A Web-Based Platform for Visualization and Analysis of Coastal Geomorphology Data

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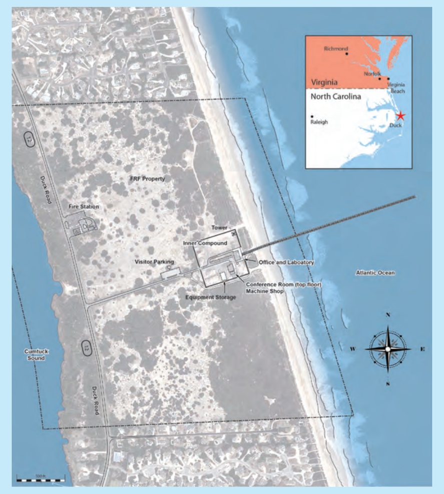
Abstract (Paper No. 156-5)

Monitoring programs that collect long-term information on beach morphology are fundamental to understanding how processes such as storms and sea level rise shape the coast. One such program, maintained by the U.S. Army Corps of Engineers (USACE) Coastal and Hydraulics Laboratory, includes a 36-year record of beach profiles, nearshore bathymetry, and meteorologic and oceanographic measurements collected at the Field Research Facility (FRF) in Duck, NC. The records have been used to study seasonal and interannual trends in beach profile changes, quantify erosion during storms, and to characterize subsequent beach recovery. Although the dataset is in the public domain, a limiting factor in its use has been rapid, reliable access to the profiles and associated oceanographic data.

Here we present a web-based platform developed to allow interactive exploration and analysis of coastal geomorphology data and to facilitate comparison with simultaneous oceanographic data (e.g., water level, currents, wave climate). The platform was developed by the USACE Mobile District Spatial Data Branch and RPS ASA for the U.S. Army Engineer Research and Development Center (USACE ERDC) and includes both a data management system and a suite of visualization and analysis tools. The system allows easy display of both beach profiles and LiDAR data and includes on-the-fly plotting functions to visualize changes in these data over time. It also provides tools for performing a variety of basic analyses, such as calculation of beach cross-sections or extraction of shoreline positions from profile data. Most importantly, the relationship between coastal morphology and environmental forcing can be examined at a variety of timescales, providing greater understanding of the evolution of sandy beaches due to both short-term (storm) events and longer-term (climatic) trends.

The platform utilizes a modern web technology stack with a Javascript front end and a Python back end to manage the web services. The design is flexible enough to support a myriad of coastal geology datasets and although developed for the USACE, the system can be readily implemented at other locations to provide scientists, engineers, planners, and science educators with a user-friendly tool for monitoring coastal change and placing it in context of environmental forcing.

USACE Field Research Facility (FRF)



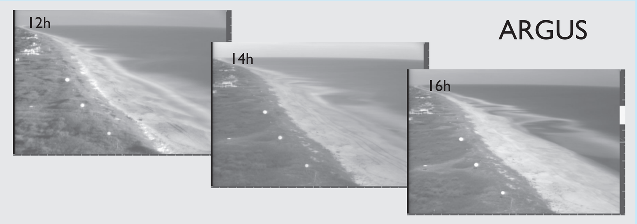
Located on the Outer Banks, near the town of Duck, NC, the Field Research Facility (FRF) is a premier coastal science observatory that was established in 1977 to support the U.S. Army Corps of Engineers (USACE) coastal engineering mission. The facility is situated on 176 acres between the Atlantic Ocean and Currituck Sound and is part of the USACE Coastal and Hydraulics Laboratory (headquarters in Vicksburg, MS). The FRF is staffed by a small (approx. 10-person) group of engineers, and scientists that collect data and conduct research on a wide range of coastal processes including waves, air-sea interactions, beach morphodynamics and sediment transport. Coastal scientists from other agencies, universities, and private industry are also encouraged to use the FRF facilities for research.

