Weather, Climate and Health: Integrating the Social and the Physical Sciences

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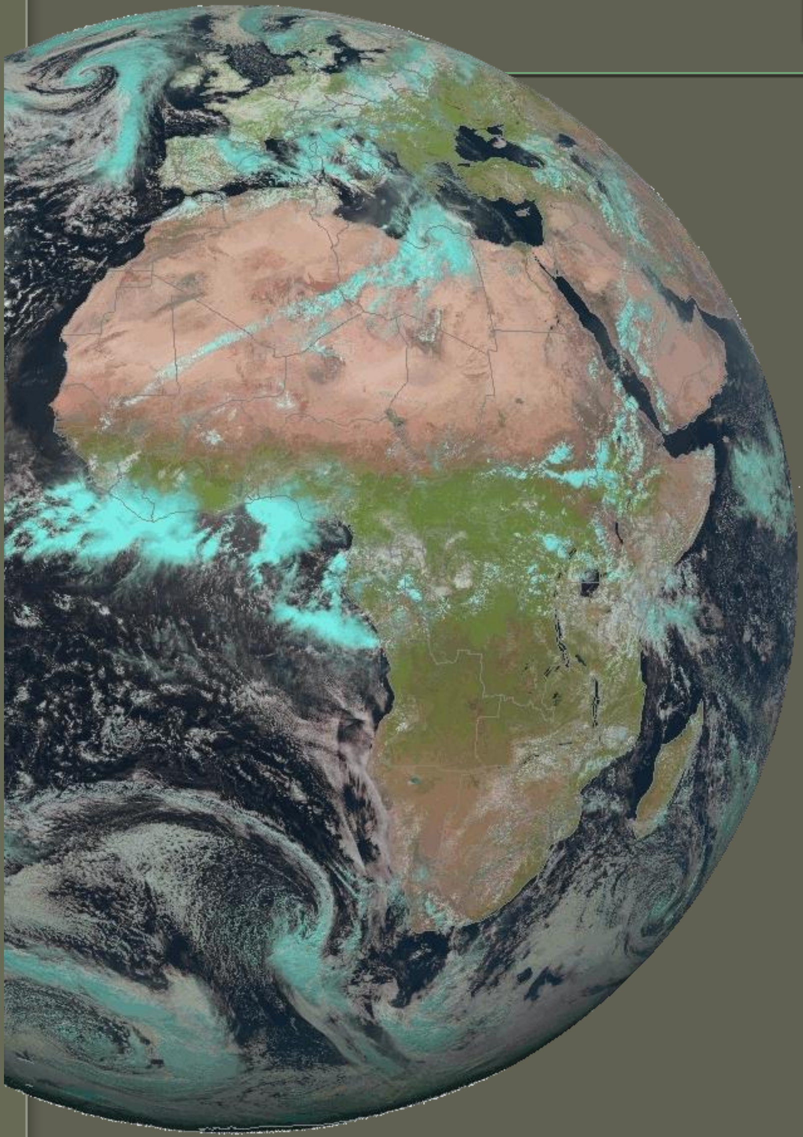
NCAR

Presentation Outline

- Weather and Meningitis
- Plague
- Extreme Heat

The Weather-Meningitis Research Project



google.org

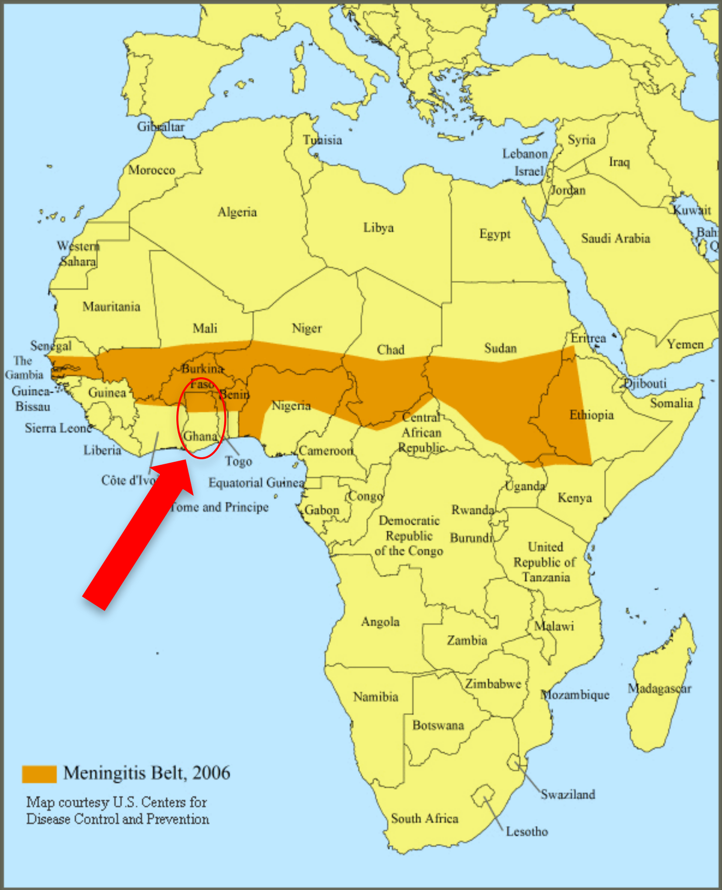
Applying Meteorology to Help Manage Meningitis

- Project goal:
  - Minimize meningitis incidence by providing 1-14 day weather forecasts to target dissemination of scarce vaccine

- Project objectives:
  - Investigate utility of meteorological forecasts to inform vaccination campaigns
  - Identify and analyze meningitis risk factors

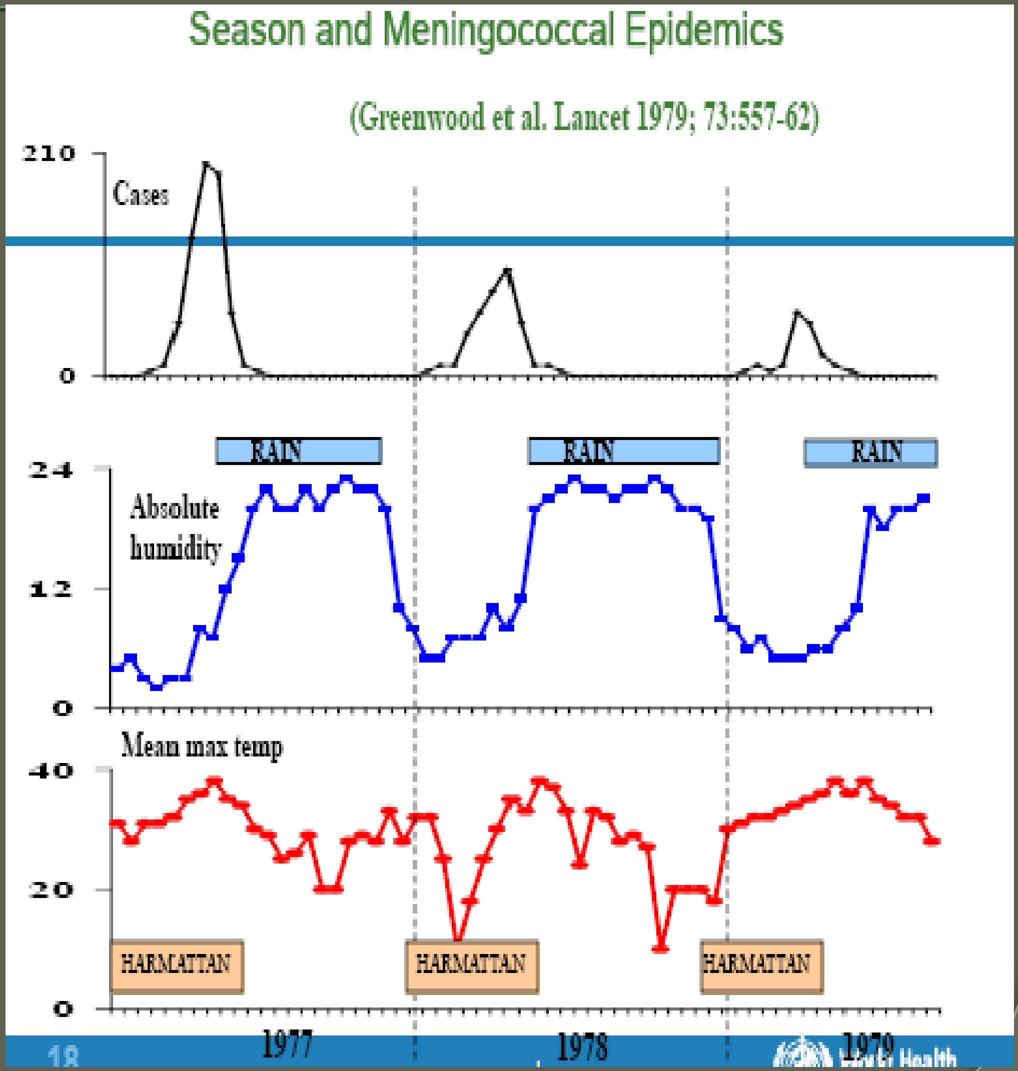
Managing Meningitis in the Sahel

- Meningitis is endemic in the Sahel in countries with a distinct wet-dry season
- Infectious disease due to bacterium – *Neisseria meningitidis*
- Epidemic in 1996-1997 resulted in 250,000 cases and 25,000 fatalities
- Person-to-person transmission through respiratory and throat secretions – between 10-25% of population may carry bacteria at any time; higher during epidemics
- A **reactive** vaccine strategy is currently used to manage epidemics
    - *Doesn't prevent transmission of the disease by the individual vaccinated*
    - *Only lasts one-to-two years*
    - *Doesn't produce an immune response in children under two*



Weather Affects Meningitis Transmission

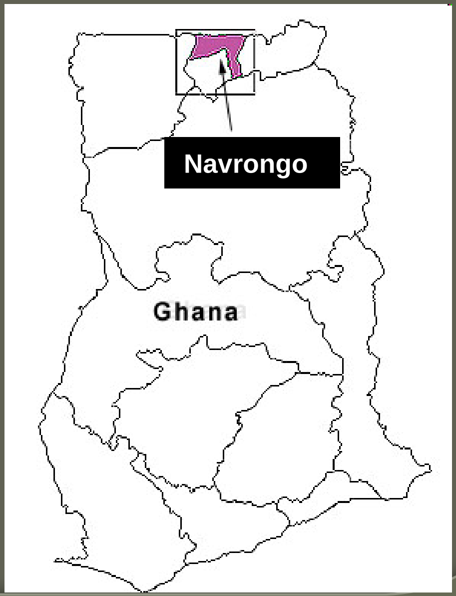
- *Nm. meningitidis* epidemics need three factors to occur:
  - A population susceptible to the emerging serogroup
  - A hyperinvasive/virulent strain
  - *Risk factors (environmental factors/social factors)*
- *Nm. meningitidis* epidemics occur in the dust season and end with the onset of the rainy season



Navrongo Health Research Centre, Ghana

- Available Epidemiological Data
  - Navrongo, in UER of northern Ghana, has excellent meningitis surveillance data going back 10+ years
  - Reference lab for the region for confirming and serogrouping
- Local Expertise
  - Drs. Abudulai Adams-Forgor and Abraham Hodgson
  - Former NCAR post-doc, Dr. Benjamin Lamptey, provides ties to the operational weather community in Ghana

Navrongo Health Research Centre Main Entrance (above) and Region of surveillance (below)



