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Seasonal variability of total suspended matter in Minas Basin, Bay of Fundy

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ABSTRACT

Total suspended matter (TSM) concentrations were derived from ocean colour imagery (MERIS satellite data) in Minas Basin. Analysis of time series of TSM in 1-km^2 pixel boxes revealed an annual cycle in TSM in most parts of the Basin. Higher TSM of up to 85 g/m^3 was observed in late-winter (February–March), and lower TSM of 5–10 g/m^3 characterized late-summer (July–August). The largest annual variation occurred in the centre of Basin, and the smallest variation occurred in shallow areas. Satellite-derived TSM, supported by *in situ* observations, were compared to predictions using the Delft3D model. Increasing model erosion rate in winter relative to summer improved agreement between model and satellite-derived TSM. In comparison with the satellite-derived estimates, the model underestimated TSM in shallow areas in summer and overestimated it in winter. This discrepancy is likely due to inaccurate satellite-derived TSM in shallow, high-concentration areas of the Basin.

1. Introduction

Macrotidal estuaries are ecologically diverse and productive environments that are affected by anthropogenic processes (Bianchi, 2007). They are important centers of human population and shipping (Mitchell and Uncles, 2013), and they are also an attractive target for development of tidal power (Morris, 2013). These environments are characterized by tidal ranges greater than 4 m (see Hayes, 1975) and large total suspended matter (TSM) concentrations. The large TSM concentrations affect productivity, water quality, navigation, and coastal defence, so understanding of the factors that cause large TSM concentrations is vital to effective and sustainable use of these environments (Mitchell and Uncles, 2013; Morris, 2013). Tidal currents, waves, and sediment input from rivers all affect TSM in macrotidal estuaries, but biological processes may also play a significant role, primarily by binding bottom sediments with biofilms that make them less erodible (Mitchell and Uncles, 2013). The goal of this research is to investigate linkages between seasonal changes in TSM and seabed erodibility in Minas Basin of the Bay of Fundy in eastern Canada.

The Bay of Fundy is a large macrotidal embayment situated on the east coast of Canada between the provinces of New Brunswick and Nova Scotia. It is characterized by a semi-diurnal tidal regime with a maximum tidal range of 16.3 m and high suspended sediment concentrations (van Proosdij et al., 2009). The Minas Basin system extends off the central Bay of Fundy to the east, and it has been divided into four regions: Minas Channel, Minas Passage, Minas Basin and Cobequid Bay (Fig. 1a). The ocean environment in Minas Basin is dominated by wind, waves and tidal currents (Fader et al., 1977). The resident suspended sediment volume in Minas Basin was calculated to be 3×10^7 m^3 (Greenberg and Amos, 1983). The abundance of sediment in Minas Basin is the result of erosion of Triassic sandstone cliffs that surround the shoreline, supplemented by the input of glacial outwash sand and clay (Thomas, 1976; Stea, 2003). The area of the tidal flats in Minas Basin is about 358 km^2 in extent, almost half of it in Cobequid Bay. The TSM in Cobequid Bay is much higher than that in the Bay's tributary rivers where the tidal influence is weak. The high concentration of suspended sediment at the sea surface is likely related to the re-suspension of mud from intertidal mudflats through wave and current activity (Dalrymple et al., 1990).

The temporal-spatial distribution of TSM in the Bay of Fundy is complex (Dalrymple et al., 1990). Previously *in situ* sampling, remote sensing and numerical modelling have been used to understand sediment dynamics in the study area. *In situ* observations