Central to the FRF is a 560-m-long steel and concrete pier that extends to the 7 m water depth contour. The facility is also home to collection of specialized vehicles and instruments for conducting coastal research including:

The Coastal Research Amphibious Buggy (CRAB) – a three-wheeled vehicle equipped with centimeter-level DGPS used for precisely surveying beach profiles to water depths of 9 m

The Coastal LIDAR and Radar Imaging System (CLARIS) – a fully mobile system that integrates terrestrial lidar and X-Band radar for simultaneous collection of oceanographic and beach morphology data during storms.

The LARC-5 (Army) amphibious vehicle, used to deploy instruments, survey bathymetry in the surf zone, support diving activities, and tow a variety of sensor and survey equipment.

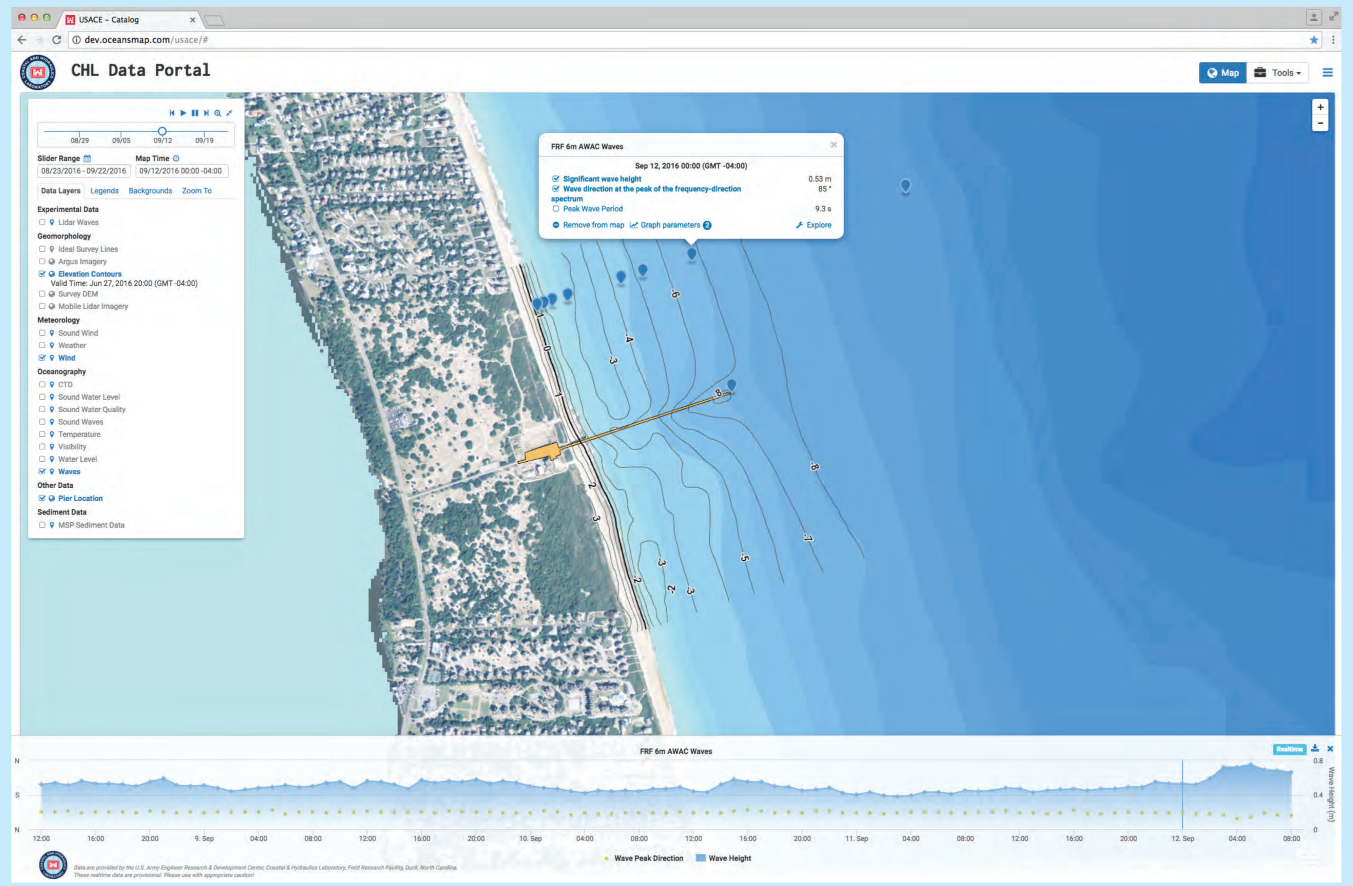


