Predicting the Distribution and Properties of Buried Submarine Topography on Continental Shelves

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LONG-TERM GOALS

Compile geological data and develop methods to predict the distribution and properties of features hypothesized to be responsible for sonar geoclutter. Geological structures just beneath the seafloor, such as steep-walled channels, may have high-angle reflecting surfaces that can return false sonar alarms to ships operating in the littoral zone. The major goal is to contribute to the reduction or mitigation of geologic clutter observed on fleet sonar systems.

Two issues define the problem.

- Landscape forming issue: In area ‘x’, can the Navy expect geoclutter features and if so what are their sonar characteristics, i.e. channel orientation.
- Landscape burial issue: If geoclutter features are expected in area ‘x’, will the features be exposed or buried. Areas of low interest to the Navy include locations where Holocene deposits are thick. Areas of high interest to the Navy include locations where Holocene deposits are thin thereby allowing for the shallow burial of Pleistocene topography.

OBJECTIVES

- Define the character of different kinds of buried channels (size, shape, properties).
- Define the spatial distribution of these buried channels (river, tidal, hyperpycnal).
- Develop a global atlas of candidate geoclutter features and their characteristics.
- Develop and merge global databases of pertinent geological and oceanographic data.
- Develop predictive models and apply to margins of interest. Test predictive models in a known geoclutter rich area.
- Share and merge these databases, models and results with those in the Geoclutter Research Group working on tracking algorithms.

APPROACH

1) <u>Compile a global database of pertinent geological and oceanographic data,</u> for use as initial inputs and constraints for sediment flux models (*HydroTrend* and *SedFlux*).

2) <u>Measure and analyze terrain attributes.</u> Perform a comprehensive analysis of real and simulated elevation grids using RiverTools® and other GIS software. Calculate the geometric and statistical characteristics of landforms and how these characteristics vary from one geologic setting to another.

3) <u>Classify terrain from geologic information.</u> Classify "terrain types" in terms of the initial and boundary conditions (e.g. geology, erosion rates, excess rain rates) that produced the terrain types, using physics-based landform models.

4) <u>Determine the burial depth potential of low-sea level produced topography</u>. Develop simple scaling relationships for deposition rate as a function of sediment input rates from rivers, wave and current conditions, and shelf geometry. Refine these bulk estimates with more detailed consideration of the nature of sediment delivery to the shelf (e.g., episodic storm-driven flooding vs. seasonal snowmelt flooding; the role of estuaries) and sediment redistribution, bypassing and deposition on the shelf (e.g., the long-term manifestation of short-term, episodic, storm-driven transport on the shelf).

5) <u>Model the flux of sediment to and across continental shelves.</u> Use process-based models (*HydroTrend*) to obtain a detailed consideration of the nature of sediment delivery to the shelf and sediment redistribution, bypassing and deposition on the shelf.

WORK COMPLETED

1) Last year we acquired NCAR-CCM model results of precipitation, surface temperature, wind vectors and other climatic parameters for the following geological intervals: 3.5kyr, 6kyr, 8.5 kyr, 11 kyr, and 21kyr. The spatial resolution is 10 degrees, and temporal resolution is one month. This year we reran the 21ka results at a daily basis and at 1-degree resolution, to obtain temperature and precipitation intra-monthly statistics necessary for *HydroTrend*. Glacial extent for the Late Glacial Maximum originally constrained with output from the ICE-4G model, have been updated with new ice melt estimates to constrain the significant glacial meltwater fluxes during the eustatic sea level lowering off of New Jersey.

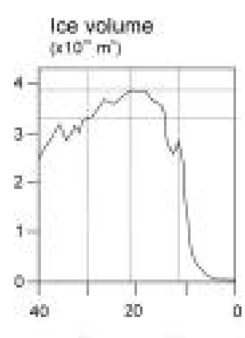

Figure: Ice volume changes ranging over 4 x 1015 m3 across 40,000 yr are used in HydroTrend modeling.

