tests using the remotely sensed precipitation show improvement in both soil moisture and land surface flux estimates over those using sparse ground-based precipitation.

### H41H-07 1150h

## Multiscale Kalman Filter for Optimal Assimilation of Near-Surface Soil Moisture into VIC-3L

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We undertake an alternative and novel approach to assimilation of near-surface soil moisture into land surface models by means of an extension of multiscale Kalman filtering (MKF). While most data assimilation studies rely on the assumption of spatially independent near-surface soil moisture observations to attain a computationally tractable problem, MKF allows us to explicitly and very efficiently model the spatial dependence and scaling properties of near-surface soil moisture fields. Additionally, the Expectation Maximization (EM) algorithm is used in conjunction with MKF so that the statistical parameters inherent to the assimilation algorithm may be optimally determined directly from the data at hand and allowed to vary over time. This constitutes a significant advantage since these parameters (e.g., observation and model error noise variances) largely determine the performance of the assimilation approach and have so far been most commonly prescribed heuristically and not allowed to evolve in time. We apply MKF to assimilate the near-surface soil moisture fields derived from ESTAR during the Southern Great Plains Hydrology experiment of 1997 (SGP97) into the Three-layer Variable Infiltration Capacity (VIC-3L) hydrologically based land surface model. We extensively test the relevance of using optimal statistical parameters for assimilation and thoroughly evaluate the effect that the spatial resolution of the ESTAR data has on improving the predictive capabilities of VIC-3L. The results obtained show that assimilation greatly improves the spatial structure of near-surface soil moisture as predicted by VIC-3L. Moreover, VIC-3L seems capable of conveying the assimilated information forward in time. Significant impacts on the way VIC-3L partitions energy fluxes are also observed to result from assimilation of near-surface soil moisture.

### H41H-08 1205h

## Surface Soil Moisture Assimilation From ASAR Imagery for Root Zone Moisture Predictions at Basin Scale

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The state of the root-zone soil moisture is a key variable controlling surface water and energy balances. Emerging efforts in data assimilation seek to guide land surface models (LSMs) with periodic observations of surface soil moisture. Montaldo et al. (Water Resour. Res., 2001) and Montaldo and Albertson (Adv. Water Resour., 2003) developed an operational multi-scale assimilation system for robust root zone soil moisture predictions at the local scale. The assimilation scheme, developed for a force-restore method based LSM, updates the measured surface soil moisture, the root zone soil water content and the soil hydraulic conductivity, in a manner that compensates for both inaccurate initial conditions and model parameter estimates. In this presentation we describe the development and testing of an operational assimilation system for robust root-zone soil moisture predictions at the basin scale. High resolution data of the new ASAR (advanced synthetic aperture radar) sensor aboard European Space Agency's Envisat satellite offers the opportunity for monitoring surface soil moisture at high resolution (up to 30 m), which is suitable for distributed mapping within the small scales of typical Mediterranean basins. Indeed, adequate spatio-temporal monitoring of the soil moisture is essential to improve our capability to simulate the water balance. As part of a recently-approved European Space Agency (ESA) Envisat AO project, ASAR-based soil moisture mapping of the Mulargia basin (area of about 65 sq.km), sub-basin of the Flumendosa basin in Sardinia, are available . This semi-arid basin has a key role in the water resources management of Sardinia. Semi-arid regions, such as Sardinia island, suffers from water scarcity, which is increasingly due to the broad desertification processes of the Mediterranean area. Within the basin, land surface fluxes are well monitored through two evapotraspiration measurement systems (one eddy correlation technique based station, and one Bowen ratio station), and spatially distributed soil moisture ground-truth data needed to assess the ASAR imagery are collected over the whole basin through the TDR technique and the gravimetric method. The objectives of this work are to: 1) test the high resolution ASAR imagery accuracy for producing maps of surface soil moisture patterns at the catchment scale, 2) develop and test an operational assimilation system for robust root-zone soil moisture predictions at the basin scale. The developed assimilation system will have two components, 1) ASAR observations will be merged with the model for robust surface soil moisture estimates though the Ensemble Kalman Filter, and 2) the surface soil moisture estimates will then drive an assimilation engine for robust root-zone soil moisture predictions.

