CSDMS
Community Surface Dynamics Modeling System

CSDMS1.0 Final Report (2007-2012)

NSF Cooperative Agreement 0621695

COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

Executive Summary

In 2012, reviewers of CSDMS 1.0 have indicated: "CSDMS (Community Surface Dynamic Modeling System) is now a Keystone component of the earth surface community. It is particularly needed as we go forward in a complex, changing earth: the earth's surface is where we will experience the change; the CSDMS modeling foundry will be essential in helping to anticipate future states- and perhaps even to guide alternative futures"; and "the broad overview of modeling-based research gained by such an organization is of fundamental importance to the identification and implementation of interdisciplinary research connections." CSDMS integrates a diverse community of more than 1000 geoscientists representing 440+ international institutions (academic, government, industry) from 64 countries. The effort is supported by a CSDMS Interagency Committee (21 Federal agencies), and by more than 20 companies. By distributing more than 200 Open Source models and modeling tools, by providing access to high performance computing clusters in support of developing and running models, CSDMS is supporting the STEM education and knowledge transfer for our future earth scientists.

This Final report provides a review of the first five years of the CSDMS project covering the period 2007-2012. The report documents the organizational structure and finances (Chapters 1, 9, 11), the cyber infrastructure advances (Chapters 3, 4, 5, 7), education and knowledge transfer achievements (Chapter 5), and scientific accomplishments (Chapters 6, 7, 8, 12).

CSDMS 1.0 Final Report

Chapters

Chapter 1: CSDMS Mission and Community

Original CSDMS goal: *Create a unified capacity to predict the erosion, transport, and accumulation of sediment and solutes in landscapes and sedimentary basins over a broad range of environments and time and space scales. This modeling environment should catalyze Earth-surface process research over the coming decades by: empowering a broad community of scientists and students with computing tools and knowledge from interlinked fields, streamlining the process of idea generation and hypothesis testing through linked surface dynamics models, and enabling rapid creation and application of models tailored to specific settings, scientific problems, and time scales. The community is to include geoscientists with expertise and interests in the fields of hydrology, fluvial processes, biogeochemistry, sedimentology, stratigraphy, geomorphology, glaciology, oceanography, marine geology, climate forcing, active tectonics, surface geophysics, remote sensing, geomathematics, computational fluid dynamics, computer science, and environmental engineering.*

How well did we do: The Community Surface Dynamics Modeling System (CSDMS) has been realized to catalyze new paradigms and practices in developing and employing software to understand the earth's surface — the ever-changing dynamic interface between lithosphere, hydrosphere, cryosphere and atmosphere. CSDMS focus is on the movement of fluids and the sediment and solutes they transport through landscapes, seascapes and sedimentary basins.

CSDMS supports the development, integration, dissemination and archiving of community open-source software that reflects and predicts earth-surface processes over a broad range of temporal and spatial scales. The CSDMS Model Repository hosts 166 open-source models, 51 modeling tools, and 55 plug-and-play components, including: i) Cryospheric (e.g. glaciers, permafrost, icebergs), ii) Hydrologic, from reach to global scale, iii) Marine (e.g. ocean circulation), iv) River, coastal and estuarine morphodynamics, v) Landscape or seascape evolution, vi) Stratigraphic, and vii) Affiliated domains (e.g. weather & climate models). CSDMS also provides members access to high performance computing clusters in support of developing and running models, and offers a suite of products for education and knowledge transfer. About 70% of the models are distributed through a central Repository; others are distributed through linkages to existing community efforts. Centralized downloads exceed 10,700 and redirected download traffic to other sites is similarly high.

CSDMS works to continually increase its profile within relevant research, educational and industrial communities, both nationally and internationally. CSDMS continually interacts with its community to address community needs (i.e. model and education repositories), to provide a leading edge in Earth surface dynamics modeling. The CSDMS community grew from approximately 80 scientists in 2007 to more then 1,000 members (as of 05/01/13) represent 166 U.S. institutions (123 academic, 22 private, 21 federal) and 275 non-U.S. institutions from 63 countries (177 academic, 28 private, 70 government). There are now 441 affiliated institutions plus another 30 private memberships. CSDMS has a diverse membership that comes from all requisite environmental disciplines. The community is organized into disciplinary groups that while developed as subsets of the larger CSDMS community meet annually and share their advances with each other. All of the working groups have members who are also members of other groups.

NSF's Commodity Governance project conducted interviews with Integration Facility staff, and members, government users and students within the larger CSDMS community. More than 300 members have participated in various CSDMS meetings. Many others have utilized the model and education repositories on line, or have stayed informed through the CSDMS wiki website (more than 14 million visits), membership email correspondence, discussion forums, and twitter. The CSDMS YouTube Channel offers 141 short movies that have been viewed 112,605 times. About 15% of CSDMS members have contributed code and metadata, and about 15% of the membership use the common supercomputing resources.

New users of CSDMS software are trained annually in clinics and courses, with positive effects on self-efficacy and recruitment of new advanced developers. CSDMS has organized, hosted or sponsored 120 workshops, symposia and meetings, providing 15 short courses and 35 clinics. Student and professional awards are established.

CSDMS software architecture employs frameworks and services that convert stand-alone models into flexible "plug-and-play" components to be assembled into larger applications. Since certain aspects of surface processes are not well understood, the CSDMS modeling environment avoids “locking in” a particular approach, but instead allows users to easily swap components. The CSDMS Component Modeling Tool or CMT increases performance of contributed models and their ease of maintenance and use, flexibility, stability, portability, and future proofing. The CSDMS framework offers CMT as a platform-independent GUI that incorporates: i) language interoperability with Babel; ii) component preparation and project management using Bocca; iii) model coupling within a HPC environment using Ccaffeine; iv) single-processor spatial regridding (OpenMI Regrid) or multi-processor spatial regridding (ESMF Regrid) of all grid types; v) component interface standards BMI and CMI that operate with open-source standards to avoid proprietary dependencies (e.g. CCA, SIDL, OpenDAP, NetCDF, OGC, MPI); vi) visualization of large datasets in a multiple processor environment (VisIt); and vii) message passing within a HPC environment using MPI (MPICH), OpenMP and PETSc. Presently, 55 models are available as CMT components in aid of both research and education, by allowing users to run models on the CSDMS HPC without having to be an expert. So far, >60 graduate students reported in post-course surveys that they were unfamiliar with the use of running models on a HPCC beforehand, but after the course were able to comfortably run models and visualize simulations.

The Integration Facility offers model guidance to more than 50 CSDMS-related software development teams (see below).

CSDMS Collaboration and Support of U.S. Research Projects

1. Boulder Creek Critical Zone Observatory
2. Continental Shelf mud dispersal
3. Modeling water and sediment fluxes in the Fly River system
4. Model and data interoperability framework
5. Framework for integrating Earth Sciences data.
6. Humans Transforming the Water Cycle
7. Source To Sink Modeling
8. Landscape evolution modeling, Hawaii
9. Coupling Models and Information Systems for Hurricane Inundation
10. Modeling with a Virtual Globe Interface
11. Climate Change and Resilience across a gradient of Social-Ecological-Systems
12. Component-based modeling environment for watershed management,
13. Cyber-infrastructure to Advance Modeling & Teaching in Water-Related Sciences
14. A Fresh Approach to Modeling Shallow Marine Carbonate Sediments
15. Decadal Local Sea Level Forecasts Based on an Integrated Earth System Approach
16. Reconstructing ancient passive margin dynamics
17. Coastal Geomorphic Consequences of Wave Climate Change
18. Landscape evolution in the Anthropocene
19. Coupled modeling for vulnerability assessment and mitigation planning
20. Cause, consequence, and correction of bias in measurement of deposition rates
21. Modeling Floodplain Dynamics
22. Tectonic and Vegetation Controls on Deltaic Landform Evolution
23. Modeling the Critical-Zone Continuum Across Multiple Time Scales
24. Pedagogically tested teaching modules and software with models

25. Component-Based Software Architecture for Computational Landscape Modeling
26. Landscape-Scale Modeling of Sediment Routing
27. Sensitivity of Braided River Morphodynamics
28. Linking Erosional and Climatic Processes in Regions of Active Mountain Building
29. Interactive software infrastructure for sustaining a collaborative community
30. Innovation in the hydrologic sciences.
31. Deformation, material strength and landscape evolution modeling
32. Integrated Modeling and Analysis for the Anthropocene
33. Human-Landscape Systems
34. Rivers meandering in bedrock: Lithologic, climatic, and process controls
35. Reduced Complexity Modeling in the Environmental Sciences
36. Restoration of large, fine grained deltas: changes in hydrology and human activities
37. Sustainable path for coastal communities on the Mississippi River Delta
38. Sea-level rise and vegetation controls on deltaic landform evolution
39. Climate change adaptation in a coupled geomorphic-economic coastal system
40. Watershed analysis, visualization, and exploration

CSDMS Collaboration and Support of International Research Project

41. UK: Development of an International Anthropocene Research Community
42. UK: Glacimarine model development
43. UK: Development of integrated environmental modeling
44. Italy: Distributed Research Infrastructure for Hydro-Meteorology
45. New Zealand: Terrestrial Landscape Change: Margins Source-to-Sink
46. New Zealand: Long-term landscape response to a large Alpine Fault earthquake
47. Australia: Next generation spatially distributed model for soil profile dynamics
48. Denmark: Greenland Ice Sheet-melt modeling
49. Denmark: Integrating Dynamic Stratigraphy & Biochemical Cycles in ES Modeling
50. Norway: Coupling sedimentary, ecosystem and biogeochemical processes
51. Canada: Improved Quaternary stratigraphic framework for understanding Beaufort Sea
52. Multi-country Belmont Forum initiative on Delta Sustainability.
53. Multi-country 20th century European coastal flooding and erosion reanalysis

CSDMS Interaction with State or Federal Agencies

1) **CSDMS workshops** (USGS, Army Corps, ONR, NRL, ARO, USPS, USFS, NOAA, NASA, EPA, BOEM, NWS, DOE)
2) **CSDMS interagency discussions** (USGS, Army Corps, ONR, ARO, NOAA, NASA, USGS, EPA, BOEM, NWS, DOE)
3) **Funded projects** USGS, ONR, NSF, NOAA, NASA, BOEM, NOPP.
4) **Model coupling and reuse meetings** (EPA, USDA, BGS, ARO).
5) **CSDMS HPCC *Beach*** The USGS has partly funded the CSDMS High Performance Computing Cluster
6) **Meetings and code sharing:** DOE and National Labs (IDL, SNL, ANL, LANL, ORNL)

Institutional Membership.

U.S. Academic Institutions: as of 30 April 2013

1. Arizona State University
2. Auburn University, Alabama
3. Binghamton University, New York
4. Boston College
5. Boston University
6. Brigham Young University, Utah
7. California Institute of Technology
8. California State University - Fresno
9. California State University - Long Beach
10. California State University – Los Angeles
11. Carleton College, Minneapolis
12. Center for Applied Coastal Research, Del.
13. Chapman University, California
14. City College of New York, City U of NY

15. Coastal Carolina University, South Carolina
16. Colorado School of Mines, Colorado
17. Colorado State University
18. Columbia/LDEO, New York
19. Conservation Biology Institute, Oregon
20. CUAHSI, District of Columbia
21. Desert Research Institute, Nevada
22. Duke University, North Carolina
23. Florida Gulf Coast University
24. Florida International University
25. Franklin & Marshall College, Pennsylvania
26. George Mason University, VA
27. Georgia Institute of Technology, Atlanta
28. Harvard University
29. Idaho State University
30. Indiana State University
31. Iowa State University
32. Jackson State University, Mississippi
33. John Hopkins University, Maryland
34. Louisiana State University
35. Massachusetts Institute of Technology
36. Michigan Technological University
37. Monterey Bay Aquarium Research Inst.
38. Murray State University
39. North Carolina State University
40. Northern Arizona University
41. Northern Illinois University
42. Nova Southeastern University, Florida
43. Oberlin College
44. Ohio State University
45. Oklahoma State University
46. Old Dominion University, Virginia
47. Oregon State University
48. Penn State University
49. Purdue University, Indiana
50. Rutgers University, New Jersey
51. Scripps Institution of Oceanography, CA
52. South Dakota School of Mines, S Dakota
53. Stanford, CA
54. State University (Virginia Tech), VA
55. Syracuse University, New York
56. Texas A&M, College Station, TX
57. Texas Christian University
58. Tulane University, New Orleans
59. United States Naval Academy, Annapolis
60. University of Alabama - Huntsville
61. University of Alaska – Fairbanks
62. University of Arkansas
63. University of Arizona
64. University of California – Berkeley
65. University of California - Davis
66. University of California – Irvine
67. University of California – Los Angeles
68. University of California - San Diego
69. University of California -Santa Barbara
70. University of California – Santa Cruz
71. University of Colorado – Boulder
72. University of Connecticut
73. University of Delaware
74. University of Florida
75. University of Houston
76. University of Idaho
77. University of Illinois-Urbana-Champaign
78. University of Iowa
79. University of Kansas
80. University of Louisiana – Lafayette
81. University of Maine
82. University of Maryland, Baltimore County
83. University of Memphis
84. University of Miami
85. University of Michigan
86. University of Minnesota – Minneapolis
87. University of Minnesota – Duluth
88. University of Nebraska – Lincoln
89. University of Nevada – Reno
90. University of New Hampshire
91. University of New Mexico
92. University of New Orleans
93. University of North Carolina – Chapel Hill
94. University of North Carolina – Wilmington
95. University of North Dakota
96. University of Oklahoma
97. University of Oregon
98. University of Pennsylvania – Pittsburgh
99. University of Pittsburgh
100. University of Rhode Island
101. University of South Carolina
102. University of South Florida
103. University of Southern California
104. University of Tennessee - Knoxville
105. University of Texas – Arlington
106. University of Texas – Austin
107. University of Texas – El Paso
108. University of Texas – San Antonio
109. University of Utah
110. University of Virginia
111. University of Washington
112. University of Wyoming
113. Utah State University
114. Vanderbilt University
115. Villanova University, Pennsylvania
116. Virginia Institute of Marine Science (VIMS)
117. Virginia Polytechnic Institute, VA
118. Washington State University
119. West Virginia University
120. Western Carolina University
121. Wichita State University
122. William & Mary College, VA
123. Woods Hole Oceanographic Inst.

U.S. Federal Labs and Agencies: as of 30 April 2013

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

U.S. Private Companies: as of 30 April 2013

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

19. Warren Pinnacle Consulting, Inc., Warren, VT
20. Von Braun Center for Science & Innovation
21. The Water Institute of the Gulf, Louisiana
22. UAN Company

Foreign Membership: as of 30 April 2013

63 countries outside of the U.S.A.: Algeria, Argentina, Armenia, Australia, Austria, Bangladesh, Belgium, Bolivia, Brazil, Bulgaria, Cambodia, Canada, Chile, China, Colombia, Cuba, Denmark, Egypt, El Salvador, France, Germany, Ghana, Greece, Hong Kong, Hungary, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Kenya, Malaysia, Mexico, Morocco, Myanmar, Nepal, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russia, Scotland, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Turkey, UK, United Arab Emirates, Uruguay, Venezuela, Việt Nam.

Foreign Academic Institutes: as of 30 April 2013

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

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

174. Wuhan University, Wuhan, China
175. Xi-an University of Architecture & Technology, China
176. York University, Canada

Foreign Private Companies

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

Foreign Government Agencies

1. Agency for Assessment and Application of Technology, Indonesia
2. Bedford Institute of Oceanography, Canada
3. Bhakra Beas Management Board (BBMB), Chandigarh, India
4. British Geological Survey, UK
5. Bundesanstalt fur Gewasserkunde, Germany
6. Bureau de Recherches Géologiques et Minières (BRGM), Orleans, France
7. Cambodia National Mekong Committee (CNMC), Cambodia
8. Center for Petrographic and Geochemical Research (CRPG-CNRS), Nancy, France
9. CETMEF/LGCE, France
10. Channel Maintenance Research Institute (CMRI), ISESCO, Kalioubia, Egypt
11. Chinese Academy of Sciences – Cold & Arid Regions Environmental & Engineering Res. Institute
12. Chinese Academy of Sciences – Institute of Mountain Hazards and Environment, China
13. Chinese Academy of Sciences – Institute of Tibetan Plateau Research (ITPCAS), China
14. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
15. Consiglio Nazionale delle Ricerche (CNR), Italy
16. French Agricultural and Environmental Research Institute (CEMAGREF)
17. French Research Institute for Exploration of the Sea (IFREMER), France
18. Geological Survey of Canada, Atlantic
19. Geological Survey of Canada, Pacific
20. Geological Survey of Israel, Jerusalem, Israel
21. Geological Survey of Japan (AIST), Japan
22. Geosciences, Rennes France

23. GFZ, German Research Centre for Geosciences, Potsdam, Germany
24. GNS Science, New Zealand
25. *GNU VNIIGiM*, Moscow, *Russia*
26. Group-T, Myanmar
27. Helmholtz Centre for Environmental Research (UFZ), Germany
28. Indian National Centre for Ocean Information Services (INCOIS), India
29. Institut des Sciences de la Terre, France
30. Institut National Agronomique (INAS), Algeria
31. Institut Teknologi Bandung (ITB), Indonesia
32. Institute of Atmospheric Sciences and Climate (ISAC), Italian National Research Council (CNR), Italy
33. Institute for Computational Science and Technology (ICST), Viet Nam
34. Institute for the Conservation of Lake Maracaibo (ICLAM), Venezuela
35. Institute of Earth Sciences (ICTJA-CSIC), Spain
36. Instituto Hidrografico, Lisboa, Lisbon, Portugal
37. Instituto Nacional de Hidraulica (INH), Chile
38. Instituto Nazionale di Astrofisica, Italy
39. International Geosphere Biosphere Programme (IGBP), Sweden
40. Iranian National Institute for Oceanography (INIO), Tehran, Iran
41. Italy National Research Council (CNR), Italy
42. Japan Agency for Marine-Earth Science Technology (JAMSTEC), Japan
43. Kenya Meteorological Services, Kenya
44. Korea Ocean Research and Development Institute (KORDI), South Korea
45. Korea Water Resources Corporation, South Korea
46. Lab Domaines Oceanique IUEM/UBO France
47. Laboratoire de Sciences de la Terre, France
48. Marine Sciences For Society, France
49. Ministry of Earth Sciences, India
50. Nanjing Hydraulics Research Institute, China
51. National Institute of Water and Atmospheric Research (NIWA), Auckland, New Zealand
52. National Research Institute of Science and Technology for Environment and Agriculture (
53. National Institute for Space Research (INPE), Brazil
54. National Institute of Oceanography (NIO), India
55. National Institute of Technology Rourkela, Orissa, India
56. National Institute of Technology Karnataka Surathkal, Mangalore, India
57. National Institute of Water and Atmosphere (NIWA), New Zealand
58. National Marine Environmental Forecasting Center (NMEFC), China
59. National Research Centre for Sorghum (NRCS), India
60. National Research Council (NRC), Italy
61. National Space Research & Development Agency, Nigeria
62. Scientific-Applied Centre on hydrometeorology & ecology, Armstatehydromet, Armenia
63. Senckenberg Institute, Germany
64. Shenzhen Inst. of Advanced Technology, China
65. South China Sea Institute of Technology (SCSIO), Guanzhou, China
66. The European Institute for Marine Studies (IUEM), France
67. The Leibniz Institute for Baltic Sea Research, Germany
68. UNESCO-IHE, Netherlands
69. Water Resources Division, Dept. of Indian Affairs and Northern Development, Canada
70. World Weather Information Service (WMO), Cuba

Independent Researchers (both U.S. and Foreign): **31** members self-identify as independent researchers.

Chapter 2: CSDMS Management and Oversight

The proposed administrative structure *for CSDMS was to consist of an advisory board, steering committee, National Center, working groups, and individual scientists. An Advisory Board was to consist of approximately 7 members who offer advice, are scientifically well connected, and provide an international reach. They were to: 1) act as CSDMS advocates with government agencies and industry; 2) provide feedback on mission, governance and deliverables through an annual review process; and 3) provide tie-in to national and international initiatives. A Steering Committee was to be an interdisciplinary body drawn from the research community and end-user communities (agencies, industry), and operate as the governing body of the CSDMS initiative. The National Center was to house the core server and management, computational and educational staff to advance the CSDMS initiative.*

How well did we do: The CSDMS Bylaws were adopted June 14, 2007, and approved with revisions on Feb 15, 2008. The proposed Advisory Board was renamed the **CSDMS Steering Committee**, consisting of representatives of U.S. Federal Agencies, Industry, and Academia. The Steering Committee assesses the competing objectives and needs of the CSDMS; assesses progress in terms of science, outreach and education; advises on revisions to the 5-year strategic plan; and approves the Bylaws and its revisions. The proposed Steering Committee was renamed the **CSDMS Executive Committee** and comprised of organizational chairpersons. The Executive Committee is the primary decision-making body of CSDMS, and ensures that the NSF Cooperative Agreement is met, oversees the Bylaws & Operational Procedures, and sets up the annual science plan (Fig. 1.1). The Executive Committee approves the business reports, management plan, budget, partner memberships, and other issues that arise in the running of CSDMS. The National Center was renamed the **CSDMS Integration Facility** and maintains the CSDMS Repositories, facilitates community communication and coordination, public relations, and product penetration (Fig. 1.2). The Integration Facility develops the CSDMS cyber-infrastructure (e.g. coupling framework, tools, services and software protocols), and provides software guidance to the CSDMS community. The IF maintains the CSDMS vision and supports cooperation between observational and modeling communities. CSDMS' IF is located at INSTAAR, University of Colorado-Boulder.

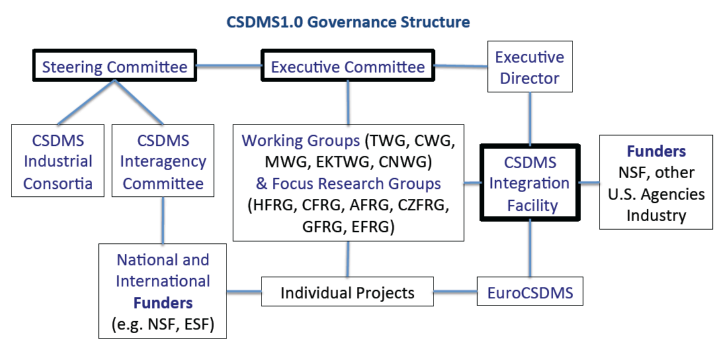


Fig. 1.1 CSDMS Governance Structure

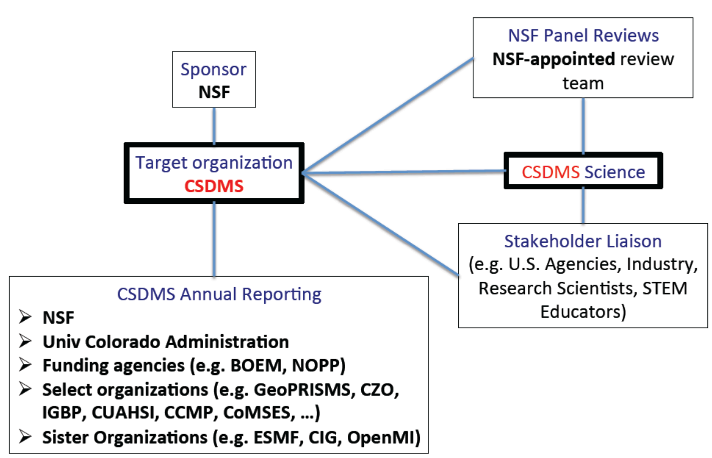


Fig. 1.2 CSDMS Reporting Structure

The CSDMS Steering Committee (April, 2007-2012)

- Rudy Slingerland (April, 2007-2012), Chair, CSDMS Steering Committee, Penn State U., University Park, PA
- Tom Drake (April, 2007-2012), U.S. Office of Naval Research, Arlington, VA
- Bert Jagers (April, 2007-2012), Deltares and OpenMI, Delft, The Netherlands
- Rick Sarg (April, 2007-2012), Colorado School of Mines, Golden, CO
- Gary Parker (April, 2007-2012), Univ. Illinois Urbana-Champaign, IL
- Dan Tetzlaff (April, 2007-2012), Schlumberger Ltd, Cambridge, MA
- Dave Furbish (April, 2007-2012), Vanderbilt University, Nashville, TN
- Chris Paola (Sept, 2009-2012), NCED, U. Minnesota, Minneapolis, MN
- Cecilia DeLuca (Sept, 2009-2012), ESMF, NOAA/CIRES, Boulder, CO
- Boyana Norris (Sept, 2009-2012), Argonne National Lab, Argonne, IL
- James Syvitski (*ex-officio*) (April, 2007-2012), CSDMS Executive Director, INSTAAR-CU, CO
- Bilal Haq (*ex-officio*) (April, 2007-2012), National Science Foundation, DC
- Paul Cutler (*ex-officio*) (*Oct 2010*), National Science Foundation, DC.

Departures

- Tom Dunne (April, 2007-2009), UC-Santa Barbara, CA
- Mike Ellis (*ex-officio*) (April, 2007-Sept 2008), National Science Foundation, DC
- Richard Yuritech (*ex-officio*) (Sept 2008- July 2010), National Science Foundation, DC

The CSDMS Executive Committee (ExCom) (April, 2007-2012)

- Rudy Slingerland (April, 2007-2012), Chair, CSDMS Steering Committee, Penn State U., PA
- Brad Murray (April, 2007-2012), Chair, Coastal Working Group, Duke U., NC
- Pat Wiberg (April, 2007-2012), Chair, Marine Working Group, U. Virginia, VA
- Greg Tucker (April, 2007-2012), Chair, Terrestrial Working Group, CIRES-CU, CO
- Eckart Meiberg (Jan, 2009-2012), Chair, Cyberinformatics & Numerics WG, U. Cal.-Santa Barbara, CA
- Irina Overeem (Oct, 2011-2012), Chair, Education & Knowledge Transfer WG, INSTAAR-CU, CO
- James Syvitski (*ex-officio*), CSDMS Executive Director, INSTAAR, University of Colorado, CO
- Scott Peckham (*ex-officio*) Chief Software Architect, INSTAAR-CU, CO

Departures

- Lincoln Pratson (April, 2007-October, 2008), Chair, Education & Knowledge Transfer WG, Duke U., NC
- Tao Sun (April, 2007-2008), Chair, Cyberinformatics & Numerics Working Group, ExxonMobil-URC, TX
- Karen Campbell (October, 2008-July 2011), Chair, Education and Knowledge Transfer WG, NCED-UM, MN

Integration Facility staff *as of Dec 2012 (multiple funding sources)*

• Executive Director, Prof. James Syvitski (April, 2007)
• Executive Assistant, Ms. Marlene Lofton (Aug. 2008)
• Chief Software Architect, Dr. Scott Peckham (April, 2007)
• Chief Software Engineer, Dr. Eric Hutton (April, 2007)
• Cyber Scientist Dr. Albert Kettner (July, 2007)
• EKT Scientist Dr. Irina Overeem (Sept, 2007)
• Accounting Technician Mary Fentress (April, 2007)
• Systems Administrator Chad Stoffel (April, 2007)

The proposed Working groups *were to represent the knowledge base. They were to identify and manage the input of various process modules, and provide continuity to meet the long-term CSDMS objectives. They were to set up and solve integrated problems outlined in the science plan, identify gaps in knowledge, foster interdisciplinarity within and between groups, and work with the larger community of individual scientists. Working groups were to advise on what tools or processes are in their disciplinary toolkit.*

CSDMS Working and Focus Research Groups consist of members organized into 5 working groups (Terrestrial, Coastal, Marine, Education, Cyberinformatics) and 3 focus research groups (Hydrology, Carbonate, Chesapeake) as of 12/31/11:

Terrestrial	**328**	**Cyber**	**104**
Coastal	**259**	**EKT**	**101**
Hydrology	**240**	**Carbonate**	**55**
Marine	**189**	**Chesapeake**	**39**

Members provide model code and support tools, educational material, and data for model initialization, testing and benchmarking, and assessing contributed models. The semi-annual, annual and rolling Strategic Plans transparently reflect input from member. In 2008, the CSDMS Executive Committee authorized the establishment of Focus Research Groups (FRGs) that cut across our Environmental Working Group structure. Focus Research Groups differ from Working Groups in that they serve a unique subset of our surface dynamics community, and usually represent a well-developed community. FRGs are often co-sponsored by another organization, but are similarly supported by the CSDMS Integration Facility as Working Groups. FRG Chairs report directly to the CSDMS Executive Director, and often to the Director of the co-sponsoring organization. The **Hydrology Focus Research Group** represents the hydrological modeling community, and is co-sponsored by **CUAHSI**, the Consortium of Universities for the Advancement of Hydrologic Science, Inc. This FRG deals with aspects of the hydrological system that impact earth-surface dynamics. The **Carbonate Focus Research Group** is the outgrowth of an NSF effort to coordinate the carbonate modeling community and their development of a numerical carbonate workbench. The Carbonate Focus Research Group addresses the grand challenges for fundamental research on ancient and recent carbonate systems, through creation of the next generation of numerical carbonate process models under the umbrella of CSDMS. The **Chesapeake Focus Research Group** is a 'geographically-focused' effort representing and co-sponsored by the **Chesapeake Community Modeling Program**, with their unique collection of models and field data set. Through support from Chesapeake Research Community member institutions and the NOAA Chesapeake Bay Office, CCMP modelers have committed to developing a modeling framework that will enable free and open access to code specific to the Chesapeake Bay region.

CSDMS Industrial Consortium

Industry partners play an important role in contributing to the success of CSDMS through their financial or in-kind contributions. Sponsorship supports the CSDMS effort and thus the next generation of researchers working to develop innovative approaches towards modeling complex earth-surface systems. CSDMS consortium members: 1) demonstrate corporate responsibility and community relations; 2) contribute to the direction of CSDMS research and products; 3) access the latest CSDMS products and information; and 4) join an association of diverse scientists, universities, agencies, and industries. Approximately 11% of CSDMS members are with industry.

CSDMS Interagency Committee

This group is comprised of the 21 US agencies (see community membership section) and may host non-US government agencies. Focus is on how best to move models from research grade to operational grade level, avoiding duplication of effort. Most agencies use models to address practical applied problems, for example: operational forecasts; regulatory assessments, permitting, risk assessments, remedial action plans, emergency response, and outreach to stakeholders. Most agencies rely on models that are developed or are funded in-house, for reasons of quality control, specificity, familiarity (with the developers, agency users, and contractors), and cost of changing. Still, the CSDMS community and its products might offer agencies coupled models that these same agencies might like to see developed. However there is a long path from first successful coupled runs to acceptance and/or utility within agencies. In the near term, CSDMS can contribute to understanding of how to build and deploy coupled models. Individual agencies might be "early adopters" and leverage CSDMS to develop coupled models to address specific topics. A task force of the CSDMS Interagency Committee has agreed to explore early adoption strategies.

Chapter 3: CSDMS Cyber infrastructure

CSDMS modeling environment Goal: *Simplify the task of linking models and guide users to build models from a library of standardized subroutines (Fig. 3.1). Key functions of the modeling environment include: model building, model linking, guidance (warnings on linkages, usage, time-steps), resource management (I/O, data storage, archiving, distributed computing), debugging tools, and help systems. The intent is to make CSDMS useful both for model application and model investigation. Modules were to be transparent to safeguard users from module inconsistencies (e.g. scale & structure).*

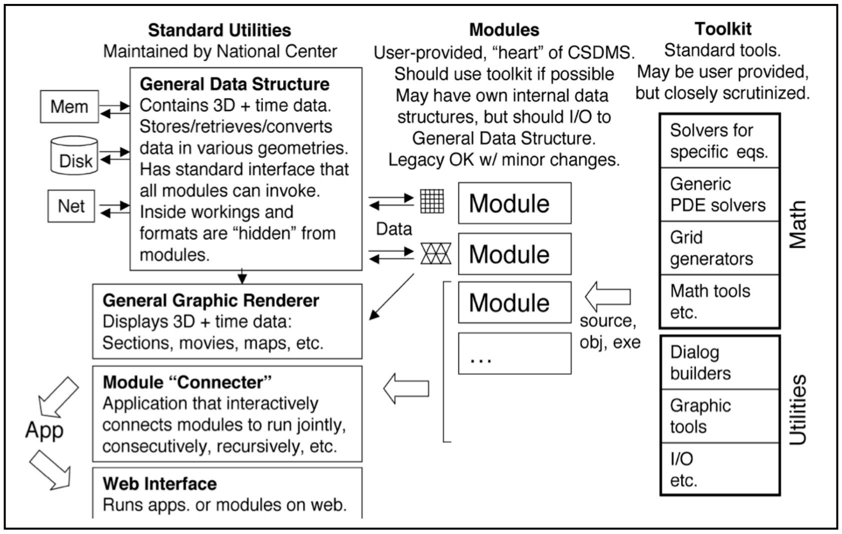


Fig. 3.1 CSDMS Computational Architecture from the original CSDMS proposal generated during the initial community-planning meeting held in Boulder in 2002.

How well did we do: Figure 3.1 shows the original conceptual design of the CSDMS architecture. At the highest level it consisted of Standard Utilities, Modules (mostly models) and a Toolkit. The Standard Utilities were imagined to contain a General Data Structure (to deal with issues such as grid and time step differences), a General Graphics Renderer, a Module Connector and a Web Interface (GUI). During its initial five-year period of funding, CSDMS 1.0 evolved to meet the needs of the earth surface process modeling community and can now be viewed as consisting of the following key parts:

(1) **Model Repository:** A repository of contributed models in many different languages.
(2) **Standard Model Interfaces:** Standards for converting models to reusable, plug-and-play components.
(3) **Componentized Models:** A set of models converted to plug-and-play components.
(4) **Service Components:** Special components that reconcile differences (i.e. mediators) between coupled models (e.g. regridding) or provide additional capabilities (e.g. writing model output to a standardized NetCDF file, solvers, etc.).
(5) **Modeling Framework:** A low-level environment in which componentized models are instantiated, configured and connected to create composite models, calling service components when necessary.
(6) **Modeling Framework GUI:** A user-friendly GUI to (a) simplify interaction with the modeling framework, (b) launch and manage remote jobs on a HPCC and to (c) provide integrated visualization of model output.

Each of these key parts is explained in greater detail in the following six sections.

1. Model Repository

CSDMS has assembled a large repository of surface process models that now includes over 166 open-source models and 51 tools. Some models can be obtained from the CSDMS Subversion repository and others can be obtained from external sites. The CSDMS wiki website provides metadata for each contributed model, obtained with an online questionnaire. Developers add an open-source license (one of their choice) to their codes upon submission. Code is compiled on the CSDMS HPCC upon submission. The repository now contains terrestrial, coastal, marine, hydrological, carbonate and atmospheric models. Geodynamics and ecosystem models will be added over the next few years. Any model in the repository can be downloaded and used in "stand-alone" mode. Through the Working Groups and Focus Research Groups, CSDMS members prioritize and help to facilitate the conversion of popular models to model components that can be easily coupled to other models within the CSDMS Modeling Framework. So far, 55 of the 166 models in the repository have been wrapped for use as reusable plug-and-play components but the conversion rate is expected to accelerate as a result of automated wrapping procedures made possible by the introduction of the BMI interface standard. The CSDMS Model Repository can be viewed at: http://csdms.colorado.edu/wiki/Model_download_portal.

2. Standard Model Interfaces

BMI and CMI.

A major achievement of CSDMS 1.0 was the development of an innovative, two-level wrapping process (BMI/CMI) that greatly simplifies the process of converting contributed models to interoperable, plug-and-play components. The Basic Model Interface (BMI) is a simple model interface standard that developers are asked to implement. In this context an interface is a named set of functions with prescribed function names, argument types and return types. The BMI functions make a model self-describing and fully controllable by a modeling framework. The BMI functions can be grouped into 5 categories: Model Control Functions (i.e. initialize, update and finalize), Model Information Functions, Variable Information Functions, Variable Getter and Setter Functions and Grid Information Functions. Several of these functions utilize the new CSDMS Standard Names, described below. BMI and CMI are documented with examples on the CSDMS wiki at: http://csdms.colorado.edu/BMI_Description and http://csdms.colorado.edu/wiki/CMI_Description and in Peckham et al. (2013).

By design, the BMI functions are straightforward to implement in any of the languages supported by CSDMS, which include C, C++, Fortran (all years), Java and Python. Even though some of these languages are object-oriented and support user-defined types, the BMI functions use only simple (universal) data types. Also by design, the BMI functions are noninvasive. A BMI-compliant model does not make any calls to CSDMS components or tools and is not modified to use CSDMS data structures. BMI therefore introduces no dependencies into a model and the model can still be used in a "stand-alone" manner.

Any model that provides the BMI functions can be easily converted to a CSDMS plug-and-play component that has a CSDMS Component Model Interface (CMI). BMI-enabled models basically just "plug into" a CMI wrapper. The BMI functions are called by the CMI, by the framework and by service components. It is not necessary for a developer to learn anything about CMI, CSDMS resources, other models or framework concepts in order to get their model into the system. Any model that provides the BMI functions should also be straightforward to ingest as a component into other component-based modeling frameworks. For example, all model coupling frameworks use Model Control Functions very similar to those of BMI, so providing them helps get a model ready for plug-and-play. Once a BMI-enabled model has been wrapped to become a CSDMS component, it gains many new capabilities that are provided automatically by the CSDMS framework service components. This includes the ability to be coupled to other models even if their (1) programming language, (2) variable names, (3) variable units, (4) time-stepping scheme or (5) computational grid is different. It also gains (1) the ability to write output variables to standardized NetCDF files, (2) a "tabbed-dialog" graphical user interface (GUI), (3) a standardized online wiki help page and (4) the ability to run within the point-and-click CSDMS Modeling Tool (CMT).

By working closely with its members, CSDMS has found that BMI only places a small burden on model developers (similar to providing documentation in code) and is an acceptable target for them (i.e. something they are willing to do). The use of BMI has also dramatically reduced the effort required by CSDMS staff to create and maintain components. There is now really just one universal CMI wrapper to maintain that BMI-enabled models "plug into".

Sharing Components Between Frameworks via BMI. Another anticipated benefit of the BMI/CMI approach is that it provides a mechanism for sharing models between modeling frameworks. There is nothing framework-related in a BMI-enabled model and yet the BMI interface allows a caller to retrieve anything it needs for deployment in a framework. It is therefore straightforward to wrap a BMI-enabled model to provide an interface other than CMI, as would be needed for use in another framework like ESMF, OpenMI or OMS (Object Modeling System).

