# Headland bypassing: Pathways and thresholds for sediment transport into an enclosed embayment

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## Background

Natural headlands form obstacles for longshore sediment transport between neighbouring coastal cells. Sediment connectivity around headlands only occurs for certain wave and tidal conditions. **This study investigates the thresholds and pathways for sediment transport into Slocums Embayment**, a bay situated at the mouth of Buzzards Bay, Massachusetts, USA, isolated from the surrounding shoreline by two headlands (Figure 1). In this natural embayment, sediment has accumulated near the inlet of a small river feeding into the bay, leading to concern over inlet closure and water quality.

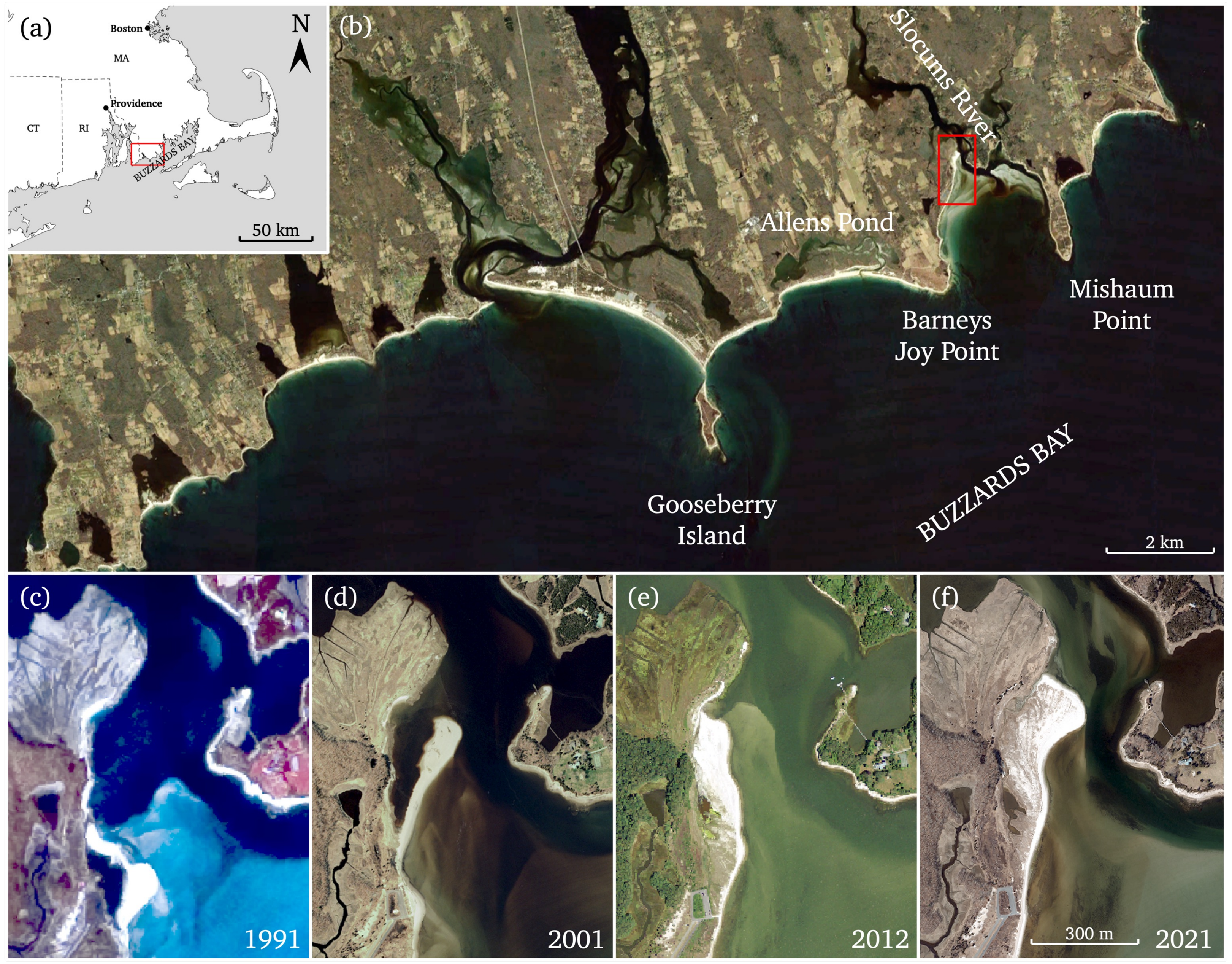


**Figure 1. (a-b)** Location of Slocums Embayment at the mouth of Buzzards Bay. **(c-f)** Temporal evolution of the spit at Slocums River inlet between 1991 and 2021 (Google Earth).

