# American Water Resources Association
# 2009 SPRING SPECIALTY CONFERENCE
## *Managing Water Resources Development in a Changing Climate*
### May 4-6, 2009
***Anchorage, Alaska***

## POSTER SESSION
### Monday, May 4, 8:30 AM – 6:30 PM
### Tuesday, May 5, 8:30 AM – 3:30 PM

(**Note:** The Presenter of each paper/poster is in **BOLD** type immediately following the paper title. Co-authors are then listed in parentheses. **Also:** All session abstracts can be accessed using the Session Title link.)

**1. Climate Change Impact Assessment on Korean Water Resources by Multi Model Ensemble - Deg-Hyo Bae**, Sejong University, Seoul, Korea (co-authors: Il-Won Jung, Byong-Ju Lee, Taehyun Jun)

Korean climate has recently experienced a meaningful change due to global warming. The temperature during the 20th century was increased by 1.5 □, which is above the world average and the increasing rainfall intensity and decreasing number of rainy days were obvious. This causes direct increase of flood and drought damages during last 10 years in this country. Several researches have asserted that the water resources management will be much more difficult due to climate change in the future. However, those previous studies have some limitations involving uncertainties of their studies, mainly caused by the use of single greenhouse gas emission scenario and the adoption of single hydrologic model. In this study, we propose a method to reduce the uncertainties of water resources impact in a climate change and provide the test results over the whole Korean watersheds. The outcomes will be the probabilistic results of climate change impacts on river discharge during the period of 2071-2100. The 13 GCM simulations with three emission scenarios (A2, A1B and B1) from IPCC AR4 are used for the analysis. Eight different hydrological models are applied for the members of multi-model ensemble (MME). We will provide the spatial variations of air temperature, precipitation, evapotranspiration and river discharge. It also delivers seasonal variations of the meteorological and hydrologic variables. It will be the first time to demonstrate the climate change impact assessment on water resources by multi model ensemble for the whole Korean peninsula.

**2. Use of Winter Low–Flow Measurements and Open-Water Surveys to Characterize Surface-Groundwater Interaction – a Case Study from Southwestern Alaska - Robin Beebee**, HDR Alaska Inc., Anchorage, AK

Many parts of Alaska are underlain by recent or prehistoric glacial deposits of varying thickness and porosity. In these areas, complex surface water-groundwater interactions are common. Groundwater upwelling is often linked to productive fish habitat, especially during the winter. Losing stream reaches may go dry during low-flow periods despite surface flow upstream and downstream, and create a barrier for fish. Surface water may infiltrate into the ground, cross beneath a topographic divide, and upwell in an adjacent basin. Prior to development or diversion of surface water in these areas, the potential for interbasin water transfer, loss of flow to groundwater, and upwelling patterns should be studied to avoid unintended consequences to downstream resources. Low flow conditions occur when stream discharge is supplied by inflow of groundwater (baseflow) in the absence of direct runoff from precipitation or snow melt. These conditions often occur in Alaska during winter freeze. Patterns of groundwater flow and surface upwelling are most discernable during winter low flow periods, when some stream reaches run dry, while nearby reaches contain flow under ice or are ice-free because of the input of warm groundwater. A study of low-flow stream conditions is ongoing as part of the environmental baseline studies for the proposed Pebble Project. Low flow discharge measurements are repeated at 21- 43 stations along three headwater streams in Iliamna prior to thawing, to create discharge profiles. In addition, surveys of open (ice-free) stream reaches and dry reaches each year are used to delineate upwelling and losing stream reaches. Results from 2004-2008 have indicated that all three streams have gaining and losing reaches as they cross permeable glacial deposits, and that groundwater crosses topographic divides in two places.

**3. North Slope Decision Support for Water Resources Planning and Management: Technological Aspects - Stephen Bourne**, Post, Buckley, Schuh & Jernigan, Inc., Tampa, FL (co-authors: Leslie Gowdish, Kelly Brumbelow, Amy Tidwell, William Schnabel)

Ice roads and ice pads provide a cost-effective means of oil and gas exploration on Alaska's North Slope with minimal impact to the sensitive underlying tundra. Consequently, such ice structures have become integral to oil and gas exploration. Their widespread use represents a challenge to water resource managers, however, due to the large volume of water necessary to construct and maintain them. As the proximity of available fresh water sources has a

significant impact on the planned location of ice roads and ice pads, changes in water resource management strategies could significantly impact oil and gas exploration activities. This paper will describe the technological aspects of the North Slope Decision Support System (NSDSS) a project currently underway to develop a water resources management solution in support of oil and gas exploration on the North Slope. Sponsored by the Department of Energy, the NSDSS will consist of an information system, software tools for decisions support, and methodologies for facilitating stakeholder involvement in the decision making process. Envisioned as a framework for general water resources planning on the North Slope, the NSDSS will not only apply to the water management issues considered here, but will also be applicable to broader environmental management issues and industry development applications. The NSDSS will consist of 1) a service oriented architecture (SOA) based cyberinfrastructure composed of a node-link network of federated databases at Fairbanks, Anchorage, and Barrow Alaska, 2) a desktop-based workbench tool, which is an extension to ESRI's ArcMap software, and 3) a virtual globe-based web browser tool. The cyberinfrastructure will contain databases of GIS data, time series of meteorological and hydrological data at points and as gridded products, and papers describing scientific findings relevant to the North Slope. Using the workbench, users will be able to assess the impact of proposed management alternatives vis-a-vis important stakeholder criteria by simulating the implemented alternative in an integrated model of the physical systems on the North Slope (hydrologic, meteorological, ecological, etc). The web browser will provide an intuitive view of the North Slope, the data available, and indeed the data gaps to be filled.

**4. The Role of Climate Change in Alaskan Bluff Erosion: Kenai Case Study - David Broadfoot**, Tetra Tech, Inc., Portland, OR (co-authors: Krey Price, Christy Miller)

In recent years, coastal communities in Alaska have been experiencing accelerated erosion that threatens homes, harbors, and other infrastructure. Global climate change is one parameter within a multifaceted set of contributing factors accelerating historical erosion rates in Alaskan coastal communities. One example of a coastal community affected by erosion with multiple underlying causes is the City of Kenai on Alaska's Kenai Peninsula. This poster presents the Kenai bluff line over time based on 60 years of historical aerial photographs, topographic surveys, and bathymetric surveys. Additional figures show building pads and structures falling victim to the erosion. Erosion has severely affected many miles of Cook Inlet Bluff; however, this poster is focused on a one-mile stretch of bluff located along Cook Inlet at the mouth of the Kenai River. In this area, the bluff is subject to wave action from Cook Inlet, river currents and associated transport of eroding sediments, groundwater piping on over consolidated glacial till, freeze-thaw cycles, overland drainage, direct rainfall runoff, and a number of other forces. Up to 200 feet of lateral bluff erosion has occurred over the 60-year period of record. From decade to decade, the erosion rate has been fairly constant; however, in examining the rate of bluff erosion from year to year, individual storm events and tectonic changes must also be considered. Following the 1964 Great Alaska Earthquake, for example, a particular increase in the erosion rate is apparent. This poster shows a comparison of the bluff before and after the earthquake. Several changes in the bluff are apparent, some of which may be attributable to subsidence and other mechanisms. Placement of fill that otherwise might have been attributed to natural processes is also apparent on oblique historical photographs. In the case of Kenai, the eroding bluff would require intervention under any climatic scenario, whether subject to global warming or global cooling. Although global climate change may increase the magnitude and frequency of wave attacks, the processes in Kenai are complex and interrelated and the primary mechanisms appear to be unrelated to climate change.

**5. North Slope Decision Support for Water Resources Planning and Management: Institutional Aspects - Kelly Brumbelow**, Texas A&M University, College Station, TX (co-authors: Stephen Bourne, Amy Tidwell, William Schnabel)

Alaska's North Slope hosts a phenomenal wealth of natural, cultural, and economic resources. It represents a complex system, not only in terms of the biophysical system and its global importance but also from the standpoint of its social dynamic. A major challenge at the forefront of domestic energy development on the North Slope is the need for best management practices that will ensure benefits for all stakeholders. To do so requires stakeholder cooperation that enables cost-effective development strategies that fit within a broader context of long term cultural, economic, and environmental sustainability. The North Slope Decision Support System (DSS) is currently under development as a technology in support of oil and gas exploration and development that explicitly considers optimal water use, direct and cumulative environmental impacts, and multiple objectives and values among stakeholders. Development of the DSS is a collaborative effort of academic and industry personnel with significant stakeholder involvement from multiple agencies of local, state, and federal government, private energy companies, and non-governmental organizations. The collaborative process is being accomplished through traditional means such as workshops and internet-based means such as discussion forums. In development is a self-organized structure to govern technology development and use and sustain the system over the long term. A further innovation is the development of "institutional requirements" in parallel with functional and non-functional requirements as part of the technology development process. The overarching goal of the process is a viable and integrated technology and management process.

