science for a changing world

Proceedings of the Third USGS Modeling Conference, June 7–11, 2010, Broomfield, Colorado: Understanding and Predicting for a Changing World

Scientific Investigations Report 2011–5147

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

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Edited by Shailaja R. Brady

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

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U.S. Geological Survey
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Preface

The Third USGS Modeling Conference was held June 7–11, 2010, in Broomfield, Colorado. The conference focused on the development and application of analytical and theoretical models and data availability that support managing the Nation's resources and help protect lives and property. Participants at the conference included scientists and managers from Department of the Interior (DOI) Bureaus; national and international Federal, State, and local agencies; academic institutions; and nongovernmental organizations. The conference was organized according to DOI priorities and the strategic directions of the USGS Science Strategy; the following themes were emphasized: (1) Understanding Ecosystems and Restoring America's Treasured Landscapes; (2) Climate Change and Impact; (3) New Energy Frontier and Minerals for America; (4) A National Hazards, Risk, and Resilience Assessment Program; (5) Role of Environment and Wildlife in Human Health; (6) A Water Census of the United States; and (7) New Methods of Investigation and Discovery. The conference theme—"Understanding and Predicting for a Changing World"—focused on the following goals: advance development and application of models; provide tools that address management issues; present state-of-the-art models ranging from individual phenomena to integrated systems; and foster a working community among scientists and managers. This publication includes abstracts for the 148 of 125 oral presentations and 23 posters presented at the conference.

The organizing committee for the conference included the following individuals:

Laurie Balistrieri	Jenifer Bracewell
Shailaja R. Brady (Co-Chair)	Brian Cade
Thomas Doyle	Kevin Gallagher
Linda C. Gundersen	Dave Govoni
Leanne Hanson	Shuguang Liu
Thomas Philippi (National Park Service)	Steve Regan
Rudy Schuster	June Thormodsgard
Mark Wildhaber (Co-Chair)	Nathan Wood

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

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Quantitative Hydrogeological Framework Interpretations Using Helibourne Electromagnetic Surveys for the North Platte Valley, Western Nebraska Groundwater model (oral presentation)

By Jared Abraham,[1] James Cannia,[2] and Steve Peterson[3]

[1]U.S. Geological Survey, Denver, Colo.

[2]U.S. Geological Survey, Mitchell, Neb.

[3]U.S. Geological Survey, Lincoln, Neb.

Increasingly complex groundwater management requires more accurate hydrogeologic frameworks for groundwater models used in resource management. These complex issues have created the demand for innovative approaches to data collection. In complicated terrains, groundwater modelers benefit from continuous high-resolution geologic maps and their related hydrogeologic-parameter estimates. The U.S. Geological Survey (USGS) and its partners have collaborated to use airborne geophysical surveys for near-continuous coverage of areas of the North Platte River valley in western Nebraska. The objective of the surveys was to map the aquifers and bedrock topography of the area to help improve the understanding of groundwater-surface water relations to be used in water management decisions. Frequency-domain helibourne electromagnetic (HEM) surveys were completed, using a unique survey flight line design, to collect resistivity data that can be related to lithologic information to refine groundwater model inputs. To make the geophysical data useful to multidimensional groundwater models, numerical inversion is necessary to convert the measured data into a depth-dependent subsurface resistivity model. This inverted model, in conjunction with sensitivity analysis, geological ground truthing (boreholes), and geological interpretation, is used to characterize hydrogeologic features. The interpreted two- and three-dimensional data provides the groundwater modeler with a high-resolution hydrogeologic framework and a quantitative estimate of framework uncertainty. This method of creating hydrogeologic frameworks improved the understanding of the actual flow path orientation by redefining the location of the paleochannels and associated bedrock highs. The improved models represent the actual hydrogeology at a level of accuracy not achievable using previous datasets. This allows the groundwater model to be used as a management tool.

Mapping Evapotranspiration at High Resolution with Internalized Calibration: Model Overview (oral presentation)

By R.G. Allen,[1] J.H. Kjaersgaard,[1] R. Trezza,[1] and C. Robison[1]

[1]University of Idaho, Kimberly, Idaho

Application of remote-sensing algorithms solving the energy balance using high-resolution satellite imagery has proven useful for establishing estimates of evapotranspiration (ET) for large populations of field and water users (Bastiaanssen and others, 1998; Allen and others, 2007).

ET is generally estimated in energy balance processes as a residual of the energy balance as:

$$LE = R_n - G - H,$$

where LE is the latent energy consumed by ET, R_n is net radiation flux density at the surface, G is heat flux density into the ground, and H is sensible heat flux density into the air.

Models that solve the energy balance to estimate ET include Mapping Evapotranspiration at High Resolution with

Internalized Calibration (METRIC) (Allen and others, 2007). In METRIC, R_n is estimated by solving the radiation balance. G is estimated as a function of surface temperature, net radiation, and a vegetation index. METRIC utilizes an innovative Calibration using Inverse Modeling at Extreme Conditions (CIMEC) method as pioneered by Bastiaanssen for estimating sensible heat flux by inverse modeling of the near-surface temperature gradient (dT) for each image pixel based on a relationship between the dT and radiometric surface temperature at two "anchor" pixels. The advantage of the CIMEC approach to develop the dT vs. T_s (surface temperature) relationship is that many biases in energy balance components are factored out, including those in T_s. The anchor pixels ideally represent the conditions of an agricultural field having full and actively transpiring vegetation cover and a bare agricultural field having no vegetation cover and little residual evaporation. The METRIC procedure utilizes the alfalfa-based reference evapotranspiration ET_r to establish the energy balance at the cold pixel, thus establishing a ground reference for the satellite image-based ET estimate. ET_r is calculated outside of METRIC using hourly (or shorter) weather data from a weather station preferably located toward the center of the study area. The use of ET_r is generally effective in tying down the energy balance calibration, especially in arid and semiarid climates having advection. The use of ET_r for calibration and extrapolation of ET to longer time periods makes the METRIC process congruent with traditional ET_r-based estimation methods. One of the outputs from METRIC is a map of the ET from each pixel stated as a fraction of ET_r, ET_rF. ET_rF is synonymous with the well-known K_c (for an alfalfa reference basis). Daily ET_a maps are calculated by multiplying the instantaneous ET^rF calculated for each pixel with the 24-hour summed ET_r. The resulting high-resolution maps of ET cover regions typically up to 150 kilometers (km) in scale. When used properly, METRIC provides a rapid and cost-effective method to determine ET for focused regions.

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Downscaling from Global Climate Models to Regional Climate Models for Use in Multiscale Modeling of Riverine Ecosystems and Responses of Fish Populations (oral presentation)

By Christopher J. Anderson,[1] Mark L. Wildhaber,[2] Christopher K. Wikle,[3] Kristie J. Franz,[4] and Scott H. Holan[3]

[1]Climate Science Initiative, Iowa State University, Ames, Iowa

[2]U.S. Geological Survey, Columbia, Mo.

[3]Department of Statistics, University of Missouri, Columbia, Mo.

[4]Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa

Increasingly, evidence has emerged documenting ecological changes due to climate change (for example, Walther and others, 2005). Although much of this evidence comes from field observations, there is increasing reliance on models that relate climate variables to biological systems for understanding sensitivity of biological systems to scenarios of change in climate variability. Typically, climate scenarios are implemented in global climate models (GCMs). The main limitation of addressing ecological effects of global climate change is the exceedingly difficult task of quantifying sources of uncertainty (in data, models, and parameters) given the highly nonlinear nature of interactions between climate variables and community-level ecological processes. While a complete climate prediction may be intractable at this time (for instance, the climate projections may not incorporate land-use changes and solar fluctuations into the boundary conditions) we illustrate a framework to quantify uncertainty, using multiscale climate models, that is also flexible enough to adapt to advances in climate predictions.

Downscaled GCM simulations from the North American Regional Climate Change Assessment Program (NARCCAP) (*http://www.narccap.ucar.edu/*) provide temperature and precipitation time series suitable for analysis of Missouri River Basin hydrology. NARCCAP simulations are produced by regional climate models (RCMs) driven by GCMs over a domain covering most of North America. Ultimately, this program will feature simulation results from six RCMs and four GCMs.

Currently, results are available from all six RCMs forced with National Center for Environmental Prediction (NCEP) reanalysis data for 1979–2004. Such runs can give insight into potential model biases relative to observed climatology. Future climate change scenarios are based on the A2 emissions scenario [less international cooperation in which CO_2 concentration is prescribed to increase to near 850 parts per million by volume (ppmv) by 2100 which is more than double the 2000 CO_2 concentration of 369 ppmv] developed through the Intergovernmental Panel on Climate Change (IPCC) as described in Nakicenvoic and others (2000) in the Special Report on Emissions Scenarios that was commissioned by the IPCC. This scenario is one of the higher SRES emissions scenarios. Thus, it is considered to be important for studying realistic impacts and adaptation strategies.

We will present results from the NARCCAP reanalysis-driven simulations. Our presentation will discuss biases in variables used as input to the hydrological model.

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Mapping Evapotranspiration and Drought Using Multiscale Thermal-Infrared Remote Sensing Data (oral presentation)

By Martha C. Anderson[1] and W.P. Kustas[1]

[1]U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS), Hydrology and Remote Sensing Laboratory, Beltsville, Md.

Many of the natural and managed ecosystems in the western United States are sparsely or partially vegetated during much of the annual growing cycle. Partial vegetation cover conditions present challenges to single-source evapotranspiration (ET) algorithms based on thermal-infrared (TIR) remote sensing because they do not explicitly account for significant differences in atmospheric coupling of the soil and plant components within the thermal pixel. Errors from single-source models are exacerbated when they are applied to coarse resolution TIR data (≥1 km), where small-scale vegetation and moisture features in the landscape become unresolved.

In this paper we will discuss a two-source (soil + canopy) Atmosphere-Land Exchange Inverse surface energy balance model and related flux disaggregation algorithm that can be applied reliably over a range in vegetation cover conditions, from bare soil to partial cover and full canopy, and at a range in spatial scales. Techniques are being developed to integrate multisensor TIR imagery within this system to generate routine, regional ET maps at both high spatial and temporal resolution for water-resource management applications. The system combines hourly 5–10-km resolution TIR and insolation data from the Geostationary Operational Environmental Satellites with ~daily/1-km and ~biweekly/100-m resolution TIR images from a moderate resolution imaging spectroradiometer (MODIS) and Landsat, respectively. It will be shown that Landsat-scale imagery is critical for capturing water-use dynamics of small hydrologic features, such as irrigated fields, riparian buffers, canals, and reservoirs. The potential of this modeling system for operational water management and drought monitoring will be discussed.

Evaluating Management Practices for Groundwater Availability Under a Changing Climate (oral presentation)

By Matthew P. Bachmann,[1] D. Matthew Ely,[1] and John J. Vaccaro[1]

[1]U.S. Geological Survey, Tacoma, Wash.

The Yakima River basin in eastern Washington, like many areas of the arid American West, struggles with issues of water allocation. The $1 billion agricultural economy in the basin lowlands is one of the largest in the United States and primarily is based on the diversion of about 6,000 cubic feet per second (ft^3/s) of surface water. The mountainous uplands generate the snowmelt runoff for irrigation and fish habitat, making riverine transport of surface water of paramount importance. Surface water in the basin is fully appropriated in average years and over-appropriated in dry years, but there are increasing demands for water for municipal, fisheries, agricultural, industrial, and recreational uses. These demands must be met through the use of groundwater, increased storage, greater conservation, and (or) purchasing water rights. In some areas, groundwater pumping has caused water-level declines of more than 300 ft, potentially reducing streamflow in reaches with senior surface-water rights or instream flow requirements for endangered species. A variety of analytical tools have been developed to address the issues of water management under existing conditions, future growth scenarios, and potential regional climate change, including a comprehensive assessment of groundwater. A 3D Finite-Difference Groundwater Flow Model (MODFLOW)-2000 groundwater has been designed to evaluate (1) surface-water effects from existing pumpage and potential new pumpage, (2) effects of projected changes in climate on groundwater use, (3) potential improvements in irrigation efficiencies on water availability, (4) artificial recharge and aquifer storage systems, and (5) the relative utility of various aquifer management strategies. In combination, these approaches may help to accommodate municipal, agricultural, and ecological needs of the basin within the physical limitations of the hydrologic system.

Accounting for Spatial Flows to Map Ecosystem Services Supply and Demand (oral presentation)

By Kenneth J. Bagstad,[1] Ferdinando Villa,[1] Gary W. Johnson, Jr.[1], Marta Ceroni,[1] and Brian Voigt[1]

[1]Gund Institute for Ecological Economics, University of Vermont, Burlington, Vt.

Ecosystem services mapping to date has largely focused on the "supply side"—the provision of benefits by ecosystems to humans. This has largely taken place through static mapping of levels of potential service provision that incorporates ecological process models with spatial data. By comparison, the "demand side," or human demand for and use of ecosystem services, has received less attention. In addition, the spatial flow of these services from ecosystems to people has been qualitatively conceptualized but not quantitatively modeled. We describe a process used by the Artificial Intelligence for Ecosystem Services (ARIES) project (Villa and others, 2009) that links spatial data and ecological knowledge to map the spatial dynamics of ecosystem services—their provision, use, and spatial benefit flows.

We first describe the concrete benefits and human beneficiaries (or "endpoints," Boyd, 2007) provided by ecosystems, as opposed to the popular but abstract list of ecosystem services used in the Millennium Ecosystem Assessment. For each specific benefit, we describe a matter, energy, or information carrier, along with a benefit-specific flow pattern (for example, movement through hydrologic or transportation networks, spatial proximity, line of sight, or uniform mixing). Then, for each ecosystem service, we model the potential provision, users, and "sinks" that can deplete the carrier quantity as it moves across space. Provision, use, and sinks can be modeled using established ecological process models or ad hoc probabilistic models as appropriate. Finally, a set of agent-based "Service Path Attribution Network" (SPAN) models (Johnson and others, 2010) quantify the carrier flow based on benefit-specific movement rules, quantifying actual levels of ecosystem service provision, and use.

The resulting provision, use, and flow maps provide a more realistic view of the spatial dependencies between regions that provide ecosystem services and their human beneficiaries. Such mapping operationalizes the ecosystem service flow concepts developed elsewhere (Fisher and others, 2008; Tallis and Polasky, 2009) while providing support for conservation and economic development planning, economic valuation of ecosystem services, and cross-boundary analysis for public land management or other transboundary decisionmaking.

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The Lake Coeur d'Alene Story: A Physical and Biogeochemical Model to Simulate Zinc and Nutrient Cycling and to Assist Management Decisions (oral presentation)

By Laurie S. Balistrieri[1] and Matthew R. Hipsey[2]

[1]U.S. Geological Survey, University of Washington, Seattle, Wash.

[2]School of Earth and Environment, The University of Western Australia, Crawley, Australia

Vast quantities of metal-enriched mine waste were produced during historical milling, concentrating, and smelting of silver-lead-zinc (Zn)-rich ores in the Coeur d'Alene mining district in northern Idaho. Prior to environmental regulation in 1968, the waste was deposited into the South Fork Coeur d'Alene River and its tributaries. Dynamic physical, chemical, and biological processes now influence the distributions and concentrations of particulate and dissolved metals in the river basin (Balistrieri and others, 2002). Stream transport, especially during major floods, carries metals from their sources in the district to downstream repositories, including Lake Coeur d'Alene. The health of humans and other biota in the basin is affected by this legacy of contaminated water, soil, and sediment. In particular, dissolved Zn concentrations govern water quality in the region because of their adverse impact on the health of fish.

In collaboration with the U.S. Geological Survey, the Centre for Water Research at the University of Western Australia developed a three-dimensional numerical hydrodynamics-biogeochemical model (ELCOM-CAEDYM) to understand the interplay among physical transport processes, primary production and nutrient cycling, and dynamics and toxicity of Zn (Dallimore and others, 2007; Hipsey and others, 2007). The goals of the work were to (1) describe the cycling of Zn and nutrients in the lake, (2) improve the understanding of feedbacks between Zn toxicity and eutrophication, (3) provide information on data gaps and sampling strategies, and (4) evaluate alternative remediation scenarios. Data collected in the lake were used to validate the model and identify processes currently controlling Zn concentrations in the lake, and long-term scenarios were run to evaluate how the lake may respond to different remedial actions.

Of particular importance to lake managers and decision-makers, the simulations indicated that (1) a combination of low phosphate and Zn toxicity keeps the biomass low; (2) the lake is more sensitive to phosphate than to Zn concentrations; specifically eutrophication pressure due to development may be more important than upstream remedial action to reduce Zn loading; and (3) a strategic monitoring plan is needed to improve model use and prediction.

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Modeling the Spatial Distribution of Shallow Rainfall-Induced Landslides (oral presentation)

By Rex L. Baum[1] and Jonathan W. Godt[1]

[1]U.S. Geological Survey, Denver, Colo.

Mathematical modeling commonly represents shallow landslides, typically less than 3 or 4 meters thick, in digital landscapes as uniform slabs using the one-dimensional (1-D) infinite-slope stability analysis. This approach neglects the effects of irregular topography, variable thickness of slope deposits, and other conditions that violate the assumption of laterally constant stress. Model accuracy also decreases as the ratio of slab depth to length increases, as in the case of models based on digital, high-resolution (<10-m cell spacing) topography, so that many isolated, small landslides are incorrectly predicted. These effects of variable geometry and depth-to-length ratio contribute to the overprediction of unstable areas by distributed 1-D slope stability models.

Use of three-dimensional methods of slope stability analysis with gridded elevation models accounts for interaction between grid cells and improves the accuracy of predictions of landslide location, size, and shape. Whereas distributed 1-D methods compute factor of safety (*F*) cell by cell, 3-D methods compute composite *F* values for contiguous groups (3-D) of cells. Although 1-D analyses commonly identify clusters of unstable grid cells ($F<1$) that roughly coincide with mapped shallow landslides, these analyses also identify isolated unstable cells and scattered small groups of unstable cells away from mapped slides. Many of these isolated cells and scattered groups are incorrect because they are supported by adjacent stable cells: 3-D methods correctly predict $F>1$ in most of these nonlandslide areas. Further, 3-D analyses correctly predict larger landslides in observed landslide areas where 1-D analysis predicts unstable cells interspersed with stable, low *F* (<1.3) cells. Using 3-D analyses to predict landslide size and location reduces spurious clusters of unstable cells and improves accuracy. For example, receiver operator characteristics analysis shows that simple 3-D analysis improves prediction of landslide points (true positives) with only a slight increase in the number of false positives.

Model Assessment for Nonlinear Geophysical Inverse Problems (oral presentation)

By Paul A. Bedrosian[1] and Burke Minsley[1]

[1]U.S. Geological Survey, Denver, Colo.

Model assessment is arguably one of the most important aspects of geophysical inversion. The inherent nonuniqueness of the geophysical inverse problem, coupled with the reality of incomplete and inexact data, frustrate recovery of a true-earth model. Artifacts in inverse models arise from a range of issues, including regularization, model parameterization, linearization of the inverse problem, data density, error specification, and data sensitivity. These factors may also give rise to an absence of structure, which can be equally misleading. Model assessment can be loosely broken down into: (1) data-fit statistics and formal measures of sensitivity, (2) the effects of regularization, (3) methods for exploring the permissible model space, and (4) investigation of spatial and geometric resolution.

Formal approaches to model assessment include normalized X^2 statistics and transformations or decomposition of the sensitivity matrix, which relates changes in the data to linear perturbations of the model parameters. Regularization concerns the effects of trade-off parameters, model norm, and starting and prior models on the resulting inverse model. For example, multiple starting models can be used to help assess the nonuniqueness of the inverse problem, and are also useful in determining the region of model space that is strongly influenced by the data (Oldenburg and Li, 1999). A number of approaches are taken to explore the permissible model space. These range from linear sensitivity analysis, valid in assessing the sensitivity to small model perturbations, to global search methods that employ a probabilistic approach to exhaustively sample the model space. In practice, a combination of forward modeling and constrained inversion are commonly used to investigate alternate models. This is generally a hypothesis-driven approach in which the geometry or physical properties of parts of the model are altered. A final aspect of model assessment is spatial resolution: What is the minimum-size structure that can be resolved, and with what accuracy can the geometry and physical properties be recovered? Some inverse problems, such as seismic refraction tomography, employ checkerboard tests (Zelt, 1998) to determine the minimum resolvable structure. Others, including electrical inverse problems, are plagued by the strong nonlinearity between the modeled physical property and the measured data. Analysis of the model resolution matrix, a function of the sensitivity and data errors, is one approach to assessing resolution, but can be cumbersome for large inverse problems.

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Using the Variably Saturated 2-D Transport (VS2DT) Program to Simulate Year-Round, Deep Subsurface Drip Irrigation with Coal-Bed Methane Produced Waters (oral presentation)

By Carleton R. Bern[1] and Richard W. Healy[1]

[1]U.S. Geological Survey, Denver, Colo.

Coal-bed methane (CBM) is a rapidly expanding energy sector in the United States. In Wyoming's Powder River Basin, development of this resource produces large volumes of water with sodium-bicarbonate chemistry and relatively high total dissolved solids. Deep (~90 cm) subsurface drip irrigation (SDI) is an emerging technology and has been pursued as a disposal option for CBM waters for several years. SDI is attractive because it offers the possibility of deriving beneficial use by growing water-intensive crops like alfalfa in a semiarid landscape. Simultaneously, solutes associated with the CBM water are potentially stored in the unsaturated zone. A concern with using SDI to dispose of saline water is salinization of surface soil or groundwater, or both.

Our goal is to better understand and predict the fate of native and introduced solutes in SDI fields. Computer simulation is a tool we use to assess complex interactions between the numerous parameters and processes controlling transport of water and solutes. The introduction of irrigation water and solutes is controlled by the depth and spacing of injection points, as well as timing and rate of water injection. Seasonality and amount of precipitation influence the availability of low-solute water in near-surface soil. Evapotranspiration is the major sink for precipitation and irrigation water and is influenced by seasonal and interannual climate variability, as well as vertical and horizontal crop root distribution. Water flow in soil is largely a function of soil texture and interactions between degree of saturation and hydraulic conductivity.

Multiyear simulations of water and solute movement through a two-dimensional vertical slice of an SDI field are being run using the U.S. Geological Survey program Variably Saturated 2-D Transport (VS2DT). The simulations are refined by comparing model output to laboratory data on samples of SDI field soils and measurements from an array of underground sensors. The striking two-dimensional patterns of water and solute distribution in SDI field soils provide good qualitative targets for assessing simulation accuracy. The resulting models should unravel some of the complexity of deep SDI using saline waters. Predictions could be made as to how such systems might be managed in different climates or settings to reduce the risk of soil salinization.

A Dendrohydrological Reconstruction for the Walker River Watershed (Eastern Sierra Nevada/Western Great Basin, U.S.A.) Using New Modeling Techniques (oral presentation)

By Franco Biondi,[1] Jose D. Salas,[2] Scotty Strachan,[1] and Laurel Saito[3]

[1]Department of Geography, University of Nevada, Reno, Nev.

[2]Civil and Environmental Engineering Department, Colorado State University, Colo.

[3]Natural Resources & Environmental Science Department, University of Nevada, Reno, Nev.

High-resolution models that address the data needs of wildlife and water-resource managers include reconstructions of hydroclimatic variability with seasonal-to-annual resolution over several centuries, since these long-term records are ideal to determine the historical range of variability of moisture conditions in specific habitats and of surface-water resources in specific watersheds. Tree-ring records recently obtained from single-needle pinyon (*Pinus monophylla*) stands were used to extend the instrumental record of hydroclimatic variability in the Walker River basin, at the boundary between Nevada and California. Two different ring-width standardization methods, one based on cambial age (the “C-method”) and one based on a cubic smoothing spline with a known frequency response, were used to produce two sets of tree-ring chronologies from the increment core samples. The C-method has been found to provide a theory-based alternative to the empirical “conservative” standardization option, and to perform equally well as the well-known Regional Curve standardization method. Available tree-ring series for the Walker River basin span the past four to five centuries at annual resolution, and the record extension model REXTN, which includes both a noise term and an autoregressive term, was used to perform the reconstruction. The dendrohydrological time series is presented, and its features are discussed and interpreted in terms of dry/wet episode duration, magnitude, and peak. This approach allows for a quantitative representation of the likelihood of droughts or pluvials that can be expected in this region.

Detailed Soil Properties from the Soil Survey Geographic database for USGS Modeling (oral presentation)

By Norman Bliss[1]

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

Many environmental models need soil data to accurately represent vegetation growth, hydrological processes, erosion and sedimentation, and carbon storage and fluxes. For example, the quantity of soil organic carbon (SOC) stocks forms a foundation for understanding potential sequestration or release of carbon in the future in response to changes in land management and climate. The Soil Survey Geographic (SSURGO) database, developed by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), is now 86% complete for the conterminous United States. These data have much more spatial detail than the previous maps formed from the State Soil Geographic data developed by the NRCS in 1994. A new capability is being developed to extract information from the hundreds of attributes in the SSURGO database and provide the information as data layers ready for use in models. Simple queries are based solely on the SSURGO data. More complex queries show relationships between soil properties and other spatial data, such as land cover, elevation, slope, aspect, relief, landscape position, hydrologic unit, and Federal land ownership status. The newly available data formats are expected to enable USGS scientists and the U.S. Department of the Interior land managers to spatially improve their spatially explicit modeling of regional carbon dynamics, evapotranspiration, and vegetation growth.

Monitoring and Modeling Climate Change on the Navajo Nation, Southwestern United States (poster)

By Rian Bogle,[1] Margaret Hiza,[1] Debra Block,[1] John Vogel,[1] Miguel Velasco,[1] Amy E. Draut,[2] and Barry Middleton[1]

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

[2]U.S. Geological Survey, Santa Cruz, Calif.

Native Americans of the Southwest live on ecologically sensitive semiarid-to-arid lands with limited resources. On the 65,000 km^2 Navajo Nation, southern Colorado Plateau, traditional people often live a subsistence lifestyle. Increased temperature and changing precipitation are transforming the landscape, negatively impacting the residents. For people to continue to inhabit these lands successfully, we must both understand the processes that are rapidly altering these drylands and develop mitigation strategies. Our research objective is to record, assess, and model the interactions between: (1) climate variability, (2) landscape sensitivity to eolian processes, (3) landscape response to changes in native and invasive vegetation, and (4) fluvial processes in relation to flooding and sediment availability. To this end, our team is: (1) using a network of meteorological stations to calculate and map ratios of precipitation to potential evapotranspiration; (2) establishing in-situ automated cameras to record changes in dune morphology and capture dust transport; (3) performing repeat high-precision GPS and terrestrial light detection and ranging (LIDAR) surveys to assess dune migration rates; (4) using high-resolution remote sensing to record changes in vegetative cover, speciation, and phenology, as well as landscape vulnerability to eolian processes; and (5) documenting planform changes in the Little Colorado River. With these data we are creating a record of climate variables and coincident landscape change on the Navajo Nation that will provide for modeling the effects of climate change on the landscape. Initial assessments indicate that the areal extent of sand susceptible to mobilization has increased significantly; recorded sand dune migration rates are in excess of 35 meters per year and regionally significant dust storms emanating from the study area are becoming common. Additionally, remobilized surfaces are rapidly changing in vegetative cover and composition. Furthermore, channel change, although influenced by changing riparian vegetation, appears to be driven by flow variation that is in turn related to precipitation variability.

The National Hydrologic Model Portal (oral presentation)

By Nathaniel Booth,[1] Lauren Hay,[2] and Steve Markstrom[2]

[1]U.S. Geological Survey, Middleton, Wisc.

[2]U.S. Geological Survey, Lakewood, Colo.

A Web-based National Hydrologic Model Portal (NHMP) for the U.S. Geological Survey (USGS) is proposed to address the data and model distribution needs of the hydrologic modeling community. The USGS is a leader in providing watershed modeling expertise, data, and analysis; however, this status is compromised when USGS environmental simulation models do not incorporate the best available data sources, despite being readily available. This situation is particularly frustrating for USGS scientists who are (1) producing datasets that are timely, relevant, and nationwide in scope, and (2) developing and applying simulation models that are used to support sound decisionmaking and further the understanding of the natural world. Techniques that reduce data errors, misinterpretation and (or) misuse, and duplication of effort related to model development must be of the highest priority for the USGS. We propose a National Hydrologic Modeling Structure (NHMS) to support coordinated and robust hydrologic model development and application within the USGS. The NHMS will address: (1) methods which focus on multiple spatial extents and resolutions within a single data structure; (2) support for multiple temporal contexts (historical, current, and future); and (3) a National Hydrologic Model Portal (NHMP). This structure will support cross-discipline, cross-center, and cross-office collaboration and long-term archival of model outputs in a simple discoverable and accessible form. The NHMP service will facilitate continental scale studies, such as climate change, ecological impacts, hazard evaluation, and water supply, while also addressing the needs of regional- or local-scale modeling studies by providing data of consistent coverage and quality. Regardless of scale or resolution, the NHMP will bring scientists together by making the best data available and easy to use in models.

Climate Change and Thermokarst Activity in Russian Altay Mountains (poster)

By Pavel S. Borodavko[1]

[1]Department of Ecological Research, Institute of Monitoring of Climatic and Ecological Systems SB RAS, Tomsk, Russia

The Altay Mountains is the largest area of widespread mountain permafrost in Siberia. In Russia, it occupies approximately 92,000 km^2 (square kilometers). The climatic variations during the 20th century, and especially during the last three decades, have impacted on current permafrost temperatures. Observations over the last 40 years show that permafrost warmed by 0.3–0.4 °C, and average active-layer thickness increased by 20–25 percent in comparison with the 1960s.Thermal degradation of ice-rich permafrost with coincident subsidence of the ground surface has recently resulted in extensive thermokarst and creation of new lakes on the Eshtikol Plateau (EP) and Dzhulukul District (DD) in South-East of Russian Altay. Thermokarst is a type of pseudokarst. This term is the abbreviation of the phrase “the thermal karst.” It was introduced by Ermolaev in 1932 and has been used in Russia and in other countries for describing subsided landforms generated due to the thawing of permanently frozen rocks with a very high content of the underground ice. The thermokarst is generated primarily by changes in the conditions of heat exchange between the frozen grounds and atmosphere, which results in an increase in the depth of the seasonal active layer.

GIS analysis of aerial photography and satellite images indicated that widespread ice wedge degradation had not yet occurred before 1952. Our study documented a net increase in lake area and the number of lakes exceeding 0.2–2 ha in size in the continuous permafrost zone and suggests an increase of 52 percent on a 3,000 km^2 territory (EP and DD) between 1952 and 2009, with the greatest increase between 1972 and 2000. Field observations indicate that in some locations, thawing permafrost creates thermokarst lakes, while in other situations, thawing promotes talik development and draining of lake.

Ecosystem Performance Models for Five Rangeland Types and Climate Change Impacts on Big Sagebrush (*Artemesia Tridentata*) Sustainability in the Owyhee Uplands, U.S.A (oral presentation)

By S.P. Boyte,[1] B.K. Wylie,[2] Y. Gu,[3] and D.J. Major[4]

[1]SGT, Inc., Sioux Falls, S. Dak.

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

[3]ARCS Research and Technology Solutions Sioux Falls, S. Dak.

[4]Bureau of Land Management, Boise, Idaho

The introduction of annual grasses and noxious weeds since settlement, and increasing fire frequency and severity, have had grave ecological consequences for the Great Basin, including the Owyhee Uplands. In this study, we used regression tree models that incorporate interannual weather variations to predict ecosystem performance (growing season Normalized Difference Vegetation Index—NDVI) of five rangeland types. Unlike many greenness studies, our technique separated weather variations from management and disturbance impacts. By comparing the modeled ecosystem performance maps (from 2000 to 2008) with the actual growing season NDVI for each rangeland type, we identified performance anomalies, or areas that were more or less productive than expected. The results were validated with information on the percentage of bare ground and the stocking rate. We located persistent anomalies from these annual maps and created a map to identify areas trending toward degraded states. We used historical weather data from 1950 and 1970 and future trends climate data for 2040 to assess the sustainability of the Big Sagebrush (*Artemesia tridentata)* community, a critical habitat for this region. We currently use this method to analyze ecological consequences of a potential land conversion from marginal cultivated cropland to grassland for biofuels production in the Greater Platte River Basin area.

Models as Tools for Linking Science and Management (oral presentation)

By Laura A. Brandt[1]

[1]U.S. Fish and Wildlife Service, Davie, Fla.

The mission of the U.S. Fish and Wildlife Service (FWS) is working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people. Meeting this mission requires work grounded in thorough, objective science. In light of the 21st century conservation challenges, it will be even more important for FWS staff to have access to tools that will help to identify science-based conservation strategies for fish and wildlife habitat and population management. Development and application of models is one way that science can provide information for landscape planning, ecosystem restoration, and adaptive management. Forecasting models at appropriate spatial and temporal scales are needed to help understand changes that could occur. For example, use of projections of sea level rise, changes in temperature, precipitation, water availability, and land use provide information about stressors on natural communities and fish and wildlife and plant populations. Outputs from those models can serve as inputs to models that link fish, wildlife, and plant populations to habitat and other limiting factors. These models can provide a foundation for making decisions on where, how much, and what kind of habitat is necessary to ensure landscapes that can support sustainable populations. Having such information will put FWS in a better position to respond proactively. In this presentation, I will discuss the kinds of modeling that may be useful for FWS decisionmakers, using examples from the Southeast region.

The Puget Sound Ecosystem Portfolio Model: A Regional Analysis to Support Restoration Planning (oral presentation)

By Kristin B. Byrd,[1] Jason Kreitler,[1] William Labiosa,[2] and John P. Bolte[3]

[1]Western Geographic Science Center, U.S. Geological Survey, Menlo Park, Calif.

[2]Western Geographic Science Center, U.S. Geological Survey, Seattle, Wash.

[3]Department of Biological & Ecological Engineering, Oregon State University, Corvallis, Oreg.

The U.S. Geological Survey (USGS) Puget Sound Ecosystem Portfolio Model (PSEPM) is a decision-support tool that supports land-use and restoration planning in Puget Sound, Washington. This tool models changes in metrics that relate scenarios of Sound-wide land-use change and shoreline modifications to nearshore biophysical changes relevant to human well-being and ecosystem services. We describe results for three submodels within PSEPM, the Beach Erosion Index, the Recreation Model, and the Shellfish Pathogen Model that evaluate three alternative growth scenarios: (1) status quo, (2) managed growth, and (3) unconstrained growth. These decadal scenarios are forecasted out to 2060 by the geographic information system (GIS)-based ENVISION model developed at Oregon State University. Our three submodels are intended to translate potential changes in terrestrial and nearshore land use to their effects in the nearshore environment. The Beach Erosion Index provides a score for each bluff-backed and barrier beach that indicates the potential of that beach to erode relative to other beaches due to loss of sediment from shoreline armoring. The extent of armored bluffs updrift of a beach serves as a potential measure of sediment supply loss to that beach and combined with other factors such as fetch distance, its relative potential to erode. To attribute cumulative updrift bluff armoring to a beach, a Network Analysis Upstream Accumulation method was applied in ArcGIS, which calculated for each beach the length of updrift bluffs that are armored within a drift cell, a unit of coastline that represents a sediment transport sector from source to deposition. The Recreation Model relates changes in population and land use to annual visitation rates at State Parks throughout the Sound. A regression model explaining current recreation use from 2008 State Park visitation data and the alternative future scenarios data are used to forecast and determine the differences in likely future recreational use at those parks. The Shellfish Pathogen Model relates the probability of high fecal coliform concentrations in commercial shellfish-growing areas to watershed land-cover patterns. The model identifies watershed area, percent cover of evergreen forest, and percent cover of development as important explanatory variables. Combined with Washington Department of Fish and Wildlife shellfish harvest records, overlaps between seasonal patterns of shellfish consumption and pathogen concentrations were identified to project where and when higher risks of exposure may occur. Finally, a Beach Value submodel compiles presence data for beach features of value in terms of quantification, such as public access and eelgrass habitat. This tool enables end users to modify how beach value is calculated based on stated preferences, and use model results to prioritize sites for restoration based on impairment predictions from the three models discussed above.

Ensemble Modeling of Fall-Run Chinook Production in the Klamath Basin, Oregon and California (oral presentation)

By Sharon G. Campbell,[1] Noble Hendrix,[2] Steve Lindley,[3] Chuck Huntington,[4] and John Heasley[5]

[1]U.S. Geological Survey, Fort Collins, Colo.

[2]R2 Resource Consultants, Inc., Redmond, Wash.

[3]NOAA Fisheries Service, La Jolla, Calif.

[4]Clearwater BioStudies, Inc., Canby, Oreg.

[5]Resource Analysis Systems, Fort Collins, Colo.

As part of the upcoming Secretarial Determination to either retain or remove four hydropower dams from the Klamath River, a population dynamics model capable of predicting annual abundances of fall-run Chinook with uncertainty was developed. The initial approach was to construct a conceptual model that: (1) captured the biological processes of interest; (2) captured existing hypotheses about environmental or anthropogenic factors thought to affect the population dynamics; (3) identified sources of data for those factors; (4) identified pathways for management actions; and (5) when using statistical methods, identified sources of data that could be used as indices of abundance. Several existing models were embedded in a new full life cycle model for fall Chinook, an adult migration model, an upper basin production model (EDT), an outmigrant mortality model (SALMOD), a retrospective ocean survival model, and a harvest model. Using the conceptual model as a blueprint, a life-stage model (for example, Leslie-matrix type model) with transition among stages described by stage-specific Beverton-Holt functions was constructed.

The modeling development effort involved four Federal agencies, U.S. Geological Survey, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, and the National Oceanic and Atmospheric Administration Fisheries, and three consultants, as well as university, State, tribal, and other Klamath Basin stakeholders that all provided models, data, and expert opinion.

The model was used to compare existing conditions (hydropower dams in place) and several alternatives without dams. Preliminary results of model application for analysis of the Secretarial Determination alternatives (with dams, historical and future, and without dams, future predictions) will be presented.

