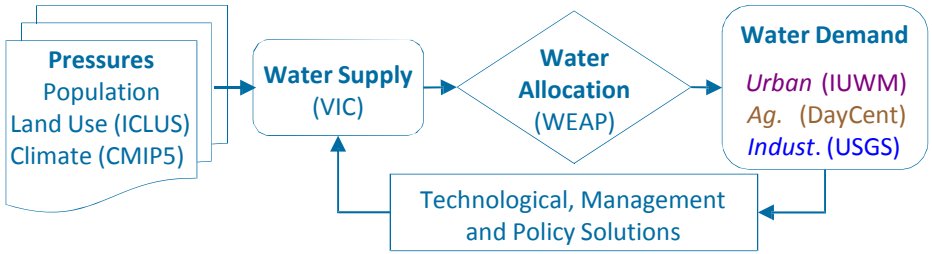
PROJECT A1-1:
QUANTIFYING VULNERABILITY, RESILIENCY, AND ADAPTABILITY OF U.S. URBAN WATER SYSTEMS TO CLIMATIC AND SOCIO-ECONOMIC VARIABILITY

National Science Foundation

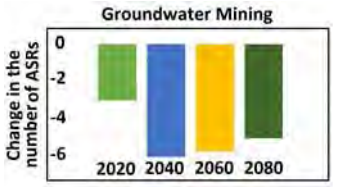
MOTIVATION AND OBJECTIVES

- 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.



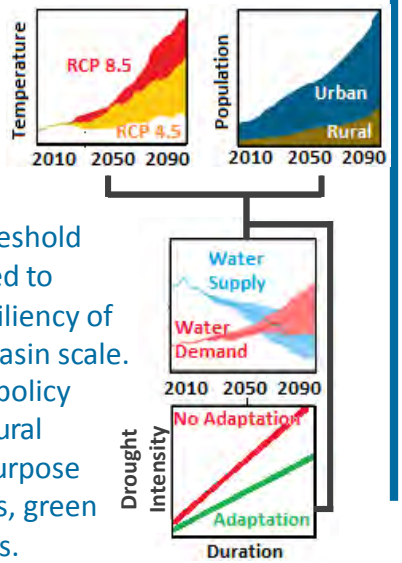
PROGRESS

- Projected future climate data were obtained from the MACA dataset.
- The Variable Infiltration Capacity (VIC) model was enhanced, calibrated and tested for watersheds in the Contiguous United States (CONUS). Monthly water yield time series for the 1980-2100 period were computed.
- Water use by sectors (i.e., municipal, agricultural, industrial, and others) was estimated at the Census County scale.
- The effects of a number of adaptation strategies were examined.



APPROACH

- The **Pressure-State-Response** framework was adopted to characterize the sustainability of U.S. Water Supply.
- A novel mixed Gamma-Peak Over Threshold (POT) probability model was developed to assess 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

- Water supply shortages are likely to pose challenges for cities in the more arid parts of the United States, especially in the central and southern Great Plains, southern portions of the Intermountain West, the Southwest, and parts of California.
- Future groundwater mining at levels similar to those of the past few decades is by far the most effective adaptation, providing roughly a 20 to 50-percent reduction in the number of basins expecting shortages.
- A wide range of other adaptations, from reductions in irrigated area to additions in reservoir capacity to added flexibility in managing transbasin diversions, have relatively modest effects on the number of basins projected to incur annual shortages.
- Substantial increases in shortage were estimated for even the most sanguine projections of future levels of population and climate change.

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

PRODUCTS

- AGU Hydrology Days 2018: Hadi Heidari, Mazdak Arabi, Andre Dozier, Ali Tasdighi, An Analytical Framework for Assessing Municipal Vulnerability to Water Shortage and Drought Characteristics under Nonstationary Supply and Demand Conditions, 19 March 2018
- International Congress on Environmental Modelling and Software 2018: Hadi Heidari, Mazdak Arabi, Andre Dozier, Ali Tasdighi, An Analytical Framework for Assessing Water Shortage Vulnerability under Nonstationary Supply and Demand Conditions, 24-28 June 2018

PROJECT TEAM

- Mazdak Arabi, PhD – Colorado State University
- Hadi Heidari, Graduate Research Student, Colorado State University Thomas C. Brown, PhD – USDA Forest Service
- Jorge Ramirez, PhD – Colorado State University Travis Warziniack, PhD – USDA Forest Service

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

National Science Foundation

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

-Obtained input-output data

-Collection of water rates for U-WIN regions

-Papers-in-progress with UWIN collaborators

-Participation of 4 graduate students and 4 undergraduates in research at Michigan State and Arizona State Universities

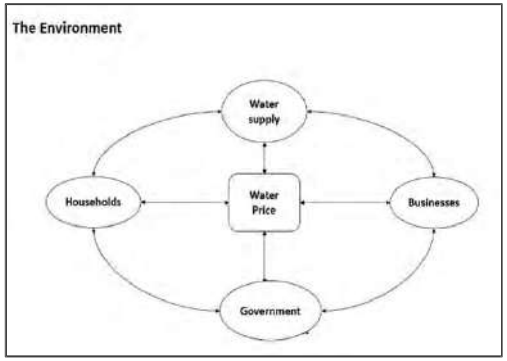
APPROACH

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

-National news coverage about water affordability issues in the United States. Coverage by PBS Newshour, the Huffington Post, and Vice Motherboard

-Plosone article has over 40,000 views on *Plosone* website

-Engagement of variety groups concerned about water

-Training of students in water research

-Participation in summer REU program for undergraduates

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

PRODUCTS

Papers:

- Mack, E. A., & Wrase, S. (2017). A burgeoning crisis? A nationwide assessment of the geography of water affordability in the United States. *PloS one*, *12*(1), e0169488.
- Issue of Region Magazine from the Regional Studies Association about Urban Infrastructure. This issue contains 5 articles from the U-WIN project.

3 articles in preparation (all include students):

- A multivariate comparative index to assess pressures on water systems across scales *(led by E. Mack)*
- Spatial analysis of water rates in Detroit (*led* by S. Wrase)
- Input-output analysis of projected water trends (*led* by Kevin Credit)

Data sets:

- Shapefile of Census tracts At-Risk and at High-Risk for Water Affordability Issues. https://erams.com/map/

Presentations:

- Colloquium: Human Dimensions of the Urban Water Innovation Network (U-WIN). Earth and Environmental Sciences Seminar Series, Wayne State University. March 7, 2018.
- 2 presentations at the University Undergraduate Research and Arts Forum (UURAF) Michigan State University.
- 2 sessions organized and 2 papers presented at the American Association of Geographers annual meeting (2017 and 2018)

PROJECT TEAM

- Elizabeth Mack, Assistant Professor, Department of Geography, Environment, and Spatial Sciences, Michigan State University
- Michigan State graduate students: Jonah White, Kyle Redican, and Kevin Credit
- Arizona State student: Lianzheng Mu
- Michigan State undergraduate students: Sarah Wrase, Alexander Brown, Matt Chiavetta, and Benjamin Dougherty

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

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).

