# The Community Surface Dynamics Modeling System

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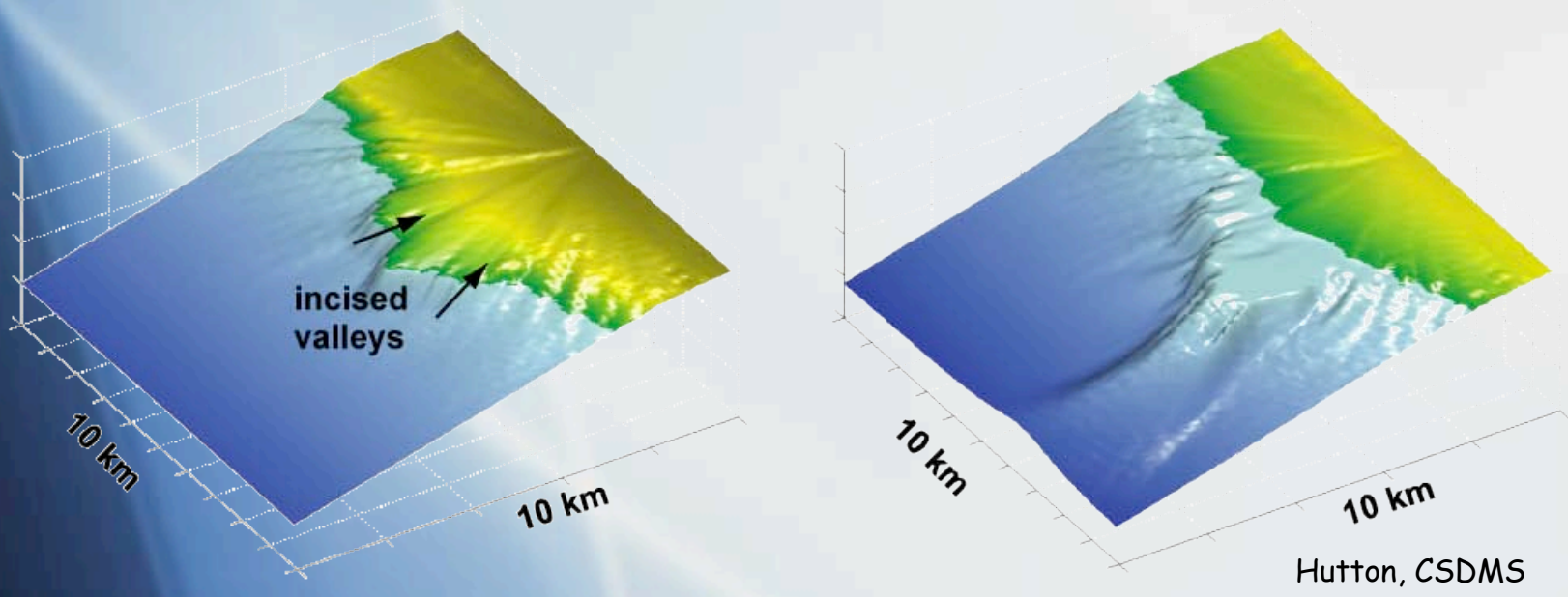
*U.Colorado—Boulder*



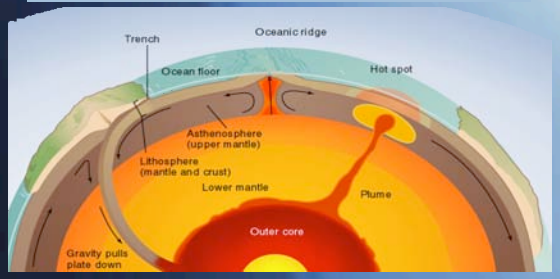

Hutton, CSDMS

COMMUNITY SURFACE DYNAMICS
CSDMS
MODELING SYSTEM

# What is CSDMS?

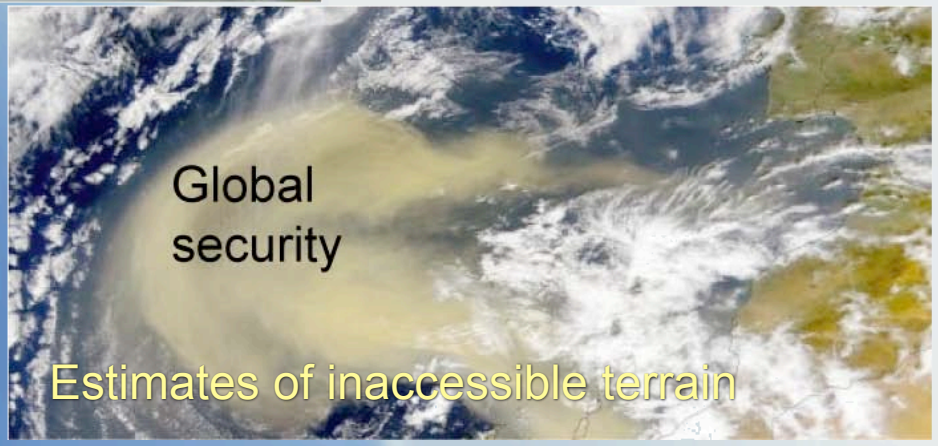
- An integrated community of experts to promote the modeling of earth-surface processes.
- Protocols for the library of community-generated, continuously evolving, open software.
- Cyber-infrastructure to distribute software tools & models in aid of applied and education uses.
- Partnerships with related scientific programs, providing strong linkage between predictions and observations.

Modeling Planet Earth
(CIG, CSDMS, CCSM)



CSDMS

NRC National Imperatives will be addressed by the CSDMS Effort




**CSDMS Goal:**
Develop and disseminate software to predict the erosion, transport, and deposition of sediment & solutes in landscapes and their sedimentary basins.

