Report of the USGS Coastal and Marine Geology Modeling Workshop

Pacific Marine Science Center, Santa Cruz, CA

March 22–23, 2005

By Christopher R. Sherwood

Open-File Report 2005–1193

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
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U.S. Geological Survey
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Suggested citation:
Sherwood, C.R., 2006, Report of the USGS Coastal and Marine Geology Modeling Workshop, Pacific Marine Science Center, Santa Cruz, CA, March 22–23, 2005: U.S. Geological Survey Open-File Report 2005–1193, 15 p.

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Summary

A U.S. Geological Survey (USGS) Coastal and Marine Geology (CMG) Modeling Workshop was held to discuss the general topic of coastal modeling, defined broadly to include circulation, waves, sediment transport, water quality, ecology, sediment diagenesis, morphology change, and coastal evolution, on scales ranging from seconds and a few centimeters (individual ripples) to centuries (coastal evolution) and thousands of kilometers (tsunami propagation). The workshop was convened at the suggestion of CMG Program Management to improve communication among modelers and model users, assess modeling-related activities being conducted at the three centers (Florida Integrated Science Center, FISC; Pacific Marine Science Center; PMSC; and Woods Hole Science Center; WHSC), and develop goals, strategies, and plans for future modeling activities. The workshop represents a step toward developing a five-year strategic plan, and was timed to provide input for the FY06 prospectus. The workshop was held at the USGS Pacific Marine Science Center in Santa Cruz on March 22–23, 2005.

One the first day, 25 CMG scientists presented short descriptions of ongoing projects, and discussed the overall project goals and how modeling-related activities were (will be) used to meet some of these goals. The presenters described their advances in science, modeling technology, and any challenges (scientific, technical, or programmatic) they had encountered. The talks revealed broad ranges of modeling activities and of specific models.

On the second day, attendees broke into three discussion groups to discuss CMG modeling. Their charge, for the first discussion session, was to assess the status of modeling at CMG. A second discussion session to outline goals and strategies for improving the program was planned, but instead these topics were discussed in a plenary session.

Participants noted the importance of modeling at CMG and the interplay between process studies, regional studies, and modeling. Most felt that modeling plays a critical role in CMG science, and that CMG can play a special role in advancing coastal science because the USGS has a unique ability to study problems at the appropriate time and space scales. This ability, and the ability to include everything from fundamental process

studies to final publicly accessible products, is the special Federal role that USGS can bring to regional and national studies.

The Modeling Workshop provided a much-needed opportunity for exchange of information among CMG modelers, model users, and interested researchers. More than half of the projects discussed were concerned with nearshore processes, erosion hazards, or shoreline change. This is a niche in which CMG leadership is both required and expected.

CMG projects use many models, including proprietary models (Delft3D and DHI models) and open-source models (SWAN, ROMS). Choices exist between application of fully-featured proprietary models and the development of custom, open-source models, and between diversification and focus, but these choices were viewed as a positive and productive aspect of CMG science.

Participants suggested that CMG should continue to collaborate with other Federal agencies (OFA) that have complementary interests in coastal and marine processes. We need to continue to interact with the Office of Naval Research (ONR), the U.S. Army Corps of Engineers (USACE), and the U.S. Environmental Protection Agency (USEPA) on issues of modeling and field programs for evaluating and improving models. Specifically, workshops should be held with these agencies and external scientists to coordinate modeling and model evaluation activities.

The importance of OFA funds in CMG research was discussed, and it was recognized that OFA funds could influence our research directions, but no strategies for managing OFA opportunities were defined.

A list of activities that will enhance CMG modeling, primarily by improved communication among modelers, model users, and interested scientists, was developed. It includes: exchange of experts among the centers; internal review of modeling projects; increased use of established web sites; and annual meetings such as this one.

Introduction

A U.S. Geological Survey (USGS) Coastal and Marine Geology (CMG) Modeling Workshop was held to discuss the general topic of coastal modeling, defined broadly to include circulation, waves, sediment transport, water quality, ecology, sediment diagenesis, morphology change, and coastal evolution, on scales ranging from seconds and a few centimeters (individual ripples) to centuries (coastal evolution) and thousands of kilometers (tsunami propagation). The workshop was convened at the suggestion of CMG Program Management to improve communication among modelers and model users, assess modeling related activities being conducted at the three centers (Florida Integrated Science Center, FISC; Pacific Marine Science Center; PMSC; and Woods Hole Science Center; WHSC), and develop goals, strategies, and plans for future modeling activities. The workshop represents a step toward developing a five-year strategic plan, and was timed to provide input for the FY06 prospectus.

