



SEMI-ANNUAL REPORT
JULY 30, 2010

NSF COOPERATIVE AGREEMENT 0621695



Preface

CSDMS is the virtual home for a diverse community of experts who foster and promote the modeling of earth surface processes, with emphasis on the movement of fluids, sediment and solutes through landscapes, seascapes and through their sedimentary basins. CSDMS develops, integrates, disseminates & archives software that reflects and predicts earth surface processes over a broad range of time and space scales. CSDMS deals with the Earth's surface—the ever-changing, dynamic interface between lithosphere, hydrosphere, cryosphere, and atmosphere. CSDMS employs state-of-the-art architectures, interface standards and frameworks that make it possible to convert stand-alone models into flexible, "plug-and-play" components that can be assembled into larger applications. The CSDMS model-coupling environment offers language interoperability, structured and unstructured grids, and serves as a migration pathway for surface dynamics modelers towards High-Performance Computing (HPC). This Semi-Annual Report covers the period from March 2010 to July 2010, and provides an update since the last 2009 Annual Report to NSF.

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CSDMS 'JUST THE FACTS'

CSDMS Model Repository

The CSDMS **Model Repository** offers metadata and links to 167 CSDMS-related models and source code to 112 open-source models (e.g. basin evolution models, morphodynamics models, transport models, climate and ocean models) comprising 3 million lines of code written in ten languages.

Repository statistics as of July 2010:

Language	Projects	Comment	Source	Total
Fortran 77/90/95+	34	495246	1233292	1728538
c/c++	61	260715	918001	1178716
Python	4	24840	23768	48608
MATLAB	9	12338	27946	40284
IDL	1	16730	18426	35156
Statistical Analysis	1	2390	5796	8186
Java	1	1107	6422	7529
Visual Basic	1	537	5735	6272
Total	112	813903	2239386	3053289

Model by Environmental Domain

88 Terrestrial models,
57 Coastal models,
27 Marine models,
46 Hydrology models,
3 Carbonate models.

Model code is downloaded ~2500 times per year. The top ten most downloaded models by version:

	Model	No. Times	Topic
1.	topotoolbox	239	A set of Matlab functions for topographic analysis
2.	child	218	Landscape evolution model
3.	midas	192	Coupled flow- heterogeneous sediment routing model
4.	topoflow	162	Spatially-distributed, D8-based hydrologic model
5.	2dflowvel	136	Tidal & wind-driven coastal circulation routine
6.	storm	92	Wind field simulator for a cyclone
7.	waveref	90	Wave refraction routine
8.	gc2d	72	Glacier / ice sheet evolution model
9.	stvenant	70	1D gradually varied flow routine
10.	bing	62	Submarine debris flows

CSDMS Data Repository

Data Repository Lists as of June 30, 2010

Data Type	Databases	
Topography/bathy	15	Land cover 2
Climate	2	Substrates 2
Hydrography	5	Human Dimensions 2
River discharge	5	Sea level 1
Cryosphere	3	Oceanography 1
Soils	2	Network Extraction 8
		GIS Tools 12

CSDMS is actively working to add three new data holdings, all of which are still being added to, as new floods occur:

- 1) Global Flood Atlas (digital GIS data showing flooded lands as observed via orbital remote sensing, and with associated recurrence intervals/exceedance probabilities for the inundation outlines)
- 2) River Watch (estimated daily river discharge values from remote sensing for ~2500 sites, distributed along major rivers and tributaries on all continents, July 1, 2002 to present)
- 3) Global Active Archive of Large Flood Events (catalog of flood events and associated attributes for each, such as geographic centroid coordinates for area affected, duration, calendar start and end dates, fatalities, severity estimates, etc: for 1985-present).

CSDMS Education & Knowledge Transfer Repository

The **Education and Knowledge Transfer Repository** offers undergraduate and graduate modeling courses, educational modules, modeling labs, and process and simulation movies. Model animations illustrate earth surface processes. Every animation has an associated fact-sheet with a short description of the animation.

Climate and Oceanographic Animations	15
Terrestrial Animations	10
Coastal Animations	5
Marine Animations	3
CSDMS Movie Gallery	16
Terrestrial Images	90
Coastal Images	47
Marine Images	2

Modeling Labs

- "Landscape Evolution Numerical Experiments" W. Luo
- "Coastal Stratigraphy Numerical Experiments" I. Overeem

Modeling Lectures

- "Earth-surface Dynamics Modeling & Model Coupling" 7 lectures by JPM Syvitski
- "1D Sediment Transport" 13 lectures by G. Parker
- "Morphodynamics of Rivers" 15 lectures by G. Parker
- "Geological Modeling" 7 lectures by I. Overeem

Modeling Textbooks

CSDMS works with modelers in the community who have published textbooks on modeling. We keep the associated code in the model repository so that it is easy to get for faculty and students alike.

1. Quantitative Modeling of Earth Surface Processes *By: Pelletier, J.D.*
2. Simulating Clastic Sedimentary Basins: Physical Fundamentals and Computing Procedures *By: R.L. Slingerland, K. Furlong and J. Harbaugh*
3. 1D Sediment Transport Morphodynamics with applications to Rivers and Turbidity Currents *By: G Parker*

CSDMS Experimental Supercomputer

The CSDMS High Performance Computing Cluster has been operating well, and has in recent days reached peak capacity by the 109 CSDMS members who have accounts on the system and have met the use criteria:

- Running a CSDMS model(s) to advance science
- Developing a model that will ultimately become part of the CSDMS model repository.
- Developing a new data systems or visualizations in support of CSDMS models.

The CSDMS HPCC is an SGI Altix XE 1300 that consists of 64 Altix XE320 compute nodes (512 cores, 3.0

GHz E5472 Harpertown processors). 54 of the 64 nodes have 2 GB of memory per core, while the remaining nodes have 4 GB of memory per core. The cluster is controlled through an Altix XE250 head node. Internode communication is accomplished through a non-blocking InfiniBand fabric. Each compute node has 250 GB of local temporary storage. All nodes are able to access 36TB of RAID storage through NFS. The CSDMS HPCC hosts more than 10 compilers. The main power management is an APC UPS with 30 minutes of uptime at 50% load. The CSDMS head nodes are backed-up by a separate SGI installed UPS system. The HPCC is supported by the CU ITS Managed Services under contract to CSDMS. Another 128 compute cores will be coming on line by fall of 2010 with an associated increase in RAID.

CSDMS Community

There are 8 Working and Focus Research Groups, consisting of members from 76 US Academic Institutions, 17 US Federal labs & agencies, 63 Foreign Institutes in 24 countries, and 11 companies.

Membership in **Working and Focus Research Groups** as of 07/15/10:

Terrestrial	204
Coastal	142
Marine	110
Hydrology	110
Cyber	77
EKT	45
Carbonate	38
Chesapeake	27

Participating US agencies include: NSF, Office of Naval Research, Army Corps of Engineers. Army Research Office, U.S. Geological Survey, NASA, National Oceanic and Atmospheric Administration, National Oceanographic Partnership Program, Idaho National Laboratory, National Park Service, National Forest Service, U.S. Dept of Agriculture, EPA, Argonne National Laboratory, National Weather Service, Naval Research Laboratory, National Center for Atmospheric Research, Nuclear Regulatory Commission. A CSDMS Interagency Committee serves the function of both communication and coordination.

Industry Partners include: BHP Billiton Petroleum, Chevron Energy Technology, ConocoPhillips, Deltares, ExxonMobil Research and Engineering, Japan Agency for Marine-Earth Science & Technology (JAMSTEC), Schlumberger Information Solutions, Shell International, Petrobras, Statoil, and URS Corporation. These organizations collaborate via the participation of representatives in CSDMS committees and working groups, including a CSDMS Industrial Consortium.

CSDMS Personnel

New CSDMS staff:

Sagy Cohen	(NASA post doctoral fellow)
Benjamin Hudson	(NSF OPP Ph.D. student)
Fei Xing	(NSF EAR Ph.D. student)
G Robert Brakenridge	Director, Dartmouth Flood Observatory
Aaron Zettler-Mann	CSDMS Undergrad student

Visiting Scientists or Students

• Hernan Arango	Prof Marine Sci	Rutgers University, New Jersey	2010 March
• John Gallant	Prof Geol Sci	CSIRO, Australia	2010 April
• Adam Campbell	Ph.D. Student	U. Washington, Seattle	2010 April
• Elchin Jafarov	Ph.D. Student	U. Alaska, Fairbanks	2010 April
• Vittorio Maselli	Ph.D. Student	University of Bologna, Italy	2010 May – June
• Silke C. Lutzmann	M.Sc. Student	University of Bonn, Germany	2010 March – June
• Juan Restrepo	Prof Geol. Sci	EAFIT University, Columbia	2010 July

CSDMS Publications since Jan 1, 2010:

- Berlin, M, Overeem, I, McGrath, D, Rick, U, 2010, Regional runoff season duration from sediment plume analysis in the Kangerlussuaq area, Greenland, 40th International Arctic Workshop, 10 – 12 March 2010, Winter Park, CO, USA.
- Brakenridge, GR, Syvitski, JPM, Kettner, AJ, Overeem, I, Sneddon, C, Fox, C, 2010, Predicted Effects of Future Dams and Levees on Flood Hydrology, Sediment Fluxes, and Deltas: Implications for Sustainable River Management. The Global Dimensions of Change in River Basins - Threats, Linkages, and Adaptations, 6 – 8 December 2010, Bonn, Germany.
- CSDMS Brochure dated 2.12.10 (July 20, 2010, PDF format)
- Kettner, A.J. Xing, F., Ashton, A. 2010. Are Human influences responsible for the existence and possible drowning of (parts of) the Ebro Delta, Spain? 18th International Sedimentological Congress, Mendoza Argentina.
- Kettner, A.J., Overeem, I., and Syvitski, J.P.M., 2010. Deriving event scale discharge records from low resolution data. 18th International Sedimentological Congress, Mendoza Argentina.
- Kettner, A.J., Restrepo, J.D., Syvitski, J.P.M., 2010, A spatial simulation of fluvial sediment fluxes within an Andean drainage basin, the Magdalena River, Colombia. *J Geology* 118: 363-379.
- Kettner, AJ, Hannon, M, Syvitski, JPM, 2010, Simulating hourly discharge fluxes through the Niger delta. *Eos Trans. AGU*, 91(26), West. Pac. Geophys. Meet. Suppl., Abstract H31B-05
- Kettner, AJ, Overeem, I, Syvitski, JPM, 2010, Downscaling discharge variability: can we predict daily flow characteristics based on annual flow characteristics? *Eos Trans. AGU*, 91(26), West. Pac. Geophys. Meet. Suppl., Abstract H32A-06
- McCarney-Castle K., Voulgaris, G., and Kettner, A.J., 2010, Analysis of Fluvial Suspended Sediment Load Contribution through Anthropocene History to the South Atlantic Bight Coastal Zone, U.S.A *J Geology* 118: 399-416.
- Overeem, I., Climatic Influences on Stratigraphy – Applications of Numerical Models. AAPG 2010, Abstract Vol, New Orleans, LA.
- Overeem, I., Syvitski, J.P.M., 2010, Experimental exploration of the stratigraphy of fjords fed by glacio-fluvial systems, In: *Fjords: Depositional Systems and Archives*, J. Howe (Editor), Geological Society, London
- Overeem, I., Syvitski, J.P.M., 2010, Shifting Discharge Peaks in Arctic Rivers, 1977-2007, *Geografiska Annaler* 92: 285-296.
- Perillio, G, Picollo, C, Syvitski, JPM 2010. Delta geomorphology: is it in equilibrium with present day dynamic conditions? 18th International Sedimentological Congress, Mendoza Argentina.
- Perillo, G, Syvitski, JPM, 2010, Mechanisms of sediment retention in estuaries. *Inprint Newsletter of the IGBP/IHDP Land Ocean Interaction in the Coastal Zone* 2010/1: 3-5.
- Perillo, G.M.E., Syvitski, J.P.M. 2010. Mechanisms of sediment retention in estuaries. *Estuarine, Coastal and Shelf Science* (2009), doi: 10.1016/j.ecss.2009.10.026
- Pyles, D.R., Syvitski, J.P.M., and Slatt, R.M., in press, Applying the concept of stratigraphic grade to reservoir architecture along the shelf-edge to basin-floor profile: an outcrop perspective, AAPG
- Slingerland, R, Syvitski, JPM, 2011, Community Approach to Modeling Earth- and Seascapes. *Treatise on Geomorphology*, in press
- Syvitski, J.P.M. 2010, Projecting Arctic Coastal Change. In: D.L. Forbes (Ed.) *State of the Arctic Coast 2010*, Scientific Review and Outlook. IASC/IPA/LOICZ, Potsdam. pg 89-92
- Syvitski, J.P.M., E Grunsky, 2011, Recommended Protocols for Model Software Developers. *Computers & Geosciences*, in press
- Syvitski, J.P.M., Peckham, S.P., David, O., Goodall, J.L., Delucca, C., Theurich, G. in press. Cyberinfrastructure and Community Environmental Modeling. In: *Handbook in Environmental Fluid Dynamics*, Editor: H.J.S. Fernando, Taylor and Francis Publ.
- Syvitski, J.P.M., R.L. Slingerland, P. Burgess, E. Meiburg, A. B. Murray, P. Wiberg, G. Tucker, A.A. Voinov, 2010, Morphodynamic Models: An Overview. In: Vionnet et al. (eds) *River, Coastal and Estuarine Morphodynamics: RCEM 2009*, Taylor & Francis Group, London, ISBN 978-0-415-55426-8 CRC Press, p. 3-20.

