First Author/Short Title Index for Posters

Regional Modeling Projects

RM-1 *Chen,* Coupling Study of RSM and VIC over Southwest
RM-2 *Li,* The Effects of Sea Surface Temperatures on Hydrological Processes over Southwest U.S.
RM-3 *Liu,* Parameter Estimation for Locally Coupled Land Surface-Atmosphere Models
RM-4 *Mahmoud*, Mesoscale Surface Hydrological Fluxes over the Rio Grande Basin
RM-5 *Nunes,* Physical Initialization in the Regional Spectral Model
RM-6 *Vivoni,* High Performance, Multiple Resolution Modeling of Semi-Arid Hydrology
RM-7 *Xu,* Impact of Assimilating Rainfall Derived from Radar and Satellites on Rainstorm Forecasts
RM-8 *Zhu,* Effective Hydraulic Parameters In Heterogeneous Soils

Rio Grande Basin Projects

RG-1 *Beeson,* E-T-R Arrays: A Dynamical Approach to Estimation of Evaporation-Transpiration
RG-2 *Brookshire,* Water Allocation in the Middle Rio Grande
RG-3 *Chermak,* Using Experiments to Fill Data Gaps: Improving Estimates of Consumer Response
RG-4 *Costigan*, Regional Modeling of the Upper Rio Grande Basin
RG-5 *Dadakis,* Sources of Recharge and Salinity in the Shallow Aquifer near El Paso, Texas
RG-6 *Dressler,* Differences in SWE Values Between Snow Telemetry (SNOTEL) Snowcourse
RG-7 *Ewers,* An Optimal Crop Model Applied to the San Luis Valley, Colorado
RG-8 *Fritchel,* Evaluation of a Hydrologic Model of the Rio Grande Using a Long-Term Dataset
RG-9 *Gastelum,* System Dynamics Applied to the Conchos Basin
RG-10 *Guan,* Evaluating Distributed Mountain-Block Recharge at the Hillslope Scale
RG-11 *Hong,* Toward Higher Quality of Precipitation Product for the Southwest United States
RG-12 *Kim,* Nonparametric Approaches for Bivariate Drought Characterization
RG-13 *Lacey,* Investigating Instantaneous and Long-Term Water Quality Trends in the R.G.
RG-14 *Molotch,* Estimating the Spatial Distribution of Snow Water Equivalent in an Alpine Basin
RG-15 *Oelsner,* Water and Solute Sources Along a 1000 km Reach of the Upper Rio Grande
RG-16 *Qu,* A Multi-Scale, GIS-Based, Hydrologic Modeling Tool for Dynamic Water Balance
RG-17 *Roach,* Increasing Demands, Finite Supply: Water Allocation Choices and Tradeoffs
RG-18 *Sandvig,* Ecohydrological Control on Soil Moisture Fluxes in Arid Vadose Zones
RG-19 *Schmid,* Capabilities of the New FARM Package for MODFLOW-2000
RG-20 *Bales,* Hydro-ecological controls on water cycling across semiarid ecosystems in the R.G.
RG-21 *Hong*, Evapotranspiration and Soil Moisture Estimation in Middle Rio Grande Basin
RG 22 *Bhark,* Quantifying the spatial heterogeneity and covariance between surface hydrologic

San Pedro Basin Projects

SP-1 *Baillie,* Isotopic Tracers for Quantifying Mountain Front Recharge and Groundwater
SP-2 *Baird,* A New Method For Determining Riparian and Wetland Evapotranspiration
SP-3 *Bark,* New Approaches to Assessing and Valuing Riparian Resources in Arid Regions
SP-4 *Brown-Mitic,* Characterizing Water, Energy and CO_2 Exchange for a Sky Island Subalpine
SP-5 *Harms,* Riparian N Cycling: Impacts of Plant Communities and Fluctuating Groundwater Table
SP-6 *Hinnell,* Application of Electrical Geophysical Techniques to Hydrology
SP-7 *Ip,* Toward the Development of a Routing Procedure that Parameterizes the Grid-scale
SP-8 *Krezelok,* Factors Affecting Microbial Respiration in Stream Sediments During Monsoonal
SP-9 *Kumar,* Detecting Spatial and Temporal Modes of Climate and Landuse From Historical

SP-10 *Lemon,* The Effects of Land Use and Regional Hydrology on Surface Water Quality in the
SP-11 *McPhee,* Decision Support System for Sustainable Groundwater Management in Semi-Arid
SP-12: *Migoni,* San Pedro News and Comment
SP-13 *Patel,* Permeability of Soil on Mt. Lemmon and Water Sampling at the San Pedro River
SP-14 *Showa,* Air Permeability
SP-15 *Whittier,* Groundwater Flow Model of the Lower San Pedro River Basin for the Conservation
SP-16 *Valdés*, SAHRA International Collaboration: The Upper San Pedro Basin
SP-17 *Yalcin,* Evaluation of Water Conservation Measures in the Upper San Pedro Basin
SP-18 *Yatheendradas,* Calibration and Application of the Distributed NOAH Land Surface Model
SP-19 *Petti,* Impact of 2002 and 2003 Wildfires on SAHRA's Mt. Bigelow EC Site
SP-20 *Blasch,* Cooperative Public Outreach - It Can be Accomplished

Education and Knowledge Transfer Projects

ED/KT-1 *Adams,* Rainwater Harvesting in Nogales, Sonora
ED/KT-2 *Marburger,* Monsoon Madness
ED/KT-3 *Potts,* Making a SPLASH: Creating and Implementing a Regionally Focused Water
ED/KT-4 *Nelson,* Water Education for Native Americans
ED/KT-5 *Weber,* FREE WATER! Analyzing Residential Reuse in Tucson
ED/KT-6 *Woodard,* Interpreting the Hydrology of a Desert Mountain Stream to a General Public
ED/KT-7 New Knowledge Transfer Initiatives
ED/KT-8 *Shaler,* SAHRA's Global News Watch
ED/KT-9 *Woodhouse,* Southwest Hydrology: The Resource for Semi-Arid Hydrology
ED/KT-10 *Whitaker,* GLOBE Border Area Field Investigations
ED/KT-11 *Browning-Aiken,* ECOSTART

Poster Abstracts

Regional Modeling Projects

RM-1

Coupling Study of RSM and VIC over Southwest

Ji Chen, John Roads, and Masao Kanamitsu
Experimental Climate Research Center, Scripps Institution of Oceanography, University of California, San Diego

The Variable Infiltration Capacity (VIC) macro-scale 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).

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RM-2

The Effects of Sea Surface Temperatures on Hydrological Processes over Southwest United States and Mexico in Monsoon Seasons of 2001-2003

Jialun Li, Xiaogang Gao, and Soroosh Sorooshian
Dept. of Civil and Environmental Engineering, University of California, Irvine

Sea surface temperature (SST) is recognized as a major contributor to atmospheric circulation from short (weekly to seasonal) to long (annual to decadal) time scales. In this research, the effects of SSTs on hydrological processes from weekly to monthly are examined using the NCAR/PENN MM5 mesoscale model. The period of study was the monsoon seasons in years of 2001-2003. To examine the relative importance of the SST in hydrological process, different types of SSTs are employed as sensitivity tests. They include; Reynolds 1^o by 1^o weekly SST, FNL 1^o by 1^o skin temperature, and MODIS-Aqua/Terra SSTs that include mid-infrared (IR) channels and thermal IR channels retrieved SSTs.

The preliminary results show that when high-resolution MODIS SST was used, the estimates of precipitation were much improved over arid/semiarid southwestern United States and northwestern Mexico regions. Furthermore, changes in precipitation were experienced over the US interior when SSTs changed. The effect of SST on precipitation lags 3-4 days over costal areas and 5-7 days over the US interior.

RM-3

Parameter Estimation for Locally Coupled Land Surface-Atmosphere Models: Sensitivity Analysis and Model Calibration

Yuqiong Liu[1], Hoshin V. Gupta[1], Soroosh Sorooshian[1], and Luis A. Bastidas[2]
[1] Dept. of Hydrology and Water resources, University of Arizona
[2] Dept. of Civil and Environmental Engineering, Utah State University

Using the NCAR single-column model (SCCM) and data from the ARM-CART SGP site, a multi-objective sensitivity analysis was conducted to investigate the influence of land-atmosphere interactions on model sensitivities. The results show that, compared to the off-line case, the locally coupled model is sensitive to more land parameters from the multi-objective point of view, while the land-atmosphere interactions seem to have different influences on the sensitivities of different surface fluxes/variables from the single-objective point of view. For calibrations in the locally coupled environment, the results show that atmospheric parameters are of critical importance and atmospheric forcing variables generally contain more useful information for calibration than land-surface fluxes/variables. In the coupled environment, step-wise calibration schemes appear to be superior to the single-step calibration schemes, in that the former can provide better-converged optimal solutions with less uncertainty. In addition, better calibration effects achieved in the partially decoupled environment by replacing model-generated precipitation and net radiation with the corresponding observations to drive the land part of the model indicates the dominant importance of precipitation and radiation for the two-way interactions within the coupled system.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RM-4

Mesoscale Surface Hydrological Fluxes over the Rio Grande Basin

Mohammed Mahmoud, Soni Yatheendradas, and Bart Nijssen
Dept. of Hydrology & Water Resources, University of Arizona

The ultimate aim of the Medium Resolution Integrated Modeling group is the implementation of an integrated model for the Rio Grande river basin. The integrated model will consist of a land surface model, a regional atmospheric model, a groundwater model, and an ecosystem model, which together represent the physical system. Eventually, this model representing the physical system must allow for the interaction of the physical system with the institutional, socio-demographic, and economic activities that are part of human behavior. As the first step towards building this integrated model we present model-simulated mesoscale surface hydrological fluxes over the Rio Grande Basin upstream of El Paso. These simulations are based on the NOAH model and a model forcings dataset from the University of Washington. Model results are presented for the period 1997-1999 at a one-eight degree spatial resolution, and are compared to an earlier model simulation based on the Variable Infiltration Capacity (VIC) model.

