its modern level, and impounded an additional 80 cubic kilometers of water. The highstand lake initially overtopped the lowest area on the caldera rim to establish a semi-stable outlet controlled by a sill of older welded ignimbrite. Headward erosion through thick but unwelded Oruanui pyroclastic further east established a new, lower outlet at 405 mASL prior to 22.5 ka, releasing c. 60 cubic km of water in a flood that transported enormous boulders and which may have permanently changed the course of the largest river in the North Island. More recently, the 1800a Taupo eruption also blocked the outlet to the lake, resulting in a 34 m rise in lake level. Catastrophic failure of the ignimbrite dam following overtopping generated a flood whose discharge peaked at 17 000 - 30 000 cubic metres per second, releasing 5 years of normal outflow in 3 weeks. The geomorphic expression of this flood is found in boulder deposits, erosion surfaces, and overbank aggradation deposits and buried forests that can be traced for over 200 km downstream. Further north, Lake Rotorua is also fringed by extensive terrace and shoreline deposits that, coupled with downstream evidence, suggest multiple break-out flood events, while Lake Tarawera has been the source of volcanogenic floods c. 700 years ago and as recently as 1904 A.D.. Outbreak floods from caldera and crater lakes are a recurrent feature of volcanism in New Zealand and constitute a significant new and far-reaching hazard.

H42M MCC: 3020 Thursday 1600h

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

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

H42M-01 1600h

Assessing the Importance of Incorporating Spatial and Temporal Variability of Soil and Plant Parameters into Local Water Balance Models for Precision Agriculture: Investigations within a California Vineyard

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Due Due to the high cash crop nature of premium winegrapes, recent research has focused on developing a better understanding of the factors that influence winegrape spatial and temporal variability. Precision grapevine irrigation schemes require consideration of the factors that regulate vineyard water use such as (1) plant parameters, (2) climatic conditions, and (3) water availability in the soil as a function of soil texture. The inability to sample soil and plant parameters accurately, at a dense enough resolution, and over large enough areas has limited previous investigations focused on understanding the influences of soil water and vegetation on water balance at the local field scale. We have acquired several novel field data sets to describe the small scale (decimeters to a hundred meters) spatial variability of soil and plant parameters within a 4 acre field study site at the Robert Mondavi Winery in Napa County, California. At this site, we investigated the potential of ground penetrating radar data (GPR) for providing estimates of near surface water content. Calibration of grids of 900 MHz GPR groundwave data with conventional soil moisture measurements revealed that the GPR volumetric water content estimation approach was valid to within 1 percent accuracy, and that the data grids provided unparalleled density of soil water content over the field site as a function of season. High-resolution airborne multispectral remote sensing data was also collected at the study site, which was converted to normalized difference vegetation index (NDVI) and correlated to leaf area index (LAI) using plant-based measurements within a parallel study. Meteorological information was available from a weather station of the California Irrigation management Information System, located less than a mile from our study area. The measurements were used within a 2-D Vineyard Soil Irrigation Model (VSIM), which can incorporate the spatially variable, high-resolution soil and plant-based information. VSIM, which is based on the concept that equilibrium exists between climate, soils, and LAI, was used to simulate vine water stress, water use, and irrigation requirements during a single year for the site. Using the simple water-balance model with the dense characterization data, we will discuss: (1) the ability to predict vineyard soil water content at the small scales of soil heterogeneity that are observed in nature at the local-scale, (2) the relative importance of plant, climate, and soil information to predictions of the soil water balance at the site, (3) the influence of crop cover in the water balance predictions.

H42M-02 1615h

Evaluation of canopy transfer models for growing vegetation using in-canopy profile measurements

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Estimates of the roughness lengths and the in-canopy transfer of momentum and sensible and latent heat are needed for any determination of the fluxes from a vegetated area. We use in-canopy measurements of the wind and temperature profiles taken with needle anemometers in acorn crop to test models of the in-canopy transfer. Profile measurements were taken during the course of the day, and over a larger portion of the growing season, as the corn grows from approximately 80cm to above 2 m. The changes in canopy height and closure led to a varying relationship of roughness height and displacement height, and affected the choice of best model for the in-canopy sensible and latent heat transfer. The implications of our measurements and analysis for estimating fluxes from a larger-scale area are explored.

