DCDC 2012-2013
Annual Progress Report

Decision Center for a Desert City II:
Urban Climate Adaptation
SES-0951366

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DCDC 2012-2013
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Decision Center for a Desert City II

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- Charles L. Redman (Co-PI, Co-Director)
- Margaret C. Nelson (Co-PI)
- Kelli L. Larson (Co-PI)
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ASU ARIZONA STATE UNIVERSITY

I. Introduction to DCDC

The Decision Center for a Desert City (DCDC) at Arizona State University (ASU) was established in 2004 with funding from the National Science Foundation (NSF) to advance the scientific understanding of environmental decision making under uncertainty. With additional funding awarded by NSF in 2010, "DCDC II" has expanded its already extensive research agenda, engaged the policy-making community, and built stronger ties between scientific knowledge and decision making enterprises. New DCDC research has developed fundamental knowledge about decision making under uncertainty from three interdisciplinary perspectives: climate impacts, urban dynamics, and adaptation decisions. Simulation modeling and boundary organization studies cut across these themes and are a core component of DCDC activities.

DCDC is focused on developing, implementing, and studying an interdisciplinary decision-support process for environmental decision making based on principles derived from social science research. Through an integrated approach to research, education, and community and institutional outreach, DCDC is training a new generation of scientists who can work successfully at the boundaries of science and policy. Broader impacts are realized as research informs innovative solutions to society's pressing environmental challenges. To accomplish these goals, DCDC has built a dynamic bridge between ASU and local, regional, and national policy communities to foster local to-global solutions for water sustainability and urban climate adaptation.

During the reporting period, DCDC has produced: (1) an intellectually-important and impactful body of research, including 48 journal articles, 1 book, and 21 book chapters; (2) a major revision, upgrade and release of WaterSim 5.0, our signature dynamic water-simulation model that serves as an important basis for stakeholder engagement and decision support, a point of articulation for interdisciplinary research, and an experimental setting to study decision making under uncertainty; (3) an extensive network of mutually-beneficial relationships with regional water managers and resource decision makers; (4) productive partnerships with research and education efforts affiliated with ASU's Global Institute of Sustainability (GIOS), including the Central Arizona–Phoenix Long-Term Ecological Research (CAP LTER) project, the Decision Theater, and the School of Sustainability; and (5) a significant and growing set of comparative and collaborative partnerships linking our Phoenix-based case study to water sustainability and urban climate adaptation efforts nationally and internationally.

Institutional Context: Sustainability at ASU

DCDC II benefits from its connection to ASU's Global Institute of Sustainability (GIOS), which has developed highly visible, trans-disciplinary research projects that convene faculty members from different units and link environmental science, social science, and policy. As the intellectual home of DCDC II, GIOS offers access to resources on the leading edge of sustainability science and practice—a field centered on the interconnectedness of economic, social, and environmental systems. Through a wealth of local, national, and international partnerships, GIOS facilitates DCDC II's efforts to build scientist-stakeholder relationships and disseminate the principles of managing environment risk more widely. ASU's Decision Theater offers a decision laboratory and visualization space for experimenting with, and applying these science-based solutions for societal problems. GIOS fosters solutions to important societal problems through interdisciplinary centers, such as the Central Arizona–Phoenix Long-Term Ecological Research (CAP LTER) project, and offers degree programs in sustainability from its School of Sustainability. GIOS' focus on urban systems examines the potential for broader impacts in a world where more than half the population lives in cities and, as such, produces interdisciplinary research that directly supports the vision and mission of DCDC II.

The vision, mission, and goals are established by the DCDC Co-Directors and Executive Committee in consultation with the External Advisory Committee and with guidance from the National Science Foundation. The vision, mission, and goals are outlined in an NSF-approved strategic plan, which is evaluated regularly to create an adaptive and nimble institution. The vision, mission, and strategic goals establish priority objectives for core research, education, and outreach activities. These goals and objectives are implemented by internal leadership groups – faculty, students, and staff – and success is measured by formal metrics that track progress and ensure accountability.

Vision

Within the Center's activities:

- Research, learning and outreach are synergistic activities that feed upon and reinforce one another.
- Discovery occurs at the intersection of basic and applied research where new strategies are found to address societal problems.
- New data collection and analysis are mixed with synthetic discoveries based on integrating existing data, models, and knowledge.
- Problem solving is adaptive and reflexive, building upon past experiences and lessons learned in other centers engaged in the newly evolving field of urban climate adaptation.
- Emphasis is placed on feedbacks and nonlinearities that produce unintended consequences and reveal hidden vulnerabilities in complex urban resource systems.
- Scenarios, simulation modeling, and principles of decision making under uncertainty build capacity to anticipate the future.

Mission

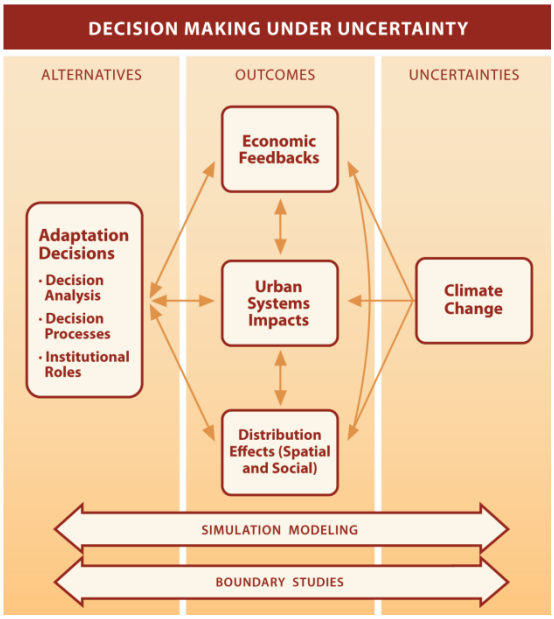
- Develop new understandings of how complex urban systems will function in a changing climate.
- Translate climate modeling and research into tools for managing complex urban systems in the face of climate change and other environmental risks.
- Build a boundary organization in which science is informed by and informs policy and decision making.
- Develop and implement learning opportunities at the boundary of science and policy for students interested in urban climate adaptation.
- Communicate the need for urban climate adaptation to decision makers and larger public audiences.

