On-Road Vehicle Emissions Summary

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Overview

- *Rapid Science Synthesis questions*
- *Preliminary findings from 31 Oct 2006 version of RSS report*
- *Summary of work presented at this week's Austin meeting*
- *Suggested modifications to RSS preliminary findings*

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

On-Road Vehicle Emissions: RSS Question and Preliminary Finding

(31 Oct 2006 version of report)

Question D: What distribution of anthropogenic and biogenic emissions of ozone and aerosol precursors can be inferred from observations?

Preliminary Finding D2:

•On-road mobile emission inventories developed from MOBILE6 have significant shortcomings.

•MOBILE6 consistently overestimates CO emissions by about a factor of 2.

•It accurately estimated NO_x emissions in the years near 2000, but it indicates decreases in NO_x emissions since then, while ambient data suggests NO_x emissions have actually increased.

•Consequently in 2006, NO_x to VOC emission ratios in urban areas are likely underestimated by current inventories.

RSS Preliminary Findings: Measured & Inventory Mobile Source CO/NO_x

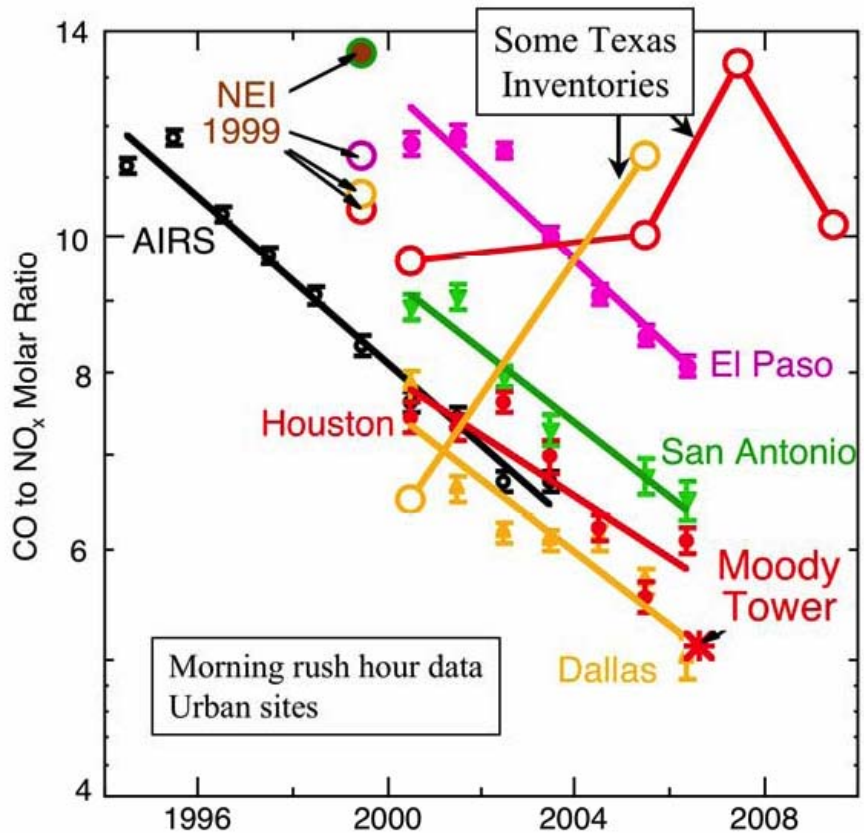


Figure D3. Determination of CO to NOx ratio in Texan on-road mobile emissions from monitoring data (solid symbols) compared to example emission inventories (open symbols) color coded according to urban area. The black symbols are for all stations in the EPA AIRS network. (Data from TCEQ; Lefer et al. - U. Houston)

Ambient Data

- Dallas and Houston routine monitoring and nationwide AIRS CO/NO_x data agree well
- TexAQS 2006 Moody tower CO/NO_x data in good agreement with routine monitors
- Significant differences for El Paso and San Antonio: older vehicle fleets

Inventory Comparison to Observations

- Texas inventories generally overestimate urban/mobile CO/NO_x
- Inventories show no significant temporal decreases in CO/NO_x

