Advisory Council on Clean Air Compliance Analysis Section 812 Benzene Case Study – Air Quality Modeling & Exposure Modeling

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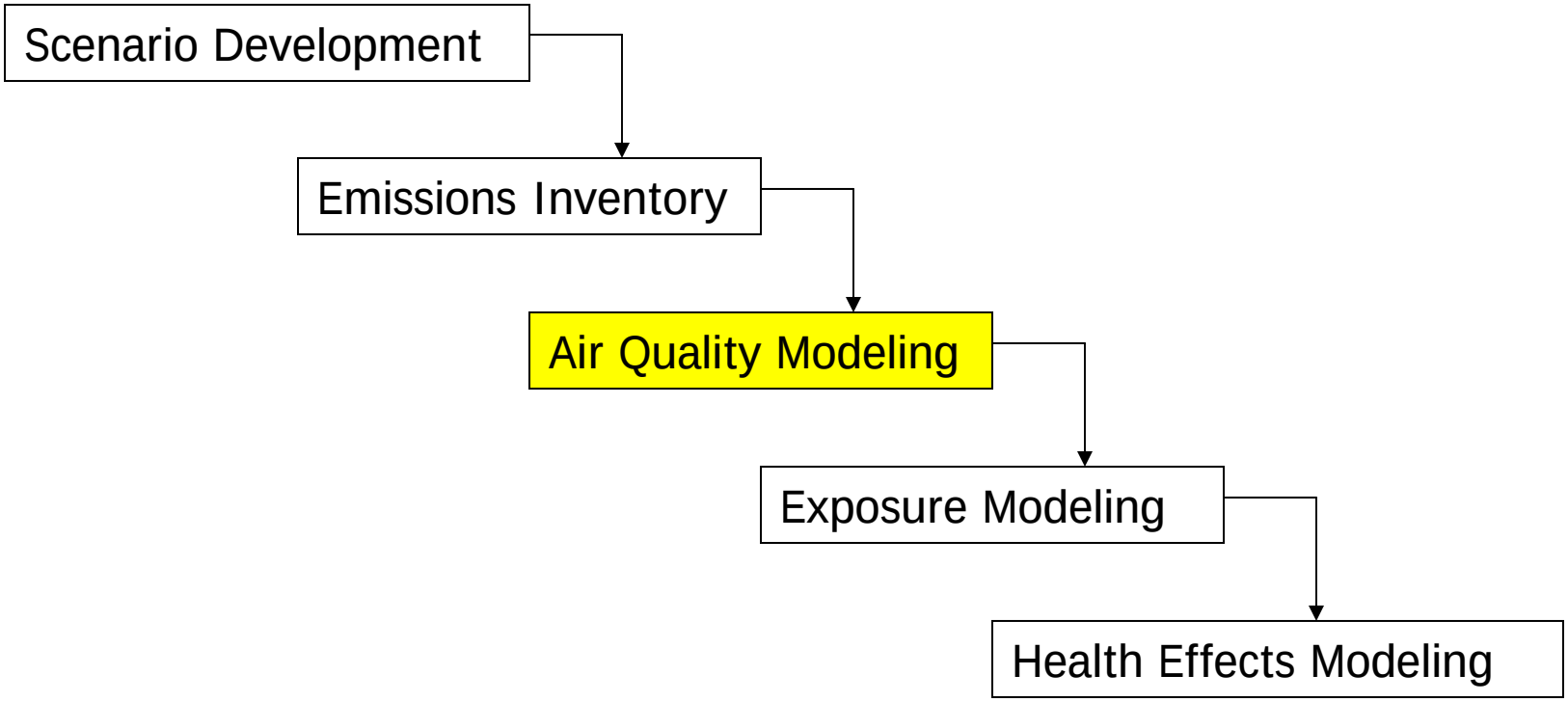
Charge Question #3

- Air Quality Modeling and Exposure Modeling. EPA used the American Meteorological Society/US EPA Regulatory Model (AERMOD) to estimate changes in ambient concentrations and the Hazardous Air Pollutant Exposure Model (HAPEM6) to estimate individual exposures to benzene levels. Please comment on this approach.

