The Neuse prototyping effort will result in an implementation plan for a hydrologic observatory that will include • Design concepts to address both CUAHSI science drivers as well as local-interest hypotheses • The resulting data collection network, including an strategy for integration with existing activities within the basin • A coordination plan with local universities, various government agencies, and stakeholder groups (such as watershed associations to enable collection of data on private lands) • Detailed budget, including buildout strategies, capital, operating and staffing costs. • Plans to disseminate information to the community coordinated with the Hydrologic Information Science (HIS) committee, including contributions to the HIS concept of “Digital Watersheds” • Design of infrastructure to facilitate use of the observatories by individuals or groups of scientists by competitive proposal Two of the three data pools described by Reckhow et al. (this session) will be designed by this effort: the core data and the design data. Core data will be made public as soon as possible and will be subject to oversight by CUAHSI to achieve comparability of data among all observatories. The design data will be proprietary to the principal investigators for a reasonable period of time (e.g., 2 years) to permit interpretation and publication of results. The third data pool, the “network” pool, is data collected specifically to enable intersite comparisons to be made. The intersite studies will be awarded on a competitive basis once multiple observatories have been established. In the long run, we envision resources to be divided evenly among these three activities, although the proportions may shift in favor of the first two pools as observatories are being established. Once the Neuse plan has been reviewed by the community and comments have been received, CUAHSI will hold a competition to select approximately 10 additional groups to develop implementation plans at sites around the Nation. (The Neuse basin is not eligible for such an award.) Information gathered as part of these implementation plans will be used to develop additional “Digital Watersheds” in conjunction with the HIS group. This will extend and make further available detailed information on a set of regional watersheds to the hydrologic community. With the set of “Digital Watersheds” and implementation plans in hand, we envision a subsequent refinement of network objectives to enable a detailed description of how hydrologic observatories will advance hydrologic science. The entire network plan will be submitted to NSF for evaluation for possible funding in 2005.

H12J MCC: 3024 Monday 1600h

Geohydrological Modeling in Support of Litigation *(joint with PA)*

Presiding: **G F Pinder,** University of Vermont**; J F Sykes,** University of Waterloo

H12J-01 1605h INVITED

The Future of the Utility of Groundwater Models for Water Resources Management

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Groundwater models have become indispensable tools for water resources planning and management. After more than 30 years of study, however, the model calibration problem still is not resolved completely. Hydrogeologists may not have sufficient confidence in using their calibrated models for prediction and decision-making purposes. There are two major difficulties in groundwater modeling: (1) the geological structure of a real aquifer usually is very complex and unknown, and (2) the data that can be used for model calibration usually are very limited, in both quantity and quality. These two difficulties are closely interconnected during the model calibration process. A simple model structure may not be able to both fit the observed data and produce reliable predictions. On the other hand, a complex model structure may cause overparameterization when data are limited. If a model is over-parameterized, the reliability of model prediction will decrease rather than increase. It is well understood that a model that can fit the existing data well may not necessarily be a good model for prediction when it contains significant model error. This paper proposes methods that can be used to calculate the model structure error when a simplified model structure is used to replace a more complex model structure. We consider both the fitting residual as well as the model structure error for model calibration. We propose a generalized parameterization scheme for the distributed hydraulic conductivity field that can vary from a pure zone to a continuous distribution. We also suggest a method which can be used to identify a least complex model that is useful for prediction and decision-making.

H12J-02 1635h INVITED

Modeling in Support of Groundwater-Remediation Cost Allocation

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The allocation of costs for remediation among multiple potentially responsible parties (PRPs) can be addressed using a ‘stand alone’ method developed and applied initially to water supply problems. The variant of the stand alone approach used in an allocation case in the San Fernando Valley of California involves 1) the development of groundwater flow and transport models that reflect 1) the contributions of each of the PRPs individually and , 2) the combined effect of all parties. The allocation is then based upon the proportional impact of each PRP. The proportional cost is therefore established by taking the ratio of the plume size of each PRP divided by the overall plume size multiplied by the overall remediation costs.

