Observational Evaluation of Mobile Source Emissions

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NOAA Earth System Research Laboratory, Boulder, CO
**also at CIRES, University of Colorado, Boulder, CO*
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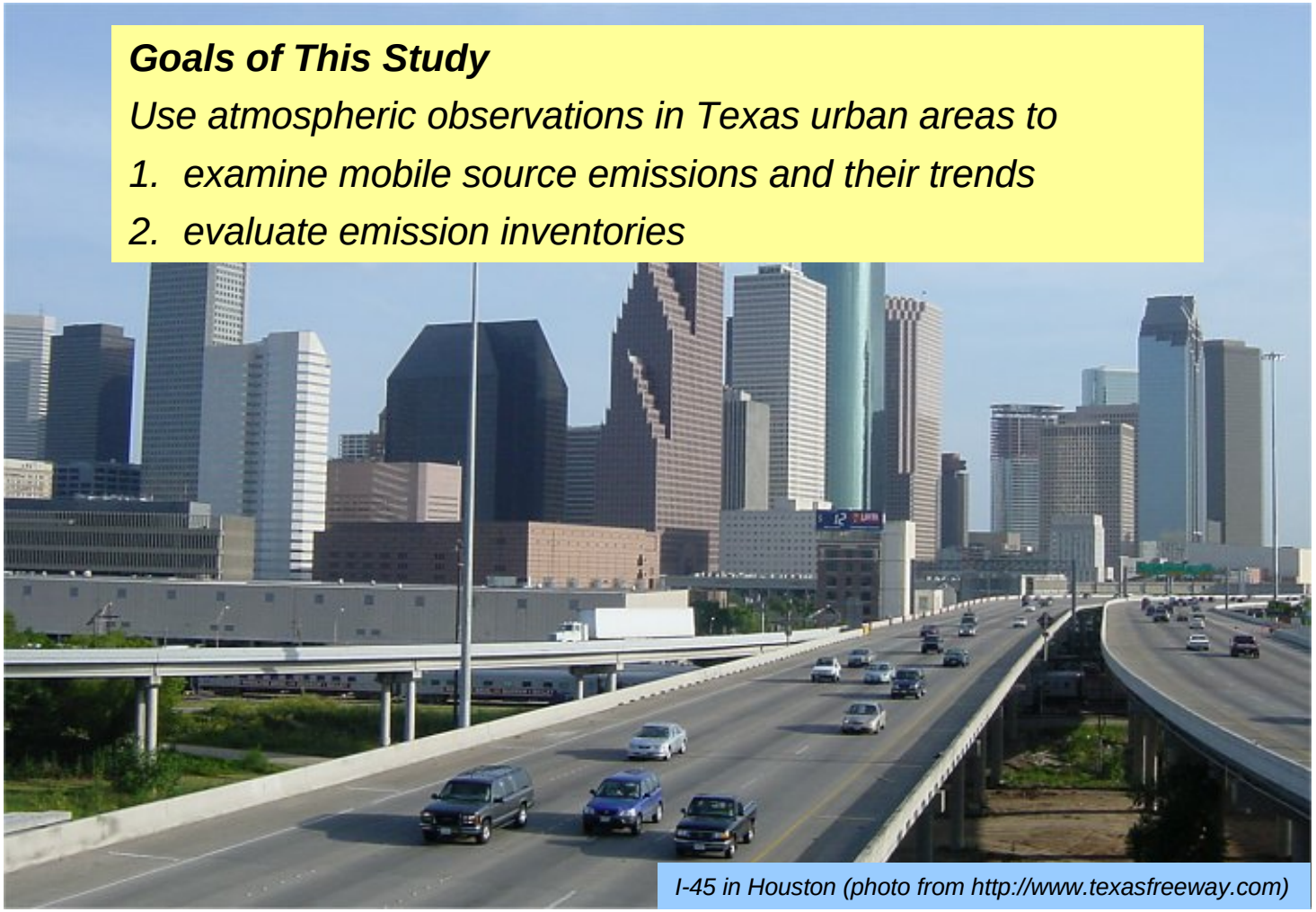
Goals of This Study

Use atmospheric observations in Texas urban areas to

1. *examine mobile source emissions and their trends*
2. *evaluate emission inventories*



I-45 in Houston (photo from http://www.texasfreeway.com)

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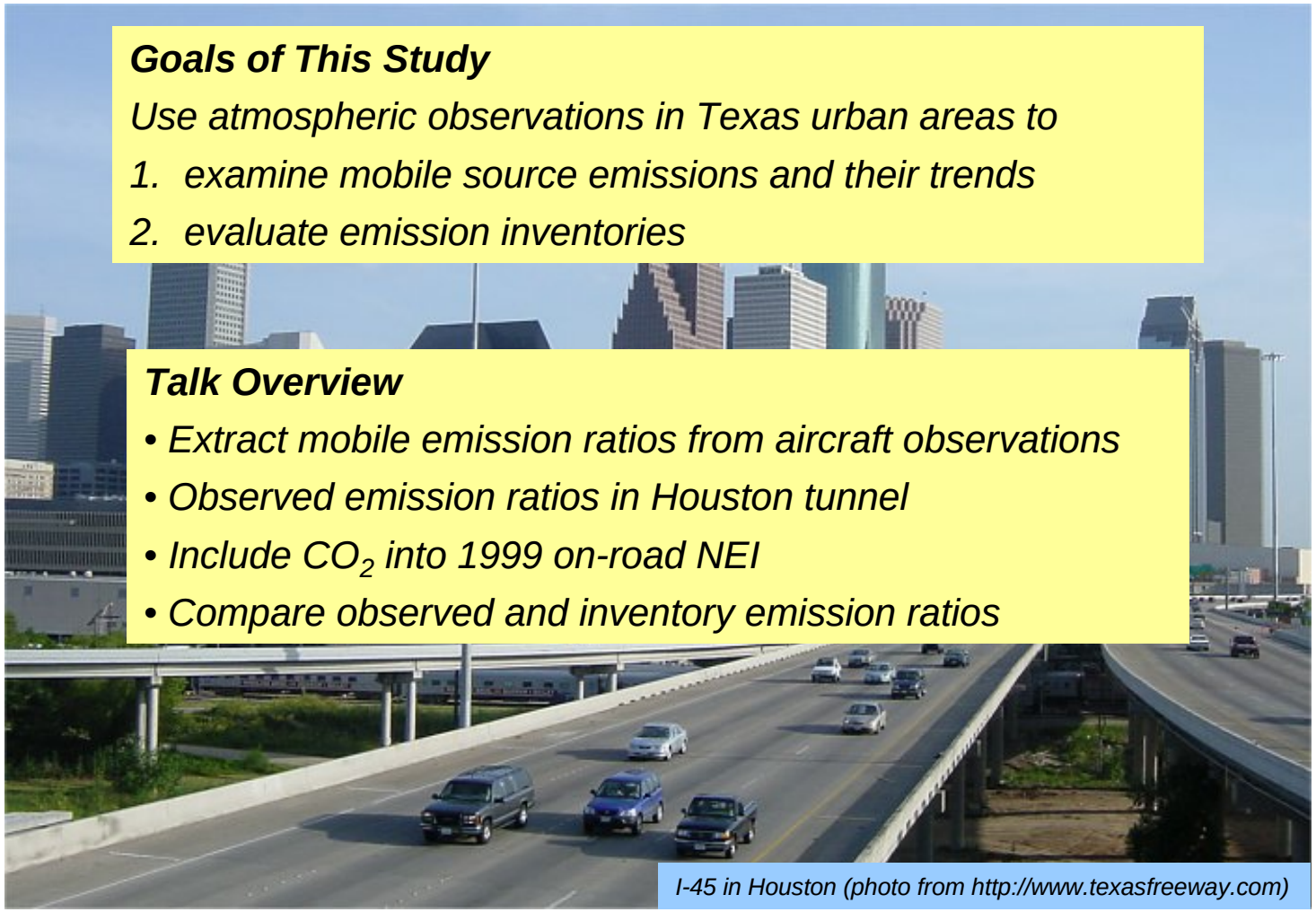

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Talk Overview

- *Extract mobile emission ratios from aircraft observations*
- *Observed emission ratios in Houston tunnel*
- *Include CO_2 into 1999 on-road NEI*
- *Compare observed and inventory emission ratios*

I-45 in Houston (photo from http://www.texasfreeway.com)

Aircraft Observations of Mobile Source Emissions

NCAR Electra: TexAQS 2000

NOAA P-3: TexAQS 2006

- 2000 and 2006 Texas Air Quality Studies
- 1-*Hz* NO_y, CO, CO_2, and SO_2 observations

