ACE-FTS observations of short-lived reactive species in the UTLS

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Key Questions

1. Behavior of short-lived species in the UTLS region measured by ACE-FTS.
   - Influence of sources, convection and transport
   - Asian vs. North American monsoons

2. Comparison of ACE-FTS measurements with in-situ measurements and global model outputs. How much can we believe ACE-FTS?
Asian summer monsoon

1. Emission
2. Convection
3. Transport

[174x499] [Park et al., 2009]
Asian vs. N. American monsoons

**Asian** CO max

**CO** (Jul-Aug) 100 hPa

**North America** H\textsubscript{2}O max

ACE-FTS H\textsubscript{2}O (JJA) 16.5 km

[Park et al., 2007]

[Randel et al., 2012]

(white contours – convection)
**OVOCs (Oxygenated VOCs)**

<table>
<thead>
<tr>
<th>species</th>
<th>sources</th>
<th>sinks</th>
<th>lifetimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>BB, NMHCs</td>
<td>OH</td>
<td>2 months</td>
</tr>
<tr>
<td>CH$_3$OH*</td>
<td>BB, <strong>Biogenic</strong></td>
<td>OH, dry/wet deposition</td>
<td>5-10 days</td>
</tr>
<tr>
<td>HCOOH</td>
<td>BB, <strong>Biog</strong>, NMHCs</td>
<td>OH</td>
<td>3-4 days</td>
</tr>
<tr>
<td>H$_2$CO</td>
<td>BB, NMHCs</td>
<td></td>
<td>&lt; 2 days</td>
</tr>
</tbody>
</table>

**CH$_3$OH (methanol)**

- the most abundant non-methane VOC
- source of CO and H$_2$CO
- precursor of tropospheric O$_3$
ACE-FTS v3.5 (2004-2013)

- Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) is a high spectral resolution infrared Fourier transform spectrometer on SCISAT-1.
- ACE-FTS measures atmospheric absorption spectra (750-4400 cm\(^{-1}\)) using solar occultation technique.
- CO, HCN, C\(_2\)H\(_6\), C\(_2\)H\(_2\), CH\(_3\)OH, HCOOH, H\(_2\)O\(_2\), H\(_2\)CO, ...
- Latitude coverage (1 year)
  - Tropical sampling during NH summer ~ Aug
  - Aug 2012
**CO - Vertical Structures**

ACE-FTS CO averaged over Asia vs. N. America

**CO enhancement**: 12-17 km (Asian monsoon)

(Park et al., 2007)
ACE-FTS – Lon vs. Lat (JJA)

short-lived species

HCOOH 14.5 km

Max over Asian monsoon

CH$_3$OH 15.5 km

Enhancement over N. American monsoon

H$_2$CO 12.5 km
ACE-FTS - Average Profiles

Asian vs. N. American Monsoons

**H₂CO**
- Asia vs N. America

**HCOOH**
- Asia vs N. America

**CH₃OH**
- Asia vs N. America

τ < 2 days

τ = 3-4 days

τ = 5-10 days

CH₃OH enhancement over N. America (10-12 km)

Do we understand this?
CO vs. CH$_3$OH (JJA)

Asia
- high CH$_3$OH
- high CO

N. America
- high CH$_3$OH

[Park et al., 2007]

Asia (16.5 km)

N. America (13.5 km)

CO (ppbv) vs. CH$_3$OH (ppbv)

High CO/High CH$_3$OH

High CH$_3$OH
Identifying Sources

Biogenic Sources

\[ \Delta \chi / \Delta \text{CO} = 0.1 \]

CO – no biogenic sources

Large increase in \( \chi \)

\[ \Delta \chi / \Delta \text{CO} = 0.001 \]

BB

CO – large BB sources

Linear correlation with \( \chi \)

(Example – \( \text{C}_2\text{H}_2 \))
$\text{CO vs. HCOOH (JJA)}$

**Asia (14.5 km)**
- High CO/High HCOOH
  - $\Delta \chi / \Delta \text{CO} = 0.1$

**N. America (13.5 km)**
- $\text{HCOOH}$ enhancement $\sim 13.5 \text{ km}$
  - $\text{HCOOH}$ enhancement is similar to CH$_3$OH
  - $\Delta \chi / \Delta \text{CO} = 0.001$

