Sediment Erosion and Redistribution in Fine-Grained Shelf Environments

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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 offer 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 FY05 were to participate in 3 cruises during the Gulf of Lions field program, making measurements of erosion rates along a cross-shelf transect near the Tet River in fall, winter and spring conditions.

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. A manuscript describing the erosion chamber data from the Adriatic (Stevens et al.) and one describing the application of the erosion rate data to modeling of shelf sediment transport in the Adriatic (Traykovski et al.) are both in press in a Continental Shelf Research special issue.

2. We participated in 3 cruises during the Gulf of Lions field experiment on the Tet Prodelta in FY05. Erosion chamber data were collected during all cruises along a cross-shelf transect. Collaborators

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14. ABSTRACT
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 offer 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

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Wheatcroft, Milligan and Hill collected complementary grain size and porosity data. Near-bed current, wave and resuspension data were collected by Durrieu de Madron and Wheatcroft.

3. The erosion chamber data have been processed and we have begun analyzing the results.

RESULTS

All field sampling was conducted during three research cruises in October 2004, February 2005, and April 2005. Sediment cores were taken at 8 sites along a cross shelf transect (Fig. 1) during the three cruises to measured erosion rates. Cores were collected using a slow coring mechanism that retrieves cores usually 30-60cm in depth with an undisturbed sediment surface. Several replicate cores were collected at each site, and these samples were utilized for various tests. Sediment erosion tests were conducted on board ship using a Gust erosion chamber. The setup of the chamber consists of the collected core, a turbidity meter, datalogger, control unit, and pump. Near bottom water from each site was pumped into the chamber while a rotating plate attached to the top of the core tube created a flow generating known shear stresses on the sediment surface of the core. Water forced out of the chamber passed through a turbidity meter, where turbidity measurements are recorded once per second. Finally, the water was collected and later filtered through 0.47 μm glass fiber filters. These filters were then transported back to our laboratory, dried and weighed for total and organic mass, and the resulting suspended sediment concentrations were used to calibrate the turbidity measured during the erosion tests. A typical erosion test began with an applied stress of 0.01Pa for approximately 20 minutes to remove any suspended material. Stress levels were then systematically increased to 0.08, 0.16, 0.24, 0.32, and 0.40Pa every 20 minutes, resulting in a total experiment run time of around 2 hours.

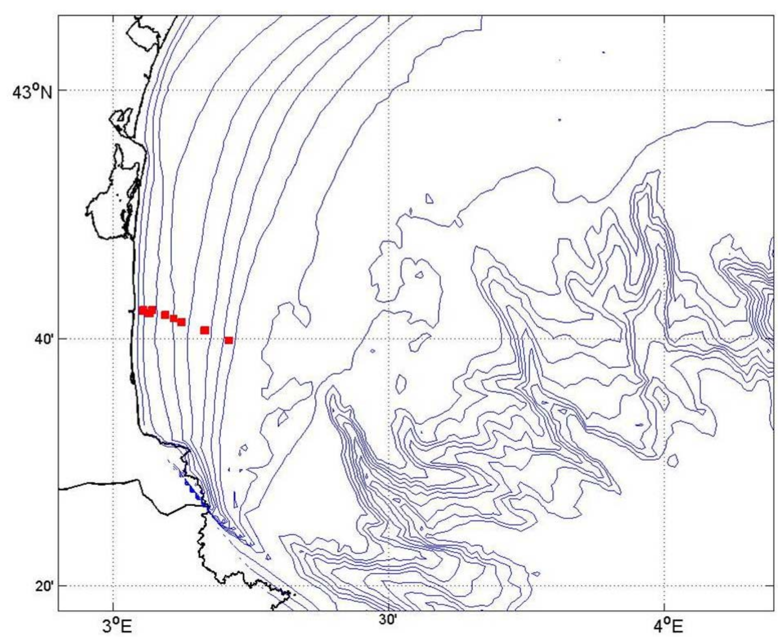

Figure 1. Study site showing the across shelf transect of sampling sites. The sampling site closest to land (T20) is immediately seaward of the Tet River.

A moored buoy at study site T28 (42°42.2'N, 3°4.3'E), deployed by Durrieu de Madron, provided measurements of significant wave height and period every hour and a half for most of the length of the study (October 2004 through mid-March 2005) (Fig. 2). Velocity and backscatter data obtained from Wheatcroft's bottom tripod at the same study site will be used to supplement the buoy data record to cover the April cruise, although additional data from the Tet buoy is expected. These data allow for the calculation of wave orbital velocities (u_b) and average bottom wave period (T_{bav}), both of which allow for the determination of wave generated bottom shear stress. Additionally, the Tet buoy recorded current magnitude and direction for the same period. Hydrographic transects that include current velocity are available from Gail Kineke, and should allow for the characterization of current speeds and direction for the entire transect. Profiles of porosity for each sampling site were collected by Wheatcroft an *In-situ* Resistivity Profiler (IRP) and calibrated using standard gravimetric methods. Surficial grain size distributions were also collected from the surface of cores that were not subjected to erosion tests, as well as on our cores following erosion experiments by Milligan and colleagues.

