Georgia Water Resources Institute
Annual Technical Report
FY 2013

Introduction

Mission Statement: GWRI strives to improve the science and practice of water resources planning and management in ways that balance quality of life, environmental sustainability, and economic growth. GWRI pursues this mission through its education, research, information dissemination, and technology/knowledge transfer programs at the state, national, and international levels.

Organizational Structure: The GWRI organizational structure includes a Director, Associate Director, Assistant Director, Advisory Board, and technical support staff. The technical support taff comprises several Ph.D. graduate students who work on GWRI projects while carrying out doctoral research, and information technology support staff. The Advisory Board includes representatives from major state and federal water agencies as well as environmental and citizen groups. At Georgia Tech, GWRI reports to the Senior Vice-Provost for Research under the Office of the Provost.

Research Program Sponsorship and Administration: GWRI activities are sponsored by (i) the Department of the Interior/USGS as part of the state and national research programs, and (ii) other national and international funding agencies and organizations supporting research in water related areas. Through its annual state and national competitive programs, GWRI provides research awards to Georgia Universities. The award process includes submission of technical proposals, technical peer reviews, and reviews for relevance to Georgia needs by the State Environmental Protection Division (Georgia EPD).

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Other External Funding: In addition to the 104B and 104G programs, GWRI generates additional funding through participation in competitive national and international research programs. Recent funding has been provided by the Georgia Environmental Protection Division, the California Energy Commission, NOAA, and the ACF Stakeholders. GWRI involvement in national and international research activities is crucial to maintaining the expert capacity and funding portfolio necessary to provide quality services to the state of Georgia and all other sponsors.

FY2013 RESEARCH PROJECTS THROUGH 104B PROGRAM

(1) Unimpaired Flows for the ACF River Basin: Improvement and Uncertainty Assessment, A. Georgakakos and and M. Kistenmacher, sponsored by USGS under grant #1266663 (Project# 2013GA333B).

(2) Tracking the impact of on-site wastewater treatment systems on stream water quality in the Metro-Atlanta area, M. Habteselassie and D. Radcliffe, sponsored by USGS under grant #1266663 (Project# 2013GA330B).

EXTENDED FY2012 RESEARCH PROJECTS THROUGH 104B PROGRAM

(1) Monitoring Diurnal and Seasonal Cycle of Evapotranspiration over Georgia using Remote Sensing Observations, Jinfeng Wang, sponsored by USGS under grant #1266663 (Project# 2012GA314B).

OTHER RESEARCH PROJECTS AND ACCOMPLISHMENTS

(1) Technical Support for the Development of a Sustainable Water Management Plan for the Apalachicola-Chattahoochee-Flint (ACF) River Basin, Aris Georgakakos PI, Georgia Institute of Technology, sponsored by the ACF Stakeholders.

JOURNAL PUBLICATIONS (CURRENT AND PRIOR YEARS)

1. Villegas, B., P. Roberts, and A.P. Georgakakos, "A Mathematical Model of the Apalachicola Bay Salinity and its Effects on Oyster Harvesting," Journal of Estuarine, Coastal, and Shelf Science, in review.

2. Lu, C., Du, P., Chen, Y., Luo, J. (2011), Recovery efficiency of aquifer storage and recovery (ASR) with mass transfer limitation, Water Resour. Res.,47, W08529, doi:10.1029/2011WR010605.

3. Lu, C., Luo, J. (2012), Boundary condition effects on estimating maximum groundwater withdrawal in coastal aquifers, Ground Water, 50(3), pp.386-393.

4. Chen, Y., Lu, C., Luo, J. (2012), Solute transport in transient divergent flow, Water Resour. Res., 48, W02510, doi:10.1029/2011WR010692.

5. Atreya, A., S. Ferreira and W. Kriesel (2012) "Forgetting the Flood? Changes in Flood risk Perceptions over Time",University of Georgia, Athens, GA. Presented at UGA Department of Agricultural and Applied Economics Seminar Series, Athens, August 17, 2011.

