CSDMS 2010 Meeting Abstracts

EVOLUTION OF GNARLY ROCKY HILLSLOPES

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Hillslopes in rugged alpine landscapes tend to be very rocky, with shallow soils and occasional outcrops. These important landforms present a modeling challenge in that they reflect the influences both of changing boundary conditions in the bounding streams, and of non-uniformity of the susceptibility of the bedrock to weathering and transport. Inspired by the landscape of the Boulder Creek Critical Zone Observatory, we present preliminary models of hillslopes in which we attempt to address these complexities. As a tool for interpretation of the landscape, we include model algorithms for the evolution of the 10Be concentrations both in the emerging bedrock and in the mobile regolith. In 1D models we attempt to mimic the blocky nature of the crystalline basement by specifying the block size and rules for the probability of release of the block that include effects of block size and the geometry of the niche in which it sits. We see that local hillslope divides migrate to ward sites of coarsely jointed rocks. In 2D models, variability of susceptibility to weathering is reflected in bedrock outcrop patterns on steep hillslopes. Regolith is steered around these outcrops, generating sinuous regolith pathways off the landscape. While periods of rapid entrenchment of the bounding stream can result in bedrock outcrops near the stream, periods of aggradation can result in a ponding of regolith on the footslopes that can deepen considerably above the mean. In the future, we will also explore 1) the roles of water routing in these landscapes, with attendant impacts on the weathering rates in the subsurface, and 2) the roles of all-important tree-cover in the landscape, which displays both asymmetry with respect to slope aspect, and temporal variation on timescales that are short relative to the timescales of change of hillslope shape.

THE REGIONAL OCEAN MODELING SYSTEM (ROMS): ALGORITHMS AND APPLICATIONS

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ROMS is an open-source, mature numerical framework used by both the scientific and operational communities to study ocean dynamics over a wide range of spatial (coastal to basin) and temporal (days to seasons, inter-annual) scales. It includes a sediment-transport model and several biogeochemical models with increasing ecological complexity.

ROMS is unique in that is the only community framework including the adjoint-based analysis and prediction tools that are available in Numerical Weather Prediction (NWP), like 4-dimensional variational data assimilation (4D-Var), ensemble prediction, observations sensitivity and impact, adaptive sampling, and circulation stability and sensitivity analysis.

An overview of ROMS framework capabilities to simulate and predict the coastal environment will be presented. Fine resolutions coastal applications are possible via multi-grid nesting and multi-model coupling.

COUPLING BETWEEN COASTLINE AND FLUVIAL DYNAMICS

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The morphology and depositional history of wave-influenced deltas reflects the interplay between the terrestrial and coastal domains. Applications of the Coastal Evolution Model (CEM) to deltaic environments using a simple, fixed location and constant rate riverine sediment source yield a range of interesting delta behaviors observed in nature, demonstrating that wave approach angle can have a first-order impact on delta shape, affecting both progradation rates and leading to the development of depositional asymmetry. To better integrate fluvial processes, we will discuss two related projects that couple fluvial and coastal models. The first project involves the one-way coupling of HydroTrend with CEM to capture how changes in sediment input rates, potentially due to natural variability, climate change, and anthropogenic impacts, affect delta evolution. These simulations are being used to understand how anthropogenic impacts and climate change may have have affected the evolution of the Ebro River, Spain. The coupling between these models, however, is one-way, and does not represent the important phenomenon of river avulsion. We will present preliminary results from the two-way coupling of SedFlux with CEM using, investigating how sediment redistribution by waves influences the river avulsion. An important element of this two-way coupling is implementation of dynamic fluvial avulsion within the SedFlux model. The coupled models can be used to investigate how sediment redistribution by waves affects the timescales and location of river avulsion. These preliminary model experiments demonstrate how two-way model coupling using the CSDMS architecture can be used to investigate the dynamics of systems at the intersection of different process realms.

EXPLORING THE CONTROLS ON PERMAFROST COASTAL BLUFF RETREAT RATE, NORTH SLOPE, ALASKA

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The arctic is a region where modern surface warming has had significant effects on geomorphological processes. Along the Beaufort Sea coastline bounding Alaska's North Slope, the mean annual coastal erosion rate has doubled from ~7 m/yr for 1955-1979 to ~14 m/yr for 2002-2007 (Mars and Houseknecht, 2007). Locally the erosion rate can reach 30 m/yr, with short-term rates that are far greater than this. A robust understanding of the processes that control the rate of coastal erosion is required to predict response to a rapidly changing climate, with implications for sediment and carbon fluxes, oilfield infrastructure, and animal habitat.

We model the evolution of the permafrost bluffs on the North Slope, constrained by time lapse imagery, and by measurements of both the oceanic and atmospheric setting. During the sea ice-free season, relatively warm waters melt a notch into the ice-rich silt that comprises the bluffs. The bluffs ultimately fail by toppling of polygonal blocks bounded by mechanically weak ice-wedges. The toppled blocks then temporarily armor the coast against further attack. The annual retreat rate is controlled by the length of the sea ice-free season, water and air temperatures, and the wave history. Our model is forced by air temperature, water temperature, water level, and wave period, and is validated using field and remote sensing observations over a variety of timescales. The model is then used to explore the expected changes in coastal retreat rates for various climate change scenarios that include increases in the duration of sea-ice free conditions, warming ocean temperatures, and changes in storm frequencies.

MODELING FLOODPLAINS AS A DYNAMIC SOURCE/SINK TERM IN WATERSHED SEDIMENT BUDGETS

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Sediment pathways through drainage networks are poorly understood. Especially difficult to constrain are the rates and mechanisms of sediment exchange between the channel and floodplain over short and long timescales. Lack of predictive models for channel-floodplain interaction limits our ability to constrain sediment budgets with sufficient precision to meet water resource management needs. Specifically, channel-floodplain exchange is critical to understanding how sediment source contributions from the watershed relate to sediment flux measured at a given location, as well as the lag times that might be expected between changes in upland management (e.g. implementation of BMPs) and improvements in water quality. The National Center for Earth-surface Dynamics (NCED) and Barr Engineering Co. (Barr) have collaborated to develop an easily applied code and graphical user interface within ESRI ArcMap software for extraction of morphological information about floodplains, as well as prediction of floodplain inundation and sediment deposition. The tool combines flow duration data with high-resolution topography and field measured cross-sections to extract floodplain inundation and valley-bottom hypsometry. We have applied this tool in the context of developing a sediment budget for the Le Sueur River watershed, southern Minnesota. Specifically we use the tool to predict the duration of floodplain inundation under several hydrologic conditions that are relevant to understanding floodplain storage as a temporary sink term in the watershed sediment budget. Thus, the results from this tool will prove valuable for development and implementation of watershed management plans. The code for the tool is open source and could be used to provide input data for NCED's sediment routing model as well as other CSDMS models focused on sediment dynamics at the channel network scale.

VARIATIONS IN SEDIMENT-TRANSPORT BETWEEN DIFFERENT DISPERSAL BASIN GEOMETRIES: A CASE STUDY OF POVERTY BAY, NEW ZEALAND

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Poverty Bay is a significant part of the Waipaoa River sedimentary dispersal system. It has acted as a sediment sink over the past 7,000 years, and processes within the bay significantly modify the fluvial sedimentary signal en route to the continental shelf. Through numerical modeling experiments, we investigated the role that basin geometry and river mouth configuration play in sediment retention within and export from Poverty Bay. The SWAN model coupled to the ROMS estimated wave characteristics, current velocities, and sediment-transport within Poverty Bay. Three different bay geometry and river mouth orientations were investigated: (1) the modern bay, (2) the modern bay circa 2 kya when the river mouth discharged at the bay's northern end, and (3) about 7 kya when the shoreline was 12 km landward of its present position. Simulations of a winter season and a 40 year

recurrence interval storm were conducted using modern and pre-anthropogenic sediment loads to determine the wave energy and sediment-transport dynamics.

Dispersal patterns were sensitive to river mouth and shoreline location. The wave sheltering generated by basin geometry was the most dominant control on sediment dispersal. Wave height on an along-bay transect of the 7 kya bay was inversely correlated with shoreline progradation rate along the same transect. Higher wave energy and proximity between the river mouth and continental shelf in the modern and 2 kya bays, compared to the 7 kya bay, lead to an increased export of sediment and coarser sediment supplied to the shelf. Relative to the modern bay, the 7 kya bay was less effective at segregating sediment by size and retained more sediment, potentially fueling the increased rate of shoreline progradation compared to that occurring more recently.

