INSIGHTS INTO CLIMATE CHANGE

Kristina W. Kintziger, PhD, MPH

Claire M. Hubbard Professor of Health and Environment

LEARNING OBJECTIVES

- Understand how sensors and novel applications of systems engineering methods can advance climate and health research
- Explore issues of sample size in epidemiologic studies

MICRO PERSPECTIVE

Extreme Temperatures

THREATS TO HUMAN-ENVIRONMENT SYSTEMS

Urban growth

- Influences humidity, precipitation, temperature, air/water quality, ecology

Climate change

- Influences urban infrastructure, ecosystems, food/water systems, air quality, human health
- Leads to morbidity, mortality, displacement

Air pollution

- Influences ecosystems, food/water systems, climate, human health
- Leads to morbidity, mortality, school/work absenteeism

RESEARCH GAPS

- Fixed-point measurements frequently used
  - Ambient data from weather stations
  - Criteria pollutant data from EPA air quality monitors
- Limitations include:
  - Sporadic locations of monitoring stations for accurate exposure measurement
  - Inconsistent relationships found in literature
  - Unexplained spatial heterogeneity in risk
- Personal/localized exposure substantially different from fixed-point measurements

MICRO-CLIMATE RESEARCH

- Wearable sensors and low-cost environmental monitoring sensors
- Personal heat exposure studies
  - Individually-experienced temperature (IET)
  - Individually-experienced heat index (IEHI)
- Indoor and outdoor air quality studies
  - Criteria pollutants
  - Airborne particulates
  - Aeroallergens

OCCUPATIONAL HEAT EXPOSURE AMONG MUNICIPAL WORKERS

OCCUPATIONAL HEAT RISK

- Outdoor workers at increased risk of heat-related illness
  - Agriculture, construction, firefighters, manufacturing, etc.
- Impacted by
  - Prolonged heat exposures
  - Limited air conditioning/ventilation
  - Physical labor strain
- Limited occupational indicators in most data sources

OCCUPATIONAL HEAT EXPOSURE STUDY

Objectives

- Examine differences in heat exposure among outdoor workers and the factors that lead to these differences
- Determine if local weather measurements are correlated to individual occupational heat exposure
- Assess opportunities or need for improved messaging, watches, and/or warnings

Design

- Recruited 50 municipal workers from May through June
- Collected demographic and risk factor information
- Provided iButtons to measure personal heat exposure
- Collected daily activity logs

IBUTTONS® AND DATA COLLECTION

Specifications

- Time, temperature (-4 to 185°F, and relative humidity (0-100%)
- Applications
  - Fresh food shipping
  - Field biology
  - Electrical power systems
  - Individual heat surveillance