Goals for this Workshop

The workshop was convened to achieve the following goals.

- Communicate CMG project goals, modeling approaches, progress, and challenges.
- Assess CMG modeling programs.
- Identify the scientific goals and scope of CMG modeling program.
- Strategize to improve our modeling capabilities significantly.
- Optimally plan, coordinate, fund, and enable our modeling program.
- Provide information for 5-year science plan with specific outcomes.
- Provide input to FY06 prospectus.

Day 1–Project Talks

One the first day, 25 CMG scientists presented short descriptions of ongoing projects, and discussed the overall project goals and how modeling-related activities were (will be) used to meet some of these goals. The presenters described their advances in science, modeling technology, and any challenges (scientific, technical, or programmatic) they had encountered. The talks revealed broad ranges of modeling activities and of specific models. Fourteen of the projects mentioned some use of SWAN, thirteen projects use Delft3D, five projects use the USGS Community Sediment Transport Model based on ROMS, and six projects were using or evaluating components of the Nearshore National Oceanographic Partnership Program (NOPP) community model NearCOM. Only three projects specifically identified water-quality or water-column ecology as important components (Tampa Bay, Coral Reefs, and Puget Sound Seagrasses), and of these, only one (Tampa Bay) used the DHI (formerly the Danish Hydraulic Institute) suite of models. Three projects specifically mentioned shoreline change models, and ten projects are developing other models (or sub-models).

Day 2–Discussions

On the second day, attendees broke into three discussion groups to discuss CMG modeling. Their charge, for the first discussion session, was to assess the status of modeling at CMG. A second discussion session to outline goals and strategies for improving the program was planned, but instead these topics were discussed in a plenary session.

Assessment

Three reports from breakout groups were presented. The first group presented a figure showing the relationship of numerical models with model-related activities (fig. 1). CMG is concerned most with three related activities: developing and testing fundamental understanding of the physical processes ("Theory/Processes"); making field and laboratory observations ("Observations/Measurements"); and performing regional studies that address science issues of societal importance ("Regional Applications"). There is synergy among these three activities. Regional applications often define the modeling needs and generate OFA support. In some cases, the questions to be addressed may require new theory or improved understanding of fundamental processes. Observations and measurements provide direct information for regional studies, and, if performed in the context of regional studies, also provide data for input to models or for testing and validation of models, and can lead to new theory and a better understanding of processes. Theory and understanding of processes can lead to improved algorithms for incorporation in the models, and can also provide impetus for new measurements.

