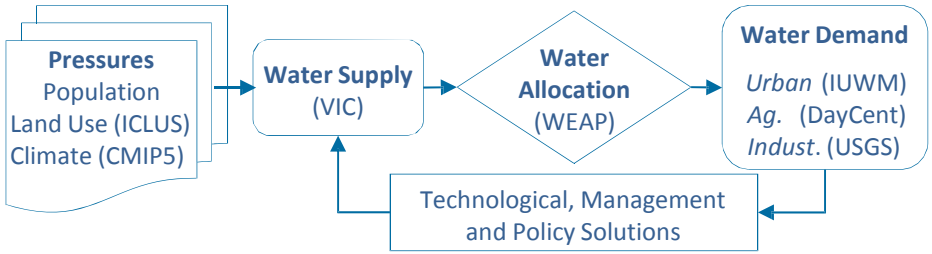
PROJECT A1-1: QUANTIFYING VULNERABILITY, RESILIENCY, AND ADAPTABILITY OF U.S. URBAN WATER SYSTEMS TO CLIMATIC AND SOCIO-ECONOMIC CHANGES

National Science Foundation

MOTIVATION AND OBJECTIVES

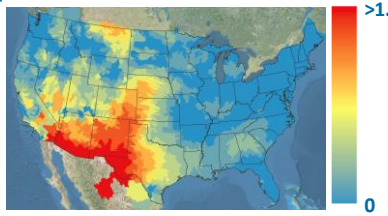
- Climatic changes combined with rapid population growth and land use change can increase the vulnerability to water shortage.
- The goal of the study is to assess regional/municipal water shortage vulnerability under nonstationary supply and demand conditions over the 21st century.



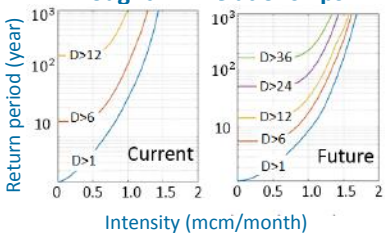
PROGRESS

- Monthly water yield were computed for the 1980-2100 period using the Variable Infiltration Capacity (VIC) model for CONUS at the HUC 8 scale under the wettest, driest, hottest, lease warm, and one that reflected a middle of these ranges.
- Changes in hydroclimatic characteristics of HUC 08 river basins were investigated.
- Current and future drought intensity-duration-frequency, and effects of urban development patterns on municipal water shortage were calculated for a case study.

Magnitude of Hydroclimatic Change (Driest climate scenario – RCP 4.5)

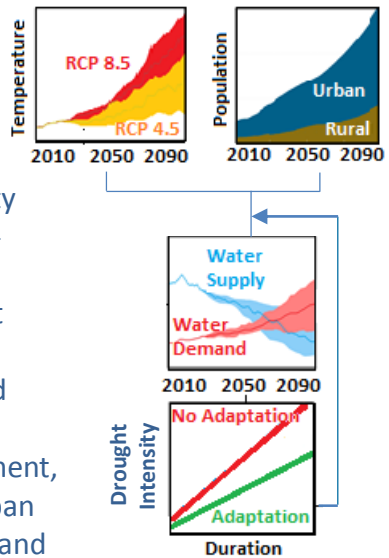


Drought IDF Relationships



APPROACH

- The **Pressure-State-Response** framework was adopted to characterize the sustainability of U.S. Water Supply.
- A novel mixed Gamma-GP probability model was developed to assess sub-annual vulnerability, reliability and resiliency of water supply systems at HUC 4 river basin scale.
- Responses include technological and policy options that foster urban and agricultural water demand management, fit-for-purpose use of alternative urban water sources, green infrastructure, and new supply systems.



ACHIEVEMENTS AND SIGNIFICANCE

- The application of the drought assessment framework for the City of Fort Collins shows that Current IDF curves substantially underestimate extreme droughts. events with longer duration and higher intensity would become more frequent.
- The demonstration study revealed that urban development patterns, i.e. sprawl versus high intensity development, have substantial implications for water shortage vulnerability at municipal scales.
- Changes in hydroclimatic characteristics under the driest scenario (RCP 4.5) indicate that river basins in the more arid parts of the United States, especially southwest will become more arid over the course of the 21st century.
- Under the middle scenario (RCP 4.5), preliminary results indicate that River basin in central CONUS will become more arid over the course of the 21st century.

PROJECT A1-1: QUANTIFYING VULNERABILITY, RESILIENCY, AND ADAPTABILITY OF U.S. URBAN WATER SYSTEMS TO CLIMATIC AND SOCIO-ECONOMIC CHANGES

PRODUCTS

- Heidari, H., Arabi., M, Dozier, A., Tasdighi, A. (2018), An Analytical Framework for Assessing Municipal Vulnerability to Water Shortage and Drought Characteristics under Nonstationary Supply and Demand Condition, AGU Hydrology Days, Fort Collins
- Heidari, H., Arabi, M., Dozier, A., Tasdighi, A. (2018), An Analytical Framework for Assessing Water Shortage Vulnerability under Nonstationary Supply and Demand Condition, International Congress on Environmental Modelling and Software (IEMSS), Fort Collins
- Heidari, H., Arabi, M., Ghanbari, M. (2018), A Novel Probabilistic Approach for Characterization of Municipal Water Shortage Vulnerability under Nonstationary Supply and Demand Conditions, AGU Fall Meeting, Washington, D.C.,
- Heidari, H., Arabi, M., Ghanbari, M., Warziniack, T. (2019), Vulnerability of the City of Fort Collins Water Supply System to Water Shortage and Extended Droughts under Nonstationary Supply and Demand Conditions over the Course of the 21st Century, AGU Hydrology Days, Fort Collins
- Heidari, H., Arabi, M., Ghanbari, M., Warziniack, T. (2019), A Mixture Gamma-GPD Probability Model for Characterization of Water Shortage Vulnerability under Nonstationary Supply and Demand Conditions, World Environmental and water resources congress, Pittsburgh
- Brown, T. C., Mahat, V., & Ramirez, J. A. (2019). Adaptation to future water shortages in the United States caused by population growth and climate change, Earth's Future,7,219–234.
- Heidari, H., Arabi, M., Ghanbari, M., Warziniack, T., Brown, T. C., (2019). A Nonstationary Mixture Probability Model for Assessment of Water Shortage Vulnerability, in preparation for submission to Water Resources Research.
- Heidari, H., Arabi, M., Warziniack, T., (2019). Changes in hydroclimetology of river basins in the United States, in preparation for submission to PNAS.

PROJECT TEAM

- Mazdak Arabi, PhD – Colorado State University
- Hadi Heidari, PhD Candidate, Colorado State University
- Travis Warziniack, PhD – USDA Forest Service
- Thomas C. Brown, PhD – USDA Forest Service

PROJECT A1-2:
IMPACTS OF WATER PRICES ON ECONOMIC GROWTH, SOCIAL EQUITY AND EQUAL OPPORTUNITY

MOTIVATION AND OBJECTIVES

Motivation: Understand water price trends and impacts of these trends on household income, regional income, and regional employment.

Objectives:
1.Create database of water prices (past, present, future)
2. Analysis of water price trends
3.Analyze economic impacts of changing consumer expenditures on water
4.Train undergraduate and graduate students in economic analyses of water prices and associated regional impacts

PROGRESS

-Collection of water rates for select U-WIN regions complete

-Analyzing water rate data

-Analyzing consumer expenditure questions about purchasing decisions due to rising water rates

-Participation of 4 graduate students and 1 undergraduate in research at Michigan State

-Started work on Integration paper, co-led with Matei Georgescu

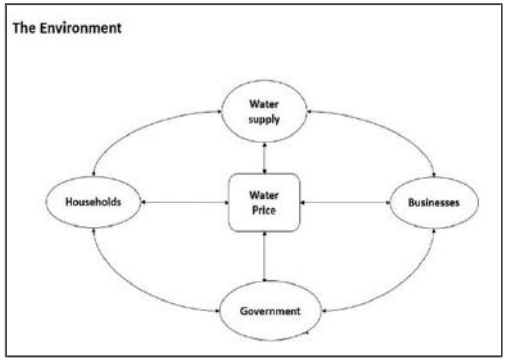
APPROACH

Implementation of a mix of quantitative methods:

-Input-output modeling to model feedbacks in regional economic systems.

-Spatial analysis of water rates

-Econometric modeling to understand linkages between water price trends and hypothesized regional drivers of prices external to utiliities.



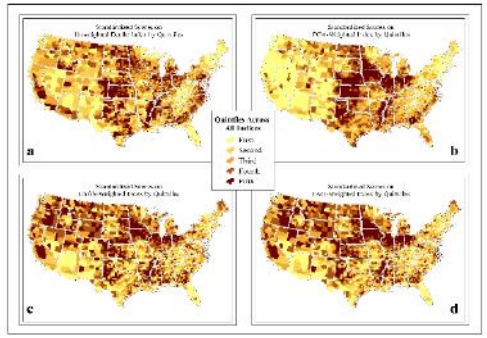
ACHIEVEMENTS AND SIGNIFICANCE

-- Completion of water rate database

-Training of students in water data sources and research

-Geography expertise has helped understand “where” people and communities are affected by affordability challenges

-Collaboration with Philadelphia Water Department to work towards affordability solutions



PROJECT A1-2:
IMPACTS OF WATER PRICES ON ECONOMIC GROWTH, SOCIAL EQUITY AND EQUAL OPPORTUNITY

PRODUCTS

Papers:

Credit, K. and **E.A. Mack**. (2019). A Multi-Regional Input-Output (MRIO) Analytical Framework For Assessing The Regional Economic Impacts of Rising Water Prices. *The Review of Regional Studies*. Accepted for publication.

Mack, E.A., Wrase, S., Dahme, J., Wright, M., and R. Muhammad. "Making Water Affordable: A Case Study of Philadelphia's Tiered Assistance Program (TAP)" Journal of the American Water Resources Association (in review)

White, J., **E.A., Mack**, S.L. Harlan, E.S. Krayenhoff, M. Georgescu, K. Redican. "Regional Multivariate Indices of Water Use Potential for the Continental United States." *Sustainability* (in review)

Articles in preparation (indicates student name):

- Spatial analysis of water rates in Detroit (*led* by S. Wrase)

Data sets:

Regional indices of water use (U.S. Counties)

Presentations:

- Mack, E.A. "A Geographic Assessment of Water and Sewer Service Affordability in the Detroit Metropolitan Area." Association of American Geographers, Washington, D.C. April 4, 2019

- Mack, E.A. An Input-Output Framework for Analyzing Consumer Responses to Changing Water Prices. North American Regional Science Association Conference. San Antonio, TX. November 7-10, 2018

PROJECT TEAM

- Elizabeth Mack, Assistant Professor, Department of Geography, Environment, and Spatial Sciences, Michigan State University
- Michigan State graduate students: Jonah White, Sarah Wrase, Michelle Church, and Laura Medwid
- Michigan State undergraduate students: Sarah Wrase, Alexander Brown, Matt Chiavetta, and Benjamin Dougherty

PROJECT A2-1:
LAND-ATMOSPHERE-HYDROSPHERE INTERACTIONS IN URBAN TERRAIN

National Science Foundation

MOTIVATION AND OBJECTIVES

- Integrate existing models of the atmosphere, surface, and subsurface in urban terrain into a comprehensive framework.
- Expand and validate the Princeton Urban Canopy Model (PUCM) into a more general framework that can dynamically represent the interplay between urban water, energy and climate (e.g. thermal comfort, role of green infrastructure and trees, urban water demand and how it is modulated by weather, etc.)
- Apply the integrated model to understand urban sustainability, particularly under historic extreme events (e.g., heat waves, floods, droughts).

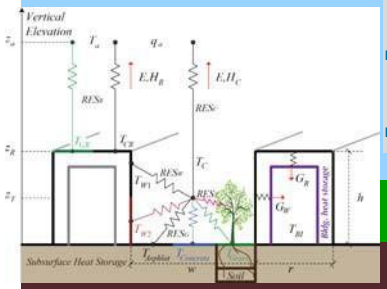
PROGRESS

- Coupling of the atmospheric component (WRF-PUCM) and the subsurface component (ParFlow) is proceeding and initial tests are encouraging.
- Trees, thermochromic roof covers, phase-change materials are now represented in PUCM.
- Studies published on (i) benefits of urban heat islands under extreme cold waves, (ii) water-savings versus urban cooling alternative in Phoenix published, (iii) dynamic downscaling, (iv) flow dynamics and transport in urban terrain.
- Sensing campaigns and studies on optimizing urban sensing strategies ongoing (1 paper published two under development).

APPROACH

Atmosphere:
Weather model (WRF) or Climate model (GCM)

- The Weather Research and Forecasting Model for the Atmosphere
- The Princeton Urban Canopy Model for the urban surface
- ParFlow for subsurface water flow



Surface: NOAH or CLM + UCM

Subsurface (Parflow)

ACHIEVEMENTS AND SIGNIFICANCE

- Despite their significance and wide application, urban geophysical models in many respects remain rudimentary. This project's primary focus is on the development of individual model components, their coupling, and their testing.
- Over 15 peer-refereed journal papers resulted so far from the project (only 13 are listed on the next slide)
- Findings broadly communicated in conferences and talks.
- All modeling components have been applied and coupled, and testing of the coupled frameworks begun.
- Developed modeling components have been delivered to other projects (A2-2).
- 5 Ph.D. students and 2 Postdocs trained through project.

PROJECT A2-1:
LAND-ATMOSPHERE-HYDROSPHERE INTERACTIONS IN URBAN TERRAIN

National Science Foundation

PRODUCTS

- Barnes, M. and Welty, C. (In Press). "Quantifying water balance components at a permeable pavement site using a coupled groundwater–surface water model" ASCE J of Hydrologic Engineering, DOI: 10.1061/(ASCE)HE.1943-5584.0001789
- Llaguno-Munitxa M. and Bou-Zeid E. (2018) "Shaping buildings to promote street ventilation: a large-eddy simulation study", Urban Climate, 26, 76-94.
- Omidvar H., Song J., Yang J., Arwatz G., Wang Z.-H., Hultmark M., Kaloush K., Bou-Zeid E. (2018) "Rapid Modification of Urban Land Surface Temperature during Rainfall", Water Resources Research, 54, 4245-4264, DOI: 10.1029/2017WR022241.
- Omidvar H. and Bou-Zeid E. (2019) "Hacking a soil water content reflectometer to measure liquid level", Flow Measurement and Instrumentation, 65, 174-179.
- Omidvar H., Bou-Zeid E., and Chiaramonte M. (2019) "Physical determinants and reduced models of the rapid cooling of urban surfaces during rainfall", Journal of Advances in Modeling Earth Systems, online first, DOI: 10.1029/2018MS001528.
- Yang J. and Bou-Zeid E. (2019) "Scale dependence of the benefits and efficiency of green and cool roofs", Landscape and Urban Planning, 185, 127-140.

