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# Increased Baseline Methane Concentrations at a Commercial Dairy Farm Associated with Anaerobic Digestion.

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## Introduction

Anaerobic digestion (AD) is an emerging technology for dairy systems in Ontario, Canada. Preceding research has examined the methane ($CH_4$) emission impacts of converting manure management from untreated systems to those using AD. However, few have looked specifically at investigating the unintended release of $CH_4$ during ordinary operating practices[1]. The purpose of this study is to estimate $CH_4$ emissions from: a) the digestate storage tank, and b) the operational AD system itself, through the application of micrometeorological techniques.

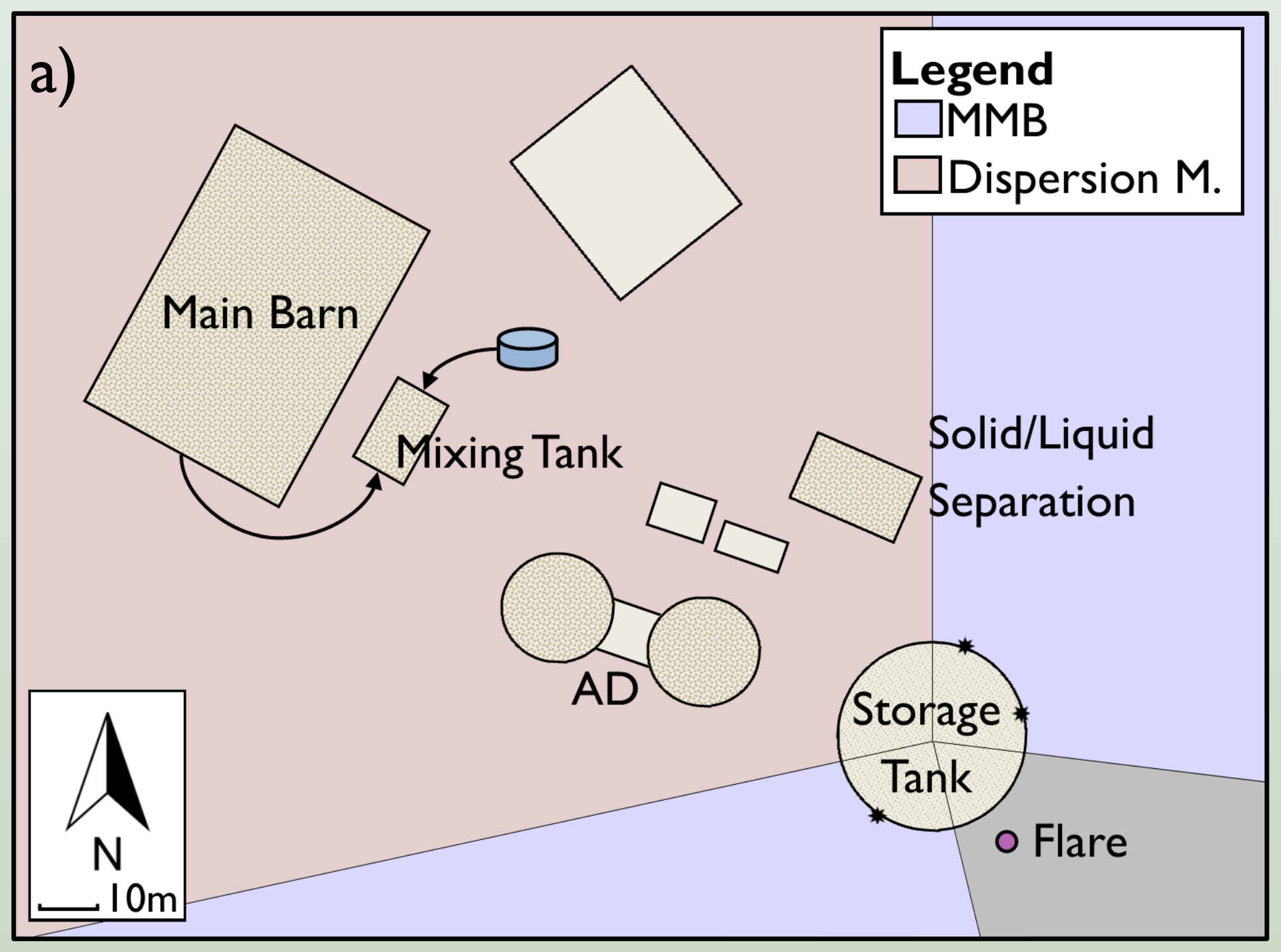

Figure 1 – a) Map of AD system components, with wind sectors contributing to each method. b) Photo of AD system in 2012. Left: barns and mixing tank. Centre: two-stage AD unit. Right: storage tank.

