

Sediment Transport by Internal Waves in EUROSTRATAFORM

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LONG-TERM GOALS

The overall long-term goal of EUROSTRATAFORM is to advance our understanding of the development and modification of sedimentary deposits and sequences on continental terraces (shelves and slopes) in the Mediterranean Sea. An essential part of this understanding comes from investigations of modern sedimentary processes in two regions: along the central and northern Adriatic Sea off Italy, and in the Gulf of Lyons off southern France.

This project investigated the role that shoaling internal waves might have in affecting sedimentation in these two regions. The primary emphasis of the research was to examine the available information on internal waves and density structure in the northern Adriatic Sea, and to make preliminary estimates of internal wave effects on sedimentation in both regions.

OBJECTIVES

- Evaluate the role of internal waves in resuspending and transporting sediment on the shallow sections of the Adriatic continental shelf off central Italy (water depths < 100 m).
- Gather information on the density field in the northern Adriatic Sea in order to estimate potential sedimentation effects by shoaling internal waves.
- Participate in planning field experiments to obtain time-series hydrodynamic and sediment data in both study areas.

APPROACH

The approach to this study had several parts:

1. Evaluate the applicability of the internal wave-slope sedimentation model developed in STRATAFORM to EUROSTRATAFORM sites.
2. Use historical and newly acquired data on internal waves and sedimentation processes in EUROSTRATAFORM to estimate internal wave effects on sedimentation.
3. Initiate development of internal-wave sediment entrainment model for modern sedimentation processes in both the Adriatic Sea and Gulf of Lyons.

4. Assist with planning and coordination of field experiments in the Adriatic Sea off the Apennine region of Italy.

This effort was aimed at three items: (1) continued development of a model for inhibited deposition and possible erosion by internal waves over sloping bottoms; (2) planning and coordination of field measurements of sedimentary processes in the Adriatic study area; and (3) gathering and preliminary interpretation of density profiles and current measurements related to internal wave dynamics in this region.

WORK COMPLETED

- We gathered available data on density structure and bathymetry in the Adriatic Sea. The density profiles in the northern Adriatic off Italy were used to compute Brunt Vaisala frequencies.
- We calculated characteristic angles (i.e., group velocity directions) from the BV frequencies and internal wave frequencies that have been reported for the region (both high frequency and near-inertial frequency internal waves).
- We made estimates of bottom velocities and bottom shear velocities from simple linearized analytical models of shoaling internal waves using available bathymetry and density data.
- We participated in planning for upcoming field work and instrument deployments in the northern Adriatic (“PASTA”) at a workshop in Winchester, England, during early September, 2002.
- We organized a special session on Internal Waves and Seabed Effects for the Annual Fall Meeting of the American Geophysical Meeting (December 6-10, 2002 in San Francisco).

RESULTS

The effects of internal waves and tides on transport of bottom and suspended sediment are poorly understood. We have approached this problem both theoretically and using new data collected during EUROSTRATAFORM experiments. The findings to date indicate the following results.

- Measurements of the upper (seasonal) pycnocline in the study region indicate considerable variability in the seasonal pycnocline. The strength of the density gradients vary from nearly well-mixed (after large storms) to prolonged periods of high stability. During the periods of high stability, Brunt-Vaisala frequencies are rather high (up to 15 cph).
- Internal waves of high frequency (2-6 cph) and at near-inertial frequencies have been reported in the Adriatic Sea. The near-inertial internal waves have also been shown to cause sediment resuspension and to generate bottom nepheloid layers in other regions of the western Mediterranean (e.g., off southern Spain).
- Internal waves along sharp pycnoclines have generated sediment ripples and larger bedforms in laboratory experiments.
- Theoretical estimates of bottom velocities caused by shoaling high-frequency internal waves exceed threshold values for entrainment of natural bottom sediment on shelves. Initial estimates for the

PASTA study area using a linear model suggest that bottom velocities exceeding 30 cm/s can be achieved. The instrumented mooring and bottom tripods that are planned for deployment in the PASTA area will provide data to compare with these theoretical estimates.

IMPACT/APPLICATIONS

Internal wave-induced bottom stresses might have a major influence on controlling erosion and deposition on shelves and slopes in the Mediterranean Sea. If the near-inertial internal waves are as energetic in the study areas as have been reported in other regions, they would be an important process in transporting fine sediment. They might also contribute to the formation and modification of large bedforms that have been observed along the Adriatic shelf and on the outer shelf in the Gulf of Lyons.

Also, if high frequency internal waves shoal and break along the seafloor in the seasonal pycnocline, erosion and resuspension of bottom sediment might occur. This process could lead to dispersal of sediment, and generation of turbid bottom layers.

TRANSITIONS

This work has applications for modeling of formation of sedimentary strata and structures on continental shelves. It may also have implications for sedimentation on certain continental shelves where turbulent shears from surface waves and other currents are relatively low (as compared with internal wave effects). The results and model can be integrated into more comprehensive sedimentation models that are under development by others (e.g., J. Syvitski and L. Pratson).

RELATED PROJECTS

The internal wave work is being done in close collaboration with other EUROSTRATAFORM investigators: Dr. Andrea Ogston (U. of Washington), Dr Pere Puig and Dr. Alberto Palanques (both at Ciencies del Mar, Barcelona, Spain), Dr. Serge Berne (IFREMER, Brest, France), and Dr. Lincoln Pratson (Duke University).

This project is closely related to those EUROSTRATAFORM projects investigating morphology and surface sedimentation on continental shelves. The work is related to projects led L. Pratson (Duke University), C. Nittrouer, and A. Ogston (all three at University of Washington), J. Syvitski (INSTAR, University of Colorado), and M. Steckler (Lamont-Doherty Geological Observatory).

REFERENCES

Cacchione, D.A. and D.E. Drake, 1986, Nepheloid layers and internal waves over continental shelves and slopes, *Geo-Marine Letters*, 6, 147-152.

Cacchione, D.A., A. Ogston, E. McPhee, R. Sternberg, and G. Tate, 1998, Internal tides and sedimentation on the continental slope off northern California, *EOS, Trans. Amer. Geophys. Union*, 79, F457.

Cacchione, D. A., L. Pratson, and A. Ogston, 1999, Internal tides, sedimentation, and seafloor slopes, *EOS, Trans. Amer. Geophys. Union*, 80, p. OS250.

Cacchione D.A. and J.B. Southard. 1974. Incipient sediment movement by shoaling internal gravity waves, *Journal of Geophysical Research*, 79, 2237-2242.