Ethane rise associated with North American oil and gas exploitation


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1. **Reversal of long-term ethane trends**
2. **Observed ethane increase over North America**
3. **Ethane emissions from bottom-up inventory**
4. **Top-down emissions from GOSAT methane**
1. Reversal of long-term ethane trends

- Atmospheric ethane abundance has been declining in the -1 to -2.7 %/yr range since the mid-1980s

- Global emissions dropped from 14.3 to 11.3 Tg/yr over 1984-2010 (Simpson et al., *Nature*, 2012)

=> primarily due to reduced oil and gas fugitive emissions and to pollution abatement measures

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**Long-term ethane evolution in the EU atmosphere**

- $C_2H_6$ surface concentrations from air sampling of the UCI global trace gas monitoring network
- $C_2H_6$ total column time series from FTIR observations at Jungfraujoch (Swiss Alps)

*Franco et al., JQSRT, 2015*
*ACE Science Team Meeting, University of Waterloo, May 2016*
1. Reversal of long-term ethane trends

- But a reversal in the long-term decline of ethane has been detected around 2009 in the Jungfraujoch FTIR time series.

- ...as well as a sharp increase (5 %/yr) of the atmospheric ethane burden from 2009 onwards.

=> It has been suggested that enhanced emissions associated with intense hydraulic fracturing and shale gas operations in North America are affecting Europe.

Franco et al., JQSRT, 2015
1. Reversal of long-term ethane trends

- Simultaneously, large hydrocarbon increases related to oil and gas industries have been detected over North American regions where the drilling productivity began to grow rapidly after 2009

=> this confirmed the observations made in EU

Distribution of active wells and shale gas plays

Franco et al., ERL, 2016

Vinciguerra et al., Atm. Chem., 2015

R² = 0.82

Marcellus Shale production

C₂H₆/TNMOC ratio

PAMS measurements at Essex, MD, located downwind from the giant Marcellus Shale play (WV, PA and NY)
1. Reversal of long-term ethane trends

- The ethane upturn and its sharp increase since 2009 can also be derived from ACE-FTS solar occultation observations over North America.

**C$_2$H$_6$** from ACE-FTS (15 - 88° N, 50 - 175° W)

Rate of change relative 2004.0

-1.75 ± 1.30 % yr$^{-1}$

Rate of change relative to 2009.0

9.40 ± 3.21 % yr$^{-1}$

*Preliminary results...*
Research objectives

• To characterize the recent $\text{C}_2\text{H}_6$ evolution over North America using ground-based NDACC-FTIR and PARIS-IR measurements:
  
  ✓ 5 sites involved (Eureka, Thule, Toronto, Boulder and Mauna Loa)
  ✓ consistent retrievals (microwindows, a priori, covariance profile, improved spectroscopy... )

• To estimate the missing anthropogenic $\text{C}_2\text{H}_6$ emissions from the most current bottom-up inventory, needed to:
  
  ✓ reconcile FTS measurements and model results
  ✓ reproduce the observed $\text{C}_2\text{H}_6$ increases

• To confirm the impact of increasing oil and gas activities by an independent model simulation implementing spatially resolved top-down emissions of ethane
2. Observed ethane increase over North America

- Slow decline of the $\text{C}_2\text{H}_6$ total columns between $-1.0$ and $-1.5\ \%$/yr prior to 2009, with consistent rates within the different latitudes.

- Reversal around 2009 and growth rates of $\sim 5\ \%$/yr at mid-latitudes and of $\sim 3\ \%$/yr at remote sites.

Franco et al., ERL, 2016

**=> Very consistent results from FTIR and PARIS-IR**
3. Ethane emissions from bottom-up inventory

Model simulations

- CHAM-chem simulation of ethane over 2003-2014, implementing the bottom-up anthropogenic inventory HTAP2

- \( \text{C}_2\text{H}_6 \) emissions from the oil and gas sector represent up to 80% of the total anthropogenic \( \text{C}_2\text{H}_6 \) emissions over North America

- The model underestimates the observed \( \text{C}_2\text{H}_6 \) abundances and does not reproduce the recent increase

\[ \Rightarrow \text{Doubling global emissions is required to reconcile the simulations and the observations prior to 2009} \]
3. Ethane emissions from bottom-up inventory

- An additional increase of the North American anthropogenic emissions (beyond the previous doubling emissions) is required to simulate the recent C$_2$H$_6$ rise over 2009-2014.