Prediction of the End of the Dry Season

- Weather forecasts
  - —WMO THORPEX TIGGE Weather Ensembles (focus: NCEP and ECMWF), 1 to 14 days
  - —optimally-combine into probabilistic forecast for humidity, 1-14 days out, over Northern Ghana
  - —verify forecast skill

Social-Environmental Factors

- Environmental factors in meningitis transmission
  - HOBO data loggers to be deployed March 2010 at 20 sites in K-N district – indoors and outdoors
- Knowledge of meningitis (symptoms and transmission dynamics)
- Personal experience with meningitis and health-seeking behavior
  - Exposure (e.g., indoor cooking; human migration)
  - Risk behavior (sharing room/utensils with sick person)
  - Traditional medicine and western medicine approaches to disease management
- Cost of illness/cost of treatment
- Vaccine access and acceptability

Socio-economic Survey, Navrongo 2010

Photo: Brant Foote, NCAR

Village in UER, Ghana

Photo: Mary Hayden, NCAR

Navrongo, Ghana

Photo: Mary Hayden, NCAR

Plague in Uganda

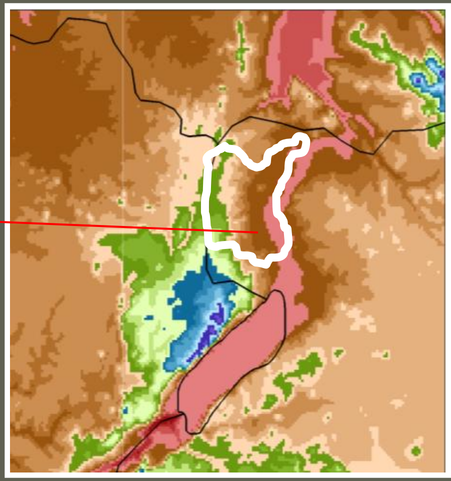
- Project goal:
  Generate 10 year high resolution climate datasets to model plague in Uganda

- Project objectives:
  Reduce incidence of plague by providing early warning
  Mobilize resources to areas where plague is predicted

Background

- Plague is a highly virulent and flea-borne zoonotic disease caused by *Yersinia pestis*.
- Bacterium that causes plague is transmitted by fleas that travel on rats
- Local rat populations fluctuate in response to climate variability
- From 1999-2007, approximately 2,000 suspect human plague cases were reported from the West Nile Region in NW Uganda.

Background

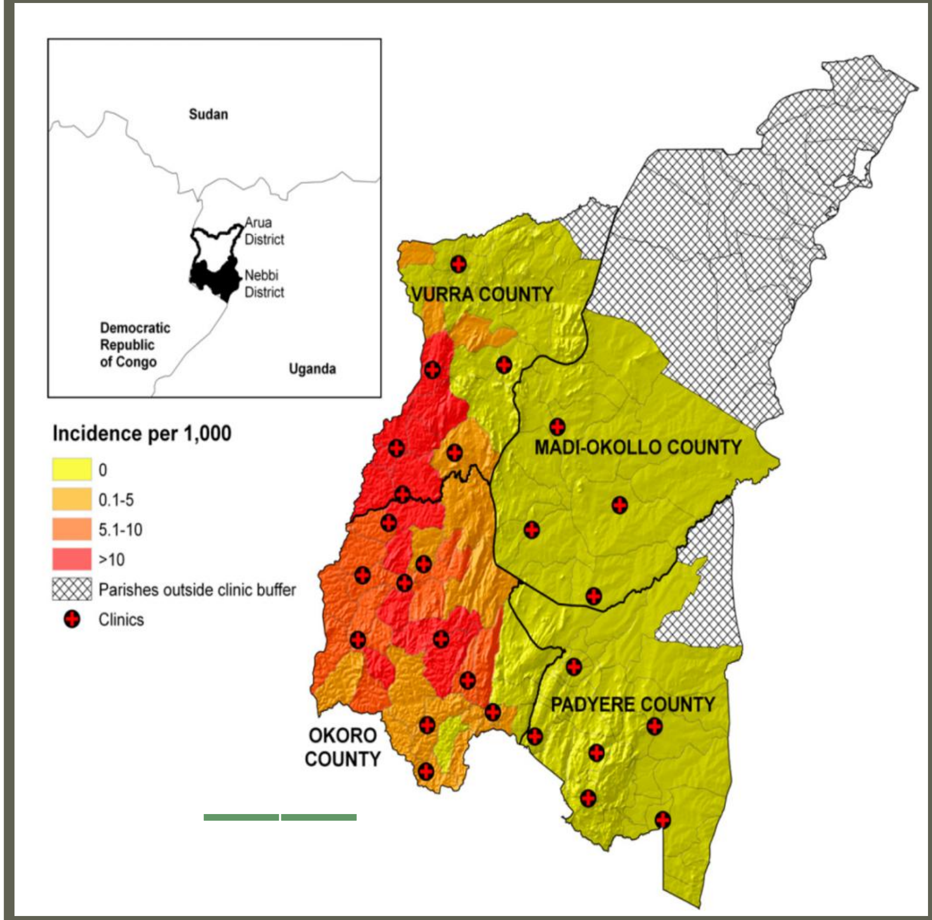


CDC is developing models based on ecological correlates with plague. Preliminary modeling has employed the following variables to project plague at the parish level:

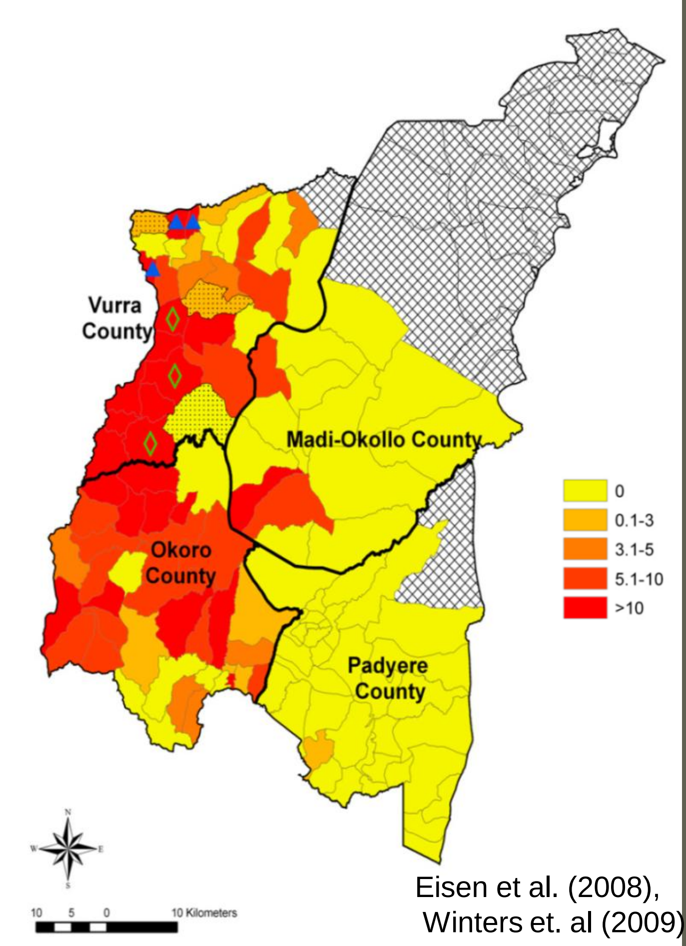
-Elevation
-Satellite-derived:
--greenness
--wetness
--brightness
--surface temperature
--land use heterogeneity

Observed* versus Modeled Plague Cases 1999-2007

Observed Plague Cases (1999-2007)



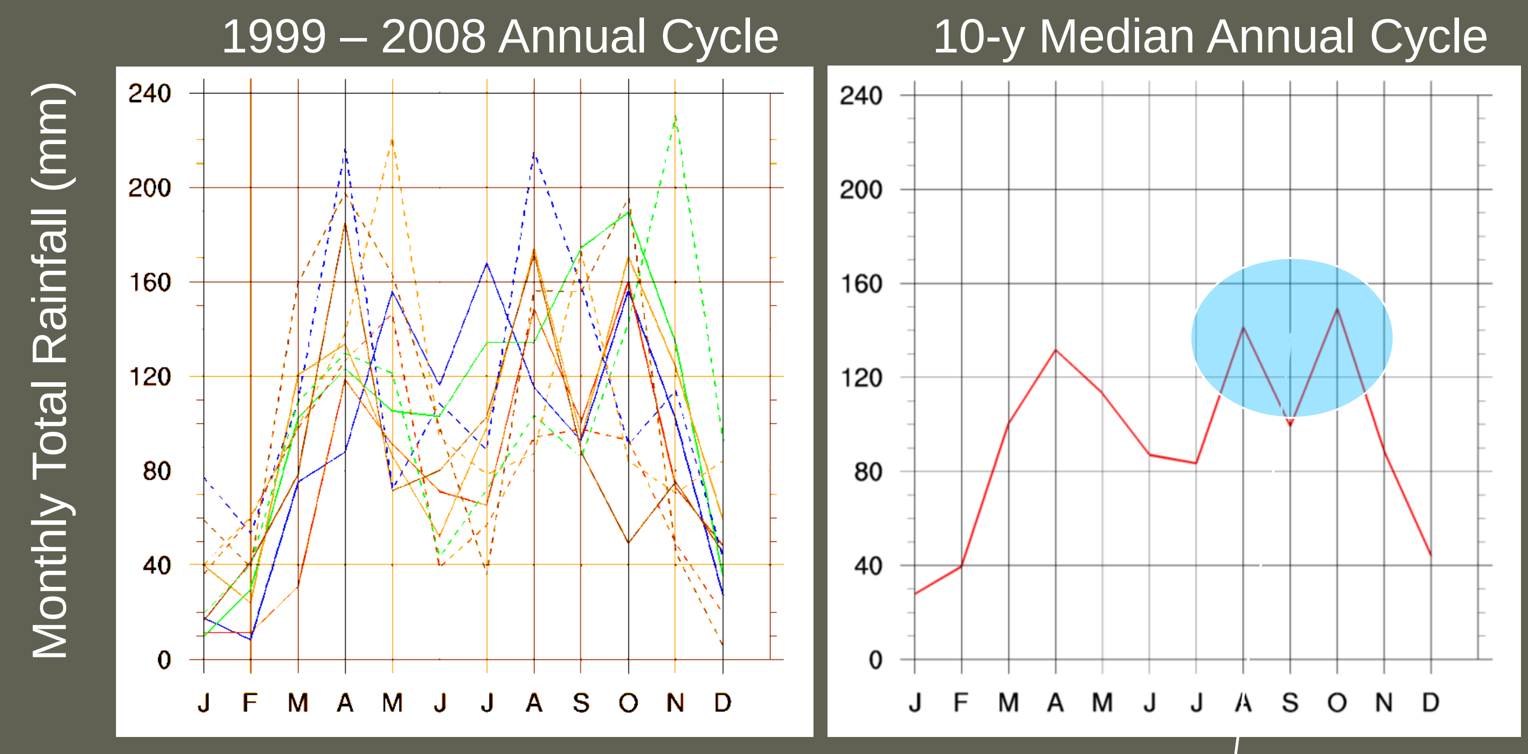
Modeled Plague Cases (1999-2007)



Eisen et al. (2008), Winters et. al (2009)