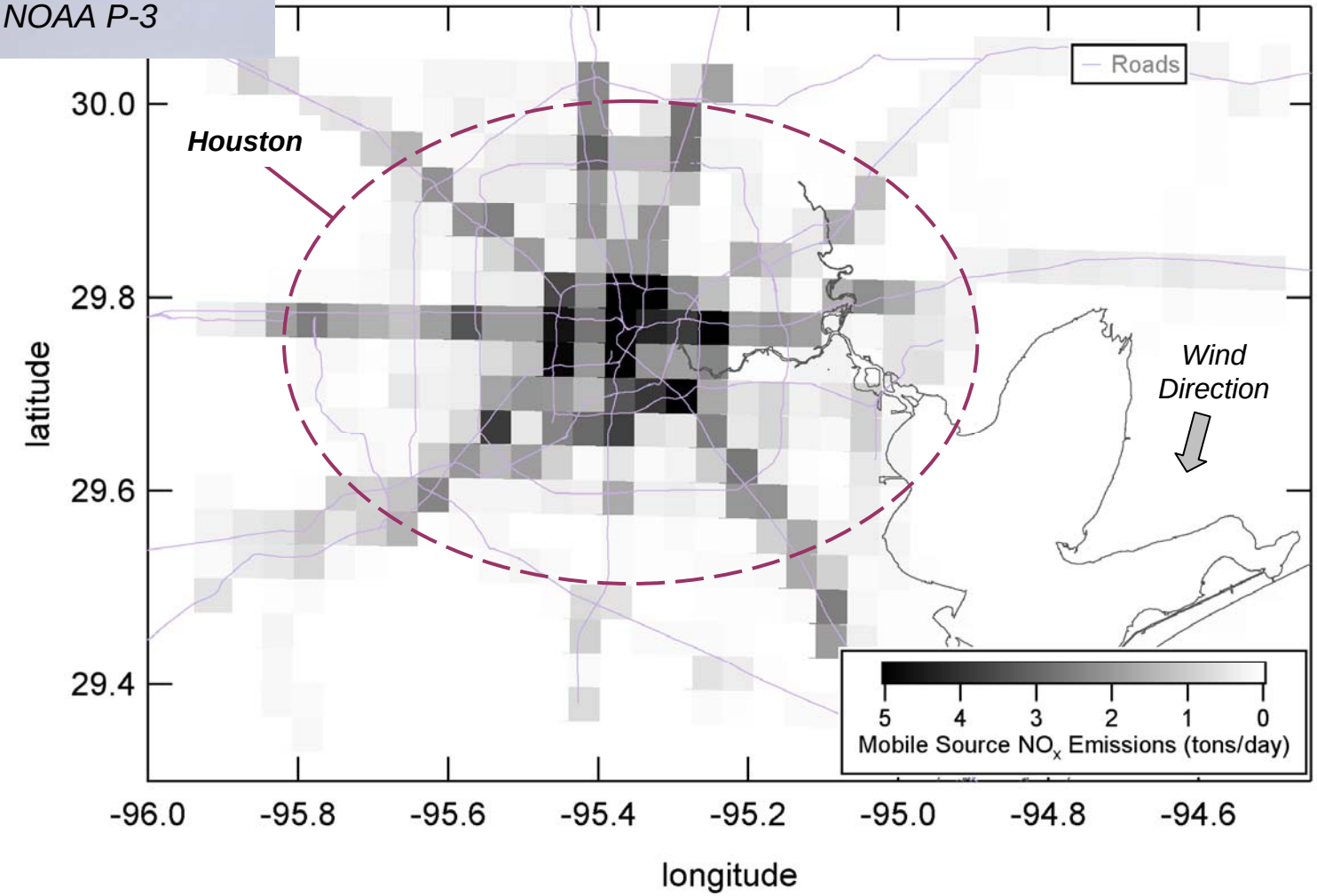
($NO_y = NO_x + HNO_3$ + *organic nitrates + other reactive N*)

- Measure pollutant-to-CO_2 concentration ratios along cross-wind transects downwind of urban areas
- Assumptions:
  - Covariance in pollutant concentrations reflects emission ratios from upwind sources
  - Dilution and mixing affects all species equally
  - No differential loss during short transit time from source
  - All emitted NO_x captured by NO_y enhancement

Aircraft Observations of Mobile Source Emissions

NOAA P-3

NOAA P-3 Observations in Houston
Tuesday, 26 September 2006, 1258-1318 CDT
400-500 m altitude



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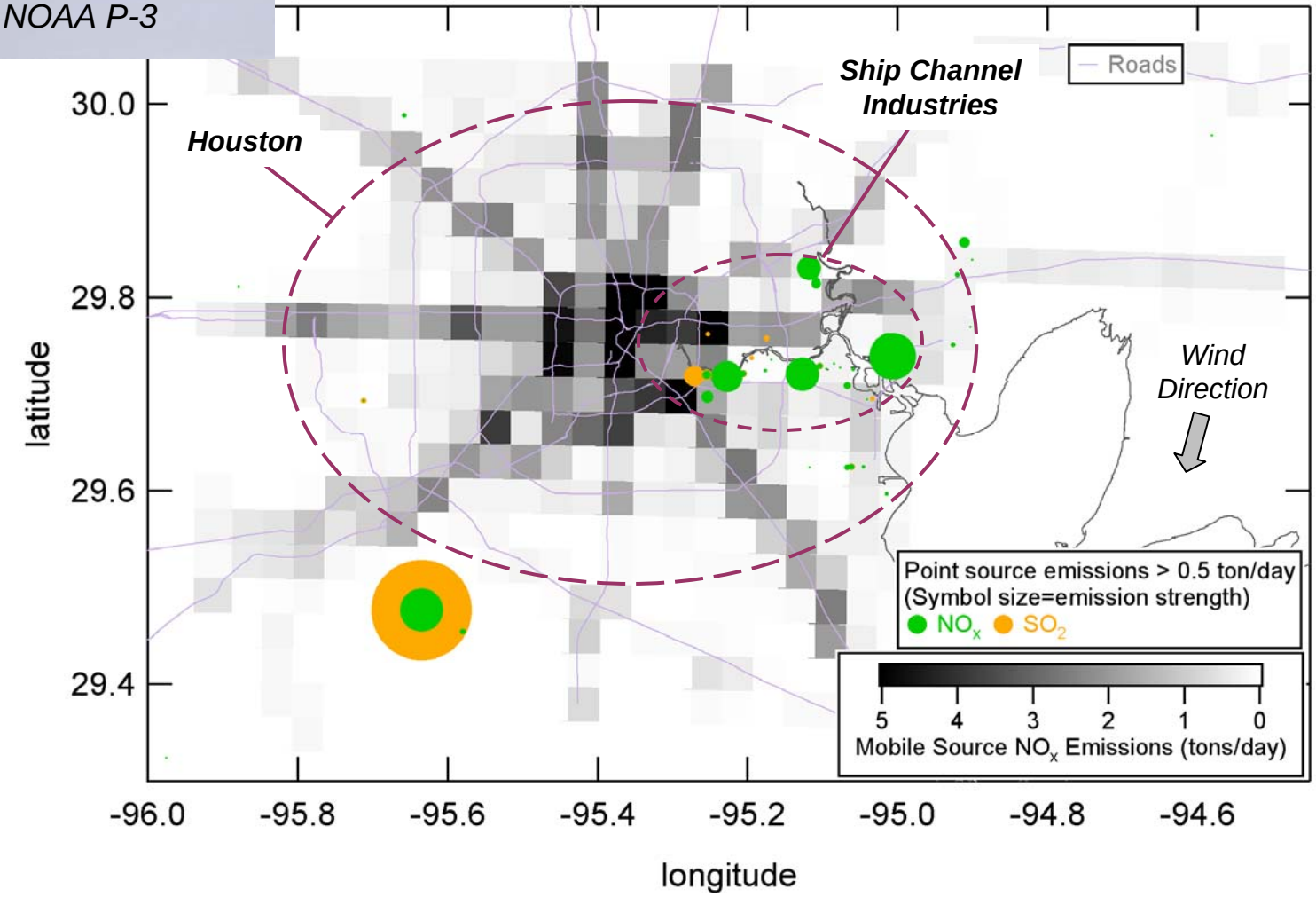

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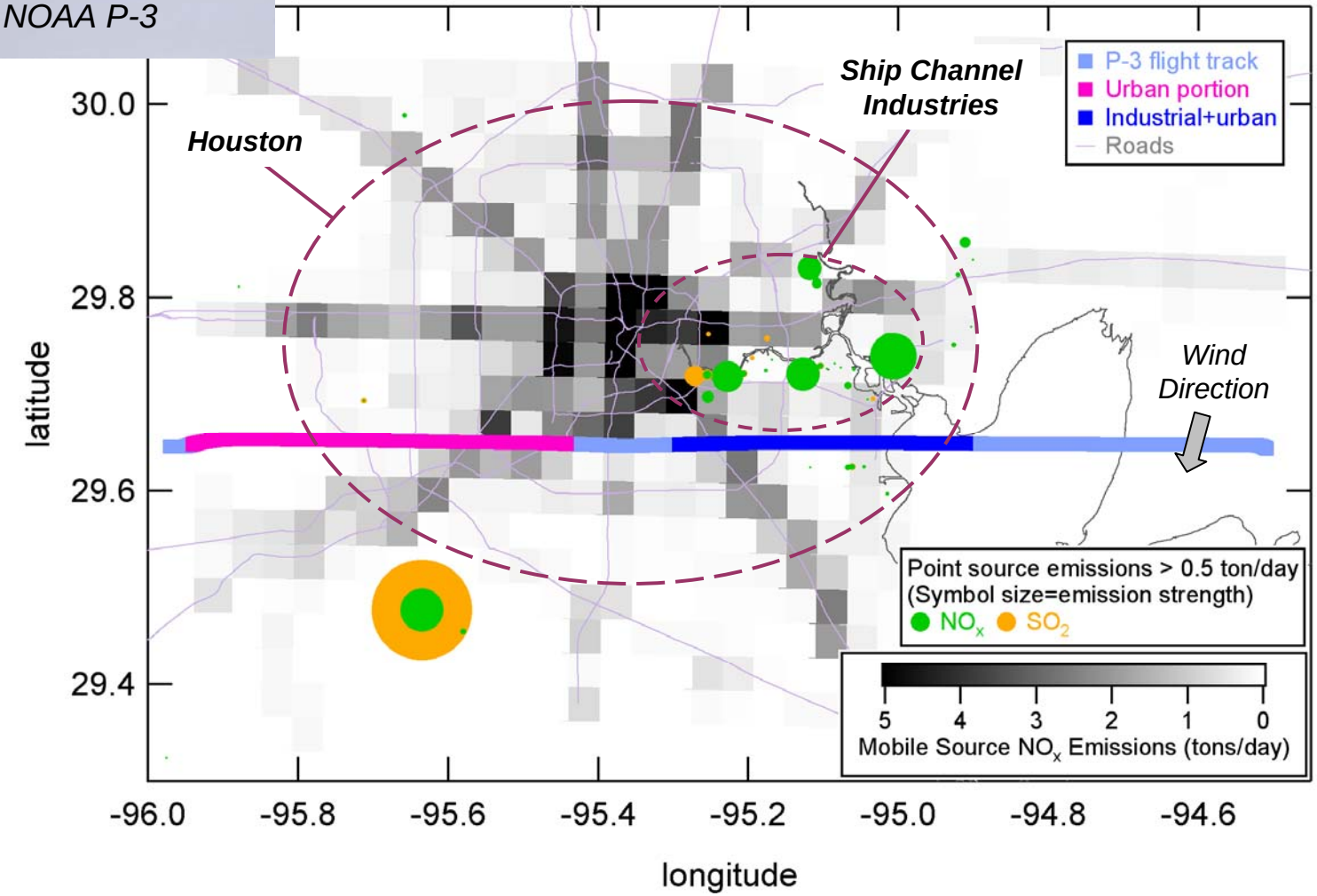