RM-5

Physical Initialization in the Regional Spectral Model: Improving Regional Climate Simulations over the U. S. Southwest

A. Nunes, John Roads and Ji Chen
Scripps Institution of Oceanography, University of California, San Diego

A Physical Initialization (PI) procedure is being implemented in the Scripps Experimental Climate Prediction Center (ECPC) Regional Spectral Model (RSM). The PI scheme mainly comprises precipitation assimilation. In this particular study, we seek to understand how the precipitation assimilation could improve climate simulations. For this purpose, control and PI extended simulations over the U. S. Southwest region were performed during the summertime. The Higgins precipitation data analyses and the National Centers for Environmental Prediction (NCEP)-Department of Energy (DOE) Reanalysis (R-2) precipitation fields were used for assimilation and verification. The preliminary results using Relaxed Arakawa-Schubert cumulus convection parameterization show that the RSM was able to assimilate the precipitation analyses very well by means of the PI scheme.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RM-6

High Performance, Multiple Resolution Modeling of Semi-Arid Hydrology at Regional Scales

Enrique R. Vivoni
Dept. of Earth and Environmental Sciences, New Mexico Institute of Mining and Technology

Hydrologists have long recognized that the interaction of climate, topography, soils and vegetation leads to spatial and temporal patterns in watershed response. Our understanding of these complex relationships is aided through fine-resolution numerical models that best represent our knowledge of the physical processes occurring in basins. The aim of this poster is to introduce a multiple resolution model, known as the TIN-based Real-time Basin Simulator (tRIBS), for studying basin hydrologic response to meteorological forcing. The model has several distinguishing features: (1) coupled unsaturated and saturated zones through a dynamic water table, (2) coupled energy and hydrologic balance at the land-surface, (3) topographically-driven moisture redistribution, radiation and evapotranspiration. Accurate terrain representation with low computational expense is achieved through the use of a triangulated irregular network (TIN). By integrating topography, land-surface properties and rainfall data, the distributed model can be used to generate multi-year, multi-gauge flood forecasts, to study the effects of land-use and climate change on hydrologic dynamics, and to couple the land-surface hydrologic state to meteorological predictions. Most importantly, the tool provides a complete description of the spatio-temporal variability and organization of the underlying hydrologic processes. Model capabilities and future prospects in SAHRA will be highlighted for an application to the Río Grande Basin, New Mexico.

RM-7

Impact of Assimilating Rainfall Derived from Radar and Satellites on Rainstorm Forecasts over the Southwestern United States

Jianjun Xu[1], Xiaogang Gao[2], and Soroosh Sorooshian[2]
[1]Dept. of Hydrology and Water Resources, University of Arizona
[2]Dept. of Civil & Environmental Engineering, University of California, Irvine

The Four-Dimensional Variational (4DVAR) data assimilation technique is a powerful tool to improve model initial conditions for weather forecasts. In this study, the MM5-4DVAR system is used to investigate the impact of rainfall assimilation on the forecasts of convective rainfall over the mountain areas in southwestern United States. The assimilation rainfall is derived from radar and/or satellite information. This study evaluates the 4DVAR rainfall assimilation skill through a convective rainstorm event occurred over southern Arizona during 5-6 August 2002.

Six experiments consist of 2 options of assimilation window (i.e., 3-hour and 6-hour) and 3 options of rainfall data sources (i.e., radar-derived, satellite-derived, and radar-satellite rainfall) were conducted. The results show that using rainfall assimilation can produce more realistic moisture divergence and temperature fields in initial conditions, thereby, forecast rainstorm closer to observations in both quantity and pattern. The crucial minimization process in the 4DVAR is found sensitive to the assimilation rainfall data source and the length of assimilation window. The effective duration of forecast depends on the length of the assimilation window. For the study case, 3-hour assimilation window in the 4DVAR system works well for the 6-hour rainfall forecast, but 12-hour rainfall forecast requires the use of 6-hour assimilation window.

Rio Grande Basin Projects

RG-1

E-T-R Arrays: A Dynamical Approach to Estimation of Evaporation-Transpiration and Recharge for Water Table Depths Less than 20m

Peter Beeson and Christopher J. Duffy
Civil and Environmental Engineering, Pennsylvania State University

E-T-R Arrays (evaporation-transpiration-recharge arrays) are being instrumented to close the water budget and improve estimates of vertical and horizontal fluxes in the presence of a water table within the riparian corridor of the Middle Rio Grande Basin. When fully implemented, the arrays will utilize 4-6 soil pressure-moisture sensors in each soil profile, and pressure transducers in each piezometer below the water table. The piezometers and soil profile sensors are laid out in a block-centered 3-D grid. The installation design allows direct application of the finite volume model equations to the observed soil moisture and hydraulic head time series (Duffy, 2004; Qu and Duffy, 2004). The parameters of the array are estimated using optimization tools, and estimates of the evapotranspiration, recharge, lateral groundwater flow and vertical leakage are estimated within the finite volume. The E-T-R array is meant to serve as an improvement or complement to Eddy Correlation and Bowen ratio approaches to ET estimation, in that the footprint of the E-T-R array is fixed and does not depend on the surrounding wind field and terrain conditions. The figure illustrates the arrays which are being implemented at sites operated by Cliff Dahm and his team from UNM. Cliff is using Eddy-Correlation at five sites and Bowen-Ratio at another 8 sites. All sites are in riparian areas. Several new sites are in the planning stage in the Jemez Mountains and within the drainage of the Rio Salado.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-2

Water Allocation in the Middle Rio Grande

David S. Brookshire, Kate Krause, Janie M. Chermak, Julie Coonrod, Anne Demint, Rick Watson, Paul Mathews
Dept. of Economics, University of New Mexico

The population of the semi-arid Southwest has grown dramatically over the last few decades. Further issues of endangered fish have risen to the forefront along with concerns regarding the agrarian culture. All of these pressures have generated the need for a discussion of reallocation of water.

In the Middle Rio Grande valley of New Mexico there are many stakeholder groups that range from urban users, agricultural to in-stream flow and riparian health advocates. In the valley the available water supply water is fully allocated thus requiring in any reallocation process either more efficient use of water in order to free up wet water for reallocation and/or the reduction of an activity. To date, a stakeholder reallocation process that is fully constrained has not been developed.

We developed an experimental setting whereby stakeholders from various groups participate in a reallocation exercise. The backbone of the experiment is a GIS-distributed, watershed modeling framework that enables any proposed reallocation from one use to another to comply with water balances. GIS-generated maps illustrate land-use patterns under the initial water allocation, and information is provided regarding annual water availability.

These experiments investigate water allocation when scarcity is explicit and when information about changes in allocation is provided graphically. Participants enter water use decisions and a hydrological model of surface water in the Middle Rio Grande calculates the resulting changes. Economic models embedded in the hydrological model are used to calculate payoffs based on the value of water to each group. Allocations that are infeasible reduce all participants' payoffs. Multiple rounds allow participants to view the consequences of aggregate allocations over time.

RG-3

Using Experiments to Fill Data Gaps: Improving Estimates of Consumer Response in the Case of Residential Water Markets

Janie Chermak, Kate Krause, and David S. Brookshire
Dept. of Economics, University of New Mexico

Concern over the adequacy of water resources in semi-arid regions has led to increased interest in policies that promote water conservation. The success of such policies will be determined, in large part, by the accuracy of the analytic tools used for policy assessment. Vital components of these tolls will be water market models that include accurate demand and supply components. This research focuses solely on the demand side of the water market. While existing research efforts have empirically modeled the demand for water in most cases water prices in the historical data are over an extremely limited range that reflect neither the full cost of the water nor the increased scarcity of water in many semi-arid regions. Thus the predictive ability of these models for consumer response is over a very limited, and low, price range.

There is the potential that the existing data can be augmented by experimental data, providing that responses in the laboratory are consistent with those in then field. This research provides a first step in the effort to align experimental responses to real world data. If experiments generate consumer responses that are consistent with actual water consumption we can extend the prices, and thus the predictive range of the models, outside the historic price range. Fifty-three water consumers from the Albuquerque, New Mexico metropolitan area participated in this project. Each consumer 1) supplied a water use history, 2) responded to a detailed survey concerning water use and attitudes towards water scarcity, 3) provided basic demographic and socio-economic information, and 4) participated in an experiment that simulated water use in a variety of price, income and rainfall conditions. Our preliminary results indicate that a context-specific experiment can elicit responses that correlate to actual water use.

Given these results, a second set of experiments extends the price range into a more realistic range for the future and emphasizes specific tradeoffs in water use in the short run and capital changes in the long run. Econometric analysis of these experiments will provide consumer response estimates to augment the existing data.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-4

Regional Modeling of the Upper Rio Grande Basin

Keeley Costigan, Everett Springer,George Zyvoloski, Pat Fasel, Sue Mniszewski, Gary Langhorst, and Larry Winter
Los Alamos National Laboratory

The objectives of the LANL coupled modeling effort include the development of an integrated computational model of arid and semi-arid basins, using existing models, to simulate the entire water cycle. A second objective is to use the computer model to better understand and predict the complex effects on the system, including feedbacks, by forcings such as climate variability and land use change. A third objective is to provide a fundamental scientific basis for decision-making with regard to water resources. Our focus has been on the upper Rio Grande basin and results of simulations of the 1992-1993 water year will be presented.

We will include discussion of recent development on the coupled modeling system, which has concentrated on the inclusion of the sub-surface hydrology model, Finite Element Heat and Mass (FEHM). We are working to produce a fully unstructured multiple processor FEHM, which will have the ancillary benefit of coupling UZ and SZ problems as well as many other multiple problem, multiple physics applications. We are also currently installing a surface flow module in FEHM for use in modeling of the complete water cycle.

RG-5

Sources of Recharge and Salinity in the Shallow Aquifer near El Paso, Texas: A Geochemical Assessment

Jason S. Dadakis[1], Christopher J. Eastoe[2], James F. Hogan[1], Brenda Ekwurzel[1,2], Barry J. Hibbs[3], William R. Hutchison[4]

[1]SAHRA, Dept. of Hydrology and Water Resources, University of Arizona

[2]Dept. of Geosciences, University of Arizona

[3]CEA-CREST, California State University – Los Angeles, Dept. of Geological Sciences

[4]El Paso Public Water Utilities

Long neglected in hydrologic studies due to its inferior water quality, the shallow aquifer (also referred to as the Rio Grande aquifer or alluvium) near El Paso, Texas is now recognized as critical pathway for recharge and salinity input to both the underlying Hueco Bolson aquifer and the overriding Rio Grande. The Hueco Bolson aquifer serves as the main water supply for the cities of El Paso (pop. 580,0000) and neighboring Ciudad Juárez, Mexico (pop. 1,200,000), whereas the Rio Grande provides the irrigation waters for extensive local agriculture. We seek to identify sources of recharge and salinity to the shallow aquifer via geochemical tracer analysis of 40 groundwater samples. Stable isotope analyses of hydrogen and oxygen indicate the Rio Grande is the significant source of recharge to the shallow aquifer, but also show recharge waters with varying degrees of evaporation from their source prior to infiltration. The variable evaporation is accompanied by distinct ^{3}H and ^{14}C values, leading us to hypothesize that the less evaporated waters recharged prior to the completion of the Elephant Butte Dam in 1916. Stable isotope analyses of sulfur and major ion chemistry ratios provide strong evidence for saline groundwater discharge as a significant source of salinity to the Rio Grande in the southeastern portion of the study area.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-6