H42M-03 1630h

The impact of uncertainty in evapotranspiration on the water balance at a pasture site in Florida

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The difference between precipitation (P) and evapotranspiration (ET) provides the net atmospheric input of water to watersheds. Precipitation data commonly are available. However, ET data are scarce and coarse estimates of ET routinely are used in hydrologic analyses. Measured ET values over a 986-day period at a pasture site in Florida provided a unique opportunity to evaluate the sufficiency of coarse estimates of ET in hydrologic analyses. A simple, daily hydrologic model was used to evaluate the sensitivity of the flow system to error in ET. The day-to-day variation in measured vegetation coefficients (ratio of actual to potential ET) was replaced within the hydrologic model with a simple, annually-invariant pattern of monthly vegetation coefficients. This approach was proven to be effective in reproducing unbiased estimates of daily water table fluctuations and flow terms and was successful despite the substantial fluctuation in measured daily vegetation coefficient and significant year-to-year variation in measured vegetation coefficient for a given month. Coarser estimates of the vegetation coefficient (a constant, average value of 0.86 and values biased +/-10%) poorly reproduced the flow system. Errors in estimated flow terms increased by tens of percent and substantial biases were introduced to these estimates. Despite the unbiased estimates of ET produced by a constant, average vegetation coefficient, this approach produced biased partitioning of net atmospheric input into recharge (-13% error) and runoff (5% error). The modest +/-10% bias to vegetation coefficients (and therefore to ET) produced a +/-20% error in net atmospheric input through residual error amplification. This error was further amplified in the fraction of net atmospheric input becoming recharge (+35% / -63%) and again in the fraction of recharge that became subsurface flow (+48% / -86%), indicating that use of unbiased estimates of vegetation coefficient is critical to hydrologic simulation. The results suggest that annually-invariant, monthly vegetation coefficients are the appropriate level of coarseness for hydrologic analyses at the study site. Estimates of potential ET, derived either from a simple meteorological station or remote-sensing approaches, combined with these monthly vegetation coefficients are suitable for generation of historical or ongoing ET estimates in environmental settings similar to the study site. The particular vegetation coefficients and acceptable level of coarseness of these coefficients at other environmental settings can be defined by methods outlined in the present study.

H42M-04 1645h

Scaling Evapotranspiration Depletion Rates in Native and Non-native Vegetation Along the Middle Rio Grande Riparian Corridor

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This research uses ground-based measurements and remote sensing techniques to scale evapotranspiration (ET) estimates along the middle Rio Grande riparian corridor in central New Mexico. Previous estimates of riparian evapotranspiration (ET) along the corridor range from between 20 to 50 percent of the total water depletions. These depletions are believed to be increasing due to the invasion of non-native species. The University of New Mexico (UNM) Departments of Civil Engineering and Biology have been working to better define ET depletion values in native and non-native field plots within the riparian forest. Currently, half hourly ground based micrometeorological data are being collected using four instrumentation towers installed in native cottonwood and non-native saltcedar sites. The tower data form the basis for calculating ET at the four tower sites using the 3-D eddy covariance method. These ET values are arguably the most accurate estimates of ET available within the middle Rio Grande; however, they are limited to only four points along the 320-kilometer riverine corridor. In order to scale ET calculations to the entire corridor, we first scale ET to eight additional study sites using the relationship between Leaf Area Index and ET. This provides an adequate number of points for groundtruthing remote sensing imagery. Next we compare the Landsat 7 ETM+ imagery with the groundtruthing points and develop relational equations. These equations are applied to a vegetation classification map also derived from Landsat 7 imagery. The resulting maps allow us to quantify ET depletions for both saltcedar and cottonwood canopies.

H42M-05 1700h

The Role of Vegetation Dynamics on the Soil Water Balance in Water-Limited Ecosystems

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The structure and function of the vegetation regulates the exchange of mass, energy and momentum across the biosphere-atmosphere interface. Vegetation dynamics are usually neglected, other than seasonal phenology, in land surface models (LSMs). However, changes in vegetation densities, influencing the partitioning of incoming solar energy into sensible and latent heat fluxes, can result in long-term changes in both local and global climates (e.g., precipitation and temperature), which in turn will feedback to affect the vegetation growth. In semi-arid regions, this may result in persistent drought and desertification, with substantial impacts on the human populations of these regions through reduction in agricultural productivity and reduction in quantity and quality of water supply. With an objective of finding a simple vegetation model able to accurately simulate the leaf area index (LAI) dynamics, vegetation models of different level of complexity (e.g., including or not the modeling of the root biomass or the modeling of the dead biomass) are developed and compared. The vegetation dynamics models are coupled to a LSM, with the vegetation models providing the green biomass and the LAI evolution through time, and the LSM using this information in the computation of the land surface fluxes and updating the soil water content in the root-zone. We explore the models on a case study of a water limited grass field in California. Results show that a simple vegetation model that simulates the living aboveground green biomass (i.e., with low parameterization and computational efforts) is able to accurately simulate the LAI. Results also highlight the importance of including the plant growth model in the LSM when studying the climate-soil-vegetation interactions and the impact of watershed management practices on the scarce water resources over moderate to long time scales. The inclusion of the vegetation model in the LSM is demonstrated to be essential for assessing the impact of climate change (e.g., decrease of precipitation and increase of air temperature) on the water budget of a water limited region.