**6. Thermal Stability of Permafrost Affected Soils - Rena Bryan**, University of Alaska Fairbanks, Fairbanks, AK (co-authors: Chien-Lu Ping, Larry Hinzman)

The landscape shifts expected for the future restrain estimates of carbon dioxide and methane flux to the atmosphere and shape considerations of these local and regional measurements in the global budget. We modeled present and future top of the permafrost temperatures throughout the Yukon River Watershed. We made point thermal conductivity measurements along the Elliot, Dalton, Richardson, Alaska, Klondike, and Taylor Highways to improve input into TTOP model. Organic matter content has an inverse relationship on thermal conductivity. Mineral soils have higher thermal conductivity, but there is a difference between soils in the tundra region and those in the boreal forest. The former have higher clay contents (clay loam or loam), thus the soils have higher density. The latter have less clay but more fine sand. We observe steeper increase in thermal conductivity through horizons of soils in tundra regions versus in boreal forests along a north-south bioclimate transect. Further analysis of Yukon River Watershed soils will help assign thermal conductivity to soil types. Meanwhile, soil thermal conductivity estimates correlate with spatially interpolated meteorological station air and surface temperatures by vegetation type and elevation to enable model predictions of present permafrost temperatures. These results compared with future results, driven by the ECHAM5-AIB Global Climate Model, depict the thermal stability of permafrost in the Yukon River Watershed.

**7. Estimating Hydrologic Change in an Area Underlain by Discontinuous Permafrost on the Seward Peninsula of Alaska - Robert C. Busey**, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, AK (co-author: Larry D. Hinzman)

Alaska's Seward Peninsula is underlain by warm (near freezing), shallow, continuous and discontinuous permafrost. These conditions make it more susceptible to changing climatic conditions such as acceleration of the hydrologic cycle or general atmospheric warming. This study examines the Snake River watershed, an important water resource flowing through the regions' most populace town, Nome. Permafrost restricts subsurface flow so modeling potential changes to both soil moisture and river discharge are important to the ecology of the area and how local residents use the resource in the future. Using a physically based hydrologic transport model, the present hydrologic system is compared to the future using observational data for the present and GCM output for the end of the 21st century. Unlike most of Alaska, climate records and river stage have been recorded in Nome for many years providing a solid basis for modeling. For the future modeling comparison, the Max Planck Institute Echam5 SRES A1B scenario was selected because the 20th century run for this model best represents the current climatology in Alaska (Walsh et al in press). Initial conditions for the thermal regime of the ground and permafrost distribution for the present and future is estimated using previous work (Busey et al 2008). Past work has also involved modeling discharge at four smaller basins in the interior of the Peninsula (Carr 2003). This study expands that research to a larger watershed with a higher population with more diverse water needs.

**8. Distributed Snow Modeling for Forecasting Tundra Travel and Driving Conditions - Sarah Byam**, University of Alaska Fairbanks, Fairbanks, AK (co-author: Jessica Cherry)

Construction of ice roads and safe travel across the tundra requires knowledge of snow distributions and blowing snow conditions. A new project is described wherein the aim is to couple a weather forecast model to a snow model in order to simulate blowing and redistribution of snow. The atmospheric model is the Weather Research and Forecasting model used by both the weather prediction and model development communities. The default snow models in the WRF package, which are part of either the Noah or the RUC land surface schemes, neglect redistribution of snow via wind. This is known to be a key process in the evolution of the annual snow pack across Alaska's North Slope. Validated performance of a different snow model is shown, as well as the coupling with the WRF model for this application.

**9. Watershed Scale Response to Climate Change: Clear Creek, Iowa - Daniel Christiansen**, U.S. Geological Survey, Iowa City, IA

2008 marked the start of the U.S. Geological Survey Global Change study "An integrated watershed scale response to climate change in selected basins across the United States". The long term goal of this study is to provide the foundation for hydrologically-based climate-change studies across the nation. Precipitation Runoff Modeling System (PRMS), a deterministic, distributed-parameter, watershed model developed to evaluate the effects of various combinations of precipitation, temperature, and land use on streamflow and general basin hydrology, was calibrated and evaluated at fourteen sites. PRMS results for Clear Creek in Iowa are summarized below. Six General Circulation Models (GCMs) incorporating four climate change scenarios were used to develop an ensemble of climate change scenarios for PRMS. GCM results indicate a trend toward an overall increase in temperature for Clear Creek. However, there are large uncertainties (especially maximum temperature) associated with these GCM projections. Changes in precipitation for Clear Creek are highly variable, with a trend toward a minor increase over the modeled time period 2001-2099. The large range in the precipitation projections also indicates a large amount of uncertainty. Surface, subsurface, and ground-water flow results all show a decrease in the later part of the 21st century. A slight decrease in streamflow would show that the effects of climate change on the flow regime of Clear Creek indicate an overall drying of the basin. These results do not address potential land-cover changes, including but not limited to

increasing urban growth, and private and public water-use, which may affect future flow regimes in the Clear Creek basin. Future work needs to address the combined effects of climate and land-cover dynamics on streamflow regimes.

**10. Defining Southern Appalachian Riparian Zone Width Using Structure and Function - Barton D. Clinton,** USDA Forest Service, Otto, NC (co-authors: J.M. Vose, J.D. Knoepp, K.J. Elliott, B.K. Reynolds)

Effectively defining riparian zone width is at the center of an on going debate about the protection of critical aquatic and terrestrial processes and habitats in southern Appalachian ecosystems. In this study we characterized structural and functional variation along 50-m transects from the stream-side into the uplands. Our objective was to identify parameters that exhibited significant transitions along these transects to aide in defining riparian zone width. Four sites were selected and eight transects were installed perpendicular to the stream on each site. Both structural and functional components were examined. For structure, we quantified CWD and forest floor mass N and C, total soil C and N by horizon, soil depth, woody and herbaceous vegetation, litter fall amount and quality by species, and microclimate. Functional parameters included litter decomposition, soil micro-arthropods, soil CO2 evolution, soil solution chemistry, and exchangeable ions. Some parameters exhibited distinct transitions along the stream-side to upland gradient. For example, forest floor litter mass, N and C all increased significantly with distance from stream with a transition point of approximately 10 to 20-m from the stream. Soil depth also increased significantly with distance from stream and transitioned around 10-m from the stream. In contrast, litter fall rate (kg N ha-1d-1), CWD, soil C and N in the A-horizon, and soil solution [NO3] all decreased with distance from stream and all showed significant transition points along the transects. Certain overstory tree species were more abundant at one extreme of the gradient or the other, and herbaceous species were similar in number but varied in their proportions along the stream to upland gradient consistent with specific microsite preferences. Taken together, these results suggest a key riparian to upland transition at about 10 to 20 m from the stream.

**11. Characterization of Soil Properties to Derive Pedo-Transfer Functions to Map Soil Moisture at a Regional Scale: A Comparative Study - Shanon Connelly**, USF St. Petersburg, St. Petersburg, FL (co-author: Barnali Dixon)

The rapid availability of soil moisture data will be an extremely useful data set for hydrological, climatic, meteorological, agricultural, and biogeochemical models. Needless to say, the role of soil moisture in various climate scenarios is also an important variable in climate change research. The study of soil moisture sensitivity in the presence of increased carbon dioxide has a growing importance in climate model experiments. This research attempts to map soil moisture content at a higher spatial resolution by integrating various methodologies (multiple data sources as well as multiple interpolation techniques) in an innovative way to generate soil moisture maps at a regional scale. The overall goal of the research is to compare methodologies for interpolation from point data that will be combined with mass-balance methods and pedo-transfer functions (PTF) to derive soil moisture maps. The specific objectives of this research are to (1) integrate point data for soil properties and weather data from the Oklahoma Mesonet using various interpolation methods, (2) incorporate these various interpolated surfaces into the mass-balance methods to generate spatial coverage of the soil moisture maps, (3) calibrate and validate the resultant maps using soil moisture data collected at the Oklahoma Mesonet, (4) incorporate NEXRAD WSR-88D data (as surrogate for rainfall input) to the interpolated soil properties maps to create soil moisture maps by using grid-based mass-balance equations, and (5) validate the spatially explicit soil moisture maps derived from various interpolation techniques using remotely sensed data. The preliminary results were conducted for August and October 2000 and for March and April 2003. Landsat TM and Landsat ETM+ data were used to derive soil moisture maps from remotely sensed methods. The research showed that soil moisture maps derived from various interpolation techniques used with the Oklahoma Mesonet data showed considerable variations, however, provided comparisons of various methods provided insights into the resultant map accuracy for the soil moistures.

