collected in support of a broader project investigating the role of spatial variation in soil moisture and hydrologic connectivity on the transport and biogeochemical cycling of nitrogen in the watershed. Local mean soil moisture in upland areas closely followed a linear trend with the topographic wetness index. Bottomland mean soil moisture typically remained above this linear trend with topographic wetness index, and bottomland soil moisture variance at the plot level was typically much higher than the variance in the uplands. Local variance of soil moisture was highest under intermediate values of soil moisture, decreasing under both wet and dry conditions. We show that both local mean and variance of near surface soil moisture have important sets of controls on nitrogen cycling and export from the basin, and that the spatial and temporal patterns of these parameters in the bottomland are most closely coupling with the biogeochemical behavior of the stream.

H42G-1156 1330h POSTER

Simplicity from complexity: How lateral soil pipes define clear threshold relations at the hillslope scale

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The importance of lateral pipe flow on runoff generation in hillslopes has been described in many case studies from around the world. However, most pipe flow studies published to date have focused on only a few storms at any given site. Consequently, the overall controls on pipe flow response remain poorly understood. We present an intercomparison of pipe flow response to storm rainfall at four well instrumented sites: Panola (Georgia, USA), Toinotani (Kyoto, Japan), Jozankei (Hokkaido, Japan) and Hakyuchi (Tokyo, Japan). Our objective was to whittle down the complexities of lateral pipe flow on hillslopes by looking for commonality across different hillslopes. Despite the large differences between the study sites in topography, climate, soil type and soil matrix hydraulic conductivity, we found several common pipe flow responses to storm rainfall. Most evident was the highly threshold-like behavior of lateral subsurface stormflow and pipeflow, where despite differences in pedon scale soil properties, all of the hillslopes displayed a clear threshold-like response to storm rainfall. We used the results from the comparison to develop a decision tree to help define the conditions necessary for significant pipe flow (and hence, significant hillslope lateral flow generation) to occur. This decision tree is a useful organizational framework to summarize and organize comparative analyses and may provide a structure for defining the hierarchy of process controls. Our comparative analyses demonstrate the effectiveness of site intercomparison for extracting common controls on complex hillslope processes.

H42G-1157 1330h POSTER

Development of an Air Permeameter for Monitoring Changes in Hydraulic Conductivity of Surface Soils due to Fire: Measurements Made Following the 2003 Aspen Fire in Sabino Canyon, Arizona

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In the Southwest, severe fires can destroy as much as 90% of the vegetation and litter cover. Exposed, burned soils are highly vulnerable to intense monsoon rains, leading to increases in surface runoff, peak flows, and erosion rates. The Aspen Fire in the Coronado National Forest north of Tucson burned in excess of 80,000 acres and destroyed more than 300 structures. As part of an integrated investigation of the hydrologic impacts of this fire, we have developed an air permeameter to rapidly measure the hydraulic conductivity of burned and unburned soils. Results are shown that demonstrate the ability of the air permeameter to rapidly characterize changes in average permeability and spatial variability of permeability over large areas in rocky terrain.

H42G-1158 1330h POSTER

Using Green and Ampt with Redistribution to Simulate Recharge for Saturated Groundwater Modeling in Support of Surface Water Applications

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The Gridded Surface Subsurface Hydrologic Analysis Model (GSSHA) employs a one-dimensional finite difference approximation of the head based form of Richards' equation to calculate groundwater recharge for saturated groundwater simulations needed for groundwater/surface water interaction studies. When used to simulate sharp wetting fronts, solution of Richards' equation can be computationally very expensive. This computational cost may not be justified if Richards' equation is being solved merely to provide estimates of groundwater recharge for saturated groundwater simulations. For large problems, the computational cost may preclude the used of automated calibration methods which allow a more complete exploration of the parameter space but may require hundreds of simulations to do so. In addition to the Richards' equation solution the GSSHA model also includes Green and Ampt based infiltration models. These Green and Ampt approaches have historically been used to compute infiltration under Hortonian conditions, where saturated groundwater has little influence on surface water flows. It is hypothesized that the Green and Ampt based method of computing infiltration may prove adequate for computing groundwater recharge for use in saturated groundwater simulations. The GSSHA model is modified to allow the Green and Ampt with Redistribution model of infiltration to provide values of groundwater recharge for saturated groundwater simulations. The formulation results in infiltrated water immediately becoming recharge. The modified model is employed in two studies where groundwater surface water interaction is critical to the prediction of stream flow. In both cases the model is able to produce acceptable results in terms of predicting stream flow. The method appears useful for determining values of groundwater recharge for use with saturated groundwater simulations. The reduced simulation times with the method make the use of automated calibration methods possible.