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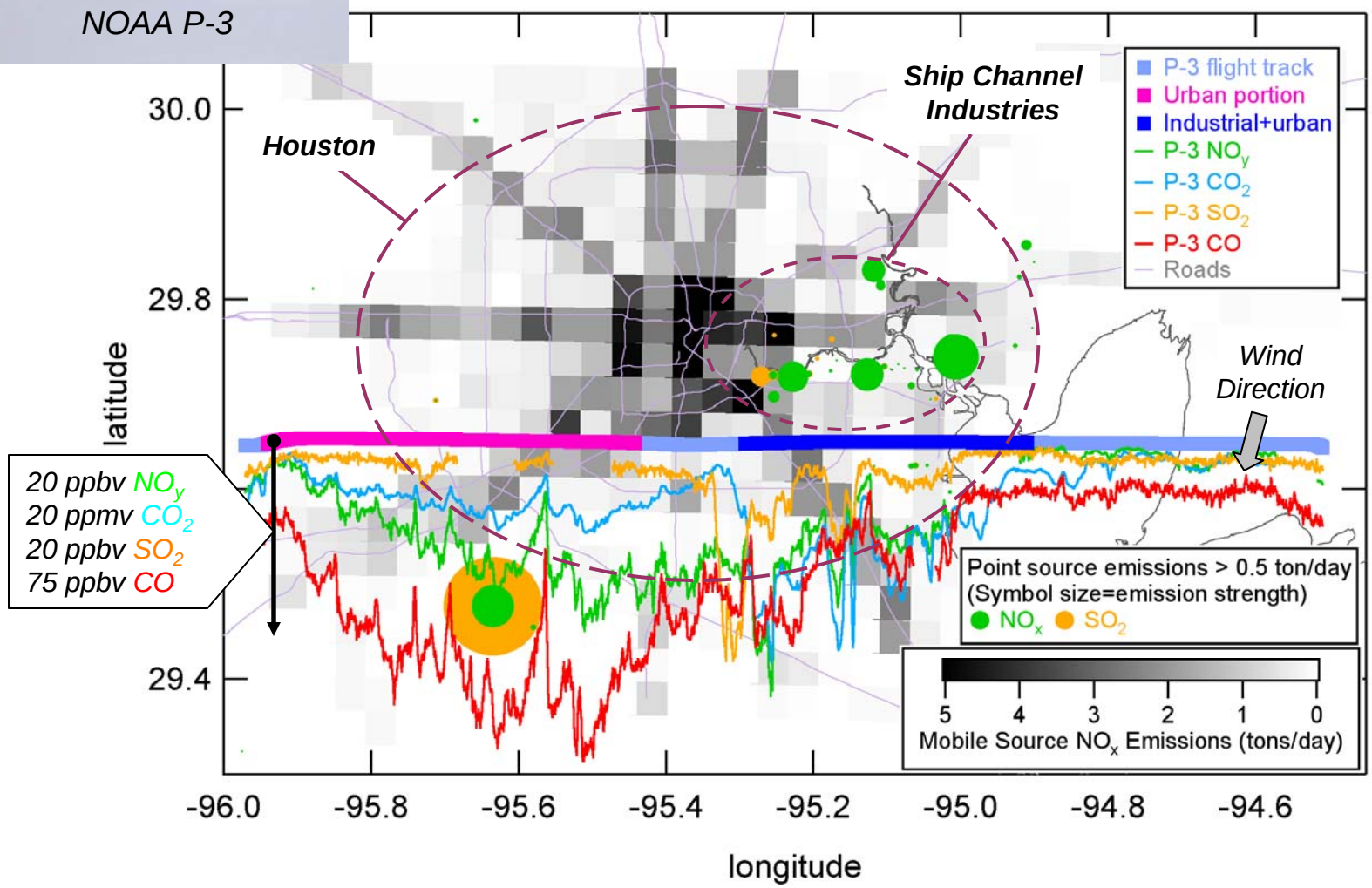

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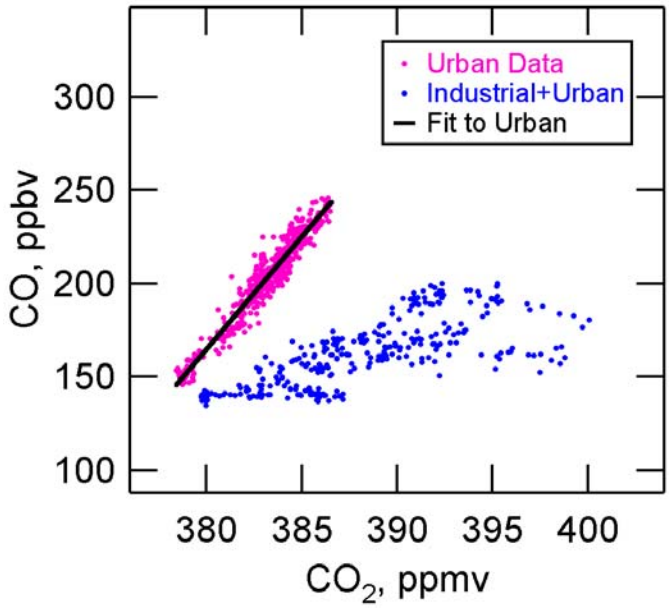

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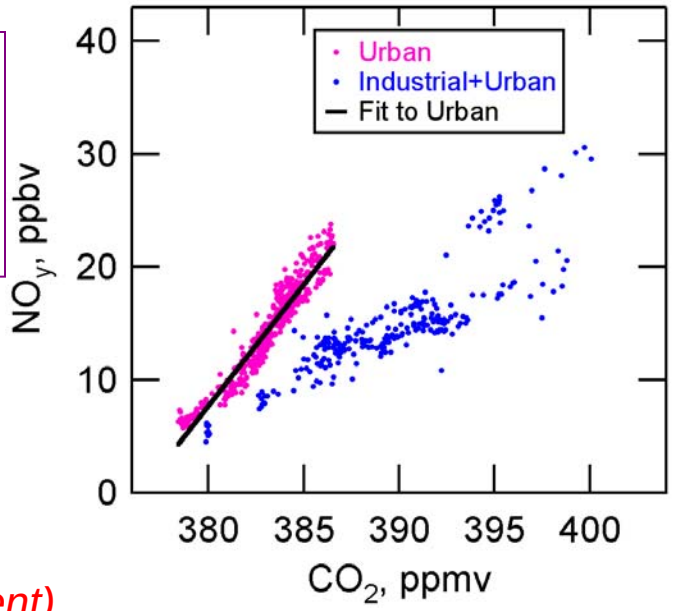
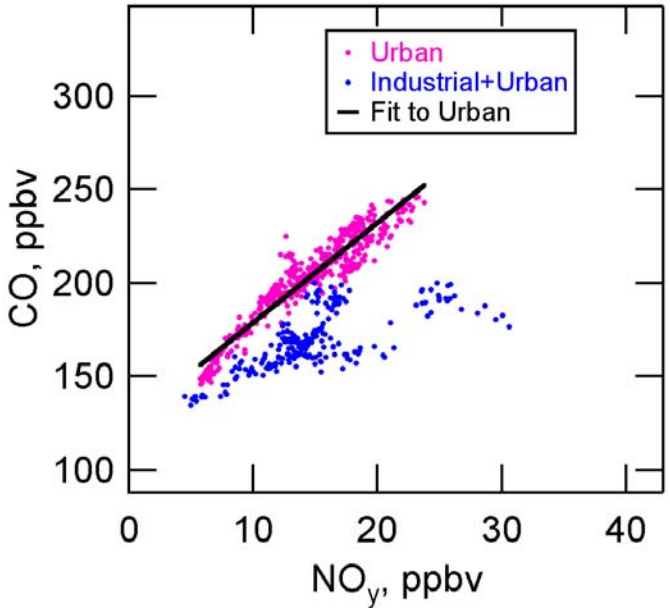




