Measuring CO, CH₄, CO₂ & H₂O in A Single Instrument; Using New CRDS Technology to Characterize Urban Plumes & the Well-Mixed Atmosphere

Gloria Jacobson, Eric Crosson, Chris Rella,
Picarro Inc., 3105 Patrick Henry Drive, Santa Clara California 95054 USA

The World’s Highest Performance and Easiest-to-Use Analyzers
Experiment Motivation

• What information can be gained from “rooftop” (10m or lower) measurements made in dense urban settings?

• In particular,
  a) Do nearby sources (e.g., vehicles) dominate the measurements?
  b) Can you partition anthropogenic and biogenic emissions of CO$_2$ using measurements of CO?
  c) Can you quantify source locations and/or temporal behavior?
Experimental Set Up

4 Species Analyzer
CO, CO₂, CH₄, H₂O

H1 (32 ft)
H2 (22 ft)
H3 (10 ft)

Reference Cylinder

Picarro Flagpole
4- Species Analyzer

- Measures concentrations of CO, CO$_2$, CH$_4$, & H$_2$O
- Measures all 4 species w/in 5 seconds
- Meets precision spec (1-sigma of 5 min avg)
  - CO $< 2$ ppb
  - CO$_2$ $< 50$ ppb
  - CH$_4$ $< 0.7$ ppb
  - H$_2$O $< 50$ ppm
- Automatically corrects & reports dry mol fraction
- Instrument was calibrated once prior to experiment
Zoom In on Time Series

Sampling Scheme

1. Bottle (6 min)
2. H1 (4 min)
3. H2 (4 min)
4. H3 (4 min)
5. H1 (4 min)
6. H2 (4 min)
7. H3 (4 min)
8. Repeat

Total Cycle = 30 min
Bottle Data – Instrument Stability

- Single bottle measured 6 minutes every ½ hour
- Used only for quality control – no calibration changes
Instrument Validation Testing

Instrument Calibration

- AL5001: 1 every 2 hrs
- G2401: Once / 10 days

*Data courtesy of Christoph Zellweger, EMPA*
Drive-by Events

- Raw data from all heights is shown.
- CO/CO₂ plots of individual CO peaks have distinct signatures.
- Looks like single and multi-car drive-bys are captured.
Vertical Profile of Median Data

- High
- Medium
- Low

**Variables:**
- CO₂ (ppm)
- CO (ppm)
- CH₄ (ppm)

**Legend:**
- Valve state

**Axes:**
- Local Time (days)

**Graphs:**
- CO₂, CO, CH₄ concentration over time.
Well-Mixed During Daytime

- Small vertical gradient of about 0.1 ppm / meter in CO$_2$ observed at nighttime
- Overall difference between top and bottom std. dev = 1.6 ppm
- Daytime CO$_2$ std. dev = 0.7 ppm
- Daytime CO std. dev = 7 ppb
Do The Time Signatures Make Sense?

- CO signatures from transit convolved with atmospheric transport
- Wind speed accounts for some of the difference
- PBL and direction may account for the rest…

Wind data: [www.wunderground.com](http://www.wunderground.com) @ SJC Airport
Emissions Sources

- Daytime should have clearest transit signal - high traffic and relatively low biogenic activity due to cold, 50 F temps and overcast

- Nighttime has mixed transit and biogenic signature
Does This Make Sense?

- Bishop and Steadman (Dec 2007)

1 gCO/kg fuel = 0.5 ppb CO / ppm CO₂
1. Calc CO\textsubscript{2} ff using CO / ppm CO\textsubscript{2} = 7.1 ppb and background values of CO = 110 ppb & CO\textsubscript{2} = 390 ppm

2. Subtract CO\textsubscript{2} ff from total to get CO\textsubscript{2} bio
Methane

CH4 ‘enhancement’ strongly dependent on wind direction

Strong source to the NW (known sources: active and inactive landfills, wetlands)

Uses background of 1.86 ppm for CH₄ and 390 ppm for CO₂
Next Steps

- Longer term data to confirm traffic signatures
  - Add traffic volume data

- Use simple inverse modeling to locate emission sources
  - Add PBL

- Add a web cam for verification of traffic events
– Thank You! –
Precision & Drift Testing

**CO**
- DRIFT (PPB)
- Avg Drift (ppb)
- PRECISION (PPB)
- Avg Precision (ppb)

**CO₂**

**CH₄**

**H₂O**
- 1-sigma (5 min avg over 24 hrs)
Flight Simulation Test

Drift specs with changing pressure up to 1.4 Torr/second, peak to peak of 30 sec avg

- CO: < 50 ppb
- CO₂: < 700 ppb
- CH₄: < 7.5 ppb

- Analyzer in hyperbaric chamber with pressure ramps (blue)
- Measure constant concentration gas at chamber pressure 30 second avg shown
Using CO to measure $\text{CO}_2^{\text{ff}}$

- CO is a better proxy for fossil fuel $\text{CO}_2$ than excess $\text{CO}_2$