CSDMS

COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

ANNUAL REPORT

JULY 2017

NSF COOPERATIVE AGREEMENT 0621695

Executive Summary

The Community Surface Dynamics Modeling System (CSDMS) is a NSF-supported, international and community-driven effort to transform the science and practice of earth-surface dynamics modeling. CSDMS integrates a diverse community of 1572 members that represent 204 U.S. institutions (140 academic, 32 private, 34 federal) and 360 non-U.S. institutions (244 academic, 34 private, 82 government) from 68 countries. CSDMS distributes 286 Open Source models and modeling tools, provides access to high performance computing clusters in support of developing and running these models, and offers a suite of products for education and knowledge transfer. The CSDMS architecture employs frameworks and services that convert stand-alone models into flexible "plug-and-play" components to be assembled into larger applications. CSDMS activities are supported through multiple NSF funding units. This report highlights CSDMS cyber infrastructure including the modeling tools PyMT and WMT, model development protocols and tools like the *Bakery* and the *Babelizer*, web portal developments, model uncertainty support services, and the CSDMS software stack distribution system. Reports from each of the six CSDMS Working Groups and seven Focus Research Groups are also provided. We outline recent achievements and plans towards implementing the CSDMS Strategic Plan. The theme for the 2017 annual meeting *"Modeling Coupled Earth and Human Systems: The Dynamic Duo"*, is highlighted throughout the report. This Annual Report covers the period from July 2016 through July 2017.

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1.0 CSDMS Mission and Community

1.1 Mission

The Community Surface Dynamics Modeling System (CSDMS) catalyzes new paradigms and practices in developing and employing software to understand the earth's surface — the ever-changing dynamic interface between lithosphere, hydrosphere, cryosphere, and atmosphere. CSDMS focuses on the movement of fluids and the sediment and solutes they transport through landscapes, seascapes and sedimentary basins. CSDMS models also include those that include ecosystem and human dimension interactions. 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.

1.2 CSDMS2.0 Science Questions and Community Functions

Some fundamental questions motivating CSDMS scientists:

1. How do transport processes interact with properties of morphology, geology, ecology, climatology, oceanography and human activities?
2. What processes support self-organization and pattern formation in surface systems?
3. How do material fluxes and surface evolution vary across time and space scales? How are these fluxes recorded in sedimentary deposits?
4. How are physical, ecological & human processes coupled within surface systems and constrained by Earth's interior and Earth's atmospheric dynamics?

To address these fundamental questions the Integration Facility supports 8 CSDMS2.0 community functions:

1. Capacity building and community networking;
2. Maintenance and enrichment of open-source repositories (Models, tools, data, education);
3. High perform computing cluster access and support;
4. Development and maintenance of education and knowledge products;
5. Maintenance or advancement of community protocols for model development and coding practice, along with a web-based GUI for to run standalone or coupled model simulations;
6. Community model reuse including model coupling through advanced architectures, language neutral compilers, and a component-based framework designed for plug and play model simulations;
7. Development of service tools in support of model benchmarking, model intercomparisons, and determining model skill and model-data uncertainties;
8. Develop and employ semantic mediation protocols and ontologies in aid in coupling data – model or model-model.

1.3 The CSDMS International Community

CSDMS is a growing international community. Members represent 520 institutions from 68 countries. Most members are based in the US (58%). Membership is growing at a steady rate (~150 members per year), with an increased growth rate in 2017 (Fig. 1.1). There are 1572 members as of July 2017.

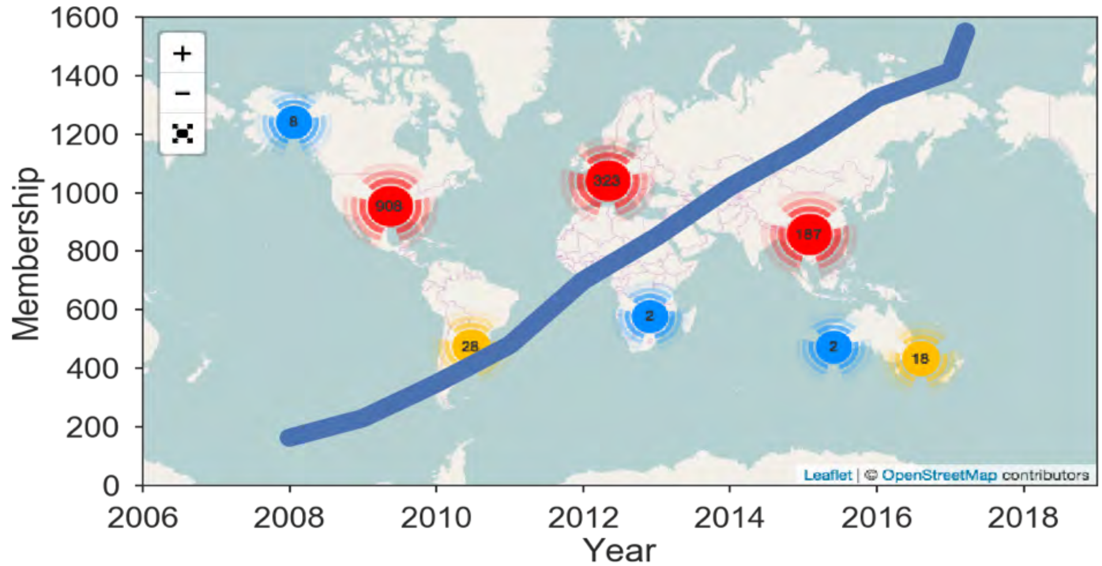


Figure 1.1. Growth of CSDMS membership superimposed on CSDMS member location. The community is strongly growing in 2017.

Members per country

1. United States (921)
2. China (84)
3. United Kingdom (76)
4. India (44)
5. Canada (44)
6. France (40)
7. Netherlands (38)
8. Italy (31)
9. Germany (30)
10. Spain (17)
11. Australia (14)
12. Indonesia (12)
13. Korea, South (12)
14. Brazil (12)
15. Bangladesh (11)
16. Norway (9)
17. Portugal (8)
18. Argentina (8)
19. Poland (8)
20. Pakistan (7)
21. Nigeria (7)
22. Chile (7)
23. Japan (7)
24. Belgium (7)
25. New Zealand (6)
26. Ireland (6)
27. Denmark (6)
28. Israel (5)
29. Greece (5)
30. Colombia (5)
31. Egypt (5)
32. Switzerland (5)
33. Sweden (5)
34. Vietnam (5)
35. Malaysia (4)
36. Russia (4)
37. Iran (4)
38. Romania (3)
39. Peru (3)
40. Hungary (3)
41. Turkey (3)
42. United Arab Emirates (2)
43. Philippines (2)
44. El Salvador (2)
45. Ghana (2)
46. Mexico (2)
47. Cuba (2)
48. Singapore (2)
49. Thailand (2)
50. Venezuela (2)
51. Uruguay (2)
52. Nepal (1)
53. Saudi Arabia (1)
54. Bulgaria (1)
55. Ecuador (1)
56. Bolivia (1)
57. Qatar (1)
58. Iraq (1)
59. Jordan (1)
60. Burma (1)
61. Kazakhstan (1)
62. Armenia (1)
63. Austria (1)
64. Algeria (1)
65. Kenya (1)
66. South Africa (1)
67. Morocco (1)
68. Cambodia (1)

1.4 New Institutional Memberships (since July 2016)

There are currently 1572 members representing 204 U.S. institutions (140 academic, 32 private, 34 federal) and 360 non-U.S. institutions (244 academic, 34 private, 82 government) from 68 countries (see appendix 1 for complete listing). Below are joining institutions since July 2016:

U.S. Academic Institutions:

- Kansas State University
- Montana State University
- Montclair State University, New Jersey
- University of Buffalo, New York
- University of Central Florida
- University of Denver, Colorado
- University of Illinois – Chicago, Illinois
- University of Kentucky

U.S. Federal labs, agencies, and NGOs

- Brookhaven National Laboratory (BNL)
- California Coastal Commission
- Global Facility for Disaster Reduction and Recovery
- Institute for Social and Environmental Transition
- Pacific Northwest National Laboratory (PNNL)
- Utah Geological Survey
- World Bank, Washington DC

U.S. private companies:

- Moffat & Nichol
- Raincoast Scientific
- Target Source

Foreign private companies:

- Dynamic Flow Technologies, UK

Foreign government agencies:

- Alfred Wegener Institute for Polar & Marine Research, Germany
- Israel Oceanographic & Limnological Research, Israel
- National Institute for Environmental Studies, Japan

Foreign academic institutes:

- Indian Institute of Science - Delhi
- Instituto Superior Technico, Portugal
- McMaster University, Canada
- Nanjing Normal University, Japan
- National University Columbia, Columbia
- NIIT University, India
- Niger Delta University, Nigeria
- North Maharashtra University, SSUPS Science College, India
- Prince Songkla University, Thailand
- Pune University, India
- Saint Francis Xavier University, Canada
- Tohoku University, Japan
- Ulster University, UK
- Universidad Austral de Chile, Chile
- Universidad Politecnica Catolica de Chile, Chile
- Universite de Toulouse, France
- Universite Grenoble Alps, France
- University of Nottingham, UK
- University of Saskatchewan, Canada

1.5 The CSDMS Steering Committee (SC) includes representatives of U.S. Federal agencies, industry, and academia:

- **Patricia Wiberg** (Sept. 2012-August 2017), Chair, U. Virginia, VA
- **Brad Murray** (Chair Elect starting August 2017), Duke U., Durham, NC
- **Tom Drake** (April 2007—), U.S. Office of Naval Research, Arlington, VA
- **Bert Jagers** (April 2007—), Deltares, Delft, The Netherlands
- **Marcelo Garcia** (Dec. 2012—), U. Illinois at Urbana-Champaign, IL
- **Chris Paola** (Sept. 2009—), NCED, U. Minnesota, Minneapolis, MN
- **Cecilia DeLuca** (Sept. 2009—), ESMF, NOAA/CIRES, Boulder, CO
- **Boyana Norris** (Sept. 2009—), U. Oregon, Eugene, OR
- **Guillermo Auad** (Jan. 2013—), Bureau of Ocean and Energy Management, Herndon, VA
- **Efi Foufoula-Georgiou** (March 2016—), U. California, Irvine, CA
- **David Mohrig** (March 2016—), U. Texas, Austin, TX
- **Jai Syvitski** (*ex-officio*), CSDMS, U. Colorado, Boulder, CO
- **Richard Yuretich** (*ex-officio),* National Science Foundation

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

1.6 The CSDMS Executive Committee (ExCom) is comprised of organizational chairpersons:

- **Jai Syvitski**, Chair ExCom & CSDMS Executive Director, INSTAAR, U. Colorado – Boulder
- **Greg Tucker** (Nov. 2015—) CSDMS Deputy Director, CIRES, U. Colorado – Boulder
- **Patricia Wiberg** (April 2012-August 2017) Chair CSDMS Steering Committee, U. Virginia, VA
- **Brad Murray** (August 2017—) Chair Elect CSDMS Steering Committee, Duke U., NC
- **Chris Sherwood** (Sept. 2014—) Chair CSDMS Interagency WG, USGS, Woods Hole, MA
- **Nicole Gasparini** (April 2016—) Chair Terrestrial WG, Tulane U., New Orleans, LA
- **Andrew Ashton** (August 2017—) Co-Chair Coastal WG & Coastal Vulnerability Initiative, Woods Hole Oceanographic Institution, Woods Hole, MA
- **Eli Lazarus** (August 2017—) Co-Chair Coastal WG & Coastal Vulnerability Initiative, U. Southampton, UK
- **Courtney Harris** (April 2012—) Chair Marine WG & Continental Margin Initiative, VIMS, VA
- **Tom Hsu** (Sept. 2015—) Co-Chair Cyberinformatics & Numerics WG, U. Delaware, Newark, DE
- **Scott Peckham** (April 2017—) Co-Chair Cyberinformatics & Numerics WG, U. Colorado – Boulder, CO
- **Wei Luo** (Sept. 2015—), Chair Education & Knowledge Transfer WG, N. Illinois U., Dekalb, IL
- **Brian Fath** (Nov. 2014—), Co-Chair Ecosystem Dynamics FRG, Towson U., Towson, MD & International Institute for Applied Systems Analysis, Laxenburg, Austria
- **Kim deMutsert** (August 2016—) Co-Chair Ecosystem Dynamics FRG, George Mason U., Fairfax, VA
- **Peter Burgess** (Sept. 2008—) Co-Chair Carbonate & Biogenics FRG, U. Liverpool, UK

- **Chris Jenkins** (Nov. 2015-) Co-Chair Carbonate & Biogenics FRG, U Colorado– Boulder, CO
- **Venkat Lakshmi** (Sept. 2015 —) Co-Chair Hydrology FRG, U. South Carolina, Columbia, SC
- **Mary Hill**, (March 2017—) Co-Chair Hydrology FRG, U. Kansas, Lawrence, KS
- **Raleigh Hood** (July 2014—) Chair Chesapeake FRG, U. of Maryland, Cambridge, MD
- **Alejandro Flores** (Oct. 2014—) Co-Chair Critical Zone FRG, Boise State U., ID
- **Michael Young** (July 2017—) Co-Chair Critical Zone FRG, U. Texas— Austin, TX
- **Mark Rounsevell** (Nov. 2014 —) Co-Chair Human Dimensions FRG, Karlsruhe Inst. Tech., Germany
- **Moira Zellner** (August 2016—) Co-Chair Human Dimensions FRG, U. Illinois— Chicago, IL
- **Phaedra Upton** (March 2013—) Co-Chair Geodynamics FRG, GNS, Lower Hutt, New Zealand
- **Mark Behn** (March 2013—) Co-Chair Geodynamics FRG, Woods Hole Oceanographic Inst., MA

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. The ExCom approves the business reports, management plan, budget, partner memberships, and other issues that arise in the running of CSDMS.

1.7 CSDMS Working and Focus Research Groups

Members are organized within 6 working groups (Terrestrial, Coastal, Marine, Education and Knowledge Transfer, Cyberinformatics and Numerics, Interagency) and 7 focus research groups (Human Dimensions, Carbonate & Biogenics, Hydrology, Critical Zone, Geodynamics, Chesapeake, and Ecosystem Dynamics).

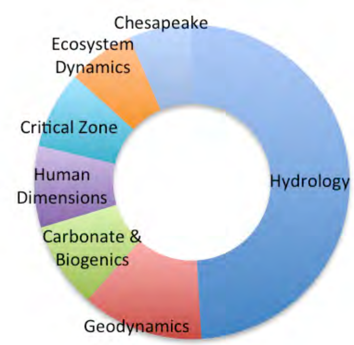


Figure 1.2. *(Left) Membership distribution per working group with EKT = Education and Knowledge Transfer group. (Right) Membership distribution per focus research group.*

Terrestrial	747	Geodynamics	150
Hydrology	590	Carbonate & Biogenics	106
Coastal	580	Human Dimensions	101
Marine	368	Critical Zone	96
Education	239	Ecosystem Dynamics	82
Cyber	223	Chesapeake	78

1.8 The CSDMS Integration Facility (IF)

CSDMS IF Staff: The Integration Facility maintains the CSDMS repositories and facilitates community communication and coordination, public relations, and product penetration. The Facility develops the CSDMS cyber-infrastructure, provides software guidance to the CSDMS community, maintains the CSDMS vision, and supports cooperation between observational and modeling communities. As of July 2017, CSDMS IF staff includes:

- Executive Director, Prof. Jai Syvitski (April, 2007-September 2017) CSDMS & CU support
- Executive Assistant, Lynn McCready (Dec. 2015 —) CSDMS support
- Senior Software Engineer, Dr. Eric Hutton (April 2007—) CSDMS support
- Software Engineer, Dr. Mark Piper (Oct. 2013—) CSDMS & other NASA support
- Cyber Scientist, Dr. Albert Kettner (July 2007—) CSDMS, other NSF, NASA & World Bank support
- EKT Scientist, Dr. Irina Overeem (Sept. 2007—) CSDMS, other NSF & NASA support
- Research Scientist, Dr. Kimberly Rogers (March 2012—) Other NSF support
- Research Associate, Dr. Mariela Perignon (June 2015 —) CSDMS & other NSF support
- Director, Flood Observatory, Dr. G Robert Brakenridge (Jan. 2010—) NASA & World Bank support
- Senior Research Scientist, Dr. Christopher Jenkins (Jan. 2009—) NSF & other support
- Systems Administrator, Chad Stoffel (April 2007—) Multiple grant support
- Accounting Technician, Chrystal Pochay (July 2013 – Feb. 2017) Multiple grant support
- Accounting Technician, Lindsay McCandless (March 2017—) Multiple grant support

Visiting Scientists and Scholars: Between July 2016 and July 2017, several scientists and scholars visited the CSDMS Integration Facility:

Date	Visitor
7/2016	Lejo Flores, Boise State University, ID
8/2016	Michael Barton, Arizona State University, AZ
8/2016	Dale Rothman, University of Denver, CO
8/2016	Juan Restrepo, EAFIT University, Medellin, Columbia
8/2016	Josh Tewksbury, Future Earth, US Secretariat, CO
8/2016	Dimitrios Stampoulis, JPL NASA, Pasadena, CA
8/2016	Ruangdech Poungprom, World Food Program, Bankok, Thailand
8/2016	Lara Prades, World Food Program, Rome, Italy
8/2016	Dan Slayback, NASA, Washington, D.C.
8/2016	Sarah Muir, World Food Program, Rome, Italy
8/2016	Amy Chong, World Food Program, Bankok, Thailand
8/2016	Andrea Amparore, World Food Program, Rome, Italy
9/2016	Mike Steckler, Lamont-Doherty Earth Observatory, NY
10/2016	Kathy Hibbard, NASA, PNNL, Richland, WA
10/2016	Andy Large, Newcastle University, UK
10/2016	Guy Schumann, Remote Sensing Solutions
3/2017	Jed Brown, CU, Boulder, Department of Computer Sciences
4/2017	Ben Livneh, CU, Boulder, Civil, Environmental and Arch. Engineering
5/2017	Michael Young, International Soil Modeling Consortium, U. Texas, Austin
6/2017	Megan Melamed, International Global Atmopheric Chemistry, CU, Boulder
6-11/2017	Lutz Schirrmeister, AWI, Potsdam, Germany
7/2017	Juan Restrepo, EAFIT University, Medellin, Columbia

2.0 CSDMS CSDMS Cyber Infrastructure

2.1 The CSDMS Modeling Framework

2.1.1 Model metadata standards

The CSDMS Model Metadata provides a detailed and formalized description of a model. This includes information about:

- Identifying information about the model. For example, model author(s), citations for the model, URL to the source code, etc.
- A description of the model API, if it has been wrapped with a Basic Model Interface. This includes how to build the model, depending on the language, and the include statements that are needed.
- A description of input file parameters. This includes default values, acceptable parameter ranges, and units.
- Template input files that contain special markup where parameters from the metadata parameter description can be placed.
- A description of how to run the model from the command line.

The CSDMS Model Metadata is extensible with new metadata additions expected. Current specifications minimally describe a model as being either standalone or one able to be coupled to another model(s). Whereas the BMI answers run-time queries of a model (e.g. the current time of a model simulation, the value of a particular output variable), the CSDMS Model Metadata provides a static description of a model. The Model Metadata, along with a BMI implementation, allows a model to automatically be incorporated as a component in the CSDMS Python Modeling Toolkit (PyMT).

Identifying information about the model, e.g.:

Sedflux3d is a basin filling stratigraphic model that simulates long-term marine sediment transport and accumulation into a three-dimensional basin over time, on scales of tens of thousands of years. It simulates the dynamics of strata formation of continental margins based on distribution of river plumes and tectonics.

url: http://csdms.colorado.edu/wiki/Model_help:Sedflux
author: Eric Hutton
email: eric.hutton@colorado.edu
version: "2.1"
license: MIT
doi: "10.1594/IEDA/100161"
cite_as:
    @article{hutton2008sedflux,
    title={Sedflux 2.0: An advanced process-response model that generates three-dimensional stratigraphy},
    author={Hutton, Eric WH and Syvitski, James PM},
    journal={Computers & Geosciences},
    volume={34},
    number={10},
    pages={1319--1337},
    year={2008},
    publisher={Pergamon}

Description of the model API, e.g.:

name: Sedflux3D
language: c
register: register_bmi_sedflux3d
includes: "#include <sedflux3d/bmi_sedflux3d.h>"
cflags: pkgconfig: sedflux3d
libs: pkgconfig: sedflux3d

Parameters Section, e.g.:

run_duration:
description: Total model run time
value: default: 36500.0
range:
min: 0.
max: 1.79769313486e+308
type: float
units: d
starting_sea_level_elevation:
description: Sea level at simulation start
value: default: 0.0
range:
max: 1000.0
min: -1000.0
type: float
units: m
ending_sea_level_elevation:
description: Sea level at simulation end
value: default: 0.0
range:
max: 1000.0
min: -1000.0
type: float
units: m

Run Section

How the model is to be run.

run: config_file: sedflux_3d_init.kvf

Template File

Template input files consist of a sample input file with placeholder for parameters to be filled in. A parameter placeholder is an identifier surrounded by curly braces where the identifier is one specified in the parameters metadata.

0., {starting_sea_level_elevation}
{run_duration}, {ending_sea_level_elevation}

2.1.2 Model Metadata Tools

The CSDMS model Metadata Python package provides tools for working with CSDMS Model Metadata. Contained within this package are tools for:

- Reading and parsing model metadata that follow the CSDMS Model Metadata Standards.
- Setting up model simulations either programmatically or through a command line interface. Although model metadata may describe models with different interfaces, the model metadata tools provide a common interface for staging simulations.
- Validating input parameter units, ranges, and type checking. If, for instance, a user provides an input value that is out of range, an error can be issued.
- Running simulations, which have already been staged, through a common interface.

These tools are currently used by:

- The Web Modeling Tool server to validate input parameters and stage model simulations.
- The CSDMS Execution Server and PyMT for running BMI-enabled models.
- Command Line utilities for querying model metadata, and staging model simulations.

The source code is available under the MIT license at GitHub at:

- https://github.com/csdms/model_metadata.

2.1.3 Upgrade to Babel 2.0

Babel provides the foundation for inter-language communication in the CSDMS Modeling Framework, and it is the core of the Babelizer (https://github.com/bmi-forum/babelizer), which transforms BMI-wrapped models into CSDMS components. With an upgrade from Babel 1.4 to Babel 2.0, the CSDMS IF software engineers can take advantage of new features such as language support for Fortran 2003.

2.1.4 Expanding Fortran support within the CSDMS Modeling Framework

In the spring of 2017, the CSDMS IF software engineers updated the Basic Model Interface (BMI) bindings for Fortran 90/95 and created a new set of fully object-oriented bindings for Fortran 2003.

Why two different Fortran BMIs? Though Fortran 90/95 has the concept of an interface, it doesn't allow procedures to be included within types. This is difficult to reconcile with BMI, which, in Fortran, would ideally be implemented as a collection of procedures in a type. Thus, the Fortran 90/95 BMI is set up as an example that a user can copy and modify, substituting their code for code in the example. This is somewhat cumbersome. The Fortran 2003 BMI implementation acts a true interface—it can be imported as a type from a module into a Fortran program and its methods overridden. The CSDMS IF software engineers recommend using the Fortran 2003 bindings; however support will continue for the Fortran-90/95 bindings for users in the CSDMS community who are not comfortable using the object-oriented features of Fortran 2003. Both BMI implementations are backward compatible with Fortran 77. All that is needed is a compiler that is capable of handling the more recent versions of Fortran; for example *gfortran* in the GNU Compiler Collection.

All code used to develop the Fortran BMIs is freely available on GitHub:

- Fortran 90/95 BMI: https://github.com/csdms/bmi-f90
- Fortran 2003 BMI: https://github.com/csdms/bmi-fortran

As always, the CSDMS IF software engineers welcome feedback—through, comments, issues, and pull requests—on the software that they develop for the community.

2.1.5 Expanding Java support within the CSDMS Modeling Framework

Allen Lee (Arizona State University) contributed a new build process for the Java BMI bindings. Allen replaced the existing ant-based build process with *maven*, and reorganized the code base according to the *maven* filesystem layout. Allen updated the instructions for building, installing, and testing the bindings. Once built, the bindings can be imported into any Java program and their methods overridden.

The code for the Java BMI bindings is available on GitHub:

- Java BMI: https://github.com/csdms/bmi-java

2.1.6 From Model to Component

To help describe and clarify the process of transforming a model provided by a community member into a CSDMS plug-and-play component, a flow diagram was created (Figure 2.1.1):

1. A model developer who has submitted their model to the CSDMS Model Repository employs instructions found on the CSDMS Portal (https://csdms.colorado.edu/wiki/BMI_Description) to add a BMI to their model, using the supported language of their choice (C, C++, Fortran, Java, or Python). If they implement a C or a Python BMI, they can use the BMI Tester to test their BMI. Note that the model and its BMI are separate; the model can still be run without its BMI.
2. Next, the model developer works with a CSDMS IF software engineer to add BMI metadata (see Section 2.1.1) for their model. This metadata helps describe the model within the CSDMS Modeling Framework.
3. The model and its metadata can now be run through the Babelizer (https://github.com/bmi-forum/babelizer) to create a Python-wrapped component. The Babelizer is built upon the CCA Toolchain, including *babel*, *cca-spec-babel*, *bocca*, and *ccaffeine*, and provides inter-language communication. The result of this step is a CSDMS component.
4. Binary versions of both the BMI-ed model and the Babelized component are built for Linux and macOS, and stored and distributed through the CSDMS Bakery, described in Section 2.4.1.
5. The Python Modeling Tool (PyMT, see Section 2.2), a Python package that provides services for coupling CSDMS components, provides the run environment.
6. The new component can be included in the CSDMS Web Modeling Tool (WMT, discussed in Section 2.3), which consists of an executor, a server, and a client (the user's web browser). PyMT forms the basis for the executor of the model coupling triad. Starting from the model's BMI metadata, a CSDMS IF software engineer seeks the input of the model developer to create WMT metadata, in order to ensure the component's parameters are organized, described, and displayed correctly in WMT.

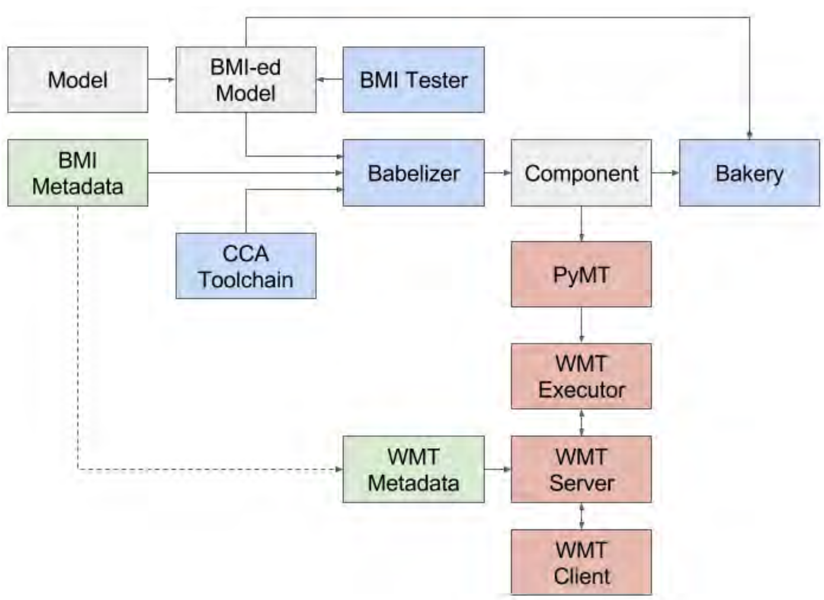


Figure 2.1. *A flow diagram describing steps taken to transform a model into a CSDMS plug-and-play component.*

2.1.7 Tracking stratigraphy: landlab.layers

The CSDMS IF has worked with the landlab team (NSF award number 1450412) to develop and add new data structures to *landlab* that track the deposition and erosion of heterogeneous sediment layers. Each layer tracks a range of user-defined sediment properties (e.g. porosity, bulk density, cohesion, age of deposition), as well as the distribution of multiple sediment types. Within *Landlab*, a sediment type is defined as sediment that is described by a particular set of sediment properties. These properties are similar to the bulk properties of a layer but describe the property for a homogeneous package of sediment.

landlab provides functions for calculating bulk sediment properties of layers from the distribution of grain types within that layer. A bulk property may be a simple weighted average of the properties of the constituent sediment types, or could be, say, a maximum or minimum value. For most properties we assume a layer is a linear mixture of sediment types such that the bulk property is a (weighted) sum of the individual properties. Future possibilities include calculating the bulk properties of well mixed layers whose bulk property is a non-linear combination of its components. Thus far, there are two implementations of layering. The first saves all layers for a simulation while the second averages layers to a user-specified vertical resolution.

A layer for every time step

In the case of non-binned layers, sediment layers are tracked at full resolution. That is, a layer is saved no matter how large or small it is and is saved at every grid cell - even where grid cells may see zero deposition. Although this provides a lossless record of the evolving stratigraphy, it can also be memory intensive since a layer is saved - over the entire grid - for every time step of the model.

The non-binned layer tracking procedure was designed for, and is being used by the NSF funded project, *Tectonics in the Western Anatolian Extension Province from sequence stratigraphic modeling of multichannel seismic data in the Gulf of Kusadasi* (NSF award number 1559098). As part of the modeling component of this award, a new model is being written using the landlab modeling toolkit that will track the evolution of the Gulf of Kusadasi and match existing seismic records.

Binned Layers

Because of the high memory overhead of the non-binned layer method, *landlab.layers* also implements a binned layer method. In this case, a user specifies a vertical resolution over which layers are combined. As sediment is deposited, the sediment is combined with the topmost layer in the sediment column until the combined layer reaches the user-specified resolution. After this point, a new bin is added to the top of the sediment column into which new sediment is added. This method may be in some cases computationally more expensive but can significantly reduce the amount of memory used by a model simulation.

RESTful Interface to landlab grids

The landlab team, in cooperation with the CSDMS IF, had designed a RESTful interface for landlab model grid data structures. The interface specifies a web interface for queries of the topology of modeling grids. For instance, a query could be made that gives the locations and connectivity of all the elements of a specified uniform rectilinear grid.

In conjunction with this interface, a web service was built, using the Python microframework *Flask* that exposes this interface. The web service is deployed as a docker image to be run either locally or in the cloud. Thus far, it has been deployed on the NSF funded XSEDE Jetstream service but most applications have been to run the service locally. The CSDMS IF will work with the landlab team to deploy the service on the main CSDMS web server.

2.2 The CSDMS Python Modeling Toolkit (PyMT)

2.2.2 Plugin framework for Python components

PyMT plugins are components that expose the CSDMS Basic Model Interface and provide CSDMS Model Metadata. With these two things, third-party components can be imported into the PyMT modeling framework.

By default PyMT searches a package named csdms, if it exists, for possible plugins that implement a BMI. The corresponding model metadata for each plugin is assumed to be located under share/csdms in a folder named for that plugin. This is the file structure that the CSDMS babelizer tool uses when wrapping models.

Although components written in Python can be processed with the babelizer to bring them into PyMT, this step should not be necessary as they are already written in Python with a BMI. For these models, plugins can be specified by a string that gives the fully qualified name of the module (in dotted notation) that contains the object followed by a colon and the name of the class that implements the BMI. For example,

pypkg.mymodule:MyPlugin

Standard plugins (those contained in the csdms package) are automatically loaded while other plugins are dynamically loaded with the pymt load_plugin function.

2.2.3 Enhanced PyMT interface to include model coupling tools

The initial release of the CSDMS PyMT focused mainly on the integration of BMI-enabled components, written in a variety of languages (C, C++, the Fortrans, Python, Java), into a single Python based framework (the PyMT) that is targeted to model developers. Since the initial release, the CSDMS IF has worked to incorporate of the CSDMS model-coupling tools into this framework in a way that is easy for developers to use. Of note are the following utilities:

- **Grid mapping:** CSDMS uses the grid mappers developed by the Earth System Modeling Framework (ESMF) for mapping values from one grid to another. The newest version of PyMT uses the latest (2017) release of the ESMF grid mappers as well as adding an easy to use interface that extends the familiar *set_value* interface of the BMI.
- **Time interpolator:** For models that are unable to run at a specified time step (for instance if the specified time step is not a multiple of a model's fixed time step), PyMT is able to linearly interpolate in time to the requested time. This is now done automatically without user intervention.
- **Unit conversion:** PyMT uses the cfunits package developed by Unidata to convert between units. As with grid mappers, the latest version of PyMT extends familiar BMI methods to specify what units to use. For example, the *get_value* method in PyMT now accepts a *units* keyword that a user can use if they require a value to be returned with particular units.

2.2.4 Incorporating model metadata into PyMT

PyMT uses the CSDMS model_metadata package, to incorporate CSDMS Model Metadata into BMI-enabled components when they are imported into PyMT. This ensures that:

- Identifying model information stays with the component as it appears within the CSDMS Modeling Framework. This ensures that the original author of the model is given appropriate credit and not forgotten in the wrapping of their model. In addition, a citation(s) is clearly displayed for the model. This ensures that a user running the model, either through PyMT or otherwise, will properly cite the original work that describes to model when publishing results that use the model.
- Model input parameters are validated and model input files are properly constructed when preparing a model simulation

2.3 The CSDMS Web Modeling Tool (WMT)

Version 1.1 of WMT, incorporating improvements to the client interface and server-side code, along with bug fixes, was released in September 2016. Information on this release is given on the CSDMS portal:

- WMT 1.1: http://csdms.colorado.edu/wiki/WMT_1.1_release

To build trust in the continued development and maintenance of WMT, the CSDMS IF will continue to issue yearly updates, including a scheduled WMT 1.1.1 release, containing bug fixes, in September 2017. WMT continues to be actively developed. Since the version 1.1 release in September 2016, there have been

- 66 commits to GitHub,
- 8 issues reported (6 of which have been resolved), and
- 36 files changed, with 1440 insertions (+) and 57 deletions (-).

WMT development is divided into five GitHub repositories:

- Database and data servers: https://github.com/csdms/wmt
- Execution server: https://github.com/csdms/wmt-exe
- Web client: https://github.com/csdms/wmt-client
- Metadata for components: https://github.com/csdms/wmt-metadata
- WMT landing page: https://github.com/csdms/wmt-selector

Each repository is completely open source software under the MIT License. The CSDMS community is encouraged to contribute to the development of WMT by forking and cloning its GitHub repositories, then sending pull requests with improvements back to the CSDMS IF.

A new WMT project, ***wmt-permafrost***, was created in spring 2017 under the affiliated Permafrost Modeling Toolkit and Permafrost Benchmarking System projects. It is currently populated with six components, with additional components under development. Access this new project through

- Main WMT site, https://csdms.colorado.edu/wmt, or
- https://csdms.colorado.edu/wmt-permafrost.

Irina Overeem used the **wmt-permafrost** project to teach a hands-on clinic at the 2017 CSDMS Annual Meeting. Other project in WMT, including the all-inclusive WMT –analysist and the ROMS project, have been used at the CSDMS Annual meeting, May 2017 and the NCED-Summer Institutes in both 2016 and 2017. WMT has been used in several other US-based universities in 2016-2017 in classes (generally at the graduate level, but including advanced undergraduate). Educational labs utilized included labs focused on sedimentary systems and stratigraphy (University of Florida), hydrology and landscape evolution (University of Utah, Logan), and coastal processes (University of Virginia and VIMS). The WMT serves as an introduction to certain models or components, and graduate students and postdoc run models occasionally first through WMT to then continue with downloading the source code and employing it for more detailed research.

2.4 Software Distribution Methods

CSDMS distributes its complete software stack as pre-compiled, ready-to-run binary packages (for Mac and Linux) distributed with the Anaconda package manager. Packages include:

- Community-contributed software,
- Externally developed dependencies, and
- CSDMS-developed software.

A complete list of the packages distributed by CSDMS can be found on the CSDMS channel of Anaconda Cloud (https://anaconda.org/csdms). CSDMS currently maintains a collection of over 50 packages built for both Linux and macOS operating systems. CSDMS also maintains both a stable and a development version of each package. The development version is updated whenever new changes are committed to its code base, while the stable versions are updated less frequently and correspond to software releases.

2.4.1 The CSDMS Bakery

The CSDMS IF has expanded the scope and size of its repository of distributed software. The CSDMS *Bakery* now includes not only recipes that describe how to build software packages but also how to build, test, and deploy these software packages on a regular basis ranging from once a day to once a month. In addition, the Bakery incorporates continuous integration so that software is also rebuilt, retested, and redeployed whenever changes are pushed to their corresponding repositories on GitHub.

- List of recipes in the CSDMS bakery: https://github.com/csdms/csdms-stack
- Build, test, deploy and model status: https://travis-ci.org/csdms-stack
- The conda package manager: https://github.com/conda

CSDMS will add new packages to the stack as more codes are submitted to the CSDMS repository. The current collection of packages is principally core packages required to run CSDMS software. However, packages that can run independently of CSDMS software are also included in the Bakery as a service to the community and to encourage model submission.

2.4.2 Docker

CSDMS maintains a GitHub repository of Dockerfiles (https://github.com/csdms/dockerfiles) used to build Docker images used by CSDMS. Dockerfiles contained in this repository fall into one or more of the following categories:

- They provide the basic tools used to build the CSDMS Software Stack. This includes particular versions of compilers (gcc, gfortran, etc.) and particular versions of operating systems.
- They provide images of the complete CSDMS Software Stack built (and tested) on various operating systems with a range of compilers.
- Images to be deployed that either run the CSDMS execution server, or the WMT server.
- General purpose images used by CSDMS or that the CSDMS community may find useful.

2.5 Deployment of CSDMS software stack to the cloud

CSDMS is exploring the moving of PyMT (as a set of web services) and WMT into the cloud. As part of this effort, the CSDMS has successfully deployed its software stack to the NSF-funded **XSEDE Jetstream** platform. This includes both the CSDMS execution server stack, as well as the server-side stack. Once operational, users will be able to access the WMT (and future PyMT web services) from Jetstream and then run their (possibly parallel) simulations in the cloud also on Jetstream or, as before, on dedicated high-performance clusters (such as CSDMS' *beach* cluster).

2.6 Automated Wrapping for Moving BMI Components into PyMT

The CSDMS IF continues to automate and simplify the building and wrapping of BMI-enabled components so that they are available from within the PyMT framework. Work in progress includes the creation of templates for the Fortran 90/95 and Fortran 2003 BMIs (see Section 2.1.4) that assist the *Babelizer* in making Python-wrapped components.

2.7 Automated BMI Generation

In support of increasing the ease with which developers can create BMI-enabled models, the CSDMS IF has created several examples that provide complete examples of Fortran code that developers can use to create their own BMI-enabled components. The new BMI examples include sample implementations for Fortran 90 and 95 (semi-Object Oriented) and 2003 (Object Oriented). These complement the previous collection of examples written in the other *babel*-supported languages.

The CSDMS IF has used these examples as part of clinics (such as that given at the 2017 CSDMS Annual Meeting), which are published online, that walk participants through the process of adding a BMI to their model; for example:

- BMI Live! (https://github.com/csdms/bmi-live-2017)
- BMI Tutorial (https://github.com/mcflugen/bmi-tutorial)

The CSDMS-IF has extended the BMI-Tester command-line tool, which checks a BMI implementation for conformance to the current BMI standards, to include a wider range of tests that more fully tests a BMI implementation. In addition, the BMI-Tester is now more integrated into the PyMT.

- bmi-tester on GitHub (https://github.com/csdms/bmi-tester)

2.8 New Components

The CSDMS IF continues to add models with a BMI to the CSDMS Modeling Framework. The following components either have been or will be added to the framework and made available in PyMT and/or WMT by the end of the current funding year.

- ***Compaction:*** Compact sediment layers, and corresponding porosity variations, following the method of Bahr et al. (2001) where the rate of compaction is proportional to the weight of the overlying sediment load (minus excess pore-water pressure). This compaction component is written in Python and makes use of the newly available landlab layers package.

- *CEM+:* The Coastline Evolution Model (or CEM) is a one-contour line model that focuses on sandy, wave-dominated shoreline evolution, simulates the plan-view evolution of a coastline due to gradients in alongshore sediment transport. A unique aspect of CEM, by dividing the plan-view domain into a 2-dimensional cell array, is its ability to process an arbitrarily sinuous shoreline, allowing the simulation of complex shoreline features including spits and capes. The model is exploratory in nature, designed to simulate large-scale (10^3 to 10^6 m) and long-term (10^2 to 10^5 yr) shoreline evolution. CEM+ is a new version of CEM, written from the ground up and BMI compliant that adds additional process as cliff rock erosion and barrier overwash.
- *Geombest:* GEOMBEST is a morphological-behaviour model that simulates the evolution of coastal morphology and stratigraphy resulting from changes in sea level and sediment volume within the shoreface, barrier, and estuary. Originally written in Matlab, the code could not be incorporated into the CSDMS Modeling Framework. However, the CSDMS IF has translated much of the code into Python. Once complete, GEOMBEST will be freely available using an Open Source language and be ready to be given a BMI and incorporated into PyMT.
- *WindWaves:* Calculate significant wave height and peak period using the JONSWAP wave spectrum method (Haseelmann et al., 1973) with gam = 33.
- *BottomWaveVelocity:* Calculate sea bottom orbital velocit and period from significant wave height and period using a parametric spectrum formulation (the user can choose between either Donelan or JONSWAP formulations).
- *BRaKE:* The Blocky River and Knickpoint Evolution Model (BRaKE) is a 1-D bedrock channel profile evolution model. It calculates bedrock erosion in addition to treating the delivery, transport, degradation, and erosion-inhibiting effects of large, hillslope-derived blocks of rock. It uses a shear-stress bedrock erosion formulation with additional complexity related to flow resistance, block transport and erosion, and delivery of blocks from the hillslopes.
- *AnugaSed:* ANUGA, developed by the Australian National University and Geosciences Australia, is an open-source Python package capable of simulating small-scale hydrological processes such as dam breaks, river flooding, storm surges, and tsunamis. Because of its modular structure, additional components have been incorporated into ANUGA that allow it to model suspended sediment transport and vegetation drag.
- *CRUAKTemp:* This component provides access to a netCDF file containing spatially resampled CRUNCEP monthly mean surface temperature fields for Alaska. It has been developed as a prototype for a BMI-enabled dataset in the CSDMS Modeling Framework.
- *KuGeoModel* and *FrostNumberGeoModel*: These components are extensions of the existing KuModel and FrostNumberModel that operate over a geographical area. FrostNumberGeoModel can be coupled with the CRUAKTemp component.
- *ILAMB:* The International Land Model Benchmarking (ILAMB) project is a model-data intercomparison and integration project designed to improve the performance of land models and, in parallel, improve the design of new measurement campaigns to reduce uncertainties associated with key land surface processes. ILAMB software can be used to quantitatively compare CMIP5-compatible model outputs with a set of benchmark datasets. Skill scores computed by ILAMB are returned in both tabular and graphical formats. Both ILAMB1.0 written in NCL, and LAMB2.0 completely rewritten in Python, have been componentized.

2.9 Analysis of Model Uncertainty

The CSDMS IF continues to develop a Python interface for Dakota, the CSDMS Dakota Interface, codenamed Dakotathon. The Dakotathon source code is MIT-licensed open source software, freely available on GitHub:

- Dakotathon: https://github.com/csdms/dakota

Dakotathon is currently tagged at version 0.3.1. Since the release of this software at the end of the 2016 fiscal year (version 0.2.3), there have been:

- 115 Commits
- 14 issues reported (9 of which have been resolved)
- 107 files changed, with 2506 insertions(+) and 1947 deletions(-)
- 8 pull requests (all have been merged)

Dakotathon is now a CSDMS component that can be called from PyMT in a WMT executor. For example, to perform a vector parameter study on Dakota's built-in sample Rosenbrock function using the Dakotathon BMI, the following code can be used:

```
from pymt.components import VectorParameterStudy
from dakotathon.utils import configure_parameters

d = VectorParameterStudy()

parameters = {'analysis_driver': 'rosenbrock', 'interface': 'direct',
'descriptors': ['x1', 'x2'], 'initial_point': [-0.3, 0.2],
'final_point': [1.1, 1.3], 'response_descriptors': 'y1'}

dparameters, _ = configure_parameters(parameters)
d.setup('.', **dparameters)

d.initialize('dakota.yaml')
d.update()
d.finalize()
```

The call to the BMI *initialize* method sets up the Dakota experiment, including writing a **dakota.in** file. The call to *update* runs the entire Dakota experiment. The *finalize* method cleans up any intermediate files produced by Dakota. The resulting **dakota.dat** file produced by this experiment contains the following output:

%eval_id	interface	x1	x2	y1
1	CSDMS	-0.3	0.2	2.9
2	CSDMS	-0.02	0.42	18.646816
3	CSDMS	0.26	0.64	33.311776
4	CSDMS	0.54	0.86	32.519456
5	CSDMS	0.82	1.08	16.646176
6	CSDMS	1.1	1.3	0.82

The Dakotathon repository on GitHub contains several other examples in the form of Python scripts and Jupyter Notebooks.