6. Atreya, A., S. Ferreira and W. Kriesel (2012) "Forgetting the Flood? Changes in Flood risk Perceptions over Time",University of Georgia, Athens, GA. Presented at UNICT- EAERE- FEEM Belpasso International Summer School on Environmental and Resource Economics, Belpasso, Sicily, Italy, Sept 4-10, 2011.

7. Atreya, A. and S. Ferreira (2012) "Analysis of Spatial Variation in Flood Risk Perception" Presented at UGA Department of Agricultural and Applied Economics Seminar Series, Athens, January 18, 2012.

8. Atreya, A. and S. Ferreira (2011) "Flood Risk and Risk Perception: Evidence from Property Prices in Fulton County, Georgia" Presented at CIMR- Climate Information for Managing Risk, Local to Regional Adaptation and Mitigation Strategies, An International Symposium, Orlando Florida, May 24-27, 2011.

9. Atreya, A. and S. Ferreira (2012) "Variation in Flood Risk Perception: Does Scale Matter?" Presented at ICARUS- Initiative on Climate Adaptation Research and Understanding through the Social Sciences, Columbia University, New York, May 18-20, 2012.

10. Atreya, A. and S. Ferreira (2012) "Spatial Variation in Flood Risk Perception: A Spatial Econometric Approach" To be presented Agricultural and Applied Economics Association 2012 Annual Meeting, Seattle, Washington, August 12-14, 2012.

11. Atreya, A., S. Ferreira and W. Kriesel (2012) "Forgetting the Flood? Changes in Flood risk Perceptions over Time" Submitted to Land Economics.Kellock, K., B. Trushel, P. Ely, C. Jennings and R.B. Bringolf.

12. Kellock, K. and R.B. Bringolf. 2011. Assessment of endocrine disruption in fish and estrogenic potency of waters in Georgia. Proceedings of the 2011 Georgia Water Resources Conference, Athens, GA, April 11–13, 2011.

13. Intersex fish in small impoundments: why won't the boys be boys? Iowa State University, Department of Natural Resource Ecology and Management. Ames, IA. May 4, 2012.

14. Intersex fish in Georgia. University of Georgia Fisheries Society. Athens, GA. February 16, 2012. 15. A survey of intersex bass in Georgia: Serendipity strikes again? University of Georgia, Warnell School of Forestry & Natural Resources. Athens, GA. September 22, 2011.

16. Intersex fish: not just in Wastewater anymore. Auburn University, Department of Fisheries and Allied Aquaculture. Auburn, AL. September 16, 2011.

17. K. Kellock, C. Jennings, P. Ely, B. Trushel, and R.B. Bringolf. Intersex fish: Not just in wastewater anymore. Presented at the 2012 Southeast Regional Chapter of the Society of Environmental Toxicology and Chemistry. Pensacoala, FL. Mar. 16-17, 2012.

18. Kellock, K.A., C.A. Jennings, P. Ely, B. Trushel, and R.B. Bringolf. Intersex fish influenced by factors other than municipal wastewater effluent. Presented at the 2012 annual meeting of the Georgia Chapter of the American Fisheries Society. Macon, GA. Feb. 7-9, 2012.

19. Bringolf, R.B., K. Kellock, B. Trushel, P. Ely, and C. Jennings. Intersex fish: Not just in wastewater anymore. Presented at the 2012 annual meeting of the Southern Division of American Fisheries Society. Biloxi, MS. Jan. 26-29, 2012.

20. Kellock, K. and R.B. Bringolf. Intersex fish influenced by factors other than municipal wastewater effluent. Presented at the 2011 Society of Environmental Toxicology and Chemistry North America Meeting. Boston, MA. Nov. 7-12, 2011.

