Sediment Dispersal in the Gulf of Lions:
Water Column Dynamics and Potential for Cross-Margin Transport

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LONG-TERM GOALS

The most general long-term goals of this study, as part of EuroSTRATAFORM, are to investigate the oceanic processes that erode, transport,and deposit sediment in the margin system, and how fine sediment erosion, transport and accumulation impact water-column turbidity and seabed strata where modern fluvial sediment is transferred across a continental shelf.

OBJECTIVES

This project is a continuation of the EuroSTRATAFORM project and has two parts: analysis of results from PASTA (Po and Apennine Sediment Transport and Accumulation) and preparation for new field work in the Gulf of Lions beginning in October 2004.

The specific objective for PASTA is to document the structure of the Western Adriatic Coastal Current and related sediment transport. The specific objective for the Gulf of Lions is to investigate the interaction of water column dynamics with trapping and transport of suspended sediment.

APPROACH

PASTA: To understand the mechanisms of sediment dispersal once delivered to the marine environment, a combination of water column (surface to very near bottom) and bottom boundary layer time-series measurements are necessary. As part of the overall objectives of EuroSTRATAFORM, the work accomplished within the scope of this project is one part of a greater whole. The focus of this work is on water-column observations that complement mooring, bottom boundary layer measurements, and 3-D modeling results.

The area of interest encompasses the coastal current, the inner shelf influenced by the input from the Po and Apennine Rivers, and the water column overlying the region of sediment accumulation. The observational approach for the water-column studies included repeated hydrographic surveys (CTD, optical measurements for suspended sediments, and water sampling) from the Po River to the Gargano Peninsula during different river discharge conditions and wind regimes, as well as additional focus on the Apennine shelf in February, maximizing probability of capturing discharge from the flashy Apennine Rivers and Bora wind events (strong winds from the NE). Particular effort was made to

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document nearbottom, nearshore conditions by using a small CTD/transmissometer/Niskin bottle that measures from the sea surface to 20 cm above the seabed. Hydrographic surveys only provide a snapshot in time, but the substantial effort to accomplish them in a nearly synoptic way, and repetition of the large-scale survey multiple times during the time-series deployments, provide a large-scale picture of mean conditions as well as a measure of variability under different forcing.

Gulf of Lions: This project will focus on documenting the influence of the water column response to changing wind conditions as a means to trap sediments close to the river mouth and then potentially transport them across the shelf. The goal is to continuously document the vertical distribution of water column properties (salinity, temperature, and therefore density) and suspended sediment, in conjunction with time-series measurements of the flow.

The area of interest is the western region of the Gulf of Lions (Fig. 1). The Gulf is semi-circular in shape and approximately 70 km wide at the mid-point. The input of fine sediments to the shelf from the Rhône and other smaller rivers has resulted in distinct sedimentary units, one of which is the mid-shelf mud belt between 20 and 90 m depth (Durrieu de Madron et al. 2000). Much of the shelf from 90 m to the shelf break is characterized by relict sands. The slope is incised by a number of submarine canyons which are accumulating modern sediment. The dominant hydrodynamic processes include the Northern Current which flows southwestward along the slope, input of freshwater from the Rhône and several other rivers, distinct wind regimes, and cold water formation. The question of how sediments are transported from the inner shelf to the canyon heads is perhaps the most intriguing sediment transport issue in the Gulf of Lions. While cold water flows have been observed, and are known to have a distinctive turbid signal as well as low temperature, the frequency of these events, spatial extent, or magnitude of transport is unknown. While the spatial extent may be difficult to determine within the context of this project, other critical aspects of the transport will be investigated.

The principle tool will be an Autonomous Profiler (AP). An instrument package, equipped with a CTD and Optical Backscatterance Sensor (OBS), is attached to a programmable, submersible winch. The buoyant instrument package when reeled in sits on the bottom, and is released to the surface at a pre-programmed time interval, and then reeled back down to the bottom, recording CTD/OBS. Combined with an upward looking ADCP, quasi-continuous high resolution (vertically) water column properties, suspended sediment, and velocity are obtained throughout the entire water column. In the case of the Gulf of Lions, where changes from well-mixed to stratified (upwelling) conditions may determine the likely pathway for sediment dispersal (i.e. coastal current or episodic gravity flows), quasi-continuous records of the entire water column will be important for assessing the importance of these different pathways.