STRATEGIES FOR DEVELOPMENT AND EVOLUTION OF A COMMUNITY MODELING SYSTEM: A MUTISCALE, MULTISTATE FRAMEWORK

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The water cycle is often presented in terms of a simple concept, understandable in principal but with huge uncertainty in spatial and temporal detail. Our ability to accurately predict the distribution, availability, variability and quality of water is limited by the complex interaction of different hydrologic processes, and disparity of environmental data that defines the relationship among these processes. Hydrologic models have evolved from empirical to lumped to distributed in terms of parameter and process representation. The Penn State modeling system is a physics-based integrative strategy that attempts to deal with the data-model complexity. PIHM (Penn State Integrated Hydrologic Model) represents our approach for the synthesis of multi-state, multi-scale distributed hydrologic models using the integral representation of the underlying physical process equations and state variables. PIHM is open source that allows it to evolve in terms of process representation and adapting to any particular modeling needs on source code level. The object oriented data structure provides flexibility to incorporate new processes.

Physics based distributed hydrologic model require extensive process of data acquisition, manipulation, and assignment. Steps involved in setting up a model require (1) acquiring different geo-hydrologic data such as climate, terrain, soil coverage, geology, land use and land cover (2) parameter assignment to the model kernel using the data described earlier (3) model simulation and analysis of model simulated results. PIHMservices provides a web based interactive user interface to obtain national dataset (a) USGS DEM (b) SSURGO Soil (c) NLCD 2001 Land cover and (d) NLDAS-2 climate forcing parameters for any area in the continental United States. Often, geo-hydrologic data are available in GIS format. PIHMgis has been developed as a 'tightly' coupled GIS interface to PIHM based on a shared data model. PIHMgis facilitates a procedural framework for efficient domain decomposition; seamless data transfer from the geo-database and data assignment. It also allows models simulation and visualization of model-simulated results.

The research also discusses various applications of PIHM in different hydrologic settings to investigate process coupling and dynamics of hydrologic processes to evaluate the ability to predict various hydrologic states and fluxes.

STATE OF THE ART CARBONATE FORWARD MODELLING: HISTORY, PROGRESS AND RECENT DEVELOPMENTS

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Carbonate systems have been a subject of morphodynamic forward model development since the late 1980s. During that time carbonate morphodynamic models have focused on carbonate platform geometry, spatial distribution of carbonate sediment production, carbonate platform interior stacking patterns, and early diagenetic alteration of carbonate strata. These models they have generated much new insight into how carbonate depositional and diagenetic processes work, and evolved from simple 1D models to more complex pseudo-3D representations of multiple interacting carbonate processes. Perhaps most importantly however, these models have helped establish that carbonate strata are the product of complex interactions between biological, chemical and physical processes, and that these interactions maybe responsible for much of the heterogeneity observed in carbonate strata. Based on these findings, and given the limits of existing carbonate models, there is a growing requirement for a next-generation forward modeling system to represent and study in more detail the process interactions leading to heterogenous carbonate strata. Defining and meeting this requirement is a key aim of the carbonate focused research group which is currently working to address this gap in numerical modeling capability and provide prototype forward modeling tools and related databases to better understand heterogeneity in carbonate strata.

DOUBLE-DIFFUSIVE AND GRAVITATIONAL INSTABILITIES IN PARTICLE-LADEN RIVER OUTFLOWS

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When a sediment-laden river flows into the salty ocean, various instabilities may arise. In an initially static environment, these instabilities can be due to either double-diffusive or gravitational effects. As a function of the governing Peclet numbers and the particle settling velocity, we investigate via linear stability analysis under which conditions each instability mode dominates, and when the modes coexist. We find that the settling velocity has a non-monotonic effect on the temporal instability growth rates. While small settling velocities can serve to increase the growth rate of the instability, larger settling velocities are found to reduce the growth rate.

TAKING IT TO THE STREETS: THE CASE FOR MODELING IN THE UNDERGRADUATE CURRICULUM

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The United States faces a crisis in education: a dire shortage of students sufficiently prepared in the STEM (Science, Technology, Engineering and Mathematics) disciplines to competitively enter the workforce. At the same time, there is increasing demand for well-trained Earth scientists in a variety of careers related to the environment and natural resources. Many efforts, including the recently released Earth Science and Climate Literacy Principles, seek to promote better Earth Science education, as well as to strengthen the Earth science literacy of the entire US population. Yet even those undergraduate students who choose to major in Geology or related Earth science disciplines rarely acquire sufficient quantitative skills to be truly competitive graduate students or professionals. Experience with modeling, during their undergraduate careers can greatly increase the quantitative literacy of Earth science majors and help them appreciate the real world applicability of mathematics and computational methods in their future careers in the Earth sciences.

NUMERICAL MODELLING OF HYDRODYNAMICS AND EROSIONAL POWER IN THE FLY RIVER DELTA, PAPUA NEW GUINEA

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A two-dimensional numerical model is used to study tidal hydrodynamics and distribution of bed shear stresses in the Fly River Delta, Papua New Guinea. The model describes the propagation of the tidal wave within the delta and along the lower Fly river. Model results indicate that tidal discharge at the mouths of the distributary channels is between 10 and 30 times larger than the river discharge, and that the upstream part of the delta is flood dominated, whereas near the mouth the delta is ebb dominated. Numerical simulations allow us to investigate the sensitivity of fluxes and bottom stresses with respect to variations of sea level and area of delta islands. The results suggest that a decrease in the total area of the delta occupied by islands increases the tidal prism and, therefore, bed shear stresses. Similarly, an increase in sea level reduces the dissipation of the tidal signal and speeds up the propagation of the tidal wave within the delta, thus yielding higher discharges and increased bed shear stresses.

WEATHER RESEARCH & FORECASTING MODEL (WRF) FOR SURFACE DYNAMICS AND ENVIRONMENTAL CHANGE STUDIES

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Keynote Presentation

MODELING GLOBAL SCALE SEDIMENT FLUX, A NEW COMPONENT IN THE SPATIALLY DISTRIBUTED FRAMEWORK FOR AQUATIC MODELING OF EARTH SYSTEM (FRAMES)

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The Framework for Aquatic Modeling of Earth System (FrAMES) is a spatially and temporally explicit multi-scale (local through global) hydrological/biogeochemical modeling scheme. It is an ongoing interdisciplinary project allowing predictions of changing material flux from major continental rivers in response to changing environmental conditions. Here we present an initial evaluation of a new component within this framework, a spatially explicit sediment flux model. We expend the BQART sediment flux model from point (river outlet) to distributed (pixel) scale by integrating it into the WBM_{plus} continental hydrology model. BQART is an analytical model describing the empirical relationship between basin geomorphic (area and relief), climatic (temperature and precipitation), geologic (lithology and ice cover) and human (reservoir and soil erosion) characteristics and short and long-term sediment flux. WBM_{plus} is a spatially explicit model describing varying components of global hydrological cycle. We integrate BQART into WBM_{plus} for two main reasons: (1) WBM_{plus} include most of the spatially and temporally explicit input data needed for distributed BQART and (2) WBM_{plus} has already been implemented and used as part of the FrAMES platform. We validate the new model by

comparing its distributed sediment flux predictions to measured fluxes at both river mouths and tributaries.

NUMERICAL SIMULATION OF MEANDERING EVOLUTION

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Two-dimensional depth-averaged hydrodynamic model is developed to simulate the evolution of meandering channels resulting from the complex interaction between downstream and secondary flows, bed load and suspended sediment transport, and bank erosion. The depth-averaged model calculates both bed load and suspended load assuming equilibrium sediment transport and simulates bank erosion with a combination of two interactive processes: basal erosion and bank failure. The mass conservation equation is solved to account for both vertical bed elevation changes as well as lateral migration changes when sediment is removed through basal erosion and bank failure. The numerical model uses deformable elements and a movable grid to simulate the gradual evolution of a near-straight deformable channel into a highly sinuous meandering channel. The model correctly replicates the different phases of the evolution of free meandering channels in experimental laboratory settings including: (1) downstream and upstream migration; (2) lateral extension; and (3) rotation of meander bends.

MORPHODYNAMIC MODELS OF DELTAS

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Predictions of delta response to various external forcings are needed now, yet our modeling capabilities are quite inadequate, and particularly so in the United States. Predicting a delta's response to relative sea level rise or a change in water or sediment discharge requires a model complex enough to compute morphodynamic adjustment of a multi-channel network. This includes changes in channel width, depth and friction factors, overbank flows, avulsions, mouth bar formation and destruction, and possibly even sediment critical shear stress evolution due to vegetation changes. This is a grand challenge for CSDMS. As an illustration of these challenges, we will present examples of deltas computed by Delft3D-Flow, a morphodynamic model from Deltares.

CLIMATE CHANGE IMPACT: WHAT DO WE NEED TO MODEL AND HOW DO WE BEST DO IT?

