

Preview of Award 1135482 - Annual Project Report

Cover

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Project Title: Collaborative Research: CI-WATER, Cyberinfrastructure to Advance High Performance Water Resource Modeling

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Principal Investigator

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Recipient Organization: Brigham Young University

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Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions) Norman L Jones

Accomplishments

* What are the major goals of the project?

The objectives of the CI-WATER Project Consortium are: (from the proposal)

1. Enhance cyberinfrastructure facilities.
2. Enhance access to data- and computationally-intensive modeling.
3. Advance high-resolution multi-physics watershed modeling.
4. Promote STEM learning and water science engagement.

In the current project year the goals of each objective were:

1. Procure computing hardware and mass storage system.
2. Identify appropriate standards and develop a software stack to develop Cloud-based modeling applications to drive generic hydrological models and identify data models/servers to populate HPC models.
3. Work towards development of a fully-coupled high-resolution hydrological model that operates on an unstructured grid (mesh) on very large watersheds, and work with partners to identify existing codes and methods that we can leverage in our development.
4. Fully engage our educational partners by providing educational opportunities in topics related to the CI-WATER project, and promote a diverse and skilled workforce by providing opportunities for underrepresented groups.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities: In the second project year the CI-WATER project held three high level meetings. These meetings provided a forum for a review of activities across the consortium, opportunities to increase collaboration, and lead to significant improvements in our project.

The first meeting was held in Salt Lake City, Utah, September 4-6, 2012. This meeting with our External Advisory Committee (EAC) included presentations by project lead researchers, staff, and students. Feedback from our advisory committee was used to improve our project collaborative framework. Recommendations included the following:

- Improve collaboration between institutions.
- More use of open source systems as foundation for software stack
- Improved organization of project website.

The second meeting in held in Salt Lake City on March, 4-5, 2013 was a review by the AAAS of the CI-WATER project. Similarly to the EAC meeting, the lead investigators, staff and several students(?) made presentations to the AAAS evaluators. The most important feedback from the AAAS review recommended improved integration of research activities in Objectives 2 and 3 across consortium members.

The third meeting was held May, 29-30, 2013, in Salt Lake City, and was aimed at improving consortium-wide integration as suggested by both the EAC and AAAS reviews. This meeting involved no external reviewers, rather it was an “all hands” meeting. Presentations by lead researchers were limited to brief progress updates. Detailed presentations by project research staff and students made up the bulk of the meeting to facilitate discussions on collaboration and to promote a more integrated research plan going forward.

In addition to the three primary meetings, we conducted monthly team meetings involving teams associated with each of the four project objectives (teams include members from each institution), bi-weekly steering committee meetings, and various ad hoc meetings of project members from different institutions.

Specific Objectives: Objective 1.

1. Complete acquisition of computational nodes for the University of Wyoming Advanced Research Computational Cluster. This computational resources is available to the consortium.
2. Complete acquisition of mass-storage device for the University of Utah data center. This computational resource is available to the consortium.

Objective 2.

1. Develop a web-based system that to enable Utah and Wyoming water

researchers and practitioners to:

- Access data to run hydrologic and water resources models
 - Execute tools to define modeling domains and configure model inputs
 - Execute models on HPC resources
 - Download and visualize the results
1. Identify and assemble climate, hydrologic, and water resources management infrastructure data from nationally available and region specific datasets.
 2. Host or facilitate access to this data in a web based system.
 3. Support rapid development of custom, easy-to-use, web-based modeling applications for a variety of water modeling and management scenarios.

Objective 3.

1. Improve Talbot-Ogden infiltration scheme to include groundwater dynamics.
2. Develop work flow for processing large watershed (288,000 km²) digital elevation model data at 10 m resolution to produce unstructured model mesh.
3. Develop work flow for stream feature data extraction.
4. Use hydrological scaling theory to develop a relationship between drainage basin area and bankfull discharge.
5. Examine relationships between bankfull discharge and cross-sectional properties to assign model parameters.
6. Develop, test and validate a 2-D overland flow routing methodology with both dynamic-wave and diffusion-wave solvers that conserves mass on an unstructured mesh.
7. Develop, test, and validate a 2-D ground water routing methodology on an unstructured mesh.
8. Couple the 2-D overland flow and ground water routing scheme using the improved Talbot-Ogden infiltration scheme.
9. Work with collaborators at NCAR to examine existing land-surface codes to identify suitable methods for calculating land surface fluxes due to evapotranspiration.
10. Work with collaborators at Utah State University to develop methodology to couple Utah Energy Balance snow melt model.
11. Develop, test, and validate 1-D channel routing model coupled to both groundwater and overland flow.

