Ethane rise associated with North American oil and gas exploitation

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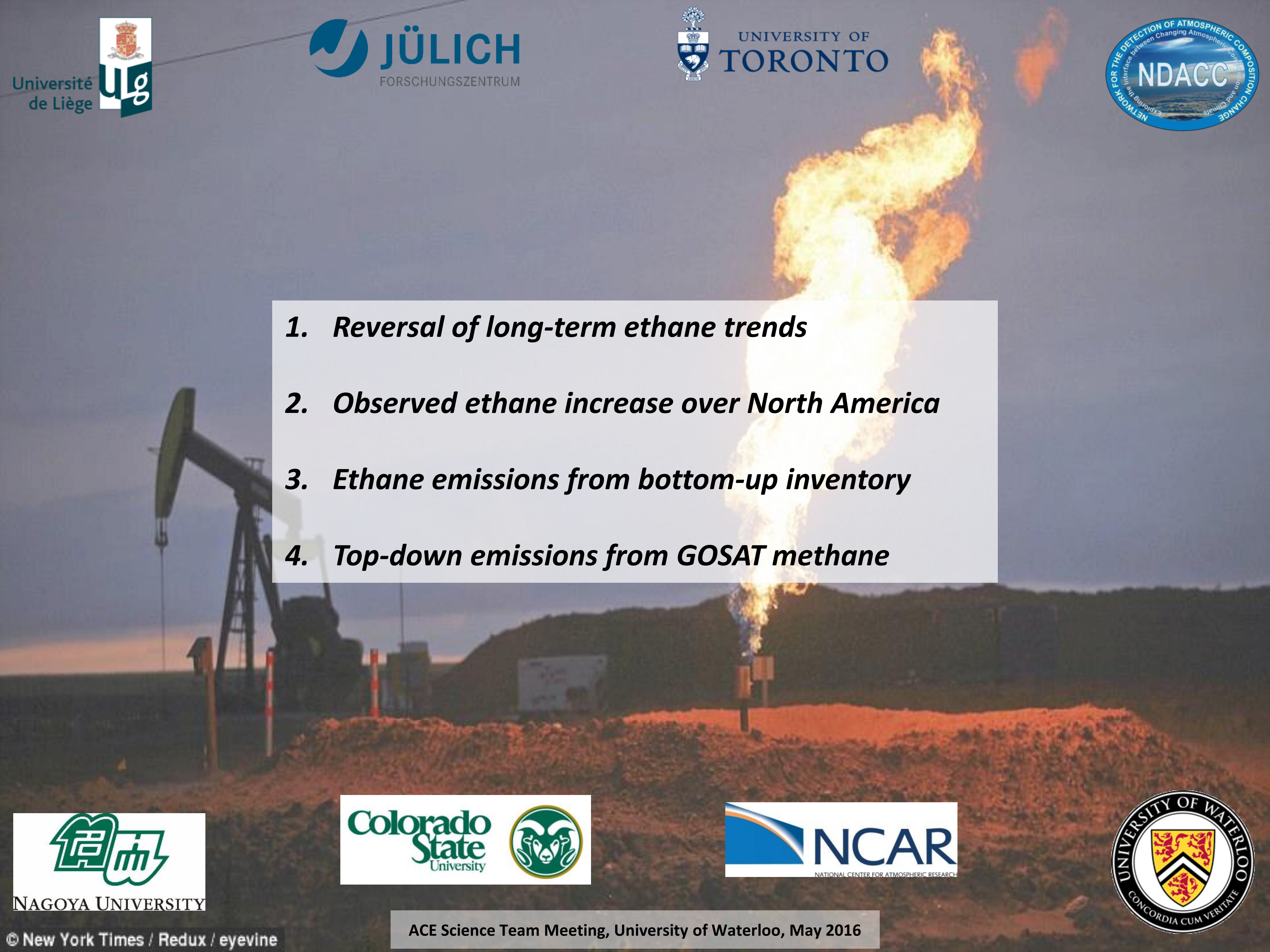
ACE Science Team Meeting, University of Waterloo, May 2016



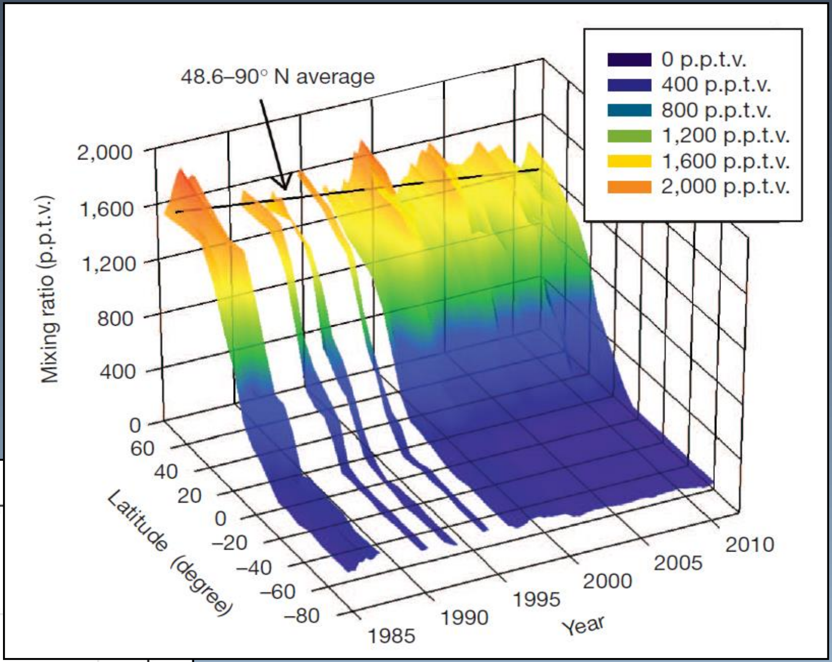
1. *Reversal of long-term ethane trends*
2. *Observed ethane increase over North America*
3. *Ethane emissions from bottom-up inventory*
4. *Top-down emissions from GOSAT methane*