CSDMS Standard Names

Most models require input variables and produce output variables. In a component-based modeling framework like CSDMS, a set of components becomes a complete model when every component is able to obtain the input variables it needs from another component in the set. Ideally, we want a modeling framework to automatically:

1. Determine whether a set of components provides a complete model.

2. Determine whether a set of components have compatible assumptions and physics.

3. Connect each component that requires a certain input variable to another component in the set that can provide that variable as output.

However, this kind of automation requires a ***semantic matching mechanism*** for determining whether — ***and the degree to which*** — two variable names refer to the same quantity and whether they use the same units and are defined or measured in the same way.

CSDMS began developing the CSDMS Standard Names in 2012 to provide a practical solution to this semantic mediation problem and as an early contribution to CSDMS 2.0. It is a large, ongoing, cross-domain effort that is attracting the attention of several other cyber-infrastructure projects. While the CF Convention Standard Names that were introduced in the domain of ocean and atmosphere modeling have somewhat overlapping goals, the CSDMS Standard Names provide a more comprehensive set of naming rules and patterns for creating unique labels for model variables that are not specific to any particular modeling domain. These naming conventions consist of an extensive set of patterns that cover a wide variety of cases gleaned from models in the CSDMS repository as well as from the CF Standard Names.

The CSDMS Standard Names can be viewed as a ***lingua franca*** that provides a bridge for mapping variable names between models. They play an important role in the Basic Model Interface (BMI) developed by CSDMS. Model developers are asked to provide a BMI interface that includes a mapping of their model's internal variable names to CSDMS Standard Names and a Model Metadata File that provides model assumptions and other information. If widely adopted, this naming system could also provide other benefits, such as a better discovery mechanism for finding models on the web.

3. Componentized Models

Due to the design of BMI and CMI, explained previously, the key step in converting any model to a CSDMS plug-and-play component is to implement the BMI interface for it. CSDMS now has automated tools for converting a BMI-enabled model to a model component that has a CMI interface and is therefore ready to be used in the CSDMS Modeling Framework. The models listed in this section were all converted to CSDMS components during CSDMS 1.0, but since some of them pre-date the development of BMI and the CSDMS Standard Names, there are still a few that have not yet been retro-fitted with fully-compliant BMI interfaces. However, BMI is now enjoying rapid adoption and a number of new models have recently implemented (or are in the process of implementing) the BMI interface. Notable examples include: WRF (Weather Research and Forecasting), RAPID (an HPC-based river routing model), SWAN (Simulating WAves Nearshore), and the suite of CUAHSI-HIS HydroModeler components. Each is therefore very close to becoming a CSDMS component. Going forward, CSDMS Working Groups are also expected to produce (by whatever means) at least one BMI-enabled model from their group's modeling domain each year. In addition, other projects such as the recently NSF-funded LandLab project intend to produce a set of BMI-compliant process models.

A few of the models mentioned in previous reports posed unique challenges that have delayed their conversion to CSDMS components. One of these is an ecological model, identified as Bioenergetics in previous reports. The unique challenge here is that it models fish in a lake, and there are processes acting on both the fish and on the lake. CSDMS learned valuable lessons from this model and is considering extensions to its framework that will accommodate situations such as this. Another example is ParFlow, which is unique in how its various HPC components are connected using TCL/TK scripts. CSDMS did not have sufficient resources to develop a solution for this case. Models from the CUAHSI-HIS HydroModeler project have an OpenMI interface and are written in C#, which though similar to Java, is not a Babel-supported language. CSDMS staff is continuing to work with a graduate student whose project is to repackage these hydrologic models as BMI-enabled models in a Babel-supported language.

ROMS. ROMS is a free-surface, terrain-following, primitive equations ocean model widely used by the scientific community for a diverse range of applications. It is a modern code supporting serial and parallel computing. In its parallel part, both shared (OpenMP) and distributed-memory (MPI) paradigms coexist together in a single code. ROMS's serial capability has been wrapped as a CSDMS component and can be run either from CSDMS's CMT front-end graphic tool or from a command-line script. ROMS's parallel code has been componentized and is able to run within an alpha version of CMT that can run components within an MPI environment.
SVN Repository: https://www.myroms.org/
Description: http://csdms.colorado.edu/wiki/Model_help:ROMS

ROMS Builder and ROMS Compiler Components. ROMS (Regional Ocean Modeling System) has been a top priority by the Marine and Coastal Working Groups and the Chesapeake and Carbonate Focus Research Groups. ROMS differs from most models in our repository in that each user creates and compiles their own, customized version of ROMS, based on the science questions involved and the module options one needs. Recognizing this, CSDMS created two new components called "ROMS Builder" and "ROMS Compiler" that allow a user to perform this task within the graphical user interface of the CSDMS Component Modeling Tool. Each of these components creates a ROMS "cppdefs.h" file (https://www.myroms.org/wiki/index.php/cppdefs.h) and then compiles a new instance of the ROMS model with those CPP options. ROMS Builder additionally wraps the resulting executable to produce a customized ROMS component that can be used within the CSDMS CMT and that automatically appears in the palette. Each has a tabbed-dialog GUI. Each new ROMS component created with ROMS Builder has a tabbed dialog GUI (with 10 tabs and over 135 input variables) that creates the ROMS input file called "ocean.in" (https://www.myroms.org/wiki/index.php/ocean.in) and launches ROMS. ROMS Builder was tested by CSDMS member Aaron Bever (UMCES) and improved based on his feedback.

ChesROMS, UMCES_ROMS and CBOFS2 (ROMS). On specific request of the Chesapeake Focus Research Group, ROMS Builder has been used to create CSDMS components for four different instances of ROMS: (a) CBOFS2, (b) UMCES, (c) "Upwelling Example" and (d) ChesROMS. Each has a different spatial resolution and is used for modeling the Chesapeake Bay. For each of these ROMS versions, all associated input data and grids were collected on the CSDMS high-performance cluster and "BLD files" were created that allow CMT users to select and run those ROMS versions with that data. Each new ROMS component created with ROMS Builder gets a BMI (Basic Model Interface) that includes many additional functions, including getters and setters. A CMI wrapper for Fortran models was also created and used to wrap BMI-enabled versions of both ROMS and LTRANS (Lagrangian Transport model). Due to these enhancements, ROMS is now a CSDMS component that can be dynamically coupled to other CSDMS components, as demonstrated through direct (runtime) coupling to LTRANS.

LTRANS. In the wake of the BP oil spill, CSDMS staff surveyed existing models for oil spill tracking and discovered there were no open-source models of this type available. CSDMS staff worked on an NSF RAPID grant with E. North, C. Sherwood and others to create an open-source model to fulfill this need. LTRANS version 1 (Larval TRANSport) was augmented with oil droplet physics to create LTRANS version 2 (Lagrangian TRANSport) that includes the ability to track oil droplet transport for a large region such as the

Gulf of Mexico. It was also provided with a BMI interface and a tabbed-dialog GUI and is now available as a plug-and-play component through the CMT. LTRANS v.2 was released in January 2012. Within the CSDMS framework, LTRANS can be used as a stand-alone model that reads input from a ROMS history file, or can be coupled directly to ROMS (i.e. not through files) and run in tandem. See http://northweb.hpl.umces.edu/LTRANS.htm for more information. (FORTRAN)

MARSSIM. A landform evolution model that operates at the drainage basin or larger scale, this landscape evolution model can now be run through the CMT, has a tabbed-dialog GUI and has passed a series of test cases. MARSSIM supports fluvial processes, cratering (as on Mars) and the influence of vegetation. (FORTRAN 90)

Flexure. This flexural and non-flexural isostasy model provides 1D and 2D solutions. Flexure is the first model submitted by a new graduate student, who fully committed to help bring the model code online as a component in the CMT. Flexure has been refactored to provide the BMI interface and is very close to appearing as a plug-and-play component in the CMT. It will have many coupling options in both the terrestrial model projects as well as in the coastal and marine model projects. This model has strong interest from CSDMS industry partners to allow coupling applications with stratigraphic models.

TopoFlow Model Process Components. TopoFlow is a physics-based, spatially-distributed hydrologic model that provides multiple methods for modeling each of the many different hydrological processes that operate within watersheds. These include channelized flow (kinematic, diffusive and dynamic wave), diversions (sources, sinks and canals), infiltration, evaporation, snowmelt and subsurface flow. Its goal is to accurately predict how various hydrologic variables will evolve in time in response to climatic forcings. It was originally developed as one model with a GUI and written in IDL (Interactive Data Language) that allowed toggling between its different process options. Each of its process options was repackaged as a stand-alone Python/NumPy model (using I2PY) for the CSDMS project which resulted in 16 separate plug-and-play CSDMS components. TopoFlow has played a key role in the design and testing of various CSDMS innovations, such as the BMI/CMI approach to model coupling.

CUAHSI-HIS Web Service Component. This component demonstrates interoperability between CSDMS and CUAHSI-HIS, which provides the ability to discover and download hydrologic time series data on the web. This component is fully documented in Peckham and Goodall (2013).

Erode3 Components. Four new components from Peckham's NSF-CMG project were made available to the CSDMS community through the CMT. These include (1) **D8_Global***:* fills depressions in a DEM, creates a D8 flow grid and contributing area grid, (2) **DEM Smoother**: modifies an existing DEM so that all of its elevation profiles vary smoothly downstream (with smoothly decreasing and nonzero slopes), (3) **Erode_Global**: a landscape evolution model that uses "global", adaptive timesteps and (4) **Erode_Local** a new (and much more efficient) landscape evolution model that uses an innovative new "local timestepping" algorithm. Erode_Global and Erode_Local each use a new stability condition and natural, transport-based depression filling.

GC2D. This is a 2D glacier dynamics model that simulates the dynamics of either valley glaciers or ice sheets. Originally written in MatLab, it was converted to Python (with NumPy) by CSDMS staff and then linked (via its ice meltrate output variable) to the TopoFlow hydrologic model as an early CSDMS demonstration project. As GC2D operates at a much longer time step than TopoFlow, this project was mainly used as a test problem.

AquaTellUs. This model aims at modeling floodplain sedimentary architecture on a timescale of 100-100's of years, it can potentially be coupled to river and delta models and to other stratigraphic models. AquaTellUs now has a complete IRF structure, and a compatible basic modeling interface (BMI). Tabbed dialogues have been designed and implemented and this first version of AquaTellus has been published in CMT in 11/2011. Additional development on floodplain modeling algorithms and further improvements to the BMI coupling to other components are funded through efforts in 2012-2013.

Coastal Evolution Model (CEM). The Ashton Coastal Evolution Model (CEM) component was refactored as a CMT plug and play component. It now communicates with wave and river components that provide incoming wave characteristics and water and sediment discharge across a delta, respectively. The Coastline Evolution Model (CEM), simulates the evolution of a shoreline due to gradients in breaking-wave-driven alongshore sediment transport. The original CEM has been componentized to consist of the longshore transport module (CEM) and a wave input module (the Waves component). The CEM model assumes that the coast consists of a high percentage of mobile sediment and its other assumptions are more applicable at shoreline lengths of km's and larger. The model was initially designed to investigate an instability in the shape of the coast caused by waves approaching with 'high' angles (with the angle between deepwater crests and the coast > 45 degrees). Although a number of wave (and geometry) parameters can be entered, the most vital input control for CEM is the wave climate. The current version of the CEM is driven by simplified directional wave climate controlled by two main input parameters: the asymmetry of the incoming waves angle and the proportion of high-angle waves. This model is not designed to accurately simulate a specific geographic location in detail but rather to more generally represent how a shoreline with highly mobile sediment may respond to varying wave angles. The value in this model is in the breadth it offers in representing how different wave climates can result in different potentially interesting shoreline configurations. Ashton and Murray (2006b) present a more thorough description of the model parameters and theoretical underpinning.
SVN Repository: https://csdms.colorado.edu/svn/cem
Description: http://csdms.colorado.edu/wiki/Model_help:CEM

Waves. The new Waves component is based on the Ashton wave generator that was incorporated into the original CEM model. Waves provides time-varying incoming wave angles, wave heights, and lengths. It produces a directional wave climate through two main input parameters: asymmetry of incoming waves angle and proportion of high-angle waves. Although originally intended to couple with the CEM component, Waves provides wave characteristics that can be used other components that use such input.
SVN Repository: https://csdms.colorado.edu/svn/cem
Description: http://csdms.colorado.edu/wiki/Model_help:Waves

HydroTrend. HydroTrend creates synthetic river discharge and sediment load time series as a function of climate trends and basin morphology and has been used to study the sediment flux to a basin for basin filling models. As a drainage basin simulator, the model provides time series of daily discharge hydraulics at a river mouth, including the sediment load properties. HydroTrend was designed to provide input to lake or shelf circulation and sedimentation models, and study the impact of land-sea fluxes given climatic change scenarios. HydroTrend simulates the major processes that occur in a river basin, including:

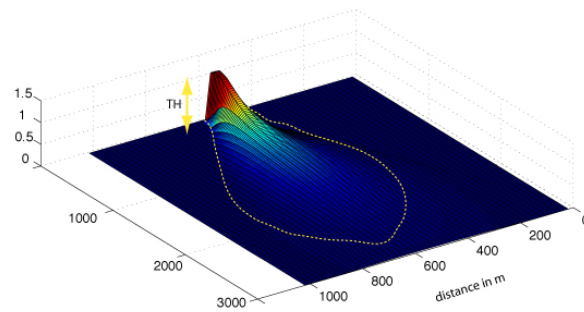
- Glacierized areas with advances and retreats depending on the climate scenario,
- Snow accumulation in the winter and melt in the subsequent spring/summer,
- Rainfall over the remaining portions of the basin with canopy evaporation,
- Groundwater recharging and discharging,
- The impact of lakes and reservoirs on the stream flow as well as on the sediment load due to sediment retention.

SVN Repository: https://csdms.colorado.edu/svn/hydrotrend
Description: http://csdms.colorado.edu/wiki/Model_help:HydroTrend

Avulsion. CSDMS staff componentized the Avulsion model part of the SedFlux model family. Avulsion routes water and sediment to the coast from one or more streams and from a delta "hinge point". The partitioning of distributary discharge is governed by streambed slope. Avulsion bridges between components that provide sediment and water discharge (e.g. HydroTrend) and components that distribute sediment along a coastline (e.g. CEM). The configuration of CEM coupled with Avulsion is an example of two-way coupling — CEM uses output from Avulsion (sediment discharge at river mouths) but also provides input to Avulsion

(delta-plain elevation). A set of "pre-wired" CSDMS model configurations were developed and tested for use by new users as working examples, for benchmarking and as educational material.
SVN Repository: https://csdms.colorado.edu/svn/cem
Description: http://csdms.colorado.edu/wiki/Model_help:Waves

Plume. Plume simulates hypopycnal plumes generated by a river draining its suspended sediment load into a receiving basin. Satellite images of any river-delta emphasize the importance of river plumes. A plume's behavior is dependent on the density contrast between the river water and the standing water (Albertson, 1950; Bates, 1953). Ocean water has a high density, and the plumes often flow buoyantly on the surface (hypopycnal). The river's sediment concentration adds density to the freshwater, but usually the effluent remains below the density of seawater. The shape that a hypopycnal plume will have, depends on a variety of factors:



- Angle between the river course and the coastline
- Strength and direction of the coastal current
- Wind direction influencing local upwelling or downwelling
- Mixing tidal or storm energy near the river mouth
- Latitude and thus the strength of the Coriolis effect.

The plume equations follow those of Albertson (1950) developed for a jet flowing into a steady receiving basin. Plumes of similar shape but differing concentrations result for each grain size in the model. Fine sand will generally settle rapidly, whereas clay can travel much larger distances. Naturally, this affects the geometry of the deposited sediments on the basin floor.
SVN Repository: https://csdms.colorado.edu/svn/sedflux
Description: http://csdms.colorado.edu/wiki/Model:Plume

Subside. The Subside component, part of the larger SedFlux model, is a 1D and 2D flexure model. Subside simulates lithospheric deflection due to evolving changes in overlying load. Depending upon how the load distribution develops, this flexure can result in the basin uplifting or subsiding (or both). The pattern of subsidence in time and space largely determines the gross geometry of time-bounded units because it controls the rate at which space is created for sedimentation.
SVN Repository: https://csdms.colorado.edu/svn/sedflux
Description: http://csdms.colorado.edu/wiki/Model_help:Subside

CHILD. This is a popular landscape evolution model that uses a computational grid of Voronoi polygons and associated Delaunay triangles. CHILD simulates the evolution of a topographic surface and its subjacent stratigraphy under a set of driving erosion and sedimentation processes and with a prescribed set of initial and boundary conditions. Designed to serve as a computational framework for investigating a wide range of problems in catchment geomorphology, CHILD is both a model, in the sense that it comprises a set of hypotheses about how nature works, and a software tool, in the sense that it provides a simulation environment for exploring the consequences of different hypotheses, parameters, and boundary conditions. The model provides a general and extensible computational framework for exploring research questions related to landscape evolution. It simulates the interaction of two general types of process: "fluvial" processes, a category which encompasses erosion or deposition by runoff cascading across the landscape, and "hillslope" processes, which includes weathering, soil creep, and other slope transport processes. CHILD can be run with an adaptive grid that provides greater spatial resolution where needed. It has been successfully coupled to the raster-based SedFlux model (Fig. 3.2).
SVN Repository: https://csdms.colorado.edu/svn/child
Description: http://csdms.colorado.edu/wiki/Model_help:CHILD

Sedflux2D and Sedflux3D. Sedflux is a basin-fill model, written in ANSI-standard C, able to simulate the delivery of sediment and their accumulation over time scales of tens of thousands of years. It simulates the dynamics of strata formation of continental margins fuse information from the atmosphere, ocean and regional geology, and it can provide information for areas and times for which actual measurements are not available, or for when purely statistical estimates are not adequate by themselves. The Sedflux2d component model predicts sediment distribution along (usually a dip) profile of a basin. The resulting stratigraphic map thus gives stratigraphy that varies in two dimensions (vertically, and with distance from the rive mouth). Sedflux3D generates a stratigraphy cube that varies vertically and both in the along shore and cross-shore directions.

SVN Repository: https://csdms.colorado.edu/svn/sedflux
Description: http://csdms.colorado.edu/wiki/Model_help:Sedflux

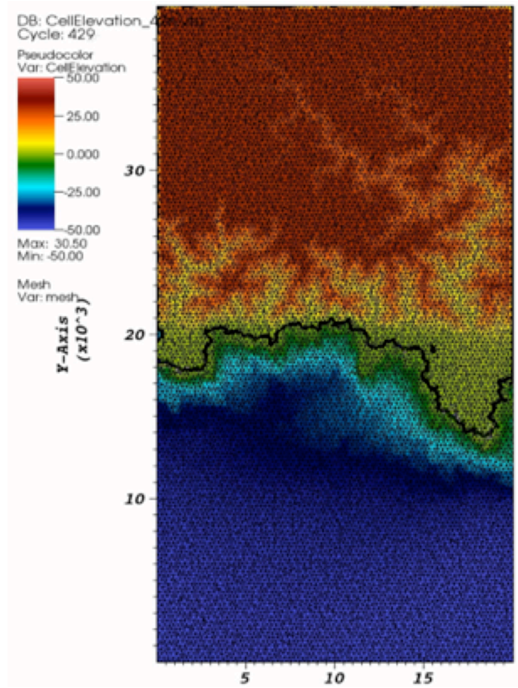


Fig. 3.2 An output of coupled CHILD & SedFlux3D

1D Sediment Transport Morphodynamics. The STM project is the set of Gary Parker's eBook, "1D Sediment Transport Morphodynamics" wrapped as CSDMS plug-and-play components. STM is a collection of models that deals with 1-dimensional sediment transport morphodynamics with application to rivers and turbidity currents. The book includes 27 independent models covering various aspects such as threshold of motion and suspension, bulk relations for transport of total bed material load, 1D aggradation and degradation of rivers, morphodynamics of bedrock-alluvial transitions, formulation for slope and bankfull geometry, and plunging of turbidity currents. Each model is now a CSDMS plug-and-play component with enhanced user-friendly graphical interfaces.
SVN Repository: https://csdms.colorado.edu/svn/stm
Description:
http://csdms.colorado.edu/wiki/1D_Sediment_Transport_Morphodynamics_with_applications_to_Rivers_and_Turbidity_Current

Carbonate Workbench. While not yet BMI-compliant, members of the Carbonate Focus Research Group have completed 3 new carbonate models that are on the path to becoming CSDMS components and therefore deserve mention here. CarboCAT is a cellular automaton model of facies geometries. CarboCELL is a cellular model of organism competition and growth for scales of 1 to 100 meters. CarboLOT is a multispecies population model based in Lotka-Volterra methods. The models build carbonate facies for periods of time as long as 100ky incorporating environmental and biological forcing events. Papers are being prepared and the model source code will be placed with CSDMS as soon as the papers are submitted.

4. Service Components

The CSDMS IF has created several service components and classes that help to (1) reconcile or mediate differences between models, (2) manage common tasks such as component port management and (3) provide new capabilities to models, such as the ability to write model output to standardized NetCDF files.

CMIPortQueue. The IRFPortQueue class manages the CMI uses-ports of a component. This service class manages the connection and disconnection of a component's CMI ports, controls the exectution of each port's initialize, update and finalize functions, as well as grid mapping of the "get_value" functions. This class was originally called the IRFPortQueue.

Component:
http://csdms.colorado.edu/viewvc/components/trunk/import/csdms/components/edu.csdms.tools.CMIPortQueue/
Python utility: http://csdms.colorado.edu/viewvc/cmt_py_utils/trunk/cmt/port_queue.py

PrintQueue. The PrintQueue class manages the printing of uniform rectilinear and non-uniform gridded data. It also manages printing intervals for components when these intervals may not be the same as a component's time step. This class consists of two parts: the ***NCRasterFile class***, which writes uniform rectilinear grids to NetCDF format, and the ***VTKFile class***, which writes non-uniform meshes to VTK files. The NCRasterFile class (formerly called FileWriter) writes model output variables that vary in time, including 0D (time series), 1D (profile series), 2D (grid stack) and 3D (cube stack) to NetCDF files that contain descriptive metadata (e.g. CF and CSDMS standard names) and which can be imported into the high-performance visualization software, VisIt. The VTKFile class writes output variables on unstructured grids in binary format using the "new-style" XML format for VTKs. Since this work pre-dates the recent development of CF conventions for unstructured grids, it stores these grids in a format developed by CSDMS staff which consists of the following variables:

- x: Values of the x-coordinate for each node.
- y: Values of the y-coordinate for each node.
- connectivity: An array of integers that provide indices into data arrays for each element of the mesh.
- type: An array of integers that indicate the shape of each element (triangle, polygon, cube, etc.). Element types are defined in the same way as the VTK standard.

Variable values (at either nodes or elements) are listed with the same ordering as the x and y, or connectivity arrays.

Component: http://csdms.colorado.edu/viewvc/components/trunk/import/csdms/components/edu.csdms.tools.PrintQueue/
Python utility: http://csdms.colorado.edu/viewvc/cmt_py_utils/trunk/cmt/print_queue.py

ComponentHandler. This class provides a general tool for running CMI-enabled components and connecting them to other components. When used within the CSDMS Modeling Framework, this class, written in Python, allows components of all languages to share the same code base when wrapped as a CSDMS component. This allows for the automatic wrapping of new BMI components brought into the CSDMS family of models.

Component Builder: Through the CSDMS Component Modeling Tool (CMT), users are now able to run components that themselves create new components. As a proof-of-concept, these so-called ***component factories*** have been used to create new components based on a Regional Ocean Modeling System (ROMS) component. To create the new component, the component factory downloads, compiles, and installs a new version of the model on the CSDMS cluster, *beach*. The model is built to the specifications of the user as provided by configuration menus in the CMT. The component factory then goes on to auto-generate the wrapping code necessary to create a usable component within the CSDMS modeling framework. Following this process, the user now is able to use this new component within the CMT.
Subversion repository: http://csdms.colorado.edu/viewvc/component_builder/trunk

CMTCL. The CSDMS IF developed a command-line tool, CMTCL, that enables users to connect, configure, and run coupled components from the command line. This provides many of the same functions as the CMT but allows for easy scripting of batch jobs through either Python or shell scripts. Using a CMT resource file as input, CMTCL configures and connects components, sets up the users environment as necessary, and submits the resulting job to the CSDMS HPC cluster.

Subversion repositories: http://csdms.colorado.edu/viewvc/ccafe_gui/trunk/CMT; http://csdms.colorado.edu/viewvc/cmt/trunk

Model GUI Builder. Completed a general tool that allows a tabbed dialog GUI to be generated automatically from a file that provides an XML description of the dialog. This allows developers to easily add or subtract which input items are available to the end user of the model component. This can be done quickly at run-time without needing to rebuild the component or project.

Bocca Extensions: The CSDMS integration facility has developed a suite of tools that extend the CCA bocca utility. Included in this collection is ***bocca-clone***, a command-line utility that wraps a model as a CSDMS-CCA component for use within the CSDMS-CCA modeling framework. The model must expose the appropriate BMI interface (along with value getters and/or setters), with details of the model's interface and how it has been installed on the target platform described in a configuration file (e.g. lists of exchange items, names of interface functions, paths to shared libraries, etc.). The bocca-clone tool has been tested for use with C and C++ components but has yet to be used with the remaining CCA-supported languages. These tools are written in Python and are also available for use outside of the CSDMS modeling framework .

Subversion repository: http://csdms.colorado.edu/viewvc/bocca_tools/trunk/scripts/

CSDMS GridMapper. Written in Python and wrapped as a CCA class, the new CSDMS grid mapping tools are capable of mapping structured and unstructured meshs between CMI components. Currently, these tools are able to map point data to cell data, cell data to point data, and point data to point data. In addition, a Python API for these tools is available for use outside of the CSDMS modeling framework .

Component:
http://csdms.colorado.edu/viewvc/components/trunk/import/csdms/components/edu.csdms.tools.CSDMSGridMapper/
Python utility: http://csdms.colorado.edu/viewvc/cmt_py_utils/trunk/cmt/mapper.py

ESMFRegrid. CSDMS IF has also incorporated the ESMF regridding tools into our infrastructure. We currently use two versions of the tools, along with the CSDMS regridding tools. The first version is a serial version to be used on single-processor platforms, while the second makes use of the Message Passing Interface (MPI) to use multiple processors for the mapping. Although not yet completely integrated into the CSDMS framework, the parallel version of the mapper has been tested on the CSDMS High Performance Computing cluster and shown to scale nearly linearly up to several dozen processors.

The ESMF field regridding operation moves data between fields that lie on different grids for the purpose of model coupling through a sparse matrix multiply interpolation between source field and destination grid. The ESMF regridding module has been componentized and will work as a service component within CMT. In addition, an algorithm for automating parallel partitioning unstructured mesh of randomly distributed triangles has been implemented and tested to improve regridding performance. However, this capability is currently only available in the "offline" CSDMS toolbox. The mappers are capable of mapping elements from one unstructured grid to another. Although grid elements must be either three or four sided, the ESMF team is developing a more general tool that can deal with a larger variety of element types. Once completed, the newer version will be incorporated into the current Grid Mapper class.

CSDMS Time Interpolator. Earth surface process models may use fixed or adaptive time-stepping schemes, and two models to be coupled may use time-steps that are significantly different in size. A fairly typical example would be a snowmelt model, with time-steps on the order of an hour coupled to a channelized flow model, with time-steps on the order of several seconds. It would clearly be inefficient to run the snowmelt model with time-steps appropriate to a channel model and the state variables of the snowmelt model vary much more slowly. However, it can be somewhat jarring to the channel model when a state variable it uses from the snowmelt model suddenly steps up to a new value that is then maintained without change for many channel time-steps. This issue is sometimes referred to as "temporal misalignment." In such cases it makes sense to fit a smooth interpolation function to each of the state variables in the model with the larger time-step. The model with the smaller time-step can then retrieve and use interpolated values that vary more smoothly and which can be updated (with every time-step) with very low computational cost.

CSDMS has experimented with a variety of methods to address time interpolation, starting with methods that required calling the time interpolator from within a model's source code and which utilized a simple "stair step" approach. However, with the advent of the two-level, BMI/CMI approach to componentization, CSDMS staff began work to design and implement a new time interpolation component that would be consistent with the BMI/CMI philosophy. That is, it was to be ***noninvasive*** (not called from within a model's source code) and automatically invoked (as a service component) when needed by the CSDMS framework (as determined from BMI function calls). The ultimate design ***automatically*** does the following: (1) uses CSDMS Standard Names to identify every output variable (that is actually used by another component) of every component in a set of components, (2) creates a class container that stores the interpolates and all interpolation parameters for every variable, at the CMI level, leaving BMI -level code and variables untouched, (3) calls each model's BMI update function whenever necessary to update the interpolation variables, (4) accommodates array variables of any rank and data type and (5) accommodates both fixed and adaptive time steps. Meeting all of these requirements (especially items 3 and 5) while providing multiple interpolation options was more difficult than expected and required a significant time investment. In addition, the use of cubic splines for "dynamic interpolation" or interpolation in time is nontrivial. Cubic splines do not simply fit a cubic polynomial using values of a state variable from four different times (i.e. using values at four "nodes" or "knots") over three adjacent time intervals. While both "stair step" and "linear" interpolation methods are supported, CSDMS is continuing to experiment with a dynamic cubic spline option. Note that while this new service component has been tested in a Python-based model coupling framework, deploying it within the CSDMS framework will require some changes (ongoing) to our current "port queue" approach.

5. Modeling Framework

At the start of the CSDMS project, a variety of other model framework and model interface projects were evaluated to determine whether they would be able to meet the specific requirements of the (academic) earth surface process modeling community (Peckham, 2008). In particular, ESMF, CCA, MCT, OpenMI, OMS and FRAMES were examined. These other projects ranged from fairly new or experimental to fairly mature. Some were intended for PCs and others for HPC systems. All of them were based on the concept of models as components that could be coupled with standardized interfaces. Each project had its own approach to how to provide a standardized interface to an existing (legacy) model. One thing that became clear is that the modeling community to be supported by CSDMS was characterized by a high level of heterogeneity and therefore required a mechanism to support interoperability of models written in many different computer languages and "mediators" to reconcile other differences between models. For a variety of reasons, mostly related to support for language interoperability and HPC, CSDMS adopted the CCA (Common Component Architecture) standards developed by DOE. This provided a number of key tools that form the foundation on which the CSDMS Modeling Framework is built. This includes Babel, Bocca and Ccaffeine, which have been discussed extensively in previous reports. However, while the CCA tools provided the necessary (open-source) infrastructure, they did not provide any guidance (or constraints) on what type of component interface would be most appropriate for CSDMS model coupling.

In order to realize the full power and benefits of component-based modeling, a modeling framework like CSDMS needs an efficient mechanism to convert as many open-source models as possible to reusable plug-and-play components. Since this necessarily requires some involvement from each model's developer, this mechanism must be designed to:

(1) require minimal effort from the model developer,
(2) allow the model to continue to be used in a stand-alone manner,
(3) not introduce new dependencies into the model,
(4) not interfere with the developer's design,
(5) not require any modeling framework-specific knowledge on the part of the developer,
(6) not require the addition of new code which accommodates the needs of other models.

These requirements became clear during the first few years of the CSDMS project by working directly with model developers and listening to their concerns and complaints about early designs and other frameworks.

This eventually led to the innovative design of the CSDMS Modeling Framework, which is built upon the Basic Model Interface (BMI), Component Model Interface (CMI) and CSDMS Standard Names that were described in previous sections. This design, illustrated in Figures 3.3 and 3.4, can be summarized as follows:

Step 1. Model developers implement the CSDMS Basic Model Interface (BMI), which honors the requirements listed above. BMI has three "model control functions" that allow the model to be fully controlled by a modeling framework. BMI also has several "model self-description" functions that use standardized terms to describe the model's grid, input and output variables, time-stepping scheme and so on. This also maps the model's internal variable names to CSDMS Standard Names.

Step 2. CSDMS staff uses a simple script that calls Babel and Bocca to compile the BMI-enabled model as a dynamically linkable library that has the CSDMS Component Model Interface (CMI), which is the component interface used within the CSDMS framework. This includes language bindings that allow the CMI functions to be called from all Babel-supported languages.

Step 3. A CSDMS member, using either the CMT GUI or writing a script, indicates which plug-and-play CSDMS components are to be connected and provides configuration data for each of them. All of this information is collected in a script that gets passed to the CSDMS framework. The CSDMS framework instantiates and dynamically links all of the components and starts the model.

Step 4. Pulling the "model self-description" information up from the BMI level to the CMI/framework level, the framework is able to determine whether the variables that are to be passed between two linked models use a different: computational grid, time-stepping scheme (e.g. fixed or adaptive) or units. If so, the framework automatically calls service components (or mediators) before passing the variable to the model that needs it. Service components include regridders, time interpolators and unit converters. For example, the CSDMS framework can be toggled between using the CSDMS regridder or the ESMF regridder that can use multiple processors. Another CSDMS service component allows output variables from any model component to be written to a NetCDF file with standardized metadata. Service components may operate "behind the scenes" with default settings or can be configured or replaced by advanced users.

In pursuit of a design that best meets the needs of its modeling community, CSDMS has incorporated powerful, open-source software solutions, when available to address a particular need, such as the CCA tools, the ESMF regridder and the VisIt visualization software. But CSDMS has also developed powerful, new technology to address problems like simplified componentization, semantic mediation and ease of use, in cases where such solutions were not already available.

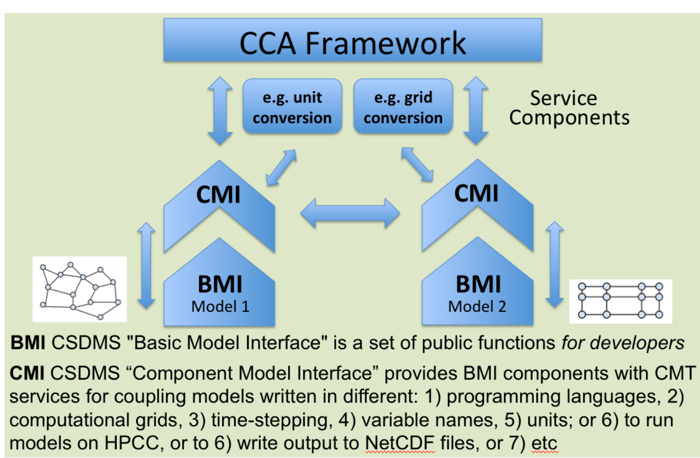


Figure 3.3. How models couple with each other and a Framework using interface standards, BMI & CMI.

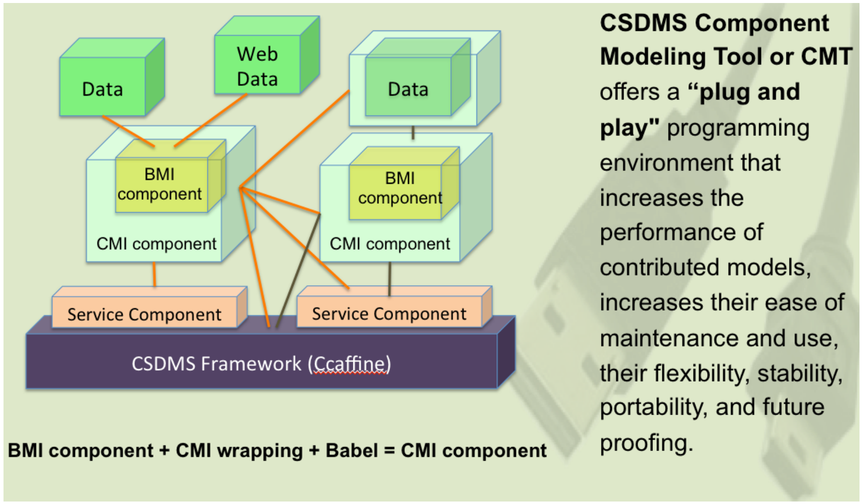


Figure 3.4 The CSDMS CMT plug and play programming environment.

6. Modeling Framework GUI

The CSDMS Modeling Tool (*CMT*) is a key CSDMS product that provides an easy-to-use graphical user interface (GUI) for the CSDMS Modeling Framework. It allows earth scientists with modest coding experience to run models in standalone mode or to graphically build coupled model configurations, for surface dynamics research and education. On June 14, 2010, CSDMS announced the first official release of the CSDMS Modeling Tool, version 1.4. *CMT* is a lightweight client application written in Java that can easily be downloaded and installed on any computer that supports Java. This allows it to be used on Mac, Window, and Linux operating systems. CMT creates a Ccaffeine script that describes which CSDMS components a user has selected for dynamic linking, along with all of the model configuration settings the user entered for each of those components. This script is then typically sent to a remote computer (e.g. the CSDMS HPCC) that passes the script to the CSDMS Modeling Framework (built on top of Ccaffeine) for execution. See http://csdms.colorado.edu/wiki/CMT_information for more information.

Requirements for New Users of CMT: The CMT installation process has been streamlined for new users, including three requirements before one can run experiments on the CSDMS HPCC:

1. Be a CSDMS member,
2. Get an account on the supercomputer *Beach*,
3. Install VPN software and gain a secure connection to the CU network.

The general layout of *CMT*, including the Palette, Arena, and Console, is demonstrated (Fig. 3.5).

Integrated Visualization of Model Output with VisIt: *VisIt* is a free interactive parallel visualization and graphical analysis tool for viewing scientific data on Unix and PC platforms, developed by the Department of Energy's Advanced Simulation and Computation Initiative. The CSDMS wiki now contains detailed instructions on how to install *VisIt* for both Mac and Unix and PC systems. csdms.colorado.edu/wiki/CMT_visualization. *VisIt* uses the computing power of *Beach*. Students have commented that *VisIt* is not straightforward to use. As a consequence we provide tutorials on common visualization tasks. 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 Movies" provides detailed instructions on creating movies using *VisIt*. In this case, *VisIt* is launched from *beach* rather than from the user's local machine, in order to produce better quality MPEG movies.

