Mapping the spatial distribution of methane in Houston, Texas

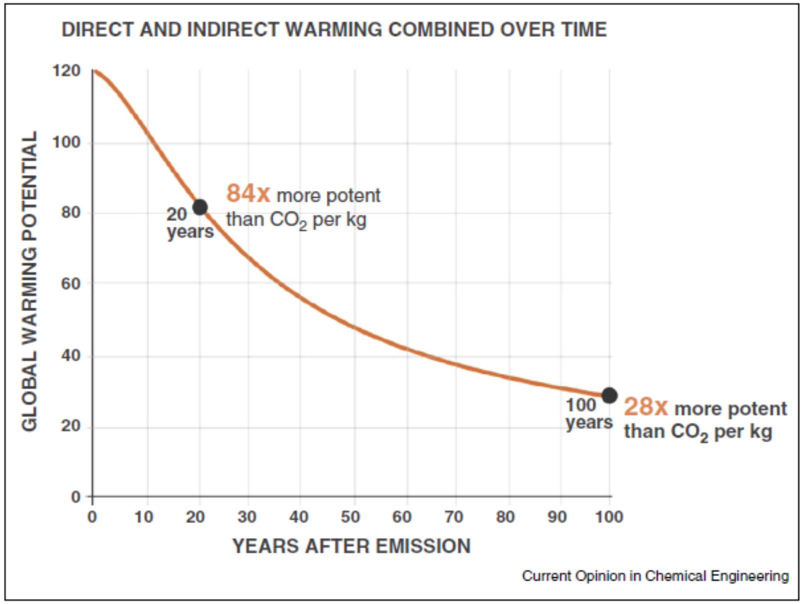
Beata Czader, Daniel Cohan, Nancy Sanchez,
Frank Tittel, and Robert Griffin

Rice University
Department of Civil and Environmental Engineering

RICE

Motivation

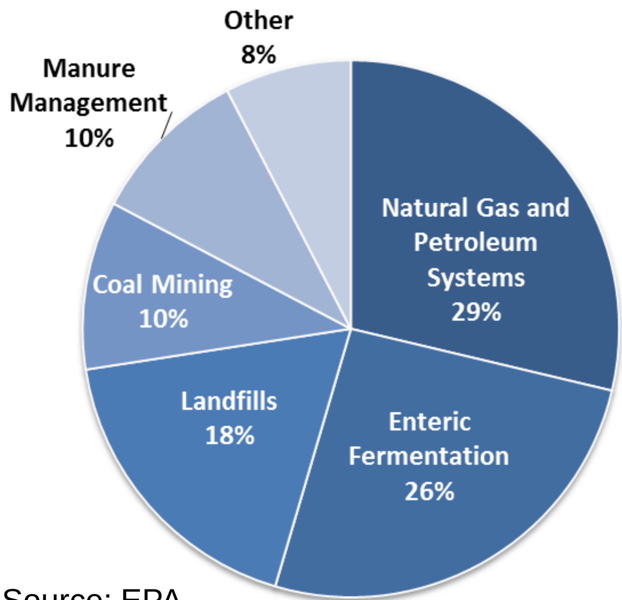
- Technologies such as hydraulic fracturing and horizontal drilling have greatly increased the production and accessible reserves of natural gas in the United States.
- Switching from coal and oil to natural gas has the potential to reduce CO_2 emissions
- Potential reductions could be offset by leaks of **methane**, which is the primary constituent of natural gas
- **Methane** contributes to background levels of ozone pollution
- **Methane** is a greenhouse gas that traps heat in the atmosphere and affects our climate



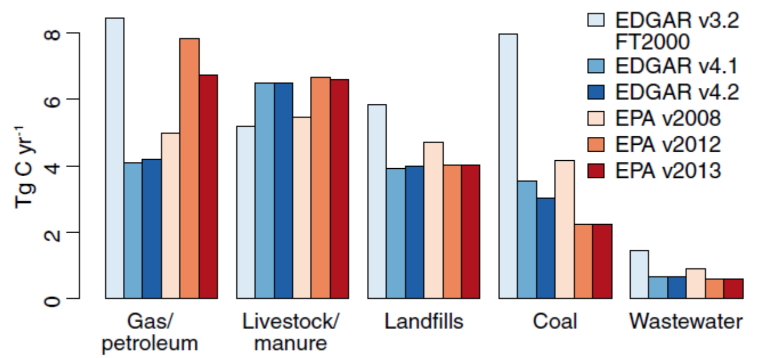
Source: Alvarez et al. 2012

Methane emissions

Anthropogenic ~60%



Source: EPA
http://www.epa.gov/climatechange/ghgemissions/gases/ch4.html



Source: Miller et al. 2013

NG loss from production:

~6-12% in oil and gas fields in Colorado (top-down estimates) from NG production (Karion et. Al. 2012)

~17% leaks from local NG production in LA (Peischl et al. 2013)

NG loss from dlistribution system:

~1.6% in Washington D.C. (Jackson et al. 2014) → **Leak rates (Washington D.C.):**

~ 3% in Boston (McKain et al. 2014)

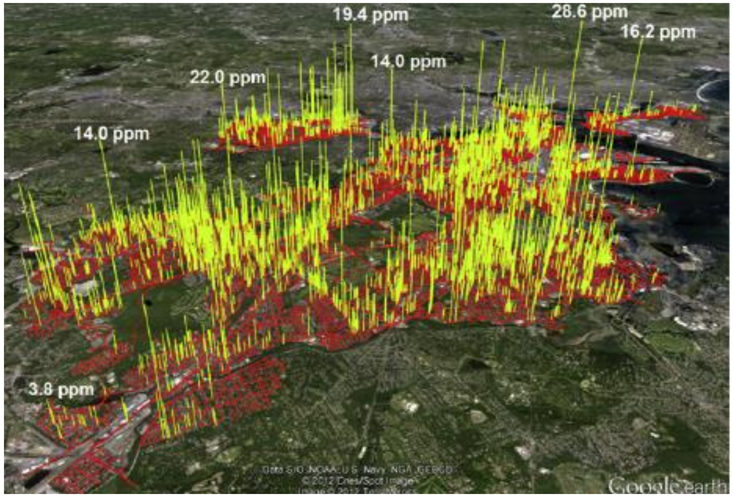
~2.5-6% in LA (Wennberg et al. 2012)

9200 – 38 800 L/day per leak

NG usage of 2 – 7 homes

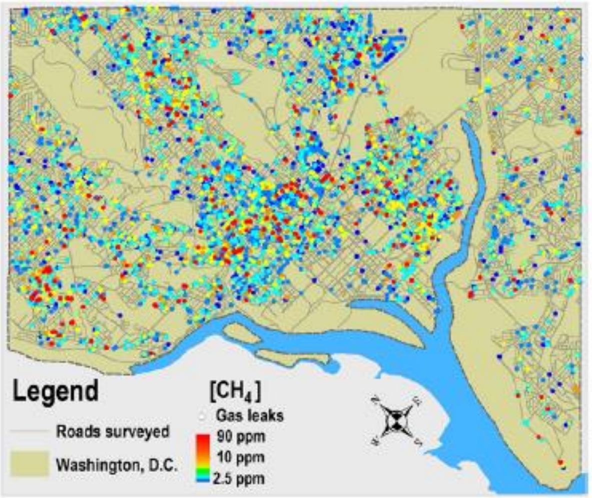
Methane loss from NG distribution system

Boston



~ 3400 leaks across 785 road miles (Phillips et al. 2013)

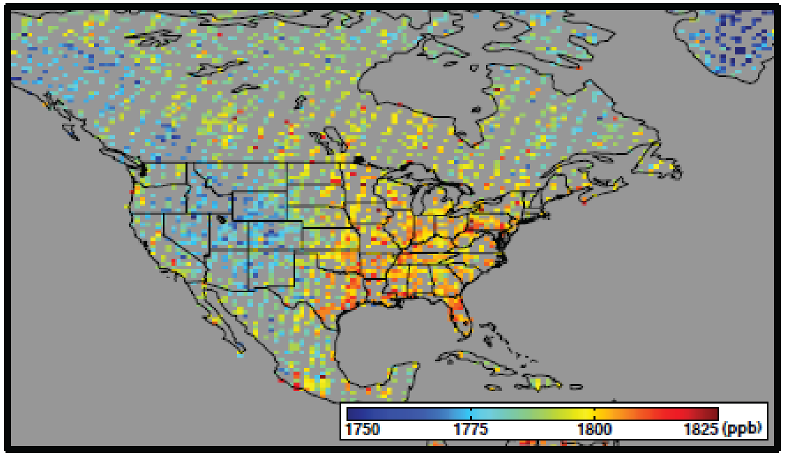
Washington D.C.