- Syvitski, JPM, 2010, Adventures of an explorer in the Canadian and Greenland Fjords. Program and Abstracts of the American Polar Society Meeting 2010, Institute of Arctic and Alpine research (INSTAAR), Univ. of Colorado at Boulder p. 20.
- Syvitski, JPM, 2010, Both Sea Level Rise and Accelerated Subsidence put Deltas at Risk. Future Oceans, Kiel, Germany.
- Syvitski, JPM, 2010, The Death of a Delta: The sad story of the Indus Delta. 18th International Sedimentological Congress, Mendoza Argentina.
- Syvitski, JPM, Brakenridge, GR, 2010, Connection Between Floodplains and Delta Plains with Examples: Indus, Yellow and Niger. Landscapes into Rock, Geological Society, London.
- Syvitski, JPM, Brakenridge, GR, Kettner, AJ, 2010, Divergent Flow of Water and Sediment in Lowland Coastal Settings. 18th International Sedimentological Congress, Mendoza Argentina.
- Syvitski, JPM, Brakenridge, GR, Kettner, AJ, Overeem, I, 2010, Storm Surge Flooding of Deltas Made Susceptible by Human Activities, Storm Surges Congress (LOICZ), Hamburg, Germany.
- Syvitski, JPM, Kettner, AJ, Hutton, EWH, 2010, Hyperpycnal Current-Sensitive Continental Margins, Eos Trans. AGU, 91(26), West. Pac. Geophys. Meet. Suppl., Abstract OS53B-01
- Syvitski, JPM, Kettner, AJ, Hutton, EWH, 2010, Observing Coastal-Resuspension associated with Tropical Cyclones, Eos Trans. AGU, 91(26), West. Pac. Geophys. Meet. Suppl., Abstract OS54B-03
- Syvitski, JPM, Kettner, AJ, Overeem, I, Hutton, EWH, Hannon, MT, 2010, Human and Natural Controls on a Delta's Surface Elevation Relative to Local Mean Sea Level, AAPG 2010 Abstract Vol, New Orleans, LA p 251.
- Voinov, C. DeLuca, R. Hood, S. Peckham, C. Sherwood, J.P.M. Syvitski, 2010, A community approach to Earth systems modeling. EOS Transactions of the AGU, 91(13): 117-124.

Progress on Year 4 Goals (April – July, 2010)

Goal 1) CSDMS Website 'A Gateway into the CSDMS World'

The aim is to transform the website to an efficient, easy to use, gateway to the 3 core repositories with a fast portal to the CSDMS Modeling Tool CMT.

Milestones:

The CSDMS website offers the community as well as other CSDMS website users the possibility to stay up to date automatically of any newly added information in 4 ways:

1. We have begun work on devising a simpler interface that promptly informs members and new CSDMS users what the Community Surface Dynamics Modeling System is all about, how to use CSDMS services, and how to become involved in the CSDMS community.
2. Website has been partially redesigned as an efficient gateway into the three core Repositories that CSDMS maintains and develops, but still needs further development and testing. The focus of the redesigned website is to 1) provide simple straightforward access to the three repositories, 2) highlight new added material, 3) get new CSDMS members up to speed efficiently. Implementation is scheduled after testing has been complete.
3. Each Repository is being set up in a database structure to allow for efficient searching, and retrieval of information and downloads. The model and data repositories are set up as a database structure, with an efficient search tool. As an example, the educational repository contains 5 sub categories (movies, images, labs, lectures, and textbooks), and is set up with an icon-based structure. Uploading of material is now greatly facilitated so that submission of EKT products, model, data and their metadata is both easy and fast.
4. Fast portal for members to download the 'CSDMS Modeling Tool' (CMT), and within a few steps allow for the secure use of the CSDMS compliant models through the Ccaffeine Graphical User Interface for running models on the CSDMS HPCC. The newest version of the CMT is made

available for download or launch from the CSDMS front page (<http://csdms.colorado.edu>). A link to the CMT guide for developers and users is also available on the front page. CSDMS members have to request an HPCC account, which is stated on the login screen of the CMT as well as in the users guide, provided with a link to the HPCC account web form. The “Help” pages (<http://csdms.colorado.edu/wiki/Help:Contents>) provide a documentation section which contains the users and developers guide for the CSDMS Modeling Tool.

Goal 2) Usability of the ‘CSDMS Modeling Framework’

The CSDMS Modeling Tool is a key product of the overall project, as it allows earth scientists with relatively modest computer coding experience to use the CSDMS modules for earth surface dynamics research and education. On June 14, 2010, CSDMS announced our first official release of the CSDMS Modeling Tool, version 1.4. The CMT Tool has a MAC/Windows/Linux version, so there is basic platform independency.

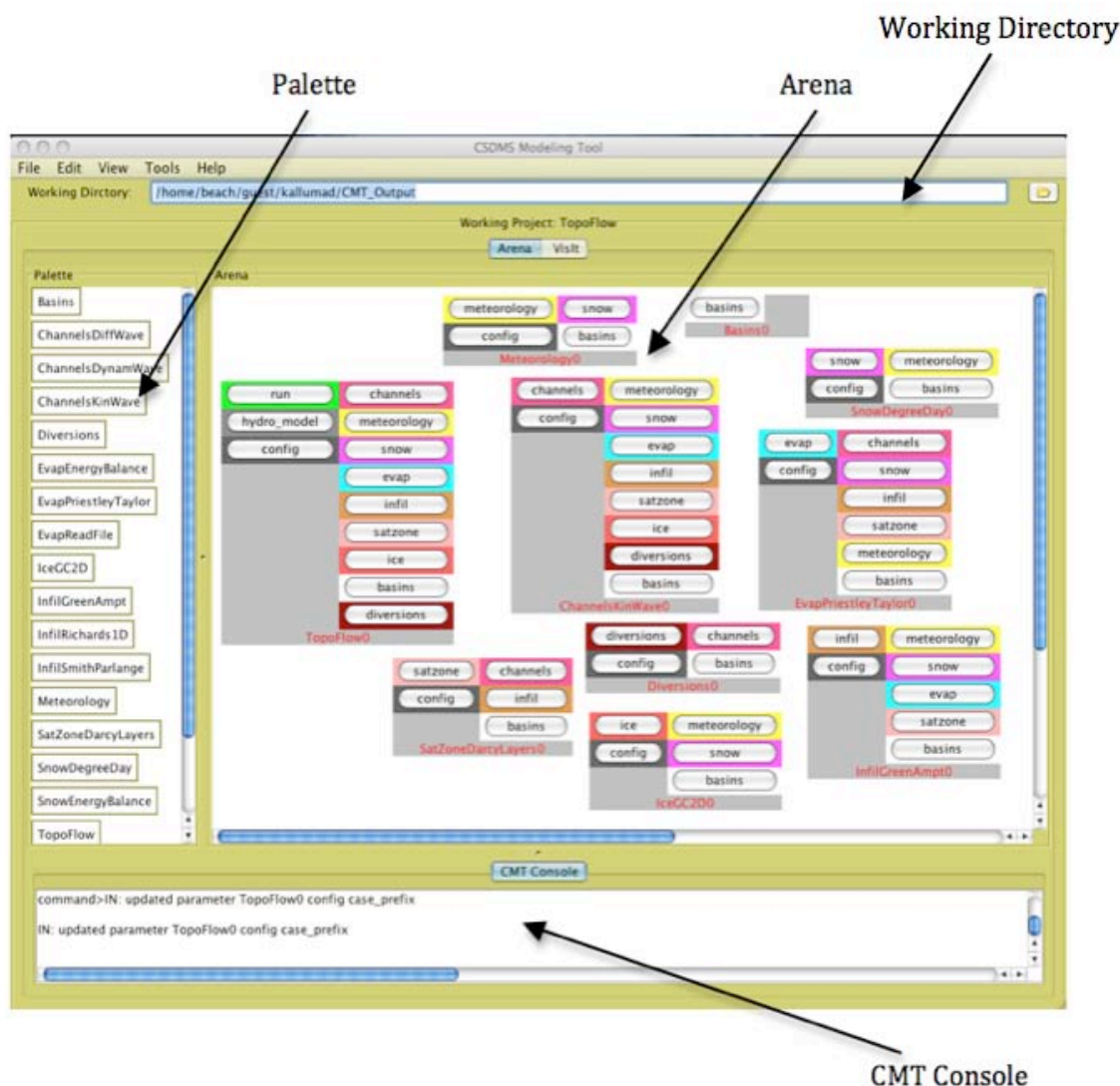


Figure 1. The window environment for coupled modeling: CMT Tool. Users can drag and drop the components from a Terrestrial Project environment, with a few mouse movements from the Palette of available components to the active working simulation; the Arena. The component connections and input-output are visually enhanced by color-coding the connections.

CSDMS Modeling Framework made user-friendly.

CMT 1.4 contains many features that make this tool user-friendly for both novice and expert users. A few of the features are listed below:

- Easy to start up: Improved Remote Access Functionality
 - Log-in screen bypasses SSH command line interaction of users
 - SSH tunneling via CMT
 - Straightforward capability of Sftp transfer of input and output files from server to local machine and vice versa
- Easy to click and work: Improved Look and Feel
 - Customizable background color and screen font
 - Component connections are color-coded so that coupling is visually apparent (Figure 1).
 - Wired and wireless options for creating models; wireless option can automatically connect components in the Arena.

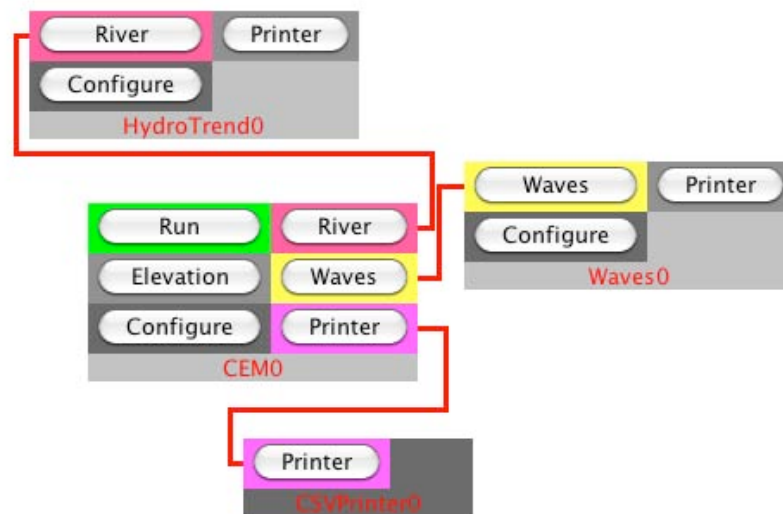


Figure 2. Zoom-in of a 'wiring diagram' for a coupled HydroTrend-CEM simulation. The HydroTrend model provides the river input; i.e. water and sediment load, this is subsequently used by the Coastal Evolution Model to simulate a wave-dominated delta evolution. Users can drag and drop the components from a Coastal Project environment, with a few mouse movements. Tabbed configuration menus allow the specification of simulation parameters. Click on 'run' and the coupled components will execute on the CSDMS HPCC Beach.

- Easy to debug and save multiple experiments: Improved Input/Output Operations
 - A Console window prints model run messages, these can be saved as log files for debugging.
- Easy save settings for new or multiple experiments
 - Open & Save Configuration of experiments so that re-runs of simulations are efficient
 - Import Example Configurations by loading tested 'pre-wired' example .bld files
- Usability for Advanced Users to quickly switch environments
 - Set default model
 - Option to Remove/Delete components and Clear Arena
 - Project Refresh & Reload options
 - Configure Dialog, to configure the input and output parameters and files for each model component
 - Preferences page
- Visualization Tool
 - Added access to visualization tool (VisIt) for output figures and movies

- Changed input and output files of many components to have NetCDF capability to visualize through VisIT.
- Help has been added at Introduction level, at Example Configuration Level and at the Most Advanced Process and Parameter level (this aspect is further discussed under EKT).
 - Tutorials
 - Report a bug
- Help (About...)
- MAC/Windows/Linux versions

Facilitated non-expert users by developing clear and concise tutorials on the installation and use of the CSDMS Modeling Framework and integrated within the ‘Help’ system of the downloadable applications.

Getting Started: CMT 1.4 can be launched directly from the CSDMS website (through Java Web Start), or downloaded to the user’s computer as a java application (Mac, Windows, and Linux versions are available). Upon opening CMT 1.4, the user is prompted to enter their login information for the “beach” computing cluster. A link to the CSDMS website is provided at the login prompt if the user has not already obtained access to beach.

Upon logging in to beach, the opening screen of CMT 1.4 starts on the “About CMT” tab, which shows a general help page: Getting Started with the CSDMS Modeling Tool. This page briefly describes the purpose and development of CMT, and provides step-by-step instructions on how to start and login to CMT. The general layout of CMT including the Palette, Arena, and Console is described. This document also describes each of the commands on the menu bar. If the user navigates away from this page, the Getting Started document can be accessed from the Help menu (Help >> Getting Started >> General) or by clicking the About CMT tab (or by “^H”). Another “Getting Started” help page is available on how to create a model. This page briefly outlines the steps to build a model from scratch by opening a project within CMT and dragging components from the Palette into the Arena.

VisIt is a free interactive parallel visualization and graphical analysis tool for viewing scientific data on Unix and PC platforms. The CSDMS wiki contains detailed instructions on how to install VisIt for both Mac and Unix and PC systems (http://csdms.colorado.edu/wiki/Help:Caffeine_GUI#VisIt_-_Introduction). Once users have installed VisIt on their local machine, they may follow along with a brief tutorial “Getting Started” under the Help >> VisIt menu. This tutorial walks the user through the interface by which they can select model output files stored on beach, and visualize these results using VisIt. An additional tutorial under the Help >> VisIt menu, “Create Movie,” provides detailed instructions on creating movies using VisIt. In this case, the VisIt application is launched from beach rather than from the user’s local machine, in order to produce better quality MPEG movies.

Compliant CSDMS modules are given associated ‘HTML Help Pages’, listing vital information on the model processes and parameters stored within the Model Repository for download.

