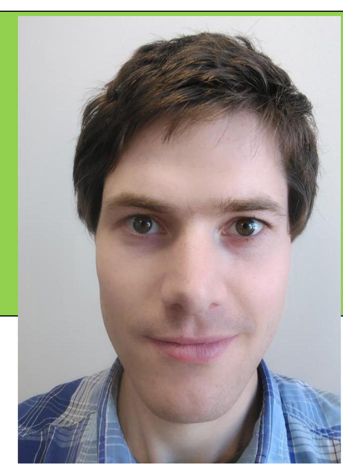
Development and validation of a point source emission quantification method based on eddy covariance



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1. Objectives

Validate the use of eddy covariance to measure methane emission from grazing cattle:

- Select a footprint model which could deliver results consistent with the real emission rate
- Identify the turbulent flux calculation method and QA/QC filtering which is best suited for point source emission estimation
- Assess the robustness and the precision of the emission estimate

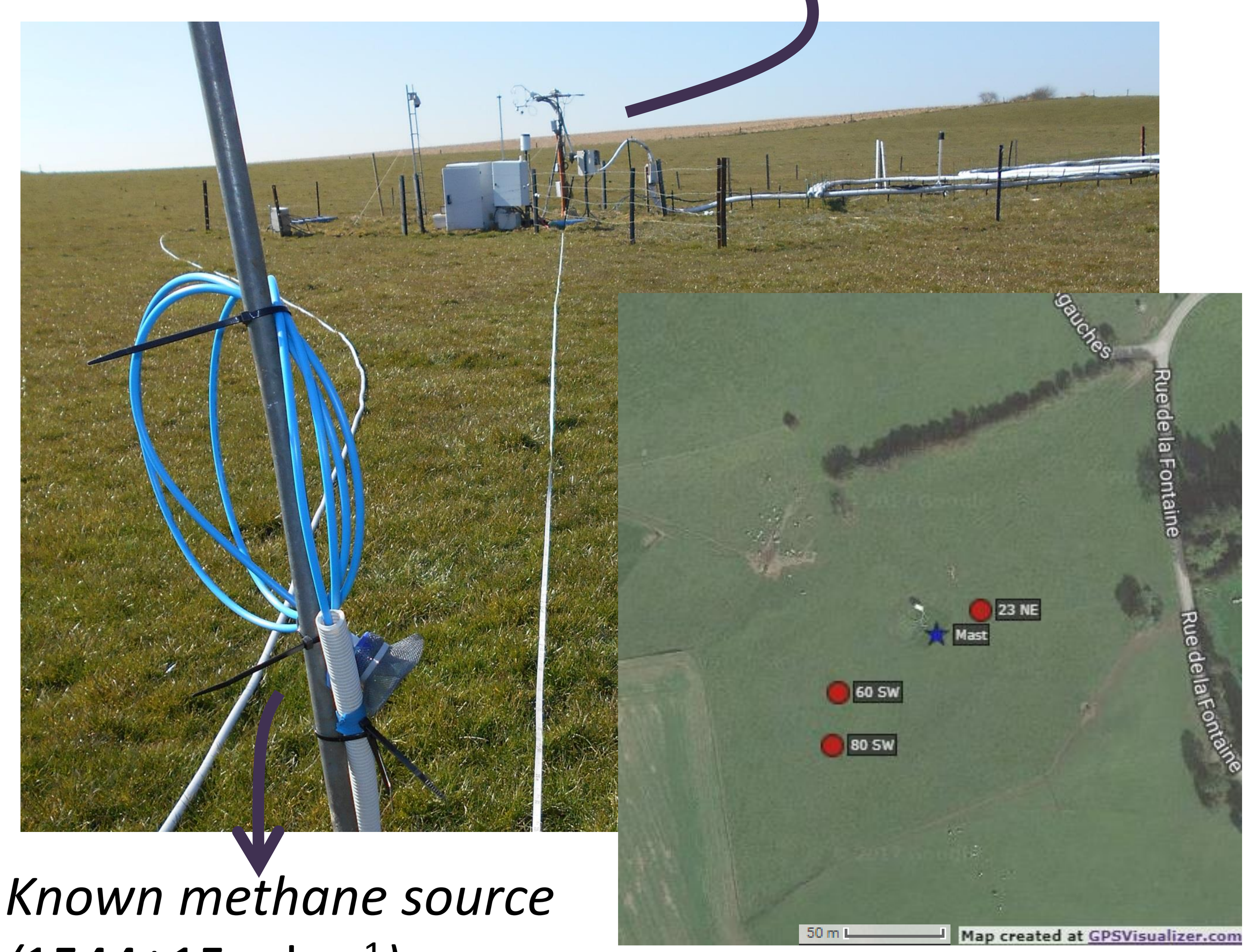
These objectives were answered by working with an artificial methane source in a methane-free environment