Objective 4.

1. Manage public communication and engagement through the CI-WATER.org website, social media, newsletters, press releases, broadcast programs and public events.
2. Conduct engagement activities for key audiences including high school students, teachers, undergraduates, graduate students, researchers, internal CI-WATER teams, and water resource managers.
3. Extend water science and STEM education through project activities including Toolkits for K-12 schools, Hydroinformatics graduate level course, Code Camps, teacher workshops, research experiences for undergraduates and the annual symposium.

Significant Results: **Objective 1.**

Consortium Wide

Internet connectivity tests between the University of Wyoming Advanced Research

Computing Cluster and the University of Utah Data Center.

Storage space on the University of Utah mass storage system allocated.

Brigham Young University

Purchased laptops and other misc computer resources for use by research team.

Utah State University

Together with iUTAH RII Track I established a computing cluster consisting of virtual hosts and shared storage at USU to support the server needs of the iUTAH and CI-WATER projects.

The University of Utah

Specified and ordered the mass-storage system as proposed.

University of Wyoming

Completed acquisition of \$1.0M total high-performance computing hardware for the University of Wyoming Advanced Research Computing Cluster (UWARCC).

Objective 2.

Consortium Wide

Designed a software stack of open source GIS, database, and mapping tools to support the development of Cloud-based modeling applications.

Identified methods to provide needed data for ADHydro model (Obj. 3) .

Brigham Young University

Reviewed open source GIS systems that would potentially support the development of Cloud-based modeling tools envisioned by Team 2.

Installed and optimized various servers associated with the software stack on servers hosted at the UU Data Center.

Reviewed options for a web framework to support Cloud-based modeling tools.

Developed use cases and investigated several systems, selected the CKAN

system.

Developed a PostGIS data model for the GSSHA hydrological model.

Developed GSSHA model test cases for the Cloud-based modeling applications. Test cases include climate change, snow melt, burned areas, and land use changes.

Developed Python script to access snow depth and temperature data using web services as a prototype of a system that could be used to continuously update snowmelt predictions in selected basins in the spring months.

Tested the HT Condor system for distributed computing.

Developed a prototype cloud-based modeling application to generate water level maps using current and historical water level measurements.

Collaborated with the iUTAH EPSCoR project by presenting work on web-based modeling and visualization at symposiums on 10/18/12, 11/16/12, 3/29/13, and 7/19/13.

Utah State University

Using Utah Energy Balance (UEB) snowmelt model as a simple first use case to drive system development with data management based web server with REST user interface. Data currently hosted by the prototype includes

- Digital elevation model (DEM)
- Land Cover from National Land Cover Dataset
- Climate data from DAYMET

The prototype also includes the capability to retrieve watersheds from an EPA watershed delineation service. Produces model outputs for selected watershed and extracts climate data from DAYMET for the model time period.

Reviewed the structure of several common water management models and developed a generic data model for water management data.

University of Utah

Climate modeling results for future projections are partially completed

Projection of future extreme climate conditions (Hot-dry, Hot-wet, Warm-dry, Warm-wet and middle) based on statistical downscaled results (CMIP3)

Hydrologic simulations based on climate extreme scenarios for the Parleys Creek

Analysis of climate-hydrologic-water supply system simulation results indicate system reliability can be improved more efficiently and less costly through water

conservations measures than through infrastructure enhancements (constructing additional storage)

WRF configuration with lake model and urban irrigation validated against observed fields including precipitation, lake surface temperatures, and surface latent heat flux measurements

Stochastic climate simulator reproduces precipitation statistics from current climate

Objective 3.

