CSDMS

COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

FIVE-YEAR STRATEGIC PLAN

NOV 1, 2013 TO OCT 31, 2018

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1.0 CSDMS Mission

The Community Surface Dynamics Modeling System (CSDMS) catalyzes new paradigms and practices in developing and employing software to understand the Earth's surface — the ever-changing dynamic interface between lithosphere, hydrosphere, cryosphere and atmosphere. CSDMS focuses on the movement of fluids and the sediment and solutes they transport through landscapes, seascapes and sedimentary basins. CSDMS supports the development, integration, dissemination and archiving of community open-source software, that reflects and predicts earth-surface processes over a broad range of temporal and spatial scales.

CSDMS

- Produces protocols for community-generated, continuously evolving, open software
- Distributes software tools and models
- Provides cyber-infrastructure to promote the quantitative modeling of earth surface processes
- Addresses the challenging problems of surface-dynamic systems: self-organization, localization, thresholds, strong linkages, scale invariance, and interwoven biology and geochemistry
- Enables the rapid development and application of linked dynamic models tailored to specific landscape to basin-evolution problems, at specific temporal and spatial scales and supporting data
- Partners with related computational and scientific programs to eliminate duplication of effort and to provide an intellectually stimulating environment
- Supports a strong linkage between what is predicted by CSDMS codes and what is observed, both in nature and in physical experiments
- Supports the imperatives in Earth Science research: 1) discovery, use, and conservation of natural resources; 2) characterization and mitigation of natural hazards; 3) geotechnical support of commercial and infrastructure development; and 4) stewardship of the environment.
- Supports community access to High Performance Computing resources and national geospatial and temporal data sources
- Supports community sharing of experimental data for the testing earth surface models (e.g., Critical Zone Science)

The CSDMS Executive Committee, with contributions from the CSDMS Steering Committee, CSDMS Working and Focus Research Group members, and the CSDMS staff, has collaboratively developed this 2013 CSDMS Strategic Plan.

2.0 CSDMS Long Range Goals and CSDMS Cyber-Infrastructure

CSDMS has two overriding long-range goals. The first long-range goal is to

- *Develop a robust modular modeling environment capable of significantly advancing fundamental earth-surface and ocean science* (see section 3).

CSDMS software architecture employs frameworks and services that convert stand-alone models into flexible "plug-and-play" components to be assembled into larger applications. Because certain aspects of surface processes are not well understood, the CSDMS modeling environment avoids "locking in" a particular approach, but instead allows users to easily swap model or service components. The CSDMS Component Modeling Tool or CMT is being designed to increase the performance of contributed models and their ease of maintenance and use, flexibility, stability, portability, and future proofing. The CSDMS framework CMT presently incorporates: i) language interoperability; ii) component preparation and project management; iii) model coupling within a high-performance computing (HPC) environment; iv) single- or multi-processor spatial regridding of all grid types; v) component interface standards that operate with open-source standards to avoid proprietary dependencies; vi) visualization of large datasets in a multiple processor environment; and vii) message passing within a HPC environment. As of July 2013, 55 models are available as CMT components in aid of both research and education, allowing users to run models on the CSDMS HPC without having to be an expert.

To expand the accessibility and scope of CSDMS models and computational tools available both to model developers and to users who work on single-user desktop computers as well as high performance computing clusters, we propose to address this goal by:

1) Developing a web-based Component Modeling Tool (CMTweb) that allows users to run CMT directly through a web browser, and thereby increase the maintainability, sustainability, and accessibility of computational resources.

2) Deploying the CSDMS software stack on other HPC clusters, and to thereby increase the stability and sustainability of the modeling tool.

3) Distributing pre-built executables of models and tools able to run on a wide range of platforms as a means to increase access to these models.

4) Automating the wrapping process to allow more legacy code in the Model Repository to become plug-and-play components.

5) Incorporating uncertainty tools into the CMT, and to also explore other strategies for quantifying various types of model uncertainty.

6) Developing CSDMS Standard Names for model coupling. This kind of automation requires a *semantic matching mechanism* for determining whether — *and the degree to which* — two variable names refer to the same quantity and whether they use the same units and are defined or measured in the same way. The CSDMS Standard Names can be viewed as a *lingua franca* that provides a bridge for mapping variable names between models.

The second long-term goal of CSDMS is to:

- *Develop fully functional and useful repositories for CSDMS data, for CSDMS models and numerical tools, and for educational use.*

CSDMS has assembled a large repository of surface process models that now includes over 166 open-source models and 51 tools (as of July 2013). Some models can be obtained from the CSDMS Subversion repository and others can be obtained from external sites. For each contributed model, the CSDMS wiki website provides metadata, obtained with an online questionnaire that developers fill out during model submission. Developers also add an open-source license (one of their choice) to their codes upon submission. Submitted code is then compiled on the CSDMS HPCC. The repository contains terrestrial, coastal, marine, hydrological, carbonate and atmospheric models. Geodynamics, ecosystem, and human-dynamics models will be added over the next few years. Any model in the repository can be downloaded and used in "stand-alone" mode. Through the Working Groups and Focus Research Groups, CSDMS members prioritize and help to facilitate the conversion of popular models to model components that can be easily coupled to other models within the CSDMS Modeling Framework. We propose to address goal 2 by:

1) Collecting and incorporating benchmark data into the CSDMS modeling framework, including where appropriate data from the CSDMS field and experimental community.

2) Developing a robust mechanism for ingesting and utilizing semantic mediation databases within its modeling framework (see goal 1, point 6).

3) Fully integrating the Semantic MediaWiki (SMW) to allow CSDMS databases to be queried and visualized, and to further integrate different classes of model and data information.

4) Enhancing model metadata and transparency through new capabilities such as the visualization of functions applied in models. Because equations can sometimes be non-intuitive, we propose to incorporate a web tool named MathML to help users visualize key model functions within pop-up graphs.

5) Advancing community plazas as convenient forums for discussion amongst like-minded modelers. For example, these might include societally relevant implementations, model vetting, or model benchmarking.

6) Advancing CSDMS model animations to NOAA's 'Science on a Sphere'.

7) Expanding the current EKT repository adapted to meet the needs of students.

8) Expanding Training Clinics on Educational Resources.

CSDMS METRICS FOR SUCCESS

- Coupling and launching of different models on a HPCC through a web browser
- Making CSDMS software stack operational on other HPCC platforms
- Numbers of new CSDMS components
- New functionality to clone, edit and redeploy CSDMS components
- Service component to ingest benchmark data into CSDMS components
- Ability to couple models with different semantics
- Web portal visits and use
- Research proposals that draw on or use CSDMS
- Numbers of incoming models to the Integration Facility
- Getting diverse communities to work together and solve problems through new focus groups
- Linking the CSDMS effort with community data centers: CZO, Delta Collaboratory, NCED and other experimental data centers
- Use of the educational tool kits and products
- Number of workshop participants
- Number and quality of publications
- Special sessions at national / international society meetings and subsequent publications
- Improved predictions of earth system phenomena
- Improved time to solution – getting models and tools into the hands of researchers
- Increased diversity of users within CSDMS community activities

3. Proof-of-Concept CSDMS Community Challenges

Nine fundamental scientific challenges form the foundation and motivation for the CSDMS effort:

Challenge1: Predicting the Transport and Fate of Fine Sediments & Carbon from Source to Sink

Carbon dynamics as addressed by CSDMS will focus on those processes involving fine sediment: fluvial and marine transport, reservoir impoundment, and environmental sequestering (floodplains, wetlands, continental shelves). Focusing on carbon ensures that CSDMS will incorporate key geochemical linkages in its design and allow the System to contribute to an immediate scientific debate having societal relevance.

Challenge2: Sediment Dynamics in the Anthropocene

The *Anthropocene* refers to that part of the Earth's recent history and Earth's future in which humans have become a major force for change in Earth systems. By combining CSDMS transport models with data sets addressing human-influenced as well as pre-human conditions, the CSDMS effort aims to quantify human influence on landscape evolution and sediment dynamics. Focusing on the human time scale allows for CSDMS models to investigate the cumulative effects of human activities on the environment, including: 1) changes to sediment generation (e.g., changes in hillslope stability), 2) interruptions to sediment routing and storage (i.e. reservoirs), and 3) impacts on riverine and coastal ecosystems (e.g. through the elimination of flooding on delta surfaces). The human-timescale focus also allows CSDMS-related activities to address the two-way couplings between human dynamics and landscape change processes.

This challenge allows for CSDMS to evolve with access to modern global databases and large integrated data sets, and to reach out to the global change research community. The creation of an Anthropocene Focused Research Group within CSDMS (section 4.10), as well as priorities to address human/landscape interactions in coastline and delta settings (sections 4.2 and 4.12), highlight the growing emphasis on this challenge.

Challenge3: Tracking surface dynamics through glacial cycles

The sequence of high-frequency sea level and climatic cycles that characterize the Pleistocene poses an exciting challenge to CSDMS. Modeling the earth-surface response to glacial cycles involves coupled drivers such as ice cover, geophysical response to both ice and ocean loads, water and sediment delivery, base level, and wave/current climate, plus associated changes in ecosystems. The results — fluvial valley development and filling, major shoreline migration, and glacial advance and retreat —- are sufficiently well documented to provide relatively strong constraints on CSDMS simulations. The glacial-cycle problem will test the ability of CSDMS to handle critical features such as dynamic moving boundaries (e.g. the shoreline) between transport domains, abrupt climate changes, ice-river interactions, and ice-ocean-sediment interactions. The challenge will allow CSDMS to evolve with access to global paleo-databases (e.g., paleoclimate proxy data, vegetation history data) and simulations (e.g., climate model predictions, glacial simulations, paleo-ocean predictions). This challenge also reaches out to the Quaternary and glaciological communities, including the International Ocean Drilling Project.

Challenge 4: Arctic Coastal Zone at Risk: Prognosis and Modeling

The Arctic coastal zone is rapidly changing. Significant, directed research effort is required to attain a level of sophistication and computational efficiency necessary to address complex anthro-bio-geo-physical interactions inherent in modern Arctic Coast Zone models. Because of high socio-economic impacts associated with projected Arctic climate change, particular importance should be placed on understanding model uncertainty, limitations, and quantifying outcomes. In addition to known processes (such as those associated with permafrost, sea ice, and surface waves), such error propagation considerations should become part of the model framework development. The Arctic Coastal Zone provides an opportunity given the comparatively trophic-level simplification and minimum level of direct human impact, yet the simplification points to the limited level of data to adequately validate ecosystem models. No long-term coastal morphodynamic model is identified suitable to the Arctic Coastal Zone, e.g., one that takes into account permafrost or other ice-sediment interactions.

Challenge 5: Mechanisms of Sediment Retention in Estuaries

Present numerical models are not capable of predicting estuarine evolution over long periods (hundreds to thousands of years), as there remain many problems in defining and quantifying the conditions at the open boundaries. Future progress should advance toward coupling models operating across different spatial and temporal scales. Behind each model lies commonly used concepts such as tidal pumping and scour and settling lags that require further improvements. A hybrid model may facilitate a better solution to the sediment transport problem. Boundary conditions are the biggest problem in modeling, whereas calibration and verification require detailed synoptic-scale data. Bedform predictions are very difficult but cannot be up-scaled. Model-coupling frameworks like CSDMS provide a solution to advancing our understanding of how estuaries, for example, can change from exporter to importer of sediment.

Challenge 6: Dynamics and Vulnerability of River Delta Systems

As a result of human development and global changes, deltas are now perilously out of dynamic equilibrium, being maintained at lower elevations and farther offshore than in natural conditions. While providing separation from quotidian delta dynamics, human stabilization of naturally dynamic deltaic systems is likely to result in less frequent, but catastrophic failures of delta system components following extreme events. Compounding chronic problems of deltas, extreme events may contribute to the collapse of entire deltaic systems. Although delta ecosystems are among the most productive and provide environmental goods and services of regional and global importance, human development within deltas and further upstream in the drainage basin may push deltas over ecological collapse thresholds. Our ability to preserve deltas depends strongly on a better understanding of the fundamentals of system-scale sediment, nutrient, and ecological dynamics from the watershed to the receiving basin. Research must be designed to address the full range of responses of this complex dispersal system to external forcing, and to assess its internal controls. Future programs should focus on (1) developing modeling methods for coupling biological, geochemical, physical, and human dynamics, and (2) acquisition of detailed information on forcing factors such as paleodischarge, high resolution sea level and subsidence histories, and past records of energy regimes in the receiving basin.

The new Coastal Vulnerability Initiative within CSDMS (section 4.12), and Working Group priority plans (section 4.2), demonstrate a focus on this challenge (and similar challenges for low-lying open-ocean coastlines).

Challenge 7: Prediction of margin stratigraphy

A new generation of predictive, process–response models provides insight into how sediment-transport processes work to form and destroy strata, and interact to influence the developing architecture along continental margins. The spectrum of these models ranges from short-term sedimentary processes (river discharge, surface plumes, hyperpycnal plumes, wave-current inter-actions, subaqueous debris flows, turbidity currents), to the filling of geological basins where tectonics and subsidence are important controls on sediment dispersal (slope stability, compaction, tectonics, sea-level fluctuations, subsidence). The CSDMS effort coordinates individual modeling studies and catalyzes Earth-surface research by: 1) empowering scientists with computing tools and knowledge from interlinked fields; 2) streamlining the process of hypothesis testing through linked surface dynamics models; 3) creating models tailored to specific settings, scientific problems and time-scales. The extreme ranges of space- and time-scales that define Earth history demand an array of approaches, including model nesting, rather than a monolithic modeling structure. Numerical models that simulate the development of landscapes and sedimentary architecture are the repositories of our understanding about basic physics underlying the field of sedimentology.

Challenge 8: Integration of surface dynamics and the silicate Earth

At the spatial scale of rivers, glaciers, coasts and structural features such as fault zones, current landscape theory and models struggle to fully investigate feedbacks between tectonic and surface processes. By linking with other initiatives, such as GeoPRISMS and CIG (Computational Infrastructure for Geodynamics), CSDMS will extend its modeling suite to include the Earth response to tectonic forcing by coupling surface process models with geodynamic models that characterize large-scale surface displacements in response to regional tectonic forcing and the rheologic structure of the lithosphere. These coupled models will quantify how landscape evolution responds to evolving pore pressure fluctuations, seismic cycles, and fault damage.

Challenge 9: Integration of data and models for high resolution water cycle predictions

The evaluation of ecosystem and watershed services, such as the detection and attribution of the impact of climatic and land-use changes are example of the pressing need for high resolution, spatially explicit resource assessments that resolve upland catchments. However, accessibility of the necessary geospatial data sources in support of distributed hydrologic models is limiting our ability to advance water cycle predictions at high spatial resolution, while underutilizing important data libraries for climate, soils, geology, terrain, and land cover. The essential data resource itself (climate reanalysis products, stream flow, groundwater, soils, land cover, satellite data products, etc.) resides on many federal servers such that fast and efficient access to the data during model development, analysis and simulation is not yet feasible. How can we align and support evolving regional geospatial and geo-temporal data products with new watershed model discretizations and parameterizations, support versioning of models and new data sources, while also offering the benefits of these new services to scientists, resource managers and stakeholders with regional, national or global interests?

4.0 Working Group and Focus Research Group Goals

4.1 CSDMS Terrestrial Working Group

The CSDMS Terrestrial Working Group (TWG) has four overarching objectives:

1) Facilitate scientific discovery in terrestrial surface dynamics through computational modeling.
2) Enhance the community's standards of practice and computational fluency.
3) Enhance technological capabilities for the computational study of earth-surface dynamics.
4) Contribute to national and international education in terrestrial surface dynamics.

These objectives might be alternatively phrased as follows: recognizing the value of numerical computing in scientific reasoning, visualization, and hypothesis testing, the Terrestrial Working Group seeks to promote scientific discovery and advance broad understanding of science by enhancing the current human and technological capabilities for computational modeling in terrestrial-surface dynamics and evolution.[1]

The role of the TWG in meeting these objectives is to use CSDMS technology to advance science, to contribute technology and training to CSDMS, and to guide the activities of the CSDMS Integration Facility staff. To meet these objectives, the Terrestrial Working Group has formulated the following short-, medium, and long-term goals.

Long-term goals

- Undertake and publish, both individually and in small self-organized groups, research that uses CSDMS technology to advance knowledge in sciences pertaining to land-surface dynamics and evolution.
- Contribute five or more CSDMS-capable models to the Model Repository, either by contributing new code or by adding Basic Model Interfaces to existing codes in the repository.
- Develop and contribute data sets that can be used for model testing, validation, and/or inter-comparison.
- Demonstrate a culture of practice in robust, consistent model benchmarking through analytical solutions and standard, consistent test cases.
- Demonstrate enhanced use of uncertainty analysis in terrestrial surface-dynamics modeling.
- Contribute to understanding feedback between solid-earth and surface-earth evolution by working with the Geodynamics Focus Group to develop a coupled model.
- Actively exchange ideas, concepts, and tools related to scientific computing.
- Provide continuing guidance to Integration Facility staff on design and infrastructure.

Medium-term goals

- Develop one or more case studies in model-data comparison.

[1] Note that the domain of interest within the Terrestrial Working Group also includes the surfaces of other planets and satellites; hence "terrestrial" here refers both to earth itself as well as to the terrestrial planets and moons in our solar system.

- Seek independent funding to support research that takes advantage of CSDMS technology and capabilities.
- Contribute material to the CSDMS Education and Knowledge Transfer library.
- Increase the number of CSDMS-capable models in the repository (by at least two or three).
- Develop a set of standard test inputs/cases for at least one class of model.
- Identify legacy data sets that could be used for model testing/validation in areas such as runoff and soil erosion; where feasible, develop these into web-hosted products.
- Create a prototype, Python-based software collection to support rapid development of 2D models and model components, particularly those dealing with geophysical processes and flows on/across terrain (such as soil moisture and vegetation dynamics, runoff, sediment transport, impact cratering, etc.)
- Actively exchange ideas, concepts, and tools related to scientific computing.
- Provide continuing feedback to Integration Facility staff on design and infrastructure.

Short-term goals

- Form two or more small groups ("theme teams") to collaborate, share, and advance particular topics, contributing to CSDMS and science along the way. (A list of possible groups was developed at the 2013 All-Hands Meeting.)
- Contribute at least one new (or newly integrated) model to the repository.
- Undertake at least one research project that uses CSDMS models, tools, HPCC, and/or model coupling capabilities to advance terrestrial science.
- Contribute to community training in computational tools and techniques through clinics held at the annual meeting.
- Demonstrate best practice in scientific software development and application.
- Actively exchange ideas, concepts, and tools related to scientific computing.
- Provide continuing feedback to Integration Facility staff on design and infrastructure.

There are several mechanisms for meeting these goals. Individual members and self-organized small groups are asked to help achieve these goals by using CSMDS technology in their own research, by guiding the work of the Integration Facility through formal and informal feedback, and by contributing new or enhanced code, educational material, data, documentation, and/or training. Small, thematic teams organized in years one and two will help identify gaps in the model repository and capabilities, and work with the Integration Facility team to rectify them. Members will contribute to training by providing lectures and clinics at the annual meeting, and/or in conjunction with other professional meetings. Members will also contribute to enhancing the standards of practice in terrestrial surface-dynamics computing by demonstrating "best practice" (such as the use of version control, unit tests, and clear documentation) in their own work. The TWG will gather annually, typically in conjunction with a CSDMS "all hands" meeting, to plan, reflect on progress, and provide feedback to the Integration Facility. The TWG Chair will foster these activities by facilitating and reporting on annual group meetings, participating in Executive Committee meetings, and periodically communicating with the group through electronic media.

