CSDMS

COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

SEMI-ANNUAL REPORT
FEBRUARY 1, 2008 TO AUGUST 15, 2008

NSF COOPERATIVE AGREEMENT 0621695

Preface

The Community Surface Dynamics Modeling System (CSDMS) develops, supports, and disseminates integrated software modules that predict the movement of fluids, and the flux (production, erosion, transport, and deposition) of sediment and solutes in landscapes and their sedimentary basins. CSDMS involves the Earth surface — the dynamic interface between lithosphere, atmosphere, cryosphere, and hydrosphere. This Semi-Annual Report covers the period from February 2008 to August 2008, and provides an update since the last 2007 Annual Report to NSF.

Table of Contents

Definitions

Computer jargon can be intimidating. Below we define some of the core acronyms and jargon used in the semi-annual report, in aid of understanding the report.

Babel: A language interoperability tool (and compiler) that automatically generates the "glue code" that is necessary in order for components written in different computer languages to communicate. It currently supports C, C++, Fortran (all years), Java and Python. Babel is much more than a "least common denominator" solution; it even enables passing of variables with data types (e.g. objects, complex numbers) that may not normally be supported by the target language. Babel uses SIDL (see below). Babel was designed to support high-performance computing and is one of the key tools in the CCA tool chain.

Bocca: A development environment tool to enable application developers to perform rapid component prototyping while maintaining robust software- engineering practices suitable to HPC environments. Bocca provides project management and a comprehensive build environment for creating and managing applications composed of Common Component Architecture components Bocca operates in a language-agnostic way by automatically invoking the lower-level Babel tool. Bocca was designed to free users from mundane, low-level tasks so they can focus on the scientific aspects of their applications.

CCA: Common Component Architecture (http://www.cca-forum.org/) is a software architecture adopted by federal agencies (largely the Department of Energy and its national labs) and academics to allow components to be combined and integrated for enhanced functionality on high-performance computing systems. **CCA** defines standards necessary for the interoperation of components developed in the context of different frameworks. That is, software components that adhere to these standards can be ported with relative ease to another CCA-compliant framework.

Component: A software object, meant to interact with other components, encapsulating certain functionality or a set of functionalities. A component has a clearly defined interface and conforms to a prescribed behavior common to all components within an Architecture. Multiple components may be composed to build other applications. In object-oriented terminology, components are usually implemented as classes.

ESMF: Earth Surface Modeling Framework (ESMF) is software for building and coupling weather, climate, and related models. ESMF (http://www.esmf.ucar.edu/) helps to support operational models principally for NOAA and DoD. ESMF also includes toolkits for building components and applications, such as regridding software, calendar management, logging and error handling, and parallel communications.

Framework: The software environment or infrastructure in which components are linked together to create applications. A framework typically provides a set of services that all components can access directly. A CCA framework is a specific implementation of the CCA architecture standard, typically associated with a particular computing environment. For example, the Ccaffeine Framework is used for parallel computing and the XCAT Framework is used for distributed computing.

HPC: High-performance computing (HPC) uses supercomputers and computer clusters to solve advanced computing problems. Computer systems approaching the teraflops-region are counted as HPC-computers.

Interface Standard: A standardized set of rules (and supporting infrastructure) for how a component must be written or refactored in order for it to more easily exchange data with other components that adhere to the same standard. A set of components that conform to this standard can then be linked together to build new applications. Such a standard promotes interoperability between components developed by different teams across different institutions.

OpenMI: Open Modeling Interface (OpenMI) is an open source software-component Interface Standard for the computational core of numerical models. Model components that comply with this standard can, without any programming, be configured to exchange data during computation (at run-time). This means that combined systems can be created, based on OpenMI-compliant models from different providers, thus enabling the modeler to use those models that are best suited to a particular project. The OpenMI standard supports two-way links where the involved models mutually depend on calculation results from each other. Linked models may run asynchronously with respect to time steps, and data represented on different geometries (grids) can be exchanged using built-in tools for interpolating in space and time.

Refactoring: Code refactoring is the process of changing a computer program's code, to make it amenable to change, improve its readability, or simplify its structure, while preserving its existing functionality.

SIDL: Scientific Interface Definition Language (SIDL) is a language developed for the Babel project whose sole purpose is to describe the interfaces (as opposed to implementations) of scientific model components. The Babel tool uses a "language-neutral" SIDL or XML description of an interface (e.g. function arguments, return values and their data types) to create the glue code that is necessary for components written in different languages to communicate. SIDL has a complete set of fundamental data types, from Booleans to double precision complex numbers. It also supports more sophisticated types such as enumerations, strings, objects, and dynamic multi-dimensional arrays.

Standard interfaces: Allows disparate software components to be composed together to build a running application. Such a standard will promote interoperability between components developed by different teams across different institutions.

SDK: Software Development Kit (also known as a native developer kit or NDK) is typically a set of development tools that allows a software engineer to create applications for a certain software package, software framework, hardware platform, computer system, video game console, operating system, or similar platform.

Subversion: SVN is a version control program that can be used to track changes in a directory tree, either to individual files, or to the tree itself. The latter would include addition, deletion or renaming of files or subdirectories. Subversion can track changes for any collection of files, but is best suited to tracking changes in text files, such as program source code or documentation.

Teraflop: A teraflop is a measure of a computer's speed and can be expressed as 10 to the 12th power floating-point operations per second.

Progress on Year 2 Goals

Goal 1) Establish interface standards that define precisely the manner in which components can be connected. **Milestone:** Evaluation of existing interface standards.

Various model-interface standards were examined for their suitability for adoption within the CSDMS Architecture and Framework, which is based around CCA. Of the two main community standards (ESMF and OpenMI), the CSDMS community has chosen to adopt OpenMI. As an interface standard, OpenMI transcends any particular programming language, operating system or framework. However, up until now it has only been implemented and tested in Microsoft's .NET framework, with C# as the language and Windows as the operating system. In order to demonstrate the utility of OpenMI, its developers wrote an SDK (software developer kit), which is a large set of supporting tools that form the backbone of OpenMI. These tools perform a variety of low-level tasks, but their main purpose is to accommodate differences between models such as time steps, units, dimensionality (1D, 2D or 3D) and the manner in which space is discretized (e.g. squares or triangles). In addition to the C#/.NET/Windows version, a Java/JDK version is nearly complete that allows use on non-Windows computers. CSDMS is currently combining the best features of OpenMI and CCA by implementing the Java version of OpenMI within a CCA framework. To this end, CSDMS software engineers recently converted the Java version of the standard itself (not the SDK) to SIDL and then used Bocca to create an "OpenMI port". Since CCA's Babel supports Java, OpenMI's Java SDK can be used in a CCA framework without major changes. CSDMS is currently working on a tool that will add an OpenMI interface to any "properly refactored" model component. The goal is to make it as easy as possible to add an OpenMI interface (as a CCA port) to an existing model component, because by design, any two components with this interface can be linked together (if it makes sense to do so).. Documentation on the details of this procedure will be part of the "CSDMS Handbook" that is being developed. Users will learn how to write "get values" routines for their models so that they are ready to be wrapped with an OpenMI interface.

Goal 2) Link refactored code contributions from the community as CSDMS components within the CSDMS framework. **Milestone:** Link SedFlux model to CHILD model using CCA.

SedFlux 3D (originally 100,000 lines of code) was previously (pre-CSDMS) refactored (now 70,000 lines of code) and results are documented on http://sedflux.googlecode.com /. Individual component models that were within SedFlux are now available to the CSDMS community as stand-alone models (or components) (http://csdms.colorado.edu/wiki/index.php/Models_page). SedFlux is now CCA compliant and ready to be wrapped with an OpenMI interface. SedFlux 3D users have been communicating using the code.google site with queries and to receive code updates, or to request help in modeling activities. The SedFlux 3D source code is contained in the CSDMS subversion repository: https://csdms.colorado.edu/svn/sedflux/. The latest stable version can be obtained: http://csdms.colorado.edu/pub/csdms/models/marine/sedflux/.

CHILD is a 2D landscape evolution model, "Channel-Hillslope Integrated Landscape Development" (http://www.colorado.edu/geolsci/gtucker/child/index.html). CSDMS software engineers have worked with CHILD's developer to refactor CHILD so that it is ready to be wrapped with an OpenMI interface. Once both SedFlux and CHILD have an OpenMI interface, linking them together will be straightforward. We will soon be adding a link to the CSDMS website to allow users to download the open source code.

Goal 3) Implement a glacier erosion model (e.g. GC2D) with a distributed hydrologic model (e.g. TopoFlow) as an application built from CCA-compliant components.

TopoFlow http://csdms.colorado.edu/wiki/index.php/TopoFlow_Information and http://csdms.colorado.edu/topoflow/ is a spatially distributed hydrological model. It has been converted from IDL to open source Python language using an advanced version of open source i2py. This required CSDMS software engineers to add significant extensions to i2py. Lessons learned from this conversion exercise will be described in the soon-to-be-released "CSDMS Handbook", particularly the technical issues dealing with the conversion of pointers and structures.

The glacier erosion model GC2D has been converted from MATLAB to Python. The CSDMS IF has wrapped the new Python version of GC2D, to comply with the preliminary CSDMS interface standards based on OpenMI. Testing of the translation of the GC2D model from MATLAB to Python continues. GC2D is wrapped as a component class that has member functions, init, finalize, and get_values. init reads input files and initializes the model grid, finalize frees resources at the end of the simulation, and get_values retrieves a set of variables at a specified time and location from the model. This allows a set of variables to be transferred between models. The source code is contained in the CSDMS subversion repository at: https://csdms.colorado.edu/svn/gc2d/ and a distribution of the latest stable version can be obtained at: http://csdms.colorado.edu/pub/csdms/models/terrestrial/gc2d/.

The two models GC2D and TopoFlow cannot be presently linked using CCA/OpenMI, as the GC2D model has not been designed to provide a time-dependent surface/subsurface runoff (from glacier melt), as an output variable. Once this new hydrological process component is added to GC2D, the two models should be able to be linked.

Goal 4) Implement a landscape evolution model and a coastal evolution built as CCA compliant components.

The CSDMS IF has wrapped the coastal evolution model SedFlux 3D to be compliant with initial CSDMS interface standards. This includes functions that initialize, run, and finalize SedFlux 3D. The initialize function is called once to setup the model simulation, and the finalize function is called once at the end of the simulation to free computational resources. The run function advances the model to a specified simulation time and calculates a set of specified variables. The calculated variables can now be passed along to a landscape evolution model, for example, the CHILD model.

Goal 5) Explore the coupling of a 3D hydrodynamic ocean model within CSDMS/CCA (e.g. ROMS or Delft3D-Flow).

The CSDMS Integration Facility has obtained the source code for Delft3D (http://csdms.colorado.edu/wiki/index.php/Delft3D_Information) and will work to see how the model can be implemented in CSDMS. Note that Delft3D is a product of Delft Hydraulics (now Deltares), one of the companies that helped to develop the OpenMI standard. So Delft3D is already or soon will be OpenMI compliant.

Goal 6) Begin to assemble a set of standard components that transcend model components and facilitate their linkage of components into working applications. **Milestone:** Evaluate solvers such as PETSc & format converters

As discussed in Goal 1, the Java SDK for OpenMI contains a variety of low-level tools that help to accommodate differences between models, such as basic regridding and interpolation tools. CSDMS has acquired this set of tools and will be repackaging much of it in the form of CCA framework services. In addition, CSDMS software engineers have identified various open-source "toolkits" such as a suite of tools for reading and writing many standard data formats that has been made available by the OGC (Open Geospatial Consortium). The USDA's OMS (Open Modeling System) project also has a number of hydrologic process components and low-level tools that are all written in Java. The GEOTOP project, based in Italy, has also developed a large number of tools in Java in support of their modeling efforts and we are working with them to share components and expertise. There is also a large and growing set of tools available as extension modules for Python, including things like XML and HTML parsers, file-format converters, GUI development tools and plotting/visualization tools. Python is rapidly gaining popularity in the modeling community, as evidenced by special sessions at AGU and recent work by many of our colleagues. As mentioned previously, both Java and Python are CCA-supported, object-oriented and highly portable languages.

