The ability of the US Dept. of Energy Parallel Climate Model (PCM) to reproduce selected precipitation statistics over the continental U.S. was evaluated using a historical climate run and gridded observations over a range of temporal scales from sub-daily to annual. The observation data, taken from long-term Cooperative Observer stations and gridded to 1/8 degree over the U.S., were aggregated to the PCM scale (T42 horizontal resolution, about 2.8 degrees) for comparison. Primary statistics of interest included: a) spatial variation in the annual mean and spread; b) reproduction of the monthly/seasonal cycles, by region; c) a variety of statistics at the daily scale, including dry/wet days per year and transition probabilities between the two states, mean storm inter-arrival lengths and storm durations, by season, and daily precipitation intensity distributions, by season; and d) reproduction of the diurnal precipitation cycle along selected latitudinal and longitudinal transects.

H12E-0337 1330h POSTER

Analysis of VEMAP II Projections of Future Runoff in the U.S. Under Climate Change

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The VEMAP II model experiments investigate the response of biogeochemical and biogeographical models to variability in climate over the conterminous United States using historical and projected transient scenarios of climate and atmospheric CO2. We have been analyzing the runoff produced by five of the models. Validation of the runoff generated during the historical period of 1895-1993 was the focus of our initial work. Here we build upon that work by extending our analysis to 2100 to cover the future scenarios period during which both CO_2 and temperature increase. For each of the five models we examine two scenarios (with and without CO_2 increases of 1% a year) derived from two GCMs, the Hadley Centre's HadCM2 and the Canadian Climate Centre's CGCM1. In general, the CGCM1 projects a US climate that is warmer and drier than the HadCM2 projection. The forcings derived from both GCMs under the increased CO_2 scenario yield increases in annual runoff by three of the VEMAP models (CENTURY, MC1, and LPJ) and a decrease by BiomeBGC. However, the magnitude of the increases is smaller under CGCM1 than HadCM2, and the decrease is larger under CGCM1 than HadCM2. TEM shows no difference between the scenarios as the model's hydrologic processes are insensitive to changes in CO_2. The effects on 13 selected watersheds are presented including changes in the magnitude and timing of runoff compared to a baseline period of 1961-1990.

H12F MC: 130 Monday 1330h

Evaluation of Unsaturated Flow Models, Recent Advances, and Applications I

Presiding: **B R Scanlon,** Univ. of Texas at Austin**; J Simunek,** USDA, ARS

H12F-01 1330h

Modeling Preferential flow in Soils

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Preferential water flow and solute transport are first defined, and the mechanisms underlying different preferential flow/transport processes in the unsaturated zone are briefly described. Various approaches to modelling preferential water flow and solute transport in the unsaturated zone are then reviewed and compared. One case study is presented of the field application of a dual-porosity dual-permeability model to quantify the impact of macropore flow on tracer, pesticide and nitrate movement through the unsaturated zone of a well-structured clay soil in south-west Sweden. Finally, some unresolved issues concerning process descriptions in preferential flow models are discussed, as well as the possibilities and problems of parameterizing these models through the use of pedotransfer functions and by automatic inverse procedures.

H12F-02 1350h

Inclusion of Dynamic Capillary Pressure in Unsaturated Flow Simulators

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Traditional equations to describe unsaturated flow assume an algebraic relationship between capillary pressure and saturation. This algebraic relationship is consistent with an assumption of instantaneous equilibrium between phase pressure differences and phase saturation. Both experimental and theoretical evidence point to a more general dynamic relationship between pressures and saturation, with the traditional algebraic relationship being reached only at equilibrium. This so-called dynamic capillary pressure equation may be expressed as a first-order differential equation, with the time rate of change of saturation being equal to a measure of disequilibrium between the dynamic phase pressures and the equilibrium capillary pressure. The dynamic equation may be combined with the mass balance and Darcy equations for the water phase, and coupled to an assumption of infinitely mobile air phase, to produce a new set of equations to model water flow in unsaturated soils. The equations may be solved directly as a set of two coupled equations, or the two equations may be combined to form a single equation that takes the form of the traditional Richards' equation with an additional mixed derivative term. In either formulation, one new parameter is introduced, which characterizes the time scale for local saturation to respond to local changes in pressure. In this presentation, we review relevant experimental and theoretical evidence for dynamic behavior between saturation and pressure, present the modified forms of the governing equations, discuss discretization and numerical solution techniques, and present example simulations to demonstrate the effects of dynamic capillary pressure on unsaturated flow systems.

