Engineering Research Center for
Collaborative Adaptive Sensing of the Atmosphere

Context Aware Weather Warning Systems

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VLAB Forum
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Collaborators & Funding Sources

ACADEMIC

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- Q. Yu, UMass, Geosciences
- D. Westbrook, UMass, CS
- A. Bajaj, UMass, ECE
- C. League, W & S Consulting, sociology, geography
- E. Lyons, UMass, Systems Engineering
- M. Zink, UMass, Computer Networking

PRACITIONERS

- Molly Thoerner (North Central Texas Council of Governments)
- Amanda Everly (City of Fort Worth Emergency Management)
- Joe Frizzell (Mayor Pro Tem, City of Midlothian)
- Ranjan Mutttiah, Ft. Worth Storm Water
- National Weather Service Weather Forecast Office (KFWD)
  - T. Bradshaw
  - T. Ryan
  - M. Fox

FUNDING

- NSF: “Hazards SEES Type 2: Next Generation, Resilient Warning Systems for Tornados and Flash Floods” NSF-AGS
- NSF: “PFI:BIC: CityWarn A Smart, Hyperlocal, Context-Aware Hazard Notification Service System” NSF-PFI
- North Central Texas Council of Governments
- National Weather Service

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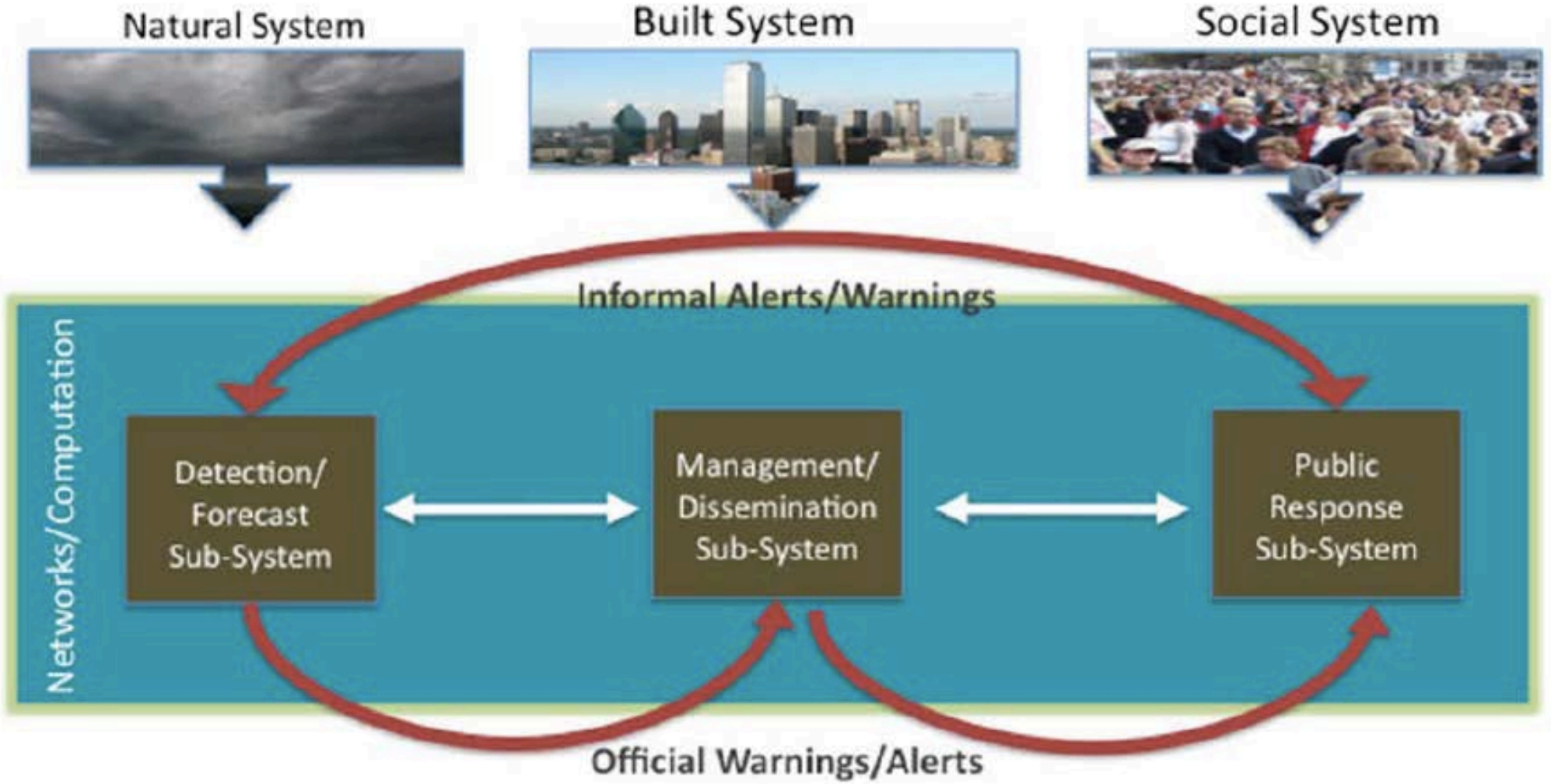
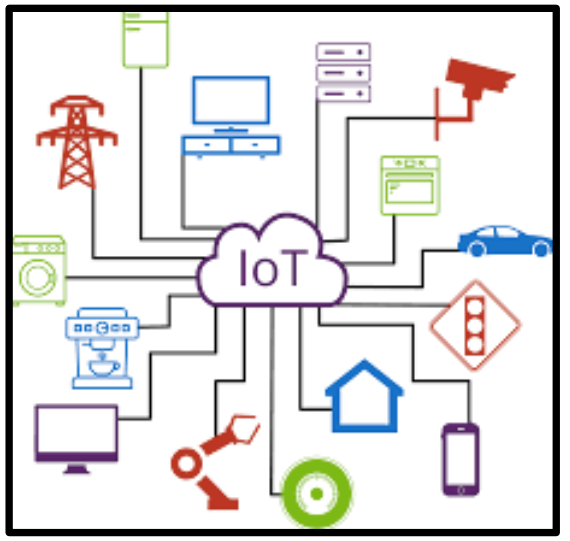
Severe Weather Warning Systems Are Complex



Modified from Mileti, D. S., & Sorensen, J. H. (1990).

Technology Trends & Severe Weather Warning

- Mobile phone penetration & usage
- Attitudes towards privacy & sharing
- Social media
- Internet of Things (IoT)/Cloud Computing
- Mobility-optimized Information & Communications Technology (ICT)



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What are the opportunities for Severe Weather Warning Systems?

- How should we integrate the current broadcast paradigm and the potential for dynamic, personalized warnings?
- Can IoT help us better understand the linkages among warning system components?
  - Human interpretation, perception and response
  - New types of weather information: high resolution radar data, ensemble forecasts, etc.
  - New warning policies
- What are innovative ways to research these types of questions given the complexity of warning systems?