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The impact of climate change is typically and iconically characterized as an increase in temperature or precipitation. These global and necessarily coarse resolution outputs from general circulation models are then used to generate "climate change scenarios" which are used to assess the response of impacted systems (often qualitatively). This is a flawed single approach for several reasons: 1. downscaling is difficult, 2. temporal information is generally lacking, 3. results are limited to emissions scenarios that are themselves outdated and possibly flawed, and perhaps most significantly, 4. the response of environments to climate change is likely to be non-linear, such that probability distributions of climate change will not map simply onto the probability of impacts. A useful and

responsible assessment of climate change impacts requires the development of a fully coupled, high-resolution, in spatial and temporal scales, environmental sensitivity model (i.e. an LEM at short time scales that incorporates as many processes as are necessary). Some progress has been made in parts of our broad community and in parts of the environment, but there is a need for a concerted and integrated effort if we are to go beyond the iconic image of climate change impact.

THE UNIVERSITY OF OKLAHOMA'S COUPLED ROUTING AND EXCESS STORAGE (CREST) HYDROLOGIC MODEL

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The University of Oklahoma (OU) Remote Sensing Hydrology Group (RSHG) is developing the Coupled Routing and Excess Storage (CREST) hydrologic model for global and local flood prediction. An overview of the principles and motivation behind the development of CREST will be given. Followed by results from historical reruns of CREST which show improvement over the first generation global flood model. Operational usage of CREST which is currently running in real time globally with a 1/8th degree grid resolution forced with TRMM Multisatellite Precipitation Analysis (TMPA) will be highlighted. Additionally, CREST has been used for targeted flood prediction on the Nzoia river basin in Kenya. MODIS and ASTER flood inundation maps have been used for the calibration of CREST over the Nzoia basin in an experiment to show that orbital sensors providing the spatial extent of flooding can provide valuable information to hydrologic modelers. Initial case study results on the applicability of CREST to CONUS flash flood prediction will also be shown for three flash flood events which caused death and destruction in the United States during 2010.

APPLICATION OF CSDMS TO CHESAPEAKE BAY MODELS

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Keynote Presentation

COMPUTER SIMULATIONS OF SELF-ORGANIZED MEGARIPPLES IN THE NEARSHORE

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Megaripples are bedforms with heights of 20-50 cm and lengths of 1-10 m that are common in the surf zone of natural beaches. They affect sediment transport, flow energy dissipation, and larger-scale hydro- and morpho-dynamics. They are thought to be dynamically similar to bedforms in deserts, rivers, and deeper marine environments. Here, a self-organization model (similar to models for subaerial bedforms) is used to simulate the formation and development of megaripples in the surf zone. Sediment flux is determined from combined wave and current flows using stream power (Bailard 1981) and bed shear stress (Ribberink 1998) formulations as well as a third formulation for transport based on simple rules which represent sheet flow. Interestingly, the transport formulation has little effect on model results. Random bed irregularities, either imposed or resulting from small variations in transport representing turbulence, are seeds for bedform development. Feedback between the bed and the flow in the form of a shadow zone downstream of a bedform and increasing flow acceleration with elevation over the crests of bedforms alter the transport such that organized bedforms emerge. Modeled bedform morphology (including cross-sectional shape and plan view) and dynamics (including growth and migration) are similar to natural megaripples. The model can be used to extend the field observations of Clarke and Werner (2004) which suggest that, if conditions remain the same, megaripples will continue to grow. Contrary to many bedform models (e.g., Hulscher et al. 1996, Nielsen 1981, Clifton 1976, Wiberg and Harris 1994), this model supports the idea that bedform spacing grows continually. At this time the model is being extended in an effort to predict co-existing bedforms of multiple scales in the combined flows (including steady, tidal, wave, and wave driven currents) of river mouths and tidal inlets.

USING THE CHILD MODEL TO CONSTRAIN THE TIMING OF UPLIFT AND NATURE OF FLUVIAL PROCESSES IN THE DADU RIVER, CHINA

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We use the CHILD model to explore two intertwined questions in the Dadu River, China: 1.) What river incision model most closely recreates the observed channel profile and erosion patterns? and 2.) What is the uplift history of the area? The Dadu River is incising into low relief, relict topography and becomes more deeply incised downstream, implying a downstream increase in erosion rates. Further, detrital cosmogenic concentrations from Dadu tributaries indicate a similar pattern of erosion rates. Interpretation of thermochronological data suggests that uplift rates increased dramatically between 9 and 13 million years ago, resulting in 4 km of uplift. We use the CHILD model along with channel profile data and erosion and uplift constraints to gain further insight into the evolution of this region. We explore numerous modeling scenarios, including both spatial and temporal patterns in uplift and various fluvial incision models. Our results suggest that the Dadu is experiencing a transient wave of erosion, rather than a spatial pattern of uplift. In order to sustain the transient signal over 9 – 13 million years, uplift rates likely started low and increased in time. Although the current Dadu channel has many large landslide deposits, we find that sediment-flux erosion models do not create transient profiles similar to that of the Dadu. Only the stream power incision model can recreate the large knickpoint that is currently present in the Dadu. Further, the incision model must have a slope exponent value that is less than one to match the patterns and values of Dadu channel gradients. Lastly, we find that a mixed transport-limited/detachment-limited model fits the observed channel profile and erosion patterns slightly better than the detachment-limited model alone, but it is difficult to decisively discern between the two process models.

NUMERICAL MODELING OF WAX LAKE DELTA

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Wax Lake Delta (WLD) is a small fluvial-dominated delta in the western part of the Mississippi Delta Complex. Since it began forming in the 1940s, WLD has been well studied (Fisk (1952), Roberts et al. (1980), van Heerden (1983)), resulting in detailed knowledge of its bathymetry, seasonal flow rates, and sediment composition. Abundant vibracore data, coupled with a suite of orthorectified aerial photographs, provide detailed knowledge of the morphologic evolution and the development of internal stratigraphic architecture for WLD (see Wellner et al. (2005)). As a result, numerical simulations of the evolution of this delta can be reasonably well-constrained in terms of initial and boundary conditions. The ExxonMobil process-based forward model was applied to the WLD scenario. This model couples a shallow water flow solver and equations of sediment transport to a 3D basin model. Using topography from 1942 and multiple flow scenarios, the simulations produced sedimentary bodies with similar morphologic expression to those found in WLD. Synthetic cores show qualitative agreement with vibracores taken in representative locations. These simulations also provide a direct link between fluid flow and the formation of sedimentary bodies, yielding insight into the physical mechanisms underlying the evolution of delta morphology.

INTEGRATING OROGRAPHIC PRECIPITATION INTO THE CHANNEL-HILLSLOPE INTEGRATED LANDSCAPE DEVELOPMENT MODEL (CHILD)

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Although some studies suggest that orographic precipitation should affect river discharge, erosion patterns and channel profiles in mountainous regions, most modeling studies still assume uniform precipitation as the driver of channel evolution. We have relaxed this assumption by integrating a linear orographic precipitation module into the Channel-Hillslope Integrated Landscape Development Model (CHILD). Wind direction is an important parameter controlling the movement of air masses across the landscape in the precipitation model. We incorporate a linear interpolation method across the triangular irregular network (TIN) in CHILD in order to track the movement of moisture and calculate precipitation rates. We present a series of simulations that contrast landscape development with and without orographic precipitation. Wind direction and the nondimensional delay time in the orographic precipitation model are the two main parameters impacting the rainfall and erosion patterns. Furthermore, there are a number of feedbacks between precipitation and topography. High topography can lead to higher precipitation rates, but higher precipitation rates lead to higher erosion rates and changes in the relief and concavity of channels. In a steady-state mountain range, channels are more developed and concave on the windward side than on the lee side, and the main drainage divide is displaced from the center of the domain to the lee side. Finally, we explore how vegetation growth may buffer the effects of orographic precipitation by reducing runoff and erosion rates in areas with high precipitation rates.

COUPLING SEDIMENT DYNAMICS AND BIOGEOCHEMICAL MODELS WITHIN ROMS WITH APPLICATION TO THE LOUISIANA – TEXAS SHELF

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The Regional Ocean Modeling System (ROMS) contains modules for both sediment transport and biogeochemistry. To date, however, these components have operated independently. Within the

biogeochemistry model of Fennel (2006), for example, processes occurring within sediment have been represented using a simplifying assumption whereby material instantly demineralizes once it settles to the sea bed. This therefore neglects the role played by burial and diagenesis in biogeochemical cycles. The incorporation of organic matter within the sediment matrix implies that, besides undergoing degradation there, it could be subject to burial, consolidation, resuspension, and redistribution through processes that are treated within the sediment transport model. To address this gap within the biogeochemical model, we are coupling the sediment transport routine to the biogeochemical model within ROMS. Examples from a one-dimensional test case will demonstrate recent progress within this project. Ongoing efforts are adding biodiffusion of both particles and dissolved matter to the sediment bed model. Our eventual goal, once model development has progressed within the one-dimensional framework, is to apply the coupled biogeochemical – sediment model within a physical oceanographic model of the northern Gulf of Mexico.