21. Kellock, K. and R.B. Bringolf. Assessment of endocrine disruption in fish and estrogenic potency of waters in Georgia. Presented at the 2011 Georgia Water Resources Conference, Athens, GA, April 11–13,2011. Awarded Best Student Presentation.

22. Bringolf, R.B., K. Kellock, B. Trushel, P. Ely and C. Jennings. Survey of intersex bass and estrogens in GA waters. Presented at the 2011 Meeting of the Georgia Chapter of the American Fisheries Society. Perry, GA. Feb. 2-3, 2011.

23. Georgakakos, K.P., Graham, N.H., Cheng, F.-Y., Spencer, C., Shamir, E., Georgakakos, A.P, Yao, H., and Kistenmacher, M., "Value of Adaptive Water Resources Management in Northern California under Climatic Variability and Change: Dynamic Hydroclimatology," J. Hydrology, in press, on line reference doi:10.1016/j.jhydrol.2011.04.032, 2011.

24. Georgakakos, A.P, Yao, H., Kistenmacher, M., Georgakakos, K.P., Graham, N.H., Cheng, F.-Y., Spencer, C., Shamir, E., "Value of Adaptive Water Resources Management in Northern California under Climatic Variability and Change: Reservoir Management," J. Hydrology, in press, on line reference doi:10.1016/j.jhydrol.2011.04.038, 2011.

25. Zhang, F. and A. P. Georgakakos, "Joint Variable Spatial Downscaling," Climatic Change, in press, on line reference doi.org/10.1007/s10584-011-0167-9, 2011.

26. Chen, C-J., and A.P. Georgakakos, "Hydro-Climatic Forecasting Using Sea Surface Temperatures—Methodology and Application for the Southeast U.S.," Journal of Climate Dynamics, in press.

Research Program Introduction

Two research projects were funded through the 104B Program (each at $18,000) in FY2013:

(1) Unimpaired Flows for the ACF River Basin: Improvement and Uncertainty Assessment, A. Georgakakos and and M. Kistenmacher, sponsored by USGS under grant #1266663 (Project# 2013GA333B).

(2) Tracking the impact of on-site wastewater treatment systems on stream water quality in the Metro-Atlanta area, M. Habteselassie and D. Radcliffe, sponsored by USGS under grant #1266663 (Project# Fund 2013GA330B).

However, due to delays in receiving funding from USGS, both project deadlines were extended until 8/16/2014. As such, the associated projects reports are formally considered to be a part of Fiscal Year 2014 and will be contained in the FY2014 Annual Report.

Another project initiated in FY2012 received an extension and was completed in FY2013:

(1) Monitoring Diurnal and Seasonal Cycle of Evapotranspiration over Georgia using Remote Sensing Observations, Jinfeng Wang, sponsored by USGS under grant #1266663 (Project# 2012GA314B).

Monitoring Diurnal and Seasonal Cycle of Evapotranspiration over Georgia using Remote Sensing Observations

Basic Information

Title:	Monitoring Diurnal and Seasonal Cycle of Evapotranspiration over Georgia using Remote Sensing Observations
Project Number:	2012GA314B
Start Date:	3/1/2012
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	GA
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Surface Water, Climatological Processes
Descriptors:	None
Principal Investigators:	Jingfeng Wang

Publications

There are no publications.

Progress Report of GWRI 104B

Monitoring Diurnal and Seasonal Cycle of Evapotranspiration over Georgia using Remote Sensing Observations

PI: Jingfeng Wang
with
Husayn A. El Sharif and Shawna McKnight

24 May 2013

1. Research Activities

The objective of this project was to test and develop a new method of monitoring diurnal and seasonal variations of evapotranspiration over Georgia using satellite-based remote sensing observations for agricultural and water resources management. An agricultural model, Decision Support System for Agrotechnology Transfer – Cropping Systems Model (DSSAT-CSM) was modified and expanded to allow the use of remote sensing soil moisture data for predicting yield various crops at field and regional scales. This effort has led to the Georgia Tech team (Wang, Georgakakos and Bras) to be selected one of the early adaptor teams of the NASA Soil Moisture Active Passive (SMAP) mission. As an SMAP early adaptor team, we participated in the SMAP Validation Experiment 2012 (SMAPVEX12) in Winnipeg, Canada 6 June – 19 July 2012. Two graduate students have participated in the research activities including model development and simulation and field experiment.