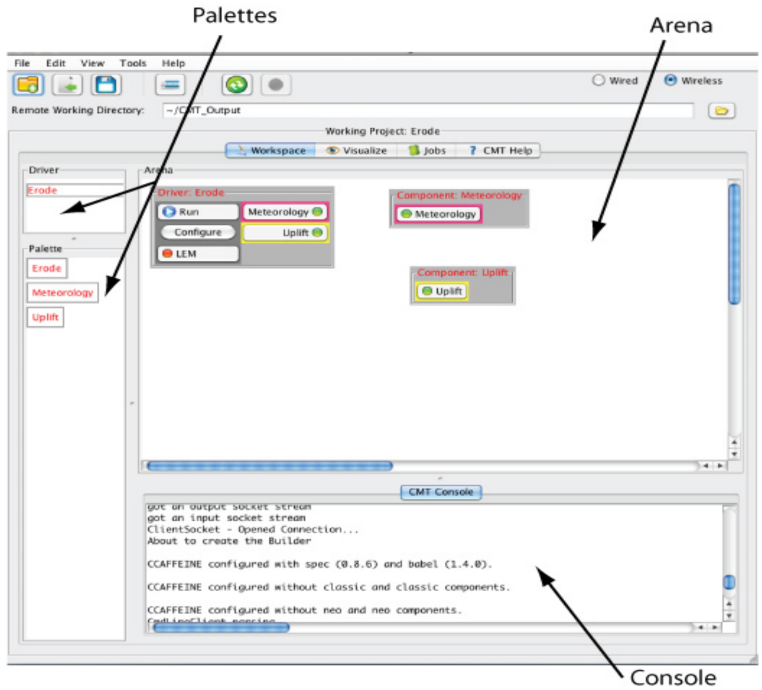


Figure 3.5. The CMT GUI for model coupling on the CSDMS HPCC Beach. Users can drag and drop components from in this example a Terrestrial Project environment, to activate the working Arena. Color-coded bullets visually enhance model connections, along with input-output linkages: green buttons shows active connections.

Key Features of CMT

- Communication from the user's computer to *Beach*
    - *CMT* can be download directly from the CSDMS website as a Java application (Mac, Windows, and Linux versions are available).
    - For fast access by experienced users, one can go to the database of model components on the CSDMS wiki and start the *CMT* directly for *CMT* compliant models.
    - Users are automatically informed when a new version is available upon start up.
- Remote Access Functionality to link users to *Beach*
    - Login screen bypasses SSH command line interaction of users.
    - SSH tunneling is automatically funneled via *CMT*.
    - Sftp transfers input and output files from *Beach* to users local machine and vice versa.
- Look and Feel
    - Components are labeled with their model name, to make apparent what connections are active.
    - Clear distinction between a 'Driver', which orchestrates the simulation, and other components.
    - Component connections are color-coded so that coupling can be visualized (Fig. 3.6).
    - Wired and wireless options for creating models; wireless option can automatically connect components in the Arena. Green buttons indicate whether connection is active.
    - Customizable background color and screen font
- Input/Output Operations
    - A Console window prints model run messages that can be saved as log files for debugging.

    - 'Submit Job' is an option, apart from 'running the CMT while watching its progress'. This functionality is useful when doing multiple scenarios, sensitivity experiments or testing, all of which are situations where multiple experiments need to be run at the same time. Using the job manager of the CMT bypasses expert-use of scripts and direct job management on *Beach*. Users can decide whether to receive an email upon completion of their requested job.

- 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
    - Configure Dialogs, for user to configure the input and output parameters and files for each model component in a Graphical User Interface. Some models have never had a GUI for setting up simulation, for example the Regional Oceanographic Ocean Model ROMS, and so it is a real novelty to provide a click and play environment for these models (Fig. 3.7).

- Advanced Users Can Quickly Switch Environments
    - Set a default modeling project
    - Option to Remove/Delete components and Clear Arena
    - Project Refresh & Reload options
    - Preferences page

- Integrated Visualization Tool
    - Access to HPCC visualization tool (VisIt) for creating figures and movies
    - Output from CSDMS models is written to VisIt-viewable NetCDF files
    - Help within the context of the CMT has been added at Introduction level, at Example Configuration Level and at the Most Advanced Process and Parameter level

Moving the CMT beyond 'the black box'. Model users should have access to a model's background information, its process equations and its parameter definitions. Each compliant CSDMS module is given 'HTML Help Pages' on the CSDMS wiki, listing information on the model's processes and parameters. Developers ensure the information posted on our wiki-based site is accurate. Upon opening a CMT project, users may choose to open example configuration files (where model components are already configured in the CMT Arena), or to drag components into the Arena from the model Palette. Each component has a "Configure" button that opens a tabbed dialog box where the user may click on the "Help" button to open a CSDMS wiki help page.

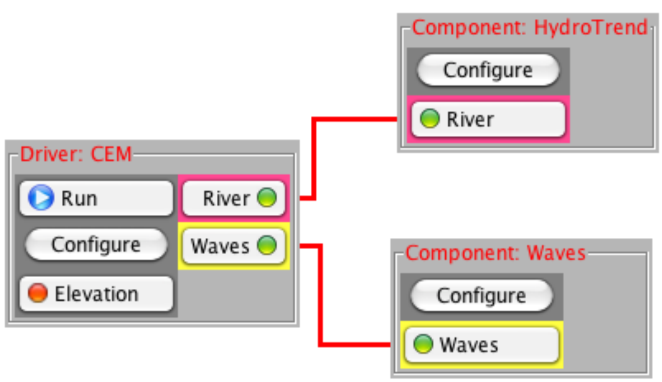


Figure 3.6. Wiring diagram shows coupling of HydroTrend (simulator of water and sediment discharge), with Waves (wave climatology simulator), driven by the Coastal Evolution Model to simulate a delta evolution. Users can drag and drop the components from a Coastal Project environment. Tabbed 'configure' menus for each component allow the specification of simulation parameters. A click on 'run' and the coupled components execute on simulation on the CSDMS HPCC Beach.

The help pages 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 the majority of model components. For some components the "Help" button connects to the model's metadata on the CSDMS wiki or to alternate community portals (e.g. ROMS, which is extensively documented elsewhere). All example configuration (.bld) files are tested (execution and output); this does not include extensive testing with different parameter combinations.

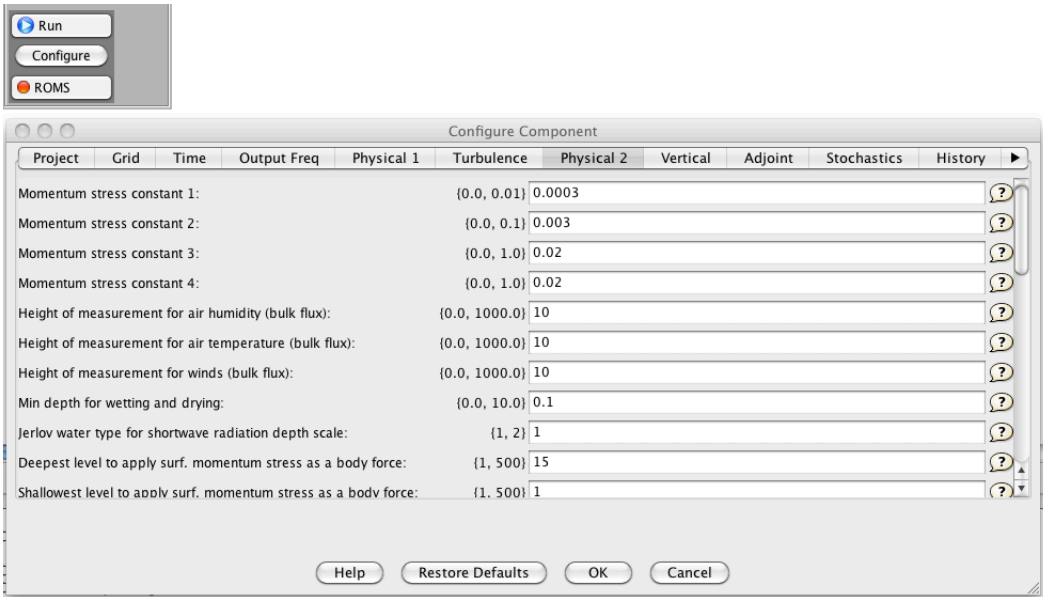


Figure 3.7. ROMS-the Regional Ocean Modeling System can be run stand-alone in CMT. Users click on the 'configure' tab and set simulation parameters. The 'help' button on the bottom-left leads to advanced documentation on model setup and parameters. Given ROMS vibrant user-base and documentation on its wiki website, the 'help' her leads to the MyROMS community user page.

Deploying CMT on Other Platforms. The CSDMS IF has built the CSDMS tool chain, which consists of upward of 20 separate software packages, on a variety of platforms. The target platforms range from single-user machines to large high performance computing clusters that contain tens of thousands of computing cores (the NSF/CU High Performance Computing Center, Janus). Target operating systems are Linux-based and include several versions of RedHat (5.6, 5.2), Fedora (17), and Darwin (11.3). Compilers used include the GNU compiler set and the intel compilers.

Building this many packages on such a wide range on platforms is time consuming and error prone. To address this, we have developed a plugin-based program, developed in Python, that automates the build process of the CSDMS software stack, and it's dependencies. Although not yet fully automated, our software stack builds with little human intervention. The CSDMS package builder, bob, is available as either a Python egg, or as source code. Both can be downloaded from the CSDMS website. The bob package builder,

- SVN repository: https://csdms.colorado.edu/svn/bob/trunk
- Source-code: https://csdms.colorado.edu/tools/bob/bob-0.1.tar.gz
- Python egg: https://csdms.colorado.edu/tools/bob/bob-0.1-py2.7.egg

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Chapter 4: CSDMS Portal

Data Set Archive Goal: *Design a system to: 1) store data that is needed as boundary conditions for different models and 2) store sample data for testing and benchmarking models and subroutines. Users could mine this Archive to condition their modeling efforts over a range of scales (e.g. a regional sea level curve when modeling coastal evolution). Where possible, the Archive was to point to viable download pages (e.g. National or World Data Centers). The community was to provide generic testing and benchmarking data sets for sub-environments of the surface system. Integrated data sets will be assembled to test the functionality of coupling various CSDMS modules. The National Center staff will maintain the Archive data structure.*

How well did we do: A structure is set up that modelers can upload their model input data on their model metadata page on the CSDMS website. This data can be used for model testing, so for example for people who downloaded and compiled the source code and want to make sure they compiled it right on their machine. Secondly, model developers can upload data together with their model source code to the model repository (subversion). In this way, different input data files can be easily linked to specific versions of a model. Lastly a data Repository is set up on the CSDMS website is created that points to sites of other communities to mostly gridded and geo-referenced data types that are meant to establish boundary conditions for the different models. The following datasets are pointed to:

Data Repository as of May 2013 csdms.colorado.edu/wiki/Data_download

Data Type	Databases
Topography/bathy	18
Climate	6
Hydrography	5
River discharge	8
Cryosphere	5
Surface Properties	5
Land cover	4
Substrates	3
Human Dimensions	2
Sea level	1
Oceanography	9
GIS Tools	12
Network Extraction	7

CSDMS Data Repository website points the community to the following mostly gridded and geo-referenced data types that are meant to establish boundary conditions for the different models:

- Bathymetric data: 1) GEBCO (General Bathymetric Chart of the Oceans); 2) Smith & Sandwell (1 minute Global seafloor topography); 3) IBCAO (International Bathymetric Chart of the Arctic Ocean); 4) Coastal DEMs from NOAA's NGDC (National Geophysical Data Center); 5) ETOPO1 (1 arc-minute integrated bathymetric-topographic relief model); 6) Global Multibeam Bathymetry (NGDC's multibeam database); 7) Great Lakes Bathymetry (Bathymetric models and contours of the US Great Lakes; 8) Marine Geophysical Trackline data (Trackline surveys of e.g. bathymetry);

- Climate data: 1) E-Obs (daily gridded precipitation and temperature for Europe), 2) GHCN (NOAA Global Historical Climate Network); 3) GOBALSOD (NOAA Daily Global Summary of Day Station Data); 4) PMIP-2, paleo climate modeling results; 5) TRMM (Tropical Rainfall); and 6) Tropical cyclone data.

- Topographic data: 1) GDEM (ASTER global topography); 2) CGIAR-CSI SRTM (3rd generation SRTM topography); Coastal DEMs (NGDC high-resolution coastal DEMs); 3) ETOPO1 (Global 1 arc-minute gridded elevation data); 4) GEBCO (global integrated bathymetry – topography 1 arc-minute DEM); 5) GLOBE (Global topography, 30 arc-second); 6) GTOPO30 (30 arc-second global digital elevation model); 7) Global Topography (1 minute and 30 arc-second resolution bathymetry – topography relief models); 8) IBCAO (as a 500m grid, integrated Bathymetry-topography model of the arctic ocean); 9) NED (US National elevation dataset, 1/9 arc-second); 10) SRTM (1st and 2nd generation SRTM topography data); 11) Southern Alaska Coastal Relief model (bathymetric-topographic relief model of southern Alaska at 24 arc-second), and 12) world vector shoreline.

- Discharge data: 1) USGS national water information system (Daily and monthly discharge and water quality maintained by the USGS); 2) HYDAT (A data-base of daily and monthly river discharge of Canadian Rivers maintained by Water Survey of Canada); 3) R-Arctic Net (A data-base of Arctic-wide monthly river discharge); 4) Dartmouth Flood observatory (daily flood extend & history as well as discharge observed from satellite); 5) GRDC (Global runoff Data Centre); 6) Sage (Global River Discharge Database); and 7)World River Sediment Yields Database (annual sediment yields worldwide).

- Cryosphere data: 1) ICE-5G (Global ice sheet thickness from paleo to present); 2) Permafrost Alaska (USGS borehole temperature logs for Alaska); 3) World Glacier Inventory (NSIDC Information on glaciers for over 100,000 glaciers through out the world); and 4) Sea Ice Concentrations (NSIDC through passive microwave analyzes)

- Human dimensions data 1) World Population Prospects United Nations Population Database, incorporating total pop, and pop density for all UN countries. The data covers 1950-2005 and projects to 2050 with 5 year intervals. 2) World Urbanization Prospects United Nations Population (2007 revision) Database. This data shows total pop, rural pop and urban pop as well as annual growth rates for all UN countries. The data covers 1950-2005 and projects to 2050 w/5 yr intervals.

- Hydrography data: 1) DDM30 (Global 30 minutes raster map of drainage direction); 2) Hydro1K (USGS developed global 30 arc-second among other stream and drainage basin data); 3) HydroSHEDS (Hydrological data derived from SRTM product, global coverage, e.g. river network, drainage direction); 4) NHD (US National Hydrography Dataset); and 5) SWBD (Shuttle radar topography water body dataset).

- Land cover data: 1) 3D Land Mapping (global scale mapping of vegetation by combining Lidar and Radar); 2) GIMMS (Global Inventory Modeling and Mapping Studies, using NDVI to map land cover between 1981-2006); and 3) NLCD 1992 – 2001 (US national land cover database).

- Sea Level Data: 1) PSMSL is the global data bank for longterm sea-level change information from tide gauges. The PSMSL collect data from several hundred gauges situated globally.

- Oceanography data: 1) Geoscience data (IEDA data services of observational Geoscience data from the Ocean); 2) MLD (2 by 2 degrees gridded global mixed layer depth climatology); 3) OSCAR (Ocean Surface Current Analyses in real time); 4) ReefBase (Coral reef database); 5) Ocean sediment thickness (a 5 arc-minutes gridded NOAA product); 6) TPXO6.2 (Global inverse simulated tides); 7) WaveWatch III™ (A 3rd generation wave model); and 8) World ocean atlas (one degrees grid of ocean variables).

- Surface properties data: 1) GSHAP (Global Seismic Hazard Assessment data); 2) HWSD (Harmonized World Soil Database); 3) NCED data repository (Field and laboratory data related to earth-surface dynamics); 4) RESSED (Reservoir Sedimentation Database); and 5) STATSGO (US general Soil Map).

CSDMS Website Goal: *Design a system to: 1) provide the mission of the center, protocols, FAQ, 2) accept submissions of user-contributed code via a web form, 3) provide access to contributed subroutine library and standard utilities, 4) provide access to the data set archive, 5) allow download of the modeling environment and included models.*

How well did we do: The CSDMS website evolved at a rapid pace, maturing to become the portal for open source surface dynamics models, almost always ranking number one for Google searches on specific model names, and now number one when searching for CSDMS. CSDMS uses its website that is build upon open source code MediaWiki, as the main communication to the outside world and to its members. Becoming a member and tracking membership is therefore fully handled by the site as is sharing information and resources. Currently there are over 1000 members (Fig. 4.1). Over the past several years the web portal extended to 6,154 pages and 2,654 files (images, documents, presentations) where uploaded. All members can submit edits the content management system, which lead to over 146,241 web page edits. All those contributions resulted in a high quality website containing surface model resource that generated over 14,316,150 page views since the website is up and running (Early 2008).

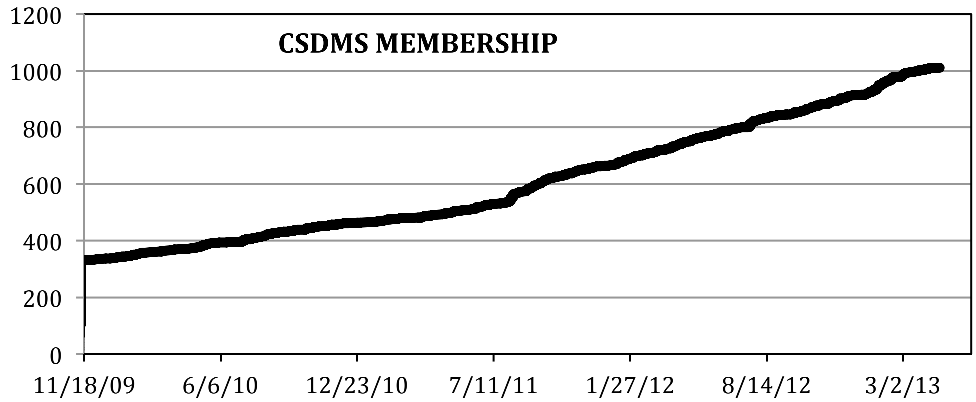


Figure 4.1 Growth in Active membership (y-axis) per day as of November 2009 (x-axis)

Several new content management developments have taken place over the last year to become and stay *the* portal for open source surface dynamics models. Listed below are the major achievements to serve our community.

Links:

- Membership: http://csdms.colorado.edu/wiki/All_CSDMS_members
- Website statistics: http://csdms.colorado.edu/wiki/Special:Statistics

CSDMS web forms developed to make contributions easier for members

CSDMS has implemented forms to its content management system to serve the following goals: 1) to make contributions to the website as easy as possible for our members (no knowledge of wiki code is needed), 2) to allow query of submitted data such that people can search the wiki database on the fly or dynamically display form content, and 3) to be able to statistically analyze submitted information. These forms have been developed and implemented for capturing the following information: Membership registration, Model metadata, Meeting announcements, CSDMS annual meeting registration and abstract submission, HPCC account request, Input data submission, presentation submission, Movie submission. The forms have been used alternativelu to surveys CSDMS members on specific topics.

Links:

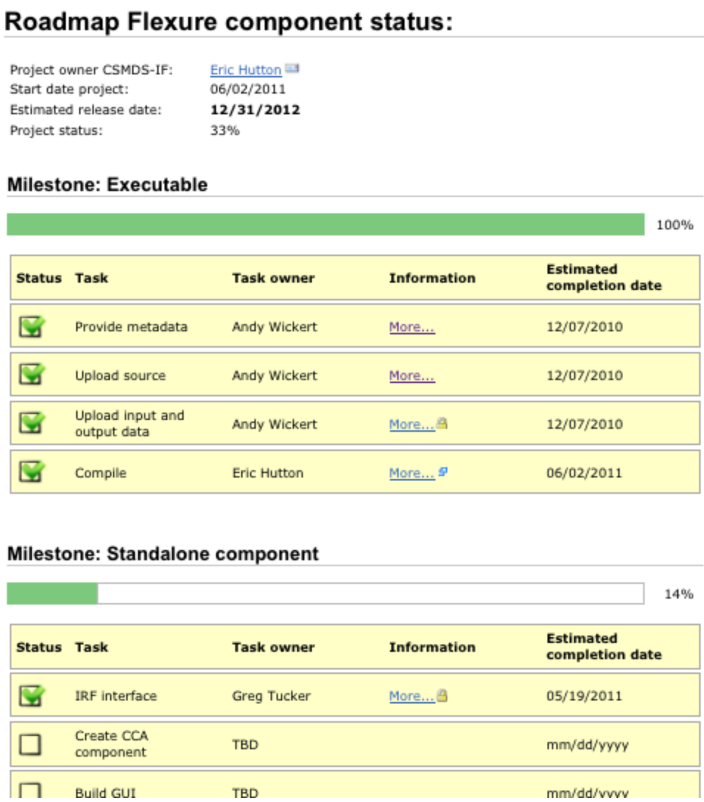
- Meeting form: http://csdms.colorado.edu/wiki/Meetings
- Member registration: http://csdms.colorado.edu/wiki/Form:CSDMS_new_member_Signup
- Input data submission: http://csdms.colorado.edu/wiki/Form:Input_data
- Model questionnaire for metadata: http://csdms.colorado.edu/wiki/Form:Module_questionnaire
- Movie submission: http://csdms.colorado.edu/wiki/Form:Movie-animation_upload
- Presentation submission: http://csdms.colorado.edu/wiki/Form:File
- HPCC account requests: https://csdms.colorado.edu/wiki/HPCC_account_request
- Survey: http://csdms.colorado.edu/wiki/Modeling_course_questionnaire_form

CSDMS development tracking: Roadmap to component status

A roadmap displaying duration, tasks and person responsible is automatically generated and tracked by IF staff and/or the model owner once it is decided to be incorporated as a model into the CMT (Fig. 4.2). The roadmap is constructed to give a quick overview of the status of the project and contains the option for each of the task owners, as well as for the project owner to incorporate links containing detailed information regarding specific tasks. Three milestones during the development process are displayed: executable, standalone component and coupled component. A green checkmark is placed when a task is fulfilled; a red cross is displayed when a task could not be executed. A task is displayed as light gray in cases where this task will not be fulfilled within the scope of the project; not every model will be configured as a component that can be coupled. The roadmap informs membership about the status of a model to become a CMT component and provide detailed information of each of the involved tasks and which person to contact in case members have specific questions.

Links:

- Roadmap example: http://csdms.colorado.edu/wiki/Roadmap:Flexure



Roadmap Flexure component status:

Project owner CSMDS-IF: Eric Hutton
Start date project: 06/02/2011
Estimated release date: **12/31/2012**
Project status: 33%

Milestone: Executable

100%

Status	Task	Task owner	Information	Estimated completion date
	Provide metadata	Andy Wickert	More...	12/07/2010
	Upload source	Andy Wickert	More...	12/07/2010
	Upload input and output data	Andy Wickert	More...	12/07/2010
	Compile	Eric Hutton	More...	06/02/2011

Milestone: Standalone component

14%

Status	Task	Task owner	Information	Estimated completion date
	IRF interface	Greg Tucker	More...	05/19/2011
	Create CCA component	TBD		mm/dd/yyyy
	Build GUI	TBD		mm/dd/yyyy

Figure 4.2. The roadmap for the Flexure model, describing the project status of componentizing

Tools analyzing model repository downloads

Significant changes have been made to the infrastructure of the model repository to accommodate community members to: 1) store and retrieve all source code of modules that are in the CSDMS database from a single place, 2) track basic information of who is downloading what module from the CSDMS database and 3) monitor how often a module is downloaded from the CSDMS database. All source code is now only stored in Subversion. People who download a module access subversion automatically through the website, select the desired version of the source code of a module, which then is automatically zipped before the download process starts. We do solicit email address and name during download, this information is provided to the original developer annually (or at any time upon request). Monthly download statistics are presented on the model metadata webpage, and a total monthly download is presented on the CSMDS front-page (Fig. 4.3). Complete download statistics of the model repository are provided (see links below).

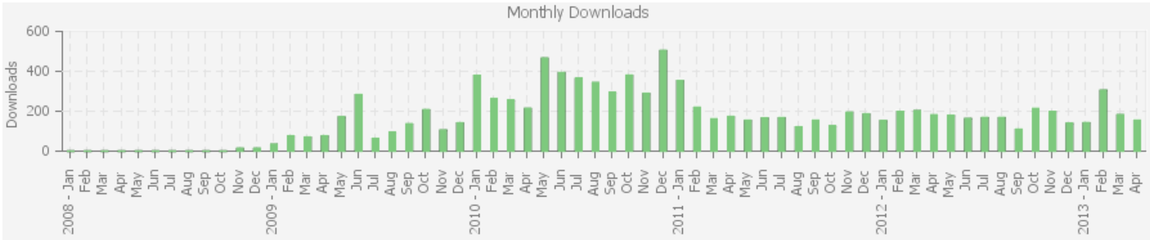


Figure 4.3. Model download on a monthly basis, only for models in the CSDMS model repository.

Links:

- Download a model: http://csdms.colorado.edu/wiki/Download_models
- Monthly overview of a model download e.g.: http://csdms.colorado.edu/wiki/Model:SIBERIA
- Complete download report: http://csdms.colorado.edu/wiki/Model_download_Page

Tools to track source code statistics

Subversion software is used to store source code in the CSDMS model repository. The software provides the capability to track source code history (version control) as well as the option to analyze content. For example to generate basic model information (Fig. 4.4) on: 1) the number of source code lines, 2) the number of blank lines & comment lines, 3) the language. This information helps CSDMS determining what the key program languages are that need to be able to communicate together in the component-coupling tool (CMT).

Project	Language	Blank	Comment	Source	Total
MITgcm	Fortran 77/90	91148	92458	333949	517555
Regional Ocean Modeling System (ROMS)	Fortran 77/90	34763	90660	380656	506079
The Weather Research & Forecasting Model (WRF)	Fortran 77/90	79107	95442	309177	483726
Penn State Integrated Hydrologic Model GIS (PIHM gis)	c/c++	68530	83696	253907	406133
Telemac	Fortran 77/90	31887	105124	122126	259137
ParFlow	c/c++	36835	36446	98198	171479
Anuga	Python	42501	24487	101716	168704
Finite-Volume, primitive equation Coastal Ocean Model (FVCOM)	Fortran 77/90	28641	27692	92876	149209
ADCIRC	c/c++	18934	23123	81202	123259
sedflux	c/c++	21970	21375	76008	119353
MODFLOW	Fortran 77/90	10125	22325	64278	96728
SWAN	Fortran 77/90	8277	49330	38624	96231
WAVEWATCH III (tm)	Fortran 77/90	7245	50209	28424	85878
Glimmer-CISM	Fortran 77/90	16524	22515	44951	83990
GEOtop	c/c++	20417	12667	27528	60612
CHILD	c/c++	7828	15058	28884	51770
Regional Hydro-Ecologic Simulation System (RHESSys)	c/c++	4864	18745	26088	49697
SPHYSICS	Fortran 77/90	8491	6686	28782	43959

Figure 4.4. SLOC page provides basic information of the models in the CSDMS model repository.

Links: SLOC page: http://csdms.colorado.edu/wiki/Model_SLOC_Page

Web tracking tools

The CSDMS web site incorporates a tool to monitor any changes on pages that are of interest to a certain user, as well as feeds. Users can either subscribe to single pages, to every edit on the CSDMS website, or subscribe to receive email updates of edits that are made on pages selected by the user. These are described at csdms.colorado.edu/wiki/Help:Watchlist. The CSDMS website also offers the community the possibility to stay up to date automatically of any newly added information in three ways:

1. *Subscribing to RSS (or ATOM) feeds per single page of interest.* The web browser will display on each page a RSS icon (see example figure on the right). Depending on the web browser this icon will appear in the URL text box (Firefox, Safari) or on in the menu bar

(Explorer).

2. *Subscribing to the "Recent Changes" page with RSS (or ATOM) feeds.* The "Recent Changes" page (csdms.colorado.edu/wiki/Special:RecentChanges) displays changes that are done on the website at a given day and time, who made the changes and a short description of the newly added information. The "Toolbox" on the left side of the web site contains the RSS or ATOM feed subscribing option. By subscribing the CSDMS web site user can stay up to date of all the added changes through for example Google Reader.
3. *Receiving emails of the "Watch" pages that the CSDMS member is subscribed to.* This option is only available for CSDMS members. Every CSDMS member has a CSDMS website account, this is automatically set up when a person applies to become a CSDMS member. As soon as a member logs into the CSDMS website a "watch" option appears for every page in the "Page edit toolkit" on the left side of the website. By pressing "Watch", the page is added to a list: (csdms.colorado.edu/wiki/Special:Preferences).

Google Analytics to monitor key web-use parameters is integrated into the CSDMS website.

Google Analytics content management monitoring software informs on how people touch upon and explore the CSDMS website. With this information we analyze which pages are most often viewed, how people reached those pages, which pages are more buried and hard to find by the user, and where we should place content that needs visibility. The monitoring software has been integrated within the CSDMS website since January 8th, 2010. Some of the results we would like to share with our users by integrating key parameters monitored by Google Analytics into the CSDMS website (Fig. 4.5).

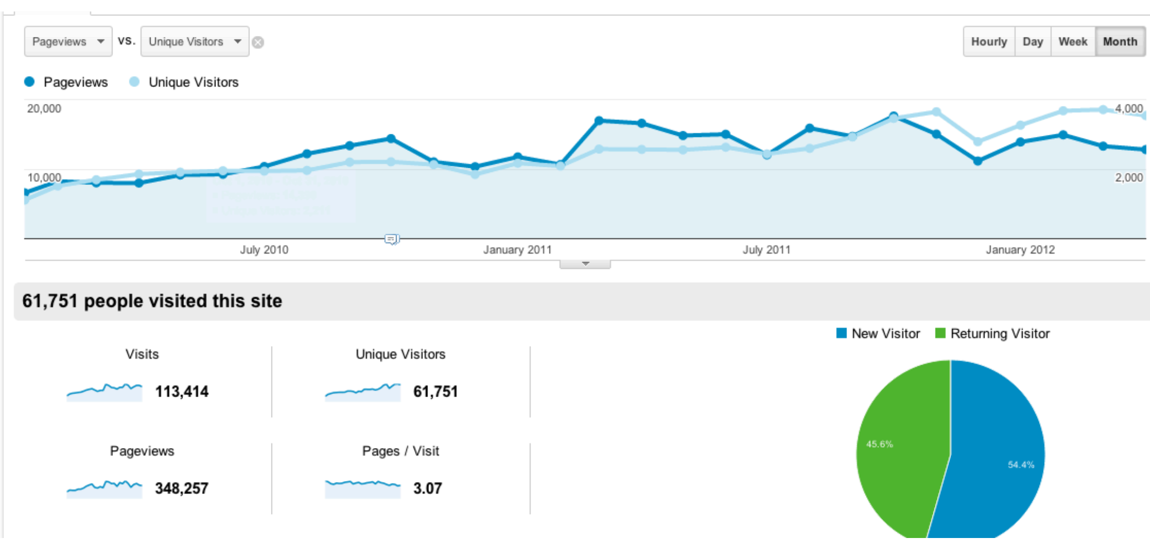


Figure 4.5. Monthly pageviews & unique (first time) visitors statistics of the CSDMS website since 2010.

Digital Object Identifier (DOI) for models

DOI, or Digital Object Identifier, is a unique string to identify an object in a digital environment. The object could be a paper published in a scientific journal or a specific dataset. A DOI guaranties that an object can always be traced by simply resolving a web address that is constructed by a DOI search engine URL "http://dx.doi.org/", combined by the unique identifier. The DOI contains metadata, including a URL that points to the specific object. Objects with a DOI are 5 times more likely to deliver active links to the digital content than objects without. To guaranty access to source code of numerical models CSDMS has, in close cooperation with Dr. K. Lehnert (Director of Integrated Earth Data Applications Research Group (IEDA)) and Dr. L. Hsu, both from Lemont-Doherty Earth Observatory, requested a DOI for each Model in the CSDMS repository. Despite over 50 million DOI strings, CSDMS is the first in history to request DOIs for numerical models. A list of all the numerical models of the CSDMS model database together with limited metadata for each model is provided to IEDA and DOI are generated and added to the metadata page of each model. Each half year CSDMS will apply for DOI codes through IEDA by providing a list of new models or substantial upgraded versions of existing models.

Links:

- DOI information page: http://csdms.colorado.edu/wiki/DOI_system_for_models
- Example DOI page: http://csdms.colorado.edu/wiki/Model:Sedflux

Model info box & QR-code for models

A fully automated dynamic "Model info" box (Fig. 4.6) is created for each model questionnaire page to serve model developers and users with summary information regarding the author of the numerical model (name, other models made by the author) as well as give a direct link to the download location for the source code. The model authors name is linked to his user profile page (when the author is a CSDMS member), which contains at the minimum contact information. The DOI code of a model is displayed here as well (This is only provided to models that are submitted to the CSDMS model repository).

Figure 4.6 An example of the Model info box. QR-codes are incorporated in the Model info box.

Links: All model pages, e.g.: http://csdms.colorado.edu/wiki/Model:CMFT

CSDMS implemented an automatic process by developing a python script to generate QR-code images on the fly for its entire numerical model database and placed the images on the represented web addresses. QR-codes (Quick Response Code), are two-dimensional barcodes became more popular after the introduction of the smartphone in 2007. Unlike the barcode, these images can be scanned or captured by a phone or tablet that has a camera. People with a smartphone or tablet can scan the QR-code and will be automatically directed to the encrypted website URL, without typing in a long web address. So e.g., a QR-code can now be used in oral or poster presentations to easily direct a person to their specific CSDMS model questionnaire page (Fig. 4.6).

Links: All model pages, e.g.: http://csdms.colorado.edu/wiki/Model:CMFT

Updated Model metadata, adding key-papers

Metadata of models is of utmost importance to provide potential model users information such that they can decide if a certain model might fulfill their needs. Therefore CSDMS implemented a few years ago a model questionnaire that model developers have to fill out, describing their model, if they want to add their model to the CSDMS model repository. Each model questionnaire contains a field where people can describe the key papers that describe their model. However, not everybody has taken the effort to provide this information. CSDMS took the effort to search journal databases to identify the top 3 to 5 scientific papers that describe each model that is provided on the CSDMS web, and incorporated this into the existing metadata for each model.

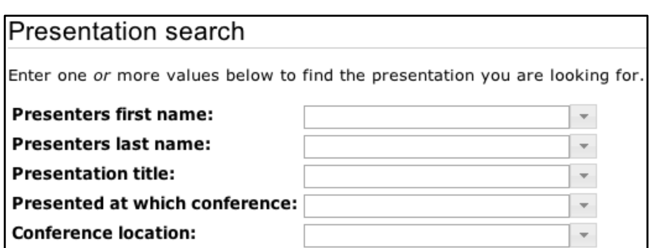


Figure 4.7. Query website page to search for any given presentation (PowerPoint or poster) given at a CSDMS meeting

Presentation query capabilities

Over the last 5 years CSDMS members have given several hundred presentations. In agreement with the presenters, those presentations have always been made available to the public during or shortly after each meeting, by placing them on each specific CSDMS meeting website. However, with the growing number of presentations stored in the

CSDMS meeting repository, the need for a database query tool became more urgent. Therefore metadata (Presenters name, title presentation, conference name and location) was added to each presentation file and a query environment was developed to serve the need to provide easy access to CSDMS presentations. This query tool is now available on the CSDMS website (Fig. 4.7).

Links: Presentation query page: http://csdms.colorado.edu/wiki/Special:RunQuery/Files_query

Web maintenance

CSDMS cyber infrastructure builds upon the open software package Mediawiki and numerous third-party extensions (over 62 extension as of now) to extend cyber infrastructure capability and to provide the latest cyber tools to CSDMS web visitors to guaranty the easiest experience to interact through the web. About every half year the core software (mediawiki) is significantly upgraded and with it most third party software extensions, to guaranty performance, security, and to incorporate new features. It is required by the University of Colorado (CU) to upgrade cyber infrastructure to a newer version when a security upgrade becomes available, to reduce possible cyber attacks directed to CU. CSDMS executed latest major cyber infrastructure upgrade (upgraded to mediawiki version 1.20.6) conform CU standards. Additional effort were made to adapt the CSDMS website appearance (skin) to the latest version as well as making all extensions operable under the new core software. Were needed outdated extensions were replaced to guaranty functionality.

Links:

- MediaWiki: http://www.mediawiki.org
- CSDMS is currently using MediaWiki version: http://csdms.colorado.edu/wiki/Special:Version

The CSDMS YouTube channel for educational movies, tutorial and model animations.

CSDMS has ported all of its contributed animations and movies to YouTube to enlarge the impact of the community and expose the public to some of the community gained insights. Detailed description of each movie remains on the CSDMS website, under the educational section (http://csdms.colorado.edu/wiki/Movies_portal), and can also be found at the meeting portal (http://csdms.colorado.edu/wiki/Past_Meetings). While movies will still play from the CSDMS website they are hosted from the 'CSDMSmovies YouTube channel' (http://www.youtube.com/user/CSDMSmovie). The channel has currently 69 subscribers and incorporates 8 playlists: Coastal animations (*22*), Environmental animations (*8*), Laboratory movies (*13*), Marine animations (*10*), Real event movies (*32*), Terrestrial animations (*21*), Meeting movies (*35*), and CSDMS tutorials (*4*). In 2011, the University of Colorado started to encourage departments and institutes to provide animations and movies to the university media page as well. CSDMS contributed all its movies to CU to further enlarge the exposure to the public. There are presently 147 movies & animations on the CSDMS YouTube channel, generating more than 116,538 views. Thanks to this effort, at least one move was incorporated in a documentary (http://damocracy.org/).

Table 1: Top 10 views of CSDMSmovies YouTube channel:

Movie / animation	Nr. of views May 2013
Global circulation	40,821
Lauren tide Ice Sheet evolution	8,015
Delta formation	5,724
Spit evolution	4,467
Sand ripples	3,504
Floodplain Evolution	3,410
World dams since 1800	2,766
Meandering river	2,344
Allier river meander	2,219
Barrier Island	2,029

The goal to enlarge the impact of the community by making the movies more accessible is successful. The CSDMS movies YouTube channel has been highlighted several times for being in the "Top 50 most viewed channel" of the "non profit" category.

Links:

- Movie descriptions: http://csdms.colorado.edu/wiki/Movies_portal
- CSDMS YouTube channel: http://www.youtube.com/user/CSDMSmovie
- Univ. of Colorado YouTube channel: http://www.youtube.com/user/univcoloradoboulder#p/c/0A49CA0F0E6D8EDA

CSDMS will actively share news through social networking; Twitter.

A twitter account has been set up to reach out within and beyond our community (Fig. 4.8). Several options (wiki external plugins) has been investigated to incorporate the provided 'tweets' within the CSDMS website for users to view older tweets as well. Providing new tweets and a fully integration of old tweets into the CSDMS website will be one of the targets for the second half of this year.

Links:

- Twitter page of CSDMS: http://twitter.com/#!/CSDMS

Figure 4.8. CSDMS is 'tweeting'.