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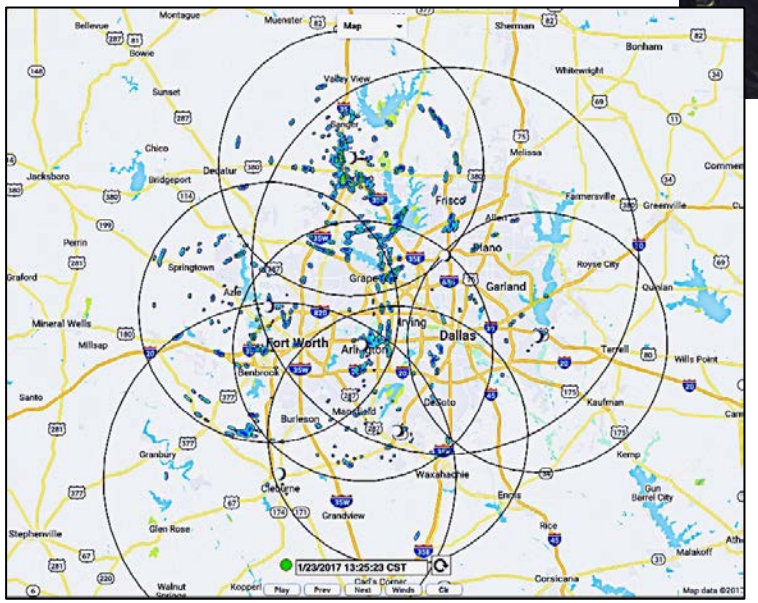
Today's Talk

1. Background: CASA and the CASA DFW Living Lab
2. Context-aware warning systems
3. Current Research Projects (Three of many!)
   - Publics' perception of rain intensity & radar data
   - Mobility patterns & warning
   - Flash flood case study
4. Broader implications and next steps

Background

My Background

- Co-director, CASA: severe weather warning system innovations
- Sociotechnical systems research: integrating natural/technical/behavioral parts of warning systems
- Research in real-world contexts: living labs, test beds
- Multidisciplinary research, “spanner”



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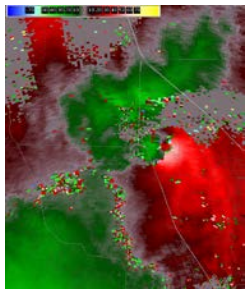
CASA DFW Living Lab: Technology, People, Real-world, Real-time Contexts & Urban Scales (since 2011)

Sensors & Software



WX Info

CASA Alerts App

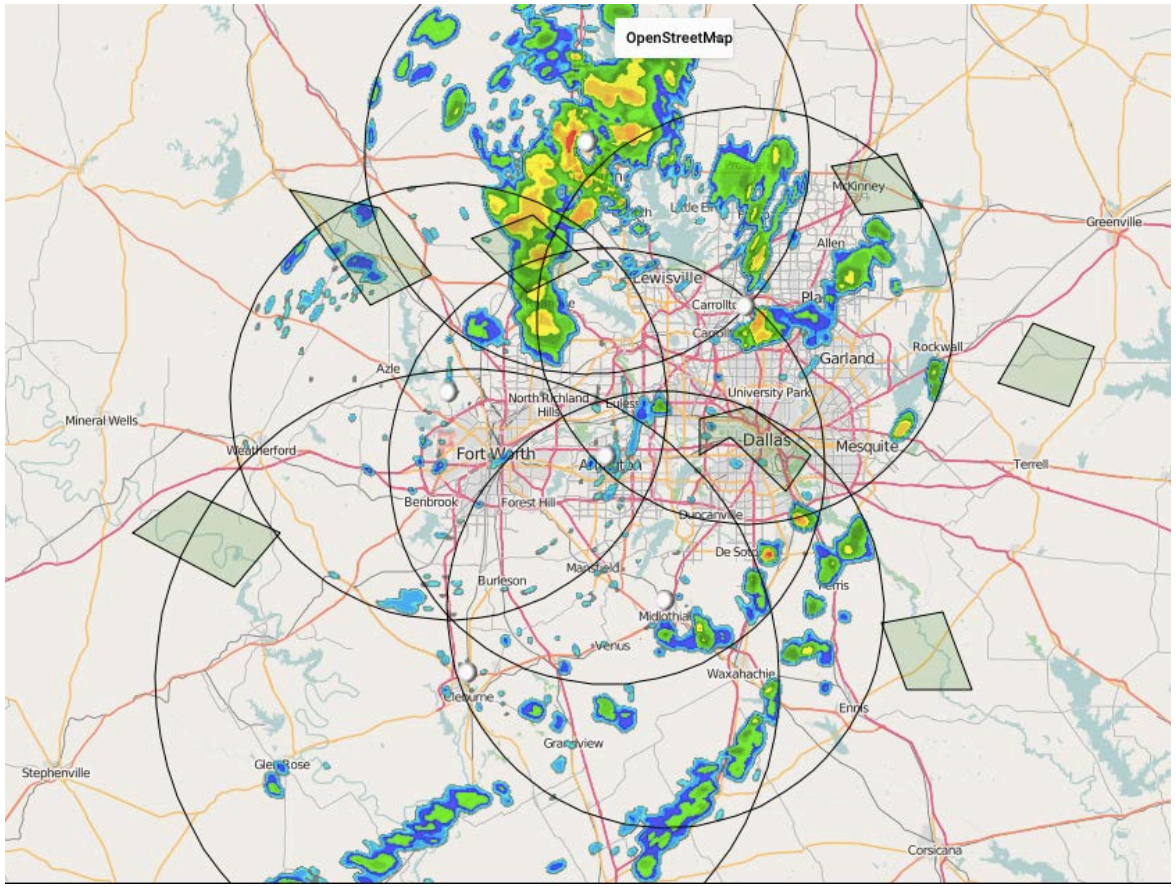
Stakeholders

Publics

- Sensors-to-People Severe Weather Warning System centered around X-band CASA radars & other sensors
- Demonstrates benefits of high resolution, lower atmosphere sensing: Urban, gaps, users
- Multidisciplinary research in live environment (physical, technical, social sciences)
- Flexible infrastructure for technology development & R2O
- Co-Creation with users through a public private partnership

CASA DFW Living Lab: Concept of Operations

- 7 node network, doppler, dual polarization radar + other sensors
- Operates year round when there is precipitation
- Real-time single & merged radar data, + derived products (QPE, hail, winds, nowcasts, forecasts)
- CASA radar data available on AWIPS2 to NWS-FWD, SRH
- CASA products available on CASA WX website for real-time operational use with low latency
- 1500+ users: ~750 local public safety users from 50 NTX cities and counties, ~600 App holders



CASA network covers approximately 32,000 sq. km. radar range is 40 – 60km. Overlapping coverage helps to address X-band attenuation

North Central Texas community contributes resources for installation and operation of radar network

University of North Texas | Johnson County | City of Addison

- North Central Texas Council of Governments coordinates local efforts through 5-year agreement with CASA. In second renewal period.
- Local Exec Committee of EMs, media, NWS sets local policy
- A membership fee to local towns and cities supports radar operations. ~$1 million in fees to date.

Community sponsored installations
UT Arlington, UNT, Cities of Addison and Midlothian

KFWD issues tornado warning based on CASA data on 01/15/17

165
WFUS54 KFWD 160204
TORFWD
TXC251-160230-
/O.NEW.KFWD.TO.W.0007.170116T0204Z-170116T0230Z/

BULLETIN - EAS ACTIVATION REQUESTED
Tornado Warning
National Weather Service Fort Worth TX
804 PM CST SUN JAN 15 2017