The ARGUS automated video system – high resolution video cameras mounted on top of the 43-m FRF observation tower to monitor changes in sand bar morphology or shoreline position through both time exposed and rectified imagery.

CHL Data Portal

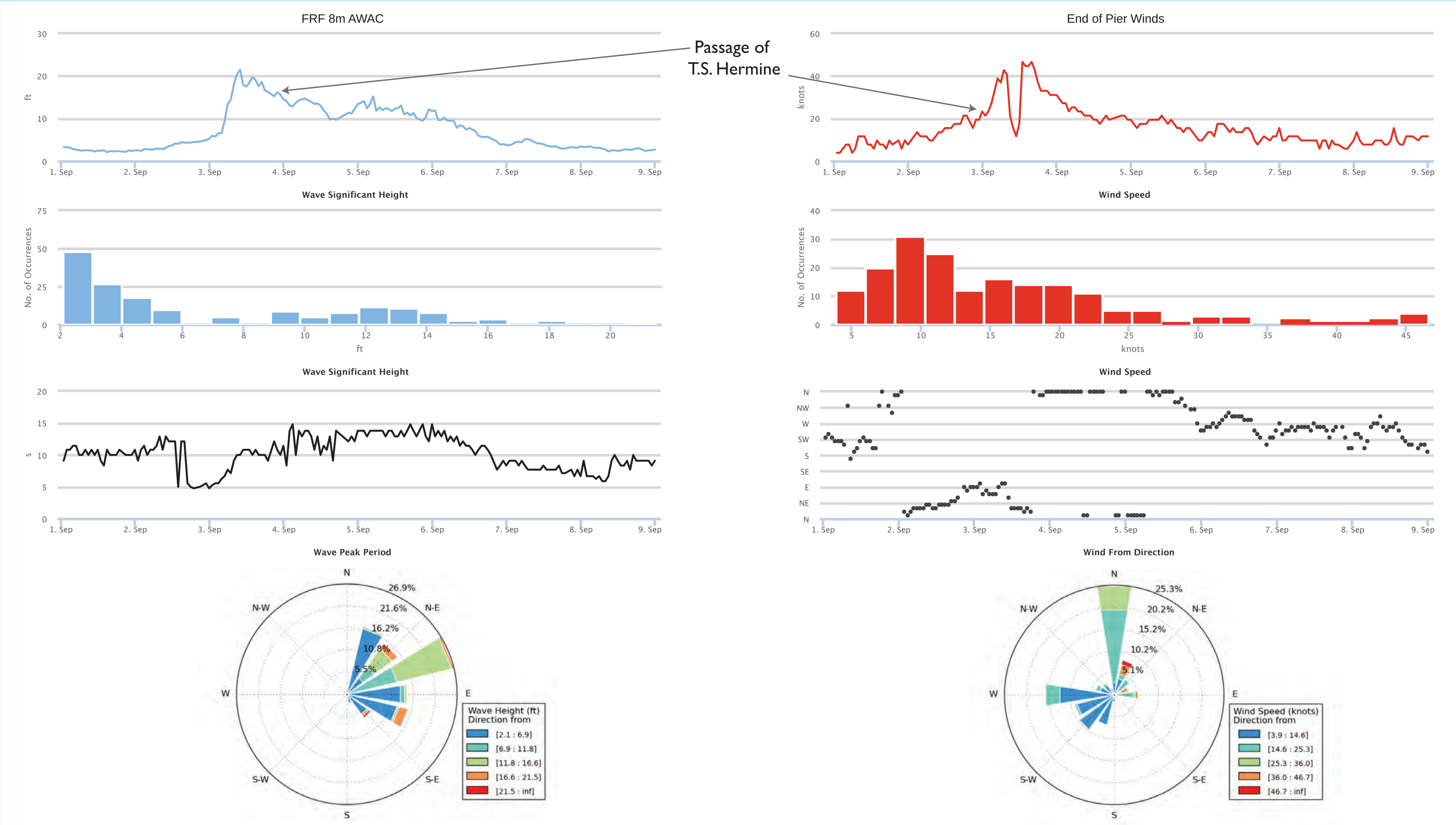
The CHL Data Portal was developed in partnership with the USACE Coastal and Hydraulics Laboratory (CHL) and includes a data management system and a front-end web portal featuring a suite of visualization and analysis tools. The portal connects users to both real time oceanographic and weather observing stations and numerous archived datasets developed at the FRF (e.g. beach profiles, mobile lidar). The interface was built using RPS ASA's OceansMap framework (Javascript, HTML, CSS) and a Python back end for the web services and plotting. All project metadata is managed using Geoportal.