Analytical Approach



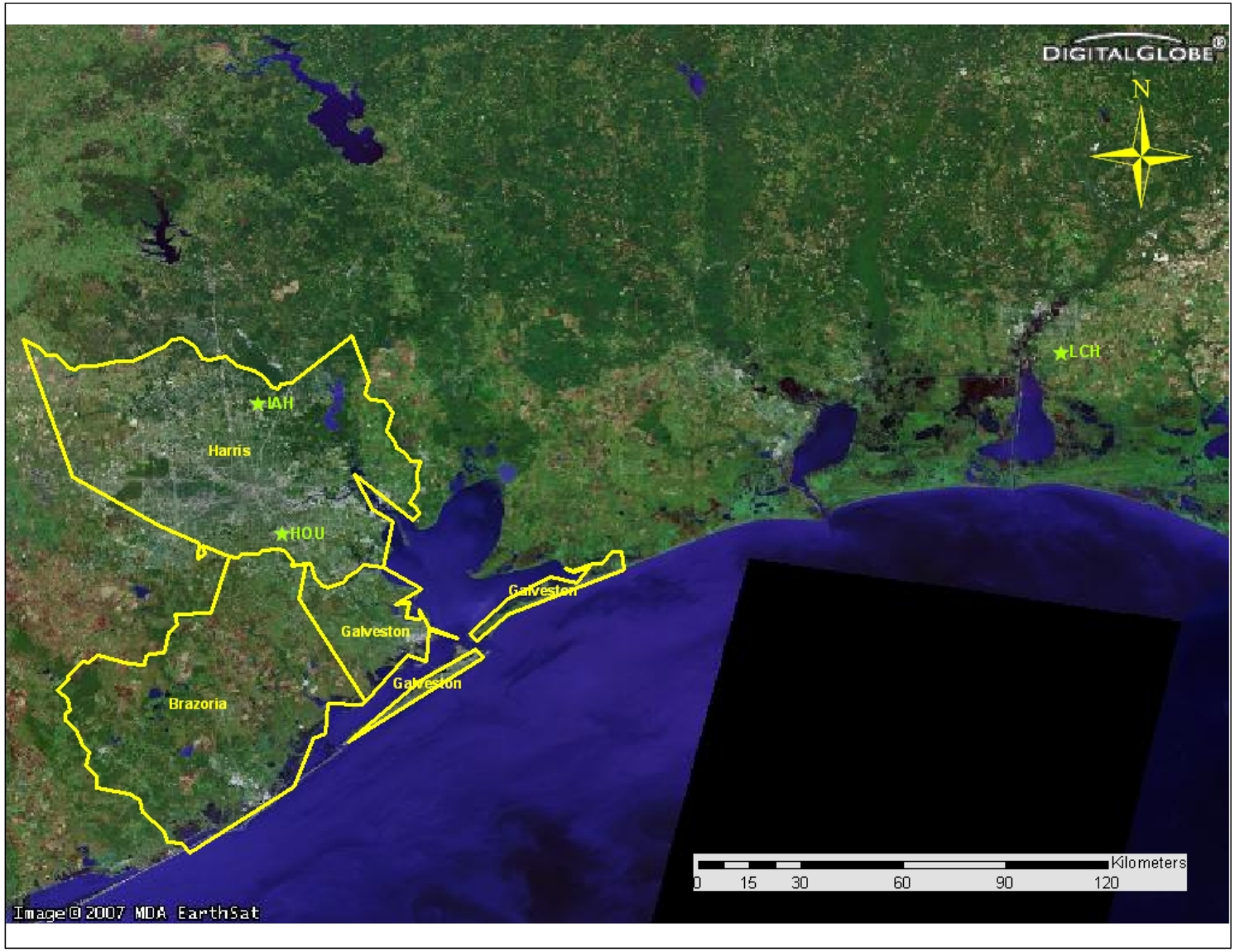
Air Quality Modeling Approach

- Dispersion Model
  - American Meteorological Society/U.S. EPA Regulatory Model (AERMOD) version 40300
- Study Domain
  - Three county Study Area (Brazoria, Galveston, Harris)
  - Modeled at block group level
    - 1990 Base Case - 1990 Census boundaries.
    - 2000-2020 Scenarios - 2000 Census boundaries.
- Model Options:
  - Terrain Flat
  - Air toxic option
  - Urban/rural based on population density
  - No building downwash

Air Quality Modeling Approach (cont)

- Meteorological Data
  - Processed with AERMET
  - 1990 base year – George Bush International /Lake Charles 1990
  - 2000-2020 Scenarios – Houston Hobby Field /Lake Charles 2000
- Background Levels
  - County-specific 1999 NATA to account for mid-range to long-range transport.
    - Brazoria – 0.363 ug/m3
    - Galveston – 0.397 ug/m3
    - Harris – 0.464 ug/m3

Meteorological Stations



Air Quality Modeling Approach (cont)

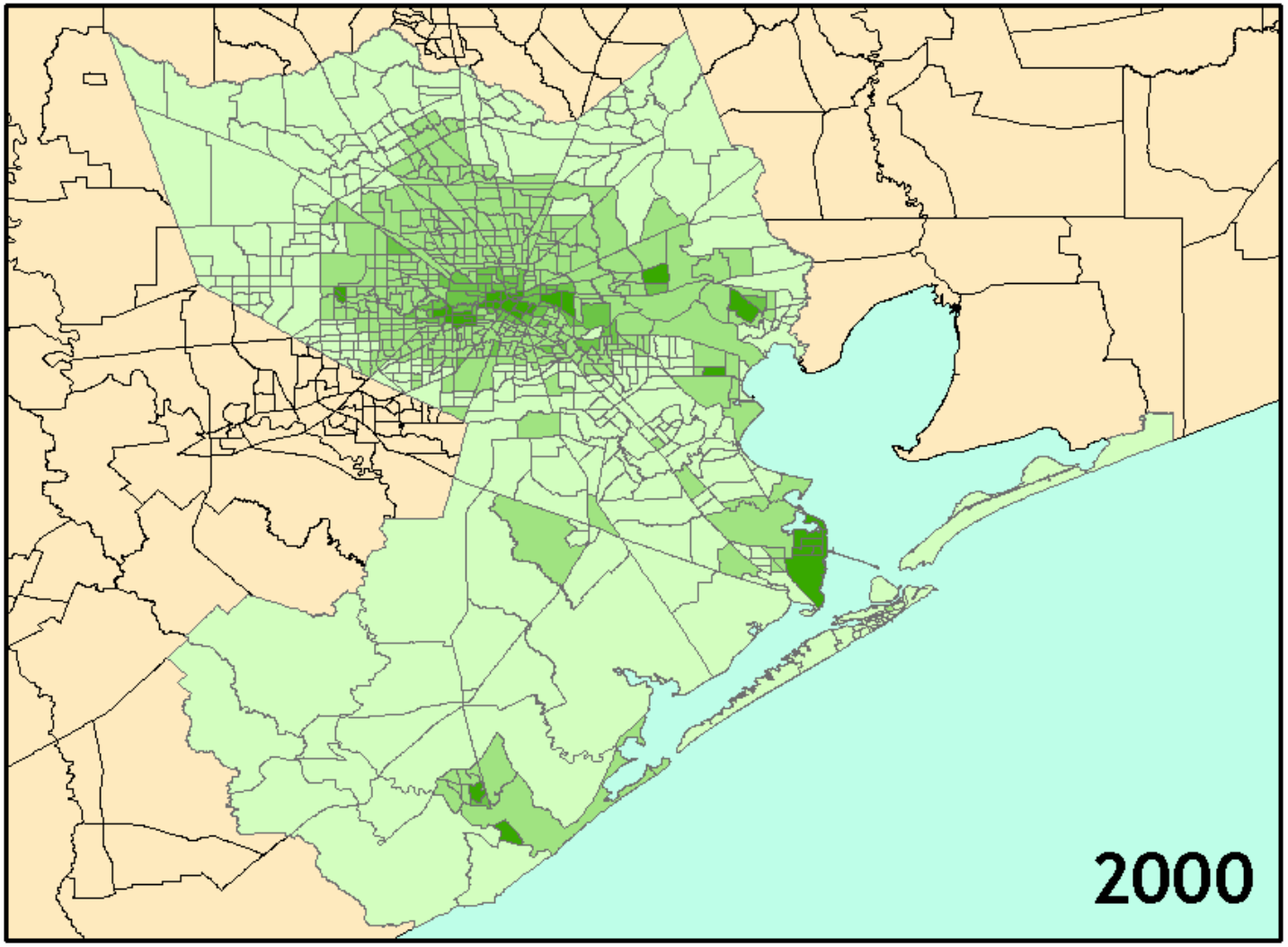
- Source Representation
  - Point Inventory
    - Modeled at stack locations as “point” sources
  - Nonpoint and Nonroad Inventories
    - Generally county Level emissions allocated to census tracts using surrogates
    - Modeled as “area” source using census tract polygon
    - Airports emissions assigned to airport polygon
  - Mobile Inventory
    - Emissions allocated to roadway “links”
    - Modeled as “area” source using link locations

POPULATION-WEIGHTED MEAN REDUCTION IN AMBIENT ANNUAL AVERAGE BENZENE CONCENTRATION DUE TO CAAA, BY YEAR AND COUNTY

Study Year	MEAN CHANGE IN BENZENE CONCENTRATION, ug/m3 (RANGE)		
	BRAZORIA	GALVESTON	HARRIS
2000	1.0 (0.04 - 25)	0.8 (0.04 - 18)	0.8 (-3 - 34)*
2010	1.0 (0.08 - 25)	0.9 (0.05 - 17)	1.0 (-4 - 33)*
2020	1.2 (0.09 - 28)	1.0 (0.06 - 20)	1.2 (-4 - 37)*

* Seven of the 1,911 census block groups in Harris County showed dis-benefits under the *With-CAAA* scenario. Of these, five reported increases of 0.3 μg/m3 or less. The smallest reductions estimated were between 0.02 and 0.1 μg/m3.