**12. Copper Runoff To San Francisco Bay From Brake Pad Wear Debris: A Modeling Assessment - Anthony S Donigian Jr.,** AQUA TERRA Consultants, Mountain View, CA (co-authors: Brian R Bicknell, Kirsten Sinclair Rosselot, Elizabeth A. Wolfram)

This watershed modeling effort was conducted as part of a larger study by the Brake Pad Partnership (BPP) that examines the potential impact of copper from brake pad wear debris released to the environment in the San Francisco Bay (SF) Region. The BPP is a mulitstakeholder effort of manufacturers, stormwater agencies and environmentalists to better understand the impacts of this source of copper on water quality. The watershed model provides runoff loads to a Bay modeling effort to assess resulting concentrations in SF Bay. The U.S. EPA's Hydrological Simulation Program-FORTRAN (HSPF) model, was set up for each of the 22 BPP modeled sub-watersheds that drain to the SF Bay. HSPF Model runs were performed for each sub-watershed for the entire time period of water year 1981 through water year 2005. Model results were processed for flow, sediment and copper loads, and annual and mean annual loads were tabulated. Uncertainty in both non-brake and brake release estimates was assessed by representing alternative scenarios of source loadings. Three cases of copper release scenarios were modeled -- with high, low, and median releases. Each of these three scenarios was modeled with and without releases from brake pads in order to determine the relative contribution of copper from brake pads in runoff to the Bay. The total anthropogenic contribution from brake pad wear debris towards total loads of copper to the Bay for the

median estimate case varies from 15% to 57%. As expected, the brake pad contribution is much lower for the rural sub-watersheds than for the heavily urbanized sub-watersheds, reflecting alternative human activity and traffic levels. Additional scenario runs were performed to assess the impacts of copper lost through the normal buildup/washoff attenuation algorithms and the time period for when copper loads would return to background levels if all sources were eliminated. Scenario runs also considered impacts of climate changes such as wet and dry periods, and the relative impacts on loadings.

**13. Mapping River Changes Using Low Cost Autonomous Unmanned Aerial Vehicles - Huifang Dou**, Utah State University, Electrical and Computer Engineering Dept., Logan, UT (co-authors: Yiding Han, Yangquan Chen)

The path of a river flow might change due to drought, flood or other natural calamities. The aerial images of the river path nowadays, however, are mostly either outdated or in low quality, making it difficult to perform studies of the changed river and the variations of its nearby ecological system. In this paper, a high resolution multi-spectrum camera system, including one GRB camera and one NIR camera, installed on a low-cost autonomous Unmanned Aerial Vehicle (UAV) is introduced. This paper also proposes a novel algorithm for calculating and detecting a river flow path in order to provide an efficient flight plan of the UAV. The flight plan with 3D waypoints is formed by integrating flow line data from NHDPlus (National Hydrography Dataset Plus) and DEM (Digital Elevation Model) from USGS (U.S. Geological Survey). The images captured by the cameras are processed in real time. Based on the information derived from these images, waypoints are dynamically generated for the autonomous navigation so that the UAV can exactly follow the changed river path and the focus of each image from the camera system is on the center of the river. Simulation results indicate that the combination of GIS (Geographic information systems) based pre-programmed flight plan and dynamic auto-navigation is able to pilot the UAV more efficiently and accurately. The actual flight results collected in several flying experiments along a river verify the effectiveness of the approach proposed in the paper. In addition, by comparing the actual flight results to simulation ones, the cause of flight path error in the actual flights is identified and discussed in this paper.

**14. Fort Smith's use of an Alternate Water Supply in Response to a Significant Drought - Paul Easley**, City of Fort Smith, AR

Fort Smith, Arkansas has two independent water sources. Our primary water source is the Frog Bayou watershed, a 74 square mile forested valley located in the Boston Mountains, 2 miles north of Mountainburg, Arkansas. Fort Smith’s other water supply is the Lee Creek watershed, a 439 square mile area located in both the States of Arkansas and Oklahoma. Beginning in 2005 and continuing into 2007, the area around these watersheds experienced a significant drought almost completely depleting the City’s available water supply. Faced with the real possibility of running out of water, the City began to evaluate its water supply options. In 1991, a basin management plan was instituted for the City’s watersheds. Basin management plans document the results of the statewide watershed management process, including selected management strategies and stakeholder roles and serve as reference points for future basin management. Included in this plan are measures for evaluating management effectiveness, a monitoring program to measure success and guide future basin management plan revisions. Data assembled from implementation of this management plan proved to be useful in formulating use of an alternate supply during drought conditions. In 1992, an engineering firm was selected to conduct an environmental assessment and alternatives analysis for four new water supply alternatives. An expansion of Lake Fort Smith was selected as the preferred alternative. The expansion project would combine the existing Lake Fort Smith and Shepherd Springs into one lake. The dam at Lake Fort Smith was to be raised 101 feet, creating a lake with a surface area of 1,398 acres capable of reliably providing up to 50 million gallons of water a day. Construction on the expansion project began in June 2002, however, was not scheduled to be completed until late 2006. This poster presentation will focus on the effects the drought had upon the existing water supply, monitoring program utilized to make decisions, water quality variations, operational problems, customer complaints. This information will be presented utilizing charts, graphs and photographs to depict and display data.

**15. Assessing Risk to Shoreline-Dependent Birds Due to Climate Change and Human Disturbances at Florida Military Installations - Richard Fischer**, U.S. Army Engineer Research & Development Center, Vicksburg, MS (co-authors: Igor Linkov, Gregory Kiker, Resit Akçakaya, Lev Ginzburg)

Coastal military installations in Florida provide key seasonal habitats for shoreline-dependent birds. Climate change (via sea-level rise and altered weather patterns) is expected to significantly alter low-lying coastal and intertidal areas important to these and other coastal organisms. Potential land use changes and human population increases, coupled with uncertain predictions for sea-level rise, and storm frequency and intensity have created a significant planning challenge for natural resource managers in the face of climate change. This project will integrate multi-scale climate, land use and ecosystem information into a systematic tool set to explore how climate variability and change effects may influence habitat and population dynamics for Snowy Plovers, and simplified habitat effects on Piping Plover and Red Knot on Eglin Air Force Base (AFB) and Tyndall AFB, FL. We will present methodology to: (1) assess current vulnerability scenarios and information on selected Florida bases by documenting and reviewing Florida-specific climate, land use databases and information; (2) develop a set of habitat- and species-based models for selected coastal Threatened, Endangered, and Sensitive At-Risk Species (TER-S); (3) assess the current prediction

level and assumptions of selected categories of TER-S models for use in benchmarking model performance and uncertainty levels; and (4) integrate the scientific data, modeling and uncertainty results into a risk-informed, multi-criteria decision analysis system to allow systematic analysis of potential management options.

**16. Water Level Changes in a Sub-Arctic Lake near Fairbanks, Alaska: Past, Present, and Future - John Fox,** University of Alaska Fairbanks, Fairbanks, AK

Harding Lake is a deep, oligotrophic lake approximately 60 km southeast of Fairbanks, Alaska, that has been an important and accessible recreational and seasonal residential site since the early 1920's. Lake levels appear to have declined nearly 1.5 meters through the 1970's with some recovery in the 1980's followed by continued decline in the 1990's and into the 2000's. This lake level decline translated into over 100 meters of shoreline retreat in places where broad, shallow littoral zones existed. This shoreline retreat has adversely affected pike habitat, recreational opportunities, and water access from on-shore cabins. This study reports on efforts to reconstruct historic lake levels in the absence of on-site hydrologic data or quantitative lake level measurements. Old maps, ground and aerial photographs, original land survey notes, oral histories, and field reconnaissance served to build a case for why and when the hydrologic regimen of the lake changed. In 2006 an in-stream structure was built to help restore desirable lake levels. Three years of lake level measurements prior to management intervention and two years of lake level measurements after management intervention are reported. These data and simple modeling results are used to access the likelihood and timing of achieving the lake level restoration target.

