include cloud cleared radiances, sea surface temperatures, cloud fraction, cloud top pressures and temperatures, and profiles of temperature and water vapor. We describe here case studies of retrieved quantities for several atmospheric regimes observed by the AIRS instrument suite over ocean during the month of January 2003 in the latitude band 40 S to 40 N. These regimes include shallow and deep tropical convection, regions of temperature inversions with associated low-level clouds, and conditions near the midlatitude storm tracks. These studies are intended to establish the foundation for more detailed examinations of atmospheric phenomena observed by AIRS. We also present initial results of a multiparameter analysis of AIRS retrieved products using a statistical clustering method.

H22F MCC: 3020 Tuesday 1340h

Recent Advances in GIS and Data Visualization in Regional-Scale Groundwater Modeling II

Presiding: **C Zheng,** University of Alabama**; P Hsieh,** U.S. Geological Survey

H22F-01 1340h INVITED

Arc Hydro Groundwater Data Model - A GIS Framework for Groundwater Information

Gil Strassberg[1] (512-471-0073; gilstras@mail.utexas.edu)

David Maidment[1] ((512) 471-3131; maidment@mail.utexas.edu)

[1]University of Texas at Austin Center for Research in Water Resources, CRWR Pickle Research Campus Bldg 119, MC R8000 University of Texas, Austin, Tex 78712, United States

A progress report on the development of the groundwater section of the Arc Hydro data model is presented. The Arc Hydro surface water data model is a synthesis of geospatial and temporal information that characterize a "hydrologic information system" which supports hydrologic analysis and modeling in the ArcGIS environment. In order to better describe the full hydrologic cycle a groundwater section is developed to be incorporated into Arc Hydro. The integration of the groundwater data model will enable the characterization of surface water and groundwater simultaneously within ArcGIS. Representing the 3-dimensional nature of the subsurface and describing the hydrogeologic architecture of groundwater systems in a GIS framework is an important aspect of this study. The data model is designed to be scalable and will support the management of regional scale data as well as site scale information. The model will also describe surface water - groundwater connectivity by connecting the existing surface water data model with the groundwater section developed. The representation of groundwater systems will be utilized to develop interfaces between the ArcGIS environment and groundwater models such as MODFLOW.

H22F-02 1355h INVITED

Visualizing and Analyzing Geologic and Hydrologic Models of the Death Valley Regional Ground-water Flow System, Nevada and California

Claudia C. Faunt[1] (858-637-6842; ccfaunt@usgs.gov)

Carma San Juan[2] (303-236-5050x239; csanjuan@usgs.gov)

[1]U.S. Geological Survey, 5735 Kearny Villa Rd., Suite O, San Diego, CA 92123, United States

[2]U.S. Geological Survey, Denver Federal Center, P.O. Box 25046, MS 421, Denver, CO 80225, United States

Numerical modeling of the Death Valley regional ground-water flow system, Nevada and California, involves the conceptualization and simulation of a complex and heterogeneous geologic and hydrologic system. The hydrogeologic characteristics of the region result from an arid climate and complex geology. Interbasin regional ground-water flow occurs through a thick Paleozoic carbonate-rock sequence, a locally thick Tertiary volcanic-rock sequence, and basin-fill alluvium. Throughout the system, deep and shallow ground-water flow may be controlled by extensive and pervasive faults and fractures. Understanding ground-water flow requires the formulation of conceptual and digital models that characterize the three-dimensional (3D) hydrogeologic framework within which the water moves. Part of this study includes the construction of a digital 3D geologic model that provides a description of the geometry and composition of the hydrogeologic units and structures that control ground-water flow. These hydrogeologic units and structures are then simulated in the hydrologic model using the Hydrogeologic Unit Flow (HUF) Package and the Horizontal-Flow Barrier (HFB) Package of the ground-water modeling code MODFLOW-2000. The HUF Package allows the geometry of the hydrogeologic units to be defined explicitly using hydrogeologic units that can be different from the defined flow-model layers. The HFB Package allows the simulation of features that retard flow. Likewise, zone and multiplication arrays can be utilized to incorporate hydraulic property detail, such as facies changes within a particular unit. Utilizing these capabilities significantly contributes to the ability of the modeler to better simulate the hydrogeologic conceptual model of the flow system. As geologic and hydrologic modeling software increase in complexity, modelers have the ability to better visualize and interact with the simulated hydrogeologic system and flow-model results. Post-processing utilities such as MODPATH and ZONEBUDGET allow the calculation of information helpful for analyzing the vast quantities of data. New and existing geographic information system (GIS) techniques can be used to visualize these results, such as flow paths and water-budget data, as well as water-level altitudes, hydrogeologic units, zone arrays, and flow-model layers. For example, three-dimensional views of particle paths along with the geometry of hydrogeologic units and structures provide insight into which features may be controlling ground-water flow paths. Employing GIS to develop maps of flux in and out of particular parts of the system aids in the visualization of the water budget. In addition, with the advent of the newer techniques and modeling tools the scientist can better explore the links between the hydrogeologic framework and the flow system. For instance, the scientist may conduct hypothesis testing regarding the hydraulic parameters associated with specific units or features based on visualizations analyses performed with the aid of GIS. Thus, the power of combining the GIS techniques and modeling packages is that, in addition to helping the scientist calibrate the ground-water model, it allows the scientist to test the degree to which the flow-model results match the conceptual model.