Estimated CAAA - Related Reductions In Benzene Concentrations (AERMOD)



Reductions in Concentration: >2.5 µg/m³ | 1.5 to 2.5 µg/m³ | 0.5 to 1.5 µg/m³ | <0.5 µg/m³

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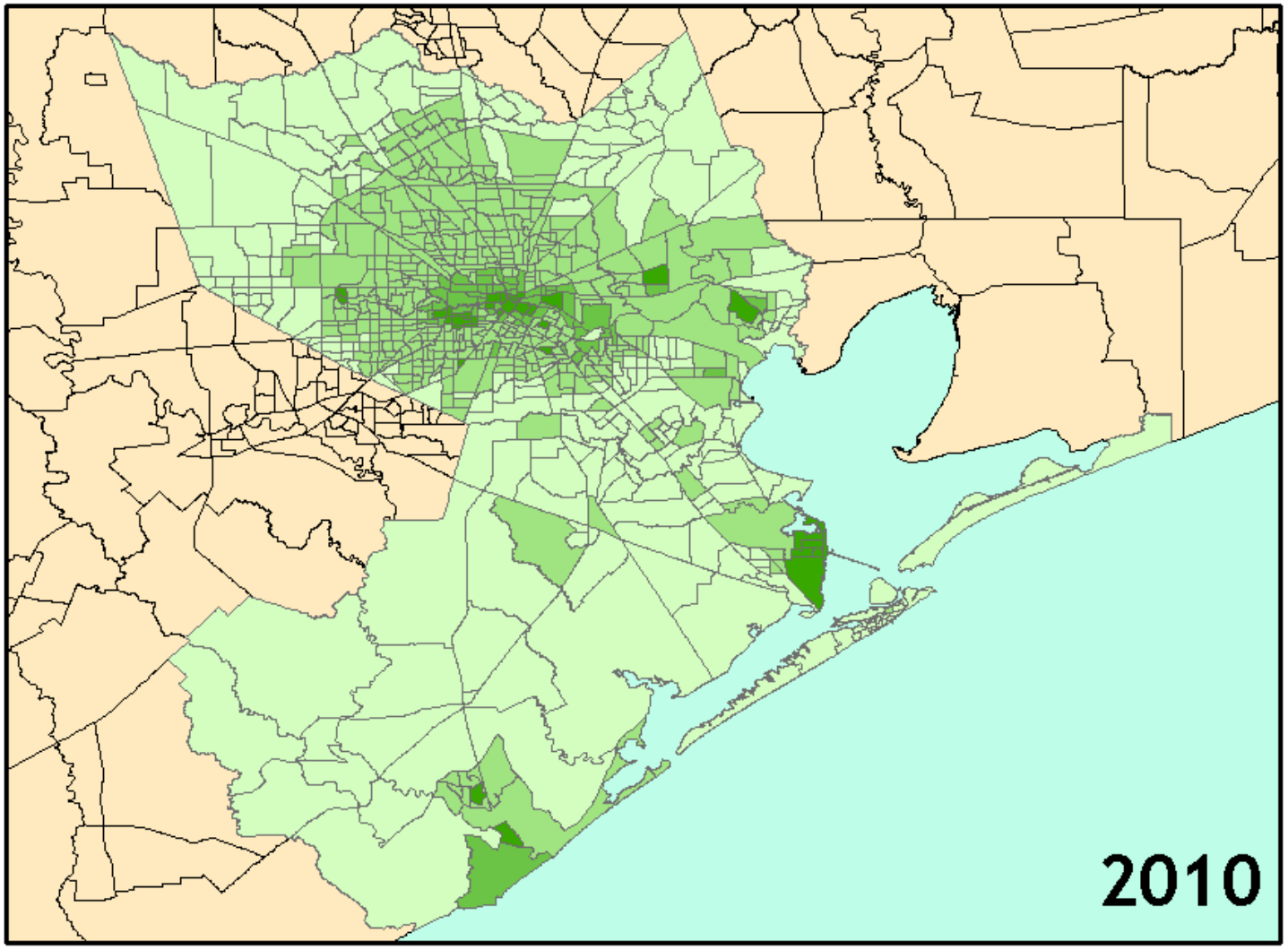

