Quantification of methane fluxes from local sites using a combination of a tracer release method, a Gaussian Model and an atmospheric statistical inversion approach

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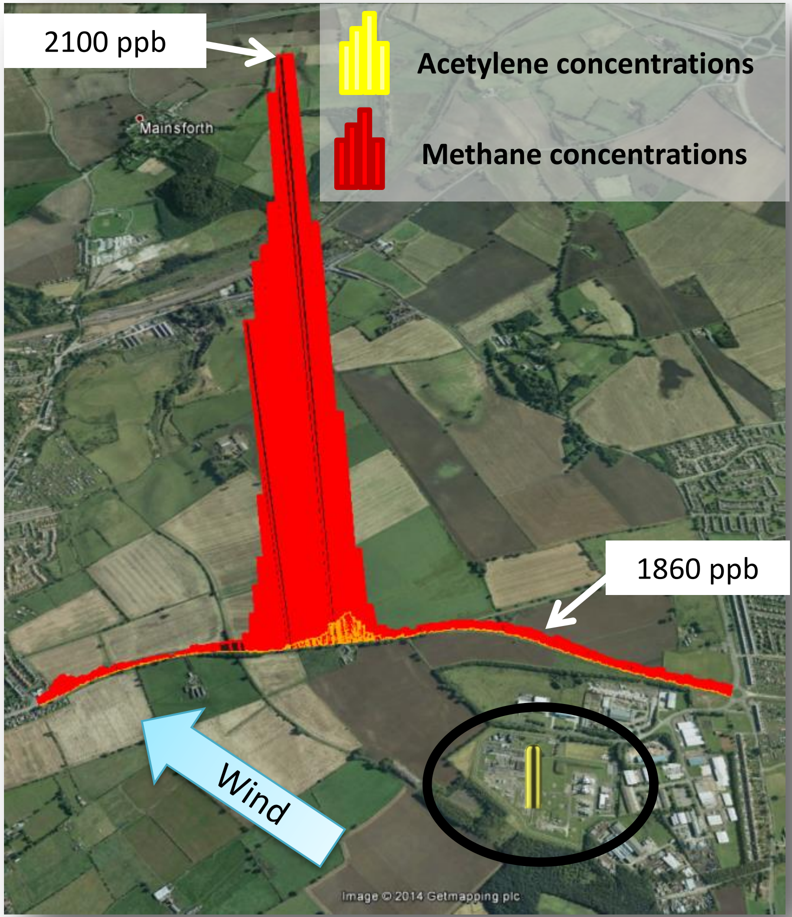
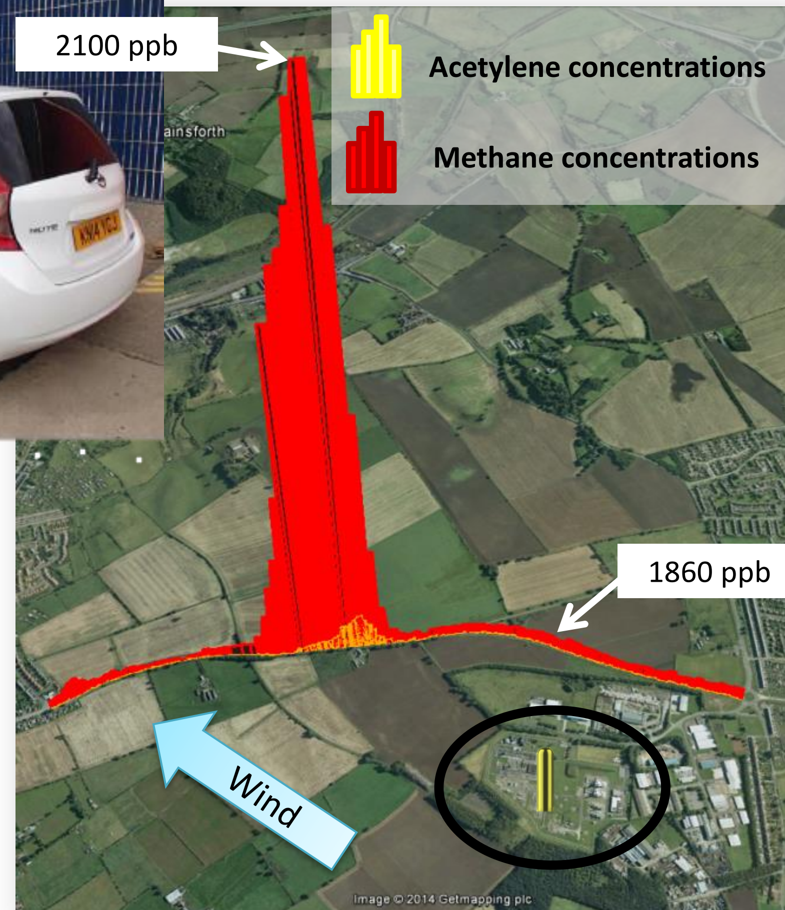
The tracer release method