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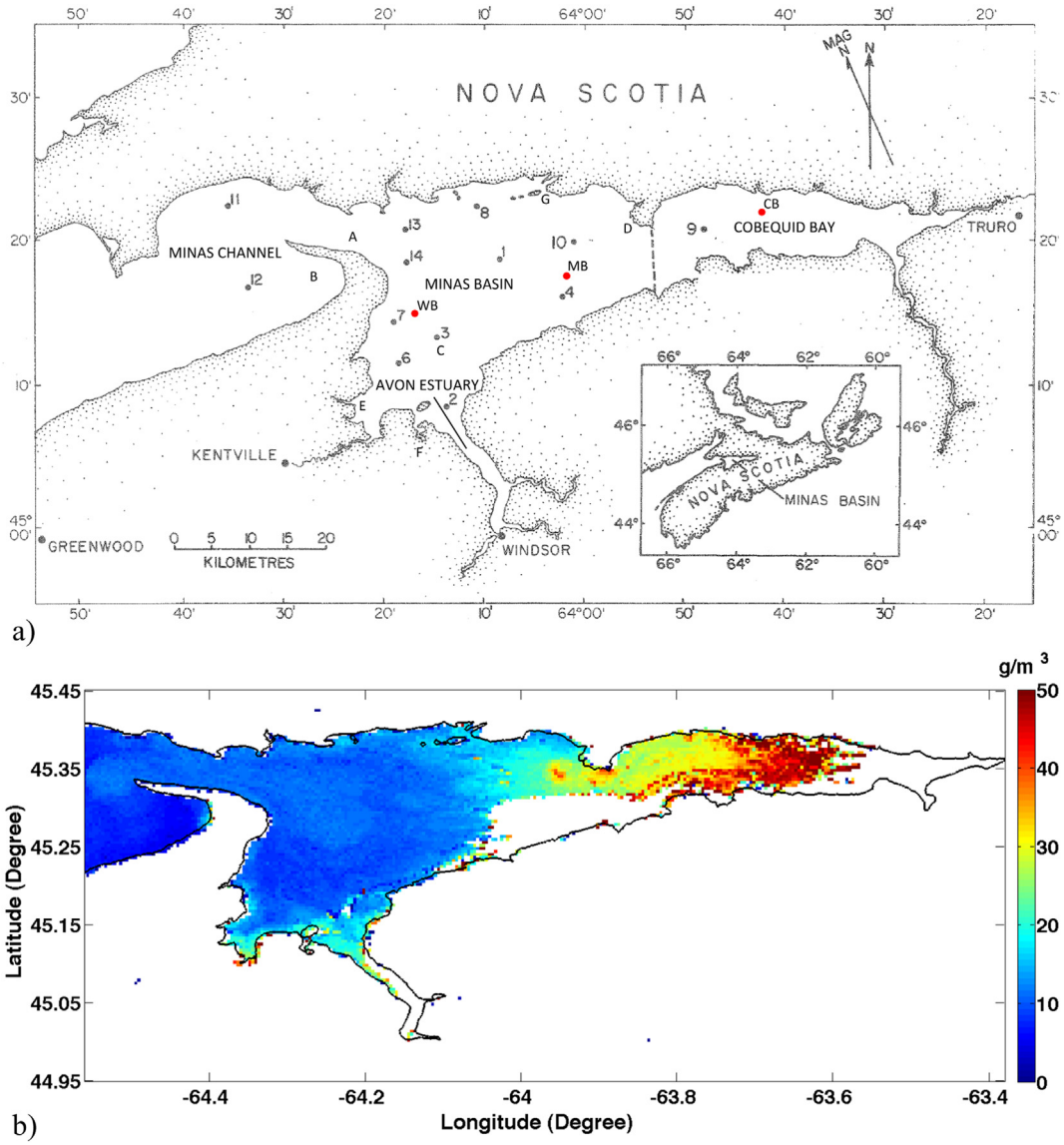

Fig. 1. a: Map of Minas Basin, Nova Scotia, Canada. A-Minas Passage, B-Scot's Bay, C-Windsor Bay, D-Economy Point, E-Cornwallis Estuary, F-Gaspereau Estuary, G-Five Islands (modified from Amos and Joice, 1977). *In situ* survey locations during 1975–76 are indicated at 1–14. Red dots are MERIS observation sites. b: Instantaneous total suspended matter (TSM; g/m^3) derived from a MERIS image in Minas Basin on 1506 GMT, February 10th, 2010.

of TSM made in Minas Basin include collection of suspended sediment samples from moorings and cruise surveys. The TSM concentration in the Bay of Fundy ranges from 0.2 to 30.4 g/m^3 with an average of 6.6 g/m^3, and concentration ranges from approximately 20 g/m^3 to 200 g/m^3 in Minas Basin (Amos and Alfoldi, 1979). Satellite-based estimates of water quality complement conventional monitoring techniques and have found widespread applications. Ocean color observations from space can produce nearly daily synoptic views of the distribution of water substances and concentrations with large spatial and temporal coverage, which is not available from other sources (Shen et al., 2010a). Remote sensing of TSM in very turbid waters (e.g., Changjiang estuary and the Bay of Fundy) is quite challenging due to the difficulty of atmospheric correction over turbid water and the empirical nature of the retrieval algorithms, which are limited to a specific range of concentrations, areas and seasons (Shen et al., 2010b).

Numerical models can be used to simulate various fundamental physical conditions of the coastal environment such as water height, currents and sediment processes. Wu et al. (2011) described the sediment transport in Minas Basin, including bed load and suspended particulate load, and evaluated the model against independent remote sensing images. Generally, the comparison between the model results and "observed" transport of suspended load showed reasonable agreement. The "observed" transport of suspended load was calculated using the MERIS TSM concentration and total velocity from hydrodynamic model. The FVCOM model used by Wu et al. (2011) appeared to overestimate the transport in Minas Basin and underestimate it in Cobequid Bay, indicating that the results are sensitive to the model input parameters. Mulligan et al. (2013) used the Delft3D model to examine the changes in currents and suspended sediments in Minas Basin.

In this study, *in situ* measurements, satellite observations and numerical modelling are used to advance the description and understanding of the spatial-temporal variability of surficial TSM over Minas Basin in the Bay of Fundy. The focus of the study emerged from recent research into seasonal changes in TSM and mudflat