4.2 CSDMS Coastal Working Group

Overarching Goals

1 Improve the understanding of, and ability to forecast, how a broad range of coastal environments evolve, including the effects of: the dynamic feedbacks among physical, biological, and human processes; interactions between different environments along coastlines; and interactions among coastal, terrestrial, and marine environments--all under a range of climate and management/land-use scenarios. (Initial goals for the next five years listed as 'specific science goals' below.)

2 Address societally important science questions, and assemble a set of model tools facilitating investigation of coastal impacts and vulnerability, and their variability-- and to enhance the ability of coastal managers and policy makers to use and interpret the modeling tools and results (in collaboration with the Education and Knowledge Transfer Working Group, key stakeholders, and decision makers).

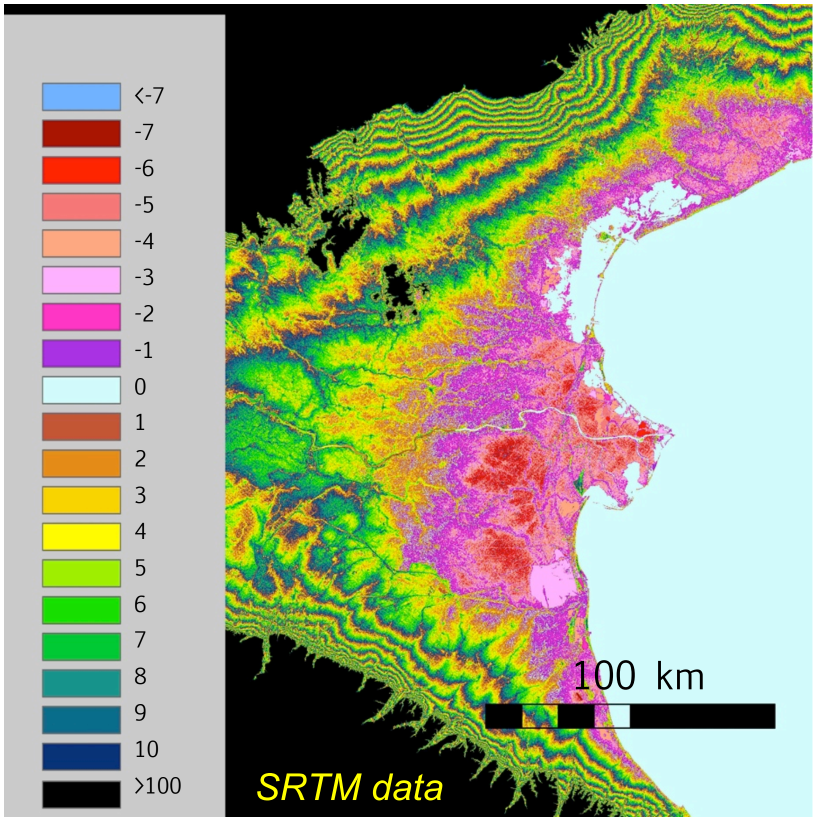
Specific Science Goals (SSG's) Under these Umbrellas, and Steps Toward Them

SSG1: To improve understanding of and ability to hindcast/forecast past and possible future *delta evolution on decadal to millennial time scales, as affected by couplings between terrestrial, fluvial, coastal, wetland, floodplain, subsidence, ecological and human processes*. This could ultimately include coupling between 1) long- term changes in delta morphology/ecology and 2) storm-event impacts to morphology, vegetation, and human dynamics and infrastructure. Based on a recent Working Group Meeting report (as well as the CSDMS 2.0 proposal), the science questions that a suite of coupleable delta-evolution model components can be used to address include:

- *What are the fundamental controls on delta size, shape, and elevation?*
- *How might deltas change as dams are removed and sediment flux is restored to a pre-dam level?*
- *How do human manipulations of fluvial processes on deltas alter delta evolution?*
- *What determines the extent of wetlands, under various scenarios of human manipulations, relative sea-level rise (including subsidence) and upstream land-use changes?*
- *How do storm surge and flooding threats vary among different scenarios?*

Short Term Step (1 - 2 years)

- Begin to build on the coupling between CHILD and SEM (Seascape Evolution Model) to develop a suite of coupleable models to achieve the long-term delta-evolution goal. Specifically, construct a model component for dynamic river avulsions (requires community effort), and couple CEM to SEM (CSDMS Integration Facility effort).
- Discuss the possibility of establishing a particular site, or sites, for the community to focus study on, in addition to the Wax Lake Delta that the Delta Dynamics Collaboratory (an NSF Frontiers of Earth System Dynamics project). Desirable attributes for additional sites include the availability of data sets appropriate for model testing and inter-comparison, and conditions that contrast with those at the Wax Lake Delta, including more significant human presence and manipulation (possibilities include the Gambia Delta—please see the initial plans for the Coastal Vulnerability Initiative).



Elevations of the Po Delta, Italy, and the coastal lowlands

Medium Term Steps (3 + years)

- Add to the delta-evolution coupleable-component model suite a model (or models) of wetland and floodplain accretion, and couple the existing subsidence component (coupleable) to the others in the suite.
- Couple long term delta evolution with storm surge models; run a hydrodynamic model (e.g. ADCIRC) on the morphology resulting over decadal to century time scales under various climate and human-manipulation scenarios to assess how storm impacts vary.
- Better determine the role of organic sediment accretion and vegetation dynamics in delta evolution.
- Improve our ability to reproduce delta morphology using hydro- and sediment-dynamic models (e.g. Deft3D) more realistically.
- Record the stratigraphic record of delta ecomorphodynamic evolution— e.g. under what conditions the stratigraphic signal is dominated by foresets vs. topsets—under various climate, sea-level-rise, and human-forcing scenarios (the capability exists within SedFlux components).
- Add human-dynamics modeling components, ranging from traditional economic analytic approaches to agent-based models of how human react to changing coastline morphology and rates of change.

SSG2: To improve our understanding of and ability to forecast how the *morphology, ecology, and human components of sandy coastal environments co- evolve under different scenarios of changing storm climate, sea level rise, and human manipulation* --including coastal environments ranging from urban to undeveloped.

Short Term Steps (1 - 2 years)

- Identify what models should be included in the model suite to address sandy coastline eco-human-morphodynamics (including interactions between dune growth, storm impacts and recovery, land-use, and barrier island evolution).
- Decide on criteria that would determine which sites would be useful for benchmarking and intercomparison, after determining which models we want to test (possibilities for developed sites include the New Jersey Coast—please see the initial plans for the Coastal Vulnerability Initiative).

Medium Term Steps (3 + years)

- Investigate, using coupled hydrodynamic, eolian, ecological, and human- development models, how storm impacts and post storm recovery processes on sandy coastlines depend on ecomorphodynamic state and on human development patterns, and under what climate and human forcing scenarios thresholds may cause rapid and dramatic shifts in the morphologic/ecologic/development states.
- Improve our understanding of biological processes and interactions between biological and physical processes.
- Increase the involvement of social scientists in these investigations, to address couplings between physical/ecological and socio-economic processes (through model coupling).

Cape Hatteras, NC, after Hurricane Sandy made landfall nearby in 2003, showing storm-related flooding, old groynes that have influenced coastline morphology, and a landmark lighthouse that had recently been transported a kilometer farther inland after a century and a half of chronic shoreline erosion threatened it.

SSG3: To improve our understanding of and ability to forecast how *rocky and soft-cliffed coastlines change over time, as human manipulations (e.g. river damming and coastal armoring) and changes in climate affect interactions* *between cliff erosion, sediment production, and sediment redistribution*-- and how these interactions affect coastal communities.

Short Term Steps (1 - 2 years)

- Identify what models should be included in the model suite to address rocky coastline human-morphodynamics, in addition to CEM Rocks (the version of CEM including lithological variations, cliffs, and nonlinear interactions between cliff erosion rate, sediment production, and beach sediment redistribution).

Medium Term Steps (3 + years)

- Add a BMI to CEM Rocks and other prioritized rocky-coastline models
- Conduct model experiments addressing rocky coastline evolution, and how it interacts with local engineering projects (including river damming, cliff defenses, jetties, groynes, and beach nourishment).

Science-Facilitation Goals (SFGs)--In Support of SSGs, and More Broadly

SFG 1: Provide open access to a toolbox of stand-alone and linkable models and modules that represent the scientific state of the art—while continually adding to it as knowledge and modeling capabilities improve.

a. Enhance the efficiency of scientific advance, as individual scientists and research groups use the models in the toolbox, both stand-alone and linked, to address new intra- and inter-environment questions (with reduced need for new model development).

b. Allow the broader community, including educators and environmental managers, to use state-of-the-art science and modeling capabilities (and animations) when addressing landscape and ecosystem evolution, global change (including direct human manipulations of landscapes as well as climate change) and exposure to natural hazards—and to educate them about the uncertainties and caveats associated with each modeling endeavor.

Short Term Steps (1 - 2 years)

- Update evaluation of present knowledge of processes in coastal environments (nearshore, inner shelf, barrier islands, sandy coastlines, rocky coastlines, estuaries, lagoons and marshes, eolian, deltas)— including the human component of those systems (i.e. direct couplings between human manipulations and landscape evolution in deltas and coastlines)—and identify the numerical models presently in use.
- Identify gaps in knowledge and areas where model development is needed—both poorly understood phenomena requiring basic research and exploratory modeling, and better understood systems for which model reliability should be improved.
- Continue to gather available models; reach out to researchers with useful models that are not yet contributed to the CSDMS, making them available to other scientists and the broader community.
- During year 1, prioritize MODEL X for the roadmap (community effort for BMI development, followed by Integration Facility effort for CMI; see below). Priority targets include: SWAN; ADCIRC; and a simple fluvial avulsion component based on the Jerolmack/Paola model.
- Identify the models to add to the CSDMS coupleable-component toolbox (i.e. the next 'roadmap' models) in years 2 and 3, based partly on successes during year 1. Priorities in addition to those listed above under short-term steps may include a version of CEM including rocky-coastline dynamics, and the Barrier Island ecomorphodynamic model.

THE CSDMS 2.0 ROADMAP *to componentize a model:*

1. *Identify a community need*
2. *Identify a specific model.*
3. *Refactor model to comply with BMI standards (task of model developers). Documentation on CSDMS wiki http://csdms.colorado.edu/wiki/BMI_Description. CSDMS IF to offer support through Skype or work with developer(s) at the IF. BMI seminars will be given at meetings.*
4. *Generate XML– GUI file for component (developers & IF staff)*
5. *Provide input and output test data (developers)*
6. *Test stand alone component on CSDMS HPCC (IF staff)*
7. *Component help pages created (developers & IF staff)*
8. *Component tested for a coupled simulation.*
9. *Coupled run simulations lead parties to publishable paper*

Medium Term Steps (3 + years)

- Identify the models to add to the CSDMS coupleable-component toolbox

  (i.e. the next 'roadmap' models) in years 4 and 5.
- Encourage the coastal science community to propose to funders scientific projects that will help fill gaps in knowledge and gaps in modeling capabilities.
- Persuade the modeling community to continue to adopt CSDMS protocols as new models and model components are developed, so that models can be more readily shared and in some cases linked to other models and components.
- Encourage the community to undertake the linking of specific models of different environments (within and beyond coastal environments); to broaden our thinking to include scientific questions we don't currently entertain, and to write proposals to address such questions involving multiple environments. Roadmap projects we identify will provide examples.
- Collaborate with the EKT WG (and end users/stakeholders) to facilitate future use of the toolbox, and interpretation of model results; for example, what information needs to be provided along with the model toolbox to help non-modelers understand various sources of uncertainty?

SFG 2: Increase model benchmarking and model intercomparison activities, by enhancing the accessibility of key data sets (targeted to model-testing needs), and groups of data sets (e.g. a range of variables measured in one region, or the same variables measured in a range of different environmental settings).

Short Term Steps (1 – 2 years)

- Determine the most appropriate data sets (and sets of data sets) form model testing (comparing models to nature) and intecomparison (comparing models to models)
- Discuss the most appropriate ways to test and compare models -- e.g. reproducing specific time/space changes (short term) vs. statistical comparisons (longer term morphodynamics and ecomorphodynamics)
- Seek out data rich sites involving significant perturbations to the background conditions, because the relatively rapid re-adjustments provide challenging targets for models to reproduce. (One possible example: in the Netherlands, a recent massive beach nourishment project is being very closely monitored, providing data appropriate for testing coastline-change models.)

- Begin to gather data sets most needed to test, benchmark, and compare models
- Notify the community that the open-source GIS package GRASS can be useful for model testing, benchmarking and intercomparison, facilitating analysis of, for example, sediment volumes, or dune characteristics.

Medium Term Steps (3+ years)

- Evaluate and describe the uses, intended goals, and limitations of the available models. Which of them are designed to address abstract, basic science questions; which are designed to provide detailed and accurate simulations of processes and evolution in either specific locations or generic environment types; which fall between these end members; and how well do the models accomplish their goals (e.g. numerical fidelity and stability)? This large task will require significant community input, via the CSDMS wiki, as well as through peer-reviewed journal articles.
- Evaluate the uncertainty that results from stochastic initial and boundary conditions (i.e. suite of model runs using different initial, boundary, or forcing conditions will produce different results in detail), as well as that from parameter uncertainty, model imperfections, and forcing input error.
- Encourage the community to engage in model testing, benchmarking, and intercomparison activities.

SFG 3: Compile a set of coupleable, interchangeable process-oriented model components (tools) representing, for example, hydrodynamics, sediment dynamics, and ecological dynamics that can be used to address morphodynamic (and ecomorphodynamic) evolution in a range of contexts.

Short Term Steps (1 – 2 years)

- Target process-oriented models to add to this tool suite through the roadmap process. Initially prioritized candidates include a wave- transformation model (e.g. SWAN), a coastal hydrodynamic model (e.g. ADCIRC), and a generic bed-elevation model (may require significant model development).

Medium Term Steps (3 + years)

- Sequentially add more models to this suite, including vegetation-dynamics models (likely separate models for different vegetation types—e.g. seagrass, marsh grass, and dune grass).

4.3 CSDMS Marine Working Group

The Marine Working Group meets the challenges of representing continental shelf, carbonate, slope, and deep marine environments within surface dynamics models, as well as linking oceanographic processes to surface dynamics in neighboring and coupled systems, like coastal, atmospheric, and fluvial environments. In the coming decade, the working group especially encourages the use of advanced numerical modeling techniques to address the following large-scale goals and research issues.

- **Develop understanding of global variability** of shelf morphology, stratigraphy, and margin transfer processes as a function of external drivers (e.g., river discharge, coastal energy, etc.) under past, present, and future conditions.
- **Produce tools for quantifying human impacts** to the global ocean and coastal regions including ramifications of climate change, sea level rise, pollution and nutrient input.

- **Advance insight into how marine surface dynamics and biogeochemical systems interact** using interdisciplinary models to evaluate the ramifications of physical and geological processes in ecosystems and biogeochemical processing.
- **System understanding at large space and time scales** should be informed by more detailed studies that resolve smaller scales.
- **Coupling of atmospheric, wave, ocean, sediment and biogeochemistry models** can enhance our quantitative understanding of continental margin systems .

Intermediate – to – long-term goal:

A key advantage offered by CSDMS is the coupling it facilitates, which will aid in addressing the long-range research goals of the Marine Working Group listed above. In the next phase of the program, therefore, research problems that can be tackled through model coupling hold special promise. Additionally, now that CSDMS has matured, research programs that include expertise from multiple working groups may be well suited to both capitalizing on CSDMS infrastructure and addressing exciting science questions. Toward this, the Marine Working Group should focus on research issues that could most benefit from improved connections between the marine domain and other disciplines (coastal, terrestrial, carbonate, etc.), and encourage proposals involving Marine Working Group members and researchers from other groups.

Short Term Goals

Effort during 2008 – 2012 was expended to incorporate version(s) of the Regional Ocean Modeling System (ROMS) within CSDMS, to provide the Marine Working Group and others a marine hydrodynamic and sediment transport model within CSDMS. Use of ROMS, however, requires some expertise, and the model includes features that are not necessarily relevant to many CSDMS applications, such multiple advection schemes, data assimilation, etc. Additionally, as research code, ROMS continues to be updated. To capitalize on the previous effort and facilitate the use of a marine hydrodynamic / sediment transport model within CSDMS, the Marine Working Group recommends that

- **CSDMS provide a stable version of a hydrodynamic model for research and teaching**, which could be a simplified version of ROMS. CDMS should provide inputs and sample output for archetypal estuary and shelf configurations, such as are available as ROMS test cases. Students and researchers should be able to quickly get the code, run it, modify model inputs, and generate reasonable hydrodynamic and sediment transport fields.
- **A second ocean model be incorporated**, perhaps a finite-volume model like FVCOM, or one with a large user base like Delft-3D. Another alternative would be a one-dimensional (vertical) model instead of a three-dimensional model. Candidates include Wiberg (1994) and the SEDTRANS code of Li, Amos, and colleagues.

Other short term goals include efforts that should benefit marine surface dynamics modeling in general, regardless of the choice of hydrodynamic model. These include

- CSDMS should provide a module for translating Matlab code to Python. Many marine researchers use Matlab for model development and data processing, but, unlike Python it requires a software license.
- A wind model should be added to the CSDMS repository such as the WRF (Weather Research and Forecasting) model, because coastal hydrodynamics are especially sensitive to wind forcing.

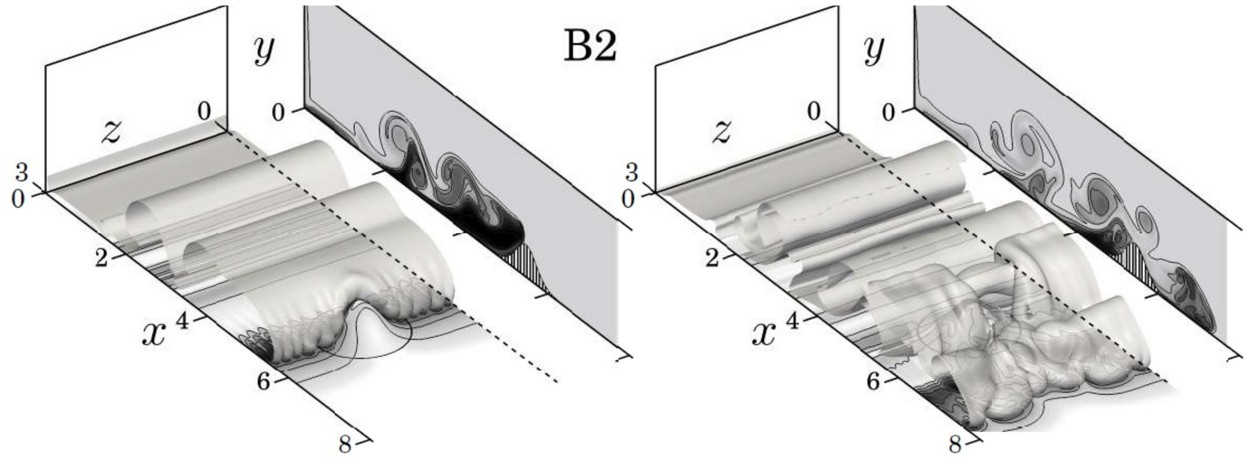
CSDMS encourages the development of studies that involve Marine Working Group expertise in concert with researchers from other disciplines. Members of the Marine Working Group are especially excited by the following ideas for capitalizing on CSDMS functions to address compelling research questions.