2. Material and Methods

Site Description

The experiment took place at the Dorinne Terrestrial Observatory, Belgium. An artificial methane source was placed at 80 cm height (muzzle height) at 3 distances from the mast: 23 m at the NE (6 days), 60 m at the SW (8 days) and 80 m at the SW (41 days).

Measurement of CH_4 flux using eddy covariance (Picarro G2311-f)



Known methane source ($1544 \pm 15 g\ day^{-1}$)

Site map

Measurement method

For each half hour we calculate an emission per source using:

$$f = \frac{F_T}{\sum_i \sum_j n_{ij} \phi_{ij}}$$

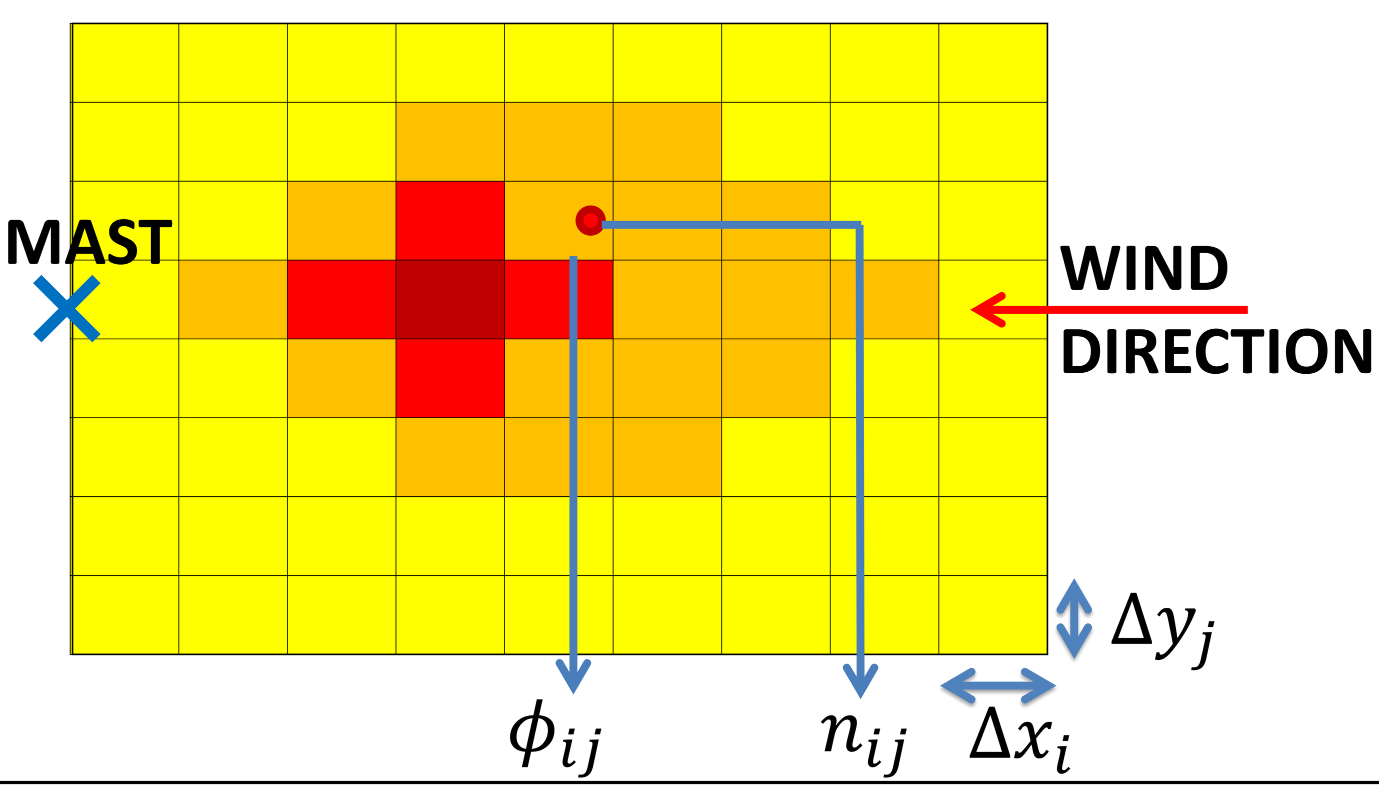
Source Density in the footprint (=SD_f)