Navigation

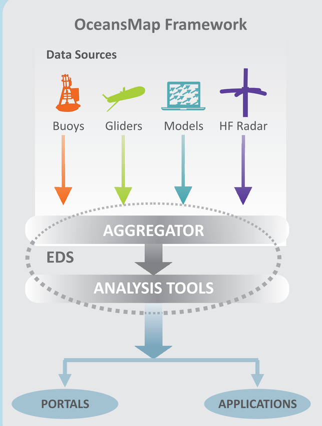


The map is a central feature of the portal and allows users to pan and zoom to a region or instrument of interest and toggle between real time and archived data layers. Stations and profile lines are symbolized on the map pane and selecting the icon returns a list of available parameters. Users can also plot time series of recent observations alongside the map and specify the temporal range using the time slider.

Data Exploration and Plotting



The Tools menu provides on-the-fly plotting functions including the ability to compare data from multiple stations (as above) and/or time periods (as below). Elevation profiles from multiple beach survey dates can be graphed alongside each other.



FRF Datasets

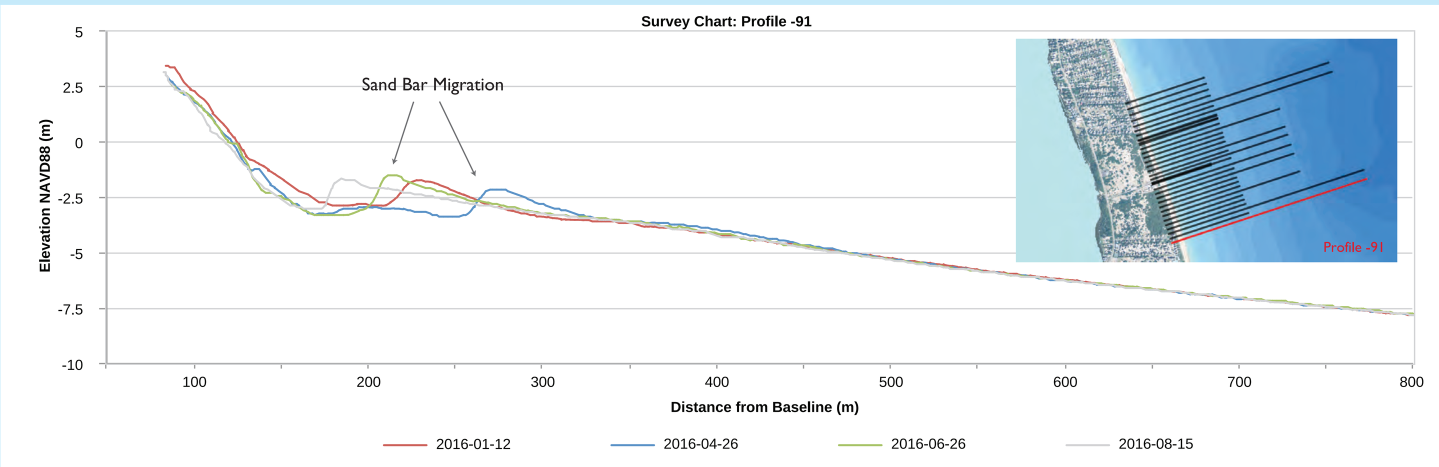
The CHL Portal is implemented using RPS ASA's OceansMap framework - a web-based metocean data visualization and analysis platform that aggregates a broad range environmental data including both real-time observation and model data. Geomorphology data from the FRF is made available through ArcGIS Server, while the oceanographic data sets have been formatted to netCDF4 and made available through a THREDDS server.