Goal 7) Create two educational modules, conduct a training workshop and assist the CSDMS community in preparing code and model contributions that comply with the CSDMS standards and interfaces.

A "CSDMS Handbook" is in progress and will be distributed to code contributors, new hires and technical contacts to help them understand what we require from them and how CSDMS is combining several new technologies to achieve project goals.

A policy paper entitled "A Community Approach to Modeling Earth Surface Dynamics" is nearing the final stages of completion with coauthors from the CSDMS, ESMF, CSTMS, and CCMP, the main representative community programs in earth-surface dynamics (see Appendix 1 for a draft).

Having wrapped the SedFlux3D and GC2D models to comply with the initial interface standards, the CSDMS IF now has examples that demonstrate how to wrap a model written in either Python or c, and thus how to make a model CSDMS compliant.

Goal 8) Develop the three CSDMS repositories (Data, Model, & Education), with community contributions.

Target: A doubling of the number of data sets, contributed models and educational presentations hosted on the CSDMS site; track community interest and use of this material.

The CSDMS IF now hosts an anonymous ftp site for contributors to locate downloadable content for their models. The CSDMS now hosts the over 20 models or subroutines ftp://csdms.colorado.edu/pub/csdms/ (browsers that don't support ftp can browse the repository at http://csdms.colorado.edu/pub/csdms).

The CSDMS IF has set up a Subversion server for the community to use. The server has been set up in such a way that model owners can upload their models to the CSDMS server for version control. Unless otherwise specified, the contributed code can be browsed and downloaded by anybody, but only members of the owner's modeling group can upload changes made to the model. The model owner will control who belongs to the model's group.

The CSDMS IF has added 23 new models to its model repository. Source code snapshots of these models are available for download at: http://csdms.colorado.edu/pub/csdms/models. Those wishing to further develop these models are able to checkout the latest development version of the code through the CSDMS svn repository at: http://csdms.colorado.edu/svn/. The specific repository for each model can be found at each model's web page on the CSDMS website. Each model has been verified to compile with standard GNU development tools (gcc, gfortran, make, etc.) and to run under a UNIX environment. The CSDMS IF now hosts over 140,000 total lines of code. To see the full CSDMS source line statistics, readers are referred to the http://csdms.colorado.edu/wiki/index.php/Model_SLOC_Page.

CSDMS model & subroutine repository statistics as of August 23rd 2008:

Model domain	**Listed models & subroutines**	**Questionnaires filled out**	**Source code available**
Terrestrial	43	31	16
Coastal	63	27	11
Marine	23	12	3

To help with the testing of models, the CSDMS IF has begun development on a testing framework called Damian. Users specify input files, output files, and a test to perform. Damian automatically sets up, runs, grades, and cleans up the test. The user is provided with a report card of the series of tests. The source code is contained in the CSDMS subversion repository: https://csdms.colorado.edu/svn/damian/. A distribution of latest stable version can be obtained at: http://csdms.colorado.edu/pub/csdms/tools/damian/. The project web page is at: http://damian-csdms.googlecode.com/.

'Geological Modeling' graduate level course has been developed and offered through the CSDMS website, http://csdms.colorado.edu/wiki/index.php/Products. The course aims at exploring Geological Modeling techniques as:

- Learning tools to study complex interactions of sedimentary depositional systems and time varying boundary conditions.
- Quantitative tools to create geological models of the subsurface, including realizations of subsurface properties like grain-size distribution, porosity and permeability.
- Means to quantify uncertainties in the subsurface models by running sensitivity tests.
- Ten presentations and 5 classroom exercises can be downloaded for teaching purposes.

Coastal erosion and permafrost photos are now featured on the CSDMS website under the 'Coastal photo gallery', available to the community for teaching purposes http://csdms.colorado.edu/wiki/index.php/Coastal_GL4.

The CSDMS Education Repository distributes model simulations, CSDMS-related educational presentations, reports and publications, CSDMS-related short course materials, CSDMS images, and CSDMS-hosted or sponsored workshop and meeting presentations. Educational tutorials hosted on the CSDMS web site presently include: 1) Charge to the CSDMS Working Groups; 2) Advantages of the Common Component Architecture (CCA) for CSDMS; 3) Comparing Model Coupling Systems: An Example; 4) CCA Recommended Reading List; 5) Mini-tutorial on *Subversion*; 6) Evaluation of model coupling frameworks for use by CSDMS, and 7) Powerpoints on Graduate Level course 'Geological Modeling'.

Goal 9) Purchase and setup the CSDMS Experimental Supercomputer, test compilers with SedFlux, develop and open up to the CSDMS community for job sharing.

High-performance computing (HPC) has provided numerous advances to ocean and atmospheric science, but these advantages are not well exploited by land-surface dynamics (LSD), basin evolution (BE), and distributed transport (DT) models. LSD-BE-DT models (e.g. spatially-distributed hydrologic and fluvial landscape evolution models, ice-sheet dynamic models, coastal dynamic models) are similar to atmosphere and ocean models in that the time evolution of several spatial grids is modeled for one or more vertical layers by solving a set of coupled PDEs. However, the physically important spatial scales are much smaller than those of coupled ocean–atmosphere models, where 5m to 100m grid cells (vs. 1km to 100km cells) are required to resolve surface dynamic processes. In addition, coupled land-surface and subsurface processes are often integrated at different time scales, from seconds or minutes for channelized surface flow, to hours or days for overland and subsurface flows.

The CSDMS Integration Facility has been working with the vendors SUN, SGI, and IBM in configuring and costing a CSDMS dedicated HPC. The computer is being financed entirely by the University of Colorado at Boulder Graduate School and the Institute of Arctic and Alpine Research, with a smaller contribution from the U.S. Geological Survey. The details of the final configuration remains in progress but should have the following noteworthy features: 1) 520 cores using either a) E5450 Quad core "harpertown" 3 GHz chip with 1.333GHz front side bus, or b) E5472 Quad core "harpertown" 3 GHz chip with 1.6 GHz front side bus, both operating at 80 watt. 2) 2GB/core memory with a) 667 Megabytes/s or b) 800 Megabytes/s, all within a nonblocking InfiniBand fabric. 3) 72 TB of total raw capacity RAID storage with 2 storage controllers (quad core +16GB memory). 4) 3 Racks, 5) 3 yr warranty, 6) Universal Power Supply.

CSDMS Executive Director, James Syvitski is a Co-Investigator on the new NSF award entitled **MRI-Consortium: Acquisition of a Supercomputer by the Front Range Computing Consortium.** This grant offers to potential CSDMS researchers a state of the art HPC, once their code can be scaled up to take advantage of a Tier 3 HPC. The computational power is derived from 10 Sun Blade 6048 Modular System racks, nine deployed to form a tightly integrated computational plant, and the remaining rack to serve as a GPU-based accelerated computing system. Each computational rack is composed of four integrated Sun Blade 6000 series chassis units, containing 12 blades connected by an internal quad-data-rate InfiniBand fabric; a 24-port Network Expansion Module (NEM) provides external connectivity. Each blade is composed of two dual-socket boards with each socket containing a quad-core Intel Nehalem-EP processor clocked at an expected frequency of ≈ 3.3 GHz, with a byte to FLOP ratio of 0.6. Each dual-socket board has eight 2 GB DDR-3 DIMMS for a total of 16 GB of RAM (2 GB per core). Each rack contains 192 processors (768 cores), for a total of 7680 cores (including the accelerated computing rack), with a peak performance exceeding 10 Teraflops/s for aggregate system peak performance of 101.4 Teraflop/s. The storage solution will consist of a high-performance Lustre file system built on 12 to 16 Sun Thumper- 2 storage server chassis. Each of the Thumper-2 units has 48 internal disks, an 8x PCI-Express IB Host Bus Adapter (HBA), and utilizes the Sun ZFS block allocation layer to provide in excess of 800 Megabytes per second per Thumper. Using 1 Terabyte disks, the total raw capacity is between 576 and 768 Terabytes. The remaining computational rack provides the accelerated computing component using NVIDIA Tesla 870 GPU technology. The Tesla 870 GPU system is a 1U chassis containing four 128-simultaneous thread GPUs and 6 Gigabytes of RAM accessible at 76.8 Gigabytes per second. The entire system will utilize a standard Linux-based software stack, vendor-supplied IB-based MPI, and the Coordinated TerraGrid Software and Services. In addition, the Grid environment will provide access to NCAR's mass storage system.

Goal 10) Further develop the CSDMS Wiki website in aid of community integration and participation. **Target:** Active use in the website by CSDMS management and members of the five Working Groups, in support of the 2008-09 goals.

The CSDMS Wiki is successfully being used to communicate CSDMS-sponsored meeting information; active use is now easy. Since the website was converted to a Wiki, on March 27, 2008, the 102 CSDMS web pages have been viewed a total of >200,000 times. The front page itself has been visited more than 11,000 times in these months. For security the CSDMS Website has been updated by:

a. Site can now block 'not wanted' IP addresses before they are able to do any harm to the CSDMS website, by employing a blacklist of IP addresses from the web and adding them to the CSDMS blacklist (MediaWiki: Openproxylist).
b. Securing CSDMS forms with a 'form spam block' script.
c. Adding the Captcha tool to prevent automated login scripts to be able to create a WIKI account. It is harder for unwanted users to 1) create external web links and 2) create new pages.

To improve administration, the CSDMS Website has:

i. Incorporated a script to reset passwords (for users who forget their password), using Sysops privileges.
ii. Added a script to retrieve user information upon sign up for the WIKI.
iii. Added the CSDMS WIKI to Google Analytics (a free Google web tool). Google Analytics is a tool to analyze where web site visitors (who are logged in) are coming from and how they browse on the CSDMS site.

The CSDMS Website has added functionality:

a. Uploading documents was limited to a few file formats (pdf, jpg, tar, rar). This has been extended to ppt, doc, docx, zip.
b. Incorporated a "Job" page to post CSDMS related job offers.

The CSDMS Website lay out has been improved, e.g.

a. Selecting a main tab will now automatically change the color of the 'sub tab' bar.
b. The web pages are presented over the whole width of the browser window.
c. The static front page of CSDMS now offers a more dynamic page where people can directly choose a link to the page they want to go to.
d. Added a favicon for a more professional look.

SVN source code version control is now accessible on the server so people can upload and download models. The source code of HydroTend and SedFlux models are used as examples, and uploaded to SVN.

Goal 11) Organize and/or sponsor and/or host 3 workshops (Clinoform, Sedibud, CUAHSI Natl. Meeting), 5 working group meetings, 4 management meetings, 1 Open Town-hall meeting and 1 short course (coding camp).

Since the last Annual Report of CSDMS, the Integration Facility has sponsored, &/or hosted, &/or organized the following meetings:

- Cyberinformatics and Numerics Working Group startup meeting, Feb. 4-5, 2008, INSTAAR, Boulder, CO (see Chapter 4, Section 1 of the CSDMS Strategic Plan for its findings: http://csdms.colorado.edu/wiki/images/CSDMS_Strategic_Planv3F-48-op.pdf). Attendance: 9 working group members plus 4 CSDMS staff members
- CSDMS Community Sediment Model for Carbonate Systems, Feb. 27-29, 2008, Colorado School of Mines, Golden, CO; http://csdms.colorado.edu/wiki/index.php/Carbonates_2008 (see Appendix 2 for a summary of the Workshop). Attendance: 32 international attendees (20 from universities and research institutes, 8 from the petroleum industry, plus 4 CSDMS staff members)

- Coastal Working Group startup meeting, March 8, 2008, Orlando, FL (see Chapter 4, Section 3 of the CSDMS Strategic Plan for its findings: http://csdms.colorado.edu/wiki/images/CSDMS_Strategic_Planv3F-48-op.pdf). Attendance: 29 working group members plus 4 CSDMS staff members
- Marine Working Group startup meeting, March 8, 2008, Orlando, FL (see Chapter 4, Section 4 of the CSDMS Strategic Plan for its findings: http://csdms.colorado.edu/wiki/images/CSDMS_Strategic_Planv3F-48-op.pdf). Attendance: 29 working group members plus 4 CSDMS staff members
- CSDMS Executive Committee Meeting, July 17-18, 2008, Boulder CO (all present except EKT Chair)
- SEPM - CSDMS Research Conference on Clinoform Sedimentary Deposits: Aug. 15-18, 2008, Rock Springs, WY. http://csdms.colorado.edu/wiki/index.php/Clinoform_2008 (also see Appendix 3). Attendace: 71 participants.
- I.A.G./A.I.G./ CSDMS SEDIBUD workshop on Sediment Budgets in Changing High-Latitude and High-Altitude Cold Environments, Boulder, CO, Sep. 9-13, 2008 http://csdms.colorado.edu/wiki/index.php/SEDIBUD_2008

Goal 12) Host the Industry Consortium first meeting, the U.S. interagency partners, further develop the EKT Working Group, represent CSDMS within the U.S. and abroad, run the day to day CSDMS operations in an efficient and smooth manner.

