CSDMS

community surface dynamics modeling system

CSDMS 3.0 Five-Year Strategic Plan

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1.0 CSDMS 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, biosphere, cryosphere, and atmosphere. CSDMS focuses on the movement of fluids, sediments, and solutes through landscapes, seascapes, and sedimentary basins. CSDMS' scope also includes the interactions of ecosystems and human activities with earth surface processes. 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.

2.0 CSDMS 3.0 Overarching Goals and Vision

The overarching CSDMS 3.0 goals are to streamline the processes of idea generation, hypothesis testing, and prediction by (1) supporting and disseminating community-generated software; (2) developing cyber tools and standards for efficient model construction, analysis, coupling, and hypothesis testing; and (3) providing training opportunities and resources for scientists, engineers and decision-makers.

The "D" in CSDMS stands for **dynamics**, and it signals the community's quest to understand *change through time* on scales ranging from seconds to eons. Historically, quantifying change has been among the foremost challenges in earth-surface science because of the great difficulty in measuring changes in the earth's bathymetry, topography, and stratigraphy. Today's emerging technologies, some coming into widespread use only in the past few years, are rapidly altering that picture. For example, the ongoing revolution in geodetic technology—through laser, acoustic, and optical sensors mounted on platforms ranging from satellites to drones to submersibles—has already begun to yield huge volumes of *high-resolution, multi-temporal digital images of bathymetry and topography* (Figure 1).

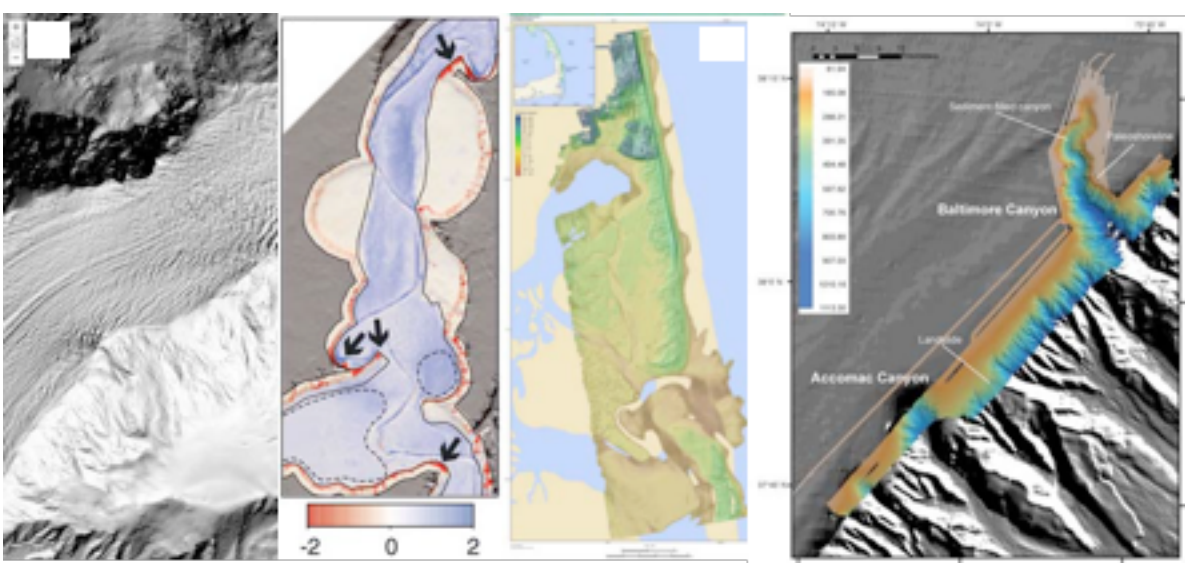

Figure 1: Examples of advances in earth-surface imaging. (a) Excerpt from ArcticDEM, developed from satellite photogrammetry; (b) LIDAR difference image of erosion/deposition patterns along the

Rio Puerco; (c) high-resolution topography of Cape Cod National Seashore derived from drone- and ground-based photogrammetry (C. Sherwood, USGS); (d) 5–10 m resolution multibeam bathymetry of mid-Atlantic canyons

Similarly, advances in sediment experimental laboratory technology are now providing detailed quantitative databases of evolving three-dimensional sedimentary strata. CSDMS 3.0 will help the community capitalize on this opportunity. The core challenge lies in using these new data to dramatically improve models, leading toward deeper understanding and ultimately better predictive ability. Thus, the vision of CSDMS 3.0 is to ***harness the earth-surface data revolution to improve models and enhance the understanding and predictive capability that models embody***. Such model-data synthesis helps to assess the degree of readiness of models for use by decision-makers in modeling scenarios of future earth-surface states. This vision aligns with NSF's vision of harnessing data for science and engineering and acknowledges CSDMS' unique role as the only national facility of its kind.

In addition to maintaining CSDMS core activities for community, computing, and education, over the next five years, CSDMS will expand efforts that embrace the modeling challenges posed by today's revolution in earth-surface data. CSDMS will meet this challenge by providing the community with new data-model synthesis technology, new training opportunities, and enhanced community coordination.

3.0 Science and Engineering Challenges in the CSDMS Community

Understanding the processes that re-shape the earth's surface is a fundamental challenge in the geosciences. In addition to sculpting our home planet, geomorphic processes can also generate natural hazards, whether from debris flows, river floods, submarine landslides, or coastal storms. Furthermore, sediment and solute transport are central to issues of water quality, ecosystem health, soil erosion, and waterway navigability. On longer time scales, the same processes that carve topography and bathymetry create the sedimentary record. For this reason, models that evolve sedimentary structure assist efforts in natural resource extraction and management, be it groundwater, minerals, or hydrocarbons, and provide examples for how earth systems may respond to historically unprecedented climate change. Examples of some of the compelling scientific challenges identified by the earth-surface science communities include:

- Understanding the dynamic interactions among climate, tectonics, and surface processes
- Understanding how coastal and estuarine systems are influenced by changes in land use, hydrology, and upwelling from the deep ocean
- Predicting Arctic landscape and morphodynamic evolution under changing climate
- Deciphering the co-evolution of ecosystems and landscapes
- Forecasting earth-surface responses to climate and land-use change
- Quantifying soil, water, and biogeochemical dynamics in the Critical Zone
- Building conceptual, computational, and numerical models that account explicitly for human interactions with earth's surface

All of these challenges lie at the intersection of domains. They call for integrative, multidisciplinary study that brings otherwise fragmented communities together to predict how landscapes and seascapes evolve and interact with the atmosphere, biosphere, hydrosphere, and lithosphere. All rely on computing, which provides the glue between data and theory. In particular, addressing each of the above scientific challenges requires computational modeling of the movement of water, sediment, and biogeochemical constituents across the earth's surface. The use of computational modeling to advance discovery is most efficient and effective when supported by a community facility that can provide coordination, shared cyberinfrastructure, and education.

4.0 CSDMS 3.0 Major Objectives

The CSDMS Integration Facility (CSDMS IF) seeks to **facilitate advances in earth-surface science and engineering**, in part by providing **enabling technology, standards, and best practices**. CSDMS IF also seeks to promote scientific and professional workforce development through **education and bi-directional knowledge transfer in modeling earth-surface systems**. Collectively, these form the three major objectives of CSDMS 3.0. The following sections review these three objectives, the means of achieving them, and examples of indicators that they have been met.

4.1 Community Research & Discovery (Objective 1): Facilitate advances in earth-surface science

Objective: CSDMS aims to accelerate the pace of scientific advancement in earth-surface dynamics research. An important goal is to facilitate advances that would previously have been harder or more costly to accomplish.

Approach: To reach this goal, CSDMS engages in the following activities:

- The CSDMS IF provides **direct technical support** to community members, through consultation with software engineers (the *Research Software Engineer as a Service* program), site visits, proposal support, and the *CSDMS Help Desk*.
- CSDMS IF enables **sharing and dissemination of model codes and tools**, and their associated metadata, through the CSDMS Model Repository.
- CSDMS IF develops and disseminates enabling **technology and standards** that accelerate research and increase cost effectiveness (see Objective 2, below).
- CSDMS *Working Groups*, *Focus Research Groups*, *Initiatives,* and other community members demonstrate **research that takes advantage of CSDMS IF tools and protocols.**
- CSDMS IF builds and coordinates a community that spans the breadth of earth-surface dynamics, by **organizing meetings and workshops**, and **engaging members** through social media, quarterly newsletters, and an extensive web portal.
- Science works best when it is open to participation by all who are interested and motivated, and when the community includes a diversity of voices and creative visions. To that end, CSDMS IF promotes **inclusion and diversity in earth-surface research** by providing stipends to students, by mindfully seeking speakers and clinic leaders, and by ensuring diverse CSDMS leadership on the Executive and Steering Committees. CSDMS 3.0 strives to empower its members to be agents of change.

These activities facilitate research both directly and indirectly. Examples of direct research facilitation include application of CSDMS IF-built technology, collaboration with CSDMS IF personnel, and demonstration of capabilities through projects organized by CSDMS Community Groups and Initiatives. Examples of indirect support include connecting researchers with resources (such as discovery and use of codes in the Model Repository), enabling re-use of code for new applications (because the developer followed CSDMS standards and best practices), and facilitating new cross-domain collaborations (through connections made at meetings and workshops).

Potential indicators of progress: What evidence would indicate successful progress toward this goal of *facilitating scientific advances*? One measure of direct facilitation is scientific publications, and in particular (1) publications on research that makes use of CSDMS technology and standards, (2) publications to which CSDMS IF personnel have contributed directly, as well as (3) publications arising from CSDMS groups, workshops, and initiatives. Other indicators of success include: proposals for which CSDMS IF support or partnership was requested and provided; research consultations and site visits; and successfully resolved queries on the CSDMS Help Desk.

Indirect research facilitation is harder to track, because it largely relies on investigators to acknowledge CSDMS' role (for example, in the acknowledgments section of a journal article). Nonetheless, some indication of success can be found in the CSDMS Portal web traffic statistics; meeting and workshop attendance and post-meeting surveys; and published use of codes that are cataloged in the CSDMS Model Repository.

CSDMS strives to be an open and inclusive community, and sets a goal of gender, ethnic, and racial diversity among its meeting participants, keynote speakers, clinic leaders, and committee membership. Through its community engagement activities (such as meetings and webinars), CSDMS 3.0 offers dedicated activities to empower its members to be agents of change and has as its goal to increase participation of its members in activities that promote diversity.

4.2 Computing Technology (Objective 2): Equip community with enabling tools and resources

Objective: CSDMS IF provides scientists, professionals and decision-makers community with tools and resources that reduce the "time to science" by making computational work more efficient, more standardized, and more easily reproducible. These tools and resources are designed to help community members carry out common tasks related to computational modeling, such as: operating a model; accessing input data in the right format; analyzing model output; coupling models to explore system feedbacks; comparing the predictions of alternative models or model elements; and creating new models using component parts. In addition to technology development, CSDMS 3.0 also aims to catalyze culture change in computational research: helping the community transition from a culture of "geohacking," to one of habitually applying the *FAIR* principle—Findable, Accessible, Interoperable, and Reproducible—to computational earth-surface science.

