Quantifying Distributional Health Damages of Extreme Weather Events

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ANNUAL GRANTEE MEETING

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Additional health damages can be incorporated into estimating costs of GHGs

- Estimate, in dollars, of the economic damages that would result from emitting one additional ton of greenhouse gases into the atmosphere
- Used in benefit cost analysis for climate policy evaluation—a required component of federal regulations
- Health damages are a major contributor to the recently estimated higher costs ($51 to $190 per ton), but currently only account for temperature-related mortality.

Number of Billion-Dollar events in the United States between 1980-2020

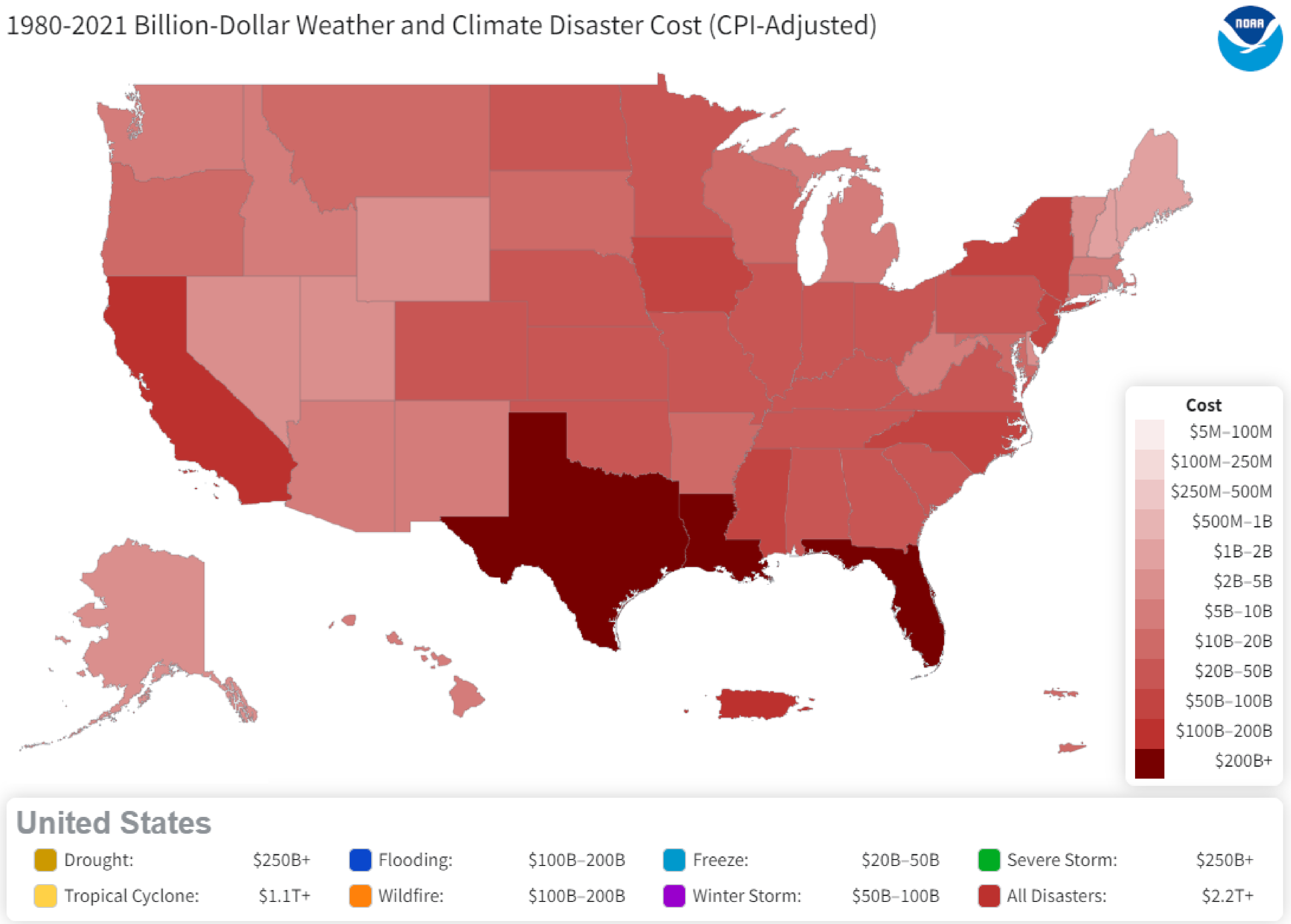


Table 1. Billion-dollar extreme temperature and flooding events in Texas between 2015-2021 [3]

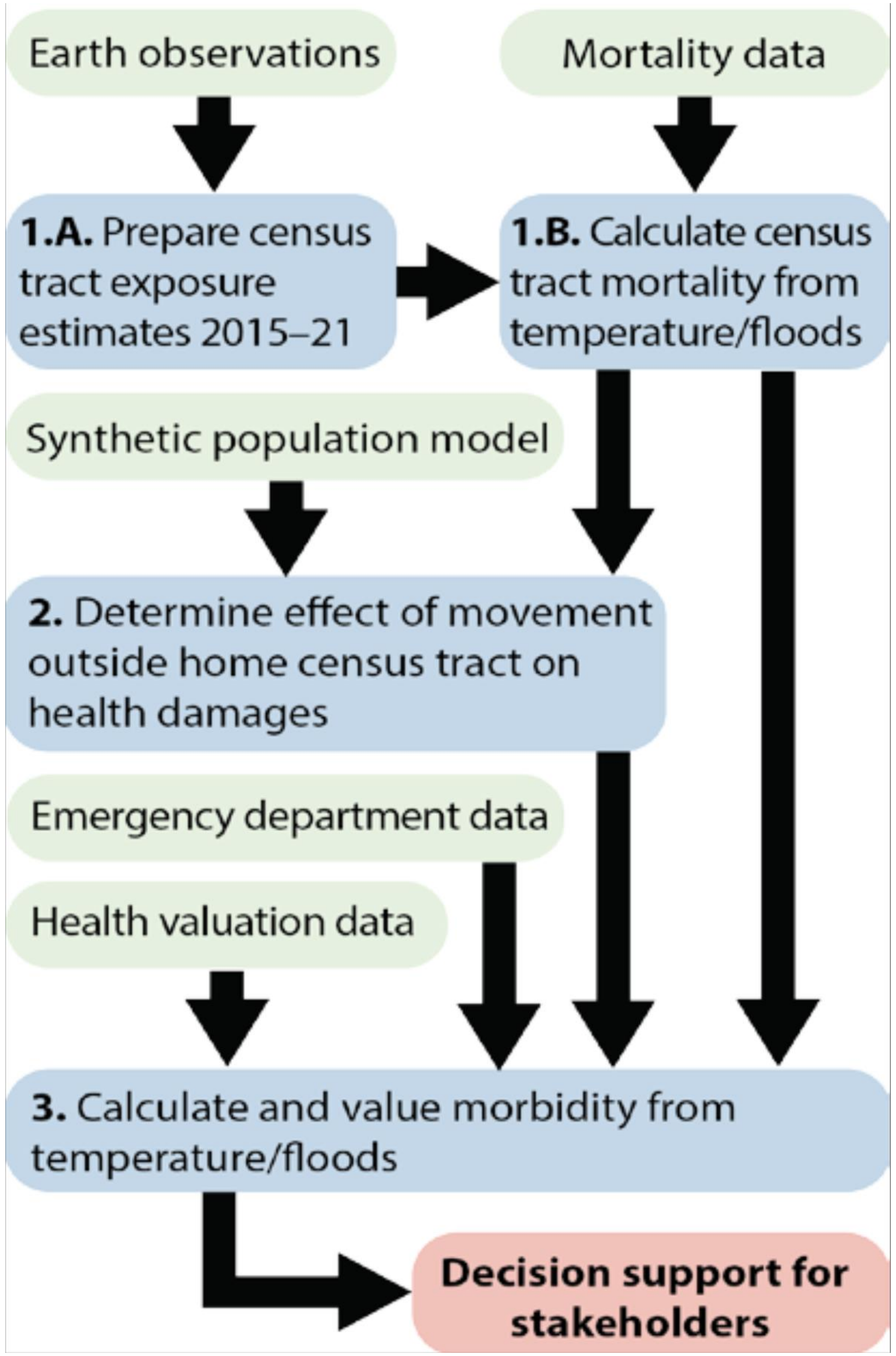
Event Type	Total Cost ($ Billions)	Fatalities from NWS Storm Data
Flooding and Severe Weather (May 2015)	2.8	31
Flooding (March 2016)	2.5	5
Flooding (April 2016)	3	8
Flooding and Severe Weather (May 2017)	1.8	20
Hurricane Harvey (August 2017)	133.8	89
Drought (Summer-Fall 2018)	3.1	0
Flooding (May-June 2019)	6.4	4
Tropical Storm Imelda (September 2019)	5.1	5
Hurricane Hanna (July 2020)	1.1	0
Hurricane Laura (August 2020)	19.2	42
Hurricane Delta (October 2020)	2.9	5
Drought and Heatwave (Summer-Fall 2020)	4.5	45
Storm and Cold Wave (February 2021)	TBD, > 10	138