Strategic Goals

- Advance fundamental knowledge about critical linkages and feedbacks in urban resource systems.
- Apply the principles of decision making under uncertainty to environmental decision making.
- Identify critical tradeoffs inherent in managing urban systems in the face of a changing climate.
- Establish best practices for developing, implementing, and disseminating the concept of a boundary organization.
- Mentor the next generation of interdisciplinary scientists skilled in linking knowledge to action.

Research Activities

We have organized DCDC II to understand water, climate and environmental decisions in a complex, dynamic urban system and structured our research in terms of an integrated decision process. DCDC II's conceptual approach posits that the uncertainties of climate change affect individual and societal alternatives (adaptation decisions), which function through an urban system with economic feedbacks and distributional (social and spatial) consequences. Points of focus for our interdisciplinary research agenda are: 1) climatic uncertainties, 2) outcomes (economic feedbacks, urban system dynamics, and distribution effects), and 3) adaptation decisions. Activities cutting across these themes are simulation modeling and boundary studies.



Climatic Uncertainties

Hydrologist Enrique Vivoni leads a team investigating the geographic regions that generate the central Arizona water supply and the impact of land use change and climate change scenarios on water supplies and extreme events including floods and droughts. Vivoni's team is using a distributed hydrologic model to quantify and predict the watershed responses to meteorological forcing by combining meteorological measurements or forecasts and geospatial data into a predictive model. Vivoni's team is also evaluating streamflows during the North American monsoon by conducting simulations using high-resolution data, both in nested watersheds and at forest locations, to reproduce the flood hydrograph in the model and compare results from ground data and satellite products.

Postdoctoral scholar Hernan Moreno is conducting research to reveal the distributed and time-evolving hydrological responses occurring because of climate and land cover changes in the Salt, Verde and Tonto (SVT) basins in central Arizona. His goal is to model components of the water balance by building and testing a physically based distributed model forced with downscaled IPCC climate models. The TIN-based Real Time Basin Simulator (tRIBS) will be calibrated and used to represent historical observed runoff, snow, groundwater, evapotranspiration and soil moisture dynamics and projections of those variables in views of change, distinguishing between climate and land cover change, and individual and coupled effects on average and extreme (floods and droughts) hydrologic behaviors.

Decision Science and Policy

Our decision science research is led by Erik Johnston, School of Public Affairs and the Center for Policy Informatics, and Ajay Vinze, W. P. Carey School of Business, along with graduate students from Public Affairs and Computing, Informatics, and Decision Systems Engineering. This work examines cooperative behavior and collaboration amongst diverse stakeholders to achieve collective goals by evaluating the effects of information technology, such as WaterSim, on decision making.

Psychology of Environmental Decision Making

Professors Steven Neuberg and Douglas Kenrick from the ASU Department of Psychology lead an active team including doctoral student Becca Neel and several undergraduate REUs. They employ both evolutionary and sociocultural models in an energetic research program including several interrelated experiments examining the psychology of water/energy use and perceptions of climate change beliefs

and science. In recent work – inspired in part by recommendations from the DCDC External Advisory Committee – the psychology team has begun to focus more directly on how uncertainty affects individual adaptation decisions. A new set of studies examines the effect of uncertainty framing on public trust in climate science and scientists.

Institutional Roles

Hallie Eakin, Rimjhim Aggarwal, Abby York, and Amber Wutich are conducting institutional analyses to study the capacity of urban governance systems to anticipate and adapt to a changing climate. New collaborative research and outreach is examining agricultural water conservation and institutional constraints on adaptation. The future of agriculture is critical to climate adaptation and water sustainability in Arizona. Along with collaborators from the University of Arizona Cooperative Extension and the Arizona Cotton Growers Association, Eakin, Aggarwal, and York are examining how water policy affects farmers' engagement with adaptation to future scarcity. Wutich continued her leadership on The Global Ethnohydrology Study. This project examines cross-cultural understandings of water institutions, water scarcity, climate change uncertainty, and water reuse across ecologically, culturally, and politically distinct world regions.

Water Economics Research

Economist Kerry Smith continues to lead a dynamic program of research in water economics. Smith and colleagues are conducting research into structural and quasi-experimental estimates of price elasticities, heterogeneity and residential water demand, landscape and water demand, and effects of municipal price structure. This line of research benefits from deep and sustained interaction with stakeholders, particularly from the municipal water services departments in Phoenix and Tucson, Arizona. Smith and colleagues are also using hedonic analysis to examine interactions between landscape, urban heat island, and water use in central Arizona. The ultimate goal of this research is to develop a structural model capable of linking land and water use – or an "economics of land architecture" model. To accomplish this goal, Smith is collaborating with colleagues from the NSF-funded CAP LTER project at ASU including geographer Billie Turner and sociologist Sharon Harlan.

Urban Systems Dynamics

Postdoctoral scholar Ariane Middel led a team including Anthony Brazel, Soe Myint and Ph.D. student Shai Kaplan to analyze the daytime cooling efficiency of Phoenix neighborhoods. The researchers investigated the daytime cooling–water use tradeoff and the timing of cooling. In another project, an interdisciplinary microclimate study involved Middel, Brazel, plant biologist Chris Martin, urban planner Subhrajit Guhathakurta, and Kathrin Häb, a Ph.D. student visiting from Germany. The goal of this study was to find effective urban form and landscaping strategies for Phoenix to lower temperatures during the summer months and, consequently, reduce residential energy use and increase human comfort.

Decision Support Tools – WaterSim

We continue to implement and refine WaterSim to investigate how alternative climate conditions, rates of population growth, and policy choices interact to affect future water supply and demand conditions in central Arizona. WaterSim is available for use by researchers, water managers, and the general public in three ways: WaterSim in the Decision Theater, WaterSim on the Web, and WaterSim API Version 5.0, a public domain model programming interface. The WaterSim Steering Committee developed recommendations for model improvements based on feedback from the research community and community partners. The new version of WaterSim, includes a Microsoft.Net-based standalone model with a documented application interface (API) and base condition data sets for central Arizona. New

research is underway using WaterSim 5.0 to evaluate a range of climate impacts, urban adaptation policies, and feedbacks.

