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Observations of intertidal bars welding to the shoreline: examining the mechanisms of onshore sediment transport and beach recovery

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BACKGROUND

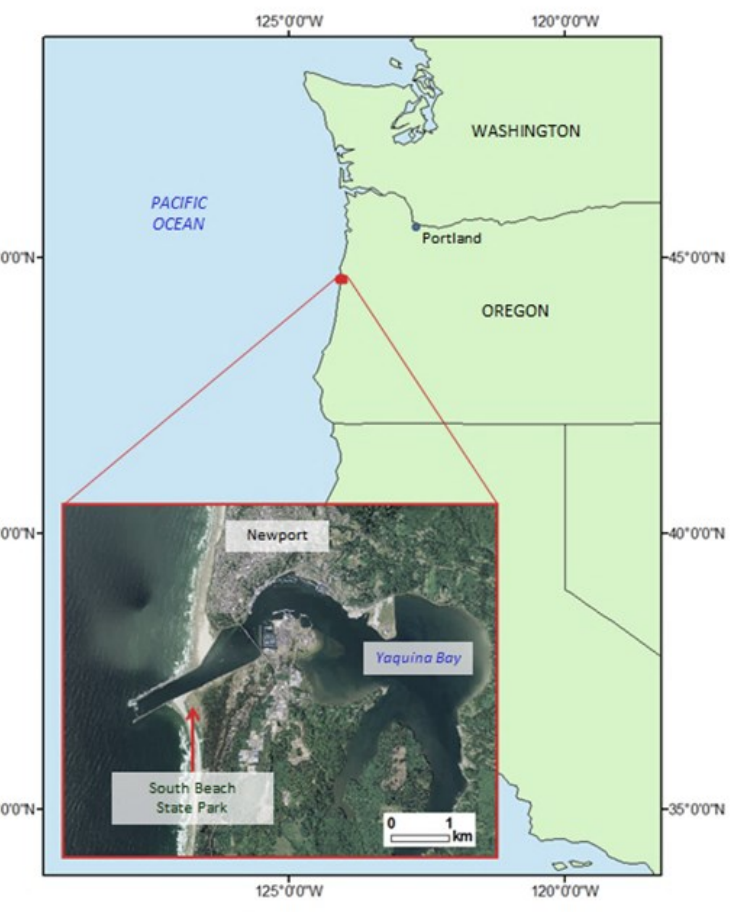


Figure 1. Location of South Beach State Park in Newport, OR

Many coastlines throughout the world are in a net erosional state due to factors such as climate change and anthropogenic activities. While most coastal erosion occurs episodically during major storms, beaches recover during extended periods of low wave energy. Despite the importance of beach recovery on limiting coastal vulnerability, the mechanisms driving onshore sediment transport are much less well understood than those of storm-driven offshore transport. Intertidal bar welding to the shoreline is one mechanism of sediment delivery from the nearshore to the backshore [1]. However, studies of swash bars and their contribution to beach building are scarce because of the sporadic nature of these events and difficulty measuring sediment fluxes in the intertidal zone [2].

Several beaches in the US Pacific Northwest are prograding rapidly in part due to highly dissipative conditions, an abundant sediment supply, and/or a response to coastal engineering structures. For example, at South Beach State Park (SBSP) in Newport, OR the shoreline accreted at an average of 6 m/yr from 1960 to 2002 [3]. To explore the role of intertidal bar welding on supplying sediment to this dynamic backshore, we recently completed a boutique field experiment at SBSP (henceforth referred to as SBSP14).