Slopes of Linear Fits
Units = mole/mole
(r = correlation coefficient)

$CO/CO_2 = 0.0121$ (r = 0.96)

$NO_y/CO_2 = 0.00215$ (r = 0.96)

$CO/NO_y = 5.32$ (r = 0.95)

La Porte Freeway (Texas 225) with Shell Deer Park Refinery in background (photo from http://www.texasfreeway.com)

Tunnel Observations of Mobile Source Emissions

McGaughey et al. (2006) Atmos. Environ., 38, 3363-3372

Washburn Tunnel, Houston
TexAQS 2000
29 August (Tuesday) - 1 September (Friday)

photo from http://www.texasfreeway.com

CO, NO_x, & CO_2 emission ratios measured for 2-hour sampling periods
- 1200-1400 CDT: higher fraction of heavy-duty diesel vehicles
- 1600-1800 CDT: afternoon rush hour, higher fraction of gasoline vehicles

Summary of Texas Mobile Source Emission Observations

Platform	Washburn Tunnel	NCAR Electra	NOAA P-3
Year	2000	2000	2006
Date Range	29 Aug - 1 Sept	28 Aug - 7 Sept	11 Sept - 11 Oct
Day Range	Tues - Fri	Mon - Fri	Mon - Sun
Time Range (CDT)	1200-1400,1600-1800	1100-1800	1100-2200
# Samples Total	16	16	33
# Samples in Houston	16	7	30
# Samples in Dallas	0	9	3

Including CO_2 in NEI 1999 On-road Mobile Sector

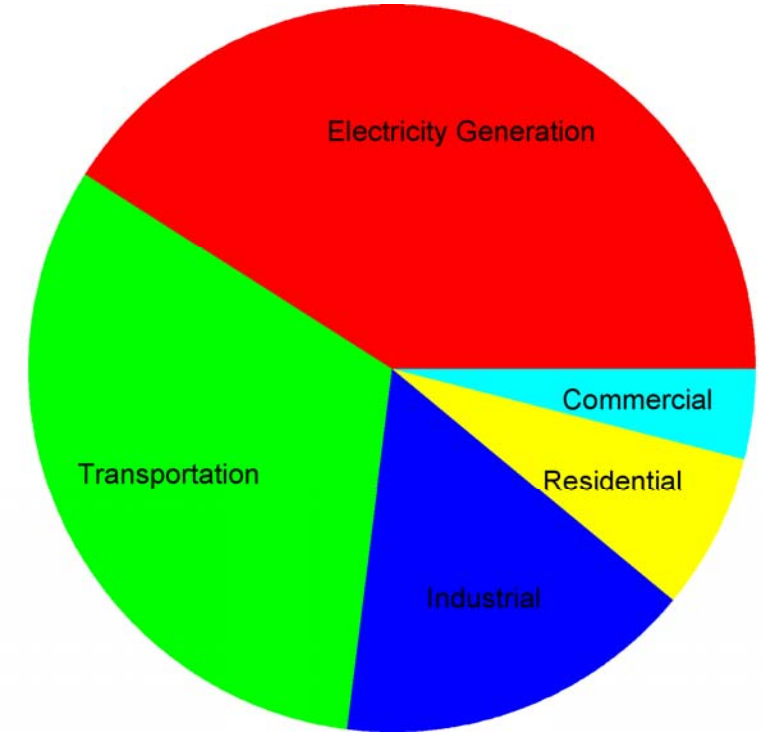
- Combine fuel-use data with NEI to produce CO_2 and criteria pollutant inventory for on-road mobile sources

- S☐tructure and grid from NEI 1999
  - ➢NO_x, SO_2, CO, VOCs, NH_3, $PM_{2.5}$, PM_{10}
  - ➢horizontal resolution: 4x4 km^2
  - ➢hourly emissions
  - ➢summer ozone season day

- Benefits*:*
  - *•Multi-pollutant fossil fuel emission inventory*
  - *•High spatial and temporal resolution*
  - *•Useful for both air quality and climate studies*

Dallas-Ft Worth metroplex at night from International Space Station (photo from http://www.texasfreeway.com)

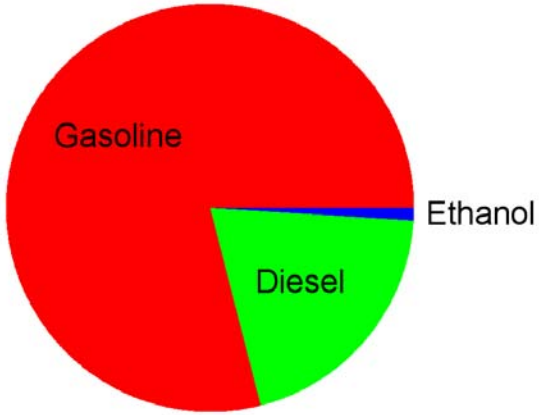
1999 Fossil Fuel CO_2 Emissions (percent by mass)



Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2004, US Environmental Protection Agency, Rep. No. 430-R-06-002, 2006

NEI99 + CO_2 Development: National Statistics

Step 1. 1999 On-road Fuel Use by State:
Federal Highway Administration



1999 US On-road Fuel Use = 1.607×10^{11} gal/yr

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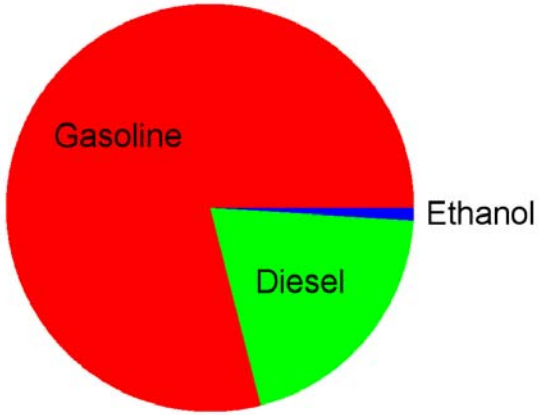

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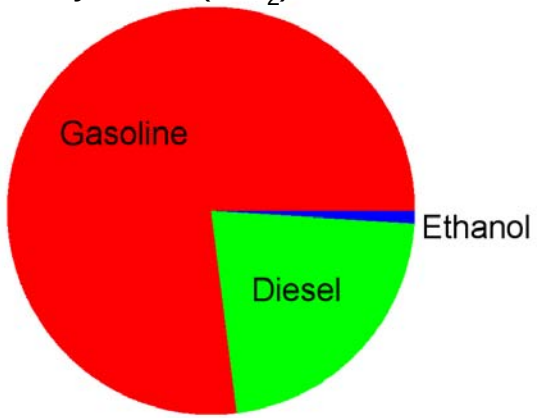

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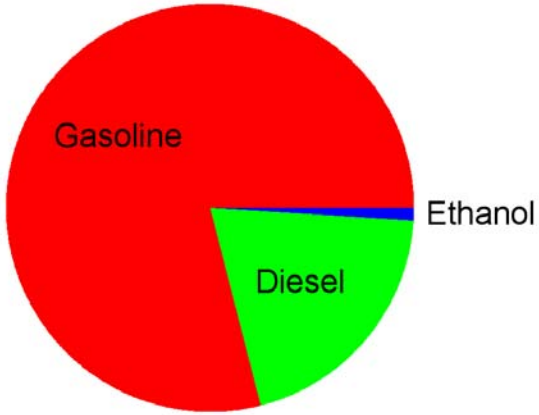

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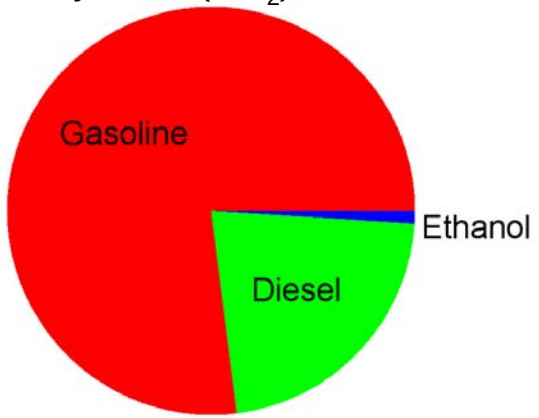

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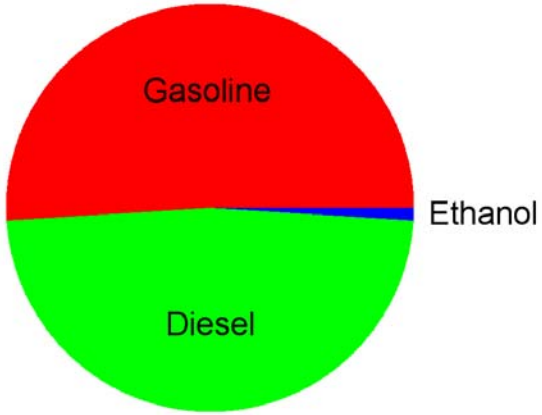
EPA 1999 National Emission Inventory (NEI99)