Where f corresponds to an emission per source ($nmol\ source^{-1} s^{-1}$),

F_T is the measured flux ($nmol\ m^{-2} s^{-1}$),

n_{ij} the number of sources in the cell ij and

ϕ_{ij} is the footprint contribution of the cell ij (m^{-2}) calculated either using the model described by Kormann and Meixner *(2001)* or by Kljun *et al. (2015)*.

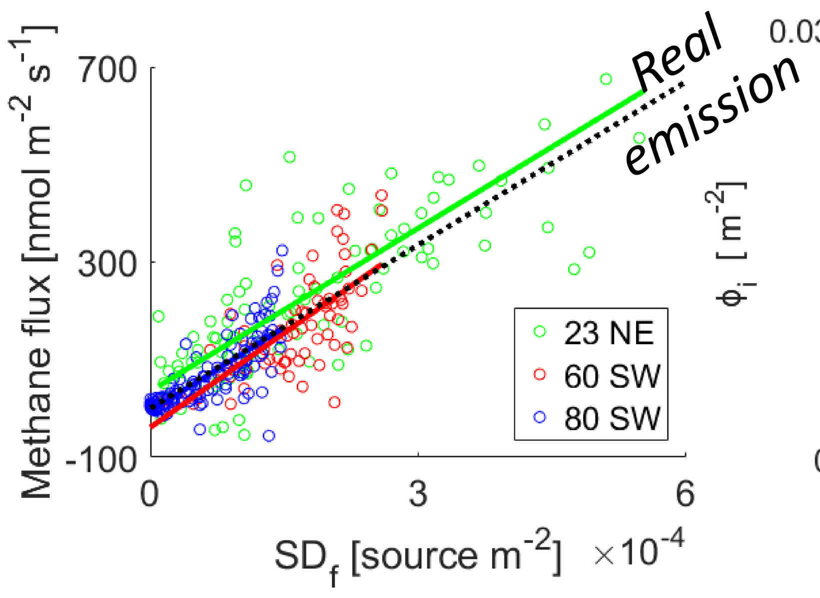


3. Results

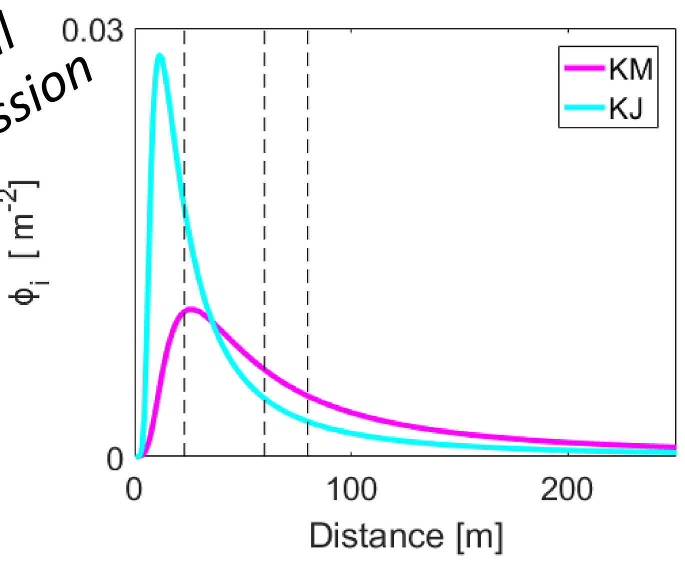
Footprint function

Among available state-of-the-art and popular footprint models two were tested:

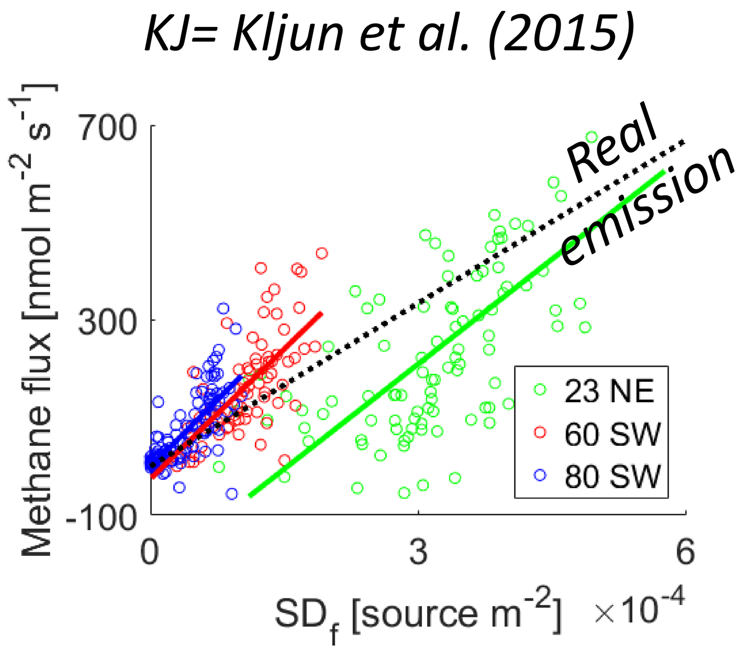
KM= Kormann & Meixner (2001)



KM vs KJ



KJ= Kljun et al. (2015)



❑ All three regression curves are almost parallel to the real emission curve

❑ KM and KJ footprint models produce very different footprint function shapes

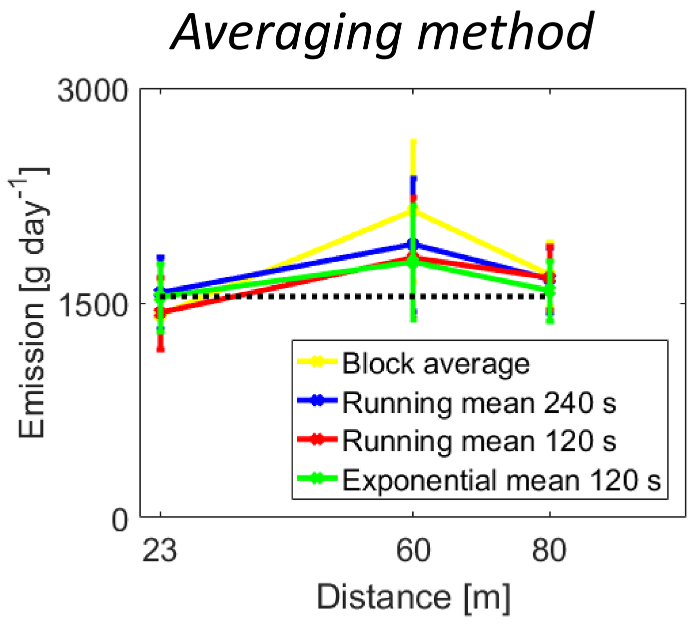
❑ Regression curves are not parallel and do not correspond to the real emission curve

The KM footprint model provides accurate and stable emission estimates (=> Selected)