## Methodology

The study was conducted at a commercial dairy farm before (Jan 2011- Nov 2012) and after (Dec 2012- Nov 2015) the installation of a two-stage anaerobic digester. Vertical profiles of $CH_4$ concentration were measured in three locations around a digestate storage tank by a closed-path trace gas analyzer (TGA-100A, Campbell Scientific). To make an estimate of $CH_4$ emissions from AD:

- Micrometeorological mass balance (MMB) technique was used to measure emissions directly from digestate storage[2](Fig. 1) using three towers placed around the tank with air intakes at four heights (Fig. 2a,b).

MMB measurements were filtered to remove periods in which there were low wind speeds, or when wind angle prevented suitable definition of upwind and downwind concentrations.

- External (or fugitive) emissions were estimated by an inverse plume dispersion model (Fig. 1a) based on atmospheric conditions and a spatially-defined building source, according to:

$$Q = \frac{31.4\,\sigma_y\,\sigma_z\,K}{10^6 \times \exp\left[-\frac{1}{2}\left(\frac{Y}{\sigma_y}\right)^2\right] \times \left\{\exp\left[-\frac{1}{2}\left(\frac{Z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{Z+H}{\sigma_z}\right)^2\right]\right\}}$$

Where $Q$ is emission rate (g $CH_4$/s), $K$ is measured [$CH_4$] (half-hour average), $\sigma_y$ and $\sigma_z$ are horizontal and vertical dispersion coefficients, $Y$ is horizontal distance from measurement to plume centre line, $Z$ is measurement height (4.5m), and $H$ is related to building height (Fig. 2c).

Dispersion model results underwent a filter which limited useful data to times when the source in question was upwind, as well as a filter based on atmospheric stability.

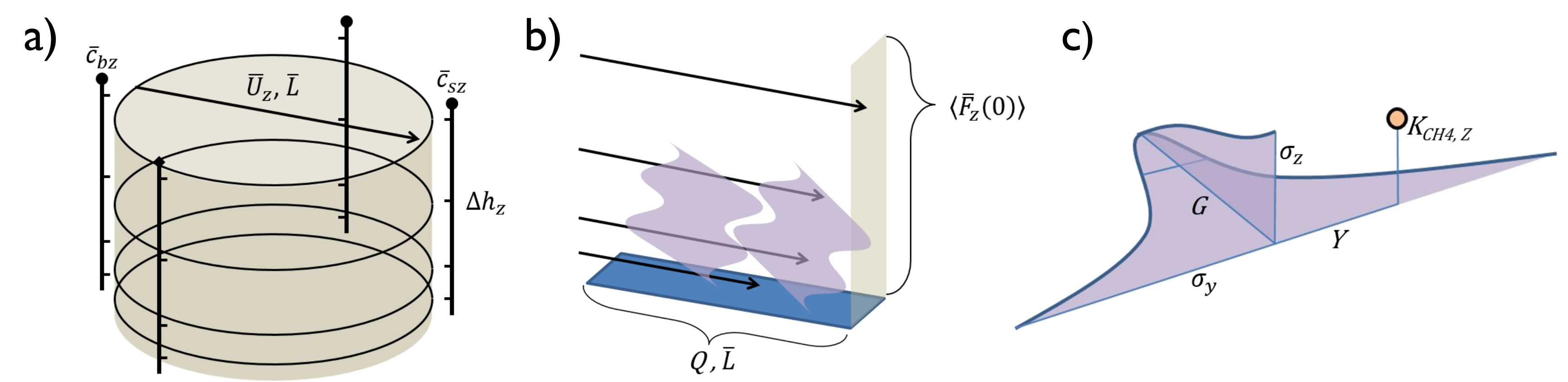

Figure 2 – Schematic illustrations of: a) the measurement system in place around the storage tank for the length of the study, b) the underlying premise of MMB method, and c) the Gaussian dispersion model used to estimate upwind emission rates.

## Results

- In the first three years observed, there was no significant difference in background concentration (Fig. 3).
- After the proportion of input off-farm material increased (Fall 2013), there was a 0.43 ppmV increase in mean background $CH_4$ (Fig. 3).
- This background increase was associated with the northwest quadrant (AD system; Fig. 4).
- The diffusion model showed an average 203% increase in $Q$ from the barn/mixing tank between 2012 and 2015 (10.3 and 31.1 g/s, respectively), and a likewise 228% increase in $Q$ from the AD unit itself (2.55 and 8.37 g/s, respectively).
- MMB method measured an increase in the storage tank $CH_4$ flux from an average of 0.07 g/s in 2013 to 0.20 and 0.29 g/s in 2014 and 2015.