PROJECT TEAM

- Elie R. Bou-Zeid, Professor, Princeton University
- Zhihua Wang, Associate Professor, Arizona State University
- Hamidreza Omidvar, Ph.D. student, Princeton University
- Jiachuan Yang, Postdoc, Princeton University
- Mahdad Talebpour, Ph.D. student, University of Maryland, Baltimore County
- Claire Welty, Professor, University of Maryland, Baltimore County
- Qi Li, previous student, Princeton University
- Chenghao Wang, Ph.D. student, , Arizona State University
- Maider Llaguno-Munitxa, Postdoc, Princeton University

PROJECT A2-2:

LAND-ATMOSPHERE-HYDROSPHERE INTERACTIONS IN URBAN TERRAIN: PROJECTING FUTURE ENVIRONMENTAL CHANGE IN URBAN AREAS

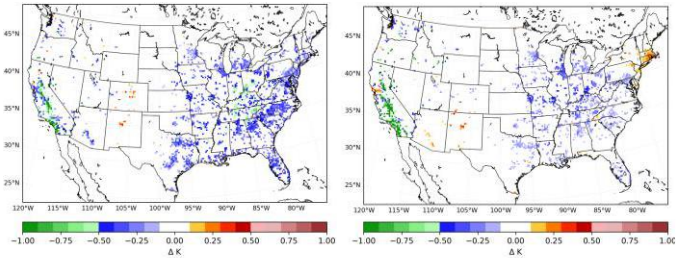
National Science Foundation

MOTIVATION AND OBJECTIVES

- Quantify the dynamically interactive effect of increased emissions of greenhouse gases (GHGs) and anthropogenic landscape change associated with urban expansion for CONUS.
- Examine the diurnally varying efficacy of locally deployed urban adaptation and mitigation solutions (e.g., street trees, cool and evaporative roofs, and lightweight materials) at continental and local scales.

PROGRESS

- Quantified the relative magnitude of urban expansion relative to GHGs across the diurnal cycle and determined that climate change and corresponding urban expansion interact nonlinearly to reduce summer night-time warming by 0.5-1.0 K.

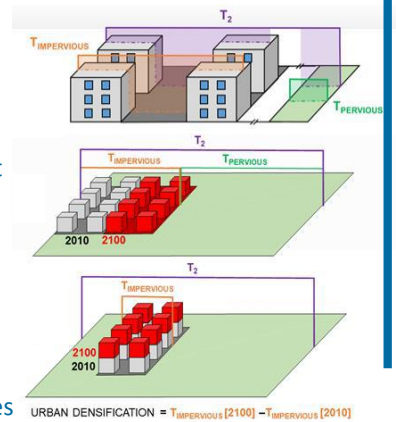


Summertime urban air temperature change resulting from dynamic interaction between 90-year projections of urban expansion and climate change. Climate models downscaled and scenarios are CESM RCP 8.5 (left panel) and GFDL RCP 8.5 (right panel). Data shown for 0300 Local Mean Solar Time (LMST). Each point represents a decadal mean JJA subgrid near-surface urban temperature change within a 20 km by 20 km model grid square (from Krayenhoff et al., 2018).

APPROACH

Utilized state-of-the-art Weather Research and Forecasting model within a high performance computing framework with modifications that include:

- Spatially-explicit urban fraction from ICLUS impervious surface projections into the WRF preprocessor to better represent static terrestrial data;
- MODIS IGBP 500 m resolution land cover was input to WRF such that all areas previously designated as urban are converted to the most common vegetation type within a 100 km radius which are consistent with locally dominant vegetation;
- Two additional near-surface air temperature diagnoses are added ($T_{impervious}$ and $T_{pervious}$), based on the sensible heat flux and surface temperatures of impervious urban (i.e. street-canyon plus roofs), and pervious (non-urban) portions of the grid cell.



ACHIEVEMENTS AND SIGNIFICANCE

- Quantify the diurnally varying interplay of urban and GHG-induced warming and adaptation cooling across CONUS.
- Developed a scenario-based multi-terabyte dataset (of unprecedented temporal resolution: 3-hourly frequency for a contemporary and a future decade) that includes multiple projections (through dynamical downscaling) of:
  - multiple GCMs/RCPs and,
  - urban expansion and,
  - infrastructure related solutions
  - This dataset has been partially housed on erams.com

PROJECT A2-2:
LAND-ATMOSPHERE-HYDROSPHERE INTERACTIONS IN URBAN TERRAIN: PROJECTING FUTURE ENVIRONMENTAL CHANGE IN URBAN AREAS

PRODUCTS

[Only 2018 manuscripts listed]

- Krayenhoff, E.S., M. Moustaoui, A. M. Broadbent, V. Gupta and M. Georgescu (2018), Diurnal interaction between urban expansion, climate change and adaptation in 21st century U.S. cities, *Nature Climate Change,* 8(12), 1097. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.

- Krayenhoff, E. S., Moustaoui, M., Broadbent, A. M., Gupta, V., & Georgescu, M. (2018). Diurnal interaction between urban expansion, climate change and adaptation in US cities. *Nature Climate Change*, *8*(12), 1097. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.

- Broadbent, A. M., Coutts, A. M., Nice, K. A., Demuzere, M., Krayenhoff, E. S., Tapper, N. J., & Wouters, H. (2019). The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET v1. 0): an efficient and user-friendly model of city cooling. *Geoscientific Model Development*, *12*(2), 785-803. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.

- Broadbent, A. M., Krayenhoff, E. S., Georgescu, M., & Sailor, D. J. (2019). The observed effects of utility-scale photovoltaics on near-surface air temperature and energy balance. *Journal of Applied Meteorology and Climatology*, (2019). Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.

PROJECT TEAM

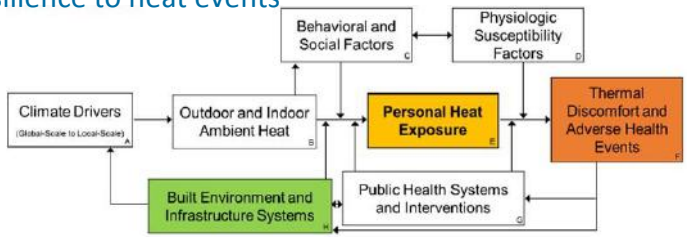
- E. S. Krayenhoff, Assistant Professor, Guelph University
- M. Moustaoui, Associate Professor, Arizona State University
- A. M. Broadbent, Post-doctoral Scholar, Arizona State University
- V. Gupta, Research Assistant, Basis High School/Arizona State University (now enrolled at Stanford University)
- M. Stuhlmacher, Research Assistant, Arizona State University
- J. Lee, Research Assistant, Arizona State University
- A. Middel, Assistant Professor, Arizona State University (now Assistant Professor at Temple University)
- Jennifer Vanos, Assistant Professor, Arizona State University
- Meng Wang, Research Technician, Arizona State University
- Chingwen Chen, Assistant Professor, Arizona State University
- M. Georgescu, Associate Professor, Arizona State University

PROJECT A2-3:
ASSESSING THE THERMAL COMFORT IMPLICATIONS OF URBAN WATER

National Science Foundation

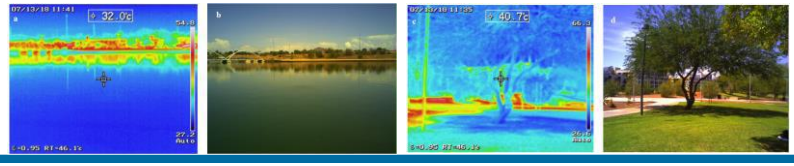
MOTIVATION AND OBJECTIVES

- Measure microclimatic conditions experienced by urban residents
- Understand microclimate effects on human health and well-being
- Assess role of urban water infrastructure in supporting resilience to heat events



PROGRESS

- Conducted national-scale assessment of urban thermal equity using satellite imagery and census data
- Compared residents' perceptions of urban trees with biophysical properties and social data in the Phoenix metro area
- Analyzed 20 stakeholder professional interviews to understand management strategies for a cascading heat disaster
- Completed additional microclimate field campaigns to assess effects of urban green and blue infrastructure



APPROACH

- Targeted thermal comfort assessments
- Citywide temperature and humidity measurements
- Human energy balance modeling
- Statistical modeling of heat-health risks
- Thematic coding of vignette-style interviews

ACHIEVEMENTS AND SIGNIFICANCE

- Inequitable distributions of urban heat previously documented in single and few-city case studies are the dominant pattern in cities across the country
- Residents' perceptions of urban green infrastructure are closely coupled with the biophysical properties of the landscape as well as socioeconomic variables
- More than 30% of heat-related deaths in Maricopa County (AZ) may be attributable to the urban heat island effect
- Urban tree canopy lowers daytime air and radiant temperatures but increases those parameters at night
- Water bodies are less effective at reducing ambient and radiant temperatures than urban tree canopy

PROJECT A2-3:
ASSESSING THE THERMAL COMFORT IMPLICATIONS OF URBAN WATER

PRODUCTS

- Hondula, D. M., Balling, R. C., Andrade, R., Krayenhoff, E. S., Middel, A., Urban, A., ... & Sailor, D. J. (2017). Biometeorology for cities. *International journal of biometeorology*, *61*(1), 59-69.

- Kuras, E. R., Richardson, M. B., Calkins, M. M., Ebi, K. L., Hess, J. J., Kintziger, K. W., ... & Hondula, D.M. (2017). Opportunities and challenges for personal heat exposure research.

- Hondula, D. M., Davis, R. E., & Georgescu, M. (2018). Clarifying the connections between green space, urban climate, and heat- related mortality.

- Hondula, D. M., Middel, A., Vanos, J. K., Herdt, L., & Kaiser, A. (2017). Urban Water Infrastructure for Cooling: Case Studies from Humid and Arid Cities. *Regions Magazine*, *306*(1), 20-23.

- Harlan S.L., Chakalian P.M., Declet-Barreto J., Hondula D.M., & Jenerette D.G. (2019). Pathways to Climate Justice in a Desert Metropolis. In: People and Climate Change: Vulnerability, Adaptation, and Social Justice. Lisa Reyes Mason and Jonathan Rigg, eds., published April 2019.

PROJECT TEAM

- David Hondula, Assistant Professor, Arizona State University
- Jennifer Vanos, Assistant Professor, Arizona State University
- Ariane Middel, Assistant Professor, Arizona State University
- Ales Urban, Postdoc, Czech Academy of Sciences
- Graduate students at ASU: Riley Andrade, Liza Kurtz, Mary Wright
- Undergraduate students at ASU and URP participants: Alanna Kaiser, Tiffany Justice, Harrison Ambrose, Lolya McWest, Samuel Meltzer

PROJECT A2-4:
ASSESSMENT AND DESIGN OF INNOVATIVE DESIGN OF BUILDING SYSTEMS AND URBAN INFRASTRUCTURE

MOTIVATION AND OBJECTIVES

We aim to improve the understanding of how the systems and infrastructure designed in the urban environment can be improved through applied research. The motivation is from the significant role that buildings play in developing demand for water, and the role that urban fabric plays at the building scale on water and climate interactions, including heat and social/environmental equity. Our goal is to provide analyses at the building and neighborhood scale that can inform modeling of climate, watershed, and integrated water management. We also aim to provide a link to conceptual design frameworks to help bridge between disciplines through architecture and urban planning contexts.

PROGRESS

We have successfully mapped urban heat in NYC using thermal cameras.
We have successfully deployed new sensing techniques for radiant heat in Philadelphia with Araine Middel – SMART sensor + MarRTy, and are finalizing paper
We have discovered the most common tool for measuring radiant heat, the black globe, has a systematic flaw in its use.
We analyzed the variation of humidity around cooling towers
We have modeled new geothermal systems tied to district heating that could be used in conjunction with wastewater heat sources
We built several prototype cooling panels that leverage desiccant systems and evaporation to more efficiently manage water and cooling
New collaboration with Torino on atmospheric water capture

APPROACH

We use sensors and thermal imaging techniques to evaluate the variation of urban surfaces. The thermal mapping is used to identify problems with heat and water storage in physical materials, and also identifies opportunities for green infrastructure to mitigate heat.

We are developing new sensor systems and techniques to more accurately map and understand the radiant heat transfer related to urban water

We are also using modeling techniques to identify synergies between district water demand and district heating systems.

We design new evaporative/desiccant based humidity management systems that can capture water from the atmosphere

Finally, we use studio teaching and to develop new design pathways for novel systems

ACHIEVEMENTS AND SIGNIFICANCE

We published a paper on challenges urban heat in NYC

We were invited and exhibited at NYU Galliton Gallery a 3D model of NYC with urban heat displayed, and also an active model of a building and trees that used thermoelectrics to emit radiant heat that visitors could experience (cold from trees, hot from building).

We published a paper reviewing the challenges of the use of black globes for measuring radiant heat

We presented several new systems we have designed that use evaporation and desiccation and received Exxon support.

We presented research on several water system projects at International Building Physics Conference.

PROJECT A2-4:
ASSESSMENT AND DESIGN OF INNOVATIVE DESIGN OF BUILDING SYSTEMS AND URBAN INFRASTRUCTURE

PRODUCTS

- Teitelbaum, E., Rysanek, A., Pantelic, J., Aviv, D., Obelz, S., Buff, A., … Meggers, F. (2019). Revisiting radiant cooling: condensation-free heat rejection using infrared-transparent enclosures of chilled panels. Architectural Science Review, 1–8. https://doi.org/10.1080/00038628.2019.1566112
- Meggers, F., & Teitelbaum, E. (2018). Expanding psychrometrics to enable humidity management through warm radiant comfort delivery. Indoor Air 2018. Presented at the Indoor Air 2018, Philadelphia, USA.
- Teitelbaum, E., Rysanek, A., Pantelic, J., Aviv, D., Obelz, S., Luo, Y., … Meggers, F. (2018, September 23). Condensation-free radiant cooling using infrared-transparent enclosures of chilled panels. 6. Syracuse, NY.
- Keeley-LeClaire, T., Teitelbaum, E., Shim, S., Bozlar, M., Stone, H. A., & Meggers, F. (2018, September 23). Extracting Radiant Cooling From Building Exhaust Air Using the Maisotsenko Cycle Principle. 6. Syracuse, NY.
- Bozlar, M., Teitelbaum, E., & Meggers, F. (2018, September 23). Liquid Desiccant-Polymeric Membrane Dehumidification System for Improved Cooling Efficiency in Built Environments. 5. Syracuse, NY.
- Guo, H., & Meggers, F. (2018, September 23). Analytical and Numerical Investigation on Depth and Pipe Configuration for Coaxial Borehole Heat Exchanger, A Preliminary Study. 8. Syracuse, NY.
- Meggers, F. (In)visible Urban Heat. Exhbiition in Collapse*: Climate, Cities, & Culture.* Global Design NYU. The Gallitin Galleries. Jun 12 – Jun 29, 2019.

