Proceedings of the First All-USGS Modeling Conference, November 14–17, 2005

Scientific Investigations Report 2006-5308

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Preface

The First All-USGS Modeling Conference was held November 14–17, 2005, in Port Angeles, Washington. U.S. Geological Survey (USGS) participants at the conference came from USGS headquarters and all USGS regions and represented all four science disciplines—Biology, Geography, Geology, and Water. The conference centered on selected oral case study presentations and posters on current USGS scientific modeling capabilities and activities. Abstracts for these case study presentations and posters are presented here.

On behalf of all the participants of the First All-USGS Modeling Conference, we appreciate the support of Dee Ann Nelson and the staff of the Olympic Park Institute in providing the conference facilities; Dr. Jerry Freilich and Dr. Brian Winter of the National Park Service, Olympic National Park, for organizing and leading the conference field trip; and Debra Becker and Amy Newman, USGS Western Fisheries Research Center, Seattle, Washington, and Tammy Hansel, USGS Geospatial Information Office, Reston, Virginia, for providing technical support for the conference.

The organizing committee for the conference included Jenifer Bracewell, Jacoby Carter, Jeff Duda, Anne Frondorf, Linda Gundersen, Tom Gunther, Pat Jellison, Rama Kotra, George Leavesley, and Doug Muchoney.

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Proceedings of the First All-USGS Modeling Conference, November 14–17, 2005

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Development of Multi-Scale Simulation Software for Studying Earthquake Physics: A Component of the Computational Infrastructure for Geodynamics (Poster)

By Brad Aagaard,[1] Charles Williams,[2] and Matthew Knepley[3]

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The physics of earthquakes involves cycles of slow strain accumulation, sudden dynamic stress changes during earthquake rupture, and slow postseismic deformation. Accurate assessment of seismic hazards requires that we understand this deformation occurring across many spatial and temporal scales. Most studies of earthquake physics focus on only a small range of the spatial and temporal scales and either ignore or greatly simplify the interactions with the processes occurring at other scales. Continuing advances in computer hardware and software development now provide the tools necessary to enable multiscale three-dimensional (3D) studies of the physics of earthquakes.

We are developing finite-element software for 3D dynamic, quasi-static, and static modeling of crustal deformation. The modeling spans spatial scales of from tens of meters to hundreds of kilometers. The temporal scales in the dynamic modeling range from milliseconds to minutes and in the quasi-static modeling range from minutes to thousands of years. This software is part of the National Science Foundation (NSF)-funded Computational Infrastructure for Geodynamics (CIG), which involves collaborations between CIG software developers and geophysicists to create state-of-the-art parallel modeling codes for geodynamics. Current development is focused on reorganizing and merging a quasi-static crustal deformation finite-element code (Lithomop, which is a descendant of “Tecton”) and a spontaneous earthquake rupture finite-element code (EqSim). Future development plans include extending the software to allow coupling of multiple simultaneous simulations. For example, this could include (1) coupling an interseismic deformation simulation to a spontaneous earthquake rupture simulation (each using subsets of the software), (2) coupling a spontaneous earthquake rupture simulation to a global wave propagation simulation, or (3) coupling a short-term crustal deformation simulation to a mantle convection simulation and an orogenesis and basin formation simulation.

Integration of Hydrologic and Geographic Models With Remotely Sensed Data for Real-Time Flood Mapping Applications (Poster)

By Kwabena O. Asante,[1] Jerad D. Bales,[2] Silvia Terziotti,[2] and James P. Verdin[3]

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A variety of high-resolution elevation data from ground-based and space-borne light detection and ranging (LIDAR) and radar systems is now available for use in real-time flood forecasting and mapping applications. Scientists analyzing flood events must balance the need for highly accurate geographic and hydraulic representations with the need to provide timely information on the expected magnitude, timing, and impact of the event. Multidisciplinary teams with a variety of hydrologic, remote sensing, and geographic analysis skills are needed to effectively exploit these high-resolution elevation datasets to produce maps of flood events that are both reliable and timely. This poster presents a modeling approach developed by a team of hydrologists and geographers for integrating high-resolution digital elevation data with hydrologic models for real-time flood mapping applications. The modeling approach is well suited for real-time applications because it involves the development of a library of preprocessed flood maps associated with flows at river gauges. During actual flood events, streamflow forecasts at the representative gauge are used to select the applicable flood scenario from the digital map library to generate a warning. The poster presents two applications of this flood mapping approach. The first application is in a data-rich setting in North Carolina and uses LIDAR data, flows from National Weather Service river forecast points, and existing hydrologic models. The second application is in a data-sparse environment in southern Africa. Satellite rainfall estimates are ingested into the Geospatial Streamflow Model (GeoSFM) developed at the U.S. Geological Survey Center for Earth Resources Observation and Science (USGS/EROS) to forecast flows at in situ gauges. The flow forecasts are then used in conjunction with inundation maps derived from Shuttle Radar Topography Mission (SRTM) data for rapid generation of spatially specific flood warnings during actual flood events.

Novel Modeling Approaches for Vertebrate Mapping in the Northwest Gap Analysis Project (Poster)

By Jocelyn Aycrigg,[1] Gary Beauvais,[2] and Larry Master[3]

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[3]NatureServe, Arlington, Va.

The Northwest Gap Analysis Project, which was started in September 2004 and encompasses Idaho, Montana, Oregon, Washington, and Wyoming, is taking a novel modeling approach to mapping vertebrate species. First, we are engaging Natural Heritage Programs in each state to assist with data collection and maintenance at the beginning of the modeling process. These programs already have in place occurrence data, expertise, and infrastructure that cannot be replicated. Duplication of records is eliminated because each program maintains data for only one State and common software and standards for the database are already established. Each program continually reviews, conducts quality checks of, maintains, and updates their database so the most current version is always available. Second, we plan to map the range, distribution, and habitat of each species separately. A species range is the total area that a species occupies. A species distribution (a spatial subset of its range) reflects the spatial arrangement of suitable environments occupied by the species. We defined a species habitat (a spatial subset of its distribution) as the environments in which individuals can on average achieve positive reproductive and survival rates. And third, we will use both deductive and inductive modeling approaches. Range maps will be created using deductive modeling because they include known occupation using coarse spatial extent. Distribution maps have a fine spatial extent and resolution, however, and will require inductive modeling approaches using the intersection of multiple environmental gradients. Habitat maps will use a deductive modeling approach because our intent is to help managers use these data for directly informing finer-scale modeling. Using these modeling approaches to map vertebrate distributions for the Northwest Gap Analysis Project will improve our model outputs, engage data users early in the process, and increase the likelihood of these models being applied to biological conservation.

Status of MODFLOW: The U.S. Geological Survey Modular Ground-Water Flow Model (Poster)

By Paul M. Barlow,[1] Arlen W. Harbaugh,[1] and William M. Alley[1]

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The U.S. Geological Survey (USGS) modular ground-water model, commonly called MODFLOW (Harbaugh, 2005), has become the most widely used ground-water flow model both within and outside of the organization. MODFLOW's modular design has provided a robust framework for integration of related models that build upon or enhance the simulation of ground-water flow. Since its initial release in 1984, an important aspect of MODFLOW has been its capability to simulate coupled ground-water/surface-water interactions, including those with rivers, lakes, and reservoirs. This capability has improved over time from initial approaches that treated ground-water/surface-water interactions in relatively simple ways, such as MODFLOW's River Package, to more complex algorithms in which MODFLOW was coupled directly with steady and unsteady surface-water flow models, such as the DAFLOW (Jobson, 1989) and BRANCH (Schaffranek and others, 1981) models. Currently, a major emphasis of MODFLOW's development is to fully integrate the code with the Precipitation-Runoff Modeling System watershed model (Leavesley and others, 1983); the resulting coupled model currently is being called GSFLOW. GSFLOW will enhance MODFLOW's applicability to complex issues in environmental science and management. Another important extension of MODFLOW has been coupling it with solute-transport models to simulate advective transport, hydrodynamic dispersion, and chemical reactions of dissolved constituents. A recent advance in this area has been the development of the SEAWAT code (Langevin and others, 2003) to simulate variable-density ground-water flow, which is necessary for accurate simulation of saltwater intrusion in coastal aquifers and brine movement in inland aquifers. Lastly, a ground-water management process has been added to MODFLOW to provide the capability to solve several types of ground-water management problems using linear and nonlinear optimization techniques (Ahlfeld and others, 2005); such problems include limiting ground-water level declines or streamflow depletions, managing ground-water withdrawals, and conjunctively using ground water and surface water.

MODFLOW development is led by the USGS Office of Ground Water, which also prioritizes and coordinates code development by scientists outside the Office and coordinates training and technology transfer of the code throughout the

USGS. The latest version of MODFLOW, called MODFLOW-2005 (Harbaugh, 2005), includes the capability to support multiple grids in a single model simulation. This capability makes it possible to incorporate a higher-resolution local grid within a coarser-grid model.

References Cited

Ahlfeld, D.P., Barlow, P.M., and Mulligan, A.E., 2005, GWM—A ground-water management process for the U.S. Geological Survey modular ground-water model (MODFLOW-2000): U.S. Geological Survey Open-File Report 2005-1072, 124 p.

Harbaugh, A.W., 2005, MODFLOW-2005, The U.S. Geological Survey modular ground-water model—The ground-water flow process: U.S. Geological Survey Techniques and Methods 6-A16, variously paginated.

Jobson, H.E., 1989, Users manual for an open-channel streamflow model based on the diffusion analogy: U.S. Geological Survey Water-Resources Investigations Report 89-4133, 73 p.

Langevin, C.D., Shoemaker, W.B., and Guo, Weixing, 2003, MODFLOW-2000, The U.S. Geological Survey modular ground-water model—Documentation of the SEAWAT-2000 version with the variable-density flow Process (VDF) and the integrated MT3DMS transport process (IMT): U.S. Geological Survey Open-File Report 03-426, 43 p.

Leavesley, G.H., Lichty, R.W., Troutman, B.M., and Saindon, L.G., 1983, Precipitation-runoff modeling system—User's manual: U.S. Geological Survey Water-Resources Investigations Report 83-4238, 207 p.

Schaffranek, R.W., Baltzer, R.A., and Goldber, D.E., 1981, A model for simulation of flow in singular and interconnected channels: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 7, Chap. C3, 110 p.

Pebbles to Politics: Ecosystem Models in the Decision Landscape (Case Study Presentation)

By G. Ronnie Best,[1] Donald L. DeAngelis,[2] and Frank Mazzotti[3]

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Restoration of natural ecosystems has been a high priority within many Federal and State agencies for the past several years. As was made apparent at the first National Conference on Ecosystem Restoration (NCER-04), held in December 2004 (http://conference.ifas.ufl.edu/ecosystem), several large-scale and numerous small-scale restoration activities are ongoing throughout the Nation. The Greater Everglades restoration was highlighted as a prominent national-scale restoration activity. What was also made evident at NCER-04 was that, although there is much science relevant to ecosystem restoration in existence, we still have much to learn.

The restoration of natural ecosystems is, in broad terms, the recovery of defining ecological characteristics of a pre-disturbance natural ecosystem. To be successful, restoration goals, policies, and implementation strategies must incorporate our best understanding of the ecological processes and interactions necessary for sustained ecosystem health, productivity, resilience, and continued provision of goods and services of the natural ecosystem. Science is the backbone of restoration, and adaptive management is the unifying concept for integrating science into Greater Everglades restoration. Within the context of ecosystem restoration, adaptive management is a scientific and systematic approach to finding answers to ecosystem restoration and management questions. Adaptive management enables restoration practitioners to move forward even as new information (new science, new and improved models, and so forth) is continually developed.

Using examples drawn from the South Florida Ecosystem Restoration Initiative, we will demonstrate a synthetic approach that combines new and existing efforts to apply science to ecosystem restoration. In the Greater Everglades, the U.S. Geological Survey (USGS) and its partners have been actively involved in developing, implementing, improving, and integrating ecosystem hydrologic, ecological, and landscape models. Because models have been and continue to be a critical component in the decisionmaking process relevant to Greater Everglades ecosystem restoration, restoration managers are challenging scientists to make those models more scalable, more readily available, and easier to use. The objective is to ensure that science—through monitoring, experimental research, and modeling—is an integral component of the adaptive management decisionmaking process.

The many components of restoration include economics, policy, politics, consensus-building, and science. The ripple effect that science has on the decisionmaking process depends on the relevance, the timeliness, and the ease with which science can be integrated into the complex process of decisionmaking—hence, the need for decision support tools. The better the decision support tools are at synthesizing and integrating critical information into relevant, usable, and user-friendly tools for the decisionmaker, the larger the ripple effect of science in restoration activities.

A Fuzzy Rule-Based Spatial Modeling Approach to Delineating the Habitat of Coccidioides (Poster)

By Mark Bultman[1]

[1]U.S. Geological Survey, Tucson, Ariz.