H12J-03 1650h

The Toms River Childhood Cancer Cluster: Coupled Groundwater and Water Distribution System Modeling

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Toms River, New Jersey is the location of a statistically significant childhood cancer cluster. A 1995 cancer investigation indicated that relative to the state, the Toms River section of Dover Township had excess childhood cancer incidence for all malignant cancers combined, brain and central nervous system (CNS) cancers, and leukemia. Children under the age of five were found to have a seven-fold increase in brain and CNS cancer. The community’s concern focused on the possibility that exposure to environmental contaminants may be related to the incidence of these childhood cancers. Two Superfund sites in Dover Township were implicated as having a possible impact on the local water supply. One of these, the Reich Farm site, is a source of contaminants to the aquifer that serves a major well field for Toms River. Contaminants in the aquifer include TCE, PCE and styrene-acrylonitrile (SAN) trimer. In 1997, the New Jersey Department of Health and Senior Services and the Agency for Toxic Substances and Disease Registry began an epidemiology study to evaluate the relationship between the environmental exposure pathways and the elevated childhood cancer incidence. Toxicity studies for the SAN trimer were also initiated. Groundwater modeling was undertaken to establish the historical relationship between the Reich Farm site and the municipal well field and to aid in the management and protection of the aquifer and well field to ensure both water quality and quantity. The modeling of the water distribution system for Toms River was also part of the study. Groundwater flow from the Reich Farm Superfund site to the municipal well field for Toms River was modeled for a thirty-year time period using MODFLOW. To account for the growth and development of the well field within the modeling domain, a transient model was constructed. The use of Geographic Information Systems (GIS) and databases to manage, maintain, and compile field observations for model input and calibration was an important part of the work. GIS and databases were important tools in assessing the quality of the data, discovering and correcting errors in the field data (including surveying inconsistencies), as well as providing an efficient and automated means to visualize the data. Model calibration exercises indicated that a more physically based spatial and temporally variable recharge was necessary to account for dramatic fluctuations in water levels due to seasonal variations. The accurate simulation of the transient groundwater flow system was essential for the subsequent prediction of contaminant migration from the superfund site to the municipal wells and then subsequently into the modeled water distribution system. The independent estimation of the adsorption parameters of the SAN trimer on the porous media of the aquifer was an important aspect of the determination of both the average travel time and the breakthrough of the chemical at the municipal well field. The modeling methodology included an uncertainty analysis of the estimated exposure concentration in the water distribution system given uncertain groundwater parameters. Distributed computing with a Monte Carlo analysis was used for this work. The results of the modeling study were used to assist in the definition of the temporal integration periods in the epidemiology study. The predicted historical breakthrough curve of the SAN trimer in the municipal wells correlates with the period with the excess childhood cancer incidence.

H12J-04 1705h

Groundwater Flow Model for Taos, New Mexico

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The New Mexico Office of the State Engineer - Hydrology Bureau (OSE) has developed a regional groundwater flow model for Taos, New Mexico. The MODFLOW 2000 model will serve as a tool to evaluate alternatives in settlement negotiations in an on-going water rights adjudication. If current settlement negotiations fail, it is conceivable that the model might be used in support of litigation. OSE produced the model in cooperation with technical representatives of the various parties to the adjudication. Regional hydrogeologic data including well records, aquifer test results, stream flow measurements and seepage studies have been shared relatively freely among the parties. A recent deep drilling program conducted in conjunction with the negotiation effort has added substantially to the hydrogeologic data set. Among the hydrologic processes simulated by the model are mountain front recharge; areal recharge from precipitation; evapotranspiration; discharge from springs; river and stream flow; accretions to groundwater from irrigation return flow, seepage from acequias, canals, and ditches, and deep percolation; and pumping by municipal entities and mutual domestic water users associations. The resulting model files are available for all parties to review and evaluate. Comments are assessed and many have resulted in significant improvements to the model. At this stage, however, it is unclear whether adopting this cooperative approach will increase the likelihood of model acceptance by the parties.