~ 5893 leaks across 1500 road miles (Jackson et al. 2014)

~4 leaks/road mile

GOSAT satellite column averaged methane



Leak concentration (Washington D.C.):

Mean = 4.6 ppm CH_4 →2.5 higher than background concentrations

Median = 3.1 ppm CH_4

Max = 88.6 ppm CH_4

Source: Turner et al. 2015

Low leaks from NG distribution system

Lamb et al. 2015

Table 1. Comparison of National Methane Emission Factor Estimates from Underground Pipeline Leaks Based on the Current Study and the 1992 EPA/GRI Study

	this study			1992 GRI/EPA		
pipeline material	*n*	emission factor (g/min)	95% UCL (g/min)	*n*	emission factor (g/min)	90% UCL (g/min)
			main pipelines			
cast iron	14	0.90	3.35	21	3.57[a]	5.60[a]
unprotected steel	74	0.77	2.07	20	1.91	3.70
protected steel	31	1.21	4.59	17	0.76	1.40
plastic	23	0.33	0.67	6	1.88	8.20
			services			
unprotected steel	19	0.33	0.93	13	0.74	1.53
protected steel	12	0.13	0.19	24	0.34	0.54
plastic	38	0.13	0.19	4	0.11	0.27

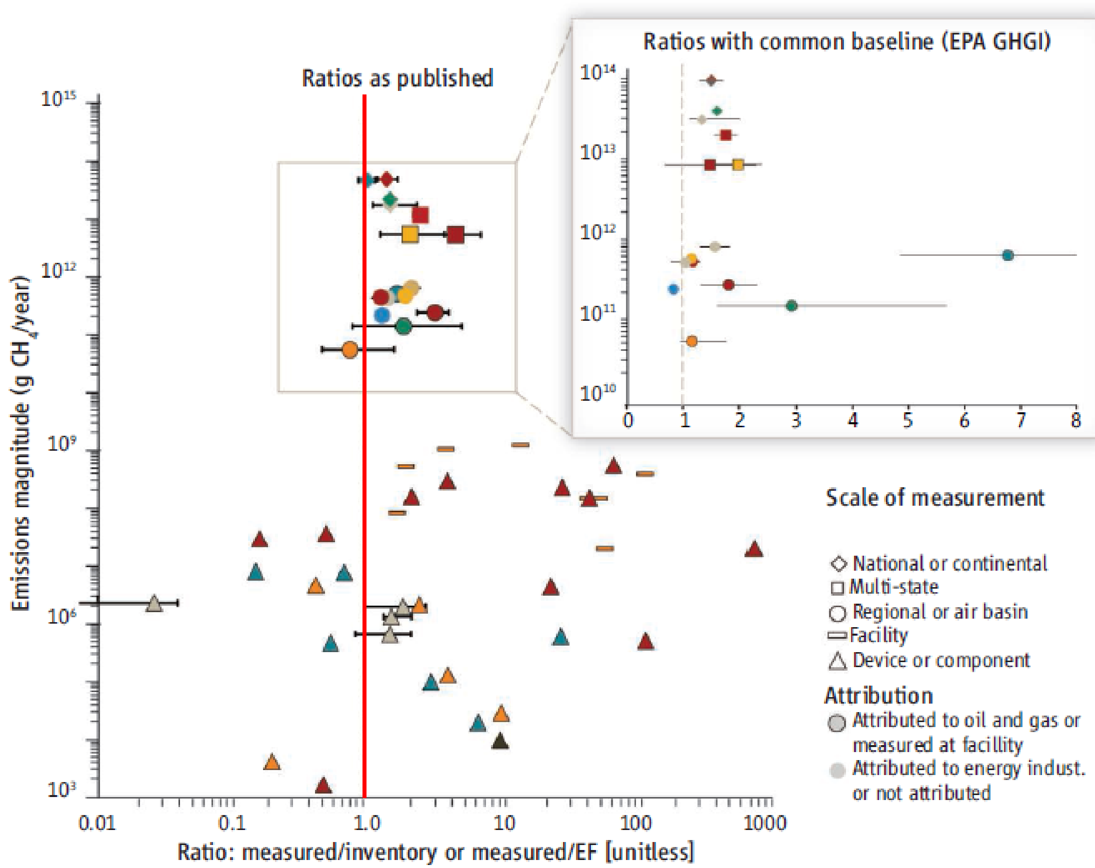
[a]GRI/EPA EF converted from SCF/mile to g/min/leak using cast iron pipeline miles and equivalent leaks from this study.

Emission Factors (EF) in Lamb et al. (2015) are 2 times lower than reported in the 1992 GRI/EPA study

The lowest emission factors are associated with plastic pipelines

Methane emissions & emission factors

Brandt et al. 2014



Typical measured emissions are ~1.5 times those in EI

NG and oil sectors are major contributors

Goal

Quantify methane leaks in the Houston metropolitan area

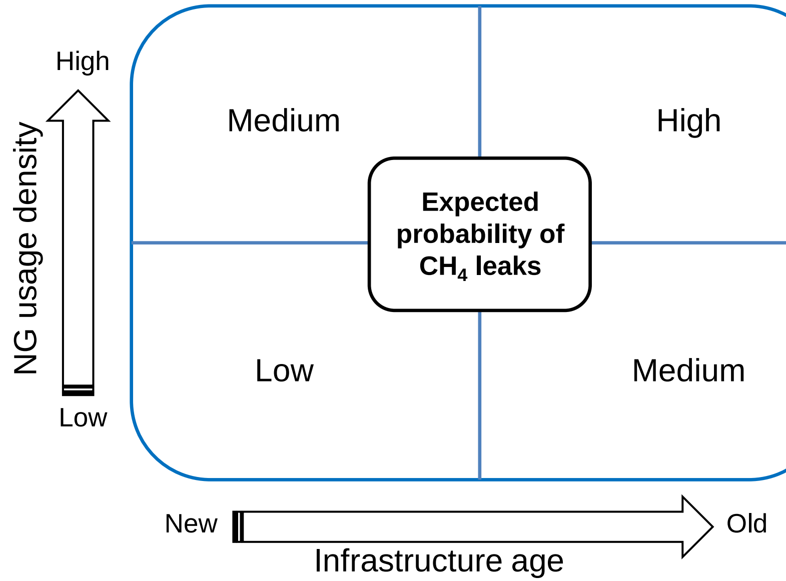
and identify potential discrepancies

between emission inventories and actual emission rates

1. Develop a spatial distribution of expected leaks in Houston
2. Simulate methane mixing ratios
3. Measure methane leaks
4. Identify discrepancies between measured and modeled emission rates

PART 1: Develop a spatial distribution of expected methane leaks

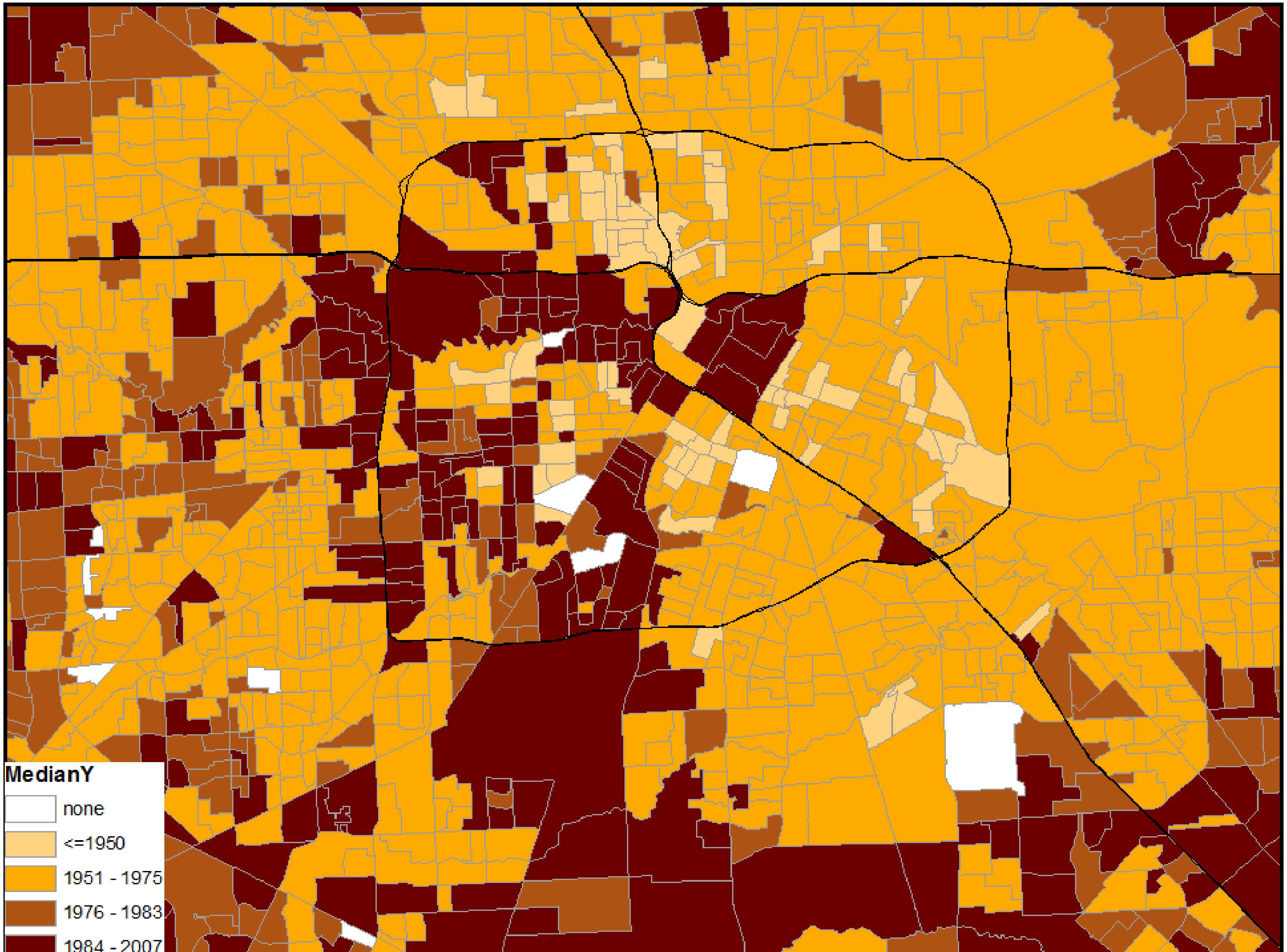
- Older, cast-iron and unprotected steal pipes are associated with higher frequency of leaks
  (Phillips et al. 2013, McKain PNAS 2015, Lamb et al. 2015)