Consortium Wide

All hands meeting in May, 2013 educated those not directly involved in ADHydro model development on status and plans

Identified how data efforts (Obj. 2) can support ADHydro model in terms of data and web services, data standards and formats

Agreed on how we can use existing codes to speed ADHydro model development

Brigham Young University

Investigated options for visualization of massive datasets over using a web-based mapping plug-in

Worked with UWYO team to ensure visualization tools will be ADHydro-compliant

Utah State University

The Utah Energy Balance snow melt code has been ported to C++ and parallel implementation is under development to facilitate integration into ADHydro

Some functionality of the TauDEM watershed delineation and stream network package generalized to support the needs of ADHydro

University of Wyoming

Improved infiltration scheme

Developed a 2-D dynamic/diffusive wave overland flow routing methodology

Developed a 2-D ground water routing scheme that conserves mass on a mesh

Coupled the 2-D surface and ground water routing schemes via infiltration scheme

Tested the surface and ground water flow simulators against laboratory data and

analytical solutions

Tested the coupled surface water/ground water schemes using a synthetic open book watershed, and analytical and published data sets

Developed a simple scaling relationship between drainage basin area and flood magnitude for different flood frequency (paper in preparation)

Explored relationship between cross-sectional properties and bank full flow

Developed workflow for processing massive Digital Elevation Model data sets to identify watershed boundaries and stream features

Objective 4.

Consortium Wide

Website updated and other public information materials produced, September - July

Session at the American Geophysical Union Fall meeting in San Francisco, California, on Tuesday, Dec. 4, 2012, "Advanced Computational Modeling Paradigms for Hydrologic Systems"

Hydroinformatics Course, Fall Semester 2013

Water Week on UEN-TV, May 5–11, 2013

CI-WATER Toolkits Activity Pilot, May 9, 2013

CI-WATER Second Annual Symposium, May 29 and 30, 2013

CI-WATER Student Poster Session, May 29, 2013

CI-WATER Public Event: Miriah Meyer, May 29, 2013

Project Team e-News, June – July 2013

BYU Code Camp for High School Students, June 11, 2013. Students toured labs and completed coding and modeling exercises in a computer lab.

UWyo REU Workshop on High Performance Computing and Hydrology, June 17 - July 19, 2013

CI-WATER Curriculum Development Summer Institute, June 24–28, 2103

USU Code Camp for High School Students, July 11, 2013

UWyo HBCU Workshop on Hydrology, July 22 - 26, 2013

Brigham Young University

Teams of graduate and undergraduate students designed games to teach concepts of water resources management and modeling to high school students. E.g. a card

game that teaches forecast uncertainty, and how different types of data can be used to predict diverse weather. In another game, players consider risk and competing interests such as urbanization and environmental protection to maximize certainty.

Utah State University

A graduate course in hydroinformatics was co-offered across the three Utah universities in the Fall semester of 2012 (<https://usu.instructure.com/courses/127332/>).

University of Utah

Coordination of all Objective 4 projects at the University of Utah /Utah Education Network. The Education-Outreach team representing BYU, USU, UWyo and UU held monthly web meetings to coordinate tasks and progress toward accomplishing Objective 4 goals.

University of Wyoming

The CI-WATER toolbox introduced and used in collaboration with Wyoming Track 1 project. A second toolbox delivered and a permanent display under construction at Casper Science Zone.

Key outcomes or Other achievements: In addition to the items above, the CI-WATER.org website received 6,847 visits. Of these, 55% were returning visitors. Peak visits coincided with our annual water symposium and public event in May. Website visits continue to be sustained after the public symposia events, indicating sustained engagement. (See figure)

*** What opportunities for training and professional development has the project provided?**

Hydroinformatics Course: 32 University students and 1 Auditor from three locations (Utah State University, the University of Utah and Brigham Young University) connected via distance learning technology to participate in a graduate course team-taught by faculty at all three locations, Fall semester 2013.

Water Week on UEN-TV: 24 hours of water-related programs aired across Utah via UEN-TV, including shows for young children, teens and adults, with a total of 45 programs over 7 days.

CI-WATER Activity Pilot: 10 teens in Youth Teaching Youth, a science education club for students from an underserved school district tested a water resources role-playing game at the Natural History Museum of Utah, three hours.

CI-WATER Second Annual Symposium: 40 Researchers and other project participants collaboratively planned for the next phase of CI-WATER in a two-day meeting at the Natural History Museum of Utah.

CI-WATER Student Poster Session: 8 high school and university students presented to 25+ visitors, interacting with 25+ CI-WATER researchers and patrons of the Natural History Museum of Utah for two hours.

CI-WATER Public Event: Miriah Meyer: 64 Attendees, including teens, researchers and the general public learned about the importance of computer visualization in finding new insights in big data from Dr. Miriah Meyer in an hour-long talk at the Natural History Museum of Utah.