**17. Hydro-climatic Changes of the Yukon River Basin - Shaoqing Ge**, WERC, Fairbanks, AK (co-authors: Daqing Yang, Douglas Kane)

This study analyzes climatic and hydrologic data during 1977 and 2006 over the Yukon River Basin. Preliminary results show that the discharge in winter is low and has small variations; in summer, the runoff is high with big variations; maximum discharge occurs in June due to snowmelt over the basin, except the Nenana River, which occurs in July due to glacier-melt; daily discharge analyses show that the time of peak flow shifts to an earlier time. The basin discharge trend analyses indicate that the positive trend (177,000ft3/s) in early summer (May) has confidence over 97%. The positive trend (4,586ft3/s) in April has confidence over 85%. The negative trends (7,502ft3/s-12,184ft3/s) in January, February, and December are significant around 85%. The basin temperature analyses (data available from 1977-2004) show that: the basin temperature maximum temperature occurs in July (18.0oC). The warm season is from May to September (8.7oC -18.0oC). The cold season is from October to April (-18.2oC -0.3oC). Temperatures in warm season have little variation, except an increase of 2.5oC in June with confidence level over 99%. In cold season, the temperature increase of 3.0oC in April has confidence over 90%. The increases (maximum 4.0oC) and decreases (maximum 3.0oC) in other months are not statistically significant. The basin precipitation analysis shows: The high precipitation period (43mm-63mm) of the basin is from June to September, with maximum precipitation in August (63mm). The low precipitation period (13mm-28mm) is from October to May. Negative trend is observed in June (15mm) with confidence level over 93%; the decrease (10mm) in December has confidence level below 80%; Positive trend in February (13mm) has confidence level above 87%. Other positive trends in January (4mm), May (8mm), July (8mm), August (15mm), September (8mm), and October (2mm) are not statistically significant. Results of this study indicate that the discharge increase in late spring and early summer over the Yukon River is due to the early warming in winter and spring. Precipitation increase in spring is also a factor for the runoff increase in early summer.

**18. Improving Flow Measurement Accuracies in Water Systems - Bryan Heiner**, Utah State University, Logan, UT (co-author: Steven L. Barfuss)

Today's water distribution and irrigation managers must utilize their systems in such a way that they can meet increased demands. With populations growing and global warming causing a decrease in source water, meeting larger demands is becoming increasingly difficult. In order to meet increased water demands, water distribution systems must be carefully managed; an important aspect to the wise management of water systems is to ensure that accurate flow measurements are achieved. In some cases, no flow measurement devices are available, or are no longer in use, resulting in arbitrary flows being set. On the other hand, even when flow measurement devices are installed in a system, it should be noted that they will only provide accurate measurements when installation and maintenance requirements are met. When installation requirements deviate from design criteria, inaccuracies in water measurement occur and management practices become difficult. This paper briefly discusses several different types of open channel flow measurement devices that are used in open channel distribution systems including parshall, cutthroat, and ramp flumes, weirs, and rated sections. Advantages and disadvantages of installing open channel measurement devices on systems that currently do not monitor flows are presented. In addition, the specified accuracies of open channel devices and some possible causes for measurement errors are discussed. Field data are used to compare manufacturer or design manual specifications to actual measurement results. When possible, manufacturer and design manual specifications are compared for consistency. Typical differences that occur between field and design applications are discussed. Small errors in flow measurement may seem unimportant, but over time these errors accumulate to what can be very large volumes of mismanaged water. When accurate flow

measurements are achieved, it is possible to better manage and conserve water in distribution systems to help meet increasing demand requirements with decreasing supply.

**19. Cascading Effects of Landscape Modification on Microclimate, Energy and Water Usage - Indumathi Jeyachandran**, Tennessee Tech University, Santa Clara, CA (co-authors: Steven J Burian,. Eric R. Pardyjak)

Landscape modification due to urbanization has been observed to influence the urban water cycle components largely and the inter-connected factors: microclimate, energy usage. The water cycle component evapotranspiration is significantly influenced by landscape and it has an impact on the urban microclimate and energy usage and water use for energy generation. Through an integrated modeling framework, the effect of various landscape patterns on the sensible and latent hear fluxes, the microclimate, energy and water use are modeled and the results are presented in this paper. The sensible and latent heat fluxes are modeled using an urban heat flux models which models heat fluxes using the inputs of vapor pressure deficit, wind speed, soil moisture, aerodynamic and surface resistances. The heat flux outputs the heat flux output is fed into an urban microclimate model and the effect on the urban microclimate is modeled and the results are presented in this paper. The results from the urban microclimate model are fed into an energy usage model which is again connected to a water use model and the cascading effects of urban form on the water cycle components, energy usage and water usage are modeled. The study was conducted for irrigated grass and xeriscaped yards scenarios and the cascading effects for the two scenarios were studied and the results are presented in this paper. The xeriscaped yard scenario was observed to increase the urban air temperature and the energy usage and water usage for energy generation. Also, the latent and sensible heat fluxes for varying vapor pressure deficit is modeled and a similar study was also conducted for soil moisture and this was done to study the effect of the parameter vapor pressure deficit and soil moisture on the interconnected water cycle-microclimate and energy usage.

**20. Regional Water Security, Contemporary Farm Landuse Trend, and Global Climate Change Impact in Northern Region of Alabama - Girma Kebede**, Alabama A&M University, Normal, AL (co-authors: M. Wagaw, T. Gabre, W. Tadesse, B. Bekele, T. Tsegaye)

Huntsville City is experiencing a high rate of expansion. The land use/land cover across the Madison and Limestone Counties is being rapidly transformed from a predominantly cotton-farm or pastoral-land to a new urban, suburban one. The completely new ramifying conditions for surface water flow and groundwater recharging are part of the permanent transformations induced by such rapid dynamics. This process combined with global climate change is posing a challenge to secure sufficient water resource for a healthy eco-system and balanced regional economic growth. The recent past recurrent agricultural drought had shown the vulnerability of North Alabama’s water system to induced weather-regime fluctuation and change. In this poster we analyze two Landsat TM images and weather observations at five different stations across the region. Historical trends of water supply, rain-fall and temperature distribution over the past seven decades is discussed and future research direction presented.

**21. An ENSO-Based Wavelet Time Series Model for Nitrate Loads in the Little River Watershed - Victoria Keener**, University of Florida, Gainesville, FL (co-authors: James W. Jones, David D. Bosch, Richard Lowrance)

There is a recognized difficulty in dealing with climate variability on a global or regional level, either in the Global or Regional Circulation Models currently in use. Current climate models do not simulate El-Niño/Southern Oscillation (ENSO), and therefore do not adequately reproduce precipitation in areas of the world where ENSO is a significant factor, such as the southeast United States. ENSO is a global climate phenomenon with strong effects on the weather patterns of the southeast United States. ENSO has predictable effects on stream flow, rainfall, crop yield, and nutrient loads in runoff. As IPCC reports have concluded that climate variability and extreme events will be more common in the future, research and models that focus on understanding and predicting climate variability effects will be increasingly helpful for making robust management decisions in an uncertain world. To better understand the relationship between Sea Surface Temperature (SST) anomalies in the equatorial Pacific Ocean and hydrology and climate in the southeast United States, we have done an analysis in the frequency domain on 30 years of SST, precipitation, flow, and nutrient load data from an agricultural coastal plain watershed in Tifton, Georgia. We found that the 3-7 year mode of variability of ENSO cycles exists in the Little River Watershed's precipitation, flow, nitrate and total phosphorus load time series. SST's and both nutrient loads, stream flow and precipitation time series also demonstrated shared periodicity and high covariance in the 3-7 year period in cross and coherence wavelet analysis. This indicates that ENSO signal can be used as a predictor for nutrient loads in the southeast United States. Significant reconstructed components (RC) from each time series were extracted and used to create a monthly multivariate time series nutrient load model. This model could be useful for land and water managers in the southeast United States, as high risk months for greater than average nutrient loading could be identified and managed in advance.

