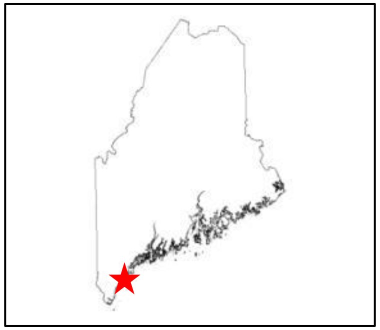
Geologic Site of the Month

February, 2010

Using LIDAR to monitor beach changes: Goochs Beach, Kennebunk, Maine



43° 20' 51.31" N, 70° 28' 54.18" W

Text by
Peter Slovinsky

Introduction

Light Detection and Ranging (LIDAR) is a remote sensing system used to collect topographic data (NOAA, 2010a). LIDAR is vital to the collection of large-scale, highly accurate topographic data within the coastal zone which can serve a multitude of purposes. Maine has been fortunate enough to have had several different LIDAR data collection flights. Data has been flown for different coastal sections of southern Maine in 2000, 2004, 2006, and 2007 (NOAA, 2000 and 2004; FEMA, 2006; US Army Corps, 2007). All of the LIDAR data that has been collected in Maine is highly accurate, with overall vertical accuracies in the 13-30 cm range (5-12 inches). Data with an overall vertical accuracy of 30 cm is considered to be adequate to create 2-foot contour interval maps (FEMA, 2002).

Over the years, the Maine Geological Survey (MGS) has been using LIDAR data to support a variety of project efforts, ranging from monitoring changes in the coastal environment (erosion or accretion of beaches and dunes), to simulating the potential impacts of sea level rise on both the built and natural environments. This Geologic Site of the Month will investigate the use of available LIDAR data to determine beach topography changes at Goochs Beach, Kennebunk, Maine.

Goochs Beach is an approximately 1.3 km long east-west trending pocket barrier located adjacent to the mouth of the Kennebunk River and bounded by bedrock headlands of Oaks Neck and Old Fort Point.

Goochs Beach

The site is shown on 2003 aerial orthophotographs (Figure 1) from the Maine Office of GIS (2003). Approximately 90% of Goochs Beach is fronted with a wooden seawall, though a very small active frontal dune is located adjacent to a jetty at the river mouth. The beach profile is generally flat and low and, due to the lack of sand exchange with most of the dune system and repeated wave action on the seawall, has a minimal summer berm (Slovinsky and Dickson, 2007).

Figure 1. Location of Goochs Beach, Kennebunk on an aerial orthophotograph courtesy of Maine Office of GIS.

LIDAR Data

The following LIDAR data sets were available and used to analyze topographic changes at Goochs Beach:

- September 28 and 30, 2000 data by NOAA/USGS/NASA for the Airborne LiDAR Assessment of Coastal Erosion (ALACE) Project for the U.S. Coastline. Data is in 5 m cell size, and has a vertical accuracy of ±15 cm RMSE.
- May 5 and 6, 2004 data by NOAA Coastal Services Center. Data is in 2 m cell size and has a vertical accuracy of ±10 cm RMSE.
- November 25-27, 2006 data by FEMA. Data is in 2 m cell size and has a vertical accuracy of ±18.5 cm RMSE.
- August, 2007 data by the U.S. Army Corps of Engineers. Data is in 2 m cell size and has a vertical accuracy of ±10 cm RMSE.

LIDAR Data

The 2000, 2004, and 2007 data is available for download at the Digital Coast website maintained by NOAA (2010b). A closer view of Goochs Beach with 2007 topographic LIDAR data used to create a color-coded grid of elevations which was overlain onto 2003 aerial orthophotographs is shown in Figure 2.

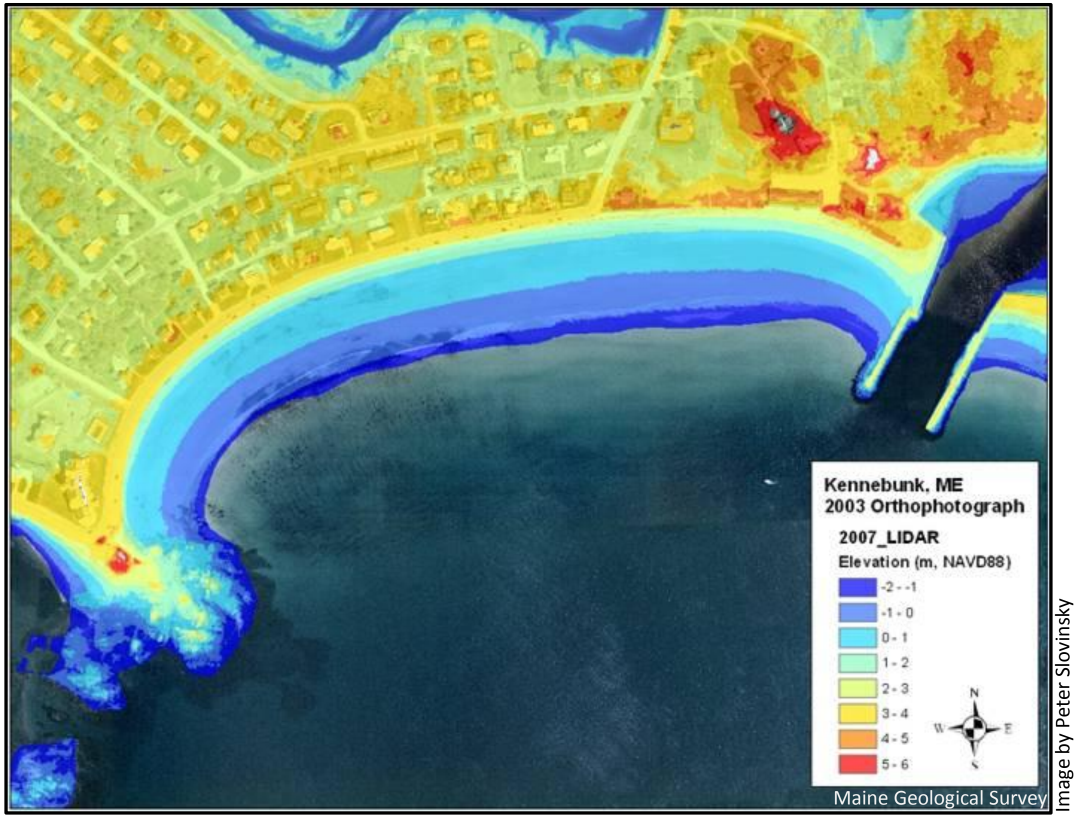


Figure 2. Example of color-coded gridded 2007 LIDAR data at Goochs Beach overlain onto an aerial orthophotograph. Photo courtesy of MEGIS (2003).