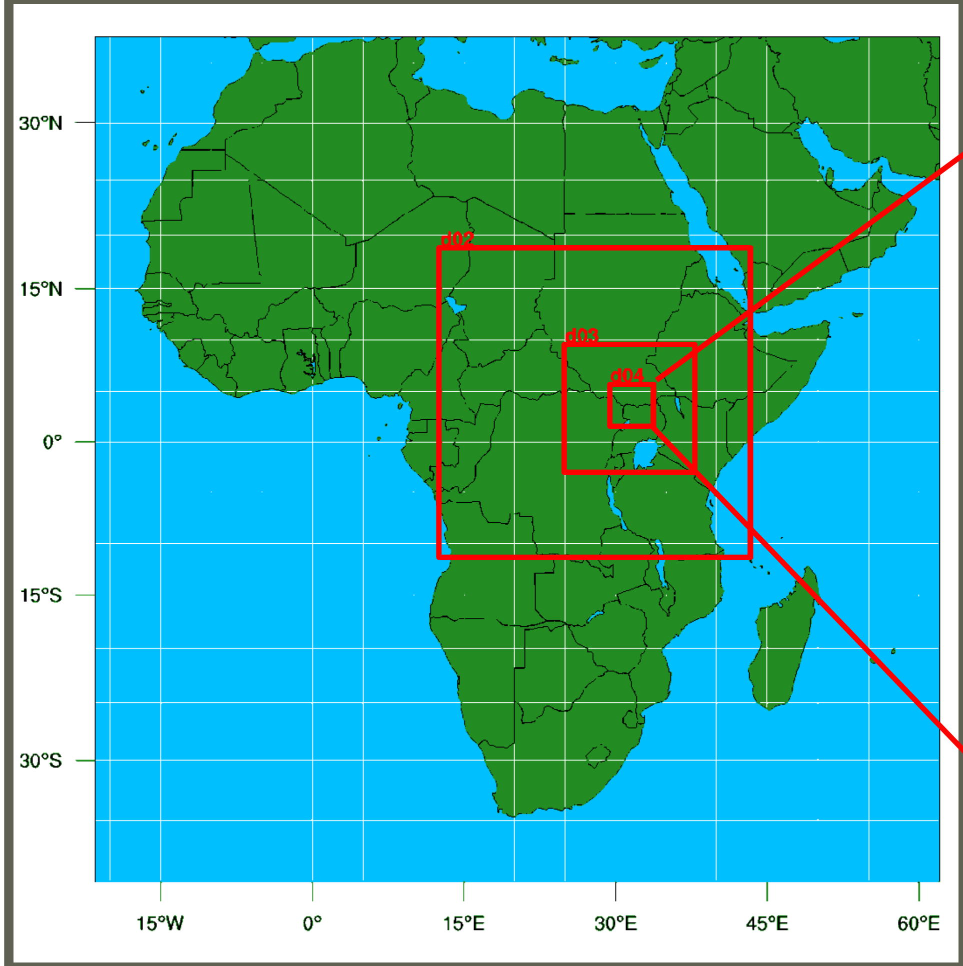
Annual Cycle of Rainfall over Study Region

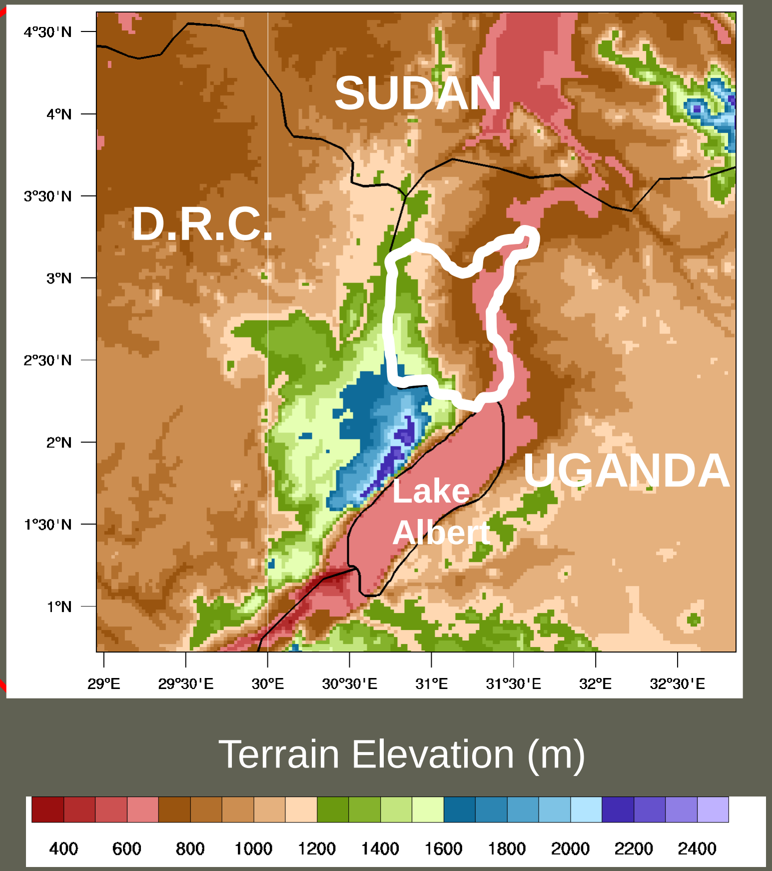
(Rainfall calculated from Tropical Rainfall Monitoring Mission (TRMM)



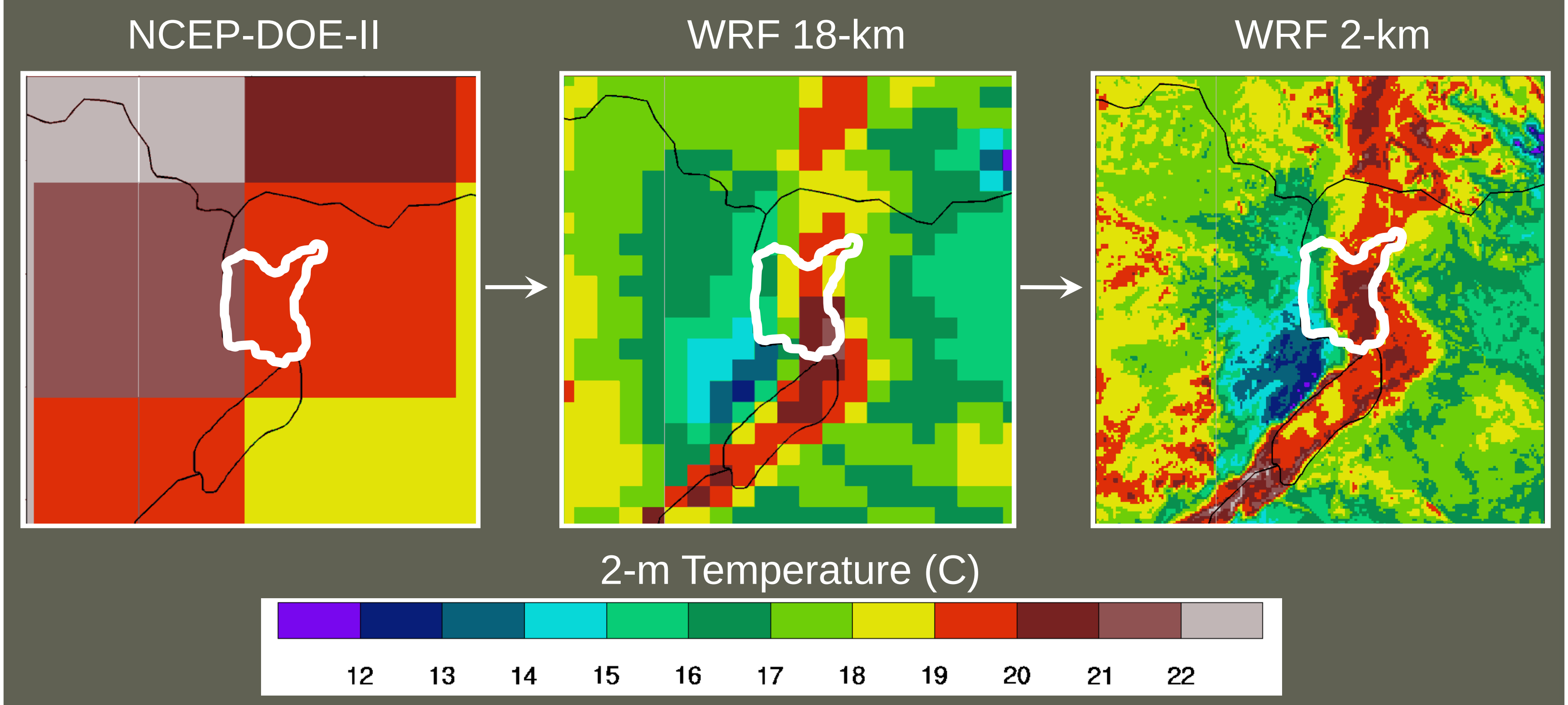
Focus on Aug-Nov Rainy Season

WRF Model Domain and Topography





Climate Downscaling over Uganda: 200-km to 2-km resolution



Challenges

- MODIS skin temperature data used to constrain the Rift Valley lake temperatures within the model (Lake Albert and Lake Victoria) - dramatically improved precipitation estimates b/c it corrected a cold bias from the WRF model.
- Soil temperature and moisture profiles from GLDAS (Global Land Data Assimilation System) used to set the lower boundary conditions in WRF.

Societal Factors

- Plague has a short incubation period (2-6 days), and is often fatal if antibiotic treatment is delayed or insufficient.
- Need to better understand health care seeking behavior and access to health care to reduce fatalities
- Household scale interviews with traditional healers and drug shop employees