H12K MCC: 3020 Monday 1600h

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Hydrogeophysics: Characterization and Monitoring of Soil Properties and Processes in the Laboratory II *(joint with NG, MR)*

Presiding: **M Prasad,** Stanford University**; X Comas,** Rutgers University

H12K-01 1600h

Intrinsic Anisotropy In Sediments And Its Sesimic Potential

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In this paper we present a study of intrinsic anisotropy focusing on stratification of poured sediments using Vp. We describe the experimental procedure to detect the intrinsic anisotropy with Vp in sand and glass bead samples. We then offer a method to determine textural anisotropy with the spatial autocorrelation function. In this method we use the spatial autocorrelation function and its variation with direction to characterize the stratification texture from images of the samples. To determine if there is a relation between Vp and the textural anisotropy, we compare velocity anisotropy and the spatial autocorrelation function. We find that velocity anisotropy reveals internal packing.

H12K-02 1615h

Near-Seafloor Overpressure in the Deepwater Gulf of Mexico Interpreted from Laboratory Experiments

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Consolidation experiments on two silty clay samples from 1318 m water depth in the Gulf of Mexico (Marion Dufresne giant piston core MD02-2567, Mississippi Canyon Block 855, 90 km offshore Louisiana, USA) show that sediment is overpressured at 6.8 and 19.2 m below the seafloor (mbsf). The transition from elastic to elastic-plastic deformation is well defined, and is used to predict normalized overpressure (λ^*) equal to 0.5 [$\lambda^* = (P-P_h)/(S_v-P_h)$]. P is fluid pressure, P_h is hydrostatic fluid pressure, and S_v is overburden stress. In situ permeability, estimated from constant rate of strain experiments, is $1x10^{-16}m^2$ at 6.8 mbsf and decreases to $1x10^{-17}m^2$ at 19.2 mbsf. The compressibility and low permeability of the sediments (1) controls the rate at which pressure is generated during deposition, (2) influences the ability of external pressure sources to alter the sediments, and (3) hinders pressure dissipation to hydrostatic conditions. The constant rate of strain experiments were controlled at 0.5%/hr, which maintained an overpressure to total vertical stress ratio of 0.1 for a 1.8 cm drainage path. Both specimens deformed along the virgin compression curve with void ratio <1.1 (porosity <52%). Minor differences in initial laboratory void ratio and virgin consolidation trends are interpreted as a function of observed grain size variation between the samples. The grain size variations, however, appear to dramatically impact permeability. Overpressure in the shallow subsurface decreases effective stress that is already low. Higher overpressure in the past may have facilitated failure along a regional detachment surface imaged in seismic data at 125 mbsf. We hypothesize that pressure dissipation from a shallow water flow (SWF) sand at 250 mbsf at this location is a source of near-seafloor overpressure in this region of the Gulf of Mexico. Ongoing experiments from locations where the SWF sand is deeper will characterize how depth to the sand influences fluid pressure and strength of low permeability sediments that overlie the sand.

H12K-03 1630h

Changes in Wetting Hysteresis During Bioremediation: Changes in fluid flow behavior monitored with low-frequency seismic attenuation