NOAA NCEI 2022: https://www.ncei.noaa.gov/access/billions/

Project Objectives

- Compare estimates of mortality associated with temperature extremes and flooding across urban and rural areas in Texas between 2015-2021.
- Determine contributions of movements outside of home census tract to health damages associated with extreme temperatures and flooding.
- Determine morbidity contributions to health damages associated with extreme temperatures and flooding.

Workflow


Earth observations
Mortality data
1.A. Prepare census tract exposure estimates 2015–21
1.B. Calculate census tract mortality from temperature/floods
Synthetic population model
2. Determine effect of movement outside home census tract on health damages
Emergency department data
Health valuation data
3. Calculate and value morbidity from temperature/floods
Decision support for stakeholders

Obj 1: Using EO to spatially define exposure—*EO Data Sources*

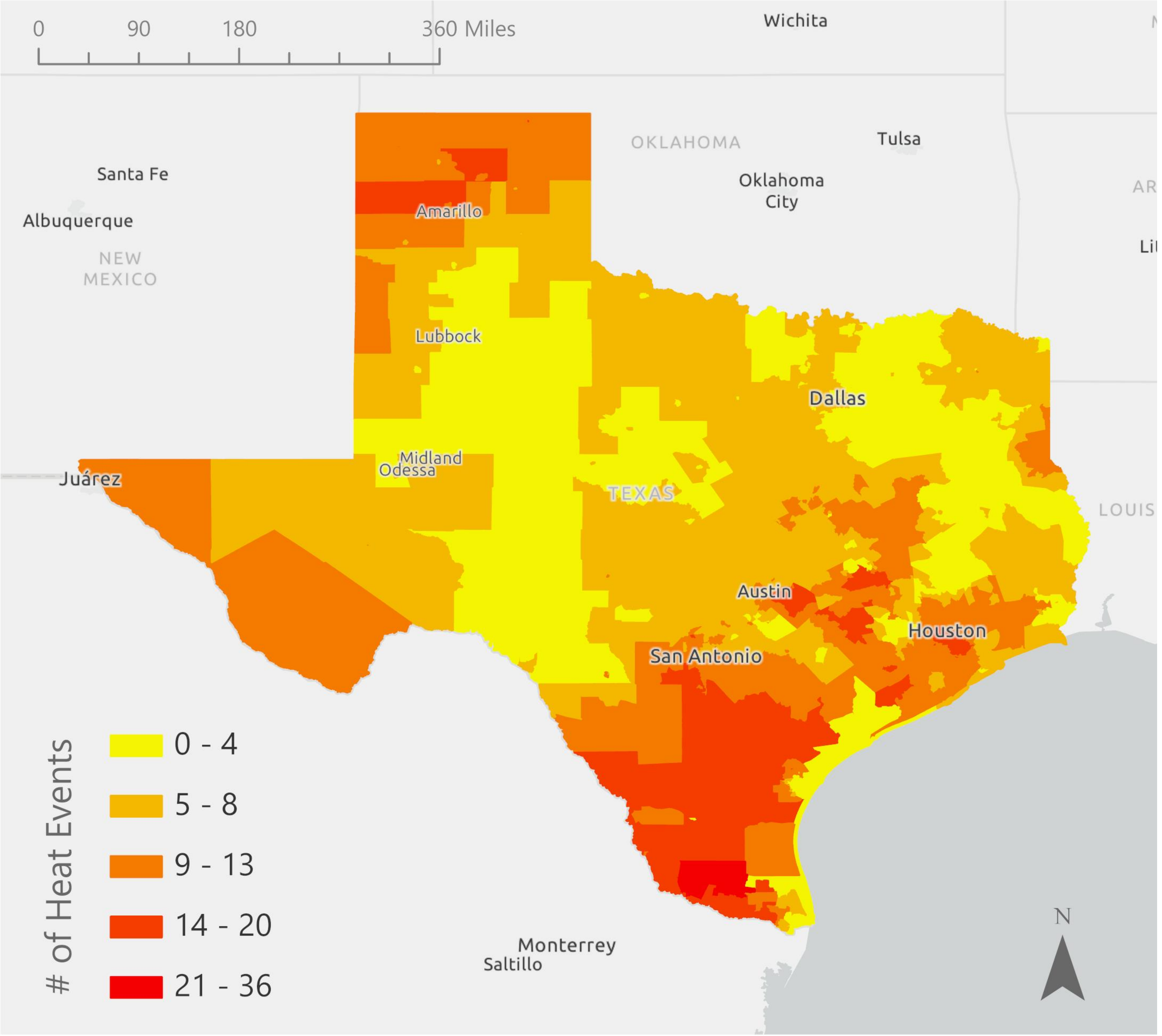
	Product Name	Spatial Resolution	Variables
Heat/Cold Extremes	**Parameter-elevation Relationships on Independent Slopes Model (PRISM)**	**4 km**	**Daily Max/Min/Mean 2-m Air Temp., Precipitation, Min/Max Vapor Pressure Deficit, Mean Dewpoint Temp.**
	Gridded Surface Meteorological (gridMET) Dataset	**4 km**	**Daily Solar Radiation, Wind Speed**
	Climate Hazards InfraRed Temperature with Stations (CHIRTS)	5 km	Daily Min/Max 2-m Air Temp.
	Visible Infrared Imaging Radiometer Suite (VIIRS)	1 km	Daily/8-Day Nighttime and Daytime Temp.
Flooding	**AER FloodScan**	**10 km**	**Daily Inundation Estimates**
	MODIS Near Real Time (MODIS-NRT) Flooded Area	250 m	1, 2, 3-day Flooded Area
	Sentinel-1 Synthetic Aperture Radar (SAR) Derived Flooded Area	20 m	12-day Flooded Area
Air Quality: Chronic	Ozone Monitoring Instrument (OMI)	1 km	Annual NO2
	Global satellite-derived PM2.5 (Hammer et al.)	~1 km	Annual PM2.5
Air Quality: Acute	TROPOspheric Monitoring Instrument (TROPOMI)	5 km	Daily NO2
	Ozone Monitoring Instrument (OMI)	1 km	Daily NO2
	VIIRS Aerosol Optical Depth Product	0.75 km & 6 km	Daily PM2.5
	Atmospheric Infrared Sounder (AIRS)	~100 km	Daily Ozone
	EPA Air Quality System (AQS)	In Situ	NO2, PM2.5, and Ozone