- **Coupling between land use practices and estuarine water quality.** A land-use model that predicts freshwater, sediment, and nutrient runoff could be coupled into a estuarine hydrodynamic / water quality model to study the feedbacks. The CSDMS Chesapeake Focus Research Group has expertise in this area and could work to link land use models to, for example, the ChesROMS community model.
- **Subaqueous delta evolution** involves feedbacks between fluvial discharge and shallow marine circulation, but many geomorphic and hydrodynamic models neglect this coupling. CSDMS could be used to link shelf and river circulation and sediment transport to the evolution of subaqueous deltas.
- **Sediment routing from fluvial and coastal sources to offshore sinks** is poorly represented by models, and the processes that trigger transport episodes have not been decisively identified. CSDMS could provide a platform for coupling turbidite and / or contourite models to hydrodynamic circulation and sediment transport models.
- **The evolution of carbonate systems** respond strongly to conditions in their shallow marine environment, and likewise impact hydrodynamics and mixing there. To explore these feedbacks, the CSDMS could be used to link carbonate production and morphology to ocean circulation, turbidity, nutrients, light penetration, etc. using a hydrodynamic model coupled to a carbonate model.

Past efforts within CSDMS identified the following processes as essential marine components that have received a fair amount of attention within CSDMS: dynamics of muddy seabeds (including biological mixing); dynamics of sandy seabeds (including bed form dynamics); dynamics of mixed sediment-size/composition beds; gravity-driven flows; bedload and suspended load transport (including nepheloid layers); isostasy; subsidence; and tectonics. Conversely, several topics that were originally identified as high priority do not seem to have yet received much research focus. Therefore, within the next phase of the project, we encourage research in areas such as particle aggregation/disaggregation; dynamics of muddy seabeds (including irrigation, diagenesis); dynamics of carbonate sediments (including effects on porewater chemistry, seabed scour); and sediment-related ice dynamics.

4.4 CSDMS Cyberinfrastructure and Numerics Working Group

Extensive discussions among the Working Group members during the most recent CSDMS Annual Meeting identified several scientific research topics that are of interest to a number of group members, and that can serve as focal areas around which the group's activities can crystallize during CSDMS 2.0. Chief among these research topics are the fields of computational fluid dynamics (CFD) and sediment transport. In these areas, the group members have extensive expertise in the development and application of a suite of sophisticated computational codes to address transport mechanisms over a wide range of length scales, ranging from grain-scale dynamics, to intermediate laboratory scales (e.g. Open Foam including particles; TURBINS), to field experimental scales (TURBINS-LES), and to full field scales (Delft 3D), (ROMS). The group furthermore combines extensive expertise in the areas of Cyberinfrastructure: software componentization, coupling, interoperability, standards, semantics, algorithms, databases, social networks, hardware and related topics. In addition, the Working Group has a strong interest in possible extensions of its activities to ecological applications, such as the coupling of fluid dynamics/sediment transport with vegetation, larvae transport, transport of nutrients and pollutants and related issues.



Turbidity current traveling over a local seamount (from Nasr-Azadani and Meiburg, 2013).

The above areas of expertise and research interests, in conjunction with access to simulation software, led to the identification of the following set of research directions and goals:

Key directions and long-term goals

- Make existing models accessible and useful to the widest possible community
- Create legacy databases that can benefit wide research community
- Develop nested models to address multiscale phenomena
- Help improve capabilities of reduced complexity models
- Uncertainty quantification
- Perform model inter-comparisons
- Develop strong ties with EarthCube

These long-term goals can best be achieved by pursuing a set of more specific and concrete intermediate goals:

Medium term goals

1. Perform model inter-comparisons between TURBINS, Open Foam, LES, RANS models for a few canonical sediment transport problems
2. Target one or two of the above codes for creating demo examples of computational models and databases that address the needs of the community, such as:
   - Standardized way of accessing models/databases
   - Easy access even from developing countries (outreach)
   - Databases need to be interoperable ("internet of things")
   - Ability to query datasets for various quantities (velocities, sediment concentrations etc.) at arbitrary locations
   - Allow for easy visualization of databases
   - Accommodate large data files (bring model to the data, instead of the other way around?)

- Searchable in automated fashion (semantics)
- Ability to feed real-life data into ongoing simulations (such as updated rainfall statistics)
- Employ social networking tools to build user communities, track user experience, create discussion forums (Google groups)

3. Continue to provide Python, MATLAB, Octave clinics, offer Q&A sessions, post on YouTube

4. Create systematic infrastructure for performing model comparisons

As an overarching idea for the activities of the group, the concept of **"Earth-on-a-Chip"** will be useful, in the sense of developing advanced modeling concepts in support of the environment, as well as water and energy resources.

4.5 CSDMS Education and Knowledge Transfer (EKT) Working Group

What is the business of CSDMS EKT, and What Have We Accomplished?

We are in the business of developing and transferring CSDMS tools and knowledge to the following groups:

•Researchers with model and visualization tools

•Planners with decision-making tools to run scenarios,

•Educators with pre-packaged models

For our educational materials, we should provide materials that help develop quantitative skills, and critical evaluation of model assumptions and outputs. Our principal Education audiences are university students, professionals, teachers at the secondary school and college levels, and the general public.

Based on the questions above, here is one possible framework for considering EKT products:

- *Fundamental process models (perhaps 1D)*
- *Fundamental process models in space and time (multidimensional)*
- *Coupled processes in specific environments*
- *Processes and products linking surface environments*

Guiding questions for our considerations: 1) *What groups need which products? 2) Where do we stand with respect to product development and transfer to meet these general objectives?*

Where are we regarding our CSDMS 1.0 goals?

CMT: A CSDMS graduate Class has been taught 4 times, with summer clinic, using the CMT as a basis for instruction. However, CMT has a ways to go before it is ready for classroom use.

Non-CMT tools: We have had contributions of class materials from a number of individuals, but the collection is still limited. We need more applications for classroom use, more buy-in from other contributors.

Long-term goals for EKT group

Four directions: classroom education, research community, decision-makers, and government outreach programs (Science on a Sphere)

Education

Educational products could be steered towards distinct user groups:

1) For instructors who want to introduce students incrementally to applications of mathematics and code development: incremental stepping up of complexity in quantitative exercises, from chalkboard calculations to spreadsheets to simple code

2) For instructors who want to use packaged programs, or CMT components, to allow exploration of concepts and processes:

executable packages that include CSDMS-required metadata, equation explanation, and help files. These executables, and CMT components, can also be used by researchers who are seeking relatively simplified versions of more complicated models, such as discussions of ROMS-Lite, in the Marine Group.

For both educational trajectories, important concepts and processes include (but are not limited to):

1. Conservation of Mass,
2. conservation of energy
3. diffusion, advection, reaction
4. Uncertainty: sources, types, and estimation
5. Parameter estimation
6. Feedbacks and complex systems
7. Sediment Transport laws (sediment, contaminants)
8. equilibrium
9. feedbacks
10. residence times
11. thresholds
12. kinetics
13. steady state v. dynamic
14. adsorption/desorption
15. redox reactions
16. ion exchange
17. flocculation/deposition
18. mud consolidation and associated changes in critical shear stress(i.e. mud vs. sand)
19. scaling relationships
20. self-similarity and organization, like channel bifurcation

Sources and Examples:

- Look to the hydrologists: create a EKT hydro toolbox (see Gary Parker's ebook)
- SERC geomorphology vignettes
- Carlton educational repository. Could link to relevant SERC vignettes to get more exposure. http://serc.carleton.edu/NAGTWorkshops/geomorph/vignettes.html
- Python wiki on CSDMS web site, that is presently hidden but searchable

Products for Decision Makers (government agencies, NGO's industry)

Primary requirement includes advanced visualization and GIS enablement. A major long-term goal would be to integrated complex, nested, and coupled models linked through CMT with open-source GIS

Two separate approaches:

1. Two-way coupling of open-source GIS and computational models, such as interaction of sediment transport, erosion, and deposition with DEM. This will allow adherence

with CSDMS mandates for open source tools. One example of this is Andy Wickert's embedding of FLEXURE (Doi: 10.1594/IEDA/100123) in the GRASS openware GIS.

2. One-way coupling of models with GIS, using industry standard formats for model output, to allow use of GIS engines for visualization and communitcation (e.g., SHP, KMZ, etc.). This approach will acknowledge the widespread use of some proprietary formats and GIS environments (ESRI and SHP for example).

Elements to consider in these approaches:

- -Ensemble runs in a geospatially registered environment, running several scenarios using different perturbations then comparing outputs
- -Embed uncertainty
- -Reach out to other communities: i.e. landscape architects, regulatory managers, coastal management/deltaic community, to determine tools most in need.

Government Outreach Programs

Test case: Science on a Sphere

Several models are presently available for global implementation. Examples include:

-global river drainage basin/discharge

-Wavewatch 2 and 3

-temperature/climate of different regions around the globe

-watershed variability

Short-term action plan to achieve long-term goals

Year One: CSDMS2.0 Course Materials — Call to CSDMS community for contribution of exercises and assignments with modeling focus at a range of educational levels, with goal of at least one contribution per group WG.

- Polish and post products
- Develop simple assessment rubrics
- Distribute to pilot team of at least one person per WG for classroom use, with assessment
- Compile results and experiences and prepare/submit paper to Journal of College Science Teaching, with plan authors and testers as co-authors
- Hold a clinic at CSDMS 2014: "Bringing CSDMS to the classroom".
- Promote development of web-enabled CMT environment, to circumvent complications of getting large groups to use HPC
- Consider posting to Carleton College Earth Science Education website
- Implement high quality visualization for all products
- Consider uncertainty for all products
- Promote development of web-enabled CMT environment, to circumvent complications of getting large groups to use HPC.

Years One-Two: education and research for non-specialists. Develop streamlined model packages for classroom and researcher use, as binaries or simple CMT implementations

- Query CSDMS community to identify target models
- Componentize and/or prepare stable executables for offline use
- Prepare test cases submitted by user groups or developers
- Promote development of web-enabled CMT environment, to circumvent complications of getting large groups to use HPC
- Implement high quality visulalization for all products
- Consider uncertainty for all products
- Consider developing test cases for existing componentized models for educational use and tutorials for non-specialists, one or more per WG

Year Two and farther out: Coupling between GIS and CMT.

- Seek out and advertise the existing proof-of-concept examples
- Develop tool to couple GRASS GIS and CMT
- Query end-users to identify key modeling tools and GIS environments for future implementation
- Promote development of web-enabled CMT environment, to circumvent complications of getting large groups to use HPC

4.6 CSDMS Carbonate Focus Research Group

Carbonate FRG Progress To Date

- Of the more than 60 members only a few of these members are currently active coding and compiling data with some NSF support
- Despite this, we have developed multiple carbonate forward models since representing a range of innovative new modelling approaches
- We have also developed a prototype database of rates for carbonate systems. This has been populated with some prototype data and will imminently be released to the wider FRG community for feedback, further population and use in modelling studies.

Carbonate FRG Long-Term Goals

- The original group vision from 2008 remains valid; we aim todevelop a componentized "workbench" of carbonate models and encourage non-modellers to use them as the default tools to represent and understand carbonate depositional systems, both modern and ancient.
- The ultimate goals of this work is to better understand the nature ofcarbonate rock heterogeneity and to make 100 year predictions of carbonate response to environmental change. This will be achieved with a suite of new next-generation components that more properly represent complex carbonate biology and chemistry
- What is unique in our approach:
  - Population dynamics in carbonate models
  - An emphasis on spatial organization, facies mosaics, and their statistical analysis

- More explicit representation of trophics and water chemistry in the forward models
- An integrated knowledge base used to supply rate data to model runs
- Model runs that address research questions in both modern and ancient carbonate settings

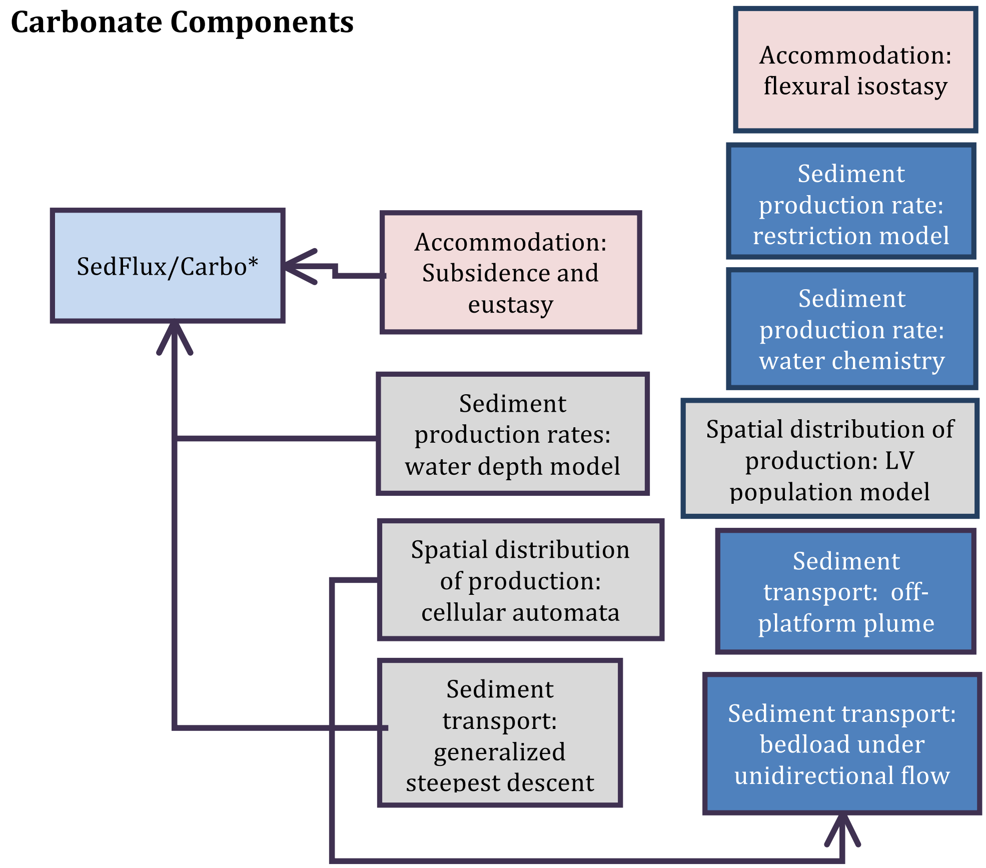
Carbonate FRG Long-Term Strategy: Specific Steps:

1. Develop BMI "wrapped" coupled carbonate model components that do all that the currently separately developed carbonate models (e.g. CarboCAT, CarboLOT, CarboCELL) do
   - Represents an evolution of the original Carbonate Workbench concept from 2008-2009
   - Components will represent both short time scale (decadal+) and long time scale processes (100Ky+) to satisfy the range of potential users
   - Will make extensive use of existing elements of SedFlux for representation of deposition as accumulated strata and for sediment transport elements. Non-relevant parts of SedFlux will be turned off
2. Complete development and population of a carbonate knowledge base and integrate it with carbonate model components. The prototype has been developed in Excel and is about to be shared with the wider Carbonate-FRG for feedback, further population and use in modelling studies.
3. Re-engage with the 60 members of the FRG community and grow the community by offering the developed components as a focal point for testing, benchmarking, further development and use as educational tools.

Carbonate FRG Short to Medium-Term Strategy Summary plan:

1. Detailed plans to engage with industry, NSF Steppe and NGOs
   - Tasks defined for PhD students, possibly funded by NSF Steppe & direct industry funding
   - Engage with NGOs for prediction for coastal defence reef growth
2. Document and share the carbonate knowledge base in its current form and open it up to contributions from and development by the wider carbonate community
   - Document the existing parameters that are in the knowledge base
   - Share the knowledge base on Google documents
   - Publish via CSDMS web site as an online database product
3. Recruit more carbonate coders
   - Coding group is gradually growing
   - Actively seeking new people who can help us write component code e.g. PhD students and postdocs

Change of leadership if Euro-CSDMS progresses rapidly



Proposed Carbonate Component Schema showing how a subset of several available carbonate workbench components (right column) could be selected to create a carbonate forward model (large blue box on the left) to tackle specific problems.

4.7 CSDMS Hydrology Focus Research Group

The Hydrology Focus Research Group is a partnership between CSDMS and the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI, http://www.cuahsi.org). CUAHSI is a nonprofit research organization supported by the National Science Foundation (NSF) and represents more than 100 U.S. universities and water-related organizations. Two of the projects under the CUAHSI umbrella are the CUAHSI Hydrologic Information System (HIS) and a service of Community Hydrologic Modeling Initiatives. There are important synergies between these CUAHSI projects and the CSDMS, and the Hydrology FRG was formed to foster exchange and interoperability between CUAHSI and CSDMS activities.

Hydrology FRG Activities to Date

- 376 members, making it the largest Focus Research Group within CSDMS.
- 52 hydrological models (43 CSDMS Modeling Tool, CMT, compliant) and 38 hydrological tools are indexed within CSDMS as of September 27, 2013. These include a set of modular models called TopoFlow that provide granular control for constructing coupled hydrological models using CMT.
- Designed and implemented a methodology for providing interoperability between CSDMS and

CUAHSI HIS through the use of CUAHSI HIS data services as CSDMS components (Peckham and Goodall, 2013).

Hydrology FRG Short-term Goals

- *Establish ways of collaborating between related activities that are currently happening within the hydrology community.* The Hydrology FRG was established to foster collaboration and interoperability between CSDMS and CUAHSI, but there are other related activities, especially with the addition of the NSF Earth Cube initiative. Our goals are to have clear strategies for collaboration between existing community/grassroots efforts, have the result of the collaboration be a force multiplier, and to leverage currently funded projects and activities to contribute to CSDMS.

- *Identify mechanisms for having more hydrologists participate in CSDMS*. While the Hydrology FRG has a large group of members, the fraction of these users that are actively participating in building and using CSDMS models is small. Encouraging more hydrologists to participate in CSDMS also requires acknowledgement that hydrology is a highly fragmented community, making it more challenging to make progress in community-based hydrologic modeling.

- *Propose a session on "Community Tools for Advancing Hydrologic Science" at the American Geophysical Union Fall Meeting.* The purpose of this meeting will be to engage the broader hydrology community (including but not limited to the current Hydrology FRG members) that are working in community hydrologic modeling and to provide an opportunity for this group to meet and network outside of the CSDMS Annual Meeting time. The session should be coordinated with related efforts, especially those organized through CUAHSI, in order to have broad participation in the session.

Hydrology FRG Mid-term Goals

- *Establish methods for model benchmarking and tests to assess model skill.* Benchmarks should assess minimum level of model capability while skill tests should assess model's range of application, as no model is skillful enough to address all questions posed by hydrologists. These benchmark and skill assessments should be standardized and well documented to allow for intermodal comparisons. The results of these tests will serve as an important model metadata metric that community members can use when selecting models for studies.

- *Determine specific needs within the community for new tools, algorithms, or models.* Have the community contribute specific computational needs and, potentially, also ask the community to rank the needs in order of importance. If there is insufficient engagement by the community in ranking the needs, then establish a committee to rank proposed needs to establish clear priorities for the community to contribute to through grant proposals.

- *Establish "challenge problems" that targeted specific needs of the community that are clearly articulated and of high priority.* Similar to how the X-Prize has encouraged innovation through competition, these "challenge problems" will engage the community in addressing community needs and be rewarded if their solution is selected as a prize winner. This approach should specifically target "next generation" scientists and engineers and should require the use of community tools (e.g., CSDMS) in their solution.

Hydrology FRG Long-term Goals

- *Lower barriers for hydrologists to participate in addressing important hydrologic challenges.* A fundamental challenge in hydrologic modeling that cuts across most modeling activities is that too much time is spent on basic activities (data preprocessing) and this limits innovation in advancing hydrologic models. CSDMS should address this challenge as one component of the community modeling needs for hydrology.