2. Model Development and Simulation

The goal of model development is to assess the value of incorporating remotely sensed soil moisture information from the NASA SMAP mission into the agricultural model for predicting crop yield, irrigation water-budget allocations, and preparedness for climate change induced extreme hydrological events at regional scales. Furthermore, once the agricultural model of focus in this project (DSSAT-CSM) is reformulated into state-stage space, a dynamic programming approach may be adopted to optimally allocate irrigation decisions to produce a desired regional crop yield.

DSSAT-CSM Crop-Systems Model The Decision Support System for Agrotechnology Transfer – Cropping Systems Model (DSSAT-CSM) is a widely used bio-physical model for simulating the phenology, growth, development, and yield of various crops and cultivars given inputs of soil, weather, and management conditions (Jones, et al., 2003). DSSAT-CSM version 4.5 includes 29 crops and fallow fields (Tsuji, et al., 1994; Hoogenboom, et al., 1999; Jones, et al., 2001; Jones, et al., 2003; Daroub, et al., 2003; Brumbelow and Georgakakos, 2007a, b; Liu, et al., 2011). DSSAT-CSM is composed of a main driver program, a land unit module, as well as modules for weather, soil, plant, soil-plant-atmosphere interface, and management. The main driver program controls each of the primary modules and allows each module to read its own inputs, initialize variables, compute rates, integrate its own variables, and write outputs independent of other modules (Jones, et al., 2003). This feature is especially important to this project as the soil-plant-atmosphere module has been modified in this project in order to incorporate remotely-sensed soil moisture data.

Regional Climate Model To forecast near-term and long-term regional soil moisture distribution under projected various climate change scenarios including extreme hydrological events (droughts and floods), the Weather Research and Forecasting (WRF) model developed by a "collaborative partnership, principally among the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), the National Centers for Environmental Prediction (NCEP), the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). WRF affords researchers the ability to conduct simulations reflecting either real data or idealized configurations. WRF is an operational forecasting model that is flexible and efficient computationally, while offering the advances in physics, numerics, and data assimilation contributed by the research community" (WRF, 2013). Recently the WRF model has been coupled with one of the most sophisticated hydrologic models, Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator with VEGetation Generator for Interactive Evolution (tRIBS-VEGGIE) (Ivanov et al., 2008a,b). The coupled WRF-tRIBS-VEGGIE model is intended to downscale soil moisture data products to 1 km spatial and daily temporal resolution.

SMAP Early Adopter Simulation Data Set The National Snow and Ice Data Center (NSIDC) archives and distributes SMAP validation data (i.e. SMAP test bed) accessible only to SMAP Early Adopters. The SMAP test bed data available to SMAP Early Adopters are an SMAP-like product with one year of global coverage. Of particular interest to this project is the Level-2 Radar Soil Moisture (Active) data set featuring simulated soil moisture data at 3 km resolution. The simulation data will be used for testing the modified DSSAT-CSM model to allow the use of remote-sensing soil moisture data inputs from SMAP once the satellite observations become available in early 2015.