**22. Integrating Climate Change Impacts into Water Resources Planning - Anwar Khan**, HDR Engineering, Inc., West Palm Beach, FL (co-authors: Lewis Hornung, Eli Brossell, Daryl Schneider)

The Intergovernmental Panel on Climate Change has recognized that global climate change is likely to have significant adverse impacts on water resources throughout the world. These impacts will result from complex set of interactions between a multitude of factors including increased atmospheric and ocean temperatures, altered precipitation patterns and evapotranspiration rates, change in the frequency and intensity of storms, variations in the timing and magnitude of runoff, and sea level rise. Few standard protocols are currently available for integrating climate change issues into large water resources planning efforts. This paper will discuss approach and methodology used by a multi-agency water resources planning team for incorporating climate change issues into a feasibility study conducted for the Lake Okeechobee Watershed (LOW) Project. The LOW Project is one of the major components of the Comprehensive Everglades Restoration Plan (CERP). Its primary objectives are to contribute towards holistic restoration of Lake Okeechobee by providing better management of lake water levels, improving lake water quality, and minimizing frequency of damaging freshwater releases to the two northern estuaries. During the planning process, a final set of three alternative plans were identified through a comprehensive screening process. Costs, benefits, risks, and uncertainties associated each of the three alternative plans were evaluated and compared to each other and to the no action alternative. A scenario analyses was conducted to evaluate the ability of each of the three alternative plans to meet stated project goals and objectives. Factors related to climate change such as sea level rise, changes in precipitation patterns, and increase in frequency and intensity of storms were subjectively assessed and the results were used to guide the selection of the plan that best met stated project goals and objectives. Incorporating climate change issues into the planning process in a holistic and timely manner ensured that factors that have the greatest level of uncertainty or pose the largest risk of compromising achievement of project objectives were identified early and appropriately evaluated. Information on how the tentatively selected plan would perform across a range of selected possible future climatic conditions is vital for the decision makers.

**23. El Nino, La Nina, and the Variability of Precipitation and Precipitation Effectiveness in Korea - Gwangseob Kim**, Kyungpook National University, Daegu, Korea (co-author: Kun Yeun Han)

The variability of precipitation and precipitation effectiveness in Korea during different climatic conditions such as El Nino, La Nina and Normal periods was analyzed using 58 year monthly precipitation data from January 1950 to December 2007 for 14 sites. Ground weather stations were located in different environments such as urban and rural area, inland and costal area, and different elevations. Therefore the regional impact of climatic change was analyzed for different local characteristics. Also monthly and seasonal variability of precipitation for different climatic conditions were analyzed. El Nino and La Nina monthly scenario of the climate prediction center of NOAA was used to compare the behavior of precipitation during normal and abnormal period. Results show that the variability of annual precipitation according to the climatic conditions is different according to the regional characteristics. For El Nino period, annual precipitation is usually greater than that of normal and La Nina periods. However annual precipitation of urban area does not affected by climate conditions. Also for island area, it shows very reverse results, annual precipitation during El Nino is less than that of normal and La Nina period. The monthly variability of precipitation shows that monthly precipitation during July and August is greater than that of normal year and monthly precipitation during June and September is smaller than that of normal year. For La Nina years, monthly precipitation during August is smaller than that of normal year. The availability of water resources is related to not only precipitation change but also air temperature change. Therefore precipitation effectiveness combined variable of precipitation and air temperature was analyzed to understand the water resources availability during different climatic conditions in Korea. Results show that despite of consistent increase trend of air temperature, the overall behavior of precipitation effectiveness is similar to that of precipitation but detail behavior of monthly data shows some difference between two variables. The characterization of the variability of precipitation during different climatic conditions allows us to do the better water resources planning and management.

**24. Analysis of the Spatial and Temporal Variability of Soil Moisture in Korea - Gwangseob Kim**, Kyungpook National University, Daegu, Korea (co-author: JongPil Kim)

The impact of climate change has caused variation of the regional water environment. Soil moisture is key variable in hydrologic process and water energy balance behavior since it links atmosphere and ground. Therefore analysis of spatial and temporal variability of soil moisture is important to understand the regional impact of climate change on the local water environment. The advances in remote sensing technology allows large scale mapping of soil moisture. The Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) instrument on the NASA EOS AQUA satellite provides global microwave measurements of soil moisture with coarse spatial resolution. However enough long-term wide area soil moisture data are not available so far. Last decades, previous studies showed that there is strong relationship between soil moisture and NDVI (Normalized Difference Vegetation Index) data. In this study, we estimated the relatively long-term fine resolution soil moisture data using the ground soil moisture network data from RDA (Rural Development Administration) of Korea and 4-minute (approximately 8km resolution) NDVI data from AVHRR (Advanced Very High Resolution Radiometer). Results show that AVHRR NDVI is highly related to the ground measured soil moisture. The spatial and temporal variability of generated soil moisture data were analyzed using eigen techniques such as empirical orthogonal function (EOF) analysis. The leading modes of EOF analysis demonstrate not only the main spatial variability and its temporal variation but also its dependency to the topography and land use change etc. The results allow us better understanding of soil moisture variability and better predictability of soil moisture field.

**25. Hydrology And Water Operations Modeling for Climate Change Risk Assessment in California's Southern Central Valley - Michael Kiparsky**, Energy and Resources Group, University of Californa Berkeley, Berkeley, CA (co-authors: William Collins, David Groves, Michael Hanemann, Brian Joyce, David Purkey, Charles Young)

The first generation of climate change impacts modeling studies consisted largely of sensitivity analyses that compared results from deterministic models run under historical conditions and to those run with fixed temperature perturbations or driven by time series of general circulation model output. Having established that hydrologic and water resources systems are sensitive to climate change, the next generation of studies is beginning to respond directly to the fact that since future climate cannot be predicted with certainty, preparing for climate change will revolve around questions of uncertainty and risk. We describe a modeling study investigating risks to water supply from climate change in California's Central Valley, and comparing the risks from climate change to the effects of other key uncertainties of land use change and population growth. We present a simulation model of the Stanislaus, Tuolumne, and Merced River Basins using the Water Evaluation and Planning (WEAP) platform. The model represents hydrology and water operations, enabling climate change scenario analysis driven directly by downscaled general circulation model output. The model is driven by climate data from six downscaled general circulation models, each run under the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios A2 and B1 emissions scenarios. Uncertainty in population growth and land use change is represented with a Latin Hypercube re-sampling approach based on a range of spatially explicit population growth model projections and variability in historical land use. Hydrology in the modeled basins is sensitive to the climate scenarios, exhibiting increased variability and drying trends as compared to historical conditions. We describe the potential impacts of these climatic, hydrologic, and water demand changes on water operations and supply reliability. We then compare the water supply impacts resulting from climate change with those arising from uncertainties in land use change and population growth. We discuss the resulting implications for resource management, and how this information might inform future decision-making.

**26. Sediment Flux and Changing Lake Bathymetry in the Pro-glacial Mendenhall Lake/River System - Nick Korzen**, UAS ENVS program, Juneau, AK (co-authors: Cathy Connor, Eran Hood, Sonia Nagorski)

Ongoing rapid ice ablation and glacier thinning has continued the buoyancy-driven, large-scale calving events and ice terminus collapse of the Mendenhall Glacier. New bathymetric data collected from Mendenhall Lake between 2004 and 2008 reveal a shallowing of the lake basin adjacent to the 2008 glacier terminus. Since 2000, the lake has expanded beyond its 3.7 km2 footprint and 0.19 km3 volume as it elongated to the north filling its old Pleistocene ice-scoured cirque basin. The northeastern-most deep in the lake basin reached a maximum depth of ~ 81.6 meters below mean lake level in 2004. Since that time this deep shallowed to the north decreasing to 76.9 meters below mean lake level, and along the 2008 glacier terminus depths range from 1.4m – 62.1m below mean lake level. This bathymetric data will be used to estimate changes in lake sedimentation rates and lake basin morphology since the early 1970s when original lake surveys were conducted by the Alaska Department of Fish and Game. Changes in bathymetry combined with measurements of suspended sediment in the Mendenhall River allow us to estimate the sediment flux through the Mendenhall Lake-River system. Furthermore, a comparison of lake basin volume with river discharge data will help to better define the seasonal contribution of glacier meltwater to Mendenhall River summer discharge, which reached 50% during the summer of 1998.

**27. Rainfall and Runoff Variation Under Climate Change In Korea - Hyun-Han Kwon**, Korea Institute of Construction Technology, Goyang-Si, Korea (co-authors: Byun-Sik Kim , Seok-Young Yoon, Bokyung Kim)

Hydrologic pattern under climate change has been paid attention to as one of the most important issues in hydrologic science group. Rainfall and runoff is a key element in the Earth's hydrological cycle, and associated with many different aspects such as water supply, flood prevention and river restoration. In this regard, a main objective of this study is to quantity rainfall and runoff variation under climate change through holistic approach. First, a conditional stochastic weather generator that can consider an exogenous variable as inputs is employed. The model is a 2-state first-order Markov chain and a canonical correlation analysis (CCA) based statistical downscaling model. The CCA model links the climate change patterns with four model parameters. Second, a semi-distributed SLURP model that can consider hydraulic structures like reservoirs within the model is used to evaluate runoff variation using the simulated rainfall from the proposed downscaling model. Finally, the runoff ensemble series are derived. It was found that seasonal pattern can be changed under climate change. The results showed that peak runoff during summer is shifted from July to August, and minor changes on extreme runoff such as drought and flood from flow duration curve are detected.