- *Make hydrologic models more open and transparent for both scientific investigations and to support policy and decision makers.* Models in hydrology have grown so complex that modelers are often forced to treat the models as effectively black boxes because they are unable to understand the internal physical representations within the models. CSDMS can address this problem by breaking complex models into components that are easier to understand as a component within a larger modeling system.

- *Improve data management capabilities as they specifically relate to supporting hydrologic models.* Hydrology is a "big data" field and we need to work on techniques to more effectively handle the data we have now and the data we will have in the future for addressing hydrology research questions. Advance the science of model linking/coupling, which is a complex problem within itself. Advance the science of multiscale models, especially those that cross multiple communities within CSDMS.
- *Foster culture shift in hydrologic modeling community toward collaborative and community-based model development.* Encourage scientists to be more willing to contribute to a community effort. Have community agreed on and widely adopted standards for model and data sharing and integration. Specific efforts must be made to target the next generation of hydrologic scientists and researchers so that they "grow up" thinking about modeling frameworks, model coupling standards, HPC, big data, etc. as core tools for doing their research.

4.8 CSDMS Chesapeake Focus Research Group

The Chesapeake Focus Research Group is a partnership between CSDMS and the Chesapeake Community Modeling Program (CCMP, http://ches.communitymodeling.org/), which is currently run by the Chesapeake Research Consortium (CRC). CCMP developed as the Chesapeake Bay research community came together with the common goal of cooperatively building an open source system of watershed and estuary models. Through support from CRC member institutions and the NOAA Chesapeake Bay Office, CCMP modelers have committed to developing a modeling framework that will enable free and open access to code specific to the Chesapeake Bay region. Together, CCMP and the Chesapeake FRG are striving to develop a comprehensive model system consisting of interchangeable individual modules covering diverse aspects of hydrodynamics, ecosystem dynamics, trophic exchanges, and watershed interactions.

Chesapeake FRG Progress To Date

- During CSDMS 1, the Chesapeake FRG co-hosted/co-sponsored three workshops in the Chesapeake region to help facilitate community awareness of CSDMS and its potential applications to Chesapeake related issues.
- As an outgrowth of the third of these three workshops, the Scientific and Technical Advisory Committee of the Chesapeake Bay Program produced a 28-page report (STAC Publication 11-04) entitled "Chesapeake Bay Hydrodynamic Modeling".
- In cooperation with the U.S. IOOS Coastal and Ocean Modeling Testbed, three ROMS-based 3D hydrodynamic models of the Chesapeake Bay have been added to CSDMS with BMI wrappers (CBOFS2, ChesROMS, and UMCESroms).

Chesapeake FRG Short-Term Term Goals

- Continue to populate the CSDMS with existing open-source Chesapeake Bay region models.
- Pursue avenues for group proposals including funding for full-time or nearly full-time Chesapeake FRG oriented personnel, such as a dedicated post-doc.
- Give priority to Chesapeake FRG related projects which focus on models with management implications, such as land use, water quality, ecosystem function, storm surge, etc.

Chesapeake FRG Intermediate Goals

- Train members of the Chesapeake FRG on use of CSDMS tools.

- Construct very simple land use and water quality box models for a Chesapeake FRG "sandbox" for members of the Chesapeake FRG to practice linking and implementing models within CSDMS.
- Post key common forcing data sets at CSDMS.

Chesapeake FRG Long-Term Goals

- Implement additional distinct, swappable land use models, hydrodynamic models, water quality models, ecosystem models, etc., in BMI format at CSDMS.
- Utilize CSDMS to make side-by-side comparisons of model performance and differences in output by systematically swapping model components.
- Utilize CSDMS to perform ensemble modeling (i.e., using multiple distinct models) of future Chesapeake environmental conditions under various management scenarios.

4.9 CSDMS – Geodynamics Focus Research Group

The Geodynamics FRG is new to CSDMS 2 and is co-sponsored by GeoPRISMS. It was formed with the aim of understanding the interplay between climatic, geomorphic, and geological/tectonic processes in governing Earth surface processes and landscape evolution. The Geodynamics FRG will move toward an integrated-coupled modeling suite that has the capability to account for paleo-topography, geology, substrate lithology, crustal deformation, climate, vegetation, runoff production, and ensuing sediment transport and storage. The FRG will be closely aligned to the CSDMS Terrestrial Working Group. Our road map for the next five years consists of :

1. Short-term goals focused on building up a community, determining key questions and identifying existing codes and how they might fit into the CSDMS framework;
2. Intermediate-term goals focused on building on existing codes and developing a robust coupled geodynamic-landscape evolution model(s);
3. Long-term goals that will build a community around these model(s), benchmark models and train users.

Short-term goals (1-2 years, 2013-2015)

- Reach out to the geodynamic community through GeoPRISMS and CIG (Computational Infrastructure for Geodynamics). Seek feedback from the community on our goals and strategy for moving forward.
- Convene special sessions at large conferences such as AGU and run one or more workshops to engage the community. [One such session is planned for the 2013 Fall AGU along with an evening Mini-Workshop sponsored by GeoPRISMS.]
- Evaluate state-of-the-art understanding and modeling of coupled geodynamic and geomorphic systems. This includes identifying existing models, their potential for inclusion into CSDMS, research needs, and areas where models, datasets, and understanding of key processes are missing.
- Identify potential proof-of-concept applications and data sets. Develop a set of criteria for proof-of-concept applications. Where coupling is not seen as feasible in the short term, these criteria should address the barriers to that feasibility.
    - Include a component of both surface dynamics and solid Earth deformation
    - Well-constrained boundary conditions

  Proof-of-concept applications could include:

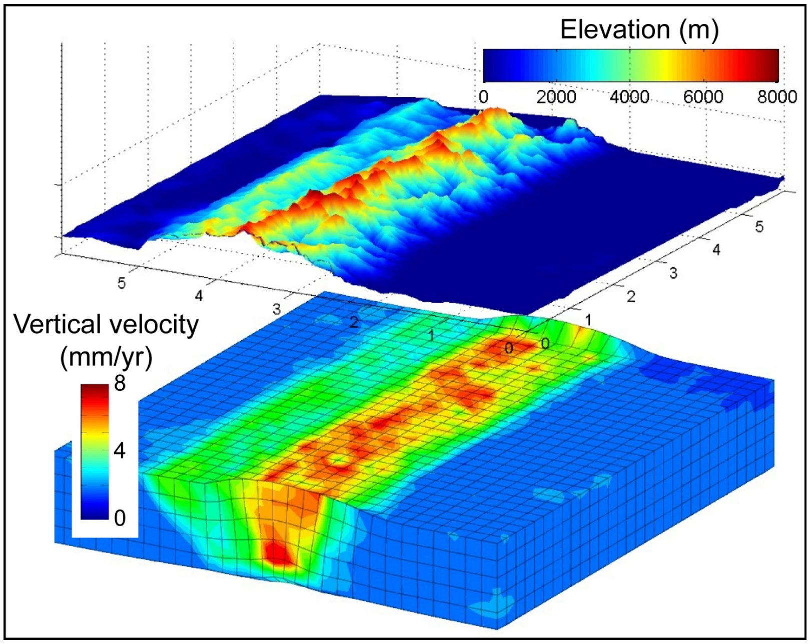
  - Modeling how one (or a system) of growing normal fault(s) evolve while simultaneously exposed to surface processes (erosion and deposition) and/or;
  - Modeling simple two-sided mountain ranges such as Taiwan or the Southern Alps
- Evaluate available codes and their potential for inclusion in BMI (Basic Model Interface) and CMT (Component Modeling Tool).
- Define and prioritize education needs/training within the CSDMS framework.

Intermediate-term goals (3-4 years, 2015-2017)

- Stimulate proposals from the community for projects that will address important science questions while completing steps necessary for realizing the overall goals of CDSMS, including (1) developing and improving software for CSDMS, (2) developing proof-of-concept modeling applications, and/or (3) developing strategies to test model predictions. In particular, encourage proposals that integrate a landscape evolution model and a geodynamic model within the CSDMS framework.
- Identify one or two models to focus development efforts and work with the Integration Staff to refactor the code with a BMI. Add code to the CMT.
- Implement proof-of-concept application(s) identified above. The application(s) will include a component of both surface dynamics and solid earth deformation, well-constrained boundary conditions, be testable by field or experimental data, and (ideally) will be used for model benchmarking and inter-comparison.
- Begin model benchmarking and inter-model comparison. The way we go about this will depend on which models we have decided to focus on, as well as which proof-of-concept applications have been chosen. Model benchmarking will assist users when determining which model/set of models to use for their research problem by highlighting the strengths and weaknesses of each model/set of models.
- Make modeling tools available for educational use. Including the contribution of simple model animations to the Quantitative Surface Dynamics Educational Toolbox.

Long-term goals (5 years and beyond, 2017-)

- Develop and test a fully coupled geomorphic/geodynamic problem (either within CMT or outside CMT). A framework problem would potentially include:
  - Underlying geology and structure
  - Tectonic boundary conditions
  - Surface processes (e.g., runoff production and ensuing sediment transport and storage)
- Contribute to the EKT (Education and Knowledge Transfer) program with the aim of seeing a new generation of computationally literate graduate students, versed in how to take maximum advantage of CSDMS tools and capability, begin to join the research community.
- Continue contributing to the Quantitative Surface Dynamics Educational Toolbox with animations, 'Concept to Model' exercises, simplified models for students to 'play' with, and more complex models for students to explore dynamic coupling problems.
- Develop and run hands-on training courses to build community involvement with specific codes and coupled modeling systems.



Example model of a coupled FLAC^{3D}/CHILD run of an evolving two-sided wedge. Information such as vertical velocity, amount of erosion and deposition is passed between CHILD and FLAC^{3D} as the run cycles between the mechanical and the surface processes solution. Models created and run by P Upton, P Koons, G Tucker and S Roy.

4.10 CSDMS – Anthropocene Focus Research Group

The Anthropocene FRG is new to CSDMS 2 and is a response to the clear resonance that has sounded throughout the scientific and wider communities to the proposition that we are now living in the age of humans, the *Anthropocene*. One of the challenges posed by the Anthropocene is the need to codify the human and societal processes into models of a future Earth. This challenge will require the engagement of related disciplines that typically approach the relationship between humans and nature from very different perspectives and with very different methodologies.

The goal of the Anthropocene FRG is to foster the development of models that attempt to understand the earth's critical zone environment in the face of human activities. To do this requires the incorporation and/or the development of new methods (e.g. next-generation agent based models, economic models) to quantify human influences (behavior and decision making) that affect earth system responses. It is important, too, to acknowledge the two-way travel of human processes, such that human activities impact the earth-system, but the earth-system (e.g. landscapes) influence the behaviour of humans. There is a potential therefore for both positive and negative feedbacks in emergent Anthropocene environments.

To quantify the state of the Anthropocene, there must be a consideration of a linked or a single human-earth system, comprising the dynamics of both biophysical and social systems with some coupling between them. This requires a diverse set of scientists working together, learning the languages and methods of each other's disciplines.

Our road map for the next five years is:

1. short-term goals are focused on building a community that is sufficiently broad to identify key issues and questions and to identify existing codes that might fit into the CSDMS framework.
2. The intermediate-term goal is to trial run a particular coupled model in order to gain experience in future earth modeling.
3. Long-term goals are to sustain an Anthropocene modeling community in an environment of shared models and exemplar (case-study) applications.

Short-term goals (1-2 years, 2013-2015)

- Communicate with related groups (both within and without CSDMS) in order to develop *buy-in* to the CSDMS effort of sharing and coupling relevant models.
- Convene an Anthropocene workshop that tackles the short-term goals described in the road map. Outputs would include a nascent membership of the Anthropocene FRG, key issues and questions, identified codes, and a set of possible case studies to pursue over a longer time scale.

4.11 CSDMS Critical Zone Focus Research Group

The new Critical Zone FRG will attempt to address the integrative and organic nature of team research in earth sciences where collocated experiments and coupled theories are breaking new ground in linking phenomena for the water cycle, ecosystem services, climate and landuse change, C-N dynamics, landscape evolution and geochemical weathering. The implicit challenge is to support the integration of disciplinary models and experimental data into a modern computational framework necessary for advancing prediction within Critical Zone. This framework should be data-driven, moving beyond numerical experiments or "toy models" to address fundamental processes at small-scale experimental sites to continental scales and national data sets.

The next 1-2 years:

1. Develop the on-line community of CZ researchers, their computational models and supporting data through the CSDMS website including international partners.
2. Create a Wiki that offers CZ researchers a chance to discuss their experience in using their models and data for CZ science.

The next 5 years:

1. Carry out an investigation under the auspices of EarthCube that evaluates the integrative experience of CZ researchers in utilizing CZ community models, assessing their computational requirements and relating their successes and failures in the integration of models and processes across earth systems domains and across multiple time and space scales.

4.12 CSDMS Coastal Vulnerability Initiative

Demolished, condemned, and threatened houses on the North Carolina Outer Banks, after Hurricane Isabelle made landfall in 2003 (courtesy of Lisa Valvo).

Scope

At an initial break-out session at the 2013 CSMDS All Hands Meeting to launch this Initiative, we discussed the definition of 'coastal vulnerability', and agreed that for us, this term refers to both the vulnerability of human coastal infrastructure and habitation to coastal processes that can impact them, and to the vulnerability of coastal ecosystems, which provide critical ecosystem services to society.

We discussed the relationship between the Coastal Working Group and the Coastal Vulnerability Initiative. Clearly, because the discussions in the Coastal WG included substantial and enthusiastic suggestions for WG goals that address human and ecosystem vulnerability in coastal environments, a subset of the current Coastal WG goals apply to the new Coastal Vulnerability Initiative—those involving the impacts of coastal processes on human infrastructure and activities, as well as the reverse. (Below we include the main goals articulated by the Coastal WG, with highlights showing which aspects apply to the Coastal Vulnerability Initiative.)

Discussion in the initial break out session focused on how the CSDMS community can most effectively contribute to addressing issues of coastal vulnerability and sustainability. Clearly, through modeling of storm impact using detailed hydrodynamic and sediment-dynamic models, we can contribute to the ability to forecast the effectiveness of alternative coastal- management policies, and associated engineering efforts, in protecting coastal infrastructure. Coupling state of the art models in the CSDMS toolbox will facilitate such assessments.

However, this group can also offer unique contributions to our understanding of how the long-term evolution of coastal environments depends on human actions, from land-use changes to coastal policy decisions. Typically, engineering interventions to protect or enhance human use of coastal environments is undertaken and evaluated in the context of impacts on scales up to kilometers and years. The relatively small-scale engineering interventions, however, alter the landscape-forming processes, and therefore the long-term, large-scale trajectories of landscape evolution (including ecological and human-development states).

Human decisions regarding coastal management and defense of coastal infrastructure, in turn, depend on how coastal environments change—ranging from rates of coastline erosion to flooding frequencies and the severity of storm impacts. Therefore, human dynamics and coastal dynamics are intimately intertwined. The CSDMS modeling community is uniquely capable of evaluating the long-term (decades to centuries), large-scale consequences of alternative engineering and coastal management approaches.

Given this thorough coupling between the long-term evolution of human actions and coastal morphology and ecology, the Coastal Vulnerability Initiative is also clearly linked with the Anthropocene Focused Research Group.

Geographical Scope

We agreed that this initiative should clearly focus on studies of delta environments, as well as sandy coastlines, and possibly rocky coasts as well. In each case, human decisions help shape the future of coastal environments and the future set of hazards human coastal habitation faces.

The town of Hatteras, NC, a week after Hurricane Isabelle made landfall in 2003. The image shows extensive overwash, gaps in beachfront development where houses were removed, and in the foreground, an inlet created during the storm (and subsequently enlarged by tidal currents) that cut the only highway linking the barrier community to the mainland.

We agreed that the idea of concentrating community efforts on the study of a small number of case-study regions, raised initially in Coastal WG Breakout sessions, makes especially good sense in the Coastal Vulnerability context. For example, the Gambia Delta, already the focus of World Bank attention, could provide a highly relevant case study to test coupled-model studies of delta and human dynamics against. In addition, the Netherlands coast offers the combination of intensive coastal defense efforts (specifically beach nourishment) and intensive monitoring of the results. The New Jersey coast, in the wake of superstorm Sandy, offers clear advantages for studying how coastal development density and style affects storm impacts, and in in the longer term barrier island morphological evolution—and therefore future human habitation. How do management reactions to Sandy vary from community to community, and what might the long term results be for the human/island system? As the shape of the Coastal Vulnerability Initiative emerges, we should discuss the most appropriate case-study regions.

Partners Scope

How the Coastal Vulnerability Initiative will evolve in the coming months will depend on the fate of several pending proposals. This includes multiple Belmont Forum consortia (multinational, interdisciplinary efforts involving physical and social scientist as well as a strong component of end-user involvement), Coastal SEES (NSF Science, Engineering and Education for Sustainability call for proposals), and FESD (NSF Frontiers of Earth Surface Dynamics call for proposals). The currently funded Delta Dynamics Collaboratory FESD project should certainly be involved in this initiative. In addition, we several USGS personnel should be asked to join this Initiative.

We clearly need to engage a growing number of social scientists (e.g. economists and anthropologists) in the studies of couplings between landscape/ecosystem changes and human dynamics. Along with helping us investigate coupled human/landscape evolution, social scientists can help evaluate the costs/benefits associated with alternative management strategies.

Intended Stakeholder/Decision-Maker Audience Scope

We disused what level of government entity would be most likely to make use of the information we could help provide, and agreed that community level planners were less likely to be interested in longer-term, larger-scale consequences of local actions than are than region- scale entities (governmental, NGOs, and corporate—including insurance and re-insurance). On the other hand, reaching out to stake holders at the household level, for example with interactive games showing the long-run consequences of alternative management policies, could help create a better informed constituency. In any case, effectively reaching out to stakeholders likely requires the involvement of social scientists and/or specialists in science communication, which we will lobby for the Education and Knowledge Transfer Working Group to focus more directly on, in collaboration with those involved in this initiative.

Selected Coastal Working Group goals (5 years +), illustrating overlap with Coastal Vulnerability overlap Initiative

Overarching Goals

1. Improve the understanding of, and ability to forecast, how a broad range of coastal environments evolve, including the effects of: the dynamic feedbacks among physical, biological, and human processes; interactions between different environments along coastlines; and interactions among coastal, terrestrial, and marine environments--all under a range of climate and human management scenarios. (Initial goals for the next five years listed as 'specific science goals' below.)
2. Address societally relevant science questions, and assemble a set of model tools facilitating investigation of coastal impacts and vulnerability, and their variability--and to enhance the ability of coastal managers and policy makers to use and interpret the modeling tools and results (in collaboration with the Education and Knowledge Transfer Working Group, key stakeholders, and decision makers).

Specific Science Goals (SSG's) Under these Umbrellas, and Steps Toward Them

SSG1 To improve understanding of and ability to hindcast/forecast past and possible future *delta evolution on decadal to millennial time scales, as affected by couplings between terrestrial, fluvial, coastal, wetland, floodplain, subsidence, ecological and human processes*, ultimately including coupling between 1) long- term changes in delta morphology/ecology and 2) storm-event impacts to morphology, vegetation, and human dynamics and infrastructure.

SSG2 To improve our understanding of and ability to forecast how the *morphology, ecology, and human components of sandy coastal environments co- evolve under different scenarios of changing storm climate, sea level rise, and human manipulation* --including coastal environments ranging from urban to undeveloped.