Sensitivity of Crop Yield and Irrigation Demand to Soil Moisture Data Resolution The impact of the spatial and temporal resolution of soil moisture records on crop yield and irrigation demand can be simulated by selecting random samples of SMAP soil moisture pixels and using interpolation methods such as the inverse distance weighting method to create regional soil moisture maps. The interpolated soil moisture map can then be used as model input of the DSSAT-CSM. Results from multiple model runs using an increasing number of randomly sampled SMAP pixels will allow for quantifying the change in uncertainty (standard deviation) in regional crop yield and irrigation demand in comparison to that using all available SMAP pixels. The statistical analysis will be performed with the following steps: (1) start from a soil moisture map provided by SMAP data products for a region at the beginning of the growing season. This map would contain a total of N pixels. Soil moisture at the center of a pixel, θ_i, is taken as the representative value for the pixel. (2) Randomly select J data points from the grid of θ_i points as control points. Each control point is referred to as θ_j and participates to create a new interpolated soil moisture map. (3) With J randomly selected control points, use the inverse distance weighting method (Shepard, 1968) to estimate soil moisture at each point of the original grid according to,

$$\hat{\theta}_i = \sum_{j=1}^{J} \frac{\theta_j {d_{i,j}}^{-\alpha}}{\sum_{m=0}^{J} {d_{i,m}}^{-\alpha}}$$

where $\hat{\theta}_i$ is a soil moisture estimated at location (point) i based on a summation of "real" soil moisture data at control points represented by θ_j which are weighted inversely by the distance, $d_{i,j}$, between points i and j. m is a dummy index. The exponent α is a power parameter that further increases the importance of nearby control points when α is greater than 1 and is recommended to be taken as 2 (Shepard, 1968). (4) Calculate the domain mean of estimated soil moisture, $\bar{\bar{\Theta}}$, for the experiment k:

$$\bar{\bar{\Theta}}_k = \frac{1}{N} \sum_{i=1}^{N} \hat{\theta}_i$$

(5) Initialize DSSAT-CSM using the $\hat{\theta}_i$ values and simulate the total yield and irrigation demand for the region at the end of the growing season. (6) Repeat steps 3-5 many times (depending on the spatial extent of the soil moisture grid) to create a histogram of $\bar{\bar{\Theta}}_k$ to fit selected probability distributions. Based on the Central Limit Theorem, a Gaussian distribution is the most probable distribution with mean μ_Θ and standard deviation σ_Θ estimated from the histogram. Follow the same procedure for total domain crop yield and irrigation demand. (7) Repeat steps 2-6 to test the sensitivity of the distribution by using different number of data points J.

Results from these experiments will be used to quantify the uncertainty in crop yield and growing season irrigation demand as a function of the uncertainty in the mean soil moisture of the domain. Such results can be used to characterize the utility of the finer resolution data provided by the SMAP mission. The experiments are also intended to derive the probability distribution of crop yield and irrigation demand for the entire season from that of domain mean soil moisture at the beginning of the growing season.

Findings At this stage of the project, the source programming code of the DSSAT-CSM software has been successfully modified to incorporate remotely-sensed soil moisture data products. Input files are in ASCII text file format with date and "observed" soil moisture reading. These input files are used to override the water balance calculations of the DSSAT-CSM water balance sub-module in the topmost (0 – 5cm) soil layer. Preliminary experiments have been carried out using synthetically generated daily soil moisture data sets along with default DSSAT-CSM soil, weather, and crop data sets. The DSSAT-CSM is primarily intended to operate at the field scale. As such, regional analysis of crop yields can be conducted by aggregating model results for multiple fields, each with their own required input data sets. This requires running multiple iterations of DSSAT-CSM as well as automating the management and processing the data outputs of each model run. To accomplish this, the modified DSSAT-CSM software suite was incorporated into a UNIX computer cluster environment provided by Georgia Institute of Technology consisting of 256 nodes (CPUs) each with 2.2 GHz and 252 GB RAM to allow multiple runs. To test the automation procedure an experiment was conducted using a default year 1981 DSSAT-CSM maize crop data set for Florence, South Carolina along with synthetically generated daily soil moisture data. The experiment involved developing a 4 x 4 spatial grid of individual fields, each with their own daily soil moisture sequence. Each field or "pixel" was assigned spatial coordinates such that the previously mentioned inverse distance weighting (IDW) interpolation procedure could be carried out. Using the IDW procedure, the quantity of control points, J, ranged from 1 to 16. For each possible J, 10 iterations were carried out in which fields were randomly selected to participate in the interpolation. For each iteration, final crop yield was modeled for the 16 pixels in the spatial domain. 2,560 runs of DSSAT-CSM were conducted, producing the following results:

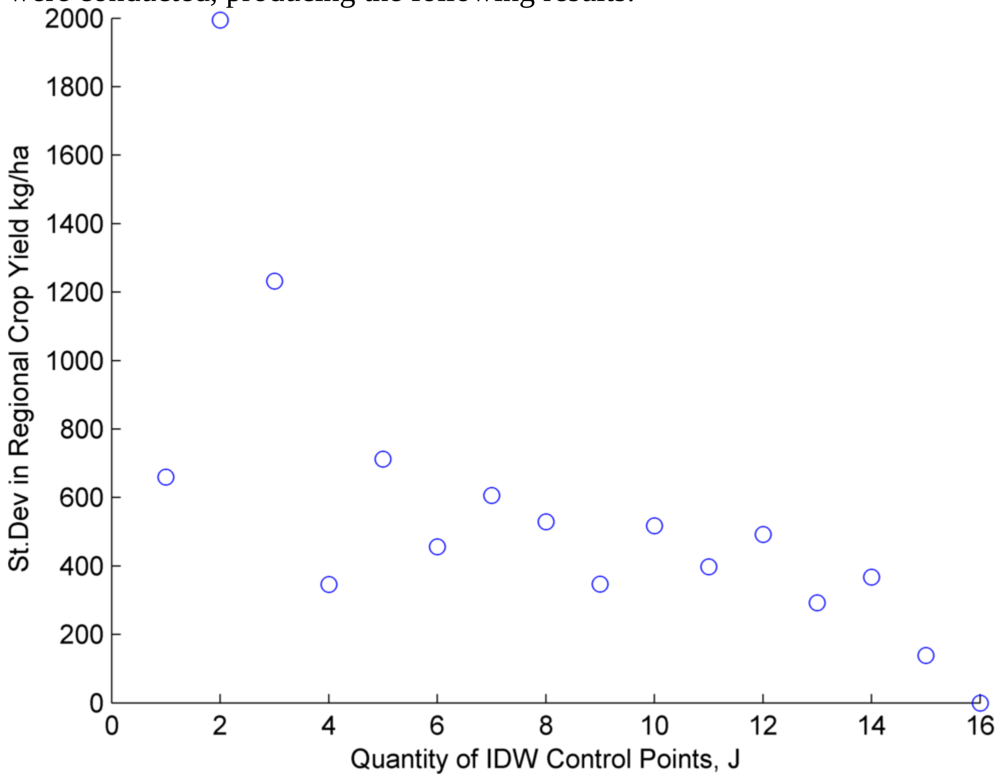

Figure 1: Uncertainty in regional crop yield for a given quantity of control points participating in inverse distance weighting interpolation of soil moisture. Note: soil moisture data at participating control points were synthetically generated.

As expected, using the synthetically generated soil moisture data sets, uncertainty in regional crop yield (represented by the standard deviation in regional crop yield) decreases as the resolution of the "observed" soil moisture data set (represented by J) increases. Interestingly, when J was in the range of 6 – 13, increases in J resulted in relatively minor decreases in uncertainty. This may suggest that thresholds exist beyond which increased spatial resolution of soil moisture data will not provide significant benefits to crop yield modeling. Determining the existence and magnitude of this threshold requires non-synthetic soil moisture data; however, this experiment provides a procedural template to carry out such an analysis.