Sediment transport in the vicinity of Slocums Embayment is explored using a coupled Delft3D-FLOW/WAVE model. Model boundary conditions are derived from the North Atlantic Coast Comprehensive Study (NACCS). Sediment volume changes of the spit at the Slocums River Inlet based on a series of LIDAR DEMs are used to validate the modelled sediment transport.

## Modelled sediment transport

Under regular conditions, the tidal flow in and out of Buzzards Bay completely bypasses Slocums Embayment. Only under extreme wave conditions (return period ≤ 1 year) a sediment pathway into the embayment is created. A *net average hourly sediment transport rate* into Slocums Embayment is calculated for 36 storm scenarios (4 wave height, 3 wave direction, 3 water level, Fig. 2a).

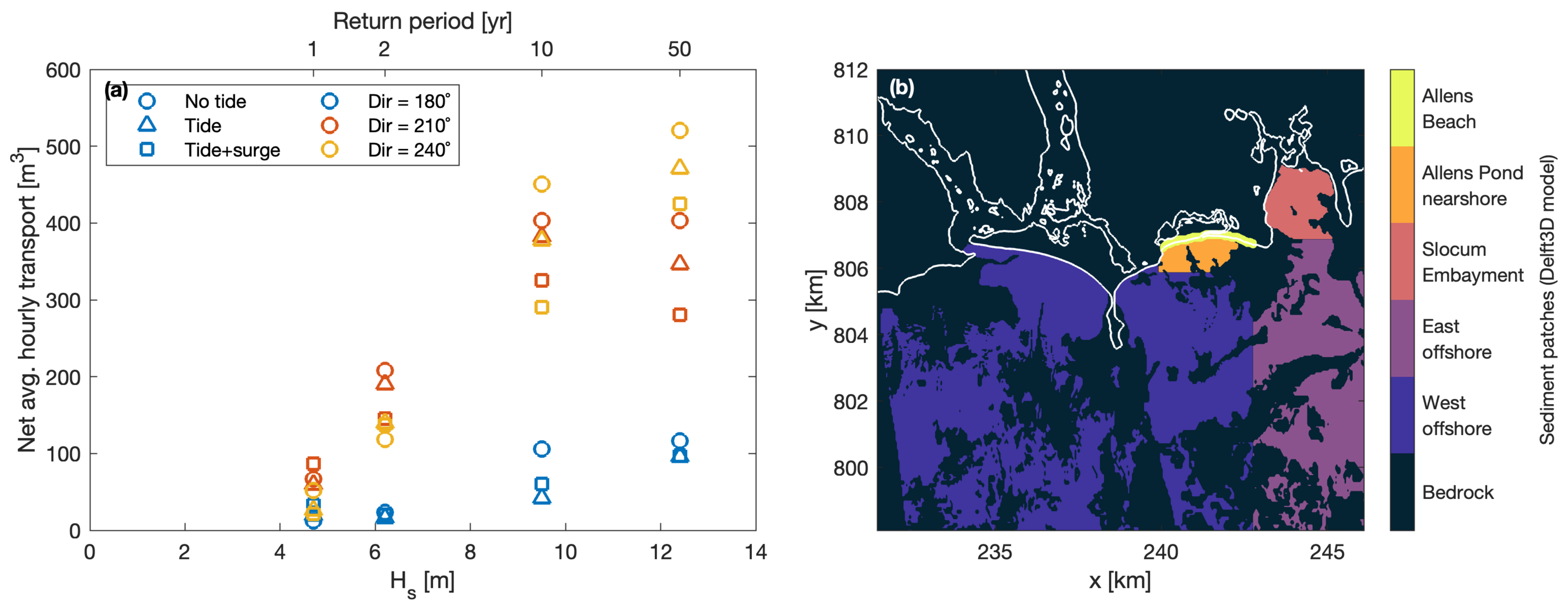


**Figure 2. (a)** Average hourly net sediment transport into Slocums Embayment for 36 storm scenarios. **(b)** Modelled sediment distribution, separated in zones of origin.

A *representative transport rate* was calculated (net avg. hourly sediment transport divided by return period) to account for the occurrence frequency of the storm conditions (Figure 3a). This revealed that smaller, more frequent wave events cumulatively contribute more sediment to the embayment than the most extreme events. Most of the sediment deposited inside the embayment is primarily sourced from the nearshore and beach zone of Allens Pond (Figure 2b and Figure 3b-f).