From American Community Survey → **Density of usage:** House heating fuel
Infrastructure age: Year structure build

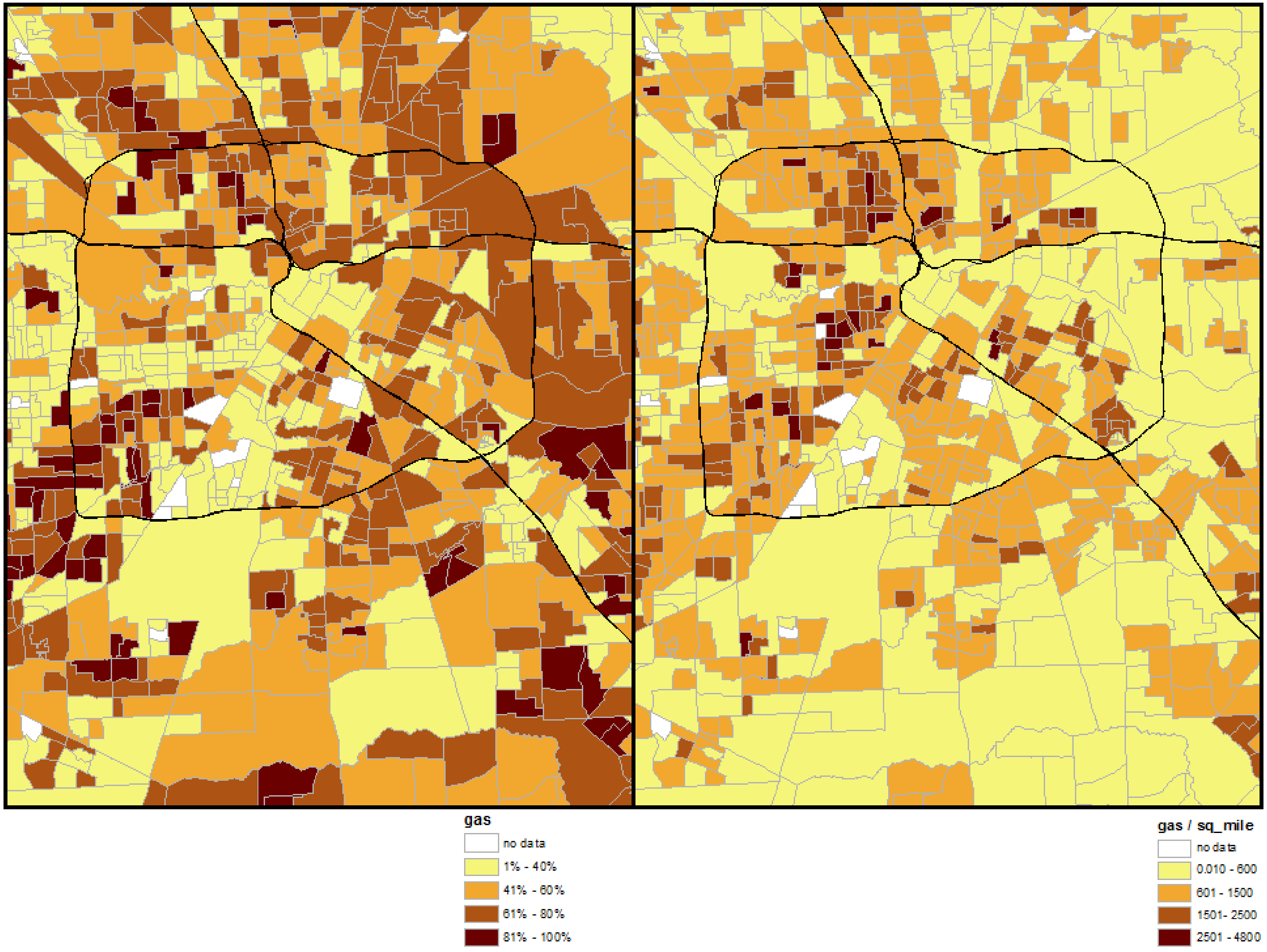
Year of a construction unit

Data on median year structure build (house, condos, apartments) by census block
From American Community Survey, 5-year average



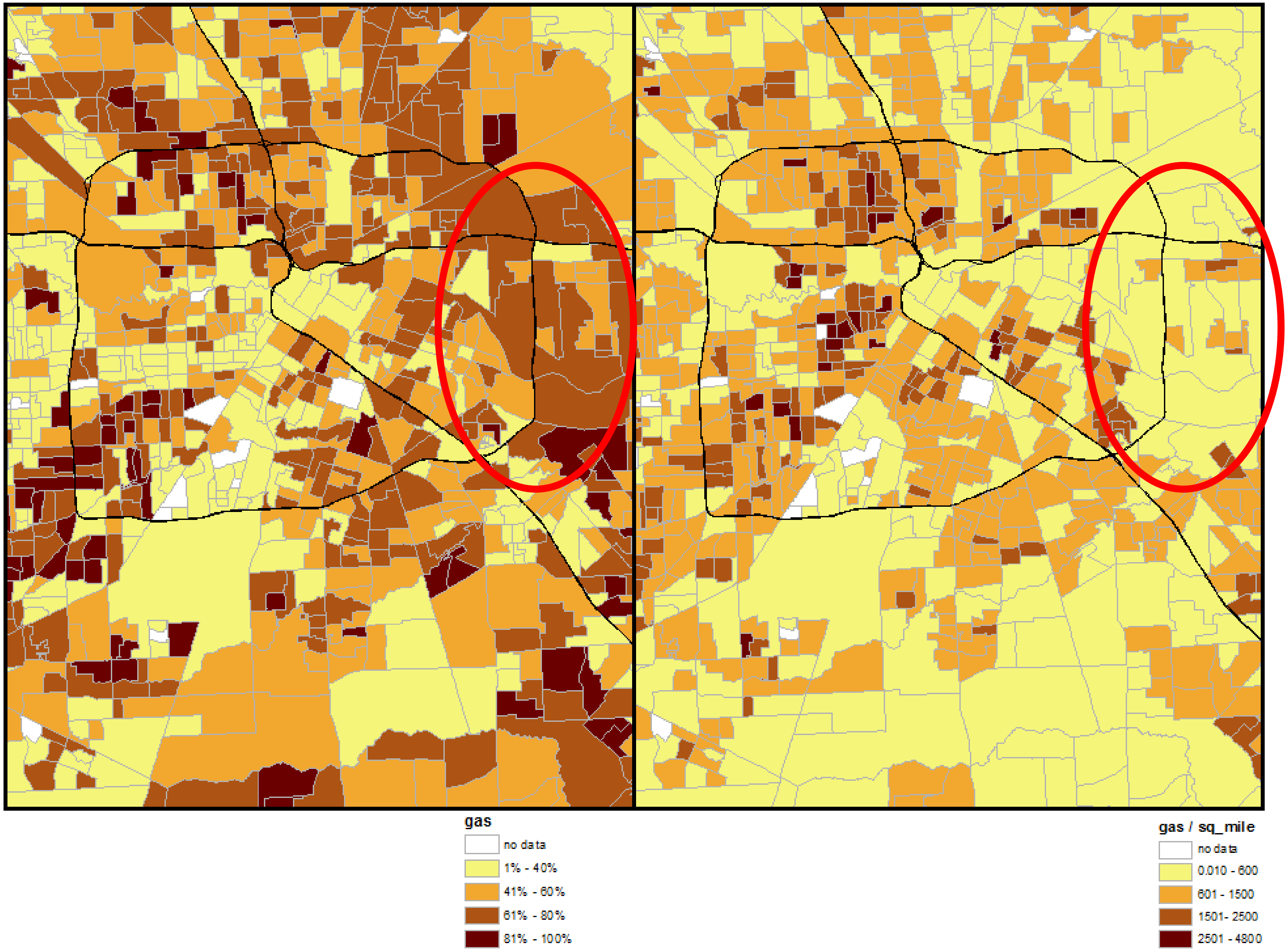
Gas heating housing units

Data on heating fuel by block
From American Community Survey, 10-year time interval



