Center for Water Resources
Annual Technical Report
FY 2009

Introduction

California's National Institute for Water Research is located at 1111 Franklin Street, Oakland, CA 94607. The Director is Barbara Allen-Diaz, Associate Vice President, Academic Programs and Strategic Initiatives for the University of California, Division of Agriculture and Natural Resources.

The people and resources of the University of California Division of Agriculture and Natural Resources system serve every county in California. These professionals connect and deliver resources from the entire University of California, forming integrated teams to work on complex issues and develop innovative multidisciplinary solutions. ANR professionals have a unique, proven, respected ability to bring together the resources needed to solve tough problems. They connect with the faculty from the California State University system; private colleges and universities; the staff and resources of federal, state and local government agencies; agricultural, natural resource, and nongovernmental organizations; and others, including leaders and citizens representing environmental, agricultural, youth, and nutrition interests and issues.

Research Program Introduction

ANR Initiative to improve Water Quality, Quantity, and Security California must address our challenges to ensure a high quality of life, a healthy environment, and economic success for future generations. The following multidiscipline, integrated initiative represent the best opportunities for ANR's considerable infrastructure and talent to seek new resources and new ways of partnering within and outside UC to find solutions for California. Water is the life blood of California's economy. As such, water supply and quality for agricultural, urban, and environmental systems is a critical issue facing the state over the next 20 years and beyond. Several issues are paramount: The supply of water will be limited for all users.   Competition for water will intensify among agricultural, urban, and environmental users, with water being transferred from agriculture to the latter two groups.   Short-and long-term climate trends will exacerbate the problems associated with water availability   Degradation of water quality will become more important as a major public issue.   Legal and regulatory decisions will have significant impacts on water use and quality among all sectors. ANR's role in improving watershed and water management practices and policies: Develop innovative scientific techniques, products, and processes to improve water use efficiency and water conservation management practices.   Develop and encourage the adoption of management practices that prevent degradation of watersheds and water resources caused by pesticides, salinity, chemicals, animal wastes, nutrients, sediment, and pathogens.   Assisting in the development of flexible and effective water policies and strategies using UC'S economic, hydrological, and policy expertise.   Science-based research and educational approaches to address these issues in partnership with others, including agricultural groups, environmental groups, and regulatory entities.

Joseph G. Prosser Trust The Irrigation Management Program, funded by the Joseph G. Prosser Trust, supports a broad spectrum of research related to crop irrigation management, focusing on optimizing yields, conserving water and improving irrigation efficiency. Emphasis is placed on research outputs that improve current practices, and on dissemination of information. Some recent projects funded by this program include: Coupling automated overhead, low-pressure irrigation systems with conservation tillage; A new irrigation, crop and drainage management paradigm for the Central San Joaquin Valley? (Jeff Mitchell, UC Davis) Toward improved Irrigation Efficiency through Real-time Assimilation of Multi-spectral Satellite Remote Sensing Data into Crop Models (Steven A. Margulis, UCLA)   Reducing Water Use in Navel Orange Production with Partial Root Zone Drying   Comparison with Conventional Irrigation at the Same Reduce3d Irrigation Rates (Carol J. Lovatt, UC Riverside and Ben Faber, UCCE Ventura County)

Rosenberg International Forum on Water Policy The overarching theme of the Rosenberg Forum is: To Reduce Conflict in the Management of Water Resources. Specific sub-themes are chosen by the Advisory Committee for each individual Forum. The objectives of the Forum address this theme in an explicit fashion. The primary objective is to facilitate the exchange of information and experience in the management of water resources. The problems of managing and husbanding water are surprisingly common around the world. However approaches and solutions may differ depending upon the available financial resources as well as social and cultural norms. Discussions of alternative approaches and identification of what works and what doesn't are intended to aid in devising more effective and efficient water management schemes. There are two sub-objectives which provide specificity and support in achieving the main objective and in addressing the overarching theme. The first of these is to emphasize the role of science in the making of water policy and in the management of water resources. The second and related sub-objective is to promote exchange and interaction between scientists and policy-makers for the purpose of facilitating the use of science as a basis for the making of water policy. Participants at each Forum are a mix of scientists and policy makers and the presentations and discussions focus equally on illumination of the pertinent science for policy making and on the experience with different policies in different settings around the world. The primary objective of the Rosenberg International Forum on Water Policy is to facilitate the exchange of information and experience in the management of water resources. The problems of managing and husbanding water are common problems but approaches and solutions may differ depending upon the financial resources available to address the problem as well as social and cultural norms. Discussions of alternative approaches and identification of what works and what doesn't should aid in devising more effective and efficient water management schemes.

Model Development for Conjunctive Use Planning and Aquifer Protection in Semi-arid Regions

Basic Information

Title:	Model Development for Conjunctive Use Planning and Aquifer Protection in Semi-arid Regions
Project Number:	2005CA137G
Start Date:	9/1/2005
End Date:	8/31/2009
Funding Source:	104G
Congressional District:	30
Research Category:	Ground-water Flow and Transport
Focus Category:	Nitrate Contamination, Management and Planning, Models
Descriptors:	
Principal Investigators:	William W-G. Yeh

Publications

1. Tu, M-Y, F. T-C. Tsai and W. W-G. Yeh, 2005, "Optimization of Water Distribution and Water Quality by Hybrid Genetic Algorithm," Journal of Water Resources Planning and Management, ASCE, 131 (6): 431-440.
2. McPhee, J. and W. W-G. Yeh, 2007, Groundwater Management using Model Reduction via Empirical Orthogonal Functions, to appear in Journal of Water Resources Planning and Management.
3. McPhee, J., Yeh, W. W-G., Groundwater Management using Model Reduction via Empirical Orthogonal Functions, Journal of Water Resources Planning and Management, ASCE, 134(2): 161-170, March 2008.
4. Chiu, Y-C., Objective-Oriented Groundwater Modeling for Conjunctive Use Planning of Surface Water and Groundwater, PhD Dissertation, Directed by W. W-G. Yeh, Department of Civil and Environmental Engineering, UCLA, 2009.
5. Chiu, Y-C., Nishikawa, T, Yeh W. W-G., Optimal Pump and Recharge Management Model for Nitrate Removal in the Warren Ground-water Basin, California, Journal of Water Resources Planning and Management, ASCE, 136(3): 299-308, 2010.
6. Bray, B., Tsai, F. T-C., Sim, Y., Yeh, W. W-G., Model Development and Calibration of a Saltwater Intrusion Model in Southern California, Journal of American Water Resources Association, 43(5):1329-1343, October 2007.
7. Bray, B., Yeh, W. W-G., Improving Seawater Barrier Operation with Simulation-Optimization in Southern California, Journal of Water Resources Planning and Management, ASCE, 134(2): 171-180, March 2008.

PROJECT TITLE: Model Development for Conjunctive Use Planning and Aquifer Protection in Semi-arid Regions

AGREEMENT NO.: 05HQGR0161

PRINCEPAL INVESTIGATOR: William W-G. Yeh

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RESEARCH PROPRAM

Project summary:

In the semi-arid region of the southwestern U.S., population and economic growth are making increasing demands on the water supply. For example, almost 40% of the water supply in southern California is from groundwater. To protect groundwater from over-pumping and contamination, there is a critical need to develop surface water and groundwater management tools that can be used to predict water level variations and solute concentrations in the aquifer under different management scenarios. By controlling the total water resources of a region, conjunctive use planning can increase the efficiency, reliability, and cost-effectiveness of water use, particularly in river basins with spatial and temporal imbalances in water demand and natural supplies.

