

FINAL REPORT

Texas High School Coastal Monitoring Program: 2017–2018

Tiffany L. Caudle



Bureau of Economic Geology

Scott W. Tinker, Director

Jackson School of Geosciences

The University of Texas at Austin, Austin, Texas 78713-8924

June 2018



FINAL REPORT

Texas High School Coastal Monitoring Program: 2017–2018

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

Tiffany L. Caudle

Report to the Texas Coastal Coordination Council pursuant to
National Oceanic and Atmospheric Administration Award No. NA16NOS4190174

Final report prepared for General Land Office under contract No. 17-188-000-9825.

Bureau of Economic Geology
Scott W. Tinker, Director
Jackson School of Geosciences
The University of Texas at Austin, Austin, Texas 78713-8924

June 2018



CONTENTS

INTRODUCTION	1
PROGRAM DESCRIPTION	2
Goals.....	2
Methods	4
Training	6
Data Management, Data Analysis, and Dissemination of Information.....	6
STUDENT, TEACHER, AND SCIENTIST INTERACTIONS DURING THE 2017–2018 ACADEMIC YEAR.....	7
High Island High School.....	10
Ball High School.....	10
Matagorda Area Schools.....	12
Port Aransas High School	12
Cunningham Middle School	13
Port Isabel High School.....	15
Brazosport High School	16
EFFECTS ON SCIENCE CURRICULUM	17
EFFECTS ON SCIENTIFIC RESEARCH, COASTAL MANAGEMENT, AND PUBLIC AWARENESS	17
SCIENTIFIC RESULTS: 1997–2018.....	24
CONCLUSIONS.....	40
ACKNOWLEDGMENTS	41
REFERENCES	42
APPENDIX A: PROFILE INFORMATION	44
APPENDIX B: GRAPHS OF VOLUME, SHORELINE, AND VEGETATION-LINE CHANGE.....	45
APPENDIX C: GRAPHS OF BEACH PROFILES	55
APPENDIX D: MAPS OF GPS SHORELINE AND VEGETATION LINE POSITIONS.....	107

Tables

1. Schools involved in THSCMP 7

Figures

1. Location map of participating schools 2

2. Students using a sighting level to determine vertical offset between Emery rods and a metric tape to measure horizontal distance..... 5

3. Students mapping the vegetation line and shoreline (wet/dry line) using handheld GPS units..... 5

4. Students using a sighting compass to measure dune orientation and measuring how far along the shoreline the float (an orange) drifted to determine longshore current..... 6

5. Location map of High Island High School monitoring sites 10

6. Location map of Ball High School monitoring sites 11

7. Location map of Matagorda area schools monitoring sites 13

8. Location map of Port Aransas High School monitoring sites 14

9. Location map of Cunningham Middle School monitoring sites..... 15

10. Location map of Port Isabel High School monitoring sites 16

11. Lidar topographic-relief image of Galveston Island State Park and Pirates Beach subdivision 19

12. Shoreline position comparison at Galveston Island State Park site BEG02..... 21

13. Shoreline position comparison at South Padre Island site SPI08 22

14. Shoreline position comparison at Mustang Island sites MUI02 and MUI03 23

15. Profile volume, shoreline, and vegetation-line changes at Galveston Island State Park, September 1994–April 2008 25

16. Plot of pre- and post-Hurricane Rita beach profiles measured at Galveston Island State Park 26

17. 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	28
18. BEG02 datum reset post-Hurricane Ike profile plus data collected by Ball High School students	29
19. MAT03 pre- and post-Hurricane Ike profile data collected by Palacios High School students	30
20. Shoreline position change at Matagorda Peninsula	31
21. Changes in beach and dune volume, shoreline position and vegetation line position at MAT03 on Matagorda Peninsula	32
22. Foredune expansion at MUI01 on Mustang Island.....	33
23. Excavated dune profile at MUI01 on Mustang Island.....	34
24. Excavated dune at MUI01 on Mustang Island looking north toward Horace Caldwell Pier and landward	34
25. Mustang Island pre- and post-Hurricane Harvey profile data collected by Port Aransas High School and Texas A&M University Corpus Christi.....	35
26. Changes in sand volume and shoreline and vegetation line position at SPI02 on South Padre Island due to beach-nourishment projects and the installation of sand fences	36
27. Sand volume and shoreline position changes at SPI08 on South Padre Island due to beach-nourishment projects and the installation of sand fences.....	38

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 2017–2018 academic year. During this time, Ball High School on Galveston Island completed its 20th year in the program, and Port Aransas and Port Isabel High Schools completed their 19th year (**fig. 1**). Through collaboration with the Lower Colorado River Authority, the program works with two schools in the Matagorda area: Van Vleck High School completed their 14th year in the program and Palacios High School completed its 12th year. Cunningham Middle School in the Corpus Christi Independent School District marked its 10th year in the program. High Island High School on Bolivar Peninsula joined THSCMP during the 2015–2016 academic year. These seven schools anticipate continuing with the program during the 2018–2019 academic year. Brazosport High School in Freeport, Texas will be joining THSCMP during the next academic year monitoring beaches in Quintana and Surfside Beach. Discussions of data collected by the students are included in this report. The program is also enhanced by a continuously updated website (<http://www.beg.utexas.edu/coastal/thscmp/>).

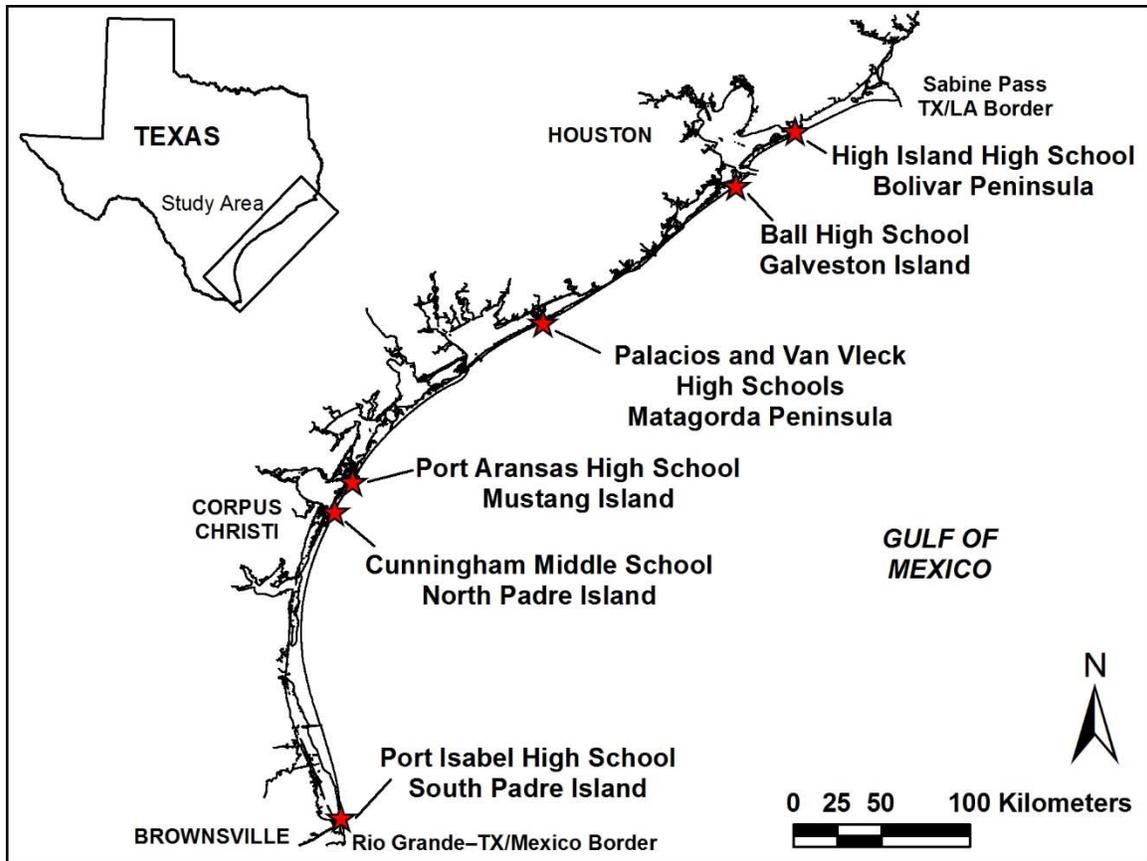


Figure 1. Location map of participating schools.

PROGRAM DESCRIPTION

Goals

The coastal monitoring program has three major goals:

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

collaboration with working scientists on an actual research project, the students gain an enhanced science education.

(2) Increase public awareness and understanding of coastal processes and hazards.

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

(3) Achieve a better understanding of the relationship between coastal processes, beach morphology, and shoreline change and make data and findings available for solving coastal management problems.

The Bureau of Economic Geology (Bureau) at UT has conducted a 40-year research program to monitor shorelines and investigate coastal processes. An important part of this program is the repeated mapping of the shoreline and measurement of beach profiles. Over time, these data are used to determine the rate of shoreline change. A problem we face is the limited temporal resolution in our shoreline data. The beach is a dynamic environment where significant changes in shape and sand volume can

occur over periods of days or even hours. Tides, storms, and seasonal wind patterns cause large, periodic or quasiperiodic changes in the shape of the beach. If coastal data are not collected often enough, periodic variations in beach morphology could be misinterpreted as secular changes. The THSCMP helps address this problem by providing scientific data at key locations along the Texas coast. These data are integrated into the ongoing coastal research program at the Bureau and are made available to other researchers and coastal managers.

Methods

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

- (1) *Beach profile (fig. 2)*. Students use a pair of Emery rods, a metric tape, and a hand level to accurately survey a shore-normal beach profile from behind the foredunes to the waterline (Emery, 1961; Krause, 2005; O'Connell, 2001). The students begin the profile at a pre-surveyed datum stake so that they can compare each new profile with earlier profiles. Consistently oriented photographs are taken with a digital camera. The beach profiles provide detailed data on the volume of sand and the shape of the beach.
- (2) *Shoreline and vegetation-line mapping (fig. 3)*. GPS mapping provides measurements of the rate of change. Using handheld GPS units, students walk along the shoreline and vegetation line mapping these features for display on Geographic Information System software. A comparison of positions determined through GPS mapping over time allows students to visual shoreline and vegetation line changes.



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



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

(3) *Beach processes (fig. 4).* Students measure wind speed and direction, estimate the width of the surf zone, and observe breaker type. They note wave direction, height, and period and estimate longshore current speed and direction using a float, stopwatch, and tape measure. Students also take readings of shoreline and foredune orientation. From these measurements, they can infer relationships between physical processes and beach changes in time and space. Students also learn to obtain weather and oceanographic data from resources on the Internet.



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

Training

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

Data Management, Data Analysis, and Dissemination of Information

The web is central to the dissemination of data collected for this program. A UT-based website (<http://www.beg.utexas.edu/coastal/thscmp/>), implemented toward the end of the 1998–1999 academic year, provides all the information needed to begin a beach-monitoring program, as well as curriculum materials for high school

teachers. Each school in the program has an area on the website for posting its data and observations, including digital photos. After Bureau scientists manage the data in an electronic database and evaluate it in light of coastal management problems, they then make it available to the public.

**STUDENT, TEACHER, AND SCIENTIST INTERACTIONS
DURING THE 2017–2018 ACADEMIC YEAR**

In 1997, BEG researchers developed a pilot beach-monitoring program with Ball High School on Galveston Island (Caudle and Paine, 2012; Hepner and Gibeaut, 2004). THSCMP has since expanded several times to now include a total of eight schools (Table 1). Seven actively participated in 2017–2018. Expansion of the program has not only increased the number of high schools in THSCMP but also introduced middle school students, who make the same field measurements and observations as the high school students. Students in the program are enrolled in classes such as physics, environmental science, biology, aquatic science, and general science.

Table 1. Schools involved in THSCMP.

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

BEG researchers work with the same teachers each academic year. Researchers communicate directly with teachers to schedule field trips in the fall (September or October), winter (January or February), and spring (April or May). The teacher arranges transportation to the study sites (bus or SUV, depending on class size) and

a substitute teacher to cover his or her classroom for the day. In order to encourage school districts to continue participation in THSCMP, project support provides funding to cover the cost of student transportation and substitute teachers. A stipend is also provided to the participating teachers.

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

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

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

Dividing students into five- to eight-member teams works well. Aside from conducting the beach profile and measuring processes and the shoreline, additional tasks can be assigned to the team that finishes first. It is important to assign each

student a job to keep him or her focused and interested, although time for a little fun is also allowed. People normally think of the beach as a place of recreation, and participation in this project should not change that. In fact, it is hoped that program participants will enjoy going to the beach even more because of their newly acquired knowledge and observation skills.

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

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

High Island High School

High Island High School joined THSCMP during the 2015–2016 academic year. Ms. Caudle worked with High Island High School science teacher Maria Skewis to start the Program in the High Island Independent School District. Science students collected data from three sites on Bolivar Peninsula on October 4, 2017; January 24, 2018; and May 17, 2018. Two of the monitoring sites are adjacent to Rollover Pass, BOL02 to the west and BOL03 to the east of the Pass (**fig. 5**). The third site (HIB01) is seaward of High Island just past the eastern end of Highway 87 (**fig. 5**).

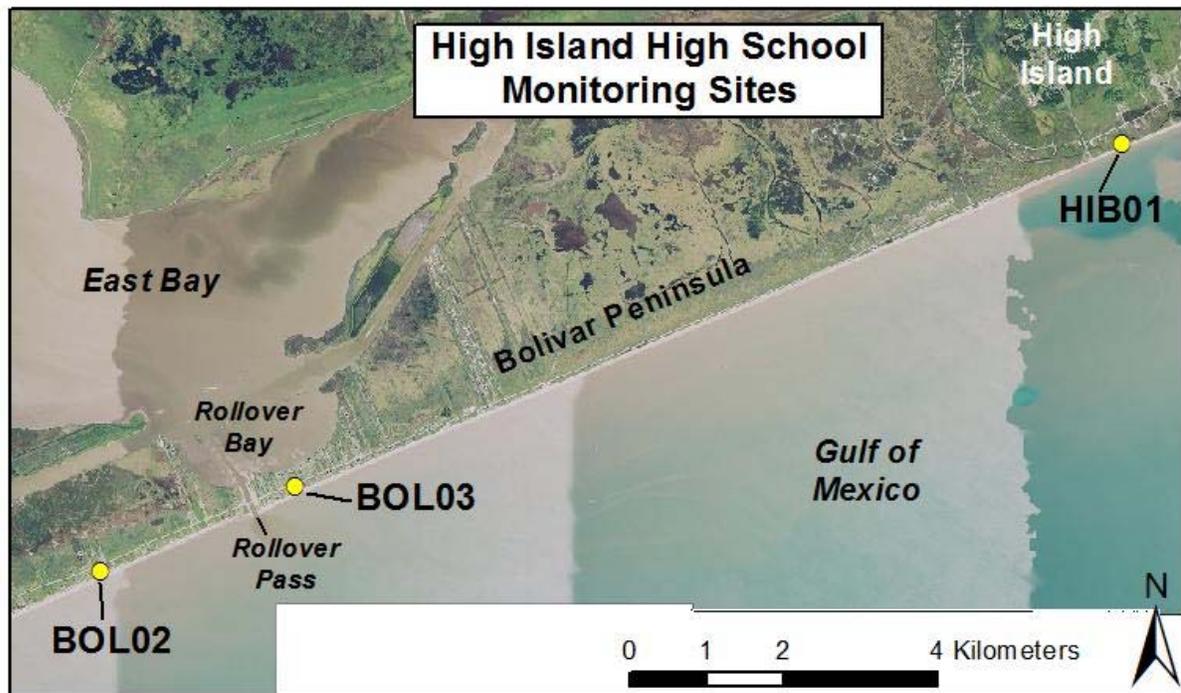


Figure 5. Location map of High Island High School monitoring sites.

Ball High School

Dr. Daniel Hochman's AP Environmental Science classes at Ball High School participated in field trips on October 5, 2017; January 25, 2018; and May 18, 2018. Students conducted surveys at Galveston Island State Park, BEG02 (**fig. 6**)—a profile that the Bureau has been measuring since the 1980's. Ball High School

students also started collected data at two new locations, JAM02 in Jamaica Beach and DEL01 at the Dellanera RV Park (**fig. 6**). Both of these sites will monitor beach nourishment and Coastal Erosion Planning and Response Act (CEPRA) beach and dune restoration activities. It is important to note that during the fall field trips (October 2017) for both Ball and High Island High Schools water levels were exceptionally high. The waterline on Bolivar Peninsula and Galveston Island was very close to the vegetation line at all of the monitoring sites, leaving very little beach exposed. The elevated shoreline positions are evident in the plots of shoreline change in Appendix B, the beach profile data in Appendix C, and the GPS mapped shoreline in Appendix D.



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

Matagorda Area Schools

Van Vleck High School environmental science students participated in field trips on September 21, 2017; January 26, 2018; and May 17, 2018. Sherry Martinez's class collected data at MAT01 (**fig. 7**). Physics students from Palacios High School participated in field trips September 20, 2017; January 24, 2018; and May 2, 2018. Richard Davis' students collected data at MAT02 (**fig. 7**). Tidehaven High School decided to no longer participate in THSCMP. The students from Tidehaven collected data at MAT03 (**fig. 7**) in the past. The MAT03 profile location has seen a significant increase in beach width including a coppice mound field with intermittent swales that usually contain water and marsh plants. The students were required to transverse an area that also contains species of venomous snakes. Without proper gear, it had become dangerous for students, the teacher, and staff to collect data at this location. In addition, the teachers that have participated in the past were retiring. Due to these conditions Tidehaven ISD decided to withdraw from the program. While the beach profile data will no longer be collected at MAT03, Van Vleck and Palacios High Schools will continue to collect GPS data mapping the shoreline and vegetation line positions at this site.

Port Aransas High School

The City of Port Aransas was heavily impacted by the landfall of category 4 Hurricane Harvey on August 25, 2017. The schools were closed until early October following the storm. Post-storm data was collected by staff from Harte Research Institute, Texas A&M University Corpus Christi. Port Aransas students participated in field trips on January 31, 2018 and April 25, 2018. Ryan Piwetz's Aquatic Science class collected data at three profile locations on Mustang Island: MUI01 near Horace Caldwell Pier, MUI02 in Mustang Island State Park, and MUI03 (**fig. 8**). Port Aransas High School has been measuring these profiles sites since 1999.

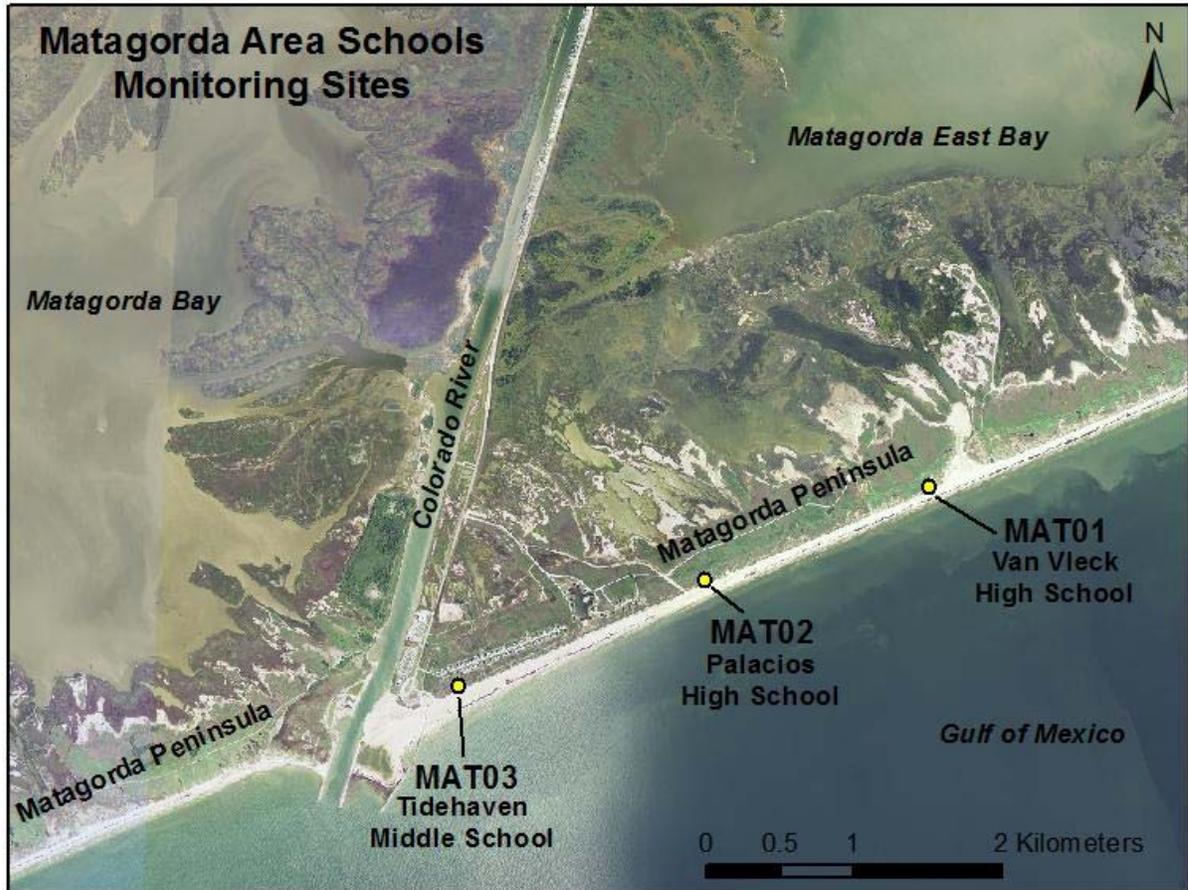


Figure 7. Location map of Matagorda area schools monitoring sites.

Cunningham Middle School

The Bureau collaborates with graduate students and staff at TAMUCC to conduct field trips with students from the Innovation Academy at Cunningham Middle School. The students are split into two groups during each field trip. One group works on the topographic profile while the second makes observations on wind, waves, currents and collects GPS shoreline and vegetation line data. The groups rotate for the second monitoring site. Cunningham Middle School 8th graders participated in field trips on February 1, 2018 and April 26, 2018. Eunice Silva’s students collected data at NPI08 on North Padre Island (**fig. 9**). A new site on the North Padre Island seawall (NPC06) was added for the 2015–2016 academic year (**fig. 9**) that monitors beach restoration and maintenance activities seaward of the seawall.

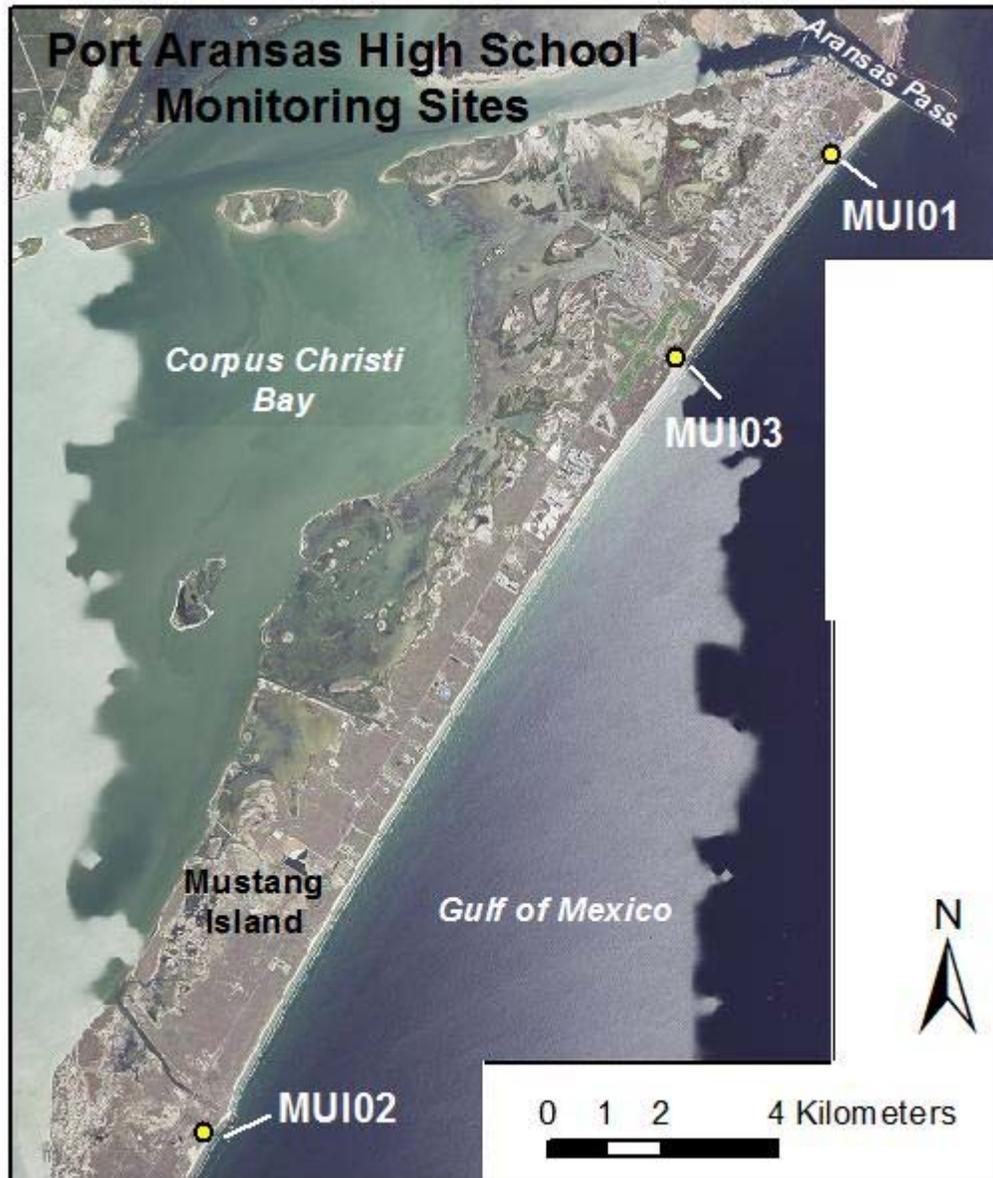


Figure 8. Location map of Port Aransas High School monitoring sites.



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

Port Isabel High School

Port Isabel students participated in field trips on September 13, 2017; January 10, 2018; and April 18, 2018. Students from Dr. Michelle Zacher's Advanced Placement Environmental Science class collected data at three profile locations on South Padre Island: SPI01 in Isla Blanca Park, SPI02 at Beach Access #13, and SPI08 at the Tiki Condominiums (E. White Sands Street) (**fig. 10**). Port Isabel High School has been measuring SPI01 and SPI02 since 1999, and SPI08 since 2007.



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

Brazosport High School

Brazosport High School in Freeport, Texas was contacted to determine if the school would be interested in participating in THSCMP starting in the 2018-2019 academic year. A new Environmental Science class will be added to the Brazosport curriculum for the new school year. Students taking Environmental Science will begin monitoring the beaches of Quintana and Surfside Beach as members of THSCMP.

EFFECTS ON SCIENCE CURRICULUM

The THSCMP addresses several requirements of Texas Essential Knowledge and Skills (TEKS) for Science. The program was relevant in these 2017–2018 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 2017–2018 academic year, Ball High School students measured a profile location in Galveston Island State Park (BEG02, **fig. 6**). The students had measured this same location in previous years, and the Bureau had conducted quarterly surveys here from 1983 through 1985 after Hurricane Alicia. Since 1985, however, the beaches had been surveyed on an irregular schedule, about once a year, and only when specific projects were funded to do so or when Bureau personnel were in the area conducting other work. The THSCMP helps ensure that time series at these key locations are continued. The data have increased scientific understanding of recovery of beaches and dunes following recent storms (Hurricane Alicia, Tropical Storm Frances, Hurricane Claudette, Hurricane Rita, Hurricane Ike, and Hurricane Harvey) that have impacted the area.

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

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

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

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

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

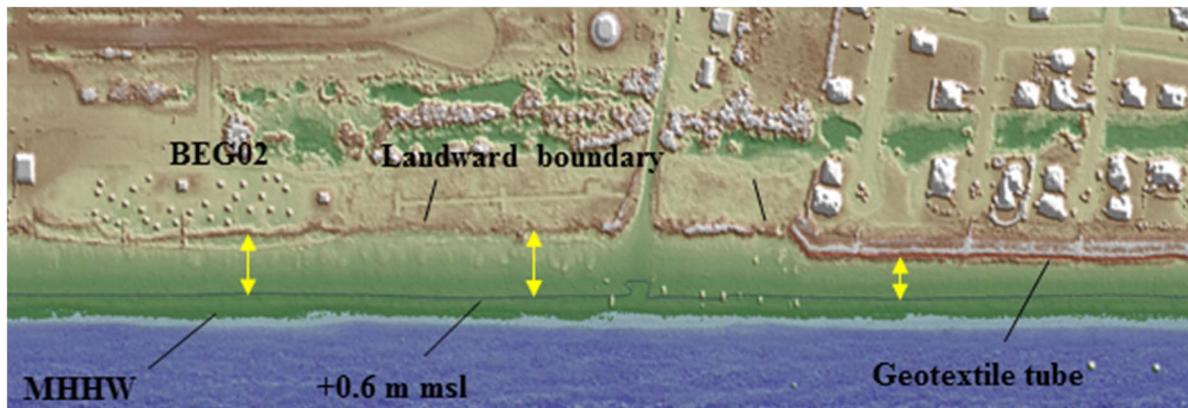


Figure 11. Lidar topographic-relief image of Galveston Island State Park and Pirates Beach subdivision. Note the difference in beach width between the natural beach and the area in front of the subdivision. From Gibeaut and others (2003).

Data collected by THSCMP students are invaluable in verifying shoreline position for updates of Texas' long-term shoreline-change rates, which are widely used by public officials, corporations, and private citizens. These comparisons, in some cases from ground-based GPS data acquired within a few days to weeks of the imagery or lidar survey date, generally show good agreement (within a few meters) between boundaries interpreted from ground-based data, imagery, and those extracted from lidar data. Small discrepancies in the position of the lidar-derived shorelines, imagery-derived shorelines, and the wet-beach/dry-beach boundary are likely to reflect real differences in beach morphology between the dates of the lidar surveys,

imagery acquisitions, and ground-based GPS surveys in these dynamic environments.

A pre-Hurricane Ike update of long-term rates of shoreline change along the entire Texas coast were determined based on the mapping of the shoreline position on 2007 aerial photography. Beach profiles and GPS-mapped shorelines (wet beach/dry beach boundary) collected by THSCMP students were used to confirm the shoreline position digitized on the 2007 aerial photography. The student-collected data proved vital in validating interpretation of the shoreline position on Galveston Island, Follets Island, Matagorda Peninsula, Mustang Island, and South Padre Island. The georeferencing of the photographs and interpretation of the position of the wet beach/dry beach boundary was checked by superimposing GPS-based wet beach/dry beach boundary data acquired in 2007 by THSCMP and the photo-interpreted 2007 wet beach/dry beach boundary used for change-rate calculations (Paine and others, 2011). At Galveston Island State Park (**fig. 12**, Paine and others, 2011, 2012), the GPS-based wet beach/dry beach boundary mapped on September 20, 2007, at BEG02 lies generally a few feet landward of the same boundary mapped on a 2007 aerial photograph acquired 3 days earlier (September 17, 2007).

Long-term rates of shoreline change on the Texas Gulf coast were updated through 2012 based upon extraction of the shoreline position from aerial lidar data collected in 2012 (Paine and others, 2014). GPS-mapped shorelines collected by THSCMP students were used to confirm the elevation of the 2012 shoreline position proxy that was used for shoreline change calculations. On South Padre Island (**fig. 13**, Paine and others, 2014), there is positional agreement between the 2012 lidar-extracted shoreline; the wet beach/dry beach boundary as interpreted on National Agriculture Imagery Program (NAIP) aerial imagery acquired April 23, 2012; and the wet beach/dry beach boundary surveyed using GPS by THSCMP students on September 26, 2012.

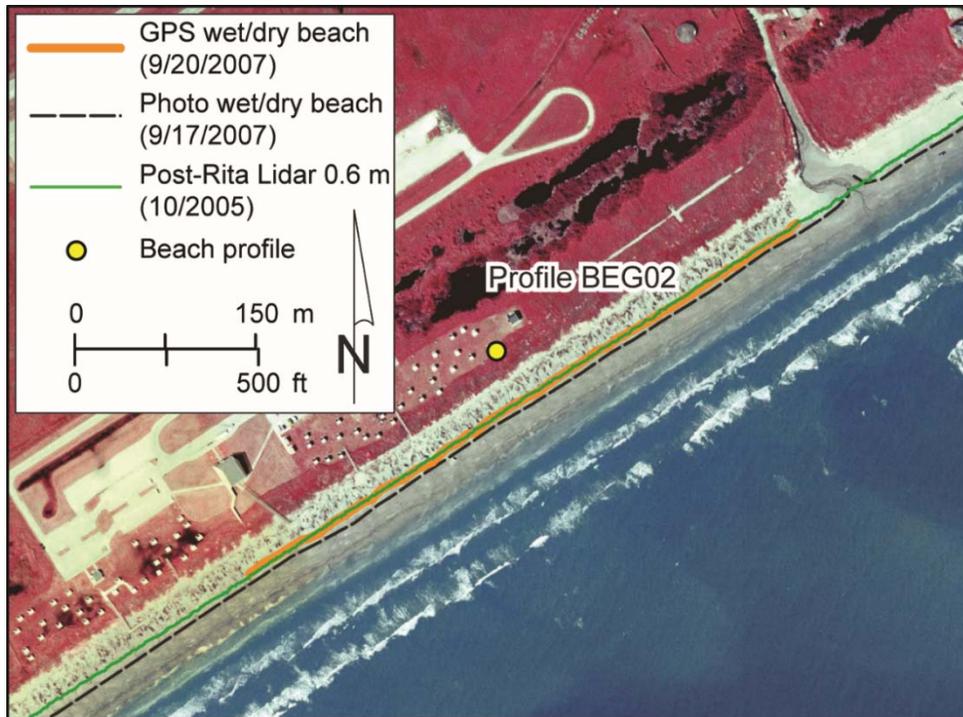


Figure 12. Shoreline position comparison at Galveston Island State Park site BEG02. Shorelines include the 2007 wet beach/dry beach boundary mapped on aerial photographs taken September 17, 2007; the wet beach/dry beach boundary mapped on September 20, 2007, by THSCMP students using ground GPS; and the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

The latest update of long-term rates of Gulf shoreline movement along the Texas coast have been determined through 2016 from a series of shoreline positions that includes those depicted on aerial photographs from the 1930s to 2016, ground GPS surveys, and airborne lidar surveys in 2000, 2012, and 2016 (Paine and Caudle, 2018). The 2016 shoreline was determined from 2016 NAIP aerial imagery and a lidar survey conducted by the U.S. Army Corps of Engineers (USACE) between September 9 and October 10, 2016 using the CZMIL airborne lidar system (USACE, 2017). A shoreline positional check, which addressed the relative position of the shoreline proxy and the wet-beach/dry-beach boundary, was accomplished by superimposing the lidar-derived shoreline proxy and GPS-based, wet-beach/dry-beach boundary data acquired in the fall of 2016 by the THSCMP (where available) on georeferenced 2016 NAIP imagery.

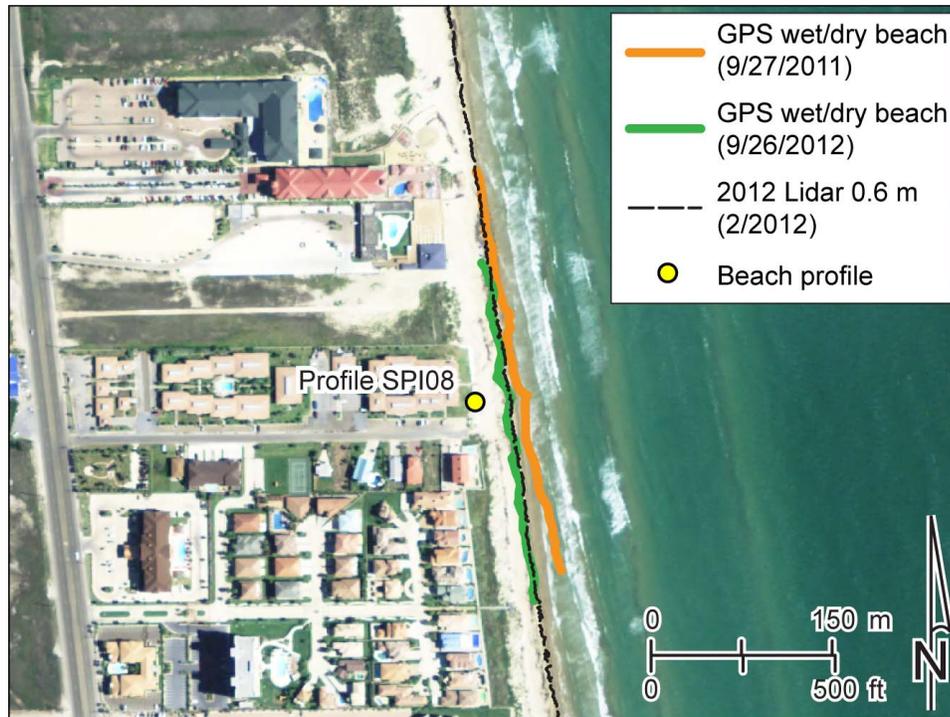


Figure 13. Shoreline position comparison at South Padre Island site SPI08. Shorelines include the wet beach/dry beach boundary mapped on September 27, 2011 and September 26, 2012 by THSCMP students using GPS and the shoreline proxy extracted from airborne lidar data acquired in February 2012. Shorelines are superimposed on NAIP imagery acquired on April 23, 2012. From Paine and others (2014).

Comparisons of lidar-extracted shoreline and wet-beach/dry-beach positions were conducted for THSCMP beach profile sites at Bolivar Peninsula, Galveston Island State Park, Matagorda Peninsula, Mustang Island, and northern and southern Padre Island. Lidar, imagery, and GPS comparisons on Mustang Island (sites MUI02 and MUI03, **fig. 14**) show good agreement between the lidar-extracted shoreline from the September-October 2016 survey and the wet-beach/dry-beach boundary evident on NAIP imagery acquired on September 30, 2016. GPS surveys of the shoreline acquired by THSCMP students on September 28, 2016 indicate a shoreline position that coincides with the lidar-extracted shoreline. Site MUI02 is located in Mustang Island State Park where a gap in the 2016 lidar coverage begins. The 2016 shoreline was mapped based on the wet-beach/dry-beach boundary on the NAIP imagery acquired on September 30, 2016 (**fig. 14a**).

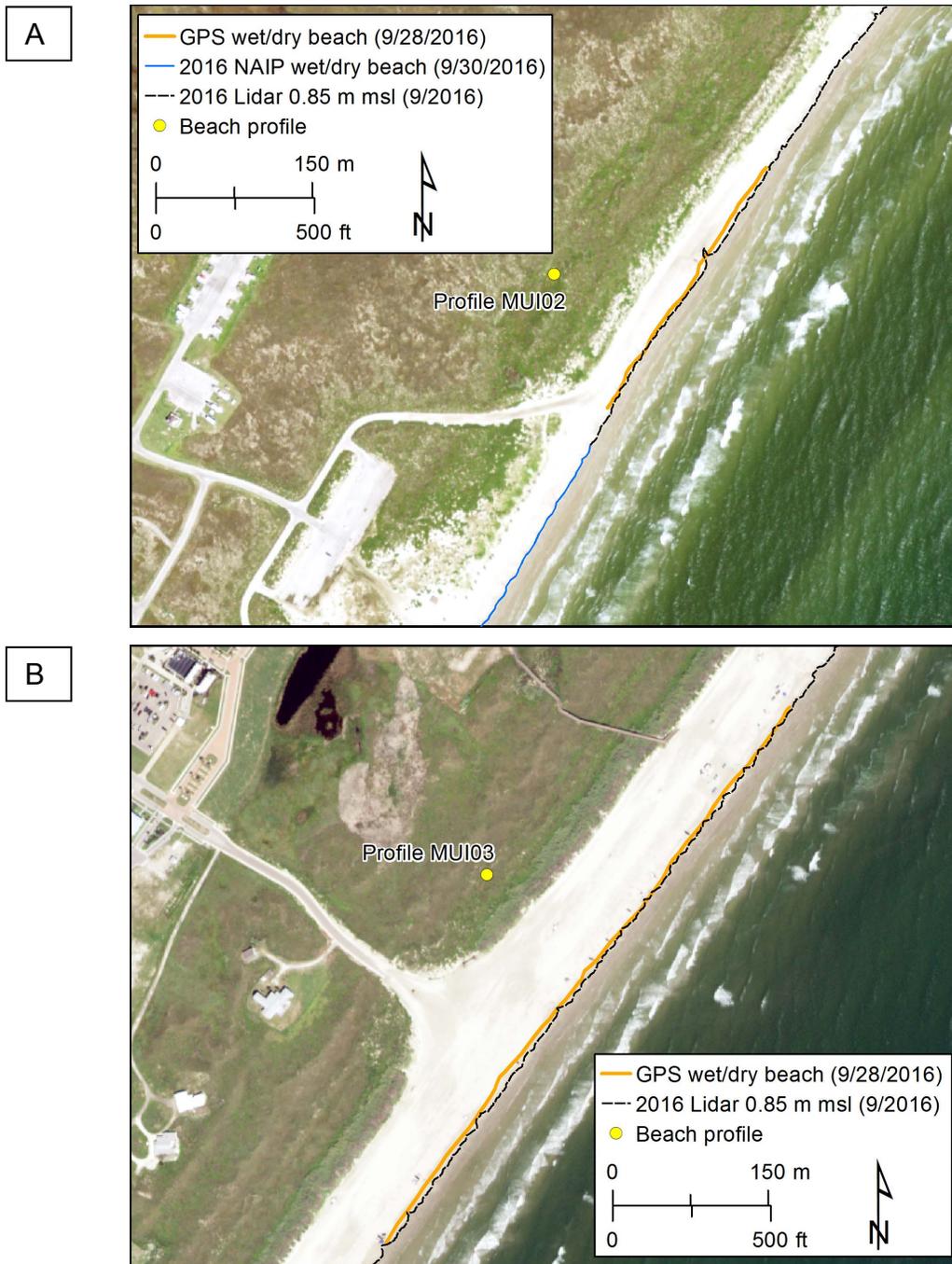


Figure 14. Shoreline position comparison at Mustang Island sites (A) MUI02 and (B) MUI03. Shorelines include the wet-beach/dry-beach boundary mapped on September 30, 2016 by THSCMP students and staff using ground GPS and the shoreline proxy extracted from airborne lidar data acquired in September 2016, superimposed on NAIP imagery acquired on September 30, 2016. From Paine and Caudle (2018).

The THSCMP has increased public awareness of coastal issues through the students themselves, as well as through media reports and presentations at conferences. Port Isabel High School students presented THSCMP to coastal visitors at the Winter Outdoor Wildlife Expo (WOWE) in January 2017 and 2018 at the South Padre Island Birding Center. One student gave an overview of the Program to the entire group while the rest of the students created teams to demonstrate the data collection activities. Tiffany Caudle presented a talk on the scientific impacts of the THSCMP at the Texas Chapter of the American Shore and Beach Preservation Association Symposium in Port Aransas, Texas in April 2017. A technical communication paper was published May 2017 in the Journal of Coastal Research describing the critical scientific data collected by THSMP students that helps scientists and coastal managers address coastal issues and understanding of dune and beach dynamics on the Texas coast (Caudle and Paine, 2017). A chapter about long-term monitoring of Mustang Island beaches by THSCMP students was written for a Geological Society of America guidebook that will be published later this fall. The website, too, continues to be instrumental in extending the reach of the program and increasing public awareness.

SCIENTIFIC RESULTS: 1997–2018

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

in Appendix C. GPS mapped shoreline and vegetation line data for each monitoring site are found in Appendix D.

Students participating in THSCMP have been collecting critical data since 1997 that is used by scientists at the Bureau to increase understanding of beach and dune recovery stages following major storms. Storm damage to beaches and dunes are indicated by the landward movement of shoreline and vegetation line positions and a decrease in sediment volume in the beach profile immediately after storms (**fig. 15**). The gradual seaward migration of the shore and vegetation lines plus sediment volume increases, tracks beach and dune recovery in the years following storms.

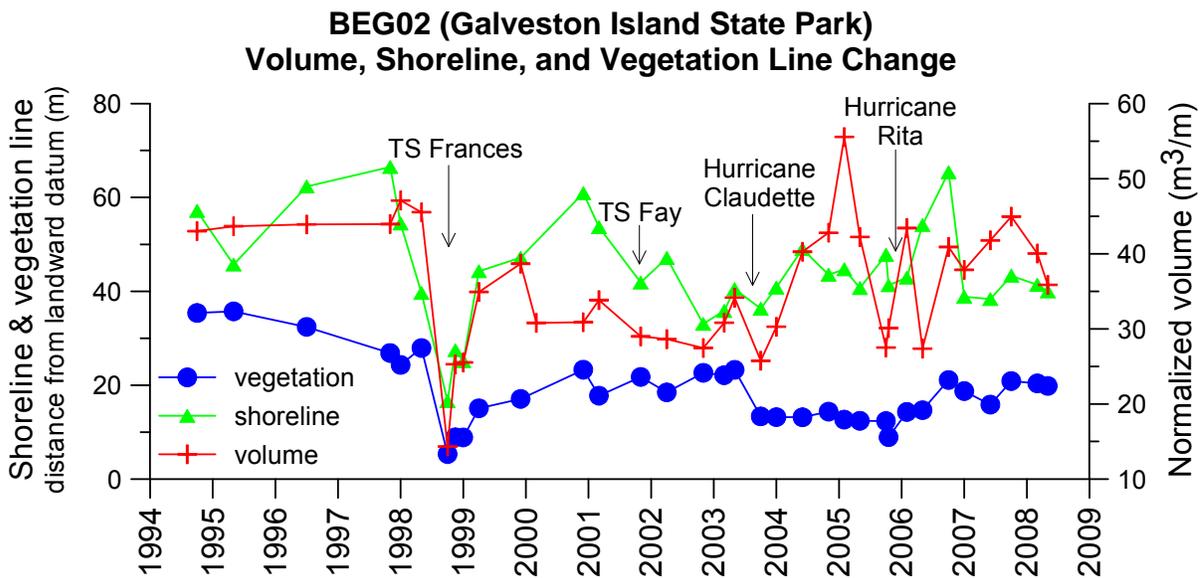


Figure 15. Profile volume, shoreline, and vegetation-line changes at Galveston Island State Park, September 1994–April 2008.

Tropical Storm Frances (September 1998) played a major role in reshaping the beaches on the upper Texas coast. Data collected by Ball High School students on Galveston and Follets Islands documented that Frances caused significant damage to beaches along the southeast coast of Texas comparable to damage caused by Hurricane Alicia in 1983 (Gibueat and others, 2002; Hepner and Gibeaut, 2004; Morton and Paine, 1985), a category 3 hurricane on the Saffir/Simpson scale (Simpson and Riehl, 1981). Several other severe storms have also impacted the

Galveston study area. Tropical Storms Allison (June 2001) and Fay (September 2002) and Hurricanes Claudette (July 2003) and Rita (September 2005) have each caused varying degrees of damage to beaches and dunes along the Texas coast (fig. 15). Ball High School students provided important pre-storm beach topography data from their field trips during the 2004–2005 and 2007–2008 academic years.

Hurricane Rita, a category 3 hurricane (Simpson and Riehl, 1981), made landfall at Sabine Pass on the Texas–Louisiana border in September 2005. Overall, Rita did not cause the kind of episodic beach or dune erosion on Galveston or Follets Islands that Frances did in 1998. **Figure 16** is a plot of pre- and post-storm beach profiles measured at BEG02 in Galveston Island State Park (fig. 6). Rita flattened the profile and caused a small amount of overwash deposition, but positions of the vegetation line and shoreline were not greatly affected (fig. 15; Gibeaut and others, 2008).

