Sediment Flux to the Coastal Zone: Predictions for the Navy

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LONG-TERM GOALS

Determine the magnitude, seasonality, and geographic distribution of mine burial rates, as a function of landward and seaward forces. The central premise is that the nature of upland drainage basin characteristics (including human forcings) defines the spatial distribution, timing, frequency and intensity of river-dominated fluxes of suspended sediments. Develop a set of quantitative estimates of continental-scale suspended sediment flux that can be derived from currently available global biogeophysical data sets. Determine the accuracy of these simulated outputs through comparison to measured fluxes.

OBJECTIVES

1. Develop a compendium of global and regional databases in a GIS system. Optimize for sediment flux analysis (e.g. high-resolution river networks, geological maps of source areas, ocean currents, wind vectors).

2. Develop an approach that is global in scope for determining the potential burial rate using "quick look models".

3. Develop burial models at the regional scale, at specific locations, after consulting synoptic models. These models should provide reliable forecasts based on coupled-processes including meteorological and oceanographic conditions of river discharge, wind, waves, tides, and coastal currents, and their duration and variation for coastal areas.

4. Evaluate the seasonal to decadal large-scale seabed deposit cycles through an exploration of inter-annual variability and controls of continental transports.

APPROACH

A) Develop an approach to predicting the flux of sediment from land to the sea at 1/2°

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14. ABSTRACT

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15. SUBJECT TERMS

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cells for the global coastline. Develop an approach to predicting sediment-dispersal patterns at 1/2° cells.

a) <u>Annual mean conditions</u> (with interannual variations). Describe the coastline in terms of low, medium and high sedimentation rates, with an analysis of the factors causing these spatial variations.

b) <u>Seasonal influences</u>. A coastal environment may experience one or more seasons where ocean conditions are stable, and river discharge is low. Other possibilities include: 1) high flux of sediment, calm ocean conditions; 2) low sediment flux, stormy conditions; and 3) high sediment flux, stormy conditions.

c) <u>Extreme events</u>. Develop a mine-burial probability density function, through an examination of flood potential for major seafloor perturbations. For example, the Eel River in 1964 discharged more sediment in 3 days than the previous 8-yr. combined. In contrast, the Amazon River has small annual and interannual variability in terms of sediment flux to the Atlantic Ocean.

d) <u>Influence of man</u>. Develop models that will include the effect of man on discharge to the coastal zone, for example the sediment load to the China Sea when the Three Gorges Dam comes on line.

WORK COMPLETED

During the initial start-up phase of the project during 2000-2001 we have focused on database and tool development. We have capitalized on the GIS-based drainage basin characterization system for upland drainage basins developed by the UNEP/Global Environmental Monitoring System-Water Program, the International SCOPE Nitrogen Project, the International-Geosphere-Biosphere Program's Biospheric Aspects of the Hydrological Cycle Core Project (IGBP-BAHC), and the newly formed Global Change Programs Water Group. We now have 20 classes of spatially distributed data sets that can be used to quantitatively describe each of more than 6000 individual drainage basins in our global data compendium at 30' (longitude x latitude) spatial resolution.

To determine the hydrographic state of the world's continents, we have assembled and analyzed global-scale river discharge data sets, since these physical fluxes are necessary precursors for sediment flux estimates. Collaborative work with the World Meteorological Organization's Global Runoff Data Center (GRDC) has yielded a high-resolution runoff/discharge climatology data set for the entire non-glacierized landmass of the Earth (Fekete et al. in review). We have also obtained the GRDC archive, which can be used, in our ongoing analysis. We developed computer codes to assemble each day the entire near-real time archive of the US Geological Survey. This will support our efforts at developing fine-scale models over the data-rich USA. The use of discharge data to analyze sediment and other constituents in river plumes in conjunction with satellite ocean color sensors was also assessed (Salisbury et al. 2001).

