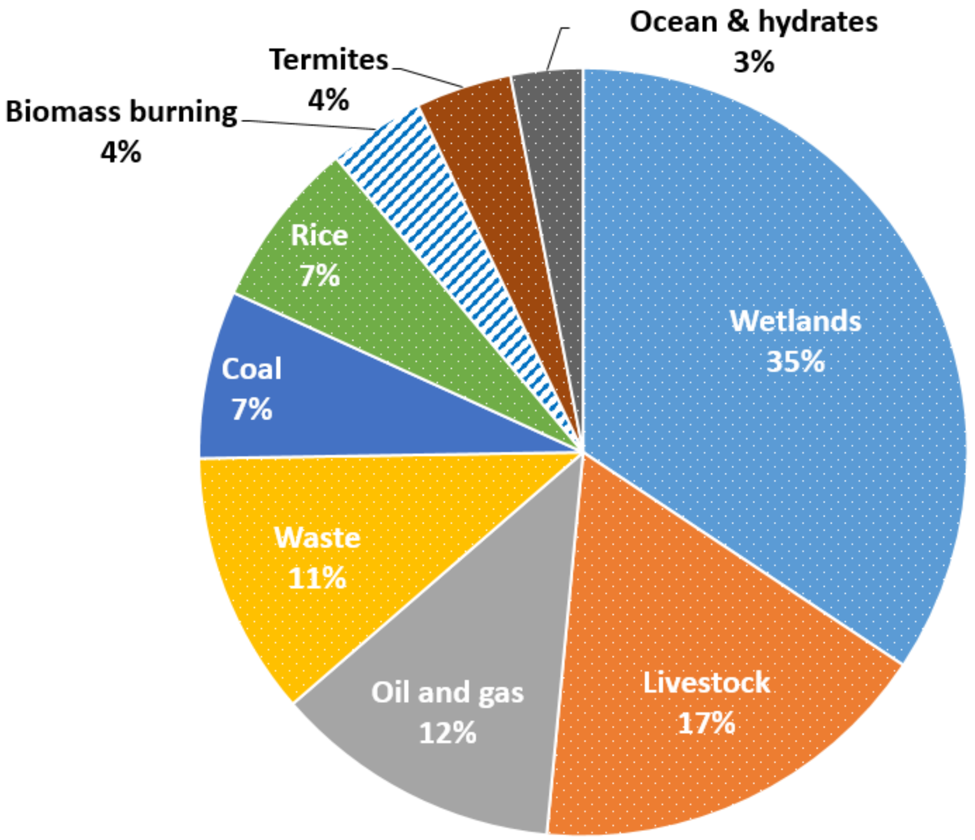
The recent increase of methane from 10 years of NDACC ground-based FTIR observations

Bader, W. et al., Ten years of atmospheric methane from ground-based NDACC FTIR observations, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-699, in review, 2016.

Atmospheric methane

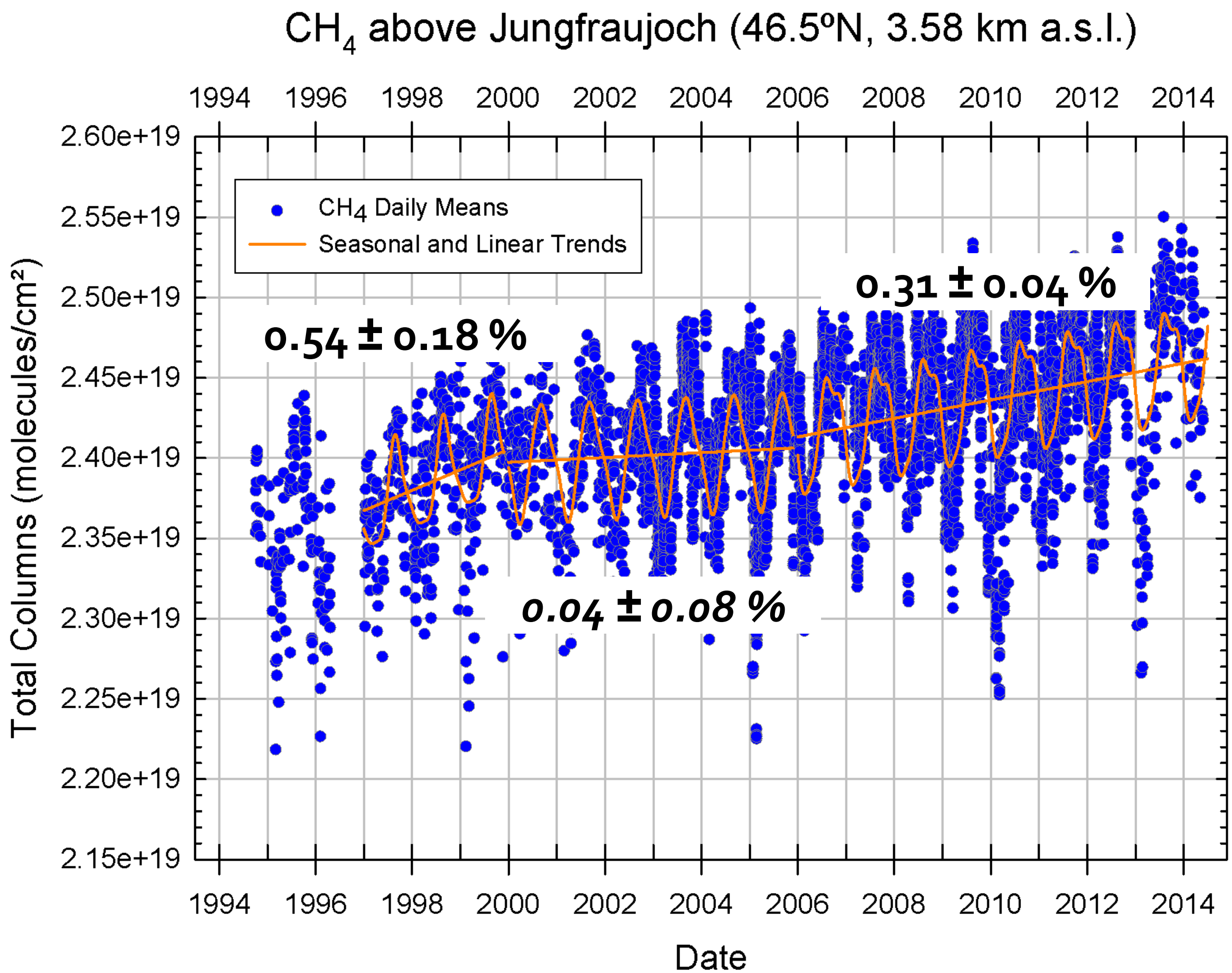
- 2nd most important anthropogenic greenhouse gas
- 1/5 of anthropogenic radiative forcing since 1750 is due to methane
- 3 types of emission processes :
  - biogenic (dotted)
  - thermogenic (plain)
  - pyrogenic (hatched)
- 1 major sink
- oxidation by OH