Coccidioidomycosis is a public health issue of increasing importance in parts of North, Central, and South America. It is caused by Coccidioides, a dimorphic soil-inhabiting fungus that can become airborne and be dispersed by the wind. If airborne Coccidioides spores are inhaled, primary infection may occur. About 100,000 new infections occur in the U.S. annually with most individuals being asymptomatic. About 30 percent of infected persons become sick with self-limited influenza-like symptoms. About 10 percent of infected persons seek medical attention and, in 1 to 2 percent of infected persons, the disease disseminates outside the pulmonary system and can cripple or kill. This project is mapping the soil habitat of the saprophytic phase of Coccidioides at select locations with a fuzzy rule-based spatial model. It is extremely difficult to identify Coccidioides in the environment, so statistical approaches cannot be used. The fuzzy model translates what is known about Coccidioides habitat into a flexible numerical framework and processes it with a series of if-then rules called fuzzy associative memory (FAM) rules. These rules are applied to each cell in a spatial database using a geographic information system (GIS). The FAMs are capable of dealing with differing precision in the data and can even use linguistic data. The rules are processed with Mamdani inference techniques, and the resulting product is a map that depicts favorableness of soils for hosting Coccidioides on a scale of 0 to 1. The technique allows modelers to change and update relationships between the variables as more is learned about Coccidioides habitat. This mapping may help mitigate the risk of acquiring coccidioidomycosis by suggesting where dust control measures are needed, by helping to locate public facilities and activities away from areas likely to host Coccidioides, and by providing information on the infectivity of wind storm- or earthquake-generated dust from particular areas.

An Individual-Based Modeling Approach for Blue Crab in Chesapeake Bay: Merging Economics With Biology (Poster)

By David B. Bunnell,[1] and Thomas J. Miller[2]

[1]U.S. Geological Survey, Ann Arbor, Mich.

[2]Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, Md.

The blue crab population in Chesapeake Bay has remained at consistently low levels since the late 1990s. In response to the decline of this commercially and ecologically important species, the Maryland and Virginia management authorities agreed to implement a target exploitation fraction (μ) that would protect 20 percent of the spawning potential of an unfished population (herein μ20%). This level of fishing is assumed to be sustainable. We first developed an individual-based biological model to estimate μ20% = 0.45, which is greater than field-based estimates of μ in 64 percent of the years since 1990. Hence, the commercial fishery has likely contributed to the recent population decline in Chesapeake Bay.

Our next step was to integrate economic revenues from different market categories of blue crabs so that we could estimate the harvest regime that maximizes revenue while maintaining a sustainable exploitation fishing mortality (μ20%). To incorporate revenue into our biological model, we used monthly data from the State of Maryland’s Market Dealer Survey (1998–2003). In our bioeconomic model, we evaluated two different harvest scenarios: (1) varying soft-shell harvest (as a percentage of the total harvest), and (2) varying female hard-shell harvest (as a percentage of the total hard-shell harvest). Our model revealed that increasing soft-shell harvest will concomitantly increase fishery revenue, whereas increasing the male harvest (and subsequently decreasing female harvest) had only a limited impact on fishery revenue. Hence, sustainable revenues can be increased by increasing the proportion of the soft-shell harvest. Future simulations will consider changes in minimum size for blue crab harvest and will also incorporate the costs of operating soft-shell versus hard-shell fisheries.

Using a Neural Net Paradigm to Integrate Expert Systems in STELLA Models (Poster)

By Jacoby Carter[1]

[1]U.S. Geological Survey, Lafayette, La.

STELLA is a popular visual programming language for rapidly creating models of system flows. It has been used to model a variety of complex systems across multiple scales, including population dynamics, food webs, aquatic lake systems, nutrient and water flows, growth systems, and chemical reactions. It has important limitations, however. One of these is its limited logic language, which makes it difficult to integrate expert system approaches or other complex logic into flow models.

To address this problem, I have developed a method that creates decisionmaking structures in STELLA based on a neural net model. A network of converters is used to (1) evaluate the current state of the model and (2) make decisions based on predetermined cutoff values using the graph function. Such decisionmaking heuristics as habitat suitability index models can now be integrated into flow models. Furthermore, these heuristics are dynamic and can be used to regulate decisionmaking in the model. For example, the question “should I nest” need no longer simply be a one-dimensional function

("Is it the right time of year?" or "Do I have enough energy?") but can be based on several dimensions and have multiple combinations that result in different decisions.

The Land Use Portfolio Model: A Multi-Disciplinary Approach for Natural-Hazards Risk Assessment (Case Study Presentation)

By Richard A. Champion, Jr.,[1] Laura Dinitz,[1] and Richard Bernknopf[1]

[1]U.S. Geological Survey, Menlo Park, Calif.

Natural hazards pose a significant threat to public safety and economic health nationwide, especially as more people come to vulnerable areas. As financial losses from natural-hazard events continue to rise, decisionmakers need a strategy for investing scarce resources to protect communities. This type of applied research requires integrating knowledge and techniques from multiple fields, including geology, hydrology, ecology, geography, mathematics, statistics, and economics. We constructed a model that combines natural-hazard and socioeconomic information to help communities evaluate alternative natural hazard mitigation policies.

The Land Use Portfolio Model (LUPM) is an innovative modeling, mapping, and risk-communication tool that can help public agencies and communities both understand and reduce their natural-hazards vulnerability. The LUPM builds upon financial-portfolio theory, which is a method for evaluating alternative investment choices on the basis of estimated distribution of risk and return. The model is set within an interactive, geographic information system (GIS)-based decision-support system (DSS) that stakeholders can use to select locations in which to invest a hazard-mitigation budget, evaluate such metrics as the mean and variance of community wealth, and compare and rank mitigation policies. Research has shown that mitigation policies that produce similar means and variances of community wealth can differ in investment cost by many millions of dollars, and that scientific uncertainty can affect the preference ranking of these mitigation policies, which could potentially influence natural-hazard-management decisions.

Ongoing research includes expanding the LUPM to function with multiple hazards, improving uncertainty estimation, estimating a covariance term, adding a temporal component, and adapting the model to such environmental issues as ecologic sustainability. These improvements also require careful planning for maintaining the DSS code. Applications are currently underway for southern California; Memphis, Tenn.; south Florida; and Vancouver, British Columbia, Canada. Finally, a user-needs assessment is being conducted to evaluate, obtain feedback on, and improve the usability by decisionmakers of the DSS.

Suboptimal Estimation of Ecosystem Carbon Fluxes Using an Ensemble Kalman Filter (Poster)

By Mingshi Chen,[1] Shuguang Liu,[1] Larry L.Tieszen,[2] and Wenping Yuan[3]

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Inherent drawbacks exist in the measurement and modeling of ecosystem carbon dynamics. Measurement is usually patchy in space and discontinuous in time, and modeling is always built on principles that include assumptions and imperfectly defined parameters. Advanced data assimilation techniques can overcome these drawbacks by combining a series of measurements with dynamic models based on statistics or optimization theory. This research focuses on using an Ensemble Kalman Filter (EnKF) to incorporate time-series data into a dynamic gross primary production (GPP) model. The time-series data include fluxes of carbon and energy, remotely sensed data, and observations of weather and hydrology. Daily measurements were collected by the Moderate Resolution Imaging Spectrometer (MODIS) and eddy flux towers located at the Howland (Maine), the Boreas (Thompson, Manitoba, Canada) and the Niwot Ridge Forest (Colorado) stations from 2000 to 2005. The GPP model is based on the fact that GPP is primarily a function of the normalized difference vegetation index (NDVI) from MODIS, air temperature, photosynthetically-active radiation, vapor pressure deficit, and ecosystem light-use efficiency. Model parameters were derived from data collected from these stations (downloaded from the Internet at www.modis.ornl.gov/modis/index.cfm) using nonlinear regression methods. The analyses demonstrate that EnKF achieves the asymptotically optimal estimate of GPP by gradually minimizing the "distance" between the GPP model representations and a real system described by data. The assimilation results at the Howland station show that EnKF, when assimilated flux data are temporally sufficient, can reduce variance of GPP estimates by one-half compared with using the GPP model alone. In addition, we also investigated the effects of observation noise and frequency on GPP estimation. The results also show that simultaneously adjusting the GPP model parameter values using EnKF can dramatically improve the performance of the predictive GPP model. This is because the parameters can also be regarded as state variables within the EnKF paradigm, and they can be automatically updated by the analysis along with other model variables. Consequently, EnKF provides insight into the evaluation and development of ecosystem carbon exchange models and the selection of measurement frequency (or inversely filling data gaps) for flux tower sites.

Linking Hydrologic Modeling and Ecologic Modeling: Application of a Spatially Explicit Species Index (SESI) Model for Adaptive Ecosystem Management in the Everglades Mangrove Zone of Florida Bay (Poster)

By Jon C. Cline,[1] Jerome J. Lorenz,[2] and Eric D. Swain[3]

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The Across Trophic Levels System Simulator (ATLSS) is a collection of ecological models designed to assess the impact of changes in hydrology on a suite of higher trophic level species of the southern Florida ecosystem. ATLSS requires hydrologic input to assess the effects of alternative proposed restoration scenarios on trophic structure. An ATLSS model (ALFISH) for functional fish groups in freshwater marshes in the Everglades of southern Florida has been extended to create a new model (ALFISHES) to evaluate the spatial and temporal patterns of fish density in the resident fish community of the Everglades mangrove zone of Florida Bay. The ALFISHES model combines field data with hydrologic data from the Southern Inland and Coastal System (SICS) model to assess the impact of salinity on fish biomass. The model output may be used to assess the impact of changes in hydrology on fish biomass and its availability to the Roseate Spoonbill (Ajaia ajaja), which is a key indicator species, and other wading birds.

To facilitate linkage of hydrologic and ecological model components, we used a multimodeling approach. We report on recent advances in the development of a generic multilevel modeling framework for ecological modeling. The model framework includes an extensible markup language (XML)-based metadata format, support for a model repository that allows dynamic loading of model components specified by metadata, and a simulation server that provides a discrete event system specifications (DEVS) environment for assembling and running hierarchical modular models. An object model that includes support for open geospatial data standards for grid coverages and simple features is used to exchange model state information between model components and between the simulation server and a user-friendly geographic information system (GIS) client.

Computational Modeling and Visualization Infrastructure at the USGS/EROS (Case Study Presentation)

By Brian Davis[1]

[1]U.S. Geological Survey, Sioux Falls, S. Dak.

The U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) has participated in projects that use supercomputing, parallel processing, Beowulf clusters, and interactive network applications. Currently, EROS is collaborating with universities to research cluster-based visualization systems over optical wide area networks. Just as computational resources are becoming more commodity-based, high-end visualization resources are becoming more affordable and scalable, thus enabling efficient integration of computation and visualization.

The EROS cluster-based visualization system was used as an interim processing resource for the LANDFIRE project, which generates vegetation, fuels, and fire characteristics across the United States. Although LANDFIRE now has dedicated computer resources, the interim solution demonstrated that the computer science necessary for executing computational models on parallel processing systems mirrors the expertise required to implement cluster-based visualization systems. Use of existing infrastructure greatly reduced the time, effort, and cost required to integrate computer science components into computational modeling results, and pooled financial resources and the contributions of model experts, computational scientists, and system support staff were also critical.

To compute models in a time-effective manner and convey results in a cost-effective manner, an interdisciplinary team is required. The required computational science resources, which include hardware, software, networking, visualization, information technology professionals, and computational and earth scientists, must be efficiently integrated to ensure success.

Additionally, ongoing support of a research-suitable infrastructure will shorten the time needed to initiate future computational modeling projects. Future resources in place at USGS and collaborator sites that are professionally managed and continuously available will remove barriers to scalability by enabling extension to larger problem sizes, datasets, and geographic extents.

Finally, complementary interactive visualization over high-speed networks will become increasingly possible within these developing infrastructures. Evolving technology is blurring lines of distinction between computational and visualization systems. Leveraging these technologies will be necessary for the effective communication of results to policymakers, decisionmakers, and the public.

Modeling Snail Kite Population Viability in a Variable Hydrologic Environment (Poster)

By Donald L. DeAngelis,[1] Wolf M. Mooij,[2] Wiley M. Kitchens,[3] and Julien Martin[3]

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The Florida snail kite (Rostrhamus sociabilis) is an endangered raptor that occurs as an isolated population, currently of about 2000 birds, in the wetlands of southern and central Florida. Its exclusive prey species, the apple snail (Pomacea paludosa), is strongly influenced by seasonal changes in water abundance. Droughts during the snail kite breeding season have a direct negative effect on snail kite survival and reproduction; however, droughts are also essential to maintain aquatic vegetation types favorable to snail kite foraging for snails.

We used a spatially explicit individual-based model, EVERKITE, to determine how water-level temporal variation affects snail kite population viability under different temporal drought regimes in its wetland breeding habitat. EVERKITE is a spatially explicit, individual-based model designed as a management scenario evaluation tool for the endangered Florida snail kite. The model is part of the USGS Across Trophic Level System Simulation (ATLSS) program, and can be used to assess the viability of the snail kite population under different hydrologic scenarios. Specifically, the model is designed to project how hydrologic changes in the major wetlands of southern and central Florida affect the movement, reproductive success, and mortality of the snail kite.

We focused on three causes of water-level variations that are likely to affect snail kites: (1) drought frequency; (2) drought duration; and (3) drought timing within the year. We modeled a 31-year historical period using four different scenarios in which the average water level was held constant but the amplitude of water-level fluctuations was modified. Our results reveal that temporal variations in water levels affect snail kite population dynamics in a highly complex manner. Management implications of these results are discussed.

A Robust Space/Time/Phenomenon Data Structure (Poster)

By Lee De Cola[1]

[1]U.S. Geological Survey, Reston, Va.