PROJECT TEAM

- Forrest Meggers, Assistant Professor - Princeton University
- Hongshan Guo, Graduate Student - Princeton University
- Dorit Aviv, Graduate Student - Princeton University

PROJECT A3-1:
VEGETATION, BIODIVERSITY, ECOSYSTEM FUNCTIONING RELATIONSHIPS AND GREEN INFRASTRUCTURE

National Science Foundation

MOTIVATION AND OBJECTIVES

Develop a set of biodiversity and ecosystem services indicators that characterize current and alternative future climate land covers.

Assess vegetation biodiversity distributions and vegetation density distributions.

Evaluate effects of vegetation density on a key amenity, local cooling within UWIN regions.

Provide training opportunities for graduate students, undergraduate students, and citizen scientists to better understand urban ecological concepts associated with water sustainability.

PROGRESS

Developed new method for mapping urban ET associated with outdoor vegetation.

Deploying a network of air temperature sensors distributed across 900 sampling locations in nine cities.

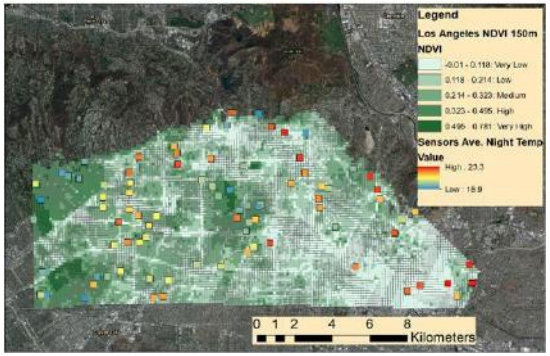
Developing algorithms for processing Landsat satellite imagery to evaluate monthly vegetation and surface temperature relationships at metropolitan scales.

Inventoried plant diversity in parks from Baltimore, MD and greater Los Angeles, CA.

Developed new citizen science engagement platform for urban vegetation.

APPROACH

Field inventories
Mobile eddy covariance
Environmental sensor networks
Repeating satellite image analysis



ACHIEVEMENTS AND SIGNIFICANCE

Documented urban response to a major drought was associated with changes in vegetation and water use.

Identified air temperature cooling by urban vegetation primarily measured at night while surface temperature cooling primarily occurs during the day throughout southern California.

Engaged more than 1000 citizen scientists and 25 community groups in southern California.

PROJECT A3-1:
VEGETATION, BIODIVERSITY, ECOSYSTEM FUNCTIONING RELATIONSHIPS AND GREEN INFRASTRUCTURE

PRODUCTS

- Jenerette GD. 2018. Ecological contributions to human health in cities. Landscape Ecology 33:1655-1668
- Tayyebi A and GD Jenerette. 2018. Assessing diel urban climate dynamics using land surface temperature harmonization model. International Journal of Remote Sensing 39:3010-3028
- Ibsen P, GD Jenerette, MV Santelmann, H Greydanus, D Hondula, M Wright, C Swan, D Borowy, M Sukop, T Dell, T Meixner. Regional aridity drives urban nighttime vegetation derived air cooling. American Geophysical Union. Washington DC December 2018
- Jenerette GD. Opportunities for urban ecology at the United States and Mexico border. Ecological Society of America Annual Meeting. New Orleans August 2018
- Jenerette GD. Experimental landscape ecology. United States Chapter of the International Association of Landscape Ecologists. Chicago IL April 2018
- Ibsen P, M Talal, C Swan, D Borowy, D Hondula, M Wright, and GD Jenerette. Continental scale variation in the cooling effect of urban vegetation. United States Chapter of the International Association of Landscape Ecologists. Chicago IL April 2018
- Luketich, Anthony, Papuga, Shirley, Guertin, Phil, and Crimmins, Mike. Differential Impacts of Passive versus Active Irrigation on Semiarid Urban Forests (2018). Web Thesis: https://repository.arizona.edu/handle/10150/630556

PROJECT TEAM

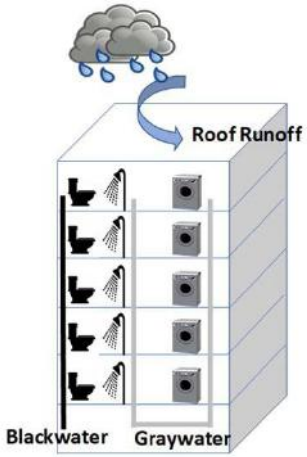
- Darrel Jenerette, Professor, University of California Riverside
- Peter Ibsen, Graduate Student, University of California Riverside
- Julie Ripplinger, Postdoctoral Researcher, University of California Riverside
- Dion Kucera, Graduate Students, University of California Riverside
- Chris Swan, Professor, University of Maryland Baltimore County
- Dorothy Borowy, Graduate Students, University of Maryland Baltimore County
- Tom Meixner, Professor, University of Arizona
- Anthony Luketich, Graduate Student, University of Arizona
- Mary Santelman, Professor, Oregon State University
- Michelle Talal, Graduate Student, Oregon State University
- Shirley Papuga, Associate Professor, Wayne State University

PROJECT B1-1a:
WATER MANAGEMENT SOLUTIONS TO ENAHNCE CAPACITY FOR USE OF ALTERNATE WATER SOURCES

MOTIVATION AND OBJECTIVES

Assess benefits and consequences of various scales (building to neighborhood) and configurations of water management solutions:

- Use of alternate water sources (graywater, roof runoff, wastewater, stormwater)
- Separate supply of non-potable water
- Impact of development patterns



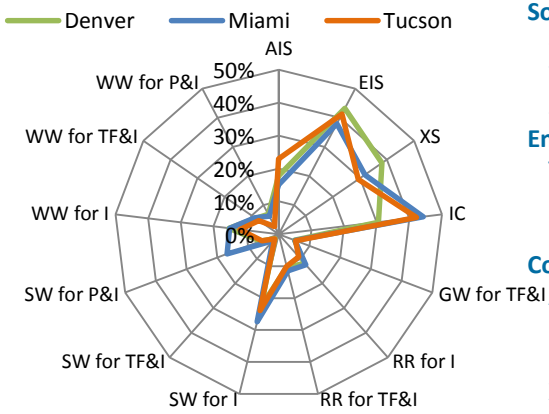
PROGRESS

- Assessed centralized and decentralized strategies for separate supply of potable water via enhanced decision support framework
- Assessed drivers of water use across UWIN study cities
- Assessed tradeoffs between cost and demand reduction potential in Miami, Tucson, and Denver
- Conducting national scale study to assess water conservation and reuse strategy efficacy
- Assessing impact of changes in climate, land use and population on efficacy of water conservation and reuse strategies.
- Assessing co-benefits of water conservation and reuse strategies across regions

APPROACH

- Enhance Integrated Urban Water Model for application in UWIN Study Cities (Denver, CO, Miami, FL and Tucson, AZ)

ACHIEVEMENTS AND SIGNIFICANCE



Source Waters
GW: graywater
WW: wastewater
SW: stormwater

End Uses
TF: toilet flushing
P: potable
I: irrigation

Conservation
AIS: advanced irrigation system
EIS: efficient irrigation system
IC: indoor conservation
XS: xeriscape

PROJECT B1-1a:
WATER MANAGEMENT SOLUTIONS TO ENAHNCE CAPACITY FOR USE OF ALTERNATE WATER SOURCES

PRODUCTS

- Lacky, Katy, S. Sharkey, S. Sharvelle, P. Kehoe, T. Chang (2019) Decentralized Water Reuse: Implementing and Regulating Onsite Non-Potable Water Systems, Journal of Sustainable Water in the Built Environment, accepted with revisions. Status = Under Review; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
- Luthy, R. G., Sharvelle, S. E., Dillon, P. (2019) Urban Stormwater for Enhancing Water Supply *Environmental Science and Technology,* 53:10. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
- Daigger, G. T., Sharvelle, S. E., Arabi, M., Love, N. G. (2019). Progress and Promise: Transitioning to the One Water/Resource Recovery Integrated Urban Water Management Systems. *Journal of Environmental Engineering*, in press. Status = Awaiting Publication; Acknowledgement of Federal Support = No; Peer Reviewed = Yes.
- Cole, J., Sharvelle, S., Grigg, N. S., Pivo, G., Haukaas, J. (2018). Collaborative, Risk-Informed, Triple Bottom Line, Multi-Criteria Decision Analysis Planning Framework for Integrated Urban Water Management. *Water, 10*(12), 1722. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
- Neale, M., Sharvelle, S., Arabi, M. (2019) “Cost-benefit evaluation of water conservation and reuse strategies using the Integrated Urban Water Model for three U.S. cities”, Hydrology Days, Fort Collins, CO. Status = published, acknowledgment of federal support = no, peer reviewed = no.
- Alja’fari, J., Sharvelle, S., Crall, A., Newman, G. (2019) “Off the Roof: A Citizen Science Project to Measure the Microbial Characteristics of Roof Runoff”, Hydrology Days, Fort Collins, CO. Status = published, acknowledgment of federal support = no, peer reviewed = no.
- Neale, M., Sharvelle, S., Dozier, A., Arabi, M. (2018) "Identifying Optimal Water Conservation and Reuse Strategies Using an Urban Water Demand Model for a Selection of U.S. Cities with Distinct Climatic Conditions and Land Cover Characteristics," 9th International Congress on Environmental Modelling and Software Fort Collins, CO. Status = published, acknowledgement of federal support = no, peer reviewed = no
- Batista, G, Sharvelle, S., Dozier, A., Arabi, M., (2018) "Evaluation of Water Conservation Strategies Using the Integrated Urban Water Model in Sao Paulo, Brazil," 9th International Congress on Environmental Modelling and Software, Fort Collins, CO. . Status = published, acknowledgement of federal support = no, peer reviewed = no
- Sharvelle, S., A. Dozier, M. Arabi, B. Reichel (2017). A Geospatially-Enabled Web Tool for Urban Water Demand Forecasting and Assessment of Alternative Urban Water Management Strategies. Environmental Modelling and Software, 97:213-228. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.
- Sharvelle, S., N. Ashbolt, E. Clerico, R. Holquist, H. Leverenz and A. Olivieri (2017) Risk Based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems, WEFTEC 2017, Chicago, IL. Status = published, acknowledgement of federal support = no, peer reviewed = no.
- Sharvelle, S., N. Ashbolt, E. Clerico, R. Holquist, H. Leverenz and A. Olivieri (2017) Risk Based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems, International Water Association Conference on Water Reclamation and Reuse, Longbeach, CA. Status = published, acknowledgement of federal support = no, peer reviewed = no.
- Sharvelle, S. (2017) Developing Guidelines for Performance of Decentralized Non-Potable Water Systems, WE&RF Onsite Systems Workshop, Los Angeles, CA. Status = published, acknowledgement of federal support = no, peer reviewed = no.
- Neale, M., A. Dozier, S. Sharvelle, M. Arabi (2018) Identifying Optimal Water Conservation and Reuse Strategies Using and Urban Water Demand Model for a Selection of US Cities with Distinct Climatic Conditions and Land Cover Characteristics, Hydrology Days, Fort Collins, CO. Status = published, acknowledgement of federal support = yes, peer reviewed = no.
- Sharvelle, S., M. Arabi, M. Sukop (2018) The National Science Foundation’s Research Networks Program, Resilient Utility Coalition – Operationalizing Resilience Summit, Miami, FL. Status = published, acknowledgement of federal support = yes, peer reviewed = no.

PROJECT TEAM

- Sybil Sharvelle, Associate Professor, Colorado State University
- Andre Dozier, Post-doctoral Associate, Colorado State University
- Jeanne Cole, PhD candidate, Colorado State University
- Michael Neale, MS student, Colorado State University

PROJECT B1-1b:
ASSESSMENT OF URBAN INFRASTRUCTURE RESILIENCE

MOTIVATION AND OBJECTIVES

Evaluate long-term resilience of urban water infrastructure

- Examine technological and infrastructure solutions to enhance urban water infrastructure resilience in both demand and supply sides
- Develop integrated simulation models of urban water infrastructure system resilience (Fig 1)

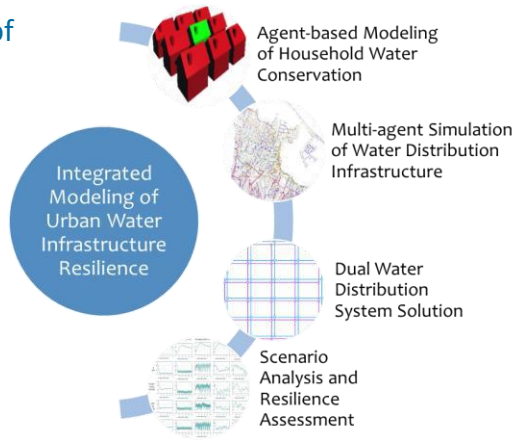


Fig 1. Project Overview

PROGRESS

- Analyzed households behavior related to adoption of water conservation technologies in the City of Miami Beach using agent-based modeling (Fig 3)
- Examined long-term resilience behavior of urban water distribution networks to population changes, aging infrastructure, and funding constraints
- Compared long-term performance and life-cycle costs of dual and singular water distribution systems for the City of Fort Collins (Fig 4)

Fig 3. Agent-based Model of Water Conservation

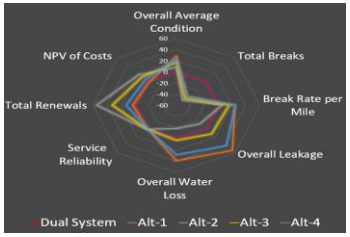


Fig 4. Multivariate Comparison of Dual vs. Singular

APPROACH

- Propose a complex systems resilience framework for assessment of water infrastructure resilience (Fig 2)
- Develop Agent-based and Multi-agent simulation models to understand underlying mechanisms of water infrastructure resilience