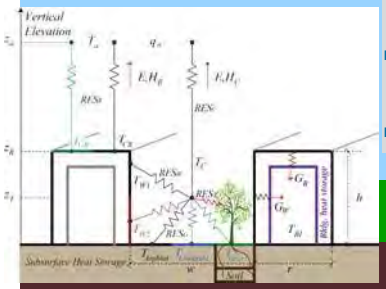
PROGRESS

- 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

PRODUCTS

- El-Samra R. , Bou-Zeid E., El-Fadel M. (2018) “To What Extent Does High Resolution Dynamical Downscaling Improve the Representation of Climatic Extremes over an Orographically Complex Terrain?”, *Theoretical and Applied Climatology,* online first, DOI 10.1007/s00704-017-2273-8.
- El-Samra R., Bou-Zeid E., El-Fadel M. (2018) "What Model Resolution is required in Climatological Downscaling over Complex Terrain?", Atmospheric Research, 203, 68–82.
- Li Q, Wang ZH (2017) Large-eddy simulation of the impact of urban trees on momentum and heat fluxes, Agricultural and Forest Meteorology, 255, 44-56.
- Li Q., Bou-Zeid E., Anderson W., Grimmond S., Hultmark M. “Quality and Reliability of LES of Convective Scalar Transfer at High Reynolds Numbers”, *International Journal of Heat and Mass Transfer,* 102, 959–970.
- Llaguno-Munitxa M., Bou-Zeid E., Hultmark M. (2017) "The influence of building geometry on street canyon air flow: validation of large eddy simulations against wind tunnel experiments", *Journal of Wind Engineering & Industrial Aerodynamics*, 165, 115-130.
- Malings C., Pozzi M., Klima K., Bergés M., Bou-Zeid E., Ramamurthy P. (2017) "Surface Heat Assessment for Developed Environments: Probabilistic Urban Temperature Modeling", *Computers, Environment and Urban Systems*, 66, 53-64.
- Ramamurthy, P and Bou-Zeid, E (2017), Heatwaves and Urban Heat Islands: A Comparative Analysis of Multiple Cities Using a High-Resolution Numerical Model, Journal of Geophysical Research-Atmospheres, 122, 168-178.
- Song J, Wang ZH (2016) “Evaluating the impact of built environment characteristics on urban boundary layer dynamics using an advanced stochastic approach”, *Atmospheric Chemistry and Physics*, 16, 6285-6301.
- Song J, Wang ZH (2016), Diurnal changes in urban boundary layer environment induced by urban greening, *Environmental Research Letters*, 11: 114018.
- Song J, Wang ZH, Wang C (2017), Biospheric and anthropogenic contributors to atmospheric CO_2 variability in a residential neighborhood of Phoenix, Arizona, *Journal of Geophysical Research: Atmospheres*, 122:3317-3329.
  Wang C, Wang ZH (2017), Projecting population growth as a dynamic measure of regional urban warming, *Sustainable Cities and Society,* 32: 357-365.
- Wang ZH, Fan C, Myint SW, Wang C (2016) Size matters: what are the characteristic source areas for urban planning strategies? PLoS One, 11(11):e0165726.
  Wang ZH, Li Q (2017), Thermodynamic characterisation of urban nocturnal cooling, *Heliyon*, 3: e00290.
- Yang J, Wang ZH, Georgescu M, Chen F, Tewari M (2016) “Assessing the impact of enhanced hydrological processes on urban hydrometeorology with application to two cities in contrasting climates”. *Journal of Hydrometeorology*, 17, 1031-1047.
- Yang J. and Bou-Zeid E. (2018) “Should cities embrace their heat islands as shields from extreme cold?” Journal of Applied Meteorology and Climatology, online first, DOI: 10.1175/JAMC-D-17-0265.1.

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

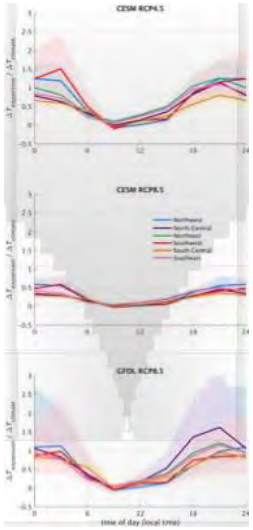
National Science Foundation

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

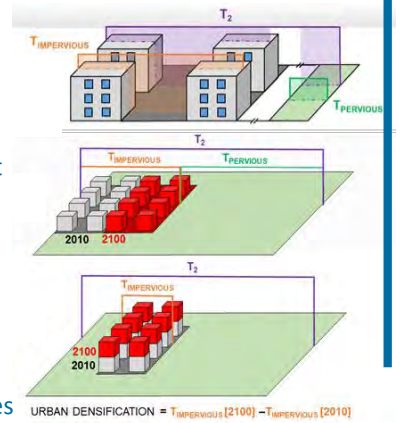
- Performed climate scale simulations for contemporary (2000-2009) and projected (2090-2099) future climate change (GHGs and urban expansion) across CONUS.
- Quantified the relative magnitude of urban expansion relative to GHGs across the diurnal cycle and determined that climate change and corresponding urban expansion interact nonlinearly to reduce summer night-time warming by 0.5-1.0 K.



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

  aimed at reducing urban heat that will be of value to a broad spectrum of scientists ranging from economists to climatologists.

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*, Status = In Review (less than 50% of submitted papers to NCC are sent for Review), Acknowledgement of Federal Support = Yes.

- Broadbent, A. M., E. S. Krayenhoff, M. Georgescu, and D. J. Sailor (2018), The observed effects of utility-scale photovoltaics on near- surface air temperature and energy balance. *Journal of Applied Meteorology and Climatology*, Status = In Review, Acknowledgement of Federal Support = Yes.

- Clinton, N., M. F. Stuhlmacher, A. Miles, N. U. Aragon, M. Wagner, M. Georgescu, and P. Gong (2018), A Global Geospatial Ecosystem Services Estimate of Urban Agriculture, *Earth's Future*, https://doi.org/10.1002/2017EF000536. Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.

- Cao, Q., D. Yu, M. Georgescu, J. Wu, and W. Wang (2018), Impacts of future urban expansion on summer climate and heat-related human health in eastern China. *Environment International*, doi: https://doi.org/10.1016/j.envint.2017.12.027, Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.

- Cao, Q., D. Yu, M. Georgescu, and J. Wu (2018), Substantial impacts of landscape changes on summer climate with major regional differences: The case of China, *Science of the Total* Environment, doi: https://doi.org/10.1016/j.scitotenv.2017.12.290, Status = Published; Acknowledgement of Federal Support = Yes; Peer Reviewed = Yes.