Obj 1: Using EO to spatially define exposure—*EO Processing*

	Product Name	Spatial Resolution	Variables		Data Processing
Heat/Cold Extremes	**Parameter-elevation Relationships on Independent Slopes Model (PRISM)**	4 km	Daily Max/Min/Mean 2-m Air Temp., Precipitation, Min/Max Vapor Pressure Deficit, Mean Dewpoint Temp.	→	• Overlap-Weighted Census Tract-Level Daily Variable Estimates • Identification of Heat and Cold Events • Heat Index, Wet Bulb Globe Temp. Calculations • Identification of Binary and Detailed Heat Index Risk Days • Disaggregation of Daily, Spatial Meteorological Data to Hourly Timesteps thru MetSim
	Gridded Surface Meteorological (gridMET) Dataset	4 km	Daily Solar Radiation, Wind Speed		
Flooding	**AER FloodScan**	10 km	Daily Inundation Estimates	→	• Overlap-Weighted Census Tract-Level Daily Estimate of % Tract Inundated • Comparison to Static FEMA NRI Flood Maps and First Street Foundation Flood Factor Data

Obj 1: Using EO to spatially define exposure—*Heat Event Example*

Number of Heat Events by Census Tract, 2017

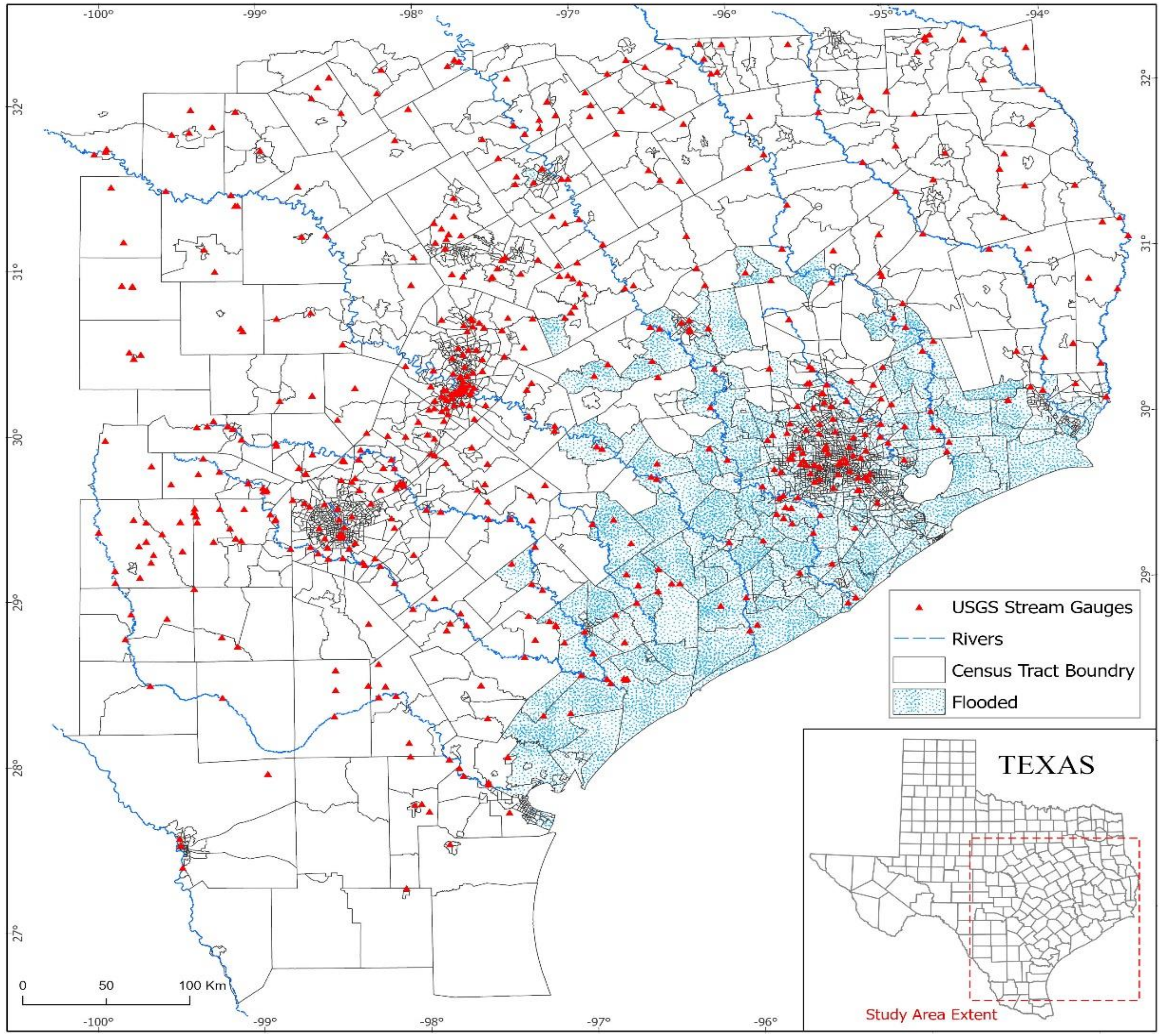


Heat Events are defined as two or more days at >95th percentile of the tract's mean Heat Index. Heat Index calculations are derived from daily, census-tract level overlap-weighted PRISM and gridMET data for the state of Texas, 2017.