SSG3 To improve our understanding of and ability to forecast how *rocky and soft-cliffed coastlines change over time, as human manipulations (e.g. river damming and coastal armoring) and changes in climate affect interactions between cliff erosion, sediment production, and sediment redistribution*--and how these interactions affect coastal communities.

4.13 CSDMS Continental Margin Initiative

Through this initiative, CSDMS encourages the development of models that can represent fluvial, oceanic and atmospheric events that are capable of routing sediment from terrestrial or shallow marine environments to the deep sea. The relative contributions of sediment fluxes triggered by highly energetic, but infrequent, storms or floods should be evaluated in relation to those occurring under more mundane but frequently-occurring conditions. This implies the need for numerical models capable of estimating sediment transport during a range of forcing storm, wave, and flood conditions. Additionally, the modeling system must be capable of representing the range of sediment processes that operate on a continental margin, including terrestrial sediment input, suspended sediment flux, slope failure, and turbidity currents. Though the CSDMS repository includes component models that separately represent each of these processes, they have not yet been coupled, which prevents us to address feedbacks and interactions between the different processes.

Government agencies need models to address practical applied problems, and the Continental Margin Initiative promises to increase our ability to quantify sediment fluxes to the deep sea, which critically affects offshore oil and gas infrastructure. The CSDMS community and its products might offer agencies such as the Bureau of Ocean and Energy Management (BOEM) coupled models that increase our ability to estimate sediment fluxes from turbidity currents, and explain their generation and triggering mechanisms. Many government agencies, including BOEM, see the need for developing model framework capable of providing operational forecasts, but this capability has not been realized for problems involving sediment fluxes to the deep sea.

These issues are especially relevant in the northern Gulf of Mexico, US, where oil and gas infrastructure continues to migrate into deeper waters. As a proof of concept, and with support of the Marine Working Group, CSDMS will work toward coupling a high resolution large-eddy-simulation (LES) turbidity current model to a coarser resolution Reynolds-averaged Navier-Stokes (RANS) ocean circulation model. The Regional Ocean Modeling System (ROMS) will form the framework for the hydrodynamic model, including implementation of the Community Sediment Transport Modeling System (CSTMS). This LES-RANS model coupling will employ CMT and also couple with other data and model components. The project is funded through a Rutgers University cooperative agreement with the BOEM, and CSDMS will use this opportunity as a proof-of-concept at getting academic (research grade) models into an operational workflow.

5.0 Achieving Our Long-Range Goals

The long-term goals of CSDMS described generally in Section 2 and then in detail in Section 4, essentially involve two high level tasks:

- *Develop a modular modeling environment capable of significantly advancing fundamental earth-system science.*
- *Develop fully functional and useful repositories for CSDMS data, models, tools, and education.*

To achieve this first long-range goal, CSDMS must demonstrate that new paradigms and practices being employed are the most suitable and flexible to simulate earth surface processes over a broad range of time and space scales. Software products being developed must demonstrate broad accessibility and ease-of-use. The CSDMS architecture should allow stand-alone models to become flexible "plug-and-play" components in larger applications. CSDMS must be seen to promote a quantitative revolution in Earth surface processes by bringing high-performance computing to students and professionals in surface process sciences.

Goal one would therefore provide major leap forward in the support of quantitative surface dynamics modeling. The CSDMS Modeling Framework used through a web browser (CMTweb), or on a wider variety of platforms, or by deploying the CSDMS software stack to operate on other clusters offers practical support towards the goal. Methods developed to speed up the conversion of models in the Repository into CSDMS components will also support our integrated modeling efforts. Plans need to be developed for quantifying various types of model uncertainty, including those related to data, sensitivity, optimization and calibration. Plans include incorporating benchmark data into the CSDMS modeling framework to support model benchmarking and model inter-comparison. Our long-term vision is to have robust mechanisms for ingesting and utilizing semantic mediation databases within the Modeling Framework.

Implicit within the first long-term goal is the need to define and promote a proof-of-concept challenge. The challenges have already been defined (see Section 3). CSDMS must organize scientists who can develop one or more coupled sets of models, enlist trial users in the community, and provide datasets with which to test the multi-scale, multi-physics model set. CSDMS must also integrate a series of new initiatives and community efforts responsive to the larger earth surface community beyond the existing Working Groups (Terrestrial, Coastal, Marine, Education, Cyberinformatics) and Focus Research Groups (Hydrology, Carbonate, Chesapeake) by supporting workshops, clinics, courses, and model development priorities. Six new community initiatives have been identified: i) *earth - ecosystem modeling initiative* to capture ecosystem dynamics and ensuing interactions with landscape processes, ii) *geodynamics initiative* to investigate the interplay among climate, geomorphology, and tectonic processes in governing surface processes and landscape evolution, iii) *Anthropocene modeling initiative*, to incorporate mechanistic models of human influences on landscapes and ecosystems, iv) *coastal vulnerability modeling initiative*, with emphasis on deltas and their multiple threats and stresses, v) *continental margin initiative*, to model extreme oceanic and atmospheric events on generating turbidity currents in the Gulf of Mexico, and a vi) *CZO Focus Research Group*, to foster communication between CSDMS modeling and data protocols, and Critical Zone Observatory model development and data records.

To achieve the second long-range goal requires archiving and distributing useful data for model initializations and boundary conditions, for benchmarking of individual models/modules, and for CSDMS framework-integrated validation experiments. The Model/Tools Repository must be populated with stand-alone models and tools relevant to surface dynamics, including novel computational strategies. The models must be distributed to users as both source code and binaries that have been precompiled for common operating systems. Finally, the Education Repository must distribute CSDMS model simulations, educational presentations, reports and publications, short course materials, and CSDMS-hosted or sponsored workshops. We propose to develop a Quantitative Surface Dynamics Educational Toolbox designed to have different entry levels, and which will allow a progressive topical track throughout the modeling curriculum. Another education initiative will see webinars and workshops aimed at teachers, faculty and policy-makers, to increase their self-efficacy in surface process modeling. We propose to enhance model metadata and transparency through visualization of the key functions embedded, as well as hosting model animations of the key processes within a model.

6.0 Community Computational Resources

Beach: The CSDMS Experimental Supercomputer

csdms.colorado.edu/wiki/HPCC_information

The CSDMS High Performance Computing Cluster (HPCC) *beach.colorado.edu* is an 8 TFlops Altix XE 1300 SGI cluster (with a total of 704 cores) that consists of:

- 64 Altix XE320 compute nodes (8 cores; 3 GHz Harpertown processors; 16 GB memory)
- 24 Altix XE320 high memory compute nodes (8 cores; 3 GHz Harpertown processors; 32 GB memory; 250 GB temporary storage)
- Altix XE250 login node (8 cores; 3 GHz Harpertown processors; 16 GB memory; 250 GB temporary storage)

Computes nodes are connected with both and fully non-blocking quad-data rate InfiniBand fabric (measured unidirectional bandwidth of 12 Gb/s; bidirectional bandwidth of 21 Gb/s), as well as gigabit Ethernet. All nodes are able to access 72 TB (40 TB usable) of RAID storage through NFS. Beach provides GNU and Intel compilers, a suite of various MPI compilers (mvapich, mpich, openmpi) that have been optimized for the cluster's configuration. Users are also provided with versions of Matlab, IDL, Python, as well as visualization software. The main power management is an APC UPS with 30 minutes of uptime at 50% load. The *Beach* login node and storage are backed-up by a separate SGI installed UPS system. *Beach* is supported by the CU ITS Managed Services (UnixOps) under contract to CSDMS. Hardware upgrades (nodes, memory, storage) is scheduled for the later part of 2013.

Beach contains all of the necessary tools for needed for high performance computing. In particular, the PETSc and hypre libraries are optimized for the particular configuration of the CSDMS HPCC. Other installed HPC tools include various MPI implementations — mpich2, mvapich2, and openmpi. These packages are customized to use high speed InfiniBand for inter-node communication. Alongside the set of GNU compilers, the CSDMS HPCC now contains the complete set of the fortran and C/C++ intel compilers optimized for the Intel Harpertown processors.

Janus: Research Computing Supercomputer

The *Janus* supercomputing cluster, funded in part by NSF under Grant CNS-0821794, is now online and available for use by CSDMS members that have accounts on *Beach*. This provides CSDMS members with 16,416 computational cores and 32TB of memory. Users are allowed 50,000 core-hours by default and must submit an allocation request for more computational time. The CSDMS high-performace computing cluster, *Beach* is connected to the *Janus* cluster through a private 10 Gb/s network. This enables *Beach* users to quickly and easily share large data sets between the two clusters and use *Janus* 1PB lustre file system.

The Janus system consists of 1368 nodes, each containing two 2.8 GHz Intel Westmere processors with six cores each (16,416 cores total) and 24 GB of memory (2 GB/core) per node. Nodes are connected using a fully non-blocking quad-data rate InfiniBand interconnect, and the system's initial deployment will provide about 1 PB of parallel temporary disk storage. This system is available to CU-Boulder researchers and collaborators. Additionally, the Research Computing group provides of a small "Analytics and Visualization" cluster where each node has 48 cores and 0.5 TB of memory for data intensive applications and pre- and post-processing.

7.0 Organizing Community Participation

Software development for the proposed activities will use best practices for distributed development. Key elements include configuration management of code, documents, and tests on open source development environments. Software elements will use *Trac* for project management and issue tracking, and will be hosted on CSDMS computing resources. Users are encouraged to submit tickets and report bugs or feature requests, edit software documentation through the CSDMS content management system, view Subversion repositories, timelines, and project milestones. Code will be freely available on the web and distributed under an open source license.

Software sustainability will be addressed on three fronts: i) design, ii) dependencies, and iii) documentation and user outreach. Our software design choices are all evaluated in terms of sustainability. In particular, our Component Modeling Interface (CMI) builds on a core set of interface functions considered essential in every model-coupling project. Models that expose this interface are not tied to any particular framework but can be included in our framework or similar future frameworks. We use software tools that we consider sustainable, and which have large user bases, are mature, and are open-source. Software elements created by the CSDMS Integration Facility will not be released unless they are accompanied with adequate developer and user targeted documentation.

The main coordination mechanism at the Integration Facility will be weekly development meetings in which developers describe status and plans to each other and coordinate activities, followed by a session in which detailed technical issues may be raised and discussed. Development priorities will be guided through community meetings and online input from community members. CSDMS operates with a mature set of by-laws available at the CSDMS website. Its organizational structure includes:

1) An **Executive Committee** (elected Chairs of Working Groups) **and Director —** the primary decision-making body of CSDMS, and ensures that the NSF Cooperative Agreement is met, oversees the Bylaws & Operational Procedures, and sets up the annual science plan. This committee approves the business reports, management plan, budget, and partner memberships.

2) A **Steering Committee** (representatives from national academies, agencies and industry). This committee assesses the competing objectives and needs of CSDMS, its progress in terms of science, outreach, and education, and approves the By-laws and revisions.

3) Its **Members** — are organized into Working and Focus Research Groups that provide model code and support tools, educational material, and data for model initialization, testing and benchmarking, and assessing contributed models. The semi-annual, annual and rolling Strategic Plans transparently reflect input from members.

4) An **Interagency Committee** — This group coordinates their members' collaboration with, and support of, CSDMS efforts, with particular focus on moving models from research grade to operational grade level, and avoiding duplication of effort.

5) An **Industrial Consortium —** The consortium contributes through financial or in-kind contributions, and helps develop CSDMS strategies for applied modeling.

6) An **Integration Facility (IF) — The IF is located** at CU-Boulder. Its role is to maintain the CSDMS repositories, facilitate community coordination, public relations, and product penetration, develop the cyber-infrastructure, provide software guidance, and support cooperation between observational and modeling communities.

8.0 User Training

A key objective of CSDMS is the widespread adoption of CSDMS-developed software by the general Earth science community and, in particular, by geophysicists, engineers, environmental scientists, geomorphologists, hydrologists, sedimentologists, glaciologists and oceanographers. Significant training and comprehensive documentation are required. The CSDMS website offers its members recommended reading lists, mini-tutorials, and wiki-based web sites that offer easy communication with the CSDMS software engineers. The community will continue to explore how to organize the learning cycle on various community models, beyond the annual meeting setting.

Beyond the existing tools, the EKT Working Group has established specific goals for education and outreach that are enumerated in Section 4.5. Some key goals regarding user training are reiterated below.

We acknowledge the tremendous influence that teachers and faculty have on student learning; not everything can be done online, and learning is driven by good teachers. The EKT Working Group will recruit members who will help identify toolbox components and be early adopters of the toolbox to help evaluate the products from the earliest stages. Specific steps in this process from Section 4.5 will include toolbox development, development of exercises and assessment rubrics, distribution of products, and collaborative evaluation of toolbox efficacy through team preparation of a paper for a science-education journal. We propose to organize webinars and small workshops to train and get feedback from teachers, faculty and policy-makers. These interactions will both increase end-user self-efficacy in surface process modeling, and provide CSDMS with much-needed guidance on product improvement to better serve target user groups, especially educators. Instructor self-efficacy is highly correlated with student gains. Teacher confidence will be enhanced by fostering CSDMS forums online for interaction and professional discussions on changes in the curriculum and their effects.

9.0 CSDMS Membership and Communication

CSDMS integrates a diverse community of more than 1050 members (as of 08/01/13) representing 166 U.S. institutions (123 academic, 22 private, 21 federal) and 275 non-U.S. institutions from 67 countries (177 academic, 28 private, 70 government). There are now 443 affiliated institutions plus another 30 private memberships. The CSDMS web site keeps an active list of members and details of their affiliations and their interests. Each year the Annual Report publishes an active institutional membership list (also see Appendix 3), an individual member list is available through the CSDMS Web site.

Membership Maps Feb 2013

Communication Strategy

Member representatives and individuals within the larger CSDMS community (including those at member institutions) will be kept informed in several ways.

- Through e-mail. CSDMS maintains several list servers through the CSDMS website including several for the main committees (e.g., Executive Committee, Steering Committee, Industrial Consortium) as well as for working groups and general information. A CSDMS Newsletter highlighting new developments and capabilities with appropriate links to the CSDMS website will be distributed by email on a regular quarterly basis.

- Through the http://csdms.colorado.edu web site. The upcoming CSDMS calendar of events is posted and continuously revised. Nearly all CSDMS documents including the annual revision of the CSDMS Strategic Plan, By-Laws, etc., are posted on this site. The Web site is the principal means for standard software downloads, sharing of community benchmarks, specifications of standards, and distribution of user & training manuals. Documents and presentations from various CSDMS-sponsored workshops and meetings are also posted to the site for the benefit of the entire community.

- CSDMS sponsored and co-sponsored workshops and training sessions. The current status of CSDMS will be presented at these workshops and we expect that CSDMS members will attend such workshops.

10.0 Five Year Management Plan

The **CSDMS Bylaws** were adopted June 2007, reviewed by the CSDMS Steering Committee on December 2007, revised and approved by the ExCom January 2008, and a approved by the CSDMS Steering Committee February 2008. They have been somewhat revised for this Strategic Plan release (Oct. 25) --- see Appendix 1.

10.1 CSDMS Working Groups

The **Terrestrial Working Group** (*currently 503 members*) deals with erosion, sediment and solute transport, and deposition on land. The processes concerned are wide ranging, from the sculpting of glacial landscapes to the formation of soil and the transport of erosional materials to the coastline.

The **Coastal Working Group** (*currently 384 members*) deals with delta, shallow-bay, wetland, and nearshore challenges.

The **Marine Working Group** (*currently 260 members*) deals with shelf, deep-estuary, carbonate, slope, and deep marine challenges.

The **CSDMS Education and Knowledge Transfer (EKT) Working Group** (*currently 169 members*) focus is on knowledge transfer to three CSDMS end-user groups: researchers, planners, and educators.

The **Cyberinformatics and Numerics Working Group** (*currently 163 members*) deals with technical computational aspects of the CSDMS, ensures that the modeling system properly functions and is accessible to users; software protocols are maintained, along with model standardization and visualization; and works with our cyberinformatic partners.

The **Hydrology Focus Research Group** is a research group (*currently 379 members*) co-sponsored by CUAHSI, the Consortium of Universities for the Advancement of Hydrologic Science, Inc. The goal is to provide input to the CSDMS effort on how to best represent hydrological processes and models within CSDMS. Another role that the Hydrology FRG will play is to facilitate links to other community hydrologic modeling activities, including those led by CUAHSI.

The **Carbonate Focus Research Group** (C-FRG) (*currently 71 members*) aims to identify and address the grand challenges for fundamental research on ancient and recent carbonate systems. The initiative is driven by the idea that open-source numerical models and associated quantitative datasets can be state-of-the-art repositories for our knowledge of how carbonate systems work, as well as being experimental tools to apply to develop and enhance that knowledge.

The **Chesapeake Focus Research Group** is the first Geographically-Focused Research Group (*currently 48 members*) associated with CSDMS. The group is a partnership between CSDMS and the Chesapeake Community Modeling Program (CCMP, http://ches.communitymodeling.org/). This FRG coordinates an open source system of watershed and estuary models.

The **CSDMS Critical Zone Focus Research Group** is new to CSDMS2.0 (*currently 19 members*) that is co-sponsored by Critical Zone Observatory (CZO). The goal is to provide input to the CSDMS effort on how to best represent Critical Zone data and models within CSDMS.

The **CSDMS – Anthropocene Focus Research Group** is new to CSDMS2.0 (*currently 19 members*) and is a response to the clear resonance that has sounded throughout the scientific and wider communities to the proposition that we are now living in the age of humans, the *Anthropocene*. One challenge is to codify the human and societal process into models of a future Earth.

The **Geodynamics Focus Research Group** is new to CSDMS2.0 (*currently 29 members*), and is co-sponsored by GeoPRISMS, a follow-on to the NSF MARGINS Program. GeoPRISMS is a decadal program, funded by NSF, committed to the amphibious study of the origin and evolution of continental margins through interdisciplinary, community-based investigations.

10.2 The CSDMS Executive Committee (ExCom)

The Executive Committee is the primary decision-making body of CSDMS, and ensures that the NSF Cooperative Agreement is met, oversees the Bylaws & Operational Procedures, and sets up the annual science plan. ExCom approves the business reports, management plan, budget, partner memberships, and other issues that arise in the running of CSDMS. The committee is elected by the membership and is comprised of the scientific Chairpersons.

Pat Wiberg (April, 2012 —), Chair, CSDMS Steering Committee, Univ. of Virginia, VA

Brad Murray (April, 2007 —), Chair, Coastal Working Group, Duke Univ., NC

Courtney Harris (April, 2012 —), Chair, Marine Working Group, VIMS, VA

Greg Tucker (April, 2007 —), Chair, Terrestrial Working Group, U. Colorado-Boulder, CO

Eckart Meiburg (Jan, 2009 —), Chair, Cyberinformatics & Numerics WG, U.C. - Santa Barbara, CA

Samuel Bentley (Sept, 2012 —), Chair, Education & Knowledge Transfer WG, LSU, LA

Peter Burgess (Sept, 2008 —), Chair, Carbonate Focus Res. Group, Royal Holloway, U. London, UK

Carl Friedrichs (April, 2009 —), Chair, Chesapeake Focus Research Group, VIMS, VA

Jonathan Goodall (Nov, 2010 —), Chair, Hydrology Focus Research Group, U. South Carolina, SC

Chris Duffy (Mar, 2013 —), Chair, Critical Zone Focus Research Group, Penn State U., PA

Michael Ellis (Jan, 2013 —), Co-Chair, Anthropocene Focus Res. Group, British Geol. Survey, UK

Kathleen Galvin (Jan, 2013 —), Co-Chair, Anthropocene Focus Res. Group, Colorado State U, CO

Phaedra Upton (Mar, 2013 —), Co-Chair, Geodynamics Focus Research Group, GNS, New Zealand

Mark Behn (Mar, 2013 —), Co-Chair, Geodynamics Focus Research Group, WHOI, MA

James Syvitski *(ex-officio),* CSDMS Executive Director, University of Colorado – Boulder, CO

10.3 The CSDMS Steering Committee (SC)

The CSDMS SC assesses the competing objectives and needs of CSDMS; assesses progress in terms of science, outreach and education; advises on revisions to the 5-year strategic plan; and approves the Bylaws and its revisions.

