Recent Updates to Spatial Surrogates for Modeling U.S. Emissions Sources

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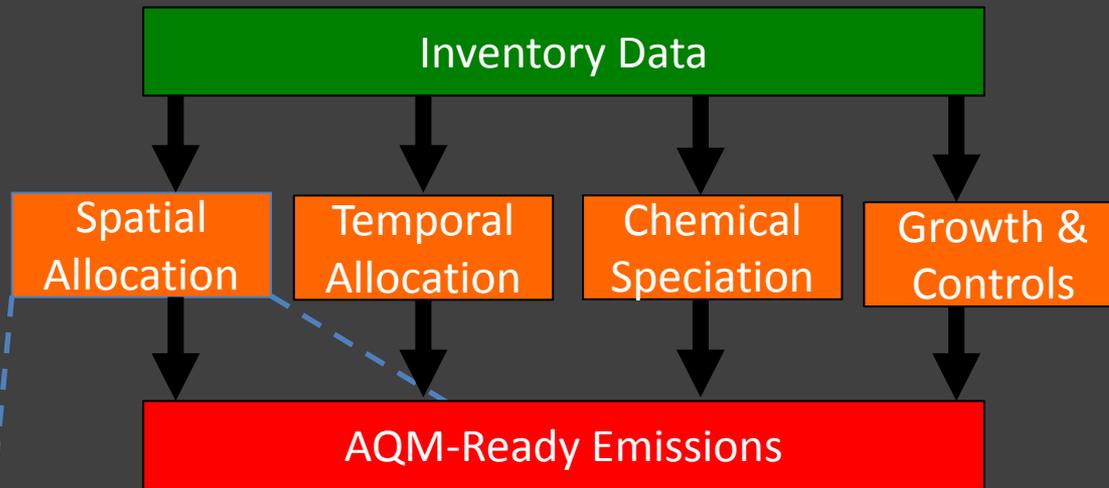A. Bar-Ilan, T. Shah

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What is a Spatial Surrogate?

Inventory Data

- Spatial Allocation
- Temporal Allocation
- Chemical Speciation
- Growth & Controls

AQM-Ready Emissions

County Total Emissions → `Gridded Emissions
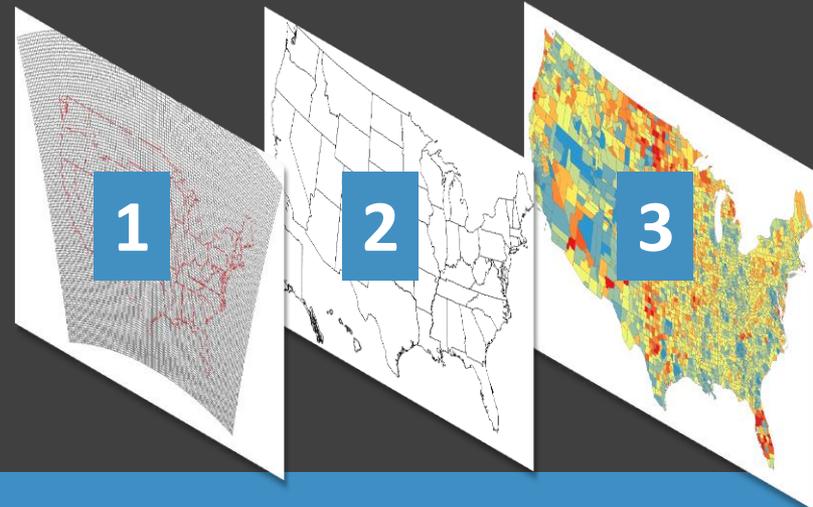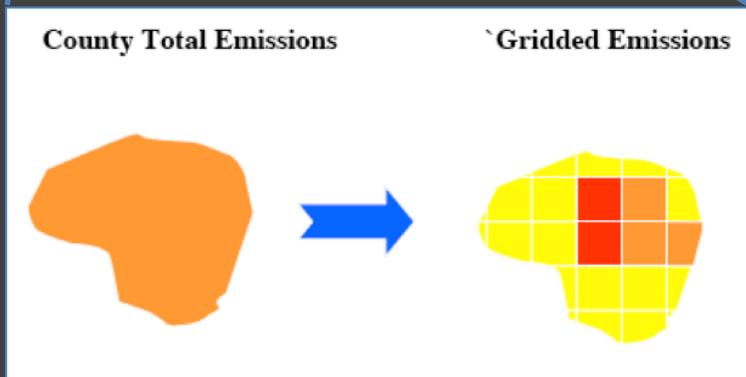
Spatial surrogates define the mapping between inventory spatial units (e.g. counties) and air quality model grids
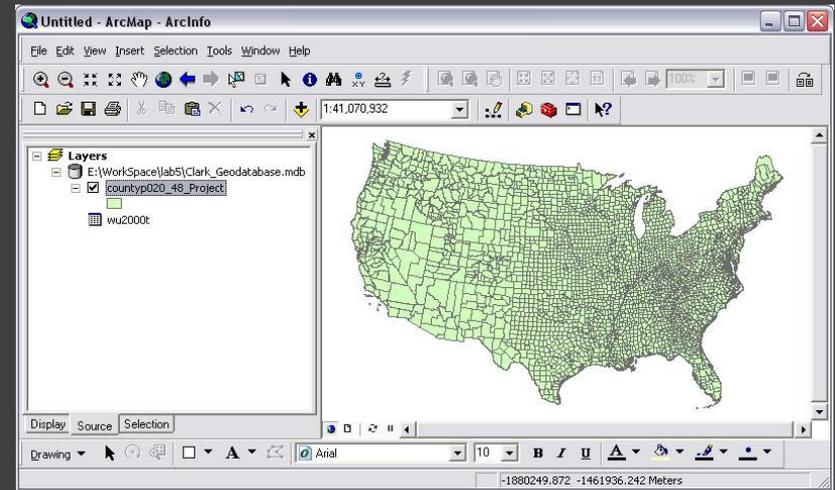
Surrogate Components:
1. Model grid definition
2. Data GIS Shapefile
3. Weight GIS Shapefile