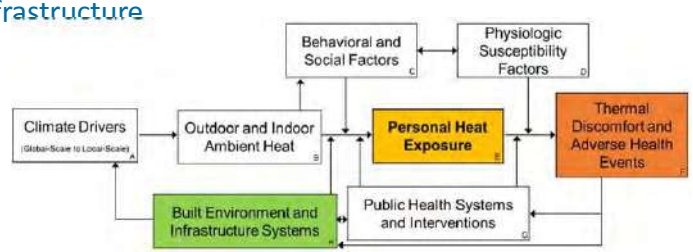
PROJECT TEAM

- E. S. Krayenhoff, Post-doctoral Scholar, Arizona State University (now Assistant Professor at 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
- M. Stuhlmacher, Research Assistant, Arizona State University
- J. Lee, Research Assistant, Arizona State University
- A. Middel, Assistant Research Professor, Arizona State University (now Assistant Professor at Temple University)
- M. Georgescu, Associate Professor, Arizona State University

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

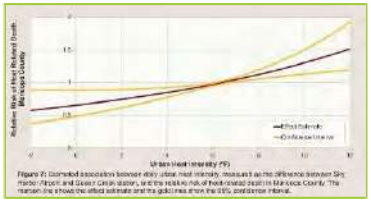
MOTIVATION AND OBJECTIVES

- Measure microclimatic conditions experienced by urban residents
- Understand influence of water on thermal comfort and heat stress
- Model thermal comfort impacts of changes to urban water infrastructure



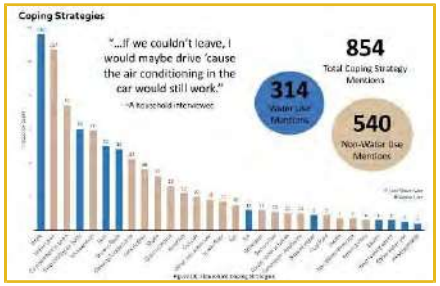
PROGRESS

- Completed targeted thermal comfort assessments focusing on vulnerable neighborhoods and evaporative misters
- Collected temperature & humidity data from ~100 field sites across Phoenix metro area in collaboration with NofN initiative
- Analyzed 42 household interviews to understand water-related coping strategies for a cascading heat-power failure disaster
- Developed statistical models of health risks from urban heat



APPROACH

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



ACHIEVEMENTS AND SIGNIFICANCE

- Air temperatures are well correlated with indicators of greenness across a sample of nearly 100 sites in Phoenix metro
- Energy balance assessment reveals different variability in heat stress across urban microclimates than would be estimated from conventional methods (air, surface temperature)
- There is a distinctive effect of urban heat on heat-related mortality independent of the overall temperature effect
- Households perceive water as a critical resource for coping with a heat-power failure cascading disaster but have varying understandings of supply and reliability

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.

PROJECT TEAM

- David Hondula, Assistant Professor, Arizona State University
- Jennifer Vanos, Assistant Professor, University of California San Diego
- Ariane Middel, Assistant Professor, Temple 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

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.

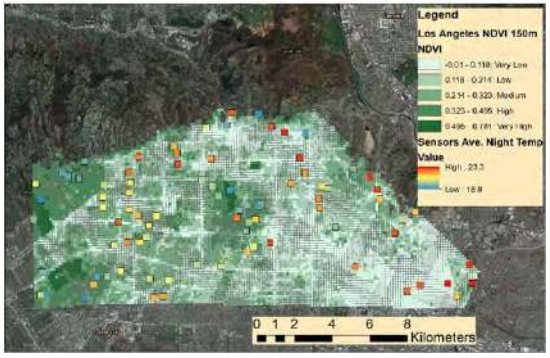
Developing algorithms for processing Landsat satellite imagery to evaluate monthly vegetation and surface temperature relationships at metropolitan scales.

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 mainly occurs 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

- 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
- Swan, C. M., Johnson, A., Nowak, D. (2017). Differential organization of taxonomic and functional diversity in an urban woody plant metacommunity. Applied Vegetation Science, 20(1), 7-11.
- Roman LA, H Pearsall, TS Eisenman, TM Conway, RT Fahey, S Landry, JM Vogt, NS van Doorn, JM Grove, DH Locke, AC Bardekjian, JJ Battles, M Cadenasso, CC Konijnendijk van den Bosch, M Avolio, A Berland, GD Jenerette, SK Mincey, DE Pataki, C Staudhammer, 2018. Human and biophysical legacies shape contemporary urban forests: A literature synthesis. Urban Forestry and Urban Greening 31:157-168
- Johnson, A., Borowy, D., Swan, C. M. (2017). Land use history and seed dispersal drive divergent plant community assembly patterns in urban vacant lots. Journal of Animal Ecology.
- Jenerette GD, LW Clarke, ML Avolio, DE Pataki, TW Gillespie, S Pincetl, J McFadden, D Nowak, L Hutyra, M McHale, and M Alonzo. 2016. Climate tolerances and trait choices shape continental patterns of urban tree biodiversity. Global Ecology and Biogeography 25:1367-1376
- Crum SM and GD Jenerette. 2017. Vertical and horizontal micrometeorological variation among urban land covers. Journal of Applied Meteorology and Climatology 56:2531-2543.
- Crum SM, S Shiflett, and GD Jenerette. 2017. Vegetation and the moderation of urban microclimates. Journal of Environmental Management 200:295-303
- Liang LL, RG Anderson, SA Shiflett, and GD Jenerette. 2017. Urban outdoor water use and response to drought assessed through mobile energy balance and vegetation greenness measurements. Environmental Research Letters 084007

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:
URBAN WATER 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)

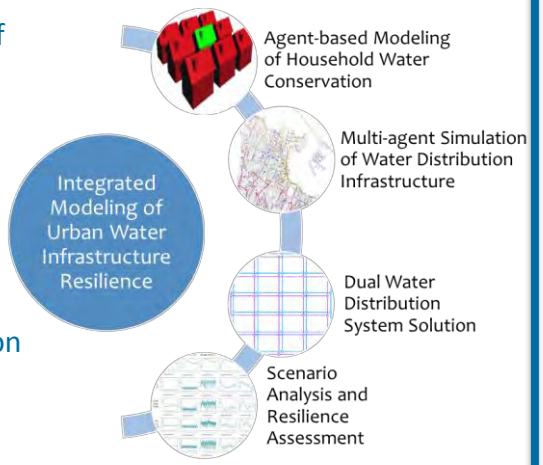


Fig 1. Project Overview

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)

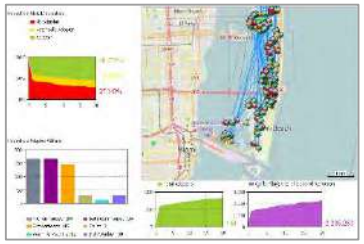
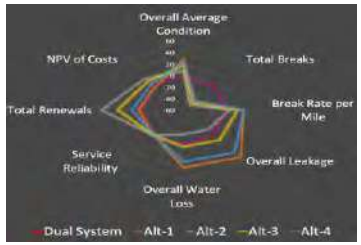


