Emission measurements with micrometeorological methods

PICARRO AMMONIA SUMMIT
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JESPER NØRLEM KAMP
TENURE TRACK RESEARCHER

Outline

- Outline
- Who am I?
- Introduction
- Inverse dispersion modelling
- Measuring emissions after slurry application
- Aerodynamic gradient method after slurry application

Who am I?

Jesper Nørlem Kamp

Tenure track researcher

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Section of Environmental Engineering

Department of Biological and Chemical Engineering

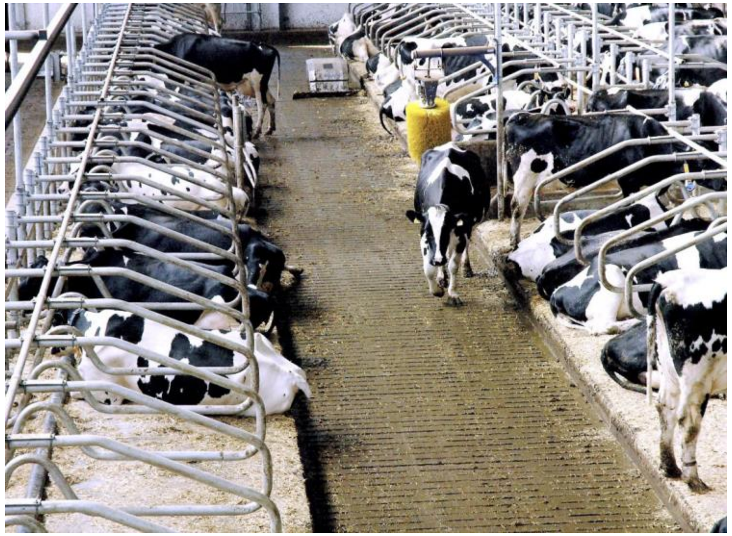
Aarhus University

M.Sc. Chemical Engineer, 2016

Ph.D. Environmental Engineering, 2021

- Development and application of technologies for measuring gas emissions from agriculture

Emission measurements from agriculture



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Emissions

Different requirements for analyzer

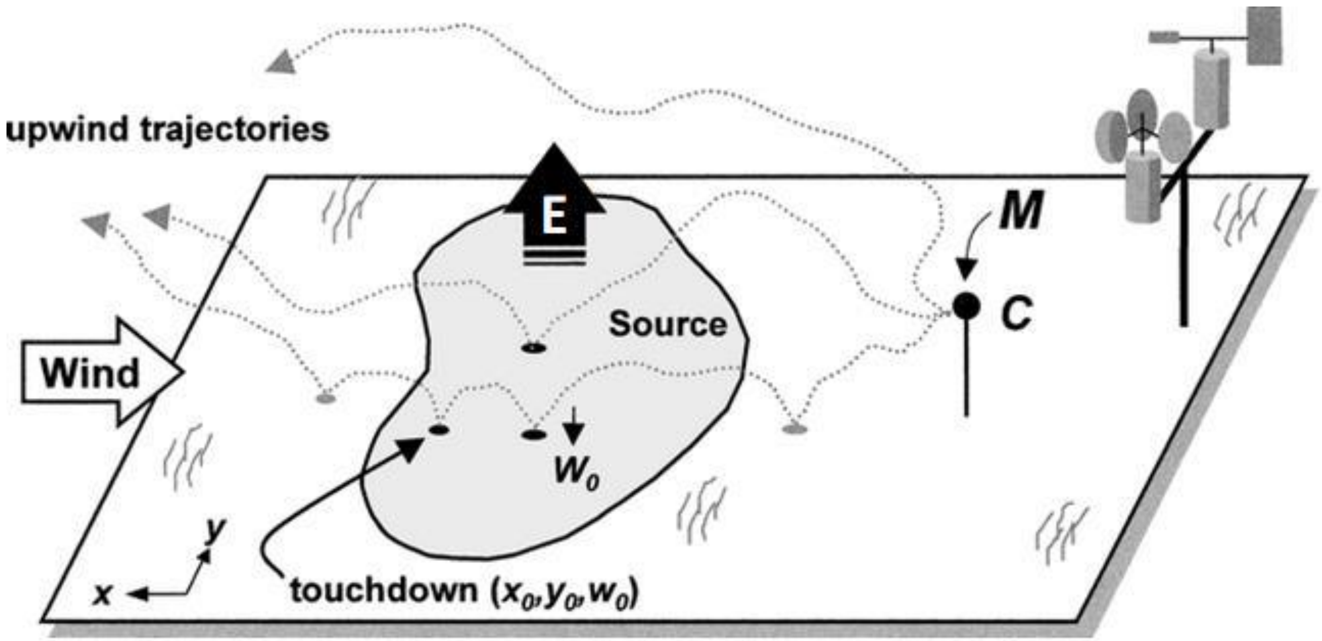
- Emission source
- Emission strength
- Emission method

Possibilities with the available equipment and methods

Emission rates

Inverse Dispersion model

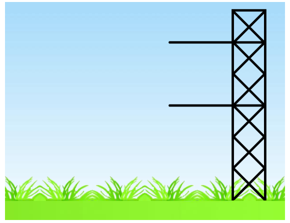
Backward Lagrangian stochastic (bLS)model