# H42A MCC: Level 2 Thursday 1330h

## Observations and Theoretical and Numerical Studies of Land Surface Heterogeneities on Land-Atmosphere Modeling Posters *(joint with A)*

***Presiding:*** **J Chen,** University of California, San Diego**; E Maurer,** Santa Clara University

### H42A-1057 1330h POSTER

## Soil Water Access Heterogeneity in Land-surface Parameterisation Schemes

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Confidence in Atmospheric General Circulation Models' (AGCMs') predictions, the predominant tools with which we predict future climate, depends on successful validation of their simulations. Land-surface climates, particularly important for people as the land is where we live and grow food, suffer from the lack of high quality global observational datasets of variables such as evapotranspiration and soil moisture that are not directly observable at scales appropriate to atmospheric models. We evaluate simulations by 20 AGCMs participating in the second phase of the Atmospheric Model Intercomparison Project (AMIP2) (Phillips *et al.*, 2002, Irannejad *et al.*, 2003) under the auspices of the Project for Intercomparison of Land-surface Parameterisation Schemes (PILPS, Henderson-Sellers *et al.*, 2002), against available observations and reanalyses along with a global off-line land surface simulation by the Variable Infiltration Capacity (VIC) scheme. Our hypothesis is that the largest contribution of soil moisture variability to precipitation variability will arise in models that use land-surface parameterization schemes (LSSs) that derive the largest fraction of their evapotranspiration from rooting zone soil moisture. This is based on the Dickinson *et al.* (2003) suggestion regarding differences in the partitioning of evapotranspiration and the Henderson-Sellers *et al.* (2003) demonstration that different LSSs cause differences in the prediction of continental surface climates that are not compensated by atmospheric feedbacks in coupled simulations. Underlining the importance of land-surface parameterization for climate prediction, Koster *et al.* (2002) demonstrated that different LSSs coupled to different GCMs generate a wide range of simulations of precipitation and its variability resulting from soil moisture variability. Here we use the AMIP2 results to (i) examine the validity of the Dickinson *et al.* hypothesis; and (ii) discover a means of ranking LSS parameterizations.

### H42A-1058 1330h POSTER

## Investigating Effects of Land Surface Cover Heterogeneity on the Uncoupled and Coupled RSM and VIC

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The Variable Infiltration Capacity (VIC) macroscale hydrologic land surface model is being coupled with the Regional Spectral Model (RSM). The land surface heterogeneity in VIC is modeled by representing one sub-grid for one vegetation type in each model grid. Increasing the number of sub-grids in each grid will improve modeling land cover heterogeneity at the expense of an increased computational burden. Our goal is to explore the significance of land cover heterogeneity by investigating the influence of increasing heterogeneity on the simulated soil moisture, surface runoff and baseflow, and fluxes between the land and the atmosphere. In particular, we are developing off-line and coupled experiments. For the off-line experiments we are using one-day forecast products from the coupled VIC and RSM model along with observed precipitation from the Climate Prediction Center (CPC) as forcings. These off-line experiments will then be compared to coupled experiments initialized from the offline runs. We focus in particular on the semi-arid areas over the southwestern United States, i.e., the study region of the project for the Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA).

