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Efficient, robust simulation of groundwater flow in the unsaturated zone remains computationally expensive, especially for problems characterized by sharp fronts in both space and time. Standard approaches that employ uniform spatial and temporal discretizations for the numerical solution of these problems lead to inefficient and expensive simulations. In this work, we solve Richards' equation using adaptive methods in both space and time. Spatial adaption is based upon a coarse grid solve and gradient-based error indicators, while the spatial step size is adjusted using a fixed-order approximation. Temporal adaption is accomplished using variable-order, variable-step-size approximations based upon the backward difference formulas up to fifth order. Since the advantages of similar adaptive methods in time are now established, we evaluate our method by comparison with a uniform spatial discretization that is adaptive in time for four different test problems. The numerical results demonstrate that the proposed method provides a robust and efficient alternative to standard approaches for simulating variably saturated flow.

H11G-0954 0830h POSTER

Delineation of Free Convection Pathways in a Heterogeneous Low-permeability Unit

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Study of free convection in heterogeneous geologic units poses challenges to hydrogeologists in solute transport modeling and in predicting the effective Rayleigh Number, which is the ratio of bouyancy driving forces to the viscous resistance to flow and the diffusive dissipation of solutes. Downward convection of dense fluid through heterogeneous low-permeability strata follows preferential pathways of groundwater flow and contaminant transport. In this study, the concepts of boundary layer and critical Rayleigh number are used to delineate free convection pathways in a suite of permeability field realizations. A boundary layer is formed when the upward evaporative flux stabilizes the downward groundwater movement in a saline lake environment. Onset of free convection occurs when the effective Rayleigh Number (NRa) exceeds certain value, the critical Rayleigh Number, The threshold value of permeability that permits free convection in a system where denser fluid overlies a less-denser fluid is approximately 10-14 m2 for a boundary layer of 0.315 m and a NRa of 8.5 to 10. Invasion percolation theory (an invasion process that proceeds along a path of least resistance) is used in the searching algorithm that identifies the paths for free convection in 60 different heterogeneous permeability fields. By comparing with modeling results of variable density flow through these different k-simulations, the delineation of pathways provides insight into predicting the occurrence of free convection, groundwater flow, and solute distribution in heterogeneous low-permeability systems. Individual long and wide pathways promote free convection, which indicates that local heterogeneity controls solute transport. Vertically continuous zones of high permeability form pathways that support the initiation and growth of freely-convecting solute plumes.

H11G-0955 0830h POSTER

Rare Earth Element Speciation Along Groundwater Flow Paths in Two Different Aquifer Types (i.e., Sand vs. Carbonate)

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Groundwater samples were collected in two different types of aquifer (i.e., Carrizo sand aquifer, Texas and Upper Floridan carbonate aquifer, west-central Florida) to study the concentrations, fractionation, and speciation of rare earth elements (REE) along groundwater flow paths in each aquifer. The solution complexation of REEs in these two aquifers was modeled using Humic Ion-Binding Model V. The results of the REE speciation modeling indicate that the solution complexation of REEs is controlled by pH, alkalinity, and DOC concentration. Because DOC is low (less than 0.65 mg/L) in Carrizo aquifer, organic complexation of REEs is not significant in these groundwaters. For LREEs, LnCO3+ and/or Ln(CO3)2- are the dominant species when pH is above 7.0, but when pH is below 7.0, besides LnCO3+, Ln3+ and LnSO4+ are also significant and their importance increases with decreasing pH. For HREEs, LnCO3+ and/or Ln(CO3)2- are always the dominant species, however, LnPO4o is important in some groundwaters. The similar general patterns of inorganic solution complexation of the REEs are also observed in groundwaters from the Upper Floridan aquifer. However, because of the relatively high DOC concentrations measured in the Floridan groundwaters, organic complexation of REEs, especially LREEs, is also predicted to be significant in some groundwaters. Linear correlation coefficients for total REE, Nd, Gd, and Yb concentrations, and (Yb/Nd)SN vs. pH, CO3, DOC, SO4, Fe, and Mn indicate that for the Carrizo groundwaters, REE concentrations are not correlatd to any of these factors. However, (Yb/Nd)SN is inversely related to pH and the [CO32-] concentration of these groundwaters. Because REE speciation is strongly related to pH and the [CO32-] concentration, it is reasonable to expect that REE solution complexation plays a greater role in fractionating REE than controlling absolute concentrations in the Carrizo Sand aquifer. In Upper Floridan aquifer, LREE concentrations are positively correlated to DOC and inversely related to [CO32-] and pH. MREEs do not correlate with DOC but show a weakly inverse relationship to [CO32-] and pH. The HREEs are inversely related to DOC and positively correlated with the [CO32-] concentration and pH. (Yb/Nd)SN is positively related to pH and [CO32-] and negatively related to DOC in the Floridan groundwaters. Thus, in contrast to our observations for the Carrizo Sand aquifer, REE solution complexation appears to affect both REE fractionation patterns and their absolute concentrations for groundwaters of the Upper Floridan aquifer.