CSDMS

USGS
science for a changing world
OFFICE OF NAVAL RESEARCH
GEON PORTAL
neon
NATIONAL ECOLOGICAL OBSERVATORY NETWORK
NATIONAL SCIENCE FOUNDATION
US Army Corps of Engineers
NASA
CZO
CZEN
NCED
Earth · Water · Life
MARGINS
to understand the complex interplay of processes that govern the evolution of continental margins
RDECOM
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
U.S. Army Research, Development and Engineering Command
U.S. Army Research Laboratory
CUAHSI
universities allied for water research
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE
The National Center for Atmospheric Research
sponsored by NSF
NCAR
managed by UCAR to serve the community
GWSP
Global Water System Project
LOICZ
IAHS AISH
NOPP
National Oceanographic Partnership Program
Promoting Partnerships for the Future of Oceanography
International Council for Science
Scientific Committee on Oceanic Research
GLOBAL CHANGE
IGBP
International Geosphere-Biosphere Programme
IASC
International Arctic Science Committee
NSF
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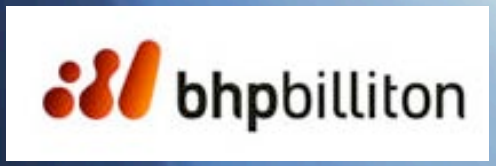
# CSDMS is developing industrial consortiums: (Environment & Engineering; and Geological)

*The following have provided members to CSDMS working groups.*



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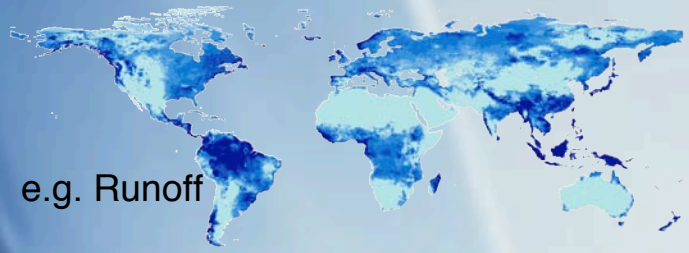
# The CSDMS Data Repository

Climatology: T°C, PPT, Wind, Waves

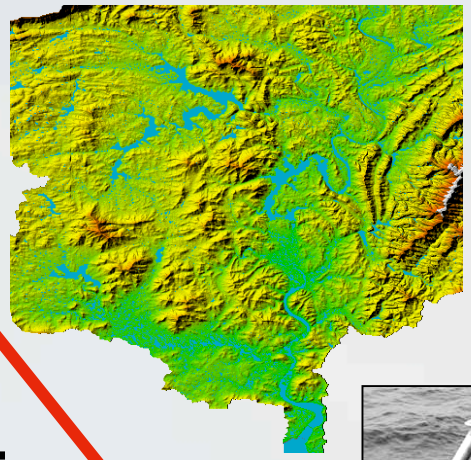


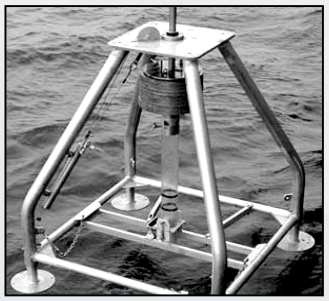
e.g. Runoff

e.g. Lithology

**Gridded Boundary Conditions**

Topography/Bathymetry/Sea Level



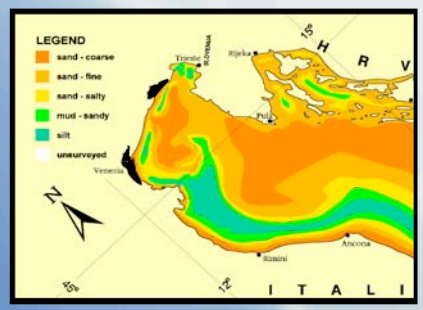


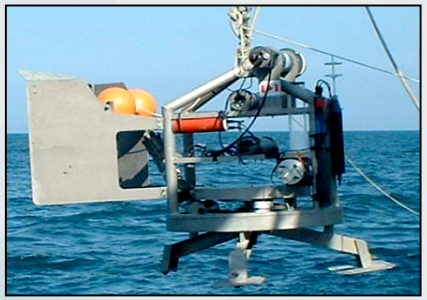
**Data Integration in Modeling**

$$Q^{x}_{s,s} = \int_{z=\delta wbl}^{h} c_s U dz$$

**Gridded Initializations**

Ice Sheet Cover
Soil Type/Thickness
Grain Size
Lakes/Reservoirs
Human Factors: GNP, Pop.
Vegetation
Lithology



**Domain Parameterization**

Flocculation
Critical Shear Stress
Bioturbation
Weathering grade
Productivity
Authigenesis

http://csdms.colorado.edu/models/data.html

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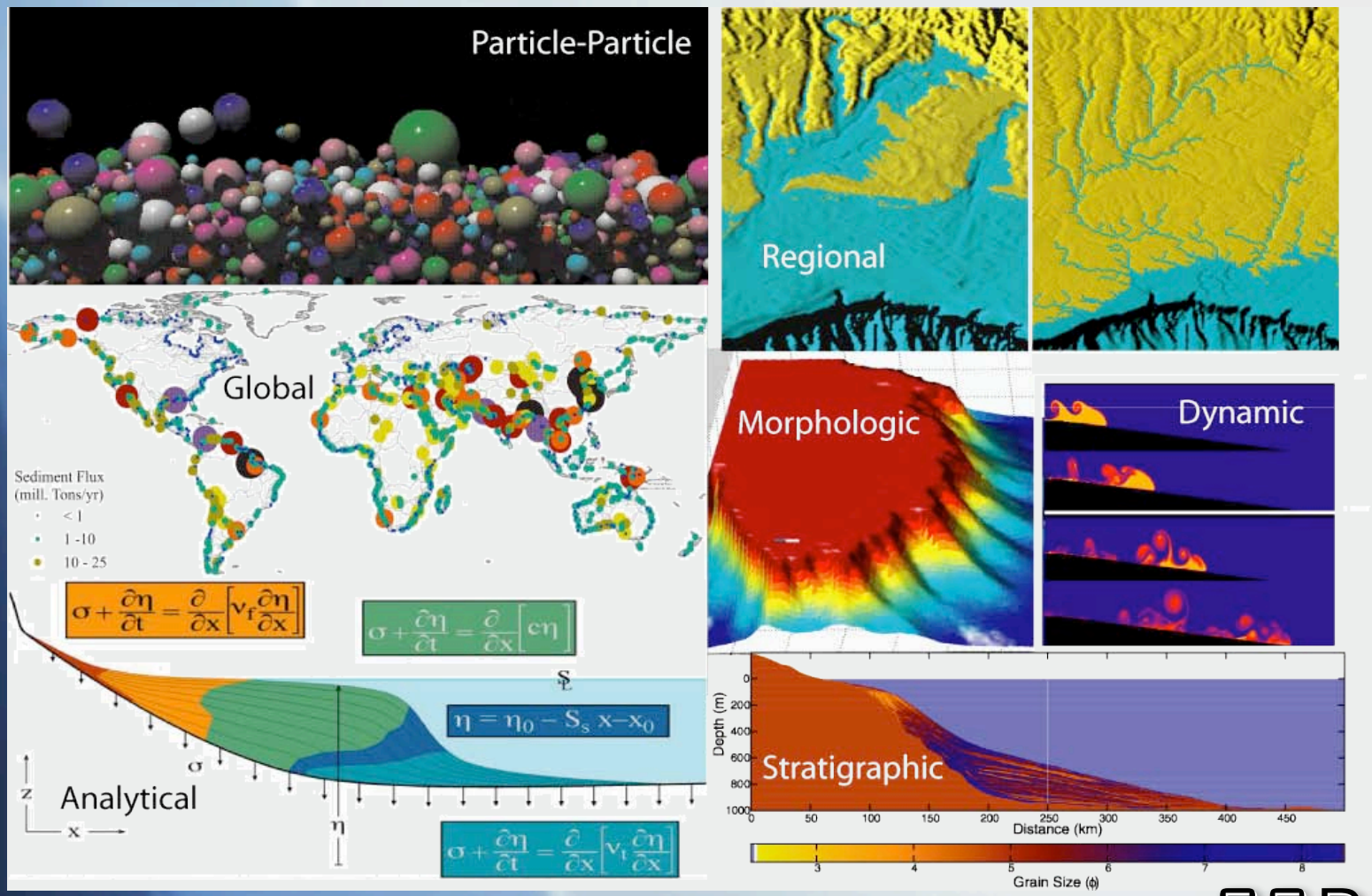
# The CSDMS Model/Tools Repository