Differences in SWE Values Between Snow Telemetry (SNOTEL) Snowcourse Stations in the Colorado River Basin

K.A. Dressler[1], S.R. Fassnacht[2], and R.C. Bales[3]

[1]Dept. of Hydrology and Water Resources, University of Arizona

[2]Dept. of Forest, Rangeland, and Watershed Stewardship, Colorado State University

[3]Dept. of Engineering, University of California, Merced

Snow water equivalent (SWE) was originally collected by the NRCS at key index sites known as snowcourses. In the late 1970s, the SCS began replacing manual snowcourse measurement sites with an automatic network of SNOTEL stations. While site placement of SNOTEL was based on locations for which snowcourses showed a high correlation with streamflow, differences in SWE measured at co-locations of snowcourse and SNOTEL occur. Because SWE is ultimately used as a tool for streamflow prediction, differences between co-located SWE measurements are evaluated. SNOTEL and snowcourse SWE data (1990-1999) are examined, and a three-year subset (1993, 1998, and 1999) was selected and spatially distributed, representing a range of water years (e.g. average, below average) in relation to SWE volume. Highest correlation (0.94) of co-located SWE values occurred during the average and below average snow years (1998 and 1999), respectively, while RMSE interpolation error of the distributed SWE was not significantly different between SNOTEL and snowcourse. Snowcourse SWE volume was an underestimation with respect to SNOTEL SWE volume within all elevation bands at the sub-basin scale but was an overestimation on the whole basin scale. Semi-variogram analysis shows that SNOTEL has a smaller correlation length scale (300 km) than snowcourse (400-500 km), indicating that snowcourses are more regionally representative than SNOTEL.

RG-7

An Optimal Crop Model Applied to the San Luis Valley, Colorado

Mary Ewers, David S. Brookshire, Janie M. Chermak, and Emily Hepker
Dept. of Economics, University of New Mexico

The San Luis Valley, Colorado is an agrarian community located near the headwaters of the Rio Grande. There is no water storage in the Valley and so the agricultural sector is dependent on mountain front runoff and groundwater. Of interest is the possibility of enhancing the efficiency of water use through differing crop mixes, water banking institutions, or even changes in the current rules governing water trades within the Valley.

We developed a crop allocation model that maximizes agricultural profits constrained by land by and water availability. The decision making unit on at the level of a single ditch, which maximizes net income by choosing the optimal cropping pattern, land and water usage, given input and output prices. Additional relevant constraints are included that are consistent with farming practices in then Valley. The model finds the optimal cropping pattern and land usage for the southern portion of the Valley, given water availability. It also allows us to observe optimal water transfers across ditches in periods when water availability is a binding constraint. In addition, we estimate the overall impact on the regional economy including both primary and secondary effects. We find that, for a year similar to 1997, a change in the cropping pattern that would have includes more potatoes and less pasture would have resulted in not only increased primary benefits to the Valley but also increased secondary benefits.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-8

Evaluation of a Hydrologic Model of the Rio Grande Using a Long-Term Dataset of Land Surface Fluxes and States

Patrick E. Fritchel, Douglas P. Boyle, and Joseph R. McConnell
Division of Hydrologic Sciences, Desert Research Institute

Researchers at the Desert Research Institute (DRI) are conducting SAHRA-related research aimed at (1) developing and calibrating both operational and physically based numerical models that can be used to predict the quantity and timing of runoff in semi-arid regions where the majority of runoff originates in the seasonal snow pack; and (2) understanding the spatial and temporal distribution of snow and water balance above the mountain front. Unfortunately, observations of hydrologic variables (precipitation, streamflow, evapotranspiration, snow water equivalent, etc.) are sparse in the semi-arid regions of the western United States and, therefore, the evaluation of model accuracy (usually in terms of streamflow) is often very limited. However, comparisons of model output with newly developed high-resolution estimates of hydrologically based land surface fluxes and states may provide insight to model accuracy in areas with limited observed information. In this study, we continue earlier activities by applying a hydrologic model to the Rio Grande (above El Paso, TX) and comparing the model output to observed streamflow and snow water equivalent (SWE) estimates at various locations within the watershed. Specifically, the USGS Precipitation-Runoff Modeling System (PRMS), within the Modular Modeling System (MMS), is applied to the watershed at a daily time step with a spatial resolution of 1/8 degree. Many of the model parameters are derived directly from spatial information describing important hydrologic characteristics of the watershed (e.g., soils, vegetation, slope, aspect, etc.) using existing empirical relationships. Model output for streamflow is generated at the watershed outlet (El Paso, TX), as well as for each hydrologic response unit (12 km HRU grid). From this comparison, we hope to gain a better understanding of the role of basin scale, grid resolution, and uncertainty associated with current prediction methods.

RG-9

System Dynamics Applied to the Conchos Basin

Jesus Gastelum[1], Juan B. Valdes[2], Steven Stewart[3]
[1]Dept. of Hydrology and Water Resources, University of Arizona
[2] Dept. of Civil Engineering and Engineering Mechanics, University of Arizona
[3] Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA)

During recent years the Rio Conchos basin has become important because it is the single largest tributary to the lower part of the of the Rio Grande/Rio Bravo. Recent droughts in the Conchos basin have resulted in smaller water deliveries by Mexico than required by the 1944 Treaty that divides Rio Grande/Rio Bravo waters between the U.S. and Mexico. We develop a system dynamics model (SD) to identify and better understand the important elements related to water supply and demand and their interaction in this basin. Model simulations including hydrologic profiles, ecosystem variability, changes in irrigation technology, and changes in reservoir management regimes within the basin will inform decision makers of changes that could increase water supply or manage demand for water in the short and long-term for the whole watershed. The model will also help Mexican decision makers address water deficits due to drought conditions under the International Treaty of 1944.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-10

Evaluating Distributed Mountain-Block Recharge at the Hillslope Scale

Huade Guan and John L. Wilson
Dept. of Earth and Environmental Science, New Mexico Institute of Mining and Technology

The first step to distributed mountain-block recharge is to partition precipitated water on the hillslope. If there is any water moving through the block to the adjacent basin, it must enter the mountain block at this scale. Steady and quasi-steady simulations have been conducted on conceptual semi-arid hillslopes to understand the water partitioning at the hillslope soil-bedrock interface. The results confirm conventional opinion that water availability and bedrock (matrix and fracture) permeability are primary controls on the amount of water partitioning from the land surface into the underlying bedrock of semi-arid mountain blocks. Both steady and quasi-steady simulations show that the annual percolation rate across the soil-bedrock interface approaches saturated bedrock hydraulic conductivity when the mean net infiltration rate into the soil exceeds rock conductivity. When the mean infiltration rate is lower, the percolation rate approaches the mean infiltration rate. Evapotranspiration, slope, and macropore-flow in the soil affect the water availability at the soil-bedrock interface. High temporal-resolution precipitation data, ET modeling, and macropore-flow modeling are required to accurately simulate water partitioning on the hillslope. A preliminary two-component ET model, designed for openly vegetated surface in a typical semi-arid environment is also presented.

RG-11

Toward Higher Quality of Precipitation Product for the Southwest United States: A New Operational Rainfall Estimation Model-Cloud Classification System (CCS)

Yang Hong[1], Kuolin Hsu[2], Xiaogang Gao[2], Soroosh Sorooshian[2], and Bisher Imam[2]
[1]Department of Hydrology and Water Resources, University of Arizona
[2] Dept. of Civil and Environmental Engineering, University of California

Measurement of high quality of precipitation is a key challenge for semi-arid and mountainous region. A satellite-based rainfall estimation system, named PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks), has been providing global rainfall products at 6-hour 0.25^o x 0.25^o resolution. In this continuing study, a new operational PERSIANN-CCS system that processes the information contained from cloud patch instead of from pixel or window, is developed to estimate rainfall at hourly 0.04^o x 0.04^o scales.

The resulting rainfall estimates of PERSIANN-CCS are then validated with ground rainfall observations over a range of spatial (0.04^o, 0.12^o, 0.24^o, 0.5^o, and 1.0^o) and temporal scales (from hourly to monthly) over Rio Grande Basin. The results show consistent and significant improvements in comparison with other existing rainfall algorithms such as Adjusted GOES Precipitation Index (GPI), PERSIANN, Auto-Estimator (AE), and Universal Adjusted GPI (UAGPI). Validation results demonstrate that operational PERSIANN-CCS system is capable of providing seamless high spatial/temporal resolution of precipitation product for full coverage of North American Monsoon Experiment (NAME) and Southwest of USA (interest of SAHRA).

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-12

Nonparametric Approaches for Bivariate Drought Characterization: Case Study in the Conchos River Basin in Mexico

Tae-Woong Kim[1], Juan, B. Valdés[1], and Javier Aparicio[2]
[1]Dept. of Civil Engineering and Engineering Mechanics, University of Arizona
[2]Hydrologic Technology Division, Mexican Institute of Water Technology (IMTA)

The increasing vulnerability to recurrent droughts in the Conchos River Basin affects the sustainable water resource management in the Lower Grande/Bravo River Basin. A comprehensive drought analysis is required to mitigate drought-related impacts. Preliminary results of the SAHRA research during last two years show that nonparametric approaches allow more flexibility for drought characterization by approximating the probability distribution function of interest. This study focuses on the development of nonparametric methods in which, using a kernel density estimator, a nonparametric random procedure is proposed for synthetic generation of hydrologic time series. The synthetically generated data from the nonparametric distribution allows a bivariate characterization of droughts. Based on the nonparametric probability density function estimator, comprehensive approaches for evaluation of drought characteristics both at a site and on a regional basis are presented.

RG-13

Investigating Instantaneous and Long-Term Water Quality Trends in the Rio Grande Using Environmental Tracers

Heather F. Lacey, Suzanne K Mills, and Fred M. Phillips
Dept. of Earth and Environmental Science, New Mexico Institute of Mining and Technology

Since August of 2000, seven semi-annual synoptic sampling trips have been performed along the Rio Grande from the headwaters in Colorado to Ft. Quitman, TX. Samples from August of 2001 and January of 2002 were analyzed for chloride (Cl^-) and bromide (Br^-) and employed in an instantaneous steady-state mass balance model for this ~1200 km length of river. These models suggest that agricultural systems, the low-flow conveyance channel, riverbed seepage, and major reservoirs play important roles in movement and storage of salts in the Rio Grande system.

Furthermore, comparison of chloride burden data from these synoptic sampling trips, as well as weekly to monthly samples collected by K-12 schools participating in the GLOBE program, has provided quantitative information about the chloride budget of the Rio Grande, which will be presented and compared with historical chloride burden data.