Chapter 5: CSDMS Educational Mission

The CSDMS Educational Goal: *Our principal Education audiences were defined as university students, professionals, teachers at the secondary school and college levels, and the general public. Broadly speaking, CSDMS' educational goals were to (1) provide professional training in the use of CSDMS and its components, (2) use CSDMS technology to enhance undergraduate earth science education, (3) provide CSDMS-based tools for enhancing secondary-school teaching in earth-surface science, and (4) contribute to the public understanding of Earth-surface dynamics by working with informal education institutions such as science museums. Overall, our plans were to jump-start our Education and KT activities by coordinating them closely with the EKT programs at the National Center for Earth-surface Dynamics (NCED), a funded NSF Science and Technology Center devoted to developing a predictive, quantitative understanding of the processes that shape the Earth's surface.*

How well did we do: The CSDMS EKT Working Group and CSDMS Education Specialist refined the way the modeling research community can make lasting and meaningful contributions to geoscience education. The EKT Working Group members emphasized as a first priority the importance of educating the variety of model users within the CSDMS community; model developers, model users and model data users. Objective (2) to enhance modeling in undergraduate education, was perceived to be of prime importance as well. Development of online wiki-based teaching resources, at all levels, would guarantee that these resources become as widely available as possible.

Training in the use of CSDMS modeling framework

The CSDMS modeling framework aims at allowing users to run and couple models in a high-performance computing environment. CSDMS Modeling Tool (CMT) is one of the tools of the CSDMS project; it allows earth scientists with little prior modeling experience to use and couple models for surface dynamics research and education on the CSDMS computing cluster through a graphical user interface. The CMT was developed from 2009 onwards and was officially released for use to the community in October 2010; details on the CSDMS framework and the CMT GUI are reported in the section of this report describing the CSDMS Cyberinfrastructure. We here solely focus on the educational aspects and the knowledge transfer to the community with regards to modeling and the use of the CSDMS framework. Our education and knowledge transfer efforts targeted a variety of learning styles by presenting lectures, demonstrations, movies, online instructions and hands-on labs. These efforts have been targeted towards CSDMS community members with graduate students being our focus group.

Tutorials, Demos and Clinics by CSDMS Integration Facility Staff

The integration staff of CSDMS has shared its advances and trained the CSDMS members from the start of the project. Software architects and the web specialist provided the working groups with short, applied presentations and demonstrations of the use of the wiki, the tools that were being developed, and the protocols for developers to make their code compliant with the CSDMS framework from 2008 onwards. Presentations were shared amongst the larger community through the CSDMS website and wiki.
(e.g.: http://csdms.colorado.edu/wiki/Cyberinformatics_2008).
From 2010 onwards, CSDMS has organized a joint annual meeting featuring technical clinics. Some of the clinics are topical, others are more focused on building new skills (see Section – Meetings). Feedback from the meeting participants was extremely appreciative about these clinics.

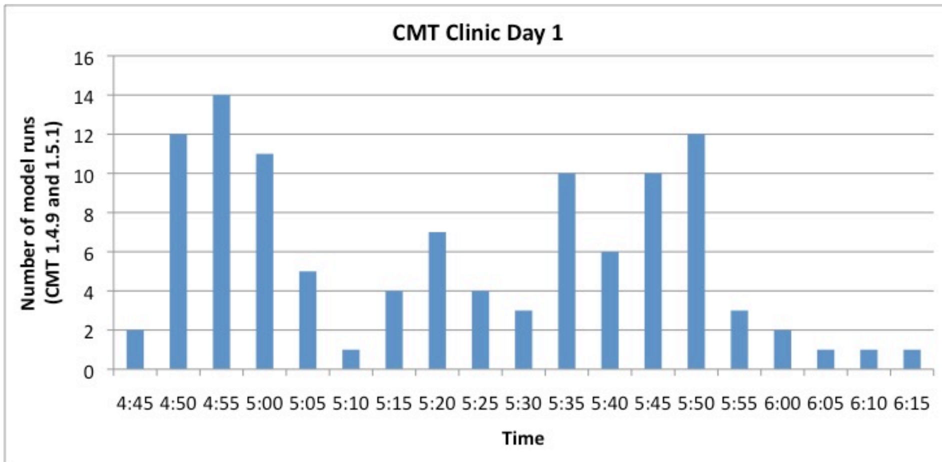


Figure 5.1. Unique new users running CMT on the CSDMS supercomputer during hands-on portion of the San Antonio clinic.

Post-meeting, participating members rated the 2011 clinics as 4.2 out of 5 points, which is even more significant since 83% of respondents of the post-meeting survey indicated that their first objective for attending the meeting was meeting other scientists. CSDMS now considers clinics an integral part of their annual meeting.

CSDMS staff guest lectured on integrated modeling and the CMT as part of a graduate-level course called "Interdisciplinary Modeling: Water-Related Issues and Changing Climate" (NRES 730). This course, sponsored by NSF/EPSCoR, was offered at the University of New Mexico in Reno and had an enrollment of 24 graduate students from EPSCoR states.

Summer Institute on Earth-Surface Dynamics (NCED/CSDMS)

The NCED Summer Institute on Earth-Surface Dynamics, or SIESD, is a two-week institute, which combines lectures with practical experiences in the laboratory and the field. SIESD target advanced graduate students, postdocs and young faculty. This two-week institute is now newly expanded with CSDMS modeling clinics.

SIESD topic in 2011 was 'Coastal Processes and the Dynamics of Deltaic Systems', the course was successfully held from August 10-19, University of Minnesota for 32 participants. Two days in the summer institute are specially dedicated to the use of numerical modeling and quantitative techniques in research and teaching. A selection of the CMT and spreadsheet exercises was developed and evaluated for teaching purposes during this 2-day part of the SIESD course.

SIESD topic in 2012 was 'Future Earth: Interaction of Climate and Earth-surface Processes', the course was successfully held from August 14-23, University of Minnesota for 30 participants. Two days in the summer institute are especially dedicated to the use of numerical modeling and quantitative techniques in research and teaching and were co-taught by Dr. Irina Overeem and Working Group Chair Prof. Greg Tucker. *CHILD* and *SedFlux* exercises were developed and evaluated for teaching purposes during this 2-day part of the SIESD course. Learning objectives and skills include (amongst topical learning objectives on landscape evolution and stratigraphy):

1) Modeling as a Scientific Method in the Earth Sciences
2) Uncertainty in Models and How to deal with results
3) Familiarization with coupled modeling tool and high-performance computing clusters

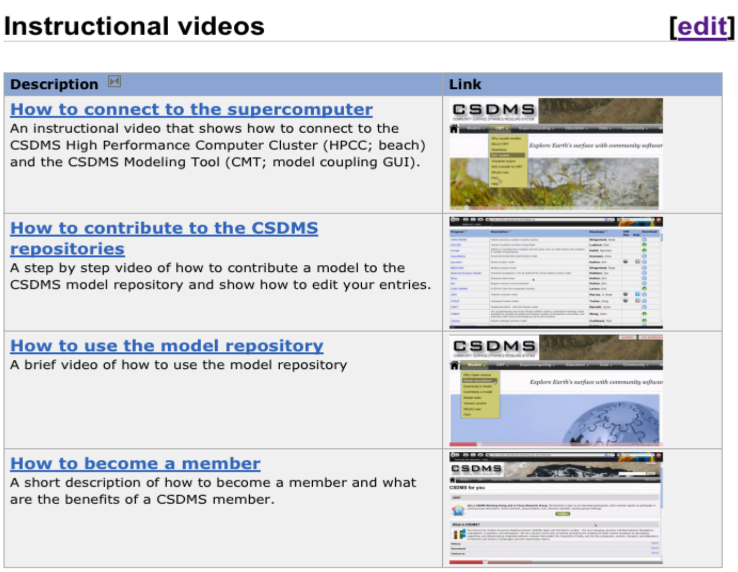
Skills on HPCC use have consistently been positive by participants in courses and clinics in 2010 & 2011. The course material was posted at the CSDMS wiki and has been viewed >2,600 times after the completion of the course: http://csdms.colorado.edu/wiki/SummerInstitute2012

Training of Student Modeler Award Winners

CSDMS asked its membership to nominate undergraduate or graduate students from earth or computer sciences to compete for the "Annual CSDMS Student Modeler Award" judged on the basis of ingenuity, applicability, and contribution towards the advancement of geoscience modeling. CSDMS invites the winner(s) to visit to Boulder, Colorado to learn more about CSDMS, and to work with IF staff scientists to develop their model into a CSDMS component or contribute to the educational repository.

The 2009 winners (tie) were: (1) Adam Campbell for his MSc work on 'Numerical Model investigation of Crane Glacier in response to collapse of the Larsen B ice shelf, Antarctic Peninsula' — ice sheet dynamics from a physics-based perspective. (2) Elchin Jafarov for his 'Numerical Modeling of Permafrost Dynamics in Alaska Using a High Spatial Resolution Dataset' involving coupling of GCM's to thermal dynamics. In 2010, Mohamad Nasr-Azadani of the University of California was the winner of the CSDMS student modeler award for his work on TURBINS; a high-resolution model capable of modeling turbidity currents interacting with complex topographies both 2D and 3D. In 2011, Man Liang, of St Anthony Falls Laboratory, University of Minnesota received the Student Modeler Award for her research titled: 'A Reduced-Complexity Channel-Resolving Model for Delta Formation (Fig. 5.2). Each of the awardees has visited with CSDMS in Boulder for several days and has received targeted training and instruction in the advanced use of the CSDMS HPCC and modeling framework.

Fig. 5.2 Man Liang receives the Student Modeler Award, at the CSDMS Annual meeting 2011



Instructional videos [edit]

Description	Link
How to connect to the supercomputer An instructional video that shows how to connect to the CSDMS High Performance Computer Cluster (HPCC; beach) and the CSDMS Modeling Tool (CMT; model coupling GUI).	
How to contribute to the CSDMS repositories A step by step video of how to contribute a model to the CSDMS model repository and show how to edit your entries.	
How to use the model repository A brief video of how to use the model repository	
How to become a member A short description of how to become a member and what are the benefits of a CSDMS member.	

Figure 5.3. Tutorial videos. http://csdms.colorado.edu/wiki/Help:How_to_videos

Online Video Tutorials

CSDMS members are exposed to a lot of content that at a first glance seems difficult or time consuming to achieve comprehension. Topics are well explained in written documents and posted on the community website, but have been either difficult to find if the user doesn't know where to look for them, or the user simply does not have the time to read all instructions, which eventually results in reduced participation of the community. To increase participation, four video tutorials are developed to make CSDMS processes more comprehensible for our members: 1) How to connect to the CSDMS HPC, 2)

How to contribute to the CSDMS repositories, 3) How to use the model repository, and 4) How to become a member (Fig. 5.3). The tutorial videos (posted on the CSMDS YouTube channel) are embedded in the CSDMS website and are between 2.5 and 8 minutes long, taking the user step by step through a particular process. The videos are featured under the "Help" menu on the main menu bar of the website as well as embedded on pages that describe a specific process. These highly specialized instructional videos received >800 views.

Links:

- How to videos: http://csdms.colorado.edu/wiki/Help:How_to_videos
- CSDMS movie channel: http://www.youtube.com/user/CSDMSmovie

Graduate Course on "Surface Process Modeling" 2010

We developed a 2 credit graduate level course *'Surface Process Modeling: Applying the CSDMS Modeling Tool'* targeted towards earth sciences and engineering graduate students, with focus on surface process and hydrological models available in the CSMDS Model Repository and with application of these tools for own research purposes. The class consisted of 6 4-hour labs with 6 independent modeling projects. Initial focus was on principles of modeling on a supercomputer, and how to visualize model output. Student assignments addressed: long term sediment supply modeling, infiltration modeling, model intercomparison, coupled river-delta modeling, coupled glacial-hydrology modeling, and dynamic time-stepping for numerical stability. Students conducted independent modeling project ranging from landscape evolution to plume sedimentation. All classroom lectures and labs are open-access and available though the CMT examples and EKT lecture and lab repositories: csdms.colorado.edu/wiki/Lectures_portal and csdms.colorado.edu/wiki/Labs_portal. The course has been used as a 'use-case' for the NSF-funded project, "Scaling Up: Introducing Commodity Governance into Community Earth Science Models." The course provided an opportunity for evaluating how current cyber-infrastructure can support educational goals of similar courses.

Online CMT Portal and Help System

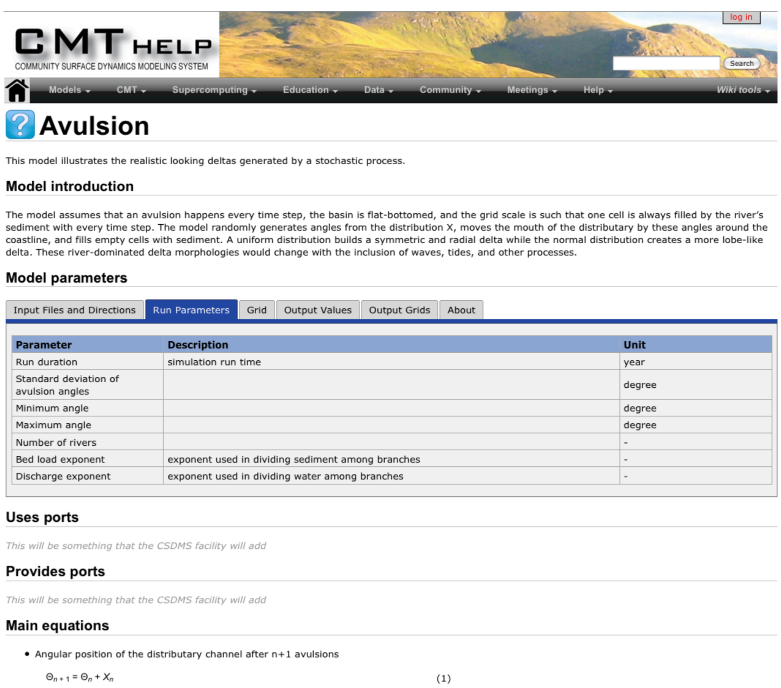


Figure 5.4. Users have single-click access to the model equations behind CMT components. This functionality helps prevent users of experiencing components as a black box --- core model equations are only a single-click away for any arbitrary model component.

The CSDMS Modeling Tool, CMT, has 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 continue to be refined by users for clarity. Each new user is confronted with a general "Help System' and instruction on 'How to Create a model in a few steps. These concise learning modules help new students and other science users to get their first hands-on experience with *CMT*. CMT has it own portal: http://csdms.colorado.edu/wiki/CMT_portal . The CMT features a standardized 'CMT Help System' with detailed descriptions of model equations for each of the 53 components. The Help system mirrors tabbed-dialogue user-driven menus in the models themselves. No user has to experience CMT components as a 'black box', core model equations are only a single-click away for any arbitrary model component. These help pages are intentionally shared through both the CMT directly and through the CSDMS wiki, which allows the original model developers to improve and continuously update documentation.

We value transparency in our CMT software development project. For those CSDMS members that want to monitor progress of development we created a wiki-based progress and workflow-mapping tool. We call this tool a 'component roadmap'; its purpose is to explicitly show what steps a model has to go through before coming online as a CMT component, it also lists the developer or scientist responsible for the steps and sets an approximate timeline.

One more direct feedback option for advanced users is the "Report a bug" option, which allows feedback through the CSDMS Track page. Active tickets are created and posted and are accessible for all stakeholders. 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.

Modeling in Undergraduate Geoscience Education

An inventory of existing standards and modeling courses was conducted by CSDMS and NCED scientists, as an initial appraisal of the importance of modeling within the geosciences curriculum (Campbell et al., 2013). This study strengthened the perception of the CSDMS community that computational models, with their ability to let students not only see simple generalized animations, but also change variables and collect quantitative data through a model are important teaching tools. Models offer a partial solution to how we can prepare undergraduates to "hit the ground running" as they enter highly quantitative graduate or professional Earth sciences careers. Earth science models are interactive tools; students can learn by doing when they interact with the models and receive instant feedback. Quantitative data generated by model simulations has the potential to engage students in sophisticated analysis of time-series and statistics. More complex models can familiarize students with coupled process domains and non-linear system responses. Models can help to bring real-world problems in a 'hands-on' way into the classroom. Lastly, frequent exposure to quantitative models throughout the curriculum will help students to appreciate common model challenges and uncertainties; a vital competency for future model data interpretation as a scientist or as a citizen (Campbell et al., 2013).

The course survey of 37 representative members of the Association of American Universities (AAU) shows that most institutions do offer quantitative Earth process modeling courses. However, we found that geosciences courses focused on creating an active modeling environment in which students not only solve problems, but also define their own problems and even build the (simple) tools to resolve them are much sparser. Teaching resources that address both types of modeling in the geosciences classroom were prioritized as a more narrowly defined objective for CSDMS EKT. Materials to be used in quantitative modeling classes include model animations, real-world event movies that provide a view of rare events, and quantitative data on surface processes for instructors to include in lectures. Especially targeted to undergraduates, hands-on spreadsheet exercises on Earth surface process topics are to be developed as lessons to focus on teaching both science context and a variety of quantitative skills. All these resources are shared through on-line repositories at NCED and CSDMS websites.

CSDMS Education & Knowledge Transfer Repository

The Education Repository offers on-line undergraduate and graduate modeling courses, educational modules, modeling labs, and process and simulation movies. This resource is available to the community and to learners worldwide. The EKT repository is the landing page for educational efforts and short courses taught by CSDMS staff and for topical use of the CSDMS modeling framework.

Then again, the EKT working group proposed to develop the educational repository such that there are different levels of teaching resources on surface process modeling; simple spreadsheet modeling, web-based relatively simple 'slider' models with limited parameter space, and ultimately more advanced modeling with CMT. CSDMS EKT specialist and CSDMS graduate students developed a number of spreadsheet exercises with special focus on teaching quantitative skills. These exercises all include student notes, instructor notes, a lesson plan highlighting topical content and which general quantitative skills are being taught. Downloadable labs include hydrological processes (e.g. Evaporation, Infiltration and Interception), Delta Evolution (e.g. Sinking Deltas), Glacio-fluvial Processes (e.g. River Discharge Measurements), and a source-to-sink exercise on Sediment Supply and Human Influences. CSDMS established contacts with new scientists and groups who developed online interactive models. We link to a Coastal Engineering Toolbox (Prof. Dalrymple, University of Delaware) and to the Phet Earth Science Simulations.

We have recorded 'page views' and 'average time on the page' through Google Analytics to document the use of this material from January 2010 onwards. We do not archive pages that are significantly updated, so that use of continuing evolving teaching material such as labs is more difficult. Movies can also be searched through YouTube directly, so these numbers are inconsistent with each other and partly additive. In general the more easily accessible and useable material is (such as movies) the more use there is from the community and the public.

Animations library csdms.colorado.edu/wiki/Movies_portal (15,000 views on wiki)

Environmental Animations	8	Marine Animations	10
Terrestrial Animations	21	Laboratory Movies	14
Coastal Animations	22	Real Event Movies	32

Image Library csdms.colorado.edu/wiki/Images_portal (10,000 views on wiki)

Terrestrial Images	90
Coastal and Marine Images	49

Modeling Labs csdms.colorado.edu/wiki/Labs_portal (13,000 views on wiki)

Modeling Labs are being designed to have a tiered approach. There are spreadsheet labs that emphasize quantitative skills, but address earth surface process questions/problems with reduced parameter space. These labs are focused on undergraduate education and include lesson plans and teacher material. Whereas CMT-based modeling labs offer additional complexity and simulations can be run with more freedom in complexity level. The EKT web pages point to members who have active online teaching resources.

1. Glacio-Hydrological Modeling
2. River-Delta Interactions
3. Sediment Supply to the Global Ocean
4. Landscape Evolution Experiments with WILSIM
5. Landscape Evolution Modeling with ERODE
6. Earth Science Models for K6-12
7. Coastal Engineering Experiments
8. Hydrological Processes Exercises
9. Sinking Deltas
10. Stratigraphic Modeling with Sedflux
11. Get Started with CMT
12. Modeling River Plumes
13. Simple Sediment Transport Experiments
14. Coastal Stratigraphy Numerical Experiments

Modeling Lectures and Courses csdms.colorado.edu/wiki/Lectures_portal (13,000 views)

1. Surface Dynamics Modeling with CMT — I Overeem & SD Peckham
2. Quantitative Earth-surface Dynamics Modeling — JPM Syvitski
3. 1D Sediment Transport — G Parker
4. Morphodynamics of Rivers — G Parker
5. Source to Sink Systems around the World — Keynote Chapman Lectures
6. Plug and Play Component Technology — JPM Syvitski and I Overeem
7. Geological Modeling — I Overeem

Modeling Textbooks csdms.colorado.edu/wiki/Modeling_Textbooks (12,000 views)

1. Mathematical Modeling of Earth's Dynamical Systems *By: Slingerland, R., Kump, L.*
2. Geomorphology; the Mechanics and Chemistry of Landscapes *By: Anderson, R., Anderson, S.*

3. Quantitative Modeling of Earth Surface Processes *By: Pelletier, J.D.*
4. Simulating Clastic Sedimentary Basins: Physical Fundamentals and Computing Procedures *By: R.L. Slingerland, K. Furlong and J. Harbaugh*
5. 1D Sediment Transport Morphodynamics with applications to Rivers and Turbidity Currents *By: G Parker*

Figure 5.5. Frame from the tidal bore movie csdms.colorado.edu/wiki/Movie_GL. Associated fact sheet distinguishes a tidal bore from a tsunamis wave.

Figure 5.6. Frame from the CEM movie example of spit evolution csdms.colorado.edu/wiki/Animation_Coastal

Real-world earth surface processes movies are collected and brought online with documentation during large earth surface dynamics events, such as the Japan tsunami, March 2011, and Mississippi flooding, May 2011. This 'rapid response' approach provoked a large number of views: during the May 2011 Mississippi floods the 'CSDMSmovies' YouTube channel had the largest number of views for a not-for-profit science and technology channel.

We intentionally focus on surface dynamics process aspects of these world events. As an example, CSDMS posted a rare movie to explain the concept of a sand boil near a river levee as a result of flood discharge and pressure gradients between the river channel and the surrounding floodplain.

Movies from the educational repository were picked up in early 2011 by the North Carolina Museum of Natural Sciences for video exhibits in their Nature Research Center, as well as by the Oregon Public Broadcasting for their NASA funded educational website on Carbon connections focused on teaching resources on climate science.

Knowledge Transfer to Larger Audiences: Advertising CSDMS Science

CSDMS launched its new web portal December 2010. The new web portal aims to enthuse, inform and engage end-users by more frequent updates on CSDMS science and new discoveries. Two sections, 'Model highlight' and 'Science in the spotlight' are embedded at the front page of the CSDMS website for this purpose. Each section provides a summary of a topic with a link to the full article. So far 11 topics (See table 2) have been featured generating in total more than 22,000 hits.

Table 2: Recent Model highlights and Science in the Spotlight Topics

Model highlight (*11,199 views*)	**Science Spotlights** (*11,496 views*)
TopoFlow	Boom-and-bust in island retreat
TURBINS: An immersed boundary, Navier-Stokes code for the simulation of gravity and turbidity currents	Retreating Arctic Coasts
Delft3D	Where do Salmon thrive
SedBerg	Irreversible Peatland Subsidence
SPARROW	New Modeling Textbook
SNAC	StGermaiN Analysis of Continua
A sediment load model for the world's drainage basins	Elwha River Dam Removal
Modeling the Transition from Tidal Flat to Salt Marsh	Tucker receives Bagnold Medal 2012
XBeach Applied to Coral Reef	2011 Mississippi Flood Deposits

Links:
- Entrance page CSDMS: http://csdms.colorado.edu
- Model highlight history: http://csdms.colorado.edu/wiki/Model_highlight
- Science in the spotlight history: http://csdms.colorado.edu/wiki/Science_spotlights

Concepts of Supercomputing for Middle School Students

CSDMS scientists and software engineers participated in the INSTAAR Open House 2010 and 2011. The INSTAAR Open House hosted over 170 and 195 middle school students who participated in hands-on science measurements and activities. The CSDMS Integration Facility team teaches 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. Students played a science game that pitted different computing methods—parallel processors vs. single processors—against each other, using Duplo blocks to perform tasks. Students toured the HPCC facility and experienced first hand how heat is generated from calculations performed by the supercomputer.

http://instaar.colorado.edu/news-events/instaar-news/195-middle-school-students-visit-instaar-and-nsidc-during-annual-open-house/

Knowledge Transfer to Industry Partners

CSDMS formulated an industry consortium in 2008. The CSDMS Director gave a CSDMS presentation at a Research Collaboration Partnership Meeting with petroleum companies at Colorado School of Mines, Golden, CO, Tues., Feb. 26, 2008 to kick-off partnerships. CSDMS received varying amounts of support from Exxon, Shell, Chevron, and Concoco-Phillips over 2008-2012. These partnerships have been fostered throughout the five-year project. Several CSDMS Working Groups have strong industry participation. For example, the CSDMS Community Sediment Model for Carbonate Systems, Feb. 27-29, 2008, Colorado School of Mines, Golden, CO had 32 international attendees (20 from universities and research institutes, 8 from the petroleum industry, plus 4 CSDMS staff members). Analysis of the CSDMS membership data showed that about 5% of the CSDMS members are in industry (Overeem et al., 2012). CSDMS director and EKT specialist attend and present at the Annual Meeting of AAPG (American Association of Petroleum Geologists) when possible. Discussion with company representatives result in requests for technical talks as well as short courses on 'source to sink modeling' for consortium members. Company-wide technical talks were presented on the CSDMS community and modeling tools, and followed by more detailed technical talks for specialist reservoir modeling and basin modeling groups. A dedicated 2-day meeting and discussions for future model improvements on floodplain sedimentation was provided to Conoco-Phillips representatives in March 2012. To target new industry members and policy makers more efficiently, CSDMS EKT with help of Research Media Ltd designed a new brochure highlighting the 5 year accomplishments of CSDMS presented in the June 2012 Issue of International Innovation. The 3 page article is titled "Encouraging Development of Coupled Earth Models' and was send out to over 300 industry partner members and governmental agency partners.

Chapter 6: CSDMS Open-Access Software Repository

Distribution of software *that enters the CSDMS framework was to be handled to allow the greatest penetration and end-use of the products by academic institutions and government agencies. The Open Source license chosen would 1) allow software to be made available for peer review as a companion to publications; 2) encourage others to experiment with and validate the code; 3) establish an early response that may shape the future direction of the research; 4) encourage development and extensions by third-parties; 5) increase demand for follow-on, complementary software products; and 6) include provisions that allow control integrity of the code and re-distribution.*

How well did we do: CSDMS Framework is established: 1) Support for multiple operating systems: *Linux, Mac-OSX & Windows, 2)* Support for parallel computation *(via MPI standard), 3)* Language interoperability: *C, Fortran & object-oriented languages (e.g. Java, C++, Python), 4)* Support for both legacy (non-protocol) code and structured code (procedural and object-oriented), 5) Interoperable with other coupling frameworks, 6) Supports for both structured and unstructured grids, 7) platform-independent GUI *(e.g. via wxPython), 8)* Large offering of open-source tools, 9) Open source software license, industry-friendly, protection for authors, tracks modifications, GPL2 compatible OSI approved.

1) Contributed software should hold an open-source license [e.g. GPL2 compatible; OSI approved].

2) Contributed software should be widely available to the community of scientists [e.g. CSDMS Model Repository; Computers & Geosciences Repository].

3) Contributed software should receive some level of vetting [e.g. by a colleague; manuscript reviewer; CSDMS Working Group]. At the minimum level, software should be determined to do what it says it does.

4) Contributed software should be written in an open-source language (C, C++, any Fortran, Java, Python), or have a pathway for use in an open-source environment [e.g. IDL & Matlab code can be made compatible].

5) Code should be written or refactored to become componentized with an interface (initialize, run, finalize), with specific I/O exchange items (getters, setters, grid information) documented.

6) Code should be accompanied with a metadata description file, e.g. http://csdms.colorado.edu/wiki/Form:Module_questionnaire, and test files (input files to run the model; output files to verify the initial model run).

7) Code should be clean and documented. Source code annotated using keywords within comment blocks to provide basic metadata for the model and its variables.

CSDMS HPCC (*Beach*) usage is open-access

CSDMS uses Ganglia, a scalable distributed monitoring system, to monitor beach, the high-performance cluster of CSDMS for its members. Real-time monitoring information is of key value for cluster operators but can also be very relevant for its users. Therefore key output parameters of ganglia are made available on the beach cluster. Users can monitor status and activity of the cluster as a whole as well as of each of the nodes (http://beach.colorado.edu/ganglia).

The CSDMS Model Repository hosts open-source models, modeling tools, and plug-and-play components, including: i) Cryospheric (e.g. glaciers, permafrost, icebergs), ii) Hydrologic, from reach to global scale, iii) Marine (e.g. ocean circulation), iv) River, coastal and estuarine morphodynamics, v) Landscape or seascape evolution, vi) Stratigraphic, and vii) Affiliated domains (e.g. weather & climate models). Of the ~5.7 million lines-of-code held in the Repository, 61 projects are in Fortran, 100 in C or C++, 31 in Python, 17 in Matlab, with the remaining in C#, IDL, SAS, Java, or VB. About 70% of the models are distributed through a central Repository; others are distributed through linkages to existing community efforts. Centralized downloads exceed 10877 and redirected download traffic to other community modeling sites is similarly high. The 217 projects noted below may involve more than one model.

Repository lines of code statistics as of May 2013: csdms.colorado.edu/wiki/Model_SLOC_Page

Language	Projects	Comment	Source
Fortran 77/90/95+	61	1067184	2457617
c/c++	100	353465	1153207
Python	31	98933	149186
C#	1	29344	160373
MATLAB	17	39662	59157
IDL	5	38834	36954
Statistical Analysis Software	1	2390	5796
Java	2	2214	12851
Visual Basic	1	537	8581
Total	217	1632563	4043722

Models, Tools & Components by Environmental Domain http://csdms.colorado.edu/wiki/Main_Page

Domain	Models	Tools	Components
Terrestrial	76	45	33
Coastal	52	3	5
Marine	44	4	8
Hydrology	52	38	43
Carbonate	3	1	0
Climate	10	2	0

Models run on the CSDMS supercomputer without download are not included in these statistics. Community models downloaded from other sites (e.g. ROMS, NearCOM) are also not counted.

CSDMS Model Repository

Component **(C)**/Program, Description, Developer

(1) 2DFLOWVEL, Tidal & wind-driven coastal circulation routine, Slingerland, Rudy

(2) ACADIA, A finite element formulation of the non-conservative form of the vertically integrated advection/diffusion/reaction (ADR) equation, Gentleman, Wendy

(3) ADCIRC, Coastal Circulation and Storm Surge Model, Luettich, Rick

(4) ADI-2D, Advection Diffusion Implicit (ADI) method for solving 2D diffusion equation, Pelletier, Jon

(5) **(C)** Acronym1, E-book: program for computing bedload transport in gravel rivers, Parker, Gary

(6) **(C)** Acronym1D, E-book: program for computing bedload transport in gravel rivers over time, Parker, Gary

(7) **(C)** Acronym1R, E-book: program for computing bedload transport in gravel rivers with a Manning-Strickler relation for flow resistance, Parker, Gary

(8) **(C)** AgDegBW, E-book: Calculator for aggradation and degradation of a river reach using a backwater formulation, Parker, Gary

(9) **(C)** AgDegNormGravMixPW, E-book: calculator for aggradation and degradation of sediment mixtures in gravel-bed streams, Parker, Gary

(10) **(C)** AgDegNormGravMixSubPW, E-book: calculator for evolution of upward-concave bed profiles in rivers carrying sediment mixtures in subsiding basins, Parker, Gary

(11) **(C)** AgDegNormal, E-book: illustration of calculation of aggradation and degradation of a river reach using the normal flow approximation, Parker, Gary

(12) **(C)** AgDegNormalFault, E-book: Illustration of calculation of aggradation and degradation of a river reach using the normal flow approximation; with an extension for calculation of the response to a sudden fault along the reach, Parker, Gary

(13) **(C)** AgDegNormalGravMixHyd, E-book: A module that calculates the evolution of a gravel bed river under an imposed cycled hydrograph, Parker, Gary

(14) **(C)** AgDegNormalSub, E-book: Program to calculate the evolution of upward-concave bed profiles in rivers carrying uniform sediment in subsiding basins., Parker, Gary

(15) AlluvStrat, Rules-based model to generate a 2-dimensional cross section of alluvial stratigraphy based on fluvial processes, Wickert, Andrew

(16) Anuga, ANUGA is a hydrodynamic modelling tool that allows users to model realistic flow problems in complex 2D geometries, Habili, Nariman

(17) AquaTellUs, Fluvial-dominated delta sedimentation model, Overeem, Irina

(18) Area-Slope Equation Calculator, Pixel scale Area-Slope equation calculator, Cohen, Sagy

(19) **(C)** Avulsion a.k.a. Debouche, Stream avulsion model, Hutton, Eric

(20) BEDLOAD, Bedload transport model, Slingerland, Rudy

(21) BOM, Bergen Ocean Model, Berntsen, Jarle

(22) **(C)** BackwaterCalculator, E-book: program for backwater calculations in open channel flow, Parker, Gary

(23) **(C)** BackwaterWrightParker, E-book: calculator for backwater curves in sand-bed streams, including the effects of both skin friction and form drag due to skin friction, Parker, Gary

(24) BatTri, A graphical Matlab interface to the C language 2-D quality finite element grid generator Triangle, Shewchuk, Jonathan

(25) Bedrock Erosion Model, Knickpoint propagation in the 2D sediment-flux-driven bedrock erosion model, Pelletier, Jon

(26) Bedrock Fault Scarp, This is a two-dimensional numerical model that computes the topographic evolution of the facet slope in the footwall of an active normal fault, Tucker, Greg

(27) **(C)** BedrockAlluvialTransition, E-book: calculator for aggradation and degradation with a migrating bedrock-alluvial transition at the upstream end, Parker, Gary

(28) Bing, Submarine debris flows, Hutton, Eric

(29) Bio, Biogenic mixing of marine sediments, Hutton, Eric

(30) CAM-CARMA, A GCM for Titan that incorporates aerosols, Larson, Eric

(31) **(C)** CBOFS2, The Second Generation Chesapeake Bay Operational Forecast System (CBOFS2): A ROM-Based Modeling System, Lanerolle, Lyon

(32) **(C)** CEM, Coastline evolution model, Murray, A. Brad

(33) **(C)** CHILD, Landscape Evolution Model, Tucker, Greg

(34) CICE, Los Alamos sea ice model, Hunke, Elizabeth

(35) CMFT, Coupled salt Marsh - tidal Flat Transect model, Mariotti, Giulio

(36) CREST, The Coupled Routing and Excess STorage (CREST) model is a distributed hydrologic model developed to simulate the spatial and temporal variation of atmospheric, land surface, and subsurface water fluxes and storages by cell-to-cell simulation, Wang, Jiahu

(37) Caesar, Cellular landscape evolution model, Coulthard, Tom

(38) CarboCAT, Carbonate cellular automatacyclicity, Burgess, Peter

(39) Channel-Oscillation, Simulates Oscillations in arid alluvial channels, Pelletier, Jon

(40) **(C)** ChesROMS, Chesapeake Bay ROMS Community Model (ChesROMS), special case of ROMS, Long, Wen

(41) Compact, Sediment compaction, Hutton, Eric

(42) CosmoLand, 2-D model tracking cosmogenic nuclides and mixing in landslide terrain, Burgess, Peter

(43) Coupled1D, Coupled 1D bedrock-alluvial channel evolution, Pelletier, Jon

(44) CrevasseFlow, The module calculates crevasse splay morphology and water discharge outflow of a crevasse splay, Chen, Yunzhen

(45) Cyclopath, A 2D/3D model of carbonate cyclicity, Burgess, Peter

(46) DELTA, Simulates circulation and sedimentation in a 2D turbulent plane jet and resulting delta growth, Slingerland, Rudy
(47) DHSVM, DHSVM is a distributed hydrologic model that explicitly represents the effects of topography and vegetation on water fluxes through the landscape., DHSVM, Administrator
(48) DR3M, Distributed Routing Rainfall-Runoff Model--version II, U.S., Geological Survey
(49) DROG3D, 3-Dimensional drogue tracking algorithm for a finite element grid with linear finite elements, Blanton, Brian
(50) Delft3D, 3D hydrodynamic and sediment transport model, Delft3D, Support
(51) **(C)** DeltaBW, E-book: Calculator for evolution of long profile of a river ending in a 1D migrating delta, using a backwater formulation, Parker, Gary
(52) **(C)** DeltaNorm, E-book: Calculator for evolution of long profile of a river ending in a 1D migrating delta, using the normal flow approximation, Parker, Gary
(53) DeltaSIM, Process-response model simulating the evolution and stratigraphy of fluvial dominated deltaic systems, Hoogendoorn, Bob
(54) **(C)** DepDistTotLoadCalc, E-book: Illustration of calculation of depth-discharge relation, bed load transport, suspended load transport and total bed material load for a large, low-slope sand-bed river., Parker, Gary
(55) Detrital Thermochron, Code for estimating long-term exhumation histories and spatial patterns of short-term erosion from the detrital thermochronometric data, Avdeev, Boris
(56) Diffusion, Diffusion of marine sediments due to waves, bioturbation, Hutton, Eric
(57) **(C)** DredgeSlotBW, E-book: calculator for aggradation and degradation of sediment mixtures in gravel-bed streams subject to cyclic hydrographs, Parker, Gary
(58) ECBILT-CLIO, ECBILT-CLIO, Schrier, Gerard
(59) ELCIRC, Eulerian-Lagrangian CIRCulation, Zhang, Yinglong
(60) ENTRAIN, Simulates critical shear stress of median grain sizes, Slingerland, Rudy
(61) ENTRAINH, Simulates critical shields theta for median grain sizes, Slingerland, Rudy
(62) Eolian Dune Model, Werner's model for eolian dune formation and evolution, Pelletier, Jon
(63) **(C)** Erode, Fluvial landscape evolution model, Peckham, Scott
(64) FLDTA, Simulates flow characteristics based on gradually varied flow equation, Slingerland, Rudy
(65) FTCS1D-NonLinear, Forward Time Centered Space (FTCS) method for 1D nonlinear diffusion equation, Pelletier, Jon
(66) FTCS2D, Forward Time Centered Space (FTCS) method for 2D diffusion equation, Pelletier, Jon
(67) FTCS2D-TerraceDiffusion, Forward Time Centered Space (FTCS) method for 2D Terrace diffusion, Pelletier, Jon
(68) FUNDY, a 3-D diagnostic model for continental shelf circulation studies, Naimie, Christopher
(69) FUNWAVE, Fully Nonlinear Boussinesq Wave Model, Kirby, Jim
(70) FVCOM, The Unstructured Grid Finite Volume Coastal Ocean Model, Chen, Changsheng
(71) FVshock, Finite Volume two-dimensional shock-capturing model, Canestrelli, Alberto
(72) **(C)** FallVelocity, E-book: Particle fall velocity calculator, Parker, Gary
(73) FillinPitsFlatsDEM, Filling in pits and flats in a DEM, Pelletier, Jon
(74) Flex1D, Fourier filtering in 1D while solving the flexure equation, Pelletier, Jon
(75) Flex2D, Fourier filtering in 2D while solving the flexure equation, Pelletier, Jon
(76) Flex2D-ADI, Solving the flexure equation applying Advection Diffusion Implicit (ADI) method, Pelletier, Jon
(77) Flexure, Direct 2D finite difference solution of lithospheric plate flexure, Wickert, Andy
(78) Fourier-Bessel-integration, Numerical integration of Fourier-Bessel terms, Pelletier, Jon
(79) FractionalNoises1D, 1D fractional-noise generation with Fourier-filtering method, Pelletier, Jon
(80) FractionalNoises2D, 2D Gaussian fractional-noise generation with Fourier-filtering method, Pelletier, Jon
(81) GEOMBEST, Geomorphic Model of Barrier, Estuarine, and Shoreface Translations, Stolper, David
(82) GEOtop, Distributed hydrological model, water and energy budgets, Rigon, Riccardo