Geomorphology
- Beach profiles
- Elevation contours
- Digital elevations
- Mobile LiDAR
- ARGUS imagery

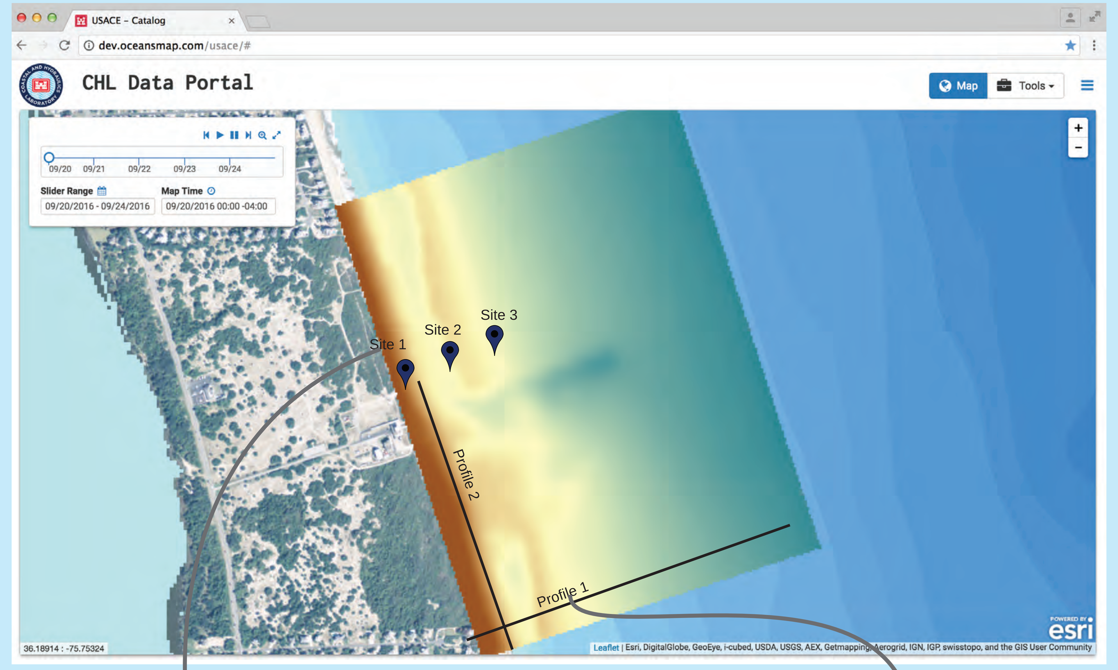
Oceanography
- CTD (end of pier)
- Water level
- Wave height, period, direction
- Water quality

Meteorology
- Wind speed, direction
- Weather (P, T, dew point, etc)