2) Using GTOPO30 DEMs (elevation grids) for the eastern United State as a test case, *RiverTools* waqs used to measure topographic attributes for every 1-km pixel in the DEM, including: basin contributing area, basin relief, latitude, longitude, mean basin latitude, topographic index (ln a/S), downstream slope, profile curvature, longest channel length (distance to divide), longitudinal profiles and hypsometric curves. Paleo-basins are defined with algorithms in *Arc/Info* that use flow direction of a DEM to map hydrologic drainage divides. Estimated paleo-basins provide boundaries by which to sample climatic data for input to *HydroTrend*, for calculation of the paleo-flux of sediment to the shelf.

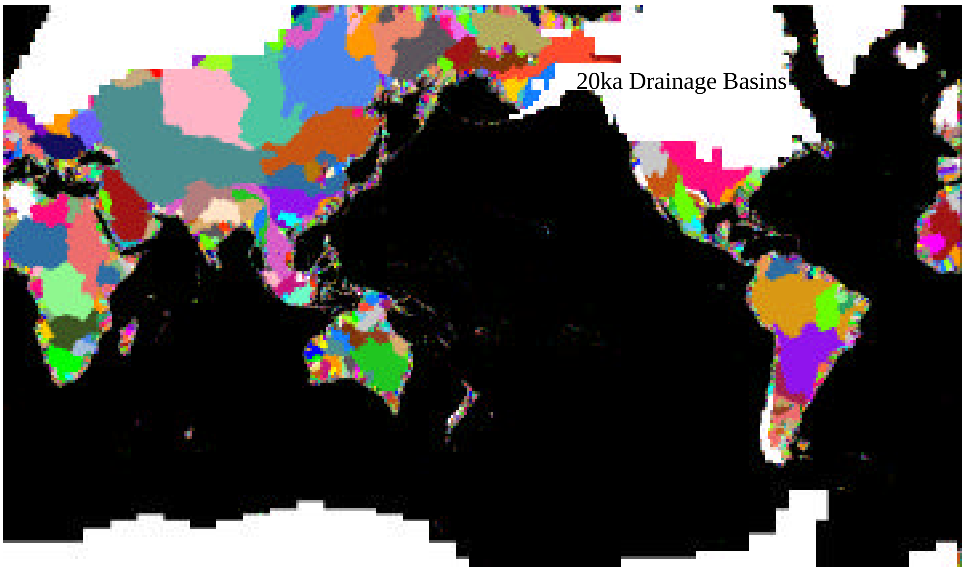

Figure: Global model of drainage basins 20,000 years ago.

3) A collection of IDL programs were developed to identify coastal pixels and to extract the measured attributes for all coastal pixels with contributing areas larger than a specified value. Measured values were then used to compute mean annual sediment discharge for coastal pixels for the 400 U.S. East Coast river basins. Since this process is automated and can handle very large elevation grids, it can be rapidly applied to other parts of the world.

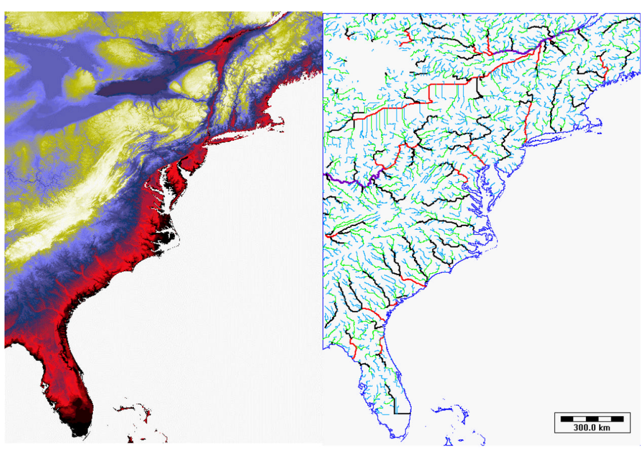

Figure: Hydro1K Digital Elevation Model of the U.S. East Coast (left panel) and the river channels (right panel) as determined using RiverTools.

4) The above datasets have been combined into GIS layers for easy selection and query for input into *HydroTrend*. The process is close to being automated. A new formulation was developed to compute the volumetric sediment discharge to a given coastline position, given paleo conditions (changes in a rivers drainage basin area due to sea level fluctuation, changes in basin temperature). Similarly the volumetric water discharge is being computed from the paleo basin area to compute channel width, velocity and depth for channels which discharge to the coast.