(83) GIPL, GIPL(Geophysical Institute Permafrost Laboratory) is an implicit finite difference one-dimensional heat flow numerical model, Jafarov, Elchin
(84) GISKnickFinder, This python code can be used to find knickpoints and extract information about streams, it utilizes built-in functions of ArcGIS, Rengers, Francis
(85) GISS AOM, GISS Atmosphere-Ocean Model, Rind, David
(86) GISS GCM ModelE, GISS GCM ModelE, Schmidt, Gavin
(87) GMODEL, GMODEL, Burgers, Gerrit
(88) GNE, Set of biogeochemical sub-models that predicts river export, Seitzinger, Sybil
(89) GOLEM, Landscape evolution model, Tucker, Greg
(90) **(C)** GSDCalculator, E-book: Calculator for statistical characteristics of grain size distributions, Parker, Gary
(91) **(C)** Gc2d, Glacier / ice sheet evolution model, Kessler, Mark
(92) Glimmer-CISM, Dynamic thermo-mechanical ice sheet model, Hagdorn, Magnus
(93) **(C)** GravelSandTransition, E-book: Calculator for evolution of long profile of river with a migrating gravel-sand transition and subject to subsidence or base level rise, Parker, Gary
(94) HIM, Hallberg Isopycnal Model, Hallberg, Robert
(95) HSPF, a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants, Bicknell, Bob
(96) **(C)** HydroTrend, Climate driven hydrological transport model, Kettner, Albert
(97) Hyper, 2D Turbidity Current model, Imran, Jasim
(98) Ice-sheet-Glacier-reconstruction, Sandpile method for ice-sheet and glacier reconstruction, Pelletier, Jon
(99) Iceages, Stochastic-resonance subroutine of Pleistocene ice ages, Pelletier, Jon
(100) Inflow, Steady-state hyperpycnal flow model, Hutton, Eric
(101) LEMming, LEMming landscape evolution model: a 2-D, regular-grid, rules-based, hybrid finite-difference / cellular automaton model that is designed to explore the effect of multiple rock types on landscape evolution, Ward, Dylan
(102) LITHFLEX1, Lithospheric flexure solution, Furlong, Kevin
(103) LITHFLEX2, Lithospheric flexure solution for a broken plate, Furlong, Kevin
(104) LOADEST, Software for estimating constituent loads in streams and rivers, Runkel, Rob
(105) LOAM, Lamont Ocean-AML Model, Naik, Naomi
(106) LOGDIST, Logrithmic velocity distribution solution, Slingerland, Rudy
(107) LONGPRO, Dynamic evolution of longitudinal profiles, Slingerland, Rudy
(108) LTRANS, The Larval TRANSport Lagrangian model (LTRANS) is an off-line particle-tracking model that runs with the stored predictions of a 3D hydrodynamic model, specifically the Regional Ocean Modeling System (ROMS), North, Elizabeth
(109) LandLab, Software components for building 2D models that involve flows of mass/energy over terrain, Greg Tucker
(110) LavaFlow2D, 2D radially symmetric lava flow model, Pelletier, Jon
(111) **(C)** MARSSIM, Landform evolution model, Howard, Alan
(112) MFDrouting, Multiple Flow Direction (MFD) flow routing method, Pelletier, Jon
(113) MFDrouting-Successive, Successive flow routing with Multiple Flow Direction (MFD) method, Pelletier, Jon
(114) MICOM, Miami Isopycnic Coordinate Ocean Model, Bleck, Rainer
(115) MIDAS, Coupled flow- heterogeneous sediment routing model, Slingerland, Rudy
(116) MITgcm, The MITgcm (MIT General Circulation Model) is a numerical model designed for study of the atmosphere, ocean, and climate, Lovenduski, Nicole
(117) MODFLOW, MODFLOW is a three-dimensional finite-difference ground-water model, Barlow, Paul
(118) ModelParameterDictionary, Tool written in Python for reading model input parameters from a simple formatted text file, Tucker, Greg
(119) Mrip, Mrip is a self-organization type model for the formation and dynamics of megaripples in the nearshore, Gallagher, Edith

(120) NEXRAD-extract, Extract data from NEXRAD Doppler Radar NetCDFs, Wickert, Andy
(121) NUBBLE, A turbulent boundary layer model for the linearized shallow water equations, Naimie, Christopher
(122) NearCoM, Nearshore Community Model, Kirby, James
(123) OTEQ, One-Dimensional Transport with Equilibrium Chemistry (OTEQ): A Reactive Transport Model for Streams and Rivers, Runkel, Rob
(124) OTIS, One-Dimensional Transport with Inflow and Storage (OTIS): A Solute Transport Model for Streams and Rivers, Runkel, Rob
(125) OpenFOAM, Open Field Operation and Manipulation is a toolbox for the development of customized numerical solvers, Weller, Henry
(126) PIHM, PIHM is a multiprocess, multi-scale hydrologic model., Duffy, Christopher
(127) PIHMgis, Tightly coupled GIS interface for the Penn State Integrated Hydrologic Model, Duffy, Christopher
(128) PRMS, Precipitation-Runoff Modeling System, Leavesley, George
(129) PSTSWM, Parallel Spectral Transform Shallow Water Model, Worley, Patrick
(130) ParFlow, Parallel, high-performance, integrated watershed model, Maxwell, Reed
(131) Pllcart3d, 3D numerical simulation of confined miscible flows, Oliveira, Rafael
(132) Plume, Hypopycnal sediment plume, Hutton, Eric
(133) Point-Tidal-flat, Point Model for Tidal Flat Evolution model, Fagherazzi, Sergio
(134) PrattyAiry, Simple isostatic compensation, Wickert, Andy
(135) Princeton Ocean Model (POM), POM: Sigma coordinate coastal & basin circulation model, Ezer, Tal
(136) PsHIC, Pixel-scale Hypsometric Integral Calculator, Cohen, Sagy
(137) QTCM, Quasi-equilibrium Tropical Circulation Model, Neelin, David
(138) QUAL2K, A Modeling Framework for Simulating River and Stream Water Quality, Chapra, Steve
(139) QUODDY, A Modeling Framework for Simulating River and Stream Water Quality, Chapra, Steve
(140) REF-DIF, Phase-resolving parabolic refraction-diffraction model for ocean surface wave propagation., Kirby, James
(141) RHESSys, Regional Hydro-Ecologic Simulation System, Tague, christina
(142) **(C)** ROMS, Regional Ocean Modeling System, Arango, Hernan G.
(143) **(C)** ROMSBuilder, ROMSBuilder is a CCA-CSDMS Modeling Tool (CMT) compliant component that creates another CMT compliant ROMS component. The new ROMS component is built as per the C-preprocessing options that defines a particular ROMS application, Kallumadikal, Jisamma
(144) **(C)** RecircFeed, E-book: calculator for approach to equilibrium in recirculating and feed flumes, Parker, Gary
(145) **(C)** RiverWFRisingBaseLevelNormal, E-book: Calculator for disequilibrium aggradation of a sand-bed river in response to rising base level., Parker, Gary
(146) **(C)** RouseVanoniEquilibrium, E-book: Program for calculating the Rouse-Vanoni profile of suspended sediment., Parker, Gary
(147) SBM, Sorted Bedform Model, Murray, A. Brad
(148) SEA, Southamption—East Anglia, Stevens, David
(149) SELFE, Semi-implicit Eulerian–Lagrangian Finite Element, Zhang, Yinglong
(150) SETTLE, Partical settling velocity solution, Slingerland, Rudy
(151) SIBERIA, SIBERIA simulates the evolution of landscapes under the action of runoff and erosion over long times scales., Willgoose, Garry
(152) SIGNUM, SIGNUM (Simple Integrated Geomorphological Numerical Model) is a MAtlab TIN-based landscape evolution model, Capolongo, Domenico
(153) SNAC, An updated Lagrangian explicit finite difference code for modeling a finitely deforming elasto-visco-plastic solid in 3D, Choi, Eunseo
(154) SPARROW, The SPARROW Surface Water-Quality Model, Alexander, Richard
(155) SPHYSICS, Smoothed Particle Hydrodynamics code, Dalrymple, Robert
(156) STORM, Windfield simulator for a cyclone, Slingerland, Rudy

(157) STSWM, NCAR Spectral Transform Shallow Water Model, Hack, James
(158) STVENANT, 1D gradually varied flow routine, Slingerland, Rudy
(159) STWAVE, Steady-State Spectral Wave Model, Smith, Jane
(160) SUSP, Suspended load transport subroutine, Slingerland, Rudy
(161) SVELA, Shear velocity solution associated with grain roughness, Slingerland, Rudy
(162) SWAN, SWAN is a third-generation wave model, SWAN, Team
(163) SWAT, SWAT is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds., Arnold, Jeff
(164) SWMM, Storm Water Management Model, Rossman, Lewis
(165) Sakura, 3 Equation hyperpycnal flow model, Kubo, Yusuke
(166) SedBerg, An iceberg drift and melt model, developed to simulate sedimentation in high-latitude glaciated fjords., Mugford, Ruth
(167) **(C)** Sedflux, Basin filling stratigraphic model, Hutton, Eric
(168) Sedtrans05, Sediment transport model for continental shelf and estuaries, Neumeier, Urs
(169) Spirals1D, 1D model of spiral troughs on Mars, Pelletier, Jon
(170) **(C)** SteadyStateAg, E-book: calculator for approach to equilibrium in recirculating and feed flumes, Parker, Gary
(171) StreamPower, Modeling the development of topographic steady state in the stream-power model, Pelletier, Jon
(172) **(C)** Subside, Flexure model, Hutton, Eric
(173) **(C)** SubsidingFan, E-book: calculator for evolution of profiles of fans in subsiding basins, Parker, Gary
(174) **(C)** SuspSedDensityStrat, E-book: Module for calculating the effect of density stratification on the vertical profiles of velocity and suspended sediment., Parker, Gary
(175) Symphonie, 3D primitive equation ocean model, Marsaleix, Patrick
(176) TAo, tAo is a software designed to model the interplay between lithosphere flexure and surface transport (erosion/sedimentation), particularly during the formation of orogens and foreland sedimentary basins (see details)., Garcia Castellanos, Daniel
(177) TELEMAC, A powerful integrated modeling tool for use in the field of free-surface flows, Hervouet, Jean-Michel
(178) TISC, TISC integrates quantitative models of lithospheric flexure, fault deformation, and surface mass transport (erosion/transport/sedimentation) along drainage networks, Garcia Castellanos, Daniel
(179) TOPOG, TOPOG is a terrain analysis-based hydrologic modeling package, Silberstein, Richard
(180) TURB, Gausian distribution calculator of instantaneous shear stresses on the fluvial bed, Slingerland, Rudy
(181) TURBINS, An immersed boundary, Navier–Stokes code for the simulation of gravity and turbidity currents interacting with complex topographies, Nasr-Azadani, Mohamad
(182) TauDEM, A suite of Digital Elevation Model (DEM) tools for the extraction and analysis of hydrologic information from topography as represented by a DEM. TauDEM 5 is a new version implemented to take advantage of parallel processing, Tarboton, David
(183) ThawLake1D, 1-D numerical model of permafrost and subsidence processes, Matell, Nora
(184) **(C)** TopoFlow, Spatially-distributed, D8-based hydrologic model, Peckham, Scott
(185) **(C)** TopoFlow-Channels-Diffusive Wave, Diffusive Wave process component for flow routing in a D8-based, spatial hydrologic model, Peckham, Scott
(186) **(C)** TopoFlow-Channels-Dynamic Wave, Dynamic Wave process component for flow routing in a D8-based, spatial hydrologic model, Peckham, Scott
(187) **(C)** TopoFlow-Channels-Kinematic Wave, Kinematic Wave process component for flow routing in a D8-based, spatial hydrologic model., Peckham, Scott
(188) TopoFlow-Data-HIS, The CUAHSI Hydrologic Information System, Peckham, Scott
(189) **(C)** TopoFlow-Diversions, Diversions component for a D8-based, spatial hydrologic model., Peckham, Scott

(190) **(C)** TopoFlow-Evaporation-Energy Balance, Evaporation process component (Energy Balance method) for a D8-based, spatial hydrologic model, Peckham, Scott

(191) **(C)** TopoFlow-Evaporation-Priestley Taylor, Evaporation process component (Priestley-Taylor method) for a D8-based, spatial hydrologic model, Peckham, Scott

(192) **(C)** TopoFlow-Evaporation-Read File, Evaporation process component (read from file method) for a spatially-distributed hydrologic model, Peckham, Scott

(193) **(C)** TopoFlow-Infiltration-Green-Ampt, Infiltration process component (Green-Ampt method) for a D8-based, spatial hydrologic model, Peckham, Scott

(194) **(C)** TopoFlow-Infiltration-Richards 1D, Infiltration process component (Richards 1D method) for a D8-based, spatial hydrologic model, Peckham, Scott

(195) **(C)** TopoFlow-Infiltration-Smith-Parlange, Infiltration process component (Smith-Parlange method) for a D8-based, spatial hydrologic model, Peckham, Scott

(196) **(C)** TopoFlow-Meteorology, Meteorology process component for a D8-based, spatial hydrologic model, Peckham, Scott

(197) **(C)** TopoFlow-Saturated Zone-Darcy Layers, Saturated Zone process component (Darcy's law, multiple soil layers) for a D8-based, spatial hydrologic model, Peckham, Scott

(198) **(C)** TopoFlow-Snowmelt-Degree-Day, Snowmelt process component (Degree-Day method) for a D8-based, spatial hydrologic model, Peckham, Scott

(199) **(C)** TopoFlow-Snowmelt-Energy Balance, Snowmelt process component (Energy Balance method) for a D8-based, spatial hydrologic model, Peckham, Scott

(200) TopoToolbox, A set of Matlab functions for topographic analysis, Schwanghart, Wolfgang

(201) UMCESroms, Chesapeake Bay Application, special case of Regional Ocean Modeling System (ROMS), Li, Yun

(202) VIC, VIC (Variable Infiltration Capacity) is a macroscale hydrologic model that solves full water and energy balances, originally developed by Xu Liang at the University of Washington, Lettenmaier, Dennis

(203) WACCM Dust-Sulfur, Whole atmosphere module of sulfate aerosols, Neely, Ryan

(204) WACCM-CARMA, atmospheric/aerosol microphysical model, English, Jason

(205) WACCM-EE, GCM for deep paleoclimate studies, Wolf, Eric

(206) WAVEREF, Wave refraction routine, Slingerland, Rudy

(207) WAVEWATCH III ^TM, Spectral wind wave model, Tolman, Hendrik

(208) WBM-WTM, Water Balance/Transport Model, Fekete, Balazs

(209) WBMsed, Global sediment flux and water discharge model, Cohen, Sagy

(210) WDUNE, GUI implementation of the Werner (1995) cellular automata aeolian dune model, Barchyn, Tom

(211) WILSIM, Landscape evolution model, Luo, Wei

(212) WINDSEA, Deep water significant wave height and period simulator during a hurricane routine, Slingerland, Rudy

(213) **(C)** WPHydResAMBL, E-book: Implementation of the Wright-Parker (2004) formulation for hydraulic resistance combined with the Ashida-Michiue (1972) bedload formulation, Parker, Gary

(214) WRF, Weather Research and Forecasting Model, Skamarock, Bill

(215) WSGFAM, Wave and current supported sediment gravity flow model, Friedrichs, Carl

(216) XBeach, Wave propagation sediment transport model, Roelvink, Dano

(217) YANGs, Fluvial sediment transport model, Slingerland, Rudy

(218) Zscape, A simple parallel code to demonstrate diffusion, Connor, Chuck

Chapter 7: CSDMS Computational Resources

Beach: The CSDMS Experimental Supercomputer *csdms.colorado.edu/wiki/HPCC_information*

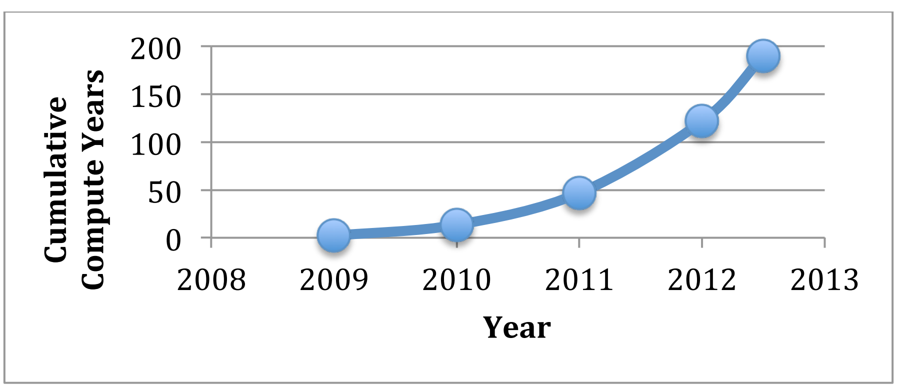
The CSDMS High Performance Computing Cluster (HPCC) *beach.colorado.edu* is an 8 TFlops Altix XE 1300 SGI cluster (with a total of 704 cores) that consists of:

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

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

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

Compute years on *Beach* (equivalent of 1 processor operating 24 hours-a-day, non-stop, for one year) has steadily increased.



Janus: Research Computing Supercomputer

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

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

CSDMS Projects That Use Beach and/or Janus

The following sections contain brief descriptions of 17 noteworthy CSDMS-projects that relied on the use of either the Beach or Janus clusters. Following each description are references to peer-reviewed papers, posters, and abstracts that describe the new science that was a direct result of each project.

High-Resolution Regional Climate Modeling

The High-Resolution Regional Climate Modeling project uses the Advanced Research Weather Research and Forecasting Model (ARW) to simulate projected climate based on Atmosphere-Ocean General Circulation Model (AOGCM) boundary and initial conditions. Regional solutions include much of North America and projections currently extend to 2050.

Objective: to provide high-resolution climate projections in support of research and management needs for wildlife and water resources. Funded projects include modeling response of migratory birds to projected climate change in the Great Plains, response of karst aquifers and associated stygobitic (subterranean) fauna to climate change, effects to ecosystems in National Parks and Monuments, and snowpack modeling in the Northern Rockies. Several such studies require projections of surface temperature and precipitation at daily time steps, and additional climate variables such as winds and temperatures aloft, snowpack, soil moisture, and evapotranspiration. ARW is used to simulate these variables.

References:

Norton, P.A., and Stamm, J.F., 2012, WRF dynamically downscaled simulation of projected climate in the Missouri River watershed: 2000-2050: 13th Annual WRF Users Workshop, Boulder, CO, Extended abstract.

Stamm, J.F. and Norton, P.A., 2012, Contemporary and projected climate in the Missouri River watershed: 1901-2050: Western South Dakota Hydrology Conference, http://sd.water.usgs.gov/WSDconf/2012conference.pdf

Skagen, S.K. and others, 2011, Avian conservation in the Prairie Pothole Region, northern Great Plains: Understanding the links between climate, ecosystem processes, wetland management, and bird communities: U.S. Geological Survey Fact Sheet 2011-3030, 4 p.

Combining a MODIS-based snow water equivalent product and statistical interpolation methods to estimate snowpack and streamflow conditions in the Colorado headwaters

The project seeks to develop a snow-water equivalent (SWE) monitoring technique that can leverage both point scale measurements and spatially explicit patterns of SWE from remote sensing in near real-time. Current estimates of SWE distribution are frequently interpolated from point measurements based on physiographics with a observations of SCA occasionally used to constrain modeled values. Statistical models relating physiography and SNOTEL SWE only explain up to ~15% of the observed variability and thus these techniques provide limited credibility for water resource applications. Recent improvements in SWE estimates have been obtained using SWE reconstruction models whereby satellite data of SCA are coupled with fully distributed energy balance modeling to reconstruct peak snow mass. The first goal of this project is to combine a statistical interpolation model with remote-sensing based spatially distributed reconstructed SWE to augment resources available to water managers. The second goal of this project is to incorporate explicitly modeled patterns of SWE and use it as a spatial distribution field for winter precipitation in a streamflow modeling exercise. The intention is to examine the sensitivity and potential improvement in simulated streamflow timing and volume due to an improved representation of the physiographic distribution of SWE.

Objectives:

- Utilize past patterns of observed SWE in conjunction with ground observations to model real-time SWE.
- Compare streamflow using different SWE products as spatial fields for winter precipitation in a streamflow model.

References:

Schneider, D., N.P. Molotch. 2013 A regression-based approach for combining ground-based observations, distributed models, and remotely sensed data for real-time SWE estimates. Western Snow Conference, Jackson, WY. Poster.

Schneider, D., N.P. Molotch. 2012 A regression-based approach for blending remotely-sensed and in-situ snow water equivalent estimates in the Colorado River Basin". AGU Fall Meeting, San Francisco, CA. Poster.

Coupling fluvial discharge and coastal evolution models

Deltas are critical landforms at the land-sea interface that preserve the effects of both terrestrial and marine processes. In regions that have been affected by human civilization, deltas can serve as a record of the land-use changes across large watersheds. The Ebro Delta, Spain, with its distinctive plan-view shape, has seen significant changes in the last two millennia, changes that could be related to anthropogenic activities. Combining field research, fluvial modeling, and coastal evolution modeling, this proposed research will address the hypothesis that humans have helped shape the Ebro Delta by investigating what aspects of the delta's morphology and depositional history can be attributed to external (allogenic) forcing, such as human activities or climate change, and what aspects resulted from background natural variability and autogenic mechanisms such as avulsion and reworking by waves.

Although there have been many studies of the terrestrial input of sediment to the coast, the reworking of sediment by marine processes, and the resultant stratigraphic deposits, this proposed research will uniquely combine all three of these components controlling delta evolution. Although cartographic material suggests a rapid development of the Ebro Delta during post-Roman times, sparse data and limitations on the accuracy of historic maps hinder chronologic interpretation; we propose field investigations to refine the Ebro Delta age model. The climate-driven hydrological model HydroTrend will be used to compute fluvial sediment discharge to the coast, and a modified version of an existing shoreline evolution model will be used to evolve the morphology of the subaerial delta. A key component will be the direct linking of these models as part of the Community Surface Dynamics Modeling System (CSDMS). Model simulations will be constrained by and compared to the field data.

Objectives:

- What is the timing (and style) of the Ebro Delta's evolution?
- Have humans exerted a first-order control on the fluvial delivery of sediment by the Ebro River to the coast?
- Does wave angle climate act as a first-order control on the morphology and progradation rates of the Ebro (and other wave-influenced deltas)?

References:

Ashton, A.D., Hutton, E.W.H., Kettner, A.J., Xing, F., Kallumadikal, J., Nienhuis, J., Giosan, L., 2013, Progress in Coupling Coastline and Fluvial Dynamics. Computers & Geosciences 53: 21-29

Double-diffusive instabilities in sediment-laden systems with applications to riverine outflows

When a layer of particle-laden fresh water is placed above clear, saline water, both double-diffusive and Rayleigh-Taylor instabilities may arise. Such a configuration can arise from hypopycnal river outflows into the salty ocean. The presence of these two instabilities can increase the flux of sediment out of the plume beyond that predicted by Stokes settling of individual particles. In addition, the presence of settling particles modifies traditional double-diffusive fingering to create a distinctly different mode. With this motivation in mind, we study the modification of the double-diffusive instability in the presence of settling particles using the tools of linear stability (LS) and direct numerical simulation (DNS).

An important parameter that arises from LS results is the ratio of the unstable layer thickness to the diffusive interface thickness of the salinity profile. When this value is small, the instability eigenmodes primarily resemble double-diffusive modes, while at larger values the sediment and salinity interfaces become increasingly decoupled and the dominant instability mode becomes Rayleigh-Taylor like. Results from DNS show that this parameter quickly grows before plateauing at a constant value for the rest of the simulation. The balance between the sediment settling flux and the sediment fingering flux is characterized by the settling velocity, the salinity Schmidt number, and the stability ratio. For settling-dominated situations, we show that the resulting instability mode becomes a phase-locked fingering mode. This mode has the same spectral content as the traditional fingering mode but the large scale convective overturning generated by the Rayleigh-Taylor mode creates a phase-locking that results in very thin, wisp-like plumes released from the base of the unstable layer. Across a large range of parameters, the interfacial sediment flux is seen to scale most appropriately with the pure double-diffusive flux. This is contrary to the traditional method of basing the flux on the Stokes settling velocity. In addition, a flux enhancement coefficient is calculated which corrects the double-diffusive flux in settling-dominated systems.

Objectives:

- To understand in a general way how the double-diffusive and Rayleigh-Taylor instability modes interact in a sediment-laden fluid.
- To understand the origin on the leaking mode, as opposed to the traditional fingering mode in double-diffusion, and how this mode modifies the flux out of the river plume.
- To predict the type of instability mode that will be present in a given system *a priori* of its development.

References:

Burns, P. and Meiburg, E. 2012 Sediment-laden Fresh Water above Salt Water: Linear Stability analysis. J. Fluid Mech. 691. pp 279.

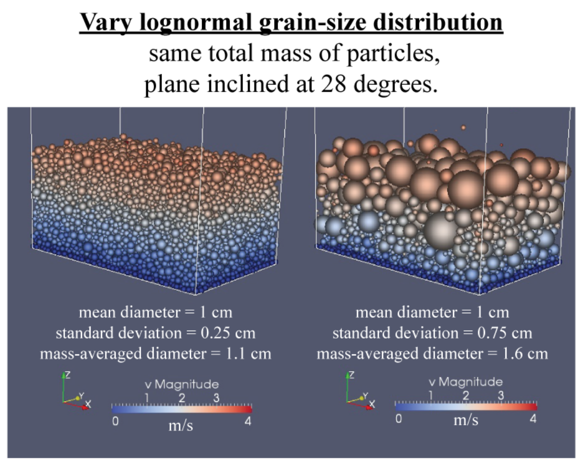
Hydrodynamics and Sediment-Transport in the Poverty Bay Portion of the Waipaoa Sedimentary System

Poverty Bay is located on the eastern coast of the North Island of New Zealand, and is situated between the terrestrial and marine portions of the Waipaoa River Sedimentary Dispersal System. Poverty Bay acts as an important transition zone, where any riverine signals are potentially modified before reaching the continental shelf. The Poverty Bay shoreline has been prograding at an ever-decreasing rate for the last 7 kyr, implying that some sediment is sequestered within the bay. This project aims to better understand the transfer of sediment from the mouth of the Waipaoa River through Poverty Bay onto the continental shelf. To this aim, hydrodynamic and sediment-transport observations were collected within the nearshore of Poverty Bay and are used along with coupled hydrodynamic and wave numerical models that extend to the shelf break to better understand the routing of sediment through Poverty Bay on a daily to seasonal time-scale. Also, multiple Poverty Bay geometries are modeled to investigate how changing the geometry of the dispersal basin affects the oceanographic energy available to cause marine dispersal, and how any changes to marine dispersal effect the amount of sediment sequestered within Poverty Bay or any changes to the characteristics of the sediment supplied to the continental shelf.

References:
Bever, A.J., Harris, C.K., McNinch, J.E., 2011. Hydrodynamics and sediment-transport in the nearshore of Poverty Bay, New Zealand: Observations of nearshore sediment segregation and oceanic storms. Cont. Shelf Res. 31: 507-526

Investigating controls on bedrock erosion by granular flows using an open source discrete element model

Although steep valleys are ubiquitous in mountainous terrain and there is evidence that episodic scour by debris flows is an important erosional process in these valleys, there is no agreed upon mechanical framework to describe debris flow incision into bedrock. Hence our goal is formulate a defensible stochastic debris flow incision rule.



We hypothesize that the rate of bedrock incision will scale with the product of the intensity at which flow particles impact the bedrock channel floor (measured as impact force or energy) and the impact flux. We use grain-scale numerical experiments (discrete element method simulations) of free-surface, gravity-driven granular flows to quantify how impact intensity and impact flux, and hence the rate at which debris flows incise bedrock, change as a function of field measureable channel and flow properties such as grain size, flow depth, and channel slope.

References:
McCoy, S. W. (2012), Controls on Erosion and Transport of Mass by Debris Flows, PhD dissertation, University of Colorado.

Investigating valley spacing regularity on evolving mountain fronts

One of the most striking geomorphological features noticed by many authors on mountain fronts is the apparent regularity in the spacing of river basins. This regularity has been observed also in different geological contexts: orogens (extending mountain fronts), passive margins (e.g. coastal zones, extending fault systems, etc.), as well as in soil mantled low relief landscapes. Such regularity is so striking, that many authors have sought explanations due to primary physical principles and paradigms. Actually, a simple relation involving basin spacing regularity seems to be derivable from Hack's law, which models the scaling of basin area vs. basin length. To support such observations, many experiments have been devoted to simulate landscape evolution through numerical models, to see if such regularity is actually an effect of the fundamental mass-conservation equations that shape the landscapes. For instance, Perron et al. (2008) showed that this may actually be the case, although their experiments are related to small-scale basins as in soil mantled low relief landscapes. Recently, experiments were also performed through so-called "hardware" models, i.e. real-world, reduced-scale artificial reproductions of river basins evolving through erosion effects by pouring water. One of these works (Bonnet, 2009) simulated the migration of the drainage divide due to a spatial gradient in precipitation intensity, and observed how river basin regularity seems to be conserved throughout the landscape temporal evolution, on both the extending and the "shrinking" sides of the migrating divide. Some of the suggested mechanisms which could induce river basins to split or converge to maintain constant length-to-width ratio are, however, somewhat controversial.

Questions:

- Is valley spacing maintained through basin evolution as the orogen evolves?
- How do erosion, tectonic and climate process parameters influence valley spacing?
- How is valley spacing maintained during divide migration and how does the fluvial network evolve?
- How do valley spacing change and fluvial network reorganization influence the sediment flux leaving the orogen?

References:

Tucker, G.E., and van der Beek, P. (2012) A model for post-orogenic development of a mountain range and its foreland. Basin Research, v. 12, p. 1-19

Tucker, G.E., and Hancock, G.R. (2010) Modelling landscape evolution: Earth Surface Processes and Landforms, v. 35, p. 28-50.

Linking climate model output with landscape evolution models

To quantify the effects of past and future climate change on landscape evolution, we would like to use climate models to inform landscape evolution models. A key difficulty in coupling these types of models is the separation of time and spatial scales involved. Global climate models typically run on grids of 1 degree or more, at temporal resolution of seconds and run lengths of years to decades. Landscape evolution models (LEMs) reside at the other end of both dimensions, with typical spatial resolutions of meters to km and temporal resolutions of years or decades. The entire duration of a climate model run may be shorter than the time-step of a typical LEM.

Objective: to bridge the relevant scales by downscaling large-scale climate model output for last-glacial and modern times with NCAR's regional-scale Weather Research and Forecasting (WRF) model. The predicted precipitation fields are input to a hydrologic model to generate realistic discharge statistics useful for landscape modeling.

Lithology Image Strips Extraction for the Ocean Drilling Program

The Ocean Drilling Program drilled 653 seabed sites and recovered 236km of core in the years 1985-2003. The core recoveries were photographed, but on a frame in varying light conditions. Modern visualisation software requires image strips, which today are scanned electronically. This project extracted image strips compatible with the modern scannings, from the legacy photos. The photos show in great detail the sediments, rock and structures that were sampled by the IODP in all oceans of the world, extending back over 120My of earth history.

Objective: to bring this huge resource of valuable data up to modern standards and into high useability.

Niger Delta Project

Riverine flow through a deltaic distributary system is an understudied subject. No large distributary channel system of a delta has ever been monitored for a significant period of time, as simultaneous monitoring of each distributary is expensive and often complex due to tidal influences. However, gaining a better understanding of deltas is of importance, as deltas are fragile geomorphic features that can change dramatically under a modest alteration of the controlling environment. Here we present analyzes of fresh water and sediment fluxes flowing through the tropical Niger Delta, Nigeria for a 7-year period.

The Niger Delta is exceptional as precipitation on the delta itself more than doubles the water discharge at the time it reaches the ocean. Tropical Rainfall Measurement Mission (TRMM) based precipitation estimates, with a 0.25° x 0.25° spatial and a three hour temporal resolution from 2000 – 2006 combined with MOD16, 1 x 1 km spatial and a 8 day temporal resolution, satellite evapotranspiration estimates are applied as input to the hydrological model TopoFlow to route water discharge through each of the 26 deltaic sub-basins of the Niger. The BQART long-term sediment routine together with the PSI model were coupled with the TopoFlow model to simulate the hourly sediment flux for each of the distributaries.

Simulation results provide insight in the ungauged flow dynamics of the Niger delta. Results indicate which channels transport the highest water discharge, riverine sediment load distribution, and the effects monsoonal precipitation has on the hydrograph for each of the 26 deltaic sub-basins.

Objective:

- Determine dispersal mechanisms of the terrestrial flux of sediment and the coastal trapping of sediment of deltaic distributary channels with focus on the Niger Delta, Nigeria.
- Conduct a hydrological assessment of the fluxes of water and sediment to the shorelines of Niger Delta.
- Assess the timing of discharge events, suspended load and bed load.

References:

Kettner, A.J., Hannon, M.T., and Syvitski, J.M.P., 2010. Simulating hourly discharge fluxes through the Niger delta. Eos Trans. AGU, 91(26), West. Pac. Geophys. Meet., Abstract H31B-05.

Hannon, M.T., Syvitski, J.P.M., Kettner, A.J., December 2008. Hydrologic modeling of a tropical river delta by applying remote sensing data: The Niger Delta and its distributaries. fall meeting, San Francisco, USA.

Numerical Modeling of Permafrost Dynamics in Alaska using a High Spatial Resolution Dataset

Recent publications report a gradual increase of mean annual permafrost temperatures in Alaska (Romaniovsky et al., 2010 and Smith et al., 2010). Thawing of permafrost might cause the land to sink and collapse, damaging forests, homes, and infrastructure. Economists estimate that thawing permafrost will add billions of dollars in repair costs to public infrastructure.

The nature of permafrost existence is complex enough and cannot be addressed based only on climatic data. In this project we employed more sophisticated approach which includes all important factors affecting permafrost thermal regime such as snow, organic layer, soil physical properties and subsurface water content. We employ GIPL2-MPI transient heat flow model for the entire Alaska permafrost domain. As a climate forcing we used the composite of five IPCC Global Circulation Models that according to Scenarios Network for Alaska Planning (SNAP) performed the best in Alaska. Researchers from SNAP scaled down the outputs from these five models to 2 kilometers resolution using the PRISM model, which takes into account elevation, slope, and aspect. All derived values represent a single month within a given year for the five-model composite with A1B carbon emission scenario.

To determine the social-economic impact of permafrost thaw on ecosystem and infrastructure higher spatial resolution is required. In order to employ the model to simulate the ground temperatures in higher spatial resolution we need make it parallel by distributing the amount of computational load between processors. The GIPL2-MPI is a modified parallel version of the GIPL2 spatial model used by Marchenko et al.

Objectives:

- How well is the simulated map represent the current thermal state of permafrost? (model calibration and validation)
- The importance of microclimate and other environmental controls affecting permafrost thermal regime.
- What might be the possible permafrost thermal state by the end of 21st century?

References:

Romanovsky, V.E., Smith, S.L., Christiansen, H.H., 2010. Permafrost thermal state in the polar northern hemisphere during the international polar year 2007–2009: a synthesis. Permafrost and Periglacial Processes 21, 106–116.

Smith, S., Romanovsky, V., Lewkowicz, A., Burn, C., Allard, M., Clow, G., Yoshikawa, K., Throop, J., 2010. Thermal state of permafrost in North America: a contribution to the international polar year. Permafrost and Periglacial Processes, Fall Meet. Suppl., Abstract C12A-02 21, 117–135.

Numerical simulations of turbidity and gravity currents interacting with complex topographies

Turbidity currents represent a large-scale geophysical flow phenomenon that plays an important role within the global sediment cycle, and in the formation of deep-sea hydrocarbon reservoirs (Meiburg and Kneller, 2010). Turbidity currents can be maintained for hours or even days, transport many km^3 of sediment, and propagate over distances up to 1,000km. The sediment deposits generated by these currents, known as turbidites, extend over tens or even hundreds of kilometers along the bottom of the ocean, and they frequently are hundreds of meters deep. The interaction between turbidity currents and their deposits via erosion and deposition results in the formation of pronounced topographical features on the seafloor, such as channels, gullies, levees and sediment waves. Due to the infrequent and unpredictable occurrence of turbidity currents in remote areas, and their destructive nature, field data regarding their structure and evolution are very difficult to obtain. Consequently, in addition to laboratory experiments, high-resolution simulations have become an important tool for the exploration of their dynamics. These simulations are typically based on an augmented form of the Navier-Stokes equations. Ideally, they should be fully three-dimensional, incorporate erosion as well as deposition, respond dynamically to pre-existing and evolving sediment bed topography, and explicitly describe the thickness and grain-size distribution of the resulting deposits. The computational effort required for turbidity current simulations is largely a function of the Reynolds number Re = UH/nu, where U represents the front speed, H is a measure of the current height, and nu denotes the kinematic viscosity of the fluid, usually water. Direct Navier-Stokes simulations typically can reach Reynolds numbers of $O(10^3$- $10^4)$, which makes it impossible to simulate geophysical turbidity currents in the ocean, which can reach Re = $O(10^9)$. These orders of magnitude make clear the need for large-scale, massively parallel simulations, combined with accurate turbulence modeling efforts.

The present investigation describes the development and validation of a computational code called TURBINS (TURBidity currents via Immersed boundary Navier-Stokes simulations), which addresses many of the above needs. TURBINS, a highly parallel code written in C, is capable of modeling gravity and turbidity currents interacting with complex topographies in two and three dimensions. Accurate treatment of the complex geometry, implementation of an efficient and scalable parallel solver, i.e. multigrid solver via PETSc and HYPRE to solve the pressure Poisson equation, and parallel IO are some of the features of TURBINS.