+ 260% since 1750

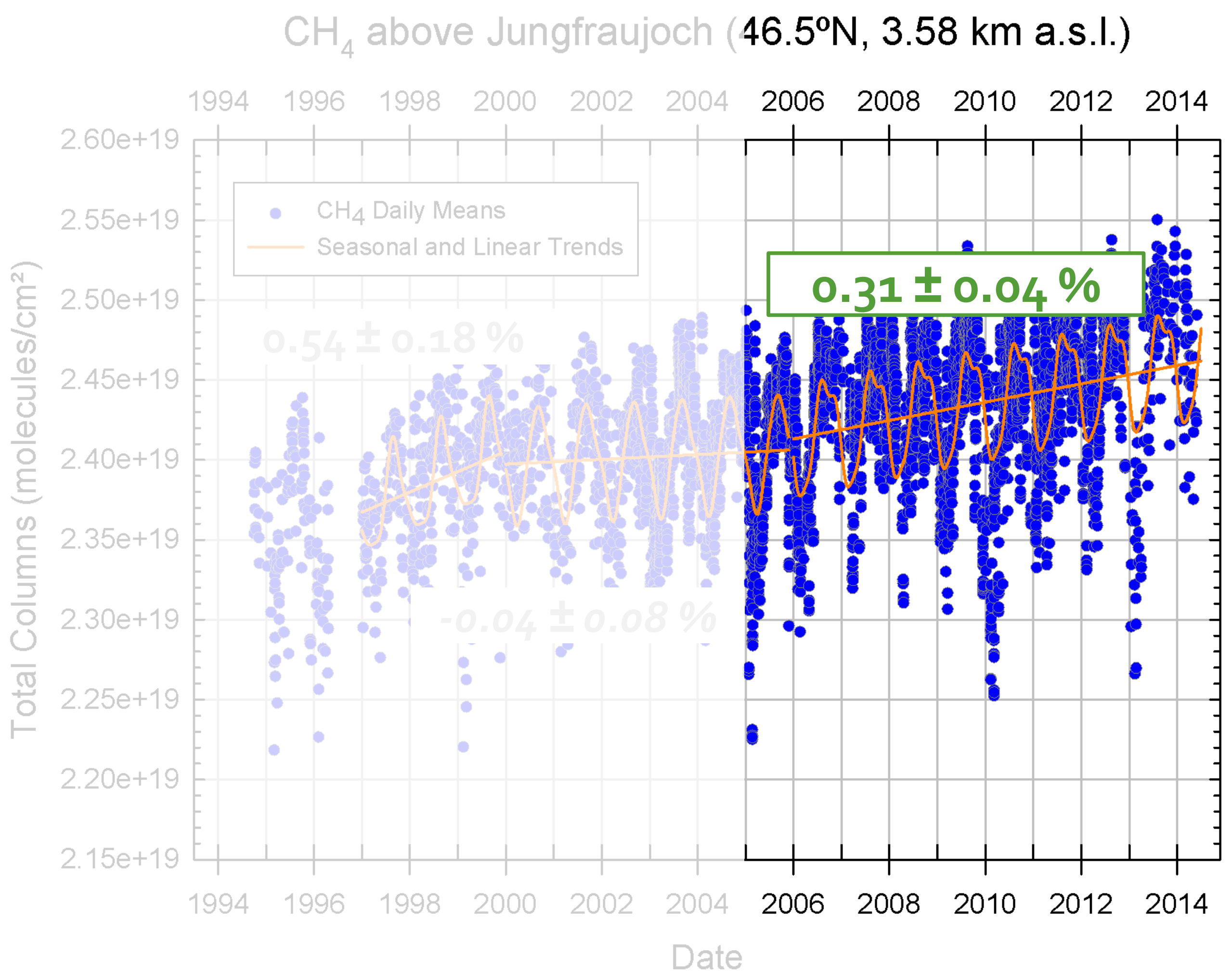


Trends of methane in the last 20 years

Jungfraujoch : Swiss Alps – Remote site – Northern mid-latitude
Solar observations from Fourier Transform Infrared spectrometer