URL: http://ecpc.ucsd.edu/projects/uastc/

### H42A-1059 1330h POSTER

## A Simple Model to Determine the Effects of Surface Inhomogeneity in the Inner Region

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Remote sensing has potential to provide measurements of water vapor content over larger areas with fairly high spatial and temporal resolution. Over a horizontally homogeneous area, these measurements can be used to calculate evaporation for the entire region measured. However, there are problems in areas of heterogeneity: because of wind and turbulent mixing in the atmosphere, water vapor concentration gradients at one location may not be a good estimate of evaporation at that exact surface location. A model has been developed to predict the effects of single and multiple surface emission step changes on water vapor concentrations profiles. Using this model, correction factors are suggested for the determination of evaporative fluxes using the Monin-Obukhov similarity method. These correction factors adjust the concentration profiles for an upwind step change in emission rates given a neutral atmosphere. The addition of a correction factor for various atmospheric stabilities will be presented which will move further towards estimating evaporation over a heterogeneous surface.

### H42A-1060 1330h POSTER

## Calibration Strategies for Global Land Surface Modeling

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Simulated datasets of global land surface fluxes and states are a major element of strategies to evaluate the effect of global warming on the land surface hydrologic

H

cycle. Generating these datasets requires some level of calibration of model parameters to ensure that the resultant fields are as accurate as possible. This can be a difficult task given the lack of large scale validation datasets and the computational limitations of employing recursive calibration strategies. Using the Variable Infiltration Capacity (VIC) land surface model and a 50-yr forcing dataset we show an efficient strategy for calibration over large spatial scales. This strategy consists of multi-seasonal and multi-objective calibration, the use of representative sampling techniques and geostatistical interpolation based on climate zoning and soil and vegetation distributions. In most past studies, observed streamflow has been the sole calibration index for small and large basin scale hydrology. This study also uses evaporation as a calibration index as it is generally a larger component of the water balance than runoff and can provide information about the dynamics within the basin. The evaporation dataset used for calibration is derived from a 20-yr global and a 50-yr US simulated dataset. Calibration is only carried out on representative sets of grid cells to reduce the computational burden of running multiple simulations. These cells are chosen to be collectively representative of the larger area in terms of their hydrologic response and as such reflect the variability in the climate and land surface of the region. This fact is used to spatially interpolate the resulting calibrated parameters over the whole modeling domain using geostatistical techniques. The calibrated model is being used to generate global fields of land surface fluxes and states for climate studies.

## H42A-1061 1330h POSTER

### Impacts of Land Surface Condition on Regional Climate-Chemistry Modeling of East Asia.

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Influences of terrain elevation and landuse type on a regional climate-chemistry modeling system applied to East Asia are tested. Terrain and landuse data of different resolutions and origins are interpolated to the model grid by various methods (terrain interpolation with different search radius along the coastline and small islands, landuse interpolation by aggregation and nearest proximity pick). The impact of these approaches and datasets on both meteorological variables, such as momentum, water vapor and heat exchange between atmosphere and land surface, that affect trace gas and particulate concentrations, transport, and deposition, as well as the tracer and particulate concentrations fields themselves are analyzed. Different parameterizations of aerodynamic resistance are tested under various micrometeorology and land surface conditions. Of particular interest are the potential errors introduced into the model results by subgrid-scale inhomogeneity in regions with complicated and rapidly varying topography and landuse. The utility of using a mosaic-type parameterization in the chemical tracer deposition module to account for these subgrid-scale variations is discussed.

## H42A-1062 1330h POSTER

### Soil Hydraulic Parameter Upscaling for Steady State Flows with Plant Rootwater Uptakes in Heterogeneous Soils

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In this study, we investigate the soil hydraulic parameter upscaling in terms of the optimal averaging schemes for steady state flows with rootwater uptakes in heterogeneous soils. The effective soil hydraulic parameters of the heterogeneous soil formation are calculated by conceptualizing the soil formation as an equivalent homogeneous medium that will discharge the same ensemble-mean surface flux. The derived optimal effective powers for the hydraulic parameters define an optimal averaging scheme for the soil hydraulic parameter fields. One of the major findings of this study is that although the plant rootwater uptakes influence the overall water budget, their impact on the effective hydraulic parameter averaging schemes is secondary.