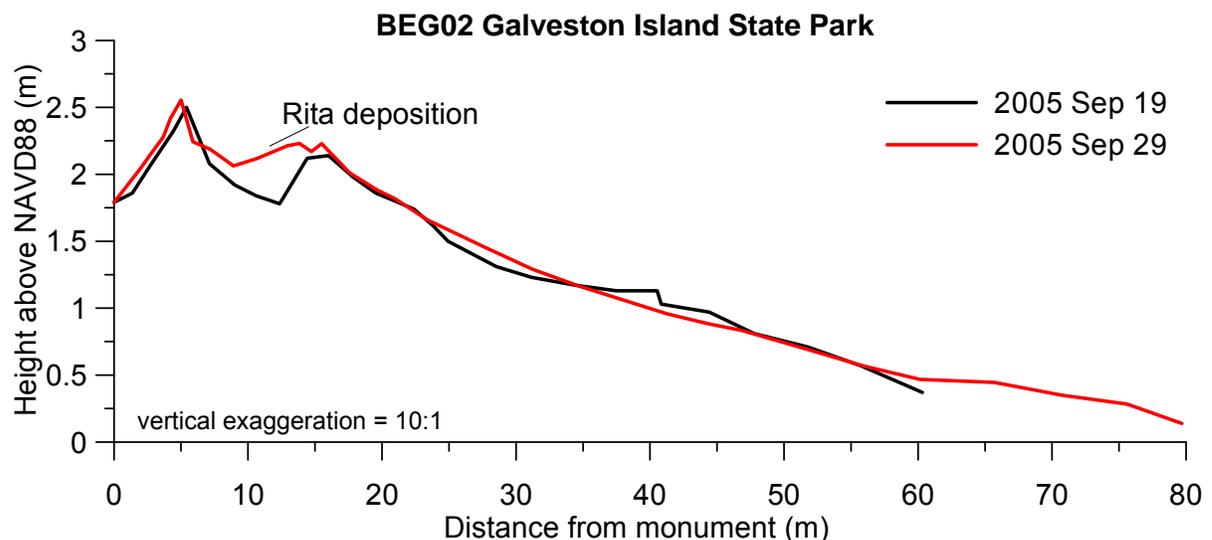


Figure 16. Plot of pre- and post-Hurricane Rita beach profiles measured at Galveston Island State Park.

The upper Texas coast was severely affected by the landfall of Hurricane Ike in September 2008. Galveston Island experienced significant beach and dune erosion, as well as extensive damage to property and infrastructure. Ball High School students were unable to participate in the THSCMP during the 2008–2009 academic year because of safety concerns while accessing their monitoring sites. Bureau and

TAMUCC scientists visited Galveston Island in early October 2008 to conduct ground surveys—beach profiles, photography, and observations of beach and dune conditions—of the area impacted by the hurricane. During this reconnaissance trip, scientists visited profile location BEG02 in Galveston Island State Park, where they discovered that the datum marker at BEG02 had been destroyed by the storm. Scientists used GPS techniques to navigate to the horizontal location of the datum marker, which post-storm was on the open beach. (Before the storm, the marker had been at the corner of a concrete picnic pavilion landward of the foredunes.) BEG02 (**fig. 6**) was reset approximately 60 m landward of the old datum marker along the same azimuth line. The new marker (a buried metal pipe) is landward of a washover feature. Reestablishing the marker allowed students to continue to monitor activities and storm recovery, and continue to compare pre- and post-storm profiles, at this location.

Ball High School students from the 2007–2008 academic year provided extremely valuable pre-storm profile data on February 8, 2008, and April 23, 2008. These data have been used to determine how much the beach and dunes changed after Hurricane Ike. **Figure 17** is a profile plot at BEG02 comparing the Ball High School pre-storm profile (April 2008) with the post–Hurricane Ike profile measured on October 7, 2008. The post–Tropical Storm Frances profile from September 16, 1998, is also plotted for comparison. At Galveston Island State Park the dune system was completely destroyed; the shoreline (wet beach/dry beach boundary) moved 53 m landward between April 23, 2008, and October 7, 2008; the vegetation line moved 56 m landward; and the old datum point was 1.14 m above the post-storm surface of the beach (**fig. 17**, Caudle and Paine, 2017). Data from one year post-storm is also included. This profile shows that the elevation of the beach had been restored, the beach width (dunes to waterline) has increased, and incipient dunes are beginning to form (**fig. 17**).

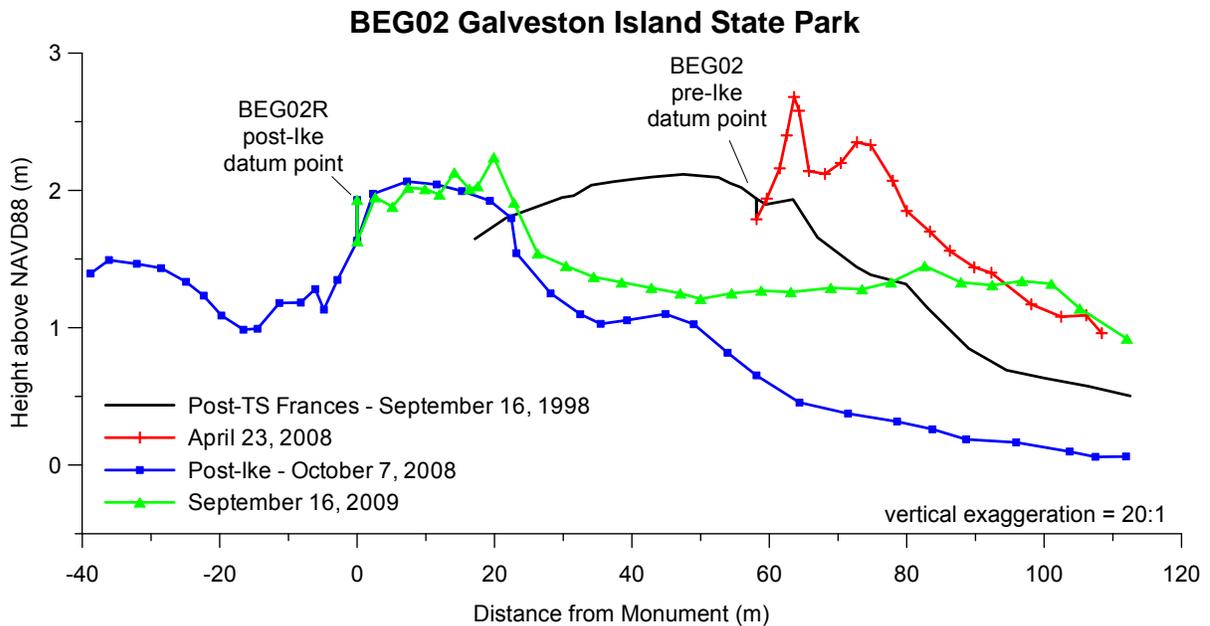


Figure 17. Beach-profile plots from BEG02 in Galveston Island State Park comparing the post–Hurricane Ike profile with a pre-storm profile from early 2008 and the post–Tropical Storm Frances profile from September 1998. Data from September 2009 (one year post-storm) is also included.

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 BEG02 (**fig. 18**), beaches and dunes had continued to recover post–Hurricane Ike. Between September 2009 and January 2011, the foredunes at BEG02 had begun to grow. Whether initial growth of the foredunes is due to natural recovery processes or human intervention is unclear. The foredune ridge has continued to grow in the intervening years. A wide vegetated zone with expanding coppice dunes has developed between the seaward base of the foredunes and the landward extent of wave run-up (**fig. 18**).

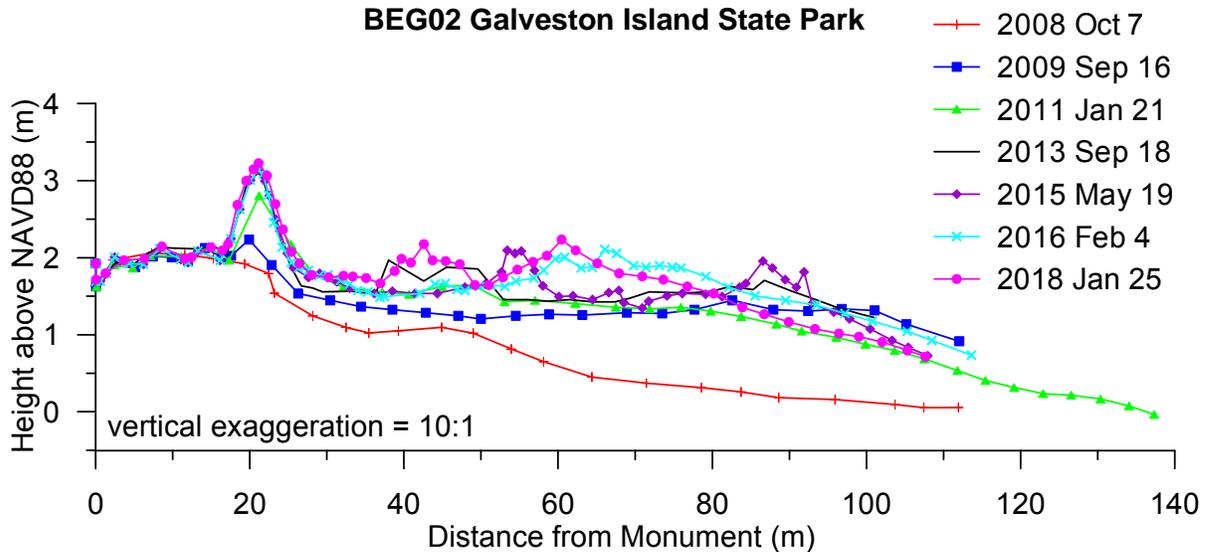


Figure 18. BEG02 datum reset post-Hurricane Ike profile plus data collected by Ball High School students. Students are monitoring recovery of the beaches and dunes at this site.

Despite Ike being only a category 2 storm on the Saffir/Simpson scale (Simpson and Riehl, 1981) at the time of landfall, the sheer size of the hurricane caused impacts along the entire Texas coast. Dune erosion due to Hurricane Ike was documented on the middle Texas coast at Matagorda Peninsula and to a lesser extent on Mustang Island (see Appendix C). Van Vleck and Palacios High Schools students have been monitoring the recovery of the dunes (**fig. 19**) and the seaward movement of the vegetation line post-Hurricane Ike on Matagorda Peninsula (**fig. 7**).

Palacios, Van Vleck, and Tidehaven students have continued their beach measurements on the beaches adjacent to Matagorda Bay Nature Park. The park has two special circumstances that make this monitoring especially informative and important. (1) Monitoring sites have been established on the updrift side of the jetty at the mouth of the Colorado River and (2) at sites that allow students to compare a beach/dune system where vehicular traffic on the beach will be limited (MAT03) with an adjacent area where vehicular traffic will continue to be unrestricted (MAT01 and MAT02). Impacts of coastal structures (jetties) are critical to coastal management,

and impacts of vehicles on Texas' beaches are not well documented. Vehicular traffic was permitted on the beach adjacent to the Nature Park until 2007. Vehicular traffic was restricted in the section for several years. Currently, vehicles are able to access this section of beach but traffic is limited due to difficult driving conditions.

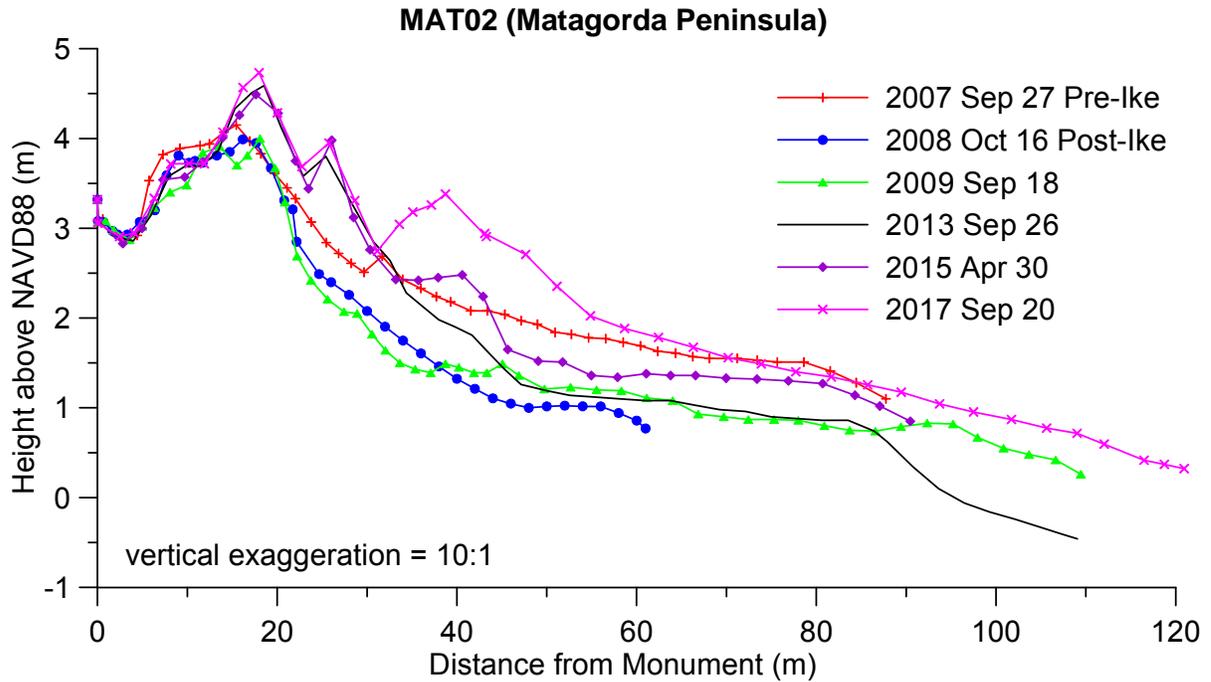


Figure 19. MAT02 pre- and post-Hurricane Ike profile data collected by Palacios High School students. Students are monitoring recovery of the foredune at this site.

During the 2009–2010 academic year, the U.S. Army Corps of Engineers began constructing a new east jetty at the mouth of the Colorado River. GPS-mapped shorelines from September 2009 and September 2012 show a 45-m seaward movement of shoreline position at MAT03 updrift of the new jetty (**fig. 20** and Appendix D). Student data at MAT03 has shown that the new jetty on east Matagorda Peninsula has caused the shoreline to move seaward at an average rate of 11 m per year between 2009 and 2016.

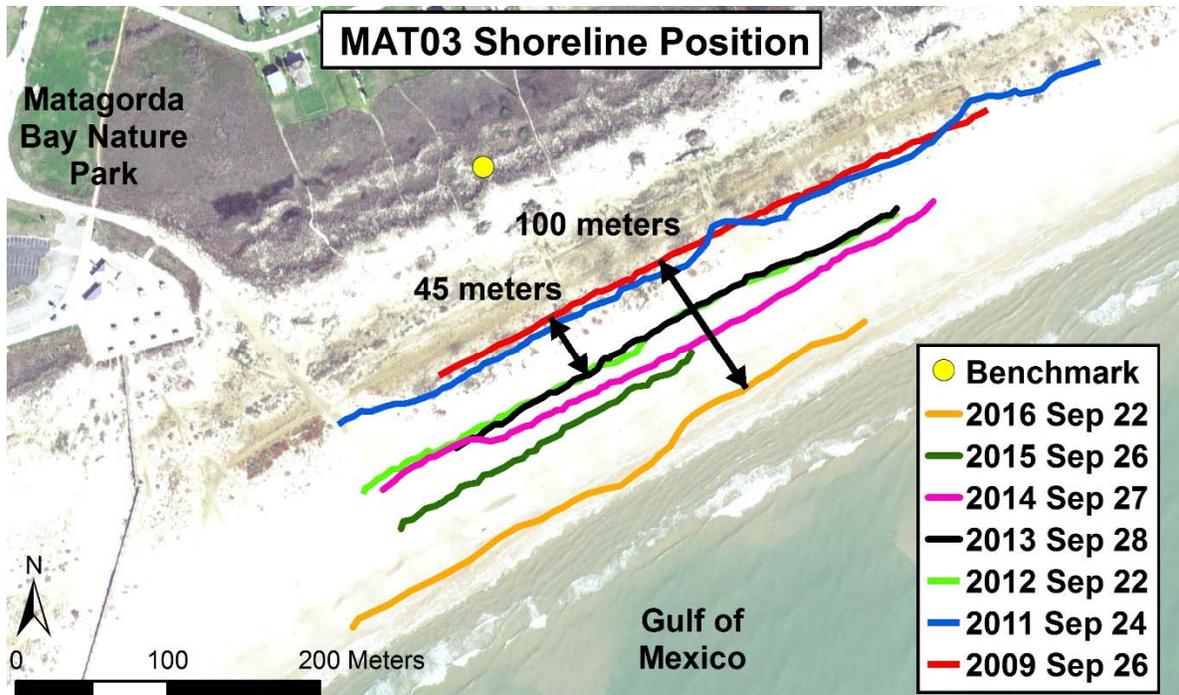


Figure 20. Shoreline position change at Matagorda Peninsula.

The shoreline and vegetation line position have been continuously moving seaward and volume has been increasing at this site throughout the study period (**fig. 21**). The combination of the new jetty impounding sand on the updrift side and the decreased vehicle access at MAT03 has allowed for coppice dune formation to occur on the expanded backbeach area and for new vegetation to develop without being disturbed. On the field trips during the 2015–2016 and 2016—2017 academic years, it was documented that salt marsh plants have become established on the widened backbeach area in the swales between the coppice dunes. Due to the increased width of the backbeach, the salt marsh environment in the swales, and the numerous venomous snakes in the area profile data will no longer be collected at this site by Tidehaven High School. Students from Van Vleck and Palacios High Schools will continue to monitor the shoreline and vegetation line positions at MAT03 to document if this site continues to advance or eventually stabilize.

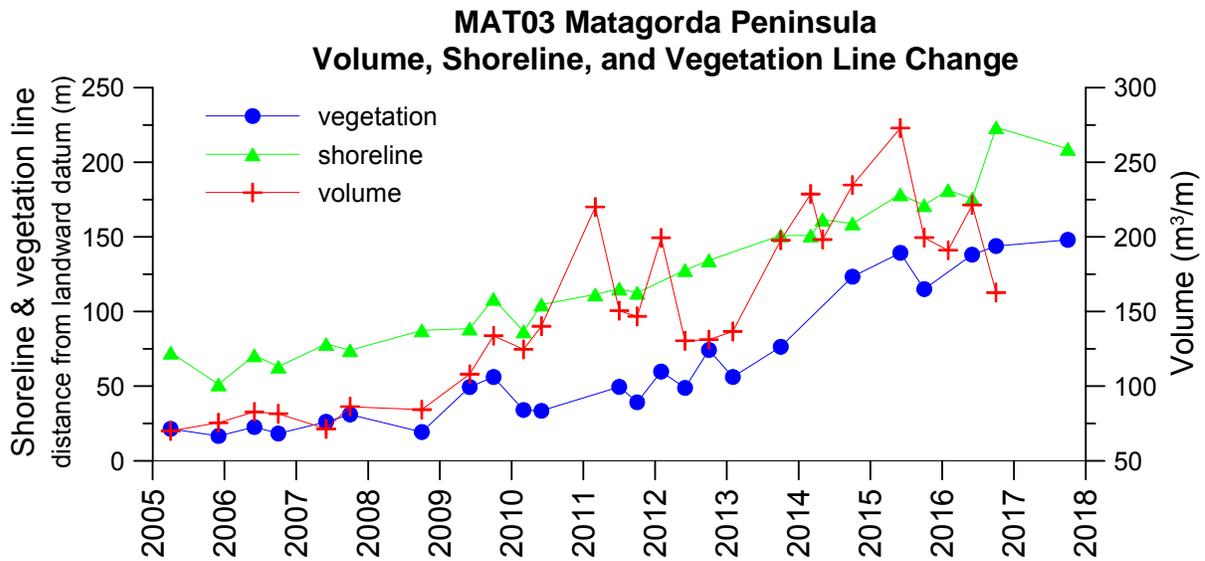


Figure 21. Changes in beach and dune volume, shoreline position, and vegetation line position at MAT03 on Matagorda Peninsula.

The beach-monitoring activities of Port Aransas High School students have provided beneficial information about the beach and dune system on Mustang Island (**fig. 8**). 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. Beach maintenance practices vary along the island and have changed over time which the students have documented through their data. Several beaches on Mustang Island, particularly within the City of Port Aransas boundaries, are regularly scraped to remove seaweed (*Sargassum*) from the forebeach. 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 22** 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 relatively stable.

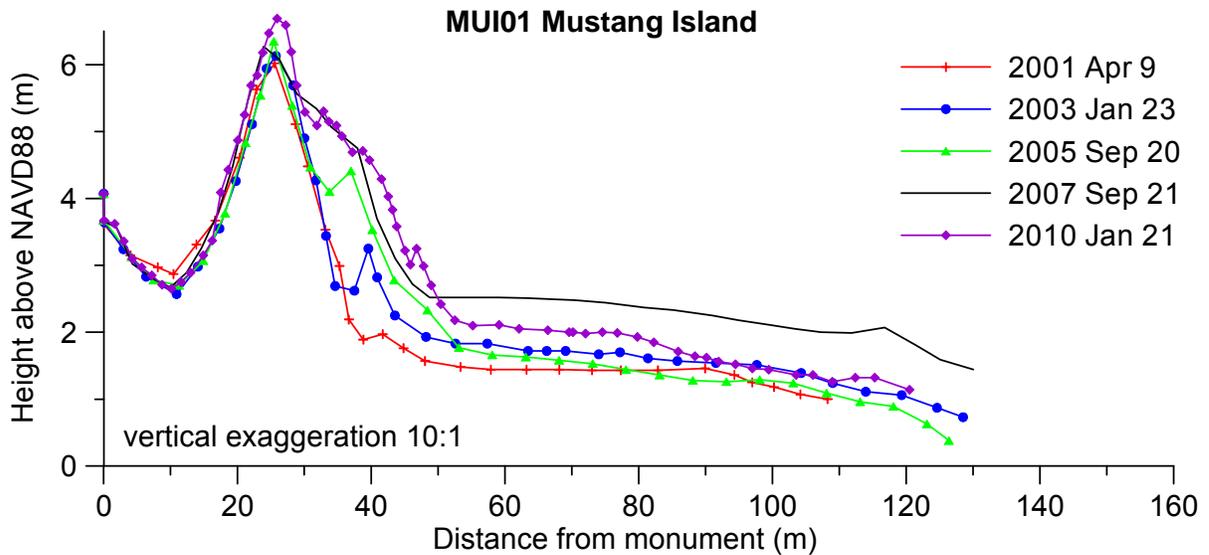


Figure 22. Foredune expansion at MUI01 on Mustang Island.

When Port Aransas students arrived to collect profile data in October 2012, a large part of the dune face had been excavated (**figs. 23, 24**) 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 had again been excavated since the 2014–2015 academic year. The current width of the foredune is narrower and the volume of sand in the profile is significantly less than when THSCMP began monitoring in 1999 (see change plot in Appendix B). Also the crest of the foredune is lower in elevation because the dune crest is no longer stabilized by vegetation and sand is being carried away by the wind. The excavated area was slowly being filled in. During the field trips of the 2017–18 academic year the foredune had been completely refilled (**fig. 24**).

Hurricane Harvey made landfall on San Jose Island (northeast of Mustang Island) on August 25, 2017 as a category 4 storm. The City of Port Aransas was devastated by impacts from a storm surge from the bay and Aransas Pass and wind and rain damage. The school remained closed for several weeks. Students and staff from the Harte Research Institute at Texas A&M University Corpus Christi collected post-storm profiles on September 5, 2017 which were compared to pre-storm profiles collected by Port Aransas High School students on May 4, 2017. Despite the

proximity to the landfall of a major hurricane, the beach and dune system monitored by THSCMP suffered minor impacts. The Mustang Island beaches were planed (lowered) but there is no evidence of scarping on the dunes (**fig. 28**). The greatest impact to the Mustang Island beach was documented at MUI01, the profile closest to the south jetty at Aransas Pass and center of the hurricane (**fig. 28A**). The beach recovered to pre-storm conditions at all three profile locations by January 2018. Beach erosion and dune breeches are present on San Jose Island where Harvey made landfall but this area is not monitored by THSCMP students.

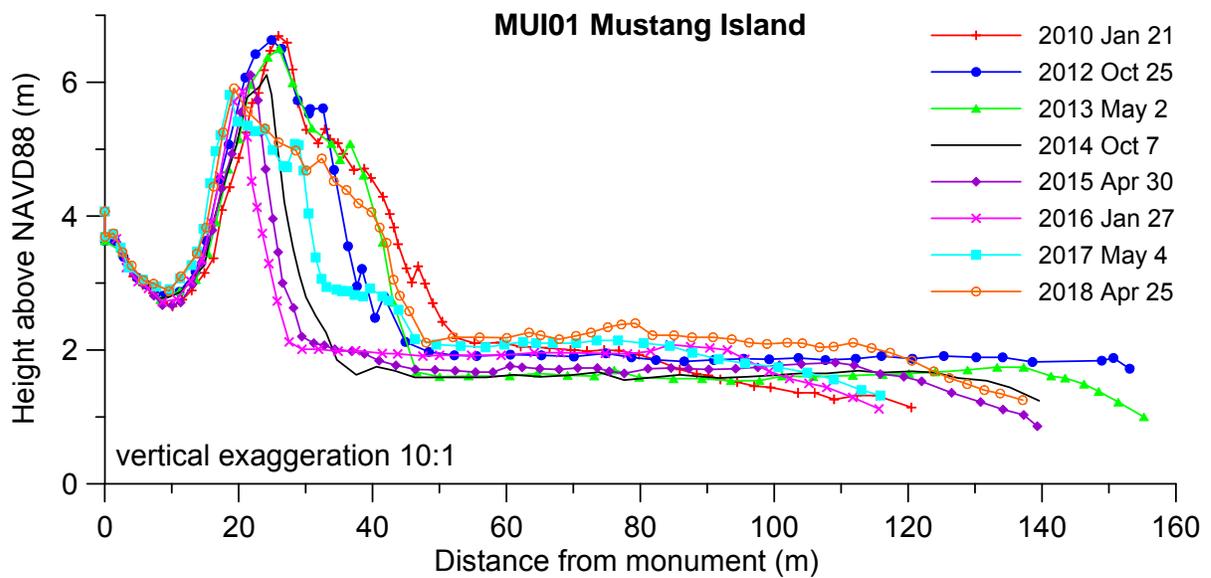


Figure 23. Excavated dune profile at MUI01 on Mustang Island.



Figure 24. Excavated dune at MUI01 on Mustang Island looking (A) north toward Horace Caldwell Pier, and (B) landward.

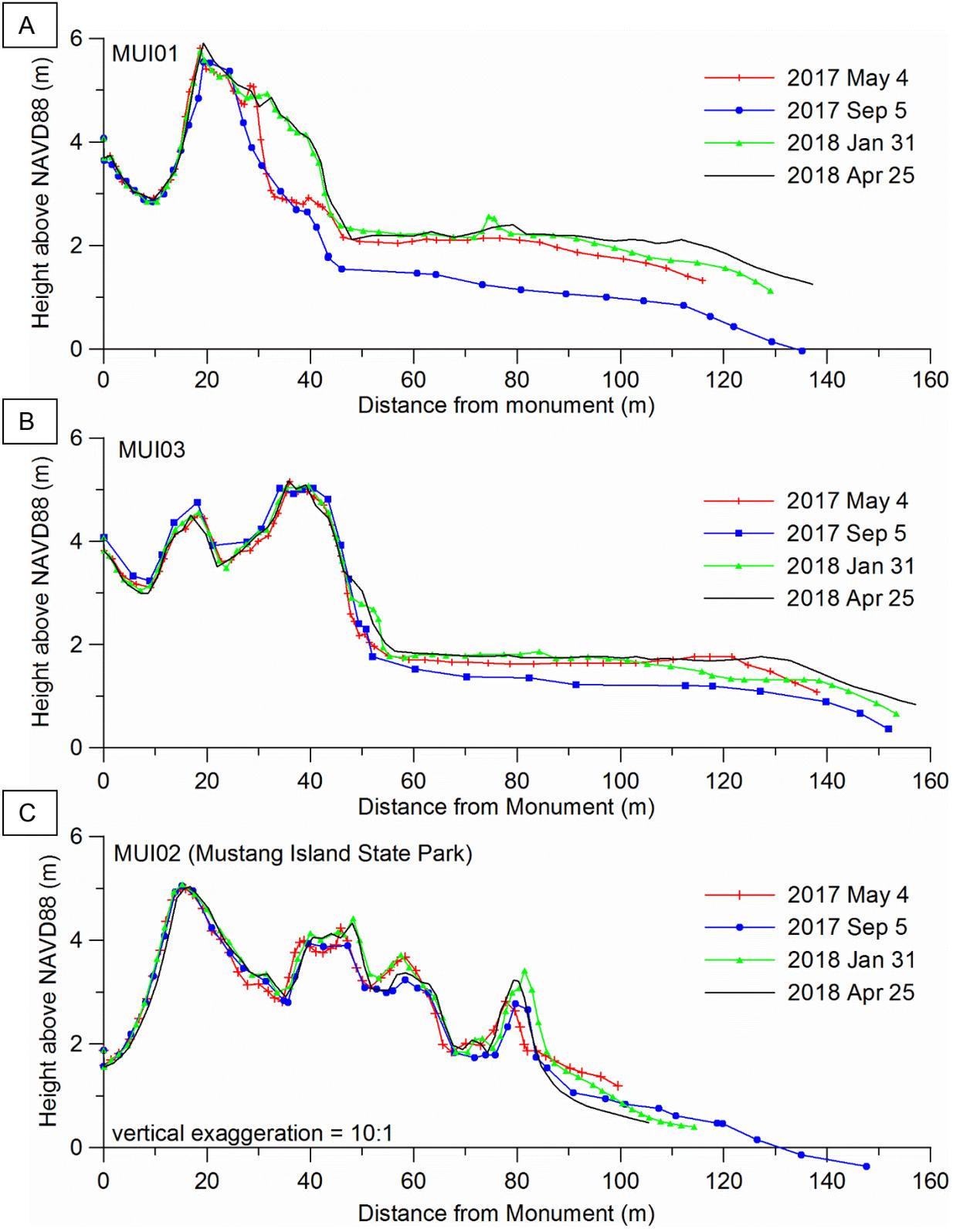


Figure 25. Mustang Island pre- and post-Hurricane Harvey profile data collected by Port Aransas High School and Texas A&M University Corpus Christi at (A) MUI01, (B) MUI03, and (C) MUI02.

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

The SPI02 (fig. 10) monitoring site has been used by students and scientists to monitor the growth of dunes (sand volume) and shoreline movement. When SPI02 was established in August 2000, there were no dunes between the retaining wall and waterline at this location. Since that time, student collected data has been quantifying the effects of the installation of sand fences, planting of vegetation, and numerous BUDM nourishment projects (fig. 26). Port Isabel data have documented an overall trend to shoreline advancement and sediment-volume increase throughout the study period (Caudle and others, 2014).

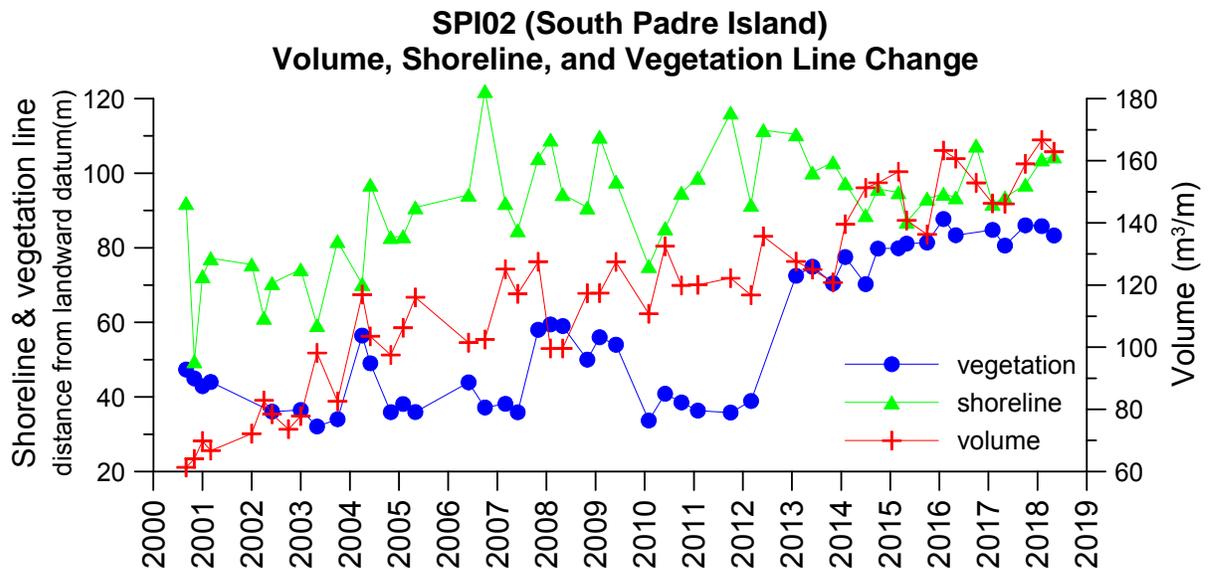


Figure 26. Changes in sand volume and shoreline and vegetation line position at SPI02 on South Padre Island due to beach-nourishment projects and the installation of sand fences.

The vegetation line had remained in a relatively stable position prior to 2012. Since that time, a push-up dune was created by beach-maintenance practices (beach scraping to remove seaweed). The sand and seaweed scraped from the beach was placed just seaward of the vegetation line, and vegetation has begun to grow on the piled material (**fig. 26**).

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

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

A large beach-nourishment project using BUDM from Brazos Santiago Pass was completed on South Padre Island in early 2011. The width of the beach and volume of sand significantly increased at the SPI08 location, although there were still no dunes or vegetation in front of the retaining wall (**fig. 27**). On the May 13, 2011, field trip, Port Isabel students observed that a 0.5-m scarp had formed at the shoreline. The students continued to monitor this site during the 2011–2012 academic year to determine whether the nourished beach would reach equilibrium. The shoreline position had returned to the pre-nourishment position. After an initial significant decrease in beach volume (to pre-nourishment levels), volume on the back beach has increased steadily because of the re-installation of sand fences. In May 2013,

the sand fences remained in place, serving to trap sand in front of the retaining wall at this site, and vegetation had been planted on the incipient dunes. On the final field trip of the 2013–2014 academic year, a large push-up dune was present seaward of the vegetation line. Throughout the 2014–2015 academic year, this location remained stable. The large spike in beach volume in late 2015 was due to a new push-up dune.

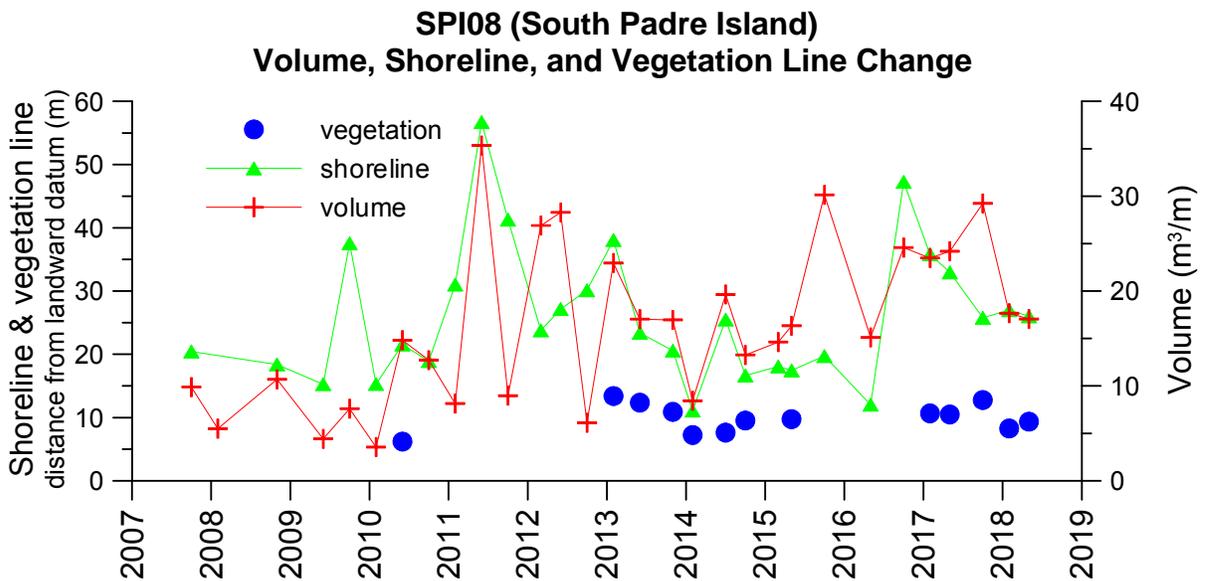


Figure 27. Sand volume and shoreline position changes at SPI08 on South Padre Island due to beach-nourishment projects and the installation of sand fences.

A beach nourishment project using beneficial use material from Brazos Santiago Pass, took place during the winter of 2015–2016. Profile data could not be collected on the January field trip because the area in front of the condominiums was blocked by dredging equipment. The spring 2016 data collection showed that shoreline position and beach volume were similar to the pre-nourishment conditions (**fig. 27**). This profile site benefited from a small nourishment project located just to the south in late 2016. Throughout the 2016–2017 academic year, the shoreline position was stabilized in a more seaward location than it had been in previous years (**fig. 27**). Increased beach volume was also stable due to a vegetated dune. Volume decreased and shoreline position moved seaward during the 2017–2018 academic

year. Port Isabel students will continue to monitor this rapidly changing and chronically eroding location.

Cunningham Middle School students have witnessed remarkable changes in the dune crest elevation at their profile location after 9 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 had been transported from the top of the foredune down the back slope of the dune so that the landward toe of the dune buried the new datum pipe. This North Padre Island site has added a highly dynamic foredune location to the THSCMP system that is interesting to monitor and to compare with the well-vegetated foredunes to the north on Mustang Island.

Six new monitoring sites were added during the 2015–2016 academic year. The addition of High Island High School to THSCMP created three new monitoring sites on Bolivar Peninsula (**fig. 5**). Two of the sites are adjacent to Rollover Pass. The location of these sites will allow for monitoring of the effects to adjacent beaches when the pass is closed. Ball High School students added sites at Jamaica Beach and the Dellanera RV Park southwest of the Galveston Seawall (**fig. 6**). The Jamaica Beach site monitors a CEPRAsponsored dune restoration project. The Dellanera site monitors a beach nourishment and dune creation project at this chronically eroding location. Cunningham Middle School added a site on the North Padre Island seawall (**fig. 9**). This location monitors the effects of beach nourishment using beneficial use material from Packery Channel and beach maintenance practices seaward of the seawall.

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 also valuable data for coastal researchers and decision makers. The 2017–2018 academic year was productive, with Ball, High Island, Palacios, Port Aransas, Port Isabel and Van Vleck High Schools and Cunningham Middle School collecting data on two or three field trips throughout the academic year. Brazosport High School has been recruited to join THSCMP 2018–2019 academic year to replace Tidehaven ISD.

In the 21 years since the inception of the program, work by students participating in THSCMP has been beneficial to Bureau researchers and coastal managers in several research projects. Analysis of the data has been used to investigate storm effects and monitor recovery; impacts to the beach and dune system due to beach nourishment, construction of jetties, and beach maintenance practices; and verify shoreline positions for calculating change rates. Through this successful student research program, scientists, students, and the public continue to gain a better understanding of processes and shoreline change along the Texas coast.

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

ACKNOWLEDGMENTS

This project was supported by grant number 17-188-000-9825 from the Texas General Land Office to the Bureau of Economic Geology, The University of Texas at Austin. Tiffany Caudle served as the Principal Investigator. The project was funded under a Coastal Management Program (Cycle 21) 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 NA16NOS4190174. Additional funds to support the project came from the Trull Foundation and The Jackson School of Geosciences. Field trip support was provided by staff at Matagorda Bay Nature Park, Lower Colorado River Authority and graduate students from the Coastal & Marine Geospatial Sciences Lab at the Harte Research Institute, Texas A&M University Corpus Christi.

REFERENCES

- Caudle, T. L. and Paine, J. G., 2012, Pre-college student involvement in Texas coastal research: Gulf Coast Association of Geological Societies Transactions, v. 62, p. 27-38.
- Caudle, T. L. and Paine, J. G., 2017, Applications of coastal data collected in the Texas High School Coastal Monitoring Program (THSCMP): Journal of Coastal Research, v. 33, no. 3, p. 738-746.
- Emery, K. O., 1961, A simple method of measuring beach profiles: Limnology and Oceanography, v. 6, no. 1, p. 90-93.
- Gibeaut, J. C. and Caudle, T. L., 2009, Defining and mapping foredunes, the line of vegetation, and shorelines along the Texas Gulf coast. The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas General Land Office under GLO contract number 07-005-22, 30 p.
- Gibeaut, J. C., Gutiérrez, R, and Hepner, T., 2002, Threshold conditions for episodic beach erosion along the southeast Texas coast. Gulf Coast Association of Geological Societies Transactions, v. 52, p. 323-335.
- 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.
- Krause, G., 2004, The "Emery-Method" revisited—Performance of an inexpensive method of measuring beach profiles and modifications: Journal of Coastal Research, v. 20, no. 1, p. 340-346.
- O'Connell, J., 2001, Beach and dune profiles: An educational tool for observing and comparing dynamic coastal environments: Marine Extension Bulletin, Woods Hole Oceanographic Institution Sea Grant Program, Massachusetts, 6 p.

- Paine, J.G., and Caudle, T. L., 2018, Shoreline movement along the Texas Gulf Coast, 1930s to 2016: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas General Land Office under GLO contract number 16-201-000, 59 p.
- 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.
- Paine, J. G., Mathew, S., and Caudle, T., 2012, Historical shoreline change through 2007, Texas Gulf coast: rates, contributing causes, and Holocene context, Gulf Coast Association of Geological Societies Journal, v. 1, p. 13-26.
- Paine, J. G., Caudle, T. and Andrews, J., 2014, Shoreline movement along the Texas Gulf Coast, 1930's to 2012: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas General Land Office under GLO contract number 09-074-000, 52 p.
- Simpson, R. H. and Riehl, H., 1981, The hurricane and its impact: Baton Rouge, Louisiana State University Press, 398 p.
- U.S. Army Corps of Engineers, 2017, 2016 USACE NCMP topobathy lidar DEM: Gulf Coast (TX), Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX), Charleston, SC.

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 Geoid12B Ellipsoid Model. Profile sites are listed in the order they appear along the Texas coast starting from the northeastern most site closest to the Texas-Louisiana border and traveling south.

Profile	Latitude (deg min)	Longitude (deg min)	Easting (m)	Northing (m)	HAE (m)	NAVD88 (m)	Azimuth (M)
HIB01	29 33.08	94 23.04	365917.69	3269868.01	-25.18	1.64	150
BOL03	29 30.60	94 29.64	355196.55	3265428.50	-23.26	3.54	150
BOL02	29 30.00	94 31.20	352663.65	3264343.08	-23.62	3.17	150
DEL01	29 14.44	94 52.38	317984.46	3236109.93	-23.84	2.74	130
BEG02¹	29 11.64	94 57.09	310255.20	3231059.16	-24.75	1.79	139
BEG02R	29 11.67	94 57.11	310228.82	3231110.58	-24.61	1.93	139
GLO06²	29 11.12	94 58.05	308696.85	3230117.35	-24.32	2.20	138
JAM02	29 10.86	94 58.38	308140.86	3229662.18	-24.73	1.79	140
BEG08³	29 3.22	95 8.90	290838.52	3215830.51	-24.21	2.16	145
MAT01	28 36.67	95 56.55	212269.73	3168453.74	-22.77	3.79	148
MAT02	28 36.31	95 57.47	210751.39	3167825.80	-23.25	3.32	148
MAT03	28 35.91	95 58.48	209090.26	3167112.23	-21.81	4.78	148
MUI01	27 49.53	97 3.40	691396.24	3079393.46	-22.29	4.07	123
MUI03	27 47.66	97 5.08	688697.42	3075882.34	-22.24	4.07	125
MUI02	27 40.42	97 10.19	680502.60	3062387.97	-24.22	1.88	120
NPC06	27 35.99	97 12.66	676557.71	3054150.56	-21.76	4.19	110
NPI08	27 35.86	97 12.78	676359.73	3053901.89	-23.32	2.62	110
SPI08	26 8.17	97 10.10	683116.29	2892056.38	-18.32	3.22	75
SPI02	26 6.79	97 9.93	683438.99	2889509.24	-18.11	3.39	78
SPI01	26 4.57	97 9.46	684274.71	2885422.83	-18.48	2.97	70

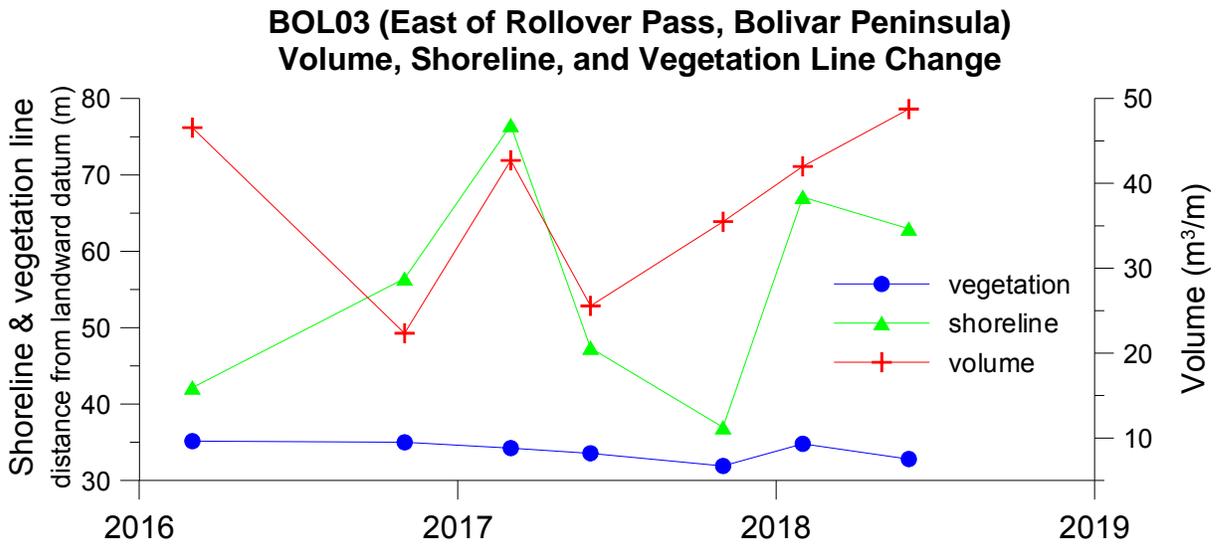
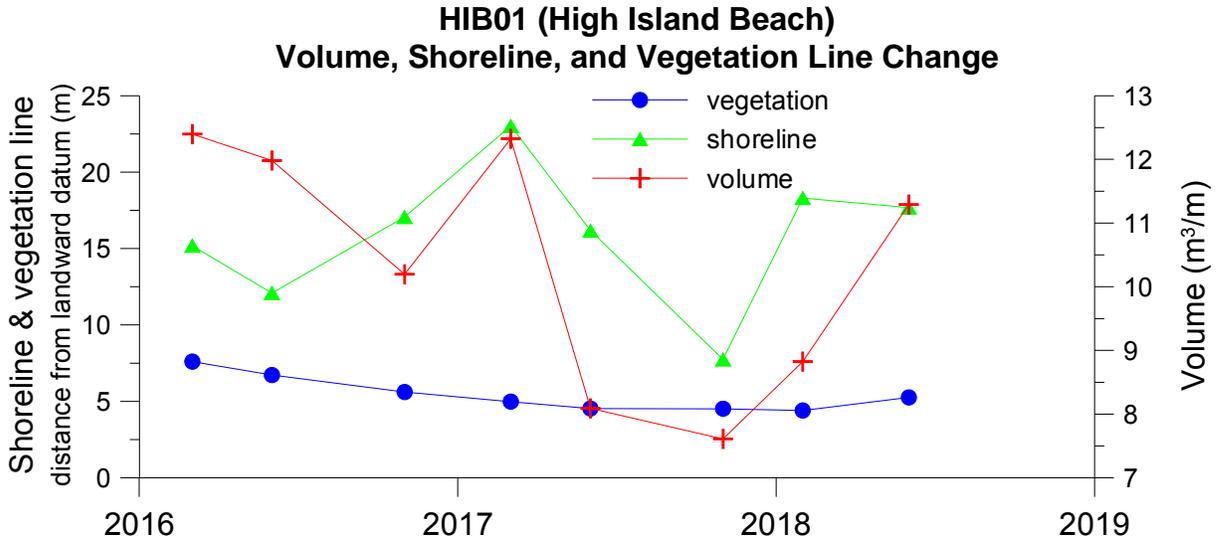
¹BEG02 reset in October 2008 after Hurricane Ike.

²GLO06 was monitored by Ball High School from post-Hurricane Ike until the Jamaica Beach (JAM02) site was added in October 2015. JAM02 is adjacent to the GLO06 site and monitors a CEPRA dune restoration project.