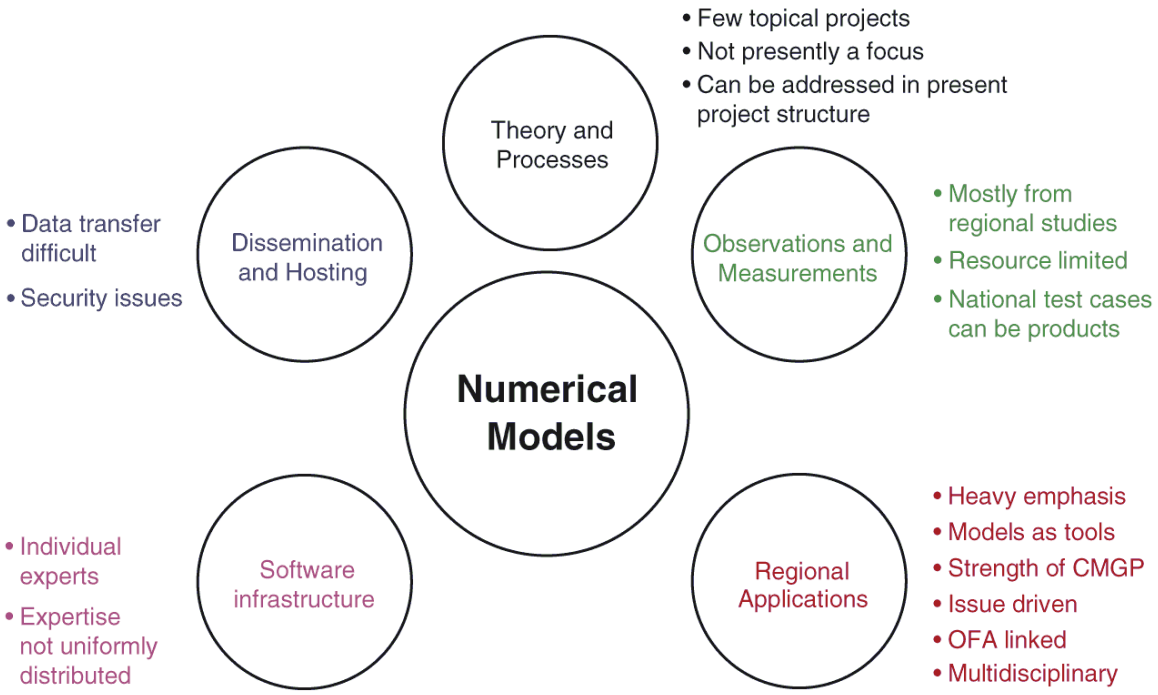

Figure 1. Illustration of model-related activities.

The two areas in which CMG has not traditionally played a large role are in "Dissemination and Hosting" of models or in development of "Software Infrastructure". For example, CMG does not run any models in near-real time, does not have prominent web sites with model code, and does not have any computer scientists dedicated to developing code. However, individual researchers have played important roles in developing code and disseminating it among the research community. For example, Rich Signell and John Warner have made significant contributions to raw model code, and CMG has hosted quite a lot of code related to models and/or data analysis, including various codes from Dave Rubin, Rich Signell, Chuck Denham, Chris Sherwood, Jingping Xu, and (more recently) in-house contributions from Marinna Martini, Jessie Lacy, and Dan Hanes and collaborators.

The second and third groups presented lists of viewpoints (or statements) regarding CMG modeling. The merged and reordered lists are as follows.

Advantages CMG Brings to Model Development and Application

- Modeling is an important component of virtually all CMG research programs.
- Field data is limited by the collection environment, and models allow scientists to investigate an expanded environment and integrate field results.
- CMG field efforts provide valuable data sets for improving models because our regional projects often provide a more diverse set of measurements, over larger areas or longer time periods, than issue-specific measurements.
- CMG projects allow comparison of models and measurements over a wide range of environments and applications. This comparison allows us to identify weaknesses in models.
- CMG researchers publish results in peer-reviewed literature.
- CMG studies require a wide variety of processes to be modeled.

Role of Federal Government in Coastal Research and Modeling

- CMG problems tend to be more applied than most National Science Foundation (NSF)-funded research, but CMG can conduct fundamental research that may be required to address these questions.
- CMG can approach some problems of societal importance with broader research efforts than local or state agencies or academic research programs.
- CMG efforts on societal problems can identify weaknesses and improve models or solutions generated by academic research.
- CMG efforts sometimes overlap with academic research, but CMG can also supplement large academic research programs with expertise, instrumentation, and a broader perspective.
- CMG research is sometimes mandated by Congress.
- CMG researchers and conclusions are generally perceived as objective and unbiased.

- CMG methods, data, and results are often nonproprietary and available to the public.
- CMG can direct SIR funding to address important and timely issues that require improved scientific understanding.

Role of Proprietary Models in CMG Research

- Sometimes proprietary models are the best technology available to address important issues.
- Some proprietary models are professional products that (a) are designed to be robust, efficient, and tolerant of real-world use (b) are professionally supported, (including user manuals and support) (c) have graphical user interfaces that allow nonexpert users to operate the model.
- Some proprietary models are the result of significant investment and development that CMG might not want or be able to duplicate.
- Use of proprietary models allows CMG to respond to stakeholder questions in an efficient and timely manner.
- In several instances, proprietary models include processes that are not included in CMG models and that are required to address specific problems. In other instances, the integrative capabilities of proprietary models confer significant advantages in their use.
- Collaboration with developers of proprietary models allows CMG modelers to build insight and expertise, and transfer that knowledge into our own research and models.

Issues Associated with Proprietary Code

Use of proprietary model code has several potential disadvantages.

