to the southwestern basin of Lake Erie, Old Woman Creek Watershed (OH).

H12E-1030 1330h POSTER

Effect of Medium Characteristics on Optimal Remediation Design: Sorption and First-order Decay Rate

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Optimal remediation design using the pump and treat method is obtained for a hypothetical contaminant transport with natural attenuation represented by first-order decay and sorption. The total pumping volume is set to the decision value. Simulation-optimization method is used to minimize the total volume and find optimal pumping locations. When the first-order decay rate becomes higher, less pumping volume is required but the pumping wells stay at the same positions. The location of pumping wells is on the centerline of domain and down-gradient region from highly contaminated zone. First-order decay rate has influence on the portion of the pumping rate; the lower decay rate causes the higher pumping rate is to be assigned. The sorption also influences on the optimal design. More pumping rate and pumping wells are required when the sorption effect increases. Most of additional wells are located on highly contaminated zone.

H12F MCC: 3022 Monday 1340h

Observations and Modeling of Land Surface Hydrological Processes III

(joint with A, B, C)

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

H12F-01 1340h

Assessment of Scale-Dependent Runoff Generation Mechanisms in TOPLATS and Noah-router

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Until recently, contemporary land surface models neglected the realistic treatment of runoff. However, the decreasing scale at which land surface models are being applied necessitates the inclusion of lateral surface and subsurface runoff in order to properly close local water budgets. In this study we compare two, distinct, offline land surface models that have been dynamically coupled to runoff schemes. Comparisons of simulated runoff volumes, land surface fluxes, soil moisture states are made using TOPLATS, which uses the conceptual runoff formulation of TOPMODEL and Noah-router', which uses an explicit dynamical approach. Particular emphasis is placed on assessing the differences in runoff production zones and runoff generation mechanisms (i.e. infiltration and saturation excess and exfiltration) between the two models. Scale dependent behavior of the models is also explored by comparing runoff generation processes when the models are run at different grid scales typical of contemporary rainfall-runoff models.

H12F-02 1355h

Estimation of Drainage and Evapotranspiration from Time Series of Soil Moisture, Potential Evaporation, and Precipitation

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A previous study demonstrated that the dependence of soil water outflow on soil moisture can be estimated by averaging precipitation conditioned on soil moisture. The methodology is non parametric and relies only on the assumed stationarity of the soil moisture time series. Here we present a method for partitioning out the evapotranspiration component of total outflow. One goal is to structure the model with as few assumptions about model form as possible. for example we set evapotranspiration efficiency to increases monotonically with moisture and to be concave down, while the net drainage (capillary rise to or percolation from the root zone) is made to depend on moisture in a concave upward fashion. The functions used to represent these behavior are piecewise continuous polynomials or line segments. After generating a set of feasible partitions using a linear programming technique, we evaluate the relative likelihood of each by estimating the entropy of the time series of soil water storage that results from integrating the fluxes. We show that the entropy of the series is proportional to the likelihood that the increments that make it up come from a stationary process, and use this as a basis for model selection. We also estimate the growth of variance of the time series, and decompose this into an equilibrium process (that saturates with time due to a negative correlation among increments) and an error process which (for white noise model, measurement and sampling errors) leads to a random walk term. A unique feature of the method is that it does not fit model predictions to soil moisture, but instead evaluates the stationarity of the running series of soil water storage values implied by the partitioning. Because of this feature the method can be driven with indices of soil moisture (like brightness temperatures) rather than site-specific water contents.

H12F-03 1410h

Towards a unified approach for remote estimation of chlorophyll-a in both terrestrial vegetation and turbid productive waters