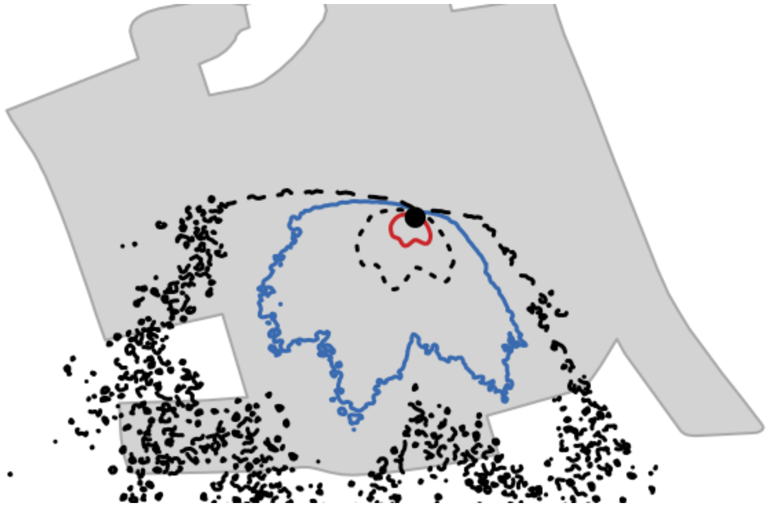
Flesch et al., 2004, Vol. 43, Journal of Applied Meteorology

Micrometeorological method

Aerodynamic Gradient Method



Footprint correction needed for specific source estimate



Kamp et al., 2021, 12, 102, Atmosphere

Inverse Dispersion Modelleling

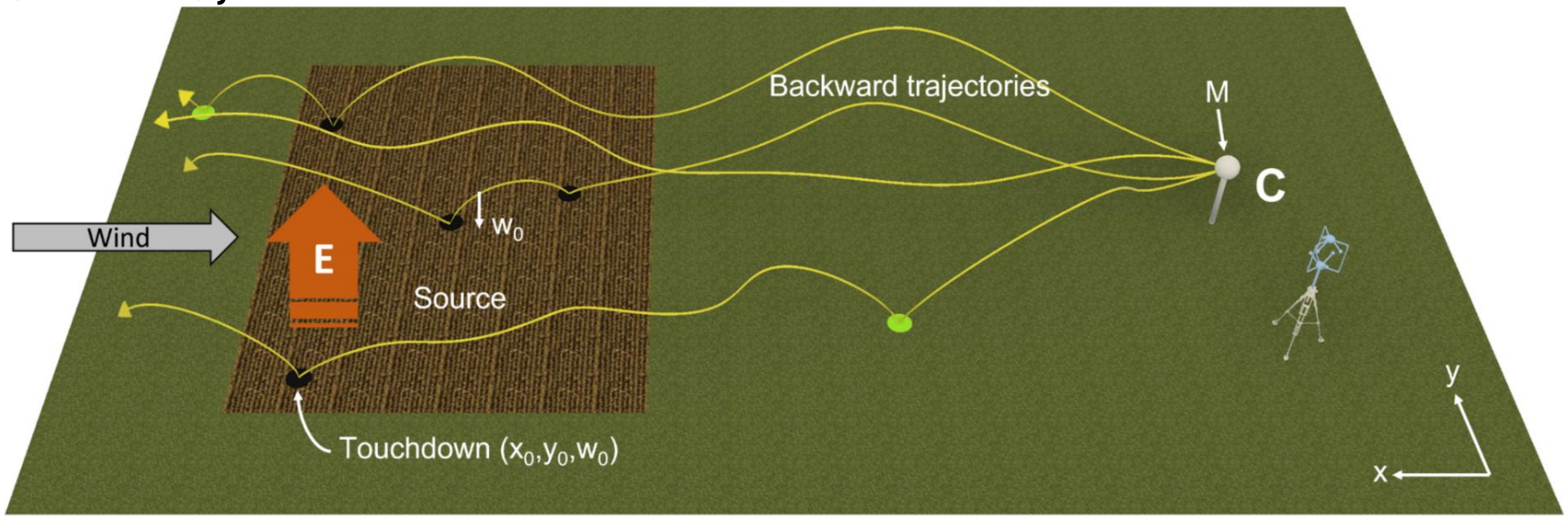
Backward Lagrangian Stochastic (bLS)

- Provides non-invasive source specific emissions estimates
- Determine emission rates from a defined area in 10-60 min intervals
- Possible to use complex geometry
- Concentration measurements (line or point)

Inputs:

- Concentrations (up- and downwind)
- Wind statistics
- Source geometry
- Sensor position

Bühler (2022)



Possibilities with bLS

Continuous emission measurements from sources with complex geometry

Fields

Tanks

Buildings

Major limitations:

1. Computational time
2. Dispersion assumptions must be fulfilled
3. Concentration difference

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Example bLS: Measurement methods

