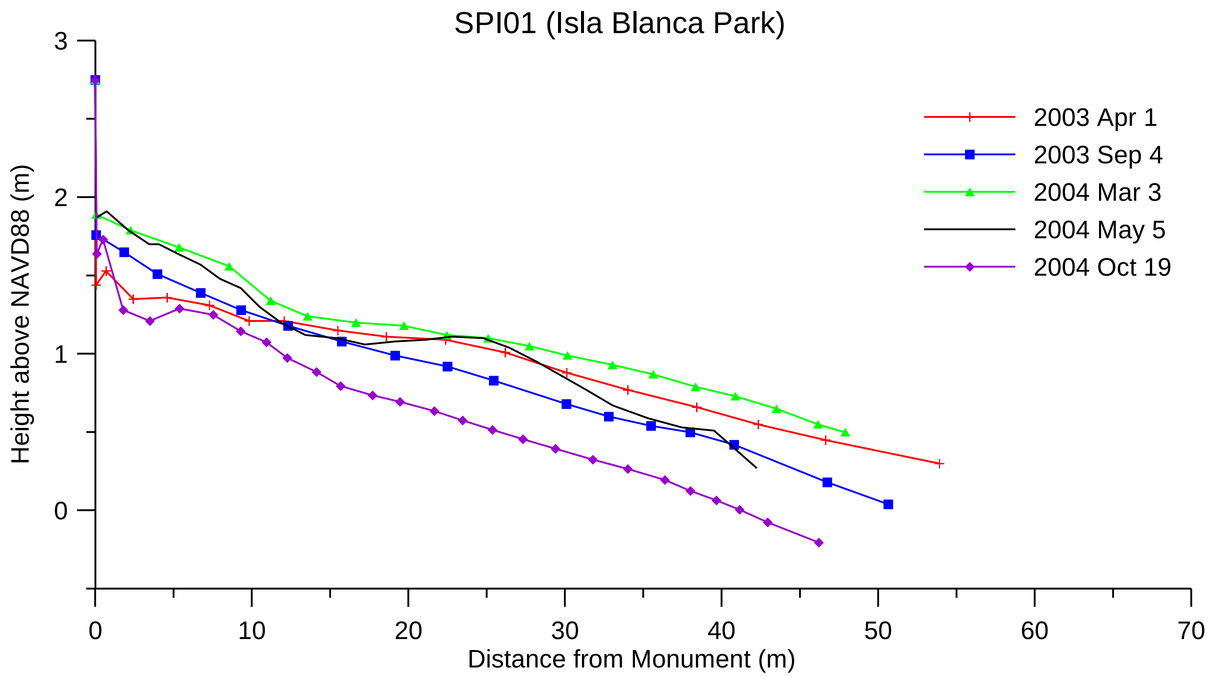


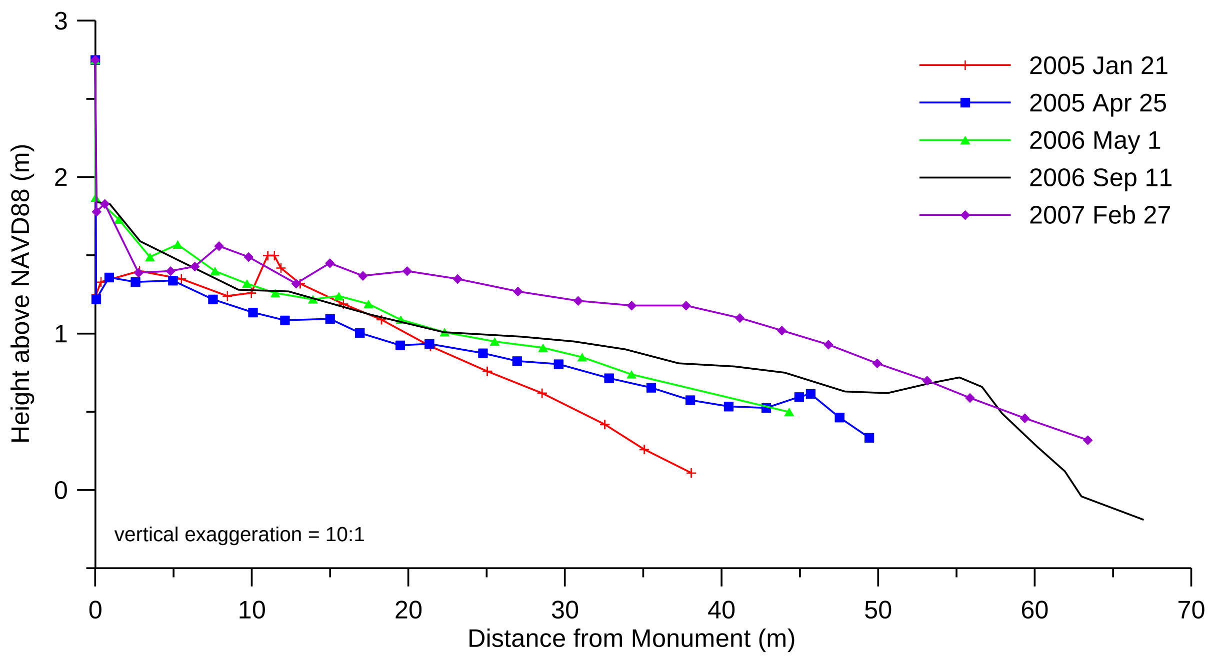

NPI08 (North Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2014 Jan 31
2014 Apr 25
2015 May 1
vertical exaggeration = 10:1
0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
140