Fig 3. Agent-based Model of Water Conservation



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

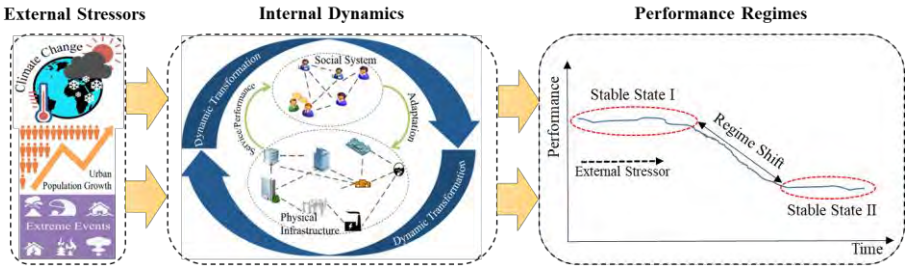


Fig 2. Complex Systems Resilience Framework

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 B1-1a:
URBAN WATER INFRASTRUCTURE RESILIENCE

PRODUCTS

Journals Papers

- K Rasoulkhani, A Mostafavi (2018). *Resilience as an Emergent Property of Human-Infrastructure Dynamics: A Multi-Agent Based Simulation Model for Characterizing Regime Shifts and Tipping Point Behaviors in Infrastructure Systems.* Journal of PLOS One. (Under Review)
- K Rasoulkhani, BN Logasa, MP Reyes, A Mostafavi (2017). Understanding fundamental phenomena affecting water conservation technology adoption of residential consumers using Agent-based modeling. *Water*. (Under Review)

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

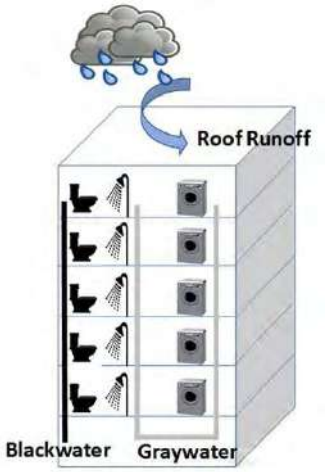
PROJECT B1-1b:
WATER MANAGEMENT SOLUTIONS TO ENAHNCE CAPACITY FOR USE OF ALTERNATE WATER SOURCES

National Science Foundation

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

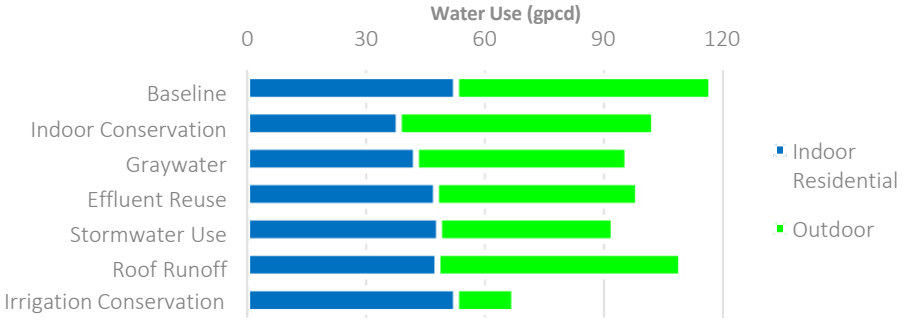
- Assessed centralized and decentralized strategies for separate supply of potable water via enhanced decision support framework
- Assessing drivers of water use across UWIN study cities
- Enhancement of IUWM to capture irrigation behaviors southeast region of US where there is little response to weather
- 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

- Irrigation conservation and stormwater use are most effective in Fort Collins, CO
- Transition from low and medium density development supports population growth without increased water demand



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

PRODUCTS

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

National Science Foundation

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's to baseline results 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
- Characterizing current and future energy mixes for utilities serving case study cities.
- Preparing data and methods to update 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.
- Have obtained or are in the process of obtaining electricity mixes in case study cities for evaluating the emissions from the use of electricity.

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

PRODUCTS

None to date.

PROJECT TEAM

- Arpad Horvath, UC Berkeley, PI
- Jennifer Stokes-Draut, UC Berkeley
- Fiona Greer, UC Berkeley

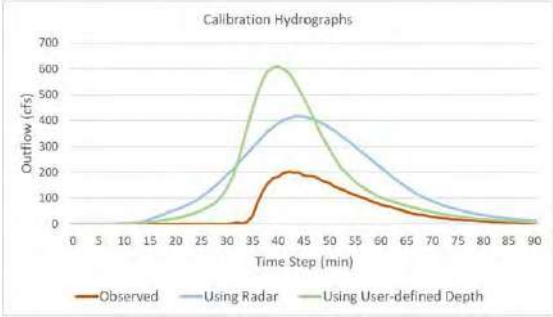
PROJECT B2-1:
COMPARATIVE IMPACT OF GREEN INFRASTRUCTURE ACROSS URBAN SYSTEMS

MOTIVATION AND OBJECTIVES

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

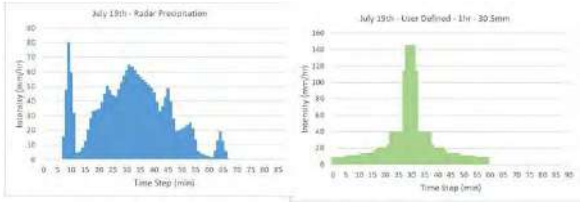
PROGRESS

1. Compiled monitoring data for multiple watersheds
2. Constructed and calibrated model for on Tucson watershed proceeding on the second
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 increase of biogeochemical processing of urban GI versus control soils
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.

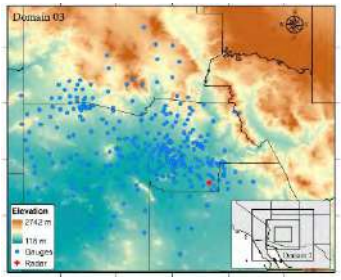
PROJECT TEAM

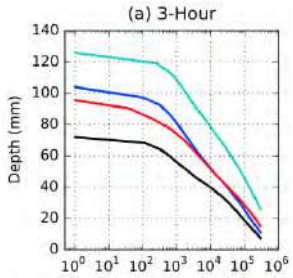
- Thomas Meixner, Professor University of Arizona
- Phil Guertin, Professor, University of Arizona
- Yoganand Korgaonkar, Grad Assistant, University of Arizona
- Neha Gupta, Grad Assistant, University of Arizona
- Jack Anderson, Grad Assistant, University of Arizona
- Tyler Rockhill, Grad Assistant,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

PROJECT B2-2a:
FLOOD HYDROLOGY AND RAINFALL FREQUENCY

MOTIVATION AND OBJECTIVES

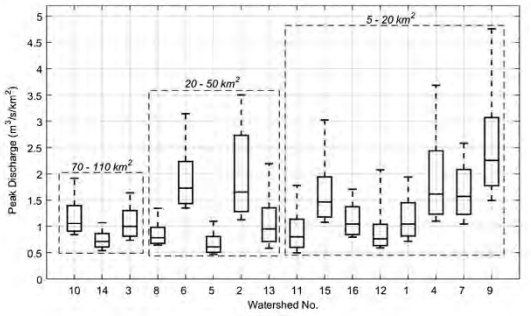
- Demonstrate a predictive understanding of urban flood hydrology
- Characterize the climatology of flood-producing storm systems in urban regions
- Develop procedures for rainfall and flood frequency analysis that can serve as the foundation for assessing urban flood hazards.