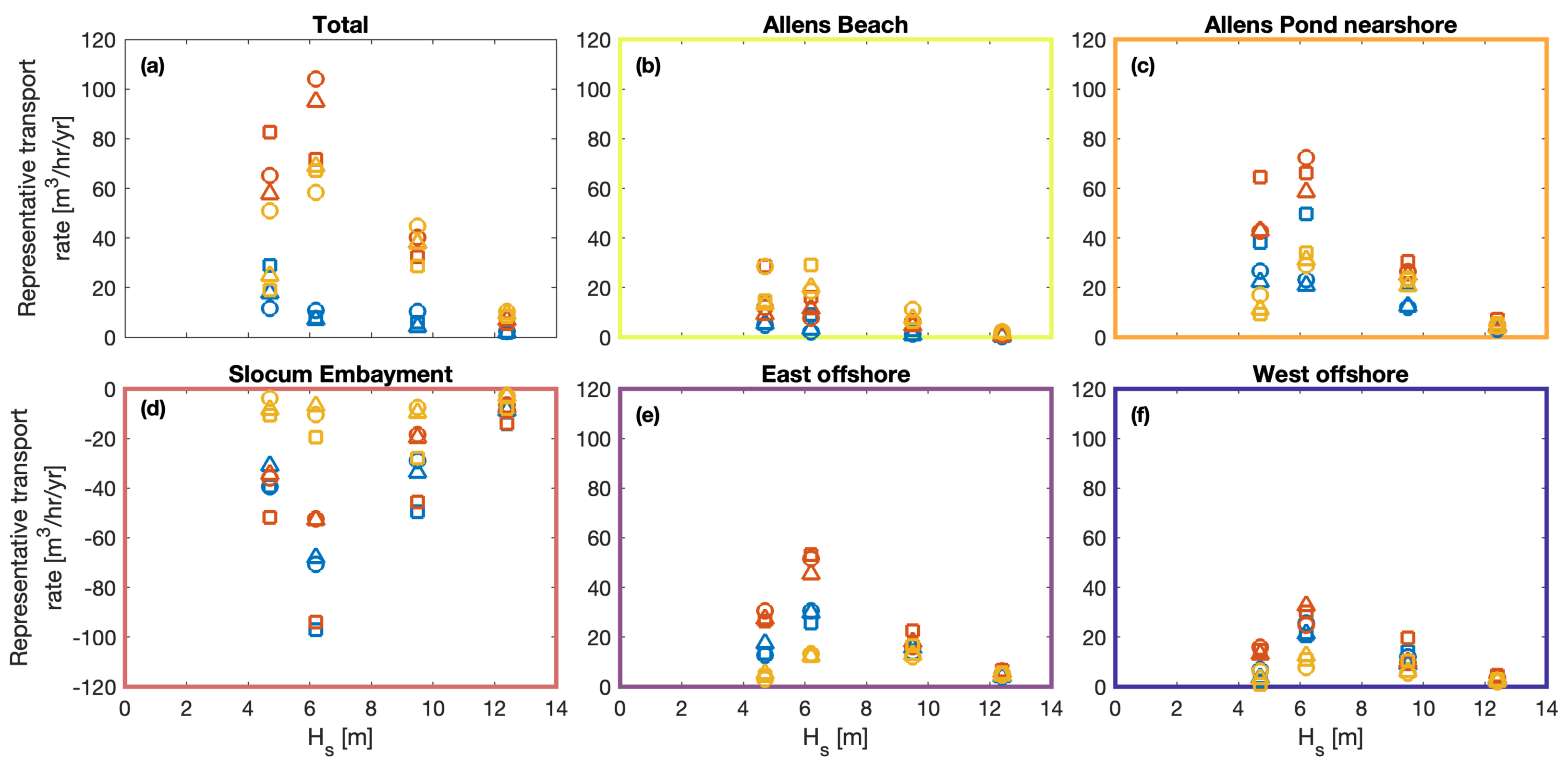


**Figure 3.** Representative transport rate for **(a)** the total sediment volume and **(b-f)** split up into contributions of each region of origin of the sediment (see Figure 2b).

## Spit volume change based on LIDAR

Long-term headland bypassing volumes can be linked to sediment accumulation in a spit near Slocums River inlet. A series of LIDAR DEMs is used to estimate the volume change. Between 2005 and 2018, the spit system gained a volume of ca. 33.700 m$^3$, or approximately 2600 m$^3$/year (Figure 4).