Upon opening a given project within CMT, users may choose to open example configuration files (in which all model components are already configured and made available in the Arena), or to drag components in to the Arena from those available in the Palette. Each component has a “Configure” button that will open a tabbed dialog box. From any tab within these configuration dialog boxes, the user may click the “Help” button to open an html help file. The help files are component-specific and provide detailed information on the processes, governing equations, and parameters for each model component, as well as relevant references. Component-specific help files are currently available for TopoFlow and Erode model components. For components that do not have specific html help files yet (CEM and HydroTrend), the “Help” button connects to the model questionnaire on the CSDMS wiki. We are still working to provide links to documentation for the Water Tank, CHILD, Sedflux, and Waves components. All example configuration (.bld) files were tested to insure that they ran successfully and produced the correct output files; however, we did not extensively test different parameter combinations within the configuration settings. Note that .bld

files were not created for the ODE or PDE components, as these are examples from the CCA Forum Tutorial.

Framework tested by non-experts who are not part of the Integrations Facility team.

Members of the Integration Facility team have conducted most of the framework testing. Aaron Zettler-Mann, a summer Research Assistant at CSDMS, has been running tests of the HydroTrend, CEM, TopoFlow, and WaterTank components and assisting in the development and troubleshooting of model tutorials. Vittorio Maselli, a PhD student from the University of Bologna in Italy and a member of our Marine Working Group, plans to assist in testing the SedFlux model components for his study of modeling of sequence geometry in the central Adriatic Sea.

Goal 3) Componentizing the CSDMS Model Repository

With the success of the model coupling proof-of-concept projects of Year 3, CSDMS engineers are converting as time permits user-contributed code into CSDMS plug-and-play components according to project needs and feedback from the working groups. Many low-level utilities are now in place that greatly simplify wrapping contributed models as CSDMS components.

We are working on wrapping the programs in Gary Parker's eBook, "1D Sediment Transport Morphodynamics" as CSDMS plug-and-play components and several of them are now complete. They were previously converted to C and refactored to have a basic IRF interface. We are expanding their interface with getters and setters and are encapsulating some of their common requirements into new Channel and Sediment components to make them more flexible. Six Parker components have been completed.

Work on ROMS, the Regional Ocean Modeling System, is underway with the goal to become a CSDMS component by the all-hands meeting in October. It will have tabbed-dialog GUI and HTML help pages.

We have created and tested an ever-growing set of "pre-wired" CSDMS model configurations that can be used for (1) new users to use as working examples, (2) test suites and (3) educational materials

Goal 4) Advancing Goals of the Working Groups and Focus Research Groups

Completed a CUAHSI HIS "web service component" that can download hydrologic time series data and either share it through a CCA/IRF port with other components or write the data to files. It has a tabbed-dialog GUI and an HTML help page. Virtually the same code will allow us to create other web-service components, such as (1) an OpenDAP component (for grids and grid stacks) and (2) a component that can download a USGS NED (seamless) DEM for a specified bounding box.

Completed a set of low-level Python components for the Terrestrial Working Group that can perform fundamental DEM processing tasks like (1) filling depressions in a DEM, (2) extracting drainage networks, (3) computing slope grids and (4) computing contributing area grids. The fluvial landscape evolution model Erode that has been fully wrapped as a CSDMS component currently uses this toolkit.

Installed and tested the new, parallel version of TauDEM on beach, which also performs DEM processing tasks like those above, but using multiple processors.

SedFlux is being deconstructed into separate process components. The modules that have been separated out so far are plume, avulsion, subsidence and a 2D (vs.) 3D SedFlux component. The avulsion component is being incorporated into a new CEM-delta-avulsion project. Tabbed dialogs for these new components are under development.

A prototype of a new carbonate component has been written with an IRF interface but is not yet complete.

Abstraction of SedFlux's low-level data structures to create a "SedGrid" toolkit (for the Carbonate Focus Group) has begun, with a basic prototype expected by October.

A postdoc to work on the goals of the Chesapeake Focus Group will be hired in 2010.

EKT and CyberInfromatic Goals are discussed under Goals 6 and 7.

Goal 5) Conferences, Meetings, and a CSDMS Special Issue

CSDMS staff participated in the following meetings since the 2009 Annual Report:

01/2010	CSDMS ExCom Teleconference	Boulder CO, USA
02/2010	NSF MARGINS Successor Planning Workshop	San Antonio, TX, USA
03/2010	CSDMS Interagency Meeting	Arlington, VA, USA
03/2010	NERC-NSF Critical Zone Observatories	Arlington, VA, USA
03/2010	Arctic Workshop	Winter Park, CO, USA
04/2010	Joint annual meeting of AAPG and SEPM	New Orleans, LA, USA
05/2010	Climate Innovation Workshop Group, EPSCoR	Valles Caldera, NM, USA
05/2010	BP Gulf Oil Spill Teleconference	Boulder, CO, USA
05/2010	CSDMS ExCom Teleconference	Boulder, CO, USA
05/2010	The American Polar Society meeting	Boulder, CO, USA
05/2010	ONR Coastal Geosciences PI meeting	Chicago, IL, USA
06/2010	The Western Pacific Geophysics AGU conf	Taipei, Taiwan
07/2010	NSF CUAHSI Open Meeting	Boulder CO, USA
07/2010	Desert Research Institute meeting	Reno, NV, USA

Plans continue for the all hands CSDMS 2010 Meeting 'Modeling for Environmental Change' in San Antonio TX (Oct. 14-17). The meeting will bring together CSDMS members to present scientific insights in the modeling of surface dynamics and environmental change; new advances in cyber-infrastructure (CSDMS Model-coupling Tool, HPC techniques); development and use of CSDMS models in education (short clinics on EKT products); and allow the CSDMS Working Groups and Focus Research Groups to strategize on the direction of CSDMS for the next 5 years (i.e., the CSDMS Strategic Plan and Renewal).

A CSDMS Special Issue of 'Computers and Geosciences' has been welcomed by the C&G editors.

Goal 6) Technical Advances in the CSDMS Cyber-Infrastructure

CSDMS staff has worked on a suite of cyber issues to aid the future direction of the CSDMS modeling environment, including issues related to semantics and ontologies.

Wrote new components to save time-indexed model output of four different types to netCDF files. The types are time series (0D), profile sequence (1D, e.g. soil moisture profile evolving in time), grid sequence/stack (2D), and "cube" sequence (3D).

Modified virtually all of our existing model components to write their output to netCDF files using these new tools.

Coordinated with the developer of VisIt so that its "basic" netCDF reader can now read and display each of these 4 types correctly as a time-varying database.

One of the 4 new netCDF I/O tools is now CF compliant (as confirmed with an online compliance checker tool) and the other 3 will soon be compliant as well.

Completed a general tool that allows a tabbed dialog GUI to be generated automatically for Python components from a "template" in the form of a text file. Note that this same text file now also serves as a component's low-level configuration/input file. A similar tool for components written in C is nearly complete. Almost all of the CSDMS components now have tabbed-dialogs for input with a uniform look and feel.

All CSDMS components now have the ability to use separate directories for input and output. They also prompt for a "site prefix" and "case prefix" that they use to generate default filenames for output. The site prefix describes the location or study site and the case prefix describes the model run scenario.

Wrapped a powerful regridding tool that was developed within the ESMF project as a CSDMS component.

Added a tool to generate a simple, standard report upon completion when components are used in stand-alone mode. The report contains information such as run time and input/output directories, etc.

Goal 7) Educational and Knowledge Transfer

We envision the CSDMS Modeling Tool (CMT) will play an important role in making surface dynamics modeling accessible for student users. The beta version of the CMT has been launched with documentation for ease of use at a number of levels; ranging from general notes on installation, remote access requirements and software use on our wiki, to detailed notes on a certain parameter in a model equation within the menus of the relevant component. This documentation will undergo its own testing by a variety of users for clarity. A new user will always be confronted with most general "Help System" and instruction on 'How to create a model run in a few steps' (Figure 3). These concise learning modules help new students and other science users to get their first hands-on experience with the CMT Tool.

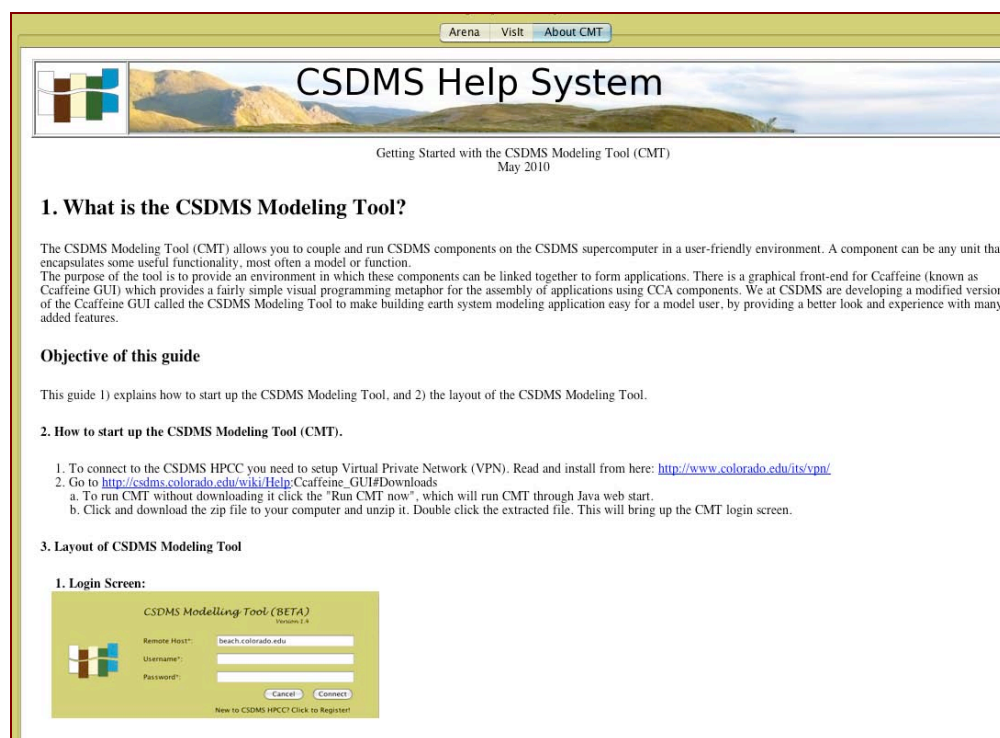


Figure 3. A new user will launch the CMT and then be taken to the first part of call; the 'Getting Started with the CSDMS Modeling Tool' guide.

The CSDMS Modeling Tool now includes all the relevant and in most cases multiple, coupled components to do simple model experiments. The following examples are launched in the beta version in July 2010:

- 1) Event-driven Precipitation influencing Landscape Evolution (CHILD or ERODE)
- 2) Valley Glacier Dynamics affecting Basin Hydrology (GC2D+TOPOFLOW)
- 3) Stratigraphic Architecture Storage Component (SEDFLUX 2D and 3D)
- 4) River Sediment Fluxes into a Wave-Dominated Coastal Environment (HYDROTREND + CEM)

Each of these coupled models or components now has enhanced documentation in the CSDMS Model Repository, and if manuals were available they have been incorporated, to make it easier for new users to familiarize themselves with the relevant models and their model theory and equations.

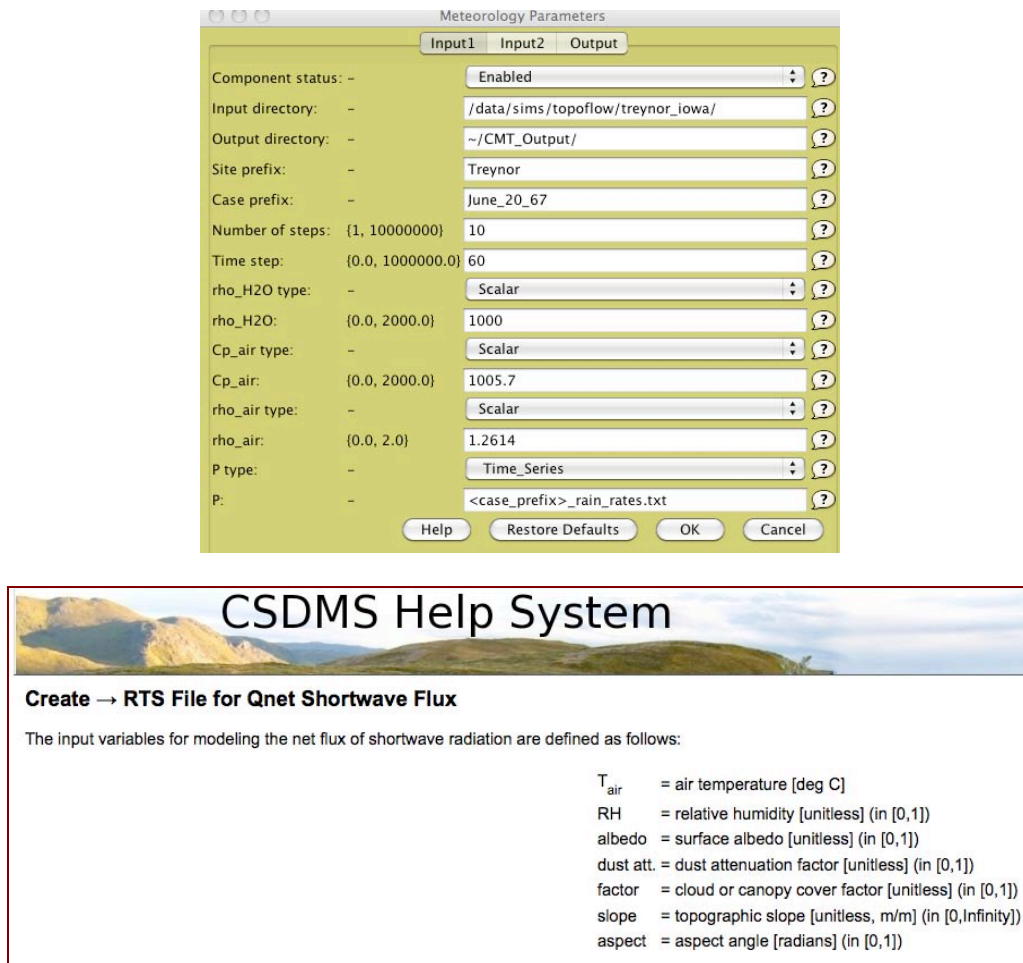


Figure 4. Example of a Model Configuration Menu of the meteorology component in the TOPOFLOW model. This configuration menu allows user experimentation with specific parameter settings. 'Help' buttons direct users to documented model theory and concise parameter descriptions.