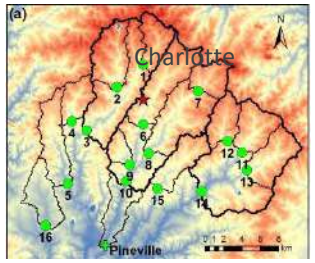




PROGRESS

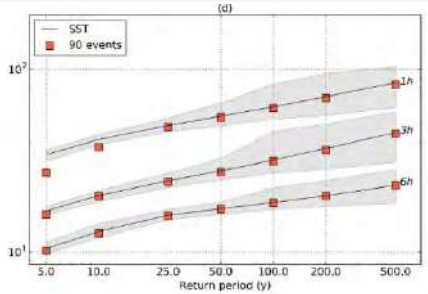
- Development of rainfall data sets for urban study regions
- Development of rainfall frequency analyses procedures (Stochastic Storm Transposition) for spatially heterogeneous urban regions
- Hydroclimatological characterization of extreme rainfall in urban regions.

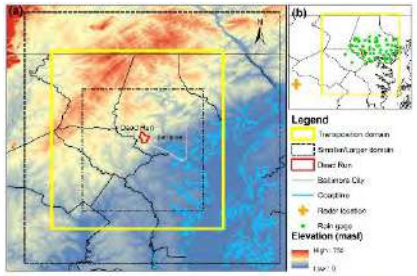




APPROACH

- Storm Catalogs of radar rainfall fields
- Stochastic Storm Transposition
- Hydroclimatological analyses using the Weather Research and Forecasting Model
- ”Upper Tail Ratio” analyses of extreme floods





ACHIEVEMENTS AND SIGNIFICANCE

- The hydroclimatoloy of extreme rainfall in the Phoenix-Tucson “Sun Corridor” is linked to anomalies in water vapor transport.
- Extreme floods in urban watersheds vary in predictable fashion with storm properties and the distribution of impervious cover;
- The Upper Tail Ratio provides a useful tool for characterizing the upper tail of flood peak distributions
- “Collapsing” thunderstorm systems are important flood agents for urban
- Spatial heterogeneities of flash flood producing rainfall over Baltimore are linked to interaction of the Bay Breeze circulation and Urban Heat Island

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
- Mary Lynn Baeck
- Molly Chaney
- Long Yang

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

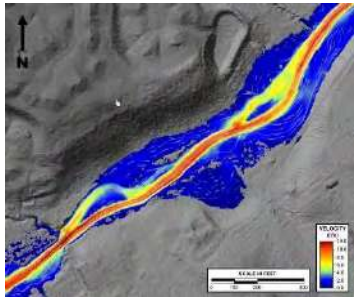
National Science Foundation

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.

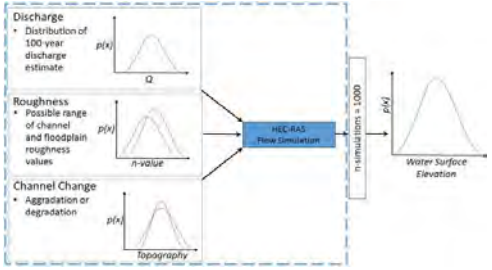
PROGRESS

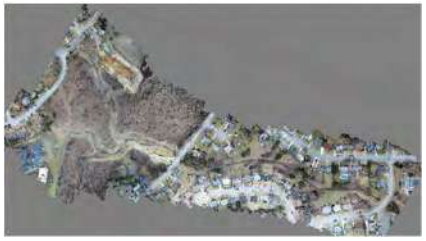
- Developed a method for conducting Monte-Carlo simulations of floodplain hydraulics to create probabilistic flood inundation maps.
- Quantified and compared the level of uncertainty around inundation probability in two hydro-climatically distinct regions.
- Constructed high-resolution topographic models 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

The objectives of the study are to:

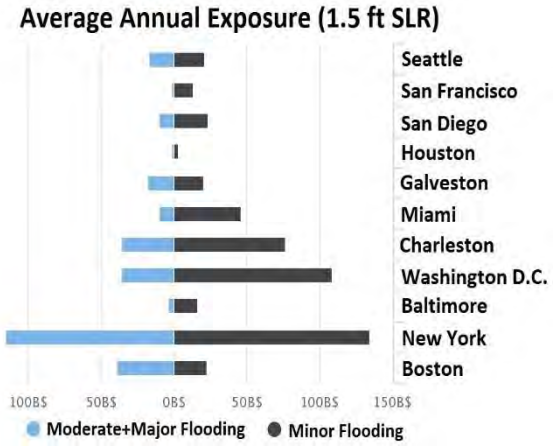
- Characterize observed and future changes in flood frequency for cities across the U.S.
- Develop a framework for assessing flood risks to assets and communities
- Assess effects of interventions and responses on the vulnerability of communities to coastal, riverine, and compound flooding

Minor Flooding in Charleston

Major Flooding in New York

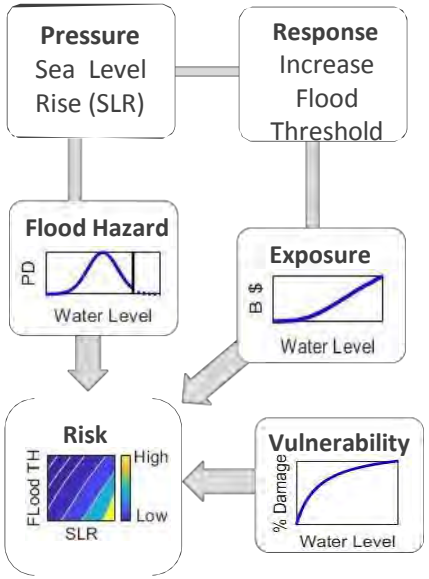
PROGRESS

- Future frequency and frequency amplification were estimated for 3 coastal flood categories (Minor, Moderate and Major) under different sea level rise scenarios.
- Current and future Average Annual Exposure from coastal flooding were estimated for 20 populated coastal cities in the United States under different sea level rise scenarios.



APPROACH

- A Mixed Normal-Generalized Pareto Distribution (GPD) probability model was developed to quantify coastal flooding risks from minor, moderate and major events under alternative sea level rise scenarios.
- Coastal flooding risks to assets, e.g. average annual losses, were assessed for 20 highly populated cities across the coastal U.S. using the probabilistic framework and FEMA's HAZUS exposure and damage databases.