Within this poster we will present recent one-dimensional (vertical) test cases that include erosion, deposition, and seabed diffusion of particulate and dissolved tracers. Additionally, we will highlight three dimensional model estimates for the dispersal of Mississippi and Atchafalya sediment in the northern Gulf of Mexico under both fair-weather and storm conditions for the year 1993.

REGIONAL-SCALE MODELING OF PERMAFROST DISTRIBUTION IN ALASKA USING THE GIPL-MPI TRANSIENT MODEL

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According to SWIPA (Snow, Water, Ice and Permafrost in the Arctic: An Arctic Council Project) the arctic cryosphere is undergoing dramatic changes. Major factors contributing to this change are sea ice retreat, the melting of the Greenland Ice Sheet and glaciers, permafrost thawing and less snow.
This project addressed permafrost thawing for the State of Alaska. Our goal was to produce a high spatial resolution map of permafrost distribution and dynamics in Alaska for the past, present and future. To achieve this we implemented the GIPL-MPI transient model for the entire Alaska permafrost domain. As a climate forcing we used SNAP (Scenarios Network Planning for Alaska) dataset, which consist of the composite of five IPCC models that performed the best for Alaska. The outputs from these five models have been scaled down to 2 kilometers resolution using the PRISM model (http://www.prism.oregonstate.edu/), which takes into account elevation, slope and aspect. All derived values represent a single month within a given year for the five model composite, for three different emission scenarios. The poster shows modeling results based on boreholes drilled in Alaska. We calibrated GIPL-MPI transient model with past ground thermal development data. Results from downscaled GCM scenarios were used to address possible future ground temperature changes.

BIOGEOMORPHOLOGICAL MODELING

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We are working on improving the modelling capabilities concerning the interaction of flow (optionally waves), vegetation, and morphodynamics for riverine and estuarine applications. This introduces all kinds of interesting questions from small-scale flow-vegetation interaction (including turbulence) to long-term impact on the evolution of the morphology and stratigraphy of rivers and deltas.

STRATEGIC CHOICES IN CARBONATE MODELING

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Numerical models of carbonate sedimentation (NMCS) describe the creation of carbonate essentially from the ambient seawater, on pathways mediated by opportunistic, competing creatures. The carbonate is then subject to dissolution and erosion/transport processes. NCSM tend to be either: (i) rules based, using environmental conditions, or (ii) population ecology based. Looking at (ii) - the second generation NCSM - the general approach is mostly agreed: sets of ordinary differential equations for logistic growth reflect reproduction, competition and mortality under resource limitations. Then growth and calcification rate functions are superimposed. Geologic factors act by varying the resource limitations. But under this there is substantial lack of agreement on ways to proceed. What is the population unit (functional group, dominant species, community)? What are the sharpest resource limitations (light, temperature, stability, sediment)? What type of the competition is in play (prey-predator, for space or nutrients)? How do we treat the various types and timings of reproduction (gamete, vegetative, brooded)? Should a model be verified for stasis first before applying a geological history (such as sea-level change)? Computer code, even high-performance code, is unable to deal with biological levels of complexity. Therefore the question becomes: What is the most effective set of (the above) processes and limitations to model? For example, should the model be general enough to be able to simulate metazoan, algal and bacterial production? What is the most valuable target output for validations against field? How best to encode external events, especially a-periodic extreme events? It is clear that - unlike for clastic models - a Knowledge Base (KB) will have to support the modeling. That KB will hold information and datasets which drive and parameterize biologic characterizations such as reproduction, growth and mortality, and environmental zonations and perturbations. Making that KB will require a great amount of expertise in ecology, focused sharply on the needs of the numerical equations, and encoded in an efficient, machine-accessible way.
Using a prototype model and knowledge base, we explore these strategic questions facing the development of numerical models for carbonate sedimentation.

OIL SPILL RISK ANALYSIS MODEL

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The oil spill risk analysis (OSRA) model, originally developed by Smith et al. (1982), simulates oil-spill transport using realistic data fields of winds and ocean currents. The model plays an essential role in analyzing oil spill risks in the U.S. continental shelf for the U.S. federal government. The model was recently completely updated and improved to meet the new challenges in the oil spill risk analyses. Many things have been changed since the 1980s, including 1) the needs of OSRA customers have changed and increased; 2) the computer hardware and software have been improved and became much more powerful; 3) mathematical methods and computational schemes have made great progress; and 4) our understanding in the oil spill processes and physical oceanography are also greatly improved. The objectives of this study include: 1) Efficiency: the updated OSRA should be more efficient in terms of computational time. Parallel programming methods are needed for this purpose. 2) Consistency: the updated OSRA should be able to produce results that are consistent with our previous analyses. 3) More user-friendly by incorporating GIS tools. 4) Options for including new mechanisms.

The OSRA model is driven by analyzed sea surface winds and model-generated ocean surface currents. Instead of focusing on individual oil spill events, the OSRA examines oil spill risks over long

periods of time (from 5 years to decades) and large spatial scales (up to thousands of kilometers). Also a statistical model, the OSRA model calculates thousands of hypothetical oil spill trajectories over extended areas of U. S. continental shelf and tabulates the frequencies with which the simulated oil spills contact the geographic boundaries of designated environmental resources. An oil spill on the ocean surface moves around by the complex surface ocean currents exerting a shear force on the spilled oil from below. In addition, the prevailing wind exerts an additional shear force on the spill from above, and the combination of the two forces causes the transportation of the oil spill away from its initial spill location.

The newly improved OSRA model is tested on a Microsoft Windows-based workstation with 8 CPUs. The combination of code parallization, code optimization, and I/O optimization has greatly improved the computational efficiency. The new model is now more than 50 times faster than the old one. Applying the model to the Gulf of Mexico using 16 years of winds and ocean currents, we find that the newly improved OSRA model can provide important information on the behavior of oil spills more accurately and efficiently. Ultimately, this information will be used in the pertinent environmental impact studies and in the development of oil-spill response plans.

SEDIMENT DYNAMICS OVER TIGER AND TRINITY SHOALS OFF THE LOUISIANA COAST

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Two oceanographic surveys were conducted at the Tiger-Trinity shoal complex in December 2008 and March-April 2009. Oceanographic Tripods were deployed along a transect for monitoring both wave and currents fields on the shoal and adjacent environment. During the 2008 deployment, which lasted for two weeks and with a single tripod deployed over Tiger shoal, three cold fronts crossed the study area and significantly influenced the hydrodynamics of the region. The maximum wind speed observed was 14.2 m/s while the maximum wave height recorded was less than 1 m. This substantial wave attenuation observed for Tiger Shoal can be attributed to the nature of the bottom sediments. The highly viscous bottom sediments dissipate incoming waves, a phenomenon confirmed by previous studies conducted along this coast. Except for a few instances,, the wave-induced shear stress at the bottom was strong enough to re-suspend sediment, during the entire deployment period. The data from the 2009 deployments are being analyzed and will also be discussed in the presentation. A suit of hydrodynamic models was also implemented, as a preliminary study, to estimate the effect of waves and currents on the shoal dynamics. MIKE 21/3 wave and Hydrodynamic models were implemented for the Tiger and Trinity shoal system. A substantial reduction in wave height was observed seaward off Trinity Shoal. This can be attributed to rapid decrease in slope off Trinity Shoal. Also, our preliminary hydrodynamic model data demonstrated that strong currents existed over the shoal region, which are critical in the redistribution of sediment, although the precise patterns and magnitude are still to be quantified, especially during the winter storm period.

SUFFICIENT CONDITIONS FOR DEVELOPMENT OF VALLEY NETWORKS DOMINATED BY DEBRIS FLOWS

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Simulations of landscape evolution are used to determine the suite of geomorphic transport laws necessary to reproduce key features of observed landscapes where large parts of the channel network appear dominated by debris flow scour. Processes tested include the following: chemical weathering, which reduces rock density at a point; physical weathering, which increases with decreasing rock density and decreases with increasing soil depth at a point; shallow landsliding, which is dependent on topography and root strength for a cluster of points; and debris flow scour, which may affect bedrock and may therefore increase with decreasing rock density. These processes are newly incorporated within the Channel-Hillslope Integrated Landscape Development model (CHILD). Simulations will test whether all of these processes or a limited set are sufficient to produce observations from the Oregon Coast Range: topography, as represented by LiDAR-derived digital elevation models (DEMs); rock hardness, assumed proportional to density; and soil thickness, where the latter two are found in the literature. The latest results from this study will be presented.

