

Acknowledgements

- P.I., **Connecting the Smart-City Paradigm with a Sustainable Urban Infrastructure Systems Frame- work to Advance Equity in Communities**, NSF(Award 1737633), \$2.5 M, 9/1/2017 - 8/31/2020.
- Co-P.I., **Planning Grant: Engineering Research Center for Intelligent Infrastructure for Safe, Efficient and Resilient Mobility**, NSF,(Award [1840432](#)), 97K, 9/18-8/19, (with A. Misra, U of Kansas, et al.).
- Co-P.I., *Cloud-Connected Delivery Vehicles: Boosting Fuel Economy Using Physics-Aware Spatio- temporal Data Analysis and Real-Time Powertrain Control*, USDOE ARPA-E, \$1.78M (1.4M fed.), 2/17 - 2/20. (with W. Northrop)
- P.I., *Identifying and Analyzing Patterns of Evasion* (HM0210-13-1-0005), USDOD-NGA, \$0.6M, 6/13- 12/18.
- Co-P.I., *Increasing Low-Input Turfgrass Adoption Through Breeding, Innovation, and Public Education*, USDA/NIFA/SCRI (contract 2017-51181-27222), \$5.4 M, 9/17 - 8/21. (with E. Watkins et al.).



A Service Announcement

New from CRA: Database of Candidates for Academic and Industrial/Government Laboratory Positions

In: [November 2018, Vol. 30/No.10, Current Issue](#)

CRA has started a new service intended to improve the recruiting process for academic and industrial/government laboratory research positions.

Candidates for these positions can upload their resumes, research and teaching statements, job objectives and other preferences, and a link to a presentation video. Recruiting officers with access are able to search this information and are encouraged to contact candidates.

The database can be accessed through <https://cra.org/cv-database/>. For further information, including an instructional video, visit: <https://cra.org/cv-database/#Info>.



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OUTLINE

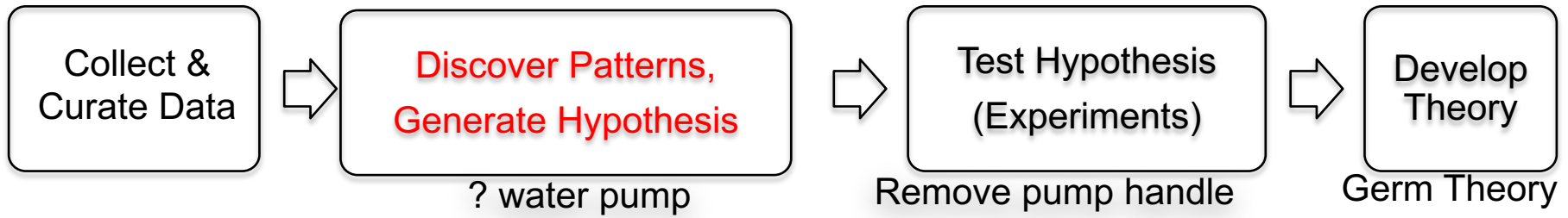
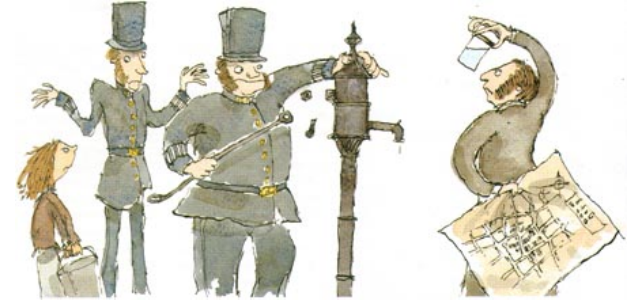
- ❑ Motivation
 - ❑ Spatial Methods and Industrial Cities
 - ❑ Spatial Computing in Modern Cities
- ❑ Knowledge Co-production (KC)
- ❑ KC Story 1: Evacuation Planning
- ❑ KC Story 2: A S&CC Project
- ❑ Conclusions



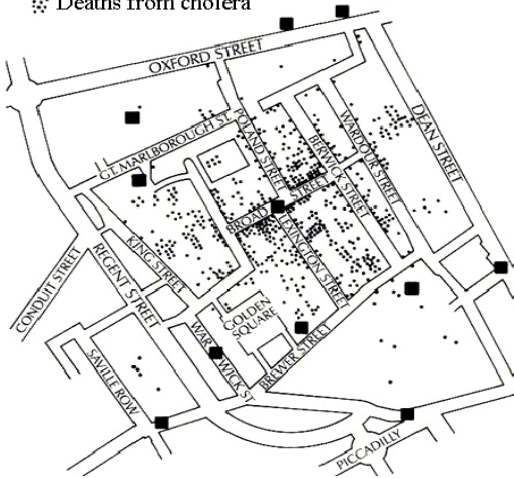
History of Transforming Cities with Spatial Computing

1854: What causes Cholera?

Miasma theory



■ Pump sites
⊞ Deaths from cholera



Impact on cities:

Health & well-being, parks,
sewer system to protect
drinking water, ...



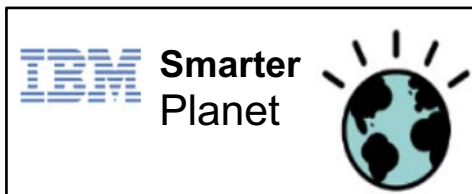
Q? What are Choleras of today?
Q? How may Spatial Computing Help?



Spatial Computing Examples



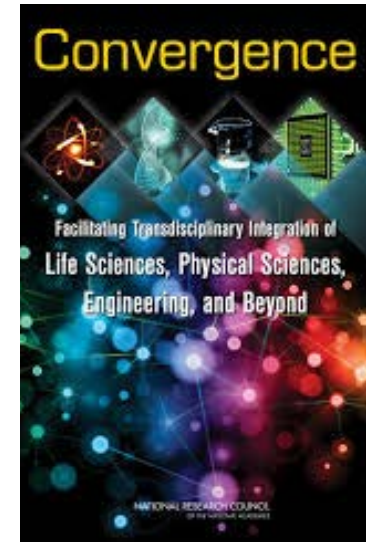
Google Earth Engine



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What is Spatial Computing?

- A **convergence** of **revolutions** in sub-areas
 - Positioning, e.g., GPS, wi-fi, ...
 - Remote Sensing, e.g., nano-satellites, cloud-hosted data
 - GIS, e.g., virtual globes, Geo-design, ...
 - Spatial Data Science, e.g., spatial data mining, ...
 - Spatial DBMS, e.g., SQL3/OGC
- To solve Societal Problems
 - Food : Precision Agriculture, Global Agriculture Monitoring, ...
 - Mobility : Navigation, e.g., Google Maps
 - Mobility : Ride-sharing services, e.g., Uber, Didi, ...
- Details:
 - Spatial Computing, Communications of the ACM, 59(1), Jan. 2016.



The Changing World of Spatial Computing

	Last Century	Last Decade
Map User	Well-trained few	Billions
Mappers	Well-trained few	Billions
Software, Hardware	Few layers, e.g., Applications: Arc/GIS, Databases: SQL3/OGIS	Almost all layers
User Expectations & Risks	Modest	Many use-case & Geo-privacy concerns



Spatial Computing is a Critical Infrastructure Today!

- 2 billion GPS receivers in use, will hit 7 billion by 2022.
- Besides location, it **reference time** for critical infrastructure
 - Telecommunications industry
 - Banks
 - Airlines...
- GPS is the single point of failure for the entire modern economy.
- 50,000 incidents of deliberate (GPS) jamming last two years
 - Against Ubers, Waymo's self-driving cars, delivery drones from Amazon



Bloomberg Businessweek

July 25, 2018, 4:00 AM CDT

The World Economy
Runs on GPS. It Needs a
Backup Plan

Source: <https://www.bloomberg.com/news/features/2018-07-25/the-world-economy-runs-on-gps-it-needs-a-backup-plan>

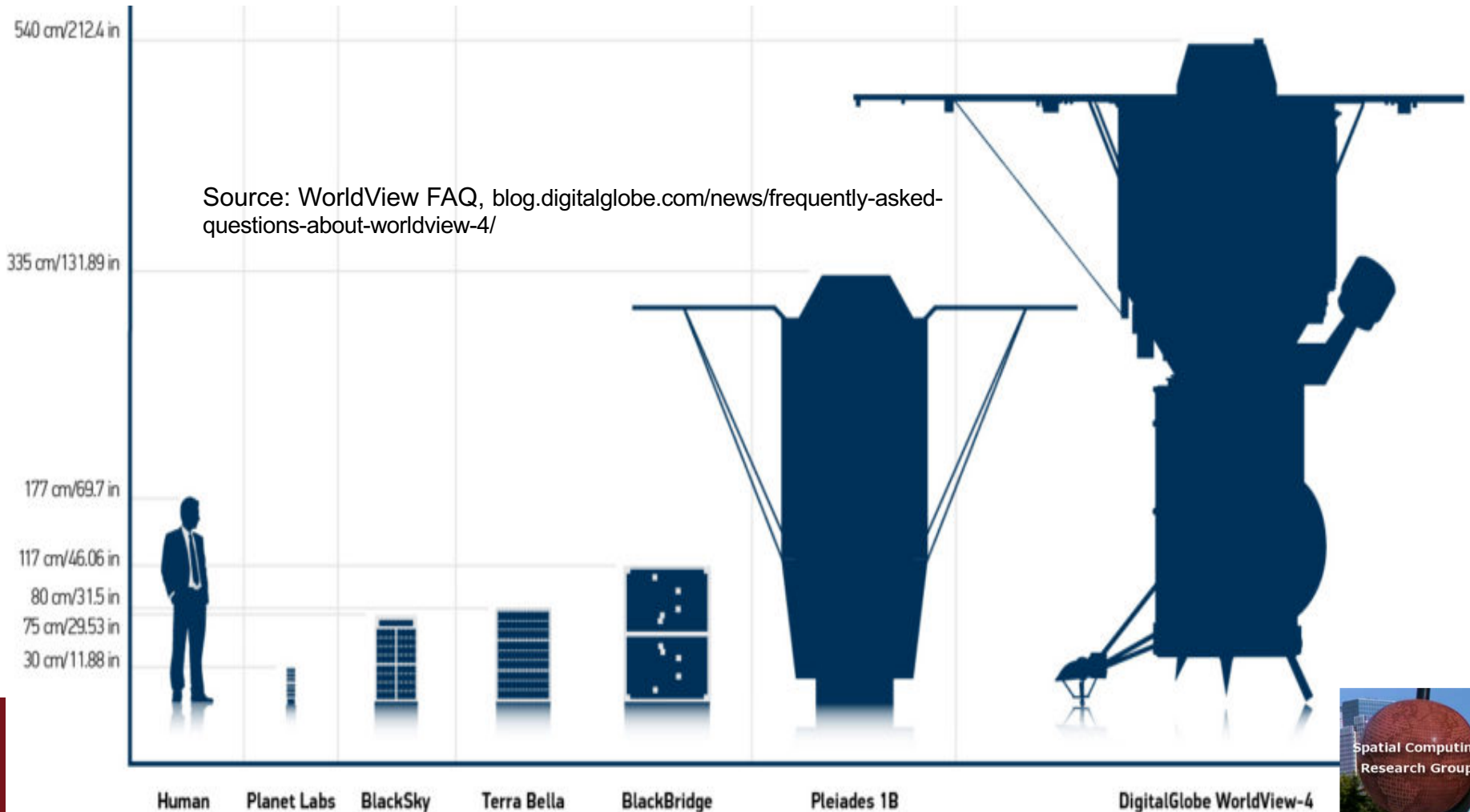


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Large Constellations of Small Satellites

- **Hi-frequency** time-series of imagery of entire earth
- **Large Constellations** Ex. Planet Labs: 100 satellites: daily scan of Earth at 1m resolution



Cheap (or free) satellite data on cloud computers

- 2008: USGS gave away 35-year Landsat satellite imagery archive
 - Analog of public availability of GPS signal in late 1980s
- 2017: Many cloud-based Virtual collaboration environment
 - Explosion in machine learning on satellite imagery to map crops, water, buildings, roads, ...