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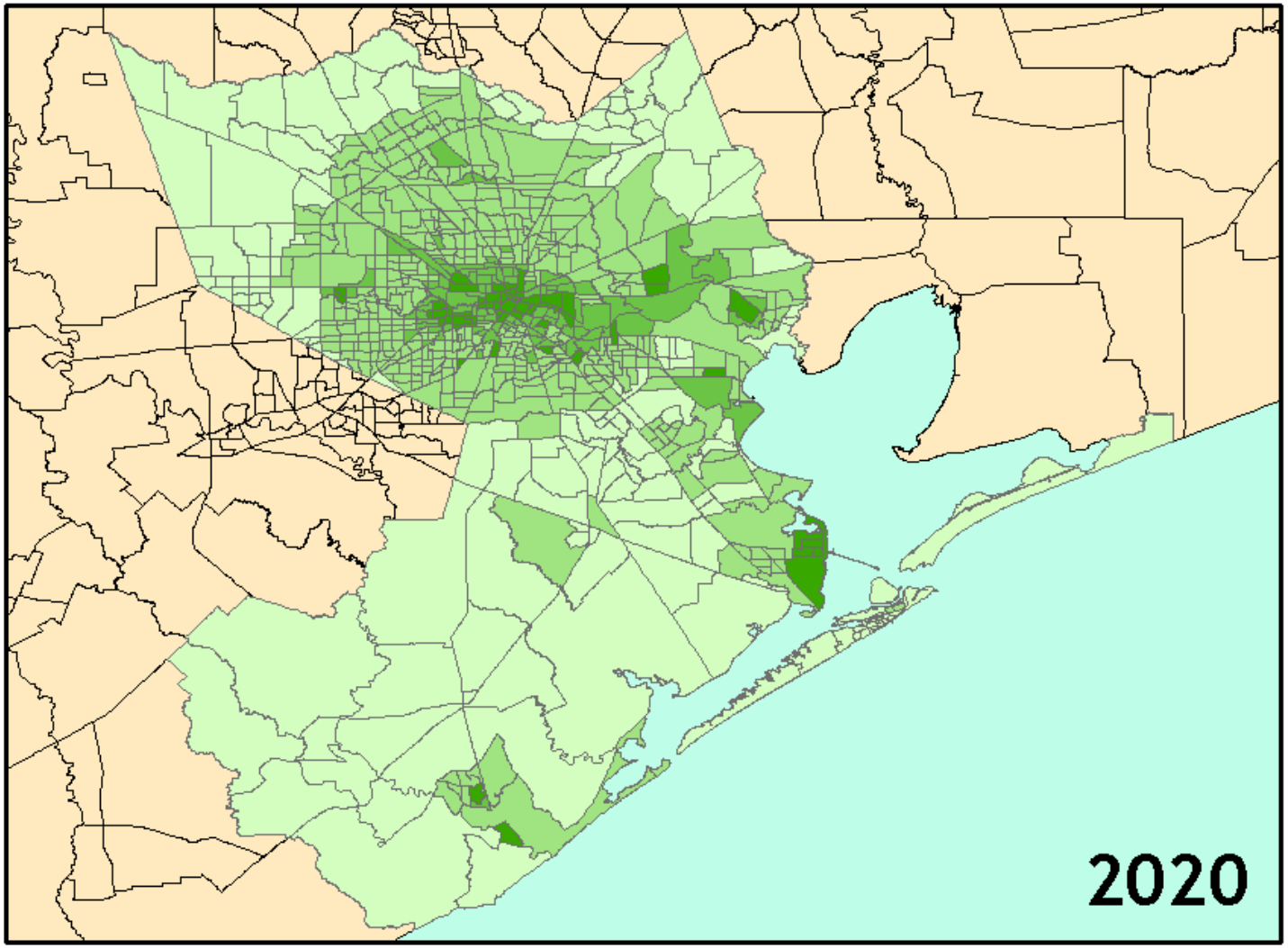

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