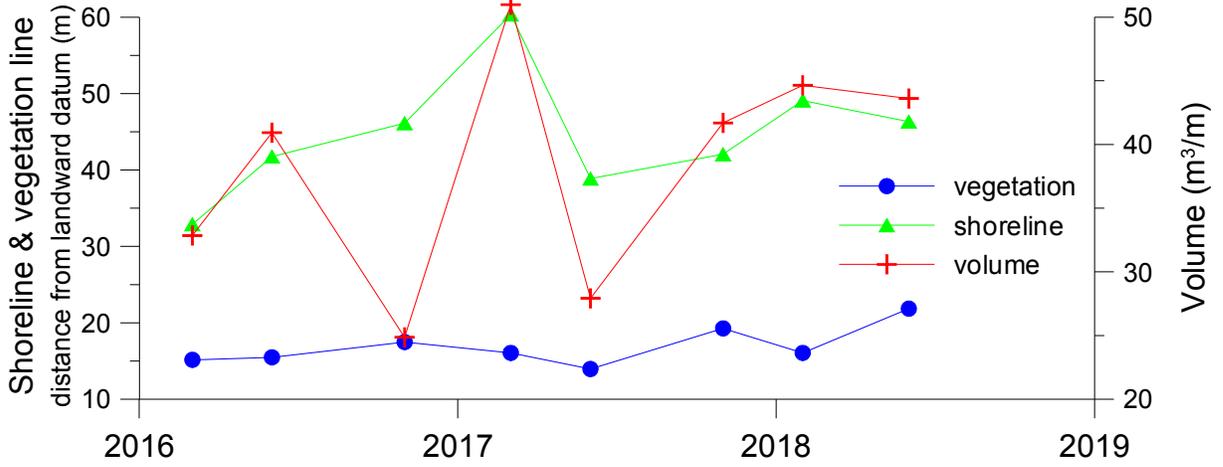
³BEG08 cannot be monitored by Ball High School students post-Hurricane Ike. The original datum was lost in the storm. The reset mark is landward of the Bluewater Highway and therefore too dangerous for students to monitor.

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

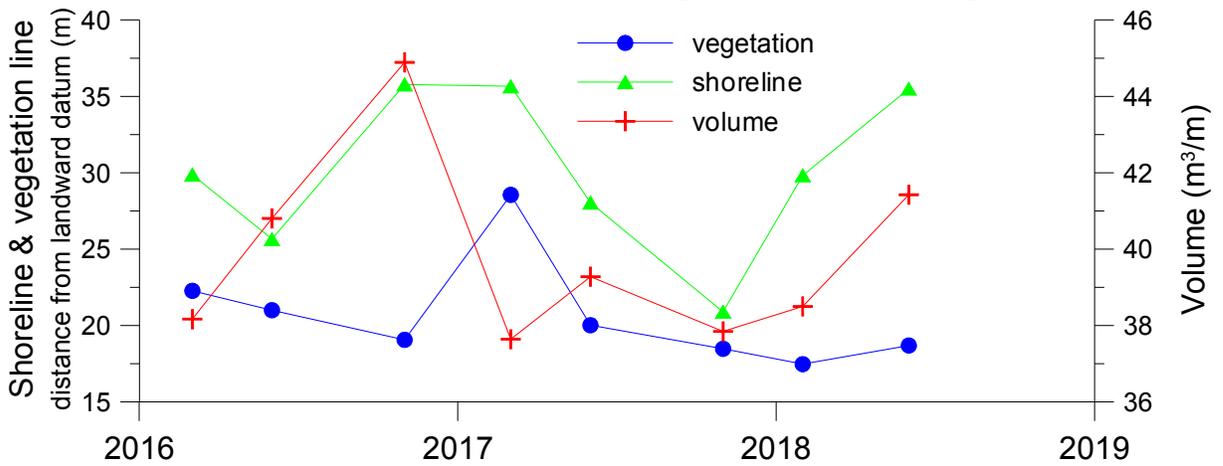
Sediment volume was calculated above 1 meter NAVD88 for all profiles unless otherwise indicated. Profiles that did not extend below the 1 meter NAVD88 elevation were extrapolated.



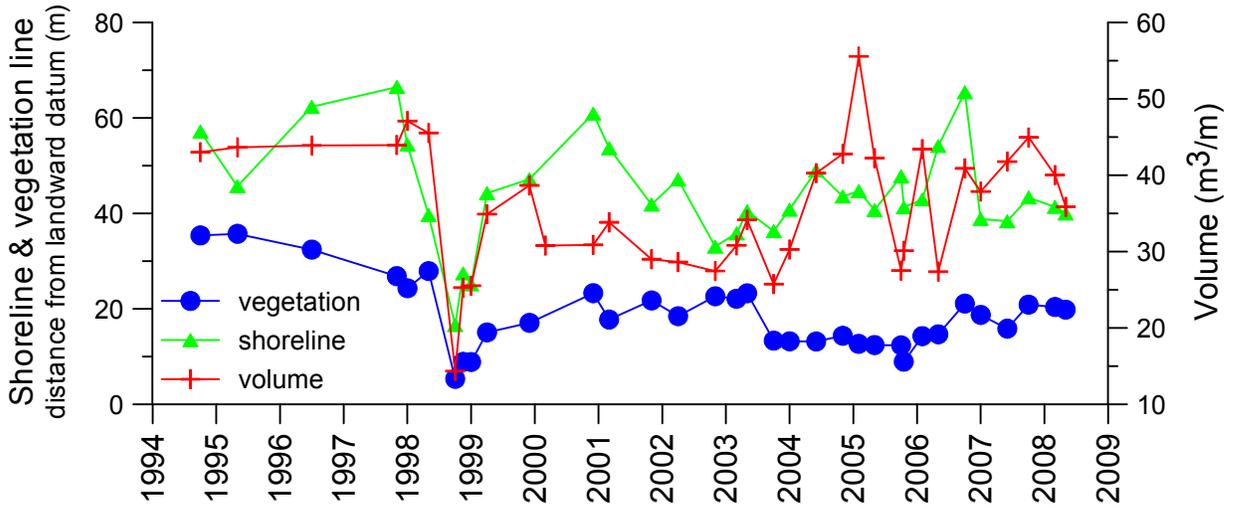
**BOL02 (West of Rollover Pass, Bolivar Peninsula)
Volume, Shoreline, and Vegetation Line Change**



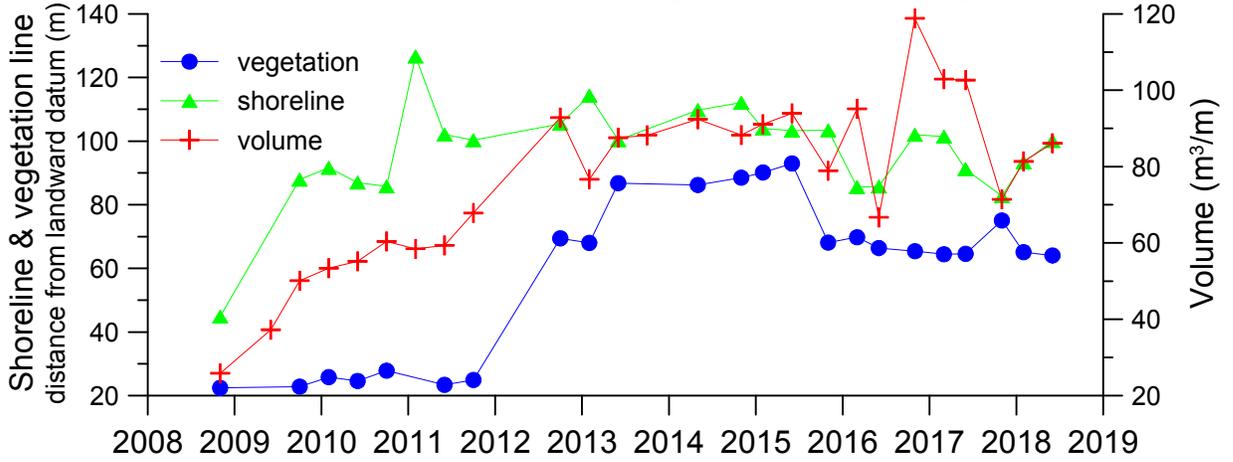
**DEL01 (Dellanera RV Park, Galveston Island)
Volume, Shoreline, and Vegetation Line Change**



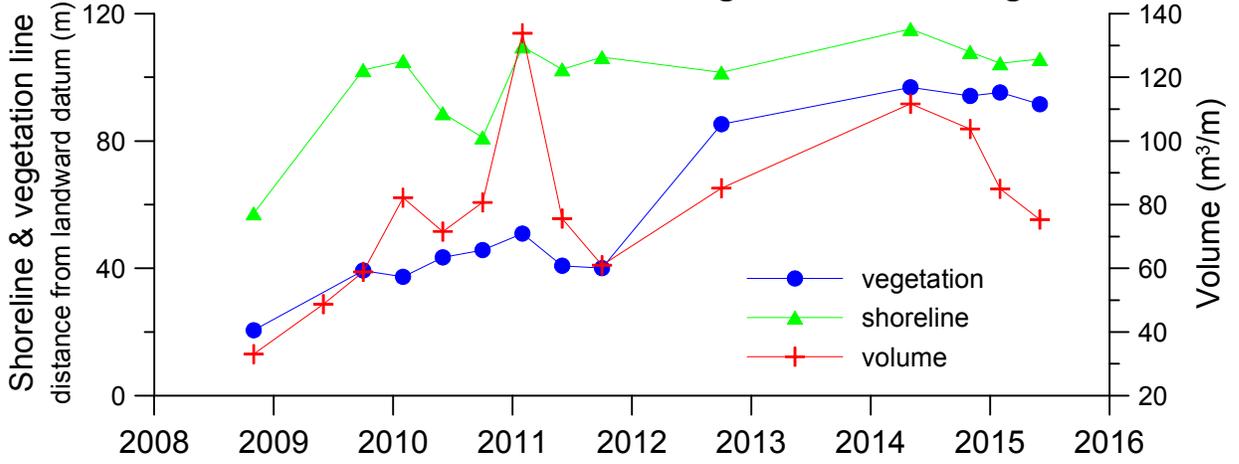
**BEG02 (Galveston Island State Park)
Volume, Shoreline, and Vegetation Line Change**



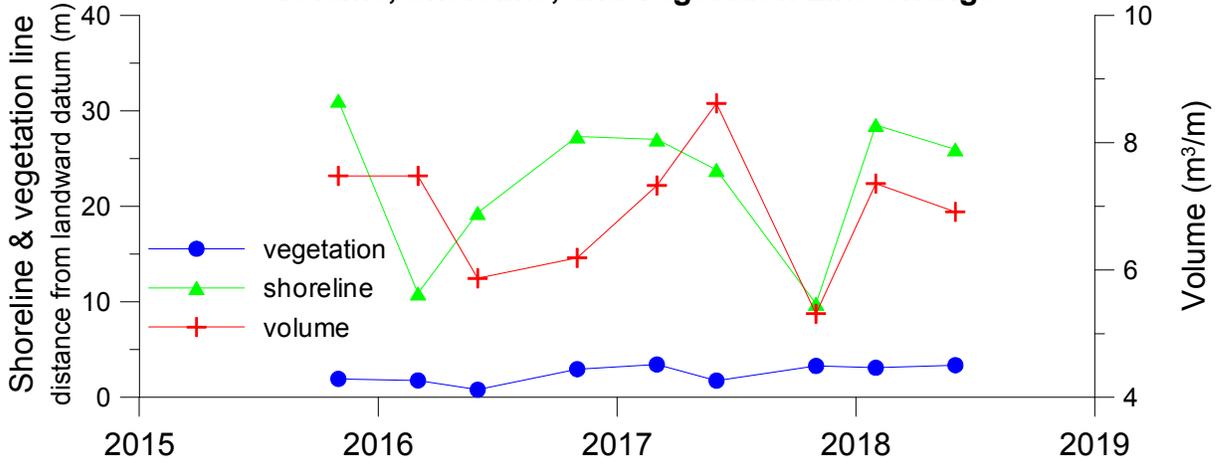
**BEG02R Post-Ike (Galveston Island State Park)
Volume, Shoreline, and Vegetation Line Change**



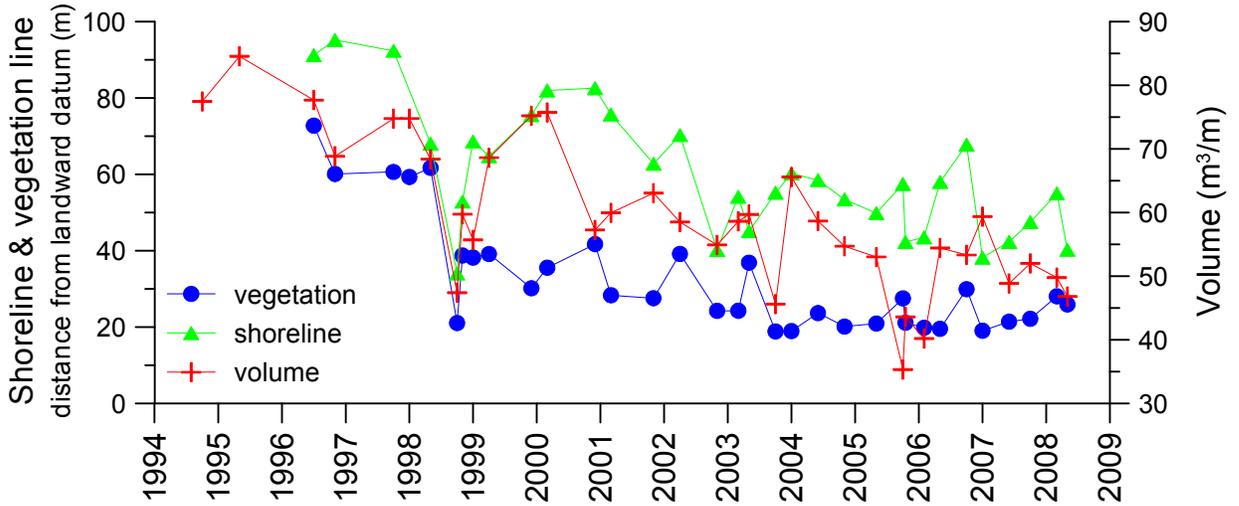
**GLO06 (Galveston Island State Park)
Volume, Shoreline, and Vegetation Line Change**



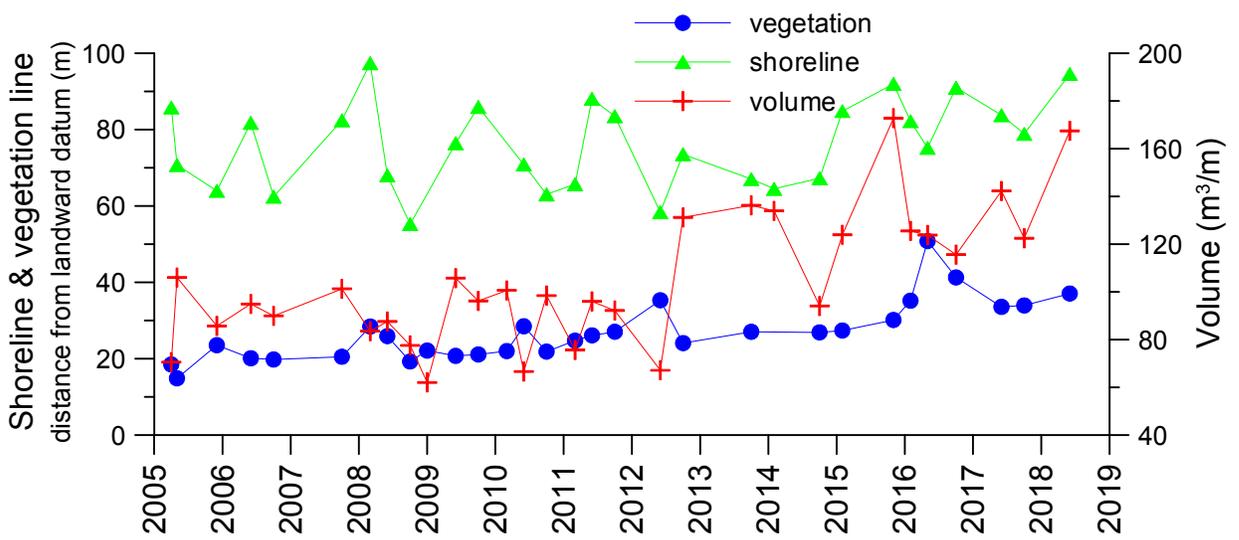
**JAM02 (Jamaica Beach, Galveston Island)
Volume, Shoreline, and Vegetation Line Change**



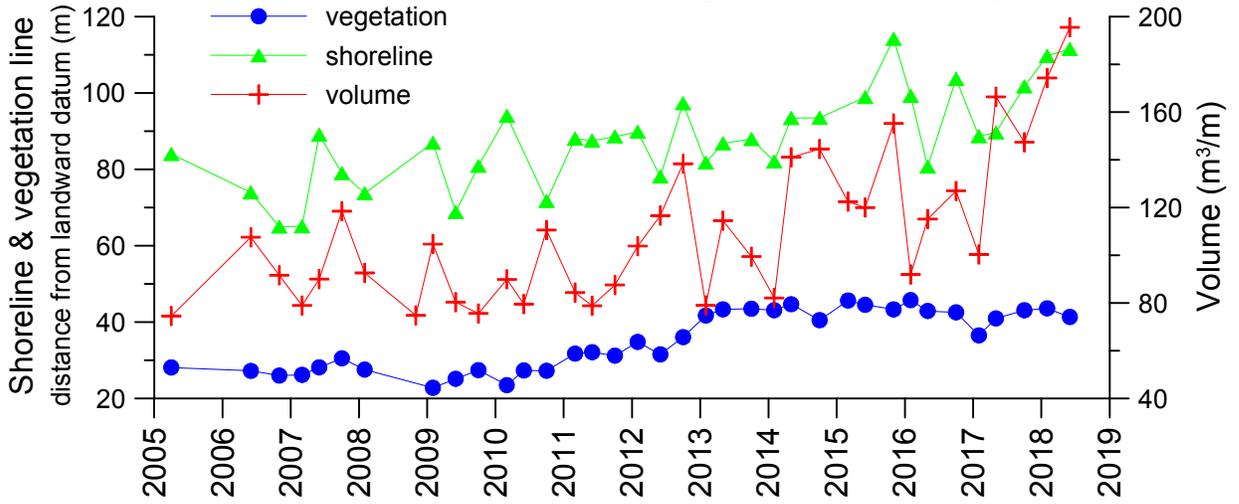
BEG08 (Follets Island)
Volume, Shoreline, and Vegetation Line Change



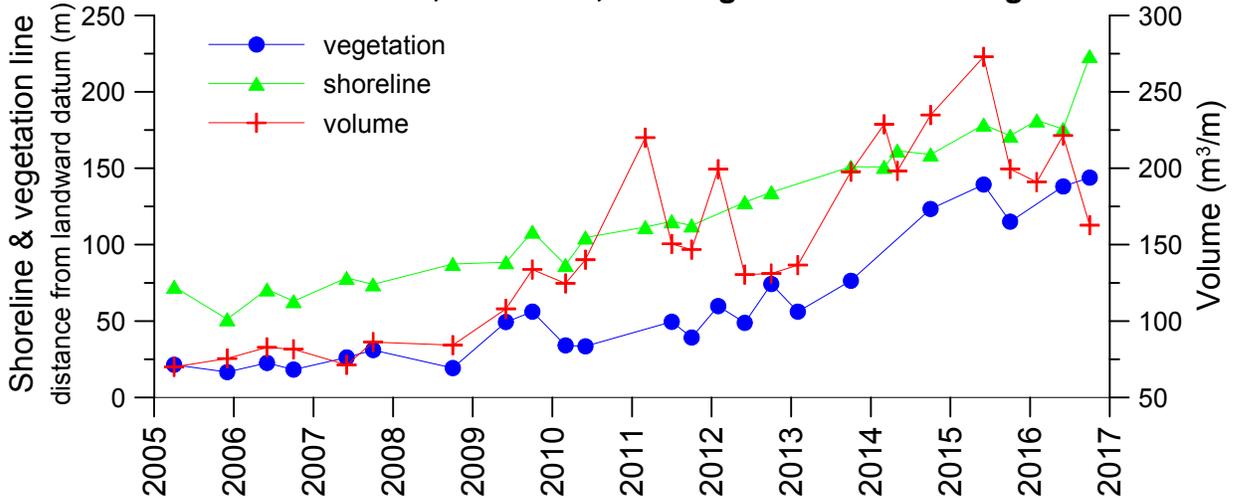
MAT01 (Matagorda Peninsula)
Volume, Shoreline, and Vegetation Line Change



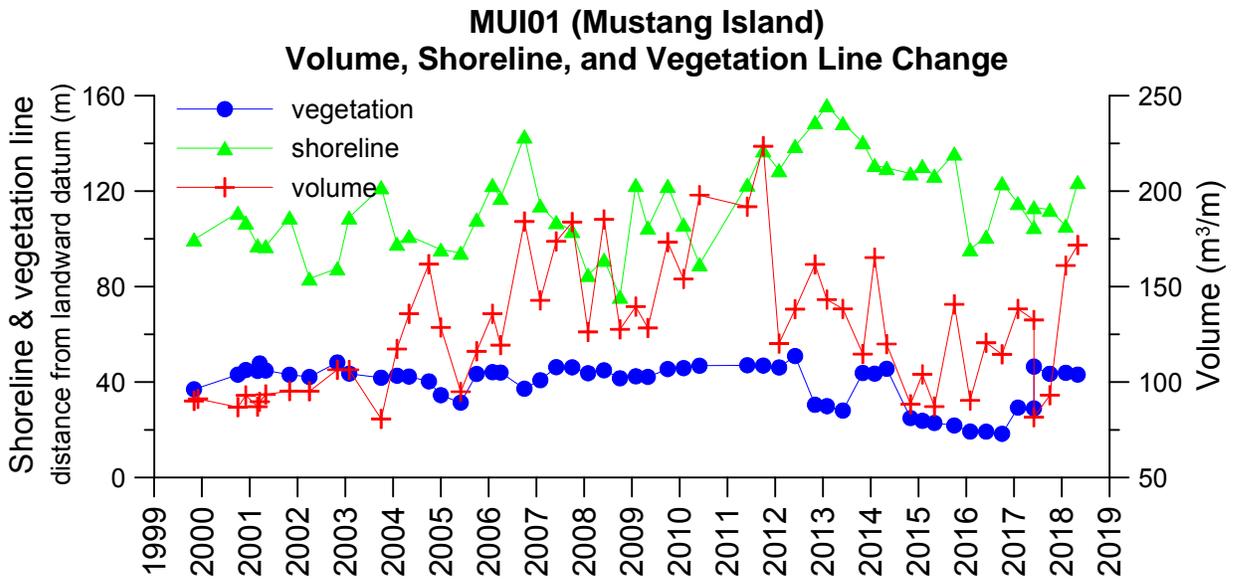
MAT02 (Matagorda Peninsula)
Volume, Shoreline, and Vegetation Line Change



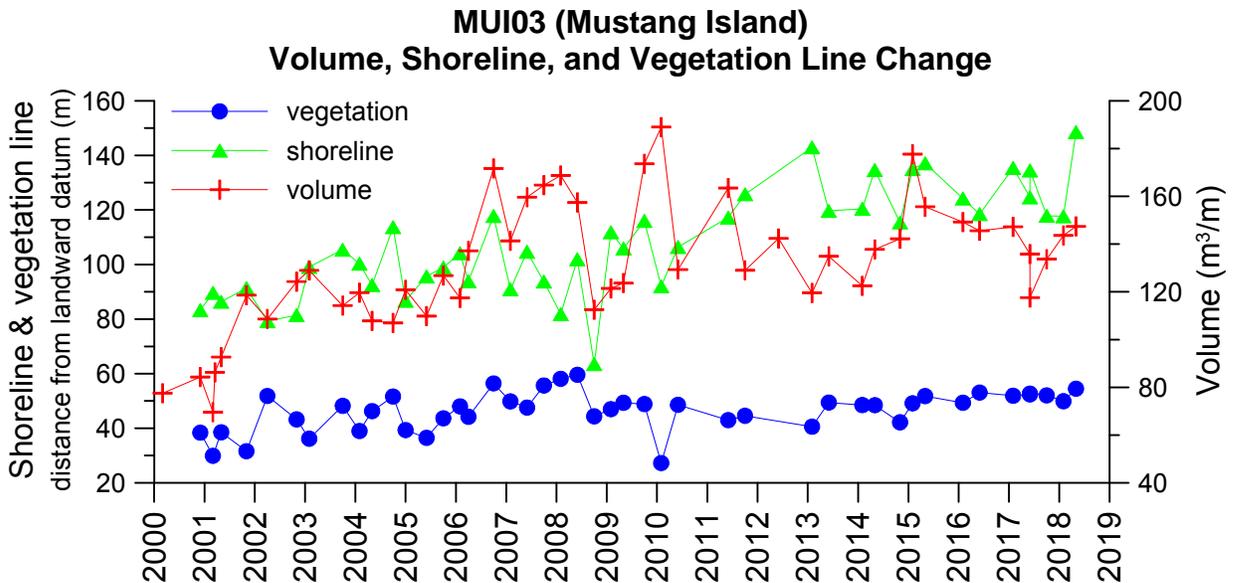
MAT03 Matagorda Peninsula
Volume, Shoreline, and Vegetation Line Change



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

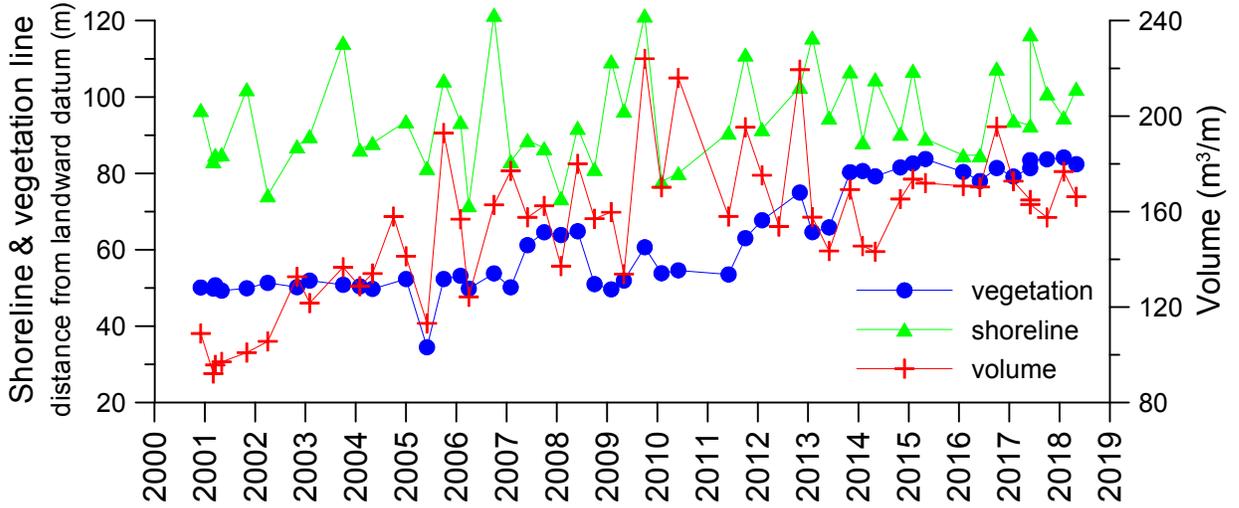


MUI03 volumes were calculated above 1.5 meters NAVD88. Profiles that did not extend below the 1.5 meter NAVD88 elevation were extrapolated.

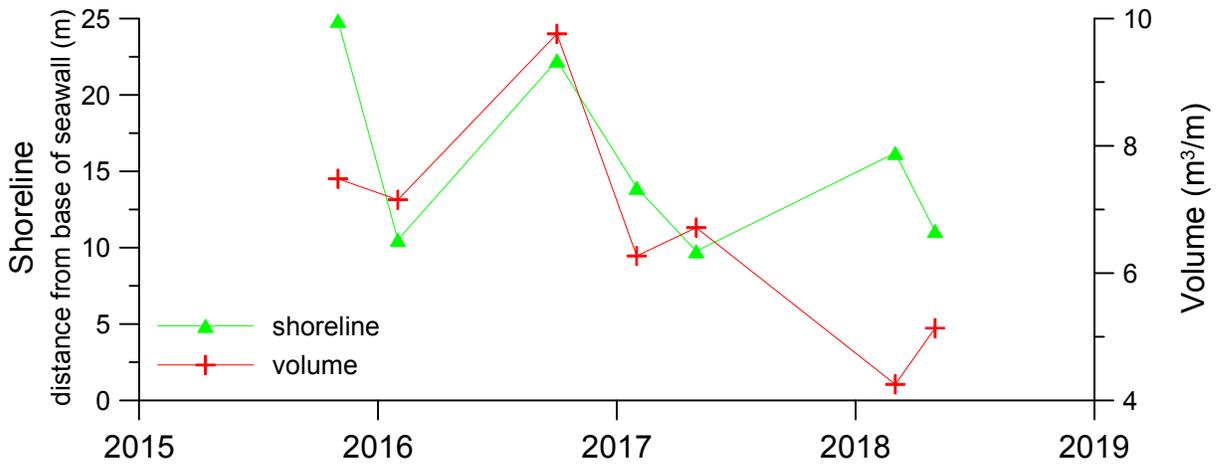


MUI02 volumes were calculated above 1.25 meters NAVD88. Profiles that did not extend below the 1.25 meter NAVD88 elevation were extrapolated.

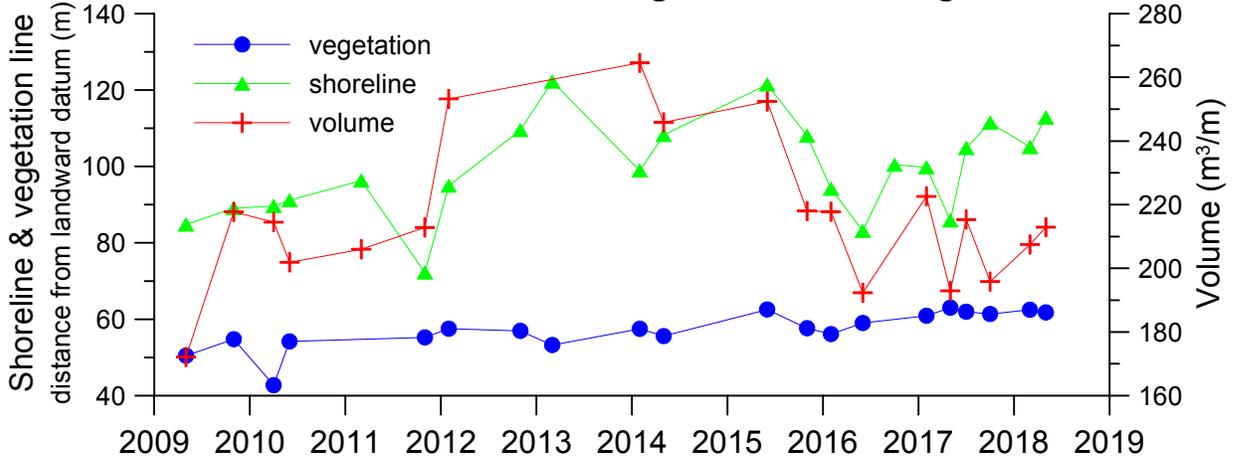
**MUI02 (Mustang Island State Park)
Volume, Shoreline, and Vegetation Line Change**



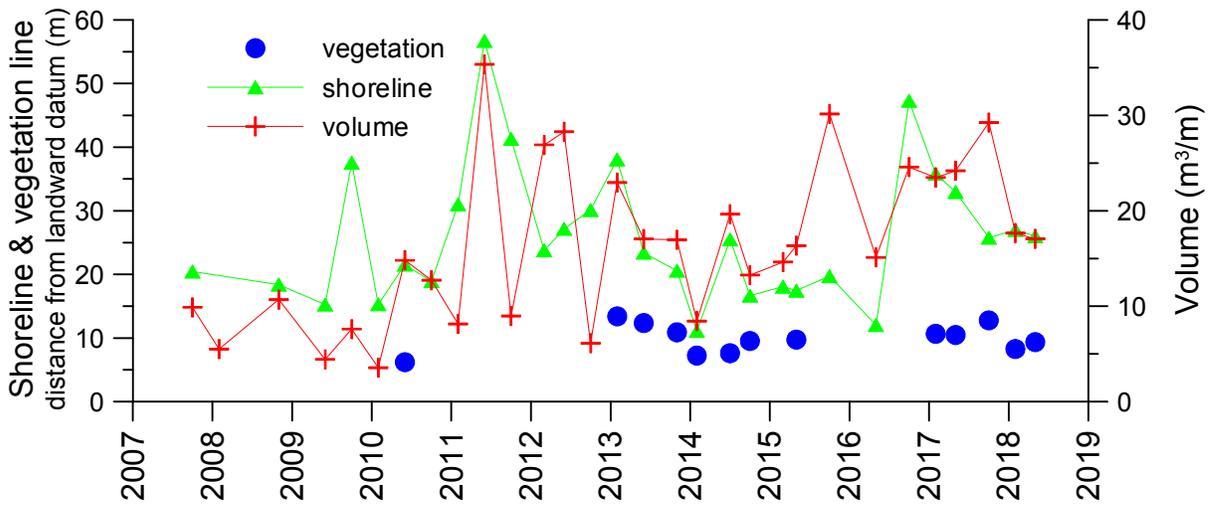
**NPC06 (North Padre Island Seawall)
Volume and Shoreline Change**



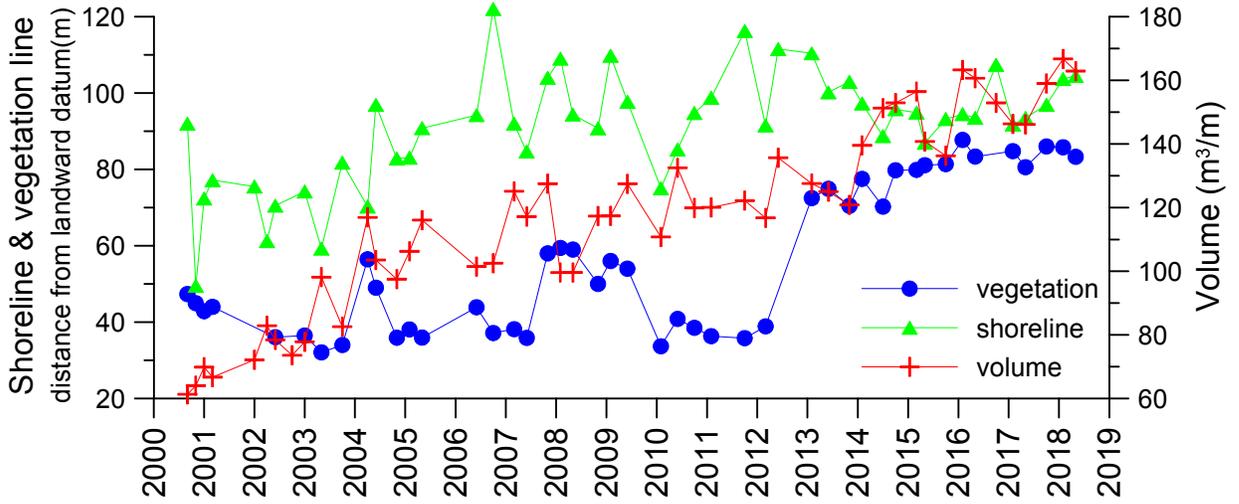
NPI08 (North Padre Island)
Volume, Shoreline, and Vegetation Line Change



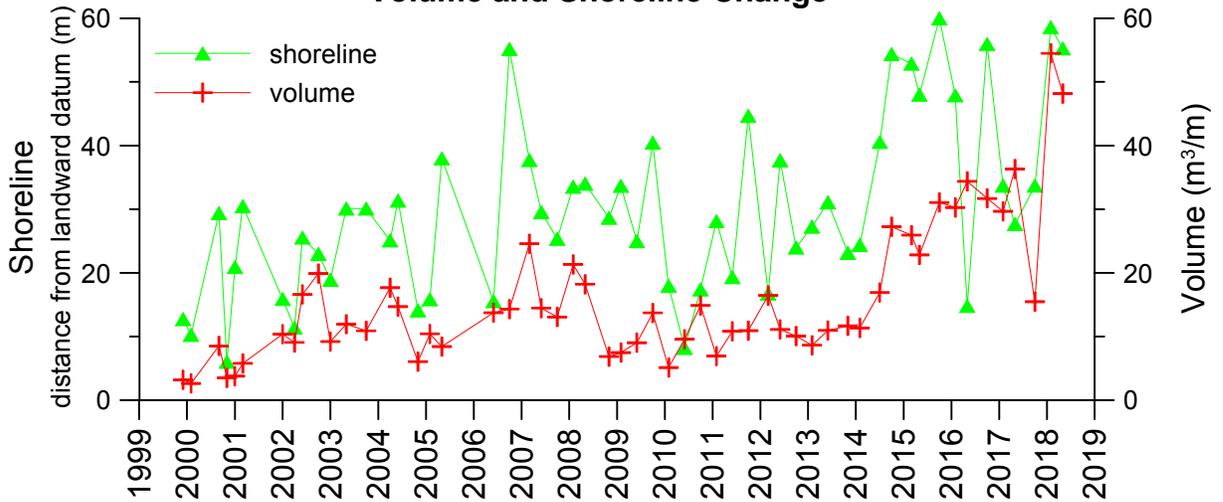
SPI08 (South Padre Island)
Volume, Shoreline, and Vegetation Line Change



SPI02 (South Padre Island)
Volume, Shoreline, and Vegetation Line Change



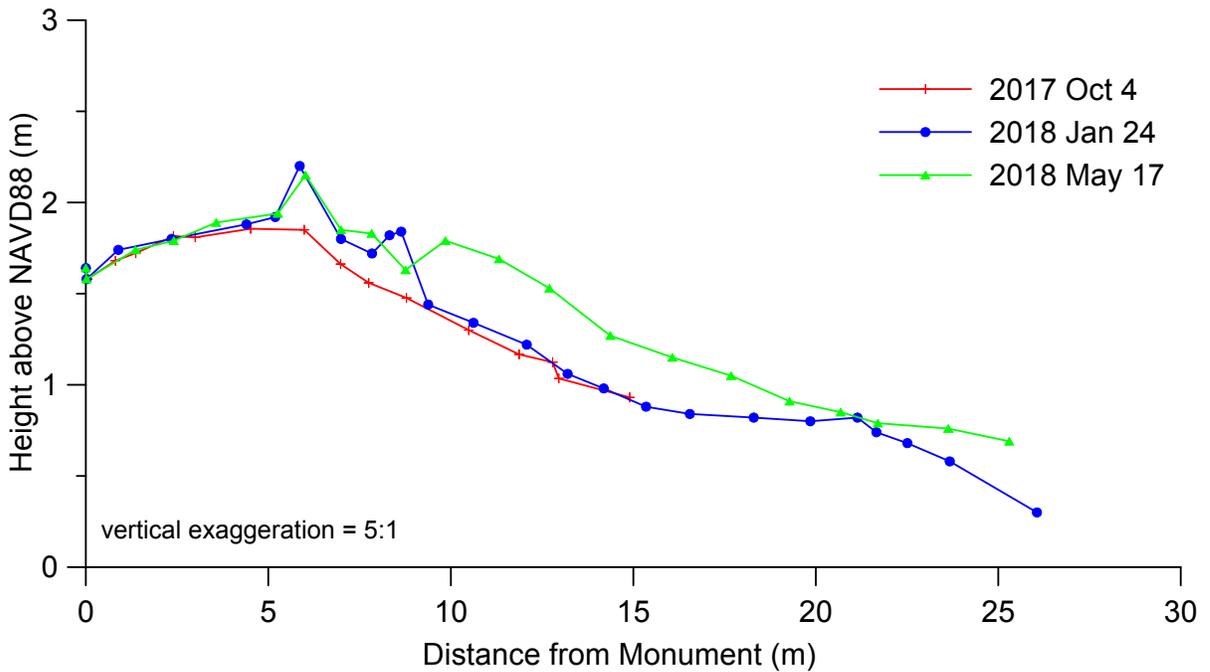
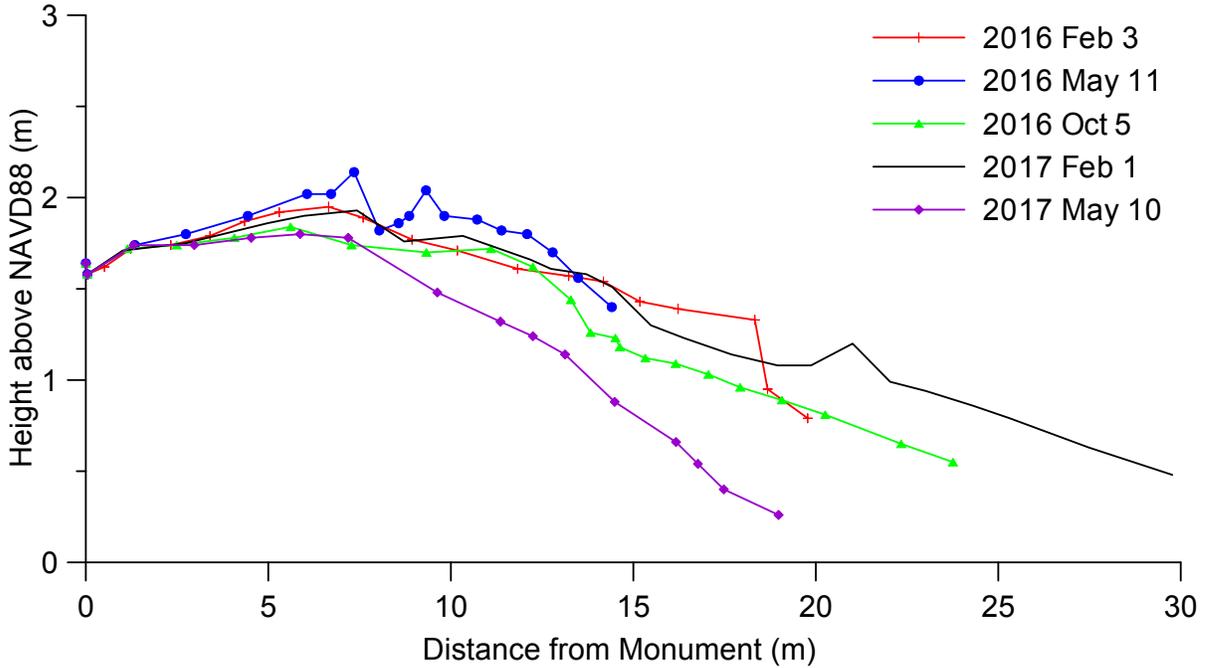
SPI01 (South Padre Island)
Volume and Shoreline Change



APPENDIX C: GRAPHS OF BEACH PROFILES

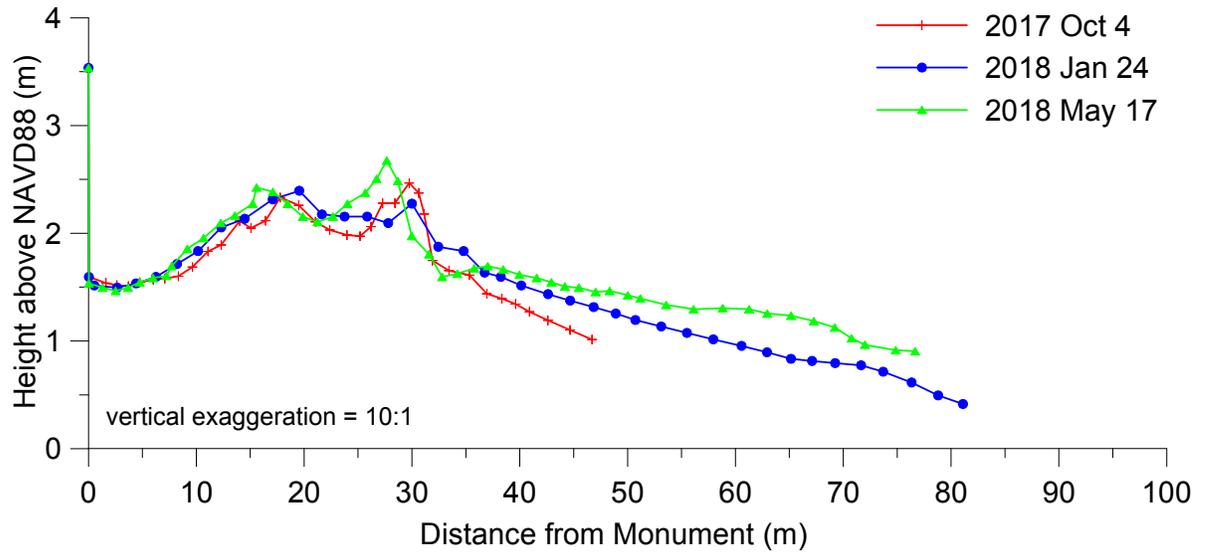
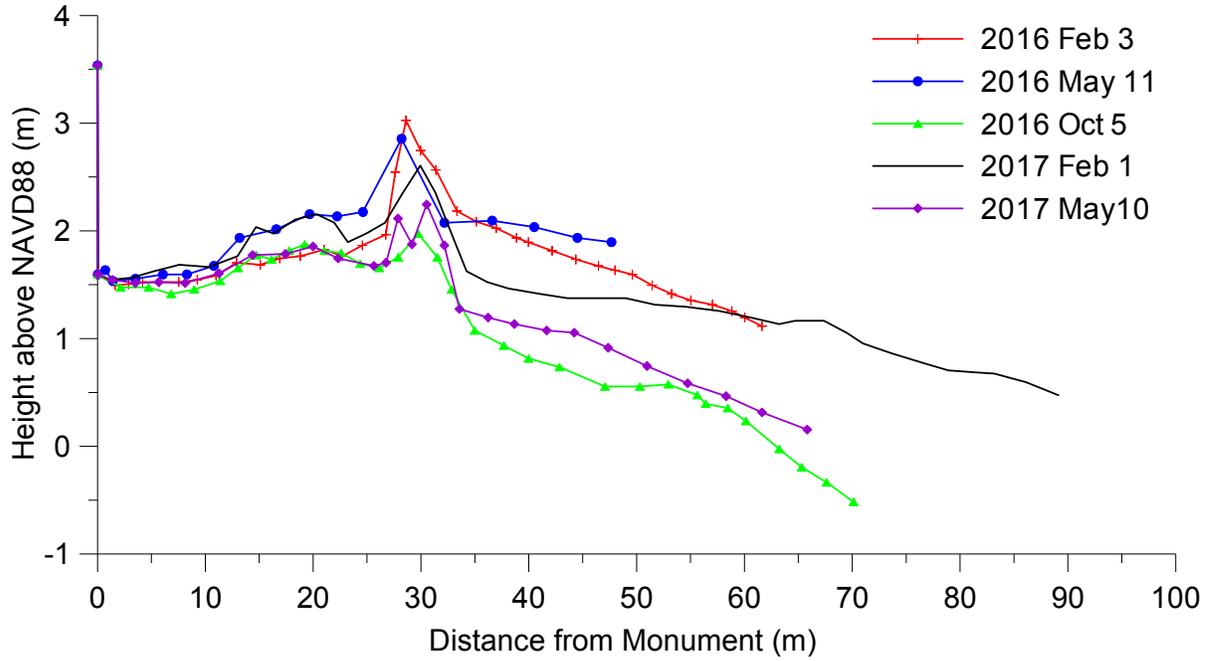
HIB01

HIB01 (High Island Beach)