Science-Policy Interactions and Boundary Organizations

Seeking to expand our attention to multiple types and dimensions of uncertainty in water and urban climate decision making, PI Dave White examined the role of framing as a type of boundary work in the development of environmental decision support systems. White analyzed the social processes in the development of WaterSim to reveal how modelers and researchers defined the water sustainability problem and implied solutions. A new, integrative research project, led by Arnim Wiek, Dave White, and Kelli Larson, is linking empirical survey research assessing the preferences of water decision makers with WaterSim modeling to create and evaluate the sustainability of a series of distinct value-based future scenarios.

II. Findings of Research Activities

DCDC scientists and modelers have developed new knowledge and decision support tools to affect the way actors and institutions make decisions about water and climate adaptation in central Arizona.

DCDC researchers have catalyzed the use of innovative tools and concepts such as exploratory modeling, advanced scenario planning, anticipatory governance, resilience, and adaptive capacity to help solve water sustainability and climate change challenges. Researchers and modelers are collaborating with water managers and state regulators to link science and modeling to regional and state planning efforts. Pat Gober has argued for an increased emphasis on the human and social dynamics of water systems and increased cooperation between water and land planners. In a recent editorial in *Water Resources Management*, Gober (2013) argued that water institutions, which have historically been insular, conservative, and dominated by engineering perspectives, must embrace principles of decision making under uncertainty to build resilience and adaptive capacity. She recommends the greater use of exploratory modeling of alternative futures, scenario planning, and a shift from a predict-and-plan paradigm to a more anticipatory approach. In a related article in *Society & Natural Resources*, Gober et al. (2013) surveyed land and water managers in Phoenix, AZ and Portland, OR to assess their perceptions of vulnerability to climate change for community water systems. The authors identified areas of divergence between land and water managers; for instance, land planners were more concerned about residential water consumption and inadequate access to water resources as factors in future shortages, whereas water managers were more concerned about population growth and lack of adequate planning. While climate change was rated as a low priority for both land and water managers in both Portland and Phoenix, climate variability and outdoor water use were seen as higher-priority concerns. Thus, focusing attention on these issues provides a potential cross-walk to increase coordination while also providing adaptation co-benefits, yet avoiding the political tensions associated with climate change.

New research is underway using WaterSim to evaluate a range of climate impacts, urban adaptation policies, and feedbacks. One study is under review for an invited chapter to a forthcoming special publication of The Geological Society of London, *Model Fusion: Integrating Environmental Models to Solve Real World Problems*. Gober, White, Quay, Sampson, and Kirkwood (in review) evaluate the impact of applying the 100-year assured water supply rule to urban municipalities in Phoenix. The research evaluated 72 scenarios varying dry and wet flow conditions (from historic records) and altered surface water supplies from the Colorado River and Salt/Verde Rivers (representing the range of reductions represented by downscaled GCM models). The simulations show that strict state-level enforcement of existing policy would enable continued growth, albeit in a different form, reduce the overall vulnerabilities of water shortage, reward communities for sustainable water practices, and bring land development and water policies into conformance.

In recently published work, decision science and policy researchers Erik Johnston and Ajay Vinze found that when participants deliberated on water policy by interacting in a designed deliberation space with a communal display, participants showed more cooperative behavior in a social dilemma scenario than those interacting with individual laptops and multiple mouse controls (Hu et al. 2013, *The Journal of Community Informatics*).

DCDC economists, working in collaboration with other social scientists and water managers, have developed new techniques to reveal price elasticities, improve the understanding and projection of residential water demand, and examine interactions among landscape, urban heat, and water use in Arizona.

In an article forthcoming in *Land Economics*, Smith and colleagues develop a new strategy for estimating water demand responses with two innovations (Klaiber et al. in press). Their approach a) considers how order statistics, summarizing the distribution of use constructed at the Census block, change with exogenous price changes; and b) exploits changes in marginal prices over time to reflect provider cost increases that can be matched by month so the position of water consumption in the price structure is unchanged. This matching process assures the increment to the marginal price can be used as an exogenous change from the household's perspective. This indicates that matching a simple theoretical model of demand response with an exogenous source of price variation can allow measurement of demand elasticities. In a second article forthcoming with *Land Economics*, Klaiber and Smith (2013) examines two issues, including conversion of land cover from desert to wet landscape and hazardous waste site cleanup, to evaluate whether the property value capitalization effects measured with quasi-experimental methods offer reliable estimates of willingness to pay for changes in amenities.

Working in interdisciplinary teams, DCDC social scientists have developed new theory and knowledge about water governance institutions and potential pathways toward more resilient, adaptive, and just institutions.

Researchers Arnim Wiek, Kelli Larson, and doctoral student Lauren Withycombe Keeler developed a systemic framework for evaluating regional water governance regimes (Wiek and Larson 2012, *Water Resources Management*). Their framework 1) employs a systems-wide perspective on regional water systems; 2) focuses on social actors and investigates what people actually do with water and why, thereby building upon proposals to integrate systems and actors perspectives; 3) explicates values and preferences as they pertain to sustainability while specifying their relevance for all water activities; and 4) advances a comprehensive sustainability perspective, for instance, by expanding the discourse from safe yield to sustainability. A companion article (Larson et al. 2013, *Journal of Environmental Management*) applied the framework to conduct a sustainability appraisal of water governance in central Arizona. The authors concluded that in Phoenix greater attention is needed to ecosystem functions and resource maintenance as well as social equity and public engagement in water governance.

DCDC researchers have uncovered fundamental psychological motives affecting individual water use decisions and developed an integrated theoretical approach to understanding the sociocultural basis of multidimensional environmental attitudes.

Recently completed work used trade-off experiments to examine priorities in residential water use (Sadalla et al. in press, *Environment and Behavior*). This research found that even though outdoor uses typically account for more than half of all residential water consumption in Phoenix, participants in this study prioritized indoor water use and preferred low water use outdoor landscaping, suggesting that, under a restricted budget, some residents would be willing to forgo more water-intensive outdoor landscaping. The study also found that access to a swimming pool was a high priority but owning a private pool was not. Future urban development promoting shared community pools could contribute to lowering per capita residential water demand without negatively affecting quality of life. Another recently completed study examined self-presentational barriers to low water use residential landscaping (Sadalla et al. in review, *Journal of Environmental Psychology*).