This stage of the project was primarily focused on developing the environment for analysis of modeled regional crop yield and irrigation demand given input of remotely-sensed soil moisture products. The DSSAT-CSM software suite was successfully modified to accept daily resolution soil-moisture inputs derived from observations or interpolation. An automation procedure was developed to allow DSSAT-CSM to provide results at regional scales. The next stage of research will involve spatial and temporal downscaling of SMAP-Early Adopter and SMAP-similar remotely sensed soil moisture data sets using the coupled WRF-tRIBS-VEGGIE hydrologic model. With this information, the sensitivity of modeled regional crop yield to increased resolution soil moisture data products can be practically determined. Further research will also include the incorporation of dynamic programming to optimize regional irrigation allocations which would involve the reformulation of essential components of the DSSAT-CSM to state-stage space.

3. Field Experiment

The SMAP Validation Experiment 2012 (SMAPVEX12) was conducted in Winnipeg, Canada 6 June–19 July 2012 to collect ground data of soil moisture and other hydro-meteorological variables. The study domain is a 13x70 km^2 in Southwest of Winnipeg. 55 agriculture fields containing canola, cereals, corn, grasslands, pastures, and soybean were sampled throughout the duration of the campaign. Five additional forest sites were sampled to assist in the radar algorithm development for forest soil moisture retrieval. The relatively long sampling period allows for data collection for the bulk of the growing period to be documented as well as multiple soil dry-down periods. Each field contains 14 individual sampling sites arranged into two parallel transects approximately 200m apart. Each point within a transect is approximately 100 m apart. Three of the soil sampling sites in each field were also used for vegetation sampling. Measurements of plant height, stem diameter, LAI and biomass were taken to document growth, phase and structure of the vegetation as the growing season progressed. Ground radiometer measurements were also taken weekly on vegetation sampling days. Soil moisture were taken at the first and last points of each transect for calibration of the hydro-probes. With the exception of the pasture, grasses and cereals, the vegetation is planted in rows in troughs of soil. These troughs and rows cause heterogeneity in the soil moisture throughout the field. Soil moisture measurements were taken three times at each site so that an average could be obtained to allow for continuity throughout the field. Measurements were taken at the top, side and bottom of each trough. Soil temperature, skin temperature and shaded skin temperature were also recorded at the first and last point in each transect. Most sites also contain an in-situ soil moisture station to provide more frequent sampling. The Passive/Active L-band Sensor (PALS) was installed on a Twin Otter airplane that flew when weather permitted. Flights were concurrent with soil moisture sampling days. The experiment site condition and field experimental work are shown in the graphics below.