The Integration of Ecological Data in a Minerals Assessment in Southeastern Madagascar (oral presentation)

By Jacoby Carter[1]

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

The Anosy region of southeastern Madagascar is a region of concern for conservation biologists because it has a high level of endemism and is also one of the poorest regions in one of the poorest countries in the world. In the Anosy, ecosystem services provided by forests, wetlands, and other habitats are an important part of the local and regional economy. However, in many locations in the region, current land-use practices are unsustainable. Both governmental and nongovernmental organizations have come to the consensus that to preserve biodiversity, a program of sustainable development must be pursued. The U.S. Geological Survey (USGS) was invited by the World Bank and the Malagasy government to conduct a minerals assessment for the Anosy. This assessment used the standard minerals assessment methodology that has been developed by the USGS. To assess the economic potential of hard rock mining, this approach combines: remote sensing; historical documents; on-the-ground inspection of geology and mineral deposits; consideration of infrastructure (for example, roads, power grids); and the economic value, both on the local and world markets, for various hard rock minerals. In addition to the written report, the assessment also includes a geographic information system (GIS) in a format in which cost-benefit analyses and synergies can be examined. However, unlike previous studies, our analysis also included region-wide assessments of hydrology and ecology. This presentation will focus on the approaches developed to integrate ecological information into the larger minerals assessment framework at multiple scales using available data layers.

Alternative Measures of Road Network Characteristics for Modeling Environmental Change (oral presentation)

By Alisa W. Coffin[1] and Raymond D. Watts[1]

[1]U.S. Geological Survey, Fort Collins, Colo.

Investigations of ecosystem change in human-affected landscapes require the incorporation of parameters that estimate the extent and scale of human influence. Road networks provide clear evidence of human presence and potential use in the landscape. Road networks are significantly related to numerous changes in ecosystems, including land-cover change, the fragmentation of animal populations, and the spread of invasive species. Not surprisingly, parameters that estimate road networks are commonly used as proxies for human influence in ecosystem change models. Typically, a few measures, such as road density, distance-to-road, and occasionally road surface type and traffic, are incorporated into models that include “road effects.”

Few studies have considered alternative ways to measure and characterize road networks that relate to ways that people actually use the road network, or consider the spaces adjacent to roads in their estimation of the potential effects of the system of roads. This paper presents two alternative approaches for including parameters of road networks in models of landscape change. The first approach uses network analysis to abstract the road network as connected sets of weighted elements that quantitatively describe changes in structure and function. The second approach considers the spatial isolation of the road in relation to all other roads within a relevant neighborhood. Examples of road networks in north-central Florida and the Colorado Front Range were modeled using these techniques. In both areas, the road networks were measured in approximately 20-year intervals to record changes as the population in these regions grew and the transportation systems expanded.

Changes in road network characteristics included changes in extent, connectivity, and accessibility. An important change in the structure of the road networks included the proliferation of relatively short, local, dead-end roads, and an overall increase in their proportion within the networks. This characteristic was also associated with land-use intensification at those points, as the creation of dead-end roads preceded land-cover transformation in many places. This suggests that such topological changes to the network may provide leading indicators of change, including increases in road density or impervious surface area. Over time, spatial isolation decreased as spaces between the roads were invaded by small penetrating roads, suggesting that the invulnerability of the landscape to human-induced ecological change decreased.

Regardless of the methods used to characterize them, road networks are a fundamental and critical piece of information in analyzing and predicting the human dimensions of ecological change. One of the greatest challenges in using these data is the acquisition of accurate, timely geographic data of the locations and attributes of all roads, including small local roads. While such maps may exist for one county or State, they may be nonexistent or outdated for others. Given the relative importance of these data for predicting human-induced environmental changes, we suggest the adoption of comprehensive, national road mapping standards, which clarify the mapping and attribution of road networks, including local roads.

Development of Decision Support Systems for Estimating Salinity Intrusion Effects Due to Climate Change on the South Carolina and Georgia Coast (oral presentation)

By Paul A. Conrads,[1] Edwin A. Roehl Jr.,[2] Charles T. Sexton,[3] Daniel L. Tufford,[4] Gregory J. Carbone,[5] Kirstin Dow,[5] Ruby C. Daamen,[2] and John B. Cook[2]

[1]U.S. Geological Survey, Columbia, S.C.

[2]Advanced Data Mining, Greenville, S.C.

[3]Beaufort-Jasper Water and Sewer Authority, Okatee, S.C.

[4]University of South Carolina, Biological Sciences, Columbia, S.C.

[5]University of South Carolina, Geography, Columbia, S.C.

The ability of water-resource managers to adapt to future climatic change is especially challenging in coastal regions of the world. The balance between the hydrological flow conditions within a coastal drainage basin and sea level governs the characteristics and frequency of salinity intrusions into coastal rivers. There are many municipal water intakes along the Georgia and South Carolina coast that are proximal to the saltwater-freshwater interface of tidal rivers. An increase in the extent of saltwater intrusion along the coast due to climate change could threaten freshwater intakes for the cities of Myrtle Beach, Georgetown, and Beaufort in South Carolina and Savannah in Georgia. During the Southeast's record-breaking drought from 1998 to 2002, salinity intrusions inundated one of the coastal municipal freshwater intakes, limiting water supplies during the height of the tourist season. For long-range planning purposes, water-resource managers need estimates of the change in the frequency, duration, and magnitude of salinity intrusion near their water intakes that may occur as a result of climate change.

Salinity intrusion results from the interaction of three principal forces—streamflow, mean tidal water levels, and tidal range. To analyze, model, and simulate hydrodynamic behaviors at critical coastal gage locations along the Atlantic Intracoastal Waterway and Waccamaw River near Myrtle Beach, S.C., and Savannah River near Savannah, Ga., data-mining techniques were applied to more than 20 years of hourly streamflow, coastal water-quality, and water-level data. Artificial neural network (ANN) models were trained to learn the specific variable interactions that cause salinity intrusions. Streamflows into the estuarine systems are input to the models as time-delayed variables and accumulated tributary inflows. Tidal inputs to the models were obtained by decomposing tidal water-level data into a "periodic" signal of tidal range and a "chaotic" signal of mean water levels. The ANN models were able to convincingly reproduce historical salinity dynamic behaviors in both systems. User-defined hydrologic and coastal water-level inputs (for example, from downscaling of regional climate models) can be simulated in the salinity intrusion models to evaluate various climate change scenarios. The models for the two systems are deployed in a decision support system (DSS) and disseminated as a spreadsheet application to facilitate the use of the models for management decisions by a variety of coastal water-resource managers. Preliminary model results near a municipal freshwater intake indicate that a sea-level rise of 1 foot [ft, 30.5 centimeters (cm)] would double the daily frequency of water with a specific conductance value of 2,000 microsiemens per cm over a 7-year simulation, and a 2-ft (61-cm) sea-level rise would quadruple the frequency. Water-resource managers can use this information to plan mitigation efforts to adapt to potential effects from climate change. Efforts could include timing of withdrawal on outgoing tides, increased storage of raw water, timing-increased releases of regulated streamflow, or the blending of higher conductance surface water with lower conductance water from an alternative source such as groundwater.

EverVIEW: Bringing Ecological Modeling, NetCDF Data Manipulation, and Visualization to the Natural Resource Manager's Desktop (oral presentation)

By Craig Conzelmann,[1] Stephanie Romañach,[2] and Dustin Roszell[3]

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

[2]U.S. Geological Survey, Davie, Fla.

[3]IAP World Services, Lafayette, La.

Natural resource managers in the Greater Everglades have expressed their need to view and manipulate ecological modeling data on their desktop computers. Managers not only want to view model output on their desktops, but also to run ecological models, adjust model parameters when assessing alternative restoration plans, and have a spatially explicit visualization environment for comparing these alternatives. Working through the U.S. Geological Survey Priority Ecosystem Science (PES) program, the National Wetlands Research Center has created Ever***VIEW*** to help address the needs of resource managers.

Ever***VIEW*** is a desktop application developed in Java for multiple operating systems. The application was designed in a framework that facilitates deploying functionality as tools or plug-ins. Ever***VIEW*** exposes tools to the user through various toolboxes such as the Data Manipulation Toolbox and the Modeling Toolbox. Tools can be incorporated into Ever***VIEW***, the umbrella application, or downloaded and run as standalone executables.

The Greater Everglades modeling community is progressively moving to Network Common Data Form (NetCDF) as the default data container for modeling inputs and outputs. Ever***VIEW*** is designed to view NetCDF data in a spatially explicit environment, but also allows the user to view other local or Web mapping service (WMS)-enabled spatial datasets. The "NetCDF Slice & Dice Tool" from the Data Manipulation Toolbox was the first tool released. This tool allows the end user to create subsets of NetCDF files through user-defined filters. Users can filter data using desired date ranges, seasons, spatial envelopes or polygon geometry, and other ranges of data values.

A unique feature of Ever***VIEW*** is an ability to instantiate multiple mapping panels, each of which can be populated with different datasets, allowing the end user to spatially compare modeling inputs and outputs. Users are able to download models from the Modeling Toolbox and view inputs and outputs on map panels arranged on the screen simultaneously. For example, after downloading the spoonbill habitat model, users can choose to view salinity, water-depth, and nest-location inputs in separate map panels, and the resulting habitat-suitability output in another panel.

The Greater Everglades management community can finally perform side-by-side model comparisons on their desktops using that information to make better informed decisions. Ever***VIEW*** will continue to evolve to maintain its relevance in meeting the needs of natural resource managers.

Modeling Heterogeneous Ecosystems with Large Herbivores (oral presentation)

By Michael B. Coughenour[1]

[1]Colorado State University, Natural Resource Ecology Laboratory, Fort Collins, Colo.

A spatially explicit landscape ecosystem model called SAVANNA has been used, further developed, and updated for research and decisionmaking in heterogeneous ecosystems with native and domestic large herbivores for more than two decades. It is a generalized model that has been applied in a wide variety of habitats and vegetation types. Applications in the United States have included Rocky Mountain and Yellowstone National Parks, and the Pryor Mountain Wild Horse Range. Applications have also been developed in Eastern and Southern Africa, Australia, and Inner Mongolia. The most common uses have been assessments of sustainable ecological carrying capacity for large herbivores and assessments of ecosystem responses to climatic variability and change. A process-based modeling approach is used to predict plant growth, vegetation dynamics, nutrient cycling, water budgets, herbivore foraging, energetic status, and population dynamics. Spatial data are used to initialize the model, and spatial-dynamic outputs can be viewed with the "Savanna Modeling System" or a Geographic Information System. Multiple plant and animal species or functional types can be simulated, enabling assessments of interactions between woody and herbaceous vegetation, effects of herbivory on vegetation composition and function, and interactions between wild and domestic herbivores. This presentation will provide an overview of this approach to spatially explicit ecosystem modeling.

Energy Development Changes Ecosystem Services as Modeled by Integrated Valuation of Ecosystem Services and Tradeoffs (Invest) in the Green River Basin, Wyoming (poster)

By William Curtiss[1] and Jay E. Diffendorfer[1]

[1]U.S. Geological Survey, Denver, Colo.

Ecosystem services are the benefits humans derive from natural systems. Studies of ecosystem services attempt to understand how ecosystem services are generated, consumed, and flow through space and time, as well as establish methods for estimating their monetary and nonmonetary value. Ecosystem services, by allowing comparisons of costs and benefits, create a framework for decisionmaking and understanding human impacts on landscapes and the ecosystems they harbor. InVEST estimates ecosystem services with an open-source set of tools that run within ArcGIS. Each module allows coarse estimation of a suite of variables for a particular ecosystem service. InVEST allows scenario comparison and has been used in a number of decisionmaking contexts.

We applied InVEST to assess the effects of Coal-Bed Methane (CBM) production on a subset of ecosystems services in Southwest Wyoming. Secondarily, we investigated the utility of InVEST as an "off the shelf" modeling platform. We mapped the disturbance caused by CBM extraction in 1994 and 2007 at the Jonah Field, using high-resolution aerial imagery, converted the maps to a binary (disturbed, not disturbed) layer, and used two maps to develop "before and after" comparisons. Other input layers came from preexisting data sources. We applied the Biodiversity, Avoided Reservoir Sedimentation, and Carbon Sequestration models in InVEST to both the 1994 and 2007 disturbance layers, then calculated changes in the ecosystem service estimates from InVEST before and after intensive energy development.

Between 1994 and 2007, build out of the Jonah field resulted in 7,659.27 hectare (ha) of disturbed habitat, mostly caused by new roads linking individual wells. Inter-Mountain

Basins Big Sagebrush Shrubland declined by 3,861 ha and Inter-Mountain Basins Big Sagebrush Steppe lost 1293.3 ha from development. We will present these changes in light of ecosystem services. As a tool, InVEST was relatively easy to understand and utilize. Given its recent development, we did encounter bugs in the biodiversity module but they were rapidly fixed by InVEST support staff. In addition, documentation for InVEST and its modules is still underway so some modules required considerable trial and error, posts to a user forum, and direct communication with InVEST programmers before successful model runs were completed.

Developing Essential Climate Variables for Terrestrial Modeling and Monitoring (oral presentation)

By Tom Dinardo[1] and John Dwyer[1]

[1]U.S. Geological Survey, Denver, Colo.

The growing record of satellite observations and in situ data collected from ground-based networks, coupled with advances in computational resources and data assimilation models, afford the opportunity to provide more meaningful and usable datasets at regional and continental scales. Numerous agencies from the United States and the international community, in collaboration with university researchers, have defined a strategy for developing tiers of higher level data products derived from satellite remotely sensed data that address the needs for terrestrial monitoring and predictive modeling scenarios. Fundamental climate data records are geophysical parameters (for example, surface reflectance and temperature) that can be derived from well-calibrated remotely sensed data and further processed to generate essential climate variables (for example, surface albedo, surface-water extent, snow and ice, land cover, and fire disturbance). The USGS Geography discipline is currently developing a science strategy and implementation plan by which to develop a suite of essential climate variables that address the requirements of the Department of the Interior land managers as well as the Nation's international interests.

Remotely sensed data collected by satellite and aircraft platforms are used in a broad range of research investigations and land-management applications to monitor changes in the state and condition of the landscape. Remotely sensed data complement in-situ measurements collected from numerous existing and planned ground networks by providing a framework within which to integrate measurements and observations collected at varying spatial and temporal scales. The increasing amount and types of data being collected drive requirements to process and reduce these data into geophysical and biophysical parameters that can be assimilated into numerical models, data visualizations, and decision-support systems used by scientists and land managers perform quantitative assessments of the response of terrestrial systems to climate variability and human activity.

Dynamically Downscaled Climate Projections for Ecohydrological Applications Over the Southwest (oral presentation)

By Francina Dominguez[1] and Christopher Castro[1]

[1]Department of Atmospheric Sciences, University of Arizona, Tucson, Ariz.

Predicting the impacts of climate change on terrestrial ecosystem requires an understanding of how climate variables will change at the regional scale. Unfortunately, state-of-the-art climate change estimates are based on global climate projections using global climate models (GCMs), and while these models can give us a rough estimate of the climate at very large scales, they are not useful at the local or regional scales—the scales that have the most important for ecosystems impacts. Hydrologic studies using raw coupled climate output yield poor results due to their coarse resolution and unrealistic land-surface hydrologic representation. The goal of this work is to improve warm-season climate projections in the North American Monsoon Region to be used in hydrological and ecological applications. To do this, we are dynamically downscaling both historical and future global climate model data from the Hadley Centre for Climate Prediction and Research/Met Office UKMO-HadCM3 model. This model was chosen because it surpassed all other available models in representing the climate of the Southwest United States when evaluated using a set of relevant metrics. The dynamical downscaling uses the Weather Research and Forecasting (WRF) regional climate model and generates data at 6-hour intervals and at a 33-kilometer (km) resolution covering the period from 1960 to 2081. Our hypothesis is that the regional models will improve upon the coarser resolution driving GCMs, particularly during the warm season, due to the fact that the physical mechanisms of rainfall during the summer are more related to mesoscale processes, such as the diurnal cycle of convection, low-level moisture transport, propagation and organization of convection, and surface-moisture recycling. In general, these are poorly represented in global atmospheric models, and better captured in the regional models. Preliminary simulations show that WRF-downscaled simulations can provide a more realistic representation of convective rainfall processes. Thus, a regional climate model (RCM) can potentially add significant value in climate projections of the warm season, provided the downscaling methodology incorporates spectral nudging to preserve the variability in the large-scale circulation while still permitting the development of smaller scale variability in the RCM. With this condition, downscaled simulations can produce realistic continental-scale patterns of warm-season precipitation. This includes a reasonable representation of the North American monsoon in the Southwest United States and northwest Mexico, which is notoriously difficult to represent in a global atmospheric model. We anticipate that this research will help lead the way toward substantially improved projections of North American summer climate with a RCM.

A Software Developer's Perspective on Integrating Spatially Explicit Models (oral presentation)

By David I. Donato[1]

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

Spatially explicit models tend to be both data intensive and computation intensive. For this reason, such models are generally and necessarily implemented with the complex computer software required to carry out millions of processing iterations over voluminous geographic rasters, sets of agents, components of physical systems, numerous time steps, and multiple Monte Carlo trials. Thus, the problems of integrating or coupling distinct, spatially explicit models include integrating the models in software and can be neither fully understood nor solved without due consideration for the constraints and possibilities of model integration in software. The methods, materials, tools, and concerns of the coupling and integration of spatially explicit models, particularly of the integration of land-change models with physical environmental models, will be surveyed and discussed from the perspective of a software developer. The discussion will distinguish coupling from integration and will cover modeling languages and frameworks, operating environments, intersystem and interprocess communication, points of contact among models, software-development costs and constraints, design trade-offs, and computational efficiency.

Simulation of Near-Surface Hydrologic Response and Slope Failure Assessment at the Coos Bay, Oregon Experimental Catchment (oral presentation)

By Brian A. Ebel[1] and Keith Loague[2]

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

[2]Geological and Environmental Sciences, Stanford University, Stanford, Calif.

Shallow landslides present a natural hazard to human life, the built environment, and ecosystems. While prevailing conceptual models of failure initiation rely primarily on the reduction of effective stress by positive pore-water pressure development, recent research has demonstrated that capillary stress reduction from declines in matric suction can also trigger shallow slope failure. The growing field of hydrogeomorphology emphasizes the role of hydrologic drivers of slope instability, regardless of whether a given failure is triggered by unsaturated- or saturated-zone mechanisms. The most promising protocol for improving the methodology of hydrologically driven slope-stability assessment is the “measure and model” approach, which employs field observations and measurements to parameterize and evaluate models.

Here we present an application of the measure and model paradigm at the Coos Bay Experimental Catchment in the Oregon Coast Range, U.S.A.. The hydrologic response to three controlled sprinkling experiments and 6 years of natural storms was simulated using the Integrated Hydrology Model (InHM). InHM employs the finite-element method to solve the fully coupled governing equations of three-dimensional variably saturated subsurface and two-dimensional surface-water flow and solute transport. The hydrologic model was parameterized using estimates of saturated hydraulic conductivity, porosity, and in-situ hysteretic soil-water retention curves. Detailed comparisons of simulated results against observations of discharge, matric potential, soil-water content, total head, and tracer concentrations facilitate a diagnostic assessment of model performance. Slope stability is evaluated using the relatively simple infinite slope model for variably saturated soils driven by the simulated pore-water pressures. The slope-failure assessments focus on a November 18, 1996 storm with a total rainfall of 225 millimeter (mm) and a peak intensity of 40 mm/hour, which initiated a debris flow.

Hydrologic-response simulations were conducted for the failure-initiating storm using a hysteretic soil-water retention curve in addition to the primary wetting curve, the primary drying curve, and an intermediate (or “mean” curve) between the primary wetting and drying relationships. Comparison between simulated slope-failure potential at the Coos Bay site for the different soil-water retention curve scenarios suggests that (1) employing the drying soil-water retention curve or a mean of the primary wetting and drying soil-water retention curves underestimates failure likelihood; (2) the wetting soil-water retention curve, which is seldom measured, is more appropriate when hysteresis cannot be considered; and (3) unsaturated zone storage provides an important control on failure initiation and sets the stage for fracture-flow-driven triggering of instability at the Coos Bay site.

A Brief Introduction to Inverse Modeling (oral presentation)

By Karl J. Ellefsen[1] and Claire R. Tiedeman[2]

[1]U.S. Geological Survey, Denver, Colo.

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

Inverse modeling is a powerful tool for developing and calibrating simulation models used in the earth sciences. It is based on a model of a physical system that includes observable inputs to the system, observable outputs of the system, a well-defined mathematical relation between the inputs and the outputs, and parameters that specify the mathematical relation. The goal of the inverse modeling is to estimate those parameters using the observable inputs and outputs. There are two general methods of estimating the parameters: maximum likelihood estimation (including its many variations) and Bayesian inference. During inverse modeling, several key questions must be considered: Is the model a suitable representation of the physical system? How sensitive are the model parameters to the data? How do noise and measurement error in the inputs and outputs affect the estimated model parameters? How uncertain are the estimated model parameters? If using maximum likelihood estimation, has the optimal model been found? Inverse modeling and the related methods of sensitivity analysis and uncertainty evaluation provide tools to help answer these questions. For example, these methods enable improved understanding of the processes governing the physical system dynamics, effective data-model integration, and evaluation of the uniqueness of model parameters. Models developed with inverse modeling usually represent better the physical system than models developed with trial and error.

Scaling Plant Water Use from Organs to Ecosystems in Semiarid Shrub and Forest Ecosystems Responding to Drought and Bark Beetles (oral presentation)

By Brent E. Ewers,[1] Elise Pendall,[1] David Reed,[2] Bhaskar Mitra,[3] David S. Mackay,[3] Julia Angstmann,[1] Kusum Nathani,[1] Holly Barnard,[4] Timothy Aston,[1] Urszula Norton,[5] David Williams,[6] and Ramesh Sivanpillai[7]

[1]Department of Botany and Program in Ecology, University of Wyoming, Laramie, Wyo.

[2]Program in Ecology, Department of Atmospheric Science, University of Wyoming, Laramie, Wyo.

[3]Department of Geography, SUNY-Buffalo, Buffalo, N.Y.

[4]Department of Renewable Resources, University of Wyoming, Laramie, Wyo.

[5]Department of Plant Sciences, University of Wyoming, Laramie, Wyo.

[6]Department of Renewable Resources, Botany and Program in Ecology, University of Wyoming, Laramie, Wyo.

[7]Department of Botany and WyGISC, University of Wyoming, Laramie, Wyo.

Predictive understanding of semiarid ecosystem water use from remote-sensing models will be greatly improved by cross-scale validation applying mechanistic measurements at the leaf-to-watershed levels. To address this validation, our questions are the following: What plant structure scalars work best for moving from organs to stand transpiration? Is the spatial patterning of transpiration predictable from plant structure and (or) temporal drivers? To answer these questions, we have focused on an elevation gradient from seasonally drought prone sagebrush dominated basins through bark beetle-impacted montane and subalpine forests of Wyoming. In each of these ecosystems, we have employed a combination of plant leaf gas exchange, sap flux and eddy covariance approaches to quantifying transpiration and evapotranspiration. In sagebrush ecosystems, we have found that plant leaf area from shrub allometric relationships scales water use well in stands greater than 40 years old whereas younger stands require additional herbaceous plant estimates. In contrast, sapwood area is a better scalar than leaf area in the forested areas. This scalar becomes even more prominent with bark beetle infestation because sapwood changes from blue-stain fungi occlusion of xylem (causing a 50-percent reduction in transpiration) are detectable months before leaf area changes. These scalars were further evaluated by showing that spatial autocorrelation in leaf area in the sagebrush stands was ca. 2 m and sapwood area in the forests was ca. 30 m. In the forest, spatial autocorrelation in transpiration linearly declined from

60 to 20 m as vapor pressure deficit increased from 0.5 to 2.0 kilopascal (kPa). This finding can be predicted from hydraulic transport mechanisms. In sagebrush ecosystems, soil moisture below 45 centimeters (cm), driven by spring moisture, was the dominant driver of evapotranspiration and has been further verified with watering experiments. These spatial and temporal drivers of transpiration are being tested in the Terrestrial Regional Ecosystem Exchange Simulator (TREES) model. Scaling within stands is tested through stable isotopes of soil, plant tissue, and water vapor. Scaling beyond the stand level is being evaluated through Remote Sensing platforms, including Aerocam, Landsat, and the moderate resolution imaging spectroradiometer (MODIS).

Realistic, Stochastic, and Geologic Modeling Capabilities (poster)

By Michael Fahy[1]

[1]Evergreen, Colo.

Aquifer heterogeneity, which includes flow and transport, is primarily controlled by the spatial distribution and connectivity of hydrofacies. A typical best-practices model-construction workflow first models the facies as geologic objects with realistic connectivity and then populates the discretization of each facies with its corresponding specific porosity and permeability distributions (facies parameters). This model construction is currently constrained by the limitations of the one- and two-dimensional tools based on two-point statistics (variogram).

Variogram-based simulation techniques, such as transitional probability (TPRoGS), allow construction of facies models conditioned to borehole geologic and geophysical data, but the simulated depositional elements often do not look geologically realistic. As an example, the statistical correlation of two points is not sufficient to model curvilinear or long-range, continuous facies bodies such as sand channels.

Multiple-point statistics (MPS) combines the ability to simulate the shapes of geologic objects with the speed and ease of data conditioning provided by the variogram-based techniques. A two- or three-dimensional training image is used to infer a higher order of MPS. MPS extracts patterns characterized by MPS moments from the training image and anchors these patterns to the borehole data.

In areas of sparse data, a geologist’s interpretation of borehole data and depositional setting may be required to control the spatial distribution of the simulated facies between the boreholes. Facies depositional modeling (FDM) allows the modeler to quantify such information into a facies probability cube that can be spatially variable in order to constrain the MPS model.

The images compare simulations of similar channel network geologies: the first image, using a MPS simulation of a channel network, matches the relative proportions and simulates the connectivity of the geologic objects. The second image, using a TPRoGS realization (plan view), matches the relative proportions of facies as well as the local teo-point transitional probabilities, but does not simulate well the connectivity of the geologic objects.

Putting the Parameters in Parameter Estimation (oral presentation)

By Michael N. Fienen[1]

[1]U.S. Geological Survey, Middleton, Wisc.

A key decision made as part of any model parameter estimation effort—in groundwater or otherwise—is the selection of a parameterization strategy. This decision has profound ramifications on many aspects of the parameter estimation, including numerical stability, computational expense, and solution quality. This work focuses on benefits gained from parameter flexibility and illustrates important implications for the use of prediction uncertainty for the acquisition of new observations.

Hadamard (1902) discussed three aspects that, when met, result in well-posed problems. These are existence, uniqueness, and stability of a solution. Existence is generally met in groundwater applications, but both uniqueness and stability pose challenges.

To overcome a lack of uniqueness and stability, practitioners have traditionally reduced the number of unknown parameters to fewer than the number of field observations. Rather than regarding these as discrete, it is useful to consider the amount of information contained in observations that is imparted on parameters through the estimation process. In this way, even with a large and distributed parameter field, a combination of field observations and soft knowledge (expressed as pseudo-observations) can be specified to meet the *conditional* uniqueness requirement in that an estimated set of parameters is unique, conditional upon the data used for the estimation process. This conditionality is explicitly considered in a Bayesian context, but extends beyond mathematical formalism.

Retaining distributed parameter fields can result in great computational expense, and flexibility is accompanied by the possibility of overfitting, resulting in unrealistic parameter estimates. Luckily, the computational expense can be overcome through parallel computing owing to the embarrassingly parallel nature of the computations, and recent advances in cloud computing, accompanied by appropriate tools, have made this power accessible to all practitioners. The problem of overfitting is addressed by balancing soft knowledge with the field observations in such a way that the hydrogeologic understanding of the practitioner plays a direct role in guiding the parameter estimation.

Recent work has explored the role played by parameterization in the use of prediction uncertainty in designing efficient strategies for acquiring new information to calibrate the model. Following a Bayesian approach, a prediction made by a model is also conditional on the data used to calibrate the model. This can be formulated such that data are evaluated using their effect on the certainty of model predictions. This serves two important purposes: first, it recognizes that a model should be designed with a specific objective (prediction) in mind; and second, field campaigns can be designed such that observations that best meet the objective of the model are given priority. While several approaches to this are possible, and some are more expensive than others, linear propagation of uncertainty has been shown to be a useful compromise between expense and rigor. However, when a model is restricted in its flexibility through limiting the number of parameters, spurious results are possible.

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Using Noise Model Simulation (Nmsim) as a tool for resource management decisions In National Parks (oral presentation)

By Charlotte D. Formichella,[1] Kurt Fristrup,[2] and Damon Joyce[2]

[1]Colorado State University, National Park Service Natural Sounds Program, Fort Collins, Colo.

[2]National Park Service, Natural Sounds Program, Fort Collins, Colo.

The National Park Service (NPS) Natural Sounds Program (NSP) office was established in 2000 to help parks manage sounds in a way that protects park resources and provides access and enjoyment for visitors.

Management of NPS acoustical environments is an increasingly important issue, and visualizing noise impacts through models is one method of conveying acoustical information in an approachable way. Models such as Noise Model Simulation (NMSim) that can simulate sonic conditions in a park can facilitate understanding of complex scenarios, and have great potential to inform the decisionmaking process. NMSim utilizes topography, ground impedance, ambient sound levels, and custom source spectra to generate spatially explicit animations of vehicle and aircraft-noise propagation through space and time. The NSP has been generating NMSim models for several national parks. This presentation will give a case in which NMSim is used to investigate the impacts of different vehicle types (cars, motorcycles, and buses), as well as a second case focusing on aircraft noise.

At Glacier National Park (GLAC), backcountry hikers have reported hearing vehicle and motorcycle noise at remote locations. Several models were generated in NMSim to explore noise propagation of different vehicle classes, including a customized motorcycle-noise class based on field measurements of vehicle-noise characteristics. The second study focuses on aircraft in Grand Teton National Park (GRTE). NMSim allows researchers to investigate the noise impacts of known flight routes and aircraft types.

Both GLAC and GRTE points of interest (overlooks and campgrounds) were included in the models. This allows for the generation of metrics such as the number of minutes that a single noise event is audible at given locations. These metrics, combined with noise propagation animations, are excellent ways to explain and visually represent noise impacts.

These studies demonstrate that NMSim is capable of providing a wide range of robust quantitative results. They also underline NMSim's ability to clearly and efficiently convey these results to scientists, planners, and managers alike.

Groundwater Flow Model of Bainbridge Island, Kitsap County, Washington (poster)

By Lonna M. Frans[1] and Matthew P. Bachmann[1]

[1]U.S. Geological Survey,Tacoma, Wash.

The U.S. Geological Survey Washington Water Science Center, in cooperation with the City of Bainbridge Island, is developing a numerical model of groundwater flow for Bainbridge Island. Local stakeholders have raised concerns that residential development and increased domestic water usage might lower the water table of Bainbridge Island, and lead to seawater intrusion. This project focuses on the effects of groundwater withdrawals on the Island's aquifers.

Data collection for the project included establishing a groundwater and surface-water monitoring network. The network allowed for determining base-flow stream discharge in 20 streams and monitoring monthly or continuous water levels in more than 70 domestic and unused wells. Drillers' log data were interpreted and paired with a digital elevation model derived from light detection and ranging (LIDAR) data to construct a hydrogeologic framework for the model.

The numerical flow model SEAWAT, which combines MODFLOW and MT3D, was used to simulate variable density groundwater flow. The model includes well withdrawals from domestic- and public-supply systems, recharge modeled using the Deep Percolation Model and augmented by septic-return flows, stream and lake boundary conditions, and submarine discharge to Puget Sound. The model was calibrated to monthly transient conditions using the water levels collected as part of the monitoring network and parallel parameter estimation (PPEST), and is being used to simulate hydrologic conditions that are expected to exist in the year 2035 under different management scenarios.

Downscaling from Regional Climate Models to River Hydrodynamics for Use in Multiscale Modeling of Riverine Ecosystems and Responses of Fish Populations (oral presentation)

By Kristie J. Franz,[1] Mark L. Wildhaber,[2] Christopher K. Wikle,[3] Christopher J. Anderson,[4] and Scott H. Holan[3]

[1]Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa

[2]U.S. Geological Survey, Columbia, Mo.

[3]Department of Statistics, University of Missouri—Columbia, Columbia, Mo.

[4]Climate Science Initiative, Iowa State University, Ames, Iowa

Changes in discharge, channel morphology, water quality, and biota have been implicated as causative agents in dramatic declines in Missouri River native fishes, in particular, pallid sturgeon (*Scaphirhynchus albus*) (Hesse and Sheets, 1993). Understanding potential impact that climate change may have on sustainable fish populations resulting from changes in river dynamics will be critical to any attempts at recovery of the Missouri River ecosystem.

Downscaling regional climate models to river systems requires translating climate variables, such as air temperature and precipitation, to water temperature and discharge, commonly through use of hydrologic models. Reliance on a single model often leads to predictions that represent some phenomenon well at the expense of others (Duan and others, 2007). Varying strengths and weaknesses of individual models in capturing physical processes in the catchment prevent the ability to convincingly declare any one model to be the "best" (Smith and others, 2004; Beven, 2006). To account for the uncertainty introduced by structural errors inherent in any model, we will use several hydrologic models to produce watershed runoff at key locations along the Missouri River. Models will range in complexity from simple watershed-based models available in the U.S. Army Corps of Engineers Hydrologic Modeling System to the grid-based Variable Infiltration Capacity model (Woods and others, 1997).

Multiple hydrologic models will provide an ensemble of runoff simulations to link with a hydraulic model for stream-level simulations. Translating watershed runoff into river temperature and discharge is being done through one-dimensional models such as CHARIMA (Wright and others, 1999); statistical downscaling (Vrac and others, 2007); or development of empirical relationships between watershed runoff and temperature and mainstem discharge and temperature (Larson and Schwein, 2004). We are developing discharge distribution uncertainties based on runoff information from the previous stage using a deterministic model for river depth and velocity.

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Intelligent Post-Fire Hydrologic and Geomorphic Landscape Modeling (poster)

By Michael J. Friedel[1]

[1]U.S. Geological Survey, Denver, Colo.

Few studies attempt to model the range of possible hydrologic and geomorphic responses following rainfall on a burned basin. Some reasons are the sparseness of data and the complex-coupled, nonlinear, spatial, and temporal relationships among response, initiation, and process variables. In this paper, an unsupervised artificial neural network (ANN) model is developed and used to project multidimensional data from 606 burned basins in the western United States onto a two-dimensional grid called a self-organized map (SOM). The sparsely populated dataset included independent numerical landscape categories (weather, land surface form, geologic texture, and post-fire condition); independent landscape classes (bedrock geology and state name); and dependent categorical classes (flooding, sediment flows, landslides, and debris flows). Based on pattern analysis visualized in SOM-based component planes and U-matrix, the relationships among explanatory and response variables were extracted and interpreted. Stochastic cross-validation of the ANN model demonstrated its ability to provide globally unbiased predictions of likely initiation processes (runoff, landslide, and runoff-and-landslide combination) and responses (debris flows, floods, and no events) following rainfall on burned basins, and to quantify the degree of uncertainty in which false positives and negatives occurred. In addition, application of the Davies-Bouldin criteria to *k*-means clusters of the SOM neurons identified eight conceptual post-fire regional models. These models represent hypotheses of coupled and nonlinear post-fire hydrologic and geomorphic landscape interaction. These conceptual models provide a basis for future development of regional, predictive models using empirical, numerical, and other intelligent discovery techniques.

Forecasting Climate Change Effects on Groundwater Recharge Using an Unsupervised Artificial Neural Network (poster)

By Michael J. Friedel[1]

[1]U.S. Geological Survey, Denver, Colo.

Optimal groundwater resource management under changing climate requires knowledge of the rates and spatial distribution of recharge to aquifers. This paper presents an alternate methodology to estimate recharge from available and uncertain hydrologic, land-use, and topographic information without long-term monitoring. The method was applied to twelve basins in southeastern Wisconsin where recharge observations were determined using a recession-curve-displacement technique and normalized by annual precipitation. Uncertainty was introduced and correlation preserved among these explanatory and response variables using a Monte Carlo (MC) technique. An unsupervised artificial neural network algorithm reduced dimensionality by projecting common patterns among the MC realizations onto a two-dimensional self-organized map (SOM). Fitted data vectors in the SOM were used to estimate normalized recharge ratios that compared well with the observations and published results based on a linear multivariate model. The effects of climate change on spatial recharge were estimated using the model and precipitation extremes associated with the El Niño southern oscillation. This new methodology provides an alternative approach to forecasting the effects of climate change on groundwater resources in basins with perennial streamflow.

Intelligent Exploration for Shallow Groundwater in Fractured Rock Systems (poster)

By Michael J. Friedel[1]

[1]U.S. Geological Survey, Denver, Colo.

It is not possible to predict well yield in the semi-arid climate and fractured crystalline rocks of northeastern Brazil by traditional groundwater modeling. For this reason, an alternative paradigm is used in which the relations associated with a sparsely populated set of hydrogeologic data (electrical conductivity, geology, temperature, and well yield) and airborne geophysical measurements (electromagnetic, magnetic, and radiometric) are found using the self-organizing map technique. Selected variables exhibiting a statistically significant relation to well yield are then used with symbolic regression to discover predictive models based on evolutionary heuristics. An objective function that simultaneously maximizes fitness and minimizes root-mean-squared error identifies the best well-yield models evolved from unprocessed, processed, and mixed sets of the airborne measurements. All models exhibit unbiased predictions that are within a few percent of the known well-yield observations. Estimates of nonlinear uncertainty limits reveal that models evolved from processed measurements may result in a biased prediction at low well yields (<1 $m^3\ hr^{-1}$; m = meter, and hr = hour). For a particular combination of model and measurement type, the computed range of prediction uncertainty generally is reduced when increasing the number of measurement variables. The best well-yield predictor is a function of three unprocessed airborne electromagnetic measurement variables. These findings suggest that the combination of data mining, knowledge discovery, airborne electromagnetic measurements, and predictive analysis may provide a low-cost alternative to traditional modeling in challenging groundwater environments, such as semi-arid and fractured rock aquifers in northeastern Brazil.

Post-Fire Debris Flow Prediction Using a Two-Step Hybrid Approach (poster)

By Michael J. Friedel[1]

[1]U.S. Geological Survey, Denver, Colo.

