DEVELOPMENT OF LITTORAL CELLS FOR SHORELINE MANAGEMENT IN THE CHESAPEAKE BAY

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Abstract: Littoral cells for Chesapeake Bay were developed using remotely sensed data and output from a sediment transport model. Results compare favorably, and littoral cells do exist at spatial scales (1-5 km in length) useful for sediment management in the Bay. Further refinements are needed and are expected to yield better results.

Introduction

Investigating nearshore sediment transport in estuarine waters of Chesapeake Bay and tributaries is critical for maintaining vital habitats, improving water clarity, and defending against storm surges and rising sea level. While watersheds are now the accepted unit of terrestrial system analysis and management, a new paradigm is needed for management of the coastal land/water interface. Littoral cells (or sediment cells) are the best analog, incorporating intertidal and nearshore movement of sediment in relatively self-contained reaches that are intimately affected by riparian zone and upland land-use, and human alteration. Anthropogenic influences often cause unintended consequences, and advancing our knowledge of sediment transport and distribution in shoreline systems is a necessary step to protect the Bay and better manage sediment and sediment-dependent resources.

Background

Significant work on littoral cells has been conducted on open ocean coasts (e.g. Patsch and Griggs 2006, Bray and others 1995), but less so in estuaries that tend to have lower energy environments. The Committee on Mitigating Shore Erosion along Sheltered Coasts found that less is known about the physical processes of sheltered coastal systems compared to open coasts, and there is a lack of information on erosion enhancing effects of shoreline structures on adjoining properties. They recommended a regional, or more comprehensive, approach to shoreline management, including use of littoral cells and sediment budgets to understand sediment transport and erosion, including cumulative impacts, along shorelines (CICEET 2006).

Chesapeake Bay, located in Virginia and Maryland on the mid-Atlantic coast, is the largest estuary in the U.S. (Figure 1) and is the focus of many research studies, as well as federal and state agencies, local governments, and the general public. The shoreline of Chesapeake Bay has undergone steady alteration as human populations continue to migrate to coastal areas starting in the 1950's, and as sea level has risen. Ongoing shoreline hardening of various types, such as bulkheads, riprap, breakwaters, and groins, can significantly affect sediment transport by disrupting longshore currents, trapping sediments, and promoting erosion. Present management decisions about shoreline structures are done on an ad hoc basis and consider only a few adjoining properties at most, usually encompassing a few hundred meters of shoreline.

Figure 1. Location of Chesapeake Bay, along the mid-Atlantic coast of Eastern U.S.

Littoral cells may be delineated using techniques that include geomorphic features (e. g. Stauble and Morang 1992), littoral drift indicators, shoreline structures, field surveys, and aerial imagery, or models that range from statistical (Spoeri and others 1985) to complex multidimensional spatially distributed approaches (SCHISM, 2015). The spatial and temporal scales of interest influence the size of littoral cells. At most scales littoral cells are not completely closed and some sediment may be transported into neighboring cells. Also, sediment moves in multiple directions in these dynamic systems, so we are looking at long-term net movement of sediment (not seasonal or annual variability).

Objectives

The length of shoreline involved in the Bay (e.g. ~8900 km in Virginia) means it is not possible to conduct detailed field studies of the entire system. Shoreline structures tend to have a life span of 50-100 years and management strategies can only reasonably be applied within 1-5 km reaches of shoreline. As part of a larger project, two questions to be addressed here are:

1. Is it possible to identify littoral cells in Chesapeake Bay using a variety of remotely sensed data, and refine the delineation of cells with a sediment transport model?
2. Do littoral cells exist in Chesapeake Bay at a scale that is useful for management decisions, and can we use the information to improve management of Bay shorelines?

This paper discusses preliminary findings for early stages of the project.

Methods

Initial cell delineation for Virginia was done using geographic information systems and data that includes geomorphic features, bathymetry, fetch, and high-resolution aerial imagery, with the same approach being applied to Maryland. To determine if a cell boundary occurs at an inlet, criteria included width and depth of inlet, and whether sand bodies were present in the inlet, suggesting the possibility of sediment bypassing at the scales of interest (Figure 2).