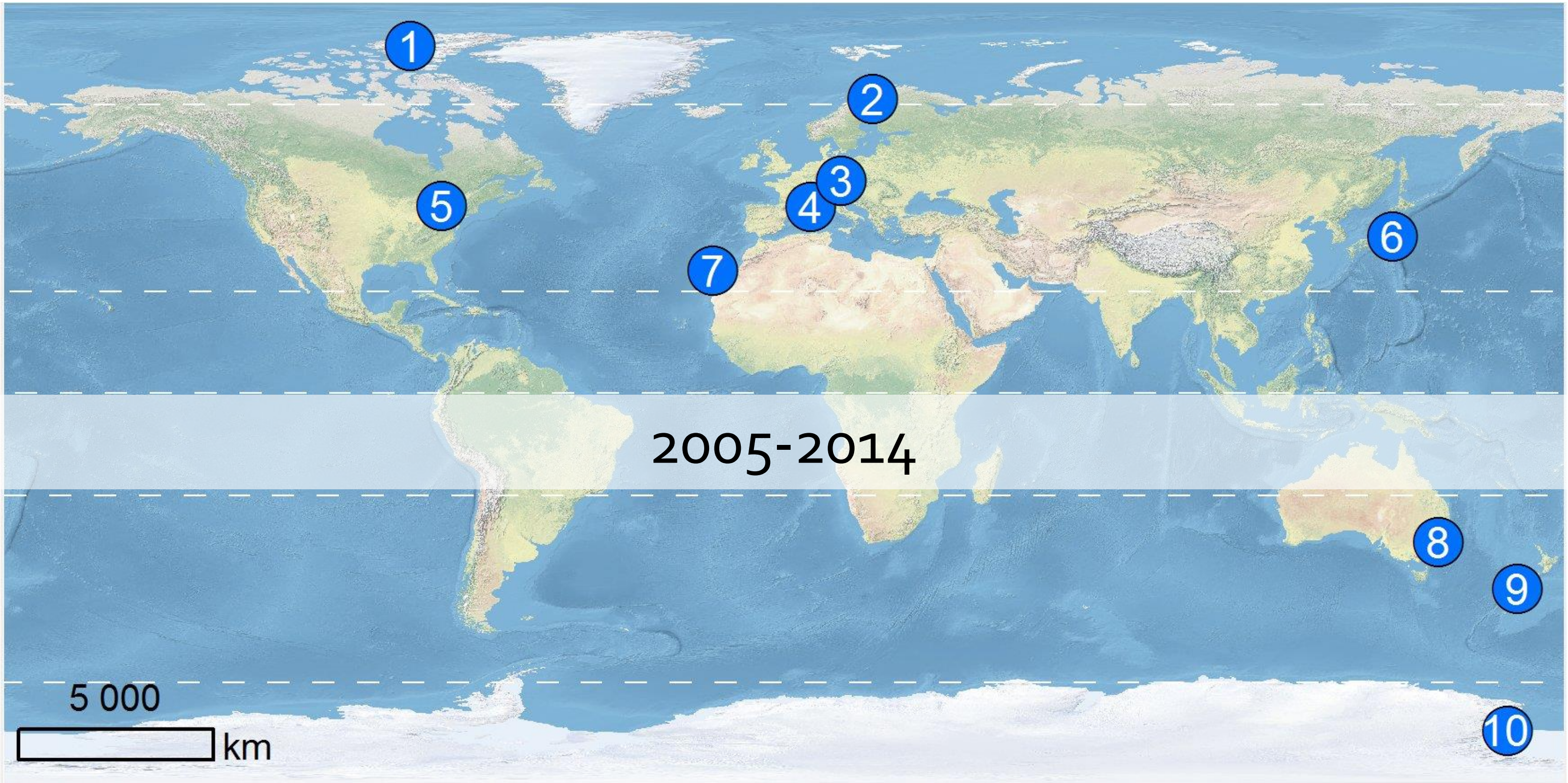


Unexplained increase since ~2005



10 years of NDACC FTIR observations

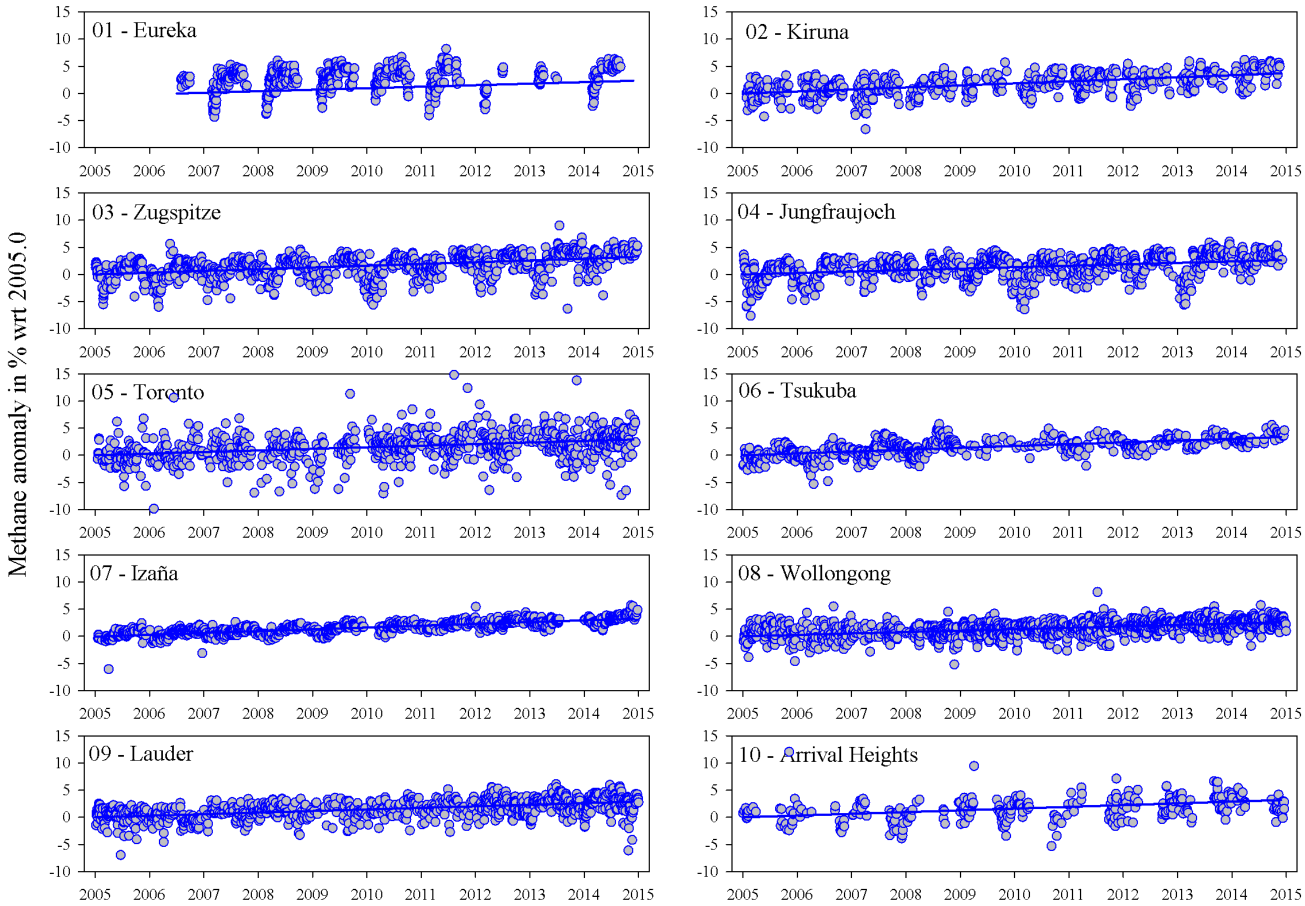
1- Eureka (80 °N)
2- Kiruna (68 °N)
3- Zugspitze (47 °N)
4- Jungfraujoch (47 °N)
5- Toronto (44 °N)
6- Tsukuba (37 °N)
7- Izaña (28 °N)
8- Wollongong (34 °S)
9- Lauder (45 °S)
10- Arrival Heights (78 °S)