Approach: To reach Objective 2, CSDMS 3.0 engages in the following activities:

- CSDMS IF continues to promote and maintain the **Basic Model Interface (BMI)** standard, and to provide templates and documentation that support its use. BMI is an interface design standard that describes a common set of control functions, analogous to having a standard set of controls in every motor vehicle (steering wheel, brake pedal, gear shift). Model codes equipped with a BMI are easier to learn and operate, easier to couple, and easier to incorporate in modeling frameworks such as the CSDMS Python Modeling Tool (pymt).
- The CSDMS IF develops and releases versions of the **Python Modeling Tool (pymt)** and its associated documentation, starting with a 1.0 version in year 1. The CSDMS pymt enables researchers to run BMI-equipped models in a Python environment, even if the model itself is written in another language (e.g., C, C++, or Fortran). Pymt provides access to a variety of different models within the highly popular Python programming environment. Pymt facilitates hypothesis testing by making it easier to compare alternative models for the same process or system. The CSDMS pymt also greatly simplifies the process of coupling models, which can be done using a Python script or notebook. By allowing a user to operate a model using standardized (BMI) functions (which can be used, for example, to run a model for a specified period of time and then pause for plotting), pymt also makes it easier to experiment and "play around" with models. CSDMS 3.0 will facilitate remote access and computing with pymt, through cloud resources or via CSDMS-hosted notebook servers.
- The CSDMS IF continues to support, maintain, and document the CSDMS **Web Modeling Tool (WMT)**, which allows users to run and couple component models on a high-performance computing system, which is accessed using a browser-based graphical interface.

The CSDMS pymt underlies this tool, and with an evolution to more pymt modeling examples and documented teaching resources, it is anticipated that pymt may gradually replace WMT.

- The CSDMS IF and CSDMS Community Groups work together to **expand the library of available component models**. Groups identify priority needs for models of particular systems or processes and identify candidate codes. Group members who are model developers or maintainers work with CIF personnel to equip suitable model codes with BMI functions.
- The CSDMS IF provides support and ongoing development for the **Landlab Toolkit**, a Python package that greatly simplifies the process of model construction by providing built-in grid data structures. It already offers a library of landscape evolution, vegetation, hillslope, hydrology and stratigraphy *process components*. CIF formally adopts Landlab and merges the components with the pymt when the Landlab development grant ends in 2020.
- To facilitate model-data integration, the CSDMS IF builds and demonstrates a concept design for **Data Components:** Python-language programs that provide access to important community datasets using BMI standard functions. These components simplify access to data sets by removing the need for a user to know details about the data set's file format or web-access protocols.
- CSDMS 3.0 promotes **adoption of concepts, tools, and technologies**. CSDMS IF does this through community advocacy and training. Group leaders do so by using these tools and concepts (leading by example), and by spreading the word among their constituent communities.

Indicators of progress: One basic indicator of success is simply the availability of the products listed above. Each should be findable online, and it should be installable (where applicable) and functional. The number and range of model components is another indicator. A reasonable expectation might be to have around 50 pymt components, with at least one representing each of the major domain processes (terrestrial, coastal, marine, hydrology, critical zone, cryosphere, ecosystem and human dimension processes). One important element of success in scientific software is simply the awareness that a particular product exists; therefore, one milestone is to expose a certain fraction of the community to these tools and concepts and to provide training opportunities (see below). A reasonable expectation might be that a significant fraction of active CSDMS members is exposed to the existence of major CSDMS products, ideally by engaging in a hands-on introduction to at least one of the above products (through a clinic, workshop, webinar, hackathon, or self-study using online material). Another metric is that CSDMS tools are applied towards several of the compelling scientific challenges outlined above. Publications using CSDMS tools and protocols are an obvious indicator that these products are being adopted and used by the community (see Goal 1, above).

4.3 Education (Objective 3): Foster learning and skill development

Objective: CSDMS 3.0 helps students, and earth-surface researchers, professionals and decision-makers who may use these tools to enhance their skills in relevant computational science concepts, tools, and techniques. This goal is motivated by the recognition that computational work is central to modern earth-surface research, and that a more computationally skillful community is a more efficient and effective one. CSDMS 3.0 also contributes to developing the future geoscience workforce, by providing teachers with resources related to earth-surface dynamics and computational modeling.

Approach: To reach this objective, CSDMS 3.0 engages in the following activities:

- CSDMS continues to offer multiple **clinics** at annual meetings: hands-on training sessions led by member volunteers that introduce participants to a particular technique, concept, model code, dataset, or other useful resources. Groups identify potential topics and clinic leaders; CSDMS IF coordinates the events.
- CSDMS 3.0 organizes and runs a series of **webinars** on diverse topics, ranging from particular tools, to general concepts such as the *FAIR Data Principles*. These webinars provide easy access

to community members far and wide, including those who lack the resources to attend meetings and workshops in person. Recordings of the webinars are made publicly available on the web portal as online learning resources. Groups and CSDMS IF identify potential topics and speakers; CSDMS IF advertises and hosts the webinars and curates the recordings.

- CSDMS continues to build and curate the **Educational Repository**, an online library of diverse educational resources for the earth-surface science community. Potential audiences for these materials are not restricted but are primarily undergraduate to graduate level learners. Chairs and other Group members provide materials, while CSDMS IF maintains the Repository.
- CSDMS 3.0 provides **Jupyter Notebook examples and tutorials** that demonstrate how to use its tools and technologies. CSDMS IF develops notebooks for in-house products and concepts, while Groups and Initiatives develop notebooks for particular models and tools. Groups provide feedback to improve notebooks. CSDMS IF hosts and curates the notebooks.
- CSDMS 3.0 develops **online documentation** to accompany its tools and technologies.

Indicators of progress: While it is not a simple matter to measure the ultimate impact of CSDMS' educational activities, there are several metrics that provide an indication that there *is* an impact. Participation in clinics and webinars provides a measure of the community's interest in learning about various new tools and concepts. Post-activity surveys indicate the efficacy of meeting clinics and workshops. Likewise, the number of downloads of different types of resources from the Education Repository provides an indication of how widely these materials are being discovered and used. Usage metrics on Jupyter Notebooks and documentation pages provide an indication of their impact.

Appendices

A1.0 Community Goals

Through a series of meetings conducted in 2018 and 2019, the CSDMS Working and Focus Research Groups developed goals for their efforts over the next 5 years. These efforts will be led by the group chairs and conducted by teams of community members working in concert to achieve the stated goals. The role of the CSDMS IF is to support these efforts by providing the cyberinfrastructure and basic HPC needs for the projects, providing targeted Software Engineering support, and by facilitating meetings, hackathons, and workshops focused on driving progress toward group goals.

A1.1 Group Goals

A1.1.1 Terrestrial Working Group

Short Term

- Disseminate information about models, data, papers, members' research, and educational opportunities via newsletter (approximately) three times annually. (*to be repeated for the medium- and long-term timeframes*)
- Solicit at least one TWG member to give a CSDMS webinar. (*to be repeated for the medium- and long-term timeframes*)
- Continue educational opportunities for TWG members via clinics at the CSDMS annual meeting. (*to be repeated for the medium- and long-term timeframes*)
- Co-lead a 2019 AGU short course (application was submitted.)
- Continue to give our Spotlight award (two awards annually). We will solicit nominations for early career scientists and/or underrepresented scientists. (*to be repeated for the medium- and long-term timeframes*)
- Submit a short paper on using/teaching computing in undergraduate earth science classes, possibly to EOS or GSA Today.
- Solicit feedback from TWG community on:
    - desired cross-disciplinary modeling efforts.
    - desired model-data integration projects.
    - supporting their efforts on model-data integration.
- Recruit a TWG social media czar.

Medium Term

- Offer educational opportunities for TWG members at a CSDMS Summer School (pending funding). (*to be repeated for the long-term timeframe*)
- Development of new educational tools available via CSDMS and other linked websites. Possibilities include tools using pymt and/or Landlab. (*to be repeated for the long-term timeframe*)
- Lead a session at the GSA annual meeting, co-sponsored by the Geoinformatics and Quaternary Science groups, to increase awareness of the efforts of CSDMS TWG to the GSA community. (*to be repeated for the long-term timeframe*)
- Improve awareness of models from Federal agencies that pertain to the TWG community.
- Improve participation of federal scientists in the TWG community.
- At least two proposals submitted to NSF that include cross-disciplinary modeling efforts enabled by CSDMS infrastructure.
- Work with CSDMS integration team to enable better data integration with some key TWG models.
- Emotionally support a TWG social media czar. (*to be repeated for the long-term timeframe*)

Long Term

- Develop a path for integrating some models from Federal agencies with TWG models.
- Achieve an increased understanding of TWG identity and increased frequency of information sharing among members, as a result of short and medium-term goals.
- Demonstrate a measurable increase in TWG activity (via social media, CSDMS wiki activity, and other metrics mentioned in the strategic plan (section A2.4)).

A1.1.2 Coastal WG

Our group's overall strategy is to increase participation across the large coastal group without sacrificing the productivity that has been achieved through strong hands-on efforts of our group's main contributors.

Short Term

- Prepare survey to identify scientific needs and develop science teams
  - Keep following up until people participate in the survey
  - Science team concepts both based on landscape feature and technical aspects (see list below)
- Form science teams using feedback and identify leaders through self-identification or positive recruitment
- Propose and organize a meeting to address Modeling Strategies, Possibilities, and Challenges for Coastlines and People under CSDMS banner in response to NSF CoPe letter to colleagues
- Begin discussion with Landlab team about how lessons/capabilities could be used for coastal modeling

Medium Term

- Identified high-functioning science teams and prioritize integration help to get these done
- Have the CoPe conference
- Investigate potential to develop a scalable data repository of important coastal driving data and to take advantage of big data explosion
  - physical (winds, waves, tides, bathy, sediment info, historical changes)
  - social
  - economic
- Work with human dimensions group on tools of simple interactive coastal decision-making (groins/sea walls)

Long Term

- Have new working coastal models within pymt/Landlab for community use
- Have educational/outreach tools specific to several developed coastal problems.

In terms of potential science teams, we (participants) identified both landscape-feature-based and technical challenge-based potential teams. Many of these have been identified as landscapes of interest across the duration of CSDMS and previous strategic plans.

Landscape (to focus spatial scale and processes that would lead to a successful coupling that addresses focused science questions)

- deltas
- barrier systems
- the developed coast (tied into Coastal Vulnerability Initiative)
- water quality/coastal ocean
- tidal/wetlands/estuarine
- polar
- rocky coasts
- carbonate (particularly in terms of future of the carbonate WG)

Technical (to provide and focus community support as well as address key identified obstacles.

- Model coupling/BMI
- Data analysis and management
- Dealing with moving and abrupt boundaries
- Wave transformation computation
- Tools for Decision making

A1.1.3 Marine WG

Short Term

- Increase the number of marine working group models that can be coupled via BMI and run using pymt. This should include a revisit of ocean hydrodynamic models for inclusion in the BMI.
- Encourage the use of the marine working group (MWG) models that can be coupled via BMI and run using pymt. This would be evidenced by proposals that anticipate use of coupled models.
- Encourage proposals that use CSDMS facilities / infrastructure (including BMI and pymt) to tackle problems such as parallelization of MWG codes.
- Contribute to funding or implementing CSDMS training mechanisms for graduate students in the use of and interpretation of MWG models.
- Provide MWG webinar for the CSDMS.
- Identify gaps in MWG activities especially for deep sea (continental slope and deeper) transport processes. Identify researchers working in this area and reach out to recruit this community to CSDMS. Suggest keynote speaker for the 2020 CSDMS who specializes in deep sea processes.
- Provide a MWG clinic for CSDMS annual meeting in 2020.
- Encourage MWG CSDMS presence at 2020 Ocean Sciences meeting. The meeting theme "For a Resilient Planet" is relevant to several CSDMS working groups.

Medium Term

- Contribute to pursuing funding and implementing training mechanisms (such as CSDMS summer school) for graduate students in the use of and interpretation of MWG models.
- Foster engagement of MWG community via newsletter communications and CSDMS social media.
- Encourage MWG proposals and publications that use CSDMS facilities / infrastructure.
- Some of the "grand challenges" that face MWG researchers could be approached using methods that build off of CSDMS infrastructure and facilities. For example, the following

would benefit from model coupling and processing methods being advanced by CSDMS: to tackle some of the "grand challenges":
  - Continental margin transport: from source to sink.
  - Interdisciplinary issues that cut across working groups (for example sediment / geochemistry).
  - Upscaling in time or space.

Long Term

- Sustain engagement of marine modeling community, via communication and inclusion of research from deep-sea (slope and beyond) environments, inclusion of more MWG models that make use of BMI and pymt, and CSDMS tools for model implementation and analysis.