- Dakotathon examples: https://github.com/csdms/dakota/tree/master/examples

Dakotathon is strengthened by contributions from CSDMS member Katy Barnhart (University of Colorado Boulder) who added a new Dakota analysis method, Morris One-At-A-Time (MOAT), and code to make Dakotathon Python 3 compliant. Dakotathon was highlighted in an oral presentation at the 2016 AGU Fall Meeting:

- Abstract: https://agu.confex.com/agu/fm16/meetingapp.cgi/Paper/189887

2.10 Model Benchmarking and Model Inter-comparison

CSDMS-IF personnel, along with researchers from the National Snow and Ice Data Center and Los Alamos National Laboratory, are conducting benchmarking studies of permafrost models through a collaborative project, the Permafrost Benchmark System (PBS; NASA award 14-CMAC14-NNX16AB19G). Key to the PBS project is the use of software from the International Land Model Benchmarking (ILAMB) project. ILAMB project personnel have developed a modular and open source software tool that allows researchers to compare CMIP5-compatible model output with a set of benchmark datasets, focusing on variables such as gross primary production of carbon, precipitation, albedo, and soil moisture. Version 1 of the ILAMB software, though written in the NCAR Command Language (NCL), was wrapped with a Python BMI by the CSDMS IF software engineers and componentized. It can be accessed through the **wmt-permafrost** instance of WMT (see Section 2.3). Version 2 of the ILAMB software was completely rewritten in Python, and rolled out at the 2016 AGU Fall Meeting. The BMI for this version of ILAMB is under development, and will be completed by the end of the fiscal year.

Figure 2.2. *Mark Piper conducting a CSDMS Hackathon with Mariella Perignon.*

3.0 CSDMS Portal

3.1 Data Repository

CSDMS offers the community the ability to share data resources. A new web form allows contributors to easily describe a data source and include an external link to the actual data. Smaller datasets can be hosted on the CSDMS server as well. The table below list the 91 datasets described, per domain as of July 2017. http://csdms.colorado.edu/wiki/Data_download

Data type	Databases	Data type	Databases
Topography	23	Oceanography	12
Climate	7	River discharge	11
Cryosphere	5	Surface properties	8
Human dimensions	4	Sea level	1
Hydrography	8	Substrates	4
Land cover	8		

3.2 Data Organizations

CSDMS embraces the modeling challenge posed by the ongoing explosion of earth-surface data. To strengthen our bonds and enhance communications with the data community, CSDMS has joined the EarthCube Council of Data Facilities (https://earthcube.org/group/council-data-facilities). The CSDMS Model Repository is also now listed in the Coalition on Publishing Data in the Earth and Space Sciences (COPDESS) Directory of Repositories (https://copdessdirectory.osf.io/). We hope that by combining forces with these organizations, we will have the opportunity to deepen our understanding of the dynamics of our planet's surface by confronting models with data.

3.3 Wiki, Analytics, Maintenance

Integration of Knowledge management system (Semantic Web)
CSDMS has integrated knowledge management systems or Semantic Web into the main community web portal. Web data can be easily queried, shared and reused across applications, webpages, and other community sites. The backend of its CSDMS website uses the latest version of Mediawiki; the system relies on the knowledge management systems extensions 'Semantic MediaWiki (SMW)' and 'Cargo' to enable Semantic Web functionality. Additional Semantic Web functionality is guaranteed by the extensions: Semantic Internal Objects, Semantic result Formats, Page Forms, and Maps.

Five CSDMS repositories / databases are now converted to a Semantic Web structure: members, models, data and movie datasets, and model reference papers. For each of the repositories, a form is developed allowing members to fill in information by form-field. Once saved these form fields are displayed on an individual page just like a regular website, but they can also be queried; for example displaying how many members are located in each member country. This enriches the CSDMS website allowing data entered once to be used on multiple pages, and decreases the manual maintenance of webpages less of a burden. A good example is the model repository overview page (http://csdms.colorado.edu/wiki/Model_download_portal) that provides access to models of the various model domains to be populated automatically.

The CSDMS knowledge management systems (http://csdms.colorado.edu/mediawiki/api.php) allows querries and displaying of data by external websites and databases using RESTful API technology, allowing direct, high-level access to the data contained in MediaWiki databases.

Advantages of RESTful APIs are numerous, including data querries, including client programs able to log in to the wiki, get data, and post changes automatically by making HTTP requests to the CSDMS web service. Functionality includes:

1) Automatically enrichment of the website by determining the lat-long coordinates of new members based on city and country, which than can be imported and displayed on the membership map (http://csdms.colorado.edu/wiki/All_CSDMS_members_spatial);
2) Updating each model's *h-index* when new journal references are submitted (http://csdms.colorado.edu/wiki/CSDMS_models_by_numbers#Total_citations_and_H-index_for_Models_-_tools).

RESTful APIs allow other organizations to integrate CSDMS databases seamlessly into their own websites. Updates of datasets get automatically pushed to these additional sites. HydroShare (https://www.hydroshare.org) is currently query the CSDMS model database to display metadata of hydrological models into their website and are considering whether to use the CSDMS RESTful APIs.

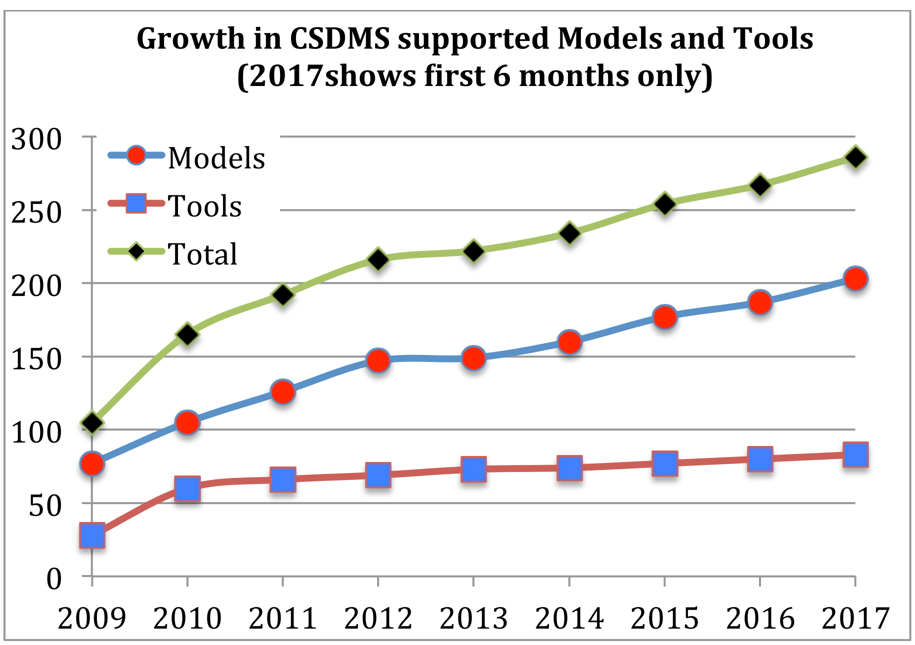
Visualizations of functions to enhance model metadata and transparency

CSDMS has integrated the 'Math' extension to support rendering of mathematical formulae. Markup languages (e.g. LaTeX) is supported on the CSDMS website to display equations, making it possible to display formulae in a readable format. For example a quadratic formula that is defined in LaTeX as: x=\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} will automatically be displayed in an internet browser as shown in figure 1. Key functions used in numerical models are thus easier to display in the CSDMS model questionnaire or model help pages and available within the CSDMS Web Modeling Tool (WMT) (e.g. http://csdms.colorado.edu/wiki/Model_help:Sedflux). All mathematical functions entered in the CSDMS web management system are delivered first as MathML output to the various browsers, with fallback to SVG or PNG images respectively.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

***Figure 3.1**. CSDMS web generated LaTeX function*

Figure 3.2. *Growth in the CSDMS Model Repository*



CSDMS uses RESTful API Mathoid services from the external party http://api.formulasearchengine.com/v1/?doc to render MathML or SVG formats, in part to reduce software maintenance costs. Disadvantages of using an external service is that availability is not guaranteed 24/7. CSDMS will soon invest in setting up its own Mathoid service if the formula search engine service proves unsatisfactory.

Extending the model reference system

CSDMS members and model developers may include model references within each model page on the CSDMS web portal. People can submit references to our model reference repository by filling out each required field, like authors, title, journal, year of publication, etc. Applying sementic web technology (described above), the CSDMS portal keeps a main reference repository but also populates on each model page with the publications that are associated with that model. Citations are added for each publication using the total number of citations per publication from google scholar. These get updated ~3 times a year. Based on the citations per publication, CSDMS generates automatically a citation h-index for models. Each publication that is added will be included in the model h-index within 24hours.

A new feature recently included is that references now simply can be added by providing minimal information of the reference: a Uniform Resource Locator (URL), a Digital Object Identifier (DOI), an International Standard Book Number (ISBN), a unique identifier number used in PubMed (PMID), or a PubMed Central reference number (PMCID). The CSDMS website will automatically connect to a public API endpoint provided by the Citoid project to retrieve all necessary fields like authors, title, year of publications, journal, etc., to properly cite a paper, and stores it locally in a database. The stored reference information is then linked back to the specified model or models. We assign a unique number that is used with each publication such that it is associated with google scholar after which we can retrieve automatically the number of citations per publication.

In the current configuration, each model page has now two entry points through which references can be submitted: 'Automatically enter Reference by DOI' and 'Manually enter Reference'. We kept the manual entry option as not all publishers offer a DOI or equivalent unique identifier needed to request reference information. When entering a reference, members must indicate if the publication is a model overview, or a model application, or a discussion of theory, and if the paper discusses one or multiple models. The Integration Facility does not have sufficient resources to enter all current references for each model and update as new publications come out but some attempt is made. We have included the 'Automatically enter Reference by DOI' option so model users and developers can enter references that they think are of interest for the community. The CHILD model page (http://csdms.colorado.edu/wiki/Model:CHILD#References) is an example of displaying CHILD model references.

CSDMS lists the calculated h-indexes for the models not only on the specific CSDMS model page, but also in a separated section of the CSDMS portal, named: CSDMS by the numbers. Here people can find among others the total citations per model as well as the h-index (http://csdms.colorado.edu/wiki/CSDMS_models_by_numbers#Total_citations_and_H-index_for_Models_-_tools). Note that it really depends on the completeness of publications that is submitted for a specific model to establish its accurate h-index. CSDMS reference repository holds as of July 5th 973 references and their associated citations. More information on how the model h-index is established can be found at: http://csdms.colorado.edu/wiki/Citations.

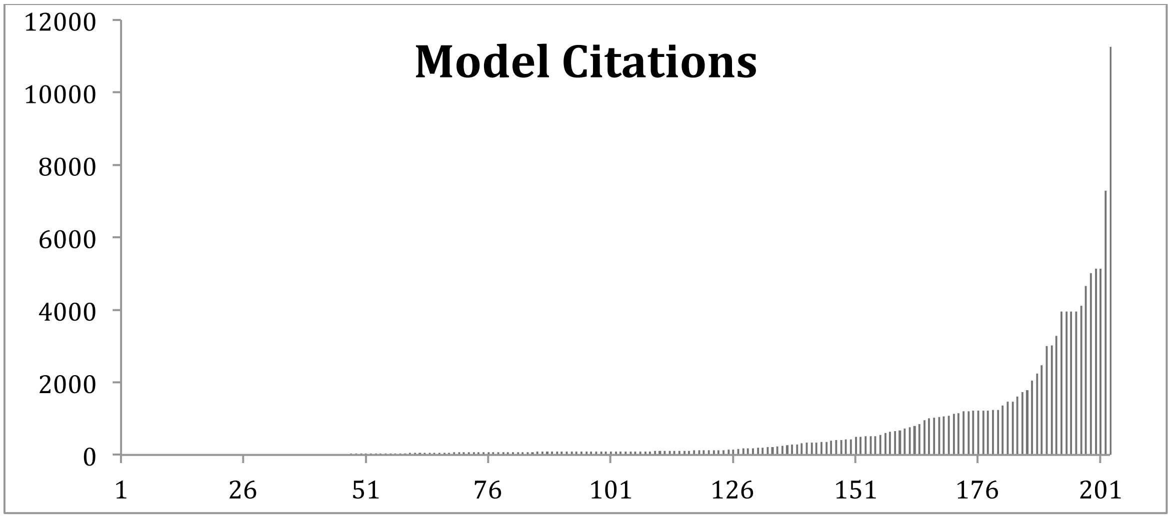


Figure 3.3. *Number of journal citations (y-axis) for each of CSDMS 203 registered models (x-axis). 46 models have each generated more than 1000 citations, 5 models have each generated more than 5000 citations.*

The CSDMS portal has a modernized look and feel

The CSDMS web portal is the main platform through which people get informed, learn, and use one or more IF or community developed techniques, tools and or standards. Web portals are like the world of fashion— they change over time to please visitors by keeping up with the latest functionality and change their look and feel over time. The CSDMS portal has been around for almost 10-years and has been updated significantly twice. These updates accommodate for intuitive web use, for computer and laptop users but also for smartphone and tablet devices. The Integration Facility has developed an entirely new frontend of the website to improve user experience and making the website more intuitive. The design process involved our team's technical, educational and logistics experts, working to guarantee that users in different focus areas are served by web functionality and available resources. Early design considerations have also been shared with the CSDMS EXCOM and we have solicited input from the community members as a whole with the objective of providing a web site useful to many members.

On the technological side, we upgraded the frontend to be based on the popular Bootstrap 3 software, while keeping all MySQL databases that allow for quantitative analysis, data manipulation, and advanced search functionality in place. The Bootstrap 3 frontend was modified and tested over Fall of 2016 before incorporating it on the CSDMS portal to guarantee a smooth transition in early 2017. To improve transparency, the new frontend has fewer main categories in the top menu bar but more intuitive menus for the community, as well as a more clear organization of what products and services CSDMS is offering. In response to community recommendations, we have set up a preliminary section that lays out for CSDMS members at what levels they can tap into CSDMS resources, how they can visit or receive letters of support, and how to more intensely collaborate through science projects. The education section, reachable through the main menu bar, will be further updated in the coming months applying semantic web technology.

CSDMS uses now its main landing page to inform the community with: highlights of the latest science of the community, giving the twitter feed a noticeable place on the web portal and by having a section included that discusses how the community can either contribute to or gain from the CSDMS community effort. Specific events, like the annual meeting that builds the CSDMS community are given a prominent place on the front page of the CSDMS portal as well.

Web portal maintenance and informing the community
CSDMS complies with the University of Colorado regulations for updating software packages to guarantee performance and minimize the security risk that comes with open access platforms. New upgrades of its core web portal software (MediaWiki) and its external party extensions have been installed. Web structures have also been adjusted to accommodate for changes in external party extensions.

To keep the CSDMS community up to date, the portal is used for: a) job opportunities related to numerical modeling positions for students and early to mid-career scientists and for opportunities in the private sector), and b) upcoming conferences, meetings and short courses. Developed web forms make it easy for community members to post their own advertisements or meetings when desired. The CSDMS annual meeting material is available through the web as well, including information for those who could not attend, including plenary presentations available through the CSDMS YouTube channel.

Web analytics
CSDMS portal
CSDMS has seen an increase in the number of people visiting the CSDMS portal that offers a combination of latest information on numerical modeling of surface dynamic systems and information from past meetings. The CSDMS portal relies on 'Google Analytics' software to monitor web traffic. Over the first half of 2017 the CSDMS portal alone was viewed on ~571 times per day (a 6% increase over the previous year). Since January 2010, the main CSDMS portal http://csdms.colorado.edu has received 1,228,352 views. Last year, 34% of web visitors were from the United States, followed by 28% and 3.9% from India and China respectively. Most users used a windows operating system (67%), but remarkably, 16% of the visitors visited the CSDMS website using an Android operating system (tablets and smartphones) and thus are tacking advantage of the new bootstrap frontend. For the 2010 – 2011 monitoring period, for comparison, 98.8% of the users used an operating system associated with laptops and PCs.

Most popular pages based on last year;s page views are the front web page (http://csdms.colorado.edu; 14%), the model repository page (http://csdms.colorado.edu/wiki/Model_download_portal; 2.7%), and the hydrological model domain website (2.3%). The job opportunity section accounted for 2.3% of page views, and the annual meeting registration page generated (1.7% of page views). 48% of last year's web views go to the top ten pages. The core open-source web portal software CSDMS uses makes it possible for all community members to participate, collaborate, modify content, and share models and tools, findings, events, educational material and more, by simply using a web browser. The software itself provides the capability to keep track of some basic statistics:

Content Pages	1,958
Total Pages	14,339
Upload Files	4,299
Total Page Edits	307,450

From September 2015 until August 2016, the community contributed 20% of web updates, the Integration facility made 44% of edits, and 36% were made by web bots that can modify text as a batch process on request by CSDMS-IF web super-users.

CSDMS YouTube channel
The CSDMS YouTube channel currently hosts 260 movies, distributed over the following 8 channels:

Channel	Number of movies
Annual meeting material	108
Terrestrial animations	36
Environmental animations	11
Coastal animations	39
Marine animations	14
Real events	35
CSDMS tutorials	5
Laboratory movies	12

Movies hosted on the CSDMS channel were visited last year 58,024 times (a 5.7% increase compared to prior year), a total of 50-days of continuing watching CSDMS content. The CSDMS YouTube movies are integrated into the CSDMS website, and can also be viewed through the CMSDS movie portal:

http://csdms.colorado.edu/wiki/Movies_portal

or through YouTube:

http://www.youtube.com/user/CSDMSmovie.

Last year, most visitors were from the United States (44%), followed by Denmark (9.7%) and the United Kingdom (6.5%). The top 5 movies: Global circulation (61%), Laurentide Ice Sheet (10%), Sand Ripples (4.4%), Modeling Coastal Sediment Transport (4.4%) and World dams since 1800 (2.3%). Movies were shared 287 times with other people, and 300 people subscribed to the CSDMS channel (a 20% increase over previous year). These view stats help orient the limited time available by Integration Facility staff.

Figure 3.4. *Nicole Gasparini conducting a Landlab Clinic at the 2017 CSDMS Annual Meeting.*

4.0 CSDMS Educational Mission

4.1 Educational Toolbox

The design for topical short courses in earth surface process modeling – in the quantitative toolbox- has been completed. Design decisions are evaluated in coordination with the CSDMS EKT working group and the ExCom. The design included a review of strategies of other main educational portals; i.e. large audience portals like Coursera and Khan academy, but mostly more domain-specific and academia targeted portals such as SERC and COMET.

Topics are the main organizing principle, a tiered approach allows for a learning progression from watching and questioning, to more actively running of models with WMT, to developing code. Lab material in addition is explicitly annotated to include the skills to be developed within the context of the lab. Skills are meant to empower learners with familiarizing themselves with common research problem solving tasks. CSDMS prioritizes certain common open-source practices and standards and the skill building is designed to emphasize these practices. As one example; even in simple model realizations we work with NetCDF files, a common HPCC modeling I/O file format.

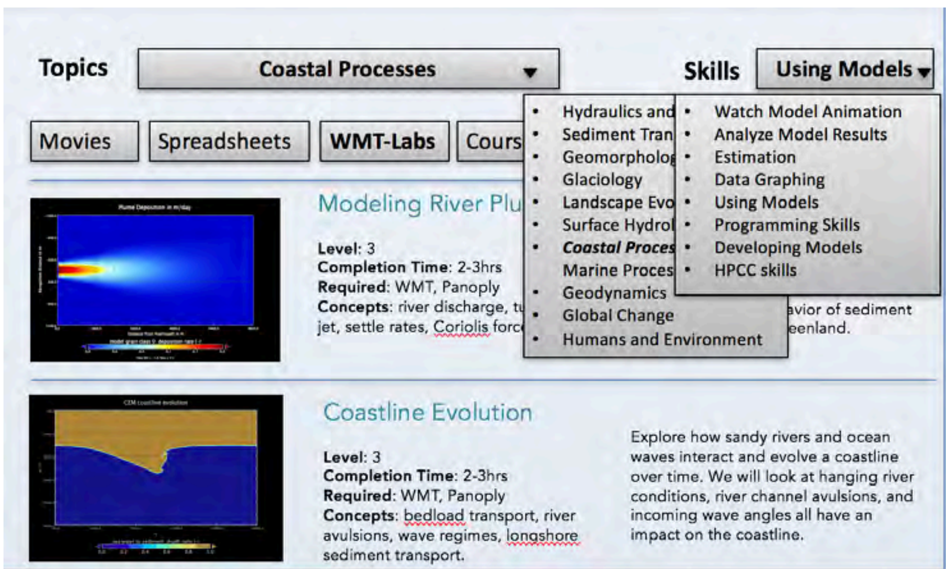


Figure 4.1. Example of designed prototype for mini-courses in the EKT repository

There are >100 lectures that have been presented as keynote talks during CSDMS Annual Meetings. These are all posted online, in the section on 'Past Meetings' but they have sofar not been systematically keyed for educational use. A more tight integration between the mini-courses and these state-of-the-art overviews is part of the recasting of the EKT material.

To better assess learning with modeling labs, CSDMS has adopted techniques from Martin et al., 2003; Libarkin and Stevenson, 2005; Arthur and Marchitto, 2011. These include concept inventories to determine beforehand what concepts students already know, and what concepts student are confused about or have not previously encountered. We designed the first concept inventory for the Regional Ocean Modeling (ROMS-Lite) WMT Labs. The assessment consists of 11 multiple choice questions as casted with VIMS faculty partners. These questions are both topical and fundamental (in this specific case they include continuity, velocity, momentum loss, units, plumes, waves, sediment settling, shear stress).

A PDF of survey is posted online with the lab for the instructor to use pre and post course. This concept inventory was used in collaboration with faculty volunteers at VIMS and University of Virginia with students, and will be improved/refined based on initial feedback. We plan to develop a web form: 'Take Our Quiz' (see the earlier design figure for the mini-courses).

4.2 Online Materials

The Educational Repository contains 145 model animations with documentation, more than 40 hands-on modeling labs with lecture notes and detailed notes for learners, lectures and reviews of several textbooks. New labs, as of the Summer 2017, include permafrost process modeling with several newly contributed components in the WMT. Focus is on predicting the occurrence of permafrost, understanding active layer dynamics, and coupling of climate data with permafrost thermal models. In addition, new labs focused on delta and river processes have been designed. These include a lab using the PyDelta-RCM – the Python reduced complexity model, and the floodwater river dynamics prediction model, ANUGA-SED. The latter will be tested in August 2017 with a cohort of ~30 students at the NCED-SIESD 2017, and will be made available online during that week.

The CSDMS community and EKT working group is interested in developing i-Python notebooks to foster the progression of students from model user to model developer. Work to redo the codes on coastal processes (originally by Bob Dalrymple as Java Applets) is underway during the summer of 2017. First prototypes of i-Python notebook exercises have been designed in parallel with the permafrost labs as well.

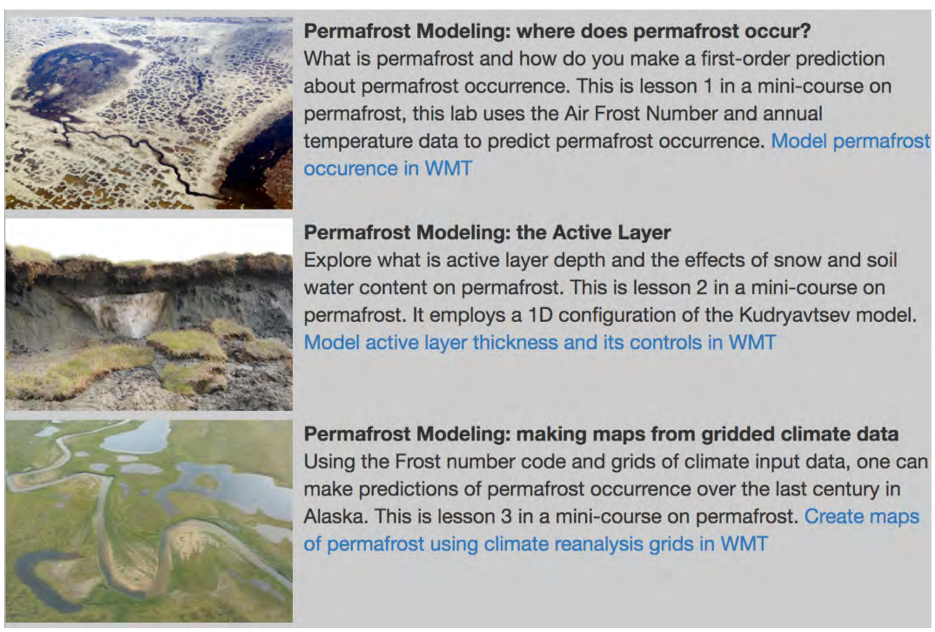


Figure 4.2. Mini-course on permafrost process modeling in Educational Repository

4.3 Science on a Sphere

CSDMS submissions to the Science on a Sphere are actively being displayed at museums and science discovery centers worldwide. The top hit of the CSDMS contributed datasets is the Wave Heights dataset, which has seen 9289 plays (since November 2015 submission). Not all submitted datasets are actively monitored; we report only on sites monitored by the SOS system. Timelines of the monitored datasets show most use of the datasets occurs in the initial months after submission, with clustered peaks of intense usage in the subsequent months.

Animation Name	No of Plays
Wave Heights 2012	9289
Dams and Reservoirs 1800-2010	8482
Wave Power, 2012	6839
Wave Heights during Hurricane Sandy	2288
Wave Heights during Hurricane Katrina	2189
Flood Events 2000-2009	1877
River Daily Discharge	1595
Dams and Reservoirs Mississippi	922
Dams and Reservoirs Yangtze	870

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

CSDMS EKT helps convene the NCED-SIESD 2017 with a jointly organized program and theme on *"Investigating scale in earth-surface systems to better inform predictions"*. CSDMS Integration Facility staff will participate in the National Center for Earth Dynamics Summer Institute (NCED-SIESD) over 10-day in August 2017. There will be two short courses offered to the course participants, which typically comprise graduate students and postdoctoral fellows from many universities across the US, and some from abroad. The short courses are targeted to both help students with building programming and data analysis skills for their own research. The 'Programming Bootcamp' is a 1-day immersion in modern programming skills with an introduction to a unix-based supercomputing environment, Python, and best practices for open source code development (GitHub). A more topical component of surface process modeling consists of modeling of coastal and deltaic processes with CSDMS coupled component and the Regional Ocean Modeling System. A demonstration of the use of sensitivity modeling with CSDMS capability of the use of Dakota Tools is designed to be of use for the participants own research projects.

4.5 Trainings (clinics, bootcamps, software carpentry)

CSDMS Integration Facility staff teaches two programming 1-day bootcamps every year; one associated with the Annual Meeting (May 2017), another one for participants of the NCED-Summer Institute at the University if Minnesota, August 2016/2017. These bootcamps are designed after the Software Carpentry principles, hands-on exercises on Unix shell scripting, Github software sharing practices, and basic Python programming. The audience of the bootcamps varies from students wanting to get first exposure to skills needed for their research, to advanced scientist and faculty who are seeking an update to their own traditional programming skills. For much more advanced modelers, a 1-day intensive skills clinic on High Performance Computing techniques was offered in conjunction with the Annual Meeting of CSDMS by Thomas Hauser of the University of Colorado Supercomputing Center.

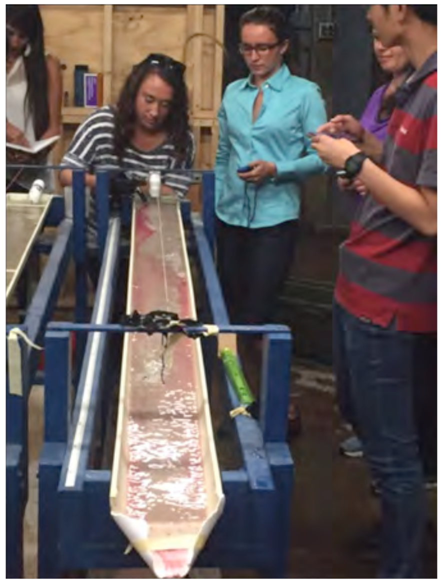


Figure 4.3. Experimenting and Modeling during NCED-SIESD 2016, photo Irina Overeem

In addition, community members and integration facility staff jointly present 2-hr clinics at the Annual Meeting. Twelve clinics were offered at the May 2017 meeting, a full list of these clinics is included in the Annual Meeting reporting section. The clinics cover individual models (e.g. Sister, ANUGA-Sed, Ecopath), best practices (e.g. Reproducibility), development of framework software (e.g. Landlab, Dakota and Perma-toolbox) and new technology (e.g. BMI Live).

We note that these clinics are well-received and well-evaluated by participants. As an example, the clinic on 'Bringing Models into the Classroom was attended by 89% academics and 11% government affiliates, with about 33% being at the stage of their career that they were actively teaching. Participants indicated their domains of study spanned all earth surface processes domains, and overwhelmingly responded that they expect to use the tools and learned skills.

All clinics, with one exception, received marks over 3.5 on a scale of 1-4 from participants. We have shared the evaluation results with the clinic leaders, and an overall summary survey is listed as an appendix to this report. In general, these clinics are perceived as a highlight of the CSDMS Annual meeting.

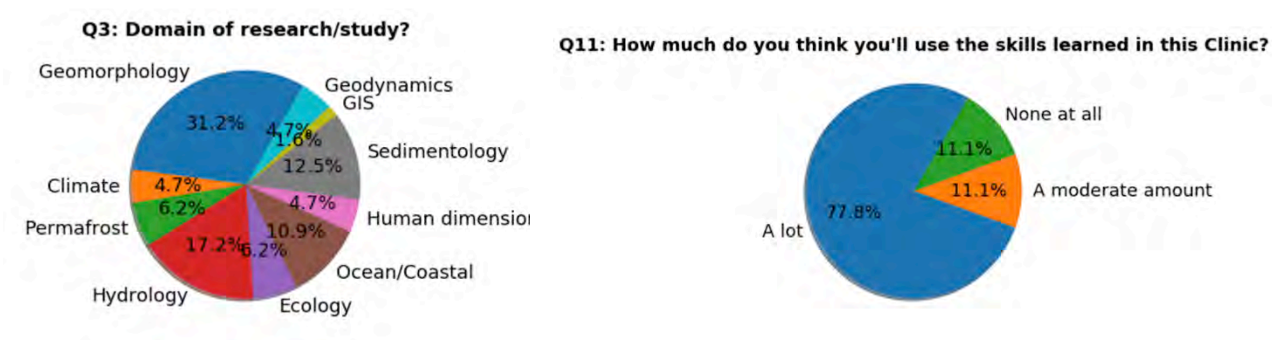


Figure 4.4. Evaluation results from one of the clinics at the Annual Meeting 2017

For the first time in 2017, CSDMS invited meeting participant to participate in a post-meeting 1-day Hackathon. The hackathon had participants bring their own codes and perhaps their initial attempts at wrapping the codes to become fully functional components, and to review their code with CSDMS software engineers (Eric Hutton and Mark Piper). The hackathon participants received pre-meeting instructions and were invited to share their codes beforehand, to allow for a more efficient interaction. The group attending may have been small, but this clinic appears to be a highly efficient way of boosting individual members' efforts to make use of CSDMS cyberinfrastructure tools for their own research objectives. Two to three newly completed components will likely result from this immersion class.

4.6 Student Modeler Award Winners

We received 19 submissions of students for the CSDMS Student Modeler Award 2017. For the first time in 2017, the selection committee requested and evaluated code submissions. We developed a new rubric which values code development, open source code availability, adherence to best practices, in addition to the science problems solved, scientific modeling strategy, and model complexity. We will publicize the rubric for the 2018 call for submissions. Submissions ranged over all disciplines; tectonics, terrestrial sediment transport, coral reefs, ecohydrology and more.

The Student Modeler Award winner for 2017 was Julia Moriarty. Her submission was titled: *"The Roles of Resuspension, Diffusion and Biogeochemical Processes on Oxygen Dynamics Offshore of the Rhone River, France"*. Her talk is posted: http://csdms.colorado.edu/wiki/CSDMS_2017_annual_meeting_Julia_Moriarty

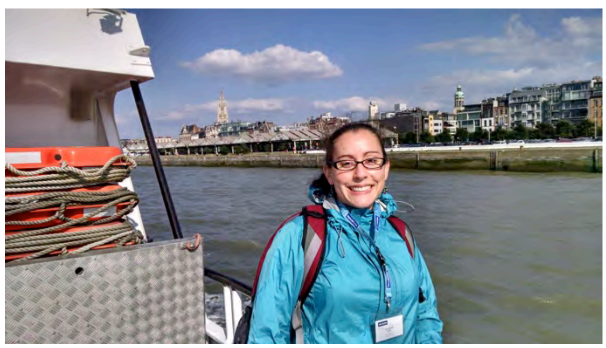


Figure 4.5. Julia Moriarity of VIMS, NC, received the Student Modeler Award 2017.

The annual meeting provides an opportunity for students to showcase their results more informally, and at an earlier stage of research. Every year, meeting participants vote on the best poster. The winner of the Best Poster Award 2017 was undergraduate student Nesha Wright, St Francis Xavier University, Canada "*Predicted changes in high temperature events over North America within CORDEX simulations"*.

4.7 Knowledge Transfer

The CSDMS team has intentionally sparked new connections to the Polar research community. CSDMS tools and cyberinfrastructure ideas have been presented at the US Department of Energy meeting for building cyberinfrastructure for environmental system science in April 2017. Other initiatives included teleconferences with the Permafrost Carbon Network, the Interagency Arctic Research Policy Committee (IARPC) and a keynote on CSDMS tools and services at the Forum for Arctic Modeling & Observational Synthesis (FAMOS) workshop, November 2016.

Most concretely, we presented the Web Model Tool and the development on 'PermaToolBox' at the International Permafrost Association, June 2016, Germany and more recently in Japan, July 2017. New CSDMS model components that are now online available include the 1D Frost model, the 2D Frost Model-GEO, the 1D and 2D Kudrayatsev model. This domain of Arctic surface process modeling has sparked the development of prototypes of a CSDMS data component; a dataset that can be coupled to CSDMS components. The example dataset is derived from the CRU climate data reanalysis for Alaska. The NSF Polar cyberinfrastructure award supports this targeted interaction with the permafrost field research community.

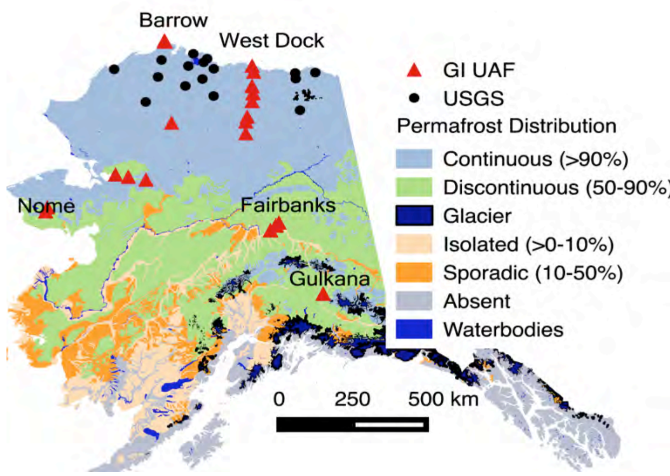


Figure 4.6. Overview map of a benchmark dataset of soil temperature in Alaska (Wang et al., in review).

In addition, the CSDMS web-modeling tool has been presented in a stakeholder workshop aimed at exploring interest of coastal managers in predictive tools. We presented 'WMT-Deltas' in a Stakeholder Workshop of Belmont Forum-DELTAS: "Catalyzing Action Towards Sustainability of Deltaic Systems with an Integrated Modeling Framework for Risk Assessment", Sept 12-16th, at CUNY, New York. This included presentation of the new CSDMS model component for reduced complexity modeling of deltas; PyDeltaRC. The component generated interest from Bangladesh engineers and Water Development Board officials as a tool to assess the effects of sediment nourishing in tidal polders. This resulted in a small research effort in collaboration with the University of Texas, Austin for 2017-2018.

A new CSDMS data component; Indian Rivers Linkages data is presented in the CSDMS data repository and has been shared with stakeholders in India and Bangladesh. A paper analyzing, documenting the data and code is in review in a CSDMS-led Special Issue on 'Deltas in the Antropocene' is currently being worked on with Elementa (a collection of 8 manuscripts are in advanced stages of revision).

4.8 Diversity Efforts

Diversity at the CSDMS Annual Meeting

CSDMS has sofar not recorded data on diversity from their members, or from meeting attendees, a deliberate decision stemming from the fact that member profiles and meeting registration are generated through our wiki web platform. A wiki is editable by community members, and by definition is a totally open web environment, this suits the CSDMS efforts that rely on community input and editing of web resources and documents. However, it would mean that any sensitive information on members personal diversity metrics is not fully protected and thus it has not been deemed appropriate to collect this data.

However CSDMS does have as its objective to build and leverage a diverse and inclusive community of earth surface process modelers. As we stated before, women and minorities are traditionally underrepresented in the STEM sciences, and form between 17-23% in the Geophysical Sciences (Rhodes, 2010; NSF Advisory Committee for Geosciences, 2014). We speculate that these numbers are likely even lower in the field of earth surface process modeling with emphasis on modeling and the analysis of "big data," and increasingly high performance computing.

CSDMS features a significantly higher representation of women in meeting attendees than the average published representation of women in the Geophysical Sciences. At our CSDMS Annual Meeting 2017, 34% of attendees were women, including women scientists at all career levels: students, PDF's, assistant professors, and full professors or senior scientists.

Annual Meeting Attendees

- 98-male
- 50-female
- 2-non binary

Academic: 120

- 49-graduate students
- 12-post-doctoral fellows
- 12-assistant professors
- 32-associate to full professors
- 11-research scientists

Non-academic institutions: 30

- 17-Government Agency
- 3-Industry
- 9-Non-profit Research
- 1-Other

Engaging a diverse student population in the CSDMS Annual Meeting

CSDMS has reached out through platforms aimed at non-traditional students to encourage students from all walks of life to participate in the CSDMS Annual Meetings. In 2017, CSDMS has awarded 5 student scholarships to underrepresented students with the explicit goal to increase diversity in the field of surface dynamics modeling. We explicitly call for students to submit applications for a stipend and send these announcements to mailing lists explicitly targeting minority students across the US.

We have posted announcements on the annual student scholarship through the regular email servers, but explicitly to gateways typically used by underrepresented students to become familiar with targeted opportunities in the STEM sciences. These included:

1) NSF Alliances for Graduate Education and the Professoriate (AGEP), Institute for Broadening participation, its mission is: "*to increase diversity in the Science, Technology, Engineering and Mathematics (STEM) workforce. We design and implement strategies to increase access to STEM education, funding, and careers, with special emphasis on reaching underserved communities and diverse underrepresented groups.* ***www.PathwaysToScience.org*** *makes it easy for faculty and administrators to access resources that can assist them in their efforts to reduce barriers to participation, create environments rich in the positive factors that support student success on the STEM pathway, and conduct outreach to underserved communities and underrepresented groups*

by implementing recruitment and retention strategies that broaden participation and increase diversity." In 2017, CSDMS became an official sponsoring member of the institute of Broadening Participation.
http://www.pathwaystoscience.org/index.aspx

2) AGEP listserv, especially for underrepresented groups at CU Boulder

3) UNAVCO RESESS and UCAR SOARS program lists.

We also distribute this information to faculty having a strong involvement with minority communities in our community, requesting them to personally invite students from their outreach programs. Stipends allowed these students to attend the entire annual meeting 2017, and present on their research.

Diversity and representation in CSDMS leadership

Bell and Karsten (2004) found that of all employed PhD in the geosciences only 13% were women, whereas this study is now a decade old, and representation may have improved over the last 10 years to 17-23% (Rhodes, 2010), it is likely still a valid estimate for women scientists in a career stage where they are called upon for leadership roles. Many of the CSDMS Working Groups and Focus Research Group chairs, and thus its executive committee are women (with new chairs and co-chairs of 2017, we are now at 37%), and we have a diverse group of chairs as well. The CSDMS steering committee is chaired by and features 33% women. Overall, a broad participation of scientists and students from underrepresented groups remains a priority, but we have informally received comments from faculty about playing an important role in identifying role models for the new generation of earth surface process modelers.

NSF Advisory Committee for Geosciences 2014. Dynamic Earth: GEO Imperatives & Frontiers 2015–2020
Bell, R., Karsten, K., 2004. Righting the Balance: Gender Diversity in the Geosciences ADVANCE library Paper 47.
Rhodes, D.D., 2010. Changes in the demographic characteristics of AGU membership 2006-2010. AGU Fall Meeting 2010, abstract #ED31B-0666.

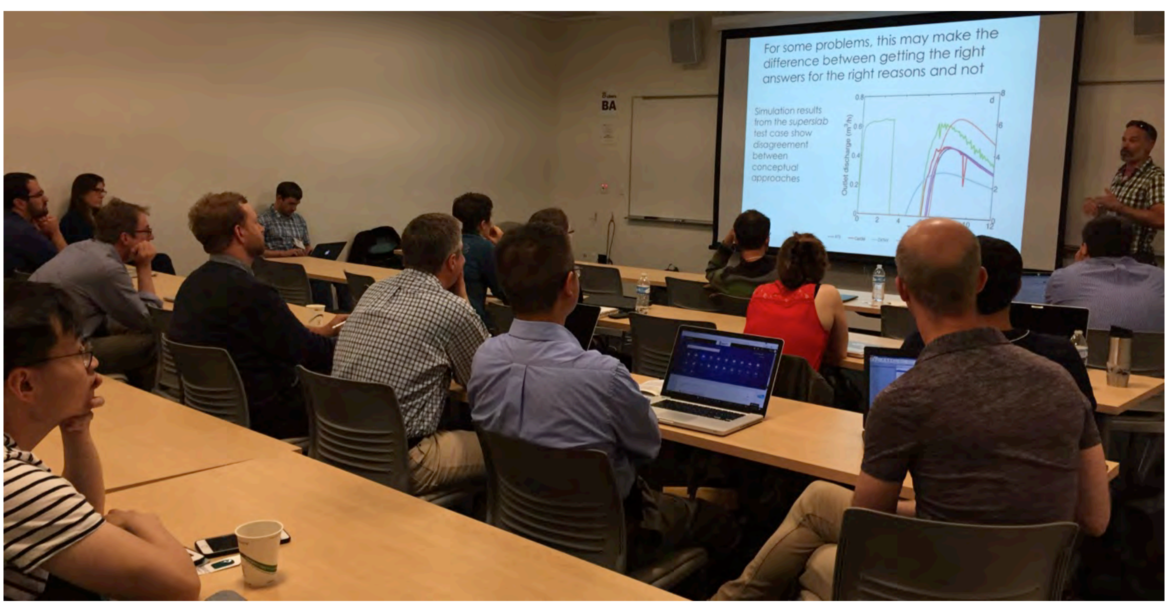


Figure 4.7. Clinic instructor Reed Maxwell offering thoughts on Parflow at the 2017 Annual Meeting

5.0 CSDMS Open-Access Software Repository

The CSDMS Model Repository is the place to get more information about the various surface dynamics models and to locate open-source models, modeling tools, and plug-and-play components. About 32% of all models and 82% of all tools are distributed through a central repository hosted at GitHub (https://github.com/csdms-contrib); others are distributed through linkages to existing community efforts. The centralized model repository at GitHub makes source code version control, contributions, sharing, down loading and managing individual code repositories easier with more control for the code developer. GitHub does not allow for tracking number of source code downloads anymore, so those numbers are not presented. The table below reports on the total number of source code projects (285) per domain. Notice that one model or tool project could be in multiple domains.