To complement the "traditional" approach, a sediment transport model currently is being developed for Chesapeake Bay using the SCHISM modeling system (a derivative from the original SELFE model), an open-source, community-supported, interdisciplinary modeling system (SCHISM 2015). The model uses an unstructured grid and data inputs such as bathymetry, wave climate, bottom sediment grain size, shoreline erosion rates, shoreline structures, and river input, among others.

Figure 2. High-resolution aerial photography of two inlets. **a** shows wider inlet with no sand bodies; **b** shows inlet with narrow channels and numerous sand bodies.

Results from the cell delineations are being coupled with the sediment transport model output to verify and refine the initial cell boundaries, help identify inlets where sediment bypassing is occurring at management scales, and quantify the magnitude and direction of longshore transport.

Discussion

Littoral cell delineations for Virginia are shown in Figure 3, with cells grouped and color-coded by length. There are more than 80 cells, with lengths that range from 0.5 to 40 km. Cells are smaller where the shoreline is divided by multiple small inlets or bays (#1 and 2) while longer, straighter sections of the major tributaries have larger cells (#3 and 4). Thirty-four percent of the cells are 5 kms or less, the approximate length that is within management limits, but a majority are overly large. Shoreline structures were not included in the first iteration of cell delineations or the sediment transport model, and their incorporation will most likely cause cells to be subdivided.

Output from the model does match shoreline conditions well, in that transport directions agree with geomorphic indicators on the shoreline (e.g. sediment buildup on updrift side of groin). Figure 4 shows correspondence between cell boundaries (red arrows) from littoral cell delineations and the model vector field in the York River, Virginia.

Future work includes refinement of cell delineations using the completed sediment transport model. Output from the model also provides rates of sediment transport and distance offshore that longshore currents operate, both useful in aiding shoreline management strategies.

Conclusions

Using a suite of remotely sensed data, it is possible to identify littoral cells in Chesapeake Bay, and boundaries compare favorably to output from a sediment transport model. Preliminary findings show some cells (~34%) that are at spatial scales (1-5 kms) useful for management decisions. It is expected that further refinement of cell delineations using shoreline structures incorporated into the sediment transport model will result in a reduction in cell lengths, increasing the number of cells that may be used for shoreline management in Chesapeake Bay.

