Sediment Erosion and Redistribution in Fine-Grained Shelf Environments

Patricia Wiberg
Department of Environmental Sciences, University of Virginia
P.O. Box 400123, Charlottesville, VA 22904-4123
phone: (434) 924-7546 fax: (434) 982-2137 email: pw3c@virginia.edu

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LONG-TERM GOALS

My long-term goal within the EuroSTRATAFORM program is to increase our ability to predict sediment transport in fine-grained regions of the continental shelf. Field work and the development and application of models during STRATAFORM increased our understanding of these processes and improved our ability to predict them. The Adriatic and Gulf of Lions EuroSTRATAFORM sites have characteristics (forcing, margin configuration) that contrast with the Eel shelf STRATAFORM study area. Testing and extending our conceptual and numerical sediment transport models at these sites is an important goal of the EuroSTRATAFORM shelf process studies.

OBJECTIVES

The objectives of this project are to 1) measure across-shelf and temporal variations in critical shear stress and entrainment rates; 2) compare suspended sediment concentrations measured by bottom tripod with values calculated using measured entrainment rates; and 3) explore the implications of spatial variations in critical shear stress on cross-shelf sediment transport and deposition. The specific objectives during FY06 were to analyze erosion rates data collected during 3 cruises in the Gulf of Lions along a cross-shelf transect near the Tet River in fall, winter and spring, incorporate them into shelf sediment transport model calculations, and compare results with available data.

APPROACH

Our approach is to use an erosion chamber that fits onto a core tube to make shipboard measurements of critical shear stress and entrainment rates of freshly collected seabed sediment. The results are then used to develop expressions for the entrainment rates of fine-grained sediment at the measurement sites. Sediment transport calculations using these entrainment rates are tested against near-bed field data. Porosity and grain size data collected by other scientists are combined with measured entrainment rates to examine spatial and temporal controls on fine sediment resuspension.

WORK COMPLETED

1. Adam Meurer, an MS student supported by this project, completed his thesis: Across-shelf variation in erodibility and sediment transport in the Gulf of Lions, NW Mediterranean Sea (August 2006), which combined our erosion chamber measurements with modeling of shelf sediment transport. A paper describing this work is in preparation for a special issue on the Gulf on Lions, likely in Continental Shelf Research, with Rob Wheatcroft, Tim Milligan, Paul Hill and Brent Law as co-

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authors. We have also been collaborating with Xavier Durrieu de Madron and Jorge Guillen at the Univeristy of Perpignan.

2. I hosted the final EuroSTRATAFORM workshop at the University of Virginia in April 2006. It was attented by about 40 people, including colleagues from Italy and Spain. Summary powerpoint presentations of key EuroSTRATAFORM results were prepared for ONR. I have also volunteered, along with Pere Puig and Xavier Durrieu de Madron to co-edit a special volume on EuroSTRATAFORM, EuroDelta and Promess research in the Gulf of Lions .

3. I served as a co-editor of the STRATAFORM master volume and co-author of 3 chapters, including co-lead author with Rob Wheatcroft on post-depositional alteration and preservation of strata.

RESULTS

Data Analysis

Sediment erodibility, porosity, grain size distributions, sediment organic content, and local wave and current data were collected offshore of the Tet River mouth located in the Gulf of Lions as part of the EuroSTRATAFORM field program. Data collection occurred during three research cruises conducted in October 2004, February 2005, and April 2005 over an across-shelf oriented transect comprising sites ranging from 20-74m in depth. Data obtained from erosion tests show that sediment erodibility varied both spatially and temporally. In general, sediment at the deeper sampling sites (h>45m) was more erodible at the lower shear stresses (τ_b<0.24Pa) compared to the shallower sites, and more sediment was removed from the shallow sediments at higher stresses (Fig. 1). The exception to this generalization is site T56 in October. However, only one replicate was retrieved at this site during the October cruise due to equipment problems, and therefore this sample may not be representative. Fig. 1 also shows that generally more mass was removed during the February tests than in October or April, especially at the shallow sites. No seasonal pattern is discernable for the deeper sites.