ACE Science Team Meeting, University of Waterloo, May 2016

1. Reversal of long-term ethane trends

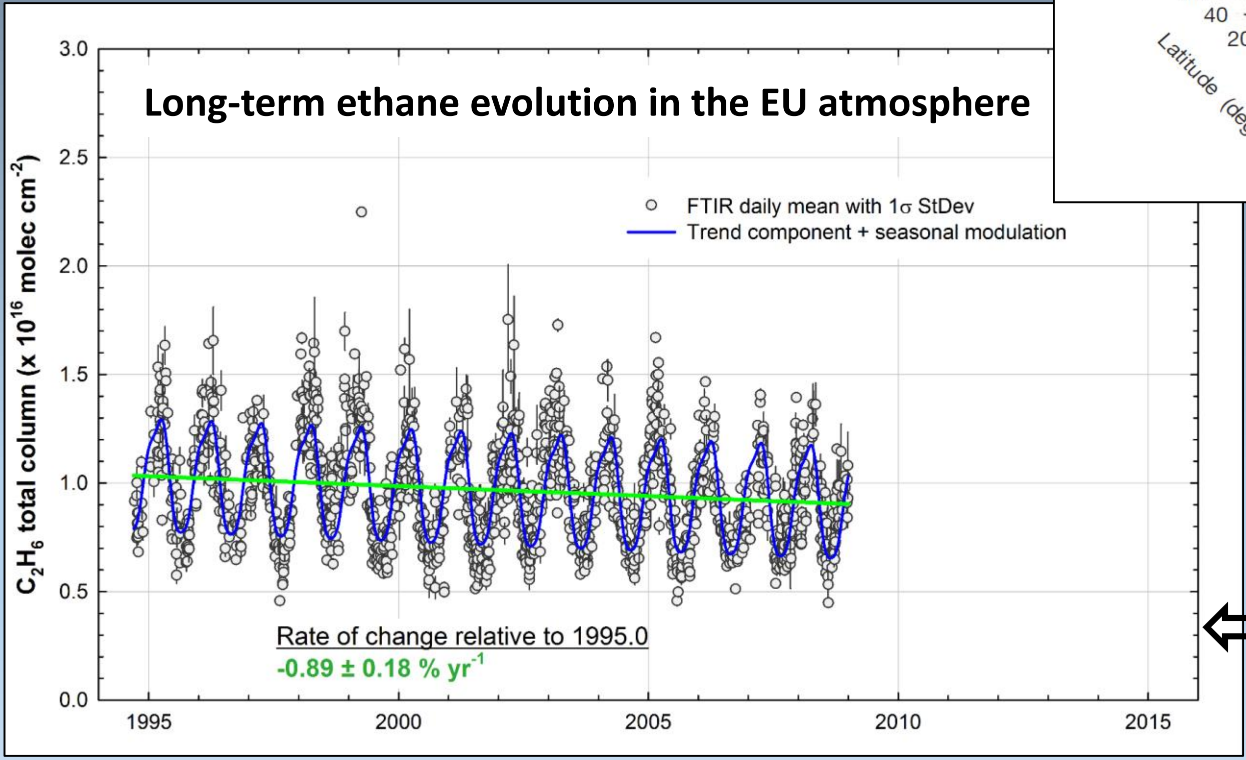
- Atmospheric ethane abundance has been declining in the -1 to -2.7 %/yr range since the mid-1980s
- Global emissions dropped from 14.3 to 11.3 Tg/yr over 1984-2010 (Simpson et al., *Nature*, 2012)

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



Simpson et al., Nature, 2012

C_2H_6 surface concentrations from air sampling of the UCI global trace gas monitoring network