$$E_{gas} = Q_{tracer} \cdot \frac{\int_{Plume\ end\ 1}^{Plume\ end\ 2} C_{gas}\, dx}{\int_{Plume\ end\ 1}^{Plume\ end\ 2} C_{tracer}\, dx} \cdot \frac{MW_{gas}}{MW_{tracer}}$$

The tracer release method



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The tracer release method

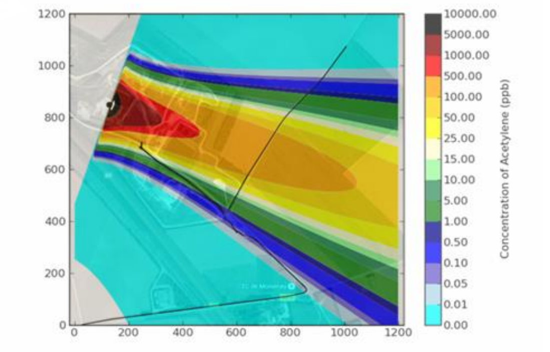
Pros	Cons
• Simple to implement • Enable the estimation of a large number of sites	• Non-collocation of the tracer • Multiple sources • Spread sources

The Gaussian model

Wind conditions →

Emission rates →

Gaussian model →



⇒ Use of meteorological conditions that are stationary in time and homogeneous in space within the study period and area.

⇒ Cannot account precisely for the local topography and buildings.

The Gaussian model

Polyphemus Gaussian model developped by **CEREA**

$$C(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z\bar{u}} \exp\left(-\frac{(y-y_s)^2}{2\sigma_y^2}\right) \times \left[\exp\left(-\frac{(z-z_p)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+z_p)^2}{2\sigma_z^2}\right)\right]$$

Cerea
Centre d'Enseignement et de Recherche en Environnement Atmosphérique

Q : source emission rate
$\bar{u}$: mean wind speed velocity
y : crosswind horizontal direction
y_s : source coordinate
z : vertical coordinate
z_p : plume height above the ground
σ_y and σ_z : gaussian plume standard deviations in the horizontal (crosswind) and vertical directions

σ_y & σ_z ?

- Doury
- Briggs
- Pasquill

The Gaussian model

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σ_y & σ_z ?