Scope

Evaluate differences related to measurement methods

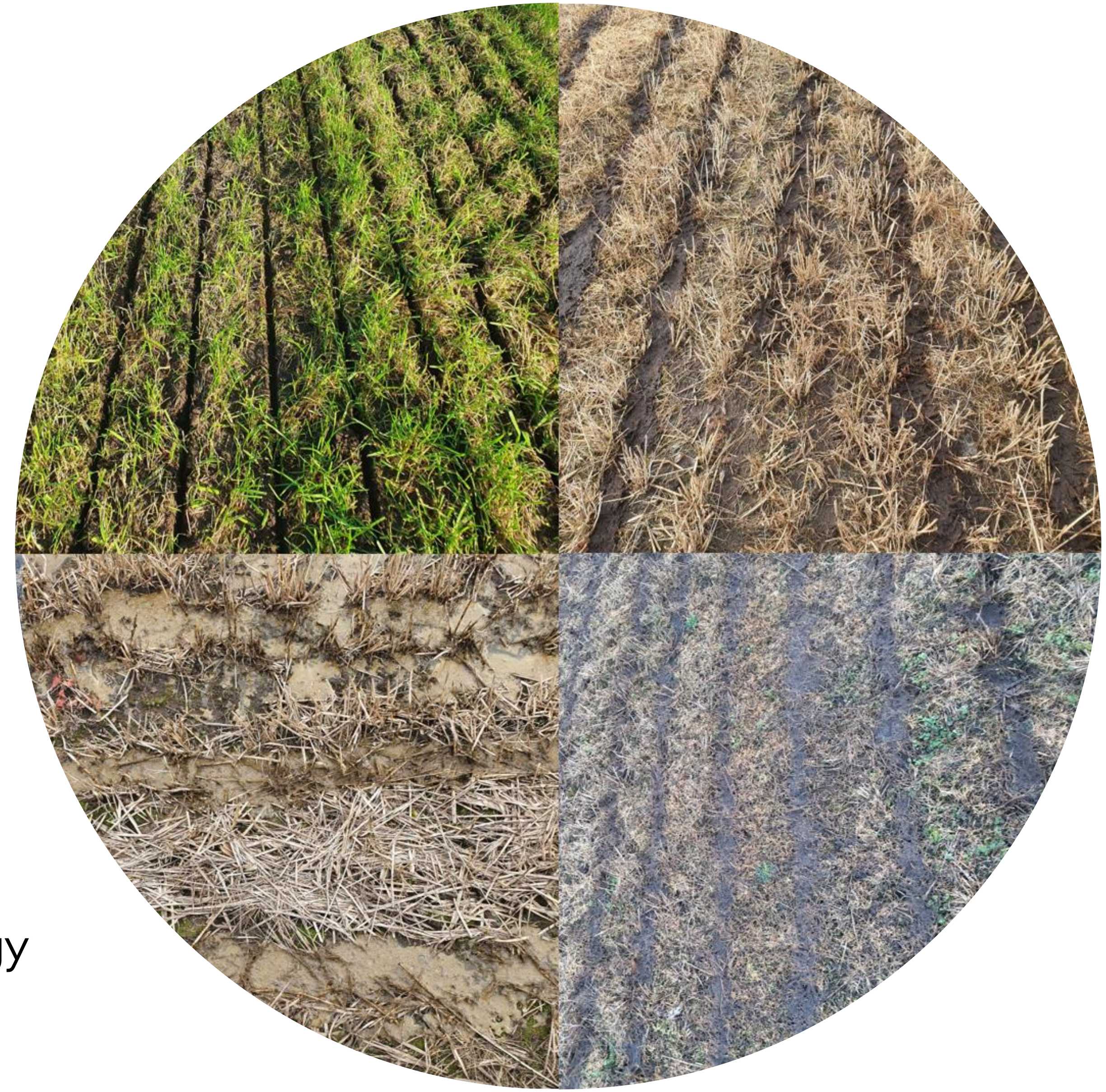
- Effect of local soil, weather, application method, applicator, etc. eliminated

Methods

- Time averaged and spot
- Absolute and relative
- On site and off site

Manuscript in review:

Kamp et al., Agricultural and Forest Meteorology



Measurement methods

Aarhus University (AU)	Wageningen University & Research (WUR)	Johann Heinrich von Thünen Institute (Thünen)
Wind tunnels with Cavity Ring-Down Spectroscopy **WT**	Flux Chambers with Impingers **FC**	Dräger Tube Method **DTM**
bLS with Cavity Ring-Down Spectroscopy **bLS-CRDS**	bLS with Impingers **bLS-Impingers**	bLS with Passive ALPHA Samplers **bLS-ALPHA**
	Integrated Horizontal Flux with Impingers **IHF**	

Measurement methods

	Aarhus University (AU)	Wageningen University & Research (WUR)	Johann Heinrich von Thünen Institute (Thünen)
Enclosure methods	Wind tunnels with Cavity Ring-Down Spectroscopy **WT**	Flux Chambers with Impingers **FC**	Dräger Tube Method **DTM**
Micrometeorological methods	bLS with Cavity Ring-Down Spectroscopy **bLS-CRDS**	bLS with Impingers **bLS-Impingers**	bLS with Passive ALPHA Samplers **bLS-ALPHA**
		Integrated Horizontal Flux with Impingers **IHF**	