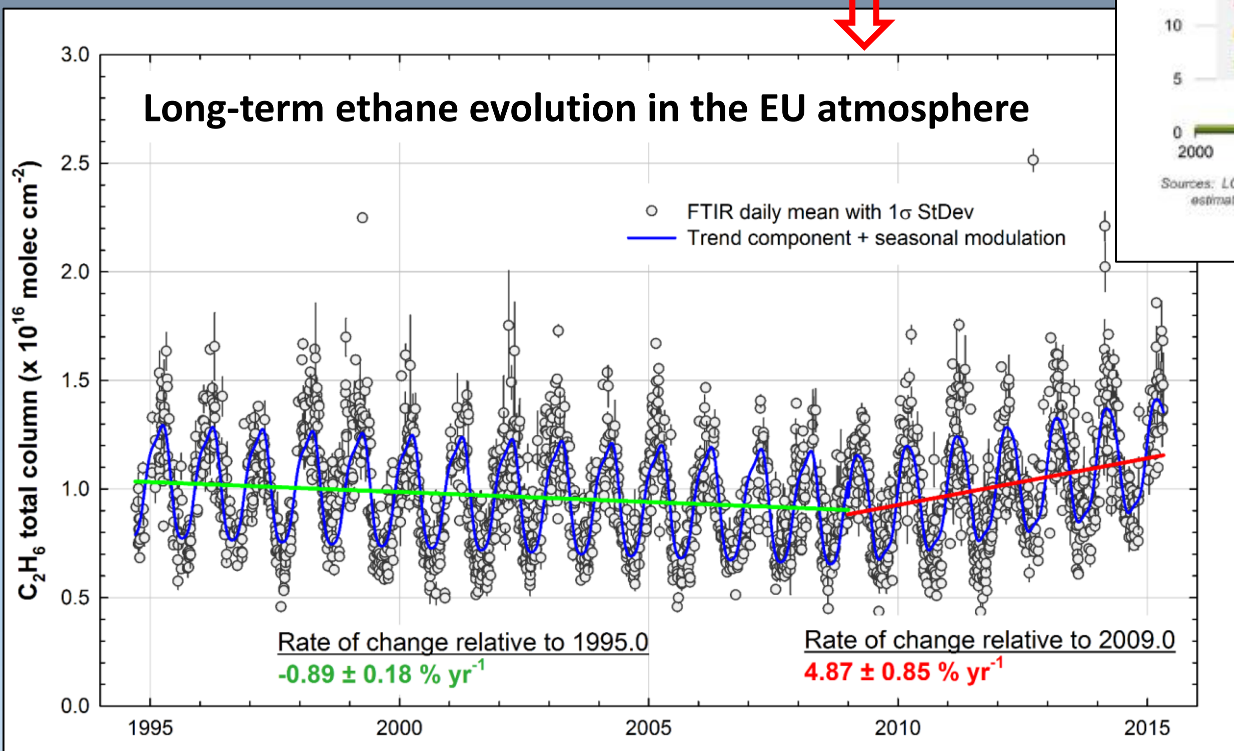


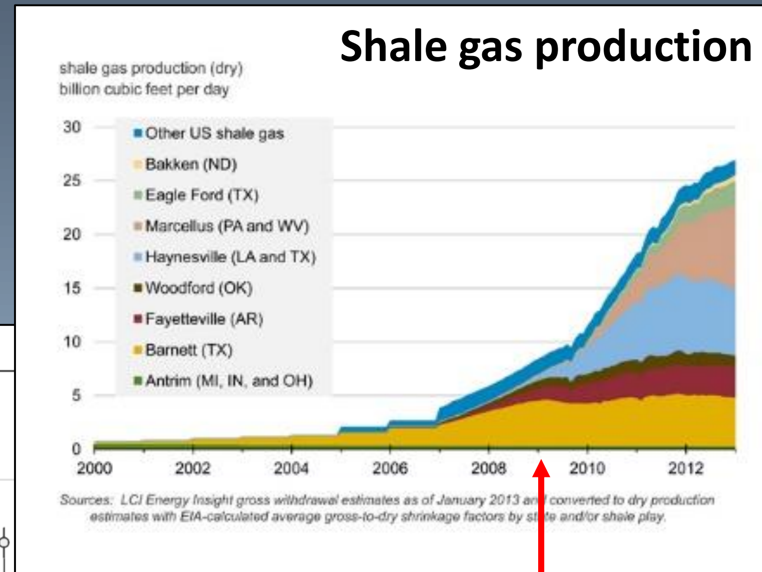
Franco et al., JQSRT, 2015

C_2H_6 total column time series from FTIR observations at Jungfraujoch (Swiss Alps)

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 (**<u>5 %/yr</u>**) of the atmospheric ethane burden from 2009 onwards





2009

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

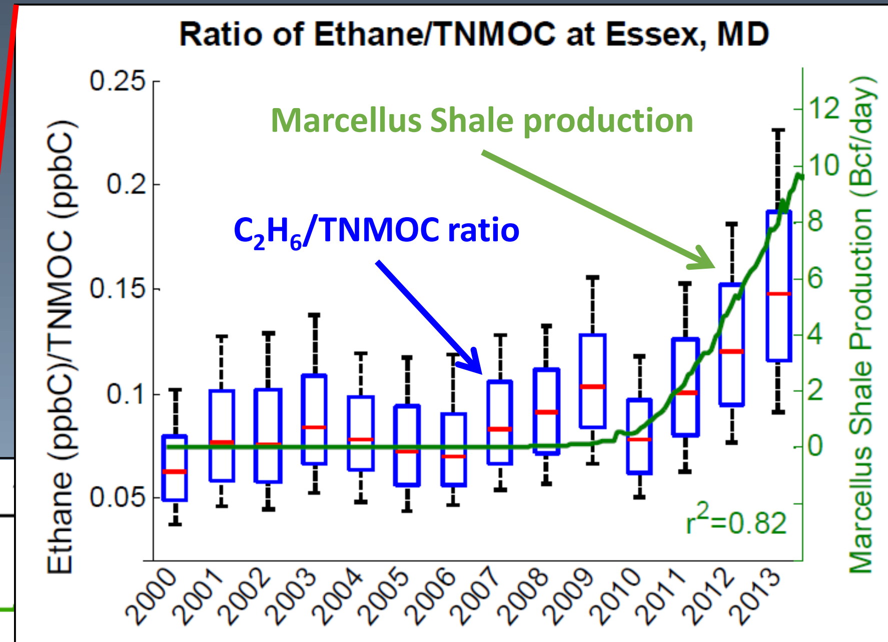
Franco et al., JQSRT, 2015

1. Reversal of long-term ethane trends

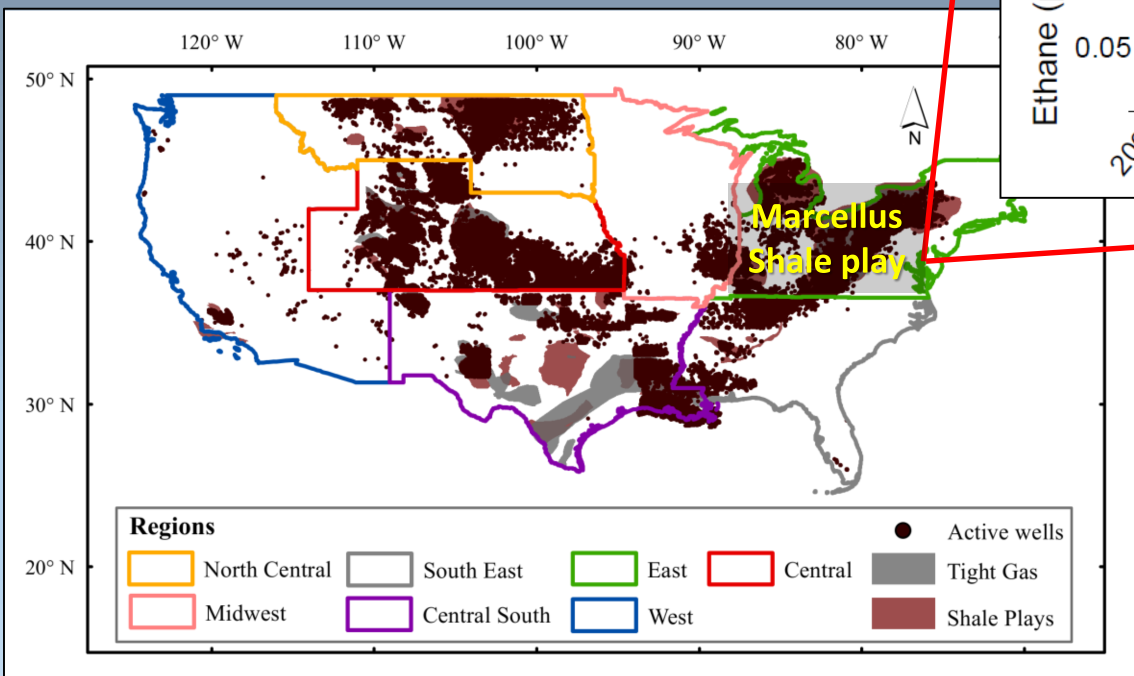
- Simultaneously, large hydrocarbon increases related to oil and gas industries have been detected over North American regions where the drilling productivity began to grow rapidly after 2009