10 years of NDACC FTIR observations

> Anomaly with respect to 2005.0
Averaged increase : 0.31 ± 0.03 %/year

0.26 ± 0.02 %/year : Wollongong
0.39 ± 0.09 %/year : Toronto



GEOS-Chem v9-02. Tagged simulation

- Resolution : 2° x 2.5° and 4° x 5°
- 47 vertical levels - Output : 3 hours
- Meteo fields : GEOS5 (Dec 2003 - May 2013)
- Spin-up over 2004 (70 spins for initialization)
- Emission inventories
  - Anthropogenic emissions : EDGAR v4.2
  - Biomass burning : GFED3 (8h)
  - Wetland model [Pikett-Heaps, 2011]
  - Termites [Fung et al., 1991]
  - Biofuels [Yevich and Logan, 2003]
  - Soil absorption [Fung et al., 1991]
- Main sink : 3D OH monthly [Park et al., 2004]
- Lifetime : 8.9 years

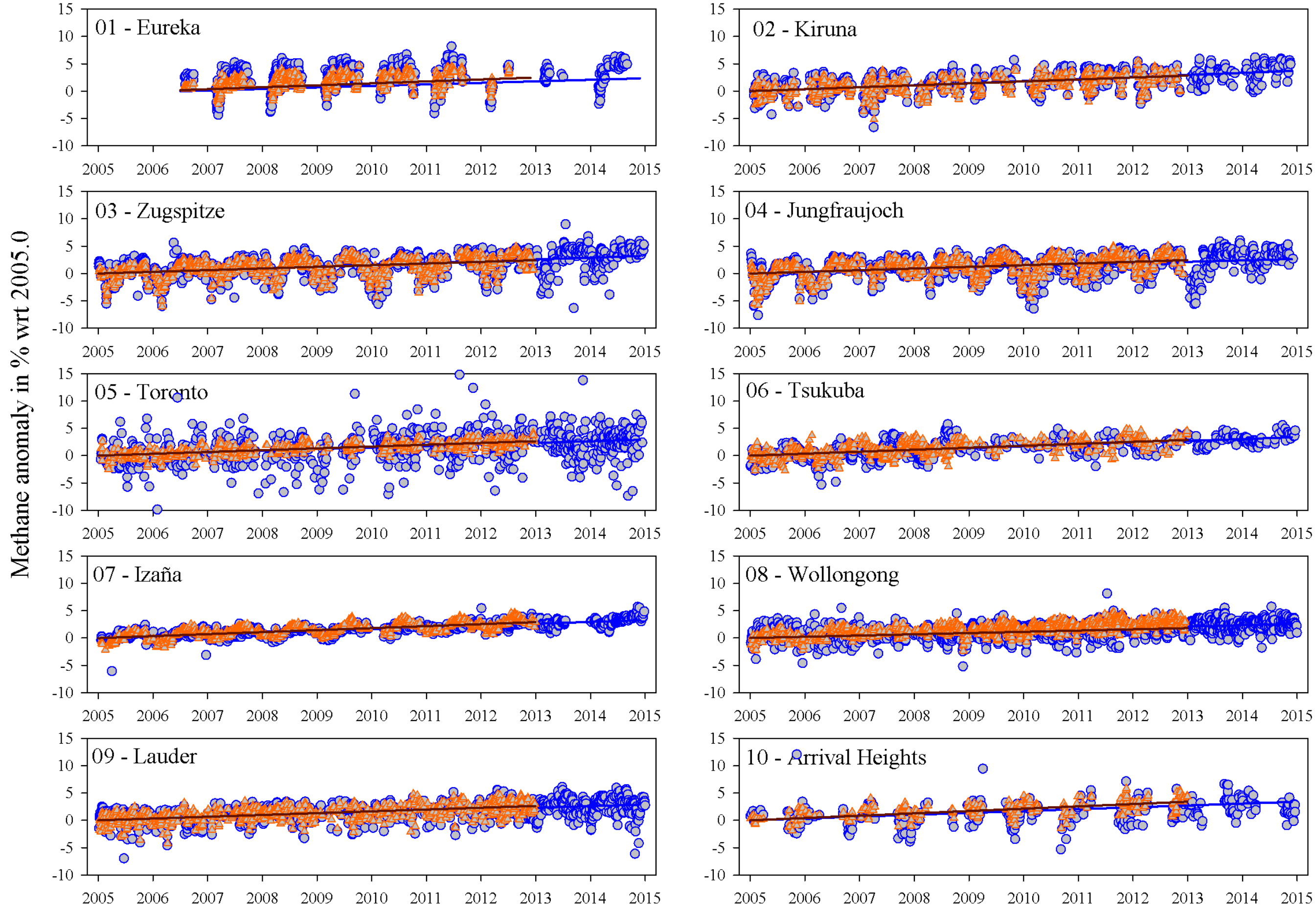
Each tracer represents the contribution of each source to the simulated total column of methane

Tracers
1- Total
2- Gas and oil
3- Coal
4- Livestock
5- Waste management
6- Biofuels
7- Rice cultures
8- Biomass burning
9- Wetlands
10- Other natural
11- Other anthropogenic
12- Soil absorption