ACHIEVEMENTS AND SIGNIFICANCE

- Under 1-ft sea level rise scenario, it is expected that while major flooding will become frequent along the Atlantic, Gulf, and northwest Pacific coasts, southwest Pacific coast is not likely to be vulnerable to major flooding.
- Under 2-ft sea level rise scenario, major flooding is likely to occur with multiple annual occurrences in all regions across the coastal U.S.
- Under 2-ft sea level rise scenario, locations along west pacific coast can expect very large frequency amplification in major flooding compare.
- The average annual losses exposure (and losses) in coastal cities to minor flooding will increase considerably as a result of small increases in mean sea level (i.e., up to 1-ft). However, under higher sea level rise scenarios, expected annual losses will be primarily from major flooding.

PROJECT B3-1:

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

PRODUCTS

- EWRI World Environmental & Water Resource Congress 2017: Mahshid Ghanbari, Mazdak Arabi, Current and Future Flood Losses in the Southeast Florida, 24 May 2017
- AGU Hydrology Days 2018: Mahshid Ghanbari, Mazdak Arabi, Jayantha Obeysekera, William V. Sweet, Risk to Assets and Communities from Coastal Flooding: Quantifying the effect of sea level rise and flood adaptation strategies, 19 March 2018
- International Congress on Environmental Modelling and Software 2018: Mahshid Ghanbari, Mazdak Arabi, Jayantha Obeysekera, William V. Sweet, Risk to Assets and Communities from Coastal Flooding: Quantifying the effect of sea level rise and flood adaptation strategies, 24-28 June 2018

PROJECT TEAM

- Mazdak Arabi, PI, Colorado State University
- Mahshid Ghanbari, Graduate Student, Colorado State University
- Jayantha Obeysekera, Sea Level Solutions Center, Florida International University William Sweet, NOAA, Center for Operational Oceanographic Products and Services

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

National Science Foundation

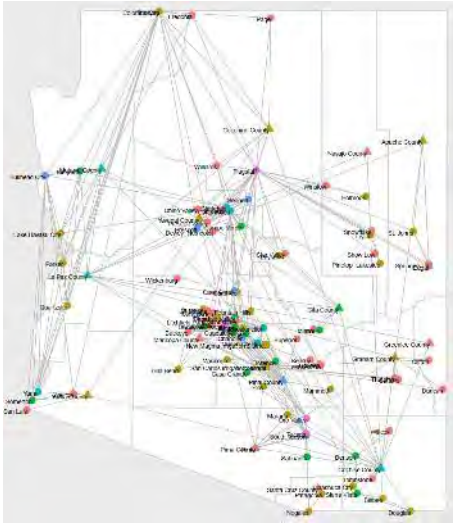
MOTIVATION AND OBJECTIVES

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?

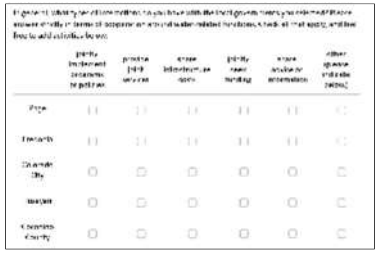
PROGRESS

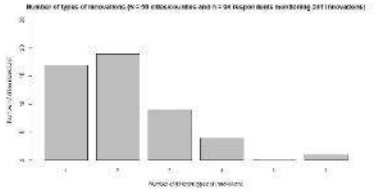
- Completed surveys of local water governments and water organizations in Arizona, including Sun Corridor region.
- Networks analysis on local government networks completed; analysis of organizational networks forthcoming.
- Sampling of water organizations in other UWIN regions complete; surveys to be implemented in AY 2018-2019.



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

- Local government innovation is related to intensity of collaboration with other local governments.
- Collaboration in turn is driven by a perception of having shred problems, and to some extent the innovativeness of other places.
- Results presented at major public management meetings, including APPAM and PMRC.

Table 1: Effect of collaboration network on water sustainability innovations

	Perceived innovativeness (logit)	Program diversity (OLS)
Degree centrality	0.279 **	0.088 *
Betweenness centrality	-0.004 #	0.000
% collaborators using GI	-0.746	-0.146
Constant coeff.	-3.518	1.477
N	69	47
R^2 (OLS) / pseudo-R^2 (logit)	0.219	0.145

Note: Regression models estimated with robust standard errors; stars indicate significance of coefficients: # p<0.1, * p<0.05, ** p<0.01, *** p<0.001.

Table 2: ERG models of network structure

	NETWORK TYPE				
	jointly implement programs	provide joint services	share infrastructure costs	jointly seek funding	share advice or information
Shared problems	0.093	-0.540 **	0.235	0.863 ***	7.292 ***
Innovative alter	0.261	0.094	0.570 *	1.618 *	6.415 ***
Triadic closure	-0.029 ***	-0.323 ***	-0.087 ***	-0.141 ***	-0.180 ***

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

PRODUCTS

- Gomez-Fernandez, E.L., A.D. Henry, G. Pivo, & A. Sanderford. October, 2017. Association of Collegiate Schools of Planning Annual Conference, Measuring Fragmentation of Water Governance in US Cities: Theory and Evidence Examined .
- Bell, E., A.D. Henry & G. Pivo, November 2017. APPAM 39th Annual Fall Research Conference, A Coding Frame to Link Policies and Beliefs.
- Henry, A.D., E.L. Gomez-Fernandez, & G. Pivo, November 2017. APPAM 39th Annual Fall Research Conference, A Network Approach to Understanding Fragmentation and Sustainability in Local Governance.
- Henry, A.D., E.L. Gomez-Fernandez, & G. Pivo, March, 2017. The International Association for the Studies of the Commons. Workshop: Multi-methods Approaches for Investigating Polycentricity in Common Pool Resources.
- Henry, A.D., L. Berger, G. Pivo, May, 2018. Network Drivers of Local Water Sustainability Innovations. 2018 Public Management Research Conference, Singapore.
- POSTER PRESENTATION: Gomez Fernandez E. Liliana, A. Henry, and G. Pivo, August, 2017. UWIN 2nd Annual Meeting, Influence of Governmental Fragmentation in Adoption of Sustainable Policies and Innovation in Urban Water Management.
- ACCEPTED ABSTRACT: Henry, Adam. E. L. Gomez-Fernandez, and G. Pivo. February 2018. Accepted for the Annual Public Management Research Conference, in May 2018. Network-Based Measurement of Functional Fragmentation in Governance Systems: An Application to Urban Water Management

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 updates and design
- Survey design and pilot testing
- Sample frame development