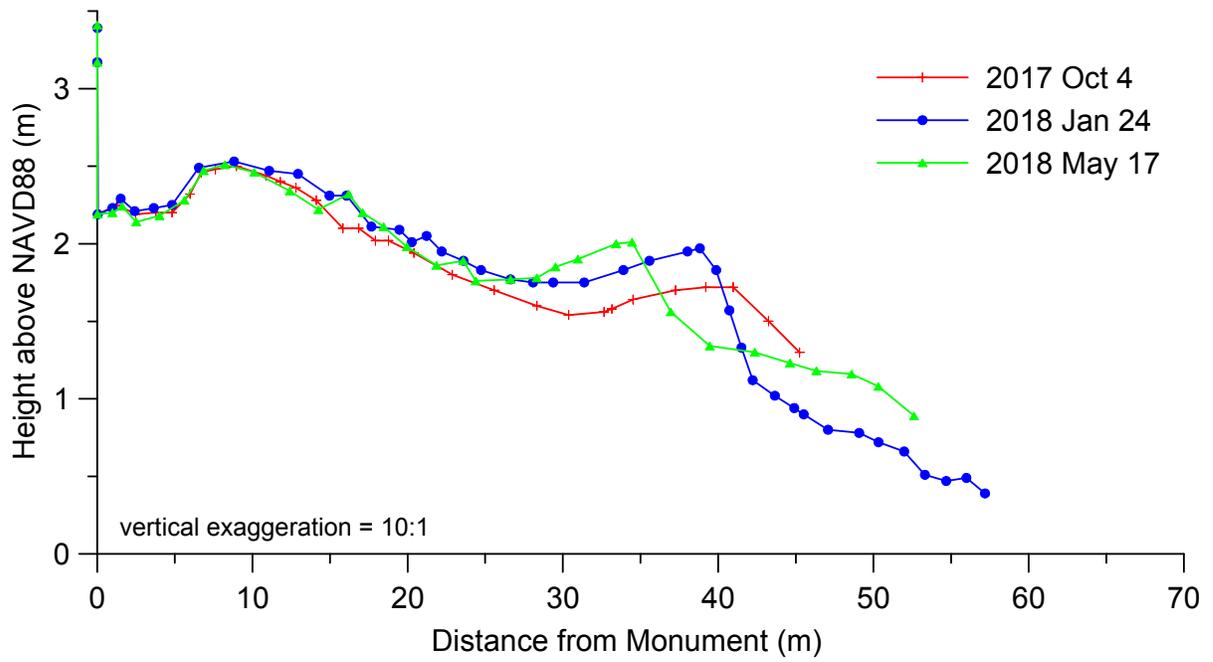
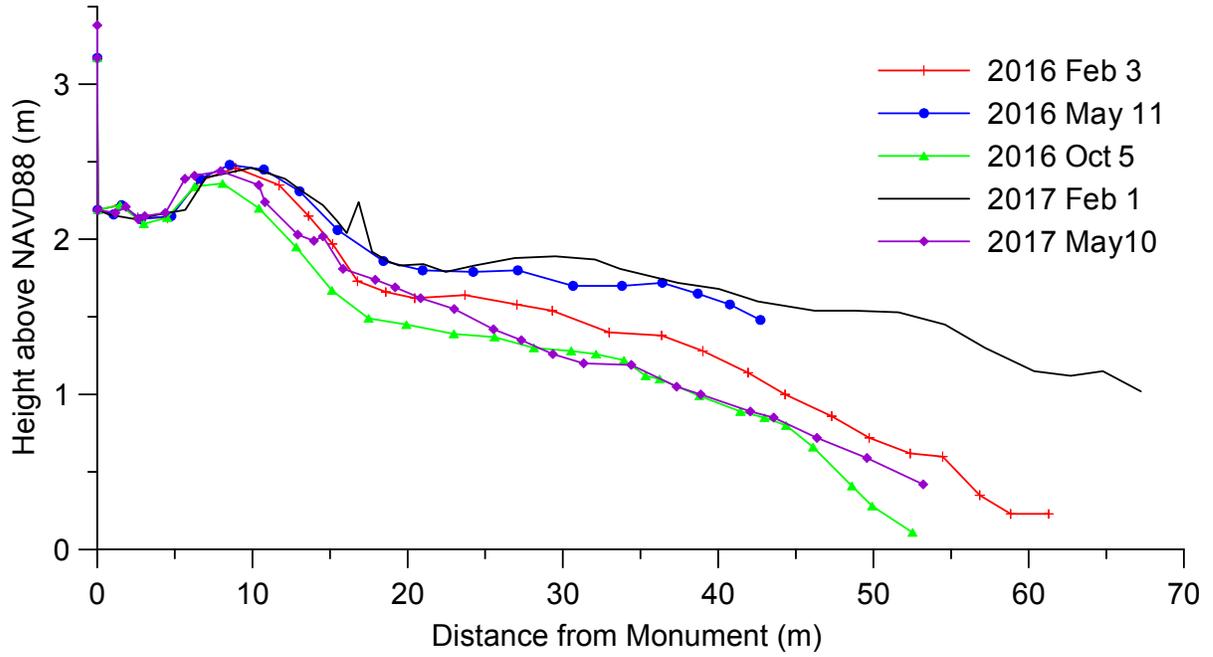
BOL03

BOL03 (East of Rollover Pass, Bolivar Peninsula)

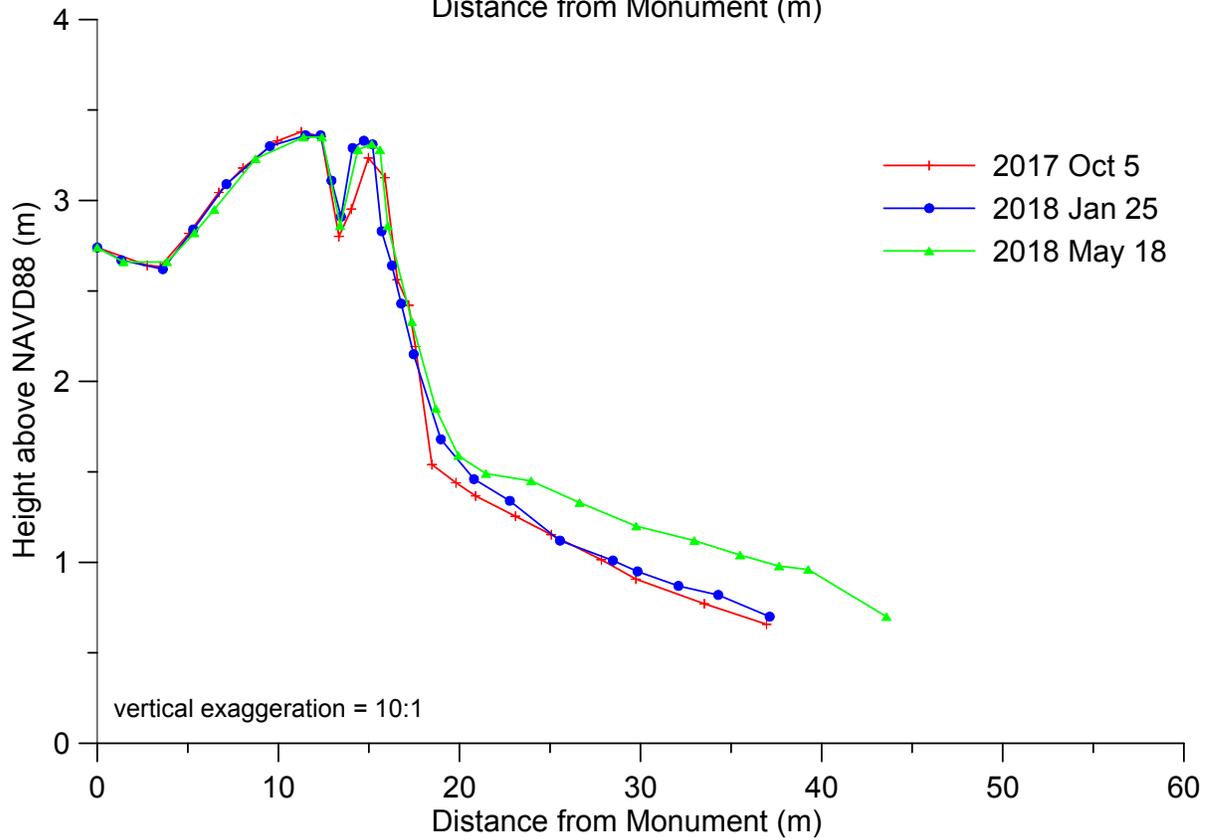
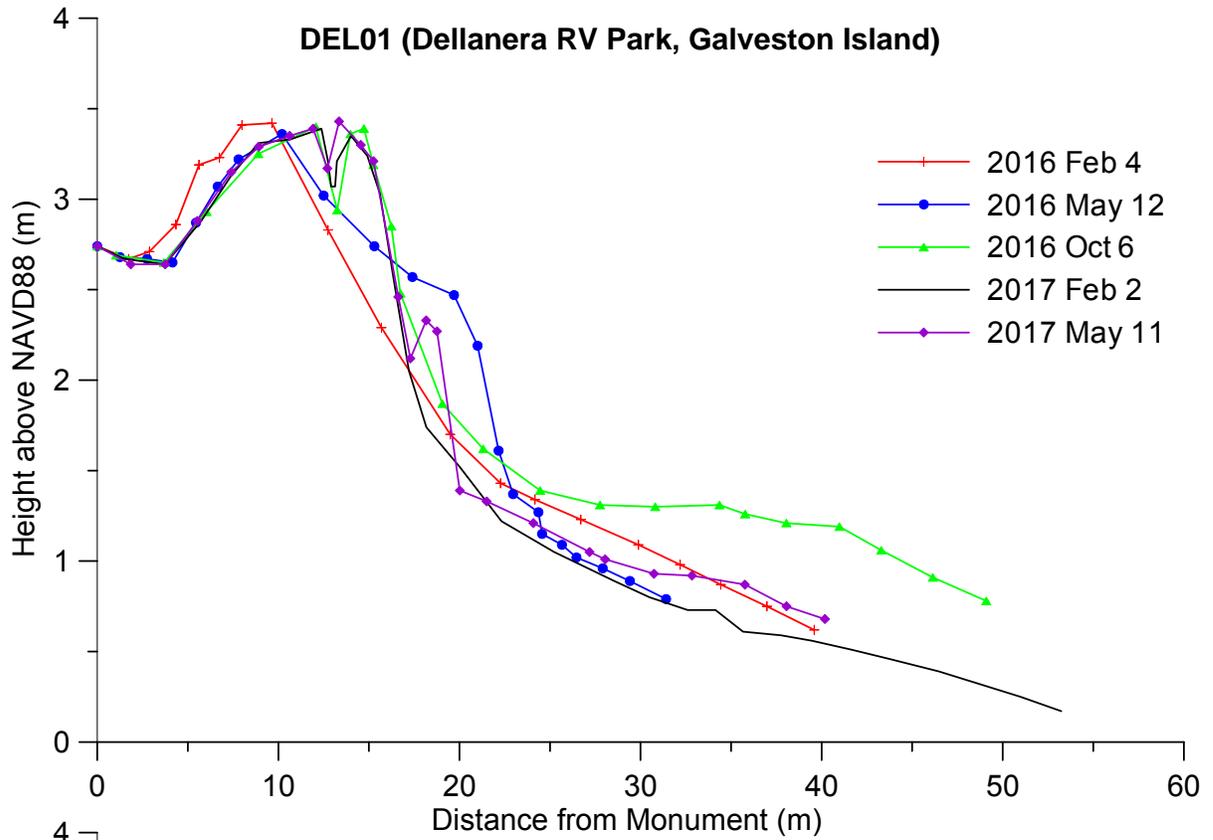


BOL02

BOL02 (West Rollover Pass, Bolivar Peninsula)

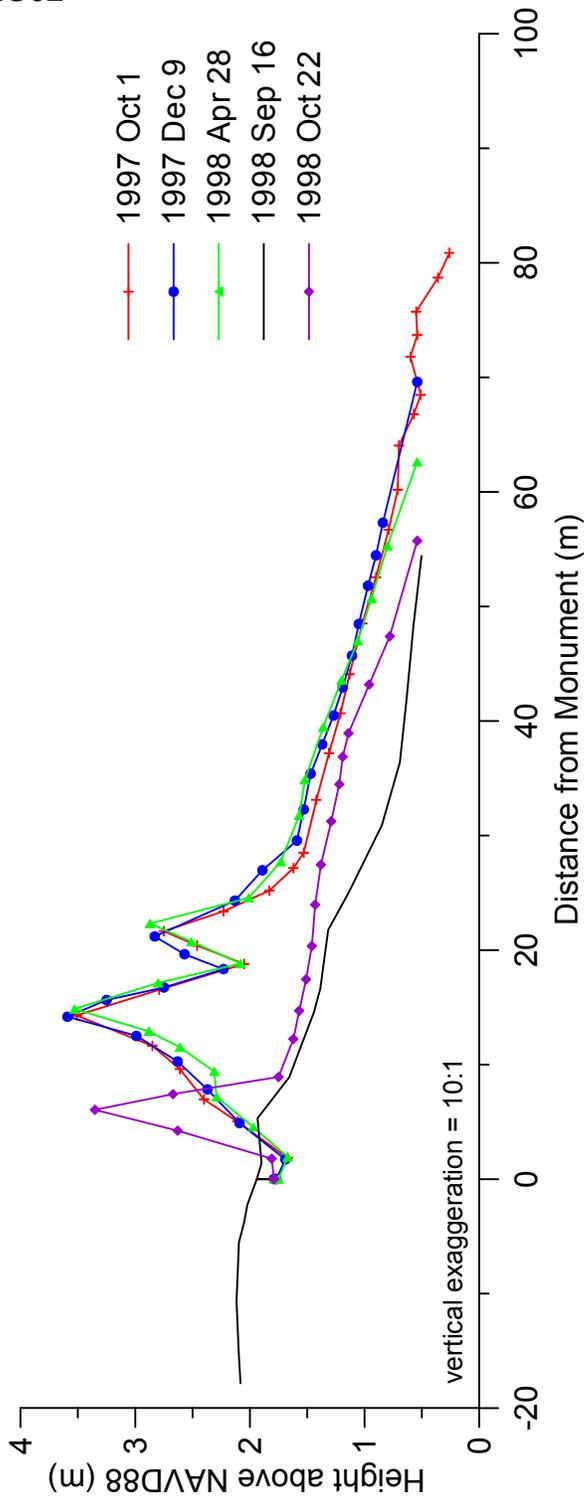


DEL01

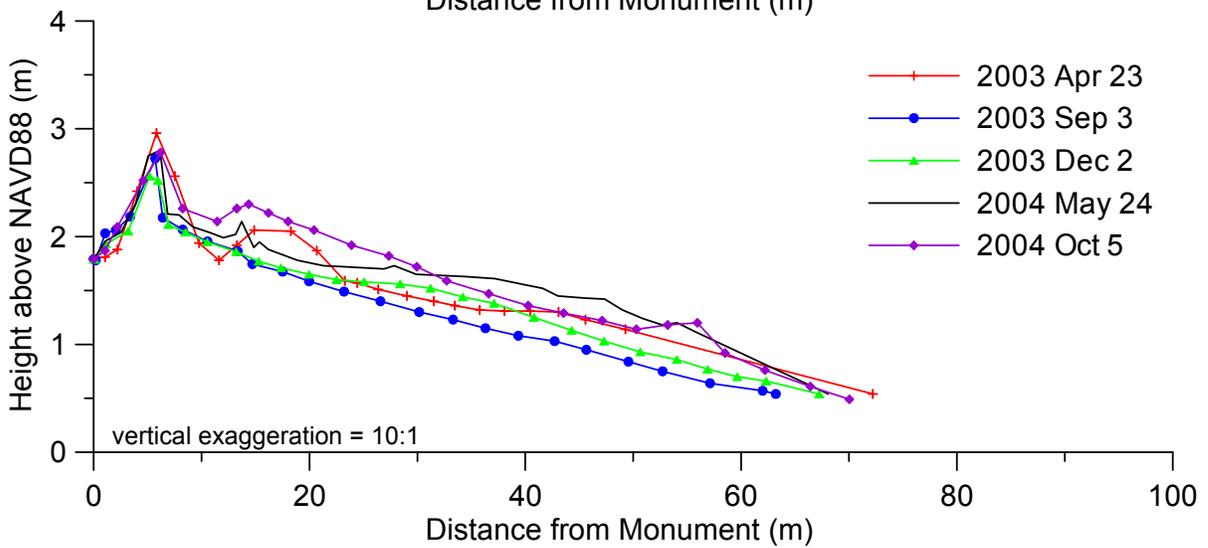
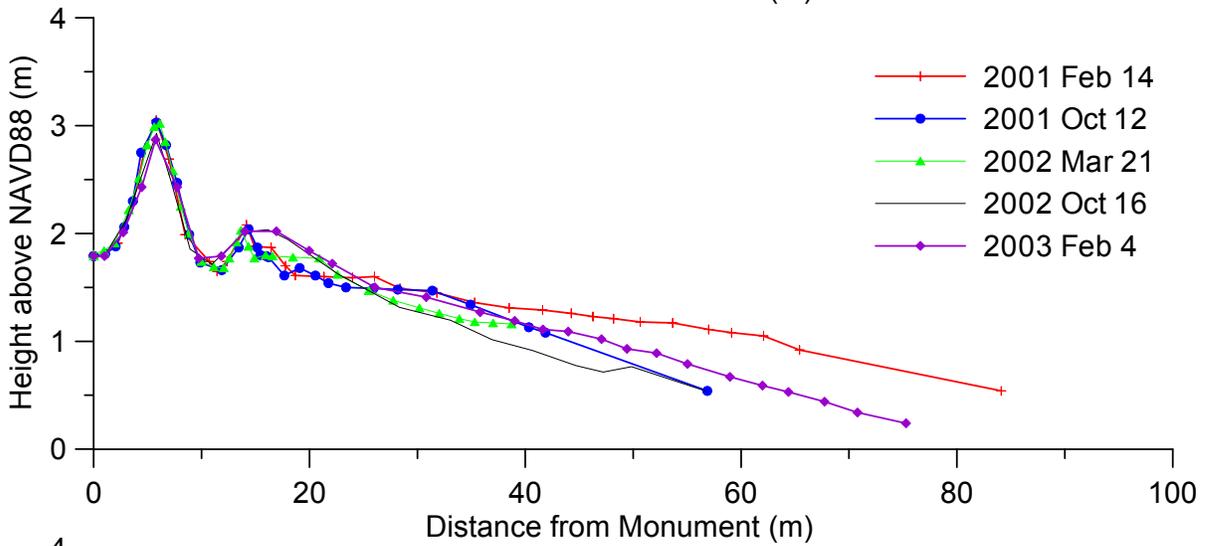
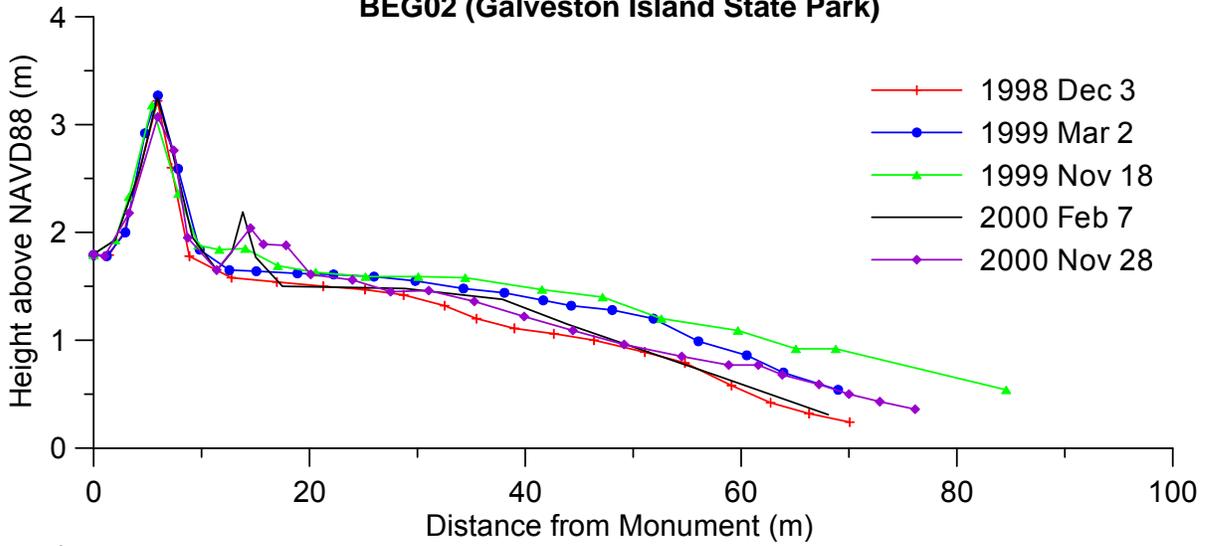


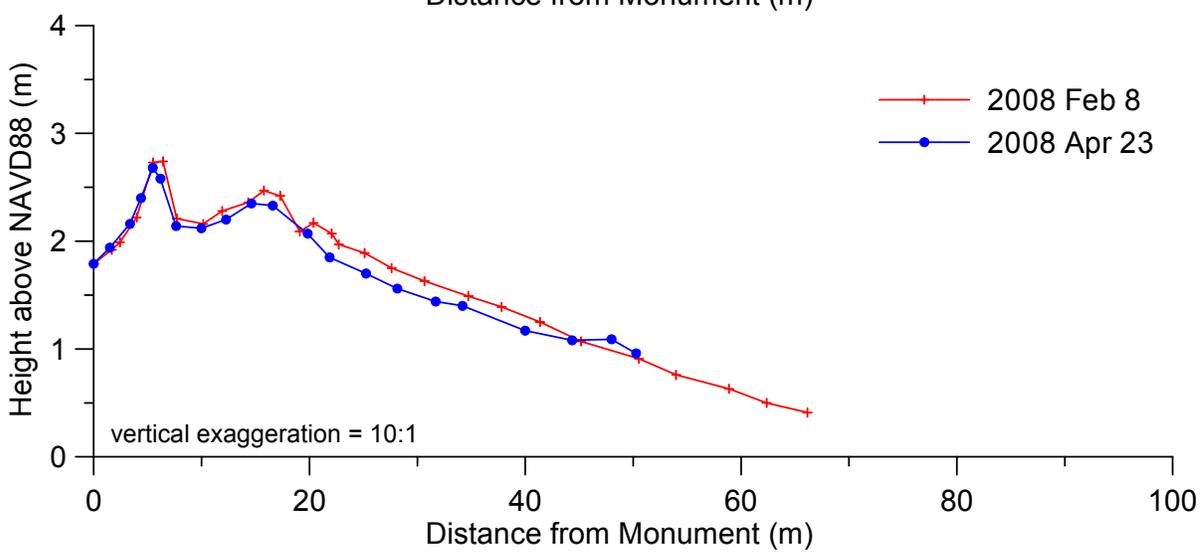
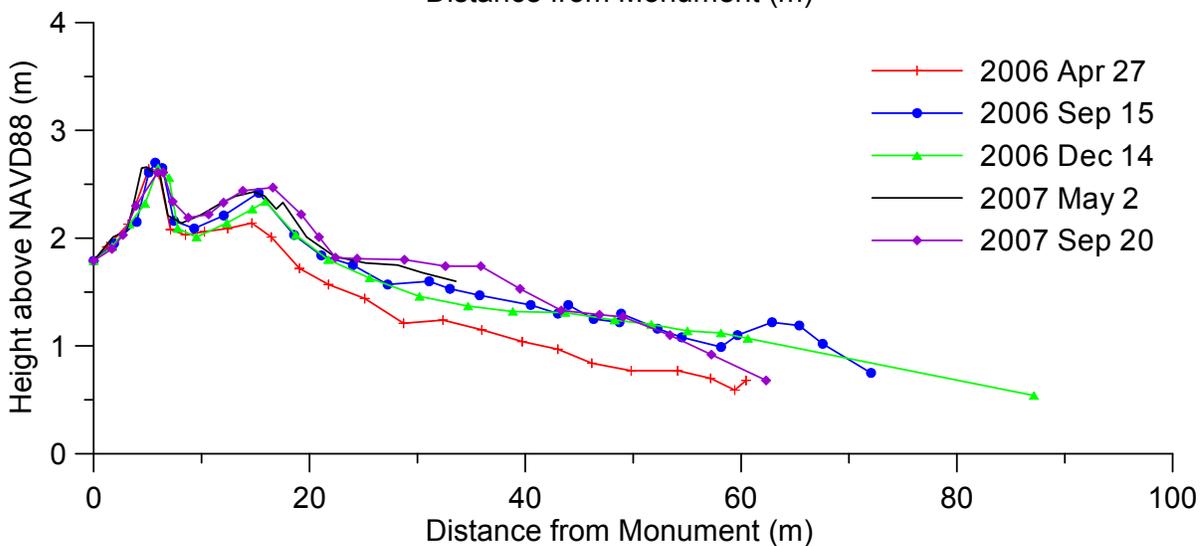
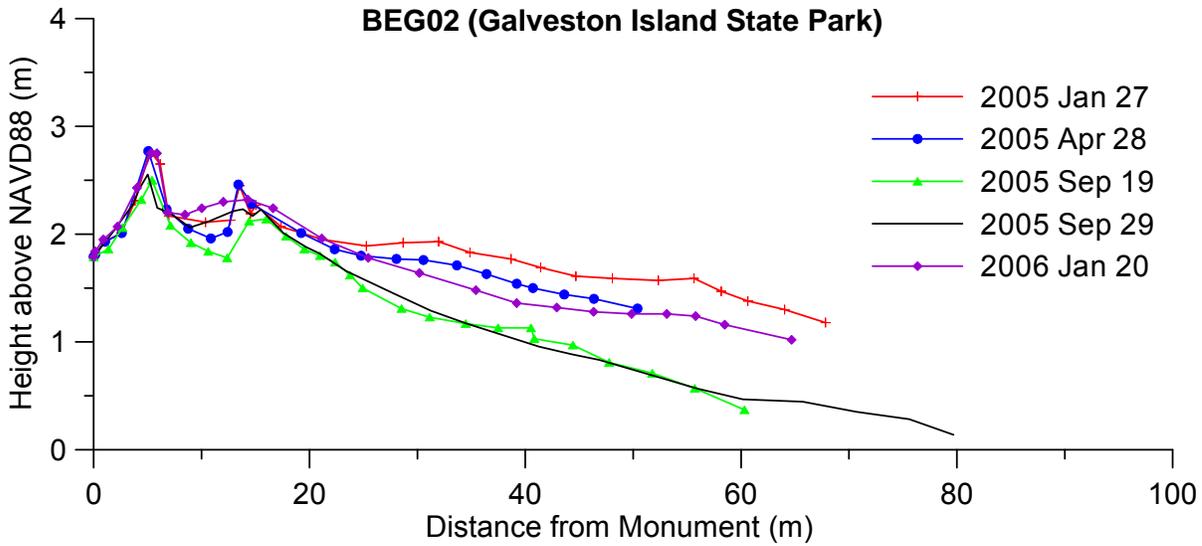
BEG02

BEG02 (Galveston Island State Park)



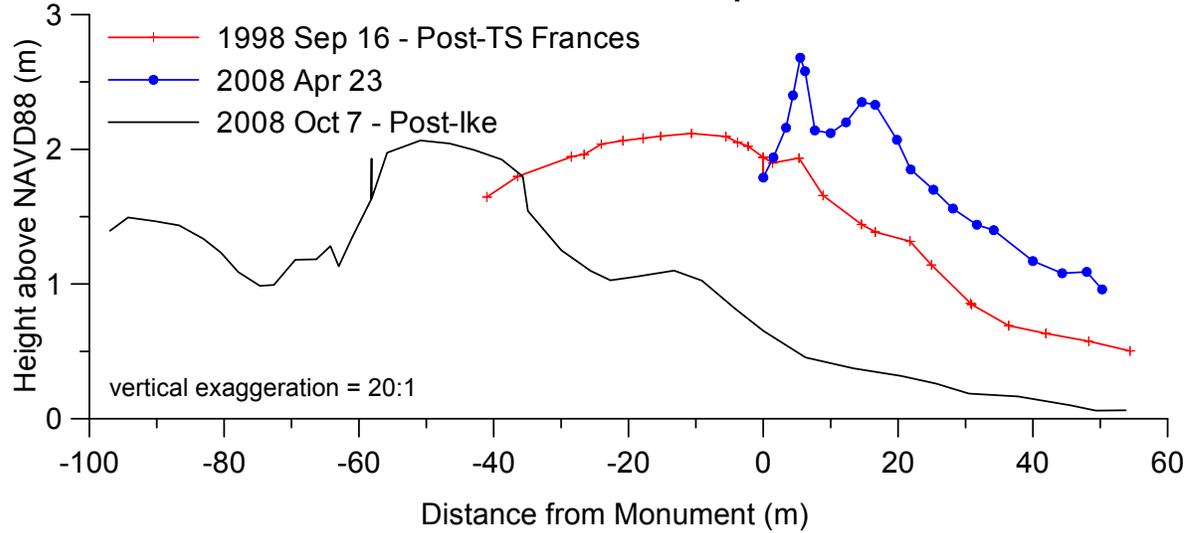
BEG02 (Galveston Island State Park)



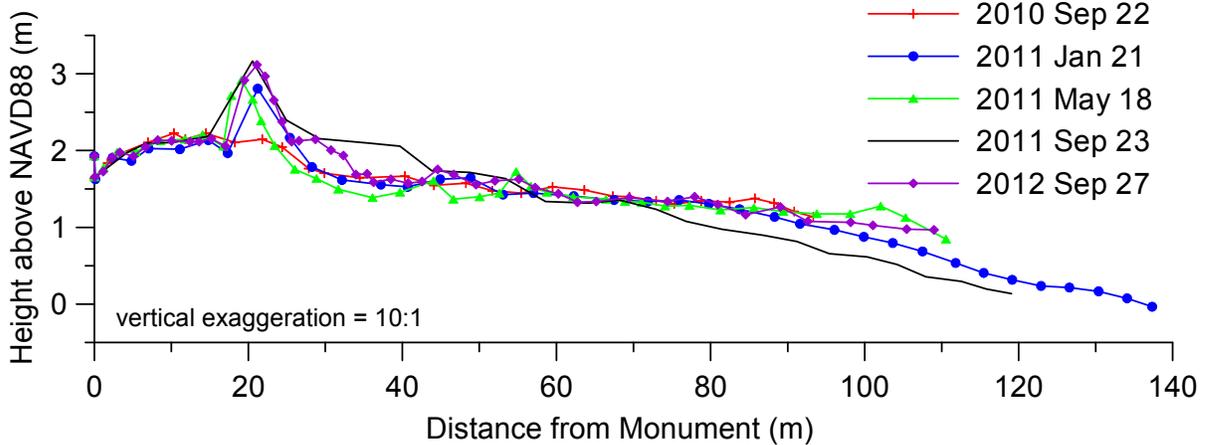
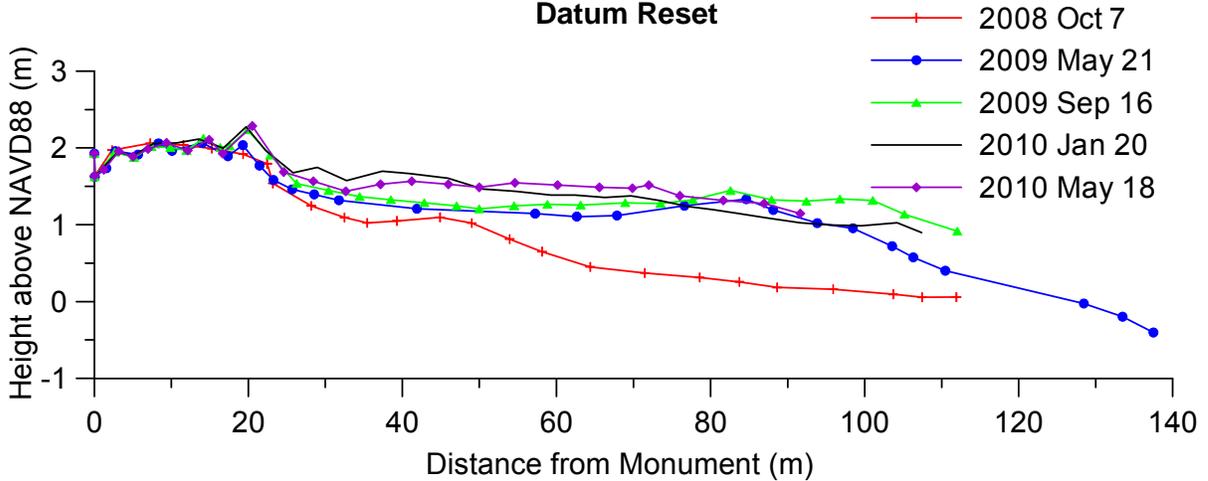


BEG02R

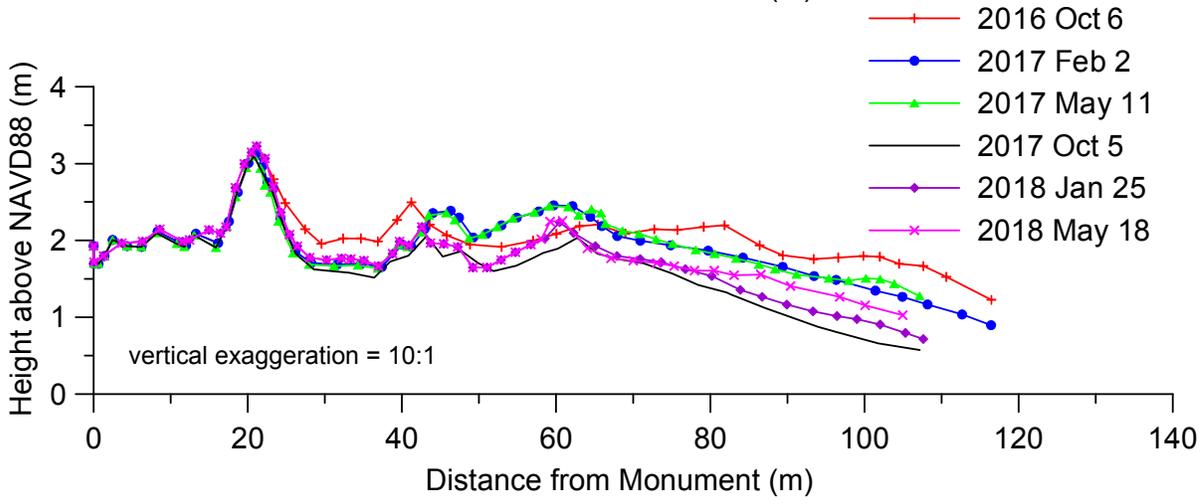
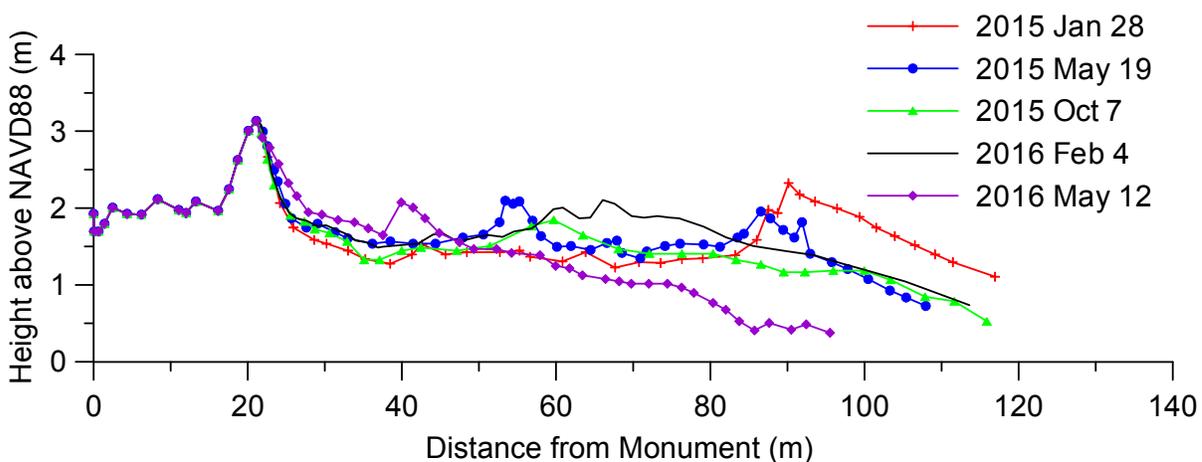
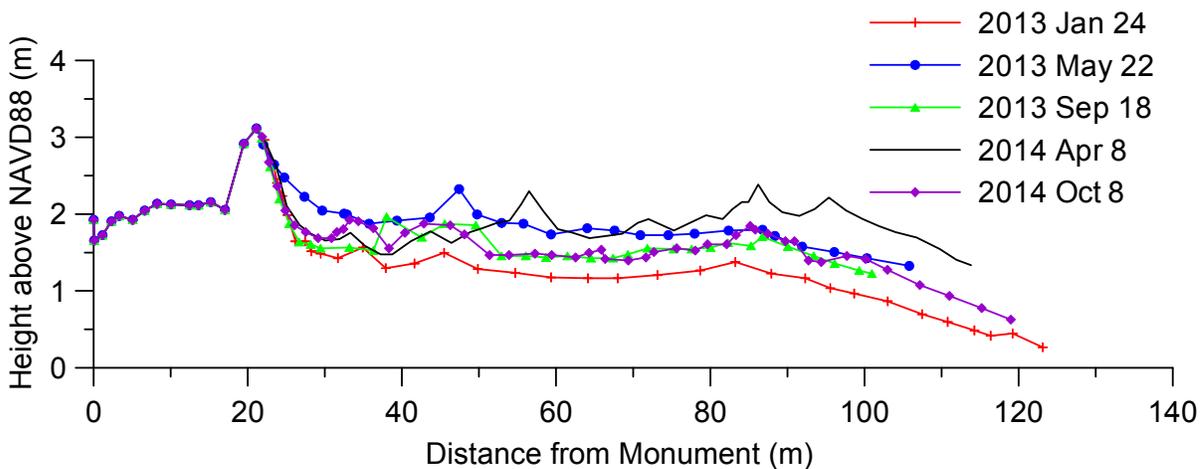
**BEG02R (Galveston Island State Park)
Pre- and Post-Ike Comparison**



**BEG02R (Galveston Island State Park)
Datum Reset**

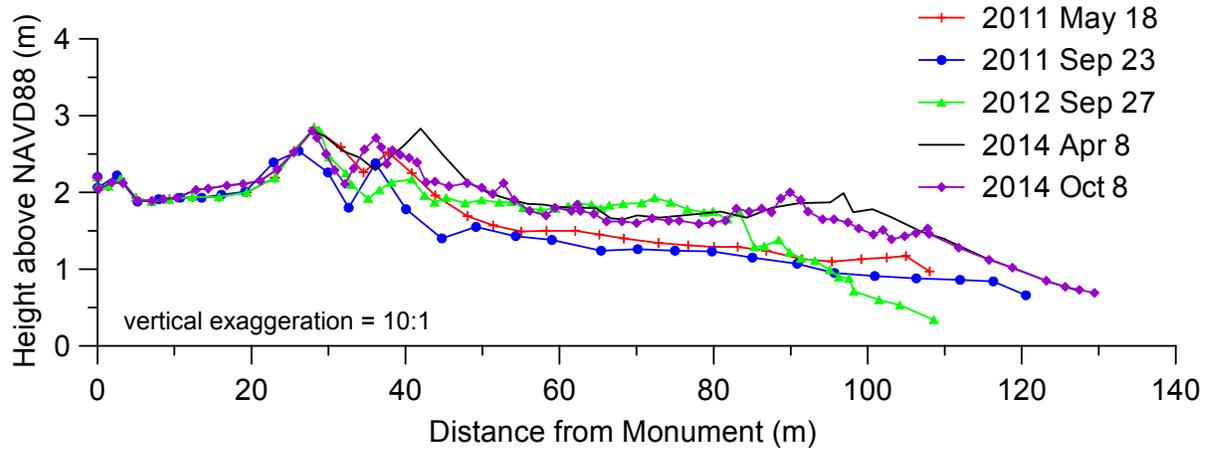
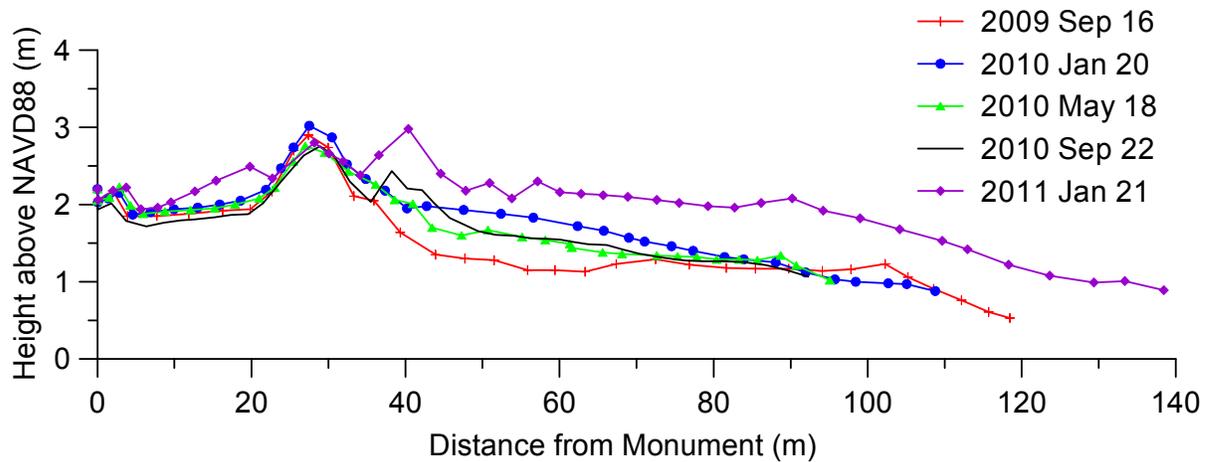
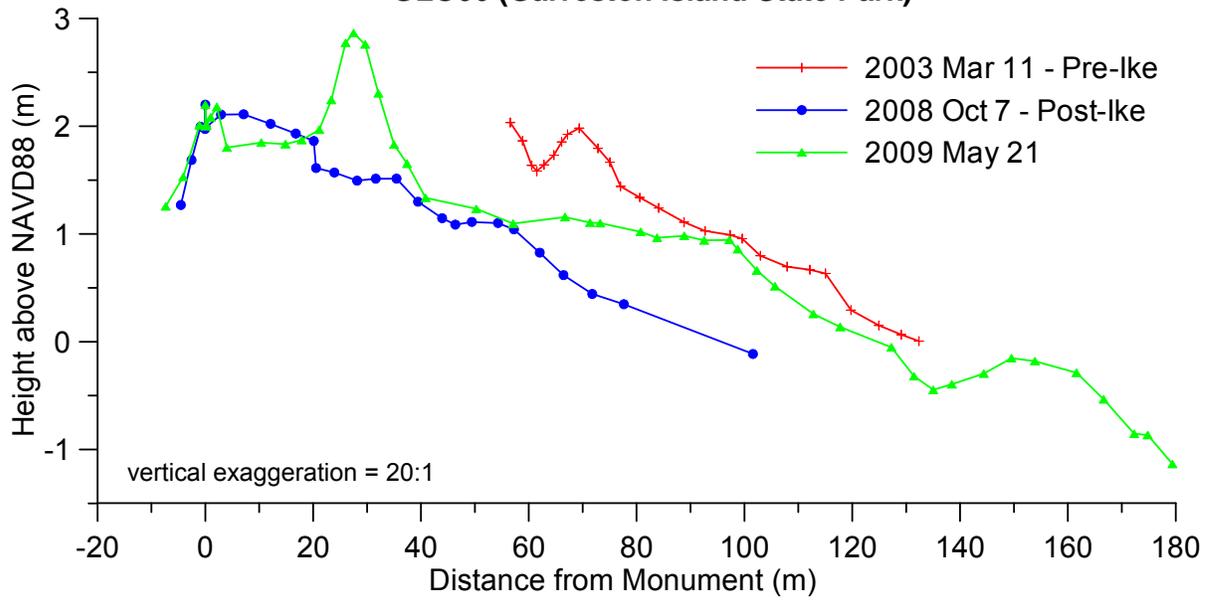


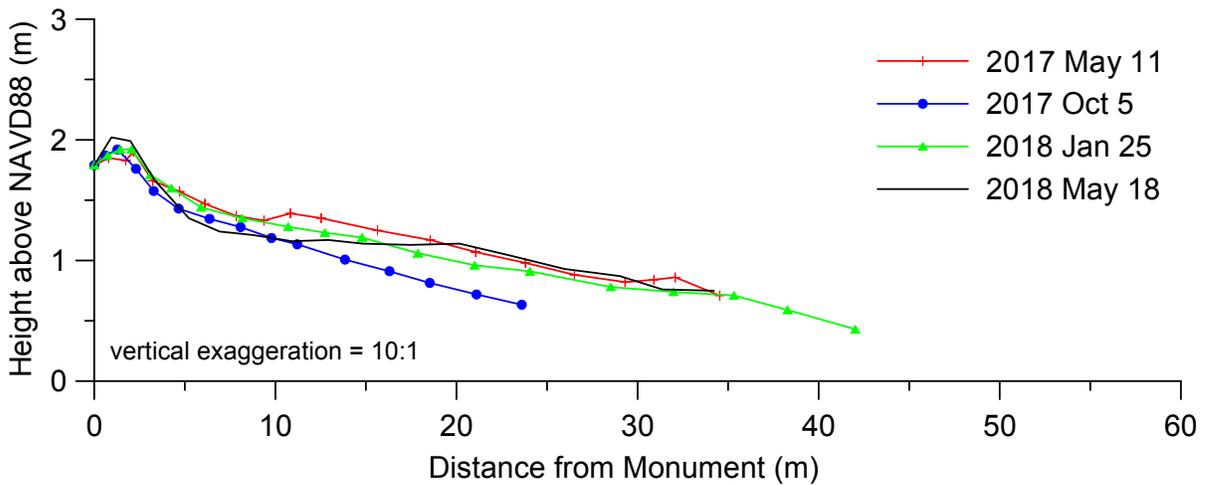
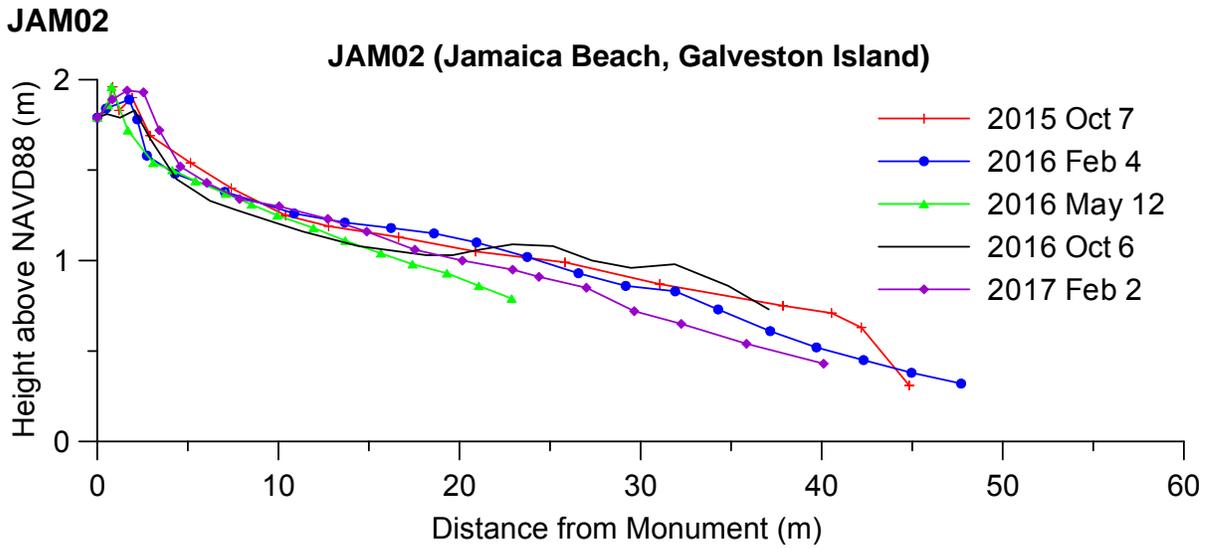
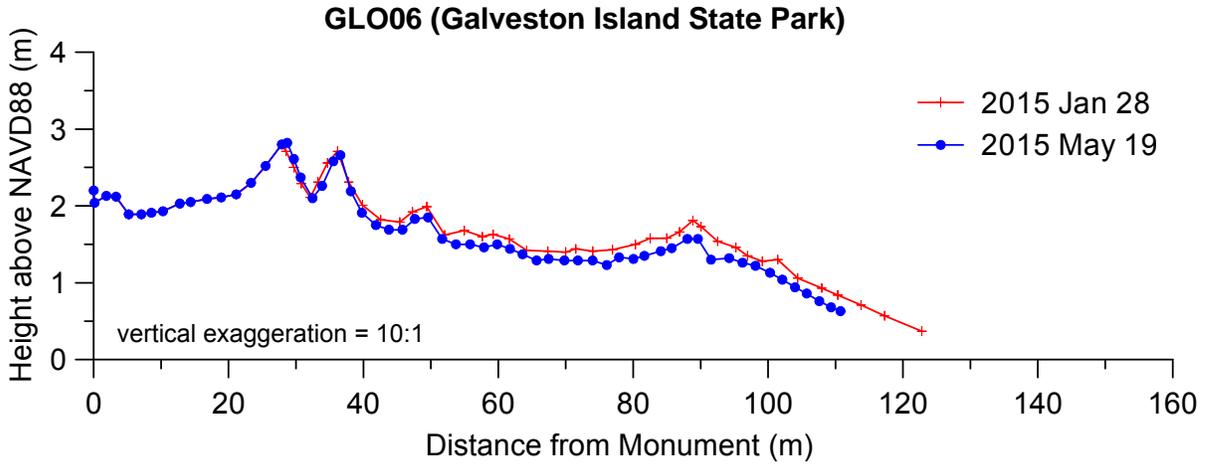
BEG02R (Galveston Island State Park) Datum Reset