Measurement methods

	Aarhus University (AU)	Wageningen University & Research (WUR)	Johann Heinrich von Thünen Institute (Thünen)	
High time resolution	Wind tunnels with Cavity Ring-Down Spectroscopy **WT**	Flux Chambers with Impingers **FC**	Dräger Tube Method **DTM**	Spot samples in time
	bLS with Cavity Ring-Down Spectroscopy **bLS-CRDS**	bLS with Impingers **bLS-Impingers**	bLS with Passive ALPHA Samplers **bLS-ALPHA**	
		Integrated Horizontal Flux with Impingers **IHF**		

Integrating over time

Measurements

Trial 1

Denmark:

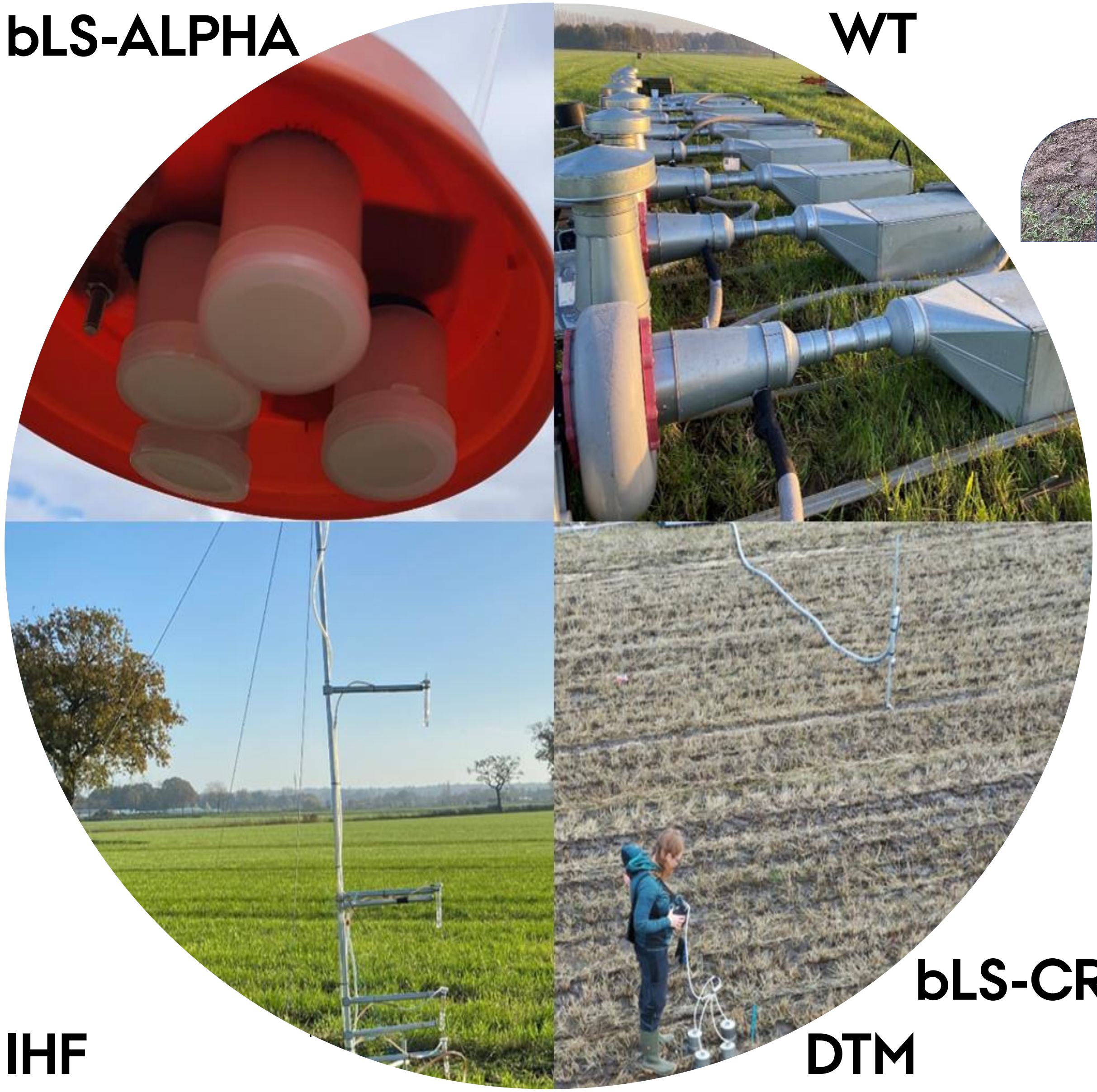
WT

bLS-CRDS

bLS-ALPHA

DTM

bLS-ALPHA **WT**



IHF **DTM** **bLS-CRDS**

FC

Trial 2

Netherlands:

WT

bLS-CRDS

bLS-Impinger

IHF

FC

Ammonia flux

Unpublished data removed.