Village in Zeu, Uganda

Photo: Brant Foote, NCAR

The treatment room

Photo: Brant Foote, NCAR

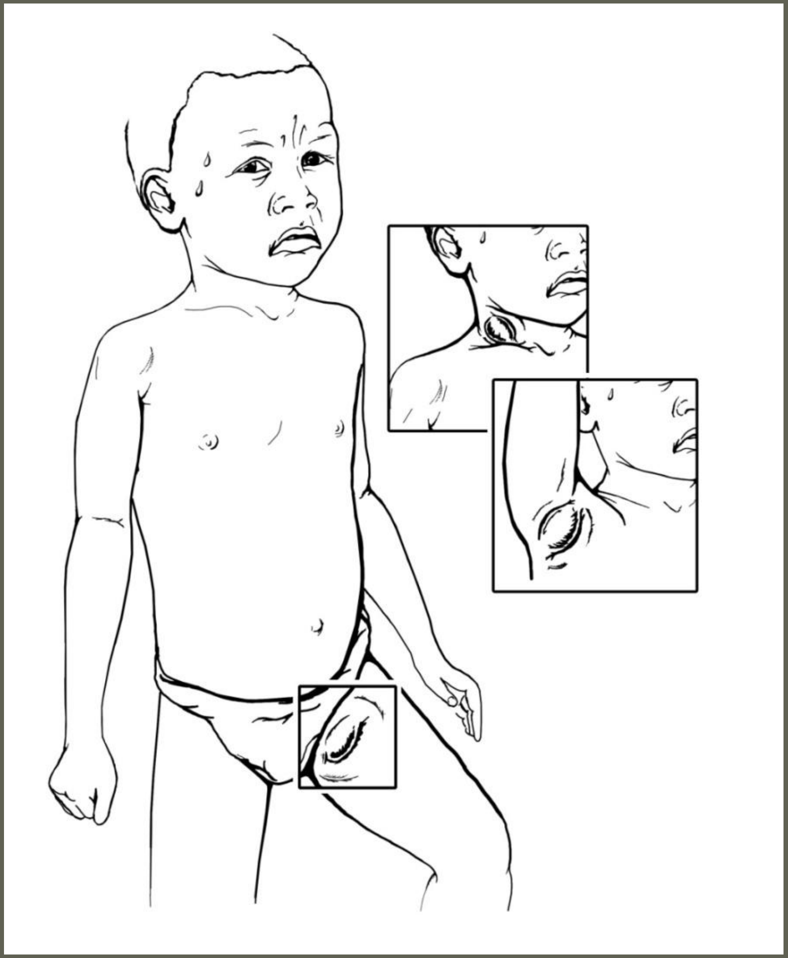
Traditional Healer

Photo: Kerry Cavanaugh

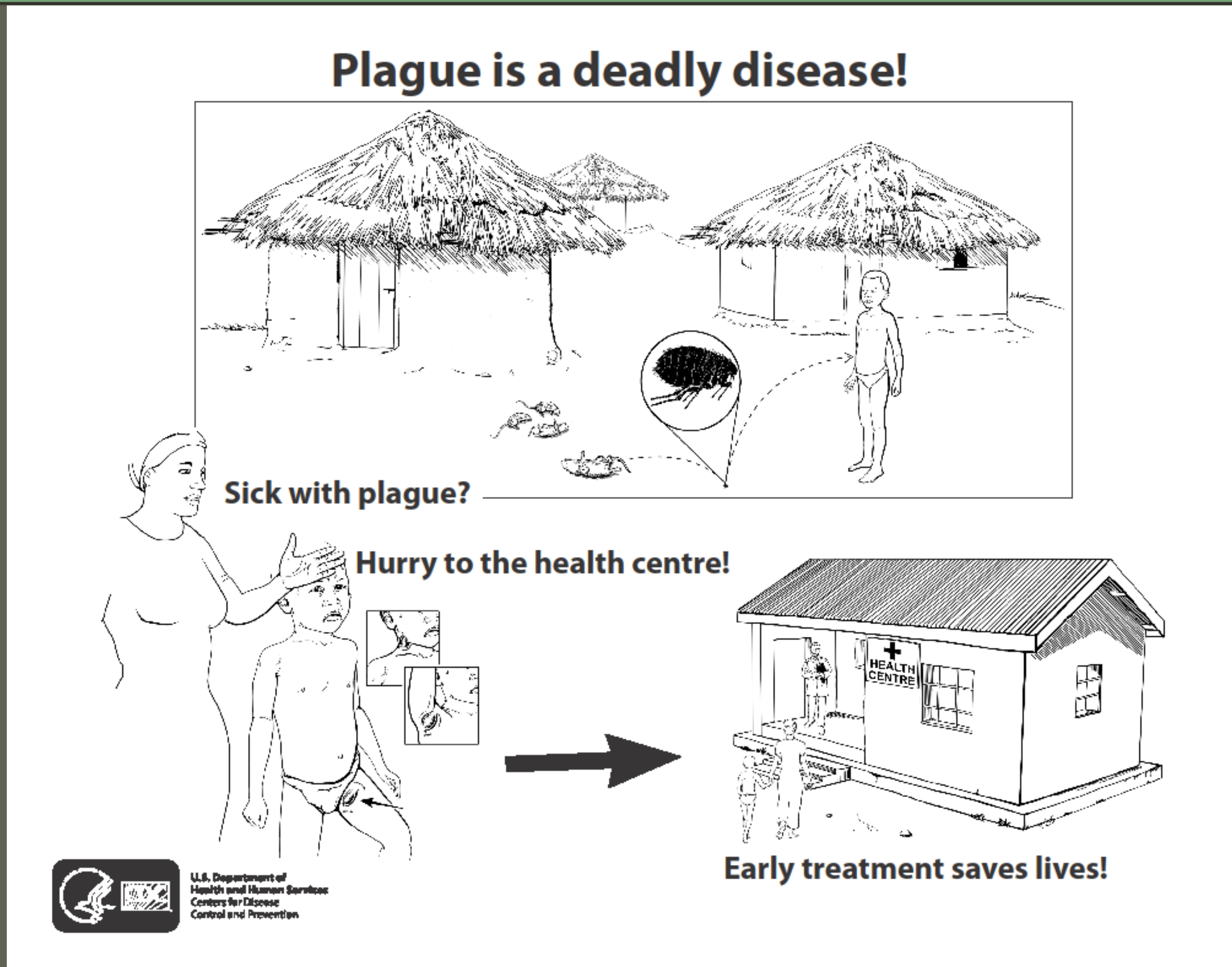
Plague: Next Steps

- Field test low-literacy guide to enhance awareness of plague
- Train traditional healers to recognize plague symptoms
- Provide cell phones and bicycles to enhance interaction between healers and health clinics
- Couple spatio-temporal risk maps with focal dissemination of health information and provider training to target high risk populations

Plague: Next Steps



Next Steps


Plague is a deadly disease!
Sick with plague?
Hurry to the health centre!
HEALTH CENTRE
Early treatment saves lives!
U.S. Department of Health and Human Services Centers for Disease Control and Prevention

A Framework for Spatial Assessment of Local Level Vulnerability and Adaptive Capacity to Extreme Heat

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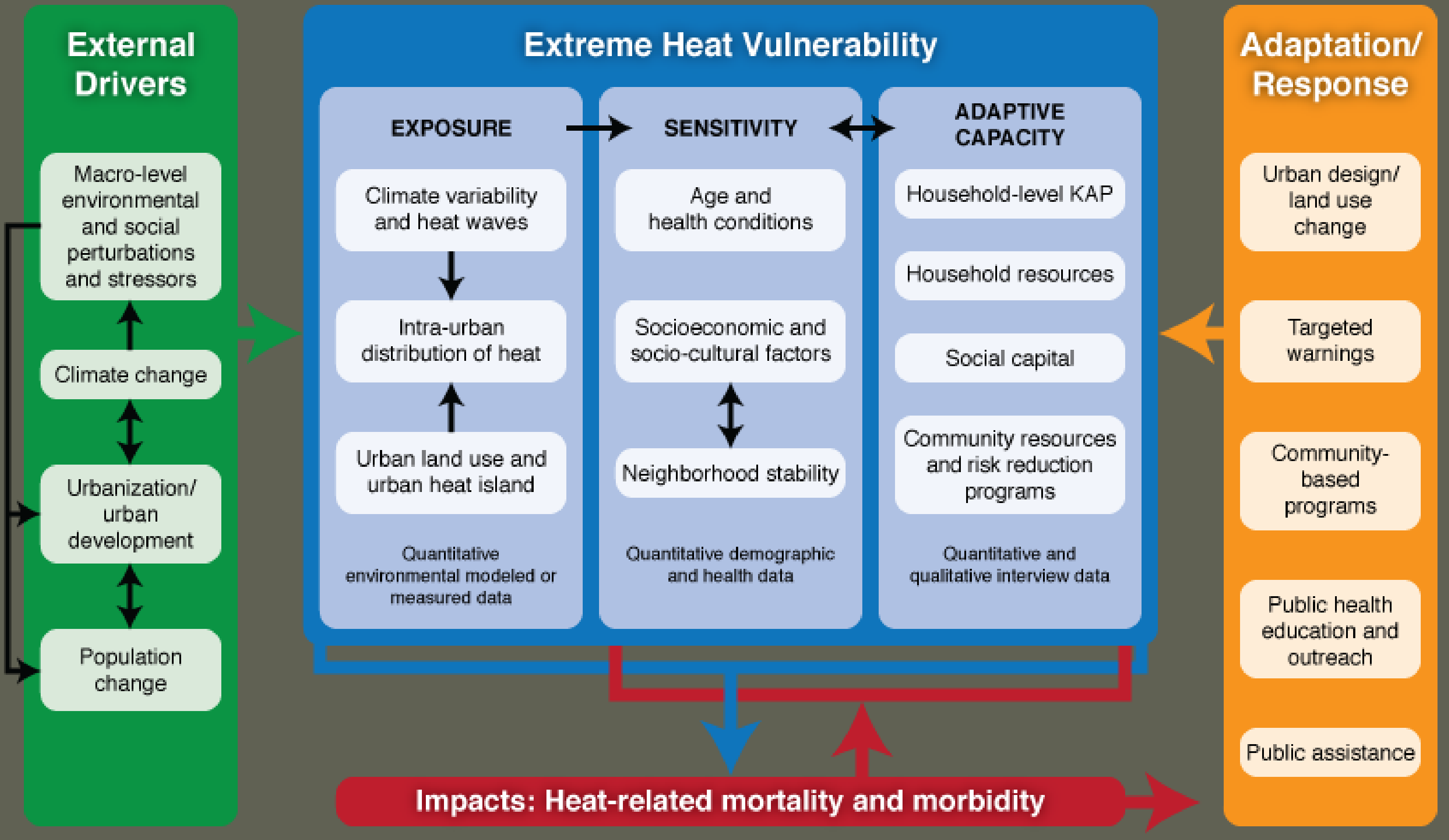
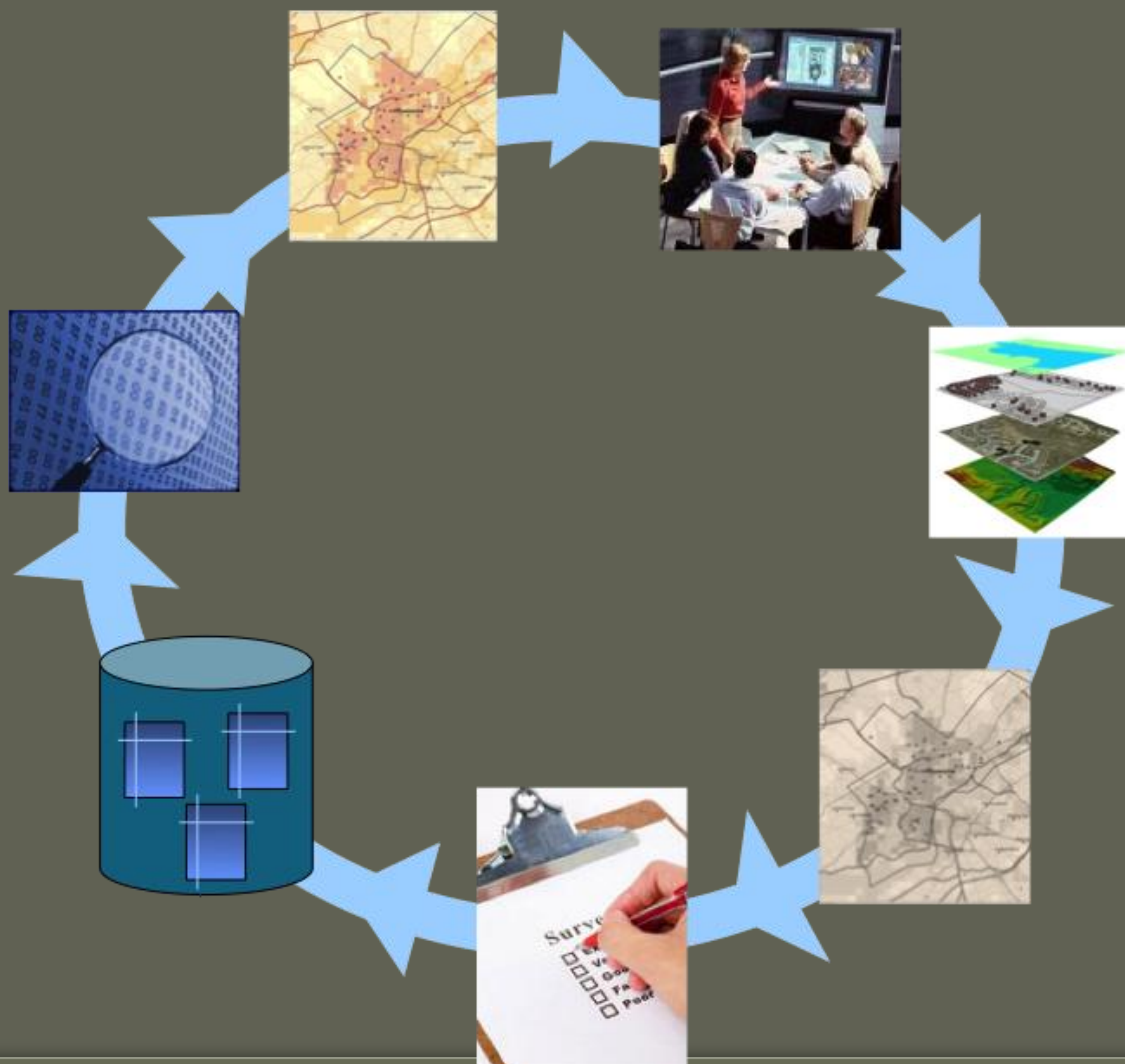
- Project goal:
  Understand dynamics of societal vulnerability and adaptive capacity to excessive heat
- Project Objective:
  Refine a methodological framework for extreme heat vulnerability analysis through spatial integration of quantitative and qualitative data