CSDMS welcomes stand-alone models/languages & tools relevant to surface dynamics, including novel computational strategies, moving boundary methods, distributed source terms, & nested modules

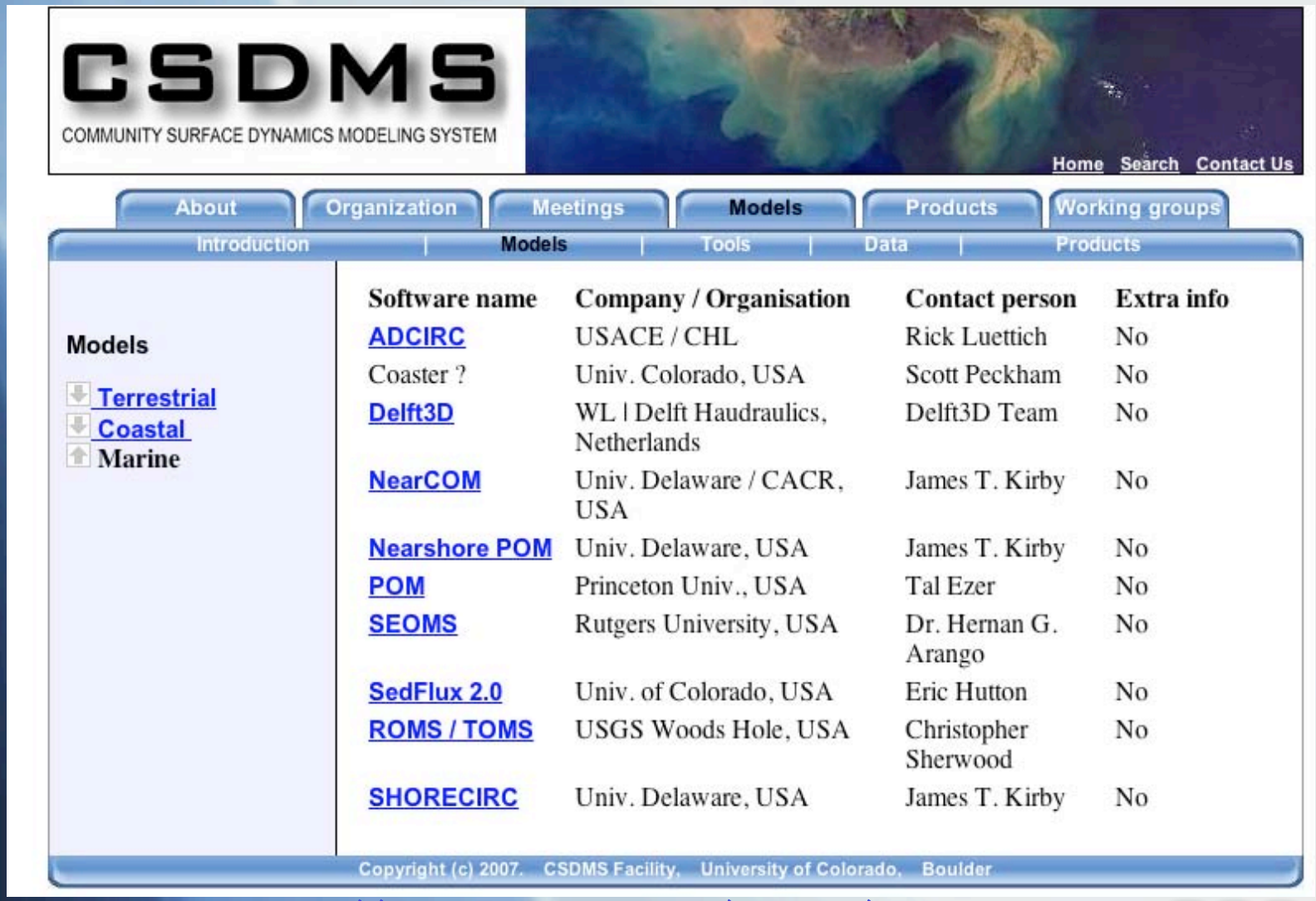



http://csdms.colorado.edu/models/introduction.html

CSDMS

# The CSDMS Model/Tools Repository

CSDMS will point to, or distribute, legacy models/code




http://csdms.colorado.edu/models/models.html

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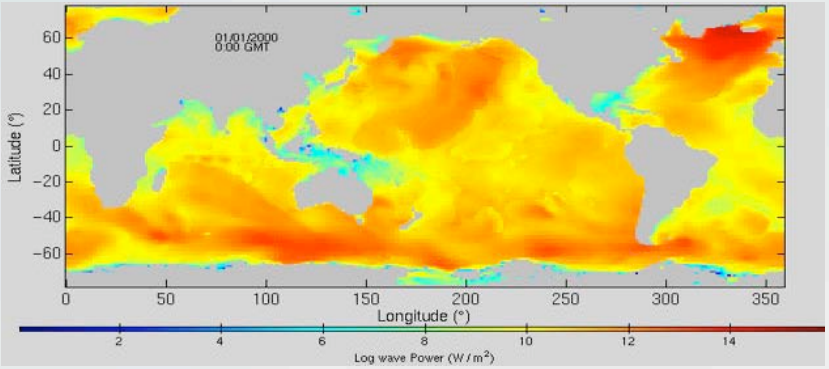
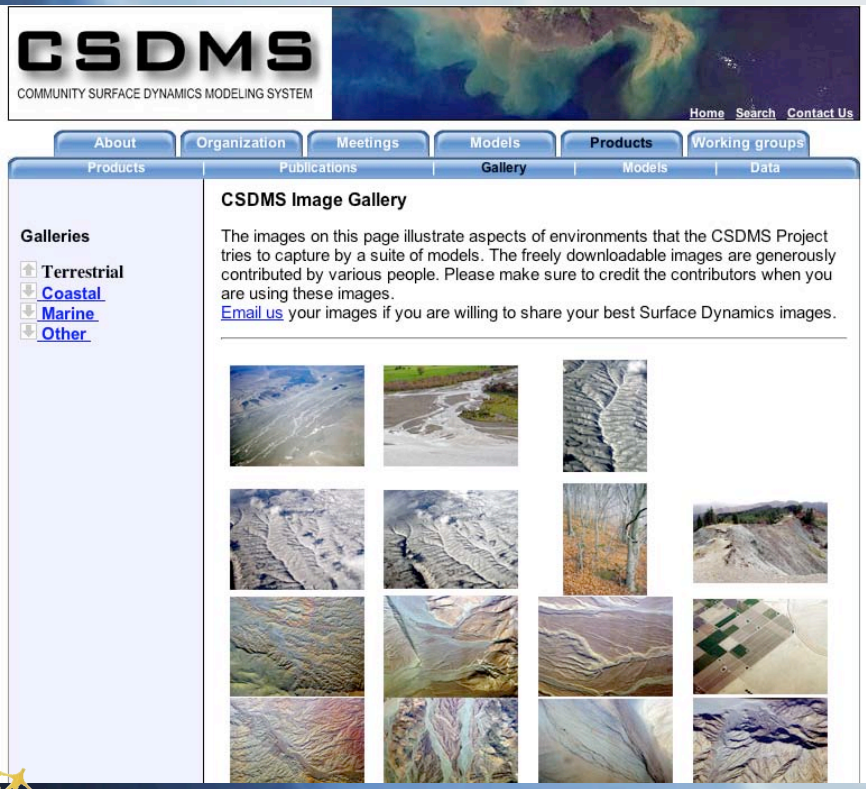
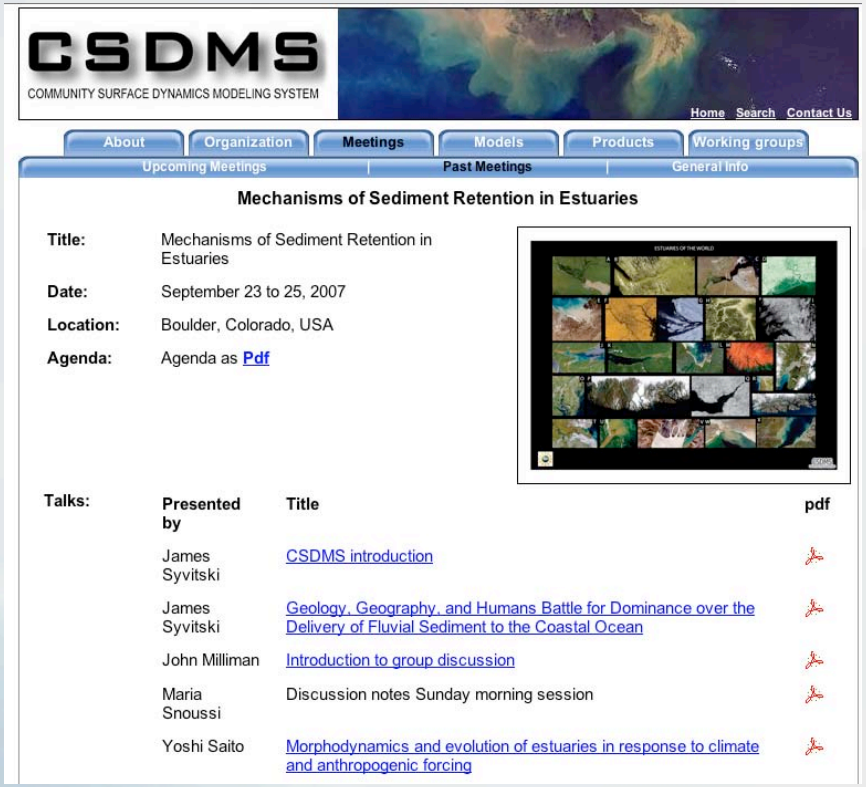
# The CSDMS Education Repository

CSDMS will also distribute: 1) model simulations, 2) Educational PPTs, 3) Reports, Publications, 4) Short Course Materials, 5) Images, 6) Workshop presentations.




http://csdms.colorado.edu/models/models.html