Figure 2. Example of an intertidal bar

EXPERIMENT SETUP

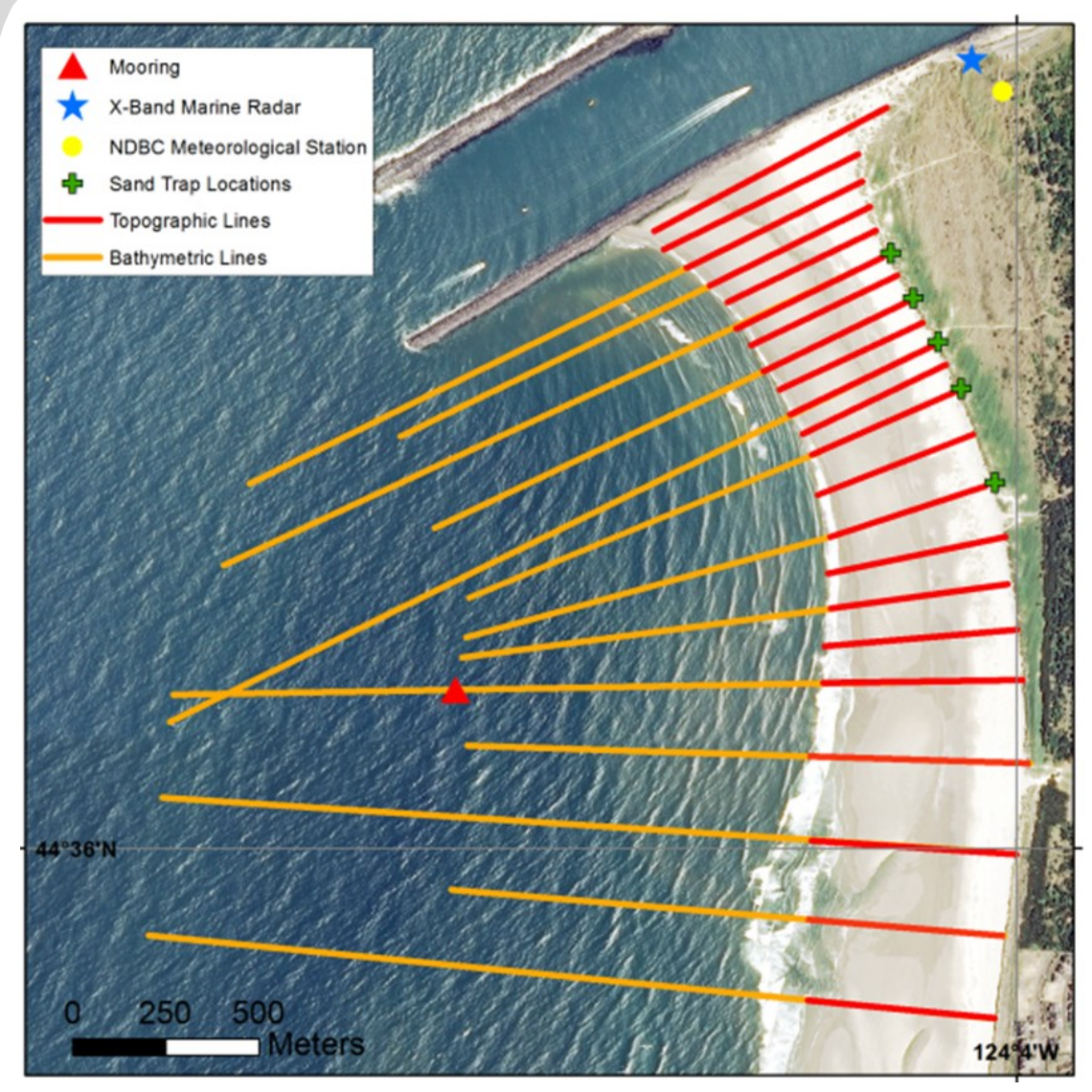


Figure 3. Field program map at SBSP

In order to capture short-term changes to the coastal landscape during SBSP14, elevation measurements of the sub-aerial beach were taken bi-weekly or more frequently along 22 cross-shore transects during July to Sep. 2014 using backpack based real-time kinematic (RTK) GPS equipment. During the period from Aug. 18-29 daily measurements of the intertidal zone and backshore were completed to provide detailed insight into intertidal bar dynamics. Additionally, depth soundings were collected from 12 m water depth to the shoreline using the Coastal Profiling System, a personal water craft based bathymetric surveying system equipped with RTK GPS, five times during SBSP14.

Concurrent with the intensive surveying program a mooring was deployed at 12 m water depth offshore of the study site to measure waves, currents, suspended sediment concentrations, and the density structure of the water column. A co-located X-band marine radar and meteorological station (NDBC NWPO3) also provided information regarding spatially complex wave transformations [4] and the forces driving aeolian sediment transport, respectively.

Figure 5. Field photos at SBSP showing intertidal bar (top), the flat dissipative beach (middle), and the lander being deployed off of the R/V Elakha (bottom)