1   2   3

GIS Shapefiles

- Common format (Esri) of geospatial vector data
- Data collected primarily from U.S. government agencies
  - U.S. Census Bureau, USGS, DOT, FEMA
  - Avoid or masked proprietary data to support public access
- A few shapefiles generated in-house
  - Upstream oil and gas, extended idle locations, commercial shipping lanes, rail yards
- All shapefiles transformed to Lambert Conformal Conic projection and a normal (WRF) sphere to match regional CONUS modeling domains

U.S. Spatial Surrogate Database

- 43 Shapefiles for U.S. emission source-related features
- 116 surrogates
- 36/12/4-km resolution surrogates for a unified CONUS modeling grid
- All surrogate computations done with open source Spatial Allocator
- All surrogates gap-filled and normalized

- Surrogate Classes
  - Population/Housing
  - Home heating
  - Transportation
  - Shipping and Ports
  - Building Square Footage
  - Land cover/Land use
  - Energy production
  - Industrial/Commercial

Motivation for Updates

- New Shapefile data after 2010
  - 2010 U.S. Census (Fall 2011)
  - Annual releases of TIGER roadway and rail data
  - Annual releases of National Transportation Atlas Database
  - FEMA HAZUS-MH v2.0 (Fall 2011)
  - 2006 NLCD
  - Gas station locations
- New focus on different sectors
  - Oil and gas production data for 2008 and 2011
  - Agricultural ammonia sources
  - Residential wood combustion
- New emissions models and modeling studies
  - MOVES for on-road mobile sources
  - National-Scale Air Toxics Assessments (NATA)

Census-based Surrogates

- Decadal 2010 U.S. Census presented many new geospatial features for surrogates
  - Population – Census block group population densities used to classify as urban (>= 1000 ppl/sq. mi) or rural (<1000 ppl/sq. mi)
  - Housing – Census block group housing unit densities used to classify housing units as urban (>1000), suburban (>=125 and <1000), exurban (>=6 and < 125), or rural (<6)
  - Housing unit change – 2000 → 2010
  - Home heating fuels – utility gas, wood, fuel oil, coal, LP gas