H22F-03 1410h

Ground Water Data Management Using the ArcObjects Library

Norman L. Jones[1] (801-422-7569; njones@byu.edu)

Doug Gallup[1] (801-422-2812; gallup@byu.edu)

[1]Environmental Modeling Research Laboratory, 242 Clyde Building Brigham Young University, Provo, UT 84602, United States

The principal advantage of utilizing GIS technology for regional ground water modeling is that it allows the model development to occur on the conceptual model level. The principal model features can be defined using points, arcs, and polygons. For example, production and observation wells can be input as points. Rivers, drains, and head-dependent boundary conditions can be defined using arcs. Lakes, recharge zones, seepage faces, and hydraulic conductivity zones can be represented using polygons. Once the conceptual model has been defined, the model can be discretized to the model grid. The feature objects are intersected with the model grid to determine which cells coincide with each model feature. The cell-by-cell model input can then be automatically extracted from the feature object data. This conceptual model approach has numerous advantages: 1. Model development much is more efficient since the tedious discretization process can be automated. 2. Since the conceptual model is defined independent of the model grid, the modeler can quickly test various grid resolutions. 3. Existing GIS data can be integrated into a modeling project with minimal effort. When building a GIS-based ground water modeling tool, one of two approaches is typically used: 1) the tools be built entirely within an existing GIS such as ArcGIS, or 2) the tools can be built in a stand-alone program that imports data provided by a GIS. There are several advantages/disadvantages to each of these methods. We have chosen to build our system in a stand-alone program called the Groundwater Modeling System (GMS). The Map Module in GMS provides an interface for building conceptual models and converting conceptual models to a variety of models including MODFLOW & MT3DMS. One important component of a GIS-based modeling system is the capability to import GIS data. Traditionally, we have used the "shapefile" format for importing and exporting GIS data. The shapefile format is a fairly simple file format designed for exchanging GIS data. The main drawback of the shapefile approach is that not all GIS data are available in shapefile format. Recently, we have developed an entirely new method for importing GIS data for ground water modeling. This method is based on the new ArcObjects software library provided with the ArcGIS software. With ArcObjects, it is possible to embed a large portion of the ArcGIS functionality directly within your own application, provided that ArcGIS has been installed on the computer running the software. In GMS, we have developed a new "GIS Module" that incorporates the ArcObjects technology. With the ArcObjects tools, we can use the native ArcGIS "Add Data" dialog box to open virtually any GIS database supported by ArcGIS. We can then plot the imported database using the ArcObjects code, resulting in high quality map displays. In many cases, a GIS database contains substantially more information than is required by a modeling study. Using the ArcObjects code, we can select a subset of the database either by a graphical selection or by an SQL query. The selected data are then transformed to the format used by GMS for defining the conceptual models. When GIS data are initially developed, the format and naming conventions used are often non-standard. During this transformation process, the user is allowed to identify a filter for the attribute table that controls how the feature object attributes are to be mapped to the corresponding conceptual model attributes.