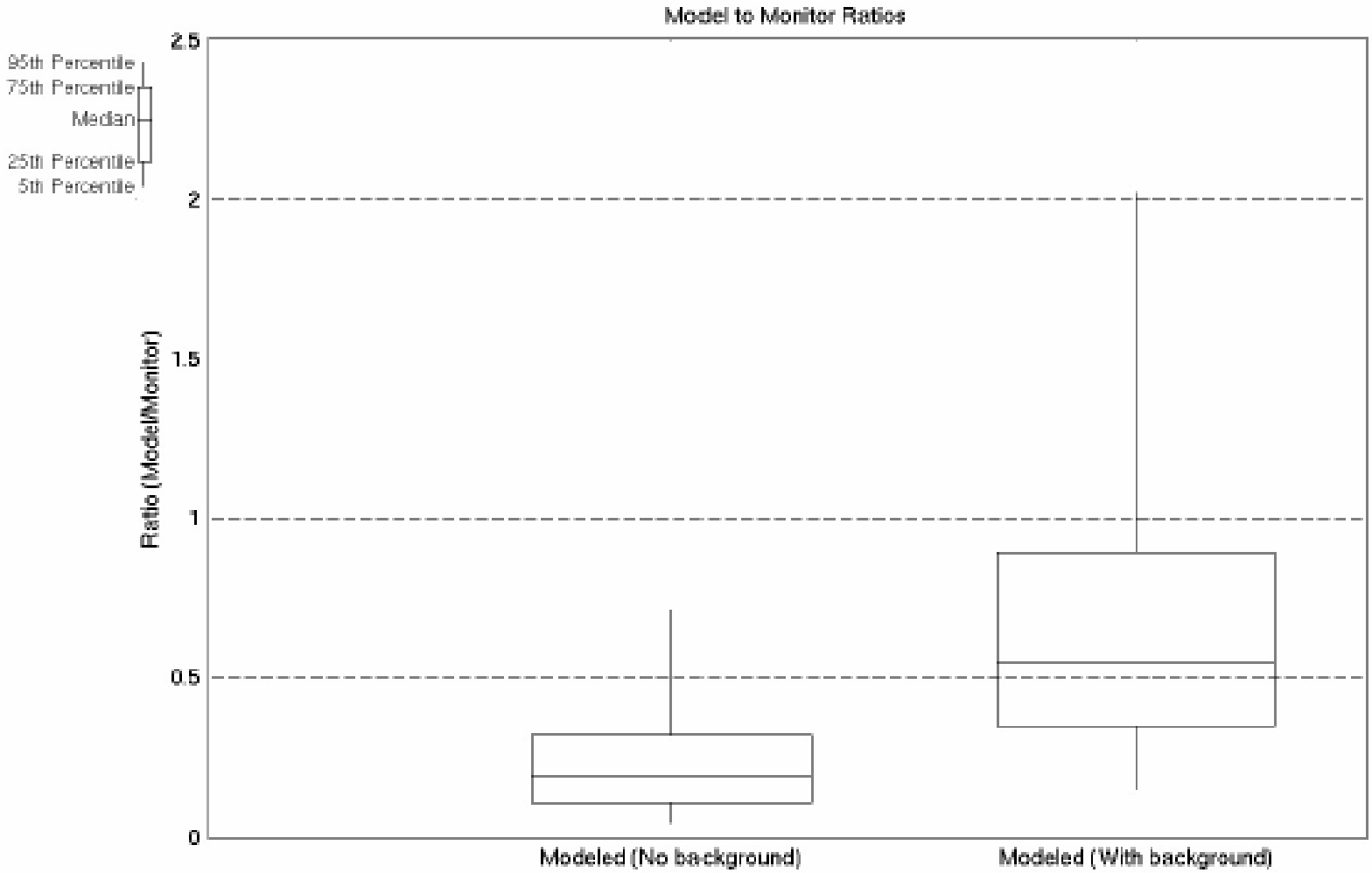
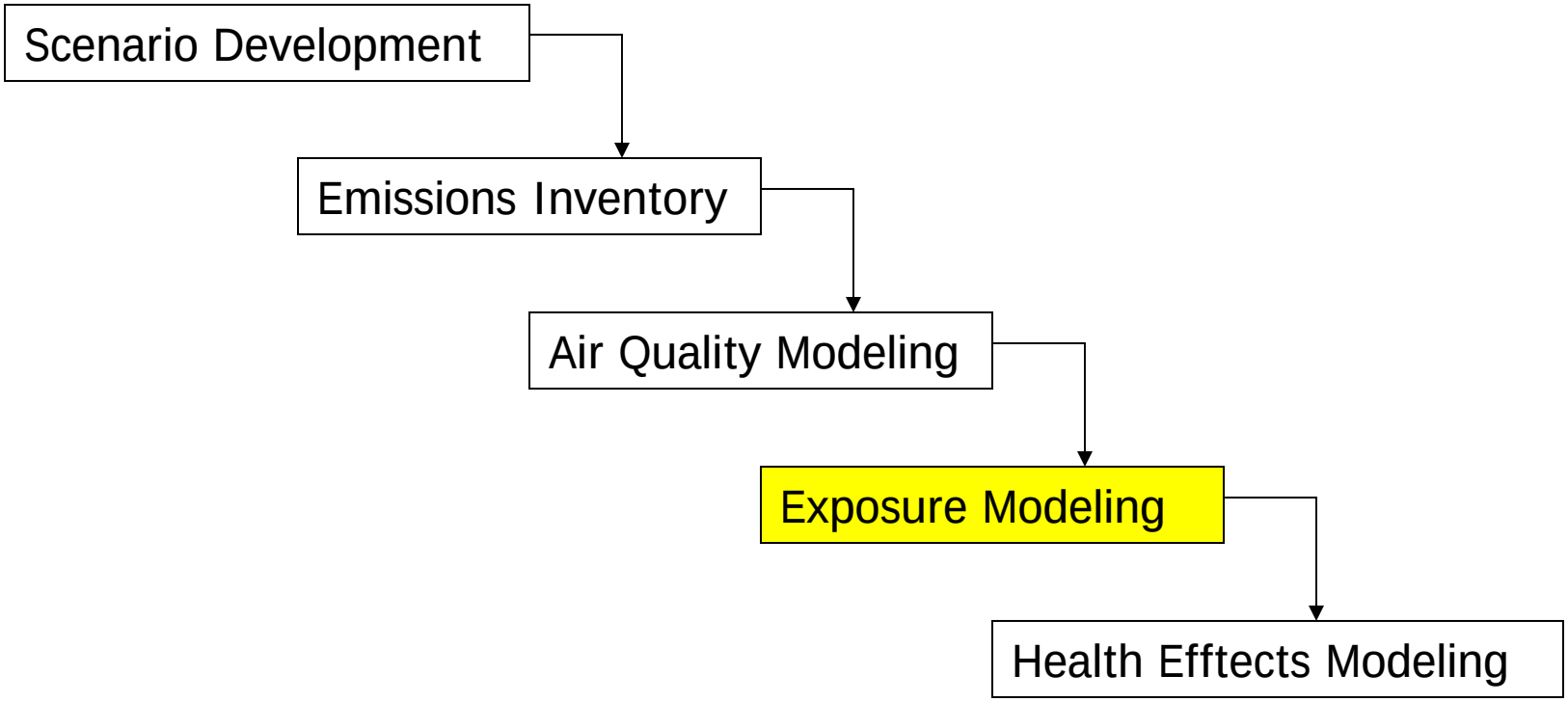
Model to Monitor Analysis 2000 CAA vs. Monitors