The erosional behavior observed during erosion tests varied along the transect. Tests conducted at shallow and deep sites show an initial increase in suspended sediment concentrations (SSC) at the start of a new stress step. What differs between the shallow and deep sites (i.e. T28 and T56) are the magnitudes of those increases, as well as the erosion behavior following those jumps in SSC. Site T28 did not experience significant erosion until a stress step of 0.32Pa was reached (Fig. 2), and then gradually declined as the stress step progressed. Jumps in SSC occured at lower stresses for T56, but the magnitudes are lower, and concentrations declined rapidly, resulting in a lower overall cumulative mass eroded. The subsequent decline in SSC is of particular interest because this behavior allows for the site to be classified with a particular erosion behavior. The rapid drop in SSC at T56 is indicative of depth-limited erosion characteristic of cohesive sediment, while a more gradual and sometimes non-existent decline observed at T28 suggests a mixture of non-cohesive and depth-limited behavior with a relatively slow increase in critical shear stress with depth.

No distinct spatial pattern in organic matter was apparent. Although sites along the transect varied in the amount of organic material present, those differences were not consistent during a particular sampling period. A distinct temporal pattern was observed at all stations, however, that showed increasing organic material from February, April, to October.

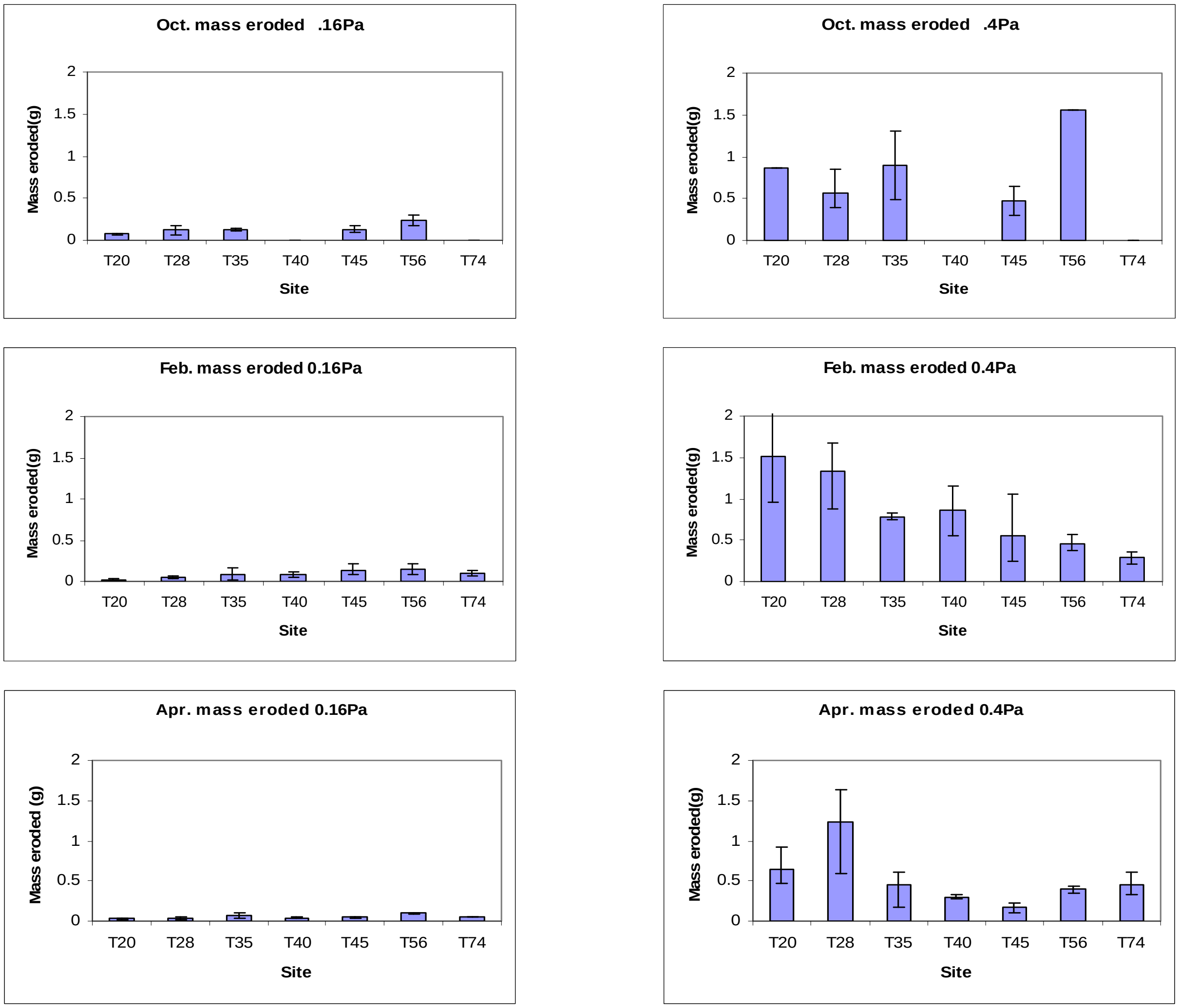

Figure 1. Mean mass eroded from erosion tests across the sampling transect in October (top panel), February (middle), and April (bottom) at stresses of 0.16 Pa (left column) and 0.4 Pa (right column). Vertical bars represent the range of replicate measurements.