Extreme Heat Vulnerability Framework



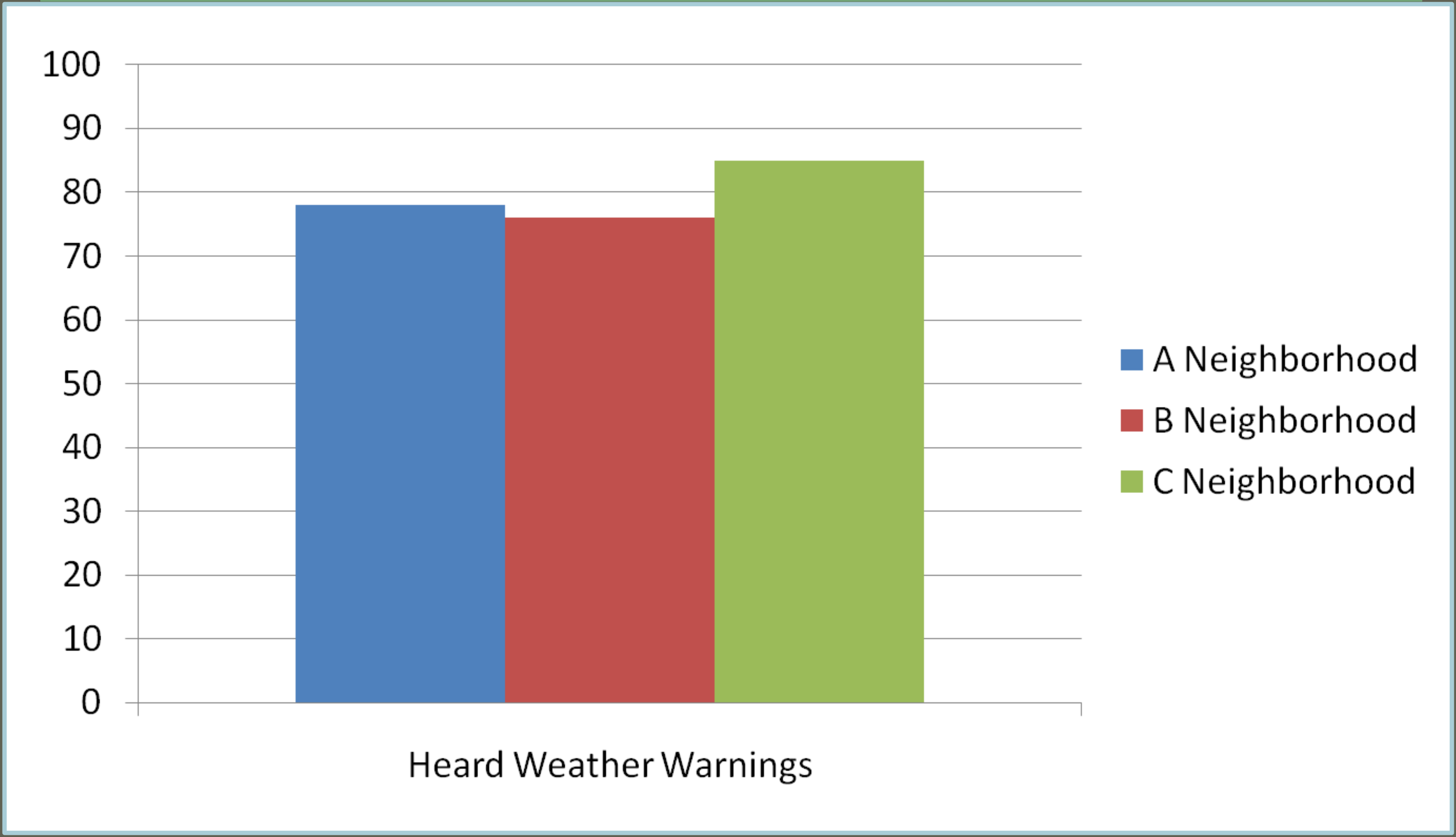
Iterative Research Process



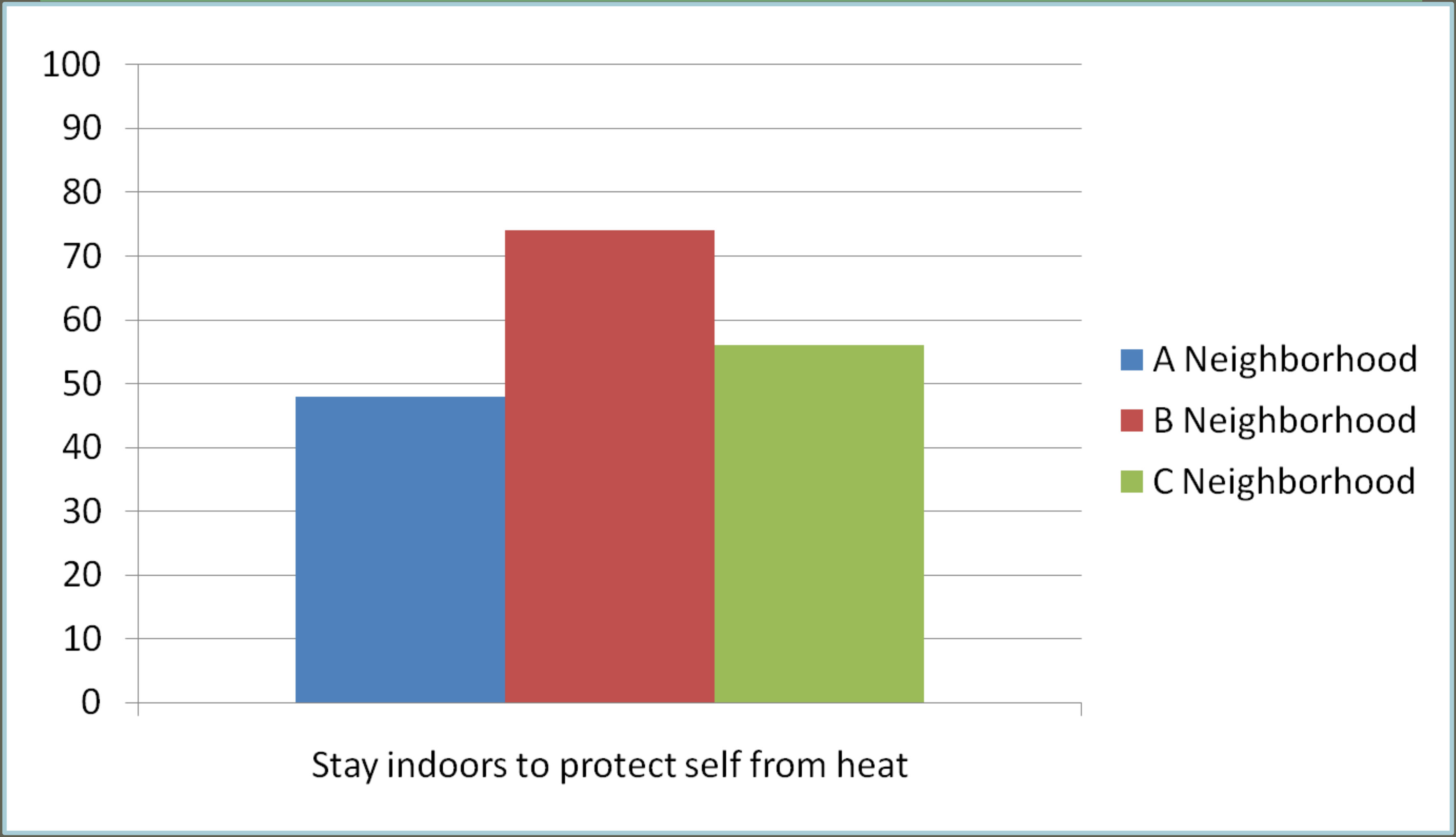
Household survey data

- Survey instrument
  - Questionnaire focuses on indicators of adaptive capacity (e.g., knowledge of heat stress; social capital, household and community resources) and sensitivity.
    - Collaboration with ASU researchers and Arizona public health officials
- Selection of neighborhoods for door-to-door interviews
  - GIS mapping of exposure/sensitivity and health outcomes (2006-07 mortality cases; 2005 911 calls)
  - SES and ethnically diverse communities (focus on more vulnerable neighborhoods)
  - 359 households from 3 neighborhoods – differential vulnerability in all three neighborhoods