The AP will be deployed at a site off the Tet River in approximately 27 m water depth (Fig. 1). In the same location is a meteorological buoy maintained by French colleagues, and a bottom tripod with an upward looking ADCP, nearbed ADV, as well as other instruments for characterizing bottom sediment (Wheatcroft, OSU). The time series measurements will be supplemented by hydrographic surveys consisting of a number of cross-shelf transects from the shallow shelf to the heads of submarine canyons in the western Gulf of Lions.

WORK COMPLETED

PASTA: Five large-scale hydrographic surveys were completed between November 2002 and May 2003. Effort during the last year has been spent on analysis and integration with time-series measurements and modeling results in collaboration with Geyer, Mullenbach, and Sherwood.

Gulf of Lions: The AP has been modified for deployment in the Gulf of Lions. The major modifications were: the motor was replaced, wave-following capabability was added, and Argos data transfer capability was added. The system was tested in Vineyard Sound in July and August 2004.

RESULTS

PASTA: Close collaboration with R. Geyer (WHOI) and B. Mullenbach (TAMU) has occurred during all phases – field work planning and execution, shared inventory of instrumentation, and data analysis and interpretation now in progress. More recently, field observations have been compared with 3-D model results (Sherwood, USGS) to address interpretation with respect to coastal current structure, sediment transport, and location of the sand-mud transition.

Repeated hydrographic transects encompassing a Bora wind event during February 2003 documented variability of the cross-shelf extent of the coastal current, significant changes in the width of the front, vertical stratification, and suspended sediment inventory over periods of a few days. Data from two transects off the Chienti River on the Apennine margin are presented in Figure 2 with simplified drawings to illustrate dominant transport processes. During calm conditions, suspended sediment concentrations (SSCs) off the Apennine margin were generally low, 10 mg/l or less in water depths of < 10 m, with the maximum close to shore. During Bora conditions, the coastal current deepens and destratifies as the result of downwelling. The SSC maximum increases and moves seaward to approximately 15 m depth in the vicinity of the sand-mud transition (SMT), bounded on the seaward side by the cross-shelf density front.

The maximum in SSC is likely the result of interrelated factors: a) the mix of grain sizes at the SMT are more easily resuspended than coarser sediments closer to shore and more cohesive sediments seaward; b) depth of resuspension due to waves; c) adjustment of the coastal current during Bora events and subsequent relaxation. The latter could be important with respect to moving sediment offshore, as well as governing the location of the sand-mud transition. Fine sediments from the Apennine Rivers initially deposited in shallow water are easily resuspended and transported along shore (most of the flux) within the coastal current (bottom left panel, Fig. 2). With wave resuspension and downwelling, sediments are distributed throughout the water column extending to greater depths, but are confined by the density front (bottom right panel, Fig. 2). With relaxation of the Bora event, stratification is re-established and sediments in the vicinity of the front are deposited in deeper water, resulting in net transport offshore. Comparison with realistic simulations from a 3-dimensional numerical model support the key features of the interpretation including change in width and depth of the coastal current, location of the SSC maximum, and a boundary shear stress minimum at the front. The greatest variability in suspended sediment within the coastal current was observed to occur between the sites with time series measurements. The next step in the analysis which is comparison of results from a finer-spatial resolution numerical model run, will be important for assessing this mechanism for cross-shelf transport.

Gulf of Lions: There are no results to date. Field work begins October 2004.

IMPACT/APPLICATIONS

Gulf of Lions: There is potential impact of this work in two areas. First, the development of the profiling CTD and deployment on the shelf is a technological advance with great potential for future work. It is analogous to the advance of single point velocity measurements from rotor or electromagnetic current meters to continuous water column profiles of velocity from an acoustic doppler current profiler. Second, in this experiment specifically, the hypothesis of cold water formation as a means of cross-shelf transport can be tested directly by continuous measurement of salinity, temperature, and optical characteristics.