CUAHSI:

- CSDMS SSE attended the WebEx meeting and presentation to CUAHSI members about CCA and CSDMS, Wed., Feb. 6, 2008.
- CSDMS SSE co-chaired the Community Models for Hydrologic and Environmental Research session (with Larry Murdoch, Clemson); CSDMS ED co-chaired the Surface Processes, Sediments and Landscape session (with Ben Hodges, Efi Foufoula-Georgiou) July 14-16. CUAHSI Biennial Colloquium on Hydrologic Science and Engineering, NCAR Conference Center, Boulder, CO (http://www.cuahsi.org/biennial/)
- CSDMS SSE represented CSDMS at CUAHSI Scoping Workshop for the proposed Community Hydrologic Modeling Platform (CHyMP), March 25-28, 2008, National Academy of Sciences, Washington, D.C. and presented a talk about CSDMS and its work with CCA.
- CSDMS SSE represented CSDMS at EU-NSF OpenMI Workshop April 5-11, hosted by the Centre for Ecology and Hydrology and Wallingford Software Ltd., Wallingford, UK and presented talk. Participated in technical breakout group meeting to work through the details of the OpenMI interface standard with its developers. Leaders of CUAHSI's proposed CHyMP project formally agreed to coordinate their efforts with those of CSDMS and felt that a possible Hydrology working group would be a logical next step.
- CSDMS SSE offered a presentation titled: "Evaluation of model coupling frameworks for use by the Community Surface Dynamics Modeling System (CSDMS), Apr. 19-21, IGWMC "ModFlow and More" meeting, Colorado School of Mines, Golden, CO.
- CSDMS SSE represented CSDMS at the Computational Methods in Water Resources, XVII International Conference, San Francisco, CA, July 8-12, with talk entitled: "Evaluation of model coupling frameworks for use by the Community Surface Dynamics Modeling System (CSDMS)".

Industry

CSDMS ED gave a CSDMS presentation at a Research Collaboration Partnership Meeting with petroleum companies at Colorado School of Mines, Golden, CO, Tues., Feb. 26, 2008.

CSDMS Industry Consortium Meeting held Tues., April 22; San Antonio, TX: 17 representatives from 5 oil companies (Chevron, ConocoPhillips, ExxonMobil, Shell, StatoilHydro) were invited to learn more about the CSDMS Industry Consortium.

ESMF

CSDMS Delta Force staff met with Cecelia DeLuca of Community Climate System Model (CCSM), National Center for Atmospheric Research (NCAR) to discuss how that community has worked to link code, models and modules using Earth System Modeling Framework (ESMF)), March 19, 2008.

OpenMI

OpenMI and Jupiter API Short Course, Colorado School of Mines, Golden, CO. See: http://typhoon.mines.edu/short-course/JUPITER_08.htm

DoE/INL

CSDMS ED represented CSDMS during CU site visit of Idaho National Lab (INL) March 31, 2008; formed a partnership between CSDMS by INL.

MARGINS

CSDMS ED represented CSDMS during a "Futures" source-to-sink NSF meeting, held in Orlando, FL, March 2, 2008.

Chesapeake Community Modeling Program

CSDMS ED represented CSDMS at a CCMP Workshop on Communicating Models and Data, Annapolis, May12-14, 2008

NSF

CSDMS ED provided a reverse site visit with EAR and OCE program directors, at the National Science Foundation, May 15, 2008

NCALM

CSDMS ED represented CSDMS at the NSF-sponsored workshop on Studying Earth Surface Processes with HR Topographic Data, UCAR, Boulder, June 16-18, 2008

Cyber-Infrastructure

CSDMS ED represented CSDMS at the NSF-sponsored at the Cyber-Infrastructure Forum on Environmental Observatories, UCAR, Boulder, May 5-7, 2008

NEON

CSDMS ED met with the NEON Chief Scientist Michael Keller to examine relationships between CSDMS and NEON, Aug. 20, 2008

Other Updates:

CSDMS Personnel:

• A new CSDMS Executive Assistant S. Marlene Lofton has been hired (graduate degree community psychology, business administration).

• The CSDMS Integration Facility is posting two computational and/or geophysical *post-doctoral fellow* positions with experience in software development, to work in a team as a software engineer in the development of an integrated framework for the modular modeling of Earth-surface dynamics. For more information go to http://csdms.colorado.edu/wiki/index.php/Jobs.

CSDMS Repository

The CSDMS Data site supplies the community with the following gridded and geo-referenced data types:

- Bathymetric data: 1) GEBCO (General Bathymetric Chart of the Oceans); 2) Smith & Sandwell (1 minute Global seafloor topography); IBCAO (International Bathymetric Chart of the Arctic Ocean)
- Climate data: 1) GCRP (Global Climate Resource Pages); 2) GHCN (NOAA Global Historical Climate Network); 3) GOBALSOD (NOAA Daily Global Summary of Day Station Data); and 4) PSD (Climate and Weather data)
- Topographic data: 1) LiDAR / ALSM (Airborne Laser Swath Mapping); 2) TOPO2 (Global 2-minute gridded elevation data); 3) ETOPO5 (Global 5-minute gridded elevation data).

Since the last Annual Report the following data or data links have been added to the CSDMS website (http://csdms.colorado.edu/wiki/index.php/Data)

- Discharge data: 1) USGS national water information system (Daily and monthly discharge and water quality maintained by the USGS), 2) HYDAT (A data-base of daily and monthly river discharge of Canadian Rivers maintained by Water Survey of Canada), and 3) R-Arctic Net (A data-base of Arctic-wide monthly river discharge)
- World Glacier Inventory (NISDIS Information on glaciers for over 100,000 glaciers through out the world)
- New climate data: 1) TRMM (Tropical Rainfall Measuring Mission) precipitation data; and 2) Unisys Weather (hurricane/Tropical data)
- New Topographic data: 1) GLOBE (Global Land One-km Base Elevation), 2) GTOPO30 (Global 30 Arc-Second Elevation Data Set), 3) NED (National Elevation Dataset; USA), 4) SLA-02 (Shuttle Laser Altimeter III), and 5) SRTM (Shuttle Radar Topography Mission)
    - Developed new algorithms for processing TRMM 3B42 data (0.25 x 0.25 degrees on a 3 hourly basis), so as to determine for a defined area the intra-daily, monthly, and yearly precipitation statistics and the inter-monthly and yearly precipitation statistics

Newly posted **CSDMS Documents and Reports** include: 1) CSDMS Five Year Strategic Plan (April 2008, PDF format); 2) CSDMS Industry Consortium Document (February 2008, PDF format); 3) CSDMS Bylaws (February 2008, PDF format), and 4) CSDMS Annual Report to NSF (February 2008, PDF format).

The CSDMS Model Repository

Terrestrial

Program	Description	Developer
AquaTellUs	*Model*: Fluvial-dominated delta sedimentation model	**Overeem**, Irina
Avulsion	*Model*: Stream avulsion model	**Hutton**, Eric
BEDLOAD	*Subroutine*: Bedload transport model	**Slingerland**, Rudy
Caesar	*Model*: Cellular landscape evolution model	**Coulthard**, Tom
Cascade	*Model*: Landscape evolution model	**Braun**, Jean
CHILD	*Model*: Landscape Evolution Model	**Tucker**, Greg
DECAL	*Model*: Aeolian dune landscape model	**Baas**, Andreas
Delft3D	*Model*: 3D hydrodynamic and sediment transport model	**Delft3D support**
Dionisos	*Model*: 3D basin-scale stratigraphic model	**Granjeon**, Didier
DRAINAL	*Model*: Surface process model	**Beaumont**, Chris
DR3M	*Model*: Distributed Routing Rainfall-Runoff Model	**U.S. Geological Survey**
ENTRAIN	*Subroutine*: Simulates critical shear stress of median grain sizes	**Slingerland**, Rudy
ENTRAINH	*Subroutine*: Simulates critical shields theta for median grain sizes	**Slingerland**, Rudy
Erode	*Model*: Fluvial landscape evolution model	**Peckham**, Scott
FLDTA	*Subroutine*: Simulates flow characteristics based on gradually varied flow equation	**Slingerland**, Rudy
gc2d	*Model*: Glacier / ice sheet evolution model	**Kessler**, Mark
GNE	*Model*: Set of biogeochemical sub-models that predicts river export	**Seitzinger**, Sybil

GOLEM	*Model*: Landscape evolution model	**Tucker**, Greg
GPM	*Model*: Sedimentary process modeling software	**Tetzlaff**, Daniel
GSSHA	*Model*: Gridded Surface Subsurface Hydrologic Analysis model	**Ogden**, Fred
HEBEM	*Model*: Hydrologically Enhanced Basin Evolution Model	**Niemann**, Jeffrey
HydroTrend	*Model*: Climate driven hydrological transport model	**Kettner**, Albert
LITHFLEX1	*Subroutine*: Lithospheric flexure solution	**Furlong**, Kevin
LITHFLEX2	*Subroutine*: Lithospheric flexure solution for a broken plate	**Furlong**, Kevin
LOADEST	*Model*: A fluvial seven-parameter linear regression load model	**Runkel**, Robert
LOGDIST	*Subroutine*: Logrithmic velocity distribution solution	**Slingerland**, Rudy
LONGPRO	*Subroutine*: Dynamic evolution of longitudinal profiles	**Slingerland**, Rudy
MARSSIM	*Model*: Landform evolution model	**Howard**, Alan
MIDAS	*Model*: Coupled flow- heterogeneous sediment routing model	**Slingerland**, Rudy
MIKE SHE	*Model*: Advanced integrated hydrological modeling system	**DHI**
PIHM	*Model*: Penn State Integrated Hydrologic Model	**Duffy**, Christopher
PIHM GIS	*Model*: Penn State Integrated Hydrologic Model incorporated into a GIS package	**Duffy**, Christopher
SETTLE	*Subroutine*: Practical settling velocity solution	**Slingerland**, Rudy
SimClast	*Model*: basin-scale 3D stratigraphic model	**Dalman**, Rory
SOBEK	*Model*: 1D hydraulic numerical model	**SOBEK support**
Subside	*Model*: Flexure model	**Hutton**, Eric
SVELA	*Subroutine*: Shear velocity solution associated with grain roughness	**Slingerland**, Rudy
SIBERIA	*Model*: Landscape evolution model	**Willgoose**, Garry
SUSP	*Subroutine*: Suspended load transport subroutine	**Slingerland**, Rudy
TOPOG	*Model*: Terrain analysis-based hydrologic modelling package	**Butt**, Tony
TopoFlow	*Model*: Hydrological model	**Peckham**, Scott
Tremp	*Model*: Eocene Tremp foreland basin model	**Clevis**, Quintijn
TUGS	*Model*: Fluvial gravel and sand transport model	**Cui**, Yantao
TURB	*Subroutine*: Gaussian distribution calculator of instantaneous shear stresses on the fluvial bed	**Slingerland**, Rudy
WILSIM	*Model*: Landscape evolution model	**Luo**, Wei
YANG's routine	*Subroutine*: Fluvial sediment transport model	**Slingerland**, Rudy
ZScape	*Model*: Landscape evolution model	**Densmore**, A. & **Connor**, C.