BYU Code Camp: 22 high school students, including several from rural schools, learned about STEM careers and engaged in a series of coding challenges and water resource activities at Brigham Young University in a day-long event.

REU in High Performance Computing with emphasis on hydrological modeling was attended by one undergraduate from Utah State University, four undergraduates from the University of Wyoming, and one high school student from Laramie, Wyoming. The course lasted for 5 weeks with an option for a further 3 weeks of project work at the discretion of the students.

CI-WATER Curriculum Development Summer Institute: Led by staff from the University of Utah Genetics Science Learning Center, 11 Earth and Life Science teachers from Wyoming and Utah learned from 5 CI-WATER researchers, a water manager, and other staff about the project and hydrological modeling, developed lesson plans, toured the University of Utah Data Center and explored the CI-WATER Teaching Toolboxes at the University of Utah, 4 days.

USU Code Camp: 16 high school students toured USU's high performance computing and data storage facilities, learned Python coding skills, and applied those skills to code and solve a water resources reservoir operations code challenge. The students also learned about the work STEM professionals at Utah State University do during the day-long event.

HBCU Workshop: 6 students and 1 faculty member from Jackson State received intense instruction of how hydrology modeling is used to monitor and plan for water usage. Field data was collected and incorporated into a state of the art hydrology modeling system to compare with similar lab experiments. Also in attendance were one undergraduate student from Utah State University and two graduate students from the University of Wyoming. The tutorial section of the course was co-taught by a University of Wyoming undergraduate student.

The collaboration with Salt Lake City Public Utilities has led to workforce development opportunities for water management professionals on topics related to climate change, climate modeling, systems modeling, and use of integrated modeling to assess water supply system reliability. Numerous seminars have been given on these topics in regular meetings. This collaboration has also provided the opportunity for faculty and staff on the project to learn more about the water management actions of water management professionals.

CI-WATER toolbox activities:

- January 26, 2013: Professional development opportunity in Utah.
- May 14, 2013: Three workshops with NASA Space Grant Consortium's Women in Science Program.
- May 22-23, 2013: Two classes at Douglas Middle School.
- Four Wyoming students and one Utah student participated in the Summer Research Apprentice Program.
- CI-WATER toolbox activities done with SRAP students.

Wyoming PBS aired 1.5 hours of programming, including Glen Canyon: A Dam, Water and the West and Water: The Lifeblood of Energy.

Five students from HBCUs and one from Utah attended the summer short course on Water Modeling.

The Wyoming EPSCoR blog successfully transferred from a 'test' blog to a general blog covering both Wyoming EPSCoR and CI-WATER news. To date, the blog has 68 stories, 13 of which have a CI-WATER focus. Many of these blogs were adapted to be shared on the main CI-WATER website. Jenn Gibbs, from the University of Utah, and Kali McCrackin, from the University of Wyoming, provided new content for the website on a weekly basis. CI-WATER's other social media platforms, Facebook and Twitter, have increasing numbers of followers. These platforms are updated on a nearly daily basis and during the CI-WATER Symposium, both were used extensively.

A new element to the social media efforts this year is a video project. This project is in coordination with the Utah

Education Network, who provided a film crew, animator, and expertise. Jenn orchestrated the preparation process with assistance from Kali. Footage was shot during the CI-WATER Symposium with the goal of creating three videos. These are expected to be released in early fall.

As year three begins, the CI-WATER social media team will face a change in staffing on the Wyoming front. Robin Rassmessen, recently hired by Wyoming EPSCoR, will take Kali's place this year to maintain the Wyoming EPSCoR blog, work with Jenn Gibbs on content for the website, and manage the CI-WATER Facebook.

*** How have the results been disseminated to communities of interest?**

Public events, Water Symposium, Courses, Website, and other activities described above. Other institutions/partners include:

- CI-WATER Activity Pilot: The Natural History Museum of Utah provided 1 staff member to lead the event.
- REU Workshop: Utah State provided 1 undergraduate.
- USU Code Camp: 2 graduate students funded by iUTAH assisted with the camp.
- BYU Code Camp
- HBCU Hydrologic Modeling Workshop: Jackson State University provided 5 students, Utah State 1, University of Wyoming 1 undergraduate and 2 graduate students.
- Workshop at Wind River Tribal College/ Tribal DEQ planned for September, 2013.