Models, Tools and WMT components by Environmental Domain
http://csdms.colorado.edu/wiki/CSDMS_models_by_numbers#Models.2C_tools_and_components_per_domain

Domain	Models	Tools	Components
Terrestrial	85	75	6
Coastal	62	7	7
Marine	51	7	4
Hydrology	65	46	20
Geodynamic	13	1	1
Carbonates & Biogenics	3	4	1
Climate	12	4	2

Sixteen new models have been submitted to the CSDMS repository over the last year and source code can be found on the CSDMS github site or is made available through external sites. See also: http://csdms.colorado.edu/wiki/Model_download_portal. CSDMS has >200 models described on the community portal. The new models and tools are:

Model	Description	Developer
AeoLiS	AeoLiS is a process-based model for simulating aeolian sediment transport in situations where supply-limiting factors are important, like in coastal environments.	Bas Hoonhout
ApsimX	The Agricultural Production Systems sIMulator (APSIM)	Dean Holzworth
BRaKE	Computes evolution of a bedrock river longitudinal profile in the presence of large, hillslope-derived blocks.	Charles Shobe
EF5	Ensemble Framework For Flash Flood Forecasting	Zac Flamig
Elv-GST	Numerical 1D research code Elv applied to gravel-sand transitions	Astrid Blom
Frost Model	Frost model predicts the likelihood of occurrence of permafrost in the land surface based on the monthly temperature distribution	Irina Overeem
GST-extendedmodel	Extended GST model: combination of an analytical	Astrid Blom

	GST migration model combined with closure relations based on the assumption of quasi-equilibrium conditions	
ISSM	Ice Sheet System Model	Eric Larour
Kudryavtsev Model	Permafrost Active Layer Thickness Model based on Kudryavtsev's parametrization	Irina Overeem
LateralVerticalIncision	Geometric model to explore autogenic increase of vertical incision rate in entrenching alluvial rivers.	Luca Malatesta
MCPM	A stand alone model for the morphological evolution of an idealized transect across a marsh channel-and-platform.	Giulio Mariotti
Meander Centerline Migration Model	Simulation of the long-term migration of meandering rivers flowing above heterogeneous floodplains	Manuel Bogoni
Mocsy	Routines to model the ocean carbonate system	James Orr
PyDeltaRCM	Reduced complexity river delta formation and evolution model with channel dynamics	Mariela Perignon
River Network Bed-Material Sediment	Bed-material sediment transport and storage dynamics on river networks.	Jonathan Czuba
SLAMM 6.7	The Sea Level Affecting Marshes Model (SLAMM)	Jonathan Clough

Tool	**Description**	**Developer**
Dakotathon	A Python API for the Dakota iterative systems analysis toolkit.	Mark Piper
Hydromad	Hydrological Model Assessment and Development	Felix Andrews
ILAMB	The International Land Model Benchmarking (ILAMB) toolkit.	Nathan Collier
KnickZone-Picker	Matlab-based script to extract topometrics for catchments and river knickpoints.	Bodo Bookhagen
RivMAP	Matlab toolbox for mapping and measuring river planform changes	Jon Schwenk

6.0 CSDMS Computational Support & Resources

6.1 CSDMS HPCC (*Beach*)

Over the last year 72 individuals were given a new account on the CSDMS High-Performance Computing Cluster, beach. In total now 669 CSDMS members have an account. To obtain an account on beach users meet the following criteria:

- Run a CSDMS model(s) to advance science
- Develop a model that will ultimately become part of the CSDMS model repository
- Develop a new data systems or visualization in support of the CSDMS community

The CSDMS High Performance Computing Cluster (HPCC) System *beach* (Syvitski is PI) is an SGI Altix XE1300 with 88 compute nodes (704 cores, 3.0 GHz Harpertown processors ≈ 8 Tflops). 64 nodes have 16 GB of memory each; 16 nodes have 32 GB of memory each. Internode communication uses a non-blocking InfiniBand fabric. Each compute node has 250 GB of local temporary storage and can access 72TB (raw) of RAID storage through NFS. Beach provides GNU and Intel compilers as well as their MPI counterparts (mvapich2, mpich2, and openmpi). Beach is supported by the CU ITS Managed Services (UnixOps) under contract to CSDMS. CPU Utilization rates on Beach average 70%.

Table 6.1: Top 10 Beach users since July 2016. In the last year beach has seen jobs submitted from 91 users for a total of 112 processor years.

Investigator	Institution	Processor Days
Jim McElwaine	U Cambridge, UK	35927
Jennifer Glaubius	U Kansas, USA	1217
Frances Dunn	U Southampton, UK	890
Omer Yetemen	U Washington, USA	682
Charles Shobe	U Colorado, USA	534
Katherine Ratliff	Duke U, USA	418
Mariela Perignon	U Colorado, USA	404
Theodore Barnhart	U Colorado, USA	375
Gaetano Achille	Osservatorio Astronomico di Teramo, Italy	199
Katherine Barnhart	U Colorado, USA	114

6.2 CSDMS-supported HPCC (*Janus*)

The larger *Janus* supercomputing cluster (Syvitski is Co-PI) consisted of 1368 nodes, each containing two 2.8 GHz Intel Westmere processors with six cores each (16,416 cores total) and 24GB of memory (2 GB/core) per node. Nodes were connected using a non-blocking quad-data rate InfiniBand interconnect, and 1 PB of parallel temporary disk storage. Beach was connected to the Janus cluster through a private 10 Gb/s network. *Janus* is in the process of being disassembled and has been replaced by S*ummit*.

6.3 CSDMS-supported HPCC (*Summit*)

The largest CU supercomputing cluster *Summit* (Syvitski is Co-PI) consists of a highly flexible and experimental architecture (see comparison table below). The architecture offers far fewer (405 CPU and 10 GPU) nodes, with more (24) cores per node and clock frequencies that range from 2.5 to 3.3 GHz. 380 of the nodes offer 5GB/c of RAM and 25 nodes offer 42 GB/c. Memory bandwidth has increased to 100 GB/s using the latest Omni-Path system. The file system is now GPFS that is extremely good at parallel transfers and small file operations. CU Research Computing manages *Summit*. Peak TFLOPS is nearly 3 times the speed of Janus. The HPCC is now available for jobs that have been successfully vetted by CU Research Computing managers.

Table 6.2. Comparison of three CU HPCCs: Beach, Janus and Summit.

Feature	Beach	Janus	Summit
CPU nodes	88	1368	380; 5; 20
GPU nodes	0	0	10
CPU cores/node	8	12	24
Clock frequency	3.0 GHz	2.8 - 3.2 GHz	2.5 - 3.3 GHz
RAM/core	2-4 GB/c	2 GB/c	5 GB/c; 42GB/c
Memory bandwidth	32 GB/s	32 GB/s	68 GB/s
Interconnect type	QDR InfiniBand	QDR InfiniBand	Omni-Path
Bandwidth	21 Gb/s	40 Gb/s	100 Gb/s
Filesystem	NFS	Lustre— optimized for large parallel transfers	GPFS— Good at parallel transfers & small file operations
Storage	72 TB	1000 TB	1000+ TB
Peak TFLOPS	8	153	290; 7; 53 39 Total >400

7.0 CSDMS Working & Focus Research Group Updates

7.1 Terrestrial Working Group

The terrestrial working group (TWG) continues to work on communication with members. The listserve was used minimally in the past year, but remains the main method for communication. Members desire to hear about eachother's new papers, job opportunities, data availability, and other pertinent issues. Members liked the idea of starting a newsletter. Gasparini will be in charge, and Leslie Hsu (USGS) will be working with her. Hsu will collect information on relevant data papers and datasets. The first newsletter is scheduled to go out on September 1, 2017, and a "mini" newsletter was sent on July 7, 2017.

Clinics at the annual meeting are always very much appreciated by the TWG members. This was revealed in discussions and clinic feedback. Members are eager for more learning opportunities in the form of extended, multi-day hackathons and/or formal software, programming, and numerical methods training. The group would like 3 - 5 day workshops in which at least a day is devoted to a single piece of software or topic so that attendees can gain a deeper understanding beyond the 2-hour clinic format. Given the breadth of membership of the TWG, the group felt it was important that these opportunities be available not just to students and postdocs, but also to scientists in industry and government. Topics of interest include:

- Parallel computing
- Numerical methods
- Data structures and working with large data sets
- Geodynamic models
- OpenFoam/CFD software
- Delft3D
- Liggghts
- DAKOTA
- PyMT

Formation of science teams was also discussed at the annual meeting. There was great enthusiasm for this idea, and Gasparini is testing different ways to make it happen. These include repeatedly floating the idea in newsletters and also targeting different members to form science teams.

7.2 Coastal Working Group & Coastal Vulnerability Initiative

Because the goals and activities of the Coastal Working Group (WG) and the Coastal Vulnerability Initiative (CV) overlap, we report on the progress and plans for these efforts jointly.

Activities and Accomplishments

We focus here on select accomplishments most relevant for the community-defined WG and CV priorities in the CSDMS Strategic Plan, especially those related to short- and medium-term goals articulated at previous Working Group/Vulnerability Initiative meetings:

*Specific Science Goal 1 (SSG1): D*evelop a medium-complexity suite of coupled models to explore "delta evolution on decadal to millennial time scales, as affected by couplings between terrestrial, fluvial, coastal, wetland, floodplain, subsidence, ecological and human processes".

- Building on earlier modeling (coupling the Coastline Evolution Model, CEM, and HydroTrend) by Ashton, Nienhuis and others, Katherine Ratliff developed a model component for dynamic river profile evolution and river avulsions, and with Eric Hutton (CSDMS IF), has coupled it to the CEM. The river module incorporates existing knowledge about long-term fluvial floodplain deposition dynamics, although improving knowledge on this key topic remains an open priority. Using the coupled model, Katherine has conducted initial experiments addressing how sea-level-rise rates and wave climate affect: 1) delta shape; 2) avulsion locations; 3) avulsion timescales; and 4) autogenic variations in sediment flux.
- Goals for this modeling effort include: 1) adding couplings with modules for subsidence, wetland dynamics, floodplain deposition (knowledge gap!), and human dynamics/manipulations; and 2) conducting a further sets of experiments addressing the effects of changing sediment delivery rates and human/landscape couplings.
- Complementary delta modeling efforts abound, including those of Doug Edmonds, William Nardin, and others using Delft3D; Man Liang using a reduced complexity model (DeltaRCM), Rebecca Lauzon adding vegetation dynamics to DeltaRCM, Anthony Longjas and other using network models, Jaap Nienhuis and Andrew Ashton using CEM (and Delft3D), and Ehab Meselhe and others using the applied Integrated Compartment Model. As part of the ESPA Delta project, Balaji Angamuthu, Steve Darby and Robert Nicholls are modeling tidally dominated deltas, and Frances Dunn is modeling sediment deposition on deltas. Mariela Perignon (IF) has translated DeltaRCM into PyDeltaRCM.

SSG2 addresses how the morphology, ecology, and human components of sandy coastal environments co-evolve under different scenarios of changing storm climate, sea level rise, and human manipulation— including coastal areas ranging from urban to undeveloped.

- Laura Moore, Orencio Duran, Peter Ruggiero, Elsemarie DeVries, Evan Goldstein and others have continued to develop the Coastal Dune Model (CDM), and to analyze model results and field data to explore questions including what factors determine the vulnerability of specific dune and barrier island systems to changes in climate forcing.
- Related recent work addresses what factors determine dune shape (e.g. height, continuity), which affects vulnerability of landward environments and infrastructure to storm hazards.
- Progress toward coupling CDM, XBeach and Aeolis continues (Peter Ruggiero, Nick Cohn, Laura Moore, Orencio Duran, Evan Goldstein, Danno Roelvink, and others).
- Lorenzo-Trueba and Ashton developed a new model of barrier response to sea-level rise (and other influences) based on dynamic shoreface evolution.
- Efforts to measure effects of development on storm-driven sediment fluxes, and model the long-term consequences for and feedbacks with the morphological and ecological evolution of sandy coastal environments, resulted in an initial paper. (study focusing on NJ after Sandy, and related modeling: Rogers, Moore, Goldstein, Hein, Lorenzo-Trueba, Ashton). More work is needed!
- A team of economists and geomorphologists (Marty Smith, Brad Murray, Dylan McNamara, Sathya Gopalakrishnan, Laura Moore, Andy Keeler, and Craig Landry)

continue to address couplings between physical/ecological and socio-economic processes on developed sandy coastlines.

- Rose Palermo and Andrew Ashton are also coupling economic and physical dynamics, addressing barrier settings
- The Coastline Evolution Model (CEM) and the Barrier Island Model (BIM) were coupled as part of an effort to forecast how increasing rates of sea level rise, changing wave climates, and localized shoreline stabilization efforts, might affect the Virginia coastline in the next 50 years (Margaret Jones, Laura Moore, Dylan McNamara, Brad Murray, and others). Results will be broadly available online as part of The Nature Conservancy's Coastal Resilience Tool.
- Modeling of coastline change driven by changing storm/wave climate is ongoing (Jose Antolinez, Fernando Mendez, Murray, Moore and others), and complementary modeling coupling CEM and SWAN is planned (Hailey Johnson, Pete Adams)
- Two groups are pursuing complementary modeling endeavors to address couplings between the dynamics of barriers and backbarrier marshes and shallow bays: 1) Jorge Lorenzo-Trueba and Giulio Marriotti are coupling back-barrier dynamics (based on the Marriotti and Fagherazzi model) to the barrier evolution model from Lorenzo-Trueba and Ashton; and 2) Laura Moore, David Walters, Rebecca Lauzon and others have added back-barrier dynamics to the barrier evolution model GEOMBEST, to produce GEOMBEST+.
- Robert Weiss and Jen Irish are leading an NSF GLD supported project addressing Tsunami and Tropical Storm Sediment Dynamics and Products.

SSG3 involves modeling rocky and soft-cliff evolution, including the effects of human manipulations from river damming to coastal armoring.

- As part of these efforts, with Eric Hutton, Pat Limber and others, Hailey Johnson is applying a Basic Model Interface (BMI) to a unified version of the Coastline Evolution Model (CEM) that can address rocky coastlines and beach-cliff interactions, as well as delta-related processes (and other relatively new capabilities).
- Work addressing human manipulations is mostly still pending.

SFG1 targets select prioritized modules to add to the couple-able model repository—modules that will be useful for a range of different modeling endeavors.

- CEM (above)
- The wave transformation model SWAN has consistently been listed as a high priority. Hailey Johnson is applying a BMI to SWAN (initially coupled to CEM, building on earlier coupling work by Pat Limber and others).
- ANUGA-SED wrapped into the new PyMT (Mariela Perignon)
- BMI for XBeach (Nick Cohen and others working on this).
- Develop BMIs for a marsh model (e.g. the D'Alpaos et al. model),
- and a barrier-island groundwater model (e.g. SEW-WAT); and
- couple a Tsunami model (e.g. GEOCLAW, BASILISK) with a coastal hazards and sediment transport event model, e.g. STRICHE (Robert Weiss)

- The community added a priority within this goal: Applying a BMI to Mike Walkden's Soft Cliff and Platform Evolution model SCAPE (already wrapped in OpenMI as part of the iCOASST project in the UK).

SFG2 involves Model Inter-comparison and Benchmarking Projects. Possibilities include:

- Prediction of marsh accretion rates under specified scenarios for sea-level-rise rate, suspended sediment flux, etc.
- The 'Sand Engine' project in the Netherlands, involving a well monitored mega-nourishment of a north sea coastline, already simulated by different hydrodynamics-resolving models, but not yet by simpler models. Progress comparing alongshore sediment transport formulations underway.
- A coastal hazards flooding scenario.
- Southern California beaches and bathymetry dataset, comparable to Duck dataset.
- Beach/nearshore data sets from Duck (North Carolina) and NCEX (California) massive experiments. Seek funding for such model-intercomparison projects

EKT goal: Contribute to the EKT WG with featured models to excite and educate a range of students:

- Coastal Dune Model (CDM),
- Tusnami model e.g. GEOCLAW.
- iPython notebooks for basic Hydrodynamics concepts, and/or sediment transport, bedforms calculations (good graphics, perhaps w/ equations)—along the lines of Dalrymple's applets. Robert Weiss is taking the lead.

Plans for the CSDMS3.0

Coastal Vulnerability Book

We are developing plans for a book (+ other media) addressing vulnerability to climate change and 'adaptation science' in the coastal context (led by Vice Chair for Coastal Vulnerability Hans Peter Plag and Working Group chair Brad Murray).

- The book will involve multiple academic and applied communities and multiple chapter authors. Existing liaisons between the WG/CVI and various groups, as well as representatives from other communities, will be recruited for participation.
- The book will address natural and developed coastlines,
- And will address observational as well as modeling opportunities and needs.

Community engagement next steps

Building on the experience Vice Chair for Community Engagement Chris Thomas has had with the Newsletter, we will to try to increase the breadth of active participants and spur new collaborations and new ideas involving coupling between different environments or processes by turning the WG/CVI email lists into a moderated list that members can use for timely, and brief communications of success stories, opportunities, and ideas. The Newsletter will be transformed into a cumulative archive. Any Blogs written by WG/VI members could be shared via list serve, e.g. 'Exploring the quantitative world', Robert Weiss.

Plans for Coastal WG and VI in CSDMS3.0:

At the 2016 and 2017 CSDMS meetings, attending members of the WG and CVI discussed plans for the next incarnation of CSDMS. These plans include the continuation of select existing goals and activities, plus new themes and questions outlined below. These themes and questions have been circulated to the full memberships of the WG and CVI in the form of a google document that all are invited to contribute. These (and likely other) themes will be translated into science goals that can spur collaborations and proposals to address compelling questions and lead to the development of new models and new couplings between models (of different environments or different sets of processes), which will ultimately increase CSDMS's usefulness to the research community.

Toward CSDMS3.0 Possible Themes:

- How can our modeling best take advantage of new high-resolution observations (the data 'supernova'; e.g. lots of high-res remote sensing)?
- End-member generic possibilities: for event-scale modeling, models become higher resolution; for models addressing change over decades and longer, we incorporate/synthesize observations into empirically based parameterizations.

Specific opportunities:

- Seismic data for US coast (e.g. Sergio Fagherazzi and Alan Howard's efforts modeling stratigraphy could now be tested)
- Emerging global high-resolution DEM's of coasts, and topographic changes and their rates, present a tremendous opportunity. Could we integrate modeling with this data opportunity to enhance our ability to assess coastal vulnerability? The DIVA model (Robert Nicholls and others) could serve well for this purpose. (Jaap Nienhuis's global inventory of Delta related data could relate to this as well.) This topic could be the theme of a WG/VI meeting, or a workshop, maybe aiming to write a visionary review paper of what could be possible over the next 10 years.
- We still need to facilitate more interactions between observationalists and modelers.
- Lidar data needs to be quality controlled.
- Delta channel network properties (e.g. topological analyses) can be extracted from many deltas, allowing us to test models of how delta morphology depends on different input and forcing conditions, as well as relevant processes.
- Fine and mixed sediment, stratigraphy: how does it affect coastal change (e.g. erosion)?
    - Fine, cohesive sediment plays key roles in models addressing coastal marshes and bays—but can we improve the way erosion, transport, and deposition are treated? How about the role of sandy sediment in these environments?
    - In addition, models of coastline dynamics often assume all coarse sediment. Stratigraphy into which the shoreline/shoreface erodes typically includes a mix of grain sizes—which affects erosion rates, and creates feedbacks with alongshore-transport dynamics.
    - Gravel and boulders, as part of sediment mixtures, involves challenging physics, but is very relevant for hazards modeling.
- How can event-scale modeling most effectively and meaningfully synergize with longer-term modeling (past and future)?
    - e.g. we can model hydrodynamic processes like tides and surge well, especially given the present landscape shape as a boundary condition. Modeling such event-scale processes, including associated short-term sediment fluxes, could potentially be very valuable in a model of longer-term evolution of coastal environments. But how to marry the two, when past or future boundary conditions are not as well defined, and

time scales contrast (and when high computational costs prohibit running event-scale models many times with different boundary condition scenarios)?
  - Not only do we not know the future landscape and ecosystem configurations well, but in developed coastlines, the development itself and associated structures built to protect development from event-scale hazards (from constructed dunes to seawalls to nourishment) are key elements of the boundary conditions for event-scale modeling; e.g. surge patterns and associated sediment fluxes are dictated by these boundary conditions. What will the human components of the coastal system look like decades or a century in the future? (This question involves the possibilities of changing patterns of land use, as well as migration into and out of coastal zones.)
  - The configuration of the human components depends partly on how the landscape and ecosystems evolve—which depends on how the human components evolve… need to treat human components as dynamic rather than as static snap shots (see next bullet).
- Need more coupling between Earth-surface scientists and:
  - Social scientists (economists to demographers), to incorporate dynamics of human components in long-term models. Earth scientists and social scientists need to interact more, to learn what each can offer the other, and how the dynamics of each system are coupled.
  - Hazards/resilience community (event focused); Human actions taken to reduce vulnerability of coastal environments/development on the event timescale can directly affect the longer-term evolution of the landscape—and therefore future event-timescale risks, and the future development… Actions that reduce vulnerability on the event timescale can increase vulnerability over longer timescales (e.g. on barrier coasts).
  - Need more work addressing couplings between ecological and physical (and human) processes—much has been accomplished, but this is still a forefront in coastal science.

7.3 Marine Working Group

- Developing a set of models that can be coupled via BMI.
  Deltares is developing Delft3D-FLOW Flexible Mesh, which is to be released in open source later this year by Deltares. This version will include a BMI compatible interface, and other components will likely follow over time. If the project remains on schedule, this will be accomplished by the Fall, 2017. Marine working group has interest in having an atmospheric / wind model available via BMI, and also interest in having morphodynamic models.

- Providing a hydrodynamic model to the CSDMS that is easier to use.
  - An idealized continental shelf model has been provided that uses ROMS (the Regional Ocean Modeling System) to calculate hydrodynamics, salinity, and sediment transport fields for an idealized, planar shaped continental shelf onto which a freshwater plume flows. A pre-compiled version of the model, with necessary input files, was ported to the CSDMS supercomputer, beach. We call this implementation "ROMS-LITE". The implementation can now be run within the WMT, and users have choices to modify some key sediment transport parameters via the WMT GUI.
  - The ROMS-LITE forms the basis of a series of Lesson Plans developed with input

from the CSDMS EKT working group. In 2016, these lesson plans were made available for use by the CSDMS community. Instructors from multiple universities used the ROMS – LITE lesson plans during the 2016 – 2017 academic year, and provided suggestions for improving the integration between the actual modeling exercises and the lesson plan descriptions.

    - The MWG suggests that future CSDMS work within ROMS might rely on the COAWST (Coupled Ocean Atmosphere Waves – Sediment Transport) branch, which uses ROMS as it's ocean model, but also provides the most up-to-date sediment transport routines.

- At the Fall Meeting of the American Geophysical Union (AGU) in San Francisco, the Marine Working Group joined with the Chesapeake Research Group, and the Coastal Working Group to host a session: *Bridging Boundaries in Surface Dynamics of Estuarine, Coastal, and Marine Systems using Models, Laboratory Studies, and Observations*. The session was able to convene three oral sessions (24 talks), with the rest of the submissions (about 100) presented as posters.
- Summary of Marine Working Group Resources:
    - The repository currently lists forty-eight marine models and 6 marine modeling tools.
    - Models that have BMIs and are allied with Marine Working Group interests include SWAN, SedFlux, OceanWaves, CEM, ROMS-Lite.
- At the Annual Meeting, Marine Working Group members discussed linkages between biogeochemical models and physical and geological models (like hydrodynamics and sediment transport). The group notes that ocean models have been tackling these issues for some time, usually relying on having the biogeochemical routines embedded within the ocean model, rather than coupled to it. CSDMS may provide an alternative method for linking these types of models
- Also discussed at the Annual Meeting were efforts to link models from the Marine Working Group to planning exercises. Examples discussed included the Louisiana Coastal Master Plan, which delivers output from models into a Decision Support Tool.

7.4 Education and Knowledge Transfer Working Group

Accomplishments over 2016-2017:
The EKT working group organized an education session at AGU 2017, titled 'ED13C: Earth Surface Modeling for Education: Adaptation, Successes, and Challenges Posters' jointly convened by the CSDMS and faculty from SERC, Carleton, and the University of Florida. The number of abstracts was limited to 5. In future, we could start to promote it earlier and use all possible ways of advertising.

1. The EKT chair revived connection to SERC, and they have reached out to us asking for reviewers for their curricular materials related to modeling.
2. There were 12 modeling clinics taught at this year's annual meeting.
3. CSDMS integration facility facilitated two preconference bootcamps.
4. The first learning assessment tool has been developed for web-based modeling courses. A concept inventory for pre- and post course assessment of learning was designed for the coastal processes ROMS-Lite modeling exercises. It has been tested in a course at Univ. of Virginia and at VIMS in the Spring semester of 2017. Based on initial testing,

the inventory will be revised, to closer match the teaching goals of the modeling exercises.

1. Discussions and vision of the working group:

The group has identified that there is a trend in reforming geosciences education now with more emphasis on quantitative geosciences. Several Working group members report about curriculum reform within their own university/departments. What was identified as a significant gap: the intermediate step between going from a concept to a theoretical model, or from a concept to a quantitative model. This is the first step before get into details of coding. Working group discussions at the annual meeting noted that so-called 'iPython notebooks' are great for this. They are a friendly environment for open-source coding and code sharing. The group formulated the ideas to develop a small series of iPython notebooks in relevant earth surface process modeling, based on existing classroom resources. Derive equations for fluid flow (based on class material from Robert Weiss). Pat Wiberg has a starter dataset, for physical hydrology. In addition, notebooks could potentially be created from Bob and Greg's sediment transport class. Jupiter/ iPython notebooks offer students insight into the models themselves.

This may have logistical advantages: hosting on the web is simple, i.e., a centralized cloud based model (sagemathcloud.org?), so students can access easily even with start phone and don't have to install anything. You can give codes at the most introductory levels, and then propagate through the curriculum. The EKT WG can put science teams towards this goal? One idea was to deal with the maintenance through teaching assistants?

2. Future goals:

- We already have many educational materials on the CSDMS website. So here the goal is to improve, update, maintain, and add education materials on the CSDMS website (e.g., making sure all the links work, all the WMT modules work, update of any outdated materials, making sure there is detailed instruction for first time users to get started quickly).
- Develop iPython notebooks based on existing resources in hydrology, coastal processes, river dynamics and sediment transport.
- Priorities for earth surface modeling topics and cross disciplinary concepts that can be incorporated/developed into education material:
  - An example of an Agent-based model that involves stake holders for decision making (Jonathan Gilligan, floodplain model for stakeholders),
  - Animations for geodynamics models that could be appealing to undergraduate students and provoke interest in models and modeling (e.g.:https://umaine.edu/earthclimate/research/geodynamics/course-projects/)

    http://wiki.geodynamics.umaine.edu/index.php/University_of_Maine_SECS_Numerical_Laboratory)
- A priority for the EKT working group is to develop material for controlled testing in classroom. Wei Luo has pioneered this approach for the simple landscape evolution model, i.e. the WILSIM-GC project. The objective of such efforts would

be to test the hypothesis that using models for learning new concepts is more efficient than a traditional teaching method.

- WMT and visualization is important! In future, we'd like to develop more advanced metrics on use of WMT; the capability of archiving simulations is developed but sofar has been untapped for developing shared teaching resources.
- Slider models have their value. In the 100-level courses.
- Another idea would be to use CSDMS as a broker between faculty sharing teaching strategies and resources. Perhaps a structure of teaching faculty and testers which would be facilitated by CSDMS. Connecting Prof A with Subject A with Prof B who also teaching Subject A. A small start-up fund to develop content would be a desirable way of helping to spark and consolidate these efforts.
- Webinars on skills, the EKT group recommends to do these in the beginning of the semester so that students can benefit from the get-go. Tape them to make them available as online resource and redo them with advances in the technology.
- The EKT WG email list can be used more frequently, for example to send the NSF Education calls for proposals around.

7.5 Cyberinformatics and Numerics Working Group

The Cyberinformatics and Numerics Working Group, currently has 223 members, served as the liaison between the broad CSDMS community and the integration facility personnel regarding cyberinformatics and numerics demands. In particular, we focus on technical computational aspects of CSDMS and work with our cyberinformatic partners and other working groups (or focus groups) to ensure that the modeling system properly functions and is accessible to users, and ensure that software protocols are maintained along with model standardization and visualization. As a group effort, we also inform CSDMS new tools in cyberinformatics and numerics (community needs) and tackle new challenges in computations and modeling of earth surface processes.

In 2016, we organized a successful session in the 2016 AGU Fall Meeting called "Moving down the chain — studying earth surface processes using computational fluid dynamics approaches across scales". We received 29 abstracts, organized into 1 oral session and 1 poster session. CSDMS Executive Director Jai Syvitski gave an invited talk to discuss the progress made in modeling turbidity currents triggered by hurricanes, a challenging multi-scale earth surface problem that provided an excellent example benefiting the CSDMS concepts. Other presentations include grain-scale process, turbulence and fluvial/coastal morphodynamics. In Fall 2016, we also formed a science steering committee for the working group in order to better coordinate WG activities and ensure that they are relevant to the broader research community. The current lineup of the science team includes, Dr. Randy LeVeque (University of Washington), Dr. Joseph Calantoni (Naval Research Laboratory), Dr Xiaofeng Liu (Penn State University), Dr. C. Emre Ozdemir (Louisiana State University) and Dr. Elchin Jafarov (Los Alamos National Laboratory).

At the 2017 CSDMS Annual Meeting in Boulder, we had extensive discussions during the breakout sessions, particularly with much input from the WG science team. Discussions mainly focused on identifying new tasks for future CSDMS efforts. Major highlights include:

- Initiate communication with DesignSafe/SimCenter (Dr. Peter Mackenzie, who represented DesignSafe was invited to participate in the WG breaking session).
- Better develop, integrate, archive & disseminate software to define the earth's surface dynamics, including adding online visualization tool box, extending parallel computing to visualization, and enhancing outreach to high schools.
- Tackling complex multi-scale, multi-physics earth surface processes with innovative approaches. In particular, effective link and communication between regional scale and sub-scale physics are essential. We discussed extensively of using a probabilistic approach to link between scales (such as Bayesian Network and Machine Learning methods). With the demonstrated success of model coupling in a plug-and-play manner using BMI, there were also discussions on selecting several new open-source codes as new candidate for model coupling, such as OpenFOAM.

With the success of the special session in the 2016 AGU Fall Meeting, two members of the WG science team (Dr. Xiaofeng Liu and Dr. Joseph Calantoni) and WG Chair Tom Hsu proposed such special session again in the 2017 AGU Fall Meeting. The session was accepted and we are now soliciting abstracts. We hope to organize such session in the future as a regular activity of CSDMS to include boarder research community interested in computational aspect of earth surface modeling.

7.6 Interagency Working Group

The goal of the Interagency Working Group (IWG) is to build relationships between Federal and State agencies and CSDMS. CSDMS stands to benefit from these interactions directly through input of agency resources, and indirectly by demonstrating the utility of CSDMS science and technology. Agencies benefit by taking advantage of CSDMS technology and resources to advance their mission. Chris Sherwood (USGS, Woods Hole) was nominated as Chair of the IWG in 2015. A strategy for IWG activities was developed last year, as described below.

Encourage existing relationships between CSDMS and agencies

There have been several successful CSDMS research programs with significant agency involvement, but agency involvement in CSDMS has continued at a low level for the past three years. The uncertainty in both Federal Agency funding and the timing and content of CSDMS 3.0 were factors in 2017. The Sandia National Laboratories Dakota software continues to be a valuable resource. The USGS is supporting the IWG and exploring the possibilities of developing coastal morphological models in the LandLab framework. A highlight of the 2017 Annual Meeting was the presentation of the NOAA National Water Model by David Gochis (UCAR).

Develop at least one, ideally two, new projects where agencies leverage CSDMS resources or infrastructure toward agency mission.

Ideas have been solicited from both agency and CSDMS scientists and two opportunities are still active.

- Interest remains for the use of CSDMS model-coupling technology to develop a coupled model of coastal morphologic evolution that combines the recent advances in marine and coastal sediment transport has been made. Discussions among LandLab developers (Gasparini) and Coastal Dune Model users (Moore) continue, and interest has been expressed by the USACOE (Smith). An agreement to explore coupling coastal processes within the LandLab framework was reached. This model system would be used to evaluate short-term (event- to decadal time scales) evolution of coastal systems. Interested agencies might include ONR, USGS, BOEM, NPS, FWS, and USACOE.

- Chesapeake Bay Focus Research Group Chair Raleigh Hood led a successful workshop proposal to the Chesapeake Bay Scientific and Technical Advisory Committee in 2016. The workshop will be held in January 2018 to explore modeling options for the next phase of the Chesapeake Bay Program. IWG Chair Sherwood is on the steering committee for the workshop, and one topic that will be considered is used of the CSDMS model coupling technology to enable various combinations of alternative estuarine, watershed, and airshed models. Interested agencies include EPA, USGS, NOAA, and state agencies from the CB watershed.

There was no Interagency Working Group meeting this last year.

7.7 Human Dimensions Focus Research Group

The HDFRG has defined 4 areas of endeavor that members of the FRG will develop over the coming year. These are:

1. Developing and advancing human dimensions models
2. Coupling human dimensions models with biophysical models
3. Using models to support participatory processes (with decision makers)
4. Capacity building

The CSDMS annual meeting (Boulder, May 2017) was used as an opportunity to bring the HDFRG community together to discuss these areas of endeavor. This meeting followed earlier workshops in Boulder (May 2016), Kyoto (Sep 2016), and Potsdam (March 2017) to which HDFRG members contributed. These workshops were held in collaboration with the Future Earth AIMES project (Analysis & Modelling of the Earth System). Ideas for action and development were proposed within each of the four areas of endeavor. This included actions that could be pursued within the coming year (highlighted) along with the HDFRG members who are responsible for leading on these actions (summarized below).

Ambition	**Action**
Developing and advancing human dimensions models	
Initiate an activity to develop a new Agent-Based Model of land use change at the global scale.	Organise a meeting to conceptualise the design of such a model (Garmisch, Germany, dates being found for early 2018)
Explore connections with other areas of CSDMS to support model development	Organise a joint session with the coastal vulnerability working group at next year's CSDMS annual meeting (May 2018)
Seek research funding for new model development	Apply for suitable grants in the European Union, Belmont Forum and the US (DOD, intelligence community, NSF) (1-3 years)
Develop methods	Adaptive self-learning models

	More explicit representation of SES feedbacks in all directions (demographic and macro-economic trends)
Coupling human dimensions models with biophysical models	
Explore existing examples of human dimension – biophysical model coupling	Write a paper based on existing examples of model coupling – the paper was submitted to Earth System Dynamics in June 2017, and is currently in review and available online: http://www.earth-syst-dynam-discuss.net/esd-2017-68/
	White paper about the range of reasons we need to couple models of human/biophysical dynamics.
	Define a spectrum of coupled human/natural models (from simple to complex) to help us understand and manage our complex and interactive socio-economic-ecological-technological system
	Data repository
	Publicize what coupled models exist. Include docs on BMIed models.
	Develop Netlogo – Python – Jupyter Notebook architecture to support coupling actitivies (12 months)
Develop appropriate computing environments to couple human dimensions and biophysical models	Review new computational architectures (e.g., MICs, GPUs) and identify particular modeling approaches well suited to them
	Universal interfaces/BMI between models
	Tools for metamodeling so we do not have to couple full, detailed models. Model componentization-microservices.
	Create an ontology for human dimensions models (12 months), and for biological sciences, to communicate variables across model types
Develop methods	Compile types of scenarios from which model coupling could potentially inherit assumptions for a target research question
	Evaluate ways to detect harmonization issues within coupled model outputs
	Internal methods for characterizing uncertainty, across scales and models.
	Develop intellectual frameworks to develop multi-scale, hierarchical/nested, coupled biophysical/socio-economic models: what do we lose with less detail, which applications are OK? Evaluate scale-dependent assumptions. Implications for computing environments (see above).
	Understand how results differ between standalone and coupled models.
	Remove numerical daemons?
	Develop models of polycentric governance of SESs

Applications	Linking rural-urban migration to city development
	Civil conflict as a potentially good lens to look into: people -> vegetation -> climate interactions
	Geophysical models as cultural, i.e., as one kind of interpretative framework
	Modeling extreme events in coupled human-environmental systems
Funding	Belmont, NSF, SI2, DOD
Using models to support participatory processes	
Communicate examples of participatory modeling approaches of coupled systems	Produce a special issue with a collection of academic articles on using models in participatory processes (12 months)
	Create a repository of cases with example approaches
	Model comparison discussion tool (parallel effort funded by SESYNC) (12 months)
	Develop/refine more frameworks for best practices in participatory modeling (parallel effort funded by SESYNC) (12 months)
	How to better communicate uncertainty and risk in participatory modeling processes
Develop methods for participatory modeling	Collaborate with ethnographers at different stages of the modeling process
	Identify appropriate policy entry points for modeling to more effectively influence policy change
	Develop appropriate simple models for use by managers to learn about adaptive management, and to work with stakeholders, assessing impact on learning and policy change.
	Identify barriers to non-researcher participation and propose remedies (parallel effort funded by SESYNC)
	Stakeholder driven validation and evaluation
	Irrigation districts: use coupled models for scenario planning
Application areas	New energy economy and implications at the individual household level
	Submit a proposal to NSF to develop a suite of simple models to be used in participatory settings to inform water management (12 months)
Seek funding for further activity in this field	Pursue an NSF PIRE opportunity
Capacity building	

Communicate the use of human dimensions models to the broader CSDMS modelling community	Develop web-based training materials, based on existing resources to expand FRG website (12 months): troubleshooting forums for different levels of expertise, model education clearinghouse, collate existing YouTube videos on BMI/PythonMT, etc.
	Develop a primer on human dimensions modeling for physical scientists, and a primer on biophysical modeling for social scientists (12 months)
	Participate in on-going winter and summer schools (12 months)
	Present models at an AGU session (Dec. 2017)
	Publish in new SESMO open journal (September deadline for inaugural special issue)
	Develop virtual seminars from our group to explain methods/projects (2018?)
	Create "BMI for Dummies" materials
	Develop model coupling training seminars
Train others on coupled modeling	Develop lessons for high school teachers in social sciences and STEM
	Develop teacher training workshops to teach modeling to undergraduates
	Develop games to enable sustainability (like Monopoly for capitalism, or SimCity for planning)

List of meeting participants

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Human Dimension FRG Discussion, 2017 CSDMS Annual Meeting.

7.8 Chesapeake Focus Research Group

The Chesapeake Focus Research Group (CFRG) currently has 78 members who are all active scientists and/or managers. The CFRG is integrated with the Chesapeake Community Modeling Program (CCMP), and so the CCMP Steering Committee provides oversight for both the CCMP and the CFRG. Over the past year the CCMP/CFRG has been working toward a goal of convening a "visioning workshop" that will provide a comprehensive review of the status of the current Chesapeake Bay Program (CBP) management modeling system and discuss future directions for management modeling in the CBP with a view toward developing a roadmap for future CBP modeling beyond 2018.

Description of Workshop:

CCMP, CSDMS/CFRG and the CBP have been funded by the CBP Scientific and Technical Advisory Committee (STAC) to convene a three-day workshop in January, 2018 to undertake a comprehensive review the status of the current CBP management modeling system and discuss future directions for management modeling in the CBP with a view toward developing a roadmap for future CBP modeling beyond 2018. This workshop will be guided by the following overarching questions:

1. *Description of needs:* What are the mandates and the scientific, computational, and data management challenges the CBP faces in the coming years and what critical changes and upgrades will have to be made to the CBP modeling system to meet these challenges?

2. *Review of advice:* How can information and recommendations from previous workshops and committee reports and organizations like the STAC, National Research Council (NRC), CCMP and CSDMS be brought to bear to address these needs?

3. *Description of resources:* What human and infrastructure resources are going to be available to meet these future needs and challenges? How can resources be used more efficiently and collaboration among government, private, and academic partners be

maximized? What additional resources might be needed and how might the various stakeholders and partners work most effectively to find these?

4. *Visioning for 2015 and beyond:* Can a well-informed, realistic, and unified vision for future CBP modeling be created to guide us into the future?

This meeting will begin with a plenary session that will review the purpose of the CBP models, the current state of the CBP modeling system, and the goals of the workshop. In this plenary there will also be presentations and discussion related to overarching considerations, like how new technologies and modeling approaches can be used to address CBP modeling needs.

Most of the workshop time will be spent in breakout sessions, organized around each of the major components of the CBP modeling system (land use, watershed, airshed, estuarine physics and water quality, living resources, and socio-economic). These breakout groups will address all four of the overarching workshop questions. A final plenary session will consist of concise reports from the breakouts and a discussion of the compatibility between proposed components, with a view toward formulating a realistic and unified vision for future CBP modeling that can be used to guide us into the future.

Justification for Proposed Topics and Management Implications:
The CBP's reliance on the modeling system as a planning tool to inform strategic management decisions and adaptation toward Bay restoration will continue into the foreseeable future. Yet it has been more than a decade since STAC has convened a dedicated workshop to discuss future directions for modeling in the CBP (http://www.chesapeake.org/pubs/modbay2010report.pdf).

Moreover, there have been rapid advances in physical process understanding, computer science, and modeling techniques in recent years. There have also been several workshop activities and resulting reports that have provided recommendations for how the CBP Modeling Work Group (MWG) should consider evolving the modeling system in the future to keep up with the state-of-the-art in land use, watershed, airshed, estuarine, living resources, and socio-economic modeling for its restoration efforts. These include STAC sponsored workshops on multiple/ensemble modeling, shallow water modeling and uncertainty assessment. They also include an NRC-motivated report and recommendations from the Modeling Laboratory Action Team (MLAT) on how the CBP might reorganize its modeling infrastructure. In addition, the CCMP has long advocated that the CBP should continue efforts to more fully adopt open-source and community modeling approaches. There have also been two recent NSF-funded projects in Chesapeake Bay on the development of approaches for engaging stakeholder communities in the model development process. And, finally, the NSF-funded CSDMS CFRG brings state of the art modular modeling approaches and tools to the table along with the CSDMS Interagency Working Group (IAWG), which seeks to engage federal, state, and local agencies in model development efforts. All of these new technologies, approaches and recommendations should be considered in planning for the future.

Looking back on the last visioning workshop and the subsequent developments, it is clear that it is time to motivate another workshop along these lines. Indeed, based on past workshop experience and what has been learned since, we believe that this workshop will be highly successful in formulating a vision for future CBP modeling that can be used to guide us into the future.

Moreover, the CBP's Phase 6 modeling effort for setting nutrient reduction targets and TMDLs is well underway with the 2017 Midpoint Assessment (MPA) happening now, which will continue through all of 2018. Immediately after the MPA the CBP MWG will begin the next phase of planning the development of its modeling system using the latest science, data, tools, and modeling approaches. Although the CBP is understandably focused on the 2017/2018 MPA, it is now time to start thinking about how the CBP's modeling suite should be changed and upgraded beyond 2018 to meet future management needs.

Potential Speakers:
The Steering Committee for the workshop (see below) will identify potential speakers that have expertise in (1) the Bay Program's modeling system (and/or other similar models), (2) multiple/ensemble modeling, (3) shallow water modeling, (4) uncertainty assessment, (5) open source and community modeling, (6) stakeholder engagement and social science, (7) modular modeling approaches and (8) CBP management needs for a post 2018 modeling system. In addition, the Steering Committee will invite speakers who were/are members of the CSDMS CFRG, the NRC-motivated MLAT and the CSDMS IAWG. The selected speakers will address the workshop objectives and will be asked to significantly contribute to the workshop products. The Steering Committee will specifically seek experts from regions outside of the Chesapeake Bay watershed to offer new perspectives and knowledge to the workshop.

Detailed Description of Workshop Products:
The workshop will generate specific recommendations for CBP MWG to consider for how the CBP's modeling suite might be changed and upgraded beyond 2018 to meet future management needs. The workshop will develop recommendations specific to each component of the CBP modeling system (land use, watershed, estuarine physical and water quality, living resources, and socio-economic). These recommendations will include consideration of the potential benefits of state-of-the-art modeling approaches and the potential need for changing the CBP modeling infrastructure. The recommendations, along with a justification and priority for each, will be developed into a workshop report and submitted to the CBP within 90 days of the workshop. Another major outcome/product of this workshop will be a peer-reviewed paper summarizing the major findings and recommendations.