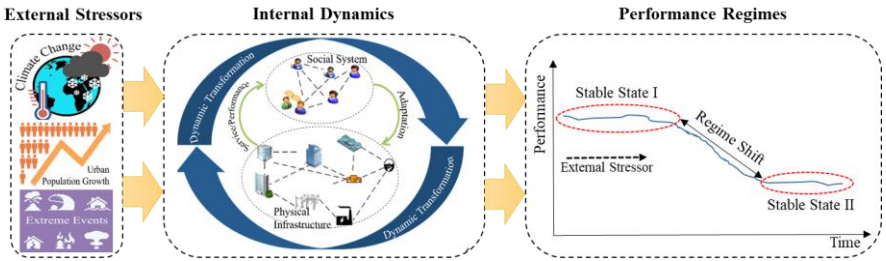


Fig 2. Complex Systems Resilience Framework

ACHIEVEMENTS AND SIGNIFICANCE

- Theoretical Achievement: Built a complex system-based framework for infrastructure resilience through a better understanding of internal dynamics, performance regimes, and tipping points.
- Computational Achievement: Developed a novel agent-based model capturing adaptive mechanisms, such as peer effect and innovation diffusion, in households water conservation; And created a multi-agent model simulating various performance measures (e.g., average condition, service reliability, leakage and breakage) of water distribution networks over a 100-year horizon
- Practical Achievement: Identified infrastructure renewal strategies, water pricing structures, and other decision factors leading towards a resilient and sustainable water infrastructure system

PROJECT B1-1b:
ASSESSMENT OF URBAN INFRASTRUCTURE RESILIENCE

PRODUCTS

Journals Papers

- Rasoulkhani, K. and Mostafavi, A., 2018. Resilience as an emergent property of human-infrastructure dynamics: A multi-agent simulation model for characterizing regime shifts and tipping point behaviors in infrastructure systems. PloS one, 13(11), e0207674.K
- Rasoulkhani, K., Logasa, B., Presa Reyes, M. and Mostafavi, A., 2018. Understanding Fundamental Phenomena Affecting the Water Conservation Technology Adoption of Residential Consumers Using Agent-Based Modeling. Water, 10(8), p.993.Conference

Presentations/Papers

- K Rasoulkhani, MP Reyes, A Mostafavi (2017). Emergence of Resilience from Infrastructure Dynamics: A Simulation Framework for Theory Building. International Workshop on Computing for Civil Engineering (IWCCE 2017). Seattle.
- K Rasoulkhani, BN Logasa, MP Reyes, A Mostafavi (2017). Agent-based modeling framework for simulation of complex adaptive mechanisms underlying household water conservation technology adoption. Winter Simulation Conference (WSC 2017). Las Vegas.
- K Rasoulkhani, BN Logasa, MP Reyes, A Mostafavi (2017). From Factors to Actors: Uncovering Fundamental Mechanisms Underlying Adoption of Residential Water Conservation Technology Using Agent-based Modeling. International Workshop on Computing for Civil Engineering (IWCCE 2017). Seattle.
- K Rasoulkhani, A Mostafavi (2018). Long-term performance and life-cycle cost assessment of dual vs. singular water distribution infrastructure systems. ASCE Construction Research Congress (CRC 2018). New Orleans.

PROJECT TEAM

- Ali Mostafavi, PhD - Principal Investigator; Assistant Professor, Zachary Department of Civil Engineering, Texas A&M University
- Sybil Sharvelle, PhD - Co-Principal Investigator; Associate Professor, Civil and Environmental Engineering, Colorado State University
- Kambiz Rasoulkhani – Research Scientist; PhD Candidate, Zachary Department of Civil Engineering, Texas A&M University

PROJECT B1-2:
SPATIALLY-AND-TEMPORALLY-INFORMED LIFE-CYCLE ASSESSMENT OF URBAN WATER SYSTEMS

MOTIVATION AND OBJECTIVES

- To support a shift to water- and energy-efficient communities by increasing the quality and quantity of local water supplies.
- To provide decision-support tools for evaluating non-traditional water sources and innovations (e.g., resource recovery) under current and future conditions using life-cycle assessment (LCA).
- To characterize existing centralized conventional urban water infrastructure in UWIN case-study cities (Miami, Denver, Tucson) compared to future water supply scenarios identified by Project B1-1 for case study cities on the basis of life- cycle energy and environmental performance.
- To connect ReNUWIt (renuwit.org) and UWIN researchers doing similar research to maximize synergies.

PROGRESS

- Evaluating baseline energy and material use in urban water systems in Miami, Denver, and Tucson.
- Defining comparisons between alternative water options and case study cities, in collaboration with B1.1 researchers
- Quantifying costs and energy consumption associated with alternative water supply options generally and in case study cities
- Characterized current and future energy mixes for utilities serving case study cities.
- Updated our LCA-based decision support tools (WEST and WWEST, see http://west.berkeley.edu).

APPROACH

In case-study cities, analyze urban water systems under existing conditions and a range of future water supply scenarios using LCA (see graphic)

Quantify INPUTS (materials, energy, water, etc)

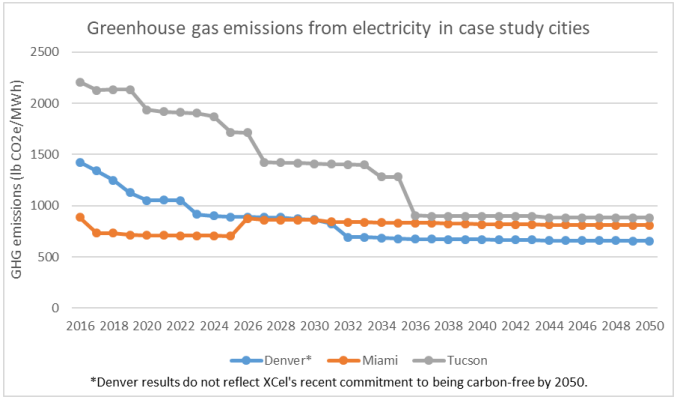
Estimate OUTPUTS (products, byproducts, emissions, wastes, etc)

To :

Target improvements | Benchmark utility performance | Educate consumers
Set design goals | Evaluate technology performance | Identify tradeoffs
Prioritize investments | Enable more sustainable solutions | Inform planning & policy

ACHIEVEMENTS AND SIGNIFICANCE

- Engaged stakeholders in case-study cities
- Have obtained or are in the process of obtaining water utility-specific operational data needed to evaluate baseline conditions.
- Projected changes to electricity mixes in case study cities and associated emissions from the use of electricity (see Figure)



PROJECT B1-2:
SPATIALLY-AND-TEMPORALLY-INFORMED LIFE-CYCLE ASSESSMENT OF URBAN WATER SYSTEMS

PRODUCTS

None to date.

PROJECT TEAM

- Arpad Horvath, Professor - UC Berkeley
- Jennifer Stokes-Draut, Research Scientist - UC Berkeley
- Fiona Greer, Graduate Student - UC Berkeley

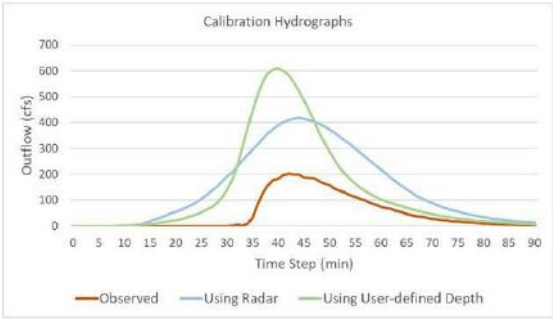
PROJECT B2-1:
COMPARATIVE IMPACT OF GREEN INFRASTRUCTURE ACROSS URBAN SYSTEMS

MOTIVATION AND OBJECTIVES

We are seeking to understand how GI influences hydrologic response and water quality response across cities

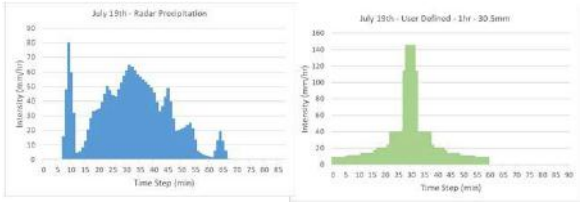
PROGRESS

1. Compiled monitoring data for multiple watersheds
2. Constructed and calibrated model for two Tucson watersheds
3. Developed collaboration with B2-2 groups on flood analysis and rainfall



APPROACH

1. Further development of KINEROS2 urban modelling capability
   A. Build data sets
   B. Use LIDAR and land cover data to develop initial model
   C. Develop GI scenarios for basin
   D. Analyze scenarios for impact on water quantity and quality
2. Collaborate broadly across UWIN
   A. Link KINEROS2 to HEC modelling of flood inundation
   B. Use Radar developed rainfall



ACHIEVEMENTS AND SIGNIFICANCE

1. Successfully showed that maintenance practice can have a significant impact on infiltrations rates and thus function of Green Infrastructure
2. KINEROS2 urban module has been tested and found to be robust
3. GI has significantly higher water holding capacity and hydraulic conductivity than surrounding soils
4. Regular maintenance appears to negatively impact the hydrologic function of GI
5. No observable impacts of GI on runoff yet but analysis continues

PROJECT B2-1:
COMPARATIVE IMPACT OF GREEN INFRASTRUCTURE ACROSS URBAN SYSTEMS

PRODUCTS

- Guertin, D. Phillip, Yoganand Korgaonkar, I. Shea Burns, Carl Unkrich, David C. Goodrich, and William Kepner. 2016. Using AGWA and the KINEROS2 Model to Model Green Infrastructure in Two Typical Residential Lots in Prescott, AZ. Presented at: 2016 AWRA Summer Specialty Conference: GIS and Water Resources IX, Sacramento, CA, July 11-13, 2016.
- Gupta, Neha - Comparison of Runoff Data to Assess Impact of Stormwater Green Infrastructure, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona April 9,2018.
- Korgaonkar, Y., Guertin, D.P., Goodrich, D.C., Unkrich, C., Kepner, W., and Burns, I.S. (2018). Modeling Urban Hydrology and Green Infrastructure using the AGWA Urban Tool and the KINEROS2 Model. Submitted to Frontiers in Built Environment.
- Meixner, T., Papuga, S.A., Luketich, A.M., Rockhill, T., Gallo, E.L., Anderson, J., Salgado, L., Pope, K., Gupta, N., Korgaonkar, Y. and Guertin, D.P., 2017, December. Green Infrastructure Increases Biogeochemical Responsiveness, Vegetation Growth and Decreases Runoff in a Semi-Arid City, Tucson, AZ, USA. In AGU Fall Meeting Abstracts.
- Meixner, Thomas— Green Stormwater Infrastructure Increases Infiltration, Soil Carbon and Biogeochemical Response, 2018 – Arizona Hydrological Society Annual Symposium, Flagstaff AZ, September 7, 2017.
- Anderson, Jack - Bioswales: Benefit or Burden?, Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona April 9,2018.
- Rockhill, Tyler, Influence of Soil Physical and Chemical Properties on Soil Co2 Flux in Semi-Arid Green Stormwater Infrastructure, MS in Hydrology, University of Arizona, December 2017, pp. 63.https://arizona.openrepository.com/handle/10150/626391
- Swartz, Samantha - Evaluating Rainwater-Harvesting Basin Curb-Cuts: How Volunteer Maintenance Impacts Infiltration Rates. Presentation at El Dia Del Agua y la Atmosfera, Department of Hydrology and Atmospheric Sciences, Tucson AZ, University of Arizona April 9,2018.

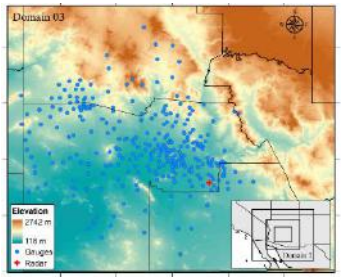
PROJECT TEAM

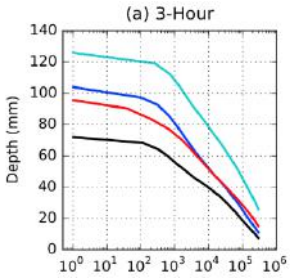
- Thomas Meixner, Professor University of Arizona
- Phil Guertin, Professor, University of Arizona
- Yoganand Korgaonkar, Grad Assistant, University of Arizona
- Neha Gupta, Grad Assistant, University of Arizona
- Jack Anderson, Grad Assistant, University of Arizona
- Tyler Rockhill, Grad Assistant, University of Arizona
- Samantha Swartz, Grad Assistant, University of Arizona
- Adriana Arcelay, Grad Assistant, University of Arizona

PROJECT B2-2a:
FLOOD HYDROLOGY AND RAINFALL FREQUENCY

MOTIVATION AND OBJECTIVES

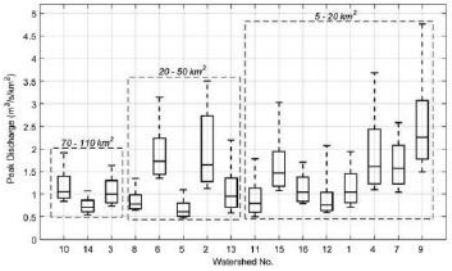
- Demonstrate a predictive understanding of urban flood hydrology
- Characterize the climatology of flood-producing storm systems in urban regions
- Develop procedures for rainfall and flood frequency analysis that can serve as the foundation for assessing urban flood hazards.

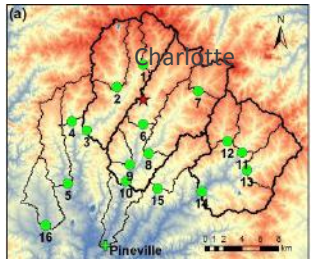




PROGRESS

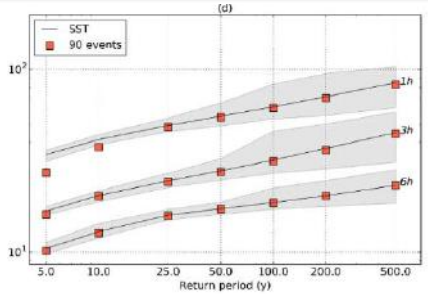
- Development of storm catalogs and rainfall frequency analysis procedures for heterogeneous urban environments.
- Hydrometeorological analyses of urban impact on Hurricane Harvey.
- Analyses of extreme rainfall and flooding in urban environments – Ellicott City storms of 2016 and 2018.

