Erodibility of Mud: Characterization and Prediction

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LONG-TERM GOALS

To improve our capabilities for measuring and predicting erosion rates, sediment flux, water clarity and bed strength in muddy coastal environments, particularly with respect to their evolution through time on tidal flats.

OBJECTIVES

The objectives of my current work within the Tidal Flats DRI are:

1) Measure temporal variations in erodibility and shear strength of tidal flat and channel sediment in Willapa Bay.
2) Measure temporal variation in consolidation and erodibility of sediment from Willapa Bay under controlled laboratory conditions;
3) Correlate temporal and spatial variations in erodibility with sediment shear strength.
4) Use the results to improve formulations for mud deposition, consolidation, resuspension and net erosion in shelf sediment transport models.

APPROACH

Laboratory and field measurements of erodibility are made using a Gust erosion chamber. The erosion chamber permits shear stresses from 0.01Pa – 0.40Pa to be applied to the surface of sediment in a core tube and the resulting suspended sediment to be sampled for concentration, grain size and mass eroded. Cores are collected in the field using a hand corer that leaves the sediment-water interface undisturbed. Cores are created in the lab by slurrying sediment from the field site with salt water and allowing the suspension to settle and form a deposit in the core tube. Ideally, the field experiments are made in conjunction with measurements of porosity, shear strength, grain size and water-column properties (velocity, suspended sediment).

The modeling will extend and combine several models for the dynamics of muddy seabeds that I have developed with ONR funding. The first is a 1-dimenionsional, steady-state shelf sediment transport model that includes wave-current interaction, resuspension, sediment-induced water-column

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stratification, evolution of graded storm beds (though not net erosion or deposition), dynamic roughness, and bioturbation. This model has been adapted to directly use the results of the erosion chamber tests to set the bottom boundary condition on sediment in suspension. The second model is similar, but is time-dependent and includes flocculation dynamics for suspended sediment and active bed consolidation (Wiberg et al., in prep.) and lacks a correction for stratification. The model is applicable to tidally dominated environments as well as open shelves and could be an ideal model to use in conjunction with the field measurements. Sanford's (2008) recent formulation for bed consolidation will be incorporated into this model. My plan is to use the laboratory and field erosion measurements to test and improve the characterization of consolidation and resuspension of mud deposits by tidal flows in my 1D models.

WORK COMPLETED IN FY09

1. Field measurements of erosion rates in secondary channels and on tidal flats in southern Willapa Bay in September 2008, March 2009 and July 2009.
2. Measurements of tidal elevation, wave conditions and channel geometry of Willapa Bay study area in July 2009.
3. Processing of filtered samples for almost all erosion tests.
4. Laboratory measurements of consolidation (changes in bed level, bulk density and porosity) and erosion of Willapa Bay sediment.
5. Work on model for erosion of sand-mud mixtures.

RESULTS

In collaboration with other investigators – particularly Wheatcroft (measuring porosity), Hill/ Milligan/ Law (measuring turbulence, erodibility, properties of suspended, bed and eroded particles), and Boudreau/Johnson (measuring sediment strength) – I made field measurements of erosion rates for sediment from tidal flats and secondary channels in southern Willapa Bay, WA, in September 2008, March 2009 and July 2009 (Figure 1). Results from September 1) indicate that the banks of a secondary channel (D channel near Round Island) are more erodible than the flats and 2) suggest that erodibility of the flats does not vary greatly within the study area. Results from March and July at the C-channel and adjacent tidal flat (B-flat) CL-transect sites (Figure 2a) suggest seasonal differences in erodibility of channel bottom sediment but not for the tidal flats; tidal flat values were generally comparable to those measured in September. Measurements of erosion were made along the channel axis in July (Figure 2b) to better define the channel that has been our focus in FY09 (C-channel). The results indicate low erodibility near the mouth of C-channel and at the upstream end of the sampling reach (Figure 1), with one very highly erodible sample in the middle.

In all 3 field campaigns, Bruce Johnson measured sediment strength for all cores used for erosion testing; Brent Law measured grain size of surface sediment and eroded sediment for all cores used for erosion testing. Rob Wheatcroft measured porosity for a number of our cores and also made in situ measurements. Paul Hill and Tim Milligan measured water column properties. During the upcoming year, erodibility, shear strength and grain size information will be put together to develop a more comprehensive picture of sediment properties and erosion on the tidal flats and secondary channels in