H42M-06 1715h

Role of Vegetation in Controlling Water Balance at the Land-Atmosphere Interface in Water Limited Ecosystems

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Understanding the role of vegetation in the water balance at the land-atmosphere interface is critical for assessing the impact of changes in vegetation and climate on the near surface water balance. Monitoring nonvegetated and vegetated weighing lysimeters in the Mojave Desert in Nevada USA over an eight-year period demonstrated strong coupling between large increases in soil-water storage in response to El Nino cycles in 1994/1995 and 1998 winter periods and vegetative response that rapidly removed the infiltrated water through evapotranspiration (ET). Soil water storage in the vegetated lysimeter was about half of that in the nonvegetated lysimeter at the end of the 8 yr monitoring period, which indicates that even in this arid climate, vegetation is extremely important in removing water from the soil through ET. The lack of monitored drainage in the nonvegetated lysimeter is an artifact of the seepage face lower boundary condition, which prohibits drainage unless the soils become almost saturated. Modeling analysis indicated that increased soil water storage in the nonvegetated lysimeter should result in drainage if the seepage face is replaced with unit gradient conditions as in the natural system. Traditional approaches for water balance modeling that use vegetative parameters, such as Leaf Area Index (LAI), as forcing greatly underestimated soil water storage because they did not include the two-way coupling between water storage and vegetation dynamics. Inverse modeling was used to demonstrate the two-way coupling between soil water storage (related to climate) and vegetation dynamics and involved minimizing the sum of squared residuals between measured and simulated soil water storage by varying LAI, which was used as a surrogate of vegetation dynamics. Inverse modeling reproduced the measured water storage much better than forward modeling using prescriptive LAI because feedback between water availability and vegetation dynamics was included in the inverse modeling approach. This monitoring and modeling analysis reveals strong coupling between vegetation dynamics and soil water storage changes related to precipitation and underscores the need to incorporate this dynamic interaction between climate and vegetation in numerical simulations to reproduce the monitored water balance. The role of vegetation in controlling the water balance of these arid systems has important implications for water resources and waste containment. The tight coupling between vegetation and soil water storage indicates that land use change could significantly alter the water cycle and that vegetation changes associated with climate change could affect the impact of climate change on the water cycle.

H42M-07 1730h

Ecotonal Control on Vadose-Zone Fluxes in Arid Regions Over Very Long Time Scales

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Recent studies indicate that vegetation plays an important role in regulating recharge in semiarid and arid basins over very long time scales. Several lines of evidence from desert floor environments in the southwestern United States suggest that vegetation has established essentially permanent upward hydraulic gradients, effectively precluding diffuse recharge since the transition from woodland to xeric scrub in the early Holocene. However, less xeric vegetation (such as the pygmy piñon and juniper forest) may support significant diffuse recharge. We show comparative water potential and porewater chemistry profiles collected from various vegetation communities in the Chihuahuan Desert of west Texas. The modeled soil water (vapor and liquid) flux regimes illustrate a conversion from substantial downward fluxes under the mixed woodland to upward fluxes under grassland and xeric scrub. Model results also indicated a trend in increasing drying front propagation depth from the grassland to recently-encroached xeric scrub to well-established xeric scrub. Drying fronts are the result of upward soil water fluxes initiated up to 16 thousand years ago in the xeric scrub community. In contrast, the nearby woodland community supports active, and likely episodic, recharge on the order of 5 to 15 mm yr^{-1}. The mechanism by which some vegetation takes up essentially all seasonally available moisture within the root zone, preventing downward soil water fluxes for periods of thousands of years, but adjacent vegetation communities regularly permit downward fluxes, remains to be determined. Nevertheless, these results suggest that understanding the relation between vegetation community and vadose-zone hydrological processes may be the most profitable avenue toward quantifying diffuse groundwater recharge. We hypothesize that vegetation type may be a reasonable proxy for estimating recharge in semiarid and arid basins. Ongoing research is intended to test the hypothesis of ecotonal control on soil water fluxes by means of a vadose-zone drilling project along an aridity index gradient in central New Mexico.