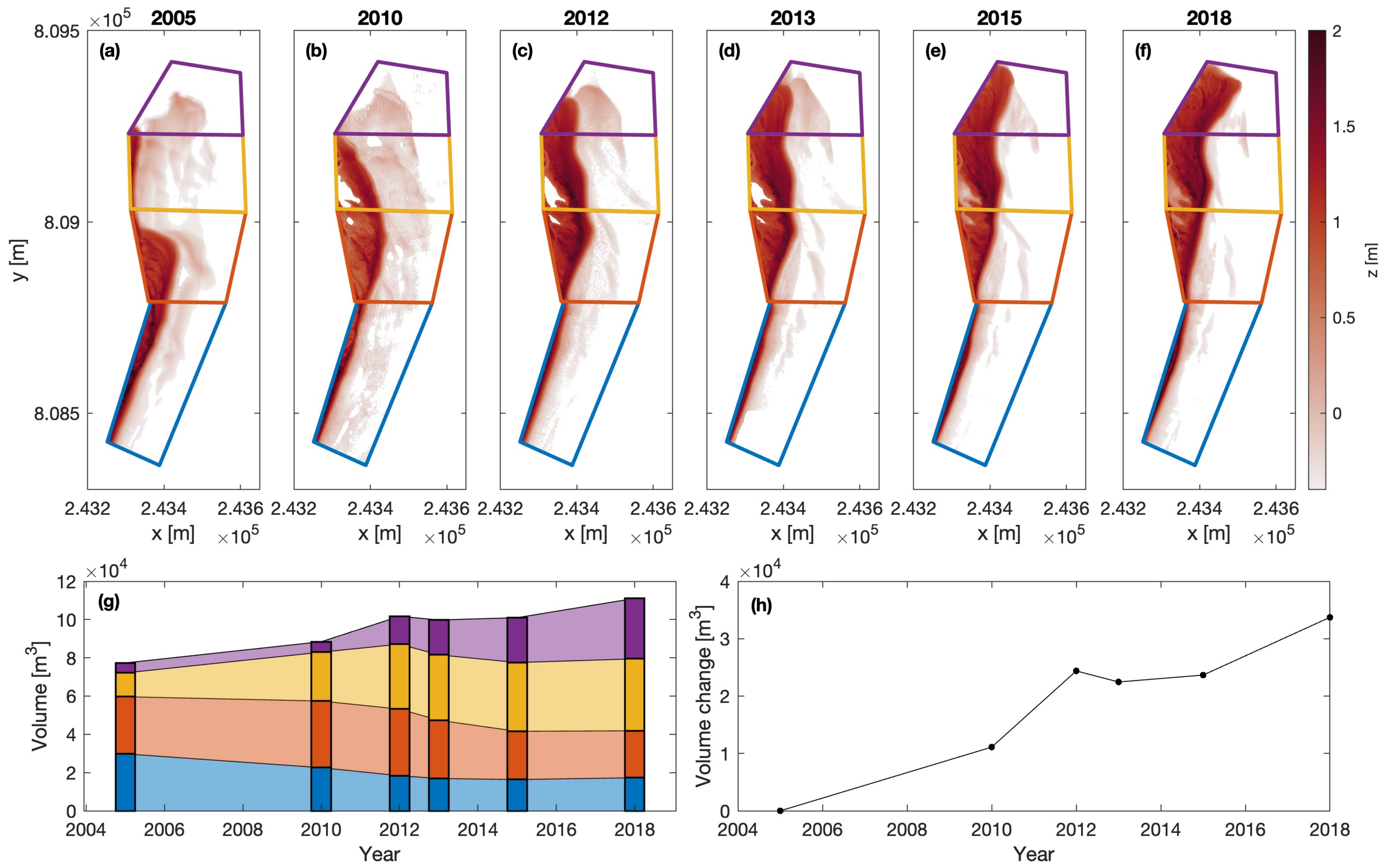


**Figure 4. (a-f)** Evolution of the spit volume near Slocums River inlet based on LIDAR. **(g)** Total volume of the spit above -0.4 m NAVD88. **(h)** Volume change (compared to '05).

## Conclusions

- Slocums Embayment is a closed coastal cell under most conditions, headland bypassing only occurs during extreme storms (return period ≤ 1 year)
- Storms with a return period of 1-2 years contribute most to headland bypassing
- Despite its microtidal regime, sediment transport into Slocums Embayment is strongly influenced by tidal currents in and out of Buzzards Bay

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