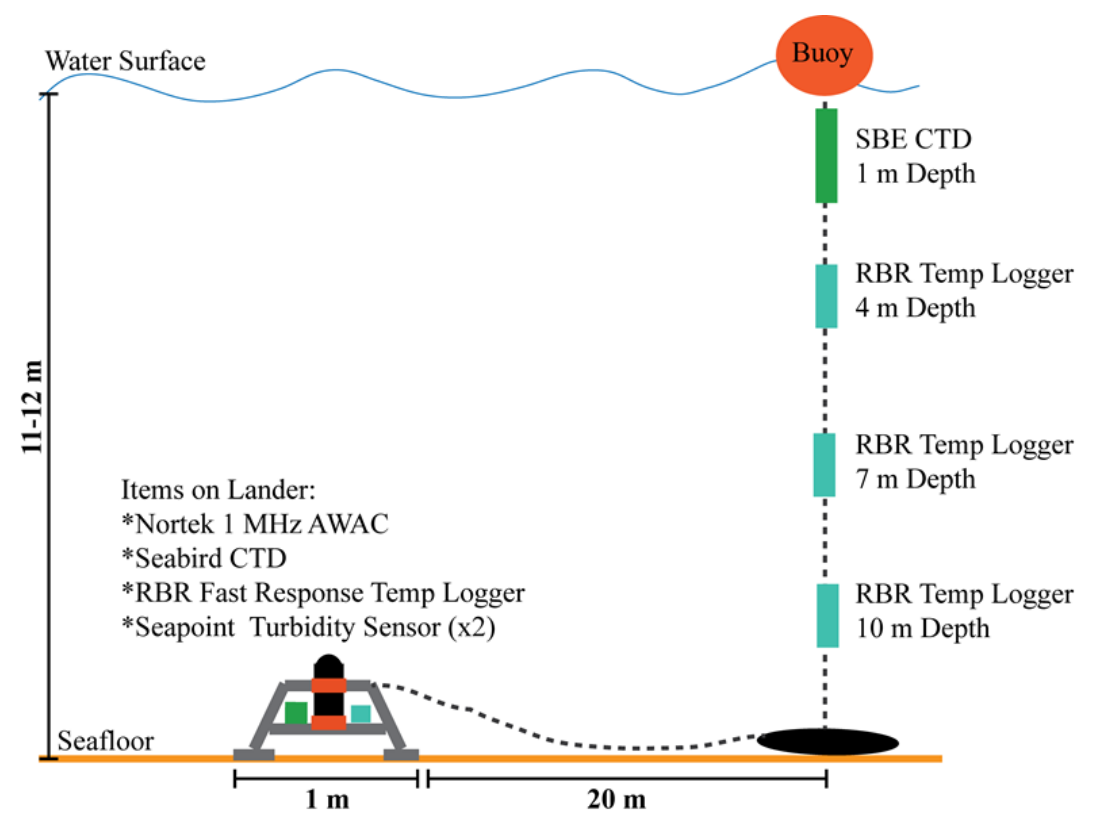


Figure 4. Mooring deployed offshore SBSP

ENVIRONMENTAL MEASUREMENTS

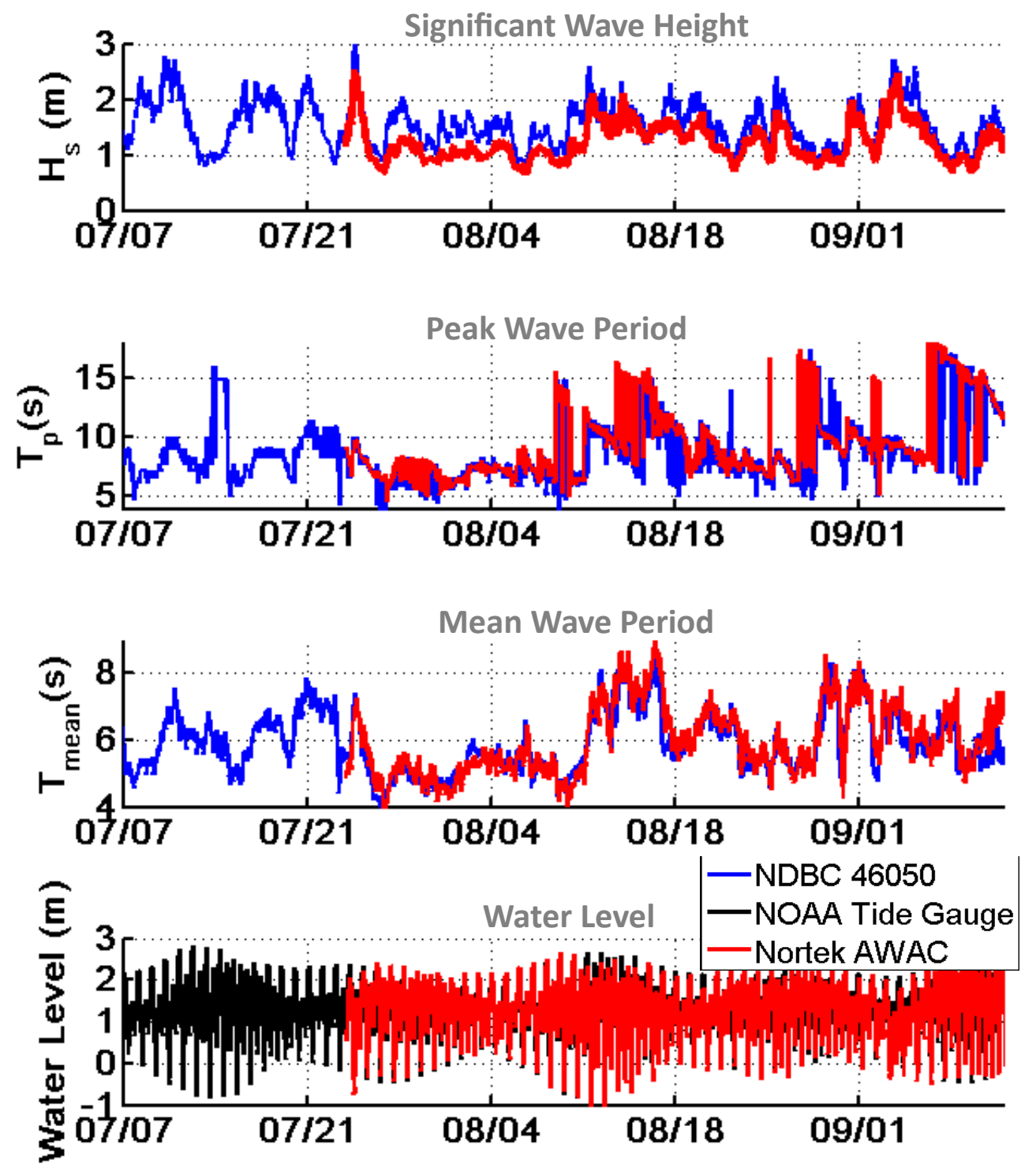


Figure 6. Time series of environmental conditions during the experiment

During the experiment the wave climate was relatively moderate, with an average wave height of 1.2 m and significant wave heights never exceeding 2.7 m (as measured by the AWAC). Comparison to data from NDBC buoy 46050 (located 20 miles west of Newport) indicates that the waves become more shore normal and reduce in height as they propagate over the shelf (Figures 6 and 10). As a result of shadowing at the jetty, wave energy directly at SBSP was typically lower than the measurements suggest (Figures 8 and 9).

Currents show significant vertical variability, with surface currents being largest in magnitude. Mean currents throughout the water column are about 8 cm/s (Figure 7).

Water levels vary significantly with time based on the neap-spring cycle, wind and wave driven setup, and sea level anomalies, with an average tidal range of about 2m during SBSP14 (Figure 6).