Census-based Surrogates: Home Heating Fuels

Home Heating Fuel Surrogate Plots

- Surrogates derived from 5-year American Community Survey
- Based on random surveys of heating fuel used for on-site boilers/stoves
- No gapfilling in these plots
- 4-km surrogate plots
- Actual surrogates gapfilled with housing and population.
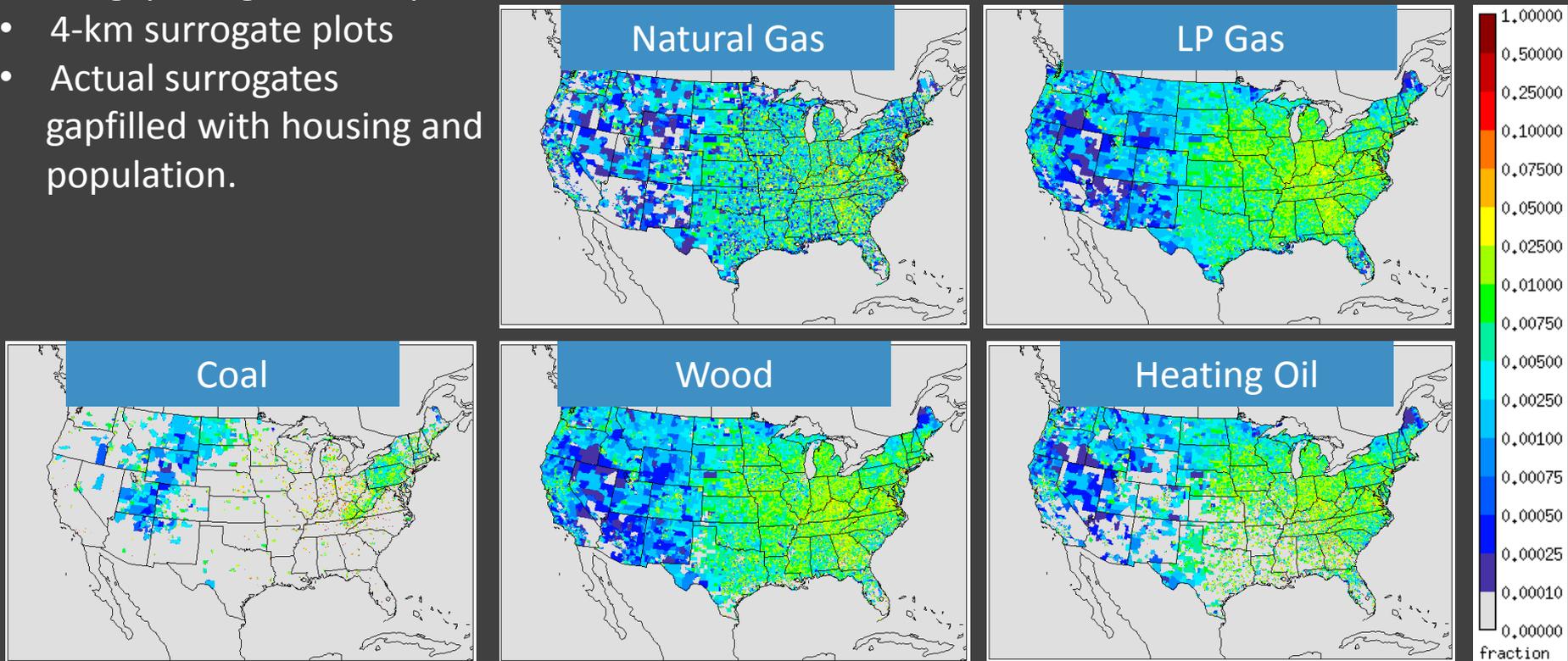
Landcover/Landuse Surrogates

- National Land Cover Database
  - 2006 release
  - 30-m resolution rasters dissolved to 250-m resolution vectors
  - Dominant NLCD LULC class

Surrogate	Surrogate ID	NLCD Class	Description
Low/Med/Hi Intensity Development	300/301/302	22/23/24	Land area with 20-100% impervious surface
Open space	303	21	Land area with <20% impervious surface
Total agriculture	310	81+82	Pasture/Hay + Crops
Pasture land	318	81	Pasture/Hay > 20% of vegetation cover
Crop land	319	82	Crops > 20% of vegetation cover
Total forest land	320	40	Tree canopy 25-100% of vegetation cover
Total land area	340	10	
Total county area	346	10+11	Land + water area in a county
Total water area	350	11	