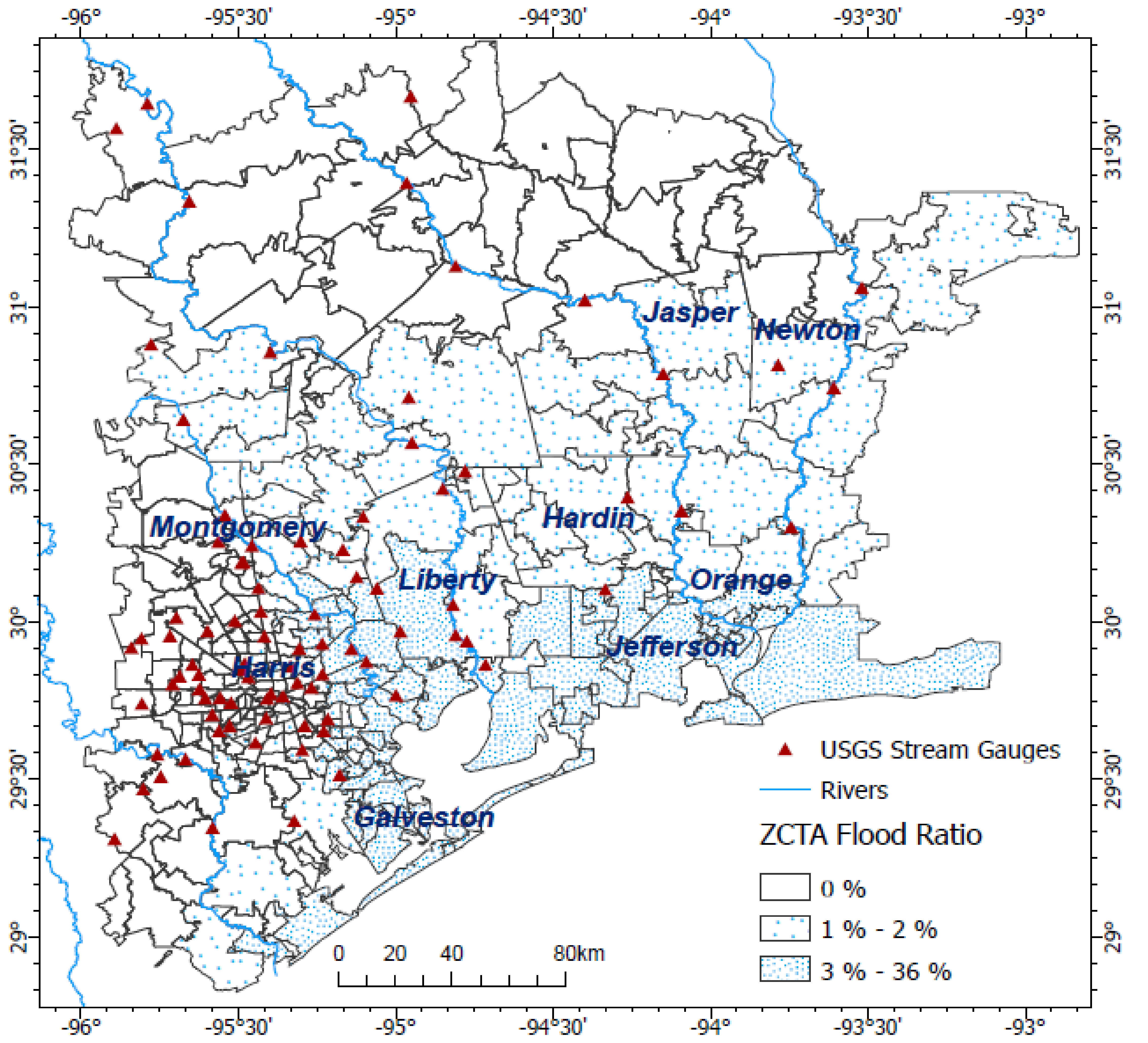
Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA

Obj 1: Using EO to spatially define exposure—example of flooding extents during Hurricane Harvey and Tropical Storm Imelda

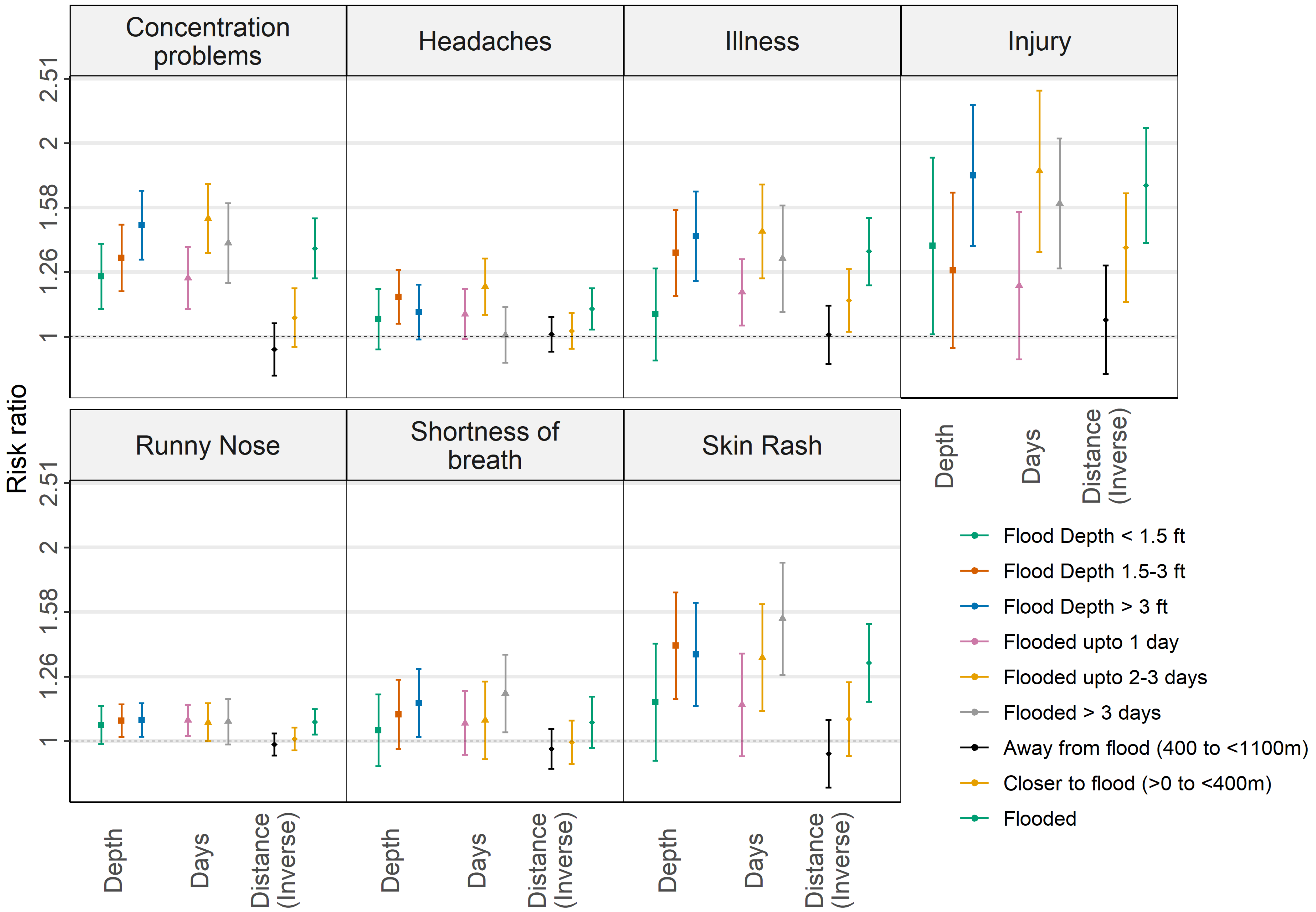
Hurricane Harvey (August 2017)