H11G-0956 0830h POSTER

Fully Determined Fluid Velocity Fields for Complex 2D Media with Multi-Scaled Heterogeneity.

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Numerical schemes for fluid flow in complex rock geometries rely on comparison with existing empirical data for their validation. When available, these data are generally limited to non-unique, bulk measurements of properties such as hydraulic conductivity and permeability and are not adequate to fully validate complex numeric schemes. Here we describe an experimental system which has been developed to fully quantify velocity fields throughout synthetic two-dimensional heterogeneous media. We first create a digital image with the desired combination of matrix and fracture porosity, incorporating detail over several orders of magnitude. This image is then translated into a physical medium using either stereolithography or wire EDM machining. The result is a flow cell comprising two transparent plates with a thin section of material, identical to the digital image of the medium, between them. In order to observe and measure fluid velocity, the flow cell is integrated in a purpose built experimental rig and a controlled flow of fluid, seeded with neutrally dense micro-particles, is induced. Local velocities are then measured throughout the medium with a high-resolution digital particle image velocimetry system. Simultaneously fluid flow is simulated in these geometries using a variety of numerical schemes. Direct comparison is then made between measured and predicted velocity fields for geometries that include complex combinations of matrix and fracture flow, investigations of the effect of fracture roughness on the flow field and scaling laws in the region of the percolation threshold. Results and conclusions are presented.

URL: http://www.science.ulst.ac.uk/crg/geophys/research/nerc_fluids.htm

H11H MCC: 3022 Monday 1020h

Observations and Modeling of Land Surface Hydrological Processes II

(joint with A, B, C)

Presiding: **V Lakshmi,** University of South Carolina**; A Cahill,** Texas A&M University

H11H-01 1020h

Demonstrating the Importance of "Good" Models of Land Surface Hydrological Processes

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To reduce the uncertainty in the prediction of land surface climates, , the Atmospheric Model Intercomparison Project (AMIP) Diagnostic Subproject 12 (DSP 12) and the Project for Intercomparison of Land-surface Parameterisation Schemes (PILPS) have analysed dependence of climate simulations on the land-surface schemes (LSSs). This analysis has comprised three efforts: (i) proving that LSSs matter in coupled simulations; (ii) investigating whether improvements in LSSs have occurred over time; and (iii) searching for novel means of validating LSS predictions. In the first, Irannejad *et al.* (2003) introduce a novel method for evaluating the dependence of 19 AMIP AGCMs' LH on the LSS by excluding the impact of the atmosphere. Pseudo LSSs (PLSSs) for LH in the form of multi-variable linear models expressing mean monthly LH as a function of atmospheric forcing are developed. Analysis over three large and climatically diverse river basins shows estimates of mean annual LH from the PLSSs agreeing well with the AGCMs' simulations. RMS errors range from 0.4 to 2.2 W m^{-2} depending on the region and the AGCM. When the PLSSs are driven by single atmospheric forcings, different LSSs behave differently, and the variability of mean annual LH among AGCMs increases. The second strand of our investigation uncovered a clear generational sequence of land-surface schemes: first generation 'no canopy'; second generation 'SiBlings'; and 'recent schemes'. We conclude that although continental surface modelling has improved over the last 30 years, full confidence remains elusive, in part due to tuning to available observations. Finally, we show that stable water isotopes challenge predictions of evaporation and condensation processes. These three-pronged findings prove that LSSs are important to AGCM and coupled climate predictions; demonstrate that new, or changed, land-surface components increase diversity among simulations; underline the need for validation data and also challenge current parameterisations with novel observations.