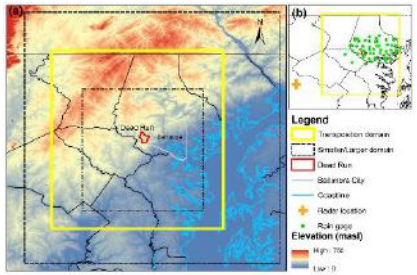




APPROACH

- Storm Catalogs of radar rainfall fields
- Stochastic Storm Transposition (SST) methods for rainfall frequency analysis
- Hydroclimatological analyses using the Weather Research and Forecasting Model





ACHIEVEMENTS AND SIGNIFICANCE

- Enhanced SST procedures capture spatial heterogeneities of extreme rainfall over Baltimore metropolitan region.
- Spatial heterogeneities of catastrophic rainfall from Hurricane Harvey over Houston were likely related to spatial gradient in surface roughness over the Houston metropolitan region.
- Relationships between extreme rainfall and atmospheric water vapor in the Phoenix metropolitan region exhibit pronounced nonstationarities, in contrasts to assumptions typically used in deriving design storms.

PROJECT B2-2a:
FLOOD HYDROLOGY AND RAINFALL FREQUENCY

PRODUCTS

- Yang, L. and J. A. Smith, Sensitivity of extreme rainfall to atmospheric water vapor the arid/semi-arid Southwestern US: Implications for PMP estimates, J. Geophysical Research (Atmospheres), 123, 1638 – 1656, 2018.
- Zhou, Z., J. A. Smith, L. Yang, M. L. Baeck, M. Chaney, M.-C. ten Veldhuis, and S. Liu, The Complexities of Urban Flood Response: Hydrologic Analyses for the Charlotte, North Carolina Metropolitan Region, Water Resources Research, 53(8), pp. 7401–7425, 2017.
- ten Veldhuis, M.-c., Z. Zhou, L. Yang, S. Liu and J. A. Smith, The role of storm dynamics in controlling urban flood response, Hydrology and Earth System Sciences, DOI10.5194/hess-2017-197, 1 – 28, 2017.
- Yang, L., J. A. Smith, M. L. Baeck, E. Morin, and D. Goodrich, Flash Flooding in Arid/Semi-arid Regions: Dissecting the 19 August 2014 Flood over Arizona, Southwestern United States, J. of Hydrometeorology, 18(12), 3110 – 4124, 2017.
- Ryu, Y.-H., J. A. Smith, M. L. Baeck and E. Bou-Zeid, The influence of land-surface heterogeneities on heavy convective rainfall in the Baltimore-Washington metropolitan area, Monthly Weather Review, 144, 553–573, 2016.
- Wang, W., J. A. Smith, P. Ramamurthy, M. L. Baeck, E. Bou-Zeid and T. M. Scanlon, On the correlation of water vapor and CO2: application to flux partitioning of evaporation, Water Resources Research, 52, 9452–9469, doi:10.1002/2015WR018161, 2016.
- Smith, B. K., J. A. Smith and M. L. Baeck, Flash flood producing storm properties in a small urban watershed, J. of Hydrometeorology, 17, 2631 - 2647, 2016.
- Yang, L., J. A. Smith, M. L. Baeck and Y. Zhang, Flash flooding in small urban watersheds: storm event hydrologic response, Water Resources Research, 52(6), pp. 4571 – 4589, doi:10.1002/2015WR018326, 2016
- Yang, L., J. A. Smith, M. L. Baeck, B. K. Smith, F. Tian and D. Niyogi, Structure and evolution of flash flood producing storms in a small urban watershed, J. of Geophysical Research (Atmospheres),121, 3139–3152, 2016.

PROJECT TEAM

- Jim Smith, Professor – Princeton University
- Mary Lynn Baeck, Research Scientist – Princeton University
- Molly Chaney, Graduate Student – Princeton University
- Long Yang, Postdoctoral Fellow – Princeton Unibersity

PROJECT B2-2b:
HYDROLOGY AND HYDRAULICS OF URBAN FLOODPLAINS

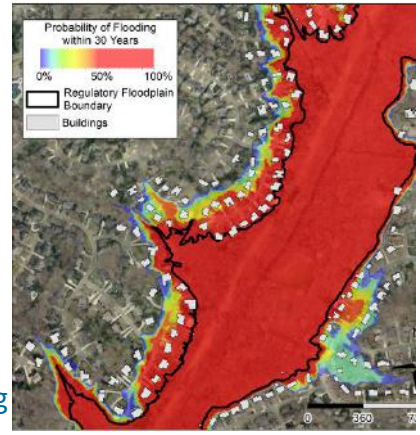
National Science Foundation

MOTIVATION AND OBJECTIVES

- Addresses interactions between flood flows and urban channels, floodplains and riparian zones as influenced by green infrastructure and efforts to mitigate impacts of urban development on flood response and other environmental consequences.
- Overarching goal is to use hydraulic analysis of urban floodplains to examine how integrated floodplain networks and sustainable urban drainage systems can be strategically designed and positioned to simultaneously enhance flood resilience, moderate temperatures and improve human comfort, and support biodiversity.

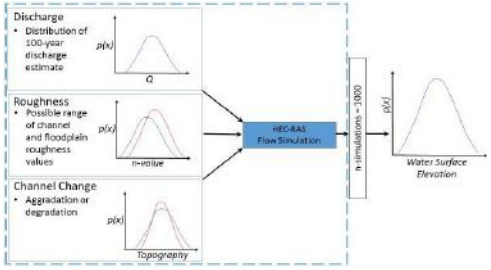
PROGRESS

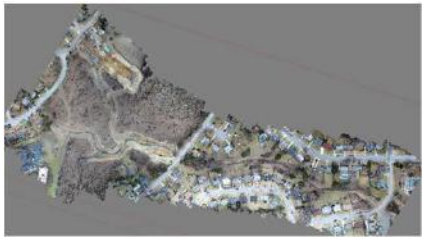
- Developed a method for conducting Monte-Carlo simulations of floodplain hydraulics to create probabilistic flood inundation maps.
- Quantified and compared the level of uncertainty around inundation probability in two hydro-climatically distinct regions.
- Constructed high-resolution topographic models of several urban stream restoration sites using structure from motion and used in 2D hydraulic modeling in HEC-RAS to observe changes to the hydraulics of the channel.



APPROACH

- Uncertainty around model input and parameters are statistically quantified and sampled in a Monte-Carlo framework to simulate floodplain hydraulics.
- Used photography from UAV flights to create high resolution DEMs using Structure from Motion
- Compared the 2D hydraulic modeling outcomes of historical versus current channel morphology in HEC-RAS.





ACHIEVEMENTS AND SIGNIFICANCE

- Probabilistic flood inundation maps helped elucidate how uncertainty in traditional flood hazard estimates is spatially distributed across the landscape.
- Probabilistic flood inundation maps provide an alternative method of hazard depiction that incorporate uncertainty and serve as a tool for floodplain management.
- Examining the evolution of simulated hydraulic modeling of flood behavior in pre- and post-restoration and current channel morphology provides insight into how successful urban restoration projects are in the long run and how successful the restoration projects were in their stated goals.

PROJECT B2-2b:
HYDROLOGY AND HYDRAULICS OF URBAN FLOODPLAINS

PRODUCTS

- Lee, G., and A.J. Miller, 2017. Monitoring Urban Stream Restoration Efforts in Relation to Flood Behavior Along Minebank Run, Towson, MD. Abstract H31I-1629, Fall 2017 Annual Meeting, AGU, New Orleans, LA, 11-15 Dec.
- Miller, A.J., G. Lee, B.P. Bledsoe, and T. Stephens, 2017. Mitigation of Flood Hazards Through Modification of Urban Channels And Floodplains. Abstract H31I-1630, Fall 2017 Annual Meeting, AGU, New Orleans, LA, 11-15 Dec.
- Stephens, T., B.P. Bledsoe, A.J. Miller, G. Lee, 2017. Mapping flood hazards under uncertainty through probabilistic flood inundation maps. Abstract H31I-1633, Fall 2017 Annual Meeting, AGU, New Orleans, LA, 11-15 Dec.

PROJECT TEAM

- Brian P. Bledsoe, Professor, University of Georgia
- Tim Stephens, PhD student, University of Georgia
- Andrew J. Miller, Professor, UMBC
- Gina Lee, PhD student, UMBC

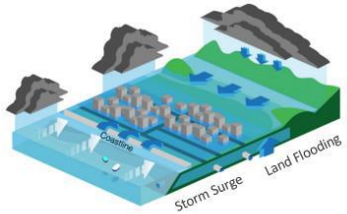
PROJECT B3-1: FLOOD RISK TO ASSETS AND SOCIOECONOMIC SECTORS IN A CHANGING WORLD: PREVENTION, ADAPTATION AND MITIGATION STRATEGIES

National Science Foundation

MOTIVATION AND OBJECTIVES

- Develop a coherent statistical model for coastal flood frequency analysis under nonstationary sea level conditions and corroborate the model for long term tidal stations along the Contiguous U.S. (CONUS) coast.
- Estimate the chronic and acute coastal flood risks to assets and communities in Southeast Florida.
- Evaluate the potential increase in flood risks due to the co-occurrence of heavy precipitation and storm surge (Compound flooding) across the CONUS coast.

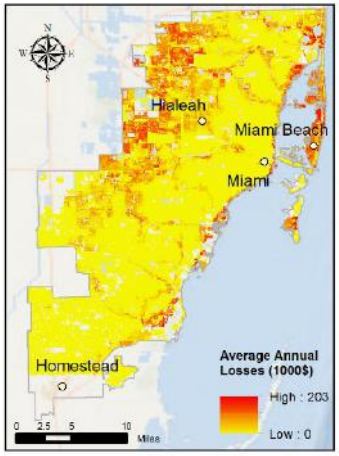
Minor Flooding (Miami)



Credit: Theodore Scontras/University *of Maine*

PROGRESS

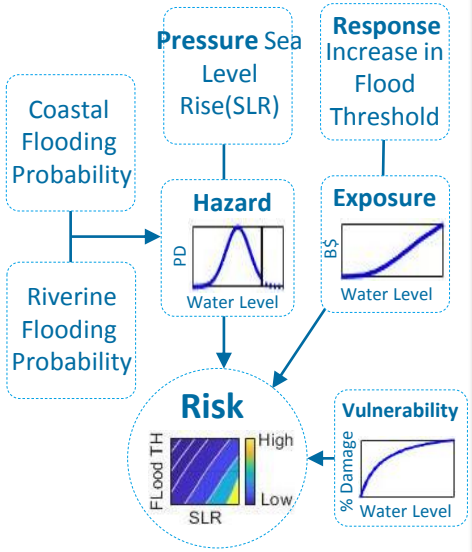
- A mixture probability model was developed to simultaneously assess the frequency of acute and chronic coastal flooding under nonstationary sea level conditions.
- The performance validity of the model was corroborated for 68 tidal stations in U.S.
- Future chronic and acute coastal flood risks were estimated for major U.S. coastal cities.
- The spatial distribution of future coastal flood risks by socioeconomic factors (Race and level of income) were explored.
- Adaptation strategies to address the rising coastal flood risks were evaluated.



Average Annual Losses from Storm Surge in Miami-Dade County under 2-ft SLR

APPROACH

- The frequency of coastal flooding is estimated using a nonstationary mixture Normal-Generalized Pareto distribution.
- The HAZUS-MH model is used to estimate damages to buildings.
- Copulas theory is used to estimate the frequency of compound flooding events.



ACHIEVEMENTS AND SIGNIFICANCE

- While Pacific coast regions should expect the highest major flood frequency amplification, the highest frequency amplification in minor flooding is expected along the Gulf and northeast Atlantic coasts.
- Under current sea-level conditions, expected annual damages are dominated by the exposure to occasional extreme events in Miami-Dade County. However, the expected damages from repetitive flooding will exceed those from extreme floods under future sea-level scenarios.
- As sea levels rise, vulnerability to coastal flooding in Miami-Dade County will also increase due to the greater exposure of more vulnerable populations.

PROJECT B3-1: FLOOD RISK TO ASSETS AND SOCIOECONOMIC SECTORS IN A CHANGING WORLD: PREVENTION, ADAPTATION AND MITIGATION STRATEGIES

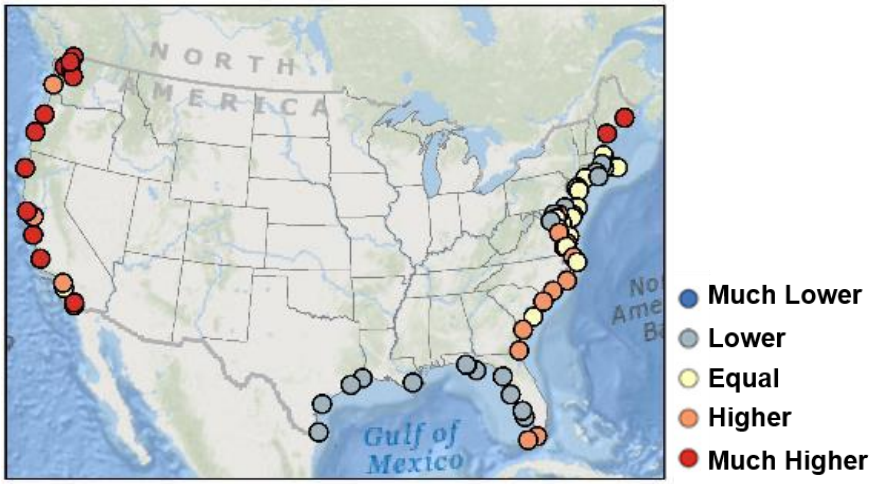
PRODUCTS

Journals Papers:

- Ghanbari, M., Arabi, M., Obeysekera, J., & Sweet, W. (2019). A coherent statistical model for coastal flood frequency analysis under nonstationary sea level conditions. Earth's Future, 7, 162–177.

Conference Presentations:

- Ghanbari, M., Arabi, M., Obeysekera, J., & Sweet, W. (2019). A coherent statistical model for coastal flood frequency analysis under nonstationary sea level conditions, EWRI World Environmental & Water Resource Congress, Pittsburgh, Pennsylvania. 20-23 May 2019.
- Ghanbari, M., Arabi, M., Obeysekera, J., & Sweet, W. (2019). A nonstationary statistical model for coastal flood frequency analysis, AGU Hydrology Days, Fort Collins, Colorado. 27-29 March 2019.
- Ghanbari, M., Arabi, M., Obeysekera, J., & Sweet, W. (2018), Coastal flooding risks on the rise, AGU Fall Meeting, Washington D.C. 10-14 December 2018.