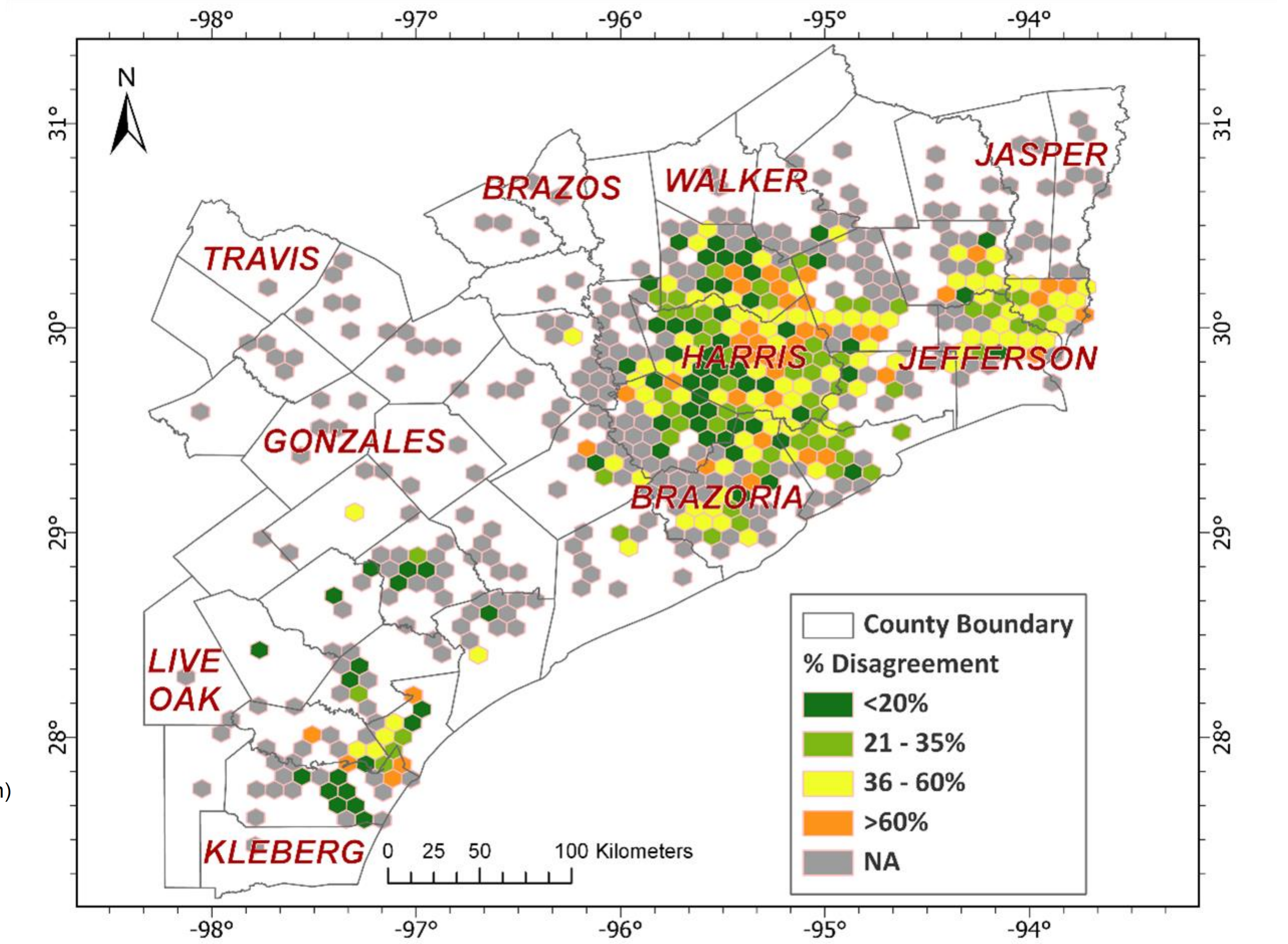


Tropical Storm Imelda (September 2019)



Association with health outcomes stronger for home flooding compared to EO defined flood extents using Texas Flood Registry data





Ramesh et al. 2023 *GeoHealth* Accepted

Objective 2

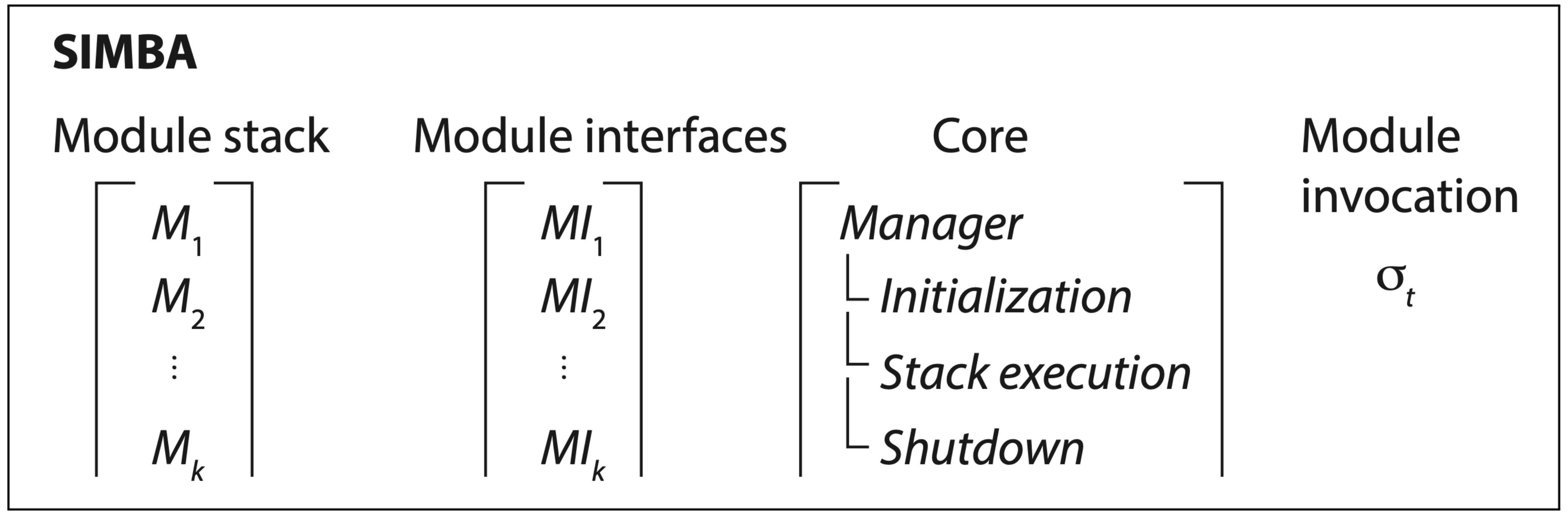
Determine contributions of movements outside of home census tract to health damages associated with extreme temperatures and flooding, accounting for differences in air pollution exposures.