1999 US On-road NO_x Emissions = 2.34×10^4 ton/dy

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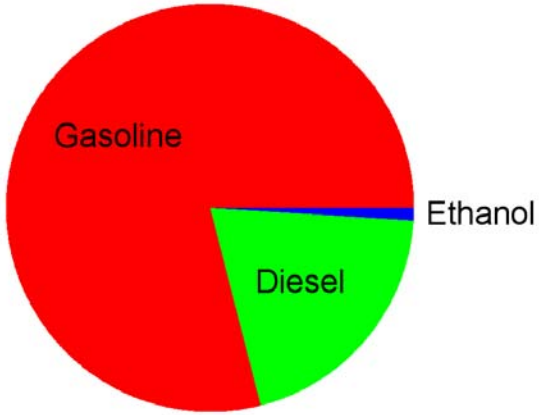

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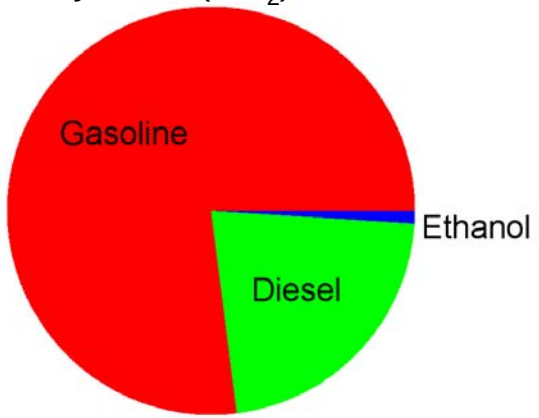

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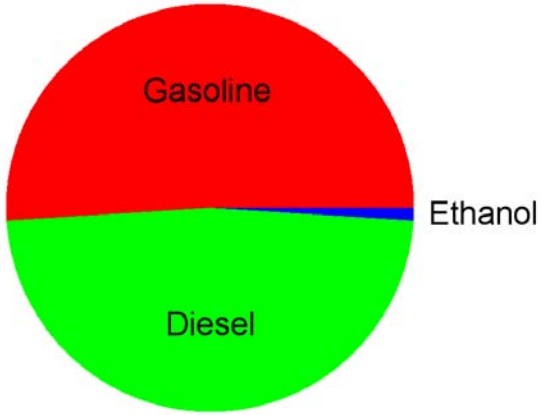
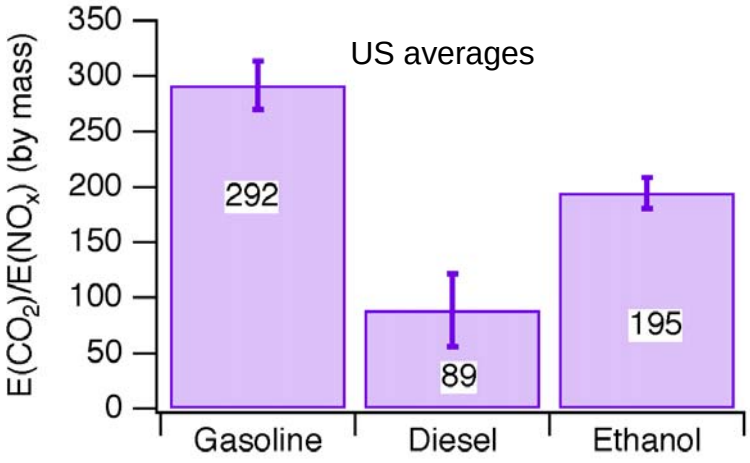


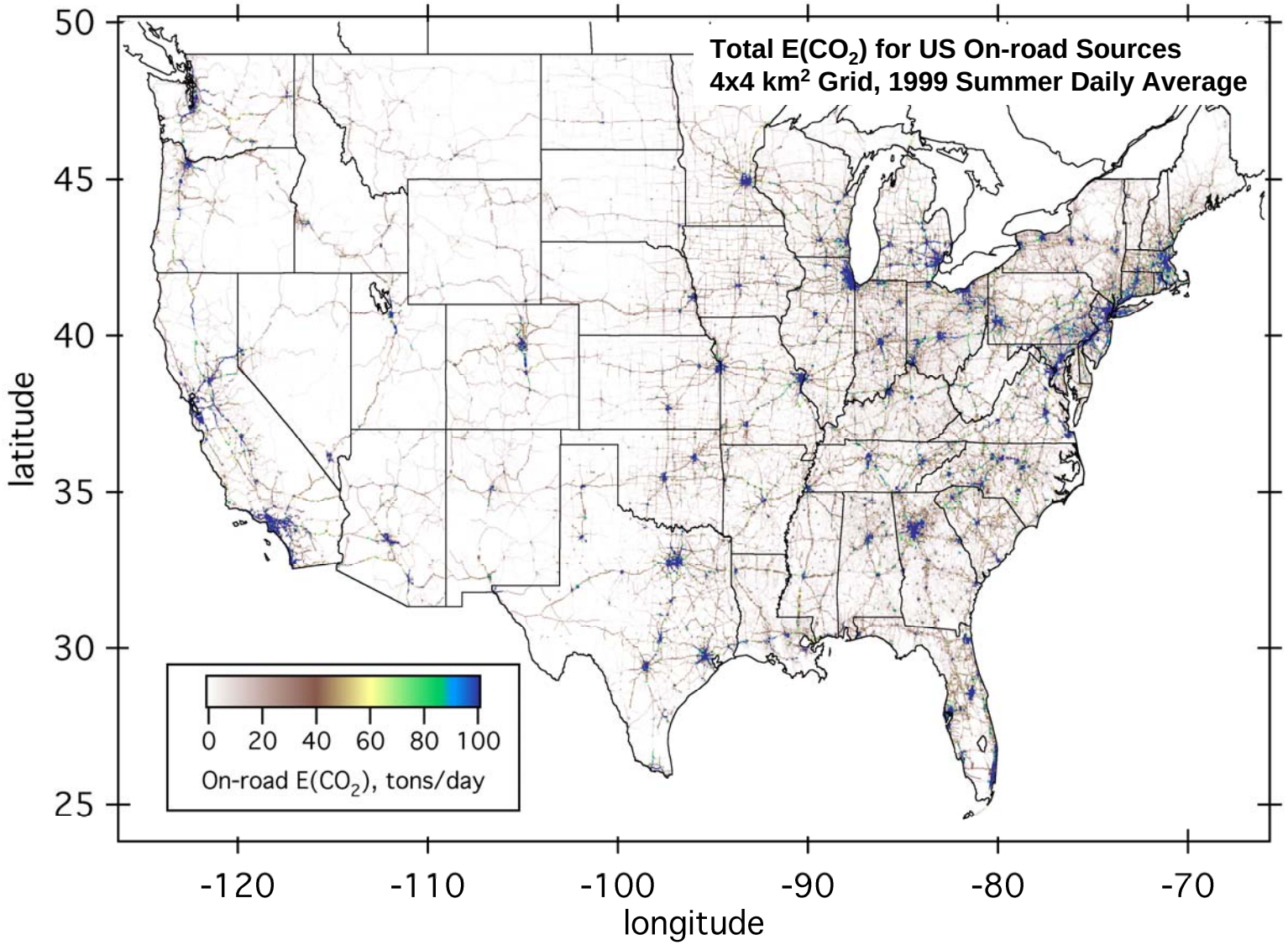
1999 US On-road NO_x Emissions = 2.34×10^4 ton/dy