The ratio of frequency amplification of major to minor flooding under 2ft sea level rise scenario

- Ghanbari, M., Arabi, M., Obeysekera, J., & Sweet, W. (2018). Risk to assets and communities from coastal flooding: Quantifying the effect of sea level rise and flood adaptation strategies, International Congress on Environmental Modelling and Software, Fort Collins, Colorado. 24-28 June 2018.
- Ghanbari, M., Arabi, M. (2018)., Risk to assets and communities from coastal flooding: Quantifying the effect of sea level rise and flood adaptation strategies, AGU Hydrology Days, Fort Collins, Colorado. 19-21 March 2018.
- Ghanbari, M., Arabi, M. (2017), Current and future flood losses in southeast Florida, EWRI World Environmental & Water Resource Congress, Sacramento, California. 22-25 May 2017.

PROJECT TEAM

- Mazdak Arabi, Professor (PI) - Colorado State University
- Mahshid Ghanbari, Graduate Student, - Colorado State University
- Jayantha Obeysekera, Research Scientist - Florida International University
- William Sweet, Research Scientist National Oceanic and Atmospheric Administration (NOAA)

PROJECT C1-1:
UNDERSTANDING ADOPTION OF SUSTAINABLE URBAN WATER SOLUTIONS

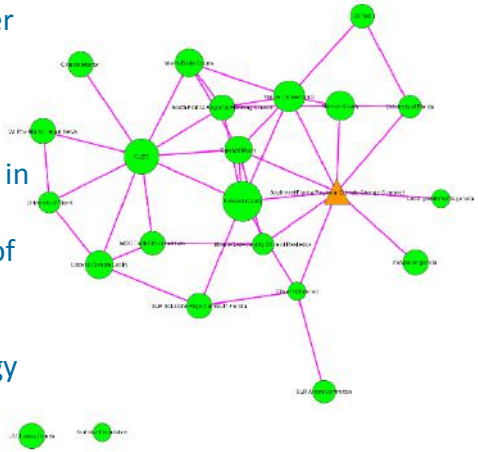
MOTIVATION AND OBJECTIVES

How do networks between organizations and local governments influence the adoption of water sustainability innovations?

Key questions about networks:
1)What network structures are most likely to promote learning of new water sustainability innovations?
2)What does a "typical" network look like among water organizations in the five UWIN regions?
3) How do these networks self-organize?
4)How do external factors, such as collaborative institutions, influence the structure of these networks?

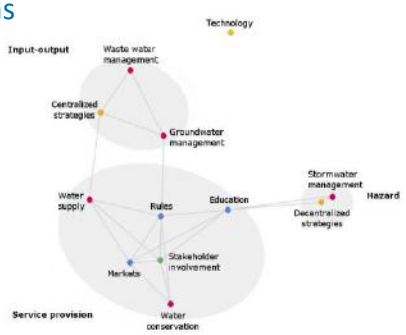
PROGRESS

- Completed surveys of local water governments and water organizations in Arizona and Florida.
- Sampling of water organizations in other UWIN regions complete.
- Completed survey and analysis of climate change adaptation networks in Southeast Florida.
- Manuscript prepared on typology of policy innovations for water sustainability.



APPROACH

- Sampling of local water organizations (public private, nonprofit) and identification of water professionals working in these organizations through archival research and by nominations of other water professionals.
- Survey of water organizations to measure network relationships as well as water sustainability practices.
- Statistical modeling of networks using network correlation and exponential random graph models.



ACHIEVEMENTS AND SIGNIFICANCE

- Shared belief systems and shared problems significantly predict the formation of ties between organizations.
- Local governments use a broad array of strategies to achieve urban water sustainability.
- The networks adopted by governments and organizations have a substantial influence on their propensity to innovate.

	cooperates with (1)	advice / information (2)
Network		
Intercept	−2.472*** (0.097)	−2.563*** (0.097)
Transitivity	1.558*** (0.149)	1.727*** (0.151)
Characteristics		
Surface Water (d)	0.001*** (0.0002)	0.001*** (0.0002)
Type of Organization (d)	−0.291*** (0.097)	−0.352*** (0.103)
Beliefs		
Water Problems Severity (d)	0.039** (0.016)	0.036** (0.018)
Technology for Policy (d)	−0.062 (0.109)	−0.034 (0.116)
Perceptions of Collaborators		
many financial resources	0.020*** (0.007)	0.016** (0.007)
innovative sustainability	0.038*** (0.012)	0.033*** (0.012)
similar problems to ours	0.029*** (0.004)	0.024*** (0.004)

PROJECT C1-1:
UNDERSTANDING ADOPTION OF SUSTAINABLE URBAN WATER SOLUTIONS

PRODUCTS

- Adam Douglas Henry, Lena Berger, Gary Pivo, Edna Liliana Gomez Fernandez. "Network drivers of local water sustainability innovations." Presented at 2018 Public Management Research Conference (PMRC), Singapore, June 2018.
- Adam Douglas Henry, Edna Liliana Gómez Fernández & Gary Pivo. "Sustainability Innovations through Collaboration in Urban Water Management." Paper presented at Association for Public Policy Analysis and Management (APPAM) Fall Research Conference, Washington, D.C., November 2018.
- Edna Liliana Gomez Fernandez. "Water Sustainability Innovations through Collaborative Networks." Paper presented at Southern Political Science Association (SPSA) Annual Conference, Austin, Texas, January 2019.
- Edna Liliana Gomez Fernandez, Adam Douglas Henry & Gary Pivo. "Collaborative Governance in Urban Water Management in Arizona: Belief Systems, Perceptions, and Common Problems." Presented at Consortium on Collaborative Governance (CCG) Emerging Scholars Workshop, Tucson, Arizona, February 2019.
- Adam Douglas Henry, Lena Berger, Edna Liliana Gomez Fernandez & Gary Pivo. "What distinguishes local government innovators in water sustainability?" Climate Change Adaptation Science & Solutions Speaker Series, Tucson, Arizona, March 2019.
- Lena Berger, Adam Douglas Henry & Gary Pivo (2019). “Multiplexity of Local Government Actions for Urban Water Sustainability.” Under review in *Environmental Research Letters*.

PROJECT TEAM

- Gary Pivo - Professor, College of Planning and Landscape Architecture, University of Arizona
- Adam Douglas Henry - Associate Professor, School of Government and Public Policy University of Arizona
- Edna Liliana Gomez Fernandez - PhD candidate, School of Government and Public Policy University of Arizona

PROJECT C2-1:
USING DYNAMIC INFORMATION ACCELERATION (CHOICEFLOW) TO UNDERSTAND AND FORECAST HOMEOWNER ADOPTION OF GREYWATER TECHNOLOGIES

MOTIVATION AND OBJECTIVES

- One of the greatest challenges in forecasting homeowner adoption is accurately predicting demand for products and technologies that do not currently exist or that people are not knowledgeable about
- "Choiceflow" allows for laboratory-based study of choice behavior in realistic, user-designed, environments where individuals gather information from different media, learn, and make decisions based on those media
- To understand and predict adoption behaviors including:
  - Processes people prefer for learning about technologies (e.g., news, social media, technical reports); and
  - The choices that will be made, conditional on learning path.

PROGRESS

Tasks completed

- Choiceflow software design
- Survey design and pilot testing
- Sample frame development
- Data collection across 5 UWIN regions, 1500 responses

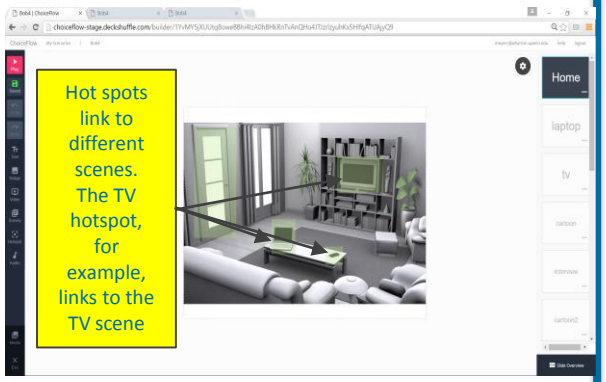
Tasks in progress

- Second round of data collection and early analysis are underway
- Data collection and analysis should be complete by end of July

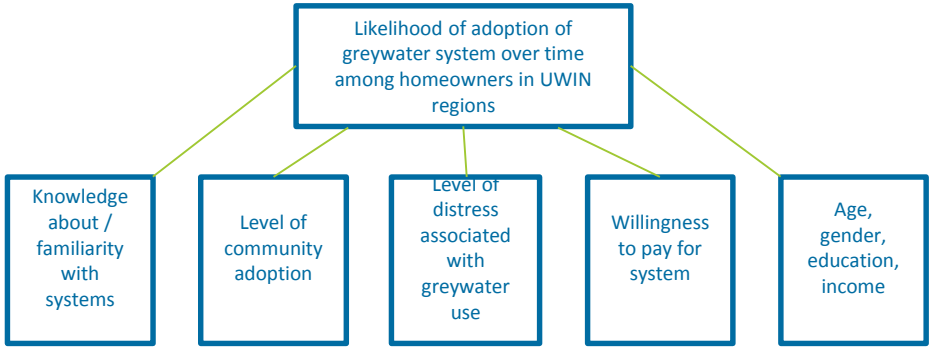
Virtual living room used for experiment

APPROACH

- Greywater systems adoption experiment developed for Choiceflow
- Pre and post simulation surveys created through Qualtrics
- Choiceflow software linked directly to Qualtrics survey software
- 1500 surveys and simulations administered



ACHIEVEMENTS AND SIGNIFICANCE



The Choiceflow software has been developed for rapid experimental design. Results from 5 UWIN regions are revealing relationships between different factors and adoption of innovative water saving technologies and indicating individual preferences for information.

PROJECT C2-1:
USING DYNAMIC INFORMATION ACCELERATION (CHOICEFLOW) TO UNDERSTAND AND FORECAST HOMEOWNER ADOPTION OF GREYWATER TECHNOLOGIES

PRODUCTS

None to date

PROJECT TEAM

- Jessica Bolson- Postdoctoral Fellow, Florida Int. Univ. Southeast Environmental Research Center
- Robert Meyer- Professor & Co-Director, Risk Management & Decision Processes Center, Wharton- Univ. Pennsylvania
- Kenny Broad- Professor & Director Abess Center for Ecosystem Science and Policy, Univ. Miami
- Dave Letson- Professor Department of Marine Ecosystems and Society, Univ. Miami
- Tim Kirby- PhD student, FIU

PROJECT C3-1:
SOCIAL EQUITY AND ENVIRONMENTAL JUSTICE IN URBAN WATER SYSTEMS

MOTIVATION AND OBJECTIVES

Infuse awareness of social equity and environmental justice **(SEEJ)** into all UWIN research, engagement, and education activities

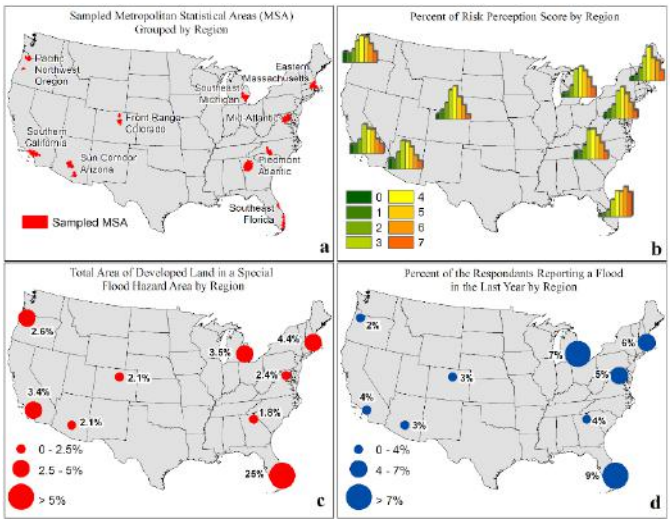
- Conduct two new research projects on water pressures perceived by urban households and community leaders
- Collaborate with UWIN climate and flood researchers to highlight SEEJ issues
- Engage EJ communities in stakeholder dialogue about water
- Train social science students to participate in and lead interdisciplinary environmental projects

PROGRESS

- Completed online, geographically-referenced survey of 9,900 households in 9 UWIN study metro-regions
- Analyzed 45 semi-structured interviews with leaders of community organizations in 8 study regions
- Papers published and in progress with UWIN collaborators
- SEEJ collaborating on 3 integration efforts
- 12 students participated in SEEJ research at Northeastern and Michigan State Universities

APPROACH

- Mixed methods using rigorously designed sample surveys, GIS for merger with economic and biophysical data, and best practice qualitative methods



Tim Stephens, SWISSH and FEMA data

ACHIEVEMENTS AND SIGNIFICANCE

- Searched an extensive scientific literature on water equity for major themes and findings
- Seed grant with Northeastern University School of Law to study laws on water shutoffs, tax liens, water assistance programs and impacts of high water bills on public health in Massachusetts communities
- Michigan State University collaborated with the Philadelphia Water Department to write an article describing their solution to the water affordability challenge in Philadelphia.
- Significance will be to increase understanding of historical and present water inequities among scientists, water managers, and policymakers

PROJECT C3-1:
SOCIAL EQUITY AND ENVIRONMENTAL JUSTICE IN URBAN WATER SYSTEMS

PRODUCTS

Harlan, S.L., P. Chakalian, J. Declet-Barreto, D.M. Hondula, G.D. Jenerette (2019) Pathways to climate justice in a desert metropolis. Chapter 2 in *People and Climate Change: Vulnerability, Adaptation, and Social Justice*, L.M. Reyes and J. Rigg (eds.) Oxford University Press.

White, J., E.A., Mack, S.L. Harlan, E.S. Krayenhoff, M. Georgescu, K. Redican. (2019) Regional multivariate indices of water use potential for the continental United States. *Sustainability 11:2292; doi:10.3390/su11082292*.