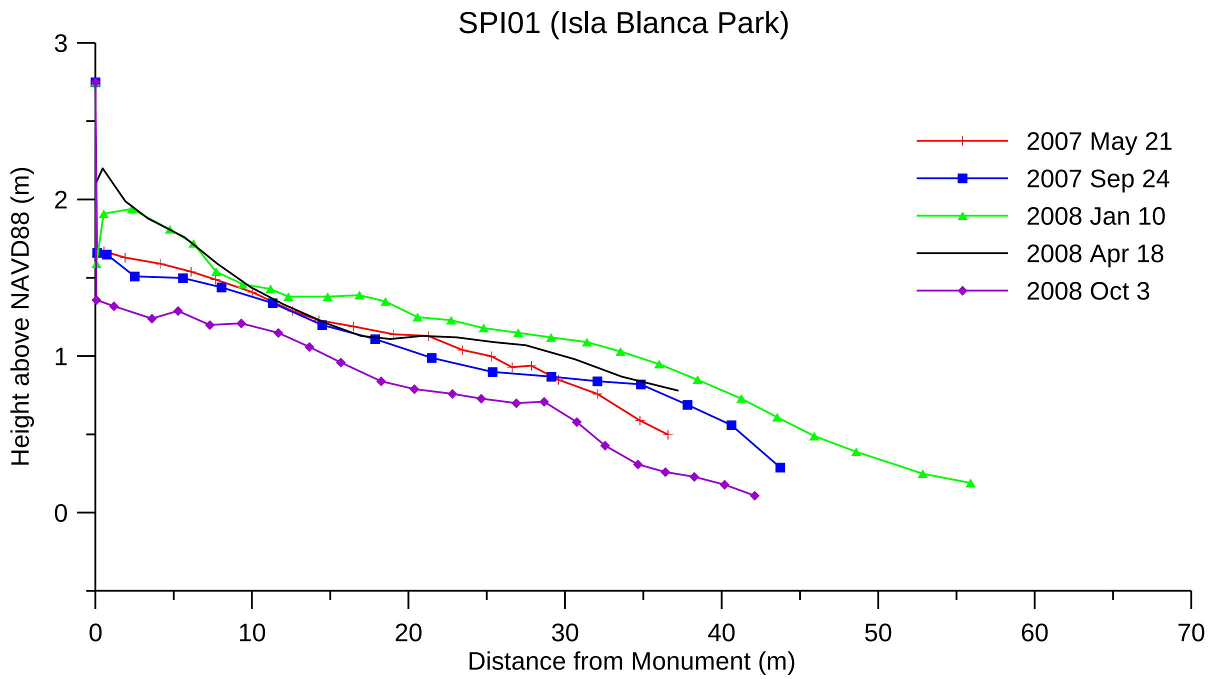
SPI01 (Isla Blanca Park)