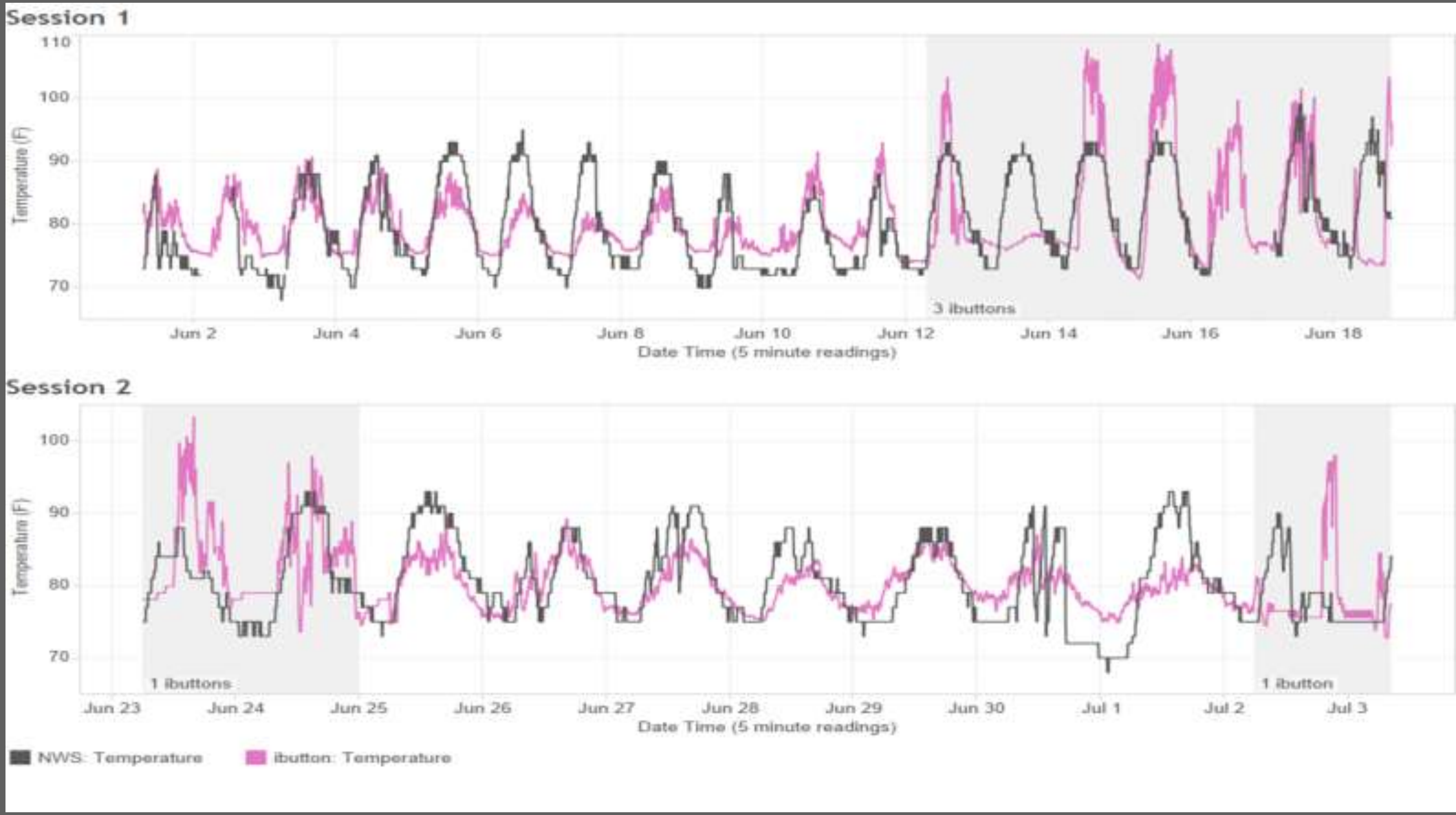
Credit: E. Kuras, 2014

Data Collection

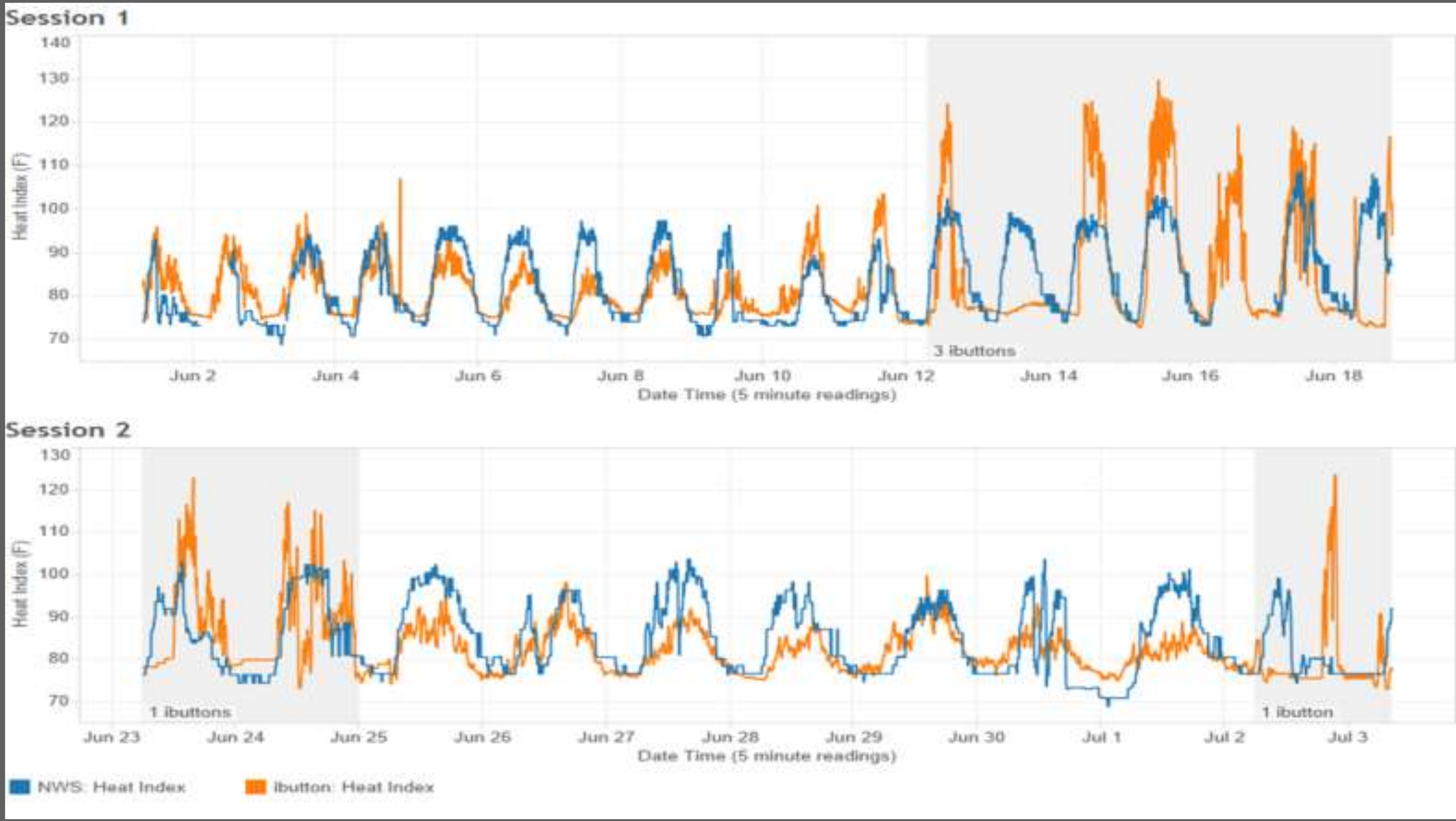
- Collection interval (5-30 minutes)
- Delay start option
- Requires reader
- Software generates graph/outputs

Credit: M. Jagger, 2015

TEMPERATURE TIME SERIES



HEAT INDEX TIME SERIES



SURVEY RESULTS

- BMI: under (6%), normal (12%), **over (38%), obese (44%)**
- Department: **Solid Waste (54%)**, Fleet (18%), Parks/Rec (16%), Other (12%)
- Occupational cooling features: **AC access in vehicle (78%)**, central AC (36%), fan (12%), open windows/doors (6%), none (16%)
- Home cooling features: **central AC (90%)**, window AC unit (8%), none (0%)
- **42% recalled hearing heat warnings** from previous summer
  - Of these, 90% reported changing their behavior accordingly
- **20% reported having HRI symptoms** in previous summer
  - Of these, 80% reported symptoms occurring more than once

PUBLIC HEALTH IMPLICATIONS

- Excellent outreach opportunity to local workforce
- Individual-level exposure information provided to participants
- May help improve public health messaging for occupational exposures to heat
- May provide more detailed understanding of causal pathways and individual vulnerabilities

URBAN HEAT ISLAND AND VULNERABLE POPULATIONS IN KNOX COUNTY, TN

Study 3

OBJECTIVES

- Characterize the impact of diurnal rhythms of heat on the human-environment systems in Knox County, Tennessee
  - Focus on identifying high-risk populations
  - Identify the scope of UHI effects
  - Assess social and health-related vulnerabilities
- Develop a Heat Task Force of Knox County stakeholders
  - Identify community-based adaptation strategies to improve outcomes for vulnerable populations

AIM 1: INDOOR & OUTDOOR OVERNIGHT HEAT

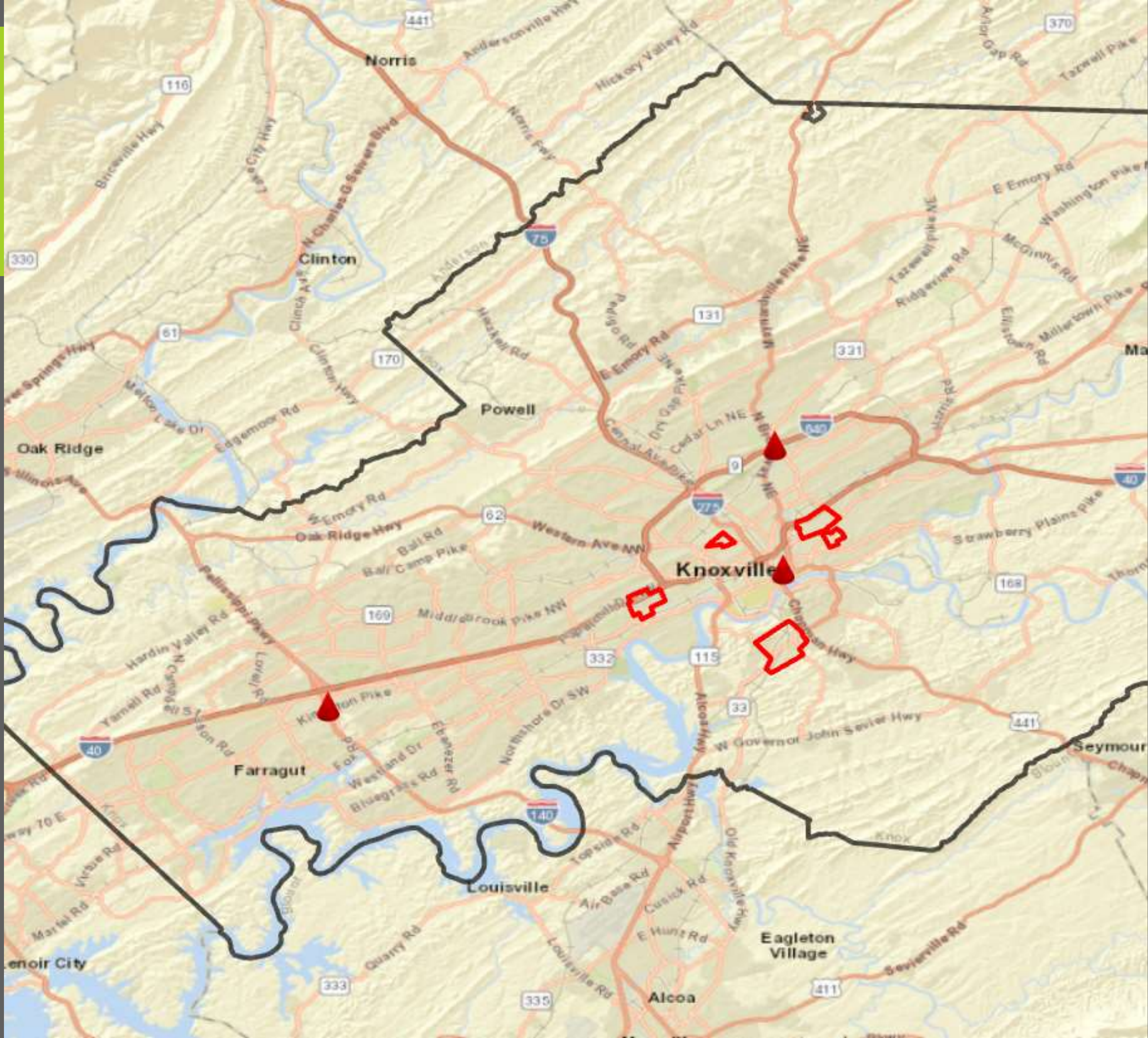
Using weather station and individually-experienced temperature data

WHY STUDY OVERNIGHT HEAT?

