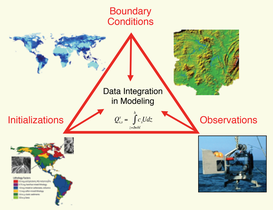
CSDMS2.0: Computational Infrastructure for Community Surface Dynamics Modeling

James PM Syvitski, Eric WH Hutton, Scott D Peckham, Irina Overeem, Albert J Kettner
CSDMS Integration Facility, INSTAAR, U. Colorado, Boulder CO,
http://csdms.colorado.edu/wiki/Main_Page; James.syvitski@colorado.edu

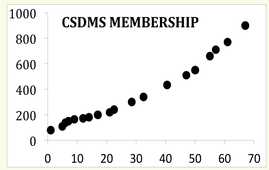
Goal:
The Community Surface Dynamic Modeling System (CSDMS) is an NSF-supported, international and community-driven program that seeks to transform the science and practice of earth-surface dynamics modeling. CSDMS develops, integrates, disseminates & archives software to define the earth's surface dynamics.

CSDMS offers:
1) Capacity building & community networking
2) Open-source Model Repository
3) HPCC test bed & support for running models
4) Education & Knowledge Products
5) Protocols & GUI for running models
6) Model Coupling & Model Reuse



CSDMS capacity building and community networking :
* ~900 members contribute to 8 Working or Focus Research Groups,
* a CSDMS Interagency Committee (22 Federal agencies),
* a CSDMS Industrial Consortia (18 companies),
* more than 380 International institutions from 60+ countries :
Argentina, Australia, Austria, Bangladesh, Belgium, Bolivia, Brazil, Bulgaria, Cambodia, Canada, Chile, China, Columbia, Cuba, Denmark, Egypt, El Salvador, France, Germany, Ghana, Greece, Hong Kong, Hungary, India, Indonesia, Iran, Iraq, Ireland, Italy, Japan, Kenya, Malaysia, Myanmar, New Zealand, Nigeria, Norway, Pakistan, Peru, Poland, Portugal, Scotland, Singapore, South Korea, Spain, Sweden, Switzerland, Taiwan, The Netherlands, UK, United Arab Emirates, Uruguay, USA, Venezuela, Viet Nam

Terrestrial	400
Coastal	320
Hydrology	310
Marine	225
Cyber	140
EKT	130
Carbonate	60
Chesapeake	45



CSDMS Open-source Model Repository :
* More than 200 Open Source models and modeling tools; >5.7 million lines of code;
* Valuable metadata; key references; I/O test data
* Codes: 47% C or C++, 27% Fortran, 16% Python, 10% other
* CSDMS **Model Domain**: i) Cryosphere (glaciers, permafrost, icebergs), ii) Geodynamic & Stratigraphic Models, iii) Hydrosphere: reach to global, iv) Marine circulation, surges, tides, waves, gravity flows, v) Climate & Weather
* **Model approaches**: 1) Landscape / Seascape Evolution Models, 2) Morphodynamic Models, 3) Transport / Circulation Models
* **CSDMS Data Repository** includes model initialization data; data tools; test & validation data; benchmarking data

Domain	Models	Tools	Components
Terrestrial	75	45	33
Coastal	51	3	5
Marine	43	4	8
Hydrology	51	38	43
Carbonate	2	1	0
Climate	10	2	0

Increasing Complexity ➡
- Geometric ➡ Diffusive ➡ ADM ➡ SWEM ➡ RANS ➡ LES ➡ DNS
- Boussinesq ➡ non-hydrostatic
- FDM ➡ FVM ➡ FEM
- Explicit ➡ implicit
- 1D ➡ 2D ➡ 3D
- Eulerian ➡ Lagrangian
- Steady-state ➡ non-steady state
- Newtonian ➡ non-Newtonian
- Depositional ➡ post-depositional
- Time marching ➡ compute & drift ➡ event-based
- Local ➡ regional ➡ global
- Siliciclastic ➡ carbonate
- Abiotic ➡ biotic