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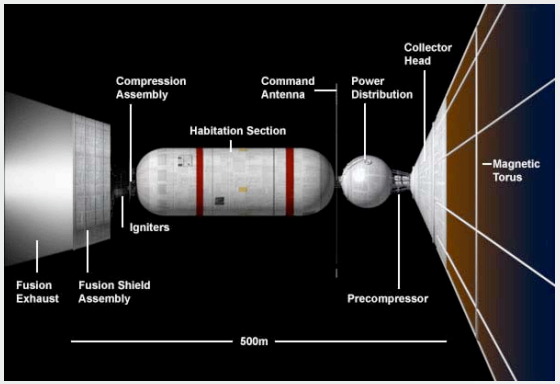
# The CSDMS Compliant Repository

Contributed compliant code able to function within the CSDMS integrated modeling framework




## Specs for the CSDMS Framework

Supports multiple operating systems: *Linux, OSX & Windows*

Supports parallel computation *(via MPI standard)*

Language interoperability: *C, Fortran, Java, C++, Python)*

Supports both legacy (non-protocol) code and structured code (procedural and object-oriented)

Interoperable with other coupling frameworks (*e.g. ESMF*)

Supports both structured and unstructured grids

Supports platform-independent GUI *(e.g. via wxPython)*

Large offering of open-source tools

Open source software license, industry-friendly, protection for authors, tracks modifications, GPL2 compatible OSI approved.

