Scaling and Integration of Process-Response Stratigraphic Models

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LONG-TERM GOALS

Formulate predictive and diagnostic models on how sedimentary processes create strata, and contribute to the stratigraphic record. Of special concern are capturing the important rare events affecting strata formation (e.g., slides, floods) that are often difficult to observe but can control the stratigraphic development of a margin. The cumulative impact of these rare events can be predicted through numerical experiments, within the context of other relevant marine processes (e.g., earthquakes, tsunamis, climate, storms, river discharge).

OBJECTIVES

1A) Set up a computational facility at INSTAAR, offering remote log-on access by the STRATAFORM modeling community.

1B) Implement the ONR-MG plan entitled the Integrated Modeling System for Simulating the Evolution of Continental Margin Stratigraphy, i.e.
• Refine the *SedFlux* model to include 3 shelf-sediment transport (SST) modules.
• Test SST upgrades to *SedFlux* against known environmental conditions (Eel Margin).
• Couple the latest acoustic module from Duke U. to *SedFlux*.
• Ensure the *Sequence* model is completed and tested against a known environment.

2A) Construct a numerical model to simulate delta-lobe switching that will include autocyclic processes and allow for the influences of allocyclic forces. Add the module to *SedFlux*. The 3D-version of the model should numerically handle complex shorelines (boundary shapes).

2B) Develop upscaling routines for *SedFlux-2D* to allow for application of the model to simulate long period geological periods.

2C) Determine how large sediment waves form on continental margins as a result of river floods. Determine optimal conditions for sediment wave formation, including bed slope, macro-roughness wavelength, sediment size, sediment concentration.

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14. ABSTRACT
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APPROACH

1A) Install Sun Enterprise 5500 and 6500, 25 work stations, UPS, and implement RAID tape system. Contract tape back up to CU-UnixOps. Install air conditioning, printers, scanners and plotters. Secure the facility through hardware and software. Install operating software (various compilers, ARC, IDL, MatLab, Mathematica, and so on). Make facility available to ONR MG users. Install ONR MG models.

1B) Ensure STRATAFORM shelf modelers are aware of *SedFlux* architectural needs, boundary conditions, operating environment. Once received, imbed stand-alone shelf Bottom Boundary Layer models into *SedFlux*, including: a) a vertically-averaged advection-dispersion formulation (Wiberg, UVA); b) an analytical gravity-driven model (Friedrichs and Scully, VIMS); and c) a 2-D model (vertical and cross-shelf) climate-driven transport model (Reed and Niederoda, URS). Carry out benchmark tests comparing model simulations under the different shelf transport engines. Coordinate a mid-course modeling assessment meeting at ONR-HQ.

2A) Using Brownian motion theory, implement a delta-lobe switching model in *SedFlux* and test model results against the switching frequencies of well-studied deltas (Po, Yellow, Mississippi) and data from the U. Minneapolis laboratory experiments.

2B) Employ probabilistic density functions in *SedFlux* to run river discharge and plume sedimentation modules. Determine scaling relationships between St. Anthony Falls laboratory experiments and continental margin observations.

2C) Employ an event-based layer-averaged formulation (*Inflo*) to determine optimal conditions for sediment wave formation.

WORK COMPLETED

1A) The Environmental Computation and Imaging (ECI) Facility is now operational at CU, and employed by ONR participants (Wiberg, Pratson, Friedricks, Syvitski, Hutton, Peckham, O'Grady, Hilberman) and others at INSTAAR. ONR software is installed, tested and in some cases multithreaded.

1B) *SedFlux* team met in Ponce (PR) and the *Sequence* team met at LDEO (NY) to coordinate their research activities. Three shelf boundary layer models (VIMS, UVA, URS) are compiled on the INSTAAR ECI Facility. The VIMS and UVA models are imbedded and tested in *SedFlux*. Inter-model comparisons remain 2nd year activities. Duke U. new acoustic model is compiled on the INSTAAR supercomputer, and remains to be coupled with *SedFlux*. *Sequence* and *SedFlux* intermodel comparison remains a 2nd year activity.

2) A numerical lobe-switching model is operational and implemented in 2D-*SedFlux*. It has been successfully tested against a U. Minneapolis tank experiment (Paola et al.,

2001). A 3D version is also developed, but not yet tested. The 2D-*SedFlux* now employs probabilistic density functions of river discharge and plume sedimentation (paper in prep.). Numerical experiments have demonstrated the self-amplification of sediment waves (Lee et al., in press).