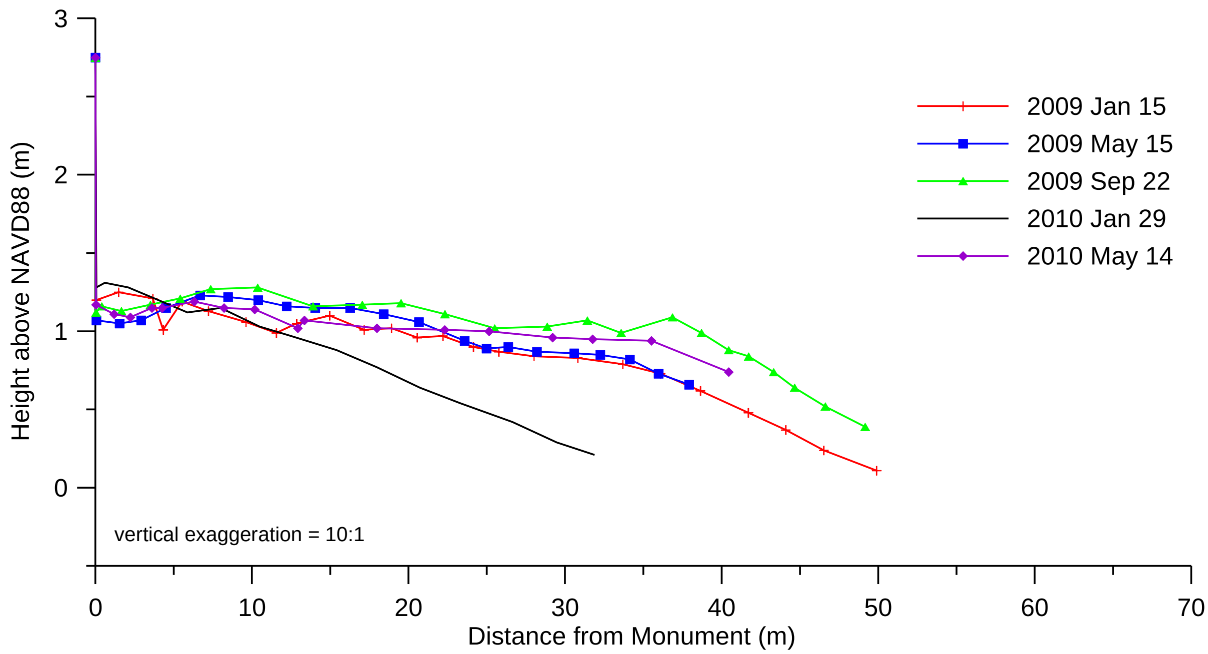


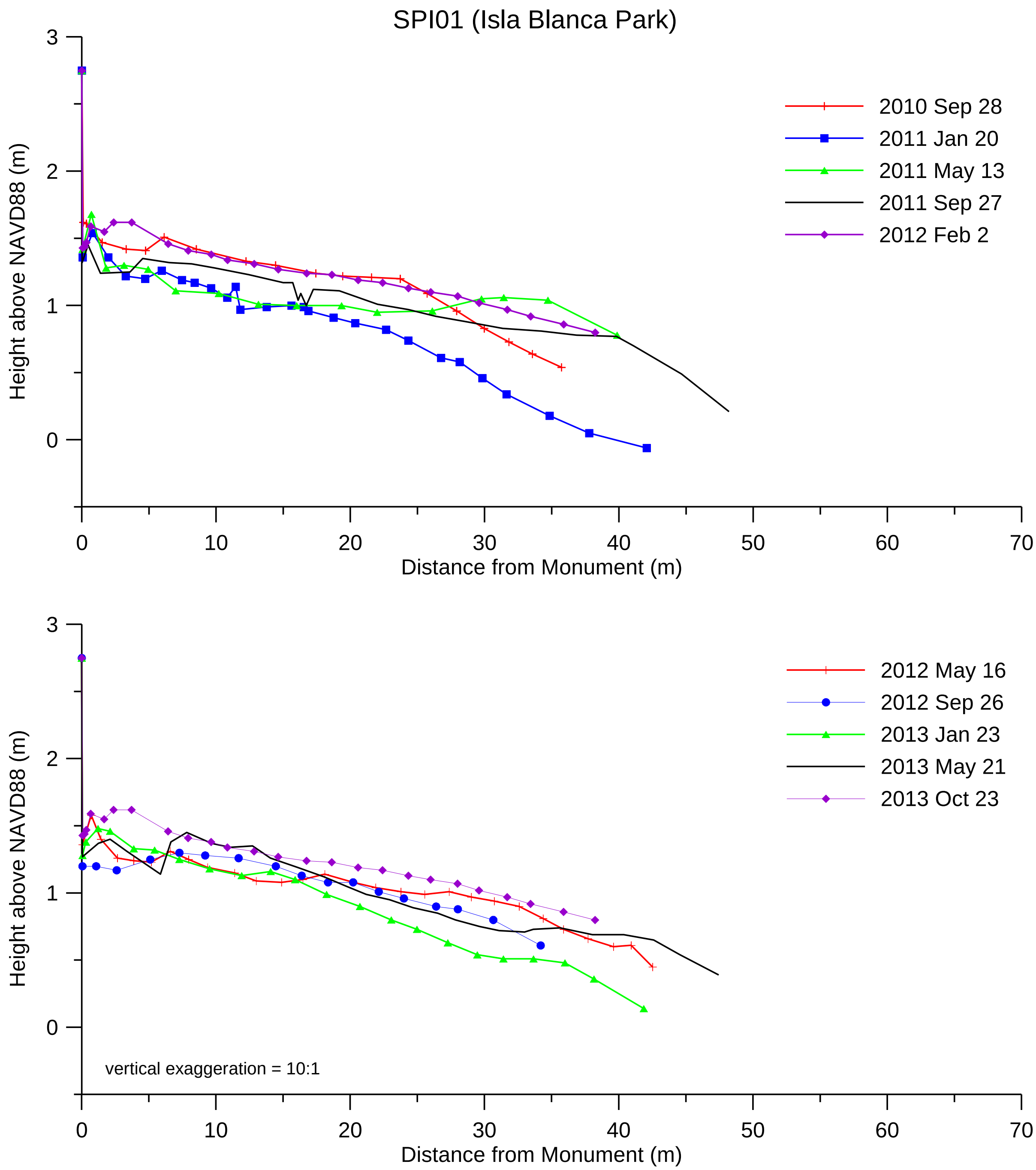


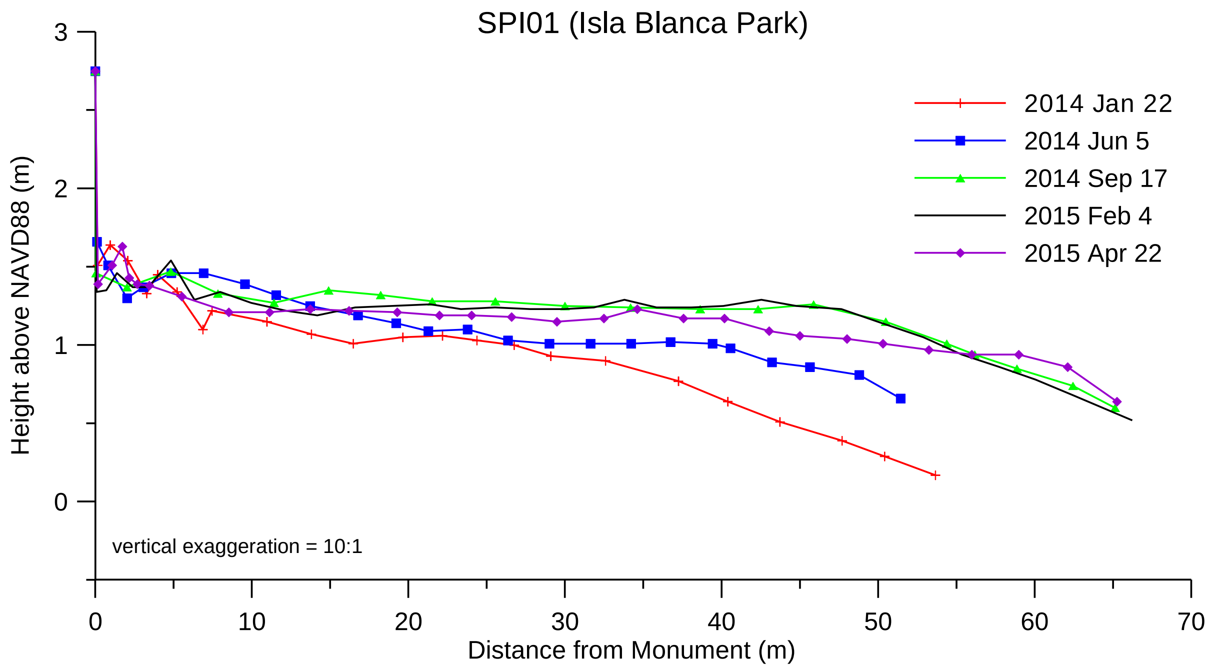

SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
2003 Apr 1
2003 Sep 4
2004 Mar 3
2004 May 5
2004 Oct 19
0
1
2
3
0
10
20
30
40
50
60
70


Height above NAVD88 (m)
Distance from Monument (m)