Typical of southern California, the Warren groundwater basin, located in San Bernardino County, has seen sustained population growth and increased water demands since the 1950's. Since groundwater is the only local source of water supply available, water levels experienced a steady decline of up to 300 ft in some areas between 1956 and 1994. In 1995, the Hi-Desert Water District (HDWD) implemented a recharge program using imported State Water Project (SWP) water and two recharge pond sites. As a consequence, water levels rose up to 200 ft in some areas. However, nitrate concentrations increased drastically, from a baseline level of approximately 10 mg/l to values in excess of 100 mg/l. A study conducted by the USGS showed that the increase in nitrate concentrations is due to entrainment of seepage from septic tanks and irrigation, previously stored in the unsaturated zone, by the artificially elevated water table.

The goal of this research is to develop a decision support system (DSS) for sustainable groundwater management, including conjunctive use planning of surface water and groundwater, and aquifer protection. We have successfully accomplished this goal. We developed a coupled simulation and optimization model to remove the high nitrate concentration and supply the water demand while maintaining the ground-water levels at the desired targets for the Warren groundwater basin. The model was monthly; therefore, only continuity – via a set of continuity equations – was required to be satisfied with regard to pumping and recharge in the formulation of the management model.

**Project expired on August 31, 2009.

The developed management model can be used by the water resources managers for conjunctive use planning of surface water and groundwater in a real-world problem. The optimized pumping and recharge strategy obtained from the management model can provide managers with a decision-making tool which can be used to achieve their goal and at the same time minimize the operational cost. The developed management model is highly flexible with regard to changing the objective function and constraints as well as changing the supply and demand patterns.

Award No. 04HQAG0001 Spatially Explicit Modeling and Monitoring of Hydroclimatic Extremes: Reducing the Threat to Food Security in the Developing World

Basic Information

Title:	Award No. 04HQAG0001 Spatially Explicit Modeling and Monitoring of Hydroclimatic Extremes: Reducing the Threat to Food Security in the Developing World
Project Number:	2005CA187S
Start Date:	10/1/2003
End Date:	6/30/2009
Funding Source:	Supplemental
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	Drought, Management and Planning, None
Descriptors:	
Principal Investigators:	Andrew Chang, Katheryn Ivanetich

Publications

1. Funk, C. and Brown,. M., 2006, A maximum-to-minimum technique for making projections of NDVI in semi-arid Africa for food security early warning, Int. J. of Remote Sensing. 101. 249-256.
2. Verdin J., Funk C., Senay, G., Choularton, R., 2005. Climate Science and Famine Early Warning, Philosophical Transactions of the Royal Meteorological Society, B. 360. 2155-2168.
3. Husak, Gregory. Methods for Statistical Evaluation of African Precipitation. Ph. D. Dissertation, Geography, University of California, Santa Barbara, Santa Barbara, CA.
4. Freund, Jeremy, Aids for Estimating Crop Area and Production in Kenya: A Multi-Temporal Remote Sensing Approach, M.A. Thesis , Geography, University of California, Santa Barbara, Santa Barbara, CA.
5. Funk, Chris, Jeremy Freund, Mike Budde, Elijah Mukhala and Tamuka Magadzire, 2006, Analysis of MODIS -NDVI for 2000 through 2006. FEWS NET Report. ftp://hollywood.geog.ucsb.edu/pub/AnalysisOfMODIS_NDVIforZimbabwe_JTF4.zip. 8 pages.
6. Funk, C. and J. Michaelsen, 2004: A simplified diagnostic model of orographic rainfall for enhancing satellite-based rainfall estimates in data poor regions, Journal of Applied Meteorology, V43. October, 2004
7. Funk, C., J. Michaelsen, J. Verdin, G. Artan, G. Husak, G. Senay, H. Gadain, and T. Magadazire, 2003: The Collaborative Historical African Rainfall Model: Description and Evaluation. International Journal of Climatology, 23, 47-66
8. Brown, M. & Chris Funk, 2008, Early Warning of Food Security Crises in Urban Areas: the Case of Harare, Zimbabwe, 2007. Submitted.
9. Funk, C., Ederer, G., Pedreros, D. (2008) The Tropical Rainfall Monitoring Mission, NIDIS Knowledge Assessment Workshop: Contributions of Satellite Remote Sensing to Drought Monitoring, Feb 6-7, Boulder, CO, Extended Abstract

10. Funk C. & M. Budde, (2007) National MODIS NDVI-based production anomaly estimates for Zimbabwe, Crop and Rangeland Monitoring Workshop, Nairobi, March 2007. Extended Abstract.
11. Funk, C., Husak, G., Michaelsen, J., Love, T. and Pedreros, D. (2007) Third generation rainfall climatologies: satellite rainfall and topography provide a basis for smart interpolation, Crop and Rangeland Monitoring Workshop, Nairobi, March 2007, Extended Abstract.
12. Husak, G.J. and Funk, C., 2007. SPI Forecasting in the Conterminous United States. American Association of Geographers Annual Meeting: San Francisco, California.
13. Husak GJ, MT Marshall, J Michaelsen, D Pedreros, C Funk, G Galu, 2008. Crop Area Estimation Using High and Medium Resolution Satellite Imagery in Areas with Complex Topography. Journal of Geophysical Research. (Accepted, 2008)
14. Funk, C., Brown, M., Choularton, R., Verdin, J., Dettinger, M., (200-), FEWS NET Climate Change Impact Report, Special Report for USAID (accepted)
15. Husak, G., Michaelsen, J., Funk, C., (2007) Use of the Gamma Distribution to Represent Monthly Rainfall in Africa for Drought Monitoring Applications, Int. J. of Clim. 27(7): 935-944.
16. Brown, M.E., Funk, C.C., Galu, G. and Choularton, R. (2007). Earlier Famine Warning Possible Using Remote Sensing and Models. EOS, Trans. Am. Geo. Union, 88(39): 381 382.
17. Funk, C., Budde M., (2008) Phenologically-tuned MODIS NDVI-based production anomaly estimates for Zimbabwe, Rem. Sens. Env. (accepted, 2008)
18. Brown, M and Funk, C., (2008) Food security under climate change, Science, (319): 580-581.

The Famine Early Warning System Network (FEWS NET) efforts at UCSB this past year have focused on monitoring some of the most food insecure regions of the developing world. In addition to research personnel at UCSB critical scientific contributions and have been performed by the team of foreign scientists stationed in Central America, Africa and Afghanistan.

Significant effort under this grant was used to develop cropped area estimates for Ethiopia, Niger Zimbabwe, Northern Nigeria and Afghanistan where questions about the amount of area being planted and harvested creates large uncertainty in food production estimates and ultimately the number of people facing food insecurity. The cropped area assessments were created using manually interpreted high-resolution satellite imagery along with physical variables such as elevation, slope and precipitation which dictate cropping patterns in these countries. Much work has also been done to develop long-term rainfall climatologies for Central America which can be used with real-time satellite estimates to create gridded rainfall estimates which are used to drive hydrologic and crop models.
Work under the FEWS NET umbrella also supported the development of new computational tools such as the GeoWRSI, which utilizes crop-specific parameters and environmental information to estimate crop yield by assessing how well the crop's growing requirements are being met. Finally, many resources in this project have been used to perform GIS and remote sensing trainings, and other forms of capacity building in our regions of interest. These efforts have resulted in improved understanding and distribution of FEWS NET monitoring products by placing well-qualified people at national agencies. These people have a working understanding of the impacts that the scientific efforts of our team can have, and they are familiar with our foreign staff, resulting in easy communication with stakeholders and decision-makers in the developing world.