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The photosynthetic pigment chlorophyll-a is an indicator of biomass and productivity of both terrestrial and aquatic ecosystems. Numerous medium specific, independent techniques to extract information on chlorophyll-a concentration from reflectance have been developed. However, the differences and similarities of methods for extracting chlorophyll-a amounts from reflectance spectral data collected over different types of media (e.g. water bodies and plant leaves) have not been compared and generalized. Recently a conceptual model, relating remotely sensed reflectance and pigment content in higher plant leaves has been developed. The model was devised to isolate the absorption coefficient of the pigment of interest from reflectance spectra using three spectral regions. The model allowed accurate estimation of chlorophyll content in leaves and leaf area index in crops. In this study we tested the applicability of the model to retrieve chlorophyll-a concentrations from reflectance spectra of turbid productive waters. We tuned the conceptual model according to the optical characteristics of the aquatic medium, and accurately predicted chlorophyll-a concentrations in water bodies over a wide range of optical conditions (chlorophyll from 7 to 194 mg m^{-3}; total suspended matter from 0.1 to 214 mg L^{-1}; absorption coefficient of dissolved organic matter from 0.7 to 2.3 m^{-1}). Three spectral bands (the red, red edge and near infrared) were used in the model, which accounted for 94% of the variance ($p<0.0001$) of chlorophyll-a concentrations measured analytically. In the range of chlorophyll variation from 7 to 194 mg m^{-3}, the root mean square error (RMSE) of chlorophyll-a estimation was less than 11 mg m^{-3}. The model was validated by independent data set yielding a RMSE of chlorophyll-a prediction lower than 13 mg m^{-3}. Our results provide evidence that this technique may be considered as a general solution, independent of the type of medium, for assessing chlorophyll concentration in optically deep media using remotely sensed data.

H12F-04 1425h

A Complementary Evaporation Approach to Scalar Roughness Length Estimation

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The difference between momentum and scalar roughness lengths has been well-established both theoretically and experimentally. Accurate experimental estimates of the scalar roughness length require knowledge of the actual scalar concentration at the surface, which is rarely known and is generally poorly defined for vegetation canopies. However, estimates of the scalar roughness length for water vapor can be made using the advection-aridity model for evaporation for cases in which the evaporation is known. These estimates require no knowledge of surface characteristics except the momentum roughness length. Based on the complementary relationship between actual and potential evaporation, the advection-aridity equation is only likely to be valid under conditions of minimal advection. Data from a grassland site at CASES-97, collected by Russell Qualls (University of Idaho), were screened to ensure that only data representing minimal advection conditions were retained. The scalar roughness length for water vapor was determined from the advection-aridity equation, and its dependence upon land surface characteristics was investigated.

H12F-05 1440h

Precipitation and Radiation Forcings in Off-line Assimilation of Soil Moisture

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In order to facilitate the eventual inclusion of space-based remote sensing data in operational soil moisture assimilation, an off-line surface assimilation system is currently being developped at the Meteorological Service of Canada (MSC). In this new system, our best estimates for atmospheric forcings, i.e., precipitation, downwelling radiation (solar and infrared), low-level air temperature, humidity, and winds, are used to drive the Interactions Soil-Biosphere-Atmosphere (ISBA) land surface scheme. The behavior of this new system was compared with the strategy currently used operationally at MSC, which is based on a statistical interpolation that relate model-errors on low-level air temperature and relative humidity to errors in soil moisture. Results show that improving precipitation forcings (obtained from NEXRAD Level III data) slightly alters the evolution of soil moisture, with non-negligeable impacts on 2-m air temperature and relative humidity. Another sensitivity experiment indicates that, at least for the case examined in this study, reasonably large changes to downwelling solar radiation did not modify much the evolution of soil moisture, but had a significant impact on low-level air characteristics. The implications of these results for future soil moisture assimilation will be discussed at the conference.

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H12F-06 1455h

Impact of Mesoscale Surface Heterogeneity on Larger Scale Precipitation and the Surface Water and Energy Balances

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High-resolution summertime simulations that capture storm-scale dynamics over many diurnal cycles and over several 100 x 100 km2 regions are conducted over the central United States using the Regional Atmospheric Modeling System (RAMS). The focus is on two different synoptic regimes in order to quantify the impact of clouds and precipitation associated with atmospheric dynamical systems on soil moisture and surface fluxes, both domain averages and spatial heterogeneity: one where large-scale dynamic forcing is strong and one where it is weak. The evolution of the surface water and energy balances controls mesoscale circulations that subsequently impact future convection and precipitation. This mesoscale surface heterogeneity is both relatively static (i.e., resulting from land cover and topographic features) and time-varying (i.e., resulting from spatial variability in rainfall and hence soil moisture). Control simulations, validated against observations, including rainfall, soil moisture, and surface fluxes, show that RAMS has the ability to capture the relevant processes during both synoptic regimes. The three-way interaction between large-scale atmospheric dynamics and precipitation, surface-forced mesoscale circulations, and the surface water and energy balances over multiple diurnal cycles controls the overall hydrologic evolution within the model domain. An improved understanding of this linkage is important for improving our ability to model hydrologic processes on basin scales.