The National Weather Service in Fort Worth has issued a

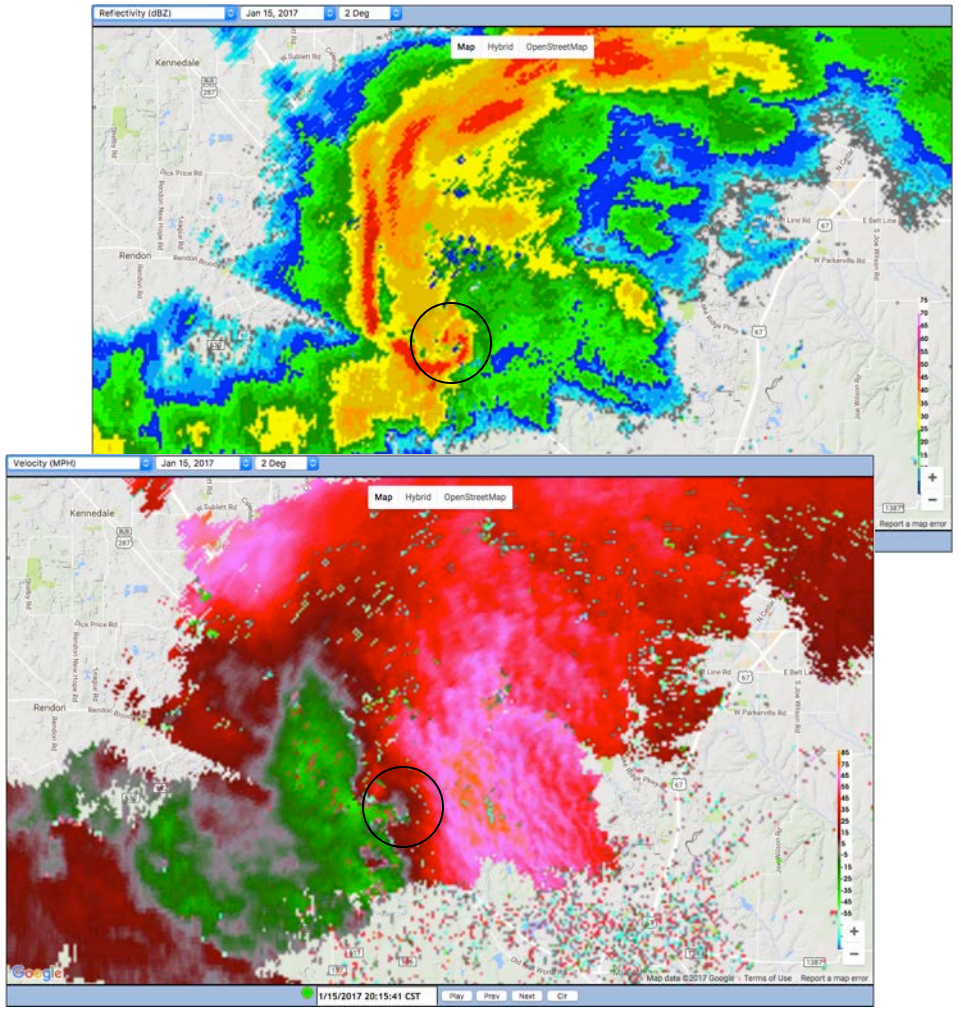
* Tornado Warning for...
Northeastern Johnson County in north central Texas...

* Until 830 PM CST

* At 802 PM CST, a severe thunderstorm capable of producing a tornado was located just north of highway 67 between Alvarado and Venus. CASA radar indicates that this circulation will approach Pleasant Point and Lillian over the next few minutes.

HAZARD...Tornado.

SOURCE...Radar indicated rotation.



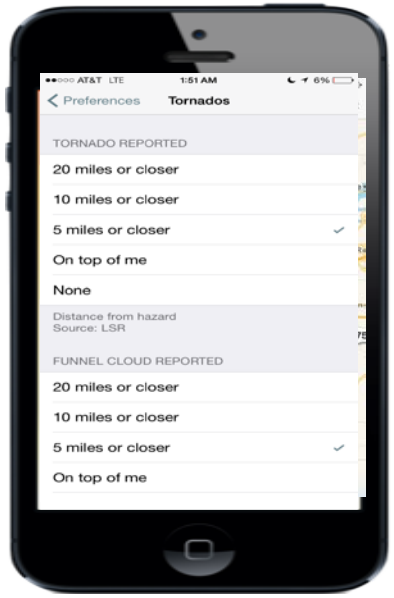
EF0 tornado near Mansfield, TX
captured by CASA radar

Media Pilot: NBCDFW Using CASA Radar Data 5/3/18

Context Aware Warning Systems

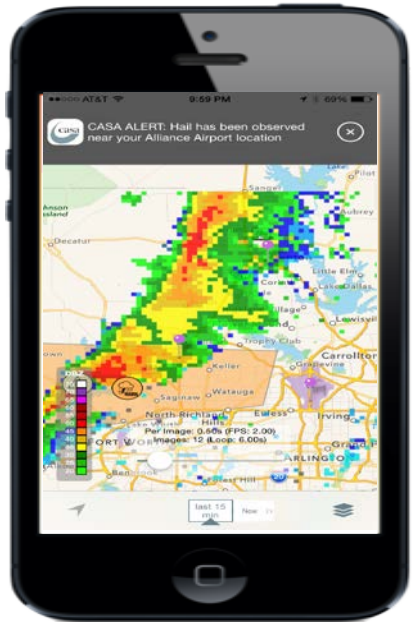
CASA Alerts App Enables Research on User Perception & Response to Weather Infomration

Alerting/ Preferences

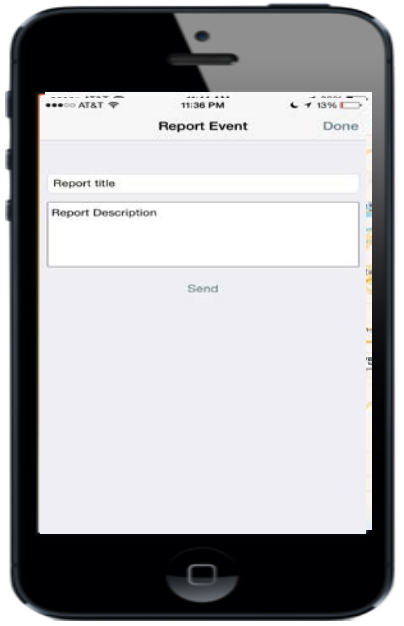


Locations

Text & Visual WX Info



Surveys /Reports

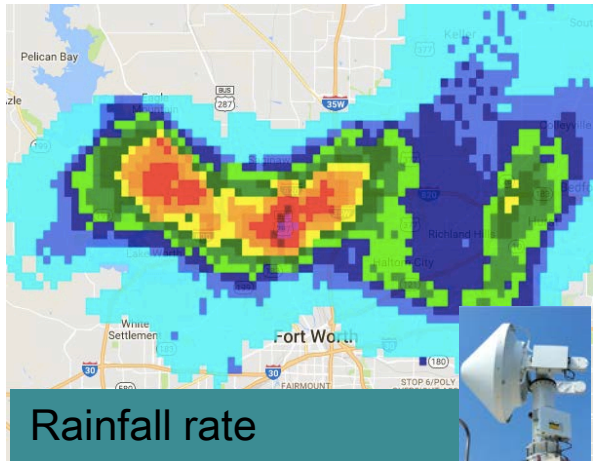


- 600+ app users
- Random sample
- Convenience sample
- Location tracking

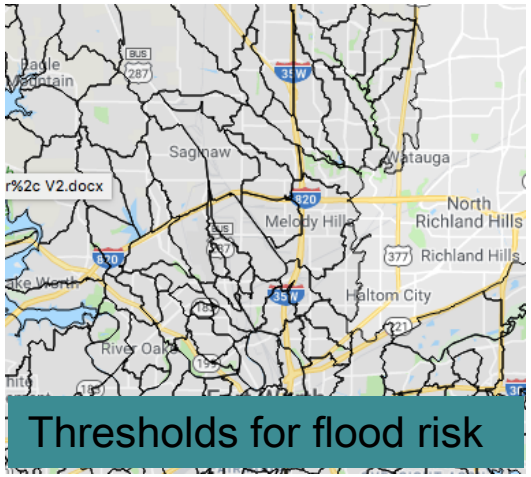
- Pre-experiment surveys
- Event-based mobile phone surveys
- Link location, surveys responses, weather, environment via archive data base

Context-Aware Warning System: Links Hazards Infrastructure, Policy, People Contexts Dynamically in Time & Space