The FEWS NET project at UCSB represents a successful system to develop new scientific tools, have them implemented in a meaningful way, and get the results distributed to influential parties in a timely manner. Our team of domestic and international researchers, and the support of agencies such as the US Geological Survey, the US Department of Agriculture and others, create an environment where new science and applications can have an impact on reducing food insecurity, maintaining farmer incentive, and ultimately saving lives.

Improving aquifer storage recovery operation to reduce nutrient load and benefit water supply

Basic Information

Title:	Improving aquifer storage recovery operation to reduce nutrient load and benefit water supply
Project Number:	2007CA195G
Start Date:	7/1/2008
End Date:	6/30/2011
Funding Source:	104G
Congressional District:	17th
Research Category:	Ground-water Flow and Transport
Focus Category:	Water Supply, Water Quality, Nitrate Contamination
Descriptors:	
Principal Investigators:	Andrew Fisher, Marc Los Huertos, Charles Geoffrey Wheat

Publications

1. Papers Presented at Professional Meetings (*student co-authors) *Schmidt, C., A. T. Fisher, M. Los Huertos, B. Lockwood, 2008. Processes, controls, and potential for in-situ nutrient removal during managed aquifer recharge to a shallow aquifer, Am. Geophys. Union, Fall Meet. Suppl., Abstracts on CD-ROM.
2. *Racz, A., A. T. Fisher, B. Lockwood, M. Los Huertos, C. Schmidt*, J. Lear, 2008. Quantifying the distribution and dynamics of managed aquifer recharge using mass-balance and time-series thermal methods, Am. Geophys. Union, Fall Meet. Suppl., Abstracts on CD-ROM.
3. *Schmidt, C., A. T. Fisher, M. Los Huertos, B. Lockwood, The magnitude and controls on denitrification during managed aquifer recharge into a shallow, unconfined aquifer in a coastal groundwater basin, Am. Geophys. Union, Fall Meet. Suppl., Abstracts on CD-ROM, 14-18 December 2009.
4. *Racz, A., A. T. Fisher, B. Lockwood, M. Los Huertos, C. Schmidt*, J. Lear, Spatial and temporal variations in seepage during managed aquifer recharge, Am. Geophys. Union, Fall Meet. Suppl., Abstracts on CD-ROM, 14-18 December 2009.
5. *Schmidt, C., A. T. Fisher, A. Racz, C. G. Wheat, J. Sharkey, B. Lockwood, Processes and controls on rapid nutrient removal during managed aquifer recharge, 27th Biennial Groundwater Conference, Abstracts with programs, Sacramento, CA, October 6-7 2009.

The focus of this research is in improvements that can be made to aquifer storage recovery activities so as to improve both the quantity and quality of water made available to stakeholders. We are collaborating on this research with a local water agency, and with researchers at other academic institutions and the U.S. Geological Survey. The review period included in this summary of results includes the second half of the 2009 water year and the first half of the 2010 water year. Prior to the start of each water year, we have instrumented the base of a managed aquifer recharge (MAR) pond that is used to recharge fresh water into a shallow, perched aquifer. This water is used by local growers in lieu of pumping groundwater from a regional aquifer that is impacted by ovrerdraft and resulting seawater intrusion. The water put into the pond is diverted from a nearby wetland system during the wet (rainy) season, when flows are sufficient high and water quality is good.

We are monitoring the rates of shallow infiltration through the base of the full pond using mass balance techniques, and determining rates of recharge at points along the base of the pond using heat as a tracer. This last technique involves innovative use of time-series analysis to resolve changes in diurnal temperature changes in shallow soils below the pond. We monitor groundwater levels and quality using eight shallow and one deeper monitoring well, arranged spatially around the recharge pond. We have deployed water content, pressure, and thermal sensors around the based of the pond (at nine locations in 2008-09 and 22 locations in 2009-10), allowing us to assess rates of infiltration at different locations. We sampled shallow soils before each recharge season and are sampling these materials again at the end of each recharge season to evaluate the influence of recharge on soil grain size, soil carbon content, and hydraulic properties.

We are monitoring water quality at multiple locations in the wetland (water source) throughout the water year. We monitor water quality in the recharge pond, and in the shallow subsurface using piezometers and lysimeters. Samples are being analyzed for major elements and nutrients, and for nutrient isotopic composition in order to quantify rates of denitrification that occur during recharge.

Full pond inflitration rates are typically 1–5 m/day during the initial 2–3 weeks after the MAR pond is filled, but decrease rapidly to 0.2–0.4 m/day and remain at this rate for the next 6–8 weeks. In addition, we see large spatial and temporal variations in infiltration rates that sweep across the MAR pond during a 6–8 week period. The greatest rates of infiltration are initially at the northwestern end, but the center of the highest rate of infiltration sweeps across the pond to the southeast, as the magnitude of infiltration rates decreases with time. Grain size analyses of samples collected before and after each recharge season suggest that initial periods of infiltration cause the loss of fine grained material from the upper 50 cm of the subsurface, at the same time as a thin crust of fine sediment accumulates at the base of the pond. The net result is that the overall rate of infiltration slows, and the extent of saturation decreases in the shallow subsurface because the rate of inflow can not keep up with the rate of drainage from below.

Evaluation of fluid chemistry shows that there is a 50-90% load reduction during the passage of water from the pond through the upper 1 m of subsurface soils, and low nitrate water arrives at the monitoring wells surrounding the recharge pond at different times as a function of distance and direction. Nitrate isotopic analyses show that the primary mechanism of nitrate removal is denitrification. Comparison of denitrification rates apparent from our data, based on combined chemical and thermal results, are at the high end of denitrification rates detected in soil and groundwater systems in other settings. It may be that this system is especially efficient at denitrification because of the high availability of organic carbon in the diverted fluids, and the availability of particulate carbon in subsurface soils. We have also found that high rates of denitrification are maintained even at some of the greatest infiltration rates, but that eventually (at the highest infiltration rates), we see the expected decrease in denitrification efficiency.

During the 2009-10 water year, we have also experimented with installation of fluid bypass trenches in the base of the MAR pond, in a effort to enhance (speed, extend) the rate of infiltration. The trenches are lined with a geomembrane and either 1/4" pea gravel or chipped redwood, and have rise pipes installed that allow MAR pond water to bypass the pond base and enter the trench. This is intended to allow the base of the pond to serve as a sediment collection system, while routing water across this boundary and into the subsurface where infiltration and recharge can occur most efficiently. We will learn how successful this effort was after the end of the current recharge season, when we can recover instruments deployed below the trenches and interpret data collected with them.

A Bayesian approach to snow water equivalent reconstruction

Basic Information

Title:	A Bayesian approach to snow water equivalent reconstruction
Project Number:	2007CA215G
Start Date:	6/1/2008
End Date:	5/31/2010
Funding Source:	104G
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Surface Water, Water Supply
Descriptors:	
Principal Investigators:	Noah Paul Molotch, Steven Margulis

Publications

1. Molotch, N.P., P.D. Brooks, S.P. Burns, M. Litvak, J.R. McConnell, R.K. Monson, and *K. Musselman, Ecohydrological controls on snowmelt partitioning in mixed-conifer sub-alpine forests, Ecohydrology, in press
2. Veatch, W, P.D. Brooks, *J. Gustafson, N. P. Molotch, Quantifying the effects of forest canopy cover on net snow accumulation at a continental, mid-latitude site, Valles Caldera National Preserve, NM, USA, Ecohydrology, Vol. 2, doi: 10.1002/eco.45, 2009.
3. Molotch, N.P., Reconstructing snow water equivalent in the Rio Grande headwaters using remotely sensed snow cover data and a spatially distributed snowmelt model, Hydrological Processes, Vol. 23, doi: 10.1002/hyp.7206, 2009.
4. Molotch, N.P., T. Meixner, and M.W. Williams, Estimating stream chemistry during the snowmelt pulse using a spatially distributed, coupled snowmelt and hydrochemical modeling approach, Water Resources Research, Vol. 44, doi:10.1029/2007WR006587, 2008.
5. Durand, M., N.P. Molotch, and S. Margulis, A bayesian approach to snow water equivalent reconstruction, Journal of Geophysical Research, 113, doi:10.1029/2008JD009894, 2008.