Step 4. 1999 CO_2/NO_x Emission Ratios by State:
Divide Step 2 by Step 3

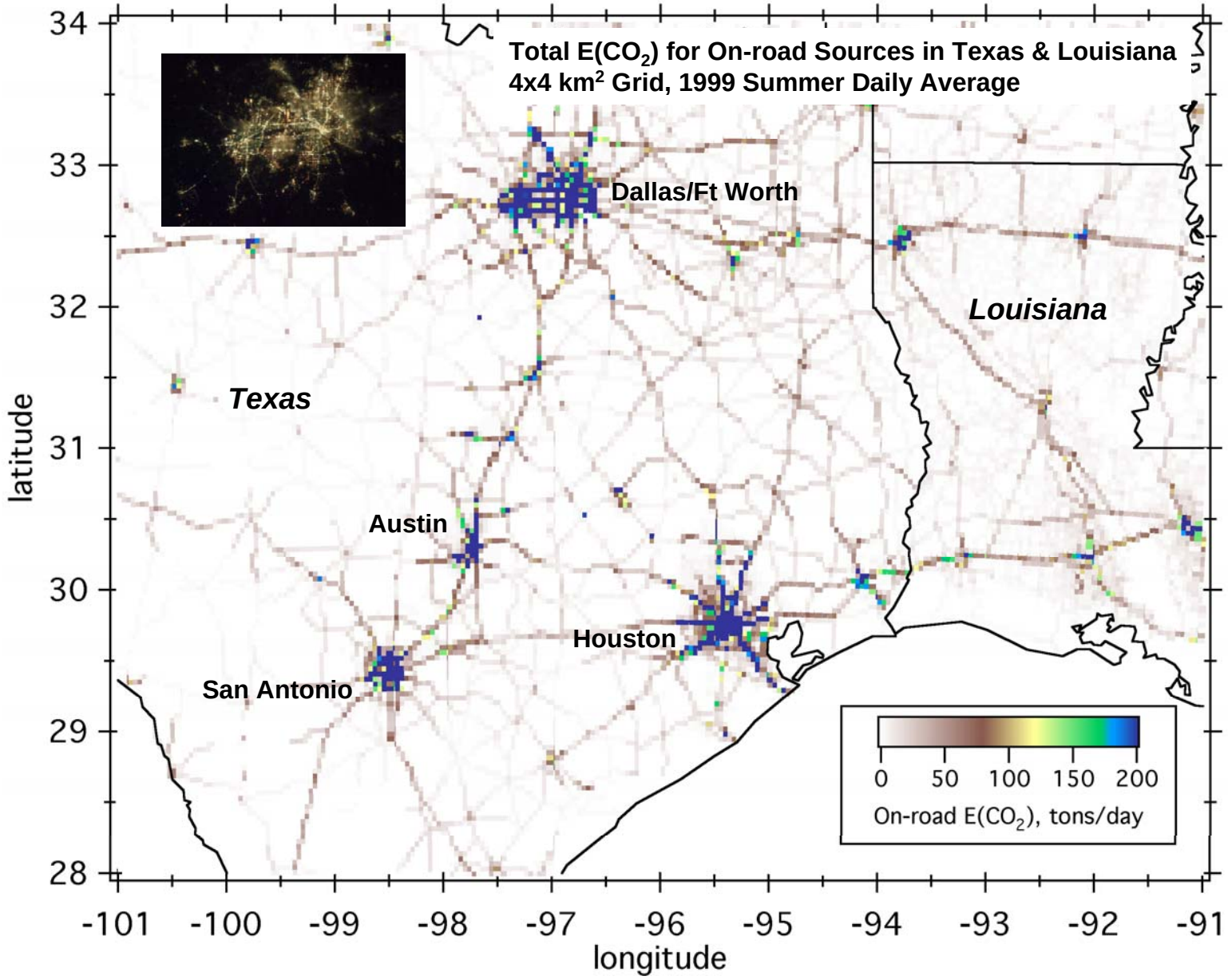


1999 On-road Mobile CO_2 Inventory on 4-km Grid

Step 5. CO_2 emissions on 4x4 km^2 grid:
Apply state-level CO_2/NO_x emission ratios to NEI99 4x4 km^2 NO_x emissions



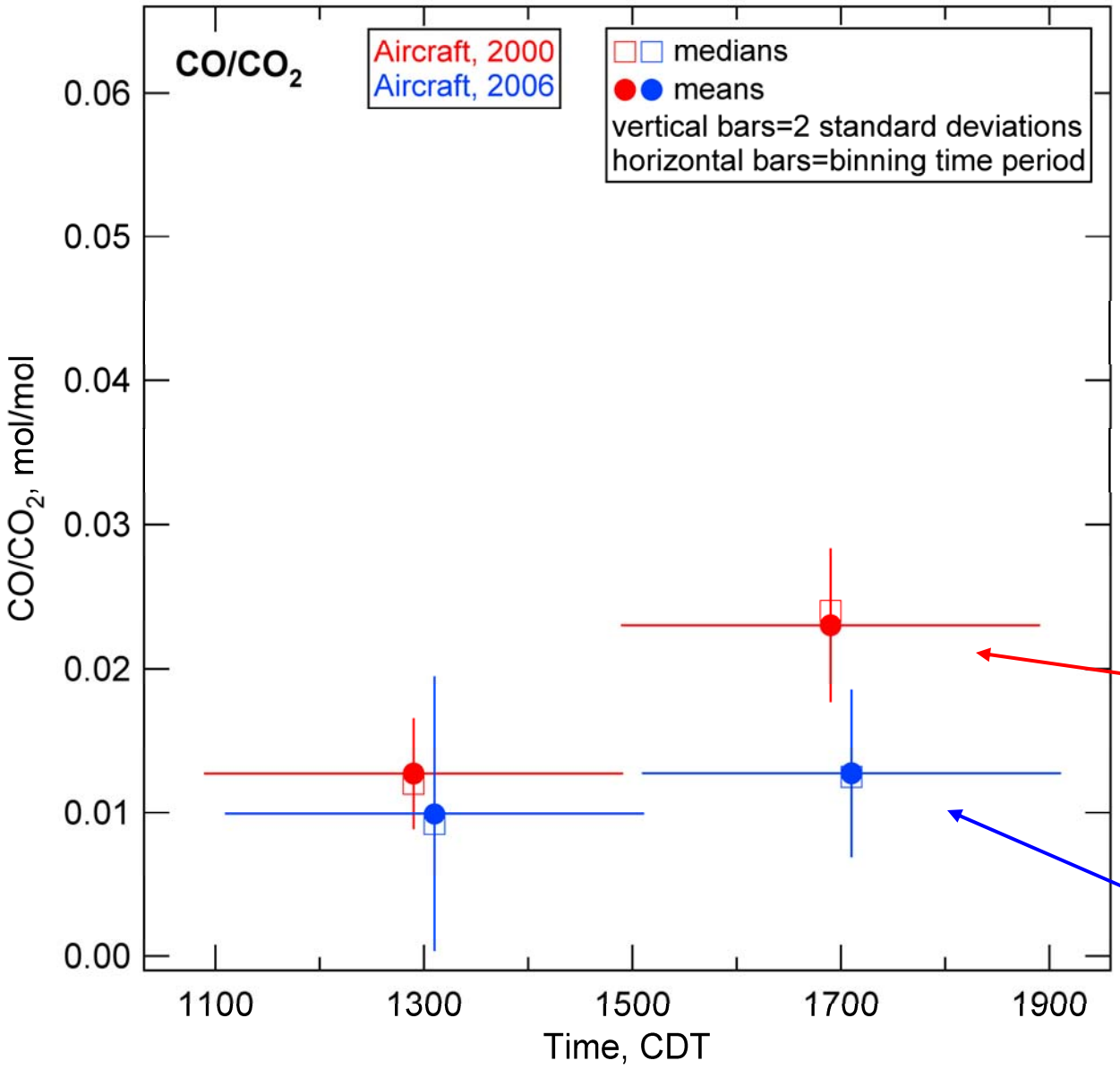
1999 On-road Mobile CO_2 Inventory: Regional Detail



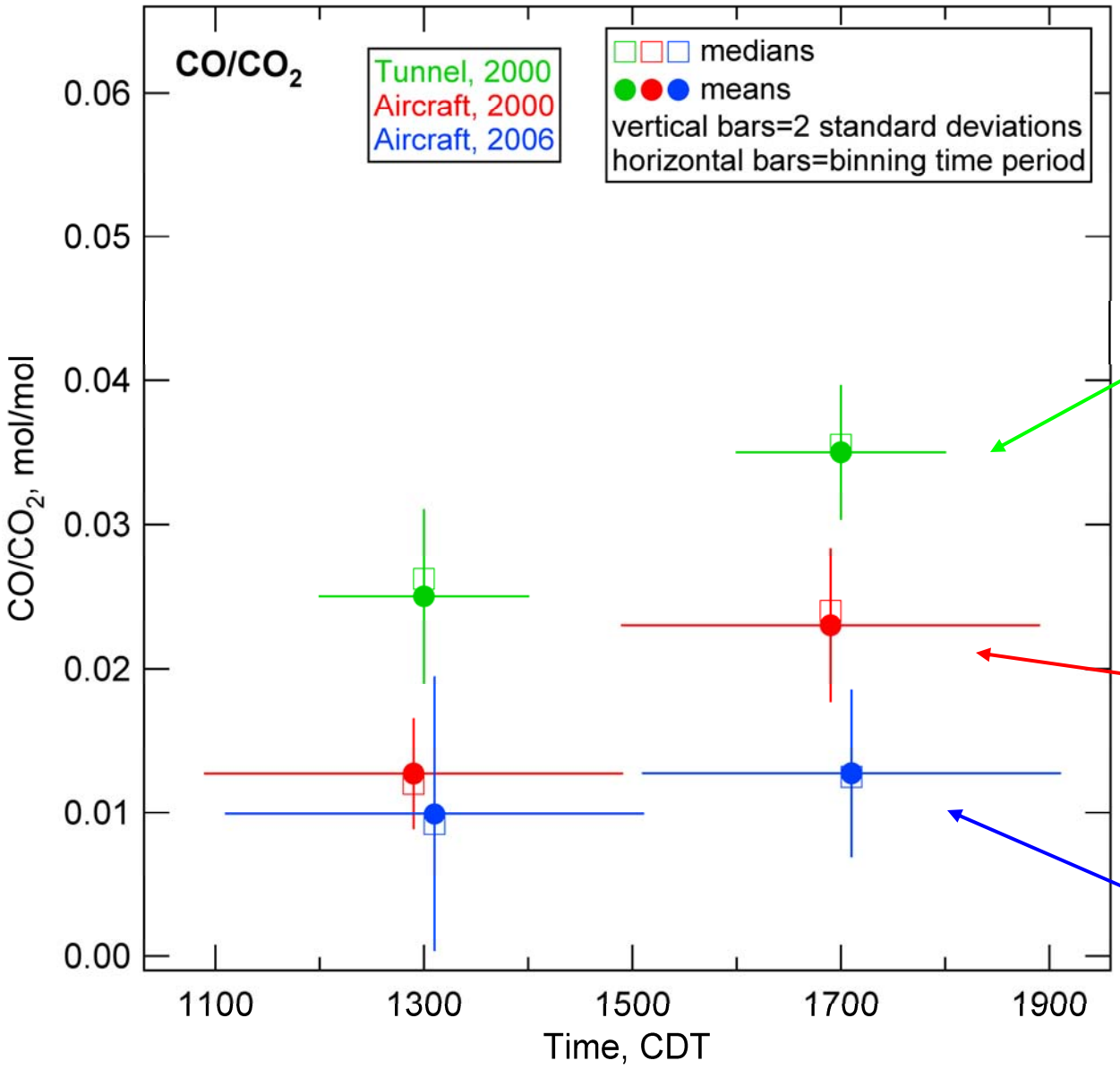
Mobile Source Emissions in NEI 2005

- 2005 NEI Version 1
- Reduced effort version based on 2002 NEI Version 3
- Key updates for this study:
  - 2005 NMIM county-level on-road and non-road emissions
  - Includes CO_2 emissions for these sectors