RSS Preliminary Findings: Measured & Inventory Mobile Source CO/NO_x

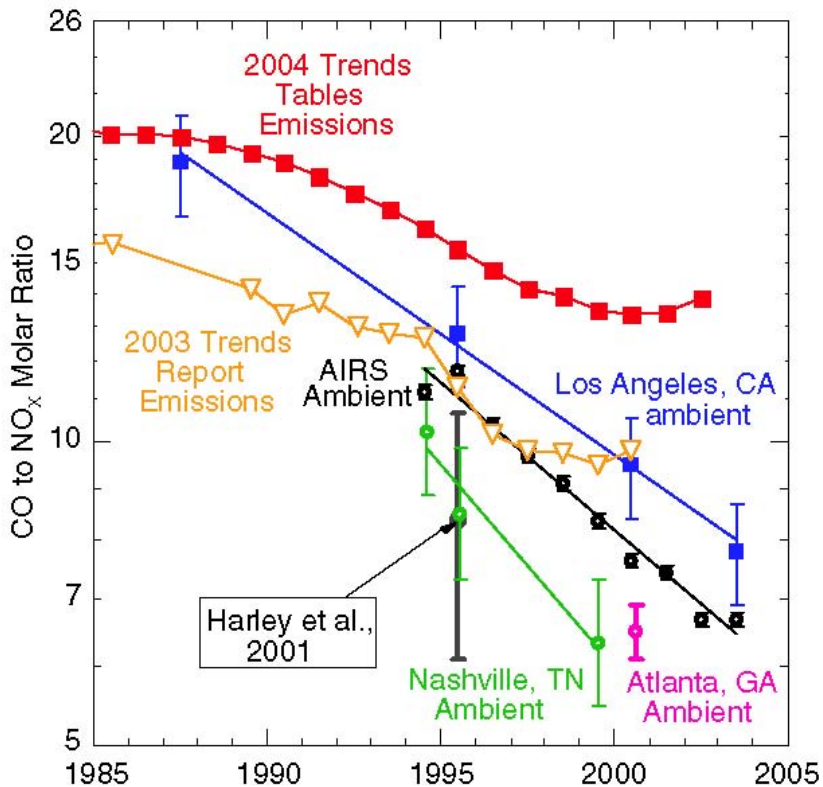


Fig. 3. Semi-log plot of temporal trends of observed urban ambient CO to NO_x ratios compared to ratios from on-road vehicle emission estimates.