H11H-02 1035h

Water Availability for the Western United States: The Role for Science

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In the American West, the availability of water has become a serious concern for many communities and rural homeowners. Water of acceptable quality is harder to find because local sources are allocated to prior uses, depleted by overuse, or diminished by drought stress. Some of the inherent characteristics of the West add complexity to the task. The most rapidly growing States in population are in the Southwestthe most arid region on the continent. There is evidence that the climate is warming, which will have consequences for the Western water supplies, such as increasing minimum streamflow and earlier snowmelt events in snow-dominated basins. Endangered species are disproportionately represented in the Western States, and water availability now means sustaining riparian ecosystems

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and individual endangered species. Periodic inventory and assessment of the amounts and trends of water available in surface water and ground water are needed to support water management. The widespread perception that the amount of water available is diminishing with time needs to be replaced with fact. For the major Western rivers, there is either no long-term streamflow trend or the trend is increasing. In contrast, systematic information is lacking to make broad assessments of ground-water availability, but for specific aquifers where data are available, the aquifers are being depleted. The complexity added to the issue of Western water availability by these and other factors gives rise to a significant role for science. Science has played a role in support of Western water development from the beginning, and the role has evolved and changed over time along with society's values. The role for science is discussed in three phasesdevelopment and construction, consequences and environmental awareness, and sustainability. The development and construction includes some historical accounting of water development for the West and how some precedents set then, still exist today. Science has played an important role in objectively pointing out the consequences of this initial phase such as; converting the Nation's rivers to reservoirs, the effects of ground-water pumping on surface water in streams, land-surface subsidence, and the changes in water quality brought about by the disposal of wastewater and manmade chemicals into the Nation's waterways and aquifers. The sustainability phase is the final goal in the evolution of water development for the West and is a threshold over which science and management has yet to cross. Sustainability, as presently interpreted, goes beyond mere water availability for water supply, and includes ecosystems and even individual species. Sustainability by this definition is superficially appealing but is and will continue to be a significant challenge for science to translate into a measurable water-management strategy. A sustainable water supply for a community would ideally provide enough water to support a growing population and economy, even during protracted periods of droughta tall order. In order to achieve sustainable use, scientists, managers, policy makers and water users at large will need to develop, communicate, and use scientific information in more effective ways. New collaborative ways of conducting monitoring and research, across disciplinary lines will be needed to develop quantitative habitat requirements for ecosystems and endangered species. The new role for science will be to support environmental decisionmaking to achieve some new level of sustainable use that will provide an assured supply of good-quality water for humans and for stream and riparian ecosystems.

H11H-03 1050h

Development of a Coupled Land Surface and Ground Water Model for use in Watershed Management

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Management of surface water quality is often complicated by interactions between surface water and groundwater. Traditional Land-Surface Models (LSM) used for numerical weather prediction, climate projection, and as inputs to water management decision support systems, do not treat the lower boundary in a fully process-based fashion. LSMs have evolved from a leaky bucket to more sophisticated land surface water and energy budgets that typically have a so-called basement term to depict the bottom model layer exchange with deeper aquifers. Nevertheless, the LSM lower boundary is often assumed zero flux or the soil moisture content is set to a constant value; an approach that while mass conservative, ignores processes that can alter surface fluxes, runoff, and water quantity and quality. Conversely, models for saturated and unsaturated water flow, while addressing important features such as subsurface heterogeneity and three-dimensional flow, often have overly simplified upper boundary conditions that ignore soil heating, runoff, snow and root-zone uptake. In the present study, a state-of-the-art LSM (CLM2.0) and a variably-saturated groundwater model (ParFlow) have been coupled as a single column model. An initial set of simulations based on data from the Project for Intercomparison of Land-surface Parameterization Schemes (PILPS) and synthetic data demonstrate the temporal dynamics of both of the coupled models. Changes in soil moisture and movement of the water table are used as indicators of conservation of mass between the two models. Sensitivity studies demonstrate the affect of precipitation, evapotransporation, radiation, subsurface geology and heterogeneity on predicted watershed flow. The coupled model will ultimately be used to assist in the development of Total Maximum Daily Loads (TMDLs - a surface water quality standard) for a number of pollutants in an urban watershed in Southern California in the United States. Sensitivity studies demonstrating the effects of watershed flow in uncoupled and coupled modes will be presented.