Percent of Participants Hearing Excessive Heat Warnings



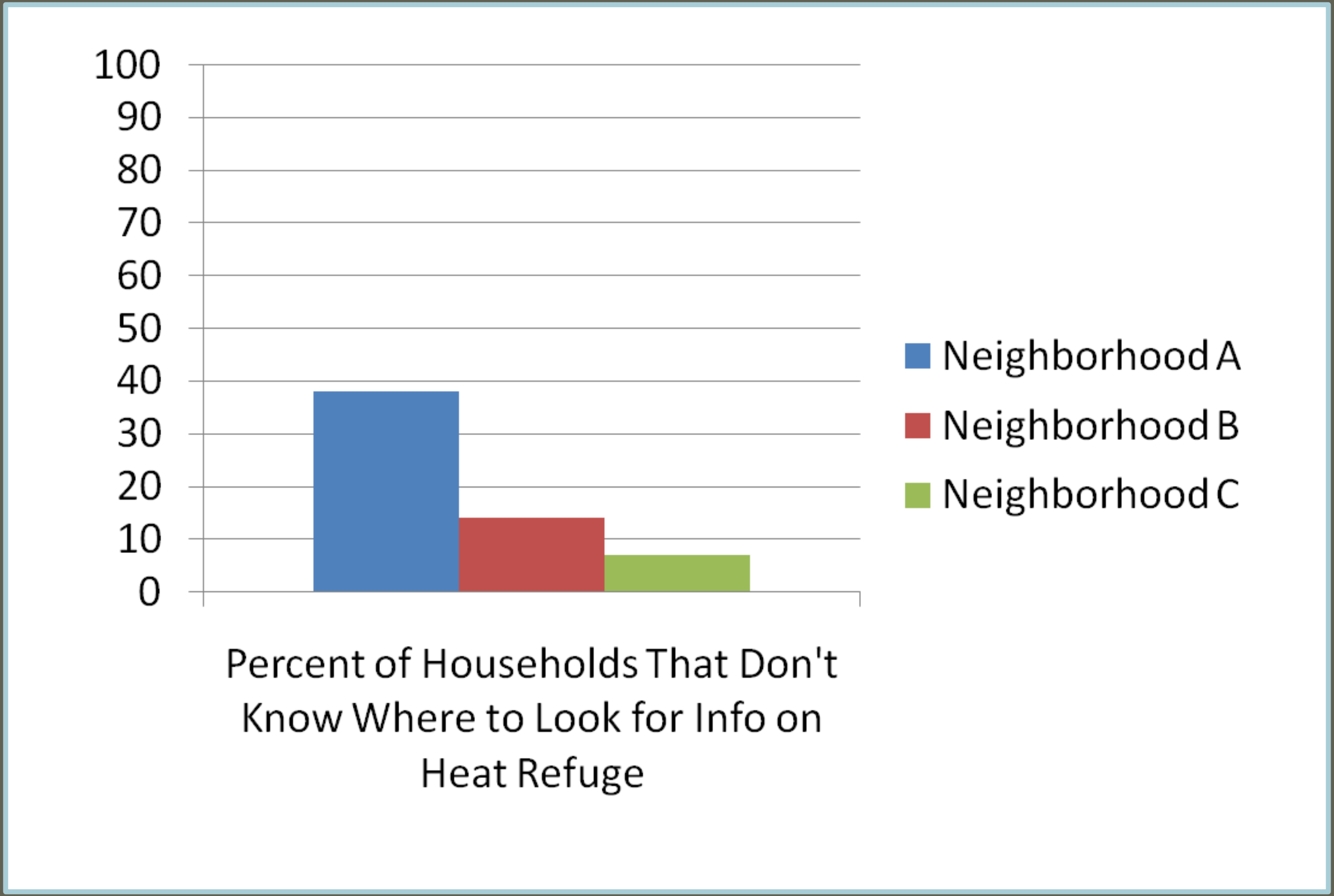
Percent of Participants Who Stay Indoors to Protect Themselves from the Heat