	Google Earth Engines	NEX	AWS Earth
Elevation, Landsat, LOCA, MODIS, NAIP	x	x	x
NOAA	x		x
AVHRR, FIA, GIMMM, GlobCover, NARR, TRIMM, Sentinel-1	x	x	
IARPA, GDELT, MOGREPS, OpenStreetMap, Sentinel-2, SpaceNet (building/road labels for ML)			x
CHIRPS, GeoScience Australia, GMap, NASS, Oxford Map, PSDI, WHRC, WorldClim, WorldPop, WWF,	x		
BCCA, FLUXNET		x	



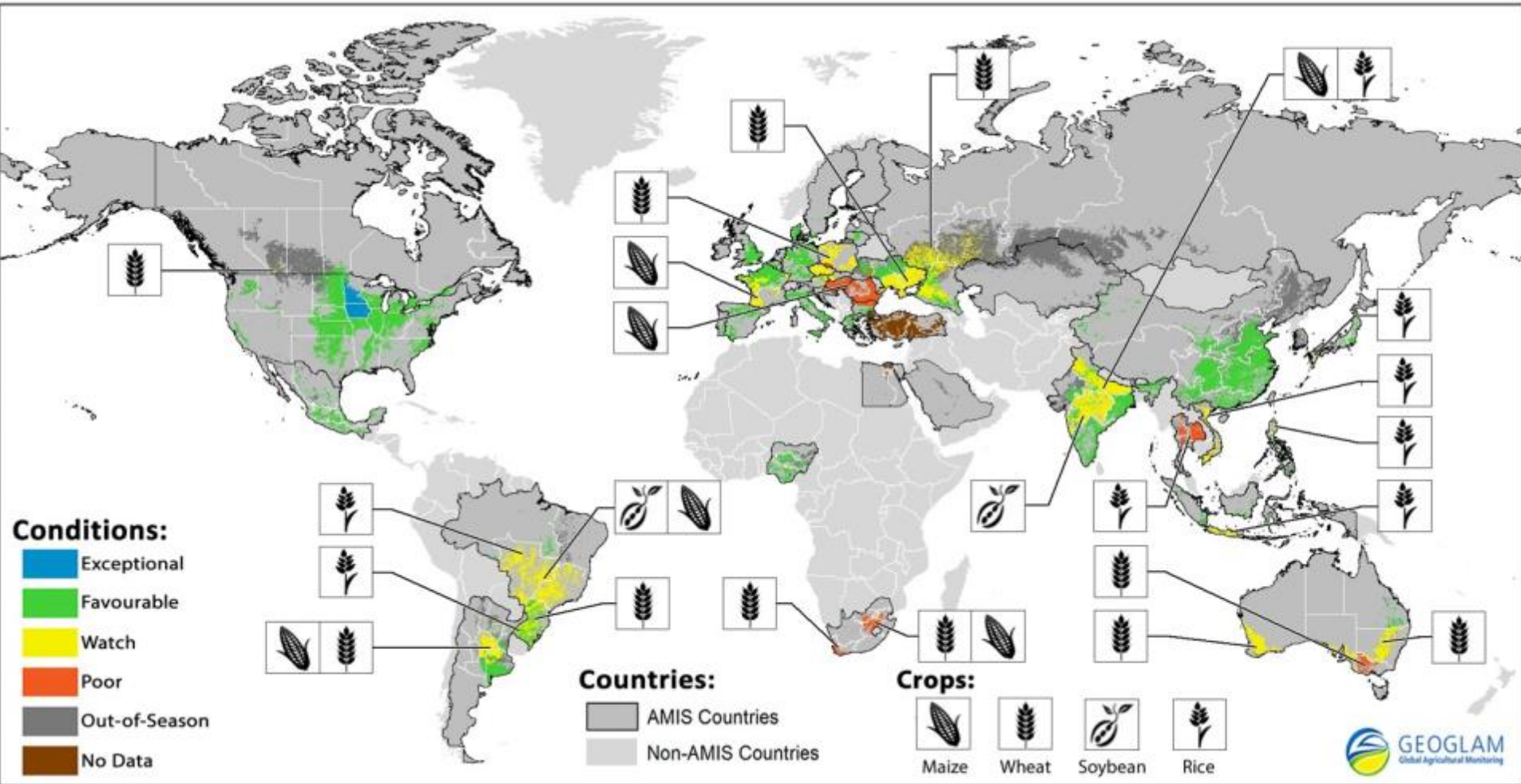
Google Earth Engine



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Global Agriculture Monitoring



Agricultural Market Information System



GEOGLAM
Global Agricultural Monitoring



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A UCGIS Call to Action:

Bringing the Geospatial Perspective to Data Science Degrees and Curricula

Data that are geographically referenced or contain some type of location markers are both common and of high value (e.g., data subject to state-specific policies, laws and regulations; demographic data from the census; location traces of smartphones and vehicles; remotely sensed imagery from satellites, aircraft and small unmanned aerial vehicles; volunteered geographic information; geographically referenced social media postings). A 2011 McKinsey Global Institute report estimates a value of “about \$600 billion annually by 2020” from leveraging personal location data² to reduce fuel waste, improve health outcomes, and better match products to consumer needs. Spatial data are critical for societal priorities such as national security, public health & safety, food, energy, water, smart cities, transportation, climate, weather, and the environment. For example, remotely-sensed satellite imagery is used to monitor not only weather and climate but also global crops³ for early warnings and planning to avoid food shortages.



University Consortium for
GEOGRAPHIC INFORMATION SCIENCE

Summer 2018



One Size Data Science Does not Fit All Data!

However, spatial data presents unique data science challenges. Recent court cases that address gerrymandering, the manipulation of geographic boundaries to favor a political party, offer a high-profile example. Instances of such exploitation of the modifiable areal unit problem (or dilemma) is not limited to elections since the MAUP affects almost all traditional data science methods in which results (e.g., correlations) change dramatically by varying geographic boundaries of spatial partitions. The fundamental geographic qualities of spatial autocorrelation, which assumes properties of geographically proximate places to be similar, and geographic heterogeneity, where no two places on Earth are exactly alike, violate assumptions of sample independence and randomness that underlie many conventional statistical methods. Other spatial challenges include how to choose between a plurality of projections and coordinate systems and how to deal with the imprecision, inaccuracy, and uncertainty of location

A UCGIS Call to Action:

Bringing the Geospatial Perspective to Data Science Degrees and Curricula



Summer 2018



Spatial Data Science Tools

measurements. To deal with such challenges, practitioners in many fields including agriculture, weather forecast, mining, and environmental science incorporate *geospatial data science*⁴ methods such as spatially-explicit models, spatial statistics⁵, geo-statistics, geographic data mining⁶, spatial databases⁷, etc.

⁴ Y. Xie et al., [Transdisciplinary Foundations of Geospatial Data Science, *ISPRS Intl. Jr. of Geo-Informatics*](#), 6(12):395-418, 2017. DOI: [10.3390/ijgi6120395](#).

⁵ N. Cressie, [Statistics for Spatial Data](#), Wiley, 1993 (1st ed.), 2015 (Revised ed.).

⁶ H. Miller and J. Han, [Geographic Data Mining and Knowledge Discovery](#), CRC Press, 2009 (2nd Ed.).

⁷ S. Shekhar and S. Chawla, [Spatial Databases: A Tour](#), Prentice Hall, 2003.

A UCGIS Call to Action:

Bringing the Geospatial Perspective to Data Science Degrees and Curricula

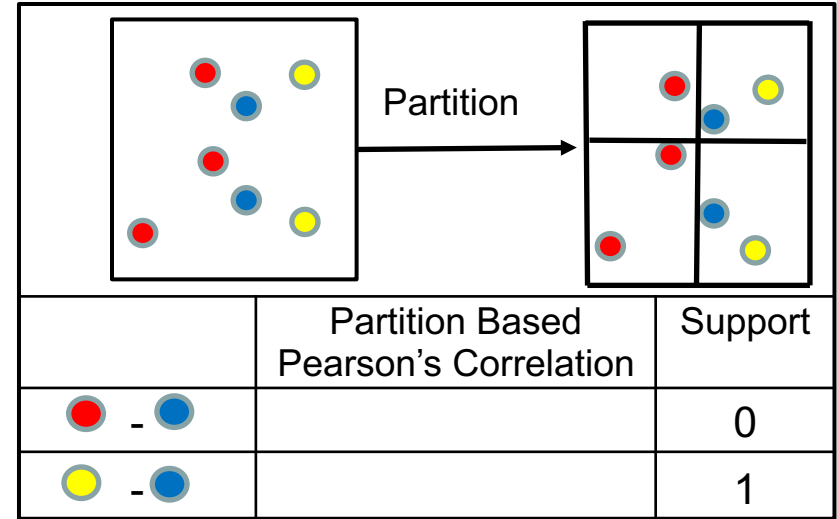
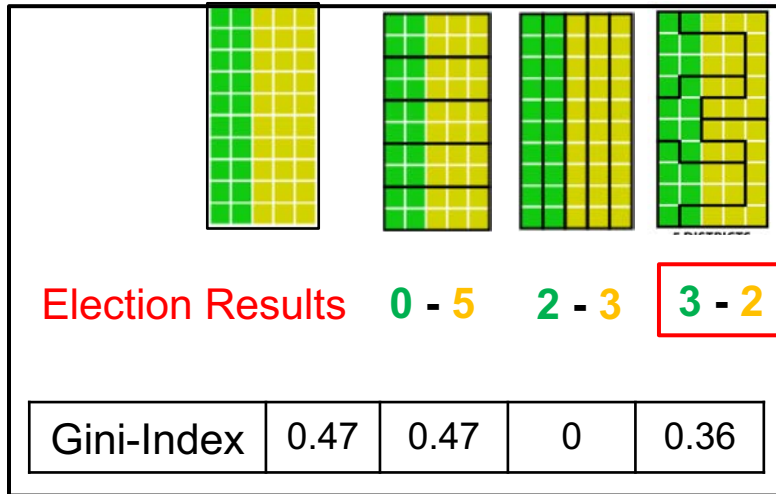


Summer 2018



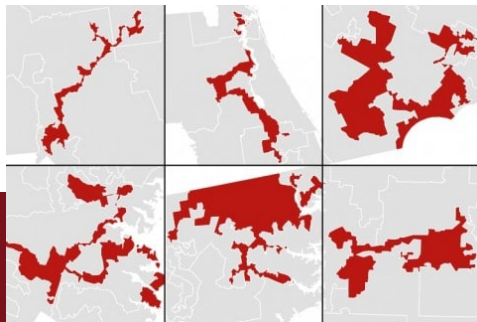
Spatial Partitioning: Gerrymandering

- Space partitioning **affects** statistical results!
 - **Gerrymandering Elections**, Correlations
 - Modifiable Areal Unit Problem (MAUP) Dilemma



Gerrymandering, a Tradition as Old as the Republic, Faces a Reckoning

Supreme Court to hear arguments on whether contorted voting maps drawn by both parties to cement power have finally gone too far



THE WALL STREET JOURNAL.

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Spatial Computing in Modern Cities

Rank	2015	2016	2017
1	(69%) Geospatial / Mapping	(93%) Public Meeting records	(53%) GeoSpatial / Mapping
2	(67%) Virtualization	(92%) Wireless Infrastructure	(48%) Cybersecurity
3	(60%) Performance Benchmarks	(91%) Redundant/ Offsite Data Storage	(34%) Predictive Policing
4	(58%) Transaction Processing	(90%) Endpoint Security	(32%) eDiscovery
5	(57%) Project Management	(85%) Broadband Infrastructure	(20%) Predictive Analytics

Source: Digital Cities Survey, Center for Digital Government, GovTech.com, 11/9/2017.



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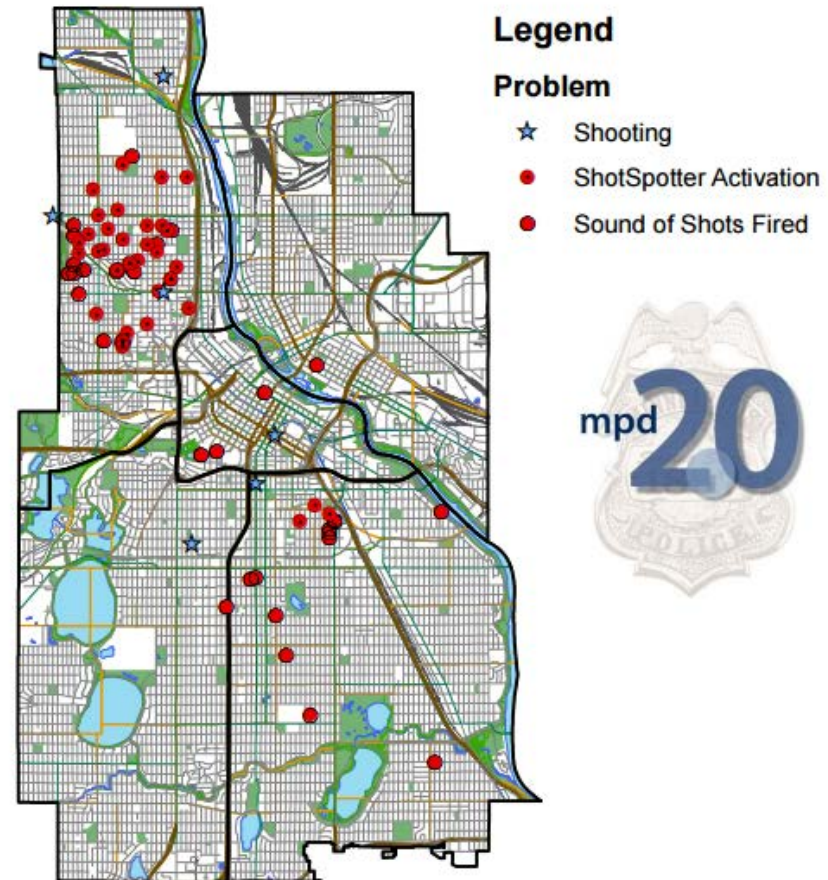
Operational Use: Emergency Services

- Gun-shot detection
 - triangulate from microphones
- E-911: Locate cell-phone calling 911
- Reverse 911
- CMAS, PLAN: Geo-targeted Alert &
- ...