H11H-04 1105h

The Occurrence of Global Drought Under Future Climate Scenarios

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GCM predictions of future climate change indicate substantial changes in globally averaged precipitation and other water balance variables. The distribution of these changes in space is predicted to be quite variable however, with some regions predicted to experience increases and others regions decreases. These combined changes may manifest themselves locally through the impact of natural hazards such as droughts and floods. The assessment of how these changes translate into actual levels of impact is useful in planning and mitigation in the face of potential change. In this study we generate scenarios of drought occurrence under potential future climates. The occurrence of drought is determined from a physically based drought index using soil moisture fields from simulations using the Variable Infiltration Capacity (VIC) land surface model. Future climate simulations are compared with historic simulations using probability density functions of soil moisture. The historic simulations are driven by a 50-yr forcing dataset based on the NCEP/NCAR Reanalysis, corrected for biases in precipitation totals and rain day statistics, air temperature, and radiation. The future climate forcings are based on data from two GCM simulations of future climates scaled to remove systematic biases. We show the predicted development of drought over the next 100 years and changes in the occurrence and intensity of drought events at regional scales.

H11H-05 1120h

Impacts of Climate Change on Regional Water Balance, With Application to the Illinois River Basin

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The objective of this analysis is to investigate the sensitivity of regional water balance components to changes in climate. To accomplish this objective, a simple model is developed to describe the partitioning of precipitation into surface runoff, groundwater runoff, and evapotranspiration. The fluxes are first described at the local-instantaneous scale and then integrated over the spatial and temporal distributions of precipitation and soil saturation to determine regional-climatological average fluxes and soil saturation. The model is applied first to the Illinois River Basin, where numerous observations are available to constrain the model components. The spatial distribution of soil saturation is found to conform to an Erlang distribution, while the temporal distribution of the spatially-averaged soil saturation conforms to a Beta distribution. Climate changes are assumed to come through changes in precipitation and potential evapotranspiration, and the sensitivity of the hydrologic components is assessed by calculating the partial derivatives of the components with respect to precipitation and potential evapotranspiration. We evaluate the sensitivity of the soil saturation as well as the main hydrologic fluxes (surface runoff, groundwater runoff, and evapotranspiration) for the current Illinois climate. We also investigate the sensitivity of hypothetical regions that differ from the Illinois base case in controlled ways. This procedure allows us to assess the roles played by various physical characteristics of the region. For Illinois, the soil saturation is observed to be more sensitive to changes in precipitation than the hydrologic fluxes. We also find that soil type is a key factor in determining the sensitivity of hydrologic fluxes to climate changes.

H11H-06 1135h

Preferential States in Continental Soil Moisture and Climate Dynamics

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Summer precipitation in continental midlatitude regions is significantly contributed by local recycling, i.e. by moisture returning to the atmosphere as water vapor through evapotranspiration from the same region. In the summer months, soil moisture availability may limit water vapor fluxes from the soil surface to the planetary boundary layer, with important effects on the regional climate. It has been argued that important dynamics arise from such land-atmosphere interactions, including drought occurrence sustained by positive feedbacks in response to initial (spring/beginning of summer) surface moisture anomalies. However, no conclusive evidences have been provided in support of the existence of such feedbacks. We provide further experimental evidences in support of the hypothesis that, in continental regions, summertime soil moisture anomalies affect subsequent precipitation. We also test the hypothesis that, due to soil moisture-precipitation feedbacks, summertime soil moisture dynamics have two preferential states evidenced by the existence of a double mode in the probability distribution of soil moisture, while intermediate conditions have low probability of occurrence. In support of these central goals we analyze existing soil moisture records from Illinois and develop simple stochastic water balance models to study the effect of precipitation recycling on summer soil moisture dynamics.

H11H-07 1150h

Streamflow Simulations of the Terrestrial Arctic Regime

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Runoff from the Arctic terrestrial drainage system represents about two-thirds of the net flux of freshwater to the Arctic Ocean. Both the amount and the timing of freshwater inflow to the ocean systems are important to ocean circulation, salinity, and sea ice dynamics. In this study, the Variable Infiltration Capacity (VIC) model is used to simulate runoff and streamflow from the pan-Arctic terrestrial domain from 1979 to 1999. The VIC model is a grid-based land surface scheme designed both for inclusion in GCMs, and for use as a stand-alone macroscale hydrological model. The key elements of the model that are particularly relevant to high latitude implementations include a two-layer energy balance snow model, a frozen soil/permafrost algorithm, a blowing snow model, and a lakes and wetlands model, none of which have previously been applied over the entire pan-Arctic domain. The model was applied over a 100km$\times$100km EASE grid mesh with full energy balance (closure for surface skin temperature) at a time step of 3 hours. A river network was developed for the model grid mesh and a routing scheme was run offline which takes daily VIC surface and subsurface runoff as input to obtain model simulated streamflows at the outlets of selected study basins. The forcing data, soil, and vegetation parameters needed by the VIC are described and evaluated, along with calibration issues. The VIC streamflow simulations for the Lena, Ob, and Mackenzie watersheds are compared with observations. For the 20-year study period, an estimate is provided of the mean freshwater flux to the Arctic and its spatial distribution, and is compared with previous estimates.