Given a dataset that represents counts within a set of N regions along T regular time intervals, the S language provides an intuitive space/time structure that is useful for data management and modeling. The structure is a simple N×T "data frame" object that is easily manipulated for visualization and analysis. A few examples are provided by using 1990-2003 United States county case data for pertussis (whooping cough). The columns of the structure can be statistically summarized (for example, by applying the sum, mean, or max functions) to provide time series information for modeling trends, autocorrelation, and forecasting. Similarly, the rows of the structure provide new data that can be joined to geographic information system (GIS) spatial datasets for choropleth mapping, surface fitting, kriging, spatial regression, and so on. It is also easy to transform the counts themselves into binary (present/absent) measurements to visualize where and when the phenomenon is present. Because the data frame corresponds to a simple space × time × phenomenon paradigm, this approach is (1) extremely robust (new phenomenological layers can be added), (2) scalable (regions can be aggregated), and (3) portable (output to text, spreadsheet, and other database formats is straightforward). In the present case, the structure provides State-level forecasts, county-level counts of the number of years the condition was reported, and a stable index that can be used to provide a kriged intensity surface. I invite collaboration with anyone who wishes to incorporate into their favorite model a fresh approach to understanding counts within regions for regular time intervals.

Modeling Mercury in Fish Tissue (Poster)

By David I. Donato[1]

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Wherever human health is concerned, the task of transforming science into policy, and then into action across levels of Government is fraught with both technical and social challenges. Of the two, the social problems—the problems of building trust, cooperation, and collaboration in spite of differing experiences, emphases, points of view, and professional dialects—are by far the more daunting. The Eastern Geographic Science Center (EGSC) has been working for several years to encourage broader use of the National Descriptive Model of Mercury in Fish (NDMMF) so that the various States' differing approaches to fish-tissue sampling and public health advisories about eating fish can be made more effective and more economical. EGSC has developed the Environmental Mercury Mapping, Monitoring, and Analysis (EMMMA) Web site and deployed the NDMMF on this site as the technological spearhead for the U.S. Geological Survey (USGS) effort to convince States and localities that they will benefit from using this national model. EGSC experiences with the EMMMA Web site illustrate new techniques for geographic analysis, scientific visualization, deployment of a complex model on a Web site, and new ideas for using a Web site as a focus for national inter-Governmental collaboration.

A Simulation Model Tracking the Role of Marine-Derived Nutrients in Pacific Salmon Population Growth and Dynamics (Poster)

By John M. Emlen,[1] Jeff J. Duda,[1] and Reg R. Reisenbichler[1]

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Stream productivity in the Pacific Northwest is generally nutrient limited. Anadromous salmon obtain 95 percent of their body mass in the ocean and transfer nutrients to their spawning streams, but because most salmon runs are depressed well below historic levels, this nutrient contribution also is depressed. To remedy this situation, managers have tried various means of nutrient supplementation, including adding carcasses, fish tissue briquettes, and liquid fertilizers to the salmon runs. Whether supplementation will boost salmon production to higher self-sustained levels is not known. We developed a simulation model to quantify the role of marine-derived nutrients in Pacific salmon population dynamics. The model targets coho salmon, which is a species with a freshwater juvenile stage of at least 1 year. The program is written in Fortran and consists of equations that describe egg production, growth, survivorship, and interactions between salmon, their food supply, and nutrient pools. We used existing data where possible to estimate vital rates, but still were left with 11 unknown parameter values. We solved for these parameters by using simulated annealing to find those values that most accurately generated known quantities (body size at 36, 78, and 84 weeks of age and contribution of carcass-derived nutrients to juvenile body mass).

Our goal was to determine whether enrichment might increase population levels and whether or not higher population levels might be self sustaining. The use of simulated annealing to optimize solutions to theoretical model expressions is relatively new in ecological modeling. We present the modeling approach and difficulties encountered in its development, as well as preliminary results that suggest that enrichment boosts population size, although the effect dissipates once the treatment is removed.

Predictive Habitat Modeling in Support of Integrated Invasive Species Management in the Midsouth (Poster)

By Gary N. Ervin[1] and John D. Madsen[2]

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Invasive species pose a serious threat to natural ecosystems, altering patterns of native biodiversity and affecting societally important ecosystem services. As a result, substantial research has been undertaken during the past decade to better understand invasion, its implications, and the potential for managing negative impacts. As part of a program to develop and implement research, extension activities, and regional coordination to address invasive species in the Midsouth, we are investigating the potential for predictive invasive species habitat modeling to guide integrated management efforts. The targets of this work to date have been the highly invasive Asian grass, Imperata cylindrica (cogongrass), and host plants of Cactoblastis cactorum (cactus moth), which threatens native Platyopuntia cacti in the Midsouth but poses an even greater threat to ecosystems of the southwestern United States and Mexico. In initial modeling efforts, a genetic algorithm for rule-set prediction (GARP) modeling approach was used to screen a set of environmental data available at a coarse landscape scale to determine which data would best inform models of a finer resolution. In modeling the extent of the most common species of Opuntia, for example, GARP models indicated that temperature- and precipitation-related variables (frost frequency, annual precipitation, wet-day frequency, and mean and maximum temperature) provided optimal fits of models to available presence data for the region. These models are to be further refined at a scale more appropriate to guiding concerted efforts at locating, monitoring, and possibly managing the spread of invasive species in the Midsouth.

Geologic Pattern Matching—Models for the Future; Hierarchical Fracture Network Modeling from Diverse Data Inputs (Poster)

By Michael Fahy[1]

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Flow in heterogeneous fractured aquifers and mechanical stability of fractured rock are predominantly controlled by the connectivity of extreme hydraulic conductivities (both high and low) and the geometric architecture of the rock mass. Naturally occurring geologic patterns create preferential flow paths that can dominate large-scale flow patterns and determine the mechanical stability of rock slopes or underground openings.

Standard modeling in these heterogeneous geologic systems results in a high entropy distribution of high and low parameter values (that is, a structureless distribution) or a uniform mechanical arrangement of rock blocks (again structureless). Most geologic processes, however, result in highly structured distributions (a few flow pathways or fractured zones). A different modeling effort needs to be used to simulate the real geologic patterns.

This poster is focused on a methodology for constructing realistic fracture networks. Deterministic modeling of all fractures is impossible owing to the large number of fractures. Not all fractures are needed, however, to resolve some questions and issues. Typically, large-scale fractures control the flow. The mechanical stability of rock masses is controlled by critically oriented fractures.

A three-dimensional (3D) hierarchical realistic fracture network model incorporates three basic models. The first is a geometric-mechanical model that uses relatively simple geometric procedures to duplicate the 3D geometry of fracture networks created by complex mechanical processes. The second is a hierarchical model that groups fractures into hierarchically related fracture sets based on field data and the geologic history of the region. The third is a stochastic model that generates fracture sets through a sequence of three stochastic processes based on the statistics of the geologic data.

The fracture network parameters that are inputs are derived from aquifer testing, borehole testing, cores, maps, and water level information. Data inputs include both direct measures of parameters (for example, orientation or spacing) and indirect measures of the effects of these parameters (hydraulic flow dimension, hydraulic conductivity, water level, and mechanical stability). There are large-scale dependencies and smaller-scale dependencies. The modeling effort needs to be consistent with all these diverse inputs. Some of this "conditioning" is "hard," some is "soft," and some is multiple scale. Hard data conditioning is more than simply using the data in the model and fixing the model to emulate these values. For example, if the region to be modeled includes known fault zones, then the extent typically observed should be modeled when a borehole penetrates a fault. Typical use of fractures in the U.S. Geological Survey (USGS) work may be limited to a form of summary modeling based on set identification, idealized geometries, or replacement of the fracture networks by equivalent homogeneous properties. Fracture models currently used for Yucca Mountain Project studies range from continuum models to discrete feature networks. Previous USGS models at Yucca Mountain demonstrated the use of a discrete feature model that shows that tortuous pathways can exist even at a scale of 3 meters. Therefore, continuum models may not be appropriate in all cases.

Fracture networks are characterized by orientation, length, aperture, and intensity. Correctly characterizing the network geometry was critical in the assessment of mechanical stability. Previous Yucca Mountain Project network geometries used to simulate rock block geometries for mechanical stability analyses were unsatisfactory in that rock block geometries did not match observed rock blocks. A new model was constructed to this purpose, where the evolution and time sequencing of fractures was interpreted and the set parameters—notably length, orientation, intensity, and fracture termination—changed with each generation of fractures superimposed on previous sets. Older and younger fracture sets shared orientations sometimes but the connectivity and architecture were set by the sequence of the fracture generation. Acceptable fracture networks were developed using the hierarchical approach. The efficacy of the model can be tested by comparing the synthetic fracture network geometries with the observed fracture network geometries.

Hypothetical Modeling of Redox Conditions Within a Complex Ground-Water Flow Field in a Glacial Setting (Poster)

By Daniel T. Feinstein,[1] Mary Ann Thomas,[2] and Roberta Bellini[3]

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As part of a National Water-Quality Assessment Program (NAWQA) study of the glacial aquifer system, we have developed a numerical modeling approach to study how redox conditions evolve under the influence of a realistically complex ground-water-flow field in a glacial valley-fill aquifer system. The distribution of redox conditions is of interest because it affects the susceptibility of an aquifer to such naturally occurring contaminants as arsenic. The approach has been applied to a typical glacial-aquifer setting in the eastern United States consisting of outwash and ice-contact deposits separated by lacustrine deposits. The MODFLOW-MT3D-RT3D suite of codes has been applied to a ground-water-flow model [originally developed by Allan D. Randall, U.S. Geological Survey (USGS)]to simulate how complex velocity patterns, hypothetical sources of electron donors, and the availability of electron acceptors (carbon dioxide, dissolved oxygen, ferric iron, nitrate, and sulfate) influence redox. Hypothetical electron donor sources are simulated as organic-rich wetlands, lacustrine deposits, and pyrite-rich horizons in different parts of the flow system. The approach incorporates a simple geochemical model based on the assumptions that redox reactions are approximately first-order with respect to electron donors and sequential with respect to electron acceptors. Estimates of electron-acceptor concentrations in recharge are based on water-quality data from NAWQA studies. The model simulates the degree to which reduced waters circulate away from areas of active redox reactions; it is also used to calculate the age mass of water moving through coarse- and fine-grained material toward discharge areas. Model simulations indicate that local electron donor sources can influence groundwater chemistry at a regional scale, giving rise to relatively widespread reducing conditions. The simulations show how pumping wells (by inducing flow from surface-water bodies and altering the age mass distribution in aquifers) change the natural distribution of redox conditions, and, consequently, change the susceptibility of the aquifer to mobilization of such redox-sensitive constituents as arsenic.

Agent-Based Modeling of Physical Factors That May Control the Growth of Coccidioides (Poster)

By Mark Gettings,[1] Frederick Fisher,[2] and Mark Bultman[1]

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A model of the wind-borne spread of spores and spore survival in soils of Coccidioides, the fungus that causes valley fever, has been completed using agent-based modeling software. The model assumes that for a new site to become established, the following four factors must be simultaneously satisfied: (1) there must be transport of spores from a source site to sites with Coccidioides-favorable soil geology, soil texture, and topographic aspect, and a lack of biomass competition; (2) there must be sufficient moisture; (3) the temperature of the soil must be Coccidioides-favorable; and (4) the temperature and moisture of the soil must remain in Coccidioides-favorable ranges long enough for the fungus to grow to depths at which spores will survive subsequent heat, aridity, and ultraviolet radiation. Modeling with only these four factors appears adequate to explain observed Coccidioides distributions. Rain probability and amount, annual and diurnal temperature variation, and wind direction and intensity were computed from weather records at Tucson, Arizona, from 1894 to 2001. Coccidioides-favorable ground was defined using a fractal tree algorithm in accordance with observations that sites that are likely to host large populations are often adjacent to drainage channels. Model runs produced the following five conclusions: (1) if any of the four factors is not isotropic, parts of the favorable areas will never become colonized no matter how long the model runs; (2) the spread of sites is extremely sensitive to soil moisture duration (wind and temperature after a rain control the time before a site becomes too dry); (3) the distribution of wind and rainstorm directions is a strong control on the spread of colonization; (4) soil temperature was the least sensitive control in the model, although it does control dormancy of a site; and (5) the model results range from complete colonization of all favorable sites to no new sites within 3 years of model simulation.