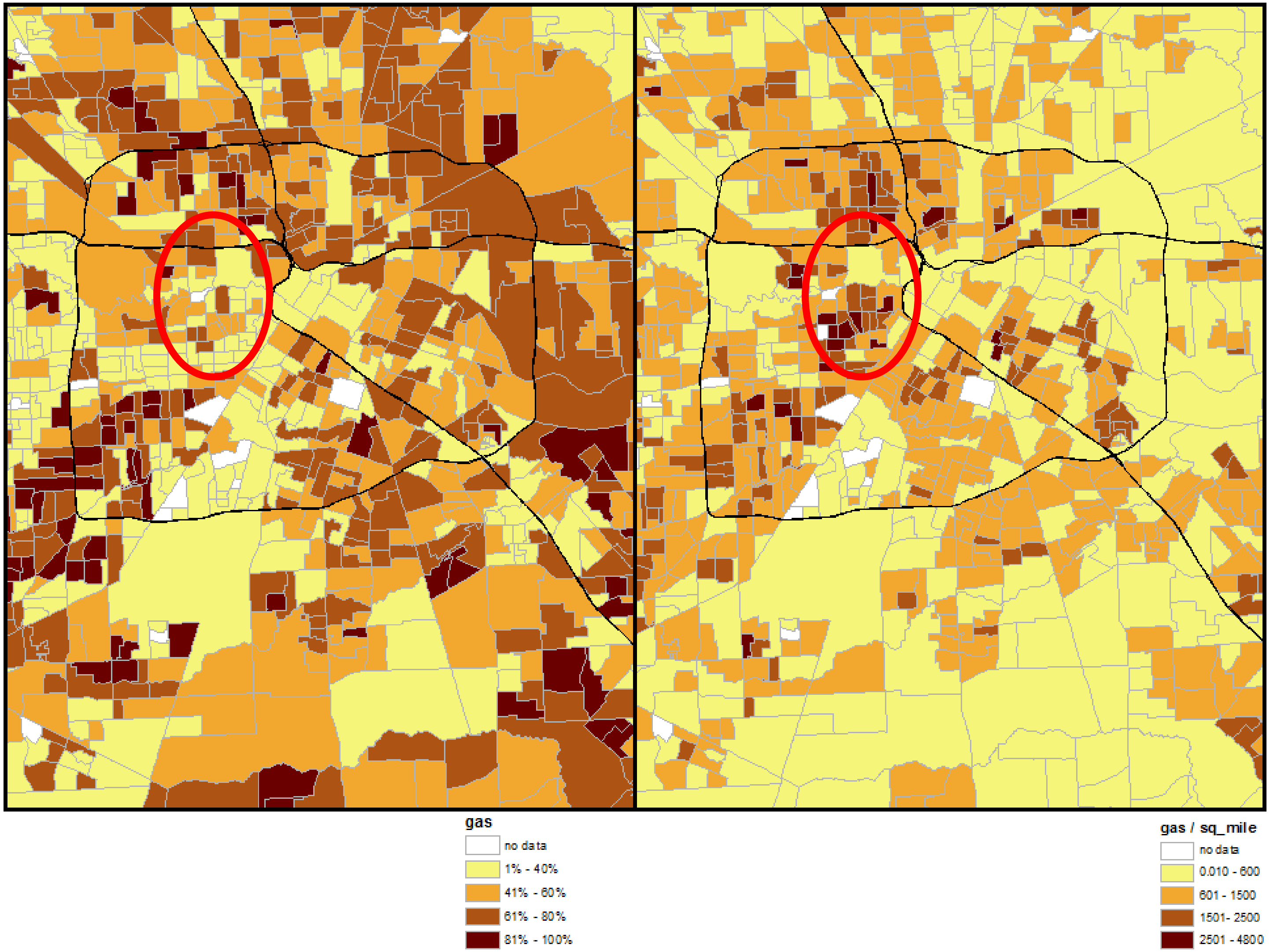
Gas heating housing units

Data on heating fuel by block
From American Community Survey, !0-year time interval