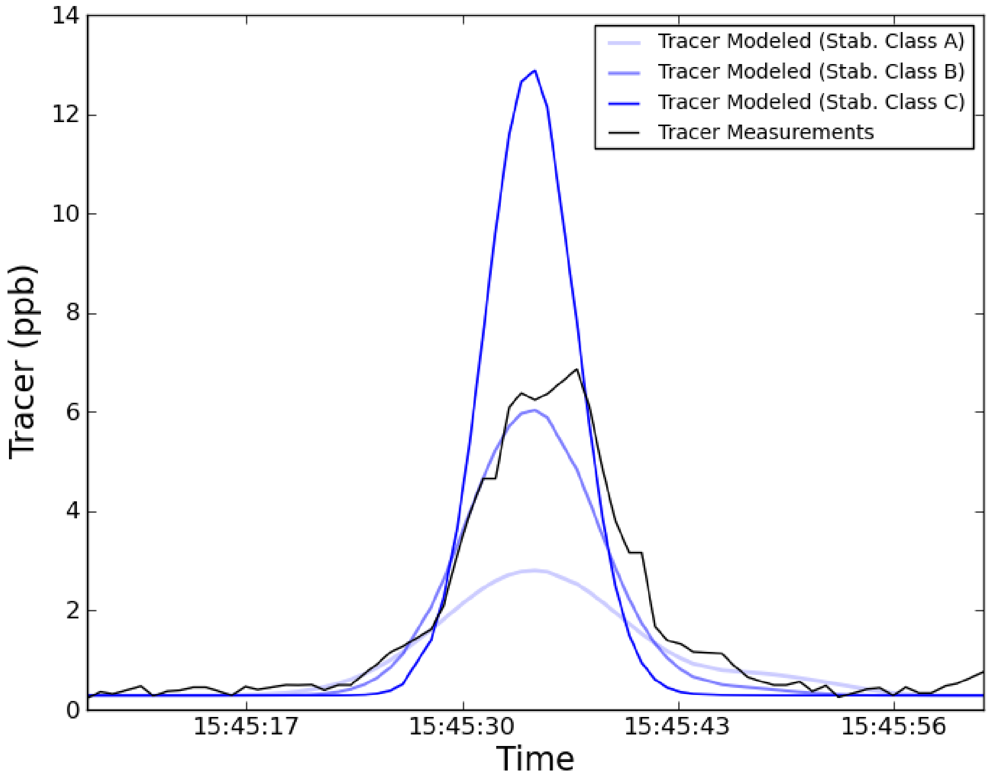
Briggs

The Gaussian model

Use of the tracer data:

⇒ Configuration optimization of the model parameterization

⇒ Assessment of the model uncertainty for the configuration of the observation errors in the statistical inversion



Statistical inversion

$$f^a = f^b + BH^T (HBH^T+R)^{-1} (y^0 - Hf^b)$$

$$A = (B^{-1} + H^T R^{-1} H)^{-1}$$

f^a	**Inverted fluxes**
f^b	**Prior fluxes**
y^0	**Observations**
A	**Covariance matrix**
B	**Covariance matrix of the prior fluxes error**
R	**Covariance matrix of the observations and model errors**
H	**Observation operator**

A test case with controlled methane emissions

Tested configurations:

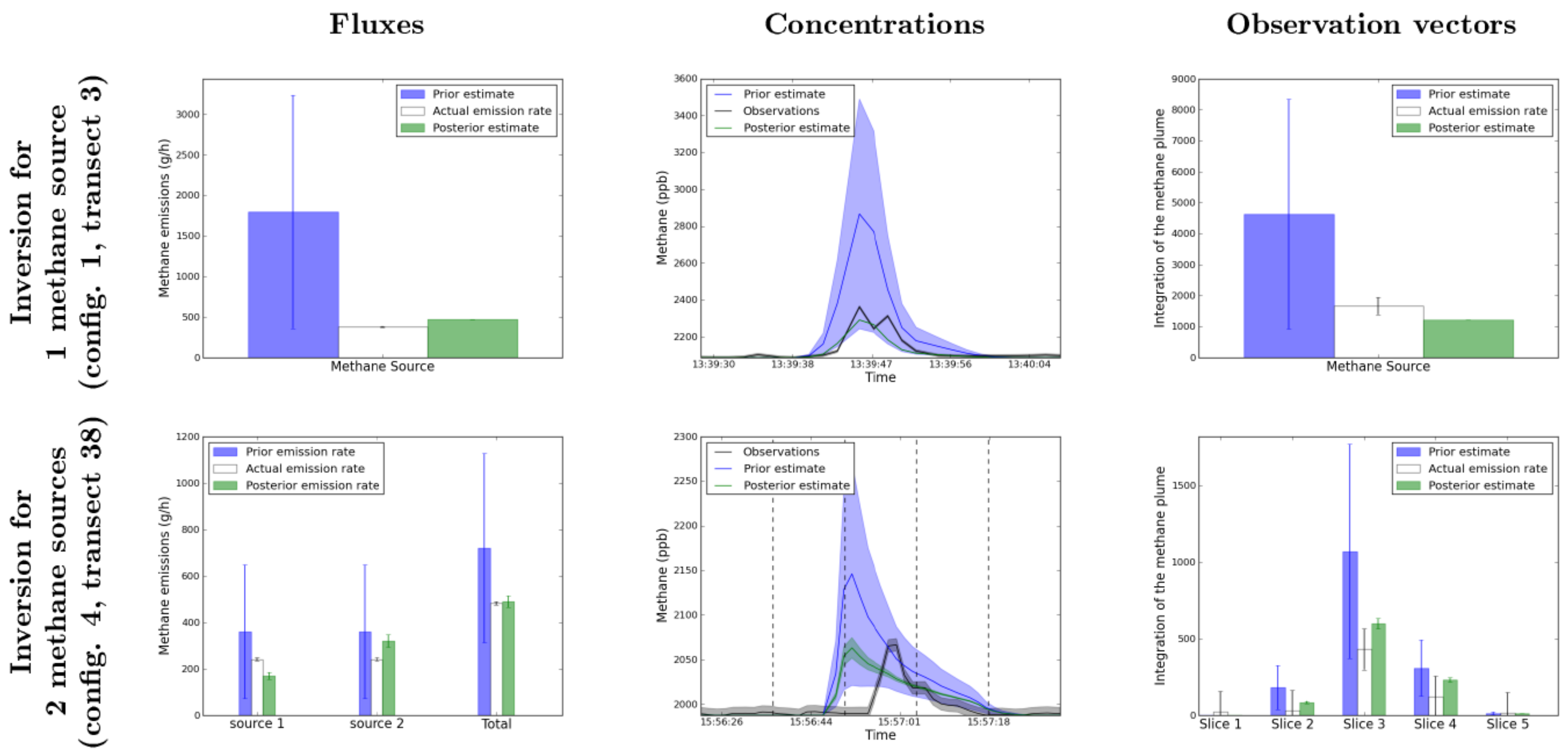
- Config. 1: Methane and acetylene collocated (blue)
- Config. 2: Methane located downwind in comparison with the tracer (orange)
- Config. 3: Lateral shift between methane and acetylene (green)
- Config. 4: Two sources of methane with and one source of acetylene (grey)

A test case with controlled methane emissions

	Configuration 1	Configuration 2	Configuration 3	Configuration 4
Controlled released methane ($g.h^{-1}$)	382 ± 7	428 ± 7	360 ± 7	482 ± 7
Tracer release method estimates ($g.h^{-1}$)	454 ± 166	551 ± 133	421 ± 281	760 ± 184
Percentage of the controlled release (%)	19	29	17	58
Combined approach estimates ($g.h^{-1}$)	472 ± 1	464 ± 1	360 ± 0	482 ± 1
Percentage of the controlled release (%)	24	8	0	0