2005 Jan 21
2005 Apr 25
2006 May 1
2006 Sep 11
2007 Feb 27
vertical exaggeration = 10:1
0
1
2
3
0
10
20
30
40
50
60
70

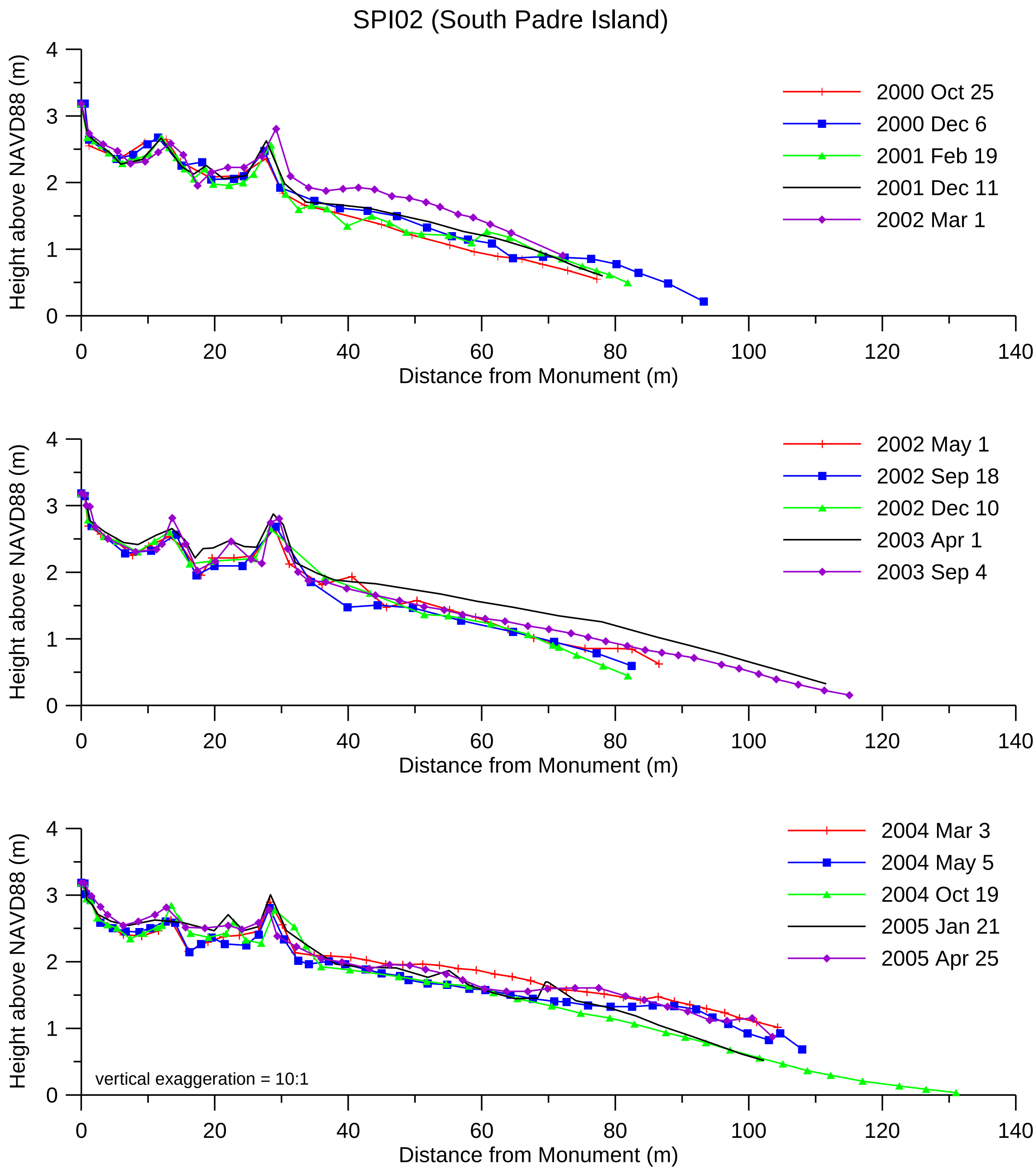

SPI01 (Isla Blanca Park)
Height above NAVD88 (m)
Distance from Monument (m)
2007 May 21
2007 Sep 24
2008 Jan 10
2008 Apr 18
2008 Oct 3