H11H-08 1205h

An Assessment of VIC-3L Hydrological Model for the Yangtze River Basin – A Case Study of Baohe Watershed

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Yangtze is the first longest river in China and the third in the world, with its main channel length of 6,300 km and a drainage area of 1,800,000 km2. The Yangtze river basin includes large urban areas and significant croplands which play important and critical roles in China's economy and the health of the ecological environment. There are many notable projects associated with the Yangtze river basin, such as the Three-Gorge Dam project, and the water transferring project from south to north. Understanding of the natural terrestrial hydrological processes over the Yangtze river basin and the interactions between land surface and atmosphere, and the impact of the Three-gorge Dam project on its ecological environment is critical and challenging. As the first step in our effort of simulating the terrestrial hydrological process for the entire Yangtze river basin, a spatially distributed Three-Layer Variable Infiltration Capacity (VIC-3L) hydrological model is applied to a watershed called Baohe river watershed with a drainage area of 2500 km2 within the Yangtze river basin. Water fluxes of this watershed are simulated using VIC-3L at a spatial resolution of about 1 km. The soil properties and vegetation information from The Landuse and Landover Database of China at 1km Spatial Resolution for the study watershed are based on the spatial distribution patterns of vegetation, land cover, and soil type at 1km spatial resolutions. The meteorological information (i.e., precipitation, wind, air temperature) is obtained from meteorological measurement and is interpolated into each grid cell by Gauss weight method. The VIC-3L model is running on daily time step. A reservoir routing scheme together with river network routing is coupled with the VIC-3L model to simulate the streamflows. Simulation results are tested using daily streamflow measurements from the hydrologic station at the outlet of Baohe basin, Jinagkou in the Shaanxi province, China, from 1992 to 2001. Analyses of the water fluxes for the watershed will be discussed.

H11I MCC: 3024 Monday 1020h

Optimization for Model Calibration and Management in Water Resources II *(joint with NG)*

Presiding: **C A Shoemaker,** Cornell University**; S Sorooshian,** University of California, Irvine

H11I-01 1020h

A Self-Adaptive Hybrid Genetic Algorithm for Optimal Groundwater Remediation Design

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Identifying optimal designs for a groundwater remediation system is computationally intensive, especially for complex, nonlinear problems such as enhanced in situ bioremediation technology. To improve performance, we apply a hybrid genetic algorithm (HGA), which is a two-step solution method: a genetic algorithm (GA) for global search using the entire population and then a local search (LS) to improve search speed for only a few individuals in the population. The inclusion of local search helps to speed up the solution process and to make the solution technique more robust. The result of this research is a highly reliable numerical tool, the enhanced self-adaptive hybrid genetic algorithm (e-SAHGA) to more efficiently and effectively solve problems using simple genetic algorithms (SGAs). With this tool, the designer can evaluate different solution alternatives in a more timely fashion. The application of the eSAHGA algorithm to a hypothetical groundwater remediation design problem showed 90% reliability in identifying the solution faster than the SGA, with average savings of 64% across 100 runs with different random initial populations. Finally, e-SAHGA was tested on a field-scale remediation design problem, re-evaluation of the remediation system for Umatilla Army Depot, by means of a domain decomposition approach. In this approach, well locations are identified first and then pumping rates are identified subsequently in separate GA runs. The domain decomposition approach was shown to be much faster than the full solution approach with no loss in accuracy of the final solution for this problem, with computational savings between 30% and 60%.

H11I-02 1035h

Uncertainty-Based Multi-Objective Optimization of Groundwater Remediation Design

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Management of groundwater contamination is a cost-intensive undertaking filled with conflicting objectives and substantial uncertainty. A critical source of this uncertainty in groundwater remediation design problems comes from the hydraulic conductivity values for the aquifer, upon which the prediction of flow and transport of contaminants are dependent. For a remediation solution to be reliable in practice it is important that it is robust over the potential error in the model predictions. This work focuses on incorporating such uncertainty within a multi-objective optimization framework, to get reliable as well as Pareto optimal solutions. Previous research has shown that small amounts of sampling within a single-objective genetic algorithm can produce highly reliable solutions. However with multiple objectives the noise can interfere with the basic operations of a multi-objective solver, such as determining non-domination of individuals, diversity preservation, and elitism. This work proposes several approaches to improve the performance of noisy multi-objective solvers. These include a simple averaging approach, taking samples across the population (which we call extended averaging), and a stochastic optimization approach. All the approaches are tested on standard multi-objective benchmark problems and a hypothetical groundwater remediation case-study; the best-performing approach is then tested on a field-scale case at Umatilla Army Depot.