Some Results of the Complex Systems Analysis of Southwest Basins Project—Seven Examples (Poster)

By Mark Gettings,[1] Mark Bultman,[1] Floyd Gray,[1] and Victor Mossotti[2]

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The complex systems analysis of basin margins in a southwestern United States project has entered its final year, and seven examples of complex systems models (CSM) have been completed. Complex systems are those made up of a large number of factors and whose behavior emerges from interactions among the factors; thus, to understand system behavior, the entire system must be considered as a whole rather than the factors considered individually. The seven studies completed in this project were as follows: (1) A quantitative mineral resource appraisal methodology based on a complex systems model approach was used to review and apply definitions of CSMs to appraisals. This study produced both a framework for generating CSMs that can better cope with the huge information content of modern surveys and a means of quantifying the information content of point, line, and map data. (2) Multifractal magnetic susceptibility distributions of hydrothermally altered rocks were modeled with a CSM composed of a multifractal fracture model and a diffusion-controlled alteration model that fits the data well. The study also demonstrated several methods of comparing data from complex systems. (3) Predictive penetrative fracture mapping of the southwest Colorado Plateau from regional potential field and geologic datasets was used to create an initial CSM for correlating multiple data layers according to logical criteria. (4) The growth of Coccidioides (the fungus that causes valley fever) in the southwestern United States, which is controlled by the interaction of wind, rain, temperature, and soil type, was modeled using agent-based techniques and produced self-organized criticality. (5) Fractal models of the weathering of building stone showed the sensitivity of various weathering measures to the weathering process scale in fractal systems. (6) Surface-water flow models were applied to model the movement of metals from acid mine drainage in arid environments of the southwestern United States and were able to predict metals distributions. (7) New developmental research in Fuzzy Cognitive Map (FCM) models showed that FCMs can provide a framework for combining extremely diverse data layers into "what if" model systems. These systems can combine qualitative data layers of the "little, some, more, and very much" variety with data layers that are precisely quantitative to make predictions about the system behavior for various parameter sets. Taken together, these seven examples demonstrate that a general CSM modeling structure using FCMs to combine the factors and data layers can provide an objective and relatively unbiased predictive model.

Modeling Transient Rainfall Infiltration and Slope Instability for Debris-Flow Initiation—Unsaturated Zone Effects (Poster)

By Jonathan W. Godt,[1] Rex L. Baum,[1] and William Z. Savage[1]

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Intense rainfall is the most common trigger of destructive debris flows. Although many debris flows result from erosive processes, many others begin as shallow landslides that result from direct infiltration of rainfall and storm runoff into hillside materials. Predicting the timing and location of debris-flow initiation is needed to assess the debris-flow hazard of an area. Theoretical models of rainfall infiltration into unsaturated hillside materials provide useful insights into the mechanisms and timing of rainfall-induced landslides. We modeled the infiltration process using a two-layer system that consists of an unsaturated zone above a saturated zone and implemented this model in a geographic information system (GIS) framework by coupling analytical solutions for transient unsaturated vertical infiltration above the water table to pressure-diffusion solutions for pressure changes below the water table. The solutions are coupled through a transient water table that rises as water accumulates at the base of the unsaturated zone. Pore pressures computed by these coupled models are subsequently used in slope-stability computations to estimate the timing and locations of slope failures. Preliminary model results for an area in Seattle, Washington, indicate that the unsaturated layer attenuates and delays the rainfall-induced pore-pressure response at depth, thereby reducing the extent of instability predicted by our modeling of typical storms. Initial wetness of the colluvium affects the intensity and duration of rainfall required to trigger shallow landslides and the timing of their occurrence. Beyond aiding our understanding of the mechanisms and timing of shallow landslides, the model can be applied to forecasting landslide occurrence using real-time precipitation data and quantitative precipitation forecasts and can be used for deterministic modeling of rainfall thresholds based on topography, mechanical and hydraulic properties of hillside materials, and rainfall patterns.

The “Big File Cabinet” Concept—Penetrating the Science-Land Management Interface (Case Study Presentation)

By R.I. Grauch,[1] R.S. Bristol,[1] A. Clements,[2] D. Murphy,[2] J. Ferguson,[2] and K. Tucker[2]

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Federal land managers increasingly must use the best available science to reach land-use decisions and formulate plans for continued husbandry of Federal lands. The interface between scientists and land managers, however, is often a barrier that is difficult to penetrate, with a lack of understanding on both sides. This is especially true for the management of vast tracks of western United States lands where anthropogenic impacts and natural processes combine in complex and poorly understood ways to impair the quality of water, air, and land.

U.S. Geological Survey (USGS), Bureau of Land Management (BLM), and Bureau of Reclamation scientists and land managers are collaborating in a multidisciplinary (all five USGS disciplines) effort to understand the complex processes responsible for harmful concentrations of salt, sediment, and selenium in portions of the upper Colorado River basin. They have made inroads into the science-land management interface by jointly developing the “Big File Cabinet” (BFC) concept. The BFC is a Web-based dynamic data management and analysis concept that will allow interactive use of multiple data layers to answer scientific and management questions. The basic building blocks of the BFC are a nonstatic collection of geospatial data and a toolbox composed of science-based software that is used to evaluate digital spatial data in a geographic information system (GIS) map format. The analyses result in maps or geospatial data that may be used by land managers for science-based land-management decisions. Obstacles include Web limitations on sharing unpublished data, useful expression of uncertainties, and integration of process models in the toolbox. The BFC concept is applicable to a wide variety of problems with geospatial data that include portions of the USGS National Map and the BLM GIS database.

Developing Fall Chinook Salmon Spawning Habitat Models at Multiple Scales in the Hanford Reach of the Columbia River (Case Study Presentation)

By James R. Hatten,[1] Kenneth F. Tiffan,[1] Donald R. Anglin,[2] Steven L. Haeseker,[2] Howard Schaller,[2] and Joseph J. Skalicky[2]

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A team of interagency scientists conducted a multivariate logistic regression analysis in the Hanford Reach of the Columbia River to construct a fall Chinook salmon spawning habitat model and to determine the impacts of hydroelectric operations on spawning habitat. The modeling team included several fish biologists, a geographer, and a statistician, from both State and Federal fish and wildlife agencies. Funding for the project was provided by the U.S. Fish and Wildlife Service and by the Alaska Department of Fish and Game because of its concern over impacts of Columbia River hydroelectric operations on the Chinook population, which is an important component of the Alaska coastal fishery. Chinook redd locations were digitized from aerial photography that was obtained during the 11-day spawning period. Geomorphic variables included bed slope, channel location, and proximity to islands. Hydrologic variables (water depth and velocity) were estimated for peak, median, and minimum flows during the spawning period with River2D, which is a shareware hydrodynamic model, in 10-kcfs (thousand cubic foot per second) increments (30 to 200 kcfs). Bathymetry was acquired from water-penetrating light detection and ranging (LIDAR) surveys and channel roughness from substrate surveys. We developed numerous fine-scaled logistic regression models for individual spawning locations of the Hanford Reach, plus a coarse-scaled model of the whole Hanford Reach. Model parameters changed depending on what scale we built the models, but water velocity was always the most important covariate. We also found that distance to islands was an important and previously undiscovered geomorphic variable in the Hanford Reach. We hypothesize that distance to islands was a surrogate for channel and bed complexity and might be related to subsurface flows. We entered the logistic regression models into ARC/INFO GRID, which is a cell-based modeler, to produce spatially explicit grids that contained the probability of spawning occurrence (0 percent to 99 percent). We used presence/absence data not used in the model-building stage to obtain model accuracy. Model accuracy ranged from 50 percent to 90 percent depending on what probability cutpoint was selected. Once the best model was selected for an individual spawning location, we created spawning habitat grids at different simulated streamflows to evaluate the potential impacts of hydroelectric dam operations on spawning habitat. Initial results indicate that large flow fluctuations associated with power generation reduce the persistence and quantity of physical conditions that make for suitable spawning habitat in the Hanford Reach.

Modeling Albuquerque's Landscape Change (Poster)

By David J. Hester,[1] Mark R. Feller,[1] and Steve C. Methven[1]

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Investigating landscape changes that result from the growth of metropolitan areas is part of the Urban Dynamics research conducted under the U.S. Geological Survey's (USGS) Geographic Analysis and Monitoring Program. By using historic maps, aerial photography, and satellite imagery, scientists construct databases showing how urban land use has changed over a period of several decades. These urban retrospective databases are used to analyze how urbanization has affected the landscape and to model future landscape patterns.

As part of the Middle Rio Grande Basin Study, the USGS modeled the Albuquerque area using the Slope, Land Use, Exclusions, Urban, Transportation, and Hillshade (SLEUTH) urban growth model developed by the University of California-Santa Barbara. The SLEUTH model is used to predict the probability of an area becoming urbanized by using a contemporary land-surface characterization database. Parameters such as the current extent of urban lands, land-surface slopes likely to develop, lands excluded from development, and probable effects of the existing road network on future land use patterns are used by the model to predict the future urban area.

To predict future urbanization patterns in the Albuquerque area, the SLEUTH model used historical urban area and roads data, lands excluded from land-use development, and land-surface slope data. By knowing the conditions in 1935 and 1991, model runs simulating this time period were used to adjust model parameters to match the known conditions in 1991. For the Albuquerque area, simulations were run to project the landscape's 2050 urban form. A 50-year prediction of the landscape was used to correspond with the Middle Rio Grande Council of Governments' FOCUS 2050 Regional Plan as well as the life expectancy of major transportation and utility infrastructure being constructed today.

If the trend of dispersed development in the Albuquerque area continues until the year 2050, approximately 125,000 acres of the Middle Rio Grande landscape will be urbanized, with a resulting population density of 11.8 persons per urban acre. The goal of landscape-change modeling is to provide accurate scientific information to allow the formation of sound policies for guiding sustainable growth. Because the Albuquerque area is surrounded by Federal and Pueblo lands, and because the availability of water may ultimately be limited, decisions on growth can only be improved by a firm foundation of scientific knowledge.

How Complex Do Our Models Need to Be? (Poster)

By Randy Hunt[1] and John Doherty[2]

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Models are a simplification of reality, but how various degrees of simplicity relate to fulfilling modeling objectives is unclear. Moreover, to reduce competition with the private sector, models constructed by the U.S. Geological Survey (USGS) often are regional in nature and do not have one prediction or a single site area in mind. Modeling reports often conclude with a desire for more data, and more calibration; there is also uncertainty in how good the model could be and how well it is able to simulate future stress, as well as how worthwhile the resulting model is to decisionmakers.

To predict the response to a future stress accurately, the parameters of the system that relate stress to response need to be included. However, these parameters are often included in the simplification process. To what level can these parameters be simplified? With limited funds, how should efforts be divided between modeling and collecting different types of data in different areas of the problem domain? Is it possible that the underlying parameter uncertainty is such that additional data collection will not reduce prediction uncertainty?

We propose one possible method for assessing the effect of including model complexity that uses regularized inversion and single-value decomposition. The systems described are parameterized to a level that more closely reflects the underlying detail of the system, and uncaptured detail is minimized. As a result, the following analyses are possible:

- A precalibration analysis that evaluates the benefits of the calibration before model calibration is started;
- An evaluation of future data collection types and locations for improving calibration and reducing prediction uncertainty; and

- An evaluation of the degree of model parameterization needed to minimize prediction uncertainty.
- A case study from the USGS North Temperate Lakes Water, Energy and Biogeochemical Budgets (WEBB) site in northern Wisconsin is presented to illustrate the approach.

Interdisciplinary Integration of Vegetation Information Into a Regional Flow Model of the Everglades Through Geographic Research (Case Study Presentation)

By John W. Jones[1] and Raymond W. Schaffranek[1]

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The U.S. Geological Survey (USGS) has developed a two-dimensional hydrodynamic transport model to simulate surface-water flow and the mixing of fresh and salt water in Everglades National Park. Topographic gradients in wetlands of south Florida are extremely small, and vegetation plays a dominant role in the flow and distribution of water. Yet, prior to the USGS model development, ecosystem-wide data and site-specific information on vegetation composition that could be adapted readily to flow models were limited, and existing regional models were impacted severely by these deficiencies. Development of a common vernacular and appreciation for discipline-specific process perspectives, information requirements, and technologies were required to effect an interdisciplinary approach that could address this problem. For example, in development of any regional flow model, temporal and spatial resolutions and simulation duration typically dictate the model implementation, simulation design, and subsequent model utility. In geographic analysis, however, the development of knowledge regarding the spatial scales over which particular processes function and the resolution(s) required to sample and represent them is a first principle. In a collaborative effort of two Priority Ecosystem Science projects in the Everglades, these two disparate disciplinary perspectives were assimilated through extensive interactions that made mutual consideration of model resolution and simulation performance issues possible.

This interdisciplinary interaction took place initially during joint iterative field data-collection campaigns designed to compile interpretive vegetation data over large spatial extents for regional model development. The use of a Global Positioning System (GPS)-enabled image-processing approach created opportunities to both immediately relate such field-observed land characteristics as vegetation composition and structure, disturbances, and substrate condition to image-derived information and discuss how this information could be used to enhance regional flow simulations. Subsequent spatial analyses of project-generated vegetation fields increased knowledge of resolution requirements for simulation and monitoring activities. However, because computational constraints preclude regional flow simulations at resolutions sufficient to treat fine-scale vegetation variability, methods of summarizing model sub-grid-scale vegetation heterogeneity at the grid cell level also were developed. The success of this interdisciplinary research would not have been possible without the availability of resources to conduct joint iterative data collection and analysis efforts.