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Research Performance Objectives and Accomplishments

Disseminate research through an average of 30 publications per year in books, chapters, and peer reviewed journal articles.

- Published 45 peer-reviewed journal articles (published and in press), 1 book, and 21 book chapters during the reporting period.
- Articles were published in leading journals such as *Bulletin of the American Meteorological Society, Climatic Change, Climate Research, Ecology and Society, International Journal of Climatology, Journal of Environmental Economics and Management, Land Economics, Landscape and Urban Planning, Social Studies of Science, The Professional Geographer, Water Resources Management, and Water Resources Research*.

Make an average of 20 presentations to national/international conferences per year.

- Disseminated scientific findings through 20 presentations to national and international conferences.
- Presentations made to leading conferences including: American Association for Advancement of Science; American Geophysical Union; Long-Term Ecological Research All Scientist Meeting; International Symposium for Society and Resource Management; and 8th International Conference on Urban Climate (ICUC8).

Leverage DCDC funding by developing and submitting 2-4 proposals per year where a DCDC investigator is Co-PI or lead PI. Serve as key partner in 2-4 proposals per year with a DCDC investigator in a supporting role.

- Submitted 8 successful proposals from September 2012-August 2013 where a DCDC investigator is Co-PI or lead PI securing more than $2,900,000 in leveraged funding.
- Submitted dozens of proposals with a DCDC investigator in a supporting role (as senior project personnel) including a $25 million USAID proposal to establish the “International Development Solutions Collaboratory” (unfunded).

III. Education and Development

K-12 Education

Decision Center for a Desert City, Arizona Project WET, Water Resources Research Center, and Maricopa County Cooperative Extension from the University of Arizona host water educators each summer to reach out to K-12 educators and provide them with teaching methods and new ideas related to sustainability, water, and climate change. The 2013 workshop focused on understanding and using models in K-12 education. Additionally, graduate fellows associated with the NSF-funded GK-12 Sustainability Science for Sustainable Schools grant continue to use DCDC research in creating classroom lessons.

Undergraduate Education

The internship program of the Decision Center for a Desert City (DCDC) bridges the world of academia with the world of water management by placing students within agencies to carry out projects with a use-inspired research component. Program partners include agencies such as city municipalities, companies, and not-for-profit organizations. Under the guidance of Dr. Margaret Nelson, students are introduced to the concepts and practical aspects of policy-relevant research. In spring 2013, DCDC supported nine students in the Internship for Science Practice Integration, who were placed with partner agencies including City of Phoenix, City of Goodyear, University of Arizona Cooperative Extension, Arizona Department of Water Resources, City of Mesa, and Audubon Arizona.

The National Science Foundation-funded Research Experiences for Undergraduates (REU) program supports participation in research by undergraduate students. Students engage with faculty and graduate students typically for a one-year period. DCDC supported three REU students during the 2012-2013 academic year. Two of these students travelled with the DCDC graduate students to present posters at the AAAS conference held in Boston in February 2013 as part of a special session on Decision Making Under Uncertainty.

Graduate Education

The Community of Graduate Scholars (CGS) is a year-long, one-credit course, guided by Dr. Margaret Nelson (Vice Dean, Barrett, The Honors College), that gives graduate students the opportunity to become leaders in transdisciplinary approaches to research, policy, and community engagement. Students work on DCDC projects, as well as related efforts at ASU. Students are involved in multiple projects, examining the relationships among them, and thus learn to articulate and promote integrated perspectives.

DCDC faculty members are involved in interdisciplinary collaborations that offer rich opportunities to graduate students. Each CGS student works on a research team that includes faculty members and both graduate and undergraduate students; this work provides them with the intellectual depth necessary to contribute to DCDC's research. The program is structured to build dialogue, thought, and action across disciplines. Through the CGS seminar, students become familiar with the issues, perspectives, and language of the researchers within DCDC, as well as with issues that emerge from interdisciplinary collaborations. The 2012-2013 Community of Graduate Scholars included 9 students (6 women, 3 men) who presented their research posters, along with two REU students, at the AAAS conference held in Boston in February 2013 as part of a special session on Decision Making Under Uncertainty.

Postdoctoral Fellowships

Opportunities for training and professional development for postdoctoral fellows are guided by the NSF-approved DCDC Postdoctoral Mentoring Plan. Our postdoctoral mentoring plan focuses on professional and career development, encompassing the six core competencies outlined by the National Postdoctoral Association. We will guide postdocs through a structured process of interdisciplinary engagement and collaboration, welcoming them as new doctorates and mentoring them so that, after two years, they are ready to establish their own independent research programs at a research university. Each postdoctoral scholar completes an Individual Development Plan for Postdoctoral Fellows, derived from the National Postdoctoral Association. This IDP ensures that the postdoc and his/her mentor develop a shared strategy for training and career advancement. Each DCDC postdoctoral fellow subsequently provides bi-weekly updates to the faculty mentor and undergoes an annual performance self-assessment as well as a formal evaluation by DCDC PI/PD Dave White. Postdocs are encouraged to participate in professional development activities such as the Preparing Future Faculty program, career development and proposal writing workshops offered by the ASU Office of Knowledge Enterprise Development, and training from the ASU Office of Research Integrity and Assurance. During the reporting period, DCDC supported two postdoctoral fellows. A new postdoc will be joining DCDC in September 2013.

Hernan Moreno joined DCDC in August 2012 after graduating from ASU with his Ph.D. completed under the direction of Dr. Enrique Vivoni in the School of Earth and Space Exploration. Hernan's focus includes modeling and projections of water resources for Arizona under varying conditions of climate and land use change. This work focuses on the estimation of climatic and hydrologic uncertainties to contribute to scientific knowledge as well as to inform decision making in water policy. Stakeholders and academic experts are involved in participatory modeling as an interactive process with benefits for both researchers and practitioners. Specific activities involve the setup of a distributed hydrological model (tRIBS) for the Verde, Tonto and Salt River basins and selection of the appropriate spatial resolution for reducing the computational load, hydrologic calibration and validation using historical information, downscaling of IPCC future climate scenarios, and consideration of future vegetation thinning and change. Coupling of climate and land cover scenarios in the hydrologic projections will allow creating a platform for decision making, a connection with reservoir models and DCDC's WaterSim model. Such a platform will integrate the different scenarios (precipitation, temperature, vegetation cover, etc.) with corresponding basin outputs (discharges, evapotranspiration, groundwater, soil moisture, snow, and runoff) in a friendly and free source-code GUI for stakeholder engagement and use.