H12F-07 1510h

Use of Thermal Information to Estimate Stream Baseflow

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During most times of the year, ground-water has a distinctly different temperature than the streams to which it discharges. As a result, areas of enhanced ground-water discharge (baseflow) may appear as thermal anomalies in the stream water or stream bed temperature. Stream water temperatures monitored in the thermal infrared range, implying that it may be possible to characterize stream baseflow through air- or space-borne thermal sensing. There are a number of impediments to this approach, however, including vertical mixing in the water column, heat exchanges with the atmosphere and stream bed, differential solar heating, and stream water dilution. Stream water dilution is particularly important because the heat balance on a stream reach requires knowledge of streamflow into the reach. Temperature surveys and streambed profiles were collected on a slow-moving stream in Southwestern New York State. Estimates of baseflow from temperature data were compared to estimates from differential current meter readings along four stream reaches. The approaches compared well, but errors depended greatly upon the acquisition of concurrent temperature and stream velocity information. Thermal profiles were not indicative of ground-water inflow, probably due to local variations in streambed permeability or the presence of focused discharge areas. Integration of streamflow modeling (based upon digitial elevation models and aerial photographs) and thermal imaging may lead to the ability to remotely predict baseflow. Further field testing and development of data assimilation techniques will be required, however, before this technique becomes generally practical.

H12F-08 1525h

Uncertainty Associated with the Remote-sensing of Stream Temperatures at Multiple Spatial Scales

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Stream temperature is an important water quality indicator, particularly in the Pacific Northwest where endangered fish populations are sensitive to elevated water temperature. Regional assessment of stream temperatures from the ground is limited by sparse sampling of temperatures in both space and time. Remotely sensed thermal infrared (TIR) images can be used to derive spatially distributed estimates of the radiant skin temperature of streams. Even for fully resolved streams, however, our limited ability to compensate for atmospheric and emissivity effects constrains the accuracy of stream temperature measurements. When the stream is not fully resolved, it is the effect of mixed image pixels and thermal scattering from the near-bank environment that dominates both the accuracy and uncertainty of stream temperature measurements. Whereas airborne thermal sensors can resolve smaller streams than spaceborne sensors, their limited spatial coverage and cost makes satellite-derived TIR data an attractive option. We examine the accuracy and uncertainty associated with recovered stream temperatures for a range of stream sizes and pixel resolutions, using remotely sensed airborne (MASTER) and satellite (ASTER, LANDSAT-TM) TIR measurements. We find that when the stream width is resolved by fewer than 3 pixels, the accuracy of TIR measurements significantly decreases, and the uncertainty is greater, largely due to the reduction of mixed pixels (bank and stream). This limits the use of satellite TIR to temperature recovery for large rivers (currently, 180 m stream widths with Landsat- TM).

URL: http://depts.washington.edu/strmtemp/

H12G MCC: 3024 Monday 1340h

Dealing with Hydrogeologic Uncertainty in Practice: Data Collection, Models, Predictions, and Regulatory Guidelines I

Presiding: **T Harter,** University of California, Davis**; M C Hill,** U.S. Geological Survey