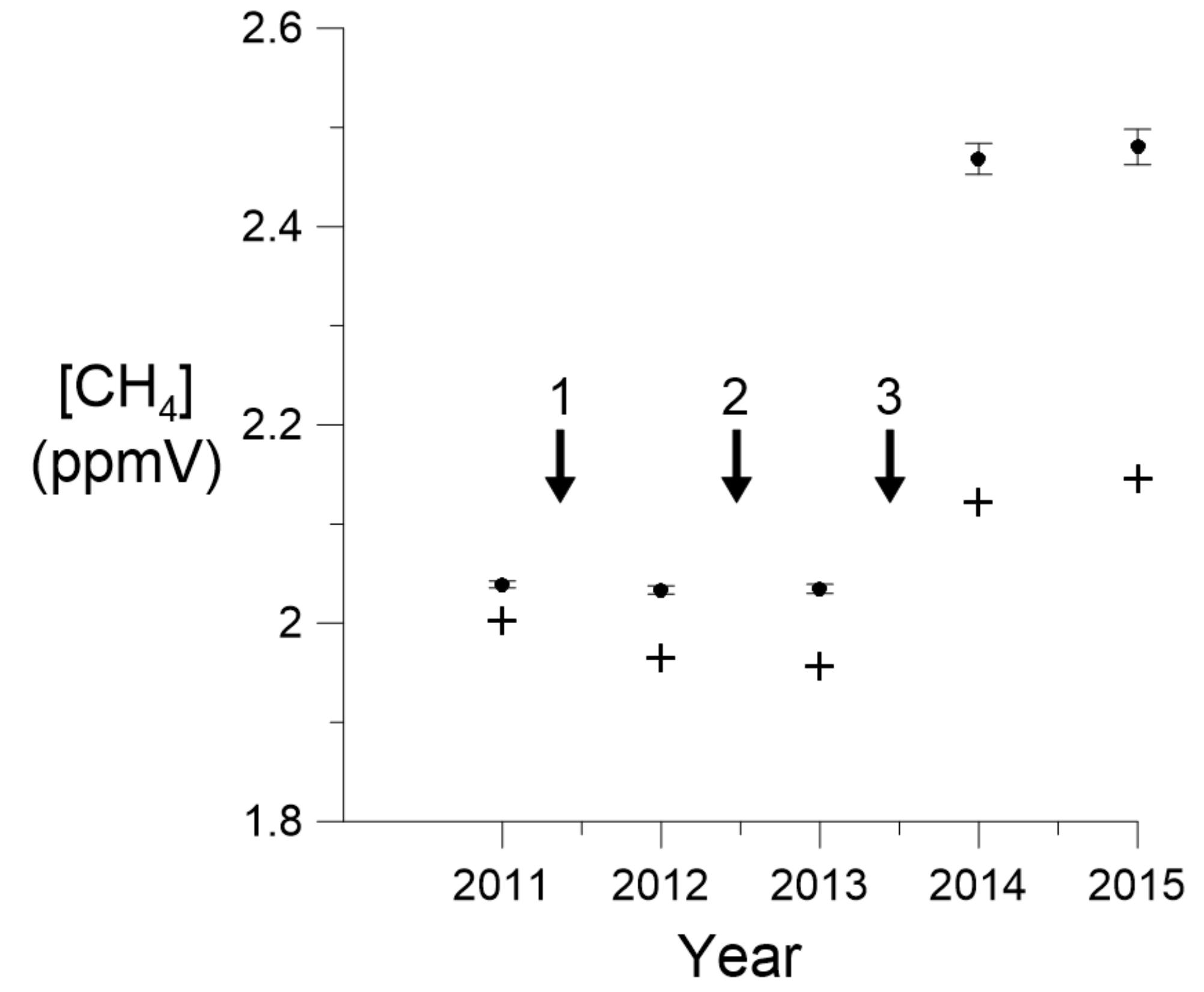

Figure 3 – Yearly mean [$CH_4$] measured upwind of the storage tank at 450 cm height are shown by (•), with error bars representing standard error of the mean. Median values are shown by (+). ↓1 is when AD began operation, at ↓2 off-farm materials began (~25% input), after ↓3 ~50% of inputs were off-farm material.