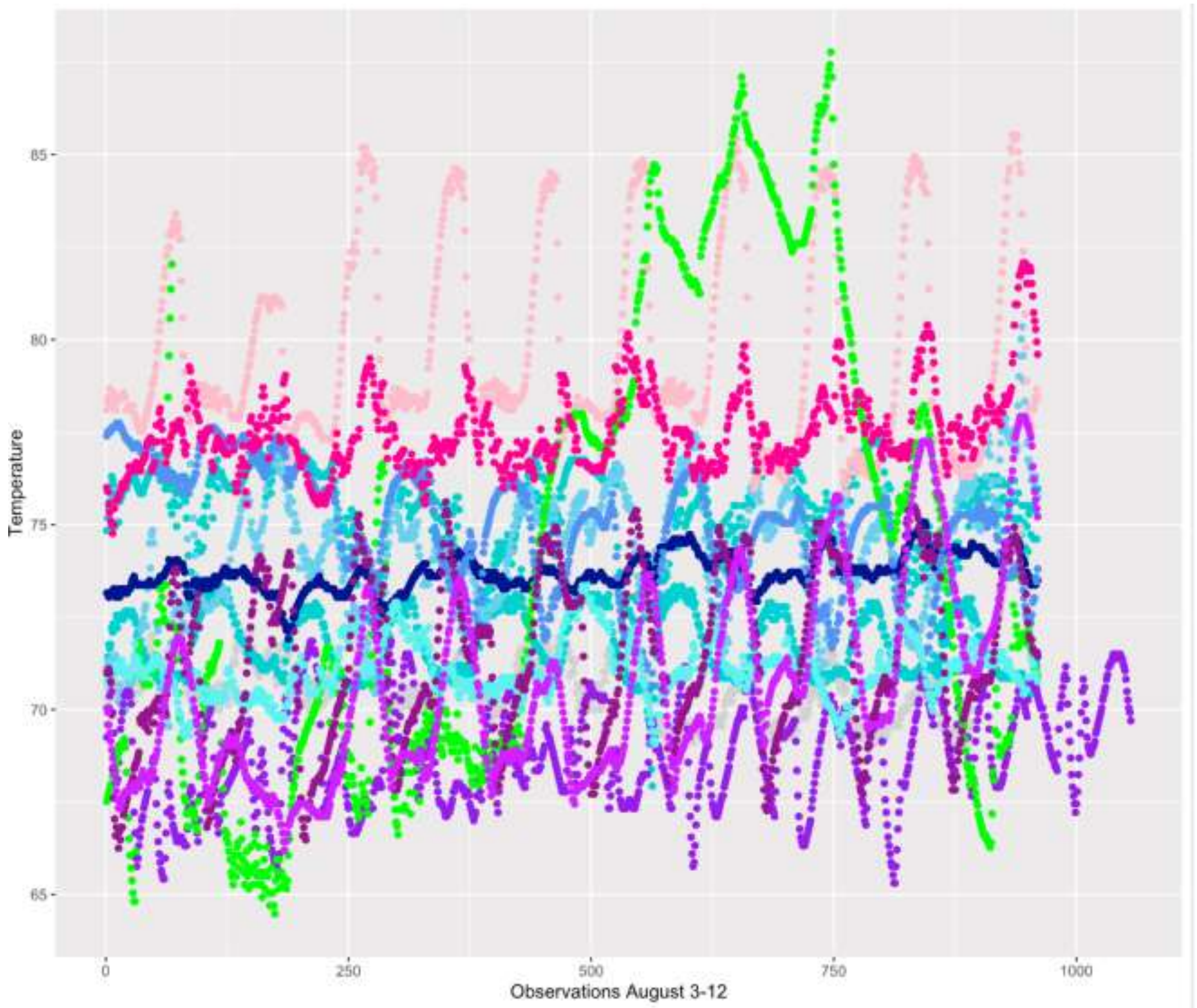
- Known effect of urban environment
- May have larger climate change signal
- Largely unknown public health impact
- Emphasizing differences in resources and vulnerabilities

DATA COLLECTION

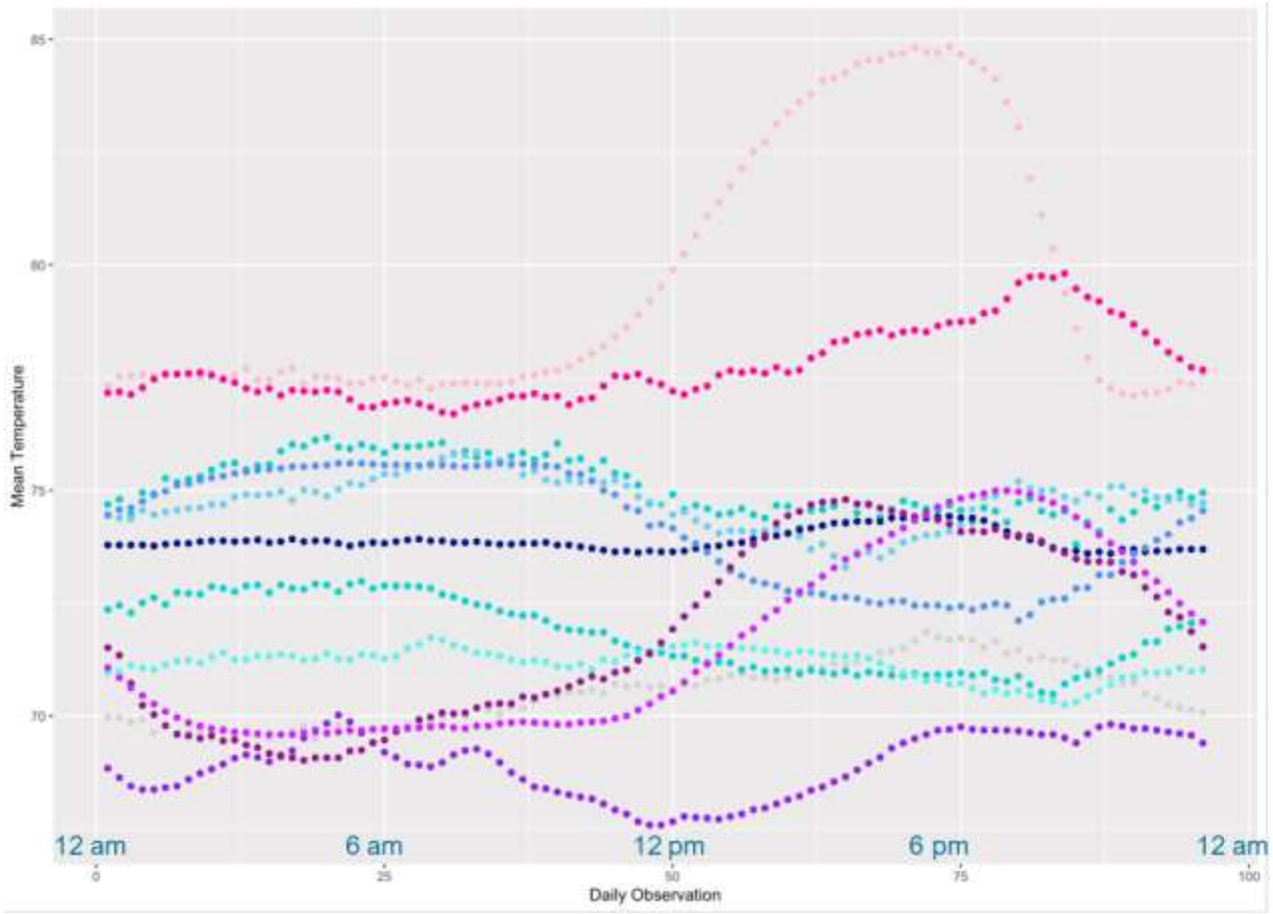
- Inside homes (n=15)
- 2 each near homeless encampments (n=6)

