EuroSTRATAFORM Numerical Modeling Study of Shelf Stratigraphy and Sedimentation

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LONG-TERM GOALS

The scientific objective of the work is to develop a quantitative understanding of the processes that control the formation of marine stratigraphy over time scales ranging from decades to millennia. This work is based on the creation and application of a series of advanced numerical models representing the dynamics of marine sediment transport, sediment accumulation, morphological change and feedback between the evolving sea floor and the hydrodynamic forcing. Field data are used to both force the models and to verify their results. The models are used to diagnose complex systems and as predictive tools.

The practical objective of the work is to produce and distribute advanced numerical models to a range of researchers and to the SEDFLUX and SEQUENCE model frameworks.

OBJECTIVES

This report covers the work during the first year of a two-year project. The objectives of the first year include:

- Develop the CST model from its initial test-bed condition to a viable tool for simulating and diagnosing the large-scale but shallow stratigraphy of a wide range of continental shelves.
- Using data from the central Italian Adriatic shelf simulate the formation of the large prograding Holocene submarine clinoform that stretches from north of Ancona to the Gargano Promontory.
- Use the CST model to determine whether distinct patterns of stratigraphic time-line facies due to millennia-scale sea level fluctuations and differences in river sediment supply rates can be distinguished.
- Incorporate a variable river sediment input routine from the ONR-funded GeoClutter Program developed by Sergio Fagherazzi.
- Contribute to the development of the 3-D version of the 2-D ONR SLICE model of event-scale marine sediment dynamics.
- Develop co-operative research with European scientists in Italy, The Netherlands, and France.
- Provide a working CST-model to EuroSTRATAFORM researchers including those developing SEQUENCE and SEDFLUX.

APPROACH

- Develop the CST (Coastal System Tract) model into a form that can reproduce and diagnose the formation of 3D marine stratigraphy over geologically relevant time scales. This includes adding sub-routines representing large-scale current advection and century-to-millennia scale sea level variations. Field examples are taken from the Florida Panhandle and Italian Adriatic coasts.
- Obtain and reduce oceanographic, watershed, geophysical and sediment data for the central Italian Adriatic coast in cooperation with C. Harris and A. Cattaneo.
- Analyze the large-scale Holocene submarine clinoform that has formed along the central Italian Adriatic shelf. Include evaluation of the relative roles of longshore and cross-scale sediment transport, the relative importance of the smaller Apennine rivers to the more distant Po River, the interaction of shelf and nearshore transport systems and the effects of low-amplitude sea level variations on the internal geometry (ie. time-line stratigraphy) of these deposits.
- Promote the distribution and application of the CST Model.

WORK COMPLETED

The research of the first year was structured into seven tasks. Table 1 shows the status of this work.

TABLE 1

Task	Title	Status	Comment
1	Provide Direct CST Model Access	Complete	Given to 23 researchers
2	Data & Literature Compilation	Complete	Needed data acquired
3	Develop CST Model Scenarios	Complete	One basic and 2 variants
4	CST Modeling Simulations	Complete	Good agreement with observed stratigraphy
5	Year 1 - Modeling Liason	Complete	Model provided
6	Year 1 – Manuscripts & Meetings	Complete	1 paper, 3 abstracts, 3 conferences
7	Project Administration & Management	Complete	

RESULTS

- The results of millennia-scale low-amplitude sea-level variations on inner shelf and shoreface stratigraphy have been successfully modeled and they are distinctive.

- The Holocene submarine clinoform that extends for 160 km (model domain) along the central Italian Adriatic coast has been successfully modeled.

- The model results provide verification that a sediment bypassing condition is an end point in the evolution of many continental shelves. Prior to these model simulations this condition had been assumed (Niedoroda et al. 1995, Niedoroda et al. 2001, Carey et al. 1999), but had not been demonstrated with corresponding measured data.

- The model results showed that coastal-wise propagation of the clinoform, caused by strong time-averaged advection, combines with the effects of large-scale shore-normal sediment diffusion to fully explain the 3-dimensional shape and internal geometry of the clinoform.