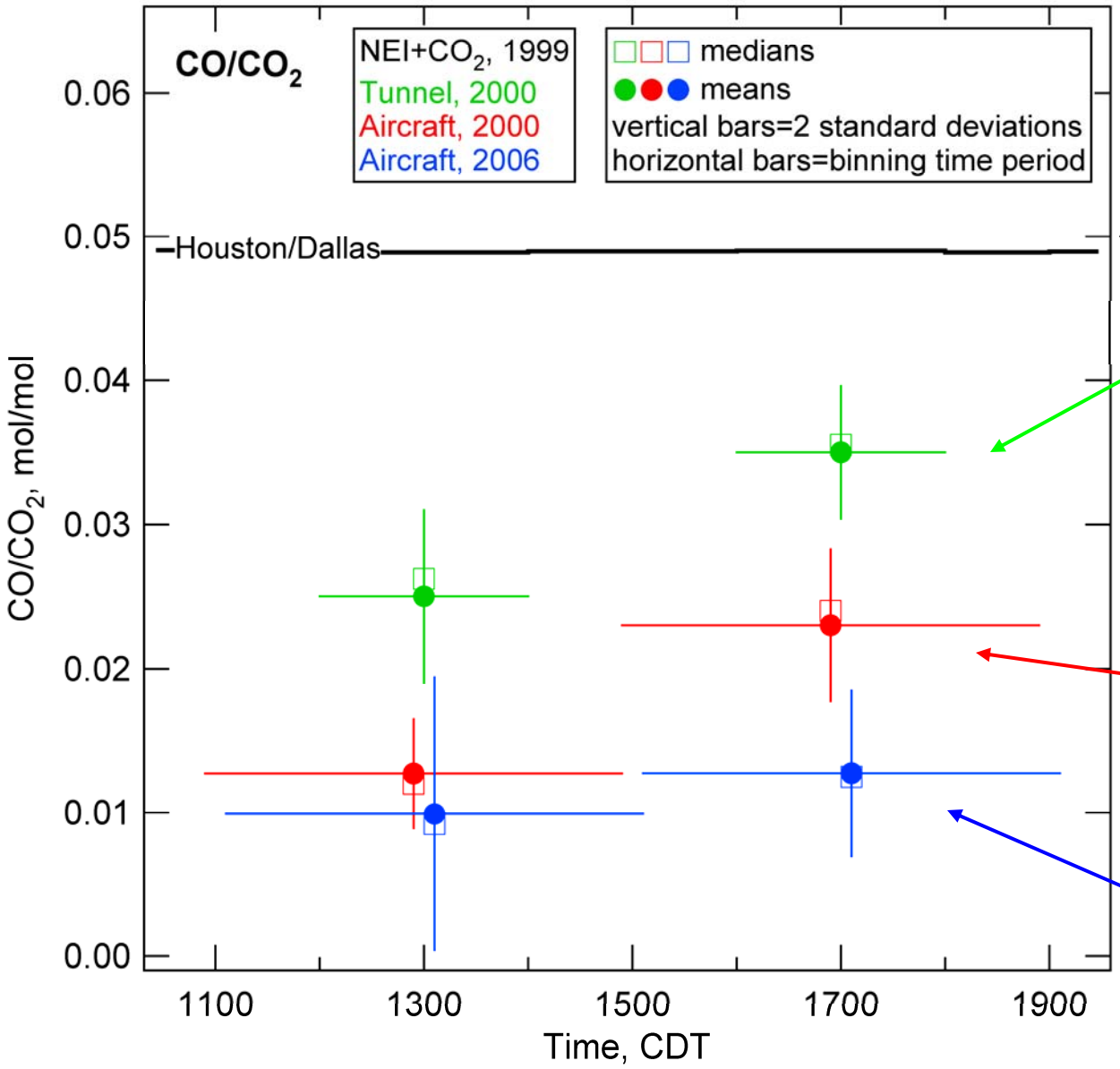
Mobile CO/CO_2 Emission Ratios: Aircraft Observations