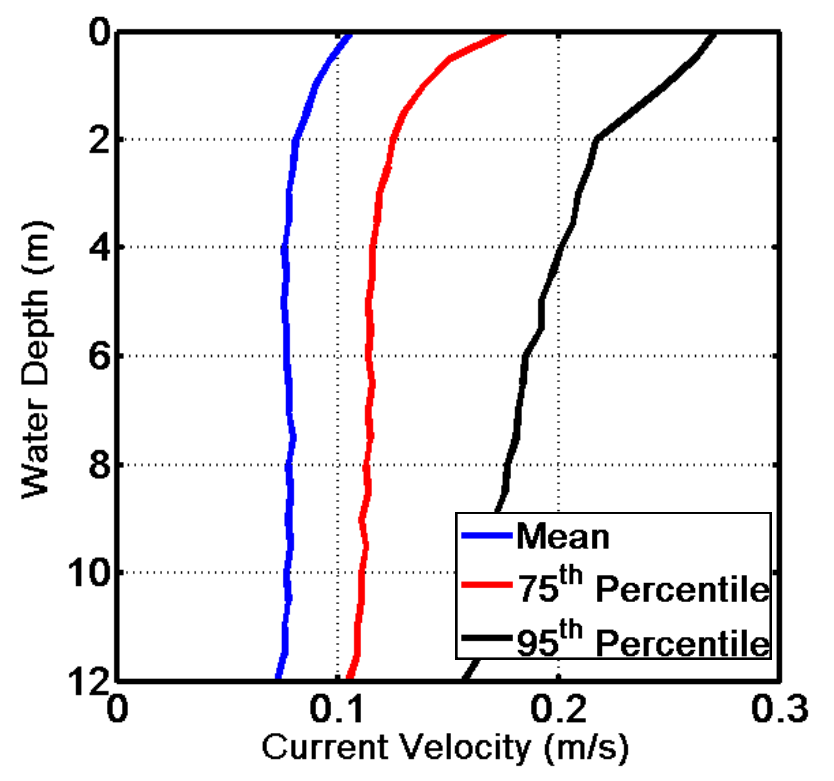


Figure 7. Vertical current structure measured during SBSP14 by the Nortek AWAC

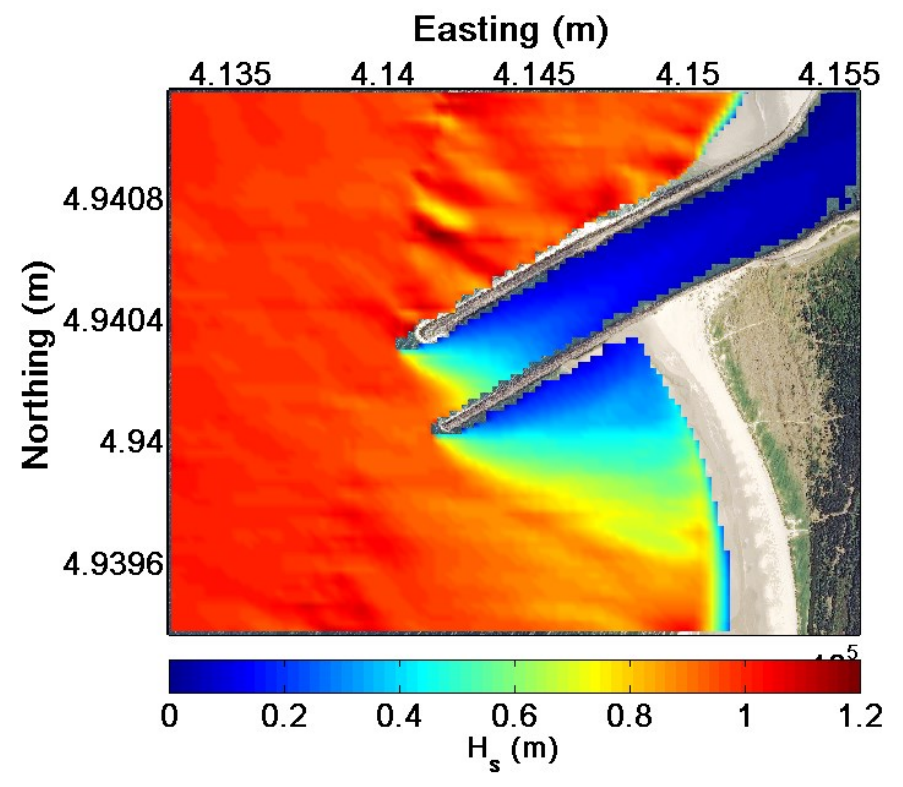


Figure 8. Modelled significant wave heights for 3 Aug 2014 at SBSP using SWAN showing shadow zone to south of the jetty (H_s = 1.2m, MWD = 320°)

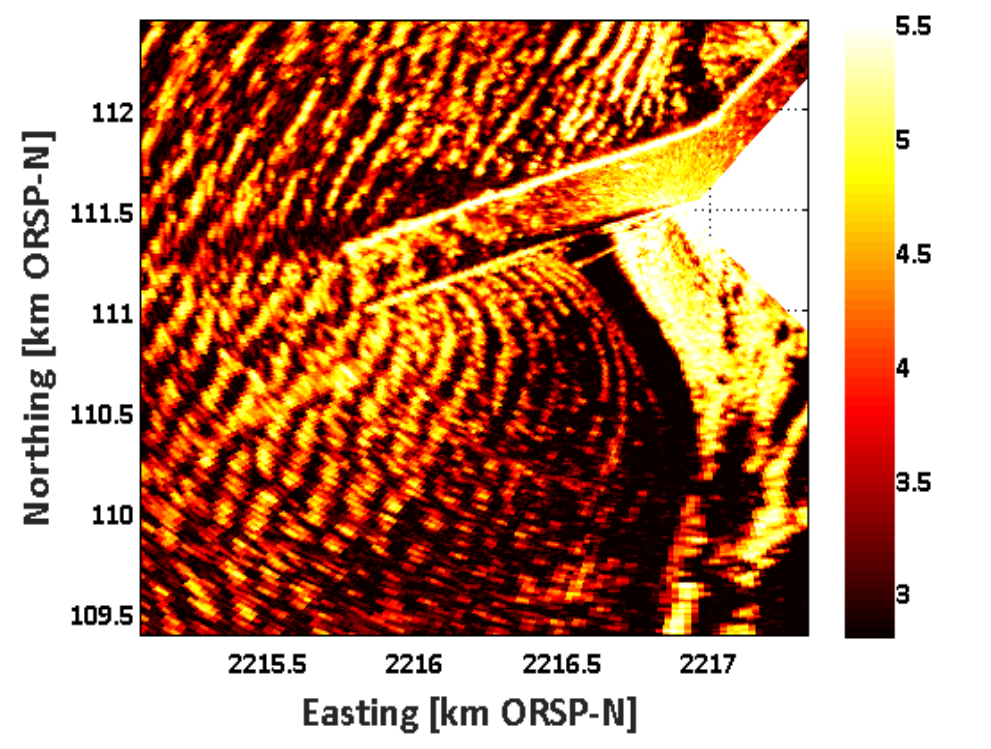


Figure 9. Observed spatial variability in backscatter intensity at SBSP from X-band Marine Radar for 29 Sep 2014 showing wave refraction patterns around the jetty