H42H MCC: 3020 Thursday 1340h

Assessing the Impacts of Vegetation on the Water Balance II *(joint with B)*

Presiding: **B R Scanlon,** University of Texas at Austin**; M A Walvoord,** U.S. Geological Survey

H42H-01 1340h

Effects of Model Resolution on Predictions of Vegetation Health in Water-Limited Ecosystems

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Water-limited ecosystems are characterized by precipitation with low annual totals and significant temporal variability, transpiration that is limited by soil-moisture availability rather than atmospheric demand, and infiltration events that may only partially rewet the vegetation root zone. Average transpiration in such environments is controlled by precipitation, and accurate predictions of vegetation health require an adequate representation of the temporal variation in the timing and intensity of plant uptake. Complexities introduced by variability in depth of infiltration, distribution of roots, and a plant's ability to compensate for spatially heterogeneous soil moisture suggest a minimum vertical resolution required for a satisfactory representation of plant behavior. To explore the effect of model resolution on predictions of vegetation health, we conduct a series of numerical experiments, comparing the results from models of varying resolution for a range of plant and climate conditions. Plant uptake is represented with a Type I model, in which flow through the soil-atmosphere-plant continuum is driven by a potential difference across a network of resistances. To isolate the effects of spatial variations in soil-moisture and uptake, infiltration is simplified to occur instantaneously in response to intermittent storms arriving as a Poisson process. From temporal and spatial scales of the underlying processes and desired output, we develop a dimensionless parameter that indicates the adequacy of a finite-resolution model with respect to reproducing characteristics of plant transpiration over multiple growing seasons. This parameter may be used to determine the spatial resolution required to predict vegetation health in water-limited ecosystems accurately.

H42H-02 1355h

Functional Relationship to Describe Temporal Statistics of Soil Moisture Averaged Over Different Depths

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Remote sensing techniques typically provide estimates of soil moisture for the top 5 cm of the soil column. Most plants have roots that extend deeper than 5 cm, where the roots interact with soil water to influence processes such as transpiration, CO_2 assimilation, and biomass production. Consequently, soil moisture deeper than 5 cm is an essential component of the soil, plant, and climate system. Detailed simulation studies, highly resolved in space and time, show that a physically controlled relationship exists among instantaneous soil moisture integrated through different soil depths. This dynamic relationship evolves in time as a function of the hydrologic inputs and soil and vegetation characteristics. When soil moisture is calculated at coarser time intervals, such as daily, the structure of the relationship breaks down and becomes undetectable. Since practical measurements tend to be performed at daily intervals or longer, the structure seen at highly resolved temporal scales cannot be captured. If statistical measures are used instead of instantaneous values, the limitation of measurement frequency can be overcome and predictions of mean and variance for variables like soil moisture can be defined over any soil averaging depth d. Then the measured (d=5 cm) mean and variance can be related to the mean and variance of soil moisture over any averaging depth d. For a water-limited ecosystem, we use a detailed simulation model to compute mean and variance for soil moisture over a number of growing seasons, driven by stochastic rainfall forcing over a range of climate conditions, with the mean and variance calculated for different soil averaging depths d. Based on these results, we generate curves that relate the temporal mean and variance of daily-averaged saturation for different averaging depths. These curves are smooth and well behaved, indicating that relationships between soil moisture statistics for different averaging depths exist for the systems under consideration. We seek a predictive framework that relates these curves to dimensionless parameters characterizing the soil, plant, and climate system.