Future research on salinity of the Rio Grande will involve building on the previous instantaneous mass balance model to incorporate historical chloride load data records in order to create a transient mass balance model to simulate solute history in the river. This will also involve preliminary analysis of non-conservative solutes in the Rio Grande and investigating chloride input from groundwater.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-14

Estimating the Spatial Distribution of Snow Water Equivalent in an Alpine Basin Using Binary Regression Tree Models: the Impact of Digital Elevation Data and Independent Variable Selection

Noah P. Molotch[1], Michael T. Colee[2], Roger C. Bales[3], and Jeff Dozier[2]
[1]Dept. of Hydrology and Water Resources, University of Arizona
[2]Donald Bren School of Environmental Science and Management, University of California, Santa Barbara
[3]Division of Engineering, University of California, Merced

This work presents a comparison of regression tree snow distribution models using different source digital elevation models (DEMs) and different combinations of independent variables. Different residual interpolation techniques are also compared. The analysis was performed in the 19.1 km^2 Tokopah basin, located in the southern Sierra Nevada of California. Snow depth, the dependent variable of the statistical models, was derived from three snow surveys (April, May and June, 1997), with an average of 328 depth measurements per survey. Estimates of distributed SWE were derived from the product of the snow depth surfaces, the average snow density (54 measurements on average), and the fractional snow covered area (obtained from the Landsat Thematic Mapper and the Airborne Visible/Infrared Imaging Spectrometer). Independent variables derived from the standard US Geological Survey DEM yielded the lowest overall model deviance and lowest error in snow depth prediction. Simulations using the Shuttle Radar Topography Mission DEM and the National Elevation Dataset DEM were improved when northness was substituted for solar radiation in five of six cases. Co-kriging with solar radiation proved to be the best method for distributing residuals for April and June, with inverse distance weighting providing the best result for May.

RG-15

Water and Solute Sources Along a 1000 km Reach of the Upper Rio Grande

Gretchen Oelsner[1], James Hogan[1], Paul Brooks[1], Suzanne Mills[2], John Villinski[1], Heather Lacey[2]
[1]Dept. of Hydrology and Water Resources, University of Arizona
[2]Dept. of Earth and Environmental Sciences, New Mexico Institute of Mining and Technology

Three years of seasonal synoptic sampling of the upper Rio Grande (north of Fort Quitman) has demonstrated that runoff from the San Juan and Sangre de Cristo mountain ranges at the headwaters of the Rio Grande is the primary source of water for the river. Water quality, both salinity and nutrient concentrations, degrades with distance downstream, with ^{36}Cl, $^{87}Sr/^{86}Sr$, and $\delta^{34}S$ indicating that the sharp increases in salinity primarily are due to deep saline groundwaters that enter the river at the ends of sedimentary basins, rather than from agricultural discharge or evaporation. In contrast, nutrient increases are due to localized surface water inputs both from agricultural and urban sources. Exchange between surface water and riparian and hyporheic systems appears to result in the net removal of nitrate from the river. Recent data show that the drought of 2002-2003 has increased solute concentrations throughout the river compared to previous non-drought years.

Current research focuses on quantifying the interactions between agricultural and urban land use and nutrient loading into the Rio Grande as well as nutrient sinks within the surface water and riparian systems. Results of this research will guide future river management practices designed to ameliorate nutrient loading.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-16

A Multi-Scale, GIS-Based, Hydrologic Modeling Tool for Dynamic Water Balance Estimation: The Rio Grande of Colorado and New Mexico

Yizhong Qu and Christopher Duffy
Civil and Environmental Engineering, Pennsylvania State University

A new distributed hydrological modeling system is presented based on a finite volume decomposition using Geographic Information System tools (ARC_GIS) for pre- and post-processing. In this approach, we approximate the coupled partial differential equations, for unsaturated-saturated groundwater flow, channel and overland flow with a semi-discrete version of the finite volume formulation, resulting in a system of fully coupled ODE's. The subsurface and surface state variables are represented as volume averages within each discrete volume-element of the terrain. In the small scale limit of prismatic elements, the approach approximates the original PDE's. For intermediate or large support scales (>1-10 km^2) of interest here, the volume-average, discrete dynamical system represents a coarse-resolution, fully coupled water budget across complex terrain.

RG-17

Increasing Demands, Finite Supply: Water Allocation Choices and Tradeoffs in the Upper Rio Grande, 2003-2040

Jesse Roach[1], Vince Tidwell[2], Kevin Lansey[1], and Gary Woodard[1]
[1]Dept. of Hydrology and Water Resources, University of Arizona
[2]Sandia National Laboratories

The upper Rio Grande is a limited and fully utilized water supply for four states in two countries. Despite significant storage infrastructure, and supply augmentation by inter-basin transfers, the upper Rio Grande River is effectively dry south of the border towns of El Paso, Texas, and Juarez, Mexico. While upper Rio Grande water supply is finite, and already fully allocated and used, industrial, municipal, and environmental demands for water are growing rapidly throughout the basin. What combination of new supply, more efficient use, re-use, continued ground water mining, shifting of water use patterns, or other possibilities as yet unconsidered will be required if these growing demands are to be met? What combination of possibilities might be most beneficial to society as a whole? Starting with existing surface water models, and building on the knowledge and experience of SAHRA researchers at Sandia Labs, the University of Arizona Department of Hydrology and Water Resources, and the University of New Mexico Economics Department, a multidisciplinary dynamic systems model is being developed to address these questions.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-18

Ecohydrological Control on Soil Moisture Fluxes in Arid Vadose Zones

Renee Sandvig and Fred Phillips
Earth and Environmental Science Dept., New Mexico Institute of Mining and Technology

Previous research on vadose zone hydrodynamics under several ecological communities was preformed at New Mexico Tech with SAHRA funding. Two closely spaced boreholes were drilled under each of these ecological communities: creosote, grassland, and juniper woodlands. The vadose zone water-potential profiles of these sites reflected an increasing trend of long-term drying from juniper to grassland to creosote. Chloride bulge profiles containing approximately 12 to 16 kyr of atmospherically derived chloride were found at the grassland and creosote sites. In contrast, low chloride concentrations characterized profiles from the juniper sites.

These previous research results have identified ecohydrological factors as possibly being crucial components in identifying the hydrological characteristics of arid vadose zones. These results also demonstrate that easily measurable vadose zone properties are a key to understanding these ecohydrological factors. The objective of this work will be to test whether there are clear and reproducible associations between ecological communities and the hydrodynamics of the underlying vadose zone. A sufficient amount of data will need to be obtained to adequately characterize the vadose zone regime under the important ecological communities. Approximately ten 10-m deep boreholes under ponderosa pine, juniper, grassland and creosote communities will be drilled.

To determine if soil-moisture fluxes in the vadose zone are governed by ecohydrological rather than hydrometeorological conditions, these ecological communities will be tested along a transect in Socorro County, New Mexico. The hydrometeorological conditions of this transect are quantified by means of the aridity index, which consists of the average annual potential evaporation divided by the average annual precipitation. The aridity index decreases gradually along the transect, from east to west. This transect also contains the four ecological communities that will be tested. If the control on vadose zone soil moisture fluxes is hydrometeorological, then a gradual transition of vadose zone characteristics along the transect should be observed. Conversely, if the control is ecohydrological, the transitions should be abrupt and coincide with ecotones.

RG-19

Capabilities of the New FARM Package for MODFLOW-2000

Wolfgang Schmid and Thomas Maddock III
Dept. of Hydrology and Water Resources, University of Arizona

A new FARM package (FMP) was developed for MODFLOW-2000. The main objective was to offer irrigators a tool for conjunctive management during drought situations. The program allows several choices of drought policy scenarios such as "optimization of acreage," "deficit irrigation," and "water-stacking for priority crops." Being linked to the Stream-Flow Routing Package of MODFLOW, the program is able to simulate surface-water supply and farm irrigation demand, as well as to estimate supplemental groundwater use required to sustain the crops growth for each of the drought scenarios. Water managers may manipulate the surface-water and groundwater supply in a model by limiting diversions from canals/laterals to certain allotments and by restricting well discharge rates to maximum capacities.

Irrigation demand and supply are in part subject to head-dependent sources and sinks such as evapotranspiration from groundwater and leakage between canals and aquifer. The program algorithms needed to account for those head-dependent boundary conditions (net-recharge from farms, demand-dependent farm well discharge, stream-aquifer leakage), for the inter-linkage between them, and to update source/sink term flow rates according to the application of a specific drought scenario.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

RG-20

Hydro-ecological controls on water cycling across semiarid ecosystems in the Rio Grande Basin: a transect of field sites in the Valles Grande and Los Alamos area

Roger Bales[1], Fred Phillips[2], J. Shuttleworth[3], E. Small[4], John Wilson[2]
[1]Div. Of Engineering, University of California at Merced
[2]Earth and Environmental Sciences, New Mexico Institute of Mining and Technology
[3] Dept. of Hydrology and Water Resources, University of Arizona
[4] Dept. of Geosciences, University of Colorado at Boulder

In semiarid drainage basins, a variety of different ecosystems are found along the precipitation and temperature gradients that exist between basin floors and mountain tops. It is expected that differences in these various ecosystems both control and reflect how water and energy cycling vary between these environments. Quantifying these differences is critical to predict how changes in ecosystems due to natural and anthropogenic processes could impact basin-wide water and solute budgets.

We are designing a series of field sites with identical instrumentation and data collection to probe the following two questions. First, how do hydro-ecological interactions control the water fluxes and storage that constitute the basin scale water balance? Two key fluxes are (1) the downward flux in the vadose zone, past the base of the root zone; and (2) hillslope runoff and streamflow, either to trunk streams or locations of preferential recharge. Second, how can hydro-ecological interactions, which are the outcome of processes that occur at the meter scale, be represented at the scale of hillslopes to basins? Identifying scale-dependence and formulating appropriate *effective parameters* is essential to represent the basin wide outcome of system perturbations such as drought. A series of new field sites are planned in the vicinity of Los Alamos National Lab and Valles Grande National Preserve, including the following ecosystems: Juniper savanna, Pinon-Juniper savanna, Ponderosa forest, Spruce-fir forest, and high elevation meadows. Data from these sites will be compared to existing SAHRA installations on Mt. Bigelow and at the Sevilleta LTER. Simulations of surface and vadose zone flow and transport will be compared to the data collected across the full range of semiarid environments found in the Rio Grande Basin.