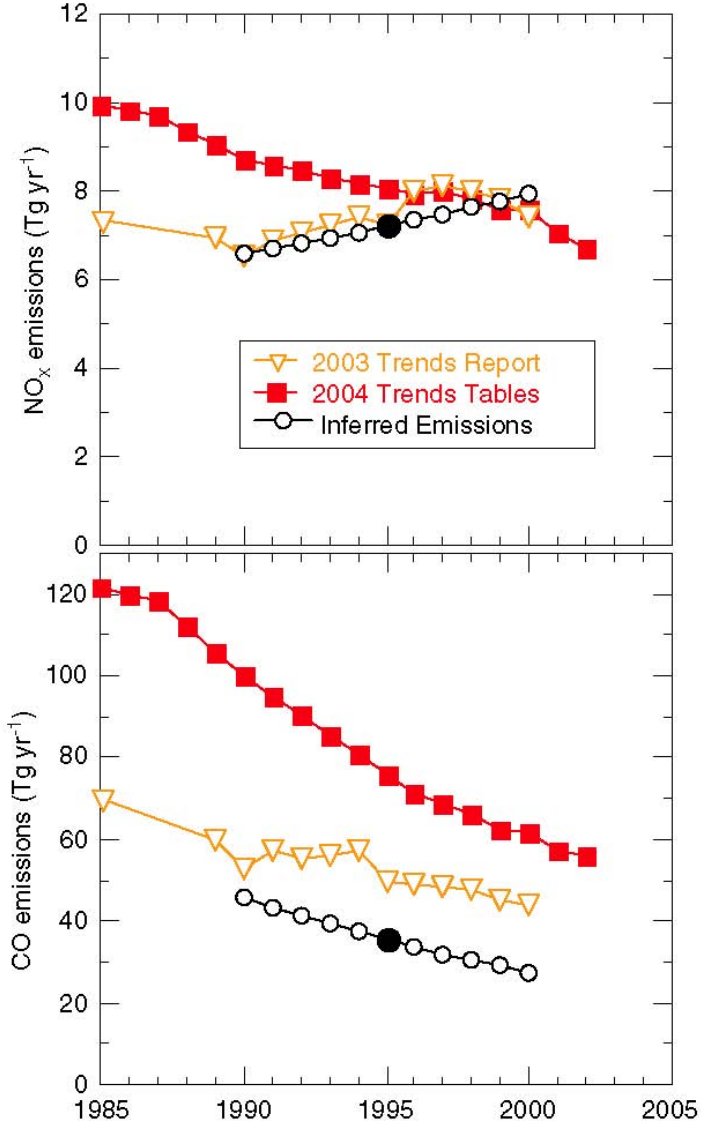


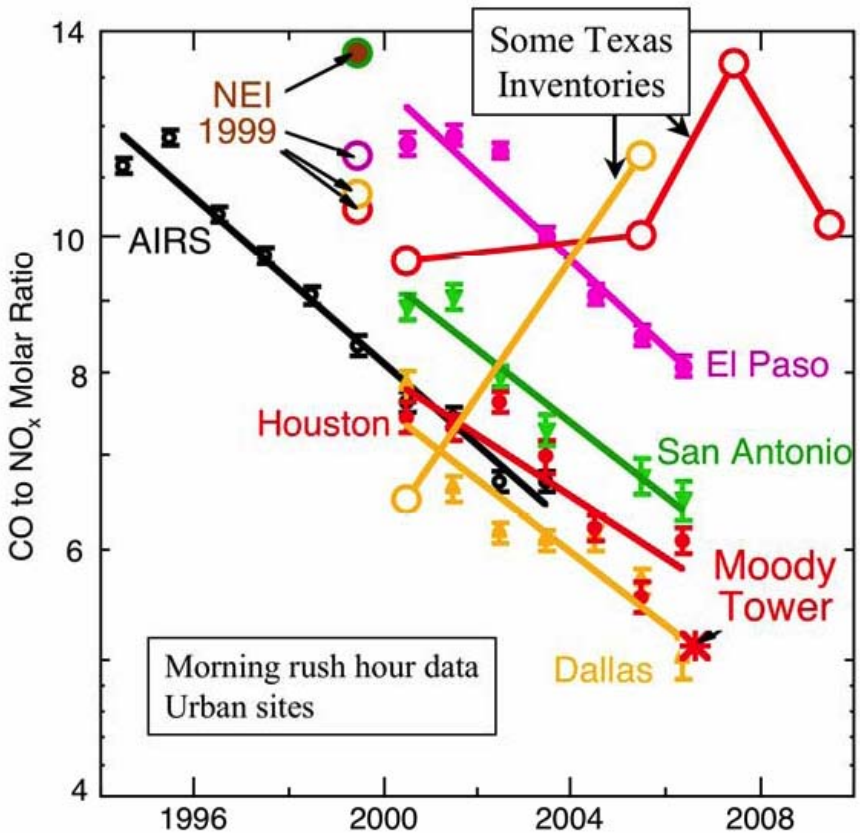
Fig. 6. Temporal trends of national on-road vehicle emissions from the two most recent US inventories in Fig. 1 compared to the emissions inferred from ambient measurements.

Parrish Inventory Evaluation of US Urban Areas

- Rapid decrease (6.6%/yr) in CO/NO_x nationally
  - slower decrease in CO emissions (4.6%/yr)
  - significant increase in NO_x emissions (~ 2%/yr)

Parrish, D. D. (2006) Atmos. Environ. 40, 2288-2300

RSS Preliminary Findings: Measured & Inventory Mobile Source CO/NO_x



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Current Texas Inventory Assessment

- Inventory overestimates mobile source CO/NO_x
  - factor of 2 overestimate in CO emissions
  - underestimate in NO_x emissions

- **In most urban areas, generally dominated by on-road mobile emissions, inventories will underestimate NO_x/CO and NO_x/VOC**

Austin Meeting Presentation (Wednesday, 30 May 2006): Observational Evaluation of Mobile Source Emissions

Greg Frost, Stuart McKeen, Michael Trainer, Ken Aikin,
Jeff Peischl, Tom Ryerson, John Holloway
NOAA ESRL CSD, Boulder, CO
Gabrielle Pétron, Pieter Tans
NOAA ESRL GMD, Boulder, CO
Robert Harley
University of California, Berkeley, CA

Goals of This Study

Use aircraft and tunnel observations from TexAQS 2000 and 2006 to:

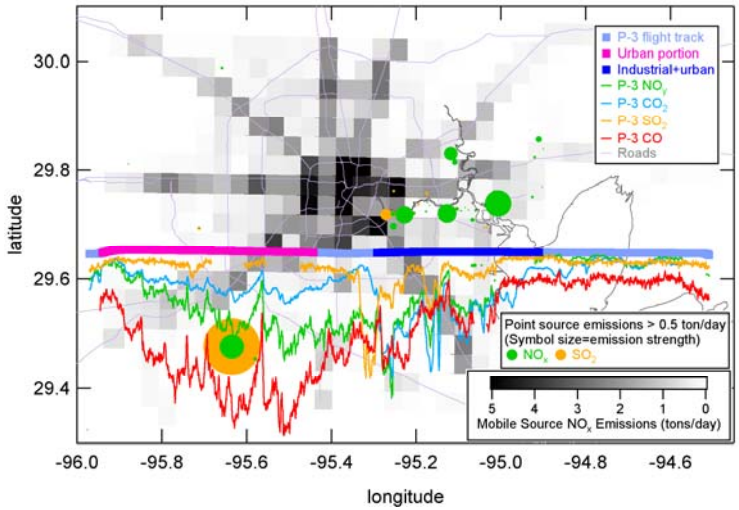
1. *examine urban mobile source emission trends*
2. *evaluate emission inventory*