Environmental Risk



Infrastructure Risk

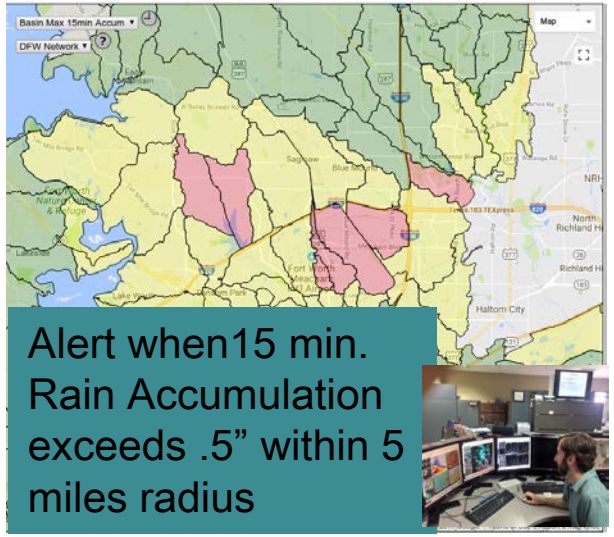


Alerts
(Automated, Manual)

Surveys

Mobile App

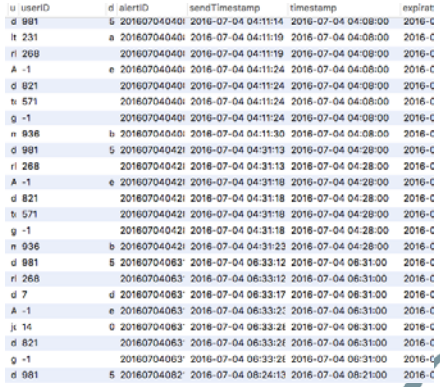
Management Policy



People

Spatio-Temporal Data
Survey Results

Data Archive



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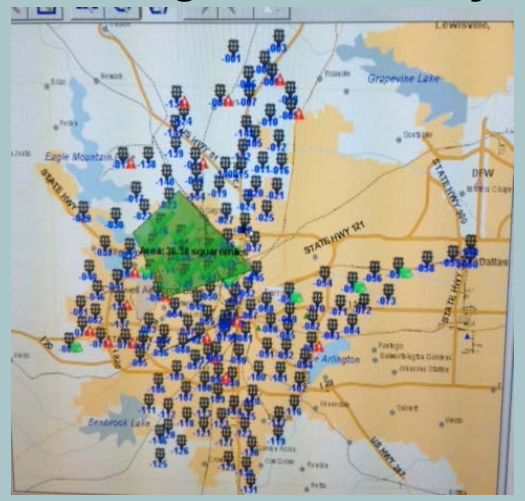
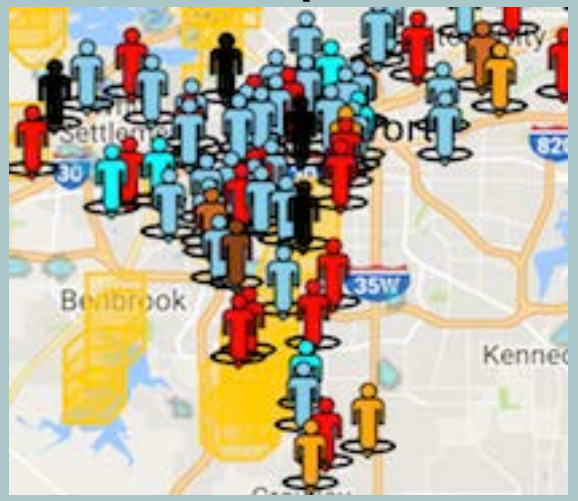
Environmental Risk

Infrastructure Risk

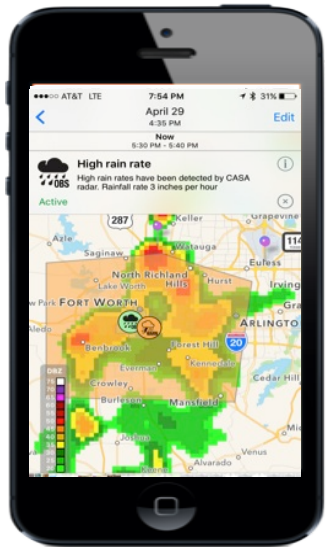
Management/Policy



People



Mobile App



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d	981	5	20160704040	2016-07-04 04:11:14	2016-07-04 04:08:00	2016-0
ht	231	a	20160704040	2016-07-04 04:11:19	2016-07-04 04:08:00	2016-0
ri	268		20160704040	2016-07-04 04:11:19	2016-07-04 04:08:00	2016-0
A	-1	e	20160704040	2016-07-04 04:11:24	2016-07-04 04:08:00	2016-0
d	821		20160704040	2016-07-04 04:11:24	2016-07-04 04:08:00	2016-0
tu	571		20160704040	2016-07-04 04:11:24	2016-07-04 04:08:00	2016-0
g	-1		20160704040	2016-07-04 04:11:24	2016-07-04 04:08:00	2016-0
m	936	b	20160704040	2016-07-04 04:11:30	2016-07-04 04:08:00	2016-0
d	981	5	20160704042	2016-07-04 04:31:13	2016-07-04 04:28:00	2016-0
ri	268		20160704042	2016-07-04 04:31:13	2016-07-04 04:28:00	2016-0
A	-1	e	20160704042	2016-07-04 04:31:18	2016-07-04 04:28:00	2016-0
d	821		20160704042	2016-07-04 04:31:18	2016-07-04 04:28:00	2016-0
tu	571		20160704042	2016-07-04 04:31:18	2016-07-04 04:28:00	2016-0
g	-1		20160704042	2016-07-04 04:31:18	2016-07-04 04:28:00	2016-0
m	936	b	20160704042	2016-07-04 04:31:23	2016-07-04 04:28:00	2016-0
d	981	5	20160704063	2016-07-04 06:33:12	2016-07-04 06:31:00	2016-0
ri	268		20160704063	2016-07-04 06:33:12	2016-07-04 06:31:00	2016-0
d	7	d	20160704063	2016-07-04 06:33:17	2016-07-04 06:31:00	2016-0
A	-1	e	20160704063	2016-07-04 06:33:22	2016-07-04 06:31:00	2016-0
ju	14	0	20160704063	2016-07-04 06:33:28	2016-07-04 06:31:00	2016-0
d	821		20160704063	2016-07-04 06:33:28	2016-07-04 06:31:00	2016-0
g	-1		20160704063	2016-07-04 06:33:28	2016-07-04 06:31:00	2016-0
d	981	5	20160704082	2016-07-04 08:24:13	2016-07-04 08:21:00	2016-0