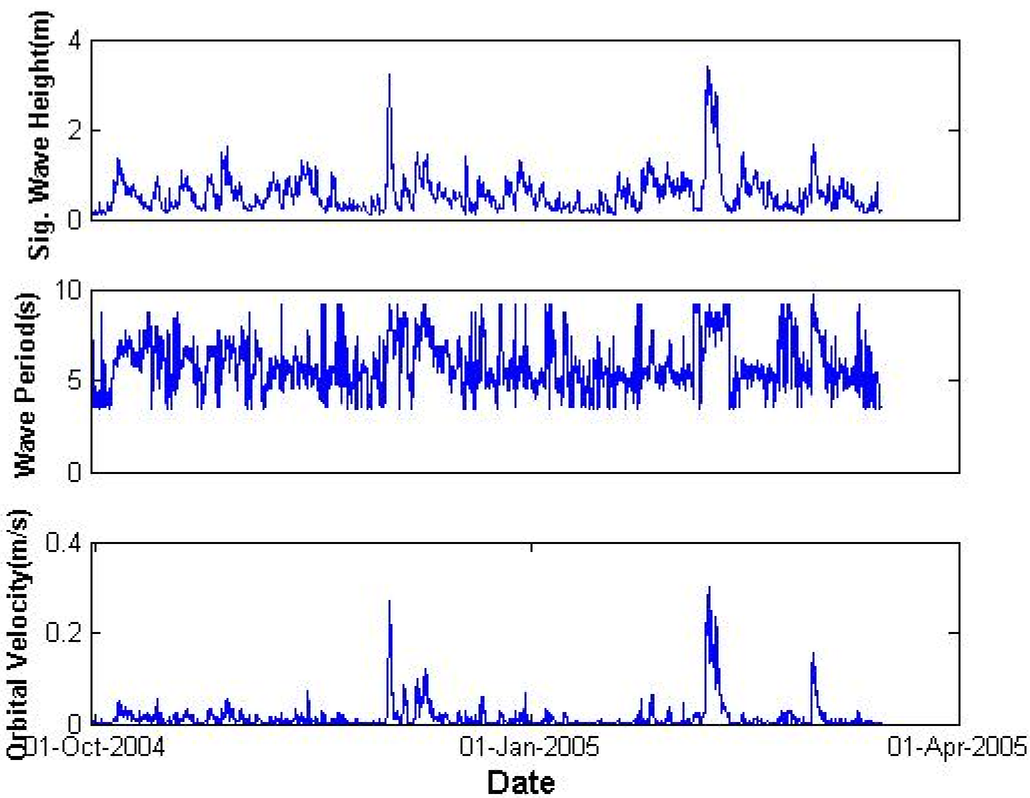

Figure 2. Time series of significant wave height (top panel), wave period (middle panel) and calculated near-bed orbital velocity (lowest panel) for the 28-m Tet mooring site maintained by Durrieu de Madron for the period Oct 2004 – Apr 2005. Two wave events generated large enough near-bed orbital velocities to resuspend sediment.

Initial results show both spatial and temporal variability in sediment erodibility. Figure 3 shows output from erosion tests conducted during the October, February, and April cruises on samples from site T28. The range in values of mass removed (g/cm^2) during erosion tests for successive replicates indicates relatively small scale spatial variability (i.e. 0.013-0.032 g/cm^2 for April replicates). Despite this variation, distinct seasonal trends can be observed. Sediment erodibility at site T28 was highest in February with 0.019-0.042 g/cm^2 of total sediment erosion, and lowest in October with 0.015-0.019 g/cm^2 of total sediment erosion. Patterns appear to be evident across the transect in that deeper water sites have more mass removed at the lower shear stresses when compared to the shallow (T20, T28, T35) sights. Initial grain size analysis partly explains these observations in that the average grain size decreases with water depth, which would theoretically result in a lower critical shear stress needed to initiate transport at the deeper sites. Furthermore, mean grain size (D_{50}) at the surface shows evidence of a seasonal shift at site T28. February has a slightly larger D_{50} (~44μm) than is observed in October (~41μm), while samples collected in April show the smallest D_{50} with a value of approximately 35μm. This observation is interesting, and suggests that grain size may not be a controlling factor in erodibility given the large difference in mass eroded between cores collected at T28 in October and February, as well as the fact that more mass was eroded in February compared to April despite an overall smaller grain size during the April sample collection.