Summary of Presentation

- *Extract mobile emission ratios from NOAA P-3 aircraft observations*
- *Observed emission ratios in Houston tunnel*
- *Development of multi-pollutant mobile source emission inventory*
- *Comparisons of observed and inventory emission ratios*

Aircraft Observations of Mobile Source Emissions

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

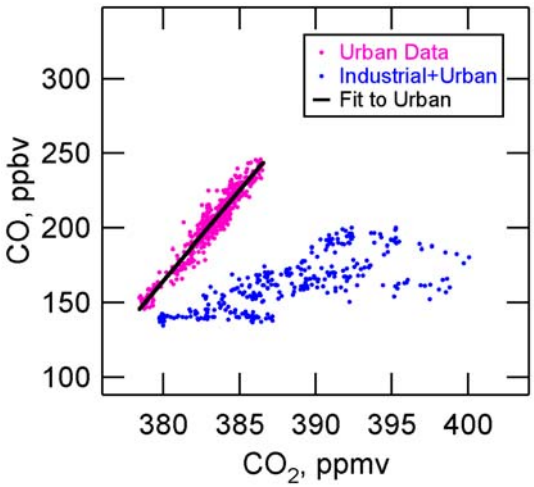


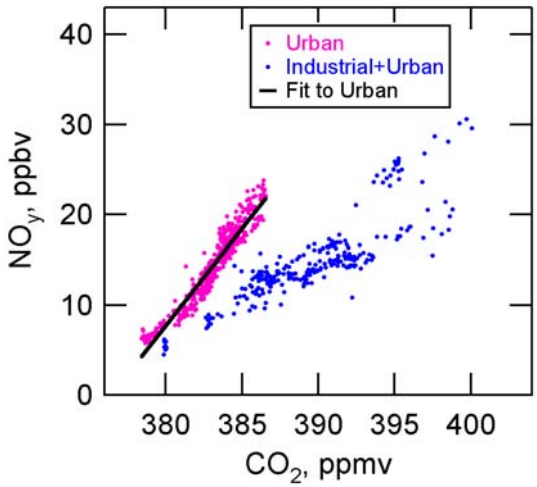
Slopes of Linear Fits
Units = mole/mole
(r = correlation coefficient)

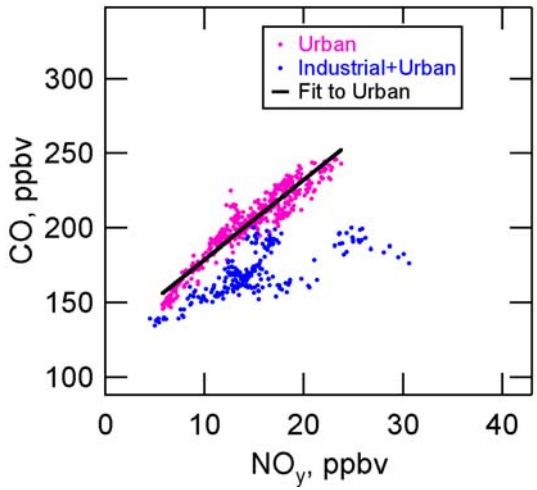
CO/CO_2 = 0.0121 (r = 0.96)

NO_y/CO_2 = 0.00215 (r = 0.96)

CO/NO_y = 5.32 (r = 0.95)