Experimental Data
- LiDAR derived wave height



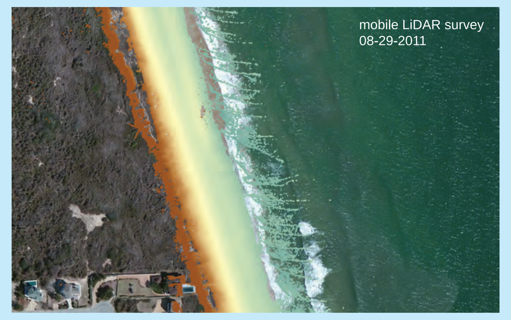
Data Analysis

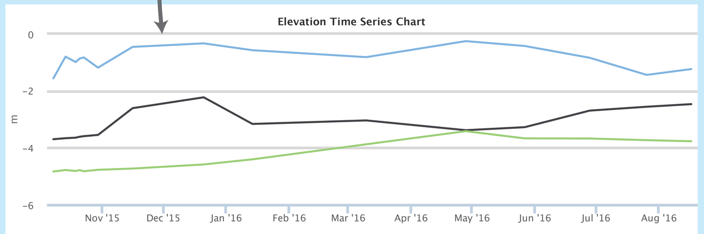


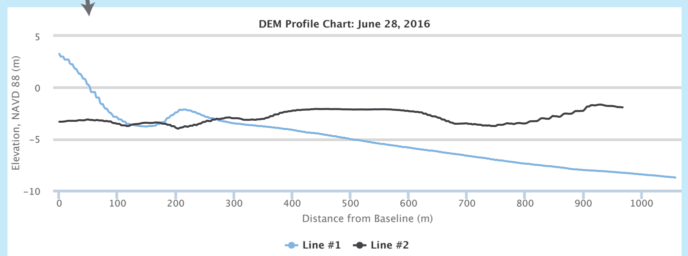
Robust analysis tools allow users to query and derive data products from over 100 digital elevation models (DEMs) derived from FRF bathymetry surveys, cross-shore profiles, and terrestrial LiDAR.

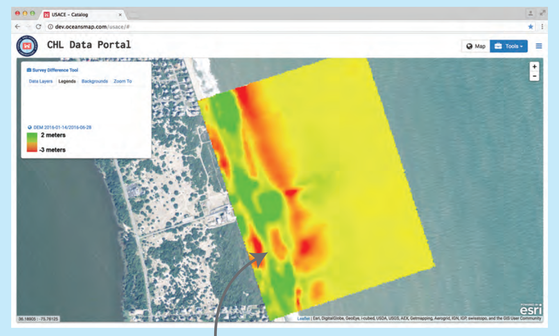
Left – With the Elevation Time Series Tool, users can extract a time series of beach or seabed elevations at multiple cells within the DEM. The Survey DEM tool provides comparisons of elevation changes along user-defined profile lines at any orientation.

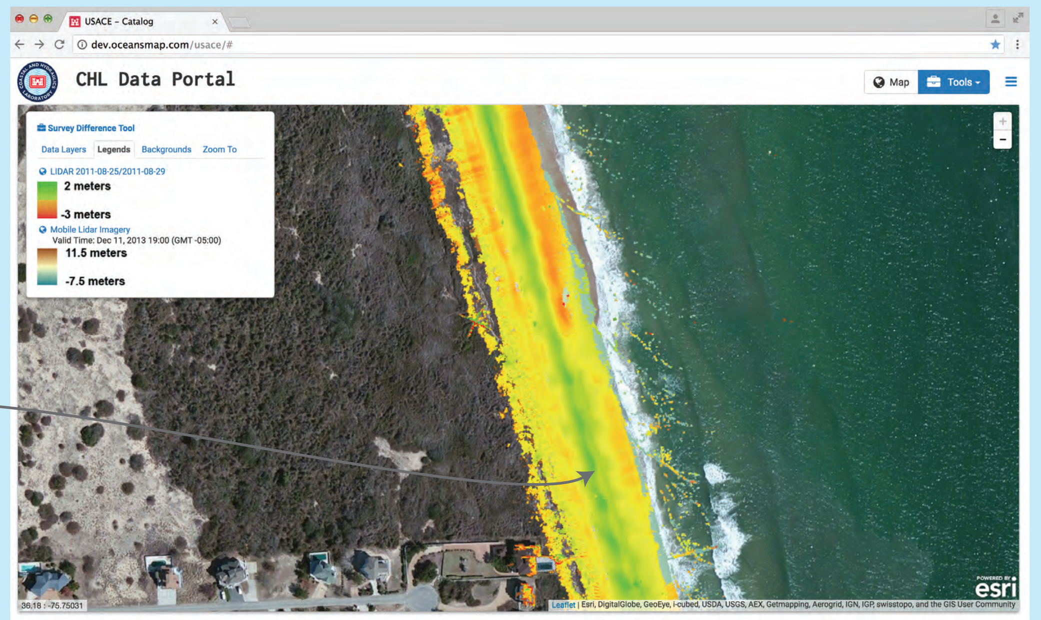
Right - The Survey Difference Tool calculate surface changes between any two elevations sets including erosion/accretion on the subaerial beach measured from mobile LiDAR.