RG-21

Evapotranspiration and Soil Moisture Estimation in Middle Rio Grande Basin with LANDSAT7 Using SEBAL

Sung-ho Hong and Jan M.H. Hendrickx
New Mexico Institute of Mining and Technology

Evapotranspiration (ET) and soil moisture are an important element of the hydrologic cycle in arid environment. The accurate information of those is significant for understanding the interaction between land surface and atmosphere over a range of space and time scales for sustainable management of water resources.

In this study, Surface Energy Balance Algorithms for Land (SEBAL) was selected to estimate ET and soil moisture in the riparian areas over middle Rio Grande Basin in New Mexico. The objective of this study is to validate SEBAL performance and to present the daily ET and soil moisture for heterogeneous large areas. The approach is to compare SEBAL ET rates with those measured on the ground with eddy covariance towers. The result of this study shows that the SEBAL approach appears to be reliable for estimation of ET and very helpful to understand the regional scale ET and soil moisture distribution.

RG-22

Quantifying the spatial heterogeneity and covariance between surface hydrologic properties at multiple scales on semarid hillslopes

Eric Bhark and Eric Small
Dept. of Geosciences, University of Colorado at Boulder

In arid to semiarid ecosystems, the spatial distribution of surface properties influences how precipitation is partitioned into infiltration, runoff, and evapotranspiration. This partitioning is critical to a variety of hydrological and ecological processes and the interactions between them, e.g., hillslope runoff contribution to a drainage network. We study hillslope surface properties that influence spatial patterns of infiltration and runoff, including vegetation mosaic geometry, microtopography, and soil hydraulic properties, from the centimeter to tens-of-meters scale. During the summer and fall of 2003, approximately 8,000 (combined) measurements of these properties were collected in creostebush shrubland and black grama grassland hillslopes in the Sevilleta National Wildlife Refuge, central New Mexico. Measurements were collected over plots of various size, with sampling designed for semi-variogram estimation. All measurements were colocated.

Auto- and cross- relationships, in the form of semi-variance functions, are first characterized between properties. These relationships are used to define spatial scales of heterogeneity and (an)isotropy within and between variables. Geostatistical models assigned to each function permit co-interpolation and conditional co-simulation of 2D spatial surface fields of these properties. Preliminary results show strong spatial correlation between properties, permitting significant improvement of primary variable interpolation using colocated secondary data. Finally, the property fields are to be used as parameter fields in simulation of surface-water flow over semi-arid hillslopes.

San Pedro Basin Projects

SP-1

Isotopic Tracers for Quantifying Mountain Front Recharge and Groundwater Flowpaths in the San Pedro River Basin, Arizona

Matthew Baillie[1], Arun Wahi[1], James Hogan[1], Brenda Ekwurzel[1,2], and Chris Eastoe[2]
[1]Dept. of Hydrology and Water Resources, University of Arizona
[2]Dept. of Geosciences, University of Arizona

The San Pedro River Basin contains the growing city of Sierra Vista and one of the few remaining desert riparian habitats. Striking a balance between increasing residential water needs while sustaining native riparian vegetation in a semiarid climate is a significant challenge. This requires us to improve our understanding of fundamental hydrologic processes in the basin. In particular, mountain-front/mountain-block recharge (MFR) is a significant component of basin recharge that is poorly quantified, with errors between 50 and 100 percent. This study will employ a suite of natural geochemical tracers to (1) improve understanding of MFR processes and rates, and (2) determine basin hydrologic flowpaths and residence times. The stable isotopes of hydrogen and oxygen will indicate precipitation source and seasonality. Noble gas concentrations will constrain the elevation of recharge. Tritium-helium and carbon-14 isotopes will determine residence times. Sampling will occur along two transects: one parallel to the mountain front and a second across the basin to examine the partitioning between recharge through the mountain block and recharge at the mountain front, identify recharge elevations, and quantify flowpath residence times. This study will improve conceptual understanding of the recharge processes in the basin and provide data to calibrate existing groundwater models.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-2

A New Method For Determining Riparian and Wetland Evapotranspiration

Kathryn J. Baird
Dept. of Hydrology and Water Resources, University of Arizona

To improve the ability to determine riparian and wetland ecosystem evapotranspiration (ET) and predict ecosystem response to changing water conditions, a new methodology to simulate ET was developed and applied in a new groundwater modeling package, RIP-ET. The traditional approaches to modeling ET processes assume a piecewise linear relationship between the ET flux rate and hydraulic head. Our methodology replaces the traditional linear relationship with a segmented, nonlinear dimensionless curve that reflects the eco-physiology of riparian and wetland plants. Plant functional groups (PFGs) based on transpiration rates, plant rooting depth, and drought tolerance are used to elucidate the interactive processes of plant ET with groundwater conditions. Measured ET rates from two semi-arid arid areas are combined with literature research to develop PFG-ET curves. For each PFG, the ET curves provide the flux rate as a function of water table depth relative to the ground surface and set the extinction and saturation extinction depths. The use of eco-physiologically based ET curves results in more accurate determination of riparian ET while simplifying the complex structure of plant communities into PFGs provides a framework for predicting ecosystem response to environmental change. Directly linking groundwater conditions and plant functional groups offers the opportunity to better manage and restore riparian and wetland systems.

SP-3

New Approaches to Assessing and Valuing Riparian Resources in Arid Regions

Rosalind H. Bark[1] , Gabrielle Katz[2], Julie Stromberg3 , Daniel E. Osgood[4] , and Bonnie G. Colby[4]
[1] Office of Arid Land Studies, University of Arizona
[2] Dept. of Geography & Planning, Appalachian State University
[3] School of Life Sciences, Arizona State University
[4] Dept. of Agricultural and Resource Economics, University of Arizona

This study investigates whether homebuyers' valuation of nearby riparian resources can be statistically linked to the biological value of the riparian habitat. We are using an enhanced hedonic price model that includes not only the typical information on the distance between residential properties and the riparian zone, but also data on the quality of the riparian habitat. The hedonic method statistically links real estate sales prices to a set of factors that influence property prices, for example, age, living area, distance to amenities/disamenities, etc. One of our project objectives is to examine whether riparian habitat quality indicators can be derived from widely available remote sensing data. To this end, detailed field data has been collected at 51 riparian field sites in urban and ex-urban Tucson, Arizona for parameters such as vegetation volume, canopy height and species diversity. In addition, qualitative amenity/disamenity parameters were recorded, such as presence or absence of trails, cemented channels and refuse. The next phase is to statistically compare remote sensing vegetation indices with our field data. The final data phase is to develop amenity indices and to include the vegetation and amenity data in hedonic analysis. For the analysis we will test if remote sensing indices are appropriate proxies for biological value and if homebuyers' valuation is actually linked to biological value.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-4

Characterizing Water, Energy and CO_2 Exchange for a Sky Island Subalpine Forest in the Southwestern USA

Constance Brown-Mitic[1], Jim Shuttleworth[1], Eleanor Burke[1], Jon Petti[1], Chawn Harlow[1], and Roger Bales[2]
[1]Dept. of Hydrology and Water Resources, University of Arizona
[2]Dept. of Civil Engineering, University of California, Merced

Among the ecosystems present in the semi-arid environment of the Southwestern U.S., *Sky Island Forest* is unique and it has a unique relationship to the sparse surface-water resources available in the region. This ecosystem exists only at the top of mountains because it is only here that, as a long-term average, precipitation input exceeds evapotranspiration to the extent that forest vegetation can survive. *Sky Island Forests*, therefore, command potentially significant source areas for the water (some originally falling as snow) that ultimately leaves topographically high ground to recharge aquifers in the plains below by mountain-front recharge. They are also very recently recognized as important carbon sinks where very little or no understanding exists of the exchange/cycling dynamics. The 30-m eddy correlation flux tower on Mount Bigelow provides an empirically based understanding of the hydro-micrometeorological dynamics of a sky island subalpine forest in the southwestern U.S. It is the first study to attempt to document, understand, and model the water, energy, and (related) carbon exchanges of the uniquely interesting and, from the water resource standpoint, uniquely important *Sky Island Forest* ecosystem. An important observation was that during the pre-monsoon season, the trees basically shut down, with the exception of brief periods in the morning and or afternoon where CO_2 uptake directly correlates with low rates of evapotranspiration. For the most part of the day evapotranspiration (E) fluctuates around zero, and becomes negative (moisture been extracted from the atmosphere, i.e. advection) around noon. This means that the evaporative fraction (E/E+H) is zero, Bowen Ratio (H/E) is extremely large, and radiative heating, i.e., sensible heat flux, dominates the energy budget. These interrelationships are directly evident in the physiological response of the vegetation as observed from MODIS vegetation indices. During the post-monsoon period (September) the ecosystem recovers very rapidly with Bowen Ratios of approximately one and high levels of CO_2 uptake. The net uptake of CO_2 by the vegetation, persist during the winter months, a situation that would not have previously been expected or assumed based on conventional understanding and assumptions.

SP-5

Riparian N Cycling: Impacts of Plant Communities and Fluctuating Groundwater Table on Microbial N Transformations

Tamara K. Harms and Nancy B. Grimm
School of Life Sciences, Arizona State University

Riparian areas are recognized hot spots for retention of nutrients, such as N, dissolved in run-off water that commonly pollute streams and groundwaters. The mechanisms underlying this high retention capacity likely link a suite of physical and biological factors but are not fully delineated. Understanding riparian N cycling will help to develop predictors of capacity to retain N within the riparian zone, an important factor in determining effects of potential pollutants on water quality.

My research addresses the relationship between two biotic components: plant species composition and microbial N transformations, and the influence of groundwater hydrology on this relationship. Plants supply organic carbon (C) to microbes and depend on microbes for conversion of organic N to inorganic, or mineralized forms which plants can access. Plant species vary in their C and N contents, and the rates at which their tissues turnover. Microbes respond to variation in C and N availability by differentially incorporating N into their biomass where it is unavailable to plants, or releasing mineralized N. I have measured plant C and N contents in plant communities of various species composition and will determine the extent to which these data explain rates of microbial N mineralization and immobilization. Further, I have measured soil and groundwater chemistry and will determine the impacts of a subsurface flowpath and fluctuating groundwater table elevations on microbial N processing.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-6

Application of Electrical Geophysical Techniques to Hydrology

Andrew Hinnell[1], Alex Furman[1], Ty Ferré[1], and Arthur Warrick[2]
[1] Dept. of Hydrology and Water Resources, University of Arizona
[2] Dept. of Soil, Water, and Environmental Science, University of Arizona

Subsurface hydrological investigations often suffer from an inability to measure hydrologic properties with sufficient spatial and temporal resolution. In some instances, electrical geophysical techniques can provide these much needed measurements at relatively low cost, with minimal disruption to the hydrological system under investigation, and at appropriate measurement scales. Examples include mapping areas of active infiltration in alluvial channels, monitoring changes in infiltration over time in focused recharge basins, and tracing solute movement between surface and subsurface regions in riparian corridors.