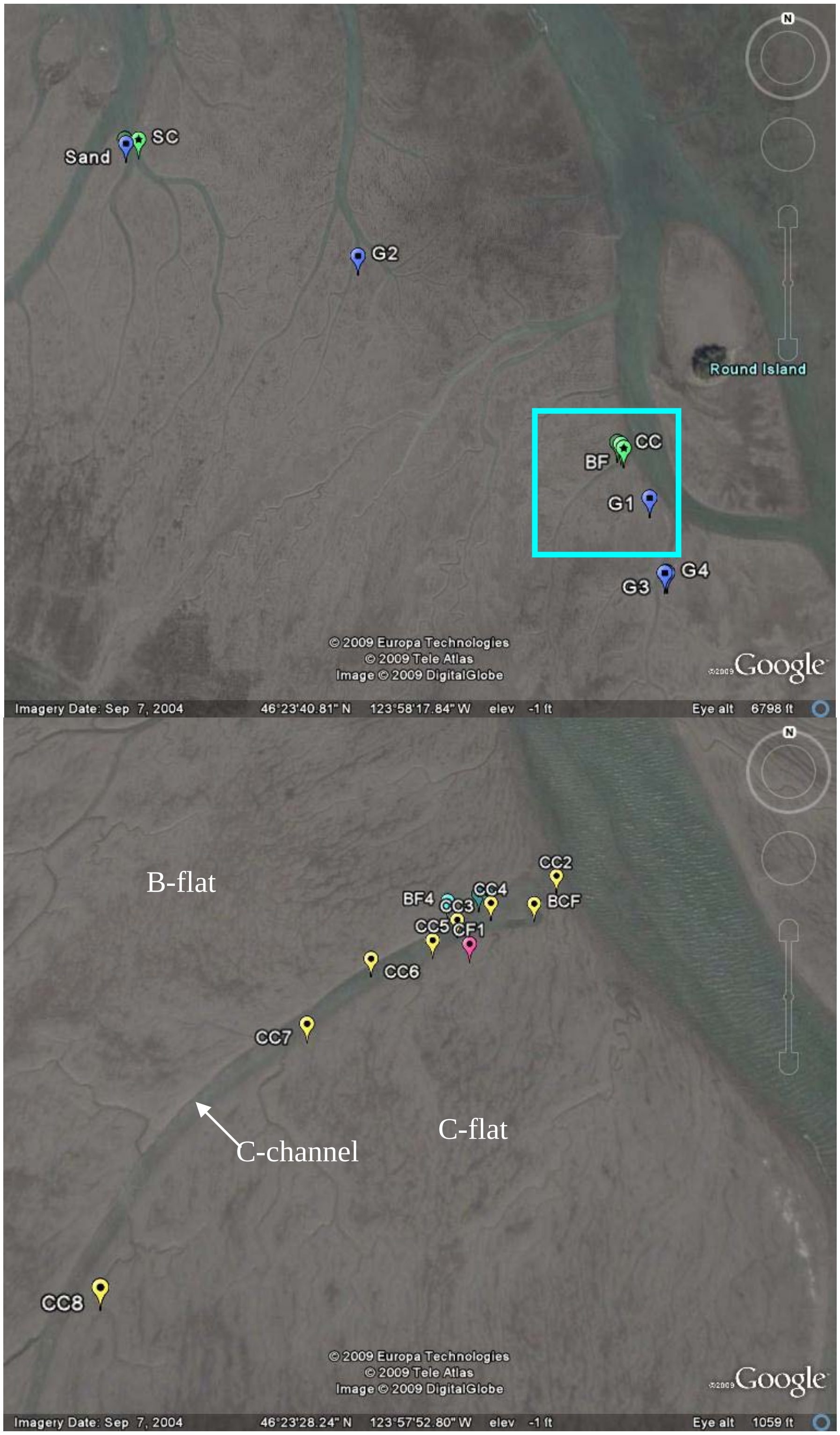

Figure 1: Top: Locations of Sep 08 (blue) and Mar 09 (green) core locations for erosion testing. Bottom: Locations of July 09 core locations for erosion testing. The box in the upper panel outlines the region shown in the lower panel.

