Observational Evaluation of Mobile Source Emissions

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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

Talk Overview
• 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

I-45 in Houston (photo from http://www.texasfreeway.com)
Aircraft Observations of Mobile Source Emissions

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

Wind Direction

Mobile Source NOx Emissions (tons/day)
Aircraft Observations of Mobile Source Emissions

NOAA P-3 Observations in Houston
Tuesday, 26 September 2006, 1258-1318 CDT
400-500 m altitude
Aircraft Observations of Mobile Source Emissions

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Aircraft Observations of Mobile Source Emissions

NOAA P-3 Observations in Houston
Tuesday, 26 September 2006, 1258-1318 CDT
400-500 m altitude
Aircraft Observations of Mobile Source Emissions

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)

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)

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
US On-road Mobile Source Emission Inventory for CO₂ and Criteria Pollutants

• Combine existing data to produce CO₂ and criteria pollutant inventory for fossil fuel combustion
• Structure and grid from EPA 1999 National Emission Inventory (NEI99)
  ➢ NOₓ, SO₂, CO, VOCs, NH₃, PM₂.₅, PM₁₀
  ➢ horizontal resolution: 4x4 km²
  ➢ 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

1999 Fossil Fuel CO₂ Emissions (percent by mass)


Dallas-Ft Worth metroplex at night from International Space Station (photo from http://www.texasfreeway.com)
Multi-pollutant Inventory Development: National Statistics

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

1999 US On-road Fuel Use = \(1.607 \times 10^{11}\) gal/yr

**Step 2.** 1999 On-road \(\text{CO}_2\) Emissions by State:
Multiply Step 1 by EIA \(E(\text{CO}_2)/\text{fuel volume factors}\)

1999 US On-road \(\text{CO}_2\) Emissions = \(4.55 \times 10^6\) ton/dy

**Step 3.** 1999 On-road \(\text{NO}_x\) Emissions by State:
EPA 1999 National Emission Inventory (NEI99)

1999 US On-road \(\text{NO}_x\) Emissions = \(2.34 \times 10^4\) ton/dy

**Step 4.** 1999 \(\text{CO}_2/\text{NO}_x\) Emission Ratios by State:
Divide Step 2 by Step 3

- Gasoline: \(292\)
- Diesel: \(89\)
- Ethanol: \(195\)

US averages
On-road Mobile CO₂ Emissions on 4-km Grid

Step 5. CO₂ emissions on 4x4 km² grid:
Apply state-level CO₂/NOₓ emission ratios to NEI99 4x4 km² NOₓ emissions
On-road Mobile CO$_2$ Emissions: Regional Detail

Total E(CO$_2$) for On-road Sources in Texas & Louisiana
4x4 km$^2$ Grid, 1999 Summer Daily Average

- Texas
- Louisiana
- Dallas/Ft Worth
- Austin
- Houston
- San Antonio

On-road E(CO$_2$), tons/day

Color scale from 0 to 200 tons/day.
Mobile Emission Estimates from P-3 Observations

Average Molar Emission Ratios
Weekdays Only

![Graph showing CO/CO₂ emission ratios over time for different locations and years.](image-url)
Mobile Emission Estimates from P-3 and Tunnel Observations

Average Molar Emission Ratios

Weekdays Only

Bars = 2 standard deviations in tunnel ratios
Mobile Emission Estimates from Observations and Inventory

*Average Molar Emission Ratios*

*Weekdays Only*

Bars = 2 standard deviations in tunnel ratios
Mobile Emission Estimates from P-3 Observations

Average Molar Emission Ratios
Weekdays Only

![Graph showing NOy/CO2 ratios for different locations and years.](image)
Mobile Emission Estimates from P-3 and Tunnel Observations

**Average Molar Emission Ratios**

*Weekdays Only*

Bars = 2 standard deviations in tunnel ratios
Mobile Emission Estimates from Observations and Inventory

Average Molar Emission Ratios
Weekdays Only

Bars = 2 standard deviations in tunnel ratios
Mobile Emission Estimates from P-3 Observations

Average Molar Emission Ratios
Weekdays Only

CO/NO_y

Time (CDT)
Mobile Emission Estimates from P-3 and Tunnel Observations

Average Molar Emission Ratios
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Bars = 2 standard deviations in tunnel ratios
Mobile Emission Estimates from Observations and Inventory

Average Molar Emission Ratios
Weekdays Only

Bars = 2 standard deviations in tunnel ratios
Preliminary Conclusions

• Extract mobile source emission ratios in Houston and Dallas from P-3 observations in 2000 and 2006
  • 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 CO₂ 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 NOₓ
• Compare observations with 1999 emission inventory
  • Inventory CO higher than observations by factor of 2-4
  • Inventory NOₓ higher than observations by up to a factor of 2
  • No hourly variation in inventory
• More analysis needed of TexAQS 2006 P-3 data
• Careful interpretation of P-3 data is crucial