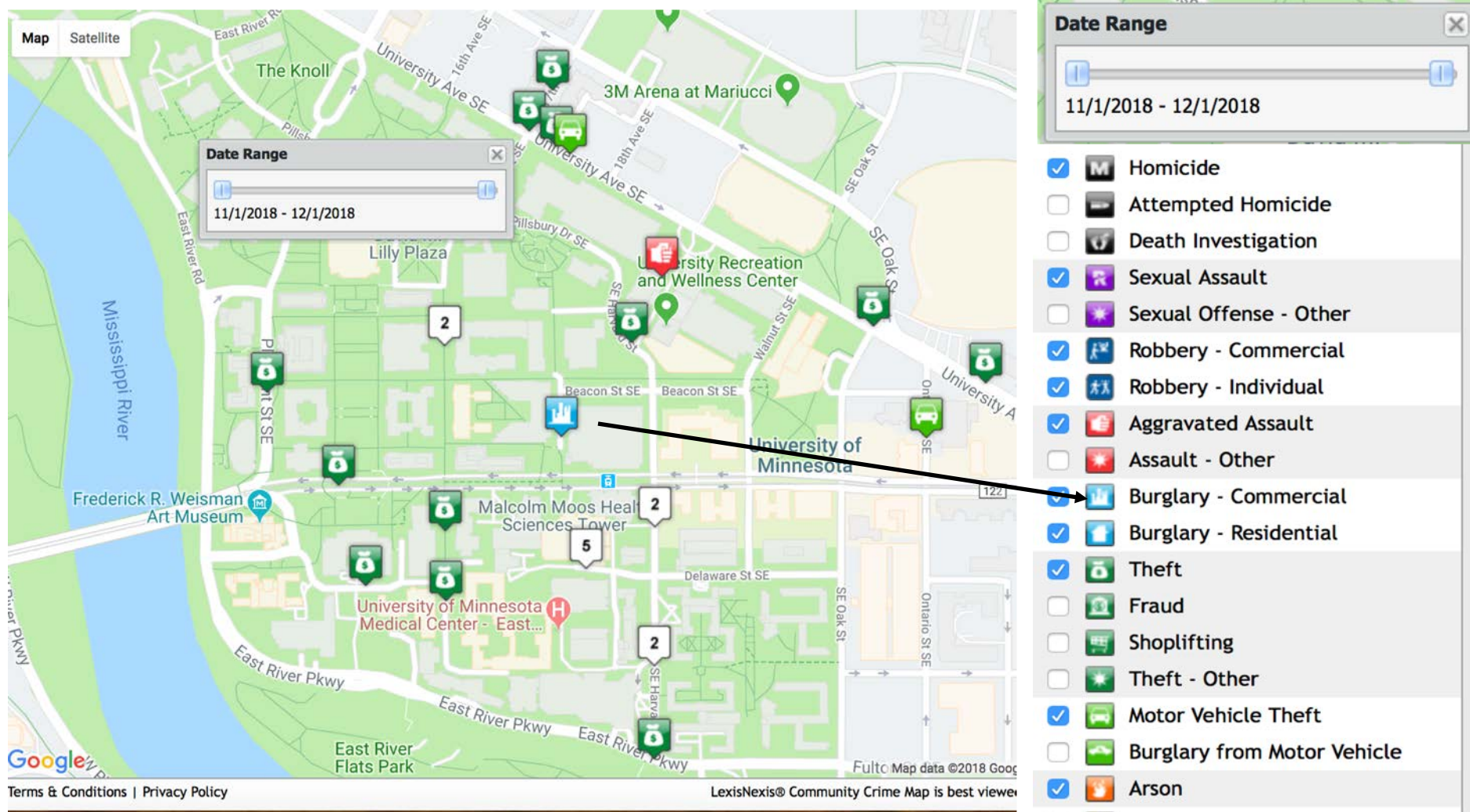
GEOTARGETED
ALERTS AND WARNINGS

Minneapolis Calls for Service Shooting - Sound of Shots Fired - Shotspotter Activation December 6, 2016 - December 12, 2016



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Operational Use: Crime Mapping



- Sources: www.ci.minneapolis.mn.us/police/statistics, communitycrimemap.com



Operational Use: Early Warning Systems

- Monitoring Tweets for disaster events & location

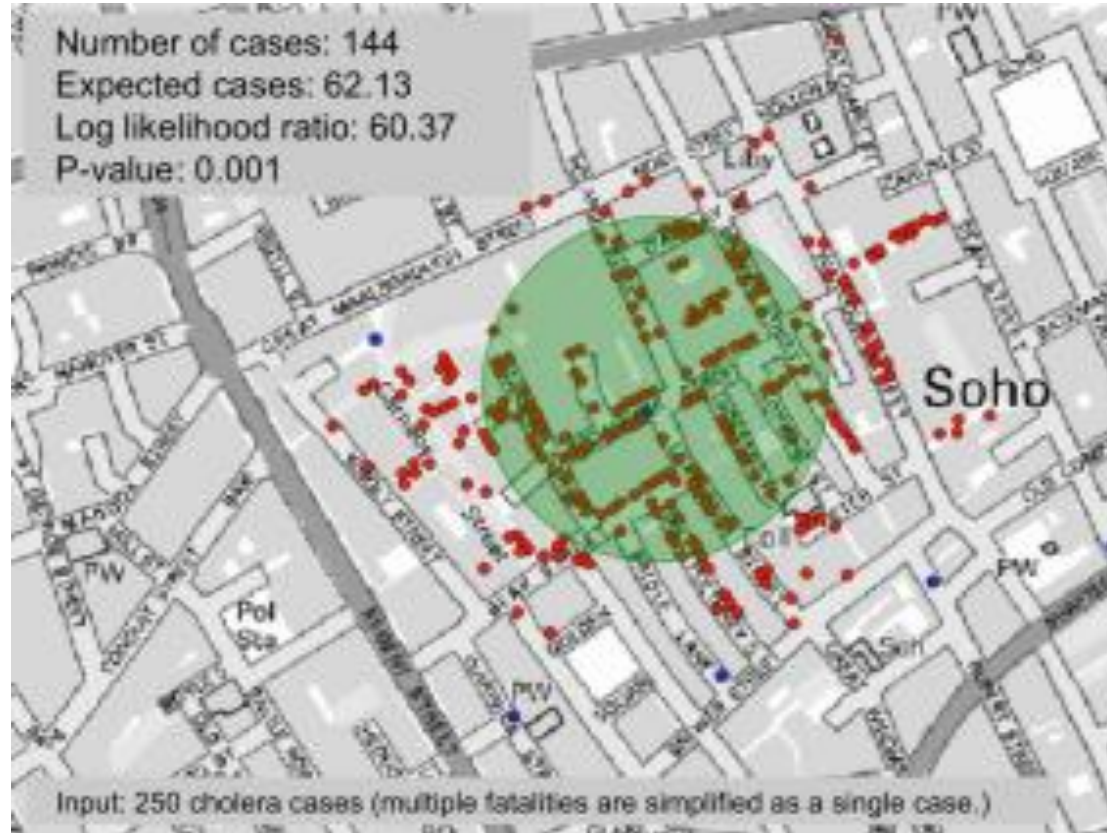
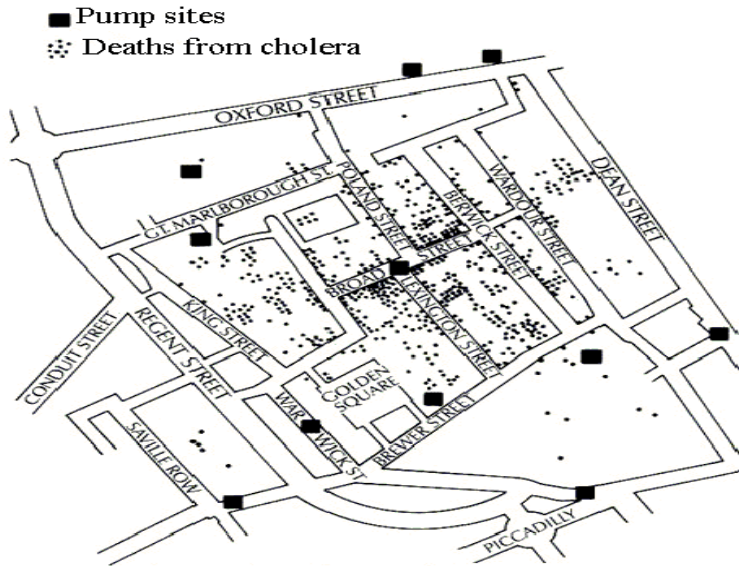


Even **before cable news** outlets began reporting the **tornadoes** that ripped through **Texas** on Tuesday, a **map** of the state **began blinking red** on a screen in the **Red Cross'** new **social media monitoring center**, **alerting** weather watchers that something was happening in the **hard-hit area**. (AP, April 16th, 2012).



Tactical Use: Hotspots

- The 1854 Asiatic Cholera in London
 - Near Broad St. water pump except a brewery



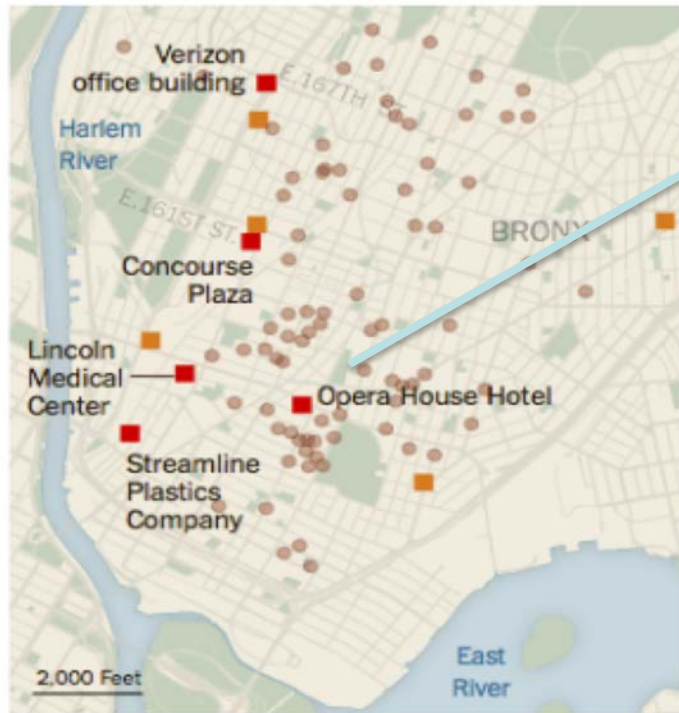
Hotel That Enlivened the Bronx Is Now a 'Hot Spot' for Legionnaires'

By WINNIE HU and NOAH REMNICK AUG. 10, 2015

Contaminated Cooling Towers

Five buildings have been identified as the potential source of the Legionnaires' disease outbreak in the South Bronx.

- Possible sources of Legionnaires' outbreak
- Additional sites found with legionella bacteria
- Locations of people with Legionnaires'

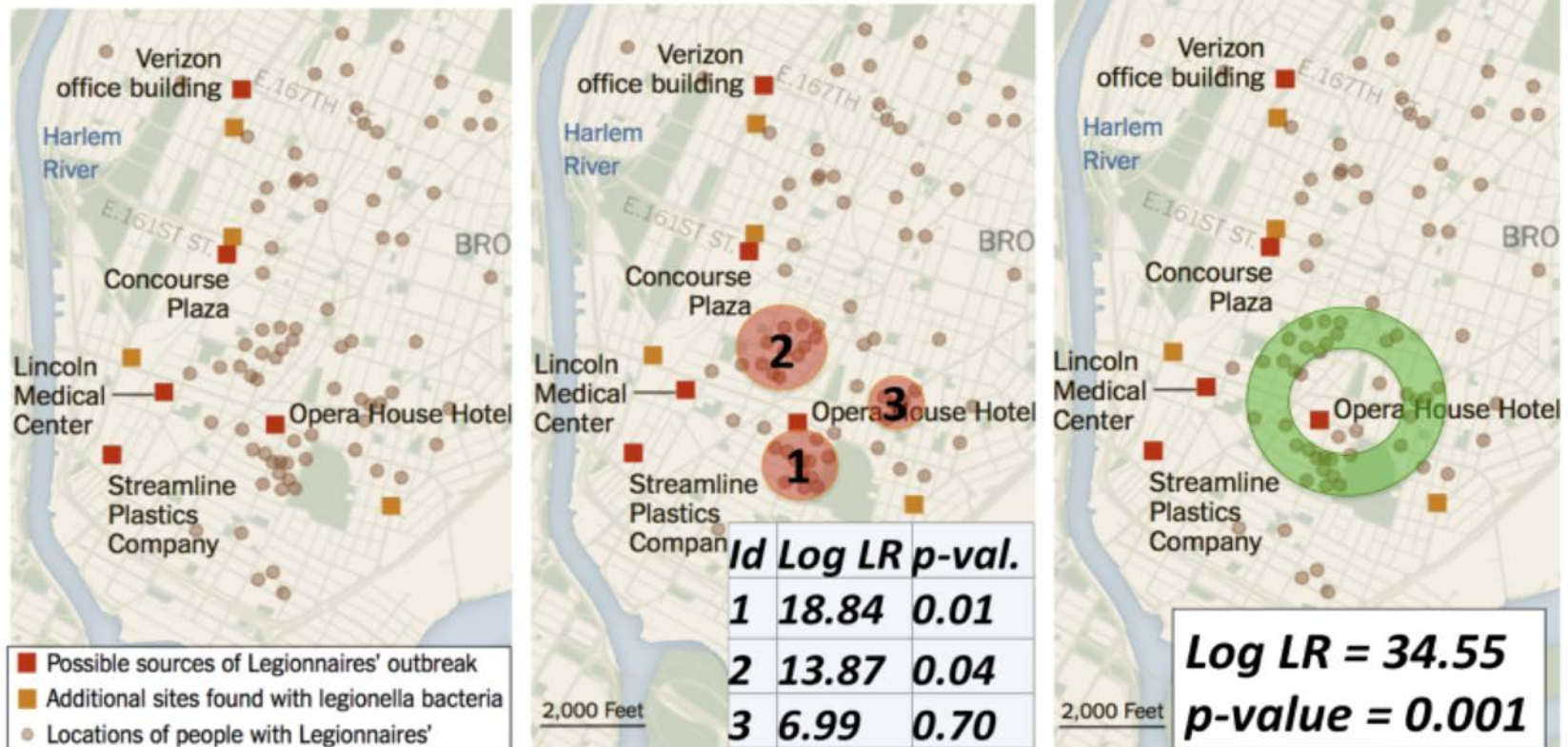


Source: New York Mayor's Office
By The New York Times



The Opera House Hotel is at the center of the outbreak. Edwin J. Torres for The New York Times