Also, each example comes with at least one and more often several example files to import. These example files, so-called 'bld-files', have been tested both by CSDMS IF staff as well as by independent users. The CSDMS Help System (Figure 4) provides help with the scientific background of the coupling as well as an example simulation and its output (Figure 5).

We are further enhancing all these examples and will be developing the remaining examples in 2010. New model components have been prioritized and will be wrapped into the CSDMS Framework that will be critical for the subsequent science issues:

- Delta Dynamics affected by Human Perturbations
- Ice Sheet Melt feeding Coastal Plumes
- Global Wind-Driven Waves affecting Coastal Zones

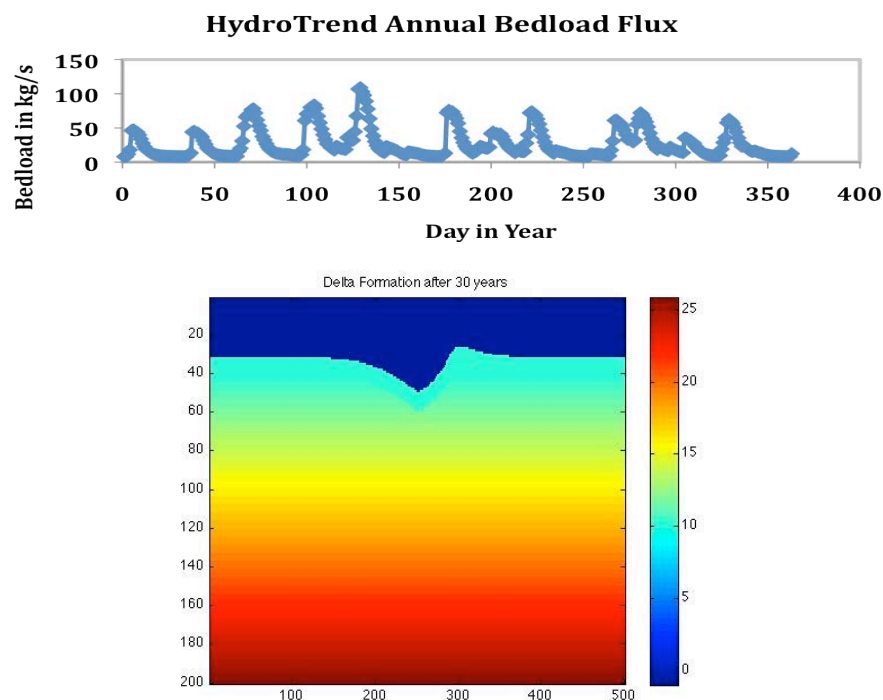


Figure 5. Documented out put from river-delta coupling. A. Time series of river bedload flux to the coast as predicted by HydroTrend over a single year. B. Planview of the grid shows the subarial part of the delta built out into the marine basin with this flux input (CEM model). The delta growth has been asymmetric, since the waves come in under an angle.

Inventory of Earth Surface Dynamics Modeling courses

The CSDMS Integration Facility staff is interested in making our products and tools accessible to the college classroom. Based on a recommendation from the EKT Working Group meeting in Fall 2009, we conducted a survey of university course catalogs to help us learn how surface process modeling is currently being taught. We targeted members of the Association of American Universities to gain a representative sample of research-intensive universities. 36 universities were surveyed; of these, 16 are also host institutions of CSDMS members. We required that either a geology or civil engineering department was required. Surveyed universities represent all regions of the United States, although the highest concentrations were in the Mid-Atlantic, Midwest, and Pacific Coast regions. Roughly equal proportions of private and public institutions were included in the survey. Undergraduate student populations ranged in size from less than 1,000 to over 75,000, and the graduate student populations varied between just over 1,000 to more than 14,000.

We reviewed course catalog descriptions and gathered information about courses that may be relevant to CSDMS, including basic details such as course name, department, level, credit hours, and format. We noted any required prerequisites, programming languages used, and the objectives from the course description. We also tallied which courses might be especially relevant to any of the CSDMS working groups or focus research groups. Course titles and keywords that were of interest include:

- modeling of earth surface processes
- GIS/remote sensing
- quantitative techniques/statistics
- sedimentary geology modeling
- hydrology/glaciology
- fluid dynamics
- groundwater hydrology/groundwater flow modeling/hydrogeology
- global change/climate modeling

For the 36 universities surveyed, we identified 1043 courses that had at least some relevance to CSDMS, in terms of subject matter or in the use of models. Geology/Geosciences and Civil/Environmental Engineering Departments had the most courses. In terms of relevance to CSDMS areas of interest, most connections were apparent to the Hydrology and Terrestrial groups. Matlab was the most common language mentioned in course descriptions, although Babel-supported languages were also present. If we focus solely on classes in which “modeling” is listed in the course description, such that these courses could directly use or benefit from CMT and other CSDMS Integration Facility products, the results are slightly different. Civil and Environmental Engineering departments become the most popular, largely due to the presence of groundwater and surface water modeling courses. From this survey, we can speculate that hydrology courses represent an opportunity for the immediate or near-term use of CSDMS products, and that civil/environmental engineering departments may be the most logical host of these courses.

An important caveat is that the results are only as reliable as the course descriptions in university catalogs, which may be out of date, incomplete, or inaccurate. We intend to administer a course questionnaire to CSDMS members as a way to validate some of our results. In addition we can then, identify common elements of these courses and experiences of instructors and students to inform the development of CSDMS educational modules. The full study is available below as Appendix 1.

CSDMS Short courses in 2010

We have identified several test-beds for courses and clinics among the different EKT user groups in 2010. Course material is developed based on the examples that have been launched in the beta version of the CMT July 2010 and its associated case studies.

Three EKT user groups are targeted:

1) Graduate students

The two winners of the CSDMS Student Modeler Award of 2009, Adam Campbell and Elchin Jafarov, have visited the CSDMS Integration Facility in April 2010 and spent time with the CSDMS Integration Facility staff to get instruction on the use of the CSDMS Modeling Tool and to explore possibilities for use of the CSDMS Modeling Tool in their own research projects. They received instruction on the HPCC system use as well.



Figure 6. Visiting scientist Vittorio Maselli with CSDMS Ph.D. student Benjamin Hudson, and recently graduated student Aaron Zettler-Mann who are preparing for fieldwork up in Greenland with PI Dr. Irina Overeem.

CSDMS IF staff is teaching a new graduate level course in the Fall Semester 2010 at CU Boulder: ‘Surface Process Modeling: Applying the CSDMS Modeling Tool’. This 2 credit course aims to familiarize earth sciences and engineering graduate students with a number of numerical surface process

models and hydrological models available through the Community Surface Dynamics Modeling System and set them up to use these tools for own research purposes. The course may be used as a ‘use-case’ for the NSF-funded project, “Scaling Up: Introducing Commodity Governance into Community Earth Science Models.” This course will provide an immediate opportunity for evaluating how our current cyberinfrastructure can support the course’s educational goals. See the initial use case description below as Appendix 2.

2) Science users outside of the core CSDMS community

CSDMS is providing a short course on models and model coupling at a conference of Future Oceans, Kiel, Germany Sept 11, 2010.

3) CSDMS Industry partners

CSDMS is providing a short course on stratigraphy models and sediment supply models as well as model coupling, targeted to a specific example for industry partners in both August and September 2010.

4) K6-12 Students

CSDMS participated in the INSTAAR Open House. The INSTAAR Open House hosts over 170 middle school students every year, they participate in hands-on science measurements and activities. The CSDMS Integration Facility team set out to teach concepts of super-computing. To illustrate parallel processing, versus fast-processing students raced to perform tasks as ‘fast processors’ or cluster teams’ and gained insights on basic supercomputing strategies. They toured the HPCC facility and experienced first hand how heat is generated from the many calculations performed by the supercomputer.

Solicit feedback from CSDMS members through the website on their experiences with using the CSDMS Modeling Framework.

All CSDMS members received an announcement of the first official release of the CSDMS Modeling Tool (CMT), version 1.4. In addition to explaining how to get started with CMT, this email also listed options in the CMT Help menu, including “Report a bug” as a way to provide feedback through the CSDMS Track page. Selecting the “Report a bug” option opens a dialog box, in which users may choose whether to create a new ticket for the bug they have discovered, or to view all active tickets. Users may contribute these bugs without needing to log in to the CSDMS Track page; however, they must provide their email address if they wish to receive replies or updates regarding the bug.

The form for entering a new bug requests a brief description of the bug, which in the CMT dialog box is explained as:

- Please explain your problem in detail
- The steps you did to hit the bug, needed for us to reproduce it
- What results did you get or else you could copy the log under CMT_Files
- For replies or updates please include your email address while creating the ticket or use RSS feed

The Track form also asks the user to characterize the bug as a defect, enhancement, or task, and to assign a priority to the bug.

Currently, each time a model is run on beach using CMT, a log file is generated that records the contents of the .bld file, indicating the configuration settings of the model run. These log files are accessible to CSDMS IF staff. Based upon the time of the run and the model name indicated in the log file, we should be able to match these log files to any Track tickets based upon the details that are provided by the user. As more users gain access to beach and begin using CMT, the log files will be useful in troubleshooting model problems as well as bugs within the CMT.

Appendix 1: Sample Inventory of Modeling Courses

Maureen Berlin and Irina Overeem

July 2010

CSDMS Mission Statement:

The Community Surface Dynamics Modeling System (CSDMS) deals with the Earth's surface - the ever-changing, dynamic interface between lithosphere, hydrosphere, cryosphere, and atmosphere. We are a diverse community of experts promoting the modeling of earth surface processes by developing, supporting, and disseminating 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 Integration Facility staff is interested in making our products and tools accessible to help supplement existing college courses related to terrestrial, coastal, marine, hydrology, and carbonate topics. Based on a recommendation from the Education and Knowledge Transfer (EKT) Working Group meeting in Fall 2009, we conducted a survey of university course catalogs to learn how surface process modeling is currently being taught. An important caveat is that the results below are only as reliable as the course descriptions in university catalogs, which may be out of date, incomplete, or inaccurate. However, we posit that instructors who use modeling would most likely attempt to promote that feature of their course rather than obscure it, in order to help recruit students.

We targeted members of the Association of American Universities (AAU) (<http://www.aau.edu/>) to gain a representative sample of research-intensive universities. Rather than surveying all 63 AAU members, we chose a representative sample of 36 institutions from this list (Figure 1). We required that either a geology or civil engineering department was present for each surveyed university. Of the surveyed universities, 16 are also host institutions of CSDMS members (Figure 1).

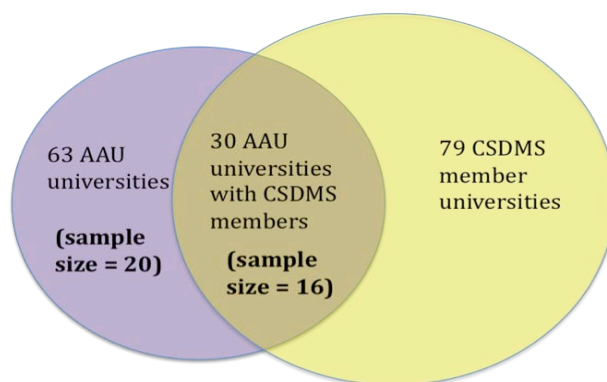


Figure 1. Overlap between AAU universities and CSDMS member universities.

All major regions of the U.S. are represented among the surveyed universities (including one Canadian university), although the Pacific Coast, Mid-Atlantic, and Midwest regions had higher concentrations, perhaps indicative of the larger population centers in those areas. Nineteen universities are public funded and seventeen are private institutions. The surveyed universities have undergraduate student populations that range in size from less than 1,000 to over 75,000, and the graduate student populations vary between just over 1,000 to more than 14,000 (Figure 2).

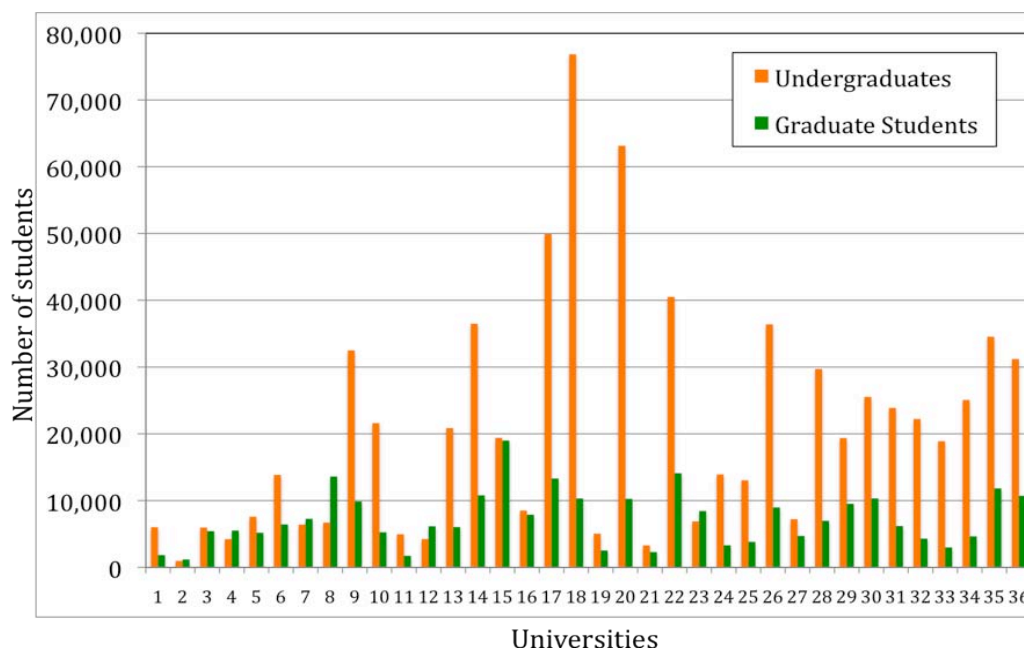


Figure 2. Range of size of student body populations at surveyed universities.