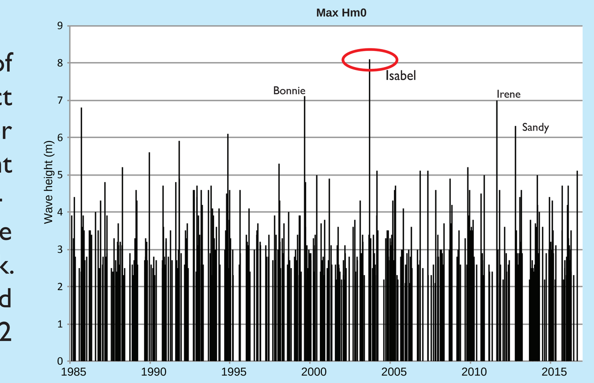
Post -Irene Difference Surfaces

Geomorphology Tools

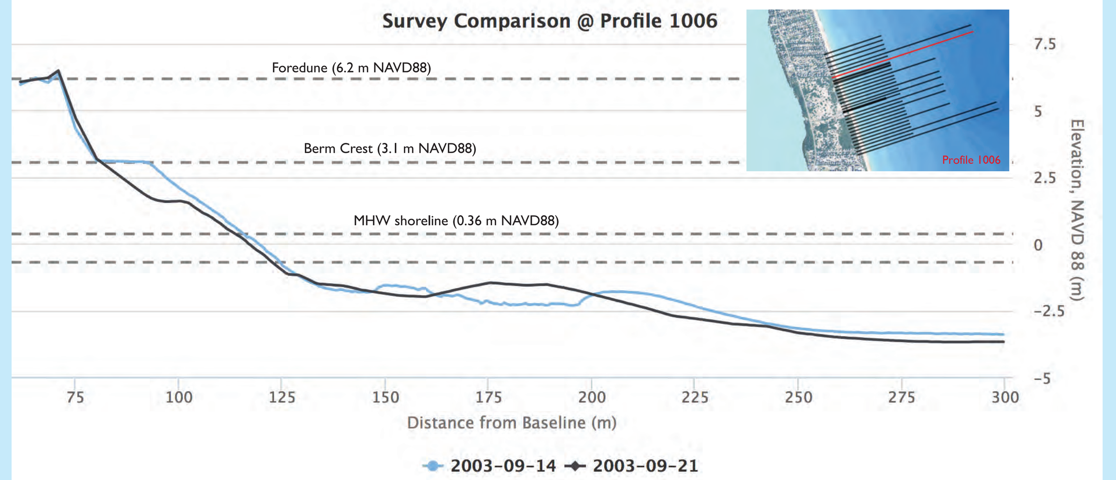
Recent updates to the portal have centered on development of new tools to automatically derive common beach metrics such as beach volume or shoreline position, and to track onshore/offshore migration of longshore bars. Standard statistical measures such as residuals, bias, and RMS are computed based on comparison of points along the full profile line. In addition, the user can define a specific cross-shore range for analysis and all subsequent calculations are updated. Examples below show how the tool can be applied to quantify the response of the coastal profile to forcing at the event (storm) and seasonal time scales.