High CO/High HCOOH (BB + transport)
**CO vs. H$_2$CO (JJA)**

- **Asia (13.5 km)**
  - High CO/High H$_2$CO
  - H$_2$CO enhancement ~ 12.5 km (similar to CH$_3$OH)

- **N. America (12.5 km)**
ACE-FTS vs. *In-situ* measurements

**NASA SEAC⁴RS** (Aug-Sep 2013)

**DC-8 measurements**

**CH₃OH** (PTRMS)

**C₂H₂** (WAS)

**CH₃OH** has a large biogenic sources over **N. America** in summer
CO vs. CH$_3$OH & C$_2$H$_2$

**SEAC$^4$RS**
- Upper Trop. (p < 400 hPa)
- Aug 2013

**ACE-FTS**
- Upper Trop. (13.5 km)
- JJA (N. Am)
**CAM-chem simulations**  (Aug 2013)

**CAM-chem** (Community Atmosphere Model with Chemistry) component of the NCAR Community Earth System Model (CESM) and is used for simulations of global tropospheric and stratospheric composition [Lamarque et al., 2012]

**GEOS-5**, resolution - 1.9° x 2.5°, 56 levels  
**FINN** (v1.5) BB emission (1x1 km) [Wiedinmyer et al., 2011]  
Dry deposition and biogenic emissions [CLM]

[Diagram showing the Coupler connecting Atmosphere Model version 4, Land Model, Ocean Model, and Sea-ice Model]  
[Lamarque et al., 2012]
CAM-chem (Aug 2013)

**CO**

150 hPa

CAM-chem CO

**CH₃OH**

CAM-chem CH₃OH

Biogenic Emissions
CAM-chem vs. ACE-FTS

150 hPa

CAM-chem CO

max

ACE-FTS CO

max

14.5 km

CAM-chem CH$_3$OH

max

ACE-FTS CH$_3$OH

max

weaker max
ACE-FTS – Zonal Mean (JJA)

Black - all sources
Red – biogenic
Green – anthro
Blue - BB

**Emissions**

**N. America**
- lon: 180°W-40°W
- lat: 20°N-80°N

**Asia**
- lon: 50°E-150°E
- lat: 20°S-40°N

[Dufour et al., 2007]

**CH₃OH** – Dominant biogenic emissions (max – summer)

**ACE-FTS CH₃OH**

**ACE-FTS CO**
Asia vs. American Monsoons

[CH$_3$OH/CO Ratio]

Asian Monsoon

N. American Monsoon?

[Park et al., 2008]
CAM-chem - Asia vs. American

CAM-chem $\text{CH}_3\text{OH}$

CAM-chem $\text{HCOOH}$ show max near $\sim 150$ hPa
Convective Signal in NH Winter?

ACE-FTS climatology (DJF)

ACE-FTS CO

Lack of max (SH)

ACE-FTS CH$_3$OH

**Max** (biogenic sources + convection over Australia)
Convection over S. America – \( \text{CH}_3\text{OH} \)

**ACE-FTS \( \text{CH}_3\text{OH} \) \( 14.5 \text{ km} \)**

**ACE-FTS \( \text{CO} \)**

**CO vs. \( \text{CH}_3\text{OH} \) \( 14.5 \text{ km} \)**

**CH\(_3\)OH** high over S. America (convection + sources)

Color: \(-30<\text{lat}<0, \ 240<\text{lon}<360\)
**CO vs. CH$_3$OH**  
(Pacific, NH Winter)

**CONTRAST** (Jan-Feb, 2014)

ACE-FTS shows general agreement with CONTRAST

(20S-20N, 10.5-18.5 km)

[Pan et al., 2015]
1. Short-lived species (HCOOH, H$_2$O, CH$_3$OH) measured by ACE-FTS show similar behavior with CO over the Asian monsoon region.

2. However, those species show relative enhancement over the N. American monsoon region, which is different from CO.

3. Different sources (e.g., biogenic) may contribute enhancement in CH$_3$OH over N. America with possible link to local convection.

4. Comparison of ACE-FTS with in-situ measurements and CAM-chem simulations suggests positive outlook.