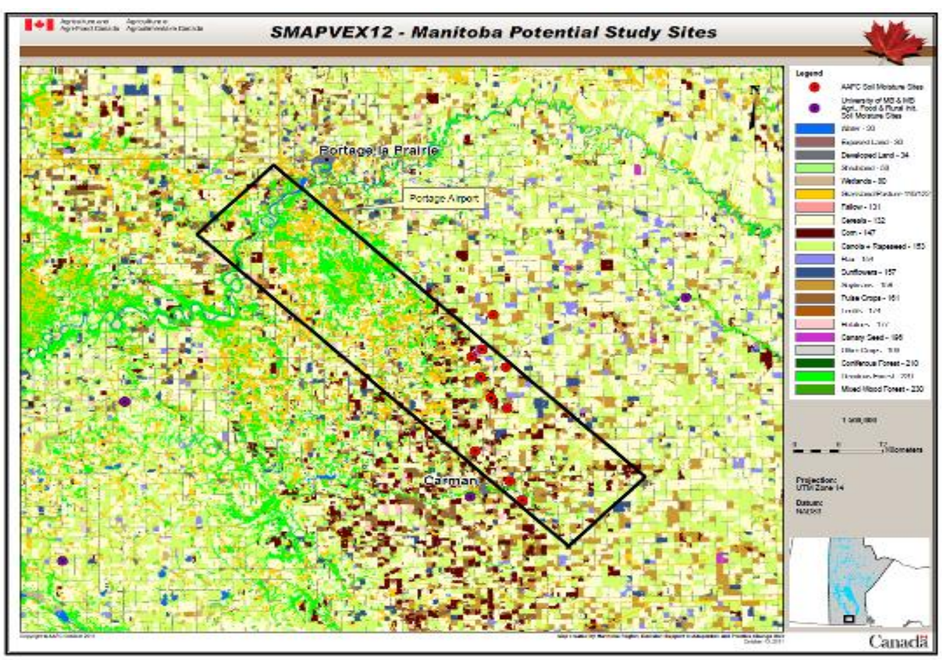

Figure 1 (above): Study site Southwest of Winnepeg in Manitoba, Canada. The black rectangle contains all 55 sampled agriculture fields. Image credit: University of Sherbrooke. http://pages.usherbrooke.ca/smapvex12/images/

Figure 2: LAI and NDVI measurements in a bean field. Image credit: Steven Chan, JPL http://smap.jpl.nasa.gov/blogs/20120713/

Figure 3: Trecking through a Winter Wheat _eld with site vegetation samples and equipment. Image credit: Steven Chan, JPL

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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	0	0	0	0	0
Masters	3	0	0	0	3
Ph.D.	4	0	0	0	4
Post-Doc.	2	0	0	0	2
Total	9	0	0	0	9

Notable Awards and Achievements

NATIONAL CLIMATE ASSESSMENT

The National Climate Assessment (NCA) is carried out under the auspices of the U.S. Global Change Research Program and aims to assess the science of climate change and its impacts across the United States, now and throughout this century. It documents climate change related impacts and responses for various sectors and regions, with the goal of better informing public and private decision-making at all levels.

A team of more than 300 experts, guided by a 60-member National Climate Assessment and Development Advisory Committee produced the 3rd Climate Assessment Report with input from public and private sector stakeholders, resource and environmental managers, researchers, representatives from businesses and non-governmental organizations, and the general public.

The assessment draws from a large body of scientific peer-reviewed research, technical input reports, and other publicly available sources; all sources meet the standards of the Information Quality Act. The report was extensively reviewed by the public and experts, including a panel of the National Academy of Sciences, the 13 Federal agencies of the U.S. Global Change Research Program, and the Federal Committee on Environment, Natural Resources, and Sustainability.

The 3rd NCA Report summarizes recent advances and findings in climate change science; assesses the climate change impacts within and across key societal and environmental sectors (i.e., human health, water, energy, transportation, agriculture, forests, and ecosystems and biodiversity) and U.S. regions (i.e., Northeast, Southeast and Caribbean, Midwest, Great Plains, Southwest, Northwest, Alaska, and Hawaiʻi and the U.S. affiliated Pacific Islands, as well as coastal areas, oceans, and marine resources); assesses the current state of responses to climate change, including adaptation, mitigation, and decision support activities; highlights major gaps in science and research to improve future assessments; and describes a vision for and components of an ongoing, long-term assessment process.

GWRI's Director, Dr. Aris Georgakakos led the development of the NCA Water Resources chapter and contributed to the southeast impact assessment.

SUSTAINABLE WATER MANAGEMENT IN THE APALCHICOLA-CHATTAHOOCHEE-FLINT(ACF) RIVER BASIN

GWRI is providing technical support to the ACF Stakeholders (a grass-roots stakeholder organization encompassing 56 stakeholder groups in Georgia, Alabama, and Florida) toward the development of a sustainable water management plan. The GWRI support includes the development of comprehensive basin-wide modeling tools, formulation of alternative development and management scenarios, development of stakeholder interest metrics, performance of comprehensive assessments, and consensus building. This is an important and hopeful contribution for the southeast region because ACF water sharing negotiations have been unsuccessful for more than two decades. However, the current negotiations are led by an inclusive stakeholder organization (rather than state agencies and governor offices), and there is cautious optimism that they will lead to a consensus water management plan.