Data Archive

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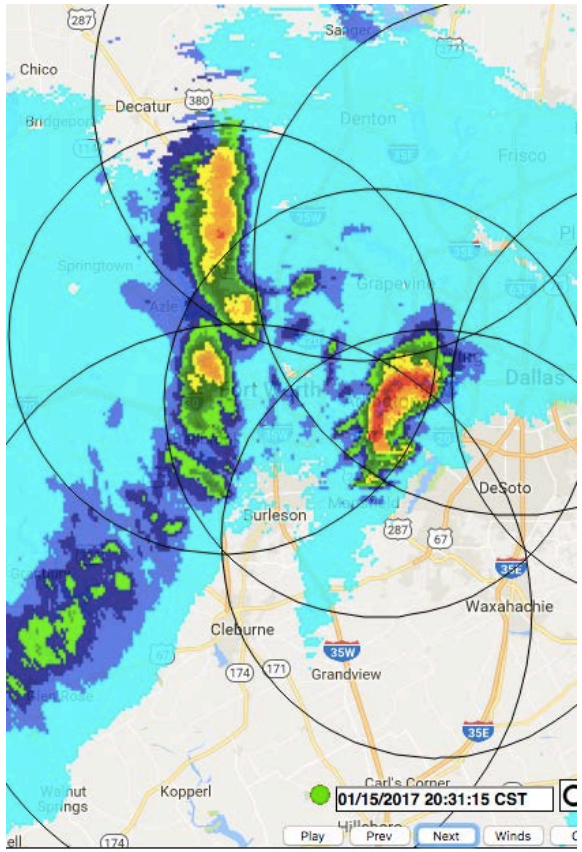
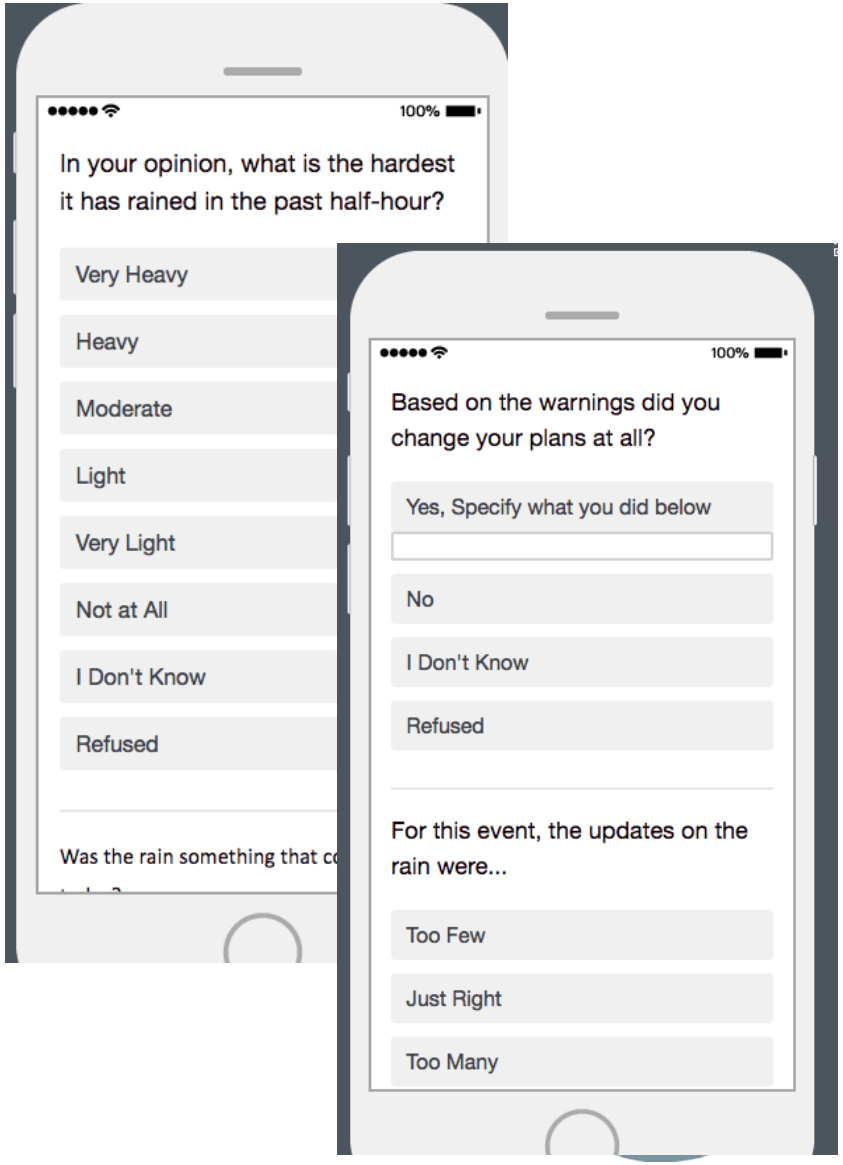
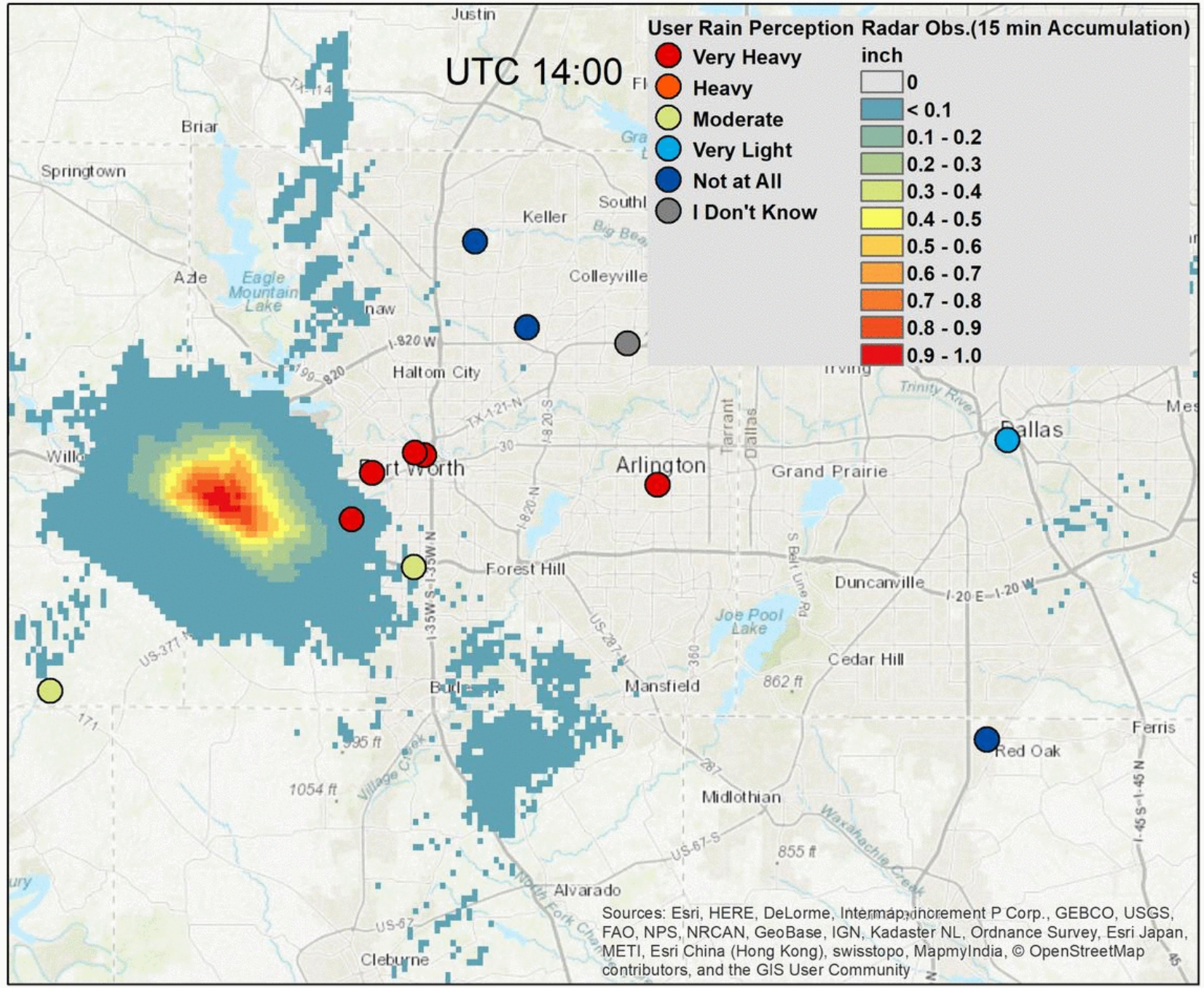
Research Projects