Contorno, L., M. Sarango, S.L. Harlan. "Environmental Justice and Sustainable Urban Water Systems: Community Voices from Selected Cities in the United States." Social Science Environmental Health Research Institute, Northeastern University, Boston, MA (October 2018) www.northeastern.edu/environmentalhealth/UWIN_Report.pdf

- 2 articles under review at *Anthropocene and Journal of the American Water Resources Association*
- 5 presentations at the Association of American Geographies, North American Regional Science Association Conference, NSF SRN Awardees Conference, Society for the Study of Social Problems, Northeastern University Research, Innovation, and Scholarship Exhibition (RISE)
- Several articles in preparation
- 3 PhD dissertations in progress

PROJECT TEAM

Sharon L. Harlan, Professor
Department of Health Sciences and Department of Sociology & Anthropology, Northeastern University

Elizabeth Mack, Assistant Professor
Department of Geography, Environment, and Spatial Sciences, Michigan State University

Jessica Bolson, Postdoctoral Fellow, Florida International University

Tim Stephens, Georgia State University

Northeastern students: Mariana Sarango, Stephanie Clark, Elisabeth Wilder, Lauren Contorno, Kelsi Furman, Kiera O'Donnell, Fatuma Mohamed, Liz Mariluz

Michigan State students: Sarah Wrase, Jonah White, Laura Medwid, Michelle Church

Eco-Youth Crew measuring industrial pollution on the Chelsea, MA waterfront

PROJECT C4-1:
FIANCIAL MODELS AND STRATEGIES TO SUPPORT THE TRANSITION TO ONE WATER

National Science Foundation

MOTIVATION AND OBJECTIVES

According to stakeholders, financial constraints are a major barrier to implementation of One Water strategies. Objectives are:

- Discover the financial connectors and levers that control how services are offered and create strategies to integrate financial sources and decisions to promote One Water.
- Connect with relevant UWIN Projects that are evaluating institutional constraints to Sustainable Water Management including A1-2, C1-2 and C3-1.
- Identify where barriers exist in the current financial programs for "One Water" Projects.

PROGRESS

Completed a draft report "State of the Sector: Funding and Financing One Water" report, which will be sent to all participating utilities.

Evaluating the revenue and demand-side relationship between residential water and energy prices.

Currently working to understand customers' willingness-to-pay for different "types" of water supply.

APPROACH

The project will develop systems concepts and models to focus on financial flows and states. It seeks long term strategies to make fundamental changes as well as near term payoffs for UWIN Stakeholders.

Surveys will be used to identified key barriers faced by each utility service (drinking water, wastewater, and stormwater). Surveys will also identify success stories and provide examples and case studies for other utilities.

Financial and legal solutions to the identified barriers will be proposed and included in a report to the water sector.

ACHIEVEMENTS AND SIGNIFICANCE

Financial strategies will be central to accomplishment of UWIN goals for progress toward One Water.

Have created a better understanding of customers' preferences and willingness-to-pay for utility services.

PROJECT C4-1:
FIANCIAL MODELS AND STRATEGIES TO SUPPORT THE TRANSITION TO ONE WATER

PRODUCTS

- Flyr, M., Burkhardt, J., Goemans, C., Hans, L., Neel, A., & Maas, A. (2019). Modeling Commercial Demand for Water: Exploring Alternative Prices, Instrumental Variables, and Heterogeneity. *Land Economics*, 95(2), 211-224.
- Maas, A., Goemans, C., Manning, D. T., Burkhardt, J., & Arabi, M. (2019). Complements of the house: Estimating demand-side linkages between residential water and electricity. *Water Resources and Economics*.
- Created and distributed a Discrete Choice survey for water supply alternatives in the Palouse Basin Aquifer (in progress) to help city councils and the Aquifer Committee understand residents' preferences.

PROJECT TEAM

- Neil Grigg, Professor of Civil and Environmental Engineering, Colorado State University
- Alex Maas, Assistant Professor, Agricultural Economics and Rural Sociology, University of Idaho
- Roshan Puri, Graduate Students, Agricultural Economics and Rural Sociology, University of Idaho

PROJECT D1-1:
MODELING PRESENT AND FUTURE VALUES FOR SUSTAINABLE WATER MANAGEMENT BLUEPRINT INDICATORS

National Science Foundation

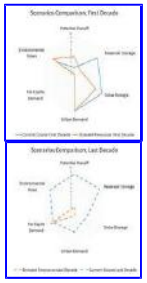
MOTIVATION AND OBJECTIVES

Motivation: To improve our understanding of how different water management strategies may help cities reduce their vulnerability to changing climate and population size by modeling present and future condition of urban water systems (UWS).

Objectives:
1. Assess the ability of different water management strategies to meet the challenges of population growth and climate change.
2. Pilot the use of Urban Water sustainability indicators to measure effectiveness of different water management solutions
3. Develop web services to quantify UW sustainability indicators

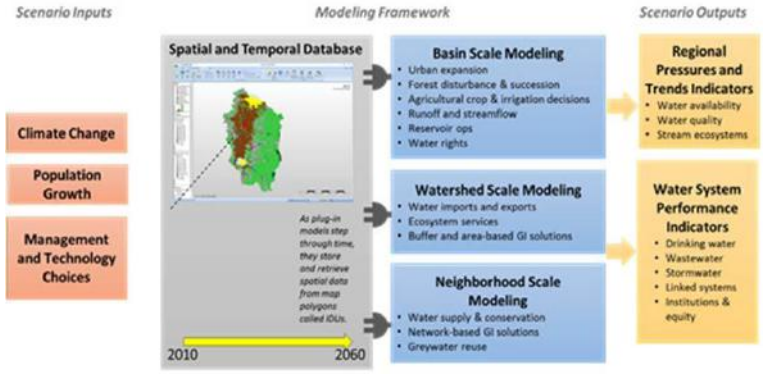
PROGRESS

- Developed a multi-scale modeling approach to evaluate future scenarios, using models selected to produce output at appropriate scales in space and time to calculate indicators identified by stakeholders as useful to decision-makers for design of future UWS.
- Produced representations of the existing landscape and future scenarios: Current Course, Integrated Water Future, and Stressed Resources at basin, watershed and neighborhood scales
- Guided graduate and undergraduate student research to produce manuscripts, reports, and presentations.



APPROACH

Project D1-1 uses a transdisciplinary, stakeholder-driven approach to develop and evaluate three alternative future scenarios for urban water systems in the Portland, OR region.



ACHIEVEMENTS AND SIGNIFICANCE

Developed version of Stormwater Management Model (SWMM) and EPA-NET for use as web services
Developed UWINvision, a version of Envision model including a SWMM plug-in specifically for studying urban water systems (UWS) and the impacts of innovations designed to improve resilience and sustainability of UWS at multiple scales
Worked with regional stakeholders and water managers to develop three alternative future scenario descriptions
Prepared and submitted manuscript describing our multi-scale approach to the design and evaluation of innovative urban water systems to journals Urban Ecosystems and Environmental Research Letters, as well as manuscripts submitted to Frontiers in Ecology and Evolution and EST.

PROJECT D1-1:
MODELING PRESENT AND FUTURE VALUES FOR SUSTAINABLE WATER MANAGEMENT BLUEPRINT INDICATORS

National Science Foundation

PRODUCTS

Papers

- Santelmann M V, Hulse D, Wright M, Branscomb A, Enright C, Talal M and Tchintcharauli-Harrison M. Submitted. A multi-scale approach for incorporating innovation into urban water systems. Submitted to Environmental Research Letters February 27, 2019.
- Santelmann, M. Hulse D, Wright M, Enright C, Branscomb A, Tchintcharauli-Harrison M. 2019. Innovation in Urban Water Systems. In: International GeoDesign Collaborative; C. Steinitz and Brian Rowland Eds. ESRI Press.
- Talal M, Santelmann M 2019 Plant community composition and biodiversity patterns in urban parks of Portland, Oregon. Submitted to Frontiers in Ecology and Evolution February 2019
- Santelmann M, Hulse D, Wright M, Enright C, Branscomb A, Tchintcharauli-Harrison M. In Review. Designing and modeling innovation across scales for urban water systems. Submitted to Urban Ecosystems September 2018

Presentations

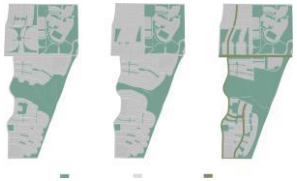
- Santelmann M V, Hulse D, Wright M, Branscomb A, Enright C, Talal M and Tchintcharauli-Harrison M. 2019. International Geodesign Collaboration: Innovation in Urban Water Systems. February 2019, Redlands, CA
- Talal M, Santelmann M. 2019 Plant community composition patterns in urban parks of Portland, Oregon Urban Ecology and Conservation Symposium February 2019, Portland, OR
- Talal M, Santelmann M. 2018. Comparison of plant greenness among neighborhoods of different income-levels in Portland, Oregon using Landsat 8 OLI/TIRS surface reflectance Ecological Society of America Annual Conference, August 2018, New Orleans, LA
- Talal M. 2019. Comparison of plant greenness among neighborhoods of different income-levels in Portland, Oregon using Landsat 8 OLI/TIRS surface reflectance. Pacific Northwest Water Research Symposium, April 2018, Corvallis, OR
- Tchintcharauli-Harrison, M.B., Santelmann, M., Haggerty, R., 2019 (Accepted), Preliminary Isotopic and Hydrochemical Findings of Surface-Groundwater Dynamics in an Urbanized Watershed, Portland, OR, Geol. Soc. of America, 115th Annual Mtg Cordilleran Section

Models and Tools

UWINvision- Envision model with SWMM incorporated
SWMM-LITE and EPANET-LITE packaged as web services
Watershed-scale version of UWINvision

Designed alternative futures

Three alternative future scenario designs (Current Course, Stressed Resources and Integrated Water Futures) with spatially-specific representations of each at three spatial scales; basin, watershed, and neighborhood



PROJECT TEAM

- Dr. M.V. Santelmann, Director Water Resources Graduate Program Oregon State University
- Dr. Roy Haggerty, Dean of the College of Science, Oregon State University
- Dr. David Hulse, Knight Professor of Landscape Architecture, University of Oregon
- Dr. David Conklin, Freshwater Simulations LLC, Portland Oregon (with Steve Drake, Brian Fulfrost and John Dalrymple) Faculty Research Associates: Alan Branscomb and Chris Enright, Univ. of Oregon; Maria Wright, Oregon State University,
- Graduate Students: Michael Harrison, Michelle Talal Undergraduate Students: Hattie Greydanus, Bijoux Schoner

PROJECT D1-2:
CROSS-SITE COMPARISONS AND CONTRASTS ACROSS ECO-HYDROLOGIC REGIONS

National Science Foundation

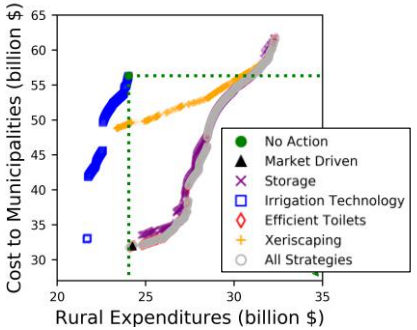
MOTIVATION AND OBJECTIVES

The overall goal of the study is to develop a unifying assessment framework and conduct case studies that demonstrate the benefits, co-benefits and system level effects of integrated urban water management solutions. Specifically, the objectives are to:

- Synthesize city water data and information from other projects
- Identify optimal water management solutions under deep uncertainty about climate, land use, and population
- Explore tradeoffs associated with water solutions for current and alternative future scenarios
- Identify water management solutions that are most consistent with stakeholders' preferences

PROGRESS

- A survey of UWIN researchers was conducted to identify a list of urban water sustainability indicators using multiple assessment frameworks, including: the triple bottom line, DPSIR, and risk-based approaches.
- The IUWM model was modified to produce, analyze, and assess primarily water use indicators and key performance indicators for sustainable management of urban water demands.
- Monthly water use data were collected From approximately 150 municipalities To train and test the IUWM model.



APPROACH

- An Urban Water Sustainability Blueprint is created to enable assessment of urban water systems at local, municipal, regional and continental scales.
- Assessment indicators are defined, characterized and quantified to provide a roadmap for the transition toward integrated management of urban water systems.
- The assessment framework incorporates multiple, and often conflicting, criteria in the decision-making process.

ACHIEVEMENTS AND SIGNIFICANCE

- The study provides observational and modeling evidences for the benefits and co-benefits of solutions that foster management of urban water systems from a “resource management” perspective.
- The comprehensive water sustainability study at the National Western Center (NWC) campus redevelopment project in Denver, CO created strategies for fit-for-purposes uses of alternative water sources.
- The study will reveal social viability, economic feasibility, and environmental sustainability and resiliency of the proposed technological, policy, and financial solutions.

PROJECT D1-2:
CROSS-SITE COMPARISONS AND CONTRASTS ACROSS ECO-HYDROLOGIC REGIONS

PRODUCTS

Journal Papers

- Daigger, G., S. Sharvelle, M. Arabi, and N. Love. 2018. Progress and Promise Transitioning to the One Water/Resource Recovery Integrated Urban Water Management Systems, ASCE Journal of Environmental Engineering, in press.
- Tasdighi A., M. Arabi, and D. Harmel. 2018. A probabilistic appraisal of rainfall-runoff modeling approaches within SWAT in mixed land use watersheds, Journal of Hydrology, 564, 476-489. https://doi.org/10.1016/j.jhydrol.2018.07.035
- Dozier, A., M. Arabi, C. Goemans, and D. Manning, Combating loss of agriculture in rapidly urbanizing semi-arid regions with institutional change, infrastructure, and conservation, Environmental Modeling & Software, in review.
- Wostoupal, B., A. Dozier, M. Arabi, and C. Goemans, Can regional urban water demand management save agriculture in semi-arid regions?, Journal of American Water Resources Association, in review.
- Olson, C., M. Arabi, T. Dell, and L. Roesner, Probabilistic Assessment of Extended Detention Basins: Role of Model Parameter

Thesis/Dissertations

- Batista, Giovana das Gracas (2018). Characterization of urban water use and performance evaluation of conservation practices using the Integrated Urban Water Model in São Paulo, Brazil. MS Thesis: Civil and Environmental Engineering, Colorado State University. Web: https://hdl.handle.net/10217/193176
- Dozier, Andre (2017). Towards integrated water resources management through modeling, optimization, and stakeholder engagement with a decision support game. Dissertation: Civil and Environmental Engineering, Colorado State University. Web: https://hdl.handle.net/10217/184012
- Wostoupal, Benjamin (2018). Exploring water management tradeoffs in semiarid regions through conservation, institutions, and integrated modeling. M.S. Thesis, Civil and Environmental Engineering, Colorado State University, Fort Collins, Colorado. Web: https://hdl.handle.net/10217/191277

PROJECT TEAM

- Mazdak Arabi, Professor (PI) - Colorado State University
- Andre Dozier, Research Scientist - Colorado State University
- Benjamin Wostoupal, Graduate Student - Colorado State University
- Chelsey Heiden, Graduate Student – Colorado State University
- Canon Furth, Graduate Student – Colorado State University
- William Rainey, Graduate Student – Colorado State University
- Omar Shebab, Graduate Student – Colorado State University
- Tyler Dell, Graduate Student – Colorado State University

PROJECT D1-3:
URBAN WATER DECISION INNOVATION SYSTEM

National Science Foundation

MOTIVATION AND OBJECTIVES

The objectives of the study are to:

- Develop the Water Connect App for engaging the urban water community to contribute to the development of the urban water sustainability blueprint
- Develop web-services for characterizing urban water sustainability indicators
- Develop a multi-criteria decision analysis tool to assess social, economic, and environmental tradeoffs in meeting desired water management targets

PROGRESS

- An initial scalable and geospatially-enabled Water Connect website was created to upload, share, and disseminate geospatial or other scientific products from UWIN project teams.
- Web services were created for easy access to current and future climate data from UWIN and other institutions.
- Monthly city water use data were collected from 150 cities in CONUS to better characterize the use of water across socio- economic, political, and eco-climatic regions.