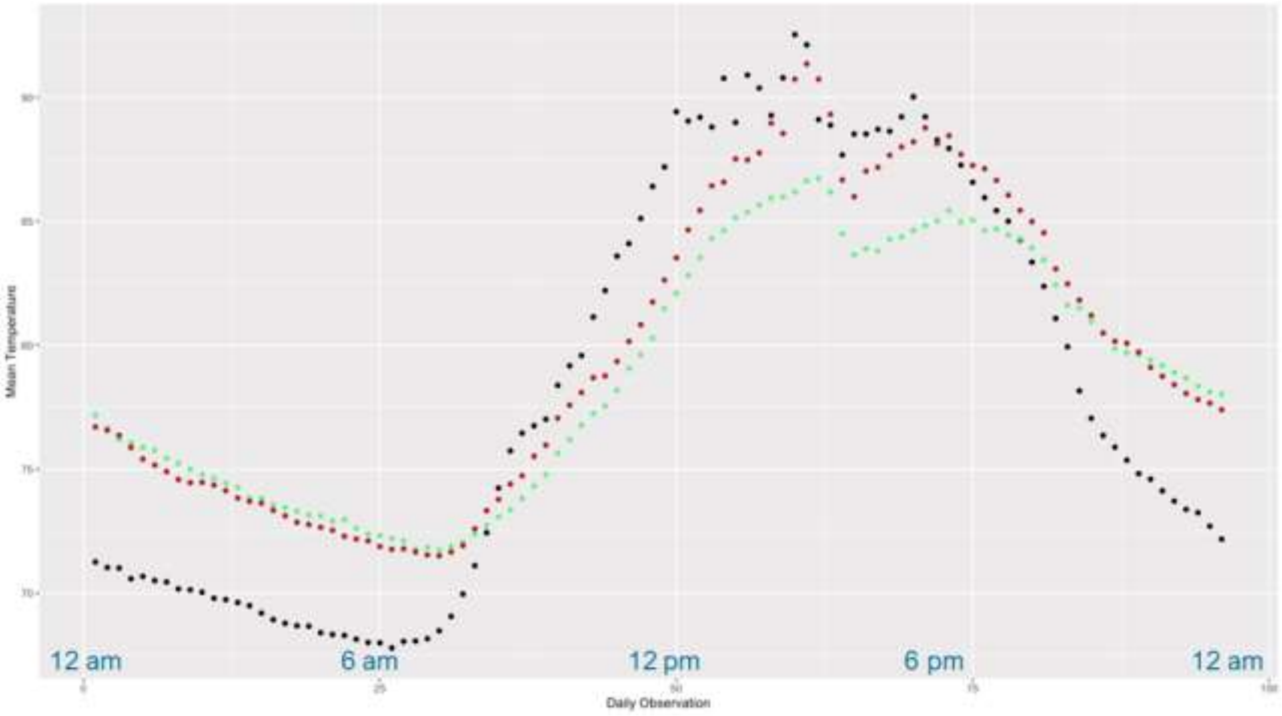


INDOOR HEAT PATTERNS

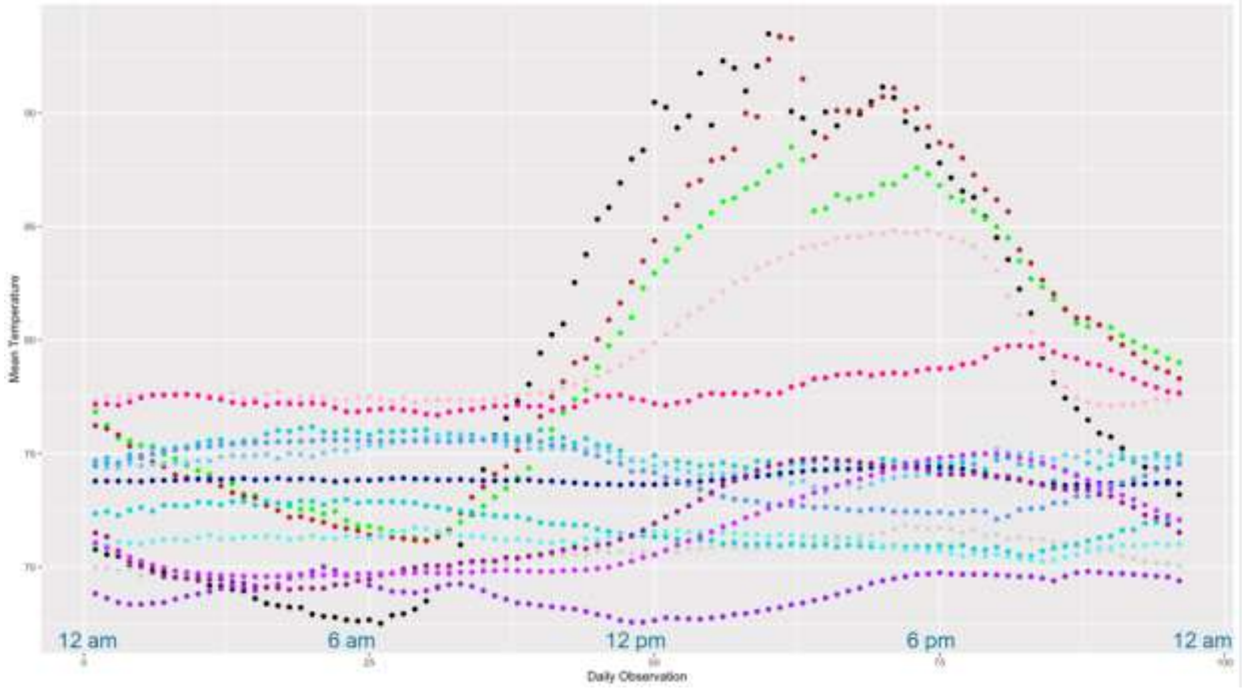


DAILY MEAN TEMPS





AVERAGE OUTDOOR HEAT PATTERNS



INDOOR VS. OUTDOOR LIVING SPACES

ELDERS ALERTS SYSTEM ABOUT IMMINENT ENVIRONMENTAL RISKS (EASIER)

