Energy research Centre of the Netherlands

Delft University of Technology

Eddy covariance observations of CH_4 and N_2O
Towards more accurate emission estimates

P. Kroon[1,2], A. Hensen[1], H. Jonker[2], A. Schrier-Uijl[3], M. Tummers and F. Bosveld[4]

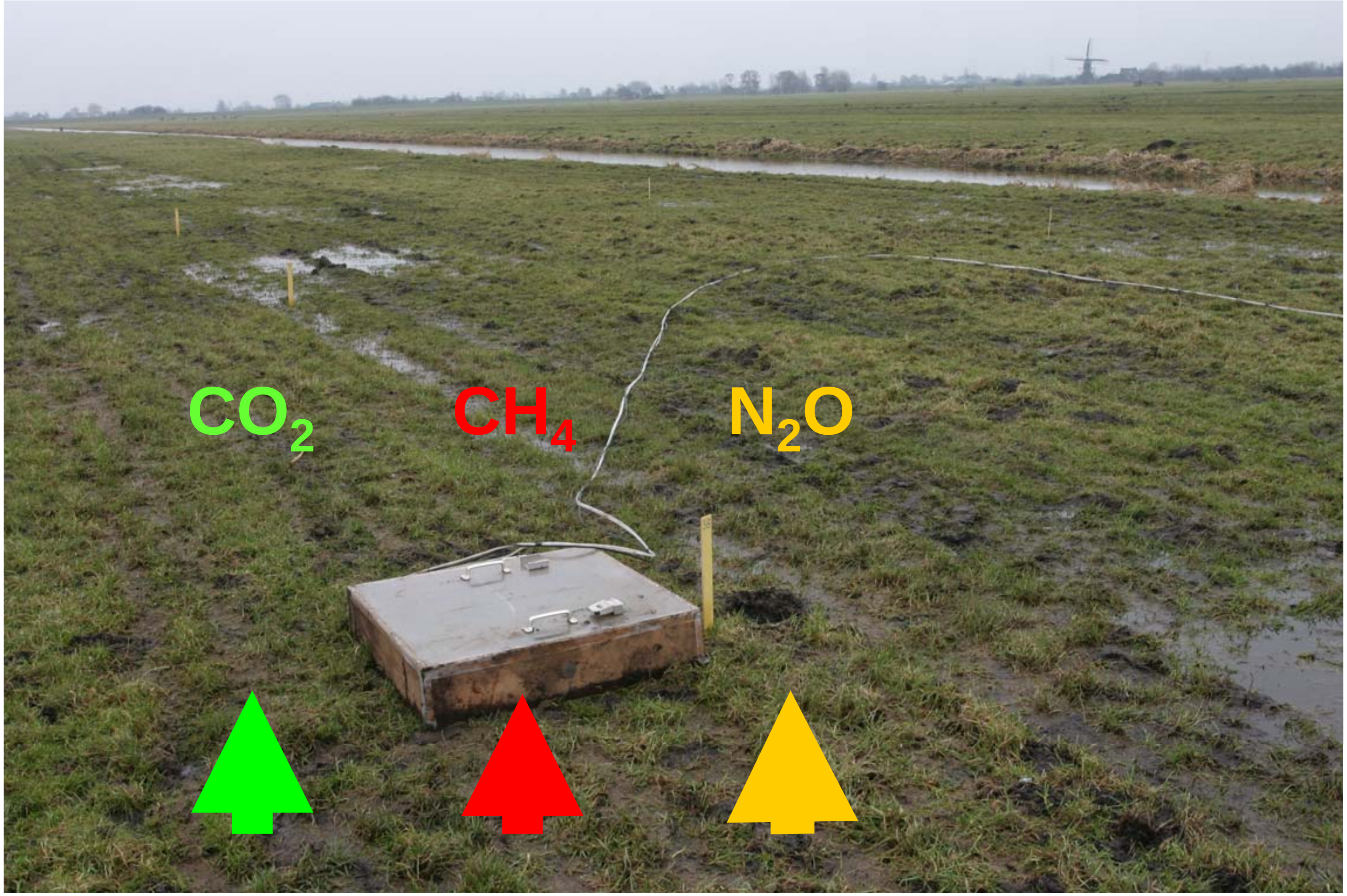
1. ECN, the Netherlands ; 2. TU Delft, the Netherlands; 3. WU, the Netherlands; 4. KNMI, the Netherlands

Supported by:

Outline

- Background
- Eddy covariance flux technique
  - Description
  - Systematic errors
  - Uncertainties
- Annual field emission
- Conclusions

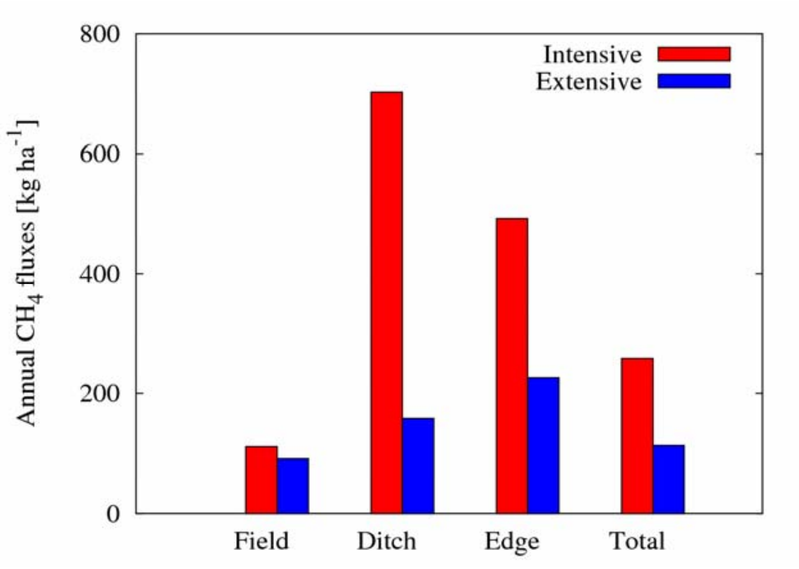
Background: GHG emissions from a managed fen meadow