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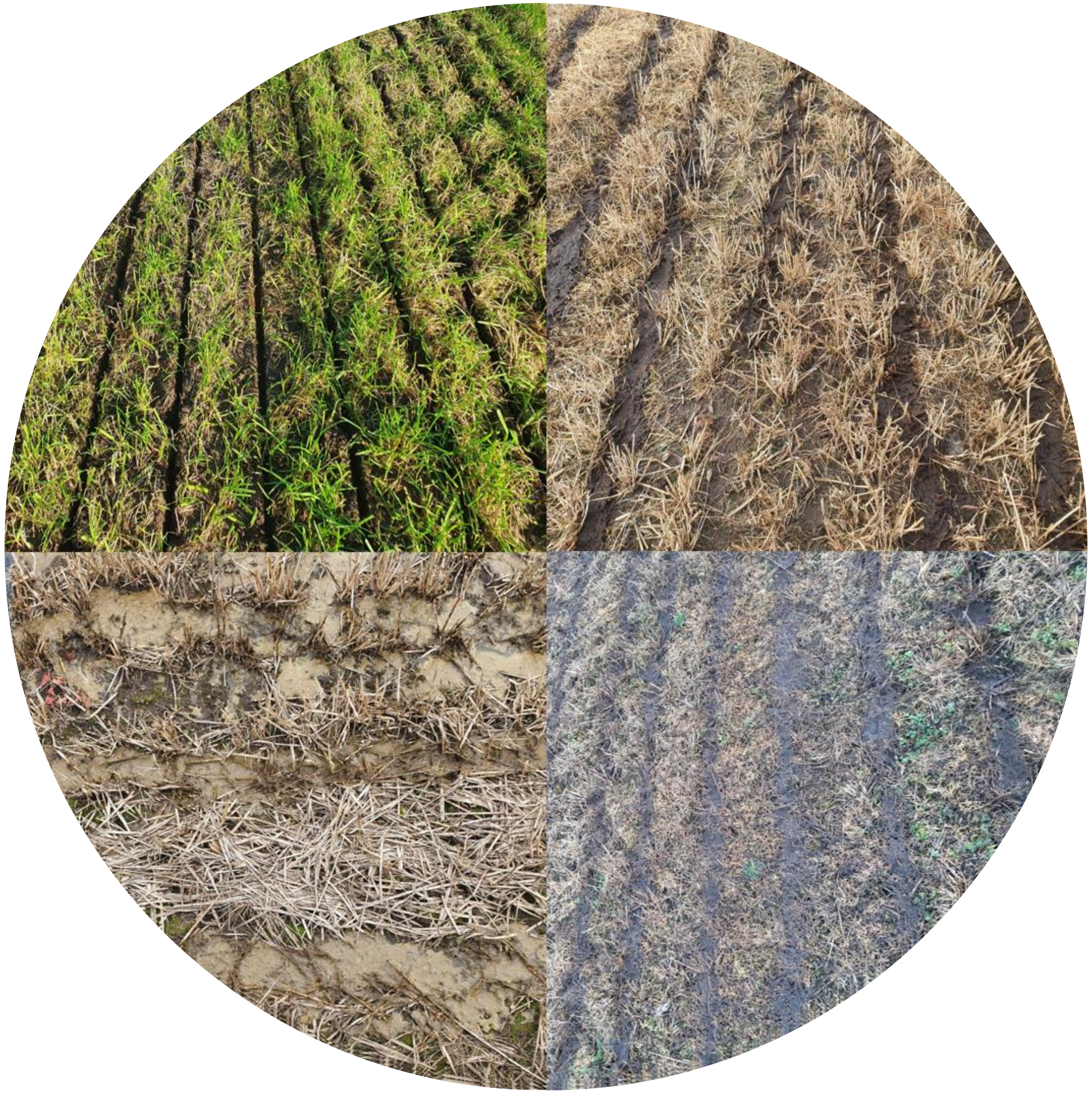
Cumulative loss (% of applied TAN)

Unpublished data removed.

Conclusions

Unpublished data removed.



The aerodynamic gradient method

Emission rates

Inverse Dispersion model

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Micrometeorological method

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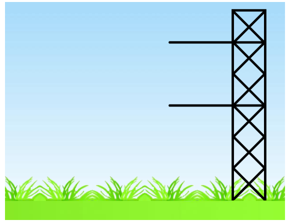