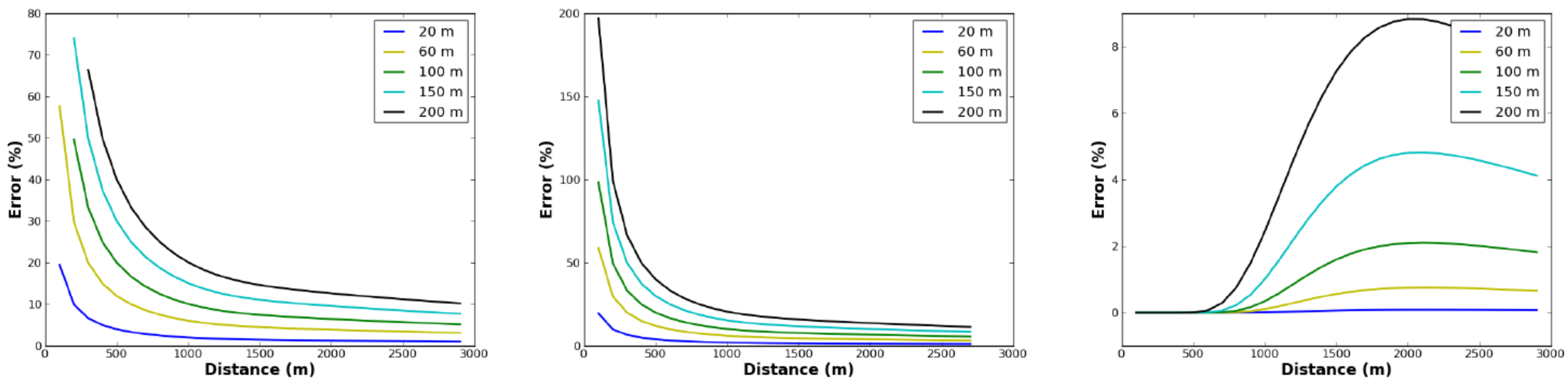
- As expected, tracer release method gives better estimates than the combined approach when the tracer and the methane sources are perfectly collocated because the tracer is a better proxy than the model in this case.
- When the tracer is not perfectly collocated or when there are several sources within a site, the combined approach gives better estimates.

A test case with controlled methane emissions



Estimate of the tracer mislocation error in an OSSE framework

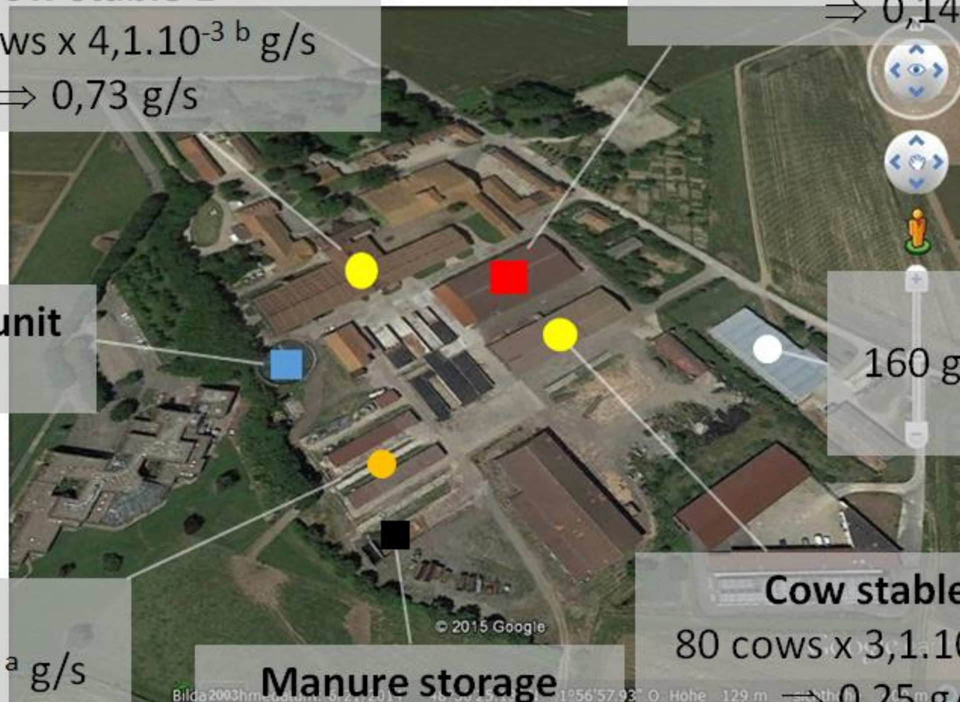
- The methane and acetylene concentrations are modeled with the Gaussian model at known emission rates.
- The emission plumes transects of both gases are integrated and used to calculate the methane emission rate with the same formula than the tracer release technique.
- The calculated emission rates are compared with the actual methane emission rates used in the Gaussian model.
- Errors are estimated for a downwind shift (a), an upwind shift (b) and a lateral shift (c).