Linking the publics' perception of rain intensity & radar data pilot study



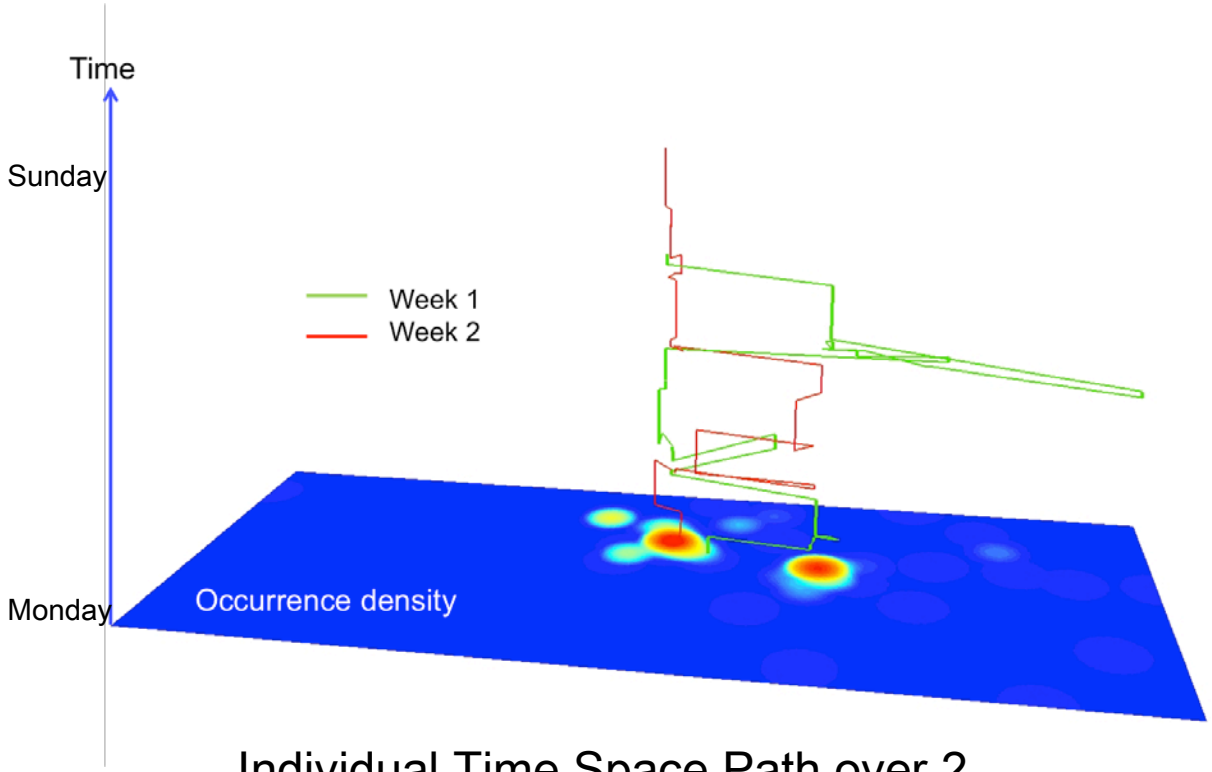
- Pilot study
- Survey automatically sent to all app users when more than 8 people are in heavy rain (.75" rain in 15 mins)
- Convenience sample
- 437 responses




UTC 14:00
User Rain Perception Radar Obs.(15 min Accumulation)
Very Heavy
Heavy
Moderate
Very Light
Not at All
I Don't Know
inch
0
< 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Justin
Briar
Springtown
Keller
Colleyville
Azle
Eagle Mountain Lake
Haltom City
Fort Worth
Arlington
Grand Prairie
Dallas
Irving
Trinity River
Forest Hill
Duncanville
Joe Pool Lake
Cedar Hill
Mansfield
Red Oak
Ferris
Midlothian
Alvarado
Cleburne
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Human Mobility Research: Individual Foot Prints

- Individual mobility patterns are largely predictable in time and in space
- 240 app holders' location sampled every 5 mins for 6 months
- Convenience Sample
- Kernal Density Function used to determine time-weighted location density & activity weighted locations
- "Hot Spots" represent home, work, places of daily activity



Individual Time Space Path over 2 weeks

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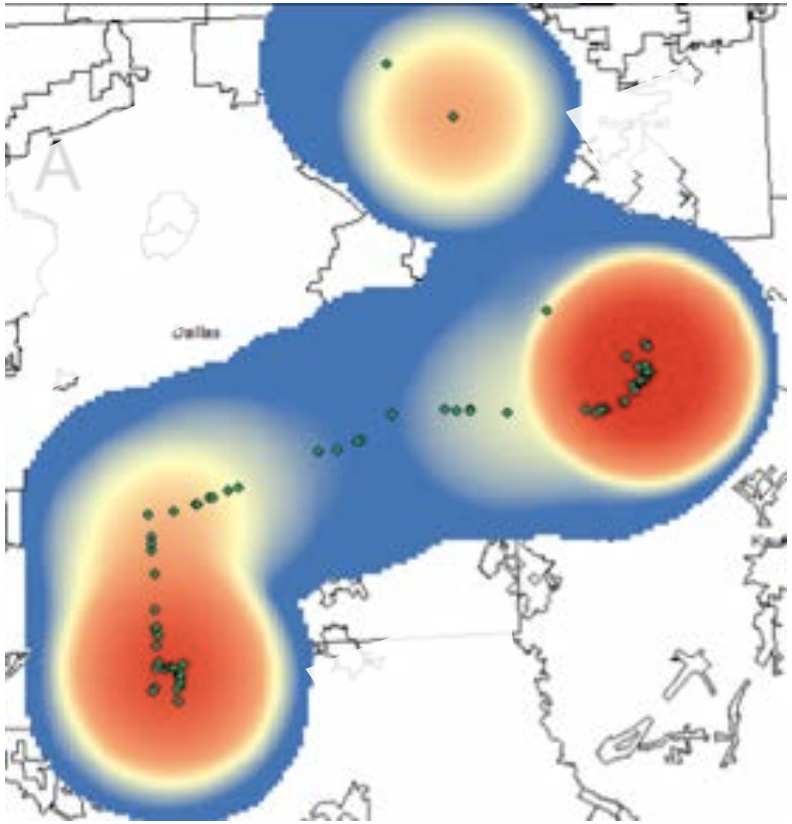
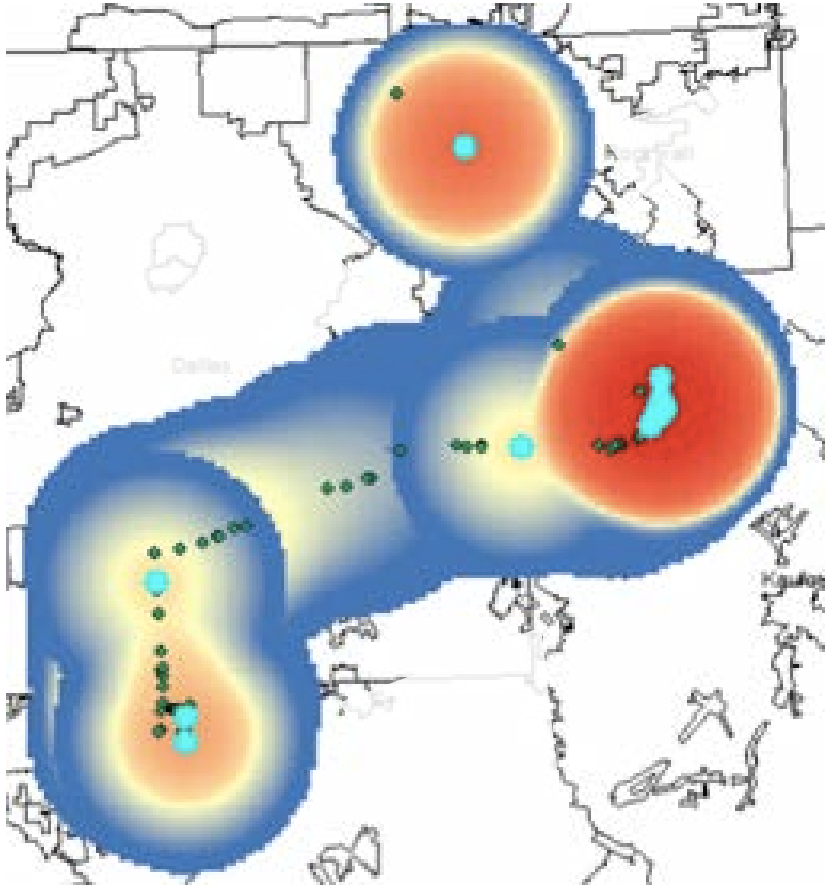
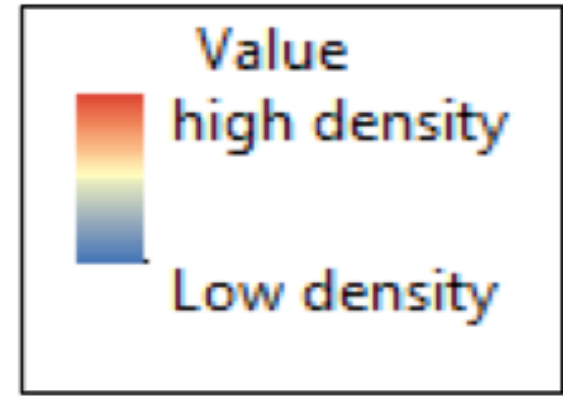
Individual Footprint: Time-Weighted Density