A CELLULAR DELTA-BUILDING MODEL WITH PARAMETERIZED CHANNEL PROCESSES

LIANG, MAN (1); Voller, Vaughan (2); Paola, Chris (3)

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In my current research, a rule-based cellular model is being developed to resolve delta growth at large scale, without ignoring the small scale details. Mouth bar process, bifurcation and avulsion are parameterized and occur naturally as the delta grows. Current result shows that with proper setup the model is capable of producing mouth bar and elongated channels. The rule-based water and sediment routing need more physical insights. This model is still at early stage and will continue throughout my PhD. In the past research, a new approach is developed using the analogy with dendritic crystal. To simulate sediment transport with channelization, two sets of rules are introduced as “building” rules and “aging” rules. An unstructured mesh of Delaunay triangulation is used. Each node is assigned several quantities, which include land elevation, sediment amount, etc. These quantities change during the simulation according to the rules. Building rules describe the diffusional process of sediment transport, which are essentially equivalent to a numerical solution of the PDE system describing diffusion of sediment in fluvial delta, or similarly, heat diffusion in dendritic crystal growth, and they develop channels automatically by selecting nodes with the quantity of sediment amount above threshold. Aging rules are applied to the cellular structure of channel networks to regulate channel growth and to mimic the natural process that some channels are filled with sediment after being abandoned. The results are compared to real deltas with fractal geometry analyses in terms of fractal dimension and bifurcation statistics. The agreement is satisfying.

VARIATIONS OF RUNOFF, SOIL MOISTURE, AND NUTRIENTS EXPORT IN NORTH AMERICA DRIVEN BY CLIMATE AND LAND USE CHANGE DURING 1895-2008

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Climate and land use have been suggested as two major factors that control variations of water yield, soil moisture, and water qualities in the world. Landscapes of the North America (NA) have been intensively disturbed or managed by human activities and have been involved in rapid economic development and urbanization in the last century. However, few integrated regional studies had been conducted to characterize how climate variations and climate change, land-use conversions, and land management have affected regional hydrological cycles and water qualities in temporal and spatially domain and further attribute these changes to different driving forces. The magnitude of carbon and nitrogen export from land to aquatic ecosystems and coastal region is far from certain, which has been identified as a major gap in our understanding of the global carbon budget and the predictions of the seasonal hypoxia in coastal estuaries. To quantify the fluxes of water and nutrients export (including DOC, POC, DIN, DON, and PON) from land to aquatic ecosystems and underlying mechanisms, we have developed a integrated Dynamic Land Ecosystem Model that couples hydrologic process, soil biogeochemical processes, vegetation dynamics, and river routine system. In this study we will focus on Mississippi River Basin and Chesapeake Bay and Mid-Atlantic region and answer the following two questions:1) What is the magnitude of river discharge and organic carbon and total nitrogen exported from terrestrial ecosystems to during 1895 to 2008? And 2) What are the relative contributions of each driving force on the variations of water fluxes and nutrient exports to Northern Gulf of Mexico, Chesapeake Bay and Mid-Atlantic region? Driving forces we considered in this study include climate variations (precipitation, temperature, solar radiation, and relative humidity), changes in land-use/land-cover conversions, and land practices (fertilization and irrigation).

A MODEL OF SEDIMENTARY DELTA GROWTH THAT ACCOUNTS FOR BIOLOGICAL PROCESSES

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Feedbacks between biological and physical processes play an essential role in determining the response of coastal dynamics to environmental changes, but to date predictive models do not take them into account. The combination of biomass production by plants and microbial decomposition in wetland environments leads to accumulation of SOC in the form of peat. Organic deposits (peat) represent a significant fraction of the sediment column in the Holocene Mississippi Delta System and several other coastal systems throughout the world. The objective of our research is to construct exploratory models that explicitly account for peat accumulation and degradation via plant growth, burial, and microbial processes influenced by salinity. We propose a set of 'lumped' models aimed at averaging the critical small scale biological processes as source and sink terms that are inserted into larger scale delta growth model. Even in a highly simplified framework, the model suggests that carbon dynamics in the sediment column can significantly influence delta evolution. In a model with pivot subsidence but without a SOC component the shoreline monotonically reaches a steady position where the mineral flux balances the subsidence rate. When we include our proposed simple SOC

source term the interactions between subsidence and delta carbon content result in a shoreline that initially advances and retreats before monotonically approaching a steady position. We hypothesize that the initial advance-retreat cycle could represent an important time scale for the role of biological processes in delta building.

MODELING HOLOCENE DISCHARGE AND SEDIMENT FLUXES FOR THE RHINE RIVER

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Long-term sediment fluxes in fluvial systems are governed by a number of external forcing factors like climate change, human impacts, sea level change and tectonic activity. Understanding fluvial response to changing external drivers is of importance to understand past, present and future changes of sediment fluxes. The climate-driven hydrological model HYDROTREND v.3.0 allows simulations of long-term water discharge and sediment loads at the river outlet of large catchments. In this study the model is applied to the Rhine River, Germany over the Holocene time period (10,000 BP – present). During this period human activity worldwide increased profoundly. The Rhine system, a 158,000 km2, has a particularly long story of intense human-riverine interactions, resulting in largely man-induced sediment fluxes from the Mid-Holocene onwards. Of advantage from a methodic point of view is the wealth of geoscientific case studies in the Rhine catchment enabling a comprehensive long-term study due to available quantitative data from various fields of Earth Surface and Social Sciences (instrumental, historical, archaeological and palaeoecological). The model results are validated against sediment load and discharge observations of the present day Rhine River. Once validated, the model will be applied over the Holocene to analyze the change in water and sediment discharge and to determine the impact of each of the forcing factors.

FROM SEDIMENT ROUTING TO FLUID FLOW: TURNING DOODLES INTO DIGITS

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Successful hydrocarbon exploration and production depends on the ability to be predictive. Prediction must transcend qualitative description by utilizing quantitative tools, workflows, and approaches that allow us to maximize and apply all available data. This presentation illustrates how process-based modeling tools predict sediment routing systems, the resulting three-dimensional sedimentary architecture, and facies distribution. A process-based, quantitative approach is used for predicting sedimentary environments by integrating data and knowledge pertaining to modern depositional systems, subsurface, outcrops, laboratory experiments, and numerical modeling tools. A more quantitative and rigorous data collection and analytical approach is required to facilitate the building of data-constrained predictive models based on first principles. Appropriate sensitivity and uncertainty analysis that captures the complexity of the predicted systems is crucial. A set of case studies demonstrate workflows that integrate diffusion-based forward stratigraphic prediction with petroleum systems prediction. Two of the case studies, one at basin scale and one at prospect scale, are from a deep-water system with a mobile substrate, and a third case study is from a basin with very high rates of subsidence and sedimentation. These case studies show the influence of accommodation, basin geometry and topography, sediment supply on the sediment routing, and impact of a high resolution, three-dimensional sedimentary model on petroleum systems prediction.

INTERNAL BORES: AN IMPROVED MODEL VIA A DETAILED ANALYSIS OF THE ENERGY BUDGET

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Internal bores, or hydraulic jumps, arise in many atmospheric and oceanographic phenomena. The classic single-layer hydraulic jump model accurately predicts a bore's behavior when the density difference between the expanding and contracting layer is large (i.e. water and air), but fails in the Boussinesq limit. A two-layer model, where mass is conserved separately in each layer and momentum is conserved globally, does a much better job but requires for closure an assumption about the loss of energy across a bore. Through the use of 2D direct numerical simulations, we show that there is a transfer of energy from the contracting to the expanding layer due to viscous stresses at the interface. Based on the simulation results, we propose a two-layer model that provides an accurate bore velocity as function of all geometrical parameters, as well as the Reynolds and Schmidt numbers. We also extend our analysis to non-Boussinesq internal bores to bridge the gap between the single and two-layer models.

UNSTABLE MISCIBLE DISPLACEMENTS IN HELE-SHAW CELLS: THREE-DIMENSIONAL NAVIER-STOKES SIMULATIONS

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We simulate unstable miscible displacements in Hele-Shaw cells based on the three-dimensional, variable viscosity Navier-Stokes equations coupled to a convection-diffusion equation for the concentration field. The simulations exhibit the formation of individual, quasisteady fingers whose properties are characterized as a function of the viscosity ratio and the Peclet number. We observe both traditional tip splitting events, as well as a novel inner splitting mechanism that has not yet been reported in the literature. This tip splitting is associated with fluid transport perpendicular to the plane of the Hele-Shaw cell, and hence cannot be reproduced by gap-averaged approaches. It has the effect of splitting the trailing sections of the finger longitudinally, while the finger tip can largely remain intact. This work is supported by NSF, CAPES and a Fulbright fellowship.