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

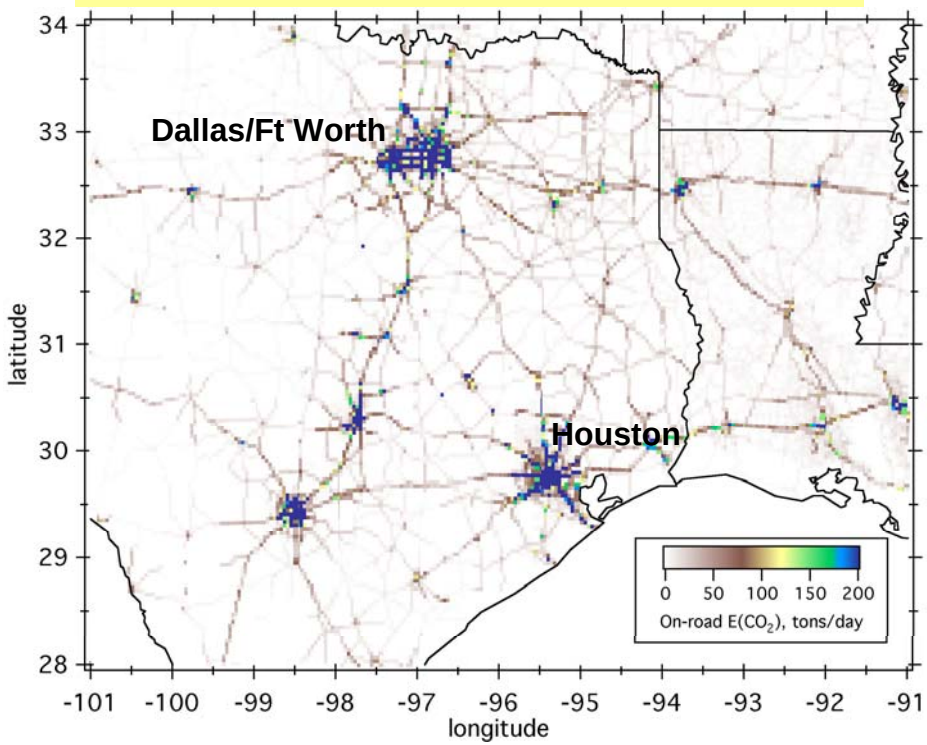
CO, NO_x, & CO_2 emission ratios measured for 2-hour sampling periods
•1200-1400 CDT: higher fraction of heavy-duty diesel vehicles
•1600-1800 CDT: afternoon rush hour, higher fraction of gasoline vehicles

•Note: Largest trucks don't use tunnel and therefore not measured

Multi-Pollutant Emission Inventory for On-road Mobile Sources

- Combine existing data to produce CO_2 and criteria pollutant inventory for fossil fuel combustion
- Criteria pollutant emissions, s□tructure, and grid from EPA 1999 National Emission Inventory (NEI99)
  - ➢NO_x, SO_2, CO, VOCs, NH_3, $PM_{2.5}$, PM_{10}
  - ➢continental US at a horizontal resolution of 4x4 km^2
  - ➢hourly emissions
  - ➢summer ozone season day
- Include CO_2 using on-road fuel use statistics by state (Federal Highway Administration)

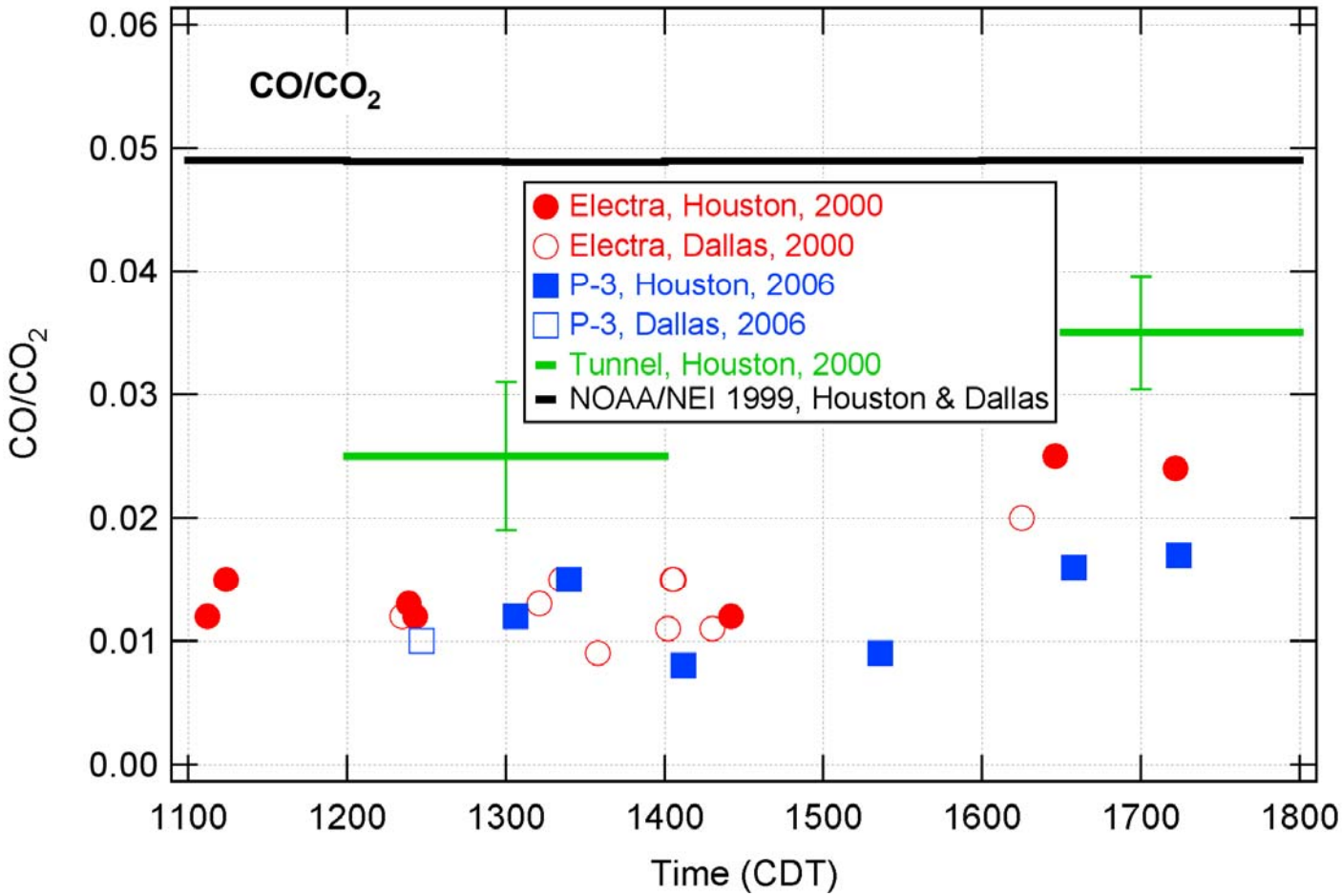
$E(CO_2)$ for On-road Sources in Texas & Louisiana
4x4 km^2 NEI99 Grid, 1999 Summer Daily Average