TRANSITIONS

See Related Projects below.

RELATED PROJECTS

Collaboration continues with Geyer, Mullenbach, Ogston, and Sherwood to integrate large scale spatial observations from the hydrographic surveys with time-series measurements and model results on the Apennine margin (PASTA). Similarly, nearshore time-series measurements at the Tet River site (Kineke, Wheatcroft) will be integrated with studies of particle dynamics (Hill, Milligan), cross-shelf hydrographic measurements (Kineke, Puig, Durrieu de Madron) and time series measurements at the mid-shelf (Ogston, Sherwood) and canyon sites (Ogston, Puig).

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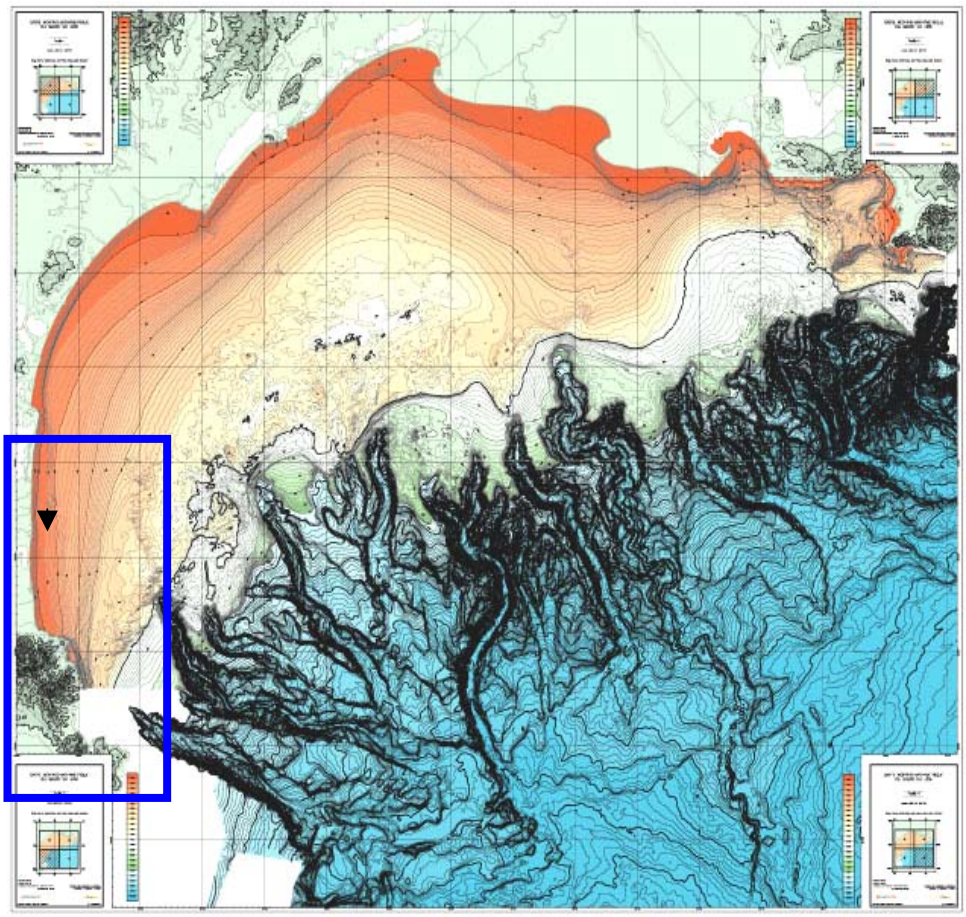

Figure 1. Bathymethric map of the Gulf of Lions (Berne et al., 2001) with study area outlined to the west and the arrow indicating the approximate location for the Autonomous Profiler and ADCP. [The Gulf of Lions is incised by numous submarine canyons.]