The prediction of debris-flow generation from burned basins is not easily conducted using traditional modeling approaches. This study explores the efficacy of using an alternative modeling paradigm based on a two-step hybrid approach. First, data mining by the self-organizing map technique is used to identify statistically significant variables comprising conceptual multistate models of the Western United States. Second, the conceptual model variables are used as information from which the genetic programming technique discovers predictive post-fire debris-flow peak discharge and total-volume equations based on evolutionary heuristics. The search space is constrained using a multicomponent, objective function that simultaneously maximizes fitness and minimizes root-mean-squared and unit errors for the discovery of fittest equations. Equations associated with the lowest root-mean-squared-error (RMSE) values tend to be physically unrealistic and associated with the largest unit errors. By accepting larger RMSE values, the equations are physically realistic, parsimonious with respect to the function set, and dimensionally correct. In contrast to the published multiple linear regression (MLR) equations, the hybrid modeling approach discovers equations whose predictions of post-fire debris-flow peak discharge and total volume are unbiased and better related to observations, and have less prediction uncertainty. For example, the estimated minimum-to-maximum total-volume prediction uncertainty for the MLR equation spans a factor of about 6, whereas the average for discovered equations spans a factor of about 2. Further reductions in prediction uncertainty may be possible when dimensional consistency is not a priority and by subsequently applying a gradient solver to fittest solutions.

Development of Regional-to-National-Scale Mineral Environmental Assessment Methodologies (oral presentation)

By Thomas P. Frost,[1] Geoffrey S. Plumlee,[2] Mark J. Mihalasky,[1] and Carma A. San Juan[2]

[1]U.S. Geological Survey, Spokane, Wash.

[2]U.S. Geological Survey, Denver, Colo.

The U.S. Geological Survey's Mineral Environmental Assessment Methodology Project (MEA) is developing, as one of a number of products, geospatial and nonspatial methodologies to identify and evaluate potential environmental impacts associated with unmined mineral deposits, mineral exploration, and future development of a diverse suite of mineral deposit types in various geological and environmental settings, and at national, regional, and watershed scales. The methodologies integrate process-based knowledge, developed at the watershed and finer scales, with regional data on geology, lithology, mineral deposits and deposit models, topography, climate, water quality, remote sensing, geophysics, vegetation, ecology, as well as the number and nature of other potential environmental stressors (that is, unremediated historical mine sites, logging, roads, or other land uses).

The geographic information system (GIS) component of the methodology will provide information and detail appropriate for the scale at which the user is most interested. Analyses made at scales finer than the decision-space can easily be aggregated to match a coarser decision space, whereas analyses made at scales coarser than the decision space cannot be easily disaggregated, and usually must be redone to be useful. For example, the methodology will focus primarily on information appropriate for 12-digit hydrologic unit subwatersheds, as this is a common scale at which decisions are made by land management agencies (LMAs). But to maximize the utility to the LMAs, the approach will also provide coverage and information aggregated for broader scales, such as for 10- and 8-digit hydrologic units across larger regions.

At the regional scale, a prototype MEA methodology is being developed based on information compiled for six southwestern States (California, Arizona, New Mexico, Colorado, Utah, and Nevada). One aspect of the GIS approach will be the development of watershed-carrying capacity maps, which will provide a qualitative to semiquantitative indication of watershed sensitivity to potential environmental impacts from unmined mineralized areas and from future mining. Premining environmental baseline maps will show naturally impacted watersheds, based on known deposit types and watershed-carrying capacity.

The MEA prototype methodology will be linked to the 1996 National Mineral Resource assessment permissive tracts for selected mineral deposit types. The prototype will be used to test a variety of methodologies, identify data gaps, determine appropriate scales of assessment and delivery, and investigate the extent to which a rigorous, quantitative approach can be applied practically to broader scales. The methodology will then serve as the basis for a national mineral environmental assessment that will accompany the upcoming new National Mineral Resource Assessment, scheduled to begin in 2012.

Modeling Urban and Exurban Development in Response to Land-Use Decisions on Public Lands (oral presentation)

By Steven L. Garman,[1] David J. Hester,[1] and Mark R. Feller[1]

[1]U.S. Geological Survey, Denver, Colo.

Land-use policies on public lands can influence social, economic, and demographic properties of adjacent towns and cities, and mediate rates and patterns of urban and exurban development. Gateway communities in proximity to the extensive lands administered by the Bureau of Land Management (BLM) in the Western United States are especially sensitive to Federal oil and gas and renewable-energy development policies. Recognizing this, the Grand Junction, Colo., BLM field office has proposed to use community-growth forecasts of different land-use strategies (energy development vs. conservation emphasis) to assess alternatives in the resource management planning process. To assist in this assessment, we developed a model to simulate the dynamics of urban and exurban development that uses agent-based modeling concepts to integrate socio-economic, demographic, and human preferences with biophysical features of land-uses on public lands. The model was developed specifically for the Grand Valley region of Colorado, and uses readily available land parcel data to determine sub-division potential of residential and agricultural land types. Each land parcel is additionally attributed with key biophysical features such as distance from roads and average percent slope. Annual housing needs are driven by regional socioeconomic factors, local socioeconomic factors that are influenced by BLM land-use decisions, and human life-cycle stage of existing and new households. Location of housing developments is determined by three factors: potential attractiveness, accessibility, and housing density of focal and neighboring parcels. Potential attractiveness is scored from viewshed assessments of scenic natural features and of proposed land uses on surrounding BLM lands. Accessibility is based on the minimum distance from roads. These three factors are weighted according to preferences of household agents, where an agent represents the socioeconomic and life-cycle stage of existing or new households. Historic trends in numbers and types of household agents and preferences of agents can be estimated from retrospective assessments and used in future forecasts. These properties also can vary temporally in response to projected variation in socioeconomic drivers, and based on different assumptions about how these drivers influence human demographics and housing preferences. The model outputs annual projections of numbers and acreage by residential and multifamily housing types, acreage of remaining undeveloped lands such as agricultural lands, and maps of subdivision frequency and housing density. We are applying this model to evaluate the effects of four BLM land-use scenarios on urban and exurban development over the next 30 years in the Grand Junction BLM planning area. Scenarios include no change from the past, a balanced resource extraction (oil and gas extraction) and conservation strategy, a conservation strategy, and a resource extraction strategy. In this presentation, we provide an overview of the parcel-based land-use change model, and results of simulations for the four BLM land-use strategies.

Two-Phase Debris-Flow Computations that Include the Evolution of Dilatancy and Pore-Fluid Pressure (oral presentation)

By David L. George[1] and Richard M. Iverson[1]

[1]U.S. Geological Survey, Vancouver, Wash.

Pore-fluid pressure plays a crucial role in debris flows because it counteracts normal stresses at grain contacts and thereby reduces intergranular friction and enhances bulk-flow mobility. Two-phase debris-flow models typically assume that pore-fluid pressure has both a hydrostatic component and a nonhydrostatic component that are established by initial conditions and dissipated diffusively in response to debris compaction driven by gravity. These models lack a key ingredient, however: explicit evolution of solid and fluid volume fractions coupled to changes in flow dynamics. This evolution is particularly important during the initial stages of debris-flow motion, when it is responsible for pore-pressure feedbacks that influence the balance of forces governing downslope acceleration. As a result of these feedbacks, a water-laden sediment mass can either creep stably or mobilize into a high-speed flow.

Here we summarize the rationale and predictions of a new depth-averaged debris-flow model that accounts for coupled evolution of flow dynamics, solid and fluid volume fractions, and pore-fluid pressure by combining approaches previously used to model landslides, debris flows, submarine granular avalanches, and other dense granular flows. The model's structure is also consistent with a long-established tenet of critical-state soil mechanics: Solid and fluid volume fractions evolve toward values that are equilibrated to the ambient state of effective stress and deformation. Dilatancy, pore-fluid pressure, and frictional resistance evolve as a consequence.

To emphasize physical concepts and minimize mathematical complexity, we focus on depth-averaged, one-dimensional motion of a two-dimensional debris flow descending a rigid, uniformly inclined, impermeable slope. Using finite-volume numerical methods that are well suited for solving hyperbolic problems, we compare computational predictions of the behavior of such a flow to data from large-scale experiments at the U.S. Geological Survey debris-flow flume. Model predictions exhibit rapid evolution of pore-fluid pressure coupled to contraction (negative dilation) of loose debris during the first few seconds of motion, leading to positive feedback that enhances flow acceleration. At later times, motion is stabilized by relatively steady pore pressures that eventually decay to hydrostatic values.

Identification of Concealed Lithologies from Disparate Data Layers Using Possibility Theory (oral presentation)

By Mark E. Gettings[1]

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

As part of the U.S. Geological Survey's Assessment Techniques for Concealed Mineral Resources Project, possibility theory has been evaluated as a method for identification of buried lithologies by comparison with the possibility distributions of measures of nearby exposed "candidate terranes." Possibility theory is a general theory of the possibility of occurrence of events in the presence of both uncertainty and knowledge that is less than complete. The possibility of an event is a continuous variable between zero and one rather than a binary off or on as in probability. Thus, any geologic variable, such as degree of fracturing or percentage of a particular lithology in a formation, can be represented. Probability theory is a subset of possibility theory where the possibility function has only nonzero values at zero (not present) and one (present with absolute certainty). Because of this, probability theory cannot distinguish the case of total lack of knowledge from certainty, whereas possibility theory is able to make the distinction.

Possibility functions based on quantitative data (for example, a histogram of anomaly amplitudes) are directly computed from the appropriate mathematical transformation and thus are objective. Possibility functions based on qualitative, linguistic, or subjective data are quantified by simple rules with uncertainties reflecting both the variability of the property and the degree of knowledge of that property. Estimates from possibility theory are conservative and automatically include uncertainty in the criteria estimates; moreover, they overcome the sharp boundary problem of interval analysis. The theory allows logical combinations of the possibility functions for quantitative, semiquantitative, and qualitative measures; thus, many disparate data types can be utilized in the decision process. For quantitative areal data (for example, aeromagnetic, gravity, and electromagnetic surveys), measures within the target and candidate areas that have been used include the distributions within a moving window of the following: anomaly amplitudes; total number of extrema; elongation ratio (peaks or troughs/all extrema); maximum curvature strike and strike standard deviation; and anomaly surface area. All of these measures contribute useful information for identifying terrane lithology and at least in the study area coincidentally identified some ordering of tectonic events. For semiquantitative and qualitative (subjective) data, geological map and structural interpretations, trends and distributions of geochemical data, and mineral resource occurrence are used to contour possibility in a spatial (map) distribution. Logical combinations of the various measures (for example, "A and B and C or D not E") determine a final possibility distribution for each candidate terrane. These distributions determine the overall ranking of the candidate lithologies for the target area.

Two examples over covered targets in the Santa Cruz Valley in southeastern Arizona unambiguously identified the targets as intrusive diorite in one case and Tertiary volcanic flows in the other. Combining qualitative geologic, mineral occurrence, and geochemical data with the quantitative geophysical data allows a quantified prospectivity estimate.

A Proposed Geochemistry Data Model (poster)

By Stuart A. Giles,[1] Matthew Granitto,[1] Carma A. San Juan,[1] Dorothy M. Trujillo,[1] and Robert G. Eppinger[1]

[1]U.S. Geological Survey, Denver, Colo.

We propose a data model to be used as a framework for geochemical databases, as a data structure for geochemical modeling, and for use in geographic information systems. This model is an outgrowth of a Microsoft Access database structure developed for and successfully utilized in USGS Mineral Resources Program projects.

The model contains two primary tables—FieldSite and Sample—that are the bilateral core around which tables of environment descriptions and analytical results are associated. Information pertaining to the sample location and its physical environment is managed through the FieldSite table, which links to tables containing data about the environment at large, such as climate, topography, geology, hydrology, ground cover, and ecosystems. Information pertaining to the chemical analyses of samples is managed through the Sample table, which links to table groups recording analytical results and associated information, such as quantitative and qualitative values, laboratories, and analytical methods and parameters. Optional ancillary tables in the model include publication references for sample sites and environmental data, and tables recording quality-assurance and quality-control data. The data model also includes a Field Name Dictionary, a standalone metadata table incorporated into the general database structure that describes all the database fields and lists all the tables that contain a particular field.

The analytical data are provided in two different table groups to facilitate different data access and query approaches. The first group consists of tables that contain aggregates of all analytical results, and the second group comprises individual tables generated for each analytical method. This duplication was designed to provide flexibility in querying, and allow the export of tables to other tabular software formats that cannot manage large datasets.

The simple structure of this data model provides a flexible interface to (1) manage large amounts of multielement geochemical data determined by many methods, (2) explore the relationships of geochemistry with various environmental factors, and (3) obtain information on the range of methods and quality of results. The architecture supports a full spectrum of geochemical and geospatial modeling and analyses, and can be implemented in several database platforms, including Microsoft Access, Oracle, and Environmental Systems Research Institute, Inc (ESRI) Geodatabases.

Vegetation Index Methods for Estimating Evapotranspiration by Remote Sensing (oral presentation)

By Edward P. Glenn[1] and Pamela L. Nagler[2]

[1]Environmental Research Laboratory, University of Arizona, Tucson, Ariz.

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

Most remote sensing methods for evapotranspiration (ET) have used thermal infrared bands on satellite sensors to measure surface temperatures to provide an estimate-sensible heat flux from the land surface. ET is then calculated as a residual in the Simplified Surface Energy Balance (SSEB) equation. Recently, simpler methods that use visible and near infrared (NIR) bands have been developed as alternatives to SSEB methods. Visible and NIR bands are used to calculate vegetation indices (VIs) that are used to estimate green foliage density over the landscape. In many agricultural and natural ecosystems, plant transpiration is the major component of ET and there is often a strong correlation between VIs measured by satellite sensors and ET measured at ground stations. VI methods cannot detect plant stress or bare soil evaporation; these must be estimated separately. This preliminary review discusses the need for VI methods for ET; their physical and biological justification; examples of different approaches and applications from agricultural and natural biomes; their limitations; and a synthesis of SSEB and VI methods, showing how they can be combined to provide maximum information about ET from vegetated landscapes.

Modeling Vadose-Zone Processes to Forecast Shallow Landslide Occurrence (oral presentation)

By Jonathan W. Godt,[1] Ning Lu,[2] Rex L. Baum,[1] and Basak Sener-Kaya[2]

[1]U.S. Geological Survey, Denver, Colo.

[2]Civil Engineering, Colorado School of Mines, Golden, Colo.

Operational forecasting of conditions conducive to shallow landslides are desired by organizations responsible for managing hazard and issuing warnings; however, hydrologic and mechanical processes in the vadose zone complicate such predictions. Infiltrating rainfall must typically pass through an unsaturated layer before reaching the irregular and usually discontinuous shallow water table. This process is dynamic and a function of precipitation intensity and duration, the initial moisture conditions and hydrologic properties of the hillside materials, and the geometry, stratigraphy, and vegetation of the hillslope. As a result, pore-water pressures, moisture content, effective stress, and propensity for landsliding vary over seasonal and shorter time scales. We describe a general framework for assessing the stability of slopes under variably saturated conditions. The framework includes profiles or fields of soil suction and moisture content combined with a general effective stress for slope stability analysis. The general effective stress, or so-called "suction stress," provides a means for rigorous quantification of stress changes due to rainfall and infiltration, and, thus, the analysis of slope stability over the range of moisture contents and soil suctions relevant to shallow landslide initiation. We apply the framework using a one-dimensional analytical solution for flow in the vadose zone combined with an infinite-slope stability analysis to examine the effect of soil hydrologic properties, antecedent soil moisture conditions, and rainfall intensity and duration on the timing of slope instability. For the limiting case of hydrostatic initial conditions and in which rainfall intensity is equivalent to the saturated hydraulic conductivity of the soil, results for hypothetical hillslopes composed of sandy and silty soils show that the timing of potential instability ranges from less than 36 hours to more than 20 days.

Modeling the Dynamic Geochemistry of Prairie Pothole Wetlands (oral presentation)

By Martin B. Goldhaber,[1] Christopher T. Mills,[1] Craig A. Stricker,[1] James W. LaBaugh,[2] David Mushet,[3] and Ned H. Euliss[3]

[1]U.S. Geological Survey, Denver, Colo.

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

[3]U.S. Geological Survey, Jamestown, N. Dak.

Spatial and temporal variation in soil and aqueous geochemistry are important landscape attributes that influence ecosystem processes, functions, and services, including the composition of biological communities. Here we focus on the geochemistry of the Cottonwood Lakes (CWL) area of Stutsman County, North Dakota. This study site has been the subject of intensive biologic, hydrologic, and geochemical research over many decades and is typical of the Prairie Pothole region of the north-central United States, which encompasses 5.3 million acres of wetlands. We are investigating the underlying controls on the very steep geochemical gradients that exist within these wetland systems, which are highly sensitive to climate and cycle between flooded and dry conditions. Geochemistry of individual wetlands can vary dramatically over distances of hundreds of meters from low salinity, rainwater-derived compositions in upland areas, to high salinity calcium, magnesium sulfate-dominated systems in adjacent lower elevation flowthrough, and groundwater discharge settings. The key processes involve a balance among inputs of rainwater and groundwater, soil-water interaction along flow paths, evapotranspiration, and biogeochemical processes. In order to understand this complex suite of processes, we are modeling the system using both inverse and predictive geochemical models. Inverse (mass balance) modeling using the U.S. Geological Survey code NetPath allows the quantification of the mass transfers that determine CWL water chemistry. Forward geochemical modeling allows prediction of the system behavior as major system variables change. To model geochemical processes, we utilize over a decade of data on wetland aqueous chemistry, archived water samples from a time period corresponding to drought recovery (1994–1996), and newly collected elemental (including trace elements), isotopic, and mineralogical data on the chemistry of Cottonwood Lake Area (CLA) waters, groundwaters, and soils. The geologic substrate is heterogeneous glacial till with a component of Cretaceous organic and pyrite-rich shale. Preliminary results indicate the oxidation of this pyrite or leaching of pyrite-derived gypsum during groundwater flow that yields isotopically light ($d^{34}S$ ~-20‰) sulfate that drives the wetland waters to a sulfate-rich end member. Concurrently, groundwater flow leaches calcium and magnesium from dolomite (as determined by x-ray diffraction) in the aquifer sediment. This interpretation is bolstered by statistical analysis of wetland chemistry that shows strong correlation among calcium, magnesium, sulfate, and lithium (lithium is strongly enriched in marine shale). Within the wetlands, the sulfate is microbially reduced to sulfide, which shifts the sulfur isotope value of sulfate to heavier values (maximum +4‰), while also leading to carbonate precipitation. The wetland water chemistry is further modified by evaporation, which causes the oxygen/deuterium isotopes of the water to evolve to heavier values (range for our data: $d^{18}O$ -10.7 to -2.3‰; dD -9.5 to -28.8‰). Small amounts of deeper groundwater, identified by the presence of chloride ion, enters distal groundwater discharge wetlands along the flow path, further modifying the wetland chemistry and adding potentially toxic arsenic and selenium. Knowledge of solute chemistry over drought and deluge cycles due to evaporation and dilution is needed to place wetlands into the proper context of processes driving wetlands to facilitate effective ecological interpretations of biological data.

Sedimentation of Prairie Wetlands Under Changing Climatic Conditions: Implications for Wetland-Dependent Avifauna (oral presentation)

By Diane Granfors,[1] Lucy Burris,[2] and Susan Skagen[3]

[1]U.S. Fish and Wildlife Service, Fergus Falls, Minn.

[2]Colorado State University, Fort Collins, Colo.

[3]U.S. Geological Survey, Fort Collins, Colo.

Agriculturally driven environmental change and global warming are major concerns in the conservation of prairie wetland landscapes, and in turn, for the conservation of wetland-dependent avifauna. Climate change models predict a warmer, wetter future for much of the Prairie Pothole Region (PPR), with warmer winters, earlier springs, and increased winter precipitation, particularly in the eastern PPR. Concurrent with a warming climate is the search for new energy technologies, and investment in biofuels has already increased the number of tilled acres throughout the PPR. Changing climate and increased agricultural production will have a direct impact on the millions of pothole wetlands that wetland dependent birds rely upon for foraging, brood rearing, and refueling during migration. Changing climate will affect water budgets and resulting habitat conditions, while changing land-use and precipitation patterns will increase erosion and wetland sedimentation.

As a tool for conservation, we are developing spatially explicit models to forecast the extent of erosion and wetland sedimentation in regions of the Great Plains of North America under future scenarios of precipitation, temperature, and land use. We are using the Revised Universal Soil Loss Equation, which is based on rainfall, erosivity, soil type, topography, and land use, to model sediment deposition into prairie wetlands. The amount of sediment entering wetlands (sediment delivery ratio) is inferred from empirical studies. Models use projections of future precipitation and temperature on an 8-km grid from downscaled climate models using Intergovernmental Panel on Climate Change (IPCC4) scenarios. To understand the implications of wetland change for migratory birds, we are building, refining, and applying spatially explicit landscape-scale niche models for wetland-dependent birds, including long-distance migrant sandpipers refueling in the prairie pothole region of North America. Under the climatic conditions of the past decade, millions of *en route* calidridine species foraged in seasonally flooded wetlands in the drier agricultural areas within the PPR, the wetland type most threatened by sedimentation.

Linking Landscape Characteristics to Local Grizzly Bear Abundance (oral presentation)

By Tabitha A. Graves,[1] Katherine C. Kendall,[2] J. Andrew Royle,[3] Jeffrey B. Stetz,[4] and Amy C. MacLeod[4]

[1]Northern Arizona University, School of Forestry, Flagstaff, Ariz.

[2]U.S. Geological Survey, West Glacier, Mont.

[3]U.S. Geological Survey, Laurel, Md.

[4]University of Montana, Cooperative Ecosystem Studies Unit, West Glacier, Mont.

Grizzly bear (*Ursus arctos*) habitat use has been extensively studied, but habitat has rarely been linked to demographic parameters, and habitat models have not accounted for variation in detection or spatial autocorrelation. We collected bear hair from bear hair traps and rub trees in and around Glacier National Park (GNP) in northwestern Montana and genotyped the samples to identify individuals. Counts of bears were formatted as a spatial mark-recapture dataset to estimate local abundance. We developed a hierarchical Bayesian model with (1) explicit landscape and habitat variables that we theorized might influence abundance, (2) separate submodels of detection probability for each sampling type, (3) covariates to explain variation in detection, (4) a conditional autoregressive term to account for spatial autocorrelation, and (5) weights to identify most important variables. Road density and percent mesic habitat best explained variation in female grizzly bear abundance, and the spatial autocorrelation term was not supported. Female abundance was higher where road density was lower and where more mesic habitat exists. Detection of females increased with rub tree sampling effort. Road density best explained variation in male grizzly bear abundance, and spatial autocorrelation was supported. More male bears occurred in areas of low road density. Detection of males increased with rub tree and hair trap sampling effort and decreased with time. Our finding that road density influences abundance concurs with conclusions of earlier studies that road density influences habitat use.

Normalized Difference Vegetation Index (NDVI)-Based Estimation of Evapotranspiration (oral presentation)

By David Groeneveld[1]

[1]HydroBio, Advanced Remote Sensing, Santa Fe, N. Mex.

Plant water use generally accounts for the largest proportion of evapotranspiration (ET); other components are interception losses and direct soil evaporation. Remote sensing of greenness using satellite data can assess spatial plant vigor using vegetation indices; however, many vegetation indices exist, some with large degrees of associated error.

The first step to build a greenness-based ET estimation method was to test which vegetation index (VI) performed best to track vegetation hydrologic response, while being resistant to accuracy-reducing atmospheric scatter and attenuation. Test data were assembled from a 17-year span (1986–2002) of mid-summer Landsat Thematic Mapper (TM) snapshots for San Luis Valley, Colo., that were processed to reflectance and corrected for atmospheric scatter. Data were then extracted and pooled from 2,953 pixels contained in 180 131-meter-diameter circles of homogeneous native phreatophyte alkali scrub where water tables had remained stable through the study period. All published VIs were calculated from this database for comparison to antecedent precipitation, a factor known to produce linear promotion of vegetation. Regression statistics (r^2 values) from the paired antecedent precipitation and average pixel-wise VI values were used to evaluate VI performance to predict the expected linear relationship. A stretched form of normalized difference vegetation index, NDVI, yielded superior results to all other VIs.

To fit an ET predictive relationship to NDVI, data measured by micrometeorological methods were obtained from three separate studies conducted in arid/semiarid shallow-groundwater environments in California, New Mexico, and Colorado. These locations have great diversity in (1) climate expression: monsoonal versus Mediterranean precipitation pattern; (2) comparatively long (versus short) growing seasons; and (3) vegetation cover: alkali scrub, shallow groundwater meadows, and monocultures of saltcedar and cottonwood. Annual total ET, (ET_a) measured from 24 site- and year-combinations were paired with NDVI extracted from corresponding locations in nine mid-summer Landsat Thematic Mapper 5 and 7 scenes during 1999–2002, with single mid-summer scenes used for estimation of annual ET_a. In a 1:1 relationship, NDVI was found to be a competent estimator of a derivation of ET, ET,* calculated by subtracting precipitation and normalizing by corrected reference ET (ET_0, minus precipitation). This relationship was used to estimate ET_a, derived solely from remote sensing and weather data. Residual error decreased at higher levels of ET_a and data scatter was well balanced, indicating lack of systematic error.

NDVI is proving to be a robust spatial scalar for ET but is only as accurate as estimates of ET_0. Formulations of NDVI can be used for estimation of groundwater discharge ET, and of crop water use in annual, or shorter, time segments.

Identification of Temporary Disaster Debris Management Sites Using Binomial Cluster Analysis (oral presentation)

By Stanislaw Grzeda,[1] Thomas Mazzuchi,[2] and Sahram Sarkani[2]

[1]Oak Hill, Va.

[2]George Washington University, Department of Engineering Management, Washington, D.C.

Considerable research continues to be devoted to understanding the nature and extent of disasters, primarily in an effort to plan, manage, simulate, and mitigate their effects. One critical aspect of disaster response and recovery research is the preselection of temporary disaster debris management sites (DMS). In addition to the basic DMS factors of ownership, size and location, Federal guidance also notes the need to address special considerations associated with environmental and historic preservation. These considerations arise from a host of Federal acts, agency regulations, executive orders and directives, which impose constraints on DMS locational requirements. States, counties, townships, and municipalities also implement local laws, regulations, and ordinances, typically derived off the United States Code (USC) and in many cases more restrictive, to reflect the specific needs of their citizens and local environment. These place further constraints on DMS.

As a result, the identification of potential debris management sites is a complex process, requiring the analysis of all relevant environmental and historic preservation issues to assure compliance to Federal and local constraints, while simultaneously assuring effective disaster preparedness. Physical site constraints include: land use, accessibility, wetlands, surface water, conservation areas, coastal boundary zones, soil suitability, floodplains, threatened species and habitats, seismic impact zones, unstable geology, and proximity to cultural point features. Because of this complexity, many regional, county, and municipal emergency management plans leave DMS selection to the response and recovery phases, typically periods of severely stressed resources. Thus, a consistent scalable, flexible, and adaptable procedure to identify potential disaster debris sites would enhance timely decisionmaking, provide for more effective response, and lead to more rapid stabilization for recovery activities.

The increased availability of geospatial, statistical, and system engineering applications, large data storage capacities, and respective county and Federal GIS datasets offers the capabilities of analyzing large amounts of combinatorial data to support identifying suitable DMS. A geospatial analysis can be conducted at the parcel level to determine each site's characteristics on a constraint presence or absence basis. Binary cluster analysis of the data matrix results in a classification of all sites, supporting DMS decisionmaking. The identification of temporary DMS prior to a disaster facilitates narrowing the potential range and more rapid identification of optimal sites; effective advanced readiness contracting to ensure contracts are in place; modeling, testing, and evaluating disaster debris scenarios to identify shortfalls; timely decisionmaking, improving response timing; and more rapid management and containment (stabilization) of immediate disaster impacts on community systems, enhancing recovery activities.

Effects of Climate Change on the Bioenergetics of Juvenile Salmonids and the Aquatic Ecosystem of the Yakima River Basin (oral presentation)

By Jill M. Hardiman,[1] Alec G. Maule,[1] Matt G. Mesa,[1] James R. Hatten,[1] Mark C. Mastin,[2] and Frank D. Voss[2]

[1]U. S. Geological Survey, Cook, Wash.

[2]U.S. Geological Survey, Tacoma, Wash.

We summarized data from water temperature models for the Yakima River Basin to explore the possible consequences of climate change on the growth of stream-rearing juvenile Chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss*. Climate change scenarios "downscaled" for the Pacific Northwest were modeled based on current temperatures, and air temperature increased by an average of 1 °C or an average of 2 °C. We used bioenergetics models, the results of water temperature models using the "downscaled" air temperature increases and information on fish size and diet in the Yakima River to model the effects of climate change on fish growth. We established a baseline scenario using existing information on temperature, diet, and fish size to evaluate the effects of temperature increases. With a constant diet and consumption rate, our simulations showed that fish living in the predicted warmer stream temperatures weighed substantially less than fish living in cooler temperatures by mid-summer, even though the warmer temperatures were within their tolerance range. We surmise that higher metabolic costs for fish inhabiting warmer waters will minimize the energy available for somatic growth. Thus, based on temperature effects alone, fish living in warmer waters will need to consume more to achieve historical sizes at time of outmigration, or perhaps they will need to modify life history characteristics (for example, out-migration timing). Further, earlier seasonal increases in river flows and the timing of freshets could affect activity levels of juvenile salmonids resulting in potentially higher activity costs and lower growth. Habitat model outputs, such as increased river velocities and warmer temperatures, along with bioenergetics modeling, suggest a habitat bottleneck could occur at the same time that fish growth is being affected. Collectively, negative growth and dwindling habitat will have a much more powerful, perhaps synergistic, impact on population viability than either variable alone. Expansion of favorable habitat conditions (that is, warmer water temperatures) for nonnative predators, such as largemouth *Micropterus salmoides* and smallmouth bass *M. dolomieu*, may further compound the negative effects of climate change on juvenile salmon populations.

Impacts of Disturbances on Ecological Carbon Sequestration and Greenhouse Gas Emissions (oral presentation)

By Todd J. Hawbaker,[1] Matt Rollins,[2]
James E. Vogelmann,[2] Hua Shi,[3] and Zhiliang Zhu[4]

[1]U.S. Geological Survey, Denver, Colo.

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

[3]ASRC Research and Technology Solutions (ARTS), Sioux Falls, S. Dak.

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

The U.S. Geological Survey is prototyping a methodology to fulfill requirements of the 2007 Energy Independence and Security Act (EISA), which requires an assessment of current carbon stocks and fluxes, and potential for ecological carbon sequestration under a range of climate, economic, and policy scenarios. Disturbances affect ecosystem dynamics and can introduce risk to carbon sequestration strategies, and thus, need to be accounted for. To meet EISA requirements, we developed a series of empirical and process-based simulation models to quantify disturbance impacts. Our approach forecasts future disturbance locations and severity, and the resulting impacts on vegetation dynamics. For fires, we relied on existing disturbance histories derived from Landsat time-series imagery, including the Monitoring Trends in Burn Severity (MTBS) and Vegetation Change Tracker (VCT) data, developed to update LANDFIRE fuels and vegetation layers. We used the MTBS and VCT data to parameterize models predicting the number of fires in relation to climate, land use and land-cover change, and socioeconomic variables at an ecoregion scale. We determined the location of individual fires with an ignition probability surface and then simulated fire spread in response to weather, fuels, and topography. Following the fire spread simulations, we determined changes in biomass pools using a burn severity model. At the end of each annual simulation, vegetation dynamics were updated using LANDFIRE vegetation types and succession models. We present an overview of the modeling approach, validation results, and forecasts of disturbances and their impacts on greenhouse gas emissions, and carbon stocks and fluxes in the southeastern United States.

Using Models To Estimate Groundwater Recharge (oral presentation)

By Richard W. Healy[1]

[1]U.S. Geological Survey, Lakewood, Colo.

Groundwater recharge is the movement of water from land surface or a surface-water body to the water table. Recharge rates affect groundwater supplies, groundwater discharges to ecosystems, and movement of potential contaminants from land surface to the water table. Therefore, knowledge of the rate, location, and timing of recharge is critical for effective management of water resources. Of the many different methods that are used for estimating groundwater recharge, models are particularly powerful tools. Models can be used to estimate current and past rates of recharge; models can also be used to predict the effects of future land-use and climate change on recharge rates.

Model complexity varies greatly. Some models are simple accounting models. Other models attempt to accurately represent the physics of water movement through each compartment of a hydrologic system; still other models are entirely empirical in nature and have no physical basis. Physically based distributed-parameter models can provide insight on processes that affect recharge; however, these models may require large amounts of data and expertise in model application. Empirical models, on the other hand, are easy to apply and are amenable to upscaling with geographic information system; empirical models, however, provide little information on factors that influence recharge. Some models provide estimates of recharge directly; for example, a model based on the Richards equation can simulate water movement from the soil surface through the unsaturated zone to the water table. Other models, such as groundwater-flow models, estimate recharge indirectly.

Space and time scales of recharge estimates vary for different models and model applications. Applications of watershed or groundwater-flow models may assume that recharge is uniform over the simulated domain, or recharge may be allowed to vary in space within the domain. In terms of time scales, recharge can be estimated on a daily, monthly, or annual basis; or recharge may be assumed constant over time.

Models for estimating recharge can be divided into the five categories: unsaturated zone water-budget models, watershed models, groundwater-flow models, combined watershed/groundwater-flow models, and empirical models. Models within each category share a common approach, but complexity and features of models vary substantially. An overview of models within each category will be presented, representative models will be described and their underlying assumptions analyzed, and examples of model applications will be discussed.

Model-Based Evaluation of Highly and Low Pathogenic Avian Influenza Dynamics in Wild Birds (oral presentation)

By Viviane C. Hénaux,[1] Michael D. Samuel,[2] and Christine M. Bunck[3]

[1]University of Wisconsin, Department of Forest and Wildlife Ecology, Madison, Wisc.

[2]U.S. Geological Survey, Wisconsin Cooperative Wildlife Research Unit,, Madison, Wisc.

[3]U.S. Geological Survey, National Wildlife Health Center, Madison, Wisc.

Since the emergence of highly pathogenic (HP) H5N1 in southern China, there is growing interest in avian influenza (AI) epidemiology to predict disease risk in wild and domestic birds, and prevent further transmission to humans. However, understanding the epidemic dynamics of HPAI viruses remains challenging because they have rarely been detected in wild birds. We used modeling to integrate available scientific information from laboratory and field studies, evaluate AI dynamics in individual hosts and waterfowl populations, and identify key areas for future research.

We developed a Susceptible-Exposed-Infectious-Recovered (SEIR) model describing the course of the disease in a population of waterfowl. We used published laboratory challenge studies to estimate epidemiological parameters (rate of infection, latency period, recovery, and mortality rates), considering the importance of age classes, and virus pathogenicity. We extended this model to wild bird populations by estimating the rate of infectious contact (θ) with virus using prevalence data from waterfowl surveys.

Infectious contact leads to infection and virus shedding within 1-2 days, followed by relatively slower period for recovery or mortality. Our sensitivity analysis demonstrated that the rate of infection plays a key role in AI epidemic dynamics. Therefore, additional laboratory challenges clarifying age-related differences in low pathogenic (LP) AI infection processes, the source of virus exposure (by direct bird-to-bird transmission or environmental transmission), and the level of exposure would expand our understanding of infection rates under various conditions.

We found a shorter infectious period for HPAI than low pathogenic (LP) AI, which may explain that HPAI has been much harder to detect than LPAI during surveillance programs. Our model predicted a rapid LPAI epidemic curve, with a median duration of infection of 50-60 days and no fatalities. In contrast, HPAI dynamics had lower prevalence and higher mortality, especially in young birds. Extensive surveillance programs for AI viruses have reported the presence of LPAI asymptomatic carrier birds all around the world; HPAI viruses have been detected in only a few healthy wild birds, and in most HPAI outbreaks, only a few dead individuals have been found. In a general sense, these observations agree with our model predictions of short epidemics for HPAI and much higher prevalence and longer duration of infection in birds with LPAI. Our model suggests increasing surveillance for HPAI in postbreeding areas, because the presence of immunologically naïve young birds is predicted to cause higher HPAI prevalence and bird losses during this season. Moreover, serological surveys to determine circulation of AI viruses in avian populations may effectively complement swab data, because immunity appears to last considerably longer than infection. Our results indicate a better understanding of immunity-related processes is required to refine predictions of AI risk and spread, improve surveillance for HPAI in wild birds, and develop disease control strategies to reduce potential transmission to domestic birds and (or) humans.

Monitoring Landscape Change and Socioeconomic Pressures in Colorado’s Energy Alley: Factors Influencing Land-Use Development (oral presentation)

By David J. Hester,[1] Mark R. Feller,[1] and Steven L. Garman[1]

[1]U.S. Geological Survey, Denver, Colo.

The nature of Federal and local land-use management and development decisions in the 21st Century are fundamentally being challenged from pressures such as unprecedented energy demand, rapid population growth, increased human presence in the Wildland-Urban Land Interface (WUI), demographic shifts, human migration, and socioeconomic changes (University of Montana, 2008). Understanding the factors influencing historical and future land transformations are required for establishing land-use model parameterization and business rules for simulating future land-use change and evaluating socioeconomic impacts and natural resource management decisions from those modeled simulations. The land-surface upon which these land-use development patterns, housing types, and population distribution evolve is the result of various social, economic, and physiographic factors. Investigating the factors that are driving, enabling, constraining, shaping, and sustaining these patterns and threshold densities provide a framework and structure for gaining insight into the variables that contributed to a region's land-use history and are potentially prerequisites for modeling future landscape change. Retrospective assessment of factors influencing land-use development in Grand Valley, Colo., and how these results can be used in forecasting future landscape change will be discussed.

For example, a driving factor is defined as an agent that encourages or induces landscape change. Demographics (population) and economics (employment) are considered major drivers of land-use development. Colorado's Garfield and Mesa counties; which fall within the geographic region known as "Energy Alley," are primed for growth and urbanization with a projected population increase of 72 percent or about 156,000 additional residents by the year 2035 (Associated Governments of Northwest Colorado, 2008), which coincides approximately with the future horizon year for the Bureau of Land Management (BLM) Grand Junction Field Office's (GJFO) Resource Management Plan (RMP).