- Additional work has been done to aid in the planning of the Gulf of Lyons research. We have combined measured hydrographic and down-canyon current data from the Lacaze -Dathiers Canyon (kindly provided by Xavier Durrien and Serge Berne) with a 2-DV finite-volume numerical model of density and turbidity currents. The initial results (recently completed) suggest that winter time cascading of cold water from the shelf are adequate to trigger turbidity currents but cannot propagate from the shelf edge to the 1000 m mooring as pure density currents.

IMPACT/APPLICATIONS

To our knowledge the CST model is the first numerical scheme that is capable of simulating large-scale 3-D fully coupled coastal systems that include beach, backbeach, river/watershed, shoreface/shelf and slope environments. The results have demonstrated that there are interactions between the components that dramatically affect the time-histories of the development of the sedimentary forms and internal stratigraphy. This provides a powerful incentive for additional application of this model framework to a wide range of field locations characterized by differing combinations of components in the coastal system tracts.

The CST Model is a direct outgrowth and application of the new and powerful Coastal System Tract concept that was developed by a team of ONR STRATAFORM and MAST III PACE project researchers (Cowell et al. 2003a and b). The concept includes the important idea that the different components of coastal marine sediment-sharing systems 'compete' for the available sediment. Therefore, it is incorrect to analyze individual components (e.g. surf zone or shoreface systems) in isolation because the relative availability of sediment is controlled by these interactions with neighboring components of the system. This problem is not especially apparent on time scales of days and months but becomes increasingly obvious at scales of years, decades and centuries. Because coastal scientists, engineers and managers are moving to system-wide, basin-wide and regional concepts the CST Model is a tool with widespread applications.

The application of the CST model to the submarine clinoform of the central Adriatic coast substantiates one of the key assumptions (the equilibrium by-passing shelf profile) used in formulating a mathematical representation of time-averaged marine sediment dynamics.

A number of detailed programming issues (e.g. sub-grid resolution of the shoreline position and shape needed for surf-zone sediment transport computations, cross-shore shoreface migration in response longshore transport gradients, coupling of river and coastal model components, representation of strong time-averaged advection, multi-line code structure) have been solved. These solutions have been given to a number of other investigators.

TRANSITIONS

This EuroSTRATAFORM project has supported sediment transport concept development and numerical modeling that is being applied by both the commercial and government agencies. This includes the conversion of some of the modeling work to the "CHANNELS" model now being adapt for inclusion into the U.S. Army Corps of Engineers SMS Modeling package. A primary application of this model is expected to be to improve the design of the deeper navigation channels (e.g. maintenance depths of 60 ft) that will be needed to keep our ports competitive in world commerce. Additionally, others of the model routines and concepts have been modified for use in applied oceanographic studies supporting the development of major deep water hydrocarbon reservoirs in the Gulf of Mexico. Recent clients include BP Exploration and Development (Atlantis and Mad Dog Prospects) and Shell (Nakika Prospect). They have also been adapted for use in support of projects by offshore engineering companies such as INTEC and Mentor and have been use in the engineering the Mardi Gras pipeline crossing of the Sigsbee Escarpment and the routing of the main offshore oil export pipeline in the Caspian Sea. We have provided Craig Shipp and Carlos Pirmez of Shell with the CST model and expect to be working to help them set it up on one of their projects.

RELATED PROJECTS

This project is part of EuroSTRATAFORM Task D3 – Shelf Transport Modeling and Task D4 – Long-term Stratigraphic Modeling. The work is being carried out in conjunction with other ONR-supported researchers including Courtney Harris, Julie Pullen, John Swenson, Michael Steckler and James Syvitski. In addition we are working with researchers supported by PROMESS (Serge Berne, Xavier Durrien) and EuroDELTA (Gert Jan Weltje, Bavio Trincardi and Antonio Catteneo). This collaboration includes sharing of model code with Michael Steckler (SEQUENCE) and James Syvitski

(SEDFLUX). We have also acquired and used data from Serge Berne (Ifremar) and Xavier Durrien (University of Perpigan).

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