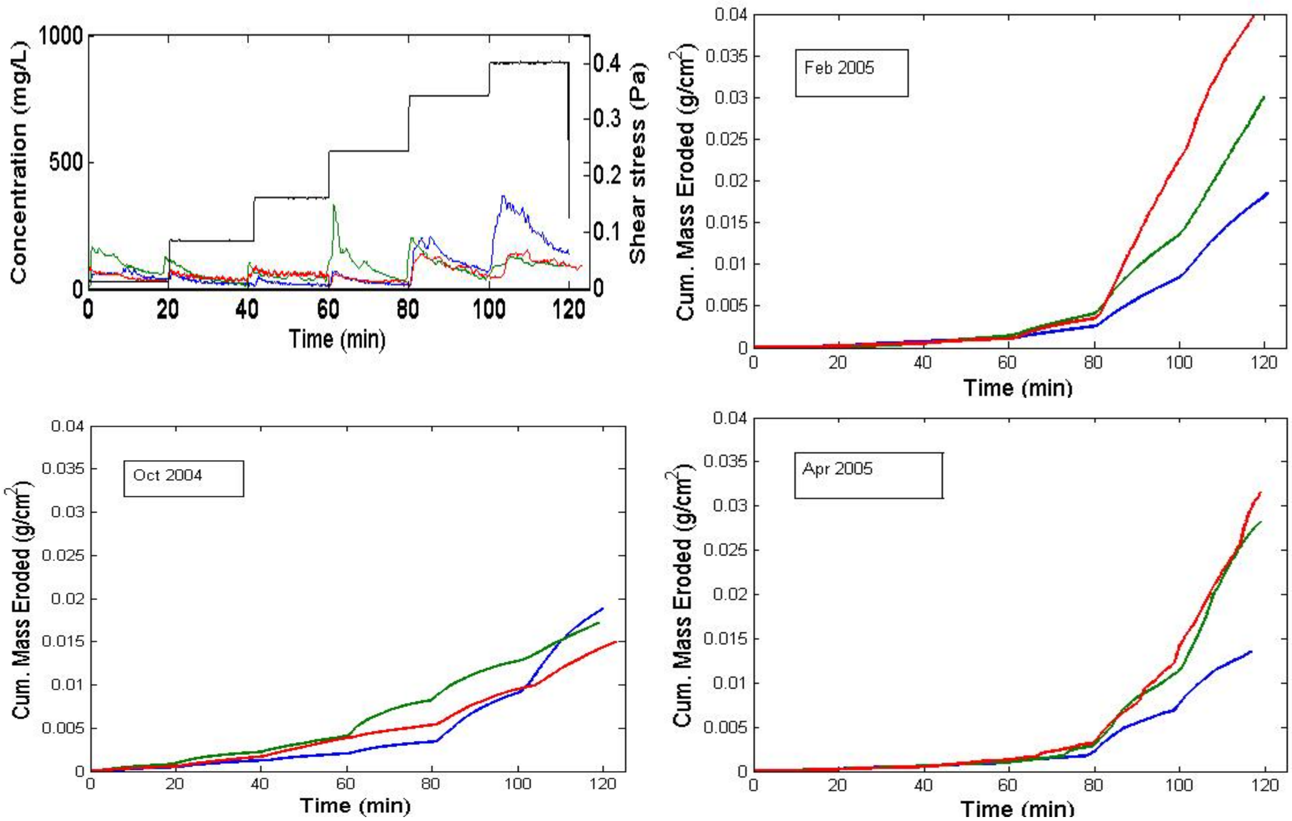

Figure 3. Erosion test results from site T28. Upper left: Time series of measured concentration for varying shear stress from Oct. Black line indicate applied shear stresses, while colored lines are measured values of replicate samples. The other panels show cumulative mass eroded as a function of time in Oct 2004 (lower left), Feb 2005 (upper right), and Apr 2005 (lower right) for replicate cores. Erosion rates were generally highest in February at this site.

Initial analysis of the porosity data collected during the October cruise reveals a seaward increase in porosity. The three shallow sites (T20, T28, and T35) show a rapid drop in porosity in the first 10mm into the bed, as well as a lower constant porosity with depth, when compared with the deeper sites

(T45, T56, T74). This pattern is consistent with the seaward fining of grain size observed across the transect. Analysis of porosity profiles from the February and April cruises is not complete, so a characterization of the temporal variability is not possible at this time. However, if the seasonal shift in mean grain size observed at site T28 is consistent at all locations, then a corresponding shift in porosity would be expected. The magnitude of that shift and its effect on sediment erodibility will be examined to determine if porosity appears to be an influential factor in sediment transport at this section of the Gulf of Lions. In addition, wave and current data are presently being gathered and processed. These data will be important to determine the potential for sediment transport once the erodibility of the sediment is adequately characterized.

Data from the Tet mooring indicates that there were several modest resuspension events during the study period (Fig. 2). Peak significant wave heights exceeded 3 m and calculated peak near-bed orbital velocities reached 30 cm/s for a depth of 28m. This should be sufficient to produce some resuspension at that site. A next step will be to run a wave-current interaction model for this period to estimate bed stresses. We will also be converting our erosion measurements into profiles of critical shear stress as a function of depth, which will then be used to calculate suspended sediment concentrations (see Traykovski et al., in press, for an example of such a calculation for the Adriatic). Similar calculations will be made for all sites along our sampling transect.

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 field programs in the Adriatic and Gulf of Lions provide near-bed sediment transport measurements against which model calculations made using entrainment rates determined in this study are being tested.

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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Syvitski, J.P.M., Pratson, L.F., Wiberg, P.L. and 9 others, in press. Prediction of margin stratigraphy. In. C. Nittrouer et al. (Eds.), *Continental-Margin Sedimentation: Transport to Sequence* [refereed].