Transportation features such as roads and telecommunications are classified as factors that enable access to undeveloped land and encourage land-use development. Dispersion of land-use patterns and housing types on the land-surface is influenced by the distance and speed that humans can commute from residence to workplace as well as from residence to cultural and natural amenities for recreational purposes. The location of Walker Field in Mesa County as a regional airport and Interstate Highway 70 are enabling factors bringing an influx of temporary visitors and permanent residents attracted to the amenities within the BLM GJFO Resource Management Plan Planning Area (RMPPA).

In coordination with BLM's revision of their 1985-vintage GJFO RMP, U.S. Geological Survey (USGS) Rocky Mountain Geographic Science Center (RMGSC) will collaborate with the BLM GJFO on using the RMP alternative development scenarios and the RMPPA as the geographic jurisdiction for understanding the factors influencing community growth and simulating future land-use development change, internal as well as external to the region.

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Use of Four-Dimensional Petroleum System Models in Oil And Gas, Climate, and Hydrologic Research (oral presentation)

By Debra K. Higley[1]

[1]U.S. Geological Survey, Lakewood, Colo.

The U.S. Geological Survey (USGS) assesses petroleum resources for basins around the world. This research is based on integration of and understanding the interplay of diverse data. Statistical, mapping, and other methods are used to interpret information. We also use one-dimensional, two-dimensional (map and cross section), three-dimensional geologic and four-dimensional (4-D) petroleum system (PS) models. Spatial information can be modeled at any scale, and models are mainly constrained by data quality and distribution, and computer processing abilities (Higley and others, 2006). PS models are pressure-volume-temperature (PVT) models that use Darcy and flow-path algorithms to model through time oil and gas (1) generation and expulsion from petroleum source rocks, (2) migration, (3) accumulation in source and reservoir rocks, and (4) loss to the atmosphere. These results are important to understanding the history of basins.

Our 4-D petroleum models allow visualization through time of geologic information that includes (1) extent, thickness, and structure of formations; (2) distribution of porosity, permeability, and lithostatic, hydrostatic, and capillary pressures; (3) vertical and lateral influences of open and closed faults on fluid flow; and (4) impact of hydrodynamics on petroleum migration. Formations in PS models are defined as petroleum source, reservoir (aquifer), and seal layers, all with assigned lithofacies; this detail is useful for hydrologic and CO_2 sequestration research. Petroleum system results (Higley and others, 2005a; 2009) and structure and isopach grids of the Western Canada Sedimentary Basin (WCSB) are available for other modeling and mapping research (Higley and others, 2005b). Modeled loss of methane to the atmosphere through time is incorporated in climate studies; the USGS 4-D PS model of the WCSB is shared with GFZ-Potsdam for use in their Methane on the Move (MoM) climate studies (*http://www.gfz-potsdam.de/*). Our 4-D PS model of the Anadarko Basin of Oklahoma, Kansas, Texas, and Colorado will be shared with the Kansas Geologic Survey for their research in CO2 sequestration.

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Identifying Important Observations Using Cross Validation and Computationally Frugal Sensitivity Analysis Methods (oral presentation)

By Mary C. Hill[1]

[1]U.S. Geological Survey, Boulder, Colo.

Sensitivity analysis, calibration, and uncertainty evaluation methods are critical to developing useful models of complex hydrologic systems for which important characteristics cannot be measured accurately and (or) completely enough to fully define model input values (Saltelli and others, 2008; Hill and Tiedeman, 2007; both textbooks published by Wiley). These methods allow the modeller to explore the relations between different types of data and the processes represented in the model, including the testing of hypotheses about system structure (alternative models).

Model nonlinearity and its consequences for model calibration and sensitivity analysis are evaluated by Kavetski and Kuczera [2007, Water Resources Research (WRR)]. Experience suggests that many models of natural systems are linear enough for local sensitivity analysis methods to be useful (see examples of groundwater flow and advective transport, conservative and reactive groundwater transport, and streamflow and transport cited by Fogli and others, 2009, WRR). This suggests that the concern expressed by Saltelli and others (2008, p. 11)—that local methods are inefficient in terms of the analyst's time is perhaps overstated, but clear comparison of nonlinear and linear methods are needed to better understand the opportunities and limitations of linear methods.

Local sensitivity analysis is based on first-order, second moment (FOSM) approximations. The linear statistics for which results are shown in this presentation are calculated using UCODE_2005 (Poeter and others, 2005, U.S. Geological Survey report). They include fit-independent and fit-dependent statistics (Hill and Tiedeman, 2007). The fit-independent statistics are dimensionless scaled sensitivities (DSS), leverage, and observation-prediction (OPR). The fit-dependent statistics are DFBETAS and Cook's D. The role of parameter interdependence as measured by parameter correlation coefficients (PCC) is discussed (only DSS does not account for parameter interdependence).

The alternative to local sensitivity analysis commonly is global sensitivity analysis (Saltelli and others, 2008). Global methods most commonly used in hydrology are Generalised Likelihood Uncertainty Estimation (GLUE) and Markov Chain Monte Carlo (MCMC). Here, we compare linear methods with results obtained through cross-validation. In cross validation, all observations are used to produce a calibrated model and associated predictions. Then one or more observations are removed, the regression repeated, and resulting changes in parameter values and predictions are evaluated. Large changes in parameter values and predictions indicate the associated observations are important.

In this work, comparisons of local sensitivity analysis and cross-validation are conducted using a groundwater model of the Maggia Valley, Southern Switzerland (Foglia and others, 2007, Ground Water); applicability to climate models is inferred using Torn and Hakim (2008, Monthly Weather Review). Results show that the frugal linear methods produced about 70 percent of the insight from about 2 percent of the model runs required by the computationally demanding methods. Linear methods were not always able to distinguish between moderately and unimportant observations. However, they consistently identified the most important observations. Importance both to estimated parameters and predictions of interest was readily identified.

Results suggest that it can be advantageous to consider local sensitivity analysis in model evaluation, possibly to provide insights used to improve the design of more demanding methods.

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Bayesian Mark-Recapture Models For Fish Survival And Population Estimation For Use In Multi-Scale Modeling Of Riverine Ecosystems And Responses Of Fish Populations (oral presentation)

By Scott H. Holan,[1] Mark L. Wildhaber,[2] Christopher K. Wikle,[1] Christopher J. Anderson,[3] and Kristie J. Franz[4]

[1]Department of Statistics, University of Missouri—Columbia, Columbia, Mo.

[2]U.S. Geological Survey, Columbia, Mo.

[3]Climate Science Initiative, Iowa State University, Ames, Iowa

[4]Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa

Population viability analyses (PVA) are used to manage recovery or maintenance of fish populations. Such models typically contain parameters for each age class that include number of individuals, probability of survival to next age class, and reproductive rate, among others. Using PVA models and inclusion of environmental variables, future population trends, and most critical model parameters can be predicted. Wildhaber and others (2007) presented a conceptual life-history model for pallid and shovelnose sturgeon that illustrates how transition (for example, survival) probabilities of sturgeon life stages determine sturgeon population structure. Concurrently, Bajer and Wildhaber (2007) developed initial age-structured models for shovelnose and pallid sturgeon populations in the Lower Missouri River (LMOR). These models are based on the current state of knowledge for these sturgeon species, including critical assumptions of survival estimates. One purpose of this research is to further develop and improve the age-structured demographic models through better survival and population estimates with separate estimates for wild and stocked pallid sturgeon and inclusion of environmental variables.

It is unknown whether stocking of geographically distinct pallid sturgeon groups will have an effect on long-term survival or how these fish will disperse into different geographically distinct segments of the LMOR and Middle Mississippi River. Progeny of locally stocked hatchery fish stocked 15 years ago have reached sexual maturity (Wildhaber and Bryan, 2006) and have begun to spawn in the LMOR (DeLonay and others, 2007). The survival of these genetically or geographically distinct fish will have ramifications for the stocking program throughout the LMOR. Additionally, the potential change in population as a result of the currently spawning hatchery progeny in the LMOR could drastically alter the need for additional hatchery fish. Models to estimate survival by size and origin of fish and dispersal patterns is important to becoming more efficient with the limited resources available for the recovery program.

Modeling the growth and survival of endangered species such as the pallid sturgeon is a difficult task due to limited information. Utilization of the more readily available information on the closely related shovelnose sturgeon will aid in development of population and survival estimate models for pallid sturgeon. This borrowing of strength across related species will come in one form through informative priors for a Bayesian analysis.

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Application Guide for Analysis of Flows in Networks of Channels (AFINCH) Described by National Hydrography Dataset Plus (NHDPlus) (oral presentation)

By David J. Holtschlag[1]

[1]U.S. Geological Survey, Lansing, Mich.

AFINCH (Analysis of Flows in Networks of CHannels) is a computer application that can be used to generate a time series of monthly flows at stream segments (flowlines) and water yields for catchments defined in the National Hydrography Dataset Plus (NHDPlus) value-added attribute system. AFINCH provides a basis for integrating monthly flow data from streamgages, water-use data, monthly climatic data, and land-cover characteristics to estimate natural monthly water yields from catchments by user-defined regression equations. Images of monthly water yields for active streamgages are generated in AFINCH and provide a basis for detecting anomalies in water yields, which may be associated with undocumented flow diversions or augmentations. Water yields are multiplied by the drainage areas of the corresponding catchments to estimate monthly flows. Flows from catchments are accumulated downstream through the streamflow network described by the stream segments. For stream segments where streamgages are active, ratios of measured to accumulated flows are computed. These ratios are applied to upstream water yields to proportionally adjust estimated flows to match measured flows. Flow is conserved through the NHDPlus network. A time series of monthly flows can be generated for stream segments that average about 1-mile long, or monthly water yields from catchments that average about 1 square mile. Estimated monthly flows can be displayed within AFINCH, examined for nonstationarity, and tested for monotonic trends. Monthly flows also can be used to estimate flow-duration characteristics at stream segments. AFINCH generates output files of monthly flows and water yields that are compatible with ArcMap, a geographical information system analysis and display environment. Chloropleth maps of monthly water yield and flow can be generated and analyzed within ArcMap by joining NHDPlus data structures with AFINCH output. Matlab code for the AFINCH application is presented.

Detection of Conveyance Changes in St. Clair River Using Historical Water-Level and Flow Data with Inverse One-Dimensional Hydrodynamic Modeling (oral presentation)

By David J. Holtschlag[1]

[1]U.S. Geological Survey, Lansing, Mich.

St. Clair River is a connecting channel that transports water from Lake Huron to the St. Clair River Delta and Lake St. Clair. A negative trend has been detected in differences between water levels on Lake Huron and Lake St. Clair. This trend may indicate a combination of flow and conveyance changes within St. Clair River. To identify where conveyance change may be taking place, eight water-level gaging stations along St. Clair River were selected to delimit seven reaches. Positive trends in water-level fall were detected in two reaches, and negative trends were detected in two other reaches. The presence of both positive and negative trends in water-level fall indicates that changes in conveyance are likely occurring among some reaches because all reaches transmit essentially the same flow. Annual water-level fall in reaches and reach lengths was used to compute conveyance ratios for all pairs of reaches by use of water-level data from 1962 to 2007. Positive and negative trends in conveyance ratios indicate that relative conveyance is changing among some reaches. Inverse one-dimensional hydrodynamic modeling was used to estimate a partial annual series of effective channel-roughness parameters in reaches forming the St. Clair River for 21 years when flow measurements were sufficient to support parameter estimation. Monotonic, persistent but nonmonotonic, and irregular changes in estimated effective channel roughness with time were interpreted as systematic changes in conveyances in five reaches. Time-varying parameter estimates were used to simulate flow throughout the St. Clair River and compute changes in conveyance with time. Based on the partial annual series of parameters, conveyance in the St. Clair River increased about 10 percent from 1962 to 2002. Conveyance decreased, however, about 4.1 percent from 2003 to 2007, so that conveyance was about 5.9 percent higher in 2007 than it was in 1962.

Combining National Wetland Inventory, Landsat, and Lidar to Model the Wetland Water Storage in the Prairie Pothole Region of the United States (oral presentation)

By Shengli Huang,[1] Shuguang Liu,[2] Claudia Young,[3] Jennifer Rover,[2] Karl Heidemann,[2] David Mushet,[4] Ned Euliss,[4] and Min Feng[5]

[1]ASRC Research and Technology Solutions, Sioux Falls, S. Dak.

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

[3]ADNET Systems, Inc, Sioux, S. Dak.

[4]U.S. Geological Survey, Jamestown, N. Dak.

[5]Chinese Academy of Sciences, Institute of Geographic Sciences and Natural Resources Research, Beijing, China

Covering an area of approximately 715,000 km^2, the Prairie Pothole Region (PPR) of North America extends from north-central Iowa to central Alberta. The landscape of PPR is dotted with many small wetlands created during the last glacial retreat approximately 12,000 years ago. The region supports many ecosystem services, including carbon sequestration, floodwater retention, waterfowl production, and pollution reduction. However, cultivated agriculture results in wetland drainage. Concern over the reduction of flood mitigation services historically provided by PPR wetlands has stimulated interest in developing spatially distributed hydrological models to simulate the effects of wetland water storage.

Many attempts have been made to model wetland water storage services of PPR wetlands; however, two main obstacles have reduced the value of these efforts. First, the availability of high-resolution elevation data is usually lacking, and researchers have had to rely on digital elevation models (DEMs) with resolutions up to 10 meters to model water storage; these coarse resolutions are usually inadequate to capture the relief of the region. Second, Nation Wetland Inventory (NWI) datasets, which are often used for wetland identification and water storage modeling in PPR, were derived principally from 1970–1980 photography; these NWI datasets are temporally static and do not reflect land-cover changes caused by human management and climate fluctuations over the past two decades.

In our research, we used a decision tree model to classify a series of Landsat images (1989, 1991, 1997, 2001, 2003, 2004, 2005, and 2008) into “water” and “no water” to capture the interannual dynamics of wetland surface water. Together with the Conservation Reserve Program (CRP) datasets, these Landsat products were composited to update the NWI dataset and compile a dataset of “current wetland distribution.” We also developed a bare earth DEM from light detection and ranging (LIDAR) at a resolution of 0.5 meters. This DEM was used to delineate each wetland catchment area as well as the position and elevation of spill points. From each catchment and its spill point, we modeled wetland water storage. The maximum water storage of an area considered each individual wetland, wetland connectivity, and surrounding land cover. The model output is being compared to field survey data from the USGS’s Cottonwood Lake Study Area, N. Dak., for accuracy assessment.

Spatial Ecology of Grizzly Bears in Northwestern Montana: Dissertation Proposal (poster)

By Tabitha A. Graves,[1] Paul Beier,[1] and Katherine C. Kendall[2]

[1]Northern Arizona University, School of Forestry, Flagstaff, Ariz.

[2]U.S. Geological Survey, West Glacier, Mont.

We will use genetic information to assess the influence of habitat and human influences on abundance, dispersal, and gene flow of grizzly bears (*Ursus arctos*) in the Northern Continental Divide Ecosystem (NCDE). We ask four questions:

1. Which landscape characteristics influence abundance of grizzly bears in the NCDE? More than 1,500 genetic captures of 545 grizzly bears collected in 2004 across the ~8 million acre Northern Continental Divide Ecosystem were formatted as a spatial mark-recapture dataset to estimate local bear abundance. We will use a hierarchical Bayes-

ian analysis incorporating (1) detection probabilities, (2) multiple sampling methods, and (3) spatial autocorrelation to identify the landscape variables most important to abundance of male and female grizzly bears.

2. What landscape and population characteristics promote dispersal in a natural population of grizzly bears? Natal dispersal comprises three key steps: (1) emigration, (2) movement through the landscape, and (3) immigration. We will identify parent-offspring pairs to look directly at the three stages of dispersal.

3. Can we quantify resistance of landscape characteristics to gene flow? Gene flow reflects a process occurring over several generations and results only when individuals disperse and reproduce. We will use a Bayesian approach with circuit theory to measure the resistance of landscape characteristics using genetic distance as a response variable.

4. What landscape or population characteristics describe areas where dispersal occurs but gene flow does not result? Comparison of our results can guide management for genetic as well as demographic connectivity.

Using U.S. Environmental Protection Agency Basins Modeling System for Linking Hydrologic Models with an Ecological Model for Aquatic Endpoint Impact Assessments (oral presentation)

By John C. Imhoff,[1] Paul R. Hummel,[1] Anthony S. Donigian, Jr.,[1] and Richard A. Park[2]

[1]AQUA TERRA Consultants, Mountain View, Calif.

[2]Eco Modeling, Diamondhead, Miss.

The U.S. Environmental Protection Agency's (EPA) Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) is a multipurpose environmental analysis system designed to perform watershed and water-quality-based studies. It was developed to facilitate the examination of environmental information, to support analysis of environmental systems, and to provide a framework for examining management alternatives. BASINS integrates environmental data, analytical tools, and modeling programs under a geographic information system (GIS). The current release of BASINS, version 4.0, is the first to be based primarily on a nonproprietary, open-source GIS foundation. BASINS encompasses a growing suite of watershed and water-quality models—from sophisticated, broad-spectrum watershed models, to agricultural and ecological models and planning and management-level models.

Of the variety of models available in BASINS, two are presented to demonstrate the linkage between hydrologic and ecological models for conducting biological impact assessments: Hydrological Simulation Program-FORTRAN (HSPF), and AQUATOX. HSPF (Bicknell and others, 2005) watershed modeling code is a comprehensive, process-based mathematical model developed under joint EPA and U.S. Geological Survey (USGS) sponsorship for simulating hydrologic and water-quality processes in natural and manmade water systems. AQUATOX, a mechanistic and dynamic fate and effects model developed with funding from the EPA, simulates the significant physical, chemical, and biological processes affecting aquatic biota in streams, rivers, ponds, lakes, reservoirs, and estuaries (Park and others, 2008). AQUATOX represents and predicts compositional shifts for periphyton, phytoplankton, invertebrates, and fish with changes in nitrogen, phosphorus, and sediment loadings.

The methodology and results of a BASINS application on Fort Benning, Ga., is presented as a case study. The Fort Benning Study incorporates military-specific land-use categories to identify impacts to aquatic biota such as the broadstripe shiner. Additionally, the discussion is expanded to include how this study and others can incorporate climate change risk evaluations by applying the newly developed Climate Assessment Tool (CAT) (EPA, 2009). CAT incorporates climate change scenarios by modifying a user-driven base period of historical temperature and precipitation data to reflect any desired future changes.

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The Role of Groundwater in Geologic Processes (oral presentation)

By S.E. Ingebritsen[1]

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

Historically, interest in groundwater and other subsurface fluids was confined to a few specific disciplines in the earth sciences, notably groundwater hydrology, soil physics, engineering geology, petroleum geology, and petroleum engineering. These disciplines tended to be "applied" in nature, with practitioners concentrating on the immediate and practical problems of water supply, water quality, mine dewatering, deformation under structural loads, and the location and recovery of fluid hydrocarbons. This situation has changed over the past few decades. Hydrogeologists and geologists are now actively modeling the role of groundwater and other subsurface fluids in such fundamental geologic processes as crustal heat transfer, ore deposition, hydrocarbon migration, earthquakes, tectonic deformation, diagenesis, and metamorphism. This talk will emphasize (1) the role of fluid properties in governing fluid flow and heat transfer at the midocean ridge and (2) the coupling between fluid pressure, seismicity, and crustal permeability.

Invasive Species and Climate Change (oral presentation)

By Catherine S. Jarnevich,[1] Bethany Bradley,[2] Tracy R. Holcombe,[1] Thomas Stohlgren,[1] and Jeffrey T. Morisette[1]

[1]U.S. Geological Survey, Fort Collins, Colo.

[2]Department of Biology, Amherst College, Amherst, Mass.

Species environmental matching models to predict species potential distributions are now commonplace, and are often based solely on climate data. Given that we are interested in the potential distribution and effects of harmful species, it is important how species-environment relationships might be affected by climate change scenarios when they are included in the models. We provide an overview of how different aspects of global change may impact species invasions, either improving or decreasing the suitability of their habitat in the future. We discuss the climate change data needs to generate useful suitable habitat models for management, and the caveats related to the applications of these models with climate change. We then provide specific examples of species environmental matching models at various spatial scales that include climate change projections. Our models show both potential contraction and expansion of invasive species ranges, highlighting the need for different management strategies. An iterative monitoring and modeling approach is required to validate and improve the models over time.

Climate Change Impacts on Freshwater Recreational Fishing in the United States (poster)

By Russell Jones,[1] Constance Travers,[1] Charles Rodgers,[1] Brian Lazar,[1] Eric English,[1] Kenneth Strzepek,[2] and Jeremy Martinich[3]

[1]Stratus Consulting Inc, Boulder, Colo.

[2]Civil, Environmental, and Architectural Engineering, University of Colorado, Boulder, Colo.

[3]Climate Change Division, U.S. Environmental Protection Agency, Washington, D.C.

We analyzed the potential impacts of climate change on stream suitability for freshwater fish assemblages in the United States. We quantified the projected changes in stream-water temperatures, stream flow, and areal extent of suitable habitat resulting from a range of projected changes in temperature and precipitation. Based on the projected shifts, we estimated potential economic impacts associated with changes in freshwater recreational fishing. Using a geographic information system, we developed a spatially explicit modeling framework of grid cells organized into 2,099 8-digit hydrologic unit code (HUC) polygons for the conterminous United States. Projected temperature and precipitation changes associated with climate change were obtained for 2030, 2050, and 2100, and three future emissions scenarios representing low, moderate, and high emissions. We then generated a grid of projected water temperatures using regional air and water temperature regressions. Habitat suitability was derived from the value of the lowest monthly average water temperature within a HUC compared to a model-calibrated maximum water temperature tolerance of cold-water and warm-water fish guilds. Although projections vary somewhat by emissions scenario and year, in general, the spatial distribution of cold-water fisheries is predicted to contract, being replaced by warm and cool water and rough fisheries. As expected, these projected changes are more pronounced with increasing time and emissions. To estimate the potential economic impacts of predicted habitat changes on recreational fishing, we used a national-scale economic model of recreational fishing, updated with current data. Using projected losses in fishing days, multiplied by per-day values derived from the current economics literature, we estimate that the total present value of estimated national economic losses to freshwater recreational fishing from 2009 to 2100 will range from $81 million to $6.4 billion, depending on the discount rate assumed, and the emissions scenario.

Lattice Boltzmann Method for Reacting Flow in Porous Media (oral presentation)

By Qinjun Kang,[1] David Janecky,[2] and Peter Lichtner[1]

[1]Computational Earth Science Group, Los Alamos National Laboratory, Los Alamos, N. Mex.

[2]Ecology & Air Quality Group, Los Alamos National Laboratory, Los Alamos, N. Mex.

We present a numerical framework based on the lattice Boltzmann method (LBM) for modeling reacting flow in porous media at the pore scale. Our numerical model accounts for multiple processes at the fundamental scale of a single pore volume, including fluid flow, diffusion and advection of species, adsorption-desorption and mineral precipitation/dissolution reactions, as well as the evolution of pore geometry due to dissolution/precipitation. Homogeneous reactions are described either kinetically or through local equilibrium mass action relations. Heterogeneous reactions are incorporated into the LBM through boundary conditions imposed at the mineral surface. The LBM can provide detailed information on local fields, such as fluid velocities, solute concentrations, mineral compositions and amounts, as well as the evolution of pore geometry due to chemical reactions. Presented are simulation examples, including crystal growth from supersaturated solution, precipitation of a mineral with evolving geometry, injection of carbon dioxide (CO_2) into a limestone rock, and bacterial growth in micromodels.

This approach is being applied in a broad spectrum of energy, environmental, and biological research, including clean energy exploitation (fuel cells and batteries), enhanced oil recovery and geothermal systems, nuclear waste disposal, geologic CO_2 sequestration, underground contaminant migration, biomedical engineering applications, and novel materials design. Perspectives of applying this method to seafloor hydrothermal systems are especially discussed.

Using Land-Cover Change as a Dynamic Variable in Surface-Water and Water-Quality Models (poster)

By Krista Karstensen,[1] Kelly Warner,[2] and Anne Kuhn[3]

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

[2]U.S. Geological Survey, Urbana, Ill.

[3]U.S. Environmental Protection Agency, Narragansett, R.I.

Land-cover data are typically used in surface-water and water-quality modeling to establish or describe land-surface dynamics. This project is designed to demonstrate the use of land-cover change data in surface-water and water-quality models by incorporating land cover as a variable condition as opposed to a static condition. Surface water and water quality are being analyzed using three different scenarios: (1) agriculture in the Plains (the effects of land-cover change on water quality in the Illinois River Basin); (2) loon habitat in New England (the effects of land-cover change on water quality in New Hampshire), and (3) forestry in the Ozarks (the effects of land-cover change on peak flow in northern Arkansas).

The Illinois River flows across the Central Corn Belt Plains and Interior River Lowlands ecoregions before its confluence with the Mississippi River. Because the area of interest is supported by sample blocks from two ecoregions, the statistics must be resampled in order to create a new region covering the specific area of interest in the Illinois River basin. This revised assessment will be used to examine how land-cover change relates to recently assessed water quality and trends developed from baseline measurements of recharge and surface water.

The U.S. Environmental Protection Agency's (EPA) Atlantic Ecology Division is working in conjunction with the Loon Preservation Committee (LPC) to develop loon-specific demographic models that integrate the risk of mercury and human disturbance across a range of stressor levels. In order to test the potential contribution of historic land-cover change, the sample blocks from ecoregions in New Hampshire will be resampled and compared to water-quality data. This research may augment the EPA's data and enable researchers to back calculate the impacts of human disturbance based on land-cover changes over time.

The timber industry has played a significant role in land-cover change in the Boston Mountains ecoregion. Generally, a land-cover class change from forest to mechanically disturbed can be representative of forest cutting for development or timber harvesting. Forest cutting can have a significant effect on land-surface dynamics, including rates of runoff. Slope and land-cover multichange data from 1973 to 1980 for a sample area in the ecoregion was organized in ArcGIS and compared to magnitudes of change in peak flows at streamgages. When all of the data were evaluated, we saw that an increasing-trend magnitude occurred at a downslope streamgage in an area that converted from the forest to mechanically disturbed land-cover class. Additionally, precipitation records from 1961 to 1980 do not indicate a significant deviance from normal rainfall in that area, confirming that the changes in the land cover may have increased rates of runoff.

Using a Bayesian Network Approach To Model the System of Effects of Urbanization on Aquatic Ecosystems (oral presentation)

By Roxolana Kashuba,[1] Song Qian,[1] Thomas F. Cuffney,[2] Gerard McMahon,[2] and Kenneth H. Reckhow[1]

[1]Nicholas School of the Environment, Duke University, Durham, N.C.

[2]U.S. Geological Survey, Raleigh, N.C.

Watershed urbanization initiates a complex series of processes, many of which lead to harmful consequences for stream biota. Though ecological conceptual models attempt to describe many of the simultaneous, interacting factors caused by urbanization that affect physical, chemical, and biological aspects of stream ecosystems, this system-level understanding cannot be translated into a quantified representation using standard statistical modeling techniques. Traditional analysis of stream-ecosystem data is limited to finding empirical relationships between pairs of environmental factors using simple regression techniques and does not incorporate the web of interconnected environmental variables, uncertainty characterization, or known ecological information about the system. In contrast, a network modeling approach can represent and parameterize the entire system of urbanization affecting aquatic invertebrates. We construct a Bayesian network model to characterize this system from prior expert knowledge, update this model with U.S. Geological Survey Effect of Urbanization on Stream Ecosystems (EUSE) data, and evaluate the resulting model incorporating both sources of information. A Bayesian network model has the flexibility of being able to add new data as it becomes available in a manner conducive to use in adaptive management. Managers can use the parameterized Bayesian network model to calculate the probabilities of attaining desired aquatic ecosystem goals assuming different levels of urban stress, environmental conditions, and management options. This Bayesian approach enables aquatic ecologists to model a comprehensive set of interacting system components in an understandable, probabilistic manner. Many anthropogenic and natural factors affect invertebrates and, rather than investigating each factor individually, a Bayesian network is used to describe the interconnected effect while acknowledging the complexity of the environmental and ecological processes driving biological response, allowing concurrent assessment of all driving factors.

The Vision of an Open Environmental Modeling Platform—Seamlessly Linking Geoscience Data, Concepts, and Models To Aid Decisionmaking in Times of Environmental Change (oral presentation)

By Holger Kessler,[1] Andrew Hughes,[1] Jeremy Giles,[1] and Denis Peach[1]

[1]British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, United Kingdom (UK)

Governments and their executive agencies across the world are facing increasing pressure to make decisions about the management of resources in light of population growth and environmental change. In the UK for example, groundwater is becoming a scarce resource for large parts of its most densely populated areas. At the same time, river and groundwater flooding resulting from high rainfall events are increasing in scale and frequency, and sea level rise is threatening the defenses of coastal cities. There is also a need for affordable housing, improved transport infrastructure, and waste disposal, as well as sources of renewable energy and sustainable food production.

These challenges can only be resolved if solutions are based on sound scientific evidence. Although we have knowledge and understanding of many individual processes in the natural sciences, it is clear that a single science discipline is unable to answer the questions and their interrelationships. Modern science increasingly employs computer models to simulate the natural, economic, and human system. Management and planning requires scenario modeling, forecasts, and predictions. Although the outputs are often impressive in terms of apparent accuracy and visualization, they are inherently not suited to simulate the response to feedbacks from other models of the earth system, such as the impact of human actions.

Geological Survey Organizations (GSOs) are increasingly employing advances in information technology to visualize and improve their understanding of geological systems. Instead of two-dimensional paper maps and reports, many GSOs now produce three-dimensional geological framework models and groundwater flow models as their standard output. Additionally, the British Geological Survey has developed standard routines to link geological data to groundwater models; however, these models are only aimed at solving one specific part of the earth's system (for example, the flow of groundwater to an abstraction borehole or the availability of water for irrigation). Particular problems arise when model data from two or more disciplines are incompatible in terms of data formats, scientific concepts, or language. Other barriers include the cultural segregation within and between science disciplines and the impediments to data exchange due to ownership and copyright restrictions. The Open Modeling Interface Standard and Geoscience Markup Language are initiatives that are helping to overcome these barriers through the building of international communities that share vocabularies and data formats.

This paper gives examples of the successful merging of geological and hydrological models from the UK and will introduce the vision of an open Environmental Modeling Platform, which aims to link data, knowledge, and concepts seamlessly to numerical process models. Last but not least, there is an urgent need to create a subsurface information system similar to a geographic information system, in which all results of subsurface modeling can be visualized and analyzed in an integrated manner and be useful for decisionmakers.

Managing the Human Dimensions of Climate Change (oral presentation)

By Jeff Kitchens[1]

[1]Bureau of Land Management, Lakewood, Colo.

This presentation will incorporate the work (cooperative efforts and mapping exercises) of various cooperative organizations dealing with the mountain pine beetle outbreak in Colorado and Emerald Ash Borer (EAB) in the East. It will provide examples to land managers on the use of spatial data to balance the various sociological and ecological factors involved with large landscape scale disturbances that might result from climate change.

Various areas throughout the United States and Canada have been dealing with large landscape scale forest disturbances over the last decade. Some of these, like the bark beetle outbreak in British Columbia, involve native pests impacting immense areas of forested landscapes. Others, like the Emerald Ash Borer, have involved exotic insects, plants or pathogens, or both, which may ultimately change some of our native vegetation landscapes forever. Various resource and land managers are increasingly being forced to try and weigh ecological and social factors simultaneously in an attempt to not only communicate such issues to their cooperators and the general public, but also to prioritize treatments to deal with both the direct (tree mortality) and indirect (increased fuel loadings and fire hazards) impacts within a changing climate.

For almost a decade, a mountain pine beetle (MPB) outbreak has been growing in severity and geographical extent across northern Colorado and southern Wyoming. This landscape scale disturbance has resulted in unprecedented tree mortality that has begun to impact various ecological and sociological resources throughout high-elevation ecosystems of Colorado. In 2005, an organization known as the Colorado Bark Beetle Cooperative (CBBC) was established to tackle resource management problems related to the extensive MPB outbreak. Since 2005, the CBBC has developed a long-term strategy, has organized a collaborative membership, and has begun the process of trying to create a mapping or spatial tool for prioritizing work on the landscape with a multitude of conflicting variables.

During the same timeframe, a nonnative pest—the EAB—was discovered in the Detroit metropolitan area of southeastern Michigan. Since its discovery in 2002, the EAB has killed millions of trees and has resulted in millions of Federal, State, local, and private dollars being spent on quarantines, eradication attempts, and outreach strategies. Various cooperatives and collaboratives have sprung up, including those sponsored wholly by tribal governments, in an attempt to prevent the loss of Ash species throughout the Midwest, Northeast, and Mid-Atlantic States.

This presentation will use the MPB outbreak in Colorado, the EAB infestations of the East, and the work of the various cooperative organizations dealing with these issues to offer spatial analysis tools to land managers for balancing the various sociological and ecological factors involved with large landscape scale disturbances that may result from our changing climate. Examples will include cooperative approaches, communication strategies, and useful technological tools. The presentation will also discuss a number of substantial accomplishments and valuable lessons learned.

Adjusting for Background Soil Evaporation When Interpolating Evapotranspiration Between Satellite Overpass Dates (oral presentation)

By J.H. Kjaersgaard,[1] R.G. Allen,[1] and R. Trezza[1]

[1]University of Idaho, Kimberly R&E Center, Kimberly, Idaho

Satellite-based surface energy balance models are now routinely operated to produce evapotranspiration (ET) products on an operational basis for use in water-resources management. To produce estimates of ET at field scale, Landsat satellite imagery is commonly used. The Landsat imagery is well suited for surface energy balance estimations because of the onboard thermal imager and the high resolution. Two Landsat satellites are currently in operation—Landsat 5 and Landsat 7—each flying in the same orbit but 8 days apart. The return time for both satellites is every 16 days.

Because of cloudiness and other atmospheric disturbances, including jet contrails and smoke, not all images or portions of images are suited for processing. Although cloud cover varies between different areas, it is common to find only one good image per month suited to be processed. Based on this one snapshot of ET, the monthly and ultimately seasonal ET are determined by interpolating a relative ET fraction

(ETrF) between image dates using, for example, a cubic spline function and multiplying by a reference ET calculated from weather data for each day of the month. A potential shortfall when performing the interpolation is whether local precipitation events such as afternoon summer rainstorms are fully accounted for, or if these events unduly dominate the ETrF image. If such an event happens within a few days prior to the satellite overpass time, the residual evaporation soil may be overestimated when that image is used as a basis for estimating the monthly ET. The result is an error in the water balance.

We, therefore, adjust the ET_rF derived for the satellite overpass date from the METRIC surface energy balance model for background evaporation from soil caused by rainfall so that the final ET map represents average conditions for the month. The method currently used for this adjustment is to establish a daily soil water balance for bare soil for each day of the month and ratio the average evaporation over the month from bare soil to the evaporation on the image date. This ratio is modified to account for shading effects of vegetation using the Normalized Difference Vegetation Index (NDVI) = $NDVI_{bare\ soil}$, with no adjustment made for areas with full vegetation cover, represented by NDVI = $NDVI_{full\ cove_r}$.

Refining Components of Satellite-Based Surface Energy Balance Models for Forests and Steep Terrain (oral presentation)

By J.H. Kjaersgaard,[1] R.G. Allen,[1] R. Trezza,[1] and Aureo Oliveira[1]

[1]University of Idaho, Kimberly R&E Center, Kimberly, Idaho

Satellite-based surface energy balance models are being used in an increasing number of water-management application in the Western United States. These models generally determine evapotranspiration (ET) at Landsat satellite scale utilizing the thermal band of Landsat. Modeling Evapotranspiration at High Resolution with Internalized Calibration (METRIC) is one of these models (Allen and others, 2007). METRIC uses the procedure Calibration using Inverse Modeling at Extreme Conditions (CIMEC) to derive a unique calibration for each image. For the operational use of METRIC, it is often necessary to employ a variety of refinements during the image processing to account for the roughness characteristics of land-use types other than agriculture and to account for changes in elevation. Other tuning parameters and the rationale behind them have been described by Allen and others (2008).

The momentum roughness length (z_{om}) is often estimated in METRIC for tall and potentially sparse vegetation, such as forests, riparian areas, or orchards, using a z_{om} function developed by Perrier (1982) that is based on Leaf Area Index (LAI) and tree canopy architecture:

$$z_{om} = \left(\left(1 - \exp\left(\frac{-aLAI}{2} \right) \right) \exp\left(\frac{-aLAI}{2} \right) \right) h$$

where the stand height h for forest vegetation is estimated as 2.5 times the LAI, which results in a maximum tree height of 15 meter (m), when LAI = 6; however, this can be adjusted. The parameter “a” is an adjustment factor for the LAI distribution within the canopy with a = (2*f*) for $f \geq 0.5$ and a = $(2(1\text{-}f))^{-1}$ for $f < 0.5$. The factor *f* is the proportion of LAI lying above h/2, that is, *f* = 0.3, 0.5, and 0.7 indicates sparsely topped canopy, uniform canopy, and top heavy canopy, respectively.

Air temperature generally decreases by 6.5 to 10 °C for each 1,000-m-elevation increase under neutral atmospheric conditions. Because the surface temperature is in strong equilibrium with the air temperature, a similar decrease in surface temperature can usually be observed. During the CIMEC procedure of METRIC, a relationship is established between the near-surface temperature difference (dT) and the surface temperature. The surface temperature is then adjusted to a common reference elevation for accurate prediction of dT. Otherwise, the surface temperature of areas at higher elevation can be misinterpreted to be low because of evaporative cooling, rather than due to elevation increase. A delapsed (artificial) surface temperature map is created for purposes of estimating dT. Elevation data are provided by a digital elevation map. For areas having steep mountains, a dual-stage delapse correction is used, with differentiated lapse rates for flat terrain and for mountainous terrain.

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Beach-Dune System Susceptibility Assessment—Applications and Verification (oral presentation)

By Robert V. Koch,[1] Daniel A. Barone,[1] and Mark J. Mihalasky[2]

[1]Coastal Research Center, Richard Stockton College of New Jersey, Port Republic, N.J.