(a) *Downwind shift* (b) *Upwind shift* (c) *Lateral shift*

Combined method applied to a concrete case

The Grignon farm



Cow stable 1
180 cows x 4,1.10^{-3} [b] g/s
⇒ 0,73 g/s

Sheepfold
550 sheeps x 2,5.10^{-4} [a] g/s
⇒ 0,14 g/s

Methanisation unit
⇒ 0,73 g/s

Goat stable
160 goats x 1,6.10^{-4} [a] g/s
⇒ 0,03 g/s

Hangar
100 sheep x 2,5.10^{-4} [a] g/s
+ 25 heifers x 2,6.10^{-3} [b] g/s
⇒ 0,09 g/s

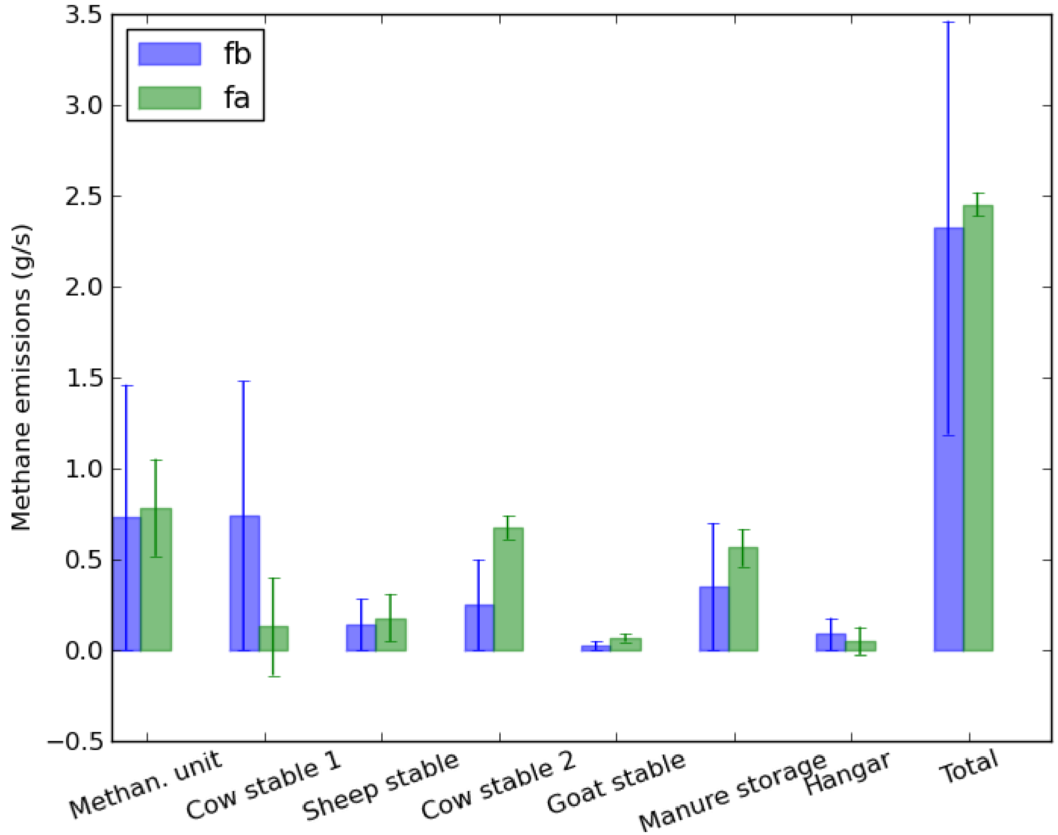
Manure storage
⇒ 0,35 g/s

Cow stable 2
80 cows x 3,1.10^{-3} [b] g/s
⇒ 0,25 g/s

[a] 2006 IPCC Guidelines for National Greenhouse Gas Inventories
[b] Jan Broucek, 2014, Production of Methane Emissions from Ruminant Husbandry: A Review, Journal of Environmental Protection, 2014, 5, 1482-1493