=> this confirmed the observations made in EU

Vinciguerra et al., Atm. Chem., 2015



Distribution of active wells and shale gas plays



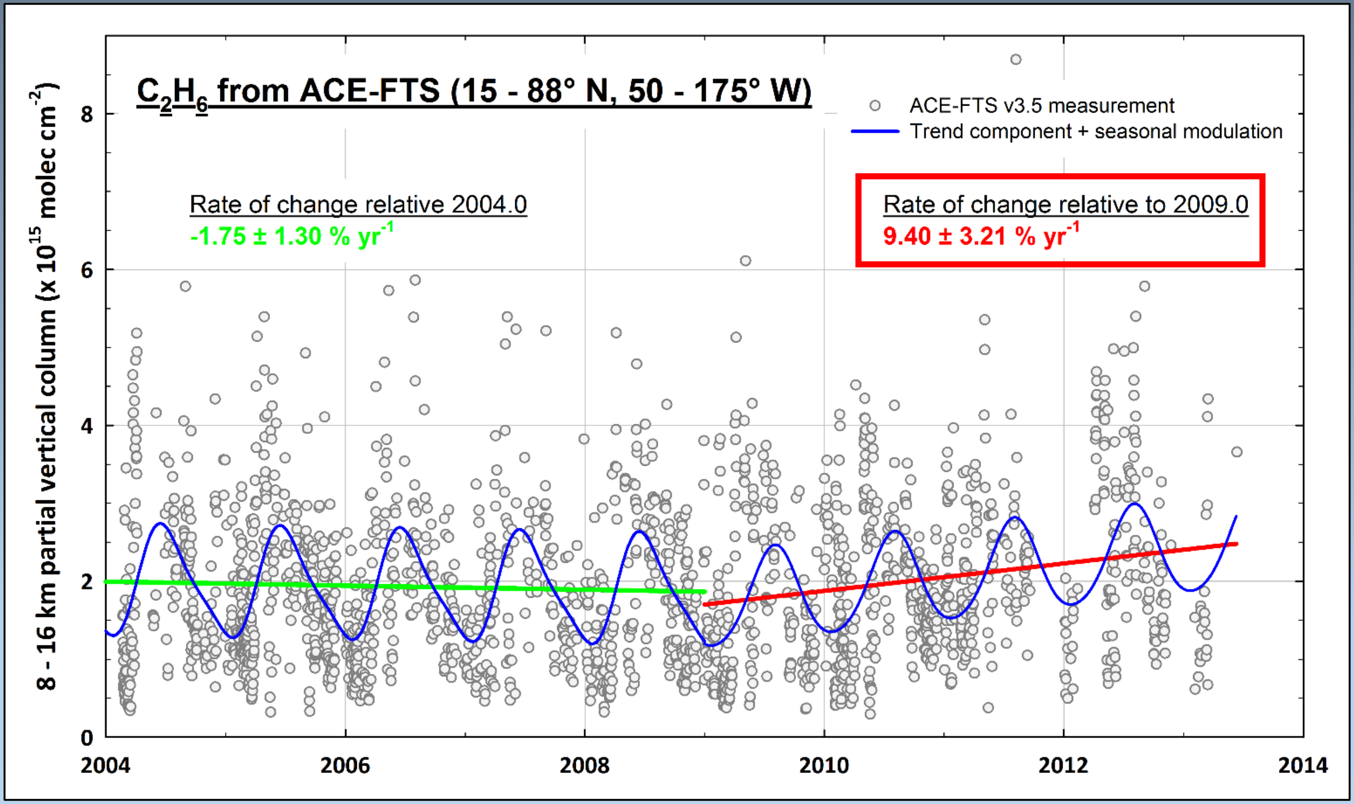
Franco et al., ERL, 2016

⇧

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 occulation observations over North America