[2]U.S. Geological Survey, Spokane, Wash.

The State of New Jersey contains areas of eroding bluff coastlines to the north and sand barrier-spit and island complexes to the south. Many of the sand beaches and shorelines along the New Jersey coast are sand starved and have been experiencing erosion for many decades. Much of this beach erosion is due to the effects of coastal storms such as hurricanes, and more commonly, northeast storms. These storms can cause catastrophic damage to the coastal infrastructure and adversely impact the livelihood of residents and tourists in these communities. Because it has a large coastal economy, New Jersey has been the most proactive State in the United States in undertaking shore protection projects to guard against beach erosion and maintain this valuable coastal resource.

The Richard Stockton College Coastal Research Center (CRC) has developed a State-wide geographic information system (GIS)-based beach-dune system susceptibility assessment. The assessment incorporates multiple geospatial and remote-sensing techniques (primarily the use of coastal light detection and radar elevation data and aerial photography) into a knowledge-driven spatial-data integration model. The goal of the assessment is to evaluate the performance of the oceanfront beach-dune system in response to various storm events. The storm-event simulations used in the CRC beach-dune susceptibility assessment are consistent with the Federal Emergency Management Agency storm classifications (that is, 2-, 5-, 10-, 20-, 50-year storm events). In addition, the beach-dune susceptibility assessment provides Federal, State, and local entities a useful tool to better manage a State's valuable coastal economy.

Recently, the New Jersey beach-dune assessment has been revised to simplify the spatial-data preparation process through the use of a stand-alone GIS software application developed by PhotoScience, Inc., in cooperation with the CRC. The application, Beach-Dune Analyst (BDA), aids in the automation of many time-consuming tasks, which allows for rapid analyses of beach-dune systems on a regional scale. In addition, BDA allows for more thorough and timely field verification of the susceptibility model, which aids in highlighting coastal areas vulnerable to storm damage. Field verifications of the susceptibility model were recently carried out in Harvey Cedars, New Jersey, following a northeast storm in November 2009, which resulted in a Presidential Disaster Declaration. The field observations coincide with the susceptibility model output.

Application of the Precipitation Runoff Modeling System in the Apalachicola-Chattahoochee-Flint River Basin in the Southeastern United States (oral presentation)

By Jacob LaFontaine,[1] Lauren Hay,[2] Roland Viger,[2] Steve Markstrom,[2] and Steve Regan[2]

[1]U.S. Geological Survey, Atlanta, Ga.

[2]U.S. Geological Survey, Lakewood, Colo.

In order to help resource managers assess potential effects of climate change on ecosystems, the Southeast Regional Assessment Project (SERAP) began in 2009. One component of the SERAP is a multiresolution hydrologic model of the Apalachicola-Chattahoochee-Flint (ACF) River Basin. The ACF River Basin supports multiple fish and wildlife species of conservational concern to Federal and State managers, is regionally important for water supply, and has been a recent focus of complementary research. Hydrologic models of varying extents and resolutions will be developed in the study area as required by the scope of the resource question and the limits of potential management actions using the U.S. Geological Survey Precipitation Runoff Modeling System (PRMS). The coarse-resolution model will comprise the entire ACF Basin, with a contributing area of approximately 19,200 square miles (mi^2) at the model outlet. Six fine-resolution PRMS models ranging in size from 153 mi^2 to 1,040 mi^2 will be nested within the coarse-scale model, and developed for the following basins: the upper Chattahoochee River, the Chestatee River, the Chipola River, Ichawaynochaway Creek, Potato Creek, and Spring Creek. All of the models will operate on a daily time step and will use existing climate, land-cover, and streamflow data for development, calibration, and evaluation. Land-cover projections will be used in conjunction with downscaled global climate model outputs to produce PRMS projections of future conditions.

Past and Future Impacts of Sea Level Rise on Coastal Habitats and Species in the Greater Everglades (poster)

By Catherine Langtimm,[1] Don DeAngelis,[2] M. Dennis Krohn,[3] Thomas J. Smith III,[3] Brad Stith,[4] and Eric D. Swain[5]

[1]U.S. Geological Survey, Gainesville, Fla.

[2]U.S. Geological Survey, Miami, Fla.

[3]U.S. Geological Survey, St. Petersburg, Fla.

[4]Jacobs Technology, Inc, Gainesville, Fla.

[5]U.S. Geological Survey, Fort Lauderdale, Fla.

This integrated science project merges biologic and hydrologic modeling to develop tools for resource managers to anticipate the projected ecological consequences of rising sea level in coastal south Florida. The project builds on prior U.S. Geological Survey (USGS) models and research in support of the Comprehensive Everglades Restoration Plan (CERP) and includes the following five components:

- Greater Everglades hydrodynamic models (the Flow and Transport in a Linked Overland/Aquifer Density-Dependent System-FTLOADDS) to simulate salinity, inundation, and water temperature across spatial and temporal scales.
- Mangrove-Hammock Model to predict vegetation regime change due to salt-water intrusion from storm surges (or tsunamis).
- Historic habitat charts and aerial photos to identify hot spots of past shoreline and vegetation change in relation to historic sea-level rise conditions.
- Historic hurricane data to test the influence of extreme hydrologic events on long-term ecological disturbances.
- Spatially explicit species and habitat suitability models to document ecologic response to hydrologic change.

New Model—Hindcast capability

We are developing a hindcast model to examine historical hydrological conditions supporting documented past vegetation conditions. The initial simulation is from1926–1932 to coincide with available aerial photography. Data include historic rainfall and surface-water feature data and historic Key West sea-level measurements that are used to represent the lower tidal levels at that time. The 1926 Miami hurricane is represented using information collected from the hurricane scenario research. This simulation represents the known coastal landscape prior to the construction of many canals and other drainage features.

New Model—Predictive capability

We will develop forecasting capability for our model based on experience and information from the hindcast model. The new model will incorporate different scenarios of projected sea-level rise and regional climate parameters downscaled from global models. To provide decision-support information to resource managers we also will incorporate various restoration scenarios from CERP, a set of possible extreme weather events that can be targeted to areas of a manager's choice, and estimated rates of erosion and accretion to shoreline elevation from measured rates under past scenarios of geomorphology, vegetation regime, and hurricane events. Output from the predictive model will be used as input into a Florida manatee and seagrass model to demonstrate the application to spatially explicit species models and habitat suitability models previously designed for CERP.

Estimating Vegetation Carbon Changes in the Western United States Due to Land-Use Change, Climate Change, And Natural Disturbance: 1951–2006 (oral presentation)

By Jinxun Liu,[1] Benjamin Sleeter,[2] Carl Key,[3] Zhiliang Zhu,[4] Shuguang Liu,[5] Terry Sohl,[5] James Vogelmann,[5] David Price,[6] Jing Chen,[7] Mark Cochrane,[8] Jeffery Eidenshink,[5] Stephen Howard,[5] Norman Bliss,[9] and Hong Jiang[10]

[1]SGT INC, Sioux Falls, S. Dak.

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

[3]U.S.Geological Survey, West Glacier, Mont.

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

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

[6]Northern Forestry Centre, Natural Resources Canada, Canadian Forest Service, Edmonton, Canada

[7]Department of Geography and Program in Planning, University of Toronto, Toronto, Canada

[8]Geographic Information Science Center of Excellence, South Dakota State University, Brookings, S. Dak.

[9]ASRC Research and Technology Solutions, Sioux Falls, S. Dak.

[10]International Institute for Earth System Science, Nanjing University, Nanjing, China

During the 20th century, continuing human-induced land-cover changes and increasing size and frequency of wildland fires have resulted in increasing losses of carbon from terrestrial ecosystems in the Western United States. However, vegetation growth may have been enhanced by carbon dioxide (CO_2) fertilization and increasing growing season length, contributing to faster vegetation recovery and offsetting carbon losses. Estimation of the net carbon change of ecosystems at landscape to continental scales is determined by the quality of land-cover disturbance data and the ability of process-based ecosystem models to correctly capture growth enhancement and disturbance effects. We used the Integrated Biosphere Simulator (IBIS) with a set of 30- to 60-meter resolution wild-land fire and land-cover change data to assess vegetation carbon changes in response to recent trends in climate, CO_2 concentration, and land-use change and disturbances for 1951–2006. Our analyses suggest that the effects of vegetation growth enhancement and land disturbance were heterogeneous over time and space. Land-cover change and disturbances caused significant fluctuations in ecosystem carbon density at county and ecoregion levels, whereas climate variability played an important role at the State and national level. Further analysis indicates that growth-enhancement effects were greater in high-elevation forests than in low-elevation forests.

Estimating Soil Erosion and Deposition under Future Climate and Land-Cover Change Scenario—USPED Model Application in the Mississippi Plains (oral presentation)

By Jinxun Liu,[1] Shuguang Liu,[2] Jennifer Oeding,[1] Terry Sohl,[2] and Norman Bliss[3]

[1]SGT INC, Sioux Falls, S. Dak.

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

[3]ASRC Research and Technology Solutions, Sioux Falls, S. Dak.

We used the Unit Stream Power-based Erosion Deposition (USPED) models, together with modeled future land-cover and climate data, to estimate the lateral movement of soils on the Mississippi Alluvial Plain and Valley Loess Plains of the United States.

Land-cover maps from FOREcasting SCEnarios model (250-m) resolution, used to generate the cover factor for the USPED], Shuttle Radar Topography Mission Digital Elevation Model data (90-m resolution), State Soil Geographic soil erodibility map (soil erodibility (K) factor), Canadian Global Climate Change climate data (10-km resolution), and Intergovernmental Panel on Climate Change Special Report on Emission Scenarios A2 were used to simulate 2001–2050 soil erosion and deposition across the region. The major purpose of this model application is to calculate the sediment supply for river systems.

Major adjustments were made for the USPED application: (1) a land-cover weight layer was used in the surface-flow accumulation calculation for USPED so that a more realistic transport capacity could be obtained; (2) a carbon factor was used to convert soil erosion to C erosion; and (3) an average distance of C movement was defined and derived from the flow-accumulation value, which was used to calculate the soil organic carbon oxidation loss to the atmosphere during the lateral movement of eroded material.

Ecological Carbon Sequestration under Projected Land-Cover And Climate Change In Mississippi Plains—Model Intercomparison and Analysis (oral presentation)

By Shuguang Liu[1]

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

Ecological carbon (C) sequestration refers to the transfer and storage of atmospheric carbon dioxide (CO_2) into vegetation, soil, and aquatic systems that help to offset C and other greenhouse gas emissions. Three biogeochemical models (Erosion Deposition Carbon Model, CENTURY, and Integrated Biosphere Simulator) are used to estimate the range and uncertainty of C stock and C fluxes as affected by climate change and land management in the Mississippi Alluvial Plain and Valley Loess Plains from 2001 to 2050. The three models have different model structure and parameterization approaches. By using the same soil, climate, and land-cover input datasets, model intercomparisons mainly focus on major model outputs, such as the ecosystem net primary productivity, living biomass stock, and soil carbon change. Model sensitivities to global change (for example, global warming, atmospheric CO_2 increase, and land-cover change) and model scaling effects are also analyzed. Recommendations for reducing overall model uncertainties are discussed.

Integrating Remote-Sensing Data with Gems To Improve Simulation of Carbon Dynamics (oral presentation)

By Shuguang Liu,[1] Zhengpeng Li,[2] and Mingshi Chen[2]

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

[2]ASRC Research and Technology Solutions (ARTS), Sioux Falls, S. Dak.

Quantifying the spatial and temporal dynamics of ecosystem carbon stocks and fluxes has been a major challenge, and there is an urgent need to improve the accuracy of quantification through combining model simulations with various observations, especially remotely sensed data. Specifically, we need modeling tools that can: (1) adequately detect and remove model structure deficiency, (2) adaptively quantify the behavior of model parameters (temporal and spatial changes), (3) optimally combine model simulations with various observations from field and remote- sensing sources, and (4) rigorously assess model output uncertainty. We developed a model-data fusion system to provide mathematical framework and software infrastructure that satisfied these needs. The model-data fusion system consists of the General Ensemble Biogeochemical Modeling System (GEMS), data from various resources, and data assimilation techniques [for example, Smoothed Ensemble Kalman Filter (SEnKF)]. We presented two studies to show the applications of GEMS-SEnKF at plot and regional scales. We first applied GEMS-SEnKF to assimilate eddy covariance measurements at two different flux network (FLUXNET) sites into GEMS. One of the sites, a cropland located in Nebraska, experienced corn-soybean rotations. The other site was a mature black spruce forest in the Delta Junction of Alaska. The simulation results suggested that GEMS-SEnKF (1) successfully detected interspecies differences, seasonal variations, and biases of the key parameters (for example, potential production rate and potential decomposition rate) in GEMS, and (2) substantially reduced uncertainty of state variables stemmed from errors of parameters, input, and structure. At the regional scale, we applied GEMS-SEnKF to simulate regional carbon sequestration capacity in a Federal land and compared the trends with those in surrounding non-Federal lands. Results indicated that assimilation of remotely sensed data can dramatically improve the capability of model parameterization to correctly represent the spatial heterogeneity of land-surface processes and model parameters.

A Hydro-Mechanical Model for Predicting Infiltration-Induced Landslides (oral presentation)

By Ning Lu,[1] Alexandra Wayllace,[2] and Jonathan Godt[3]

[1]Civil Engineering, Colorado School of Mines, Golden, Colo.

[2]Division of Engineering, Colorado School of Mines, Golden, Colo.

[3]U.S. Geological Survey, Denver, Colo.

Infiltration-induced landslides are common in hillslope environments and are one of the most deadly and costly natural hazards in these areas. Therefore, development of a tool to account for both hydrological and mechanical processes in hillslopes leading to landsliding is critical for the accurate prediction and study of such hazards. We describe a two-dimensional coupled hydro-mechanical numerical model that implements a rigorous, yet simple framework for simulating stress, deformation, and variably saturated flow. The model simulates the effects of slope morphology, transient hydrology, and stress-strain deformation on stability by computing the distribution of effective stress and implements a new definition of the factor of safety calculated at each point. The factor of safety is based on the potential stress path of the first invariant of the stress tensor that occurs at each point under an infiltration-loading condition. Finite element methods are used to couple the governing equations for variably saturated flow with classical linear-elasticity equations for analyzing the hydrologic and mechanical behavior of the slope. The state of effective stress at each point is calculated by accounting for its two components—total stress and suction stress. Slope geometry, boundary conditions, and hydrologic initial conditions are specified by the user. Results from a case study of a steep coastal bluff in the Seattle, Wash., area are presented. Contour maps with the distribution of principle effective stresses, angle of potential failure, and the factor of safety are comparable with field observations. This model provides a comprehensive tool for understanding and predicting the physical processes driving the onset of infiltration-induced mass movement in hillslope environments.

Flow Regimes in Homogeneous and Isotropic Hillslopes (oral presentation)

By Ning Lu,[1] Basak Sener Kaya,[2] and Jonathan Godt[3]

[1]Civil Engineering, Colorado School of Mines, Golden, Colo.

[2]Division of Engineering, Colorado School of Mines, Golden, Colo.

[3]U.S. Geological Survey, Denver, Colo.

Understanding of the pattern and timing of flow in hillslopes is needed for accurate assessment of mass movement potential. The distribution of moisture in a homogeneous and isotropic hillslope is a transient, variably saturated physical process controlled by infiltration characteristics, hillslope geometry, and the hydrological properties of the hillside materials. The major driving forces for moisture movement are gravity and gradients in soil moisture content. In a saturated hillslope, under the driving force of gravity and a constant pressure boundary at the slope surface, flow is always in the lateral downslope direction, invariant of transient or steady-state conditions. However, under variably saturated conditions, both gravity and moisture gradients drive fluid motion leading to complex flow patterns. In general, the flow field near the ground surface is variably saturated and transient, and the direction of flow can be laterally downslope, laterally upslope, or vertical. Previous work has considered rainfall conditions sufficient to completely control these flow regimes. We use a numerical model, calibrated with results from laboratory physical models, to show that rainfall conditions are not sufficient to determine the flow regime in isotropic and homogenous hillslopes. For example, under decreasing rainfall intensity conditions, downslope and upslope lateral flow can occur concurrently in a hillslope. We hypothesize and demonstrate that the state of wetting or drying in a hillslope defines the temporal and spatial regimes when lateral downslope or lateral upslope, or both, flow occurs. Our numerical simulations confirm this hypothesis.

From Instantaneous to Average Daily Evaporative Fraction, Minimizing Uncertainties, and Water-Balance Estimation over Large Area Using Combined Geostationary and Polar Orbiting Satellites (Case Study of Castilla Y Leon Region, Spain) (oral presentation)

By Tadesse Alemu Mamo[1]

[1]Water Resource and Environmental Management, University of Twente, Enschede, Netherlands

Water use strategy and water-resources management requires scientifically sound information on water availability, particularly in the semiarid areas like the Castilla y Leon region, Spain. This region is suffering from high evaporation and low rainfall with negligible runoff. Due to this fact and climate change, the farming system of the region is converting from rain fed to irrigation. Therefore, actual evapotranspiration (AET) and rainfall are the main surface-water-balance components for this study area. Currently, both are potentially estimated from remote-sensing observations. In the past decades, the quantification of daily actual evapotranspiration from remote-sensing data was mainly based on one time observation from sun synchronous satellites by scaling instantaneous evaporation under the assumption of constant daytime evaporative fraction (EF). However, in this work, the average daily EF over a large area was calculated using the surface energy balance system (SEBS) model derived by Su (2002) with real-time data from 40 ground meteorological stations and products from the European organization for the exploitation of meteorological satellites on land surface analysis satellite application facility (EUMETSAT LSA SAF) and moderate resolution imaging spectroradiometer (MODIS) land-surface products. The EUMETSAT LSA SAF products were derived from spinning an enhanced visible and infrared imager (SEVIRI) radiometer embarked on the meteosat second generation (MSG) platform and other European satellite systems, which have an imaging-repeat cycle of 15–30 minutes. The average daily EF was compared with the mid-day EF (instantaneous EF) for different land-cover classes on March 15, 2009. Finally, the simple water-balance estimation of the region was carried out for the months of March, April, May, and June 2009, using rainfall products from the EUMETSAT meteorological product extraction facility (MPEF) and daily AET. The results indicated that the average daily EF and instantaneous EF have shown a strong relation (R^2= 0.98, 0.90, 0.86, 0.73, 0.70, and 0.56 for water, irrigated croplands, rain-fed croplands, shrubland, mosaic forest-shrubland, and mosaic crop-vegetation, respectively). However, it shows poor agreement (R^2=0.38, 0.32, 0.05, for sparse vegetation, broad-leaved deciduous forest, and needle-leaved evergreen forest, respectively). In addition, the daily evapotranspiration was successfully validated with MSG evapotranspiration product (MET) and an eddy covariance system in sparse vegetation.

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The Precipitation Runoff Modeling System: Current and Future Capabilities (oral presentation)

By Steve Markstrom,[1] Lauren Hay,[1] Steve Regan,[1] and R.J. Viger[1]

[1]U.S. Geological Survey, Lakewood, Colo.

The need to assess the effects of variability in climate, vegetation, geology, and human activities on water availability and movement requires computer models that simulate the hydrologic cycle at a watershed scale. This presentation describes the most recent version of the Precipitation-Runoff Modeling System (PRMS-2010). PRMS-2010 is a modular-design, deterministic, distributed-parameter modeling system developed to evaluate the effects of precipitation, climate, and land use on streamflow and general basin hydrology. The primary objectives of PRMS-2010 are: (1) to simulate land-surface hydrologic processes, including evapotranspiration, runoff, infiltration, and interflow estimated by balancing energy and water budgets of the plant canopy, snowpack, soil zone, and saturated groundwater system on the basis of distributed climate inputs (temperature, precipitation, and solar radiation); (2) to predict hydrologic water budgets at the watershed scale with temporal scales ranging from days to centuries; (3) to integrate with models used for natural resource management or other scientific disciplines; and (4) to provide a modeling system with a modular design that allows for selection of alternative hydrologic process algorithms. In addition, PRMS-2010 will be an important part of the U.S. Geological Survey National Hydrologic Model by providing a single system capable of simulating hydrologic processes from coarse- to fine-spatial resolutions with a wide range of temporal resolutions.

Framework Models in Underpinning Environmental Earth Science (oral presentation)

By Steve Mathers,[1] Holger Kessler,[1] and Ricky Terrington[1]

[1]British Geological Survey, Nottingham, United Kingdom (UK)

The United Kingdom's (UK's) Natural Environment Research Council (NERC), as the parent body of the British Geological Survey (BGS), has defined the following strategic goals:

- To enable society to respond urgently to global climate change and the increasing pressures on natural resources, and
- To contribute to UK leadership in predicting the regional and local impacts of environmental change from days to decades.

Both these goals and their challenges rely on a thorough understanding of the geosphere (for example, the subsurface distribution of rocks and soils, their properties, and the inside movements and interaction of solids and fluids). The traditional outputs from Geological Survey Organizations, such as maps, reports, and databases, are usually not sufficient to meet these interdisciplinary challenges, as they are often in the wrong format, at an inappropriate scale, limited to two dimensions, or simply only deal with a single scientific theme.

From 1990 to 2000, the BGS digitized its entire data holdings (maps and boreholes) and organised them into easily accessible and interoperable formats and databases. National coverage was licensed for a digital terrain model and air photography. In 2000, the decision was taken to begin the migration of the organization and its outputs from an analog mapping to a digital modeling "culture." One of the main outcomes from the research effort during this migration was the development of the GSI3D software and methodology, which is now deployed across the organization enabling all BGS's survey and investigative geologists to construct three-dimensional (3-D) geological framework models.

GSI3D is designed for the geologist or geoscientist, rather than the highly trained expert software user. The model is built by enabling the user to construct traditional cross sections by correlating boreholes and outcrop data to produce a network of sections, or geological fence diagram. Together with a suitable digital elevation model, this geological interpretation is then used by the software engine to produce a 3-D solid model of the subsurface. For the user, this is a single click operation. The resulting "geological framework models" are simply the extension of the two-dimensional (2-D) geological map and its units into 3-D. This is the first stage in answering many the goals set out above.

The challenge now is to populate these geospatial models with properties and establish closer links to process models, such as groundwater flow models and engineering design models. Last but not least, the resulting models and scenarios need to be put into context with the real world (such as buried infrastructure, tunnels, and houses) to communicate and disseminate them to other scientists, and, most importantly, to the end users of our science such as planners and politicians. Finally, we believe one of the greatest values of these models will be in teaching students and the general public about what lies beneath their feet, thereby ensuring public buy-in and understanding of the scientific challenges that lie ahead.

Dasymetric Population Modeling To Estimate Resident Exposure to Hazards: Clackamas County, Oregon (oral presentation)

By Amy M. Mathie,[1] Rachel Sleeter,[2] and Nathan J. Wood[1]

[1]U.S. Geological Survey, Vancouver, Wash.

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

Urban development in areas prone to natural hazards amplifies the potential for losses due to future catastrophic events. In communities facing multiple hazards, detailing the extent of exposure provides vital information for emergency management planning. In Clackamas County, Oreg., population increased approximately 21 percent from 1990 to 2000. Multiple natural hazards (high volume snowfall, avalanche, advancing wildfires, volcanic unrest, and river flooding) also exist with the potential to disrupt local business and community livelihood. While numerous studies have characterized the hazards, there is significant lack in understanding the societal vulnerability among communities to such events. Such an evaluation requires better estimates of the spatial distribution of population and the changes that have occurred over time.

In the United States, emergency managers have access to decadal census data that summarizes residential populations into aggregated areal units, but these units do not reflect population distributions relative to individual residences. More precise estimates of population distribution are needed so emergency managers can better address issues related to preparedness and response planning, such as for evacuations and delivery of emergency services. Dasymetric population modeling refines coarse areal population data into more spatially relevant map units by using land-use information in the population estimation and, therefore, provides more functional data for planning purposes.

A dasymetric population modeling methodology is discussed and a time series of Clackamas County residential development and habitation from 1990 to 2007 is presented. In this analysis, U.S. Census block group records from 1990 and 2000, and estimated values for 2007 were used as population input totals. Select land-use categories were derived from the 1992 and 2001 30-meter pixel National Land Cover Dataset (NLCD). Prior to dasymetric processing, the land-use categories were filtered to remove uninhabited regions using a rasterized county dataset of specific residential structure locations. This extra step significantly improved resident estimates from large forested and agricultural land-use classes. Final processing used our online dasymetric population modeling tool (available at *http://geography.wr.usgs.gov/science/dasymetric/index.htm*). Population change in the county observed over the 17-year study period was calculated through raster subtraction of the 1990 population from that of 2007, and shows a general increase in urban development. Loss of population in certain areas may reflect the movement of people to new suburban developments located in a different census block group (for instance, to “Bedroom Communities”) or may reflect dilution of population numbers due to faster rates of residential structure development as compared to block group population totals.

Overall, dasymetric population modeling helps emergency managers better understand societal vulnerability to natural hazards by more precisely mapping the spatial distribution of residents. One of the U.S. Geological Survey (USGS) science strategies is to develop models to support emergency managers with hazard mitigation decisionmaking. Improved population modeling coupled with community hazard vulnerability analysis further assists implementation of adaptation strategies to minimize social and economic disruptions from threat events.

A National Monthly Water-Balance Model (oral presentation)

By Gregory McCabe[1] and David Wolock[2]

[1]U.S. Geological Survey, Denver, Colo.

[2]U.S. Geological Survey, Lawrence, Kans.

A monthly water-balance (WB) model that partitions water among various components of the hydrologic system is being used to aid the development of a national hydrologic model (NHM). The WB model includes the concepts of climatic water supply and demand, snow accumulation and melt, and soil-moisture storage. Using monthly temperature and precipitation data from the Precipitation-elevation Regression on Independent Slopes Model as inputs to the WB model, monthly time series of runoff have been generated for the conterminous United States on a 4-km-by-4-km grid for the period 1895 through 2009. These time series of estimated monthly runoff are aggregated to estimate runoff for river basins of various sizes across the conterminous United States for comparison with time series of measured runoff. These comparisons, and other analyses, provide direction for improving the WB model and a starting point to understanding the hydrologic model detail needed for a daily time step NHM. Some of the issues to address include accounting for groundwater contributions to surface-water runoff, improving estimates of evapotranspiration, and accounting for anthropogenic influences such as water use, reservoirs, and diversions.

Fuzzy Logic-Based Beach-Dune System Assessment Methodology: Development and Initial Applications (oral presentation)

By Mark J. Mihalasky[1]

[1]U.S. Geological Survey, Spokane, Wash.

Coastal communities and economies are important to New Jersey's prosperity and quality of life, but they are vulnerable to devastating effects from hurricanes and northeast ("nor'easter") storms. The last decade has experienced a number of unusually active storm seasons (particularly 2003–2005 and 2008), continuing a 20–25-year-long trend of enhanced activity in the Atlantic basin that began in 1995. This increasing trend in storm activity has coincided with a decreasing trend in Federal funding for shore protection and beach nourishment. Since about 2002, responsibility for protecting and maintaining the coast has incrementally shifted to State and municipal governments.

The beach and dune system of New Jersey's barrier islands and spits is a vital natural resource that protects shore communities against storm damage. Assessments of the beach-dune system are important for effective management and sustainability of this coastal zone resource, and facilitate more efficient use of limited State and municipal resources by optimizing storm hazard mitigation activities.

A geospatial beach-dune system susceptibility assessment, which uses a knowledge-driven, spatial-data integration technique (fuzzy logic), was developed to evaluate performance potential of the natural beach-dune system, identifying weaknesses and highlighting areas that may be vulnerable to storm damage (such as erosion, overwash, or breach). The beach-dune system is segmented longshore into "bins" based upon lot-block lines (for local-scale assessments) or a larger fixed interval (for regional-scale assessments). For each bin, several variables relating to dune, beach, and nearshore geomorphology, and to presence of vegetation and structures (such as groins), are collected, compiled, and evaluated in order to determine the susceptibility of the beach-dune system to potential damage from storm activity. These susceptibility variables are quantified and, using expert knowledge, assigned a weight-of-influence (or fuzzy membership value) with respect to their abilities to withstand or counteract storm erosion. Light detection and radar elevation and bathymetry-profile survey data are used in wave run-up erosion simulations to determine the failure point of the system for each bin (the point of failure is defined as dune crest breach in response to landward erosional recession of the foredune toe). Simulations are run for 2-year, 5-year, 10-year, 20-year, 50-year, and 100-year storm events using parameters developed by the Federal Emergency Management Agency. The results of the erosion simulations are used to specify the value of a fuzzy GAMMA operator, which mathematically integrates the fuzzy membership values assigned to the susceptibility variables, and to classify the resulting susceptibility values into intervals.

The assessment results are conveyed as a series of "susceptibility maps" that consist of an aerial photograph on which two bin-segmented strips are overlain along the extent of the beachfront. Individual maps are made for 2-year, 5-year, 10-year, 20-year, 50-year, and 100-year storm events. One strip is an absolute measure of vulnerability to storm erosion, and is made in relation to a 100-year intensity storm as the worst-case scenario. The other is a relative measure of vulnerability to storm erosion, and is made in comparison to all bins for a given storm intensity.

Integrated Natural Resources Assessment in Support of Regional Planning and Development—Proof-of-Concept Application, Anosy Region of Southeastern Madagascar (oral presentation)

By Mark J. Mihalasky[1]

[1]U.S. Geological Survey, Spokane, Wash.

The U.S. Geological Survey (USGS) developed an integrated, multidisciplinary, geospatial-based, natural resource assessment methodology, and in 2006, applied the technique to the Anosy Region of southeastern Madagascar. The project was financed by the World Bank, and formulated and led by the USGS on behalf of le Projet de Gouvernance des Ressources Minérales, under the auspices of Département des Mines et de la Géologie of the Ministère de l'Energie et des Mines, Madagascar. The assessment involved a team comprised of a geospatial analyst, economic geologists, hydrogeologists, ecologists, an economist, and community and regional development planners; it was undertaken within the appropriate national, regional, and local community development frameworks and authorities.

The purpose of the assessment was to enhance knowledge of natural resource potential in the region, and to provide information and decisionmaking guidance to assist with the creation of a sustainable economic development model driven by mineral resources. Relationships among geology and metallogeny, hydrogeology, ecology, and socioeconomics were used to identify priority mineral resource areas for development, as well as to provide insight into the impact of industrial and building materials on regional growth and the environment. The primary elements of the assessment are (1) the identification of areas with elevated mineral potential; (2) the delineation of development poles and corridors based upon mineral, water, environmental, and socioeconomic resource considerations, which highlight existing infrastructure and potential opportunities that could support or complement mining activities; and (3) integration of the poles across other socioeconomic sectors, such as agriculture, fishery, tourism, as well as ecological conservation and restoration, and social and physical infrastructure.

The core components of the assessment involve the compilation, reduction, and synthesis of spatial and nonspatial data and information. Spatial datasets relating to geology, metallogeny, hydrogeology, ecology, environment, and socioeconomy were used to delineate tracts of land permissive for the occurrence of (or known to possess) mineral, water, ecologic, and socioeconomic resources. The tracts were combined respectively to create maps showing elevated favorability for these resources. The favorability maps were then integrated with one another, whereby mineral resource favorability maps were refined by "filtering" them through the favorability maps of the other disciplines. In this manner, areas of high-mineral-resource favorability were downgraded when proximal to conservation areas or regions of restricted mineral activity, or upgraded when proximal to roads, water sources, or other infrastructure. Similarly, mineral resource favorability maps were integrated with various tract maps of socioeconomic resources to evaluate the impact of economic and social conditions, or benefits and detriments that could result from development in favorable areas.

The resource assessment tracts and favorability maps were delineated, combined, and integrated using expert knowledge and fuzzy logic spatial-modeling techniques. Tracts were extracted from individual datasets, or manually delineated across multiple layers. Resource favorability maps were generated by combining resource tracts using the fuzzy SUM mathematical operator, which has an overall increasive effect. Resource favorability maps were integrated with one another using the fuzzy **and** mathematical operator, which has a decreasive effect where one or more favorabilities are low.

Electrical Resistivity Parameter Estimation and Model Appraisal Using Bayesian Inference (oral presentation)

By Burke Minsley[1]

[1]U.S. Geological Survey, Denver, Colo.

Electrical resistivity data are often acquired to provide noninvasive information about subsurface structural and hydrogeologic properties. Interpretation of resistivity data is typically accomplished with traditional least-squares inversion techniques, which produce a single "best" resistivity model given the available data. In reality, however, there are many models that fit the measured data within acceptable error bounds, due to the ill-posed and nonunique nature of the inverse problem. Without strong prior information to favor one model over another, all models that fit the data must be considered plausible. Additionally, the ultimate goal is typically not just a resistivity model, but rather the answer to (hydro) geologic questions, such as the following: *What is the depth to the bottom of an aquifer?*, or *How well do the measured data constrain estimates of near-surface properties?*

To address these issues, a Bayesian Markov Chain Monte Carlo (MCMC) strategy is implemented to estimate the posterior distribution of models that fit the measured data. Analysis of this ensemble of acceptable models provides valuable information about likely parameter values, nonuniqueness, correlation, and uncertainty. Although computationally expensive, the algorithm is relatively straightforward in that it requires many evaluations of the forward problem (that is, predicting data for a given model), and is therefore easily adapted to a wide variety of parameter estimation problems. This work is based primarily on the analysis of one-dimensional (1-D) soundings that are stitched together in order to analyze two-dimensional (2-D) datasets, although an approach for directly estimating 2-D models is also proposed. A measure of model simplicity is incorporated by allowing the number of layers in the model to be a free parameter, but favoring models with fewer layers.

Combining Modis Enhanced Vegetation Index and Ground Measurements of Evapotranspiration To Estimate Agricultural and Riparian Consumptive Water Use on the Lower Colorado River (oral presentation)

By R. Scott Murray,[1] Pamela L. Nagler,[2] Kiyomi Morino,[3] John Osterberg,[4] and Edward P. Glenn[5]

[1]University of Arizona, Soil, Water, Environmental Sciences Department, Tucson, Ariz.

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

[3]University of Arizona, Laboratory of Tree Ring Research, Tucson, Ariz.

[4]U.S. Bureau of Reclamation, Colo.

[5]Environmental Research Laboratory, University of Arizona, Tucson, Ariz.

We used the Enhanced Vegetation Index (EVI) from Moderate Resolution Imaging Spectroradiometer (MODIS) to scale evapotranspiration (ET_{actual}) over agricultural and riparian areas along the Lower Colorado River in the southwestern United States. Ground measurements of ET_{actual} by alfalfa, saltcedar, cottonwood, and arrowweed were expressed as a fraction of potential (reference crop) ET_o (ET_oF), then regressed against EVI scaled between bare soil (0) and full vegetation cover (1.0) (EVI*). EVI* values were calculated based on maximum and minimum EVI values from a large set of riparian values in a previous study. These data show a satisfactory relationship was found between crop and riparian plant ET_oF and EVI*, with an error or uncertainty of about 20 percent in the mean estimate (mean ET_{actual} = 6.2 mm d^{-1}, RMSE = 1.2 mm d^{-1}). The equation for ET_{actual} was: $ET_{actual} = 1.22 \times ET_{o\text{-}BC} \times EVI^*$, where $ET_{o\text{-}BC}$ is the Blaney Criddle formula for ET_o. This single algorithm applies to all the vegetation types in the study. The algorithm was applied to irrigation districts and riparian areas from Lake Mead to the United States and Mexico border. The results for agricultural crops were similar to results produced by crop coefficients developed for the irrigation districts along the river. However, riparian ET was only half as great as crop coefficient estimates set by expert opinion, equal to about 40 percent of reference crop evapotranspiration. Based on reported acreages in 2007, agricultural crops [146,473 hectares (ha)] consumed 2.2 x 10^9 m^3 yr^{-1} of water. All riparian shrubs and trees (47,014 ha) consumed 3.8 x 10^8 m^3 yr^{-1}, of which saltcedar, the dominant riparian shrub (25,044 ha), consumed 1.8 x 10^8 m^3 yr^{-1}, about 1 percent of the annual flow of the river. This method could supplement existing protocols for estimating ET by providing an estimate based on the actual state of the canopy as determined by frequent-return satellite data.

Modeling the Phenology And Spread of Tamarisk Beetle Infestation and Impact on Water Savings (oral presentation)

By Pamela L. Nagler,[1] R. Scott Murray,[2] Edward P. Glenn,[3] Kevin Hultine,[4] Philip E. Dennison,[4] Charles van Riper,[1] and Dan Bean[5]

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

[2]University of Arizona, Soil, Water, Environmental Sciences Department, Tucson, Ariz.

[3]Environmental Research Laboratory, University of Arizona, Tucson, Ariz.

[4]Biology, University of Utah, Salt Lake City, Utah

[5]Colorado Department of Agriculture, Biological Pest Control Palisade Insectary, Palisade, Colo.

Tamarisk is an introduced shrub that is widespread in western United States riparian corridors. There is concern that it displaces native vegetation and consumes large amounts of water from riparian aquifers. Consequently, the saltcedar leaf beetle (*Diorhabda carinulata*) has been introduced into the western United States to control the spread of tamarisk. We summarize preliminary findings of our assessment of phenology and water use (sap flux and satellite derived). In two adjacent stands of beetle-infested tamarisk stands on the Dolores River, Utah, a 10-m tower was erected prior to 2008. Beetle damage was measured using canopy cover from images taken from tower-mounted visible and infrared cameras ("phenocams"). Time-lapse image sets from the cameras were compared with fine-scale estimates of water use using stem-sap flow measurements conducted over three growing seasons (2007–2009). Fractional cover from tower phenocams was comparable to cover from Moderate Resolution Imaging Spectroradiometer (MODIS) Enhanced Vegetation Index (EVI). Also, EVI was combined with meteorological data to estimate evapotranspiration (ET) at 15 release sites in Utah, Colorado, Nevada, and Wyoming, and in adjacent sites to which the beetle might have spread. ET was estimated at 16-day intervals from 2000–2009, encompassing pre- and post-release periods at each site. Ground data collected at four saltcedar-dominated sites on the Dolores River include vegetation structure, composition and phenology, as well as bird monitoring and productivity. For the last 3 years, monthly monitoring of 100 trees at each site was observed for percent flower and leaf, coupled with ratios of green-to-brown needle observations, done from spring green-up to senescence. Bird census data were collected at 100-m-radius circular plot stations (n=20) and birds were captured in mist nets, in which the type and number of birds were reported as birds per net hour. Preliminary results from the sap flux, phenocams, and imagery show that both cover and plant transpiration fell dramatically during or shortly after the defoliated period, but recovered when new leaves were produced each year. Baseline ET rates were low, 2–6 mm d^{-1} in summer (<0.5 potential ET). At 4 of

15 sites, estimated ET by MODIS decreased markedly after release. At other sites, no decrease in ET was detected, and ET tended to recover to prerelease levels at affected sites. At each location, the results support our past 3 years of findings for the ET seasonally and annually time-series curves as the beetle came into the area and defoliated saltcedar. Potential water salvage was constrained to the relatively brief period of defoliation. These preliminary findings support both satellite and phenological observations showing that beetle damage is transient, spotty, and localized at most sites, and reduction in ET is confined mainly to July when beetles are actively feeding. Because defoliation by the beetle is new to the ecosystem (~5 years), relative to the presence of tamarisk (>100 years), the long-term effect of the defoliation on water salvage is unknown. Prospects for water salvage over large areas of river so far appear to be limited as beetle–tamarisk interactions have not yet stabilized on western rivers.