CSDMS HPCC test bed & support for running models :
* >170 CSDMS members run simulations on the CU/USGS experimental HPCC Beach and have met a use criteria :
  --- Running a CSDMS models to advance science
  --- Developing a model for the CSDMS model repository.
  --- Developing a data or visualizations systems in support of CSDMS models.
* Beach 8Tflop/s HPCC: 88 compute nodes, 704 3-GHz cores, 2-4 GB/core mem non-blocking infiniband, ~100TB RAID storage; ~3PB offsite storage
* CU Janus offers 16,416-cores, 150 Tflop/s, 1368 nodes, 6 cores/processor x 2, 2.8 GHz cores, 2 GB/core memory, non-blocking Infiniband; 1PB RAID, 3PB offsite storage

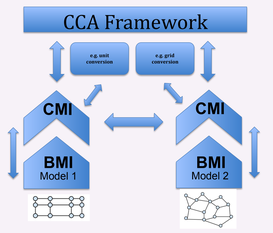


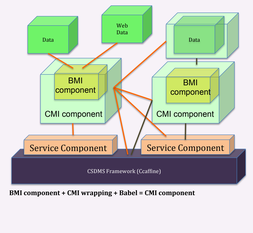
References:
Syvitski, JPM, RL Slingerland, P Burgess, E Meiburg, AB Murray, P Wiberg, G Tucker, AA Voinov, 2010, Morphodynamic models: An overview. In: Vionnet et al. (eds) River, Coastal and Estuarine Morphodynamics: RCEM 2009, Taylor & Francis Group, London, ISBN 978-0-415-55426-8 CRC Press, p. 3-20.
Hutton, EWH, JPM Syvitski & SD Peckham, 2010, Producing CSDMS-compliant morphodynamic code to share with the RCEM community. In: Vionnet et al. (eds) River, Coastal and Estuarine Morphodynamics RCEM 2009, Taylor & Francis Group, London, ISBN 978-0-415-55426-CRC Press, p. 959-962.
Syvitski, JPM, Hutton, EWH, Peckham, SD, Slingerland, RL, 2011. CSDMS — A modeling system to aid sedimentary research. The Sedimentary Record 9, 1-9.
Syvitski, JPM, Peckham, SD, David, O, Goodall, JL, Delucca, C, Theurich, G 2013. Cyberinfrastructure and Community Environmental Modeling. In: Handbook in Environmental Fluid Dynamics, Editor: HJS Fernando, CRC Press/Taylor & Francis Group, LLC. ISBN: 978-1-4665-5601-0. Chapter 28: 399-410.
Peckham, SD, EWH Hutton and B Norris 2012, A component-based approach to integrated modeling in the geosciences: The Design of CSDMS, Computers & Geosciences http://dx.doi.org/10.1016/j.cageo.2012.04.002
Peckham, SD and JL Goodall 2012, Driving plug-and-play models with data from web-services: A demonstration of interoperability between CSDMS and CUAHSI-HIS, Computers & Geosciences http://dx.doi.org/10.1016/j.cageo.2012.04.019
Overeem, I, Berlin, M, Syvitski, JPM, 2012. Strategies for Integrated Modeling: the Community Surface Dynamics Modeling System Example. Environmental Modelling and Software. doi:10.1016/j.envsoft.2012.01.012
Ashton, AD, Hutton, EWH, Kettner, AJ, Xing, F, Kallumadikal, J., Neinhuis, J, Giosan, L (2012). Progress in coupling coastline and fluvial dynamics. Computers & Geosciences. http://dx.doi.org/10.1016/j.cageo.2012.04.004