Modeling Tidal Circulation and Freshwater Mixing in Hood Canal, Washington (Poster)

By Edward G. Josberger[1] and Ralph T. Cheng[2]

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Hood Canal is a 110-kilometer (km)-long narrow fjord in the Puget Sound estuary that is 175 meters (m) deep in some areas and has a 55-m sill at its entrance. Low dissolved oxygen (DO) levels in the southern part of Hood Canal have been observed during late summer and have caused widespread fish kills. The hypothesized cause for the low DO is the combination of increased anthropogenic nutrient inputs, naturally weak mixing, and sluggish circulation. An unstructured grid three-dimensional tidal circulation model known as UnTRIM has been implemented to simulate the circulation of Hood Canal and evaluate the causes of low DO. Previously, the emphasis of numerical model development in modeling DO has been focused on reproducing the tidal hydrodynamics and the mixing processes that yield the observed stratification that results from fresh water input. For comparison to the model, we synthesized the tidal heights for eight historical tide stations in Hood Canal using published harmonic constants. For tidal current data, the USGS deployed two bottom-mounted upward-looking Acoustic Doppler Current profilers (ADCPs) in the Great Bend area for two months between late August and late October 2004. A comparison of these data to model-generated elevation and currents gives excellent agreement for the two-month simulation from September through October 2004. Simulating the vertical stratification is more challenging. To resolve the vertical structure, the model uses 33 layers; the upper layers are 1 m thick. The modeled vertical salinity depends on the vertical turbulence closure scheme, and several have been evaluated. Although none have produced satisfactory results, this is an ongoing effort. The success in implementing the numerical model to reproduce tidal time-scale processes forms the basis to begin building the model for simulations of DO in Hood Canal.

Landscape Assessment of Invasive Plants of Rocky Mountain Regions: Ecology, Models, and Maps (Poster)

By Mohammed A. Kalkhan[1]

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Spatial information [remote sensing data, geographic information system (GIS), and Global Positioning System (GPS)], field data, and geospatial statistical modeling are currently used to assess landscape-scale ecosystems at Grand Staircase-Escalante National Monument (GSENM), Utah; Rocky Mountain National Park (ROMO), Colorado; Theodore Roosevelt National Park (THRO), North Dakota; Cerro Grande Fire Site, Los Alamos, New Mexico; Grand Teton National Park (GRTE), Wyoming; and Hayman and High Meadow Fire Sites, Colorado. Each of the six sites represents a complex landscape of plant diversity; GSENM covers an area of about 1.92 million hectares (ha); ROMO, 107,200 ha; THRO, 28,510 ha; Cerro Grande Fire Site, 19,000 ha; GRTE, 134,840 ha; and the Hayman and the High Meadow Fire Sites, 135,000 ha and 10,000 ha, respectively. Key biological parameters can be estimated using multiscale sampling with multiphase design to provide unbiased estimates of vegetation and soil characteristics. We evaluated the vulnerability of various habitats to invasion by exotic plants over the entire GSENM, ROMO, and THRO, and the Cerro Grande, Hayman, and High Meadow Fire Sites (GRTE is still being evaluated). This poster will provide updated examples of invasive plants species richness and environmental variables related to the landscapes of those sites.

A multiphase sampling design (that is, double sampling) and nested multiscale plots design were used to collect field data for GSENM, ROMO, Cerro Grand, and GRTE, For the other study sites, we used stratified random sampling with simple random selection of data. For modeling large-scale and small-scale variability to predict the distribution, presence, and pattern of cryptobiotic crust cover, invasive plants, and soil characteristics, we integrated remotely sensed data, GIS data, field data, and geospatial statistics. These models are based on trend surface analysis using stepwise regression analysis or a similar approach to select the best set of independent variables. In this poster, we show the results of trend surface models that describe the coarse-scale spatial variability. Models with small variance, residuals mean square error, and Akaike's Information Criterion (AICC) information were selected. In addition, the residuals from the trend surface model were then modeled using semivariogram models with kriging and regression binary classification tree (RBCT) methods. The final surfaces were obtained by combining the trend surface model with the RBCTs. Our research program is using these new tools to forecast the landscape-scale at different levels. In addition, these new models and spatial thematic maps can be used for better resource management for such large areas as the GSENM, ROMO, and THRO, or for other national parks in the United States.

Our approach can be used by others to investigate patterns of biodiversity at different scales and to predict the patterns and spatial relationship of plant species richness and invasive species.

A Decision Analytical Model for Environmental Management Decisions: A Mercury Total Maximum Daily Load Example (Poster)

By William B. Labiosa,[1] James Rytuba,[1] Richard Bernknopf,[1] and Alex Wood[1]

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Environmental and resource managers are faced with difficult choices that are subject to large uncertainties and controversial tradeoffs between environmental targets and socioeconomic values. Integrating useful scientific information with socioeconomic considerations for better decisionmaking is in itself a very difficult modeling challenge. This work proposes a decision analytical model using a surface-water quality issue [Total Maximum Daily Load (TMDL) of mercury] as a case study to address this problem.

The approach uses a probabilistic (Bayesian) network model of the relationships between potential mercury control efforts, total mercury loadings, methyl mercury concentrations, and mercury levels in fish-tissue in the Cache Creek watershed, which is a major source of mercury into the San Francisco Bay Delta. The environmental variables of interest are modeled in a probabilistic causal network based on available data, applicable process-based models, and expert judgment. Uncertainties are propagated through the model using Bayesian network algorithms to estimate the probability of compliance for various targets by each strategy.

The decision model is used to explore the best strategies for meeting watershed targets based on tradeoffs between compliance uncertainty and mitigation costs using a parametric value model. This parametric value model does not require consensus on the prioritization of environmental targets. Instead, its purpose is to generate decision maps that decisionmakers and stakeholders can use to consider tradeoffs between goals. Various graphical methods of representing these tradeoffs are explored. Sensitivity analysis using the Bayesian network is used to demonstrate how scientific uncertainty affects the choice of the best strategy and to estimate the value of perfect information on important uncertainties. This information may be used to prioritize future information collection activities to support management decisions. An adaptive management approach can be built on such a decision model, which allows major uncertainties to be explicitly considered in the decision context when determining which hypotheses should be tested as part of the adaptive management approach.

FRAME: Integrating Science with Resource Management Through Collaborative Approaches and Adaptive Modeling Systems (Case Study Presentation)

By George Leavesley,[1] Jim Chew,[2] Christine Turner,[1] Richard Zirbes,[1] Mark Miller,[3] and Roland Viger[1]

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The Framing Research to support Adaptive Management of Ecosystems (FRAME) project currently focuses on pinyon-juniper woodland management to address (1) collaborative approaches to framing the appropriate science questions to meet resource management needs (science-management synthesis), (2) adaptive modeling tools to develop and deliver scientific information that accommodates the interrelationships of landscape parameters and their variability with changing environmental and management circumstances (tool and product development), and (3) capacity building to enhance the abilities of scientists to work in collaborative problem-solving environments, and the abilities of resource managers to use adaptive-modeling tools effectively (education). The U.S. Geological Survey Modular Modeling System (MMS) (http://wwwbrr.cr.usgs.gov/mms) provides a modular framework to address these needs. A variety of watershed, erosion, and hydraulic models in MMS are being coupled with the U.S. Forest Service model Simulating Patterns and Processes at Landscape Scales (SIMPPLLE) (http://www.fs.fed.us/rm/missoula/4151/SIMPPLLE) to support fire-management planning at Mesa Verde National Park. SIMPPLLE is a spatially explicit model that can simulate changes in vegetation conditions that result from disturbances, such as fire, insect infestation, and disease, and management actions, such as thinning. The coupling of these models will allow resource managers to develop flexible management scenarios that can account for changing conditions and spatially explicit landscape-management scenarios that incorporate the economic, environmental, legal, and social constraints that managers need to consider. Framing of the specific science questions that derive from management issues is being accomplished collaboratively through a focus group of resource managers and scientists in a variety of U.S. Department of Agriculture and U.S. Department of the Interior agencies. The integrated models and methods developed for the initial modeling efforts to support fire-management planning for pinyon-juniper ecosystems at Mesa Verde National Park will be expanded and enhanced for application to the Colorado Plateau.

Integrated Dynamic Modeling of Terrestrial Carbon Stocks and Fluxes (Poster)

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Understanding the impact of land surface processes and climate on the atmospheric carbon budget is an important and challenging earth science endeavor that has significant and profound implications for understanding the dynamics of the Earth's climate system, ecosystem sustainability, and human well-being. At present, few biogeochemical models have the capability to dynamically assimilate land use and cover change (LUCC) information into simulations of carbon dynamics over large areas. We developed the General Ensemble biogeochemical Modeling System (GEMS) to quantify the spatial and temporal changes of carbon sources and sinks in the conterminous United States by explicitly incorporating the impact of LUCC activities. GEMS consists of the following three major components: one or multiple encapsulated ecosystem biogeochemical models, a data assimilation system (DAS), and an input/output processor (IOP). The DAS consists of data search and retrieval algorithms and data processing mechanisms. The data search and retrieval algorithms are responsible for searching and retrieving relevant information from various databases according to the keys provided by a joint frequency distribution (JFD) table; data processing mechanisms downscale the information that was aggregated from individual map units to the field scale using a Monte Carlo approach. Once data are assimilated, they are incorporated into the modeling process by means of the IOP to update the default input files with assimilated data. Values of selected output variables are also written by the IOP to a set of output files after each model execution. We are quantifying the spatial and temporal changes in the contemporary terrestrial carbon stocks in the United States. In addition, we are determining the contributions of climate change and variability to the increase in atmospheric CO2 concentration and the spatial patterns and temporal trajectories of U.S. carbon sources and sinks. Management options for carbon sequestration in selected priority regions are being analyzed and presented to decisionmakers.

Stochastic Routing of Sediment and Sediment-Borne Contamination Through Rivers (Poster)

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Chemicals in the environment, including many heavy metals, radionuclides, and organic contaminants, commonly bind to soils and sediments, which are carried by rivers. Traditional methods for routing both contaminated and uncontaminated sediment through rivers start from the principle of sediment mass conservation along the channel. This approach has a fundamental problem when applied to the task of modeling the movement of contaminated sediment: it ignores the component of the sediment load that enters temporary storage in floodplains. Numerous studies have demonstrated that floodplains are dominant sinks and, consequently, long-term sources of sediment-bound contaminants in rivers. Furthermore, it is impossible to determine the fate of contaminants from the output of conventional routing models without resorting to such artificial parameters as “enrichment ratios.”

An alternative approach is to model the trajectories of particles themselves. The long-term trajectory of a sediment particle can be formulated as a finite Markov Chain—a stochastic process governed by a set of transition probabilities. These transition probabilities can be estimated from a combination of field-based work and theory. This formulation is faithful to the principle of mass conservation, can accommodate theoretical or empirical estimations of geomorphic process rates, and provides a straightforward way to track contaminated particles.

We tested this theory using 137Cs as a sediment tracer at the Los Alamos National Laboratory (LANL). The model was parameterized using a sediment budget. The uncalibrated model reasonably replicates the approximate magnitude and spatial distribution of 137Cs measured in an independent field study in 1997. The model predicts the future movement and radioactive decay of legacy cesium and its transport off LANL property. The LANL application includes some key approximations based on field observations. Nonetheless, this probabilistic formulation provides a viable approach for modeling the long-term movement of contaminated sediment through valleys and has many advantages over conventional routing models.

Towards Quantifying the Hydrologic Cycle (Poster)

By Steven L. Markstrom,[1] David E. Prudic,[2] Richard G. Niswonger,[2] R. Steven Regan,1 Paul M. Barlow,[3] and Roland Viger[1]

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Concepts of the hydrologic cycle have been known for centuries, yet the difficulties of mathematically representing flow through different parts of the hydrologic cycle—the atmosphere, biosphere, land surface, and subsurface—has resulted in scientists forming separate groups. The Water Resources Discipline of the U.S. Geological Survey (USGS) is an example of such a group. The development of digital computers and a need to assess the effects of human activity and variability in climate led recently, however, to a surge in the development of models that couple two or more parts of the hydrologic cycle.

Previously, general application models developed by separate groups in the Water Resources Discipline were limited to surface-water hydraulics, ground-water flow (such as MODFLOW), and precipitation-runoff models (such as the Precipitation-Runoff Modeling System, or PRMS). Although some surface-hydraulic models were coupled with MODFLOW, a focused effort within the USGS to integrate ground-water flow with precipitation-runoff models started in 2003 when a project supported by the Offices of Ground Water and Surface Water and the National Research Program began the integration of PRMS and MODFLOW into a new model named Ground-water/Surface-water Flow (GSFLOW). The new model allows for runoff generated by PRMS to be routed to open channels or lakes that are fully coupled with MODFLOW. Infiltration into the soil zone, which is calculated by PRMS, is transported through the unsaturated zone to the water table by use of the recently developed unsaturated-zone flow (UZF) package of MODFLOW. Ground-water discharge to land surface from MODFLOW is added to the equations in PRMS and can be used to satisfy evapotranspiration demand or to increase runoff to surface water. The coupling of the surface processes simulated by PRMS with the saturated and unsaturated subsurface processes simulated by MODFLOW greatly enhances our capability to quantify the hydrologic cycle.

A Generic Modeling Interface for Computational Surface-Water Applications (Poster)

By Richard McDonald,[1] Jonathon Nelson,[1] and Francisco Simoes[1]

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When modeling environmental fluid dynamic systems using computational models, the model user has to work through a series of processes, such as grid generation, flow computation, and post-processing or data visualization, to produce a completed product. Today, there are many graphical user interfaces (GUIs) that greatly enhance this step-by-step procedure of model development; most GUIs, however, are designed for a specific model, which requires the model user to learn a different GUI for each model in their toolbox. Generally, models—whether they are designed for ground water, surface water or the atmosphere—all have a common set of requirements, such as a description of the computational grid, input conditions, boundary conditions, and results that include both scalar and vector quantities. The U.S. Geological Survey's Surface Water Modeling System (MD_SWMS) leverages this commonality of requirements to provide a single modeling interface for surface-water applications.