TURBINS enables us to tackle problems involving the interaction of turbidity currents with complex topographies. It provides us with a numerical tool for quantifying the flow field properties and sedimentation processes, e.g. energy transfer, dissipation, and wall shear stress, which are difficult to obtain even at laboratory scales. By benefiting from massively parallel simulations, we hope to understand the underlying physics and processes related to the formation and deposition of particles due to the occurrence of turbidity currents.

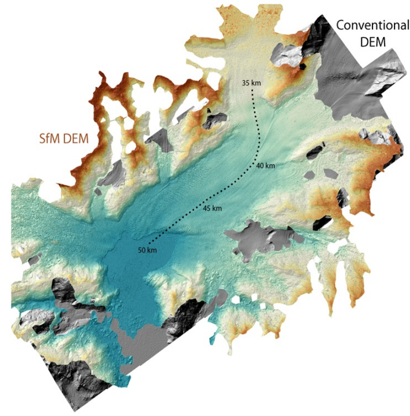
Objectives:

- Using numerical simulations to study/predict sediment transport resulting from turbidity currents
- Understanding the influence of the seafloor topographies on the fluid motion and sediment transport

References:

Meiburg, E. and B. Kneller, 2010, Turbidity currents and their deposits, Ann. Rev. Fluid Mech. 42: 135-156.

Nasr-Azadani, M.M. and Meiburg, E. 2011 TURBINS: An Immersed Boundary, Navier-Stokes Code for the Simulation of Gravity and Turbidity Currents Interacting with Complex Topographies. Comp. & Fluids 45: 14.



Repeat glacier elevation and velocity maps from multi-view stereophotography

Low frequency and high cost restricts the use of satellite and commercial aerial stereophotography for investigating short-term variability in glacier dynamics, the mechanisms by which tidewater and ice sheet outlet glaciers rapidly deliver ice to the oceans. In response, we present a flexible, low-cost, automated approach to producing glacier-wide DEMs and velocity fields requiring only a digital camera and handheld GPS.

References:

The Image as Data: Preliminary Results from Columbia Glacier, AK. 40th International Arctic Workshop, Winter Park, CO (March 10-12, 2010)

The Image as Data: Glacier Change and Citizen Science. 4th Graduate Climate Conference, Seattle, WA (October 15-17, 2010)

Quantifying Evolving (Glacial) Landscapes with Your Camera. American Geophysical Union Fall Meeting, San Francisco, CA (December 13-17, 2010)

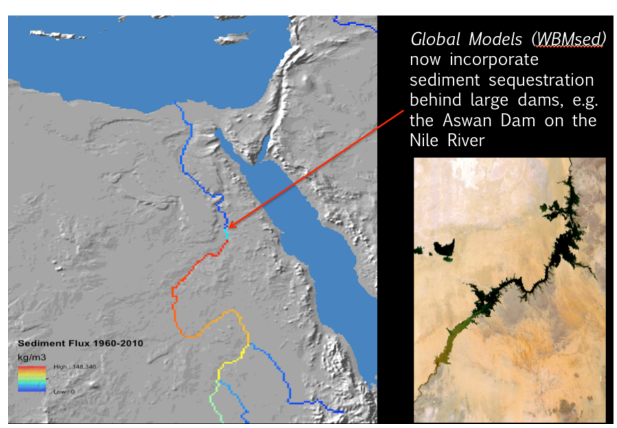
Simulation of Granular Flows

Granular flows are ubiquitous in the environment. In some cases interaction with the ambient fluid is critical, for example debris flows, turbidity currents and powder snow avalanches. In other cases the flow dynamics are governed only by the dry granular material, for example, rock-slides and dense avalanches. In both cases accurate theories are necessary for the describing the granular material, but there is no known governing equation for granular matter in the way that the Navier-Stokes equations describes fluids. The aim of this project is to study granular systems by direct simulation using the Discrete Element Method (also known as Molecular Dynamics), in which the equation of motion for each individual grain in integrated in time accounting for solid contacts and interactions with the ambient fluid.

Direct simulation of washboard road and analysis of the forces, and flow field around a moving plough or wheel. Washboard road is a particularly simple surface instability that can be viewed as a simple model for many geomorphological patterns.

Direct simulation of granular flow in a drum. Rotating drums are one of the simplest granular experiments that can be performed and are very useful for categorising geophysical materials. The aim of this project is a detailed comparison between experiments and simulations focusing on the transition between steady and avalanching motion.

Segregation in granular flows. The "Brazil Nut Effect" is where larger particles move towards a free surface in a moving granular system. This is important for understanding deposit patterns and can have a large effect on the dynamics of granular flows greatly increasing runout of rockslides for example. The aim of this project is to verify and develop improved theories of granular segregation.



The WBMsed distributed sediment flux model

The Framework for Aquatic Modeling of Earth System (FrAMES) is a spatially and temporally explicit multi-scale (local through global) hydrological-biogeochemical modeling scheme. It is an ongoing interdisciplinary project allowing predictions of changing material flux from major continental rivers in response to changing environmental conditions. In this project we develop and test a new component within this framework, a spatially explicit sediment flux model. We expend the BQART sediment flux model from point (river outlet) to distributed (pixel) scale by integrating it into the WBM continental hydrology model. BQART is an analytical model describing the empirical relationship between basin geomorphic (area and relief), climatic (temperature and precipitation), geologic (lithology and ice cover) and human (reservoir and soil erosion) characteristics and short and long-term sediment flux (implemented in the HydroTrend model). WBM is a spatially explicit model describing varying components of global hydrological cycle. The integrated model (WBMsed) allows daily predictions of global scale sediment fluxes at a spatial resolution of 30 and 6 minute.

Advantages of using *Beach*:

- Allow multiple threads of long-term simulations;
- Storage of the very large input and output datasets needed (100's GB);
- Usage of multiple code development, compilation and visualization tools (e.g. VisIt);
- Allow easy cooperation with other members of the FrAMES project;

References:

Cohen, S., Kettner AJ, Syvitski, JPM and Fekete BM, 2013 WBMsed: a distributed global-scale daily riverine sediment flux model - model description and validation. Computers & Geosciences 53: 80-93.

Brakenridge, GR, Cohen, S, Kettner AJ, De Groeve T, Nghiem, SV, Syvitski, JPM, Fekete BM, 2013, Calibration of satellite measurements of river discharge using a global hydrology model. *J Hydrology* 475: 123-136.

Cohen, S., Kettner AJ, Syvitski, JPM, submitted, Spatio-temporal dynamics in riverine sediment and water discharge between 1960-2010 based on the WBMsed v.2.0 Distributed Global Model. *Global & Planetary Change*

The impact of thermocline induction on decadal variability of the North Atlantic carbon sink

Remotely sensed and in situ data suggest that ocean biological productivity and carbon uptake are changing, but we are challenged to distinguish between anthropogenically-forced trends and natural decadal timescale variability. We need to enhance our capacity to make these distinctions so that we can better inform climate change mitigation and adaptation decision-making.

In this project, we will quantify the impact of ocean circulation-driven variability in carbon and nutrient induction on observed changes in surface ocean productivity and air-sea carbon dioxide fluxes in the North Atlantic. Induction, an injection of fluid and tracer from the permanent thermocline across the sloping base of the seasonal mixed layer, has been shown to be many times larger than Ekman upwelling and dominant to surface ocean nutrient renewal. Based on preliminary results, we propose that a spin-down of the sub-polar gyre, associated with the negative trend of the North Atlantic Oscillation from the mid-1990s to the mid-2000s, led to substantial reductions in induction of nutrients, dissolved inorganic carbon (DIC) and alkalinity (ALK). In turn, the declining induction caused (1) productivity declines, as observed in the satellite record, and (2) declines in surface-ocean DIC and ALK that have caused a pCO_2 reduction that has approximately balanced pCO_2 increases driven by warming sea surface temperature (SST) over the same period.

The objectives of this project are to (1) perform a joint analysis of satellite and ocean state estimates, (2) perform idealized modeling experiments, and (3) analyze realistic hindcast models in order to address the following science questions:

- Question 1: To what degree does nutrient, DIC and ALK induction at the base of the wintertime mixed layer contribute to surface ocean tracer budgets, their temporal variability, and related biogeochemically-relevant fluxes?
- Question 2: How do sub-polar gyre spin-down and spin-up modify tracer induction?
- Question 3: What is the net effect of sub-polar gyre spin-down and spin-up on the carbon sink of the North Atlantic?

Using Neighborhood-Algorithm Inversion to Test - Calibrate Landscape Evolution Models

Landscape evolution models use mass transport rules to simulate the development of topography over timescales too long for humans to observe. The ability of models to reproduce various attributes of real landscapes must be tested against natural systems in which driving forces, boundary conditions, and timescales of landscape evolution can be well constrained over millennia. This project aims to test and calibrate a landscape evolution model by comparing it with a well-constrained natural experiment using a formal inversion method to obtain best-fitting parameter values.

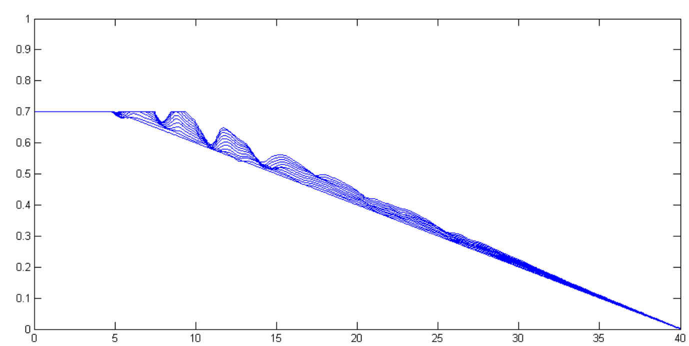
Our case study is the Dragon's Back Pressure Ridge, a region of elevated topography parallel to the south central San Andreas Fault that serves as a natural laboratory for studying how the timing and spatial distribution of uplift affects topography. We apply an optimization procedure to identify the parameter ranges and combinations that best account for the observed topography. Direct-search inversion models can be used to convert observations from such natural systems into inferences of the processes that governed their formation through the use of repeat forward modeling. Simple inversion techniques have been used before in landscape evolution modeling, but these are imprecise and computationally expensive. In this project, we are applying a more efficient inversion technique, the Neighborhood Algorithm (NA), to optimize the search for the model parameters values that are most consistent with the formation of the Dragon's Back Pressure Ridge through repeat forward modeling using CHILD.

Inversion techniques require the comparison of model results with direct observations to evaluate misfit. For our target landscape, this is done through a series of topographic metrics that include hypsometry, slope-area curves, and channel concavity. NA uses an initial Monte Carlo simulation for which misfits have been calculated to guide a second iteration of forward models. At each iteration, NA uses N-dimensional Voronoi cells to explore the parameter space and find the zones of best-fit, from which it selects new parameter values for the forward models. As it proceeds, the algorithm concentrates sampling around the cells with the best-fit models. The resulting distribution of forward models and misfits in multi-parameter space can then be analyzed to obtain probability density distributions for each parameter.

The ability of NA to provide probability distributions for parameter values gives an indication of uncertainty in each, and can be used to guide field measurements for model testing. This application of advanced inversion techniques for landscape evolution modeling is a significant step towards the use of more formal mathematical methods in geomorphology that are already applied by other disciplines in the geosciences.

References:
Using Neighborhood-Algorithm Inversion to Test and Calibrate Landscape Evolution Models: Mariela C Perignon, Gregory E Tucker, Peter Van Der Beek, George E Hilley, Ramon Arrowsmith. AGU Fall Meeting 2011 (EP21. Quantifying Geomorphic Processes and Landscape Evolution: Linking Observations and Models).

Numerical modeling of 2D turbidity currents to investigate sediment wave generation



Turbidity currents play an important role in the delivery of sediment to the deep seafloor. In some environments, repeated turbidity currents can result in sediment waves, large bedforms that appear similar to dunes but with wavelengths of up to several km. The waves are the result of greater deposition on the upstream/upslope side relative to the downstream side. This creates a distinctive upslope migration of the waveforms over successive currents that can be observed in profile. Field data for turbidity currents and their interaction with complex topographies such as sediment wave fields are very difficult to obtain. Thus, along with laboratory experiments, numerical simulation is an important means for investigating this phenomenon.

Previous modeling efforts have focused on using the depth-averaged formulation of the Navier-Stokes equations and small sets of input parameter combinations. For this investigation, we are using the 2D form of the Navier-Stokes equations in order to capture potentially important depth-wise flow structures. Additionally, we are applying a larger set of input parameter combinations in order to determine how the varying parameters affect the generation of sediment waves and the resulting morphology of any waves that may form. To do this we are using the 2D version of TURBINS. This code was developed by Mohamad M. Nasr-Azadani to be capable of modeling gravity and turbidity currents interacting with complex topographies, including erosion.

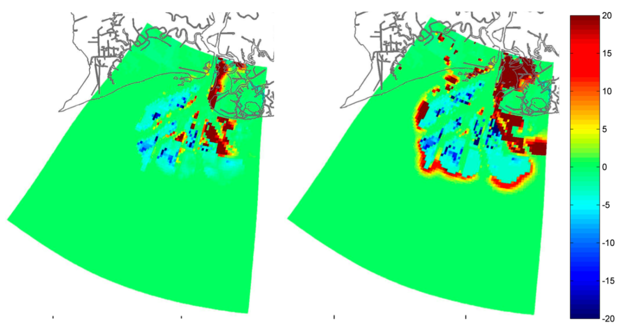
We use a lock-exchange configuration in which a region of uniform concentration sediment-laden fluid initially sits atop a ramp. The parameters we have elected to vary for this study are settling velocity, Reynolds number, slope of the ramp, and height of the initial sediment-laden region of fluid relative to the lock. For each parameter combination, we simulate several successive flows, updating the bottom geometry between each flow. Thanks to the use of the immersed boundary method in the TURBINS code, even sub-grid changes to the bottom interface naturally affect the results of subsequent flows. In order to ensure that the mass input is the same for each simulation, the lock is cleared of deposition between runs. Over several flows, upstream-migrating waveforms can develop on the initially flat slope.

References:

Nasr-Azadani M.M. and E. Meiburg, 2011: TURBINS: An Immersed Boundary, Navier-Stokes Code for the Simulation of Gravity and Turbidity Currents Interacting with Complex Topographies, *Comp. Fluids*, **45**, 14-28.

Nasr-Azadani M.M., B. Hall and E. Meiburg, 2013 Polydisperse turbidity currents propagating over complex topography: Comparison of experimental and depth-resolved simulation results. Computers & Geosciences 53: 141-153.

The impacts of vegetation on hydrodynamics and morphology of coastal wetlands, Wax Lake Delta during extreme events



The impacts of humans on natural systems are becoming more and more significant in modern times. The critical zone between ocean and land, the deltaic area, which is also the zone supporting most of population on the earth, is undergoing fast changes and becoming a high-risk zone for human society and ecosystem. Coastal Wetlands can slow down the flow velocity, dissipate wave energy, and increase soil critical shear strength, thus protect inland areas from increasing extreme events. This project mainly concentrates on hydrodynamics and morphological changes on the coastal wetlands during short-term extreme events (hurricanes, winter storms, and river floods), and also the river water and sediment changes for long-term period, which accounts for the formation of deltas.

References:

Fei Xing, Albert J. Kettner, Andrew Ashton, Eric Hutton, James Syvitski. Exploring a river-wave dominated delta evolution applying a model-coupling approach. AGU, 2011, San Francisco.

Three-dimensional miscible displacements in porous media or Hele-Shaw cells

Viscous fingering instability can occur when a less viscous fluid displaces a more viscous fluid. This hydrodynamic instability has several applications including groundwater flows and oil recovery, and it has been under investigation for many decades. Due to its similarities to porous media flows, many viscous fingering studies have been performed in a Hele-Shaw cell, an apparatus that consists of two parallel plates placed closely together. These are low Reynolds number flows, and a two-dimensional modeling that comes from averaging the Stokes equations across the gap of the Hele-Shaw cell is usually applied in the form of Darcy's law.

This project intends to perform three-dimensional Navier-Stokes simulations of miscible displacements in porous media or Hele-Shaw cells. A three-dimensional description of the problem have access to all three vorticity components, different from a two-dimensional formalism that includes only gapwise vorticity. This component of vorticity drives finger formation, and the results from this project have shown that the streamwise vorticity is responsible for the emergence of additional hydrodynamic instabilities.

References:
Oliveira, R.M. and E Meiburg. 2011, Miscible displacements in Hele-Shaw cells: three-dimensional Navier-Stokes simulations. J. Fluid Mech. 687: 431-460.
John, M. O., R. M. Oliveira, F. H. C. Heussler and E. Meiburg. 2013, Variable density and viscosity, miscible displacements in horizontal Hele-Shaw cells. Part 2. Nonlinear simulations. J. Fluid Mech. 721: 295-323.
Oliveira, R.M. and E Meiburg. 2013, Three-dimensional vorticity configurations in miscible Hele-Shaw displacements. Procedia IUTAM 7: 203-212.

Chapter 8: Proof of Concept Challenges

Concurrent with the development of the CSDMS cyber-infrastructure, Working Groups were to work with the CSDMS community and contribute to demonstration science challenges. The challenges involved technological trials for software development and code coupling: coupling between 1D-2D and 3D models, couplings between models of different programming languages, couplings between model and associated data. The science demonstration challenges were defined by the CSDMS Planning Workshops and formulated in the Strategic Plan of 2008. The CSDMS community critically evaluated its major science challenges at the Annual Meeting of 2010 and identified additional science problems requiring a community modeling approach.

Major science challenges identified in 2007:

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

Challenge2: Sediment Dynamics in the Anthropocene

Challenge3: Tracking surface dynamics through glacial cycles

Strategic science challenges identified by the CSDMS community in 2010:

Challenge4: Mechanisms of Sediment Retention in Estuaries

Challenge5: Arctic Coastal Zone at Risk: Prognosis and Modeling

Challenge6: Dynamics and Vulnerability of River Delta Systems

Challenge7: Prediction of margin stratigraphy

Each of the proof-of-concept challenges involved multidisciplinary science questions, as well as new couplings across critical domain boundaries, or challenging time and space scaling issues.

How well did we do: Most models are originally 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 output, and end the run. CSDMS strived to move towards developing models as components within modeling frameworks (Syvitski et al., 2013). 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 own areas 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 cover multiple domains by building larger models from a series of components to analyze scientific problems that could not be solved in the past (Kettner & Syvitski, 2013).

The cyberinfrastructure of CSDMS now allows more standardized functionality to benefit developers and users. The advantages of the CSDMS architecture is that each new componentized model can now:

(1) Be run by any CSDMS member, remotely, on the CSDMS HPCC.

(2) Use the CMT graphical user interface for changing model parameters.

(3) Offer new outputs or reflect new inputs.

(4) Offer improved and standardized output options (Time Series and/or Grid Sequences).

(5) Use VisIT that is integrated into CMT, to visualize output.

(6) Each be used as a Component in a coupled system or a stand-alone Model/Driver.

(7) Be linked to even more components written in other languages.

These advantages result from the completion of three model coupling projects focused on technological challenges.

Technological Challenges of Coupled Modeling

Scientists have historically coupled models by hardwiring models together, or by using the output of one model as input to the next model, whereby the outcome of the 2nd model will not influence the outcome of the first model (one-way coupling versus two-way coupling). CSDMS advanced the technology in coupling models and now allows two-way coupling. Peckham et al. (2013) present a conceptual paper in Computers & Geosciences 2013 that discusses how models can be coupled using interface standards BMI (Basic Model Interface) and CMI (CSDMS Component Model Interface). Developers can now implement the BMI interface, specifying the needs and outputs of their own model. The CSDMS Component Modeling Tool (CMT) then implement its CMI interface that allows two-way coupling between different components (Kettner & Syvitski, 2013). This interface culminated from three software proof-of-concept projects aimed at identifying architectural solutions to common model coupling challenges:

Three proof-of-concept projects were chosen to test the flexibility of the designed model-coupling framework. The six models represent "type" models in the CSDMS repository, written by six different authors or teams of authors, offering unique programming styles. The models employed four computer languages (C, C++, IDL, Matlab), three different grids (raster, non-uniform mesh or NUM, spatially-averaged or SA), and two levels of granularity (process and modular) (Fig. 8.1). Some models contributed to the CSDMS Model Repository do not offer a graphical user interface (GUI) or a command language interface (CLI). Some models needed to be translated: TopoFlow was translated from IDL to Python using the CSDMS-enhanced I2Py Translator, and CG2D was translated from MATLAB to Python.

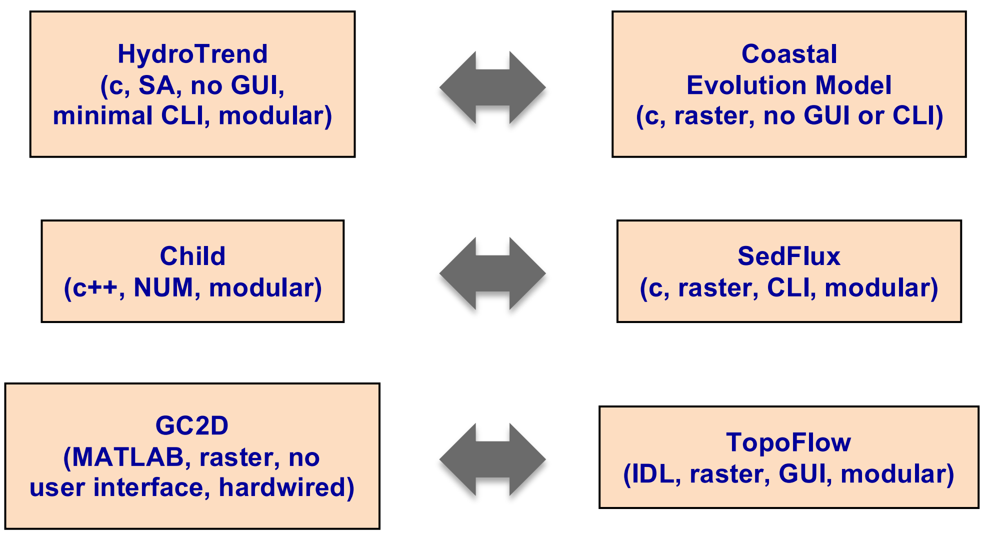


Figure 8.1. Three proof-of-concept projects representing common coupling challenges (see text for acronym details).

Proof-of-concept Project 1:
TopoFlow a fully spatial hydrologic model was successfully coupled to *GC2D*, a 2D valley glacier and ice sheet model, to build glaciers and route meltwater. This model coupling involved expertise from hydrologists and glaciologists. The coupling involved two different languages and a more modular model versus a single purpose model.

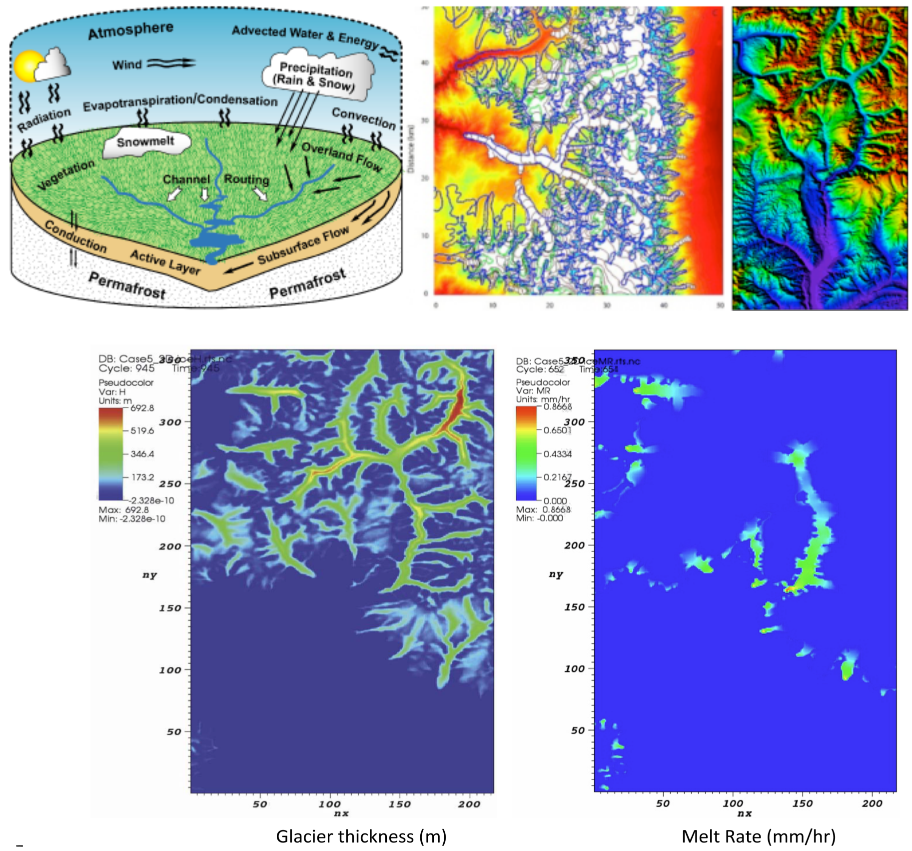


Figure 8.2. (UL) TopoFlow hydrological domain and processes; (UC) GC2D glacier domain; (UR) Digital Elevation Model of the Animas basin (Colorado) used in the Proof of Concept project; (LL) Glacier Thickness from coupled model run; (LR) Melt rate routing through basin.

TopoFlow was a fully spatial hydrologic model with multiple methods for modeling a variety of physical processes in watersheds, written in IDL (Interactive Data Language) with the following properties:

- A complete, point-and-click GUI with HTML Help System.
- Any input variable can be a Scalar, Time Series, Grid or Grid Sequence.
- Any computed variable can be saved as Time Series or Grid

After CSDMS refactored this code, TopoFlow offered 17 separate components. Each component has:

- Ability to be used as a model (driver), or as a component.
- BMI and CMI interfaces
- A wrapper to make it a CCA component (CCA "impl" file)
- Its own, separate input file (*.cfg)
- A GUI dialog to change its parameters, with HTML help.
- Its own output options.

TopoFlow was converted from 37,434 lines of IDL code to 33,058 lines of Python using I2PY 2.0, and now uses Numerical Python. The new model is completely object-oriented. Computed variables can be saved as before, and additionally as BOV (Brick of Values) or netCDF standardized data format.

GC2D is a valley glacier and ice sheet model with the following properties.

- Finite-difference, explicit time-stepping
- Ice flow is modeled via Glen's Law with basal sliding velocity derived from basal shear stress.

- Input consists of a DEM and prescribed time-dependent Glacier Equilibrium Altitude Line.
- Precipitation and ice melt processes employ a "net mass balance" method.

GC2D had 1495 lines (30 pages) of MatLab code that did not offer an OpenMI-style interface. All input parameters were hard-wired into the code. There was limited ability to save computed variables to output files. After conversion to 1966 lines of Python, GC2D is able to use Numerical Python, and can be used as either a component that provides meltwater runoff to a spatial hydrologic model such as TopoFlow, or as a stand-alone Model/Driver. GC2D can optionally be driven by TopoFlow's process components. For example, the Meteorology and Snow components can be used to provide snowfall and ice melt rates directly to GC2D. GC2D now reads all input parameters from the CMT GUI. Computed variables can now be saved as BOV or netCDF, and can now output a grid of "melt rates" for use by other models.

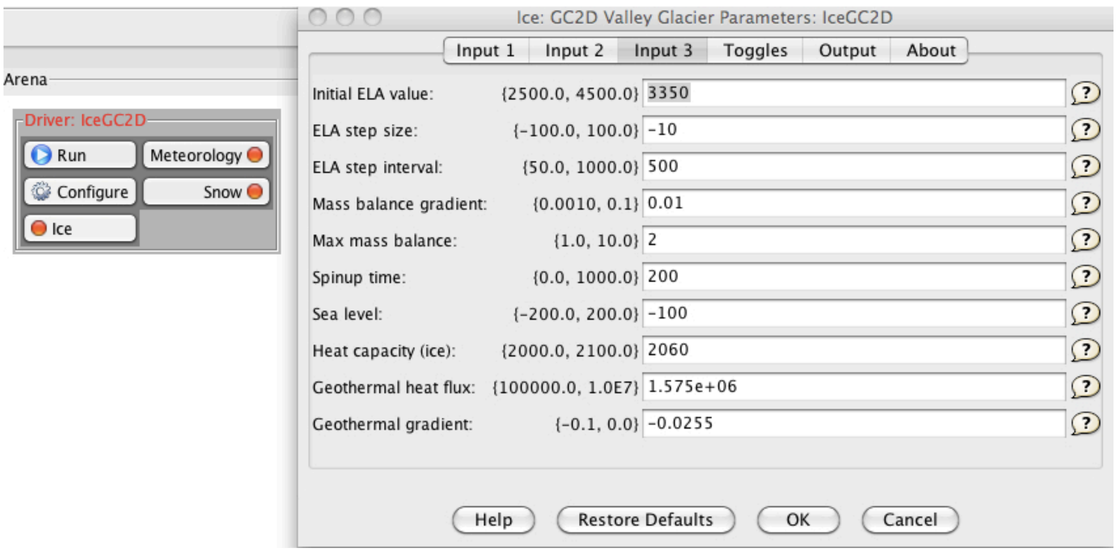


Figure 8.3. New input dialog box for the refactored GC2D model, showing typical ranges of values and model-run values with help dialog toggles to the right.

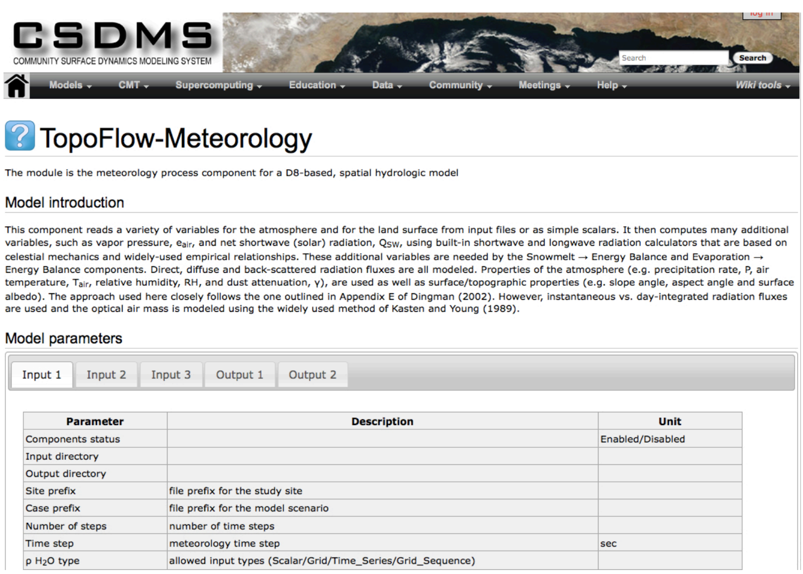


Figure 8.4 Wiki-based help for the meteorology component of the refactored TopoFlow model

Proof-of-concept Project 2:
HydroTrend is a spatially-averaged 1D hydrologic model driven by temperature and precipitation that simulates a time series of single river channel or distributary-channel delta hydraulics and sediment load (bedload and suspended load). The Coastal Evolution Model (*CEM*) is a 2D line model to predict the distribution of bedload entering a coastal zone and subjected to wave energy. The two models were successfully coupled (Ashton et al., 2013).

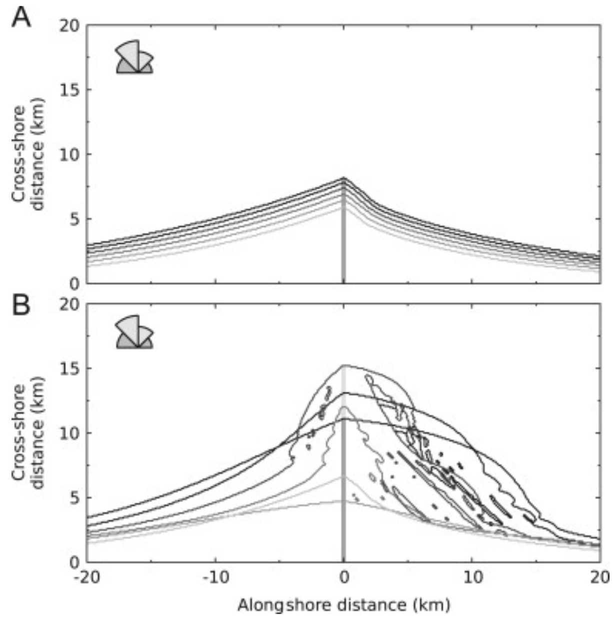


Fig.8.5 Time series of CEM shoreline plan-views of simulated deltas for select scenarios: (A) constant bed load and (B) highly variable bed load from HydroTrend, both with average delivery rates of 128 kg/s. Shorelines are plotted every 150 simulated years starting at 700 years.

HydroTrend before refactoring was 10,500 lines of C code, offering a command line interface to describe the model drainage and climate conditions. The output was a binary Hydrotrend-specific file. After refactoring, *HydroTrend* was made into a *CCA* component with 11,300 lines of C code (8% increase), offering a GUI within *CMT*, and an API that provides IRF functions, a getter for elevation, and a setter for sediment discharge, with additional standardized output formats. *CEM* before refactoring was 4,300 lines of C code offering no command line interface, no input files (hardcoded variables), operating with constant sediment supply and wave angle characteristics. After refactoring *CEM* is 4,500 lines of C code (8% increase), is available as C and Python components, offers a library, a GUI within CMT, an BMI and CMI for elevation, and sediment discharge, and various output formats (CSV, BOV, netCDF).

Proof-of-concept Project 3
CHILD is a large modular landscape evolution model that given climate and tectonic dynamics, erodes and delivers a flux of sediment. As the land rises, water erodes the landscape and carries sediment to the ocean where it is dumped at the shoreline. *SedFlux* provides a framework that keeps track of 3D stratigraphy generated by 15 coastal and marine modules. The proof-of-concept exercise was designed to link large, established models that offered little overlap. The challenge was also in the linking of different numerical grids and I/O overlap (Fig. 8.6).

Before refactoring Child was 39,000 lines of C^{++} code, was a component model with its own driver, offered a user interface through an input file, offered lots of output variables as ASCII files, and did its calculations on a non-uniform mesh. Before refactoring SedFlux was 70,000 lines of C code, was a component model with its own driver, offered a user interface through input file, and command line, had lots of output variables as binary data, and its calculations were done on a uniform mesh. CSDMS designed a universal grid mapper tool to convert initially between models. Another challenge is that Child provides a sediment flux to every grid cell. SedFlux requires deliver to the ocean through fewer river channels.

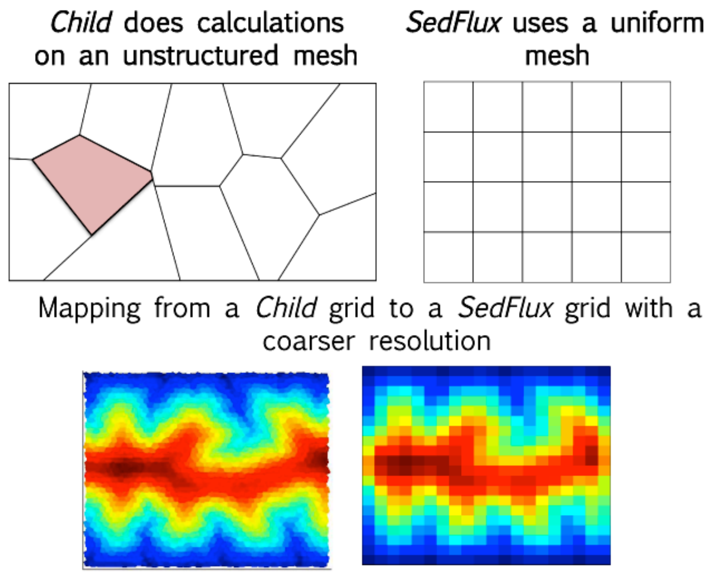


Figure 8.6. Two different meshes make linking Child and SedFlux a challenge.

Both *CHILD* and *SedFlux* now have a fully functional BMI and CMI. The *CHILD* interface retrieves the model grid's elevation, discharge, and erosion (and deposition). In addition, the interface now provides a setter method that is able to change elevation values of the *CHILD* grid. The *SedFlux* interface now retrieves elevation values and sets erosion (and deposition) values of its grid. These new interface functions allow *CHILD* to determine the amount of erosion or deposition over the delta plain, and then pass this information along to *SedFlux* to keep track of the evolving stratigraphy. Calculated discharge (both water and sediment) from *CHILD* at the shoreline can now be read by *SedFlux*, which it will then distribute into the ocean into a variable number of river mouths.

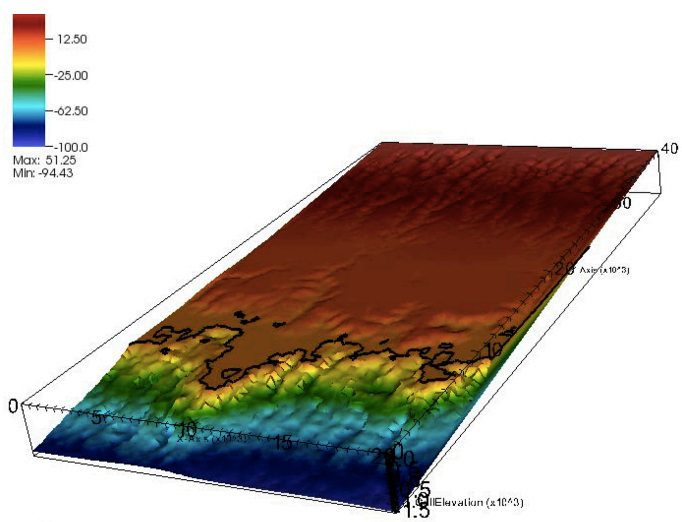


Figure 8.7 Combined Landscape and Seascape Evolution over a sea level cycle resulting from CHILD-SedFlux coupled simulations.

Towards Coupled System Modeling

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

Carbon dynamics as addressed by CSDMS focuses on those processes involving fine sediment: fluvial and marine transport, reservoir impoundment, and environmental sequestering (floodplains, wetlands, continental shelves). Focusing on carbon ensures that CSDMS will incorporate key geochemical linkages in its design and allow the system to contribute to an immediate scientific debate having societal relevance. One first step towards solving the problem of transporting and storing sediment and carbon through a landscape are distributed water transport models. The CSDMS Model Repository now documents code and metadata for 52 'Hydrological Models' and has made these easily available for the science community. Many of these models have been developed over long time periods and have undergone extensive testing before being submitted and documented in the CSDMS repository (e.g. PIHM (Kumar and Duffy, 2010), DHSVM (Wigmosta et al., 2002), WBM-WTM (Fekete et al., 1999)). TOPOFLOW has been componentized and now forms an ensemble of 14 hydrological components for coupling: meteorology, D8 flow routing, evapotranspiration, infiltration snowmelt, channel dynamics. Hydrological Models in the CSDMS model repository include models designed for pollutant and sediment transport: SPARROW and VIC being key examples. HydroTrend (Kettner et al., 2008) and WBM-Sed (Cohen et al., 2013) are two models that the CSDMS Integration Facility has advanced to deal with sediment transport from drainage basin headwaters to the global ocean. WBM-Sed now simulates 50 years of daily water and sediment transport for all the world rivers.