RESULTS

SedFlux is a complex numerical model whose components are being continuously improved by field and computational developments. *SedFlux* now handles multi-grain size compaction, important in predicting sediment porosity profiles (Bahr et al., 2001). A consequence is more realistic numerical deposits used for acoustic predictions. Six of the STRATAFORM numerical models were published as a special issue of Computers and Geoscience (Syvitski and Bahr, 2001). The volume includes the latest version of 2D *SedFlux* (Syvitski and Hutton, 2001) and a new Lagrangian model of turbidity currents (Pratson et al., 2001). *SedFlux* now includes the 2D version of delta switching routine and provides for realistic simulations of the laboratory experiments conducted by St. Anthony Falls Hydraulic Laboratory (Paola et al., 2001). Upgrades to *SedFlux* include a numerical decider for choosing how failed sediment masses are moved, i.e. as a turbidity current or as a debris flow (Syvitski and Hutton, in press). A new routine in *SedFlux* allows us to predict tsunamis wave characteristics generated during sediment failure event (invited AGU-2000 presentation). The geotechnical community has therefore taken a special interest in *SedFlux* as a tool useful in the analysis of submarine slope stability.

SedFlux has for the first time quantitatively established how continental margins form. The analysis (O'Grady and Syvitski, in press-a) has lead to a new understanding of which continental margins have established some equilibrium profile in their cross-shelf morphology and which margins are in transition. The analysis supports the global analysis of world passive margins based on recently released bathymetric data (O'Grady and Syvitski, in press-b). *SedFlux* has also been used to evaluate how abrupt climate change can affect the properties of marine deposits (Morehead et al., 2001). *SedFlux* is an ideal tool to examine which marine deposits may be ideal to recovery paleoclimate records. *SedFlux* is also shown to be useful to the acoustical community with the Navy working on transmission loss and the sonar equation.

A scaling technique was established for estimating the long term rating coefficients of sediment discharge of rivers (Syvitski et al., 2000) and was expanded upon to provide a method for estimating the inter-annual and intra-annual variability in the flux of sediment in ungauged river basins (Morehead et al., in press). Together these two methods provide a way to predict the level of water turbidity in the coastal zone, even from rare short-lived flood events.

A comprehensive paper was completed (Lee et al., in press) that demonstrates how hyperpycnal currents may generate sediment waves. The study is based on numerical and laboratory experiments and a comprehensive analysis of field data. Findings indicate that many areas of seafloor morphology previously prescribed to sediment failure are more likely to be depositional in nature, resulting from hyperpycnal plume activity. Laboratory and theoretical analysis has also lead to support of a new theory (Parsons et al., 2001) that rivers are more likely to generate hyperpycnal plumes (rather that buoyant surface plumes) during flood events than was previously considered.

IMPACT/APPLICATIONS

New numerical tools are being refined to allow for predicting the general nature of seafloor morphology and the developing sediment stratigraphy. The tools are being refined to allow for simulations in the littoral zone. The tools are being coupled to acoustic models and used to assess acoustic reverberation and propagation. Because these tools are driven by environmental data they offer the promise to provide seafloor acoustical information of continental margins at the global level. They also provide use in the oil industry in characterizing reservoirs, and their development is being partly supported by an oil company consortium.

TRANSITIONS

ExxonMobil is using versions of *SedFlux* to characterize offshore reservoirs. The geotechnical community is using *SedFlux* to investigate the role of marine slope failures in generating tsunamis. SACLANTCEN and other U.S. labs plan to use realizations of *SedFlux* in the studies of transmission loss and tactical environmental uncertainty. The SedFlux model is also being used to investigate sonar geoclutter.

RELATED PROJECTS

ONR Geoclutter: Predicting the Distribution and Properties of Buried Submarine Topography on Continental Shelves
ONR Mine Burial: Sediment Flux to the Coastal Zone: Predictions for the Navy
ONR Uncertainty: Seabed Variability and its Influence on Acoustic Prediction Uncertainty
NSF MARGINS: Experimental and Theoretical Study of Linked Sedimentary Systems
NSF MARGINS: Community Sedimentary Model Science Plan for Sedimentology and Stratigraphy.

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