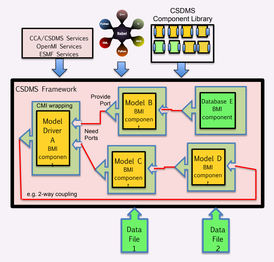
CSDMS Education & Knowledge Products:
Student labs (10), modeling short courses (7), lectures (85), textbooks (5), Meeting presentations (290), Real event movies (32), Laboratory movies (14), Model animations (60), & Imagery.
CSDMS 2.0 EKT will advance:
1) Simple model animations to function as visualization in lectures; hosted on the CSDMS YouTube channel.
2) CSDMS model animations for NOAA's 'Science on a Sphere' and Magic Planet displays.
3) 'Concept to Model' exercises to encourage students to formulate a concept model and translate this into a set of equations.
4) Simplified student 'play' models based on current CSDMS CMT technology.
5) Advanced models where learners can run complex scenarios, swap different modules in and out, and handle I/O data themselves.

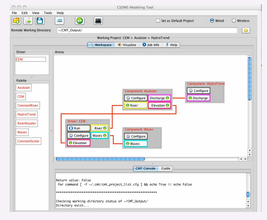
CSDMS CMT Framework & Services:
CSDMS Component Modeling Tool or **CMT** offers a "plug and play" programming environment to increase the performance of contributed models, increase their ease of maintenance and use, their flexibility, stability, portability, and future proofing.
Platform-independent GUI **CMT** (Linux, Mac OS X, Windows)
Language interoperability (C, C++, Java, Python, Fortran) with **Babel**;
Component preparation & project management using **Bocca**;
Low level model coupling within a HPC environment using **Ccaffeine**;
Single-processor spatial regridding or multi-processor spatial regridding – all grid types;
Component interface standards **BMI** & **CMI**;
Open-source standards (e.g. **CCA, SIDL, OGC, MPI, NetCDF, OpenDAP**) to avoid proprietary dependencies.
Visualization of large datasets in a multiple processor environment (**VisIt**)
Message passing within the HPC environment using MPI **(MPICH**) & **OpenMP** with **PETSc**

Protocols & GUI for running CSDMS-component models:
BMI CSDMS "Basic Model Interface" is a set of public functions for developers
CMI CSDMS "Component Model Interface" provides BMI components with CMT services for coupling models written in different: 1) programming languages, 2) computational grids, 3) time-stepping, 4) variable names, 5) units; or 6) to run models on HPCC, or to 6) write output to NetCDF files, or 7) etc



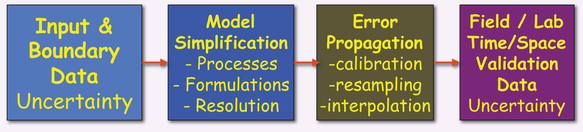






What's new in CSDMS2.0:
1) **CSDMS2.0** will support model applications within a web browser, on a wider variety of computational platforms, and on other high performance computing clusters to ensure robustness and sustainability of the framework.
2) Conversion of stand-alone models into "plug-and-play" components will employ automated wrapping tools.
3) Methods for quantifying model uncertainty are being adapted as part of the modeling framework.
4) Benchmarking data is being incorporated into the CSDMS modeling framework to support model inter-comparison.
5) Mapping model I/O variable names to CSDMS Standard Names for plug and play coupling.

New CSDMS2.0 initiatives:
1) An earth - ecosystem modeling initiative to capture ecosystem dynamics and ensuing interactions with landscapes,
2) A geodynamics initiative to investigate the interplay among climate, geomorphology, and tectonic processes,
3) An Anthropocene modeling initiative, to incorporate mechanistic models of human influences,
4) A coastal vulnerability modeling initiative, with emphasis on deltas and their multiple threats and stressors,
5) A continental margin modeling initiative, to capture extreme oceanic and atmospheric events generating turbidity currents, and
6) A Critical Zone Observatory (CZO) initiative, to develop compatibility between CSDMS architecture and protocols and CZO-developed models and data.



NSF COOPERATIVE AGREEMENT 0621695