COMPLEXITIES IN BARRIER ISLAND RESPONSE TO SEA LEVEL RISE: INSIGHTS FROM NUMERICAL MODEL EXPERIMENTS, NORTH CAROLINA OUTER BANKS

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Using a morphological-behavior model to conduct sensitivity experiments, we investigate the sea level rise response of a complex coastal environment to changes in a variety of factors. Experiments reveal that substrate composition, followed in rank order by substrate slope, sea level rise rate, and sediment supply rate, are the most important factors in determining barrier island response to sea level rise. We find that geomorphic threshold crossing, defined as a change in state (e.g., from landward migrating to drowning) that is irreversible over decadal to millennial time scales, is most likely to occur in muddy

coastal systems where the combination of substrate composition, depth-dependent limitations on shoreface response rates, and substrate erodibility may prevent sand from being liberated rapidly enough, or in sufficient quantity, to maintain a subaerial barrier. Analyses indicate that factors affecting sediment availability such as low substrate sand proportions and high sediment loss rates cause a barrier to migrate landward along a trajectory having a lower slope than average barrier island slope, thereby defining an “effective” barrier island slope. Other factors being equal, such barriers will tend to be smaller and associated with a more deeply incised shoreface, thereby requiring less migration per sea level rise increment to liberate sufficient sand to maintain subaerial exposure than larger, less incised barriers. As a result, the evolution of larger/less incised barriers is more likely to be limited by shoreface erosion rates or substrate erodibility making them more prone to disintegration related to increasing sea level rise rates than smaller/more incised barriers. Thus, the small/deeply incised North Carolina barriers are likely to persist in the near term (although their long-term fate is less certain because of the low substrate slopes that will soon be encountered). In aggregate, results point to the importance of system history (e.g., previous slopes, sediment budgets, etc.) in determining migration trajectories and therefore how a barrier island will respond to sea level rise. Although simple analytical calculations may predict barrier response in simplified coastal environments (e.g., constant slope, constant sea level rise rate, etc.), our model experiments demonstrate that morphological-behavior modeling is necessary to provide critical insights regarding changes that may occur in environments having complex geometries, especially when multiple parameters change simultaneously.

WITH SEA-LEVEL RISE AND CHANGING STORMS, HUMANS REACT TO SHORELINE EROSION—BUT SHORELINES REACT BACK (COUPLED ECONOMIC/LANDSCAPE EVOLUTION MODELING)

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When faced with persistent coastal erosion, communities often react by stabilizing the shoreline, commonly through repeated ‘beach replenishment.’ Recent numerical modeling work has shown that even a single community holding the shoreline position fixed by importing sand to keep pace with erosion can significantly affect shoreline change for surprisingly large alongshore distances. Patterns of large-scale coastline change are affected by localized human manipulations even as the humans are affected by coastline change. These two-way couplings between coastal processes and human dynamics also mean that shoreline stabilization efforts at one town affect, positively or negatively, the erosion rates, and therefore real estate values, of other towns along the coastline. Such impacts can occur even when towns are not adjacent to one another. Changing storm behaviors (e.g. intensities) change the distribution of wave influences from different directions, and such changes to wave climates tend to reshape a coastline. The associated acceleration in long-term shoreline change rates intensifies the feedbacks between humans and coastline evolution. We developed an empirically based economic model in which beach replenishment decisions are based on erosion rates, property values, and the costs for replenishment sand. Coupling this work to the large-scale coastline change model allows us to explore how coastal communities affect each other’s fates and the shape of the coastline under different sea-level rise, climate change, and sand-cost scenarios.

TURBIDITY CURRENTS IN MEANDERING CHANNELS

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We consider continuous, particle-laden gravity currents flowing along sinusoidal submarine channels bounded by levees, with special emphasis on the sediment transport. We investigate these flows via highly resolved three-dimensional direct Navier-Stokes simulations, based on an immersed boundary representation of the channel topography. Results are reported from a parametric study that focuses on shear stress profiles along the channel bed, secondary flow structures in channel cross-sections, lateral overflow over the levees, and sediment deposition, as functions of the channel geometry, the flow parameters, and the particle settling velocity.

COMPONENT-BASED SCIENTIFIC SOFTWARE DEVELOPMENT: USABILITY CHALLENGES AND TOOLS

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Component-based software development enables the creation and maintenance of integrated applications containing contributions from multiple developers and encapsulating a range of capabilities, such as different models, numerical solution methods, data analysis, and visualization. The Common Component Architecture (CCA) defines a component model which has been successfully used within CSDMS to define uniform interfaces for CSDMS models that streamline model integration. Component development entails significant developer overheads, some of which have been addressed through the creation of tools that automate parts of the development process. We will discuss the challenges of developing and maintaining component software in the scientific computing domain. We will overview existing usability support provided through open-source tools developed by members of the CCA Forum and used in CSDMS.

THE MORPHODYNAMICS E-BOOK: A LABOR OF LOVE THAT NEVER QUITE GETS FINISHED

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The e-book project began in 2002 when I was in residence as the Crosby Lecturer in the Department of Earth and Planetary Sciences at the Massachusetts Institute of Technology. Although my position did not require me to teach a full course, I decided to teach one anyway. The topic of the course was river morphodynamics. I covered sediment conservation laws, basic hydraulics and sediment transport relations, and applied these to riverbed aggradation, downstream fining, alluvial fans and delta, and knickpoint migration. I used a combination of PowerPoint lectures, Excel spreadsheets, Word documents and videos to illustrate the material. The coding was done in Visual Basic for Applications (VBA), which is built into Excel. The MIT students found this rather primitive compared to, e.g. Matlab, and MIT in general was not particularly supportive of Microsoft products. I nevertheless chose VBA because just about everyone has Excel, whereas they may or not have Matlab, Fortran, C++ or other programming languages/compilers loaded on their computer. I treated the students on the first day of class to plastic wine glasses and two bottles of wine, a good Alsatian Rhine wine and Manischewitz wine. I then told them that C++ was the Alsatian, but in this class they had to drink Manischewitz. A number of students in the class went on to become researchers in their own right. (This likely has little to do with the course, but it does speak for the quality of the students.) After MIT, I proceeded to the Tokyo Institute of Technology where I taught a 6-week intensive course on river morphodynamics. This experience allowed me not only to develop the course further, but also to prepare a Japanese language version. The MIT and TIT lectures/code/videos/text laid the basis for a full e-book. I wrote this in my spare time, using courses at the University of Minnesota as a way to extend the material. The book is online at http://vtchl.uiuc.edu/people/parkerg/. I haven't updated the website since 2006, but I do have new material developed at the University of Illinois that, someday, I will post. The book on the website is only 2/3 done, but it has given me great pleasure, not only to prepare the material, but also to see others use it. It has also served as a springboard for my own research, and that of my students (who have written or contributed to several of the chapters).

SIMULATING THE THREE DIMENSIONAL DISPERSAL OF AGING OIL WITH A LAGRANGIAN APPROACH

E. W North, Z. Schlag, E. Eric Adams, R. He, K. H. Hyun, C. R. Sherwood, R. P. Signell, S. D. PECKHAM

The objective of our program is to investigate the far field subsurface and surface dispersal of different size classes of oil released from the Deepwater Horizon well. We use the Lagrangian transport model LTRANS, an open source model, to simulate the trajectories of oil droplets as they age over time. This Lagrangian approach incorporates the effects of differences in initial droplet characteristics, as well as time-varying droplet behavior. Circulation predictions were provided by SABGOM, a ROMS model of the Gulf of Mexico and southeastern shelf, while initial droplet elevations were provided by multi-phase plume modeling. We ran the SABGOM/LTRANS model system for the time period of the Deepwater Horizon oil spill, produced maps and animations of model output, and are in the process of comparing results with available observations. Preliminary findings indicate that oil droplet diameters greater than 100 microns rise quickly to the surface. Droplets with diameters less than 100 microns have markedly different dispersal trajectories than larger droplets, and those 10 micron in diameter have similar trajectories as passive particles. Model predictions, sensitivity, and skill assessment will be presented and discussed. LTRANS v2, including new oil algorithms, will be released as open source code and adapted to run with CF-compliant model output, making it functional with multiple coastal models and allowing simulations and forecasts to be made throughout the US coastal waters.

This project is supported by an NSF RAPID grant and one of the goals of the project is to make LTRANS available as a plug-and-play component within the Community Surface Dynamics Modeling System (CSDMS). It is currently driven by ocean model input from ROMS but will be adapted so it can also use ocean model output from other models.

DRIVING PLUG-AND-PLAY MODELS WITH DATA FROM WEB SERVICES - A DEMONSTRATION OF INTEROPERABILITY BETWEEN CSDMS AND CUAHSI-HIS

PECKHAM, SCOTT D. and Jonathan L. Goodall

The CUAHSI Hydrologic Information System (HIS) is an internet-based system to support the sharing of hydrologic data. It is comprised of hydrologic databases and servers connected through web services as well as software for data publication, discovery and access. (See http://his.cuahsi.org.) The CUAHSI HIS system consists of 3 main parts that interact with one another. ***HIS Server*** is a repository of hydrologic time series data published as WaterOneFlow web services. ***HIS Central*** is a metadata catalog of data accessible through WaterOneFlow web services. ***Hydro Desktop*** is an application to access and work with hydrologic data discovered on HIS Central and acquired from HIS Servers. CUAHSI HIS currently supports a large collection of hydrologic data sets in the form of at-a-point observations that vary over time (time series) but may be extended in the future to support gridded data sets that vary over time (grid stacks).