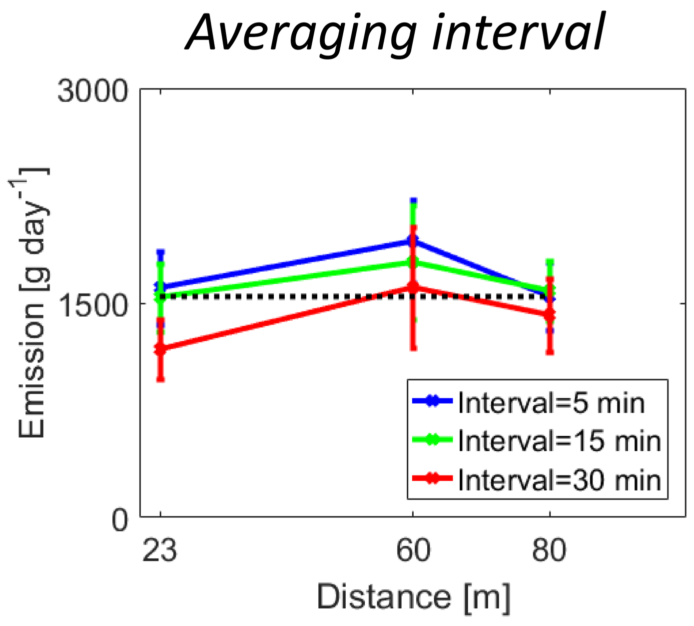
Methane emission calculation

Different turbulent flux calculation methods were tested:

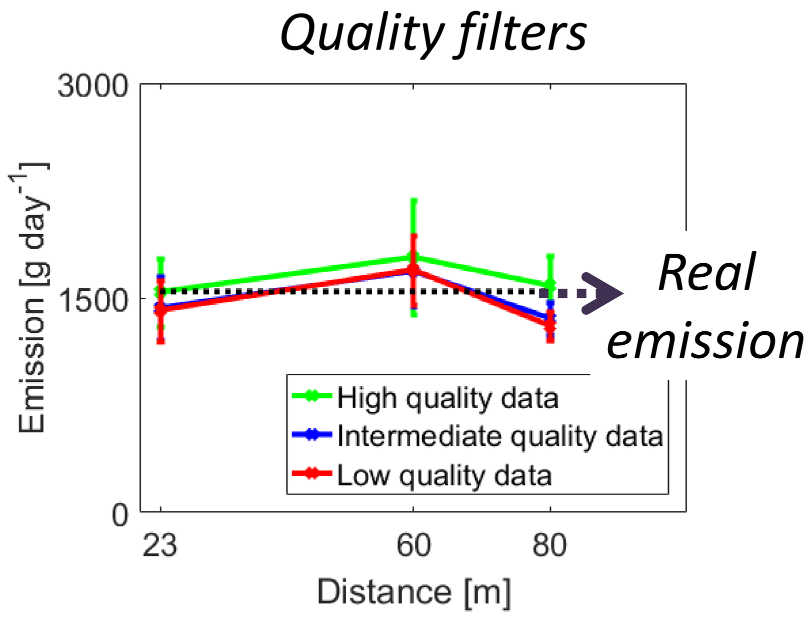
Averaging method



Averaging interval



Quality filters



❑ Highpass filtering methods (exponential or running mean) increased robustness

❑ Decreasing intervals were associated with increasing emission estimates

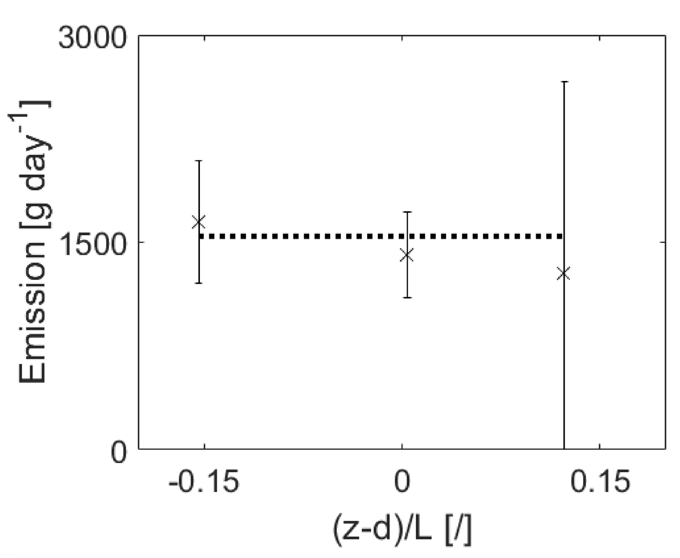
❑ Quality filters (MF=*Mauder & Foken*, 2004) had a limited impact on emission estimates