Logistics:
The workshop will be invitation-only, and we estimate that 40-50 participants will attend. The workshop will be held over a three-day period in January 2018. All STAC and CCMP members will be invited along with selected NRC MLAT, and CSDMS CFRG and IAWG members. The workshop steering committee has already begun compiling a list of potential workshop attendees.
The workshop will be convened at the National Conservation Training Center in Maryland.

Workshop Steering Committee:

Bill Ball: Executive Director of the Chesapeake Research Consortium (CRC), where he has been since January 2015, and also continues his role as a professor of environmental engineering within the Department of Geography and Environmental Engineering at Johns Hopkins University, where he has been since 1992. Bill's research revolves around physical-chemical processes controlling water quality.

Peter Claggett: Research Geographer with the USGS and has worked at the CBP since 2002. Peter coordinates the CBP Land Use Workgroup and leads the CBP Land Data Team that conducts research on land change characterization, analysis, and modeling in the Chesapeake Bay Watershed.

Lora Harris: Associate professor at the University of Maryland Center for Environmental Science Chesapeake Biological Laboratory (UMCES CBL) where she has worked since 2007. Lora's research interests revolve around marine systems ecology, theoretical ecology, ecosystem modeling and primary production variability.

Raleigh Hood (Workshop co-Chair): Professor at UMCES Horn Point Laboratory (UMCES HPL) where he has worked since 1995. He is also the program manager and steering committee chair of the CCMP, and chair of the CSDMS/CFRG. Raleigh's research interests revolve around coupled physical-biogeochemical and ecosystem modeling.

Tom Ihde: Staff scientist at the NOAA Chesapeake Bay Office (NCBO) where he has worked since 2009, and he is also currently a member of the CBP STAC. Tom has worked in marine fisheries on a wide variety of subjects and he is currently working on the development and application of a full ecosystem simulation model (Atlantis) in Chesapeake Bay.

Lewis Linker: Lewis Linker is the CBP Modeling Coordinator, and works with colleagues throughout the CBP to develop linked models of the airshed, watershed, estuary, and living resources of the Chesapeake region.

Gary Shenk (Workshop co-Chair): Hydrologist with the USGS and has worked at the CBP since 1995. Gary leads *the watershed model development and application team at the CBP*.

Chris Sherwood: Oceanographer with USGS in Woods Hole where he has worked since 2001. He is also the Chair of the CSDMS/IAWG. Chris' research interests revolve around measuring and modeling sediment and contaminant transport in the coastal ocean.

Lisa Wainger: Research professor at UMCES CBL where she has worked since 1997, and she is also currently the chair of the CBP STAC. Lisa's research interests revolve around regional-scale ecological and economic modeling.

7.9 Geodynamics Focus Research Group

The Geodynamics Focus Research Group currently has 150 members, several of whom were able to attend and present their work at the CSDMS Annual Meeting. The focus of this year's annual meeting was "*Modeling Coupled Earth and Human Systems - The Dynamic Duo*". Human timescales may seem far removed from long-term tectonics and geodynamics. Yet, while mountains are long-lived features, which take millions of years to form or erode down, the processes by which they do so can occur on human timeframes – e.g., earthquakes and landslides. The Geodynamics Focus Research Group contributes to research that impacts human lives and a number of posters at the conference showcased examples of these studies.

Unfortunately, our invited keynote speaker, Alison Duvall, was unable to attend the meeting. Jean-Arthur Olive (Lamont-Doherty Earth Observatory) ran a clinic on his MATLAB-based geodynamic modeling code SiStER (Simple Stokes solver with Exotic Rheologies, available at: https://csdms.colorado.edu/wiki/Model:SiStER), on problems that couple solid-earth deformation and surface processes. Attendees ran simulations where fault evolution, lithospheric flexure and/or mantle flow interacted with surficial mass redistribution through erosion and sedimentation.

The Geodynamics business meeting at the conference was small, but produced active discussion. Our main focus was on progress in building links with the long-term tectonics community and also the suggestion that we can do a better job linking with short-term tectonics researchers, including those modelling processes such as earthquake-rupture and landslide initiation. We discussed which geodynamics code might be suitable to wrap in the BMI format and have a couple of options we will look at in more detail over the coming year. Wrapping a large code is not trivial and so we want to put our efforts into one that will be useful to the community.

We also had an update on the workshop proposal that we are currently writing with members of the CIG (Community Infrastructure for Geodynamics) long-term tectonics community to couple tectonic and surface processes across different spatio-temporal scales. This proposal has recently been recommended for funding—so look for updates in the coming months! We currently anticipate the workshop will be held in early spring of 2018, though the exact timing and venue are still to be determined.

Recent publications from members of the Geodynamics Focus Research Group

Booth, A.M., LaHusen, S.R., Duvall, A.R., Montgomery, D.R. (2017) Holocene history of deep-seated landsliding in the North Fork Stillaguamish River valley from surface roughness analysis, radiocarbon dating, and numerical landscape evolution modeling. Journal of Geophysical Research: Earth Surface, 122 (2), pp. 456-472.

Duvall, A.R., Tucker, G.E. (2015) Dynamic Ridges and Valleys in a Strike-Slip Environment. Journal of Geophysical Research F: Earth Surface, 120 (10), pp. 2016-2026.

Ehlers, T.A., Szameitat, A., Enkelmann, E., Yanites, B.J., Woodsworth, G.J. (2015) Identifying spatial variations in glacial catchment erosion with detrital thermochronology. Journal of Geophysical Research F: Earth Surface, 120 (6), pp. 1023-1039.

Enkelmann, E., Koons, P.O., Pavlis, T.L., Hallet, B., Barker, A., Elliott, J., Garver, J.I., Gulick, S.P.S., Headley, R.M., Pavlis, G.L., Ridgway, K.D., Ruppert, N., Van Avendonk, H.J.A. (2015) Cooperation among tectonic and surface processes in the St. Elias Range, Earth's highest coastal mountains. Geophysical Research Letters, 42 (14), pp. 5838-5846.

Forte, A.M., Yanites, B.J., Whipple, K.X. (2016) Complexities of landscape evolution during incision through layered stratigraphy with contrasts in rock strength. Earth Surface Processes and Landforms, 41 (12), pp. 1736-1757.

Kravitz, K., Upton, P., Mueller, K., Roy, S. (2017) Topographic controlled forcing of salt flow: Three-dimensional models of an active salt system, Canyonlands, Utah, J. Geophys. Res. Solid Earth, 122, 710– 733, doi:10.10 02/2016JB013113.

Langston, A.L., Tucker, G.E., Anderson, R.S. (2015) Interpreting climate-modulated processes of terrace development along the Colorado Front Range using a landscape evolution model Journal of Geophysical Research F: Earth Surface, 120 (10), pp. 2121-2138.

Logan, L.C., Lavier, L.L., Choi, E., Tan, E., Catania, G.A. (2017) Semi-brittle rheology and ice dynamics in DynEarthSol3D. Cryosphere, 11 (1), pp. 117-132.

Rengers, F.K., Tucker, G.E., Mahan, S.A. (2016) Episodic bedrock erosion by gully-head migration, Colorado High Plains, USA. Earth Surface Processes and Landforms, 41 (11), pp. 1574-1582.

Roy, S. G., G. E. Tucker, P. O. Koons, S. M. Smith, and P. Upton (2016), A fault runs through it: Modeling the influence of rock strength and grain-size distribution in a fault-damaged landscape, *Journal of Geophysical Research: Earth Surface*, *121*(10), 1911-1930, doi:10.1002/2015JF003662.

Roy, S.G., Koons, P.O., Osti, B., Upton, P., Tucker, G.E. (2016) Multi-scale characterization of topographic anisotropy. Computers and Geosciences, 90, pp. 102-116.

Sutherland, R., Townend, J., Toy, V., Upton, P., Coussens, J. and the DFDP-2 Science Team (2017), Extreme hydrothermal conditions at an active plate-bounding fault, *Nature*, *advance online publication*, doi:10.1038/nature22355.

Zeitler, P.K., Koons, P.O., Hallet, B., Meltzer, A.S. (2015) Comment on "Tectonic control of Yarlung Tsangpo Gorge revealed by a buried canyon in Southern Tibet" Science, 349 (6250), p. 799b

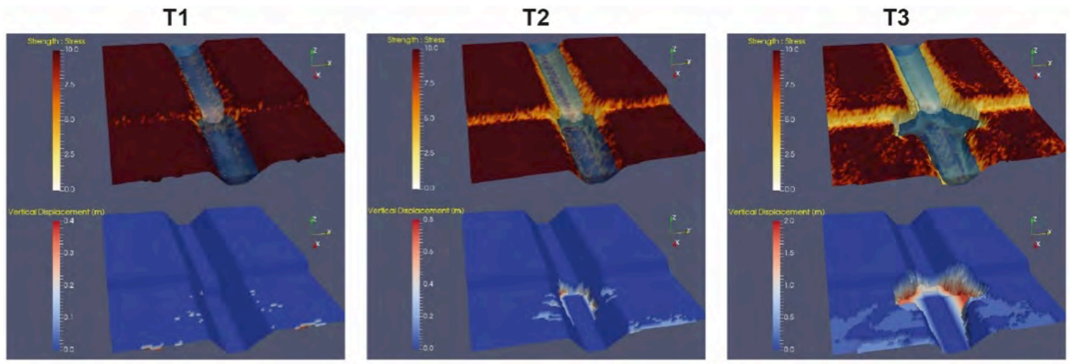

Figure 7.1: *Simulation by Nick Richmond, University of Maine, in which he couples an SPH solution for fluvial stresses to a FLAC^{3D} model of a knickpoint. Capturing the inertial forces with SPH and the 3D erosion potential of complex flows with the FLAC^{3D} model provides a comprehensive description of erosion around a knickpoint.*

7.10 Ecosystem Dynamics Focus Research Group

The addition of the Ecosystem Dynamics Focus Research Group (EDFRG) has encouraged the participation of ecological modelers in CSDMS. The growth of the relatively small group is steady; it started with 30 members two years ago, had 51 members last year, and is currently up to 85 members. In June 2016, Kim de Mutsert was added as co-chair in addition to Brian Fath, right after the ISEM conference in May 2016, where CSDMS was successfully promoted.

The EDFRG was partially formed due to a need for a model repository, and the chairs are polling members what models would be suitable for wrapping. While difficult to BMI fully, currently examination is ongoing regarding the suitability of wrapping components of the command-line version of Ecopath with Ecosim (EwE; www.ecopath.org). EwE is an open ecosystem modeling suite. Having a new interdisciplinary audience is one of the main drivers for inclusion of EwE in CSDMS, and a joint meeting with the Biogenics Focus Research Group revealed interest to use the software in fields outside of fisheries science. Two members of the Ecopath Research and Development Consortium (Joe Buszowski and Kim de Mutsert) are looking into feasibility and level of interest.

During the joint CSDMS-SEN-CoMSES 2017 annual meeting, the EDFRG was represented with a keynote address and a clinic from new co-chair Kim de Mutsert. With modeling coupling earth and human systems as the theme of this year's meeting, De Mutsert highlighted the potential of coupling fisheries ecosystem models to human systems such as agent-based fleet dynamics models. The clinic she hosted was co-convened with EwE core programmer Joe Buszowski, and served to introduce EwE to the CSDMS community with a lecture and hands-on model development. Future EDFRG goals include forming a Science Steering Committee, and promoting the inclusion of ecological models as part of the CSDMS model repository.

Keynote Kim de Mutsert at the 2017 annual meeting: Modeling a Coastal Environment with Human Elements

Relevant EDFRG group member publications in the last year

De Mutsert, K. Lewis, K.A., Buszowski, J., Steenbeek, J. and S. Milroy. Using ecosystem modeling to evaluate trade-offs in coastal management: effects of large-scale river diversions on fish and fisheries. Ecological Modelling 360:14-26. doi:10.1016/j.ecolmodel.2017.06.029

Gruss, A., Rose, K.A., Simons, J., Ainsworth, C.H., De Mutsert, K., Himchak, P., Kaplan, I.C., Froeschke, J., Zetina Rejon, M.J., and D. Chagaris. 2017. Recommendations for ecosystem modeling efforts aiming to inform ecosystem-based fisheries management and restoration projects. Marine and Coastal Fisheries. doi: 10.1080/19425120.2017.1330786

De Mutsert, K., Steenbeek, J., Cowan, J.H. Jr., and V. Christensen. 2017. Using ecosystem modeling to determine hypoxia effects on fish and fisheries. Chapter 14 *In*: D. Justic, K.A. Rose, R.D. Hetland, and K. Fennel (eds). Modeling Coastal Hypoxia: Numerical Simulations of Patterns, Controls and Effects of Dissolved Oxygen Dynamics. Springer, New York

Vasslides, J.M., De Mutsert, K., Christensen, V., and H. Townsend. 2016. Using the Ecopath with Ecosim modeling approach to understand the effects of watershed-based management actions in coastal ecosystems. Coastal Management *45 (1)*:1-12. doi: 10.1080/08920753.2017.1237241.

Lewis, K.A., De Mutsert, K., Cowan, J.H., Steenbeek, J. and J. Buszowski. Employing ecosystem models and Geographic Information Systems (GIS) to investigate the response of changing marsh edge on the historical biomass of estuarine nekton in Barataria Bay, Louisiana, USA. Ecological Modelling *331*: 129-141. doi: 10.1016/j.ecolmodel.2016.01.017.

De Mutsert, K., Steenbeek, J., Lewis, K., Buszowski, J., Cowan, J.H. Jr., and V. Christensen. 2016. Exploring effects of hypoxia on fish and fisheries in the northern Gulf of Mexico using a dynamic spatially explicit ecosystem model. Ecological Modelling *331*: 142-150. doi: 10.1016/j.ecolmodel.2015.10.013.

7.11 Hydrology Focus Research Group

National Water Center (NWC)

Opened 2014 – USGS, Army Core, FEMA, NOAA. Modeled after National Weather Center, Norman Oklahoma. Still staffing (understaffed at the time being). Most (50) are UCAR employees. CSDMS - Models are needed to help responders decide which roads to close or which areas to evacuate. CSDMS is involved through CUAHSI and its new CEO Jared Bales.

NWC activities

WRF-Hydro National Water Model, released August 2016. Now being used for weather forecasting in the United States. Resolution is a 250m land surface grid, vector routing 1km. Flood inundation mapping of the United States is the next objective.

Summer institute. Has been offered the last three years. CUAHSI run, NOAA pays NSF, NSF pays CUAHSI who pays graduate students. 7 weeks in the summer. The students work on projects that will help National Water Center. This year (2016) is urban flood inundation. Involved personnel are Maidment, Cohen and Ogden. Last summer (2015) – first responders were involved and wish to work with scientists at this center.

AGU Meeting Session Proposals.

In 2017, Hydrology FRG members are participating in 6 AGU sessions that focus on human-earth system interactions, with emphasis on resilience, evaluation of persistent water crisis in southeast US, global evaluation of large river fluxes, remote sensing and modeling of the terrestrial water cycle, how data are used in models, and the importance and evaluation of alternative models. Thus, of interest is the nuts and bolts of models and use of computers, and how these developments can be used for societal evolution and endurance.

Drones

Drones are an increasingly important tool for investigation of hydrologic conditions and their vast consequences on agriculture, energy production, and water supply. For example, using drones to map inundation during floods enables transmission of data in real time to a control room. This can be used directly and with models to coordinate rescue efforts. Analysis of drone data requires sophisticated programs. These are being developed largely in the private sector by a variety of vendors. CSDMS members have considerable experience with these programs and are developing ways of using drone acquired data with the process models of interest in CSDMS. Below we suggest a that CSDMS 3.0 venture into remote sensing using drones.

E-Board

On-line e-board for posting the latest discussion/question/answer for hydrological focus area – models, observations, analyses. Use of tags and work flow helps in answering these questions…

- Surface water – groundwater – slope stability is an example of a difficult model – three dimensional model, water flow etc would be complicated. Coupling of surface water, groundwater and soil processes – slope stability – hillslope scale and basin scale would be an excellent research agenda. In this and many other cases soil moisture would be an important input.

National and International Databases for Major Hydrologic Variables

We have the first generation databases of hydraulic conductivity and storage coefficients (Another important data set is soil type and soil hydraulic properties for input to hydrological models. Establishing a link to global soil type database and soil hydraulic properties. Establishment of the soil data type and property database or even link to existing data sets. CSDMS does not show data sets in an easily visible fashion such as models on their website. Coupling between data and models can be improved.

Ideas for CSDMS 3.0

Drones

Add drone analysis programs and their integration with process models. Chris Sherwood, Katy Barnhart, and perhaps others have expertise.

Scientific Modeling, Cell Phones, Gaming, and the Future of People on Earth

A primary challenge is developing an understanding of how scientific modeling can play a role in everyday attitudes about the environment upon which human civilization depends. The last decade has presented the scientific community, and especially the modeling community, with an opportunity. There are now mechanisms by which the thrill of discovery that comes with analysis of data and modeling of processes can be shared with a much wider audience. The very audience that needs to understand how the world them works. The mechanisms are called cell phones and tablets. If people can become experts about fictitious lands and conflicts, why can't they become experts on global hydrology, flood inundation, and the consequences of drought? CSDMS and NSF have an important place in this needed development.

Selected recent references by working group participants

Hill, M. C., Dmitri Kavetski, Martyn Clark, Ming Ye, Mazdak Arabi, Dan Lu, Laura Foglia, and Steffen Mehl. 2016. Practical use of computationally frugal model analysis methods. Groundwater. 54(2):159-170, DOI: 10.1111/gwat.12330

V Lakshmi, 2016, Beyond GRACE: using satellite data for groundwater investigations, Groundwater 54 (5), 615-618

B Kumar, V Lakshmi, KC Patra, 2017, Evaluating the Uncertainties in the SWAT Model Outputs due to DEM Grid Size and Resampling Techniques in a Large Himalayan River Basin. Journal of Hydrologic Engineering 22 (9), 04017039

7.12 Carbonate & Biogenics Focus Research Group

Biogenics. The title and therefore the scope of the FRG were widened to catch a wider membership, a broader set of initiatives, and greater relevance to biology, oceanography, climate and geochemistry. Here 'biogenic' (word first coined by Haeckel in the 1860s) embraces silicate, phosphate, organic carbon, seagrass and mangrove materials, and also structures and processes like bioturbation. These were fields not previously dealt with in CSDMS but which are most important in the earth system. They mark a broadening of the FRG away from classically geological themes of limestones and coral reefs. The FRG is distinguished within CSDMS by the need to couple biological (population ecology) modeling with geologic (materials, structures) modeling – additional to the usual environmental and temporal-spatial requirements. The FRG is not restricted to marine / coastal realms.

Ecosystem links. A highlight of the CSDMS Annual Meeting was the convergence between our group and the Ecological Dynamics FRG. A joint planning meeting was held with lively proceedings on the day. The demonstration of Ecopath with EcoSim (EwE) conducted by George Mason University and the Ecopath Research and Development Consortium was another highlight of the Annual Meeting.

Activities. The FRG will be represented by a number of members at the International Meeting of Sedimentology in Toulouse October 2017, especially and in a coordinated way in the session "Bio-Geo-Interactions in marine carbonate systems" chaired between CSDMS and Univ. Milano-Bicocca. This will present an opportunity to coordinate between process models developing in the group and remote sensing-directed statistical models. The latter offer a wonderful avenue for testing/validation of the process models. Another meeting with participation is (surprisingly) embedded within the Acoustical Society of America December 2017 meeting in New Orleans, with contributions from the CSDMS group on combining organism growth and shapes modeling with acoustic wave simulations.

Looking forward. Work has been commenced on the componentization of carbonate modules written within the FRG. This will allow carbonate growth modules to be interfaced with some very widely used coastal and marine modeling packages. The FRG is rather hamstrung by how few models addressing carbonates are available for the public repository. Partly, this is a function of the linkages that have existed in the past to economic geology in the field of carbonates. With the changes in the economic balances and particularly the increased involvement of the FRG with whole earth system sciences, this situation may change.

7.13 Sediment Experimentalist Network

By Raleigh L. Martin, Leslie Hsu, Wonsuck Kim, Kimberly Miller, Brandon McElroy

SEN (the Sediment Experimentalist Network) is an EarthCube Research Coordination Network (RCN) working to build a network of people, labs, tools, and information to make experimental geomorphology data more accessible and reusable. Our work is oriented around addressing grand challenge scientific goals, which include understanding variability in landscape evolution and sediment deposition processes, pursuing reproducibility of sediment experiments across laboratories, and relating scales of experiments to numerical models and natural systems.

SEN acts as a liaison between Earth-surface experimentalists and other communities of interest. Over the last few years, CSDMS and its network of Earth-surface modelers have emerged as natural partners in SEN efforts to document and disseminate datasets from sediment experiments. CSDMS modelers are interested in using experimentalist-generated data to parameterize and validate models; conversely, SEN experimentalists are interested in using Earth-surface models to inform and interpret observations from the laboratory.

To facilitate CSDMS-SEN collaborations and to build our respective networks of scientists, SEN served as co-sponsor for the 2017 CSDMS annual meeting, for a second consecutive year. As co-sponsor, SEN served two primary roles: (1) seeking out and funding experimentalist participants for the CSDMS meeting, and (2) hosting a clinic on the SEN Knowledge Base (SEN-KB), a resource for documentation and discovery of experimental equipment, methods, and datasets.

In total, SEN supported the registration and travel costs for 19 participants at the 2017 CSDMS annual meeting, including 3 of the SEN project leaders: Leslie Hsu (USGS), Raleigh Martin (UCLA), and Kim Miller (U Wyoming). Of these sponsored participants, all but one were early-career graduate students, postdocs, researchers, faculty, or professionals. As a condition for SEN support, all SEN-sponsored participants were required to participate in the SEN-KB clinic. In addition, most SEN-sponsored participants presented their research at poster sessions during the CSDMS meeting.

The SEN-KB clinic at the CSDMS meeting was held on Wednesday, May 23, 2017, and included a total of 33 participants with varying levels of existing familiarity with SEN activities. The 2-hour clinic included a tutorial on using SEN-KB (www.sedexp.net) to share and discover information on experiments, an introduction to using SEAD ("Sustainable Environment Actionable Data":

https://sead2.ncsa.illinois.edu/) for publishing related experimental datasets, and a "DataThon" session for clinic participants to review, contribute, and utilize entries on SEN-KB and SEAD. To better explain the features of SEAD, which has been partnering with SEN to support publication and documentation of experimental datasets, SEAD leader Jim Myers (U Michigan) attended and actively participated in the SEN-KB clinic.

SEN-CSDMS joint events like our 2017 clinic greatly accelerate the improvement and adoption of SEN's tools. We are able to learn a variety of user needs and fix issues while application developers are present. Without these partner clinics, we would not have a way to bring a large and diverse set of stakeholders together to facilitate the development of technical resources for our research community.

Though NSF funding for SEN will end in August 2017, we hope to sustain the SEN community indefinitely through crowdsourced maintenance of SEN-KB and other SEN-developed resources, and through participation in future meetings like those held by CSDMS. These efforts will become more difficult when SEN funding ends. Therefore, we are currently considering several possible funding mechanisms for sustaining SEN and its collaboration with CSDMS into the future. Our focus is to seek resources to support the following:

- **Form a science team within CSMDS that brings together scientists and technologists** to solve a science problem while adopting new technical resources, executing data-model integration, and finding solutions for model output storage and reuse.
- **Continue to support the next generation of experimentalists and modelers** by providing training for new tools and best practices, building networks between experimentalists and modelers, and cross-pollinating communities by teaching experimentalists how to incorporate numerical models to interpret their results and teaching modelers how to discover and reuse experimental datasets.

In summary, SEN's co-sponsorship of the 2017 CSDMS annual meeting built on a productive partnership between the Earth-surface experimentalist and modeling communities that we plan to carry into the future.

Participants explore new tools for curating experimental data at the SEN clinic.

8.0 CSDMS Staff Participation in Conferences / Meetings

July 2016 through July 2017

Jul-16	Newcastle University	Newcastle, UK	(Syvitski)
Jul-16	International Society for Systems Science	Boulder, CO	(Syvitski)
Aug-16	LSU Center for Coastal Resilience Symposium	Baton Rouge, LA	(Syvitski, Piper)
Aug-16	NCED Summer Institute	Minneapolis, MN	(Overeem, Perignon)
Sep-16	Prevegitation River Systems	Online Confrnce	(Syvitski)
Sep-16	Geological Society America Annual Meeting	Denver, CO	(Jenkins, Kettner, Brakenridge, Tucker)
Sep-16	LDEO Greenland Icesheet Mass Balance WS	Palisades, NY	(Overeem)
Sep-16	Belmont Forum Synthesis Meeting	New York, NY	(Overeem)
Sep-16	Binghampton Symposium, Colo State U	Fort Collins, CO	(Tucker)
Sep-16	Future Earth Cluster Workshop	Kyoto, Japan	(Syvitski)
Sep-16	ASU Aspect WS	Tempe, AZ	(Tucker)
Oct-16	CZO/LTER Meeting	Boulder, CO	(Tucker)
Nov-16	5th FAMOS Annual Meeting	Woods Hole, MA	(Overeem)
Nov-16	ESPA Deltas and the SDGs	London, UK	(Syvitski)
Nov-16	Budapest Water Summit Sci-Tech Forum	Budapest, Hungary	(Syvitski)
Nov-16	SGF Sorce to Sink Conference, U Rennes	Rennes, France	(Hutton)
Dec-16	5th GEOSS Sci and Tech Stakeholder WS	Berkeley, CA	(Syvitski)
Dec-16	AGU Fall Meeting	San Francisco, CA	(IF Staff)
Jan-17	Denver American History Association 2017	Denver, CO	(Syvitski)
Feb-17	Pages – GloSS Conference	Louvain, Belgium	(Kettner)
Feb-17	NSF SI2 PI Meeting	Arlington, VA	(Tucker)
Feb-17	USC School of Earth, Ocean & Environment	Columbia, SC	(Syvitski)
Mar-17	Tulane University, Schl Science & Engineering	New Orleans, LA	(Overeem)
Mar-17	UC Riverside, Envirn Sci Graduate Program	Riverside, CA	(Syvitski)
Mar-17	Linking Earth Sys & Socio Economic Models	Potsdam, Germany	(Syvitski)
Mar-17	Landlab Annual Meeting	Boulder, CO	(Tucker, Hutton)
Mar-17	U Victoria, Pacific Inst for Climate Solutions	Victoria, Canada	(Syvitski)
Mar-17	Rutgers University, Dept Earth & Planetry Sci	N Brunswick, NJ	(Overeem)
Apr-17	European Geosciences Union Gen Assembly	Vienna, Austria	(Kettner)
Apr-17	World's Large Rivers Conference	New Delhi, India	(Kettner)
Apr-17	Science Gateways Com. Institute Bootcamp	Indianapolis, IN	(Tucker, Hutton, McCready)
May-17	2017 CSDMS Annual Meeting	Boulder, CO	(IF Staff & Tucker)
May-17	CSDMS ExCom & Steering Com Meetings	Boulder, CO	(Tucker & IF Staff)
May-17	Coastal SEES Annual Project Meeting	Boulder, CO	(Overeem)
Jun-17	CZO All Hands Meeting	Arlingotn, VA	(Tucker)
Jun-17	CUAHSI Hydrology CyberInfrastructure WS	Cambridge, MA	(Hutton)
Jun-17	US Flood Inund Map Repos, GFP	Tuscaloosa, AL	(Kettner, Brakenridge)
Jul-17	11th Int. Conf. on Fluvial Sedimentology	Calgary, Canada	(Overeem, Kettner)
Jul-17	CUAHSI Conference on HydroInformatics	Tuscaloosa, AL	(Tucker)

9.0 CSDMS Priorities and Resource Management

9.1 2018 CSDMS Portal Goals

Improving community domains of CSDMS

The CSDMS web portal provides services to a very diverse community of experts, across many domains. However, much of its content is ordered by category (models, education, products, services), and only few repositories are sub categorized by its science domain (for example the model descriptions). The CSDMS web portal has integrated semantic web tools. These tools make it easier to provide content on demand at specific locations as well as by category in the web portal. By using Semantic Web tools, we envision to present domain specific content for each of the Working Groups and Focus Research Groups. This should make each community portal more dynamic and attractive for domain scientists, and will make groups activities more visible.

Working Groups and Focus Research Groups will each form 'Science Teams'. These teams, each consisting of 5–10 people, are led by the chair and will work on dedicated group priorities for that year. The Working Groups and Focus Research Group areas will accommodate web needs for the science teams and will function as a platform where material for the team and others can be shared. So, part of the 6 years' extension will be used to integrate dynamic content (models, jobs, meeting events, educational material) into WG and FRG areas while at the same time keeping the categories as they are presented in the main menu bar, and to integrate a working area for each science team. This in an effort to make it easier for CSDMS members to be even more successful in pursuing their goals in trying to explore Earth's surface by developing and using community software by ordering content per domain.

Make data on web portal available to other gateways

Important parts of the CSDMS web portal contain data that can be reached through a RESTful API (an application program interface (API) that uses HTTP requests to get, put, post and delete data). Several projects have shown interest in automatically retrieving content using rest API technology. Advances of using APIs instead of downloading or copying content from the CSDMS web portal are: transferring data over APIs is by far less labor intensive compared to duplicating data; content on client site will be updated instantly when changes are made at the host (CSDMS portal), and once the client has e.g. defined 'get' protocols, these then can be easily transferred to other sub categories within a repository. Variables that can be approached through rest APIs need to be described to make it easier for the client to integrate CSDMS web content into client portals. We propose to create a section within the CSDMS web portal that describes each of the variables defined using semantic web tools to make it easier for NSF supported projects like HydroShare to retrieve data from the CSDMS portal.

Maintain CSDMS portal functionality

a) **Portal maintenance** (*ongoing*). Web portal maintenance is a necessity to keep the portal operational and 24/7 accessible. The open software packages used for the CSDMS web portal require maintenance to guarantee this accessibility, performance and security. To conform University of Colorado standards, new upgrades and security patches will be installed when needed. Reference citation indexes will be kept updated to guarantee up to date information.

b) **Informing the community** (*ongoing*). CSDMS-IF includes timely information to the web portal. As such, information on numerical modeling related job opportunities as well as conferences and meetings are regularly updated on the portal. Less timely materials, like new items that are submitted to the repositories, and highlights innovative findings made by the community will be added to the portal. Minor resources are requested towards this to ensure continuity of informing the community.

Milestones:

1. Improving community domains of CSDMS. Integrate dynamic content per WG, FRG and make a supporting platform for science teams.
2. Make data on web portal available to other gateways by providing section on described semantic web variables.
3. Maintain CSDMS portal functionality:
4. Portal maintenance, installation of upgrades and security patches.
5. Maintain providing timely information to the community on a day to day base.
6. *Resources:* 0.5 FTE Web Specialist.

9.2 2018 Cyber Goals

In the coming year, the CSDMS IF software engineers will focus on four tasks:

1. componentize models,
2. improve documentation of CSDMS practices,
3. deploy the CSDMS stack to other HPC clusters, and
4. add tools to help users clone, edit, and deploy models,

as well as one additional task outlined in a supplemental proposal (9.2.5).

9.2.1 Componentize models

In the coming budget year, the CSDMS IF software engineers will continue their efforts to wrap models in the CSDMS repository with a BMI, componentize them, build binary distributions for the CSDMS Bakery, ensure that they work within PyMT, and add them to WMT.

Milestones:

1. Identify candidate models and write BMI wrappers for them.
2. Bring BMI-ed models into the CSDMS framework.
3. Ensure the new components work in PyMT and WMT.

Resources: 0.5 FTE software engineer.

9.2.2 Improve documentation of CSDMS practices

Based on community input, the CSDMS IF software engineers will provide additional documentation on CSDMS practices, at both the user and developer level. For user-level documentation, suggestions include:

- How to add a BMI to a model
- How to create BMI metadata for a model
- How to use the CSDMS Bakery to install models/components

and for developer-level documentation:

- Describe the steps needed to transform a model into a component
- How to set up a WMT server
- How to set up a WMT executor
- How to install component metadata into a WMT server

- How to install a component into a WMT executor

Resources: 0.25 FTE software engineer.

9.2.3 Deploy CSDMS stack to other HPC clusters

CSDMS owns and maintains a high-performance computing (HPC) cluster, *beach*, which has exceeded its service life and will soon be deprecated. We seek computational infrastructure solutions that are both sustainable, lasting longer than the typical 3–5 years of an HPC cluster, and scalable, accommodating not only computationally intensive runs from researchers but also multiple simultaneous job submissions from students in a classroom.

One possible replacement for *beach* is NSF's XSEDE cloud computing service, Jetstream (https://jetstream-cloud.org/). To evaluate its suitability, CSDMS IF has secured a Startup allocation on Jetstream to prototype, install, and test the deployment of the CSDMS software stack.

Another possible replacement for *beach* is the University of Colorado's condo cluster, *blanca*. In a condo cluster, partners get priority access on the nodes they own, and they can run jobs on nodes that are not currently used by others. CSDMS IF has purchased five compute nodes on *blanca*, and will use them to prototype, install, and test the deployment of the CSDMS software stack.

Milestones:

1. Take Jetstream online training course and set up initial environment.
2. Install CSDMS software stack on Jetstream.
3. Test stack internally in Jetstream.
4. Ensure that stack can be called externally from Jetstream.
5. Install CSDMS software stack on *blanca*.
6. Test stack internally on *blanca*.
7. Ensure that stack can be called externally from *blanca*.

Resources: 0.5 FTE software engineer.

9.2.4 Clone, edit and redeploy

CSDMS will develop tools to make it easier for model developers to take an existing model (clone), modify its source code (edit) and reintroduce the modified version back into the CSDMS Modeling Framework (redeploy). Although this is currently possible within the CSDMS Modeling Framework, the current workflow can be cumbersome and error prone.

Milestones:

1. Create tools for working with Python components.
2. Create tools for working with non-Python components (C, C++, Fortran)

Resources: 0.25 FTE software engineer

9.2.5 Supplemental work: Automated uncertainty quantification of model simulations

The CSDMS IF will develop a new service that adds error estimation to users' simulations by simultaneously running many (depending on the problem, this could be tens to hundreds or, potentially, more) parallel realizations with varying parameter sets. The service will use uncertainty quantification techniques available in the Dakota systems analysis software (https://dakota.sandia.gov/). Each adjacent simulation would be run with a slight change in model inputs based on, for example, a user's estimate of the error in some input parameter or parameters.

Dakota and the CSDMS Dakota Interface will then be used to marshall the outputs of these adjacent simulations and calculate statistics that are returned to the user. With this proposed service, we hope to abstract away the problems of managing the input files, templates, analyses of model outputs, and response metrics required in a typical Dakota workflow, thereby making it easier for researchers to incorporate error estimates into their modeling work.

Resources: 0.25 FTE software engineer, 0.083 FTE education specialist, 0.083 FTE web specialist.

9.2.6 Integrate landlab gridding utilities

The CSDMS model coupling software, PyMT and WMT, focus on allowing users to couple models. Models can be written in different languages and with different grid types. The Landlab modeling framework focuses on giving users tools to build grid-based numerical models within an easy-to-use Python library (Hobley et al., 2017). One of the main features of Landlab is a set of grid data structures and functions that can be used to construct and manage grid-based models. Landlab offers grid capabilities that go well beyond what now exists in the CMF, including representation of different types of grid elements and input and output formats. We will adapt Landlab's gridding utilities for use within the CSDMS Modeling Framework (CMF). The combination of these two software projects will result in a product that is greater than the sum of their parts. Combined, users will be able to build models from the ground-up that can be immediately be coupled to a wider range of models (across multiple languages and domains) in a web-based application as well as a graphical user interface. The ease of model development with Landlab, and the fact that Landlab components have "built in" BMI compatibility, promises to greatly expand the menu of BMI-enabled model components that are available to the community.

Resources: 0.25 FTE software engineer

9.3 2018 Education & Knowledge Transfer Goals

Enhance and update online educational resources.
The existing educational material will be organized into 10 mini-courses, each consisting of 2-3 labs with a progression in difficulty. Lectures given in the context of the CSDMS annual meeting are already available through browsing resources under the 'Past Meetings' on the wiki portal, but can be more systematically linked to the mini-courses.

Design and facilitate online skill-oriented webinars.
Evaluations of the clinics at the annual meeting, and the vision of the Educational Working Group support reaching out to our membership through online clinics. We propose to teach two skill webinars each academic semester through University of Colorado zoom conferencing software. In 2017-2018, these webinars will focus on model interfaces, best programming practices, CSDMS cyberinfrastructure standards, techniques for dealing with model sensitivity testing and uncertainty, and newly developed models.

Pioneer Jupyter Notebooks for Teaching.
Jupyter Notebooks provide a platform to smoothly go from model user (i.e. using the web-based modeling tool) to model developer. Code can be shared by the instructor, with even visualizations already set up. The notebook environment allows students to easily make modifications and re-run programs to see the results. We will work with volunteer faculty in the community to set up sets of notebooks on hydrology, sediment transport, fluid flow and polar processes. Documentation and testing of these new resources will be important for sharing them as a downloadable resource through the EKT repository.

Complete the learning assessment tools for Regional Ocean Modeling System.
The Regional Ocean Model (ROMS) has been set up with a configuration explicitly designed for teaching (the so-called ROMS-Lite labs). With the 3 online labs comes a pre-course survey, which functions to assess the students understanding of major concepts before engaging with the lesson material. The survey is then repeated after the labs are completed and measures whether students scores have changed. We aim to make revisions to this inventory, and focus the questions more on the modeling, and then prepare a publication for a scientific journal on the results of the design of this resource and its use in classrooms.

Michael Ellis accepting his Program Director's Award, 2017 Annual Meeting

10.0: NSF Revenue & Expenditures

($K with rounding errors)

	~ $K Year 6	~ $K Year 7	~ $K Year 8	~ $K Year 9	~ $K Year 10
A. Salaries & Wages					
Executive Director:	$57	$56	$48	$50	$51
Software Engineers:	$144	$164	$164	$170	$160
Communication Staff*	$100	$100	$90	$90	$85
Admin Staff**	$72	$42	$62	$72	$72
Total Salaries	**$373**	**$362**	**$364**	**$382**	**$368**
B. Fringe	**$103**	**$100**	**$102**	**$118**	**$111**
D. Travel					
Center Staff:	$10	$15	$15	$18	$10
Steering Committee	$6	$10	$8	$8	$6
Executive Com.	$10	$15	$30	$18	$20
Total Travel	**$26**	**$40**	**$53**	**$44**	**$36**
E. Annual Meeting	**$70**	**$72**	**$72**	**$78**	**$70**
F. Other Direct Costs					
Materials & Supplies	$1	$1	$1	$1	$1
Publication Costs	$2	$1	$1	$1	$1
Computer Services:	$25	$20	$14	$17	$17
Non Capital Equipment	$2	$6	$5	$1	$1
Official Function,	$0	$1	$2	$1	$0
Total Other Costs	**$30**	**$29**	**$23**	**$21**	**$20**
G. Total Direct Costs	**$602**	**$603**	**$614**	**$643**	**$613**
H. Indirect Cost	**$271**	**$271**	**$276**	**$288**	**$285**
I. Total Costs	**$879**	**$880**	**$943**	**$932**	**$898**
J. Carry Over	**$21**	**$41**	**($3)**	**($32)[&]**	**$2**

Notes:

1) Estimates include salaries projected 3 months to the end of the CSDMS fiscal year.
2) * Communication Staff includes Cyber + EKT Scientists
3) ** Admin Staff includes Executive Assistant + System Administrator + Accounting Technician.
4) CU completes a preliminary estimate of expenditures after 60 days of a time marker. CU provides a finalization typically within 90 days of a fiscal year.
5) & Overage covered by NSF Supplemental Venture Funding

Additional Funds Received by CSDMS IF Staff and Associates

Year 6:

NASA:	Threatened River Delta Systems: $143K, Accelerating Changes in Arctic River Discharge $75K
BOEM:	Shelf-Slope Sediment Exchange, Numerical Models for Extreme Events $75K
NSF:	Governance in Community Earth Science $85K; A Delta Dynamics Collaboratory $126K, River plumes as indicators of Greenland Ice Sheet Melt $90K
U. Colorado:	Salary support for the CSDMS Integration Facility: $73K

Year 7:

NASA:	Threatened River Delta Systems: $143K, Accelerating Changes in Arctic River Discharge $75K
BOEM:	Shelf-Slope Sediment Exchange: Numerical Models for Extreme Events $75K
NSF:	A Delta Dynamics Collaboratory $126K, River plumes as indicators of Greenland Ice Sheet Melt $90K
U. Colorado:	Salary support for the CSDMS Integration Facility: $73K

Year 8:

NASA:	Threatened River Delta Systems: $143K
BOEM:	Shelf-Slope Sediment Exchange: Numerical Models for Extreme Events $95K
NSF:	A Delta Dynamics Collaboratory $126K, Software Reuse Venture Fund FY14 $200K River plumes as indicators of Greenland Ice Sheet Melt $60K
U. Colorado:	Salary support for the CSDMS Integration Facility: $83K

Year 9:

NASA:	Permafrost Benchmark System to Evaluate Permafrost Models $114K
NSF:	A Delta Dynamics Collaboratory $280K, Software Reuse Venture Fund FY15 $120K Towards a Tiered Permafrost Modeling Cyberinfrastructure $162K Impacts of Vegetation and Climate Change on Dryland Rivers: $10K Tectonics in the Western Anatolia - sequence stratigraphic modeling: $20K
NSF/Belmont:	Sustainability of deltaic systems with an integrated modeling framework: 65K
World Bank:	Improving access, query and visualization of flood info for African regions: $25K
U. Minnesota:	Predicting highly regulated deltas: the Colorado $25K
U. Colorado:	Salary support for the CSDMS Integration Facility: $85K

Year 10:

NASA:	Permafrost Benchmark System to Evaluate Permafrost Models $114K
NSF:	Towards a Tiered Permafrost Modeling Cyberinfrastructure $162K Tectonics in the Western Anatolia - sequence stratigraphic modeling: $20K
World Bank:	Improving access, query and visualization of flood info for African regions: $120K
U. Minnesota:	Predicting highly regulated deltas: the Colorado $25K
U. Colorado:	Salary support for the CSDMS Integration Facility: $85K

11.0 CSDMS IF Publications

Submitted/in review July 2016 to June 2017: (IF Staff in bold)

Andreadis, K. M., Schumann, G. J-P, Stampoulis, D., Bates, P.D., **Brakenridge G. R.,** and **Kettner, A.J.**, *in review,* Can atmospheric reanalysis datasets be used to reproduce flooding over large scales? *Geophysical Research Letters.*

Chen, Y., **Overeem, I., Kettner, A., Syvitski, J.,** (in rev. 2017). Quantifying human-influenced sediment fluxes on the lower Yellow River during the years 1580-1849. *Earth Surface Processes and Landforms*

Cohen, S., **Brakenridge, G. R., Kettner, A.,** Bates, B., Nelson, J., Huang, Y-F, Munasignhe, D. and Zhang, J. *in review,* Methodology for Estimating Floodwater Depths from Remote Sensing Flood Inundation Maps and Topography. *J Amer. Water Resources Association.*

Higgins, S., **Overeem, I., Rogers, K.,** Kalina, E., (in rev. 2017). Impacts of India's National River Linking Project on Rivers and Deltas. *Elementa.*

Overeem, I., Hudson, B., **Syvitski, J.,** Mikkelsen A., Hasholt, B., van der Broeke, M., Noel, B., Molighem, M., (in rev. 2017). Sediment Export of the Greenland Ice Sheet is controlled by ice discharge dynamics. *Nature Geoscience.*

Rennermalm, A., Mikkelsen, A., **Overeem, I.**, Chu, V., Smith, L.C., van As, D., Mote, T., Hasholt, B., *in review,* Spatial variation of Greenland ice sheet meltwater export inferred from river discharge observations. *Geophysical Research Letters.*

Robinson DT, ADi Vittorio, P Alexander, A Arneth, C M Barton, DG. Brown, **A Kettner**, C Lemmen, BC. O'Neill, M Janssen, TAM Pugh, SS Rabin, M Rounsevell, **JP Syvitski**, I Ullah, PH Verburg submitted Modelling feedbacks between human and natural processes in the land system. Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2017-68

Rogers, K., Overeem, I., (in rev. 2017). Doomed to Drown? Sediment Dynamics in the Embanked Ganges-Brahmaputra-Meghna Delta. *Elementa.*

Tessler, Z., Vorosmarthy, C., **Syvitski, J., Overeem, I.,** (in rev. 2017). A model of water and sediment balance as determinants of relative sea-level rise in contemporary and future deltas. *Geomorphology.*

Wang, K., Jafarov, E., **Piper, M.,** Urban, F., **Overeem, I.,** Schwalm, C., Romanovsky, V., Schaefer, K., Cable, W., Clow, G., Kholodov, A., (in rev. 2017). Analysis of near-surface permafrost monitoring station data from Alaska, *The Cryosphere.*

Wang, K., Zhang, T., Zhang, X., Clow, G., Jafarov, E., **Overeem, I.,** Romanovsky, V., (in rev., 2017). Continuously Amplified Warming in the Alaskan Arctic: Implications for the Uncertainty in Estimating a Global Warming Hiatus. *Geophysical Research Letters.*

Wang, YP, JT Liu, **JPM Syvitski**, J Du, J-h Gao, J Jia, Z Zhang, G Hu, Y Yang, S Gao, *in review,* The world's "Coastal Zone Filter" traps more sediment than expected, *Nature Geoscience.*

Waters, CN, J Zalasiewicz, C Summerhayes, IJ Fairchild, NL Rose, N Loader, A Cearreta, M Head, **JP Syvitski,** M Williams, M Wagreich, AD Barnosky, A Zhisheng, R Leinfelder, C Jeandel, A Gałuszka, JA Ivar do Sul[5], F Gradstein, W Steffen, JR McNeill, C Poirier, M Edgeworth, in review, Suitability of different palaeoenvironmental archives to provide potential candidate Global Boundary Stratotype Sections and Points (GSSPs) for the Anthropocene. *Anthropocene.*

Xing, F, Syvitski, JP, AJ Kettner, EA Meselhe, JH Atkinson, A Khadka, *in review,* Morphodynamic Impacts of Hurricanes on the Wax Lake Delta, Louisiana, *Elementa*

in press July 2016 to June 2017: (IF Staff in bold)

Bendixen, M., Lonsman-Iversen, L., Bjork, A., Elberling, B., Westergaard-Nielsen, A., **Overeem, I.,** Barnhart, K, Khan, S., Box, J., Abermann, J., Langley, K., Kroon, A., (in press 2017). Prograding Greenlandic deltas defy Arctic coastal erosion trends. *Nature.*

Brakenridge, G. R. and Nghiem, S. V., *in press*, Merged AMSR-2 and GPM Passive Microwave Radiometry for Measuring River Discharge and Runoff. *IEEE JSTARS special issue*, "Contributions to Global Water Cycle Science and Applications from GCOM-W/AMSR2"

Kettner, A.J., Cohen, S., **Overeem, I.**, Fekete, B., **Brakenridge, R., Syvitski, J**. (in press 2017), Increases in flood frequency by the 21st century: A global modeling assessment, AGU Books.