FTIR vs GEOS-Chem

- Maximum bias 4.8 ± 3.5 % (Arrival Heights) ≈ FTIR systematic error

> Anomaly with respect to 2005.0

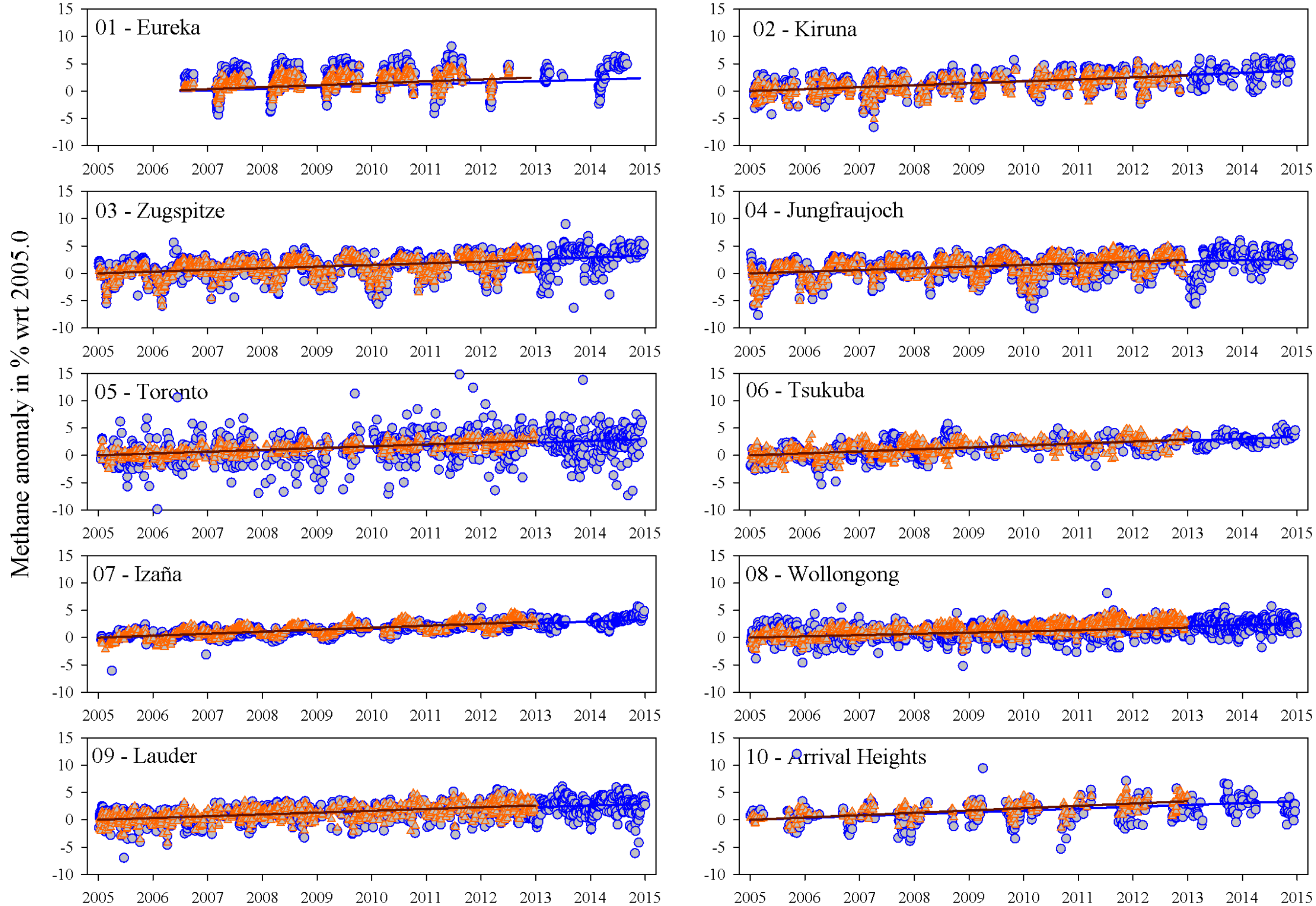


FTIR vs GEOS-Chem

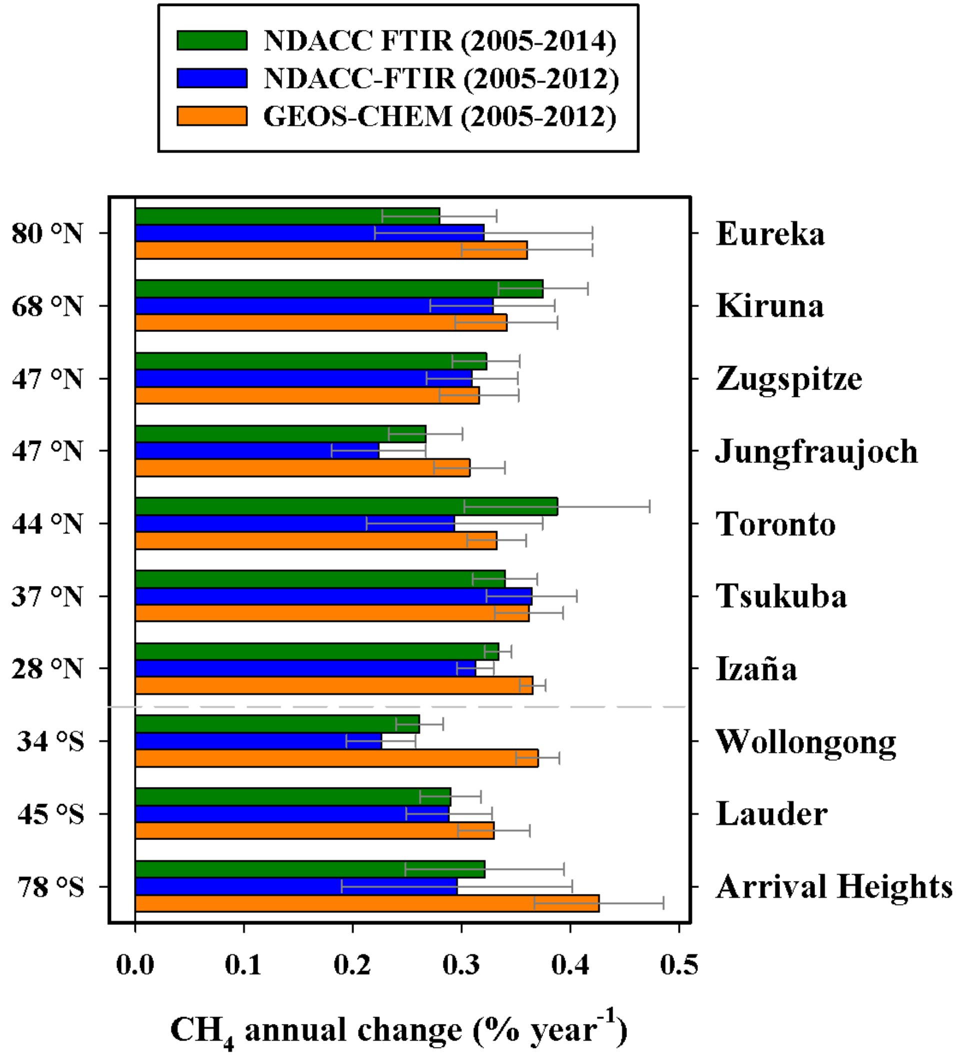
Averaged increase over 2005-2012

FTIR : 0.30 ± 0.04 %/year

GEOS-Chem : 0.35 ± 0.03 %/year



Methane since 2005



GC tagged simulation : Analysis

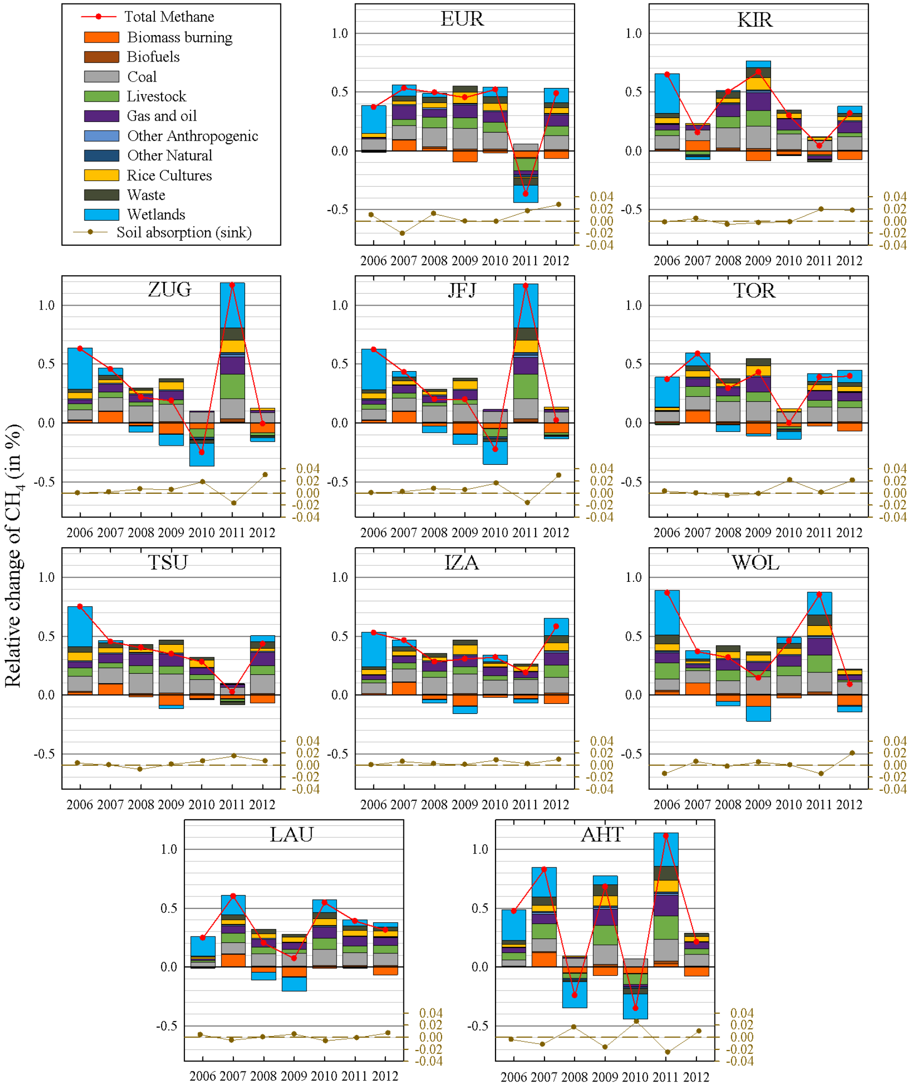
Yearly relative change in %.