APPROACH

- A data-sharing web tool is developed to host data across UWIN thrusts.
- An expert system is created that summarizes the knowledge of the UWIN network of researchers to lead cities toward sustainable solutions.
- The data and modeling tools are deployed as web-services using the eRAMS Cloud Services Implementation Services (CSIP), and provides web interfaces using geospatial capabilities.
- stakeholder-driven perspectives about performance of alternative water management strategies are incorporated in the analysis tools.
- Numerical optimization techniques and tools enables system identification based on indicators informed by participants.

ACHIEVEMENTS AND SIGNIFICANCE

- Sped up queries and aggregations for climate data significantly through distributed storage systems
- Built innovative collaborative framework for sharing and querying geospatial data
- Leveraging urban water sustainability data from the research community is hampered by the use of customized and inconsistent data frameworks including formats, units of measurement, and storage mechanisms. If not managed effectively, the I/O subsystem – with its slower access times and transfer rates – results in inefficiencies that preclude rapid data space exploration and interdisciplinary research.

PRODUCTS

Journal Papers

- Daigger, G., S. Sharvelle, M. Arabi, and N. Love. 2018. Progress and Promise Transitioning to the One Water/Resource Recovery Integrated Urban Water Management Systems, ASCE Journal of Environmental Engineering, in press.
- Tasdighi A., M. Arabi, and D. Harmel. 2018. A probabilistic appraisal of rainfall-runoff modeling approaches within SWAT in mixed land use watersheds, Journal of Hydrology, 564, 476-489. https://doi.org/10.1016/j.jhydrol.2018.07.035
- Dozier, A., M. Arabi, C. Goemans, and D. Manning, Combating loss of agriculture in rapidly urbanizing semi-arid regions with institutional change, infrastructure, and conservation, Environmental Modeling & Software, in review.
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- Wostoupal, Benjamin (2018). Exploring water management tradeoffs in semiarid regions through conservation, institutions, and integrated modeling. M.S. Thesis, Civil and Environmental Engineering, Colorado State University, Fort Collins, Colorado. Web: https://hdl.handle.net/10217/191277

PROJECT TEAM

- Mazdak Arabi, Professor (PI) - Colorado State University
- Andre Dozier, Research Scientist - Colorado State University
- Kyle Traff, Technician – Colorado State University
- Tyler Wible, Research Scientist – Colorado State University

PROJECT E1-1:
UWIN STAKEHOLDER ENGAGEMENT

MOTIVATION AND OBJECTIVES

- "… train the next generation of researchers to meet the interdisciplinary research needs of the future"
- "... promote collaboration with resource managers, policymakers, end-users and other stakeholders in the private and public sectors…
- "… direct involvement - from the outset - of participants from federal, state and local agencies and tribal communities, non-governmental and international bodies and industry"
- Years 1 and 2: Build network, understand issues and decisions
- Year 3: Develop actionable science
- Year 4: Identify best management practices

PROGRESS

- Training:
  - 50% graduate students
  - 2016 cohort: 42 individuals
  - 2017 cohort: 32 individuals
- Engagement:
  - 2016/2017/2019 Stakeholder meetings summarized:
    - https://erams.com/UWIN/2016-meetings/
    - https://erams.com/UWIN/2017-meetings/
    - https://erams.com/UWIN/2019-philadelphia-workshop/
  - 2016 findings published

APPROACH

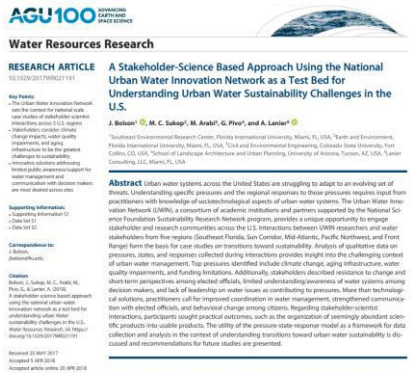
- Years 1 and 2:
  - Training & Stakeholder meetings and surveys in 5+ regions
  - Data gathering and synthesis

- Year 3:
  - Stakeholder-led Webinars (187 attendees)

- Year 4:
  - Stakeholder interviews to inform blueprint
  - Marketing strategies for water management
  - Case studies of successful urban water integration collaborations

ACHIEVEMENTS AND SIGNIFICANCE

- Top issues across country:
  - Climate change, aging infrastructure, water quality, and funding
  - Resistance to change and short-term perspectives among elected officials, limited understanding/awareness of water systems among decision makers, and lack of leadership on water
  - Practitioners call for improved coordination in water management, strengthened communication with elected officials, and behavioral change among citizens
  - Stakeholders want practical outcomes, such as the organization of seemingly abundant scientific products into usable products


AGU100

Water Resources Research

RESEARCH ARTICLE

A Stakeholder-Science Based Approach Using the National Urban Water Innovation Network as a Test Bed for Understanding Urban Water Sustainability Challenges in the U.S.

PROJECT E1-1:
UWIN STAKEHOLDER ENGAGEMENT

PROUCTS

- Bolson, J., Sukop, M. C., Arabi, M., Pivo, G., & Lanier, A. (2018). A stakeholder-science based approach using the national urban water innovation network as a test bed for understanding urban Water sustainability challenges in the U.S.. Water Resources Research, 54. https://doi.org/10.1029/2017WR021191

PROJECT TEAM

- Michael Sukop, Professor – Florida International University
- Jessica Bolson, Postdoctoral Fellow – Florida International University
- Alicia Lanier, Consultant – Lanier Consulting

PROJECT E2-1:
UNDERGRADUATE RESEARCH PROGRAM

MOTIVATION AND OBJECTIVES

- Contribute to UWIN research
- Promote students' learning and increase their identity and confidence as scholars
- Promote diversity in UWIN
- Understand transdisciplinary problem-solving/learning

PROGRESS

- Nine undergraduate students participated in URP 2018.
- We recruited 9 students from a pool of 433 applicants as well as 18 mentors for URP 2019.
- We are currently arranging for students to work and live at each of the 8 host institutions involved in the 2019 program as well as scheduling students' activities during the summer.

APPROACH

- Undergraduate students conduct independent research projects under the guidance of UWIN mentor scientists.
- Students participate in key enrichment activities providing them a deeper and broader understanding of urban water sustainability research and how transdisciplinary science is conducted.
- Students are connected to the broader UWIN community to build networks to support their continued professional development.

ACHIEVEMENTS AND SIGNIFICANCE

- All students (n=9) from the 2018 URP cohort successfully completed all the program requirements.
- The size of the 2019 applicant pool increased compared to 2018 while the percentage of under-represented minorities applying to the program remained the same (24%)
- A highly diverse group of students, mentors, and project types was assembled for the 2019 program. For example, 67% of URP participants are from underrepresented minorities. The pool of mentors includes 11 faculty, 1 post-doc, and 6 graduate students.

PROJECT E2-1:
UNDERGRADUATE RESEARCH PROGRAM

PRODUCTS

- Greydanus H., Santelmann M. 2018. Microclimate cooling of green infrastructures in Portland, Oregon. Collegiate Poster & Rapid Fire Competition. Society of Women Engineers, October 18-20 2018. Minneapolis, MN.
- Habron G., Thompson K., Maas A., Berkowitz A. 2019. Experiential model-based reasoning for undergraduate interdisciplinary urban water synthesis. American Association of Geographers Annual Meeting, April 3rd-7th, Washington DC. Oral presentation
- Lochet A., Berkowitz A., Vincent S., Habron G., Maas A., Gosselin D. 2018. Building transdisciplinary skills among undergraduate students through summer research experiences. Council on Undergraduate Research Biennial Conference, July 1st-3rd 2018, Arlington VA. Poster presentation.
- McWest L., Broadbent, A., Vanos, J., Georgescu, M., Middel, A. 2019. Impacts of urban tree canopy and water features on the thermal environment. American Meteorological Society 99th Annual Meeting, January 6-10 2019. Phoenix, AZ. Poster presentation.
- Meltzer S., Georgescu, M, Broadbent, A., Vanos, J., Middel, A. 2019. Impacts of trees on urban canyon microclimate. American Meteorological Society 99th Annual Meeting, January 6-10 2019. Phoenix, AZ. Poster presentation.
- Valencia, M.E., Jenerette D. 2018. Influence of vegetation transitions on air temperature. AGU Fall Meeting, December 2018. Washington D.C.

PROJECT TEAM

- Alan Berkowitz, Head of Education – Cary Institute of Ecosystem Studies
- Aude Lochet, URP Coordinator - Cary Institute of Ecosystem Studies
- Shirley Vincent, External Evaluator – Vincent Evaluation Consulting
- Sarah Millonig, UWIN Coordinator – Colorado State University
- Ali Mostafavi, URP Steering Committee – Texas A&M University
- Jessica Bolson, URP Steering Committee – Florida International University

CITIZEN SCIENCE PROGRAM

OFF THE ROOF: EMPLOYING CITIZEN SCIENCE TO ENABLE CHARACTERIZATION OF MICROBIAL QUALITY OF ROOF RUNOFF

National Science Foundation

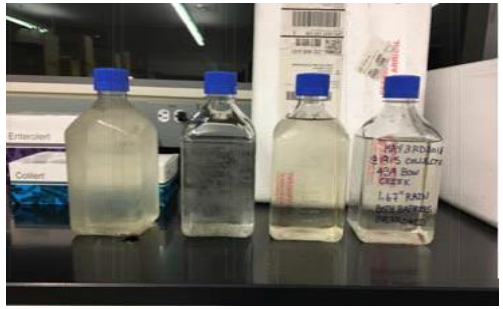
MOTIVATION AND OBJECTIVES

Roof runoff is a valuable source of water, but uncertainty remains in treatment targets for various end uses. Quantitative microbial risk assessment can be used to inform treatment targets and to characterize pathogens in roof runoff. *The overarching goal of this research is to engage citizens in roof runoff sampling that will inform the public on use of alternative water sources while also collecting data on microbial water quality to better inform treatment targets for roof runoff for various end uses.*

Characterize Pathogens in Source Water → Exposure (Based on End Use) → Select Acceptable Level of Risk → Set Log Reduction Target

PROGRESS

- Collected roof runoff from 7 households in each Fort Collin, CO (4 events), Tucson, AZ (2 events), Miami, FL (3 events), and Baltimore, MD (2 events)
- Samples analyzed for chemical water quality and fecal indicator bacteria

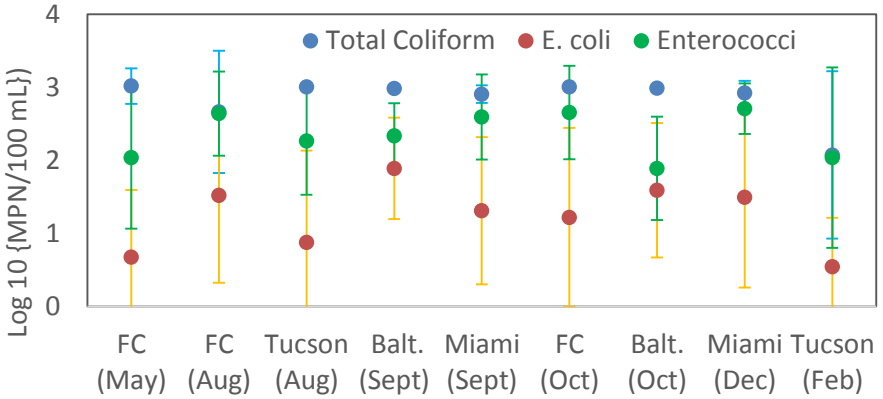


APPROACH

Citizen participants are collecting samples of roof runoff using rain barrels. Those samples are analyzed for physical and chemical parameters, indicator organisms (*E. coli* and Entercocci) and pathogens (Campylobacter, Salmonella, Cryptosproidium, and Giardia)

ACHIEVEMENTS AND SIGNIFICANCE

- Rigorous protocol developed to enable large number of samples to be collected and processed for microbial quality
- Participants educated on install of roof runoff collection system, value of roof runoff and importance of water quality



CITIZEN SCIENCE PROGRAM

OFF THE ROOF: EMPLOYING CITIZEN SCIENCE TO ENABLE CHARACTERIZATION OF MICROBIAL QUALITY OF ROOF RUNOFF

PRODUCTS

Website:
CitSci.org website

Presentations:
Alja'fari, J., Sharvelle, S., Crall, A., Newman, G. (2019) "Off the Roof: A Citizen Science Project to Measure the Microbial Characteristics of Roof Runoff", Hydrology Days, Fort Collins, CO.

PROJECT TEAM

Academic Team:
Sybil Sharvelle, Associate Professor, Colorado State University
Greg Newman, Research Scientist, Natural Resource Ecology Laboratory Alycia Crall, Paricipant Coordination
Alan Berkowitz, Plant Ecologist, Cary Institute of Ecosystem Studies Mike Sukop, Professor, Florida International University
Tom Meixner, Professor, University of Arizona
Claire Welty, Professor, University of Maryland Tom Meixner, Professor, University of Arizona

USEPA Collaborators:
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Scott Keely, USEPA National Exposure Research Laboratory
Michael Jahne, Environmental Engineer, USEPA National Exposure Research Laboratory

External Advisory Committee:
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Audra Mohan, Research Scientist, Biological Sciences Curriculum Study