

Particle Size, Bed Properties, and Transport of Sediment on European Epicontinental Shelves

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LONG-TERM GOALS

The long-term goal of our research program is to advance scientific understanding and predictive modeling of sediment-transport processes in coastal and estuarine environments. The processes are important to the Navy because they define the tactical environment in shallow water and directly affect optical and acoustic properties of the water column. The resulting seabed structure and morphology affect acoustic backscatter and ability to locate objects on or near the bottom. Predictive capabilities for coastal sedimentary processes are also of great interest to geologists, coastal resource managers, and environmental scientists interested in mitigating coastal hazards, protecting or restoring coastal resources, or remediating contaminated marine environments.

OBJECTIVES

EuroSTRATAFORM is a coordinated research program to measure and model the oceanic and geologic processes that erode, transport, and deposit sediment on continental margins, focused particularly on those events that form and destroy beds over time scales ranging from weeks to years. EuroSTRATAFORM hopes to transfer knowledge accumulated in the ONR STRATAFORM program, incorporate the expertise and insight of European investigators, and test our developing understanding of depositional marine systems in a different environmental context.

APPROACH

Our scientific objectives under EuroSTRATAFORM are to improve quantitative models describing the relationships among meteorological and oceanographic forcing, freshwater and sediment supply, particle dynamics, bed properties, and transport and accumulation of sediment in the coastal ocean. These processes are important to the Navy because they define environmental conditions in coastal regions, including current speeds, water-column turbidity, and bottom acoustic properties. The USGS participated in the Po and Apennine Sediment Transport and Accumulation (PASTA) component of

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EuroSTRATAFORM, conducted in the western Adriatic in FY03 (November 2002 – June 2003) and measured a complete time series of currents, waves, and optical and acoustic estimates suspended-sediment concentration at two sites (10 and 20 m) on a transect near the Chienti River. We proposed (as Task 1 in FY04 and 05) to analyze, interpret, and publish these data, simulate the PASTA sediment-transport events with a community sediment-transport model established with USGS, ONR, and NOPP funding, and integrate our data and results with those of other EuroSTRATAFORM investigators. We also proposed (Task 2) to refurbish our bed sediment digital microscope camera and deploy it along with other instruments in a collaborative mid-shelf field experiment in the Gulf of Lions during winter 2004-2005.

WORK COMPLETED

Analysis and Modeling of Adriatic Sea Data from the Po and Apennine Sediment Transport and Accumulation (PASTA) Experiment

We have made significant progress in analyses of the PASTA field measurements. Current meter data have been processed and posted on our web site, near-bottom measurements have been processed and used to estimate sediment fluxes, and the sonar data has been quantified and compared against wave data and ripple models (Figure 1). These data are being incorporated into several scientific papers that are in preparation.

Detailed evaluation of forcing, bed response, and particle dynamics during transport events recorded at the Chienti tripods has started, in collaboration with other EuroSTRATAFORM scientists

We have made significant progress in developing a community model for circulation and sediment-transport model, coupling this model with meteorological and wave models, and simulating sediment dynamics in the Adriatic Sea. A review of collaborative modeling efforts is in press (Sherwood et al., 2004) and several scientific papers are in preparation.

Field Measurements in the Gulf of Lions

Our objectives for this task were to redesign and rebuild our autonomous sediment digital camera (the “poking eyeball”) and deploy it along with other instruments in the Gulf of Lions. Our plan was to deploy the instrument at a mid-shelf site in France to evaluate the linkage between inner shelf resuspension and supply of sediments to a canyon head at the outer shelf. The poking eyeball was redesigned and rebuilt with USGS funds, and mounted on a tripod along with other instruments supplied by the USGS, including an upward-looking acoustic Doppler current meter (ADCP), an acoustic Doppler velocimeter, an acoustic backscatter sensor, two sonars for imaging the sea bed, a pressure sensor, and a pair of transmissometers.

We also prepared a lower resolution video camera mounted in a weighted ball for surveying the sea bed (the “flying eyeball”). The flying eyeball was designed to image bottom sediments