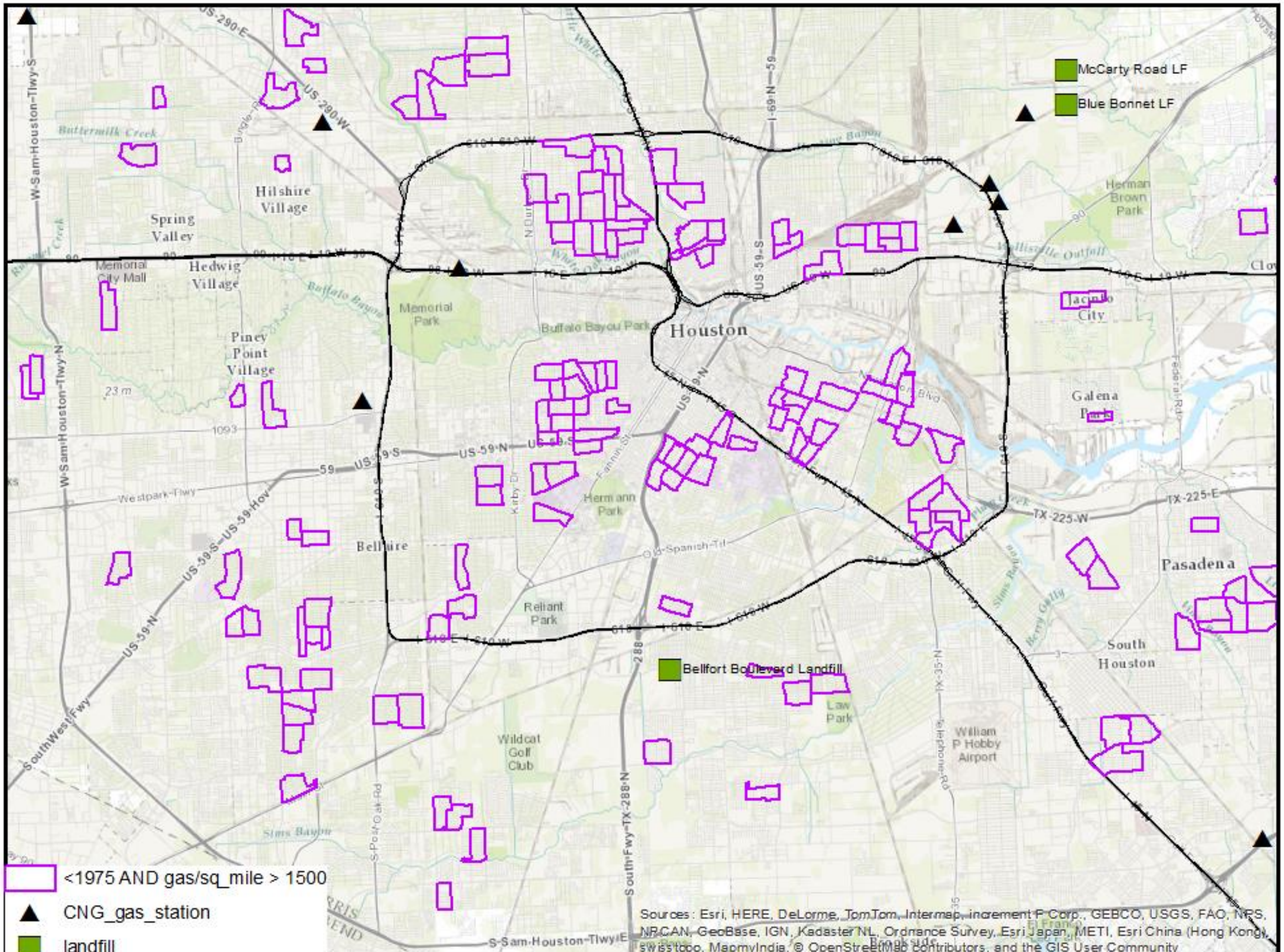
Gas heating housing units

Data on heating fuel by block
From American Community Survey, 5-year average



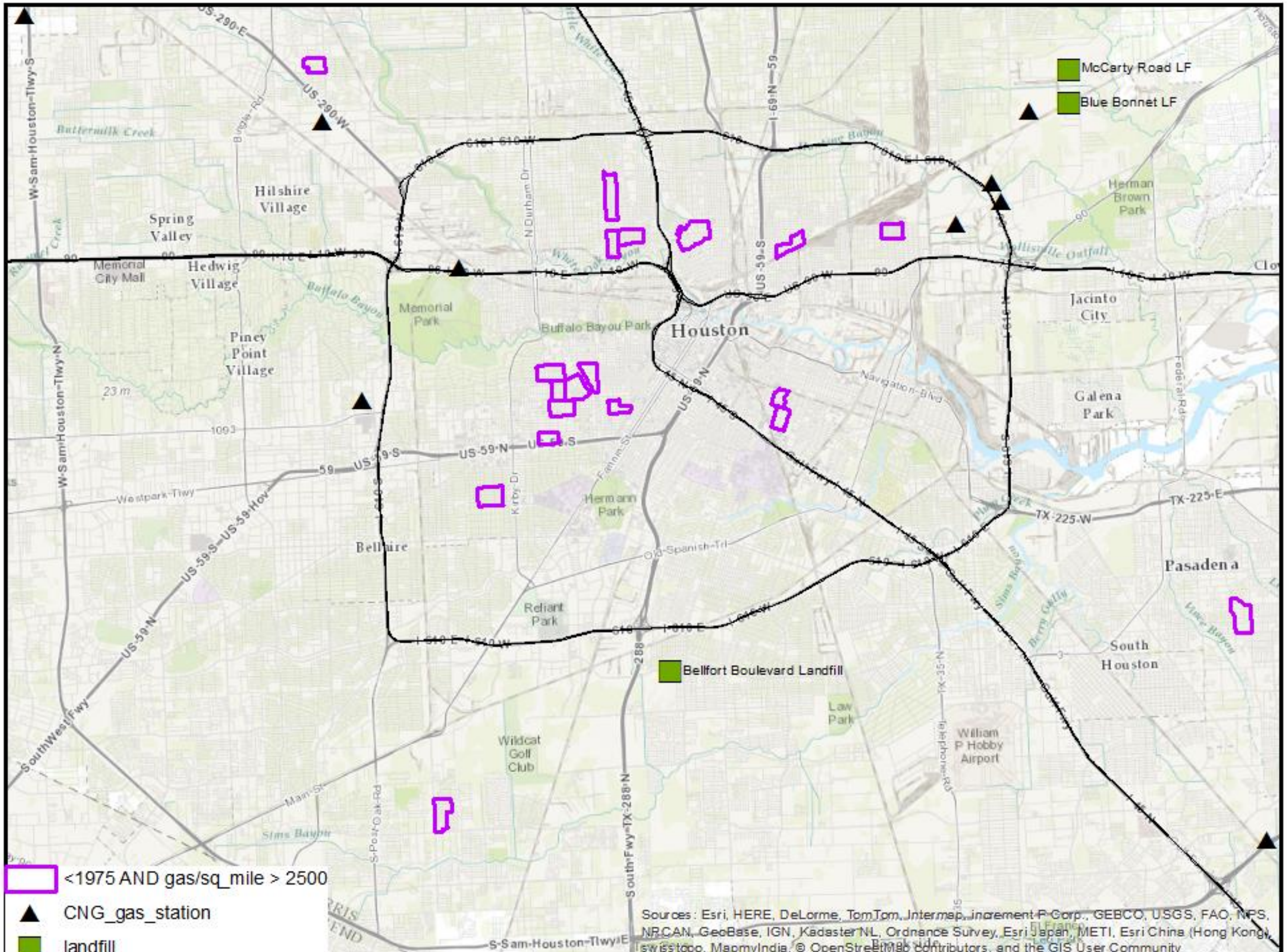
Combined: gas heating & unit age

Housing units older than 1975
Gas heating density > 1500 per mile^2



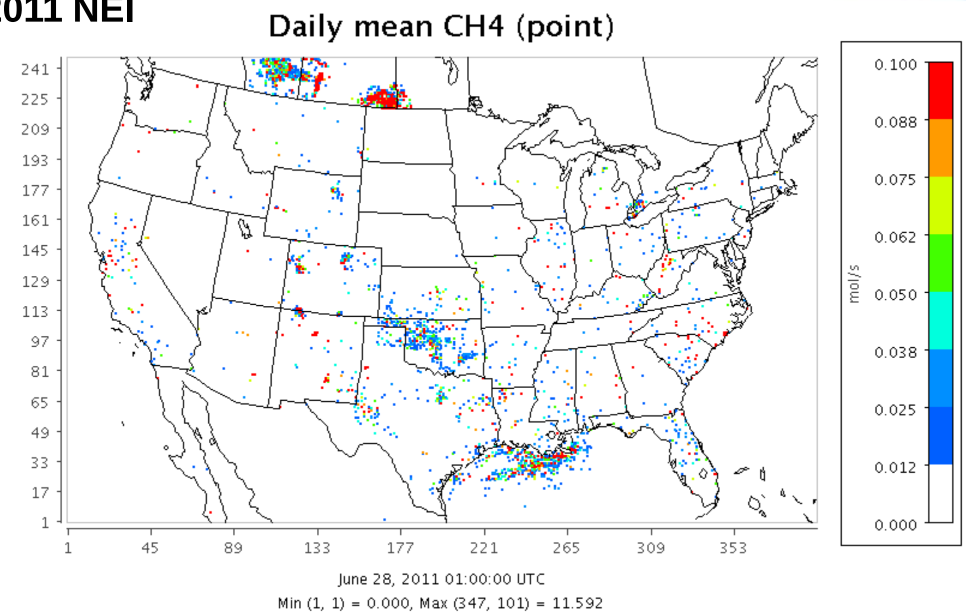
Gas heating (higher density) & unit age

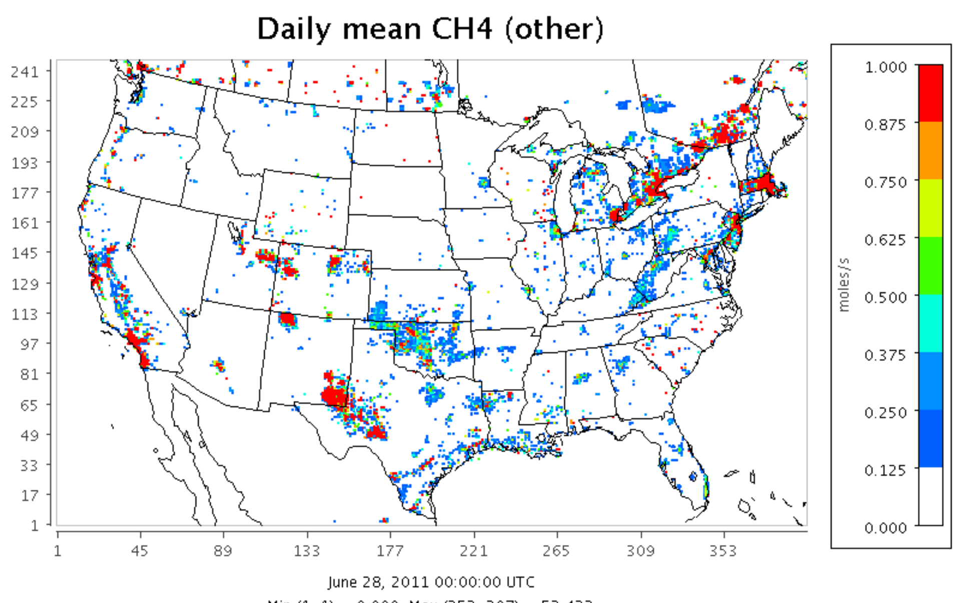
Housing units older than 1975
Gas heating density > 2500 per mile^2



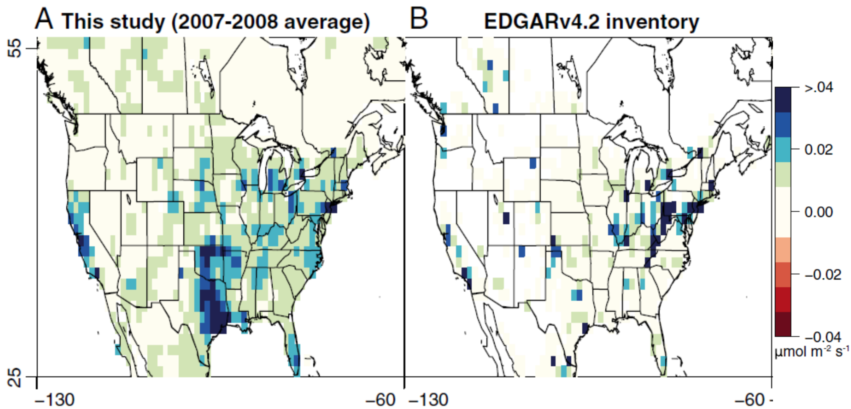
PART 2: Modeling methane

2011 NEI





CH_4 emissions available in 2011NEI



Source: Miller et al. 2013

Methane speciation profiles

2011 NEI includes methane from speciation of VOCs

EPA SPECIATE v4.4 - speciation profiles of air pollution sources

P_NUMBER	METHANE PROFILE NAME	WEIGHT (PERCENT)
0195	Residential Fuel - Natural Gas	100
5651	Landfill Gas - composite of extraction well gas	99.9
8897	Dairies - Cows and Waste	98.9
0202	Solid Waste Landfill Site - Class II	98.7
3002	Landfills	98.6
8974	Oil Field - Tank	98.2
8973	Oil Field - Tank	95.96
8957	Oil Field - Surge Tank	95.9
8950	Natural Gas Transmission	90.8
1070	Alcohols Production - Methanol - Purge Gas Vent	86.7
8986	Oil Field - Tank	86.2
5562	Biomass Burning - Charcoal Making	85.4
1213	Composite of 6 Engines Burning JP-4 Fuel at 100 % Power	83.45
0005	External Combustion Boiler - Coke Oven Gas	82.8
8912	Gasoline Exhaust - E85 gasoline, summer grade, LA92 cycle - hot start and stabilized exhaust	82.6
8954	Oil Field - Well	81.4
0122	Bar Screen Waste Incinerator	80.4
5373	Gasoline Exhaust - E20 gasoline, 20 oC, FTP cycle hot start phase 2	79.6
8951	Natural Gas Extraction Wells	79.55
8915	Gasoline Exhaust - E85 gasoline, winter grade, LA92 cycle - hot start and stabilized exhaust	77.7