Methodology for Analysis

In order to document changes the beach has undergone and to identify areas of significant shoreline erosion or accretion (seaward dune growth or beach upbuilding), we have clipped the LIDAR data to include only the beach and dunes, and therefore excluded road surfaces and structures. We then used two different techniques to analyze changes along the beaches and dunes in this area over the study period:

LIDAR grid comparison. By subtracting older topographic data (2000) from a more recent LIDAR survey data (2004), one can visualize areas where the beach or dunes have lowered due to erosion (negative values), or built up due to accretion (positive values). This can also be done using the first (2000) and last (2007) datasets to give a net change. Resulting grids from the subtraction were color-coded such that areas of different shades of green to blue denote elevation loss (negative values), while areas of shaded yellow to red indicate elevation gain (positive values). Although some error from differences in processing out vegetation and creating the "bare earth" LIDAR elevations exists, this is generally considered minimal.

LIDAR contour comparison. By comparing the horizontal (i.e., landward or seaward) positions of specific elevation contours on the beach and near the dune, one can determine whether or not a beach or dune is accreting, or eroding. Typically, if a beach is accreting, contours will move in a seaward direction from Time 1 to Time 2. Conversely, if a beach is eroding, contours will move in a landward direction from Time 1 to Time 2. We extrapolated 0.5 meter contours from each of the LIDAR datasets, and then compared the positions of the -1, 0, 1, and 2 m contours.

Results: 2000-2004

For each time interval, data will be described in terms of the comparison of beach topography (difference in grids) and the locations of contour lines on the beach at the -1, 0, 1, and 2 m contours. Note: Figures have grids labeled with the earlier year being subtracted from the later year.

During 2000-2004 (Figure 3), the beach showed substantial lowering between -0.75 and -1 m.

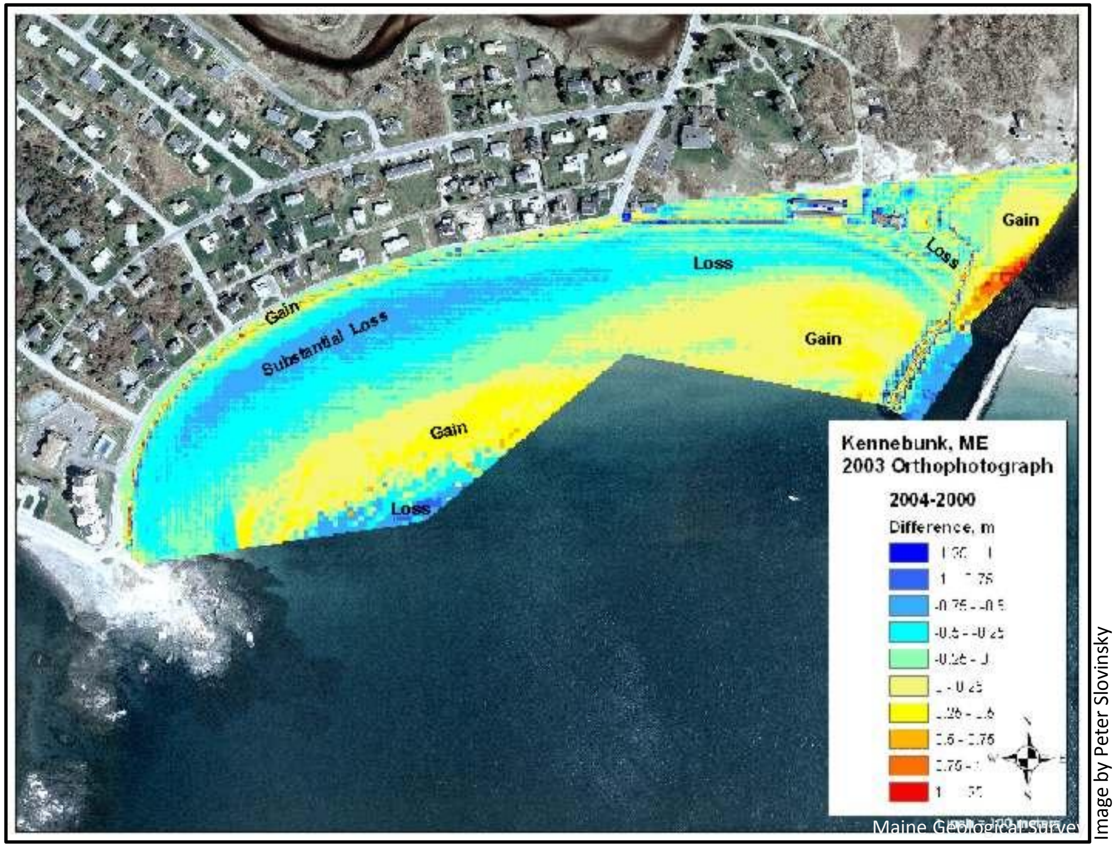


Figure 3. Resulting color-coded gridded elevation values from subtracting 2000 from 2004 LIDAR data. Photo courtesy of MEGIS (2003).