**28. A Weather State Based Downscaling of the Precipitation for Climate Change Scenarios in Korea - Hyun-Han Kwon**, Korea Institute of Construction Technology, Goyang-Si, Korea (co-authors: Young-Il Moon, Tae-Suk Oh, Jang-Won Moon)

Rainfall pattern under climate change is an issue of great interest in water resources planning. Generating rainfall scenarios that depend on varying climate circulations is a challenge that has motivated the utilization of stochastic

downscaling methods to model daily precipitation processes at multiple sites by climate change scenario with point gauge scale. Daily rainfall probabilities, the persistence of wet and dry regimes, and other rainfall statistics can vary substantially over time and space in a systematic way. A major premise of this study is that large scale climatic patterns are a major driver of such persistent year to year changes in rainfall probabilities. This study in intended to use a set of climate scenarios derived by RegCM3 RCM(27km), which is operated by KMA(Korea Meteorological Administration). A WSDM(Weather Stated based Downscaling Model) that can consider an exogenous variable as inputs is employed. Here we utilize a weather state based stochastic multivariate model as conditional probability model for simulating the rainfall field. The devised methodology is applied to a watershed in order to evaluate impact of climate change on rainfall pattern.

**29. Glacial Influences on Water Resources of the Eklutna Basin - Ann Marie Larquier**, Alaska Pacific University, Anchorage, AK (co-authors: Michael G. Loso, Chris Larsen, Louis Sass)

Glaciers act as reservoirs of freshwater, accumulating storage during cool, wet periods and releasing runoff during warm, dry periods. Warming conditions are increasing glacier melt, and reducing glacial reservoirs worldwide, which has implications for populations that rely on glaciers for drinking water and hydropower generation. Monitoring and predicting changes in glacier volume, and the distribution and timing of glacial runoff, is critical for developing feasible and effective long-term management plans for glacially-derived water resources. This is especially true in heavily glaciated southern Alaska, where the state's largest city, Anchorage, relies on meltwater from the Eklutna Glacier to recharge the municipality's main drinking water and hydropower source, Eklutna Lake. Ground-based GPS and airborne laser altimetry data from 2007/2008 document an average of 39.5 m of surface lowering over 50 years. These data, combined with measured terminus retreat of 1.7 km, document substantial volume reduction since 1957 topographic maps. A comprehensive 1989 study of the Eklutna watershed by the USGS concluded glacier melt contributed 9-19 percent of recharge to the reservoir and fine sediments were accumulating at 74 acre-feet/year with May and June being the months when storage capacity of the reservoir was most likely to be exceeded. We present evidence that the rate of glacier volume reduction has accelerated in the 20 years since that study, and argue that ongoing changes in the water and sediment budget of the West Fork Eklutna Creek pose new risks to Anchorage's water resource needs. A preliminary time series of discharge and suspend sediment concentrations from the proglacial stream in the 2008 melt season is presented, and we describe our plans for additional discharge, suspended sediment, bedload, and water temperature monitoring during the 2009 season. This includes a comparative study of the minimally glacerized East Fork Eklutna Creek, as well as gathering bedload and temperature data in the proglacial creek. These data will be used to gauge threats to the future of the water supply by analyzing results against withdraw of water for the municipal water supply and assessing how water storage capacities of both the lake and glacier will be affected.

**30. Comparison of Streamflow Generation Processes in Two Forested Watersheds Based on the Variable-Source-Area Concept - Shyue-cherng Liaw**, Dept. of Geography, National Taiwan Normal University, Taipei, Taiwan (co-author: Jeen-lian Hwong, Yung-Chung Chuang)

Understanding of streamflow generation processes in response to rainfall has been pursued over the past several decades, because this knowledge is essential for studying nutrient transport, biogeochemical processes, and forest ecosystem functioning. The major objective of this research is to simulate the flow pathways in two forested watersheds, Fushan watershed No.2 (94 ha) in northeastern Taiwan and Sanping watershed No.4 (21 ha) in southern Taiwan. The hydrological model TOPMODEL, based on the variable-source-area concept of streamflow generation mechanism, is applied to predict both amounts of saturation overland flow and subsurface flow in the study areas. Two hydrological periods are chosen, one each for model calibration and model validation. Identification of the optimal parameter set is performed through the Rosenbrock algorithm. Results show that TOPMODEL is suitable for simulating streamflow in the study areas. For Fushan watershed No.2, both model calibration and validation runs produce good fits, where model efficiencies are 0.89 and 0.82, respectively. For Sanping watershed No.4, the model efficiencies are 0.88 and 0.70. The dominant source of streamflow generation in both study areas is subsurface flow that accounts for 85.1% and 88.3% of the total simulated streamflow for the two hydrological periods in Fushan watershed No.2; however, that accounts for 75.3% and 79.6% in Sanping watershed No.4, respectively. The reasons for this difference of subsurface flow percentage between both watersheds are due to steeper topography, more intensive rainfall, and thinner soil depth in the Sanping watershed No.4.

**31. Application of a GIS-based Model to Simulate Soil Moisture and Stream Runoff in Mountainous Watersheds - Shyue-cherng Liaw**, Dept. of Geography, National Taiwan Normal University, Taipei, Taiwan (co-author: Yung-Chung Chuang)

The purpose of this research is to study the rainfall-runoff response in steep watersheds, especially focus on the soil moisture and stream runoff. Two mountainous watersheds, Lien-Hwa-Chi watersheds No.4 (5.86 ha) and No.5 (8.39 ha) in the central Taiwan, are selected for this study. We apply the Soil Moisture Routing Model (SMR), which is a geographic information system-based model, to estimate soil moisture distribution and stream runoff in the study area. The hydrological data are applied, including measured precipitation, streamflow, and evapotranspiration. There are eight transects for the field investigation of soil moisture measured by the Time-Domain Reflectometry (TDR)

(Campbell Scientific, Inc.). Results show that the SMR reproduce soil moisture distributions in the watersheds landscape well. The relative differences values between observed and simulated soil moisture are consistently, range from 15% to 27%, and the correlation coefficients (R2) are also suitable, range from 0.17 to 0.93. In addition, the values of Nash-Sutcliffe efficiency between observed and simulated stream runoff are higher, which are 0.80 and 0.82 for watershed No.4 and No.5, respectively. During the wet season period from May to September, the runoff simulation is more suitable; however, the runoff simulation in dry season is not very well.

**32. Development of an Index for Flood Risk Assessment - Kwang-Suop Lim**, Korea Institute of Construction Technology, Goyang-Si, Gyeonggi-Do, Korea (co-authors: Lee, Dong-Ryul, Choi, Si-Jung )

In Korea, for the last thirty-year period, rainfall intensity has been increased and occurred more frequently than before. Consequently, the natural damage associated with flood disaster has been dramatically increased. Flood Damages accounts for 0.35% - 1.0% of GNP. Ratio has been decrease until late 1990's; but it has increased very rapidly in 2000's. However, there is no rational assessment method available to improve disaster preparedness and the prevention of losses The purpose of this study is to develop an index that can measure the danger of regional potential flood damage. The "Flood Risk Index (FRI)" was developed for analyzing flood-prone areas and decision-making for priority of flood projects. The primary characteristics of the FRI are classified to three factors: (a) pressure (e.g. population density, capital stock and investment), (b) state (e.g. ), and (c) response (e.g. ). It has the function of comparing risk between different communities, as well as the goal of identifying whether the level of risk is primarily an outcome of the pressure, the state, or the response. FRI aimed at creating a quantitative measure that would allow for comparison of flood damage between 117 regions exposed to flood. The FRI estimated by using the linear sum of multiplication of the Z score of the assessment factors and the weight value of each. The results of the assessment are (1) to assist policy makers in identifying investment priorities to reduce risk, (2) to identify national risk-management capacities and evaluate the effects of policies and investments on risk management and (3) to determine the priority of flood protection projects for the regions.