Ariane Middel received her Ph.D. in Computer Science from the University of Kaiserslautern, Germany. Since joining DCDC in 2009, she has collaborated with the climatologists and geographers on research aimed at understanding the functional relationships between water use, energy use, and land-cover characteristics. Specifically, Ariane's research interests focus on how urban form, design and landscaping affect urban climate at the micro-scale and local scale. This understanding facilitates the targeting of more effective planning strategies for mitigating the urban heat island.

In September 2013, Ted Bohn will be coming to ASU from the University of Washington to work with DCDC. Bohn has been awarded an NSF SEES Fellowship to work under the direction of Enrique Vivoni and Dave White. Using a coupled land-atmosphere model, Bohn's work will study the impacts of changes in land cover/land use in northwestern Mexico on moisture recycling and transport to both the US and other areas of Mexico. This work will also assess the feasibility of employing land use decisions to influence the North American monsoon and thereby reduce regional vulnerability to climate variability and change.

Education Performance Objectives and Accomplishments

Support at least six graduate research assistants per year and sponsor them in the Community of Graduate Scholars seminar.

- Supported 9 graduate research assistantships.
- These students have produced 2 Ph.D. dissertations.
- Of the graduate research assistantships supported, 6 positions have been held by women and 5 come from historically underrepresented groups in STEM.

Support at least four REUs per year and sponsor them in the Community of Undergraduate Research Scholars.

- Supported 3 REUs. The investment in the REU program was downsized to shift support to the Internship for Science Practice Integration.

Host an annual poster symposium showcasing the work of graduate and undergraduate students.

- Hosted a poster symposium at DCDC showcasing the work of the Community of Graduate Scholars, Research Experiences for Undergraduates, and Internship for Science Practice Integration students.

Place and oversee at least three DCDC internships in local resource agencies.

- Supported 9 undergraduate students through the Internship for Science-Practice Integration.

IV. Outreach Activities

2012-2013 Water/Climate Briefings; Theme: Dynamics of Water in Urban Ecosystems

September 5, 2012: Dynamics of Water in Urban Ecosystems, overview
Dan Childers (moderator), Professor, ASU School of Sustainability; Juliet Stromberg, Associate Professor, ASU School of Life Sciences; Aimée Conroy, Deputy Water Services Director, City of Phoenix; Sara Porter, Executive Director, Audubon Arizona.

October 10, 2012: Stormwater: Green Infrastructure
Ray Quay (moderator), DCDC; Irene Ogata, Urban Landscape Manager, City of Tucson; Kelli Sertich, Division Manager, Maricopa County Floodplain Management & Services; Ken Vonderscher, Deputy Director, City of Phoenix.

November 14, 2012: Effluent for the Environment
Sarah Jones (moderator), DCDC; Peter Fox, Professor, ASU School of Sustainable Engineering and the Built Environment; Tom Hildebrandt, Wildlife Program Manager (retired), AZ Game & Fish, Central Arizona Regions; Bruce Prior, Hydrologist, City of Tucson Water Department; Robert F. Upham, P.E., Project Manager, Water Resources Division, City of Phoenix.

January 11, 2013: Keynote Address at the 15th Annual CAP LTER Poster Symposium (DCDC Co-sponsor): Transitions in Urban Environmental Systems: Lessons from New York City and Hurricane Sandy.
William Solecki, Director of the Institute for Sustainable Cities and Professor, Department of Geography, City University of New York.

February 27, 2013: The Dynamics of Energy and Water for Central Arizona Agriculture
Hallie Eakin (moderator), Professor, ASU School of Sustainability; Brian Betcher, General Manager, Maricopa Stanfield Irrigation & Drainage District; Ed Gerak, Buckeye Water Conservation and Drainage District; Katosha Nakai, Manager, Tribal Relations & Policy Development, Business Planning & Governmental Programs, Central Arizona Project; Ron Rayner, Manager, A Tumbling T Ranches; Karen Smith, Fellow, Grand Canyon Institute.

March 6, 2013: Environment and Water: Decision-support Tools for Managing Ecosystem Services in Arizona
Dave White (moderator), DCDC; Ann P. Kinzig, Professor, ASU School of Life Sciences; Charles Perrings, Professor, ASU School of Life Sciences.

April 23, 2013: The Future of Arizona's Forests: Anticipating the Effects of Climate Change and Fire on Water Sustainability
Dave White (moderator), DCDC; Erik Nielsen, Assistant Professor, School of Earth Sciences and Environmental Sustainability, Northern Arizona University; Thomas Sisk, Olajos-Goslow Professor of Environmental Science and Policy, Northern Arizona University; Abe Springer, Professor of Geology, Northern Arizona University.

May 1, 2013: DCDC Annual Poster Symposium
The DCDC Poster Symposium is one of the highlights of each spring semester. Student posters present the results of various research projects conducted by students enrolled in the Internship for Science-Practice Integration (ISPI), Research Experiences for Undergraduates (REU), and the Community of Graduate Scholars (CGS).

Collaborative Science and Policy Workshops

Urban Water Demand Roundtable – April 18-19, 2013

In April 2013, DCDC hosted a conference, entitled "Urban Water Demand Roundtable: Bringing Together the Best in Current Research and Applications." This event was a collaborative effort between DCDC, the Center for Environmental Economics and Sustainability Policy, and the City of Phoenix Water Services Department. The goal was to cooperatively identify the issues important to both research and policy. That is, the meeting provided the opportunity to define both new research questions and to identify partners that would be willing to work together. The event included leading academic researchers, consultants, and analysts from municipal water services departments including Phoenix, Tucson, Flagstaff, Las Vegas, San Antonio, Tampa Bay, Seattle, El Paso, San Diego, and Aurora.