Results: 2000-2004

The area of loss was widest and most prevalent at the western end of the beach, and narrowed and lessened to the east. The majority of loss was between the 0 and 1 m contour intervals. Above this level, elevation loss was less, averaging between -0.25 and -0.5 m. Below the 0 m contour, elevation gains between 0 and 0.5 m occurred, with some substantial loss at the western end of the beach.

At the eastern end of the beach, additional gain was noted adjacent to the jetty, and in the beach areas generally between the 0 and -1 m contour intervals. There was some apparent loss of elevation adjacent to the seawall in the east-central part of the beach. Just inside the jetty within the inlet of the Kennebunk River at a small pocket beach, there was elevation gain between 0.25 and 1 m.

Results: 2000-2004

Based on contour line comparison (Figure 4), it is clear that the 2004 contour lines were landward of the locations of the 2000 contours, especially at the western end of the beach; this indicates that the beach migrated in a landward direction, and subsequently underwent erosion.

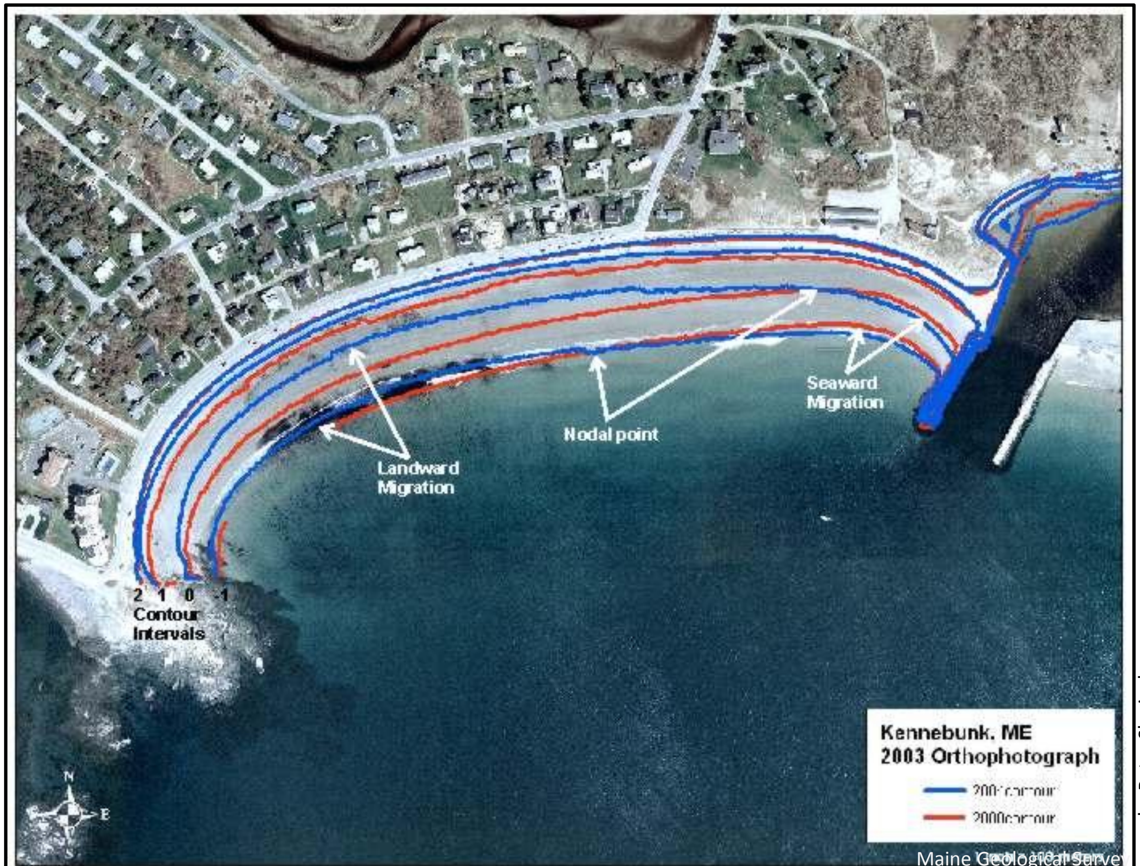


Image by Peter Slovinsky

Figure 4. Comparison of -1, 0, 1, and 2 m contour positions extrapolated from 2000 and 2004 LIDAR datasets. Photo courtesy of MEGIS (2003).

Results: 2000-2004

At the eastern end of the beach, nearer the jetty, the trend reversed, with seaward migration of the contour lines, indicating accretion. This was the case for the 0 m and -1 m contour lines. There is a nodal point that marks trend reversal, located seaward of where Beach Avenue turns at the beach. The +1 m contour line indicates landward migration (erosion), and the +2 m contour line, which is close to the seawall, shows some stability to slight landward migration, nearer the natural dune in the eastern portion of the beach.

It is important to note that the 2004 LIDAR data was collected in May. Typically at this time, beaches in Maine are "recovering" from the winter and spring storms, with less sediment on the upper portions of the beach, and more sediment stored offshore in the form of sandbars. Conversely, the 2000 data was collected in September, usually when beaches have the largest volume of sediment on the upper portions of the beach due to gentler waves and light onshore winds that move sand up the beach profile. This timing difference does appear to influence the comparison of elevation gains and losses, in addition to the locations of the contours, between 2000 and 2004.

Results: 2004-2006

When subtracting the 2004 from 2006 data, the beach appears to have undergone different changes than between the 2000 and 2004 data (Figure 5).