Legionnaires' Disease Outbreak in New York



(a) Legionnaire's in New York (2015) (b) Output of SaTScan (c) Output of RHD

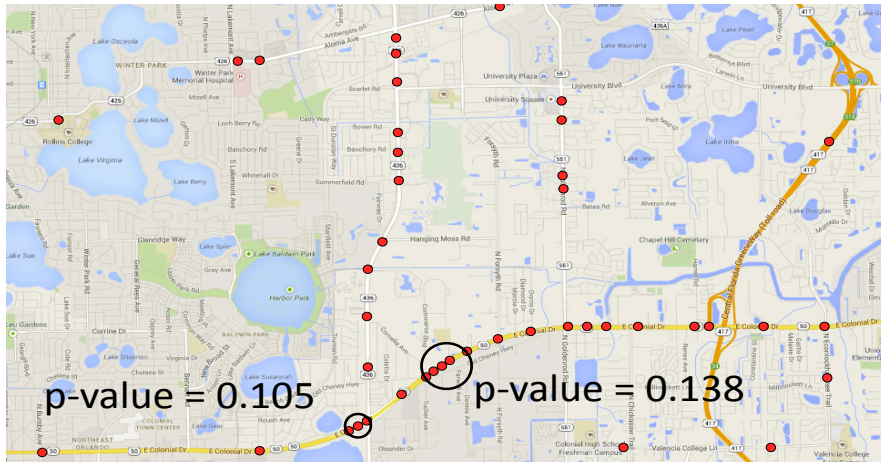
Details: Ring-Shaped Hotspot Detection, IEEE Trans. Know. & Data Eng., 28(12), 2016.

(A Summary in Proc. IEEE ICDM 2014) (w/ E. Eftelioglu et al.)

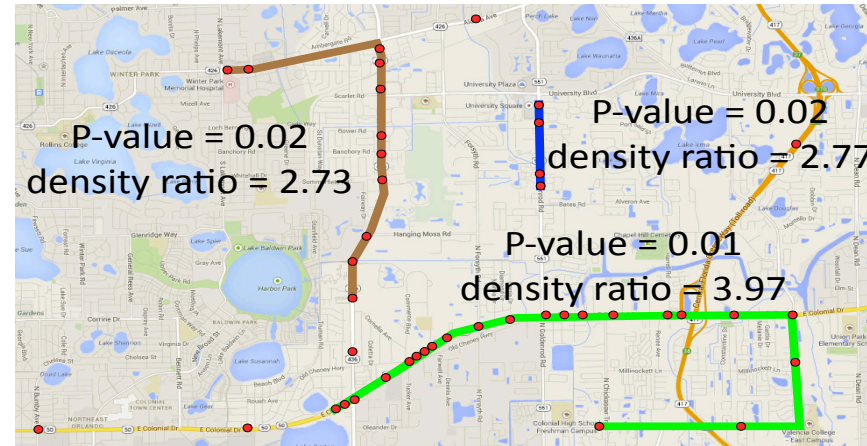
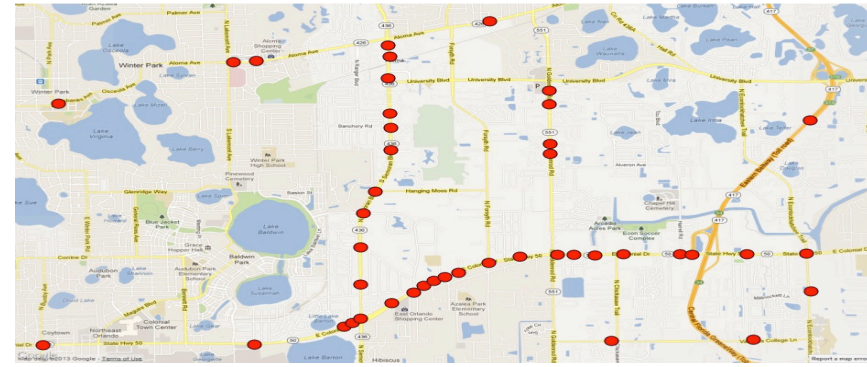


Tactical Use: Linear Hotspots

- Urban data, e.g., road accidents
- Ex. Pedestrian fatalities, Orlando, FL



Circular hotspots (SatScan)



Linear hotspots

Details: Significant Linear Hotspot Discovery, IEEE Transactions on Big Data, 3(2):140-153, 2017.
(Summary in Proc. Geographic Info. Sc., Springer LNCS 8728:284-300, 2014.)

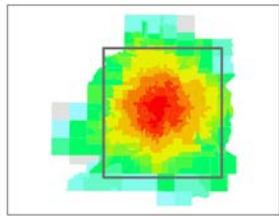


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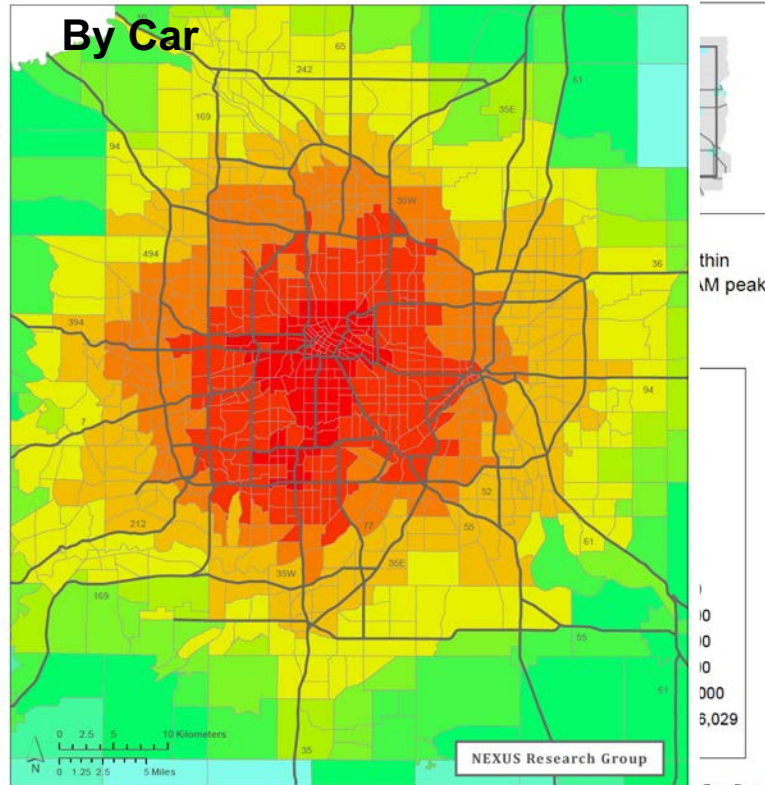
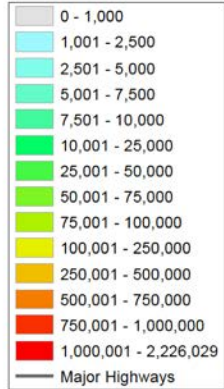


Strategic Use: Mapping Accessibility

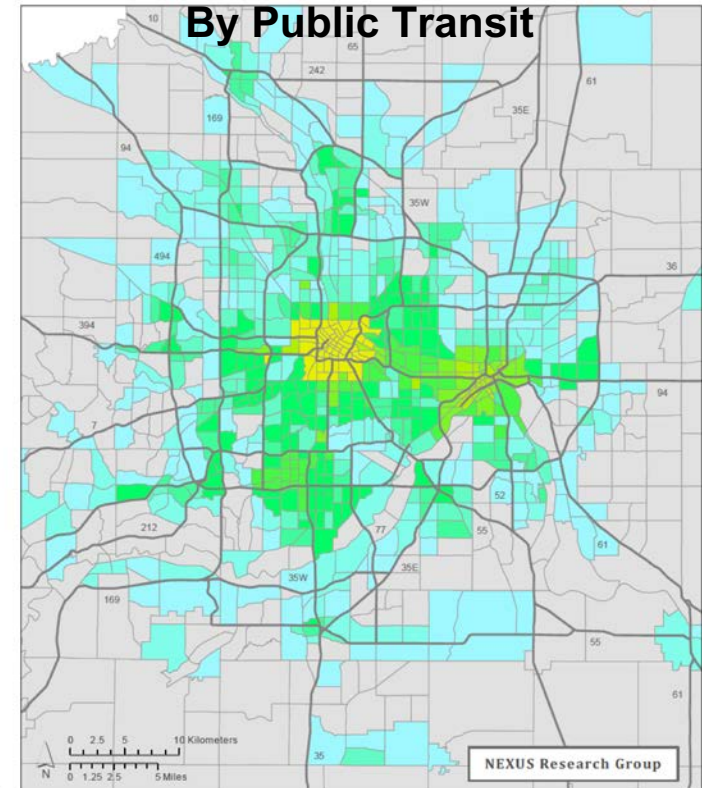
- Number of jobs Accessible in a 20-minute trip during AM rush hour 2010



Jobs accessible within
20 minutes by car (AM peak)
2010



thin
(AM peak)



Zone Boundaries
s Metropolitan Council, US Census Bureau

Zone Structure Displayed: Traffic Analysis Zone Boundaries
Primary Data Sources: MnDOT, Twin Cities Metropolitan Council, US Census Bureau

- Source: A. Owens, D. Levinson, Access to Destination, UMN CTS Report MN/RC 2012-34.



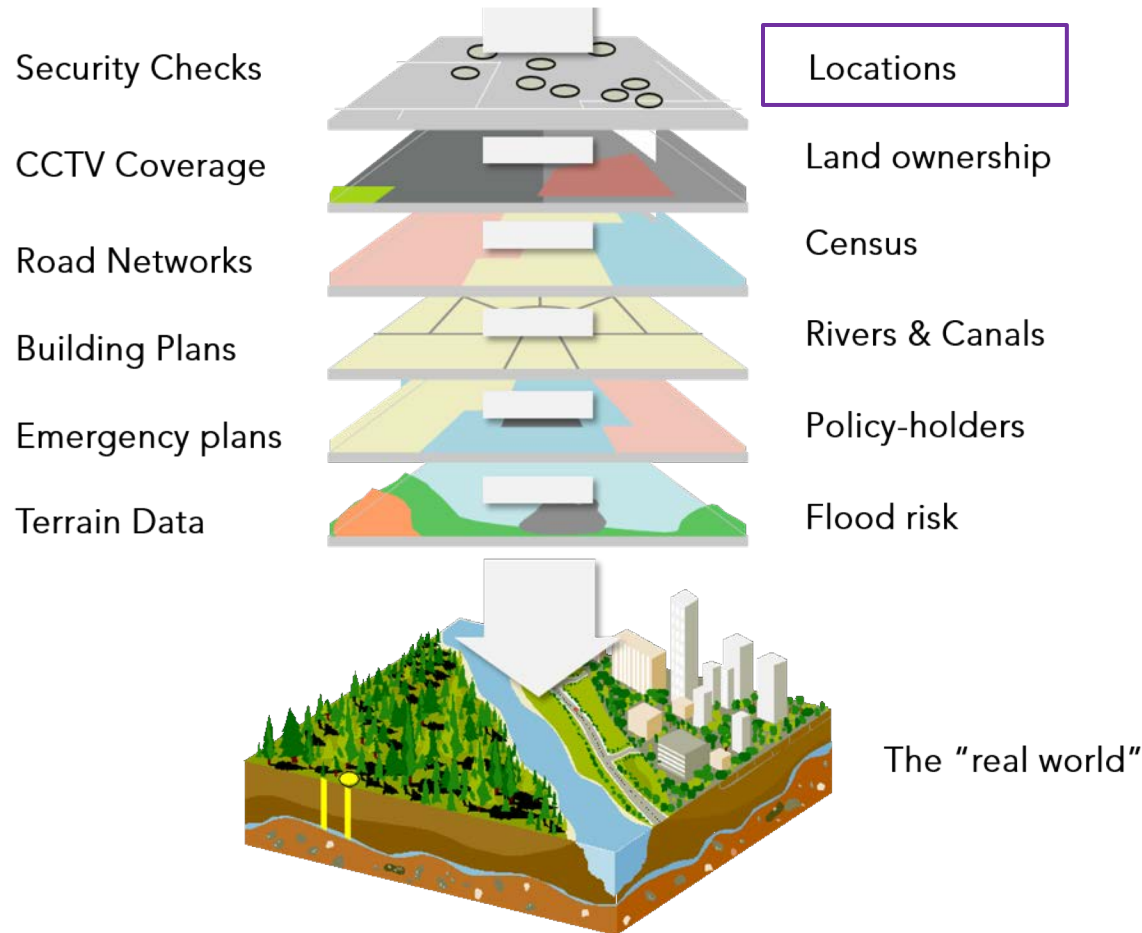
Strategic Use: Change Monitoring

- Google Timelapse:
 - Ex. MSP & Minneapolis 1984-2016
 - Global 29-frame video
 - 260,000 CPU core-hours
- Spatio-temporal Resolution
 - Planet Labs. : **daily** 1m (visual bands)