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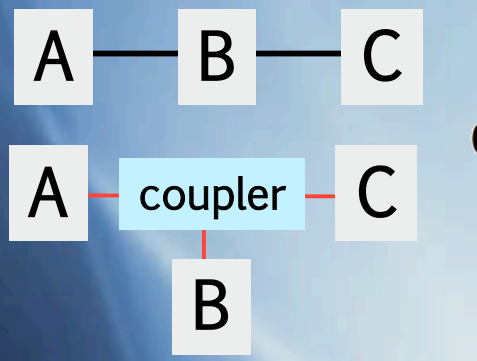
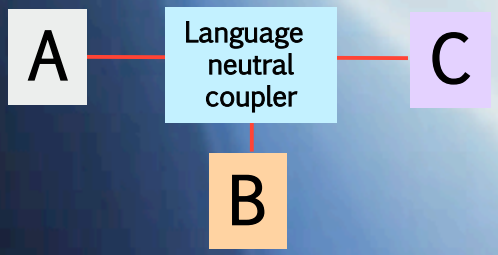
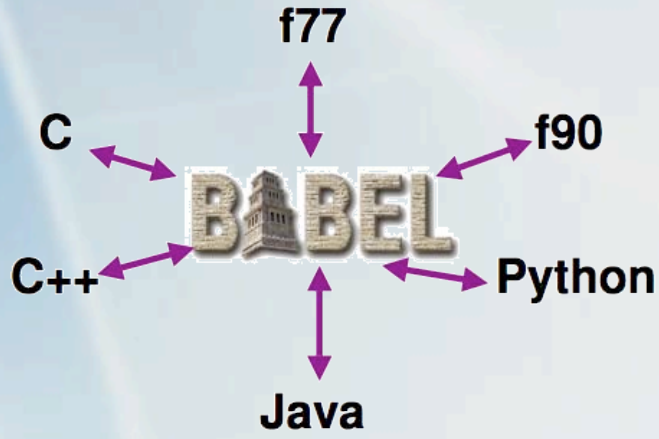
# The CSDMS Compliant Repository




***Language interoperability:*** Components written in different languages can be rapidly linked with little performance cost, allowing for open-source solutions (e.g. libraries), and access to both procedural and object-oriented strategies (legacy and modern code), with graphics & within GUIs.

CSDMS uses the CCA **Architecture** (*set of standards for component technology*), through a **Framework** (*execution rules & services, e.g. Ccaffine*), where **Components** (*modules/models e.g. CHILD or SedFlux)* are linked through **Interfaces** (*communication data protocols*) via **Ports** (*tasks related to the communication between components*).

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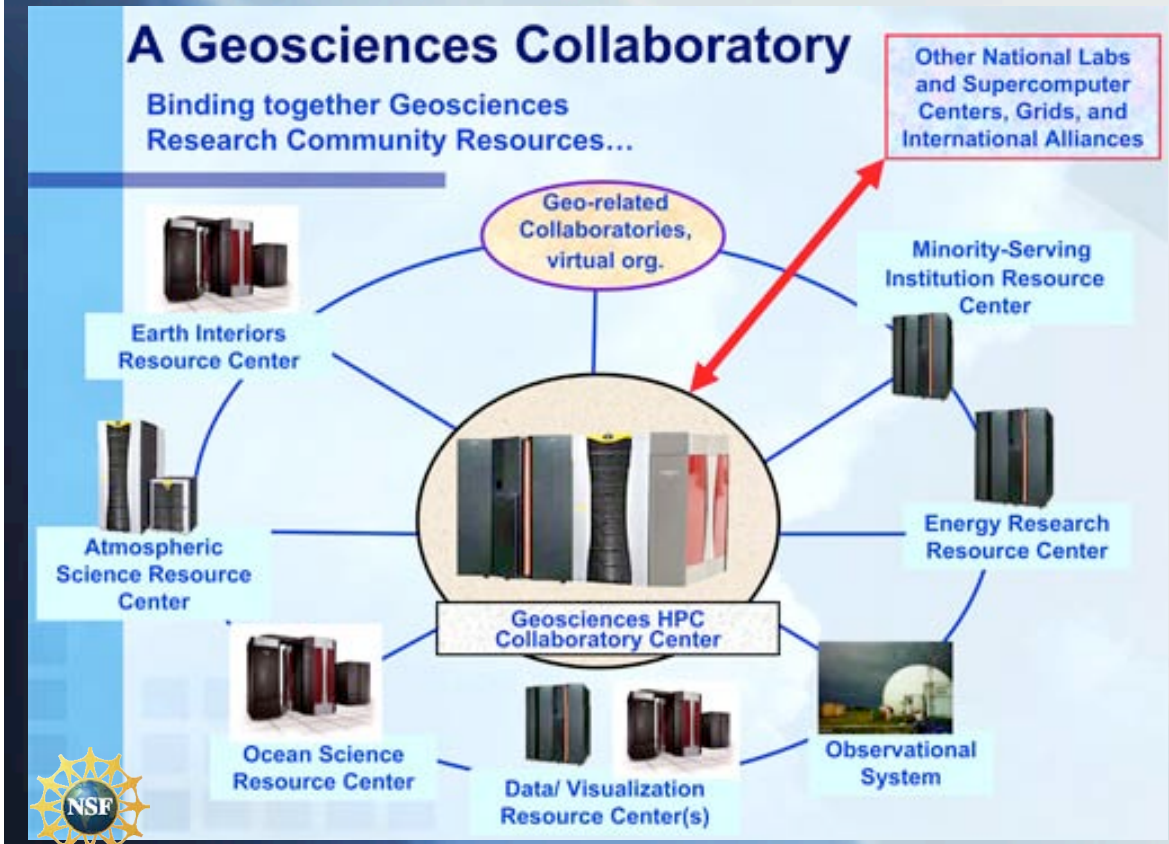
*"CSDMS accepts the NSF directive to aid the surface-dynamics community moving towards modern High Performance Computers."*

*-- Syvitski, 2006, NCAR*

The CSDMS IF will acquire a CSDMS-operated Experimental Supercomputer (ES) offering >256 cores for >4 teraflops of computing power, and configured with two HPC approaches — 1) massive shared memory among fewer processors, and 2) the more typical parallel configuration — running Linux with Fortran, C and C++ compilers.




The CSDMS ES will be linked to the proposed Front Range HPC with 7000 core, >100 teraflops, in turn linked to the US TerraGrid and the proposed Cheyenne NCAR/UCAR Petascale HPC dedicated to the NSF Geoscience Collaboratory.