Kundzewicz, Z. W., Pińskwar, I., and **Brakenridge, G. R**., *in press,* Changes in river flood hazard in Europe - a review, *Hydrological Research*.

Overeem, I., Briner, J.P., **Kettner, A.J., Syvitski, J.P.M**., *in press*, High-Latitude Valley Fills: A case-study of Clyde fjordhead, Baffin Island, Arctic Canada. *SEPM Special Issue Latitudinal Controls on Stratigraphic Models and Sedimentary Concepts.*

Syvitski JP, AJ Kettner, I Overeem, GR Brakenridge, S Cohen, *in press,* Latitudinal controls on siliciclastic sediment production and transport, *SEPM Special Issue Latitudinal Controls on Stratigraphic Models and Sedimentary Concepts*

Wang HJ, N Bi, S Li, P Yuan, A Wang, X Wu, Y Saito, Z Yang, Z Yu, S Liu, **Syvitski, JPM**, *in press,* Dam-orientated Water Sediment Regulation Scheme of the Yellow River, China: A review and perspective. *Earth Science Reviews*

Published July 2016 to June 2017: (IF Staff in bold)

Adams, J. M., Gasparini, N. M., Hobley, D. E., **Tucker, G. E., Hutton, E. W**., Nudurupati, S. S., and Istanbulluoglu, E. (2017) The Landlab OverlandFlow component: a Python library for computing shallow- water flow across watersheds. *Geoscientific Model Development*, v. 10, p. 1645–1663, doi:10.5194/gmd-10- 1645-2017.

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Brakenridge G.R., J.P.M. Syvitski, E. Niebuhr, **I. Overeem, S.A. Higgins, A.J. Kettner**, L. Prades 2017, Design with nature: Causation and avoidance of catastrophic flooding, Myanmar. *Earth-Science Reviews* 165: 81–109.

Day, JW, J Agboola, Z Chen, C D'Elia, DL Forbes, L Giosan, P Kemp, C Kuenzer, RR Lane, R Ramachandran, **J Syvitski**, A Yañez-Arancibia, 2016, Approaches to Defining Deltaic Sustainability in the 21st Century. *Coastal and Shelf Science* 183B: 275–291.

Escobar C., R., Restrepo, J.D., **Brakenridge, G.R.,** and **Kettner, A.J.,** 2016. Satellite-based estimation of water discharge and runoff in the Magdalena River, Northern Andes of Colombia. In: *Remote Sensing of Hydrological Extremes*, pp. 3-19. DOI: 10.1007/978-3-319-43744-6_1

Glade, R.C., Anderson, R.S., **Tucker, G.E.** (2017) Block-controlled hillslope form and persistence of topography in rocky landscapes. *Geology*, doi: 10.1130/G38665.1.

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Hobley, D. E., Adams, J. M., Nudurupati, S. S., **Hutton, E. W**., Gasparini, N. M., Istanbulluoglu, E., & **Tucker, G. E.** (2017) Creative computing with Landlab: an open-source toolkit for building, coupling, and exploring two-dimensional numerical models of Earth-surface dynamics. *Earth Surface Dynamics*. doi:10.5194/esurf-5-21-2017.

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Nghiem, S.V., Zuffeda, C., Shah, R., Chew, C., Lowe, S.T., Mannucci, A.J., and **Brakenridge, G.R.,** 2016, Wetland dynamics monitoring with global navigation satellite system reflectometry. *AGU Earth and Space Science, DOI: 10.1002/2016EA000194.*

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Cohen, S., **Kettner, A.J., Brakenridge, G.R.**, Rasaiah, B., Dhondia, J., Bates, B., Munasinghe, D., and Misfeldt, 2017. United States Flood Inundation Map Repository (USFIMR). Global Flood Partnership annual meeting, Tuscaloosa, Alabama.

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Harris, C.K., **Overeem, I., Hutton, E.**, Moriarty, J., Wiberg, P. 2016. Introducing students to Ocean Modeling via a Web-Based Implementation for the Regional Ocean Modeling System (ROMS) River Plume Case Study. AGU Fall Conference, San Francisco, December 2016.

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Molliex, S., **Kettner, A.J.,** Laurent, D., Droz, L., Marsset, T., and Laraque, A., 2017. Modeling sediment supply of the Congo watershed since the last 23 ka. European Geosciences Union General Assembly 2017, Vienna, Austria.

Nienhuis, J., Ashton, A., **Kettner, A.J.,** Edmonds, D., Rowland, J., Torbjorn, T., and Hoitink, T., 2017. Predicting coastal deltaic change on a global scale. European Geosciences Union General Assembly 2017, Vienna, Austria.

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Tucker, G.E., Adams, J.M., Doty, S.G., Gasparini, N.M., Hill, M.C., Hobley, D.J., **Hutton, E.W**., Istanbulluoglu, E. and Nudurupati, S.S. 2016. Using the landlab toolkit to evaluate and compare alternative geomorphic and hydrologic model formulations. In AGU Fall Meeting Abstracts, 2016.

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Potsdam AIMES, CoMSES, CSDMS Workshop on Human Dimensions Modeling.

Appendix 1 Institutional Memberships –

As of July 2017.

U.S. Academic Institutions:

1. Arizona State University
2. Auburn University, Alabama
3. Binghamton University, New York
4. Boston College, Massachusetts
5. Boston University, Massachusetts
6. Brigham Young University, Utah
7. California Institute of Technology, Pasadena
8. California State University - Fresno
9. California State University - Long Beach
10. California State University – Los Angeles
11. Carleton College, Minneapolis
12. Center for Applied Coastal Research, Delaware
13. Chapman University, California
14. City College of New York, City University of New York
15. Coastal Carolina University, South Carolina
16. Colorado School of Mines, Colorado
17. Colorado State University
18. Columbia/LDEO, New York
19. Conservation Biology Institute, Oregon
20. CUAHSI, District of Columbia
21. Desert Research Institute, Nevada
22. Duke University, North Carolina
23. Florida Gulf Coast University
24. Florida International University
25. Franklin & Marshall College, Pennsylvania
26. George Mason University, VA
27. Georgia Institute of Technology, Atlanta
28. Harvard University
29. Idaho State University
30. Indiana State University
31. Indiana University, Indiana
32. Iowa State University
33. Jackson State University, Mississippi
34. John Hopkins University, Maryland
35. Kansas State University
36. Louisiana State University
37. Massachusetts Institute of Technology
38. Michigan Technological University
39. Montana State University
40. Montclair State University, New Jersey
41. Monterey Bay Aquarium Research Inst.
42. Murray State University, Kentucky
43. New Mexico Institute of Mining and Technology, New Mexico
44. North Carolina State University
45. Northern Arizona University
46. Northern Illinois University
47. Northwestern University, Illinois
48. Nova Southeastern University, Florida
49. Oberlin College, Ohio
50. Ohio State University
51. Oklahoma State University
52. Old Dominion University, Virginia
53. Oregon State University
54. Pennsylvania State University
55. Portland State University, Oregon
56. Princeton University, New Jersey
57. Purdue University, Indiana
58. Rutgers University, New Jersey
59. San Diego State University, CA
60. San Fransisco State University, CA
61. San Jose State University, California
62. Scripps Institution of Oceanography, California
63. South Dakota School of Mines
64. Stanford University, CA
65. Virginia Polytechnic Institute and State University
66. Syracuse University, New York
67. Texas A&M, College Station
68. Texas Christian University
69. Towson University, Maryland
70. Tulane University, New Orleans
71. United States Naval Academy, Annapolis
72. University of Alabama - Huntsville
73. University of Alaska – Fairbanks
74. University of Arkansas
75. University of Arizona
76. University of Buffalo, New York
77. University of California – Berkeley
78. University of California – Davis
79. University of California – Irvine
80. University of California – Los Angeles
81. University of California – San Diego
82. University of California – Santa Barbara

83. University of California – Santa Cruz
84. University of Central Florida
85. University of Colorado – Boulder
86. University of Colorado – Denver
87. University of Connecticut
88. University of Delaware
89. University of Denver, Colorado
90. University of Florida
91. University of Houston
92. University of Idaho
93. University of Illinois – Chicago, Illinois
94. University of Illinois-Urbana – Champaign
95. University of Iowa
96. University of Kansas
97. University of Kentucky
98. University of Louisiana – Lafayette
99. University of Maine
100. University of Maryland – Baltimore County
101. University of Memphis
102. University of Miami
103. University of Michigan
104. University of Minnesota – Minneapolis
105. University of Minnesota – Duluth
106. University of Nebraska – Lincoln
107. University of Nevada – Reno
108. University of New Hampshire
109. University of New Mexico
110. University of New Orleans
111. University of North Carolina – Chapel Hill
112. University of North Carolina – Wilmington
113. University of North Dakota
114. University of Oklahoma
115. University of Oregon
116. University of Pennsylvania – Pittsburgh
117. University of Pittsburgh
118. University of Rhode Island
119. University of South Carolina
120. University of South Florida
121. University of Southern California
122. University of Tennessee – Knoxville
123. University of Texas – Arlington
124. University of Texas – Austin
125. University of Texas – El Paso
126. University of Texas – San Antonio
127. University of Utah
128. University of Virginia
129. University of Washington
130. University of Wyoming
131. Utah State University
132. Vanderbilt University
133. Villanova University, Pennsylvania
134. Virginia Institute of Marine Science (VIMS)
135. Virginia Polytechnic Institute, VA
136. Washington State University
137. West Virginia University
138. Western Carolina University
139. Wichita State University
140. William & Mary College, VA

U.S. Federal Labs, Agencies, State and Local Government, Non-Profit:

1. Argonne National Laboratory (ANL)
2. Brookhaven National Laboratory (BNL)
3. California Coastal Commission
4. Global Facility for Disaster Reduction and Recovery
5. Idaho National Laboratory (IDL)
6. Institute for Social and Environmental Transition
7. Los Alamos National Laboratory (LANL)
8. National Aeronautics & Space Administration (NASA)
9. National Center for Atmospheric Research (NCAR)
10. National Forest Service (NFS)
11. National Science Foundation (NSF)
12. National Oceanic & Atmospheric Administration (NOAA)
13. National Oceanographic Partnership Program (NOPP)
14. National Park Service (NPS)
15. National Weather Service (NWRFC)
16. Naval Research Laboratory
17. Oak Ridge National Laboratory (ORNL)
18. Pacific Northwest National Laboratory (PNNL)
19. Sandia National Laboratories (SNL)
20. South Florida Water Management District
21. U.S. Army Corps of Engineers (ACE)

22. U.S. Army Research Office (ARO)
23. U.S. Department of Agriculture (USDA)
24. U.S. Department of the Interior – Bureau of Reclamation
25. U.S. Department of the Interior – Bureau of Ocean Energy Management (BOEM)
26. U.S. Environmental Protection Agency (EPA)
27. U.S. Geological Survey (USGS)
28. U.S. Nuclear Regulatory Commission (NRC)
29. U.S. Office of Naval Research (ONR)
30. Utah Geological Survey
31. Woods Hole Oceanographic Inst., MD
32. World Bank, Washington D.C.

U.S. Private Companies:

1. Airlink Communications, Hayward CA
2. Aquaveo LLC, Provo, Utah
3. ARCADIS-US, Boulder, CO
4. BP America, USA
5. Chevron Energy Technology, Houston, TX
6. ConocoPhillips, Houston, TX
7. Deltares, USA
8. Dewberry, Virginia
9. DHI, Solana Beach, CA
10. Everglades Partners Joint Venture (EPJV), Florida
11. ExxonMobil Research and Engineering, Houston, TX
12. Fugro Marine GeoServices, Inc., USA
13. Geological Society of America Geocorps
14. Idaho Power, Boise
15. Leonard Rice Engineers, Inc., Denver, CO
16. Moffat & Nichol
17. PdM Calibrations, LLC, Florida
18. Philip Williams and Associates, Ltd., California
19. RPS Group Plc
20. Raincoast Scientific
21. Schlumberger Information Solutions, Houston, TX
22. Science Museum of Minnesota, St. Paul, MN
23. Shell USA, Houston, TX
24. Straus Consulting, Boulder, CO
25. Stroud Water Research Center, Avondale, PA
26. Subsurface Insights, Hanover, NH
27. URS–Grenier Corporation, Colorado
28. Target Source
29. The Von Braun Center for Science & Innovation, Inc.
30. UAN Company
31. Warren Pinnacle Consulting, Inc., Warren, VT
32. Water Institute of the Gulf, Baton Rouge, LA

Foreign Membership: Current total of 356 with 22 new members from July 2016 – July 2017 (**68** countries outside of the U.S.A.: Algeria, Argentina, Armenia, Australia, Austria, Bangladesh, Belgium, Bolivia, Brazil, Bulgaria, Burma, Cambodia, Canada, Chile, China, Colombia, Cuba, Denmark, Ecuador, Egypt, El Salvador, France, Germany, Ghana, Greece, Hungary, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Malaysia, Mexico, Morocco, Myanmar, Nepal, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan (Republic of China), Thailand, Turkey, UK, United Arab Emirates, Uruguay, Venezuela, Việt Nam).

Foreign Academic Institutes:

1. Aberystwyth University, Wales, UK
2. Adam Mickiewicz University (AMU) Poznan, Poland
3. AGH University of Science and Technology, Krakow, Poland
4. AgroCampus Ouest, France
5. Aix-Marseille University, France
6. Anna University, India
7. ANU College, Argentina
8. Architectural Association School of Architecture, UK
9. Aristotle U of Thessaloniki, Greece
10. Australian National University, Australia
11. Babes-Bolyai University, Romania
12. Bahria University, Islamabad, Pakistan
13. Banaras Hindu University, India
14. Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

15. Birbal Sahni Institute of Palaeobotany, India
16. Bonn University, Germany
17. Blaise Pascal University, Clermont, France
18. Brandenburg University of Technology (BTU), Cottbus, Germany
19. British Columbia Institute of Technology (BCIT), Canada
20. Cardiff University, UK
21. Carleton University, Canada
22. Chengdu University of Technology, China
23. China University of Geosciences- Beijing, China
24. China University of Petroleum, Beijing, China
25. Christian-Albrechts-Universitat (CAU) Kiel, Germany
26. CNRS / University of Rennes I, France
27. Cracow University of Technology, Poland
28. Dalian University of Technology,
29. Liaoning, China
30. Dankook University, South Korea
31. Darmstadt University of Technology, Germany
32. Delft University of Technology, Netherlands
33. Democritus University of Thrace, Greece
34. Diponegoro University, Indonesia
35. Dongguk University, South Korea
36. Durham University, UK
37. Earth Sciences Federal University of Parana, Brazil
38. East China Normal University, China
39. Ecole Nationale Superieure des Mines de Paris, France
40. Ecole Polytechnique, France
41. Eidgenossische Technische Hochschule (ETH) Zurich, Switzerland
42. Eötvös Loránd University, Hungary
43. FCEFN-UNSJ-Catedra Geologia Aplicada II, Argentina
44. Federal Ministry of Environment, Nigeria
45. Federal University of Itajuba, Brazil
46. Federal University of Petroleum Resources, Nigeria
47. Federal University Oye-Ekiti, Nigeria
48. Federal University of Santa Catarina, Brazil
49. First Institute of Oceanography, SOA, China
50. Free University of Brussels, Belgium
51. Glasgow University, UK
52. Guanzhou University, Guanzhou, China
53. The Hebrew University of Jerusalem, Israel
54. Helmholtz-Zentrum University Germany
55. Heriot-Watt University, Edinburgh, UK
56. Hohai University, Nanjing, China
57. Hong Kong University, China
58. IANIGLA, Unidad de Geocriologia, Argentina
59. Imperial College of London, UK
60. India Institute of Technology – Bhubaneswar, India
61. India Institute of Technology – Delhi
62. Indian Institute of Technology – Gandhinagar, India
63. India Institute of Technology – Kanpur
64. India Institute of Technology - Kharangpur
65. India Institute of Technology – Madras
66. India Institute of Technology – Mumbai
67. Indian Institute of Science – Bangalore
68. Indian Institute of Science - Delhi
69. Indian Institute of Technology– Bombay
70. Institut Univ. Europeen de la Mer (IUEM), France
71. Institute of Engineering (IOE), Nepal
72. Institute of Geology, China Earthquake Administration
73. Instituto de Geociencias da Universidade, Brazil
74. Instituto Superior Technico, Portugal
75. Kafrelsheikh University, Kafrelsheikh, Egypt
76. Karlsruhe Institute of Technology (KIT), Germany
77. Katholieke Universiteit Leuven, KUT, Belgium
78. King's College London, UK
79. King Fahd University of Petroleum and Mineral, Saudi Arabia
80. Kocaeli University, Izmit, Turkey
81. Kwame Nkrumah University of Science and Technology (KNUST), Ghana
82. Lanzhou University, China
83. Leibniz-Institute fur Ostseeforschung Warnemunde (IOW)/Baltic Sea Research, Germany
84. Leibniz Universitat Hannover, Germany
85. Loughborough University, UK
86. Lund University, Sweden
87. McGill University, Canada
88. McMaster University, Canada
89. Mohammed V University-Agdal, Rabat, Morocco
90. Mulawarman University, Indonesia
91. Nanjing Normal University, Japan
92. Nanjing University of Information Science & Technology (NUIST), China
93. Nanjing University, China
94. National Cheng Kong University
95. National Taiwan University, Taiwan, China
96. National University Columbia, Columbia
97. National University of Cordoba, Spain
98. National University (NUI) of Maynooth, Kildare, Ireland

99. National University of Sciences & Technology, Pakistan
100. National University of Sciences & Technology, (NUST), Pakistan
101. Natural Resources, Canada
102. NIIT University, India
103. Niger Delta University, Nigeria
104. North Maharashtra University, SSUPS Science College, India
105. Northwest University of China, China
106. Norwegian University of Life Sciences, Norway
107. Ocean University of China, China
108. Padua University, Italy
109. Paris Diderot University, France
110. Peking University, China
111. Pondicherry University, India
112. Pukyong National University, S. Korea
113. Prince Songkla University, Thailand
114. Pune University, India
115. Royal Holloway University of London, UK
116. RWTH Aachen University, Germany
117. Saint Francis Xavier University, Canada
118. Sejong University, South Korea
119. Seoul National University, South Korea
120. Shihezi University, China
121. Simon Fraser University, Canada
122. Singapore-MIT Alliance for Research and Technology (SMART), Singapore
123. Southern Cross University, United Arab Emirates (UAE)
124. Sriwijaya University, Indonesia
125. SRM University, India
126. Stockholm University, Sweden
127. Tarbiat Modares University, Iran
128. The Maharaja Sayajirao University of Baroda, India
129. Technical University, Hamburg, Germany
130. Tianjin University, China
131. Tohoku University, Japan
132. Tsinghua University, China
133. Ulster University, UK
134. Universidad Agraria la Molina, Peru
135. Universidad Austral de Chile, Chile
136. Universidad Complutense de Madrid, Spain
137. Universidad de Chile, Chile
138. Universidad de Granada, Spain
139. Universidad de Guadalajara, Mexico
140. Universidad de la Republica, Uruguay
141. Universidad de Oriente, Cuba
142. Universidad de Zaragoza, Spain
143. Universidad Nacional Autónoma de México
144. Universidad Nacional de Catamarca, Argentina
145. Universidad Nacional de Rio Negro, Argentina
146. Universidad Nacional de San Juan, Argentina
147. Universidad Politecnica de Catalunya, Spain
148. Universidad Politecnica Catolica de Chile, Chile
149. Universidade de Lisboa, Lisbon, Portugal
150. Universidade de Madeira, Portugal
151. Universidade do Minho, Braga, Portugal
152. Universidade Estudual de Campinas, Brazil
153. Universidade Federal do Rio Grande do Sul (FRGS), Brazil
154. Universit of Bulgaria (VUZF), Bulgaria
155. Universita "G. d'Annunzio" di Chieti-Pescara, Italy
156. Universitat Potsdam, Germany
157. Universitat Politecnica de Catalunya, Spain
158. Universitas Indonesia, Indonesia
159. Universite Bordeaux, France
160. Université de Bretagn Occidentale, France
161. Université de Grenoble, France
162. Universite de Rennes (CNRS), France
163. Universite de Toulouse, France
164. Universite du Quebec a Chicoutimi, Canada
165. Universite Grenoble Alps, France
166. Universite Joseph Fourier, Grenoble, France
167. Universite Montpellier 2, France
168. Universiteit Gent, Ghent, Belgium
169. Universiteit Stellenosch University, South Africa
170. Universiteit Utrecht, Netherlands
171. Universiteit Vrije (VU), Amsterdam, Netherlands
172. Universiti Teknologi Mara (UiTM), Mayalsia
173. Universiti Malaysia Pahang, Malaysia
174. University College Dublin, Ireland
175. University of Bari, Italy
176. University of Basel, Switzerland
177. University of Bergen, Norway
178. University of Bremen, Germany
179. University of Brest, France
180. University of Bristol, UK
181. University of British Columbia, Canada
182. University of Calgary, Canada
183. University of Cambridge, UK
184. University of Cantabria, Spain
185. University of Concepcion, Chile
186. University of Copenhagen, Denmark
187. University of Dhaka, Bangladesh
188. University of Dundee, UK
189. University of Edinburgh, Scotland
190. University of Edinburgh, UK
191. University of Exeter, UK
192. University of Geneva, Switzerland
193. University of Ghana, Ghana
194. University of Guelph, Canada

195. University of Haifa, Israel
196. University of Ho Chi Minh City, Vietnam
197. University of Hull, UK
198. University of Kashmir, India
199. University of Lethbridge, Canada
200. University of Liverpool, UK
201. University of Manchester, UK
202. University of Malaya, Kuala Lumpur, Malaysia
203. University of Milano-Bicocca, Italy
204. University of Natural Resources & Life Sciences, Vienna, Austria
205. University of Newcastle, Australia
206. University of Newcastle upon Tyne, UK
207. University of New South Wales, Australia
208. University of Nigeria, Nsukka, Nigeria
209. University of Nottingham, UK
210. University of Padova, Italy
211. University of Palermo, Italy
212. University of Pavia, Italy
213. University of Portsmouth, UK
214. University of Potsdam, Germany
215. University of Queensland (UQ), Australia
216. University of Reading, Berkshire, UK
217. University of Rome (INFN), "LaSapienza", Italy
218. University of Saskatchewan, Canada
219. University of Science Ho Chi Minh City, Viet Nam
220. University of Southampton, UK
221. University of St. Andrews, UK
222. University of Sydney, Australia
223. University of Tabriz, Iran
224. University of Tehran, Iran
225. University of the Philippines, Manila, Philippines
226. University of the Punjab, Lahore, Pakistan
227. University of Twente, Netherlands
228. University of Waikato, Hamilton, New Zealand
229. University of Warsaw, Poland
230. University of West Hungary – Savaria Campus, Hungary
231. University of Western Australia, Australia
232. University of Western Ontario, Canada
233. Victoria University of Wellington, New Zealand
234. Vietnam Forestry University, Vietnam
235. VIT (Vellore Institute of Technology) University, Tamil Nadu, India
236. VUZF University, Bulgaria
237. Wageningen University, Netherlands
238. Water Resources University, Hanoi, Vietnam
239. Wuhan University, Wuhan, China
240. Xian University of Architecture & Technology, China
241. York University, Canada
242. Yuzuncu Yil University, Turkey
243. Zhejiang University, China

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. Dynamic Flow Technologies, UK
9. Energy & Environment Modeling, ENEA/UTMEA, Italy
10. Environnement Illimite, Inc., Canada
11. Excurra & Schmidt: Ocean, Hydraulic, Coastal and Environmental Engineering Firm, Argentina
12. Fugro-GEOS, UK
13. Geo Consulting, Inc., Italy
14. Grupo DIAO, C.A., Venezuela
15. Haycock Associates, UK
16. H.R. Wallingford, UK
17. IH Cantabria, Cantabria, Spain
18. InnovationONE, Nigeria
19. Institut de Physique de Globe de Paris, France
20. Institut Francais du Petrole (IFP), France
21. Jaime Illanes y Asociados Consultores S.A., Santiago, Chile
22. METEOSIM, Spain
23. MUC Engineering, United Arab Emirates (UAE)
24. Petrobras, Brazil
25. Riggs Engineering, Ltd., Canada
26. Risk Management Solutions Inc., India
27. Saipem (oil and gas industry contractor), Milano, Italy
28. Shell, Netherlands
29. SEO Company, Indonesia

30. Soluciones en Technologia Empresarial (STE), Peru
31. Statoil, Norway
32. Tullow Oil, Ireland
33. Vision on Technology (VITO), Belgium

Foreign Government Agencies:

1. Agency for Assessment and Application of Technology, Indonesia
2. Alfred Wegener Institute for Polar & Marine Research, Germany
3. Arpa-Emilia-Romagna, Italy
4. Bedford Institute of Oceanorgraphy, Canada
5. Bhakra Beas Management Board (BBMB), Chandigarh, India
6. British Geological Survey, UK
7. Bundesanstalt fur Gewasserkunde, Germany
8. Bureau de Recherches Géologiques et Minières (BRGM), Orleans, France
9. Cambodia National Mekong Committee (CNMC), Cambodia
10. Center for Petrographic and Geochemical Research (CRPG-CNRS), Nancy, France
11. CETMEF/LGCE, France
12. Channel Maintenance Research Institute (CMRI), ISESCO, Kalioubia, Egypt
13. Chinese Academy of Sciences – Cold & Arid Regions Environmental and Engineering Research Institute
14. Chinese Academy of Sciences – Institute of Mountain Hazards and Environment, China
15. Chinese Academy of Sciences – Institute of Soil and Water Conservation, China
16. Chinese Academy of Sciences – Institute of Tibetan Plateau Research (ITPCAS), China
17. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
18. Consiglio Nazionale delle Ricerche (CNR), Italy
19. French Agricultural and Environmental Research Institute (CEMAGREF)
20. French Research Institute for Exploration of the Sea (IFREMER), France
21. Geological Survey of Canada, Atlantic
22. Geological Survey of Canada, Pacific
23. Geological Survey of Israel, Jerusalem, Israel
24. Geological Survey of Japan (AIST), Japan
25. Geosciences, Rennes France
26. GFZ, German Research Centre for Geosciences, Potsdam, Germany
27. GNS Science, New Zealand
28. GNU VNIIGiM, Moscow, Russia
29. Group-T, Myanmar
30. Helmholtz Centre for Environmental Research (UFZ), Germany
31. Indian National Centre for Ocean Information Services (INCOIS), India
32. Indian Space Research Organization
33. Institut des Sciences de la Terre, France
34. Institut National Agronomique (INAS), Algeria
35. Institut National de la Recherche Agronomique (INRA), France
36. Institut Physique du Globe de Paris, France
37. Institut Teknologi Bandung (ITB), Indonesia
38. Institute of Atmospheric Sciences and Climate (ISAC) of Italian National Research Council (CNR), Italy
39. Institute for Computational Science and Technology (ICST), Viet Nam
40. Institute for the Conservation of Lake Maracaibo (ICLAM), Venezuela
41. Institute of Earth Sciences (ICTJA-CSIC), Spain

42. Instituto Hidrografico, Lisboa, Lisbon, Portugal
43. Instituto Nacional de Hidraulica (INH), Chile
44. Instituto Nazionale di Astrofisica, Italy
45. International Geosphere Biosphere Programme (IGBP), Sweden
46. Iranian National Institute for Oceanography (INIO), Tehran, Iran
47. Israel Oceanographic & Limnological Research, Israel
48. Italy National Research Council (CNR), Italy
49. Japan Agency for Marine-Earth Science Technology (JAMSTEC), Japan
50. Kenya Meteorological Services, Kenya
51. Korea Ocean Research and Development Institute (KORDI), South Korea
52. Korea Water Resources Corporation, South Korea
53. Lab Domaines Oceanique IUEM/UBO France
54. Laboratoire de Sciences de la Terre, France
55. Marine Sciences For Society, France
56. Ministry of Earth Sciences, India
57. Nanjing Hydraulics Research Institute, China
58. National Geophysical Research Institute, India
59. National Institute for Environmental Studies, Japan
60. National Institute of Water and Atmospheric Research (NIWA), Auckland, New Zealand
61. National Research Institute of Science and Technology for Environment and Agriculture, France
62. National Institute for Space Research (INPE), Brazil
63. National Institute of Oceanography (NIO), India
64. National Institute of Technology Rourkela, Orissa, India
65. National Institute of Technology Karnataka Surathkal, Mangalore, India
66. National Institute of Water and Atmosphere (NIWA), New Zealand
67. National Marine Environmental Forecasting Center (NMEFC), China
68. National Oceanography Centre – Liverpool, UK
69. National Research Centre for Sorghum (NRCS), India
70. National Research Council (NRC), Italy
71. National Space Research & Development Agency, Nigeria
72. Qatar National Historic Environment Project
73. Scientific-Applied Centre on hydrometeorology & ecology, Armstatehydromet, Armenia
74. Secretaria del Mar, Ecuador
75. Senckenberg Institute, Germany
76. Shenzhen Inst. of Advanced Technology, China
77. South China Sea Institute of Technology (SCSIO), Guanzhou, China
78. The European Institute for Marine Studies (IUEM), France
79. The Leibniz Institute for Baltic Sea Research, Germany
80. UNESCO-IHE, Netherlands
81. Water Resources Division, Dept. of Indian Affairs and Northern Development, Canada
82. World Weather Information Service (WMO), Cuba

Appendix 2 CSDMS 2017 Annual Meeting

The CSDMS 2017 Annual Meeting, *"Modeling Coupled Earth and Human Systems: The Dynamic Duo"*, was attended by 150 individuals, the largest CSDMS Annual Meeting to date. This year's meeting was co-sponsored by the following organizations and projects:

Network for Computational Modeling for SocioEcological Science (CoMSES): provided a keynote lecture by Marco Janssen, ASU, entitled *"Two Modeling Cultures"* and a clinic by Allen Lee, ASU, entitled *"Good Enough Practices for Reproducible Scientific Computation"*. Additionally, CoMSES provided travel and attendance support for six CoMSES Directorate/Executive Board Members and affiliates. Michael Barton, ASU, CoMSES Directorate Member, provided an introductory talk about the CoMSES Network. CoMSES is an NSF-funded scientific research coordination network to support and expand the development and use of computational modeling in the social and life sciences. The primary goals of CoMSES Net are to confront and begin to mitigate challenges of scientific infrastructure that have impeded the widespread use of computational modeling in research domains where it could be most profitably used. These include constraints on disseminating modeling-related research through existing scientific channels, lack of frameworks that permit researchers engaged in modeling to build on each others work, the lack of a common descriptive language for models, and difficulties in evaluating the quality and applicability of modeling-related research. To accomplish this, the COMSES Net serves as a self-organized community of practice and a conduit to expedite knowledge exchange for computational modeling in SES.

Sediment Experimentalist Network (SEN): provided a clinic by Raleigh Martin, UCLA, entitled *"The Sediment Experimentalist Network (SEN) Knowledge Base"*. Additionally, 20 meeting attendees were fully supported by SEN. SEN integrates the efforts of sediment experimentalists to build a knowledge base for guidance on best practices for data collection and management. The network facilitates cross-institutional collaborative experiments and communicates with the research community about data and metadata guidelines for sediment-based experiments. Their efforts aim to improve the efficiency and transparency of sedimentary research for field geologists and modelers as well as experimentalists.

Towards a Tiered Permafrost Modeling Cyberifrastructure (NSF-funded project): The Permafrost project offered eight competitive student scholarships for participation in the Permafrost ToolBox Clinic and 2017 Annual Meeting.

A2.1 Keynotes and Posters

Abstracts of presentations are included below. All plenary keynote presentations were recorded and provided through the CSDMS YouTube channel that is also embedded in the CSDMS web portal for people to view at their convenience.

The Competition Between Frequent and Rare Flood Events: the Impact on Erosion Rates and Landscape Form

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Nicole Gasparini, *Tulane University New Orleans Louisiana, United States.* ngaspari@tulane.edu
Gregory Tucker, *University of Colorado Boulder Boulder Colorado, United States.* gtucker@colorado.edu
Erkan Istanbulluoglu, *University of Washington Seattle Washington, United States.* erkani@u.washington.edu

It has been hypothesized that large, rare flooding events in semi-arid to arid climate regimes may do more erosive work than the frequent storm events that occur in humid or temperate climates. Previous work has demonstrated that added variability in modeled climate or water discharges may be linked to changes in landscape form or channel characteristics. Many landscape evolution models do not capture hydrograph dynamics, so they may miss critical aspects linking flood events and erosion. To explore how different climates shape landscapes, this work uses a hydrodynamic model to simulate flooding and erosion processes. Precipitation time series, based on observed event frequency data from NOAA, are used to differentiate modeled wet and dry regimes. The drier regime is characterized by a heavy-tailed flood probability distribution, where the rarest events have a greater magnitude than storms of a similar recurrence in wetter regions. Hydrographs driven by these precipitation time series are used to erode the topography of a synthetic watershed. Simulations are run with and without an incision threshold. After 10^4 modeled years, landscape characteristics such as relief and channel concavity can be compared. Total eroded depths are evaluated for the different storm frequencies to explore how individual floods and the cumulative work of all floods sculpt landscapes. We propose when an incision threshold is considered, the higher magnitude events in arid regimes will be more effective at shaping watersheds than events of the same frequency in temperate climates. These results inform the discussion of how fluvial erosion may change if anthropogenic climate change leads to the aridification of presently temperate regimes. Additionally, this study will illustrate how hydrograph shape and duration impact modeled landforms, processes not captured in traditional landscape evolution models.

The Effects of Changing Boundary Conditions on Modeled Heat and Salt Diffusion in Subaquatic Permafrost Offshore of Muostakh Island, Siberia.

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Pier Paul Overduin, Department of Periglacial Research, *Alfred Wegener Institute for Polar and Marine Research Potsdam, Germany.* paul.overduin@awi.de
Mikhail Grigoriev, *Permafrost Institute, Siberian Branch of the Russian Academy of Sciences Yakutsk, Russia.* grigoriev@mpi.ysn.ru
Sebastian Westermann, *Department of Geosciences, University of Oslo, Oslo, Norway.* sebastian.westermann@geo.uio.no
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Geophysical datasets, thermal modelling, and drilling data suggest that most Arctic shelves are underlain by submarine permafrost due to their exposure during the glacial low water stands. The degradation of subsea permafrost depends on the duration of inundation, warming rate, the coupling of the seabed to the atmosphere from bottom-fast ice, and brine injections into the seabed. The impact of brine injections on permafrost degradation is dependent on seawater salinity, which changes seasonally in response to salt rejection from sea ice formation and terrestrial freshwater inflows. The relative importance of the upper boundary conditions responsible for permafrost table degradation rates, however, remain poorly understood. This study evaluates the effects of changing upper boundary conditions on subaquatic permafrost thaw rates using CRYOGRID, a one-dimensional heat diffusion model, which was extended to include coupled dissolved salt diffusion. More specifically, the impacts of using a seasonally varying seabed temperature function compared to a mean annual seabed temperature for both freshwater and saline water bodies were assessed. For saline conditions, the effects of different salinity regimes at the seabed, including mean annual concentrations and seasonal variations. Daily observations of seabed temperature and electrical conductivity from 01-09-2008 to 31-08-2009 offshore of Muostakh Island in Siberia were used to set up the upper boundary conditions for the base case model runs. For saline water bodies, sensitivity analyses for mean annual salt concentrations and seabed sediment type were also performed. In all model runs, a steady-state heat conduction function was used to calculate the initial ground thermal regime prior to inundation. The initial state of permafrost was assumed to contain no salt and the ramp-up time from a terrestrial to a sub-aquatic upper boundary condition was one year for all simulations. Generally, it was found that using a mean annual seabed temperature overestimates subaquatic permafrost thaw for shallow freshwater by approximately 2 metres after 65 years of inundation. Seasonal variation of the seabed temperature led to seasonal freezing and thawing of the sea bed. However, for water bodies with high mean annual concentrations of salt (i.e. 420 moles NaCl/m3), it was found that the difference between using mean annual versus seasonally varying seabed temperatures was negligible. Dissolved salts below the seabed depress the pore water freezing point sufficiently to prevent ice formation in the near-surface sediment despite sub-zero winter temperatures. Given the current trend of freshening in the Arctic Ocean, we expect seasonal freezing of the seabed to be more common for newly submerged permafrost caused by coastal erosion, and thus potentially leading to slower permafrost table degradation rates.

Modeling Reef Island Profile Morphodynamics

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Alejandra Ortiz, *North Carolina State University Raleigh North Carolina, United States*. aleja.ortiz@gmail.com
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Reef islands are carbonate detrital landforms perched atop shallow reef flats of atolls and barrier reef systems. Often comprising the only subaerial, inhabitable land of many island chains and island nations, these low-lying, geomorphically active landforms face considerable hazards from climate change. Sea-level rise and wave climate change will affect sediment transport and shoreline dynamics, including the possibility for wholesale reorganization of the islands themselves. Here we apply a hierarchical modeling approach to quantify the potential responses of reef island systems to future changes. Using parameterizations of sediment transport pathways and feedbacks from previously presented XBeach modeling results, we investigate how sea-level rise, change in storminess, and different carbonate production rates can affect the profile evolution of reef islands, including feedbacks with the shallow reef flat that bounds the islands offshore (and lagoonward). Model results demonstrate that during rising sea levels, the reef flat can serve as a sediment trap, starving reef islands of detrital sediment that could otherwise fortify the shore against sea-level-rise-driven erosion. On the other hand, if reef flats are currently shallow (likely due to geologic inheritance or biologic cementation processes) such that sea-level rise does not result in sediment accumulation on the flat, reef island shorelines may be more resilient to rising seas. This simplified modeling approach, focusing on boundary dynamics and mass fluxes, including carbonate sediment production, provides a quantitative tool to predict the response of reef island environments to climate change.

Understanding the Current State and Predictable Future Changes in the State of Permafrost Distribution in North-Western Himalayas, India

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The impacts of climate change on extent of permafrost degradation in the Himalayas are not well understood due to lack of historical ground-based observations. The area of permafrost exceeds that of glaciers in almost all Hindu Kush Himalayan (HKH) countries. However, very little is known about permafrost in the region as only a few local measurements have been conducted which is not sufficient to produce the fundamental level of knowledge of the spatial existence of permafrost. We intend to simulate permafrost conditions in Western Himalayas in India using Hyperspectral and Microwave remote sensing methods and computational models for the quantitative assessment of the current state of permafrost and the predictions of the extent and impacts of future changes. We also aim to identify the strength and limitations of remotely sensed data sets when they are applied together with data from other sources for permafrost modelling. We look forward to modelling ground temperatures using remote sensing data and reanalysis products as input data on a regional scale and support our analysis with measured in situ data of ground temperatures. Overall, we approach to model the current state and predictable future changes in the state of permafrost in Western Himalayas and also couple our results with similar research outcomes in atmospheric sciences, glaciology, and hydrology in the region.

Landlab Components for Surface Hydrology: the FlowAccumulator and the FlowDirectors

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Landlab is python software framework for the creation of surface dynamics and process models. It provides grid structures, stable and intercompatible process components, and utilities for data input, output and visualization. Here we present two new types of components within the Landlab framework: the FlowAccumulator and the FlowDirectors. These components have been designed to implement one of the basic functions of surface dynamics modeling, the routing and accumulation of water over a surface. These components split up the functionality of the previously implemented FlowRouter component in order to make it easier for the addition of new algorithms for flow direction to Landlab. As part of these components, we include a new algorithm for efficient flow accumulation when flow is routed to multiple neighboring nodes.

Routing of water over a surface can be split into two steps: direction and accumulation. Before outlining these steps, it is useful to state the terminology used to describe the grid. In Landlab the physical processes operate on a model grid which stores information about spatial location and properties that may vary in space (e.g. soil thickness, surface water discharge). The model grid is a dual plane graph in which quantities such as topographic elevation are defined at node points. Between neighboring node points are lines called links on which water, sediment, or other quantities can flow.

To route flow over the surface, flow directions at a given node must first be assigned to indicate which, if any, of the neighboring nodes will receive any flow that arrives in that node. This is typically done using the relative elevations of a node's neighbors. Previously Landlab supported the steepest descent (or D4) algorithm for both rectilinear and non-rectilinear grids and the D8 algorithms for rectilinear grids. As part of the presented improvement, Landlab includes the Multiple Flow Direction and D infinity algorithms. Each algorithm for directing flow is its own component, but all share core functionality of the FlowDirector class. This shared functionality includes attributes necessary for interacting with other Landlab components, including the FlowAccumulator. This design permits easy addition of new flow direction algorithms while maintaining interoperability with other Landlab components.

Once flow directions have been assigned, surface water discharge and drainage area can be calculated through flow accumulation. This functionality is provided by the FlowAccumulator component which is compatible with all FlowDirector components. Depending on the algorithm chosen, flow accumulation can be computationally inefficient, scaling at a rate greater than O(N). We present a new algorithm for accumulating flow for in the case where flow is directed to more than one receiver that scales with the number of links that flow is directed over.

Numerical Investigation of the Role of Slope and Flow Dynamic Characteristics on the Fill-and-Spill Process and Deposit in Linked Submarine Intraslope Minibasins.