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We observed significant reduction in wetting hysteresis with time while a diesel-contaminated quartz crystal was dipped in and out of an oil-reducing bacteria solution. This wetting hysteresis is significantly greater than the wetting hysteresis when the diesel-contaminated quartz crystal is dipped in and out of (1) water, (2) diesel and (3) the bacterial food solution that does not contain bacteria. The reduction in wetting hysteresis of the bacteria solution on the quartz surface results from a reduction in the advancing contact angle formed at the air-liquid-quartz contact with time; the receding contact angle remains the same with time. Our results suggest that the bacteria solution moves across the quartz surface with less resistance after bioremediation has begun. These results imply that bioremediation may influence fluid flow behavior with time. For many fluid-solid systems there is a difference between the contact angle while a contact line advances and recedes across a solid surface; this difference is known as wetting hysteresis. Changes in wetting hysteresis can occur from changes in surface tension or the surface topography. Low contact angle values indicate that the liquid spreads or wets well, while high values indicate poor wetting or non-wetting. Contact angles are estimated in the lab by measuring the weight of the meniscus formed at the air-liquid-quartz interface and by knowing the fluid surface tension. In the lab, we have been able to use low-frequency seismic attenuation data to detect changes in the wetting characteristics of glass plates and of Berea sandstone. The accepted seismic attenuation mechanism is related to the loss of seismic energy due to the hysteresis of meniscus movement (wetting hysteresis) when a pore containing two fluids is stressed at very low frequencies (< 10 Hz). When fluid-fluid-solid systems that exhibit wettability hysteresis are stressed at low frequencies, we observe seismic attenuation, whereas in a system that does not exhibit wettability hysteresis we do not. From our wettability hysteresis results, we conclude that we may be able to monitor bioremediation progress using seismic attenuation data. We are measuring low-frequency seismic attenuation in the lab while flowing bacteria solution through Berea sandstone and we are testing this application in the field.

H12K-04 1645h

Soil-Moisture Retention Curves, Capillary Pressure Curves, and Mercury Porosimetry: A Theoretical and Computational Investigation of the Determination of the Geometric Properties of the Pore Space

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Immiscible displacement protocols have long been used to infer the geometric properties of the void space in granular porous media. The three most commonly used experimental techniques are the measurement of soil-moisture retention curves and relative permeability-capillary pressure-saturation relations, as well as mercury intrusion porosimetry experiments. A coupled theoretical and computational investigation was performed that provides insight into the limitations associated with each technique and quantifies the relationship between experimental observations and the geometric properties of the void space. It is demonstrated that the inference of the pore space geometry from both mercury porosimetry experiments and measurements of capillary pressure curves is influenced by trapping/mobilization phenomena and subject to scaling behavior. In addition, both techniques also assume that the capillary pressure at a location on the meniscus can be approximated by a pressure difference across a region or sample. For example, when performing capillary pressure measurements, the capillary pressure, taken to be the difference between the injected fluid pressure at the inlet and the defending fluid pressure at the outlet, is increased in a series of small steps and the fluid saturation is measured each time the system reaches steady. Regions of defending fluid that become entrapped by the invading fluid can be subsequently mobilized at higher flow rates (capillary pressures), contributing to a scale-dependence of the capillary pressure-saturation curve that complicates the determination of the properties of the pore space. This scale-dependence is particularly problematic for measurements performed at the core scale. Mercury porosimetry experiments are subject to similar limitations. Trapped regions of defending fluid are also present during the measurement of soil-moisture retention curves, but the effects of scaling behavior on the evaluation of the pore space properties from the immiscible displacement structure are much simpler to account for due to the control of mobilization phenomena. Some mobilization may occur due to film flow, but this can be limited by keeping time scales relatively small or exploited at longer time scales in order to quantify the rate of film flow. Computer simulations of gradient-stabilized drainage and imbibition to the (respective) equilibrium positions were performed using a pore-scale modified invasion percolation (MIP) model in order to quantify the relationship between the saturation profile and the geometric properties of the void space. These simulations are similar to the experimental measurement of soil-moisture retention curves. Results show that the equilibrium height and the width of the equilibrium fringe depend on two length scale distributions, one controlling the imbibition equilibrium structure and the other controlling the drainage structure. The equilibrium height is related to the mean value of the appropriate distribution as described by Jurin's law, and the width of the equilibrium fringe scales as a function of a combined parameter, the Bond number, Bo, divided by the coefficient of variation (cov). Simulations also demonstrate that the apparent radius distribution obtained from saturation profiles using direct inversion by Jurin's law is a subset of the actual distribution in the porous medium. The relationship between the apparent and actual radius distributions is quantified in terms of the combined parameter, Bo/cov, and the mean coordination number of the porous medium.