Box 1. Surveyed Universities

Brown University	Purdue University
California Institute of Technology	Rice University
Carnegie Mellon University	Rutgers, The State University of New Jersey
Case Western Reserve University	Stanford University
Columbia University	Stony Brook University-State University of New York
Cornell University	Syracuse University
Duke University	Texas A&M University
Harvard University	Tulane University
Indiana University (Bloomington)	The University of Arizona
Iowa State University	University at Buffalo, The State University of New York
The Johns Hopkins University	University of California, Berkeley
Massachusetts Institute of Technology	University of California, Davis
McGill University	University of California, Irvine
Michigan State University	University of California, Santa Barbara
New York University	University of Colorado at Boulder
Northwestern University	University of Florida
The Ohio State University	University of Illinois at Urbana-Champaign
The Pennsylvania State University	
Princeton University	

We reviewed course catalog descriptions and collected basic information such as course name, department, level, credit hours, and format. If a course was offered in multiple departments, we identified it either with the main host department, or the first instance of the course in the catalog. We noted any required prerequisites, programming languages used, and the objectives from the course description. We also tallied which courses might be especially relevant to any of the CSDMS working groups or focus research groups.

Course titles and keywords that were of interest include:

- modeling of earth surface processes
- GIS/remote sensing

- quantitative techniques/statistics
- sedimentary geology modeling
- hydrology/glaciology
- fluid dynamics
- groundwater hydrology/groundwater flow modeling/hydrogeology
- global change/climate modeling

We generally excluded those courses that were limited to the following topics, as these seemed peripheral to the types of modeling tools and educational products that CSDMS is developing:

- geophysics/geophysical or geological fluid dynamics/geodynamics
- paleoclimate
- pure computer science (e.g. C programming)
- general physical geology (too generic)
- numerical solutions of partial differential equations/numerical methods
- courses on high performance scientific computing or parallel computing
- statistics/time series analysis
- finite element modeling of geological materials/geotech/soil mechanics/soil science
- atmospheric modeling/meteorology (unless oceans are mentioned)
- geochemistry
- 1-credit seminars or reading seminars
- “Special Topics in...” with no course description (these may still be of interest to us, as evidenced by the upcoming CU course using CMT, which will be listed under Special Topics)
- field courses

For the 36 universities surveyed, we identified 1043 courses that had at least some relevance to CSDMS, either in terms of subject matter or in the use of modeling in the earth sciences. Of these courses, 717 were undergraduate level, 469 were graduate level, and 143 were cross-listed at both levels.

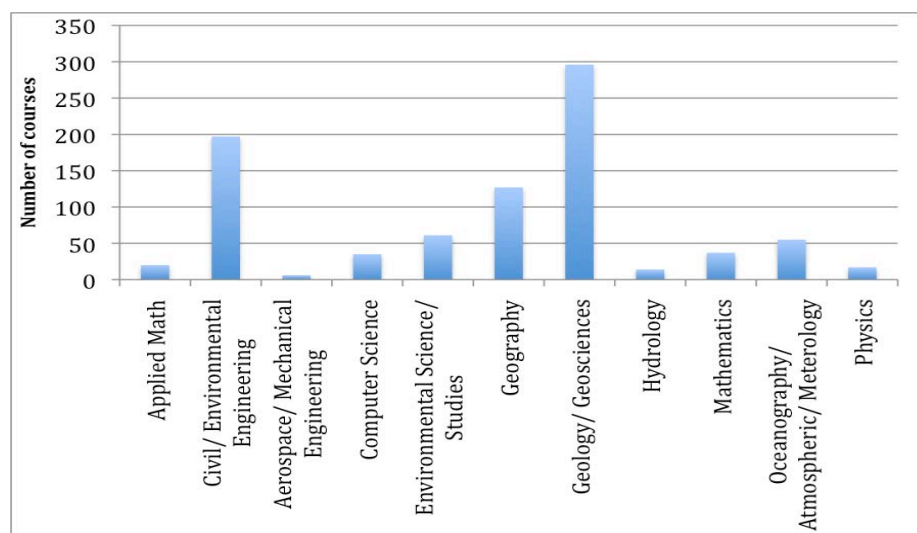


Figure 3. Frequency of all surveyed courses by university department.

Of the university departments offering CSDMS-relevant courses, Geology/Geosciences and Civil/Environmental Engineering Departments had the most courses (Figure 3). We also tallied which courses would have content that is relevant to CSDMS Working Groups and Focus Research Groups (and also mentioned climate, even though that is not a CSDMS group). Many of the surveyed courses can be connected to the Hydrology and Terrestrial Groups (Figure 4). It is interesting to note that although the

Terrestrial Working Group is the largest in terms of CSDMS membership and number of models, it does not correspond to the highest number of surveyed courses (Figure 4).

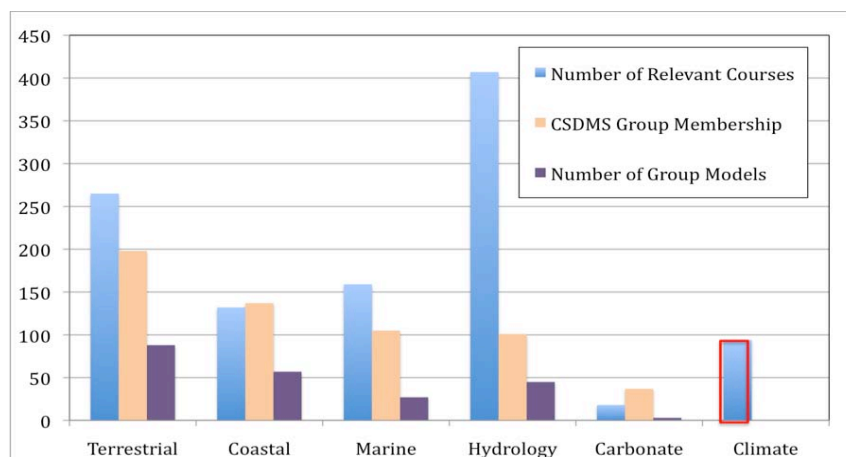


Figure 4. Comparison of frequency of courses relevant to CSDMS Focus Research Groups and Working Groups, membership within those groups, and number of group models as of July 2010.

Although CSDMS does currently focus on GIS or remote sensing services, we did tally the use of these software packages in addition to programming languages. Matlab was the most common language mentioned in course descriptions, although many Babel-supported languages (Fortran, C/C++, Python, and Java) were also indicated (Figure 5).

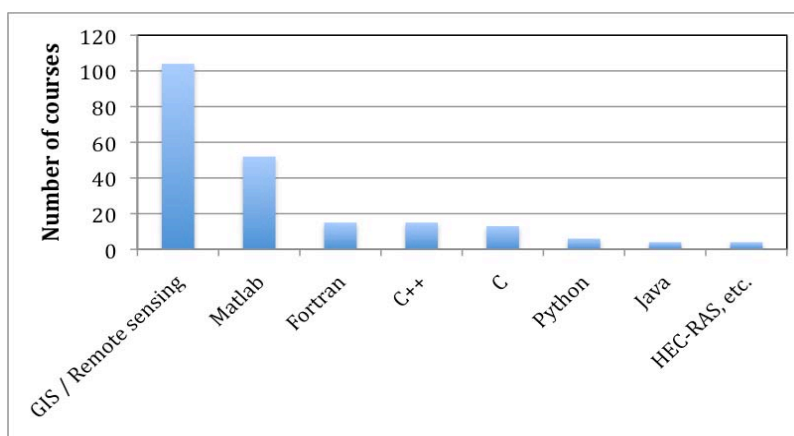


Figure 5. Frequency of courses that specified a software package or programming language.

In general, universities with larger undergraduate student body populations had more courses that we tracked as relevant to CSDMS (Figure 6). This trend did not hold with the graduate student population size (Figure 7).

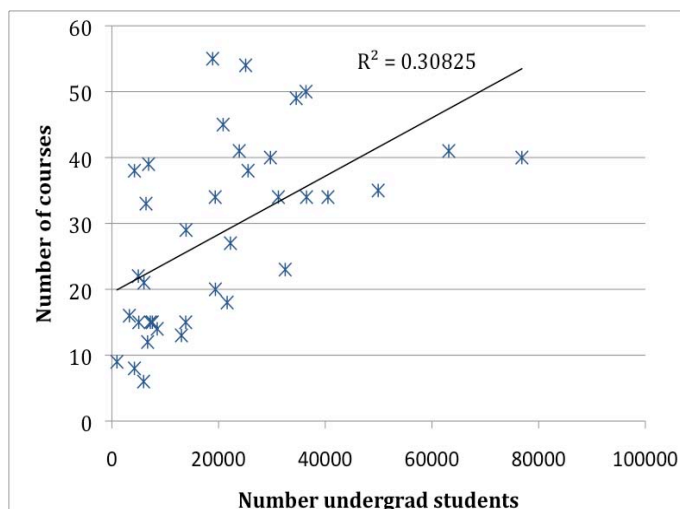


Figure 6. Number of surveyed courses vs. number of undergraduate students at each university.

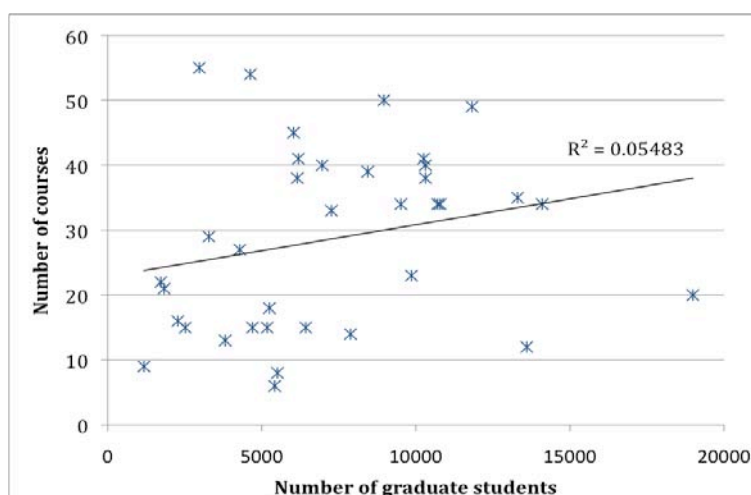


Figure 7. Number of surveyed courses vs. number of graduate students at each university.

On average, for each of the 36 surveyed universities, approximately 29 courses listed in the course catalogs would have some relevance to CSDMS modeling and educational efforts. The schools with the highest number of relevant courses were:

- University of California, Santa Barbara (55)
- University of Colorado, Boulder (54)
- Texas A&M (50)
- University of Florida (49)
- McGill (45)
- Purdue, University of California at Davis (41)
- Penn State, University of Arizona (40)

“High-Relevance” Courses:

During the process of gathering information from course catalogs, we made special note of courses that have “high relevance,” based on the following criteria:

- “Modeling” is listed in course description
- Hands-on activities may be emphasized
- Quantitative problem solving using computers
- Courses that could directly use or benefit from CMT and other CSDMS Integration Facility products

We identified 167 courses that are highly relevant to CSDMS. Selected course titles for which the course descriptions met these criteria include:

- Physical Hydrology
- Coastal and Ocean Modeling
- Groundwater Modeling
- Computer Simulations in Earth and Planetary Sciences
- Geological Modeling
- Sequence Stratigraphy
- Sediment Transport and River Mechanics
- Advanced Watershed Hydrology
- Earth Systems Science
- Marine Sedimentology

The course descriptions for these high-relevance courses include some of the following elements:

- application of numerical analysis to mathematical modeling in the natural sciences
- watershed analysis, watershed hydrology with analytical and numerical models
- model building and validation; quantitative problems, forward and inverse modeling; model construction and simulation; computational analysis
- spatial/temporal modeling of water on landscapes
- scientific computing with science applications; software development for scientists
- environmental fluid mechanics and sediment transport with numerical models
- environmental quality numerical modeling
- computer simulation models of hydrology; hydrological forecast modeling
- quantitative modeling of fluids and sediments; sediment transport
- numerical modeling of coasts and oceans; model development for ocean circulation
- quantitative surface processes with numerical modeling
- simulations of hydrologic cycle; modeling hydrologic response to different climates
- mathematical modeling of river and coastal currents
- numerical modeling of groundwater flow; subsurface fluid flow; fate and transport of pollutants
- lake, river, coastal contaminant transport model development
- hydrologic/hydraulic computer modeling; surface water hydrology, floodplain hydraulics; 2D flow modeling; streamflow modeling
- developing numerical geoscience models
- use of computer programs for runoff calculation from catchments
- simulations of oceanic processes; advanced topics in modeling for ocean and estuarine environments using existing techniques and codes; numerical design of ocean models
- modeling of modern environmental problems
- computer-based methods of analysis in geomorphology; numerical models of sediment/debris flows
- hands-on applications using numerical modeling; numerical algorithms
- quantitative methods in natural resources and environmental sciences

Most universities have at least a few high-relevance courses, and on average, 15% of surveyed relevant courses at a given university were classified as highly relevant (Figure 8).