This project is focused on questions related to temporal and spatial variability in snow distribution patterns in the Sierra Nevada Mountains. In year one of our project we have made significant progress toward developing a new method of snowfall estimation. This involves using an Ensemble Kalman Smoother to assimilate new remotely sensed snow measurement capabilities into physically based mass and energy balance models. Densely distributed clusters of ultrasonic snow depth sensors spanning the elevational gradients of the seasonally snow covered portions of the Sierra Nevada will be used to develop this new technique by accounting for both sub-grid variability and the spatial representativeness of the ground observations. The combination of these new modeling and measurement capabilities will enable new understanding of the spatial snow accumulation processes.

The project scope and objectives are driven by recent evidence suggesting that the mountain snowpack is responding to increases in regional air temperature associated with climate change. Sensitivity to climate change varies across gradients of physiography (e.g. elevation, vegetative community structure, and latitude) but the drivers and degree of this sensitivity in different mountainous landscapes are not fully comprehended. Similarly, the impact of these changes on basin-scale snowpack water storage cannot be determined because observations are not distributed across a range of elevations and other physiographic conditions that control snow distribution. As a result, statistical interpolation models of these scarce observations inadequately represent spatial patterns of snow accumulation. For nearly three decades, remotely sensed observations of snow cover depletion have been used to forecast seasonal snowmelt runoff and (indirectly) seasonal snow accumulation integrated over a watershed. The scarcity of ground-based observations needed to evaluate model performance and refine algorithms has restricted detailed snowpack modeling studies to small headwater catchments. To address these inadequacies this research project has made steps toward developing new observing and modeling systems for estimating the spatial distribution of snow accumulation. Year one achievements have been made in two categories. First, we have made significant progress in collecting the in situ snow measurements needed for the model validation. Second, we have developed our modeling framework and we have compiled all of the necessary model forcings. These achievements are described in more detail below.

1. Include Problem and Research Objectives, Methodology and Principal Findings and Significance for your project.

   In the western U.S., mountain river basins sustain the water demand of over 60 million people. Operational water supply outlooks in these supply-limited systems are based, in part, on historical relationships between snow observations and observed runoff. These empirical models perform best near mean conditions but perform poorly during conditions not represented in the historical record. Changes in mountain climate, and associated changes in snow accumulation and melt patterns, suggest that such anomalous conditions may be occurring with increased frequency and intensity with local to regional signatures. To deal with this situation deterministic modeling approaches for characterizing snow distribution are needed to develop robust water supply outlooks. Perhaps the largest source of uncertainty in our current modeling abilities is associated with distributing precipitation over complex terrain. Furthermore, knowledge of interannual spatial patterns of precipitation is crucial in understanding how spring streamflow magnitude timing will be modulated by a changing Sierra Nevada climate. The techniques which we have developed in year one of this research bridges a critical gap in making spatially distributed runoff forecast models operational.

Modeling activities. Our year one modeling methodologies largely flow from our original proposal and our continued efforts in year 2 will be unchanged from our original plan. In this regard, we have compiled model forcings (solar and longwave radiation, wind speed, temperature, pressure, specific humidity, and precipitation) from the North American Land Data Assimilation System (NLDAS). On our Hydro Cluster at UCLA we have compiled 10 years of these hourly model forcings. Using these forcings we have conducted a number of sensitivity tests in our data assimilation scheme which ingests forcings and remotely sensed snow data into the Simplified SiB land surface model. Initially, we have focused our detailed analysis of the model runs over our detailed field site in Sequoia National Park. In this regard, we have run a 25 km box and have performed simulations of SWE at 1-km spatial resolution. Hence, we have aggregated the 500-m MODIS snow cover data to 1km to match the model resolution (Figure 1). Future efforts will transform this modeling scheme to a 500-m model grid to match the MODIS data. To date, we have conducted both synthetic tests (Figure 1) and tests using MODIS snow cover observations 2000 – 2008. Beginning with synthetic tests was needed as we need to test our overall model scheme. This modeling scheme involves several new sub-routines (e.g. forcing dissagregation) and an evaluation of the sensitivity of the model to the number of ensemble replicates. In this regard, we have run the SSiB3 code on 1, 4, 8, 16, 32 nodes using 12, 24, 48, and 96 replicates. Our results of these tests indicate that the model computational demand is quite high, requiring all 32 nodes and the full 96 replicates. Further, our results indicate that dissagregation of solar radiation NLDAS forcings based on topography add significant information for the model.

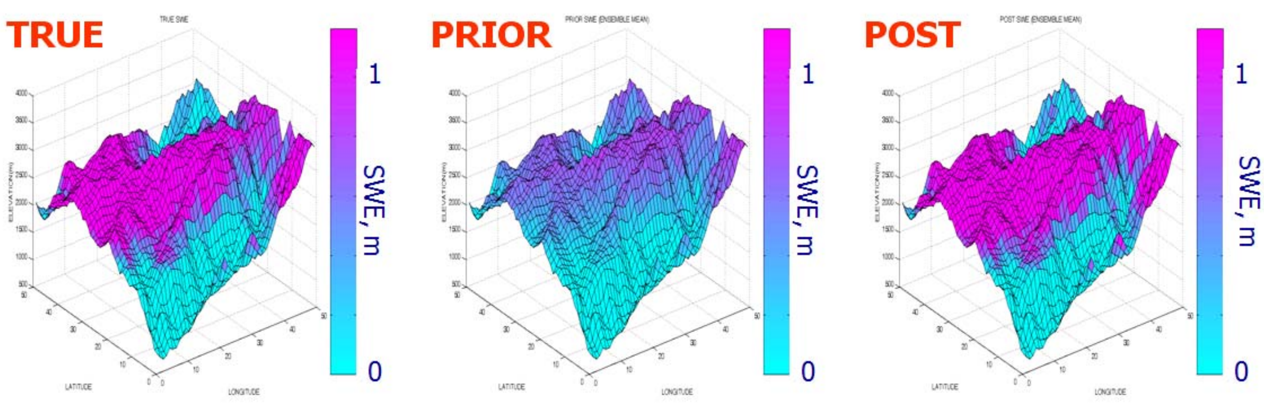

Figure 1. Synthetic truth (left), prior (middle), and posterior snow water equivalent (right) for January 6, 2005 over a 25X25 km area in Sequoia National Park. Note the prior estimates underestimate SWE while the assimilation of the MODIS snow cover depletion data results in a closer match between the posterior SWE and the truth.