Surrogates for MOVES2014

- Design surrogates around MOVES2014 emissions processes

MOVES2014 mode	Emissions Process	Spatial Surrogates
Rate-per-distance (RPD)	On-network sources	Roadways
Rate-per-profile (RPP)	Off-network vapor venting	Gas stations, locations of parked vehicles
Rate-per-vehicle (RPV)	Off-network starts, stops, and evaporative	Locations of parked vehicles
Rate-per-hour (RPH)	Off-network HDD extended idle/hoteling	HDD truck parking spaces

Surrogates for MOVES2014

Mode	Surrogate	ID
RPD	Urban Primary Roads	200
	Rural Primary Roads	210
	Urban Secondary Roads	220
	Urban Unrestricted Roads	221
	Rural Secondary Roads	230
	Rural Unrestricted Roads	231

Mode	Surrogate	ID
RPH	Extended Idle Locations	205

Mode	Surrogate	ID
RPV + RPP	Off-Network Short-Haul Trucks	256
	Off-Network Long Haul Trucks	257
	Transit Bus Terminals	259
	Education Buildings	506
	Heavy Light Construction + Industrial Buildings	507
	Commercial + Industrial Buildings	510
	Residential Non-Institutional Buildings	526
	Residential+Commercial+Industrial+Institutional+Government Buildings	535
	Gas Stations	600

MOVES2014 On-network Surrogates

- **RPD:** TIGER 2010 roadways merged with 2010 population
  - Urban primary, rural primary, urban secondary, rural secondary
- **RPD:** Urban and rural unrestricted roads
  - Unrestricted roads don't have ramps
  - Surrogate for MOVES local and secondary road SCCs
  - NEI 2011v1 VMT used to derive splits between secondary and local roads
  - Merge population (proxy for local roads) and secondary roads

NEI 2011v1 Annual State Total Secondary and Local road VMT

Chart annotations: $y = 0.0002x + 0.7829$ (Secondary), $y = -0.0002x + 0.2171$ (Local)

Legend: Local, Secondary, Linear (Local), Linear (Secondary)
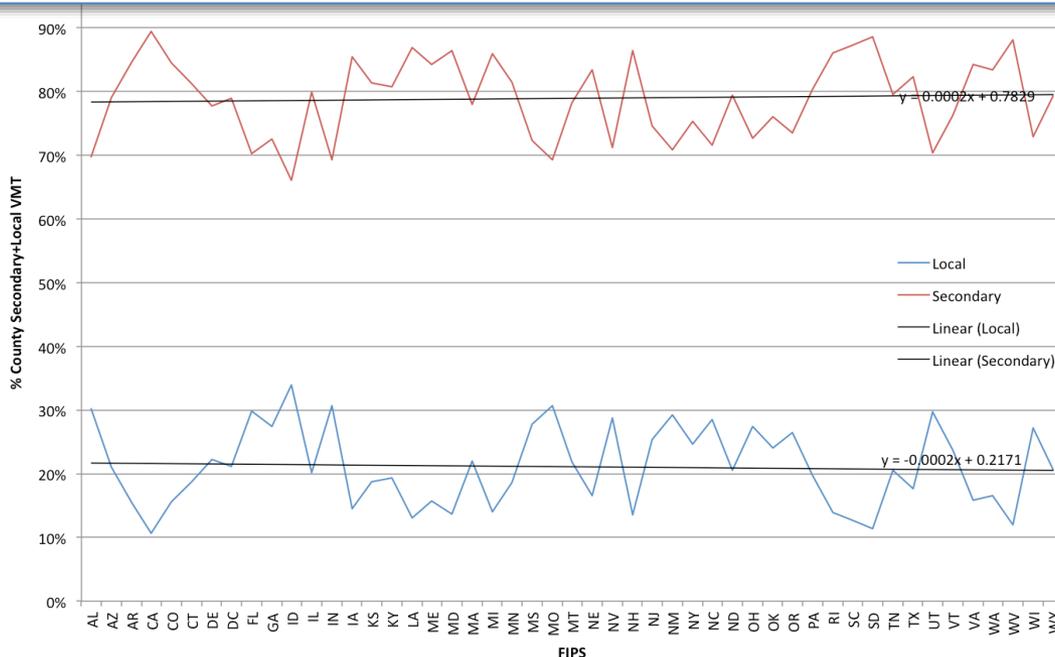
National Average VMT Splits