Storm-induced erosion

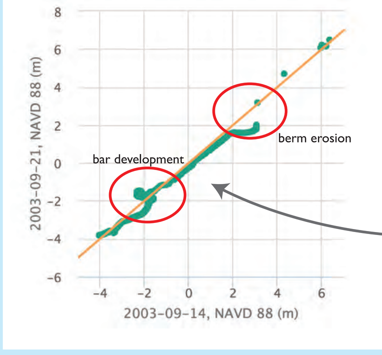
Changes to the beach profile following the passage of Hurricane Isabel (18 September 2003) at transect 1006, approximately 500 meters north of the FRF pier are summarized below. Isabel was the most significant event to have impacted the site over the nearly 40-year history of the FRF. The eye of the hurricane made landfall near Ocracoke Inlet, 113 km south of Duck. The storm produced the largest wave ever recorded at the FRF (12.1 m). Significant wave heights above 2 m (storm waves) were sustained for over 3 days.



Maximum significant wave heights measured during storms at the FRF (storms defined as waves > 2m and duration > 8hrs)



The storm removed over 31 m^3/m of sediment from the beach at profile 1006. Although the foredune remained relatively stable at this location, the wide summer berm is absent in the post-storm profile (sediment redistributed to the offshore bar). Shoreline changes at this site range between 16 m (at the berm crest) and 2 m at the MHW contour.

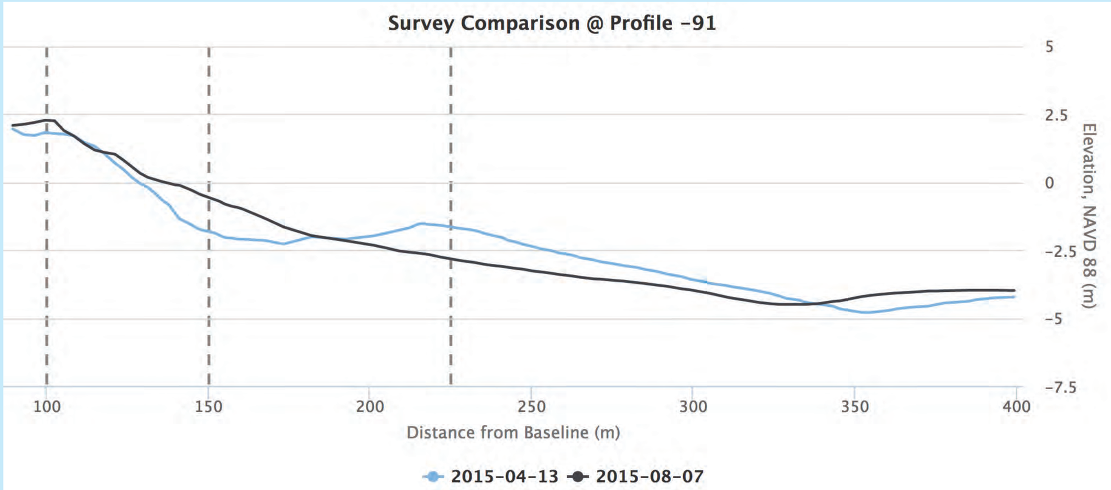


Scatter of profile comparison points helps to identify areas of greatest change.

	Cross -shore position		
	14-Sep	21-Sep	Retreat (m)
Foredune	71 m	71 m	0
Berm crest	91 m	80 m	-11
MHW	115.5 m	113.6 m	-1.9
MLLW	124 m	122.4 m	-1.6

Seasonal profile changes

The geomorphology tools also allows for calculation of differences in elevation at user specified cross-shore locations. Comparison of profile -91 in spring (13 April) and summer (07 August) of 2015 provides an example of changes in cross-shore sediment distribution due to seasonal wave conditions. Sand volumes remain relatively conserved (<5m3/m change), although the subaerial beach gains elevation from sand stored in the nearshore. The wide berm and relatively smooth offshore relief are typical of the summer profile. Elevation losses occur between 200 and 300 m due to onshore migration of the bar.



Acknowledgments

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