Coastal

Program	Description	
2DFLOWVEL	*Subroutine*: Tidal & wind-driven coastal circulation routine	**Slingerland**, Rudy
AquaTellUs	*Model*: Fluvial-dominated delta sedimentation model	**Overeem**, Irina
BarSim	*Model*: Barrier island simulation model	**Storms**, Joep
BITM	*Model*: Barrier Island Translation model	**Masetti**, Riccardo
BSM	*Model*: Moving boundaries shoreline model	**Swenson**, John
BTELSS	*Model*: Barataria-Terrebonne Ecological Landscape Spatial Simulation model	**Reyes**, Enrique
CARB3D+	*Model*: Forward Simulation Model for Sedimentary Architecture and Near-Surface Diagenesis in Isolated Carbonate Platforms	**Smart**, Peter
CELLS	*Model*: Landscape simulation model	**Reyes**, Enrique
CEM	*Model*: Coastal evolution model	**Murray**, Brad
CST	*Model*: Coastal System Tract model	**Niedoroda**, Alan
D'Alpaos model	*Model*: Marsh evolution model	**D'Alpaos,** Andrea
DECAL	*Model*: Aeolian dune landscape model	**Baas**, Andreas
Delft3D	*Model*: 3D hydrodynamic and sediment transport model	**Delft3D support**
Delft3D for marshes	*Subroutine*: 3D plant-flow interaction model to a tidal marsh landscape	**Temmerman**, Stijn
DELTA	*Subroutine*: Simulates circulation and sedimentation in a 2D turbulent plane jet and resulting delta growth	**Slingerland**, Rudy
Fluidmud	*Model*: Wave-phase resolving numerical model for fluid mud transport	**Hsu**, Tian-Jian
DeltaSIM	*Model*: Process-response model simulating the evolution and stratigraphy of fluvial dominated deltaic systems	**Hoogendoorn**, Bob & **Overeem**, Irina
Dionisos	*Model*: 3D basin-scale stratigraphic model	**Granjeon**, Didier
FunWave	*Model*: Phase-resolving, time-stepping Boussinesq model for ocean surface wave propagation in the nearshore.	**Kirby**, James
GENESIS	*Model*: Global ENvironmental and Ecological Simulation of Interactive Systems.	**Cialone**, Alan
Geombest	*Model*: A model that simulates the evolution of coastal morphology and stratigraphy resulting from changes in sea level and sediment supply.	**Moore**, Laura
GNE	*Model*: Set of biogeochemical sub-models that predicts river export	**Seitzinger**, Sybil
GPM	*Model*: Sedimentary process modeling software	**Tetzlaff**, Daniel
HBIM	*Model*: Human/Barrier Island Model	**McNamara**, Dylan
Hyper	*Model*: 2D depth-averaged hyperpycnal flow model	**Imran**, Jasim

LITHFLEX1	*Subroutine*: Lithospheric flexure solution	**Furlong**, Kevin
LITHFLEX2	*Subroutine*: Lithospheric flexure solution for a broken plate	**Furlong**, Kevin
Marsh model	*Model*: A coupled geomorphic and ecological model of tidal marsh evolution.	**Kirwan**, Matthew
Marsh elevation model	*Model*: Simulates deposition rates as a function of horizontal distance from a channel and vegetation density in a marsh	**Mudd**, Simon
MARSSIM	*Model*: Landform evolution model	**Howard**, Alan
Physprop	*Model*: Physical and acoustic property simulator for either computer-generated or experimental strata	**Pratson**, Lincoln
QDSSM	*Model*: Quantitative Dynamic Sequence Stratigraphic Model is a 3D cellular, forward numerical model that simulates landscape evolution and stratigraphy	**Postma**, George
RCPWAVE	*Model*: Regional Coastal Processes Monochromatic WAVE Model	**Cialone**, Alan
REF/DIF	*Model*: Phase-resolving parabolic refraction-diffraction model for ocean surface wave propagation	**Kirby**, James
SBEACH	*Model*: Numerical Model for Simulating Storm-Induced Beach Change	**US Army Corps of Engineers**
SDM	*Model*: Shelf Deposition Model	**Wolinski**, Matt
Sedflux	*Model*: Basin-filling stratigraphy model	**Hutton**, Eric
Sedsim	*Model*: Sedimentary process modeling software	**Griffiths**, Cedric
SeisimID	*Model*: Simulates post-stack, time-migrated seismic data of stratigraphic simulations	**Pratson**, Lincoln
Sequence4	*Model*: Stratigraphic model, focused on the long-term development of stratigraphic sequences	**Steckler**, Michael
Shoreline	*Model*: Coastal evolution model	**Peckham**, Scott
SiAM3D	*Model*: 3D hydrodynamic model based on the hydrostatic and Boussinesq approximations	**Cayocca**, Florence
SimClast	*Model*: basin-scale 3D stratigraphic model	**Dalman**, Rory
SIMSAFADIM	*Model*: Finite element model for fluid flow, clastic, carbonate and evaporate sedimentation	**Bitzer**, Klaus
SLAMM model	*Model*: Sea Level Affecting Marshes model	**Park**, Richard & **Clough**, Jonathan
SLOSH	*Model*: Sea, Lake and Overland Surges from Hurricanes	**National Hurricane Center**
SPEM	*Model*: Shoreface profile evolution model	**Stive**, Marchel
SRSM	*Model*: Soft-Rock Shoreline Model	**Walkden**, Mike
STM	*Model*: Shoreline Translation Model	**Cowell**, Peter
STORM	*Subroutine*: Windfield simulator for a cyclone	**Slingerland**, Rudy
STVENANT	*Subroutine*: 1D gradually varied flow routine	**Slingerland**, Rudy
STWAVE	*Model*: Steady-State Spectral Wave Model	**Smith**, Jane
SWAN	*Model*: Third-generation wave model that computes random, short-crested wind-generated waves in coastal regions and inland waters.	**The SWAN team**
WAM	*Model*: Global ocean WAve prediction Model	**Jensen**, Robert
WAVE REF	*Subroutine*: Wave refraction routine	**Slingerland**, Rudy
WINDSEA	*Subroutine*: Deep water significant wave height and period simulator during a hurricane routine	**Slingerland**, Rudy
Wolinsky Delta Model	*Model*: Physically-based deterministic cellular delta model	**Wolinsky**, Matt
WSGFAM	*Model*: Wave and current supported sediment gravity flow model	**Friedrichs**, Carl
WaveWatch3	*Model*: Wave model	**Tolman**, Hendrik
XBeach	*Model*: Wave propagation sediment transport model	**Roelvink**, Dano
SedBerg	*Model*: Iceberg sediment transport model	**Mugford**, Ruth
SedPlume	*Model*: meltwater plume model	**Mugford**, Ruth
Inflow	*Model*: Steady-state hyperpycnal flow model	**Hutton**, Eric
Sakura	*Model*: 3 Equation hyperpycnal flow model	**Hutton**, Eric

Marine

Program	Description	Developer
ADCIRC	*Model*: Coastal Circulation and Storm Surge Model	**Luettich**, Rick
Carbonate GPM	*Model*: 3D forward model of carbonate production and deposition, based on the GPM model	**Hill**, Jon
Coaster	*Model*: Long shore wave driven sediment transport model	**Peckham**, Scott
Compact	*Model*: Sediment compaction	**Hutton**, Eric
Delft3D	*Model*: 3D hydrodynamic and sediment transport model	**Delft3D Support**
Dionisos	*Model*: 3D basin-scale stratigraphic model	**Granjeon**, Didier
FanBuilder	*Model*: Process-based stratigraphic evolution of turbidite fans model	**Groenenberg**, Remco
GPM	*Model*: Sedimentary process modeling software	**Tetzlaff**, Daniel
Inflow	*Model*: Steady-state hyperpycnal flow model	**Hutton**, Eric
LITHFLEX1	*Subroutine*: Lithospheric flexure solution	**Furlong**, Kevin

LITHFLEX2	*Subroutine*: Lithospheric flexure solution for a broken plate	**Furlong**, Kevin
NCOM	*Model*: Navy Coastal Ocean Model	**Keen**, Tim
NearCoM	*Model*: Nearshore Community Model	**Kirby**, Jim
NearshorePOM	*Model*: Nearshore version of POM (Princeton Ocean Moel)	**Kirby**, Jim
POM	*Model*: Princeton Ocean Model	**Ezer**, Tal
Sakura	*Model*: 3 Equation hyperpycnal flow model	**Hutton**, Eric
sedflux	*Model*: Basin-filling stratigraphy model	**Hutton**, Eric
Sedpak	*Model*: Simulation 2D empirical sedimentary fill model	**Kendall**, Chris
Sedsim	*Model*: Sedimentary process modeling software	**Griffiths**, Cedric
SEOMS	*Model*: Spectral Element Ocean Model	**Arango**, Herman
SimClast	*Model*: basin-scale 3D stratigraphic model	**Dalman**, Rory
SIMSAFADIM	*Model*: Finite element model for fluid flow, clastic, carbonate and evaporate sedimentation	**Bitzer**, Klaus
Symphonie	*Model*: 3D primitive equation ocean model	**Marsaleix**, Patrick
ROMS/TOMS	*Model*: Regional Ocean Modeling System / Terrain-following Ocean Modeling System	**Arango**, Herman
SHORECIRC	*Model*: Quasi-3D nearshore circulation model	**Svendsen**, Ib

CSDMS Focus Research Groups

The CSDMS community continues to grow. While the main body of membership approaches 200 Working Group members, the CSDMS Executive Committee authorized the establishment of Focus Research Groups (FRGs) that cut across our Environmental Working Group structure. CSDMS currently has three Focus Research Groups. FRGs differ from Working Groups in that they serve a unique subset of our surface dynamics community, and usually represent a well-developed community. FRGs often are co-sponsored by another organization. FRGs are similarly supported by the CSDMS Integration Facility as Working Groups, including access to CSDMS High Performance Computers. FRG's typically meet once per year, coordinating much of their activity via remote communication systems. Chairs of FRGs report directly to the CSDMS Executive Director, and often to the Chair or Director of the co-sponsoring organization.

Hydrology Focus Research Group represents the hydrological modeling community, and is being co-sponsored by CUAHSI. This FRG deals with aspects of the hydrological system that impact earth-surface dynamics. (Chair, Jay Famiglietti)

Carbonate Focus Research Group is the outgrowth of the recent NSF effort to coordinate the carbonate modeling community and their development of a numerical carbonate workbench (Chair, Peter Burgess)

Chesapeake Focus Research Group is our first 'geographically-focussed' effort representing and co-sponsored by the Chesapeake Community Modeling Program, with their unique collection of models and field data set (Chair, Alexey Voinov)

Integration Facility Reports, Presentations, Publications and Abstracts:

- IGWMC (International Ground Water Modeling Center) meeting, Golden, Colorado, May 19-21, 2008. Evaluation of Model Coupling Frameworks for Use by the Community Surface Dynamics Modeling System (CSDMS). Peckham, S.
- 38th Arctic Workshop, Boulder, Colorado, USA, 5-7th of March 2008. Overeem, I, Syvitski, J.P.M., Kettner, A.J. 2008. Are Arctic Rivers Unique and Are They Changing? Extended Abstract.
- 38th Arctic Workshop, Boulder, Colorado, USA, 5-7th of March 2008. De Winter, I.L., Overeem, I., Storms, J.E.A., 2008. Sedimentary Architecture of a glacio-fluvial valley fill; West-Greenland Case-Study. Extended Abstract.
- CSDMS introduction to International Arctic Research Center, Fairbanks for 'Arctic System Modeling' Workshop to be held May 19-21, 2008, Boulder. Overeem, I.
- AAPG Annual Convention and Exhibition, April 20-23 2008, San Antonio, TX, USA. Reservoir potential of fluvial sheet sandstone, Ten Boer Claystone, Southern Permian Basin. Donselaar, M.E., Overeem, I., Reichwein, J.A., Visser, C.A., 2008.