*** What do you plan to do during the next reporting period to accomplish the goals?**

No change.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
Figure.pdf	Figure of monthly CI-WATER.org visits.	Norman Jones	08/07/2013

Products

Journals

H. Yu, C. C. Douglas, and L. Deng Douglas (2013). A novel extension of the Talbot–Ogden model in the moisture content domain. *Journal on Applications and Computational Technology*. n/a (n/a), n/a.

Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; OTHER: n/a

Christensen, S. D. and N. L. Jones (2013). A Web-Based Tool for Groundwater Mapping and Drought Analysis. *Journal of Geographic Information System*. n/a (n/a), n/a.

Status = OTHER; Acknowledgment of Federal Support = Yes ; OTHER: n/a

Latu, K., N. S. Swain, S. D. Christensen, N. L. Jones and G. P. Williams (2013). Foss Gis Technologies for Hydrologic Simulation Applications in Cloud Computing." *Journal of Hydroinformatics*. n/a (n/a), n/a.

Status = OTHER; Acknowledgment of Federal Support = Yes ; OTHER: n/a

Books

Book Chapters

Thesis/Dissertations

Derrick Cerwinsky, Ph.D.. *The Theory and Practice of Algebraic Multigrid Methods..* (2012). University of Wyoming

(Laramie, WY).

Acknowledgment of Federal Support = Yes

Jesse N. Creel, M.S.. *Effects of Sedimentation on Flow Measurements from Short Crested Triangular Weirs*. (2013). University of Wyoming (Laramie, WY),.

Acknowledgment of Federal Support = Yes

Conference Papers and Presentations

Tarboton, D. G., F. L. Ogden, N. Jones and J. S. Horsburgh (2012). *Advancing Cyberinfrastructure to support high resolution water resources modeling (Invited)*. 2012 Fall Meeting, AGU. San Francisco, Calif..

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

David G. Tarboton; Fred L. Ogden; Norm Jones; Jeffery S. Horsburgh (2012). *Advancing Cyberinfrastructure to support high resolution water resources modeling (Invited)*. AGU Fall Meeting. San Francisco, Calif..

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Fred L. Ogden; Wencong Lai; Craig C. Douglas; Scott N. Miller; Ye Zhang (2012). *CI-WATER HPC Model: Cyberinfrastructure to Advance High Performance Water Resources Modeling in the Intermountain Western U.S.*. AGU Fall Meeting. San Francisco, Calif..

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Norm Jones, Fred L. Ogden; Jim Nelson (2012). *High-performance cyberinfrastructure for water resource planning and management (Invited)*. AGU Fall Meeting. San Francisco, Calif..

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Burian, S.J., Horsburgh, J.S., Rosenberg, D.E., Ames, D.P., Hunter, L.G., and Strong, C (2013). *Using interactive video conferencing for multi-institution, team-teaching*. American Society for Engineering Education (ASEE) Annual Conference Proceedings. Atlanta, GA.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Adel Abdallah, David E. Rosenberg (2013). *A Relational Model for Water Management Data*. CUAHSI Conference on Hydroinformatics and Modeling. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

n/a (2013). *Symposium of 50 years of hydrological modeling, Boulder, Colorado, September 26, 2012 CI-WATER Project Hydrologic Modeling*. Joint Seminar for Wyoming State water agencies. Cheyenne, Wyoming.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

n/a (2013). *CI-WATER Project Hydrologic Model Development Objectives*. Presented to US Army Corps of Engineers. Vicksburg, Mississippi.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

n/a (2013). *CI-WATER Project Hydrologic Model Development Objectives*. Joint meeting with NCAR and US National Weather Service Personnel. Laramie, Wyoming.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

n/a (2013). *CI-WATER Hydrologic Modeling: Land-use, Climate, and Population Change in the Rocky Mountain West*..