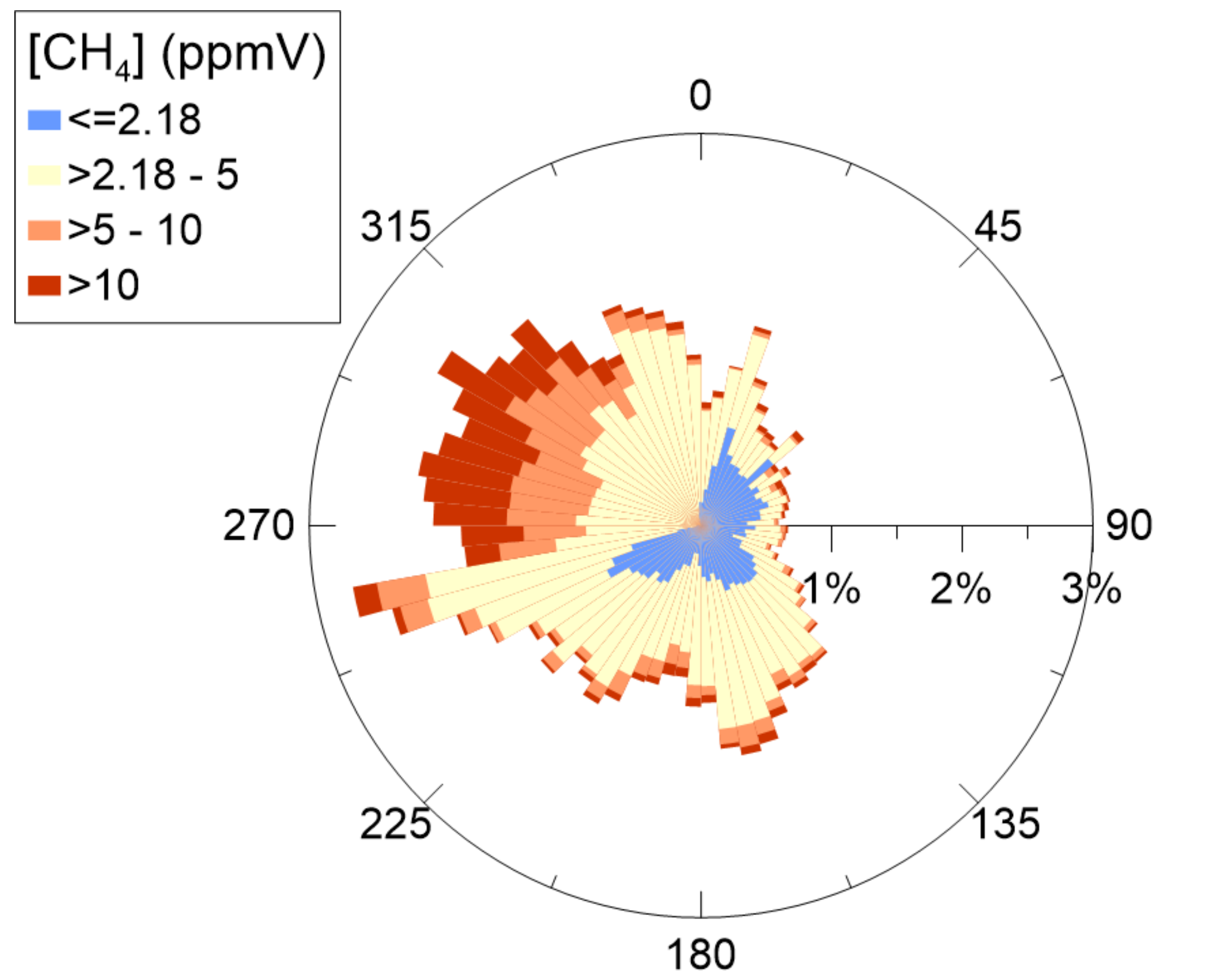

Figure 4 – Wind rose depicting areal extent of heightened [$CH_4$]. Wind direction is displayed on the circular axis in degrees clockwise from North. Radial axis denotes relative frequency (%). Concentrations are measured from a single intake at 450cm during 2014-2015. Lowest division represents overall median from 2011-2015.

## Conclusions

- Significant fugitive $CH_4$ emissions were observed during the first three years of a digester's operation, while emissions from the digestate storage tank were relatively smaller.
- The use of off-farm materials as an input feedstock should be carefully managed to avoid excess biogas production.
- The results obtained in this study will be used in the development of a full life-cycle assessment of greenhouse gas emissions from AD, which will include avoided emissions from diverting off-farm food waste from landfill.

## References

1 Flesch, T., Desjardins, R. and Worth, D. (2011). Fugitive methane emissions from an agricultural biodigester. *Biomass and Bioenergy*, 35(9), pp.3927-3935.

2 Wagner-Riddle, C., Park, K. and Thurtell, G. (2006). A micrometeorological mass balance approach for greenhouse gas flux measurements from stored animal manure. *Agricultural and Forest Meteorology*, 136(3-4), pp.175-187.

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