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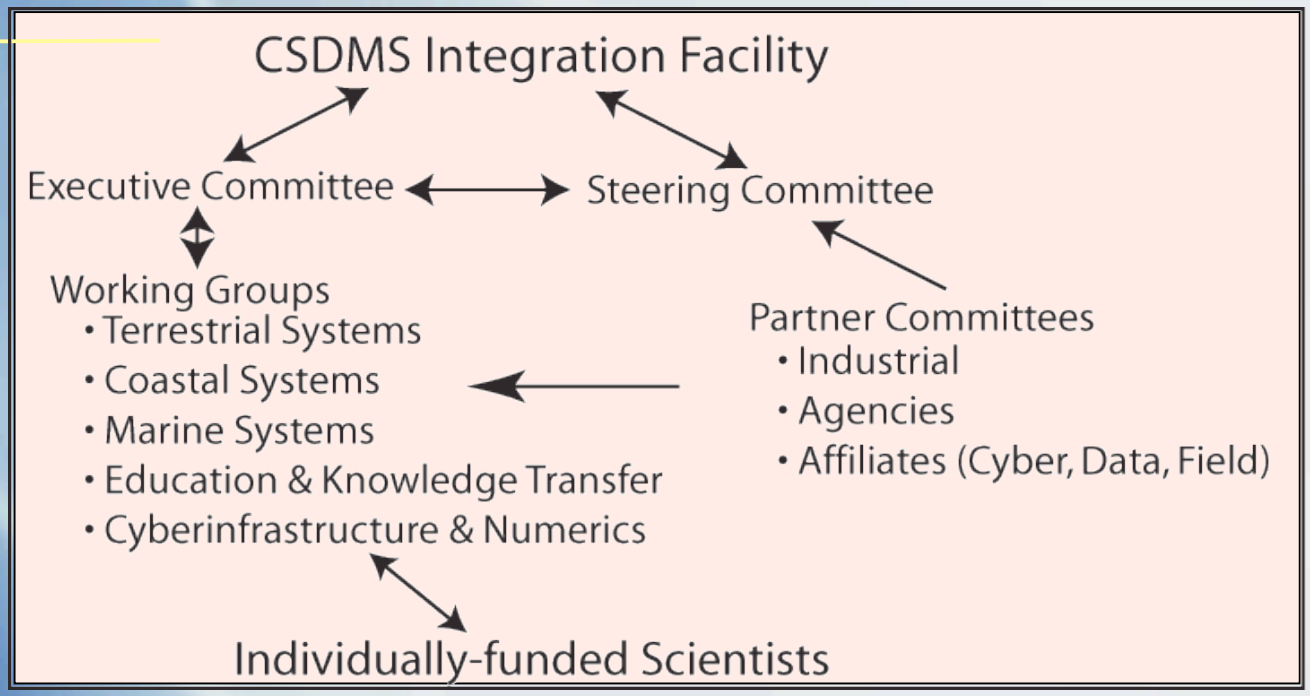
# The CSDMS Org Chart




Yr 1: CSDMS NSF-supported staff = 3.5 FTE
CSDMS non NSF-supported staff (NOPP, NASA, ONR, IC, CU) = 3.5 FTE
= 7 FTE

Yr 2: CSDMS NSF-supported staff = 4.5 FTE
CSDMS non NSF-supported staff ≈ 4.5 FTE
= 9 FTE

Yr 3: CSDMS NSF-supported staff = 7 FTE
CSDMS non NSF-supported staff ≈ 5 FTE
= 12 FTE

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# The CSDMS Team

| Terrestrial | Coastal | Marine | Cyber/Numerics | EKT |
|---|---|---|---|---|
| Tucker/CIRES | Murray/Duke | Wiberg/UVA | Tao Sun/ExxonMobil | *Pratson/Duke* |
| 66 members | 53 members | 47 members | 31 members | 13 members |
| 46 institutions | 42 institutions | 41 institutions | 27 institutions | 11 institutions |
| 9 countries | 11 countries | 9 countries | 4 countries | USA |

**CSDMS ExCom: primary** decision-making body. Ensures that the NSF Cooperative Agreement is met. Develops Bylaws & Operational Procedures, and the rolling 5-y Strategic Plan. Approves memberships and the Bylaws.

Consists of the ExDir as ExCom Chair + 5 W.G. Chairs + S.C. Chair + S.S.E.

**CSDMS Steering Committee: primary** advisory body. Assesses the competing objectives and needs of CSDMS; progress in terms of science, management, outreach, and education; and advises on revisions to the 5-y strategic plan. Approves the Bylaws.

*Chair R. Slingerland (Penn State); T. Drake (ONR), B. Jagers (Delft Hydraulics), R. Sarg (Mines), G. Parker (U. Ill. Urbana Champaign), D. Tetzlaff (Schlumberger-Doll), D. Furbish (Vanderbilt), T. Dunne (UC-Santa Barbara) + Ex officio members J. Syvitski (CSDMS ExDir) & M. Ellis (NSF).*

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# The CSDMS Integration Facility

- **Maintains** the CSDMS Repositories: 1) Data Repository; 2) Model/Tools Repository; 3) Education Repository; 4) Compliant Repository;

- **Oversees** CSDMS Membership, Communication and Governance: 1) Business Meetings (SC, ExCom, Partner); 2) Working Group Meetings; 3) CSDMS Workshops, 4) Short Courses; 5) Web Wiki, 6) Teleconference, 7) Videoconferences, and 8) Email Communication

- **Conducts** Tool/Model Protocol testing & evaluation on varied platforms

- **Evaluates** hardware & software configurations with CSDMS products

- **Develops** the CSDMS cyber-infrastructure (e.g. coupling frameworks; licenses; protocols)

- **Provides** CSDMS software modeling guidance (expertise)

- **Facilitates** Community coordination & public relations

- **Facilitates** Product Penetration

- **Maintains** the CSDMS Vision & Cooperation between disparate communities, & between field and modeling communities.

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# CSDMS Environmental Working Groups

**Identifies** processes in their disciplinary toolkit, gaps in knowledge, and areas for numerical module development.

**Keeps current** both short & long term goals

**Sets** modeling priorities for their disciplines.

**Ensures quality control** for 1) their algorithms and modules including use of benchmark or validation datasets, and 2) adequacy of supporting boundary conditions and boundary initializations.

**Coordinates** the evaluation of numerical codes according to interoperability, scientific contribution, protocol compliance, and technical documentation.