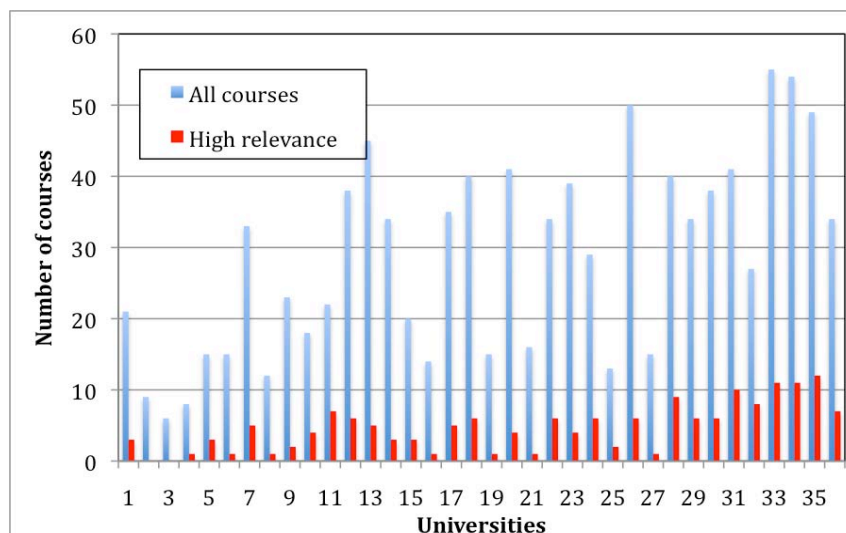


Figure 8. Frequency of all surveyed courses and high-relevance courses by university.

Civil and Environmental Engineering departments become the most popular, largely due to the presence of groundwater and surface water modeling courses (Figure 9). From this survey, we can speculate that hydrology courses represent an opportunity for the immediate or near-term use of CSDMS products, and that civil/environmental engineering departments may be the most logical host of these courses.

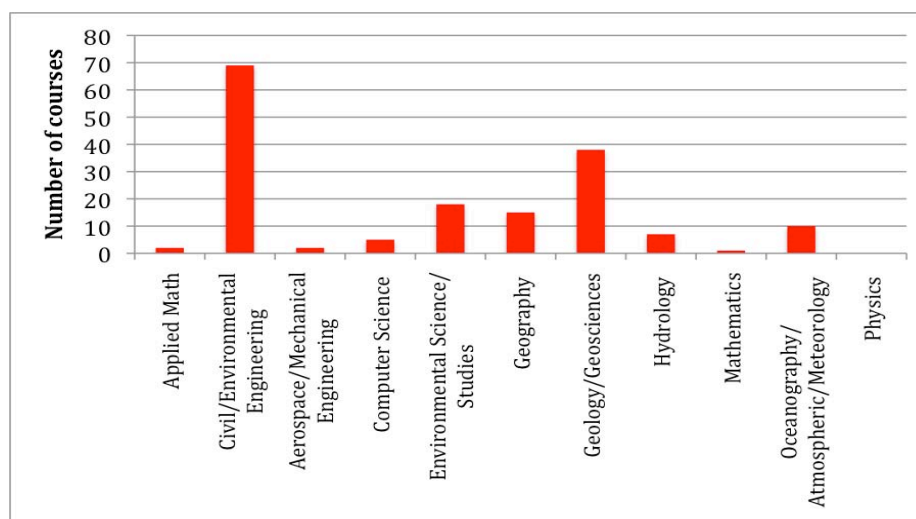


Figure 9. Frequency of high-relevance courses by university department.

The frequency of high-relevance courses was not well-correlated with size of either the undergraduate or graduate student populations (Figures 10, 11).

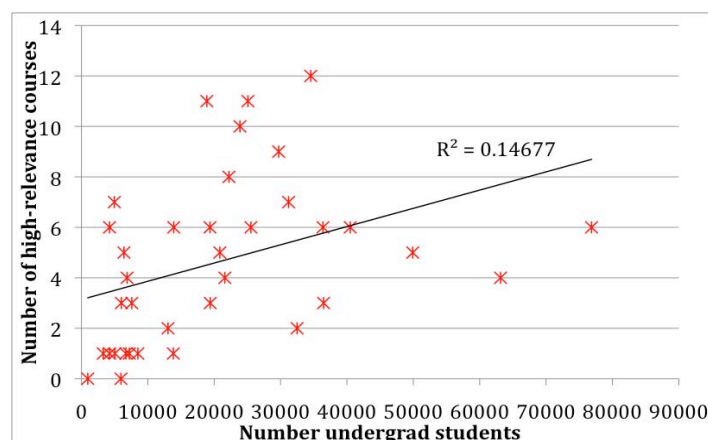


Figure 10. Number of high-relevance courses vs. number of undergraduate students for each surveyed university.

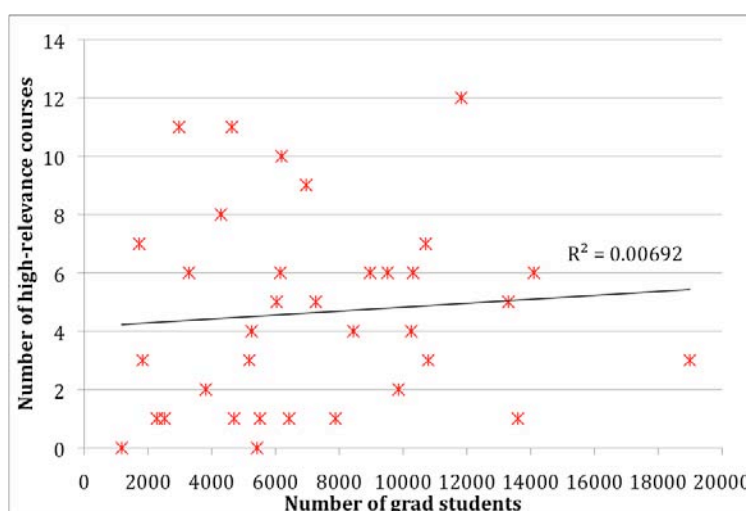


Figure 11. Number of high-relevance courses vs. number of graduate students for each surveyed university.

On average, for each of the 36 surveyed universities, approximately 4-5 courses listed in the course catalogs would be highly relevant to CSDMS modeling and educational efforts. The schools with the highest number of highly-relevant courses were:

- University of Florida (12)
- CU Boulder, UCSB (11)
- UC Davis (10)
- U. Arizona (9)
- UC Irvine (8)
- U Illinois, Johns Hopkins (7)
- SUNY Stony Brook, Rutgers, Penn State, UC Berkeley, SUNY Buffalo, Texas A&M, MIT (6)

To summarize, hydrology courses (groundwater, surface water) may represent the most immediate opportunity for use of CSDMS products. Modeling courses may be most common in civil/environmental engineering departments.

We intend to administer a course questionnaire to CSDMS members as a way to validate some of our results. We also need to consider how these results influence our modeling and educational products.

Appendix 2: CU Modeling Course Use Case

Maureen Berlin

July 2010

GEOL 5700: Surface Process Modeling: applying the CSDMS Modeling Tool

Instructors: Prof. James Syvitski, Dr. Irina Overeem, Dr. Scott Peckham.

2 credits, Fall 2010.

The CSDMS Modeling Tool (paired with the CSDMS wiki website) is used to support a semester-long two-credit course at the University of Colorado that centers on the use of numerical surface process models and hydrological models. Participants include three instructors and approximately ten (?) graduate students. Although the instructors and students will be in the same location during the class meeting times, remote access to the system and remote collaboration will be a central part of class participation. The course will involve both lectures and hands-on modeling.

Course Description:

This course aims to familiarize earth sciences and engineering graduate students with a number of numerical surface process models and hydrological models available through CSDMS and set them up to use these tools for their own research purposes.

Goal:

At the end of the course, students should be able to design and run simulations for an independently designed research question within either the hydrological-glaciological, coupled river-delta, or stratigraphic domains.

Given the short timeline for course development (classes start Aug. 23), this use case was generally written to correspond with the existing CSDMS cyberinfrastructure (see diagram below):

- CMT and associated help files and VisIt

- directories on beach for sharing and storing files

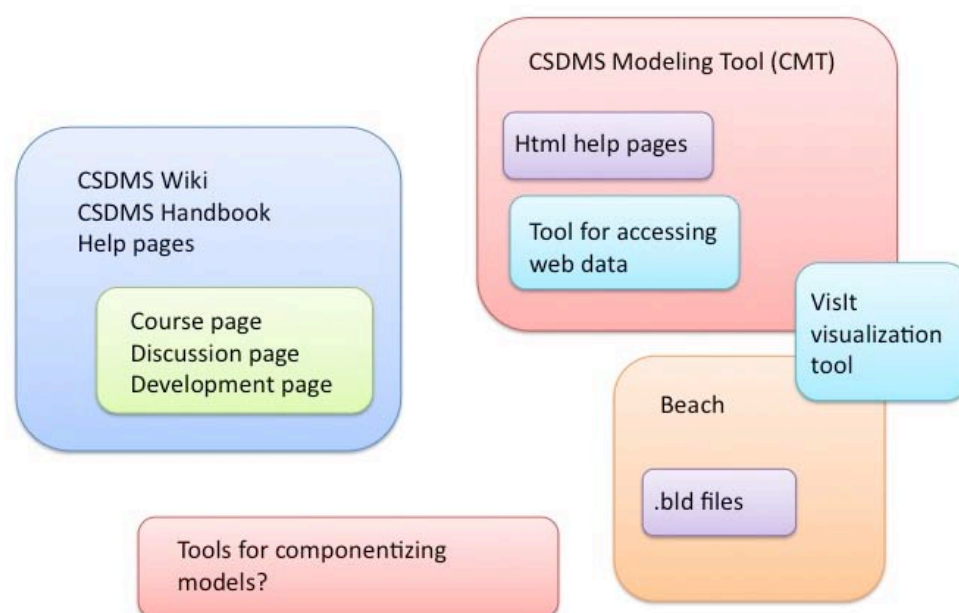
- CSDMS wiki, including a course page and a discussion page

However, we should not restrict ourselves to this infrastructure in imagining and developing future use cases, and even here I've identified some capabilities that may or may not be currently in place.

Note that Instructor1 and Instructor2 are used interchangeably below. I've also avoided issues of homework or grading in favor of a more collaborative environment. A key theme to consider throughout is that students have the tools needed to adequately document their model runs, both to support student collaboration and instructor verification of completion of assignments.

The "How" following each paragraph attempts to identify the existing capability, or cyberinfrastructure, or summarize some of the software requirements that need to be put in place.

CU Modeling Course Cyberinfrastructure



Phase 1. Preparation

Prior to the course, Instructor1 requests that all enrolled students join CSDMS and also obtain an account on beach. Obtaining access to beach through the University of Colorado will take 5-7 business days.

How: Students fill out forms on CSDMS wiki

Instructor2 creates a wiki page for the course and makes both Instructors administrators. Instructor2 posts basic course information, contact information for Instructors, a link to the course syllabus, and general references.

How: Instructors create a CSDMS wiki page with links to other documents. Syllabus should provide links to all associated wiki help pages, CSDMS Handbook sections, and tutorials for each section of the course.

Instructor1 posts links on the course page to relevant model questionnaires, CSDMS help pages, and other wiki pages for the course.

How: Model questionnaires must be available on the CSDMS wiki for each model that the course uses.

Instructor2 creates a discussion page on the CSDMS wiki, and posts an initial question for all participants: "Describe your previous modeling experiences and interests."

How: Create a discussion page on CSDMS wiki to save interactions and make them visible to others within the course; non-email discussion capability.

This capability is currently available as a "Talk" page—we just need to enforce the editing conventions.

(http://www.mediawiki.org/wiki/Help:Talk_pages)

Does this page or ones that link from it need to be password-protected to allow conversations to be just seen by those inside the course? To what extent should the course results and progress be viewed by other CSDMS members and/or the general public? Need to be able to link to other documents and pdfs within the discussion.

Phase 2. Students Join the Course

Students join CSDMS (obtaining wiki access) and sign up for a beach account (obtaining CMT and beach access). While joining CSDMS the students can provide contact information, a link to their personal website, and other profile information.

How: Students fill out forms on CSDMS wiki

Instructor1 ensures that students have read permission to the course page, and read and write permission to the discussion page. This allows them to contribute posts to the discussion page while preserving the content of the main course page.

How: Instructors must be able to change permissions for students.

Students post responses to the instructor's question on the discussion page.

How: Students must be able to properly edit the discussion page.

Phase 3. Introduction to CSDMS and its High Performance Computing System.

Students launch CMT directly from the CSDMS web and login using their beach account. Students review html help files contained within CMT to become familiar with the CMT environment.

How: Students must have Java and VPN access.

Phase 4. Lectures on theory and applications of several models.

To support the lectures, Instructor1 provides links on the course page to model documentation and .bld-specific tutorials for several models currently available in CMT.

How: Instructors must be able to link from the course page to html help within CMT.

Instructor2 uploads pdfs of scanned journal articles or textbook chapters to a specific directory on beach (this is to limit copyright restrictions and avoid photocopying?)

How: Instructors and students must have access to a course directory on beach.

Phase 5. Lab exercises to explore 1) a coupled hydrological-glaciological model, i.e. TOPOFLOW and GC2D, 2) a coupled river-delta model, i.e. HydroTrend and CEM, 3) a stratigraphic model, SedFlux, and 4) a landscape evolution model, Erode.

Students load pre-determined configuration files (.bld) and practice doing model runs. Students click on the visualization tab and are able to create several plots of the data using an interactive GUI. They can compare these figures with example figures in the corresponding tutorials for each .bld file.

How: Students must have access to VisIt.

Students modify settings from the initial .bld file (such as swapping out components, or changing parameters within a component) and save a new configuration file for their particular model run. After running the new model, students save the .bld file and output files to a shared directory so other students may learn from these runs without having to recreate them. Students post the file path from their model runs, and associated model run metadata on the discussion page.