AERMOD Uncertainty/Limitations

- AERMOD limitations
  - Spatial (50 km)
  - Photochemistry
- Source representation in model
  - Stack characteristics
  - Use of surrogates to distribute emissions
  - Urban/rural designation
- Meteorological data representation
  - Locations relative to source
  - Surface features
- Background Concentrations
  - Constant across county

Analytical Approach



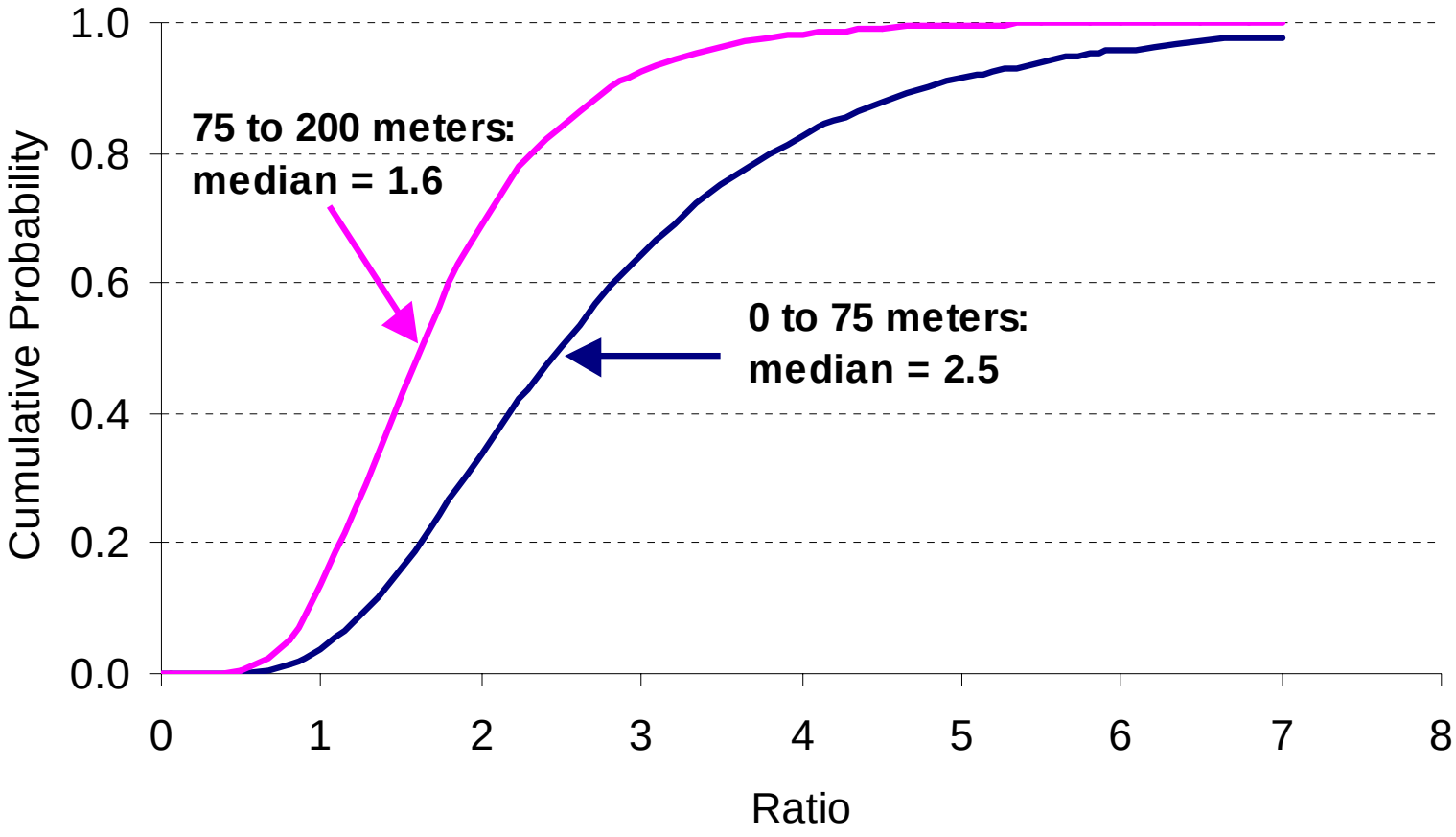
Exposure Modeling Approach

- Hazardous Air Polluant Exposure Model Version 6 (HAPEM6)
  - Screening-level exposure model
  - Long-term inhalation exposures
  - General population, or a specific sub-population
  - Five primary sources of information
    - Population data from the US Census
      - Age cohorts (0-1; 2-4; 5-15; 16-17; 18-64; >=65)
      - 1990 census for base scenario and 200 census for 2000-2020 scenarios
    - Human activity data
      - Consolidated Human Activity Database (CHAD)
      - Commuting- tract-to-tract commuting probability data derived from 2000 census commute file

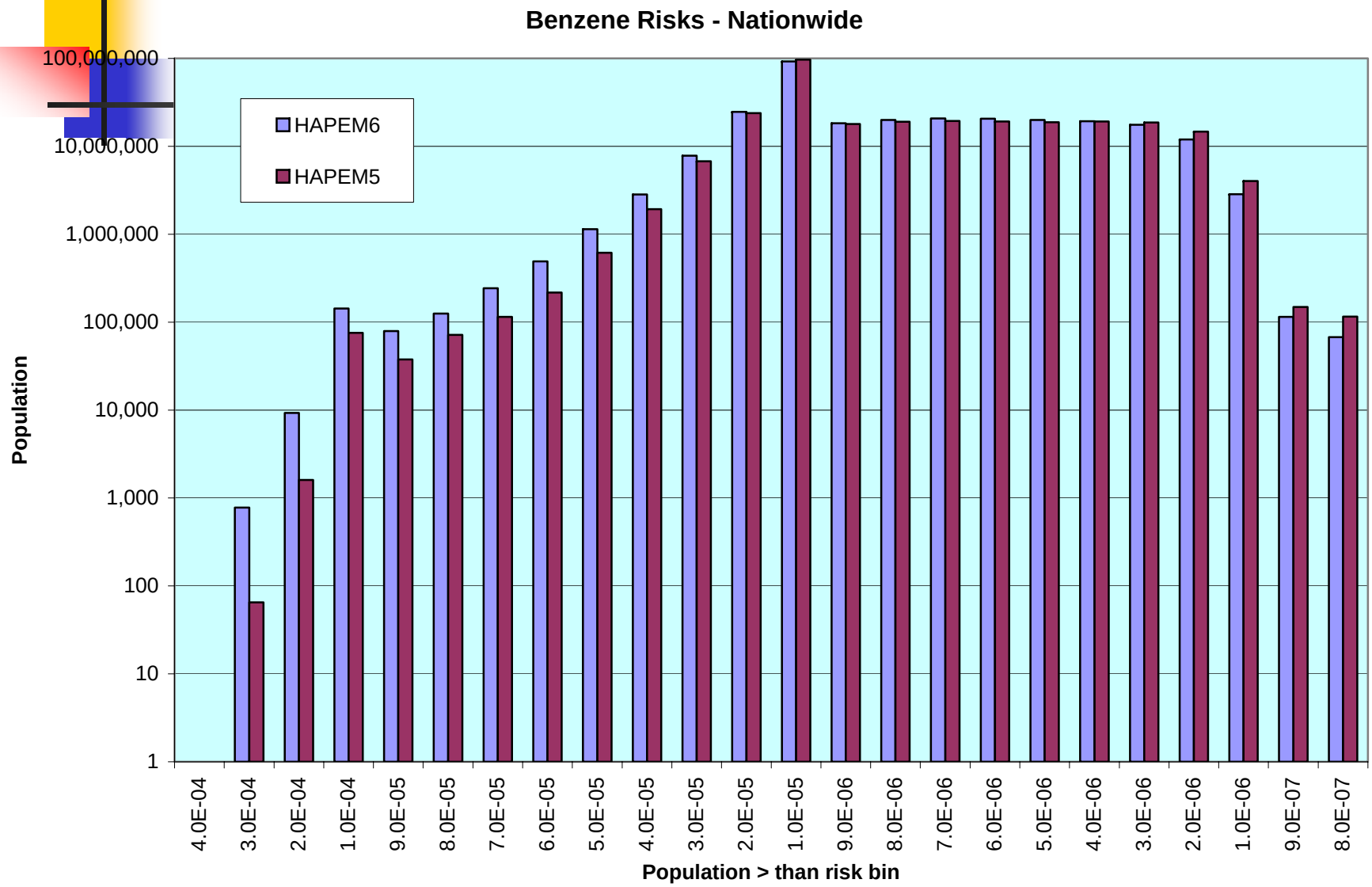
Exposure Modeling Approach (cont)

- Five primary sources of information (cont)
  - Residence and workplace relationship to roadway data
    - developed for each census tract – 75m and 200m from 4 lane roadway
  - Microenvironmental (ME) data
    - 14 different ME locations (e.g., residential, school, office, public transit, service station)
  - Air quality data
    - AERMOD annual average diurnal patterns
- Stochastic Approach
  - Yields distribution based on variability in time activity patterns and uncertainty in ME factors
- Model predicted distribution of exposures levels at census tracts (30 per tract) for each source sectors (major sources, area sources, on-road mobile, off-road mobile and background)