H12F-03 1405h

An Investigation of Numerical Grid Effects in Unsaturated Zone Automated Calibration

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Large site characterization projects such as Yucca Mountain require calibration of both unsaturated zone and saturated numerical models. Because of hydrogeologic complexity that includes many units (often dipping) and known faults, compromises are frequently made in the gridding and numerical models. These approximations are often necessary to produce a numerical model that is efficient for the many model (forward) runs used in the calibration process and later for many performance assessment calculations. We investigate one common practice. This is the neglect of connection terms in the numerical difference formula in an attempt to replicate the geometry of hydrogeologic units. This is similar to common practice in saturated zone work where finite difference cells with variable vertical thickness are used to approximate a variable thickness confined aquifer with a constant number of vertical cells. Both situations produce nonorthogonal difference schemes. In unsaturated zone simulations, the motivation for simplified differencing is more complicated. Here the nonlinearities of the relative permeability require a positive connection term for stability considerations. In a complex 3-D simulation, the easiest way to insure positive connection terms in a vertical plane while following a sloping geologic contact is to use a standard difference stencil and simply ignore any additional terms that would arise from the nonorthogonal nature of the grid. This is especially true if a complicated differencing scheme is already used in plan view. The numerical truncation error in this approach is proportional to the grid angle and would appear to be small for gently sloping formations. However, UZ flow in a complex stratigraphic setting, especially with sloping geologic contacts, produces horizontal to vertical flow ratios that varies orders of magnitude. The error arising from nonorthogonal grids directly affects this horizontal to vertical flow ratio. We investigate this effect by comparing, on a large-scale problem, the correct numerical formulation and the approximate difference formulation. By considering a synthetic problem (for calibration purposes) and varying the geologic contact angle, the effect of the approximate differencing can be determined.

H12F-04 1420h

Modeling Unsaturated Flow and Transport using Zones: Aliasing Errors

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It is difficult and costly to accurately determine the spatial statistics of unsaturated hydraulic properties, whereas it is often easier to define hydraulic property zones. When heterogeneous hydraulic property fields are subdivided into zones, however, flow and transport predictions show aliasing errors that alter predicted concentrations and breakthrough curves. The amount of error varies with the number of zones, the character of the heterogeneity, and boundary and initial conditions. The objective of this work is to determine the number of zones required to preserve critical transport behavior during numerical simulation of flow and transport. For this exercise, we consider unsaturated flow and non-reactive transport only. We assume that Richard?s Equation is valid and that the Gardner-Russo parametric model exactly describes unsaturated constitutive relationships. Correlated random parameter fields are generated and unsaturated flow and transport through these fields is simulated. The fields are then zoned using quantiles (0.25, 0.1, 0.05, and 0.025), appropriate zonal averages are determined, and flow and transport is simulated through the zoned fields. Aliasing errors are assessed by comparing the first, second and third moments of concentration for the full and zoned fields. The number of zones is varied to elucidate the character of aliasing error. The style of heterogeneity is varied to reflect geologically relevant end members (statistically isotropic vs. perfectly layered fields). Simulations are repeated under unit gradient conditions at mean tensions of 10, 100, and 1000 cm. Aliasing errors will tend to be smallest in layered systems with flow perpendicular to layering, because zonal averaging does not obscure fast paths. In statistically isotropic systems, fast paths are reduced as the coarseness of the zones increases. At higher tensions, finer zones are required to preserve transport behavior.

H12F-05 1435h

The TRACR3D Family of Unsaturated Flow and Transport Codes

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Unsaturated zone flow and transport present unique challenges from a modeling viewpoint. The governing flow equations are nonlinear, and transport lies in a different regime from the saturated zone because of the possibility of rapid diffusion of reactive components through the air/vapor phase. The TRACR3D family of codes has evolved over a couple of decades to simulate unsaturated zone processes, including air and water and vapor movement, NAPLs, chemical and biological reactions, colloid transport, interactions with surface water, complex geology, perched water zones, and parameter estimation at lab and field scale. Recent developments focus on means of capturing subgrid scale variability in flow and transport using ideas from fractal mathematics. Verification and validation of codes becomes more difficult as their capability increases. Parts of the models can be calibrated against lab and field experiments, but data for testing the full coupled models is rare, and testing of models at the field scale is generally subject to the uncertainty of unknown lithology or unanticipated processes. These issues relate to how models can be used.