## H42A-1063 1330h POSTER

### Scale-Dependent Dynamic Models for LES of the Atmospheric Boundary Layer Over Heterogeneous Surfaces: Sensitivity to Averaging Schemes

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Large eddy simulation (LES) has become an increasingly popular tool to study the effect of surface heterogeneity on regional fluxes, which need to be parameterized in weather and climate models. Accurate estimation of these fluxes is limited by the ability of the LES subgrid scale (SGS) model to properly represent the turbulent subgrid scale fluxes of momentum and scalars (e.g. heat and water vapor). A common approach used in LES of the atmospheric boundary layer (ABL) is to parameterize the SGS stresses with an eddy-viscosity model and the SGS scalar fluxes with an eddy-diffusion model. Each of these models requires the specification of one parameter: the Smagorinsky coefficient and the SGS Schmidt number in the eddy viscosity and eddy-diffusion models, respectively. These parameters can be computed dynamically at every time step and position in the flow based on the resolved LES fields with a procedure developed by Germano (1991) and recently generalized by Porté-Agel et al (2000, 2003) to account for scale dependence of the coefficients. In order to guarantee numerical stability, these dynamic models require some degree of spatial averaging of the variables involved. For the case of boundary layers over homogeneous surfaces the averaging is performed over horizontal planes. In this study we use the scale-dependent dynamic model with different local averaging schemes (more suitable than plane averaging for non-homogeneous boundary layers) in simulations of the ABL over heterogeneous surface conditions. Sensitivity of our results to the averaging scheme is explored for different surface patterns of aerodynamic roughness and scalar fluxes. Emphasis is placed on the spatial distribution of the dynamic model coefficients, scale-dependence parameters and resolved turbulent fluxes.

## H42A-1064 1330h POSTER

### A-priori Laboratory Studies to Improve Modeling of Land-Atmosphere Interactions Over Heterogeneous Surface Conditions

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A more accurate understanding of the subgrid-scale physics is essential to improve large-eddy simulation (LES) and its ability to capture the effect of heterogeneous surface conditions on fluxes of momentum, heat, and moisture in the atmospheric boundary layer (ABL). The main limitation of LES to produce the correct ABL physics over varying land surface conditions is due to errors in the parameterization of the subgrid-scale (SGS) stresses representing the effect of the unresolved (subgrid) scales on the resolved scales. In particular, SGS stresses need to be specified within the boundary layer (using a SGS model) and at the surface (through a boundary condition). Direct studies of SGS stresses have been performed by means of *a priori* wind tunnel experiments with prescribed flow properties over heterogeneous surface conditions of known roughness and length scales. Specifically, high-resolution, two-dimensional velocity fields were obtained in the turbulent boundary layer over a heterogeneous surface using particle image velocimetry. The velocity fields were spatially filtered (in 2-D) and used to calculate filtered (resolvable) velocities and SGS stresses. These filtered velocities were used to compute the local strain rate tensor and to estimate the SGS energy dissipation rate. To study the surface boundary condition, the velocity fields were synchronized with surface-shear (filtered) stress events as determined from an array of nine hot-film sensors mounted flush to the surface. Results, based on the SGS energy dissipation rates, indicate the importance of coherent structures in the transfer of energy between the unresolved and resolved scales of motion relevant to SGS modeling. These results are used to evaluate existing SGS models in simulations over heterogeneous surfaces.