Patricia Wiberg (Sept, 2012 —), Chair, CSDMS Steering Committee, Univ. of Virginia, VA

Tom Drake (April, 2007 —), U.S. Office of Naval Research, Arlington, VA

Bert Jagers (April, 2007 —), Deltares, Delft, The Netherlands

Marcelo Garcia (Dec, 2012 —), Univ Illinois at Urbana-Champaign, IL

Chris Paola (Sept, 2009 —), NCED, U. Minnesota, Minneapolis, MN

Cecilia DeLuca (Sept, 2009 —), ESMF, NOAA/CIRES, Boulder, CO

Boyana Norris (Sept, 2009 —), Argonne National Lab, Argonne, IL

James Syvitski *(ex-officio),* CSDMS Executive Director, University of Colorado – Boulder, CO

Bilal Haq *(ex-officio),* National Science Foundation

Paul Cutler *(ex-officio),* National Science Foundation

Rudy Slingerland *(ex-officio, Past-Chair CSDMS SC 2007-2012),* Penn State Univ., PA

10.4 The CSDMS Integration Facility (IF)

The CSDMS Integration Facility (IF) maintains the CSDMS Repositories, facilitates community communication and coordination, public relations, and product penetration. IF develops the CSDMS cyber-infrastructure and provides software guidance to the CSDMS community. The IF maintains the CSDMS vision and supports cooperation between observational and modeling communities. As of July 2013, CSDMS IF staff includes:

• Executive Director, Prof. James Syvitski (April, 2007—) - CSDMS & CU support

• Executive Assistant, TBD - CSDMS support

• Senior Software Engineer, Dr. Eric Hutton (April, 2007—) - CSDMS & other support

• Software Engineer, Dr. Mark Piper (Nov, 2013 —) - CSDMS & other support

• Cyber Scientist, Dr. Albert Kettner (July, 2007—) - CSDMS & other support

• EKT Scientist, Dr. Irina Overeem (Sept, 2007—) - CSDMS & other support

• PDF, Kimberly Rogers (March, 2012 —) - Other NSF support

• Ph.D. GRA, Stephanie Higgins (Sept, 2010 —) - Other NASA support

• Ph.D. GRA, Fei Xing (July, 2010 —) - Other NSF support

• Ph.D. GRA, Ben Hudson (May, 2010 —) - Other NSF support

• Systems Administrator, Chad Stoffel (April, 2007—) multiple grant support

• Accounting Technician, Chrystal Lee Pochay (July, 2013—) multiple grant support

• Director, Dartmouth Flood Observatory, G Robert Brakenridge (Jan, 2010 —) - NASA & other support

• Senior Research Scientist Christopher Jenkins (Jan 2009—) - NSF & other support

10.5 CSDMS Industrial Consortium

Industry partners (csdms.colorado.edu/wiki/Industry_partners) play an important role in contributing to the success of CSDMS through their financial or in-kind contributions (Appendix 2). Sponsorship supports the CSDMS effort and thus the next generation of researchers working to develop innovative approaches towards modeling complex earth-surface systems. CSDMS consortium members: 1) demonstrate corporate responsibility and community relations; 2) contribute to the direction of CSDMS research and products; 3) access the latest CSDMS products and information; and 4) join an association of diverse scientists, universities, agencies, and industries. Approximately 14% of CSDMS member institutions are with the private sector. (see Appendix 3 for details)

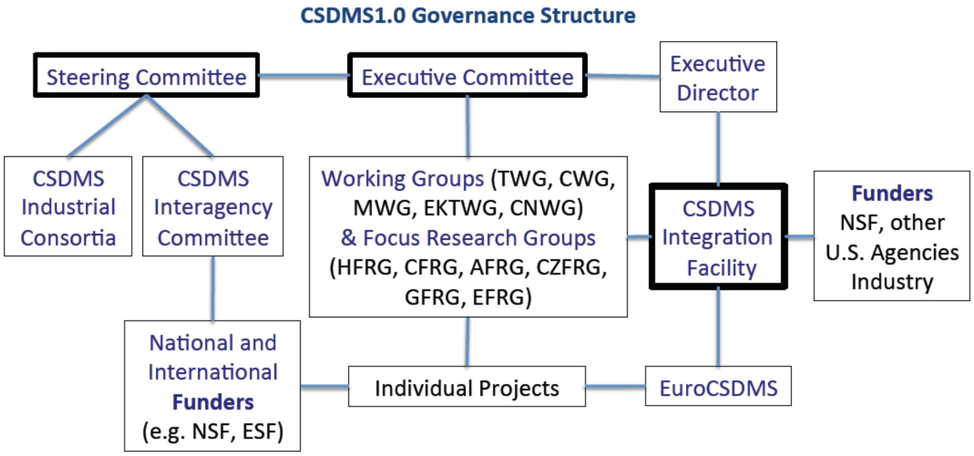
10.6 CSDMS Interagency Committee

This group is comprised of the 21 US agencies (see Appendix 3 for details) and may include non-US government agencies. The committee coordinates their member's collaboration with and support of CSDMS efforts. For 2013 the focus was to appoint a more formal Chair of the Committee. The announcement of this search has yet to be revealed, as travel funding has been tied up with the U.S. Sequester decisions. Most agencies rely on models that are developed or are funded in-house, for reasons of quality control, specificity, familiarity (with the developers, agency users, and contractors), and cost of changing. Still, the CSDMS community and its products might offer agencies coupled models that these same agencies might like to see developed. In the near term, CSDMS can contribute to understanding of how to build and deploy coupled models. Individual agencies might be "early adopters" and leverage CSDMS to develop coupled models to address specific topics. A task force of the CSDMS Interagency Committee has agreed to explore early adoption strategies.

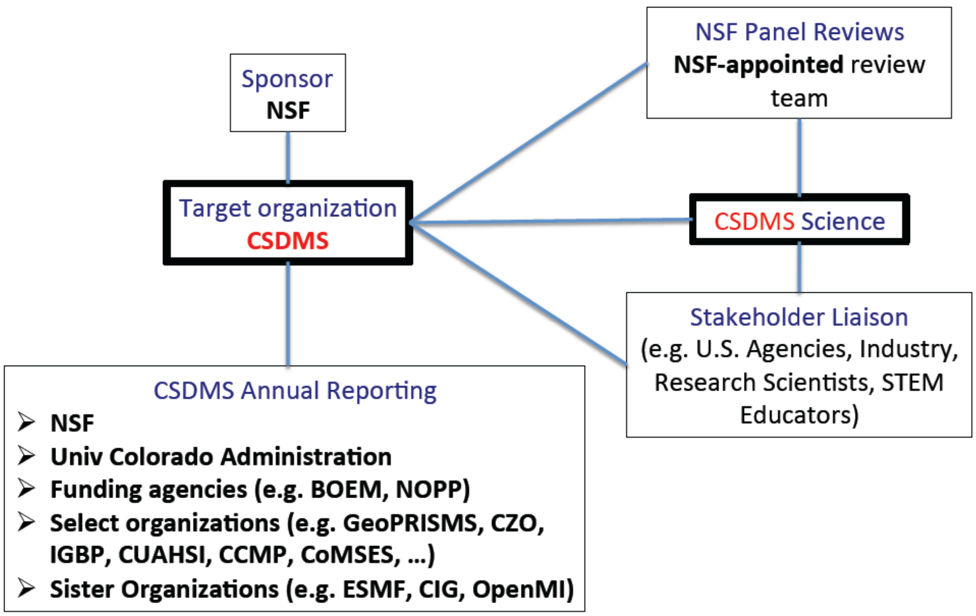
As a proof of concept, and with support of the **Marine Working Group**, CSDMS is providing help in coupling a high-resolution large-eddy-simulation (LES) turbidity current model (*TURBINS* UCSB) to a coarser resolution Reynolds-averaged Navier-Stokes (RANS) ocean circulation model ROMS with the Community Surface Transport Model enabled (Fig 3). The project is being funded through a Rutgers U. cooperative agreement with the Bureau of Ocean Energy Management (BOEM), and CSDMS will use this opportunity as a proof-of-concept at getting academic (research grade) models into an operational workflow. About 5% of the Gulf of Mexico pipelines are broken or damaged by sudden and violent cascading of sediments. Predicting the path and fate of spilled oil in the ocean is important for resource managers and spill responders.

10.7 CSDMS Priorities and Management of Its Resources

Work Package	Phase 1 (2012-2014)	Phase 2 (2013-2015)	Phase 3 (2014-2016)
1. Modeling Framework - MF	Develop CMTweb; MF installer; Porting CSDMS Tools; Componentization	Beta test CMTweb; MF on *Janus* & *Wyoming;* Componentization; Clone & edit & redeploy	Componentization; MF on *other HPCC*
2. Model Uncertainty	Explore uncertainty modeling tools –annual workshop	Adapt and test uncertainty tools in MF – clinic at annual workshop	Refine and deploy uncertainty tools in MF - clinic
3. Model Benchmarking & Intercomparison	Mine appropriate MIPs; Design metadata standards - annual workshop	Design data service components –workshop; Metrics for Inter-comparison - clinic at annual workshop	Implementation of selected methods
4. Semantic Mediation & Ontologies	Build links to other efforts; Protocol design - annual workshop	Implementation into CMT services	Implementation into CMT services
5. CSDMS Portal	Database structure; Search algorithms; Visualization of model functions; Community plaza design - annual workshop	Visualization of model functions; Model animations of key processes; Add threads to website; Community plaza tool	Model animations of key processes
Community Activities and Initiatives	Launch of new FRG (Ecosystem, CZO, Geodynamics); Launch of new initiatives (Anthropocene, Coastal vulnerability, Shelf)	New proof of concept models and modeling families; Operational model proof of concepts	Expanding proof of concept activities
CSDMS Coordination	Weekly: IF meetings, Semi-annual: ExCOM, Annual: SC, IC, IAC meetings Annual all-hands meeting or Working Group meetings etc		
EKT	QSD toolbox development – workshop; Recruitment and training of early adopters	Expansion of toolbox; Development of assessment toolbox - annual workshop	Release of educational modules with assessment tools
Publications & Presentations	Journal articles; Presentations at professional societies; Public semiannual reports	Journal articles; Uncertainty special issue Coupled-modeling special issue	Regional model for sustainability science; Presentations Final project report



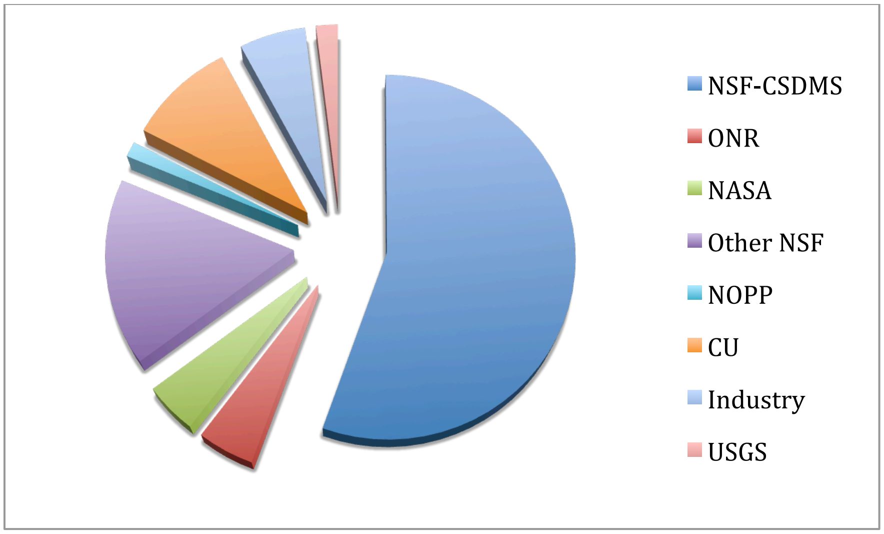
CSDMS Governance Structure



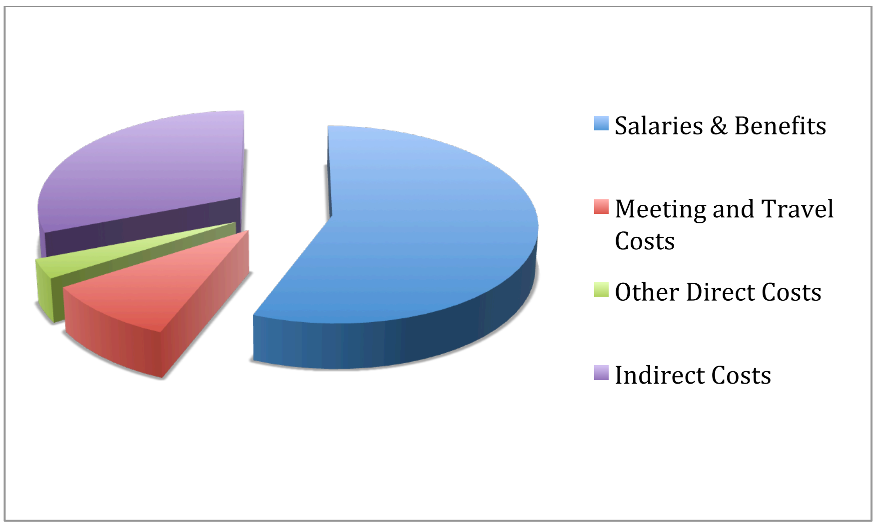
CSDMS Reporting Structure

CSDMS budget resources is roughly divided into four components: 1) 27% for supporting middleware development (e.g. CMT plug-and-play environment, BMI and CMI interface standards, support services), 2) 21% for supporting networking, capacity building and working group activities (e.g. developing the model repository, metadata), 3) 31% for CSDMS support services (e.g. HPCC operations, model simulations, data handling, and other modeling services), and 4) 21% for supporting education and knowledge products (e.g. model algorithms, numerical techniques, clinics, and short courses). This division of resources is considered optimal for the CSDMS mission and future plans. The CSDMS Integration Facility Staff juggle the competing demands of an actively engaged and ever-growing CSDMS Community at both national and international venues.

CSDMS received $4.7M from NSF during the period 2007 to 2012. CSDMS Integration Facility staff received significant additional ($3.8M) from other sources. The largest portion of the income was in the form of salaries for the CSDMS staff and students, followed by indirect cost recovery by the University of Colorado for administering and supporting the Integration Facility. The University returned a significant portion of these indirect costs in the form of salary support and by underwriting the CSDMS HPCC *Beach*.



Pie Chart of the 2007-2012 $8.5M funding received by CSDMS (all sources).



Pie Chart of the CSDMS 2007-2012 expenditures (NSF-CSDMS sources).

Appendix 1: By-Laws of the Community Surface Dynamics Modeling System (Oct. 25, 2013)

PREAMBLE

The Community Surface Dynamics Modeling System (CSDMS) assumes responsibilities to develop, support, and disseminate to the earth-science research and teaching community integrated software modules that are aimed at predicting the erosion, transport, and deposition of sediment and solutes in landscapes, seascapes and their repository sedimentary basins. The goal of CSDMS is to enable the rapid development and application of linked dynamical models tailored to specific landscape-basin evolution problems at time scales that range from years to thousands of years or longer, and spatial scales that include global, regional and local aspects of the earth's surface — from the mountain tops covered in glaciers to the deep seafloor and their sediments. To foster longer-term progress in surface modeling, CSDMS gathers and makes available models designed to elucidate poorly understood aspects of landscape and seascape dynamics. CSDMS develops and maintains a high-level of community participation to ensure:

a) Well-documented and user-friendly earth-surface dynamics software that keeps pace with both hardware and scientific developments;

b) Partnerships with related computational and scientific programs in order to eliminate duplication of effort, leverage mutual progress, and provide and benefit from an intellectually stimulating environment;

c) Appropriate training for both the users and teaching communities;

d) Hardware and personnel resources to support and facilitate software development and its use by the community;

e) Strong linkage between what is predicted by CSDMS codes and what is observed both in nature and in physical experiments.

CSDMS develops and maintains the computational system to ensure the portability and interoperability of modules, the computational efficiency of system code, and the clarity and consistency of documentation. CSDMS offers pedagogically evaluated earth-surface numerical technology to enhance and inform education in environments of high school, undergraduate programs, and science museums.

By-Laws of the Community Surface Dynamics Modeling System (CSDMS) are adopted by its Members for the purpose of conducting CSDMS business in a collegial manner. They do not override the standard responsibilities and prerogatives of Principal Investigator and his/her institution.

Articles

ARTICLE I. NAME

Section 1. Name: The name of the Organization is *Community Surface Dynamics Modeling System (CSDMS)*.

ARTICLE II. WORKING GROUPS, MEMBERS AND THEIR INSTITUTIONS

Section 1. Working Groups: The five Working Groups to support the CSDMS program include three (3) Environmental Working Groups and two (2) Integrative Working Groups. The three key Environmental Working Groups are:

i) Terrestrial WG: weathering, hillslope, fluvial, glacial, aeolian, lacustrial;

ii) Coastal WG: delta, estuary, bays and lagoons, nearshore;

iii) Marine WG: shelf, carbonate, slope, deep marine.

The two key Integrative Working Groups are:

iv) Education and Knowledge Transfer (EKT) WG: includes marketing to gain end-users, workshops to provide training for end-users, web-based access to simple models (e.g. K-12 teaching), access to archives of simulations. This WG will interact closely with its Partner Committees (Industry, Agency), field programs, and cyberinformatic partners.

v) Cyber-Infrastructure and Numerics WG: includes technical computational aspects of the CSDMS, ensures that the modeling system properly functions and is accessible to users; software protocols are maintained, along with model standardization and visualization.

Section 2. Focus Research Groups: The CSDMS Focus Research Groups (FRGs) were established in 2008 to cut across our Environmental Working Group structure, to serve a unique subset of our surface dynamics community often with support of well-developed sister organization. The current FRGs include:

i. Hydrology FRG cosponsored by CUAHSI, the Consortium of Universities for the Advancement of Hydrologic Science, Inc., and dealing with aspects of the hydrological system that impact earth-surface dynamics;

ii. Carbonate FRG is cosponsored by NSF's Sedimentary Geology and Paleobiology Program to address the grand challenges for fundamental research on ancient and recent carbonate systems, through creation of the next generation of numerical carbonate process models;

iii. Chesapeake FRG a 'geographically-focused' effort co-sponsored by the Chesapeake Community Modeling Program, to develop a watershed-estuary model consisting of interchangeable modules including hydrodynamics, ecosystem dynamics, trophic exchanges, and watershed interactions;

iv. Critical Zone FRG is co-sponsored by NSF's Critical Zone Observatory (CZO) Program to represent Critical Zone data and model development within CSDMS;

v. Anthropocene FRG is co-sponsored by the International Geosphere-Biosphere Program (IGBP) to codify the human and societal process into models of a future Earth, including next-generation agent based models, economic models, able to quantify human influences (behaviour and decision making) that affect earth system responses;

vi. Geodynamics FRG is co-sponsored by the NSF MGeoPRISMS Program, committed to better understanding and modeling the coupled geodynamic - geomorphic system through the development and innovation of numerical tools, relevant and challenging proof-of-concept questions.