Field work activities. In an effort to understand inter-storm variability in snow accumulation and to develop a robust ground-truth data set for our modeling activities we have conducted a total of 12 watershed-scale snow surveys in year one of this project. Survey measurements of snow depth, snow density, and physical snow properties were conducted at two sites in the Southern Sierra Nevada (i.e. the Wolverton and Tokopah Basins of Sequoia National Park) (Figure 2). We have also leveraged snow survey data at three sites in the Eastern Sierra (i.e. Mammoth Pass, Virginia Lakes Ridge, and Rock Creek), and at two sites in the Central Sierra Nevada (i.e. at Gin Flat and Ostrander of Yosemite National Park). The sites represent both alpine and sub-alpine environments ranging in elevation from 7,500 to 10,000 feet above sea level and covering one to 19 km2 in aerial extent. Snow surveys were timed to coincide with seasonal accumulation, maximum accumulation, and the snowmelt season. Each survey required a team of five people working for 3 – 5 days, involving undergraduate and graduate students from UCLA, UCSB, and UC Merced. On average, surveyors collected over 400 spatially distributed snow depth measurements and extensive information from three snow pits during each survey, resulting in a seasonal total of over 2000 snow depth measurements and 24 extensive snow pit observations.

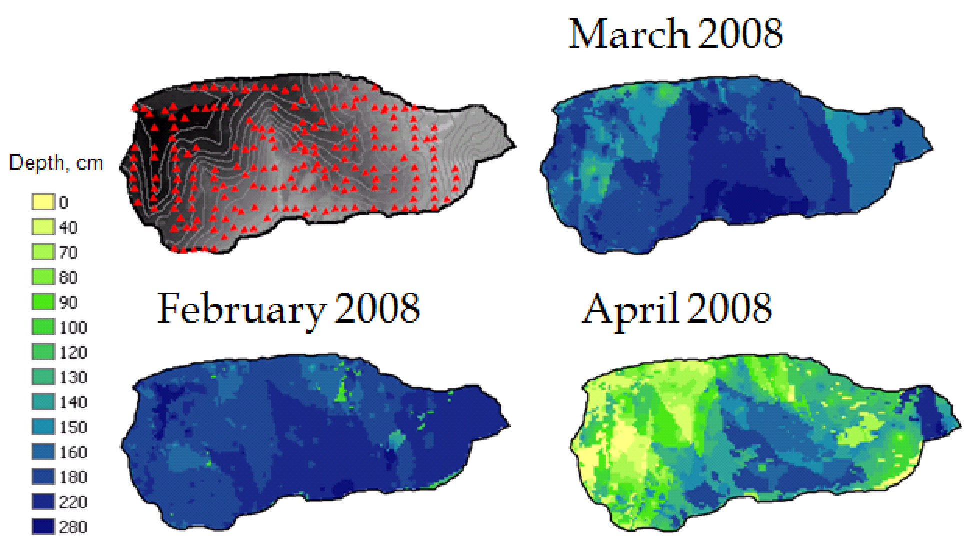

Figure 2. Spatial distribution of snow depth measurements in the Wolverton Basin of Sequoia National Park (Top Left) and resulting snow depth distributions from repeat sampling in February, March, and April of 2008. Note, the red triangles in the top left represent the snow depth measurement locations.

In addition to the manual measurements described above we have also continued maintenance and deployment of the hydrologic instrument clusters we proposed to use in this research. These instruments provide hourly observations of snow depth, soil moisture, sap flow, and atmospheric conditions to be used to validate the extrapolation of our forcing data and model parameters (Figure 3). We have four duplicates of these systems across elevational gradients in Sequoia National Park. In Yosemite National Park our colleagues at UC Merced maintain a transect of three of these clusters. To date, we have quality controlled and analyzed much of the data we have collected in Sequoia. Future efforts will analyze the data collected in Yosemite.

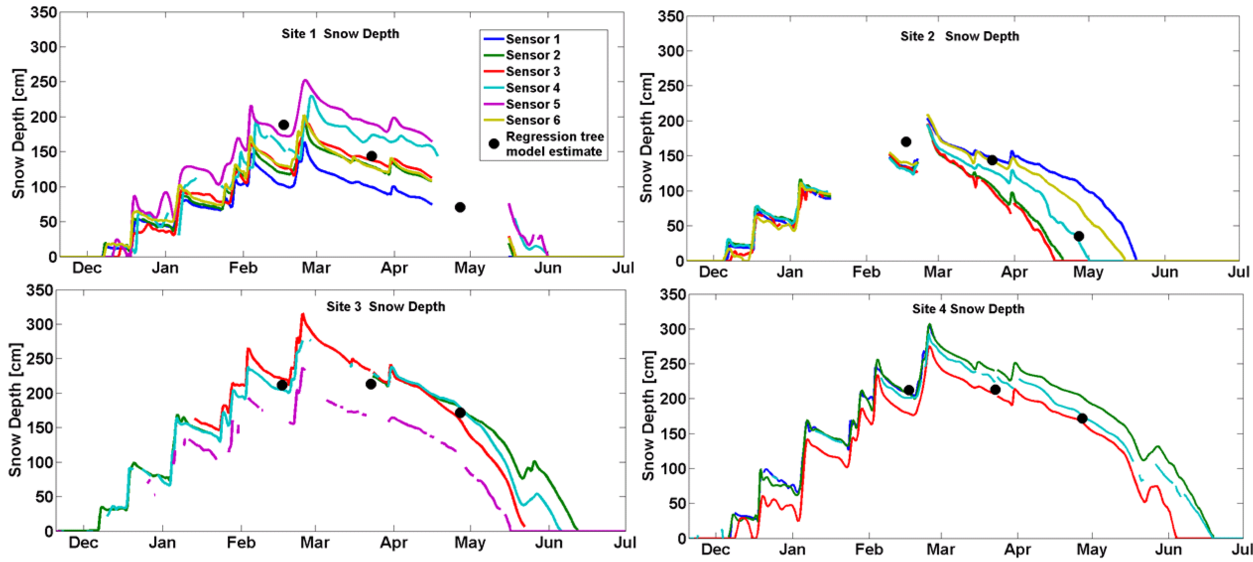

Figure 3. Measured snow depth at four instrument clusters in Sequoia National Park in 2007 – 2008. Sites are numbered 1 – 4 from low to high elevation.

Award No. G09AC0001 Monitoring and Forecasting Climate, Water and Land Use for Food Production in the Developing World

Basic Information

Title:	Award No. G09AC0001 Monitoring and Forecasting Climate, Water and Land Use for Food Production in the Developing World
Project Number:	2008CA262S
Start Date:	10/1/2008
End Date:	9/30/2011
Funding Source:	Supplemental
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	

Publications

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2. Funk C, J Michaelsen, J Verdin, G Artan, G Husak, G Senay, H Gadain, and T Magadazire, 2003. The collaborative historical African rainfall model: Description and evaluation. International Journal of Climatology, 23(1): 47-66.
3. Husak GJ, MT Marshall, J Michaelsen, D Pedreros, C Funk, G Galu, 2008. Crop Area Estimation Using High and Medium Resolution Satellite Imagery in Areas with Complex Topography. Journal of Geophysical Research, 113, D14112.
4. Verdin, J, G Galu, R Choularton, G Husak, 2008. Integrating Seasonal Forecasts into Food Security Outlook Analyses. Submitted to Food Security and Environmental Change (ENVR 2008): April 2008.
5. Husak GJ, J Michaelsen, P Kyriakidis, JP Verdin, C Funk, G Galu. The Forecast Interpretation Tool a Monte Carlo Technique for blending climatic distributions with probabilistic forecasts. International Journal of Climatology, in press
6. Wandiga, S., M. Opondo, D. Olago, A. Githeko, F. Githui, M. Marshall, et al. 2010. Vulnerability to epidemic malaria in the highlands of Lake Victoria basin: the role of climate change/variability, hydrology and socio-economic factors. Climate Change, 99: 473-497.
7. Marshall, M.T., et al. 2010. Assimilation of Surface Reanalysis and Remote Sensing Data for Monitoring Evapotranspiration. (under review Remote Sensing of Environment)
8. Marshall, M. (2010), Agricultural Drought Monitoring with Land Data Assimilation and Remote Sensing, in Remote Sensing of Drought: Innovative Monitoring Approaches, edited by M. Anderson and J. Verdin, p. 270, Taylor and Francis, London, United Kingdom.