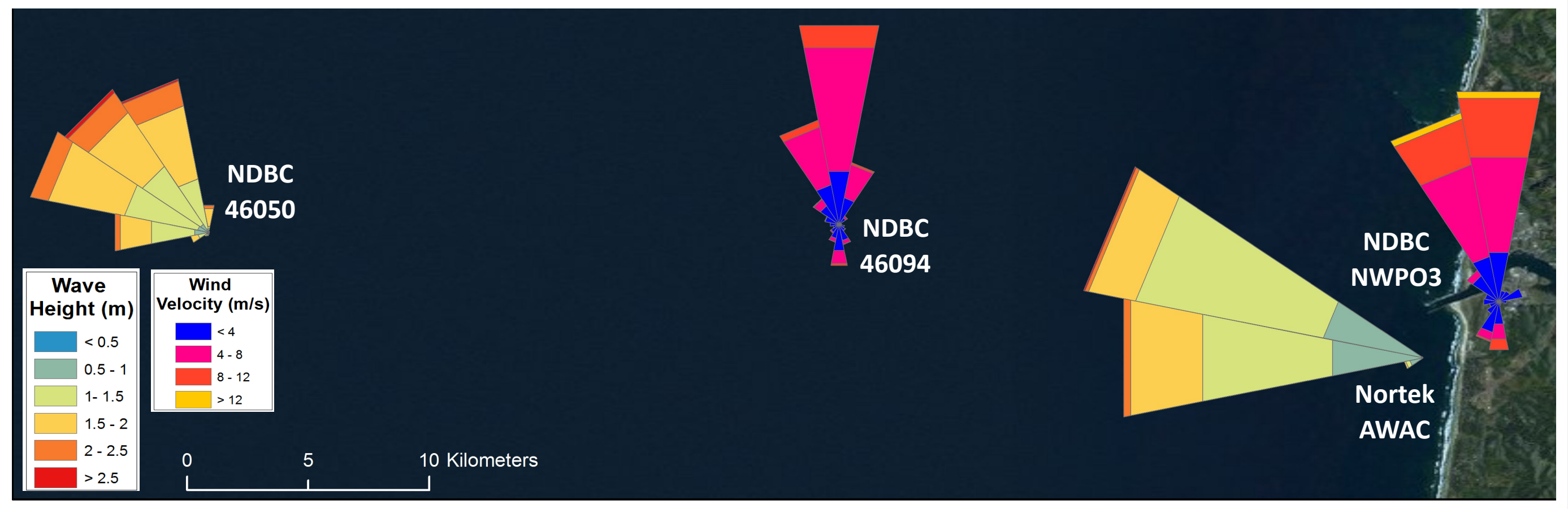
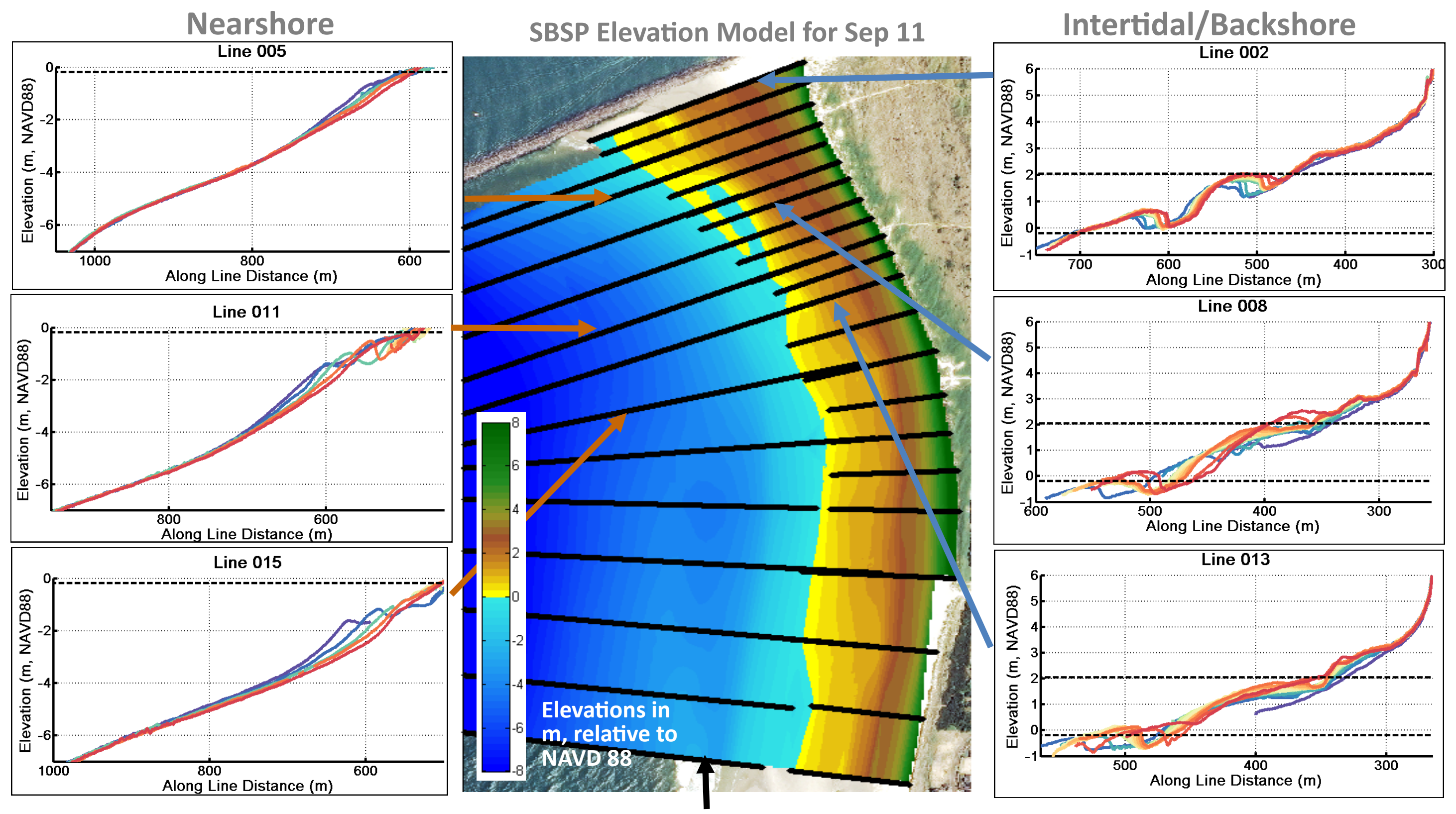


Figure 10. Wave and wind roses from NDBC 46050 (far left), NDBC 46094 (middle left), Nortek AWAC (middle right), and NDBC NWPO3 (far right) showing the directional distribution of significant wave heights and wind velocities from July/August 2014

MORPHOLOGY MEASUREMENTS



During the experiment there were intertidal bar(s) present along the majority of the coastline. There was a consistent pattern of landward sandbar migration (up to ~50 m) and in numerous locations the bar completely welded to the shoreline and dissipated in form during the course of the study. However, there was significant spatial and temporal variability in the evolution of these intertidal bars observed during SBSP14 (Figure 11).

There were also subtidal sandbars present, especially along the southern portion of South Beach. These features were observed to migrate onshore up to 100 m during the two month period.

The bathymetric data indicated that there was a net lowering the surf zone and shoreface to ~7m water depth, with the eroded sediment presumably being worked onshore through cross-shore processes including via bar welding.