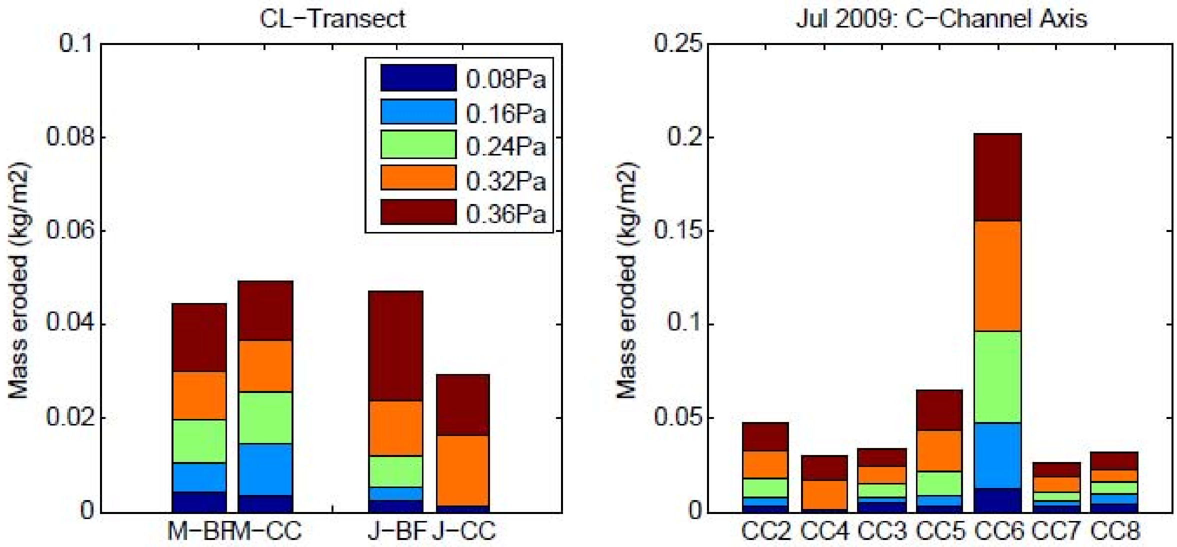

Figure 2. Left: Mass eroded from a site on B-Flat (BF) and in C-Channel (CF) in March 2009 (left pair) and July 2009 (right pair). Erosion on the flats was similar in March and July, but erosion in the channel was lower in July than in March. Right: Mass eroded from sites along the C-Channel (see Figure 1b) from the mouth (CC2) to the upstream limit of sampling (CC8). The high erosion rate at CC6 suggests that the sampling site might have been recently disturbed.

the southern part of Willapa Bay. We will also compare our results with those of Sergio Fagherazzi, who worked on different flat/channel system in southern Willapa Bay in July 2009. I will also be incorporating the field results into resuspension models for tidal flats in FY10.

In addition to the field experiments, we performed laboratory tests of consolidation and erodibility of channel (C-channel) and tidal flat (C-flat) sediment from Willapa Bay in FY09. Our general procedure was to make relatively high concentration (~ 500 g/L) suspensions of sediment in salt water in core tubes. These were initially well mixed and then allowed to settle (Figure 3a). During the settling process, we monitored change in the properties of the suspension and underlying deposit, including bulk density, porosity and erodibility. Erosion tests were run at 6, 12, 24 and 48 hrs after being mixed. Erosion rates measured for sediment from C-flat was about 10 times higher after 6 hrs of consolidation than values measured in the field (Figure 2a). However, after 4 days (96 hrs) of consolidation, erosion of the C-flat mixure was comparable to field measurements. An undergraduate student, Aryn Hoge, has helped to perform and process these measurements.

IMPACT/APPLICATION

- Better understanding of the role of spatial and seasonal variations in erodibility on tidal flats.
- Better understanding of the role of time-dependent consolidation on tidal-flat sediment erosion.

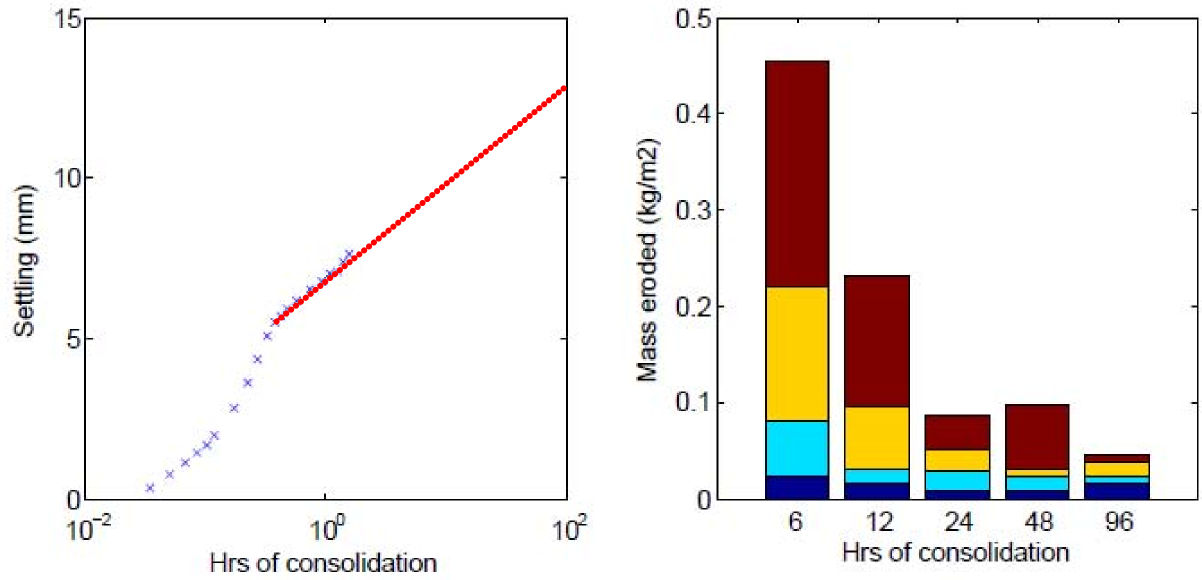

Figure 3. a) (Left): Average measured settling of a well-mixed suspension of sediment from C-flat in a laboratory core tube (blue x); the red dotted line is an extrapolation to 100 hrs. b) (Right): Mass eroded from deposits produced from the well-mixed suspensions after 6, 12, 24 (avg), 48 and 96 hrs of consolidation. Erosion after 6 hrs is about 10 times higher than values measured in the field, but after 96 hrs (4 days), erosion rates are comparable.

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