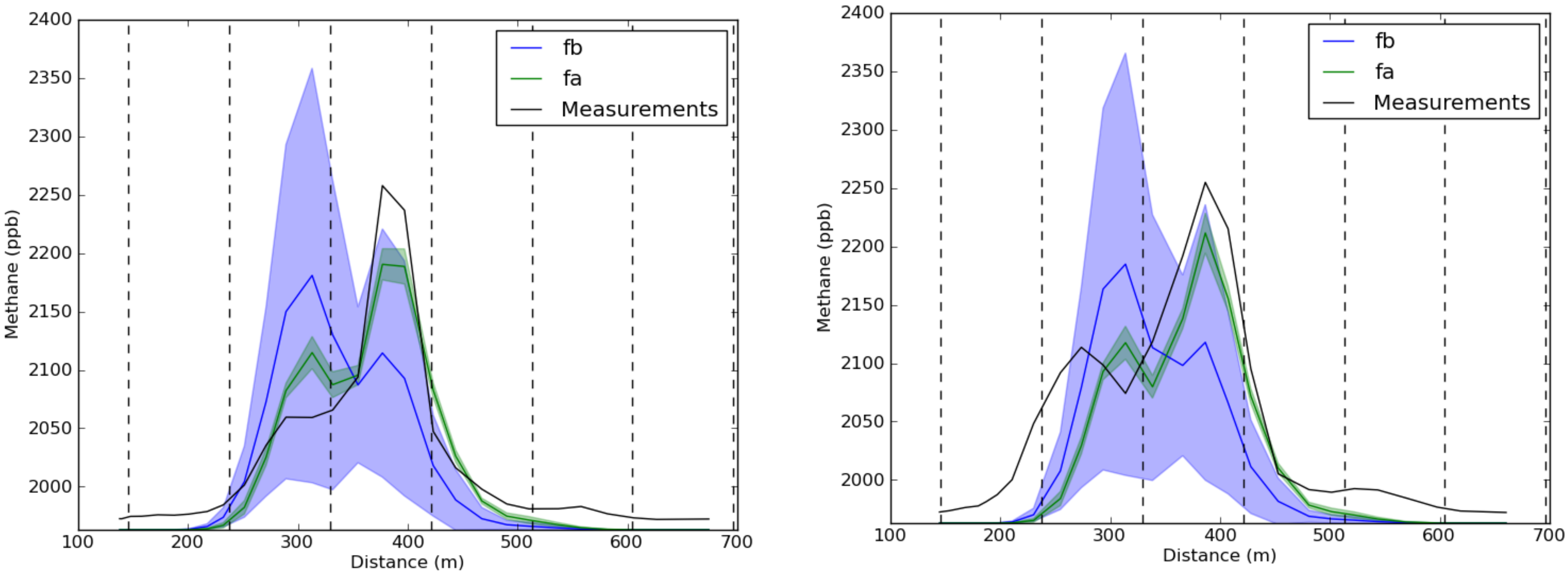
Combined method applied to a concrete case

- Prior and posterior emission rates from the statistical inversion:



Combined method applied to a concrete case

- Examples of plume transects simulated with prior and posterior emission rates:



Conclusions and perspectives

- The combination of the tracer release method, a Gaussian transport model and a statistical atmospheric inversion approach has been tested with controlled methane emissions and compared to the classic tracer release technique for several configuration of tracer and methane sources.
- The combined method gives generally better estimates of the global emission rate of a site except in the case of a perfect collocation of the tracer and the methane which is extremely rare in real industrial cases.
- The combined method is applied to a concrete case in order to estimate methane emissions from a farm. The method gives a good estimate of the total amount of methane emitted but it also diagnoses itself to have some difficulties to target all individual facilities through its diagnostic of the individual uncertainties. However the method still manage to separate some parts of the site.