OBJECTIVES

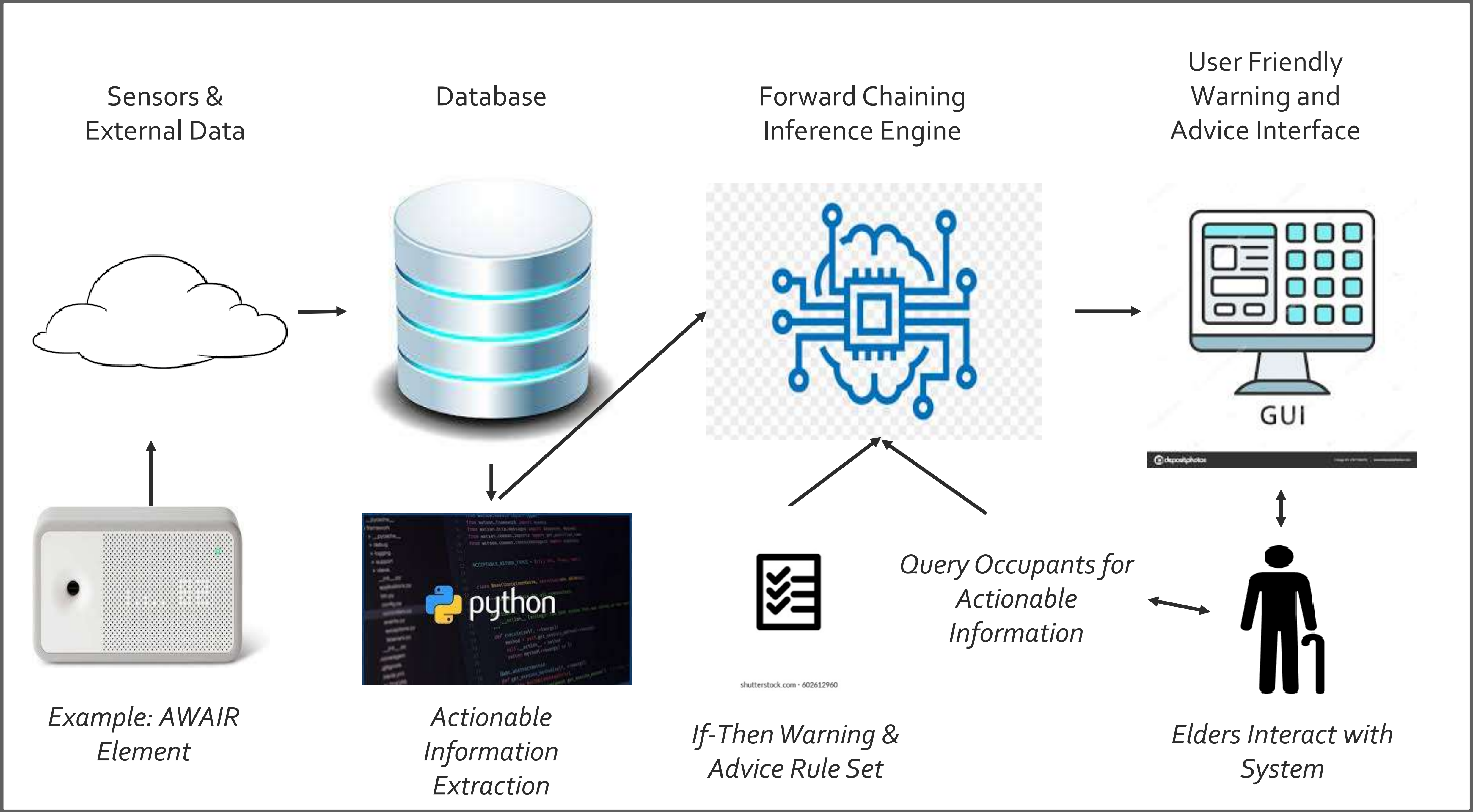
- Advance indoor environmental justice (EJ) outcomes for elders living in historically under-resourced communities of color
- Improve resilience of elders to indoor and outdoor risks

INDOOR MONITORING SYSTEM

- Indoor environmental quality (IEQ) systems installed
- Measures
  - Temperature
  - Humidity
  - PM2.5
  - CO_2
  - TVOCs
- Awair Element

OUTDOOR MONITORING SYSTEM

- Outdoor air quality monitors in participating neighborhoods
  - Purple Air
- Paired with weather conditions and weather forecast data


Sensors &
External Data
Database
Forward Chaining
Inference Engine
User Friendly
Warning and
Advice Interface
GUI
Example: AWAIR
Element
python
Actionable
Information
Extraction
shutterstock.com · 602612960
If-Then Warning &
Advice Rule Set
Query Occupants for
Actionable
Information
Elders Interact with
System

ALERTS & MESSAGING

- Good Morning Forecast and Messages
- Real-Time Weather Alerts
- “Too Cold in Home” Alerts (temperature and humidity based)
- “Too Hot in Home” Alerts (temperature and humidity based)
- Indoor Air Quality Alerts
  - CO_2
  - PM2.5
  - VOCs

"TOO HOT IN HOME"

Yellow

- Temperature > 80°F

Home is reaching unsafe temperature. Turn down thermostat on the AC.

Be on the lookout for signs of heat-related illness.

If you want more information on symptoms of heat-related illness, click **here**.

If you feel symptoms of heat exhaustion or heat stroke, click **here** so to alert your social network.

Click **here** to acknowledge receiving this message.