H12K-05 1700h

A Laboratory Study of Heterogeneity and Scaling in Geologic Media

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In rocks and soils, the bulk geophysical and transport properties of the matrix and of fracture systems are determined by the juxtaposition of geometric features at many length scales. For sedimentary materials the length scales are: the pore scale (irregularities in grain surface roughness and cementation), the scale of grain packing faults (and the resulting correlated porosity structures), the scale dominated by sorting or winnowing due to depositional processes, and the scale of geomorphology at the time of deposition. We are studying the heterogeneity and anisotropy in geometry, permeability, and geophysical response from the pore (microscopic), laboratory (mesoscopic), and backyard field (macroscopic) scales. In turn these data are being described and synthesized for development of mathematical models. Eventually, we will perform parameter studies to explore these models in the context of transport in the vadose and saturated zones. We have developed a multi-probe physical properties scanner which allows for the mapping of geophysical properties on a slabbed sample or core. This device allows for detailed study of heterogeneity at those length scales most difficult to quantify using standard field and laboratory practices. The measurement head consists of a variety of probes designed to make local measurements of various properties, including: gas permeability, acoustic velocities (compressional and shear), complex electrical impedance (4 electrode, wide frequency coverage), and ultrasonic reflection (ultrasonic impedance and permeability). We can thus routinely generate detailed geophysical maps of a particular sample. With the exception of the acoustic velocity, we are testing and modifying these probes as necessary for use on soil samples. As a baseline study we have been characterizing the heterogeneity of a bench-size Berea sandstone block. Berea Sandstone has long been regarded as a laboratory standard in rock properties studies, owing to its uniformity and "typical" physical properties. We find that both permeability and velocity exhibit complex heterogeneity at the centimeter scale. While some correlation with the outcropping of the bedding is apparent, much of the heterogeneity is not clearly associated with visual features. For the study of soil heterogeneity at a wide range of scales, we are focusing on a local glacial deposit. This deposit is a glacial kame terrace of fluvial origin with multi-scale sedimentary structures comprised of unconsolidated sands, clays, and gravels. There are also many joints and faults in the unconsolidated sediments, allowing study of these as potential fluid flow conduits or barriers. We have obtained undisturbed soil samples from this site, allowing detailed laboratory study using similar methods to those described for the sandstone block.

H12K-06 1715h

A Multi-Functional Heat Pulse Probe for Simultaneous Measurement of Water, Heat, and Solute Transport in the Vadose Zone

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A small multi-functional heat pulse probe (MFHPP) for vadose zone measurements was developed and tested in the laboratory. The probe combines a heat pulse technique for estimating soil heat properties, water flux, and water content with a Wenner array measurement of electrical conductivity (EC). The probe thus provides a simultaneous estimate of water, heat, and solute transport parameters at the same location and spatial scale. To test the MFHPP, highly controlled steady-state flow column experiments in sand were conducted over a wide range of saturations, flow velocities, and EC concentrations. The data were analyzed using the modified HYDRUS model, which includes an option for inverse modeling of simultaneous water, vapor, heat, and solute transport. The inverse estimated parameters included volumetric heat capacity, thermal conductivity, heat dispersion, water flux, moisture content, and solute dispersion. The performance of the MFHPP was compared and evaluated with independently measured data. Thermal properties, including thermal conductivity and thermal diffusivity, compared well with previously measured data for the sand. Water contents between 0.2 and 1.0 were estimated at both

static and steady-stay flow conditions with a RMSE of 0.016 cm^3 cm^{-3}. Water fluxes were estimated successfully for both saturated and unsaturated conditions within a range of 2.0E-06 m/s to 7.2E-05 m/s. Solute breakthrough curves at different water contents were analyzed and the solute and thermal dispersivities were compared. The probe constitutes a new promising vadose zone measurement technique for combined heat and solute transport estimation and for water flux and dispersion measurements.