Section 3. **Membership:** Working and Focus Research Group members shall be holders of an academic or research appointment, with major responsibilities for instruction and/or research in the earth, environmental and engineering sciences, in a department, program, or other organizational unit of their Institutions (academic institutions, not-for-profit organizations, state and federal labs, and consulting and industrial companies), and have demonstrated a major commitment to research in Earth System Science with a particular emphasis on computational earth-surface dynamics, and related fields (hydrology, fluvial processes, biogeochemistry, sedimentology, stratigraphy, geomorphology, glaciology, oceanography, marine geology, climate forcing, active tectonics, surface geophysics, remote sensing, geomathematics, computational fluid dynamics, computational science, and environmental engineering). Applicants may apply to the CSDMS Integration Facility to join one or more of the CSDMS Working and Focus Research Groups. The CSDMS Integration Facility shall maintain a list of Members and their Institutions. Working Group membership requires a two-thirds majority approval of the CSDMS Executive Committee. A membership fee may be levied on for-profit organizations. Working and Focus Research Group Chairs may appoint a Coordinating Committee.

Section 4. Responsibilities/Activities:

iv) **Group Discussion:** Stay current in the processes and models associated their disciplinary toolkit, and identify gaps in knowledge and areas where numerical tools need to be developed. Set scientific modeling priorities for their discipline. Make recommendations for resource prioritization and facilitate the movement of these priorities up the hierarchy from technology group to steering committee.

v) **Review Activities:** Ensure quality control for the algorithms and modules for their area of expertise (benchmarking and model testing). Coordinate the evaluation of numerical codes according to interoperability, scientific contribution, and technical documentation. Ensure adequacy of supporting boundary conditions and boundary initializations.

iv) **Group Project:** Address a CSDMS proof-of-concept challenge, if appropriate.

v) **Individually and collectively:** Stimulate proposals and input from the community. Create and/or manage the various environmental process modules related to their discipline. Provide community continuity to meet long-term CSDMS objectives.

vi) **Meetings:** Working Groups will coordinate much of their activity via remote communication systems, but are encouraged to meet as resources and interests permit.

vii) **Reporting:** Working Groups will report annually on their progress.

Section 4. Foreign Membership: Working and Focus Research Group members from foreign academic institutions, not-for-profit organizations, foreign government labs, and consulting and industrial companies, are offered all of the privilege of U.S. working group members, except for the privilege of voting for the Chairs of the Working and Focus Research Groups that reside on the governing body of CSDMS — the CSDMS Executive Committee.

Section 5. Resignation or Removal: Any Member may resign at any time by giving written notice to the Chairperson of the Steering Committee, or to the CSDMS Executive Director. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein. Given sufficient cause, any Member may be removed by the affirmative vote of two-thirds of the Members of the CSDMS Executive Committee.

Section 6. Quorum: Except as may be otherwise expressly required by these By-Laws, at all CSDMS Working Group meetings, attendance and/or a notification of intent to attend by thirty percent (30%) of the members then serving shall constitute a quorum. For the purpose of the election of their Executive Committee member (Working Group Chair), a quorum shall be determined by a simple majority.

Section 7. Voting: Each CSDMS WG member shall be entitled to one vote. Except as otherwise expressly required by law or these By-Laws, all matters shall be decided by the affirmative vote of a majority of the Working Group members present at the time of the vote, if a quorum is then present.

Section 8. Action without a Meeting: Any action required or permitted to be taken by the CSDMS members, or the Executive Committee, may be taken without a meeting if the CSDMS members, or the Executive Committee, consent in writing to the adoption of a resolution authorizing the action. The resolution and the written consents thereto shall be filed with the minutes of the proceedings of the CSDMS members or the Executive Committee.

ARTICLE III. CSDMS EXECUTIVE COMMITTEE

Section 1. Executive Committee of CSDMS: The Executive Committee (ExCom) will comprise a) Executive Director and PI of the award as Chair, (non-voting, except to break a tied vote), b) Chair of the Steering Committee (voting); c) Chairs of the defined working groups (voting): (i) Terrestrial, (ii) Coastal, (iii)

Marine, (iv) Cyber-infrastructure and Numerics, and (v) Education and Knowledge Transfer. The elected members of ExCom shall have terms not to exceed three years or until his or her successor is chosen and qualified. Members of ExCom other than the chair of the Steering Committee may not simultaneously serve on the Steering Committee. Chairs of the Focus Research Groups will be ex-officio non-voting members of the Executive Committee.

Section 2. Powers of the Executive Committee of CSDMS: The ExCom is the primary decision-making body of the CSDMS, and will meet twice a year to approve the annual science plan, the semi-annual reports, the management plan, budget, partner membership, and other day-to-day issues that arise in the running of the CSDMS. The Executive Committee will ensure that the objectives of the Cooperative Agreement are met. The ExCom will develop the By-Laws and Operational Procedures, to be co-approved by the Steering Committee. At all meetings of ExCom, the presence of a simple majority of its members then in office shall constitute a quorum for the transaction of business. So long as they do not conflict with the responsibilities of the Principal Investigator (the CSDMS Executive Director), power in the management of the affairs of the CSDMS Organization is vested in the CSDMS Executive Committee. To this end and without limitation of the foregoing or of its powers expressly conferred by these By-Laws, the CSDMS Executive Committee shall have power to authorize such action on behalf of the Organization, make such rules or regulations for its management, and create additional offices or special committees. The Executive Committee shall have the power to fill vacancies in, and change the membership of, such committees as are constituted by it. Appointments of Working Group membership shall rest with the Executive Committee.

The CSDMS Executive Committee will co-share authority with the CSDMS Steering committee to amend or repeal the By-Laws, or the adoption of new By-Laws.

Section 4. Executive Director: The Executive Director shall, when present, preside at all meetings of the Executive Committee and shall perform such other duties and exercise such other powers as shall from time to time be assigned by the Executive Committee. The Executive Director shall be an *ex officio* member of all CSDMS committees. The Director is the Chief Executive Officer of the Organization, and unless authority is given by the Executive Committee to other officers or agents to do so, he or she shall execute all contracts and agreements on behalf of the Organization. The Director shall be the Principal Investigator on proposals, which fund the core CSDMS Facility. It shall be his or her duty, insofar as the facilities and funds furnished to him or her by the Organization permit, to see that the purposes, orders and voting within the CSDMS Organization are carried out. The Director shall preside at CSDMS-wide town-hall meetings.

Section 5. Chairperson of the Steering Committee: The SC Chairperson when present shall preside at all meetings of the Steering Committee and perform such other duties and exercise such other powers as shall from time to time be assigned by the Executive Committee. The Chairperson of the Steering Committee shall be an ex officio member of all CSDMS committees. After the Chair's term is complete, they will be offered the honorary title of Past-Chair and provided with travel funds, when available, to attend CSDMS meeting as appropriate to their interest and CSDMS need.

Section 6. Chairs of Working Groups: Chairs of the defined working groups will be full voting members of the Executive Committee and will represent the following areas of surface dynamics expertise: (i) Terrestrial Systems, (ii) Coastal Systems, (iii) Marine Systems, (iv) Cyber-infrastructure & Numerics, and (v) Education and Knowledge Transfer. They will have the authority to call meetings of the working groups they are responsible for, and to meet the collective long-term CSDMS objectives.

Section 7. Election and Term of Office: Appointments of the Executive Committee, for the first start-up year only, shall rest with the Principal Investigator. All members of the Executive Committee must stand for election thereafter. The Chairperson of the Steering Committee shall be elected by a virtual vote of the CSDMS membership orchestrated and recorded by the CSDMS Executive Assistant, for a term not to exceed three years or until his or her successor is chosen and qualifies. Chairs of the Working Groups shall be elected by the members of the respective working groups, orchestrated and recorded by the CSDMS Executive Assistant, for terms not to exceed three years or until their successors are chosen and qualify, and they shall be eligible for re-election.

Section 9. Resignation: Any Officer may resign at any time by giving written notice to the Chairperson of the Steering Committee, or the CSDMS Executive Director. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein.

Section 10. Vacancies: Any vacancy in any Office may be filled for the unexpired portion of the term of such office by the Executive Director.

Section 11. Removal: Any officer may be removed at any time with cause by a vote of the Executive Committee.

ARTICLE IV. OPEN MEETINGS

Section 1. Annual CSDMS Meeting: An annual open meeting of the CSDMS membership will be held to solicit comment and feedback from the community. Comments from the community will be recorded and forwarded to the CSDMS Executive Committee and the CSDMS Steering Committee.

Section 2. Special Meetings: Special meetings may be called by the Chairperson of the Steering Committee, or by the CSDMS Executive Director, upon written request of at least one-fifth (1/5) of the membership of the CSDMS Working Groups.

Section 3. Place of Meetings: The CSDMS Executive Director shall designate the place and forum (face-to-face or virtual) of the annual meeting or any special meeting and which shall be specified in the notice of meeting or waiver of notice thereof. The meeting venue will be chosen to maximize community participation, for example, to be in conjunction with a popular science meeting (AGU, Ocean Sciences, GSA, etc)

Section 4. Notice of Meetings: Notice of such meeting of the CSDMS members shall be given at least sixty (60) days before the date fixed for the meeting.

ARTICLE V. STEERING COMMITTEE AND OTHER COMMITTEES

Section 1. Steering Committee: In order to carry out and oversee CSDMS operations, a Steering Committee (SC) shall be established. *Upon the recommendation of the Steering Committee, the Executive Committee approved the expansion of the Steering Committee membership. Article V Section 1 is in part revised as:*

"The Steering Committee be comprised of a minimum of ten (10) members selected by the ExCom to represent the spectrum of relevant Earth science and computational disciplines, and each of the two Partner Sub-Committees." The serving NSF program officer or his/her designate, and the Executive Director or his/her designate, will serve as *ex officio* members of the SC. During SC meetings, there may be occasions when these *ex officio* members would exclude themselves from discussions.

The SC members will serve terms up to three years duration. The Steering Committee will meet once a year to assess the competing objectives and needs of the CSDMS; will comment/advise on the progress of CSDMS in terms of science (including the development of working groups and partner memberships), management, outreach, and education; and will comment on and advise on revisions to the 5-year strategic plan. The Steering Committee will provide a timely report to the Executive Director who is to respond within four weeks.

Section 2. Partner Committees: The Partner Committees (PCs) will comprise a U.S. Federal Agencies Committee, and separately, an Industrial Partners or consortium committee. The PCs will be provided with all relevant documents in order to provide meaningful feedback to the Executive Committee and to the NSF Program Director.

Section 3. Special or Standing Committees: The ExCom may create such special or standing committees as may be deemed desirable, the members of which shall be appointed by the Executive Director from among the Membership, with the Membership approved by the Executive Committee. Each such committee shall have only the lawful powers specifically delegated to it by the Executive Committee.

ARTICLE VI. ELECTIONS

Section 1. Executive Committee: With the exception of the Executive Director, Executive Committee members will be elected by the CSDMS Membership in accordance with the procedures established in this Article.

Section 2. Nominations for the Executive Committee: In consultation with the Steering Committee, the Executive Director will nominate candidates for each position to be filled. The Membership is encouraged to suggest nominees to the Executive Director.

Section 3. Election: Election shall be conducted electronically. Electronic or Paper votes must be received by the CSDMS Integration Facility by the deadline specified in the ballot. The outcome of the election will be decided by a simple majority of the votes cast.

Section 4. Counting of ballots: Ballots shall be counted by the Steering Committee Chair or his/her designated representative.

ARTICLE VI. COMPENSATION

Section 1. Compensation: No Member shall be paid any compensation for serving on the CSDMS Executive Committee, Steering Committee or other committees and Working Groups. Representatives may be reimbursed for the actual expenses incurred in performing duties assigned to them, within limitations of the host Institution's budget associated with the NSF Cooperative Agreement 0621695.

ARTICLE VII. AMENDMENTS TO THE BY-LAWS

Section 1. Amendments: All By-Laws of the Organization shall be subject to amendment or repeal and new By-Laws may be made by the affirmative vote of two-thirds of the Executive Committee and the Steering Committee.

Appendix 2: CSDMS Industry Consortium (Feb. 1, 2008)

CSDMS is an integrated community of experts that promotes the understanding of earth-surface processes through numerical simulation experiments. The experiments employ an open-source library of community-generated, continuously evolving software. CSDMS is partnered with related scientific programs in order to provide a strong linkage between predictions and observations. The CSDMS Integration Facility provides the cyber-infrastructure to help develop and distribute software tools and models of use to the academic communities, and to those engaged in industrial applications and environmental assessments. The CSDMS program operates under a cooperative agreement with the U.S. National Science Foundation (NSF), and a community-generated set of Bylaws (Appendix 1). Industry partners, NGOs, and government agencies play an important role in contributing to the success of CSDMS through their financial or in-kind contributions. This sponsorship supports the CSDMS effort and the next generation of researchers and modelers working to develop innovative approaches towards modeling complex earth-surface systems.

The CSDMS Consortium of Industry Partners

The primary goal of the CSDMS Consortium is to engage industry stakeholders in CSDMS research. Consortium members join with the CSDMS community to address key issues in the development and use of the models and tools produced by the CSDMS initiative.

Benefits of Membership in the CSDMS Industry Consortium

1) Corporate responsibility and community relations

In addition to hard products such as code, or gaining new insights into earth-surface dynamics, members of the CSDMS Consortium demonstrate their corporate commitment to improving quality of life and promoting optimal natural resource management through the more accurate modeling of earth surface processes. The CSDMS Industry Consortium supports the imperatives in Earth-science research: 1) discovery, use, and conservation of natural resources; 2) characterization and mitigation of natural hazards; 3) geotechnical support of commercial and infrastructure development; 4) stewardship of the environment; and 5) terrestrial surveillance for global security. Member companies are recognized for their commitment and support within various CSDMS publications, promotional materials, presentations, and on our website.

2) Opportunities to contribute to the direction of CSDMS research and products

The CSDMS Consortium provides an opportunity for its members to help guide CSDMS research and product development in directions relevant to their respective activities, thus directly benefiting their companies. By identifying needs for information and processes not available elsewhere, providing input on product development, and organizing activities around new research paths, members help focus CSDMS research in respect to their industries' short- and long-term needs, while avoiding some of the related costs of in-house research infrastructure, facilities and staff. Rigorous and objective Consortium feedback strengthens the CSDMS research and products, and provides a higher level of overall credibility.

3) Access to research activities and product development

CSDMS Consortium members are provided access to current advances in CSDMS research and products — data, tools, models, papers, presentations and status reports on progress. Members are encouraged to provide feedback on these models, tools, and other products. CSDMS uses MIT X11 as its software license. MIT X11 is OSI approved, GPL v. 2 compatible, and allows for the distribution of derivative works (with minimum requirements to shield the original author from liability). MIT X11 is user-friendly, compatible with most other open source licenses, and third party developers may keep derivative works proprietary.

Consortium members can request/suggest fee-based short courses, organized through the Integration Facility and instructors chosen from the CSDMS Working Groups, offering expertise in terrestrial dynamics (e.g. flood plain models), coastal dynamics (e.g. delta development), marine dynamics (e.g. turbidity currents), computation and cyber-infrastructure (e.g. coupling science behind the linking of models across time and space).

Consortium members are invited to attend CSDMS events, in addition to an annual site visit for insight into the latest research activities, experimental data and approaches, and demonstrations of products in development. Members receive a copy of the CSDMS annual report.

4) Association with a diverse group of scientists, universities, agencies, and industries

CSDMS actively works with international scientists, both from academic and research institutions, government agencies, and industry partners. As of February 2008, over 160 scientists and engineers from 80 institutions support the CSDMS effort. The CSDMS Consortium offers its members opportunities to develop connections and gain insight with this diverse group of participants. The result is an open exchange of state-of-the-art information in aid of problem solving, allowing companies to increase their effectiveness through application of CSDMS research and products. The CSDMS connection with NSF and other agencies — the U.S. Office of Naval Research, National Aeronautics and Space Administration, U.S. Geological Survey, U.S. Army Research Office, U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration, U.S. Dept of Energy, and U.S. Environmental Protection Agency — gives CSDMS products an immediate level of professional credibility, increasing their impact, acceptance and application in practice. Consortium members gain new knowledge with, for one example, direct application to subsurface stratigraphy, sedimentology, and reservoir characterization.

CSDMS Consortium Sponsorship

Consortium partners are asked to contribute to the success of CSDMS through either a financial contributions (larger companies), or as an in-kind contribution (smaller companies).

Large multinational (e.g. petroleum and mining) companies are asked for an annual tax-deductible gift contribution in the range of $30,000 to $100,000. The CSDMS Steering Committee, comprised of representatives of U.S. funding agencies (e.g. NSF and ONR), the U.S. National Academy of Science, academic leaders, and the petroleum and environmental industry itself, hope for Consortium contributions to grow to the million dollar level, wherein the Consortium could become a true strategic partner — rising closer to the level of NSF funding (>$1M/yr) and multi-agency CSDMS-related funding of Working Group member research (>$5M/yr). An overall longer-term goal is to obtain larger investments from corporate foundations. Gifts to the CSDMS initiative are to the CSDMS Integration Facility through the CU Foundation Corporation, due April 1, or by special arrangement to suit members' accounting cycles.

Smaller companies, typified by environmental or engineering firms, are asked for in-kind support, such as covering the cost of their employees and officers participating in the CSDMS effort (CSDMS meetings and events, Working Group activities, code development, code-sharing arrangements, and program advertising), and where possible gift support.

Professional staff supported with Consortium funds will be either post-doctoral research scientists or professional software engineers. These staff will work to contribute to the CSDMS efforts, while providing intimate liaison between the Consortium and the CSDMS Integration Office. The staff would support the development of models/modules/tools that meet the prioritized needs of the Consortium, and conduct numerical experiments suggested by the consortium members.

Consortium funds could also contribute to the developing of the cyber-infrastructure: 1) the CSDMS-operated Experimental Supercomputer (ES) offering >770 cores for >8 teraflops of computing power, and 2) the Front Range High Performance Computer (HPC) with 7000 core, >150 teraflops. The Professional staff supported with Consortium funds would have access to these High Performance Computers.

Request by a Consortium member, for directed and company-specific research, must be negotiated separately with the Environmental Computation and Imaging (ECI) Facility, at the University of Colorado — Boulder. If an ECI employee is associated with CSDMS and its Integration Facility, then: 1) the generalized topic must be transparent to other members of the Consortium, and 2) is not in conflict with CSDMS goals. Results and products could be proprietary for an agreed, predetermined time.

Appendix 3: Institutional Membership — as of 1 July 2012. There are now more than 443 affiliated institutions.