MD_SWMS is a both a GUI tool and a framework that provides an easy-to-use interface to a variety of surface-water models. The MD_SWMS GUI is a sophisticated one-, two-, and three-dimensional application to build and visualize all aspects of the modeling process. The MD_SWMS framework is the Computational Fluid Dynamics General Notation System (CGNS) database. CGNS consists of the following two parts: (1) a standard format for recording the data, and (2) a software input and output interface to that format. The CGNS framework is used to separate the GUI from the models, which allows MD_SWMS to be a single tool that can be used with many applications. To illustrate the generality of MD_SWMS, we will demonstrate a simple surface-water application of streamflow using two models—one that uses a curvilinear orthogonal coordinate system and one that uses a general coordinate system.

A Case Study—Erosion Rate Measurements on Standardized Calcareous Stone: Scaling Issues in Modeling Fractal Surfaces (Poster)

By Victor G. Mossotti[1]

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This investigation integrates a number of concepts and theories, including complex systems science, agent-based modeling, and the study of singularities and multifractals, to advance understanding of the practical consequence of scaling of a physical field on the points of a fractal. Erosion rates of test materials in the eastern United States were used as a case study.

When the National Park Service (NPS) measured erosion and deposition rates on a statistically significant number of standardized test materials exposed to weathering at four sites along the U.S. eastern seaboard, they found that standardized limestone and marble test samples showed systematically different erosion rates, depending on the method used for the measurement. The following three methods were used to quantify the rate of recession of the exposed surfaces: holographic interferometry (LASER Moire), gravimetry, and chemical analysis of the runoff solution. After evaluation of the data for random errors, the observed recession rates systematically varied by as much as 400 percent from method to method, even when the test samples were exposed side by side. Although these disparities were reproducible at all exposure sites and over varying exposure periods, no reasonable explanation of the disparities has been offered until now.

My approach was to model the statistical rate-data for each method as an ensemble of measures at random points of a self-affine physical field (erosion rate) on the points of a fractal (physical surface of the sample). Because the resolutions of the methods were defined by full extent of the sample for each method (that is, the area of observation), the ensemble average of the coarse Hölder singularity index could be computed for each of the three different resolutions. A power-law plot of the first-moment partition functions for the observations show that the measure of recession rate scales with the spatial resolution of the technique used for the measurement. This finding, which may at first be counter intuitive, provides an explanation of the rate disparities.

These findings suggest that quantitative observations on surfaces that are rough over a range of scale should be interpreted with caution. This study also informs the design of agent-based simulations of inanimate processes (for example, rock fracturing, soil erosion, material transport, and landscape-hydrology interactions) where issues of agent scale are not generally apparent from context.

Heuristic Approach to Monitoring Network Optimization Using Simulated Annealing and Multivariate Statistics (Poster)

By Kenneth R. Odom[1]

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Simulated annealing and multivariate statistics were used to optimize a water-quality monitoring network for the purposes of assessing data redundancy and reducing network costs in the Great Smoky Mountains National Park. This monitoring network has undergone size reductions from approximately 300 to 90 sampling sites over an 18-year period during the 1980s and 1990s because of funding reductions and reallocations. The approach presented herein ensured a minimal loss of information when the network size was again reduced in 2004 because of funding limitations and reallocations.

The simulated annealing algorithm optimizes a user-defined objective function that is based on benefits derived from monitoring costs and multivariate statistical analyses of watershed characteristics and historical water-quality data. In the Great Smoky Mountains, the watershed characteristics and water-quality data for the existing network were analyzed using principal components, cluster analysis, and discriminant analysis to form clusters of sampling sites. Using cluster-centroid distances as a measure of variability explained, the benefits were apportioned to each sampling site. During algorithm execution, sampling sites move in and out of a proposed network; this affects the costs and benefits of the remaining sites in the proposed network change. This operation creates a seemingly infinite number of network designs, and simulated annealing provides an approach for finding an optimum solution.

The results of this study provided the Great Smoky Mountains National Park with an assessment of the historical data and an instrument for redesigning the sampling network; recommendations were accepted and implemented with only minor modifications. The redesigned network consists of 44 sampling sites and the sampling frequency was increased from 4 to 6 times per year at 32 of the 44 sampling sites.

Interactive Models and Focused Communication Are Keys to the Success of Multidisciplinary Projects (Case Study Presentation)

By Michael P. Pantea,[1] Charles D. Blome,[1] Mark R. Hudson,[1] James C. Cole,[1] Bruce D. Smith,[1] David V. Smith,[1] Jonathan S. Cain,[1] Scott A. Minor,[1] V.J.S. Grauch,[1] and Jason R. Faith[1]

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Collaboration on several interactive three-dimensional (3D) models has resulted in the successful integration of diverse data and expertise to understand complex geologic and hydrologic relationships of aquifer systems. Using commercial software, we develop and test models that incorporate hydrologic, geologic, geophysical, drill hole, environmental, surface mapping, and water chemistry data. We found that focused project management and regular communication with project personnel and cooperators are equally critical for successful development of interactive visual models.

Our projects produce visual and audio interactive 3D products, such as Three-dimensional geologic framework modeling of faulted hydrostratigraphic units within the Edwards Aquifer, Northern Bexar County, Texas (Pantea and Cole, 2004). Current research helps define the geologic framework to evaluate potential ground-water flow paths and fluxes where fault displacement of lithologic units produces barriers to ground-water migration. Our ability to create geologic framework models is continually challenged by sparse data and variable coverage of numerous data types. Different data types and sources provide information for different parts of the 3D model based on scale, coverage, and sensitivity. Combining data types, sources, and expertise, we define, interpret, and display hydrostratigraphic and geologic models to develop consensus with the various disciplines involved in our projects. Because data types are related, we validate individual data components to more accurately evaluate structure, verify drill hole information, align geophysical data, show head levels of water, and validate surface mapping. Cross-checking data leads us to reevaluate and revise infrastructure and make different geologic framework interpretations for geologic maps.

Because project participants are experts in different disciplines and are located in different offices and states, regular status meetings that are focused and well-organized are required to keep model development moving. We maintain creativity and spontaneity using “real-time” communication. Conference phones for audio and networked software for video allow dispersed project participants to hear and see current project status and to interact and manipulate product prototypes to clarify concerns. This communication focus takes advantage of available data and expertise to overcome institutional inertia and physical separation so that project participants are involved and contributing toward current and future project goals.

Reference Cited

Pantea, M.P., and Cole, J. C., 2004, Three-dimensional geologic framework modeling of faulted hydrostratigraphic units within the Edwards Aquifer, Northern Bexar County, Texas: U.S. Geological Survey Scientific Investigations Report 2004-5226, CD-ROM.

A Physical Model of the Western United States Strain Rate Field (Poster)

By Fred Pollitz[1] and Pat McCrory[1]

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We present a relationship between the long-term fault slip rates and instantaneous velocities as measured by Global Positioning System (GPS) measurements or other geodetic measurements over a short timespan. The main elements are the secularly increasing forces imposed by the bounding Pacific and Juan de Fuca plates on the North American plate and viscoelastic relaxation following selected large earthquakes. In detail, the physical model allows separate treatments of faults with known geometry and slip history, faults with incomplete characterization (that is, instances in which fault geometry but not necessarily slip history is available), creeping faults, and dislocation sources distributed between the faults. We model the western United States strain rate field, using data derived from 746 GPS velocity vectors and a leveling dataset for the Pacific Northwest provided by Ray Weldon, to test the importance of the relaxation from historic events and to characterize the tectonic forces imposed by the bounding Pacific and Juan de Fuca plates. Relaxation following major earthquakes (M >~ 8.0) strongly shapes the present strain rate field over most of the plate boundary zone. Equally important are the lateral shear transmitted across the Pacific-North America plate boundary along ~1000 kilometers (km) of the continental shelf and the downdip forces distributed along the Cascadia subduction interface. Post-earthquake relaxation and tectonic forcing constructively interfere near the western margin of the plate boundary zone and produce locally large strain accumulation along the San Andreas fault (SAF) system. However, they destructively interfere further into the plate interior, resulting in smaller and more variable strain accumulation patterns in the eastern part of the plate boundary zone. Tectonic forcing along the Cascadia subduction interface is highly segmented, with relatively small interplate coupling inferred around central Oregon.

Preliminary Cellular-Automata Forecast of Mining Permit Activity From 1998 to 2010, Idaho and Western Montana (Poster)

By Gary L. Raines[1] and Sushil Louis[2]

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Modeling the interaction of people with the environment to predict future conditions is a challenging research problem. For land management in Idaho and western Montana, the U.S. Forest Service (USFS) requested a prediction of where mineral-related activity will happen in the next decade. Cellular automata (CA) provide an approach to simulation of this human interaction with the mineral environment. Spatiotemporal information about mining permits in the last decade, public land location, and predicted location of undiscovered resources were used to calibrate a CA to calculate the known permit spatiotemporal activity. The CA implemented was a probabilistic annealed-voting rule that simulates mineral-related activity with spatial and temporal resolution of 1 square mile and 1 year based on activity from 1989 to 1998. Initially, the calibrated CA reproduced in space and time the 1989–1998-permit activity with a kappa of 32 percent and an agreement of 94 percent, which increased to 98 percent for agreement within 1 year. Analysis of the confusion matrix and kappa correlation statistics indicates that the CA underestimates high activity and overestimates low activity because the mineral activity takes place on only about 4 percent of public land. Spatially, the major differences between the actual and calculated activity are that the calculated activity takes place in a slightly larger number of small patches and is slightly more uneven than the actual activity. The CA has been implemented recently in a Web-based 10-computer parallel computing environment that uses a genetic algorithm for calibration. With this Web-based implementation, the CA can be calibrated in 10 minutes with a 50 percent improvement in accuracy as measured by kappa compared with the earlier Arcview3 implementation, which took 2 weeks to calibrate. A tiling approach to calibration has contributed to this improvement in accuracy. The tiles give a better representation of the spatially and temporally anisotropic activity. Using the calibrated CA in a Monte Carlo simulation, the Idaho and western Montana mining-permit activity has been projected to 2010 in response to the USFS request.

Fuzzy Expert System for Generalization of Geologic Maps for Geologic and Environmental Applications—The Need for GIS Geologic Standards (Poster)

By Gary L. Raines[1] and Jordan T. Hastings[1]

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Geologic maps are arguably the most complex maps made by any profession and are difficult to use because of the inconsistent use of terminology and symbols. The standard field trip to understand the map information is indicative of the discipline's failure to communicate. Standards for digital formats and associated terminology are required to communicate information effectively, to share these maps digitally, and to stimulate the development of digital analytical tools. The lack of geologic-map standards has diminished the potential use of geology for land planning. Research on the Columbia River Basin Ecosystem Management Project demonstrated that many environmental factors that are useful to land planners can be derived from geologic maps by a geologist. Since that project, research has lead to the release of the North American Data Model 4.3 and recent improvements to this standard. For land management applications in the Tahoe Basin, the Data Model 4.3 was subsequently implemented in an ESRI geodatabase. Automated generalization of geologic information for geologists and environmental properties for land planners was implemented in the geodatabase. Generalization of geologic-time and lithology hierarchies provides useful alternative simplification and symbolization of geologic information for such geologic applications as mineral exploration and geologic hazards. To calculate such environmental properties as acid buffering capacity, bioavailable potassium, land stability, trafficability for recreation uses, and other properties, a fuzzy expert system was implemented. Using fuzzy mathematics based on all lithologies that make up a map unit, environmental properties can be computed and mapped as ranks, along with an estimate of the confidence in those properties. If geologic maps were available in a standard geographic information system (GIS) format, these automated map-generalization tools could be provided with the digital geologic map to U.S. Geological Survey (USGS) customers who could then view the information in a format specific to their purposes.

Spatially Explicit Global Daily Reference ET Modeling and Evaluation (Poster)

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Accurate and reliable evapotranspiration (ET) datasets are crucial in regional water and energy balance studies. Because of the complex instrumentation requirements, actual ET values are generally estimated from reference ET values by applying adjustment factors for water stress and vegetation conditions, commonly referred to as crop coefficients. Until recently, the modeling of reference ET has been solely based on important weather variables collected from a rather sparse global network of weather stations. Since 2000, the National Oceanic and Atmospheric Administration's (NOAA's) Global Data Assimilation System (GDAS) has been producing 6-hourly data for the input meteorological variables to calculate daily reference ET for the whole globe at 1-degree spatial resolution. Scientists at the U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) have been producing daily reference ET since 2000 and the results have been used for a variety of models for drought and streamflow monitoring all over the world on an operational basis.

With the increasing availability of station-based reference ET estimates over the Internet, we evaluated the GDAS-based reference ET estimates using data from the California Irrigation Management Information System (CIMIS). Daily CIMIS reference ET estimates from more than 120 stations were compared with GDAS-based reference ET at different spatial and temporal scales using the 2004 data. Despite the large difference in spatial scale [point vs ~100 kilometers (km)] between the two datasets, the correlations between station-based ET and GDAS-ET were very high, exceeding 0.90 on a daily basis to more than 0.98 on time scales of more than 10 days. Both the temporal and the spatial correspondences in trend/pattern and magnitudes between the two datasets were satisfactory, which suggests the potential reliability of using GDAS reference ET for regional water and energy balance studies in many parts of the world.