Simulation Architecture: SIMBA

We have implemented the underlying common architecture that will be used for all simulations in this project.

SIMBA has four components:

- the SIMBA core, responsible for
  - simulation initialization
  - module stack execution
  - shutdown
- the module ensemble (or module stack),
  - collection of executables representing models, data staging, data pre-/post-processing, validation, preparation of visuals, and so on
- the module interface specification,
  - a complete declaration that for each module details the data on which it depends and the data that it will generate
- the module invocation interface
  - specification of the precise manner in which the modules in the module stack are to be invoked

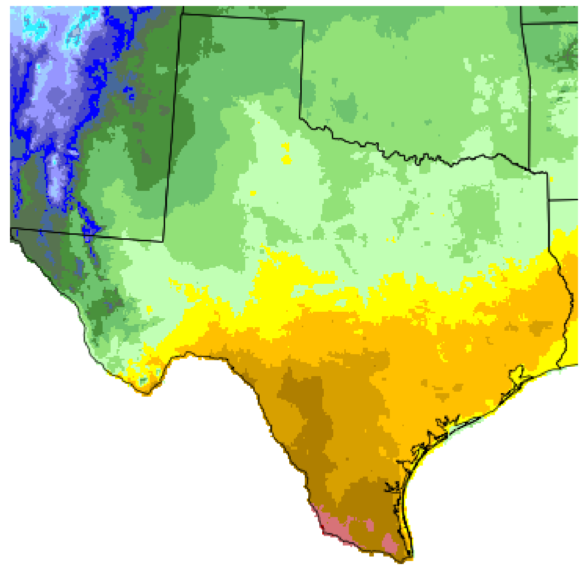


https://github.com/NSSAC/SIMBA_Schelling/

Status

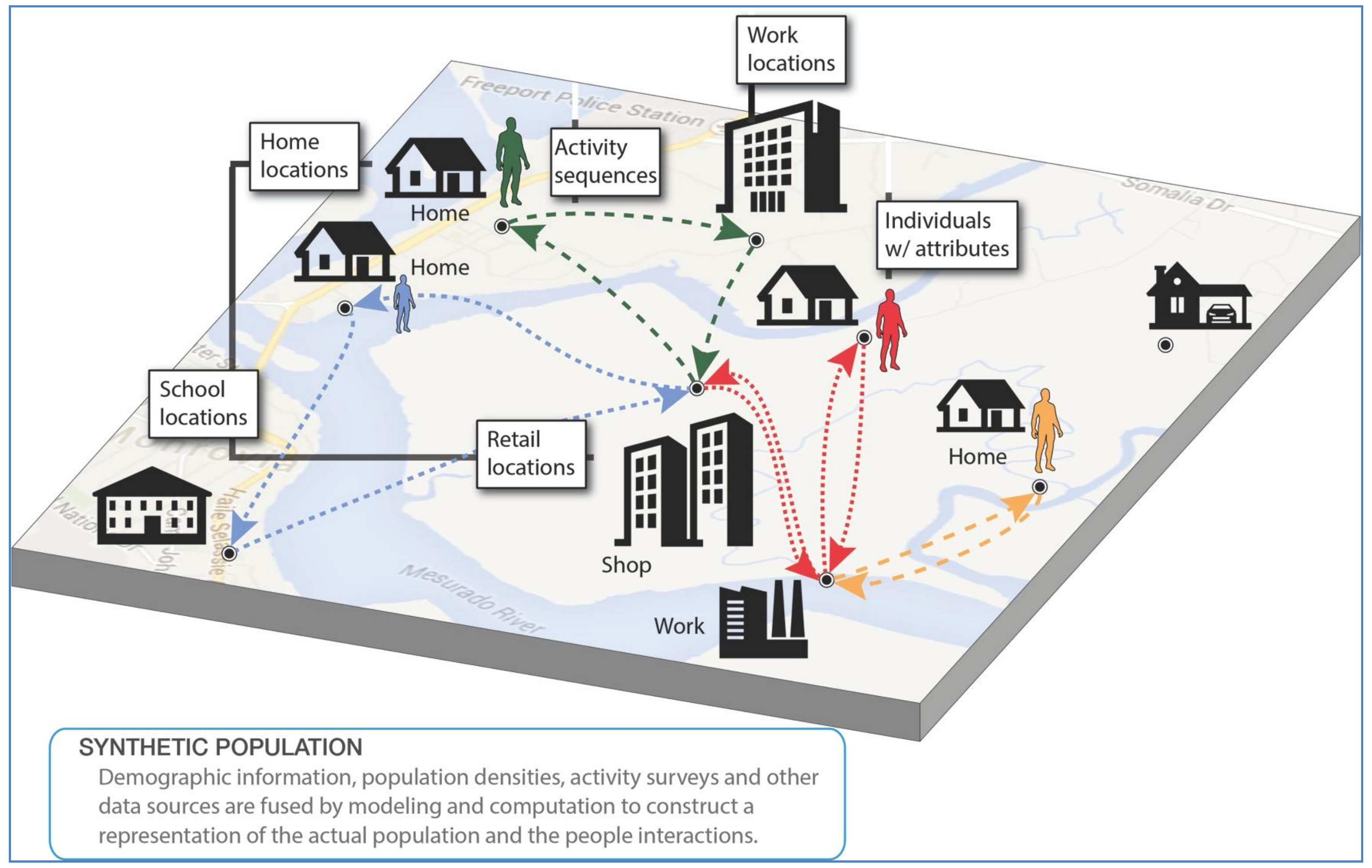
- Currently working on integrating a synthetic population with temperature data generated using PRISM and MetSim.