A1.1.4 Cyberinformatics and Numerics WG

- Reproducibility: design/develop functionality to host "reproducible study packages" to accompany modeling papers, including the source code used, inputs, outputs (or scripts to re-generate, if overly large), post-processing scripts, etc. Have a couple of modeling papers to be published before spring 2021 in journals such as Geoscientific Model Development or Computers and Geosciences.
- Tight-coupling BMI: BMI works really well for "loose coupling" in which components are run in a sequence. Some applications call for tight coupling, in which components might define elements of a matrix, which is then inverted by some coupling software (often executed in parallel). Engage other working groups to see what they need and select one or two models (or subjects) for tight coupling (now~2023).
- Formal numerical analysis of "loose coupling" of earth-surface models. Determine what criteria should one consider for time-stepping. Determine if there are general rules of thumb that apply across a range of different types of models. For example, coupling flocculation model in ROMS/COAWST (now~2021).
- Write a "prospective" style paper on opportunities and challenges in harnessing the revolution in change-detection data, with regard to morphodynamic models. Now that we've gone from drought to deluge, what are the big opportunities? What are the challenges that need to be surmounted? This could then lead to a group proposal to the HDR program. (now~2020)
- Design a recommended evaluation/vetting system that CSDMS could use for models. This could be done as a white paper, based for example on a review of how other communities (e.g., COMSESNet, CIG) do it, to what extent new software-oriented journals (e.g., JOSS) have a role to play, and what role our Groups would play. (now~2020)
- Utilizing Machine Learning to provide improved closure and parameterization for earth surface process modeling: To tackle multi-scale modeling of earth surface processes, various closure models and parameterizations of sub-scale processes are needed. ML can be used to as a novel and effective tool for this purpose. Short term goal: work with ML/AI group and other WGs to come up with a list of outstanding processes that need to be parameterized and are complex enough (also have sufficient data) to benefit from ML/AI (e.g., turbulence closure, flocculation). Mid and Long-term goal: CSDMS will provide resource to demonstrate two or three proof-of-concept studies. This may transform our community on how to tackle multi-scale problem.

A1.1.5 Education and Knowledge Transfer WG

The EKT working group is seeking to transition leadership with the coming year.

Short Term

Rally the CSDMS community, and identify interested candidates for EKT WG chair

Identify and adapt CSDMS models for undergraduate classroom use

Contribute teaching efforts to the Educational Repository

Develop tools to assess teaching resources effectiveness for learning.

Identify an EKT WG member to give a webinar in 2020

Engage with sediment transport and hydrology practicing scientists and engineers at the SEDHYD conference in Reno, Nevada, June 2019, by demonstrating CSDMS tools

Medium Term

Develop modeling tools for undergraduate education and develop tools to assess effectiveness of teaching with models. Involve members of the community to seek grant from NSF to support this effort.

Identify and adapt a proof-of-concept model that is relevant for decision-makers, in collaboration with the Coastal Working Group (e.g. groin/protection model in coastline evolution model) or Human-Dimensions Working Group (e.g. flooding and urban development).

Mobilize interested EKT Working Group members to contribute Jupyter notebooks to a CSDMS cloud-based or CU research computing server and provide widespread access to such resources via the Educational Repository.

Encourage interested EKT WG members to engage with the TWG on writing of a short paper on undergraduate teaching with models, possibly aimed at EOS/GSA Today

Working Group Chair to present Clinic on CSDMS Teaching Resources at the Educators Rendezvous.

Long Term

Propose a meeting through NSF for how modeling is being used to address and advance long-standing questions and how to implement teaching of modeling in Geoscience curriculum.

Coordinate a subgroup of interested WG members who are willing to review teaching resources and provide feedback or make improvements on web portal or within the Notebooks. Possibly in collaboration with Journal of Open Source Education.

Coordinate CSDMS educational resource development and modeling efforts with other educational efforts (E.g. SERC, Earth Educators Rendezvous, Jupyter community).

A1.1.6 Hydrology FRG

The Hydrology FRG currently has 685 members.

Short Term

Two primary goals are to (1) evaluate the current and recently increasing number of hydrologic models that have been added to the CSDMS archive, many of which are now accessible using BMI, and (2) coordinate with two ongoing CSDMS efforts that involve hydrologic models.

These codes apparently now have a BMI, or will soon: WFLOW, SUMMA, LISFLOOD, PCRGLOB, Flex Models, HBC, Marrmot, TopoFlow, HYPE. These will be reviewed and comments will be submitted to CSDMS staff.

One of the ongoing efforts is with a group in the Netherlands that CSDMS Senior Software Engineer Eric Hutton has been working with. We will discuss this effort with Eric.

The second ongoing effort is with Rich McDonald at the USGS, whom CSDMS Software Engineer Mark Piper has been working with. This is expected to yield BMI interfaces in three codes: FaSTMECH, Nays2DFlood and PRMS. Addition of MODFLOW is being discussed but a commitment has not been made.

For model codes equipped with a Basic Model Interface (BMI), it would be relatively straightforward to turn some or all these models into components in the pymt.

The Hydrology FRG will consider this list of models and their priority for inclusion in the pymt library. This will be discussed at the CSDMS meeting in May 2019 and followed up with through Spring 2020.

Medium Term

Hydrologic models are important to nearly all modeling of combined natural and human systems. We would like to review recent proposals related to this theme funded by NSF. This will include ongoing CNH and INFEWS proposals, and upcoming CNH2 proposals. Though some in these projects are involved with CSDMS, we would like to determine how wide and deep this involvement is and whether the capabilities of CSDMS can be used to greater advantage by this community. Through this effort, identify modeling needs appropriate for involvement by CSDMS Hydrology FRG.

Long Term

Based on the results of short- and long-term goals, address high priority CSDMS consistent needs within the community. We expect this to include education about methods such as Machine Learning as applied to water resources, and integration of models important to hydrologic components of larger systems simulations. However, these goals will be adapted as indicated by our ongoing efforts.

A1.1.7 Geodynamics FRG

Short Term

Develop a simplified community tutorial. Take existing resources and with small modification build a module that covers a simplified coupling between example software packages (~90 min content).

- Existing codes could be used to start with first order couplings between 1-D or 2-D landscape evolution models and 2-D tectonic models.

- Training in form of a recorded tutorial such as the CIG webinar series, or in the form of a documented web tutorial like the CSDMS labs.
- This would not only transfer necessary skills and help to identify obstacles for the more challenging full coupling case.
- After establishing a first resource, use the existing tutorial opportunities (like clinics at the annual CSDMS workshop, GeoPRISMs mini-workshops at the AGU Fall Meeting) to extend the developed module from an online to an in-person tutorial.

Medium Term

Organize a follow-on to the CTSP workshop dedicated to coupling of processes to make focused progress in defining coupling interfaces and actively work on the challenges that were identified during the CTSP workshop. The meeting could be organized within a conference series such as Penrose, Chapman, GRC.

Work towards developing MPI-parallel Surface Processes codes. Few surface processes models are designed to work in MPI-parallel computing environments, yet nearly all 3-D geodynamics codes require such an environment. Having an MPI-parallel framework that does surface processes is a key requirement to couple models from these two communities. Code development should leverage existing widely-used open-source frameworks. This will also facilitate using the tools for teaching. For more detail see the CTSP white paper.

Long Term

Compilation and synthesis of inversion and uncertainty quantification frameworks. Identify a place to compile and compare existing uncertainty quantification frameworks. This will increase the discoverability of existing tools and improve the ability of users to select the framework best suited to their needs. Moreover, many members of both communities are not experts in inversion and uncertainty quantification methods. Thus, to support scientists at all career levels we recommend that teaching/self-study resources related to these topics be created. These resources would introduce the use of these methods, the terminology used, and information regarding the appropriateness of different methods to different problems

Collect a suite of created tutorials and create an inter-community course. A long-term project to establish a collaborative training and research program for coupling tectonics and surface modeling analog to the CIDER program (http://www.deep-earth.org/) for deep Earth research. This would require a significant investment for a single research group but is feasible if it is organized as a community effort and would strongly support the transfer of critical skills and the creation of a combined community.

Facilitate creation of multiple codes that can interact with each other. Progress in computational geodynamics over the last decade has shown that creating a single code for the community isn't the best way forward. This finding is echoed by the experience of the surface processes modeling community. As we move forward, we expect to:

- Create generic computational tools make it simpler to deal with problems that are common to the different codes.
- Utilize the construction of modular model frameworks such as the Landlab Earth surface dynamics package (e.g., Hobley et al., 2017) to provide reusable model components that can be mixed and matched to meet the needs of individual researchers.

A1.1.8 Critical Zone FRG

Short Term

- Participate in the planning and execution of CSDMS 2020 focused on the ecosphere/geosphere. Activities will include convening either all-hand sessions, breakout sessions or code demonstrations.
- More strongly linking CSDMS to the International Soil Modeling Consortium (ISMC) activities, which now includes 600+ members. This includes cross-linking model repositories and selecting specific models in the ISMC repository for BMI development and sharing at CSDMS.

Medium Term

- As part of an ISMC-led initiative on soil (critical zone) model inter-comparison, work with CSDMS leadership on creating a benchmarked data repository at CSDMS that would allow inter-comparison of a small number of key critical zone related processes. For example, the European community (through TERENO) is currently compiling carefully collected and tightly constrained soil/water/plant and micrometeorological datasets on more than 20 weighing lysimeters across western Europe. These datasets, expected to be compiled and available by mid-late 2020, represent a golden opportunity to intercompare select models (in both CSDMS and ISMC repositories) of specific shallow Earth processes that are key to the critical zone.
- Further integrate critical zone and soil models into other FRG's, especially Ecosystem Dynamics and Human Dimensions, given the important role that land use decisions play on critical zone evolution and function.
- Develop manuscript(s) that discuss state-of-art modeling techniques of critical zone processes.

Long Term

- Continue strengthening relationships between critical zone modeling community and CSDMS, including soliciting key presenters at CSDMS annual meetings, and co-organizing workshops and hackathons for improving, simulating and embedding critical zone processes into larger-scale geomorphic-related models; and cultivating future collaborations through joint authorship on papers and proposals

A1.1.9 Carbonates and Biogenics FRG

Short Term

To represent modelers concerned with biogenic deposits (carbonate, organic carbon, bacterial mats, etc.) at the earth's surface, since these materials and structures have special requirements in modeling. Specifically, a newsletter will alert members of new developments, especially of new contributions to the CSDMS repositories.

Medium Term

To hold a (possibly CSDMS-supported) workshop in biogenics modelling, probably more like a hackathon in structure. Also, to hold Carbonate-Biogenic modelling issues and advances in view at CSDMS venues, especially to foster collaborations with the coastal and marine groups.

In its present form the Group is not achieving its set-out medium to long-term goals, for various reasons, including that it is not seen as the 'go-to' discussion point for carb-biogenic model innovations. Some have suggested a re-structuring and re-directing. These issues will be taken up by the Chairs at CSDMS executive meetings in the medium term.

Long Term

To improve the number and selection of models that are in place at CSDMS by convincing model-composers everywhere of the advantages of results dissemination and collaborations. The CB-FRG - as with other groups in CSDMS - should not seek to compete with commercially or otherwise available large packages, but instead develop solutions to specific knotty research challenges.