H22F-04 1425h

Role of the Analytic Element Method in regional-scale GIS-based modeling of groundwater flow and transport

Igor Jankovic[1] (716 645-2114x2328; ijankovi@eng.buffalo.edu)

Karl Bandilla (716 645-2114; bandilla@eng.buffalo.edu)

James Craig (716 645-2114; jrcraig2@acsu.buffalo.edu)

Alan Rabideau (716 645-2114; rabideau@eng.buffalo.edu)

[1]University at Buffalo, Jarvis Hall, Department of Civil, Structural and Environmental Engineering, Buffalo, NY 14260-4400, United States

The basic principle of the Analytic Element Method (AEM) is the superposition: complex regional-scale flows are simulated by adding the influences of individual analytic elements. Each analytic element contains geographic information and mathematical functions that describe its influence on regional groundwater flow. The main AEM advantage, relevant to GIS-based modeling, is a direct correspondence of analytic elements and hydrologic aquifer features (such as lakes, rivers, water-supply wells). The flow solution (water table elevation and fluxes) is created without discretization by including all relevant elements (or features). Several regional-scale groundwater models have been developed using the AEM include NAGROM (the National Groundwater Model of The Netherlands) and the Twin Cities Metropolitan Area Groundwater Model (Metro Model). The one-to-one correspondence of elements to hydrologic features allows for elegant integration of groundwater modeling and GIS software. This simplifies both model development and management. In contrast to finite-difference and finite-element based methods, the AEM does not require any grid-based data; all input data are vector-based. This representational style coincides well with the strengths of Geographic Information Systems. This presentation will focus on both the practical aspects of the AEM relevant to GIS-based modeling and the development of a new GIS-based user interface for AEM modeling. Recent computational advances related to regional-scale modeling using AEM will be discussed and demonstrated. These advances include (1) development of solution algorithms designed for massively parallel supercomputers where the same advantage (one-to-one correspondence of analytic elements and hydrologic features) is responsible for efficient implementation in parallel environments, and (2) algorithm enhancements designed for single-processor machines. Groundwater models with thousands of elements can hence be solved. A public domain GIS graphical user interface has been developed to aid in model construction and output visualization within the ArcGIS® software program ArcMap. The ArcGIS platform can handle multiple formats of geographically referenced field data in conjunction with input and output of the numerical model itself. The user interface, using many extensions available in ArcGIS, provides advanced functionality for analysis of model output and simplification of user input. The application is currently being used to develop a regional scale model of the Trout Lake area in northeastern Wisconsin.

H22F-05 1440h

An Innovative Real-time Environment for Unified Deterministic and Stochastic Groundwater Modeling

Shu-Guang Li[1] (517-432-1929; lishug@egr.msu.edu)

Qun Liu[1] (liuqu@egr.msu.edu)

[1]Department of Civil and Environmental Engineering, Michigan State University, A133, RCE, East Lansing, MI 48824, United States

Despite an exponential growth of computational capability over the last two decadesone that has allowed computational science and engineering to become a

H

unique, powerful tool for scientific discoverythe extreme cost of groundwater modeling continues to limit its use. This occurs primarily because the modeling paradigm that has been employed for decades limits our ability to take full advantage of recent developments in computer, communication, graphic, and visualization technologies. In this presentation we introduce an innovative and sophisticated computational environment for groundwater modeling that promises to eliminate the current bottleneck and greatly expand the utility of computational tools for scientific discovery related to groundwater. Based on a set of efficient and robust computational algorithms, the new software system, called Interactive Groundwater (IGW), allows simulating complex flow and transport in aquifers subject to both systematic and "randomly" varying stresses and geological and chemical heterogeneity. Adopting a new paradigm, IGW eliminates a major bottleneck inherent in the traditional fragmented modeling technologies and enables real-time modeling, real-time visualization, real-time analysis, and real-time presentation. IGW functions as a "numerical laboratory" in which a researcher can freely explore in real-time: creating visually an aquifer of desired configurations, interactively imposing desired stresses, and then immediately investigating and visualizing the geology and the processes of flow and contaminant transport and transformation. A modeler can pause to edit at any time and interact on-line with any aspects (e.g., conceptual and numerical representation, boundary conditions, model solvers, and ways of visualization and analysis) of the integrated modeling process; he/she can initiate or stop, whenever needed, particle tracking, plume modeling, subscale modeling, cross-sectional modeling, stochastic modeling, monitoring, and mass balance analyses. IGW continually provides and displays results that are intelligently processed, organized, overlaid, and displayed. It seamlessly and dynamically merges heterogeneous geo-spatial data into graphical images - integrating related data to reveal the complex interplay among the geology, hydrology and chemistry across multiple spatial and time scales. This unprecedented capability in real-time modeling, steering, integration, analysis, and visualization transforms the way we model and profoundly expands the utility of groundwater model as a tool for research, education, and professional investigation related to groundwater.