- If the code cannot be examined, it is hard to ensure the model is behaving as intended. It is also hard to ensure that the model is being used properly.
- If the code cannot be released to others, it is difficult to document, report, and confirm research methods.
- If the code cannot be altered and recompiled, it is generally hard to fix or improve the model. It cannot be maintained by CMG, ported to other machines or operating systems, or modernized.
- If the code or executables cannot be shared, the pool of potential collaborators is smaller.
- If access to the code is considered a competitive advantage, government use may infringe on private industry.

Role of Funds from Outside Funding Agencies (OFA) in CMG Research and Modeling Projects

- OFA funds are increasingly important to the CMG budget.
- Targets of OFA funds help CMG identify high-priority issues.
- Receipt of OFA funds helps demonstrate worth of CMG research.
- OFA-funded projects provide opportunities for CMG to collaborate with other agencies and address problems with an appropriate scale of resources.
- OFA funds usually do not pay the entire cost of CMG participation, so the funding agency essentially leverages CMG resources. This works to everyone's advantage if the OFA project aligns with CMG goals, but can derail CMG planning if the OFA project distorts CMG priorities.

Other Issues/Comments

Use of most models requires a significant investment of resources beyond acquisition or development of the model itself. Training in the use of the model, experience in adapting the model to specific problems, and development of model tools and analysis techniques all require significant time and energy on the part of specially trained CMG researchers.

The USGS has a unique role to play in advancing and applying coastal and marine science. CMG has a vertically integrated science and technology capability that allows us to contribute to all of the steps in the process of providing science to address problems important to society. These steps include basic research into fundamental physical processes, development of new hypotheses, formulation of these hypotheses into algorithms suitable for modeling, making critical measurements to test the hypotheses and their representation in models, incorporating advances from the general scientific community into our models and testing them, acquiring and developing new technology for making observations, conducting field and laboratory measurement programs, evaluating models against these data, and finally, applying models to address important issues in coastal and marine geology.

Goals, Strategy, and Planning

Recommendations for changes and improvement to the program were assembled in a plenary discussion session. The following list has been expanded and reordered, but is based on the list of suggestions compiled during the meeting. Attendees were not polled and no votes on these suggestions were taken, so they do not represent a consensus of the attendees.

Overall Goals and Directions

Advance understanding of processes that shape the coastal environment, incorporate hypotheses in state-of-the-art numerical models, and apply the knowledge and models to important problems related to coastal hazards and resources—The overarching goal of modeling at CMG is to advance our practical knowledge of coastal processes. Our work should provide and/or adopt sound, testable hypotheses regarding the processes involved in sediment transport over a wide range of time and space scales. These hypotheses take the form of numerical models that specify our understanding and allow us to test our understanding against observation and alternative hypotheses. The models allow us to quantify these processes for specific cases (for example, in regional studies), which means we can evaluate the importance of various processes and extend our understanding beyond available observations (i.e., use the model to synthesize or make predictions). Field observations, in turn, allow us to evaluate our models critically.

Continue to invest in a range of process research, model testing/development, and application to real problems—The general sense gleaned from attendees was that the present CMG approach is good and should be continued. That approach includes observation and process studies, model development, model evaluations, and use of models to address societally important problems.

Incorporate nearshore processes into ROMS—It was clear from the presentations and discussion that many of the present CMG projects involve nearshore dynamics. The widespread use of Delft3D and the use of the Nearshore NOPP model NearCOM indicates that CMG scientists need models that include nearshore sediment transport and shoreline evolution. There was discussion about the merits of putting these processes into the USGS Community Sediment Transport Model (built on ROMS), which would allow us to build, test, use, and distribute a public-domain model with these capabilities. The goal of incorporating nearshore physics and shallow-water sediment transport capabilities into the Community Sediment Transport Model in ROMS could be a central aspect of a long-term CMG strategy, and might be exactly the right niche. We would want to work closely (as partners) with the Nearshore NOPP community, and use regional projects to provide data for model testing. Deciding to pursue this course will involve a significant commitment of resources, but there was strong support for this among some attendees. Others attendees expressed doubts about the need for this model and whether the resources were available to bring such a model to the same level as Delft3D.

Continue to collaborate with Delft while encouraging Delft3D to be open-source—Many projects are using Delft3D to address both fundamental science and societally important issues. We have benefited from our interactions with Delft researchers and produced results with Delft3D that no other modeling system could have produced, and many attendees recommended that we continue to use Delft3D and collaborate with Dutch researchers. There is some hope that Delft3D will become open-source, but (at present) there is no guarantee that this will occur.