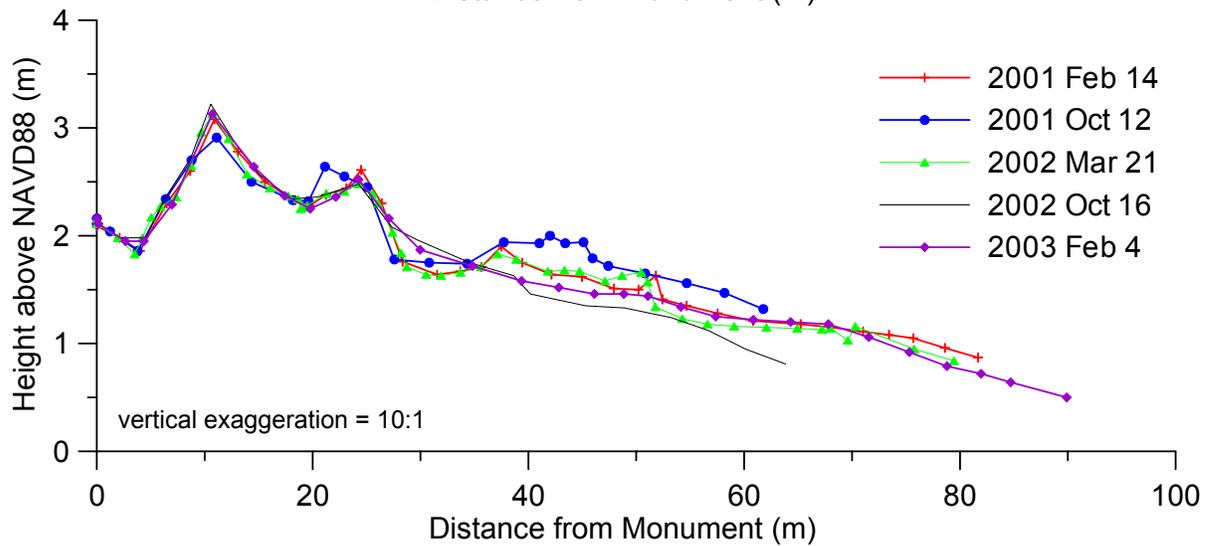
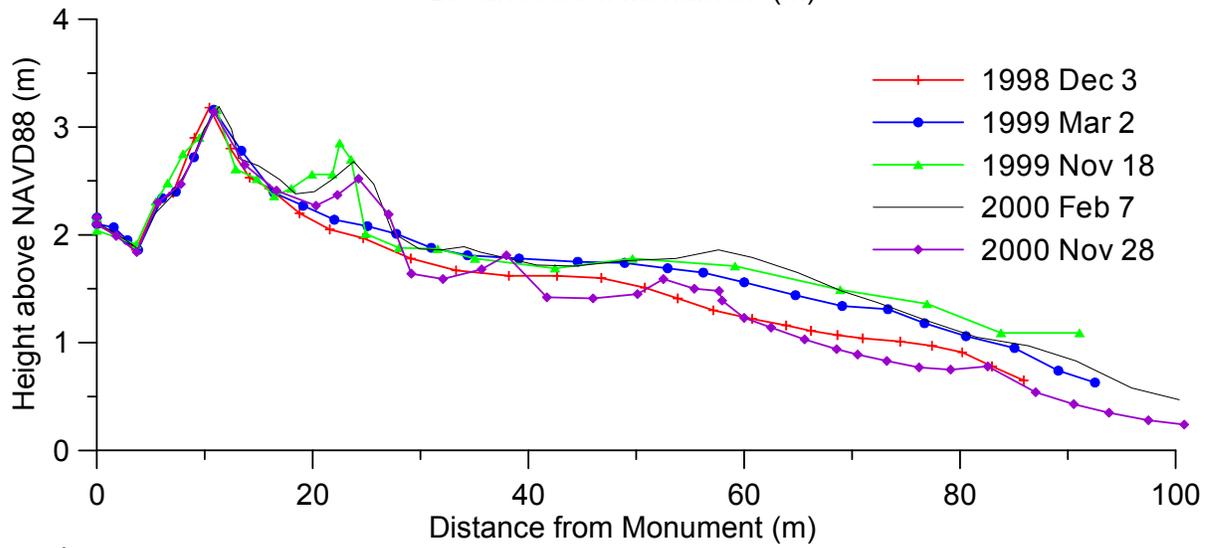
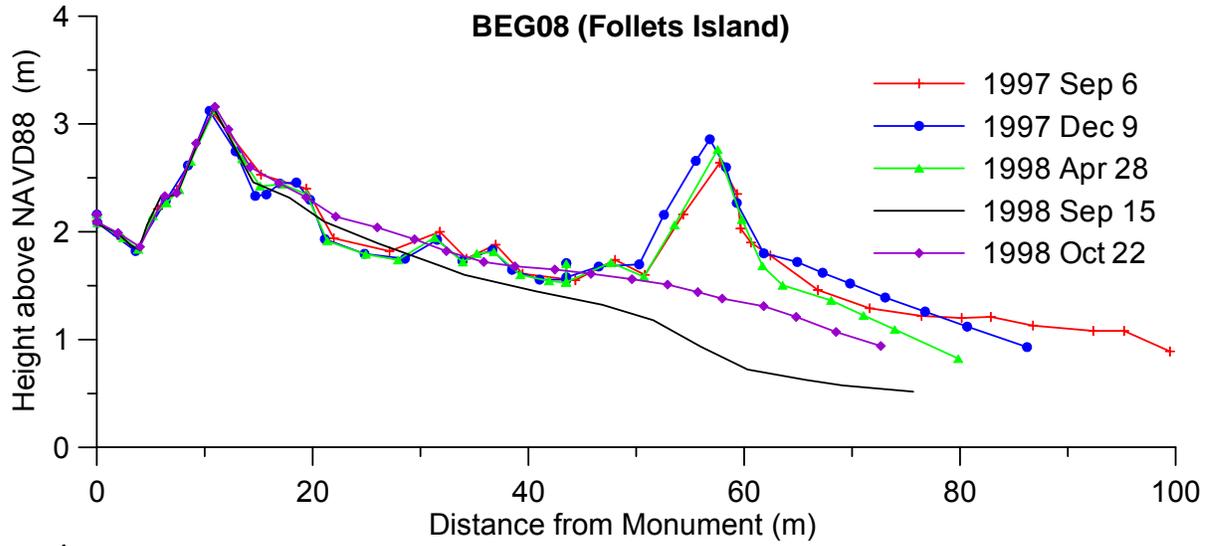
GLO06

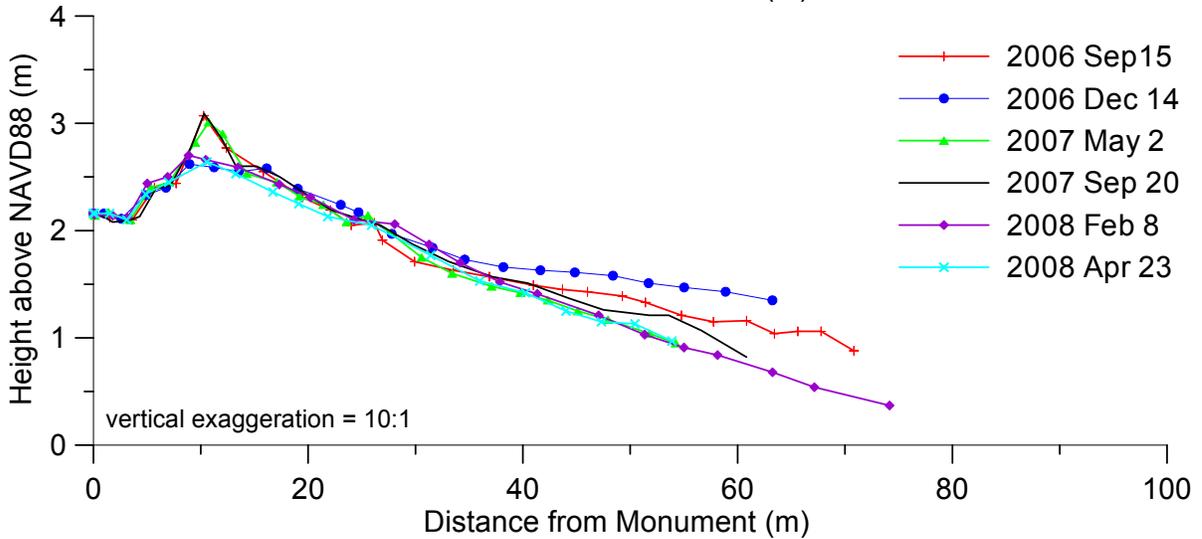
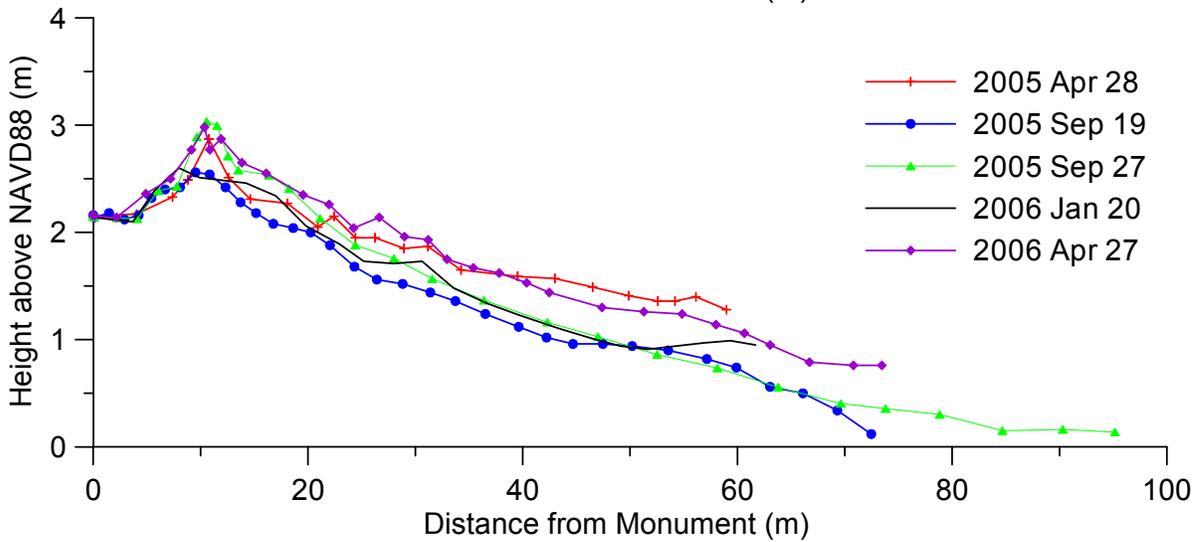
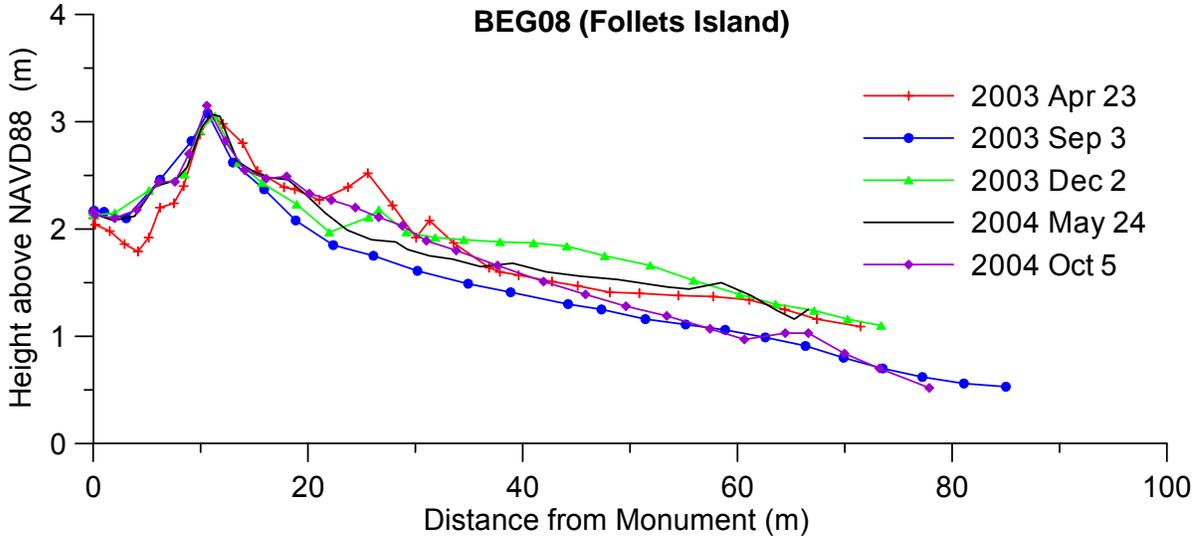
GLO06 (Galveston Island State Park)





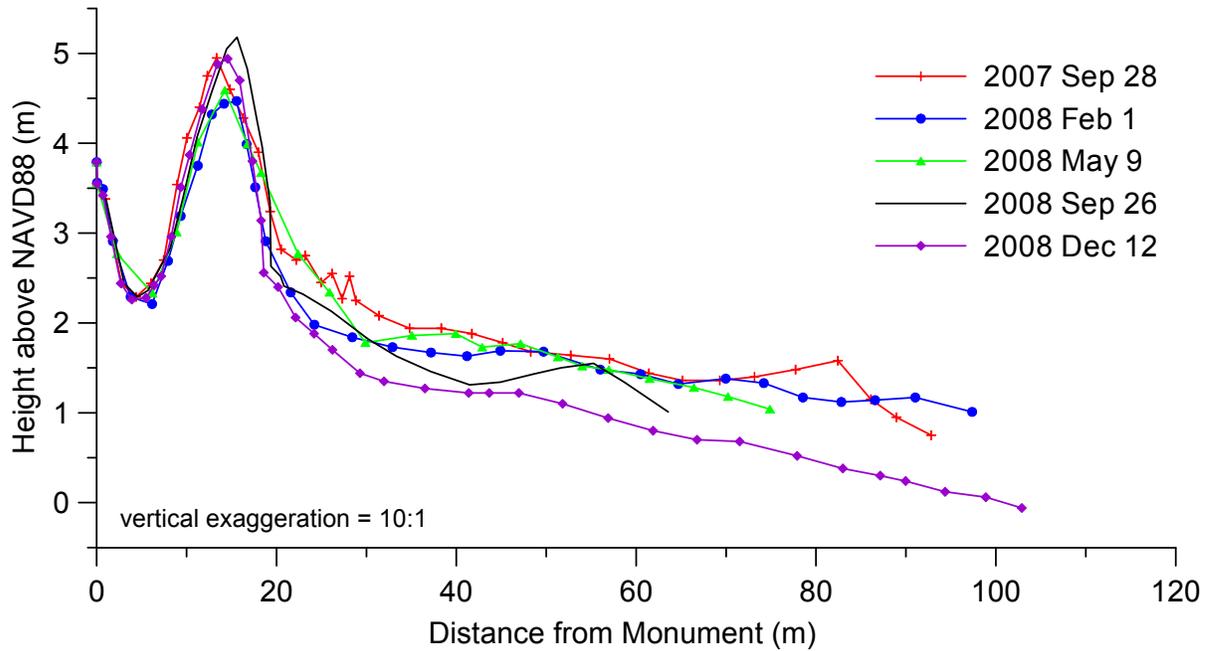
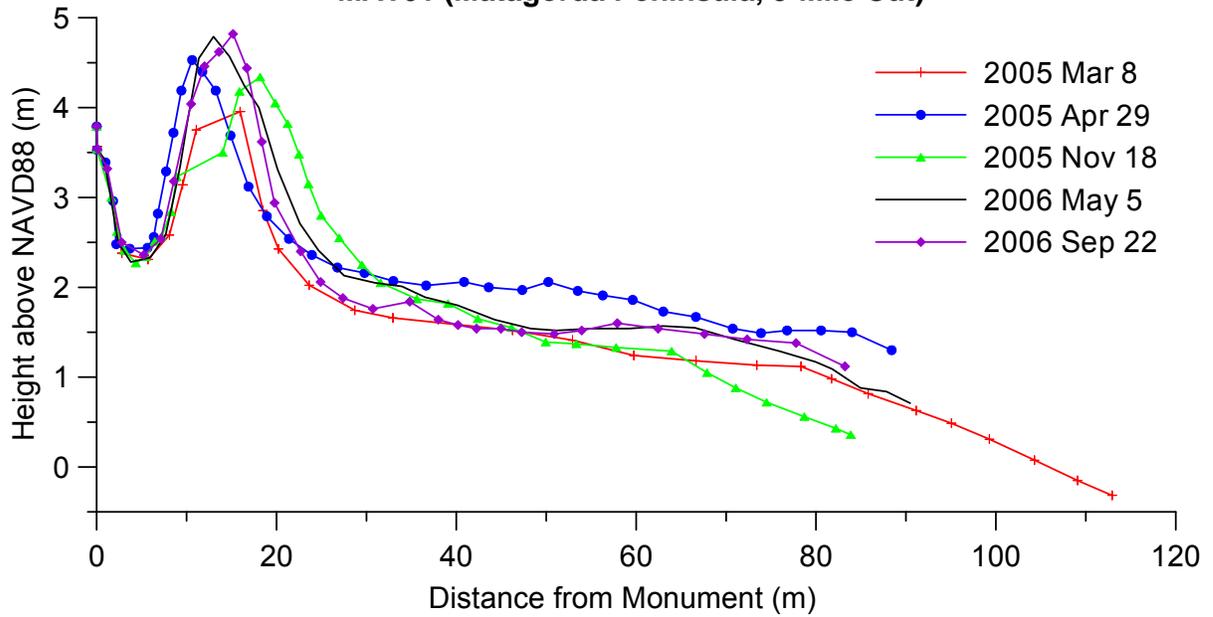
BEG08



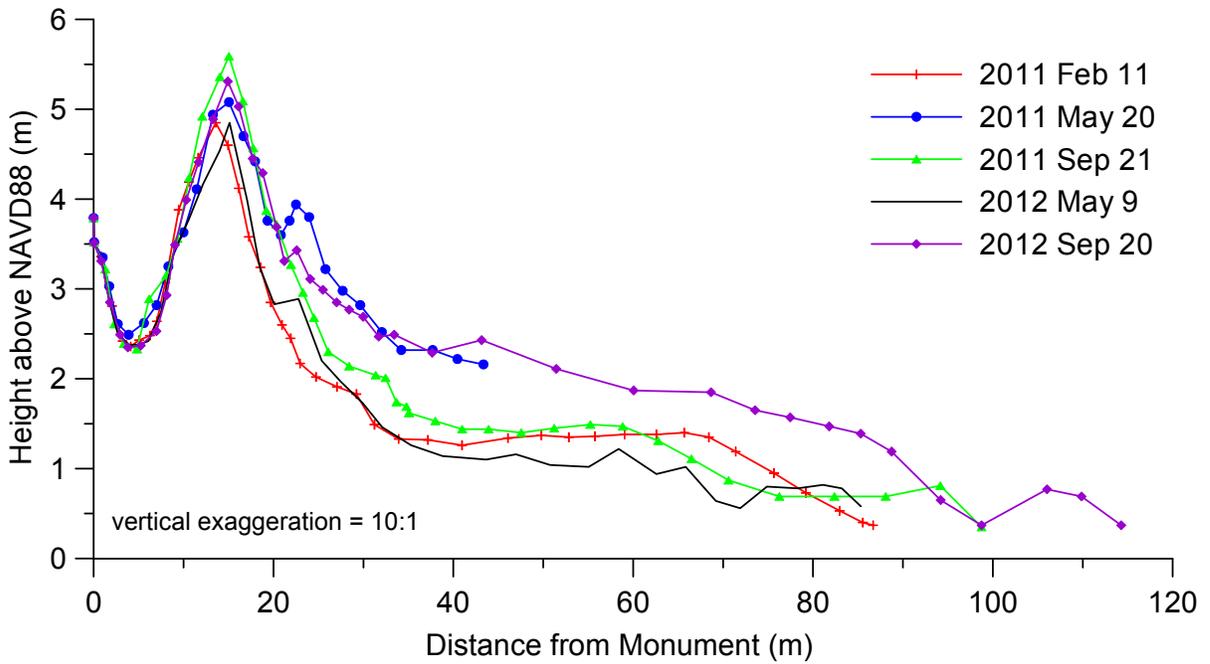
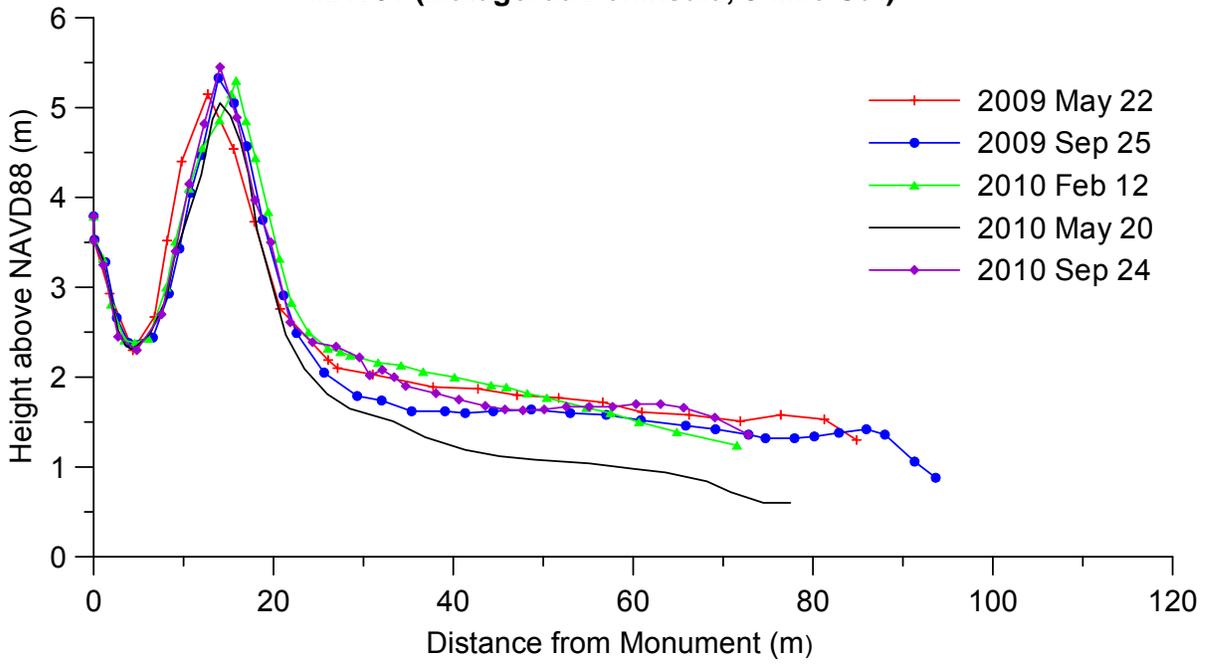


MAT01

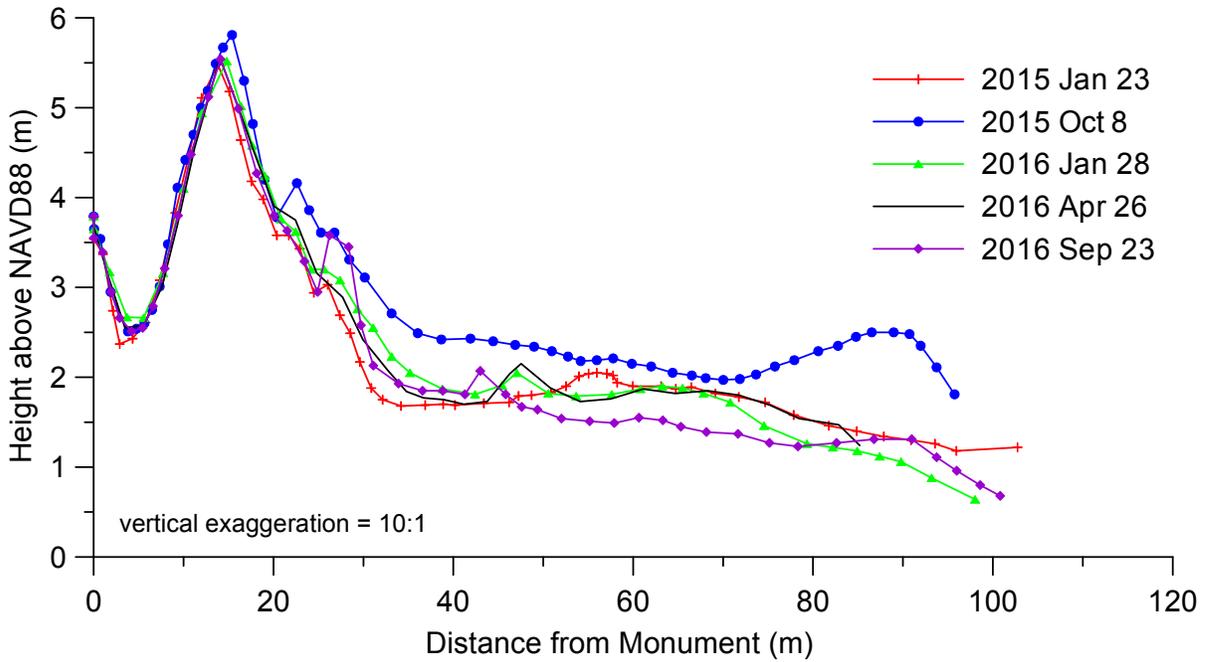
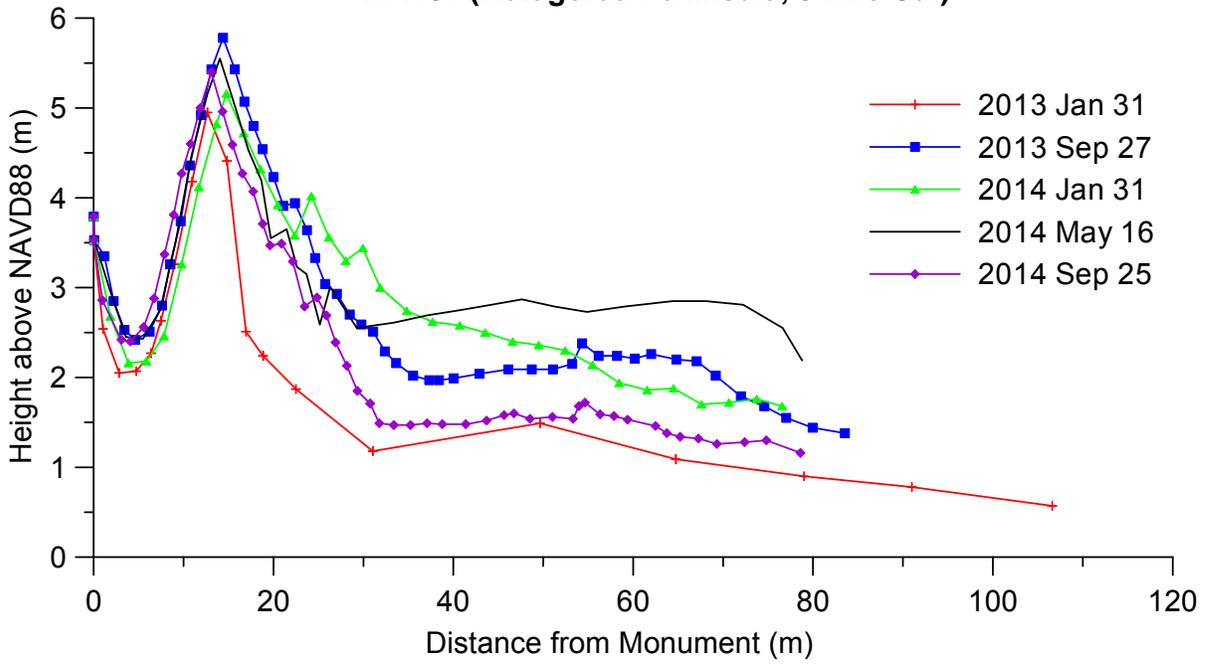
MAT01 (Matagorda Peninsula, 3-Mile Cut)



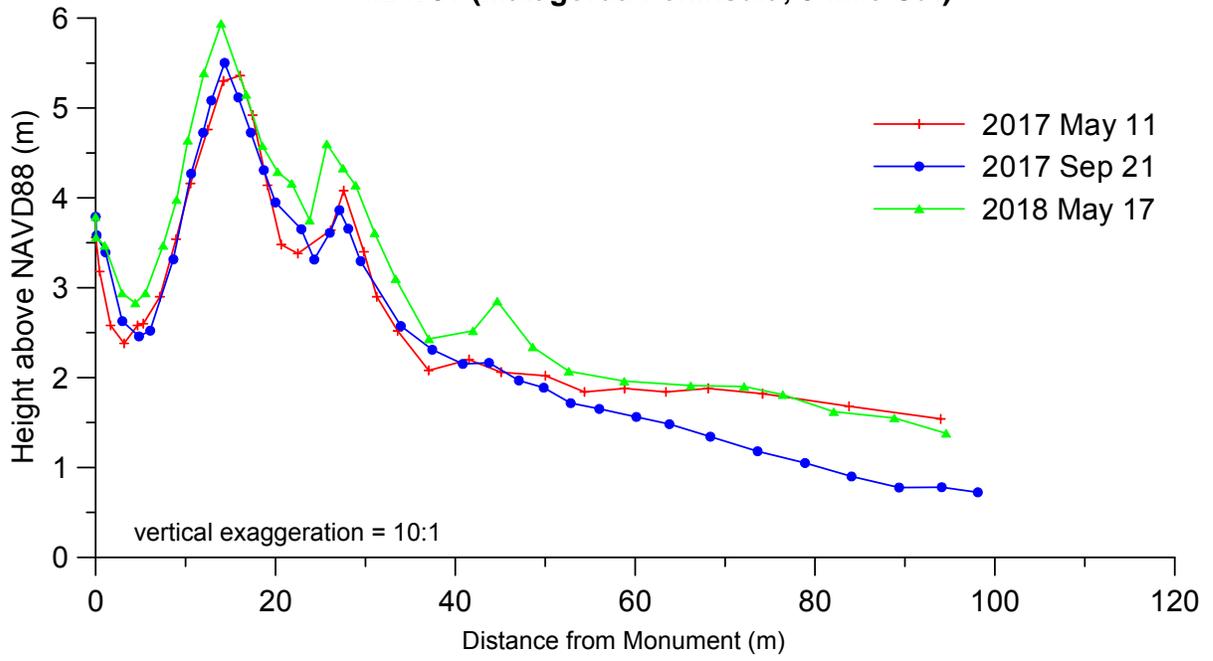
MAT01 (Matagorda Peninsula, 3-Mile Cut)



MAT01 (Matagorda Peninsula, 3-Mile Cut)

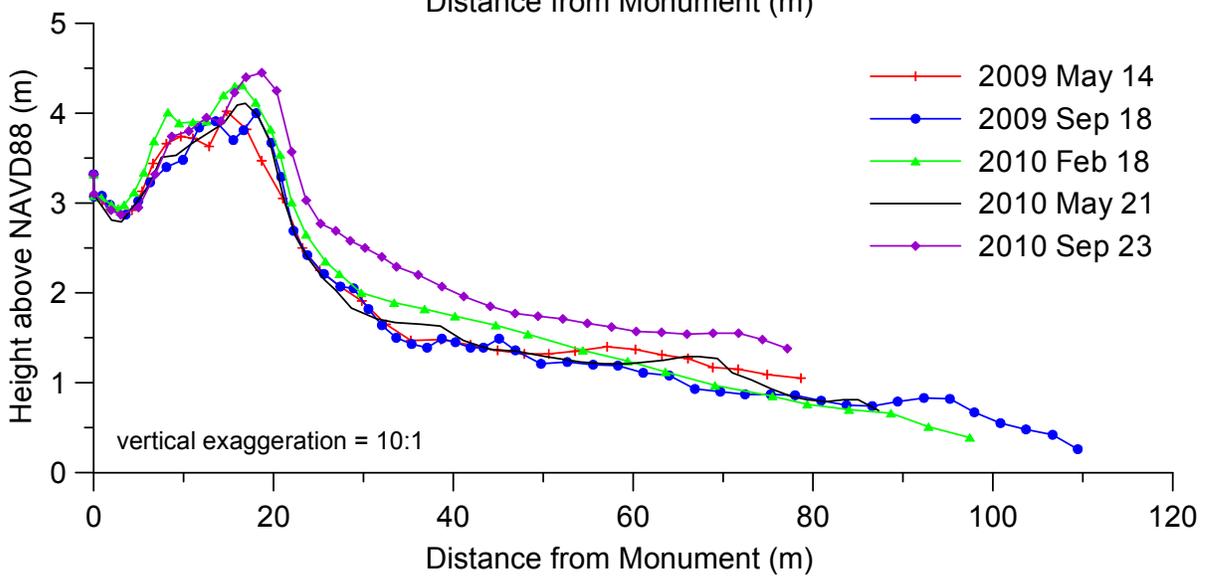
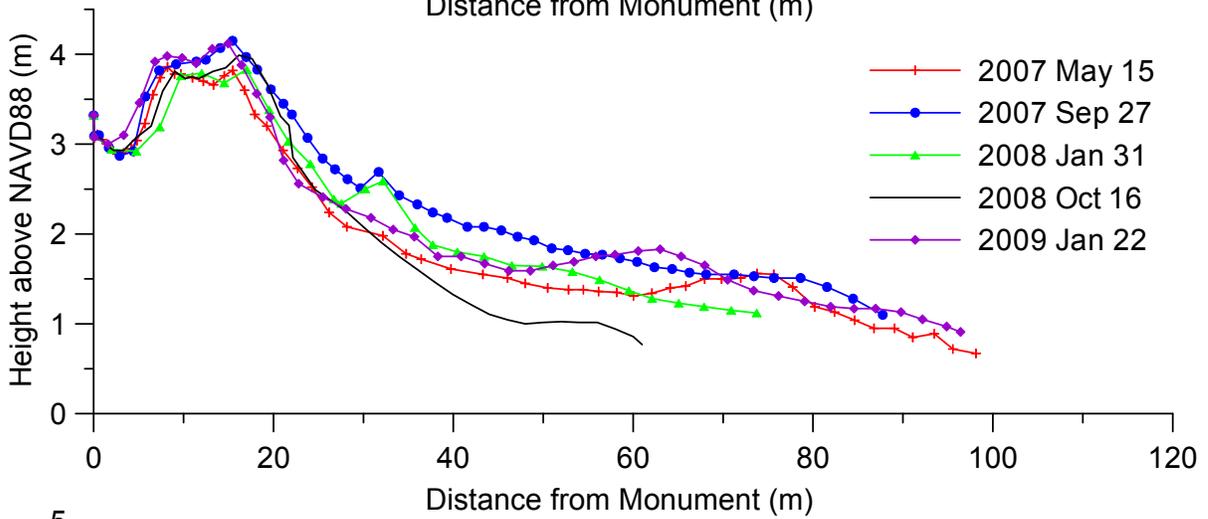
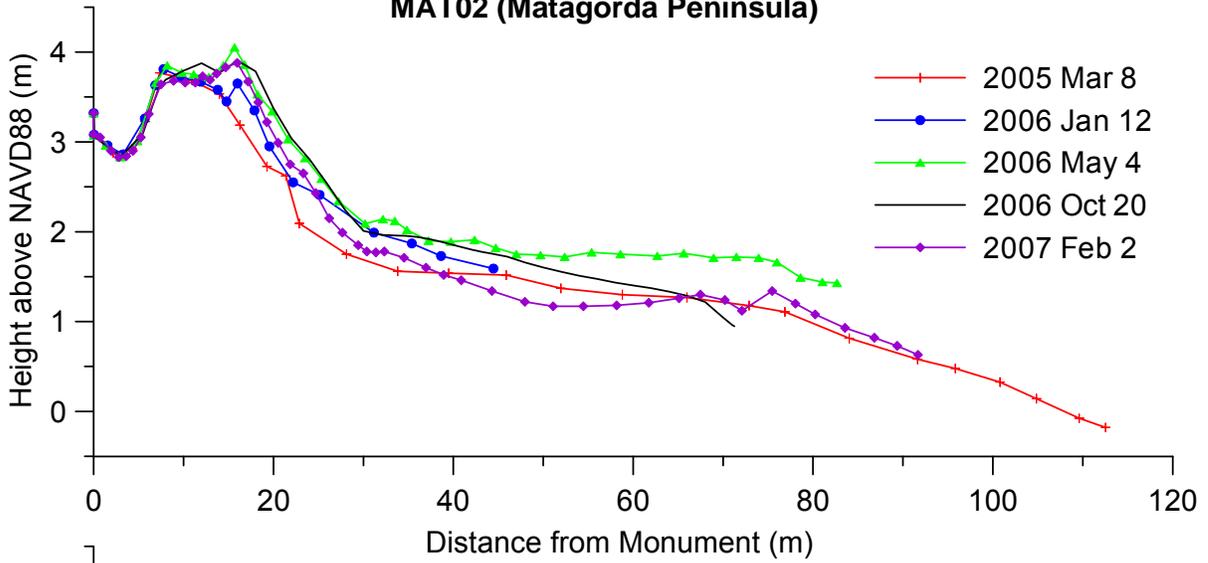


MAT01 (Matagorda Peninsula, 3-Mile Cut)

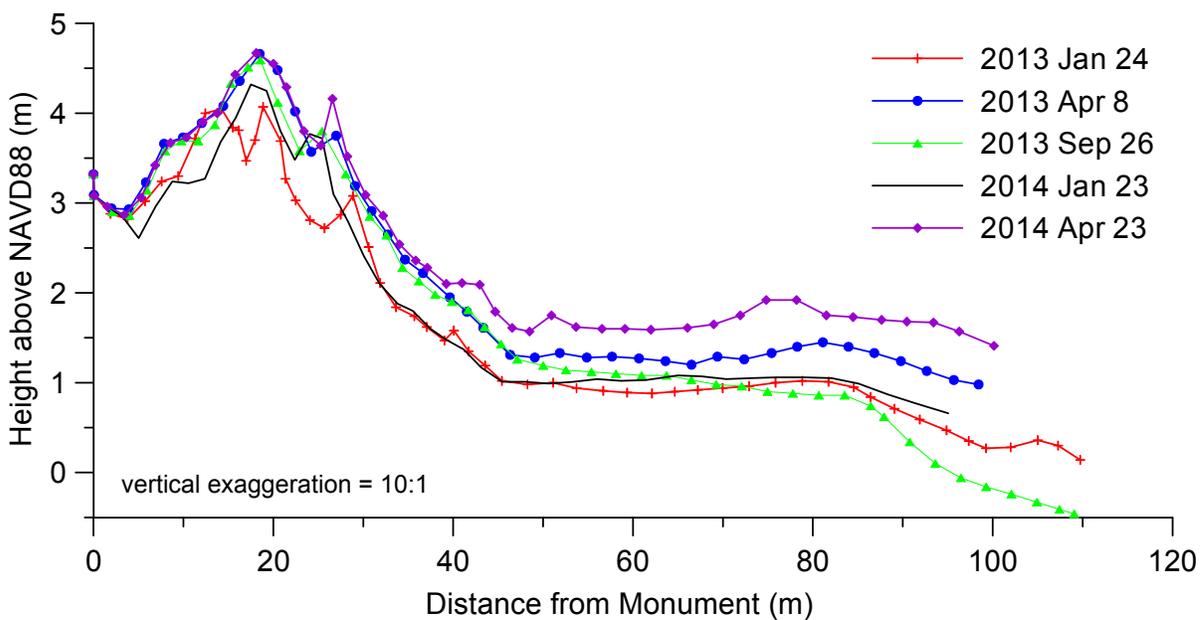
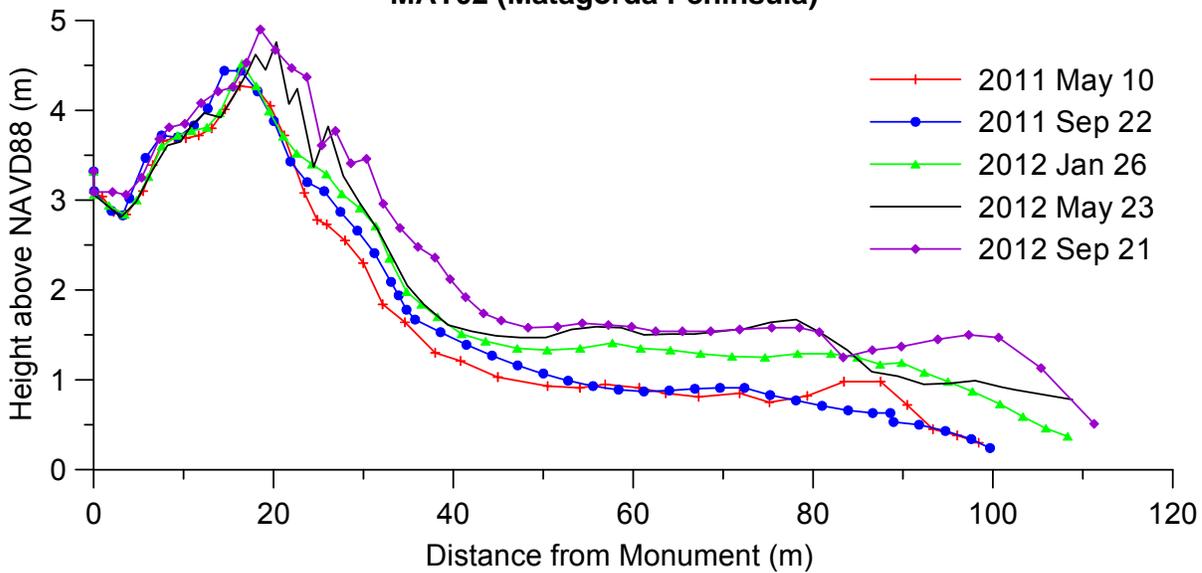


MAT02

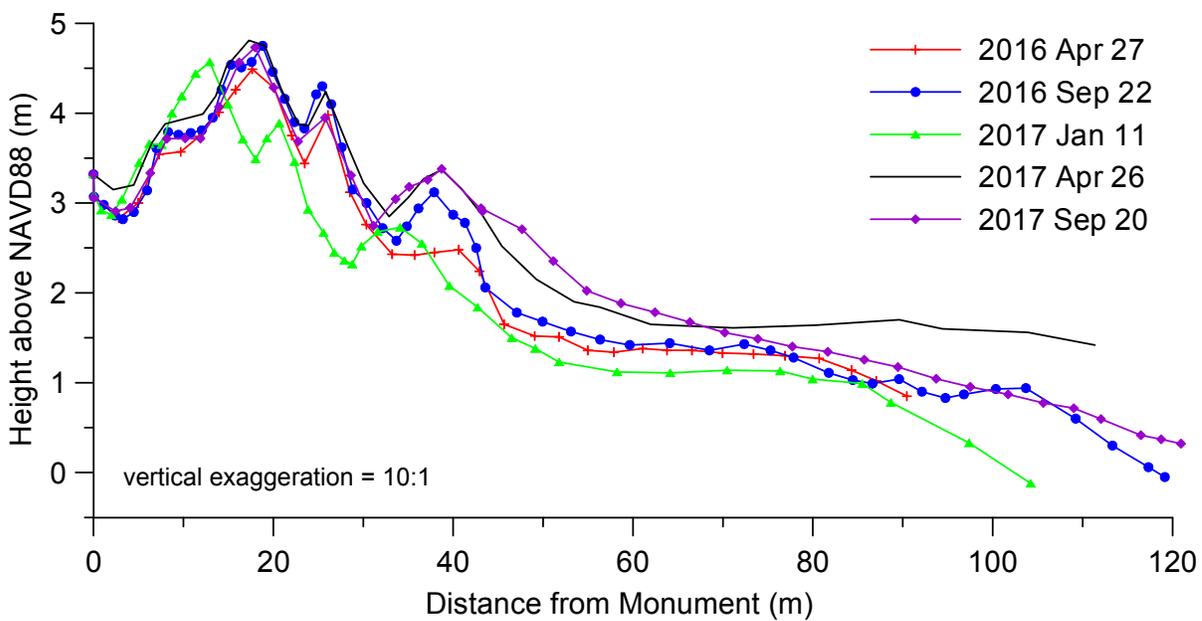
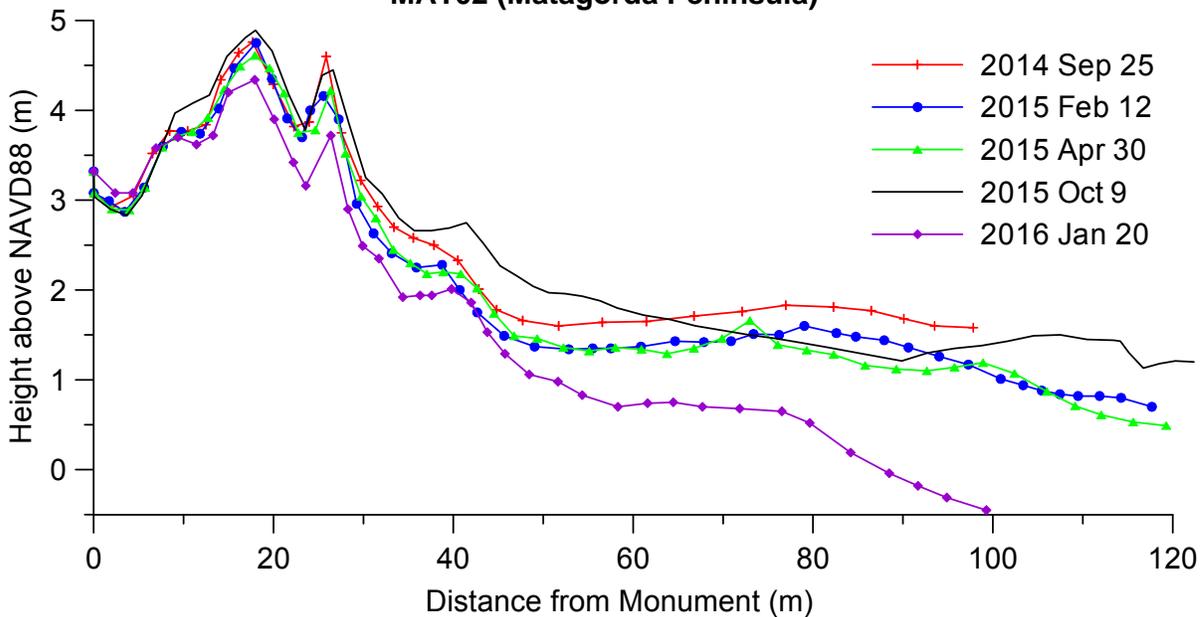
MAT02 (Matagorda Peninsula)



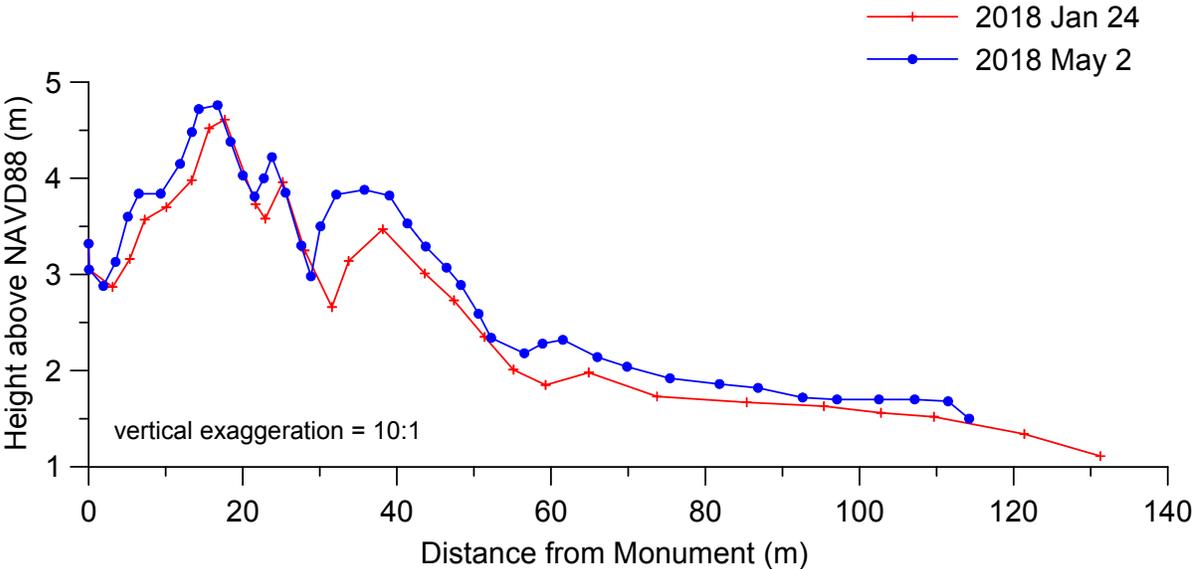
MAT02 (Matagorda Peninsula)



MAT02 (Matagorda Peninsula)