The National Aeronautics and Space Administration's Terrestrial Observation Prediction System: A Comprehensive Modeling System and Insights from Collaborations with the U.S. National Park Service (oral presentation)

By Rama R. Nemani,[1] John E. Gross,[2] and Forrest Melton[3]

[1]National Aeronautics and Space Administration (NASA), NASA Ames Research Center, Moffett Field, Calif.

[2]U.S. National Park Service, Fort Collins, Colo.

[3]California State University, Monterey Bay, Calif.

The National Aeronautics and Space Administration's Terrestrial Observation Prediction System (TOPS) is a mature, comprehensive framework that can support monitoring and forecasting of landscape-level indicators of ecosystem condition. Terrestrial Observation Prediction System integrates operational satellite data, microclimate mapping, and ecosystem simulation models to characterize ecosystem status and trends. The TOPS team collaborated with the U.S. National Park Service (NPS) and other organizations to develop indicators that support management, to refine reporting results, and to develop and refine processes and techniques to affect "technology transfer" to NPS. Our presentation will provide an overview of TOPS, and challenges and solutions necessary to develop sustainable, useful, and persistent relationships necessary to operationalize the use of remotely sensed data and associated models to inform and support management of natural resource management in protected areas.

Sensitivity Analysis for Inverse Problems Solved by Singular Value Decomposition (oral presentation)

By Bernard T. Nolan[1] and Mary C. Hill[2]

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

[2]U.S. Geological Survey, Boulder, Colo.

Truncated singular value decomposition (SVD) can be used to mitigate inverse modeling convergence problems caused by parameter insensitivity and (or) parameter interdependence (correlation). To make SVD more transparent and informative, we consider the relation of SVD to an alternative method.

In truncated SVD, SVD parameters are defined as linear combinations of process-model parameters; that is, each SVD parameter is calculated by summing terms equal to a coefficient times a process-model parameter. The number of SVD parameters equals the number of process-model parameters. Important SVD parameters have larger singular values. SVD parameters with small singular values can be omitted from the regression to achieve convergence. The rule of thumb is to omit SVD parameters with singular values less than the largest singular value by five or six orders of magnitude. Representation of the process-model parameters within estimated SVD parameters is measured using the identifiability statistic in parameter estimation software, here called the SVD parameter loading (SVD-PL) statistic. For each process-model parameter, SVD-PL is calculated by squaring and summing the associated coefficients from all estimated SVD parameters. Summation over all SVD parameters equals 1.0.

The alternative method is based solely on process-model parameters and uses composite-scaled sensitivity (CSS) and parameter correlation coefficients (PCC). The rule of thumb is to omit all process-model parameters with CSS values less than the largest CSS value by about two orders of magnitude. Also, omit enough parameters with PCC absolute values larger than about 0.98 such that the set of estimated parameters has smaller PCC absolute values.

Our test case involves the U.S. Department of Agriculture's Root Zone Water Quality Model (RZWQM2) applied at the Merced River basin, Calif. For each of five soil layers, there are three parameters: saturated hydraulic conductivity (Ks), water content at field capacity (WFC), and bulk density (BD). There is also a globally applied nirogen transformation parameter (R45). There are 1,670 observations of aqueous nitrate and bromide concentrations, soil nitrate and organic matter content, and soil moisture content and water tension.

Regression experiments suggest that 15 of the 16 process-model parameters and all 16 SVD parameters could be estimated by regression. CSS values vary from 19.5 to 0.1; the three highest are WFC1>WFC2>BD2. The largest parameter correlation was for WFC1 and BD1 (PCC=-0.94).

Singular values vary from 1,870,000 to 336. SVD-PL suggests that the top four SVD parameters are dominated, in order, by BD2, WFC2, and WFC1, which is similar to the list identified using CSS. Additionally, BD1 is almost as dominant as WFC1, which is consistent with the high PCC between these two parameters.

The test case displays how resolving inverse model convergence problems using CSS and PCC is closely connected to SVD. SVD integrates parameter sensitivity and correlation, while CSS and PCC evaluate them individually. Each approach provides useful insights. Together, the methods provide a powerful set of tools for model calibration.

Abbreviation meanings follow: BD, bulk density; CSS, composite scaled sensitivity; Ks, saturated hydraulic conductivity; PCC, parameter correlation coefficient; RZWQM2, Root Zone Water Quality Model; SVD, singular value decomposition; SVD-PL, singular value decomposition parameter loading statistic; and WFC, water content at field capacity.

Evaluating Aqueous Geochemical Models and Codes (oral presentation)

By D. Kirk Nordstrom[1]

[1]U.S. Geological Survey, Boulder, Colo.

Scientific models and computer codes are useful tools in the elucidation of environmental processes and in the development and execution of regulatory requirements. However, inappropriate applications can lead to misunderstandings of science and poor policy decisions. “Models” are simplifications that represent our understanding of physical reality, and they are not the same as codes, which are rules to convert one type of information into another; models cannot be “validated” or “verified” in any general sense of these words. A model result can disagree with independent observations and be scientifically “correct;” similarly, a model can agree with observations and be “incorrect.” Models can be used to examine possible future scenarios and can aid in prediction; however, scientific predictions are “logical” not “temporal;” that is, we cannot predict the future, only the consequences of making good assumptions combined with well-established scientific principles. We should accept that policy decisions have to be made without all the answers that science might be able to provide or even to the degree of certainty that we would like. We should continue to test and evaluate models and codes and clarify their limitations without claiming that we can extrapolate their results reliably in scenarios that can never be corroborated.

Aqueous geochemical models use speciation calculations to determine the free-ion concentrations and activities that are useful in estimating the mineral saturation state, redox conditions, biotoxicity, bioavailability, and sorption properties of a water sample. It is also essential to reactive-transport modeling. In mixed electrolyte solutions such as natural water it is difficult to confirm the accuracy of the speciation calculation. Several analytical techniques, such as ion-selective potentiometry, voltammetry, ultraviolet-visible spectrophotometry, high-performance liquid chromatography-inductively coupled plasma-mass spectrometry, synchrotron radiation, and ion-exchange separation, can often discern types of speciation. Comparisons of these analytical speciation measurements with computed speciation values have had a range of success from poor to excellent. Examples include activity measurements of ions, measurement of inorganic complexes, determinations of redox species, and determinations of organic-metal complexes. Waters known or likely to be in solubility equilibrium with well-defined minerals can be compared successfully to their calculated saturation state. Speciation calculations can also be compared to laboratory measurements of activity coefficients, activities, and solubilities. Mineral saturation indices often reflect supersaturation for minerals of moderate-to-low solubility, such as calcite, ferrihydrite, goethite, gibbsite, barite, and fluorite. Supersaturation with respect to ferrihydrite and goethite can reflect poorly characterized solutes (insufficient filtration and ill-defined redox state). These and other examples do not indicate that the thermodynamic data are in error. Calcite seems to exhibit actual supersaturation for some groundwaters and surface waters, which may be caused by kinetic processes. We cannot always assume that aqueous equilibrium speciation calculations are correct. More comparisons between computational and analytical techniques are necessary. Standard test cases should be designed to demonstrate the reliability of models and codes at several levels of sophistication from speciation to batch mass transfer to reactive transport. Multicode comparisons would be helpful in clarifying the strengths and limitations of speciation computations.

Using the Reactive-Transport Simulator Phast To Model the Fate of Nitrogen in a Waste-Water Plume (oral presentation)

By David L. Parkhurst[1]

[1]U.S. Geological Survey, Denver, Colo.

Results of reactive-transport modeling are useful in understanding many subsurface hydrogeochemical problems, including the movement of natural and man-induced contamination. However, development of a site-specific reactive-transport model is a difficult process involving translation of geographic, hydrologic, and chemical information into the formats required by the simulator. Recent development work on PHAST (computer program that simulates multi-component, reactive solute transport in three-dimensional saturated groundwater flow systems) has focused on (1) simplifying the data translation process by the use of grid-independent spatial data, such as ArcInfo shape files, and (2) providing a comprehensive graphical user interface where users can define and visualize three-dimensional data.

The new features and interface to PHAST have been used to model the transport of ammonium and nitrate in a plume of waste water from a sewage treatment plant on Cape Cod, Mass. The model considers just the ammonium in the sewage effluent, which is assumed to be retarded by surface-sorption reactions and to react with oxygen from the native groundwater. Results of the modeling indicate that approximately three-fourths of this nitrogen flows into Ashumet Pond and the remainder ultimately discharges to the rivers and estuaries of Cape Cod. In the simulations, ammonium migrates approximately half the distance to the coast before it is oxidized to nitrate. The simulated discharge of ammonium-derived nitrate to the rivers and estuaries occurs over a period of nearly 200 years, with maximum loading of about 400 kilograms per year.

Succession Modeling of Everglades Vegetation Communities for Restoration Planning and Climate Change (oral presentation)

By Leonard G. Pearlstine,[1] Steve Friedman,[1] and Matthew Supernaw[1]

[1]Everglades National Park, National Park Service, Homestead, Fla.

The Everglades Landscape Vegetation Succession Model (ELVeS) is a spatially explicit probability model for predicting shifts in vegetation communities in the ecosystem. Probabilities of vegetation community presence, given a set of environmental conditions, are computed from the niche space of each community. Transitions between community states are defined with conditional probabilities weighted by spatial neighborhood community abundance and temporal lag periods specific to each respective plant community. Model rules defining niche spaces for vegetation communities are derived primarily from the literature and expert opinions of plant community responses to ecological drivers. Vegetation dynamics are influenced by current and past climate and water-management actions that have altered flow dynamics, and changed the timing and quantity of water resulting in varying hydropatterns. The model is designed to address ecological dynamics in vegetation communities positioned along a stress and competition gradients. Species and community spatial dynamics are represented by a balance between freshwater hydropatterns, nutrients, soil salinity, and sea level, as well as large-scale influences of climate change, fire, and hurricanes. A critical component of the ELVeS model design is a framework to promote incorporation of new knowledge as it is acquired. From the user's perspective, that means a familiar Excel spreadsheet parameterization file in which new communities, new parameters, or new values for parameters can be added without modification of source code. From a programmer's perspective, the ELVeS's modular construction facilitates model expansion, improvement, and flexibility to promote open-source computing. As system knowledge improves over time, new relationships can be integrated into new model components or replace previous frameworks. Preliminary simulation results demonstrate the application of vegetation succession modeling for evaluating Comprehensive Everglades Restoration Plan scenarios.

A Circuitscape Dispersal Model and Index for Connectivity in South Florida Landscapes (poster)

By Leonard G. Pearlstine,[1] Dianna Hogan,[2] and William Labiosa[3]

[1]Everglades National Park, National Park Service, Homestead, Fl.

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

[3]U.S. Geological Survey, Seattle, Wash.

Circuitscape is a unique approach to dispersal modeling that predicts paths and patterns of animal movements in heterogeneous landscapes using algorithms from electronic circuit theory. The approach links circuit and random walk theories based on the idea that corridors connecting habitats can be represented as current flows between electrical nodes. Multiple or wider corridors between habitats will have greater conductance than narrower paths. Because circuit theory can measure all possible pathways across a landscape simultaneously, it is being adapted as a particularly effective approach for evaluating impacts of development and landscape changes on mammal dispersal and habitat connectivity. To develop a useful landscape index, the impacts of landscape scale, extent, and configuration on Circuitscape results in South Florida were tested. Results are presented in environments ranging from open habitat with increasing rock-mine development to complex urban environments with intertwined natural corridors and habitat core areas. Methods for aggregating Circuitscape results into an index of connectivity are presented.

A Regional Modeling Approach to Estimating National Forest Productivity under Climate Change (oral presentation)

By Matthew Peters[1] and Abdessamad Tridane[1]

[1]Applied Sciences and Mathematics, Arizona State University East, Mesa, Ariz.

Climate change has the potential to influence the productivity of forest in the United States. Knowing information about the yield of forests can help managers and the wood product industries estimate the availability of timber for a management period and optimize management practices. Through a regional approach, we will model the potential productivity of forest in the United States under climate change and three management scenarios. Dominant species will be considered for each region, and a series of cellular automata models will be generated to estimate timber production at several time stamps until 2100. The U.S. Forest Service Forest Inventory and Analysis (FIA) data will be used to determine species dominance and will provide information about the stocking characteristics of each stand.

Land Surface Modeling, Data Assimilation, and Parameter Estimation with the Land Information System (oral presentation)

By Christa Peters-Lidard[1]

[1]National Aeronautics Space Administration (NASA) Goddard Space Flight Center, Greenbelt, Md.

Land Information System (LIS; *http://lis.gsfc.nasa.gov*) is a flexible land-surface modeling framework that has been developed with the goal of integrating satellite- and ground-based observational data products and advanced land-surface modeling techniques to produce optimal fields of land-surface states and fluxes. As such, LIS represents a step towards the next generation land component of an integrated Earth system model. In recognition of LIS object-oriented software design, use and impact in the land-surface and hydrometeorological modeling community, the LIS software was selected as a co-winner of NASA's 2005 Software of the Year award. Land Information System facilitates the integration of observations from Earth-observing systems and predictions and forecasts from Earth System and Earth science models into the decisionmaking processes of partnering agency and national organizations. With its flexible software design, LIS can serve both as a problem solving environment (PSE) for hydrologic research, enabling accurate global-water and energy-cycle predictions, and as a decision support system (DSS) to generate useful information for application areas, including water resource and ecological assessments, agricultural-yield forecasting, numerical weather prediction, and military-mobility assessment.

LIS evolved from two earlier efforts—North American Land Data Assimilation System (NLDAS) and Global Land Data Assimilation System (GLDAS)—that focused primarily on improving numerical weather prediction skills by improving the characterization of the land-surface conditions. Both GLDAS and NLDAS now use specific configurations of the LIS software in their current implementations. In addition, LIS was recently transitioned into operations at the U.S. Air Force Weather Agency to ultimately replace their Agricultural Meteorology system, and is also used routinely by the National Oceanic and Atmospheric Administration's National Centers for Environmental Prediction/Environmental Modeling Center for their land-data assimilation systems to support weather and climate modeling. LIS not only consolidates the capabilities of these two systems, but also enables a much larger variety of configurations with respect to horizontal spatial resolution, input datasets, and choice of land-surface model through "plug-ins." Land Information System has been coupled with the Weather Research and Forecasting model to support studies of land-atmosphere coupling, enabling ensembles of land-surface states to be tested against multiple representations of the atmospheric boundary layer. LIS has also been demonstrated for parameter estimation, where the use of sequential, remotely sensed soil-moisture products can be used to derive soil-hydraulic and texture properties given a sufficient dynamic range in the soil-moisture retrievals and accurate precipitation inputs. Land Information System has also recently been demonstrated for multimodel data assimilation using an Ensemble Kalman Filter for sequential assimilation of soil moisture, snow, and temperature. Ongoing work has demonstrated the value of bias correction as part of the filter, and also that of joint calibration and assimilation.

Potential-Field Inversion—Supporting the Construction and Testing of Geologic Models (oral presentation)

By Jeffrey D. Phillips[1] and V.J.S. Grauch[1]

[1]U.S. Geological Survey, Denver, Colo.

The inversion of potential-field (gravity and magnetic anomaly) data can provide useful information for developing or testing geologic models in two or three dimensions. This information can include the locations of geologic contacts or faults, often with estimates of dip, strike, and physical property contrast; the depth to basement rocks or the thickness of basin sediments; the extent of buried volcanic rocks; and the lithology of the basement. Practical approaches to potential-field inversion include iterative inversion using forward modeling with independent constraints, direct inversion using the conjugate gradient method, and methods that estimate the parameters of simple sources. The results of inversion vary by approach from surfaces representing geologic interfaces, to images of subsurface density or magnetization, to locations and characteristics of physical-property edges. Each of these results can be incorporated into geologic models, or can be used to test existing models for agreement with the observed gravity and magnetic anomaly data.

A Bayesian Network Model for Evaluating Sea-Level Rise Impacts (oral presentation)

By Nathaniel Plant,[1] E. Robert Thieler,[2] and Benjamin T. Gutierrez[2]

[1]U.S. Geological Survey, St. Petersburg, Fla.

[2]U.S. Geological Survey, Woods Hole, Mass.

Assessing the vulnerability of the coastal zone to sea-level rise (SLR) requires integrating a variety of physical, biological, and social factors. These include landscape, habitat, and resource changes, as well as the ability of society and its institutions to adapt. The range of physical and biological responses associated with SLR is poorly understood at some of the critical temporal and spatial scales required for decisionmaking. Here we describe a Bayesian statistical analysis framework developed from a wide range of information on coastal systems and the related uncertainties in physical and process characterizations. Basic datasets characterizing geologic and oceanographic variables are used as inputs to define the initial states of coastal systems, relevant forcing factors, prior behavior, and idealized model simulations. The Bayesian network is used to integrate these data to make probabilistic predictions of the future state of coastal environments, using parameters such as shoreline change, in response to different SLR scenarios. Competing hypotheses regarding the relationships between forcing, the responses, and their interrelationships are evaluated, and their uncertainties are compared. Results from the U.S. mid-Atlantic coastal region are used to explore different scenarios, as well as identify research needed to improve predictive skill. The Bayesian network approach provides an extensible framework to support decisionmaking and to evaluate specific management scenarios for adapting to SLR.

Modeling Trends in Nekton And Associated Changes in Northeast Coastal Salt Marshes (oral presentation)

By Penelope S. Pooler,[1] Megan C. Tyrrell,[2] Kimberly A. Lellis-Dibble,[3] Holly K. Bayley,[2] and Sara Stevens[1]

[1]National Park Service, Northeast Coastal and Barrier Network, Kingston, R.I.

[2]National Park Service, Cape Cod National Seashore, Wellfleet, Mass.

[3]Department of Natural Resources Science, University of Rhode Island, Kingston, R.I.

As part of the National Park Service Inventory and Monitoring program, the Northeast Coastal and Barrier Network (NCBN) and the Cape Cod Ecosystem Monitoring program have implemented long term monitoring of nekton in salt marshes. The goal of monitoring nekton and other ecosystem indicators is to gain information about the condition of salt marshes within the Northeast coastal parks over time. Detecting trends in salt-marsh nekton community structure, abundance, and species richness and relating these trends to changes in the physical aspects of salt marshes can be challenging. Collecting quantitative nekton data is expensive and time consuming and these data are highly variable, both seasonally and annually. Our goal in modeling nekton data is to differentiate between temporal variability and sustained or consistent trends associated with changes in salt marsh condition. Although the nekton monitoring program is relatively new throughout the NCBN, we were able to model trends using data collected over 5 years at a salt marsh site in Cape Cod National Seashore. We developed and evaluated models using a multivariate response of nekton community structure, as well as univariate responses such as species richness and abundance of specific nekton species and communities. Our preliminary model results indicate that after accounting for seasonal variability and physical variables, such as dissolved oxygen, water temperature, and salinity, we are able to detect trends after as few as 4 years of monitoring. We present the different models along with the interpretation of each and how we plan to utilize them as additional nekton and other salt-marsh data are collected over time.

A Network-Based Approach for Model Integration (oral presentation)

By Song Qian[1]

[1]Nicholas School of the Environment, Duke University, Durham, N.C.

Models are simplified summaries of our understanding of the complex natural world. Simplifications are generally achieved through aggregations at various spatiotemporal scales and processes. The need for model integration arises when individual models built for limited spatiotemporal scales are to be combined to model at a less aggregated level. This talk will focus on the integration of various empirical models developed using localized data to form a regional model with an emphasis on modeling for supporting environmental management decisionmaking. The framework for integrating empirical models is based on conditional probability principles of a statistical graphic model, where components represented by various "small" empirical models are connected through a causal network. A network-based model can be easily implemented using Markov chain Monte Carlo simulation. This talk will illustrate the process of model integration using a simple data example, which will lead to a general discussion.

Bayesian Network Models for Supporting Water Quality Management (oral presentation)

By Song Qian[1] and Roxolana Kashuba[1]

[1]Nicholas School of the Environment, Duke University, Durham, N.C.

Bayesian network (BN) modeling is a graphical modeling method commonly used to build causal models representing existing knowledge on a specific subject. A BN model starts with a graphical representation of causal links and uses conditional probability for establishing quantitative relationships among the nodes in the causal diagram. Because BN was initially developed to represent the thought process of human experts in performing certain specific tasks such as medical diagnoses, a BN model can explicitly incorporate human knowledge using conditional probability-distribution tables. As a result, a BN model is capable of using information from data and expert elicitation, a combination that makes BN ideal for supporting decisionmaking under uncertainty. Applications of BN in environmental and ecological studies are mostly focused on modeling for supporting environmental management, as the computational complexity limits BN to use only categorical variables. Compared to traditional statistical modeling approach, BN is unique in that it quantifies links between two variables using conditional probability distribution. Graphical presentations of a BN model often resemble other "network-based" models, such as the structure equation model (SEM), a topic introduced in a companion presentation. This similarity in presentation illustrates a common feature of network-based modeling approaches in their intuitive representation of the underlying causal relationships of interest. This talk will introduce the basic structure of a BN model and its construction, using recently BN models for supporting stream-water-quality management. These models are based both from existing National Water-Quality Assessment data and expert opinions. The author is interested in exploring the roles of various network-based modeling approaches in both science and management, as well as future development of network-based modeling.

GSFLOW—A Coupled Groundwater and Surface-Water Flow Model for Watershed Analysis (oral presentation)

By Steve Regan,[1] Steve Markstrom,[1] Richard G. Niswonger,[2] and Paul M. Barlow[3]

[1]U.S. Geological Survey, Lakewood, Colo.

[2]U.S. Geological Survey, Carson City, Nev.

[3]U.S. Geol Survey, Northborough, Mass.

Modeling environmental resource management and policy issues requires an interdisciplinary and adaptive approach. Development of integrated models for these purposes has been hindered because individual models often have different spatial and temporal resolutions, use incompatible software and programming techniques, and lack feedback mechanisms to link the models. No existing model accounts for all environmental processes and interactions and each model and modeler produces differing results based on their different approaches and biases. A modeling structure is needed to facilitate integration of interdisciplinary scientific contributions.

To understand complex environmental resource issues, integrated modeling of the hydrologic cycle is needed. As a step towards addressing integrated modeling, the U.S. Geological Survey (USGS) has developed a coupled groundwater and surface-water flow (GSFLOW) model. It is an integration of the USGS Precipitation-Runoff Modeling System (PRMS) and Modular Groundwater Flow Model (MODFLOW). GSFLOW uses climate, solar radiation, topography, geology, land-use, and pumping data to simulate the temporal and spatial distribution of evapotranspiration, infiltration, surface runoff, snowpack and melt, interflow, recharge, streamflow, lake mechanics, unsaturated and saturated groundwater flow, and groundwater and surface-water interactions.

The extensible design of GSFLOW allows for inclusion of new solution techniques, which provides modelers with a structure to integrate additional models. It also allows for ease of comparison between alternative model components for a given process as their algorithms can be tested and compared, which can lead to improvements and better understanding of interactions, feedbacks, and sensitivities in a hydrologic system.

Future enhancements to GSFLOW include enhanced ability to simulate the effects of climate change, water quality, conjunctive use and river system management, full-hydrodynamic streamflow with fate, and transport of constituents.

Climate Envelope Modeling for Evaluating Anticipated Effects of Climate Change on Threatened and Endangered Species in South Florida (poster)

By Stephanie Romañach,[1] Laura A. Brandt,[2] Leonard G. Pearlstine,[3] Don DeAngelis,[4] Ikuko Fujisaki,[5] and Frank Mazzotti[5]

[1]U.S. Geological Survey, Davie, Fla.

[2]U.S. Fish and Wildlife Service, Davie, Fla.

[3]Everglades National Park, National Park Service, Homestead, Fla.

[4]U.S. Geological Survey, Miami, Fla.

[5]University of Florida, Fort Lauderdale Research and Education Center, Davie, Fla.

We are developing climate envelope models for the 21 threatened and endangered (T&E) terrestrial vertebrates in South Florida. By virtue of its physical features and geography, Florida, and in particular, South Florida, will be highly susceptible to climate changes, specifically with regard to sea-level rise. For each of the T&E species under consideration, we are developing bioclimatic models, also called climate envelope models. These models will allow us to relate species' geographic distributions to climate factors. Predicted future climate variables will be used to predict future species distributions. Bioclimatic models are widely used because they can effectively predict climate-induced range shifts for large numbers of species and provide a first step that can address issues and needs at different spatial and temporal scales. We are working with local partners to ensure that the tools we develop will allow resource managers to examine potential effects of climate change on species' geographic ranges for ecosystem and landscape-level planning. Our initial focus is to work with partners in the Southeast region and expand the list of species of interest in that region; however, our methodology and products will be applicable to other species and regions.

Evaluating Mercury Contamination in Fish: A Multimodel Approach (oral presentation)

By Dana K. Sackett,[1] D. Derek Aday,[1] James A. Rice,[1] and W. Gregory Cope[2]

[1]North Carolina State University, David Clark Laboratory, Raleigh, N.C.

[2]Department of Environmental and Molecular Toxicology, North Carolina State University, Raleigh, N.C.

Since the industrial revolution, mercury concentration in the atmosphere has increased substantially, largely due to anthropogenic inputs from coal-fired power plants (Pacyna and Pacyna, 2006; Schuster and others, 2002). Because of the ease with which mercury is transported in the atmosphere and its long residence time, contamination in freshwater and marine ecosystems has become a global problem (Trudel and Rasmussen, 2006). After atmospheric mercury enters water bodies, it is chemically transformed by bacteria to methylmercury, the organic, highly toxic form of mercury that biomagnifies in aquatic food webs and constitutes a threat to wildlife and humans (Holloway and Weech, 2003). The mechanisms associated with mercury methlyation and its accumulation in fish tissue remains poorly understood, and health officials are often forced to recommend fairly nonspecific fish-consumption advisories. Our study addresses this problem through a comprehensive, statewide synthesis of data on fish mercury contamination in North Carolina and the environmental factors associated with methylmercury production and transport through aquatic food webs. Using data collected by the North Carolina Department of Environment and Natural Resources, the U.S. Environmental Protection Agency, and others, we examined the relationships between a suite of biotic and abiotic factors and tissue mercury concentrations in fish from North Carolina water bodies (Sackett and others, 2009). Multivariate tests were conducted to create predictive statistical models relating environmental variables to mercury levels in fish, and Akaike's Information Criterion was used to examine the relative strengths of candidate models. The best model in our analyses ($R^2 = 0.81$) included species, fish trophic status, ecoregion (areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources), and pH. Other important drivers of mercury accumulation were land-use patterns (the percentage of the subbasin that is agricultural) and site type (swamps versus lakes, rivers, and bays). Although previous investigations have indicated similar individual relationships, our study is unique in examining the relative importance of a large number of biotic and abiotic variables across a range of environments, ecosystems, and species. The results of these analyses should help policy-makers in making risk-assessment decisions and serve as a template for future investigations.

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Modeling Avian Malaria in Hawaiian Birds—Disease, Climate, and Geographic Interactions (oral presentation)

By Michael D. Samuel,[1] Peter Hobbelen,[2] Francisco de Castro,[3] Jorge Ahumada,[4] Dennis LaPointe,[5] and Carter Atkinson[5]

[1]U.S. Geological Survey, Wisconsin Cooperative Wildlife Research Unit, Madison, Wis.

[2]Rothamsted Research, West Common, Harpenden, Hertfordshire, United Kingdom

[3]University of Potsdam, Am Neues Palais, Potsdam, Germany

[4]Conservation International, Arlington, Va.

[5]U.S. Geological Survey, Pacific Islands Ecosystems Research Center, Hawaii

Mathematical modeling of host populations and their interaction with parasites, diseases, and vectors offers a means of assessing the importance of disease agents on wildlife populations and the potential effectiveness of alternative disease management strategies. Models can also summarize what we know about a disease system and identify the relative importance of different parts of the system. Recently, modeling has become an increasingly sophisticated tool for integrating the medical, epidemiological, and ecological approaches for understanding and predicting the dynamics of disease. Avian malaria plays a major role in the population dynamics and conservation of Hawaiian native birds and the persistence and dynamics of avian malaria are influenced by a complexity of interrelated factors that produce unexpected patterns. These factors include endogenous components of the disease system (vector and host abundance) and exogenous components that drive the system (climate), as well as landscape components (elevation and habitat) that influence the rates of biological processes, distribution of species, and abundance of organisms. We developed a model of the dynamics of avian malaria in the Hawaiian forest ecosystem using a Susceptible, Infected, and Recovered (SIR) model, based on ordinary differential equations. Our model includes the dynamics of the four host species, vector, and parasite, as well as the effects of climate and landscape changes on these processes. The model was used to evaluate the potential impact of avian malaria on Hawaiian birds, determine which model variables have the strongest influence on our results, and evaluate several conservation strategies to benefit Hawaiian birds. Our model simulations illustrate several key attributes of the malaria-forest bird system in Hawaii. Malaria infection patterns are characterized by: (1) high levels of transmission in low-elevation forests with little seasonal or annual variation in infection rates; (2) episodic levels of transmission in midelevation forests with site-to-site, seasonal, and annual variation, depending on mosquito dynamics; and (3) disease refugia in high-elevation forests with only slight risk of infection occurring during summer when climatic conditions are briefly favorable to pathogen and mosquito development. These infection patterns are driven by the effects of climate (temperature and rainfall) on mosquito dynamics across an elevational gradient. Overall, our model demonstrates that the introduction of avian malaria and a competent mosquito vector can significantly reduce the diversity and abundance of native Hawaiian birds, especially the unique and highly visible honeycreepers in low-elevation and midelevation forests. Climate change is likely to have significant impacts on the future of this unique avifauna.

Modeling Approaches Using Remote Sensing Data from the National Ecological Observation Network (Neon) Airborne Observations (oral presentation)

By Dave Schimel[1] and Brian Johnson[1]

[1]National Ecological Observatory Network (NEON) Inc., Boulder, Colo.

NEON Inc., being funded by the National Science Foundation, is a continental-scale ecological observation platform for understanding and forecasting the impacts of climate change, land-use change, and invasive species on ecology. Airborne remote sensing plays a critical role in the scaling strategy underpinning the observatory design that will bridge scales from organism and stand scales captured in field samples and automated ground-sensor measurements to the scale of satellite-based remote sensing. The instrumentation consists of a high-fidelity imaging spectrometer measuring surface reflectance over the visible-to-shortwave infrared and a waveform recording light detection and ranging (LIDAR), providing spatially explicit information on regional vegetation canopy biochemistry and structure, respectively. A high-resolution digital camera is included to support land-cover and land-use identification at submeter resolution. The powerful synergy between LIDAR and spectroscopy has been exploited for detection and mapping of invasive species in Hawaii where these invasives are transforming the three-dimensional structure of the forest ecosystem (Asner, and others, 2008). In another example, LIDAR measurements of vegetation structure can be used to improve model estimates of carbon stocks. Hurtt and others (2004) take advantage of the relationship that exists between vegetation height, and ecosystem structure and dynamics, using LIDAR data as a constraint in an ecosystem-demography model estimating carbon stocks and fluxes in La Selva, Costa Rica. NEON long-term measurements of the heterogeneity in vegetation structure in sampled regions across the continent and continued development of ecosystem models can extend these results to larger scales. This paper explores the potential of combing remotely sensed airborne data with ecosystem models for improved estimates of continental-scale ecosystem structure and function.

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Identifying Limits on Aquatic Insect Density Exposed to Metals in the Presence of Colimiting Factors (oral presentation)

By Travis S. Schmidt,[1] William H. Clements,[2] and Brian S. Cade[1]

[1]U.S. Geological Survey, Fort Collins, Colo.

[2]Fish, Widllife and Conservation Biology Department, Colorado State University, Fort Collins, Colo.

Quantile regression was used to estimate the effect of metal concentrations on the density of a caddisfly (*Arctopsyche grandis*) and two mayflies (*Rhithrogena* spp. and *Drunella* spp.) at 125 discrete locations in Colorado. Akiaki Information Criteria were used to evaluate which colimiting factors (metals, basin area, elevation, stream temperature, and discharge) likely limited each quantile (0.05^{th} to 0.95^{th} by 0.05) of taxa density. Densities differed heterogeneously with increasing metal concentration and were described by multiple quantile slopes and limiting factors. High quantiles ($>50^{th}$) of density were more reliably related to metal concentrations and generally had higher rates of change (steeper slope) than lower quantiles ($<50^{th}$). Caddisfly density was not limited by metals concentrations. Maximum densities (90^{th} quantile) of the two mayflies declined by 56 to 60 percent at metal concentrations previously thought safe for aquatic life.

A Model for Estimating Spatial Subsidies Associated with the Ecosystem Services Provided by Migratory Species (oral presentation)

By Darius J. Semmens,[1] Jay E. Diffendorfer,[2] and Laura Lopez-Hoffman[3]

[1]U.S. Geological Survey, Denver, Colo.

[2]U.S. Geological Survey, Denver, Colo.

[3]University of Arizona, School of Natural Resources and Environment, Tucson, Ariz.

Migratory species support ecosystem process and function in multiple areas, establishing ecological linkages between their different habitats. As they travel, migratory species also provide an array of services to people in many different locations, producing socioeconomic linkages between different regions. These linkages create the potential for discrepancies between the areas that most support a species' population viability and, therefore, their long-term ability to provide services, and those areas that benefit most as a result of services provided by the species. Even when such discrepancies are recognized, however, there is no established method for their quantification, or for the equitable redistribution of income that could help offset the cost of conservation efforts aimed at preserving a migratory species, its unique ecological functions, and the value we derive from them.

Utilizing examples of important migratory species, we present a conceptual framework for estimating both how much a particular location supports the provision of ecosystem services in other locations, and the extent to which locally derived benefits are dependent upon other locations. We further describe a method for estimating the net payment, or subsidy, owed by or to a location that balances benefits received and support provided by locations throughout the migratory range of multiple species. The ability to recognize and quantify these spatial subsidies from migration could provide a foundation for the establishment of markets that internalize the costs and benefits of protecting migratory species, thereby creating economic incentives for cross-jurisdictional cooperative management. The information requirements to fully realize the potential of this approach are substantial; new data, data-integration, and assessment methods are necessary. We argue, however, that the utility of ecosystem services as a framework for environmental management and conservation is severely limited without the capacity to explicitly account for migration and ecosystem services provided by migratory species.

Characterizing Landscape Evapotranspiration Dynamics Using Remote Sensing and Global Weather Datasets (oral presentation)

By Gabriel Senay,[1] Stefanie Bohms,[2] David S. Morgan,[3] Michael T. Moreo,[4] Sharon Qi,[5] and Scott C. Christenson[6]

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

[2]ARTS, Sioux Falls, S. Dak.

[3]U.S. Geological Survey, Portland, Oreg.

[4]U.S. Geological Survey, Henderson, Nev.

[5]U.S. Geological Survey, Vancouver, Wash.

[6]U.S. Geological Survey, Albuquerque, N. Mex.

Landscape evapotranspiration (ET) is a key component of the hydrologic water balance of a watershed. The increasing availability of global datasets for weather variables and remotely sensed data for land-surface temperature allows us to make estimates of landscape ET. Spatial distribution of landscape ET can be used as an indicator of vegetation performance in terms of biomass accumulation, which is directly associated with water use. Furthermore, ET can be used to estimate the spatiotemporal dynamics of the rates and total amounts of groundwater recharge and withdrawal from aquifer systems in irrigated areas. We have applied the Simplified Surface Energy Balance (SSEB) modeling approach to characterize landscape ET for the Columbia Plateau, Nevada Transect and High Plains Aquifer using 10 years (2000–2009) of available satellite data. We used weather data from the Global Data Assimilation System (GDAS) to calculate reference ET. Land Surface Temperature (LST) was derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. The comparison between model-generated actual ET and independent estimates of irrigation application depth showed good correspondence ($r^2>0.90$) in the Yakima Valley with about one-third of estimated irrigation application being converted into ET. Potential groundwater recharge and withdrawal sites were identified. The spatial and temporal patterns of monthly and seasonal actual ET corresponded well with common knowledge in regard to irrigated areas and differences in land-cover types in the case of Nevada Transect and High Plains Aquifer. More validation of the ET estimates will need to be conducted using independent flux measurements and basin water-balance modeling. The method is promising for large-scale operational monitoring of landscape ET across varied landscapes for drought monitoring and water-balance studies.

Combined Geochemical and Stable Isotope Reaction Modeling: An Important Tool for Understanding Geochemical Transformations (oral presentation)

By W.C. Pat Shanks[1] and Jeff Alt[2]

[1]U.S. Geological Survey, Denver, Colo.

[2]Department of Geological Sciences, University of Michigan, Ann Arbor, Mich.

Pioneering studies by Plummer (1977) showed that combining mass transfer geochemical modeling with stable isotopes can greatly constrain water-rock reactions in natural systems, sometimes uniquely. Better constrained reaction models mean better understanding of geochemical processes and better decisionmaking in managing resources and ecosystems.