$$YC\ (in\ \%) = \frac{(\mu_n - \mu_{n-1})}{\mu_{tot,n-1}}$$

μ_n : annual mean of CH_4, year n.

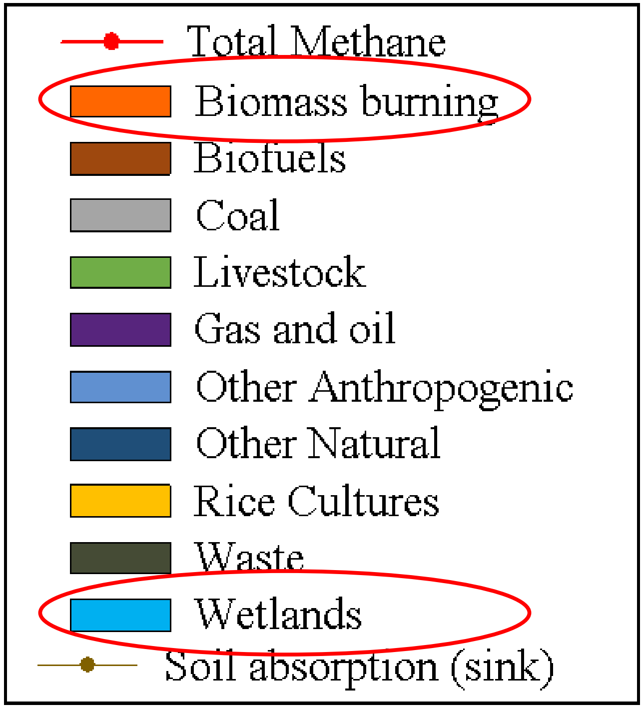
The year-to-year relative changes are computed so that when we assume a relative change of a tracer for the year n, it is expressed wrt to the previous year (n-1) as reference.

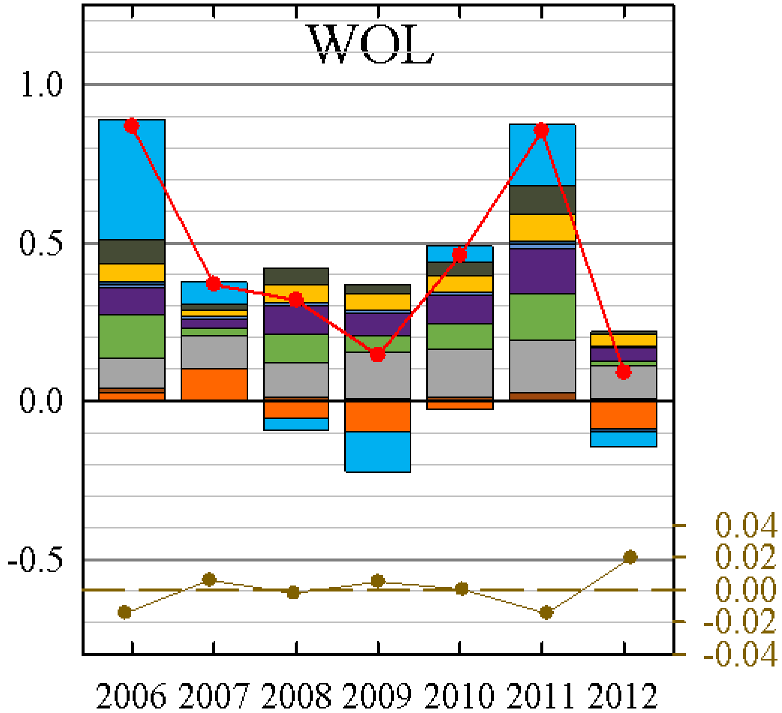
$\mu_{tot,\ n-1}$: annual mean of the simulated cumulative methane for the year (n-1)