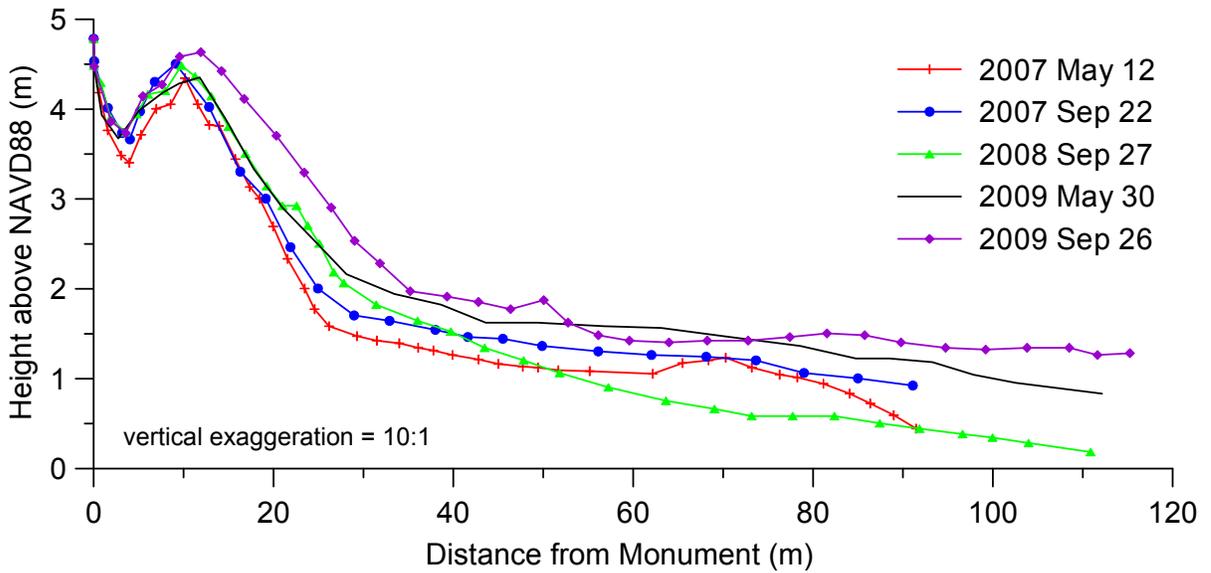
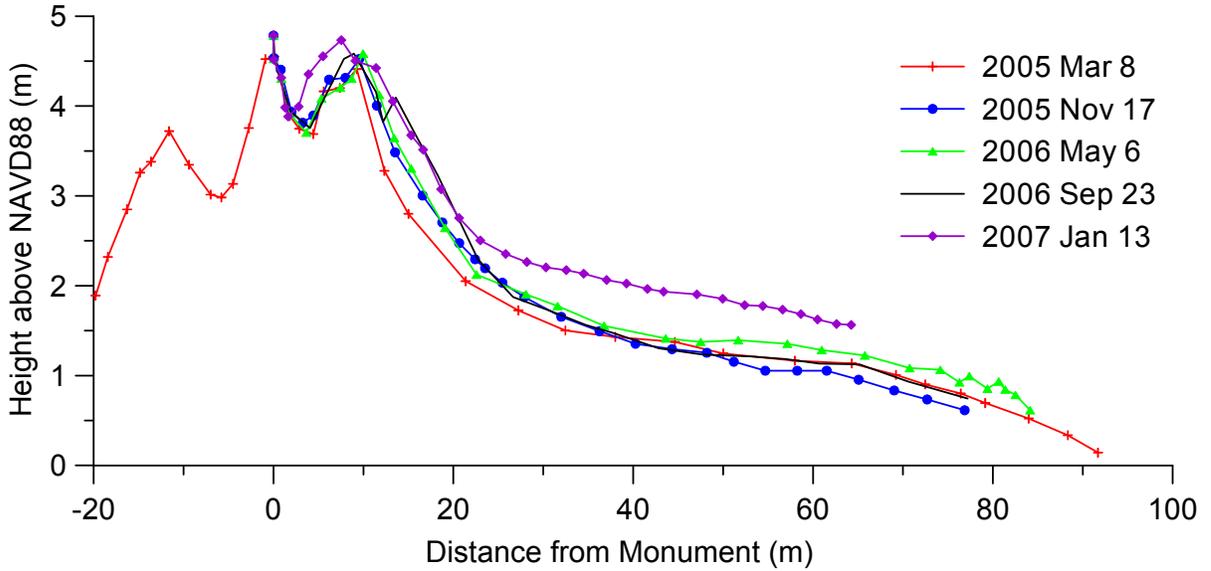


MAT02 (Matagorda Peninsula)

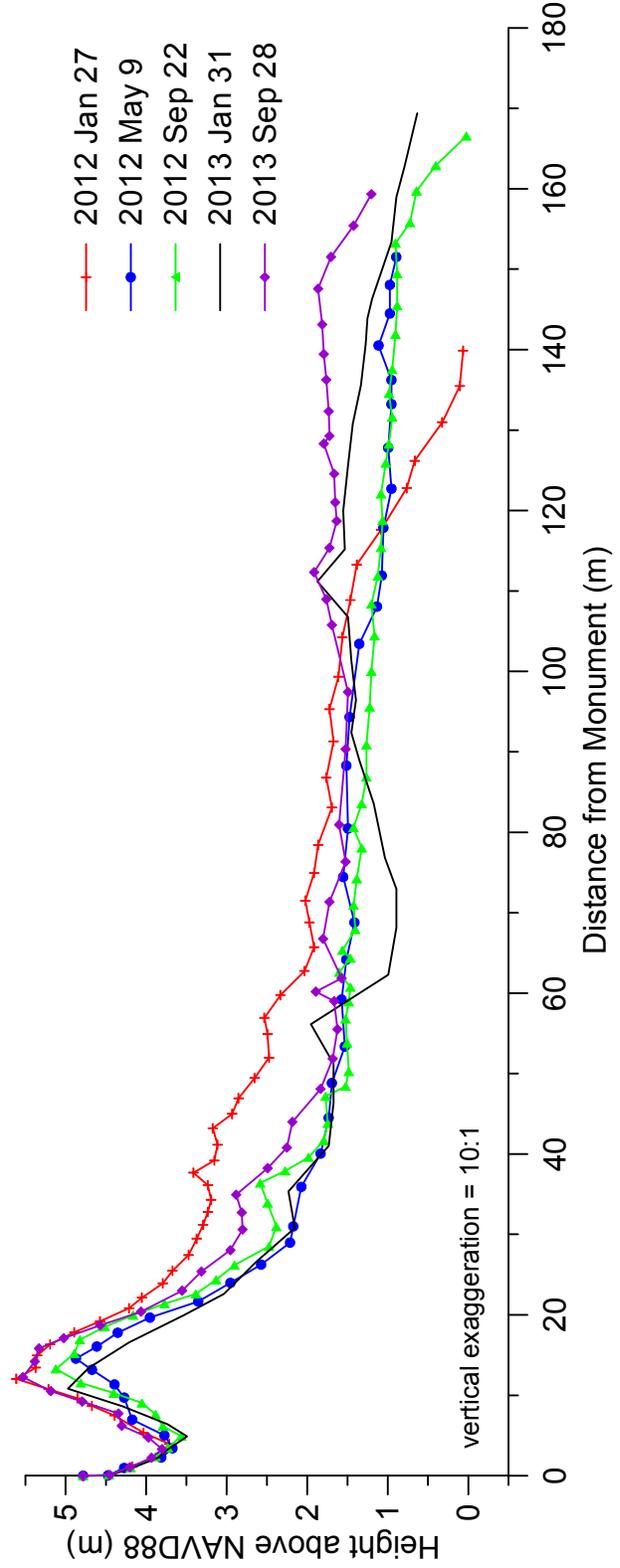
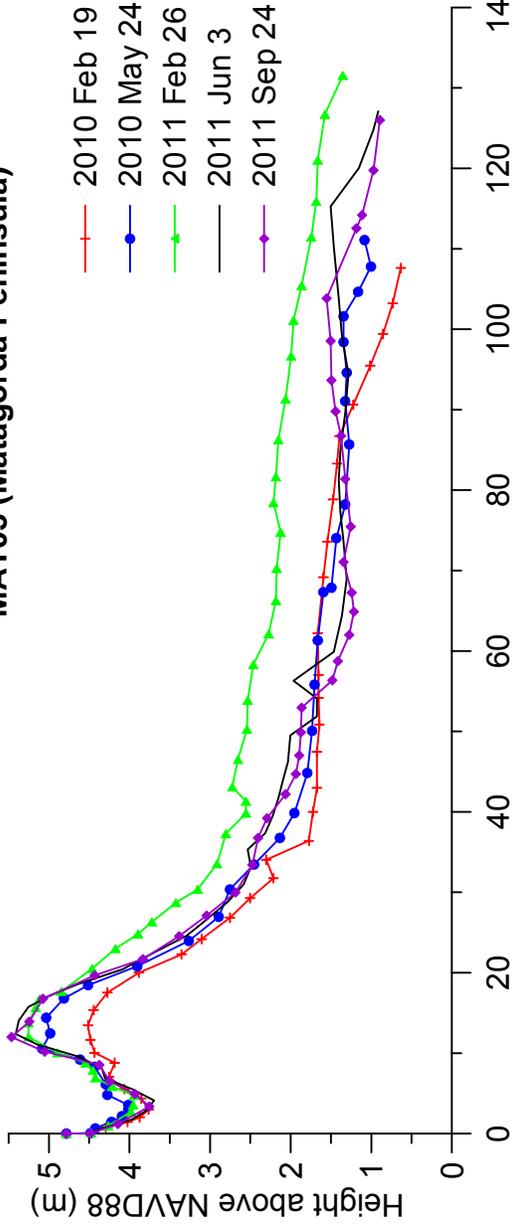


MAT03

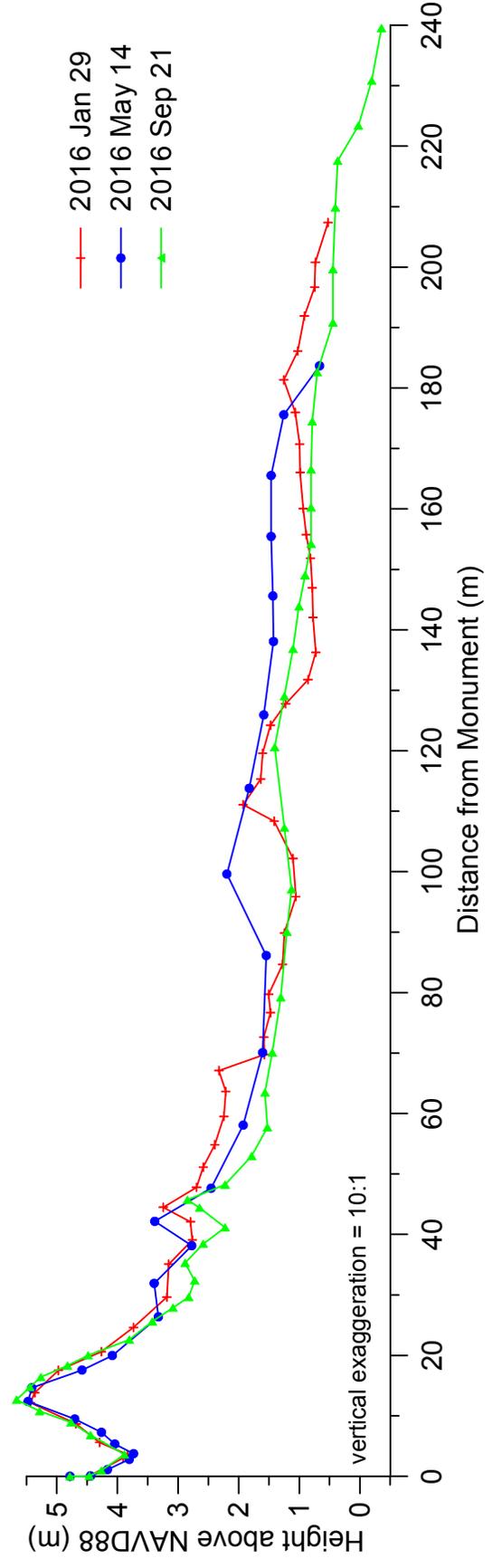
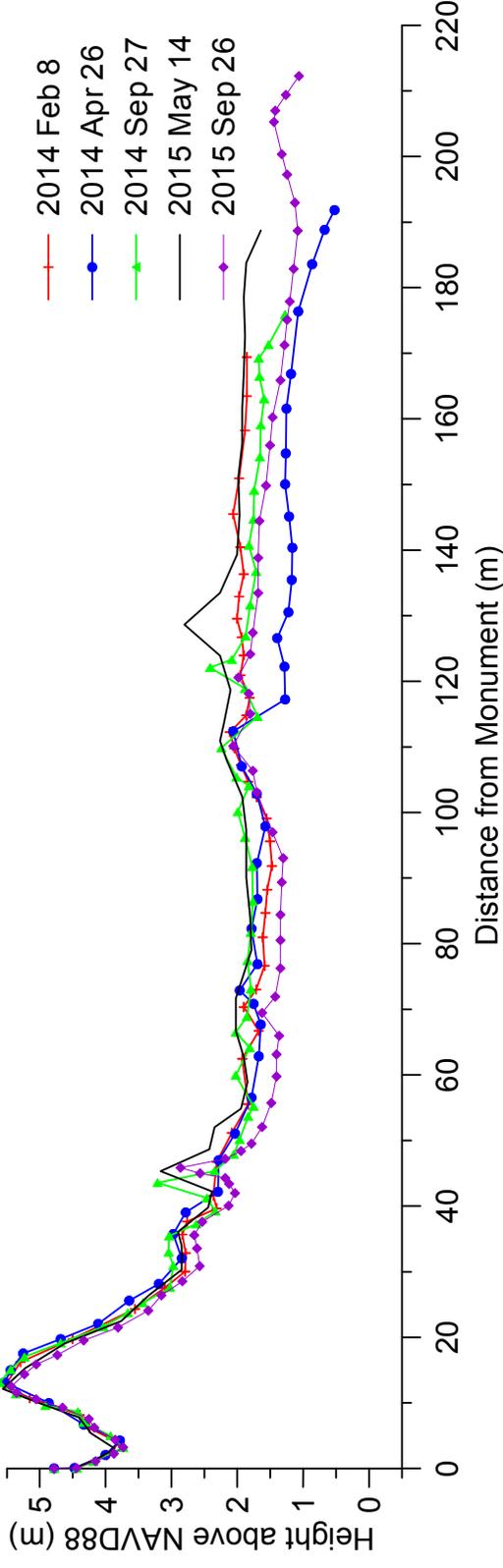
MAT03 (Matagorda Peninsula)



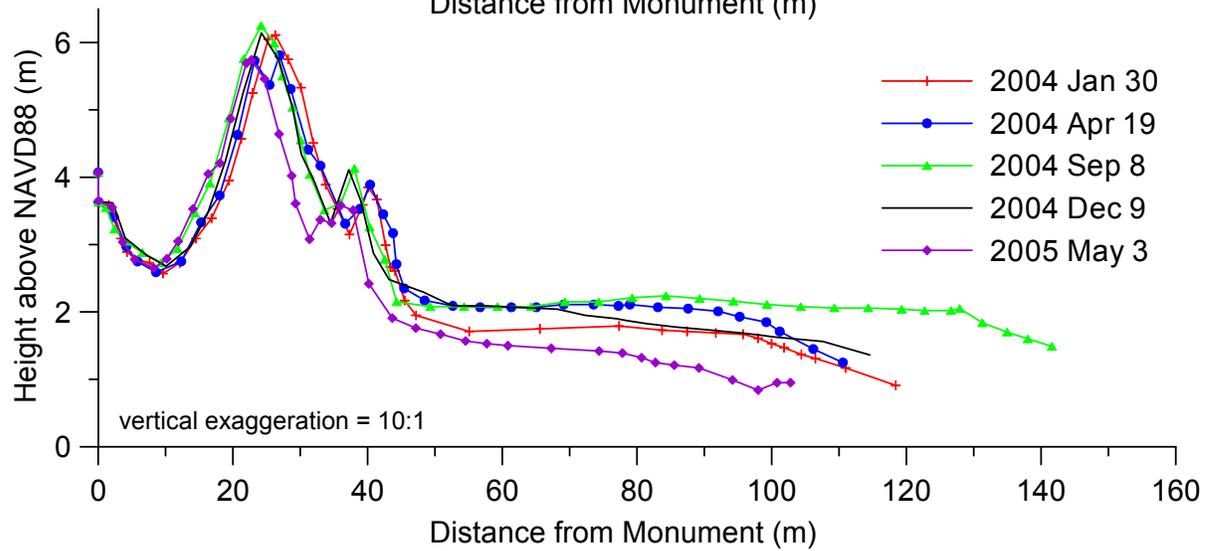
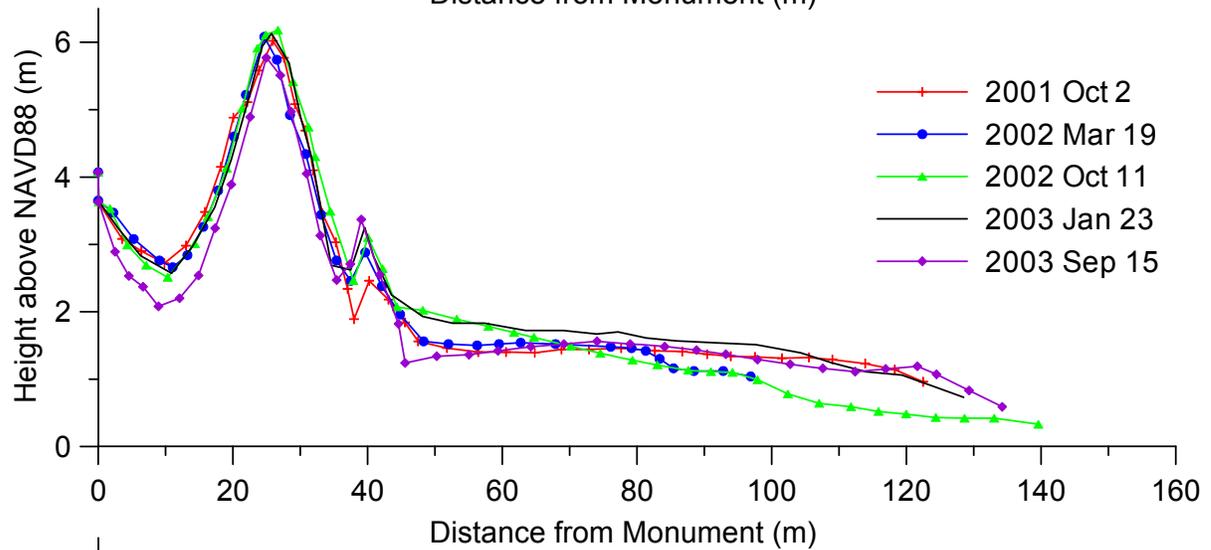
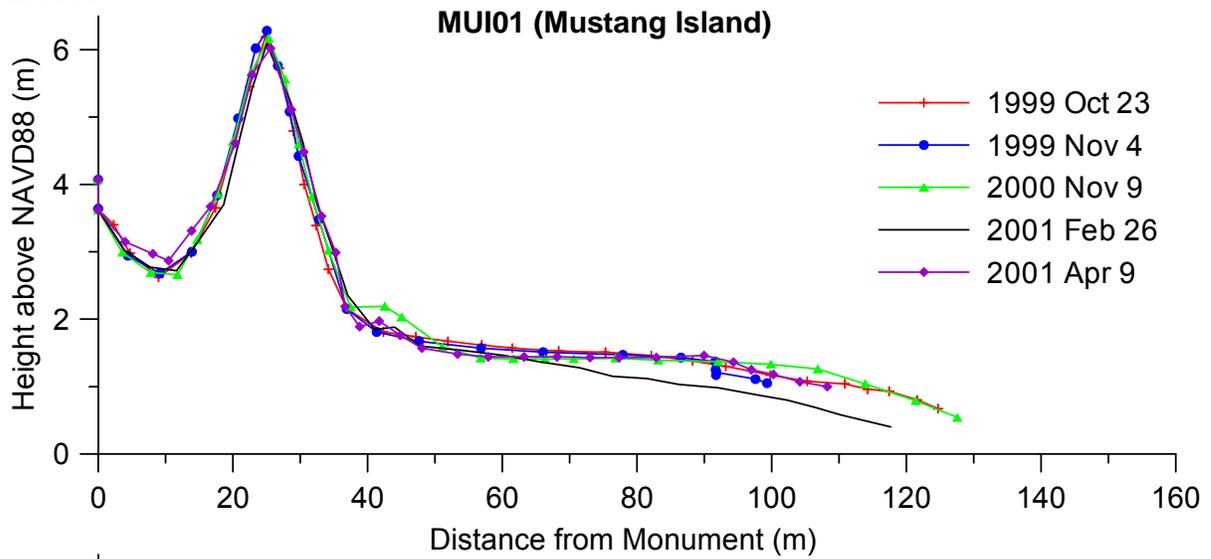
MAT03 (Matagorda Peninsula)

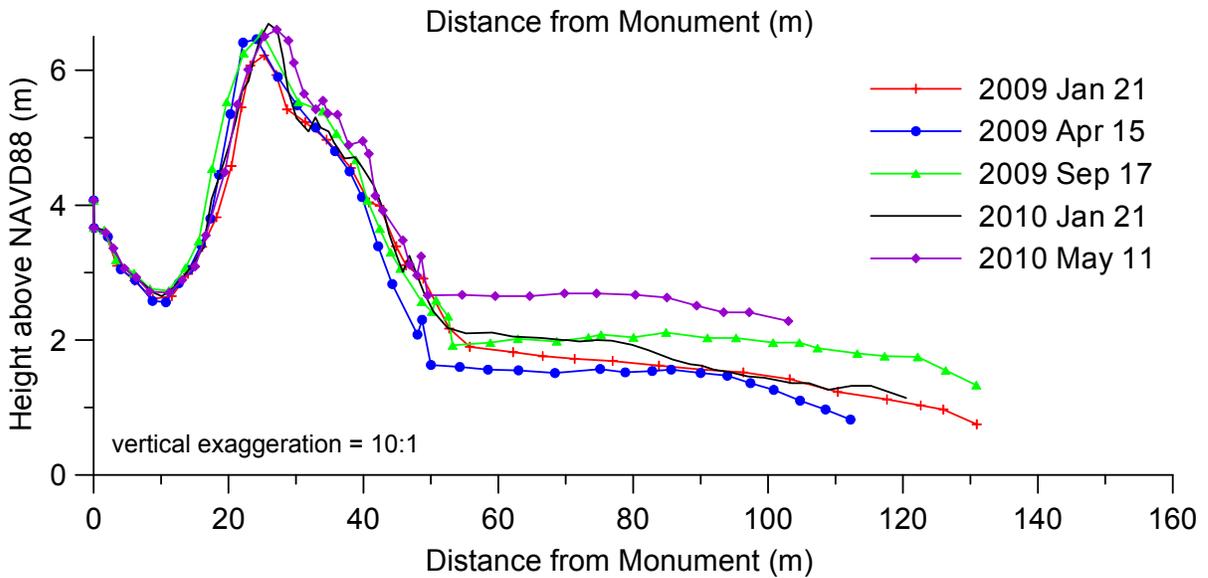
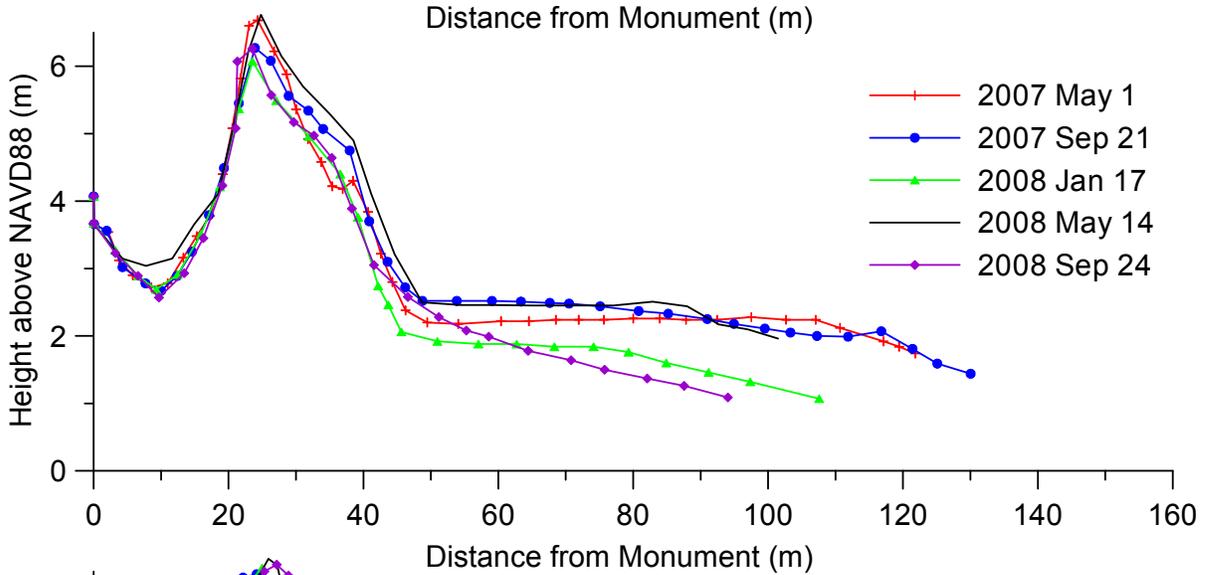
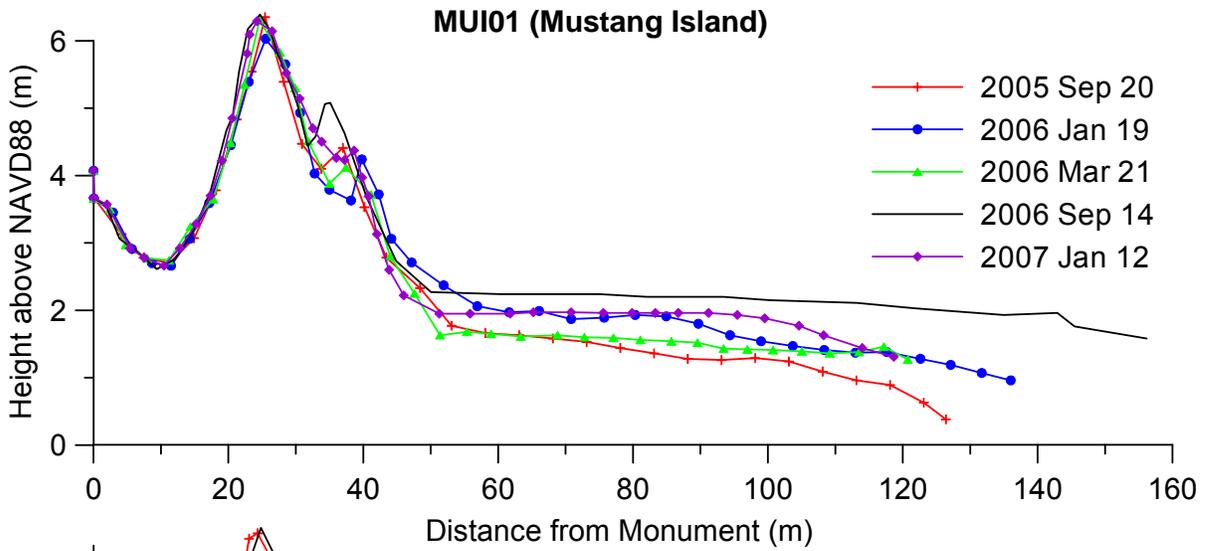


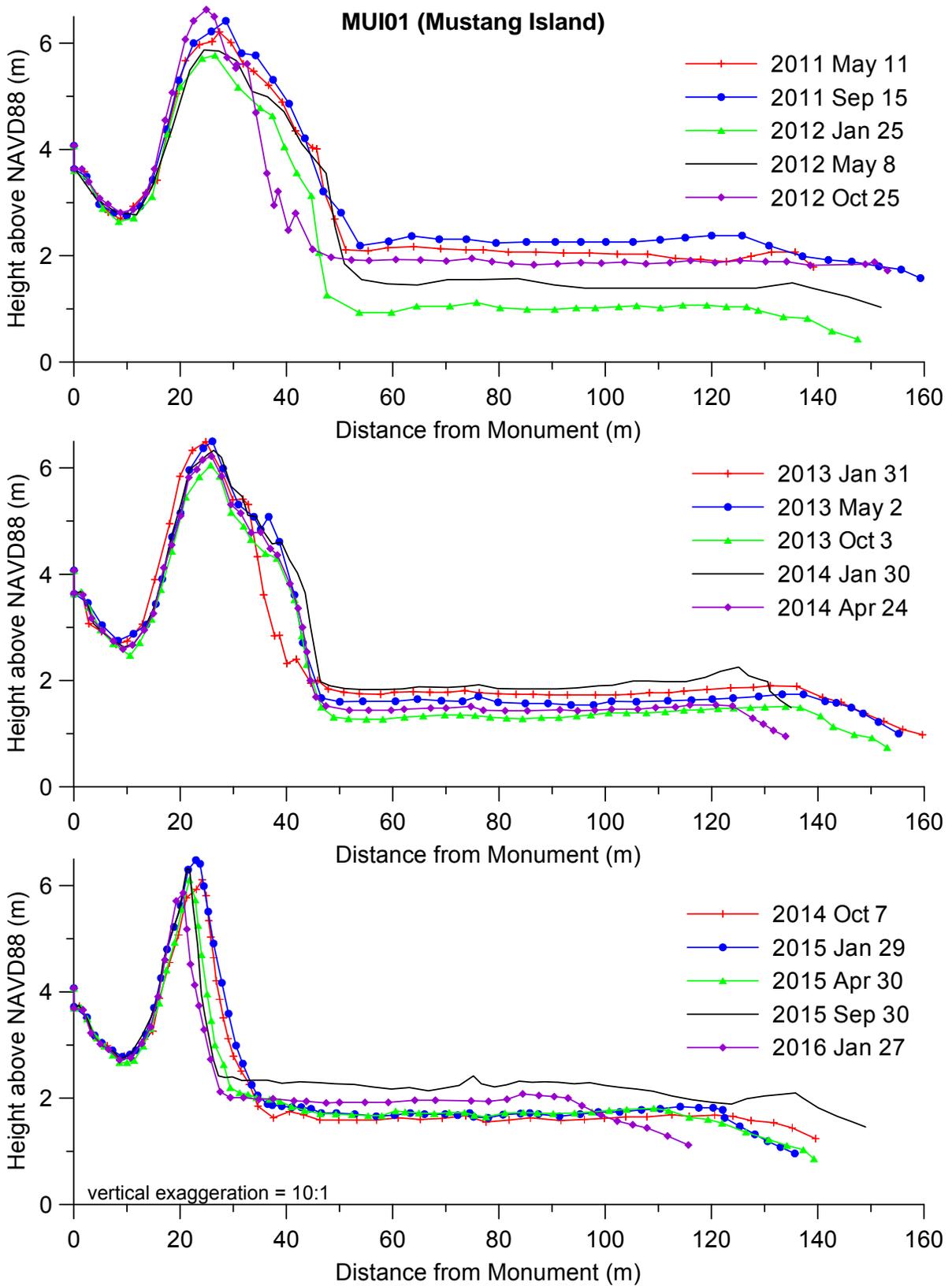
MAT03 (Matagorda Peninsula)

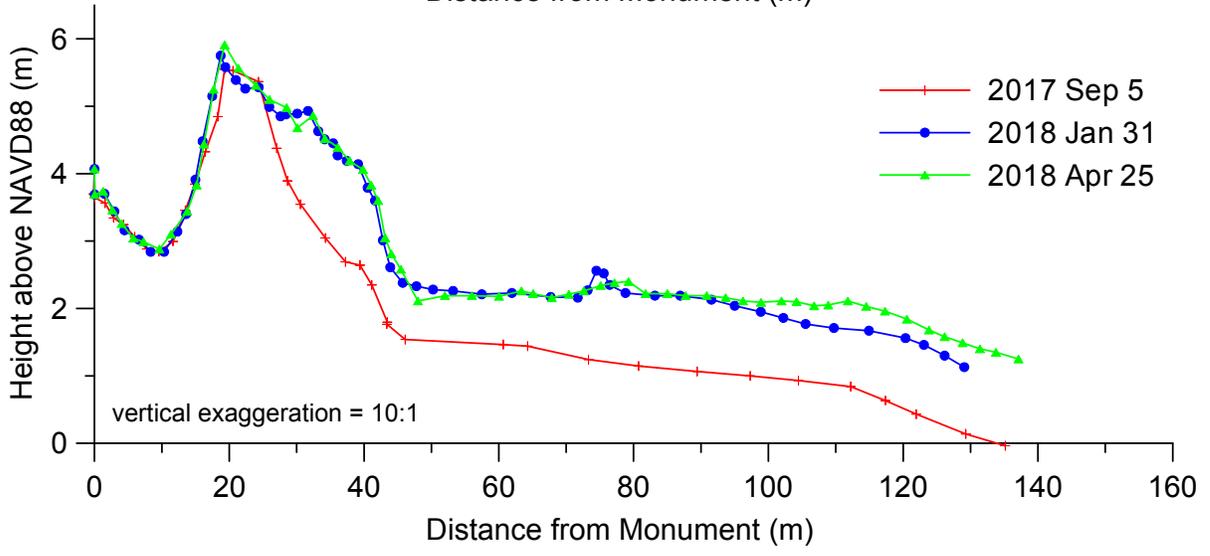
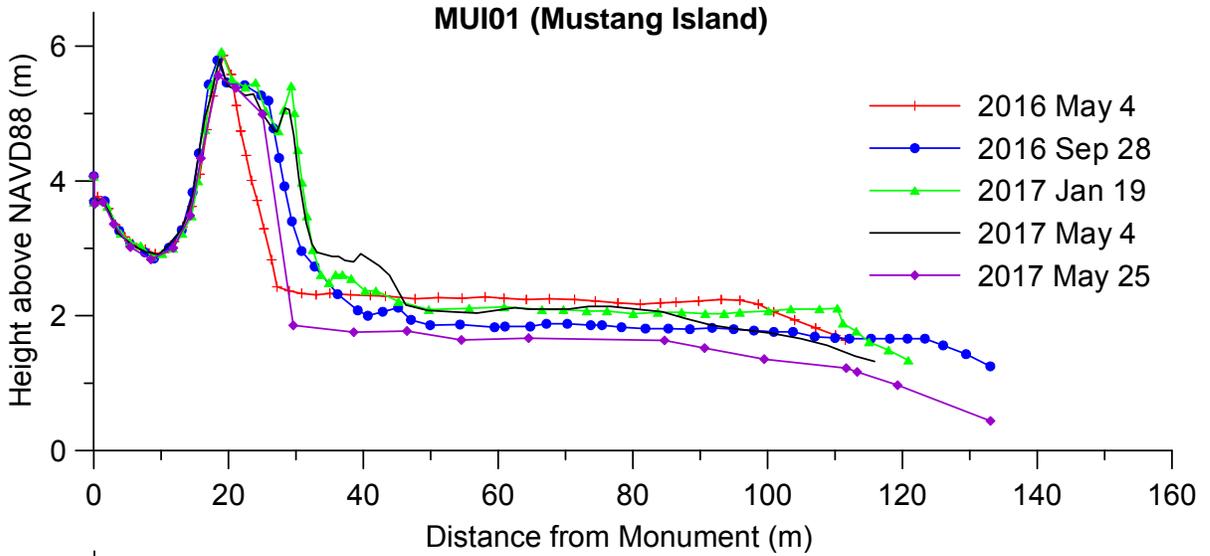


MUI01



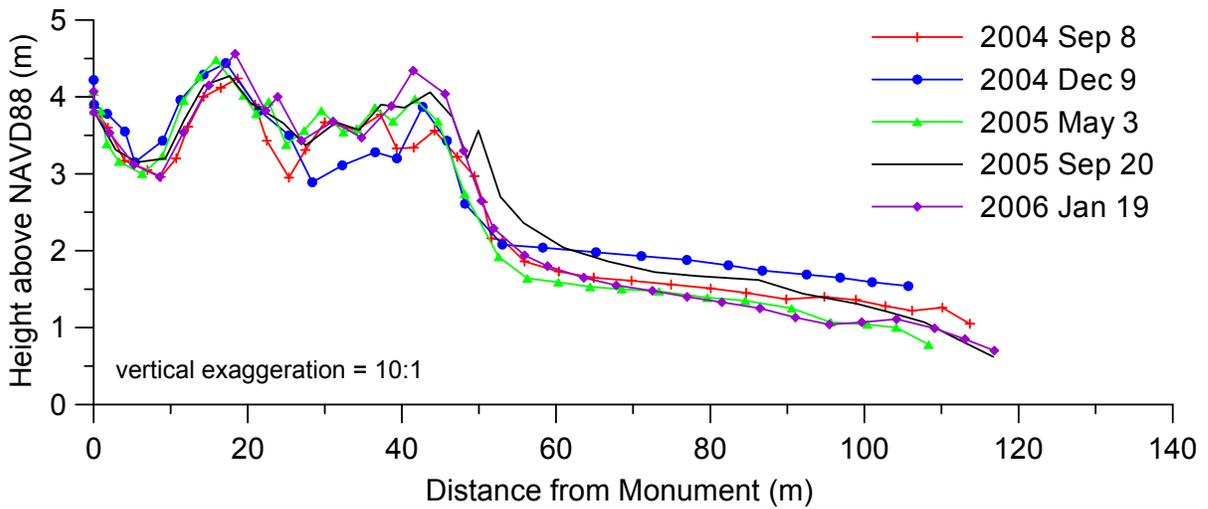
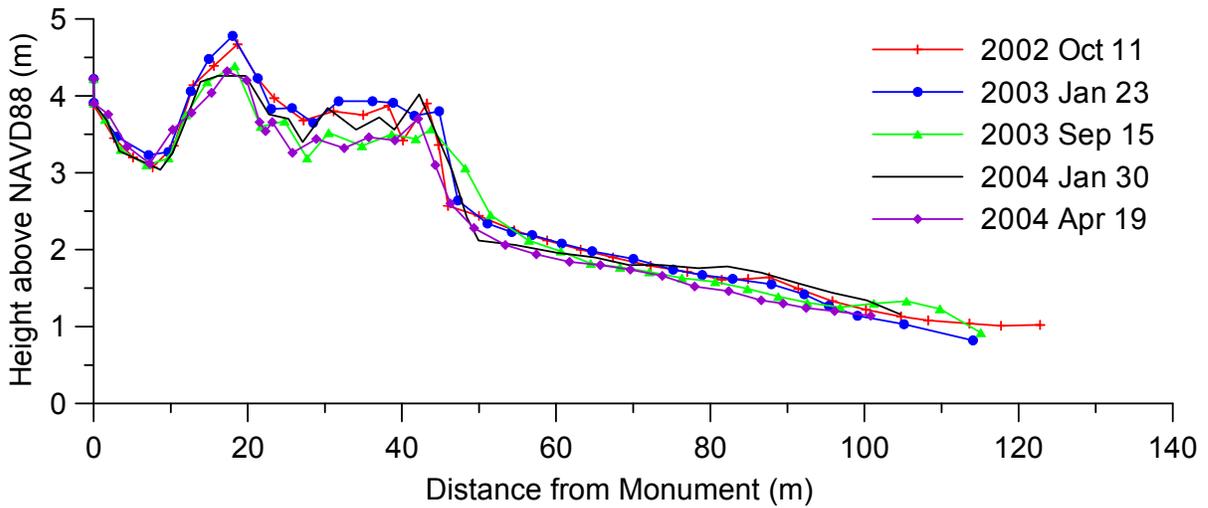
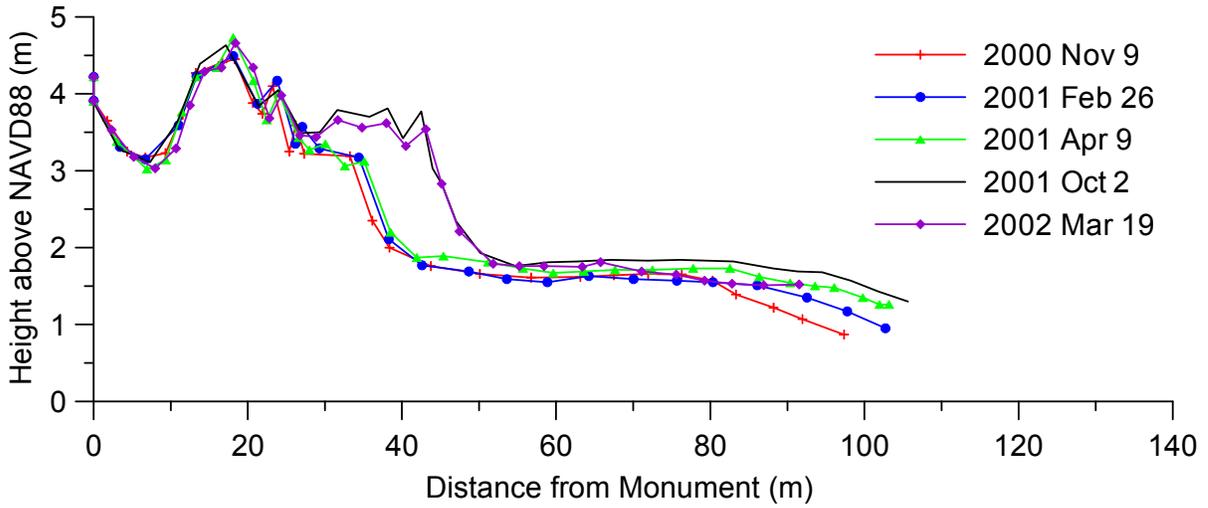




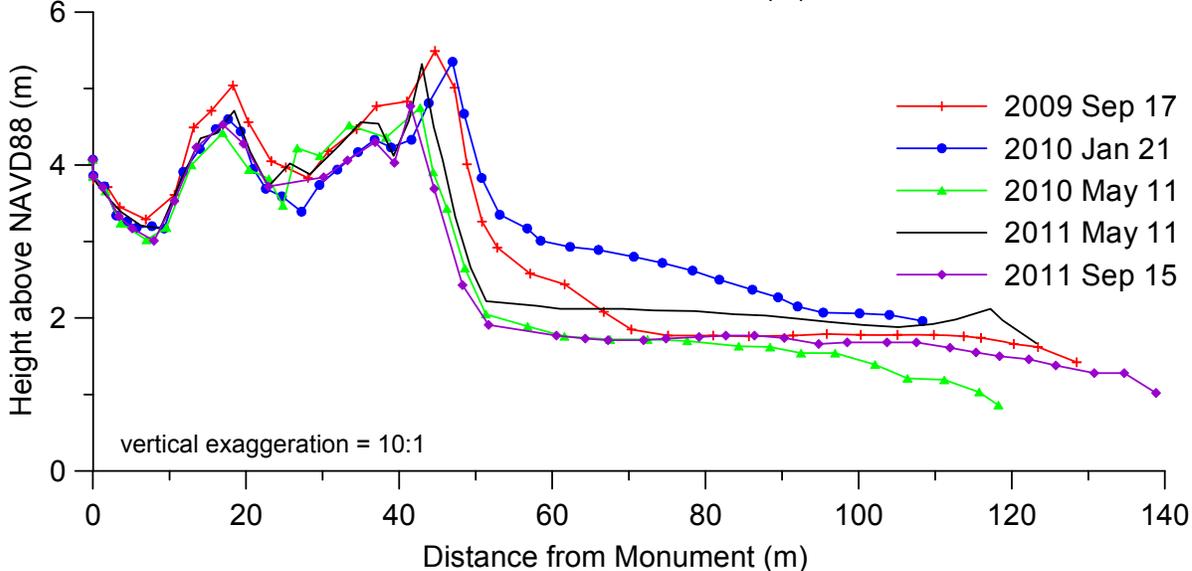
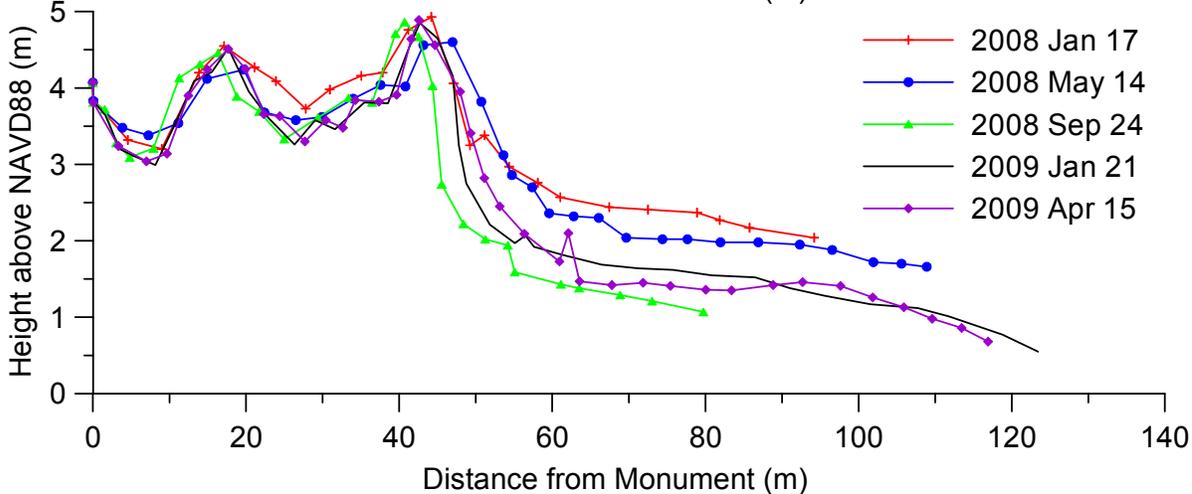
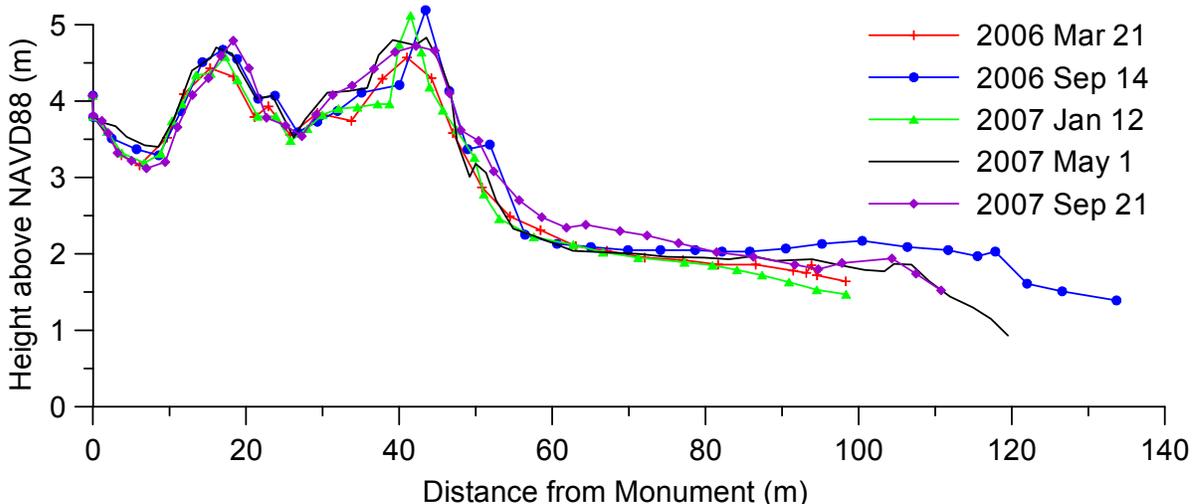