Research supported by SAHRA has helped to build capabilities within the Department of Hydrology and Water Resources at the University of Arizona for conducting hydrologic investigations using electrical geophysical methods. Investigators, working in conjunction with researchers at the United States Geological Survey, have applied these methods to monitor water movement under a variety of settings. In addition, they have made improvements to the ERT method through a detailed analysis of the spatial sensitivity of electrical resistivity measurements, and optimization of these measurements to reduce the time of measurement and increase the data worth. The result is a technique that should be better suited to the rapidly changing environment often encountered in hydrological investigations both for future SAHRA investigations and throughout the hydrologic community. The next step in our research is to test the theoretical improvements that we have developed. We hope that other SAHRA researchers will help us to test our findings by including electrical geophysical methods as a part of their site investigations.

SP-7

Toward the Development of a Routing Procedure that Parameterizes the Grid-scale Dependence of Channel Transmission Loss in a River Network for a Semi-Arid Watershed

Felipe Ip
Dept. of Hydrology and Water Resources, University of Arizona

Efforts have been undertaken to develop a methodology to parameterize the grid-scale dependence of channel transmission loss in a river network. An effective channel is built that incorporates both the linear and nonlinear characteristics of channel transmission loss during routing and will be applied to the San Pedro River basin. Channel transmission loss has long been recognized as an important process in the semi-arid regions hydrological cycle. Together with mountain front recharge, it serves as the other major source of recharge to the groundwater. Others have tried to model this process. For example, Smith and Goodrich presented a model that can simulate infiltration from rainstorms on areas exhibiting random variation in saturated hydraulic conductivity K_S in the KINEROS model. Diaz-Granados, Bras and Valdés tried to incorporate it into their Geomorphologic IUH. In this research, we present the groundwork of the application of an "effective channel" concept to runoff routing with explicit channel loss representation at the catchment scale. The meta-channel concept is used to derive the basic hydraulic and geometric parameters needed to build the effective channel. Appropriate parameters are being investigated and will be used to model the channel transmission loss, and to study the effects of grid-scale on channel transmission loss. The underlying geomorphology is implicitly built into the effective channel through the channel network width function. The spatial heterogeneity is built in through the downstream variation of hydraulic geometry, and the nonlinearity is introduced through the use of discharge dependent celerities and dispersion coefficients.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-8

Factors Affecting Microbial Respiration in Stream Sediments During Monsoonal Flow, Upper San Pedro River, Southeastern Arizona

Jamie Krezelok[1], Dean Martens[2], and Martha Conklin[3]
[1]Dept. of Hydrology and Water Resources, University of Arizona
[2]U.S.D.A. Agricultural Research Service, Tucson, Arizona
[3]Dept. of Civil Engineering, University of California, Merced

Streams in the southwestern United States have large inputs of sediments and nutrients during storm events due to high intensity rainfall and overland flow. This study examines the effects of this input of nutrients and sediments on the microbial activity in stream sediments along the San Pedro River during the 2003 monsoon season. Three flow events (>2 cms), in July and August, were monitored for dissolved constituents and sediment scour and fill. In situ respiration measurements were made before and after flow events, at the head end of a point bar, above and below the water table near the stream interface. Methane, N_2O and CO_2 flux measurements were also made above the water table at these times. During flow events dissolved levels of TOC, TDN, nitrite, and nitrate all increased, while sulfate, chloride and bromide all decreased, indicating contributions from multiple sources (e.g. soil water, runoff and rainfall). After a flow event CH_4 and CO_2 fluxes more than tripled from 0.6 μmol/hr to 21 □mol/hr and 6.6 mol/hr to 232 mol/hr respectively, which signifies that methanogenisis increases in the sediments at this time. Immediately after the floods, microbial respiration also increased (~600 mol DO/hr) with the input of nutrients and sediment to the system. Once the floodwater recedes (<0.3 cms), respiration rates decreased (~90 mol DO /hr). Flow events trigger a series of microbial processes in the sediments; the sequence appears to be triggered by the increased availability of nutrients and amount of dissolved oxygen.

SP-9

Detecting Spatial and Temporal Modes of Climate and Landuse From Historical Precipitation-Temperature-Discharge Data: Colorado River Basin

Mukesh Kumar and Christopher Duffy
Civil and Environmental Engineering Dept., Pennsylvania State University

This work is continuation of the efforts to investigate the relation between river discharge (Q), precipitation (P) and temperature (T) across the Colorado and Rio Grande River Basins. In this ongoing effort, 50 years of monthly average streamflow and 70 to 80 years of monthly average data from stations distributed from the upper Green and Colorado rivers to the Gulf of California have been used to develop hypotheses for how historical climate (precipitation and temperature) and land use are expressed in runoff from the basin. Temperature, being closely related to evapotranspiration, in unison with precipitation and stream flow (discharge), serves as the essential forcing needed for assessing characteristic modes of the climate-basin system. Singular Spectrum Analysis is carried out to identify the dominant frequency component in various parts of basin for all the three variables viz. temperature, precipitation and stream flow. The "dominant frequency" represents the seasonal, interannual, interdecadal and longer term trends. High frequency noise component was removed from the variable's time series. Reconstructed low frequency signal was used to generate the "phase-plane" trajectory plots in P-T-Q space. Preliminary interpretation of the trajectory plots suggests the importance of landform (plateau versus basin and range) on groundwater baseflow and landuse (irrigated agriculture and dams) on the trajectories. In order to identify the relation between the forcing to its physiography and spatial location, spatial principal component analysis (PCA) was performed. Factor (component) loadings were obtained by finding the correlation of each station (for each variable) to each principal component. Clustering of factor loadings reveals the forcing's dependence on various local features like altitude, spatial location within a sub-basin, and perhaps other physiographic features.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-10

The Effects of Land Use and Regional Hydrology on Surface Water Quality in the Upper San Pedro River, AZ

Michele Lemon, Paul Brooks, and Anne K. Huth
Dept. of Hydrology and Water Resources, University of Arizona

Six synoptic sampling events were performed along the Upper San Pedro River before, during, and after the 2002 monsoon season. Water samples were analyzed for conservative chemical tracers, nutrients, and organic matter to determine the effects of reach characteristics on water chemistry. During pre- and post-monsoon baseflow periods conservative tracers indicated limited solute transport between the upper, middle, and downstream regions with local land use and hydrologic characteristics affecting nutrient and dissolved organic matter concentrations. During the dry season, conservation areas (i.e. SPRNCA) had significantly higher DOC concentrations, while agricultural and grazing lands were characterized by higher dissolved organic and inorganic nitrogen levels. In contrast, solute concentrations during the monsoon season indicated the entire 95-kilometer stretch was hydrologically linked during this time period. DOM and inorganic nitrogen concentrations increased throughout the upper San Pedro River as terrestrially derived solutes were flushed into the stream by monsoon precipitation. These data suggest that land use practices away from the river in this semi-arid catchment affect surface water quality. Furthermore, limited surface connectivity during the dry season allows solutes to accumulate where they enter the stream-riparian system.

SP-11

Decision Support System for Sustainable Groundwater Management in Semi-Arid Regions

James McPhee and William W-G. Yeh
Dept. of Civil and Environmental Engineering, University of California, Los Angeles

Sustainable water resources management requires meeting today's demands while at the same time ensuring that future generations will be able to satisfy their needs. Future needs can at best be estimated based on our perception of what future generations will consider important and desirable. In water resources management, groundwater overdraft is generally undesirable and it is highly desirable to maintain the natural interaction between aquifer and surface streams. Simulation models are used as tools to predict the impact that various decisions will have on the state of the groundwater system in a river basin. This research combines simulation and optimization to optimize groundwater pumping, artificial recharge and importation policy in the Upper San Pedro River Basin. The problem is posed as a multiobjective optimization problem in which recharge/importation costs, aquifer yield and water table objectives are considered. Explicit tradeoff curves derived for the aforementioned objectives allow decision makers to discriminate between inferior and unattainable policies, therefore guiding the decision-making process. The Decision Support System constructed from the simulation-optimization approach can help answering questions such as maximum pumping rates at different locations, scheduling and intensity level of importation projects, and efficient artificial recharge rates. Furthermore, the assembled decision-support scheme can be used to assess model reliability and evaluate data sufficiency in connection with model calibration by means of a first-order analysis.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-12

San Pedro News and Comment

Luis Migoni, Anne Browning-Aiken
Udall Center for Studies in Public Policy, University of Arizona

The "San Pedro News and Comment" poster will illustrate the benefits of an electronic newsletter service that covers topics related to the Upper San Pedro River Basin in both the United States and Mexico. These topics include 1)water management, water conservation and water policy; 2)land use, growth and development; 3)U.S.-Mexico relations and border issues; 4) scientific research important to the basin; and 5) weather and climate changes. With the results of a recent survey of newsletter readers, the poster will demonstrate how the newsletter is used as a research and community outreach tool, specifically to SAHRA researchers and basin residents seeking to understand the social and political issues and perspectives of US-Mexico border residents on the topics listed above.

SP-13

Permeability of Soil on Mt. Lemmon and Water Sampling at the San Pedro River

Nikita Patel[1], Jamie Krezlock[2] and Karletta Chief[2]
[1]2003 HS Intern, Wilcox High School, Wilcox, Arizona
[2]Dept. of Hydrology and Water Resources, University of Arizona

Permeability after a fire is thought to go down, but the extent is not exactly known. Air permeability of soil requires calculations involving the Darcy's Law equation. Permeability is how well air can pass through the porous soil. Darcy's Law measures the flow of water or air through porous media. Two methods are used to find hydraulic conductivity of soil using Darcy's Law Equation. The first method is using an air permeameter, which injects air into the soil. The second method is using the Constant Head Saturated Hydraulic Conductivity. The in field measurements include trying to find k_{air} (air permeability) through the soil. The k is found by substituting in the known values of Q (air flow rate), h (air viscosity, 1.81E5 kg/ms), A (area of cylinder), differential pressure, P_a (air pressure, 101,325 Pa). k_{air} was correlated using a linear regression to find saturated hydraulic conductivity.