Footprint at all times



Footprint During Commute Time



People spent 80% of their time in 23% of their footprint

% Density	Median % of Area	Median # of Nodes	Median Sq. Miles
100	100	3	221
90	36	3	71
80	**23**	**2**	**45**
70	16	2	28
60	11	2	19
50	8	2	13
30	5	2	10
20	3	1	9
10	2	1	6

Why are individual footprints important?

- Personalization is crucial in the warning perception and response process
- Footprints contain the important locations that help with personalization: home, work, school, commuting
- Footprints are spatio-temporal artifacts that can represent people in warning system technology.

Personalization: "People's expectations of the personal impacts from an extreme environmental event" including "death, injury, property damage, and disruption to daily activities such as work." (Lindell and Perry 2012)

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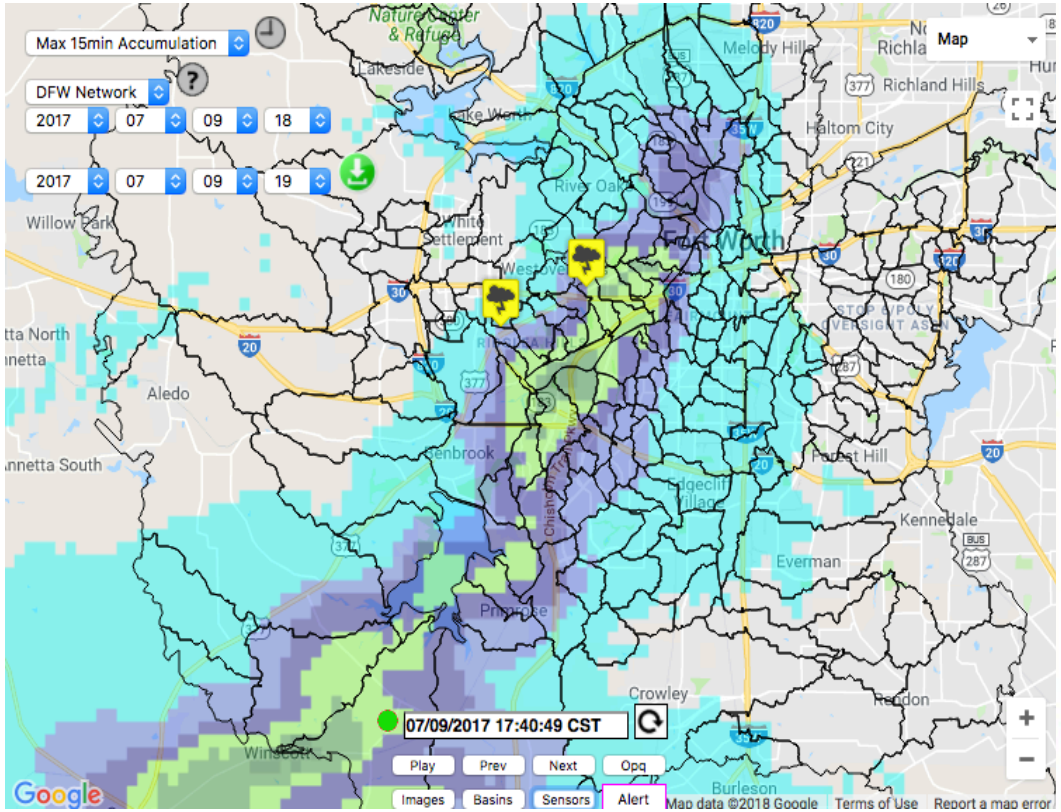
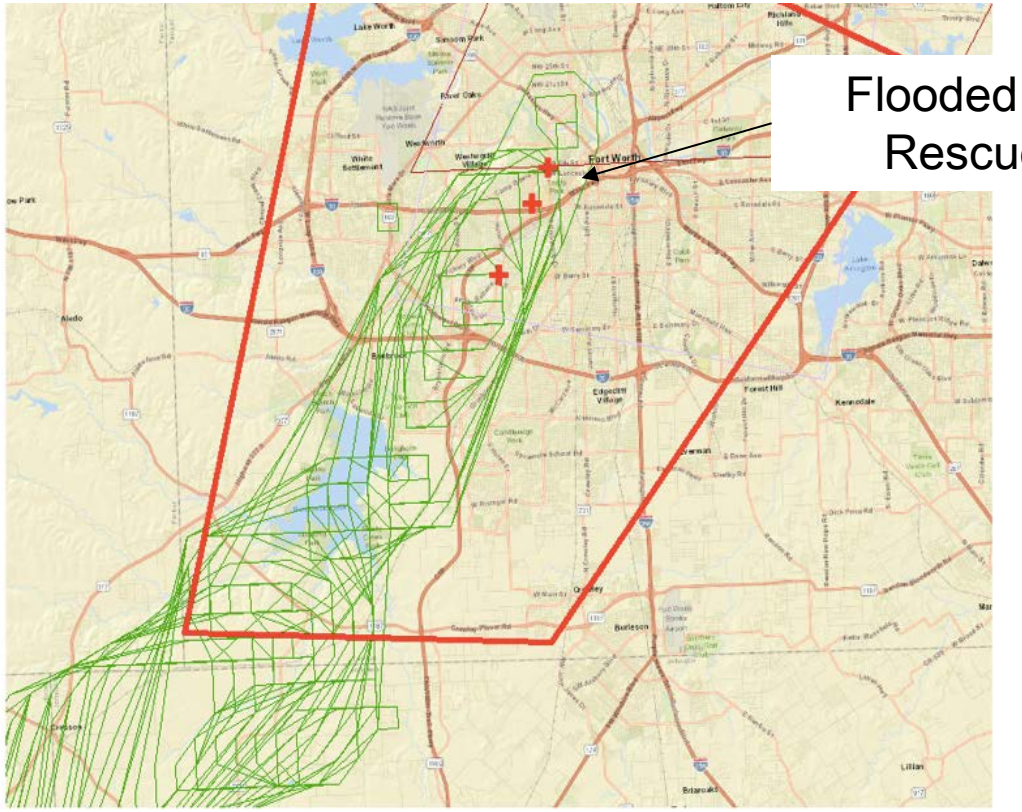
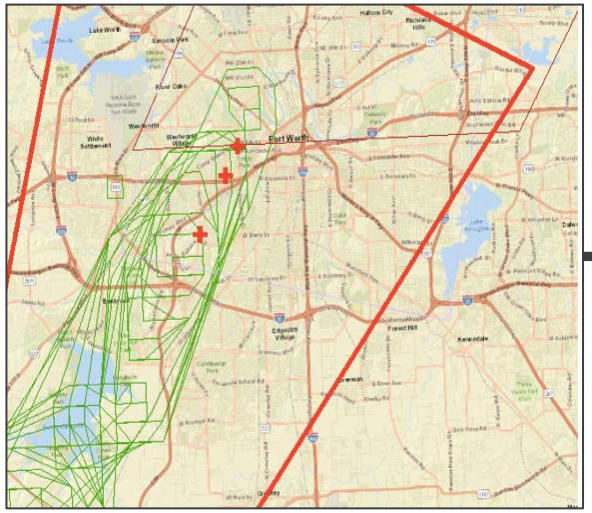
7/9/17 Flash Flood Case Study