Similar approaches, but with completely coupled reaction codes, have been successfully applied to seafloor hydrothermal systems (Bowers and Taylor, 1985; Janecky and Shanks, 1988; Bohlke and Shanks, 1994). More recently, Alt and Shanks (2003) have shown that serpentinized peridotites from the MARK (Mid-Atlantic Ridge, Kane Fracture Zone) area contain a sulfur-rich secondary mineral assemblage and have high sulfur contents (up to 1 wt.%) and elevated $\delta^{34}S_{sulfide}$ (3.7 to 12.7‰). Geochemical reaction modeling indicates that seawater-peridotite interaction at 300 to 400 °C alone cannot account for both the high sulfur contents and high $\delta^{34}S_{sulfide}$. These require a multistage reaction with leaching of sulfide from subjacent gabbro during higher temperature (~400 °C) reactions with seawater and subsequent deposition of sulfide during serpentinization of peridotite at ~300 °C. Subsequent studies of seafloor hydrothermal serpentinization reactions have provided field evidence confirming ubiquitous involvement of gabbros in these hydrothermal systems (Alt and others, 2008).

The development of programs like Geochemist's Workbench, which includes an algorithm for stable isotope calculations, and increasingly available fractionation data for new stable isotope systems (Cd, Cr, Cu, Fe, Hg, Mo, Se, Tl, W, and Zn) provides an opportunity for better constrained modeling of geochemical and microbial reactions that affect ecosystems, natural waters, and water-rock reactions.

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Developing a GIS Application for Assessing, Mapping, and Quantifying the Social Values of Ecosystem Services (oral presentation)

By Benson C. Sherrouse,[1] Jessica M. Clement,[2] and Darius J. Semmens[1]

[1]U.S. Geological Survey, Denver, Colo.

[2]Department of Forest, Rangeland and Watershed Stewardship, Colorado State University, Fort Collins, Colo.

As human pressures on ecosystems continue to increase, research needs involving the effective incorporation of social values information into the economic context of comprehensive ecosystem services assessments are becoming more critical. Including quantified and spatially explicit measures of social values in such assessments will improve the analysis of tradeoffs among ecosystem services. In response to these needs, the Rocky Mountain Geographic Science Center (RMGSC) has been developing a geographic information systems (GIS) application, Social Values for Ecosystem

Services (SolVES). SolVES can be used to assess, map, and quantify the perceived social values of ecosystem services through the derivation of a quantitative social values metric, the Value Index, from a combination of spatial and nonspatial responses to public attitude and preference surveys. SolVES also generates landscape metrics calculated from spatial data layers describing the underlying physical environment (for example, average elevation and distance to water) at locations along the Value Index gradient. The initial phase of development focused on survey data previously collected by researchers at Colorado State University regarding the Pike and San Isabel National Forests in Colorado. Using kernel density calculations and zonal statistics, SolVES derives and maps the 10-point Value Index and reports landscape metrics associated with each index value for social value types such as aesthetics, biodiversity, and recreation. This can be repeated for various survey subgroups as distinguished by their attitudes and preferences regarding public uses of the forests, such as motorized recreation and logging for fuels reduction. The Value Index provides a basis of comparison within and among survey subgroups to consider the effect of social contexts on the valuation of ecosystem services. Additionally, SolVES output facilitates statistical analysis of the relationship between the variation in index values and landscape metrics through correlation and multiple regression. These statistical methods have been used to generate regression coefficients, which when applied to their corresponding landscape data layers, have generated predicted social value maps that compare favorably with SolVES output. Based on these results, a predictive mapping function permitting value transfer to similar areas where survey data are not available has been added to SolVES. A more robust version of SolVES is being developed as a public domain tool, enabling decisionmakers and researchers to map the social values of ecosystem services and to facilitate discussions among diverse stakeholders involving the tradeoffs between different ecosystem services in a variety of physical and social contexts.

Geobiochemistry in Hydrothermal Ecosystems (oral presentation)

By Everett L. Shock[1]

[1]School of Earth and Space Exploration, Arizona State University, Tempe, Ariz.

The merger of geochemical models with advances in molecular biology enable new investigations of the interplay between geochemical and biochemical processes. Hydrothermal ecosystems, which are overwhelmingly microbial, offer opportunities for testing emerging hypotheses from this merger. Thermodynamic analysis of hot spring geochemistry reveals a wide variety of oxidation-reduction disequilibria that are potential sources of chemical energy that chemosynthetic microbes could use. These assessments rely on accurate calculations of fluid speciation, which, in turn, can be used to assess the availability of nutrients, metals, and toxins. Molecular data from environmental samples can reveal the presence of genes involved in accessing the geochemical energy sources, those linked to the uptake and cycling of nutrients and metals, and others that may be involved in the transformation or elimination of toxins. Merging these results reveals cases where geochemically provided conditions and potential biochemical pathways converge.

Thermodynamic analysis of geochemical data from hot spring ecosystems in Yellowstone National Park (YNP) allows ranking of chemical energy supplies across a wide range of temperature (40°–93° C; boiling at the elevation of YNP), pH (1.9–9.2), and several order-of-magnitude variations in nutrient and metal concentrations. These results show that oxidation of carbon monoxide, hydrogen sulfide, methane, and hydrogen all yield abundant energy across the composition spectrum, while the energy yields from oxidation of aqueous ferrous iron to magnetite, hematite, or goethite increase dramatically as pH increases (Shock and others, 2010). Environmental genomic and other molecular data are far less abundant than geochemical data for YNP hot springs, although the inventory is growing rapidly. Where data are abundant, as in the case for the Bison Pool Environmental Genome Project, they reveal the presence of genes for enzymes directly involved in hydrogen oxidation, carbon dioxide reduction, ammonia oxidation, nitrogen fixation, and numerous other processes. Tying these observations to the results of geochemical analyses and thermodynamic models enables rapid assessment of which microbial processes can occur, where, and why. Gene expression coupled with kinetic studies of oxidation-reduction processes will then pave the way for determining how geochemical challenges drive biochemical solutions, which greatly influence microbial diversity.

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Mass Movement in Northeast Afghanistan (oral presentation)

By John Ford Shroder,[1] Michael Bishop,[1] and Megan Jensen Schettler[1]

[1]Geography and Geology, University of Nebraska at Omaha, Omaha, Nebr.

Mass movements of nearly all types occur in Afghanistan; however, in the rocky and rugged, high-relief Hindu Kush and eastern Pamir mountains of Badakshan Province in northeastern Afghanistan, rockslides and rock falls are commonly intermixed into 20 large-sized slope-failure complexes with many other types and times of movement. Many smaller rock falls and rockslides occur that were not included in this study. Where higher altitudes prevail in the region, ice-cemented and ice-cored rock glaciers commonly overlie or are intermixed into the landslides. At lower altitudes in western Badakshan, covering mantles of Quaternary loess, which were deflated from the Karakumsky Desert of Turkmenistan and steppes and deserts of northern Afghanistan, thicken from close to their western sources and thin into eastern mountain repositories. Some 24 loess slides and flows were mapped and measured. Inasmuch as seismic energy sources are maximal in southern Badakshan, and relief, slope angles, low temperature, and precipitation all increase from west to east as well, causes of the pervasive mass movements are plentiful. Some weak sedimentary lithologies of late Tertiary age that were downfaulted into crystalline rocks or draped across them also contribute to instability.

Using high-resolution satellite imagery and digital elevation models, we delineated all large landslides. Landslide morphometric characteristics were then assessed using global parameters, parameter-area, and parameter-altitude functions. We then segmented each landslide into terrain units based upon geomorphometric characteristics to characterize the spatial-organization structure related to zones of erosion and deposition. Geomorphometric and object-oriented analyses indicate that many of the massive slope failures can be uniquely characterized and differentiated into various types that are reflective of their potential impacts upon the landscape. Results suggest that mass movements can exhibit unique topographic signatures that can be used to better assess hazards in many areas. Development of roads, bridges, buildings, and irrigation networks should be done with care in these regions.

Satellite-Based Evapotranspiration and Gross Primary Productivity for the Midcontinent Intensive Campaign (oral presentation)

By Ramesh Singh,[1] Shuguang Liu,[1] and Larry Tieszen[1]

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

Evapotranspiration (ET) and gross primary productivity (GPP) are tightly coupled and play critical roles in regulating the hydrological, climatic, and ecological dynamics at various scales. Accurately estimating ET and GPP over large areas is important but has been challenging due to their variability in space and time. The purpose of this study was to develop a modeling approach for estimating ET and GPP at different spatial and temporal scales. We used temporal Landsat images for the Midwestern States with an energy balance approach for estimating ET and with a light-use efficiency method for estimating GPP. The estimated fluxes were compared with measurements from flux towers. We show that energy balance and light-use efficiency methods can be effectively used in this region for estimating ET and GPP, respectively. The partitioning of available energy into latent heat (ET) at the surface (evaporative fraction) is constrained by the available moisture and evaporative demand of the atmosphere. The spatial distribution of ET was closely linked to the spatial pattern of GPP on land surfaces. The results also indicate the need for quality assessment of flux tower measurements. The modeling approach used in this study will be implemented using Moderate Resolution Imaging Spectroradiometer (MODIS) images to understand the scaling issues for continental and global study of ET and GPP.

A Land of Flowers on a Latitude of Deserts: Aiding Conservation and Management of Florida's Biodiversity by Using Predictions from "Downscaled" Atmospheric-Ocean General Circulation Models (AOGCM) Climate Scenarios in Combination with Ecological Modeling (poster)

By Thomas J. Smith III,[1] Micheal Allen,[2] Eric Chassignet,[3] Hal Davis,[4] Don DeAngelis,[5] Ann Foster,[6] Wiley Kitchens,[6] Vasu Misran[3] Franklin Percival,[6] Nathaniel Plant,[1] Daniel Slone,[6] Lydia Stefanova,[3] Brad Stith,[7] Eric D. Swain,[8] David Sumner,[9] Ann Tihansky,[1] Susan Walls,[6] and Christa Zwieg[6]

[1]U.S. Geological Survey, St. Petersburg, Fla.

[2]Department Fisheries and Aquatic Sciences, University of Florida, Gainesville, Fla.

[3]Center for Ocean-Atmospheric Prediction Studies, Florida State University, Tallahassee, Fla.

[4]U. S. Geological Survey, Tallahassee, Fla.

[5]U.S. Geological Survey, Miami, Fla.

[6]U.S.Geological Survey, Gainesville, Fla.

[7]Jacobs Technology, Inc, Gainesville, Fla.

[8]U.S. Geological Survey, Fort Lauderdale, Fla.

[9]U.S. Geological Survey, Orlando, Fla.

La Florida (Land of Flowers) straddles latitudes forming the Northern hemisphere's desert belt. Orlando is one degree latitude south of Cairo, Egypt. Florida is unique because it is a peninsula surrounded by warm water. How will Florida's biodiversity respond to a changing climate? Which species and habitats will increase and which will decrease? What role does land use and land cover (LULC) change play? Before these questions can be answered, accurate regional climate change scenarios must be developed. We are downscaling predictions from three coupled AOGCMs and making regional predictions for Florida and the adjacent southeastern United States. Climate predictions are being used as inputs to a suite of species/habitat/ecosystem models that are currently being used in two areas where we have existing ecological models: the Greater Everglades and Suwannee River-Big Bend. Selected species include: manatee, alligator, crocodile, wading birds, and a number of tropical tree species. Three scenarios of LULC are employed: past (≈1900), present, and future (2041–2070). Additional climate model runs will address the contribution of green house gasses to climate variability and change. Model perturbation experiments will be performed to address sources of variability and their contribution to the output regional climate change scenarios. We have scenarios that specifically address potential change in temperature and rainfall fields over the study region. We are providing these scenarios and modeling results to resource management groups via workshops in which the scenarios will be used to predict responses of additional selected species, habitats, and ecosystems.

Developing a Land-Use Modeling Framework To Support Analyses of Carbon Sequestration and Flux (oral presentation)

By Terry Sohl,[1] Benjamin Sleeter,[2] Kristi Sayler,[1] William Acevedo,[1] Michelle Bouchard,[3] and Stacie Bennett[4]

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

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

[3]Arctic Slope Research Corporation, Sioux Falls, S. Dak.

[4]SGT Corporation, Sioux Falls, S. Dak.

The goal of the LandCarbon project is to conduct a comprehensive and scientifically credible assessment of the Nation's ecosystems for present and future potential sequestration capacities and fluxes of three greenhouse gases, including carbon. A comprehensive and integrated land-use and land-cover (LULC) modeling framework is required to support this work, as LULC change is an extremely important factor controlling carbon flux. The FOREcasting SCEnarios of land-cover change (FORE-SCE) model (Sohl and Sayler; 2008; Sohl and others, 2007) will be utilized to provide (1) forecasts of multiple potential futures under different socioeconomic and climatic scenarios; (2) LULC forecasts at relatively high spatial resolutions (250 m) at a national scale; and (3) forecasts of sufficient thematic detail to examine carbon sequestration and flux implications.

The FORE-SCE model utilizes distinct but linked "Demand" and "Spatial Allocation" components as a means to handle driving forces of LULC operating at scales from global to local. Demand provides aspatial proportions of LULC change for a given region, that is, annual "prescriptions" for regional LULC change. Demand for the LandCarbon project corresponds to LULC change stories constructed within the framework of Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) storylines. SRES storylines describe global driving forces of LULC change. The primary elements of scenario construction are: (1) qualitative interpretation and translation of SRES storylines to national and regional scales; (2) downscaling of SRES quantitative land-use projections and (3) development of linkages between SERS products and regional land-use histories. An integration of these elements will be used to construct regionally specific LULC scenarios for each EPA Level II ecoregion, including annual prescriptions of LULC change.

Regional prescriptions of LULC change from the Demand component are used to inform the Spatial Allocation component, which spatially distributes prescribed LULC change on the landscape. The primary component of the Spatial Allocation component are probability surfaces, constructed through the analysis of empirical relationships between LULC patterns and an array of spatially explicit biophysical and socioeconomic data. FORE-SCE then utilizes a unique methodology to place LULC "change" on suitable site locations, patch-by-patch, utilizing historical LULC data from the U.S. Geological Survey Trends project to regionally parameterize realistic patch sizes and configurations for each modeled LULC transition. Forest stand age is established from Forest Inventory and Analysis (FIA) data and tracked to enable more realistic modeling of forest-cutting cycles. A Protected Areas Database of the United States (PAD-US) is utilized to restrict unrealistic LULC change in protected regions. FORE-SCE will provide LULC projections for each scenario on an annual basis from 2001 through 2050, utilizing the 2001–2010 time period to calibrate the model and validate model performance.

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Convolution-Based Particle Tracking Method for Modeling Groundwater Transport for Transient Flow Conditions (oral presentation)

By G. Srinivansan,[1] E. Keating,[2] C. Li[3], Q. Kang,[2] and E. Kwicklis[2]

[1]Los Alamos National Laboratory, Theoretical Division-Mathematical Modeling and Analysis and Plasma, Los Alamos, N. Mex.

[2]Los Alamos National Laboratory, Earth and Environmental Sciences, Los Alamos, N. Mex.

[3]Areva Federal Services, Albuquerque, N. Mex.

A convolution-based particle tracking (CBPT) method is developed to calculate solute concentrations in groundwater models under transient flow conditions. This method is valid for linear transport processes such as first-order decay or linear sorption. A pulse of particles is introduced at various times for every source location, depending on the nature of the flow. Numerical convolution of particle paths obtained at each release time and location with a time-varying source term is performed to yield the shape of the plume. The assumption of linearity allows for superposition of multiple solute sources. The CBPT method uses fewer particles for a single particle tracking run, from which source term variability, sorption, and decay can all be simulated rapidly without additional process-model runs. We demonstrate the computational efficiency and numerical accuracy of the CBPT method for transient flow, for various flow and transport scenarios with special emphasis on diffusion, in a three-dimensional porous medium.

Modeling Storm-Driven Wave Runup for Use in Forecasts of Coastal Geomorphic Change During Hurricanes (oral presentation)

By Hilary Stockdon,[1] David Thompson,[1] and Nathaniel Plant[1]

[1]U.S. Geological Survey, St. Petersburg, Fla.

Hurricanes can cause extreme changes to coastal topography, including the destruction of protective dunes, the creation of large overwash deposits, and the opening of new inlets. These changes have a profound impact on coastal environments and may increase vulnerability to future storms. The type and magnitude of barrier island response to storms is dependent, in part, on the interactions between beach morphology and the oceanographic forces associated with waves and storm surge. The shoreline manifestation of these forces includes wave runup, which is often an ignored contribution to hurricane-induced water levels. For a range of typical beach and wave conditions, the elevation of wave runup, as well as its components swash and setup, can be estimated from offshore wave height, wave period, and a local beach slope using empirical parameterizations (Stockdon and others, 2006). However, extending these runup predictions to accurately cope with extreme storm conditions requires new modeling approaches.

Because observations of runup during extreme wave events are often unavailable, a numerical model (Xbeach) was used to simulate wave-group-generated surf and swash motions during storms. Extensive comparisons between modeled, parameterized, and observed runup at the U.S. Army Corps of Engineers Field Research Facility in Duck, N.C., reveal systematic differences between modeled and observed runup. Characterizing these differences allows modeled data to be used to extend the application of the empirical runup formulation to storm conditions. This will result in improved predictions of coastal erosion due to future hurricanes and other extreme storms.

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Advances in Species-Environmental Mapping Modeling (oral presentation)

By Thomas Stohlgren,[1] Catherine S. Jarnevich,[1] Sunil Kumar,[2] and Jeffrey T. Morisette[1]

[1]U.S. Geological Survey, Fort Collins, Colo.

[2]Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colo.

Species-environmental matching models have surged in use to map rare species and harmful invasive species around the globe. We tested several models to identify suitable habitat for invasive plants, animals, and diseases. The models have proved useful in mapping suitable habitat as a hypothesis of potential species distributions to be refined as new data become available. Recent advances in data assimilation, remote-sensing integration, and innovative modeling algorithms now make it possible to address a variety of questions important to conservation biologists, resource managers, and policymakers. We provide a brief overview of species-environmental matching models, and we discuss the recent advances in the field. We discuss caveats, shortcomings, and misuses of the models before demonstrating new applications of the models to address metapopulation issues, the effects of multiple tree pathogens, and changes in species distributions over time. Then, we show how five individual models (logistic regression, boosted regression trees, random forest, multivariate adaptive regression splines, and Maxent) can be combined for an "ensemble model" for selected nonnative plant species in national parks. We conclude with a look to the future, where the models integrate climate change, land-use change, and remote sensing to map and model the leading edges of harmful invasive species. We show how citizen scientists can contribute to species mapping capabilities.

Advances and Applications of Hydrodynamic Transport Modeling Coupled to Underlying Groundwater Flow in Southern Florida, U.S.A. (oral presentation)

By Eric D. Swain,[1] Melinda Lohmann,[1] Catherine Langtimm,[2] Jeremy D. Decker,[1] Brad Stith,[3] and M. Dennis Krohn[4]

[1]U.S. Geological Survey, Fort Lauderdale, Fla.

[2]U.S. Geological Survey, Gainesville, Fla.

[3]Jacobs Technology, Inc, Gainesville, Fla.

[4]Center for Coastal and Watershed Studies, U.S. Geological Survey, St. Petersburg, Fla.

The Flow and Transport in a Linked Overland/Aquifer Density-Dependent System (FTLOADDS) is a simulator that couples a two-dimensional hydrodynamic code with a groundwater flow and salinity transport code. The capabilities of FTLOADDS address the unique hydrologic conditions in South Florida, such as the high surface-water and groundwater connectivity and dynamic coastal-flow interactions. Models developed with the FTLOADDS simulator include the Tides and Inflows to the Mangrove Everglades (TIME), the Biscayne Southeastern Coastal Transport (BISECT), and the Ten Thousand Islands (TTI) model. These three different models show the capabilities and applicability of FTLOADDS to different types of hydrological problems in South Florida.

TIME is the first application to be widely used for simulating the dynamic coastal hydrology in Everglades National Park (Wang and others, 2007). Northern inflows to TIME were modified to represent the effects of regional hydrologic modifications planned for ecosystem restoration. The simulation supplies information to ecological models of species behavior and habitat. A model of coastal fish species (Cline and other, 2004) and an American Crocodile population model make use of TIME hydrologic output.

BISECT combines the areal data from the TIME model with data from a FTLOADDS model of the Biscayne Bay urban area. BISECT has been used by the Army Corps of Engineers to examine sea-level rise effects on urban flooding and salinity intrusion. Also, three 7-year BISECT simulations between the years 1926 and 1952 were produced for a multidisciplinary study to delineate coastal-landscape changes. The 1926 Miami hurricane and other storm events were simulated and results compared with historic data such as aerial photography.

The TTI model simulates the hydrology of the Ten Thousand Islands area (Swain and Decker, 2009) to examine the effects of an ecosystem restoration project on local manatee habitats. A surface-water heat-transport component was added to the FTLOADDS code as water-temperature is important to manatee ecology. The TTI model is used to create boundary conditions for a small-scale, three-dimensional surface-water salinity and heat-flow model of the Port of the Islands, a local manatee habitat, to determine factors that contribute to thermal inversions, which benefit the manatees.

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Development and Application of a Decision Support System for Water Management Investigations in the Upper Yakima River, Washington (oral presentation)

By Colin Talbert[1] and Christopher L. Holmquist-Johnson[1]

[1]U.S. Geological Survey Fort Collins, Colo.

The need for better integration of science and decision-making in environmental management is widely documented. In light of anticipated climate change and associated changes in demographics, land-use, and water-management practices, decisionmakers are confronted with the need to make major decisions in the face of high system complexity and uncertainty. The integration of useful and relevant scientific information is necessary and critical to enable informed decisionmaking (Liu and others, 2008). The Yakima River Decision Support System (YRDSS) was designed to quantify and display the consequences of different water-management scenarios for a variety of state variables in the upper Yakima River Basin, located in central Washington. The impetus for the YRDSS was the Yakima River Basin Water Storage Feasibility Study, which investigated alternatives for providing additional water in the basin for threatened and endangered fish, irrigated agriculture, and municipal water supply. The additional water supplies would be provided by combinations of water exchanges, pumping stations, and off-channel storage facilities, each of which could affect the operations of the Bureau of Reclamation's (BOR) five headwaters reservoirs in the basin. The driver for the YRDSS is RiverWare, a systems-operations model used by BOR to calculate reservoir storage, irrigation deliveries, and streamflow at downstream locations resulting from changes in water supply and reservoir operations. The YRDSS uses output from RiverWare to calculate and summarize changes at five important flood plain reaches in the basin to 14 state variables: (1) habitat availability for selected life stages of four salmonid species, (2) spawning-incubation habitat persistence, (3) potential redd scour, (4) maximum water temperatures, (5) outmigration for bull trout (*Salvelinus confluentus*) from headwaters reservoirs, (6) outmigration of salmon smolts from Cle Elum Reservoir, (7) frequency of beneficial overbank flooding, (8) frequency of damaging flood events, (9) total deliverable water supply, (10) total water supply deliverable to junior water-rights holders, (11) end-of-year reservoir carryover, (12) potential fine-sediment transport rates, (13) frequency of events capable of armor layer disruption, and (14) geomorphic work performed during each water year. Output of the YRDSS consists of an extensive series of conditionally formatted scoring tables, wherein the changes to a state variable resulting from an operational scenario are compiled and summarized. This convention was designed to provide decisionmakers with a quick visual assessment of the overall results of an operating scenario, but the large number of individual output tables made comparison of competing scenarios difficult in practice. In order to demonstrate a better way of presenting YRDSS results, we developed a graphical user interface (GUI) that assisted with navigating DSS output. This interface was designed to provide decisionmakers with summary charts comparing operating scenarios but added the ability to progressively drill down to the specific data and modeling behind the summary statistics. Additionally, we provide decisionmakers with insight into our spatial habitat modeling by embedding a simple geographic information system (GIS) into the DSS which allows a user to visually inspect the species habitat data and the inputs that went into its creation.

Indices of Social Vulnerability to Hazards: Model Uncertainty and Sensitivity (oral presentation)

By Eric Tate[1]

[1]Department of Geography, University of South Carolina, Columbia, S.C.

Typical social vulnerability index development involves the selection of indicators, collection of associated demographic data, normalization of indicators to a common scale, and summation to a final value. As with any model, changes in input data and algorithms have the potential to significantly influence the output. Although there is broad interest in the need to quantitatively model social vulnerability, there is far less consensus regarding the ideal set of methods to be used for the production of indices. Global uncertainty and sensitivity analyses are useful tools for assessing the sensitivity model outputs to variations input data and methods. Uncertainty analysis measures the overall variation in model output due to variations in input methods, while sensitivity analysis quantifies the proportional contribution of each model factor to the total variation. Applied to index construction, the analyses help examine options and tradeoffs associated with modeling decisions such as indicator selection, data transformation, rescaling, weighting, and aggregation. Uncertainty is introduced into the modeling process whenever the index developer chooses between potential options. Unfortunately, the degree to which these choices affect patterns of modeled social vulnerability is not known. The objective of this research is to perform a detailed examination of the methodological approaches used in the construction of indices of social vulnerability to hazards. Specifically, the goal is to assess the degree to which the propagation of uncertainty through the index construction process influences the statistical and spatial distributions of modeled social vulnerability.

Terrain Analysis and Geologic Field Investigations Used To Constrain Drainage Evolution and Basin-Filling History within and near the Northern Salinas Valley Groundwater Basin, Central California Coast Range (poster)

By Emily M. Taylor,[1] Donald S. Sweetkind,[2] and Antonio F. Garcia[3]

[1]U.S Geological Survey, Denver, Colo.

[2]U.S. Geological Survey, Denver, Colo.

[3]Physics Department, California Polytechnic State University, San Luis Obispo, Calif.

Groundwater models of sedimentary basins can be improved by high-resolution stratigraphy and estimates of hydraulic properties of basin-filling materials. However, such information is often difficult to extract from well driller's records. Preserved stream-terrace deposits within and near sedimentary basins are a record of erosional history that provides a context for downstream basin aggradation, basin-margin fault-related uplift, and paleoclimate events. Here we combine terrain analysis of a digital elevation model with traditional geologic field methods and age-dating techniques to develop a record of the long-term erosional history of the Arroyo Seco drainage, near the Salinas Valley in the Central Coast Ranges of California. The Salinas Valley is drained by the 100-mile long Salinas River. Infiltration from the river and its tributaries is the source of irrigation water in this productive agricultural region. Irrigation water is pumped from the primary aquifers at depths of 180 and 400 feet (ft) (Durbin and others, 1978). Based on data from oil and gas exploration drill holes and water wells, the Salinas Valley is filled with about 10,000–15,000 ft of Tertiary and Quaternary marine and terrestrial sediments that include up to 2,000 ft of saturated alluvium.

The Arroyo Seco is a perennial stream, one of the largest tributary drainages of the Salinas River, and is the major source of recharge from infiltration in stream-channel deposits. Arroyo Seco cut a narrow canyon that opens into a 10-mile long valley that transects the Santa Lucia Range. The Arroyo Seco progrades from an elevation of 945 ft at the canyon mouth to 500 ft where it flows into the Salinas Valley. In the Arroyo Seco valley there is a spectacular sequence of at least six strath terraces and strath-terrace deposits. Strath-terrace deposits are as much as about 1,000 ft above the modern drainage; however younger deposits are 150 to <3 ft above the modern drainage. A longitudinal profile shows the vertical distance between the treads of each terrace. The highest (oldest) deposits and their terrace treads, record stream erosion and deposition prior to valley incision. A gently sloping, low-relief geomorphic surface northwest of Arroyo Seco records a pre-Arroyo Seco relict landscape above the modern drainage. Remnants of terrace deposits in Arroyo Seco overlie Miocene marine Monterey Formation, and are composed of coarse alluvial gravel less than 10 ft thick. The timing of formation and isolation of these strath deposits was controlled by both active range-front faulting as well as by paleoclimatic events. Alluvium transported by Arroyo Seco was deposited across and was cut by the Rinconda and Reliz range-bounding faults. Valley-side down, reverse movement along the faults resulted in the deposition of an asymmetric, westward-thickening alluvial wedge. This material also provides a long, relatively continuous record of basin aggradation in the Salinas Valley.

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Developing Regionally Downscaled Probabilistic Climate Change Projections for the Southeast Regional Assessment Project (oral presentation)

By Adam J. Terando,[1] K. Sham Bhat,[2] Murali Haran,[2] Katharine Hayhoe,[3] Klaus Keller,[4] and Nathan Urban[4]

[1]Department. of Biology, North Carolina State University, Raleigh, N.C.

[2]Department of Statistics, The Pennsylvania State University, University Park, Pa.

[3]Department of Geosciences, Texas Tech University, Lubbock, Tex.

[4]Department of Geosciences, The Pennsylvania State University, University Park, Pa.

The Southeast United States contains the highest levels of biodiversity in North America outside of the tropics (Jose and others, 2006). This is partly due to the climate over the last few millennia, characterized by abundant precipitation, mild temperatures, and low climatic variability. Recently, the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4) concluded that it is very likely that humans are largely responsible for increasing the global average surface temperature by one degree Celsius in the 20th century through the release of greenhouse gasses (GHG), such as carbon dioxide, into the atmosphere. This warming is expected to continue well into the future and is projected to cause sizable impacts on managed and unmanaged ecosystems. Thus, mitigation of, and adaptation to the impacts of climate change on ecosystems in the Southeast will likely be the key challenge confronting natural resource managers in the coming decades. Central to this is how to best implement an adaptive management strategy given the large uncertainty associated with climate change projections. This requires a careful treatment of this uncertainty as well as methods to downscale climate projections to the scale of ecosystem processes because of the coarse resolution of the models. To date, most studies use the range of GCM output to represent the full predictive uncertainty, thus, underestimating the actual structural and parametric uncertainty associated with these projections. This underestimation will then propagate through all levels of analysis requiring climate change projections, leading to overconfident predictions. As a result, decisionmakers may insufficiently hedge against the risks associated with extreme climatic events that have a low probability of occurrence, but are high-impact events. We address this by developing a suite of regional probabilistic climate change projections for the Southeast Regional Assessment Project (SERAP). Two core climatic datasets are used for base projections: (1) GCM simulations from the IPCC AR4 for fully coupled global-scale climate simulations; and (2) an Earth Model of Intermediate Complexity (EMIC) to sample the parametric uncertainty of key climate system variables such as ocean diffusivity. These datasets are further postprocessed through: (1) Bayesian ensemble dressing methods to estimate structural uncertainty and the accuracy of the GCMs; and (2) statistically downscaled simulations forced by boundary conditions from the GCM and EMIC runs. The probabilistic projections generated through these methods enable other SERAP researchers to propagate uncertainty to other models, thus forming the basis for projecting ecosystem changes in the Southeast over the next century.

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Using Inverse Methods and Multiple Aquifer Tests To Calibrate a Model of Groundwater Flow Through Contaminated Fractured Sedimentary Rocks (poster)

By Claire R. Tiedeman,[1] Pierre J. Lacombe,[2] and Daniel J. Goode[3]

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

[2]U.S. Geological Survey, West Trenton, N.J.

[3]U.S. Geological Survey, Exton, Pa.

Multiple aquifer tests were conducted using a network of pumping wells at the former Naval Air Warfare Center (NAWC), West Trenton, N.J., which is underlain by dipping fractured sedimentary rocks highly contaminated with trichloroethene and its biodegradation daughter products. The aquifer tests were monitored at multiple observation wells, yielding a rich dataset of water-level responses that were used to calibrate a site-scale model of groundwater flow. The flow model is a step toward development of reactive transport models of contaminant fate and transport that are used to compare different remediation alternatives at the site. The U.S. Geological Survey (USGS) groundwater modeling software MODFLOW (Harbaugh and others, 2000), and the USGS universal inverse modeling code UCODE_2005 (Poeter and others, 2005) were used to develop and calibrate the flow model.

A high-resolution three-dimensional geologic framework depicting the stratigraphy of the dipping sedimentary beds was critical to delineating the distribution of rock hydraulic properties in the model (Lacombe and others, 2010; Tiedeman and others, 2009). Using the aquifer test data in combination with the geologic framework yielded a hydrogeologic framework showing that the dominant groundwater flow paths occur in the near-surface saprolite and in a few thin fissile- or laminated-dipping mudstone beds. Crossbed fractures also play a role. On the basis of this hydrogeologic framework, a relatively small number of model parameters were used to represent the hydraulic conductivity and specific storage distribution in the model.

UCODE_2005 was used to estimate the model parameters by weighted least-squares regression solved with a modified Gauss-Newton method. Use of inverse modeling enabled quantitatively examining the effect of including different subsets of the multiple aquifer tests. Inclusion of observation data from multiple tests provides additional information about the true flow system and can more tightly constrain its representation in the model, yet it can be difficult to develop conceptual and numerical models that consistently explain the full suite of observation data. For the NAWC flow model, results showed that calibrations using data from multiple aquifer tests produced models with more reasonable parameter estimates and reduced parameter uncertainty, compared to those using data from only one test.

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Climatic Influences on Corn and Soybean Yields (oral presentation)

By Mirela Tulbure[1] and Michael Wimberly[1]

[1]Geographic Information Science Center of Excellence, South Dakota State University, S. Dak.

The recent U.S. Renewable Fuel Standard calls for 36 billion gallons of ethanol production by 2022 with over half produced from plant biomass. Currently, the only feasible biomass-based biofuels is ethanol derived from corn. The goal of our research is to assess the sensitivity of corn and soybean production to climatic change.

We used the U.S. Department of Agriculture’s (USDA) National Agricultural Statistic Service (NASS) data on United States county-level yields of corn and soybean from 1970 to 2008. We developed county-level summaries of historical parameter-elevation regressions on independent slopes model (PRISM) climate datasets from 1970–2008 and integrated them with historical NASS crop yield estimates to examine the relationship between historical crop yield and interannual climatic variability. We used PRISM climate data on minimum, maximum, and average temperature (*tmin, tmax,* and *avgt*) and precipitation (*ppt*) to model variation in corn and soybean yields as a function of climate. Climate data were averaged per month, two months, and three months. To determine the most relevant climate variables, we performed independent second-order polynomial regressions between yields and climate variables and determined their predictive power based on the coefficient of determination (R^2). Using the climate variables identified in the previous step, we used a climate-envelope approach to model 1970–1989 corn and soybean yields as a function of climate and used 1990–2008 data to quantify how well yields actually matched the climate. June-August *avgt* and June–July *ppt* for corn and summer *avgt* and *ppt* for soybean yielded the models with the highest predictive power. Predicted corn and soybean yields for 1990–2008 matched relatively well the actual yield values, indicating that this approach has potential for use to model changes in corn and soybean yields as a function of climate.

Future modeling efforts will incorporate downscaled Global Circulation Model (GCM) data for future climate change scenarios from the Community Climate System Model (CCSM) to predict potential changes in corn and soybean productivity under climate change scenarios.

Technique for Areal Population of Numerical Models With Geohydrologic Parameters Using Transitional Probabilities (oral presentation)

By Amjad Umari[1]

[1]U.S. Geological Survey, Lakewood, Colo.

Geohydrologic parameters can be geostatistically propagated from known or observed values at one site to populate numerical model grids where values are not available. The results of a gamma-ray geophysical log (surrogate for grain-size distribution and, therefore, hydraulic conductivity and effective porosity) collected in a vertical borehole in alluvium were propagated areally by assuming that horizontal and vertical variation in geohydrologic parameters are the same (Walther's Law). The range of the gamma ray values in the log (0–177 counts per second) was discretized into five intervals so that the gamma log value at a given depth was assigned a value of 1, 2, 3, 4, or 5, as appropriate. Transitional probabilities of a gamma log value at a location (X2), 1 foot vertically from a reference point (X1), were calculated and plotted by interval, given the gamma log value at the reference point. Using Walther's Law, the known gamma log value (1–5) at a specific depth in the logged well is propagated to a point 1 foot radially away by first selecting the transitional probability histogram for the new point (X2) given the known value at the well (X1).

Given this selected histogram representing the "probability density function" at the new point, a "realization" is obtained that represents a random selection from the density function. That "realization" is the propagated gamma value at the new point, which is then considered a known value in the propagation step to the next point, 2 feet radially away from the well. By continuing this pattern of propagating radially from the well 1 foot at a time, the inherent structure in the data of the known vertical gamma log values at the well is probabilistically reproduced areally. Because areal propagation is a function only of radial distance from the well, not the direction, the one-dimensional structure in the vertical gamma log is propagated axisymmetrically onto the two-dimensional horizontal plane within the assumed area of geostatistical influence of the well.

The areally propagated gamma log values can be converted to equivalent hydraulic conductivity and effective porosity values, using empirical relations between the gamma-ray log and grain-size distribution. The hydraulic conductivity and effective porosity values would be initial estimates of the values of these parameters for the cells of a numerical grid for construction of a heterogeneous model to analyze hydraulic and tracer tests conducted.

A Land Data Assimilation System for Famine Early Warning (oral presentation)

By James P. Verdin,[1] Christopher C. Funk,[2] and Christa Peters-Lidard[3]

[1]National Oceanic and Atmospheric Administration (NOAA)/Earth System Research Laboratory, National Integrated Drought Information System Program Office, Boulder, Colo.

[2]University of California, Geography Department, Santa Barbara, Calif.

[3]Hydrological Sciences, National Aeronautics and Space Administration (NASA) Goddard Space Flight Center, Greenbelt, Md.

A custom instance of NASA's Land Information System (LIS) is being created to support operations of the Famine Early Warning Systems Network (FEWS NET), the U.S. Agency for International Development's (USAID) decision-support system for international food aid programs. In the regions of concern, rural livelihood systems are typically based on subsistence agriculture and pastoralism, and are highly climate sensitive. Drought can deal a heavy blow to communities that barely get by under normal climatic conditions. A land-data assimilation system is being designed specifically for the domains, data streams, and monitoring/forecast requirements associated with food security assessment in these data-sparse, developing country settings.