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Salt and shale based minibasins are quasi-circular depression connected by submarine canyons of economic importance because they are prime locations of hydrocarbon reservoirs. The history of sedimentation of the minibasins is modulated by sea level changes, and it is strongly influenced by basin topography and continental shelf dynamics. Sedimentation in intraslope minibasins is generally described in terms of the fill-and-spill model in which the turbidity currents enter a minibasin and are reflected on the minibasin flanks. After the reflection, the turbidity currents pond and deposit the suspended sediment. As the minibasin fills, the current spill over the lowermost point of the minibasin flanks and reaches the next minibasin downslope, where the fill and spill process starts again. In this stage, deposition still occurs in the upslope minibasin with the formation of channel-levee complexes. In the last two decades field, laboratory and numerical studies focused on the description of (1) the large-scale stratigraphic architecture and evolution of the minibasins and (2) the behavior of the turbidity currents in the minibasin-canyon system. This notwithstanding, questions regarding the spatial distribution of the grain sizes in minibasin deposits, the role of the system geometry and of the flow characteristics of the turbidity current on the depositional pattern still need to be answered. The objective of the present study is to investigate with three-dimensional model simulations how the deposit characteristics change for increasing in slopes of the minibasin-canyon system. In particular, we are using a three-dimensional numerical model of turbidity currents that solves the Reynolds-averaged Navier–Stokes equations for dilute suspensions. Turbulence is modeled with a buoyancy-modified k–ε closure. The numerical model has a deforming bottom boundary to model the changes in elevation and grain size characteristics of the bed deposit associated with sediment erosion and deposition. Here we present the model validation against 1) 2D laboratory experiments of a horizontal minibasin in a constant width flume, and 2) 3D laboratory experiments on two linked minibasins. The model validation is performed comparing measured and simulated deposit geometries, vertical profiles of suspended sediment concentration and spatial distributions of sediment sizes in the deposit. In the near future, we will perform laboratory scale simulations by changing the slope of the experimental minibasin, i.e. the difference in elevation between the entrance and the exit points to study how the depositional pattern changes when the relative size of the ponded accommodation space, i.e. the space at a lower elevation than the spill point, and the perched accommodation space, i.e. the space under an ideal line connecting the spill point and the minibasin entrance.

Understanding River Terrace Formation and Destruction, Channel Lateral Mobility, and River Valley Widening from Base Level Fall Experiments

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Fluvial terraces are commonly interpreted as recorders of past environmental (e.g. tectonic or climatic) conditions. However, controls on terrace formation through river incision, and on the destruction of terraces through lateral erosion are poorly understood. Here, we present results from a physical experiment performed at the St. Anthony Falls Laboratory that provide insights into the formation and preservation potential of alluvial terraces, into dynamics of alluvial valley width, and the dependence of these parameters on external forcings: primarily on river response to base level fall. The model was performed in a wooden box with dimensions of ~4 meters by ~2.5 meters by ~0.5 meters, which was filled with silica sand with a unimodal grain size distribution (D50= 0.14 mm). Sediment and water were mixed and fed into the box via a gravel diffuser to inhibit scour. A single channel incised down to the base level, which was steadily lowered by a weir. Six experiments were performed, each with a constant water discharge of 0.1 L/s and a sediment flux of 0.022 L/s, and with a base-level fall rate of 0mm/hr, 25mm/hr, 50mm/hr, 200mm/hr, 300mm/hr, and 400mm/hr. We collected aerial photographs every 20 seconds and digital elevation models (DEMs) every 15 minutes throughout each experiment. Terraces formed in the experiments with base level fall due to incision and headwards knickpoint retreat. Major sidewall collapses and progressive valley widening were observed and controlled by the lateral migration of the channel.

Probabilistic Sediment Continuity Equation with No Active Layer

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In recent years a large number of numerical models have been developed and implemented to study basic and applied problems of research moprhodyanmics. Some of these models treat the bed material as uniform; others consider the bed material as a mixture of sand and gravel. The vast majority of the morphodynamic models that account for the non-uniformity of the bed material size are based on the active layer approximation, i.e. the channel bed deposit in two different regions. The active layer, which is the topmost part of the bed deposit, is modeled as mixed layer whose particles can interact with the bed material transport. Particles in the rest of the channel deposit, the substrate, can be exchanged with the bed material transport only when the channel bed aggrades or degrades. Morphdynamic formulations based on the active layer approximation, however, have well known limitations:1) they neglect the vertical fluxes within the deposit associated with e.g. bedform migration, 2) they cannot capture the infiltration of fine sediment and tracer stone dispersal and 3) the statistical nature of sediment entrainment is neglected. To overcome these limitations, Parker and coauthors in 2000 introduced a continuous, i.e. not layer-based, morphodynamic framework based on a stochastic description of the bed surface elevation, of the entrainment and deposition. In this framework particle entrainment rates are computed as a function of the flow and sediment characteristics, while particle deposition is estimated with a step length formulation. However, due to the lack of mathematical functions describing the variability of bed elevation, entrainment and deposition, the continuum framework has never been implemented. Here we present one of the first implementation of the continuum framework at laboratory scale and its validation against laboratory experiments on tracer stones dispersal. The validated model is then used to investigate the dependence of the model results on different particle step lengths.

Using Individual-based Models and Animal Movement to Evaluate Habitat-use Intensity in Fragmented Landscapes: a Case Study Using an Ecosystem Engineer in Central Brazil

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Agricultural expansion has led to high rates of deforestation and land-use change in tropical ecosystems, relegating many of the remaining native forests to networks of fragmented patches. As a result, large forest-dwelling ungulates may alter movement and habitat-use patterns to accommodate for the changed spatial orientation of essential resources. In turn, some native patches may be subjected to increased ungulate impacts (e.g. trampling, bioturbation, and seed dispersal/ predation), while others may be devoid of these influences. We created an individual-based model utilizing empirical ungulate movement data from white-lipped peccaries (WLP) in the Brazilian Cerrado to evaluate variations in habitat use with degree of fragmentation (e.g. connectivity and number of patches) and percent of native forest cover (FC). In the model, a peccary herd moves across a landscape with a percent FC between 10% and 100% and one to four native forest patches. We then quantified the distribution of habitat-use intensity and percent of unused native habitat after five years. To empirically quantify impacts of white-lipped peccary habitat use, we measured seedling density in 72 1x1 plots in the Cerrado, 44 with and 28 without WLP.
Results indicate that in a fully-connected landscape (one-patch simulations), as percent FC decreases, the frequency distribution of habitat use goes from narrow and left-skewed (low use in the majority of the habitat) to widely and evenly distributed (no use to high use in distinct parts of the habitat), reflecting a more heterogeneous use of the habitat with less FC. In a fragmented landscape (two-four patch simulations) below 30% FC, habitat use is driven by the degree of connectivity between forest patches. However, above 60% FC, the percent of unused forest is negligible (similar to one-patch simulations), indicating that patch spatial configuration is no longer the driving factor of habitat use past a 60% FC

threshold. Between 40% and 60% FC, habitat use is a function of both connectivity and percent FC. Preliminary empirical results suggest riparian forests have the greatest difference in mean seedling density between areas with or without WLP, while palm swamps have the least. Collectively, these results suggest conservation measures in agricultural landscapes should emphasize percent FC, connectivity, or both, depending on the amount of forest remaining and that riparian zones may be most adversely affected by the loss of large ungulates.

Groundwater Storage Contributions to Sea Level at and Since the Last Glacial Maximum

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Changing sea level and ice volume since the Last Glacial Maximum (LGM, 26-19 ka) has been an intensively studied topic for decades, and yet we have still not been able to adequately close the water volume budget at the LGM. At the LGM, global sea level was depressed by approximately 125-135 m relative to the present level. Past researchers have attempted to account for the storage of this water as an estimated 52*106 km3 of land-based ice. However, relative sea level, ice sheet morphology, and isostacy studies at local and regional scales have been unable to reasonably place high enough ice volumes to meet this global total, accounting for only approximately 120 m of sea-level change. This discrepancy has resulted in the so-called 'missing ice' problem.

We propose that some portion of this 'missing' water was stored not as ice, but in lakes and groundwater. Thus far, no studies have attempted to determine the volume of water stored in lakes and groundwater at the LGM. Groundwater storage could potentially account for a large volume of water, reducing the missing water volume by a significant margin. Differing topography and recharge rates may have resulted in greater terrestrial water storage, which can help us to close the water budget. Indeed, many large proglacial and pluvial lakes are known to have existed and may indicate higher groundwater levels. Furthermore, assessing groundwater levels at 500 year intervals from the LGM to the present day can provide insights into changes in water storage and inputs to the ocean over time.

It is challenging to assess groundwater levels with precision since various factors, including evapotranspiration, topography, and sea level all play a role in controlling groundwater level at a particular location. However, a recent model (Reinfelder et al., 2013) was able to estimate modern groundwater levels on a global scale. By using this model in combination with modelled topography and climate data for the LGM and each 500 year time step, we are able to compare the volume of water stored in the ground from the LGM to the present day to test whether groundwater would be a viable reservoir for LGM water storage. The model provides depths to water table, thus allowing computation of changing storage volumes.

The model covers the entire globe at a resolution of 30 arc-seconds. The large datasets and iterative nature of the model require MSI's computational power to perform the calculations. So far, preliminary results have shown that over a metre of additional sea-level equivalent water was stored in the ground at the LGM.

Very Fine Scale of Permafrost Distribution and Controlling Factors

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Besides long-term monitoring in changes of thermal state of permafrost and active layer thickness, the knowledge of permafrost distribution at very fine scales (tens of meters) in discontinuous permafrost is still largely unknown in Qinghai-Tibet Plateau (QTP). A permafrost island was found by using geophysical investigations in the Heihe River Basin in northeastern QTP. Permafrost island was present at PT10 site beneath alpine steppe and coarse soil with a quality of gravel in surface soil (Fig. 1, Fig. 2). In contrast, permafrost is absent at SFGT site with density land cover area and relatively less gravel. The results showed that the ground surface temperature (5 cm) at PT10 site is lower in winter and higher in summer than the SFG site. The presence of permafrost is caused by soil conditions, especially by high thermal conductivity, based on field investigations. To address the controlling factors of permafrost presentences a 1D heat transfer model is used to compare the ground temperature difference between these two sites by only changing the soil conditions.

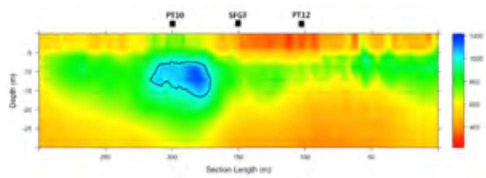

Fig. 1 ERT measurements conducted in 31/07/2015 with an electrode probe interval of 5 m. Permafrost island are roughly determined by the resistivity contour of 1010 Ω, which is the resistivity value at the interface of frozen/unfrozen. Borehole locations are marked by black squares.

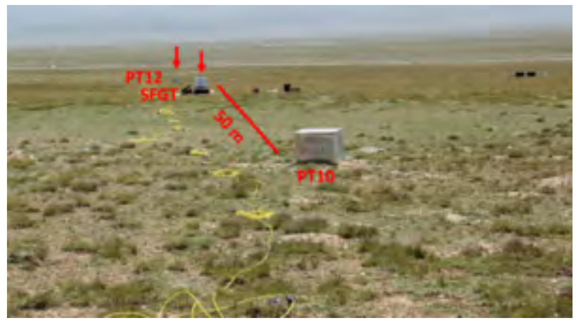

Fig. 2 Photograph of land cover taken in 31/07/2015

Intermittency, Sediment Advection Length Distribution, and Delta Island Development

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To better understand large-scale delta-network responses to fluctuating discharge, we focused on the evolution of a single channel-island node within a delta network. Using the Surface Transport and Earth-surface Processes (STEP) basin, we were able to construct and observe the evolution of mouth-bar systems and subsequent flow bifurcation around an individual island in transport-limited, turbulent conditions. Overhead time-lapse images, laser-altimetry scans, and a low-cost particle tracking velocimetry system allow us to characterize the flow and depositional evolution of our experimental islands. Two alternating discharges that model flood and interflood transport (6 l/s, 0.355 l/s) with uniform sediment (170 microns) were used to create two characteristic sediment advective lengths. Floods transport sediment in full suspension (P_flood at inlet = 0.16), while interfloods transport sediment as bedload (P_interflood at inlet = 2.7). The consequent deposits are distal steep deposits from floods raining sediment out of suspension, and proximal low-angle, leveed deposits from interfloods laterally advecting sediment and floods remobilizing sediment down-system. By varying the frequency of floods (one every 20s-20 mins) while keeping sediment and water mass constant across experiments, we are able to control the time and spatial organization of these two deposit types and examine the effect on bifurcation length and bifurcation incidence time. While the deposits are initially spatially segregated, as the interflood deposit and flood deposit accumulate sediment over time, the interflood deposit encroaches onto the flood deposit. Flow routes from the interflood deposit to the flood deposit and bifurcates because of a preferential slope gradient around the distal deposit. Rather than a single hydrodynamic condition dictating the location of bifurcation, the length to a bifurcation can be described by the intersection of multiple distributions of topographies from the variable flow of solids.

Modeling a Coastal Environment with Human Elements

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If one system comes to (my) mind where the human element is intertwined with the environment, it is the Louisiana coastal area in the Southern United States. Often referred to as the working coast, coastal Louisiana supports large industries with its ports, navigation channels, oil, and productive fisheries. In addition to that, Louisianians have a significant cultural connection to the coastal wetlands and their natural resources. Unfortunately, the land is disappearing into the sea with coastal erosion rates higher than anywhere else in the US. Due to these high rates of land loss, this system needs rigorous protection and restoration. While the restoration plans are mostly focused on building land, the effects on, for example, fisheries of proposed strategies should be estimated as well before decisions can be made on how to move forward. Through several projects I have been involved in, from small modeling projects to bold coastal design programs, I present how coupled models play a key role in science-based coastal management that considers the natural processes as well as the human element.

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Rapid Algorithm for Convolution Integral-like Flux Formulations

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Recent research has highlighted the idea that long distance particle motions can be a significant component of the hillslope sediment flux. In this situation, mathematical descriptions of hillslope sediment transport must be nonlocal. That is, the flux at a position x, is a weighted function of conditions around x. This contrasts with local conditions which state that the flux is only a function of conditions at x. There are several ways to incorporate nonlocality into a mathematical description of sediment transport. Here, we focus on implementing and testing a convolution integral-like formulation. In this case, the flux is a convolution integral of a volumetric entrainment rate and a kernel that is related to the probability distribution of particle travel distance. Computation of convolution integrals is typically done by taking advantage of the convolution theorem for Fourier transforms, where a convolution integral becomes multiplication in wavenumber domain. However, in our case, the kernel is a function of position, and therefore precludes us from taking advantage of this method. Here, we apply a method that can reduce the problem back to a proper convolution integral and therefore allows for rapid computation (Gilad and von Hardenberg, 2006). We use this method to demonstrate nonlocal transport on lateral moraines on the east side of the Sierra Nevada. This method has applications in all convolution integral-like formulations including nonlinear filtering.

(Un)sustainability of Deltas Under Potential Future Changes in Sediment Delivery

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Delta environments, on which over half a billion people live worldwide, are sustained by sediment delivery. Factors such as subsidence and sea level rise cause deltas to sink relative to sea level if adequate sediment is not delivered to and retained on their surfaces, resulting in flooding, land degradation and loss, which endangers anthropogenic activities and populations. The future of fluvial sediment fluxes, a key mechanism for sediment delivery to deltas, is uncertain due to complex environmental changes which are predicted to occur during the coming decades. Fluvial sediment fluxes under environmental changes were investigated to assess the global sustainability of delta environments under potential future scenarios up to 2100. Climate change, reservoir construction, and population and GDP (as proxies for other anthropogenic influences) change datasets were used to drive the catchment numerical model WBMsed, which was used to investigate the effects of these environmental changes on fluvial sediment delivery. This method produced fluvial sediment fluxes under 12 scenarios of climate and socioeconomic change which are used to assess the future sustainability of 47 deltas, although the approach can be applied to deltas, rivers, and coastal systems worldwide. The results suggest that fluvial sediment delivery to most deltas will decrease throughout the 21st century, primarily due to anthropogenic activities. These deltas will likely become unsustainable environments, if they are not already, unless catchment management plans are drastically altered.

Sustainability and Operational Design of Sediment Delivering River Diversions

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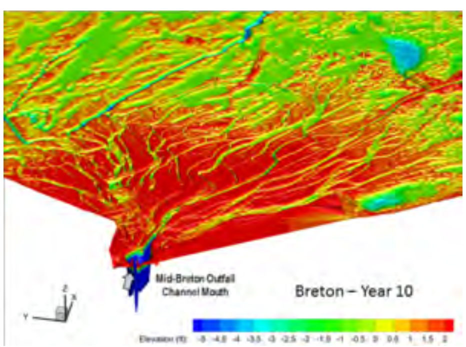
Sea level rise presents an urgent threat to the occupants of river deltas. However, while low lying deltaic landscapes are at risk of significant drowning, the ability to harness a river's sediment delivery system offers deltaic populations a mechanism to control the location and extent of land loss via land building sediment diversions. Despite their well-recognized importance there are few examples of diversions that have been intensively monitored throughout their development to the extent necessary to support engineering decisions.

In order to guide the operational design of two planned diversions in the Lower Mississippi River, we apply Delft3D to simulate diversion discharge through time as a function of the characteristics of the receiving basin. In both cases the conveyance channel connecting the river to the basin is prevented from eroding.

We find that diversions in basins that offer many outlets for flow are more likely to maintain their discharge over a ten-year time horizon. We also find that diversion performance is not significantly affected by substrate erodibilities in the range of those found in the Mississippi River Delta, but that artificially increased bed strength would lead to decreases in performance. Our work also sheds light on the spatial pattern of erosion near a diversion. We find that very little erosion into the substrate occurs away from the immediate vicinity of the outfall channel, but that the evolution of the proximal scour is a critical control on the sustainability of the diversion. Ecological considerations suggest that operating diversions at low flow might be useful, but this practice increases the risk of back flow from the receiving basin.



EF5: A Hydrologic Model for Prediction, Reanalysis and Capacity Building

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The Ensemble Framework For Flash Flood Forecasting (EF5) was developed to address a critical need for rapidly updating distributed hydrologic models capable of predicting flash floods. In the U.S. EF5 is used to run a 3-member ensemble forced by radar based precipitation as part of the Flooded Locations And Simulated Hydrographs (FLASH) product suite used by NWS. As part of the FLASH project a reanalysis was conducted from 2002-2011 to examine a climatology of flash flood events across the U.S. EF5 is also used by a NASA SERVIR applied science team for capacity building in East Africa. EF5 was designed with this use case in mind and as such is user-friendly with helpful error messages, cross-platform support, and open source.
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Connecting Human and Natural Systems: The Role of Agent-Based Simulations

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Human settlements in dynamic environmental settings face the challenges both of managing their own impact on their surroundings and also adapting to change, which may be driven by a combination of local and remote factors, each of which may involve both human and natural forcings. Impacts of and responses to environmental change play out at multiple scales which involve complex nonlinear interactions between individual actors. These interactions can produce emergent results where the outcome at the community scale is not easily predicted from the decisions taken by individuals within the community. Agent-based simulations can be useful tools to explore the dynamics of both the human response to environmental change and the environmental impacts of human activity. Even very simple models can be useful in uncovering potential for unintended consequences of policy actions. Participatory simulations that allow people to interact with a system that includes simulated agents can be useful tools for teaching and communicating about such unintended consequences. I will report on progress on agent-based simulations of environmentally stressed communities in Bangladesh and Sri Lanka and preliminary results of using a participatory coupled model of river flooding and agent-based real estate markets to teach about unintended consequences of building flood barriers.

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The Agricultural Terraces Model (AgrTerrModel): Exploring Human-Environment Interactions in Terraced Landscapes

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Integration of humans within landscape evolution models (LEM) as responsive actors in complex human-environmental systems, is still in its infancy. LEMs that included human decision-making have done so either entirely within an agent-based model (ABM) (e.g., CYBEROSION (Wainwright 2008)) or by coupling an ABM with a LEM (e.g., MedLanD (Barton et al. 2012)). These LEM-ABM examples have analyzed the effects of land use and tillage decisions on landscape evolution, but other ways in which humans interact with geomorphic systems have yet to be explored. Our research expands human-environment interaction modeling to landscapes modified by agricultural terraces to explore the long-term geomorphic evolution in these regions.
Agricultural terraces are anthropogenic landforms that have been constructed for centuries in many parts of the world. Despite their widespread distribution and well-known reduction of sediment transport, terraces have rarely been included within LEMs (cf. Lesschen, Schoorl, and Cammeraat 2009). Recent research on agricultural terraces has revealed that terrace abandonment often increases soil erosion and landscape degradation, reversing landscape evolution patterns modified by terrace construction (Tarolli, Preti, and Romano 2014/6; Arnáez et al. 2015/5). We present the Agricultural Terraces Model (AgrTerrModel), which is a coupled LEM-ABM system for analyzing long-term human-environment interactions in terraced landscapes. The LEM component is implemented using the Landlab library and features adjustments to governing landscape evolution equations to reflect changes to geomorphic processes after terrace construction, such as the impact of stone terrace walls that block sediment movement downslope. The ABM component is implemented using the Mesa ABM framework and includes mechanisms for terrace wall collapse and maintenance, as well as agents who determine

cultivation and maintenance practices for terraced land. Using the AgrTerrModel, we simulate landscape evolution in Vernazza, Liguria, Italy near Cinque Terre to analyze how the timing and amount of terrace wall maintenance affects sediment transport. The interaction between seasonal precipitation and the timing of terrace wall maintenance is of special interest due to the Mediterranean climate of the study area. This project provides new insights into the evolution of terraced landscapes and an avenue for further research into the complexity of human-environment systems.

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Process Linkages in the WRF-Hydro/NOAA National Water Model: Different Processes Operating on Different Scales

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The community WRF-Hydro system has evolved from a basic land surface modeling scheme for atmospheric models into a more comprehensive operational hydrologic prediction system. Key to this evolution was explicit accounting for the need to represent different processes at different scales or with different types of spatial representations. The most recent evolution of the WRF-Hydro system was its implementation as the modeling system supporting the new NOAA National Water Model which become officially operational in August of 2016. This presentation will discuss the different kinds of configurations utilized within the NOAA National Water Model (NWM) and how the WRF-Hydro system was adapted to meet those requirements. Specific emphasis will be placed on describing the spatial transformations and flux passing methods that were required to maintain coupling between different parts of the forecasting system. Also discussed will be future work that is planned to enable new process representations within the NWM and how modeling approaches under the CSDMS has influenced this development.

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Evaluating Luminescence as a Sediment Transport Metric

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The role of climate change on landscapes is one of the most difficult remaining challenges in geomorphology. It is thought that climate primarily modifies landscapes through sediment production and transport in rivers. However, collecting the data needed to resolve the relationship between climate and sediment transport has remained elusive. This issue stems from a lack of a methodology that can work in a wide variety of river environments. Furthermore, this problem is made pressing by a need to understand the coming effects of human-induced climate change.

To address this problem, I developed a model to capture sediment transport using luminescence, a property of matter normally used to date sediment deposition. Luminescence is generated via exposure to background ionizing radiation and is removed by exposure to sunlight. This behaviour is sensitive to sediment transport and could potentially be used to infer sediment transport parameters. I derive the model by performing a simultaneous conservation of sediment mass and absorbed radiative energy expressed as luminescence. The derivation results in two differential equations that predict the luminescence at any point in a river channel network. The model includes two key sediment transport parameters, the sediment transport velocity and the storage-center exchange rate. From these parameters, other key sediment transport variables such as the characteristic transport length-scale and the sediment virtual velocity can be calculated. These parameters can be constrained by determining the model's luminescence parameters through field measurement and lab experiments.

I test my model against luminescence measurements made in rivers where these sediment transport parameters are well known. I find that the model can reproduce the observed patterns of luminescence in channel sediment and the parameters from the best-fit model runs reproduce the known sediment transport parameters within uncertainty. The success of the model, and the advent of new technology to measure luminescence using portable devices, suggests that it may now be feasible to collect critical sediment transport data cheaply and rapidly. This method can now be used to test outstanding hypotheses of the influence of climate on sediment transport.

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Pathways at the Coastal Land Margin to Assess Climate Change Impacts with Transdisciplinary Research Outcomes

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Our extensive transdisciplinary efforts since 2010 in the northern Gulf of Mexico (Mississippi, Alabama, and the Florida panhandle) have resulted in an advanced capability to model and assess hydrodynamic and ecological impacts of climate change at the coastal land margin.
(visit http://agupubs.onlinelibrary.wiley.com/hub/issue/10.1002/(ISSN)2328-4277.GULFSEARISE1/).
The concerted efforts of natural and social scientists as well as engineers have contributed to a paradigm shift that goes well beyond "bathtub" approaches. Potential deleterious effects to barrier islands, shorelines, dunes, marshes, etc., are now better understood. This is because the methodology enables assessment of not just eustatic sea level rise (SLR), but gets to the basis of projections of climate change and the associated impacts, i.e., carbon emission scenarios. The paradigm shift, input from coastal resource managers, and future expected conditions now provides a rationale to evaluate and quantify the ability of natural and nature-based feature (NNBF) approaches to mitigate the present and future effects of surge and nuisance flooding.

Over the majority of the 20th century, the largely linear rate of eustatic SLR was realized by thermal expansion of seawater as a function of a gradual increase in the average annual global temperature. Global satellite altimetry indicates that the rate of global mean SLR has accelerated from approximately 1.6 to 3.4 mm/year. While the year-by-year acceleration of the rate of rise cannot be measured adequately, it is reasonable to assume that it was relatively stable throughout the 20th century. For the 21st century, general circulation models project that posed atmospheric carbon emission scenarios will result in higher global average temperatures. A warmer global system will introduce new mechanisms (e.g., land ice loss, isotatic adjustments, and changes in land water storage) that will contribute to relatively abrupt changes in sea state levels. The additions to thermal expansion will drive higher sea levels and the increases in sea level will be attained by further accelerations in the rate of the rise. Because of the nature of the new mechanisms that will govern sea levels, it is unlikely that future accelerations in the rate of rise will be smooth. To further address the complications associated with relatively abrupt changes in SLR and related impacts of climate change at the coastal land margin we intend to: (1) refine, enhance, and extend the coupled dynamic, bio-geo-physical models of coastal morphology, tide, marsh, and surge; (2) advance the paradigm shift for climate change assessments by linking economic impact analysis and ecosystem services valuation directly to these coastal dynamics; (3) pursue transdisciplinary outcomes by engaging a management transition advisory group throughout the entire project process; and (4) deliver our results via a flexible, multi-platform mechanism that allows for region-wide or place-based assessment of NNBFs. This presentation will share examples of our recent efforts and discuss progress to-date.

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Connecting Tidal Channels and Platforms in a Meso-tidal Mangrove Stand

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The Sundarbans National Forest (SNF) is a critical cultural, ecologic, and economic resource to the country of Bangladesh. Despite widespread land use changes in the surrounding region, sedimentation within the SNF has managed to keep pace with local rates of sea level rise (e.g., Rogers et al., 2013). This study explores some of the controls on sedimentation, with the goal of investigating their vulnerability to future change. Specifically, we examine the depth and frequency of platform inundation, suspended sediment concentration (SSC), sediment grain size, and the volume of water exchanged, and how these factors vary across time scales ranging from spring-neap tidal cycles through monsoon-dry season cycles. We observe pronounced seasonality, with the monsoon season experiencing the most frequent platform inundation, highest SSC, and greatest volume of water exchanged. Sediment grain size appears to vary spatially rather than seasonally, with a gradual decrease in grain size away from the primary tidal channel: the nominal sediment source. Of particular interest is how the seasonality of SSC varies between primary tidal channels like the Shibsa River, and the smaller tidal channels delivering sediment to the platform. On the Shibsa, spring tide SSC maxima during the monsoon and dry season are similar (~1.3 g/l), while neap tide SSC maxima are <0.5 g/l in either season. In channels within the SNF, monsoon spring tides exhibit peak SSC >1 g/l, while dry season SSC is always <0.5 g/l. Understanding why the source of local sediment (i.e., the primary tidal channel) behaves differently from the channels delivery that sediment to the platform presents an important knowledge gap that future research will examine in detail.

Flocculation and Bed Consolidation in a Partially Mixed Estuary: an Idealized Numerical Sediment Transport Model

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Particle settling velocity and bed erodibility impact the transport of suspended sediment to the first order, but are especially difficult to parameterize for the muds that often dominate estuarine sediments. For example, fine grained silts and clays typically form loosely bound aggregates (flocs) whose settling velocity can vary widely. Properties of flocculated sediment such as settling velocity and particle density are difficult to prescribe because they change in response to several factors, including salinity, suspended sediment concentration, turbulent mixing, organic content, and mineral composition. Additionally, mud consolidates after deposition, so that its erodibility changes over timescales of days to weeks in response to erosion, deposition, dewatering, and bioturbation. As understanding of flocculation and consolidation grows in response to recent technical advances in field sampling, numerical models describing cohesive behavior have been developed.

For this study, we implement an idealized two-dimensional model that represents a longitudinal section of a partially mixed estuary that mimics the primary features of the York River estuary, VA; and accounts for freshwater input, tides, and estuarine circulation. Suspended transport, erosion, and deposition are calculated using routines from the COAWST (Coupled Ocean-Atmosphere-Wave-and-Sediment Transport) modeling system. Here we evaluate the impact that bed consolidation and flocculation have on suspended sediment dispersal in the idealized model using a series of model runs. The simplest, standard model run neglects flocculation dynamics and consolidation. Next, a size-class-based flocculation model (FLOCMOD) is implemented. The third model run includes bed consolidation processes, but neglects flocculation; while the last model run includes both processes. Differences in tidal and daily averages of suspended load, bulk settling velocity and bed deposition are compared between the four model runs, to evaluate the relative roles of the different cohesive processes in limiting suspension in this partially mixed estuary. With an eye toward implementing these formulations in a realistic-grid model, we also consider the computational cost of including flocculation and consolidation.

How Significant is Irrigation for Flood Inundation Modeling in Deltas?

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Deltas are home to approximately 7% of global population and play a crucial role in regional food security owing to the favorable conditions for agriculture. As a result, these areas are often heavily irrigated as humans strive to use the local water resource to maximise production. This study aims to incorporate irrigation practices into the LISFLOOD-FP hydrodynamic model to determine the impact of irrigation on the flood dynamics of the Mekong Delta, one of the most intensively irrigated deltas. Irrigation data is based on global databases of irrigation area, crop type and crop calendars, supplemented with local information allowing for this approach to be used across irrigated areas around the world. This study therefore builds upon the localized estimates of flood storage capacity of paddy fields through the region and generates a new estimate across a wider area that is subsequently used to assess the impact on the hydrodynamics and flood inundation pattern. It is envisaged this approach can be used for future analysis of the impact of the changing irrigation practices of the Mekong Delta.

Experimental investigation of soil creep under porous flow condition

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Sediment transport modeling is challenging in all systems and flow regimes. Rivers, soils, and sea margins share a common feature: as their boundaries are mobile and constantly adapting, they tend to always be near the threshold of entrainment.

This difficulty becomes dramatic for steep soils, only doing very slow granular creep, but whose ultimately, under statistically rare conditions, can turn into a landslide, a very fast avalanche flow [Houssais and Jerolmack, 2017]. The abrupt transition from soil creep to avalanching remains mostly non-understood. Yet, capturing its dynamics -- being able to predict a regional statistics for landslide depending on topographic, tectonic and climatic conditions -- would allow for much more accurate landscape evolution modeling. We present here preliminary results of an experimental investigation of one the major triggering condition for soils destabilization: rain infiltration, and more generally porous flow through a tilted granular bed. In a quasi-2D microfluidics channel, a flat sediment bed made of spherical particles is prepared, in fully submerged condition. It is thereafter tilted (at slope under critical slope of avalanching) and simultaneously put under vertical weak porous flow (well under the critical flow of liquefaction regarding positive pressure gradients). The 2 control parameters are varied, and local particles concentration and motion are measured. Interestingly, although staying in the sub-critical creeping regime, we observe an acceleration of the bed deformation downward, as the porous flow and the bed slope are increased, until the criteria for avalanching is reached. Those results appear to present similitudes with the case of tilted dry sediment bed under controlled vibrations. Consequently it opens the discussion about a potential universal model of landslides triggering due to frequent seismological and rainstorm events.

Testing a New Global Bedload Flux Model

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Proper quantification of sediment flux has always been an area of interest both for scientist and engineers involved in hydraulic engineering and management of rivers, estuaries and coastal waters. In spite of the importance of bedload flux globally, either for monitoring water quality, maintaining coastal and marine ecology or during dam construction or even for food security, bedload data, especially for large rivers, extremely scarce. This is due to the fact that bedload flux measurements are relatively expensive and time consuming and introduce large spatial and temporal uncertainties. Lack of adequate and continuous field observation is a hindrance to developing a globally accepted numerical model. We developed a new global riverine bedload flux model as an extension of the WBMsed framework. Here we present an evaluation of the model predictions using over eighty field observations for large rivers (over 1000 km2), collected from different sources. This model will be used to study various aspects of fluvial geomorphology globally, which is most common interest area for the researcher to see the impacts of different issues at global scale. Also, considering the contribution of bedload as sediment in the global level, it will elucidate the relationship between suspended sediment and bedload. The observational dataset we compiled is in itself a unique product that can be instrumental for future studies.

Evolving Patterns of Glaciers and Summer Stream Flow in the Pacific Northwest US: 1960-2100

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The Pacific Northwest is the only region in the conterminous United States with a sizable number of glaciers (328 glaciers totaling ~380 km). The glaciers of this region have displayed ubiquitous patterns of retreat since the 1980's mostly in response to warming air temperature. Glacier melt in partially glacierized river basins in the region provides water for downstream anthropogenic systems (e.g., agricultural water supply and hydroelectric power generation) and sensitive ecological systems (e.g., fisheries, upland riparian habitat). While changes in glacier area have been observed and characterized across the region over an extended period of time, the hydrologic consequences of these changes are not fully understood. We applied a state of the art high resolution glacio-hydrological simulation model along with regional gridded historical and projected future meteorological data, distributed observations of glacier mass and area, and observations of river discharge to predict evolving glacio-hydrological processes for the period 1960-2100. We applied this approach to six river basins across the region to characterize the regional response. Using these results, we generalized past and future glacier change across the entire PNW US using a k-means cluster analysis. Our analysis shows that while the rate of glacier recession across the region will increase, the amount of glacier melt and its relative contribution to streamflow displays both positive and negative trends. Among the characteristics that control the direction and magnitude of future trends, elevation dominates and climatic factors play a secondary role. In high elevation river basins enhanced glacier melt will buffer strong declines in seasonal snowmelt contribution to late summer streamflow for some time, before eventually declining. Conversely, in lower elevation basins, reductions in glacier melt will exacerbate negative trends in summer runoff in the near term.

Modeling Hydrothermal Interaction Within 2D Hillslope

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Arctic hydrological processes impose an important feedback on permafrost thermal conditions. Changes in permafrost hydrology could accelerate its thawing, resulting in a positive effect on permafrost carbon decomposition rates. Therefore, it is important to understand how geomorphic and other landscape processes control permafrost distribution and its properties such as soil saturation, ice content, active layer thickness (ALT) and temperature. The Advanced Terrestrial Simulator (ATS) is a collection of hydro-thermal processes designed to work within a flexibly configured modeling framework. ATS includes the soil physics needed to capture permafrost dynamics, including ice, gas, and liquid water content, multi-layered soil physics, and flow of unfrozen water in the presence of phase change. In this study, we directly address one of the tasks of the NGEE-Arctic project by modeling the effect of climate and environmental drivers on ALT and permafrost thickness and its distribution along the subarctic hillslope. Model runs demonstrate the likely role of vegetation-snow-permafrost-hydrology interactions by exploring snow depth and organic layer influence on horizontal and vertical patterns of permafrost. Understanding changes in hydrologic flow paths and soil moisture is important to predict evolution of ecosystem and biogeochemical processes that control climate feedbacks. In addition, hillslope flowpaths, vegetation, soil organic matter distribution, variation in soil depth and mineralogy are important components of the subgrid spatial extent of permafrost. This study explores the ways to improve the quality of the permafrost predictions at the subgrid scale and contribute to the better modeling of the permafrost related processes at the pan-Arctic scale.

Two Modeling Cultures

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The theme of this meeting is Modeling Coupled Earth and Human Systems. Since the World3 model and the Limits to Growth report of 1972 there has been a sustained effort of integrated modeling of human activities and the Earth system. Despite the existence of integrated models, there is an increasing recognition that the social science is largely lacking from the modeling efforts. Having worked in both natural science and social science departments, I reflect on the different modeling cultures and the challenges in social science to use simulation models. Building on the work of the CoMSES Net I also provide some promising examples of agent-based models advancing social science.

https://youtu.be/q0Gb4YxTHVc
http://csdms.colorado.edu/mediawiki/images/Marco_Janssen_CSDMS_2017_annual_meeting.pptx
http://csdms.colorado.edu/mediawiki/images/Marco_Janssen_CSDMS_2017_annual_meeting.pdf

Modeling the Physical States of Intensely Biological Seabeds

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Fresh impetus has been given to efforts for a unified bio+geo understanding of seafloor physical properties. In part the requirement comes from practical needs in: the dependability of automated modules (Autonomous Underwater Vehicles), for object detection (e.g. unexploded ordinance), and for more accurate Acoustic Seafloor Classification in habitat mapping. By the combination of various techniques, and especially new information resources, the opportunities for fresh advancement in the field have recently increased.

The new information resources include semantic structures such as Encyclopedia of Life, WoRMS, Traitbank and others where the characteristics of organisms are described, including their lifecycles, engineering activities, morphologies. They also include environmental databases of ever increasing resolution and scope, such as photosynthetically available radiation, sediment types, water flows, particulate matter and nutrients.

The challenge is a significant one, to combine these factors, but there are some approaches which have been tested and found very promising. Some are described in this poster. They include simulations (rather than analytical models) with data formats derived from the 3D printing industry, agent-based approaches, population models of various types (including cellular models), and more.

Global change, often human-induced, is causing a re-balancing between 'barren' sediment-dominated areas and those which are intensely colonized. Models such as these are required to see ahead to the consequences and management of the changes.

A Service-Oriented Architecture for Coupling Web Service Models Using the Basic Model Interfaces (BMI)

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Coupling models from different domains (e.g., ecology, hydrology, geology, etc.) is usually difficult because of the heterogeneity in operating system requirements, programming languages, variable names, units and tempo-spatial properties. Among multiple solutions to address the issue of integrating heterogeneous models, a loosely-coupled, serviced-oriented approach is gradually gaining momentum. By leveraging the World Wide Web, the service-oriented approach lowers the interoperability barrier of coupling models due to its innate capability of allowing the independence of programming languages and operating system requirements. While the service-oriented paradigm has been applied to integrate models wrapped with some standard interfaces, this paper considers the Basic Model Interface (BMI) as the model interface. Compared with most modeling interfaces, BMI is able to (1) enrich the semantic information of variable names by mapping the models' internal variables with a set of standard names, and (2) be easily adopted in other modeling frameworks due to its framework-agnostic property. We developed a set of JSON-based endpoints to expose the BMI-enabled models as web services, through storing variable values in the network common data form file during the communication between web services to reduce network latency. Then, a smart modeling framework, the Experimental Modeling Environment for Linking and Interoperability (EMELI), was enhanced into a web application (i.e., EMELI-Web) to integrate the BMI-enabled web service models in a user-friendly web platform. The whole orchestration was then implemented in coupling TopoFlow components, a set of spatially distributed hydrologic models, as a case study. We demonstrate that BMI helps connect web service models by reducing the heterogeneity of variable names, and EMELI-Web makes it convenient to couple BMI-enabled web service models.

An Algorithm for Optically-deriving Water Depth in Coral Reef Landscapes in the Absence of Ground-Truth Data

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Although numerous approaches for deriving water depth from bands of remotely-sensed imagery in the visible spectrum exist, digital terrain models for remote tropical carbonate landscapes remain few in number. The paucity is due, in part, to the lack of in situ measurements of pertinent information needed to

tune water depth derivation algorithms. In many cases, the collection of the needed ground-truth data is often prohibitively expensive or logistically infeasible. We present an approach for deriving water depth from multi-spectral satellite imagery without the need for direct measurement of water depth, bottom reflectance, or water column properties within the site of interest. The reliability of the approach is demonstrated for five satellite images, each at a different study site, with overall RMSE values ranging from 0.84 m to 1.56 m when using chlorophyll concentrations equal to 0.05 mg m^{-3} and a generic seafloor spectrum generated from a spectral library of common benthic constituents. Sensitivity analyses show that the model is robust to selection of bottom reflectance inputs and errors in the atmospheric correction and sensitive to parameterization of chlorophyll concentration. ,Image:,

The Effect of River Bathymetry on Flood Simulations

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Climate change has altered the frequency and intensity of hydrologic events like precipitation and flood, yielding vulnerability of communities dwelling in coastal and inland flood plains. Flood prediction and mitigation systems are necessary for improving public safety and community resilience all over the world at Country, continental and global scales. Numerical simulation of flood event has become a very useful and commonly used tool for studying and predicting flood events and susceptibility. One of the major challenges in hydraulic modeling is accurate description of river and floodplain geometries. The increased availability of high-resolution DEMs (e.g. LiDAR data) alleviates this challenge for floodplains but (with the exception of blue/green LiDAR surveys) not for river channels. Here we investigate the effect of river bathymetry data on numerical simulations of flood events. Two numerical models (GSSHA and Mike 21) were used for comparison in the results. Three channel geometry inputs were simulated for three river reaches of different sizes: DEM-captured elevation (water surface), hydraulic geometries (empirical estimation), and observed river bathymetry.

Spatial Gradients in SSC at the Interface of an Estuary and a Salt Marsh: Implications for Sediment Supply to the Marsh

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Salt marsh provides critical estuarine habitat and shoreline protection, and is highly vulnerable to sea-level rise. Models of marsh accretion and resilience to sea-level rise rely on estimates of sediment supply, yet the factors governing sediment supply to marshes and its temporal variation are poorly understood. This presentation focuses on temporal variability in suspended-sediment concentration (SSC) and spatial gradients in SSC at the marsh edge, with two goals: 1) to identify processes important to sediment supply, and 2) to inform the choice of SSC values to use as input to marsh accretion models. We present data collected as part of an investigation of the influence of tides and wind waves on sediment supply to an estuarine salt marsh in China Camp State Park, adjacent to San Pablo Bay, in northern San Francisco Bay (tide range approximately 2 m). The long-term sediment accretion rate in the lower China Camp marsh is 3 mm/year. The marsh vegetation is predominately Salicornia pacifica, with Spartina foliosa occupying the lower elevations adjacent to the mudflat. The marsh is bordered by wide intertidal mudflats and extensive subtidal shallows. In the winter of 2014/2015 and the summer of 2016 we collected time series of SSC, tidal stage and currents, and wave heights and periods in the bay shallows, in a tidal creek, and (except for currents) on the marsh plain. On the mudflats, SSC depends strongly on wave energy, and also varies inversely with water depth, increasing toward the marsh edge and with decreasing tidal stage. Within the marsh, SSC is lower in the Salicornia-dominated marsh plain than at the marsh edge, as expected, but in the Spartina zone SSC is greater than at the marsh edge. This effect is greater in summer, when Spartina is significantly taller and denser, than in winter. SSC over the marsh was typically greater during flood than ebb tides in both seasons, indicating net deposition over the tidal cycle. However, median flood-tide SSC over the marsh, and the inferred deposition, were greater in summer than winter. We attribute the increased SSC and deposition in summer to greater sediment trapping in Spartina, followed by mobilization and transport of sediment onto the marsh during subsequent high tides.

Using a Landscape Evolution Model to Evaluate the Role of Pulses of Uplift on Bedrock Valley Width and Channel Mobility

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Understanding the factors that control lateral erosion rates in bedrock channels is a frontier in geomorphology. When lateral bedrock erosion rates exceed the rate of vertical incision on the channel bed, wide bedrock valleys are produced; if vertical incision rates then exceed lateral erosion rates, a strath terrace can be produced. Lateral erosion rates and the evolution of wide bedrock valleys are linked to bedrock lithology, sediment supply in the stream, discharge variability, and uplift.

We use a newly-developed lateral erosion component in the Landlab modeling framework to explore how the width of bedrock valleys develops under competition between lateral channel mobility and uplift rate. Two model formulations are presented, one representing the slow process of widening in a bedrock canyon, the other representing undercutting, slumping, and rapid downstream sediment transport that occurs in softer bedrock. We ran modeling experiments with a range of bedrock erodibility, sediment mobility, and uplift conditions. In order to determine the role changing uplift patterns has on channel mobility and bedrock valley width, two modeling scenarios were run: one with a fourfold increase in base level lowering and one with a fourfold decrease in base level lowering.