The Department of Geography at UCSB has a program of cooperative activities with the U.S. Geological Survey in support of the Famine Early Warning Systems Network (FEWS NET). These activities focus on the application and development of techniques for monitoring the physical variables governing crop growth, such as the timing and amount of precipitation, evapotranspiration and temperature, along with human-related factors such as cropped area, agricultural inputs, and economic indicators. We combine university-based research in the modeling, monitoring and analysis of remotely sensed estimates of environmental variables with science advisory, training, and development activities in Africa and Central America. This project brings together field scientists from Africa and Central America with research scientists at the University of California, Santa Barbara, in a single team of the UC Center for Water Resources, assembled to take on the activities needed to deal with threats to food security in the developing world.

The combination of natural variability, climate change, and the current global food crisis makes the monitoring of climate, water, and land resources for food production especially critical. Each year over 200 million people in sub-Saharan Africa face undernourishment, accounting for nearly 32 percent of the population of this region according to the Food and Agriculture Organization (FAO, 2006). This region is the only part of the world where the percentage of undernourished people has remained steady over the last 30 years. Climate, water, land use, and food supply are inextricably intertwined in the developing world where irrigation is limited and crop health is primarily dependent on the available rainfall. Monitoring of rainfall and runoff provides insight into potential crop yield reduction due to drought, as well as identifying locations which may have seen crop loss due to flood inundation. In addition to the impacts of these disasters on food supply is the effect these extremes have on the entire economy of developing countries (Kreimer and Arnold, 2000). The economic effects of hydro-climatic extremes in developing countries can easily be equivalent in cost to war (Kates, 2000).

Early detection of climate-related stress or changes in human behavior can forecast and make possible the mitigation of the impacts of below-average food production. Alerting decision-makers at agencies such as the US Agency for International Development, US Department of Agriculture, State Department, World Food Program, the Food and Agriculture Organization, and affected national governments can help mobilize action for relief efforts, management of stocks of food reserves, and other measures to reduce the harm to vulnerable populations.

Development of monitoring tools to track precipitation, soil water, evapotranspiration, crop development, cropped area and other physical parameters can, individually or collectively, indicate the potential for crisis. The earlier these events can be effectively diagnosed and communicated to decision-makers, the sooner measures can be taken to reduce their impacts, saving lives and livelihoods, and protecting hard-won gains in the economic growth of developing countries.

The University's strengths in statistical climatology, hydrology, GIS, remote sensing, and geostatistics match up well with the goals and priorities of FEWS NET. The university can use these strengths to improve the scientific research, capacity building, and applications of the USGS component of FEWS NET. Both on-campus and off-campus activities (in FEWS NET countries) are proposed.

The university's scientific focus will be on estimating food production, with emphasis on monitoring and forecasting the natural and human inputs to food production. Basic research will address improved monitoring of rainfall, crop modeling, and cropped area estimates in FEWS NET countries. Better techniques, algorithms, and modeling applications, involving exploitation of remote sensing and other geospatial data, will emerge. Uncertainty associated with monitoring products and seasonal forecasts will be made clear to users, and the spatial data infrastructure underpinning the analyses will strengthened.

1. GeoWRSI

The GeoWRSI tool is a program developed by our southern Africa field scientist. This multi-faceted program was originally designed to allow users to run their own WRSI estimates. Based on initial positive response and some feedback the scope is developing into a end-to-end program which will take satellite based rainfall fields, allow users to input their own station data, update fields of evapotranspiration or crop coefficient, and run scenarios for the remainder of the season. This work will require extensive programming and debugging efforts, but the end result is a valuable stand-alone program allowing various agencies to create products that best simulate their local conditions based on additional inputs. Products that allow users to input their own data (station or field measurements), manipulate model drivers (start-of-season, crop coefficient, length of growing period, etc.), or run simulations (i.e. mean rainfall for remainder of season, 20^{th} percentile rainfall for remainder of season, etc.) are the type of integrated approach that much of the research in this proposal seeks to produce.

2. Temperature and photoperiod inputs to yield estimation

The previous section shows how yield modeling is principally based on simulating the crop water balance through the growing season, as moisture deficits in many crops explain more of the observed inter- and intra- seasonal variability in yield than does temperature. But 21^{st} century climate forecasts simulate temperature change much more reliably than precipitation variability, and the relationship between the two is likely to become more important in terms of crop yields.

The effort described here will improve the WRSI model for monitoring seasonal crop development and yield by incorporating temperature and photoperiod as climate inputs, which will increase model accuracy, as these are also important factors in certain crop development. For example, Thompson (1968) found the single best weather variable for estimating corn yields in the Midwest U.S. to be an accumulation of the daily maximum temperatures above 32 degrees C in July and August. In general, he found that state average corn yields decreased about 63 kg/ha for each 5.5 degrees C accumulated above 32 degrees C. This period usually covers the time of corn silkening, an especially critical period for determining the number of kernels on the ear. (*Crop Reactions to Water and Temperature Stresses in Humid, Temperate Climates*, *1983*). Likewise, yield for Africa's second most important crop after maize, sorghum, is not simply a function of total seasonal rainfall, even where rainfall is the main limiting factor. The most important physiological adaptation mechanism of sorghum to climate variability, the triggering of flowering by day length signals (photoperiodism), synchronizes the final development stages of the plant with the end of the rainy season. *(Kouressy et al. 2007).* By adding crop-specific temperature thresholds and photoperiod characteristics to the current moisture-deficit simulation, the WRSI model will be an even more effective tool for monitoring crop yields throughout the season

3. Crop area estimation

Tools such as the GeoWRSI focus on the estimation of crop yield. While variability in crop yield is a large source of uncertainty in the estimate of food production, the amount of cropped area is also carries large uncertainty, especially in areas where changes in land tenure and expanding or moving populations have resulted in sudden changes in cropped area. Traditional cropped area estimates have resulted from statistical sampling through either field visits or farmer surveys. This proposal plans to improve on these estimates through the use of satellite imagery.

An example of one strategy to improve on this has been exhibited for a portion of Ethiopia (Husak et al, 2007). This study used interpreted high resolution satellite data, combined with physical information such as slope, elevation and rainfall, along with interpreted variables like landcover to estimate the cropped area in select districts. In this modeling, the interpreted high resolution imagery serves as a surrogate for field visits. High resolution image interpretation has been shown to be reasonably accurate in identifying cropped area from non-crop for studies in Niger. Using this data the model is based on tens of thousands of site “visits”, far beyond a typical field visit. Another advantage of these estimates is that the uncertainty in the model is defined, allowing for an approximate range of values which the cropped area falls within.

Studies like the one performed in Ethiopia can be replicated in other locations to ascertain cropped area for countries of interest. The statistical model needs to be developed for each country to account for local relationships between physical variables and cropped area, but the general methodology should remain consistent. Additionally, this proposal will look to include additional variables which may provide more explanatory power in defining cropped area.