GC tagged simulation : Analysis

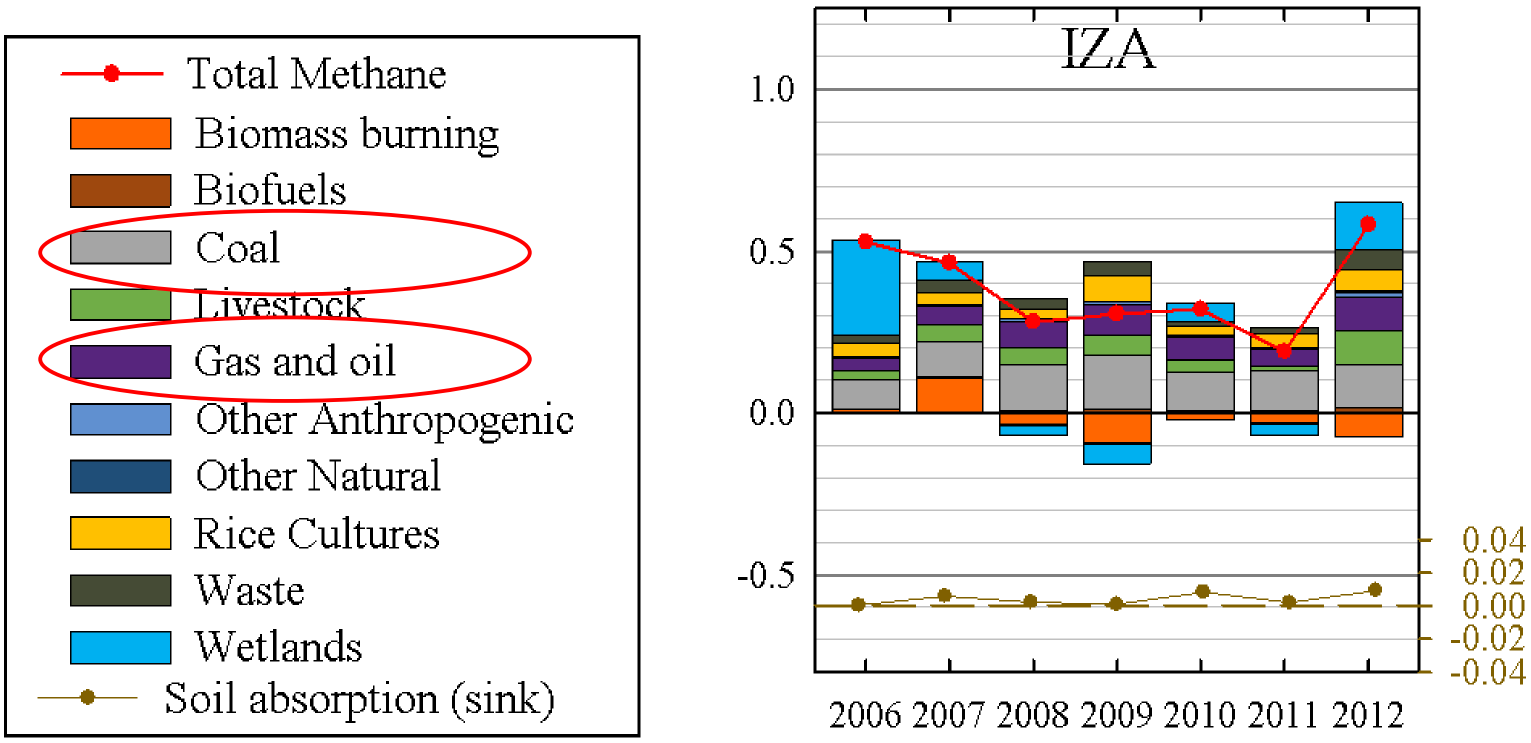
- Yearly relative change (%)
- Natural sources mainly responsible for the interannual variation
- e.g. Wollongong





GC tagged simulation : Analysis

- Yearly relative change (%)
- Secondary contributors to the budget contribute to the increase
- e.g. Izaña



GC tagged simulation : Analysis

- Contributors to the simulated increase : tracer ranking

	EUR	KIR	ZUG	JFJ	TOR	TSU	IZA	WOL	LAU	AHT
1	co	co	co	co	co	co	co	co	co	co
2	gao	gao	wl	gao	gao	gao	gao	li	gao	gao
3	wl	wl	gao	wl	wl	wl	wl	gao	li	li
4	ri	li	ri	ri	ri	li	li	wl	wl	wl
5	li	ri	li	li	li	ri	ri	ri	ri	ri
6	wa	wa	wa	wa	wa	wa	wa	wa	wa	wa
7	bf	bf	oa	oa	bf	bf	bf	bf	bf	bf
8	oa	oa	bf	bf	oa	oa	oa	oa	oa	oa
9	on	on	on	on	on	on	on	on	on	on
10	bb	bb	bb	bb	bb	bb	bb	bb	bb	bb

- Total Methane
- Biomass burning
- Biofuels
- Coal
- Livestock
- Gas and oil
- Other Anthropogenic
- Other Natural
- Rice Cultures
- Waste
- Wetlands
- Soil absorption (sink)

Methane increase : Discussion

Source attribution ?

Many studies…
Rigby et al., 2008
Ringeval et al., 2010
Bloom et al., 2010
Aydin et al., 2011
Dlugokencky et al., 2009
Sussmann et al., 2012
Kirschke et al., 2013
Nisbet et al., 2014
Hausmann et al., 2016
Schaefer et al., 2016

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On the sink side,

Rigby et al. (2008) OH – 4 ± 14 % from 2006 to 2007

Montzka et al. (2011) -1 %/year

Bousquet et al. (2011) < 1 % over the 2006-2008 time period

Dentener (2003)

"*atmospheric composition generally buffer the global OH concentrations*"

Methane increase : Discussion

Source attribution ?

From GEOS-Chem tagged simulation

Secondary contributors to the global budget of methane play a major role in the increase of methane observed since 2005.

→ coal mining, gas and oil transport and exploitation

Methane increase : Discussion

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Best emission inventories available → limitations

EDGAR v4.2

- Overestimates the recent emission growth in Asia (Schwietzke et al. 2014, Bergamaschi et al. 2013 and Bruhwiler et al. 2014).
- Chinese coal mining emissions are too large by a factor of 2 (Turner et al. 2015, from a global GOSAT inversion)
- EDGAR v4.2 vs global GOSAT inversion (Turner et al., 2015)
  - increase in wetland emissions in South America
  - increase in rice emissions in Southeast Asia

Methane increase : Discussion

Source attribution ?