U.S. Academic Institutions: Current total of 123 with 7 new members from 31 June 2012 – 30 April 2013

1. Arizona State University
2. Auburn University, Alabama
3. Binghamton University, New York
4. Boston College
5. Boston University
6. Brigham Young University, Utah
7. California Institute of Technology, Pasadena
8. California State University - Fresno
9. California State University - Long Beach
10. California State University – Los Angeles
11. Carleton College, Minneapolis
12. Center for Applied Coastal Research, Delaware
13. Chapman University, California
14. City College of New York, City University of New York
15. Coastal Carolina University, South Carolina
16. Colorado School of Mines, Colorado
17. Colorado State University
18. Columbia/LDEO, New York
19. Conservation Biology Institute, Oregon
20. CUAHSI, District of Columbia
21. Desert Research Institute, Nevada
22. Duke University, North Carolina
23. Florida Gulf Coast University
24. Florida International University
25. Franklin & Marshall College, Pennsylvania
26. George Mason University, VA
27. Georgia Institute of Technology, Atlanta
28. Harvard University
29. Idaho State University
30. Indiana State University
31. Iowa State University
32. Jackson State University, Mississippi
33. John Hopkins University, Maryland
34. Louisiana State University
35. Massachusetts Institute of Technology
36. Michigan Technological University
37. Monterey Bay Aquarium Research Inst.
38. Murray State University
39. North Carolina State University
40. Northern Arizona University
41. Northern Illinois University
42. Nova Southeastern University, Florida
43. Oberlin College
44. Ohio State University
45. Oklahoma State University
46. Old Dominion University, Virginia
47. Oregon State University
48. Penn State University
49. Purdue University, Indiana
50. Rutgers University, New Jersey
51. Scripps Institution of Oceanography, CA
52. South Dakota School of Mines, South Dakota
53. Stanford, CA
54. State University (Virginia Tech), VA
55. Syracuse University, New York
56. Texas A&M, College Station, TX
57. Texas Christian University
58. Tulane University, New Orleans
59. United States Naval Academy, Annapolis
60. University of Alabama - Huntsville
61. University of Alaska – Fairbanks
62. University of Arkansas
63. University of Arizona
64. University of California – Berkeley
65. University of California - Davis
66. University of California – Irvine
67. University of California – Los Angeles
68. University of California - San Diego
69. University of California -Santa Barbara
70. University of California – Santa Cruz
71. University of Colorado – Boulder
72. University of Connecticut
73. University of Delaware
74. University of Florida
75. University of Houston
76. University of Idaho
77. University of Illinois-Urbana-Champaign
78. University of Iowa
79. University of Kansas
80. University of Louisiana – Lafayette
81. University of Maine
82. University of Maryland, Baltimore County
83. University of Memphis
84. University of Miami
85. University of Michigan
86. University of Minnesota – Minneapolis
87. University of Minnesota – Duluth
88. University of Nebraska – Lincoln
89. University of Nevada – Reno
90. University of New Hampshire
91. University of New Mexico
92. University of New Orleans
93. University of North Carolina – Chapel Hill
94. University of North Carolina – Wilmington
95. University of North Dakota
96. University of Oklahoma
97. University of Oregon
98. University of Pennsylvania – Pittsburgh

99. University of Pittsburgh
100. University of Rhode Island
101. University of South Carolina
102. University of South Florida
103. University of Southern California
104. University of Tennessee - Knoxville
105. University of Texas – Arlington
106. University of Texas – Austin
107. University of Texas – El Paso
108. University of Texas – San Antonio
109. University of Utah
110. University of Virginia
111. University of Washington
112. University of Wyoming
113. Utah State University
114. Vanderbilt University
115. Villanova University, Pennsylvania
116. Virginia Institute of Marine Science (VIMS)
117. Virginia Polytechnic Institute, VA
118. Washington State University
119. West Virginia University
120. Western Carolina University
121. Wichita State University
122. William & Mary College, VA
123. Woods Hole Oceanographic Inst.

U.S. Federal Labs and Agencies: Current total of 22 as of 31 June 2012 – 30 April 2013

1. Argonne National Laboratory (ANL)
2. Idaho National Laboratory (IDL)
3. National Aeronautics & Space Administration (NASA)
4. National Center for Atmospheric Research (NCAR)
5. National Oceanographic Partnership Program (NOPP)
6. National Science Foundation (NSF)
7. Oak Ridge National Laboratory (ORNL)
8. Sandia National Laboratories (SNL)
9. U.S. Dept. of Agriculture (USDA)
10. U.S. DoC – National Oceanic & Atmospheric Administration (NOAA)
11. U.S. DoC – National Weather Service (NWS)
12. U.S. DoD – Naval Research Laboratory (NRL)
13. U.S. DoD – Office of Naval Research (ONR)
14. U.S. DoD Army Corps of Engineers (ACE)
15. U.S. DoD Army Research Office (ARO)
16. U.S. DoI – Bureau of Ocean Energy Management (BOEM)
17. U.S. DoI – Bureau of Reclamation
18. U.S. DoI – Geological Survey (USGS)
19. U.S. DoI – National Forest Service (NFS)
20. U.S. DoI – National Park Service (NPS)
21. U.S. Nuclear Regulatory Commission (NRC)

U.S. Private Companies: Current total of 22 with 3 new members from 31 June 2012 – 30 April 2013

1. Airlink Communications, Hayward CA
2. Aquaveo LLC, Provo, Utah
3. ARCADIS-US, Boulder, Colorado
4. Chevron Energy Technology, Houston, TX
5. ConocoPhillips, Houston, TX
6. Deltares, USA
7. Dewberry, Virginia
8. Everglades Partners Joint Venture (EPJV), Florida
9. ExxonMobil Research & Engineering, Houston TX
10. Geological Society of America Geocorps
11. Idaho Power, Boise
12. PdM Calibrations, LLC, Florida
13. Philip Williams and Associates, Ltd., California
14. Schlumberger Information Solutions, Houston, TX
15. Science Museum of Minnesota, St. Paul, MN
16. Shell USA, Houston, TX
17. Stroud Water Research Center, Avondale, PA
18. URS–Grenier Corporation, Colorado
19. Warren Pinnacle Consulting, Inc., Warren, VT
20. The Von Braun Center for Science & Innovation Inc
21. The Water Institute of the Gulf, Louisiana
22. UAN Company

Foreign Membership: Current total of 275 with 52 of them being new members from 31 June 2012 – 30 April 2013 (**63** countries outside of the U.S.A.: Algeria, Argentina, Armenia, Australia, Austria, Bangladesh, Belgium, Bolivia, Brazil, Bulgaria, Cambodia, Canada, Chile, China, Colombia, Cuba, Denmark, Egypt, El Salvador, France, Germany, Ghana, Greece, Hong Kong, Hungary, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Kenya, Malaysia, Mexico, Morocco, Myanmar, Nepal, New Zealand, Nigeria, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russia, Scotland, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Netherlands, Turkey, UK, United Arab Emirates, Uruguay, Venezuela, Việt Nam).

Foreign Academic Institutes:

1. Aberystwyth University, Wales, UK
2. Adam Mickiewicz University (AMU) Poznan, Poland
3. AGH University of Science and Technology, Krakow, Poland
4. AgroCampus Ouest, France
5. Aix-Marseille University, France
6. Anna University, India
7. ANU College, Argentina
8. Aristotle University of Thessaloniki, Greece
9. Bahria University, Islamabad, Pakistan
10. Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
11. Birbal Sahni Institute of Palaeobotany, India
12. Bonn University, Germany
13. Blaise Pascal University, Clermont, France
14. Brandenburg University of Technology (BTU), Cottbus, Germany
15. British Columbia Institute of Technology (BCIT), Canada
16. Cardiff University, UK
17. Carleton University, Canada
18. China University of Geosciences- Beijing, China
19. China University of Petroleum, Beijing, China
20. Christian-Albrechts-Universitat (CAU) zu Kie, Germany
21. CNRS / University of Rennes I, France
22. Cracow University of Technology, Poland
23. Dalian University of Technology, Liaoning, China
24. Darmstadt University of Technology, Germany
25. Delft University of Technology, Netherlands
26. Diponegoro University, Semarang, Indonesia
27. Dongguk University, South Korea
28. Durham University, UK
29. Ecole Nationale Superieure des Mines de Paris, France
30. Ecole Polytechnique, France
31. Eidgenossische Technische Hochschule (ETH) Zurich, Switzerland
32. FCEFN-UNSJ-Catedra Geologia Aplicada II, Argentina
33. Federal Ministry of Environment, Nigeria
34. Federal University of Itajuba, Brazil
35. Federal University of Petroleum Resources, Nigeria
36. Federal University Oye-Ekiti, Nigeria
37. First Institute of Oceanography, SOA, China
38. Free University of Brussels, Belgium
39. Guanzhou University, Guanzhou, China
40. Heriot-Watt University, Edinburgh, UK
41. Hohai University, Nanjing, China
42. Hong Kong University, Hong Kong
43. IANIGLA, Unidad de Geocriologia, Argentina
44. Imperial College of London, UK
45. India Institute of Technology – Bhubaneswar, India
46. India Institute of Technology – Delhi
47. India Institute of Technology – Kanpur
48. India Institute of Technology - Madras
49. India Institute of Technology – Mumbai
50. Indian Institute of Science – Bangalore
51. Institut Univ. Europeen de la Mer (IUEM), France
52. Institute of Engineering (IOE), Nepal
53. Instituto de Geociencias da Universidade Sao Paulo (IGC USP), Brasil
54. Kafrelsheikh University, Kafrelsheikh, Egypt
55. Karlsruhe Institute of Technology (KIT), Germany
56. Katholieke Universiteit Leuven, KUT, Belgium
57.
58. King's College London, UK
59. Kocaeli University, Izmit, Turkey
60. Lanzhou University, China
61. Leibniz-Institute fur Ostseeforschung Warnemunde (IOW)/Baltic Sea Research, Germany
62. Leibniz Universitat Hannover, Germany
63. Loughborough University, UK
64. Lund University, Sweden
65. McGill University, Canada
66. Mohammed V University-Agdal, Rabat, Morocco
67. Mulawarman University, Indonesia
68. Nanjing University of Information Science & Technology (NUIST), China
69. Nanjing University, China
70. National Taiwan University, Taipei, Taiwan
71. National University (NUI) of Maynooth, Kildare, Ireland
72. National University of Sciences & Technology, (NUST), Pakistan

73. Natural Resources, Canada
74. Northwest University of China, China
75. Norwegian University of Life Sciences, Norway
76. Ocean University of China, China
77. Padua University, Italy
78. Peking University, China
79. Pondicherry University, India
80. Pukyong National University, Busan, South Korea
81. Royal Holloway University of London, UK
82. Sejong University, South Korea
83. Seoul National University, South Korea
84. Shihezi University, China
85. Singapore-MIT Alliance for Research and Technology (SMART), Singapore
86. Southern Cross University, United Arab Emirates (UAE)
87. Sriwijaya University, Indonesia
88. SRM University, India
89. Stockholm University, Sweden
90. Tarbiat Modares University, Iran
91. The Maharaja Sayajirao University of Baroda, India
92. Tianjin University, China
93. Tsinghua University, China
94. Universidad Agraria la Molina, Peru
95. Universidad Complutense de Madrid, Spain
96. Universidad de Granada, Spain
97. Universidad de Guadalajara, Mexico
98. Universidad de la Republica, Uruguay
99. Universidad de Oriente, Cuba
100. Universidad de Zaragoza, Spain
101. Universidad Nacional de Catamarca, Argentina
102. Universidad Nacional de Rio Negro, Argentina
103. Universidad Nacional de San Juan, Argentina
104. Universidad Politecnica de Catalunya, Spain
105. Universidade de Lisboa, Lisbon, Portugal
106. Universidade de Madeira, Portugal
107. Universidade do Minho, Braga, Portugal
108. Universidade Federal do Rio Grande do Sul (FRGS), Brazil
109. Universit of Bulgaria (VUZF), Bulgaria
110. Universita "G. d'Annunzio" di Chieti-Pescara, Italy
111. Universitat Potsdam, Germany
112. Universitat Politecnica de Catalunya, Spain
113. Universitas Indonesia, Indonesia
114. Universite Bordeaux 1, France
115. Universite de Rennes (CNRS), France
116. Universite du Quebec a Chicoutimi (UQAC), Canada
117. Universite Joseph Fourier, Grenoble, France
118. Universite Montpellier 2, France
119. Universiteit Gent, Ghent, Belgium
120. Universiteit Stellenosch University, South Africa
121. Universiteit Utrecht, Netherlands
122. Universiteit Vrije (VU), Amsterdam, Netherlands
123. Universiti Teknologi Mara (UiTM), Mayalsia
124. Universiti Malaysia Pahang, Malaysia
125. University College Dublin, Ireland
126. University of Bari, Italy
127. University of Basel, Switzerland
128. University of Bergen, Norway
129. University of Bremen, Germany
130. University of Brest, France
131. University of Bristol, UK
132. University of British Columbia, Canada
133. University of Calgary, Canada
134. University of Cambridge, UK
135. University of Copenhagen, Denmark
136. University of Dhaka, Bangladesh
137. University of Dundee, UK
138. University of Edinburgh, Scotland
139. University of Edinburgh, UK
140. University of Exeter, UK
141. University of Ghana, Ghana
142. University of Guelph, Canada
143. University of Haifa, Israel
144. University of Kashmir, India
145. University of Lethbridge, Canada
146. University of Malaya, Kuala Lumpur, Malaysia
147. University of Milano-Bicocca, Italy
148. University of Natural Resources & Life Sciences, Vienna, Austria
149. University of New South Wales, Australia
150. University of Newcastle upon Tyne, UK
151. University of Newcastle, Australia
152. University of Nigeria, Nsukka, Nigeria
153. University of Palermo, Italy
154. University of Padova, Italy
155. University of Pavia, Italy
156. University of Queensland (UQ), Australia
157. University of Reading, Berkshire, UK
158. University of Rome (INFN) "LaSapienza", Italy
159. University of Science Ho Chi Minh City, Viet Nam
160. University of Southampton, UK
161. University of St. Andrews, UK
162. University of Sydney, Australia
163. University of Tabriz, Iran

164. University of Tehran, Iran
165. University of the Philippines, Manila, Philippines
166. University of the Punjab, Lahore, Pakistan
167. University of Waikato, Hamilton, New Zealand
168. University of Warsaw, Poland
169. University of West Hungary - Savaria Campus, Hungary
170. University of Western Australia, Australia
171. VIT (Vellore Institute of Technology) University, Tamil Nadu, India
172. VUZF University, Bulgaria
173. Wageningen University, Netherlands
174. Water Resources University, Hanoi, Viet Nam
175. Wuhan University, Wuhan, China
176. Xi-an University of Architecture & Technology, China
177. York University, Canada

Foreign Private Companies

1. Aerospace Company, Taiwan
2. ASR Ltd., New Zealand
3. Bakosurtanal, Indonesia
4. BG Energy Holdings Ltd., UK
5. Cambridge Carbonates, Ltd., France
6. Deltares, Netherlands
7. Digital Mapping Company, Bangladesh
8. Energy & Environment Modeling, ENEA/UTMEA, Italy
9. Environnement Illimite, Inc., Canada
10. Excurra & Schmidt: Ocean, Hydraulic, Coastal and Environmental Engineering Firm, Argentina
11. Fugro-GEOS, UK
12. Geo Consulting, Inc., Italy
13. Grupo DIAO, C.A., Venezuela
14. Haycock Associates, UK
15. H.R. Wallingford, UK
16. IH Cantabria, Cantabria, Spain
17. InnovationONE, Nigeria
18. Institut de Physique de Globe de Paris, France
19. Institut Francais du Petrole (IFP), France
20. Jaime Illanes y Asociados Consultores S.A., Santiago, Chile
21. MUC Engineering, United Arab Emirates (UAE)
22. Petrobras, Brazil
23. Riggs Engineering, Ltd., Canada
24. Saipem (oil and gas industry contractor), Milano, Italy
25. Shell, Netherlands
26. SEO Company, Indonesia
27. Statoil, Norway
28. Vision on Technology (VITO), Belgium

Foreign Government Agencies

1. Agency for Assessment and Application of Technology, Indonesia
2. Bedford Institute of Oceanography, Canada
3. Bhakra Beas Management Board (BBMB), Chandigarh, India
4. British Geological Survey, UK
5. Bundesanstalt fur Gewasserkunde, Germany
6. Bureau de Recherches Géologiques et Minières (BRGM), Orleans, France
7. Cambodia National Mekong Committee (CNMC), Cambodia
8. Center for Petrographic and Geochemical Research (CRPG-CNRS), Nancy, France
9. CETMEF/LGCE, France
10. Channel Maintenance Research Institute (CMRI), ISESCO, Kalioubia, Egypt
11. Chinese Academy of Sciences – Cold and Arid Regions Environmental and Engineering Research Institute
12. Chinese Academy of Sciences – Institute of Mountain Hazards and Environment, China

13. Chinese Academy of Sciences – Institute of Tibetan Plateau Research (ITPCAS), China
14. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
15. Consiglio Nazionale delle Ricerche (CNR), Italy
16. French Agricultural and Environmental Research Institute (CEMAGREF)
17. French Research Institute for Exploration of the Sea (IFREMER), France
18. Geological Survey of Canada, Atlantic
19. Geological Survey of Canada, Pacific
20. Geological Survey of Israel, Jerusalem, Israel
21. Geological Survey of Japan (AIST), Japan
22. Geosciences, Rennes France
23. GFZ, German Research Centre for Geosciences, Potsdam, Germany
24. GNS Science, New Zealand
25. GNU VNIIGIM, Moscow, RUSSIA
26. Group-T, Myanmar
27. Helmholtz Centre for Environmental Research (UFZ), Germany
28. Indian National Centre for Ocean Information Services (INCOIS), India
29. Institut des Sciences de la Terre, France
30. Institut National Agronomique (INAS), Algeria
31. Institut Teknologi Bandung (ITB), Indonesia
32. Institute of Atmospheric Sciences and Climate (ISAC) of Italian National Research Council (CNR), Italy
33. Institute for Computational Science and Technology (ICST), Viet Nam
34. Institute for the Conservation of Lake Maracaibo (ICLAM), Venezuela
35. Institute of Earth Sciences (ICTJA-CSIC), Spain
36. Instituto Hidrografico, Lisboa, Lisbon, Portugal
37. Instituto Nacional de Hidraulica (INH), Chile
38. Instituto Nazionale di Astrofisica, Italy
39. International Geosphere Biosphere Programme (IGBP), Sweden
40. Iranian National Institute for Oceanography (INIO), Tehran, Iran
41. Italy National Research Council (CNR), Italy
42. Japan Agency for Marine-Earth Science Technology (JAMSTEC), Japan
43. Kenya Meteorological Services, Kenya
44. Korea Ocean Research and Development Institute (KORDI), South Korea
45. Korea Water Resources Corporation, South Korea
46. Lab Domaines Oceanique IUEM/UBO France
47. Laboratoire de Sciences de la Terre, France
48. Marine Sciences For Society, France
49. Ministry of Earth Sciences, India
50. Nanjing Hydraulics Research Institute, China
51. National Institute of Water and Atmospheric Research (NIWA), Auckland, New Zealand
52. National Research Institute of Science and Technology for Environment and Agriculture (CEMAGREF became IRSTEA), France
53. National Institute for Space Research (INPE), Brazil
54. National Institute of Oceanography (NIO), India
55. National Institute of Technology Rourkela, Orissa, India
56. National Institute of Technology Karnataka Surathkal, Mangalore, India
57. National Institute of Water and Atmosphere (NIWA), New Zealand
58. National Marine Environmental Forecasting Center (NMEFC), China
59. National Research Centre for Sorghum (NRCS), India
60. National Research Council (NRC), Italy
61. National Space Research & Development Agency, Nigeria
62. Scientific-Applied Centre on hydrometeorology & ecology, Armstatehydromet, Armenia
63. Senckenberg Institute, Germany
64. Shenzhen Inst. of Advanced Technology, China
65. South China Sea Institute of Technology (SCSIO), Guanzhou, China
66. The European Institute for Marine Studies (IUEM), France
67. The Leibniz Institute for Baltic Sea Research, Germany

68. UNESCO-IHE, Netherlands
69. Water Resources Division, Dept. of Indian Affairs and Northern Development, Canada
70. World Weather Information Service (WMO), Cuba

Independent Researchers (both U.S. and Foreign): 31 members self-identify either as independent researchers or left their affiliation unknown.