- ... assuming that the missing emissions during this period resulted from the recent increase in oil and gas extraction in North America.

 Franco et al., ERL, 2016

\[ \Rightarrow \text{Increase of the North American anthropogenic C}_2\text{H}_6 \text{ emissions by 75\% (from 1.6 Tg/yr in 2008 to 2.8 Tg/yr in 2014)} \]
New North American top-down emissions of ethane using GEOS-Chem

- Based on CH$_4$ fluxes inferred from 50 x 50 km GOSAT measurements (Turner et al., *ACP*, 2015) and subsequently evaluated by surface and aircraft data
- By applying C$_2$H$_6$/CH$_4$ emission ratios to satellite-derived CH$_4$ emissions for the oil and natural gas, biofuel consumption and biomass burning categories

Preliminary results...

GEOS-Chem C$_2$H$_6$ surface concentration for December 2010, derived from GOSAT CH$_4$

December 2010 absolute difference in surface C$_2$H$_6$ (ppbC) for a simulation using emission ratios to CH$_4$ vs. default emission inventories

Tzompa-Sosa et al., in preparation
4. Top-down emissions from GOSAT methane

Comparison between FTIR and GEOS-Chem implementing new top-down emissions

- Good agreement at the mid-latitude sites (close to regions with high drilling productivity)
- High-bias of summertime ethane at remote sites (too low OH levels in the model)

Franco et al., ERL, 2016
4. Top-down emissions from GOSAT methane

- Good agreement between the inventory-based (1.9 Tg/yr) and GOSAT-derived (1.8 Tg/yr) ethane emissions

- ... and the top-down approach allows to allocate the ethane emissions on the basis of measurements

Annual ethane emissions from North America

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<tr>
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<tbody>
<tr>
<td>Globe—all sectors</td>
<td>9.7–10.2</td>
<td>17.3 17.9 18.7</td>
<td>13.2</td>
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<td>Globe—anthropogenic</td>
<td>7.5</td>
<td>15.0 15.3 16.2</td>
<td>10.5</td>
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<tr>
<td>Globe—biomass burning</td>
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<td>1.9 2.2 2.2</td>
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<td>Globe—biogenic</td>
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<td>0.4 0.4 0.4</td>
<td>Not included</td>
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<tr>
<td>North America—anthropogenic</td>
<td>0.8</td>
<td>1.6 1.9 2.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Franco et al., ERL, 2016

Updated bottom-up emissions

Inferred top-down emissions
4. Top-down emissions from GOSAT methane

=> Realistic C₂H₆ emissions can be used as proxies to decipher the anthropogenic emission changes of CH₄ from the growth of oil and natural gas development

C₂H₆/CH₄ emission ratios → Increase of annual C₂H₆ emissions from the updated HTAP2 inventory

North American CH₄ emissions from oil and gas activities have increased from 20 Tg/yr in 2008 to 35 Tg/yr in 2014

... but these estimates are affected by many uncertainties! (e.g., the C₂H₆/CH₄ ratios largely vary in space and time)
Conclusion

• Pursuing atmospheric monitoring activities is of primary importance for evaluating the impacts of the exploitation of shale gas and tight oil reservoirs on greenhouse gas emissions and air quality degradation.

• FTIR and surface monitoring measurements of ethane can be used to better constrain updated hydrocarbon emissions from the oil and natural gas sector.

⇒ Application to the recently developed ECHAM6-HAMMOZ atmospheric chemistry-climate model: sensitivity runs with updated ethane emissions.
Global ethane study (to start in June 2016)

- Involving consistent $C_2H_6$ measurements from more than 20 FTIR sites
- To characterize the recent $C_2H_6$ evolution at the global scale
- To refine the source attribution and identification of missing $C_2H_6$ emissions
Thank you for your attention

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