Ratio of Near-Roadway-to-Remote Concentration



Near-Roadway Effects on Population Risks



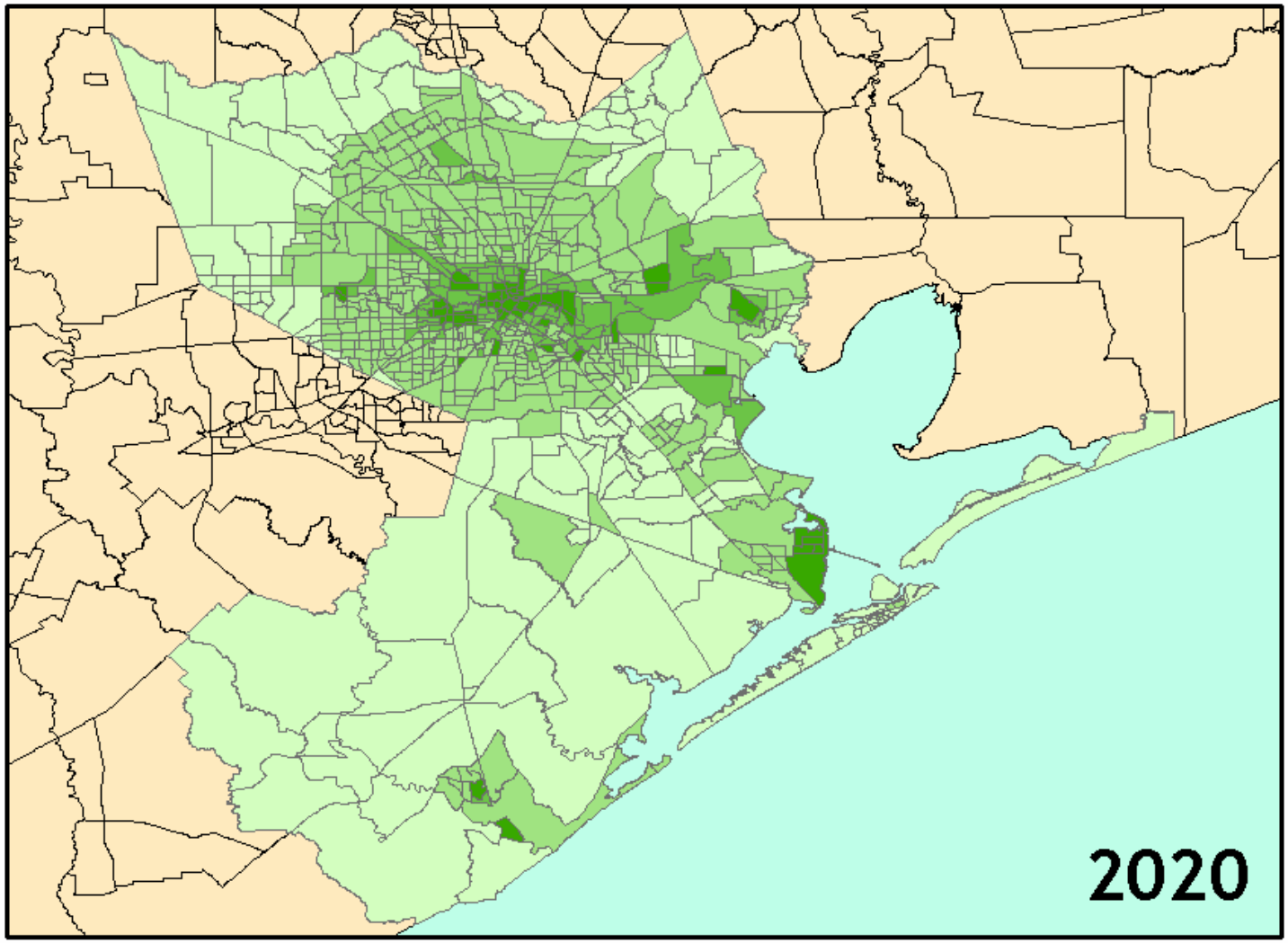
HAPEM* Estimated Mean Reduction In Annual Benzene Exposure Concentration Due To CAAA

Study Year	MEAN CHANGE IN BENZENE CONCENTRATION, ug/m3 (RANGE)		
	BRAZORIA	GALVESTON	HARRIS
2000	0.9 (0.07 - 19)	0.7 (0.08 - 14)	0.8 (-1 - 11)**
2010	0.9 (0.1 - 19)	0.7 (0.09 - 14)	0.9 (-1 - 12)**
2020	1.1 (0.1 -21)	0.9 (0.1 - 16)	1.1 (-1 - 14)**

* The HAPEM results in this table represent the exposure change for the median individual in a census tract (i.e., they are neither highly nor minimally exposed in terms of their activities and characteristics). The exposure change is an average change in exposure across all age categories.

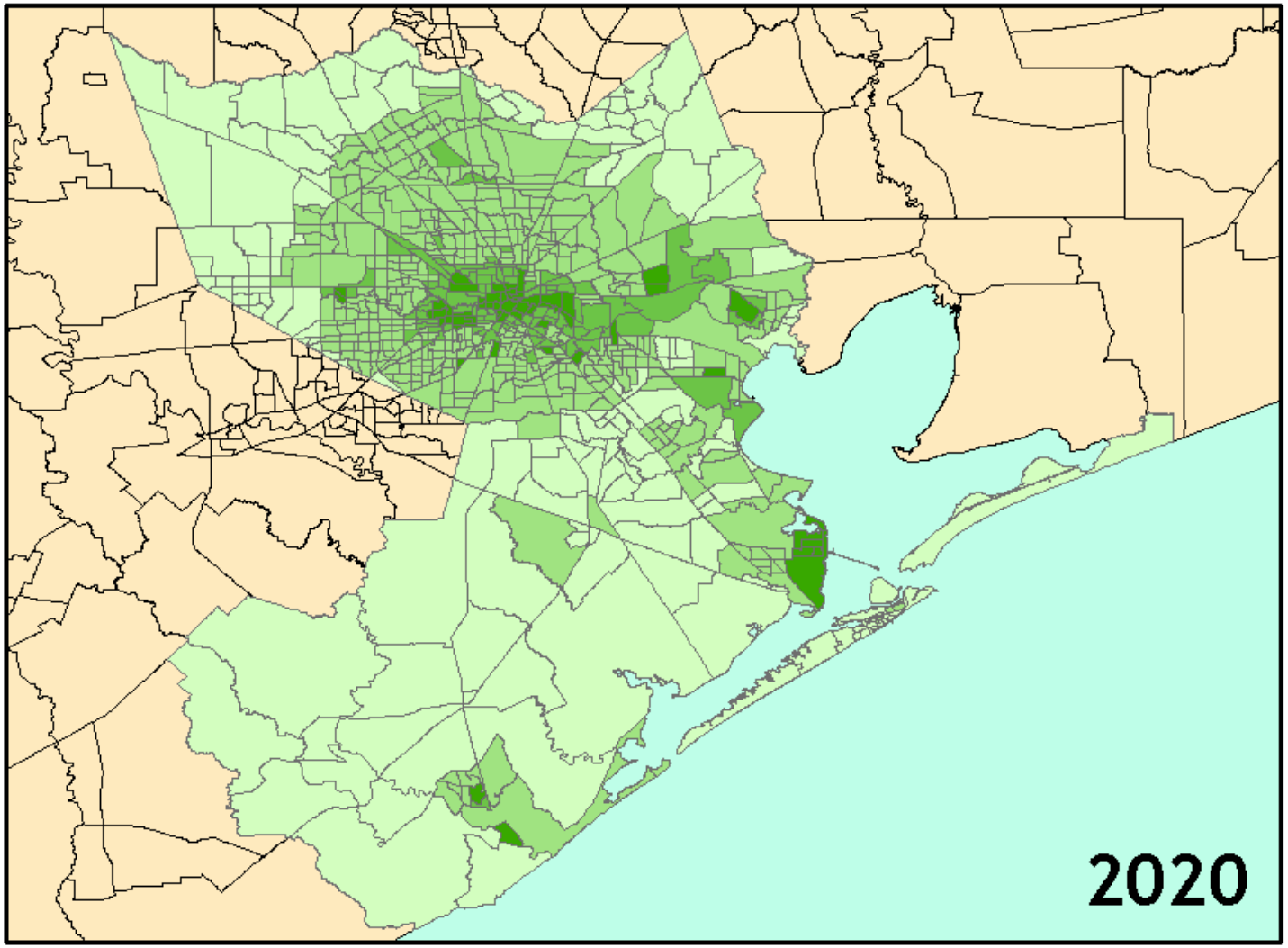
* *One of the 649 census tracts in Harris County reported dis-benefits under the With-CAAA scenario. The smallest reductions estimated were between 0.07 and 0.1 ug/m3.