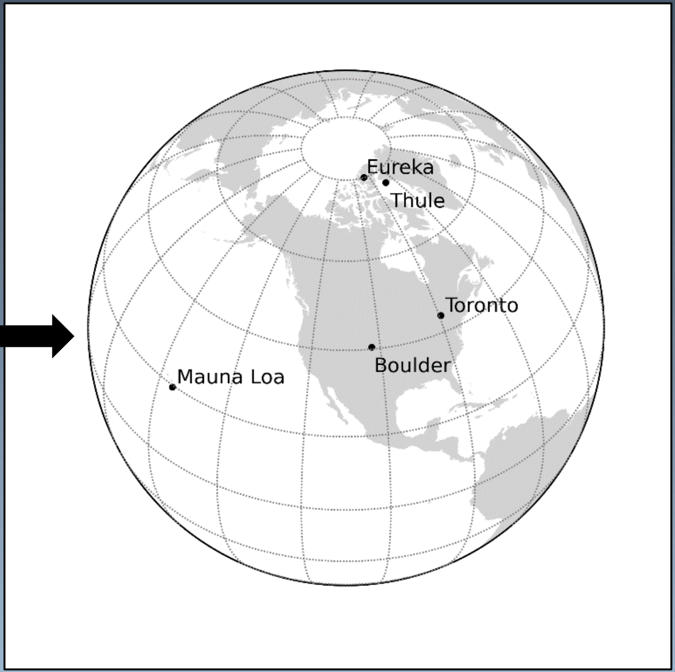
Preliminary results…

2. Observed ethane increase over North America

Research objectives

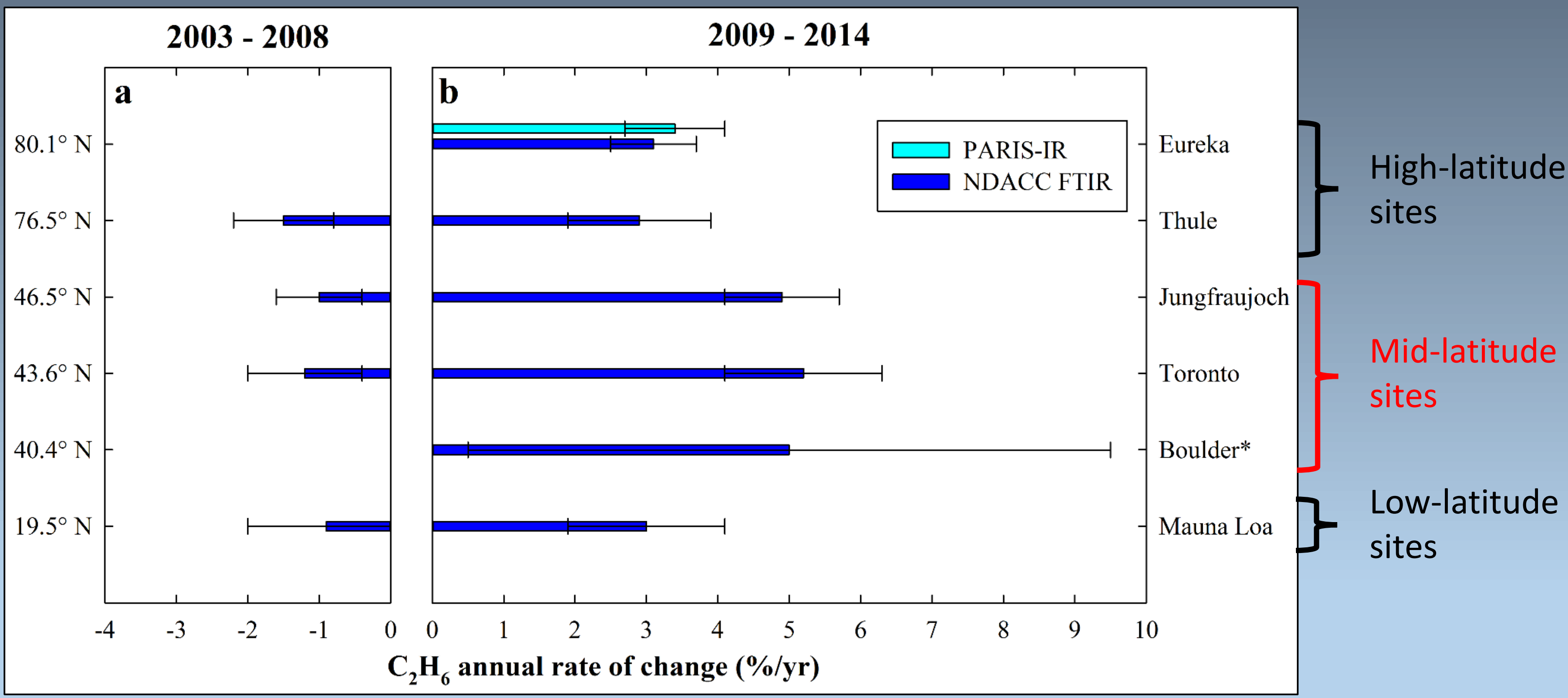
- To characterize the recent C_2H_6 evolution over North America using ground-based NDACC-FTIR and PARIS-IR measurements:
  - ✓ 5 sites involved (Eureka, Thule, Toronto, Boulder and Mauna Loa)
  - ✓ consistent retrievals (microwindows, *a priori*, covariance profile, improved spectroscopy…)
- To estimate the missing anthropogenic C_2H_6 emissions from the most current bottom-up inventory, needed to:
  - ✓ reconcile FTS measurements and model results
  - ✓ reproduce the observed C_2H_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**

North American NDACC FTS sites



2. Observed ethane increase over North America

- Slow decline of the C_2H_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~5 %/yr at mid-latitudes and of~3%/yr at remote sites



Franco et al., ERL, 2016

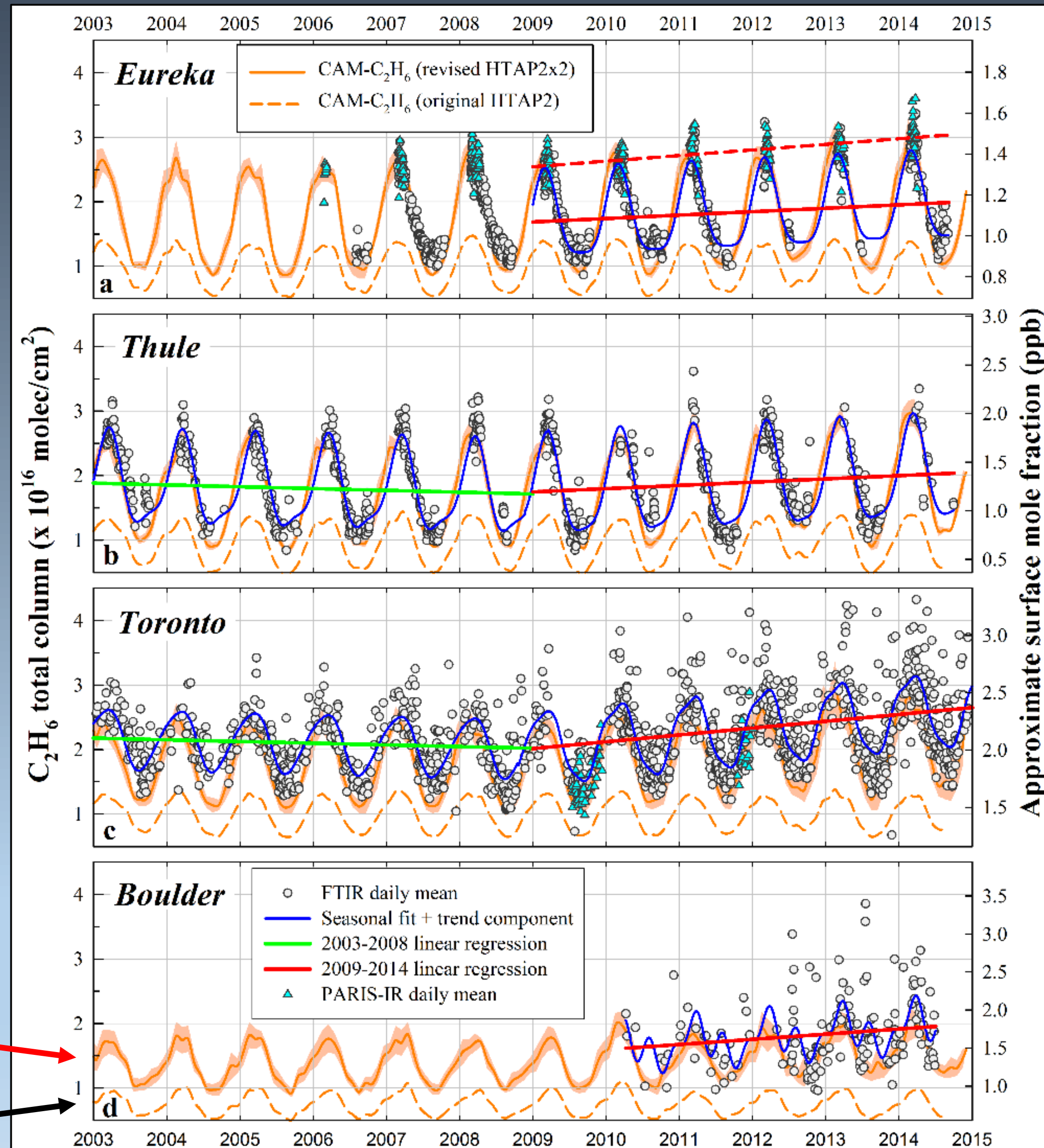
=> Very consistent results from **FTIR** and **PARIS-IR**

3. Ethane emissions from bottom-up inventory

Model simulations

- CHAM-chem simulation of ethane over 2003-2014, implementing the bottom-up anthropogenic inventory HTAP2
- C_2H_6 emissions from the oil and gas sector represent up to 80% of the total anthropogenic C_2H_6 emissions over North America
- The model underestimates the observed C_2H_6 abundances and does not reproduce the recent increase