## H42A-1065 1330h POSTER

### Variation of Evaporation Across a Corn-Soybean Production Region in Central Iowa

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Evaporation from production corn-soybean surfaces is often assumed to be uniform across a regional extent such as the Upper Midwest in the U.S.; however, there are few direct measurements of the spatial and temporal variation of evaporation to support this assumption. During a soil moisture remote sensing study in the summer of 2002 (SMEX02), fourteen energy balance stations complete with net radiometers, soil heat flux plates, a three-dimensional sonic anemometer, and fast response CO2-H2O sensors (eddy covariance) were deployed across an 25-kilometer corn-soybean production watershed in central Iowa south of Ames, Iowa. Data were collected beginning in mid-May through August and summarized into half-hourly and daily intervals. Two intercomparisons of all eddy covariance systems were conducted, one prior to the SMEX02 study (May 2002) over an alfalfa field and one after the study over a grass surface in August (2002). The coefficient of variation among the eddy covariance instruments was less than 7%. Latent heat flux values among corn and soybean fields that were greater than 7% were considered to be real differences in evaporation among fields. Diurnal differences in net radiation and latent heat fluxes were evident among both corn and soybean fields and when seasonal totals were evaluated the differences persisted. Variation in latent heat flux among corn and soybeans was attributed to soil type, water availability and spatial variation of precipitation across the watershed. The results from fourteen eddy covariance stations provide a measure of the spatial variation in latent heat flux across a region that is considered to be relatively homogenous. This information will aid in evaluating regional evaporation models.

## H42A-1066 1330h POSTER

### Characterization of land surface energy fluxes at the Salar de Atacama, Northern Chile using ASTER image classification

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Models of land surface energy fluxes often use remotely sensed data to derive surface temperature, albedo, and emissivity, important parameters in energy budget calculations. The ability to determine the spatial distribution of these parameters can lead to improved estimations of the spatial variability of land surface energy fluxes. However, other parameters used in energy flux calculations such as aerodynamic resistance are not directly linked to quantities commonly derived from remotely sensed data. If images can be accurately classified into separate land cover types, empirically determined values of unknown parameters can then be assigned separately to each land cover classification. This study examines several techniques of determining the spatial distribution of land surface energy fluxes at the Salar de Atacama, a large playa in northern Chile. Fluxes are calculated using Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER) Level 2 surface kinetic temperature, surface emissivity, and surface reflectance data in conjunction with ground-based meteorological measurements. Energy fluxes are calculated initially by applying a single value of aerodynamic resistance to the entire image area. Subsequently, the ASTER scene is classified into distinct land cover types, and land surface roughness is characterized using the ratio of ASTER band 3N (nadir-viewing) to band 3B (back-viewing). Separate values of aerodynamic resistance are then assigned to each land cover type, and energy fluxes over the entire Salar de Atacama are calculated using these spatially distributed aerodynamic resistance values. Results of both energy flux calculation techniques are evaluated at several sites on the playa using ground-based energy flux measurements.

### H42A-1067 1330h POSTER

## Contrasts in shallow cloud cover and rainfall intensity over deforested regions in the Amazon basin

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This paper addresses the impact of human induced land-use change on local and regional atmospheric circulation. To this end, the particular case of Amazonian deforestation is investigated. The first issue investigated is the enhancement of shallow cumulus clouds over deforested regions that has been observed qualitatively and in numerical model simulations. A set of shallow cumulus cloud recognition algorithms are presented, and are applied to Geostationary Operational Environmental Satellite (GOES) visible and infrared image pairs collected over the Amazon basin. Relative statistics about the occurrence of shallow clouds over forested and deforested regions are compiled, and their significance is assessed using a Monte-Carlo approach in which landcover patterns are randomized. The sensitivity of the results to the cloud recognition algorithm and landcover randomization scale are investigated. The conditional shallow cloud statistics are also stratified with respect to the synoptic circulation pattern and antecedent soil moisture conditions in order to investigate the conditions under which shallow cumulus contrasts arise. A similar analysis is performed on data from the Tropical Rainfall Measuring Mission (TRMM) precipitation radar to investigate the effect of the landcover heterogeneities on shallow warm rain cells.

### H42A-1068 1330h POSTER

## Diagnosing the influence of radiative forcing on local recycling of precipitation using a three-dimensional recycling model

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Knowledge on precipitation recycling is an important access to understand the the impact of radiative forcing on the regional water cycle and water availability. In this paper, a recycling model was developed as a precipitation recycling diagnosis tool. The recycling diagnosis tool will be introduced. Results from tests performed with artificial data will be presented to evaluate this three-dimensional diagnosis tool. We will apply the recycling diagnosis tool to data from climate model simulations performed with CCSM with recent $CO_2$ and increased $CO_2$ to examine the impact of radiation changes on local recycling of precipitation. The analysis will focus on the temporal and spatial changes.