Methane emissions from natural sources

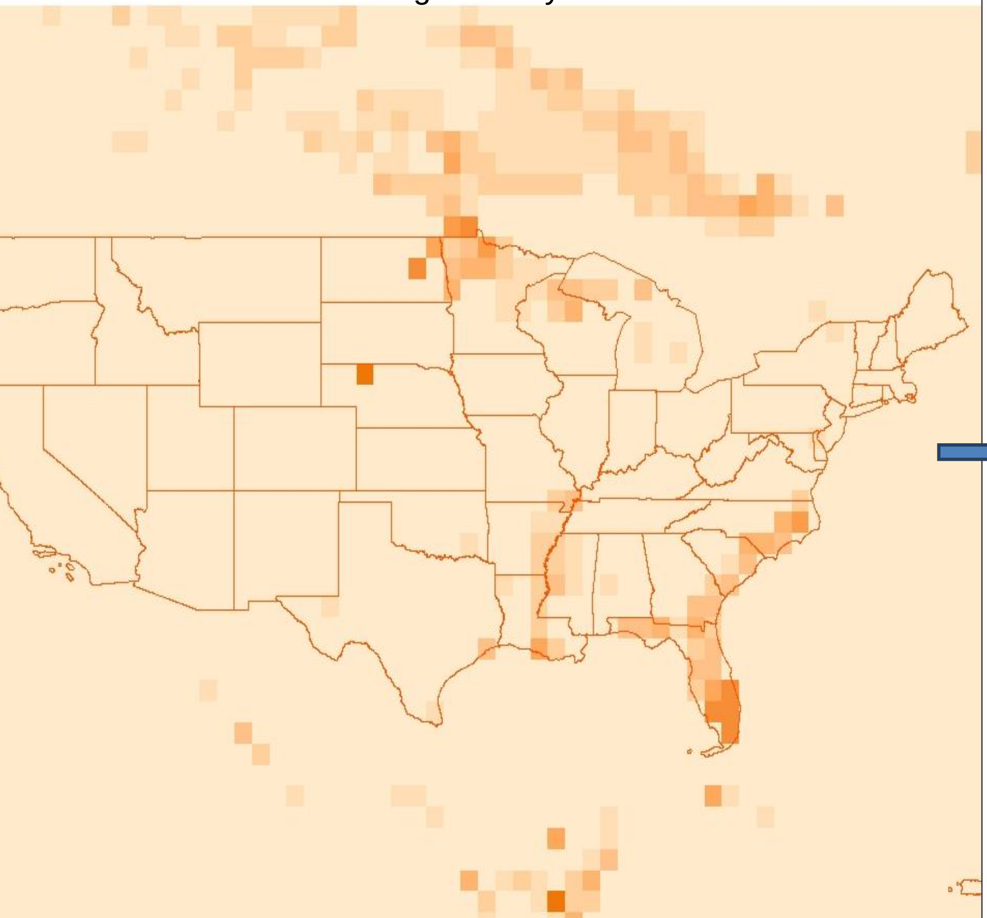
Carbon Tracker – CH_4 (NOAA ESRL)

World gridded fluxes
Monthly or seasonal avg. (up to 2010)
1 deg. grid size
Geographic coordinate system

Data from different sources:

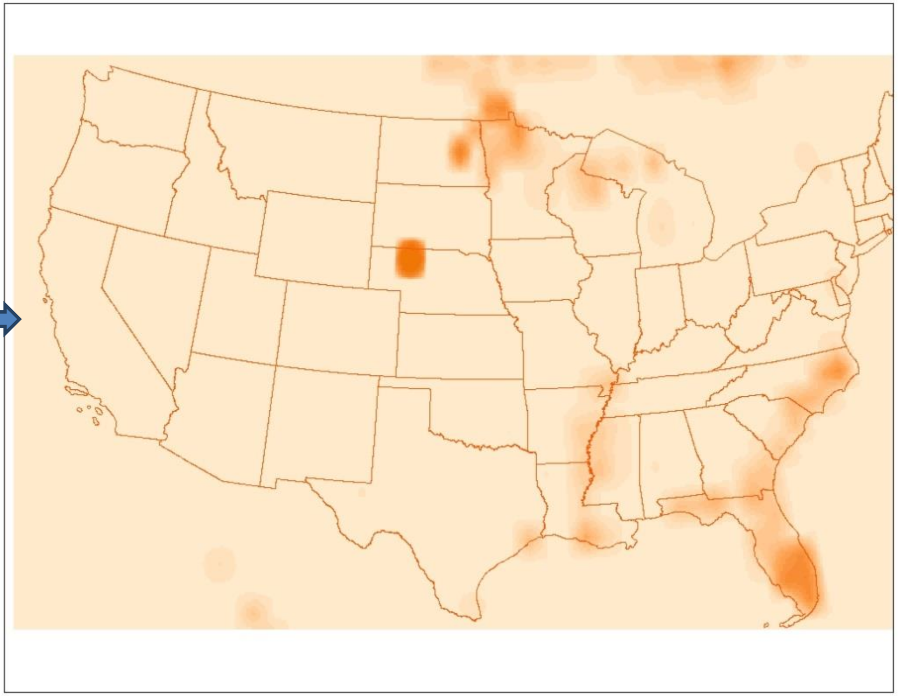
- Natural (wetlands, wild animals) (Bergamaschi et al., 2007)
- Fossil (coal, oil and gas)
- Agricultural and waste
- Biomass burning
- Oceans

Natural flux average for July 2010

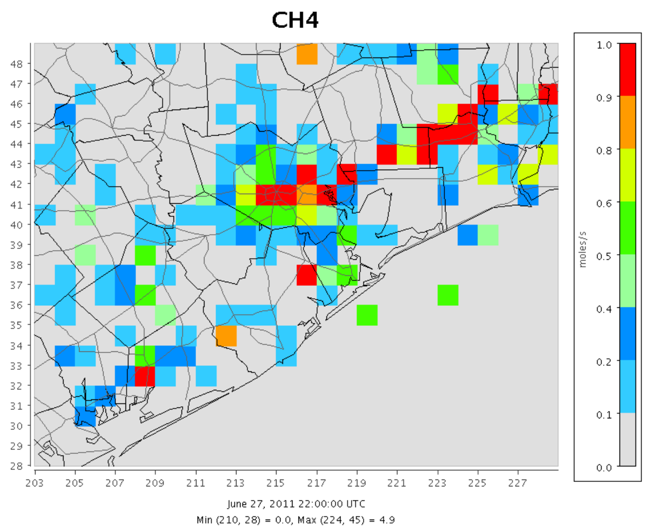


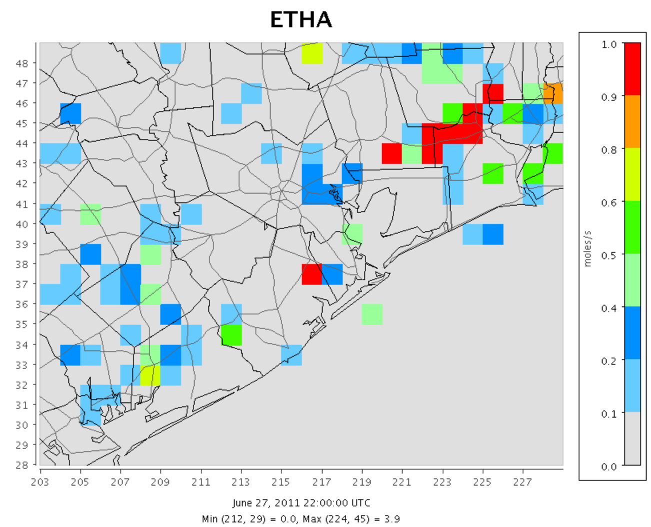
Natural flux – CMAQ modeling domain

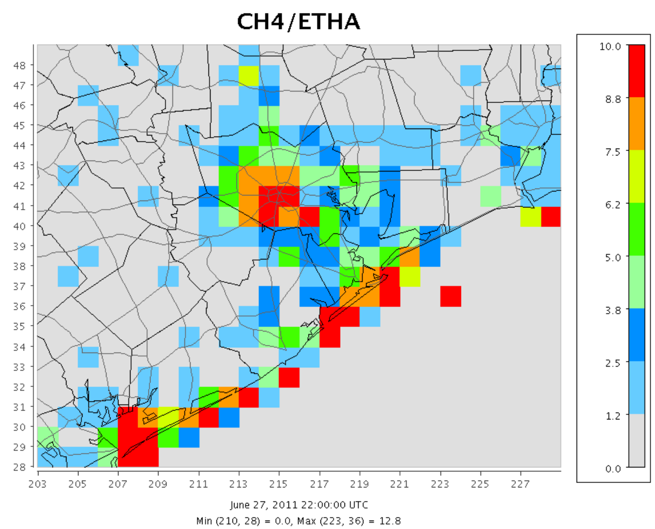
Lambert conformal conic projection
Re-grid to 12 km grid size
Clip to match CONUS modeling domain



Methane and ethane emissions in the Houston area







Methane and ethane have similar fossil fuel sources
Ethane does not have natural source

CH4/ETHA - an indicator of different emission sources

Methane in CMAQ

CMAQ

- Fixed concentration of methane → 1.85 ppb
- Does not read emissions of methane
- Methane is not a subject of transport
- Includes methane chemistry