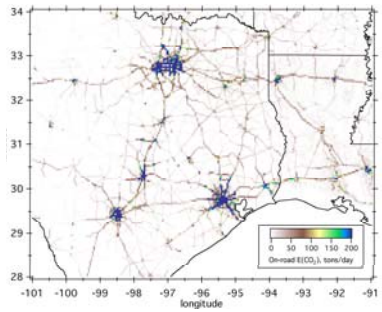


Mobile Emission Estimates from Observations and Inventory

Average Molar Emission Ratios

Weekdays Only





Bars = 2 standard deviations in tunnel ratios

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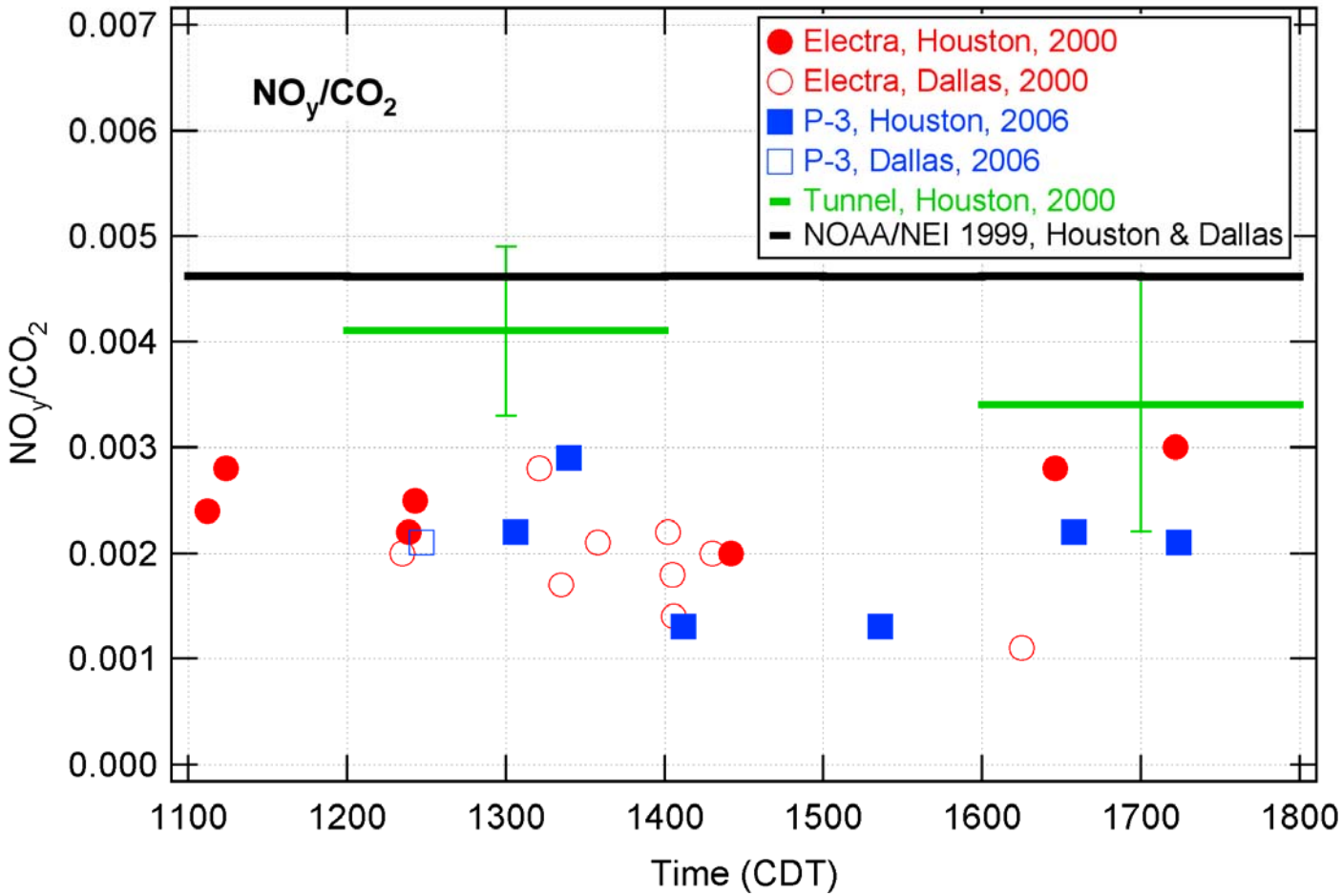