H42M-08 1745h

Vegetation, climate change, and diffuse groundwater recharge in arid and semiarid environments

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Several different types of data show that there is currently little or no diffuse groundwater recharge at many arid and semiarid sites worldwide. However, evidence for diffuse recharge has been found at some sites where mean annual precipitation (P) is much less than mean annual potential evapotranspiration (PET), particularly where soils are coarse and hydroclimatic conditions are variable. In addition, there is evidence suggesting that diffuse recharge was widespread during the last glacial period, likely a result of the climate or vegetation (or both) at that time. We investigate how vegetation and climate control the rate of diffuse groundwater recharge using a one-dimensional, liquid-only flow model for desert vadose zones. The flow model is driven by a stochastic parameterization of climate at a point that includes storm size distribution and seasonality of precipitation and potential evapotranspiration, constrained by data from over 700 climate records from the southwestern U.S. The type of vegetation is varied to investigate how constraints on transpiration resulting from physiological and phonological limitations impact recharge. Storm size distribution and seasonality control the frequency of intervals when P exceeds PET and the amount of water that accumulates in the root zone during these intervals, which in turn controls the flux out the bottom of the root zone. Climates with larger and more infrequent storms yield recharge at lower values of P/PET. Seasonality has a larger influence on recharge than storm size distribution, and the effects are similar for both coarse and fine soils. The relative timing of P and PET maxima is critical: recharge occurs at P/PET values that are lower by 0.2 when the rainy season occurs during the winter instead of the summer. The type of vegetation also provides a critical control on recharge. In particular, when plant phenology excludes transpiration during part of the year, recharge occurs at much lower values of P/PET. In contrast, the most negative water potential at which a plant can sustain transpiration has little impact on recharge, at least for the desert species studied. Finally, interactions between climate and vegetation change are critical to explain the long-term variations in diffuse recharge observed in arid and semiarid regions worldwide.

H51A MCC: 3022 Friday 0800h

Catchment Processes in the Tropics I

(joint with B)

Presiding: **R C Sidle,** Kyoto University**; A Ziegler,** National University of Singapore

H51A-01 0800h INVITED

Overland Flow in Tropical Rainforests: Causes and Consequences

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With the expansion of forest hydrology research from mid-latitudinal to tropical areas, a diversity of hydrological process patterns began to emerge that has since been tentatively explained along geographical lines. Our much improved knowledge of runoff generation processes, however, allows us to discard geographical straitjackets and explain the quite diverse hydrological functioning of tropical rainforests world-wide in terms of those soil, meteorological, and geomorphologic factors that control the movement of water on landscapes. An appreciation of these factors, which do not include land cover, is essential for an understanding of the occurrence of overland flow in tropical rainforest, which still seems to be viewed as a contradiction in terms in spite of mounting evidence to the contrary. A perceived link between hydrological processes and land cover and the intuitively appealing, perceived role of forests in the water cycle has resulted in overland flow being viewed as a consequence of human intervention, but not as the natural consequence of a set of environmental factors inherent in many tropical rainforests. This set of environmental factors includes characteristic permeability-depth profiles and rainfall regimes that, in combination, will yield overland flow as a matter of course; in fact, overland flow has emerged as a hydrological process characteristic of vast areas of rain forest-covered tropical soilscapes. These characteristic permeability-depth profiles may, in a simplifying approximation, be reduced to a sequence of two soil layers: a thin (compared to the overall soil depth) surficial layer of high permeability (compared to prevailing rainfall intensities), and a thick subsurface layer of very low permeability. This sequence reflects the decrease of nonstructural, or bioturbation-induced, macroporosity (which is in many places accompanied by a textural change) observed in some widespread tropical soils; it contrasts with rather uniform permeability-depth profiles that reflect nearly depth-independent structural, or mineralogy-controlled, macroporosity observed in other tropical soils. The latter result in a generally vertical movement of soil water, whereas the former tends to generate saturation overland flow. With overland flow established as a characteristic hydrological process of some extensive tropical rainforest ecosystems, we explore its implications for land-use change and nutrient budget studies. Where overland flow is part of undisturbed ecosystem processes, land-use change cannot possibly result in a qualitative change of hydrological processes: it may increase the amount of overland flow, but it cannot cause its occurrence. Although land-use and land cover change of tropical rainforests do affect hydrological processes in many ways, there is no evidence to support generalizations about abrupt shifts in hydrological pathways. Likewise, the effect of land-use change on nutrient losses is likely to be overestimated where the natural' nutrient losses were underestimated by ignoring overland flow-mediated and hence rainfall event-related catchment outputs. Overland flow must be recognized as an intrinsic, even typical, hydrological process of many tropical rainforests, while the casual assumption of its occurrence as the unique consequence of land-use change is not defensible.

H51A-02 0815h

Overland Flow Generation and Soil Hydraulic Properties in Two Catchments in Central Panama

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