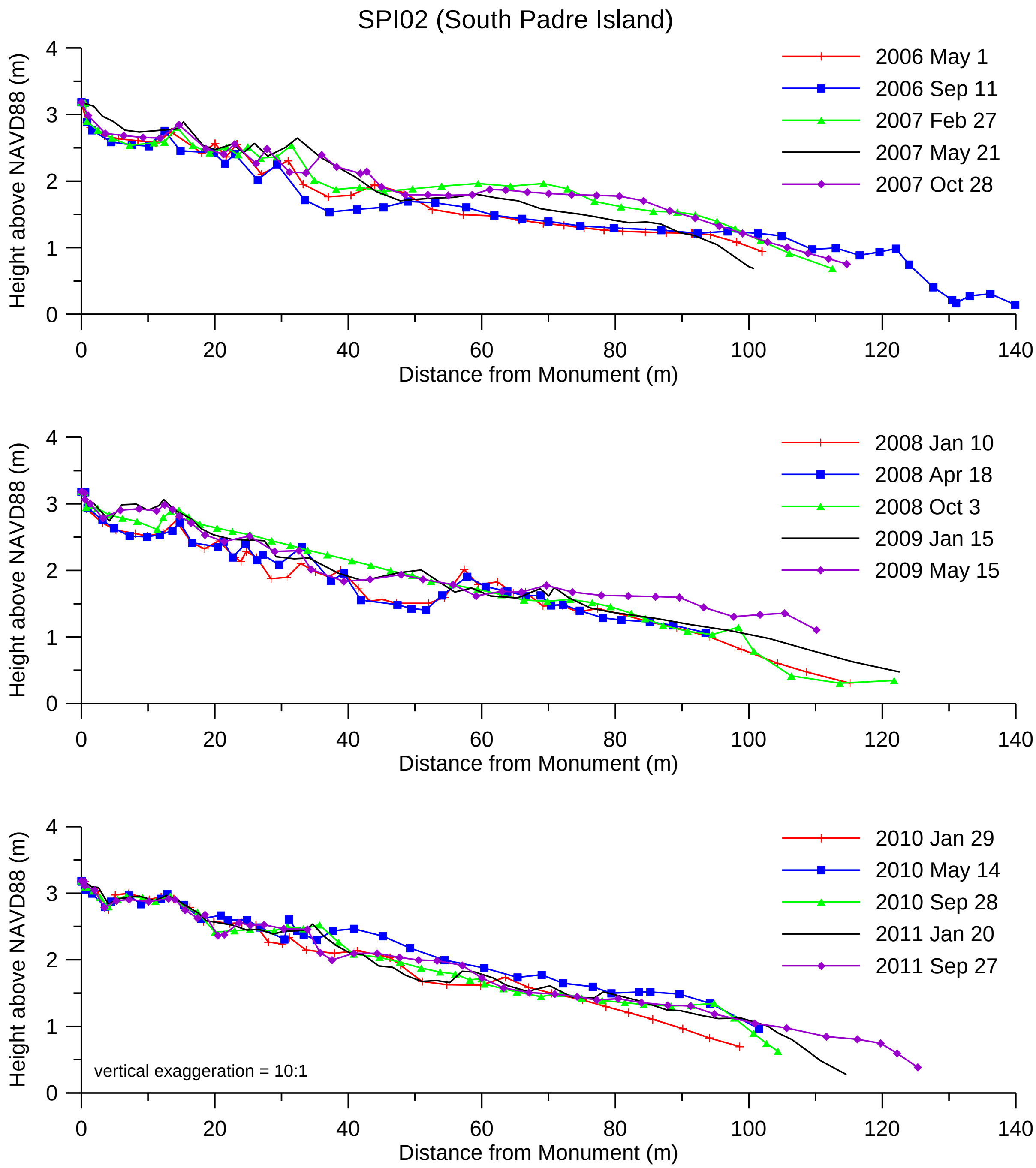

Height above NAVD88 (m)
Distance from Monument (m)
2009 Jan 15
2009 May 15
2009 Sep 22
2010 Jan 29
2010 May 14
vertical exaggeration = 10:1


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
vertical exaggeration = 10:1