Gas and oil use and exploitation (GAO)

underestimated by current emission inventories (incl. EDGAR)

Franco et al., 2015, 2016; Turner et al., 2015, 2016

Methane increase : Discussion

Source attribution ?

Gas and oil emissions : the use of C_2H_6 as a proxy

Production, transport and use of natural gas and the leakage associated to it amounts at ~ 62 % of ethane's atmospheric budget (**Logan et al., 1981; Rudolph, 1995**)

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Franco et al., 2016

- Observations : sharp increase of C_2H_6 since 2009

  → ~5 %/year at mid-latitudes, ~3 %/year at remote sites

- Massive growth of oil and gas exploitation in the North American continent, confirmed by **Helmig et al. 2016**

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Methane increase ? From C_2H_6/CH_4 ratio derived from GOSAT measurements

- → from 20 Tg in 2008, to 35 Tg in 2014
- Confirming the influence of GAO on the observed methane increase

Methane increase : Discussion

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Hausmann et al. 2016

C_2H_6/CH_4 ratio derived from an atmospheric two-box model

GAO contribution of 39 % to the renewed methane in Zugspitze between 2007 and 2014

Methane increase : Discussion

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C_2H_6/CH_4 ratio derived from an atmospheric two-box model

GAO contribution of 39 % to the renewed methane in Zugspitze between 2007 and 2014

BUT

The strength of the C_2H_6/CH_4 relationship associated to GAO strongly depends on the studied region and/or production basin

Variability rarely taken into account (Kort et al. 2016, Peischl et al. 2016)

Methane increase : Discussion

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underestimated by current emission inventories (incl. EDGAR)

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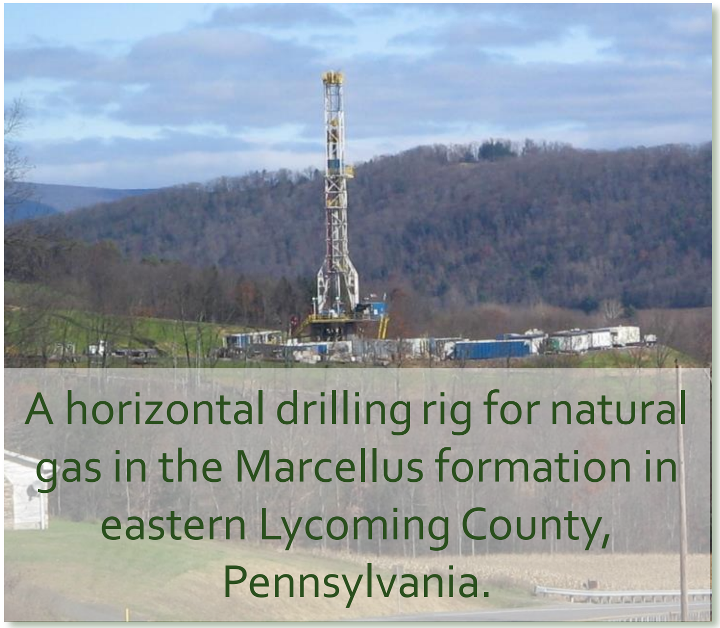
Lyon et al. (2016) pointed out that emissions from GAO well pads may be missing from most bottom-up emission inventories.



A horizontal drilling rig for natural gas in the Marcellus formation in eastern Lycoming County, Pennsylvania.

Methane increase : Discussion

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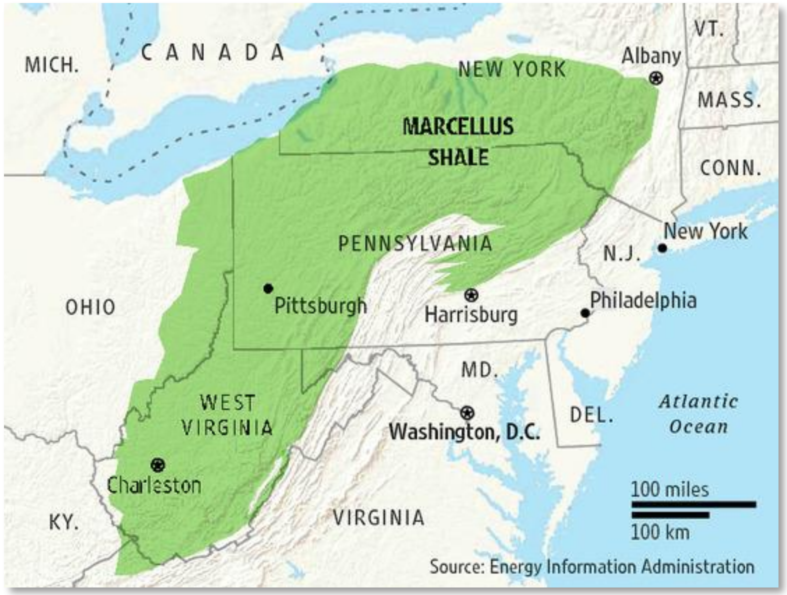
Emissions differ from one well pad to another and even within the same pad depending on the depth of the extraction.

e.g. Marcellus Basin that is actually two different overlapping basins. The depth of the well thus determines into which basin it's drilling.



Conclusions

- CH_4 change since 2005 from FTIR ground-based measurements
- 0.31 ± 0.03 %/year with respect to 2005.0
- Consistent with methane changes computed from in situ measurements

Source attribution ?

- GEOS-Chem tagged simulation : 11 tracers from 2005 to 2012
- 0.35 ± 0.03 %/year vs 0.30 ± 0.04 %/year (FTIR)
- Natural sources contribute to the inter-annual variability
- Anthropogenic sources, second contributors to the global budget methane, contribute to the observed increase
  - coal mining
  - gas and oil exploitation
  - livestock

Conclusions

- While we showed that GEOS-Chem agrees with our observations, the repartition between the different sources of methane would greatly benefit from an improvement of the global emission inventories.

- EDGAR v4.2
  - US oil and gas and livestock are underestimated.
  - Coal emissions are overestimated.

- Further attention has to be given to improved anthropogenic methane inventories, such as emission inventories associated with fossil fuel and natural gas production. This is essential in a context of the energy transition that includes the development of shale gas exploitation.

THANK YOU !

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