The U.S. Geological Survey (USGS) and FEWS NET presently handle a wide range of gridded satellite remote-sensing and atmospheric model data products from NASA and NOAA to monitor and forecast crop-growing conditions in the most food insecure countries of the world. They are used in a set of modeling applications that has developed in a piecemeal fashion over the years. The new FEWS NET Land Data Assimilation System (FLDAS) will be implemented to achieve more effective use of limited available hydroclimatic observations. It is being developed in partnership with the NASA Goddard Space Flight Center, with assistance from the University of Washington, to integrate the latest version of the Variable Infiltration Capacity (VIC) model into LIS and FLDAS. USGS/FEWS NET will gain the capacity to make multimodel ensemble runs for weekly monitoring and seasonal forecasting of land-surface variables. It will also be possible to use LIS to apply climate change modeling results to produce 21st century scenarios of land-surface states relevant to food security assessment in regions of concern in Africa.

Towards a National Hydrologic Model: Overview (oral presentation)

By John F. Walker,[1] Lauren Hay,[2] Nathaniel Booth,[1] Gregory McCabe,[2] Steve Markstrom,[2] and Jacob LaFontaine[3]

[1]U.S. Geological Survey, Middleton, Wis.

[2]U.S. Geological Survey, Lakewood, Colo.

[3]U.S. Geological Survey, Atlanta, Ga.

A National Hydrologic Model (NHM) is being developed to support coordinated and robust hydrologic model development and application within the U.S. Geological Survey. The NHM addresses four important aspects that must be considered for a relevant, comprehensive, and successful hydrologic-modeling program: (1) development of technology which makes the best available data readily accessible to modelers; (2) relevant research and developments in the field of hydrologic modeling to adapt to increasingly complex questions and take advantage of improved data sources; (3) development of standard methods that can be applied to produce consistent and comparable hydrologic model studies; and (4) development of a modeling archive system which provides a platform for model distribution, dissemination of results, comparability, and interoperability.

The development and calibration of model studies within the National Hydrologic Model is currently leveraging work in several pilot studies. Current project-specific tools for retrieving spatial and time-series data for climatological inputs and streamflows are being generalized to develop an intuitive, Web-based user interface that can be used to provide information for modeling and decision-support needs. Monthly average runoff for the period 1895 through 2009 from a national water-balance model, based on a 4-km grid across the conterminous United States, will be made available through the spatial data retrieval tool. The NHM will be based on the U.S. Geological Survey's Precipitation Runoff Modeling System (PRMS), which is a deterministic, distributed-parameter hydrologic model that runs on a daily time step and has a modular design. Research and development of the PRMS model will include evolving landscapes and dynamic parameters, uncertainty analysis and parameter-estimation techniques, simulating frozen ground and glacier dynamics, landscape recovery following wildfires, and simulating stream temperature. The initial NHM will use a coarse spatial scale, with the ability to nest finer scale models within the coarse-scale model. Several pilot studies, including the Apalachicola-Chattahoochee-Flint River study, are being used to develop the methods for creating and calibrating coarse-resolution models and nesting finer resolution models within the coarse model.

Building a Framework for Assessing Climate Change Impacts on Common Loon Habitat Suitability in Northern Wisconsin (poster)

By John F. Walker,[1] Randall J. Hunt,[1] Kevin P. Kenow,[2] Michael W. Meyer,[3] and Lauren Hay[4]

[1]U.S. Geological Survey, Middleton, Wisc.

[2]U.S. Geological Survey, LaCrosse, Wisc.

[3]Wisconsin Department of Natural Resources, Northern Region Headquarters, Rhinelander, Wisc.

[4]U.S. Geological Survey, Lakewood, Colo.

A major focus of the U.S. Geological Survey's Trout Lake Water, Energy and Biogeochemical Budgets (WEBB) project is the development of a watershed model to allow predictions of hydrologic response to future conditions including land-use and climate. The coupled groundwater and surface-water (GSFLOW) model was chosen for this purpose because it could easily incorporate an existing groundwater flow model and it provides for simulation of surface-water processes.

The Trout Lake watershed in Northern Wisconsin is underlain by a highly conductive glacial outwash sand aquifer. In this area, streamflow is dominated by groundwater contributions; however, surface runoff does occur during intense rainfall periods and spring snowmelt, and locally in near-stream/lake areas where the unsaturated zone is thin. Model calibration was performed using the automated parameter estimation suite of software (PEST) and the time-series processing utility. The calibrated model was used to simulate the hydrologic response of the study lakes to a variety of climate change scenarios culled from the IPCC Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Results from the simulations indicate climate change could result in substantial changes to the hydrologic budgets of the selected study lakes.

A framework of models is being constructed to assess the impact of climate change on the suitability of lakes for common loon use. Previous research indicates several physical attributes of lakes, including water chemistry and clarity, are associated with breeding territory selection by Wisconsin common loons. A refined loon lake habitat suitability model is being developed using additional data collected on lakes in the Trout Lake watershed and central Wisconsin. Results from the hydrologic simulations, along with particle tracking within the groundwater portion of the flow model, will be used to develop predictions of solutes into the selected lakes. Estimates of solute concentrations within the groundwater system will be based on relating flow-path residence time to concentrations based on geochemical modeling of the system. A lake model will then be used to predict changes in the key water-chemistry measures relevant to the loon lake habitat suitability model.

Using Radium Isotopes To Study Coastal Mixing Processes (poster)

By Guizhi Wang[1]

[1]Environmental Science and Engineering, Xiamen University, Xiamen, China

Naturally occurring radium isotopes are produced by thorium decay in the sediments. In the coastal ocean, the activities of radium isotopes change by decay and coastal transport processes. Short-lived radium isotopes (^{223}Ra, ^{224}Ra) have been used in the coastal ocean to calculate offshore coastal mixing rate (Moore, 2000). But in Moore's method, advection was not considered in setting up the mass-balance equation, which makes it not suitable for coastal environments where advection is significant. As an attempt to study coastal transport processes, including eddy diffusion and advection, using radium isotopes as tracers, an inverse method is applied to solve for an average advection velocity and eddy diffusivity from offshore radium distributions. Radium data of the South Atlantic Bight from previous studies (Moore, 2000; Moore, 2007) are used as the input data to test the method. Our results are consistent with meteorological data in this area and this method will be a useful tool in using radium as a tracer to study coastal transport processes in relatively hydrological complex coastal regions.

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Using Cumulative Noise Exposure (CNE) Models To Compare Management Scenarios in National Park Units (oral presentation)

By Katy Warner,[1] Damon Joyce,[2] and Kurt Fristrup[2]

[1]Colorado State University, Natural Sounds Program, Fort Collins, Colo.

[2]National Park Service, Natural Sounds Program, Fort Collins, Colo.

Since its inception in 2000, the National Park Service (NPS) Natural Sounds Program (NSP) has worked with parks nationwide to address management issues concerning the acoustical environment. The NSP is a resource for parks that do not have staff with acoustical expertise. The NSP receives requests to assist with monitoring efforts, data analysis, and data synthesis. Typically, monitoring data have been distilled into a suite of metrics that describe various aspects of the current acoustical environment. As concerns about noise management have diversified, many parks have become interested in exploring future scenarios and potential effects of management options.

We will discuss the use of cumulative noise exposure (CNE) modeling as a tool for resource managers. The NSP has been producing CNE models using two separate types of software. For road noise and point source models, the commercially available Computer Aided Noise Abatement (CadnaA) software can handle custom-point and line-source spectra, traffic-count inputs, topography, and simple vegetation categories. The typical model output is a grid-based map of CNE. The output can be viewed as a two-dimensional map, or as a three-dimensional rendering of the same output. CadnaA has the ability to export results for postprocessing using geographic information systems (GIS) software. Using GIS postprocessing, quantitative comparison of current conditions against other scenarios is possible. Recently, CadnaA added a Traffic Noise Model (TNM) module, which may qualify it for use in Federal Highways Administration and other Department of Transportation noise modeling and mitigation projects.

For aircraft noise modeling and mitigation, Integrated Noise Model (INM) is the model required by the Federal Aviation Administration (FAA). Some complex scenarios can take several weeks to model in INM, a problematic delay that makes INM difficult to use for scenario development. The NSP has developed an Interactive Noise Forecast (INF) tool to augment the value of INM. INF ingests INM metrics from a suite of single aircraft scenarios (aircraft type and route), and enables rapid computations of aggregate noise exposure from arbitrary multiples and combinations of these input scenarios. INF produces noise-impact maps displaying multiple metrics for each point. With a runtime on the order of minutes, INF is an excellent tool for exploring possible alternatives. Planners and managers can use INF to consider how changes in traffic levels, or the proportions of different aircraft types composing the traffic, could affect CNE. INF is implemented in R, an open-source data-analysis program.

Management of the acoustical environment is a burgeoning topic within the National Park Service. Models such as CadnaA, TNM and INM offer sophisticated capabilities for realistic, quantitative forecasts of noise exposure. The capacity to visualize noise exposure predictions provides a medium to express a surfeit of quantitative data in an intuitive and aesthetically appealing format. Evocative graphical renderings make noise models more approachable, and are an excellent way to convey complex information to resource managers and public audiences.

The Water, Energy, and Biogeochemical Model (WEBMOD): Semidistributed Hydrology and Water Quality Developed in the Modular Modeling System (oral presentation)

By Richard M.T. Webb[1]

[1]U.S. Geological Survey, Denver, Colo.

The Water, Energy, and Biogeochemical Model (WEBMOD) simulates hydrologic fluxes and solute concentrations using process modules coupled within the U.S. Geological Survey (USGS) Modular Modeling System (MMS). Hydrologic fluxes are simulated using routines developed for the USGS Precipitation Runoff Modeling System, the National Weather Service Hydro-17 snow model, and the topography-based hydrological model (TOPMODEL). PHREEQC, a low-temperature aqueous geochemical model, was tightly coupled to the hydrologic model to simulate reactions and isotopic fractionation as waters evaporate, mix, and react with the soils. Mass balance of water and solutes are tracked from the time that precipitation or irrigation reaches the surface to the time that the water leaves the watershed through evapotranspiration, river discharge, or regional groundwater flow.

One-, Two-, and Three-Dimensional Hydrodynamic and Water-Quality Modeling of North Carolina's Roanoke River and Flood Plain (oral presentation)

By Loren L. Wehmeyer,[1] Ana Maria Garcia,[1] and Chad R. Wagner[1]

[1]U.S. Geological Survey, Raleigh, N.C.

The downstream-most 161 kilometers of the Roanoke River basin, from Roanoke Rapids Dam to Albemarle Sound (Lower Roanoke River), supports a large and diverse population of nesting birds, waterfowl, freshwater and anadromous fishes, and wildlife, including threatened and endangered species. Much of the Lower Roanoke River basin is forested swampland in conservation by Federal (including the Roanoke River National Wildlife Refuge), State, and nonprofit entities. Streamflow, flood-plain inundation, and the corresponding water quality are primarily governed by upstream reservoir releases.

The U.S. Geological Survey has been collecting hydrologic data in the Lower Roanoke River since the early 1900s. A combination of streamflow, in-stream and flood-plain water-level, and water-quality data at 14 streamgages and 9 flood-plain gages were used to calibrate and validate coupled hydrodynamic and water-quality models of the Lower Roanoke River. Model development was bolstered by a digital elevation model with 3-meter-by-3-meter cells and a vertical accuracy of approximately 20 centimeters derived from light detecting and ranging data that facilitated the establishment of one-dimensional (Hydrologic Engineering Center's River Analysis System), two-dimensional (CE-QUAL-W2), and three-dimensional (3-D) [Environmental Fluid Dynamics Code hydrodynamic models, and two different water-quality models (Water Quality Analysis Simulation Program and CE-QUAL-W2). Results show the depth, duration, and extent of flood-plain inundation and the corresponding water quality over a 10-year simulation period.

To date, the monitoring data and models have been used to investigate the relation between hydropower operations and large storm events on dissolved oxygen (Wehmeyer and Bales, 2009a), the relation between flood-plain water levels and in-stream dissolved oxygen (Bales and Walters, 2003), cropland inundation during various sustained high flows, salinity movement from Albemarle Sound up into the Roanoke River, and the distribution of biochemical oxygen demand loading between point and nonpoint sources (Wehmeyer and Bales, 2009b). Ongoing work includes three-dimensional hydrodynamic and water-quality modeling to evaluate the implications of simulated operational changes to upstream reservoir releases as part of the John H. Kerr Dam & Reservoir (Section

216) Study. Future applications of the 3-D models that have been discussed include assessing streambank erosion, defining the effects of sea-level rise on saltwater intrusion, and evaluating the relation between flood-plain water quality and tree growth.

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Fully Coupled Hydrologic/ Geomechanical Simulations of Slope Failure Due to Rainfall Infiltration (oral presentation)

By Joshua A. White[1] and Ronaldo I. Borja[2]

[1]Lawrence Livermore National Laboratory, Livermore, Calif.

[2]Civil and Environmental Engineering, Stanford University, Stanford, Calif.

Slope-failure processes involve a tight coupling between unsaturated fluid flow and solid deformation. In modeling these events, however, we may adopt various levels of coupling for the fluid and soil interaction, including uncoupled, iteratively coupled, and tightly coupled models. In this work we discuss this spectrum of approaches and their respective advantages. We highlight a physics-based, fully coupled framework we have been developing for modeling hydrologically driven slope failure. The simulations employ a mixed finite-element formulation for variably saturated geomaterials undergoing elastoplastic deformations. The deforming soil mass is treated as a multiphase continuum, and the governing mass and momentum balance equations are solved in a tightly coupled manner. We present several numerical examples to demonstrate the key features of this approach, and compare it to traditional limit equilibrium methods. We also discuss the calibration of the continuum model from available field data, as well as how it may be used in concert with larger scale, regional hazard models. These observations are used to assess the current state of hazard prediction, and to inform the design of future field experiments. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

A Hierarchical Approach To Quantify Uncertainty in Multiscale Modeling of Riverine Ecosystems and Responses of Fish Populations (oral presentation)

By Christopher K. Wikle,[1] Mark L. Wildhaber,[2] Christopher J. Anderson,[3] Kristie J. Franz,[4] and Scott H. Holan[1]

[1]Department of Statistics, University of Missouri—Columbia, Columbia, Mo.

[2]U.S. Geological Survey, Columbia, Mo.

[3]Climate Science Initiative, Iowa State University, Ames, Iowa

[4]Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa

Models for large river fish populations are dependent on habitat conditions linked to hydrological variability of the river itself, which is linked to variation in weather variables, which are ultimately linked to potential climate variations. There is uncertainty in each linkage, and also in individual process models and parameters upon which the models rely. The hierarchical modeling approach we will present should help to account for these uncertainties, in particular the variability of relevant climate conditions across temporal and spatial scales, so projections of community or population response to a given climate change scenario include realistic measures of uncertainty. The approach incorporates various independent sources of observations, includes established scientific knowledge, and addresses uncertainties by linking system components together using formal rules of probability.

Physical, natural, and biological sciences rely heavily on numerical models for structure and evolution of features of environment at various scales in space and time. Varying amounts of relevant data are collected at different scales and with varying levels of completeness. These models and data are fraught with uncertainty. With such uncertainty, scientists from many disciplines recognize that prediction (forecasting) of complex phenomena is statistical or stochastic by nature. For ecological modeling, Levin and others (1997) noted "… models should not be expected to predict where every tree will be at each point in time; only aggregate statistical properties can be reliably predicted, typically over broad spatial and temporal scales." Any approach to modeling ecological phenomena should rely on information deemed relevant and produce predictive output that is responsive and "honest" with regard to intrinsic uncertainties. It should also be capable of combining information and data from diverse sources, relevant at differing scales in space and time, and of varying quality. It must also account for nonlinearities present in hypothesized models for physical and biological processes, as well as complex interactions across subsystems. The hierarchical Bayesian modeling approach offers such a paradigm for development of a hybrid deterministic and stochastic downscaling model. The Bayesian approach seeks the combination of science and statistics expressed mathematically through probability distributions (for example, Amstrup and others, 2007).

This talk will focus on development of probabilistic linkages to quantify implications of climate on fish populations of the Missouri River ecosystem. This approach is a hybrid between physical (deterministic) downscaling and statistical downscaling, recognizing that there is uncertainty in both. Ultimately, the model must include linkages between climate and habitat, and between habitat and population.

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Multiscale Modeling of Riverine Ecosystems and Responses of Fish Populations in the Context of Global Climate Change and Predictive Uncertainty: Introduction and Overview (oral presentation)

By Mark L. Wildhaber,[1] Christopher K. Wikle,[2] Christopher J. Anderson,[3] Kristie J. Franz,[4] and Scott H. Holan[2]

[1]U.S. Geological Survey, Columbia, Mo.

[2]Department of Statistics, University of Missouri—Columbia, Columbia, Mo.

[3]Climate Science Initiative, Iowa State University, Ames, Iowa

[4]Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa

Climate change operates over a broad range of spatial and temporal scales. Understanding its effects on ecosystems requires multiscale models. For understanding effects on fish populations of riverine ecosystems, climate predicted by course-resolution Global Climate Models (GCMs) must be downscaled to Regional Climate Models (RCMs) to watersheds to river hydrology to population response. An additional challenge is quantifying sources of uncertainty given the highly nonlinear nature of interactions between climate variables and community-level processes. This special session presents a modeling approach for understanding and accommodating uncertainty by applying multiscale climate models and hierarchical Bayesian modeling frameworks to Midwest fish population dynamics and by linking models for system components together by formal rules of probability. The proposed hierarchical modeling approach will account for sources of uncertainty in forecasts of community or population response. The goal is to evaluate the potential distributional changes in an ecological system, given distributional changes implied by a series of linked climate and system models under various emissions and use scenarios. This understanding will aid evaluation of management options for coping with global change.

Extant data and models will be used for each scale for the Missouri River. We will relate spatial and temporal patterns of Missouri River benthic fishes to physical and chemical factors (for example, Arab and others, 2008), sturgeon population models (Bajer and Wildhaber, 2007), and sturgeon life-history models (Wildhaber and others, 2007) to better understand factors affecting Lower Missouri River sturgeon spawning physiology, behavior, habitat choice, and success (for example, Delonay and others, 2007; Holan and others, 2009).

Presentations include: downscaling GCMs to RCMs, downscaling from watersheds to rivers, using downscaled results to model fish population responses, hierarchical

Bayesian mark-recapture modeling for survival and population estimation, and using hierarchical Bayesian approaches for across-scale integration of models and their uncertainty.

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Translating River Hydrodynamics into Fish Population Responses for Use in Multiscale Modeling of Riverine Ecosystems (oral presentation)

By Mark L. Wildhaber,[1] Christopher K. Wikle,[2] Christopher J. Anderson,[3] Kristie J. Franz,[4] and Scott H. Holan[2]

[1]U.S. Geological Survey, Columbia, Mo.

[2]Department of Statistics, University of Missouri—Columbia, Columbia, Mo.

[3]Climate Science Initiative, Iowa State University, Ames, Iowa

[4]Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa

The pallid sturgeon is rare throughout the Missouri River Basin and was federally listed as endangered in 1990 (Dryer and Sandvol, 1993). The shovelnose sturgeon historically was more common and widespread (Becker, 1983). Persistence and resiliency of shovelnose sturgeon in comparison to pallid sturgeon may be due to earlier maturity, lower trophic status, and adaptability to environmental conditions (Keenlyne and Jenkins, 1993). Understanding how climate change may differentially affect these two species may be useful in managing their continued existence.

Wildhaber and others (2007) introduced a conceptual life-history model for pallid and shovelnose sturgeon. The model was developed to delineate how *Scaphirhynchus* sturgeon ecology relates to river management. This model provides an illustration of how climate may interact with management actions to affect species recovery. It provides the framework for expanding Bajer's and Wildhaber's (2007) population forecasting model to include environmental variables for prediction of future population size and distribution of Missouri River pallid and shovelnose sturgeon. Because sturgeon in large rivers may move long distances (DeLonay and others, 2007), a life-history model needs to incorporate use of different parts of the river, or its tributaries. For greatest utility in assessing habitat effects on population processes, the life-history model should accommodate fine-scale, three-dimensional models of habitat use and availability, and fish behavior, nested within a broader geographic extent.

Ongoing U.S. Geological Survey Comprehensive Sturgeon and Research Program work on migration, physiology, habitat choice, and spawning success of shovelnose and pallid sturgeon provides data to inform such a model. River temperature and velocity distributions will be used within a sturgeon bioenergetics model. Although such models are based on first principles, they do include parameter estimates from the literature. We will not have local-scale information to update these parameters. However, we can accommodate such uncertainty by allowing values for these parameters to be uniformly distributed throughout ranges reported in the literature. The forcing uncertainties are accommodated through the distributions of river temperature and velocity from previous stages.

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Modeling Demographic Sensitivity to Tsunami Hazards in the Pacific Northwest Using Geographic Information System-Enabled Factor Analysis (oral presentation)

By Nathan J. Wood,[1] Christopher Burton,[2] and Susan Cutter[2]

[1]U.S. Geological Survey, Vancouver, Wash.

[2]Department of Geography, University of South Carolina, Columbia, S.C.

Tsunamis generated by Cascadia subduction zone (CSZ) earthquakes pose significant threats to coastal communities in the U.S. Pacific Northwest. A regional inventory of community exposure to Cascadia-related tsunamis on the Oregon coast indicates that tens of thousands of people live, work, and play in tsunami-prone areas. Impacts of future tsunamis to individuals and communities in the region will likely vary due to pre-event demographic differences. Given the catastrophic potential and quick arrival times of tsunamis generated by local CSZ earthquakes, emergency managers must understand who is vulnerable to tsunamis so that they can prepare realistic and effective evacuation and response procedures.

Assessing vulnerability through an inventory of demographic attributes will help managers identify isolated issues (for example, an elderly population needing assistance to evacuate quickly) but it fails to address how multiple demographic characteristics of an individual or neighborhood interact and likely amplify each other. To describe the multivariate nature of individuals living in areas prone to CSZ-related tsunami inundation, we adjust the Social Vulnerability Index (SoVI) model based on factor analysis to operate at the census-block level of geography and focus on community-level comparisons along the Oregon coast. The SoVI model is based on the use of principal component analysis, one of the most common multivariate factorial approaches, to reduce a large number of census variables into a smaller set of multivariate components. Variable members of each model component exhibit similar variation across the study area and each component explains a certain amount of the total variance of the entire dataset. This model is then merged with geographic information system tools to develop block-level maps of demographic sensitivity to tsunamis.

A principal-components analysis of populated census blocks in the Oregon tsunami-hazard zone results in 11 broad components that explain 64.6 percent of the variance. The model components that represent the highest percentages of the database variance relate to demographic attributes of wealth and education, age and tenancy, and type of employment and housing type. The number of residents from census blocks in tsunami-prone areas considered to have higher social vulnerability varies considerably among 26 Oregon cities along the Oregon coast and most are concentrated in four cities and two unincorporated areas. Model results suggest there is no apparent relationship between the number of residents considered to have high social vulnerability and the percentage they represent of the total number of residents in the tsunami-hazard zone. Variations in the number of residents from census blocks considered to have higher social vulnerability in each city do not correlate with the number of residents or city assets in tsunami-prone areas. Modeling methods presented here provide emergency managers with the means to depart from one-size-fits-all mitigation strategies that inadequately address differences in social context and, instead, to develop strategies tailored to local conditions and needs.

Impacts of Climate Change on Hydrological Components in the Upper Mississippi River Basin (poster)

By Yiping Wu[1] and Shuguang Liu[2]

[1]ARTS, Sioux Falls, S. Dak.

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

Quantifying the hydrological response to increased atmospheric carbon dioxide (CO_2) concentration and climate change is critical for evaluating regional water-resource security. In this study, the potential impacts of variation in atmospheric CO_2, temperature, and precipitation based on Intergovernmental Panel on Climate Change projections are simulated using the Soil and Water Assessment Tool (SWAT). The readily available spatial layers of digital elevation models, land-use, and soil data are used to set up the model over the Upper Mississippi River Basin (UMRB). The model is first calibrated using an 8-year (2001–2008) record of daily streamflow and sediment at the outlet (Grafton, Ill.) of the watershed, which controls a drainage area of 443,667 km^2, and then validated with data collected during another 8 years (1993–2000). The preliminary results show that climate change has significant effects on hydrological elements (for example, water yield and evapotranspiration) in the study area. For example, a doubling of atmospheric CO_2 to 660 ppm results in around a 30% increase in the 50-year average annual streamflow and about a

20% decrease in potential evapotranspiration, while a change of precipitation by ±10% correspondingly changes water yield around ±20%. Moreover, the effects of climate change on groundwater recharge and sediment yield are also examined under the different future climate scenarios.

Modeling Wetland Floristic Quality Change in Space and Time in the Prairie Pothole Region of the United States (oral presentation)

By Claudia Young,[1] Shuguang Liu,[2] David Mushet,[3] Ned Euliss,[3] Min Feng,[4] and Shengli Huang[5]

[1]ADNET System Inc., Sioux Falls, S. Dak.

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

[3]U.S. Geological Survey, Jamestown, N. Dak.

[4]Chinese Academy of Sciences, Institute of Geographic Sciences and Natural Resources Research, Beijing, China

[5]ASRC Research and Technology Solutions, Sioux Falls, S. Dak.

The Prairie Pothole Region (PPR) landscape is known for its abundance of small wetlands formed by glacier retreatment; however, many of these wetlands have been drained for farm development. Restoration of wetland habitats in the PPR is an important activity of the U.S. Department of Interior and U.S. Department of Agriculture and generally involves plugging drains to restore hydrology and planting surrounding upland catchments to perennial cover. The wetlands in the PPR provide diverse ecosystem services, including carbon sequestration, groundwater recharge, nutrient retention, runoff and flood attenuation, water storage, contaminants filtering, and wildlife habitat provisioning. However, this list of benefits is not exhaustive and additional ecological services likely have been realized at local, regional, national, and even global scales. One of the ecological services that wetlands provide is the maintenance of diverse native plant communities. Floristic quality is a measure of the condition of these communities. Two common metrics of floristic quality are mean C and Floristic Quality Index (FQI). Mean C is the average coefficient of conservatism value (C) for all native species occurring in the area. C values are assigned by a panel of botanists with local plant knowledge and are based on each species' likelihood to occur in a high-quality natural area. FQI incorporates a measure of species richness derived from mean C and the number of native species present. Different sites can have the same mean C but different FQI scores, or vice versa. Therefore, it is useful to estimate both values. Although it is well known that the indicators of mean C and FQI can be used to assess floristic quality, these metrics are sensitive to climate fluctuations, and no model is available to quantify changes over large areas for this ecological service. In our research, we used the Wetland Continuum Conceptual Model (Euliss and others, 2004) to simulate the dynamics of floristic quality from landscape to regional scale in the PPR. Through this model, the mean C and FQI of a given wetland can be defined if three components are known: (1) hydrologic relation to groundwater (groundwater of recharge, flowthrough, and discharge derived from National Wetland Inventory data); (2) hydrologic relation to atmospheric water (drought to deluge derived from the Moisture Deficit Index and Palmer Drought Severity Index); and (3) predominant surrounding landscape within a wetland (derived from the National Land Cover Database 2001). The results of this model are being compared with field survey data collected in 18 wetlands at the USGS's Cottonwood Lake Study Area for accuracy assessment. The next step of our research is to use our model to simulate the spatiotemporal change on floristic quality under three scenarios: (1) if one-third of the wetland disappeared (human drainage); (2) if all the potential wetlands are restored (wetland restoration); and (3) if the two IPCC climate scenarios (A2 and B2) are adopted (climate change).

Revision and Assessment of Water-Surface Modeling of the Everglades Depth Estimation Network (poster)

By Zhixiao Xie,[1] Zhongwei Liu,[2] Leonard G. Pearlstine,[3] Roy Shonenshein,[3] Paul A. Conrads,[4] Heather S. Henkel,[5] and Pamela A. Telis[6]

[1]Department of Geosciences, Florida Atlantic University, Boca Raton, Fla.

[2]Florida Atlantic University, Boca Raton, Fla.

[3]Everglades National Park, National Park Service, Homestead, Fla.

[4]US Geological Survey, Columbia, S.C.

[5]U.S. Geological Survey, St. Petersburg, Fla.

[6]U.S. Geological Survey, Jacksonville, Fla.

Hydrologic regime is a critical limiting factor in the delicate ecosystem in the greater Everglades freshwater wetland in southeastern Florida, and "getting the water right" is regarded as critical to the successful restoration of this unique ecosystem. The products of the Everglades Depth Estimation Network (EDEN) quantify spatial-temporal hydrologic patterns at the landscape scale, such as water depth, hydroperiods, and days since dry events. One critical EDEN component is the daily water-surface model, interpolated from water-level data collected at a network of real-time water-level gaging stations maintained by multiple agencies. The hourly water-level readings are assembled, quality assured, and missing data are filled in with estimates. The daily medians are computed and inputted into the water-surface model to create daily water surfaces on a grid comprised of 400-meter (m)-by-400-m-grid cells.

The model utilizes a radial basis function (RBF) algorithm and a combination of real and pseudo canal gages to model the discontinuities of water level across subregion boundaries of the Everglades.

The water-surface model, as well as other EDEN products, has been well received by scientists and resource mangers involved in Everglades restoration. Improvements of the model have been ongoing to accommodate the needs raised by users and to incorporate new data and improved understanding of the hydrologic dynamics in the Everglades. This presentation documents the new model developments, including the addition of new gages, datum correction for existing gages, canal water-level revisions, RBF reparameterization, model adjustment for dry conditions, and model assessment using independent water-level data collected at benchmarks of known elevation.

Appendix 1. Abbreviations and Acronyms

1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
AET	Actual Evapotranspiration
AFINCH	Analysis of Flows in Networks of Channels
AI	avian influenza
ANN	artificial neural network
ArcGIS	Arc geographic information system
ARIES	Artificial Intelligence for Ecosystem Services
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BGS	British Geological Survey
BLM	Bureau of Land Management
BMA	Baynesian Model Averaging
CBM	coal-bed methane
CBPT	convolution-based particle tracking
CERP	Comprehensive Everglades Restoration Plan
CIMEC	Calibration using Inverse Modeling at Extreme Conditions
CNE	cumulative noise exposure
CSZ	Cascadia subduction zone
CWL	Cottonwood Lakes
DD	Dzhulukul District
DEM	digital elevation model
DMS	debris management sites
DSS	decision support system
dT	temperature gradient
DTM	Digital terrain model
EDEN	Everglades Depth Estimation Network
EF	Evaporative Fraction
EFDC	Environmental Fluid Dynamics Code
EISA	2007 Energy Independence and Security Act
ELVeS	Everglades Landscape Vegetation Succession Model
EP	Eshtikol Plateau
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
EUMETSAT LSA SAF	European Organization for the Exploitation of Meteorological Satellites on Land Surface Analysis Satellite Application Facility
FDM	Facies depositional modeling
FEWS NET	Famine Early Warning System Network
FQI	Floristic Quality Index
FWS	U.S. Fish and Wildlife Service

GCM	global climate model
GDAS	Global Data Assimilation System
GIS	geographic information system
GLAC	Glacier National Park
GLDAS	Global Land Data Assimilation System
GPLCC	Great Plains Landscape Conservation Cooperative
GPP	gross primary productivity
GRTE	Grand Teton National Park
GSFLOW	groundwater and surface-water flow
GSO	Geological Survey Organization
GUI	graphical user interface
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HEM	helibourne electromagnetic
INF	Interactive Noise Forecast
InHM	Integrated Hydrology Model
INM	Integrated Noise Model
IPCC	Intergovernmental Panel on Climate Change
Landsat TM	Landsat Thematic Mapper
LBM	lattice Boltzmann method
LE	latent energy
LiDAR	light detection and ranging
LIS	Land Information System
LMA	land management agency
LMOR	Lower Missouri River
LP	low pathogenic
LPC	Loon Preservation Committee
LST	Land Surface Temperature
LULC	land use and land cover
METRIC	Mapping Evapotranspiration at High Resolution with Internalized Calibration
MODIS	Moderate Resolution Imaging Spectroradiometer
MC	Monte Carlo
MEA	USGS's Mineral Environmental Assessment Methodology Project
MLR	multiple linear regression
MPEF	Meteorological Product Extraction Facility
MPS	Multiple-point statistics
MSG	Meteosat Second Generation
MTBS	Monitoring Trends in Burn Severity
NARCCAP	North American Regional Climate Change Assessment Program
NCBN	Northeast Coastal and Barrier Network
NCDE	Northern Continental Divide Ecosystem
NCEP	National Center for Environmental Protection
NDVI	Normalized Difference Vegetation Index

NERC	Natural Environment Research Council
NetCDF	Network Common Data Form
NHDPlus	National Hydrography Dataset Plus
NHMP	National Hydrologic Model Portal
NHMS	National Hydrologic Modeling Structure
NIR	near infrared
NLCD	National Land Cover Dataset
NLDAS	North American Land Data Assimilation System
NMSim	Noise Model Simulation
NPS	National Park Service
NRCS	USDA's Natural Resources Conservation Service
NSP	Natural Sounds Program
NWI	National Wetland Inventory
PPR	Prairie Pothole Region
PSE	problem solving environment
PSEPM	Puget Sound Ecosystem Portfolio Model
PVA	population viability analysis
RBF	radial basis function
RCM	regional climate model
REXTN	record extension model
RMSE	root-mean-squared error
SDI	subsurface drip irrigation
SDM	species distribution model
SEBS	Surface Energy Balance System
SERAP	Southeast Regional Assessment Project
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SOM	self-organized map
SPAN	Service Path Attribution Network
SSEB	Simplified Surface Energy Balance
SSURGO	Soil Survey Geographic database
TIR	thermal infrared
TM	thematic mapper
TNM	Traffic Noise Model
TOPS	Terrestrial Observation Prediction System
TPRoGS	Transitional probability
TREES	Terrestrial Regional Ecosystem Exchange Simulator
USGS	U.S. Geological Survey
VCT	Vegetation Change Tracker
VI	vegetation index
VS2DT	Variably Saturated 2-D Transport
WASP	Water Quality Analysis Simulation Program
WMS	Web Map Service

WRF	Weather Research and Forecasting
YRDSS	Yakima River Decision Support System

Although the following abstracts were reviewed and approved for presentation at the conference, they have not been included in this volume for procedural reasons:

- Predicting the probability of arsenic occurrence in groundwater from bedrock wells in New Hampshire for public health studies, by Joseph D. Ayotte and Gilpin R. Robinson, Jr. (oral presentation)
- Overview of new Monte Carlo software for quantitative mineral resource estimation, by Phillip J. Brown and Michael J. Friedel (poster)
- Test results comparing the new U.S. Geological Survey Monte Carlo Quantitative Resource Estimation Simulation software application to MARK3, by Phillip J. Brown and Michael J. Friedel (poster)
- Evaluating the predictive uncertainty for the reactive transport of uranium in groundwater, by Gary P. Curtis, Ming Ye, Matthias Kohler, and James A. Davis (poster)
- Departure from quarter-power scaling of aquatic habitat richness area as a structural indicator of constraints on riverscape organization, by Nathan R. DeJager (oral presentation)
- A spatial model of Yellow-Billed Cuckoo breeding habitat, by James R. Hatten, Matthew Johnson, and Jennifer Holmes (oral presentation)
- Surveying soil chemical weathering in Parana State/Brazil: a data mining-GIS hybrid approach, by Fabio Iwashita, Michael J. Friedel, and Carlos Roberto Souza-Filho (poster)
- Evaluating the effects of positioning errors on the accuracy of species distribution models using synthetic data, by Fabio Iwashita, Silvana Amaral, Antonio Miguel Vieira Monteiro, and Michael J. Friedel (poster)
- Hydrogeomorphic and sedimentary evidence used to refine convective rainfall analyses and flash-flood characteristics, by Robert Jarrett (oral presentation)
- Pseudospectral analysis for modeling discrete spatial data, by James E. Kaufmann (oral presentation)
- Classification of karst terrain in Missouri using pseudospectral analysis, by James E. Kaufmann (poster)
- Modeling the potential vegetation locations of mesic hardwood forests in the Boxley Valley area of the Buffalo National River, Arkansas, by Keith Landgraf (poster)
- Using a porphyry copper deposit model, ASTER data, and a GIS database to help determine the number of undiscovered deposits in a mineral assessment, by John C. Mars (oral presentation)
- Modeling terrestrial landscape dynamics for the Southeast Regional Assessment Project: How the national Gap Analysis Program helped set the stage, by Alexa J. McKerrow, Adam J. Terando, James B. Grand, Jaime A. Collazo, and Kevin Gergely (oral presentation)
- Effects of the forward model nonlinearity on the inverse model solution, by Steffen Mehl (poster)
- Range dynamics of North American avian species as a function of recent climate change: tests and predictive modeling, by James D. Nichols and Jaime A. Collazo (oral presentation)
- Quantifying uncertainty in earthquake source inversions, by Morgan T. Page, Susana Custódio, Ralph Archuleta, Jean Carlson, Martin Mai, and Danijel Schorlemmer (oral presentation)
- An integrated, multiscale approach to predicting the response of lotic biota to climate change in the Southeast Resource Assessment Project, by James T. Peterson, Mary C. Freeman, W. Brian Hughes, Gary Buell, Lauren Hay, Kenneth Odom, John W. Jones, Robert B. Jacobson, Roland Viger, Jacob LaFontaine, and Sonya A. Jones (oral presentation)
- Spatial modeling of construction aggregate resources and production for land management and planning, by Gilpin R. Robinson, Jr. (oral presentation)
- Predicting climate change impacts on Great Basin wetlands, migratory birds, and their prey, by Travis S. Schmidt, Susan Haig, John Matthews, Mark Miller, Daniel Roby, and Branden Johnson (poster)
- Modeling of habitats for priority species in the Great Plains Landscape Conservation Cooperative, by Michael Starbuck (poster)
- Climate change effects on multiple stressors in the Rockies, by Sunil Kumar, Thomas Stohlgren, and Paul Evangelista (oral presentation)

- Evaluation of carbon dioxide management options: Model integration of human actions and the natural carbon cycle, by Eric T. Sundquist and Atul K. Jain (oral presentation)
- Global croplands and their water use: Remote sensing and nonremote sensing approaches, by Prasad Thenkabail (oral presentation)
- Designing sampling strategies to support groundwater modeling in the Upper Klamath Basin, Oregon and California, by Brian J. Wagner and Marshall W. Gannett (oral presentation)
- Development of multidisciplinary resource assessments, by Bronwen Wang, Frederic H. Wilson, Erik Beever, Jennifer Nielsen, Nancy Norvell, and David Selkowitz (oral presentation)

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