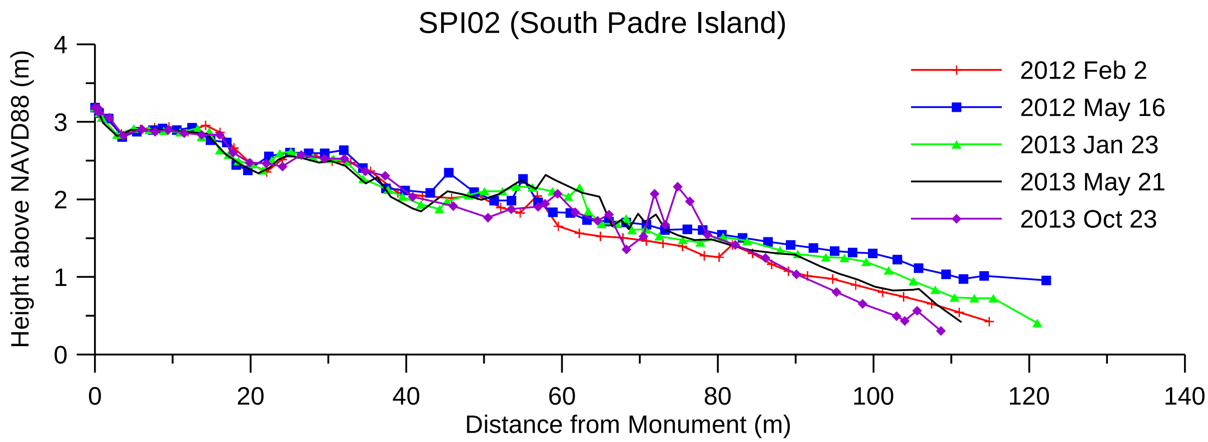


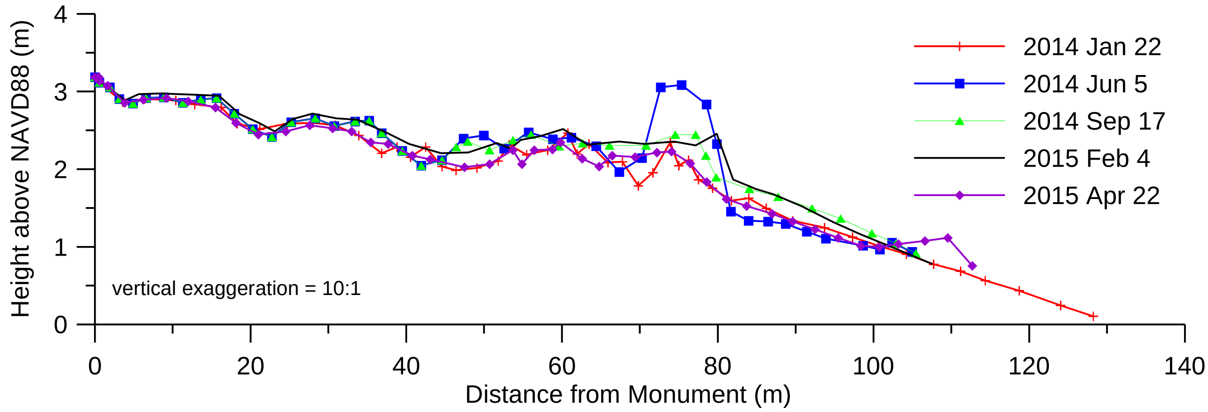
SPI01 (Isla Blanca Park)
2014 Jan 22
2014 Jun 5
2014 Sep 17
2015 Feb 4
2015 Apr 22
Height above NAVD88 (m)
Distance from Monument (m)
vertical exaggeration = 10:1
0
1
2
3
0
10
20
30
40
50
60
70

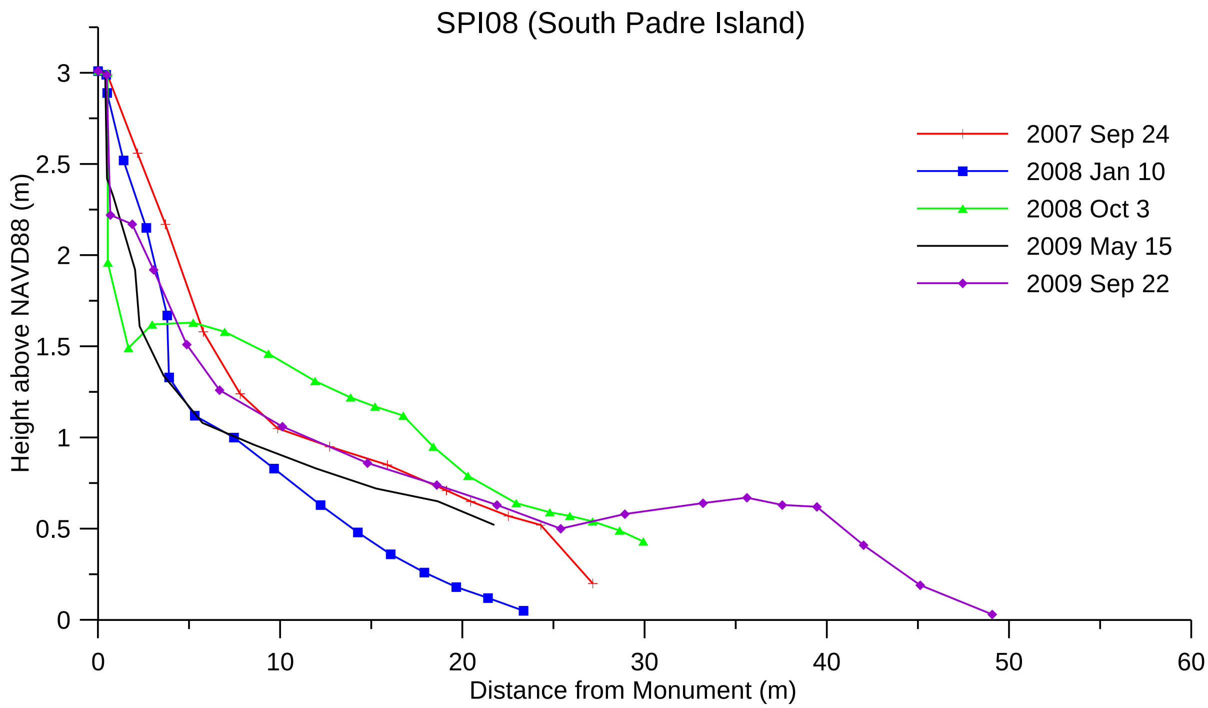

SPI02 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2000 Oct 25
2000 Dec 6
2001 Feb 19
2001 Dec 11
2002 Mar 1
2002 May 1
2002 Sep 18
2002 Dec 10
2003 Apr 1
2003 Sep 4
2004 Mar 3
2004 May 5
2004 Oct 19
2005 Jan 21
2005 Apr 25
vertical exaggeration = 10:1