- AAPG Annual Convention and Exhibition, April 20-23 2008, San Antonio, TX, USA. Delivering Terrestrial Sediment to Continental Slopes: An Overview of Mechanisms. Syvitski, J.P.M., and Hutton, E.W.
- AAPG Annual Convention and Exhibition, April 20-23 2008, San Antonio, Texas, USA. Isostatic Flexure Along the Global Coastlines Due to Sea-Level Rise and Fall. Hutton, E.W. and Syvitski, J.P.M.
- AAPG Annual Convention and Exhibition, April 20-23 2008, San Antonio, Texas, USA. Delivering Terrestrial Sediment to Continental Slopes: An Overview of MechanismsModeling Hydro-Isostasy. Syvitski, J.P.M. and Hutton, E.W
- Submitted CSDMS Five Year Strategic Plan, NSF Cooperative Agreement 0621695, via e-mail to NSF (Mike Ellis) April 2, 2008. (Syvitski, Svec)
- IAHS Publ. 325: Human catalysts or climate change: will have a greater impact on the sediment load of the Waipaoa River in the 21st century? Kettner, A., Gomez, B., and Syvitski, J.P.M. 2008.
- IAHS Publ. 325: Changing Sediment Supply in Arctic Rivers. Sediment Dynamics in Changing Environments. Proceedings of a symposium held in Christchurch, New Zealand, December 2008. Overeem, I., and Syvitski, J.P.M. 2008.
- IAHS Publ. 325: Scaling Sediment Flux across Landscapes by Syvitski, J.P.M and Kettner, A., 2008.
- SEPM Research Conference. Clinoform sedimentary deposits: The processes producing them and the stratigraphy defining them, Rock Springs, WY, August 15-18, 2008. Fjords: development of the Ultimate Sedimentary Clinoform with Falling Sea level. Syvitski, J.P.M., Overeem, I., 2008. Abstract.

Scientists Visiting the CSDMS Integration Facility

- Hosted visiting scientist **Bjarte Hannisdal**, University of Bergen, Norway for one week, March 3-7, 2008, work on adding a bioturbation model/component to SedFlux model.
- Hosted two visiting scientists for one week, March 10-14, 2008, training on Arctic sedimentary modeling; linking HydroTrend, Plume, Sakura and SedFluxv2.0: Graduate student **Ilja L. de Winter**, Department of Civil Engineering and Applied Geosciences, Delft University of Technology, The Netherlands. Postdoctoral research fellow **Ted Lewis**, Queen's University, Kingston, Canada. (Overeem)
- Hosted Gary Hoffman from Univ. of California at Santa Cruz, May 4-10, 2008, for training and running hyperpycnal flow model Sakura.

Appendix 1:

DRAFT: A Community Approach to Modeling Earth Surface Dynamics

Alexey Voinov[1], Cecelia DeLuca[2], Raleigh Hood[3], Scott Peckham[5], Chris Sherwood[4], James P.M. Syvitski[5],

[1]Chesapeake Community Modeling Program, CRC, Edgewater, MD 21037, USA
[2]Earth System Modeling Framework, National Center for Atmospheric Research, Boulder, CO 80302, USA
[3]University of Maryland Center for Environmental Science, Cambridge MD, 21613, USA
[4]USGS, Woods Hole, MA
[5]CSDMS Integration Facility, University of Colorado—Boulder, Boulder CO, 80309-0545, USA

Community models first emerged in the 1980's in the fields of air quality modeling, climate prediction, and weather forecasting. The first generation systems that were developed, including the EPA's Models-3 System, the NCAR Community Climate Model (CCM), and the Pennsylvania State/NCAR Mesoscale Model (MM5), demonstrated that freely available, portable, and the broader community would enthusiastically receive well-documented models as research tools.

The next generation of community modeling projects was more ambitious. The Community Climate System Model (CCSM), the successor to CCM, continues to assimilate new physical processes and now, human factors, at an accelerating rate. The CCSM project participated in the demanding Intergovernmental Panel on Climate Change assessments, while continuing to serve as a vehicle for research. The Weather Research and Forecast (WRF) Model, the successor to MM5, has attempted to serve both the research and operational communities. These models are widely used and have developed networks of contributors. They have also struggled to meet the demands placed on them: to satisfy diverse user bases, to keep up with the integration of new science, and to create governance bodies that can support scientific processes and scale to large numbers of participants.

It is in this context that researchers in surface dynamics and related domains are seeking to organize and create new community modeling systems. This paper outlines strategies for community modeling that reflect lessons learned as well as new challenges.

Computer modeling is a widely used and practical tool for solving scientific and engineering problems in Earth sciences. Every day, Earth science models are used by government agencies, academic institutions, and private industry in ways that can save lives, protect the environment, and enhance economic productivity. In Earth science we are dealing with complex systems that span over many disciplines, and require scientists from many backgrounds to participate in designing and testing model algorithms. Most important, we need to provide timely and adequate information to drive the decision-making process, which is goal driven, and needs to be iterative, adaptive, and flexible. Complex systems require complex models to understand them, but simple models are more appropriate for management and effective decision-making. Therefore there is no "one size that fits all" model and there is no one model that can answer all questions. Therefore models must be modular and hierarchical, so there is a need for framework and integration software and standards for modules and interfaces. Complex models are difficult to use, require lots of data, and generate lots of output, so again, design of the user interface is important, as are standards for data, model output, and Internet data sharing. Complex models must be efficient to be useful, so they require contributions by software engineers to ensure efficient and accurate numerics and implementation on fast computers

While the modeling community is rightfully proud of its successes, we also see unmet challenges. Many of these can be attributed to demands to cross disciplines and scales, to address harder problems by creating alternative models that encompass more physical processes and human factors, to use computing systems that are growing in computational and visualization power and complexity, and to harness the expertise of increasingly large and distributed development teams. A sole developer or small group working with a model of limited scope can produce results without spending much time on software processes, standards, licensing, or issues of accessibility. Yet the absence of these elements in a large endeavor results in redundant activities, inefficient information transfer, poor coding practices, minimal quality assurance, and poor documentation. It is crucial to develop sound practices that support distributed multi-developer projects, to build model software that is flexible and enables component substitutions, and to provide continuity in model development.

Open-source, community approach is the best way to build these models

A community model or modeling system is an open source suite of modeling components within a framework that is constructed and/or improved through the organized efforts of a group of individuals working together to help develop, debug, calibrate, document, run and use it. It typically includes datasets for parameters, external, initial, and boundary conditions, as well as expected outputs for a suite of test cases to verify that the modeling system is working correctly. It may also contain a suite of model data comparisons to evaluate model skills, associated tools for helping to prepare input or evaluate output, and current documentation.

The community often includes both developers and users, and is distributed among different institutions and organizations. Community modeling is a process of building, supporting, linking and integrating data and components for a community model. At its best, it can lead to efficiencies in model development, the emergence and use of scientifically sound, validated scientific components, better linkages to data systems or networks, faster development cycles through pooled technical resources, more transparency in concepts, assumptions, and model source codes, and closer connection with the user community.

Some examples of community modeling projects in Earth science include the NSF-funded CSDMS (Community Surface Dynamic Modeling System - http://csdms.colorado.edu), the EPA-funded CMAS (Community Modeling and Analysis System - http://www.cmascenter.org/), the NOAA-funded CCMP (Chesapeake Community Model Program - http://ccmp.chesapeake.org), DoD-funded CSTM (Community Sediment Transport Model - http://woodshole.er.usgs.gov/ project-pages/sediment-transport/), CCSM (?) and others. Key to these efforts is a new culture of scientific research based on open sharing of information and skills.

There are several advantages of a community approach. It provides much needed integration of effort between multiple institutions, which is crucial because models are too multidisciplinary and complex for individual research groups. It allows scientists to work with software engineers, helping to bridge the cultural and, often, institutional gap between these teams. Moreover it provides the essential link to the user community, offering much needed transparency that promotes user participation and input at early stages of the project and during the testing phase. More users yields better testing, more robust models and more acceptance of the results. Generally, more applications yield more useful models.

All community-modeling efforts rely on the open source paradigm. Open source is used to refer both to the idealistic philosophy of software development that originated in computer programming, and to the legal status conferred by an open source software license. The license supports, but is only an element of, the larger paradigm.
The reliance on open source delivers the following important features:

- Complete information transfer; this transparency is important because code is ultimate statement of scientific hypotheses
- Allows peer review and replication of results
- Code can be reused, which reduces redundancy

Since much science is funded with public funds, it makes it natural to expect that products should be publicly available. Open source is one of the ways to deliver such results to the public.

The challenges are also there

We are still learning how to best to develop open-source scientific software using a community approach. On the technical side, required are fundamental algorithms to describe processes; software to implement these algorithms; software for manipulating, analyzing, and assimilating observations; standards for data and model interfaces; software to facilitate collaborations; and substantial improvements in hardware (e.g., network and computing infrastructure). Standard metadata and ontologies to describe models and data are also needed.

However, most of the most difficult challenges are social or institutional:

- Reward structure is skewed toward publications and away from technical contributions in many institutions
- Funding is discontinuous, and not reliably available for support and technical infrastructure
- Intellectual property policies of universities and private companies are not always compatible. Software is often viewed as a competitive advantage among competitors for funding and academic honors, including graduate students that develop software for theses
- There are instances of a "not made here" culture, when researchers prefer in-house products, rather than implementations of already existing products
- There is always an overhead that comes with "soft" organization with no clear internal hierarchy. Many community projects are using the so-called "bazaar" approach that is an open-ended process of simultaneous efforts of numerous players, with no clear subordination and ruling. This does not work well with deadlines and deliverables. Such efforts may lack realistic project assessment, and clear strategies to deal with conflicts and inefficiencies.
- It is sometimes difficult to work across great distances and time zones with a diverse group of people.

We believe it is paramount to reaffirm our commitment to the fundamental precepts of science and encourage the rebuilding of a culture of collaboration and information sharing.

What's needed?
There are a number of recommendations that we find useful to enhance and support the community modeling efforts. These may fall into two categories: organizational and technical. The organizational ones are about the cultural and social background that is important for community modeling, and the programmatic decisions that can make projects more successful. The technical recommendations are about the actual software and analytical tools that are required. It is also important to keep communication lines open between the "techies" and the program managers. It is crucial that these two groups develop some appropriate protocol regarding which information needs to be "passed upward" and how best to do this. Technical details are the foundation of community software projects and the number of concepts, languages, terms, tools, systems, etc. that are involved continue to grow exponentially. The communication and time-management challenges presented by this "information overload" should not be underestimated.

Recommendations for funding agents and program managers

- Program managers should insist that code be open source and meet a minimum level of standards or protocols as a requirement for receiving federal funds.
- Funders should provide stable (longer-term) funding of software architects and engineers within the research environment, on par with the technical staff support of large academic or medical labs.

- Funders should require that code and documentation be accessible as early and openly as possible during development, and should ensure that code from a completed project be archived and accessible, in the same way the field data and measurements are now.
- Support repositories of models and software and make sure they synchronize information and standards among themselves.

Recommendations for institutional leadership

- Recognize that producing well-documented, peer-reviewed code is worthy of merit.
- Develop effective ways of for peer-review, publication, and citation of code, standards, and documentation
- Embrace open-source while protecting intellectual property rights
- Recognize the value of both open-source sharing and community efforts.
- Support collaborative environments that minimize the need for temporal and spatial locality are crucial for the success of community efforts.

Recommendations for project leaders

- Criteria and metrics for success must be assessed carefully, with consideration of factors such as whether the core user base is satisfied; whether the software is accessible, technically adequate, uses community standards, and is well documented; whether contributions are evaluated and assimilated in a clear and timely way; whether the project scope is commensurate with resources; and whether the project is able to complete its central functions.
- Community efforts require project governance at different timescales (e.g. daily, weekly, quarterly, annually, funding cycles) and involving different staff levels (e.g. developer, project manager, program manager). In particular, structures and processes must enable the project teams to set priorities, schedules, and make decisions as a unified project working towards a common goal. Project governance must accommodate, but must also be able to supersede, the interests and priorities of working groups operating in specific disciplines.
- Support collaborative environments that minimize the need for temporal and spatial locality are crucial for the success of community efforts.