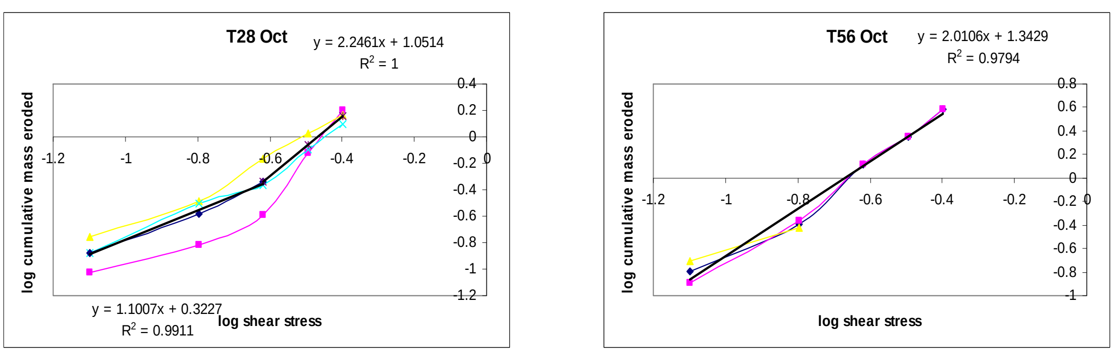

Figure 2. Examples of cumulative mass eroded versus shear stress regressions for T28 (left panel) and T56 (right panel) obtained from erosion tests.

Modeling

A 1-D shelf transport model was used to calculate suspended sediment concentrations at sites along the sampling transect, using the erosion measurements (as shown in Fig. 2) to specify the flux of sediment from the bed to the water column as a function of shear stress Model simulations run at site T28 were compared to SSC data derived from ADCP backscatter data collected by F. Bourrin and X. Durrieu de Madron. The results are presented in Fig. 3. During most of the study period (Oct 2004 – Mar 2005), currents velocities 2mab were stronger than wave orbital velocities, but significant resuspension was only observed during 2 periods of elevated waves. Wave-current shear velocities were similar for the two events (Fig. 3), though they differed in the respective contributions of waves and currents. Observed peak concentrations 2mab (from ADCP backscatter data) for both events were ~60 mg/L. Together, these suggest that similar erosion rates during the two events. The calculations shown in Fig. 3 used average erosion rates (average of Oct, Feb and Apr measurements). Resulting calculated concentrations are comparable to observed values during the first event and about a factor of two higher during the second event. The difference is largely attributable to higher currents present during the second event that allowed greater volumes of sediment to be mixed up out of the wave boundary layer into the current boundary layer. Calculated suspended sediment flux is much larger during the second event because of the larger currents and higher concentrations in the current boundary layer.