URL: http://www.egr.msu.edu/~lishug/igw

H22F-06 1455h

A generalized hierarchical paradigm for modeling and visualizing complex groundwater systems across-multiple spatial scales

Qun Liu[1]

Shu-Guang Li[1] (517-432-1929; lishug@egr.msu.edu)

[1]Department of Civil and Environmental Engineering, Michigan State University, A133, Research Complex Engineering, East Lansing, MI 48824, United States

We present in this paper a generalized hierarchical framework for modeling and visualizing complex groundwater systems across multiple spatial scales. A large-scale regional system is converted into a cascade of nested subsystems that are modeled sequentially with finer and finer resolution over a smaller and smaller domain. Higher levels are used to simulate larger scale dynamics whereas nested lower levels are used to simulate faster and smaller-scale processes. The upper level exerts constraints (e.g., as boundary conditions) to the lower level, whereas the rapid dynamics at lower level are aggregated (scaled up) and only manifest as aggregated effective values, providing initiating conditions to the upper. The subsystems at the same level interact with each other through their "parent" or "grand parent", etc. We implement the generalized hierarchical modeling paradigm in a sophisticated object-oriented, interactive software environment, called Interactive Groundwater. The system is designed such that a modeler can initiate on-line, interactively, and graphically an arbitrary number of submodels, submodels in a submodel, or most generally, a hierarchy of dynamically linked models and visualize in real-time multi-scale flow and transport. This generalized hierarchical paradigm eliminates the infamous "curse of dimensionality" in large-scale modeling and allows characterizing complex groundwater systems with unprecedented resolution and efficiency. At the meeting, we will demonstrate live the innovative software environment and the power of real-time hierarchical groundwater modeling.

URL: http://www.egr.msu.edu/~lishug/igw

H22F-07 1510h

Geostatistical Modeling of Uncertainty Attached to the Spatial Distribution of Arsenic in Groundwater of Southeast Michigan

Pierre Goovaerts[1] (1-734-913-1098; goovaerts@biomedware.com); Gillian Avruskin[1] (avruskin@biomedware.com); Jaymie Meliker[2] (jmeliker@umich.edu); Melissa Slotnick[2] (slotnick@umich.edu); Geoffrey Jacquez[1] (jacquez@biomedware.com); Jerome Nriagu[2] (jnriagu@umich.edu)

[1]Biomedware Inc., 516 North State Street, Ann Arbor, MI 48104, United States

[2]University of Michigan, School of Public Health 109 S. Observatory St., Ann Arbor, MI 48109-2029, United States

Assessment of the health risks associated with exposure to elevated levels of arsenic in drinking water has become the subject of considerable interest and some controversy in both regulatory and public health communities. The objective of this research is to explore the factors that have contributed to the observed geographic co-clustering in bladder cancer mortality and arsenic concentrations in drinking water in Michigan. A corner stone is the building of a probabilistic space-time model of arsenic concentrations, accounting for information collected at private residential wells and the hydrogeochemistry of the area. Because of the small changes in concentration observed in time, the study has focused on the spatial variability of arsenic, which can be considerable over very short distances. Various geostatistical techniques, based either on lognormal or indicator transforms of the data to accommodate the highly skewed distribution, have been compared using a cross validation procedure. The most promising approach involves a soft indicator coding of arsenic measurements, which allows one to account for data below the detection limit and the magnitude of measurement errors. Prior probabilities of exceeding various arsenic thresholds are also derived from secondary information, such as type of bedrock and surficial material, well casing depth, using logistic regression. Both well and secondary data are combined using kriging, leading to a non-parametric assessment of the uncertainty attached to arsenic concentration at each node of a 500m grid. This geostatistical model can be used to map either the expected arsenic concentration, the probability that it exceeds any giventhreshold, or the variance of the prediction indicating where supplementary information should be collected. The accuracy and precision of these local probability distributions is assessed using cross validation.

H22F-08 1525h

3D Geological Mapping : a Pioneering Tool for Underground Water Management

Damien Dhont[1] (33-5-59-40-74-25; damien.dhont@univ-pau.fr)

Pascal Luxey[2] (33-1-40-40-04-05; dglfrance@nerim.net)

Jean Chorowicz[3] (33-1-44-27-50-89; jean.chorowicz@lgs.jussieu.fr)

[1]University of Pau et des Pays de l Adour, CNRS-FRE 2639 : Imagerie geophysique CURS-IPRA Avenue de l'Universite, Pau 64000, France

[2]Dynamic Graphics Inc., 1015 Atlantic Avenue, Alameda, CA 94501, United States

[3]Paris 6 University, CNRS-UMR 7072: Laboratoire de Tectonique Case 129 4, place Jussieu, Paris cedex 75252, France