Orlob Symposium on Water Resources. University of California, Davis.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Burian, S.J., Horsburgh, J.S., Rosenberg, D.E., Ames, D.P., Hunter, L.G., and Strong, C. (2013). *Using interactive video conferencing for multi-institution, team-teaching*. American Society for Engineering Education (ASEE) Annual Conference Proceedings. Atlanta, GA.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Goharian, E., Burian, S., Bardsley, T., Kirkham, T. (2013). *Evaluating the reliability of a water supply system based on system dynamics modeling: A Case Study of Salt Lake City, Utah.* 2013 World Environmental and Water Resources Congress. Cincinnati, Ohio.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bardsley, T., Burian, S., Strong, C., Goharian, E., Livneh, B., Wood, A., Kirkham, T., Briefer, L., Miller, P. (2013). *Assessing climate change risks to a municipal water supply: A pilot project incorporating downscaled climate projections, operational hydrologic modeling, and a systems planning model*. 2013 CPASW Climate Prediction Applications Sciences Workshop. Logan, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bardsley, T., Burian, S., Strong, C., Goharian, E., Kirkham, T., Briefer, L., Livneh, B., Wood, A., Miller, P. (2013). *Assessing climate change risks to a municipal water supply: A pilot project incorporating downscaled climate projections, operational hydrologic modeling, and a systems planning model.* 2013 Spring Runoff Conference. Utah State University, Logan, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Strong C. (2013). *Understanding and using climate models for teaching.* Workshop invited by CI-WATER Professional Development Summer Institute. Salt Lake City, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Burian S, Horsburgh J, Rosenberg D, Rosenberg D, Ames D, Hunter LG, Strong C. (2013). *Burian S, Horsburgh J, Rosenberg D, Rosenberg D, Ames D, Hunter LG, Strong C.* Using Interactive Video Conferencing for Multi-Institution, Team-Teaching. Oral presentation and peer reviewed conference proceeding. Atlanta, Georgia,.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Strong C. (2013). *Future precipitation and snowpack along the Wasatch Range*. American Water Resources Association Utah Section Annual Conference. Salt Lake City, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Strong C. (2013). *Global change and its local impacts*. Monthly meeting of Humanists of Utah. Salt Lake City, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Strong C. (2013). *High-resolution climate projections for the Great Basin made accessible to diverse stakeholders and research communities*. 11th Annual Climate Prediction Applications Science Workshop (CPASW), Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Strong C. (2013). *The future balance of water along the Wasatch Range and Front*. Utah Geological Association. n/a.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Smith K, Strong C. (2013). *The hydrologic balance of the Wasatch Front: projected changes in climate and water availability*. Global Change and Sustainability Center Research Symposium. Salt Lake City, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stwertka C, Strong C. (2012). *Using a multiple-box model validated by observations to study water vapor balance and its sensitivity to projected climate variability in the Salt Lake Valley*. American Geophysical Union Fall Meeting. San Francisco, California.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Strong C. (2012). *Current and future hydrologic cycle of the Wasatch Range and Front*. Department of Plants, Soils, and Climate, Utah State University. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Strong C (2012). *Overview of the NCAR global climate model (CESM)*. SC12 Student Cluster Competition planning meeting, University of Utah. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Strong C, Steenburgh J, Stwertka C, Smith K. (2012). *Snow and water resources of the Great Salt Lake Basin: historical perspective and projections for the future*. 2012 Salt Lake Countywide Watershed Symposium. Salt Lake City, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christensen, S. D. and N. L. Jones (2013). *Web-Based Data Access and Visualization 1*. iUtah All-hand Meeting. Salt Lake City, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christensen, S. D. and N. L. Jones (2013). *Web-Based Data Access and Visualization 2*. iUtah All-hand Meeting. Salt Lake City, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christensen, S. D. and N. L. Jones (2013). *(2012a) Web-Based Data Access and Visualization*. iUtah All-hand Meeting. Salt Lake City, Utah.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christensen, S. D. and N. L. Jones (2013). *An Automated, Web-Based Groundwater Mapping and Visualization System..* 2013 Spring Runoff Conference. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christensen, S. D., M. Burns, N. L. Jones, and G. Strassberg (2013). *A Web-Based Groundwater Mapping and Visualization Tool Using Google Earth*. MODFLOW and More 2013: Translating Science into Practice. Golden, CO.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christensen, S. D. and N. L. Jones (2013). *A Web-Based Groundwater Mapping and Visualization Tool Using Google Earth*. Water Environmental & Water Resources Congress.. Cincinnati, Ohio.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christensen, S. D., M. Burns, N. L. Jones, and G. Strassberg (2012). *A Web-Based Tool for Groundwater Mapping and*

Drought Analysis.. AGU Fall Meeting. San Francisco, Calif..