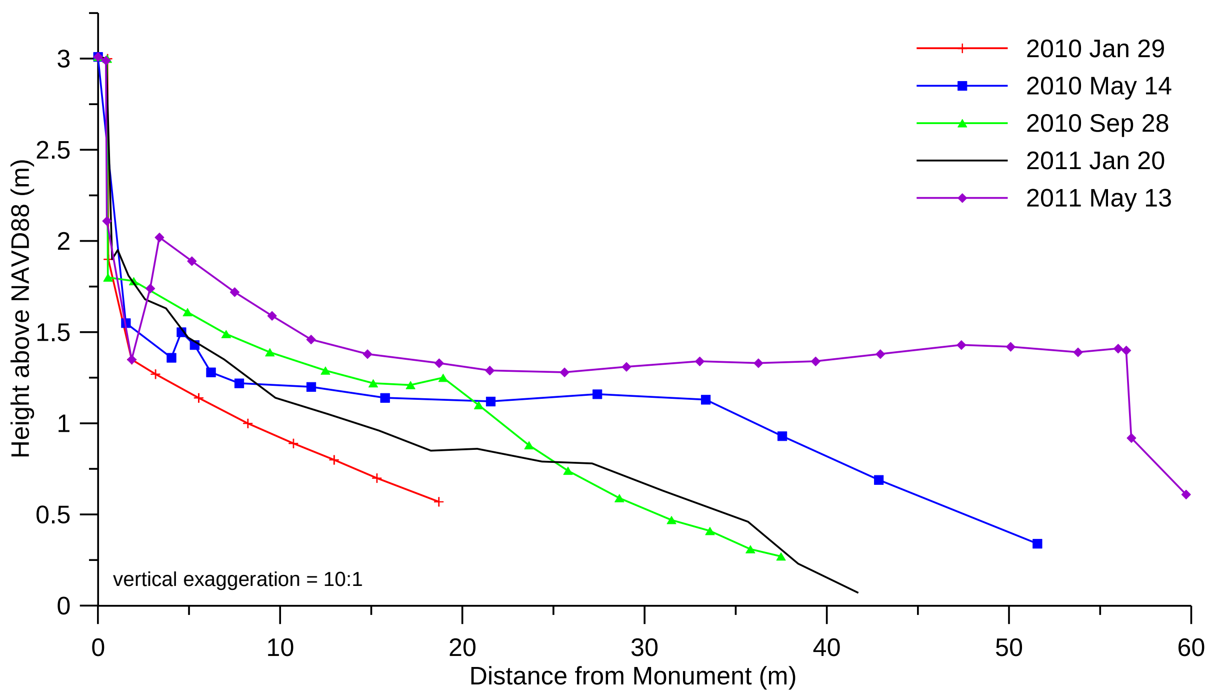


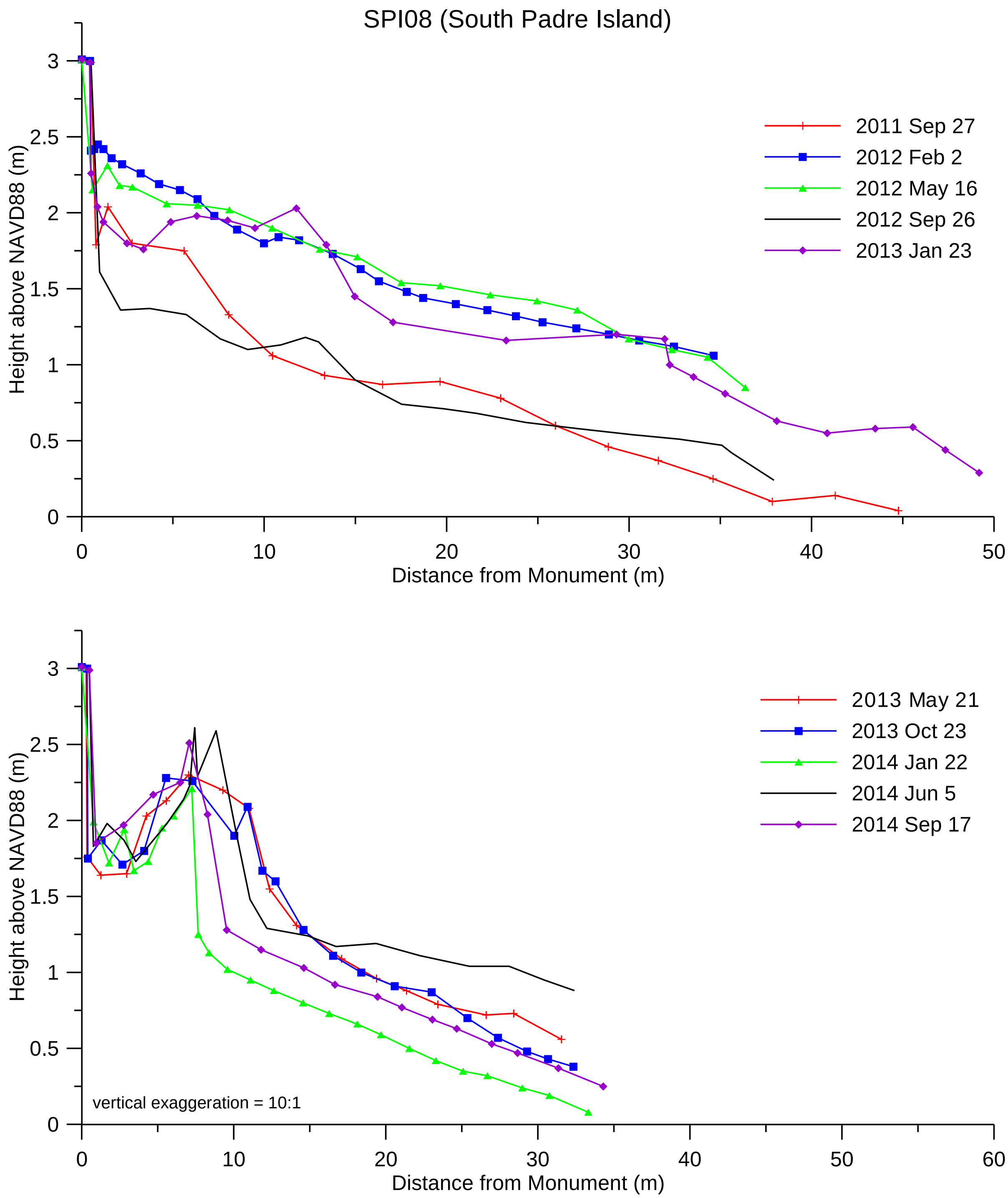
SPI02 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2006 May 1
2006 Sep 11
2007 Feb 27
2007 May 21
2007 Oct 28
2008 Jan 10
2008 Apr 18
2008 Oct 3
2009 Jan 15
2009 May 15
2010 Jan 29
2010 May 14
2010 Sep 28
2011 Jan 20
2011 Sep 27
vertical exaggeration = 10:1