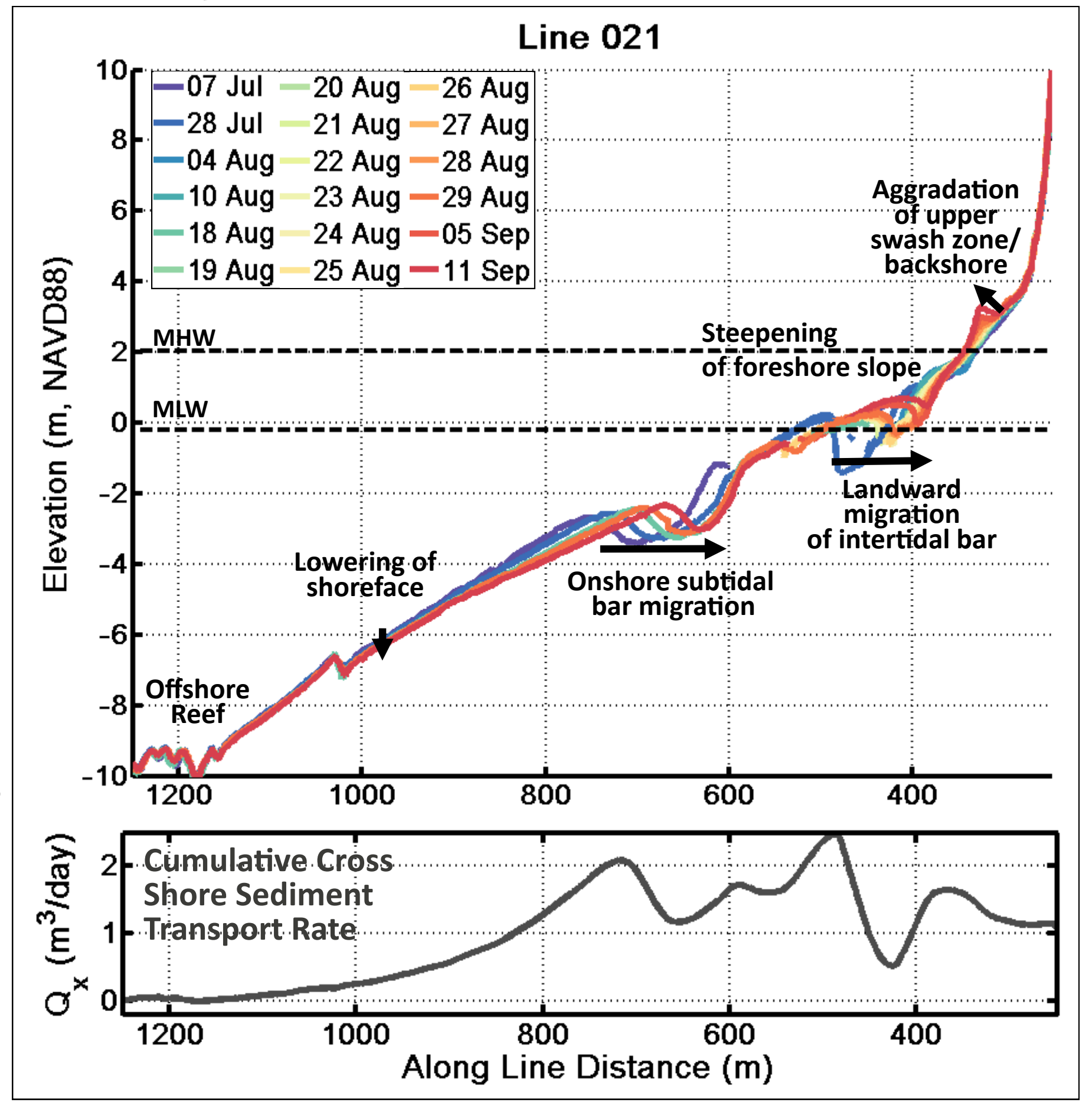


Figure 11. Topographic and bathymetric measurements made at select transects at SBSP throughout summer 2014 (upper panels). Bottom panel shows the cumulative cross shore sediment transport rate Profile 21 between July 28 and Aug 29.

DISCUSSION/NEXT STEPS

Across the 2 km stretch of beach at SBSP about 60,000 m^3 of sediment was added to the intertidal and backshore between July and September, amounting to ~30 m^3/m. Given the northerly wave direction during the experiment and the jetties role in blocking alongshore fluxes to the south, this net accumulation can be attributed almost entirely to cross-shore fluxes. During this time onshore migration of both subtidal and intertidal bars was observed, highlighting that sandbar welding is indeed an important mechanism of delivering sediment from the nearshore to the backshore.

The trends of onshore transport are not surprising at the study site given the historically high rates of local shoreline growth [3], although this pilot study demonstrates significant spatial and temporal coherence which was not entirely expected given the dynamic nature of the study site (e.g., complex wave refraction patterns and tidal/wave driven currents).

While we have identified a location where swash bars contribute significantly to the local sediment budget, a number of important questions remain, including:

- **What are the environmental conditions where onshore sandbar migration is promoted? When do these mechanisms vary in the alongshore and from site to site?**
- **How important is intertidal sandbar welding on the net sediment budget relative to other cross-shore and alongshore sources?**
- **Does synchronization of intertidal bar welding events with moderate on-shore winds provide a key sediment source for dune growth [2]?**

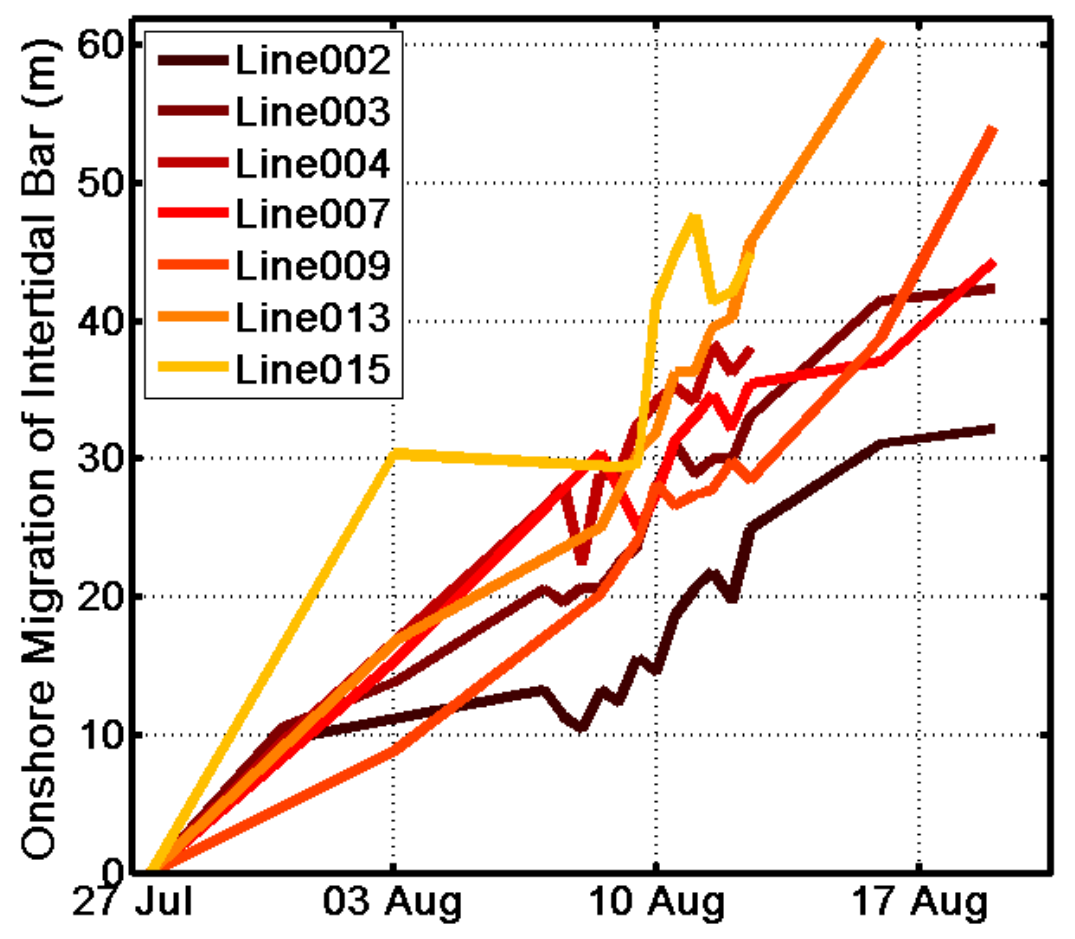


Figure 15. Temporal variability in bar crest location of the intertidal bars at select sites at SBSP. Onshore migration rates typically observed to be higher with increasing distance from the jetty.