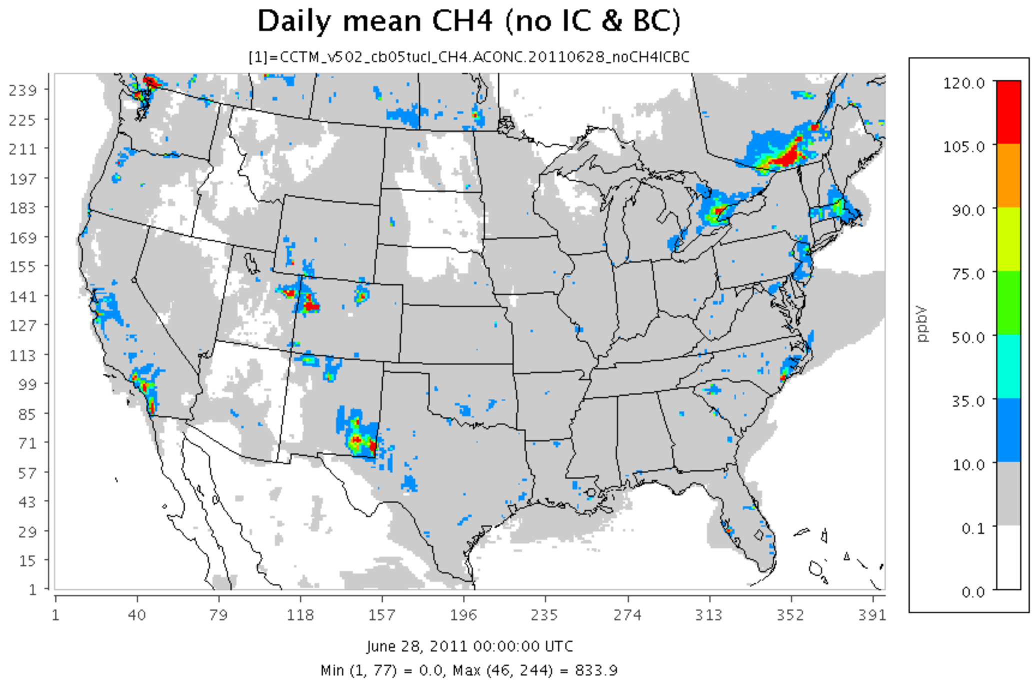
$$CH_4 + OH \rightarrow HCHO, HO_2 \rightarrow O_3$$
$$CH_4 + Cl \rightarrow HCl \rightarrow O_3$$

Modifications of CMAQ

to include calculations of methane concentration from its emissions as well as transport of methane

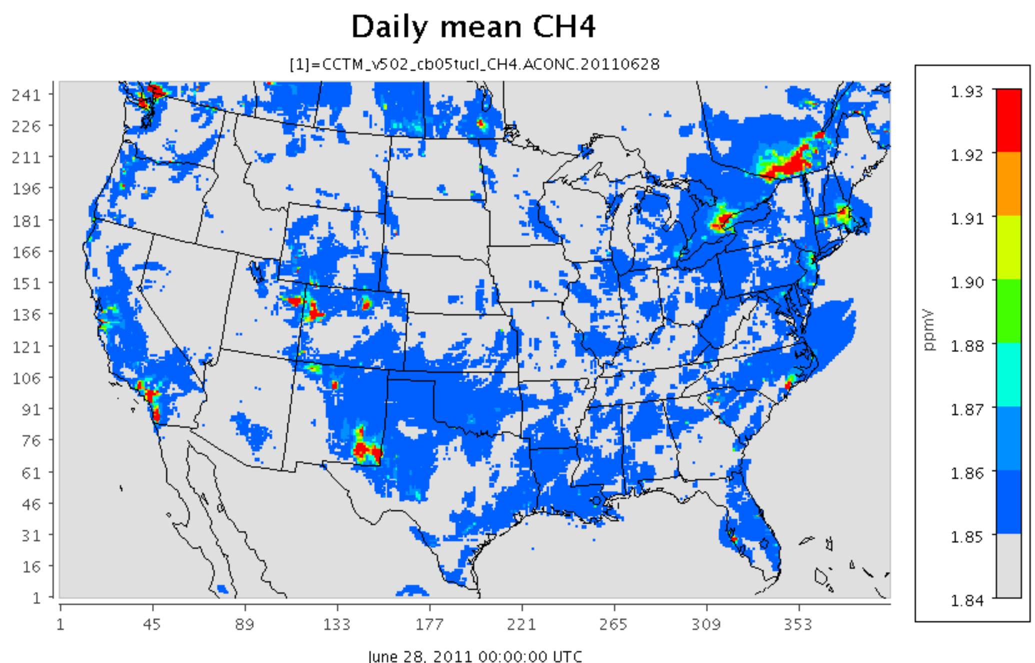
grcalcks.F
RXCM.EXT
RXDT.EXT
GC_cb05tucl_ae6_aq
mech.def

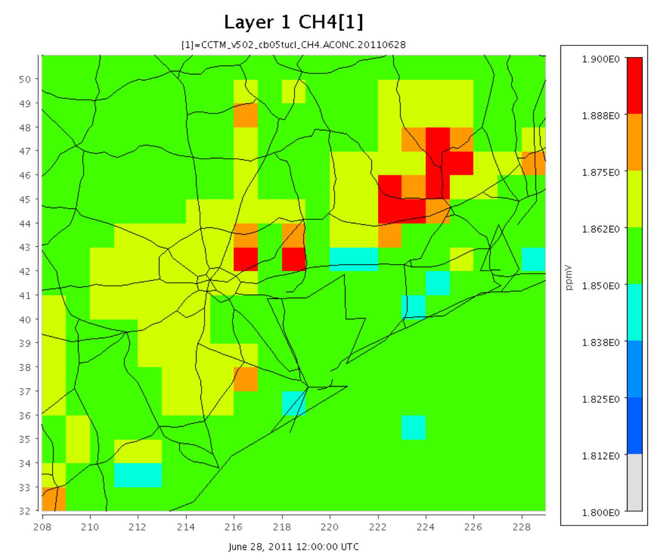
Methane mixing ratios



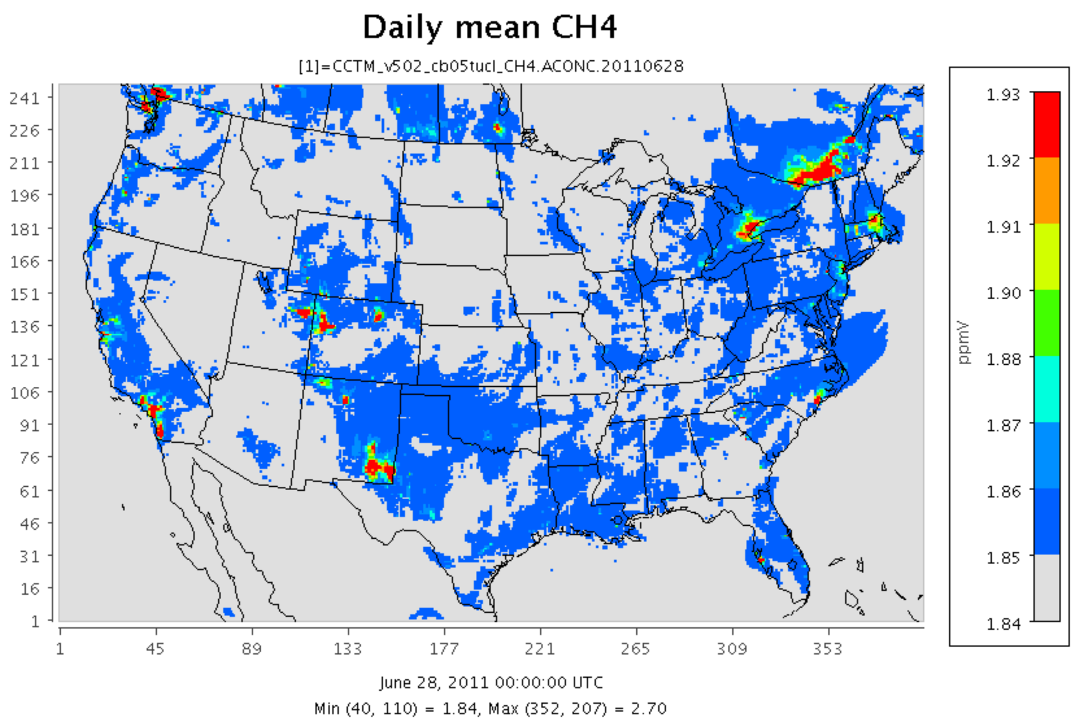
No IC and BC
Contribution from local anthropogenic emissions

IC and BC included with the value of 1.85 ppm

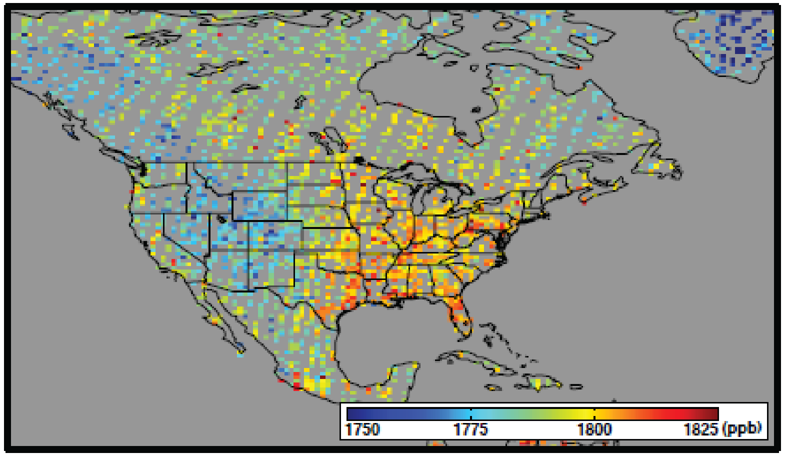




Methane mixing ratios



GOSAT satellite column averaged methane



Source: Turner et al. 2015

Initial and boundary condition:

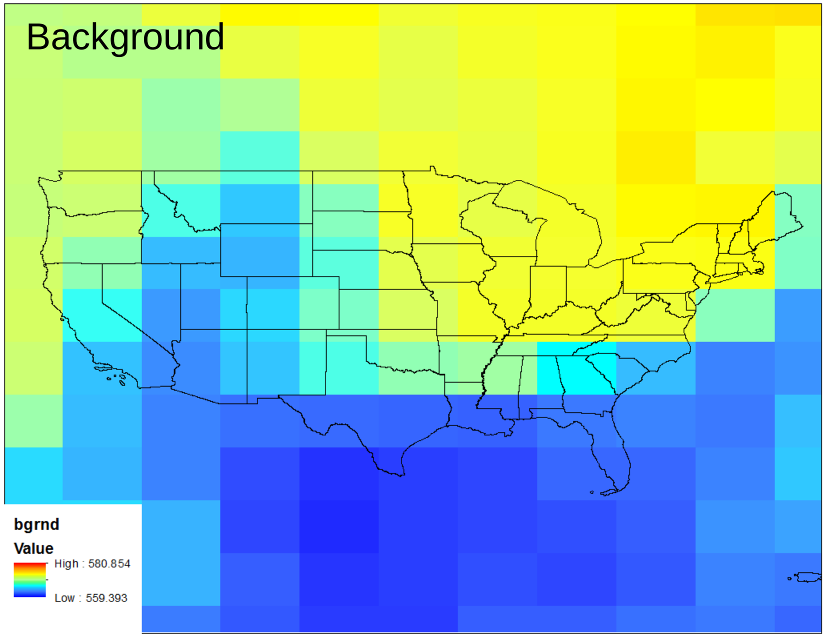
BC = 1.85 ppm
IC = 1.85 ppm

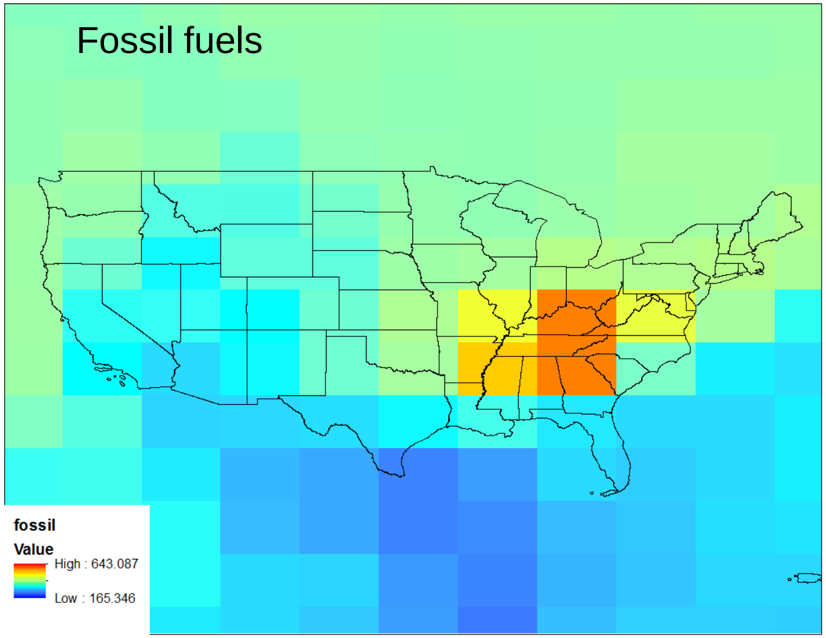
1.76 ppm global mean (IPCC)

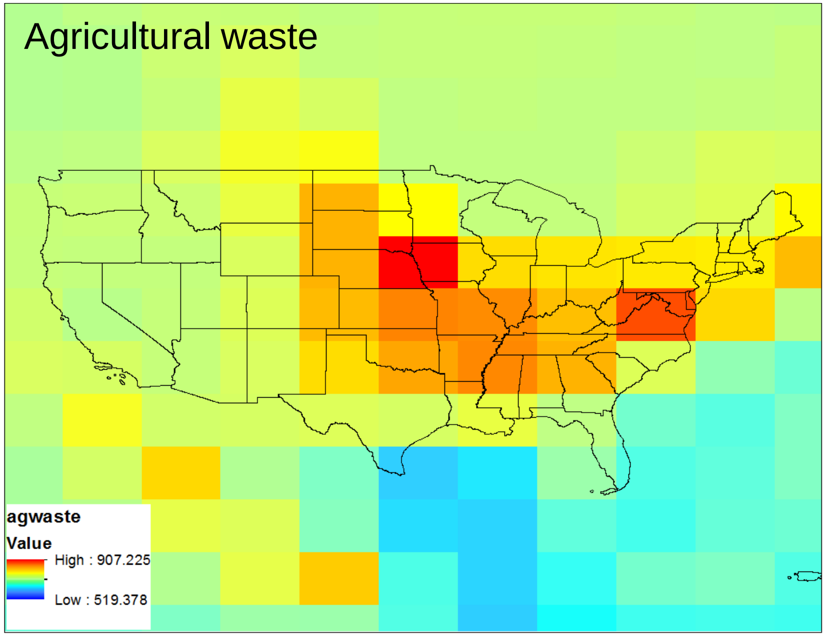
Improved CH_4 initial and boundary conditions

Carbon Tracker – CH_4 (NOAA ESRL)

Gridded concentrations
~400 km grid size
3-hourly data, 2010 is the latest
3D (34 levels)
netCDF format







Additional methane sources

Implement methane TCEQ EI for Texas:

- ❑ Oil and gas wells

  Heaters, Mud degasing, Pneumatic pumps, hydraulic fracturing pumps, pneumatic devices

- ❑ Gas flaring

- ❑ Storage tanks

- ❑ Compressor engines

Summary

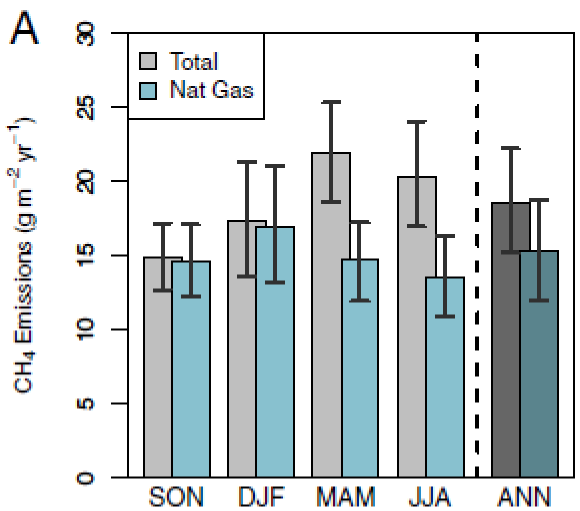
- Geospatial analysis identified areas of potential methane leaks in Houston
- Comparison of methane emissions from NEI2011 and estimates from recent publications show underprediction in Texas
- Modification of CMAQ allowed calculations of methane mixing ratios
- Modeled mixing ratios of methane are well simulated in some regions, but are underpredicted in eastern US

<u>Funding provided by Shell Center for Sustainability</u>

Additional slides

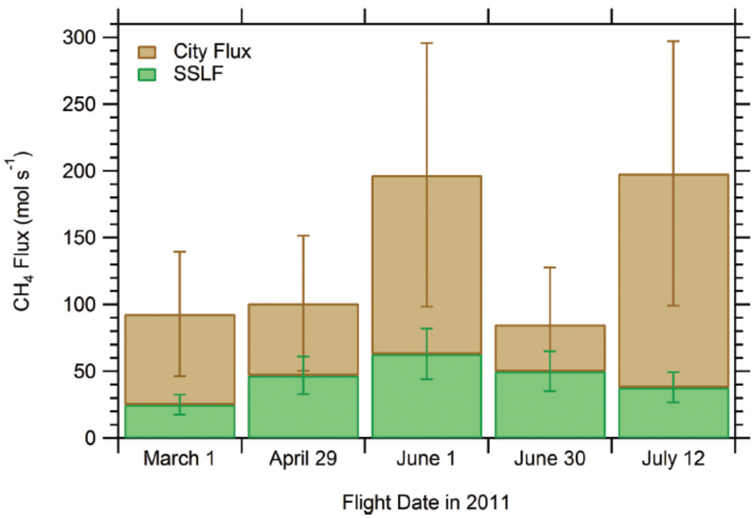
Methane loss from local NG distribution system

Boston



Source: McKain et al. 2014

Indianapolis



Source: Cambalize et al. 2015

Natural gas distribution system → ~60-100%

Landfill → 33% of the citywide emission flux
Natural gas distribution system → ~67%