The Community Surface Dynamics Modeling System (CSDMS) is a modeling framework in which different approaches to modeling different physical processes appear as interchangeable, reusable, plug-and-play components. (See http://csdms.colorado.edu.) Open-source models that are contributed to the CSDMS project form a quite heterogeneous group as they are (1) written in different languages, (2) have different interfaces, (3) have different computational grids and (4) use different input/output file formats. In order to make these model components interoperable, they must therefore be wrapped to have a common interface, i.e. they must be made to respond to a well-defined set of calling commands. The CUAHSI-HIS project must deal with a similar problem in terms of providing a common mechanism for accessing a heterogeneous group of databases that are available online. Two of the underlying tools used to achieve this are a relational database called the Observations Data Model (ODM) and an XML schema called WaterML. WaterOneFlow is a set of web services based on WaterML (similar to a model interface) that is installed on participating servers that distribute hydrologic data.

In order to demonstrate interoperability between CSDMS and CUAHSI-HIS (both funded by NSF), a prototype CSDMS component has been developed that (1) collects information (e.g. geographic bounding box, start time and end time) for a data set "query" using a tabbed dialog, (2) connects to the HIS Central web service and (3) reports on what data is available at HIS Central. These steps can be repeated in "Query mode" until a suitable data set is found, and then the component can be toggled to "Download mode" to download and save the requested data in output files or in the component's state. The new ***HISData*** component looks and operates exactly like other CSDMS model components and includes a tabbed dialog for entering input and an HTML help page that provides information as well as links to several online resources for CUAHSI HIS.

REEF GROWTH IN OPTIMAL AND MARGINAL HABITATS: PAST, PRESENT AND FUTURE

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Reef growth is the net result of interactions between processes of biological and geological accretion and physical and biological processes of destruction. These processes vary qualitatively and quantitatively among habitats on the same reef, and also vary among different reefs. Empirical data from Pleistocene to modern reefs in Papua New Guinea, Australia, Hawaii and Midway Atoll indicate the nature, magnitudes and constraints of these habitat-specific processes. Data will include preliminary results from cores taken during the 2010 IODP Expedition 325 (Great Barrier Reef Environmental Change).

BIOLOGICAL DYNAMICS AND CARBONATE PRODUCTION - LINKING SMALL-SCALE, SHORT-AMPLITUDE TO LARGE-SCALE, LONG-AMPLITUDE PROCESSES

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Carbonate systems are built from organismic skeletons and as such are reflections of life processes. The translation of the ones into the other, as is necessary for the development of growth models for carbonate systems, can present some challenges. In particular in benthic, space-limited systems such as organismic reefs, growth dynamics can be strongly influenced by local small-scale phenomena and the amplitude of life-phenomena is much shorter than that of sedimentary cycles. Thus a single sedimentary sequence can be the sum of many generations of sediment-producers and can encompass many small-scale, short-period environmental influences. To realistically model large-scale and long-amplitude patterns (i.e. the sedimentary sequence) a good understanding of the linkages across these scales is necessary. To achieve increased precision of prediction, carbonate production estimates can be anchored on dynamics of populations rather than on averaged bulk-production rates for a given system and can be integrated with environment-specific taphonomic and diagenetic information. Examples from different modern environments will show how environmental change can influence carbonate production.

FEATURE ANALYSIS OF COUPLING TECHNOLOGY FOR CLIMATE MODELS

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The notion of "coupling" is essential for implementing climate models made up of two or more interacting computer simulations. The software components that link together and mediate interactions between these models are called couplers. Couplers are well-known abstractions in the geophysical and other scientific communities, although their implementations differ vastly. With respect to Earth System Models, no standard reference architecture has emerged. Instead, couplers are designed to address particular modeling situations. The design space of couplers is constrained by properties of the existing models, such as their software architecture, dependencies on third party libraries, numerical properties, and scientific properties, as well as properties of the target computational environment. We are interested in providing support for climate scientists who may wish to couple individual, pre-existing models. Our aim is to determine the extent to which this process can be automated. In particular, we are looking into whether and how couplers can be automatically generated for numerical ESMs. As a first stage in this process, we have performed a feature analysis of coupling technologies. Feature analysis is an attempt to understand a set of related technologies by organizing their features along orthogonal dimensions. In this talk we will introduce feature analysis and feature diagrams, give examples of our analysis and describe some interesting issues that have arisen during our investigation.

OBSERVATIONS AND MODELING OF MUDDY SEAFLOOR RESPONSE TO ENERGETIC SURFACE WAVES ON THE LOUISIANA SHELF

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Surface waves and near-bed flows were measured for 6-weeks in Spring 2008 at a cross-shore transect between 7.4- and 4-m isobaths on the muddy Atchafalaya Shelf, Louisiana (e.g., Safak et al., accepted for J. Geophys. Res.). The evolution of the sea bed during an energetic wave event (up to 1.4-m significant height, with peak period of 10-s) is studied based on the observations at 4-m depth. The backscatter intensity of the acoustic signal of a current profiler is used to estimate the near-bed vertical structure of suspended sediment concentration (Thorne and Hanes, Cont. Shelf. Res. 2002). A one-dimensional bottom boundary layer model for combined wave-current flow on cohesive beds (Hsu et al., J. Geophys. Res. 2009) is calibrated to fit the estimated concentration profiles. Simulations are used to investigate the relation between flow conditions (waves, turbulence, bottom stress, etc.) and bed state (e.g., amount of sediment in suspension, conditions at which resuspension, liquefaction, and fluid mud formation occur). The results suggest that the state of bed sediment evolves from consolidated before storm, through liquefaction (when long-period swells reached 1-m

significant height) and finally to soft bed resulting from settling of suspended sediment. (This study is supported by Office of Naval Research.)

PARBREZO: A PARALLEL, UNSTRUCTURED GRID, GODUNOV-TYPE, SHALLOW-WATER CODE FOR HIGH-RESOLUTION FLOOD INUNDATION MODELING AT THE REGIONAL SCALE

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Topographic data are increasingly available at high resolutions (< 10 m) over large spatial extents to support detailed flood inundation modeling and loss estimation analyses required for flood risk management. This paper describes ParBreZo, the parallel implementation of a two-dimensional, Godunov-type, shallow-water code, to address the computational demand of high-resolution flood modeling at the regional scale (10^2-10^4 km^2). A systematic approach to unstructured grid partitioning (domain decomposition) is presented, and the Single Process Multiple Data (SPMD) paradigm of distributed memory parallelism is implemented so the code can be executed on computer clusters with distributed memory, shared memory, or some combination of the two (now common with multi-core architectures). In a fully-wetted, load-balanced test problem, the code scales very well with a parallel efficiency of close to 100% on up to 512 processes (maximum tested). A weighted grid partitioning is used to partially address the load balancing challenge posed by partially wetted domains germane to flooding applications, where the flood extent varies over time, while the partitioning remains static. An urban dam-break flood test problem shows that weighted partitions achieve a parallel efficiency exceeding 70% using up to 48 processes. This corresponds to a 97% reduction in execution time so results are obtained in a matter of minutes, which is attractive for routine engineering analyses. A hurricane storm surge test problem shows that a 10 m resolution, 12 hr inundation forecast for a 40 km length of coastline can be completed in under 2 hours using 512 processors. Hence, if coupled to a hurricane forecast system capable of resolving storm surge, inundation forecasts could be made at 10 m resolution with at least a 10 hr lead time.

LINKING DELTAIC AND MARINE SEDIMENTARY PROCESSES: A PRELIMINARY BATHYMETRIC AND SUB-BOTTOM SURVEY OF LAKE CHELAN, WASHINGTON

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Geologists have long recognized the importance of both river deltas and deep-ocean sedimentary fans as major sinks for large quantities of land-derived sediment. Indeed, studies too numerous to count have addressed these depositional systems individually. Relatively few studies, however, have directed their attention at the linkage between the two, despite the fact that the former is almost always intimately related to the latter. This linkage, however, is key to our ability to model and understand both deltaic and deep-marine sedimentation, as these dynamics provide an important boundary condition for terrestrial and marine models. This project is a preliminary study of the relationship between deltaic and deep-water sedimentation in Lake Chelan, WA, where the external forces acting on the system are relatively well-constrained, and the river is directly linked to deeper water. Detailed bathymetric and sub-bottom data were collected in order to characterize the transport and fate of fluvial sediments. These preliminary data are intended as a base-line from which a long-term monitoring study can be started, and are intended as the sort of information that would be useful as constraints on morphodynamic models.

MORPHODYNAMIC MODELS OF DELTAS

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Predictions of delta response to various external forcings are needed now, yet our modeling capabilities are quite inadequate, and particularly so in the United States. Predicting a delta's response to relative sea level rise or a change in water or sediment discharge requires a model complex enough to compute morphodynamic adjustment of a multi-channel network. This includes changes in channel width, depth and friction factors, overbank flows, avulsions, mouth bar formation and destruction, and possibly even sediment critical shear stress evolution due to vegetation changes. This is a grand challenge for CSDMS. As an illustration of these challenges, we will present examples of deltas computed by Delft3D-Flow, a morphodynamic model from Deltares.