Our understanding of onshore sediment transport processes in general is quite poor. Taking advantage of the numerous prograding beaches along the high energy, dissipative, swell dominated Pacific Northwest coast provides a means to better understand these beach recovery mechanisms for which intertidal bar welding appears to be an important process.

Figure 16. Field photos from Fall/Winter 2014 showing backshore (aeolian) sediment transport at SBSP

NET LANDSCAPE CHANGES

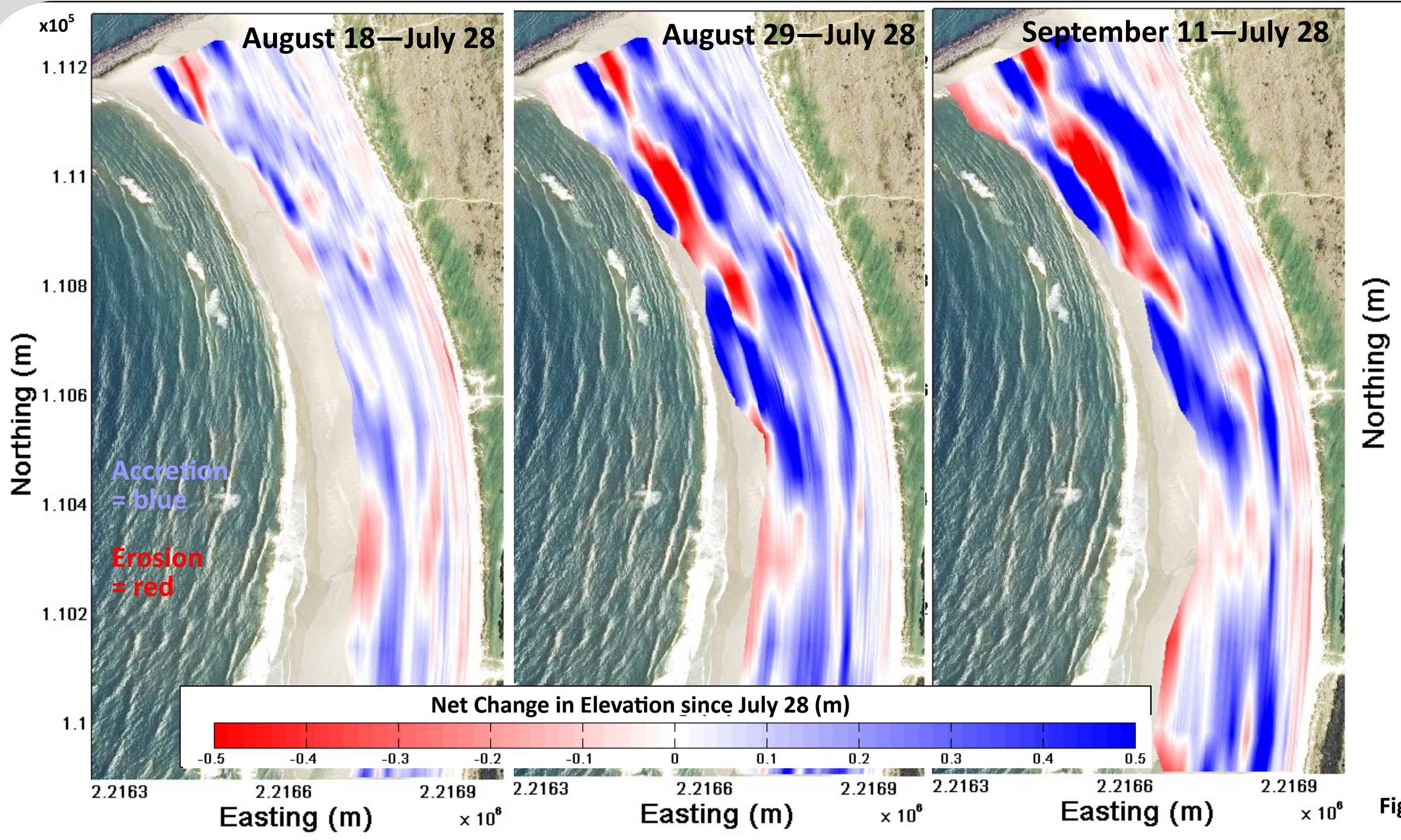


Figure 12. Elevation changes relative to July 28 for three dates: Aug 18 (left panel), Aug 29 (middle panel), and Sep 11 (right panel)