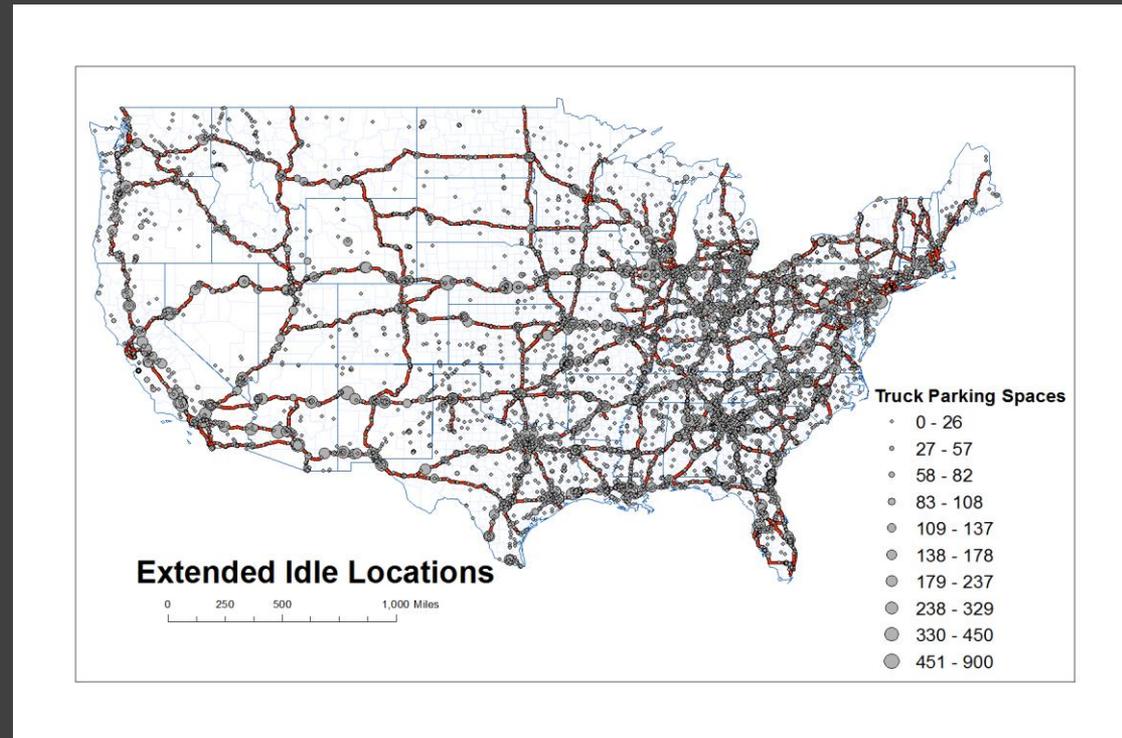|	Local	Secondary
National	21%	79%
Urban	23%	77%
Rural	19%	81%

MOVES2014 Off-network Surrogates

- RPV/RPP: Off-network locations of parked vehicles
  - Evaporative emissions, start/idle exhaust, refueling
  - Surrogates used FEMA building square footages to relate vehicle classes to building categories (i.e. school buses allocated to educational facilities)
- RPP: Off-network evaporative fuel vapor venting
  - Gas stations

MOVES2014 Off-network Surrogates

- **RPH:** Extended Idle Locations for MOVES hoteling mode
  - Collected data on different truck parking areas (e.g. private truck stops, state DOT facilities, retail parking lots)
  - National file with review and gapfilling from EPA, several states and RPOs (WV, IN, MO, WI, NC, CT, ME, UT, VA, GA, FL)
  - Developed a point shapefile of extended idle locations
  - Surrogate weighted by number of parking spots