Coastal Community Sediment-Transport Model (Case Study Presentation)

By Christopher R. Sherwood,[1] John C. Warner,[1] Richard P. Signell,[1] and Bradford Butman[1]

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The U.S. Geological Survey (USGS) Coastal and Marine Geology program is developing a community model for coastal sediment transport. The model can be used to address issues involving transport of sediment, nutrients, and contaminants in coastal regions and also serve as a research platform for testing new algorithms representing coastal or lacustrine processes. The project enhances an existing numerical model called the Regional Ocean Modeling System (ROMS). ROMS implements a three-dimensional finite-difference approximation of the equations that conserve mass and momentum in a fluid. It is designed to calculate the flow of water in coastal regions (and lakes) in response to winds, tides, river inputs, heating and cooling, eddy viscosity, bottom drag, and density gradients. ROMS is written in modular modern code (Fortran95), is optimized for multiple processors using either shared or distributed memory [using Open Multi-Processing (OMP) and Message Passing Interface (MPI)], and runs on a wide range of computers, including those with Windows or Macintosh operating systems and most varieties of Unix.

The most recent version of ROMS includes USGS enhancements and is available online at http://marine.rutgers.edu/po/index.php?model=roms. The USGS contributions include new turbulence submodels, a framework for storing state variables and parameters associated with an unlimited number of sediment classes and their distribution in the water or bottom strata, suspended sediment and bed load transport algorithms, morphology change, wave/current bottom boundary layer submodels, algorithms for ripples and sediment-transport bottom roughness, an accurate monotonic advection scheme, and an array of test cases and practical applications. New components that represent shallow-water processes, which we plan to add in 2006, will allow the model to address nearshore and estuarine problems where wave-induced currents are important and tidal range causes periodic wetting and drying of the model domain.

The model is being developed as a collaborative community effort with open source code, which offers several advantages. First, like most realistic physically based models of geophysical phenomena, coastal ocean models have become too complex to be developed by individual researchers or even moderate-sized groups. This is because improving state-of-the-art models requires not only expertise in multiple scientific disciplines (for example, meteorology, oceanography, sediment dynamics, and computational fluid dynamics) but also in data structures, numerical methods, multithreaded computer architectures, and software-design management. Second, community models can attract a large and diverse group of user-developers that add capabilities and test model components, which produces a model that is more useful, more versatile, and more robust. Third, open source models aid the scientific process by serving as a formal, quantifiable hypothesis and providing a complete record of the method used in numerical experiments. Fourth, the distribution of software developed with Government resources is an additional product delivered to taxpayers that supplements the underlying research or problem-solving. Finally, open source models provide needed transparency when used to make regulatory decisions and provide a part of the full documentation required of the decision-making process. Research scientists at the USGS are presently using the community sediment-transport model in several regional studies. Tests of the model are being performed with an extensive dataset collected in the Adriatic Sea (Italy) during several collaborative experiments conducted in 2002-03. The model is being used to examine mixing, salinity intrusion, and formation of the turbidity maximum in the Hudson River Estuary. It is also being used to examine how storms determine the fate of sediment in Massachusetts Bay and will be used to explore the effect of sediment-transport processes on bottom habitats. In addition, the model is being used to examine the impact of removing an offshore sand deposit that might provide a source of beach-nourishment material in South Carolina. Finally, the new capability to model nearshore processes will be used to study the interaction between nearshore bathymetry and recurring patterns of erosion and deposition along beaches in North Carolina.

Hydrodynamic and Particle-Tracking Models for the San Francisco Bay-Delta Estuary (Case Study Presentation)

By Peter E. Smith[1] and John M. Donovan[1]

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Hydrodynamic research on the San Francisco Bay-Delta Estuary has been underway in the California Water Science Center of the U.S. Geological Survey (USGS) for more than two decades as one component of a large interagency ecological studies program for the estuary. As part of that research, new three-dimensional (3D) hydrodynamic and particle-tracking models and graphical visualization software have been developed. The hydrodynamic model, called Si3D, is a public-domain code that uses a novel numerical formulation that is mass conservative, computationally efficient, and numerically accurate. Although the Si3D model was designed mostly for application to estuaries, it also has been applied successfully to studies of lakes. The particle-tracking model (PTM), which was programmed in Java, is designed to read large data files containing space- and time-dependent velocity, water-level, and turbulence data output from the Fortran-based hydrodynamic model. By applying the PTM in a post-processing step rather than in a coupled simulation with the hydrodynamic model, greater flexibility is allowed in conducting multiple experiments for forward or backward tracking of particles under the same hydrodynamic conditions and for interactive visualization of particle movements. Visualization of model outputs is done using a general-purpose Java software application called Gr (see http://ca.water.usgs.gov/program/sfbay/gr). Gr, in addition to standalone capabilities, is used as a pre- and post-processor for the hydrodynamic model and interfaces directly with the PTM.

Three applications of the hydrodynamic and particle-tracking models are underway in the USGS California Water Science Center. The first application is to the San Francisco Bay and a portion of the coastal ocean. The second application is to a gated control channel called the Delta Cross Channel, which is located within the northern portion of the Sacramento-San Joaquin River Delta. The third application is to a reach of the San Joaquin River near Stockton, California, which is located within the southern portion of the Delta. The first two applications are aimed at finding ways to better protect and manage San Francisco Estuary fishes, especially those species that are of special concern, such as delta smelt and the various races of chinook salmon. The application to the San Joaquin River is aimed at understanding the causes of a significant dissolved-oxygen problem that exists in the deep-water ship channel for the Port of Stockton. The applications are being done in collaboration with the nine State and Federal agencies that are members of the Bay-Delta Interagency Ecological Program and the Calfed Bay-Delta Program. The dissolved-oxygen study also is being done in collaboration with Stanford University and the University of California, Davis (UCD).

For each of the applications, the hydrodynamic model is being validated using field measurements of velocity, flow, and water level. Because appreciable vertical and horizontal gradients in salinity occur within San Francisco Bay, the model there also is being validated using measurements of salinity. The particle-tracking experiments are being done to understand how hydrodynamic conditions (including tides, freshwater flows, and delta gate operations) affect the long-term transport of neutrally buoyant particles. The capability to assign simple fish behaviors (such as day/night vertical migration) is being added to the PTM so that the model can better mimic hydrodynamic fish transport. In the case of the ship-channel study, the physical causes of low dissolved oxygen concentrations also are being explored using a 3D water-quality model developed by UCD. A few results from each of these ongoing model applications, a description of the models and modeling techniques being used, and examples of the graphical computer animations used to display model results were presented at the conference.

Modeling Demographic Parameters of Free-Ranging Animals (Poster)

By Thomas R. Stanley[1]

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In demographic studies of free-ranging animals, the following two problems are commonly encountered: (1) the entire population is not available for study (for example, because individuals are elusive or populations are large and dispersed, making cost of capture prohibitive), so inferences about population parameters must be obtained from a sample of individuals, and (2) detection or capture probabilities for individuals in the sample population are less than one, so data for a particular sampling occasion or site may be incomplete (that is, censored) or the data may be biased (for example, counts of individuals will be negatively biased). To obtain valid estimates of such demographic parameters as survival rate or abundance under these difficult conditions, the application of maximum likelihood theory is often useful. Under this approach, one starts by constructing a model that represents the probability of the sample data, which are a random vector, conditional on the parameters. Once this probabilistic model for the data has been constructed, one turns the problem around by conditioning on the data so that now the model (that is, the likelihood function) represents the probability of the parameters conditional on the data. Using a standard numerical optimization routine (for example, the Newton-Raphson method), parameter estimates and their variances are obtained by maximizing the likelihood function. I demonstrate model building and parameter estimation with maximum likelihood using two models that I published previously. For the first model, binary nest survival data (that is, survived-failed) were used to estimate stage-specific daily survival rates for a sample of avian nests. For the second model, species-specific binary occurrence data (that is, presence-absence) from a small mammal community were used to estimate species-specific detection probabilities, which were then used to estimate small mammal abundance, site-occupancy probabilities, and other parameters. Monte Carlo simulations show that both models perform as predicted by theory and provide asymptotically unbiased parameter estimates.

Computationally-Intensive Models Used in the LANDFIRE Project: Biophysical Gradient Layers and Simulating Fire and Succession on Fine-Scale Landscapes (Poster)

By Daniel R. Steinwand[1] and Mo Mislivets[2]

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The LANDFIRE project is a multiagency interdisciplinary research and development activity designed to develop a consistent and accurate methodology capable of producing geospatial data of vegetation conditions, fire fuels, risks, and ecosystem status at national, regional, and local scales for implementation of the National Fire Plan. The LANDFIRE processing flow includes two numerically-intensive models—WxBGC and Landscape Succession Model (LANDSUM). WxBGC is a modification of the Biome-BioGeochemical Cycle (BGC) model with weather summaries needed for LANDFIRE; LANDSUM is a landscape succession model that simulates fire and vegetation succession on fine-scale landscapes over thousands of years. These models were developed by scientists at the Forest Service's Fire Sciences Laboratory in Missoula, Montana. Because these models are computationally complex and the data volumes large, a parallel processing approach was needed to meet project timelines. Initially, the modelers at the Fire Sciences Laboratory consulted with computer scientists at the U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) for runtime optimizations and later for implementation in parallel processing environments. The LANDFIRE partnership between EROS and the Fire Sciences Laboratory has been successful and has taught us many things about taking models from the "idea stage" on single-processor computers with limited volumes of data covering small areas to parallel implementations on supercomputer-class machines with large volumes of data covering the conterminous United States. These models are now running on a 64-CPU Beowulf cluster, a CRAY XD-1, and on multiple, single-processor Windows computers.

Choices and Challenges for Spatial Habitat Models: Predicting Desert Tortoise Habitat (Poster)

By Kathryn A. Thomas,[1] Leila Gass,[1] Todd Esque,[2] Robert Webb,[1] and David Miller[3]

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Sound management strategies for the Mojave population of the desert tortoise (Gopherus agassizii), which is listed as "threatened" under the U.S. Endangered Species Act, rely on knowing the characteristics and distribution of suitable habitat. Our goals are to develop statistically-based spatial models of desert tortoise habitat using field-collected occurrence data and existing environmental databases, and to compare different modeling approaches to characterizing habitat suitability. Issues include nonsystematically collected occurrence data; variations in applicability, resolution (scale), and extent of environmental data; and choice of model algorithm. We filtered occurrence data for presence records, and by survey methods, spatial precision, and minimum record separation. Environmental data being considered include topography, climate, soils, geology, perennial vegetation, perennial cover, and annual plant productivity. The Genetic Algorithm for Rule-set Prediction (GARP) model is relatively easy to implement but not very interactive. Regression techniques, such as general linear models (GLM), applied spatially through such applications as Generalized Regression Analysis and Spatial Predictions (GRASP) allow selection of the best independent variables using the Akaike information criterion statistic. GLM requires presence and absence data; hence, pseudo-absence data must be created for model implementation. Ecological-Niche Factor Analysis (ENFA), when implemented with BIOMAPPER, allows prediction using only presence data. ENFA has been used previously to aid in the selection of pseudo-absence data for use in other models. We are comparing the output of GARP against at least one other modeling technique for both the entire range of the desert tortoise (Mojave population) and for smaller areas within the Mojave Desert where detailed abiotic data exist. We will verify the model output by (1) withholding part of the independent dataset to test model performance, (2) using iterative runs of single model strategies, (3) comparing different models' performance, and (4) field verification. The habitat suitability maps will then be combined with maps of anthropogenic factors to produce final maps of predicted suitable habitat.

Integrating Socioeconomic Models Into Vista, the NatureServe Biodiversity Planning Tool (Case Study Presentation)

By Alicia Torregrosa,[1] Richard Bernknopf,[1] and Laura Dinitz[1]

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In 1999, Natureserve, which is a nonprofit research organization devoted to conserving biodiversity, asked U.S. Geological Survey (USGS) Geography Discipline staff to help address a need in the land-use-planning process for access to better tools to help make decisions about tradeoffs involving sensitive natural resources. To fill this need, NatureServe is developing Vista, a desktop software application for use by county, State, and regional planners. This case study describes the lessons learned by the USGS economist and landscape ecologist who joined the software design team. These lessons are derived from a review of the model integration process, from the initial proposal objective of codifying an ecosystem prioritization process to the initial beta-testing phase. The lessons learned are grouped into the following four categories of the challenges that were faced: (1) transdisciplinary issues, such as homonyms/synonyms/jargon, noncoincident paradigms, assumptions, knowledge base, dissimilar understandings of the needs of the target audience, and differences in the construction of biological and economic theory; (2) project evolution and modification of objectives, such as integrating feedback from an advisory board, team members, and beta testers; (3) geospatial issues, such as units of analysis versus units of measure, dynamic landscapes, and landscape units with overlapping values, leading to unquantifiable heterogeneity; and (4) partnership issues, such as control, funding, authorship, and ownership.