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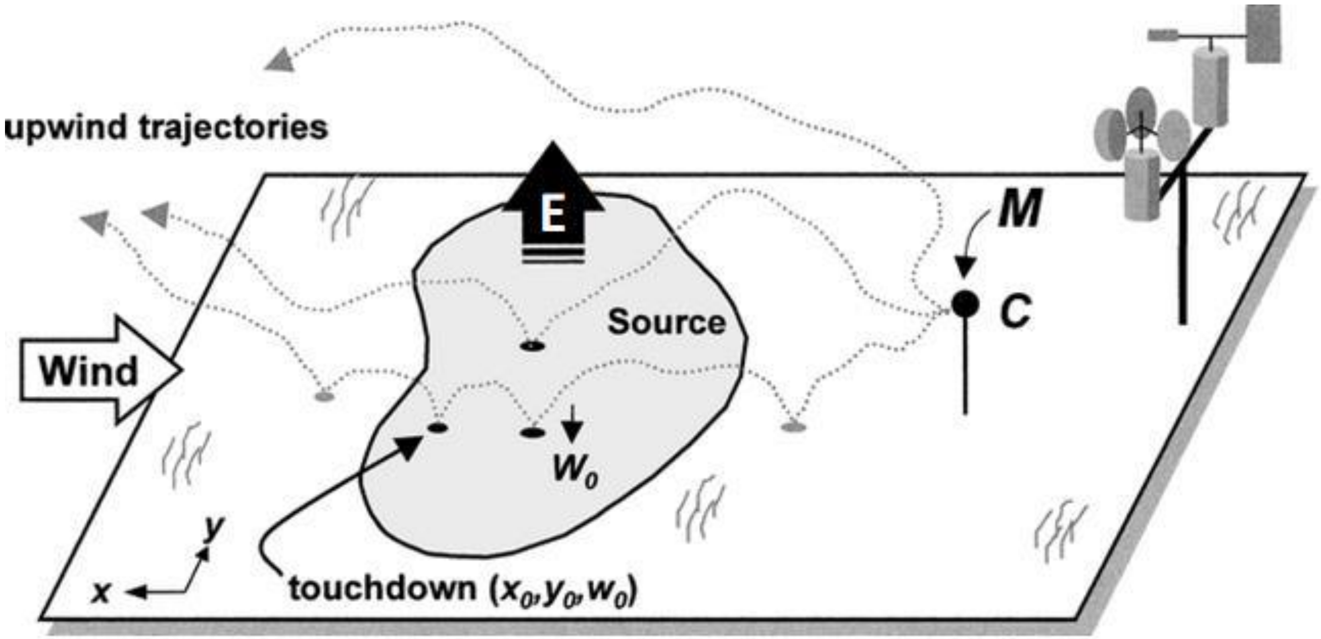

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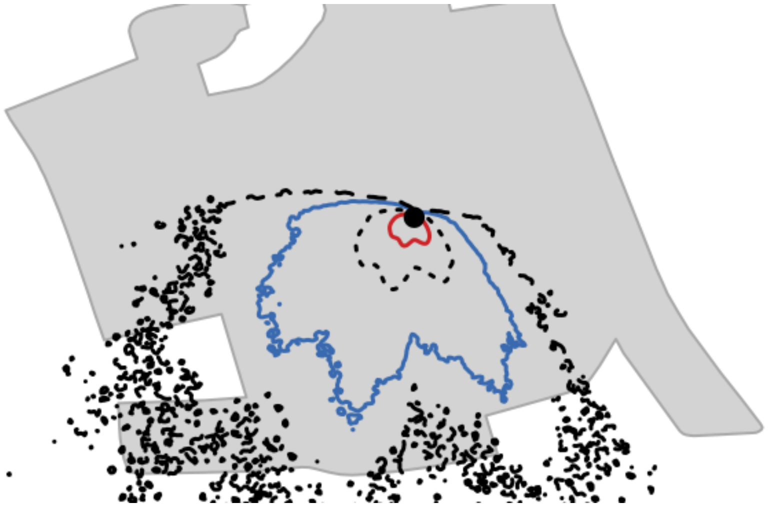

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Aerodynamic gradient method

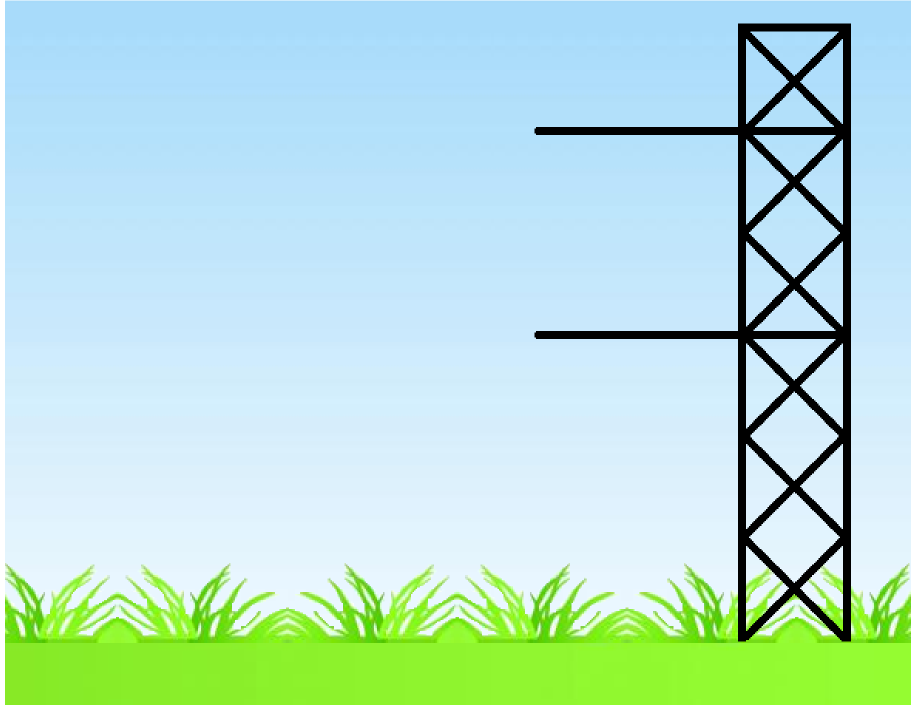
Based on Fick's law:

$$F = -K_c \frac{\partial c}{\partial z}$$

Parameterized based on Monin-Obukhov similarity theory:

$$F = -K_c \frac{\partial c}{\partial z} = -\frac{u_* \, k \, (c_2 - c_1)}{\ln\left(\frac{z_2}{z_1}\right) - \psi_{c,2} + \psi_{c,1}}$$