PRISM daily temperature data



MetSim

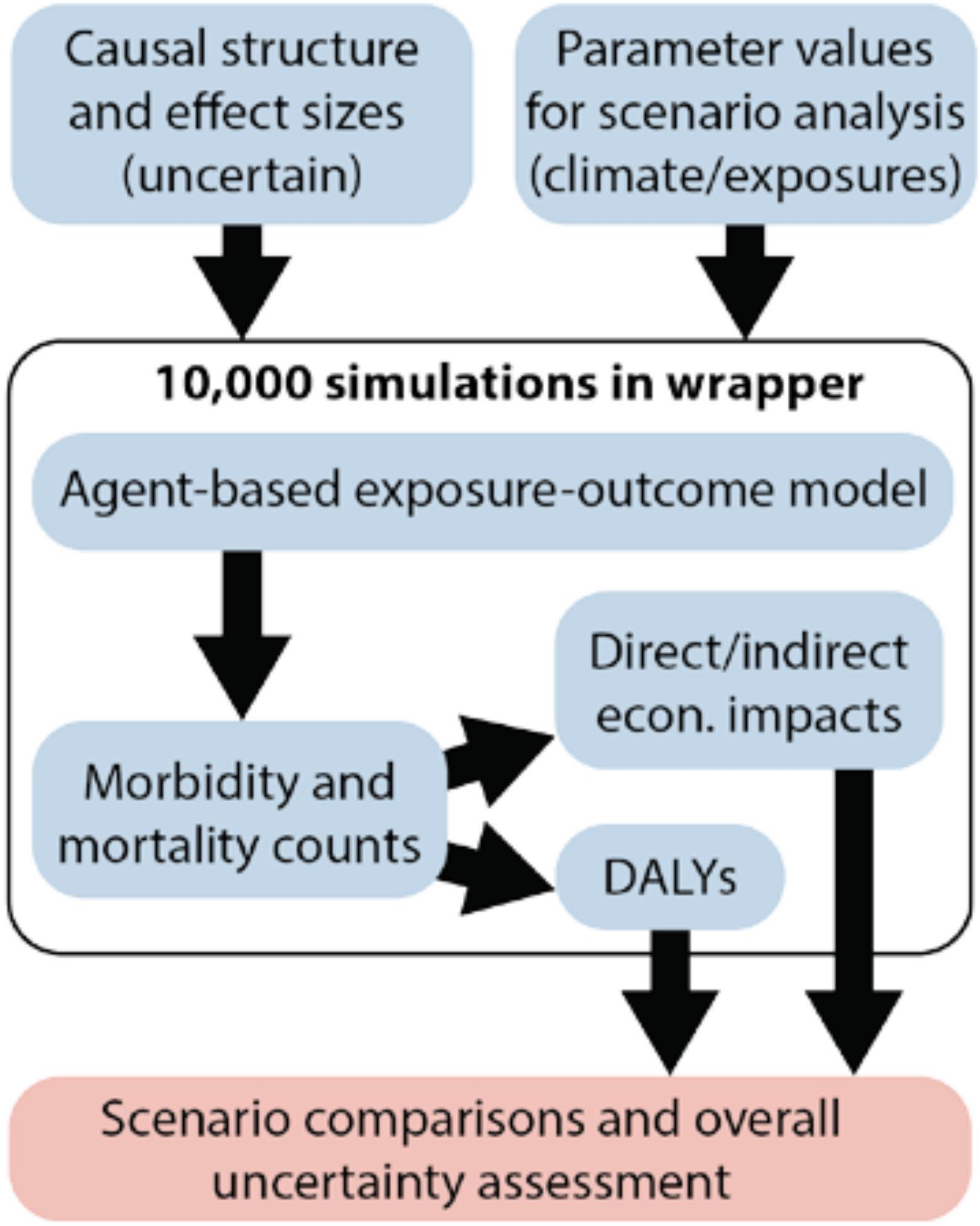
Hourly temperature data



SIMBA-backed simulation to estimate population exposures to extreme heat and cold
(Ongoing work)

Obj 3: Statistical models to describe exposure-response relationships and track uncertainties

Disparate models can make uncertainty quantification and forecasts difficult; we will put everything together in a "wrapper" to support forecasts

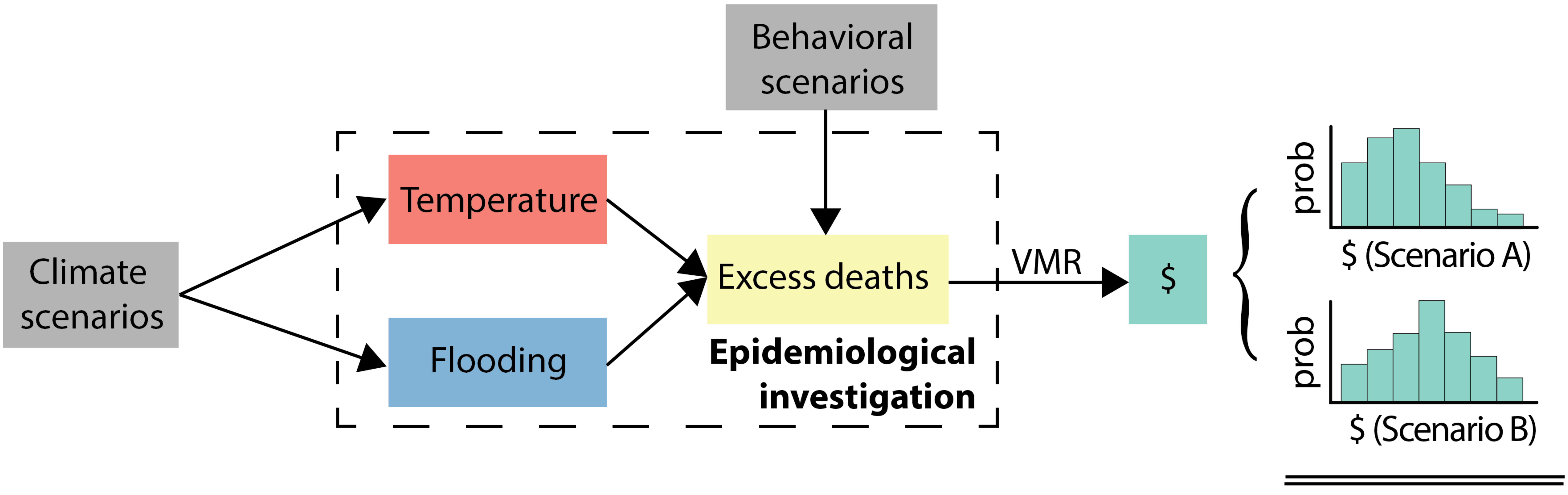


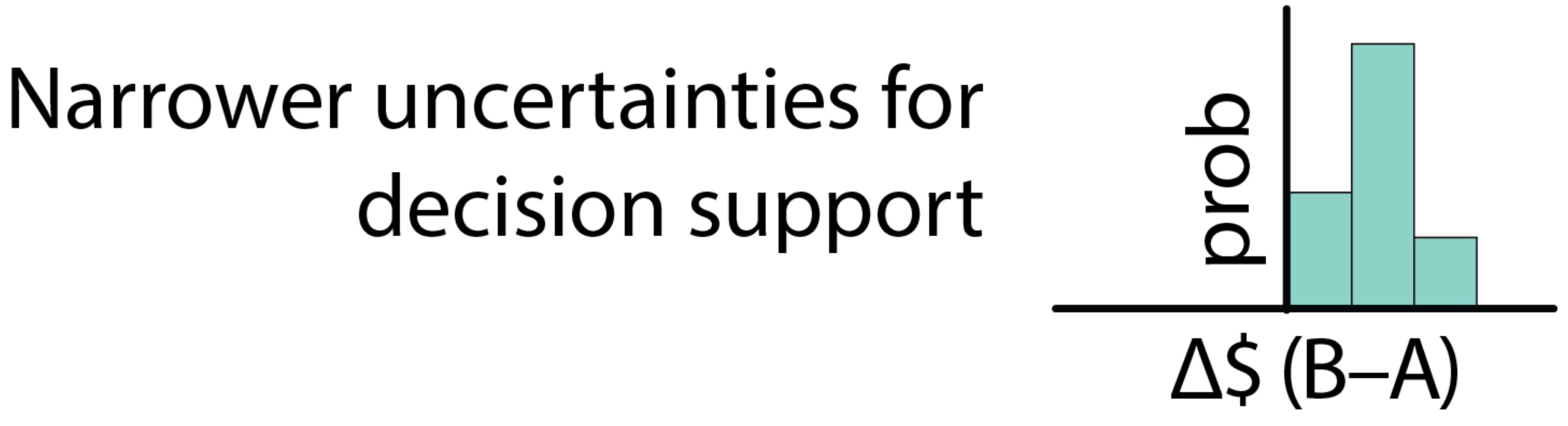
Updating global flood-related mortality model estimates