As part of our commitment to make this data available to a broad user community, we have also mounted on our WWWeb site (www.watsys.sr.unh.edu) numerous regional databases for river discharge. A CD-ROM of a database of Arctic regional discharge records (Lammers et al. 2001) has been sent for distribution to the National Snow and Ice

Data Center (Boulder). We have contributed to a strategy for establishing a global network of hydrographic monitoring stations through GCOS/GTOX/HWRP (Fekete and Vörösmarty 2000) and a call-to-action to the community (IAHS Ad Hoc Committee on Global Water Sets 2001).

We have developed an appropriate typology of river systems by which we can take information on well-monitored basins and extrapolate to more poorly understood areas of the globe. We recently published a paper describing a new typology for mountain systems of the Earth (Meybeck et al. 2001), which are of course important source areas for sediment. Another methods paper outlines our method for re-scaling river networks from any finer resolution to a more coarse scale (Fekete et al. 2001), an important capability that will allow us to "telescope" to an appropriate resolution for different purposes (i.e. when analyzing local/regional patterns vs. continental/global). In addition, we presented a strategy (Vörösmarty and Peterson 2001) for developing macro-scale models of constituent flux to the coastal zones of the world.

We have set up relational and spatial databases that facilitate the process of data acquisition, and determine a streamlined procedure to link these databases. Of the several input parameters required to drive the model *Hydrotrend* (Syvitski and Morehead, 1999; Syvitski et al., 1998), we have established methods to derive 70 percent of them in an automated way. Listed below are the different types of inputs needed for Hydrotrend with the corresponding resources we are using to derive them.

Climate Data: Temperature and precipitation parameters are derived from three databases: NOAA NCDC Global Daily Summary, NOAA NCDC GCPS Monthly Station and NOAA NCDC Daily Globalsod (Baker et al, 1994). The Global Daily Summary CD-ROM provides temperature and precipitation data for 10,000 stations from 1977-1991. The other two resources are online databases that offer daily and monthly mean values of temperature and precipitation for over 10,000 stations from 1994-1999 for the daily values and from 1697-1995 for the monthly values. While the first dataset is provided on a CD-ROM, the other two are geo-spatially formatted and accessed via the Distributed Oceanographic Data System (DODS)—developed by the University Center for Atmospheric Research. DODS allows a client, user, to remotely access data from DODS servers. Through DODS, the server-side data format is translated to the users' software data format. In our case, this means that the temperature and precipitation values are accessed as an IDL structure, facilitating the process of data acquisition and manipulation.

Lapse Rate data: NCEP Reanalysis data—provided by NOAA-CIRES Climate Diagnostics Center—is used to supply temperature values at 17 different pressure level surfaces on a 2.5 x 2.5 degree grid. This data is also accessed via DODS and manipulated in IDL to derive global lapse rates.

Basin topology: Hydro1k basin, stream and flow direction grids are available at 1 km resolution and are used to determine basin boundaries and topology. Pertinent information about specific basins is extracted through ArcInfo and transferred into

Rivertools, where input parameters such as hypsometric integral and basin length will be calculated. As the automated procedure is further developed, IDL will also serve as a translator between the basin data and the information needed by DODS to query the NCDC and NCEP sites.

Glacier Data: Glaciologist Mark Dyurgerov contributed an Excel formatted database of global Equilibrium Line Altitude (ELA) data. This data will be used to create a GIS grid of coverage of global ELA values.

Groundwater parameters: An IGBP-DIS dataset (Global Soil Data Task, 2000) will be used to generate groundwater parameters. This data is supplied on a 5 x 5 arc-minute, ASCIIGRID format.

Our methodology is motivated by the goal of creating an integrated system for a global application of *Hydrotrend* that requires the least amount of user input. We have established a DODS client on IDL to facilitate extracting climate and lapse rate data. Hydro1k is used to create coverage of stations within a given basin so as to query the DODS servers with the corresponding IWMO station identification numbers and geographic coordinates. The information from the query is then formatted in an IDL structure and used to derive input parameters. Subsequent temperature and precipitation values will be incorporated from the NOAA Global Daily Summary CD-ROM, in order to augment the time-scale from which statistical measurements are made. In addition to climate and topological data, we have also gained access to soil and glacier databases, which will be incorporated into the network of derived parameters.