H12K-07 1730h

Reconstructing the Pore Space of Sand Samples

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The structure of the pore space is essential for flow and transport in soils. Size, shape and connectivity of the pores determine the distribution of air and water, pore water velocity and solute mixing. So, for a complete understanding of transport processes in soils, the pore geometry must be known. Some processes, for example the drainage of water, depend on narrow structures with sizes of a few micrometers. For this reason, a technique to measure 3D pore structures with high resolution is needed. This presentation will describe the image processing steps needed to provide a pore space with the highest possible fidelity to the measured sample. The projection data were acquired using an imaging system based on synchrotron radiation. This technique allows us to map the pore structure in the range of 10 microns. To transform the projection data into pore space volumes, a chain of actions involving back projection, the application of various filters to suppress noise and artifacts, and segmentation is needed. During experiments at the Swiss Light Source (SLS) we scanned sand samples with diameter 5 mm containing sand particles ranging from 100 to 300 microns with a voxel size of 3.5 microns. At the Hamburger Synchrotron Laboratory (HASYLAB) sand samples with diameter 15 mm containing particles ranging from 100 to 900 microns were mapped with a voxel size of 11 microns. In addition to the scanning of completely dry samples, we intend to investigate the water and air distribution for different degrees of water saturation. Comparing these measurements with numerical simulations, we hope to understand the processes of air and water distribution in more detail.

H12K-08 1745h

Colloidal Acceleration and Dispersion in Saturated Micromodels

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Size exclusion is a mechanism affecting the transport of colloidal contaminants in porous media. We developed polydimethylsiloxane (PDMS) micromodels to examine at the pore scale the effect of particle and pore size on saturated colloid transport. The micromodels were generated using a novel soft photolithography technique developed by Quake and Scherer (2000). This easy and inexpensive technique allows us to rapidly generate patterns that have dimensions in the range of those existing at the pore space. Three patterns were designed: two regular networks with 10-m and 20-m constant channel widths, respectively and a network combining two different channel widths, 10 and 20 m. Four sizes of colloids were transported through the micromodels at different pressure gradients. The transparency of the cured PDMS allowed optical microscopy observations of the transport and dispersion of the colloids within the pores. Particle trajectories, residence times and dispersion coefficients were determined from image analysis of at least 200 different individual colloids for each pressure, micromodel and colloidal size. According to our results, particles move more rapidly when colloid size increases and pore width decreases. The acceleration factor (ratio of colloid to water velocity) depends on micromodel geometry and colloid size, varying from 0.71 in the combined-width model to 2.5 in the 10-m constant-width model. Dispersion coefficients increase as a linear function of pore velocities. For a given micromodel and pore velocity, dispersion coefficients decrease with increasing colloid size. These findings emphasize the role of size exclusion on colloidal transport and the importance of taking into account particle and pore size when predicting colloid transport in the field. Reference Quake SR and Scherer A. 2000. From micro- to nanofabrication with soft materials. Science. 290 (5496): 1536-1540.

H21A MCC: 3022 Tuesday 0800h

Hydrogeophysics: Characterization and Monitoring of Subsurface Parameters and Processes I *(joint with NG, MR)*

Presiding: **S S Hubbard,** Lawrence Berkeley National Laboratory**; A Binley,** Lancaster University

H21A-01 0800h INVITED

Recent Advances in the Use of Electrokinetic Self-Potential Signals as an Effective Tool in Hydrogeophysics to Monitor Ground Water Flow

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Ground water flow generates detectable electrical signals at the ground surface through a conversion mechanism called streaming potential. These signals can be recorded in a passive way with a set of non-polarizable electrodes and a multi-electrode digital multimeter. These signals can be inverted to image the shape of the water table and its temporal variations using new self-potential tomography (SPT) algorithms. The signal-to-noise ratio seems high enough to expect an accuracy of 10 cm in the detrmination of the depth of the water table. Then, because the sensors are cheap, we can use an important number of measurement stations and we can obtain a great amount of information to invert in a cost-effective way. In this talk, we will discuss the physics of this hydro-electric and present both forward and backward methods to interpret field data. We will show examples from three field studies in which self-potential signals are associated with hydraulic head fluctuations. We will discuss the stability of the electrodes, the sources of noise, and new challenges in combining SPT with more classical electrical resistivity tomography (ERT).