Exponentially weighted moving average on 15 minute intervals combined with full application of the MF quality filtering provides accurate and stable emission estimates (=> Selected)

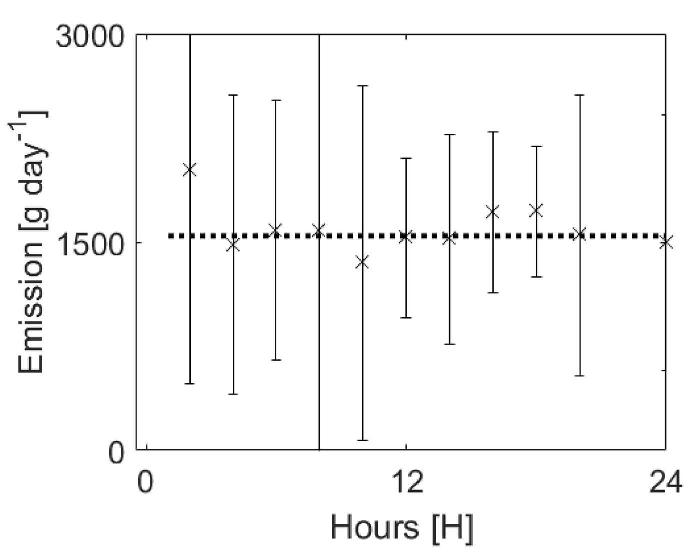
Sensitivity analysis

Using the selected calculation method estimated methane emission were tested for their robustness according to:

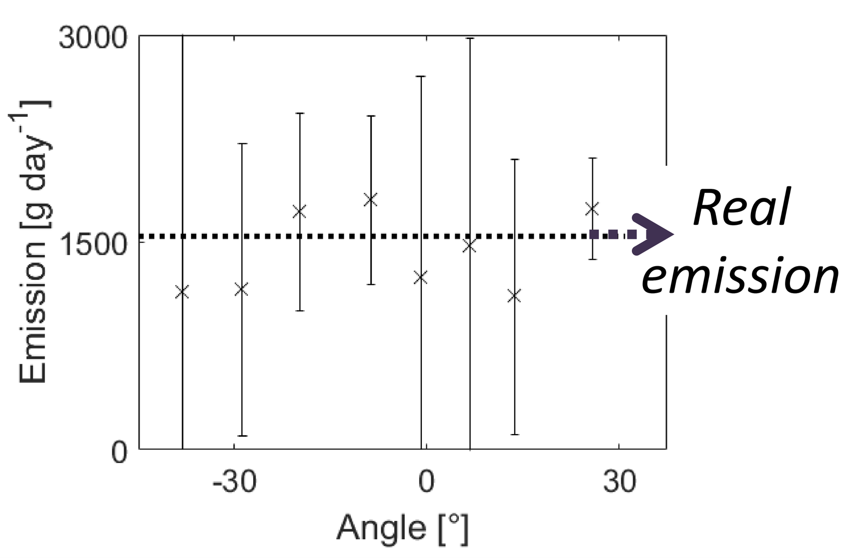
Atmospheric stability



Time of the day



Angle between the wind and the source direction



Robust mean methane emission estimation no matter the atmospheric stability, the time of the day or wind direction relatively to the source

4. Conclusions and perspectives

❑ Selected method = KM footprint model, exponentially weighted moving average on 15 minute intervals and full application of the MF quality filtering

❑ Using the selected method the emission estimate was never significantly different from the real emission (see graphs)

❑ Emission estimates are heavily impacted by methodological choices

❑ Emission estimates are only slightly impacted by meteorological conditions or deviations between the source and the wind direction

❑ The artificial source was mobile in the air referential, indicating that the present method could be compatible with moving point source (e.g. cattle)

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