SPI02 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2012 Feb 2
2012 May 16
2013 Jan 23
2013 May 21
2013 Oct 23

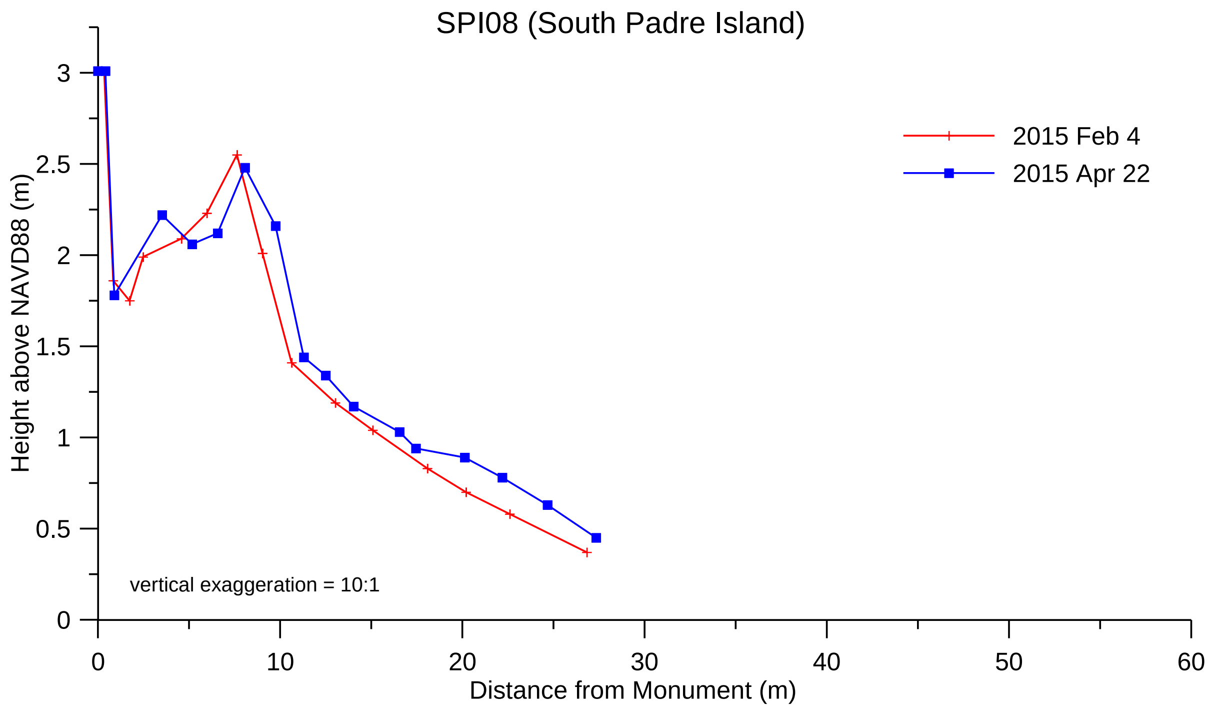

Height above NAVD88 (m)
Distance from Monument (m)
2014 Jan 22
2014 Jun 5
2014 Sep 17
2015 Feb 4
2015 Apr 22
vertical exaggeration = 10:1


SPI08 (South Padre Island)
Height above NAVD88 (m)
Distance from Monument (m)
2007 Sep 24
2008 Jan 10
2008 Oct 3
2009 May 15
2009 Sep 22
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)
2010 Jan 29
2010 May 14
2010 Sep 28
2011 Jan 20
2011 May 13
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)
Height above NAVD88 (m)
Distance from Monument (m)
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
vertical exaggeration = 10:1


SPI08 (South Padre Island)
2015 Feb 4
2015 Apr 22
Height above NAVD88 (m)
3
2.5
2
1.5
1
0.5
0
vertical exaggeration = 10:1
0
10
20
30
40
50
60
Distance from Monument (m)