Red

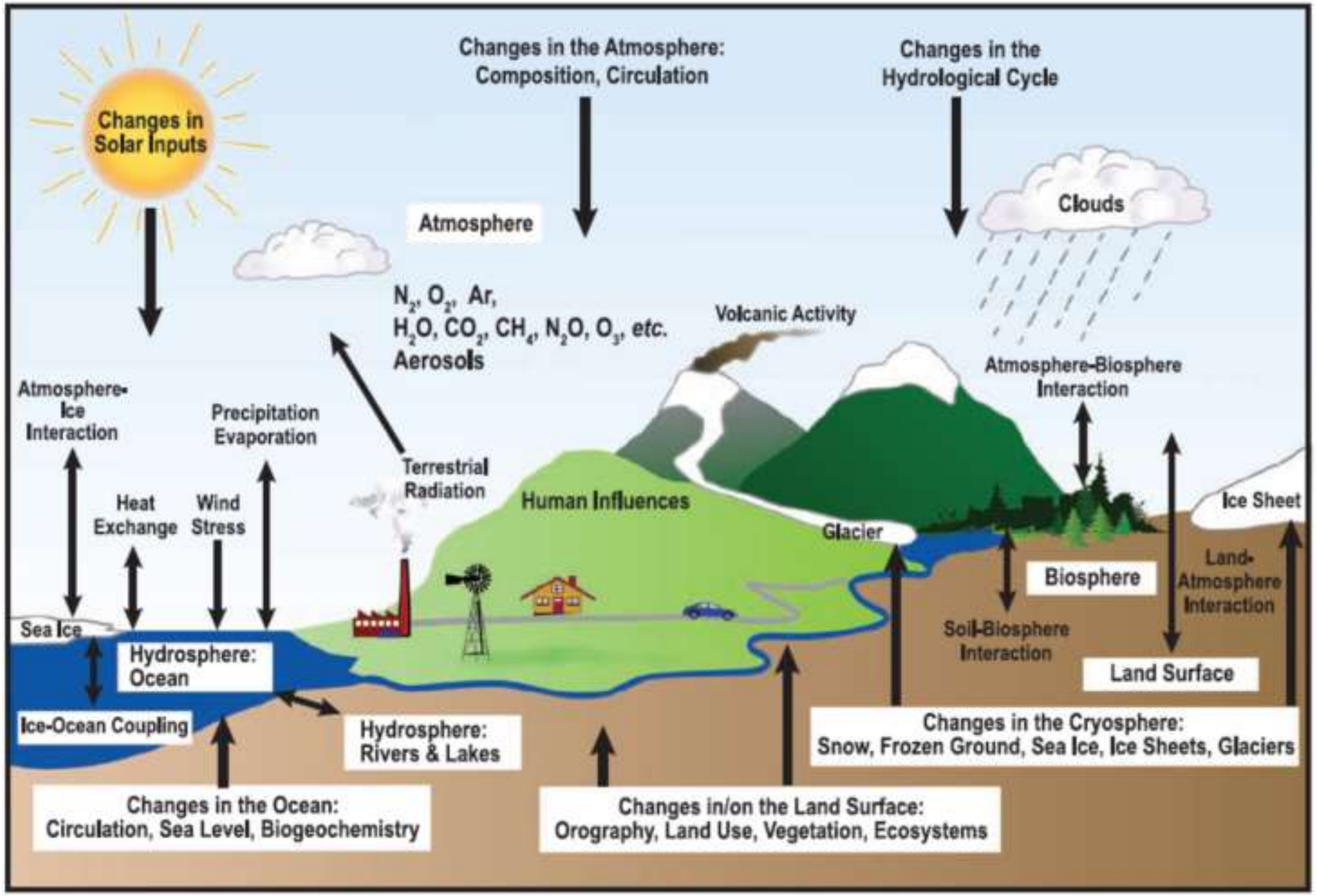
- Temperature > 86°F

MACRO PERSPECTIVE

Preparedness for Meteorological, Hydrological, and Biological Disasters

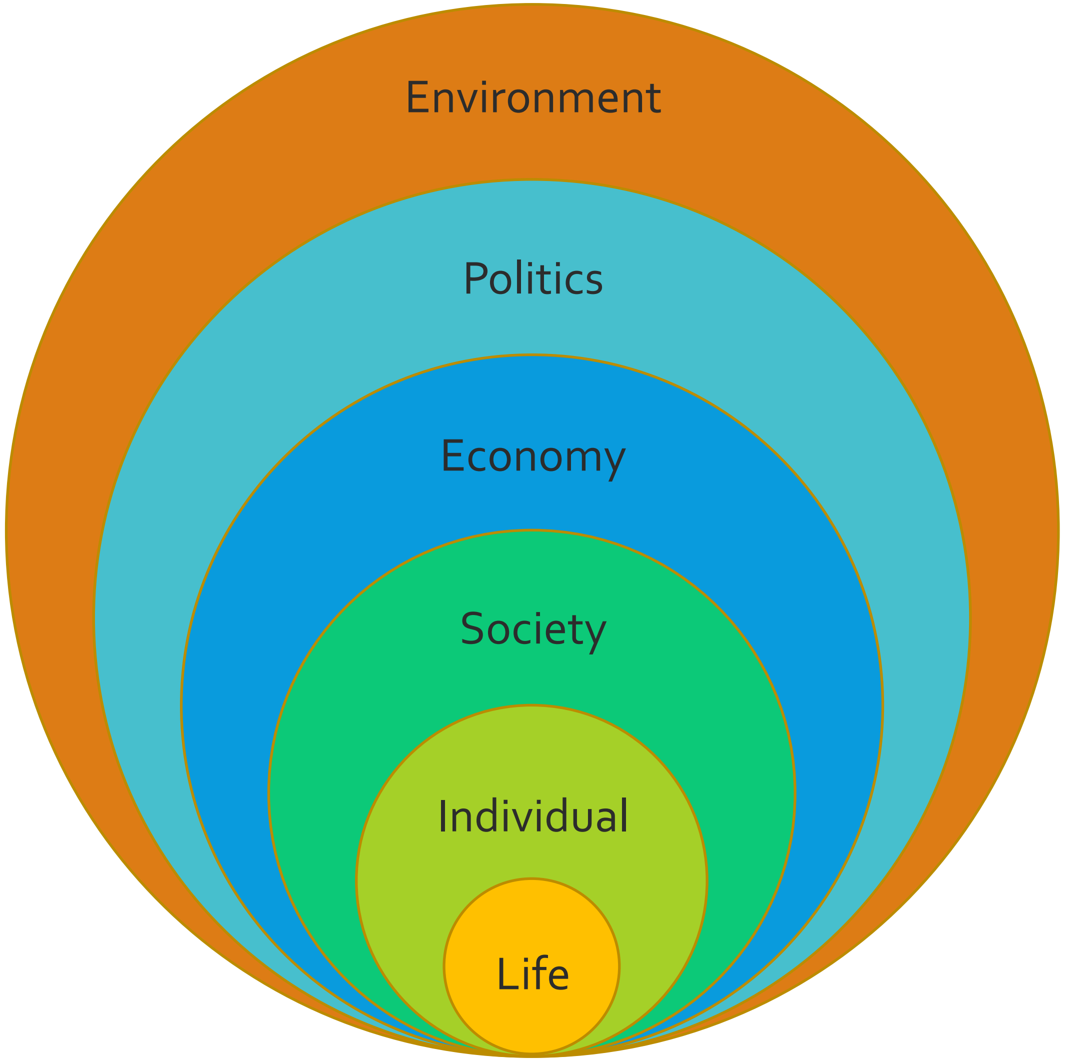
COMPLEX SYSTEMS

- Complex adaptive systems (CAS) – many individual elements interacting on a micro-level in a dynamic and non-linear manner to affect the system behavior
  - Distributed control
  - Non-linearity
  - Diversity
  - Emergent behavior/order
  - Connectivity
  - State of paradox



COMPLEX SYSTEMS & CLIMATE SCIENCE

Source: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. Averyt, M. M. B. Tignor, and H. L. Miller, eds. Climate Change 2007: The Scientific Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, UK, Cambridge University Press, 2007.



An adapted Meikirch model of individual health.

COMPLEX SYSTEMS & PUBLIC HEALTH

MULTI-METHOD MODELING TO SUPPORT PREPAREDNESS IN RURAL COMMUNITIES

BACKGROUND

- Decline in healthcare capabilities in rural communities
- Affects ability to respond to emergency events
- Public Health Emergency Preparedness (PHEP) and Hospital Preparedness Program (HPP) frameworks and guidance available to support activities

METHODS AVAILABLE

- System dynamics modeling – systems level, top-down approach
- Agent-based modeling – individual agent level, bottom-up approach
- Discrete event modeling – logical and separate sequence of events, queuing approach