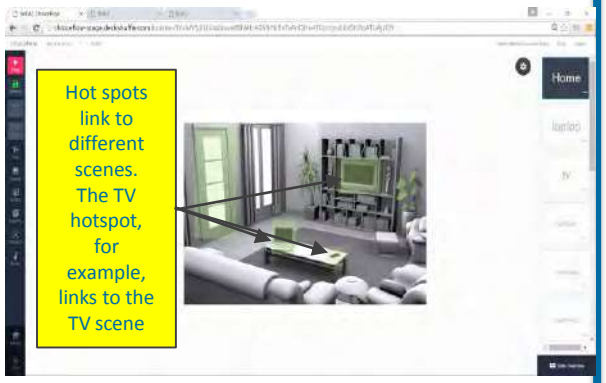
Tasks in progress

- Experiment is currently active in 5 UWIN regions
- Data collection and early analysis are underway
- Data collection should be complete by end of June

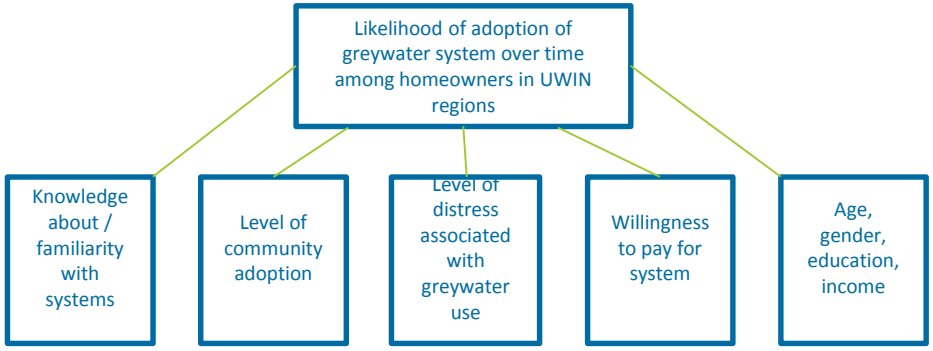
Virtual living room used for experiment

APPROACH

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



ACHIEVEMENTS AND SIGNIFICANCE



The Choiceflow software has been developed for rapid experimental design. Early results 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

National Science Foundation

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

- Conducted online, geographically-referenced survey of 9,900 households in 9 UWIN study metro-regions; multiple topics including water access, pricing, pollution, priorities for sustainable water management
- Conducted and analyzed 45 semi-structured interviews with leaders of community organizations in 8 study regions; preliminary results available soon in stakeholder communication
- Papers-in-progress with UWIN collaborators
- Participation of 10 graduate students and 4 undergraduates 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
- Interdisciplinary collaborations with urban climate modelers, hydrologists, and environmental scientists

Sample Survey Design for Miami

ACHIEVEMENTS AND SIGNIFICANCE

- Searched an extensive scientific literature on water equity for major themes and findings
- Constructed some of the first comparative regional databases on public opinion about water in the U.S.
- Enlisted several UWIN researchers to incorporate social equity or distribution of water hazards into their projects
- 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 (in press) Pathways to climate justice in a desert metropolis. In *People and Climate Change: Vulnerability, Adaptation, and Social Justice*, L.M. Reyes and J. Rigg (eds.) Oxford University Press.

4 articles in preparation (3 include students):

- A multivariate comparative index to assess pressures on water systems across scales *(led by E. Mack)*
- Environmental justice and sustainable water future for the United States: systematic review of the literature *(led by S. Harlan)*
- Narratives of water injustice across U.S. urban areas *(led by M. Sarango)*
- Community perspectives on urban water sustainability *(led by E. Wilder)*

Ortiz, D.E. (2017) Community and university partnerships to engage residents in visualizing and taking action against water pollution in Chelsea, Massachusetts. NSF-sponsored UWIN Research Experience for Undergraduates (REU) program. Report produced at Northeastern University; received graduation honors at Beloit College.

4 presentations at the American Association of Geographers annual meeting (2017 and 2018)

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

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

Northeastern students: Mariana Sarango, Stephanie Clark, Elisabeth Wilder, Lauren Contorno, Nickolas Faynshteyn, Kelsi Furman, Kiera O'Donnell, Rachel Domond, Fatuma Mohamed

Michigan State students: Sarah Wrase, Jonah White, Kyle Redican

Arizona State student: Lianzheng Mu

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

Developed a survey of Financial Officers that was reviewed with other connected UWIN projects

Tested the survey with a pilot of Financial Offices

Article on residential demand linkages between electricity and water submitted to Water Resources and Economics

Engaged Water Research Foundation and Water Environment and Reuse Foundation to distribute survey

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

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.

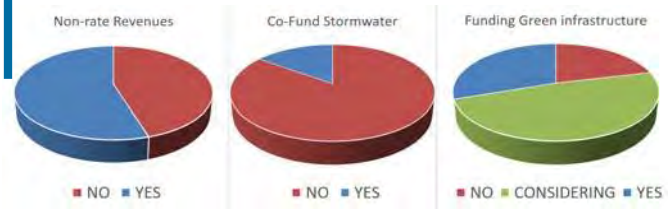
ACHIEVEMENTS AND SIGNIFICANCE

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

The project sets the stage to study financial opportunities and barriers more deeply and to promulgate study and data elements to other UWIN projects.

Quantified the current state of financial health and funding of One Water practices.

Conceptualized financial models for One Water.



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

PRODUCTS

- One Water Financial Model: From Service Provision to Resource Allocation. Neil Grigg, Theresa Connor, Alex Maas. UCOWR NIWR Conference Fort Collins. June 13-17, 2017.
- What Now? An Overview if Urban Water Infrastructure in the USA. Alexander Maas, Theresa Connor and Neil Grigg, Regions 306 Summer 2017 16-17.
- Grigg, Neil, Maas, Alexander, Connor, Theresa. Can One Water Programs Do More With Less? Water Finance and Management, August 2017.

PROJECT TEAM

- Neil Grigg, Professor of Civil and Environmental Engineering, Colorado State University
- Theresa Connor, Program Manager, One Water Solutions Institute, Colorado State University (now Program Manager, Fort Collins Water Utility)
- Alex Maas, Assistant Professor, Department of Agricultural Engineering, University of Idaho (formerly Research Associate, Colorado State University)

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

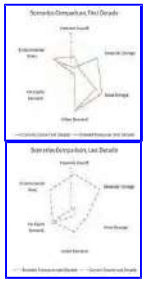
MOTIVATION AND OBJECTIVES

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 UWS sustainability indicators

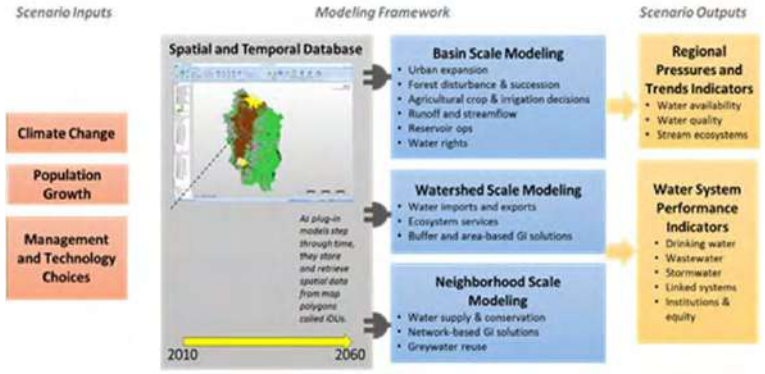
PROGRESS

- 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 Existing and Current Course at basin, watershed and neighborhood scales; developing Stressed Resources and Integrated Water Future Scenarios.
- Guided graduate and undergraduate student research to produce 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 a version of Envision model (UWINvision) for use specifically in studying urban water systems 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 the journal Landscape and Urban Planning