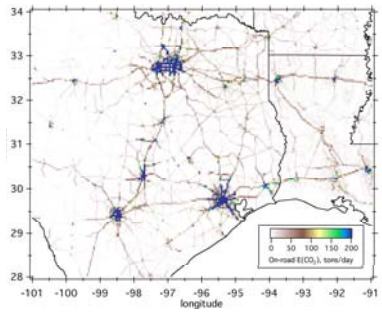

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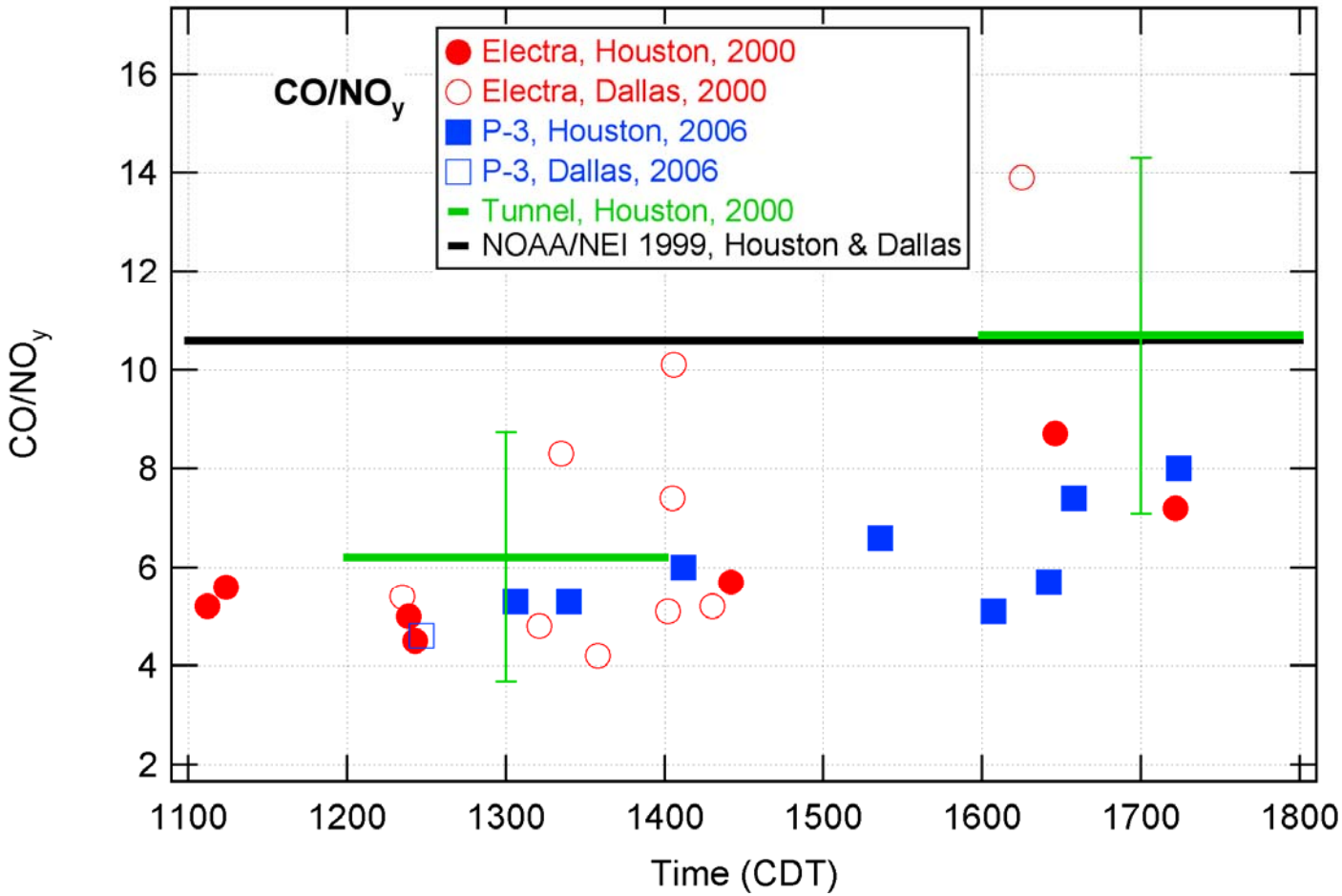