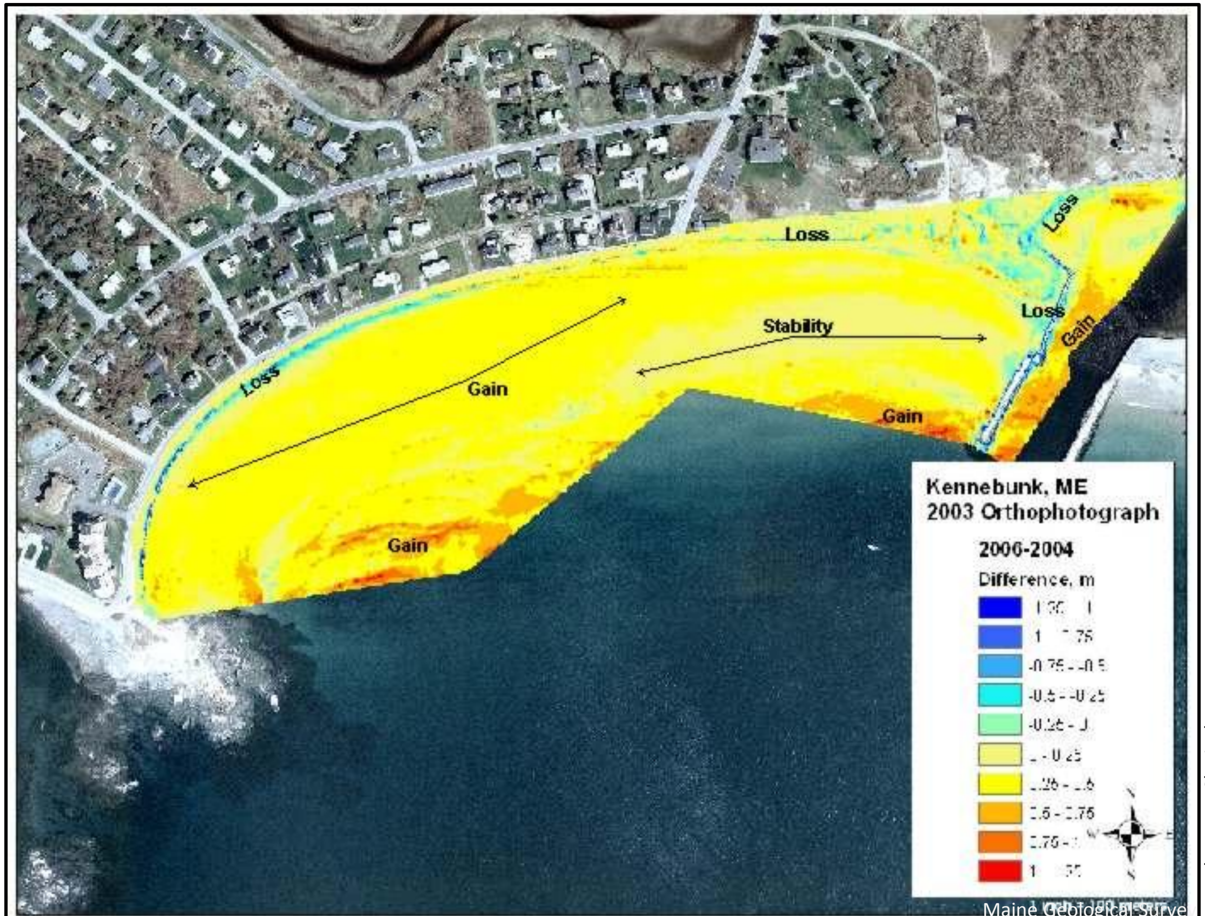


Image by Peter Slovinsky

Figure 5. Resulting color-coded gridded elevation values from subtracting 2004 from 2006 LIDAR data. Photo courtesy of MEGIS (2003).

Results: 2004-2006

For the most part, the majority of the beach slightly increased in elevation (0.25-0.5 m gain), especially at the western end of the beach. General stability to slight gain (0-0.25 m gain) was exhibited in the eastern portion of the beach, with some slight erosion of the beach and dune near the jetty, on both the beach and river sides. The largest gains of 0.5-1.0 m in elevation were noted in the offshore portions of the profile (deeper than the -1 m contour), and stability to slight gains were noted in the 0 to 2 m contour areas of the beach. Some of the largest loss occurred adjacent to the seawall at the western end of the beach, at the seawall in the east-central portion, and within the dunes adjacent to the jetty.

Results: 2004-2006

Comparison of contours between 2004 and 2006 showed that the beach generally underwent accretion, evidenced by the seaward migration of the contour lines along almost the entire beach (Figure 6).