Extended Idle Locations

0   250   500   1,000 Miles

Truck Parking Spaces
- 0 - 26
- 27 - 57
- 58 - 82
- 83 - 108
- 109 - 137
- 138 - 178
- 179 - 237
- 238 - 329
- 330 - 450
- 451 - 900

Oil and Gas Surrogates

- Surrogates for upstream sources
  - Oil production
  - Gas production
  - Number of wells
  - Number of spuds

IHS Well & Production Data
Regional Data Delivery Subscription Areas

- **Rocky Mountain Region** (2008 production levels)
  - Aggregated to 2-km grid cells with ≥ 3 wells per cell
- **Northeastern Region** (2011 production levels)
  - Aggregated to 4-km grid cells with ≥ 3 wells per cell
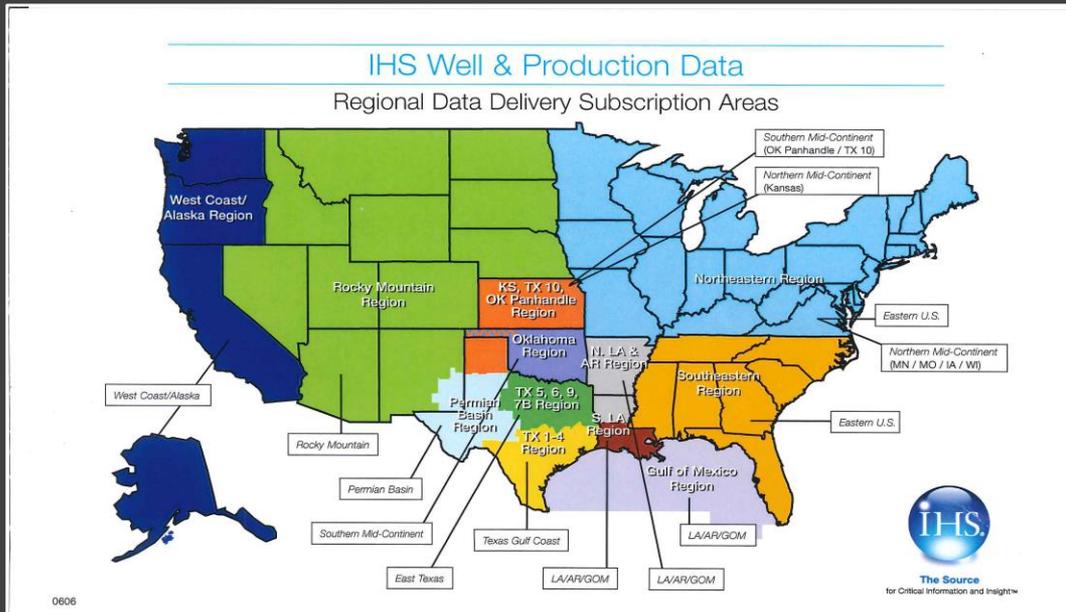
Offroad Mobile Surrogates: Rail