Work toward observational studies to evaluate models focused on cross-shelf transport and mixed sediments—A long-term (ca. 5-year) goal might be to plan multiagency field studies designed specifically to measure key processes and provide critical tests for sediment-transport models. With sufficient planning, a collaborative effort among CMG, ONR, the USACE, and possibly other agencies [NOPP, National Oceanic and Atmospheric Administration (NOAA), NSF, Federal Emergency Management Agency (FEMA), the USEPA and state agencies] might produce one or more measurement / modeling projects that could simultaneously produce insight into processes, data for forcing and testing models, and answer important resource-management questions.

Participate in observatory science planning—There will be significant expansion of funding and opportunities associated with regional and national coastal observatory systems, and the USGS needs to stay abreast of opportunities for funding and collaboration.

Recognize importance of OFA funds—OFA projects provide a mechanism for stakeholders to benefit from USGS expertise when the problems are not appropriate for private consultants. The importance of OFA funds in CMG research was discussed, and it was recognized that OFA funds could influence our research directions, but no strategies for managing OFA opportunities were defined.

Improved Communication and Efficiency

The following suggestions all encourage improved communication and collaboration among CMG scientists involved in process studies, model validation and improvement, and model applications in regional studies.

Yearly modeling science meeting—Attendees at this workshop overwhelmingly approved the suggestion that some kind of annual forum for exchange of project plans and science results be established. Most agreed that the short project reports were a valuable component of the workshop.

Internal modeling advisory committee—One suggestion for improving coordination among CMG modelers and model users was to establish an inhouse modeling advisory committee. Conceptually, this might be a small group of senior researchers representing the three centers and various disciplines that would serve as a resource for modelers and model users within CMG. They could review proposals and work plans, provide recommendations for model applications, and generally help connect modelers and users.

Use external advisory committees on big modeling projects—On large modeling projects, external advisors should be invited to review the project and provide constructive criticism.

Increased use of Lotus QuickPlace: add model-specific forums or QuickPlaces—Lotus QuickPlaces provide an easy way to transfer files and collaborate within the USGS and with a small group of outside collaborators. We will try to promote the use of the CMGSoft QuickPlace, starting with this workshop report.

Circulate modeling proposals among modelers—There was some discussion of the history (and demise) of the earlier peer-review process in CMG, and general agreement that peer-reviewing at least provided a method for communicating research plans and progress. One suggestion was to pass modeling-related proposals past the internal advisory group; another was to generally publicize modeling proposals on the CMGSoft QuickPlace.

Get a list of OFA / NSF / NOPP / ONR / USACE / USEPA opportunities—We need some way of sharing opportunities and plans as they arise so that we can optimize use of resources and make sure we are not deflected from our CMG goals by OFA projects.

Exchange experts—An effective way to exchange information is to exchange expertise (and the experts) among centers. We should encourage both short and long exchanges of modelers and field researchers among the three CMG centers. Specifically, we agreed that Rich Signell and John Warner should travel to Santa Cruz to train researchers in the use of ROMS, Cliff Hearn should travel to Woods Hole to exchange information about use of DHI in the Tampa Bay project, and Giles Lesser should travel to Woods Hole to train staff in use of Delft3D.

Develop test cases—It was suggested that we build a series of model test cases, including both simple conceptual cases and more complex real-world cases that would facilitate model testing and comparison.

Explore DHI models among centers—It was suggested that we introduce researchers at the three centers to DHI models (DHI used to stand for Danish Hydraulic Institute, but the nonprofit research institute is now formally named DHI). DHI models are a critical component of the Tampa Bay Integrated Model. Expanding the number of scientists familiar with the model would provide CMG reasearchers with a more complete view of available models and increase the number of scientists that could support Tampa Bay modeling efforts.

Resource Issues

The following items all revolved around limitations in resources presently available to CMG modelers. Most of these can be resolved without additional funds, but will require efforts supported by program management.

Try to get supercomputer resources—The fastest computers available inhouse to CMG modelers are equivalent to high-performance PCs costing about $8K. Through temporary and informal agreements, we can access faster systems (for example, Linux clusters at Texas A&M, Woods Hole Oceanographic Institution, and the Navy High Performance Computing Center), but access is limited to a few USGS researchers and subject to change. Ideally, we would like to have a formal agreement for supercomputer resources with ONR, the USACE, the Department of Energy, or other agency.