This study focused on how flood water nutrients affect the riparian corridor. Water samples and sediment samples are taken from an area of the river near Boquillas Ranch. Dissolved oxygen is measured from these samples. Three sediment samples are taken from above the water table and three sediment samples are taken from below the water table. The water samples are collected from the Auto Sampler which takes 24-hour samples from the river. These samples are then brought back to the lab and filtered. The filtered samples are run through the Ion Chromatograph, which can detect the levels of Chloride and Nitrate and other chemicals as well. The samples from the flood are especially important because they are compared to the samples prior to the flood; any change in nutrient levels is especially important. Measurements from the Quanta Probe are also done for dissolved oxygen, conductivity and temperature in the river.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-14

Air Permeability

Jinaabah Showa
2003 High School Intern, Tuba City High School, Tuba City, Arizona

When a fire occurs in a forest-type area, the soil becomes hydrophobic particularly for forests with dense ground vegetation. When a fire occurs, it burns existing vegetation and creates a residue that seeps into the soil and forms an impenetrable hydrophobic layer. The hydrophobic layer that was created by the burned vegetation causes high runoff and erosion when it rains. Not only does it affect the vegetation and soil, but it also affects the nearby streams or lakes. The rain that is carrying the ash will run into the nearby body of water. That will cause pH in the water to increase which is harmful to water organisms.

The first objective of this experiment is to find the permeability of soil using an air permeameter. The permeability is the rate which air flows through the soil or the porosity of the soil. The second objective is to compare the permeability measurement for an air permeameter using different flowmeters: a rotameter and a digital flowmeter. We tested at two sites: burned and unburned. The flow rate of the burned site is lower than that of the unburned site.

SP-15

Groundwater Flow Model of the Lower San Pedro River Basin for the Conservation of Riparian Habitats

Jonathan Whittier and Thomas Maddock, III
Dept. of Hydrology and Water Resources, University of Arizona

Water issues in the Lower San Pedro River basin in southeastern Arizona are becoming increasingly contentious as urban development, agriculture, and mining needs compete with the needs of the riparian habitat. To better understand the water demands in this basin, a new groundwater flow model has been created. First, the conceptual model was produced using various Geographic Information System (GIS) applications. A new method allocating digital precipitation data to the smaller drainages within the watershed was used to estimate mountain front recharge. Well data was gathered from both the United States Geological Survey (USGS) and Arizona Department of Water Resources (ADWR). Depth to bedrock was interpolated from an earlier gravity survey of the area. The current extent of riparian vegetation was determined by recent United States Forest Service aerial photography. GIS shapefiles were created depicting the data necessary for MODFLOW. Second, the numerical MODFLOW model was formed using GMS (Groundwater Modeling System), a graphical user interface for MODFLOW. GMS was used to create the grid, allocate the information from the shapefiles into MODFLOW input files, create the MODFLOW numerical model, and calibrate the model. This model is to be used for the conservation of the riparian habitats along the lower section of the San Pedro River.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-16

SAHRA International Collaboration: The Upper San Pedro Basin

Juan Valdés, David Brookshire, David Goodrich, Robert Varady, Anne Browning-Aiken, Kevin Lansey, Patricia Romero Lankao, Steven Stewart, Allison Davis, and Denise Moreno
University of Arizona

Rapid growth along the U.S.-Mexico border increases demands on the region's already limited surface and groundwater supplies. Improved management of shared transboundary water resources requires a multidisciplinary and binational research effort because decision-making occurs within complex ecological and socio-economic relationships, characterized by variability in information flows, unequal access to resources, and uncertain institutional support. To address these challenges, SAHRA researchers, the San Pedro Partnership, the Mexican environmental NGO Asociación Regional Ambiental de Sonora-Arizona, researchers from the University of Sonora and the College of Sonora, municipal leaders, and water managers are collaborating in binational watershed data sharing and planning meetings called "The San Pedro Dialogue on Water and Climate," facilitated by the Udall Center for Studies in Public Policy.

To better characterize the decision-making framework in Sonora, the Udall Center directed a water and climate survey of urban and rural water users, and regional water managers. The survey captures the use of hydrological and metrological information at the household level, water needs and frequency of problems with quality and quantity, impacts of environmental variability in water use, and the influence of policy framework on Sonoran management decisions. The survey complements and broadens earlier surveys conducted in the region.

To further these efforts, Brookshire and Browning-Aiken are currently designing an economic survey of water demand in the upper basin to create an allocation curve of water use, demand and value. The objective of this survey is to determine willingness to pay of Cananea municipal domestic water users in order to define a good water purchase price that will help support more efficient and reliable water delivery.

SP-17

Evaluation of Water Conservation Measures in the Upper San Pedro Basin

Derya Yalcin and Kevin Lansey
Dept. of Civil Engineering and Engineering Mechanics, University of Arizona

The Upper San Pedro basin is one of many regions in Arizona that are facing immediate challenges to meet water. The San Pedro River supports riparian forests and is home to many species, which makes it ecologically valuable. Freshwater resources in the valley are also shared by nearby cities including Sierra Vista, Huachuca City, Bisbee, and Fort Huachuca. A wide spectrum of social, cultural and economic values and interests challenges decision makers, while supplying water needs for the public as well as ensuring the sustainability of the San Pedro River.

The Upper San Pedro Partnership (the Partnership), a consortium of 20 agencies and organizations, has been cooperatively developing water management plans including implementation of conservation measures. However, tools to assist the wide range of water interests understand the impact of decisions are lacking. Supported by the Partnership, a water management tool based on dynamic simulation for the Upper San Pedro Basin, Sierra Vista sub-watershed is being developed.

The tool is the first step in a comprehensive model for the basin. Surface water and groundwater supplies, and demands such as residential and commercial needs, irrigated agriculture, etc., and San Pedro National Conservation Area (SPRNCA) are modeled as separate components. Possible water conservation methods that can be used in the demand side are modeled within each component. Then these components are tied to each other to form the water balance in the sub-basin. Given the ease of selecting and unselecting possible measures, users can quickly examine different combinations to determine if they achieve a water balance and at what cost.

The dynamic simulation model of water balance will help decision makers to see the outcomes of many "what if…" scenarios.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-18

Calibration and Application of the Distributed NOAH Land Surface Model for the San Pedro Basin Using Remotely Sensed Data

Soni Yatheendradas[1], Luis Bastidas[2], Hoshin Gupta[1], and Soroosh Sorooshian[1,3]
[1] Dept. of Hydrology and Water Resources, University of Arizona
[2] Dept. of Civil and Environmental Engineering, Utah State University
[3] Dept. of Civil and Environmental Engineering, University of California at Irvine

A distributed meso-scale medium-resolution version of the NCEP's NOAH land surface model has been setup over the San Pedro basin in Arizona. The model is driven using the 50-year hydrologically balanced land surface data set developed at the University of Washington. For analyzing the model sensitivity to the introduction of remote sensing information, the observed forcings of precipitation and radiation in this dataset were replaced with the remotely sensed forcings of The University of Arizona's PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) data and The University of Maryland's SRB (Surface Radiation Budget) data in stages. The model was calibrated for a variety of vegetation types present in the basin to ground observations of the turbulent heat fluxes and ground temperatures using a multi-criteria calibration technique. The model sensitivity to vegetation classification and model resolution was also investigated.

SP-19

Impact of 2002 and 2003 Wildfires on SAHRA's Mt. Bigelow EC Site

John Petti
Dept. of Hydrology and Water Resources, University of Arizona

From June 17 to July 12, 2003, the Aspen wildfire threatened SAHRA's eddy covariance tower on Mount Bigelow, north of Tucson, Arizona. The human-caused Aspen Fire burned 84,750 acres in the Santa Catalina range and consumed 333 structures. This is the second consecutive year that wildfire encroached on the Mount Bigelow EC site; in May 2002 the Bullock fire burned 30,563 acres mainly in the northeast section of the Santa Catalinas. The 2002 fire proved to have only a minimal impact on our research efforts, but fire prevention efforts in summer 2003 included some tree removal within the 1km footprint of the EC tower site. The flux footprint is in the only remaining unburned patch along the Catalina ridge line.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

SP-20

Cooperative Public Outreach - It Can be Accomplished

Kyle Blasch[1], Kyle Carpenter[2], Sarah Davis[3], Chris Smith[1], Jim Washburne[2], Gary Woodard[2]
[1]U.S. Geological Survey; [2]SAHRA, University of Arizona; [3]USDA Forest Service, Santa Catalina Ranger District

The U.S. Department of Agriculture, Forest Service (Santa Catalina Ranger District of the Coronado National Forest), the U.S. Geological Survey (Water Resources Discipline, Arizona District), and SAHRA have created a series of exhibits on the hydrology of Sabino Creek, an ephemeral stream within the Sonoran Desert (USA) visited by over 1 million people annually. A clear set of educational objectives established at the beginning of the process and interagency cooperation resulted in a cohesive grouping of exhibits while minimizing single agency dominance. The multimedia exhibits are a collection of visual displays along with a touch-screen kiosk that has animations and other links that expand along many avenues to educate people on ephemeral streams, sky islands, siltation, and ground-water recharge within the Sonoran Desert. In addition, the exhibit incorporates real-time climate and streamflow data collected by four science agencies. The real-time data incorporated into the kiosk and linking web page is used to educate visitors about the natural environment within Sabino Canyon and inform them about flash-flooding and fire dangers. Thus, before entering the canyon, a visitor can view the exhibit and readily determine the air and water temperature, stream activity, and several other current and historical environmental variables. In summary, the cooperative efforts between the agencies resulted in a series of exhibits that are far more beneficial to the public than if the efforts had been attempted separately.

Education and Knowledge Transfer Projects

ED/KT-1

Rainwater Harvesting in Nogales, Sonora

Kate Adams
Bureau of Applied Research in Anthropology, University of Arizona, Ambos Nogales Revegetation Partnership

A rainwater harvesting system was planned and designed for Secundaria #3, a public school in Nogales, Sonora, to address severe soil erosion due to storm water runoff and to collect water to irrigate plants and trees. The project involved collaboration between University of Arizona students, the school's ecology professor, and students from the school. A goal of the project was to teach the students about a sustainable and replicable water management system, providing them with the hydrologic literacy to address water concerns and soil erosion management in the community and surrounding region. A component of the project included establishing a method of monitoring rainfall on the school property. It is anticipated that this project will not only enhance water management practices and revegetation at Secundaria #3, but it will also serve as a model to future projects in Ambos Nogales.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

ED/KT-2

Monsoon Madness

Candice Marburger, Elizabeth Hancock, Jim Washburne and Debra Colodner
SAHRA and Flandrau Science Center, University of Arizona

Monsoon Madness was a collaborative effort between SAHRA and Flandrau Science Center to develop a summer camp that introduced children to weather and water basics as related to a desert climate. Camp Monsoon ran for three weeks, beginning July 14, 2003 and ending August 1, 2003, with the goal of allowing the campers to physically experience the monsoon while they simultaneously learned about the monsoon. Funded by SAHRA, Monsoon Madness was designed to meet the center's goals of building an understanding of key water issues and promoting hydrologic literacy through educational efforts. The main topics of the camp included the water cycle, global and local weather, the desert monsoon and human dimensions of the monsoon, all taught through a variety of activities.