In the total block erosion models, which represent hard bedrock, the migration of knickpoints through the channels controls the onset of changes in valley width. As the channel comes into a new equilibrium slope, lateral erosion is either stalled (in the case of increased uplift) or accelerated (in the case of decreased uplift). In the undercutting-slump models, increasing uplift results in short-lived valley narrowing as the knickpoint moves up the channel. But after the model domain has reached equilibrium, higher uplift results in significantly wider bedrock valleys. This counterintuitive response reflects the nature of the model algorithm, which represents undercutting, slumping, and rapid downstream transport of sediment that occurs in soft bedrock. This class of models shows that in soft bedrock, higher uplift can increase channel mobility and result in wider bedrock valleys, rather than promoting less mobile channels and valley narrowing. Through these model experiments, we evaluate the conditions under which changes in base level fall result in wider bedrock valleys and more mobile channels and conditions under which the opposite occurs.

Modeling Household Adaptation Choices Using a Dynamic Bayesian Network Model

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Deltas are threatened not only by climate and environmental changes (sea level rise, soil salinization, water shortages and erosion), but also by socioeconomic factors (high population density, intensive land use). These processes threaten people's livelihoods and wellbeing, and as a result, there is a growing concern that significant environmental change induced migration might occur from deltaic areas. Migration, however, is already happening for economic, education and other reasons (e.g. livelihood change, marriage, planned relocation, etc.). Migration has multiple, interlinked drivers and depending on the perspective, can be considered as a positive or negative phenomenon.

The DECCMA project (Deltas, Vulnerability & Climate Change: Migration & Adaptation) studies migration as part of a suite of adaptation options available to the coastal populations in the Ganges delta in Bangladesh, the Mahanadi delta in India and the Volta delta in Ghana. It aims to develop a holistic framework of analysis that assesses the impact of climate and environmental change, economics and governance on the migration patterns of these areas. The project will test plausible future scenarios and evaluate them by considering a range of perspectives.
The dynamic Bayesian Network integrated model of the DECCMA project formally brings together the project elements in fully coupled, quantitative assessment framework. The presentation introduces the overall integration concept and describes the household decision-making component in detail. This component is based on a detailed household survey from delta migrant sending and receiving areas. We describe the model structure, and contrast the model setup and sensitivities across the three study areas. In doing so we illustrate some key causal relationships between changes in the environment, livelihoods and migration decision. The output of the integrative modeling is used to objectively evaluate the simulated environmental, social and economic changes for decision makers including the benefits and disadvantages of migration as an adaptation option.

Sea-level Responses to Sediment Erosion and Deposition in the Eastern United States Since the Mid-Pliocene Climate Optimum

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The Orangeburg Scarp along the U.S. east coast is a Paleo-shoreline that formed during the mid-Pliocene climate optimum (MPCO; 3.3-2.9 Ma), a warm period considered to be an analog for modern climate. At present, the Orangeburg Scarp varies in elevation from ~33 to ~82 m along its ~1000-km length, implying that it has been heterogeneously warped since its formation. Recent studies suggest that some of the variations in the paleoshoreline elevation might be driven by regional sediment loading and unloading. In this study, we use a gravitationally self-consistent sea-level model to quantify the influence of sediment erosion and deposition on sea-level changes since the MPCO along the U.S. east coast. We drive the sea-level model with existing ice models and a new compilation of sediment redistribution, which is inferred from erosion rates in basins draining the Appalachians and deposition rates in the lower portions of these basins and offshore. Preliminary results suggest that sediment redistribution can significantly perturb Paleo-shoreline elevations along the Orangeburg Scarp, which suggests that accounting for regional erosion and deposition can advance our ability to estimate ice volume during at the MPCO and improve our understanding of the evolution of continental margins.

Using Coupled Geo-economic Models to Explore the Interplay Between Coastal Protection, Natural Processes and Economic Values along Developed

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Montclair State University,Woods Hole Oceanographic Institution , As coastal regions become more developed, many communities are considering costly engineering solutions to address coastal change, including soft approaches, such as beach replenishments or dune constructions, and hard structures, such as seawalls, revetments, bulkheads, or groins. Given current rates of sea level rise and the associated shoreline losses that coastal communities face, however, it is unclear whether the benefits generated by these protection measures justify the costs. We are building a set of integrated geologic and economic models to better understand the coupled evolution of developed shorelines under alternative protection policies. The first model incorporates dune construction and sediment overwash relocation into a morphodynamic model for dune evolution. We use this model to assess the costs of constructing an optimal cross-sectional area for a long-term dune system, and we explore the geo-economic effects on ocean views that may be diminished by constructing a dune system of particular size seaward of protected properties. A second model simulates beach width dynamics for two adjacent communities, each with their own groin structure. We use the model to analyze both coordinated and uncoordinated strategies between the two communities, reflecting individual community decisions to protect or retreat. A third model incorporates beach nourishment practices into a morphodynamic model for barrier evolution that accounts for shoreface dynamics. Results show that the efficiency of beach nourishment can be affected by the dynamic state of the shoreface during each nourishment episode. In general, these models reinforce the need to refine numerical coastal management tools to incorporate bi-directional interactions between natural processes and human responses to shoreline change.

Numerical Simulations of Transient Landscape Adjustment along the Mendocino Triple Junction

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The South Fork Eel River (SFER) in the northern California Coast Ranges exhibits characteristics indicative of transient landscape adjustment: stream terraces, knickpoints, and more slowly eroding headwater terrain. A tectonically-induced uplift wave is commonly invoked as the driver of transience in this region. The wave is attributed to the northward migration of the Mendocino Triple Junction (MTJ) where the San Andreas fault, Cascadia subduction zone, and Mendocino fracture zone meet. Nested basin-mean erosion rates calculated from 10Be detrital quartz sand increase downstream along the SFER that roughly coincides with the direction of MTJ migration. This erosion trend is attributed to the proportion of adjusted and unadjusted landscape portions upstream of the locations where the nested 10BE samples were collected. Yet to be determined are the conditions that led to transient erosion. Adjusted and unadjusted landscape portions are separated by a broad knickzone that contains 28% of topographic relief along the mainstem. Knickzone propagation and considerable stream incision is suggested by projection of the upper SFER above the knickzone through the highest flight of strath terraces. These terraces are approximately 80 m above the modern valley floor near the outlet of the SFER. Here we evaluate the pattern of transient landscape characteristics predicted by multiple uplift scenarios using the Landlab modeling framework and constraints provided by previous work in this region. Notably, model outcome when uplift is simulated as a wave is incompatible with the tectonic history of the region and field observations, and the gradient of uplift along modeled streams has an important control on knickpoint generation.

Long-term Morphodynamics of Muddy Backbarrier Basins: Fill in or Empty Out?

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Tidal forecasting and early warning center, Venice, Italy , The long-term (3000 years) morphodynamics of backbarrier tidal basins is studied using a shallow-water hydrodynamic and wind-wave model (Deltf3D-FLOW-WAVE), modified to include fully-coupled marsh organogenic accretion, biostabilization, drag increase, and wave-induced marsh edge erosion. The latter process is implemented with a novel probabilistic algorithm. In simulations run with only sand, a flood tidal delta forms adjacent to the inlet, but marshes do not establish. In simulations run with only mud, instead, marshes establish at the basin margins and prograde seaward. If enough mud is supplied to the basin from the shelf, marsh progradation counteracts edge erosion. Marsh progradation does not completely fill the basin, but leaves open a few km-wide channels, large enough for waves to resuspend sediment. Starting from a basin (almost) filled with marshes, a drop in the external mud supply or an increase in the rate of relative sea level rise cause the basin to empty out by marsh edge erosion, while the marsh platform, aided by reworking of the sediment

released by marsh retreat and mudflat deepening, keeps pace even with fast rates (10 mm/yr) of relative sea level rise. Even if the marsh does not drown, the marsh retreats faster if the rate of sea level rise increases, because more sediment is sequestered to fill the newly created accommodation space and is thus not available for marsh progradation. This study suggests that prediction of marsh erosion requires a basin-scale sediment budget, and that edge erosion, not platform drowning, is likely to dominate marsh loss.

Two-dimensional Modeling of Variable-width Gravel Bed Morphodynamics

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Rivers in natural settings are frequently characterized by downstream variations in channel width. However, the effect of width variations on bed topography and sorting patterns remains poorly understood, especially under conditions of changing sediment and hydrologic regimes. In this study we use two-dimensional numerical modeling to systematically explore how the amplitude and wavelength of sinusoidal width variations affect the shape and location of bars, sorting patterns of surface sediment, and the movement of a sediment pulse. We perform simulations with sediment regimes consisting of constant sediment supply, no sediment supply, and a sediment pulse with no background sediment supply. We also perform steady and unsteady flow simulations to explore the combined effect of hydrograph shape and width variations. Preliminary results indicate that width variations force riffle-pool topography with riffles coincident with wider channel sections and pools at narrow sections. The amplitude of width variations is the dominate factor controlling riffle-pool relief. The wavelength of the width variations controls whether central or side bars develop in the wider channel sections. These numerical simulations are complimented with ongoing physical experiments in a laboratory flume and can potentially be used to guide stream restoration and river management practices under conditions of varying sediment and hydrologic regimes.

Coupling Sediment Transport and Biogeochemical Processes: The Role of Resuspension on Oxygen & Nutrient Dynamics

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Observations in coastal environments show that seabed resuspension can impact water quality and biogeochemical dynamics by vertically mixing sediment and water, and by redistributing material that has been entrained into the water column. Yet, ocean models that incorporate both sediment transport and biogeochemical processes are rare. The scientific community frequently utilizes hydrodynamic-sediment transport numerical models, but hydrodynamic-biogeochemical models ignore or simplify sediment processes, and have not directly accounted for the effect of resuspension on oxygen and nutrient dynamics.

This presentation focuses on development and implementation of HydroBioSed, a coupled hydrodynamic-sediment transport-biogeochemistry model that was developed within the open-source Regional Ocean Modeling System (ROMS) framework. HydroBioSed can account for processes including advection, resuspension, diffusion within the seabed and at the sediment-water interface, organic matter remineralization, and oxidation of reduced chemical species. Implementation of the coupled HydroBioSed model for different locations, including the Rhone River subaqueous delta and the northern Gulf of Mexico, have helped to quantify the effects of both sediment transport and biogeochemical processes. Results indicate that resuspension-induced exposure of anoxic, ammonium-rich portions of the seabed to the more oxic, ammonium-poor water column can significantly affect seabed-water column fluxes of dissolved oxygen and nitrogen. Also, entrainment of seabed organic matter into the water column may significantly draw down oxygen concentrations in some environments. Ongoing work focuses on how resuspension and redistribution of organic matter and sediment may influence oxygen dynamics in the Chesapeake Bay.

https://youtu.be/TjatADixj5E
http://csdms.colorado.edu/mediawiki/images/Julia_Moriarty_CSDMS_2017_annual_meeting.pptx
http://csdms.colorado.edu/mediawiki/images/Julia_Moriarty_CSDMS_2017_annual_meeting.pdf

Modelling the Morphodynamic Interactions and Co-Evolution of Coupled Coast-Estuarine Environments

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The morphodynamics of coast and estuarine environments are known to be sensitive to environmental change and sea-level rise. However, whilst these systems have received considerable individual research attention, how they interact and co-evolve is largely unknown. Through a novel coupling of numerical models, this research is designed to explore the complex behaviour of these systems in terms of fluid flows and sediment fluxes. This includes elucidating the relative influence of various controls on system behaviour and exploring the effects that variable sea levels and changing wave climates may have on their evolution over the mid to longer term.
This research is being carried out through the modification and coupling of the one-line Coastline Evolution Model (CEM) with the hydrodynamic LEM CAESAR-Lisflood (C-L). Progress to date includes a new version of the CEM that has been prepared for integration into C-L. This model incorporates a range of more complex sedimentary processes in quasi-2d and boasts a graphical user interface and visualisation.
The model is being applied and tested using the long-term evolution of the Holderness Coast, Humber Estuary and Spurn Point on the east coast of England (UK). Holderness is one of the fastest eroding coastlines in Europe and research suggests that the large volumes of material removed from its cliffs are responsible for the formation of the Spurn Point feature and for the Holocene infilling of the Humber Estuary. Over the next century it is predicted that climate change could lead to increased erosion along the coast and supply of material to the Humber Estuary and Spurn Point. How this manifests will be hugely influential to the future morphology of these systems and the flood and erosion risk posed to coastal communities.

Autogenic Versus Allogenic Controls on a Fluvial Megafan/Mountainous Catchment Coupled System: Numerical Modeling and Comparison with the Lannemezan Megafan (Northern Pyrenees, France)

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Alluvial megafans are sensitive recorders of landscape evolution: the influence of both autogenic processes and allogenic forcing and of the coupled dynamics of the fan with its mountainous catchment can often be deciphered from the megafan sediment record and the system's morphometric characteristics. The Lannemezan megafan in the northern Pyrenean foreland was abandoned by its mountainous feeder stream during the Quaternary and subsequently incised. During the incision, a flight of alluvial terraces was left along the stream network. We use numerical models (CIDRE model, Carretier et al. 2015) to explore the relative roles of autogenic processes and external forcing in the building, abandonment and incision of a foreland megafan. We then compare the results with the inferred evolution of the Lannemezan megafan. We conclude that autogenic processes are sufficient to explain the building of a megafan and the long-term entrenchment of its feeding river at the time and space scales that match the Lannemezan setting. In the case of the Lannemezan megafan, climate, through temporal variations in precipitation rate, may have played a second-order role in the pattern of incision at a shorter time-scale. In contrast, base-level changes, tectonic activity in the mountain range or tilting of the foreland through flexural isostatic rebound do not appear to have played a role in the abandonment of the Lannemezan megafan.

Fish & Fire

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Salmonine fishes (salmon and trout) are resilient and have evolved to survive environmental perturbations, including flood, drought, and wildfire. The effects of these perturbations are translated through the landscape by rivers, where aquatic communities can be severely impacted. For instance, after wildfire, rivers can experience increased frequency and magnitude of flash floods, ash and nutrient loading, increased sediment flux from runoff and debris flows, destabilization and physical alteration of fluvial habitat, stream temperature impairment, and either loss or gain of refuge (e.g. deep pools, woody debris, riparian vegetation). Depending on the severity, any one of these effects could drive the extirpation of fish populations, and the response and survival of fish gets increasingly complex when faced with multiple environmental perturbations. Historically, the extirpation of fish populations would not have been as significant a risk to the extinction of entire species or subspecies of salmonids, as unrestricted migration allowed for recolonization by neighboring populations. However, increasing river disconnectivity, due to the introduction of physical barriers, has put native fish species at greater risk of extinction after natural catastrophes. In order to evaluate the viability and recovery of fish populations after catastrophe, we have developed a multi-site structured population viability analysis (PVA) model that is designed to incorporate factors that are unique to the spatial distribution of catastrophe and migration in fluvial networks. Specifically, our multi-site PVA provides the flexibility to vary both the duration and severity (i.e., multi-year catastrophe and habitat recovery) of vital rate adjustment (survival and growth). Our model also allows for a multi-mechanistic approach to vital rate adjustment after catastrophe – this is a particularly important advancement, as fluvial habitats located within the fire perimeter often experience distinctly different impacts than those outside of but downstream of fire. Both of these improvements are necessary as the negative impacts of wildfire on fish habitat and vital rates can last for years or even decades, and commonly used PVA modeling software only allows for impairment to last for one year. Additionally, previous models allow for a one, all or radial spreading approach to the spatial distribution of catastrophe, which works for disease but is inconsistent with the flow routing of catastrophe in stream networks. Finally, we have also developed a new metapopulation migration model that accounts for bidirectional river connectivity, a characteristic of migration unique to fluvial environments. Migration behavior in this model is driven by simple probabilities of life-stage structured dispersal and migration distances, measures of habitat suitability (including post-catastrophe adjustment), and site population densities. To demonstrate the utility of our multi-site PVA, we apply it to a case study of Bonneville Cutthroat Trout after the Twitchell Canyon Fire in the Fish Lake National Forest, Utah. The impact on and recovery of trout populations after wildfire was monitored across 14 sites of variable hydrologic, temperature and physical impairment (both within and outside of the fire perimeter). Using these observations along with maps of stream connectivity barriers, we model trout population viability and recovery after wildfire in this site. We also compare our results to model simulations using single year impairment, more similar to that of previous PVAs. Finally, we demonstrate the potential improvements on population recovery through simulations removing individual fish barriers throughout the network. This model presents a new framework for directly linking parameters of landscape change that may vary in both spatial and temporal distribution to the viability of fish populations after natural catastrophe. Plans for future model development include linking the PVA with models of fish bioenergetics and landscape evolution, which can provide spatially variable predictions of changes in discharge, stream temperature and sediment fluxes after fire. Ultimately, we hope to develop and provide a new management tool for evaluating the overall vulnerability of aquatic organisms to wildfire in watersheds throughout the Intermountain West.

Coupled Modeling of River and Coastal Processes: New Insights about Delta Morphodynamics, Avulsions, and Autogenic Sediment Flux Variability

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Following pioneering modeling work examining the evolution of wave-influenced deltas (Ashton et al., 2013; Nienhuis et al., 2013), we coupled the River and Floodplain Evolution Model (RAFEM) to the Coastline Evolution Model (CEM). Results of a recent suite of model experiments (conducted using the CSDMS software stack and Dakota) lead to new insights: 1) The preferred location of avulsions (a distance from the river mouth scaling with the backwater length), previously observed in laboratory models and in the field, can arise for geometric reasons that are independent of those recently suggested (Chatanantavet et al., 2012; Ganti et al., 2016). This alternative explanation applies when the river longitudinal profile tends to diffuse more rapidly than the floodplain longitudinal profile. 2) Although the timescale for avulsions is expected to increase with increasing wave influence (Swenson, 2005), we find that this depends on the angular wave distribution. When wave influence is strong and the angular mix of wave influences tends to smooth a nearly straight coastline (coastline diffusion), progradation is slowed and avulsions delayed. However if the angular wave distribution produces anti-diffusive coastline evolution, a strong wave influence still leads to cuspate delta shapes, but avulsions are barely delayed. 3) Although increasing sea-level-rise rate is expected to cause more rapid avulsions, and does in laboratory deltas, we unexpectedly find that this is not true for river-dominated deltas in our model (or for anti-diffusive wave climates). The explanation, involving the role of sea-level-rise related transgression (or decreased progradation), raises potentially important questions about geometrical differences between laboratory deltas and natural deltas. 4) The magnitude and timescale of autogenic variability in sediment delivery rates at the river mouth depends on wave climate, sea-level-rise rate (for some wave climates), and on the amount of super elevation of the river channel (relative to the surrounding floodplain) required to trigger avulsions.

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Deltas as Coupled Socio-Ecological Systems

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At a global scale, deltas significantly concentrate people by providing diverse ecosystem services and benefits for their populations. At the same time, deltas are also recognized as one of the most vulnerable coastal environments, due to a range of adverse drivers operating at multiple scales. These include global climate change and sea-level rise, catchment changes, deltaic-scale subsidence and land cover changes, such as rice to aquaculture. These drivers threaten deltas and their ecosystem services, which often provide livelihoods for the poorest communities in these regions. Responding to these issues presents a development challenge: how to develop deltaic areas in ways that are sustainable, and benefit all residents?

In response to this broad question we have developed an integrated framework to analyze ecosystem services in deltas and their linkages to human well-being. The main study area is part of the world's most populated delta, the Ganges-Brahmaputra-Meghna Delta within Bangladesh. The framework adopts a systemic perspective to represent the principal biophysical and socio-ecological components and their interaction. A range of methods are integrated within a quantitative framework, including biophysical and socio-economic modelling, as well as analysis of governance through scenario development. The approach is iterative, with learning both within the project team and with national policy-making stakeholders. The analysis allows the exploration of biophysical and social outcomes for the delta under different scenarios and policy choices. Some example results will be presented as well as some thoughts on the next steps.

https://youtu.be/tRRau8mJfrk
http://csdms.colorado.edu/mediawiki/images/Robert_Nicholls_CSDMS_2017_annual_meeting.pptx
http://csdms.colorado.edu/mediawiki/images/Robert_Nicholls_CSDMS_2017_annual_meeting.pdf

Towards Representing Thermokarst Processes in Land Surface Models

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Large-scale Earth system and land surface models often lack an adequate representation of subgrid-scale processes in permafrost landscapes. Small-scale processes such as thermokarst formation might, however, considerably impact the energy and carbon budgets in way that is not resolved within large-scale models. Since a spatially high-resolved simulation of such processes is not feasible, novel techniques for up-scaling subgrid processes are demanded.

Within this work a one-dimensional model of the ground thermal regime of land surfaces, CryoGrid 3, is employed to conceptually represent small-scale features of permafrost landscapes, particularly those related to thermokarst. For example, the model has been shown to adequately describe the degradation of permafrost underneath waterbodies in a warming climate. Using tiling approaches such point-wise realizations can be up-scaled in a statistical way in order to represent larger land surface units.

The model development is closely linked to field campaigns to the Lena River Delta in Siberia which offers very diverse land surface features such as polygonal tundra and thermos-erosional valleys. These features are related to the region's diverse soil stratigraphies, in particular the occurrence of ice-rich ground. Combining field measurements with modelling ultimately allows an improvement in the qualitative and quantitative understanding of the typical geomorphological processes in permafrost landscapes and their representation in large-scale land surface models.

Studying the Role of Disturbances on Woody Plant Encroachment in Southwestern US using a Coupled Landlab Ecohydrology Model

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Woody Plant Encroachment (WPE), an increase in density, cover and biomass of trees or shrubs in native grasslands, has been observed to be a major cause for dramatic changes in arid and semiarid grasslands of southwestern US over the last 150 years. Driven by overgrazing, reduced fire frequency, and climate change, WPE is considered as a major form of desertification. In Landlab, ecohydrologic plant dynamics, wildland fires, grazing, and resource distribution (erosion/deposition) are represented in separate components. Landlab has two existing cellular automata Ecohydrology models, built using these components, to study the impacts of WPE on the evolution of vegetation patterns. In the first model, physically based vegetation dynamics model is used to simulate biomass production based on local soil moisture and potential evapotranspiration driven by daily simulated weather, coupled with a cellular automata plant establishment and mortality rules. In this model, spatial dynamics of disturbance propagation (e.g., fire spread and intensity) is not explicitly modeled. In the second model, a simple stochastic cellular automata model with two state variables, vegetation cover and soil resource storage, are used to model resultant vegetation patterns based on probabilistic establishment-mortality interplay, mediated by post-disturbance resource redistribution, while explicit roles of climate are neglected. In this work, we coupled these two models to investigate the role of disturbances (fire and grazing) in a climate driven dynamic ecohydrologic context. In this coupled model, daily- weather driven physically based vegetation dynamics model is coupled with cellular automata plant establishment model that explicitly simulates spatial disturbance dynamics. The effects of encroachment factors and model complexity on resultant vegetation patterns are studied.

Atoll Morphometrics: Why do Atolls and Reef Islands Look the Way They Do?

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Despite the essential role sub-aerial reef islands on atolls play as home to terrestrial ecosystems and human infrastructure, the morphologic processes and environmental forcings responsible for their formation and maintenance remain poorly understood. Given that predicted sea-level rise by the end of this century is at least half a meter (Horton et al., 2014), it is important to understand how atolls and their reef islands will respond to accelerated sea-level rise for island nations where the highest elevation may be less than 5 meters (Webb and Kench, 2010). Atolls are oceanic reef systems consisting of a shallow reef platform encircling a lagoon containing multiple islets around the reef edge (Carter et al., 1994). Atolls come in a variety of shapes from circular to rectangular and size from 5 to 50 km width of the inner lagoon (Fig. 1a and 1b). I want to understand why atolls vary in their morphology and whether wave climate is the primary driver of atoll morphology. Previous work has highlighted the importance of wave energy on reef morphology and atoll morphology (Stoddart, 1965; Kench et al., 2006). Around a given atoll, the morphology of the reef islands may change significantly from small individual islets or larger continuous islets that are more suitable for human habitation (Fig. 1c and 1d). I will create a global dataset of atoll morphometrics to compare to external forcing, e.g. comparing reef width to the mean wave climate. Using Google Earth Engine, a cloud-based geospatial analysis platform to collate Landsat imagery, I can measure a range of morphometrics including atoll size and shape, reef flat width, reef island size and shape, and distribution of reef islands around an atoll. I will compare these morphometrics to global waves simulated by WaveWatch3. By compiling a global dataset of atoll morphometrics, I am able to better understand the impact of wave climate on atoll morphology and long-term evolution.

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Turbulence-resolving Two-Phase Flow Simulations of Wave and Current Supported Turbidity Flows

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Wave- and current-supported turbidity currents are new class of turbidity flows that has been discovered over the last three decades. Its significance as a carrying agent of fine sediments over low-gradient shelves has been recognized with growing evidence. Due to their vertical length scales, which are on the order of decimeters, understanding the full range of mechanisms that are responsible for and/or affect these currents cannot proceed without turbulence-resolving numerical simulations and/or high-resolution sensor deployment in a laboratory/field experiments. In this talk the culmination of two-phase, turbulence-resolving simulations, i.e. Direct Numerical Simulations (DNS), of wave- and alongshore current-supported fine sediment turbidity currents across mild bathymetric slopes will be presented. Simulation results show that such turbidity currents follow a logarithmic velocity profile across the shelf whose parameters depend on the sediment concentration, across-shore bathymetric slope, and Reynolds number while it is independent of the settling velocity of the sediments. The numerical simulations also provide significant insights on modelling these turbidities in a regional-scale model which can be used to estimate the location of mud depocenters and the dynamics of submarine geomorphology such as in the clinoform development at the continental margin.

Coupling Coastal Processes and Human Interactions Within a Littoral Cell

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Coastal landscapes are dynamic, subject to drowning by sea level rise, erosion driven by alongshore transport, and inundation by large storm events. Coastlines are also highly developed. Along the U.S. coasts, communities continuously develop and implement beach management strategies to protect coastal infrastructure and maintain recreational value. From sediment source to sink, littoral cells often span many coastal communities. Even as physical processes grade along these littoral cells, separate communities along this coast possibly enact different management strategies. By expanding upon an existing alongshore-coupled dynamic model of coastal profile and barrier evolution, we analyze the feedbacks between alongshore and cross-shore processes as well as human response to local shoreline change across multiple communities within the same littoral cell. Incorporating the possibility of intercommunity cooperation allows us to valuate variable coastal resilience strategies for communities within a littoral cell, particularly the benefit of coordinated versus uncoordinated activities. Both sediment transport processes and a cost-benefit analysis for each community determine optimal beach management strategies. Model results provide insights useful for understanding coastal processes and planning, allowing for more robust coastal management decisions, which depend upon future rates of sea-level rise.

Temporal Variability in Bed Elevation Near Shoal E, Cape Canaveral

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The increasing demand for sediments as source material for beach nourishment projects highlights the need to understand inner-shelf transport dynamics. At cape-related shoals, from where sedimentary materials are customarily extracted, the variability in particulate transport and related bedform evolution are not well understood.

To analyze bed elevation variability at a shoal adjacent to Cape Canaveral, Florida, an acoustic Doppler current profiler (ADCP) was deployed in spring 2014 at the outer swale of Shoal E, ~20 km south east of the cape tip at a depth of ~13 m. ADCP-derived velocity profiles and suspended particle concentrations were used to quantify instantaneous temporal changes in bed elevation ($d\zeta/dt$) using a simplified version of the Exner equation. Using mass conservation, temporal (deposition and entrainment) and spatial gradients in suspended sediment concentrations were calculated, although neither bed-load fluxes nor spatial gradients in velocities were considered.

Calculated values for instantaneous $d\zeta/dt$ ranged from erosion at ~1e-3 m/s to accretion at 0.5e-3 m/s. Most of the variability was found at subtidal (<1 cycle/day) and tidal (~2 cycles/day) periodicities. Bed changes were small (<0.005 m/s) when tidal motions were important, e.g. from May 6 to 16, whereas subtidal motions at periods of 1 and 8 days dominated erosion/accretion events between May 16 and 31. Values suggest a bed erosion of 3.1e-3 m during ~30 days of the experiment, which was 2 orders of magnitude less, and had a contrary tendency to the average accretion of ~150e-3 m in 37 days measured between July 28 and September 3 at the edge of Southeast Shoal, i.e. ~5 km to the northwest.

In addition to the fact that measurements were not performed simultaneously at the same location, the discrepancy in $d\zeta/dt$ could be attributed to the underestimation of bed changes due to the exclusion of bed-load fluxes. Despite several uncertainties, these findings provide preliminary evidence regarding the role of seasonal and storm-driven subtidal flows in particulate transport at cape-associated shoals. Our methodology can be used to inform numerical models of sediment transport and morphological evolution along inner continental shelves.

Stratigraphic and Hydrologic Controls on Large-volume Landslides in NW Washington

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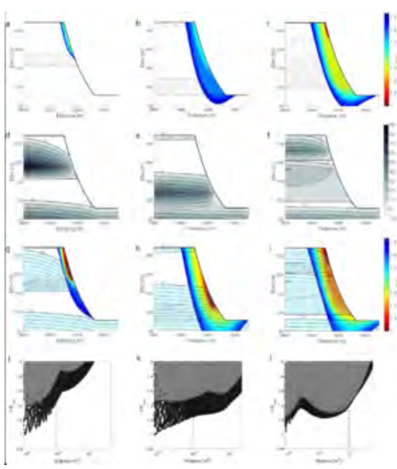

Model results for the Cedar (left column: a,d,g,j), Skagit (middle column: b,e,h,k), and North Fork Stillaguamish (right column: c,f,i,l) stratigraphic configurations. A-C show the relative subsurface factor of safety for dry model runs. D-F show groundwater flow fields from VS2Dt simulations. G-I show relative subsurface factor of safety for VS2Dt model runs. J-L show the calculated volume and factor of safety for each potential failure plane modeled in Scoops3D

Topography, material properties, and gravitationally driven groundwater flow together act to control hillslope stability. Although it is well known that material strength and hydraulic conductivity differences can alter slope stability via feedbacks with groundwater, comparatively little is understood about the role of stratigraphic sequencing in governing how hillslopes fail. In northwest Washington State, the recent occurrence of the large-volume, high-mobility SR-530 landslide brought focus to hazards associated with large terraces of glacial sediment that inundate the valleys of the western Cascades. However, observations from high-resolution LiDAR topographic data show significant differences between terraces in adjacent valleys, and both geologic and subsurface data show that each site has a unique stratigraphic configuration. Here we hypothesize that variations in the bed thickness and sequencing of glacial sediment packages within ice-marginal terraces control landslide volume and failure style. Using a three-dimensional limit-equilibrium model, Scoops3D, we show that the variable distribution of silts, clays, sands, and tills have a first-order control on both the volume and location of failures along a terrace. Predicted landslide volumes vary by over an order of magnitude between different stratigraphic configurations. Variably saturated groundwater flow simulations show that hydraulic conductivity contrasts between glacial units lead to perched water tables with localized zones of high pore fluid pressure, and in most cases (but not all) the failure pattern set by stratigraphy is amplified by the presence of groundwater flow. Model results from a range of synthetic stratigraphic configurations show that a twofold increase in the thickness of glaciolacustrine clays produces a tenfold increase in predicted landslide volume, consistent with topographic observations. Knowledge of subsurface stratigraphy may therefore help toward quantitative assessment of deep-seated landslide potential in sedimentary landforms.

Multicriteria Decision Analysis of Freshwater Resource Management in Southwestern Bangladesh

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Freshwater resources in coastal Bangladesh fluctuate with extreme periods of shortage and abundance. Bangladeshis have adapted to these alternating periods but are still plagued with scarce drinking water resources due to pond water pathogens, salinity of groundwater, and arsenic contamination. The success of attempts to correct the problem of unsafe drinking water has varied across the southern Bangladesh as a result of physical and social factors. We use a multicriteria decision analysis (MCDA) to explore the various physical and social factors that influence decisions about freshwater technologies and management schemes in southern Bangladesh.

MCDA is a holistic, analytical tool for evaluation of alternatives. MCDA is used to support public participation and provide structured, rational, and transparent solutions to complex management problems. To determine the best freshwater technologies and management schemes, we examine four alternatives, including managed aquifer recharge (MAR), pond sand filter (PSF), rainwater harvesting (RWH), and tubewells (TW). Criteria are grouped into four categories: environmental, technical, social, and economic. Weighting of social factors will be determined by community surveys, nongovernmental organizations (NGO) opinions, and academic interviews. Data include regional water quality perceptions, perceptions of management/technology success, MAR community surveys, and interviews with NGO partners. Environmental and technical feasibility factors are determined from regional water quality data, geospatial information, land use/land change, and regional stratigraphy.

Survey data suggest a wide range of criteria based on location and stakeholder
perception. MAR and PSF technologies likely have the greatest environmental and technical potential for success but are highly influenced by community dynamics, individual perspective, and NGO involvement. RWH solutions are used less frequently due to quantity limitations but are most successful at reducing the water security threats of contamination by pathogens, arsenic, and salts. This MCDA informs us of community and stakeholder water resource decisions, specifically related to their objectives and values.

Estimating Model Parameters Necessary for Simulating Post-wildfire Debris-flow Timing

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Debris flows pose a hazard to infrastructure and human life. However, predicting debris flows remains a challenge due to uncertainty in initiation mechanisms, and the difficultly in appropriately parameterizing the resistance equations that describe flow velocities. Additionally, one of the limitations to progress in modeling debris-flow timing is the lack of empirical data from natural watersheds that can be used for parameter estimation and validation of predictions. Most quantitative measurements of debris flows are conducted in flumes, or unique watersheds where debris flows are known to occur annually, both of which suggest particularly remarkable conditions that may not reflect the majority of conditions where debris flows are manifested. This research addresses those challenges by using measured debris-flow timing in nine watersheds that were burned by a wildfire in 2009 to calibrate and test debris flow model parameterizations. Debris-flow timing was captured using pressure transducers attached to the channel bed. We used a kinematic wave rainfall-runoff model that we developed in python using the landlab environment to model flow timing. We separated the nine study watersheds into two categories: calibration and testing. For the calibration watersheds, model parameters were estimated based on prior research and then changed iteratively using a storm with known rainfall to minimize an objective function of the observed and modeled flow timing. Following hundreds of model realizations, we arrived at a set of best-fit parameters for saturated hydraulic conductivity (Ks) and the Manning's roughness parameter (n). We found that a single value of Ks could be used in each of the model watersheds because, following wildfires, this parameter is typically reduced to very low values with a relatively small variance. In contrast n varied systematically as a function of upstream contributing drainage area, and thus values of n could be estimated for uncalibrated basins. When Ks and n were applied to test basins without any calibration we found that a reasonable result in estimated debris-flow timing was attained. These results suggest that given the appropriate scaling estimates it may be possible to estimate debris-flow timing within minutes and to capture multiple debris-flow surges separated by several hours.

3D Bedrock Channel Evolution with Smooth Particle Hydrodynamics Coupled to a Finite Element Earth

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An enduring obstacle to reliable modeling of the short and long term evolution of the stream channel-hillslope ensemble has been the difficulty of estimating stresses generated by stream hydrodynamics. To capture the influence of complex 3D flows on bedrock channel evolution, we derive the contribution of hydrodynamic stresses to the stress state of surrounding bedrock through a Smoothed Particle Hydrodynamics (SPH) approximation of the Navier-Stokes (N-S) equations. The GPU-accelerated SPH solution locally integrates the N-S equations by discretizing the flow into millions of particles which communicate local motions to neighbor particles using a smoothing kernel. Coupling the flow solutions to the stress-strain formulation of the Failure Earth Response Model (FERM) provides three-dimensional erosion as a function of the strength-stress ratio of each point in the computational domain. This novel approach allows the resulting geomorphic response to be quantified for bedrock channels with bends, knickpoints, plunge pools, and other geometric and hydrodynamic complexities. Strength parameters used in FERM (tensile strength, cohesion, and friction angle) are readily constrained with field observations. Fluvial stresses calculated with SPH are added to the other components of the total stress state, such as slope-generated and tectonically-generated stresses. From the coupling of SPH and FERM we gain 3D physics-based erosion and a dynamic link between complex flows and hillslope dynamics in a finite element framework. Initial results indicate that the inertial forces generated by a simple 45° bend in a bedrock channel exceed the shear forces by a factor of two or more. Capturing these inertial forces and their 3D erosive potential provides a more complete understanding of the stream channel-hillslope ensemble.

Sociocultural Dynamics in Global Human-Environmental Systems Models: Adding Local Depth to Decision Making Algorithms

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Decision making is a cultural process fundamental to slowing environmental destruction in all its guises. Although crucial to understanding environmental decision making, working toward a viable interdisciplinary model that could be used across problems and sites is not without obstacles. In order for coupled models to capture realistic lag times and interactions between social choices and the environment, algorithms of decision making must incorporate the influence of spatial-temporal local differences. This is especially true for coupled human-earth system models or agent-based models designed to inform policy. Here we provide a case study from the Paraná Delta of Argentina where a neighborhood assembly fights against pollution in the delta caused by an engineering failure. We combine components of a decision making framework with concepts from cultural and geographic theory, and then filter the combination through ethnographic description and interpretation to track how local culture influences decisions, and hence, lag times between actions and outcomes. Although fundamental to human decision making processes, sociocultural dynamics are often left out of formal behavioral modules coupled to environmental models. Through this experiment, we expand the capacity of such a framework for carrying cultural meaning and social interaction.

Global-Scale Event-Continuous Flood Event Simulation: When WBM Meets LISFLOOD-FP

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In an ongoing NASA project, our team is producing enhanced global flood hazard maps from advanced modeling, remote sensing and big data analytics. The innovation is that we couple long-term Water Balance Model (WBM) global scale hydrologic flow simulations with the 2-D LISFLOOD-FP model to generate continental scale flood inundation maps that are then integrated with the flood map information from the DFO, including their radiometry-based satellite discharge estimations, i.e. River Watch . These remotely sensed discharge stations will be employed to associate flow return periods to the DFO satellite flood maps (up to the 25-year floodplain) that can then be cross-validated with frequencies of inundation from the flood model historic simulations. Furthermore, we collaborate with Google Inc and use their EE platform for big data analytics, such as downscaling our model simulations of flood hazard to adequate resolutions for decision-makers. This poster will present first achievements for Australia, Africa and CONUS, and discuss challenges and perspectives.

Cohesive and Mixed Sediment in the Regional Ocean Modeling System (ROMS)

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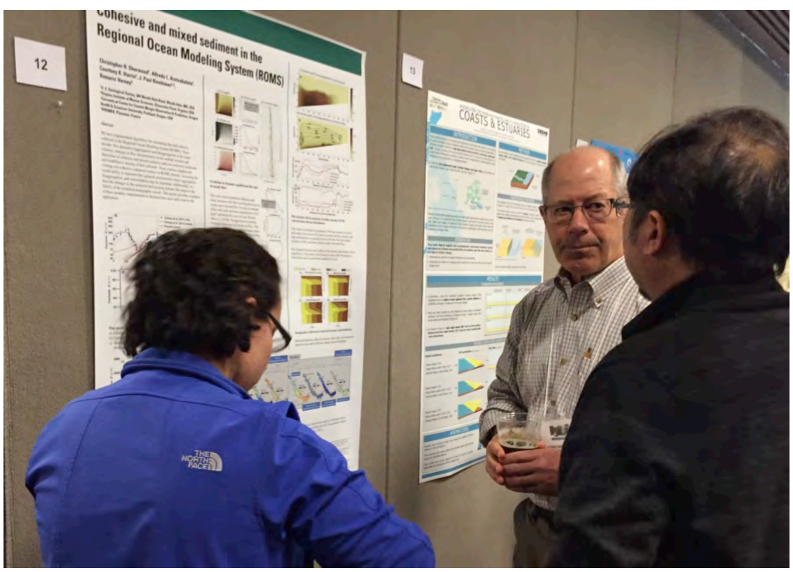

We have implemented algorithms for simulating fine and cohesive sediment in the Regional Ocean Modeling System (ROMS). These include: floc dynamics (aggregation and disaggregation in the water column); changes in floc characteristics in the seabed; erosion and deposition of cohesive and mixed (cohesive and non-cohesive) sediment; and biodiffusive mixing of bed sediment. These routines supplement existing non-cohesive sediment routines in ROMS, thereby increasing the model ability to represent fine-grained environments where aggregation, disaggregation, and consolidation may be important. Additionally, we describe changes to the sediment bed layering scheme that improve the fidelity of the modeled stratigraphic record. This poster provides examples of these modules implemented in idealized test cases and a real-world application.

Hillslope-derived Blocks, Erosion Thresholds and Topographic Scaling in Mountain Rivers

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Delivery of large blocks of rock from steepened hillslopes to incising river channels inhibits river incision and strongly influences the river longitudinal profile. We use a model of bedrock channel reach evolution to explore the implications of hillslope block delivery for erosion rate-slope scaling. We show that incorporating hillslope block delivery results in steeper channels at most erosion rates, but that blocks are ineffective at steepening channels with very high erosion rates because their residence time in the channel is too short. Our results indicate that the complex processes of block delivery, transport, degradation, and erosion inhibition may be parameterized in the simple shear stress/stream power framework with simple erosion-rate-dependent threshold rules. Finally, we investigate the effects of blocks on channel evolution for different scenarios of hydrologic variability, and compare and contrast our results with those of more common stochastic-threshold channel incision models. We show that hillslope-derived blocks have a different signature in erosion rate-slope space than the effects of constant erosion thresholds, and propose characteristic scaling that could be observed in the field to provide evidence for the influence of hillslope-channel coupling on landscape form.

Evaluating Order vs. Disorder in Fluvial System Deposits: A Statistical Analysis of Grain Size and Thickness Trends Within Vertical Successions of Sediment Packages in the Ganges-Brahmaputra-Meghna Delta, Bangladesh

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The propagation of environmental signals through the sediment routing system and their subsequent preservation or removal from the rock record is a central theme in current stratigraphic research. The identification of cyclicity and order in stratigraphic sequences with regard to vertical facies successions, thicknesses, and grain size trends is often used as indicator of preservation of non-random, extra-basinal signals (i.e. climate, tectonics, and base level). However, it is less clear to what extent the processes that alter these signals post-deposition (re-working, scour, and erosion) enhance or diminish cyclicity and order within preserved sediments. Furthermore, stratigraphic trends are often identified in subjective, qualitative terms and may be based more on a priori perception of order derived from depositional systems models than statistically robust trends inherent in the sediment archive. Here, we use a statistical metric to objectively evaluate order vs. disorder in the stratigraphic record in an attempt to identify the likelihood of a disordered (random) response to orderly (non-random) depositional processes. We utilize a quantitative geochemical and sedimentological dataset from the Ganges-Brahmaputra-Meghna delta (GMBD) to identify distinct fluvial sediment packages (defined as meter to 10s of meters thick sand packages similar in scale and character to modern bar forms) and statistical trends in their vertical successions across the delta. We begin by considering that the boundaries of these fining-upwards packages are defined by >50% increases in grain size from one sample to the next in a vertical succession (although other thresholds are evaluated as well). A runs metric r is then calculated by identifying streaks of increasing or decreasing sediment package thicknesses and volume weighted mean grain size. This metric is then compared to the output of a Monte Carlo simulation of 5000 synthetic boreholes created by random shuffles of the observed borehole data to determine the likelihood of a similar succession of sediment body thicknesses and grain size trends being generated by chance. Preliminary results indicate that the vast majority of observed thickness successions in the GBMD are statistically disordered , with regional variability correlated to discrete geomorphic provinces within the delta. Of note, sediment thickness trends from the main braidbelt exhibit the lowest probability of being generated by random chance, followed by the lower delta plain, and lastly by Sylhet basin, a semi-enclosed sub-basin in northeast Bangladesh that has

experienced episodic occupation by the mainstem Brahmaputra River throughout the Holocene. Similar results (with some notable exceptions) are found within grain size runs analyses, with Sylhet basin exhibiting the least amount of order with regard to vertical changes in grain size. Previous studies have identified Sylhet basin as a site of rapid mass extraction, suggesting a possible inverse relationship between stratigraphic order and rates of sediment extraction in fluvial systems. These results lay the groundwork for future studies in the utility of simple statistical measures in identifying random vs. ordered successions of sediment packages as indicators of process-response relationships preserved in the stratigraphic record.