PROJECT OVERVIEW

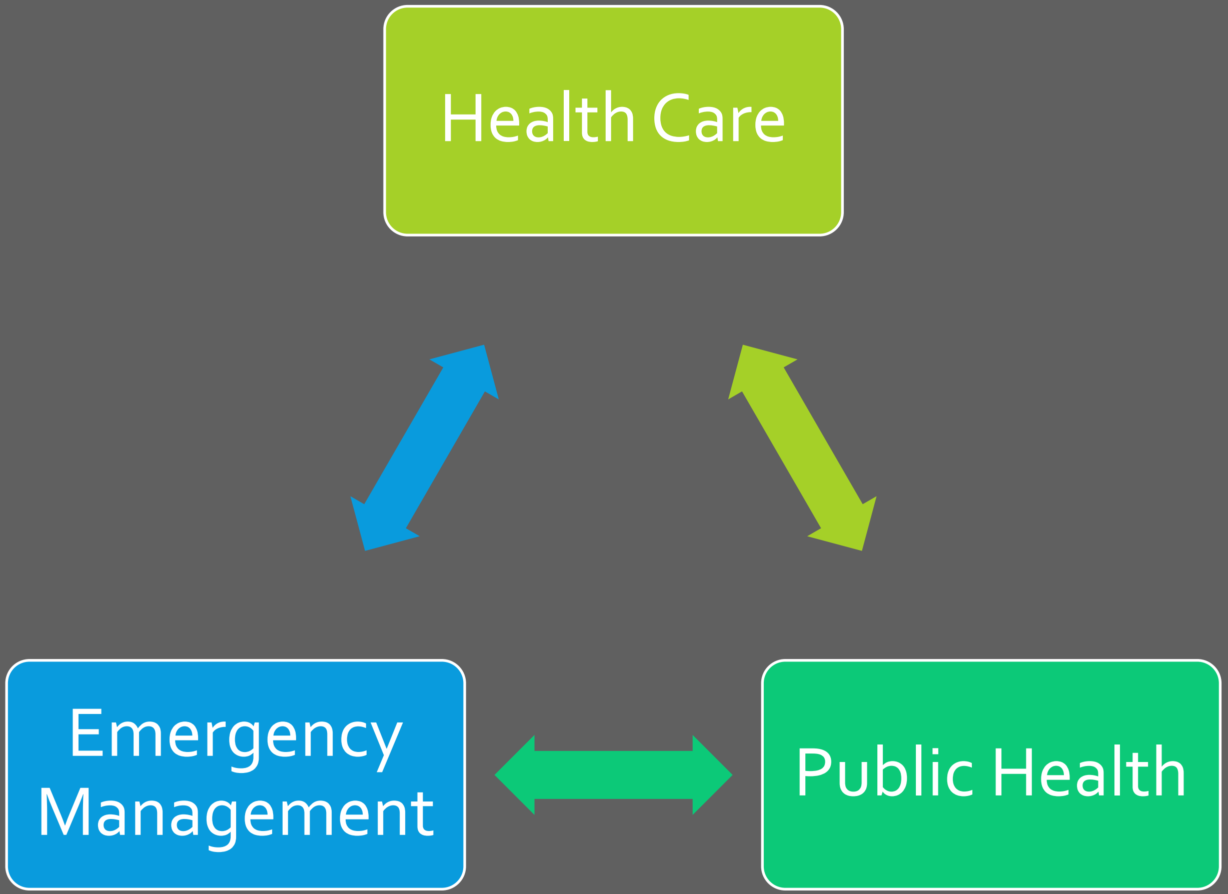
Goal

- Apply advanced model-based systems engineering methods to develop a proof-of-concept multi-method computer simulation to be used as a tool to assess the efficacy of emergency planning on health effects for rural communities

Objective

- Develop a tool based on a complex systems representation of the interactions of primary health care and emergency preparedness