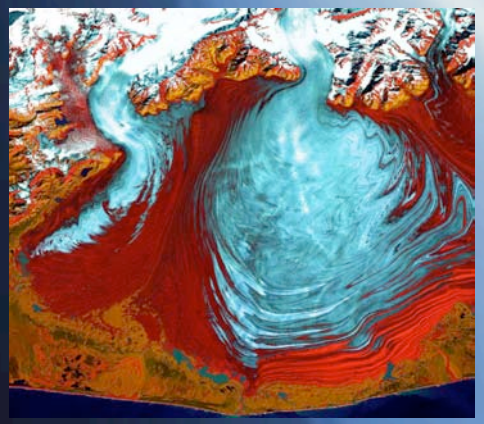
**Addresses** CSDMS proof-of-concept challenges.

**Provides** community continuity to meet long-term CSDMS objectives.

**Stimulates** proposals and input from the community.

**Reports** progress annually.

# CSDMS Terrestrial Working Group Scope



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# CSDMS Coastal Working Group Scope

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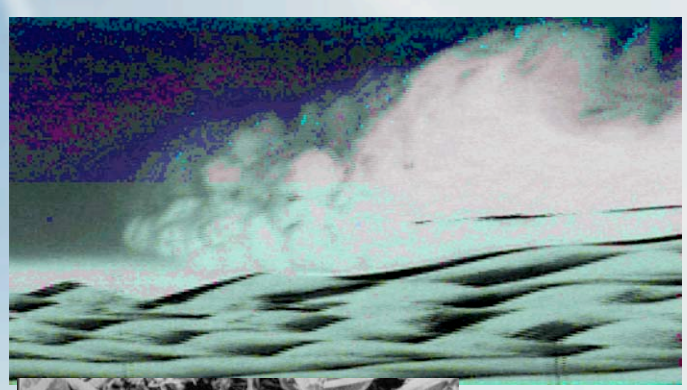
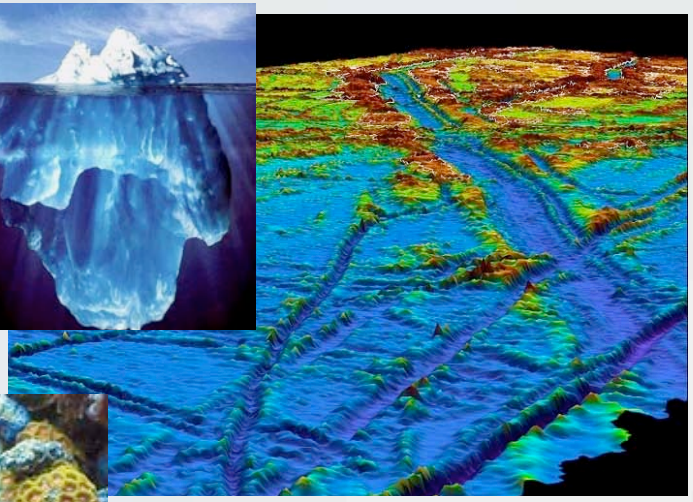
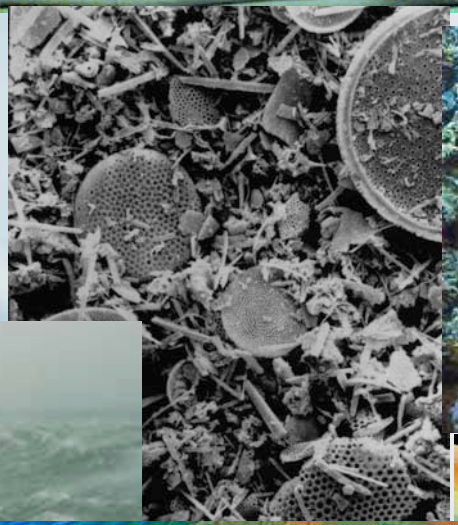
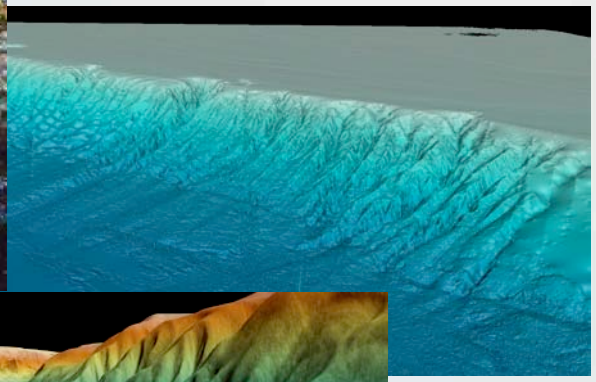
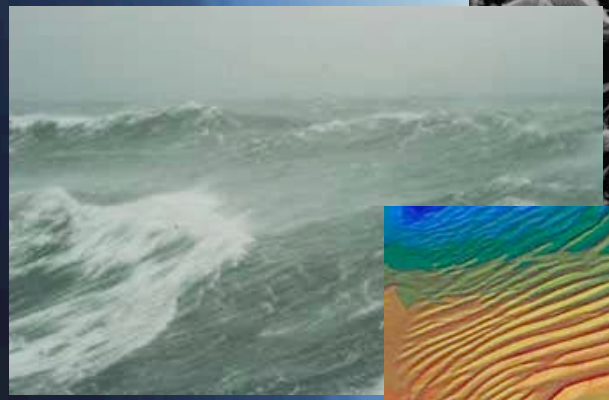
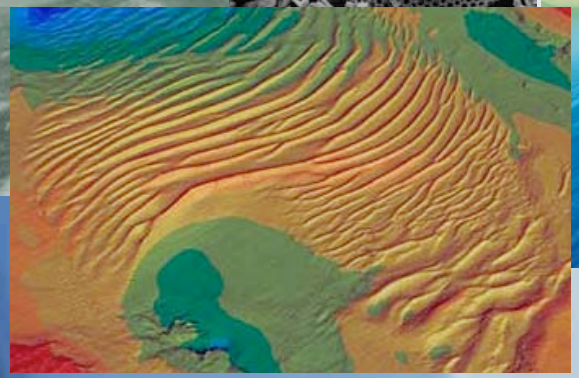
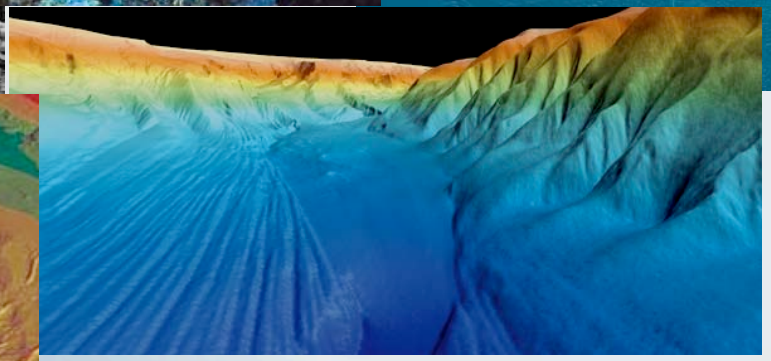
# CSDMS Marine Working Group Scope