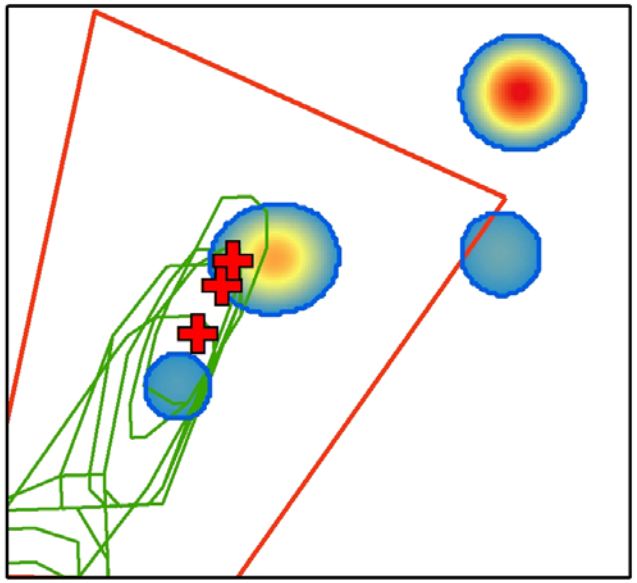
Environment and Infrastructure Risk



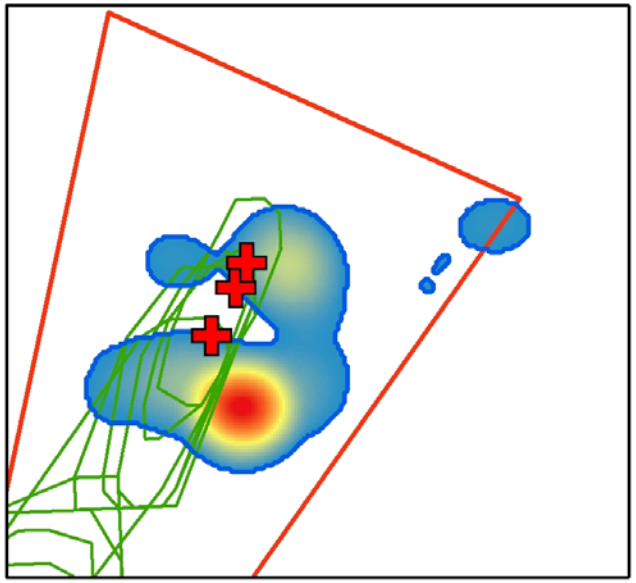
Policy and Rules: NWS Flash Flood Advisory & CASA Targeted Alerts



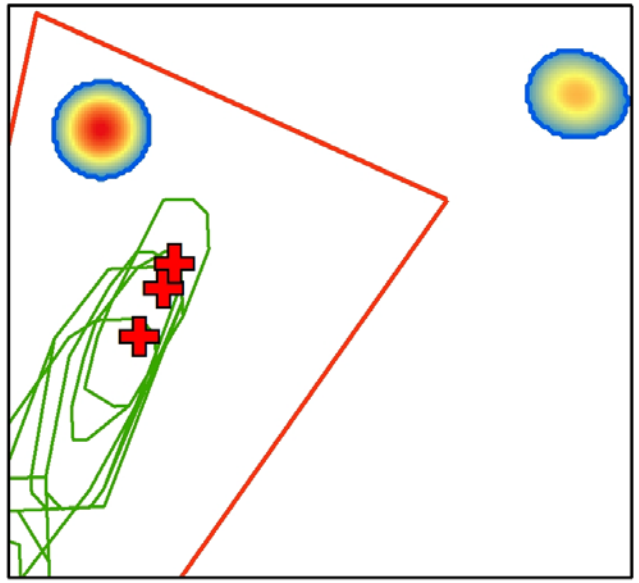
Individual footprints can represent people's spatial, temporal and perceptual contexts



Person #1 Potential Risk dependent on time of day



Person #2: High potential risk of floods



Person #3: Low potential risk of floods

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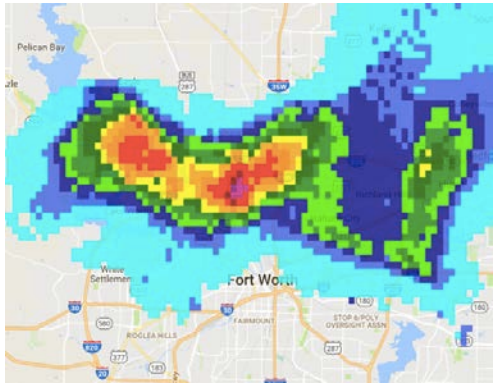
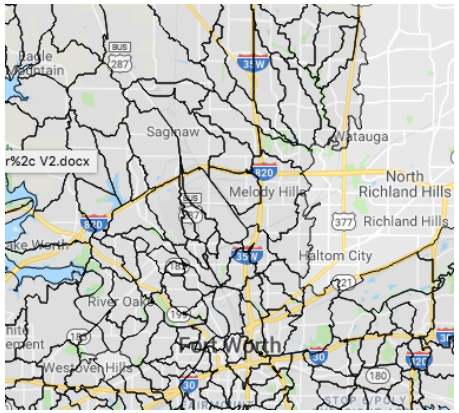
Broader Implications and Next Steps

Footprints Can Be a Spatial/Temporal Representation of People in Time and in Space in Operational Warning Systems

Environmental Risk



Infrastructure Risk



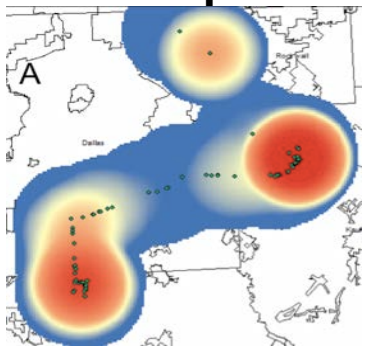
Alerts
(Automated, Manual)

Surveys

Mobile App

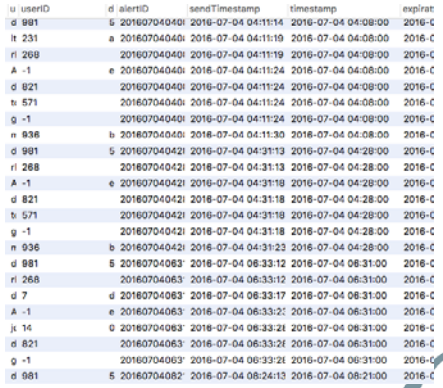
Warning Policy

People



Spatio-Temporal Data
Survey Results

Data Archive



Context-Aware Systems can incorporate and operationalize individual perception and preferences

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Next Steps

- If we can link user perception (about rain) and radar data, can we create better warning communications?
- Do footprints make a difference? Communicate hazards and warnings to people based on their footprints, anticipated locations, preferences
- Use data analytics (survey responses, app preferences, location data) to refine personalized alerting approaches
- Evaluate how current warning policy and individualized warnings can complement one another
- Address issues of convenience sampling, generalizeability, confounding variables in field experimentation

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Thank you

Questions and comments:

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Look for upcoming papers on this topic