Landscape Reorganization Under Changing External Forcing: Implications to Climate-driven Knickpoints

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A series of controlled laboratory experiments were conducted to study the effect of changing precipitation patterns on landscape evolution at the short and long-time scales. High resolution digital elevation (DEM) both in space and time were measured for a range of rainfall patterns and uplift rates. Results from our study show distinct signatures of extreme climatic fluctuations on the statistical and geometrical structure of landscape features. These signatures are evident in widening and deepening of channels and valleys, change in drainage patterns within a basin and change in the probabilistic structure of erosional events, such as, landslides and debris flows. Our results suggest a change in scale-dependent behavior of erosion rates at the transient state resulting in a regime shift in the transport processes in channels from supply-limited to sediment-flux dependent. This regime shift causes variation in sediment supply, and thus in water to sediment flux ratio (Qs/Qw), in channels of different sub-drainage basins which is further manifested in the longitudinal river profiles as the abrupt changes in their gradients (knickpoints), advecting upstream on the river network as the time proceeds.

A Top-down Modeling Approach to the Global Climate Stabilization

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This poster shows a top-down modeling work using a simple climate and economy model to examine pathways to achieve the climate stabilization targets stipulated in the Paris Agreement. A motivation for this presentation is to seek a possibility to complement this type of work with a bottom-up approach such as agent-based modeling so that climate mitigation pathways can be investigated from different angles.
In this work, we raise two issues: 1) Negative emission technologies such as Bioenergy with Carbon dioxide Capture and Storage (BioCCS) play an ever more crucial role in meeting the 2°C stabilization target. However, such technologies are currently at their infancy and their future penetrations may fall short of the scale required to stabilize the warming. 2) The overshoot in the mid-century prior to a full realization of negative emissions would give rise to a risk because such a temporal but excessive warming above 2°C might amplify itself by strengthening climate-carbon cycle feedbacks. It has not been extensively assessed yet how carbon cycle feedbacks might play out during the overshoot in the context of negative emissions.
This study explores how 2°C stabilization pathways, in particular those which undergo overshoot, can be influenced by carbon cycle feedbacks and asks their climatic and economic consequences. We compute 2°C stabilization emissions scenarios under a cost-effectiveness principle, in which the total abatement costs are minimized such that the global warming is capped at 2°C. We employ a reduced-complexity model, the Aggregated Carbon Cycle, Atmospheric Chemistry, and Climate model (ACC2), which comprises a box model of the global carbon cycle, simple parameterizations of the atmospheric chemistry, and a land-ocean energy balance model. The total abatement costs are estimated from the marginal abatement cost functions for CO2, CH4, N2O, and BC.
Our results show that, if carbon cycle feedbacks turn out to be stronger than what is known today, it would incur substantial abatement costs to keep up with the 2°C stabilization goal. Our results also suggest that it would be less expensive in the long run to plan for a 2°C stabilization pathway by considering

strong carbon cycle feedbacks because it would cost more if we correct the emission pathway in the mid-century to adjust for unexpectedly large carbon cycle feedbacks during overshoot. Furthermore, our tentative results point to a key policy message: do not rely on negative emissions to achieve the 2°C target. It would make more sense to gear climate mitigation actions toward the stabilization target without betting on negative emissions because negative emissions might create large overshoot in case of strong feedbacks.

Observable Tsunami Deposit Layers and Tsunami Inundation

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Recent post-tsunami field surveys show that sandy tsunami deposits usually cannot cover all of the tsunami flow inundation areas. The difference between the sandy tsunami deposits inland extent and the flow inundation limit can be used to estimate tsunami magnitude. However, the relationship between tsunami deposit inland extent and inundation limit is still not fully understood. This paper focuses on studying the relationship and its control factors by using a parameter study and field measurements. Deposition ratio is a ratio between the sediment layer inland extent and the tsunami inundation limit to quantify this relationship. In the parameter study carried by a state-of-the-art sediment transport model (GeoClaw-STRICHE), we change grain size, offshore wave height, and onshore slope. The deposition ratio for tsunami deposit extent (ξ_0) is not sensitive to the grain size. However, the deposition ratios for observable sediment layer inland extent ($\xi_{0.5}$ and ξ_{1}) are affected by the grain size, offshore wave height, and onshore slope. The deposition ratios for a 0.5 cm thick sediment layer from parameter study are consistent with field measurements from the 2011 T\={o}hoku-oki tsunami on Sendai Plain. The topography, especially onshore slope, strongly influences the deposition ratio in this case. The combination of different deposition ratios can be used to estimate tsunami inundation area from tsunami deposits and improve tsunami hazard assessments.

Modeling Elevation Equilibrium and Human Adaptation in Southwest Bangladesh

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The low-lying tidal reaches of the Ganges-Brahmaputra delta relies on a system of polders (embanked landscapes) to prevent against tidal inundation and storm surge. These polders have increased the total habitable and arable land allowing the region to sustain a population of ~20 million people. An unintended consequence of poldering has been the reduction of water and sediment exchange between the polders and the tidal network, which has resulted in significant elevation offsets of 1-1.5 m relative to that of the natural landscape. Tidal River Management (TRM) and other engineering practices have been proposed in order to alleviate the offset. Previous work suggests if implemented properly with sufficient suspended sediment concentrations (SSC), TRM can be effective on timescales of 5-20 years. However, communities must also agree on how and when to implement TRM. Here, we expand previous numerical simulations of sediment accumulation through field-based constraints of grain size, compaction, and sea level rise. We then model human decision-making for implementation of TRM practices.

Our sediment model employs a basic mass balance of sediment accumulation as a function of tidal height, SSC, settling velocity, and dry bulk density. Tidal height is determined from pressure sensors and superimposed sea level rise rate, as defined by the representative concentration pathways of the IPCC. SSC varies within a tidal cycle (0-3 g/L) and seasonally (0.15-0.77 g/L). Multiple grain sizes (14-27 μm) are used as proxies for settling velocity by Stokes' Law. Dry bulk density (900-1500 kg/m3) is determined from sediment samples at depths of 50-100 cm. The human dimension is introduced through an agent-based model for community decision-making regarding TRM.

Channel Geomorphology along the Fluvial-tidal Transition, Santee River, USA

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There exists a rich understanding of channel forms and processes for rivers with unidirectional flows, and for their estuarine components with bidirectional flows. On the other hand, complementary insight on the transitional reach linking these flows has not been well developed. This study highlights the analyses of high resolution, high accuracy bathymetric surveys along a coastal plain river at 30 - 94 km upstream of the estuary mouth. The goal of this work is to identify geomorphic indicators of the fluvial-tidal transition channel. Trends with sharp breaks were detected in along-channel variations of depth, hydraulic radius, channel shape, bed elevation and sinuosity, but cross-section area of flow provided the greatest insight. The transition channel is characterized as a reach with greater than 50% decline in area of flow relative to the background values at the upstream and downstream ends. Further downstream the river is a mixed bedrock-alluvium system, and a 22 km reach of discontinuous bedrock outcrops has a marked influence on local channel metrics, and corresponding backwater effects on upstream metrics. Despite the confounding effects of bedrock on channel form the transition channel linking estuarine and fluvial channel segments is apparent as a 13 km geomorphic discontinuity in flow area along a channel reach of relatively uniform width. Finally, it is proposed that bedrock outcrops enhance tidal energy dissipation and influence the position of the fluvial-tidal transition reach, and associated geomorphic and hydrodynamic features.

PyMT Demonstration

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https://youtu.be/C6rG_Rlx9-Q

Coupled Human-Earth Systems Models and the Digital Proxy Record: Connecting the Human and Natural

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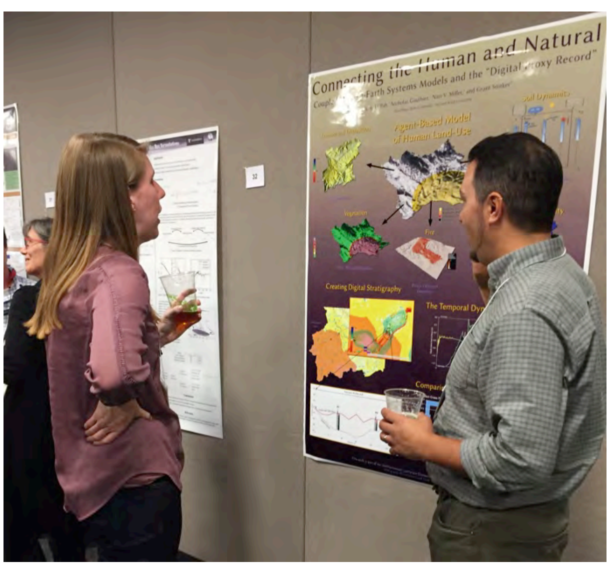

Simulation models are explicit descriptions of the components and interactions of a system, made dynamic in software. In Coupled Human-Earth Systems Science, we most often employ simulation to conduct controlled experiments in which key socio-ecological parameters are varied, and changes to system-level dynamics are observed over time. An interesting emergent property of these kinds of experiments is that they produce a range of possible outcomes for any set of initial conditions. Thus, rather than use simulations to explain particular case studies from the past, they are better suited to examine the dynamics of ancient systems in a more general way.

Model parameters need to be determined and model output needs to be validated, however. So, our simulations *do* need to be connected to empirical data; a useful model must be capable of producing the same *kinds* of patterns observed in the archaeological record (but not *only* these patterns). It is often difficult, however, to connect model output to real data. In this presentation I draw upon research and modeling techniques being developed by the Mediterranean Landscape Dynamics Project to explore ways of connecting the output of simulation models to the kinds of proxy records that we typically use to learn about the past, such as the stratigraphic record, human artifact densities, and phytolith and charcoal accumulation

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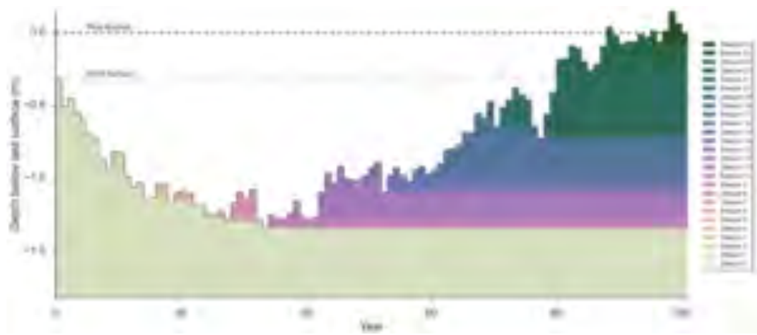

A graphic showing the temporal pattern of how a stratigraphic column is generated in a coupled human-earth system model

Links Between the Human Dimension and Long Term Tectonics

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Long-term tectonics shape the landscape we live on. Collision over 10s of millions of years has produced the Himalayan mountain chain, the Tibetan Plateau and the atmospheric disturbance that produces the Asian monsoon. But it is the dynamic, short-term manifestations of tectonics and plate boundaries and their aftermath that most dramatically impact people's lives. The shaking of a large main shock, while overwhelming, is over within minutes but the consequences of the shaking on the landscape can last for years to decades. In particular, in mountainous environments, a sedimentary hazard cascade (SHC) can dominate a region in the decades following a large earthquake. The 1999 Chi-Chi earthquake in Taiwan, the 2008 Wenchuan earthquake in China and most recently the 2016 Kaikioura earthquake in New Zealand provide the opportunity to quantify and model some of these impacts. In particular, improved knowledge of spatial and temporal variations in rock erodibility help us to understand the physical connections between tectonic structure and the Earth surface, both in the short and in the long term. Quantifying rock damage (erodibility) as a result of tectonic processes is an important step in exploring the link between the processes that occur on the timescales of the human dimension and long term tectonics.

Resilience Analysis of Bangladesh Inland Waterway Network Using Landsat Data

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The Ganges-Brahmaputra-Meghna Delta (GBMD), located in South Asia, is the largest river deltaic system in the world covering 41,000 mi2. Roughly the size of Kentucky, the GBMD is an extremely fertile region of protected mangrove forests and intensely cultivated land connected in a complex network of tidal channels, creeks, swamps, and oxbow lakes. Anthropogenic forces, natural subsidence accumulation, and eustatic sea level rise threaten deltas such as the GBMD and the quality of life of the people residing there. Most of the GBMD is located within Bangladesh and provides essential transportation services through inland waterways that carries 50% of cargo traffic and 25% of all passenger traffic mostly through the active northeastern region labeled with a dashed yellow line as shown in Figure 1. Vanderbilt's multidisciplinary Integrated, Social, Environmental, and Engineering (ISEE) research team's previous research efforts in Bangladesh focused on the physical characteristics of the deltaic system as climate change and anthropogenic forces affect it, but little is known about how channel closures affects the transportation network. Recent research has made use of available Landsat data combined with Google earth imagery to identify key metrics and attributes of the GBMD in order to link connectivity of distributary fluvial patterns to ecosystem services (Passalacqua et al., 2013). This work aims to integrate previous research using satellite imaging to model the transportation network that uses metrics such as channel width and nearest edge distance combined with available data on freight movement provided by multiple sources of information, such as the World Bank. In later stages of the project, we will use historical data of satellite imagery to capture channel dynamics that will be used to simulate disruptions to the transportation network and analyze subsequent impacts to Bangladesh's economy. This allows decision makers to better understand how natural and anthropogenic forces affect the coupled human-environment system and to identify critical links within the transportation network that have the largest impact to Bangladesh's economy when disrupted.

Reference: *Passalacqua, Paola, et al. Geomorphic signatures of deltaic processes and vegetation: The Ganges-Brahmaputra-Jamuna case study. Journal of Geophysical Research: Earth Surface 118.3 (2013): 1838-1849.*

Predicted Changes in High Temperature Events over North America Within CORDEX Simulations

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The frequency of high temperature events is increasing globally under the current climate change conditions. These extreme events have important consequences for society, affecting public health, the regional habitability and the global economy. We evaluate the changes in frequency and distribution of high temperature events over North America, using three different indices and a set of regional climate simulations from the Coordinated Regional Climate Downscaling Experiment (CORDEX). Our results show an increase in the number of high temperature days per summer, in addition to an increase in the frequency of heat wave events for the 21st century. The results reveal large variability among the regional climate models and boundary conditions from the driving models. The increase in the frequency of high temperature simulations examined over North America advocates for strategies to prevent potential effects on food availability, public health and the environment.

Modeling Permafrost Thermal State and Active Layer Thickness on the Qinghai-Tibet Plateau, China

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In China, permafrost is mainly underlain on the Qinghai-Tibet Plateau (QTP), which is the largest mid-low latitude permafrost region in the world. Owing to the unique and extremely high altitude, permafrost area on the QTP approximately amounts to 1.06 million km2. Permafrost on the QTP is one of the most sensitive indicators to global climate change, because it is the product between the earth and atmosphere system. The active layer is the interface between the earth and atmosphere. To understand the present condition of active layer and permafrost thermal state is the foundation to learn about the hydrological cycles, infrastructures built on and in permafrost, soil carbon release and uptake, and biogeochemical and ecological processes in cold regions. The observations can depict the present state of permafrost, but models are eventually essential to predict future changes of permafrost. Despite the fact that geophysical surveys and boreholes are the most reliable sources of information about permafrost, they are extremely costly and are mostly available from relatively small regions. I tried to implement the Geophysical Institute

Permafrost Lab Version2 (GIPL2) model on the Qinghai-Tibet Plateau (QTP). The GIPL2 model can provide more permafrost thermal state than those of statistical empirical models. I am interested in applying the GIPL2 model to the Qinghai Tibet Plateau in order to know the thermal state of QTP permafrost and its response to recent climate changes. The results of our present work using the original version of GIPL2 indicated that for the whole permafrost area of the QTP, the simulated ALT ranges from 0 to 8 m, with an average of 2.30 m. The simulated 18 ALT sites are generally underestimated compared with the observed values with the MBE value of -0.14 m and the RMSE value of 0.22 m.

Integrated Assessment Models for Decision Making under Uncertainty

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The Sustainable Development Goals and of the Paris Agreement declare global commitments to climate stabilization and shared prosperity, but specific pathways for their simultaneous achievement remain unclear. On smaller time scales, governmental, agricultural, and economic systems require climate adaptation solutions. Integrated assessment models (IAMs) are essential tools for managing complex systems to meet these simultaneous imperatives, but are subject to theoretical, computational, and personal limitations. In this presentation, I will discuss the role of three IAMs (GLOBIOM, FeliX, and the Resilience Indicator Multihazard Model) in service of decision making under uncertainty for science and policy.

https://youtu.be/QpV-PqOTjvk
http://csdms.colorado.edu/mediawiki/images/Brian_Walsh_CSDMS_2017_annual_meeting.pdf

Michael Young's Talk

https://youtu.be/Fa543pO7_0U
http://csdms.colorado.edu/mediawiki/images/Michael_Young_CSDMS_2017_annual_meeting.pdf

Participatory Complex Systems Modeling for Environmental Planning: Opportunities and Barriers to Learning and Policy Innovation

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Six years ago, we set out to study how complex systems simulations could support collaborative water planning. We hypothesized that, by allowing participants to see the hidden effects of land- and water-use decisions on water flow, such tools could provide a platform for collective and innovative solution-building to complex environmental problems. We first adopted a developmental and collaborative agent-based approach, where groups of stakeholders learned how to inform and use models to assess the impacts of different implementation strategies. Despite their improved understanding and enhanced exploration of solutions, participants resisted policy innovation beyond familiar strategies. We refined our approach towards facilitated interaction with complex systems models and additional interfaces to help stakeholders provide direct input to the simulations, comprehend model outputs, and negotiate tradeoffs. Participants challenged outdated and false assumptions and identified novel solutions to their water woes. Nevertheless, at times the dissonance between simulation outputs and participants' expectations was too great to accept and own. We share three stories of the obstacles encountered and offer suggestions to overcome them: keep models and interfaces simple, make both biophysical processes and values visible and tangible, and explicitly structure the social aspects of the simulation's use. We draw on our experiences to show what aspects of visualization can support participatory planning.

A2.2 Clinics

Bringing CSDMS Models into the Classroom

Irina Overeem & Mark Piper, *CU, CSDMS-IF*

CSDMS has developed a Web-based Modeling Tool – the WMT. WMT allows users to select models, to edit model parameters, and run the model on the CSDMS High-Performance Computing System. The web tool makes it straightforward to configure different model components and run a coupled model simulation. Users can monitor progress of simulations and download model output.
CSDMS has designed educational labs that use the WMT to teach quantitative concepts in geomorphology, hydrology, coastal evolution and coastal sediment transport. These labs are intended for use by Teaching assistants and Faculty. Descriptions of 2 to 4-hr hands-on labs have been developed for HydroTrend, Plume, Sedflux, CHILD, TOPOFLOW and ROMS-Lite. These labs include instructions for students to run the models and explore dominant parameters in sets of simulations. Learning objectives are split between topical concepts, on climate change and sediment transport amongst many others, and modeling strategies, modeling philosophy and critical assessment of model results.
In this clinic, we will provide an overview of the available models and labs, and their themes and active learning objectives. We will discuss the requirements and logistics of using the WMT in your classroom. We will run some simulations hands-on, and walk through one lab in more detail as a demonstration. Finally, the workshop intends to discuss future developments for earning assessment tools with the participants.

ANUGA - An Open-source Model of River Flood Morphodynamics (and other Hydrological Disasters)

Mariela Perignon, *CU, CSDMS-IF*

ANUGA is an open source software package capable of simulating small-scale hydrological processes such as dam breaks, river flooding, storm surges and tsunamis. Thanks to its modular structure, we've incorporated additional components to ANUGA that allow it to model suspended sediment transport and vegetation drag. ANUGA is a Python-language model that solves the Shallow Water Wave Equation on an unstructured triangular grid and can simulate shock waves and rapidly changing flows. It was developed by the Australian National University and Geosciences Australia and has an active developer and user community. This clinic will provide a hands-on introduction to hydrodynamic modeling using ANUGA. We will discuss the structure and capabilities of the model as we build and run increasingly complex simulations. No previous knowledge of Python is required. Example input files will be provided and participants will be able to explore the code and outputs at their own pace.

Introduction to Coupled Geodynamics-surface Process Modeling with SiStER

Jean-Arthur Olive, *Lamont-Doherty Earth Observatory*

This clinic will provide an introduction to the MATLAB-based geodynamic modeling code SiStER (Simple Stokes solver with Exotic Rheologies, available at: https://csdms.colorado.edu/wiki/Model:SiStER), with particular emphasis on problems that couple solid-Earth deformation and surface processes. Attendees will develop and run simulations where fault evolution (in rifts or orogens), lithospheric flexure and/or mantle flow interact with surficial mass redistribution through erosion and sedimentation.

Spatial Agent-based Models: Introducing Individual Interacting Actors in Environmental Models

Tatiana Filatova, *University of Twente, Faculty of Behavioral, Management and Social Sciences, Enschede, Netherlands.*

Agent-based modeling (ABM) developed as a method to simulate systems that include a number of agents – farmers, households, governments as well as biological organisms – that make decisions and interact according to certain rules. In environmental modeling, ABM is one of the best ways to explicitly account for human behavior, and to quantify cumulative actions of various actors distributed over the spatial landscape. This clinic provides an introduction to ABM and covers such topics as:

Modeling heterogeneous agents that vary in attributes and follow different decision-strategies
Going beyond rational optimization and accommodating bounded rationality
Designing/representing agents' interactions and learning.

The clinic provides hands-on examples using the open-source modeling environment NetLogo https://ccl.northwestern.edu/netlogo. While no prior knowledge of NetLogo is required, participants are welcome to explore its super user-friendly tutorial. The clinic concludes with highlighting the current trends in ABM such as its applications in climate change research, participatory modeling and its potential to link with other types of simulations.

Modeling Permafrost; a New Software Toolbox to Explore Frozen Grounds

Irina Overeem & Elchin Jafarov & Kang Wang (1) CU, CSDMS-IF, 2) LANL

Permafrost is one of the Arctic climate indicators, and feedback of thawing permafrost to the global climate system through the impacts on the carbon cycle remains an important research topic. Observations can assess the current state of permafrost, but models are eventually essential to make predictions of future permafrost state.

In this 2hr clinic, we will present a new, easy-to-access and comprehensive cyberinfrastructure for permafrost modeling. The 'PermaModel Integrated Modeling Toolbox' includes three permafrost models of increasing complexity. The IMT is embedded within the Community Surface Dynamics Modeling System Web Modeling Tool (WMT). We include multiple sets of sample inputs, representing a variety of climate and soil conditions and locations, to enable immediate use of the IMT.

The hands-on clinic teaches students and researchers how to run and use several permafrost models. The presented models are envisioned to be the suitable for quick exploration of hypotheses and for teaching purposes.

Modeling Earth-Surface Dynamics with Landlab 1.0

Nicole Gasparini, *TU, Department of Earth and Environmental Sciences*

Landlab a Python toolkit for building, coupling, and exploring two-dimensional numerical models of Earth-surface dynamics. This clinic will provide a hands-on introduction to Landlab's features and capabilities, including how to create a model grid, populate it with data, and run numerical algorithms for surface hydrology, hillslope sediment creation and transport, and stream incision. We will highlight the structure and examples from two complete models built within the Landlab framework: a ecohydrology model and an overland flow model. For participants interested in both Landlab and the Dakota toolkit, we encourage you to sign up for both this clinic and a following clinic on using Dakota in the context of Landlab models. Participants are encouraged to install Landlab on their computers prior to the clinic. Installation instructions can be found at: http://landlab.github.io (select "Install" from the menu bar at the top of the page).

Good Enough Practices for Reproducible Scientific Computation

Allen Lee, *Arizona State University*

How difficult would it be to create a transparent, fully reproducible codebase that can be downloaded from a trusted digital repository, compiled, and then run with minimal effort? How about a codebase that

can be understood, reparameterized with coherent alternative assumptions, and analyzed by other researchers or future graduate students? As of this writing, it appears to be quite hard just to locate the code necessary to build / run an executable [1] [2] and this is a problem that only gets worse over time as software and system dependencies evolve. Luckily there are many Good Enough [3] practices that can be added incrementally to your development workflow to help others understand, properly review, and build on the software artifacts that increasing numbers of research findings depend upon.
This clinic will cover practical tips, workflows, and tools to help you create reproducible [4] and citable [5] computational pipelines while avoiding common pitfalls and potential issues. We will go over good practices for version control, documentation, data and metadata management, and demonstrate how CoMSES Net is using emerging technologies like Docker containerization to facilitate reproducible computational pipelines. Other topics (depending on participant interest and experience) include automated tests, continuous integration, and modular components / microservices.

[1] - http://reproducibility.cs.arizona.edu/
[2] - https://cbie.asu.edu/practice-archiving-model-code-agent-based-models
[3] - https://swcarpentry.github.io/good-enough-practices-in-scientific-computing
[4] - https://www.practicereproducibleresearch.org
[5] - https://www.force11.org/group/software-citation-working-group

The Sediment Experimentalist Network (SEN) Knowledge Base

Raleigh Martin, *University of California, Los Angeles*

The Sediment Experimentalist Network (SEN) integrates the efforts of sediment experimentalists to build a Knowledge Base for guidance on best practices for data collection and management. The network facilitates cross-institutional collaborative experiments and communicates with the research community about data and metadata guidelines for sediment-based experiments. This effort aims to improve the efficiency and transparency of sedimentary research for field geologists and modelers as well as experimentalists.
The purpose of this clinic is to familiarize participants, experimentalists and modelers alike, with how to use and contribute to the SEN Knowledge Base (SEN-KB, www.sedexp.net). SEN-KB provides a wiki-like forum for sharing information on experimental methods, equipment, set-ups, and facilities. It also serves as a portal for discovery of datasets tied to the descriptions of experimental techniques. Such datasets are not hosted on SEN-KB; rather, data descriptions are linked to datasets stored on external servers, such as SEAD ("Sustainable Environment Actionable Data", https://sead2.ncsa.illinois.edu/). SEAD is a resource for storing and curating large (10's-100's of GB) experimental datasets, and it provides the capability for submitting these data for publication, issuance of DOIs ("digital object identifiers"), and long-term archiving on disciplinary data repositories.
After a brief introduction to using SEN-KB and SEAD, participants will divide into two groups depending on their interests. The first group of "Data Contributors" will engage in a focused session of contributing new entries and/or editing existing entries on SEN-KB and SEAD based on their own experimental work. The second group of "Data Utilizers" will formulate and begin executing plans for addressing scientific questions of interest based on utilization of existing datasets described on SEN-KB and SEAD, such as those generated at the pre-JpGU Kyoto-SEN workshop (Morphodynamics and Genetic Stratigraphy for Understanding Landforms and Strata) to be held a few days before the clinic. We expect experimentalists to affiliate with the "Data Contributors" group, whereas modelers and other non-experimentalists will affiliate with the "Data Utilizers" group. Nonetheless, participants are open to choose for themselves. Both groups will be guided by SEN-KB leaders on hand to answer questions and document software issues. Toward the end of the clinic, both groups will reconvene to discuss lessons learned a path forward.

Beyond Groundwater Modeling: Integrated Simulation of Watershed Systems using ParFlow

Reed Maxwell, *Colorado School of Mines ; Laura Condon, Syracuse University; Nicholas Engdahl, Washington State University*

Accurately characterizing the spatial and temporal variability of water and energy fluxes in many hydrologic systems requires an integrated modeling approach that captures the interactions and feedbacks between groundwater, surface water, and land- surface processes. Increasing recognition that these interactions and feedbacks play an important role in system behavior has lead to exciting new developments in coupled surface-subsurface modeling, with coupled surface-subsurface modeling becoming an increasingly useful tool for describing many hydrologic systems.

This clinic will provide a brief background on the theory of coupled surface-subsurface modeling techniques and parallel applications, followed by examples and hands-on experience using ParFlow, an open-source, object-oriented, parallel watershed flow model. ParFlow includes fully-integrated overland flow; the ability to simulate complex topography, geology and heterogeneity; and coupled land-surface processes including the land-energy budget, biogeochemistry, and snow processes. ParFlow is multi-platform and runs with a common I/O structure from laptop to supercomputer. ParFlow is the result of a long, multi-institutional development history and is now a collaborative effort between CSM, LLNL, UniBonn, and UC Berkeley. Many different configurations related to common hydrologic problems will be discussed through example problems.

Introduction to EcoPath with Ecosim

Kim de Mutsert, *GMU, Department of Environmental Science and Policy*

This clinic will offer you an introduction to developing food web models using Ecopath with Ecosim software. Ecopath with Ecosim (EwE) is an ecological modeling software suite for personal computers that has been built and extended on for almost thirty years. EwE is the first ecosystem level simulation model to be widely and freely accessible. EwE is the most applied tool for modeling marine and aquatic ecosystems globally, with over 400 models published to date, making EwE an important modeling approach to explore ecosystem related questions in marine science. In addition, Ecopath software was recognized as one of NOAA's top ten scientific breakthroughs in the last 200 years. In this clinic, we will start with a brief introduction, then download the freeware and start setting up some simple models which we will use in example exercises. Note: the software works in a Windows environment; Mac computers can be used if they are set up with Parallels Desktop or a similar application to run programs in a Windows environment on a Mac.

BMI: Live!

Mark Piper & Eric Hutton, *CU, CSDMS-IF*

In software engineering, an interface is a set of functions with prescribed names, argument types, and return types. When a developer implements an interface for a piece of software, they fill out the details of the function, while keeping the signatures intact. CSDMS has created the Basic Model Interface (BMI) for simplifying the conversion of an existing model in C, C++, Fortran, Python, or Java into a reusable, plug-and-play component. By design, BMI functions are straightforward to implement. However, when trying to match BMI functions to model behaviors, the devil is often in the details. In this hands-on clinic, we will take a simple model -- in this case, an implementation of the two-dimensional heat equation in Python -- and together, we will wrap it with a BMI. As we develop, we'll use a Jupyter Notebook to test and explore how to use the BMI. To get the most out of this clinic, come prepared to code! We have a lot to write in the time allotted for the clinic. Attendees must bring a laptop, and we recommend installing the Anaconda Python distribution. We also request that you read:

- BMI description
- BMI documentation (http://bmi-python.readthedocs.io)

before participating in the clinic. All materials used in the clinic are available at https://github.com/csdms/bmi-live-2017, including the Python source code for the BMI and a Jupyter Notebook that describes how to use it.

Model sensitivity analysis and optimization with Dakota and Landlab
Katy Barnhart, *CU, Department of Geological Sciences*

Dakota is a flexible toolkit with algorithms for parameter optimization, uncertainty quantification, parameter estimation, and sensitivity analysis. In this clinic we will work through examples of using Dakota to compare field observations with model output using methods of sensitivity analysis and parameter optimization. We will also examine how the choice of comparison metrics influences results. Methods will be presented in the context of the Landlab Earth-surface dynamics framework but are generalizable to other models. Participants who are not familiar with Landlab are encouraged (but not required) to sign up for the Landlab clinic, which will take place before this clinic.
Participants are encouraged to install both Landlab and Dakota on their computers prior to the clinic. Installation instructions for Landlab can be found at: http://landlab.github.io (select "Install" from the menu bar at the top of the page). Installation instructions for Dakota can be found at https://dakota.sandia.gov/content/install-dakota.

A2.3 Software Bootcamp

Bootcamp participants learning from Dr. Mark Piper, CSDMS IF Staff

CSDMS Bootcamp (22 participants, 1 day, instructors Mariela Perignon and Mark Piper)

CSDMS hosted a one day pre-conference programming bootcamp in conjunction with the 2017 Annual Meeting designed to introduce researchers in earth surface science to open-source programming. Participants in this intensive, hands-on workshop gained basic skills that are useful for scientific computing and model development, including the Unix bash shell, high-performance computing in the CSDMS HPCC (beach), and Python programming using Numpy. The workshop was taught by CSDMS IF staff with assistance from CoMSES staff, using lessons and examples that focused on problems relevant to earth surface modeling.

A2.4 BMI Hackathon and HPC Workshop

On the day following the 2017 CSDMS Annual Meeting, the CSDMS IF hosted its first BMI Hackathon. The hackathon was intended to be a social gathering with the goal of collaboratively creating and wrapping software with the CSDMS Basic Model Interface (BMI). The motivation is that a BMI-enabled model can be converted into a CSDMS component, which allows it to be called from PyMT and included in WMT, thereby increasing the visibility and use of the model.

The hackathon was attended by 11 participants that brought with them a wide range of models written in a wide range of languages (Python, C, C#, Fortran, NetLogo). During the half-day session attendees worked together to add BMIs to their models with CSDMS staff guiding participants and providing technical assistance. By the end of the session each participant, if not having a complete BMI, at least had a good start on getting their model wrapped.

First &	Last name	Affiliation	Model	Language
Elchin	Jafarov	LANL	GIPL	Fortran
Calvin	Prichard	ASU	DSSAT	NetLogo
Scott	Stewart	CU	GIPL	Fortran
Kang	Wang	CU	GIPL	Fortran
Allen	Lee	ASU	DSSAT	NetLogo
Gerry	Nelson	ASU	DSSAT	NetLogo
Chloe	Morris	Hull	CAESAR-Lisflood	C#
Abby	Langston	Kansas State	LandLab	Python
Chris	Vernon	PNNL	landcover change model (private)	Python
Mariela	Perignon	CU	ANUGA	C/Python
Eric	Hutton	CSDMS IF	Oceanwaves	Python
Mark	Piper	CSDMS IF	Oceanwaves	Python
Charlie	Shobe	CU	BRaKE	Python

High Performance Computing Workshop

CSDMS hosted a one-day pre-conference High Performance Computing workshop, led by Thomas Hauser, University of Colorado and his HPC Research Computing team. The objective of the workshop was to teach basic parallel programming skills. The hands-on workshop, covered the following topics:

- Basics of Parallelism
- Optimizing for current CPUs
- Parallelizing your code with OpenMP
- Introduction to MPI

Professor Thomas Hauser leading the HPC workshop.

A2.5 2017 CSDMS Annual Meeting Awards

The 2017 CSDMS Lifetime Achievement Award in Earth Surface Dynamics Modeling was presented to **Professor Robert S. Anderson (INSTAAR, U. of Colorado, Boulder)**, as part of the 2017 CSDMS Annual Meeting. Presenters included Professor Greg Tucker (CSDMS Deputy Director & Professor Geological Sciences, CU, Boulder), Dr. Mike Ellis (British Geological Survey) and Professor Jai Syvitski.

Jai Syvitski, CSDMS Executive Director, presents the lifetime Achievement award to Professor Bob Anderson.

Bob has previously received the 2015 University of Colorado Distinguished Professor award, the NSF Presidential Young Investigator Award, the GSA Gladys Cole Award for research in arid regions, Hazel Barnes Prize – the top award at CU Boulder recognizing *the enriching relationship between teaching and research*, and the 2015 G.K. Gilbert award (AGU Earth & Planetary Surface Processes). Bob is a Fellow of AGU, and of INSTAAR. With 157+ peer reviewed books, chapters and journal publications and more than 13000 Google Scholar citations, Bob is demonstrably an outstanding CSDMS member and model developer (Aeolian transport, arctic coastal erosion, and glacier dynamic). His code resides within the CSDMS repository.

Jai Syvitski, CSDMS Executive Director, presents the Director's Award to Dr. Mike Ellis, British Geological Survey

The CSDMS 2017 Director's Award was given to Dr. Michael Ellis. Mike saw the initiation of CSDMS at NSF, and later became the first chair of the CSDMS Anthropocene (now Human Dimensions) Focus Research Group. Michael is the British Geological Survey's (BGS) Director of *Land, Soil & Coast*, and formerly was BGS Director of *Climate & Landscape Change*, and BGS Head *Climate Change Science*. Michael is the Founder and the first AGU section Chair, *Earth & Planetary Surface Processes*, and was formerly NSF Director, *Geomorphology & Land-use Dynamics*.

The 2017 CSDMS Student Modeler Award went to Julia Moriarty for her submission, "*The Roles of Resuspension, Diffusion and Biogeochemical Processes on Oxygen Dynamics Offshore of the Rhone River, France*". Her research focuses on developing and implementing a coupled hydrodynamic-sediment transport-biogeochemistry model, which represents a novel and significant contribution to the geoscience modeling community. The ingenuity of her approach lies in the coupling of sediment transport and water column biogeochemistry. The most novel aspects of this strategy were (1) incorporating the Soetaert seabed biogeochemical model into the Regional Ocean Modeling System (ROMS) to directly link the available sediment transport and water column biogeochemical modules; (2) altering the sediment transport module's seabed layering scheme to resolve millimeter-scale changes in biogeochemical profiles; and (3) accounting for diffusive and advective exchange of solutes and particulate matter between the seabed and water column.

Julia's work was done as part of her PhD research at the Virginia Institute of Marine Science, College of William and Mary, Virginia.

The Best Poster Presentation Award for the CSDMS Annual Meeting 2017, was awarded to Nesha Wright, for her presentation, *"Predicted changes in high temperature events over North America within CORDEX simulations"*. Nesha is a Master's Degree student in the Department of Environmental Sciences at St, Francis Xavier University, Antigonish, Nova Scotia, Canada. Dr. Irina Overeem, CSDMS Senior Research Associate, presented Wright with a certificate and 4GB portable hard-drive at the CSDMS Annual Meeting.

Dr. Irina Overeem presenting award to Nesha Wright

A2.6 Breakout Discussions Modeling Coupled Earth and Human Systems

The 1.5-hour session focused on challenges and suggestions for linking Earth system and social system science. Meeting participants were split into small 25-person groups and the moderators started the session with background information from three other recent workshops, 1) the Human Dimensions FRG workshop, *"Linking Earth System Dynamics and Social System Modeling"*, Boulder Colorado, May, 2016; 2) Future Earth Workshop *"Linking Earth-System and Socio-Economic Models to Predict and Manage Changes in Land Use and Biodoversity"*, Kyoto, Japan, September, 2016 and 3) Future Earth Workshop *"4th Workshop on Modeling Challenges for Sustainability"*, Potsdam, Germany, March, 2017. Participants were then asked to identify and discuss similar and dissimilar approaches used in the natural sciences and social sciences. Discussion topics included:

1. Types of model classes and their limitations;
2. How each group tests for model skill, model uncertainty, validation or model inter comparison efforts;

3. Common model target issues: extreme events, natural hazard impacting the built environment, Food-Energy-Water Nexus, migration and population growth in sensitive environments, etc. and appropriate 1st step ideas for joint proposals;
4. State-of-the-art in social – natural system modeling and model coupling.

Comments and Recommendations:

General

- Engaging with social scientists requires significant efforts on both sides and mutual respect. Natural scientist and social scientists must be respectful of each other's approaches. Once differences are acknowledged, we can start on the challenge of restructuring or reframing the way we communicate.
- Some physical models are very computationally demanding (e.g a groundwater model). This makes coupling with a social model (e.g. ABM) challenging. Therefore it is paramount to increase the speed of calculations OR use simpler models. A way forward might be the use of statistical emulators of these complex models in coupled system models to make tight coupling possible.
- Physical modelers should be aware of the local context when doing modeling. Peoples' perspectives and values should/could be important for physical modelers. Therefore, physical modelers should engage more in human surveys. Ask relevant questions to build better models. Social scientists use unstructured interviews to get to understand the context and thinking of the people first, and then formulate the real quantitative questions.
- Does big data eliminate the need for social science? Statistical analysis and data mining do not require social science. Big data analysis can be useful to identify *what* is going on, but is not able to answer *why* something is happening.
- Simple scenarios are essential for stakeholder engagement. IPPC is a good example, where the scenarios are so simplified and generic that everyone can agree on these (low emission, medium emission, high emission scenarios). The hardest part is to simplify the storyline.
- Infrastructure development maybe the simplest way to incorporate social needs into biophysical modeling. It is planned year/decades ahead and has a long time-span. Could infrastructure be a proxy for future modeling of for example cities in a hurricane/storm surge model?
- When trying to combine physical and social models, start with a simple problem that can be clearly defined and fairly easily implement. E.g. growing almonds vs. groundwater pumping). Maybe land use and land cover modeling is a low-hanging fruit to start combining models, where the motivation of people and the physics limiting the use of land are quite well understood.
- Uncertainty is a challenge. Policy makers and stakeholders generally don't want to know about uncertainty in the models that are presented.
- Observationalists and modelers also need to be brought together!
- Standard names and harmonizing protocols need to be identified and utilized. Start with base of names already used by CSDMS and build in social system terms.
- Earth system modelers tend to focus on equations, data and tools whereas social science modelers are very good at identifying and approaching stakeholders – we need to link these strengths and foci.
- Need to know your audience both up and down stream (model builders, model users and end stakeholders). Need to combine academic and applied aspects.
- Need greater understanding of processes that drive human decisions and how these impact coupled models.

- Linked models should be able to measure and demonstrate success/impact of the specific models and whether they improve/change human decision-making.
- Need data to parameterize human system models.
- Need open source social/behavioral data repositories (CSDMS or CoMSES hosted?)
- CSDMS need more social scientists and economists providing talks at Annual Meetings
- There should be at least one clinic at every future CSDMS meeting on ES/SS linkages
- Tenure requirements sometimes discourage research with cross/interdisciplinary elements – need to find a way to overcome this especially because funding agencies are placing greater emphasis on integrated research. There is a general lack of incentives for cross-disciplinary research.
- Need formal mechanisms in place to encourage academic/applied collaborations

Software

- Use integrating tools like PyMT to help with coupling
- Previous workshops identified important technology needs 1) emphasis on models as components, 2) enabling cross-checking of models, 3) interactivity across models.
- Keeping models as transparent as possible (not black boxes) will assist in the general progress and usage of coupled ES & SS models
- Need to move away from larger and larger more complicated models, and toward smaller, simpler, models that can be linked. This will also stimulate people to contribute, because they can add something small and simple potentially breaking down some of the barriers to collaboration.
- Need to address modeling best practices when linking ES & SS models
- Recommendation to wrap NetLogo with BMI and link it to PyMT
- Desire for coral reef and water resource models linked with SS models
- Quality Visualizations are key to presenting models to stakeholders and simplifies decision-making.

Funding

- Need more funding for stakeholders to attend meetings and trainings to help them understand the science and the models – bring academics and applied users together (government training funds). Travel funding is a real issue.
- Funding opportunities for extreme events, water scarcity and impacts to built infrastructure is increasing – maybe start with smaller projects that target these areas
- CSDMS could work with NSF to acquire and allocate smaller (seed grants) exploratory grants for collaborative projects that could lead to larger CNH proposals.
- World Bank has funding opportunities for collaborative projects.

Curriculum Changes

- The concept of modeling needs to be introduced during K-12 education (ABMs are good for this).
- Universities need to allow social science majors into more rigorous math courses (and modeling focused programs need to require more complicated math)
- Need to encourage more interdisciplinary curricula

Training

- Need brief introductory materials for ES & SS modeling frameworks and types of models – there is a general gap in understanding of basic types of models used in the others communities

- Need a structured overview of ES & SS models relevant at different scales with metadata on spatial and temporal scales, research question which spurred the model development, input & output data produced, models limitations and it's best practice.
- Need much more low cost, low entry training opportunities and online or hybrid training for those who can't travel. Online may bring in more industry people.
- Industry specific trainings would be very useful (perhaps in conjunction with industry-specific conferences)
- Summer Institutes are strongly recommended – suggest something specializing in coupled ES & SS integration (aimed at graduate level)
- Find a way that local universities, research institutions can provide some organizational or teaching services and leverage CSDMS CoMSES training support
- Need more online labs, webinars etc. about linking ES & SS on CSDMS and CoMSES web sites
- Training classes linking ES & SS modeling could provide important opportunities for networking across disciplines
- Future Earth may be interested in supporting some interdisciplinary trainings and networking (as per Josh Tewksbury)
- Webinar needed for each model in the repository (decision trees for model choice)
- Need several scenarios linking Earth and Human Systems in the CSDMS EKT Repository

Community and Communication

- Need to expand the initial "CHESS" group into a larger community of active participants interested in working on this problem (bringing CoMSES and CSDMS HD FRG communities together is a great start).
- Need to find better ways to increase effectiveness of communication with stakeholders
- A "matching service" that would link policy makers and social scientist with the appropriate natural scientists would help overcome the networking/initial communication issue. This could lead to formation of research consortia and larger scale research projects. (UK NERC, US NSF's Coupled Natural and Human Systems program)