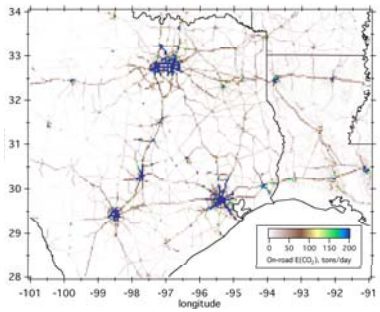

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Preliminary Conclusions from This Study

- Mobile source emission ratios in Houston and Dallas extracted from aircraft observations in 2000 and 2006
  - Houston and Dallas have similar mobile emission ratios
  - Small weekday variations between midday and late afternoon
    - Increase in CO due to higher proportion of gasoline vehicles during rush hour
  - No large changes seen between 2000 and 2006
- Compare 2000 Washburn Tunnel data to P-3 observations
  - Ratios with CO_2 somewhat higher in tunnel than in P-3 data
  - More variation between midday and late afternoon than in P-3 data
    - Rush hour increase in CO and decrease in NO_x
- Compare observations with 1999 emission inventory
  - Inventory CO higher than observations by factor of 2-4
  - Inventory NO_x higher than observations by up to a factor of 2
  - No hourly variation in inventory
- More analysis of TexAQS 2006 P-3 data is needed
- Careful interpretation of P-3 data is crucial
- Information about absolute CO and NO_x emissions obtained by analyzing ratios with CO_2, not just CO/NO_x ratios

Possible Explanations for Discrepancies Seen in This Study

- Tunnel not necessarily same as whole urban area
  - Largest trucks not measured in tunnel
  - ➢ Should see tunnel CO/CO_2 > aircraft CO/CO_2 and tunnel NO_x/CO_2 < aircraft NO_x/CO_2
  - ➢ But: ***both*** tunnel CO/CO_2 and NO_x/CO_2 > corresponding aircraft ratios
- Mobile emissions dominated by a few highly polluting vehicles
- Lots of variability across urban area
  - e.g. *Pokharel et al., Atmos. Environ., 2002:*

  Average CO/CO_2=0.018-0.044 at various Denver sites in summer 2000
- Aircraft sampling mainly in afternoon, while routine monitoring data focus on morning rush hour
- Other sources influencing aircraft observations?
  - "Off-road" mobile sources (trains, shipping, construction, …)
  - Residential sources
  - Small industrial/commercial sources not included in point source EI
- NEI 1999 out of date
  - But see big discrepancies even with 2000 observations
  - Note similarity between NEI99 and Texas 2000 EI
- NEI99 does not contain diurnal fleet variability (David Mobley)
  - ➢ Explains lack of significant diurnal cycle

Changes to RSS Preliminary Findings

Original text of Preliminary Finding D2:

•On-road mobile emission inventories developed from MOBILE6 have significant shortcomings.
•MOBILE6 consistently overestimates CO emissions by about a factor of 2.
•It accurately estimated NO_x emissions in the years near 2000, but it indicates decreases in NO_x emissions since then, while ambient data suggests NO_x emissions have actually increased.
•Consequently in 2006, NO_x to VOC emission ratios in urban areas are likely underestimated by current inventories.

Proposed modifications of Preliminary Finding D2:

•Surface monitors and tower measurements show a clear annual trend in mobile source emissions during the morning rush hour
•Aircraft sampling does not indicate an annual trend in Houston and Dallas mobile source emissions
•Inventory mobile source CO emissions are overestimated by factors of 2-4
•Inventory mobile source NO_x emissions may be overestimated by a factor of 2
•Timely, easy-to-use, well-documented inventories are crucial for these analyses
•Inclusion of CO_2 in mobile source inventories would help in determining the causes of discrepancies with ambient measurements