Mobile CO/CO_2 Emission Ratios: Aircraft & Tunnel Observations

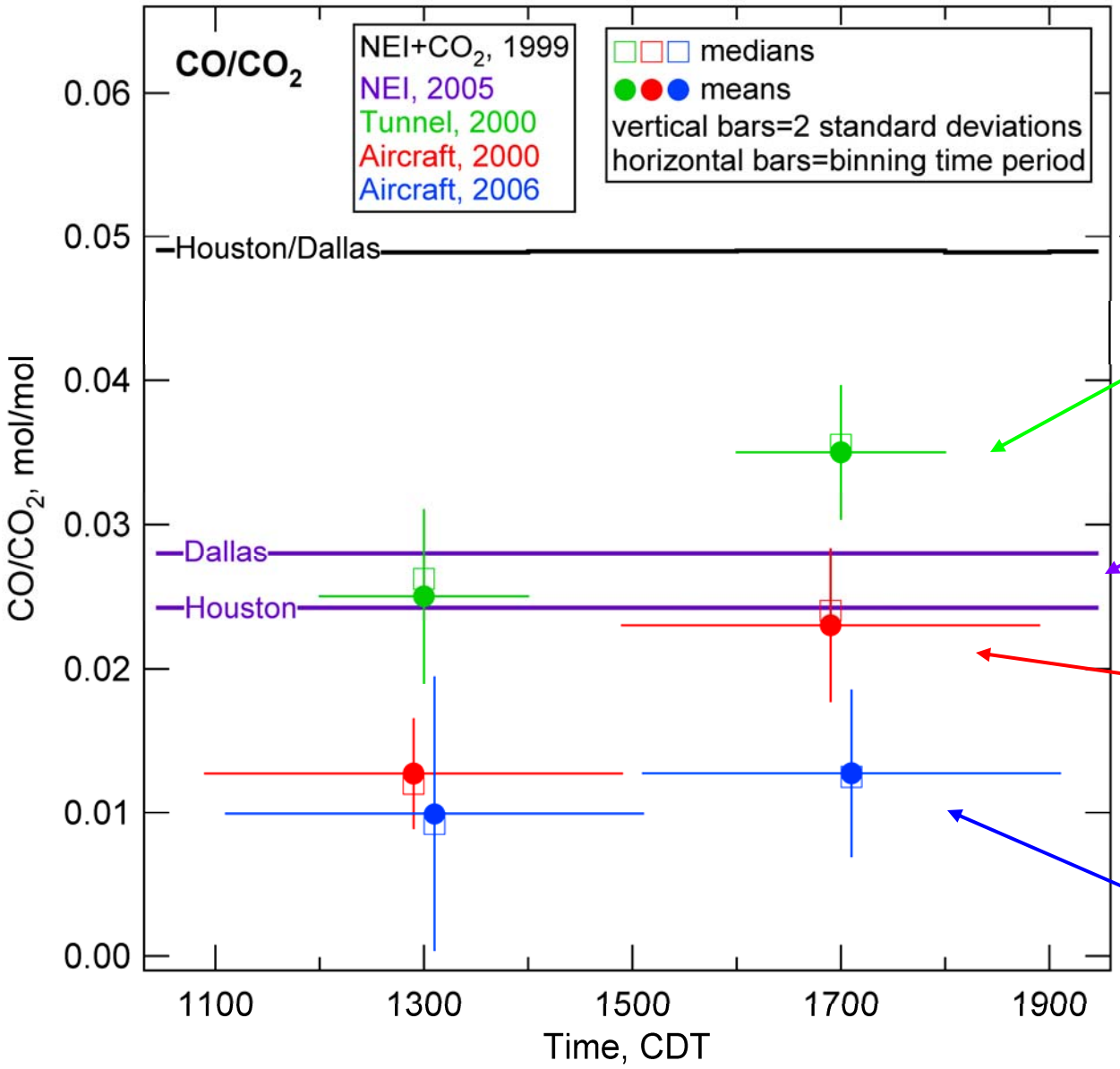


Mobile CO/CO_2 Emission Ratios: Observations & NEI 1999



NEI99+CO_2

Mobile CO/CO_2 Emission Ratios: Observations & NEI 1999/2005



NEI99+CO_2

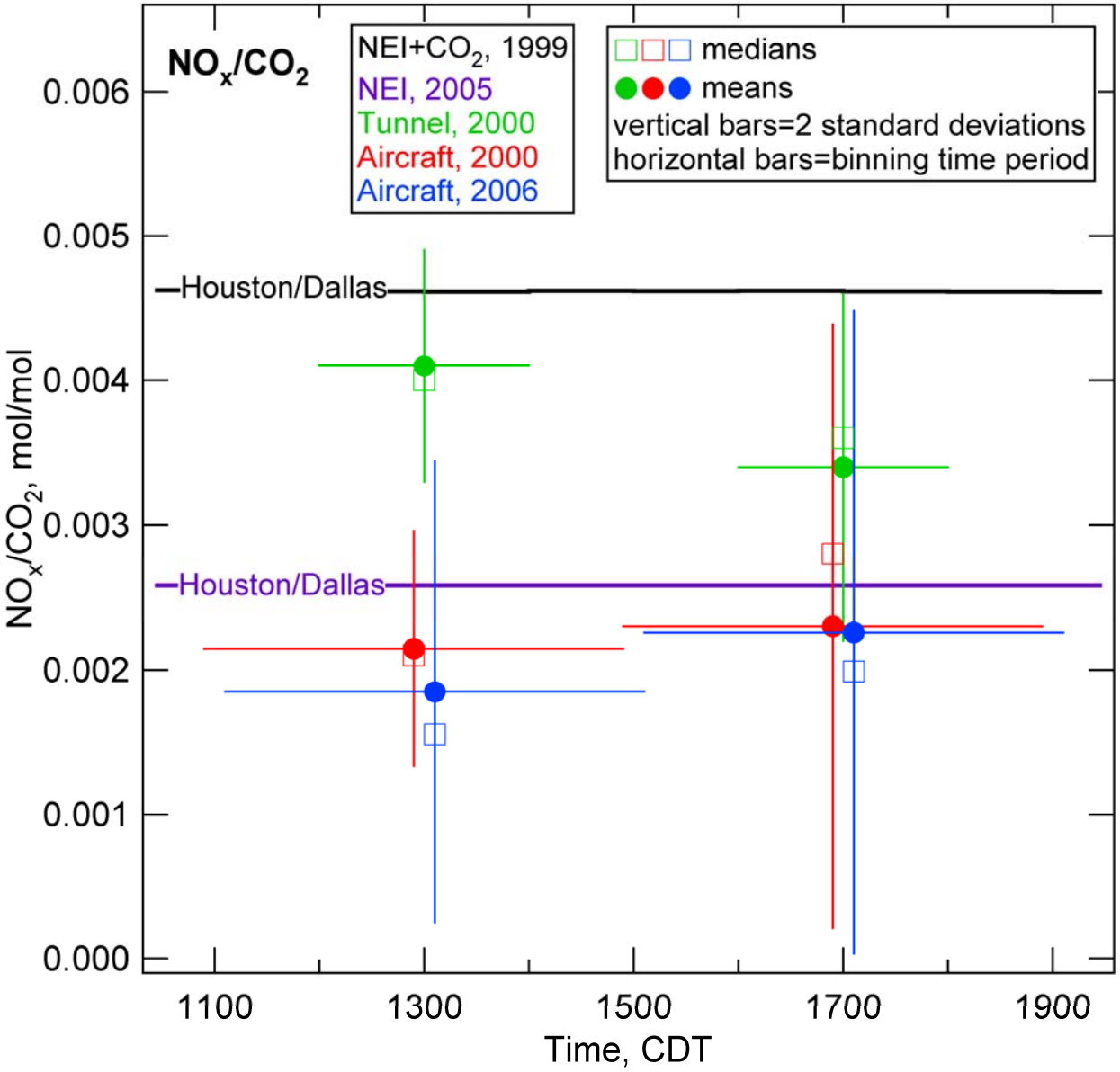
2000

NEI 2005

2000

2006

Mobile NO_x/CO_2 Emission Ratios: Observations & NEI 1999/2005



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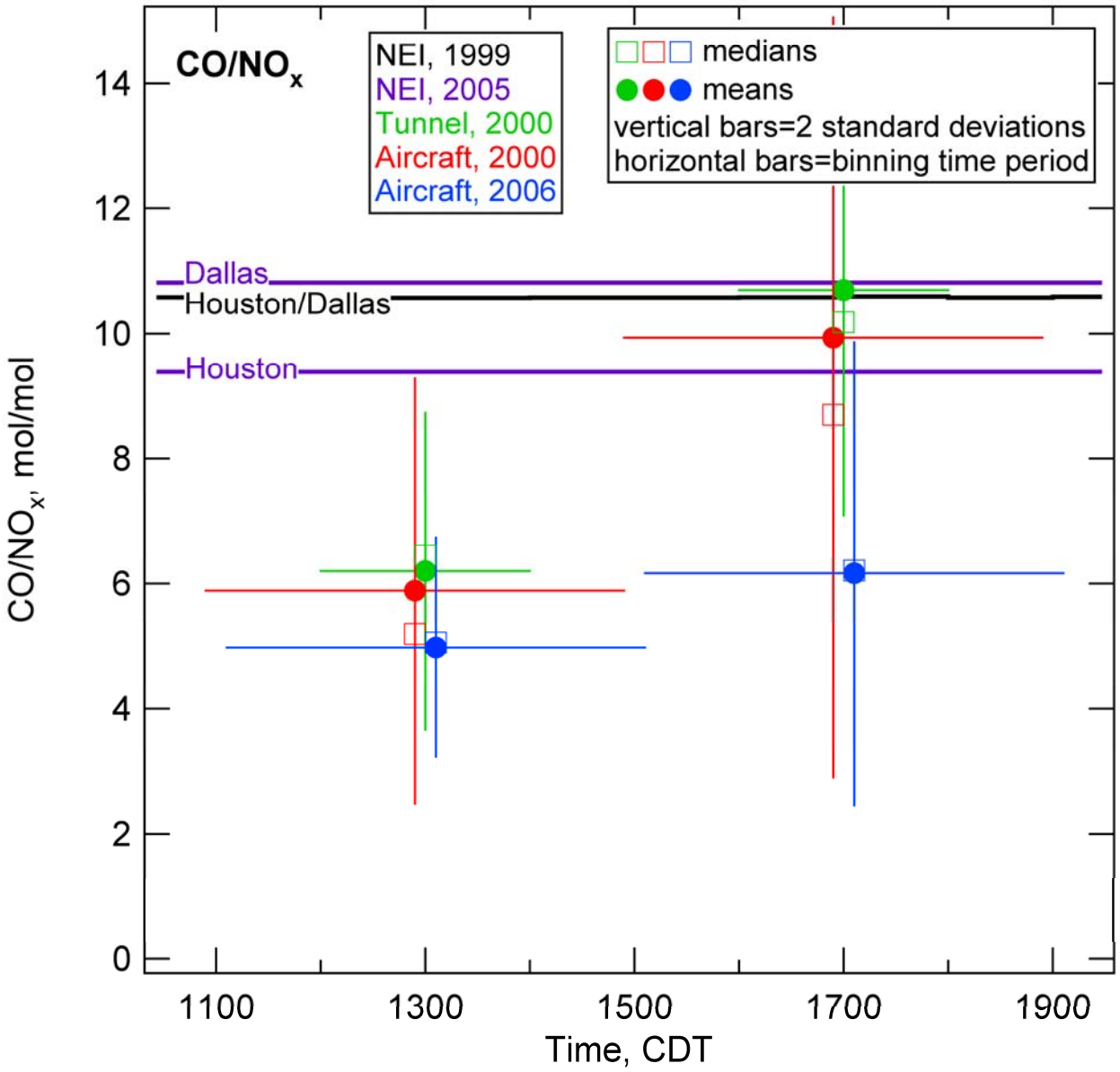


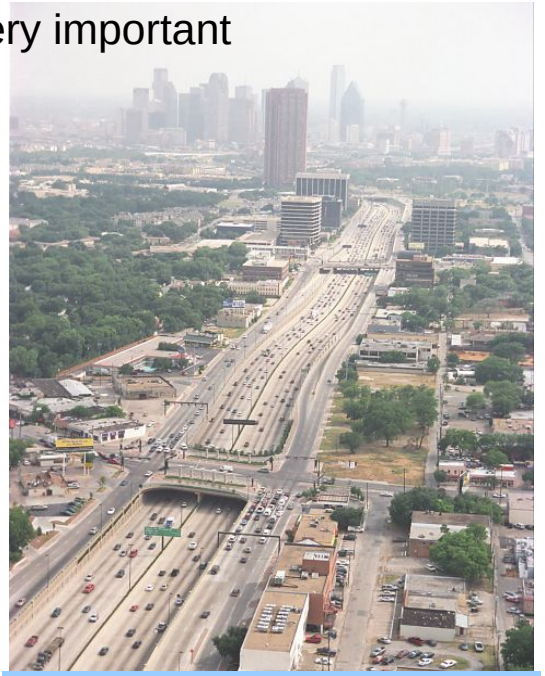
NEI99

NEI 2005

Conclusions

- Atmospheric sampling by aircraft used to estimate mobile source emission ratios in urban areas
- Pollutant ratios to CO_2 normalize emissions by amount of fuel burned: key constraint
- Detect variations between midday and late afternoon rush hour emissions
- Observe decline in mobile CO emissions between 2000 and 2006
- Reasonable comparison of aircraft and tunnel estimates considering different source mixes
- Observed CO emissions are 2-3 times lower than NEI in 2000 and 2006
- NEI 1999 - 2005 CO change similar to 2000 - 2006 observed CO change
- Discrepancies in inventory and observed mobile NO_x emissions amount and trend
- Further analysis of aircraft data in progress: careful interpretation very important

I-45 in Houston (photo from http://www.texasfreeway.com)



US-75 in Dallas
(photo from http://www.texasfreeway.com)