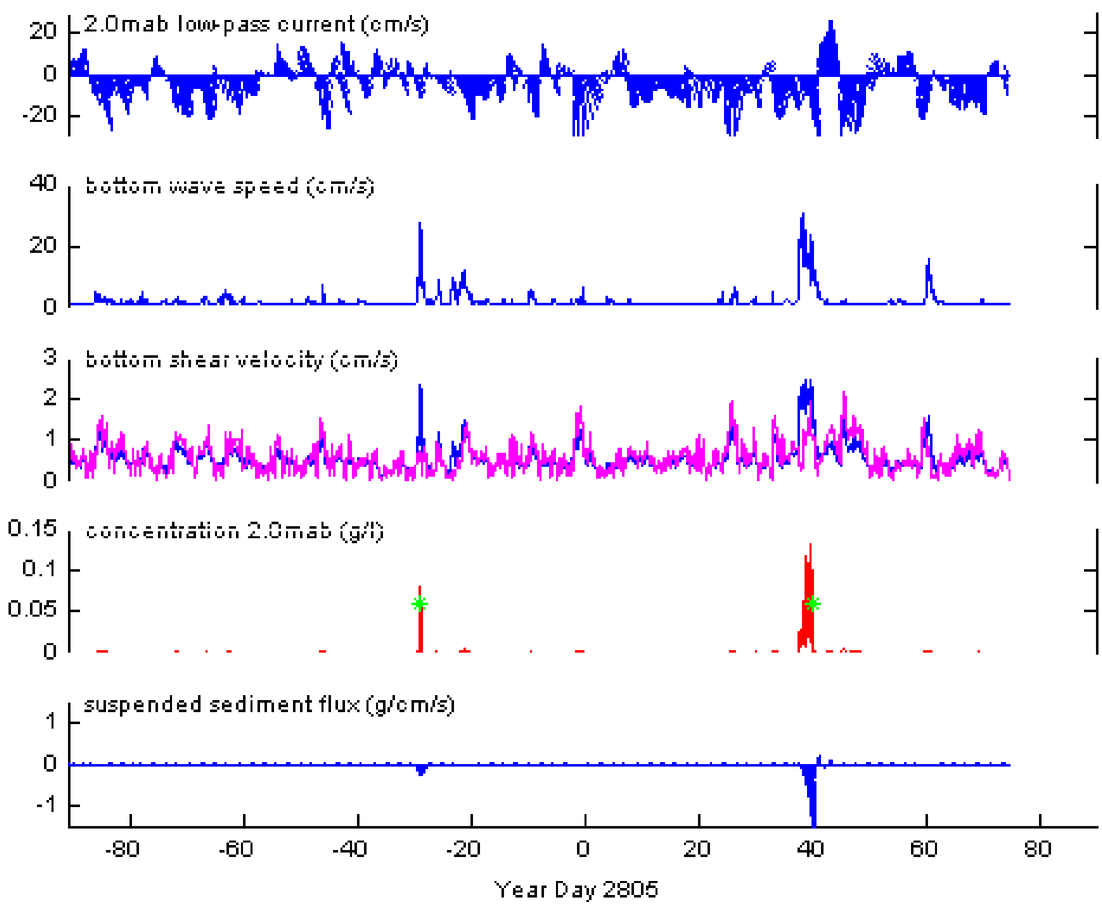

Figure 3. Time series of currents (top), wave orbital velocity (2nd panel), current and total shear velocity (middle panel), calculated suspended sediment concentration 2mab (4th panel) and calculated sediment flux (bottom panel) for the 28-m Tet mooring site maintained by Durrieu de Madron for the period Oct 2004 – Apr 2005. The green * indicate peak measured concentration.

Data are also available for transport events measured by Guillen and others during 2003-2004 at T28. This was a much more energetic year, with peak bottom wave speeds of about 1m/s and peak concentrations during December and a February events of 2 g/L and 4 g/L at a depth of 0.1-0.15 mab (measured by OBS). Grain size data indicate that the sediment at the tripod site was somewhat coarser than we measured during 2004-2005 (median diameter of ~80 um rather than 40-45 um). Calculated concentrations for 2003-04 made using the October 2005 erosion measurements (the lowest of the 3 sampling periods in 2004-05) are somewhat high (around 10 g/L). The larger bed sediment size may be reducing applicable erosion rates. We are continuing to investigate this.

During both 2004-05 and 2003-04, sediment transport during significant resuspension events was dominantly along-shelf to the SW. There was also a weak cross-shelf component. At the shallower sites, this cross-shelf component becomes briefly dominant during high energy conditions. This should produce a cross-shelf flux convergence that helps to maintain the mid-shelf mud belt in the study area.

IMPACT/APPLICATION

Critical shear stress and entrainment rates are among the most poorly constrained parameters in shelf sediment transport calculations. These measurements are improving our ability to specify these important parameters. The EuroSTRATAFORM field programs provide near-bed sediment transport measurements against which to test model calculations using measured entrainment rates.

RELATED PROJECTS

The models we are using in this project were developed in the STRATAFORM program.

PUBLICATIONS

Wheatcroft, R.A., P.L. Wiberg and 5 others, in press. Post-depositional alternation and preservation of strata. In. C. Nittrouer et al. (Eds.), *Continental-Margin Sedimentation: Transport to Sequence* [refereed].

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