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dolder, H. G. (2013). *Dbr Data Model: The First Step Towards a Multidisciplinary Modeling Framework*. 2013 CUAHSI Conference on Hydroinformatics and Modeling. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jones, N., Nelson, J., Williams, G., Ogden, F., Tarboton, D., and Burian, S (2013). *CI-WATER: Cyberinfrastructure to Advance High Performance Water Resource Modeling*. World Environmental and Water Resources Congress 2013. n/a.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jones, N. L. (2013). *Cloud-based water level mapping utility*. 2013 ESRI International User Conference. San Diego, CA.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Latu, K., N. S. Swain, S. D. Christensen, N. L. Jones, E. J. Nelson and G. P. Williams (2013). *Essential Gis Technologies for Hydrologic Simulation Applications in Cloud Computing*. 2013 World Environmental & Water Resources Congress. Cincinnati, Ohio.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

McCarty, J. and D. Merrell (2013). *Real World Applications of GSSHA..* 2013 CUAHSI Conference on Hydroinformatics and Modeling. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Perez, F., E. J. Nelson and N. L. Jones (2013). *Decision Support Systems Connected to Forecasting and Warning Subsystems for Flood Management*. 2013 CUAHSI Conference on Hydroinformatics and Modeling. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Swain, N., S. D. Christensen, K. Latu, N. L. Jones, E. J. Nelson and G. P. Williams (2013). *Distributed Hydrologic Modeling Apps for Decision Support in the Cloud*. 2013 CUAHSI Conference on Hydroinformatics and Modeling. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Swain, N., S. D. Christensen, K. Latu, N. L. Jones, E. J. Nelson and G. P. Williams (2013). *A Geospatial Relational Data Model for Ingesting Gssha Computational Models: A Step toward Two-Dimensional Modeling in the Cloud*. 2013 World Environmental & Water Resources Congress. Cincinnati, Ohio.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Swain, N. S. and K. Latu (2013). *A Software Stack for Water Resources Gis Web Apps*. 2013 Spring Runoff Conference. Logan, UT.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Publications

Technologies or Techniques

Nothing to report.

Patents

Nothing to report.

Inventions

Nothing to report.

Licenses

Nothing to report.

Websites

Nothing to report.

Other Products

Nothing to report.

Participants**Research Experience for Undergraduates (REU) funding****What individuals have worked on the project?**

Name	Most Senior Project Role	Nearest Person Month Worked
David G Tarboton	Co PD/PI	1
Norman L Jones	PD/PI	2
Erfan Goharian	Graduate Student (research assistant)	10
David Rosenberg	Co PD/PI	1
Adel Abdallah	Graduate Student (research assistant)	12
Tseganeh Gichamo	Graduate Student (research assistant)	12
Pabitra Dash	Other Professional	8
Scott Christensen	Graduate Student (research assistant)	6
Court Strong	Other Professional	1
Jeff Horsburgh	Other Professional	1
Steve Burian	Other Professional	1
Nathan R Swain	Graduate Student (research assistant)	6
Kris Latu	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Herman Dolder	Co-Investigator	2
Fidel Perez	Graduate Student (research assistant)	2

David Merrell	Graduate Student (research assistant)	2
Jeff McCarty	Graduate Student (research assistant)	2
Spencer Taylor	Graduate Student (research assistant)	2
Steven Hall	Graduate Student (research assistant)	1
Jocelynn Anderson	Undergraduate Student	1
Sarah Clark	Undergraduate Student	1
Callie Stettler	Undergraduate Student	1
Sara Hall	Undergraduate Student	1
James Nelson	Co PD/PI	2
Laura G Hunter	Co PD/PI	1
Steven C Corbato	Co PD/PI	1

What other organizations have been involved as partners?

Nothing to report.

Have other collaborators or contacts been involved? N

Impacts

What is the impact on the development of the principal discipline(s) of the project?