Integrating USGS Geospatial Modeling Methods Into the National Weather Service River Forecast System: First Steps Toward a Community Hydrologic Prediction System (Case Study Presentation)

By James Verdin,[1] Guleid Artan,[2] and Kwabena Asante[2]

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The U.S. Agency for International Development (USAID) Office of U.S. Foreign Disaster Assistance (OFDA) launched the Asia Flood Network (AFN) program in 2003 to strengthen the capacity for flood forecasting and early warning of populations at risk in countries that frequently experience hydrometeorological disasters. The U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science

(EROS) and the National Weather Service (NWS) are OFDA's technical implementing partners. One important initiative of the AFN is the integration of features of the Geospatial Stream Flow Model (GeoSFM) with the NWS River Forecast System (NWSRFS). The GeoSFM is a geographic information system (GIS)-based model for reconnaissance-level hydrological modeling in data sparse regions of the world. The GeoSFM is parameterized using grids of elevation, soils, and land cover, and forced with grids of potential evapotranspiration and satellite rainfall estimates. The NWSRFS is a robust and proven system with a 25-year legacy. NWS is now laying the groundwork for a successor system to NWSRFS, the Community Hydrologic Prediction System (CHPS). CHPS is being designed to enable a number of enhancements, which are as follows: distributed hydrological modeling, ensemble processing, flexible data access, and an expanded suite of scientific modules. A service-oriented architecture is foreseen, whereby data, algorithm, and computing infrastructure assets will be shared across networks. This approach contrasts with NWSRFS, which is a procedural, monolithic application. NWS is integrating the following GeoSFM features into NWSRFS as a first example of a CHPS-like system: use of digital elevation models (DEM), soil, and land cover data to parameterize basin boundaries; stream segments; a two-layer soil moisture accounting model; a unit hydrograph; a lag and k routing model; and the Sacramento Soil Moisture Accounting Model. Users in Asia will test the remote distributed processing approach through means of a Web interface that provides access to independent servers for algorithm and data services. The effort represents a collaborative approach, across agencies and with international partners, to develop new modeling technology with the potential to make a significant contribution to future U.S. river forecasting.

A Geospatial Approach for Fully Distributed Implementation of Mean Annual Stream Flow Regressions (Poster)

By Kristine L. Verdin,[1] Sandra Franken,[1] and Bruce Worstell[1]

[1]Science Applications International Corporation, Sioux Falls, S. Dak.

This paper describes modeling done to develop average annual streamflow estimates for rivers and streams of all 50 States. The Elevation Derivatives for National Applications (EDNA) database was used, along with climatic datasets, to develop flow estimates for every stream reach in the EDNA database. Use of an efficient geospatial basin characterization methodology made possible the rapid development of average annual streamflow estimates. The mean annual flow estimates were derived using U.S. Geological Survey (USGS) State-specific regression equations that are functions of mean annual precipitation, mean annual temperature, precipitation intensity, drainage area, and a number of elevation-derived parameters. In all, estimates of streamflow were calculated for more than 1,000,000 stream segments in the EDNA database. A Web-enabled map interface was developed to allow users to interactively calculate mean annual streamflow for any arbitrary location within the United States. Comparison of the EDNA-derived mean annual flows with observations from a subset of the USGS stream gauge network was used to validate the results.

Model-Facilitated Recovery of Endangered Fish Populations: Joint Application of Behavioral, Individual-Based, Population, Community, and Physicochemical Spatially Explicit Models (Poster)

By Mark Wildhaber[1]

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Developing and providing the best information for recovery and management of endangered fish species requires knowledge and integration of a wide range of scientific disciplines, such as ecology, population dynamics, behavior, physiology, hydrology, geomorphology, geographic information system (GIS), environmental chemistry, and mathematical modeling that incorporates the stochastic aspect of each model component. Understanding the relation of fish communities to the abiotic and biotic factors within aquatic ecosystems requires knowledge of the physiology and behavior of individual fish and population- and community-level fish interactions. Understanding how animals use behavior to control the influence of environment on their physiology, growth, and survival is essential in recovery and management efforts. Because they are ectotherms, where fish choose to be plays a major role in how their physiological processes operate. Only through behavioral regulation can fish regulate their internal body temperature and, thus, the level at which many of their physiological processes operate. Also, through behavior, fish can regulate their exposure to such other environmental factors as predators, oxygen, pH, and contaminants. Ultimately, this requires development of an effective mathematical model that incorporates thermoregulation, foraging, bioenergetics, and other behavioral and physiological mechanisms into individual-based and spatially explicit frameworks. Such a forecasting tool requires inclusion of models that effectively describe fish community dynamics based on fish physiological and behavioral responses and models that effectively describe the physical environment in which these fish live. The resulting forecasting tool will likely provide an excellent source of understanding of the dynamics of fish populations and communities that could then be applied to the field. The ultimate value of this approach is a better understanding of the causes behind and an ability to predict the short-term and long-term distribution and population trends of fish in response to management decisions.

A Review of Bayesian Methods for Estimation of Disease Prevalence With Imperfect Diagnostic Sensitivity and Specificity (Poster)

By Christopher J. Williams[1] and Christine M. Moffitt[2]

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Sampling for disease agents in fish or other vertebrate populations often makes use of samples pooled from several individual animals to increase the economic efficiency of test processing for the specific diagnostic test. Estimates of individual animal disease agent prevalence can be obtained from pooled samples using maximum likelihood, usually by making assumptions about the sensitivity and specificity of the diagnostic test, such as assuming that the tests are perfect. Use of historical datasets collected with less than optimal methods of analysis can present a problem when interpreting these results and when combining these data with those for samples analyzed with methods that provide better specificity and sensitivity. Even when using the most up-to-date methods for analysis, disease diagnostic tests are rarely perfect, and thus it is desirable to have methods to estimate animal disease prevalence from pooled samples that can incorporate information about the sensitivity and specificity of the diagnostic test. Recent work in Bayesian statistics has provided methods that can be used to estimate individual animal disease prevalence from pooled samples with imperfect tests, generally by simulating samples from the posterior distribution of prevalence, sensitivity, and specificity, using methods such as Markov Chain Monte Carlo (MCMC). However, we have found that in some circumstances when estimating prevalence from pooled samples with imperfect tests, some MCMC methods do not converge to their target posterior distribution and yield incorrect inferences about individual animal prevalence. We review several Bayesian methods for estimating prevalence from pooled samples with imperfect tests and present Bayesian methods that will reliably yield samples from the posterior distribution of interest and give more correct inferences about disease prevalence under several scenarios.

Modeling Urban Growth and Land Use Impacts Through Multi-Temporal and Spatial Sub-Pixel Imperviousness (Poster)

By George Xian,[1] Mike Crane,[2] and Cory McMahon[1]

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Urban development has experienced rapid growth in both density and extent in many metropolitan areas in the United States over the past century. Associated with this growth has been a transformation of the landscape from natural cover types to increasingly impervious urban land. To estimate urban extent and monitor its change over time, an innovative modeling approach has been used to determine sub-pixel impervious surface area (ISA) from satellite remotely sensed data. Landsat images are used as primary data sources in modeling and estimating urban imperviousness from 1991 to 2002 in the Tampa Bay watershed, Florida, and from 1984 to 2002 for the Las Vegas valley, Nevada. ISA data is used as an indicator of watershed health and is an important component in surface-pollutant loading estimation. The resulting imperviousness data are used with a defined suite of geospatial datasets to simulate historical urban development and predict future urban and suburban extent, density, and growth patterns using the cellular automaton-based Slope, Land Cover, Exclusions, Urban Areas, Transportation, Hydrologic (SLEUTH) urban growth model. Impacts of urban development on the environment have been investigated for current and future growth scenarios. Results can be integrated as inputs for modeling surface runoff, water quality and quantity modeling, and microclimate features simulation.

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Appendix 1: Conference Agenda

MONDAY, NOVEMBER 14, 2005

4:00 PM Registration opens.

5:00 PM Welcoming Reception and Poster Session 1 focused on Theme 1—Current Status of USGS Modeling—Includes ecosystem modeling, current integrated modeling efforts, types of community models, hydrologic modeling, multi-hazard, risk, and response modeling, resource modeling, and many others.

7:00 PM DINNER AT LODGE

TUESDAY, NOVEMBER 15, 2005

Theme I: Current Status of USGS Modeling

8:30 AM Oral Session 1: Meeting Objectives and Overview

Welcome, Conference Format and Logistics—Linda Gundersen, Anne Frondorf

Modeling Goals for USGS—Pat Leahy and Karen Siderelis

Modeling Survey Results—Doug Muchoney

9:45 AM BREAK

10:15 AM Oral Session 2: Case Studies of Interdisciplinary Modeling Projects

Case Study: The Land Use Portfolio Model: A Multi-Disciplinary Approach for Natural-Hazards Risk Assessment—Rick Champion

Case Study: Interdisciplinary Integration of Vegetation Information into a Regional Flow Model of the Everglades through Geographic Research—John Jones

Case Study: Developing Chinook Spawning Habitat Models at Multiple Scales in the Hanford Reach of the Columbia River—James Hatten

Case Study: Coastal Community Sediment-Transport Model—Christopher Sherwood

Case Study: Hydrodynamic and Particle-Tracking Models for the San Francisco Bay-Delta Estuary—Peter Smith

12:00 PM LUNCH + POSTER SESSION 1

2:00 PM Session 3: Breakout Discussion Groups:

1. Structuring a USGS modeling virtual center of excellence and creating a modeling forum. (Discussion Leaders: Gary Raines, Anne Kinsinger, and Kenneth Odom)

2. Technical needs: Linking models into a multi-model framework. Open source software as a model for USGS modeling? Supercomputing resources. Technical tools: databases, visualization tools, where do we go with the results of the survey? (Discussion Leaders: Chris Sherwood and Rich McDonald)

3. Visual Programming Languages as a tool for rapid model development. (Discussion Leaders: Brian Davis and Lee DeCola)

4. Integrating the interagency and interdisciplinary community. What are some of the institutional barriers? What are the hallmarks of successful collaboration? (Discussion Leaders: John Jones and Gary Ervin)

5. The data-model connection: Model testing, sensitivity analysis, calibration, and uncertainty evaluation.
–USGS and OFA API and software resources.
–Communicating model uncertainty to resource and policy managers.
(Discussion Leaders: Mary Hill and Michael Fahy)

6. How can our modeling better serve the needs of DOI bureaus? (Discussion Leaders: Paul Barlow and Ronnie Best)

3:30 PM Reportouts—10 minutes each, followed by wrap-up

4:45 PM Take down Poster Session 1 and hang Poster Session 2 focused on Theme II—Modeling in the Future—Where modeling is headed in the Federal Government and university community (integrating models, modeling libraries, use of high speed computing, modeling approaches) and on Theme III—Finding Common Ground—Common language, standards, datasets, open access, uncertainty, data reference models and ontology.

5:00 PM RECEPTION AND POSTER SESSION 2

7:00 PM Dinner at Lodge—Keynote speaker: Timothy Duane, Dept. of City and Regional Planning, University of California, Berkeley, CA; Linking Science and Policy in Conservation

WEDNESDAY, NOVEMBER 16, 2005

Field trip to the Elwha River and the Glines Canyon Dam—

8:30 AM Overview of trip—Jeff Duda (USGS), Brian Winter (NPS), Jerry Freilich (NPS)

10:00 AM Bus leaves for Elwha Dam

Lunch Discussions—Challenges, collaboration, and kinds of modeling approaches

4:30 PM Return

6:30 PM DINNER AT LODGE

THURSDAY, NOVEMBER 17, 2005

Theme II: Modeling in the Future?
Is there a common set of USGS tools that can link our models together, and what's happening in other organizations in the Federal and academic worlds? What is our modeling infrastructure? How do we get new resources, such as high speed computing, to modelers?

8:30 AM Session 4: Modeling Infrastructure—Federal Agency Panel

Justin Babendreier
EPA, National Exposure Research Laboratory

Joseph Coughlan
NASA, Ames Research Center

Olaf David
USDA, Agricultural Research Service

David Raff
DOI, Bureau of Reclamation

George Leavesley
USGS, Water Resources (Moderator)

10:00 AM BREAK

10:30 AM Session 5: Modeling Approaches and Resources in the USGS (kinds of technical models used, high speed computing, and model applications and potential misuse)

Case Study: FRAME: Integrating Science with Resource Management through Collaborative Approaches and Adaptive Modeling Systems—George Leavesley

Case Study: Computational Modeling and Visualization Infrastructure at the USGS National Center for Earth Resources and Observation Science (EROS)—Brian Davis

Case Study: Pebbles to Politics: Ecosystem Models in the Decision Landscape—G. Ronnie Best

Case Study: Integrating USGS Geospatial Modeling Methods into the National Weather Service River Forecast System: First Steps toward a Community Hydrologic Prediction System—James Verdin

12:00 PM POSTER SESSION 2 CONTINUED AND LUNCH

Theme III: Finding Common Ground

2:30 PM Session 6: Standards and Open Access (efforts to standardize, calculate uncertainty, ways to provide open access)

Case Study: The "Big File Cabinet" Concept—Penetrating the Science-Land Management Interface—Richard Grauch

Case Study: Integrating Socioeconomic Models into Vista, the NatureServe Biodiversity Planning Tool—Alicia Torregrosa

Case Study: Interactive Models and Focused Communication are Keys to Success of Multi-Disciplinary Projects—Michael Pantea

3:30 PM Wrap-up: Discuss Key Recommendations and Results—Panel and Full Group Discussion

Panelists: Rick Champion, Jon Cline, Anne Kinsinger, Rama Kotra,

Discussion Leader: Linda Gundersen

5:00 PM FINAL RECEPTION

6:30 PM DINNER AT LODGE

Appendix 2: List of Conference Participants

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