BRIDGING THE GAP BETWEEN SEDIMENTARY PROCESS MODELING AND STOCHASTIC OBJECT MODELING

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Recent developments in stochastic modeling using geometric objects (or "Boolean" modeling) include attention to the interaction between generations of inserted objects. Object location, shape, size and orientation are controlled not just by a proiri fields defined for the entire model, but also by the presence of previously inserted objects and their geometry. Thus for example, crevasse splays may be attached to previously generated stochastic channel preferenctially at points of high channel curvature, and pointing outward from the channel. Or post glacial streams may avoid topographics highs such as drumlins left by a retreating glacier. If this concept is taken far enough, it is unavoidable to incorporate true sedimentary process modeling principles into it, occasionally even showing the effect of self organization arising from simple rules. However, this type of hybrid model can be kept simpler than a true sedimentary process model, and due to its stochastic nature, is easier to condition to hard and soft data. We present preliminary results of several variations of this approach applied to glacial and fluvial environments, and show its potential for other sedimentary environments as well.

TERRESTRIAL SURFACE DYNAMICS MODELING: LESSONS AND CAPABILITIES

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Like other sciences, the study of Earth-surface dynamics involves an ongoing dance between theory and observations. Increasingly, our theoretical framework is supported by computer models that encapsulate current understanding and working hypotheses about the process that move mass across the Earth's surface. This computational infrastructure must constantly adapt change in step with emerging data and ideas. One of the key missions of CSDMS to ensure that the computational technology we use to help understand the natural world is nimble and adaptable, so that it serves to stimulate our imagination rather than impeding our progress. The CSDMS Terrestrial Working Group

is currently applying flexible and coupled modeling strategies to a wide range of science problems; some examples include coupled modeling of onshore erosion and offshore sedimentation, interaction between topography and precipitation, impact of tectonic deformation on landscapes, badland landscape development, coupled hydrologic-geomorphic modeling, and many others. To illustrate the value of flexible modeling software, I discuss the example of a landscape evolution model that has grown and evolved considerably since its beginnings 15 years ago. The Channel-Hillslope Integrated Landscape Development (CHILD) model was originally developed at MIT, as a successor to the earlier SIBERIA and GOLEM models, to study the formation of drainage basins in response to climate change. The software was designed using a modular structure, which has facilitated the addition of new capabilities over time. The model has grown substantially over the years in response to newly emerging science questions. Examples of co-evolving science questions and model capabilities include grain-size dynamics, vegetation, thrust tectonics, gully development, and alluvial stratigraphy and geoarchaeology, among others. Overall, one of the most important lessons to emerge from the CHILD experience is that early investment in scientific software design provides a platform for sustained growth, adaptation, and exploration as the frontier of knowledge advances.

APPLICATION OF CSDMS CODES TO SOURCE-TO-SINK STUDIES IN NEW ZEALAND: THE WAIPAOA AND THE WAITAKI CATCHMENTS

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The Waipaoa River catchment on New Zealand’s north-eastern coast has a mean annual suspended yield of 6780 t km-2 yr-1. The compact, mountainous and short reach of the Waipaoa River watershed produces among the highest sediment yields per unit area globally. Here, deforested and steep hillslopes composed of extremely weak mudstone argillite lithologies are exposed to a vigorous maritime climate. Sediment from the Waipaoa River is trapped in active tectonic basins on the shelf and slope. We have extended previous HydroTrend simulations of the Waipaoa River water and sediment discharge back to LGM. These predict that, given the increased catchment, similar vegetation cover and landscape susceptibility to erosion, the suspended sediment flux of the LGM Waipaoa catchment was 10-15% higher than during the late Holocene. However, when considered relative to unit area, the LGM suspended sediment yield was perhaps 60% lower than during the late Holocene, reflecting the higher Holocene precipitation. In the Waitaki River catchment, South Island, we are utilizing ~80 years of discharge readings, climate readings and some short cores from Lake Ohau to calibrate a HydroTrend model of the large glacial valleys and lakes that make up the upper Waitaki catchment. We will then use paleoclimate proxies to extend the models back to LGM. Our preliminary models suggest that the Lake Ohau record is dominated by events, large northwesterly storms, rather than seasonal variation.

A NUMERICAL MODEL TO ROUTE SEDIMENT AND COSMOGENIC NUCLIDES AT BASIN-WIDE SCALE. APPLICATION TO THE MAPLE RIVER, MINNESOTA.

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A one-dimensional numerical model that routes sediment and cosmogenic nuclides has been developed in the context of an NCED (National Center for Earth-surface Dynamics) multidisciplinary effort in the Le Sueur River Basin, southern Minnesota. The motivation of the work can be summarized with a relatively short and apparently simple question: Where is this sediment coming from? Sediment loads in the Minnesota River basin have considerably increased in the last two centuries concurrent with the development of intensive agriculture on the uplands. Consequently, sedimentation problems have occurred in the tributaries to the Minnesota River, in the Minnesota River main stem, and farther downstream. For example, measurements in Lake Pepin, a naturally dammed lake on the Mississippi River downstream from the confluence with the Minnesota River, show a five / ten-fold increase in sedimentation rates. Field and numerical work has been conducted in the Le Sueur River basin, which is characterized by one of the highest sediment yields in the Minnesota River basin. Quantification of the differences in sediment loads contributed from an hypothetical, pre-agriculture condition compared to the present, and the prediction of the effectiveness of different restoration strategies to reduce sediment loading requires two steps, 1) a detailed sediment budget, i.e. determine location and magnitude of sources and sinks and route the sediment through the system, and 2) a quantification of the sediment transport pathways, explicitly modeling channel floodplain exchange, constrained by the concentration of cosmogenic nuclides in the floodplain. In the current configuration, the model requires input of water and sediment from externally modeled sources (i.e. bluffs, ravines, tributaries, uplands) in each computational node, it can thus be thought as a potential routing component of a more complex model, where the input of sediment and water is modeled by independent modules. Preliminary results for the Maple River are presented and discussed.

'INTEGRONSTERS' AND THE SPECIAL ROLE OF DATA

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In many cases model integration treats models as software components only, ignoring the fluid relationship between models and reality, the evolving nature of models and their constant modification and re-calibration. As a result, with integrated models we find increased complexity, where changes that used to impact only relatively contained models of subsystems, now propagate throughout the whole integrated system. This makes it harder to keep the overall complexity under control and, in a way, defeats the purpose of modularity, when efficiency is supposed to be gained from independent development of modules. Treating models only as software in solving the integration challenge may give birth to 'integronsters' - constructs that are perfectly valid as software products but ugly and useless as models. We argue that one possible remedy is to learn to use data as modules and integrate them into the models. Then the data that are available for module calibration can serve as an intermediate linkage tool, sitting between modules and providing a module- independent baseline dynamics, which is then incremented when scenarios are to be run. In this case it is not the model output that is directed into the next model input, but model output is presented as a variation around the baseline trajectory, and it is this variation that is then fed into the next module down the chain. The Chesapeake Bay Program suite of models is used to illustrate these problems and the possible solutions.

AN APPLICATION FOR STUDYING SEDIMENT-INDUCED STRATIFICATION IN OPEN-CHANNEL FLOWS

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Flow containing sediment suspension subjects itself to a density gradient in the vertical direction, known as density stratification, due to the tendency for suspended sediment to settle. Velocity and concentration profiles under the effect of density stratification may differ significantly from the conventional logarithmic and Rousean distributions. It is hence important to include this effect into flow computations in order to correctly predict flow characteristics such as roughness coefficient, near-bed sediment concentration, and flow and sediment discharge. While numerous studies have investigated the effect of sediment-induced density stratification in open-channel flows, no simple tool has been developed to study and visualize the level of stratification for a given set of dimensional or dimensionless parameters. Here we introduce an application - Strat1D, for such a purpose. The application contains a user-friendly interface which allows users to compare the velocity and concentration profiles under stratification effects to the conventional distributions under a prescribed set of dimensional or dimensionless parameters. Two algebraic models (Smith-McLean, Gelfenbaum-Smith) and two differential models (k-e, Mellor-Yamada) are among the choices of turbulent closures. It has been found that the Mellor-Yamada model predicts a similar damping effect on the eddy viscosity to the Smith-McLean model, while k-e model consistently predicts a weaker influence of density stratification on both profiles. The application can also be used to study the effect of sediment mixtures on flow stratification by specifying the grain size distribution. In the presence of sediment mixtures, fine material such as mud tends to reduce the density gradient and consequently the stratification effect. With an increasing proportion of fine material in the suspension, the velocity and concentration profiles tend to approach those prevailing under neutral conditions, i.e. logarithmic and Rousean distributions, respectively.