# H42B MCC: Level 2 Thursday 1330h

## The Influence of Scale on Characterization of Fractured-Rock Aquifers I Posters *(joint with T, NG)*

***Presiding:*** **W C Burton,** U.S. Geological Survey**; A M Shapiro,** U.S. Geological Survey

### H42B-1069 1330h POSTER

## Ground Water Flow Modeling in a Layered Sedimentary Fractured Media Aquifer System using MODFLOW with the PMF Package

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Ground water movement in fractured media is markedly different from that in porous media. This difference can be summarized as a continuous change of flow properties in porous media as opposed to a discrete change of flow properties in fractured media. Therefore, the direct use of MODFLOW, which was originally developed to simulate porous media systems, to model fractured media systems is quite limited. Indeed, a special characteristic of ground water movement in fractured media, namely preferred fluid pathways, is difficult to simulate in a finite difference model such as MODFLOW. In order to define this preferred fluid pathway, the model domain should have several different categories of cells such that one would represent densely fractured areas while the others represent sparsely fractured areas in the model domain. We developed the PMF package (a Preprocessor to MODFLOW for Fractured media) using percolation theory in order to allow the model domain of MODFLOW to show preferred fluid pathways composed of fracture connections. The layered sedimentary fractured media located in Piscataway, NJ, was simulated by MODFLOW with the PMF package in this study. Its hydrogeological structure consists of a water bearing unit having a dense fracture distribution and a confining unit having a sparse fracture distribution. Ground water flows mostly through the connected fractures in the water bearing units, which can be considered to be the preferred fluid pathway. The PMF package allowed the model domain to show these two different units by the distribution of two different types of cells and produced a simulation having better fits to observation data and a better agreement with the geological characteristics of system than simulations performed by MODFLOW alone. We can conclude that the application of the PMF package to a layered sedimentary fractured aquifer to simulate ground water flow yielded superior results, as its application also provided better results in a crystalline fractured aquifer in a previous study.

### H42B-1070 1330h POSTER

## Constraining Fold-shape Models With Simultaneous Non-linear Regression to Characterize Fold Related Fractures

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Bedding-plane partings and axial-plane spaced cleavage are examples of fractures in sedimentary rocks that can be related to field scale fold structures. These fracture systems can be modelled regionally if the fold structure can be approximated mathematically through the use of fold shape models. The theory of a new technique to estimate parameters of fold shape models using geologic horizon elevation and bedding plane data is presented. Observations of the elevation of a geologic horizon are used to regress the parameters of a model of the horizon in a fold, while observations of bedding planes are used to regress the same parameters in the gradient of an isotimic surface function that reduces to the horizon model when the isotimic constant is zero. The gradient thus corresponds to the normal to the tangent (bedding) plane to the horizon, i.e. the pole to bedding. Therefore the normalized components of the gradient correspond to the direction cosines of the pole to bedding, and comprise three models in the same parameters as the horizon model. A simultaneous regression can be constructed using both the horizon elevation and bedding plane observations. The sensitivities of both the horizon model and gradient models depend upon the values of the parameters, and thus the regression is non-linear. The theory is developed and an example using a sum-of-sines function is presented for upright, symmetric folds in the Mahantango Creek watershed of Pennsylvania.