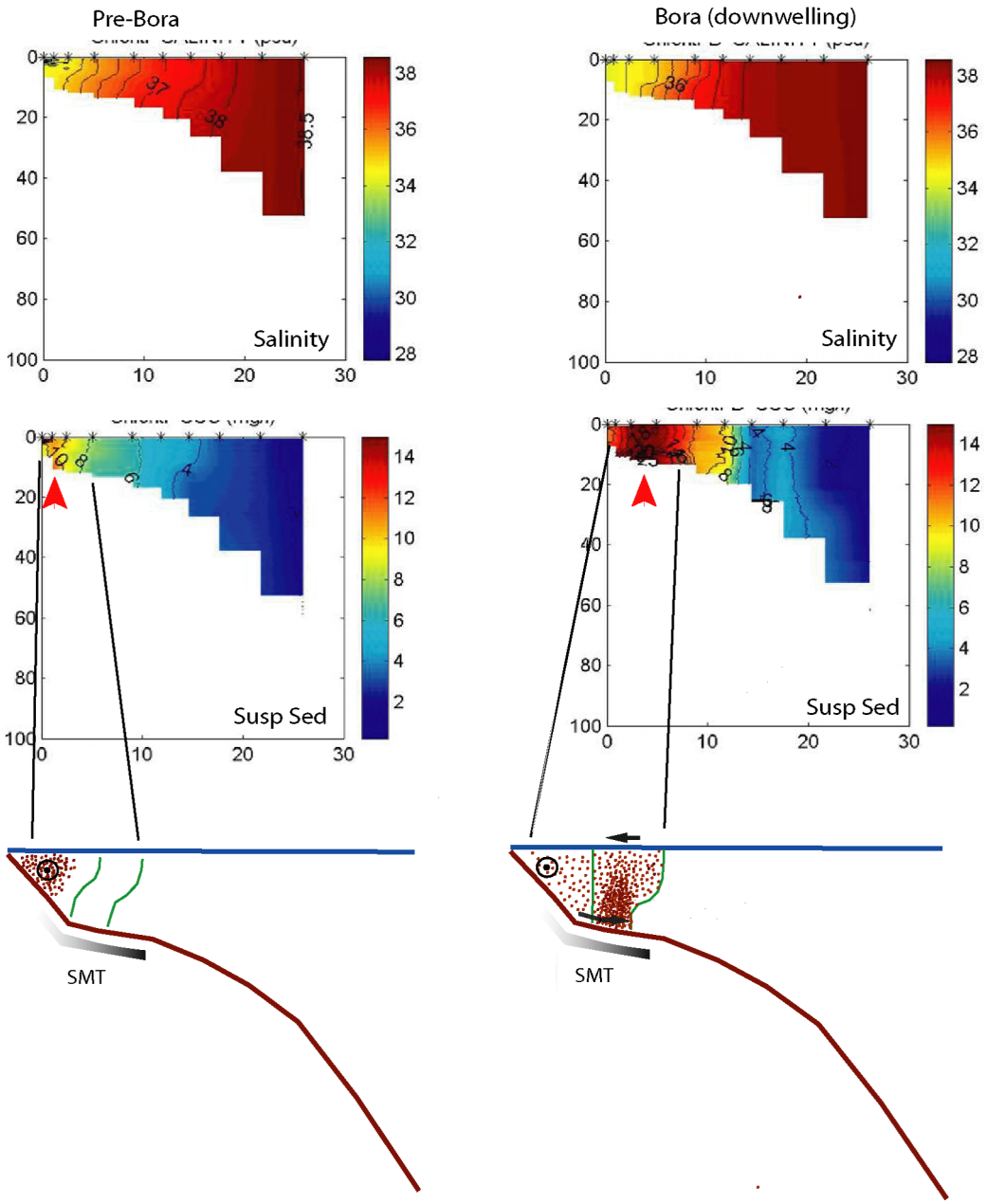

Figure 2. Examples of transects on the Apennine Margin during Pre-Bora and Bora conditions. Bottom drawings emphasize the change in structure in the coastal current and potential mechanism for moving sediment seaward in the vicinity of the sand-mud transition (SMT).