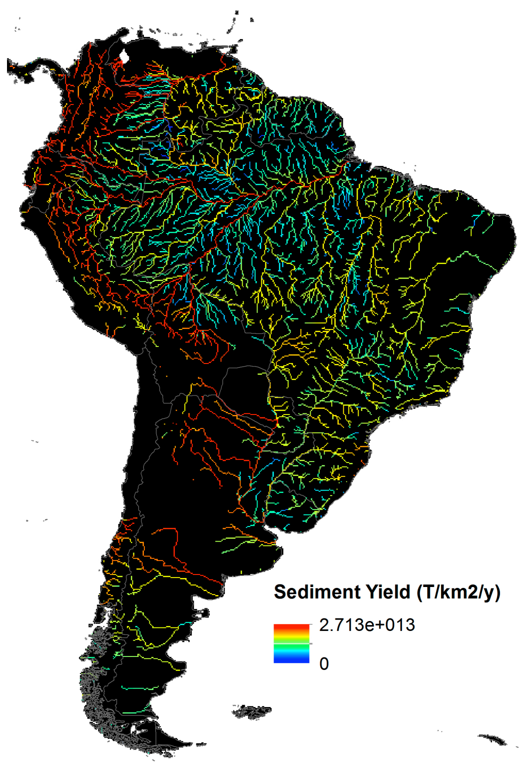


Fig. 8.8. Janus run simulation of WBMsed showing the sediment yield of South America (an extract from a global simulation (Cohen et al., Computers & Geosciences, 2013).

Storage of floodplain sediment is a critical component in a full source to sink budget of catchment modeling. CSDMS componentized a beta-version of AlluvStrat (by graduate student Wickert) and floodplain deposition model AquaTellUs (Overeem et al., 2005). Viparelli et al., (2013) contributed a novel model to CSDMS that quantifies sediment budgets based on isotopic fingerprinting.

Key Publications:

Cohen, S., Kettner AJ, Syvitski, JPM and Fekete BM, 2013, WBMsed: a distributed global-scale daily riverine sediment flux model: Model description and validation. Computers & Geosciences 53, 80-93.

Viparelli, E., Lauer, W., Belmont, P., and Parker, G. 2013, A numerical model to develop long-term sediment budgets using isotopic sediment fingerprints. Computers & Geosciences 53: 114-122.

Challenge2: Sediment Dynamics in the Anthropocene

The "Anthropocene" refers to that part of the Earth's recent history in which humans have become a major force for change in Earth systems (Syvitski, 2012). By combining CSDMS transport models with data sets addressing human-influenced as well as pre-human conditions, the CSDMS effort aims to quantify human influence on landscape evolution and sediment dynamics. Large integrated field studies funded by NSF (MARGINS) and ONR (EuroSTRATAFORM) are providing valuable data documenting Anthropogenic modification of landscapes, in basins such as the Eel, Waipaoa, Po, Rhone, and Skagit. Focusing on the human time scale allows for CSDMS models to investigate the cumulative effects of human activities on the environment, including: 1) perturbations on sediment generation, 2) interruptions to sediment routing and storage (i.e. reservoirs), and 3) impacts on coastal ecosystems (e.g. elimination of flooding on delta surfaces). This challenge allows for CSDMS to evolve with access to modern global databases and large integrated data sets (e.g. Shuttle Radar, satellite imagery, DEMs, meteorological and ocean data), and to reach out to the global change research community. CSDMS pioneered a model-data coupling system, wherein the input data for a hydrological process model is mined from available web data (the CUASHI-HIS system) (Goodall et al., 2008; Peckham & Goodall, 2013).

HydroTrend was one of the first CSDMS models to come online as a component, incorporating insights of empirical relationships (Syvitski & Milliman, 2007). This model allows simple scenarios of before and after human disturbances. The model helped quantify the tremendous effects of historical deforestation in the Waipaoa, Magdalena and Danube river basins, affecting the bays and deltas downstream (Kettner et al., 2007; Restrepo et al., 2011; McCarney-Castle, 2011).

Papers of Ashton et al. (2013) and Murray et al. (2013) provide case studies that pioneer the coupling of existing models with strong relevance for studying the impact of the humans on the environment.

The integrated of the climate-driven sediment supply model HydroTrend, an avulsion model on the coastal plain, and the wave-driven coastline evolution model proved to be a formidable task: 7 programmers worked on the original codes and now they are embedded in one overarching architecture. Ashton et al. (2013) apply genuine two-way coupling, where changes in the coastline affect the apportionment of riverine sediment leaving coeval distributaries that in turn affecting coastline morphology. Spanning multiple disciplines, Murray et al. (2013) present a unique coupling of social economic drivers and environmental change. An economic-based decision model determines whether to nourish a stretch of coastline, based on net benefits, whereas the coupled coastline evolution model (CEM) determines how a coastline evolves over time. The two-coupled models provide scenarios how coastal zones might evolve over time given changes in wave climate or economical change. Such studies should become ever more common, given the societal need for applied and interdisciplinary science (Kettner & Syvitski, 2013).

Key Publications:

Goodall, J., D.G. Tarboton, S.D. Peckham, R. Hooper 2008, New software architecture for integrated water modeling, EOS, Transactions, 89: 420.

McCarney-Castle, K., Voulgaris, G., Kettner, A.J., and Giosan, L., 2012, Simulating fluvial fluxes in the Danube watershed: The Little Ice Age versus modern day. The Holocene 22: 91-105.

Murray, B., Gopalakrishnan, S., Smith, M.D., and McNamara, D.E. 2013, Progress in coupling models of human and coastal landscape change. Computers & Geosciences 53: 30-38.

Syvitski, J.P.M. and Milliman, J.D., 2007, Geology, geography and humans battle for dominance over the delivery of sediment to the coastal ocean. J. Geology 115: 1–19.

Syvitski, JPM, 2012. The Anthropocene: An epoch of our making. Global Change Magazine, 78: 12-15.

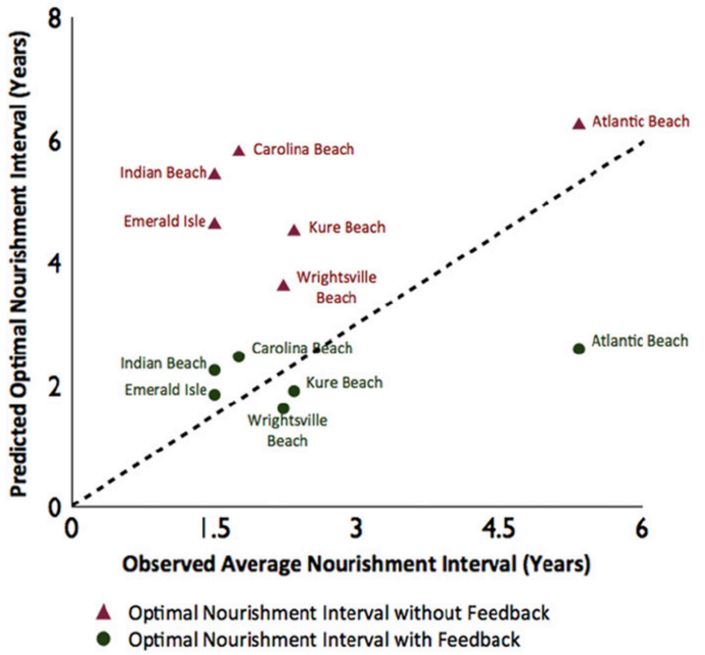


Figure 8.9 Modeling to Management: comparison of observed beach nourishment intervals and model predicted optimal nourishment interval taking coastal processes and economic drives into account (after Murray et al., 2013)

Challenge3: Tracking surface dynamics through glacial cycles

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

The glaciological model GC2D (Kessler et al., 2008) was used in a landmark demonstration of the geomorphological effects of cycles of glacial incision upon the landscape. This model was successfully incorporated into the CSDMS framework in an early stage. New developments and vast improvements to the earlier code resulted in new insights in the critical feedbacks within the glacial erosion cycle; the deeper a glacial valley is the more ice volume is needed at low elevation to fill it and this speeds up retreat cycles (Anderson et al., 2012). Other modeling efforts look into landscape dynamics on a Pleistocene timescale by inverting sedimentary records from lake and shelf cores to arrive at precipitation or storm data, which in turn drives a numerical sediment supply model. This approach constrains the storage components over the Waipaoa sedimentary system over time and provided insight in differences in erodibility over large climatic swings (Upton et al., 2013). Wobus et al (2010) ran simplified experiments to identify unique signals in incision due to climate change. This concept can now be further explored in three-dimensional space, with the coupled modeling architecture of CHILD and Sedflux having been achieved.

Sedflux is the main stratigraphic model now made available to the community through the CSDMS framework. A number of new couplings have been explored with this model: focused on interactions with isostatic rebound and sea level changes. Overeem et al., (2010) showed how critical timing of deglaciation is in the generation of fjord stratigraphy. Fundamental work by Joeet et el. (2008) and Hutton et al.,(2013) shows the profound effect of water loading on deflection of global continental shelves over glacial cycles, emphasizing the importance of fully-coupled modeling.

Key Publications:

Anderson, R.A., Dühnforth, M., Colgan, W.,Anderson, L. 2012: Far-flung moraines: Exploring the feedback of glacial erosion on the evolution of glacier length. Geomorphology, 179: 269-285. DOI: 10.1016/j.geomorph.2012.08.018

Hutton, E.W.H., Syvitski, J.P.M., and Watts, A., 2013, Isostatic Flexure of a Finite Slope Due to Sea-Level Rise and Fall. Computers & Geosciences 53: 58-68.

Jouet, G, Hutton, E.W.H., Syvitski, J.P.M., Rabineau, M., Berné, S., 2008, Modeling the isostatic effects of sealevel fluctuations on the Gulf of Lions. Computers & Geosciences, 34: 1338-1357.

Kessler, M. A., R S. Anderson, Briner, J. P., 2008: Fjord insertion into continental margins by topographic steering of ice. Nature Geoscience, 1(6): 365 369.

Overeem, I., Syvitski, J.P.M., 2010, Experimental exploration of the stratigraphy of fjords fed by glacio-fluvial systems. In: Howe, J. A., Austin, W. E. N., Forwick, M. & Paetzel, M. (eds) Fjord Systems and Archives, Geological Society, London, Spec. Publ. 344: 125-142.

Upton, P., Kettner, A.J., Gomez, B., Orpin, A.R., Litchfield, N., and Page, M.J., 2013, Simulating post-LGM riverine fluxes to the coastal zone: The Waipaoa catchment, New Zealand. Computers & Geosciences 53: 48-57.

Wobus, C. W., Tucker, G. E., Robert S. Anderson, 2010: Does climate change create distinctive patterns of landscape incision?. Journal of Geophysical Research Earth Surface, 115: F04008, DOI: 10.1029/2009JF001562

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

The Arctic coastal zone is rapidly changing (Wobus et al., 2010). Significant, directed research effort is required to attain a level of sophistication and computational efficiency necessary to address complex anthro-bio-geo-physical interactions inherent in modern Arctic Coast Zone models (Roberts et al., 2010). Because of high socio-economic impacts associated with projected Arctic climate change, particular importance should be placed on understanding model uncertainty, limitations, and quantifying outcomes. In addition to known processes (such as those associated with permafrost, sea ice (Overeem et al., 2011), and surface waves), such error propagation considerations should become part of the model framework development. The Arctic Coastal Zone provides an opportunity given the comparatively trophic-level simplification and minimum level of direct human impact, yet the simplification points to the limited level of data to adequately validate ecosystem models. No long-term coastal morphodynamic model is identified suitable to the Arctic Coastal Zone, e.g. one that takes into account permafrost or other ice-sediment interactions.

A concept modeling framework for the Arctic Coastal Zone has been built including sea-ice retreat, wave dynamics, storm surge, thermal erosion and coastal bluff toppling. (http://csdms.colorado.edu/wiki/CSDMS_2013_annual_meeting_Katy_Barnhart). More advanced models like ADCIRC and WRF are contributed to the CSDMS model repository and will become a key part of the suite of models needed to address this challenge.

Key Publications:

Overeem, I., R. S. Anderson, C. Wobus, G. D. Clow, F. E. Urban, N. Matell, 2011, Sea ice loss enhances wave action at the Arctic coast. Geophysical Research Letters, 38, L17503.

Roberts et al., (eds.), 2010. A report by the Arctic Research Community for the National Science Foundation Office of Polar Programs.

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.

Wobus, C., R.S. Anderson, I. Overeem, N. Matell, G. Clow, F. Urban, 2011, Thermal Erosion of a Permafrost Coastline: Improving Process-Based Models Using Time-Lapse Photography. Arctic, Antarctic and Alpine Research 43: 474–484.

Challenge 5: Mechanisms of Sediment Retention in Estuaries

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

At the more fundamental level Warner et al. (2008) and Wiberg (2008) pushed forward our community's ability to model in the estuarine environment. Models like FV-SED (Canestelli et al., 2013) and the coupled salt-mars and tidal flat model (CMFT) are models that are contributed by the developers and now available to other CSDMS members. A big stride forward has been made towards this challenge; ROMS – the regional ocean model – is now a fully functional component in the CSDMS framework. Uniquely, CSDMS also developed a 'ROMS-Builder', that allows compiling unique instances of ROMS through the graphical user interface of CMT. CHESS-ROMS for Chesapeake Bay may be the most advanced effort of combining sediment and nutrient transport with respect to human inputs and changing environmental conditions.

Key Publications:

Warner, J.C., C.R. Sherwood & R.P. Signell, C.K. Harris, Arango H.G., 2008, Development of a three-dimensional, regional, coupled wave, current, and sediment-transport model: Computers & Geosciences 34: 1284–1306.

Wiberg P.L. and Sherwood C.R., 2008, Calculating wave-generated bottom orbital velocity from surface wave parameters. Computers & Geosciences 34: 1243–1262.

Challenge 6: Dynamics and Vulnerability of River Delta Systems

As a result of human development and global changes, deltas are now perilously out of dynamic equilibrium, being maintained at lower elevations (Syvitski et al., 2009) and farther offshore than in natural conditions. While providing separation from quotidian delta dynamics, human stabilization of naturally dynamic deltaic systems is likely to result in less frequent, but catastrophic failures of delta system components following extreme events. Compounding chronic problems of deltas, extreme events may contribute to the collapse of entire deltaic systems. Although delta ecosystems are among the most productive and provide environmental goods and services of regional and global importance, human development within deltas and further upstream in the drainage basin may push deltas over ecological collapse thresholds. Our ability to preserve deltas depends strongly on a better understanding of the fundamentals of system-scale sediment, nutrient, and ecological dynamics from the watershed to the receiving basin. Research must be designed to address the full range of responses of this complex dispersal system to external forcing, and to assess its internal controls. Future programs should focus on (1) developing modeling methods for coupling biological, geochemical, physical, and human dynamics, and (2) acquisition of detailed information on forcing factors such as paleodischarge, high resolution sea level and subsidence histories, and past records of energy regimes in the receiving basin.

CSDMS1.0 has provided the community with a first set of models to address the problems in deltas: physical models such as CEM, Sedflux and Avulsion are now in place and can be coupled to fluvial models to explore management scenarios and dominance between components of the system (e.g, http://csdms.colorado.edu/wiki/CSDMS_2013_annual_meeting_Jaap_Nienhuis) . It can be considered a great step forward that established morphodynamical models such as Telemac (Villaret et al., 2013) and Delft3D have gone open-source (http://oss.deltares.nl/web/delft3d) and are extensively used in the CSDMS community to better couple processes (Edmonds & Slingerland 2010a, 2010b). However, Murray et al., (2013) pioneered an approach to incorporate more evident feedback between human intervention and the sedimentary system and such understanding is only beginning to be established for complex delta systems.

Key Publications:

Edmonds, D.A., and R.L. Slingerland (2010a), Significant effect of sediment cohesion on delta morphology, Nature–Geoscience, 3, 105–109.

Edmonds, D.A., R.L. Slingerland, J. Best, D. Parsons, N. Smith (2010b), The response of river–dominated delta networks to permanent changes in river discharge, Geophysical Research Letters, 37, L12404, doi:10.1029/2010GL043269.

Murray, B., Gopalakrishnan, S., Smith, M.D., and McNamara, D.E. 2013, Progress in coupling models of human and coastal landscape change. Computers & Geosciences 53: 30-38.

Syvitski, J.P.M., AJ. Kettner, MT. Hannon, EW.H. Hutton, I Overeem, G. R Brakenridge, J Day, C Vörösmarty, Y Saito, L Giosan, and Nicholls, R J., 2009, Sinking Deltas. Nature Geoscience 2: 681-689.

Challenge 7: Prediction of margin stratigraphy

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

CSDMS1.0 saw the completion of the coupling between *CHILD* (Tucker et al., 2001) and *SedFlux* (Hutton & Syvitski, 2008), which is a landmark coupling between two large frameworks and allows for the exploration of many feedback mechanisms in the source-to-sink system. Additionally, a component for subsidence modeling has come online: SUBSIDE. Indeed the integration of these models with geodynamical codes has been initiated (http://csdms.colorado.edu/wiki/CSDMS_2011_annual_meeting_Eunseo_Choi)

Whereas these overarching models necessarily have many simplifications, a role for detailed process models is evident. TURBINS simulated turbity currents on the time-scale of seconds, but still provides deep water geologists with detailed insight in deposition and stratigraphy that otherwise would not have been recognized. One approach is to nest such models in larger frameworks, another approach is to derive rules and use them in a geostatistical manner.

CHILD can now be closely compared against other landscape evolution models such as ERODE and MARSSIM that have become componentized in CSDMS1.0. Such model intercomparisons are a strongpoint of the possibilities that the CSDMS modeling framework offers the scientific community.

Key Publications:

Nasr-Azadani, M. M., Meiburg, E., 2011. TURBINS: An immersed boundary, Navier-Stokes code for the simulation of gravity and turbidity currents interacting with complex topographies. Computers & Fluids 45 (1), 14–28.

Tucker, G. E., Lancaster, S. T., Gasparini, N. M., Bras, R. L., Rybarczyk, S. M., 2001. An object-oriented framework for distributed hydrologic and geomorphic modeling using triangulated irregular networks. Computers & Geosciences 27: 959~973,

Howard, A. D., 2007. Simulating the development of Martian highland landscapes through the interaction of impact cratering, fluvial erosion, and variable hydrologic forcing, Geomorphology, 91: 332–363.

Hutton E.W.H., and Syvitski, J.P.M., 2008, SedFlux2.0: An advanced process-response model that generates three-dimensional stratigraphy. Computers & Geosciences, 34: 1319-1337.

Peckham, S.D., Hutton E.W.H. and Norris B., 2013, A component-based approach to integrated modeling in the geosciences: The Design of CSDMS, Computers & Geosciences 53: 3-12

Slingerland, R, Syvitski, JPM, 2013, A Community Approach to Modeling Earth- and Seascapes. In: John F. Shroder (ed.) Treatise on Geomorphology 2: 44-49. San Diego: Academic Press.

Voinov, C. DeLuca, R. Hood, S. Peckham, C. Sherwood, J.P.M. Syvitski, 2010, A community approach to Earth systems modeling. EOS Transactions 91(13): 117-124.

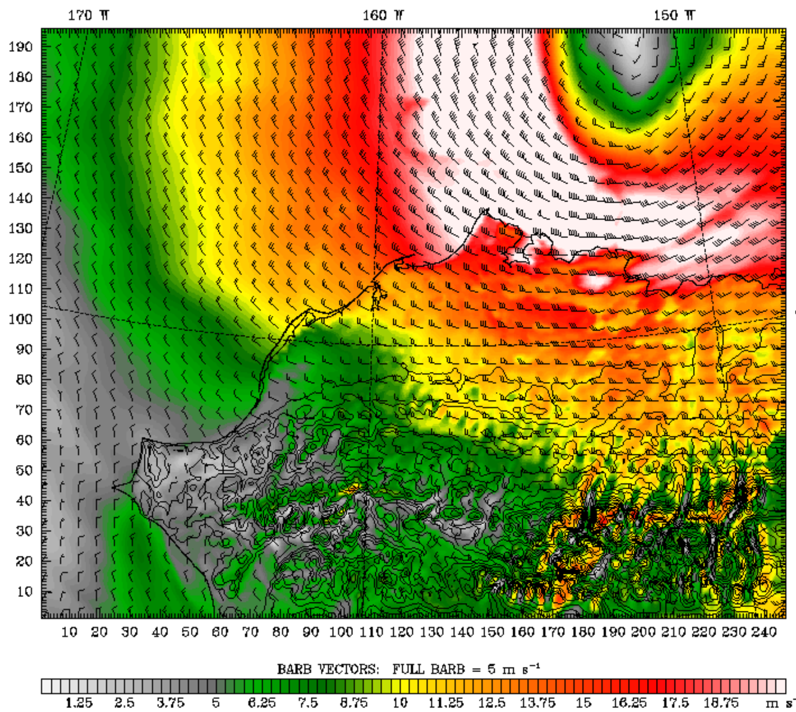


Fig. 8.10: The Weather Research & Forecasting (WRF) model was created through a partnership with National Oceanic & Atmospheric Administration, National Center for Atmospheric Research and >150 organizations and universities in the US and abroad. Simulation shown is for the WRF wind field for the north slope of Alaska (Aug 10, 2010), at 3.3 km resolution model run on the CSDMS supercomputer Beach. Testimonial — "With a compute time of <1 min per simulation hr, we are cookin' with gas! – Gary Clow"

Chapter 9: CSDMS Integration Facility Staff and Visiting Scientists (2007-2012)

Director's Office

• Executive Director, Prof. James Syvitski (April, 2007—) — CSDMS & CU support
• Executive Assistant Mr. Andrew Svec (Oct, 2007 – June, 2008) — CSDMS support
• Executive Assistant, Ms. Marlene Lofton (Aug. 2008—) — CSDMS support

Software Engineers

• Chief Software Architect Dr. Scott Peckham (April, 2007—) — CSDMS & NSF/NOAA support
• Senior Software Engineer, Dr. Eric Hutton (April, 2007—) — CSDMS, NSF & contract support
• Software Engineer, Dr. Beichuan Yan (April, 2009 – July, 2011) — CSDMS support
• Computer Scientist, Jisamma Kallumadikal (Aug, 2009 – July, 2012) — SURA & CSDMS support

Portal, and Model and Data Repository

• Cyber Scientist Dr. Albert Kettner (July, 2007—) — CSDMS, NSF, NASA & contract support

Education and Knowledge Transfer Mission

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

Financial and IT Support Staff

• Accounting Technician Mary Fentress (April, 2007 – June 2013) — multiple grant support
• Systems Administrator Chad Stoffel (April, 2007—) — multiple grant support

Additional CSDMS-related scientists

• Director Dartmouth Flood Observatory, G Robert Brakenridge (Jan, 2010—) — NASA support
• Senior Research Scientist Christopher Jenkins (Jan 2009—) — NSF & contract support

CSDMS-related support from other sources

10 Graduate students: Nora Matell (NOPP), Dan McGrath (NASA), Scott Bachman (ONR), Stephanie Higgins (NSF, NASA), Fei Xing (NSF), Mark Hannon (contract support), Ben Hudson (NSF), Yun-zhen Chen (foreign support), Andy Wickert (NSF), Katy Barnhart (NSF-NASA).
2 Undergraduate students: Cordelia Holmes (NSF), Aaron Zettler-Mann (contract support)
3 CSDMS postdocs: Sagy Cohen (NASA), Maureen Berlin (NSF), Kimberly Rogers (NSF)

60 CSDMS Visiting Scientists & Students

1. Bjarte Hannisdal, U. Bergen, 2007
2. Gywn Lintern, Geological Survey of Canada-Pacific, 2007,
3. Bert Jagers, Delft Hydraulics, 2007,
4. Belasz Fekete, University of New Hampshire, 2007
5. John Harrison Oregon University, 2007
6. Gil Hansen, BHP Billiton, 2007
7. Mike Glinsky, BHP Billiton participants, 2007
8. Ilja L. de Winter, Delft U of Technology, Netherlands 2008
9. Bjarte Hannisdal, U. Bergen, 2008
10. Ted Lewis, Queen's University, Kingston, Canada. 2008
11. Gary Hoffman U California at Santa Cruz, 2008
12. Yunzhen Chen, Nanjing University, 2009
13. Ilja L. de Winter, Delft U of Technology, Netherlands 2009

14. Juan Restrepo, Geol. Sci EAFIT University, Columbia 2009
15. Bjorn Heise, Christian-Albrechts-University Kiel, Germany, 2009
16. Bjarte Hannisdal, University of Bergen, Norway 2009
17. Hernan Arango, Marine Sci Rutgers University, New Jersey 2010
18. John Gallant, Geol Sci CSIRO, Australia 2010
19. Adam Campbell, U. Washington, Seattle 2010
20. Elchin Jafarov, U. Alaska, Fairbanks 2010
21. Vittorio Maselli, University of Bologna, Italy 2010
22. Silke C. Lutzmann, University of Bonn, Germany 2010
23. Juan Restrepo, Geol. Sci EAFIT University, Columbia 2010
24. Gary Wilgoose Prof Geol. Sci Univ. Newcastle, Australia 2010
25. Zuosheng Yang, Ocean U of China, 2011
26. Houjie Wang, Ocean U of China, 2011
27. Naishuang Bi, Ocean U of China, 2011
28. Reed Maxwell, Col. School of Mines, 2011
29. Tao Sun, ExxonMobil, 2011
30. Damian O'Grady, ExxonMobil, 2011
31. Kim Picard, GSC, Pacific, 2011
32. Phillip Hill, Geol. Survey of Canada, 2011
33. Cristen Torrey, CoG, 2011
34. Mohamad Nasr-Azadani, U California Santa Barbara, 2011
35. Laurel Saito, Univ Nevada-Reno, 2011
36. Bert Jagers, Deltares, 2011
37. Kees Sloff, Deltares, 2011
38. Ron Tingook, U Alaska, 2011
39. Michael Barton, Arizona State U, 2011
40. Liz Olhsson, UC Berkeley, 2011
41. Martin Perlmutter, Chevron, 2011
42. Michael Pyrcz, Chevron, 2011
43. Brian Willis, Chevron, 2011
44. Matthias Vanmaercke, K.U. Leuven, Belgium, 2011
45. Elchin Jafarov, U. Alaska, Fairbanks 2011
46. Daekyo Cheong, Kangwon Nntl. Univ, Korea 2011
47. James Verdin, USGS, 2011
48. Kristine Verdin, USGS, 2011
49. Phadrea Upton, GNS Science, New Zealand, 2011
50. Emilio Mayorga, University of Washington, 2011
51. Vladimir Smakhtin, IWMI, 2011
52. Benjamin Allan, Sandia National Labs, 2011
53. Hajo Eicken, University of Alaska-Fairbank, 2011
54. Kim Picard, GSC, Pacific, 2011
55. Ruth Mugford, Cambridge U, 2011
56. Robert Busey, International Arctic Research Center, 2012
57. Robert Bolton, International Arctic Research Center, 2012
58. Andreas Mikkelsen, University of Copenhagen, Denmark, 2012
59. Ron Boyd, ConocoPhillips, Houston, 2012
60. Asa Rennermalm, Rutgers University, 2012.

Chapter 10: CSDMS Conferences, Meetings, Short Courses

Workshops and meetings (April 2007 to July 2012)

1. Cyberinformatics and Numerics Working Group startup meeting, Feb. 4-5, 2008, INSTAAR, Boulder, CO: http://csdms.colorado.edu/wiki/images/CSDMS_Strategic_Planv3F-48-op.pdf).
2. CSDMS Community Sediment Model for Carbonate Systems, Feb. 27-29, 2008, Colorado School of Mines, Golden, CO; http://csdms.colorado.edu/wiki/index.php/Carbonates_2008
3. Coastal Working Group startup meeting, March 8, 2008, Orlando, FL: http://csdms.colorado.edu/wiki/images/CSDMS_Strategic_Planv3F-48-op.pdf).
4. Marine Working Group startup meeting, March 8, 2008, Orlando, FL http://csdms.colorado.edu/wiki/images/CSDMS_Strategic_Planv3F-48-op.pdf).
5. CSDMS Executive Committee Meeting, July 17-18, 2008, Boulder CO
6. SEPM - CSDMS Research Conference on Clinoform Sedimentary Deposits: Aug. 15-18, 2008, Rock Springs, WY. http://csdms.colorado.edu/wiki/index.php/Clinoform_2008
7. I.A.G./A.I.G./ CSDMS SEDIBUD workshop on Sediment Budgets in Changing High-Latitude and High-Altitude Cold Environments, Boulder, CO, Sep. 9-13, 2008 http://csdms.colorado.edu/wiki/index.php/SEDIBUD_2008
8. WebEx presentation to CUAHSI members about CCA and CSDMS, Wed., Feb. 6, 2008.
9. CUAHSI Biennial Colloquium on Hydrologic Science and Engineering, NCAR Conference Center, Boulder, CO (http://www.cuahsi.org/biennial/)
10. CUAHSI Scoping Workshop for the proposed Community Hydrologic Modeling Platform (CHyMP), March 25-28, 2008, National Academy of Sciences, Washington, D.C.
11. EU-NSF OpenMI Workshop April 5-11, hosted by the Centre for Ecology and Hydrology and Wallingford Software Ltd., Wallingford, UK
12. Apr. 19-21, IGWMC "ModFlow and More" meeting, Colorado School of Mines, Golden, CO.
13. Computational Methods in Water Resources, XVII International Conference, San Francisco, CA, July 8-12.
14. Research Collaboration Partnership Meeting with petroleum companies at Colorado School of Mines, Golden, CO, Tues., Feb. 26, 2008.
15. CSDMS Industry Consortium Meeting held Tues., April 22; San Antonio, TX.
16. CSDMS Earth System Modeling Framework (ESMF) interactions, March 19, 2008.
17. CU site visit of Idaho National Lab (INL) March 31, 2008.
18. "Futures" source-to-sink NSF meeting, held in Orlando, FL, March 2, 2008.
19. CCMP Workshop on Communicating Models and Data, Annapolis, May12-14, 2008
20. Reverse site visit with EAR and OCE program directors, at the National Science Foundation, May 15, 2008
21. NSF-sponsored workshop on Studying Earth Surface Processes with HR Topographic Data, UCAR, Boulder, June 16-18
22. NSF-sponsored at the Cyber-Infrastructure Forum on Environmental Observatories, UCAR, Boulder, May 5-7, 2008
23. Relationships between CSDMS and NEON, Aug. 20, 2008, INSTAAR
24. CSDMS Hydrology FRG meeting, Boulder, CO, Jan 20-21, 2009.
25. CSDMS Carbonate FRG meeting, Boulder, CO, Jan 26-27, 2009.
26. CSDMS Terrestrial WG meeting, Boulder, CO, Feb 2-3, 2009.
27. CSDMS Coastal WG & Marine WG, Charlottesville, VA, Feb 25-26, 2009.
28. CSDMS Cyberinformatics & Numerics WG, Santa Barbara, Mar 3-4, 2009.
29. CSDMS Chesapeake FRG Meeting, Annapolis, Mar 22-25, 2009.
30. CSDMS Carbonate & Marine Group meeting, Boulder, CO, Oct 19-20, 2009.
31. CSDMS Terrestrial & Coastal Group meeting, Boulder, CO, Oct 26-27, 2009.
32. CSDMS Chesapeake FRG Meeting, VIMS, VA, Nov 10, 2009.
33. CSDMS EKT, Cyber & Hydrology Group meeting, Boulder, CO, Nov 16-17, 2009.
34. CSDMS Steering Committee Meeting, Boulder, CO, Feb 4, 2009.

35. CSDMS Executive Committee Meeting, Santa Barbara, CA Mar 2, 2009.
36. Industrial Consortium Rep Meeting, June 2009, 2009.
37. CSDMS Executive Committee Meeting, Boulder, CO, Sept 4, 2009.
38. CSDMS Steering Committee Meeting, Boulder, CO, Dec 11, 2009.
39. Gilbert Club: Town Hall Update, San Francisco, CA, Dec 19, 2009.
40. MARGINS: Linking S2S & CSDMS, Gisborne NZ Apr 6-9, 2009.
41. Modeling Turbidity Currents, U.C. Santa Barbara, CA, Jun 1-3, 2009.
42. AAPG/SEPM: Deepwater Architecture & Models, Denver, CO, Jun 7-10, 2009.
43. IAMG: Multiscale Modeling, Stanford U., CA, Aug 23-28, 2009.
44. River Coastal Estuarine Morphodynamics, Santa Fe, Argentina Sep 20-25, 2009.
45. SEDIBUD, Kingston, Canada, Oct 13-16, 2009.
46. AGU: San Francisco, CA, Dec 14-18, 2009.
47. CSDMS ExCom Teleconference, 01/2010, Boulder CO, USA
48. NSF MARGINS Successor Planning Workshop, 02/2010, San Antonio, TX, USA
49. CSDMS Interagency Meeting, 03/2010, Arlington, VA, USA
50. NERC-NSF Critical Zone Observatories, 03/2010, Arlington, VA, USA
51. Arctic Workshop, 03/2010, Winter Park, CO, USA
52. Joint AAPG and SEPM annual meeting, 04/2010, New Orleans, LA, USA
53. EPSCoR Climate Innovation Workshop, 05/2010, Valles Caldera, NM, USA
54. BP Gulf Oil Spill Teleconference, 05/2010, Boulder, CO, USA
55. CUAHSI HIS Advisory Comm. Telecon, 05/2010, Boulder, CO, USA
56. CSDMS ExCom Teleconference, 05/2010, Boulder, CO, USA
57. American Polar Society meeting, 05/2010, Boulder, CO, USA
58. ONR Coastal Geosciences meeting, 05/2010, Chicago, IL, USA
59. CUAHSI HIS Advisory Comm. Telecon, 06/2010, Boulder, CO, USA
60. Western Pacific Geophysics Conference, 06/2010, Taipei, Taiwan
61. CSDMS-China Cooperation meeting, 06/2010, Qingdao, China
62. NSF CUAHSI Open Meeting, 07/2010, Boulder CO, USA
63. CUAHSI HIS Workshop , 07/2010, Boulder CO, USA
64. Univ. of New Mexico meeting, 07/2010, Reno, NV, USA
65. NSF RAPID oil spill modeling team meeting, 08/2010, Woods Hole, MA, USA
66. NCED Summer Institute, 08/2010, Minneapolis, MN, USA
67. Stratigraphy Tripod S2S ExxonMobil Meeting, 08/2010, Barcelona, Spain
68. CSDMS-EDF Cooperation meeting, 08/2010, Paris, France
69. CSDMS ExCom Teleconference, 09/2010, Boulder CO, USA
70. National CZO Meeting, 09/2010, Boulder, CO, USA
71. NSF RAPID oil spill modeling telecon, 09/2010, Boulder, CO, USA
72. Future Ocean Symposium:, 09/2010, Kiel, Germany
73. Storm Surges Congress, 09/2010, Hamburg, Germany
74. Geol. Soc. Landscapes Into Rock, 09/2010, London, UK
75. 18th International Sedimentological Congress, 09/2010, Mendoza, Argentina
76. CSDMS: Modeling for Environmental Change, 10/2010, San Antonio, TX, USA
77. CSDMS ExCom & SteerCom meeting, 10/2010, San Antonio, TX, USA
78. NSF RAPID oil spill modeling telecon, 11/2010, Boulder, CO, USA
79. CUAHSI HIS advisory committee meeting, 11/2010, DC, USA
80. Oceanography of Vietnam Workshop, 12/2010, Hai Phong, Vietnam
81. Intl. Summit on Integrated Environ. Modeling, 12/2010, Reston, VA, USA
82. NSF RAPID oil spill modeling telecon, 12/2010, Boulder, CO, USA
83. AGU fall meeting, 12/2010, San Francisco, CA, USA

84. Gilbert Club , 12/2010, UC Berkeley, CA, USA
85. AGU Chapman Conf. Source to Sink, Jan-11, Oxnard, CA
86. Community for Integrated Env. Modeling (CIEM), Jan-11, teleconferences
87. EPSCoR Climate IWG, Feb-11, McCall, Idaho
88. IASC Network for Arctic Glaciology, Feb-11, Winter Park, CO
89. WHOI Geodynamics Lecture, Feb-11, Woods Hole, MA
90. ONR Delta Meeting, Feb-11, Arlington, VA
91. IGBP SC Meeting, Feb-11, Washington, DC
92. Community for Integrated Env. Modeling (CIEM), Feb-11, teleconferences
93. IWMI Delta 2011: Deltas under climate change, Feb-11, Hanoi, Vietnam
94. Tulsa Geological Society Presentation, Mar-11, Tulsa, OK
95. CUAHSI CHyMP Meeting, Mar-11, Irvine, CA
96. 41st Arctic Workshop at Universite de Quebec, Mar-11, Montreal, Canada
97. CU Hydrological Symposium, Mar-11, Boulder, CO
98. Hydrologic Model Intercomparison Workshop, Mar-11, Golden, CO
99. BOEMRE teleconference, Mar-11,
100. European Geosciences Union (EGU), Apr-11, Vienna, Austria
101. Deltares OS Collaboration meeting, Apr-11, Delft, Netherlands
102. KORDI, KOPRI, KNU: CSDMS Modeling Course , Apr-11, Korea
103. Community for Integrated Env. Modeling (CIEM), Apr-11, teleconferences
104. Chesapeake FRG Mtg at SERC, May-11, Baltimore, MD
105. Lamont-Doherty Colloquium, May-11, Palisades, New York
106. British Geol. Society: The Anthropocene, May-11, London, UK
107. 11th International Coastal Symposium, May-11, Szczecin, Poland
108. CSDMS Executive Committee Meeting, May-11, Boulder, CO
109. BOEMRE Teleconference, May-11,
110. Geochemistry of the Earth Surface, Jun-11, Boulder, CO
111. DeltaNet: Impacts of Global change, Jun-11, Ainsa, Spain
112. Commodity Governance Meeting at NOAA, Jun-11, Boulder, CO
113. CCMP Hydrodynamic Model Wkshp (SERC), Jun-11, Edgewater, MD
114. BOEMRE teleconference, Jun-11,
115. CBP Modeling Quarterly Review Mtg, Jul-11, Annapolis, MD
116. BOEMRE Teleconference, Jul-11,
117. NCED Summer Course, Aug-11, Minneapolis, MN
118. IAHR River Coastal Estuarine Morphodynamics, Sep-11, Beijing, China
119. LOICZ Coastal Systems, Global Change and Sustainability, Sep, Yantai, China
120. CSDMS Annual Meeting: Impact of time and process scales, Oct-11Boulder
121. CSDMS Interagency Meeting, Nov-11, Arlington, VA
122. Chevron Integrated Modeling of Earth Surface Dynamics, Houston, TX, Jan-12
123. ConocoPhillips Integrated Modeling of Earth Surface Dynamics, Houston, TX, Jan-12
124. AGU Chapman Remote Sensing of the Terrestrial Water Cycle, Kona, HI, Feb-12
125. AGU Ocean Sciences Meeting, Salt Lake City, UT, Feb-12
126. Deltares Audit Committee, Delft, Netherlands, Feb-12
127. Second International Workshop on Global Flood, Delft, Netherlands, Mar-12
128. Planet Under Pressure Conference, London, UK, Mar-12
129. International Year of Deltas Strategic Mtg, London, UK, Mar-12
130. Shell London Lecture Series: Life at the edge: sinking deltas, London, UK, Mar-12
131. Integrated Environ Modeling: Lowering the Barriers, EPA Washington, Mar-12

132. IWRSS (Integrated Water Resources Sciences and Services) National Water Model Scoping Workshop, Chapel Hill, NC, Apr-12
133. Modeling Framework Overview meeting with ESMF, Boulder, CO, Apr-12
134. SOT/EPA Meeting, Theme E Telecon, Boulder, CO, Apr-12
135. AAPG Annual Meeting, Long Beach, CA, Apr-12
136. Delta Dynamics Collaboration FESD Meeting, Houston, TX, Apr-12
137. CSDMS Seminars: Korean (KORDI), Seoul-Ansan, Korea, Apr-12
138. BOEM Project Telecon, Boulder, CO, May-12
139. NSF EarthCube EAGER PI ESM Telecon, Boulder, CO, May-12
140. NSF EarthCube EAGER PI Telecon Layered Arch., Boulder, CO, May-12
141. Multi-Scale Integration Human Health & Environ Data, EPA Durham, NC, May-12
142. RGS: Harnessing Emerging Technologies for 2020, London, UK, May-12
143. Euro CSDMS Strategic Meeting, Egham, UK, May-12
144. NSF EarthCube Workflow Workshop, UCAR., Boulder, CO, May-12
145. Earth System Modeling Workshop, NSF EarthCube, Boulder, CO, May-12
146. SDS (Spatial Decision Support) project, Redlands, CA., May-12
147. CUAHSI Informatics Standing Committee meeting, Boulder, CO, May-12
148. NSF EarthCube 2nd Charrette meeting., Washington, DC, Jun-12
149. World Climate Research Program JSC, Beijing, China, Jul-12
150. IEEE Intl Geoscience $ Remote Sensing Symposium, Munich, Germany, Jul-12

CSDMS Annual Meeting 2010: Modeling for Environmental Change

The meeting in San Antonio, Texas – October 14-17, 2010 brought 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 (clinics on EKT products); and allow CSDMS Working and Focus Research Groups to strategize on the direction of CSDMS for the next 5 years (i.e., the CSDMS Strategic Plan and Renewal.) The meeting offered 14 keynote lectures, 4 clinics, 9 breakout sessions and more than 40 poster presentations.