4. Improved rainfall estimates

Integration of data from a variety of sources can result in a product that exploits the positive characteristics of all the input datasets. This is especially true for precipitation where satellite derived estimates can be merged with station values to create a rainfall field that is superior to either of these sources individually. The team at UCSB has developed a series of tools and techniques that allow the analysis and integration of points and raster rainfall datasets. Many of these techniques have bee developed for specific regions or to work with specific datasets and, in many cases, they are isolated and are not in a format that is easily replicated in other regions.

The work for this proposal is to integrate the existing techniques and develop new ones to create a straightforward process for the development of the most accurate possible rainfall data sets that serve as input to crop, rangeland or hydraulic models. The process would include the analysis of station data using conventional and geostatistical techniques, unbiasing satellite data using climatological means, the integration of station data with raster rainfall fields, and the creation of historical datasets in raster format. The final product is the development of a standard set of tools which can be broadly applied to many regions for local scientists to implement using available data.

Some of the work that is already done includes: high resolution (5km) cliamtological monthly means which have been temporally downscaled to create dekadal mean fields for Central America, techniques to unbias TRMM data using climatological means, integration of station data with raster rainfall. Formalizing these techniques into a suite of tools which can be universally applied is necessary to insure a widespread use and formalized methodology in the application.

Assessing Orchard and Vinyard Irrigation Needs with Thermal Aerial Imagery

Basic Information

Title:	Assessing Orchard and Vinyard Irrigation Needs with Thermal Aerial Imagery
Project Number:	2009CA254B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	43
Research Category:	Climate and Hydrologic Processes
Focus Category:	Irrigation, Climatological Processes, Agriculture
Descriptors:	None
Principal Investigators:	David Goldhamer

Publications

There are no publications.

We assembled what is believed to be the largest ground team ever assembled worldside to directly measure tree water status which was compared with an indirectly taken measure of tree stress obtained by using aerial thermal images. While the thermal images allow for easy determination of canopy temperature (more than 100 pixels per tree; each with identifiable temperature), ground-based personnel, each equipped with a pressure chamber, are very limited in the number of measurements they can take. Thus, having a team of 10, each with his pressure chamber, was a major step forward in this discipline. Due to this, we were able to take 240 individual pressure chamber measurements and compare this ground-based indicator with the remotely sensed indicator. We found strong correlations between shaded leaf water potential (ground based) with crop water stress index (aerial based); the noon flight had a linear correlation coefficient of 0.93. Similarly strong correlations were found with the morning and afternoon. These high correlations were unexpected and is remarkable for a biological system. It portends very well for the use of aerial measurements of canopy temperature in applied water management on tree crops such as almonds.

Reducing Water Use in Naval orange Production with Partial Root Zone Drying - Comparison with Conventional Irrigation at the Same Reduced irrigation Rates

Basic Information

Title:	Reducing Water Use in Naval orange Production with Partial Root Zone Drying - Comparison with Conventional Irrigation at the Same Reduced irrigation Rates
Project Number:	2009CA255B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	43
Research Category:	Biological Sciences
Focus Category:	Agriculture, Irrigation, None
Descriptors:	None
Principal Investigators:	Carol Lovatt

Publications

There are no publications.

Reducing Water Use in Navel Orange Production with Partial Root Zone Drying

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The California citrus industry produces "picture perfect" navel orange fruit for the fresh fruit market on 124,385 irrigated acres. The cost of irrigation water is a major expense associated with citrus production. Partial root zone drying (PRD) is an irrigation strategy designed to increase water-use efficiency in fruit tree crops to reduce production costs without reducing current or return yield. PRD is the practice of alternately wetting and drying the root zone on two sides of the tree.

Our research goal is to test the feasibility of using partial root zone drying (PRD) to reduce the amount of water used in citrus production and, thus, increase grower net income. Specific objectives are: (1) to reduce annual water use in a commercial navel orange orchard by alternately wetting and drying the root zone on two sides of the tree (PRD) using irrigation rates that are 25% or 50% less than the well-watered control under conventional irrigation (CI); (2) to compare the PRD treatments with CI at the reduced rates (CI-RR) of 25% and 50% less than the well-watered control and with the well-watered control; (3) to determine the effect of PRD and CI-RR treatments on soil moisture content to schedule irrigation; (4) to determine the effect of PRD and CI-RR treatments on total yield, fruit size and quality at harvest for two crop-years; (5) to provide initial soil moisture content values and number of days between irrigations for PRD or CI-RR; and (6) to provide a cost:benefit analysis of the results.

The design is a randomized complete block with five replications of each treatment in a commercial navel orchard at the University of California-Riverside Citrus Research Center and Agricultural Experiment Station. Treatments are: (1) well-watered control (based on evaporative demand); (2) 75% PRD and (3) 50% PRD – trees have an emitter on each side that alternate in delivery to one side of the tree and then the other; (4) 75% CI-RR and (5) 50% CI-RR – trees have an emitter on each side of the five trees within the row so that both sides of the tree are wet. Soil moisture content is measured on each side of a data tree in each treatment for five replications. January 2009 through harvest March 19 2010, all treatments were irrigated when soil moisture for the control trees reached -30 cb at 30 cm. PRD and CI-RR treatments delivering 25% and 50% less water per irrigation than the well-watered control reduced the total amount of irrigation water applied during the crop year to trees in each treatment 25% and 49% and 25% and 48%, respectively.

'Washington' navel orange trees receiving 25% less irrigation water by conventional irrigation (75% CI-RR) produced the same number of fruit as well-watered control trees, indicating that fruit abscission was not increased. However, the 75% CI-RR treatment significantly reduced the number of fruit 63.5 to 88.0 mm in diameter, resulting in a significant reduction in total kilograms of fruit per tree ($P < 0.0001$). All other reduced irrigation treatments significantly reduced total yields and yields of fruit 63.5 to 88.0 mm in diameter as both number and kilograms of fruit per tree compared to well-watered control trees ($P < 0.0001$). Trees in the 75% CI-RR and 75% PRD treatments produced significantly more small size fruit (diameters < 63.5 mm) (both number and kg/tree) compared to all other treatments. Total fruit number, an indicator of fruit retention, from highest to lowest was as follows: well-watered control = 75% CI-RR >

75% PRD > 50% CI-RR > 50% PRD ($P < 0.0001$). Total kilograms of fruit per tree, which reflects the interaction between fruit set and fruit size, from greatest to least was well-watered control > 75% CI-RR > 75% PRD > 50% CI-RR = 50% PRD ($P < 0.0001$). Yield of commercially valuable large size fruit (diameters 69.0-88.0 mm) (kg/tree) from highest to lowest was well-watered control trees > 75% CI-RR = 50% PRD ≥ 50% CI-RR = 75% PRD ($P < 0.0001$). Fruit from trees in the 75% and 50% PRD treatments had significantly greater concentrations of sugars ($P < 0.0001$) and acid ($P < 0.0001$) than fruit in all other treatments. This resulted in fruit in both PRD treatments having significantly lower sugar to acid ratios than all other treatments, except 50% CI-RR ($P < 0.0004$). The effect was not physiologically significant, since all fruit had ratios > 12.