Research Frontiers in Water Reuse Forum – March 26-27, 2013

This workshop was a two-day forum sponsored by Intel Corporation and was the culmination of an ongoing collaboration between ASU, Intel, and CH2M HILL's WaterMatch project to understand critical issues in water reuse with a focus on the western United States. This forum facilitated the exchange of ideas and experience among top academic researchers and decision makers in order to identify research and policy priorities and potential future collaborations between participating individuals and organizations. One goal of the forum was to develop a policy white paper on the role of water reuse in addressing water sustainability challenges in an increasingly uncertain future.

Remote Data Sensing Workshop – February 28, 2013

Many of the water utilities in the Phoenix region are beginning to focus their attention on outdoor water use. Understanding what landscapes exist at the parcel level is one piece of information that has eluded quantification. The City of Phoenix currently has a project underway using interns to review aerial photography to classify the landscapes of residential development in north Phoenix. For the last 10 years, ASU has been working on algorithms to classify landscapes using satellite imagery. At this workshop, both water providers and ASU researchers discussed what the needs for landscape classification are and how remote sensing might contribute to existing knowledge.

Other Outreach Activities

The Arizona Climate and Water Resources Alliance (ACWRA)

The goal of the ACWRA is to develop scientific knowledge relevant to decision making for anticipating and adapting to climate change impacts on central Arizona. ACWRA has been supported by the Arizona Water Institute, DCDC, the UA Climate Assessment for the Southwest, and local and regional water utilities.

Arizona Indicators

Arizona Indicators, a project managed by Morrison Institute for Public Policy, is a community partnership with major sponsorship by Arizona State University and Arizona Community Foundation, and support from the Valley of the Sun United Way and The Arizona Republic. Arizona Indicators presents interactive data visualizations and mapping tools, public opinion data, and timely policy analysis. DCDC contributes to the Sustainability and Transportation indicators. In addition, DCDC staff continue to contribute various publications regarding the sustainability indicators.

Website and Social Media

DCDC maintains an active website to improve visibility of our research and events. The DCDC website provides an intuitive experience for guiding users to our Research, Education, and Outreach products, as well as to DCDC Publications and the WaterSim Model. Visit http://dcdc.asu.edu.

We have also developed a social media strategy using our Twitter account (@DCDC_ASU), with currently more than 200 followers, to tweet and re-tweet news pertinent to DCDC's mission. Visit https://twitter.com/DCDC_ASU.

In 2011, we created a Google Scholar page to track citations of DCDC publications and to view publications by our colleagues. Visit http://scholar.google.com/citations?hl=en&user=h2jqgykAAAAJ.

We use Vimeo to share video of meetings and events with those not able to attend in person. Visit https://vimeo.com/user9066498.

Community and Institutional Outreach Performance Objectives and Accomplishments

Host 8-10 Water/Climate Briefings per year.

- Hosted 7 Water/Climate Briefings. More than 370 attended these Water/Climate Briefings.
- In 2012, we began videotaping the briefings. These recordings are now available online through the DCDC website and Vimeochannel (http://vimeo.com/user9066498/videos).

Collaborate with the Sustainable Cities Network to increase the use of WaterSim for long-term water planning.

- Collaborated with DCDC stakeholders, including Arizona Department of Water Resources (ADWR) and the Sustainable Cities Network (SCN), to increase the use of WaterSim for regional water planning.

Convene an annual Desert Cities Town Hall to increase dialogue about climate adaptation strategies.

- Revised objective to co-sponsor "Arizona Municipal Climate Planning Workshop" in cooperation with University of Arizona (October, 2012) and participate in "National Climate Assessment Regional Town Hall" (April, 2013).

Continue collaborative workshops on climate modeling and adaptation with the University of Arizona.

- DCDC hosted workshops on "Collaboration between Decision Center for a Desert City (DCDC) and the UA Sustainable Water Action Network (SWAN)."
- DCDC PI Dave White presented invited paper to workshop on "Challenges in Integrating (Hydrologic) Science into Urban^{+} Decision Making" hosted by UA Sustainable Water Action Network (SWAN) on April 20, 2013.
- DCDC post-doc Hernan Moreno presented on "Exploring the Limits of Flood Forecasting in Mountain Basins During Summer Convection" to the University of Arizona Water Resources Research Center on April 3, 2013.
- DCDC PI White presented "Research Update from the Decision Center for a Desert City" to the University of Arizona, Water Resources Research Center on April 24, 2013.
- DCDC research professional Ray Quay co-organized Arizona Municipal Climate Planning Workshop, October 18-19, 2012, with multiple UA partners.

Produce public education materials and briefs for climate adaptation, risk management, and decision making under uncertainty.

- Developed social media strategy integrated with GIOS and ASU platforms including presence on Google Scholar, Twitter, and Vimeo.
- Completed policy report, "Future of Effluent in the Arizona Sun Corridor: Increased Competition and Cost. A Potential Framework for Collaboration," with planned publication of Summer, 2013.

Contributions within the Discipline

Geographical Sciences

Researchers at DCDC continue to influence the discipline of geographical sciences, enhancing basic understanding of linkages and feedbacks between environmental and human systems in urban settings. Specifically, a growing body of DCDC research has elucidated the relationships between land use/land cover, urban form, and water and energy balances at multiple scales in urban settings. Recent research applied the Local Scale Urban Meteorological Parameterization Scheme (LUMPS) to examine how changes in land use/cover alter the local surface energy balance and contribute to distinct urban climates (Middel et al. 2012, *International Journal of Climatology*). The findings indicate the importance of the spatial and climatic context in the urban design process to mitigate the effects of urbanization.

In another contribution, DCDC researchers analyzed the daytime cooling efficiency of Phoenix neighborhoods (Middel et al. 2012, *Climate Research*). Findings suggest that drier neighborhoods with heterogeneous land uses are the most efficient landscapes in balancing cooling and water use in Phoenix. However, further factors such as energy use and human vulnerability to extreme heat have to be considered in the cooling–water use tradeoff, especially under the uncertainties of future climate change.

An interdisciplinary microclimate study (Middel et al. in review, *Landscape and Urban Planning)* used the 3D model ENVI-met to investigate effective urban form and landscaping strategies for Phoenix to lower temperatures during the summer months and, consequently, reduce residential energy use and increase human comfort. Findings show that advection is important for the distribution of air temperatures and spatial differences in cooling are strongly related to solar radiation and local shading patterns. In mid-afternoon, dense urban forms can create local “cool islands.”