Estimated CAAA - Related Reductions In Benzene Concentrations (HAPEM)



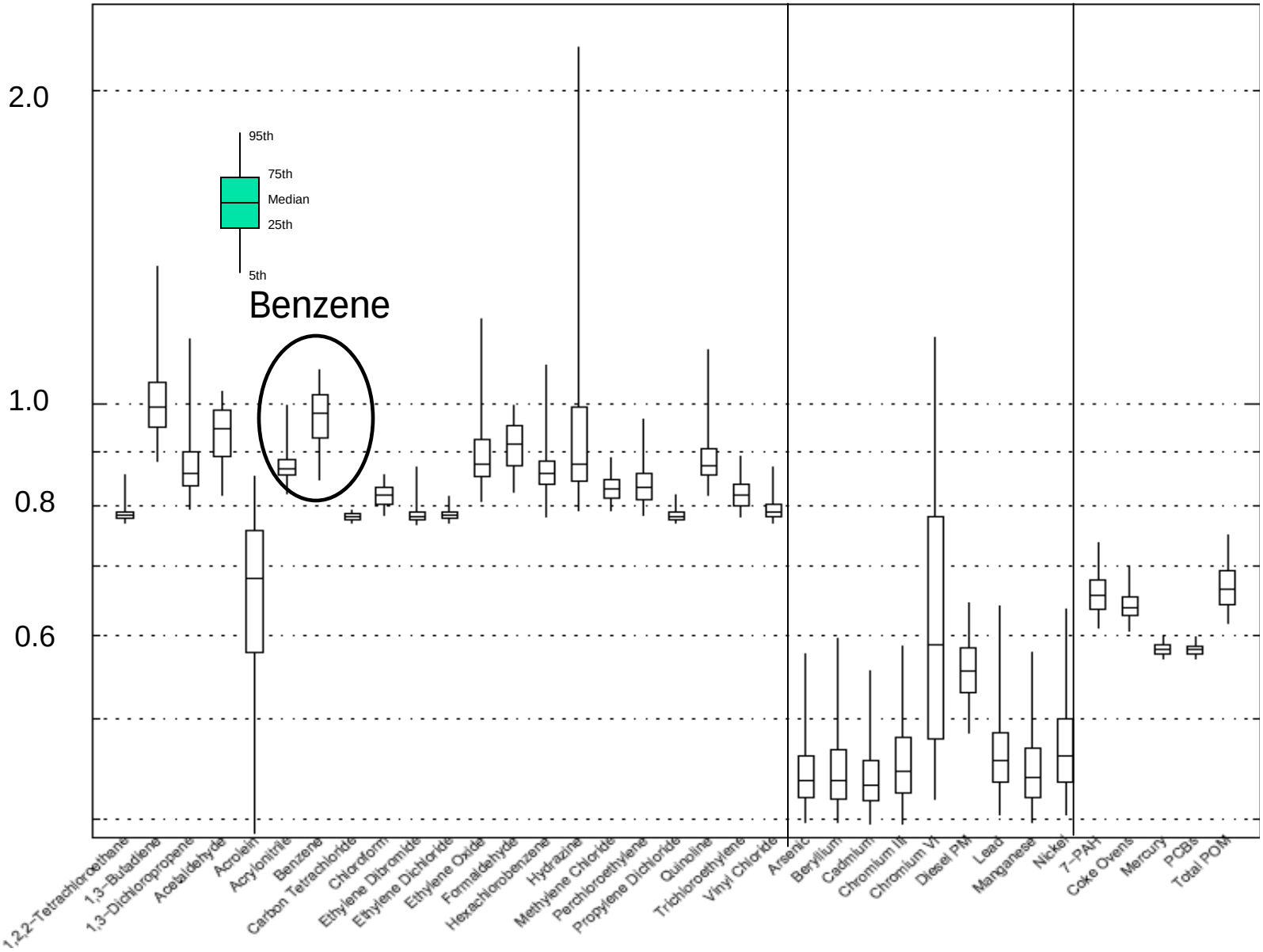
Reductions in Concentration >2.5 µg/m³ 1.5 to 2.5 µg/m³ 0.5 to 1.5 µg/m³ <0.5 µg/m³

Estimated CAAA - Related Reductions In Benzene Concentrations (AERMOD)



Reductions in Concentration >2.5 µg/m³ 1.5 to 2.5 µg/m³ 0.5 to 1.5 µg/m³ <0.5 µg/m³

Exposure vs. Ambient Concentration Comparison [1]



1 Özkaynak, Halûk, T. Palma J. Touma and J.Thurman; 2007; Modeling Population Exposures to Outdoor Sources of Hazardous Air Pollutants, Journal of Exposure Science and Environmental Epidemiology (2007), 1–14

HAPEM Uncertainty/Limitations

- Approach
  - Not suited for prediction of "extremes" in distribution of exposures
- Activity Data
  - Annual patterns built from single day diary entries (diary entries from up to 365 people to represent a single person).
  - Daily temporal sequence of activities not retained
  - Does not include ventilation rates
  - Activity patterns data for certain demographic groups is limited (non-English speaking)
- Microenvironment (ME) Concentrations
  - Limited studies to develop ME PROX and PEN factors for most HAPs
  - No variability (spatial or temporal) in ME PROX and PEN factors
  - ME concentration relationship not always linear
- Commuting Data
  - No provisions for "in route" time (uses AQ concentrations from home or work tracts only)
  - No children commuting
- Model has not yet been fully evaluated against personal monitoring data