Technical recommendations for developers and the rest of us

- Adopt existing standards for data, model input and output, and interfaces
- Develop standards for model conceptualization, formalization and scaling
- Seek to use/adapt existing tools first before developing your own.
- Provide good documentation to facilitate reuse and code/model transparency
- Establish and use good modeling practice that code maint, reusability, portable, and follows object-oriented

Appendix 2:

NSF Workshop: Community Sedimentary Model for Carbonate Systems
Convened at: Colorado School of Mines, Golden, CO
Hosted by: CSDMS Integration Facility
February 27-29, 2008

Conveners:
Rick Sarg, Colorado School of Mines, jsarg@mines.edu
Evan Franseen, KGS & Univ. of Kansas, evanf@kgs.ku.edu
Gene Rankey, Univ. of Miami, grankey@rsmas.miami.edu

INTRODUCTION, SOCIETAL RELEVANCE, AND WORKSHOP SUMMARY

Developing predictive models of carbonate systems has important implications for monitoring and managing global climate change affecting societies around the world. Carbonate sediments and rocks form an important part of the global carbon cycle. More than 80% of Earth's carbon is locked up in carbonate rocks. Almost all of the remainder is in the form of organic carbon in sediments. About 0.05% of Earth's carbon is present in the ocean in the form of the carbonate and bicarbonate ions and dissolved organic compounds, whereas 0.0008% is tied up in living organisms, and about 0.002% is in the form of CO_2 in the atmosphere. Carbonate rock is the primary ultimate sink for CO_2 introduced into the atmosphere.

Throughout most of Earth history, precipitation of mineral carbonate has been closely linked to the metabolism and activities of living organisms. An important but often neglected part of understanding the carbon cycle requires that we understand how mineral carbonate is produced, how it accumulates into sedimentary deposits, how it is altered after burial, and how it is recycled back into mobile chemical species.

Although we have learned a lot about carbonate fixation, deposition, and dissolution in open ocean deep-sea environments, our knowledge of the rates of formation of mineral carbonate in shallow waters remains rudimentary. Knowledge of the changes of rates of deposition and dissolution with rises and falls in sea level associated with climate change is largely speculative and becomes increasingly uncertain for the more distant geologic past. A better understanding of these processes is essential to progress in understanding the effects of alterations of the carbon cycle resulting from the introduction of fossil fuel CO_2 into the atmosphere.

Reefs and carbonate platforms, in general, are sensitive climatic indicators, are "global sinks of carbon", and contain important records of past climate change. They are reservoirs of biodiversity, and provide critical fisheries habitat. Changes in global climate dramatically affect carbonate systems, and the peoples that live amongst them. Rising sea level heightens erosion of islands, reduces shoreline stability, causes marine flooding of coastal freshwater aquifers, and displaces indigenous people (e.g., South Pacific). Increased global CO_2 causes ocean acidification, which in turn affects the ability of many modern carbonate-producing organisms and processes to function optimally.

Ancient carbonate platforms and systems play a significant role in the global economy. They are the raw material for construction, both as building stone and as the parent material required for manufacture of cement. Through their high permeabilities and porosities, carbonate rocks serve as important aquifers and as petroleum reservoirs. They are major freshwater aquifers critical to the health of urban and rural areas (e.g., Edwards Aquifer, central Texas, USA), and in many island nations, the primary source of fresh water. Likewise, carbonate rock reservoirs host more than half of the world's petroleum. Finally, carbonate systems that fringe island nations across the planet form the basis of tourism and food for island peoples.

Workshop Summary

In response to the needs discussed above, an NSF-sponsored workshop on carbonate systems and numerical systems modeling was held in late February, 2008, at the Colorado School of Mines. The purposes of the workshop were to identify grand challenges for fundamental research on ancient and recent carbonate systems, and to identify promising areas for advancing the next generation of numerical process models to enhance our ability to meaningfully and accurately model carbonate systems. Thirty-one attendees from academia and industry worked to initiate a carbonate community across a broad spectrum of disciplines, including sedimentology, stratigraphy, geobiology, oceanography, paleoclimatology, numerical process modeling, and carbonate diagenesis. Although attended by a small subset of the greater potential community, this workshop served to open dialog, and began to define the necessary inputs to improved modeling of carbonate systems. The results of this first carbonate systems workshop are posted on the Community Surface Dynamics Modeling System (CSDMS) website (http://csdms.colorado.edu/meetings/carbonates_2008.html). Workshop participants, through a series of presentations, break-out groups, and open dialog, evaluated recent findings and research directions on the influences of climate, ocean systems, ecology, and diagenesis on carbonate deposits, and then began to identify the "grand challenges" (e.g., modeling large facies heterogeneities; numerical simulation of diagenetic history) to the understanding and modeling of ancient and recent carbonate systems.

Through these efforts, participants recommended forming working groups to synthesize the current knowledge and research needs within each of five broad areas of carbonate research – physical processes, biological processes, diagenesis, analytical tools for studying carbonate systems, and modeling. Modeling in this context, includes all types of numerical models, such as dynamic process-based models, stochastic, and fuzzy-logic models. Although the emphasis was on addressing the needs for enhanced models, participants emphasized the need for robust data to be applied to modeling inputs (e.g., carbonate biological and physio-chemical production rates). These working group syntheses could entail collaboration between the carbonate sedimentary and modeling communities to identify gaps in documentation of parameters and/or development of algorithms.

Participants agreed that a more coordinated research effort in carbonates would be beneficial to advancing understanding, with the ultimate goal of advancing a set of quantitative predictive models for carbonate deposition and diagenesis. As a start to achieving some of the broad research objectives, workshop participants recommended interdisciplinary efforts focus on identifying a limited number of sites to conduct integrated research in selected key subsets of: (1) the modern and Pleistocene systems, to examine in quantitative and predictive detail, the effects of ocean conditions and climate change on carbonate accumulations, and the evolution of sediments into beds and strata; and (2) important analog field areas that combine outcrop, behind outcrop, and the subsurface, to build a new generation of 3-D carbonate analogs to test the validity of numerical models. A companion effort will be needed to build an archive system to capture and share data. From this standpoint, the CSDMS Integration Facility is in an ideal position to facilitate the development, and hosting of such an archive system.

Importantly, the workshop also attempted to identify promising areas for advancing the next generation of numerical models, to enhance our ability to meaningfully and accurately model carbonate systems, including both depositional processes and diagenesis (Figure 1). An important result of the workshop was the recognition of the need to integrate carbonate modeling efforts into other Earth-surface modeling efforts such as the Community Surface Dynamics Modeling System. The workshop resulted in the development of a plan for creation of a work-bench platform for carbonate knowledge generation via a suite of integrative modules that is available to the carbonate community. As a result of the participants' efforts, this workshop has served to open the dialog, and to begin to define the necessary inputs to the modeling of carbonate systems from sedimentation through burial.

This workshop also aimed to establish a framework for future workshops to engage an expanded community interested in carbonate systems, and that can better define research goals and objectives. As part of this goal, a carbonate working group has been initiated within CSDMS, providing a hub and framework to facilitate future workshops. Subgroups, covering the five areas of physical processes, biological processes, diagenesis, tools, and modeling could be established within this broader working group.

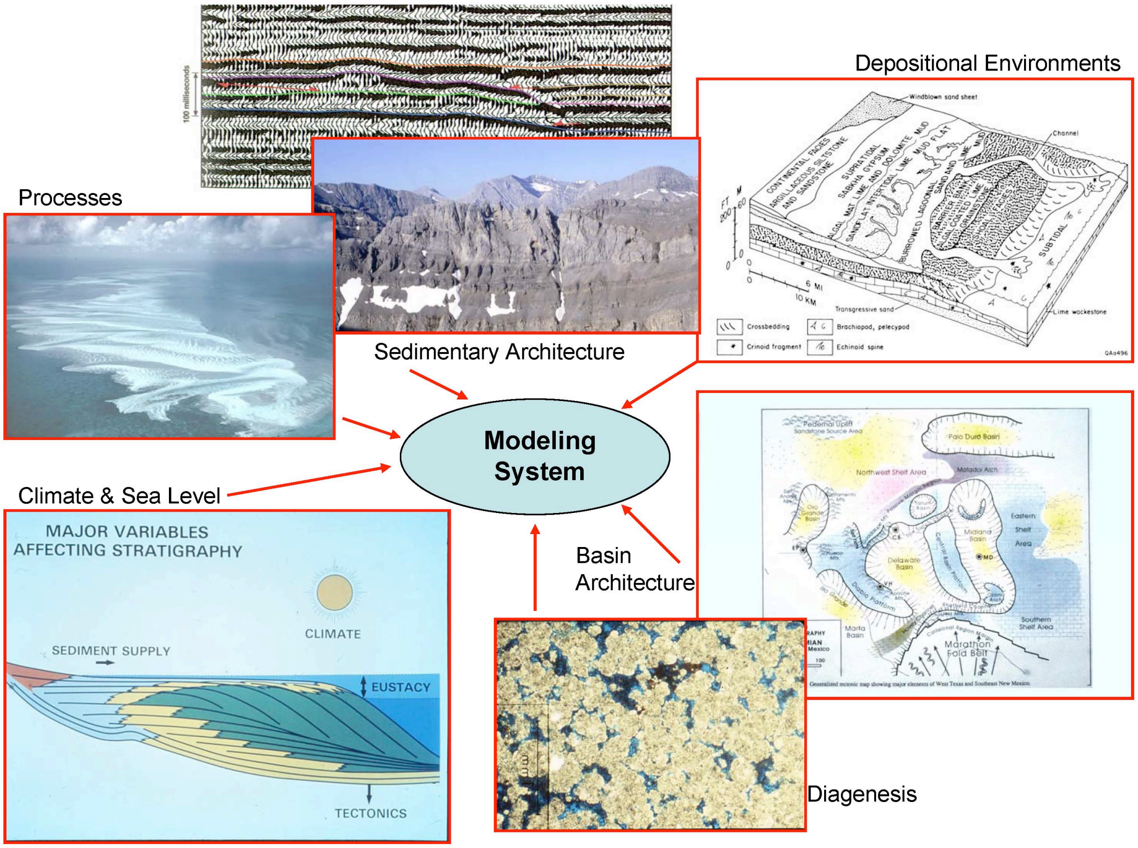

Figure 1. Components of Carbonate Community Model System.

RESULTS AND RECOMMENDATIONS

The following sections summarize workshop discussion and conclusions, and are divided into five topical areas: physical controls, biologic controls, diagenesis, numerical modeling, and tool development. They include some identified short- medium- and long-term goals for each of the topical workshop areas.

1) Physical Controls on Carbonate Deposition -

All carbonate community members face the grand challenge of quantitatively understanding and modeling facies heterogeneities, developed over various geologic timescales, as influenced by changing biotic, paleoceanographic, paleoclimatic, and sea level conditions. The first step is to understand the nature and origin of the patterns of sediment accumulation. Whereas we have a good qualitative understanding of patterns on carbonate platform tops, a rigorous quantitative understanding is lacking. Similarly, patterns and processes on platform slopes and deepwater reefs await better qualitative and quantitative exploration. Major knowledge gaps include a lack of a rigorous understanding of:

1) The effects of sea level fluctuations on sediments,
2) How to predict sedimentation patterns in a non-linear and complex system, as opposed to assessing sediments in a 1:1 linear relationship vs. depth;

3) The processes that lead to development and evolution of geomorphic and facies patterns, and the time scales of development;
4) The respective roles of quotidian and storm processes in sedimentologic and geomorphic evolution;
5) How to most accurately develop separate sector models for different environments (reefs, shoals, platform interior and tidal flats). This requires a clearer understanding of the different controls in these areas, and how sector models should be employed;
6) The interplay between physical processes and the occurrence of cemented areas (hardgrounds) and benthic mats that can influence accumulation; and
7) The effects of changes in sea water chemistry through the Phanerozoic on long-term facies development in carbonate systems.