A1.1.10 Human Dimensions FRG

The Human Dimensions FRG (143 members) is newer to CSDMS and represents the community of modelers interested in both representing human decision-making in earth systems models, and in interfacing with human stakeholders to inform policy and decision-making. The group has four major goals, each with short, medium and long-term objectives:

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

Short Term

Developing and advancing human dimensions models

- Based on a set of sessions organized for this purpose, a new working group on modeling institutions was formed, the Large-scale Behavioral Models of Land Use Change, led by Mark Rounsevell and endorsed by AIMES and GLP/Future Earth.
- Explore connections with other areas of CSDMS to support model development, for which joint sessions with other working groups have been suggested and organized.
- Seek research funding for new model development

Coupling human dimensions models with biophysical models

- Explore existing examples of human dimension – biophysical model coupling: A paper was published on existing examples, and another paper is currently in review on grand challenges in coupled human/biophysical modeling. In addition, create a data repository for these cases, and publicize the coupled models that exist, including documentation on BMIed models.
- Develop appropriate computing environments to couple human dimensions and biophysical models:
    - Develop Netlogo – Python – Jupyter Notebook architecture to support coupling activities, universal interfaces/BMI between models, and tools for meta-modeling so we do not have to couple full, detailed models. Model componentization/micro-services.
    - Review new computational architectures (e.g., MICs, GPUs) and identify particular modeling approaches well suited to them.

Using models to support participatory processes

- Communicate examples of participatory modeling approaches of coupled systems: Several publications and online dissemination is in place and will be expanded in the next year.
- Develop new methods:
    - Collaborate with ethnographers at different stages of the modeling process
    - Identify appropriate policy entry points for modeling to more effectively influence policy change.
    - Identify barriers to non-researcher participation and propose remedies

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: troubleshooting forums for different levels of expertise, model education clearinghouse, collate existing YouTube videos on BMI/pymt, etc.
    - Develop new summer schools
    - Submit to the SESMO journal
    - Develop virtual seminars from our group to explain methods/projects

Medium Term

Developing and advancing human dimensions models

- Develop new methods with more explicit representation of feedbacks in all directions in SES (demographic and macro-economic trends), and political coalition formation

Coupling human dimensions models with biophysical models

- 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 systems
- Develop appropriate computing environments to couple human dimensions and biophysical models:
    - Create an ontology for human dimensions models, and for biological sciences, to communicate variables across model types
    - Compile types of scenarios from which model coupling could potentially inherit assumptions for a target research question
    - Evaluate ways to detect harmonization issues versus interesting findings; internal methods for characterizing uncertainty, across scales and models;
- Applications:
    - Develop models of polycentric governance of SESs
    - Linking rural-urban migration to city development
- Funding: tapping into private foundations

Using models to support participatory processes

- Communicate examples of participatory modeling approaches of coupled systems: Develop/refine more frameworks for best practices in participatory modeling
- Develop new methods:

- How to better communicate uncertainty and risk in participatory modeling processes
- 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.
- Stakeholder driven validation and evaluation

Capacity building

- Communicate the use of human dimensions models to the broader CSDMS modelling community:
    - Develop a primer on human dimensions modelling for physical scientists, and a primer on biophysical modelling for social scientists
    - Create "BMI for Dummies" materials
    - Develop model coupling training seminars

Long Term

Developing and advancing human dimensions models

- Develop Adaptive self-learning models.

Continue coupling human dimensions models with biophysical models

- Develop intellectual frameworks for multi-scale, hierarchical/nested, coupled biophysical/socio-economic models: what do we lose with less details, which applications are OK? Evaluate scale-dependent assumptions and implications for computing environments (see above).
- Understand how results differ between standalone and coupled models.
- Applications:
    - 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

Continue using models to support participatory processes

- Incorporating into mainstream scenario planning, for water and energy policy and planning

Continue capacity building

- 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)

A1.1.11 Ecosystem Dynamics FRG

The Ecosystem Dynamics FRG (currently 147 members) represents the ecological modeling community and is co-sponsored by the International Society for Ecological Modelling. This research group deals with ecosystem and ecological dynamics with an emphasis on interactions with landscape processes.

Short Term

- Hold CSDMS 2020 spring meeting with an Ecosystem Dynamics theme
- Attract new ecological modelers to CSDMS facilitated by the themed meeting
- Familiarize ecological modelers with CSDMS tools through workshops and clinics
- Solicit input and models from the ecological modeling community that can be added to the CSDMS toolkit
- Establish group identity by documenting what active Ecosystem Dynamics FRG members are working on and are interested in during a spring meeting break-out group
- Form a science team consisting of the chairs and self-assigned ED FRG members
- Hold break-out group connecting ED FRG members with other groups to facilitate new model linking with the goal to produce collaborative research and papers

Medium Term

- Submit manuscripts from collaborative break-out group products
- Elect new co-chair
- Submit proposal with science team

Long Term

- Create opportunities to pitch ideas for research projects the science team could focus on; this can be in combination with addition of new/alternate science team members
- Produce proposals and papers with the science team
- Add models to the CSDMS model repository that can be shared using the CSDMS website

A1.1.12 Chesapeake FRG

The Chesapeake Focus Research Group is a partnership between CSDMS and the Chesapeake Community Modeling Program (CCMP, http://ches.communitymodeling.org/). The CCMP, founded in 2002, is a long-term collaborative effort between the Chesapeake Research Consortium (CRC) and the University of Maryland Center for Environmental Science – Horn Point Laboratory (UMCES-HPL) that is dedicated to advancing the cause of accessible, open-source, modular environmental models of the Chesapeake Bay in support of research and management efforts. As a complementary activity to the CBP management modeling effort, and with support from CRC member institutions and the NOAA Chesapeake Bay Office (NCBO), the CCMP seeks to improve modeling tools and related resources specific to the Chesapeake Bay, its watershed, and connected environmental systems by fostering collaborative open source research, modular model development, and communication. Together, CCMP and the Chesapeake FRG are striving to motivate and enable the development of a comprehensive CBP management model system consisting of interchangeable, open-source modules covering diverse aspects of hydrodynamics, ecosystem dynamics, trophic exchanges, and watershed interactions.

The work carried out by the CCMP and the Chesapeake FRG over the past several years has been focused primarily on 6 specific tasks: 1) planning and convening the biennial Chesapeake Research Symposium; 2) convening and developing the report for a STAC-sponsored CCMP/CSDMS/CBP/CRC visioning workshop for CBP modeling that was convened in January, 2018; 3) developing CCMP Newsletters; 4) planning convening two CBP management modeling technology transfer workshops with CBP and CRC collaborators; 5) participating in CBP modeling workgroup meetings; and 6) participating in CSDMS Executive Committee meetings. All of these tasks are aimed at advancing the CCMP/CFRG overarching goal of advancing the cause of accessible, open-source, modular environmental models of the Chesapeake Bay in support of research and management efforts.

Chesapeake FRG Progress to Date

- During CSDMS 1, the CCMP and the Chesapeake FRG published numerous newsletters, convened 6 biennial symposia and it co-hosted/co-sponsored five workshops in the Chesapeake region.
- Since 2016 the CCMP and the Chesapeake FRG have participated in the CBP modeling workgroup meetings.
- As an outgrowth of the fourth of the five workshops (convened in January, 2018), the Scientific and Technical Advisory Committee of the Chesapeake Bay Program produced a 62-page report (STAC Publication 19-02) in 2019 entitled "Chesapeake Bay Program Modeling in 2025 and Beyond: A Proactive Visioning Workshop Chesapeake Bay Hydrodynamic Modeling".
- In cooperation with the U.S. IOOS Coastal and Ocean Modeling Testbed, three ROMS-based 3D hydrodynamic models of the Chesapeake Bay have been added to CSDMS with BMI wrappers (CBOFS2, ChesROMS, and UMCESroms).

Short Term

- Continue publishing newsletters and participating in CBP modeling subcommittee meetings.
- Develop a manuscript for publication in the journal *Ecological Modeling* based upon STAC Publication 19-02.
- Promote and facilitate implementation of the open source models, modular modeling approaches and other recommendations for the CBP management modeling system put forward in STAC Publication 19-02 in anticipation of the 2025 mid-point assessment and Total Maximum Daily Load (TMDL).
- Continue to populate the CSDMS with existing open-source Chesapeake Bay regional models.
- Give priority to Chesapeake FRG related projects which focus on models with management implications, such as land use, water quality, ecosystem function, storm surge, etc.
- Organize and convene the second management modeling technology transfer workshop with CBP and CRC collaborators (scheduled for July 23-25, 2019).
- Plan and convene the next Chesapeake Research Symposium (ChesRS20) scheduled for early June of 2020.

Medium Term

- Continue publishing newsletters and participating in CBP modeling subcommittee meetings.
- Initiate planning of the next Chesapeake Research Symposium (ChesRS22) scheduled for early June of 2022.
- Publish manuscript based up STAC Publication 19-02 in the journal *Ecological Modeling*.
- Promote and facilitate implementation of the open source models, modular modeling approaches and other recommendations for the CBP management modeling system put

forward in STAC Publication 19-02 in anticipation of the 2025 mid-point assessment and TMDL.

- Train members of the CCMP and Chesapeake FRG on use of CSDMS tools.
- Post key common forcing data sets and management model solution sets at CSDMS.

Long Term

- Continue publishing newsletters and participating in CBP modeling subcommittee meetings.
- Plan and convene the next Chesapeake Research Symposium (ChesRS22) scheduled for early June of 2022.
- Facilitate implementation of the open source models, modular modeling approaches and other recommendations put forward in STAC Publication 19-02 in anticipation of the 2025 mid-point assessment and TMDL.
- Implement additional distinct, swappable land use models, hydrodynamic models, water quality models, ecosystem models, etc., in BMI format at CSDMS.
- Utilize CSDMS to make side-by-side comparisons of management model performance and differences in output by systematically swapping model components.
- Utilize CSDMS to help facilitate ensemble modeling (i.e., using multiple distinct models) to help characterize uncertainty in CBP management model predictions and the TMDL.

A1.2 Transdisciplinary Initiatives

Initiatives are limited-term projects that focus on emerging topics of special interest to the CSDMS community. Here we highlight plans for the newest initiative, which focuses on new opportunities in Artificial Intelligence and Machine Learning.

A1.2.1 AI & ML (Machine Learning and Artificial Intelligence)

Short Term Goals

To keep the CSDMS community aware of new machine learning techniques and applications that could enhance their work. And to create a platform and community where CSDMS members working with machine learning can ask questions, share advice, and form collaborations that unite complex datasets with machine learning expertise.

Two distinct initiatives include: (i) The 'AI&ML Conversations Portal' ("https://csdms.colorado.edu/wiki/AIML_Conversations"), which is beginning to gain momentum from users and should progress well after launching at the CSDMS May 2019 meeting. (ii) A first 'ML Challenge Dataset', launching at that meeting of gridded data layers from dbSEABED for members and others to practice their ML programs on, for achieving better mappings of seabed materials. The Challenge Dataset has potential for use in the K12 domain

A third goal is to facilitate a keynote lecture, panel discussion, and breakout session devoted to AI & ML at the 2019 CSDMS annual meeting.

Medium Term Goals

The AI&ML Initiative is a temporary vehicle, yet to be located formally within the CSDMS structure of groups. Meanwhile it will host small special events, perhaps a hackathon directed to one goal, or to a type of ML; and use those events to increase the CSDMS repository holdings of interesting and useful code.

Long Term Goals

To become a sought-after discussion place on the technology of Machine Learning; for members to get advice on pitfalls and otherwise, on reliable methods; for understanding; for realizing the best research strategies in ML for earth surface geomorphology.

A2.0 CSDMS 3.0 Integration Facility Actions

A2.1 Community

A2.1.1 Annual Meeting, Workshops, Hackathons

The CSDMS Annual Meeting brings together members to discuss science and cyberinfrastructure advances, learn about new multidisciplinary research, gain new skills, and learn hands-on about new technology and tools. It is the key event in the year to interact as a community, to unveil new computing developments, and to make strategic decisions on science priorities.