MAIN SECTORS AND SYSTEM COMPONENTS

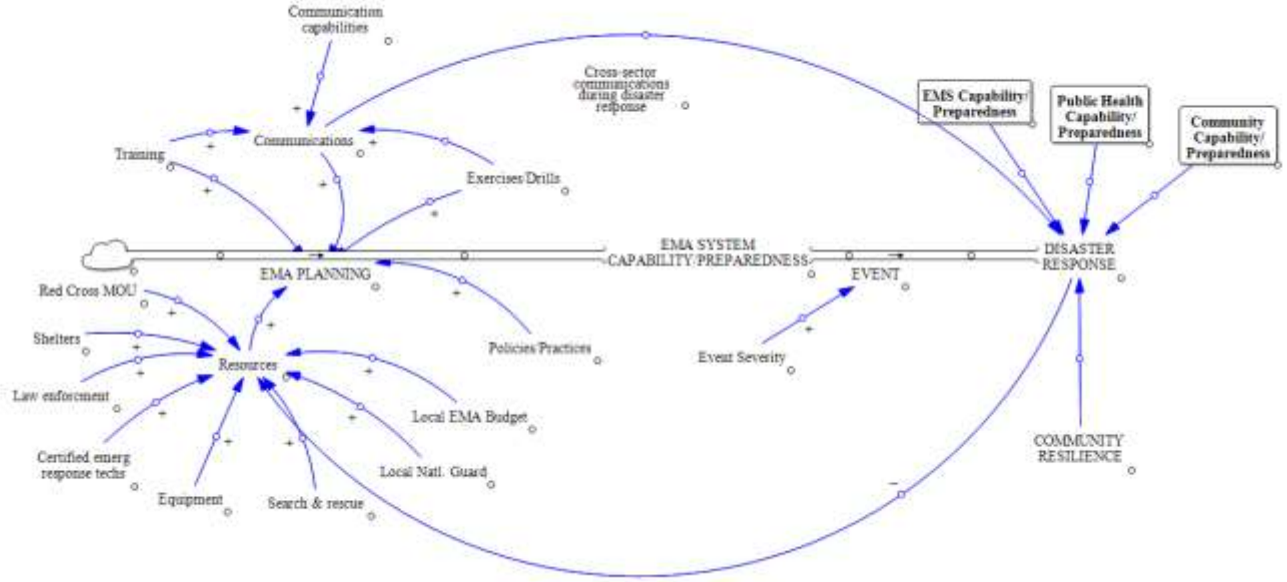


Policies & Procedures
- All hazards plan components

Communications
- Electronic data systems

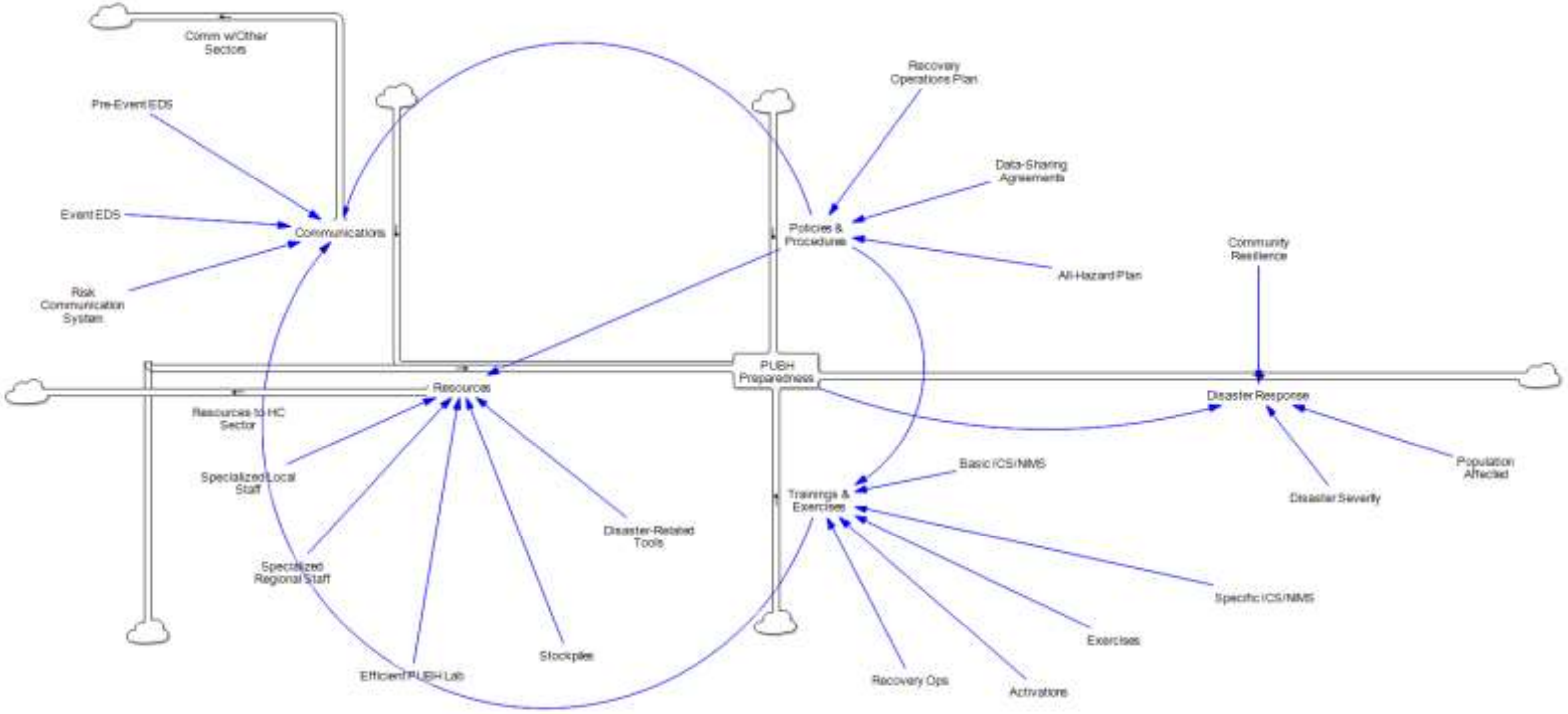
Resources
- Space/staff/stuff

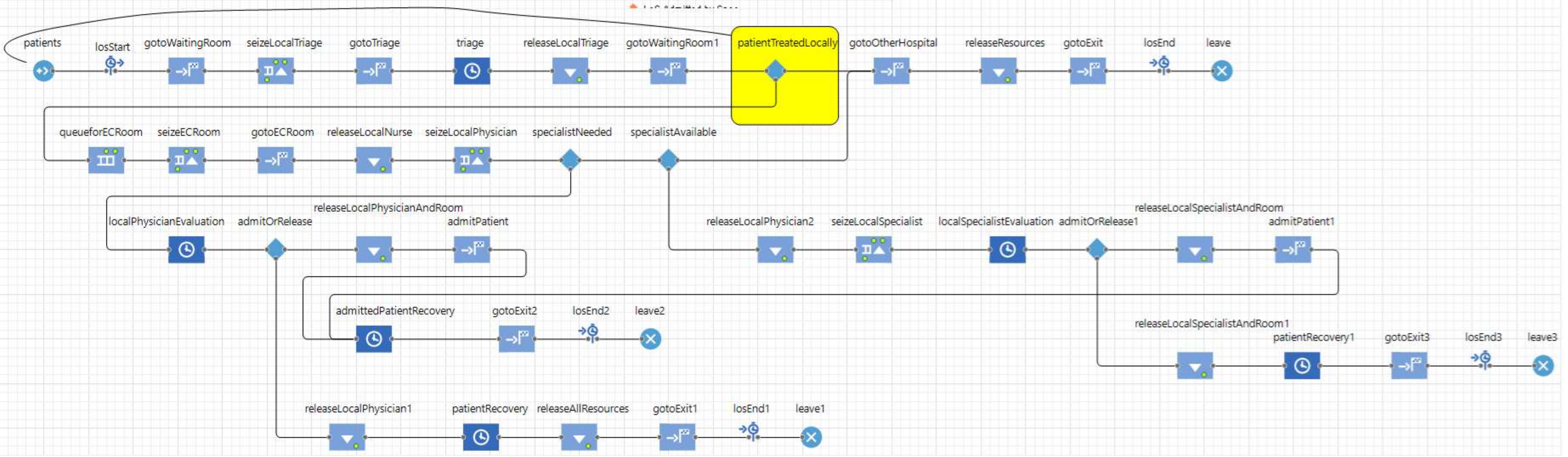
Exercises/Drills/Trainings
- Past activations



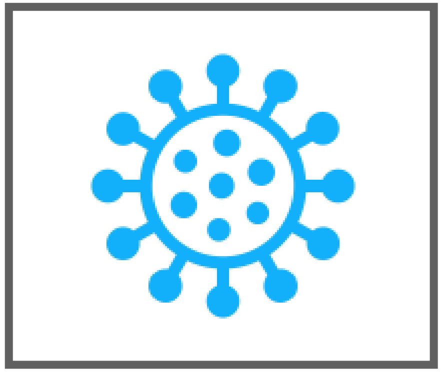
EMERGENCY MANAGEMENT

PUBLIC HEALTH PREPAREDNESS





PATIENT FLOW THROUGH HEALTH CARE DURING A DISASTER



VERIFICATION & VALIDATION

- Flooding in Humphreys County, Tennessee
- Tornado in Joplin, Missouri
- Pandemic response rural counties

ISSUES IN DESIGNING STUDIES

Sample Size Calculations

SAMPLE SIZE ISSUES

- Fundamental Point
  - Studies must have sufficient statistical power to detect differences of <u>clinical</u> interest

- High proportion of published negative trials do not have adequate power

EXAMPLE: HOW MANY SUBJECTS?

- Compare new treatment (T) with a control (C)
- Previous data suggests Control Failure Rate (P_c) is approximately 40%
- Investigator believes treatment can reduce the failure rate in controls, P_c, by 25%
  - E.g., $P_T = .30$, $P_C = .40$
- N = number of subjects/group?

SAMPLE SIZE ISSUES

- Sample size estimates are only approximate
  - Uncertain assumptions
  - Over optimism about treatment
  - Healthy screening effect
  - If what is actually observed is different than what is expected, then sample size will be incorrect
- When determining sample size, you need to examine various estimates
  - Try various assumptions
  - Must pick most reasonable
- Be conservative yet reasonable

SAMPLE SIZE ISSUES

- Investigators need to provide a statistician or biostatistician with reasonable and **clinically relevant** estimates of the effectiveness of the treatment versus control.
- Estimates from pilot data are good, but may not be ideal
- Inclusion and exclusion criteria could modify the sample size later

STATISTICAL CONSIDERATIONS

Null Hypothesis (H_0)

No difference in the response exists between treatment and control groups

Alternative Hypothesis (H_1)

A difference of a specified amount exists between treatment and control

Significance Level (α): Type I Error

The probability of rejecting the null hypothesis, H_0, given that H_0 is really true

Power = ($1 - \beta$): (β = Type II Error)

The probability of rejecting the null hypothesis, H_0, given that H_0 is really false

STATISTICAL CONSIDERATIONS

Design of the study

- Number of factors
- Number of levels in each factor
- Any repeated measures

How the outcome is measured

- Continuous
- Ordinal
- Categorical

STATISTICAL CONSIDERATIONS

- Preliminary estimates of expected differences (means, proportions, correlations, survival, OR, RR)
- Anticipated analysis that will be performed
- Consider
  - Different effects, both larger and smaller
  - Pair wise tests of interest
  - Main effects versus interaction or synergistic effects
- Estimates should be conservative

TYPICAL ASSUMPTIONS

- Statistical significance level, α = .05, .025, .01
- Power = .80, .90
  - Should be at least .80 for all design factors of interest
- δ = smallest difference hope to detect
  - Example $\delta = P_C - P_{T} =$ .40 - .30 = .10
  - 25% reduction

SAMPLE SIZE OR POWER NEEDS FOR CATEGORICAL DATA

- Categorical tests are based on proportions of “success” in the treatment and control groups
- Assumptions needed
  - Alpha
  - Power
  - Proportion in the control group experiencing “success”
  - Percent change or actual change of the proportion of “success” in the treatment group
- Analyses used include chi-square tests and logistic regression

SAMPLE SIZE FOR CONTINUOUS RESPONSE VARIABLES

- Assumptions needed
  - Hypotheses being tested
  - Alpha
  - Power
  - Expected mean for each group and the clinically relevant difference
  - A common standard deviation or the standard deviation in each group
- Analyses used include t-tests, analysis of variance, regression

SAMPLE SIZE FOR SURVIVAL ANALYSIS

- To determine sample size or power there are several assumptions that need to be made
  - The hazard rate, survival rate, or death rate within a given short period of time for each group
  - Alpha
  - Power
  - This is the ratio of treatment to control in the sample
  - The proportion of potential loss-to-follow-up
  - Hypotheses

SAMPLE SIZE FOR TESTS OF EQUIVALENCE

- Want to compare a new treatment to a standard treatment and show that the new is "as good as" the standard
- Idea is to determine some minimum difference you would consider the estimates to be equivalent and some difference you would consider the estimates to be different
- Assumptions needed
  - Expected mean response or proportion for new and standard treatment
  - Type of study design (cross over or two group design)

SAMPLE SIZE FOR TESTS OF EQUIVALENCE

- Assumptions needed
  - The upper limit on the range of equivalence.
    - If the difference is greater than the upper limit, then the treatments are not equivalent.
    - If the difference is less than the upper limit, then the treatments are equivalent
  - The lower limit on the range of equivalence
  - Alpha
  - Power
  - Standard deviation of the mean

SAMPLE SIZE FOR MULTIPLE AIMS OR HYPOTHESES

- Many studies have multiple aims, hypotheses and response variables
  - Must force investigator to rank them for importance
  - Do sample size on a few outcomes (2-3)
  - If sample size is similar, great.
  - If the estimates are vastly different
    - Use the larger number
    - Compromise, but make sure sample size/power is sufficient for the primary aim or outcome.

THANK YOU!