Chi-square = 17.40

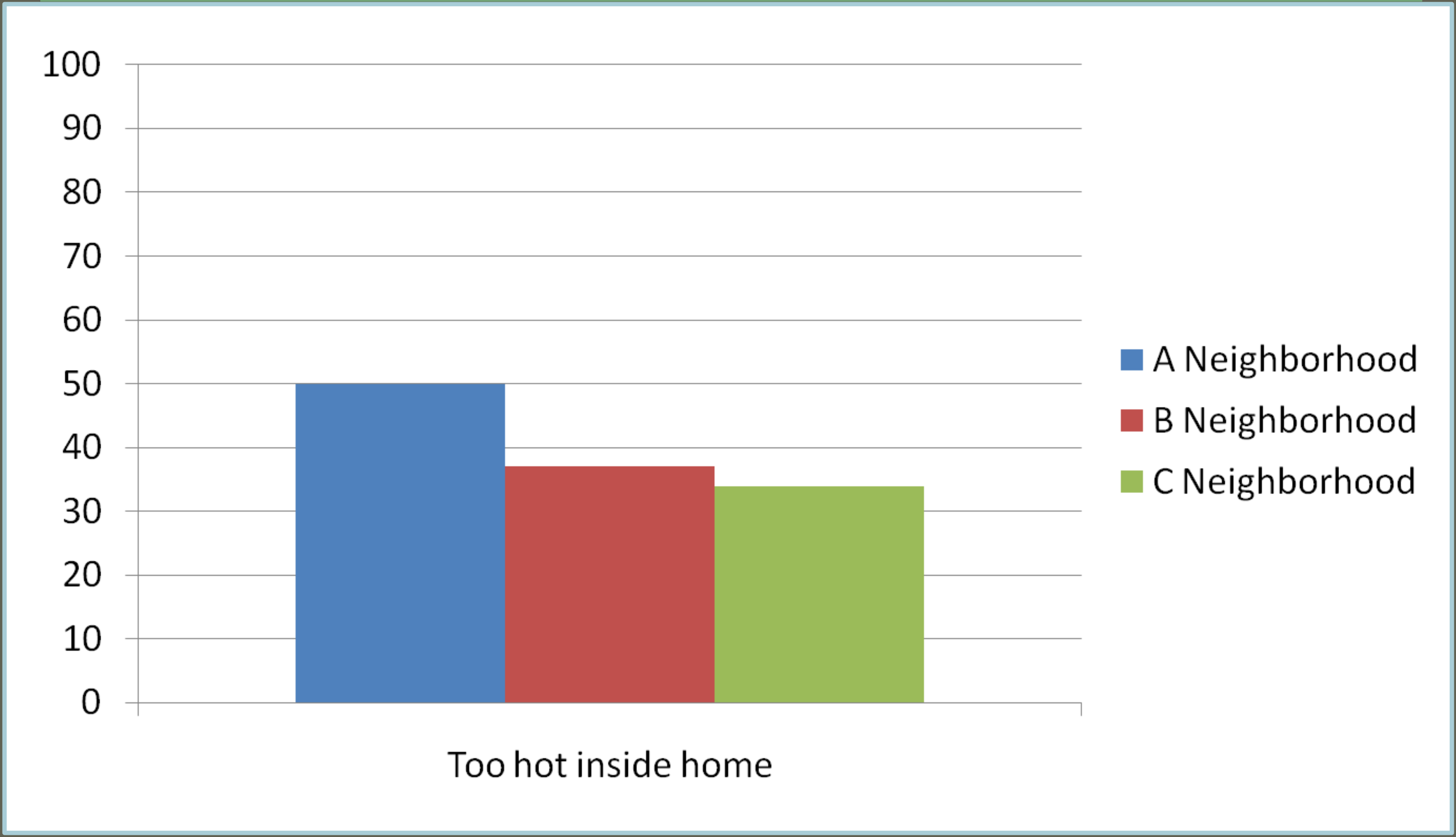
P = .000

Percent of Households – Don’t Know Where to Look for Heat Refuge Info

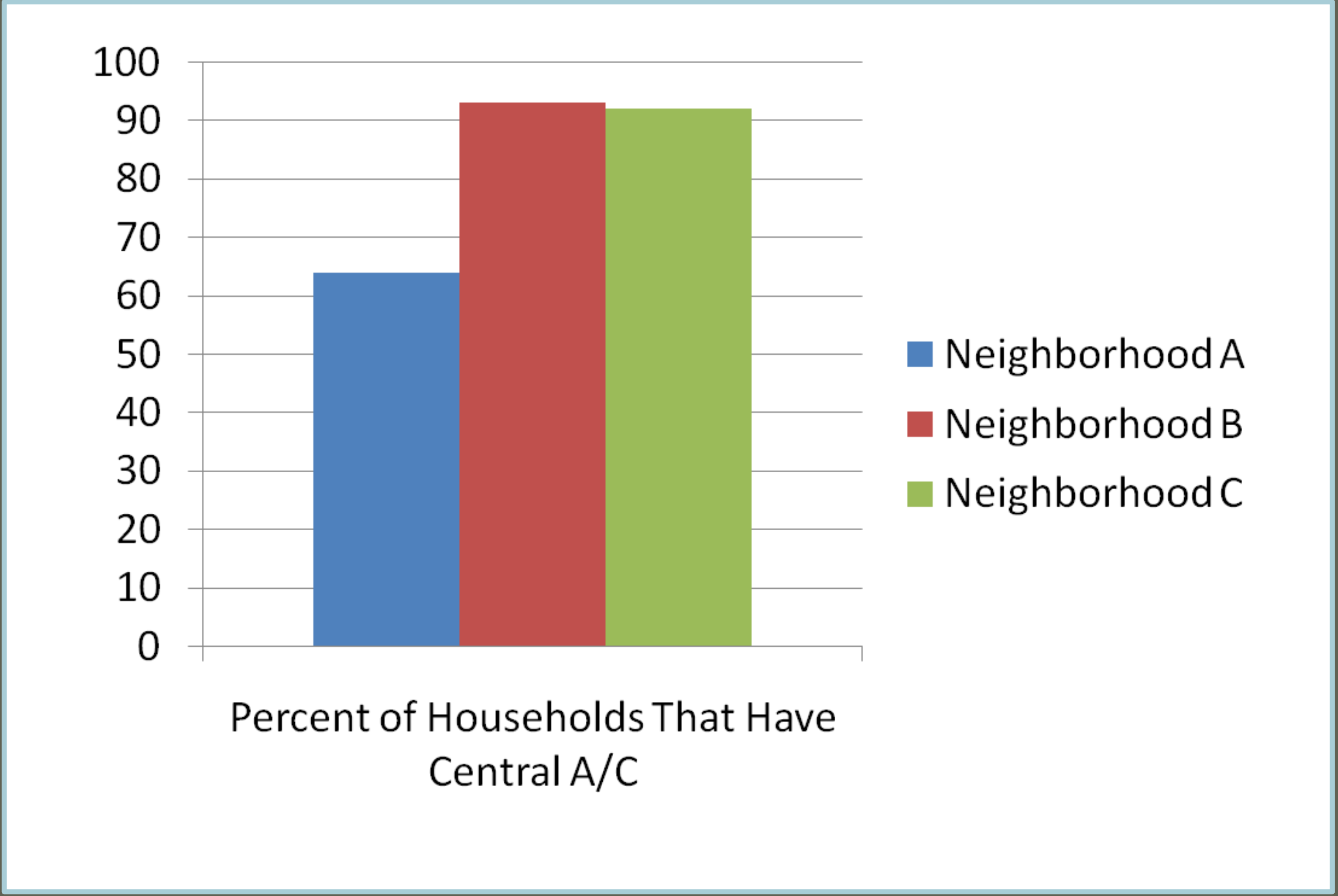


Chi-square = 19.85
P = .000

Percent of Participants Who are Too Hot Inside the Home

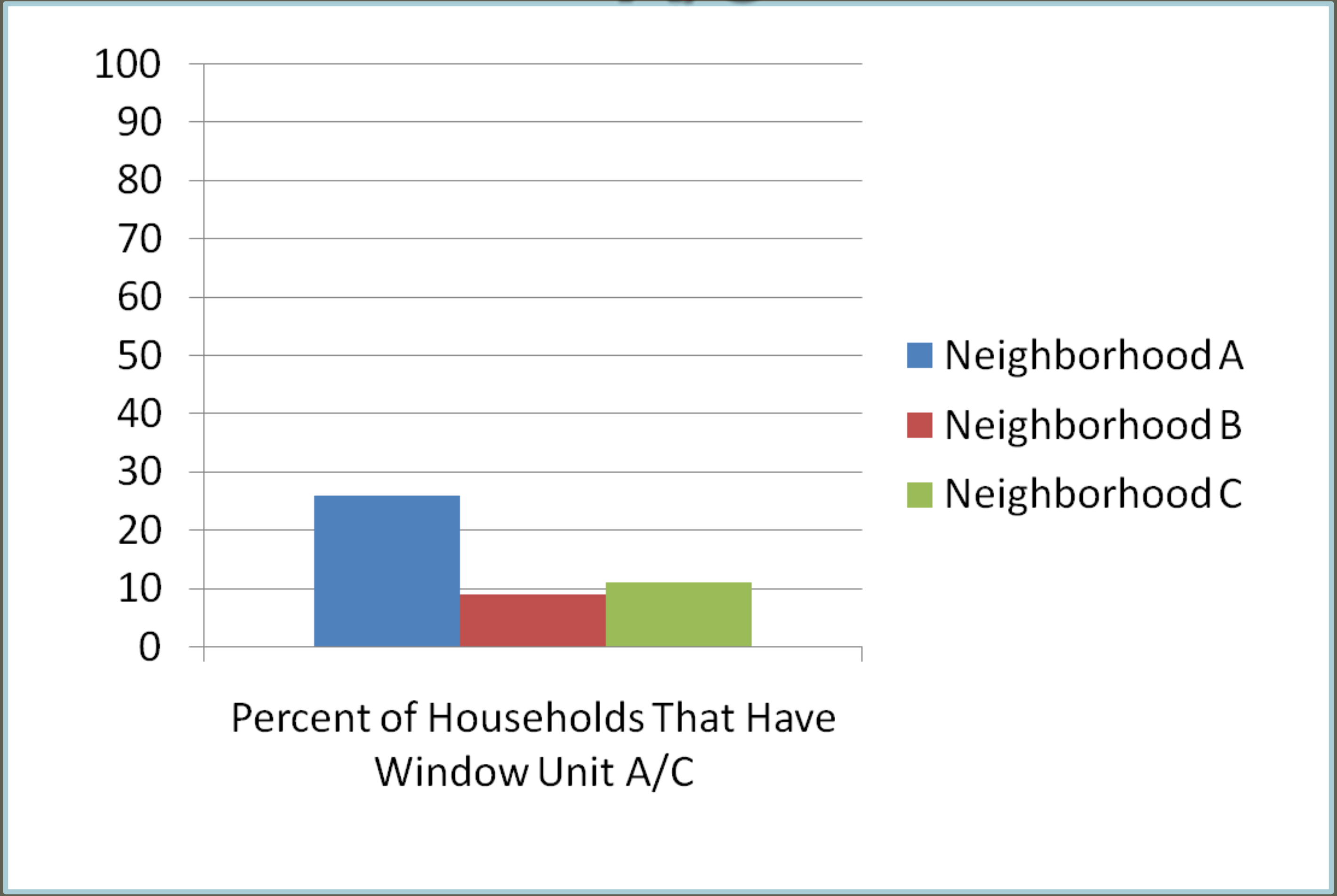


Percent of Households with Central A/C



Chi-square = 44.23
P = .000

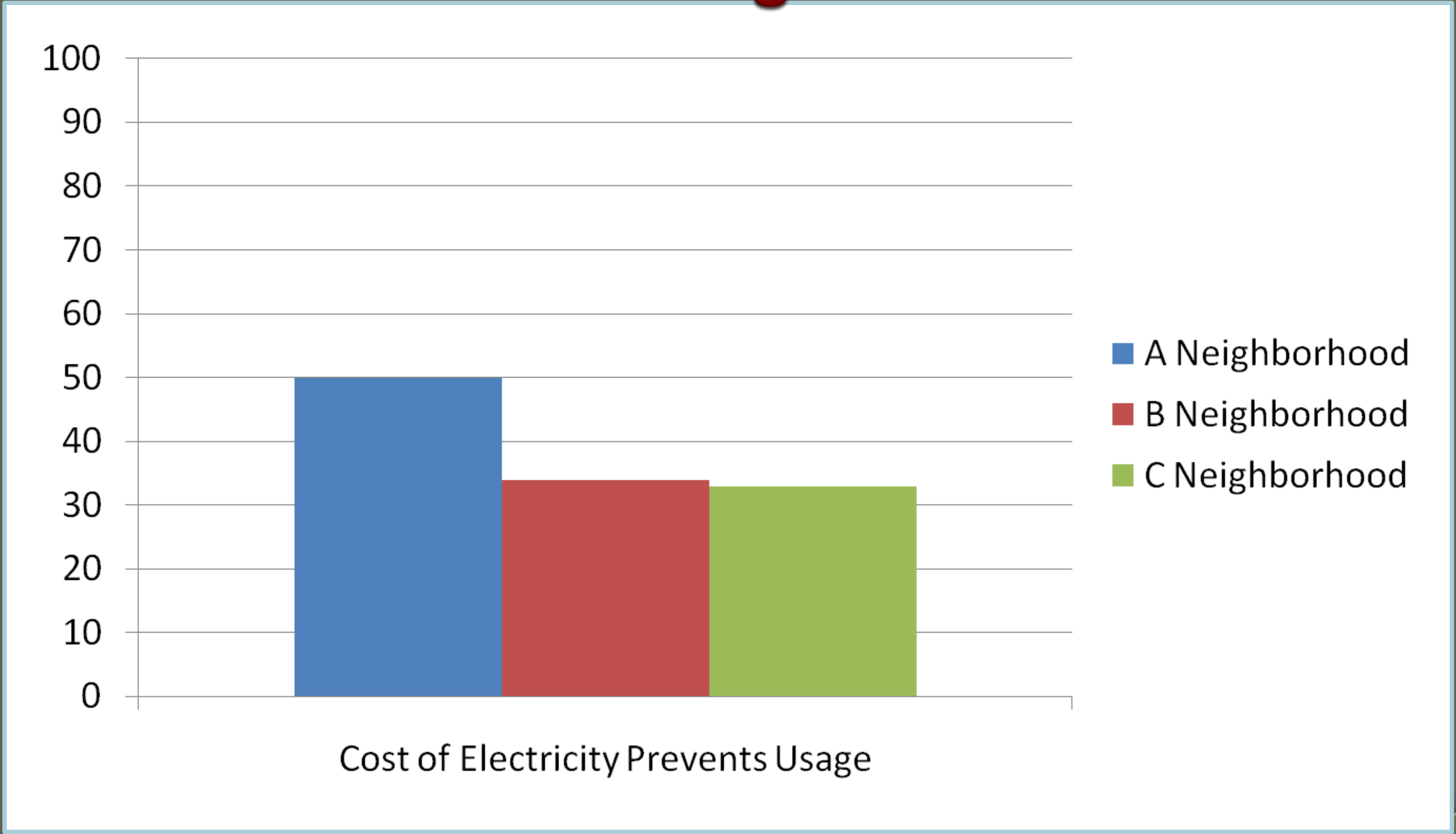
Percent of Households with Window A/C



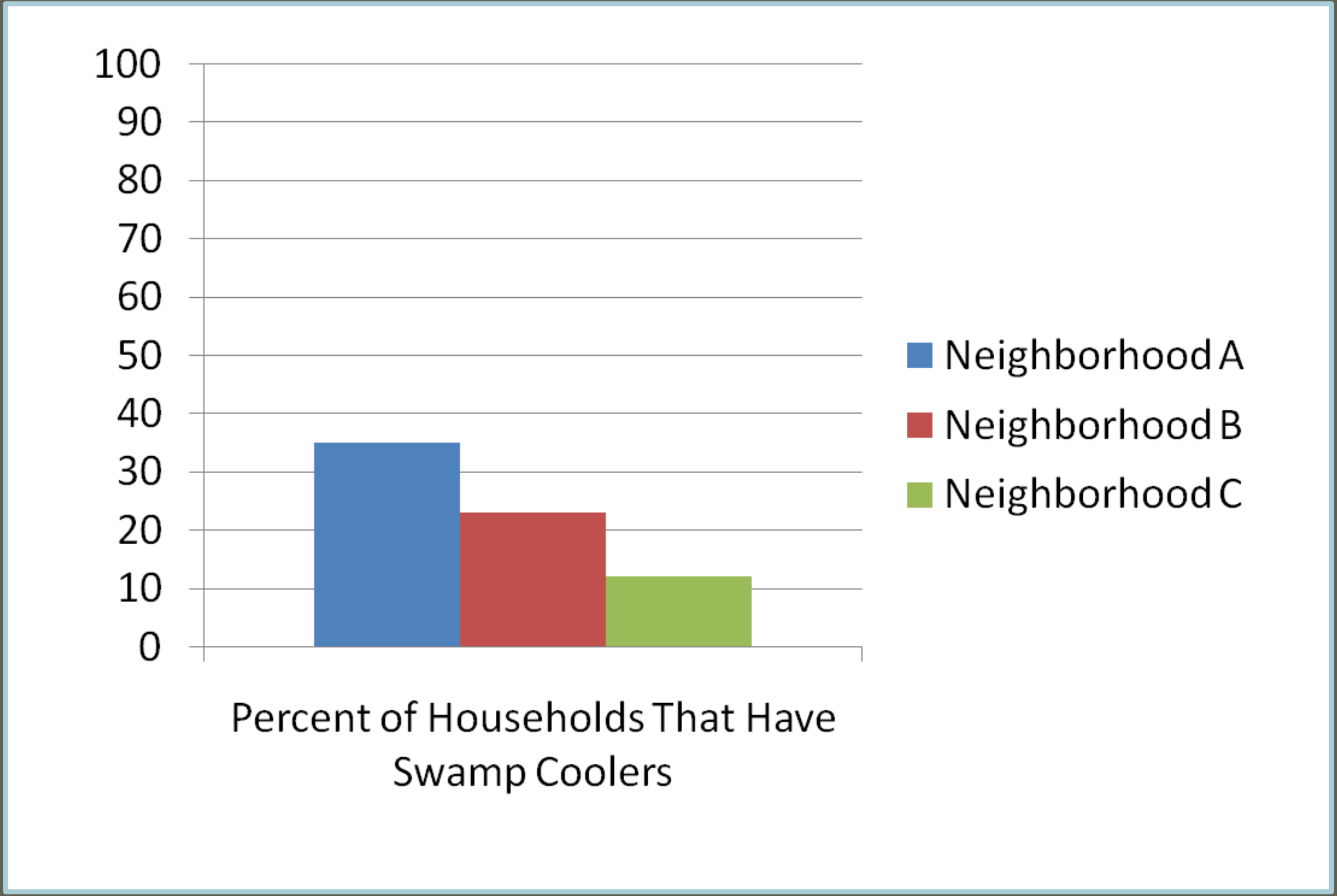
Chi-square = 10.36

P = .006

Percent of Participants for Whom Cost of Electricity Prevents Use of Air-conditioning as Needed