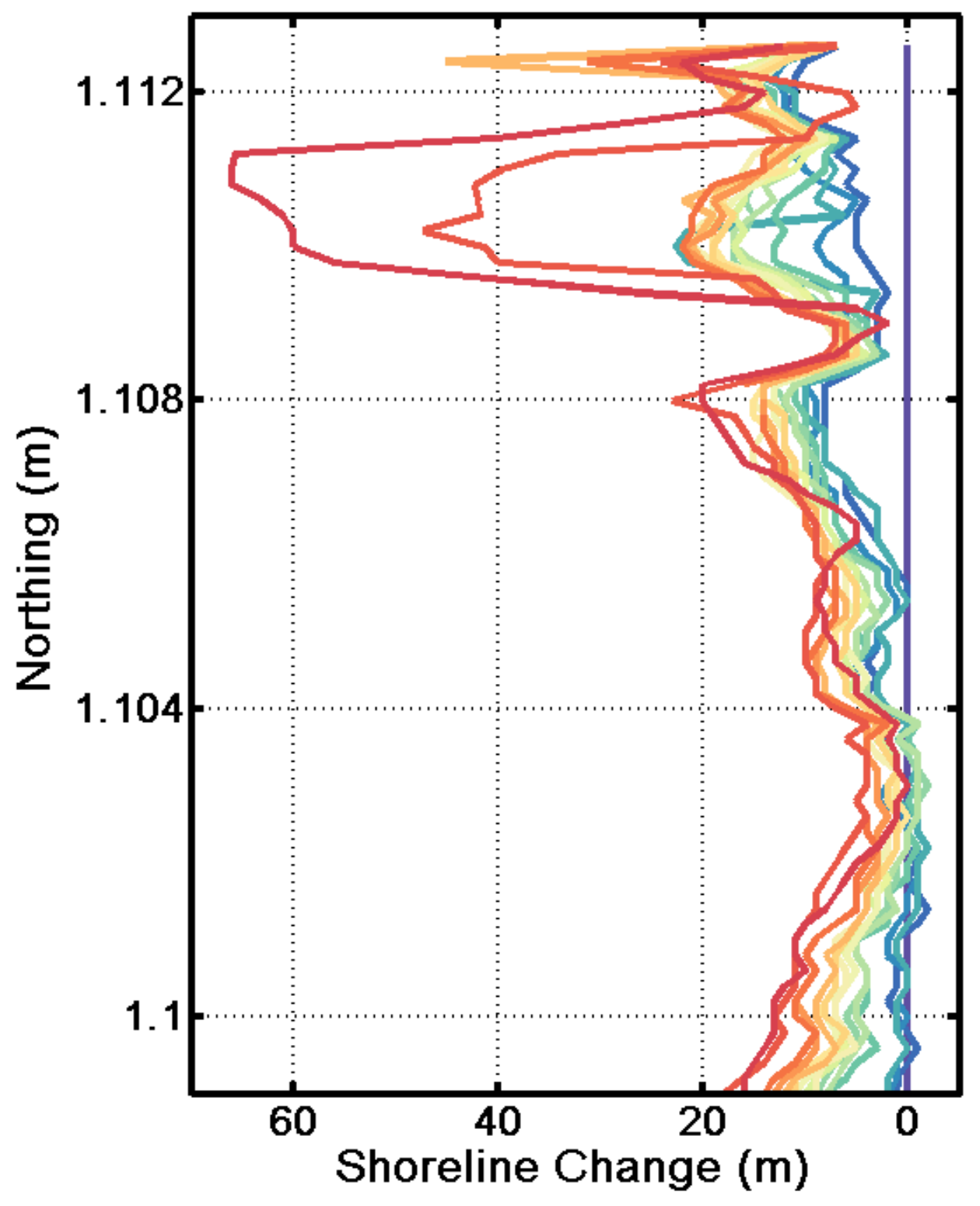


Figure 13. Net shoreline change throughout the field experiment using the 2.1 NAVD88 contour as reference. Colors indicate the dates using the same legend as in Figure 11

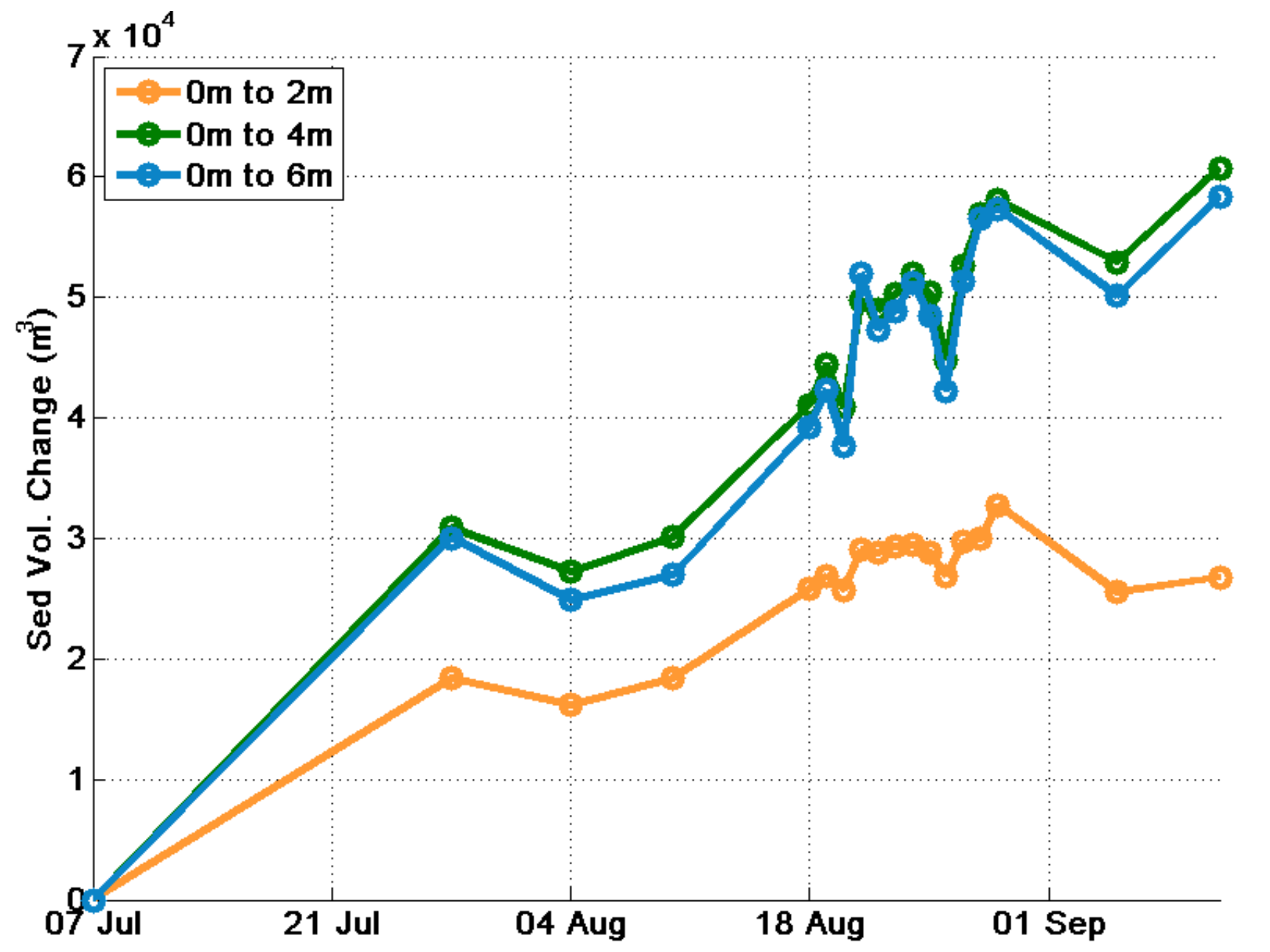


Figure 14. Net volumetric change to the beach since 7 July (for geographic region shown in Figure 12) as calculated between 0m and 2 m contours (orange line), 0m and 4 m (green line), and 0m and 6 m (blue line)

During the two months of SBSP14 the intertidal zone accreted on average by over 10 cm (Figure 12) and the shoreline (as defined by the 2.1 NAVD88 contour) prograded seaward by 17 m on average (Figure 13). The observed changes were largest where the welded intertidal bars were the most pronounced which was near the jetty and at the southernmost portion of the study area. Locally, there were regions of erosion as shown in Figure 12 associated with the landward propagation of the sandbars. During the experiment net sediment accumulation on the subaerial beach occurred primarily within the swash zone (Figure 14). Throughout SBSP14 the wind velocities were relatively weak and were rarely blowing from offshore (Figure 10) preventing significant quantities of aeolian transport to the backshore and dunes.

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