Over the duration of the project, we will organize Annual Meetings each spring. The first meeting (May 2019) will be held at the Sustainability, Energy and Environment Community (SEEC) facility at CU Boulder. Each Annual Meeting will feature a science theme, designed in discussion with CSDMS leadership and in collaboration with co-sponsoring organizations. Themes are purposefully broad and aim to promote cross-disciplinary interests. The themes are discussed and approved by the CSDMS Executive Committee. The theme for 2019 is "CSDMS 3.0 - Bridging Boundaries," focusing on cross-disciplinary research. The theme for 2020 will focus on Bio/Geosphere dynamics that will include exploration of topics on biomes, water and sediment: interaction of life and landscape/seascape morphology. The theme of the 2021 meeting is still to be determined. Each three-day program includes keynotes, poster sessions, and parallel hands-on skill clinics taught by community members and CSDMS IF staff. In addition, break-out sessions are convened to make progress toward strategic working group and focus research group goals and cross-disciplinary research initiatives. CIF staff also organize pre-meeting full-day training opportunities. The Annual Meeting is typically attended by about 130 to 150 people, a substantial fraction of whom are graduate students. Meetings of the Executive Committee and Steering Committee for CSDMS governance are associated with the Annual Meeting. The Annual Meeting provides an opportunity for networking and in-person interaction to boost CSDMS community goals and operations.

In addition to the spring annual meeting, CSDMS encourages and will provide logistical and organizational support for ancillary, community-driven workshops, meetings, and hackathons. Although CSDMS does not have funds in hand to financially support these events, the CSDMS IF will actively help community members seeking funding mechanisms and provide logistical support as needed. Remote participation options will be encouraged, when possible, for these additional events.

A2.1.2 Web Portal

Engagement of members, or first-time exposure to CSDMS of potential new members, will often be through the CSDMS web portal. Therefore, the web portal should be an easy-to-navigate content management system that broadly disseminates CSDMS and community related resources, technology, and services, and provide opportunities to members to contribute to the larger community. Therefore, it is CSDMS' main web goal to optimize user experience where possible.

With this aim in mind, CSDMS will innovate in the following domains of its website: 1) the model repository to ensure informed model selection and member-controlled model review, model usability, and a smooth pathway from model user to model developer; 2) the community area where the various Working Groups, Focus Research Groups and Initiatives are hosted to optimize participation and to provide domain targeted information; 3) the CSDMS services and products section so that the larger community can easily find information on standards, coupling tools, and techniques, and additional services provided by CSDMS.

As the CSDMS repositories are growing by contributions of the community, we want to optimize the sharing of these resources. One important web cyberinfrastructure goal is to facilitate machine-query mechanisms and allow for machine populating through application programming interfaces (APIs). The web content management system will be enhanced so that this is possible, and instructions will be provided on how to approach the various repositories that CSDMS has developed and maintained through APIs.

Indicators of progress: Web portal visits and usage statistics, including community member edits, model vetting and review, including membership participation, working group use and science team activities, and availability of API user documentation.

A2.1.3 Help Desk

Increasing use of CSDMS cyberinfrastructure will generate increased demand for user support, and only with efficient troubleshooting will usage continue to grow. Past CSDMS IF user support on topics such as code development or high-performance computing, has been provided on an informal, ad hoc basis. In order to scale with the growing community, we propose a Help Desk: a single point of contact where the community can submit questions and track their status. Internally, the CSDMS IF will operate a roster system to ensure that issues reported are quickly classified, managed in an issue-tracking system, and allocated to the responsible team member. Questions and answers will appear online, so that solutions are archived and available for the entire community. In this way, a centralized knowledge system will be built over time. By centralizing support, the CSDMS IF can prioritize community help, track question resolution, and increase efficiency by referring to the knowledge base where possible. Ultimately, the Help Desk will function as a community resource in resolving pressing software, HPCC, and modeling issues.

A2.1.4 Research Software Engineers as a Service

Although software has become fundamental to research, particularly in earth system sciences, most earth scientists have little or no training in software development. CSDMS 3.0 will bridge this gap and empower earth scientists to create sustainable software that is well tested, maintainable, modular, and robust. Along with providing scientists with the necessary tools to build sustainable software, we will also provide the community with one-on-one guidance and assistance provided by a professional Research Software Engineer (RSE). On a yearly basis, CSDMS IF will solicit proposals for software consulting support, and will review and make selections based on need, available resources, and impact. To be eligible, projects must be completely open source and must address a CSDMS-oriented goal. CSDMS will then provide an RSE to work directly with selected projects.

A2.1.5 Increase Community Diversity

Women now earn about 50% of PhDs within geoscience but remain underrepresented especially in leadership roles (estimates range from 13% to 23%). Women make up 29% of the CSDMS' Executive Committee (group chairs) and 40% of the steering committee. Broad participation of scientists and students from traditionally underrepresented groups has seen much less progress over the last decades, and thus is an acute priority. CSDMS emphasizes computational research, which builds highly marketable job skills, which is often an important motivating factor to URM students or students from economically disadvantaged backgrounds. At the entry level, CSDMS offers student who bring diversity stipends for attendance at the Annual Meeting. We propose to continue offering five scholarships that aim to increase diversity. These scholarships will be advertised nationally through the Institute of Broadening Participation (IBP). CSDMS is a core institutional member of the IBP.

Both the CSDMS IF and the Chairs exercise mindful attention to diversity and inclusion principles when seeking keynote speakers and clinic leaders for meetings, when building initiatives, when identifying potential awardees, and when filling vacancies in CSDMS leadership on the Executive and Steering Committees. The formation of Science Teams provides an opportunity to further increase CSDMS community diversity, and, especially, to seek early-career scientist participation in leadership and take into account diversity in career stage, gender, expertise, institutional origin (R1, four-year, HBCU, etc.), and other criteria.

CSDMS3.0 will promote activities, such as panels and clinics, during their annual meeting to inform members about demographics in STEM sciences, promote knowledge about funded initiatives to be agents of change, and promote skills to be efficient mentors for URMs, and in general be positive advocates for diversity and inclusion.

A2.2 Computing

A2.2.1 Python Modeling Toolkit (pymt)

The most pressing research questions in earth-surface process modeling often lie at domain boundaries. These questions are best addressed in coupled model experiments. The prototype Python Modeling Tool (pymt) is an open-source package that provides tools for running and coupling models that expose a Basic Model Interface (BMI). pymt will become the primary CSDMS toolkit for scientists to develop new models, extend existing models, couple models, or simply run an established model with a consistent interface. We will build on the current pymt prototype to create and release a fully functional product.

pymt includes couplers for models with disparate time and space scales (such as grid mappers), time-steppers that orchestrate the sequencing of models within a coupled simulation, data exchange tools for BMI-enabled models, wrappers that automatically load BMI-enabled models, utilities that support open-source interfaces (e.g., UGRID, SGRID, EarthCube Geosemantics), and a plug-in framework for adding new models to the pymt model collection.

A key advantage of pymt is that it will allow researchers to run any BMI-enabled model interactively through a Python command-line environment, which has a similar look and feel to the commercial packages MATLAB and IDL but is fully open source. Using pymt, a researcher will be able to drive any BMI-enabled model with a great deal of control; for example, they can step the model forward for a certain amount of time, pause to plot output, change variables, and perform analyses. Moreover, because all BMI-enabled models have the same set of controls, the learning curve needed to operate any particular model is greatly reduced. Coupling between models can be performed directly on the command line in real time, or by writing a Python program that uses BMI commands to iteratively update and exchange data between models, calling service components when needed.

In CSDMS 3.0, we will strengthen the early pymt prototype to create and release a fully functional application. We will work with community members to populate pymt with a set of component models that span domains and processes (for example, hydrology, permafrost processes, landscape evolution, delta evolution and stratigraphy, etc.). We will develop online documentation for pymt, and provide training to the community through webinars, workshops, and other venues. Our aim is to drive usage to create a thriving user community, who contribute back to the code base by developing and sharing their own components and tools.

A2.2.2 pymt ModelMaker

The Landlab toolkit, developed by and for the CSDMS community with support from the NSF SI2 program, is an easy-to-use Python library that gives users tools to build grid-based numerical models. Whereas pymt focuses on model coupling by providing a collection of legacy models wrapped with a common interface, and the utilities necessary for their coupling, Landlab provides a mechanism for quickly and easily building new models. A focus of CSDMS 3.0 will be to close the gap between model builder and model coupler by unifying these two tools. This will create a single, easy-to-use environment for scientists to build new models (using the Landlab library of utilities), that can immediately be coupled to other models within the pymt collection. Users will be able to build models from the ground up that can be immediately coupled to a wider range of models (across multiple languages and domains) in a web-based application. The ease of model development with Landlab, and the fact that Landlab components will have built-in BMI compatibility, promises to greatly expand the menu of BMI-enabled model components.

A2.2.3 Basic Model Interface for Data

As with models, data comes in many different flavors—different spatial and temporal resolutions, different grid types, different file formats—and, as with models, these differences pose significant hurdles when trying to analyze or bring data into a modeling framework. Given the growing interest in using real-world geospatial data with models, and the explosion of high-resolution datasets, this problem is pressing. What is needed is a common language that allows models to seamlessly communicate with data as well as with other models. To solve this problem, we propose to extend the Basic Model Interface (BMI) to include data formats and individual data sets. When applied to data, the extension of BMI allows the creation of Data Components, and acts as a common hub that connects spokes to the many data formats within the earth sciences. For example, the BMI standard get-value function will apply to datasets as well as model codes. In this way, we are able to tightly couple data and models in a common plug-and-play environment.

A2.2.4 Unified Framework for Model-Data Coupling

Given a common language for models and data, the problem now shifts to constructing an efficient and straightforward environment within which data and models can communicate with one another. The pymt becomes a natural choice to become a unified framework within which models and data are interchangeable, have a common interface, and can communicate with one another. We will implement a series of initial data components, including tools to handle particular file formats (e.g., NetCDF), and bring them into the pymt environment.

A2.2.5 Geo-enabled pymt

To fully use data that have been wrapped with a BDI, pymt must be updated to incorporate geospatial information (e.g., BMI must include descriptions of georeferenced grids) so that it can be exchanged between models. We will extend pymt to work with geospatial data by integrating existing libraries such as GDAL and GDAL/OGR Simple Features Library, as well as proj.4, a cartographic projection software. These packages provide extensive tools for working with geospatial data. With the addition of geospatial service components, BMI-enabled models and data that have been brought into pymt will automatically gain the ability to exchange georeferenced data values between grids. Thus, models and data, located on a globe, can be coupled and run together in a single plug-and-play environment. Because each component, regardless of whether it wraps a physics-based model or a dataset, exposes the same interface, they can be swapped with similar components. For example, a georeferenced dataset could be swapped with an operational model; for example, one might swap use of a global river-flow dataset with output from a hydrological model such as VIC or WBM.

A2.2.6 Integrating Model Output through Web Services

Geographic Information Systems platforms provide an intuitive way to present and interpret geospatial data and offer unique opportunities for education. Many of these platforms are well integrated in the scientific community, freely available (e.g., QGIS, GRASS GIS), and can ingest data that are provided by one or more web services. We propose to develop a prototype framework that enables OGC standard web services to visualize model simulations. These web services will be accessed through the pymt modeling environment, which provides NetCDF files as standard output. NetCDF is a file format that can be visualized using web services (e.g. a Thematic Real-time Environmental Distributed Data Services (THREDDS) Server or similar).

A2.2.7 Microdata for Metadata

To be useful, model codes and other resources must be discoverable. The potential for discoverability has been enhanced by the introduction of the HTML5 standard, which now includes a simpler way to annotate web elements such that the search engines and browsers can better understand published online content. This is done by embracing "microdata", a supporting vocabulary to describe an item that is machine-readable. Schema.org has developed common vocabulary for data, source code, and education that we propose to seamlessly integrate into the existing semantic wiki database structure, which has implemented the Dublin Core metadata standard. By incorporating microdata, CSDMS makes it possible to provide rich search results back to users, to optimize exposure of models, data, and educational material.

A2.2.8 The Evolution of BMI

Modeling studies should be reproducible and sustainable. One way to address these obligations is to isolate a model in an environment that includes all the dependencies for running it; e.g., in a container, like Docker. To communicate with a containerized model (e.g., to supply inputs and retrieve outputs), the container provides endpoints that are accessible through web services. If BMI could use this key property of containers, it would open the door for running and coupling models over the web.