Spatial Computing in Modern Cities

- Operational
 - E-911, CMAS/PLAN
 - Early Warning
 - Situation awareness
 - Public Safety, e.g., Floods
- Tactical
 - Hotspot Detection
 - Property tax
 - Site selection
 - Asset tracking
- Strategic
 - Land-use change monitoring
 - Long-term planning



Source: <https://www.cbronline.com/wp-content/uploads/2017/03/what-is-GIS.png>



Outline

- ❑ Motivation
- ❑ **Next: Knowledge Co-production (KC)**
- ❑ KC Story 1: Evacuation Planning
- ❑ KC Story 2: A S&CC Project
- ❑ Conclusions



Source: The Sheffield Mental Health Guide,
sheffieldflourish.co.uk, 5 Apr 2017.

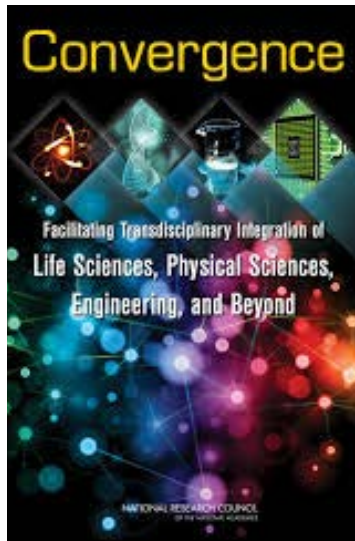


Advancing Science Discovery to Application

- Convergence
 - Solve **societal grand challenges**
 - Harness Spatial Data Revolution, e.g., Cloud hosted satellite imagery, GPS trajectories,
 - Power AI, e.g., CNN, to map buildings, roads, trees, ...



SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD



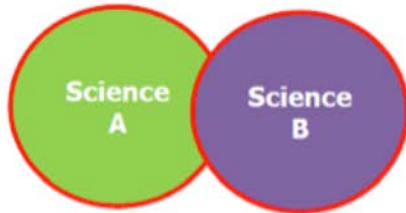
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Collaborate with Stakeholders

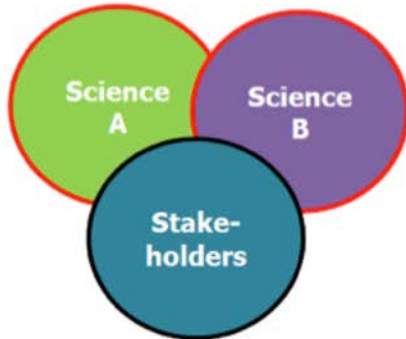
- Convergence: Solve societal grand challenges via **Transdisciplinary Research**
- Knowledge **co-production** with stakeholders



Disciplinary research within academia



Interdisciplinary (multidisciplinary) research within academia



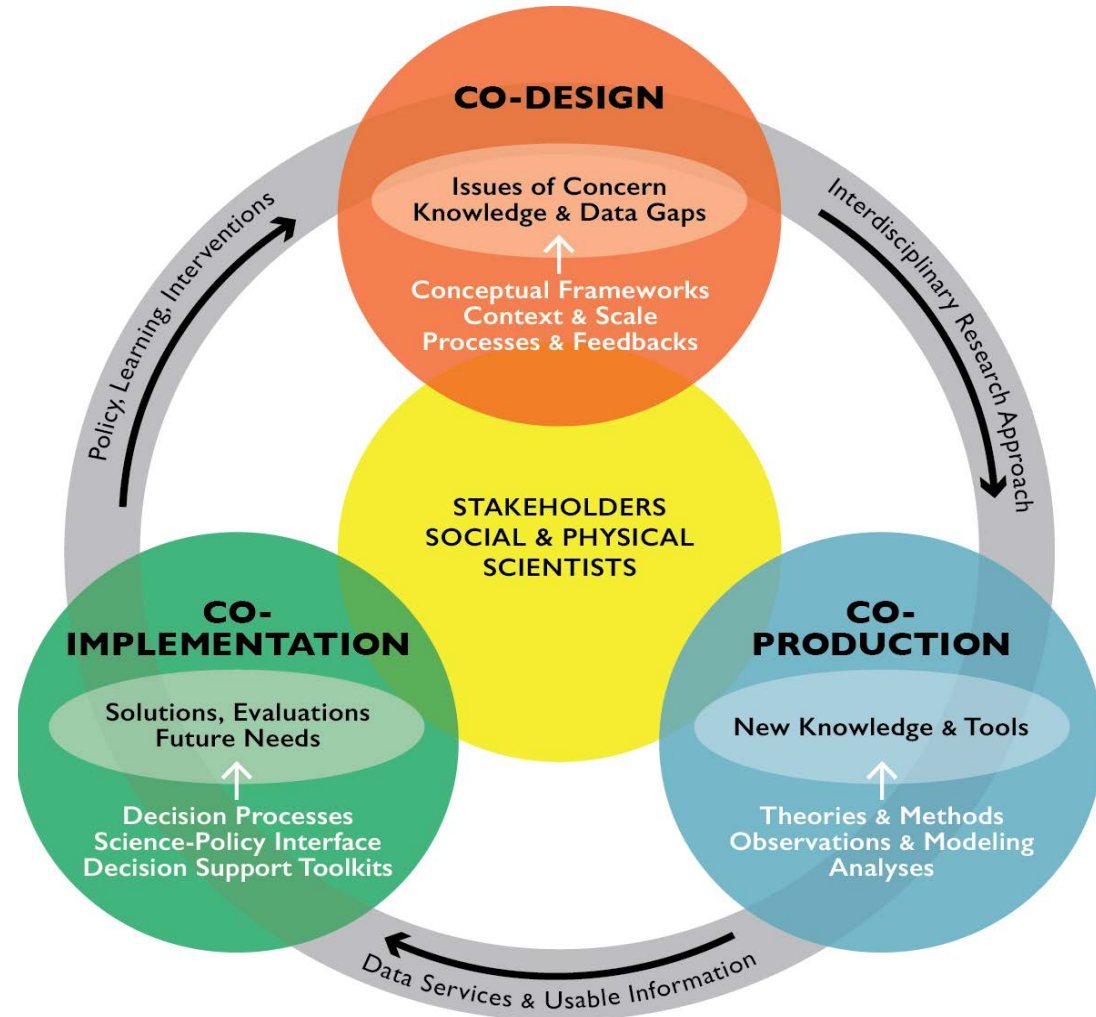
Transdisciplinary research goes beyond academia and involves stakeholders from policy, civil society etc.

Source: <https://www.thearcticinstitute.org/future-of-arctic-research/>



Knowledge Co-Production with Stakeholders

- Knowledge **co-production**
 - Co-Visioning
 - Co-define Problems
 - Co-select Science Questions
 - Co-Evaluate Discoveries
- Ex. NCAR



Source: [NCAR/UCAR 2016 Annual Report](#)

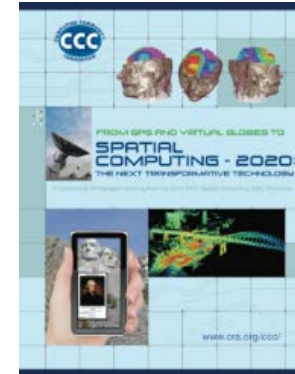


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Knowledge Co-Production

- **Co-production Initiatives**

- CRA/CCC Visioning Workshops
- (Midwest) Big Data Hubs & Spokes
- NSF Sustainability Research Networks
- NSF Smart & Connected Community

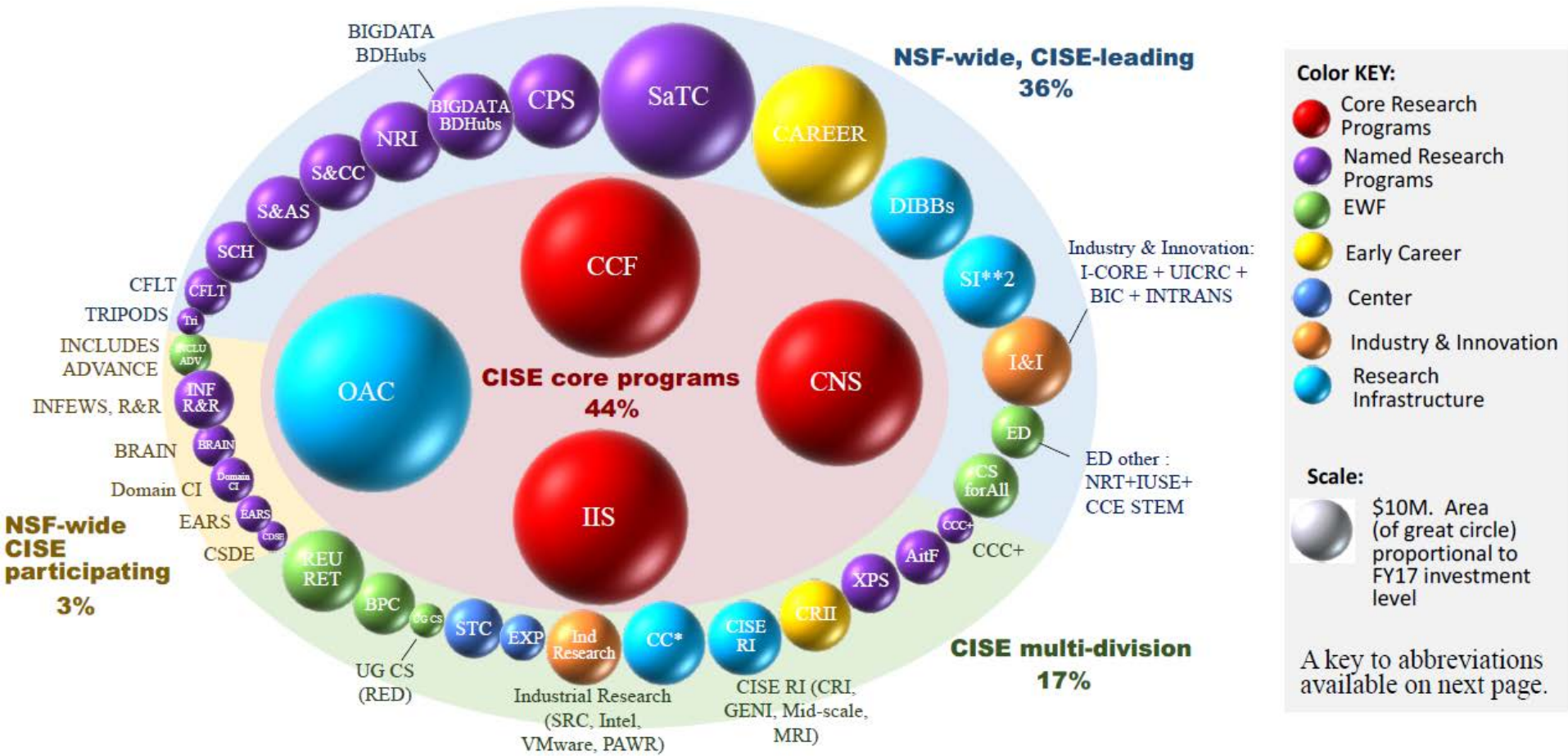


- **Co-Production Examples** in my work

- 2005: **Evacuation Planning**: MN local governments
- Current: **NSF SCC** Project: counties, cities in MN, FL



NSF CISE Budget 2017



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Knowledge Co-Production: **Evacuation Planning** (2005)

FoxTV newsclip (5-minutes), Disaster Area Evacuation Analytics Project
<https://www.youtube.com/watch?v=PR9k72W8XK8>



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KC Story 1: Evacuation Planning (2005)

- **Team:** US DHS, MN Dept. of Transportation, URS Corp.
 - Emergency Mangers, Police, Fire Fighters, Natl. Guard
- **Co-Visioning** via monthly meetings
 - Challenges: evacuees & traffic maps
 - Police: focus on what can be done!
- **Problem Co-Definition**
 - 1-mile scenarios: 5 sites, work-day or night-time
- **Co-Discovery**
 - For 1st mile, walking faster than driving
- **Co-Evaluation**
 - Walk selected routes : avoid wooden bridge near E
 - Lock parking garages during evacuation ?