Modern geology needs accurate representation of underground volumes. Because 3D geological mapping was so far based on the interpretation of expensive 2D and 3D seismic surveys, it has not been much used in water exploration and exploitation. We present a pioneering way to generate accurate and efficient 3D geological maps using already existing and inexpensive data sets, in a context of fresh water management in the Beirut watershed (Lebanon). Our approach is based only on surface information coming from a published geological map, remotely sensed data, and a Digital Elevation Model (DEM). In order to generate the 3D geological map, we used a 3D geological modeler (EarthVision developed by Dynamic Graphics Inc.) that combines and extrapolates the surface information into a coherent 3D data set, to represent volumes. Once the 3D map has been calculated, graphical representations allow the user to examine it from various directions, slice it to generate cross-sections, or disassemble it to examine individual geological units. Such 3D geological map is a powerful tool to understand both the regional geological settings and the local relationships between faults, horizons and topographic surface. A major advantage of our 3D map is that it offers the possibility to attribute rock properties to each geological volume unit. In order to illustrate how ground water reserves can be quantified, we simulate the porosity of one water reservoir leading to the calculation of rock pore volume. We also calculated a cellular grid in conjunction with the porosity model that quantifies the water circulation within the reservoir. These results are of major significance when planning future wells or for any water and reserve management tasks. Any other underground resources could also be described by such a 3D geologic model. This methodology can be applied to other parts of the world, using the same kind of input geological map, complemented with field and remote sensed data when needed and available.

H22G MCC: 3022 Tuesday 1340h

Hydrologic Flow Near the Earth's Surface I

Presiding: **D A DiCarlo,** USDA Agricultural Research Service**; D Barry,** University of Edinburgh

H22G-01 1345h INVITED

The Poisson-Boltzmann Equation as a Dynamical System

Garrison Sposito[1,2] ((510) 643-8297; sposito@ce.berkeley.edu)

[1]Department of Civil and Environmental Engineering, Environmental Engineering Group, MC 1710, University of California, Berkeley, CA 94720-1710, United States

[2]Department of Geophysics and Geomechanics, Division of Earth Sciences, MC 90/1116, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, United States

The Poisson-Boltzmann equation is a nonlinear ordinary differential equation that provides a rather accurate model for the behavior of the diffuse ion swarm near charged colloidal particles suspended in dilute aqueous media. Analytical solutions of this equation are known only for planar charged surfaces (e.g. layer type clay minerals), but an iterative method of approximate solution suggested by J.-Y. Parlange in 1972 has enjoyed widespread application to both cylindrical (e.g. polyanions) and spherical (e.g. metal oxides) charged surfaces. Since the Poisson-Boltzmann equation is a special case of a generic nonlinear ordinary differential equation whose other realizations include well known mathematical models in astrophysics, nuclear engineering, and theoretical ecology, progress in the analytical solution of the Poisson-Boltzmann equation also contributes to the elucidation of its mathematical siblings. In this paper we show that the Poisson-Boltzmann equation can be derived from a Lagrangian variational principle and that it can be put into one-to-one correspondence with a Hamiltonian dynamical system. This correspondence opens the door to utilizing the vast array of mathematical results available in Lagrangian and Hamiltonian dynamics. For example, Noether's theorem can be applied to find first integrals and an exact Hamilton-Jacoby equation can be constructed, the solution of which is tantamount to solving the Poisson-Boltzmann equation. This latter avenue is explored for planar, cylindrical, and spherical geometries emphasizing the utility of the Parlange approximation scheme.

H22G-02 1405h

Improving the Dupuit-Forchheimer Approximation for Free Surface Flow in an Unconfined Aquifer

John H Knight (-61-2-6246 5566; John.Knight@csiro.au)

CSIRO Land and Water, GPO Box 1666, Canberra, ACT 2601, Australia

The classical Dupuit-Forchheimer (DF) approximation for groundwater free surface flow in an unconfined aquifer assumes that the vertical component of the seepage velocity is zero. This assumption is expected to be least accurate when there is non-zero accretion at the free surface. The DF approximation leads to a nonlinear diffusion equation satisfied by the height of the free surface. The general principles of integral methods used by Yves Parlange are to assume some simple approximate shape for some unknown function, and then to choose the parameters of this function to satisfy some known integral relation of the flow system. The DF approximation is improved by assuming that the vertical velocity component is zero at the impermeable horizontal base, and increases linearly to its unknown value at the free surface. The well known Guirinsky potential which depends only on the free surface height