Our project is aimed at increasing accessibility of high performance computing resources to water resources researchers and managers, to predict the effects of land use, climate, and population changes in the Upper Colorado River Basin. We are making significant progress in this direction. To date:

- BYU has prototyped www interface for the Gridded Surface/Subsurface Hydrologic Analysis (GSSHA) model. This development work is leading to increased understanding of challenges with linking models through a www interface and producing tools to address these challenges. The ultimate objective of this development activity is to support a range of modeling capabilities, including the ADHydro model that is being developed at the University of Wyoming.
- Utah State University has developed a prototype website to prepare input data for the Utah Energy Balance Snowmelt Model. The prototype includes the capability to retrieve watersheds from an EPA watershed delineation service. Based on the specified outlet point, model grid size and model time period the prototype delineates the watershed, extracts DEM derived variables (slope and aspect) at the desired resolution, determines vegetation related model input parameters based on look up tables and land cover data, and extracts climate data from DAYMET for the model time period. Model input files are zipped together into a package that the user can download and use to run the model. These are important initial steps in generating the capability for web driven execution of this model on HPC systems.
- The University of Utah is running simulations to dynamically-downscale climate simulations to 4x4 km to drive hydrologic models in the Green River basin, which is the largest tributary to the Colorado River, and the Wasatch Front in Utah. A suite of hydrological models are being compared to evaluate their utility for predicting change effects in Rocky Mountain watersheds.

- The University of Wyoming is leading development of a high-resolution physics-based hydrologic simulator, called ADHydro. ADHydro is formulated to operate on an unstructured grid (mesh) allowing variable resolution. New process descriptions for coupling of surface water and ground water are novel developments. In cooperation with our development partners at the US Army Corps of Engineers and the National Center for Atmospheric Research, we are coupling to available tools that are in wide use. This coupling is allowing us to take advantage of existing widely-accepted technologies where practical and leverage them to speed our development process. The use of accepted model components is anticipated to increase development of a user community and ultimately speed model acceptance.
- The developed CI-WATER stack has brought interest to the Organization of American States (OAS) for use in a pilot project developing centralized flood forecasting that operate in the cloud for access by local communities in developing flood early warning responses. In collaboration with other projects we are piloting a flood early warning system based on the CI-WATER architecture for 2-3 states in Central America that will provide a proof of concept for the infrastructure being developed.

What is the impact on other disciplines?

Nothing to report.

What is the impact on the development of human resources?

Our project is providing educational, research, and development opportunities for approximately 3,000 high school and 300 university students. This project is providing excellent opportunities for research professionals and faculty to perform high-level collaborative transformational research.

What is the impact on physical resources that form infrastructure?

University of Wyoming

The Advanced Research Computing Cluster at the University of Wyoming was predominantly purchased using CI-WATER project funds. Other faculty and University resources have added to the cluster. As such, the cluster is almost in the top-500 list of computing resources, and is revolutionizing computational research at the University of Wyoming.

What is the impact on institutional resources that form infrastructure?

University of Wyoming

The Information Technology Department at the University of Wyoming has hired three full-time staff to support research computing.

What is the impact on information resources that form infrastructure?

Nothing to report.

What is the impact on technology transfer?

None to report this year. We expect to report results in this category next year.

What is the impact on society beyond science and technology?

None to report this year. We expect to report results in this category next year.

Changes

Changes in approach and reason for change

University of Wyoming

In 2012 the NSF funded an EPSCoR RII Track I project at UWyo. Two of the co-investigators on this Track II project are co-I's on the Track I project. Scott Miller is a lead co-I of the Track I while Ye Zhang is leading the Track I modeling activity. For this reason both Miller and Zhang are unable to participate in the Track II project to the extent envisioned in the proposal. This challenge has resulted in a shifting of all Objective 3 model development oversight to Track II P.I. Ogden, and moderate delays model development. As of this report writing we are approximately two months behind schedule on model development since becoming fully staffed in November, 2012. We anticipate the need for a one year no-cost extension to complete the project.

Actual or Anticipated problems or delays and actions or plans to resolve them

All consortium members had difficulty in staffing the project during the first year. Aggressive steps were taken to fill vacant staff and student positions in the latter half of the first project year. As of November 2012, approximately 1 year and 3 months into the project, all positions were filled.

Changes that have a significant impact on expenditures

Our current rate of expenditures is as budgeted. Delays in staffing in the first project year lead to under-spending in that year. We anticipate expending these funds in a fourth project year with a no-cost extension.

Combining the annual symposium business meeting with a public outreach event has worked well for the past two years, but has also presented a very long workday for members of the CI-WATER team. For the third year we're planning to do a series of community events with film screenings and panel discussions for area educators and residents rather than hosting a single evening event in Salt Lake City. CI-WATER community engagement events are scheduled for four areas in Utah and Laramie, Wyoming.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.

Special Requirements

Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.