We will extend BMI as a web application programming interface (API). A web API manages interactions between online services, using HTTP along with standardized JSON-encoded requests/responses as a hub language to provide a consistent, programmatic method for connecting resources. In our case, a resource will be anything that exposes a BMI—data or model. Through a RESTful interface, client applications would be able to find and query these resources. Additionally, the API would provide methods for creating and advancing the resource through time. One technique for implementing models as web services is through Open Geospatial Consortium (OGC) Web Processing Service (WPS) protocols. Similar to CSDMS standards, WPS protocols can be designed to have initialization and update phases. To expose a model as a web service using WPS, BMI will be updated to allow WPS resources to integrate with pymt. Multiple web service models can then be coupled with one another, and with data.

BMI as a web service has advantages over direct communication on a single computer. By running BMI on separate servers, we distribute the computational load—in both processing and memory—allowing resources to run in parallel. Additionally, web services hide details of the model; in particular, the language the model was written in. Finally, BMI as a web service provides the basis for a next-generation, decentralized, distributed Web Modeling Tool (WMT), allowing models and data to be coupled and run over the web in a reproducible and sustainable manner.

A2.2.9 High Performance Computing Cluster

As a service to its members, CSDMS IF provides access to a high performance computing cluster (HPCC) operated by CU Boulder's Research Computing group. CSDMS IF has purchased four compute nodes in Research Computing's Blanca condo cluster. In a condo cluster, partners get priority access on the nodes they own, and can also run jobs on others' nodes that are not currently in use. The condo agreement is scalable, allowing CSDMS IF the ability to acquire additional nodes in response to community need. CSDMS members can use Blanca without an allocation. Moreover, in keeping with the spirit of the CSDMS educational mission, Blanca can act as a training HPCC for members who are new to high-performance computing concepts. We will continue to maintain a pathway for CSDMS members to migrate from Blanca to Summit, CU Boulder's flagship HPCC.

A2.3 Education

A2.3.1 Webinars

CSDMS consists of a large and active modeling community. This community helps to promote, shape and adopt open source modeling, best model practices, model coupling, and coding standards within their research to accelerate science. Starting the Fall of 2018, CSDMS will introduce webinars to expose the CSDMS community and beyond to above related community efforts. The webinars are typically 30-minutes to an hour long on a topic that is of interest to a larger community. Webinars are recorded and shared through the CSDMS YouTube channel as well as through the CSDMS educational repository: https://csdms.colorado.edu/wiki/Webinars. **Indicators of progress:** At least 3 webinars in both the fall and spring will be provided, by either a member of the community or staff of the CSDMS IF. CSDMS IF will keep track of attendance and view metrics once a recording is posted to assess if for example a follow up, or more advanced webinar on a similar topic might be of interest.

A2.3.2 Training Seminars

The CSDMS IF offers on-site and remote training seminars to academic, government, and commercial organizations. These trainings are organized and offered at the request of the community.

A2.3.3 Learning pymt through Jupyter Notebook

pymt is the superglue that binds the CSDMS Modeling Framework. To expose pymt to the community and demonstrate how it can run and couple models, we will develop a series of Jupyter Notebooks. Descriptive, step-by-step examples, with figures, will be included in each Notebook. Users will be able to advance through the code in the Notebook, optionally modifying it to explore its behavior. An instance of JupyterHub, a multi-user, server-side application for hosting Notebooks, will be installed on a dedicated resource to run the demonstration Notebooks.

A2.3.4 Seeking Additional Support for Summer Schools

The original grand vision for CSDMS 3.0 included organizing an annual summer institute for students, which unfortunately was not funded. However, we maintain that traditional earth science education does not usually equip students with skills to become effective *cyberinfrastructure users* and *cyberinfrastructure contributors*. In order to develop innovative models for analyzing and predicting how the earth's surface responds to environmental change and human influence, the earth surface processes modeling community critically needs a platform to teach modern programming practices and High Performance Computing methods. The CSDMS IF in collaboration with the TWG Chair has pursued an Implementation/Pilot Proposal to CISE CyberTraining in 2019 to organize a10-day Cyberinfrastructure in *Earth Surface Processes Institute* (*ESPIn*) for *graduate students, postdoctoral fellows and early career faculty* at the CSDMS Integration Facility at the University of Colorado in Boulder in the summers of 2020-2021 to trains the next generation to be innovators.

ESPIn aims to transcend the traditional model of department-based graduate education through interdisciplinary, problem-based, 'Just in Time Teaching' of model use and development. Over forty participants, selected from diverse disciplinary backgrounds with explicit slots reserved for underrepresented minorities, would gain direct experience in converting their research codes into open-source distributed software. ESPIn hosts developed lesson material in online open access educational repositories. ESPIn helps to train a new generation of computationally savvy, integrative scientists, while accomplishing major community science priorities.

The purpose of this project is to help make scientific advances in the study of Earth Surface Processes (ESP) that leverage the powerful and advanced capabilities of new cyber tools, such as the Python Modeling Tool. To those ends, the primary objective is to expand the use of cyberinfrastructure among members of the ESP research community with training that (1) increases their competence and confidence with using cyberinfrastructure tools, methods, and resources, and (2) moves the larger ESP community towards more widely adopting tools to advance the fundamental science of predicting surface change. Experienced scientists, visiting faculty, and software engineers assist with training and mentoring of the participants. ESPIn offers hands-on training in best programming practices, numerical methods, open source software development, advanced use of version control systems, writing unit tests, HPC-based sensitivity testing and model uncertainty quantification techniques. Several days are dedicated to working collaboratively on authentic research and coding projects. Participants will work on developing their own codes, with the intent of making codes more robust and compliant with existing ESP CI frameworks. The Summer Institute is quantitatively evaluated for learning efficacy, and evaluations will be used to iterate on lesson material quality. And ESPIn provides all developed lesson material as online learning and teaching modules and broadly advertises these resources to the geoscience community.

A3.0 CSDMS 3.0 5-Year Management & Governance Plan

A3.1 Overall Management Structure and Governance

CSDMS operates with a mature set of bylaws available on the CSDMS web site. The bylaws are reviewed by the Executive Committee and required revisions are submitted to the Steering Committee for approval and adoption. CSDMS' organizational structure (Figure 2) includes:

- The **Executive Director** oversees the management and operation of the Integration Facility and coordinates the project. A Deputy Director supports the Director in implementing strategic plans and policies and represents CSDMS at events for which the Director is unavailable.
- The **Executive Committee** (EC) represents the community and acts as the primary decision-making body. The EC ensures that funding agreements are met, oversees the Bylaws and Operational Procedures, and guides the short- and long-range science plans of the Working and Focus Research Groups. The EC includes the chairs of the Working and Focus Research Groups. The EC approves reports, plans, partner memberships, and other major issues pertaining to the running of CSDMS. The full EC will meet semi-annually. Additional remote-participation meetings are scheduled as required.

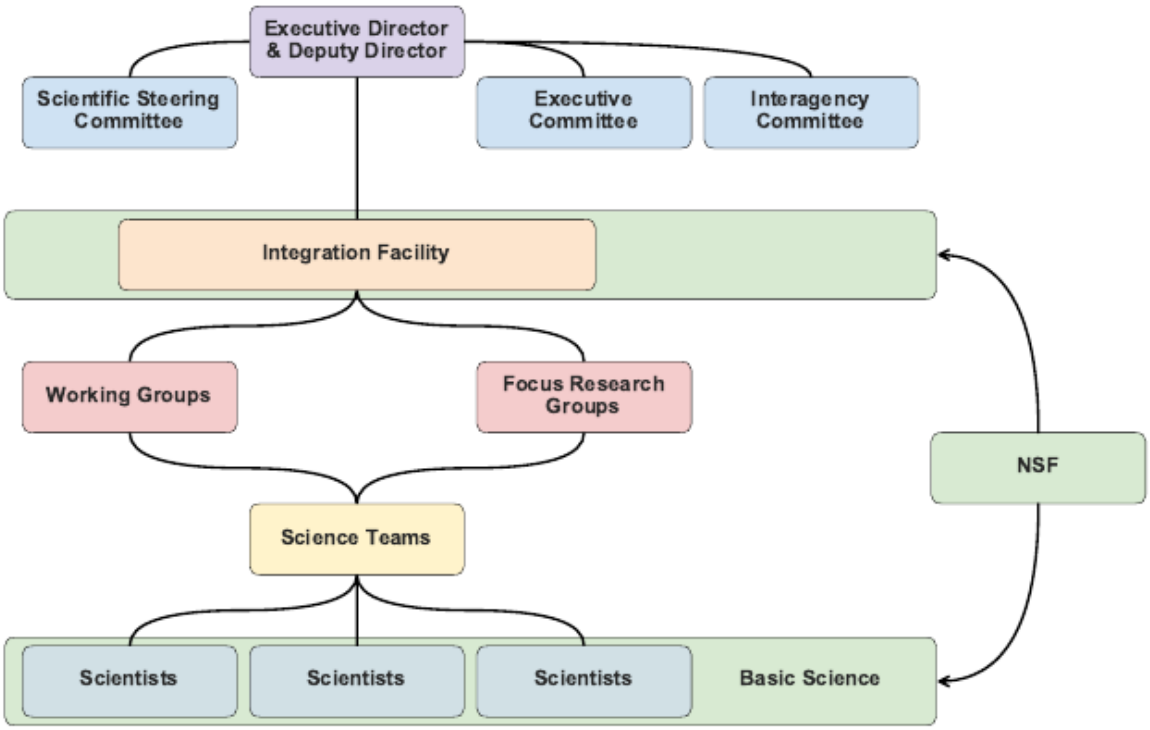

Figure 2: CSDMS Organizational Chart.

- The Scientific **Steering Committee** (SC) assesses competing objectives and needs of CSDMS, evaluates science, networking and education progress, and advises on revisions to the strategic science plan (this document). The SC also approves the bylaws and revisions. The SC meets at least once annually, with additional meetings scheduled as necessary.
- The **Community Members** are organized into Working Groups and Focus Research Groups. These groups are guided by their respective Chairs and Science Teams and conduct activities such as providing model codes and tools, educational materials, data for model initialization, testing and benchmarking, assessing contributed models, drafting of white papers and synthesis papers and general communication of new developments important to the community group. The annual plan and evolving strategic plans will transparently reflect input from members.
- An **Interagency Committee** coordinates collaborations with and communications of CSDMS efforts, with particular focus on moving models from research to operation, avoiding costly duplication of effort and improving predictions needed by decision-making entities. The committee and the CSDMS IF provides interagency meeting (approximately annually) to communicate new software developments, community initiatives and seek agency feedback.
- The **CSDMS Integration Facility** (CSDMS IF), located in Boulder, Colorado, supports the core activities of CSDMS.

A3.2 CSDMS Integration Facility Operation and Staff

A3.2.1 Key Personnel

Key personnel essential for the management and operation of the CSDMS IF are summarized below. **Executive Director and PI. Dr. Greg Tucker** is the Executive Director and Lead PI. He has overall responsibility for the project and will be engaged in all aspects of CSDMS operations, including governance, CIF management, and interactions with other model development programs. **Deputy Director and Co-PI. Dr. Irina Overeem** serves as Deputy Director and oversees workforce development efforts of the CIF. **Geospatial Web Services Expert and Co-PI. Dr. Albert Kettner** coordinates geospatial data integration into the framework, and develops CSDMS web technology, data and model portals and repositories. **Chief Research Software Engineer and Co-PI. Dr. Eric Hutton** oversees all aspects of CSDMS software development and HPC management. **Research Software Engineer. Dr. Mark Piper** is responsible for CSDMS software products and related services and also has EKT responsibilities. **A Software Engineer (new position with expected hire date of June 2019)** will provide support to the Research Software Engineers and staff the help desk. **Program Coordinator. Lynn McCready** is responsible for general CSDMS IF administrative management and logistical coordination of community activities.