Wind statistics



AGM flux after field application of slurry

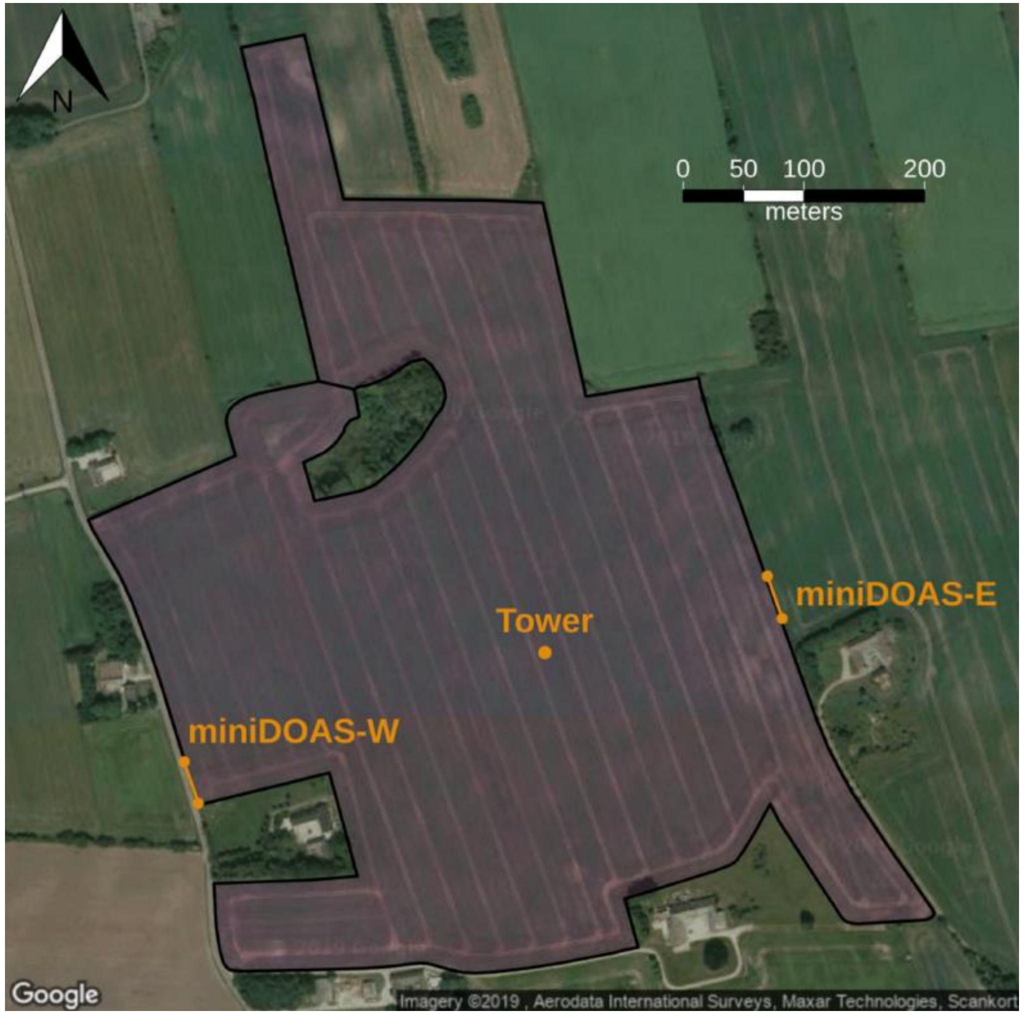
Continuous measurements at two heights
Two instruments?

- Expensive
- Systematic differences?
- Potential bias?

Discontinuous or continuous measurements?

Tested in two field trial on 26 ha field

- Two G2103



Kamp et al., 2020, 11, 1067, Atmosphere

AGM flux

Relative difference < 7% for half-hour intervals

Relative difference in total TAN < 4%.