H21A-02 0815h

Modelling Streaming Potential (SP) Signals Induced by Water Movement in the Vadose Zone

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Field estimation of soil water flux has a direct application for water resource management. Standard methods are often difficult to apply because of the heterogeneity of the subsurface. In the present study, we show that Streaming Potential (SP) monitoring can provide a cost-effective tool to help estimate the nature of the hydraulic transfers (infiltration or evaporation) in the vadose zone. We have modelled the SP response induced by the electrokinetic effect of rainfall infiltration and evaporation in an unsaturated porous medium. Our model based on Richards' equation shows that SP signals of several millivolts are generated, i.e. easily recordable with standard SP equipment and that they allow to characterize the upward or downward water flux. We have then compared our model results to two SP and hydraulic data sets acquired during both rainfall infiltration and evaporation phases and they confirmed that SP measurements allow effectively to estimate the direction of the water flux at the scale of the electrode separation (usually several decimetres), i.e. at a much larger scale than tensiometric measurements. Moreover, as streaming potential coupling coefficients are related to the nature and concentration of solutes, SP could be used in the future to characterise contaminant fluxes in soils.

H21A-03 0830h

Hydrogeophysics in the Coastal Zone: Spatial and Temporal Constraints on Groundwater Processes from Coincident Wells and Geophysical Surveys

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The electrical conductivity contrast between fresh and saline groundwaters renders DC resistivity imaging and inductive EM methods particularly useful for studying hydrologic problems in the coastal zone. However, such settings also pose unique logistical challenges, ranging from difficulty acquiring geophysical data in salt marsh or intertidal zones to complications in the analysis of geophysical data that are strongly affected by high conductivity salt water. In this study, we first describe a new inversion algorithm for inductive EM data collected in high conductivity settings where the linear relationship between induced magnetic field strength and integrated terrain conductivity breaks down. The inversion, which is based on a robust, convergent, regularized least squares approach that accounts for the nonlinearity in mutual dipole induction, produces an "image" of subsurface fresh and saline pore water distributions that closely matches the actual distribution inferred from geochemical analyses of groundwater recovered from coincident shallow monitoring wells at a permeable upland site. In the second part of the study, we report on key results from 5 years of electrical and inductive EM surveys conducted at intratidal to interannual time scales coincident with > 50 shallow monitoring wells in uplands and salt marshes of the Georgia Bight. Combining inversions of EM data, the results of extensive DC resistivity surveys, and geochemical analyses of groundwaters from our well networks, we delineate submarsh freshwater discharge pathways to adjacent estuaries, describe the dynamics of fresh and saline groundwater interactions and exchange during a tidal cycle, and constrain possible Hele-Shaw convection cells within salt marshes.

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A Comparison of Surface and Surface-Borehole ERT Arrays for Monitoring Subsurface Hydrologic Processes at the INEEL Site

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Electrical resistivity tomography (ERT) is emerging as a leading tool for tracking hydrological processes at intermediate scales. Uses include the characterization of geological structure, slowly varying water contents, and rapidly changing water content or solute concentration during infiltration and flushing. The technique makes use of the simultaneous interpretation of 10's to 1000's of individual measurements to characterize multidimensional electrical conductivity distributions in the subsurface. Although ERT has been used widely in subsurface hydrology, some major limitations still exist to its optimal application. Specifically, data acquisition is to be optimized, and the combined effects of multiple components that contribute to the bulk electrical conductivity (i.e. water content, solute concentration, and medium properties) must be identified to allow for more quantitative analysis of heat or mass transport. This can be achieved through improved survey design, which combines hydrologic understanding in the identification of suitable ERT targets and optimization of data acquisition for hydrologic interpretation. We demonstrate that the wise selection of the arrays composing a survey can improve the ability to characterize subsurface hydrologic processes. The selection is based on comparisons of the sampling volumes of surface based ERT arrays with those that make use of both surface and borehole electrodes. The method is applied to a specific example of vadose zone monitoring at the Idaho National Environmental and Engineering Laboratory (INEEL).