A3.2.2 CSDMS IF Operations

The CSDMS Integration Facility is a year-round, full-time operation with staff available from 8AM to 5PM weekdays, excepting holidays. The CSDMS IF maintains CSDMS repositories, and facilitates community communication and coordination, public relations, and product penetration. The CSDMS IF develops the CSDMS cyberinfrastructure, provides software guidance to the community, engages in workforce development, and supports cooperation between observational and modeling communities. A help desk, a web forum, and software engineering services will assist the community in efficient use of the Facility HPC resources and CSDMS framework tools. Management of CSDMS IF activities will be coordinated through weekly meetings in which staff members will discuss status and plans, coordinate activities, and address technical issues. Development priorities will be guided by the community with input from the Executive and Steering Committees.

A3.2.3 HPCC Operations Servicing the Community

As a service to its community, CSDMS provides access to an HPC cluster, blanca. The blanca cluster is serviced by the University of Colorado Research Computing group, which provides system administration, maintenance, daily backups, and a help desk. The CSDMS Research Software Engineers are responsible for setting up user accounts on blanca, communicating with Research Computing, and collecting usage statistics. Further, the Research Software Engineers assist users who require extensive computational resources for their work to migrate from blanca to Research Computing's Summit HPC system.

A3.2.4 Financial/Business Controls and Reporting

All financial and business controls follow the policies, procedures and standards required by the host institution. Primary responsibility for cooperative service agreements rest with the Office of Contracts and Grants (OCG) at CU Boulder. Post-award accounting is coordinated through the Institute for Arctic and Alpine Research (INSTAAR). A small portion of post-award accounting associated with Tucker's salary and travel takes place through his host institution at CU Boulder, the Cooperative Institute for Research in Environmental Sciences (CIRES). CSDMS 3.0 tasking is supported through a combination of Trello boards, spreadsheets for financial budgeting and Gantt Charts. Progress is reviewed weekly by the Lead PI. Any discrepancies are handled immediately and if necessary, are be reported to NSF. The Director is responsible for working with the CSDMS IF staff and Executive

Committee to prepare annual reports. All historical annual reports are available on the CSDMS web portal, and each year's new report is made available for community review and published on the website. Annual reports provide key accomplishments for the year, and include use metrics, annual revenue and expenditures, priorities and resource management for the next year.

A3.3 Community Engagement Structure

The CSDMS community is organized into five Working Groups (number of members in italics):

Terrestrial *806*, Coastal *616*, Marine *388*, Education and Knowledge Transfer *260*, and Cyberinformatics and Numerics *239*, and seven Focus Research Groups: Hydrology *622*, Carbonates and Biogenics *115*, Chesapeake *82*, Geodynamics *202*, Critical Zone *109*, Human Dimensions *120*, Ecosystem Dynamics *112*, and a proposed new FRG: Cryosphere. These groups represent the individual scientific communities that compose the CSDMS membership. Engagement with the membership will be through the web portal, help desk, email list, quarterly newsletters, social media, and CSDMS IF staff presence at international meetings. In addition, each group maintains a group-specific web portal, email list communications, and representatives meet annually in-person at the CSDMS Annual Meeting. CSDMS FRGs are co-sponsored by professional organizations and the chairs are responsible for liaising with their organizations.

A3.4 Metrics for Success

The following metrics are tracked and reported, and listed on a new "Metrics" page on the CSDMS web site:

- Membership: new members, sectors, locations, working group distribution.
- Established Science Teams and new Cryosphere Focus Research Group.
- Web portal visits and usage statistics, including community member edits.
- Social media usage statistics.
- Model vetting, including membership participation, web use, and science team activities.
- Numbers of participants at meetings, clinics and results of post-event evaluations.
- New resources (models and tools, datasets, EKT material) submitted to repositories.
- Diversity statistics for participants in CSDMS activities.
- Number of requested and allocated hours for software engineering support.
- Number of resolved HelpDesk issues, including response time and Forum usage statistics.
- Number of research proposals that use CSDMS, including dollar amounts funded, funding NSF directorates and programs.
- Linkages with community initiatives such as CZO, EarthCube, Council of Data Facilities, GEO, RE3Data, Lidar RCN (number of clinics, talks, participation in meetings).
- Presentations and special sessions at national/international meetings.
- Engagement with CSDMS through email statistics, e.g., open and click-through rate, location.
- Number of data and model components available in the CSDMS Modeling Framework.
- Number of WMT and pymt software releases, downloads, community contributions.
- New CSDMS products and services and uptake metrics, like: WMT runs (user, success rate and percentage HPC, Cloud); stand-alone vs. coupled configurations; pymt downloads, forks, and contributions; number of projects using CSDMS IF tools; robustness of framework.
- Number of new HPC accounts and running total, including top users.
- Usage of EKT tools and movies, labs and webinars (attendance and viewing rate).
- Numbers of participants at Summer School and results of post-event evaluations.
- Numbers of publications, white papers and special issues that use CSDMS products.
- Number of graduate students, postdocs, and visiting scholars who engage with CSDMS.

A3.5 CSDMS Priorities and Deliverables

Milestones CSDMS 3.0

Tasks	Phase 1 (2018-2019)	Phase 2 (2019-2020)	Phase 3 (2020-2023)
Community	Establish Science teams. Launch Cryosphere FRG. Develop and approve 5-year Strategic Plan.	Science Teams. Develop Use-Model for CSDMS services.	Science Teams. Implement Use-Model for CSDMS services.
Modeling and Coupling Tools & Standards	Integrate gridding tools in WMT and PyMT. Develop PyMT.	PyMT operational. WMT-to-PyMT tool. PyMT/WMT handle geospatial data.	PyMT GIS functionality. Extend BMI as a web API.
Data-Model Synthesis Tools	Develop BDI. Dakota Tools for additional Components.	Bridges to XSEDE to allow running UQ experiments.	PyMT and WMT GIS functionality.
Web Portal	Enhance Model-Data and EKT Repository. Web tools for Standard Names.	Improve functionality of Model Repository for model vetting and selection.	Implement web tools for learning assessment.
HPCC Resources	Compute nodes of *blanca* available to CSDMS community.		
Management Governance and Operations	Weekly team meetings, semi-annual Executive Committee meeting, annual Steering Committee, annual all-hands meeting, web portal maintenance, and regular e-communication.		
Education and Mentoring	Webinar series, learning assessment tools, Summer School.	RECCS internships. Summer School. Postdocs.	RECCS summer internships. Summer School. Postdocs.
Reporting	First CSDMS 3.0 annual report.	Annual reporting.	Annual and final reporting.
Publications and Presentations	CIF journal articles and biennial Special Issues (e.g., *Modeling Advances in Geohazards*). Presentations at co-sponsor meetings (e.g., CZO, CUASHI). Journal articles and white papers from Science teams. Special sessions at conferences.		

Table 1: Milestones for Years 1 through 3 of CSDMS 3.0.

A4.0 Bylaws of the Community Surface Dynamics Modeling System

By-Laws

Community Surface Dynamics Modeling System (Oct. 2016)

PREAMBLE

The Community Surface Dynamics Modeling System (CSDMS) assumes responsibilities to develop, support, and disseminate to the earth-science research and teaching community integrated software modules that are aimed at predicting the erosion, transport, and deposition of sediment and solutes in landscapes, seascapes and their repository sedimentary basins. The goal of CSDMS is to enable the rapid development and application of linked dynamical models tailored to specific landscape-basin evolution problems. These models should address time scales that range from years to thousands of years or longer, and spatial scales that include global, regional and local aspects of the earth's surface — from the mountain tops covered in glaciers to the deep seafloor and their sediments. To foster longer-term progress in surface modeling, CSDMS gathers and makes available models designed to elucidate poorly understood aspects of landscape and seascape dynamics. CSDMS develops and maintains a high-level of community participation to ensure:

a) Well-documented and user-friendly earth-surface dynamics software that keeps pace with both hardware and scientific developments;

b) Partnerships with related computational and scientific programs in order to eliminate duplication of effort, leverage mutual progress, and provide and benefit from an intellectually stimulating environment;

c) Appropriate training for both the users and teaching communities;

d) Hardware and personnel resources to support and facilitate software development and its use by the community;

e) Strong linkage between what is predicted by CSDMS codes and what is observed both in nature and in physical experiments.

CSDMS develops and maintains the computational system to ensure the portability and interoperability of modules, the computational efficiency of system code, and the clarity and consistency of documentation. CSDMS offers pedagogically evaluated earth-surface numerical technology to enhance and inform education in undergraduate to graduate programs, and science museums.

CSDMS Members adopt these By-Laws of the Community Surface Dynamics Modeling System for conducting CSDMS business in a collegial manner. These By-Laws do not override the standard responsibilities and prerogatives of Principal Investigator and his/her institution.

ARTICLES

ARTICLE I. NAME

Section 1. Name: The name of the Organization is *Community Surface Dynamics Modeling System (CSDMS).*

ARTICLE II. WORKING GROUPS, MEMBERS AND THEIR INSTITUTIONS

Section 1. Working Groups: The six Working Groups (WGs) to support the CSDMS program include three (3) Environmental Working Groups and two (2) Integrative Working Groups, and one (1) Interagency Committee. The three key Environmental Working Groups are:

i) Terrestrial WG: weathering, hillslope, fluvial, glacial, aeolian, lacustrial;

ii) Coastal WG: delta, estuary, bays and lagoons, nearshore;

iii) Marine WG: shelf, carbonate, slope, deep marine.

The Integrative Working Groups are:

iv) Education and Knowledge Transfer (EKT) WG: includes marketing to gain end-users, workshops to provide training for end-users, web-based access to simple models (e.g. K-12 teaching), access to archives of simulations. This WG will interact closely with its Partner Committees (Industry, Agency), field programs, and cyberinformatic partners.

v) Cyber-Infrastructure and Numerics WG: includes technical computational aspects of the CSDMS, ensures that the modeling system properly functions and is accessible to users; software protocols are maintained, along with model standardization and visualization.

vi) A CSDMS Interagency Committee has the focus of fostering linkages between the main US environmental agencies that have interest in CSDMS products, standards, and approaches.

Section 2. Focus Research Groups: The CSDMS Focus Research Groups (FRGs) were established in 2008 to cut across our Environmental Working Group structure, to serve a unique subset of our surface dynamics community often with support of well-developed sister organization. The current FRGs include:

i. Hydrology FRG is cosponsored by CUAHSI, the Consortium of Universities for the Advancement of Hydrologic Science, Inc., and deals with aspects of the hydrological system that impact earth-surface dynamics;

ii. Carbonate & Biogenics FRG is cosponsored by NSF's Sedimentary Geology and Paleobiology Program to address the grand challenges for fundamental research on ancient and recent carbonate systems, reefs and other seafloor supporting environments, through creation of the next generation of numerical carbonate and other seafloor-based biological process models;

iii. Chesapeake FRG a 'geographically-focused' effort co-sponsored by the Chesapeake Community Modeling Program, to develop a watershed-estuary model consisting of interchangeable modules including hydrodynamics, ecosystem dynamics, trophic exchanges, and watershed interactions;

iv. Critical Zone FRG is co-sponsored by NSF's Critical Zone Observatory (CZO) Program to represent Critical Zone data and model development within CSDMS;

v. Human Dimensions FRG is co-sponsored by the Future Earth Programme and their AIMES (Analysis, Integration and Modeling of the Earth System) project, and by CoMSES Net, the Network for Computational Modeling for SocioEcological Science, a scientific research coordination network to support and expand the development and use of computational modeling in the social and life sciences. The HD FRG engages to codify the human and societal process into models of a future Earth, including next-generation agent-based models, economic models, able to quantify human influences (behaviour and decision making) that affect earth system responses;

vi. Geodynamics FRG is co-sponsored by the NSF MGeoPRISMS Program and is committed to better understanding and modeling the coupled geodynamic - geomorphic system through the development and innovation of numerical tools, relevant and challenging proof-of- concept questions.

vii. Ecosystem Dynamics FRG represents the ecological modeling community and is co-sponsored by the International Society for Ecological Modelling. The FRG deals with ecosystem and ecological dynamics with an emphasis on interactions with landscape processes.