Work around Information Technology (IT) issues associated with semipublic research web sites to exchange large data sets—Department of Interior and USGS IT departments are focused on security and are not well versed in the unique IT requirements associated with numerical modeling, exchange of huge data sets, and research on experimental methods for information exchange. USGS modelers are working with nonstandard operating systems (versions of Unix and Mac OS) and experimenting with data exchange systems (for example, Distributed Ocean Data Systems (DODS), BitTorrent, map servers, etc.) that require us to distribute or access data in ways that are difficult to reconcile with traditional security guidelines. There are solutions to these problems, but we may need support from managers at the highest levels to implement them.

Permanent personnel—The distribution of modeling expertise among the three centers is skewed towards Woods Hole, and there is a need for more modeler expertise in both Santa Cruz and St. Petersburg. We also need to add support staff capable of running models and developing and applying modeling tools to generate input and evaluate output.

Conclusions

The Modeling Workshop provided a much-needed opportunity for exchange of information among CMG modelers, model users, and interested researchers. It was clear that numerical models of various coastal processes are an integral part of CMG research activities. Field or laboratory observations often provide the impetus for model advances, and models often provide the impetus for critical process studies. Numerical models are formal, quantifiable, and testable hypotheses that describe our understanding of physical, oceanographic, and sedimentological processes in coastal regions. They allow us to interpolate among sparse data and extrapolate beyond observable conditions. Models are widely used by CMG scientists to address important problems of coastal erosion, shoreline evolution, and the fates of sediments, and nutrients, contaminants in coastal settings. CMG researchers contribute to model development, testing, and application at virtually every stage in the process.

More than half of the projects discussed at the Modeling Workshop were concerned with problems involving nearshore processes, erosion hazards, or shoreline change. The USGS mandate to address coastal erosion hazards and the focus of current USGS projects requires CMG expertise in modeling nearshore processes. This is a niche in which CMG leadership is both required and expected.

CMG projects use many models, including proprietary models (Delft3D and DHI models) and open-source models (SWAN, ROMS). There are good justifications for both approaches, and good reasons to maintain a diversified suite of modeling tools. It is also apparent that CMG modeling expertise is spread thinly over a range of projects and models. Choices exist between the application of fully featured proprietary models and the development of custom, open-source models, and between diversification and focus. No recommendation for choosing a single approach was formally endorsed by the attendees, and there were suggestions that the existing multiple approaches are productive, but improved communication is needed.

We should collaborate with other Federal agencies that have complementary interests in coastal and marine processes. We need to continue to interact with ONR, the

USACE, and the USEPA on issues of modeling and field programs for evaluating and improving models.

The importance of OFA funds was recognized, but no strategy for managing this opportunity was defined.

Workshop attendees developed a list of list of activities that will enhance CMG modeling, primarily by improved communication among modelers, model users, and interested scientists. Important items on this list include exchange of experts among the centers, internal review of modeling projects, increased use of established web sites, and annual meetings such as this one.

Acknowledgments

The workshop was funded by CMG through individual projects. The author thanks his co-organizers (Dawn Lavoie, Dan Hanes, and Clif Hearn) for their efforts in preparing for and hosting the workshop. Thanks also to Jamie Lescinski, who helped with logistics in Santa Cruz, and Jeff List, Peter Ruggiero, and Jeff Williams, who reviewed earlier versions of this report and made valuable suggestions.

Table 1. List of attendees.

Organizers

Lavoie, Dawn, USGS CMG Headquarters, Reston
Hanes, Dan, PMSC, Santa Cruz
Hearn, Clif, FISC, St. Petersburg
Sherwood, Chris, WHSC, Woods Hole