Short-Term Goals: Participants noted a number of short-term goals that entail assembling existing data, including:

1) Assemble an inventory of modern platforms types and depositional systems and an associated inventory (database) of physical measurements and models from these systems. This could lead to a new classification of different platform types and depositional environments and would show where there are gaps in physical measurement data that are necessary for modeling;
2) Take existing carbonate numerical modeling packages and run sensitivity analyses on ranges of parameters in those models, to put bounds on certain physical parameters that need to be measured or better understood. For example, the "friction factor" in CARB3D$^+$ seems to be quite important although its physical meaning is vague.
3) Assemble a catalog of existing numerical siliciclastic models to assess parameters these models use as input, and explore for possible overlap.

Medium-Term Goals: Participants recommended the following:

1) Collecting oceanographic measurements (waves, tides, and currents) across one or two different platforms. Longer-term goals include a detailed coring program on one or more platforms to evaluate the platform depositional architecture, to provide information to test models.
2) Development of preliminary "sector models" of various specific environments to provide "modular" input to a larger community model. For example, we would envision a "reef model", one or more ooid shoal models; a tidal flat model, and a platform interior model. We do not have robust enough data to accurately model flow and sediment transport in these models.

Necessary partners for the short and medium term goals are physical oceanographers, especially to establish boundary conditions and measure the physical parameters on the platforms. This group should also partner with the biological working group for developing "sector models."

2) Biological Controls on Carbonate Deposition -

Modern tropical shallow-water coral reefs are comparatively well known, but many fundamental questions remain. Similarly, tropical meso/oligophotic reef systems, cool-water carbonate systems, and aphotic systems are poorly understood carbonate systems. Likewise, there is a broad base of paleontological knowledge of fossil biota. To better understand carbonate systems, however, a grand challenge centers on understanding how appropriate are Holocene tropical shallow-water reefs as analogues for ancient carbonate buildups, or, if they are not, how the ancient systems differ. Beyond this grand challenge, the fundamental questions of assessing how changes in biogeochemical boundary conditions (CO_2, alkalinity, salinity, and Mg/Ca ratios) have changed modes and rates of calcification remains.

Knowledge gaps identified by this group include lack of quantitative understanding of 1) the boundary conditions for hypercalcification; 2) rates of production and how they relate to rates of deposition/accumulation; 3) relative rates of bioerosion and physical erosion; and 4) the nature and origins of spatial heterogeneity. These unknowns center on aspects of rigorous understanding of the basic questions of 1) how carbonate producing communities function and how does the sediment produced accumulate; 2) the relative importance of different biota under different boundary conditions; 3) how does the seascape heterogeneity translate to stratigraphic heterogeneity; and 4) what are the origins of lime muds.

Participants suggested that experiments to understand how changes in geochemical parameters influence rates of biomineralization should be developed in collaboration with physiologists and geochemical modelers. Interaction with population ecologists will be key to interpret how changes in environment (chemical, physical, etc.) translate to population dynamics, and how that, in turn, translates to spatial heterogeneity within and between bottom types. Improved collaboration with paleontologists and carbonate sedimentologists will allow better analogue comparison between modern and ancient systems. Modern test cases should be developed as possible analogues for ancient carbonate buildups, using the full breadth of carbonate depositional systems worldwide, including tropical meso/oligophotic carbonates, cool-water carbonate systems, and aphotic communities. Studies might cross a broad range of environments (e.g., latitudinal such as E/W Australia, E/W Florida, E Africa, Hawaii to NW Hawaiian islands; current-dominated systems like the Nicaraguan Rise; across depth gradients that have changing light, trophic resources, temperature, internal waves, etc. (i.e., most modern margins); and in mixed settings that contain terrigenous sediments). Hypotheses developed in modern systems can then be tested in appropriate ancient systems. The answers to these could provide insights into understanding how seascape heterogeneity translates to stratigraphic heterogeneity, and how to characterize seascapes and the inherent dynamics of biota across turn-on-turn-off gradients in a more realistic and effective manner.

These inherently interdisciplinary efforts require diverse partners such as ocean observing system engineers, "landscape" ecologists and modelers, microbiologists, geochemists, geochemical modelers, developers of experimental mesocosms and macrocosms that test changing geochemical and atmospheric boundary conditions, physiologists to help translate implications of geochemical models to predicting how specific biota might have responded, paleontologists and paleobiologists to translate understanding of modern biotas to interpreting fossil systems, taphonomists and sedimentary geochemists to assist in constraining syndepositional loss, and paleoceanographers to understand oceanographic changes that influence fossil carbonate producing communities.

Short-Term Goals: Workshop participants suggested that in the short-term, an updated literature search of biota- and habitat- specific rates of carbonate production, accumulation, and bioerosion, including microbial contributions and interactions should provide essential information for modeling. Identification of key experimental sites and gradients provides a necessary first step for quantifying carbonate biotic heterogeneity.

Medium-Term Goals: Contributors suggested a need for research to constrain controls on rates and nature of calcification by key biotic groups (e.g., corals, coralline algae, calcareous green algae, larger benthic foraminifera, microbes, including cyanobacteria). They also suggested the need to constrain seascape dynamics and patterns at targeted locations, both on the surface and stratigraphically, and across gradients.

Long-Term Goals: Participants suggested that successful outcomes would include a rigorous understanding of the geochemical and physical constraints on carbonate production, and its spatial heterogeneity, and its translation into numerical models.

3) Diagenesis -

Diagenesis in carbonate systems is particularly important due to the high reactivity of carbonate minerals from their initial deposition to their deepest burial and uplift. Diagenesis on the seafloor is part of the physical controls on sedimentation. Alterations through time determine the ultimate chemistry and mineralogy of the rock (e.g., Mg cycling and dolomitization) features that are increasingly used as proxies for paleoclimate and paleoceanographic conditions in the past. Facies, diagenesis, and brittle deformation also control the heterogeneity in carbonate rock properties, and that, in turn, affects the movement of fluids through carbonate rocks. As such, diagenetic heterogeneity can affect a variety of processes of societal interest, including CO_2 sequestration, aquifer storage and recovery, contaminant plume migration in carbonate aquifers, and the production of hydrocarbons.

The grand challenge in carbonate diagenesis is to construct predictive numerical simulations of diagenetic history (e.g., mass transfer and petrophysical transformation) from pore to platform scales. Ideally, models should incorporate the entire diagenetic system and all its coupled interactions - sedimentation, chemical and biological alterations on or near the seafloor, mechanical overprints, and chemical alterations resulting from fluid flow through pore and platform burial history. Once built, diagenetic numerical models would have multiple potential uses, including: (1) evaluating general diagenetic concepts, (2) testing specific diagenetic models of ancient carbonate systems, (3) predicting rock properties (e.g., porosity) and proxies (e.g., geochemical climate or ocean signals) through time and space, and (4) evaluating the effects of decreased seafloor lithification in times of increased ocean acidification (i.e., with rising global CO_2).

In general terms, diagenetic products and processes are known as a function of various diagenetic environments (i.e., hydrochemical regimes, Figure 2). We presently have a few limited empirical and rule-based modeling tools, but these include limited linkages between sedimentation processes and post-depositional diagenesis. Major gaps in understanding include:

1) The lack of benchmarks for the 3D distribution of processes and products in time and space – decades of research has focused on establishing processes and products using representative samples along one-dimensional vertical transects.
2) Significant uncertainty in many input parameters to diagenetic models – fluid chemistries, some thermodynamic and kinetic properties of carbonate minerals, and the nature of many mechanical processes.
3) The possible existence and influence of thresholds in diagenetic processes, and the nonlinear feedbacks of processes, products, and geochemical attributes is unexplored.
4) The role of biogeochemical reactions (i.e., catalysis, facilitators), empirical rules associated with some key processes (esp. cementation), and when to use transport- vs. reaction-controlled processes.
5) the nature of diagenetic outcomes at the full spectrum of scales, from thin section to platform-scale.

To explore these needs, participants suggested that access and information is required from the "right kinds of rocks" (closely spaced shallow drill cores and 3D quantitative data sets of well constrained outcrops). Large-scale monitoring sites are needed to examine seascape alterations (cementation, dissolution) and near surface post-deposition alteration (freshwater, mixing zones, refluxing brine settings). Potential partners include crystal surface geochemists, hydrologists/hydrodynamists, structural geologists, sedimentologists and stratigraphers.

Short-Term Goals: Identified goals included:

1) Dissemination of current numerical codes to grow the user community, and to develop community libraries of validation cases.
2) Develop consistent input parameters (e.g., depositional porosities), and improve most problematic of process rules.
3) Test existing tools at pore scale.
4) Establish examples of 3D diagenetic processes and products in select settings to have data sets to validate numerical codes.
5) Partner with larger community.

Medium-Term Goals: Couple second generation diagenetic models with improved sedimentary process models.

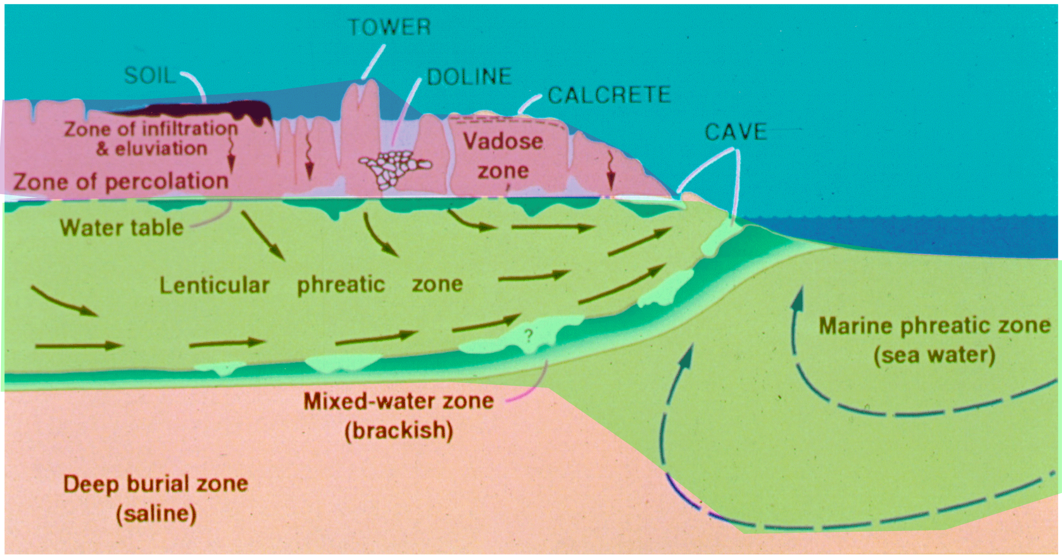

Figure 2. Diagenetic environments.

4) Numerical Modeling Strategies -

The grand challenge for numerical modeling is to make useful predictions/simulations of carbonate platform growth and diagenesis over varying time and space scales. Because it represents the numerical representation of our knowledge, this effort will require essential input and feedback from the other groups, and that the carbonate numerical community looks beyond itself, for numerical and conceptual inputs. The carbonate modeling community recognizes the need to integrate their modeling efforts into other Earth-surface modeling efforts, such as the Community Surface Dynamics Modeling System.

Knowledge gaps are wide and include 1) a lack of basic understanding of many processes, 2) uncertainties in scaling of processes temporally and spatially, 3) dearth of information on the influences of non-linearity and non-stationarity of biologic aspects of systems, 4) only qualitative insights on the feedbacks between different processes, and 5) absence of understanding of the controls on heterogeneity at different scales.

The goals for carbonate numerical process modeling are divided into four stages. The long-term goal is construction of a numerical work-bench (Figure 3) for carbonate knowledge generation that has a suite of process modules (physical, biologic, and chemical deposition, diagenesis, and structure/fractures).