**33. Modeling the Effect of Land-Use Change as Well as Soil and Water Management Practices on Water and Sediment Flux in the Mara River Basin - Liya Mango**, Florida International University, Miami, FL (co-authors: A. Melesse, M. McClain, J. Onsted, D. Gann)

Land cover and land use have long been known to have profound impacts on water resources and quality. However, quantifying and modeling this relationship in any particular region requires a great deal of data acquisition as well as technical expertise. This research examines the transboundary Mara River basin, which is shared between Kenya (65%) and Tanzania (35%). The Mara River originates from the Mau forest (2,932 m amsl) in Kenya, flowing across the border into Tanzania and into Lake Victoria at Musoma Bay (1,134 m amsl). The variable land cover and land use across the basin as well as differences in management practices has had noticeable corresponding effects on the water and sediment output of the Mara River, including increased sediment loads and erratic water flows To determine the specific correlative effects of each land use change on the water and sediment output of the Mara River Basin, a hydrological study of the basin was performed utilizing field observations, a geographical information system (GIS), remote sensing tools, and a hydrological model (SWAT). Land use changes were analyzed by means of a digital image analysis of Landsat Thematic Mapper (TM) and ASTER satellite images from 1998, 2003 and 2008. Soil and water management practices were mapped using GIS, with data obtained from field visits and a ground referencing exercise. Hydrological modeling to determine the water and sediment outputs of the basin was then performed using the semi-distributed Soil and Water Assessment Tool (SWAT) model. The results of the hydrological simulation and land use/cover change analysis successfully identify the impacts of the various land-use activities as well as soil and water management practices on the hydrology and sediment budget of the basin. These results will be beneficial to the decision support system that helps manage the basin's water resources while the technical expertise and infrastructure used to produce them can assist in the institution of solutions for corrective measures to improve water quantity and quality. Key words: Land use, soil and water management practices, hydrological modeling, sediment, GIS, remote sensing, SWAT, Mara River Basin

**34. The Effects of Surface Water Quality and Microfiltration Membrane Charge Characteristics on Membrane Fouling - Erin McDonald**, University of Alaska, Fairbanks, Department of Civil & Environmental Engineering, Fairbanks, AK (co-author: Silke Schiewer)

Rural Alaskan communities often depend upon surface water sources for drinking water supplies, which are challenging to treat due to high concentrations of organic matter. Membrane filtration produces high quality effluent, with a much smaller footprint and fewer O&M requirements than conventional systems. Microfiltration, a low pressure subset of membrane filters, can remove bacteria and macromolecules. Successful application of membrane filtration to surface water sources is dependent on the minimization of membrane fouling. In this study, bench scale systems were used to investigate fouling characteristics of different membrane materials and different influent compositions. Fouling characteristics were quantified and compared by treated water flux. Varying surface water quality conditions and membrane materials with different charge properties relates charge and influent quality to membrane fouling. Source water characteristics including pH, ionic strength, quantity of organic matter and type of organic matter all have the potential to affect membrane fouling. Identifying what raw water characteristics are most suitable for

membrane filtration guides the selection of water sources and pretreatment options. Differences in membranes' charge characteristics affect the degree of fouling and thereby the flux across the membrane. This knowledge allows selection of the most appropriate membrane material for a specific source water quality. By understanding and reducing the factors which contribute to membrane fouling, membrane filtration can be applied to a greater variety of drinking water treating applications. This leads to better drinking water quality, for example by removing organic carbon and thereby reducing disinfection byproduct formation.

**35. Estimating Percent Surface-Water Area Using Intermediate Resolution Satellite Imagery - Jennifer Rover**, U.S. Geological Survey, Sioux Falls, SD (co-authors: Bruce Wylie, Lei Ji)

Multi- spectral, intermediate spatial resolution satellite data, such as Landsat TM/ETM+, have been used widely for mapping surface-water bodies at regional and national scales. Accurate estimation of surface-water area, however, still remains a challenge because the intermediate resolution images are not capable of detecting small wetlands that are of great ecological significance in many regions. To compensate for the limitations of the intermediate resolution images for mapping small water bodies, a fuzzy classification method can be used to estimate the water area proportion at pixel level and produce a map of continuous percent water area, usually requiring a large number of field training sites. To avoid this, we developed a regression-based fuzzy classification technique capable of collecting training data from the Landsat image itself to map water features in the Yukon River Basin (YRB) and the Prairie Pothole Region (PPR). In the regression model, the predictor variables are averaged Landsat spectral reflectance bands for each 3 by 3 pixel (90 by 90m) window; the response variable is the percent water area based on the number of water and non-water pixels within those same windows. The regression model based on the 90 by 90m windows is then applied to the 30m resolution Landsat image to estimate percent water area within each 30m pixel. In the examples of YRB and PPR, the regression models showed very high goodness-of-fit: the R-squares are 0.96 and 0.94, respectively, and root mean squared errors are 7.1% and 8.2%, respectively, for the two regions. To validate this technique, high spatial resolution imagery including Spot5 and Ikonos, acquired at dates analogous with the Landsat image, will be used to derive relatively accurate percent water maps for a reference to assess the Landsat-estimated percent water area products.

**36. A Shared Vision Modeling Framework for Water Resources Management Under Climatic Uncertainty - Jae Ryu**, University of Nebraska-Lincoln, Lincoln, NE (co-authors: Ray Supalla, Cody Knutson, Xun-Hong Chen, Richard Palmer)

Climate variability and change continue to threaten the sustainability of water resources in the United States. To manage water resources effectively, it is imperative that sound water resources planning and management systems exist. Although climate change and variability will inevitably lead to changes in the regional economy and productive community (e.g., major industries, agriculture-related business sectors, and general public), few studies have evaluated the impacts of climate change on adjustments and adaptive management within decision-making processes. Although stakeholders receive information on climate-related issues through a variety of media resources, there are significant gaps in the public's understanding and many misconceptions concerning climate science and risk management options. There is an important need to improve the scientific connections within socio-economic systems related to climate-sensitive decisions, including more effective adaptation strategies and resilient responses to climate change. Therefore, this research will investigate the effects and management of climate variability and change at a watershed scale, and utilize this information to develop a web-based planning tool to enhance decision makers' capacity to cope with and adapt to extreme and changing climatic conditions. Specifically, an integrated modeling approach, incorporating a coupled climate-hydrologic model and an economic model into a water resources planning and management model (in a shared vision planning process), is utilized to assess the physical and economic effects of simulated climate- and management-induced scenarios, which will assist local stakeholders in making more informed, long-term water management decisions.

**37. Effects of postglacial succession on stream water quality and chemistry in Glacier Bay, Southeastern Alaska - Nickolas Schlosstein**, University of Alaska Southeast, Juneau, AK (co-authors: Eran Hood, Sonia Nagorski)

Glacier Bay has experienced catastrophic glacial retreat since the end of the Little Ice Age around 1750, uncovering 1,500 km2 of new land now in various stages of plant and animal succession. Shifts in the vegetation over time have consequences for the water chemistry of streams and lakes within a watershed. This study used location as a proxy for the passage of time to explore changes in stream chemistry following deglaciation from early colonization to mature forest. Over a week in June 2007, we sampled 16 watersheds in Glacier Bay National Park that from 47 to 13,000 years. In the field, measurements of dissolved oxygen, pH, conductivity, temperature, and turbidity were taken and grab samples were collected for lab analysis of cations and anions, dissolved organic carbon (DOC), and nitrogen content. To analyze the water quality data, we divided the watersheds into three groups- young, medium, and old- based upon their level of succession. A number of characteristics were found to change significantly between the age groups including: turbidity, pH, temperature, nitrogen, sulfate, dissolved oxygen, and DOC. Our results showed that turbidity decreased and stream temperature increased with stream age over time as stream channels were stabilized and the glacial influence lessened. Streamwater nitrogen content was closely linked to

trends in vegetational succession, rising over the first 150 years as early N-fixing plants build up a supply in the soil then dropping in the older streams as watersheds are covered by mature, N-limited forests. Sulfate levels showed a steady drop which may be a function of rapid pyrite weathering depleting the local supply, or by developing wetlands acting as a sulfate sink. Concentrations of DOC increased significantly in the oldest watersheds, but not between the young and medium aged watersheds. Streamwater pH decreased from 8.03 in the youngest watersheds to 7.40 in the oldest, and demonstrated a less pronounced drop over the first 100 years since deglaciation. The early drop in pH may be related to natural stream alkalinity being exhausted, however the long term changes are more likely due to increased wetland coverage.