=> Doubling global emissions is required to reconcile the simulations and the observations prior to 2009



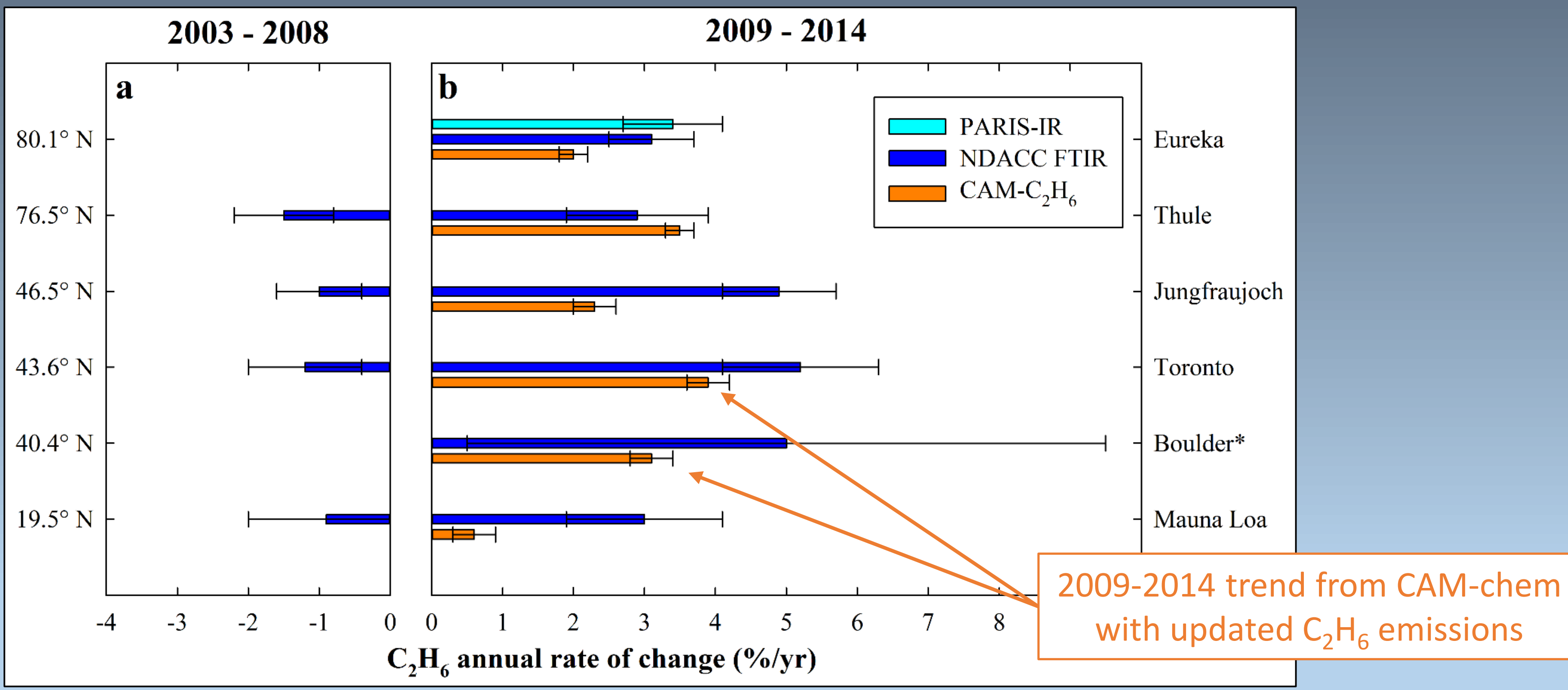
Doubled HTAP2 emissions

Original HTAP2 emissions

Franco et al., ERL, 2016

3. Ethane emissions from bottom-up inventory

- An <u>additional</u> increase of the North American anthropogenic emissions (beyond the previous doubling emissions) is required to simulate the recent C_2H_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



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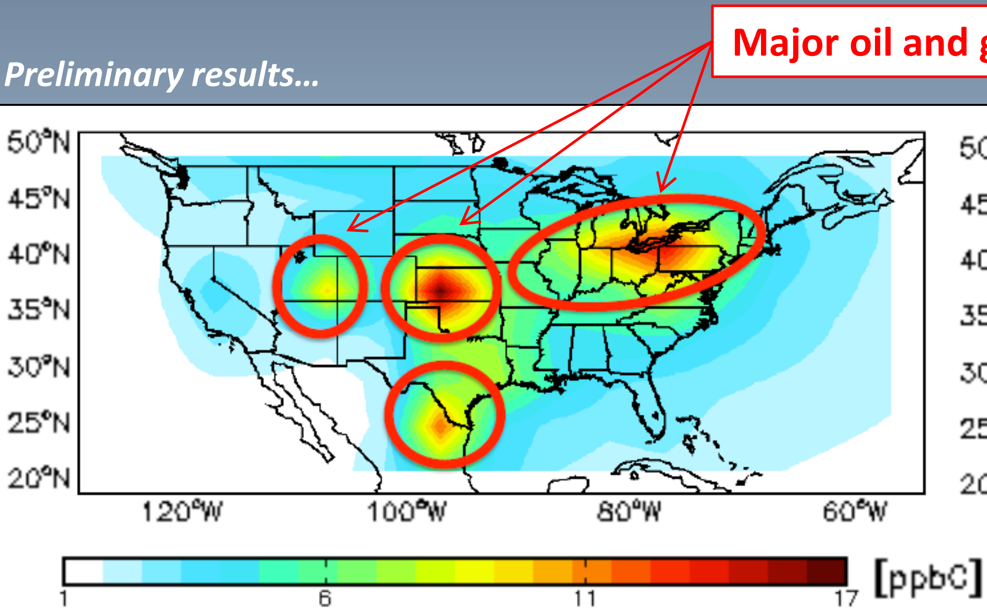
⇒ Increase of the North American anthropogenic C_2H_6 emissions by 75% (from 1.6 Tg/yr in 2008 to 2.8 Tg/yr in 2014)