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# CSDMS Cyber & Numerics Working Group

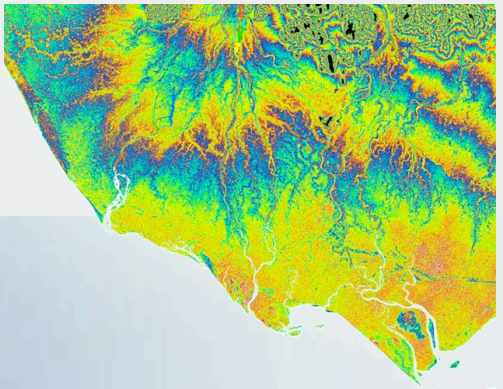
Develop the CSDMS 5-year Cyber-Infrastructure.

- Protocols for linking modules.
- Common data structures and interfaces to link transport processes.
- Incorporation of "legacy code" from the modeling community.
- Toolkits for pre- and post-processing, and model visualization.
- Standards for benchmarking and testing modules.
- Standard computational tools, including I/O error handling, data exchange, grid generators and PDE/flux solvers.
- Infrastructure to facilitate the proof-of-concept challenges
- Graphical user interface (GUI).

Metrics for success:

1) Ability to track the material flux and its characteristics, with conservation of mass and momentum, from the mountains to deep ocean,
2) Ability to link modules with dynamic feedback of state variables/arrays between modules, and
3) Ability to flip modules in and out.

Report progress annually.



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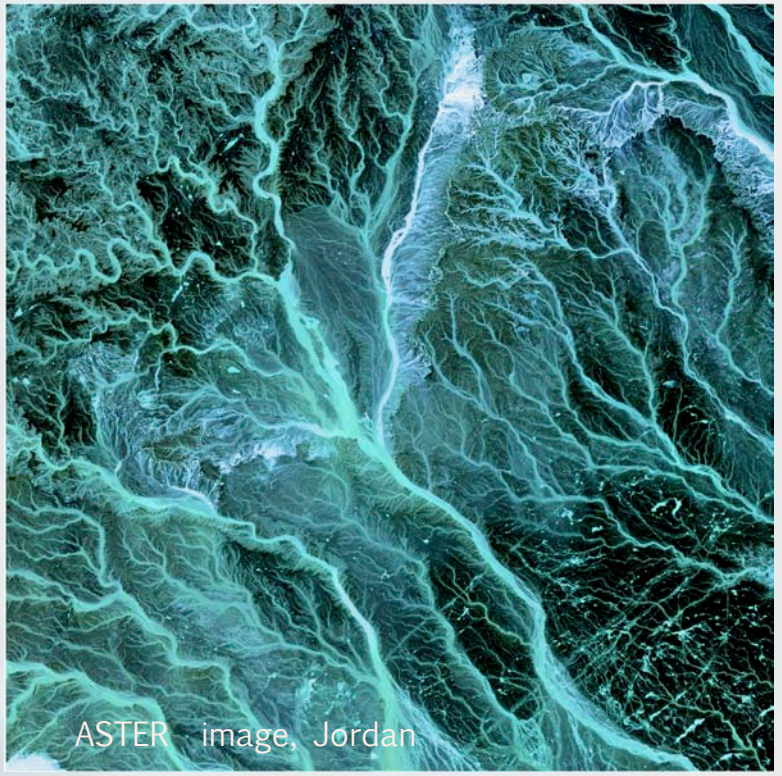
# CSDMS Proof of Concept Model Challenges

1. Models that track the transport and fate of water, sediments, carbon & nutrients.
2. Surface dynamic models that include the *Human Dimension*
3. Models that track surface dynamics across moving boundaries (sea level &/or climate, &/or glacial cycles)


ASTER image, Jordan

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# CSDMS Users:

- Tests hypotheses to support data interpretation
- Utilize pre- & post-processing visualization tools
- Tests modules as part of field campaigns

- Runs scenarios
- Relates GIS output to environmental factors & land use
- Quantifies uncertainties in decision making

- Illustrates surface processes using pre-packaged models
- Builds intuition with "what-if"-type model runs
- Develops case studies that integrate field data and model simulations.
- Prepares exploratory exercises for students

*Uncertainty, Variability, Error, Precision, Accuracy, Confidence*

CSDMS

# Membership has its privileges

- Part of a family of experts — advantages in staying current within a community taking the Earth Sciences to the next level
- Competitive funding opportunities — better integrated proposals
- Better knowledge on available models — for education and application
- Recognized service in an interesting & new field of interdisciplinary science
- Better/faster penetration of one's numerical advances, data and simulation products
- Closer interaction with a wide variety of industrial & NGO partners and federal agencies, with possible spin-off funding opportunities
- Better academic & public recognition for code development
- Increased outreach and knowledge-transfer opportunities

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Is CSDMS a Community Clastic Model? — No. It is a modeling community supporting a modeling architecture (not an uber model). It deals with hydrology, nutrients, sediment (incl. carbonates), ecosystems, glaciers, oceanography, weather, etc --- earth-surface dynamics. CSDMS protocols allow for model components to be mixed in unique ways to answer diverse question. CSDMS is interested in stand-alone models and compliant contributions.

What are the funding opportunities? — Competitive --- but 1) supported by a state-of-the-art research agenda developed by an integrated community; 2) supported by a community of modelers & software engineers; 3) access to a sophisticated modeling architecture, data systems, and high performance computing; & 4) CSDMS opportunities with NGO's, agencies, industry partners.

How are coders recognized? — 1) Through the CSDMS web site, 2) with the metadata following the model, 3) with GPL2 software license protection, 4) through community exposure, vetting and recognition & 5) through accelerated citations within CSDMS-supported peer-reviewed publications. The CSDMS Integration Facility will insist on best practices to ensure that proper credit is provided by those who use CSDMS products, along with proper protection of, for example, contributions by graduate students. CSDMS has the advantage of following in the footsteps of CCSM and CIG initiatives.

# The Promise of CSDMS

- Better understand the evolution of Earth's surface environments, while understanding the uncertainties in the predictions.
- New tools/models in support of surface-dynamic research.
- Address the complexities of feedbacks and linkages in surface science, employing a wide variety of expertise.
- Useful products for the benefit of broader society.

CSDMS