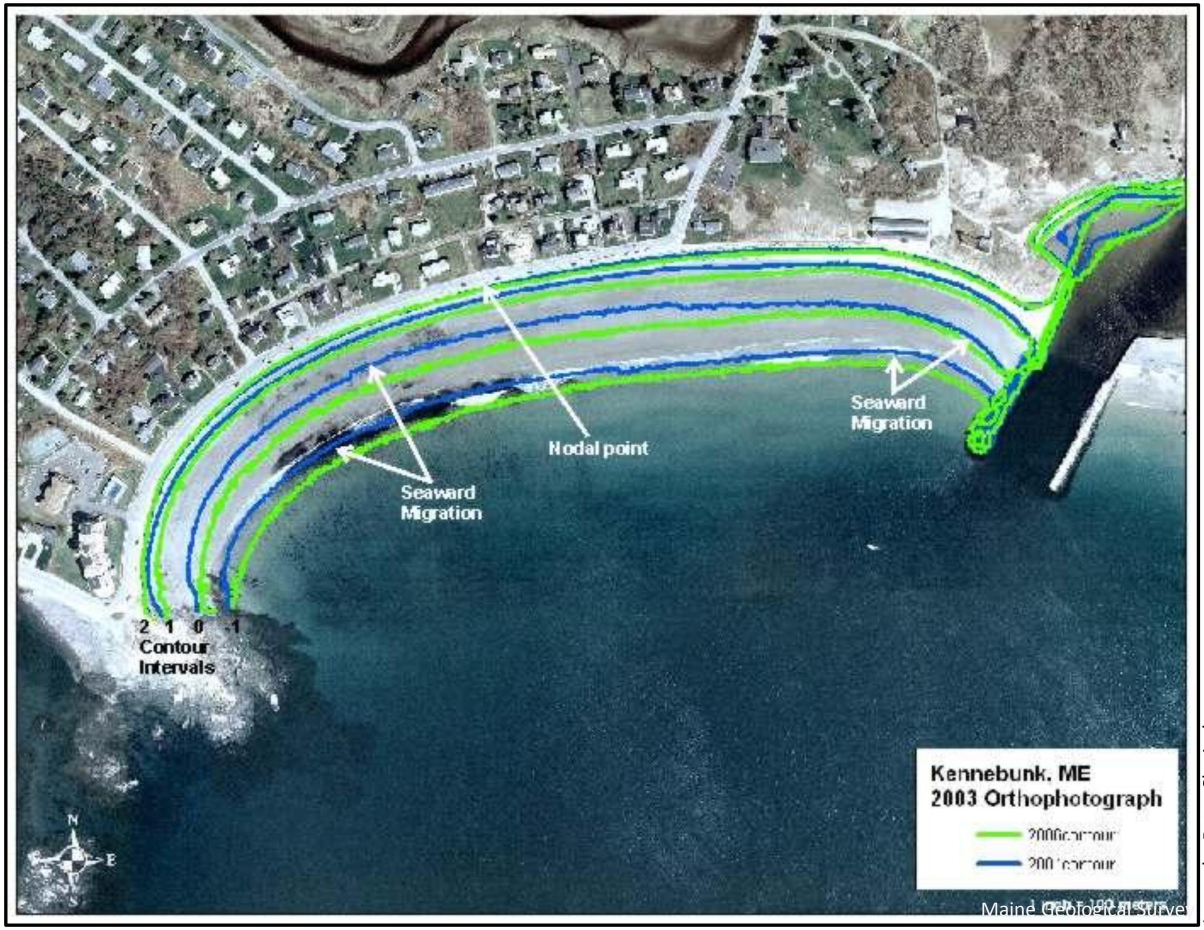


Image by Peter Slovinsky

Figure 6. Comparison of -1, 0, 1, and 2 m contour positions extrapolated from 2004 and 2006 LIDAR datasets. Photo courtesy of MEGIS (2003).

Results: 2004-2006

There is no trend reversal for all of the contours except for the 2 m contour line; the nodal point where some landward migration occurs, concentrated in the western end of the beach, is marked in Figure 6. East of this location, the 2 m contour line showed seaward migration from 2004 to 2006, indicating accretion. The pocket beach inside the jetty also showed seaward migration of the contour lines. The 2006 LIDAR data was collected in November, typically just after when beaches are most fully developed (this usually occurs in September or October, depending upon storms); in comparison with the 2004 data, which was collected in May when beaches are typically just starting to build in elevation. Thus, one might expect higher elevations (accretion) to be noted when comparing these two datasets.

Results: 2006-2007

Comparison of the 2006 and 2007 gridded LIDAR data is shown in Figure 7.

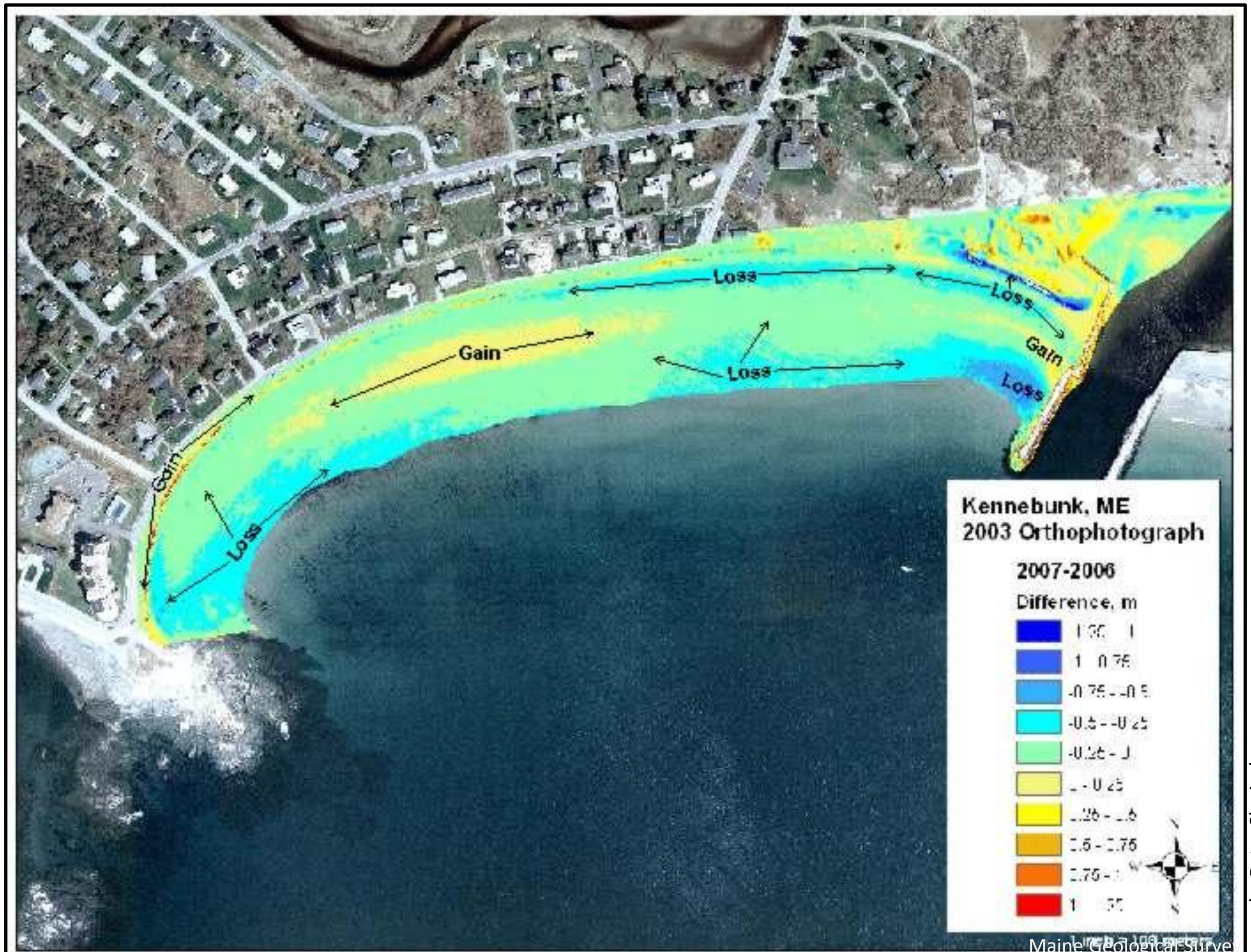


Image by Peter Slovinsky

Figure 7. Resulting color-coded gridded elevation values from subtracting 2006 from 2007 LIDAR data. Photo courtesy of MEGIS (2003).