Urban planner Subhrajit Guhathakurta led a team that included engineer Eric Williams, post-doc Ariane Middel, and several graduate students, to develop a dynamic network model to examine trends in energy use and carbon emissions associated with urban form, land-use patterns, buildings, and travel behavior. Their networked infrastructure model integrates energy use in separate categories (vehicles, travel infrastructure, buildings) into a dynamic network where each activity node depends upon other nodes of both similar and different activities. The team developed a parametric LCA model that can estimate the embedded energy and GHG emission in the material manufacturing and construction processes for most types of single-family homes in Phoenix (Frijia et al. 2012, *Environmental Science & Technology*). Guhathakurta and colleagues are currently extending the parametric model to multifamily homes and non-residential buildings. Middel will integrate the life cycle results to conduct an analysis of the total energy budget for two sub-areas in Phoenix and Gilbert, Arizona as it relates to urban form, transportation and land use patterns.

Anthropology

The findings of recent DCDC research have also contributed to the discipline of anthropology, most notably in the areas of cross-cultural perceptions of water and institutional analysis. Recent findings from the Global Ethnohydrology Study – a cross-cultural examination of perceptions of justice in water institutions (Wutich et al. 2012) – contributed to the theoretical expansion of environmental justice construct in anthropology. Specifically, this work argues for a more explicit examination of interactional justice (or recognition) in environmental justice research and a more explicit analysis of the role of

institutional norms. These contributions have the potential to enhance understanding of water institutions in areas that face resource scarcity and less-developed economic conditions.

Environmental Economics

Research by Kerry Smith and collaborators is contributing to the development of novel techniques and methods in environmental economics. In an article forthcoming in *Land Economics*, Smith and colleagues develop a new strategy for estimating water demand responses with two innovations (Klaiber et al. in press). Their approach a) considers how order statistics, summarizing the distribution of use constructed at the Census block, change with exogenous price changes; and b) exploits changes in marginal prices over time to reflect provider cost increases that can be matched by month so the position of water consumption in the price structure is unchanged. This matching process assures the increment to the marginal price can be used as an exogenous change from the household's perspective. This indicates that matching a simple theoretical model of demand response with an exogenous source of price variation can allow measurement of demand elasticities.

Simulation Modeling

We continue to implement and refine our signature computer-simulation model, WaterSim, to investigate how alternative climate conditions, rates of population growth, and policy choices interact to affect future water supply and demand conditions in Phoenix. The current version of the model, WaterSim 5.0, is comprised of (1) a Microsoft C# interface; (2) a C# library module; and (3) a simulation model (FORTRAN) that houses the rules and algorithms to model water supply and demand, all at the water provider level. WaterSim 5.0 runs on an annual time-step. WaterSim 5.0 produces water supply and use patterns for 33 Phoenix Metropolitan Area water providers. New research and applications of the model are contributing to the development of novel methods for using simulation models for anticipatory planning and advanced scenario analysis for urban climate change adaptation. New research is underway using WaterSim 5.0 to evaluate a range of climate impacts, urban adaptation policies, and feedbacks (Gober et al. in review).

Science-Policy Interactions and Boundary Organizations

In the past year, DCDC research has advanced theory and methods related to knowledge systems, learning, and social processes in boundary organizations that link science and policy. White (in press, *Society & Natural Resources*) brought the theoretical concepts of frame and framing to the analysis of boundary work in the development of environmental decision support systems. Framing provides an appropriate theoretical lens to analyze decision support system development because this approach examines the assumptions, choices, and decisions that are made by developers as social actors with independent agency and interests. Framing serves to construct boundaries for environmental problems and solutions and can narrow or widen the discourse and impact the questions asked, knowledge produced, actors empowered, and ultimately the political opportunities and decisions made. This research is contributing to a growing awareness of the importance of understanding how individual actors and social groups frame issues and how their perspectives play out through social processes in participatory, integrated water resources management.

References

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Contributions outside the Discipline

Other Disciplines

As an interdisciplinary project, DCDC links research from disciplines including decision science, economics, psychology, geography, planning, anthropology, ecology, hydrology, and engineering. Although specific research projects often focus on disciplinary questions, the overarching approach is to foster an interdisciplinary dialogue among social and environmental scientists to catalyze innovative scientific approaches. WaterSim serves as one point of articulation where researchers unite disciplinary knowledge from geography, hydrology, and climatology.

DCDC research has begun to affect theory, method, and education practices in the emerging field of sustainability science. Research led by Arnim Wiek, for instance, is using an innovative approach to integrate participatory processes for scenario analysis and construction with WaterSim modeling and sustainability assessment. These methods integrate novel concepts of anticipatory governance with sustainability research and problem-solving to create distinct scenarios of water futures in central Arizona. This work provides DCDC researchers with distinct scenarios for subsequent analysis and another point of contact for scientists and policy makers.

Development of Human Resources

The Decision Center for a Desert City provides a fruitful interdisciplinary environment for training and professional development for faculty, postdocs, K-12 teachers, graduate and undergraduate students, and staff. Promising early-career faculty, nationally renowned senior faculty, postdoctoral scholars, and students work in interdisciplinary teams to advance fundamental research and development of decision support tools for water sustainability and urban climate adaptation.

Graduate students work within the Community of Graduate Scholars to develop a broad understanding of the research process, develop an intellectual identity and voice, improve communication and presentation skills, and engage with researchers and stakeholders. The graduate students are responsible each year for organizing a panel discussion for one of the DCDC Water/Climate Briefings, providing students the opportunity to work with both faculty scientists and stakeholders to delve into the basic science and applied solutions for water sustainability and urban-climate adaptation. The DCDC graduate students also organized a joint poster symposium for the American Association for the Advancement of Science (AAAS) annual meeting, providing the students an opportunity to network with graduate students, faculty and postdocs from the other NSF-DMUU funded collaborative groups at Columbia University, Carnegie Melon University, and University of Chicago.

The DCDC Internship for Science Practice-Integration places undergraduate students within partner agencies to carry out internship projects with a research component. This experience allows students to build their professional skills and cultivate professional networks. The ISPI program allows students to engage with community organizations, develop research and management skills, explore a profession, and engage with policy and decision making aspects of sustainability science.