RESULTS

Three recent papers describe our efforts to develop a database suitable for use in generating "quick look" products. The first two (Vörösmarty et al. 2000a,b) describe the development and validation of our baseline 30' data product (available at www.watsys.sr.unh.edu). We have stressed the development of a well-documented and carefully checked product. These papers also define the nature of land-to-sea linkages as well as the fundamental geomorphometric characteristics of the system of rivers at 30' spatial scale. Of relevance to this project is the analysis of quantitative differences among river systems for coastward discharges of water and sediment. For example, from a continental (land-based) perspective, the landmass of the Earth is drained directly by low-order rivers, which serve as the source areas for most of the world's runoff and constituents. However, from a coastal zone viewpoint, most of the land mass delivers freshwater and sediments via much larger river systems with considerable processing along major river corridors.

To better quantify the human impact on sediment flux, we developed a framework for routing sediment through river basins with simultaneous consideration of siltation in artificial impoundments and the influence of anthropogenic water consumption through activities such as irrigation (Vörösmarty et al., in review). It is estimated that at least 30% of sediment is trapped through modern reservoir-building by humans. We also

published a synthesis paper on anthropogenic disturbance of the water cycle (Vörösmarty and Sahagian 2000) which was found to be significant in terms of distorting continental runoff, and hence sediment flux.

A new numerical approach (*HydroTrend*, v.2) allows the daily flux of sediment to be estimated for any river, whether gauged or not. The model can be driven by actual climate measurements (precipitation, temperature) or with statistical estimates of climate (modeled climate, remotely-sensed climate). In both cases, the character (e.g. soil depth, relief, vegetation index) of the drainage terrain is needed to complete the model domain. The *HydroTrend* approach allows us to examine the effects of climate on the supply of sediment to continental margins, and the nature of supply variability. A new relationship is defined as: $Qs = f(\psi)\overline{Qs}(Q/\overline{Q})^{\bar{c}\pm\sigma}$ where $\overline{Qs}$ is the long-term sediment load, $\overline{Q}$ is the long-term discharge, $\bar{c}$ and are mean and standard deviation of the inter-annual variability of the rating coefficient, and ψ captures the measurement errors associated with Q and Qs, and the annual transients, affecting the supply of sediment including sediment and water source, and river (flood wave) dynamics. F = F(ψ, *s)*. Smaller-discharge rivers have larger values of *s*, and *s* asymptotes to a small but consistent value for larger-discharge rivers. The coefficient $\bar{c}$ is directly proportional to the long-term suspended load $(\overline{Qs})$ and basin relief (*R*), and inversely proportional to mean annual temperature (*T*). is directly proportional to the mean annual discharge. The long-term sediment load is given by: $\overline{Qs} = \overline{CsQ} = \alpha H^{3/2} \mathring{A}^{1/2} \mathbf{T}$ where is a global constant, *H* is maximum relief; *A* is basin area; and $\mathbf{T} = 0.2 \bullet 10^{0.0578(T)}$. This new approach to providing estimate of sediment flux at the dynamic (daily) level provides us a means to experiment on the sensitivity of marine sedimentary deposits in recording a paleoclimate signal. In addition the method provides us with spatial estimates for the flux of sediment to the coastal zone at the global scale.

IMPACT/APPLICATIONS

New numerical tools are being refined to allow for predicting the flux of sediment to the littoral zone. Because these tools are driven by environmental data they offer the promise to provide seafloor information of continental margins at the global level.

RELATED PROJECTS

ONR Geoclutter: Predicting the Distribution and Properties of Buried Submarine Topography on Continental Shelves.
ONR STRATAFORM: Scaling and Integration of Process-Response Stratigraphic Models.
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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