Participants

Barnard, Patrick, PMSC, Santa Cruz
Butman, Brad, WHSC, Woods Hole
Cheng, Ralph, Water Resources Discipline, National Research Program, Menlo Park
Field, Mike, PMSC, Santa Cruz
Geist, Eric, PMSC, Menlo Park
Gelfenbaum, Guy, PMSC, Menlo Park
George, Doug, PMSC, Menlo Park
Jaffe, Bruce, PMSC, Santa Cruz
Lacy, Jessie, PMSC, Santa Cruz
Lescinski, Jamie, PMSC, Santa Cruz
List, Jeff, WHSC, Woods Hole
Noble, Marlene, WHSC, Menlo Park
Rubin, Dave, PMSC, Santa Cruz
Ruggiero, Peter, PMSC, Menlo Park
Signell, Rich, WHSC, Woods Hole
Storlazzi, Curt, PMSC, Santa Cruz
Thompson, Dave, FISC, St. Petersburg
Warner , John, WHSC, Woods Hole
Williams, Jeff, WHSC, Woods Hole
Xu, Jingping, PMSC, Menlo Park
Yates, Kim, FISC, St. Petersburg

Table 2. Agenda Tuesday, March 22, USGS Pacific Science Center Conference Room.

Speaker(s)	Topic
Hanes, Sherwood, Lescinski	Welcome
Lavoie	Introduction
Sherwood	Palos Verdes Remediation Studies
Noble	SoCal Internal Tides/Swash
Xu	Monterey Canyon Turbidity Currents
Rubin	Modeling Sediment Transport When Velocity is Irrelevant
Barnard	Ocean Beach
Yates	Tampa Bay Project
Break	
Signell	Adriatic Sea
Field	Coral Reefs
Storlazzi	Shelf Habitats
Ruggiero	Southwest Washington Coastal Erosion Study, Coastal Evolution Modeling Project
Lescinski	Coastal Evolution Modeling Project: Cross-Shore Profile Modeling
George	Capitol Lake
Lacy	Puget Sound Seagrasses / Ripple-Scale Models
Gelfenbaum	Elwha, Willapa Bay, Tsunami Inundation
Geist	Tsunami Generation / Propagation
Lunch	
List	North Carolina, National Assessment Overview
Thompson	Hurricane Wave Modeling
Jaffe	Tsunami Sedimentation, San Francisco Bay Geomorphic Change
Butman	Massachusetts Bay Mapping and Habitat
Warner	Hudson River, South Carolina
Williams	usSEABED, Seafloor Mapping and Characterization, Aggregates Assessment
Break	
Sherwood	National Community Sediment Transport Model
Hearn	Tampa Bay Integrated Coastal Model approach
Gelfenbaum	Delft3D Capabilities and Cooperative Plans
Cheng	Recent Advances in Unstructured Grid Models
Warner	ROMS Sediment Model
Signell	Modeling Tools and Data Exchange
Hanes	Role of Numerical Modeling in CMG

Table 3. Tally of models used in CMG projects discussed at workshop.

Speaker	Project	SWAN	Delft3D	ROMS	NearCom	DHI	Shoreline Change	Water Quality	Other
Sherwood	Palos Verdes Remediation Studies			1					1
Noble	SoCal Internal Tides/Swash								1
Xu	Monterey Canyon Turbidity Currents								1
Rubin	Modeling Sediment Transport When Velocity is Irrelevant								1
Barnard	Ocean Beach	1	1		1				
Yates	Tampa Bay Project		1			1		1	1
Signell	Adriatic Sea	1		1					
Field	Coral Reefs	1	1					1	1
Storlazzi	Shelf Habitats	1							1
Ruggiero	Southwest Washington Coastal Erosion Study	1	1		1		1		
Lescinski	Coastal Evolution Modeling Project: Cross-Shore Profile Modeling	1	1		1				
George	Capitol Lake		1						
Lacy	Puget Sound Seagrasses							1	
Lacy	Ripple-Scale Models								1
Gelfenbaum	Elwha	1	1						
Gelfenbaum	Willapa Bay	1	1						
Gelfenbaum	Tsunami Inundation		1						
Geist	Tsunami Generation/Propagation		1						1
Jaffe	San Francisco Bay Geomorphic Change		1						
Jaffe	Tsunami Sedimentation								1
List	North Carolina	1	1		1		1		
Thompson	Hurricane Wave Modeling (part of National Assessment)	1							
Butman	Massachusetts Bay Mapping and Habitat	1		1					
Warner	Hudson River	1		1					
Warner	South Carolina	1	1	1	1		1		
Williams	usSEABED, Seafloor Mapping & Characterization, Aggregates Assessment								
		13	**13**	**5**	**5**	**1**	**3**	**3**	**10**