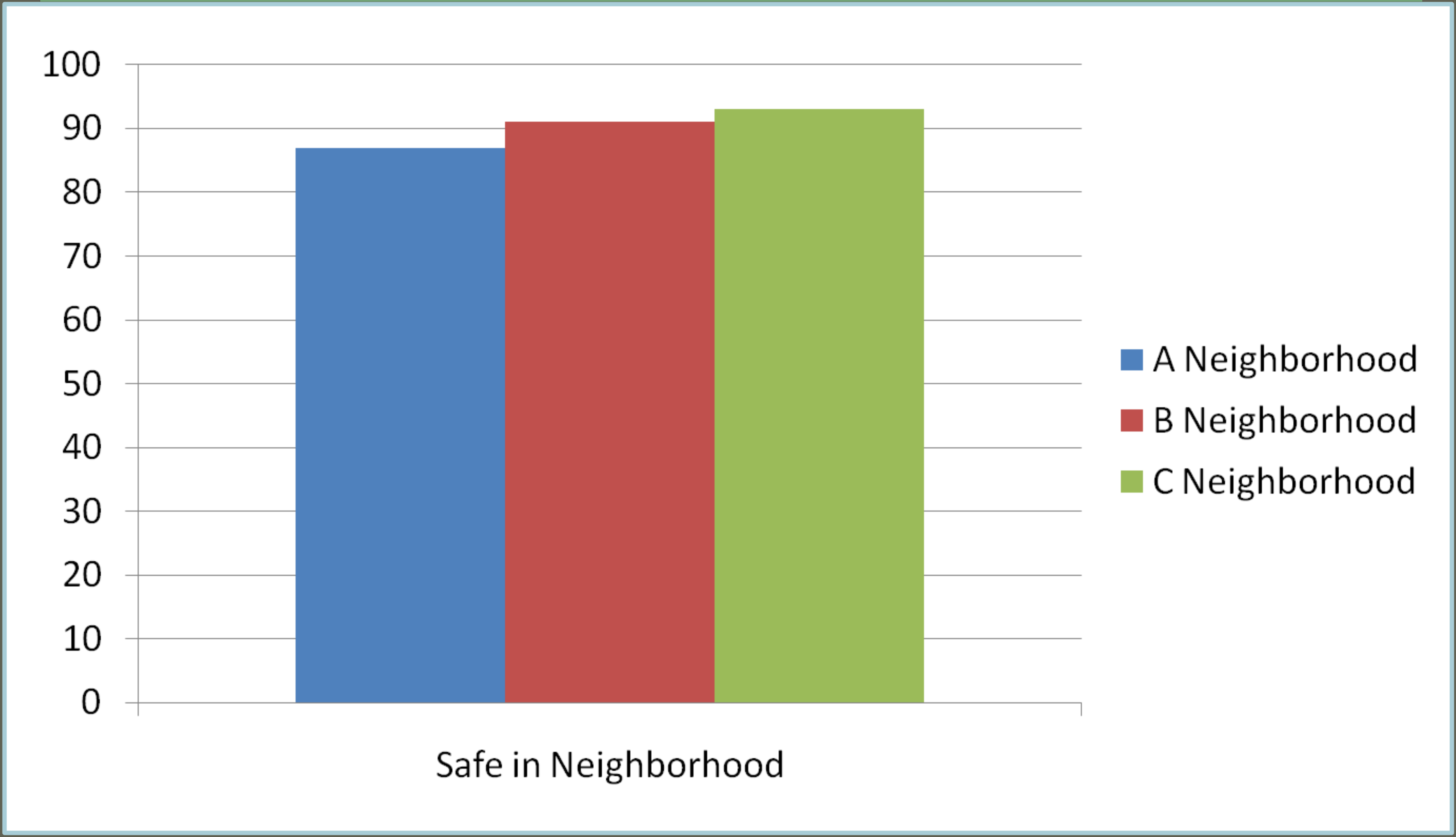
Percent of Households with Swamp Coolers



Chi-square = 14.23

P = .001

Percent of Participants Who Feel Safe in Their Neighborhoods

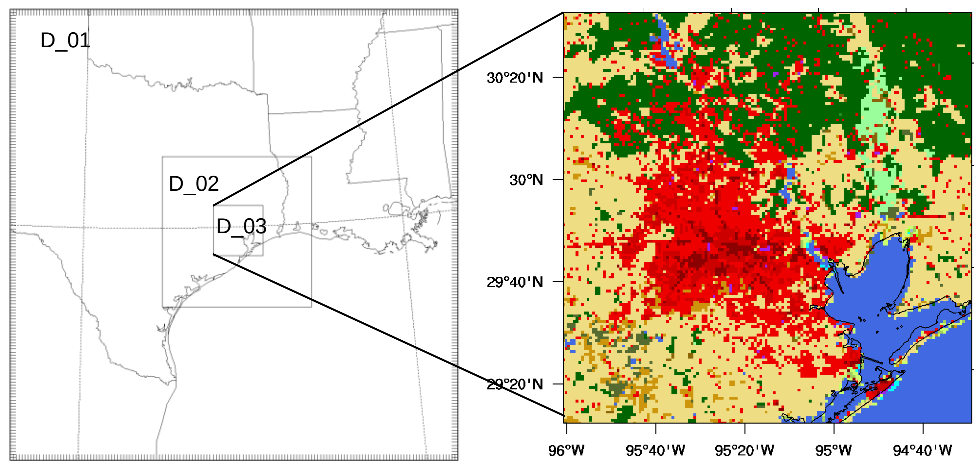


Next Steps

- Social vulnerability to extreme heat is a function of both natural and human factors
- Contextualizing vulnerability with household data can influence the process used to formulate successful approaches that are targeted locally but where resource allocation is decided at a state or national level
- GIS and data mining tools help to identify where the health risks are and what the most important elements of social vulnerability are
- More research is needed to connect place-based and people-based approaches to spatial assessments of vulnerability

NASA SIMMER

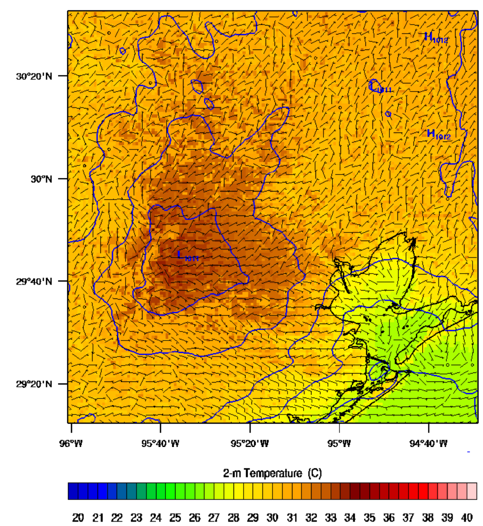
(System for Integrated Modeling of Metropolitan Extreme heat Risk)



Top left: **WRF nested model domain**

Top right: **The land-use categories for the 1-km WRF domain.**

Bottom right: **Simulated WRF near-surface temperature (colors; degrees C), wind vectors (barbs; kts), and sea level pressure (contours; hPa), at 1600 CDT 04 September 2000, for the 1-km domain**.



SIMMER research components

- Determining the combined impact of extreme heat and the characteristics of urban environmental and social systems on human health;
- Characterizing societal vulnerability and the responses (i.e., mitigation and adaptation strategies);
- Improving representation of urban land cover and its accompanying radiative and thermal characteristics at local and regional scales;
- Characterizing and modeling present and future extreme heat events at regional and local scales:

  SIMMER will use MERRA reanalysis to provide the lateral boundary conditions for the model

  NLDAS being used because it’s higher resolution dataset.

  LANDSAT will be used to help explore an initial characterization of vulnerability; i.e impervious surfaces vs. green surfaces.

Thank You!

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Knowledge Gaps

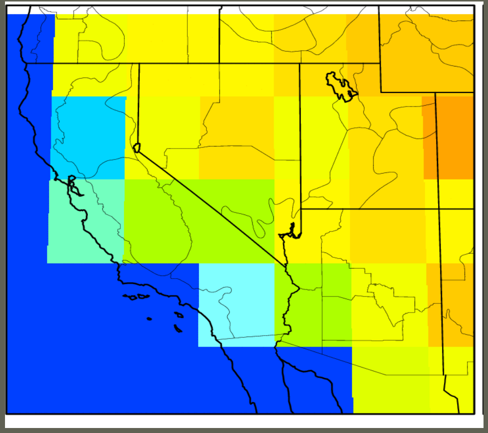
- Need better human health surveillance, as well as vector and pathogen surveillance, particularly at the margins of transmission
- U.S./MX border is a prime example of an area at the geographic margins of current dengue transmission

Knowledge Gaps

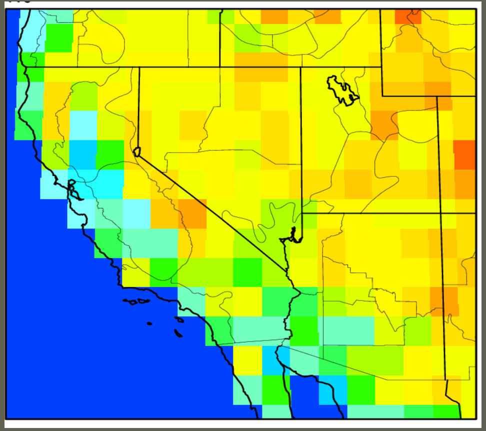
- Need convergence of scales
- Transmission/vulnerability is often local; sensitive to local variability
  - small-scale differences in temperature and rainfall
  - human modification of the landscape
  - human behavior affecting health (e.g., vector-human contact)
- Climate is global, but low spatial resolution

[redacted]

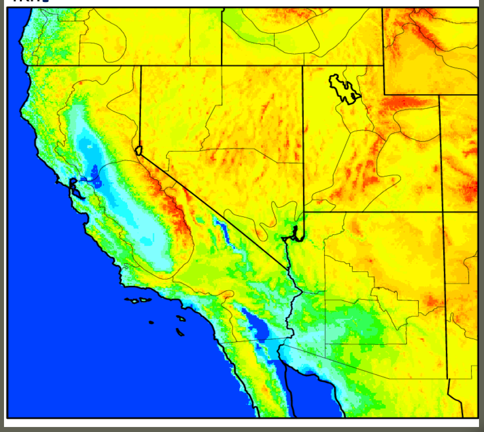
2007 IPCC AR4: 160KM Grid



2013 IPCC AR5: 55Km



Experimental NRCM: 4km

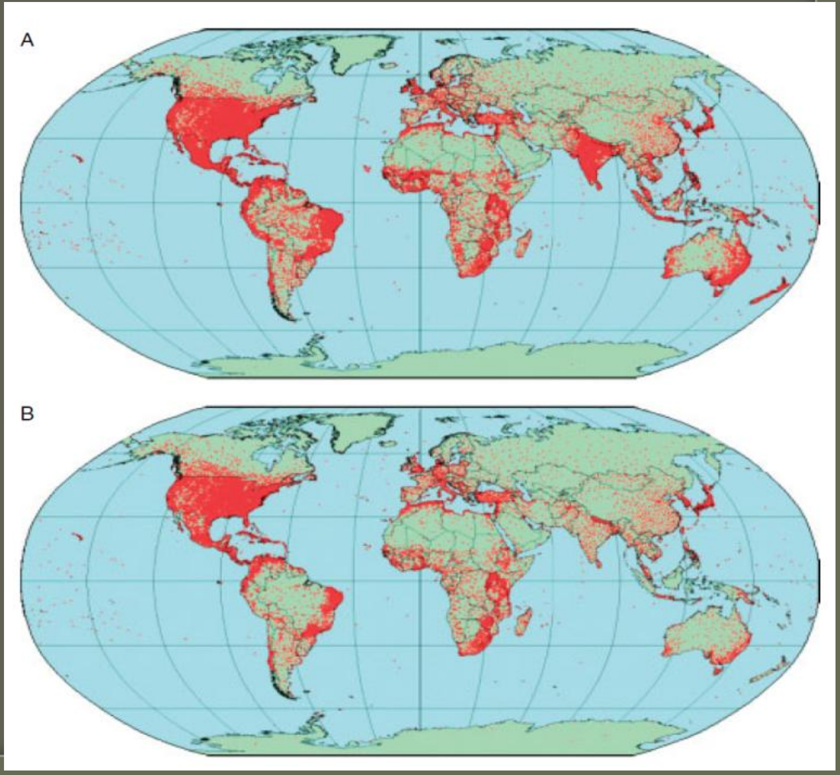


Knowledge Gaps

- Need enhanced meteorological observation networks in most vulnerable locations (e.g., Africa)

Surface Temperature

Precipitation



(Hijmans et al. IJOC, 2005)

Knowledge Gaps

- Need long-term studies:
  - Quantification of relationships between meteorological variables and human health (e.g., vector or vector-borne pathogen occurrence)
  - Examination of human behavioral influences on human health issues (e.g., vector-human contact; exposure to extreme heat)
  - Evaluation of consequences of shifting distributions of vectors and pathogens/differential vulnerability of human populations

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