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

National Science Foundation

PRODUCTS

Presentations

- Santelmann, M., Haggerty, R., Hulse, D., Conklin, D., Wright, M. (2017). Project D1-1: UWIN Envision Modeling of Present and Future Values for Sustainable Water Management Blueprint Indicators. Brief prepared for UWIN Annual Meeting, Ft. Collins, Colorado. August, 2017.
- Santelmann, M., D. Hulse, D. Conklin, B. Fulfrost, M. Harrison, M. Wright and R. Haggerty. 2017. Modeling innovation in urban water systems. AWRA meeting, Portland Oregon, Nov. 10, 2017.
- Harrison, M. 2018. Investigation of Surface-Ground Water Dynamics in an Urbanized Watershed, Portland, OR. Geology Research Symposium May 2018
- Talal, M. and M. Santelmann. 2017. Vegetation biodiversity patterns and ecosystem functioning in various types of green infrastructure in Portland, OR. Urban Ecosystem Research Symposium Portland, OR. February 6, 2017.
- Talal, M. and M. Santelmann. 2017. Vegetation biodiversity patterns and ecosystem functioning in various types of green infrastructure in Portland, OR. ESA meeting, Portland, OR. August 6, 2017.
- Talal, M. and M. Santelmann. 2018. Plant greenness and health of various income-level neighborhoods in Portland, OR using Landsat 8 OLI/TIRS surface
- reflectance. Oral presentation at Urban Ecosystem Research Symposium, Portland, Oregon. Feb 5 2018.
- Greydanus, H. & M. Santelmann. 2017. Quantifying the cooling benefits of green infrastructure on air temperatures in Portland, OR. OSU REU symposium Schoner, B., M. Wright, and M. Santelmann. 2018. Using IUWM to model urban water demand in Sherwood, OR. PNW Water Research Symposium,
- Corvallis, OR April 2018.
- Papers M.V. Santelmann, D. Hulse, Maria Wright, M. Harrison, R. Haggerty. Submitted May 2018. Designing and modeling innovation across scales for urban water systems Target journal: Landscape and Urban Planning

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, University 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

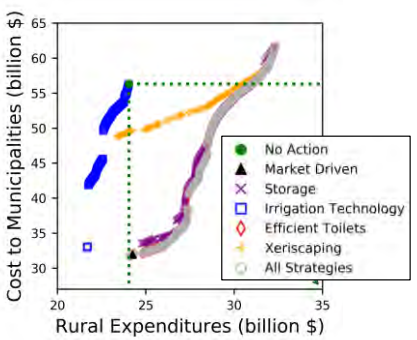
MOTIVATION AND OBJECTIVES

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

- Dozier, A. Q., Arabi, M., Wostoupal, B., Goemans, C. G., Zhang, Y., and Paustian, K. (2017). "Declining agricultural production in rapidly urbanizing semi-arid regions: Policy tradeoffs and sustainability indicators." Environmental Research Letters, 12(8), 85005. https://doi.org/10.1088/1748-9326/aa7287.

PROJECT TEAM

- Mazdak Arabi, PI, Colorado State University
- Andre Dozier, Research Scientist, Colorado State University
- Benjamin Wostoupal, 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.

PROJECT D1-3:
URBAN WATER DECISION INNOVATION SYSTEM

PRODUCTS

- Web tool for collaboratively building and disseminating scientific data and results
- A data store and web-services for data and modeling results, with MACA climate data products loaded in now

PROJECT TEAM

- Mazdak Arabi, PI, Colorado State University
- Andre Dozier, Research Scientist, Colorado State University

PROJECT E1-1:
UWIN STAKEHOLDER ENGAGEMENT

National Science Foundation

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

PROGRESS

- Training:
  - 50% graduate students
  - 2016 cohort: 42 individuals
  - 2017 cohort: 32 individuals
- Engagement:
  - 2016/2017 Stakeholder meetings summarized:
    - https://erams.com/UWIN/2016-meetings/
    - https://erams.com/UWIN/2017-meetings/
  - 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)
  - Stakeholder interviews to inform blueprint
  - Marketing strategies for water management
  - Case studies of successful urban water integration collaborations Papers

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
- Jessica Bolson
- Alicia Lanier

CITIZEN SCIENCE PROGRAM

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

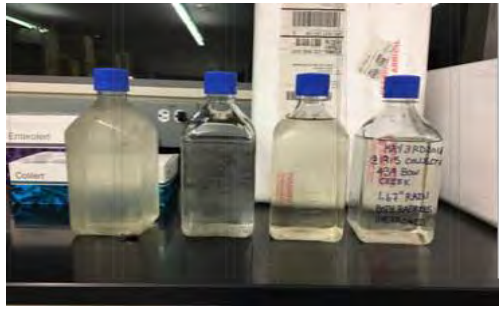
MOTIVATION AND OBJECTIVES

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

- Participants selected in Tucson, AZ, Baltimore, MD, Fort Collins, CO and Miami, FL
- Participants have installed barrels
- One trial sample collection event in Ft. Collins, CO

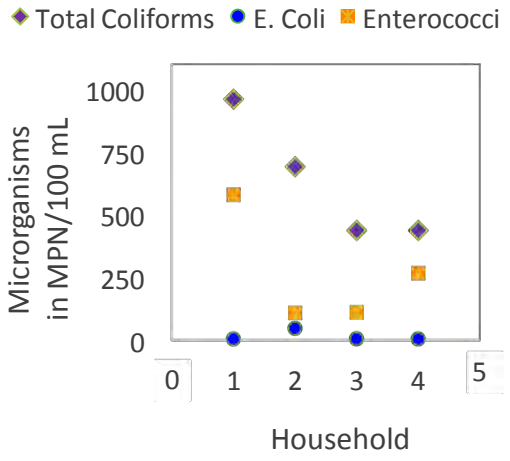


APPROACH

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 has been developed to enable large number of samples to be collected and processed for microbial quality
- Participants educated on how to install roof runoff collection system, the value of roof runoff collection and importance of roof runoff quality



CITIZEN SCIENCE PROGRAM

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

PRODUCTS

CitSci.org website

PROJECT TEAM

Academic Team:

Sybil Sharvelle, Associate Professor, Colorado State University
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Alan Berkowitz, Plant Ecologist, Cary Institute of Ecosystem Studies Mike Sukop, Professor, Florida International University
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