How: Students must be able to save output files into different directories.

Students create figures or movies from their model output files and upload these along with captions to potentially several places where the images can be viewed by other students, and/or reviewed and graded by the instructors.

- a personal page on the wiki
- the discussion page on the wiki
- a specific directory on beach

How: Students must have access to these components of the wiki, or be able to generate new html help pages.

Students use scripts to create new html files with their model figures and model run metadata (based on the model run configuration settings found in the associated .bld files). These pages can then be incorporated into CMT's set of help pages as metadata helpful for future CMT use.

How: Students must be able to generate new html help pages.

Students use the visualization tool to compare or overlay output files from their peers' model runs (using saved output files from one or more other students). They save several plots to the above listed places for discussion and grading purposes.

How: Students must have access to other students' model output. The discussion page should have a table or some way of logging when different model iterations are completed, so the class can keep track of this.

Students use components within CMT to ingest hydrologic or other data from a web server. They then use these data as input data for model runs.

How: Web-based data server access must be incorporated into CMT functionality, along with corresponding help documentation.

Phase 6. Design and run simulations for an independently designed research question within one of these modeling domains.

Working within the four domains above (e.g., using existing CMT components), students either build model configuration files from scratch or modify pre-existing .bld files to explore different research questions. Students will likely need to generate new input files. Students generate figures and movies as above and post to several places.

How: Students must be able to create and import input files for their model runs; documentation and tools must be present.

Instructor1 fields complaints that students are having difficulty with their model runs, or notices that the results students are posting have errors. They are able to examine how the model was run, make changes to the configuration, and rerun the simulation.

How: Instructors must be able to access .bld files and log files from student model runs, and then modify them.

Phase 7. Course Wrap-Up

In addition to university-led Faculty Course Questionnaires, Instructors administer an optional, anonymous survey to students regarding their experience in the course (e.g., joys/frustrations while using CMT, goals or barriers to future involvement with CSDMS, suggestions for improvements to future courses).

How: Anonymous survey form on the wiki?

Instructor1 archives student results either in a cleaned-up discussion page, or as new individual html help files that can be used by future users of CMT.

How: Instructors should be able to copy selected student .bld files over to the main example directories for CMT.

Appendix 3: Recommended Protocols for Model Software Developers

James P.M. Syvitski, Community Surface Dynamics Modeling System (CSDMS) Integration Facility,
Eric Grunsky, Natural Resources Canada, Geological Survey of Canada, 601 Booth St., Ottawa, K1A 0E8,
Canada and Editor-in Chief of Computers & Geosciences.

Abstract

Developers of research grade Geoscience models should ensure that their software contributions follow these protocols: 1) Hold an open-source ‘GPL v2’ or a ‘GPL v2 compatible’ license; 2) Be widely available to the community of scientists through an international model or code repository (e.g. CSDMS or C&G); 3) Undergo a level of peer review; 4) Be written in an open-source language, or have a pathway for use in an open-source environment; 5) Where appropriate, be written or refactored to allow for componentization by having an interface, with exchange items documented; 6) Be accompanied with a formal metadata file, along with test files; 7) Be clean and well-documented. Software may be vetted at three levels: 1) the model behaves as advertised; 2) the code meets pre-approved specifications or follows community protocols; and 3) the model provides for an acceptable depiction of nature. Freely available and open-source code allows for complete information transfer and replication of results — the foundation of modern science. Open source allows for the original developer to be recognized, protected, and their software to have the greatest impact on science.

Introduction

At the 2009 International Association of Mathematical Geosciences (IAMG) annual meeting at Stanford University, representatives of Community Surface Dynamics Modeling System (CSDMS) and IAMG met to review protocols adopted by CSDMS as a possible guide for code submission to IAMG’s journal Computers & Geosciences (C&G). Here we review this discussion and argue for protocol adoption beyond CSDMS and C&G, and for the wider Geoscience community. The paper details concepts related to code sharing in general using community modeling concepts as a guide.

About the Community Surface Dynamics Modeling System

CSDMS is an integrated community of experts who promote the quantitative modeling of earth-surface processes. CSDMS develops, supports, and disseminates integrated software modules that involve the Earth surface — the dynamic interface between lithosphere, atmosphere, cryosphere, and hydrosphere. CSDMS coordinates a growing community of more than 78 U.S. Academic Institutions, 17 US Federal labs and agencies, 67 non-U.S. institutes from 20 countries, and companies within an industrial consortium. CSDMS serves this diverse community by promoting the sharing and re-use of high-quality, open-source modeling software. The CSDMS Model Repository in January 2010 comprised a searchable inventory of more than 170 models with more than 3 million lines of code. CSDMS also offers the Geoscience community a Model-coupling Framework, a Data Repository related to the CSDMS mission, and a CSDMS Education portal.

About the journal Computers & Geosciences

C&G features research articles and application articles that describe new computation methods for the geosciences: e.g. computational infrastructure, informatics, collection, representation, management, analysis, visualization, as well as for software development and scientific and social use of Geoscience information and review articles and short notes are also accepted to support this general mission.

The aims of CSDMS and C&G overlap a great deal, and while both have complementary missions, they serve the community in different ways, the latter concentrating on peer-reviewed journal papers that may or may not be accompanied by open-source software. Code submitted to C&G is presently archived and made available to the community through an IAMG portal. In the past, code submissions were not always reviewed as part of the normal review of the submitted paper. In that sense code submitted to the C&G repository (<http://www.iamg.org/CGEditor/index.htm>) is simply parked at their portal ready for downloading. Although program code is typically tested by reviewers, no rigorous procedures are in place with specific criteria for formal testing. Questions related to downloaded code remain a private affair between a reader and the author(s).

CSDMS protocols for model contribution

Protocols are the procedures or the system of rules governing contributed community software, and provide both technical and social recommendations to model developers. Software contributions to the CSDMS Model Repository should:

- 1) Hold an open-source license.
- 2) Be widely available to the community of scientists.
- 3) Receive a level of vetting, for example the software should be determined to do what it says it does.
- 4) Be written in an open-source language, or have a pathway for use in an open-source environment.
- 5) Be written or refactored to allow for componentization by having an interface, with specific I/O exchange items documented.
- 6) Be accompanied with a formally defined metadata file, along with test files.
- 7) Be clean and documented using keywords within comment blocks to provide basic metadata for the model and its variables.

These protocols provide extensibility to software and allow for state-of-the-art tools to convert stand-alone models into flexible, "plug-and-play" components that can be assembled into larger applications (Syvitski et al., in press). The protocols also allow a migration pathway towards high-performance computing (HPC). We describe each protocol below.

Open-Source Software license

The usage and redistribution of software is defined by its software license. Software licenses come in a range of variety including proprietary, free and/or open source. Code may be distributed as an executable or as source code. Proprietary licenses control the usage or redistribution, and the copyright remains with the publisher. Proprietary software often involves commerce, made available in closed-source binary format, with legally binding use- or view-restrictions.

A free, open source license in contrast allows the software code to be: 1) inspected, 2) modified, and 3) redistributed. The GNU General Public License (GPL) also allows the original or modified version of the software to be commercially sold, even if the code remains freely available. Open source licensing requires that the source code be available. The GPL v2 license is widely used by free open source software developers and because the license:

- Provides a better quid-pro-quo for developers
- Establishes collaboration between people
- Protects the developers work
- Encourages increasing the amount of free software.

Using the GNU GPL license requires that all the released improved versions be free software. This means you can avoid the risk of having to compete with a proprietary modified version of your own work. A developers' project is likely to be more successful if it accommodates fellow developers who also use the GPL license. CSDMS urges program developers to choose 'GPL v2' or a 'GPL v2 compatible' license to make it possible to couple the model with other models such that other people can use them. Below we list approved licenses by the Free Software Foundation (FSF) that are GPL v2 compatible:

- Artistic License 2.0
- Berkeley Database License
- modified BSD license
- Boost Software License
- Cryptix General License
- Eiffel Forum License version2

- GNU Lesser General Public License
- Intel Open Source License
- ISC license
- MIT license
- Python Software Foundation License 2.0.1, 2.1.1 and newer
- W3C Software Notice and License
- zlib/libpng license
- Zope Public License version 2.0

To maximize software use by fellow scientists and to make it free software, the following lines of notice must be incorporated into the program, attached to the start of each source file to most effectively convey the exclusion of warranty. Each file should have the "copyright" line and a pointer to where the full notice is found:

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Many scientists are strong believers that science is advanced through mutual cooperation. Community modeling involves the collective efforts of individuals that code, debug, test, document, run, and apply models and modeling frameworks. Community modeling relies on open-source code to address the practical need of contributing developers to examine and modify the code. Open-source code provides complete information transfer. This *transparency* is important because code is the ultimate statement of the scientific hypotheses embodied in a numerical model, and their implementation. In the world of software, *details are important*. A scientific article describing code, as is often the case with Computers & Geosciences articles, may provide the theoretical equations, but the solution to these equations can take numerous forms, and each solution has its pyramid of assumptions and limitations. Therefore open-source code allows for full *peer review* and *replication of results* — the foundation of modern science.

If a geologist was to map outcrops in a certain part of our landscape, and subsequently write a science article about their findings, another geologist sooner or later could go to the same landscape and determine whether the original data and interpretations were legitimate and appropriate. Peer review is as important in the science of software engineering as it is in the observational sciences.

Open source code allows for reuse, often in new and clever ways. This certainly reduces redundancy. In the U.S., Congressional law dictates that software developed with public funds must become publicly available, with national security exceptions. Open-source code is an effective way to meet this requirement. CSDMS promotes the development of free open source code since it operates largely with public funds in the public domain. Yet even industry supports the CSDMS open-source efforts.

Open source does not mean that the original developer is not recognized. Developers are recognized with the metadata associated with each model, with GPL2 software license protection, through community exposure, vetting and recognition, and through accelerated citations within peer-reviewed publications.

Software Availability

In the world of science, software code is often considered “research grade”. That means that it is often relatively untested, may contain bugs, and might not be at the standards required for true “commercial grade” or “operational grade” code. Coding glitches in research grade code are often unknown by the original author. With wider community use, such problems are discovered and either rectified by the original author or the bug discoverer. Commercial grade code is widely available, limited to the details related to the financial transaction and other proprietary redistribution and use restrictions. Operational grade code describes code used by governments for monitoring or enforcing, and may or may not be widely available to the public. The Weather and Research Forecasting (WRF) model is widely adopted by weather services worldwide to make operational predictions. WRF code is open source. Other operational models, such as NOAA’s WAVEWATCH III®, an ocean wave model used for hindcasting, nowcasting and forecasting, is subject to U.S. export restrictions. The code is open source and widely available, but a short list of countries are not allowed access.

Research grade code should be widely available to the community of scientists. The best way to have the code available is through an appropriate international repository. Geoscience models can be submitted to the CSDMS Model Repository. Code associated with articles in Computers & Geosciences can be submitted to its C&G Code Repository. Since the code is open source, it can appear in more than one Repository. Too often code is issued with an open source license (or no license at all) but access to the code is restricted to access through the author. Unfortunately this allows the author to decide who they will give the code to. This runs contrary to the transparency needed in science, and we discourage this level of availability.

Some models such as ROMS, the Regional Ocean Modeling System, support a very large community (1000s) who use and develop the model. New users must register through the ROMS portal. We view this level of access as acceptable as the ROMS developers need to demonstrate a large user group, to those who fund their program activity. ROMS is open source and free without restrictions to all legitimate scientists.

Vetting Software

This is perhaps the most difficult subject of all of the CSDMS protocols. Vetting is the review and approval process of, in our case, Geosciences software. Vetting comes in many forms, from informal to formal, and from objective to subjective. Software vetting has three components: 1) verification that the model behaves as advertised; 2) confirmation that the code meets pre-approved specifications, for example is accompanied with metadata documentation or meets community protocols; and 3) demonstration that the model provides an accurate depiction of nature. Vetting in the context of C&G would mean that the software was subjected to some level of independent peer-review although there are no formal rules in place for reviewers.

In the world of community modeling, it is not unusual for software to be reviewed by a working group of specialists. Reviewers would be given a set of guidelines and standard questions, and would be asked to test the model and respond to the queries. The review officer behaves like a journal editor in the sense that identified problems might require fixes before being given the stamp of approval of the community. For a journal such as C&G, the process might involve a reviewer to provide a similar analysis. The reviewer could be independent of the paper review, or might agree to do both activities on behalf of the community and journal, even though this extends beyond the current review mandate of the journal.

Answering whether a model offers an accurate depiction of nature is complex — science is provisional, and a yes/no answer is often not possible. This is true with all scientific manuscripts to some degree, code being no different. After determining that the model does what it says it does, the reviewer might reflect on the level of testing that lies behind the model. For example and when appropriate, has the model been run against known benchmark experiments, and compared with field or laboratory observational data? Are the claims associated with the model within acceptable uncertainties related to the time and space resolutions of the model (or other appropriate resolutions)?

More subjective are questions of performance that often relate to how the conservation equations are solved. Performance often translates as the usefulness to an end user. In the field of fluid dynamics, performance varies with each level of complexity: advection-diffusion, shallow water wave equation, Reynolds-averaged Navier Stokes, large-eddy simulation, direct numerical simulation, hydrostatic, non-hydrostatic, Boussinesq, non-Boussinesq. Ultimately transparency trumps subjectivity.

Open-Source Programming Language

Computer software is written in a programming language that is able to access a target compiler to allow precise translation between source code and object code — an ‘executable’ able to run on a particular computer platform. In general all source code is written in a higher-level computer language and the executable is written in machine code. Programming languages are static only in narrow release formats. There are many versions of Fortran, for example, with new versions having greatly enhanced abilities to work with modern platforms and compilers and their libraries for enhanced functionality.