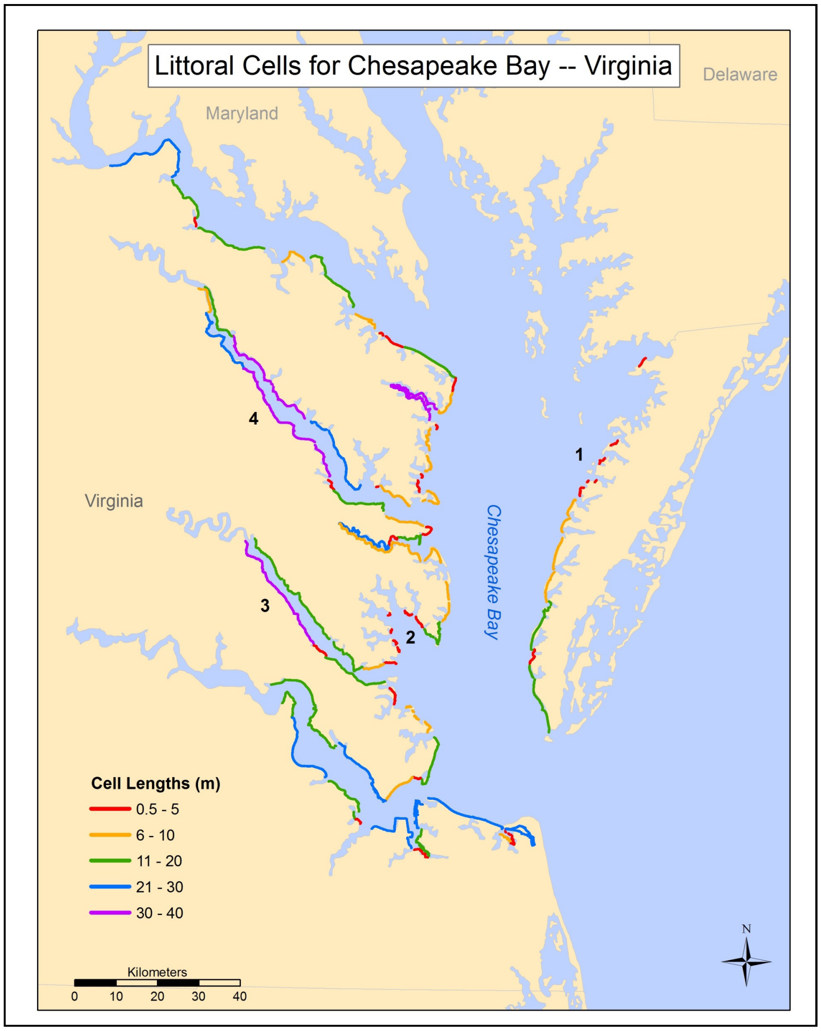

Figure 3. Initial littoral cell delineation for Virginia portion of Chesapeake Bay. 1 and 2 represent shorter cells along highly embayed shorelines; 3 and 4 are longer cells along straighter reaches.

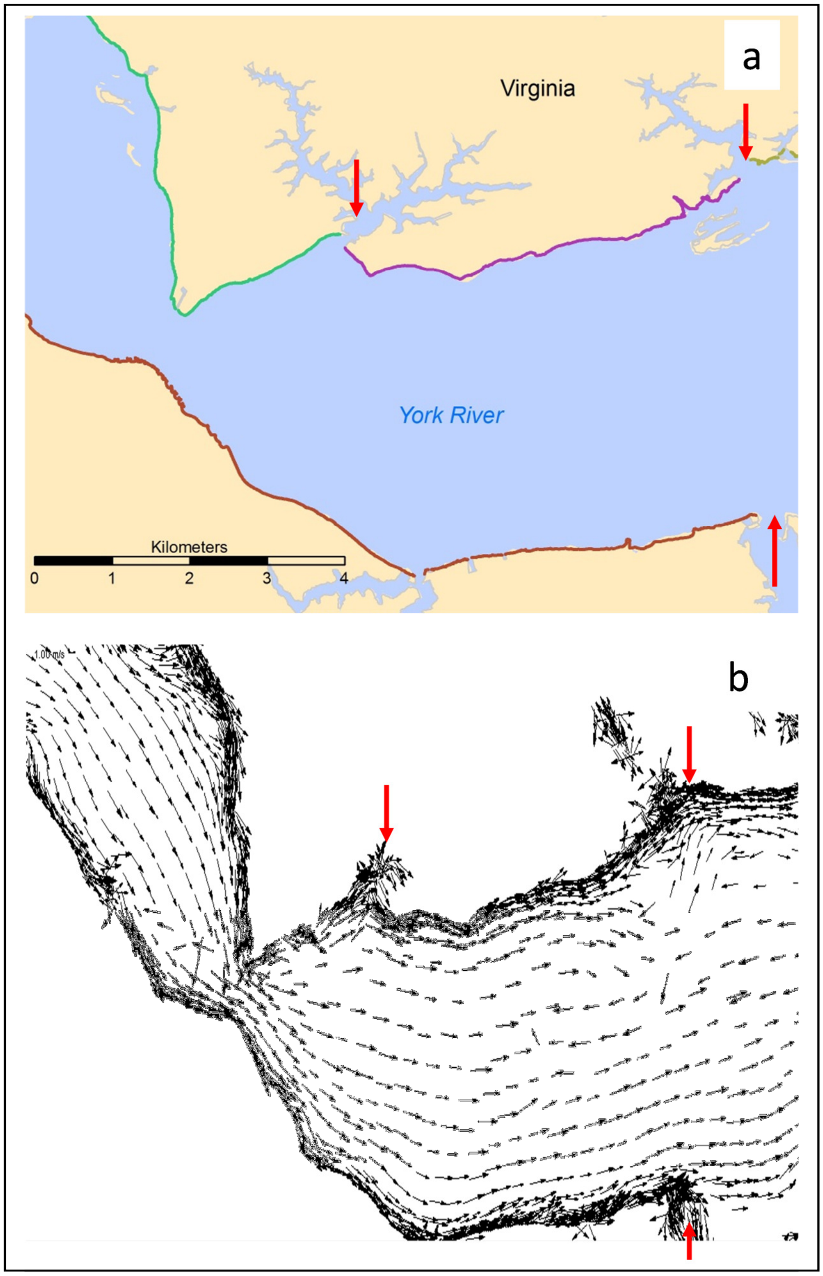

Figure 4. Cell boundaries, marked by red arrows, using (**a**)

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