H42H-03 1410h

The Radiative and Hydrologic Response of Tropical Areas to Local Deforestation

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The local effects of Tropical deforestation have been modeled at both global and regional scales. The consequent climate changes, most notably a reduction in the precipitation and evaporation, have been explained with a simplified model in which a change to the surface albedo leads to reduction in the net radiant energy absorbed in the overlying column. This leads to a

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reduction in the intensity of the monsoon circulation, and a loss in precipitation. We have done global climate simulations to see the effects of Amazon, African, and Southeast Asian deforestation on the climates of those locations. What we find is that the three areas respond differently to the change, seeing precipitation reductions that occur at different times of the annual precipitation cycle. We will examine the ways in which the three areas react to local deforestation, and study the positive and negative feedbacks that act to enhance or dampen the precipitation response. We find that the differences are partly due to geography, and partly due to variation in the strength of the feedbacks among the three areas.

H42H-04 1425h

Ecosystem Water and Carbon States: A Dynamical Systems View

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To quantify the "resilience" of ecosystems to climate fluctuations, a two-state model linking carbon and water reservoirs is developed. The model is forced by climate variables such as radiative and precipitation input, air temperature, atmospheric water vapor and CO2 concentrations. The model is first tested using 5 years of water vapor and CO2 flux measurements along with moisture content collected every 30 minutes, and net primary productivity measurements collected throughout the growing seasons in a managed pine forest near Durham, North Carolina. We show that traditional concepts from dynamical systems theory applied to equilibrium states is not useful to quantifying stability and resilience of ecosystems to climate perturbations. It is shown that such an ecosystem, defined by the water-carbon stores, is influenced by processes and excursions far from equilibrium, experience multiple equilibrium points or loss of equilibrium altogether. However, a methodology that utilizes the coherency in trajectory at the extremes of the carbon and water stores in phase-space still provides adequate measures of ecosystem resilience. Mechanisms by which elevated atmospheric CO2 alters such resilience are also discussed.

H42H-05 1440h

Impacts of vegetation change on groundwater recharge

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Vegetation change is the accepted cause of increasing river salt concentrations and the salinisation of millions of hectares of farm land in Australia. Replacement of perennial native vegetation by annual crops and pastures following European settlement has altered the water balance causing increased groundwater recharge and mobilising the naturally saline groundwater. The Redesigning Agriculture for Australian Landscapes Program, of which the work described here is a part, was established to develop agricultural practices that are more attuned to the delicate water balance described above. Results of field measurements will be presented that contrast the water balance characteristics of native vegetation with those of conventional agricultural plants, and indicate the functional characteristics required of new agricultural practices to reduce recharge. New agricultural practices may comprise different management of current crops and pastures, or may involve introducing totally new species. In either case, long-term testing is required to examine their impact on recharge over a long enough climate record to encompass the natural variability of rainfall that is characteristic of most Australian farming regions. Field experimentation therefore needs to be complemented and extended by computer simulation. This requires a modelling approach that is more robust than conventional crop modelling because (a) it needs to be sensitive enough to predict small changes in the residual recharge term, (b) it needs to be able to simulate a variety of vegetation in different sequences, (c) it needs to be able to simulate continuously for several decades of input data, and (d) it therefore needs to be able to simulate the period between crops, which often has a critical impact on recharge. The APSIM simulation framework will be used to illustrate these issues and to explore the effect of different vegetation combinations on recharge.

H42H-06 1455h

The Impacts of Vegetation Change on Regional Groundwater Balances - an Australian Perspective

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Salinity in the Australian landscape is in many cases a groundwater issue. The removal of deep-rooted native vegetation and its replacement with cropping/grazing systems has increased groundwater recharge across large regions in many regions [Walker et al., 1999]. As groundwater is already saline in many areas, this has led to expanding areas of waterlogged/saline land, and increased discharge of salt to streams. The ability to predict the timing and magnitude of the groundwater response to vegetation change is desirable. Unfortunately, groundwater data is very sparse across large areas of Australia. While complex-models can be used successfully for specific point-source problems at a local-scale, the paucity of data at a regional scale begs for a simpler approach using broadly available spatial data. Such an approach is analogous to the prediction of flows in ungauged surface water catchments with almost no neighbouring historic gauging data. In broad terms the available data consists of limited bore-data (often sparse in non-irrigated areas), historical stream flow and salinity data (used to infer salinity trends and catchment salt balances), particular individual case study catchments, as well as recently developed Groundwater Flow Systems (GFS) maps which disaggregate the landscape into broad geomorphic / hydrogeological units. We present an Australian perspective on simple methods for predicting catchment response to vegetation change. These include the use of GFS maps, building on the surface water balance work of Zhang et al. [2001], and developing simple groundwater response functions to provide prioritisation tools for predicting the effect of vegetation change on the groundwater balance across large areas. References Walker G.R., M. Gilfedder, and J. Williams, Effectiveness of Current Farming Systems in the Control of Dryland Salinity, CSIRO Land and Water: Canberra, 1999. (www.clw.csiro.au/publications/Dryland.pdf) Zhang, L., W. R. Dawes, and G. R. Walker, The response of mean annual evapotranspiration to vegetation changes at catchment scale, Water Resour. Res., 37, 701-708, 2001.