### H42B-1071 1330h POSTER

## Estimating Equivalent Continuum Scales in Fractured Aquifer Watersheds Using Discrete Feature Network Simulation

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Fractured aquifers serve as primary water resources throughout the western United States. In light of diminishing water supply, management practices must be improved to promote resource sustainability. Groundwater flow models are often the preferred management tool, but can be computationally expensive and difficult to implement in large-scale fractured environments. Discrete feature network (DFN) simulation is a robust approach for modeling fluid movement in fractured architecture, but numerically expensive for large-scale models. By using an equivalent continuum model (ECM) numerical expense may be substantially reduced. An intrinsic assumption of the ECM approach is that the geologic media is represented accurately as a continuum, requiring that grid scale discretization correspond to representative elementary scale (RES) at each location within a fractured aquifer. Heterogeneity and compartmentalization likely cause regions with large differences in fracture permeability and connectivity, resulting in spatially variable RES. Thus, while regional flow may be honored using essentially any grid pattern, failure to properly represent spatially variable RES could lead to erroneous predictions of local flow and transport, especially in highly heterogeneous zones. The purpose of our study is to determine whether head predictions from DFN flow simulations can delineate spatially variable RES in fractured aquifers. Provided there is a correlation of simulated hydraulic head to continuum scale, we hypothesize that RES can be identified using spatially disperse water level observations within a fractured aquifer watershed. Preliminary results suggest there is potential for using hydraulic head data to determine the RES. Ongoing research is necessary to confirm these preliminary results and our hypothesis.

### H42B-1072 1330h POSTER

## Interpretation of Hydraulic Tests and Implications Toward the Representative Volume Element for Bedrock Systems

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A bedrock site was studied over the past four years. The primary objective of site research was in situ bioremediation. During the course of the site research, seven wells in competent bedrock were constructed to augment the pre-existing site investigation wells. The new wells had multiple hydraulics tests performed in various lengths of discrete intervals of the open well bore. These tests included over 200 slug and 10 pumping tests. One pumping test was a site-wide test that involved wells in overburden, weathered bedrock, and competent bedrock. This wealth of information provided a database to make statistical inferences about bedrock hydraulic parameters. In addition, the analysis of the slug test data takes on new meaning when the data is analyzed by a heterogeneous conceptual model rather than the more common homogeneous models. Lastly, due to the varying size of formation investigated by the different hydraulic tests, it is possible to identify the representative volume element (RVE) - the size of formation over which small changes from average hydraulic characteristics occur. Pumping tests included standard constant rate pumping as well as non-constant pumping. Slug tests used gas pressurization and vacuum for traditional changes in instantaneous head (less than one meter), as well as large displacements on the order of 15 meters. For all data sets, data was analyzed with homogeneous analytical models (Hantush, Cooper, etc.) and a simple radial, two-zone heterogeneous finite-difference numerical model. This model used two zones, radially centered on the stressed well, with different hydraulic properties (usually with transmissivity one or two orders of magnitude higher in the outlying zone compared to the zone containing the stressed well). For the pumping tests and the large displacement slug tests, in addition to the analysis of the data from the stressed well, data from monitoring wells was also analyzed to develop hydraulic parameters. Hydraulic parameters, resulting from the analysis of the following hydraulic tests, were similar: the site-wide pumping test, the interval pumping tests, and the slug test far field (outer zone). Since each of these tests, evidenced by monitoring wells, investigated different sized portions of the bedrock and because the resulting hydraulic parameters were similar, this begins to define the bedrock RVE. More importantly, this RVE was identifiable from slug tests in single wells, for single intervals without the use of nearby monitoring wells. At this site, the RVE was on the order of 10 meters. This RVE from hydraulic tests is compatible with what can be estimated from fracture density observed in cores, outcrops, and geophysical logs. The interrelation between hydraulic testing of well bore intervals and testing the entire open well bore may in fact overlap in the description of the RVE. If one considers that an open borehole is a vertical zone in which to study hydraulic parameters, and that this zone is on the order of the RVE, then open well bore hydraulic tests may yield RVE-scale information. Arithmetic and geometric sums of well bore interval transmissivity compared favorably to the open borehole transmissivity, which supports this conclusion. The probability distributions representing the slug test hydraulic conductivity from homogeneous and heterogeneous methods will be presented and discussed. The heterogeneous, far field hydraulic conductivity probability distribution

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