Development and Application of the Coupled Vadose Zone-Ground Water Flow Modeling Environment

Basic Information

Title:	Development and Application of the Coupled Vadose Zone-Ground Water Flow Modeling Environment
Project Number:	2009CA256B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	43
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Water Use, Models
Descriptors:	None
Principal Investigators:	Jirka Simunek

Publications

1. imùnek, J., D. Jacques, N. K. C. Twarakavi, and M. Th. van Genuchten, Selected HYDRUS modules for modeling subsurface flow and contaminant transport as influenced by biological processes at various scales, Biologia, 64(3), 465-469, DOI: 10.2478/s11756-009-0106-7, 2009.
2. Twarakavi, N. K. C., J. imùnek, and H. S. Seo, Reply to Comment on Evaluating interactions between groundwater and vadose zone using HYDRUS-based flow package for MODFLOW , Vadose Zone Journal, 8(3), 820-821, 2009.
3. imùnek, J., D. Jacques, N. K. C. Twarakavi, M. Th. van Genuchten, Modeling subsurface flow and contaminant transport as influenced by biological processes at various scales using selected HYDRUS modules, Abstract for the 2nd International Conference BIOHYDROLOGY 2009: A changing climate for biology and soil hydrology interactions, Bratislava, Slovakia, September 21 24, 2009.
4. Twarakavi, N. C., S. Seo, and J. imùnek, A coupled modeling approach to incorporate vadose-zone flow and solute transport in ground water models, Eos Trans. AGU, 90(52), Fall Meet. Suppl., Abstract H41C-0902, AGU San Francisco, 14-18 December 2009.
5. Twarakavi, N. K., and J. imùnek, A coupled modeling approach to incorporate vadose-zone flow and solute, Geophysical Research Abstracts, 12, EGU2010-7646, EGU General Assembly, Vienna, Austria, May 2-5, 2010

Water flow through the variably-saturated (vadose) zone is an important part of the hydrologic cycle. However, regional-scale groundwater models often simplify or ignore vadose zone flow processes. To overcome this problem, we are developing a new one-dimensional unsaturated flow package for the three-dimensional ground water model MODFLOW, one of the most widely used groundwater flow models.

Water flow through the variably-saturated zone is an important part of the hydrologic cycle because it influences partitioning of water among various flow components. Depending upon hydrological, geological and soil characteristics, rain and snowmelt is partitioned at the land surface into runoff, infiltration, evapotranspiration, groundwater recharge, and vadose zone storage. Water flow in the vadose zone especially affects the transfer rates between the land surface and the groundwater table, which are two key hydrological boundaries. Evaluation of almost any hydrological process therefore requires that water flow through the vadose zone is appropriately taken into account. However, modeling of vadose zone flow processes is a complex and computationally demanding task that is often handicapped by the lack of data necessary to characterize the hydraulic properties of the subsurface environment. Consequently, vadose zone flow processes have rarely been properly represented in hydrological models. For example, regional-scale groundwater models often simplify vadose zone flow processes by calculating groundwater recharge externally without proper consideration of changes in groundwater levels. To overcome this frequent simplification, there is an urgent need for methods that can effectively simulate water flow through the vadose zone in large scale hydrological models. This issue is especially important for groundwater models.

To overcome this problem, we are developing a one-dimensional unsaturated flow package for the three-dimensional modular finite-difference ground water model MODFLOW-2000. MODFLOW was developed by the U.S. Geological Survey and is one of the most widely used groundwater flow models. The HYDRUS Package uses the computer program HYDRUS to simulate water movement in variably-saturated porous media by numerically solving the Richards equation. The HYDRUS package considers the effects of infiltration, soil moisture storage, evaporation, plant water uptake, precipitation, runoff, and water accumulation at the ground surface. Being fully incorporated into the MODFLOW program, the HYDRUS package provides MODFLOW with recharge fluxes at the water table, while MODFLOW provides HYDRUS with the position of the groundwater table that is used as the bottom boundary condition in the package. The HYDRUS package provides an optimal trade-off between computational effort and accuracy of model simulations for coupled vadose zone – groundwater problems. Being based on two most widely used models for simulating vadose zone flow (HYDRUS) and ground water flow (MODFLOW), the coupled software package has a tremendous potential to become widely used in both research and management, and to redefine entirely how the complex subsurface flow problems are evaluated.

UC Irrigation Water Management - Web-based Research and Information Center

Basic Information

Title:	UC Irrigation Water Management - Web-based Research and Information Center
Project Number:	2009CA257B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	43
Research Category:	Ground-water Flow and Transport
Focus Category:	Management and Planning, Surface Water, Irrigation
Descriptors:	None
Principal Investigators:	Steve Grattan

Publications

1. van Benthem, P. et al. 2009 IrRIC poster presentation. Yolo County Fair. Aug 19-23, 2009. Woodland, CA
2. van Benthem, P. et al. 2009 IrRIC poster presentation. California Climate Change Research Symposium 9 September 2009 Sacramento, CA

A web-based Irrigation Research and Information Center is currently being developed at the University of California (UC) <http://irric.lawr.ucdavis.edu/>. Our objective is to develop a user-friendly web-based Research and Information Center (RIC) that will provide users with practical irrigation water management information. Much of the research-based information would be that developed by UC ANR (Davis, Riverside and Counties) but the site will include links to other useful resources. The goal is to develop an educational outreach and extension service to facilitate and coordinate the dissemination of research-based information, educational material and activities related to irrigated agriculture.

The intended users of the website will be the general public, as well as irrigation advisors, consultants, educators, State, Federal and Local agencies and professionals related to various aspects of irrigation water management and surface and ground water quality as it relates to agriculture.

Information is currently being uploaded and organized on the website. The structure of the irrigation website will contain relevant research and extension material developed primarily by the UC related to Irrigation systems (low pressure, surface and sprinkler), Water resource management, Water quality, Irrigation scheduling and Environmental impacts on surface and ground waters. A key to the development of the website is organization and links to other web sites for specific sub-topics. Some material has already been developed and uploaded. Efforts to date have primarily been administrative (organization, logo development, copyright issue, linking strategies, etc). Much of this has been worked out and development of content is underway.

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	11	5	0	2	18
Masters	6	4	0	1	11
Ph.D.	1	2	0	0	3
Post-Doc.	1	1	0	1	3
Total	19	12	0	4	35

Notable Awards and Achievements

2007CA195G - Dr. Andrew T. Fisher, Professor of Earth and Planetary Sciences, University of Californa, Santa Cruz

Invited presentations were made during the reporting period to the following groups, including scientific and engineering personnel and the public at large [speaker was Andrew Fisher, unless otherwise noted]:

University of California, Science, Technology, Engineering and Policy for Society (STEPS) Institute, Conservation and biodiversity workshop, Santa Cruz, CA Pajaro Valley Water Management Agency, Board of Directors, Watsonville CA University of California Water Resources Center Archives, Water Colloquium, Berkeley CA San Francisco State University, Department of Geosciences, Distinguished Speaker Series, San Francisco, CA [Speaker was Graduate Student, Calla Schmidt] University of California, Center for Information Technology Research in the Interest of Society (CITRIS), Research Exchange Lecture, Berkeley CA

We were interviewed by the following media groups, generating stories that were published in major newspapers and/or broadcast on the radio:

Register-Pajaronian (newspaper), Watsonville, CA Santa Cruz Sentinel, Santa Cruz, CA KUSP (pubic radio), Santa Cruz, CA KGO (commercial talk radio), Santa Cruz, CA KALW (public radio), San Francisco, CA

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We were awarded a two-year grant to continue to develop reduced irrigation strategies for the citrus growers of California from the California Department of Food and Agriculture (CDFA) Fertilizer Research and Education Program (FREP).

This project and the results thus far were presented to stimulate a student discussion on plant responses to water-deficit stress in BPSC 143 - Plant Physiology, an upper-division undergraduate course, BPSC 239 Advanced Plant Physiology, a graduate course, and to visiting scientists from Oman, People's Republic of China, New Zealand, South Africa and Australia (were the partial root zone drying method originated).

Publications from Prior Years