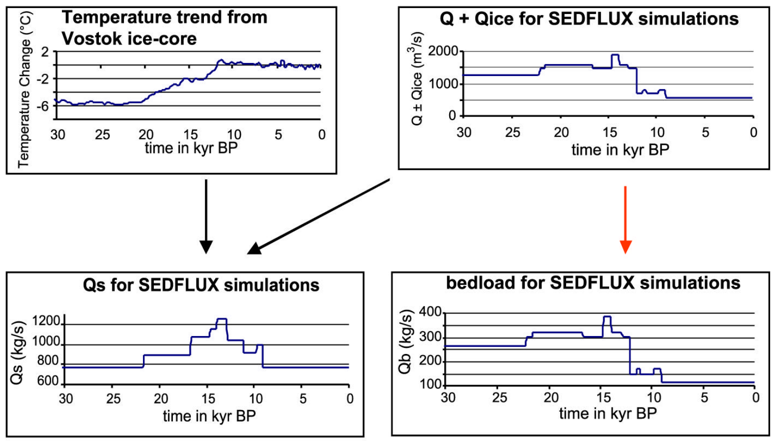

Figure: HydroTrend modeled inputs for SedFlux run of the New Jersey margin

5) We have completed a preliminary analysis of the delivery of sediment along the entire east coast of the US using the new developed techniques described above.

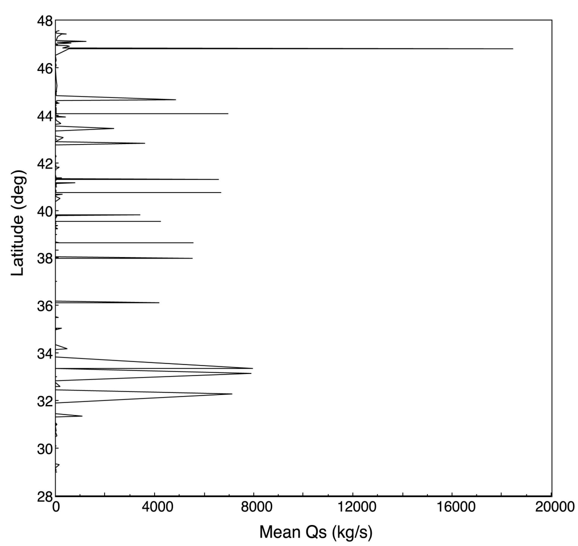

Figure: Sediment flux in units of kg/s along the entire east coast of the US, from 48° N to 28° N. 411 basins are modeled. Results show 17 significant sources of sediment that move sediment to the continental shelf.

RESULTS

The ONR Geoclutter project has forced us to evaluate available data and models for the predictions of buried channels located along continental margins. All of the data needs as required by present models have been acquired to predict the sediment flux to the U.S. east coast during the last 20 kyr. Requirements include: paleo-temperature, paleo-precipitation, glacial conditions, drainage basin characteristics (e.g. area, relief, hypsometry), and sea level fluctuations. While uncertainties exist for all of these paleo data requirements, predictions of channel burial remain reasonable. For example, model testing. The exercise has provided experience needed for the modeling of other coastlines of the world. The challenge has been to develop a system so that entire coastlines rather than individual basins can be modeled. Our results indicate that it is possible to model an entire coastline in terms of sediment flux. Perhaps the single largest contribution this past year has been improvements in the model HydroTrend in predicting the sediment flux to the ocean from ungauged and paleo basins.

IMPACT/APPLICATIONS

New numerical tools allow for predicting the burial of channels carved into the seafloor during times when the sea level was as much as 120 m lower than observed today. Because these tools are driven by environmental data they offer the promise to provide seafloor acoustical information of continental margins at the global level.

TRANSITIONS

Two Geoclutter meetings held in the fall of 2001 (Halifax NS; Arlington VA) provide the first forum to educate the acoustic community of our data and approaches to predicting the location and burial depth of channels on continental shelves.

RELATED PROJECTS

ONR STRATAFORM: Scaling and Integration of Process-Response Stratigraphic Models.
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.

PUBLICATIONS

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