Trace Gas Observations from Small Research Aircraft over the Mid Atlantic States and Hebei, China

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Outline

Methods evaluation.
Greenhouse gases in Baltimore/Washington area & Marcellus upwind.
Preliminary results form New York City.
Results for CFCs over Hebei, China.
UMD Cessna 402B Research Aircraft

**Heavy lifting: Xinrong Ren**

- **GPS Position** (Lat, Long, Altitude)
- **Met** (T, RH, P, wind speed/direction)
- **Trace gases:**
  - $O_3$: UV Absorption, modified TECO
  - $SO_2$: Pulsed Fluorescence, modified TECO
  - $CH_4/CO_2/CO/H_2O$: Cavity Ringdown, Picarro
  - $NO_2$: Cavity Ring Down, Los Gatos
  - NO: Chemiluminescence, modified TECO
  - HCHO: Fluorescence, NASA
  - VOCs: whole air samples

- **Aerosol Optical Properties:**
  - Scattering: $b_{scat}$ (@450, 550, 700 nm), Nephelometer
  - Absorption: $b_{ap}$ (565 nm), PSAP
  - Black Carbon: Aethalometer (370-950 nm)
What’s our precision? Cessna Test Flight on 2/14/2019

**Objectives:** Picarro & wind calibration.

Longitude (°) | Latitude (°) | Altitude (ft) | Cessna WS (m/s)
---|---|---|---
-77 | 38.4 | 0 | 0
-76.5 | 38.5 | 1000 | 2
-76 | 38.6 | 2000 | 4

Longitude (°) | Cessna WS (m/s)
---|---
-77 | 6
-76.5 | 8
-76 | 10
Feed the Picarro analyzer compressed air with constant $[CO_2]$, $[CH_4]$, and $[CO]$. 

Main Sample Line (~10 L/min) 

Breathing Air 

~ 1.0 L/min 

~ 0.4 L/min 

Filter 

Pump 

Picarro G2401-m 

$CO_2/CH_4/CO/H_2O$ Analyzer 

NIST support
Picarro GHG Measurement Altitude Test (1-sec data ± σ)

\[
\text{[CO}_2\text{]} = 517.19 \pm 0.03 \text{ ppm}
\]

\[
\text{[CH}_4\text{]} = 2529.3 \pm 0.3 \text{ ppb}
\]

\[
\text{[CO]} = 472.8 \pm 4.3 \text{ ppb}
\]
Picarro GHG Measurement Altitude Test
From 8000 ft. (2.4km) to ground before landing

\[
\begin{align*}
\text{[CO}_2\text{]} &= 517.20 \pm 0.03 \text{ ppm} \\
\text{[CH}_4\text{]} &= 2529.5 \pm 0.3 \text{ ppb} \\
\text{[CO]} &= 472.2 \pm 4.2 \text{ ppb}
\end{align*}
\]
We replaced a bad wind system.
Measurements from UMD Cessna over a Profiler
Published results so far, methane.

- CH$_4$ emissions from Baltimore-Washington area 8.66 ± 4.17 kg/s (2015) and 9.14 ± 4.49 kg/s (2016) or about 0.28 Tg/yr (Ren et al. JGR 2018). Compare to 0.84 Tg/yr for 5 cities (Plant et al. later today).

- CH$_4$ emissions from SW Marcellus 21.2 kg/s (0.66Tg/yr); 28% from O&NG (Ren et al. JGR 2019).

- CH$_4$ emissions from SW Marcellus ~0.5% of production; ratioing to C$_2$H$_6$ (Barkley et al. GRL 2019).

- Methane leak rates <1% of NG production, but total emissions much higher than inventories.
Published & submitted results so far, CO₂

- Aircraft mass balance emissions fossil CO₂ = 2.3±0.5 TgC/mo in Baltimore-Washington in February 2015 based on 7 aircraft flights.
- 4 bottom-up inventories suggest fossil 2.2±0.3 TgC/mo. (Ahn et al., in prep 2019).
- Model inversion total CO₂ = 2.5±0.7 TgC (Lopez-Coto et al. submitted 2019).
Correlation among CO, CO$_2$ and CH$_4$ over NYC

Afternoon Flight on May 18, 2017

Observed CO and CO$_2$, CH$_4$ and CO$_2$ as well as CH$_4$ and CO are well correlated.

CO and CO$_2$ emissions look good, but CH$_4$ emissions may be underestimated by a factor of 2-3.
Air Chemistry Research in Asia (ARIAs)

- Peking University, Beijing Normal University, Hebei Provincial weather service, and University of Maryland
- NSF funded
- May-June 2016 in Hebei Province
- 11 research flights, ~3 hours each
- Purpose: Lagrangian study of trace gases and aerosols; complement to NASA KORUS-AQ
<table>
<thead>
<tr>
<th></th>
<th>Background&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>ARIAs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pptv</td>
<td>Mean (Median), pptv</td>
</tr>
<tr>
<td>CFC-11</td>
<td>231</td>
<td>370 (280)</td>
</tr>
<tr>
<td>CFC-12</td>
<td>512</td>
<td>580 (560)</td>
</tr>
<tr>
<td>HCFC-22</td>
<td>245</td>
<td>420 (370)</td>
</tr>
<tr>
<td>CCl&lt;sub&gt;4&lt;/sub&gt;</td>
<td>82</td>
<td>89 (89)</td>
</tr>
<tr>
<td>CFC-113</td>
<td>73</td>
<td>80 (80)</td>
</tr>
<tr>
<td>CFC-114</td>
<td>16</td>
<td>40 (20)</td>
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</tbody>
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<sup>a</sup> Mauna Loa May 2016 Mean

<sup>b</sup> CONTRAST, 25<sup>th</sup> percentile below 1500 m (Jan-Feb. 2014)
Several samples below background:
- 20% uncertainty
- Stratospheric intrusions ($O_3 = 71$ ppbv)
- Elevated CFC-11 and CFC-12 correlates to >120 pptv $CCl_4$
Summary

• Elevated and highly variable CFC-11 values during ARIAs.
• Origins in Shandong and Inner Mongolia
• Strong correlations CFC-11, CFC-12, and CCl₄.
• Suggestive of new CFC production and foam blowing applications.
• Chinese emissions had an influence on downwind regions such as Korea.