Each year, DCDC also provides exposure to science and technology for teachers, as more than 25 K-12 teachers attend the annual Advanced Water Educator Workshops. This workshop empowers teachers with the most-current scientific understanding to inform their curriculum.

Institutional Resources that Form Infrastructure

Since its inception, DCDC has been designed to implement the concepts of a boundary organization linking science and policy for water sustainability and urban climate adaptation. Given this mandate, one objective of the project is to contribute to the development of institutional infrastructure by fostering coalitions that enhance institutional capacity to address critical sustainability challenges. Specifically, DCDC co-founded The Arizona Climate and Water Resources Alliance (ACWRA) with Arizona water managers and researchers from Arizona State University and the University of Arizona to develop scientific knowledge relevant to decision making for anticipating and adapting to climate change impacts on central Arizona. ACWRA has been supported by the Arizona Water Institute, DCDC, the UA Climate Assessment for the Southwest (CLIMAS), and local and regional water utilities.

Recent activities have included: 1) an interactive process to select a set of Global Climate Models (GCMs), based on scientific credibility and relevance for robust planning under multiple future scenarios; 2) downscaling GCM results to the regional level using statistical and dynamical downscaling and using these downscaled results to estimate impacts on stream flows of the Salt and Verde Rivers; and 3) a series of workshops to explore the implications of the downscaled results and their utility for local and regional water resource management. During these meetings, understanding the plausibility and possible impacts of extreme events (drought, flooding, and extended high temperatures) emerged as a key topic of interest among scientists and water managers.

The ACWRA organizes periodic collaborative science-policy workshop on topics such as climate change and extreme events. As a result of this collaborative engagement process, ACWRA, ASU and UA have developed joint research proposals to secure external funding to implement the joint research and policy agenda concepts. During the reporting period, two such proposals have been submitted to NOAA to begin exploring the viability of this approach.

Information Resources that Form Infrastructure

DCDC gathers a wide range of raw and preprocessed data to be used in classification systems, spatial analyses and models. These data include: shape files for GIS analysis; subsets from large, geo-referenced databases of census, assessor and climate data; remote sensing images; and water consumption records. DCDC continues to produce data that include simulation model outputs, social data from surveys and evaluations, shape files, maps, and graphics.

DCDC collaborates with the *Informatics Lab* in ASU's Global Institute of Sustainability (GIOS), which has a well-established information management system and an experienced Information Manager responsible for policies, procedures and technology. The research team provides complete metadata for their datasets. Data access level is determined by the data provider and can be set to public or restricted. Restricted access is available only to those with login privileges to the GIOS server. All public data are available for download. Public data are provided in ways that do not incriminate privacy and confidentiality by removing personal information and precise locality information (e.g., data are aggregated at census tract level). The data are archived and data access maintained by the *Informatics Lab.* The computer facilities used in the *Lab* are part of ASU's coordinated strategy of providing outstanding stewardship for cyberinfrastructure investment made by federal grants and contracts. All data and derived products are archived in compliance with existing data and metadata standards, and will be accessible through existing GIOS data portals. By downloading data, users agree to abide to the download policy and provide a minimum of contact information. If access level is set to restricted, only the data provider's contact information will be available to the public.

DCDC maintains an active website to improve visibility of our research and events. The DCDC website provides an intuitive experience for guiding users to our Research, Education, and Outreach products, as well as to DCDC Publications and the WaterSim Model. Visit http://dcdc.asu.edu. We have also developed a social media strategy using our Twitter account (@DCDC_ASU), with currently more than 200 followers, to tweet and re-tweet news pertinent to DCDC's mission. To follow DCDC, visit https://twitter.com/DCDC_ASU. In 2011, we created a Google Scholar page to track citations of DCDC publications and to view publications by our colleagues. This page is available at http://scholar.google.com/citations?hl=en&user=h2jqgykAAAAJ. Finally, we use Vimeo to share video of meetings and events with those not able to attend in person. Visit https://vimeo.com/user9066498.

Impact on Society beyond Science and Technology

By focusing on linkages and feedbacks between science and decision-making, DCDC has broader impacts on society. New scientific knowledge and modeling about urban-system dynamics is applied to planning and decision-making strategies to make cities less sensitive to climate risks, more resilient, and more adaptive. New knowledge about decision making in the face of long-term environmental risk aids in formulating approaches to adaptation strategies based on the best-available, social-scientific understanding of individual psychological motivations, community norms, and institutional dynamics.

Collaborative science-policy workshops such as the recent Water Reuse Forum and the Urban Water Demand Roundtable bring together scientists, consultants, and municipal water managers to facilitate exchange of knowledge and best practices to build social networks and enhance capacity for collaborative research and planning.

WaterSim serves as mechanism for advanced scenario planning and analysis and, in collaboration with ASU's Decision Theater, offers unique opportunities for engagement with a variety of community stakeholders.

Graduate students from the DCDC Community of Graduate Scholars continue to foster cross-DMUU site collaboration, and the education program is already beginning to produce the next generation of transdisciplinary scholars who can move between the worlds of science and policy.

Undergraduate students from the Internship for Science Practice Integration are embedded in local organizations to conduct policy-relevant research projects to address pressing societal needs.

VI. Partner Organizations

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Arizona Department of Water Resources; 3550 N. Central Avenue, Phoenix, AZ 85012

Arizona Project Wet; 350 N. Campbell Avenue, Tucson, AZ 85719

Audubon Arizona; 3131 S. Central Avenue, Phoenix, AZ 85040

CH2M HILL; 1501 W. Fountainhead Parkway, Tempe, AZ 85282

City of Goodyear – Water Services; 190 N. Litchfield Road, Goodyear AZ 85338

City of Mesa – Water Resources; 20 E. Main Street, Mesa, AZ 85201

City of Phoenix – Water Resources; 200 W. Washington Street, Phoenix, AZ 85003

Climate Assessment for the Southwest; University of Arizona, PO Box 210156, Tucson, AZ 85721

Intel Corporation; 4500 S. Dobson Road, Chandler, AZ 85248

Salt River Project; 1521 N. Project Drive, Tempe, 85281

United States Global Change Research Program; 1717 Pennsylvania Avenue, NW, Suite 250, Washington, DC 20006

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