CSDMS Annual Meeting 2011: Impact of Time and Process Scales

The second all hands meeting: "Impact of time and process scales" (10/28/2011 – 10/30/2011) was attended by 101 CSDMS members. The annual meeting offered 1) insights on time and space issues and how this is addressed in the software subtleties that is at the heart of all surface dynamic modeling efforts — whether landscape-evolution, morphodynamics or transport of material, 2) hands on clinics on a variety of models for beginners as well as advanced users, 3) hands on clinics on the use of the CSDMS component modeling tool and visualization software as well as for parallel programming, and 4) time for the Working Groups and Focus Research Groups to review their strategic plans. The meeting offered 20 keynote lectures, 12 clinics, 4 breakout sessions and more than 40 poster presentations.

CSDMS Short Courses (2007-2012)

1. Geological Nuclear Science, Wellington, New Zealand: Source to Sink Modeling, 2008, Syvitski (CSDMS)
2. NCED Summer Institute: Earth-surface dynamics Modeling, Minneapolis, 2009, Syvitski (CSDMS)
3. RCEM Earth-surface Modeling course, Santa Fe, Argentina 2009, Syvitski (CSDMS), Slingerland (Penn State) & Hutton (CSDMS)
4. Earth-Surface Dynamics Modeling, Christian-Albrechts Univ, Kiel, Germany, 2010, Syvitski (CSDMS)
5. Using the CSDMS Modeling Tool, San Antonio, 2010, Overeem (CSDMS)
6. New CSDMS Tools and Information for Code Contributors, San Antonio, 2010, Peckham (Peckham)
7. Introduction to Parallel Programming with MPI, San Antonio, 2010, Balaji (Argonne NL)

8. Parallel Programming with MPI and Alternate One-sided Programming Models, San Antonio, 2010, Balaji (Argonne NL)
9. Topoflow, Boulder, 2011, Peckham (CSDMS)
10. CEM Model, Boulder, 2011, Murray & Ashton (Duke University & WHOI)
11. Sedflux Model, Boulder, 2011, Hutton & Overeem (CSDMS IF)
12. Deriving Dynamic Earth System Models, Boulder, 2011, Slingerland (Penn State University)
13. CHILD, Boulder, 2011, Tucker, Gasparine & Lancester (University of Colorado, Tulane University & Oregon State University)
14. Delft3D, Boulder, 2011, Jagers & Edmonds (Deltares, The Netherlands & Boston College)
15. Cyclopath & CarboCAT, Boulder, 2011, Burgess (Royal Holloway University of London)
16. VisIt, Boulder, 2011, Pugmire (ORNL, Tennessee)
17. TauDEM, Boulder, 2011, Tarboton (Utah State University)
18. ROMS CSTMS, Boulder, 2011, Sherwood (USGS)
19. CMT, Boulder, 2011, Overeem (CSDMS IF)
20. HPCC, Boulder, 2011, Hauser (University of Colorado)
21. Source to Sink Modeling, Chungcheon Korea, 2011, Syvitski (CSDMS)
22. Earth-Surface Dynamics Modeling, Christian-Albrechts Univ, Kiel, 2012, Syvitski (CSDMS)

Integration Facility Presentations (2007-2012)

1. Ashton, A., Giosan, L., Kettner, A.J., Hutton, E.H.W., and Ibanez, C., 2011. Influence of wave angle distribution and sediment supply variation on plan-view delta morphology: application to the Ebro Delta, Spain. EGU, Vienna, Austria.
2. Ashton, A., Hutton, E.W.H., Kettner, A.J., Jerolmack, D., and Giosan, L. 2010. Doupling between coastline and fluvial dynamics. CSDMS conference, Modeling for Environmental change, San Antonio, Texas.
3. Bachman, S. and S.D. Peckham, 2008. Comparison of numerical approaches to a steady-state landscape equation, AGU Fall Meeting, San Francisco, CA.
4. Barnhart, K., Anderson, R.S., Overeem, I., Wobus, C., Clow, G, Urban, F., Stanton, T., 2010. Modeling the rate and style of Arctic coastal retreat along the Beaufort Sea, Alaska. AGU Annual fall meeting 2010, San Francisco, 12-18 December.
5. Barnhart, K.B., Anderson R.S., Overeem, I., Wobus, C., Clow, G., Urban F.E., Lewinter, A., Stanton, T.P. 2011. EP31A-0803. Modeling the rate and style of Arctic coastal retreat along the Beaufort Sea, Alaska, AGU Fall meeting, San Francisco, 2011
6. 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.
7. Brakenridge, G.R. and S.D. Peckham, 2010, Remote sensing-based flood mapping and flood hazard assessment in Haiti, Rebuilding for Resilience: How Science and Engineering Can Inform Haiti's Reconstruction, March 2010, University of Miami, FL.
8. Brakenridge, G.R., Kettner, A.J., Nghiem, S.V., de Groeve, T., Syvitski, J.P.M., 2010. Effects of Fluvial Morphology On Orbital Remote Sensing Measurements of River Discharge. Abstract H41K-02, 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.
9. 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.
10. Brommer, M.B., Weltje, G.J., Kettner, A.J., Trincardi, F., 2008. Source-to-sink analysis of the Northern Adriatic Basin over the past 19.000 years: data-model comparison using a mass balance approach. EGU meeting, Vienna, Austria, April 13-18.

11. Christoffersen, P, Heywood, K, Dowdeswell, J, Syvitski, JPM, Benham, TJ, Mugford, RI , Joughin, I, Luckman, A, 2008, Warm Atlantic water drives Greenland Ice Sheet discharge dynamics Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract: C31B-0501

12. Cohen, S., Brakenridge, G.R., Kettner, A.J., Syvitski, J.P.M., Fekete, B.Z., and de Groeve, T., 2012. Calibration of Orbital Microwave Measurements of River Discharge Using a Global Hydrology Model. American Geophysical Union (AGU) chapman, Kona, Hawaii, USA.

13. Cohen, S., Kettner, A.J., and Syvitski, J.P.M., 2011. Improved water discharge predictions in WBMsed, a Blobal riverine Sediment Flux model. CSDMS annual meeting, Boulder, CO, USA.

14. Cohen, S., Kettner, A.J., Syvitski, J.P.M., Fekete, B., 2011. Global riverine sediment flux predictions, the WBMsed v2.0 model. American Geophysical Union (AGU), San Francisco, California, USA.

15. Cohen, S., Kettner, A.J., Syvitski, J.P.M., 2010. Modeling global scale sediment flux, a new component in the spatially distributed Framework for Aquatic Modeling of Earth System (FrAMES). CSDMS conference, Modeling for Environmental change, San Antonio, Texas.

16. Cohen, S., Kettner, A.J., Syvitski, J.P.M., 2010. Modeling global scale sediment flux, a new component in the spatially distributed Framework for Aquatic Modeling of Earth System (FrAMES). Abstract H44C-01, 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.

17. Darmenova, K., Carbonari, K., Kettner, A.J., Apling, D., and Higgins, G.J., 2011. Assessment of Freshwater Availability in the Southwestern US under Changing Climate. American Geophysical Union (AGU), San Francisco, California, USA.

18. De Winter, I.L., Overeem, I., Storms, J.E.A., 2008. Sedimentary Architecture of a glacio-fluvial valley fill; West-Greenland Case-Study. 38th Arctic Workshop, Boulder, Colorado, USA, 5-7th of March 2008. Extended Abstract.

19. Donselaar, M.E., Overeem, I., 2010. Processes and Reservoir Architecture of Terminal Sheet Sandstone in a Low-Gradient Fluvial Setting: Integrated Outcrop, Subsurface and Numerical Forward Modeling Approach. AAPG 2010 Abstract Vol, New Orleans, LA.

20. Donselaar, M.E., Overeem, I., Reichwein, J.A., Visser, C.A., 2008. Reservoir potential of fluvial sheet sandstone, Ten Boer Claystone, Southern Permian Basin. AAPG Annual Convention and Exhibition, April 20-23 2008, San Antonio, TX, USA.

21. Donselaar, ME, Overeem, I. 2009. Gradual avulsion in the rock record: Outcrop example of the Huesca Fluvial Fan, Abstract for Fluvial Sedimentology meeting, Aberdeen 26-28th January 2009.

22. Donselaar, ME, Overeem, I. 2009. Reservoir Architecture modeling of the Ten Boer Claystone Member, Final Research Report for NAM-Shell, The Netherlands, February 2009.

23. Goodall, J. and S.D. Peckham, 2008. Component-based architectures for building community models, CUAHSI Biennial Colloquium on Hydrologic Science and Engineering, July, Boulder, CO.

24. Hannon, M. Syvitski, J.P.M., Kettner, A.J., 2008, Hydrologic Modeling of a Tropical River Delta by Applying Remote Sensing Data: the Niger Delta and its Distributaries. Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract: H53B-1050

25. Hannon, M.T., Kettner, A.J., Syvitski, J.P.M., and Overeem, I., 2011. Longitudinal profiles, Neotectonics, and Potential Bedload Transport. Hydrological Science symposium, Boulder CO., USA.

26. Hannon, MT, Syvitski, JPM, Kettner, AJ, 2009. Analyzing River Longitudinal Profiles Around the World. Eos Trans. AGU, 90(52), Fall Meet. Suppl., Abstract H11E-0866

27. Hudson, B., Overeem, I., McGrath, D., Rick, U., Syvitski, J., and Zettlermann, A., 2011. Sediment Plumes as proxy for melt on the Greenland Ice Sheet: Possible evidence for a long and intense 2010 melt season. Annual Arctic Workshop, Montreal, Canada.

28. Hutton, E W, Kettner, A J, Kubo, Y, Gomez, B, Syvitski, J P M, 2007, Simulating the effects of hyperpycnal events on the stratigraphy of Poverty Shelf, New Zealand. *Eos Trans. AGU, 88*(52), Fall Meet. Suppl., Abstract H41B-0503

29. Hutton, E.W.H. & J P M Syvitski, 2008, Modeling hydro-isostasy: Isostatic Flexure along the Global Coastlines Due to Sea-Level Rise and Fall, AAPG, San Antonio, April 20-23, 2008

30. Hutton, E.W.H., J.P.M. Syvitski & S.D. Peckham, 2009, Producing CSDMS-compliant Morphodynamic Code to Share with the RCEM Community. Rivers, Coastal Estuarine Morphodynamics, Santa Fe, Argentina.

31. Hutton, EWH, 2008, Comparing Model Coupling Systems: an Example. CSDMS Cyberinformatics and Numerics

Working Group meeting, Boulder, Colorado.

32. Kettner, A J, Syvitski, J P M, 2007, Fluvial responses to environmental perturbations since the Last Glacial Maximum. *Eos Trans. AGU, 88*(52), Fall Meet. Suppl., Abstract H21G-0820
33. Kettner, A.J. 2008. What can the CSDMS website mean for Education and Knowledge Transfer. Education and Knowledge Transfer Working Group startup meeting, Oct 10, 2008, Boulder, CO.
34. 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.
35. Kettner, A.J., and Brakenridge, G.R., 2011. Estimating time series of fluvial suspended sediment by applying remote sensing techniques. EGU, Vienna, Austria.
36. Kettner, A.J., Hannon, M., Hutton, E., Syvitski, J.P.M. 2007, Working towards a delta-base. Dynamics and Vulnerability of River Delta Systems – A GWSP/LOICZ/CSDMS Scoping Workshop, Sept. 26 - 28, 2007, Boulder, CO.
37. Kettner, A.J., Hannon, M.T., Syvitski, J.P.M. 2008. Exploring ways to share CSDMS model input / output. Google workshop, May 5-6 2008, Boulder, CO.
38. Kettner, A.J., B. Gomez, Syvitski, J P M, 2008, Human catalysts or climate change: will have a greater impact on the sediment load of the Waipaoa River in the 21st century? International Symposium on Sediment Dynamics in Changing Environments. Dec. 1-5, 2008, Christchurch, New Zealand.
39. 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.
40. Kettner, A.J., Overeem, I., Cohen, S., and Syvitski, J.P.M., 2011. Downscaling discharge variability: how well can daily flow characteristics be predicted based on lower resolution flow data? American Geophysical Union (AGU), San Francisco, California, USA.
41. 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.
42. Kettner, A.J., Syvitski, J.P.M., and Gomez, B., 2009. Coupling models to investigate the dispersal and accumulation of fluvial sediment delivered by the Waipaoa River, to Poverty Shelf, New Zealand over a 3000year period. Source S2S Integration and Synthesis Workshop Gisborne, New Zealand.
43. Kettner, A.J., Syvitski, J.P.M., Restrepo, J.D. 2008, Simulating Spatial Variability of Fluvial Sediment Fluxes Within the Magdalena Drainage Basin, Colombia, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract: H53C-1065,
44. Kettner, A.J., Syvitski, J.P.M., Vörösmarty, C., 2007, Evolution of the Po Delta, Italy. Dynamics and Vulnerability of River Delta Systems - A GWSP/LOICZ/CSDMS Scoping Workshop, Sept. 26 - 28, 2007, Boulder, CO.
45. Kettner, A.J., Xing, F., Ashton, A., Hannon, M., Ibanez, C., and Giosan, L., 2011. Unraveling the impact of humans versus climate on the morphological evolution of the Ebro Delta, Spain. EGU, Vienna, Austria.
46. Kettner, A.J., Xing, F., Ashton, A.D., December 2010. Are Human influences responsible for the existence and possible drowning of (parts of) the Ebro Delta, Spain? 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.
47. Kettner, AJ, B Gomez, Y Cui, Syvitski, JPM. 2009. Sensitivity of fluvial sediment flux to climate change in the 21st Century: Waipaoa River, New Zealand, Eos Trans. AGU, 90(52), Fall Meet. Suppl., Abstract U34B-07
48. 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
49. 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
50. Lutzmann, S., Kettner, A.J., 2010. Modeling Holocene discharge and sediment fluxes for the Rhine River. CSDMS conference, Modeling for Environmental change, San Antonio, Texas.
51. 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.
52. McGrath, D., K. Steffen and I. Overeem. 2009. "Sediment Plumes in Sondre Stromfjord, Greenland as a proxy for runoff from the Greenland Ice Sheet". Abstract for Copenhagen Climate Conference 'Climate Change:

Global Risks, Challenges and Decisions'. 10-12 March 2009, Copenhagen, Denmark.

53. Milliman, J.D., and Kettner, A.J., 2009. Recent Trends in Fluvial Discharge of Water and Sediment to the Black Sea CIESM International Workshop, Trabzon, Turkey.

54. Milliman, J.D., Ludwig, W., Kettner, A.J., Xu, K., 2010. Recent trends in fluvial discharge to the Black Sea *in* CIESM, 2010, Climate forcing and its impacts on the Black Sea marine biota. Nr. 39 in CIESM Workshop Monographs (F. Briand, Ed.), 152 pages, Monaco.

55. Murray, B., 2007. The Community Surface Dynamics Modeling System Initiative. Rivers, Coastal and Esturaine Morphodynamics, Twente Netherlands.

56. Murray, B., 2007. The Community Surface Dynamics Modeling System Initiative. CUAHSI Fall 2007 Regional Meeting Chicago, Il.

57. North, E.W., Z. Schlag, E.E. Adams, R. He, K.H. Hyun, C.R. Sherwood, R.P. Signell and S.D. Peckham (2010) Simulating the three-dimensional dispersal of aging oil with a Lagrangian approach, Abstract OS42A-07, 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.

58. Overeem, I, Briner, J P, Kettner, A J, Syvitski, J P M, 2007, River Response to Deglaciation: a Case-Study of Clyde Fjordhead, Baffin Island, Arctic Canada, *Eos Trans. AGU, 88*(52), Fall Meet. Suppl., Abstract C51C-07

59. Overeem, I, Syvitski, J P M, 2008, Changing sediment supply in Arctic river systems. International Symposium on Sediment Dynamics in Changing Environments. Dec. 1-5, 2008, Christchurch, New Zealand.

60. Overeem, I, Syvitski, J P M, 2008, The sediment supply in Arctic river systems. SEDIBUD workshop, September 9 - 13, 2008, Boulder, Colorado, USA.

61. Overeem, I, Syvitski, J.P.M., Kettner, A.J. 2008. Are Arctic Rivers Unique and Are They Changing? Extended Abstract.38th Arctic Workshop, Boulder, Colorado, USA, 5-7th of March 2008.

62. Overeem, I. 2008. CSDMS introduction to International Arctic Research Center, Fairbanks for 'Arctic System Modeling' Workshop to be held May 19-21, 2008, Boulder.

63. Overeem, I. and Donselaar, M.E., 2009. Outcrop Characteristics of a Gradual Avulsion, abstract for Annual Meeting American Association of Petroleum Geologists, Denver June 7th-10th, 2009.

64. Overeem, I. Wobus, C.W., Anderson, R.S., Clow, G.D., Urban, F.E., Stanton, T.P. EP43B-0658. Quantifying Sea-Ice Loss as a Driver of Arctic Coastal Erosion. AGU, 90(52), Fall Meet. Suppl., Abstract EP43B-0658.

65. Overeem, I., 2010, Controls of Delta Sedimentation; A Delicate Balance. Invited Keynote at Symposium on behalf of Prof. Kroonenberg, March 2010.

66. Overeem, I., 2010, Sea Ice Loss Induces Arctic Coastal Erosion. Program and Abstracts of the American Polar Society Meeting 2010, Institute of Arctic and Alpine research, Univ. of Colorado at Boulder.

67. Overeem, I., 2010. Arctic Coastal Erosion along the Beaufort Sea. Contribution to "A Science Plan for Regional Arctic System Modeling". In: Roberts et al., (eds.), 2010. A report by the Arctic Research Community for the National Science Foundation Office of Polar Programs.

68. Overeem, I., and co-authors, 2009. Sinking Deltas due to Human Activities. US Wetland Foundation, Washington DC, 4th November 2009.

69. Overeem, I., Anderson, R.S., Wobus, C., Matell, N., Urban, F., Clow, G., 2010. The impact of sea ice loss on wave dynamics and coastal erosion along the Arctic Coast. 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.

70. Overeem, I., Climatic Influences on Stratigraphy – Applications of Numerical Models. AAPG 2010, Abstract Vol, New Orleans, LA.

71. Overeem, I., McGrath, D., Steffen, K., 2009. Sediment Plumes as Indicators for Greenland Ice Sheet Melt. SEDIBUD October, 2009, Annual Meeting, Kingston, Canada.

72. Overeem, I., Syvitski, J., Kettner, A.J., Hutton, E., and Brakenridge, B., 2011. Sinking Deltas due to Human Activities, Invited talk for Tulsa Geological Society. In: AAPG Search and Discovery #70094.

73. 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

74. Overeem, I., Syvitski, J.P.M., 2010, Shifting Discharge Peaks in Arctic Rivers, 1977-2007, Geografiska Annaler 92: 285-296.

75. Overeem, I., Syvitski, J.P.M., and Kettner, A.J., 2012. Modeling Fluvial Floodplain Deposits (AAPG), Long Beach, CA, USA.

76. Overeem, I.; Hudson, B.; Berlin, M.; Mcgrath, D.; Syvitski, J.P.M.; and Mernild, S. 2011. Fjord sediment plumes

as indicators of west greenland ice sheet freshwater flux, Abstracts of the *AGU Chapman Conference on Source to Sink Systems around the world and through time.* Oxnard, CA, p. 55-56.

77. Peckham, S D, 2007, A Brief Introduction to the CSDMS Initiative, CUAHSI Fall 2007 Regional Meeting Boise, Idaho.
78. Peckham, S D, 2007, An Overview of Several Model Coupling Packages, June 14, 2007, CSDMS Web Address.
79. Peckham, S D, 2007, An Overview of Several Model Coupling Packages. CSDMS Terrestrial Working Group, U. California – Berkeley, Dec. 9, 2007.
80. Peckham, S D, Syvitski, J P M, 2007, Evaluation of Model Coupling Frameworks for Use by the Community Surface Dynamics Modeling System (CSDMS), *Eos Trans. AGU, 88*(52), Fall Meet. Suppl., Abstract H53C-1407.
81. Peckham, S D 2008, Advantages of the Common Component Architecture (CCA) for CSDMS. CSDMS Cyberinformatics and Numerics Working Group meeting, Fen 4-5, 2008, Boulder, Colorado.
82. Peckham, S., 2008, "Evaluation of model coupling frameworks for use by the Community Surface Dynamics Modeling System (CSDMS), Apr. 19-21, IGWMC "ModFlow and More" meeting, Colorado School of Mines, Golden, CO.
83. Peckham, S., 2008, A brief overview of model coupling frameworks, CSDMS Marine and Coastal Working Group Meeting, Orlando, FL.
84. Peckham, S., 2008, Advantages of using the Common Component Architecture (CCA) for the CSDMS project, CSDMS Cyberinformatics and Numerics Working Group Meeting, University of Colorado, Boulder, CO
85. Peckham, S., 2008, Community hydrologic modeling: Advantages of using the Common Component Architecture (CCA), Scoping Workshop on a Community Hydrologic Modeling Platform (CHyMP), National Academy of Sciences, Washington, DC.
86. Peckham, S., 2008, Community Surface Dynamics Modeling System overview and working group charge, NSF/EU Workshop on CUAHSI and OpenMI, Wallingford, UK.
87. Peckham, S., 2008, Evaluation of Model Coupling Frameworks for Use by the Community Surface Dynamics Modeling System (CSDMS). IGWMC (International Ground Water Modeling Center) meeting, Golden, Colorado, May 19-21, 2008.
88. Peckham, S., 2008, Overview and demonstration of the Community Surface Dynamics Modeling System, CSDMS Town Hall Meeting, AGU Fall Meeting, San Francisco, CA.
89. Peckham, S., 2008, Evaluation of model coupling frameworks for use by the Community Surface Dynamics Modeling System (CSDMS). Computational Methods in Water Resources, XVII International Conference, San Francisco, CA, July 8-12.
90. Peckham, S., 2008, Sediment transport in a changing Arctic: River plumes, longshore transport and coastal erosion, Arctic Change 2008 Meeting, Quebec City, Canada.
91. Peckham, S., 2008, The technology behind the Community Surface Dynamics Modeling System (CSDMS), CSDMS Education and Knowledge Transfer (EKT) Working Group Meeting, Boulder, CO.
92. Peckham, S., 2008, TopoFlow hydrologic model: A community project, Third IAG/AIG SEDIBUD Workshop: Sediment Budgets in Cold Environments, Mountain Research Station, University of Colorado, Boulder.
93. Peckham, S., 2008, Towards a system for high-performance, multi-language, component-based modeling, AGU Fall Meeting, San Francisco, CA.
94. Peckham, S., 2008, Update on CSDMS Adoption of CCA, CCA Winter Meeting, Boulder, CO.
95. Peckham, S., 2008, WebEx meeting and presentation to CUAHSI members about CCA and CSDMS, Wed., Feb. 6, 2008.
96. Peckham, S.D. 2010 A brief introduction to CSDMS, the Community Surface Dynamics Modeling System, EPSCoR Innovative Working Group meeting: "Identifying the most relevant spatial and temporal scales of climate change with respect to surface hydrologic processes, Valles Caldera National Preserve, New Mexico (May 25)
97. Peckham, S.D. 2010 A brief introduction to CSDMS, the Community Surface Dynamics Modeling System, University of Nevada, Reno, Guest lecture in course: Interdisciplinary modeling: Water-related issues and changing climate, NRES 730, sponsored by NSF/EPSCoR (July 28)

98. Peckham, S.D. 2010 Component-based hydrologic and landscape evolution models: Interoperability, standards and new algorithms, Eos Trans. Abstract H53H-07, 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.
99. Peckham, S.D. 2010 New tools and information for code contributors, Developer Clinic, CSDMS conference, Modeling for Environmental change, San Antonio, TX (Oct. 15)
100. Peckham, S.D. 2010 The Community Surface Dynamics Modeling System (CSDMS), 3rd Annual National CZO Meeting, Boulder, CO (Sept. 13)
101. Peckham, S.D. 2010 Towards landscape evolution models that run much faster, Landscapes into Rock, William Smith Meeting, Geological Society of London, London, UK. (Sept. 21-23)
102. Peckham, S.D. and Hutton, E.H., 2009, Componentizing, standardizing and visualizing: How CSDMS is building a new system for integrated modeling from open-source tools and standards, Eos Trans. AGU, 90(52), Fall Meet. Suppl., Abstract IN11A-1045.
103. Peckham, S.D. Hutton, E.W.H. and Syvitski, J.P.M. 2009. The CSDMS project and submission standards for model source code. Abstracts of the IAMG 2009 Meeting, August 23-29, 2009 Stanford, CA
104. Peckham, S.D., 2009, A brief overview of CSDMS, the Community Surface Dynamics Modeling System, presentation, University of Newcastle, July 6.
105. Peckham, S.D., 2009, A brief overview of CSDMS, the Community Surface Dynamics Modeling System, presentation, NCED Cyberseminar Series, Minneapolis, MN, April 8.
106. Peckham, S.D., 2009, A brief overview of CSDMS, the Community Surface Dynamics Modeling System, presentation, Tropical Hydrology Symposium, Smithsonian Tropical Research Institute (SRTI), Panama City, Panama, March 18.
107. Peckham, S.D., 2009, A new algorithm for creating DEMs with smooth elevation profiles, extended abstract, Proceedings of Geomorphometry 2009, Zurich, Switzerland, p. 34-37, R. Purves, S. Gruber, T. Hengl, R. Straumann (Eds).
108. Peckham, S.D., 2009, A relationship between plan and profile curvature in a fluvial landscape model, presentation, Morphometry, Glaciers and Landscapes: A Workshop in Honour of Dr. Ian S. Evans, Durham University, UK, September 6.
109. Peckham, S.D., 2009, A very brief discussion of the "Mass Flux Method", presentation, Tropical Hydrology Symposium, Smithsonian Tropical Research Institute (SRTI), Panama City, Panama, March 18.
110. Peckham, S.D., 2009, Analytic, steady-state solutions for fluvial landscape evolution models, presentation, Geomorphology 2009, 7th International Conference on Geomorphology (ANZIAG): Ancient Landscapes - Modern Perspectives, Melbourne, Australia, July 6-11.
111. Peckham, S.D., 2011. Component-based ocean modeling with the Community Surface Dynamics Modeling System (CSDMS), Chesapeake Bay Program (CBP) Modeling Quarterly Review Meeting, Annapolis, MD.
112. Peckham, S.D., 2011. Component-based ocean modeling with the Community Surface Dynamics Modeling System (CSDMS), Chesapeake Community Modeling Program (CCMP) Hydrodynamic Modeling Workshop, Smithsonian Environmental Research Center (SERC), Edgewater, MD.
113. Perillio, G, Picollo, C, Syvitski, JPM 2010. Delta geomorphology: is it in equilibrium with present day dynamic conditions? 18th International Sedimentological Congress, Mendoza Argentina.
114. Pyles, DR, Syvitski, JPM, Slatt, R., 2009, Applying the Concept of Grade to Basin-scale Stacking Patterns and Reservoir Architecture: An Outcrop Perspective. SEPM Workshop on Stratigraphic Evolution on Deep-Water Architecture, Mariarmen Alicon, Chile, Feb 22-29, 2009.
115. Rick, U., Abdalati, W., Berlin, M., Overeem, I., van den Broeke, M., 2010. Evidence for Substantial Englacial Retention of Surface Meltwater. 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.
116. Rick, U., Abdalati, W., Overeem, I., Berlin, M., and van den Broeke, M., 2011. Evidence for Substantial Englacial Retention of Surface Meltwater. IAG-workshop Mass balance of glaciers and icecaps, Presentation and abstract.
117. Slingerland, R., 2007, The Community Surface Dynamics Modeling System Initiative. NOPP Community Sediment Modeling System Meeting, Woods Hole Oceanographic Institute.
118. Storms, J.E.A. de Winter, I., Overeem, I., Drijkoningen, G.G., Bakker, M., Lykke-Andersen, H., 2010. Sediment infill characterization of Kangerlussuaq Fjord during the Holocene deglaciation. Oslo, International Polar Year Science Conference, Oslo, Norway, June 8-12, 2010.

119. Storms, J.E.A., de Winter, I., Overeem, I., Drijkoningen, G., Lykke-Anderson, H., Bakker, M., 2011, The Holocene sedimentary history of the Kangerlussuaq Fjord-valley fill, West Greenland. XVIII INQUA Congress, Bern, Switzerland.

120. Syvitski, J.P.M., 2007, Community Surface Dynamics Modeling System, CSDMS. Dynamics and Vulnerability of River Delta Systems - A GWSP/LOICZ/CSDMS Scoping Workshop, Sept. 26 - 28, 2007, Boulder, CO

121. Syvitski, J.P.M., 2007, Community Surface Dynamics Modeling System – a Working Group Overview. CSDMS Terrestrial Working Group, U. California – Berkeley, Dec. 9, 2007.

122. Syvitski, J.P.M., 2007, Community Surface Dynamics Modeling System – a Steering Committee Overview. CSDMS Steering Committee Annual Meeting, U. Colorado, Boulder, Dec. 17, 2007.

123. Syvitski, J.P.M., 2007, Community Surface Dynamics Modeling System, CSDMS. Idaho National Lab Visit to U. Colorado Boulder CO, Nov. 27, 2007.

124. Syvitski, J.P.M., 2007, Community Surface Dynamics Modeling System, Faculty Dept. Geological Sciences, U. Colorado Boulder CO, Nov. 27, 2007.

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Chapter 11: CSDMS Priorities and Management of Resources

Year 1 saw the CSDMS governance established; Committees and Working Groups populated; the Integration Facility set-up; communication systems for the community developed; outreach and coordination with US Federal Labs and Agencies, industry, and to the broader surface dynamic community; and the hosting of a variety of scientific Workshops.

Year 2 saw refinements in the CSDMS communication systems with greater community activity; establishment of a CSDMS Interagency Committee established; the Industry Consortium finalized; and outreach to the broader surface dynamic community continued through scientific Workshops and Meetings. The CSDMS high-performance computer was installed and launched as a community-open system, and further advances in the CSDMS cyber-infrastructure was achieved. Computer service costs spiked in Year 2 with the new CSDMS HPC coming on line. A software engineer hire helped with the Proof-of-concept Projects in Model Coupling.

Year 3 focused on advanced simulations through proof-of-concept projects where six models, written by six authors, in four computer languages, three different numerical grids, and two levels of granularity were coupled in an alpha-version of the CSDMS Modeling Tool *CMT*. Year 3 saw the hiring of new staff as the NSF cooperative agreement reached its first year of full funding.

Year 4 witnessed rapid growth and advances in community products, including: 1) revised web portal and services; 2) the first official release of the CSDMS model-coupling tool, CMT; 3) evermore models made into components within the CMT tool; 4) an alpha-version of the CSDMS Domain Architecture *SedGrid*; 5) new data handling abilities; 6) the first all-hands conference *Modeling for Environmental Change*; and 7) numerous pedagogically-tested educational modules, clinics, and courses.

In Year 5, CSDMS momentum accelerated with a 46% growth in membership, a 22% growth in models and components, a 41% growth in model code, a 66% growth in CSDMS HPCC users, and a 267% growth in visits to the CSDMS web resources. CSDMS became the "go to" site for models and CSDMS-related data and educational products including animations and images, modeling labs and lecture materials. CSDMS continued to organize, host or sponsor workshops, symposia and meetings, providing short courses and model clinics. The second all-hands annual conference *Impact of Time and Process Scales* was held in Boulder Colorado, that has since become the location for the CSDMS Annual Meeting.

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

CSDMS Revenue & Expenditures (2007-2012)

CSDMS received $4.7M from NSF during the period 2007 to 2012. CSDMS Integration Facility staff received significant additional ($3.8M) from other sources (Fig. 11.1). The largest portion of the income was in the form of salaries for the CSDMS staff and students, followed by indirect cost recovery by the University of Colorado for administering and supporting the Integration Facility (Fig. 11.2). The University returned a significant portion of these indirect costs in the form of salary support and by underwriting the CSDMS HPCC *Beach*.

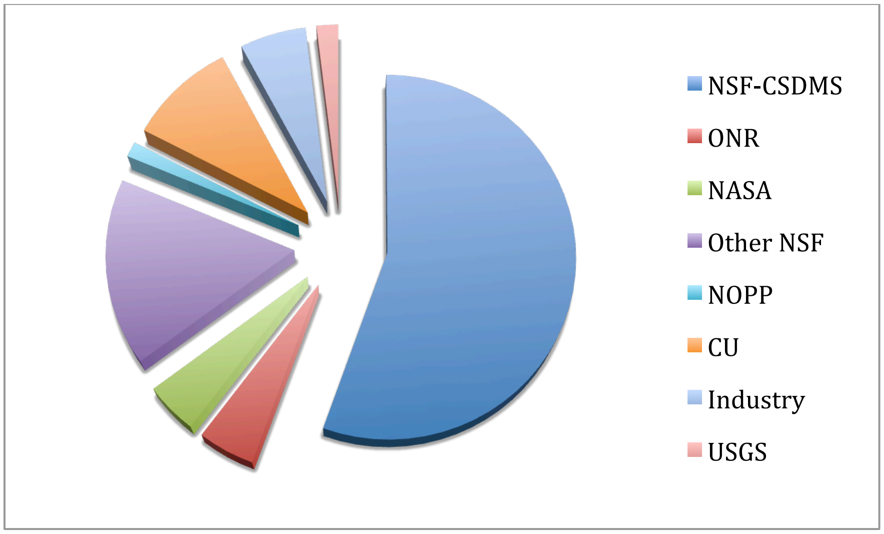

Fig. 11.1 Pie Chart of the 2007-2012 $8.5M funding received by CSDMS (all sources).

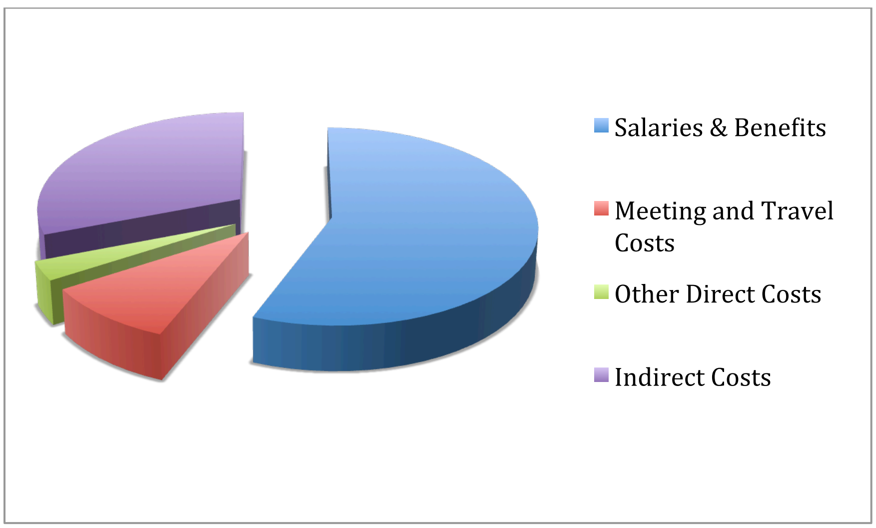

Fig. 11.2 Pie Chart of the CSDMS 2007-2012 expenditures (NSF-CSDMS sources).

Chapter 12: CSDMS Publications

Peer-reviewed papers, books & book chapters 2007-2012

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