MUI03

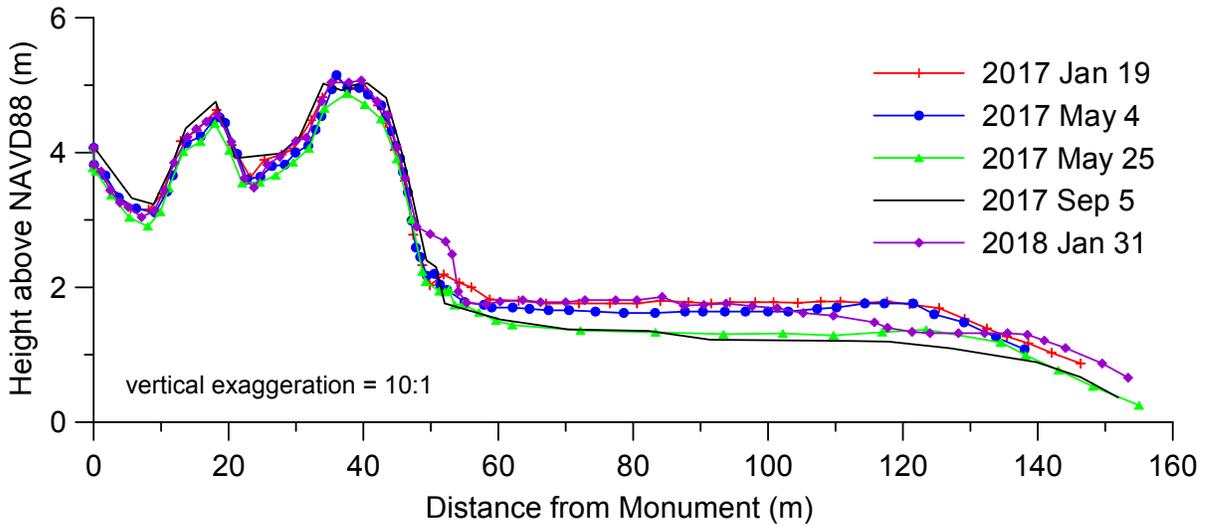
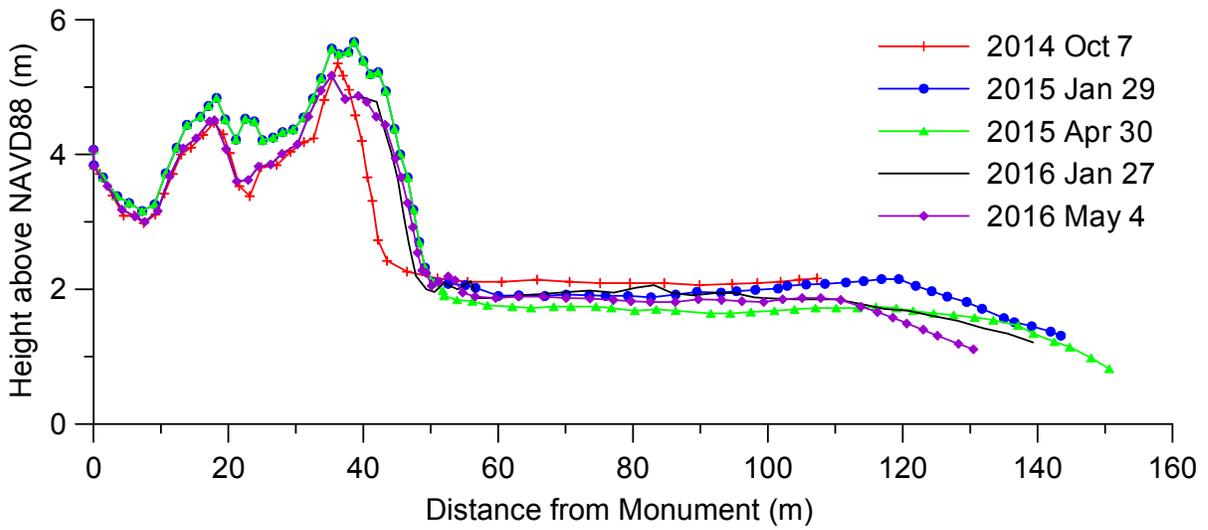
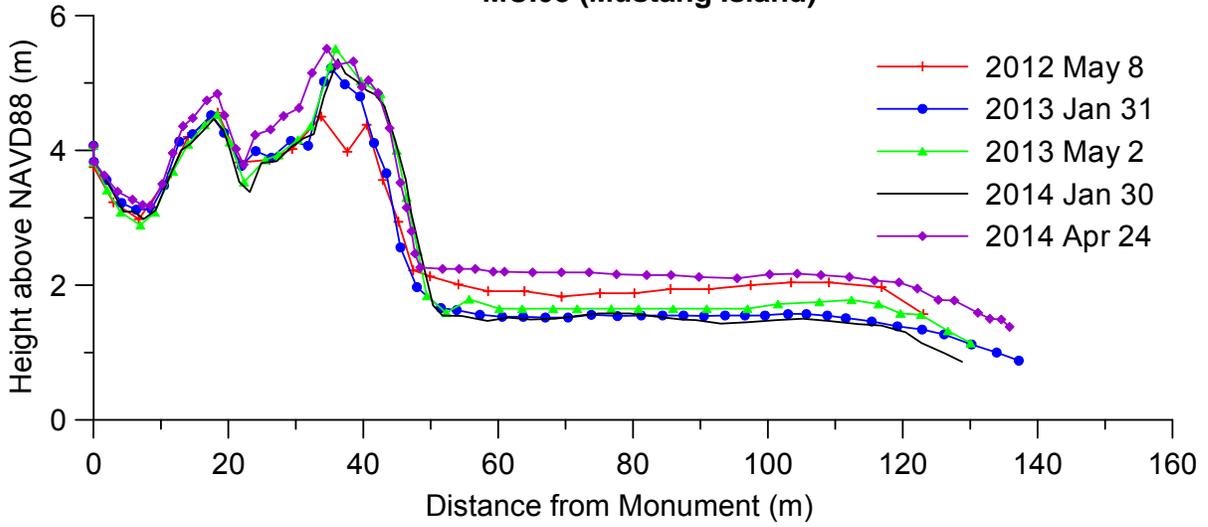
MUI03 (Mustang Island)

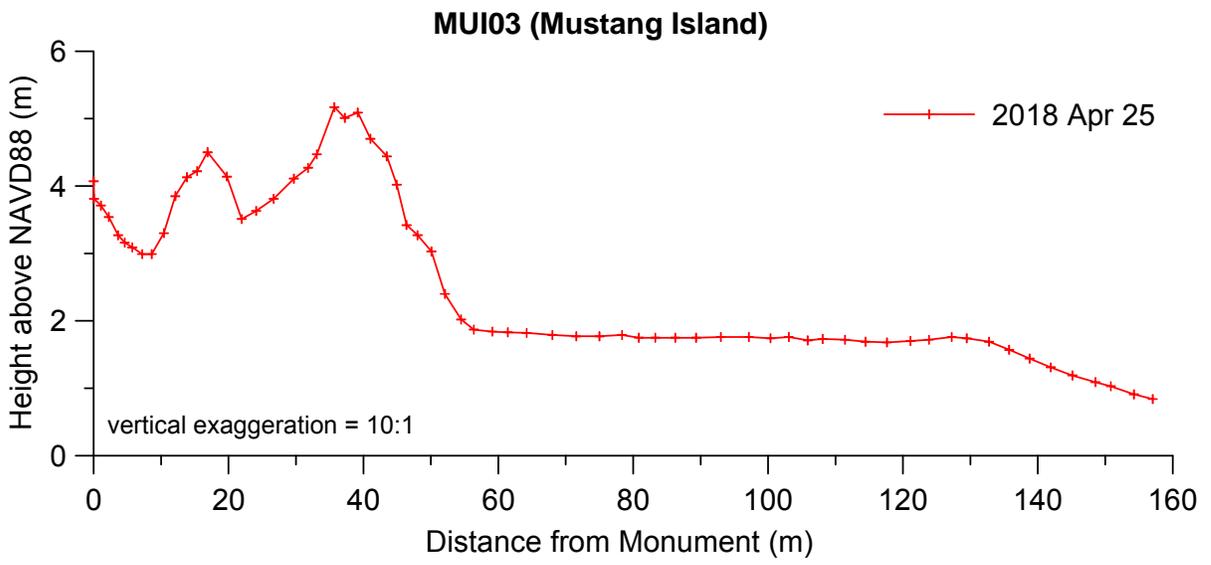


MUI03 (Mustang Island)



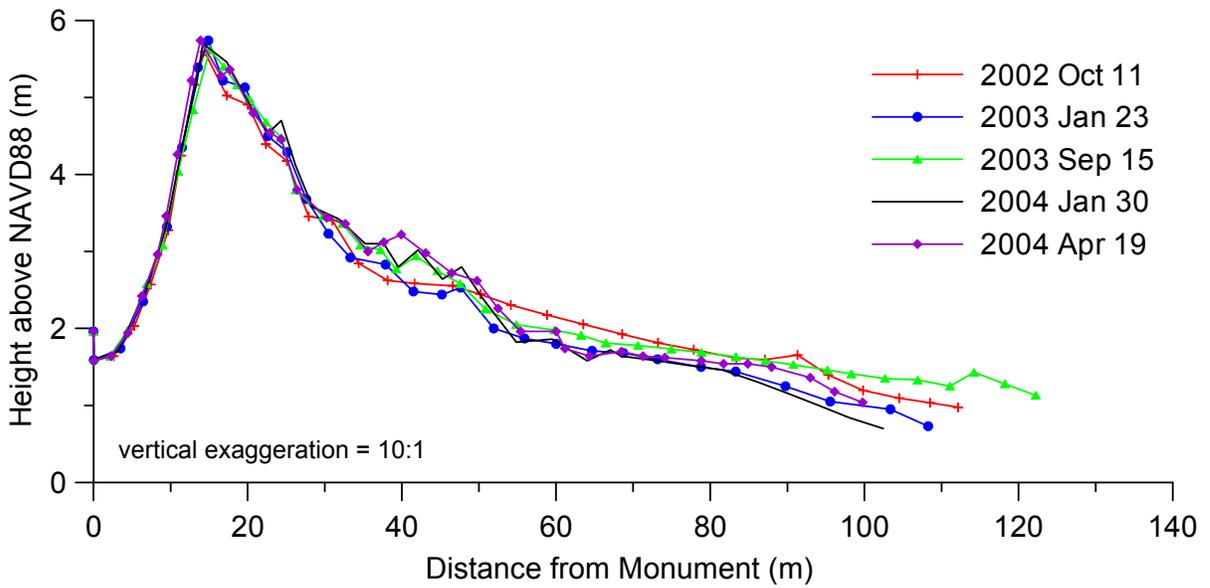
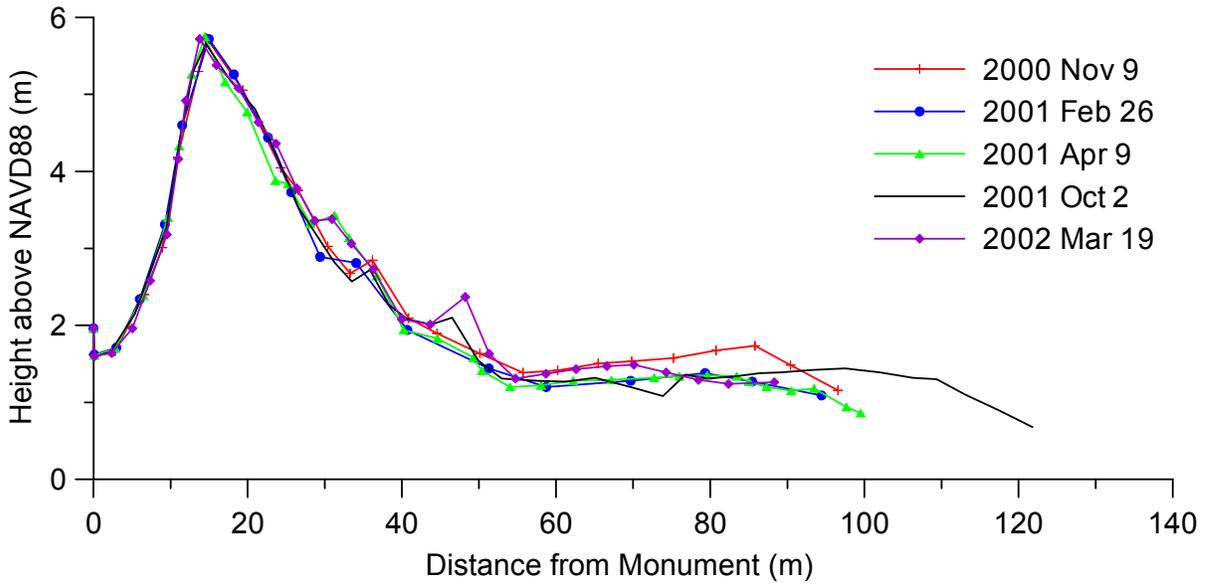
MUI03 (Mustang Island)



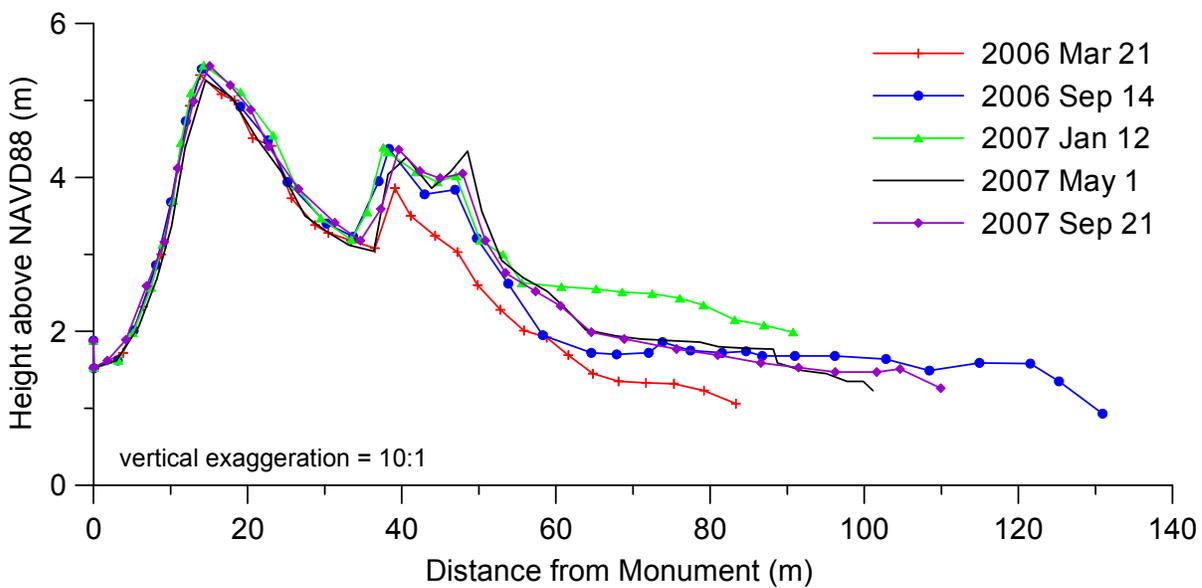
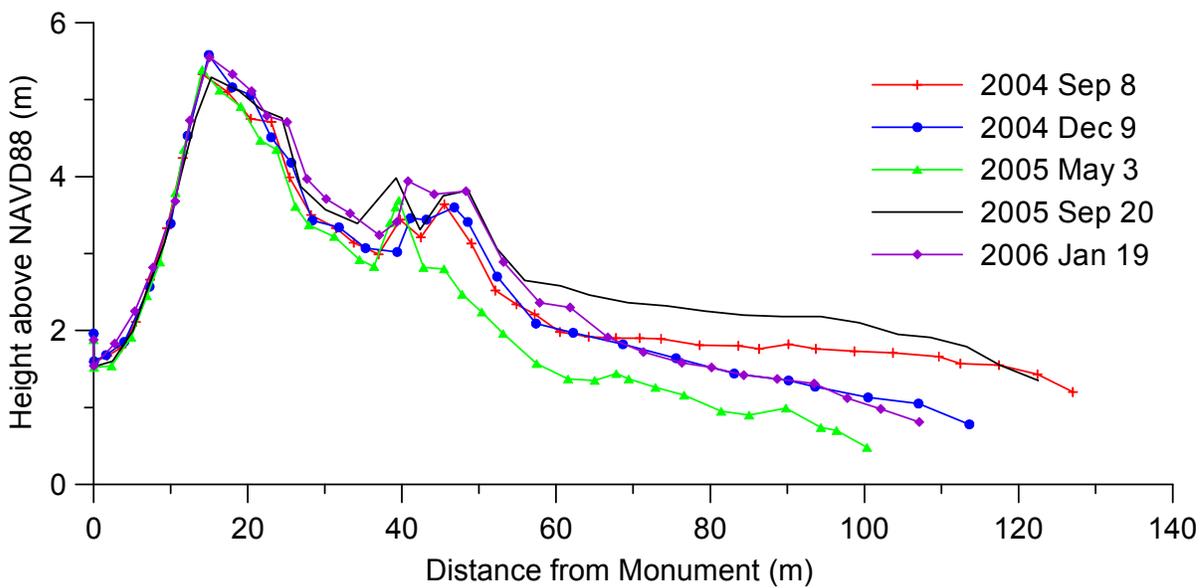


MUI02

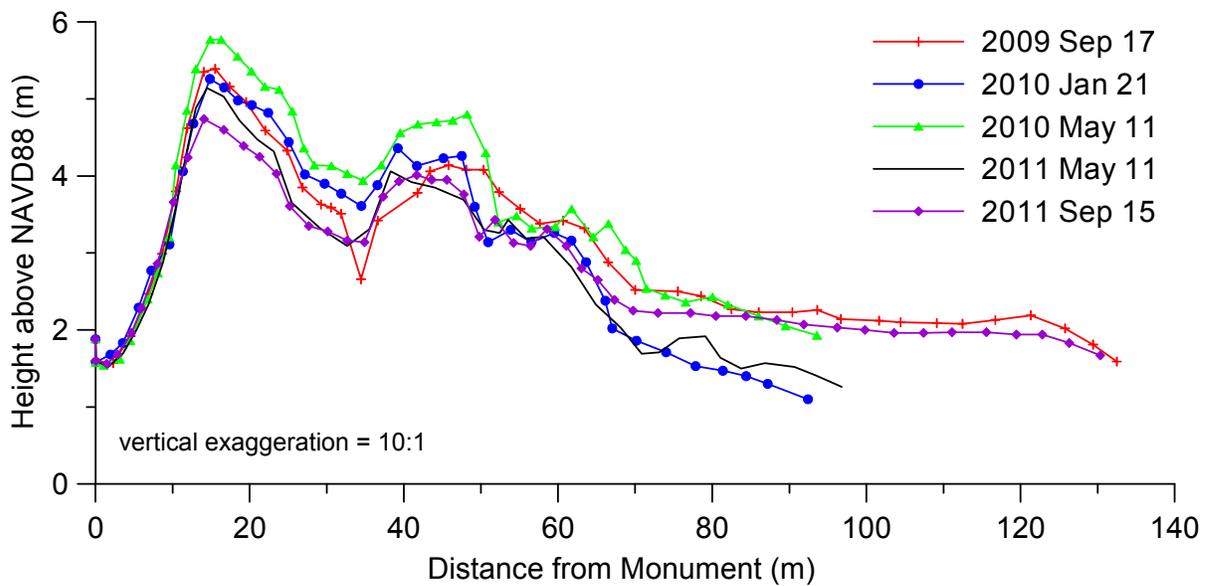
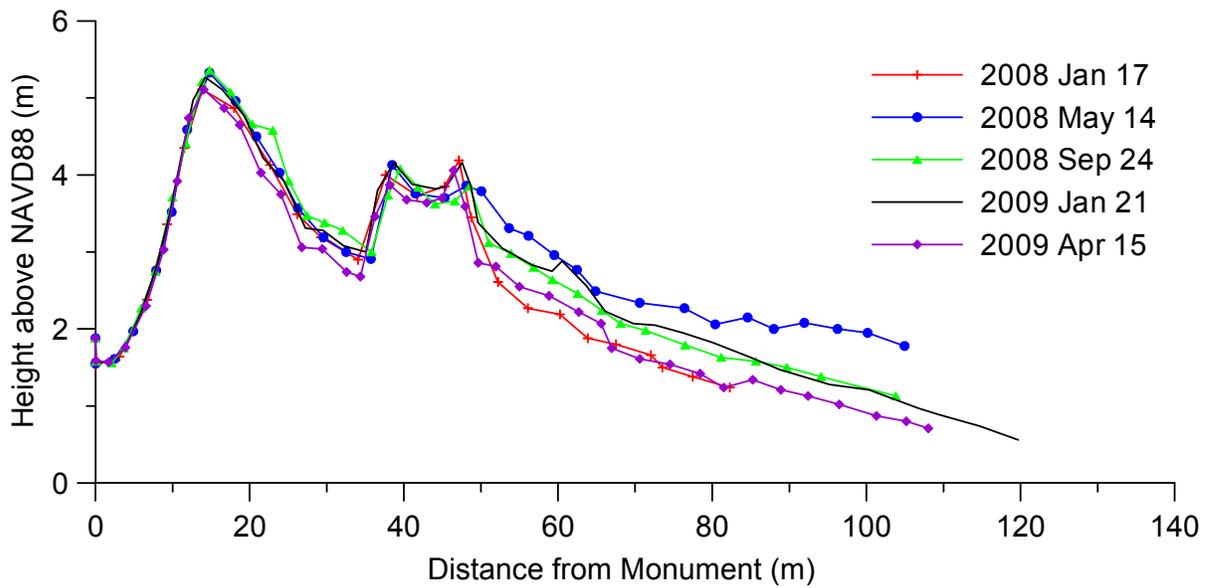
MUI02 (Mustang Island State Park)



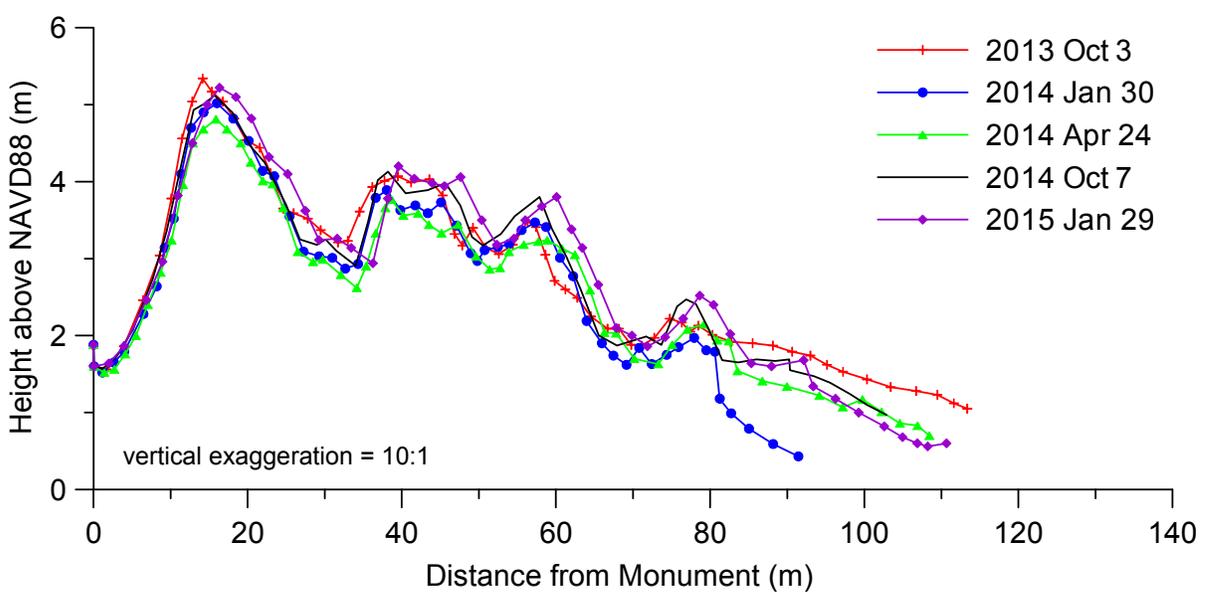
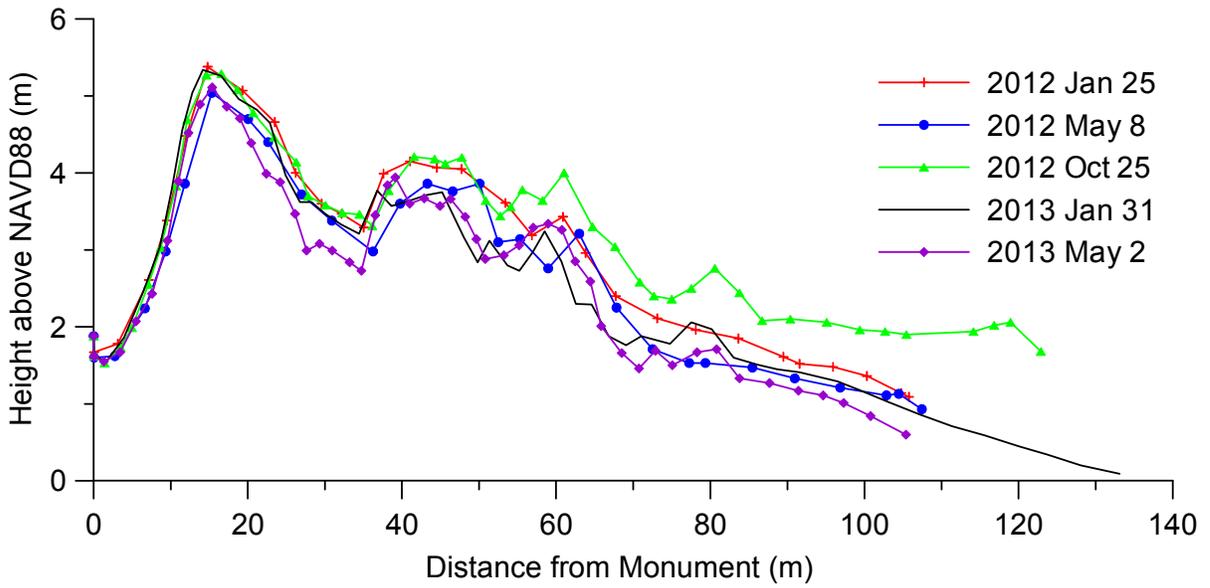
MUI02 (Mustang Island State Park)



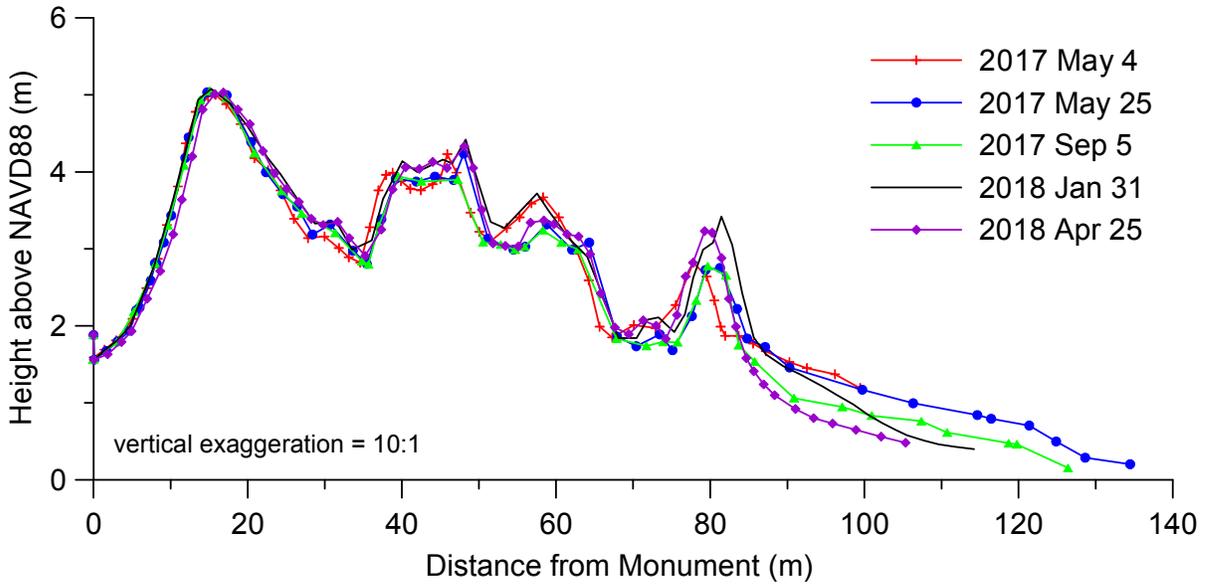
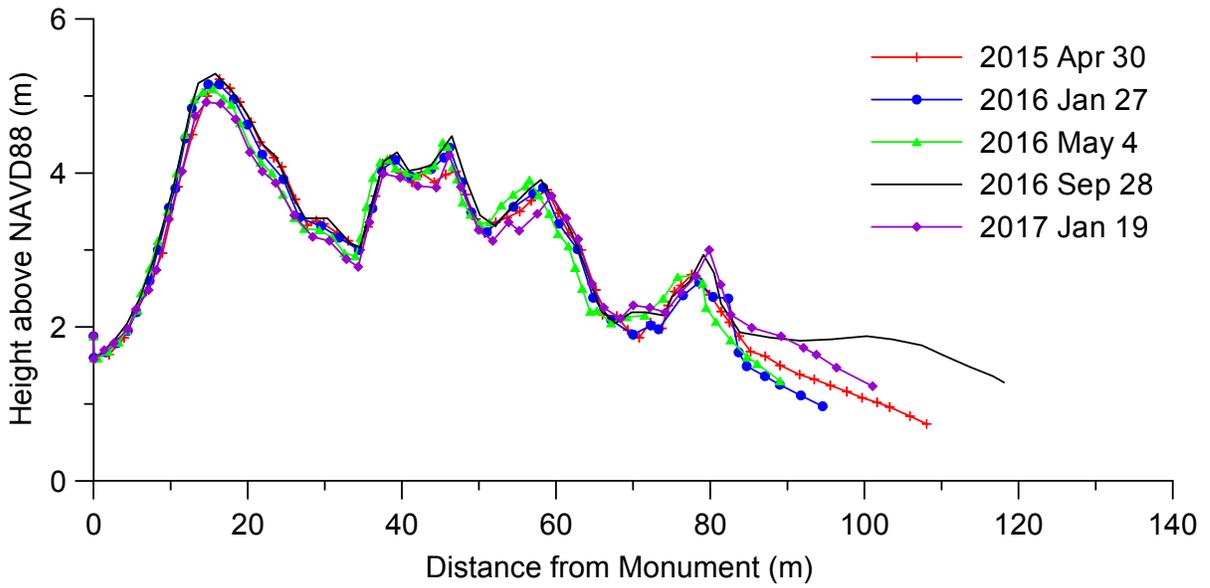
MUI02 (Mustang Island State Park)



MUI02 (Mustang Island State Park)

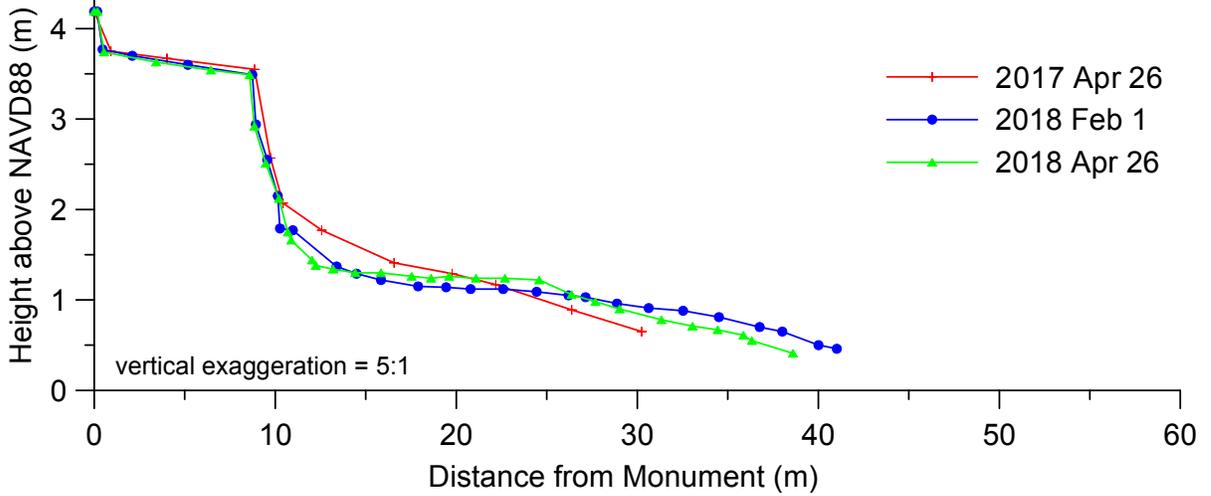
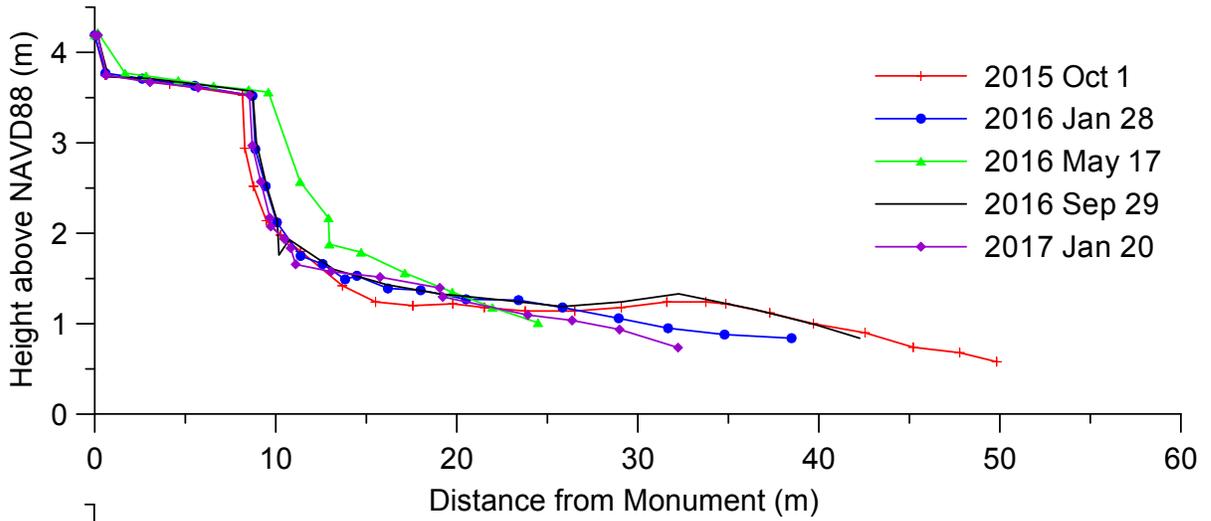


MUI02 (Mustang Island State Park)



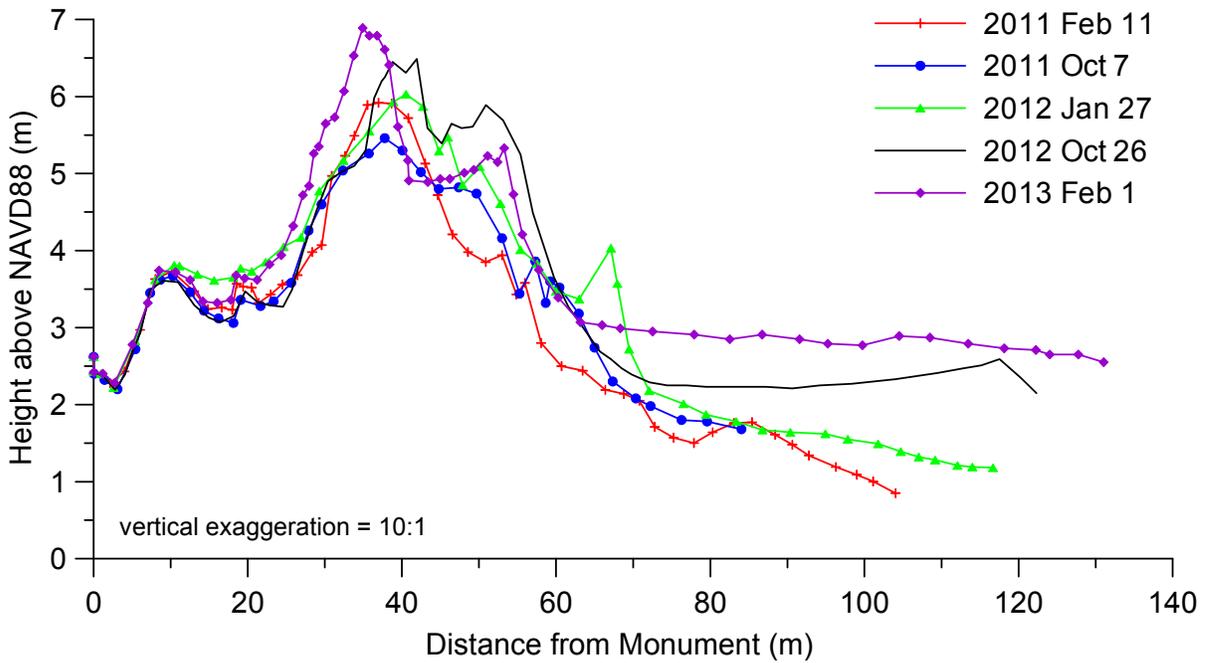
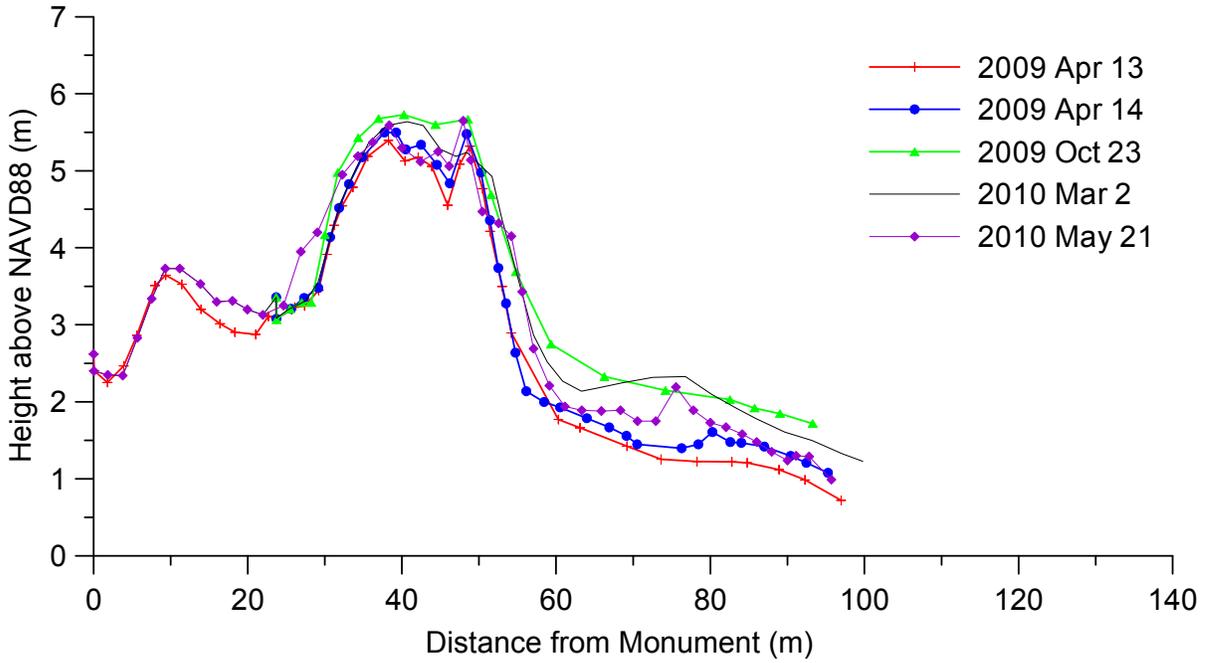
NPC06

NPC06 (North Padre Island Seawall)

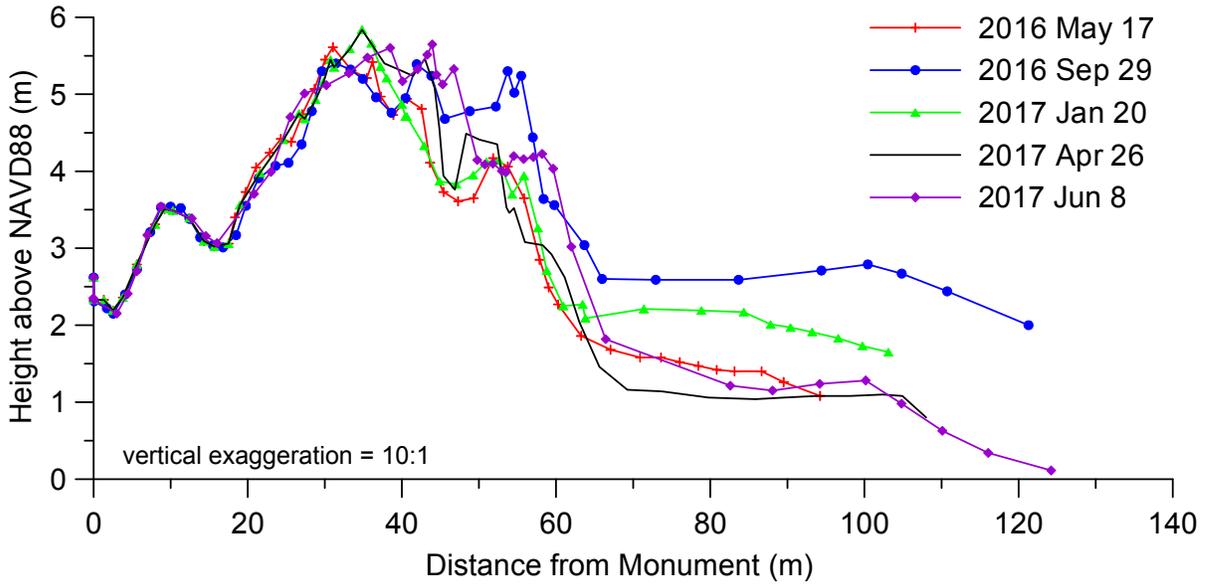
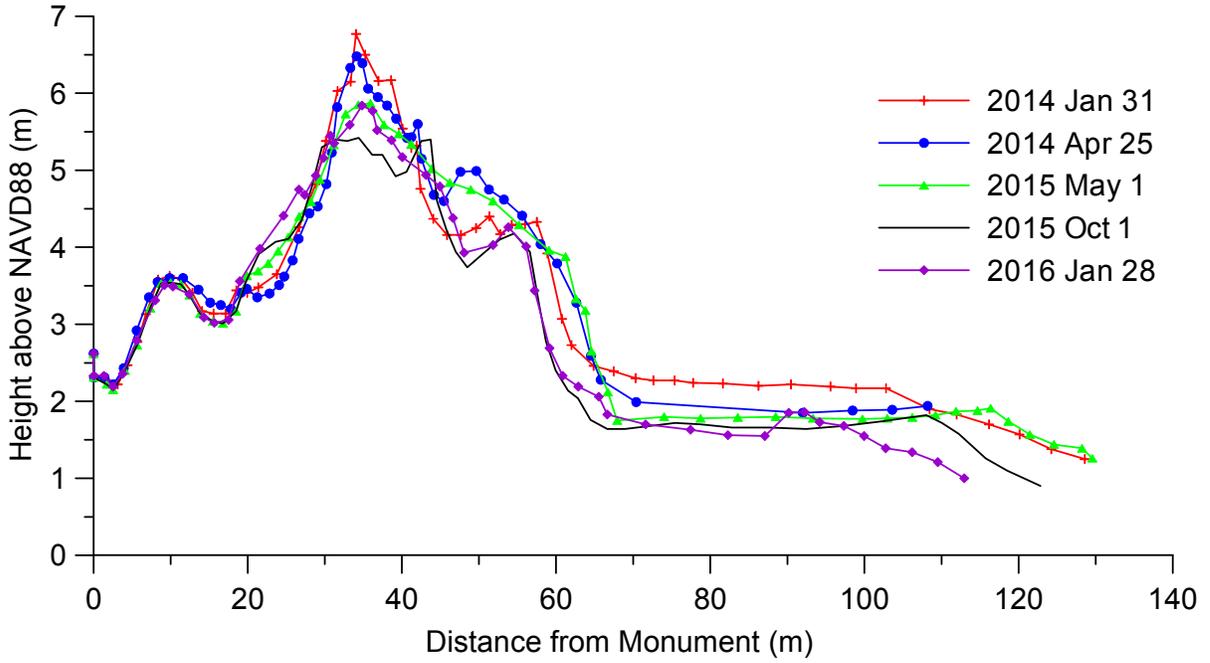


NPI08

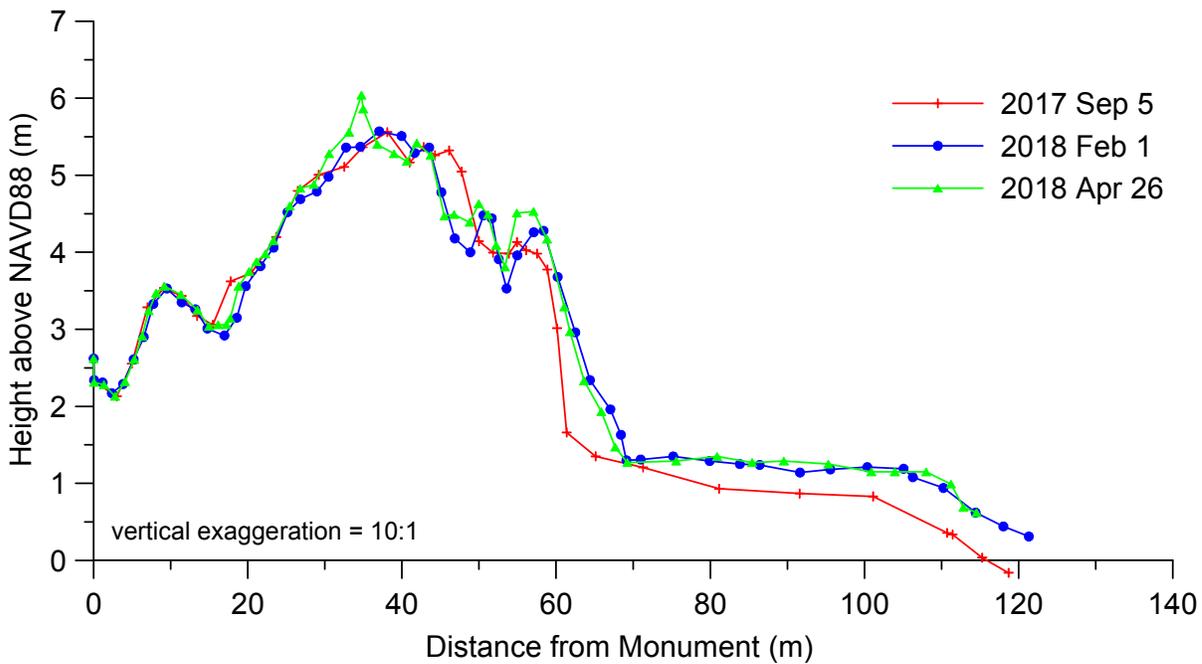
NPI08 (North Padre Island)



NPI08 (North Padre Island)

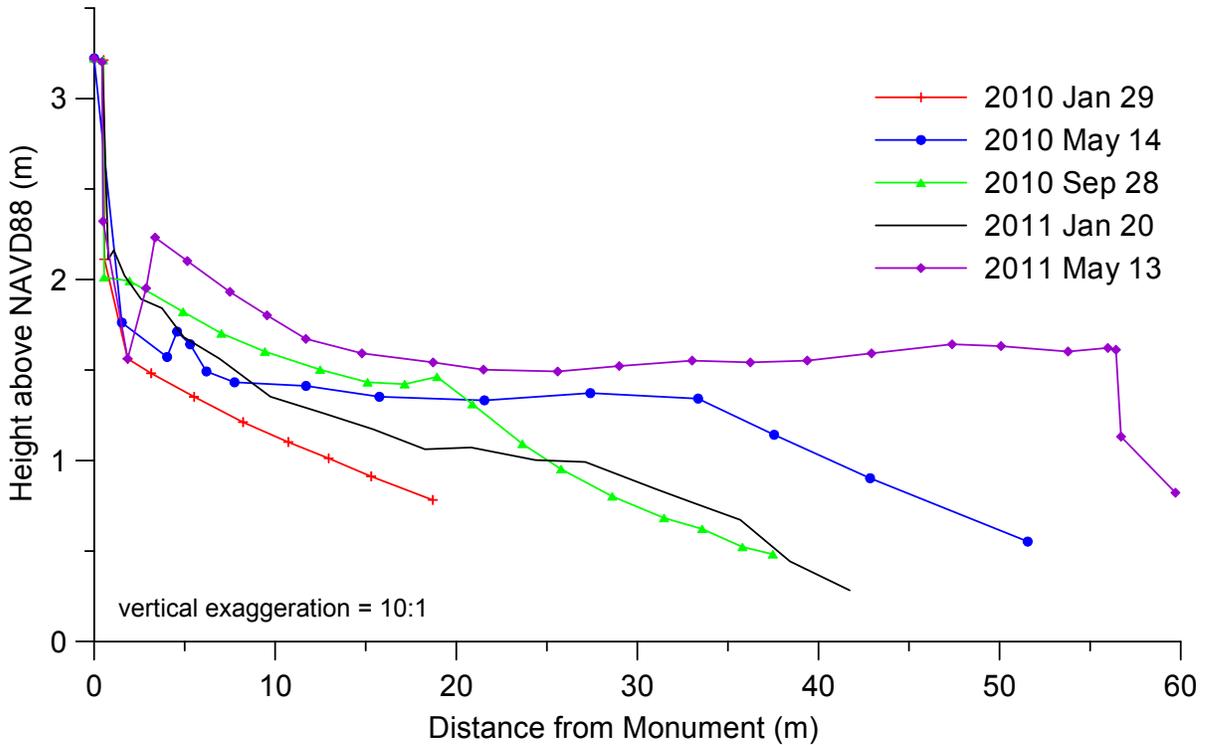
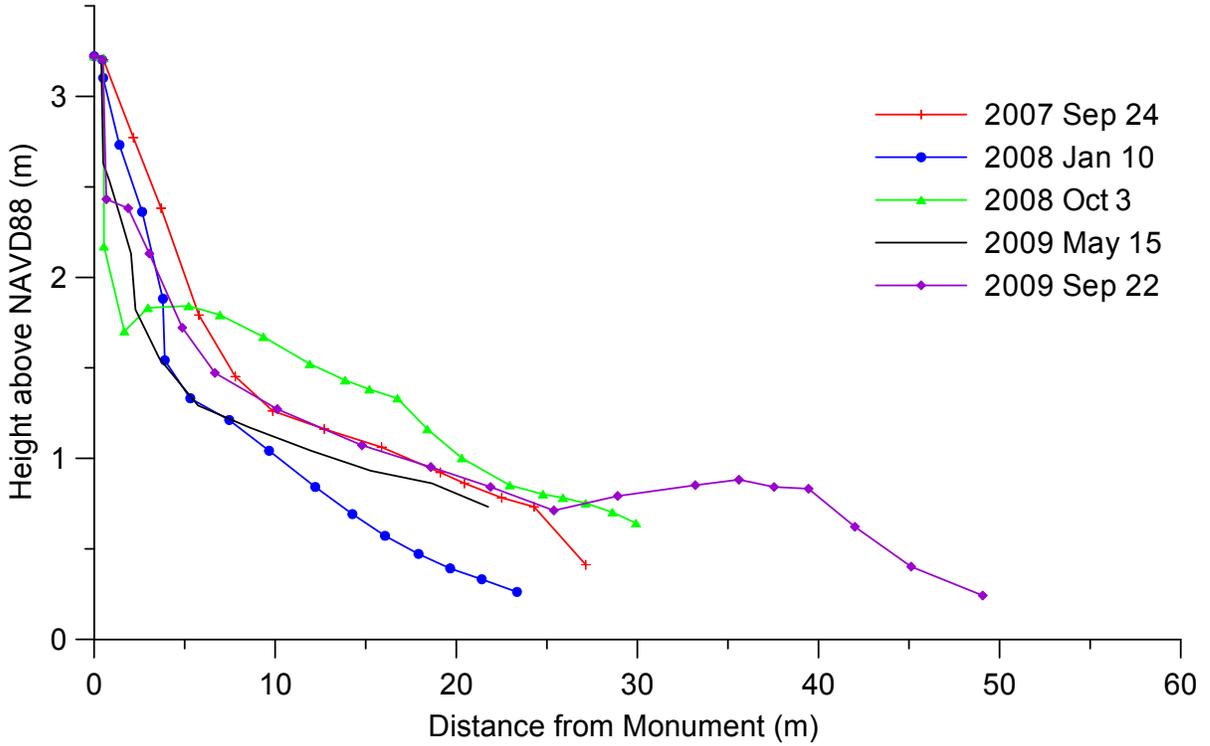