Short-term goals (2 yr):

- Assign responsibilities for the cyber-infrastructure (i.e., GUI, protocols, coupling, and visualization).
- Build a module inventory and make modules available worldwide.
- Make available 5-9 modules that could include biogenic and inorganic production, biologic ecosystems and communities, physical and biologic syndepositional processes, dissolution-reprecipitation, cementation, hydrodynamics (e.g. Delft3D, ROMS), and sediment transport (CSDMS, e.g., SedFlux, SedFloCSTMS).
- Verify modules on appropriate time scales, and establish at least one database for testing.

Potential partners in this effort are global change community, reef health community, hydrology, industry, ecosystems, geochemistry, and ocean atmosphere communities. Start an online journal repository for modules and code documentation, possibly through the CSDMS organization, with benchmarks, and where editorial board and review involves the user community.

Medium-term goals:

- Involve students from geophysics, applied math, and computer science fields to address computational issues like grid conversion and interfaces.
- Have stage 1 modules tested and improved.
- Document results to enable informed choice of modules, and begin coupling with climate/ocean/siliciclastic models.
- Conduct initial sensitivity studies, and complete a comparative numerical scheme study, including an initial comparative verification/inverse objective cost function study.
- Conduct two international workshops in carbonate computational issues, and achieve "buy-in" with non-NSF funds for module development.
- Ensure high performance computing access, and activate partnerships.
- Have modules running efficiently on HPC, and have at least one useful prediction.
- Publish a series of peer reviewed papers using the workbench modules, and conduct a number of sedimentology courses in US using the carbonate workbench as a lab tool.

Long-term goals (10 yrs):

- Numerical work-bench for carbonate knowledge generation is available to the carbonate community. The workbench will: 1) have a suite of process modules (i.e., deposition, diagenesis, deformation/fracturing); 2) accept input from other models (e.g., ocean, climate, etc.); 3) accept observations from different sources, and databases; 4) have multiple inversion/verification schemes, and multiple sensitivity/response surfaces and uncertainty quantification; 5) have multiple scales/scalability, nestedness, and up- downscaling; and 6) have multiple outputs (Eclipse, Petrel, modflo etc.).
- Workbench prediction will be able to influence observatory systems like the Global Ocean Observatory.

I/O	Light-based deposition	Parallel I/O	Fuzzy-logic
Cellular Automata	Flow	Residence time	Sediment transport
Sea-level changes	Waves	Supersaturation	Climate model integration

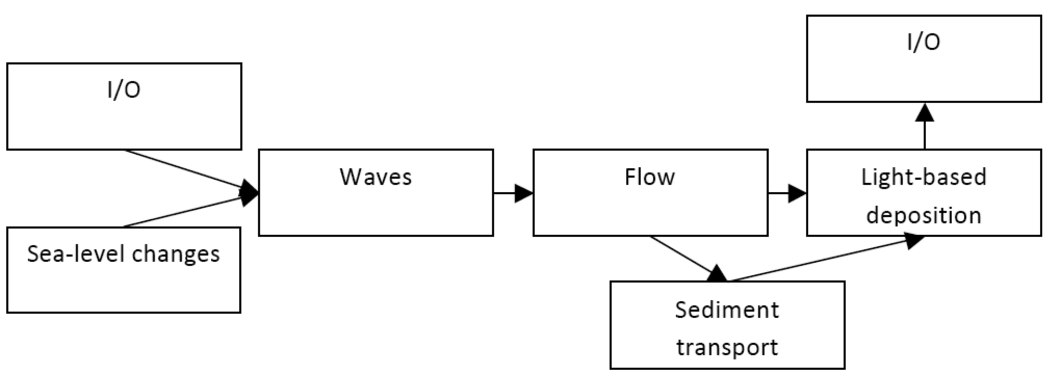

Figure 3. The carbonate "work bench" model is envisaged to contain a number of discrete modules (top), such as I/O interactions with other models, process-based factors, and stochastic process which can be linked together (bottom) to create a numerical model designed for the experiment in-hand. This frees the researcher from developing a model "from scratch" and maximizes the re-use of common functionality.

5) Tools Needs and Development -

Recent advances in the remote sensing of earth systems are providing numerous opportunities for detailed digital numerical data collection. Current tools in use to gather data in modern and near-modern systems include optical remote sensing, Lidar (airborne/land), bathymetry and spectral response, sonar (bottom topography and bottom sensing (backscatter)), acoustic Doppler profiling (current velocity and direction), in-situ wave profilers, synthetic aperture radar, and shore-based radar (wave/current measurements), and turbidity, temperature, alkalinity sensors. Research needs include developing higher resolution versions of the tools mentioned above, and developing the software and computing power to process ever larger quantities of data.

For ancient carbonate systems the advent and improvements of 3-D seismic data are beginning to provide the possibility of collecting extensive three dimensional data on architecture and morphology of ancient carbonate platforms. Many of these 3-D datasets come from mature hydrocarbon fields that have extensive well log, core, biostratigraphic, and production data that can be used to calibrate the seismic data. The challenge is to provide these data to academic researchers. Building academic-industry partnerships to achieve this should be a priority. Surface and near-surface tools, such as Lidar and GPR, provide opportunities to collect quantitative and 3-D data, and link with other subsurface data sets. These tools ultimately can provide quantitative high resolution data on geometry, facies, and diagenetic character (i.e., pore systems) of carbonate systems.

Enhanced understanding of ancient strata centers on the ability to gain accurate high-resolution chronostratigraphic, biostratigraphic and absolute time data, to better constrain correlations, dates, and rates. Most dating of carbonate systems involves a combination of biostratigraphic data and multiple other age determination techniques (e.g., Sr isotopes, magnetostratigraphy, high-precision radioisotope dating: U-Pb, U-Th and Ar/Ar dating recently improved to 0.1% error). Of notable concern is that in the area of biostratigraphy, many experts are of retirement age resulting in knowledge loss and very little of these data have been captured into publically available databases.

Future needs in studies of ancient carbonates require high resolution biostratigraphy resolving cyclostratigraphy to the 0.02-0.4 my level. This could involve partnering with Earthtime (NSF) and Earthtime Europe, CONOP (constrained optimization), and the high resolution event sequencing of assemblages of biostratigraphic sections that could provide resolving power better than 0.5 my time scale. Composite standards and coordination of data collection are needed to assure that all useful data are captured. Astronomically calibrated cyclostratigraphy offers resolving power at 0.02 to 0.4 my level for the Cenozoic-Mesozoic and modeling objectives should include testing for the astronomical signal in cyclic carbonate systems. Cyclostratigraphy validation tools include time series analysis tools that can potentially quantify the time-frequency evolution of carbonate accumulation. However, the method incorporates assumptions of the stratigraphic record, and further research is needed on effects of depositional (stratigraphic) breaks, and accumulation (thickness) changes. Spectral analysis does provide one means to assess variability of carbonate sedimentation as a function of frequency. An understanding of the degree of randomness of sedimentation, and identification of external forcing mechanisms is necessary to validate apparent astronomical signals.

SUMMARY & CONCLUSIONS

The grand research challenges for advancing understanding of modern and ancient carbonate systems identified in this first integrated community workshop include:

1) Quantitatively understanding and modeling facies heterogeneities developed over various timescales, as influenced by changing biotic, paleoceanographic, paleoclimatic, and sea level conditions;
2) Understanding the appropriateness of using Holocene tropical shallow-water reefs as analogues for ancient carbonate buildups;

3) Developing predictive numerical simulations of diagenetic history from the scale of the pore to the scale of the platform by incorporating and coupling sedimentation, chemical and biological alterations on the seafloor, mechanical overprints, and chemical alterations resulting from fluid flow;
4) Resolving cyclostratigraphy to the 0.02-0.4 my level using high resolution biostratigraphy and absolute age dates;

A more coordinated research effort in carbonate systems would be beneficial to advancing these community challenges. The group recommended research that focuses on identifying a limited number of sites to conduct integrated research on selected key subsets of: (1) the modern to Pleistocene, to examine the effects of ocean conditions and climate change on carbonate sedimentation, and the evolution of sediments into beds and strata; and (2) important analog field areas that combine outcrop, behind outcrop, and the subsurface, to build a new generation of 3-D carbonate system models.

Acknowledgements: The co-conveners would like to thank all the attendees for their enthusiastic participation in the workshop, and their contributions to this summary document. Special thanks go to Bill Hay, Jon Hill, Dave Budd, Bill Morgan, and Gene Rankey, who made substantial improvements to this summary.

Workshop participants:
Ashton, Andrew, Woods Hole Oceanographic Institution
Bachtel, Steven, ConocoPhillips
Budd, David, University of Colorado, Boulder
Burgess, Peter, Shell Oil Co.
Demicco, Robert, University of New York, Binghamton
Droxler, Andre, Rice University
Gil, Ben, University of California, Riverside
Griffiths, Cedric, CSIRO, Australia
Hallock-Muller, Pamela, University of South Florida
Hannisdal, Bjarte, University of Bergen, Norway
Harris, Mitch, Chevron
Hay, William, Estes Park, Colorado
Hill, Jon, University of Edinburgh, UK
Hinnov, Linda, Johns Hopkins University
Hsieh, Jean, Chevron
Hutton, Eric, CSDMS, University of Colorado, Boulder
Jones, Gareth, Chevron
Kendall, Christopher, University of South Carolina
Lane, H. Richard, NSF
Kettner, Albert, CSDMS, University of Colorado, Boulder
Love, Karen, ExxonMobil Upstream Research Co.
Lyons, Timothy, University of California, Riverside
Morgan, William A., ConocoPhillips
Riegle, Berhard, Nova SE, University, Florida
Smart, Peter, University of Bristol, UK
Syvitski, James P. M., Director CSDMS, University of Colorado, Boulder
Taberner, Conxita, Shell Oil Co.
Webster, Jody, James Cook University, Australia

Appendix 3:

Workshop Notes: "Clinoform sedimentary deposits"

Ron Steel, Chuck Nittrouer and Bob Dalrymple

SEPM's Field Research Conference on **'Clinoform sedimentary deposits: The processes producing them and the stratigraphy defining them'** attracted 71 participants in the Western Wyoming Community College of Rock Springs Wyoming, August 15-18, 2008. The 4-day lecture, poster and fieldtrip conference on siliciclastic clinoforms at delta and shelf-margin scales succeeded in bringing together three research communities: marine geologists on modern deltas, sedimentologists on ancient deltas and shelf margins and sedimentary-process modelers. Their goal was to focus on clinoform landscapes and on the associated clinothem deposits and processes. During two initial days there were keynote and other short talks, as well as poster presentations. Poster presenters gave a brief overview of their posters in the plenum session. The 3rd and 4th days were field trips to areas with well-exposed clinothems.

The Fox Hills river-dominated delta clinothems with overlying fluvial channel deposits

Keynote talks included the clinoform systems of the modern Ganges-Brahmaputra Delta, Amazon Delta, and Po-Western Adriatic Sea shelf clinoform system. 'Ancient' keynotes reviewed delta-scale and shelf-margin scale clinoforms. Modelers gave keynotes on experimental studies of clinoform patterns and on the modeling of fine sediment transport on shelf clinoforms. There was enthusiastic discussion after all talks. Two entire afternoons were given to the presentation and discussion of some 37 posters, the centerpiece of the Conference. During the two field days, relationships between delta clinoform steepness, facies/processes and grain size were examined in the spectacular Campanian Chimney Rock clinoforms of Minnie's Gap, and in the Maastrichtian Fox Hills shelf-edge deltas of the Washakie-Great Divide Basin near Rawlins Wyoming. The challenge of taking 70 participants into the field went without a hitch.

The success of this Clinoform Conference came from the mixing of the three communities. From a brief 'what did you learn' poll of participants, those working ancient deltas were surprised by the amount of new knowledge on modern, muddy subaqueous deltas, and by recent breakthroughs in understanding wave-assisted sediment gravity flows on modern deltas. Modelers and those working in 'modern' environments gained insights on lowstand landscapes and deltas, and on the possible limitations of the highstand present to understanding the past.