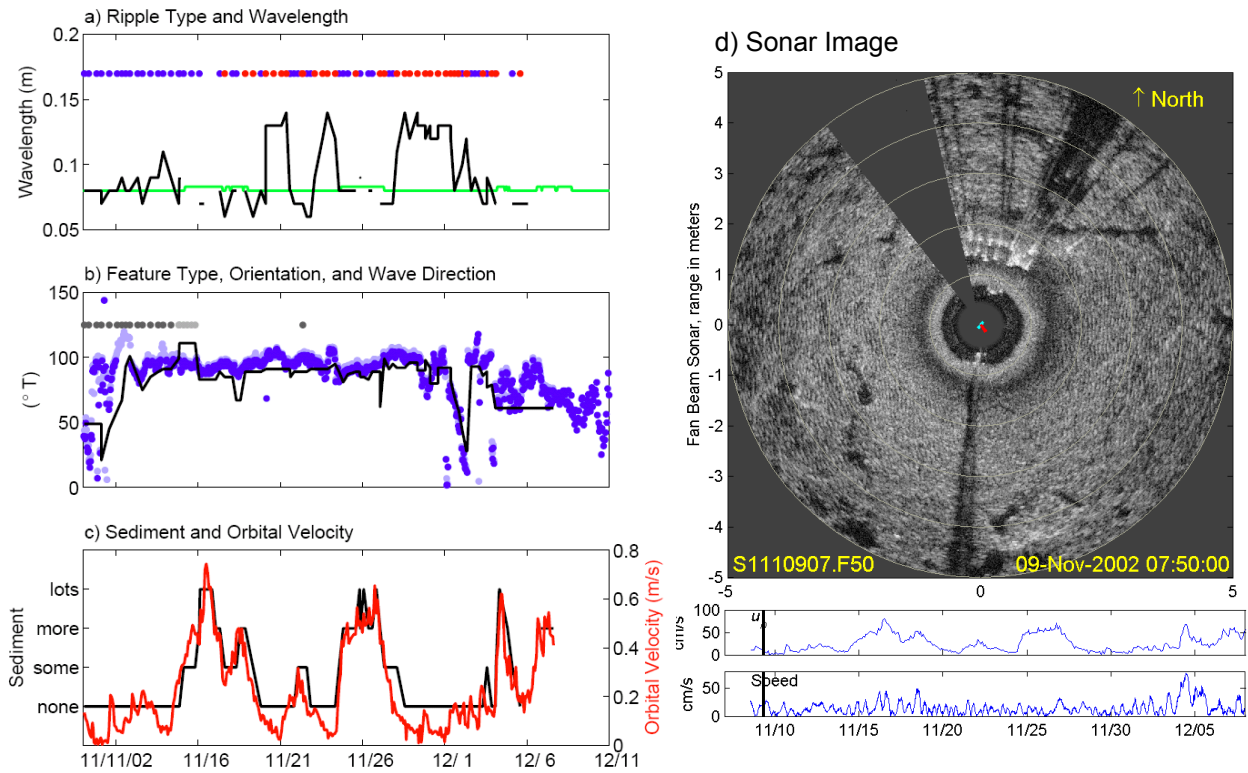


Figure 1. Interpretation of sonar and acoustic Doppler velocimeter (ADV) data from the 10-m Chienti site, Western Adriatic Sea. a) Time series of measured ripple wavelength varies from 6 to 14 cm (black) compared with predicted wavelength (green), which remains nearly constant at 8 cm. b) Measured ripple orientation (black) indicates waves normally come from 90 degrees except during a few events, and these correspond closely with wave directions measured by the ADV (dark blue) and the acoustic Doppler current profiles (light blue). c) Qualitative estimates of suspended-sediment concentrations in the sonar images (black line) correspond closely to wave-orbital velocities measured by the ADV (red line). d) Example image from the imaging sonar with time series of wave-orbital velocity and current speed plotted below.

Our instruments were loaded aboard the *R/V Oceanus* for transit to France, and the USGS deployment team participated on Leg 1 of the September – October deployment cruise, but we did not deploy the tripod. French authorities eventually granted permission for water-column studies, but did not permit deployment of bottom instruments at our planned site. No suitable alternative sites were identified in Spanish or international waters (the poking eyeball needed a sandy or silty bottom at depths less than 100 m). We performed a flying eyeball sample at a 50-m site in Spain, but were again limited by a dearth of sandy bottom sediments in the depth range of the flying eyeball winch (<80 m). In the end, USGS technicians and scientists provided assistance to other EuroSTRATAFORM scientists before, during, and after the deployment cruise, and we loaned our surface guard buoys and ADCP to the University of Washington team, but our main instruments remained aboard the *Oceanus* to return with the ship in December.

RESULTS

Work in FY2003 resulted in a comprehensive set of data describing oceanographic conditions and sedimentary processes at the Chienti transect. Model results produced in FY2004, in collaboration with other EuroSTRATAFORM researchers, provide us insight into the mechanisms that move Po River sediment hundreds of kilometers to depocenters north of the Gargano promontory. The western Adriatic coastal current (WACC) is partially buoyancy driven, a forcing that increases during floods when suspended-sediment supply is highest. Observations and models demonstrate that Po water flows around the Gargano Promontory, but because the sediment aggregates and settles rapidly, it is unlikely that much remains in suspension for the entire journey. It appears that Po sediments must travel southward in a series of episodic transport events, and that wave-induced resuspension is important in these hops.