New North American top-down emissions of ethane using GEOS-Chem

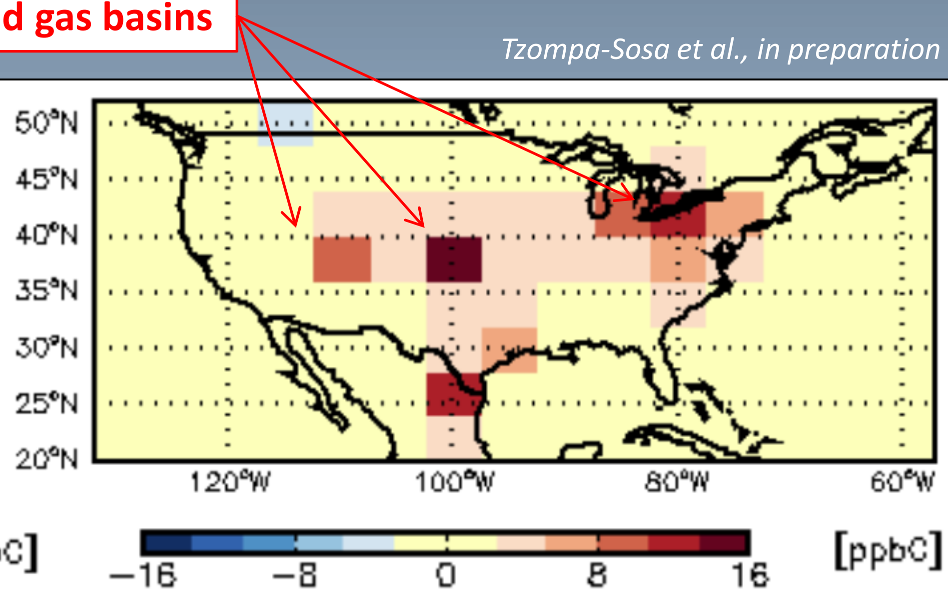
- Based on CH_4 fluxes inferred from 50 x 50 km GOSAT measurements (Turner et al., *ACP*, 2015) and subsequently evaluated by surface and aircraft data
- By applying C_2H_6/CH_4 emission ratios to satellite-derived CH_4 emissions for the oil and natural gas, biofuel consumption and biomass burning categories

Preliminary results…

Tzompa-Sosa et al., in preparation



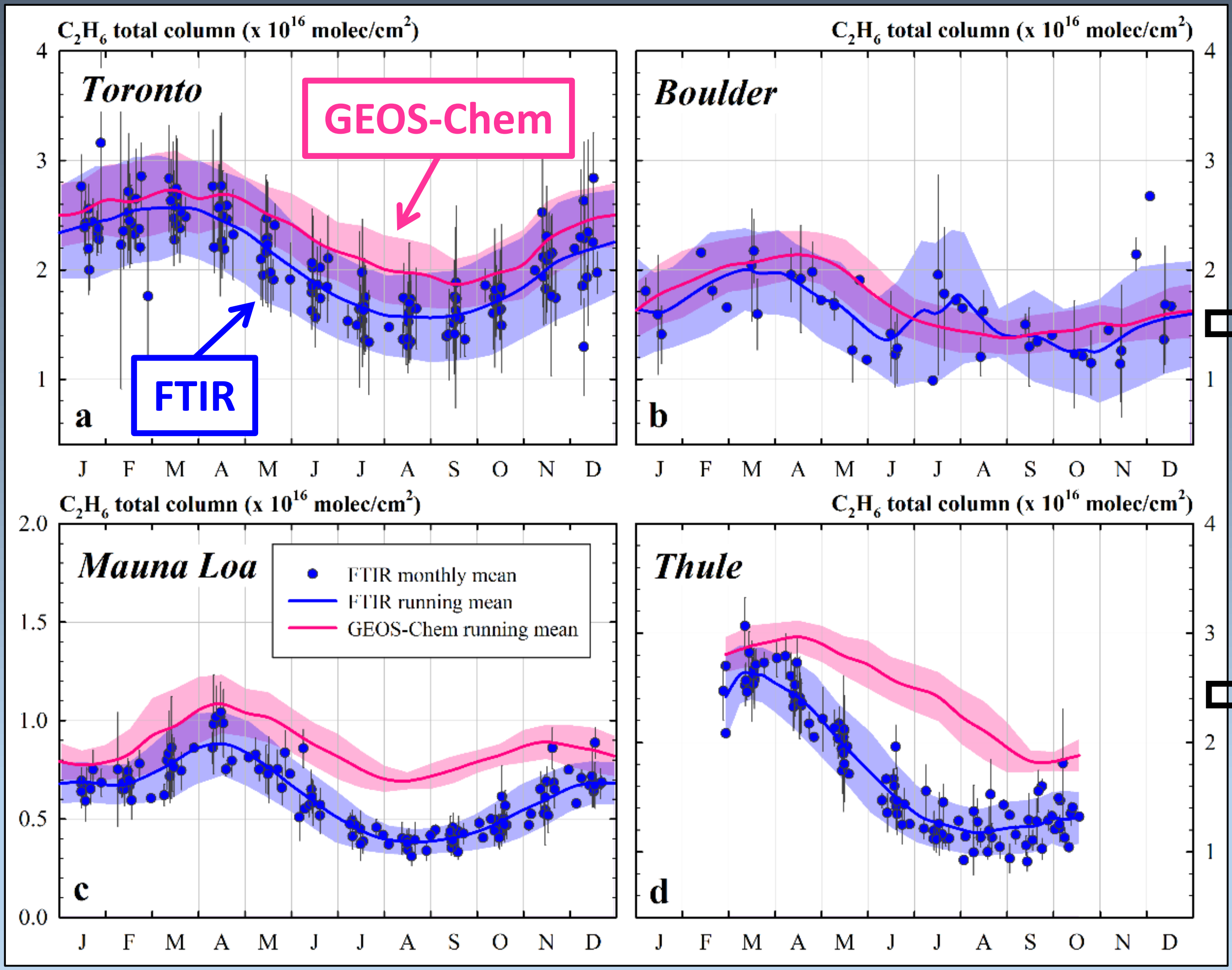
GEOS-Chem C_2H_6 surface concentration for December 2010, derived from GOSAT CH_4



December 2010 absolute difference in surface C_2H_6 (ppbC) for a simulation using emission ratios to CH_4 vs. default emission inventories

4. Top-down emissions from GOSAT methane

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



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

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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

Region—sector	$CAM\text{-}C_2H_6$ (original HTAP2)	$CAM\text{-}C_2H_6$ (revised HTAP2x2)			GEOS-Chem
	2008–2014	2008	2010	2014	2010
Globe—all sectors	9.7–10.2	17.3	17.9	18.7	13.2
Globe—anthropogenic	7.5	15.0	15.3	16.2	10.5
Globe—biomass burning	1.8–2.3	1.9	2.2	2.2	2.7
Globe—biogenic	0.4	0.4	0.4	0.4	Not included
North America—anthropogenic	0.8	1.6	1.9	2.8	1.8