Scenario	Population	Vehicle	Walking
A	143,360	4:45	1:32
B	83,143	2:45	1:04
C	27,406	4:27	1:41
D	50,995	3:41	1:20
E	3,611	1:21	0:36

Evacuation Planning System for Twin Cities Metro Area
Step 2 of 3: Adjust Scenario Settings [\(go home\)](#)

Evacuation Planning System for Twin Cities Metro Area
Step 3 of 3: Evacuation Route Plan [\(go home\)](#)



Intelligent Shelter Allotment for Emergency Evacuation Planning: A Case Study of Makkah

KwangSoo Yang, *Florida Atlantic University*

Apurv Hirsh Shekhar, *Johns Hopkins University*

Faizan Ur Rehman, *Umm Al-Qura University and University of Grenoble Alpes*

Hatim Lahza, *Umm Al-Qura University*

Saleh Basalamah, *Umm Al-Qura University*

Shashi Shekhar, *University of Minnesota*

Imtiaz Ahmed, *Umm Al-Qura University*

Arif Ghafoor, *Purdue University*

Intelligent shelter allotment faces challenges related to movement conflicts and transportation network choke points. A novel approach based on the idea of spatial anomaly avoidance provides faster evacuation.

Given maps of a vulnerable evacuee population, shelter locations, and a transportation network, the goal of intelligent shelter allotment (ISA) is to assign route and destination information to evacuee groups to minimize their evacuation time in the face of spatial disjointedness, the nonoverlapping separation of evacuation zones that's preferred by emergency managers to ensure smooth crowd movement. ISA can help in emergency planning and response by allocating shelters, exits, and routes. The goal is to speed up evacuation while reducing risks related to movement conflicts such as evacuation slowdowns, compression, and stampedes.

ISA faces numerous challenges, including bottlenecks and choke points in transportation networks (see Figure 1a), movement conflicts (when evacuee groups go to different exits or shelters), and scalability in terms of the number of evacuees and overall transportation network size. The current state of the practice is based on tabletop

Intelligent Shelter Allotment for Emergency Evacuation Planning: A Case Study of Makkah, *Intelligent Systems, IEEE*, 30(5):66-76, Sept.-Oct., 2015.



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KC Story 2: A NSF S&CC Project

- **NSF Workshops**

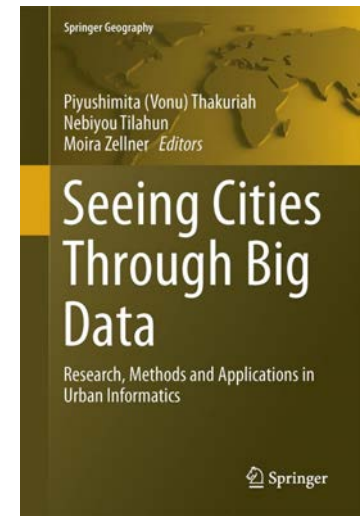
- Big Data and Urban Informatics, 2014

- **Academic History at UMN**

- Humphrey center
- Center for Urban & Regional Affairs
- Hennepin University Partnership
- Center for Transportation Studies Workshop on Smart Cities 2015

- **Local Government History**

- 2010-2020: Regional 10-year planning cycle (Metropolitan Council)
- 2013-14: Thrive MSP 2040
- 2015: USDOT Smart Cities Challenge proposal by Minneapolis



Local Plan
Implementation
and Plan
Amendments



2013 - 2014
Regional Development Guide



2014 - 2015
Regional System
and Policy Plans:
Regional Parks
Water Resources
Transportation
Housing



Fall 2015
System Statements



Fall 2015
**LOCAL PLANNING
HANDBOOK**

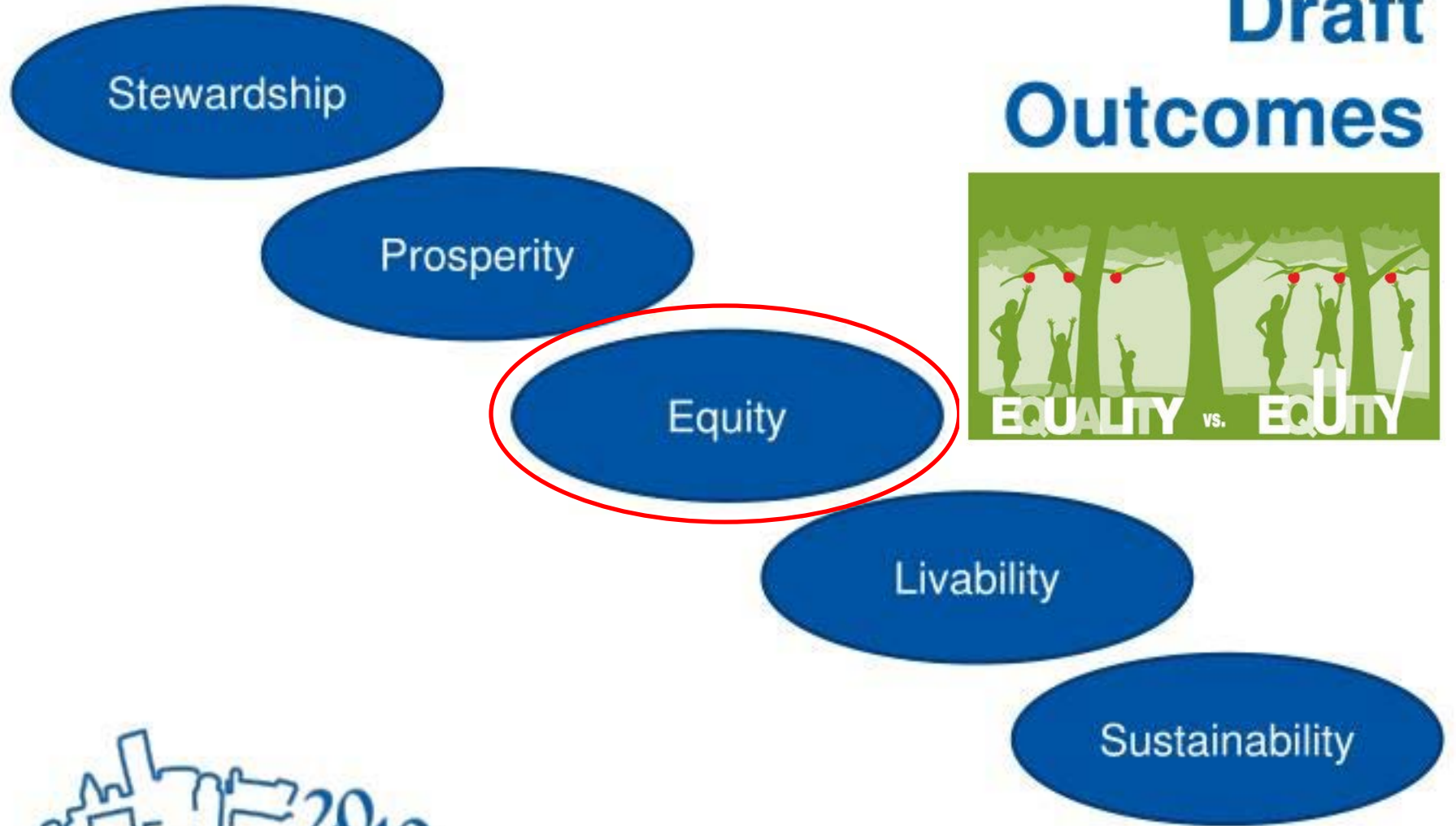


December 31, 2018
Comprehensive Plan Updates



REGIONAL 10-YEAR PLANNING CYCLE

Draft Outcomes



Broader Motivation



- 3) Good Health and Well-Being
- 9) Industry, Innovation, and Infrastructure
- 10) Reduced Inequalities
- 11) Sustainable Cities and Communities



KC Story 2: S&CC – Co-visioning



- Co-visioning Meetings (Academics + Local Governments)
 - 2014: Smart City Workshop
 - 2015-16: NSF SRN Sustainable & Health Cities – Equity
- Co-Visioning
 - Infrastructure planning for driver-less, post-carbon future, climate change
 - Advance Environment, Health, Wellbeing & Equity via infrastructure refinement
- Co-select Questions
 - Understand spatial equity in infrastructure & outcomes
 - wellbeing, health, environment
 - How does equity first approach differ from average-outcome based approaches ?
- Problem Co-Definition: How to measure spatial equity? Well-being?



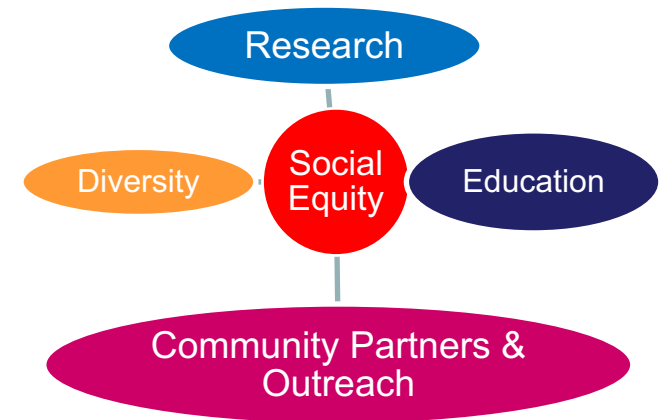
KC Story 2: S&CC – Co-select Question



- Team: U of Minnesota, Purdue U, FL State U, U of WA
 - Schools, Counties (e.g., Hennepin), Cities (e.g., Minneapolis, St. Paul, Tallahassee);
 - MetroLab Network, National League of Cities, ICLEI-USA, Intl. City/County



- Co-Discovery:
- Co-Evaluation



Academic and Community Partnerships

- **Shashi Shekhar**; UMN; PI
 - Spatial data mining & spatial DB
- **Anu Ramaswami**; UMN; Co-PI
 - Env science/policy, sustainable urban sys.
- **Julian Marshall**; UW; Co-PI
 - Env eng., air pollution & public health
- **Venkatesh Merwade**; Purdue; Co-PI
 - Civil engineering, hydrologic modeling
- **Richard Feiock**; FSU; Co-PI
 - Political science & public affairs
- **Julie C. Brown**; UMN; SP
 - Education
- **Diana M. Dalbotten**; UMN; SP
 - Diversity
- **Robert Johns**; UMN; SP
 - Leadership; strategy; and management
- **Jason Cao & Frank Douma** UMN; SP
 - Urban planning
- **Len Kne**, UMN; SP
 - Cyberinfrastructure & U Spatial



City Partners:

- Brette Hjelle & Kathleen Mayell; Minneapolis
- Michael Olson; Tallahassee

Schools Partners:

- Charlene Ellingson; Minneapolis Public Schools
- Betsy Stretch; Minneapolis Public Schools

NSF Sustainable Research Network:

- Sustainable Health Cities (SHC)

Multi-Community Organizations/Other:

- Cooper Martin; National League of Cities
- Angie Fyfie; ICLEI-USA
- Tad McGalliard; Intl. City/County Management Association
- **Ben Levine**; MetroLab Network



Objectives & Challenges

- **Scope:**
 - Cities: multi-sector, multi-scalar Social-Ecological-Infrastructural Urban Systems (SEIUS).
 - Infrastructures: Food, Energy, Water, Buildings, Transportation, Sanitation, Public Spaces
- **Objectives**
 - Understand **spatial equity** (e) in the context of **7 basic infrastructure** provisioning **and related** wellbeing (W), health (H), environment (E) and equity (e) **outcomes** in cities
 - **Advance all four outcomes** using **smart spatial infrastructure planning** in cities
- **Challenges:**
 1. **Data Gaps:** need intra-urban scale data on SEIU and EHW parameters (Theme 1)
 2. **Knowledge Gaps** (Themes 2, 3):
 - **Data science** to understand spatial interactions among SEIU-*WHEe parameters*.
 - **All-infrastructure models of spatial futures** in changing climate, with disruptive infrastructures (e.g., renewable energy) & technologies (e.g., CAVS)



Four Themes

Theme 1: Develop comprehensive data sets on SEIS-EHW at intra-urban scales:

- **Cyber infrastructure** for diverse and disparate data sets
- **Novel citizen science, sensor and survey techniques** to characterize
 - air pollution
 - near-realtime flooding
 - subjective well-being (W)

Theme 2: Advance spatial data analysis to understand SEIU-*WHEe* relationships

- **Advanced spatial computing algorithms**
- Data and Discipline-inspired Hypotheses
- Equity (e) as spatial dispersion & correlation of *WHE*-SEIU

Theme 3: Model and visualize spatial smart city futures for Equity-First Plan

- **Multiple & connected spatial infrastructure futures** scenario modeling
- **Scenario Visualization**
- **Value of information** and policy-learning

Theme 4: Education and Workforce Development: Citizen science with middle & high-school students; Interdisciplinary Graduate Certificate; Professional education; Visualization for Policy Leadership;



Community Partners

- Regular meetings with
- Cities of Minneapolis, St. Paul, and Tallahassee
- The county of Hennepin.