- One global model for estimating climate related mortality from flood events: Lloyd et al. (2016) Climatic Change
  - Based on historical mortality estimates captured in Emergency Events Database (EM-DAT) through 2010
  - Includes estimates of sea level rise and storm surge changes (DIVA model)

Current activities:

  - Comparing EM-DAT and NOAA billion-dollar disasters estimates for U.S. events
  - Utilizing updated mortality data through 2020 and splitting time periods to understand trends
  - Compare DIVA and EO derived estimates of exposed population for U.S. events





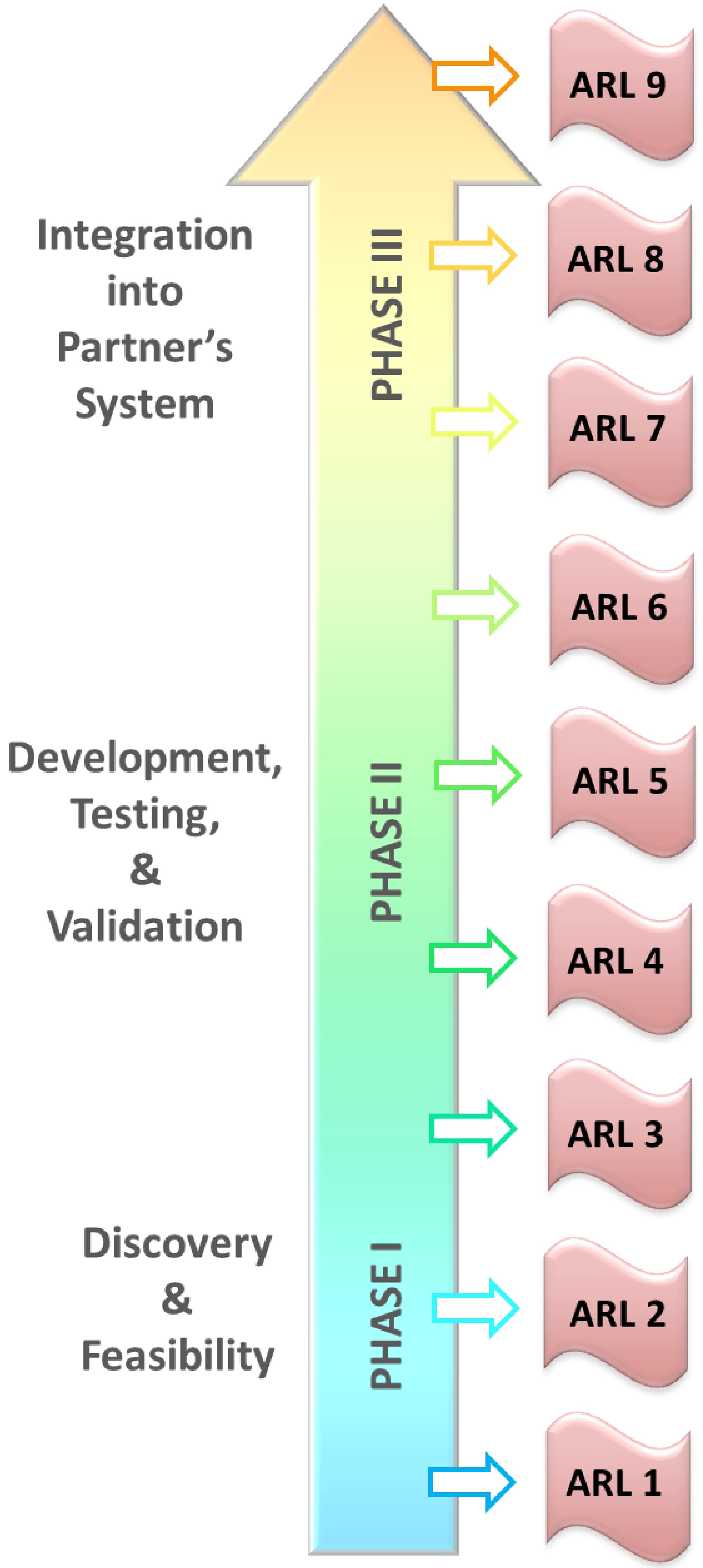
We can narrow the uncertainties in our valuations of certain decisions (e.g., improved evacuation) by controlling for uncertainties in epi model

End-user engagement

Organization Name	Organization Type	Decision Making Activity
USEPA	Federal Agency	Estimation of health damages for benefit-cost analysis
Houston Health Department	Local Health Department	Prioritization of locations for emergency services

Dec. 12, 2022: Presentation to USEPA NCEE and discussion of needs for improving the SCC.

We are planning engagement with HHD in the summer. Consultant Elena Craft participating in Earth Week events (Apr 18-19).



ARL Performance

- Start-of-Project ARL = 4 *(07/01/22)*
- Goal ARL = 7
- Current ARL = 4 *(03/29/2023)*
  - We are working with previously developed methods for estimating flood and heat-related mortality.
  - These methods are in use by national and global organizations for estimating health damages associated with climate change so technical integration issues have been worked out.
  - We will improve these methods by adding in morbidity and improving mortality estimates using EO.
  - We will use application system as is currently in use, so we expect minimal technical integration issues.
  - EO and synthetic population components have moved to ARL5.

Challenges and Risks

Rank	Type*	Risk	Mitigation Action	Date first noted/Date resolved (if applicable)
1	PM	Texas DSHS did not allow amendment to current data use and IRB protocol for acquisition of additional health data	Submitted new proposal in Jan 2023	Jan 2023
2	B	Texas DSHS will require re-purchase of data already had from previous project	Will request line item movement for increased data costs	Jan 2023

* Please designate risk type as: Technical (T), Budget (B), End-User/Stakeholder (ES), or Project Management (PM)

Upcoming project activities

- Additional emergency department and death record data request submitted to Texas DHHS (Sept 2022 and in Jan 2023)
- Earth observation data acquisition and processing (2022-2023)
- Exploring global models: Comparing flood event data in NOAA and EM-DAT databases, trialing Lloyd et al. 2016 global flood-mortality model (2022-2023)
- Fine-scale heat and cold-related distributional health damages in Texas 2015-2022 (2023)
- Fine-scale flood-related distributional health damages in Texas 2015-2022 (2023-2024)
- Monetization and uncertainty evaluation (2024)
- Define application to global and regional models of climate-related health damages (2024-2025)