Section 3. **Membership:** Working and Focus Research Group members shall be holders of an academic or research appointment, with major responsibilities for instruction and/or research in the earth, environmental and engineering sciences, in a department, program, or other organizational unit of their Institutions (academic institutions, not-for-profit organizations, state and federal labs, and consulting and industrial companies). Members shall have demonstrated a major commitment to research in Earth System Science with a particular emphasis on computational earth-surface dynamics, and related fields (hydrology, fluvial processes, biogeochemistry, sedimentology, stratigraphy, geomorphology, glaciology, oceanography, marine geology, climate forcing, active tectonics, surface geophysics, remote sensing, geomathematics, computational fluid dynamics, computational science, and environmental engineering). Applicants may apply to the CSDMS Integration Facility to join one or more of the CSDMS Working and Focus Research Groups. The CSDMS Integration Facility shall maintain a list of Members and their Institutions. Working Group membership requires a two-thirds majority approval of the CSDMS Executive Committee. A membership fee may be levied on for-profit organizations. Working and Focus Research Group Chairs may appoint a Coordinating Committee.

Section 4. Responsibilities/Activities:

iv) **Group Discussion:** Stay current in the processes and models associated their disciplinary toolkit and identify gaps in knowledge and areas where numerical tools need to be developed. Set scientific modeling priorities for their discipline. Make recommendations for resource prioritization and facilitate the movement of these priorities up the hierarchy from technology group to steering committee.

v) **Review Activities:** Ensure quality control for the algorithms and modules for their area of expertise (benchmarking and model testing). Coordinate the evaluation of numerical codes according to interoperability, scientific contribution, and technical documentation. Ensure adequacy of supporting boundary conditions and boundary initializations.

iv) **Group Project:** Address a CSDMS proof-of-concept challenge as outlined within the latest/updated CSDMS Strategic Plan, as appropriate.

v) **Individually and collectively:** Stimulate proposals and input from the community. Create and/or manage the various environmental process modules related to their discipline. Provide community continuity to meet long-term CSDMS objectives.

vi) **Meetings:** Working Groups will coordinate much of their activity via remote communication systems but are encouraged to meet as resources and interests permit.

vii) **Reporting:** Working Groups will report annually on their progress.

Section 5. Foreign Membership: Working and Focus Research Group members from foreign academic institutions, not-for-profit organizations, foreign government labs, and consulting and industrial companies, are offered all of the privilege of U.S. working group members, except for the privilege of voting for the Chairs of the Working Groups that reside on the governing body of CSDMS — the CSDMS Executive Committee.

Section 6. Resignation or Removal: Any Member or Chair may resign at any time by giving written notice to the Chairperson of the Steering Committee, or to the CSDMS Executive Director. Such resignation shall take effect at the time of receipt of the notice, or later specified therein. Given sufficient cause, any Member or Chair may be removed by the affirmative vote of two-thirds of the Voting Members of the CSDMS Executive Committee.

Section 7. Voting: For the purpose of the election of a Working Group Chair, each CSDMS WG member shall be entitled to one vote as specified in Article III, Section 7. All WG members will be offered a chance to vote, via the Internet (e.g. email, a CSDMS Web Wiki). All other voting will be through a majority of the Working Group members present at the time of the vote (e.g. Annual Meeting of the Working Group).

Section 8. Action without a Meeting: Any action required or permitted to be taken by the CSDMS members, or the Executive Committee, may be taken without a meeting if the CSDMS members, or the Executive Committee, consent in writing to the adoption of a resolution authorizing the action. The resolution and the written consents thereto shall be filed with the minutes of the proceedings of the CSDMS members or the Executive Committee.

ARTICLE III. CSDMS EXECUTIVE COMMITTEE

Section 1. Executive Committee of CSDMS: The Executive Committee (ExCom) will be comprised of: a) Executive Director and PI of the award as Chair, (non-voting, except to break a tie vote); b) Chair of the Steering Committee (voting); c) Chairs of the defined working groups (voting) — (i) Terrestrial, (ii) Coastal, (iii) Marine, (iv) Cyber-Infrastructure and Numerics, (v) Education and Knowledge Transfer, and (vi) Interagency. The elected members of ExCom shall have terms not to exceed three years or until his or her successor is chosen and qualified. Members of ExCom other than the chair of the Steering Committee may not simultaneously serve on the Steering Committee. Chairs of the Focus Research Groups will be ex-officio non-voting members of the Executive

Committee.

Section 2. Powers of the Executive Committee of CSDMS: The ExCom is the primary decision-making body of the CSDMS, and will meet twice a year to approve the annual science plan, the annual report including the management plan, budget, partner membership, and other day-to-day issues that arise in the running of the CSDMS. The Executive Committee will ensure that the objectives of the Cooperative Agreement are met. The ExCom will develop the By-Laws and Operational Procedures, to be co-approved by the Steering Committee. At all meetings of ExCom, the presence of a simple majority of its Voting members then in office shall constitute a quorum for the transaction of business. So long as they do not conflict with the responsibilities of the Principal Investigator (the CSDMS Executive Director), power in the management of the affairs of the CSDMS Organization is vested in the CSDMS Executive Committee. To this end and without limitation of the foregoing or of its powers expressly conferred by these By-Laws, the CSDMS Executive Committee shall have power to authorize such action on behalf of the Organization, make such rules or regulations for its management, and create additional offices or special committees. The Executive Committee shall have the power to fill vacancies in, and change the membership of, such committees as are constituted by it. Appointments of Working Group membership shall rest with the Executive Committee.

The CSDMS Executive Committee will co-share authority with the CSDMS Steering committee to amend or repeal the By-Laws, or the adoption of new By-Laws.

Section 4. Executive Director: The Executive Director shall, when present, preside at all meetings of the Executive Committee and shall perform such other duties and exercise such other powers as shall from time to time be assigned by the Executive Committee. The Executive Director shall be an *ex officio* member of all CSDMS committees. The Director is the Chief Executive Officer of the Organization, and unless authority is given by the Executive Committee to other officers or agents to do so, he or she shall execute all contracts and agreements on behalf of the Organization. The Director shall be the Principal Investigator on proposals, which fund the core CSDMS Facility. It shall be his or her duty, insofar as the facilities and funds furnished to him or her by the Organization permit, to see that the purposes, orders and voting within the CSDMS Organization are carried out. The Director shall preside at CSDMS-wide town-hall meetings.

Section 5. Chairperson of the Steering Committee: The SC Chairperson when present shall preside at all meetings of the Steering Committee and perform such other duties and exercise such other powers as shall from time to time be assigned by the Executive Committee. The Chairperson of the Steering Committee shall be an ex officio member of all CSDMS committees. After the Chair's term is complete, they will be offered the honorary title of Past-Chair and provided with travel funds, when available, to attend CSDMS meeting as appropriate to their interest and CSDMS need.

Section 6. Group Chairs: Chairs of the defined groups will be full voting members of the Executive Committee and will represent the following areas of surface dynamics expertise. They will have the authority to call meetings of the group they are responsible for, and to meet the collective long-term CSDMS objectives.

Section 7. Election and Term of Office: All members of the Executive Committee must stand for election. The Chairperson of the Steering Committee shall be elected by a virtual vote of the CSDMS membership orchestrated and recorded by the CSDMS Executive Assistant, for a term not to exceed three years or until his or her successor is chosen and qualifies. Chairs of the Working Groups shall be elected by the members of the respective working groups, orchestrated and recorded by the CSDMS Executive Assistant, for terms not to exceed three years or until their successors are chosen and qualify, and they shall be eligible for re-election. Focus Research Group Chairs are appointed by the CEO of the sponsoring organization and the CSDMS Executive Director.

Section 9. Resignation: Any Officer may resign at any time by giving written notice to the Chairperson of the Steering Committee, or the CSDMS Executive Director. Such resignation shall take effect at the time of receipt of the notice, or later specified therein.

Section 10. Vacancies: The Executive Director may fill any vacancy in any Office for the unexpired portion of the term of such office.

Section 11. Removal: Any officer may be removed at any time with cause by a vote of the Executive Committee.

ARTICLE IV. OPEN MEETINGS

Section 1. Annual CSDMS Meeting: An annual open meeting of the CSDMS membership will be held to solicit comment and feedback from the community. Comments from the community will be recorded and forwarded to the CSDMS Executive Committee and the CSDMS Steering Committee.

Section 2. Special Meetings: Special meetings may be called by the Chairperson of the Steering Committee, or by the CSDMS Executive Director, upon written request of at least one-fifth (1/5) of the membership of the CSDMS Working Groups.

Section 3. Place of Meetings: The CSDMS Executive Director shall designate the place and forum (face-to-face or virtual) of the annual meeting or any special meeting and which shall be specified in the notice of meeting or waiver of notice thereof. The meeting venue will be chosen to maximize community participation.

Section 4. Notice of Meetings: Notice of such meeting of the CSDMS members shall be given at least sixty days before the date fixed for the meeting.

ARTICLE V. STEERING COMMITTEE AND OTHER COMMITTEES

Section 1. Steering Committee: In order to carry out and oversee CSDMS operations, a Steering Committee (SC) shall be established. *Upon the recommendation of the Steering Committee, the Executive Committee approved the expansion of the Steering Committee membership.*

"The Steering Committee be comprised of a minimum of seven (7) members selected by the ExCom to represent the spectrum of relevant Earth science and computational disciplines, and each of the two Partner Sub-Committees." The serving NSF program officer or his/her designate, and the Executive Director or his/her designate, will serve as *ex officio* members of the SC. During SC meetings, there may be occasions when these *ex officio* members would exclude themselves from discussions.

The SC members will serve terms up to three years duration. The Steering Committee will meet once a year to assess the competing objectives and needs of the CSDMS; will comment/advise on the progress of CSDMS in terms of science (including the development of working groups and partner memberships), management, outreach, and education; and will comment on and advise on revisions to the 5-year strategic plan. The Steering Committee will provide a timely report to the Executive Director who is to respond within four weeks.

Section 2. Special or Standing Committees: The ExCom may create such special or standing committees as may be deemed desirable, the members of which shall be appointed by the Executive Director from among the Membership, with the Membership approved by the Executive Committee. Each such committee shall have only the lawful powers specifically delegated to it by the Executive Committee.

ARTICLE VI. ELECTIONS

Section 1. Executive Committee: With the exception of the Executive Director, the CSDMS Membership in accordance with the procedures established in this Article will elect voting members of the Executive Committee.

Section 2. Nominations for the Executive Committee: In consultation with the Steering Committee, the Executive Director will nominate candidates for each position to be filled. The Membership is encouraged to suggest nominees to the Executive Director.

Section 3. Election: Election shall be conducted electronically. The CSDMS Integration Facility must receive Electronic or Paper votes by the deadline specified in the ballot. The outcome of the election will be decided by a simple majority of the votes cast.

Section 4. Counting of ballots: The Steering Committee Chair, or his/her designated representative shall count Ballots.

ARTICLE VII. COMPENSATION

Section 1. Compensation: No Member shall be paid any compensation for serving on the CSDMS Executive Committee, Steering Committee or other committees and Working Groups. Representatives may be reimbursed for the actual expenses incurred in performing duties assigned to them, within limitations of the host Institution's budget associated with the NSF Cooperative Agreement 0621695.

ARTICLE VIII. AMENDMENTS TO THE BY-LAWS

Section 1. Amendments: All By-Laws of the Organization shall be subject to amendment or repeal and new By-Laws may be made by the affirmative vote of two-thirds of the Executive Committee and the Steering Committee.