Research Objective

To address the key gaps in science, data and knowledge, we propose 3 broad research themes that are closely aligned with Education:

Task Lead: PI Ramaswami

Theme 1: Develop comprehensive data sets on SEIS-EHW at intra-urban scales:

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Household level Tallahassee database

Spatial equity in energy efficiency and programs adoptions across households and neighborhoods

- Sample of 3,000 homes to entire household population
- **Energy Consumption (2011-2018)**
 - 30 mins interval energy consumption of electricity and gas, monthly consumption of water for about 120,000 customers
- **Voter Registration (2005-2016)** -- Yearly/monthly based voter affiliation, voter status, age
- **Tax Roll Record (1995-2016)** -- Property Tax data including house value, homestead exemption, housing features
- **Property Appraiser Data (2014-2015)** -- Property assessment information
- **Zillow (2018)** – Listed price, house characteristics, room type, appliances, heating/cooling system
- **Building Footprint Data (2015)** -- LiDar (GIS) data of parcel area, shape
- **Tree Cover (2015)** -- LiDar (GIS) data on tree cover percentage in 0.39 by 0.39 meter pixels.





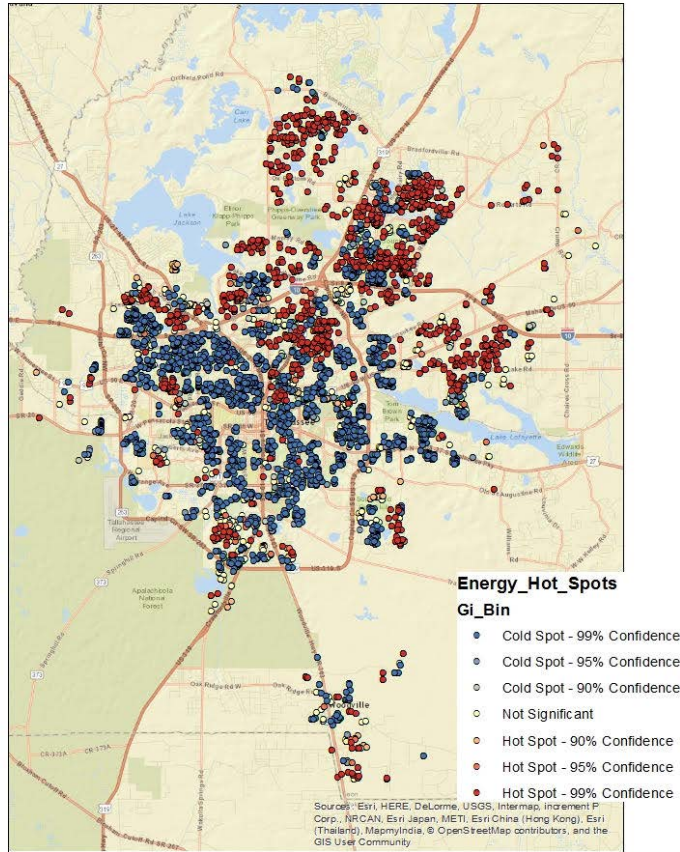
- **Energy Star Rebate Participation (2011-2017)** -- Type of rebate program, participation date and rebate amount
- **Energy Star Rebate Participation (2011-2017)** -- Type of loan program, participation date, loan time span, amount
- **Solar Farm Enrollment (2018)** -- Percentage of electricity from solar, participation date.
- **Solar Panel Installation (2007-2018)** – Capacity, estimated generation, date of participation, and information on installer
- **Energy Audit Comments (2011-2017)** -- Actual audit comment notes
- **eBill Registration (2012-2018)** -- Date of eBilling Registration
- **Neighborhood Reach (2001-2017)** -- Date of reach and house address, name neighborhood
- **Neighborhood and Homeowner associations (Current)** -- Demographic characteristics, Legal status, functional status, participation/interaction with city
- **Homeowner Association Covenants, Conditions, and Restrictions (Current)** – rules and regulations on solar panel adoption





Comparing Consumption Hot Spots

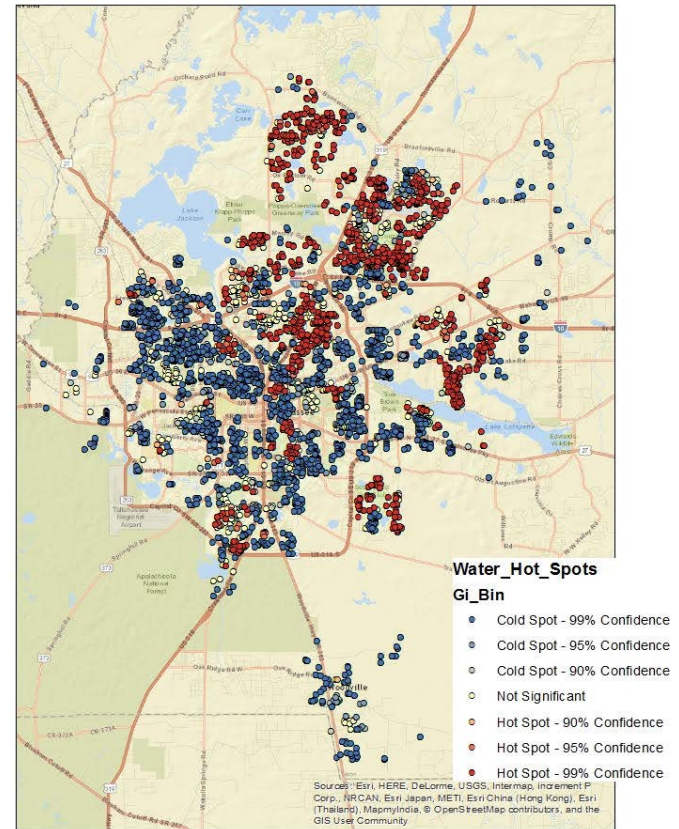
Hot Spot Analysis of Tallahassee Energy Use



0 0.751.5 3 4.5 6 Miles



Hot Spot Analysis of Tallahassee Water Use



0 0.751.5 3 4.5 6 Miles



Developing an ultra low cost passive black carbon air pollution sampling approach for citizen science

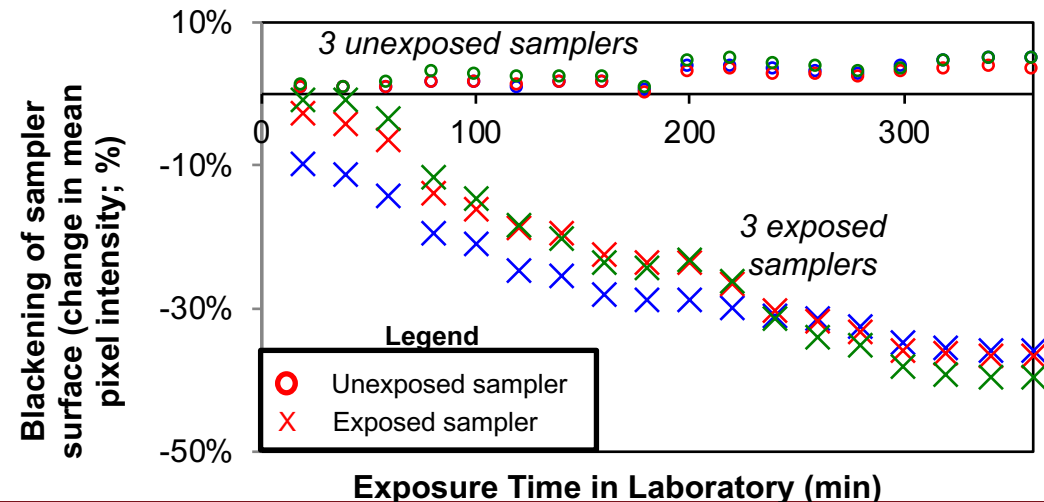
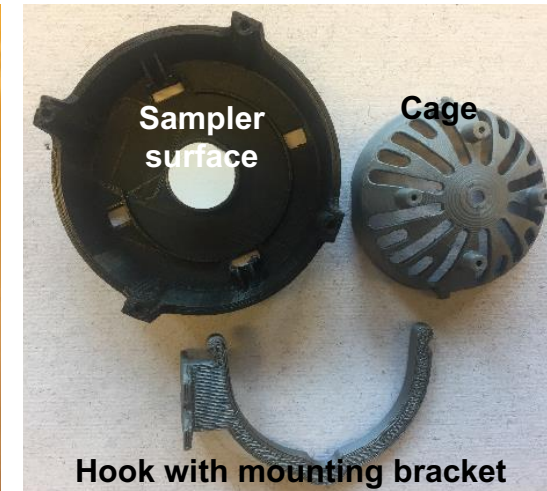
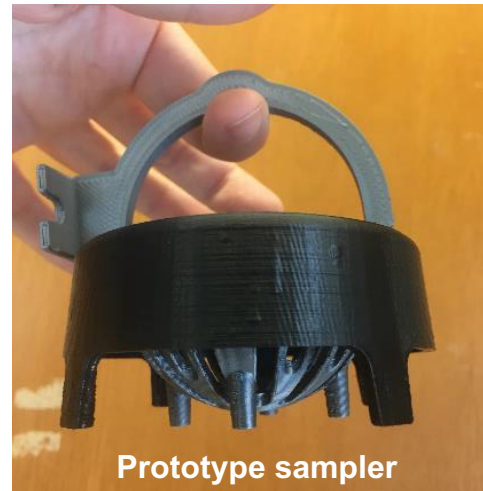
Task Lead: PI Marshall

Updates:

- Redesigned **passive** sampler prototype and sampling approach
- Tested prototype samplers in laboratory
- Tested prototype samplers in field
- Presented at Jt Annual Meeting of Intl. Society of Exposure Sc. and Intl. Society for Env. Epidemiology
- **Being tested in India**
 - **Comparison with long-term.**

Next steps:

- Develop a calibration curve using reference methods for black carbon concentration estimation



Research Objective

To address the key gaps in science, data and knowledge, we propose 3 broad research themes that are closely aligned with Education:

Task Lead: PI Shashi Shekhar

Theme 1: Develop comprehensive data sets on SEIS-EHW at intra-urban scales:

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Mapping Trees for Green Infrastructure Equity

- Theme 2: Advance spatial data analysis **Task Lead: PI Shekhar**
- Task 2A: Algorithms for spatial patterns
- Recent accomplishments: individual tree detection
 - A TIMBER (Tree Inference by Minimizing Bound-and-band ERrors)
 - Optimization to find tree locations and sizes
 - Deep learning to construct features to distinguish trees and non-trees
 - A CORE (Core Object REduction) to accelerate the detection process
 - **Details:** TIMBER: A Framework for Mining Inventories of Individual Trees in Urban Environments using Remote Sensing Datasets, IEEE Intl. Conf. on Data Mining (ICDM), 2018.



Legend

 Tree canopy



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Mapping Ash Trees for Green Infrastructure Equity

- Work in progress: Tree species classification, including ash tree
 - Idea: Use tree shadows from high-resolution leaf-off imagery
 - Data collected
 - St. Paul road-side tree inventory with location and species (no canopy size), 2018 update.
 - Tree inventory on University of Minnesota campus (no canopy size).
 - High resolution leaf-off imagery (3" resolution) by Hennepin and Ramsey County
 - About 2500 training samples of tree shadows (i.e., profile geometry)
 - Next steps
 - Algorithms for tree shadow enhancement and clipping
 - Deep learning for tree species prediction



Task Lead: PI Shekhar



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Urban Garden Detection using Aerial Imagery

City/County	Resolution	Marked Garden	Accuracy
Hennepin County	7.5 cm	1163	70%
Ramsey County	5 cm	532	NA

Types of Urban garden



Community Garden



Backyard Garden
(Hennepin County)



Backyard Garden
(Detroit)