Results: 2006-2007

Grid subtraction revealed that the overall beach underwent losses in elevation. Much of the beach saw slight losses, on the order of 0.25 to 0 m (and within the error level the data). However, several areas saw much higher losses of elevation, namely adjacent (west) of the jetty, where elevations decreased by between 0.5 to 1 m. The naturally occurring sand dune adjacent to the jetty also saw losses on the order of the same magnitude. Slightly lower loss (0.25-0.5 m) occurred mostly in areas seaward of the 0 m contour, and an area at the central portion of the beach (just seaward of the turn of Beach Avenue and to the east) located between the 1 and 2 m contours lost similar amounts. Areas of gain included dune areas landward of the dramatic dune losses adjacent to the jetty, which saw up to almost 1 m gain in elevation, and a wide area of beach located in the west-central portion of the beach which gained between 0 and 0.25 m of sand. At the western end of the beach, directly adjacent to the seawall, the beach appears to have gained up to 1 m in elevation, though this may relate to LIDAR data smoothing as opposed to actual differences in elevation between the 2 datasets.

Results: 2006-2007

When comparing contours between 2006 and 2007 (Figure 8), landward migration of contours was apparent along almost the entire beach, aside from a short stretch along the 0 and 1 m contours in the west-central portion of the beach where the contour positions are roughly unchanged.

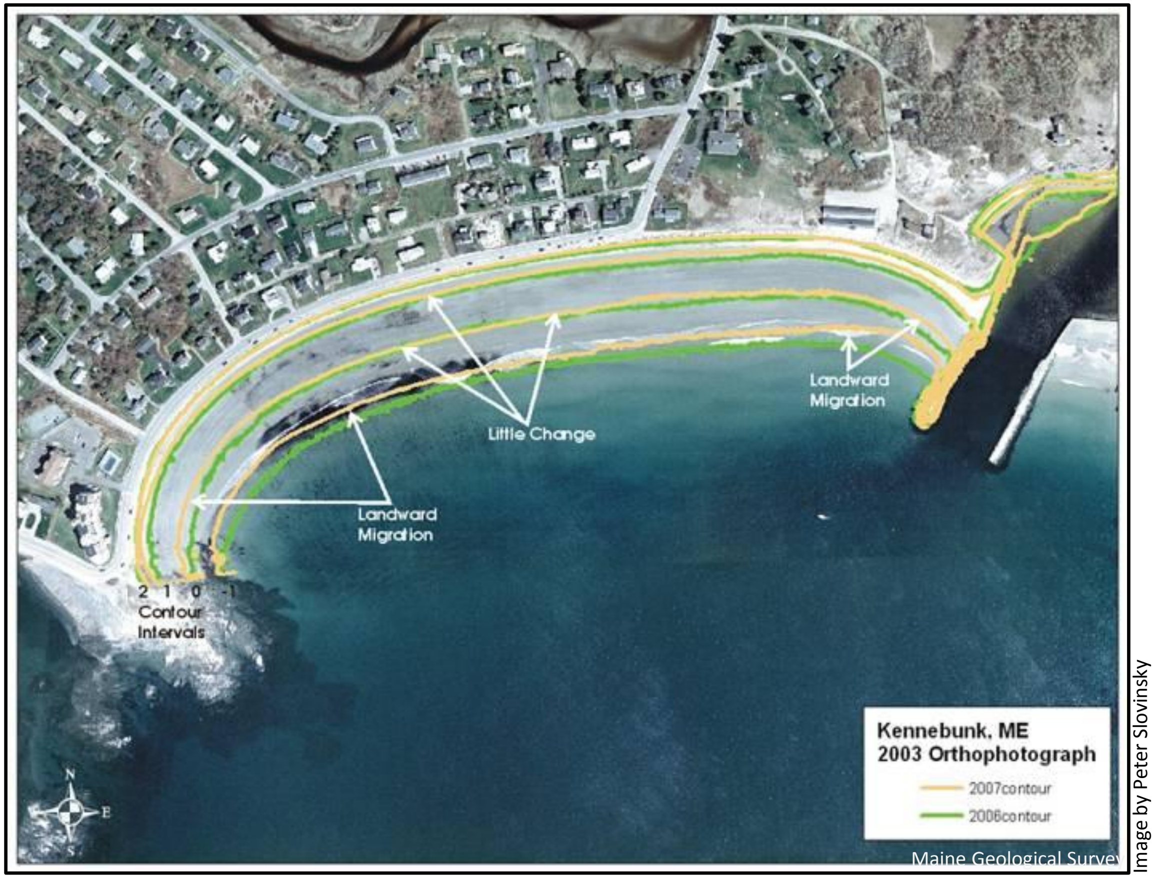


Figure 8. Comparison of -1, 0, 1, and 2 m contour positions extrapolated from 2006 and 2007 LIDAR datasets. Photo courtesy of MEGIS (2003).

Results: 2006-2007

There is little landward movement of the 2 m contour line in the west to central portions of the beach, since it is already against the seawall. East of where Beach Avenue makes a sharp turn, the landward migration of the 2 m contour line becomes more pronounced.