H42H-07 1510h

Impacts of Vegetation Change on the Water Balance of Superficial, Coastal Aquifers: a Comparative Study of Pre-clearing and Post-clearing Recharge Under Native Vegetation, and Pine Plantations

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Replacing native vegetation with pasture across the northern Perth Basin in Western Australia has profoundly altered the water balance and led to dramatic increases in recharge and groundwater levels from about the mid-1960's, whereas replacing native vegetation with pine plantations and market gardens further south in the Gnangara groundwater Mound together with declining rainfall has caused continuous declines in recharge and water levels. Long-term monitoring of water levels in the Parmelia Formation, a superficial, semi-confined aquifer of predominantly weathered sand in the northern Perth Basin, indicates maximum rates of water level rise on the order of 40 to 55 cm/yr within the past decade. In the Gnangara Mound, water levels are falling by 10 to 20 cm/yr in the unconfined aquifer. Quantifying groundwater capture due to the removal of native vegetation is crucial for predicting the extent of groundwater development in the northern Perth Basin, whereas in the Gnangara Mound, it is necessary to limit the total water use to the declining resource to arrest the trend in falling water levels. Estimates of groundwater recharge before the removal of native vegetation in the northern Perth Basin determined from chloride tracer measurements in the soil water beneath native bushland and from groundwater samples ranged from 12 to 16 mm/yr, while estimates from soil water flux at the water table are approximately 5 mm/yr. In contrast, recharge estimates under cleared conditions since 1970 are between 24 and 50 mm/yr, based on hydrograph analyses of different bores. CFC and chloride analyses of water sampled from piezometers screened at the water table gave recharge estimates of 20 to 30 mm/yr and less than 10 mm/yr, respectively. In the Gnangara Mound recharge varies between 70 to 200 mm/year; the lowest recharge values were under the pines and the highest in the urban areas. Due to increasing demand on the groundwater resources and the declining water levels, additional resources can be provided only by removing the pine plantations, proper management of the Banksia woodland areas and capture of fresh groundwater discharging to the sea.

H42H-08 1525h

Energy and Water Balance Partitioning With Vegetation

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Vegetation coupled with soil moisture conditions are control mechanisms of hydrologic processes in a watershed, including evapotranspiration and infiltration. Persistence and feedback in partitioning of latent and sensible heat fluxes as a function of vegetation canopy and soil moisture conditions play a major role in the water balance of a watershed. Two complimentary experimental watersheds are discussed in this presentation. The 200 km2 lower Feale catchment is a low-lying peaty area in southwest Ireland that is subject to flooding. The effort to determine flood mitigation strategies has required development of a detailed hydrologic balance for the wet pasture study area. An eddy correlation system was installed in the Feale catchment in 2002 to measure components of the energy balance, including evapotranspiration, along with special sensors to measure other hydrologic variables particular to this study. The problems of data management, data quality control, individual instrumentation sensitivity, potential underestimation of latent and sensible heat and possible sources of energy balance closure errors for this wet environment and micrometeorological conditions are discussed. A complimentary data set from a Bowen ratio system experiment in a more arid grass environment in Oregon is also analyzed. Long-term, 20-min frequency data from the Oregon Evapotranspiration Investigation Plot (ETIP) from spring, summer and fall periods, including a special summer dry-down experiment, are analyzed for impacts of soil moisture content on daily Bowen ratio and ratio of measured grass evapotranspiration to a Penman-Monteith reference evapotranspiration. The gradual shift in partitioning of available energy between latent and sensible heat fluxes within a growing vegetative canopy with fully developed root zone illustrates the complexity of the processes and the difficulty of determining functional relationships for the control processes.