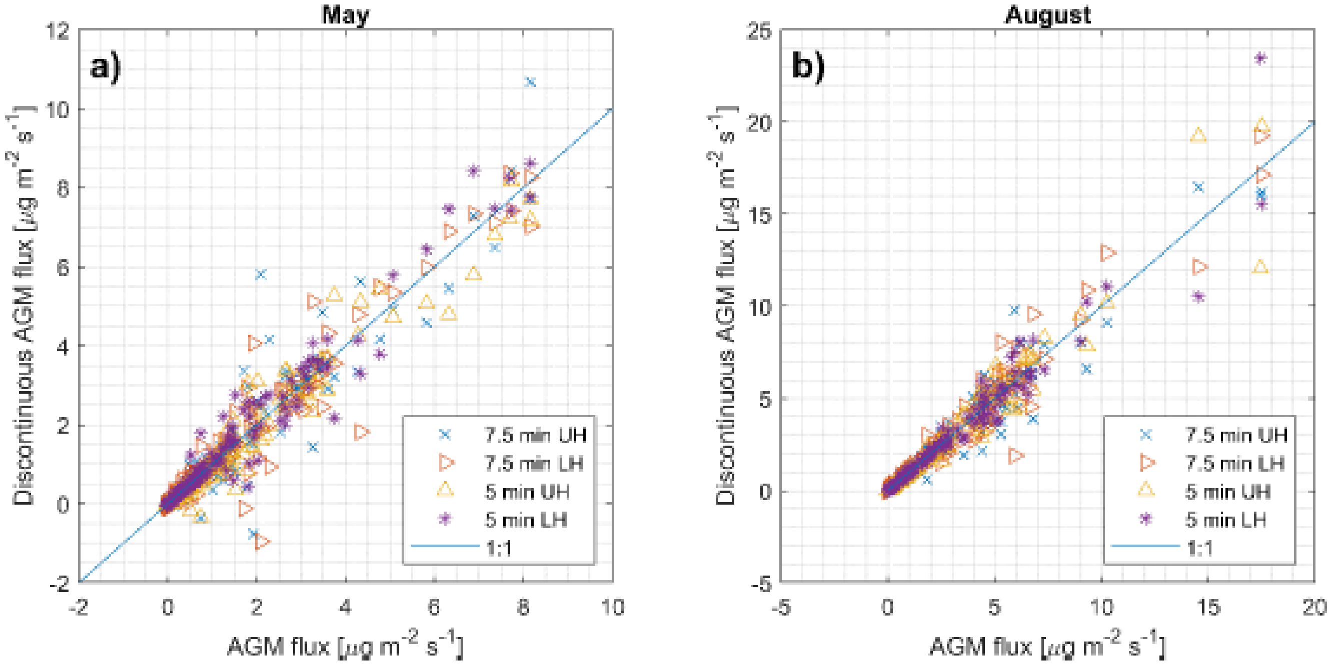
Possible to use a single instrument

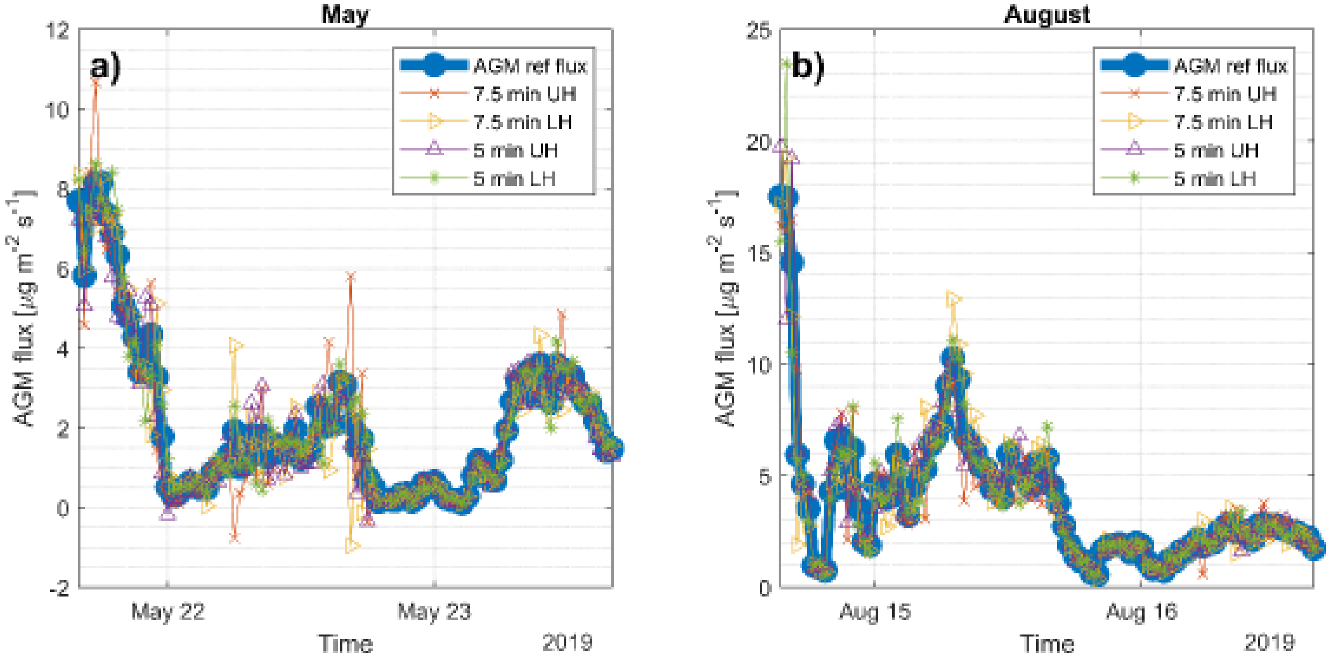
Single analyzer for average estimates

(mean flux and total loss of TAN)

Large deviations for some single intervals

Footprint model for specific area needed





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