H12G-01 1340h

A Perspective on Simulations of Environmental Systems and Prediction Uncertainty

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Prediction uncertainty is the likely discrepancy between model predictions and the actual, unrealized system responses. Contributions to uncertainty include anything that causes inaccurate predictions. This can include numerical model solution error and capability limitation, data error and deficiency, and conceptual model error. For example, using conceptual models to build simulations forces ideas about system behavior that are often vague and(or) wrong to be tested against measurements. Closer correspondence between the simulation and measurements often indicates the model more accurately represents a system. However, when models are calibrated, predictive capability can be degraded by fitting measurements too closely. This can occur when the model is overparameterized and close model fit is achieved by fitting measurement and other errors. The connection between such errors and prediction accuracy is clear, and thorough evaluation of such errors and the possibility of overfitting are critical. This is especially true for stochastic and Bayesian methods applied to models with many parameters, for which overfitting is controlled using prior information and smoothness constraints that may not be well understood by the modeler. When a reasonably accurate simulation of a system has been achieved through careful model development, calibration, and error evaluation, the simulation itself becomes an invaluable tool for sensitivity analysis, data assessment, and uncertainty evaluation. Three categories of sensitivity and data assessment methods include techniques for identifying (1) the importance of observations important to parameter values (observations that dominate model calibration); (2) parameter values that dominate the predictions; and (3) observations that dominate the predictions. For instance, gradient-based methods such as composite scaled sensitivities, prediction scaled sensitivities and the value of improved information, and the observation-prediction statistic are used to address the three categories, respectively. These local-sensitivity methods assume model linearity, but have found to be useful for nonlinear ground-water models. More computationally intensive methods that do not assume model linearity include variance-based global sensitivity analysis methods for identifying parameters important to predictions, and jackknife and bootstrap methods for identifying observations that dominate predictions. Uncertainty evaluation methods can be categorized as gradient, selective sampling, and random sampling methods. Gradient methods include linear and nonlinear confidence intervals, and are limited to propagating uncertainties related to parameter values. Selective sampling often involves establishing a most probable and one or more worst-case scenarios. Random sampling includes Monte Carlo methods such as Latin-Hypercube sampling, and can produce results similar to nonlinear confidence intervals if only parameter values are sampled and if simulations with poor model fit are omitted. Model development and evaluation are obviously complex endeavors involving a number of steps. To make wise societal decisions based on environmental model predictions, it is important to establish solid methods for evaluating the importance of observations and parameters to predictions and for quantifying prediction uncertainty.

H12G-02 1355h

Addressing Uncertainty in Predictive Groundwater Modeling in the Context of a Major Regulatory Permitting Process

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Regulatory assessments of the environmental impacts from proposed natural-resource development often require detailed information regarding potential project effects on water resources. Understanding these impacts is important for both disclosure to the public and determination of regulatory compliance in permitting. Many such projects involve pumping substantial quantities of groundwater to access the desired resource; in some cases, nearby surface water resources may be adversely affected by this groundwater withdrawal. In addition, some projects involve the management of waste materials that have the potential to contaminate area groundwater and surface waters. Because the regulatory assessment needs to address potential future conditions, predictive groundwater modeling has been used to help provide the necessary information. A case study of a proposed mine in northern Wisconsin is the focus of this discussion. In this project, both the applicant and the state regulatory agency review team recognized that substantial uncertainty would remain in model output even after conducting detailed analyses of sizeable project data sets to develop reasonable model inputs and completion of a rigorous calibration and an extensive sensitivity analysis. As a consequence, the modeling work and associated impact assessments submitted by the applicant addressed uncertainty by incorporating two scenarios: an expected case and a worst case. The agency review team, however, concluded that the level of uncertainty was so great in this situation, and the results of such importance to the impact assessment and permitting processes, that a more extensive approach to addressing uncertainty was necessary to ensure a technically defensible product. In response, the state's review team completed a number of detailed analyses of the project area information and the applicant's 3D MODFLOW regional flow model. These included: development of a 2D analytic-element model (GFLOW) to evaluate the submitted MODFLOW model boundary conditions and recharge rates; completion of Monte Carlo analyses to assess lake outlet flow and lakebed hydraulic conductivity; calculation of GFLOW-UCODE confidence intervals for prediction of mine pumping rates and associated reductions in stream baseflow; and the development of detailed analyses of project-site historical pump tests using both the regional and inset models. Numerous sensitivity analyses were performed after completing updates to the submitted model, allowing the review team to identify and evaluate the most sensitive parameters. This work on model uncertainty provided the review team's "reasonable" range for model inputs, which in turn provided two end-member scenarios that established high and low estimates of the reasonable range of project effects on the groundwater system for use in the regulatory process. The concept of reasonable ranges of model inputs and outputs was also subsequently used in the review team's work on the solute transport models submitted by the applicant to assess groundwater chemistry impacts from the proposed mine and waste facilities. This approach provides a means for communicating uncertainty to both the public and regulatory decision-makers. Moreover, it underscores the uncertainty inherent in simplified numerical representations of complex, real-world systems.

H12G-03 1410h

JUPITER Project - Joint Universal Parameter IdenTification and Evaluation of Reliability

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