Franco et al., ERL, 2016

Updated bottom-up emissions

Inferred top-down emissions

=> Realistic C_2H_6 emissions can be used as proxies to decipher the anthropogenic emission changes of CH_4 from the growth of oil and natural gas development

C_2H_6/CH_4 emission ratios → Increase of annual C_2H_6 emissions from the updated HTAP2 inventory

↓

North American CH_4 emissions from oil and gas activities have increased from 20 Tg/yr in 2008 to 35 Tg/yr in 2014

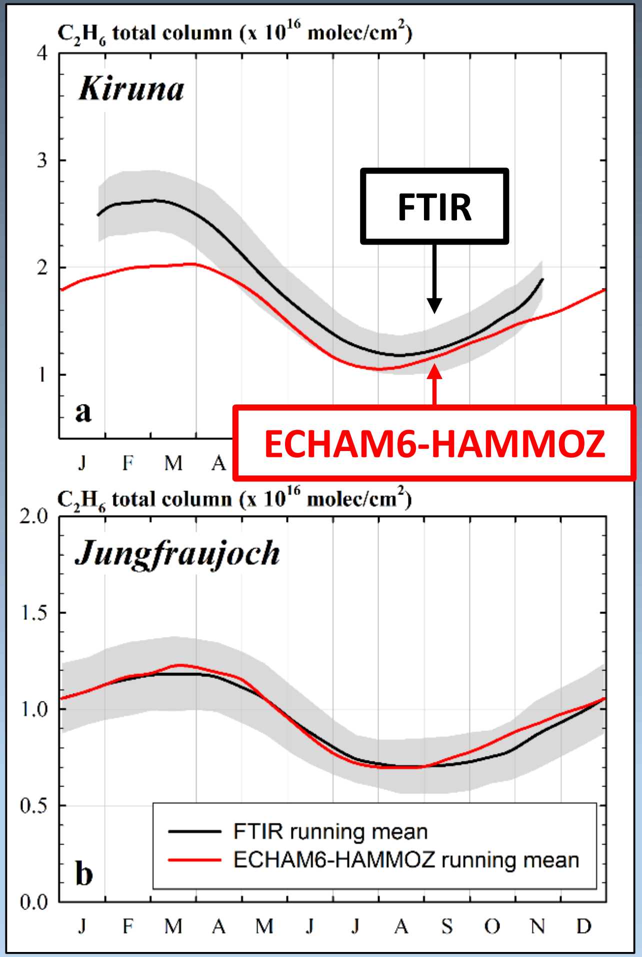
… but these estimates are affected by many uncertainties!
(e.g., the C_2H_6/CH_4 ratios largely vary in space and time)

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

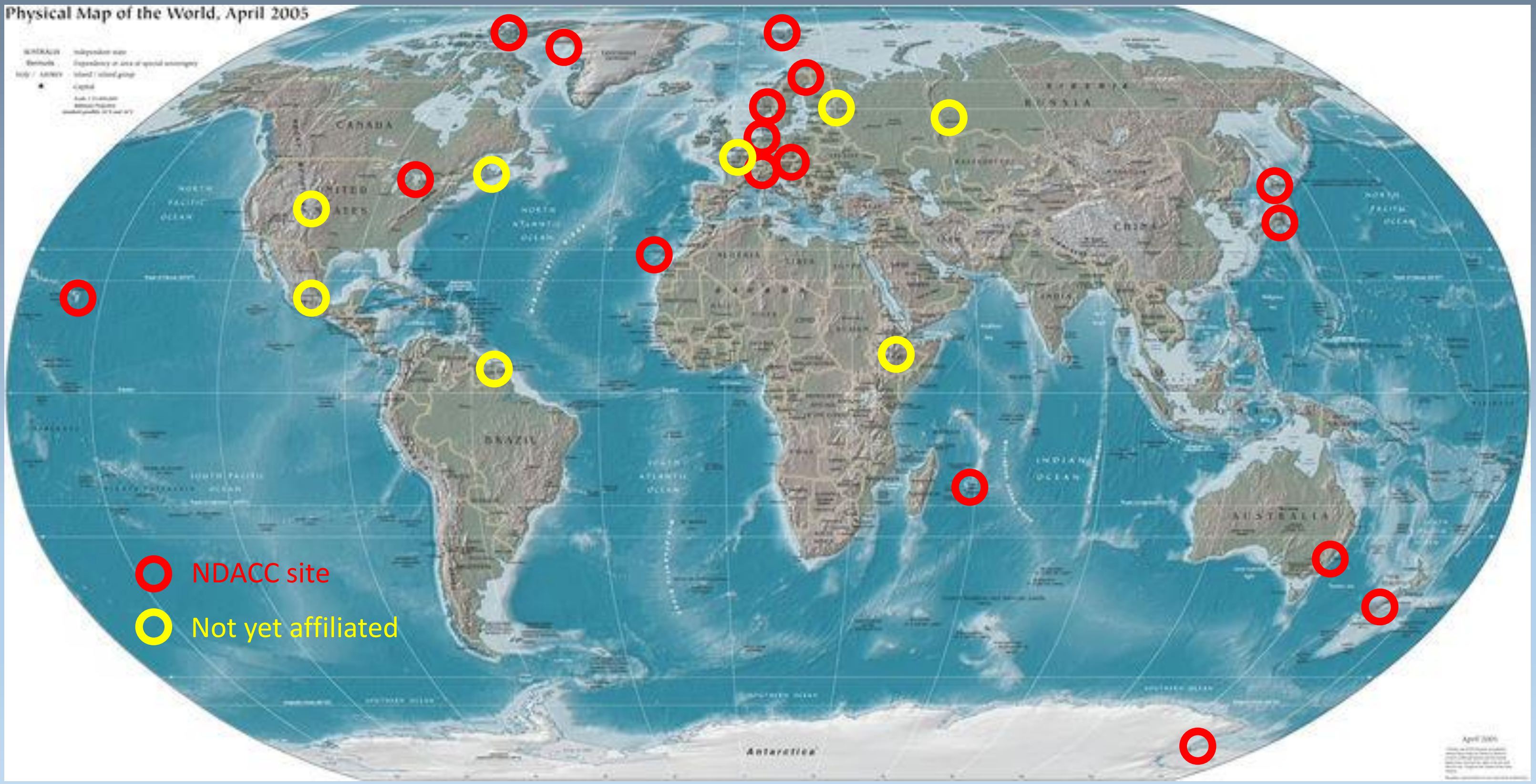
- FTIR and surface monitoring measurements of ethane can be used to better constrain updated hydrocarbon emissions from the oil and natural gas sector

  ⇒ 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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