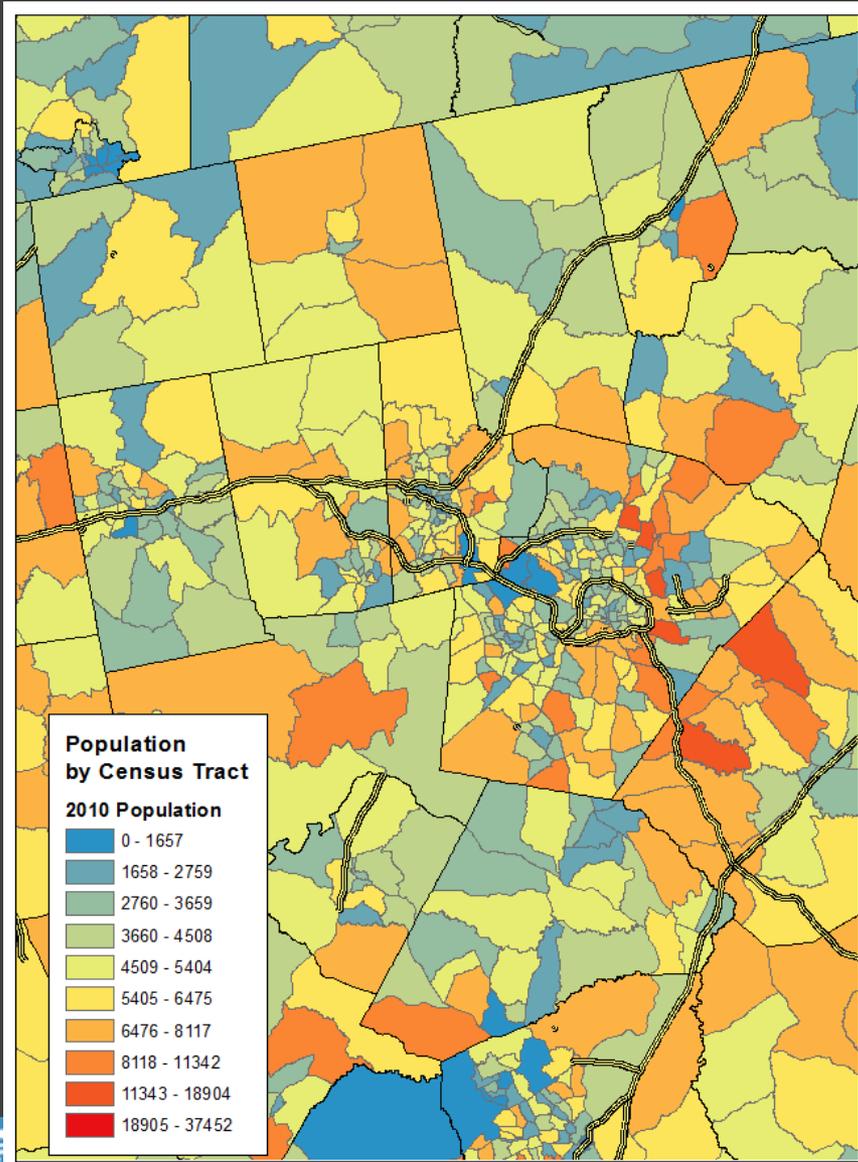| Surrogate	ID	Year	Source	Notes
Total rail miles	260	2010	U.S. Census/TIGER	Line
Total rail density	261	2012	NTAD	Line density = Mtons/mile
C1 rail miles	270	2010	U.S. Census/TIGER	Line
C1/C2/C3 rail density	271	2012	NTAD	Line density = Mtons/mile
Amtrack rail density	272	2012	NTAD	Line density = Mtons/mile
Commuter rail density	273	2012	NTAD	Line density = Mtons/mile
Rail yards	275	2012	ERTAC	Points weighted by PM2.5+NOx emissions
C2/C3 rail miles	280	2010	U.S. Censu/TIGER	Line