NPI08 (North Padre Island)

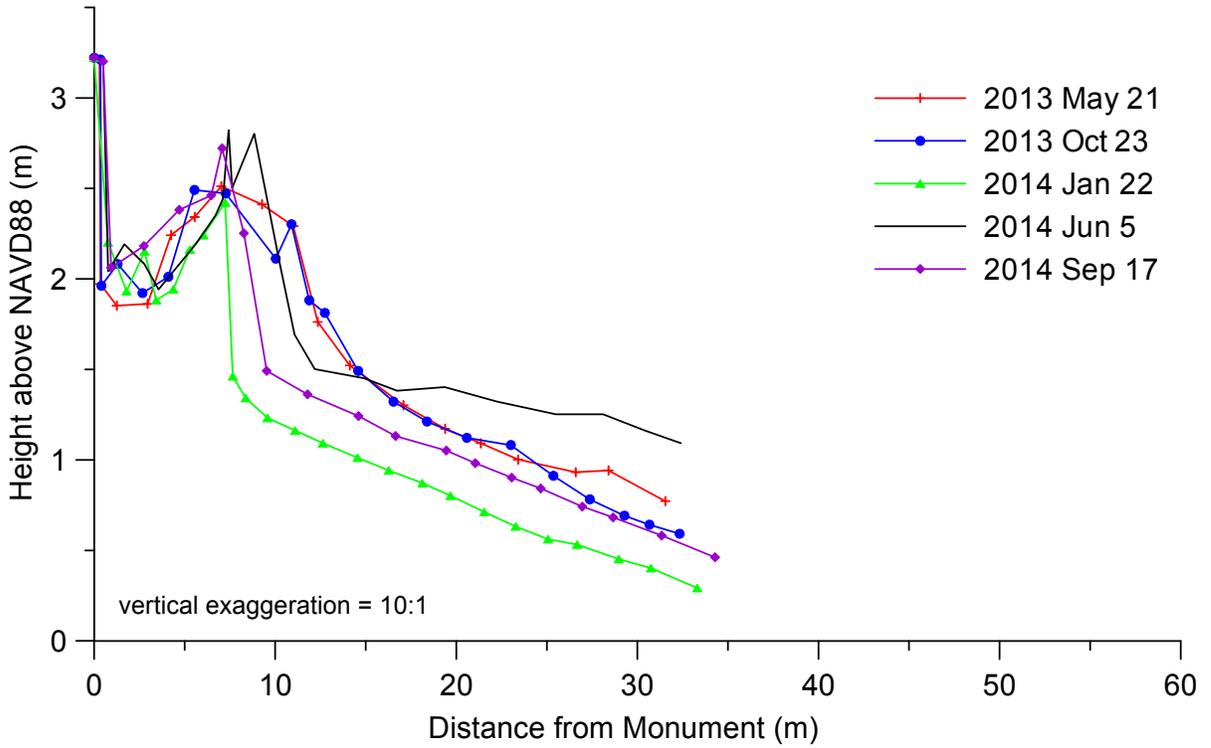
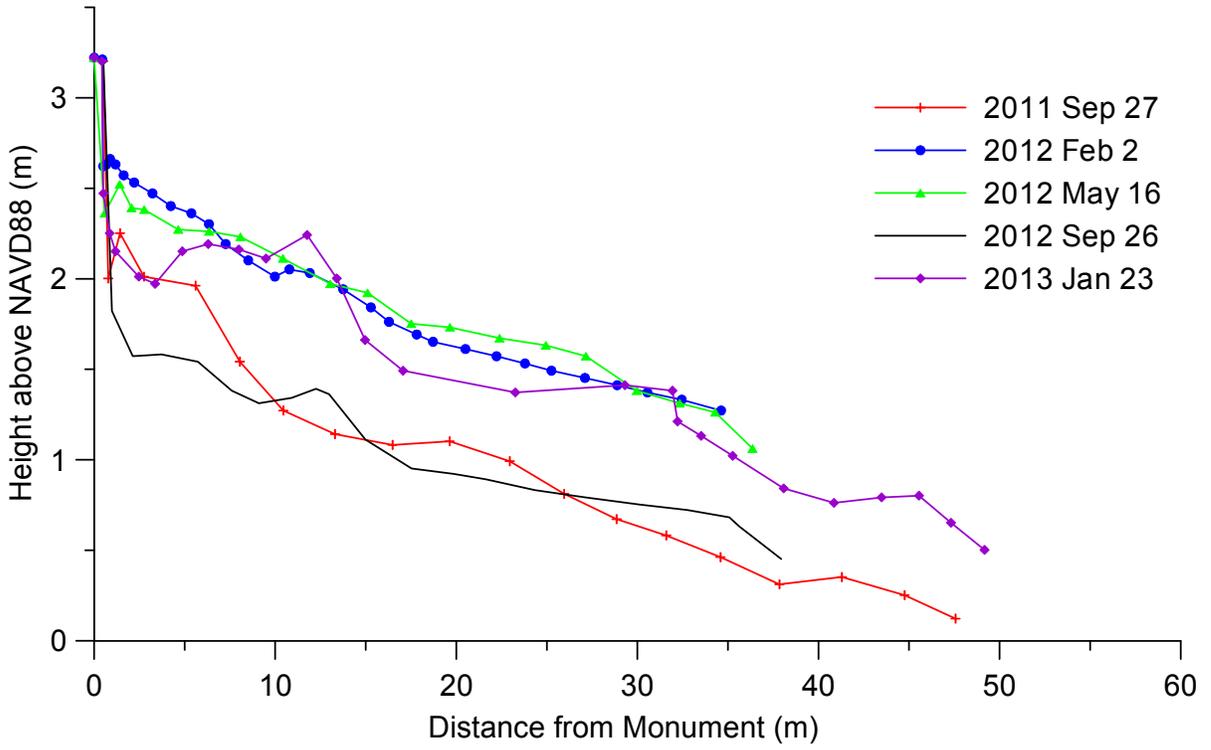


SPI08

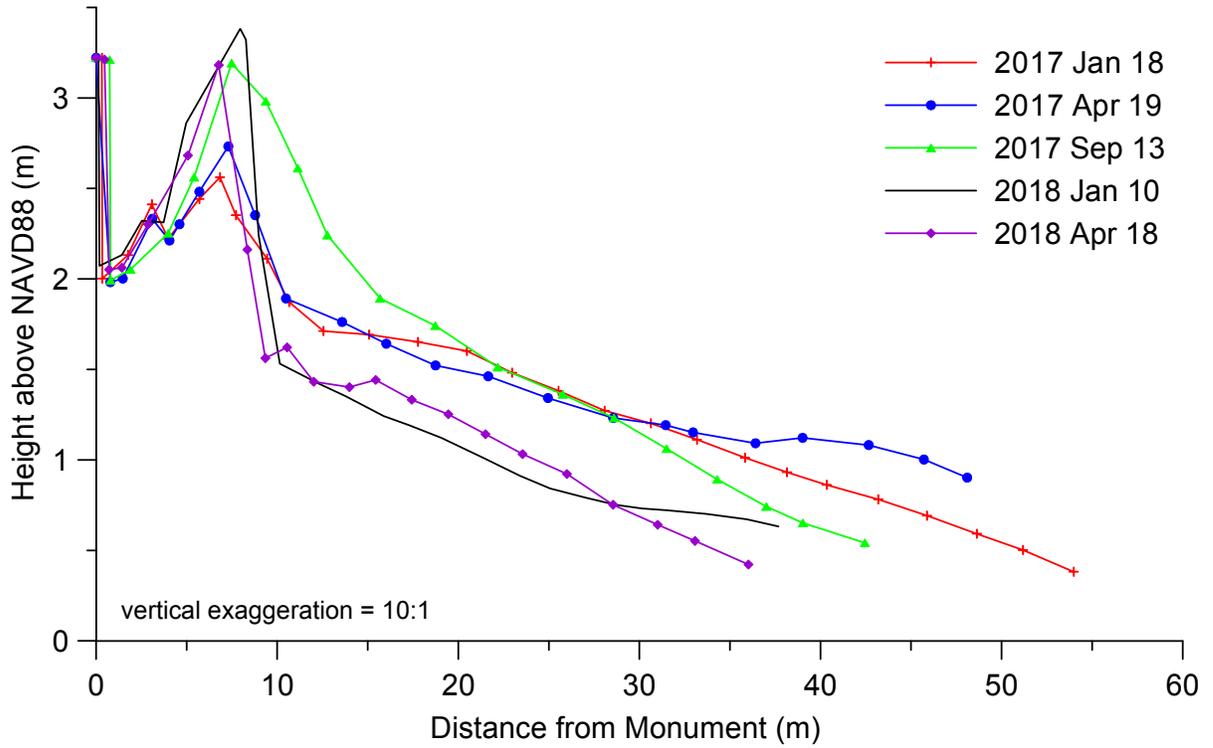
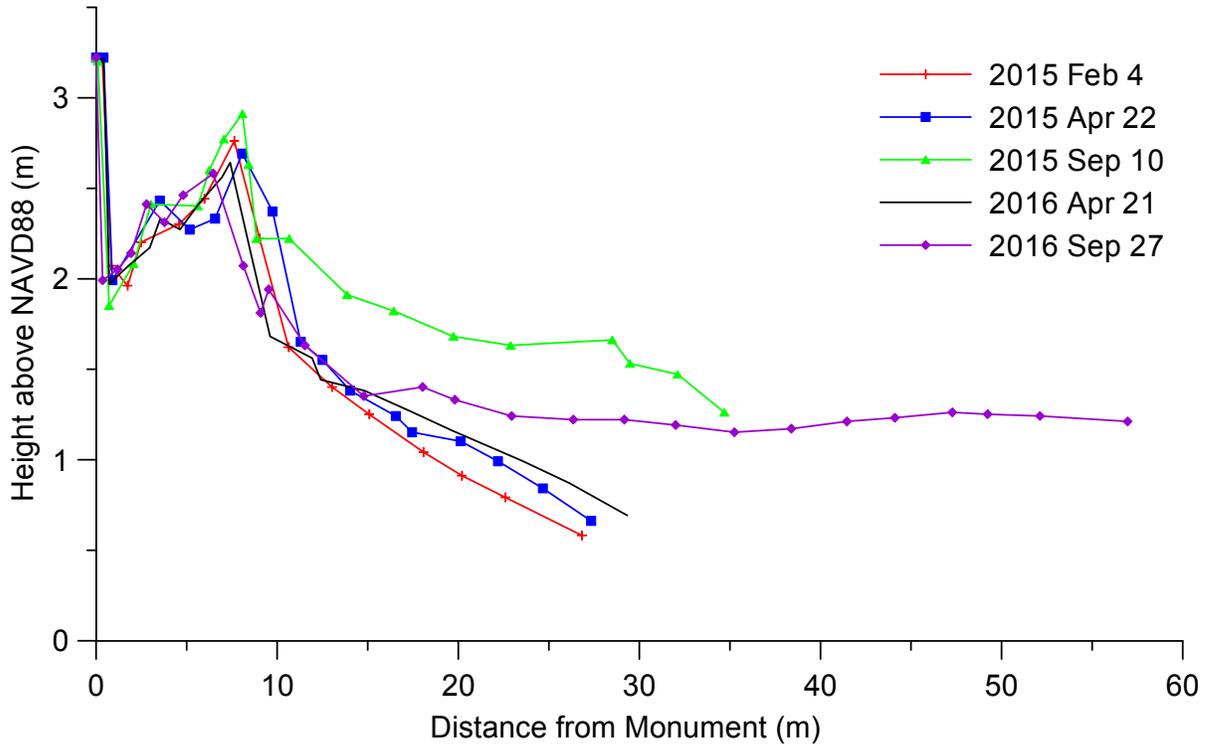
SPI08 (South Padre Island)



SPI08 (South Padre Island)

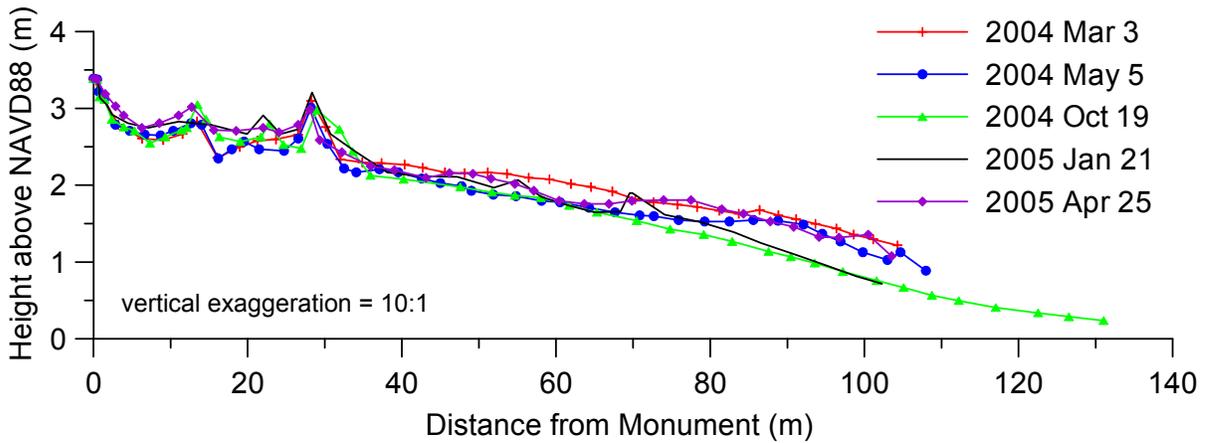
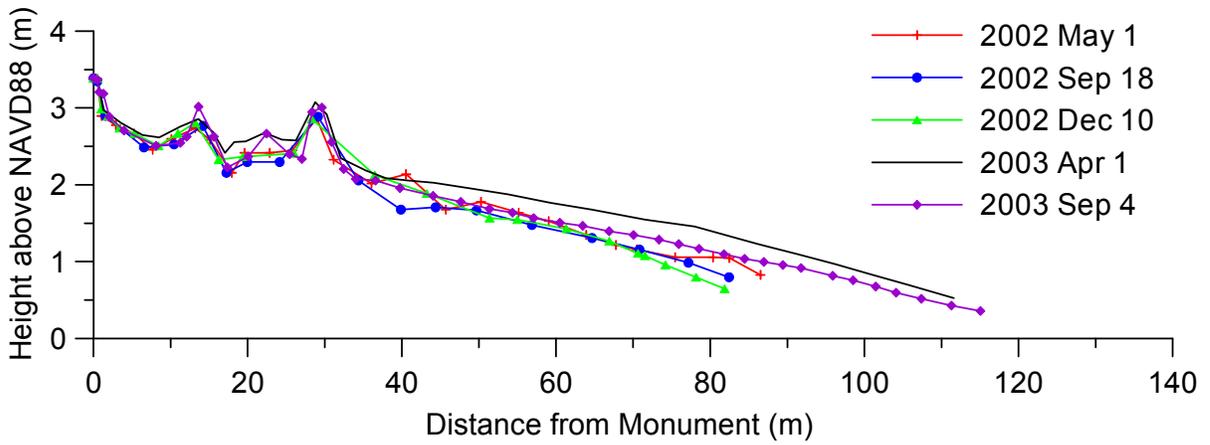
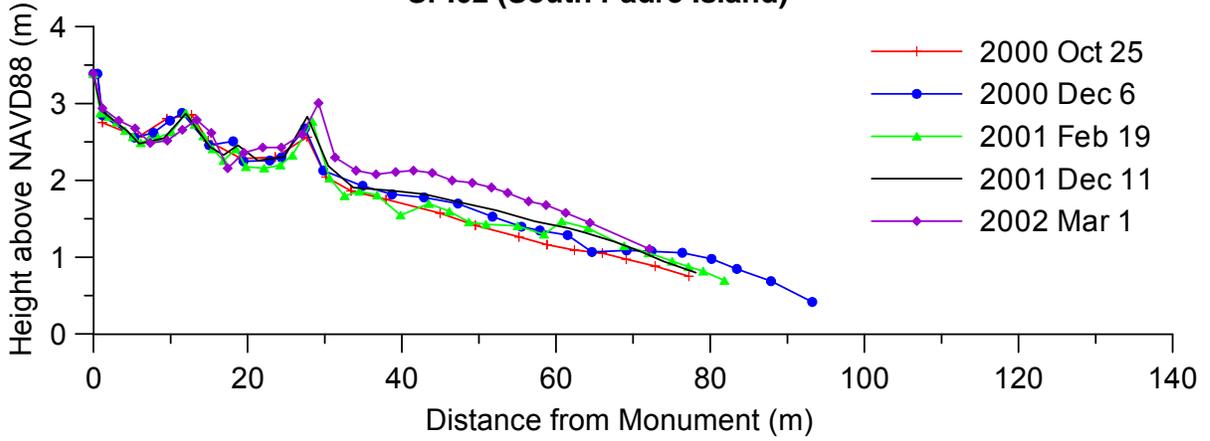


SPI08 (South Padre Island)

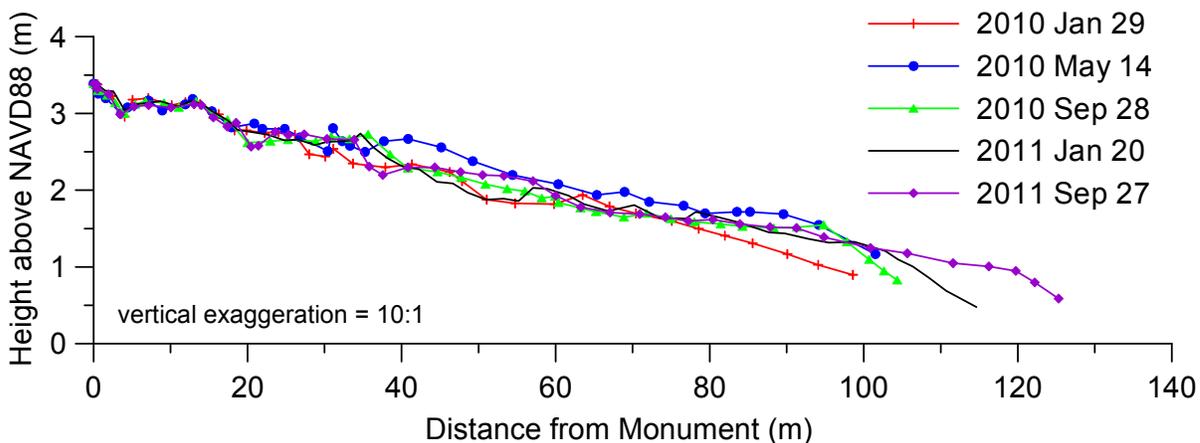
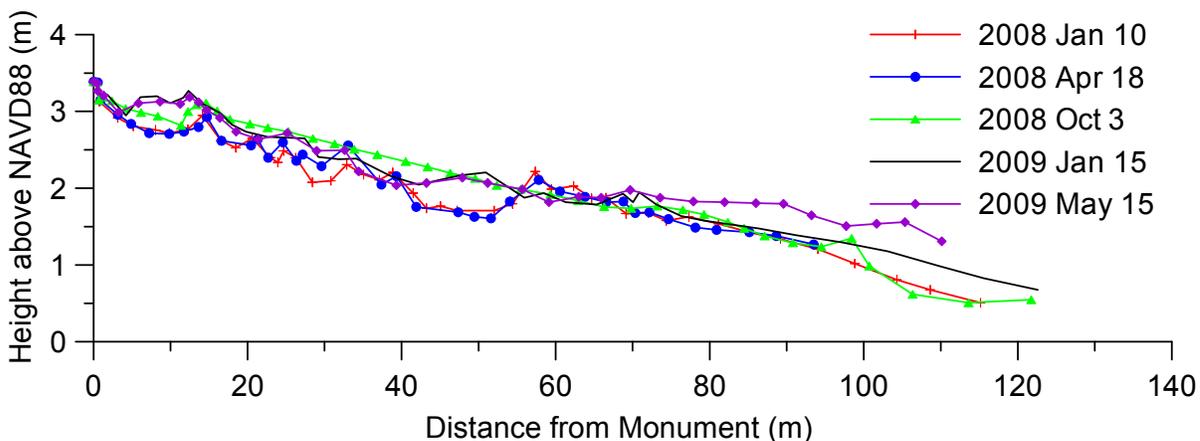
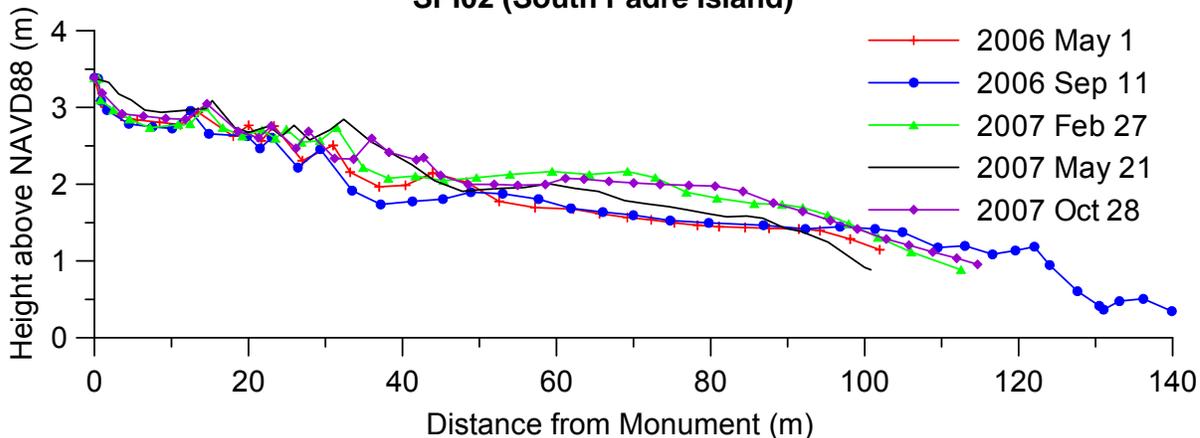


SPI02

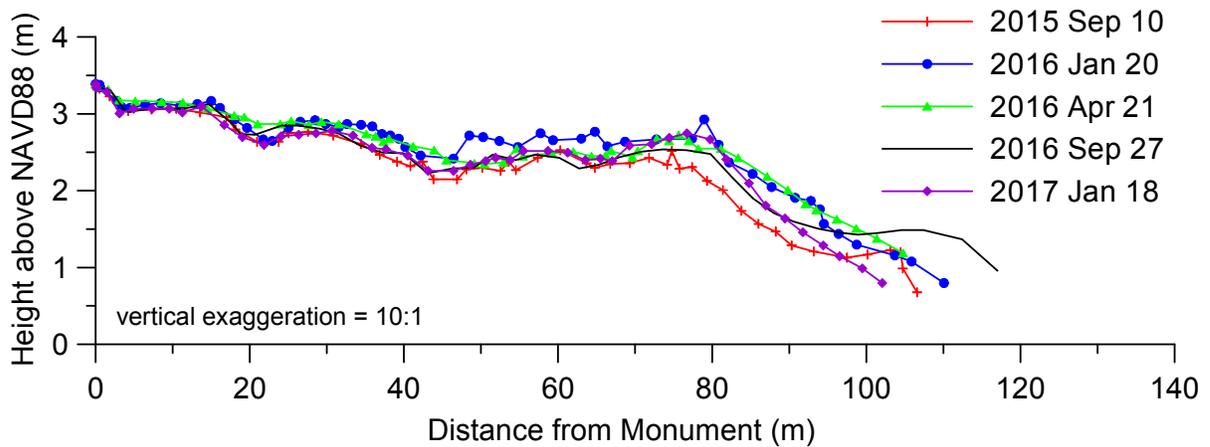
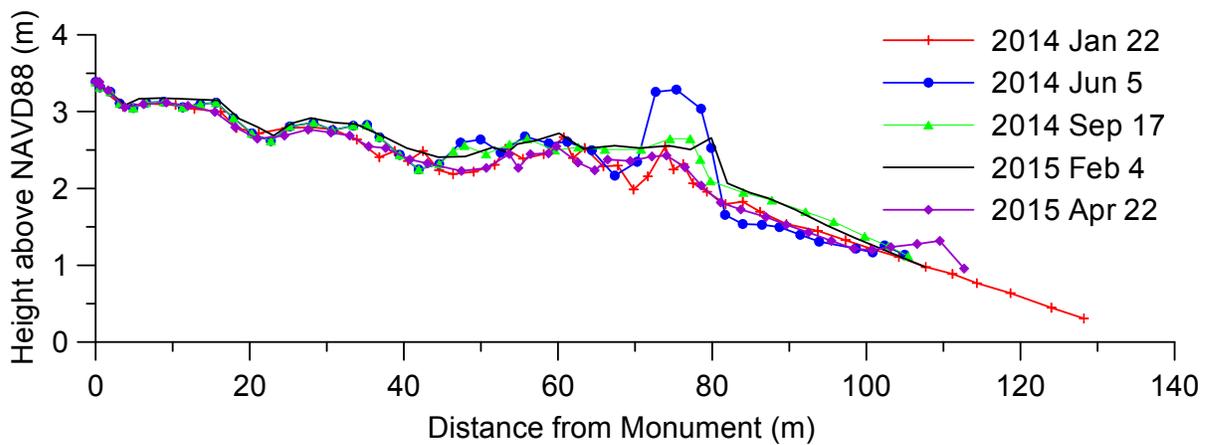
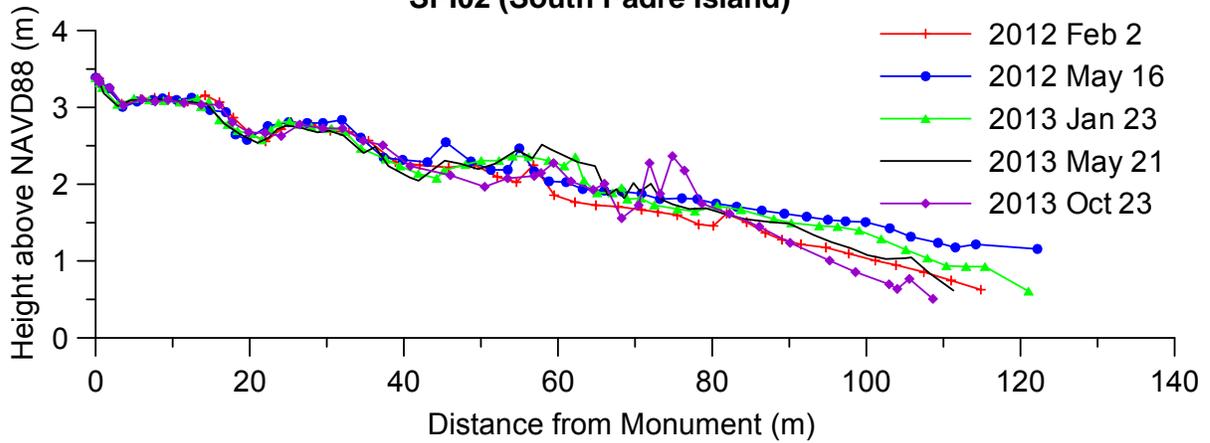
SPI02 (South Padre Island)

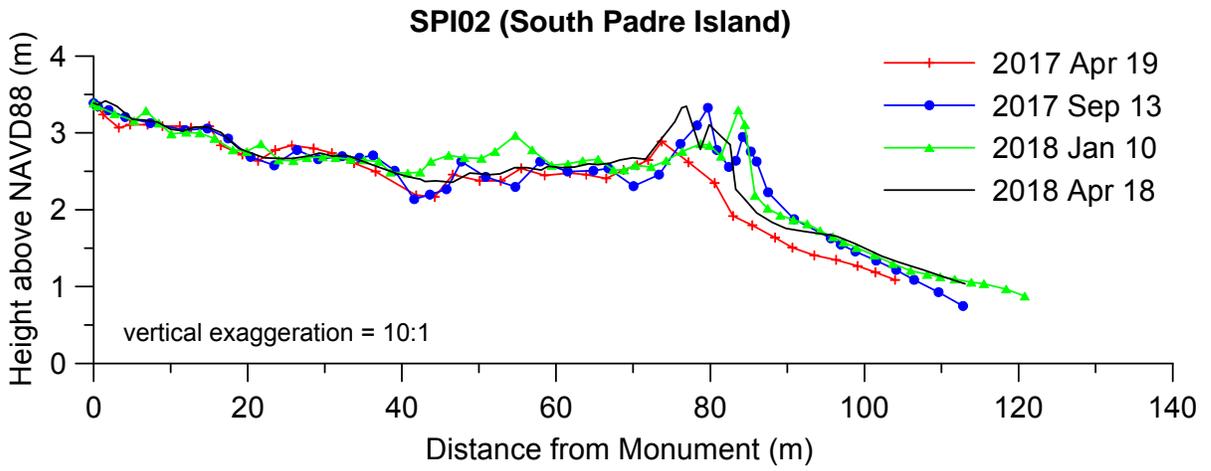


SPI02 (South Padre Island)



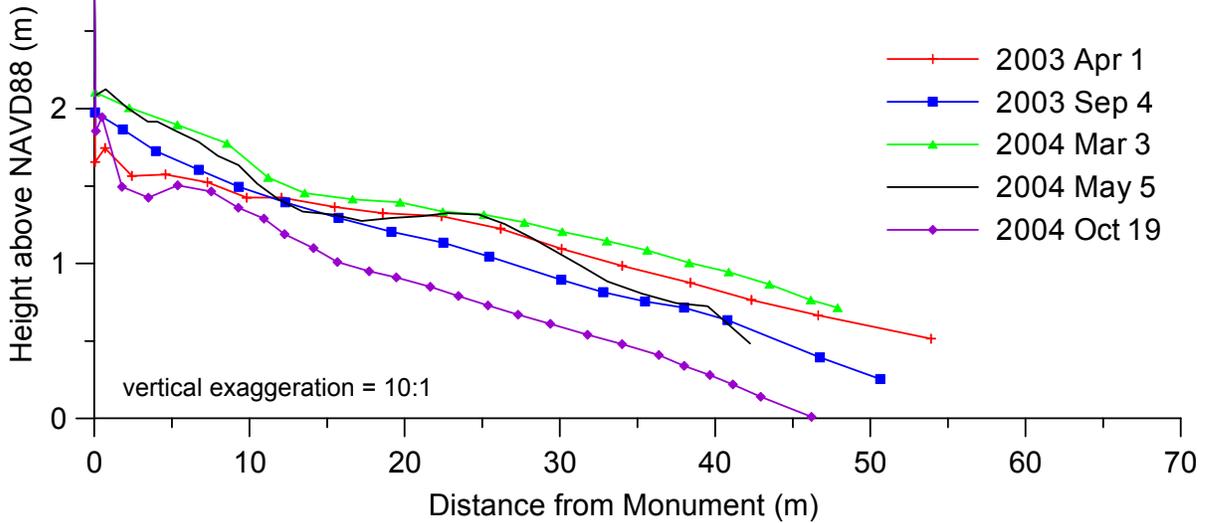
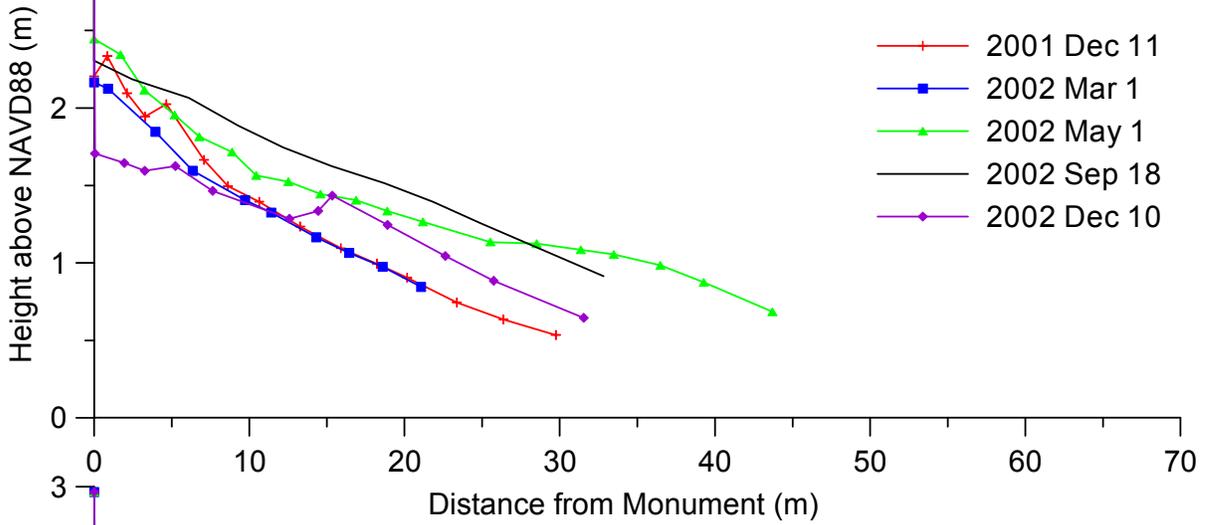
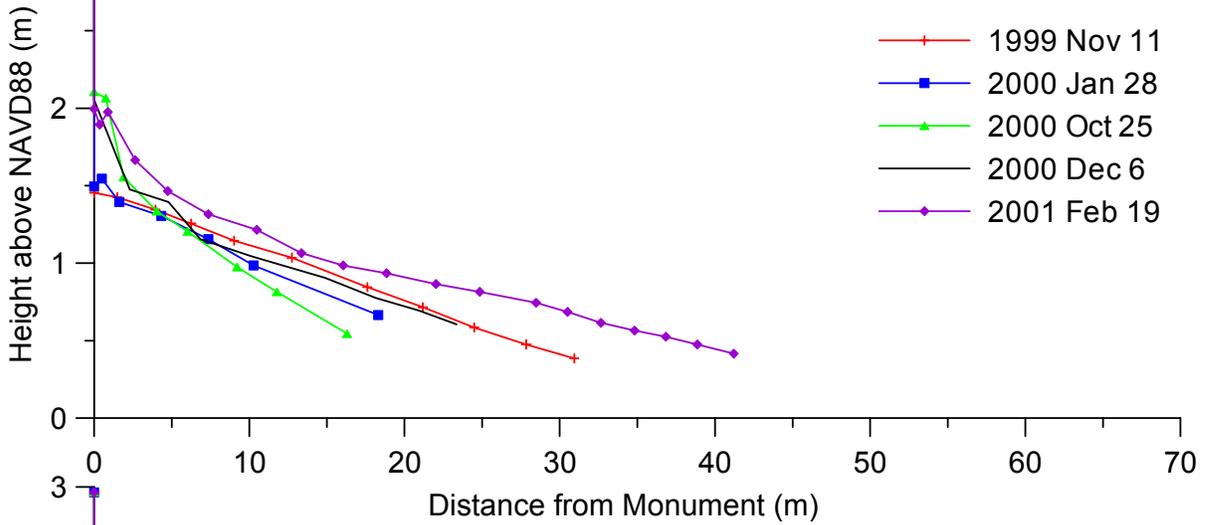
SPI02 (South Padre Island)

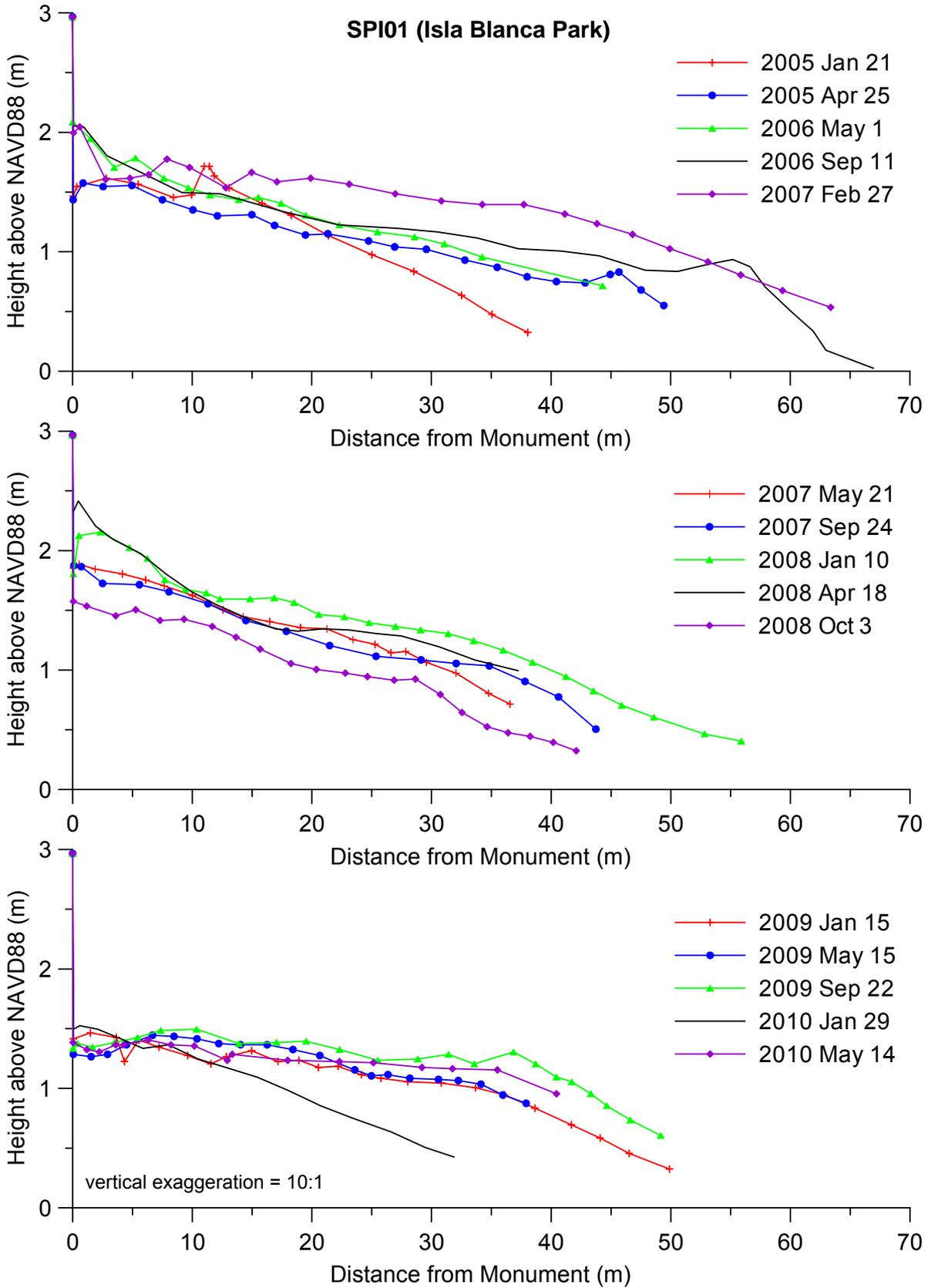


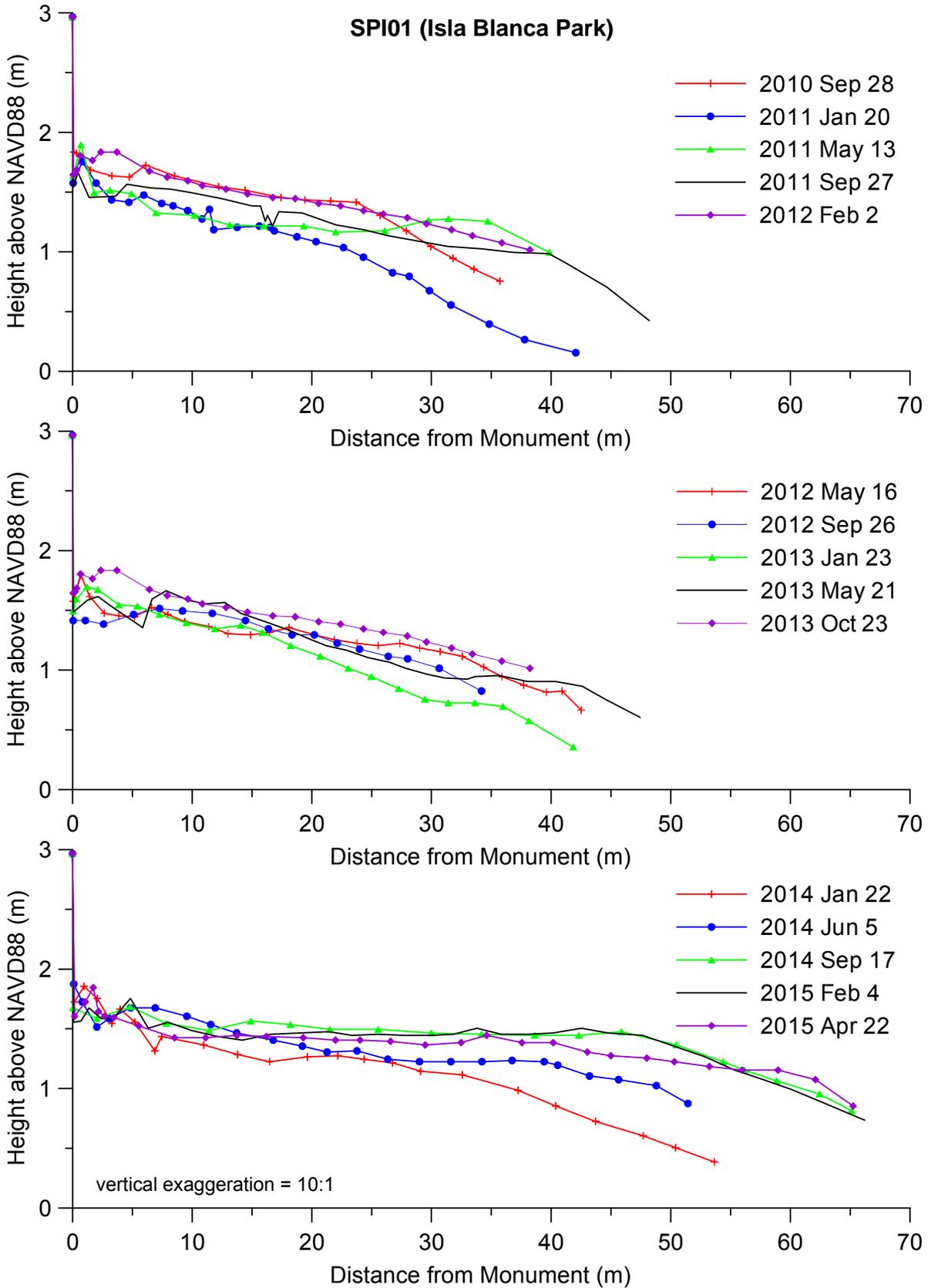


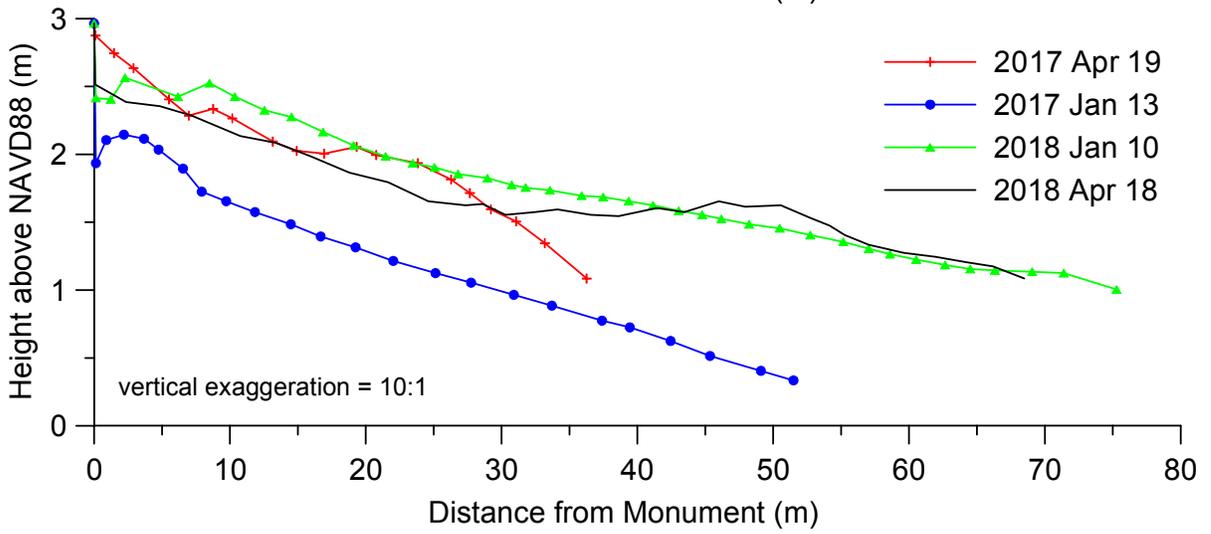
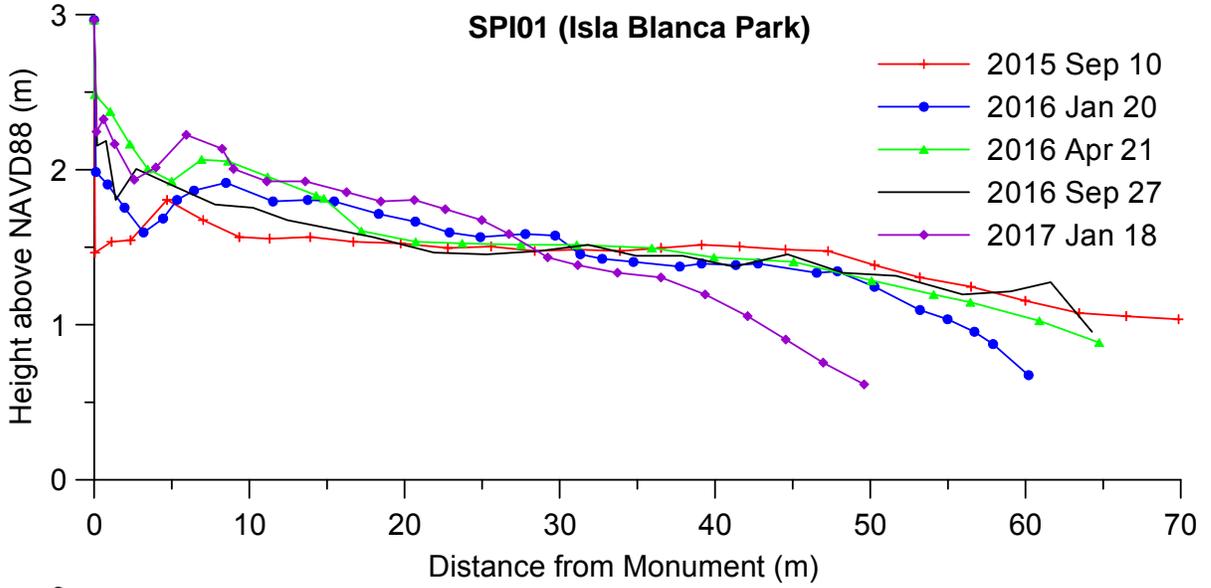
SPI01

SPI01 (Isla Blanca Park)









APPENDIX D: MAPS OF GPS SHORELINE AND VEGETATION LINE