Camp Monsoon consisted of three one-week, full-day sessions held at Flandrau Science Center. Jill Rubio, PLT State Coordinator, and Candice Marburger, Geosciences Senior, instructed the camp, although several hydrology and meteorology experts participated in the camp's instruction. Also helping were eight high school PIMAS interns that assisted in management, preparation and minor instructional tasks. Feedback was received and data collected; goals for next year include diversifying camper attendance and altering the balance of activities and instructional goals.

ED/KT-3

Making a SPLASH: Creating and Implementing a Regionally Focused Water Curriculum for Grades 9-12 in the Southwestern United States

Daniel Potts[1], Steve Uyeda[2], Elizabeth Hancock[2], Gary Woodard[2], and Jim Washburne[2]
[1] Dept. of Ecology and Evolutionary Biology, University of Arizona
[2] Dept. of Hydrology and Water Resources, University of Arizona,

SAHRA is a National Science Foundation (NSF) funded Science and Technology Center which operates in the Department of Hydrology and Water Resources of the University of Arizona. The mission of SAHRA is to promote sustainable management of water resources in semi-arid regions. In addition to pursuing stakeholder-driven interdisciplinary research, SAHRA's goals include: (1) fostering understanding of key water issues in K-16 science education and (2) promoting hydrologic literacy to positively impact water policy and water resources management.

Education is the key to providing reliable water supplies in the face of numerous challenges. Recognizing this need, SAHRA created **S**tudent-centered **P**rogram for **L**earning **A**bout **S**emi-arid **H**ydrology (SPLASH). SPLASH is a collaborative effort of educators and SAHRA scientists to create and implement a regionally focused water curriculum for grades 9-12 in the southwestern United States. The curriculum is designed to be multidisciplinary, integrating water-related science with other academic disciplines. The curriculum centers on a core module that utilizes regionally focused lessons to motivate students to learn more about water processes and policy and the importance of water-resources in shaping southwestern history. Beyond the core module, teachers can choose from among several additional modules that best align with the content and direction of their own course curriculum. It is our goal to begin pilot testing the curriculum modules in Tucson-area high school classrooms in the 2003-04 school year.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

ED/KT-4

Water Education for Native Americans

Mansel A. Nelson and Aregai Tecle
Northern Arizona University

Northern Arizona University (NAU) through the Institute for Tribal Environmental Professionals (ITEP) provides water education and outreach for Native American students and tribal professionals. The focus of Summer Scholars 2003 was on the use of reclaimed wastewater on Snowbowl, a sacred area for several Native American tribes. Using a Problem Based Learning (PBL) format, students investigated Snowbowl's proposal to use reclaimed wastewater from the City of Flagstaff to make artificial snow. The students learned about water quality using the GLOBE protocols and about wastewater treatment using Project WET activities. After a week of investigation, the students prepared web pages to share their recommendations. The students' recommendations were strongly influenced by their cultural beliefs and values; therefore the majority of the students were strongly opposed to the use of reclaimed wastewater. The Summer Scholars program description and student web pages are available at http://www.nau.edu/eeop/. Educators from the schools participated in the program as chaperones and observers. They were certified in GLOBE and Project WET. Tribal environmental professionals and NAU faculty participated as guest presenters. Follow-up from the ITEP staff includes delivering materials to the schools involved in the Summer Scholars program to support continued learning about wastewater and water quality issues.

ED/KT-5

FREE WATER! Analyzing Residential Reuse in Tucson

Matt Weber, Gary Woodard, and Steve Stewart
Dept. of Hydrology and Water Resources, University of Arizona

How have Tucson residents collected and utilized the 12 inches of yearly rainfall, that water resource delivered free from the great reservoir in the sky? What about graywater, another vast resource of 50 to 100 gallons per family per day, usually donated to the sewer system? Other reuse possibilities include evaporative cooler bleed-off, swimming pool backwash, and surface flood flow. This study analyzes these strategies of water reuse from results of a recent cross-sectional survey in the Tucson area. Overall levels of each type of water reuse will be presented, along with initial attempts to regress water reuse against socioeconomic factors. The overall context of water reuse in Tucson will also be presented, including a look at ideas from "the underground."

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

ED/KT-6

Interpreting the Hydrology of a Desert Mountain Stream to a General Public: Using Multimedia to Enhance Informal Experiential Education

Gary Woodard, Kyle Carpenter, Brad James
SAHRA, University of Arizona

Sabino Canyon near Tucson, Arizona draws over 1 million visits per year. The centerpiece of the canyon is Sabino Creek, an ephemeral stream fed by seasonal snowmelt and monsoon rains. Frequently asked questions by canyon visitors include: How can a stream flow in the desert environment? Why are the surrounding mountaintops so much cooler and wetter? How can the stream flow without recent rain or snowmelt? Where does the water go? The NSF STC for Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA) has partnered with the USGS and the USDA Forest Service to develop static displays and a touch-screen electronic kiosk for the Sabino Canyon Visitors Center that explain what streamflow is, where the waters of Sabino Creek originate, where they go, what conditions produce flash flooding, and the hydrology of sky island environments. The kiosk, and an associated Web site, also give current weather and streamflow conditions at various points in the canyon, plus typical and extreme conditions for the current date. Designing displays that attract and inform a diverse mix of visitors with varying levels of interest, reading levels, and attention spans is a major challenge. We have integrated static displays featuring light boxes with a touch-screen kiosk featuring graphics, animation, video, sound effects, and voice-overs. Optional sub-titles are in five languages. The goal is to attract visitors to the display and then meet their various interests and information needs. Hydrology is a foreign subject to the great majority of people, and opportunities to informally educate them are relatively scarce. This presentation will show how current multimedia technology can be combined with proven methods of informal experiential education to communicate some basic hydrologic principles.

ED/KT-7

New Knowledge Transfer Initiatives

Gary Woodard, Kyle Carpenter, Brad James
SAHRA, University of Arizona

The Outreach Connection web site (www.sahra.arizona.edu/pag) is being cooperatively developed by SAHRA and the Pima Association of Governments to enable water educators in the Tucson region to share information about their outreach and education efforts. The site includes an organization directory, an archive of presentations, brochures, flyers, pamphlets, training and workshops developed by the organizations, and calendar of upcoming activities and meetings.

Kartchner Caverns, Arizona's newest state park, draws 200,000 visitors per year from across the state and around the world. Cochise County's Cooperative Extension Office received a Prop. 301 grant in 2003 to work with SAHRA on research and development for an interactive display at Kartchner Caverns Discovery Center that focuses on mountain block recharge and the hydrology of caves. Real-time data from cave-based instruments will be incorporated.

The M.Eng. in Water Resources Planning program was initiated in Fall 2003 to allow middle managers in the Army Corps of Engineers to complete requirements for a masters degree at government expense in a relatively compressed time frame. Students attend the University of Arizona for one semester and take a series of required courses while in residence. They complete the remainder of courses using locally available courses and distance learning courses that meet program requirements. More information is at www.usace.army.mil/mastersdegree/arizona.htm This program is also available to other government agencies.

▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸▸

ED/KT-8

SAHRA's Global News Watch

Louise Shaler, Beery Adams, Mary Black
SAHRA, University of Arizona

SAHRA's Water News Watch Web site (www.sahra.arizona.edu/newswatch/) distributes water-related news and information on 140 countries. The service debuted in Fall 2001 and currently contains around 6,800 summaries of Web-based news and scientific reports from all over the world. News Watch currently covers material posted in seven languages: English, French, Italian, Spanish, Portuguese, Farsi, and Greek. News summaries link to full original articles, where available. Approximately 40% of the news stories are from non-English sources.

The News Watch site is searchable by the user's choice of terms or by selected topic area. Searches may be further limited by geographic area or to a particular time frame. Funding from UNESCO recently allowed SAHRA to offer a customized email service that provides alerts of news stories that match subscribers' interests.

ED/KT-9

Southwest Hydrology: The Resource for Semi-Arid Hydrology

Betsy Woodhouse
Editor, Southwest Hydrology

Southwest Hydrology is a trade magazine designed to inform and connect the water communities of the semi-arid and arid Southwest. The magazine is written by and for consultants, regulators, researchers, water managers, lawyers, policymakers, and all the people in industry who work with water issues in semi-arid regions. It is distributed free of charge six times per year to more than 4,000 subscribers in Arizona, California, Colorado, Nevada, New Mexico, Texas, Utah, and across the United States.

The semi-arid to arid climate presents unique water issues that are not frequently addressed in national publications. Conversely, the professionals of this region have developed innovative approaches, accumulated significant experience, and produced resounding successes (and some notable failures). *Southwest Hydrology* documents these experiences.

The magazine contains both departments and features. Departments include short summaries of project descriptions, news of companies and people, actions by government agencies, activities of professional societies and organizations, current research, reviews of books and software, and updates on educational and international water issues. Features consist of five to seven articles written by experts in a particular field that provide a variety of perspectives on a single topic. Recent features have included riparian restoration, remote data acquisition, desalination, regulatory aspects of the surface water/groundwater interconnection, and isotopes in hydrology.

ED/KT-10

GLOBE Border Area Field Investigations

Martha Whitaker, Jim Washburne, Ty Ferré, and Bart Nijssen
Dept. of Hydrology and Water Resources, University of Arizona

GLOBE is an international K-12 environmental education and monitoring program that makes consistent environmental measurements from over 100 countries available to schools and scientists through an Internet data archive. SAHRA seeks active collaborations with GLOBE schools to provide important baseline and supplemental observations in its basins of interest. In particular, we are building a network of schools throughout the Southwest to help collect water quality data along the Rio Grande in New Mexico and along the U.S.-Mexico border to collect soil moisture data. This last effort seeks to engage schools on both sides of the border in the North American Monsoon Experiment during the summer of 2004.

KT/ED-11

ECOSTART

Anne Browning-Aiken and Denise Moreno
Udall Center for Studies in Public Policy

ECOSTART is an environmental education and exchange program that empowers Sonoran elementary schoolteachers to develop an environmental education curriculum that broadens their communities' and schools' knowledge of ecosystem principles. This program enables Sonoran and Arizona elementary school teachers to share environmental information and student projects regarding the Upper San Pedro riparian area in which they live and teach through exchange visits. ECOSTART builds on the Sister Cities program that Cananea, Sonora and Sierra Vista, Arizona have been participating in for decades. The focus of student projects on the riparian habitat is especially relevant since the two cities, as well as Naco, Sonora, have expressed a common concern about an adequate and safe supply of water from the Upper San Pedro watershed in Arizona and Sonora.