Offroad Mobile Surrogates: Marine

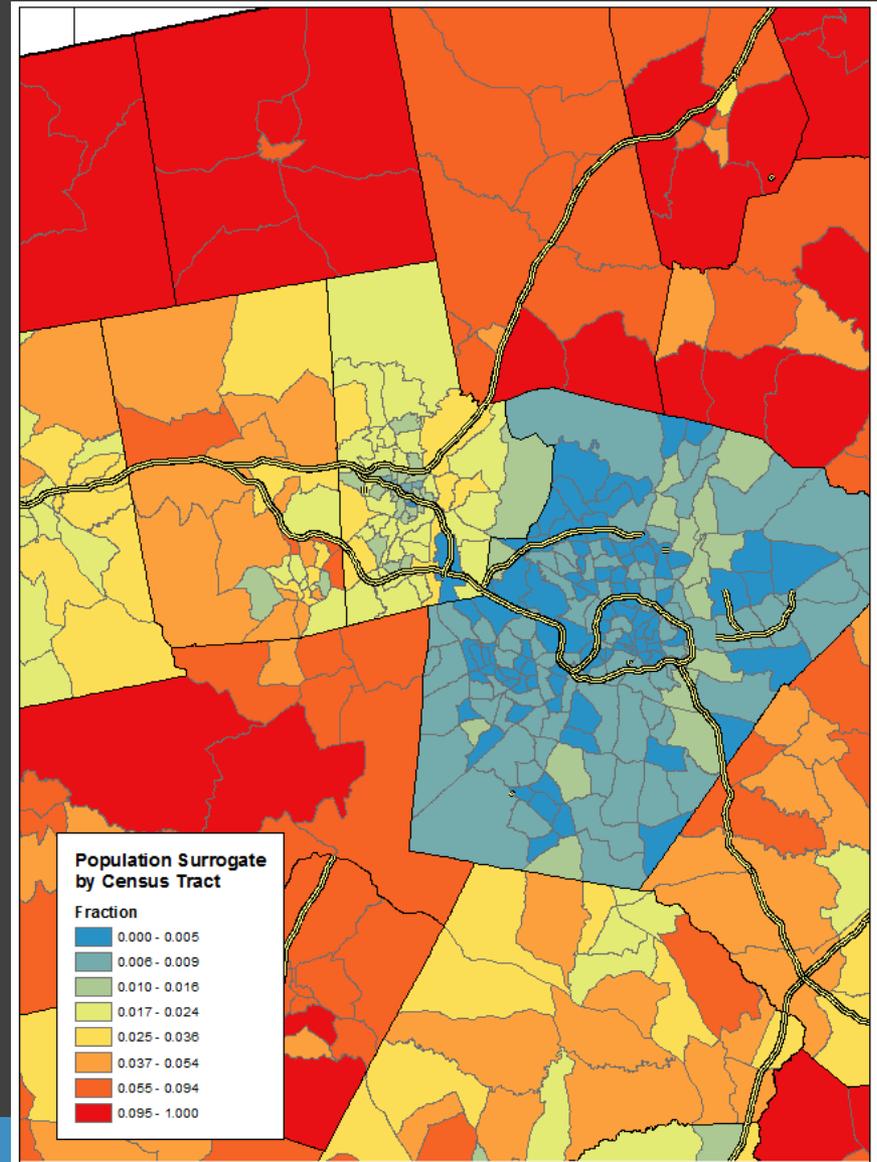| Surrogate	ID	Year	Source	Notes
Marine ports	800	2010	NTAD	Points
Port areas	801	2010	NTAD	Polygon
Shipping lanes	802	2010	UNC	Great Lakes, Gulf of Mexico, and Atlantic/Pacific shipping locations
Gulf of Mexico shipping lanes	803	2010	ERG, Inc.	Density of oil and gas platform support vessels
Offshore shipping 2011 NEIv1 NOx	806	2011	NTAD	Pacific, Atlantic, Gulf shipping areas weighted by NEI2011v1 NOx emissions
Navigable waterway miles	807	2011	NTAD	Line
Great Lakes tug zones	808	2012	U.S. EPA	Polygons 0.5-2.0 offshore
Midwest shipping lanes	812	2013	LADCO	Great Lakes shipping lanes and inland waterways
Ports NEI2011 NOx	820	2011	U.S. EPA	Port areas weighted by NEI2011v1 NOx emissions

NATA Surrogates

- Polygon surrogates for U.S. census tracts
  - Include HI, AK, PR, and USVI

- Map county NEI inventory to 2010 census tract boundaries for high spatial resolution population exposure studies

- Some new weight and boundary data needed for PR and USVI

2010 Population

Population Surrogate by Census Tract

Population by Census Tract

2010 Population

- 0 - 1657
- 1658 - 2759
- 2760 - 3659
- 3660 - 4508
- 4509 - 5404
- 5405 - 6475
- 6476 - 8117
- 8118 - 11342
- 11343 - 18904
- 18905 - 37452

Population Surrogate by Census Tract

Fraction

- 0.000 - 0.005
- 0.006 - 0.009
- 0.010 - 0.016
- 0.017 - 0.024
- 0.025 - 0.036
- 0.037 - 0.054
- 0.055 - 0.094
- 0.095 - 1.000

of NORTH CAROLINA
at CHAPEL HILL

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Conclusions and Future Work

- Public distribution via U.S. EPA CHIEF and CMAS
  - All Spatial Allocator scripts and input data
  - 36/12/4-km gridded surrogates
  - All shapefile data except gas station locations
  - NATA surrogates could be available if needed
- Maintenance
  - Update as new data become available (2011 NLCD, 2015 TIGER)
- Spatial Allocator 64-bit update