The changes observed from 2006-2007 show overall erosion and landward migration of the beach system. This may be an artifact of the influence of the April 2007 Patriots' Day Storm on the LIDAR data. The 2007 data was collected in August, just 4 months after the storm. The storm had profound impacts on the beaches of Maine, with many seeing several meters to tens of meters of horizontal erosion of dunes. At Goochs Beach, it appears that the storm forced landward migration of contours, eroded naturally occurring dunes, and eroded portions of the beach (i.e., especially adjacent to the jetty) that had seen accretion in previous years.

Results: 2000-2007

As part of this effort, we wanted to compare the net "end point" changes that occurred at Goochs Beach using the 2000 and 2007 LIDAR datasets. Over that time period, the beach appears to have undergone areas of general erosion, slight loss to stability, and accretion, as illustrated in Figure 9.

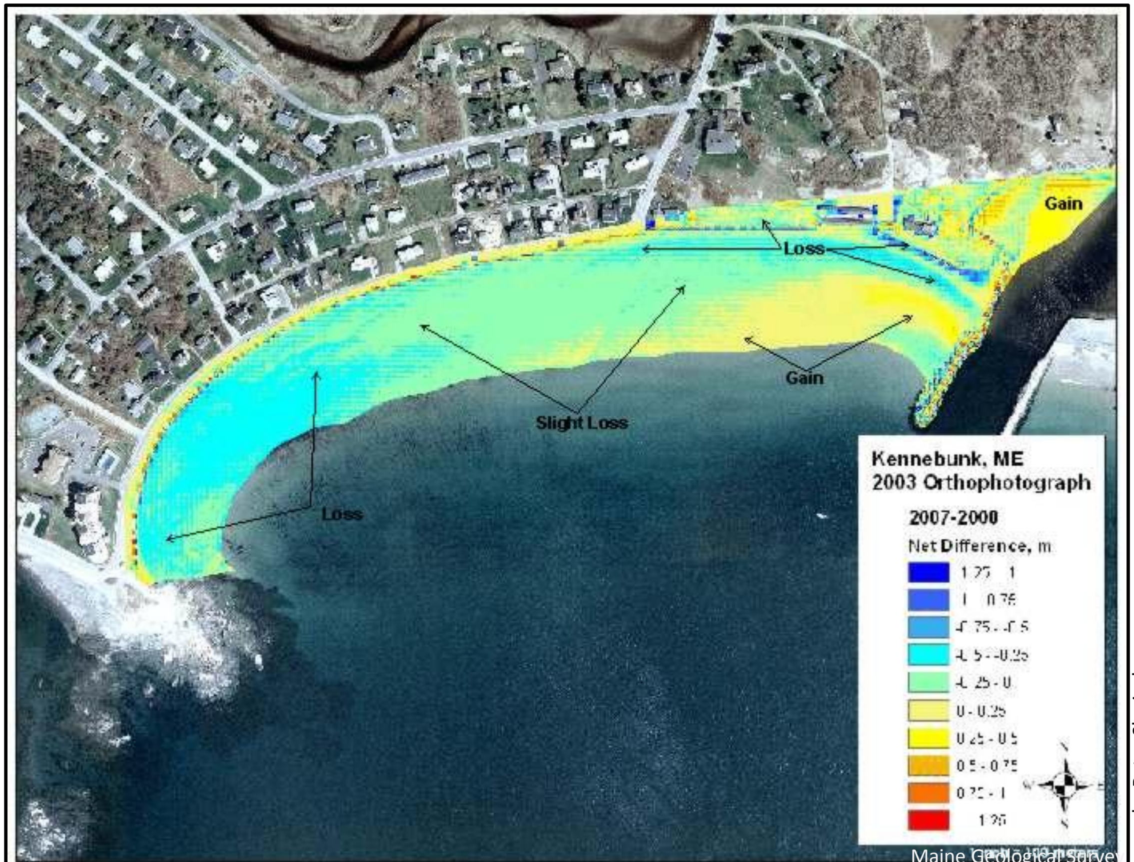


Figure 9. Resulting color-coded gridded elevation values from subtracting 2000 from 2007 LIDAR data. Photo courtesy of MEGIS (2003).

Image by Peter Slovinsky

Results: 2000-2007

The western portion of the beach saw a loss in elevation over the time period, between 0.25 and 0.5 m lower than the 2000 topography. The central portion of the beach underwent less erosion to general stability, with topographic changes mostly negative and ranging from 0 to 0.25 m. This trend continues as a narrow band along the upper portion of the beach, into the eastern part of the beach. The eastern end of the beach has undergone general accretion, between 0.25 and 0.5 m in elevation gained between the two time periods. However, in this eastern end, there has been a pocket of beach lowering adjacent to the jetty (seaward of the -1 m contour). Additionally, directly along the upper portion of the beach and within the sand dunes, the beach and dunes have lowered between 0.25 and almost 1 m in elevation. The small pocket beach inside the Kennebunk River appears to have gained elevation along its uppermost portion, lost some elevation in its middle section, and gained sediment slightly farther offshore.

Results: 2000-2007

Comparison between the 2000 and 2007 (Figure 10) contours shows that the beach has generally migrated landward, especially in the western end.