H11I-03 1050h

Identification of Spatially Distributed Soil Hydraulic Properties in Hydrologic Modeling Using Global Optimization

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In the past few years, computational capabilities have evolved to a point, where it is possible to use multi-dimensional physically based hydrologic models to study spatial and temporal patterns of water flow in the vadose zone. However, so far these models based on complex multi-dimensional governing equations have only received very limited attention, in particular because of their computational, distributed input and parameter estimation requirements. The aim of the present paper is to explore the usefulness and applicability of the inverse method to estimate spatially distributed soil hydraulic properties using the solution of a physically-based three-dimensional distributed model combined with spatially distributed measured tile drainage data from the 4000 ha BWD (BWD) in the San Joaquin Valley of California. The inverse problem is posed within a single criterion Bayesian framework and solved by means of the computerized Shuffled Complex Evolution Metropolis (SCEM-UA) global optimization algorithm. To study the benefits of using a complex spatially distributed three-dimensional vadose zone model, the results of the 3D model were compared with those obtained using a simple conceptual bucket model and a spatially-averaged one-dimensional unsaturated water flow model. District-wide results demonstrate that measured spatially distributed patterns of drainage data contain only limited information towards the identification of the vadose zone model parameters, and are particularly inadequate to identify the soil hydraulic properties. In contrast, the drain conductance, and a bypass coefficient were highly identifiable, indicating that the dominant hydrology of the BWD was determined by drain system properties and preferential flow. Despite the significant CPU time needed for model calibration, results indicate that there are advantages of using physically-based hydrologic models to study spatial and temporal patterns of water flow at the scale of a watershed, as these models not only generate consistent forecasts of spatially-distributed drainage data during the calibration and validation period, but also possess unbiased predictive capabilities of measured groundwater table depths not included in the calibration.

H11I-04 1105h

A Polygonal Cells Approach for Optimal Selection of Monitoring Wells

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This study concerns the concept, methodology, and application of an optimal strategy for groundwater contamination monitoring. The research objective is to develop a robust technique for accurately and quickly monitoring and locating the contaminant sources and plumes in a comparatively large contaminated area. The monitoring plan incorporates cycles of sampling. In each cycle the decision variables are wells selected for sampling, where the number of sampled wells at each cycle is the primary constraint. The proposed methodology approaches this optimization problem by dividing the site into area cells, and sampling a representing well within each cell, within each cycle. A Utility Function (UF) is defined for each point in the aquifer. The integral of the UF over a specific area results in a Density Utility Function (DUF) that quantifies the utility of sampling in that area. A Genetic Algorithm (GA) then divides the aquifer into area cells whose DUF's are uniformly distributed as much as possible, and whose number is equal to the number of samples available in each cycle. Exemplifying applications of the proposed methodology have shown to achieve smaller errors, which gradually decrease at each sampling cycle and thus higher efficiency of the well sampling is obtained, in comparison with other contamination monitoring algorithms.

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Inverse Problem and Management Applications in Groundwater Modeling: Equivalent Model Sets and Data Sufficiency Evaluation

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Inverse modeling is a powerful tool for calibrating complex distributed groundwater models. Traditionally, the inverse problem has been formulated as finding the parameter values that minimize a measure of the difference between model output and observed field data. Additionally, the process has been extended to include the influence of model structure error. A calibrated model, however, can be no better than the available data used in the parameter estimation process. Likewise, the fitness criteria adopted in model calibration can influence the decision of whether or not to accept a simulation model for management applications. This research aims at developing a methodology that combines management application and inverse modeling to assess the existence of a family or a set of equivalent groundwater flow simulation models. The definition of such a family is prescribed on uncertainty tolerance requirements applied in the parameter and management spaces. The parameter space is defined as the set of admissible parameter values, plus initial and boundary conditions. The management space is the set of management policies that is expected to satisfy a group of planning objectives. Multiobjective optimization and first-order approximation analysis are linked to evaluate the influence of parameter uncertainty over the set of non-inferior solutions that provides a starting point for decision-making in groundwater management.