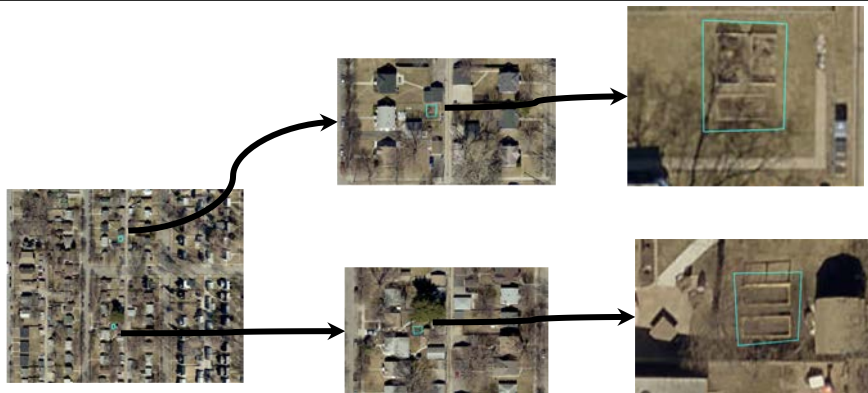
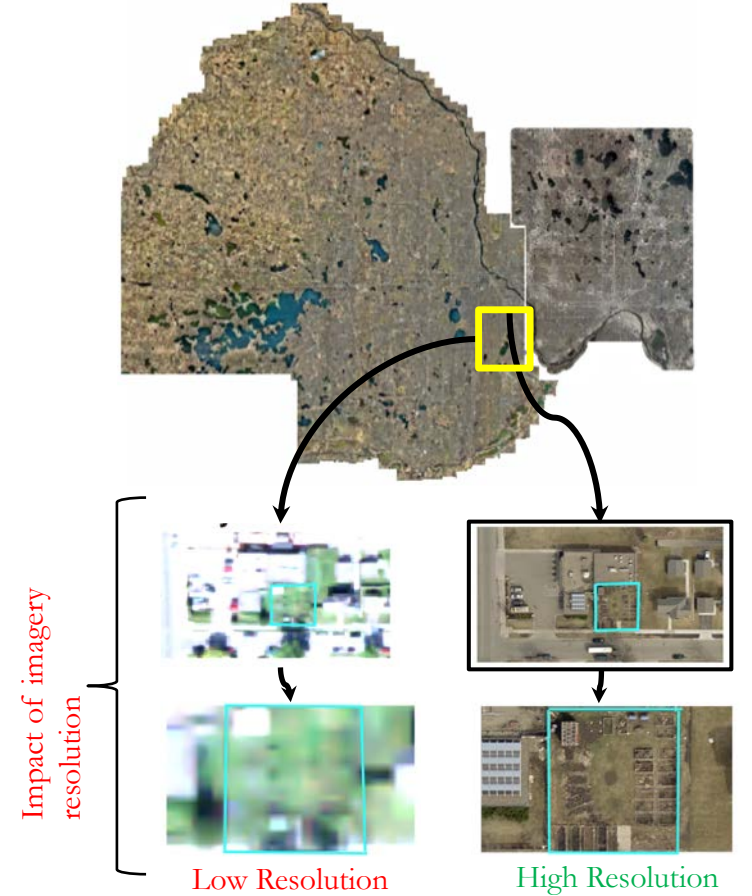


Image Annotation sequence



- Will the same approach work in other urban areas (e.g., Atlanta)

Acknowledgement.

- Data Source: PI Ramaswami, Hennepin County, Ramsey County

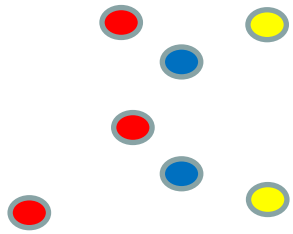
Task Lead: PI Shekhar



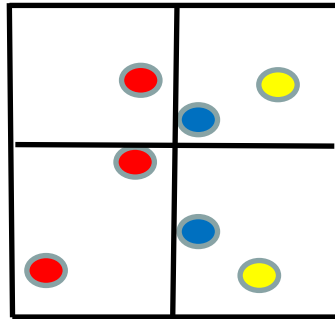
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Task 2B: Discover co-location and teleconnection patterns

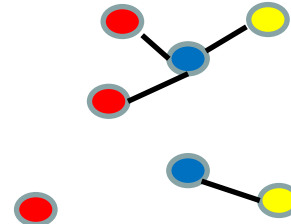
- Challenge: Traditional statistical methods miss spatial interactions
- Prelim. Results: Co-location and teleconnection reveal spatial interaction
 - between variables for point data types
- Proposed: address data with multiple levels of aggregation, e.g., areal summary







(a) a map of 3 features



(b) Spatial Partitions



(c) Neighbor graph

	Pearson's Correlation	Support	Ripley's cross-K	Participation Index (colocation)
 - 				
 - 				



Data-Intensive Science of S&CC in 21st Century

SEIU EHW

Hotspots of infrastructure deprivation, consumption, pollution, investment, disease & well-being.
Correlates?

Equity first policies

Role of policies & urban forms

Collect, & Curate
Big Data



Spatial Patterns,
Hypothesis Generation

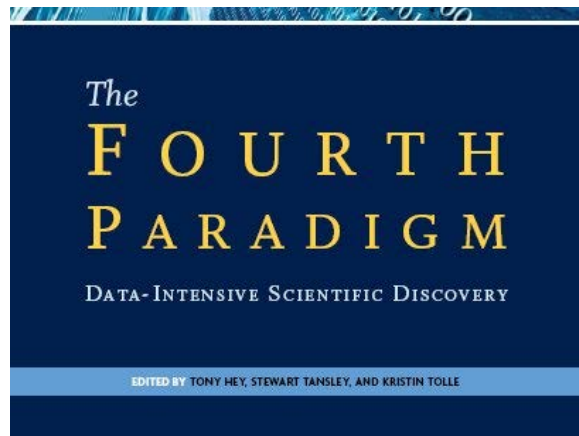


Test Hypothesis
(Policy Intervention)



S&CC
Theory

Volume, Variety



Data-driven and
Discipline-inspired
hypothesis generation



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Task Lead: PI Upadhyay



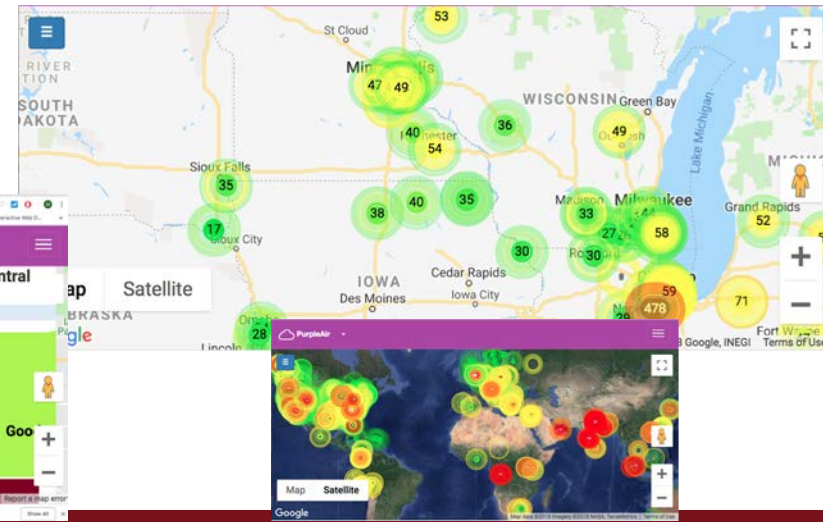
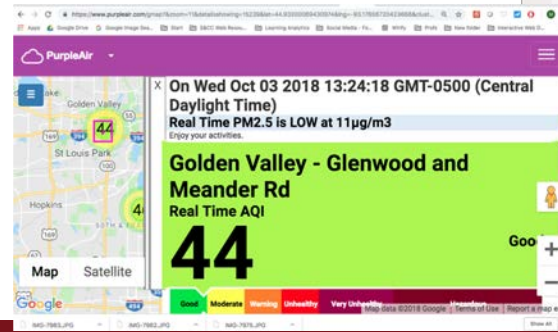
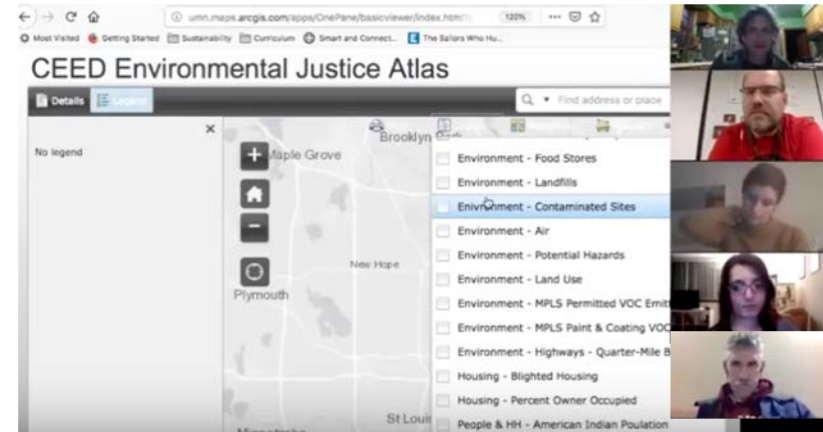
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Teacher's Workshop

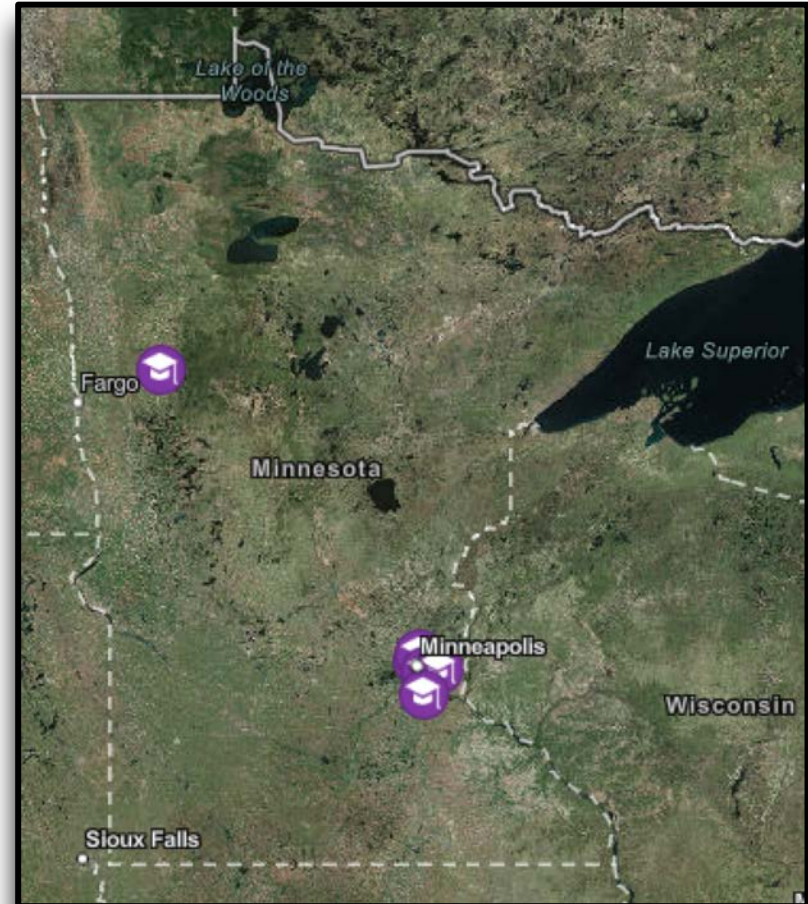
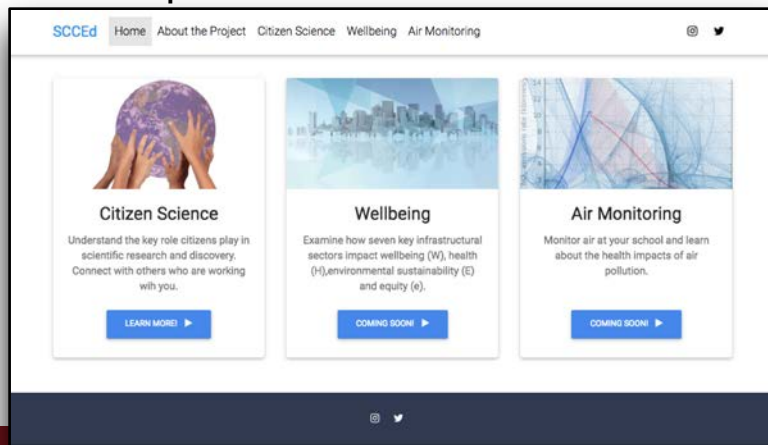
Updates

- August teacher workshop complete
- Monthly web-meetings to support teachers, provide updates, status checks and refine curriculum product
- Responsive Curriculum website set up for 8-12 classroom use
- Partial set up of Air Pollution Monitors at school locations
- Soft implementing of curriculum materials December through March



Theme 4: Next Steps

- Complete set up Air Pollution Monitors at all schools sites
- Finalize school implementation and teacher observation schedules
- Continued monthly web-meetings
- Begin implementation of curriculum modules and lessons
- Continued refinement to curriculum materials, supports for individual school contexts ie: Grade level, course or program
- Maintain updates on website



Outline

- ❑ Motivation
- ❑ Knowledge Co-production (KC)
- ❑ KC Story 1: Evacuation Planning
- ❑ KC Story 2: Spatial Computing in Smart Cities
- ❑ **Conclusions**



CONCLUSIONS & NEXT STEPS

- **Cities is societally important and facing challenges**
 - Majority live in cities
 - Challenges: climate change, aging infrastructure, ...
 - Opportunities: renewable energy, self-driving vehicles, ...
- **Spatial Computing has already transformed Cities**
 - Sanitation, green spaces, E-911, public safety, ...
- **Many Transformative opportunities lie ahead**
 - Ex. Spatial equity
- **However, these will not material without**
 - **Knowledge Co-production**: local governments, academics, businesses, ...
 - **Basic Research**, e.g., spatial data science to overcome gerrymandering challenge