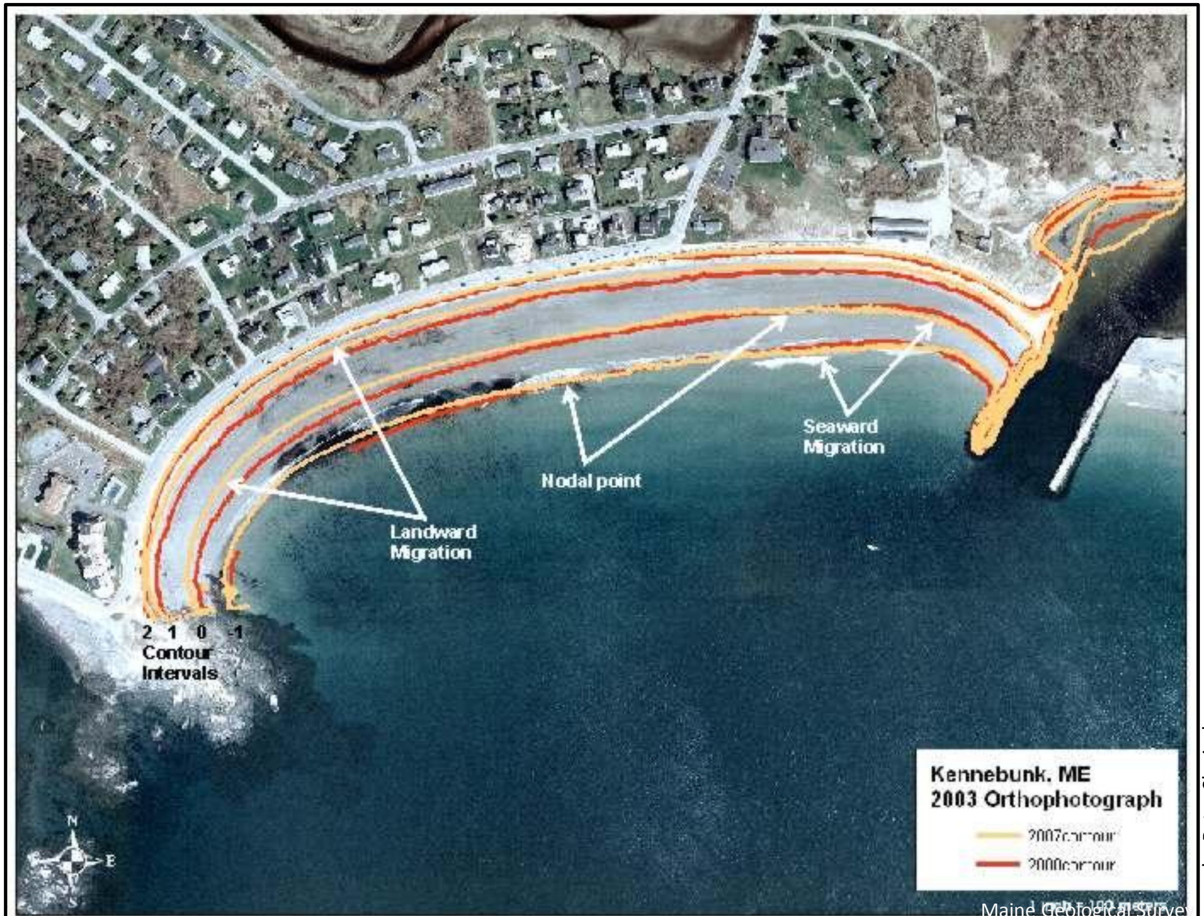


Image by Peter Slovinsky

Figure 10. Comparison of -1, 0, 1, and 2 m contour positions extrapolated from 2000 and 2007 LIDAR datasets. Photo courtesy of MEGIS (2003).

Results: 2000-2007

The previously noted nodal point exists along the -1 m contour, generally located south of the turn at Beach Avenue, and slightly east of that location for the 0 m contour. This nodal point marks the location where the contours switch to a seaward migration (indicating accretion) pattern for a stretch of the beach to the east, to near the jetty. The 1 and 2 m contours show landward migration, indicating general erosion along the upper portion of the beach along Goochs Beach. At the pocket beach in the Kennebunk River, the contours have generally migrated seaward, indicating accretion.

Conclusions

Using available topographic data from a range of dates, we investigated topographic beach and specific contour line changes along Goochs Beach, Kennebunk. Analysis of overall data shows that the beach is generally trying to migrate in a landward direction, with contours moving closer to the shore, though there are pockets of beach growth.

Based on the data, the beach can generally be broken into three different areas based on overall trends; a western portion, which is eroding, a central portion, which is stable to slightly erosional, and an eastern portion, which is generally accreting, though it appears to be susceptible to significant storm events.

Data also illustrates the fact that each LIDAR flight is a simple "snapshot" of the beach elevations at the time of the flight. Timing of these flights is important for subsequent comparison; it is difficult to compare contours and beach elevations (which undergo seasonal changes in response to changing storm patterns) from a winter or spring dataset and a summer or fall dataset. This seasonal bias in the data appears to manifest itself mostly when comparing LIDAR data with the 2004 data, which was flown in May. Additionally, inclusion of 2007 data (flown in August) shows the negative impacts on beach topography from the April Patriots' Day Storm. Monthly beach profile data that was analyzed as part of the 2009 State of Maine's Beaches Report (Slovinsky and Dickson, 2009) indicates that the beach is recovering from the erosion caused by the Patriots' Day Storm.

Future LIDAR flights will help further analysis of overall recovery of the beach, and help with continued monitoring efforts to determine the response of Goochs Beach to storm events and sea level rise.

References and Additional Information

Federal Emergency Management Agency, 2006. Light Detection and Ranging topographic data, November 25-27, 2006, provided by Maine Office of GIS to MGS.

Federal Emergency Management Agency, 2002. Guidelines and Specifications for Flood Hazard Mapping Partners.

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Slovinsky, P.A., and Dickson, S.M., 2007. State of Maine's Beaches in 2007, Maine Geological Survey Open-File 07-99, Online Edition.

United States Army Corps of Engineers (USACE), 2007. Light Detection and Ranging topographic data, August, 2007, courtesy of the New England District of the US Army Corps of Engineers, Concord, Massachusetts.

Other Related MGS Sites of Interest

Coastal Circulation in the Vicinity of the Kennebunk River and Goochs Beach

The Patriots' Day Storm at Willard Beach in South Portland, Maine

Coastal Erosion at Crescent Beach State Park, Cape Elizabeth, Maine

Beach Nourishment at Western Beach, Scarborough, Maine