**38. Water Resources Variability as a Result of Changing Climate: A Case Study in the Lake Tana Basin, Blue Nile Ethiopia - Shimelis Setegn**, The Royal Institute of Technology (KTH), Stockholm, Sweden (co-authors: Assefa M. Melesse, Bijan Dargahi, Ragahavan Srinivasan)

The climate variability and water resources reduction will be a major threat to the Nile basin countries in the forthcoming decades. In this study, an attempt was made to investigate the sensitivity of water resources to the changing climate in the Lake Tana Basin, Ethiopia. A review of the variability of the climate and hydrology is presented. The physically based Soil Water Assessment Tool (SWAT) model was applied to determine the impact of climate change on the surface and ground water resources availability in the Lake Tana Basin Ethiopia. The model was calibrated and validated using the flows from four tributaries of Lake Tana. The calibration exercise was implemented after determining the most sensitive hydrological parameters in each inflow river basins. This study focuses on analysis of water resources variability in the Lake Tana Basin in particular and Blue Nile River basin in general. The outputs of different Global climate model (GCM) were used for assessing the impact of climate change on water resources availability in the area. Different sets of temperature and rainfall scenarios were developed using GCM. The weather trend has shown an increase in temperature and decrease in rainfall. The analysis of climate change impact on the surface and ground water resources of the basin indicated that the Lake Tana Basin will experience a change in water balance due to a change in the inflow rivers streamflows in the forthcoming decades.

**39. North Slope Decision Support for Water Resources Planning and Management: Water Science Aspects - Amy Tidwell**, University of Alaska Fairbanks, Fairbanks, AK (co-authors: Kelly Brumbelow, Stephen Bourne, William Schnabel, Erica Betts)

Water resources are vital to Alaska's North Slope, supporting ecosystem functions as well as domestic and industrial human activities. Although the North Slope has a semiarid climate, it hosts vast wetland complexes as a result of the nearly impermeable underlying permafrost. As much as 40% of the coastal plain is covered with water, and more than 80% is classified as wetlands. These wetlands support an array of tundra vegetation, fish, and wildlife. A significant industrial water use on Alaska's North Slope is ice infrastructure, which has long been used as a cost-effective means of winter transportation across the tundra and to support exploratory drilling sites. The North Slope Decision Support System (DSS) is currently under development as a technology in support of oil and gas exploration and development that explicitly considers optimal water use, direct and cumulative environmental impacts, and multiple objectives and values among stakeholders. The project's climate and hydrologic research effort consists of three foci: data analysis, modeling investigations, and climate change impact assessment. The central question being addressed with data analysis is to what extent can existing observational data characterize North Slope hydroclimatology? The modeling effort aims to understand how climate and terrain interact at the landscape scale to affect local hydrology and water resources. Finally, the data analysis and modeling efforts will be combined with future climate scenarios to address the how future climate can be expected to impact water resources and winter exploration on the North Slope?

**40. Remotely Sensed Precipitation Data for Hydrologic Applications from a Spectrum of Climatic Regimes - Kenneth Tobin**, Center for Earth and Environmental Studies, Laredo, TX (co-author: Marvin Bennett)

There is great debate over whether remotely sensed precipitation data can support surface hydrological modeling. Our recent research, which has focused on three semi-arid basins from northern Mexico to Oklahoma, has demonstrated that the National Weather Service (NWS) Multi-sensor Precipitation Estimator (MPE) product can robustly support modeling at a monthly and daily timescale. Satellite-based products are not nearly as robust. The TRMM 3B42 (Research Quality, Version 6) product, which uses ground rain gauge data to correct for bias, provides acceptable results at only a monthly timescale. Conversely, pure satellite products (TRMM 3B42 - Real-time, Version 6; CMORPH) have positive biases compared with ground-based data, which is significant because of the non-linear response of surface hydrologic parameters to modulations in precipitation can result in a gross amplification of simulated peak streamflow events. Given the drive to support real-time modeling at a fine temporal scale the question of whether the bias in the pure satellite products is consistent across climatic regimes becomes important. Consequently, this study compares the performance of rain gauge, MPE, TRMM 3B42 (Research Quality and Real-time), and CMORPH products in the modeling of one arid and three humid large watersheds within the United States. Simulations are derived using the Soil and Water Assessment Tool (SWAT) model. The arid basin is Upper San

Pedro and is from Southern Arizona and contains the USDA Walnut Gulch test watershed. Humid basins include the Alapaha watershed from southern Georgia that has the USDA Tift watershed within the larger basin and from North Carolina the Upper Tar and Lower Tar basins. The two North Carolina basins are located within the eastern NOAA Hydrometeorological Testbed area. Preliminary analysis of data indicates that there is a strong positive bias in precipitation values associated with TRMM 3B42 (Real- time) compared with TRMM 3B42 (Research Quality) for coastal pixels but inland the two products compare closely. In conclusion, this study will provide insights that will allow land algorithm developers to better correct for local bias in satellite products, which will be critical as we move into the era of the Global Precipitation Measurement Mission.

**41. Hydro-Climatological Variability in the Chilean Andes Mountains - Jose Vergara**, Buentiempo Ltda., Santiado, Rm, Chile

In the Andes mountains range, evaluated the hydrological response to future climate change is the major challenge due to limited weather data and the extreme weather conditions. The real water regulation capacity of the Chilean for the agriculture, hydropower, water supply system, etc., is in the snow accumulated in the mountain, any variation in the snowfall, rainfall, temperature in the mountain and the river flow produced a significantly impacts on the national economy. This work aim at evaluating the impacts of climatic change over Andes mountain range. The current analysis uses daily monthly time series of snowfall, rainfall, temperature and river discharge in the of Chilean Andes Mountains. The period of study covers about 40 years period (1960 to 2007). Trends analysis show positive trends for the snowfall, temperature and river flow over the high mountains and in the case of lower mountain level (<2000 m. above. s. l.) the time series of rainfall, temperature, but in this case the snowfall show a negative trends because the increased of temperature and reduced of snow fall events in the lower level of the mountains, in this case of river discharge show positive trends and also the hydropower productions. The results also show a strong relationships between the El Niño-Southern Oscillation (ENSO) and the Inter-decadal Pacific Oscillation (SOI) on the long-term river flow.

**42. An Overview of Watershed Responses from Across the United States to Climate Change - Roland Viger**, U.S. Geological Survey, Denver, CO (co-authors: Lauren E. Hay, Steven L. Markstrom)

The U.S. Geological Survey Global Change study, “An integrated watershed scale response to climate change in selected basins across the United States,” was initiated in 2008. The long-term goal of this study is to provide the foundation for hydrologically based climate-change studies across the Nation. Fourteen basins, at which the Precipitation Runoff Modeling System (PRMS) previously was applied, were selected as study sites. Automated procedures were developed to generate ensembles of climate-change scenarios from General Circulation Models (GCMs) for each watershed. The scenarios were used as input to PRMS and the simulated changes in streamflow over time were analyzed. The climate-change scenarios included increases in minimum temperature, maximum temperature and precipitation over time for most basins. In general, uncertainty in the GCM climate predictions increased over time, particularly for maximum temperature. In addition, the uncertainty of these simulations was highly variable across the watersheds. Despite the general pattern of increases in precipitation, increases in streamflow were not always estimated by the watershed model. Streamflow change was variable through time, with uncertainty in the simulations usually increasing through time. The presentation will provide an overview of the watershed simulations, highlighting localized effects of climate change on different watersheds around the country.

**43. Climate and Cryosphere (CliC) Project Update - Daqing Yang**, Water Research Center, University of Alaska Fairbanks, Fairbanks, AK (co-authors: Barry Goodison, Vladimir Ryabinin, Konrad Steffen, Tony Worby )

The cryosphere is an important and dynamic component of the global climate system. The global cryosphere is changing rapidly, with changes in the Polar Regions receiving particular attention during the International Polar Year 2007-2008. The Climate and Cryosphere (CliC) Project is a core project of the World Climate Research Programme (WCRP) and is co-sponsored by WCRP, SCAR (Scientific Committee for Antarctic Research) and IASC (International Committee for Antarctic Research). The principal goal of CliC is to assess and quantify the impacts that climatic variability and change have on components of the cryosphere and the consequences of these impacts for the climate system. To achieve its objectives, CliC coordinates international and regional projects, partners with other organizations in joint initiatives, and organizes panels and working groups to lead and coordinate advanced research aimed at closing identified gaps in scientific knowledge about climate and cryosphere. CliC has advanced significantly over the last several years. This presentation will provide an update of recent developments of its research themes, highlighting regional projects and their results, interaction and collaboration with other international projects, and outlining the future direction of the CliC project.