In the open source community, developers develop their models using an open-source language (e.g. C, C++, any Fortran, Java, Python), or a language that has a pathway for use in an open-source environment. A developer should test whether their code can compile using an open source compiler (e.g. GNU Fortran compiler). This will ensure the greatest chance of portability of the code from one computational platform to another, minimizing problems.

The CSDMS community requires its code to be written in an open-source language so that the various models can communicate with each other using ‘Babel’. Babel is an open-source, language interoperability tool (and compiler) that automatically generates the “glue code” that allows components written in different computer languages to communicate (Dahlgren et al. 2007). Babel currently supports C, C++, Fortran 77, 90, 95 & 2003, Java and Python. Almost all of the Geosciences models held in the CSDMS Model Repository are written in one of these languages. Babel enables the passing of variables with data types that may not normally be supported by the target language (e.g. objects, complex numbers). To create the glue code needed components written in different programming languages to pass information between them, Babel only needs to know about the interfaces of the components. It does not need any implementation details. Babel can ingest a description of an interface in one of two “language neutral” forms, XML (eXtensible Markup Language), or SIDL (Scientific Interface Definition Language). SIDL provides a description of a scientific software component interface, including the names and data types of all arguments and the return values for each member function.

Software written in other high-level languages might have a translation pathway to one of the BABEL-supported open-source programming languages. For example, CSDMS offers the community an enhanced version of ‘i2py’ designed to convert IDL source code to the open-source Python language.

Refactoring a Model into a Component

Most models are written to be stand-alone models. In other words, the software is designed to define and initialize its variables and arrays, read in any needed input data, run the program to get realizations according to its discretized algorithms, write out its output, and end the run. In the field of environmental science, a model would cover a given domain, for example lake dynamics. After some time, the model may be further developed to cover other environmental domains, so for example a lake model might gain a river basin model. Large codes often involve more than one environmental process or domain, for example wind-driven currents plus wave dynamics in oceanography, or channelized flow overland flow and groundwater flow in

hydrology. Codes that involve multiple domains often involve a diversity of experts needed for their development, and thus the birth of community modeling. Inevitably when the codes reached a certain level of complexity, the codes became modeling frameworks. Too large for individuals to understand all the details, developers would pass on their process modules to be implemented by a master(s) of the code.

Modern software engineering has developed new standards for data exchange, model interfaces, and ways to employ varied computational platforms (laptops, servers, high performance computing clusters, distributed or cloud computing). In the world of community Geosciences modeling, there has been strong movement towards developing models as components within architectures and frameworks, each offering interfaces, exchange items (Syvitski et al., in press). Below we introduce these terms and show how the CSDMS community has adopted these concepts. While these concepts may not be appropriate for all contributions to the journal Computers and Geosciences, they are highly appropriate for developers wishing to enter the world of community modeling.

Frameworks increase a developer's productivity, and a user's functionality. Environmental modeling frameworks support the coupling of models into functional units (e.g. components, classes, or modules), component interaction and communication, time stepping, regridding of arrays, scaling of spatial data, multiprocessor support, and cross language interoperability. A framework may also provide a uniform method of trapping or handling exceptions (i.e. errors).

An Architecture is the set of standards that allow components to be combined and integrated for enhanced functionality, for instance on high-performance computing systems. The standards are necessary for the interoperation of components developed in the context of different frameworks. Software components that adhere to these standards can be ported with relative ease to another compliant framework.

Components are functional units that once implemented in a particular framework are reusable in other models within the same framework, with little migration effort. One advantage of using a modeling framework is that pre-existing components can be reused to facilitate model development. Component-based modeling brings about the advantages of "plug and play" technology. Component programming builds upon the fundamental concepts of object-oriented programming, with the main difference being the presence of a framework. Components are generally implemented as classes in an object-oriented language, and are essentially "black boxes" that encapsulate some useful bit of functionality. A framework provides the environment wherein components can be linked together to form applications. A component differs from an ordinary subroutine, module or class, because they can communicate with other components written in a different programming language.

Components typically provide one or more interfaces by which a caller can access their functionality. In the context of plug-and-play components, the word interface refers to a named set of member functions (methods), defined with regard to argument types and return types but without any actual implementation. An interface is a user-defined type, similar to an abstract class, with member function "templates" but no data members. A component contains an actual implementation for each member function (and possibly member functions beyond the ones that comprise a particular interface). Therefore it is possible and often useful for a single component to expose multiple, different interfaces, allowing a component to be used in a greater variety of settings.

Most surface dynamics models advance values forward in time on a grid or mesh and have a similar internal structure. This structure consists of lines of code before the beginning of a time loop (the initialize step), lines of code inside the time loop (the run step) and finish with additional lines after the end of the time loop (the finalize step). Virtually all component-based modeling efforts (e.g. ESMF, OpenMI, OMS, CSDMS) recognize the utility of moving these lines of code into three separate functions, with names such as Initialize, Run and Finalize, or **IRF** for short (Syvitski et al., in press). These three IRF functions constitute a simple model-component interface that provides a calling program with fine-grained access to a model's capabilities and the ability to control its overall time stepping so that it can be used in a larger application. The calling program "steers" a set of components and so is referred to as a driver.

A meaningful linkage of components often requires both data exchange and IRF functions. A model's interface must also describe functions that access data that it wishes to provide (getter functions) and methods that allow other components to change its data (setter functions). With getter and setter interface functions, connected components can query generated data as well as alter data from the other model. Component connections are made through 'provides ports' and 'uses ports' within a Common Component Architecture framework (Armstrong et al. 1999). The first provides an interface to the component's own functionality (and data). The second specifies a set of capabilities (or data) that the component requires from another component to complete its task. A provides-port that exposes an IRF interface, allows another component to gain access to its initialize, run, and finalize steps. The uses-port presents functionality that it lacks itself and therefore requires from another component. The component is not able to function until it is connected to a component that has the required functionality. This allows a model developer to create a new model that uses the functionality of another component without having to know the details of that component or to even have that component exist at all.

This style of plug-and-play component programming benefits both model programmers and users. Within a framework model developers are able to create models within their areas own of expertise and rely on experts outside their field to fill in the gaps. Models that provide the same functionality can easily be compared to one another simply by unplugging one model and plugging in another, similar model. In this way users can easily conduct model comparisons and more simply build larger models from a series of components to solve new problems.

For example standalone models are made into component models by dividing them into tasks that other component models could use (Fig. 1).

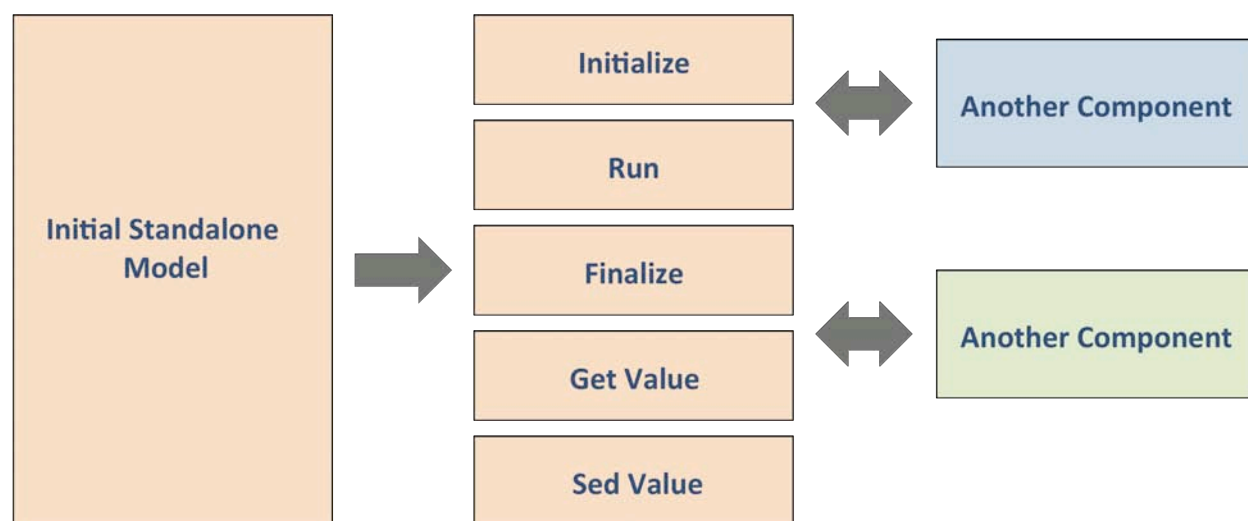


Figure 1. Refactoring a stand-alone model for linkage to other model components.

Once a contributed model has been refactored into a component model, it becomes available to be linked to other appropriate models within the CSDMS component library to provide value added products beyond the intention or domain of the original model (Fig. 2). The language neutral compiler BABEL allows for models to communicate across various languages (Fig. 2). Access to CCA/CSDMS, OpenMI and ESMF Services, such as grid remapping tools, is then made available. Databases and files can also be componentized and coupled within the CSDMS framework.

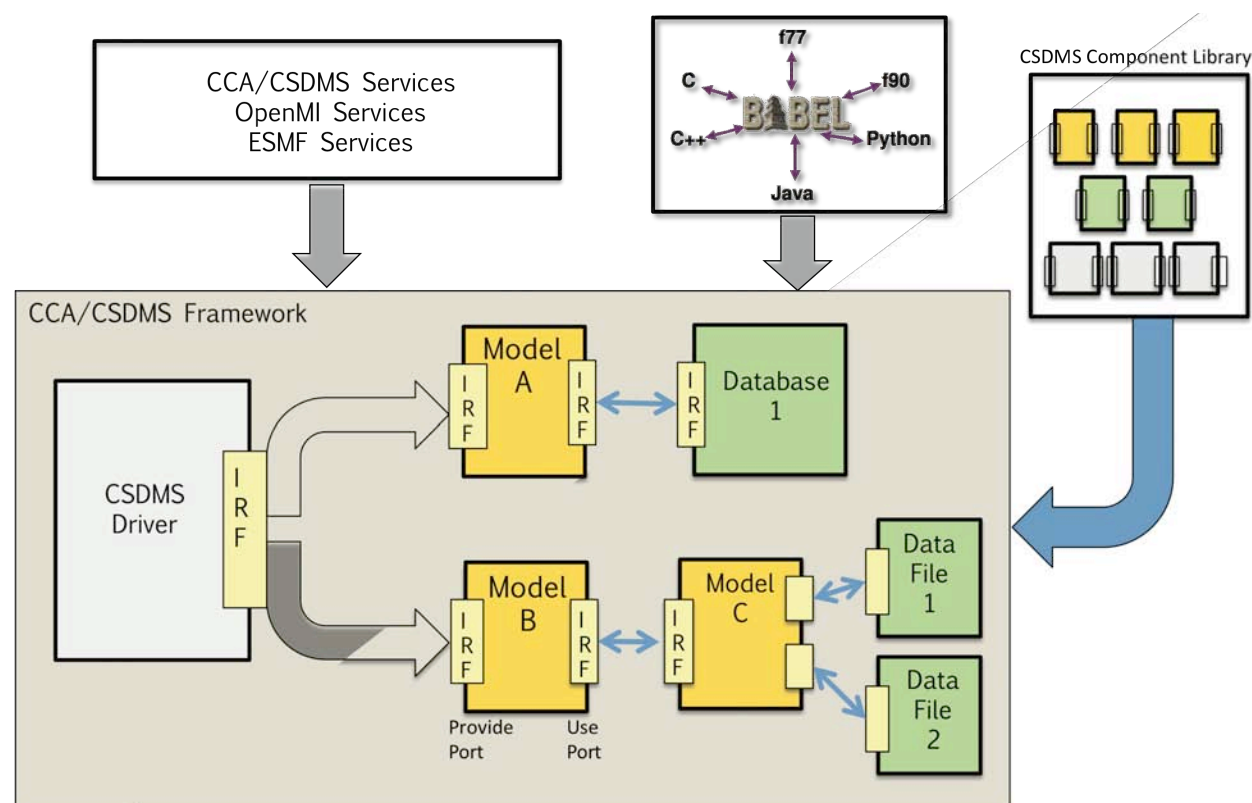


Figure 2. The CSDMS model coupling domain.

Metadata Description File

Information that describes contributed software is a necessary requirement for any code submission to either CSDMS or C&G. Appropriate metadata should cover contact information on the code developer(s), and information on the model: model domain, spatial dimensions (e.g. 2Dxz), and spatial extent (e.g. regional scale). The model description, if it is not already described in a paper, should include processes represented, key equations and key parameters, length scale and resolution constraints, time scale and resolution constraints, and numerical limitations and issues. Technical description should include: supported platforms, programming language, code optimization (e.g. parallel computing), development period, code availability and repository, software license, framework or interface compliance, memory requirements, and typical run times. Metadata should also include a description of the input and output files, including their format and whether pre- or post-processing is needed, and type of visualization software that is required. Unless described in an accompanying paper, the level of testing should be described. Input files to run the model and output files to verify the initial model run should also be included with the metadata.

Clean and Documented Code

Submissions to a model or code Repository should be refactored for maintenance and extensibility (Fowler, 1999; Kerievsky, 2004). Extraneous source lines that have been commented out should be removed. Code should be well documented both for future developer readability and to eliminate future mistakes. Where possible source code should be annotated using keywords within comment blocks to provide basic metadata for the model and its variables. Units should be well defined.

Summary

While the CSDMS protocols are mission oriented, they also offer good practice for code submission to the Computers & Geosciences Repository, and for code development in general. CSDMS protocols have been widely vetted within its extensive community (Hutton et al., 2010), and among other affiliated modeling

communities (Voinov et al., 2010). The protocols provide developers with recognition and protection, increased longevity and usability of the source code, and greater penetration into the community of a model development or its accomplishments. The protocols reflect the increased level of accountability required by funders. They eliminate duplication and further the advance and enhance science. We recommended these protocols for code submission to Computers and Geosciences

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