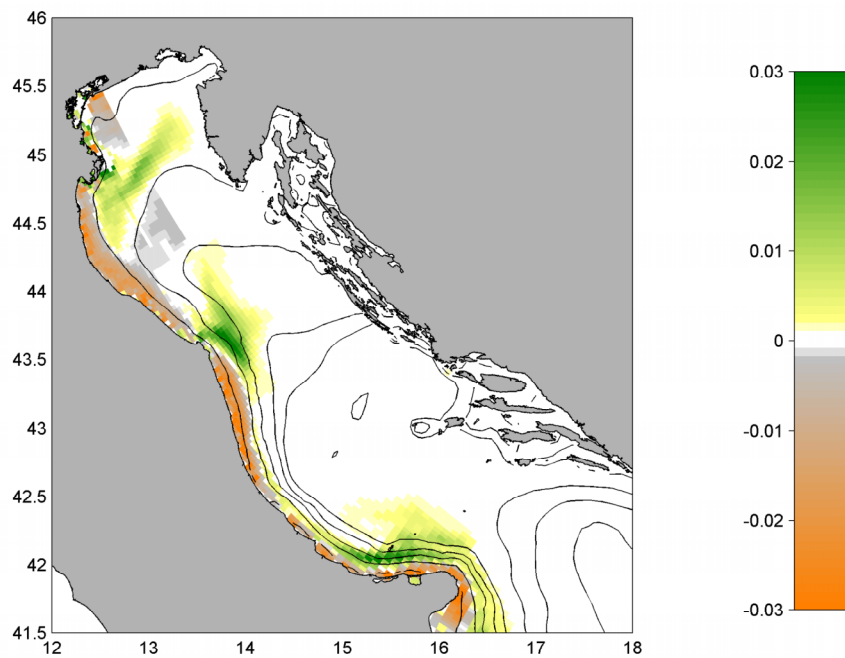


Figure 2. Modeled net deposition (green) and erosion (orange) from the ROMS community sediment transport model simulation for November 2002 – June 2003 coupled with the Local Area Model Italy (LAMI) meteorological model and the SWAN wave model. The erosion close to the coast between the Po River and Ancona, and near Chienti are artifacts from the unrealistic uniform initial sediment distribution. The depositional regions off the Po delta and north of the Gargano promontory match regions of long-term Holocene deposition identified in seismic data.

Bora winds generate large waves in the western Adriatic and enhance flow in the WACC, so it is reasonable to expect that correlated wave resuspension and stronger-than-average southward flow in the WACC combine to generate southward sediment flux. However, our data and model results show only a weak correlation between wave height and southward flow velocity in the WACC on the Chienti transect. The best correlation between WACC flow at Chienti and modeled wind is with wind near Trieste, nearly 200 km from the Chienti transect. This is evidence that wind-driven circulation in

the northern Adriatic has a very large scale, and that waves are not necessarily collocated with Bora-enhanced southward flow. The model indicates that Scirocco winds can generate large waves that resuspend sediment without reversing flow in the WACC, suggesting that southward transport is likely to prevail regardless of the timing or mechanisms for resuspension.

Although research is ongoing to assess the skill of these models, results from the simulations are already helping us gain a better understanding of the mechanisms that form deposits on the margins of epicontinental seas.

IMPACT/APPLICATIONS

These data will be integrated with measurements of other PASTA researchers and those of other participants in Adriatic experiments last winter. Combined, this will be one of the most detailed and comprehensive studies of circulation and sediment dynamics in a coastal sea. Analyses of these data, and their use in testing and improving models, will likely yield new insights to coastal processes.

PUBLICATIONS

Sherwood, C. R. and co-authors. 2004. Sediment dynamics in the Adriatic Sea investigated with coupled models. *Oceanography*, 17(4), in press.

RELATED PROJECTS

USGS Community Sediment-Transport Modeling Project – USGS participation in EuroSTRATAFORM is closely linked with the community sediment-transport modeling project because the outstanding data set from Adriatic experiments in 2002-2003 provides an unparalleled opportunity to test and improve models of circulation and sediment transport. As noted in the Long-Term Goals section, the USGS and ONR have significant overlapping scientific interest in coastal ocean processes. The USGS has contributed salary and operating expenses to the PASTA and Gulf of Lions experiments and invested significant resources into the design and construction of the poking eyeball. The USGS will continue as a partner with ONR to help advance coastal ocean modeling capabilities.

Instrumentation to Measure Bottom Roughness from GEOPROBE Tripods (Award Number: N0001401F0263) – The USGS received ONR funding to develop the imaging/profiling sonar system. That project was completed in FY2002 with successful dockside testing of the new instrument. The new instrument was successfully deployed during the PASTA experiment, and obtained high-quality data (Figure 1). Plans and software for the system have been provided to other ONR investigators.

Transport of Sediments and Strata Formation on the Adriatic Epicontinental Shelf (Award Number N0001402IP20011) – The current project continues and expands research initiated with this project.