Background: Lack of accurate annual sums

Due to spatial variation

Top view Reeuwijk site in the Netherlands

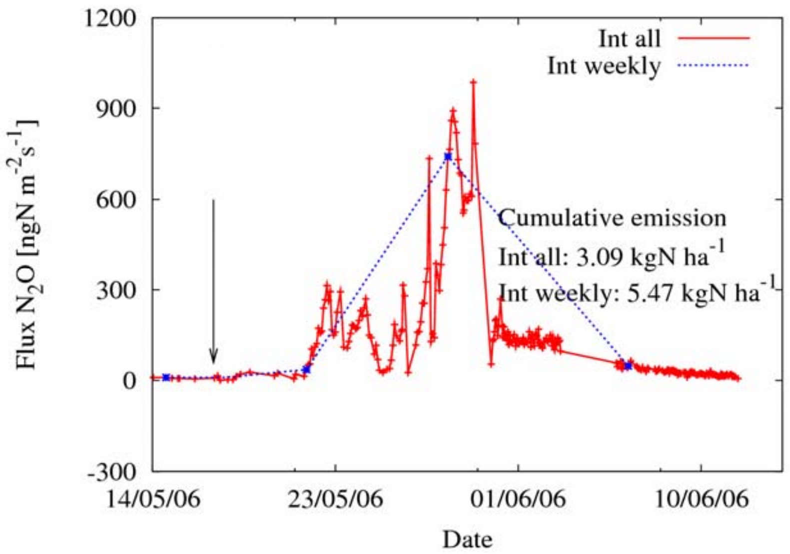


Based on Schrier-Uijl et al., BGD, 2008

Background: Lack of accurate annual sums

Due to temporal variation

Managed site in Reeuwijk in the Netherlands



Kroon et al., Nutr. Cycl. AgroEcosyst., 2008

Uncertainty in N_2O annual estimates derived by chamber may be as high as 50%.
(Flechard et al., Agric. Ecos. Environ., 2007)

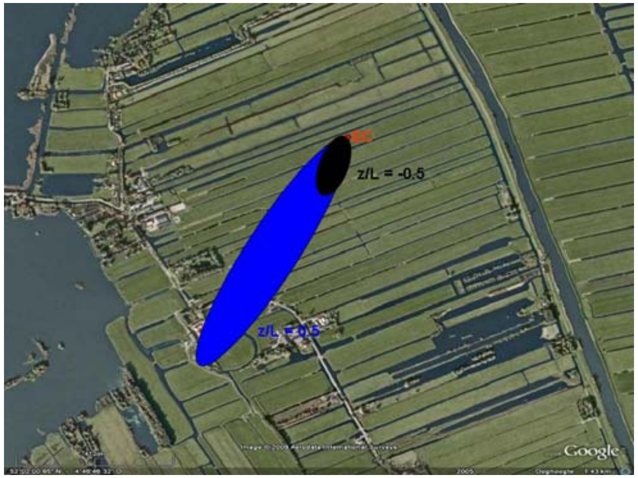
Background: Measurement techniques

Chamber

$$F_{wc} = h\frac{dC}{dt}\bigg|_{t=0}$$

Eddy Covariance

$$F_{wc} = \frac{1}{T_a}\int w'(t)C'(t)dt$$



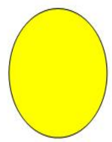
Background: Measurement techniques

Chamber

Eddy Covariance

Can EC flux measurements contribute to a decrease of the uncertainty in annual estimates of CH_4 and N_2O?

Eddy covariance flux technique: Description



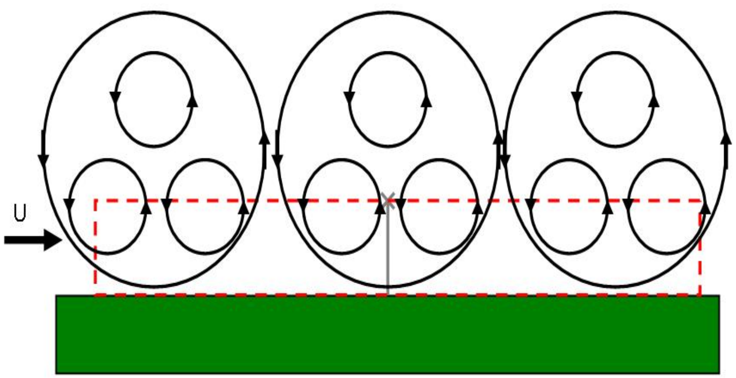
Tracer conservation equation

$$\underbrace{\frac{\partial \bar{c}}{\partial t}}_{I} + \underbrace{\cancel{\bar{u}\frac{\partial \bar{c}}{\partial x} + \bar{v}\frac{\partial \bar{c}}{\partial y}}}_{II} + \underbrace{\cancel{\bar{w}\frac{\partial \bar{c}}{\partial z}}}_{III} + \underbrace{\cancel{\frac{\partial \overline{u'c'}}{\partial x} + \frac{\partial \overline{v'c'}}{\partial y}}}_{IV} + \underbrace{\frac{\partial \overline{w'c'}}{\partial z}}_{V} = \underbrace{S}_{VI}$$

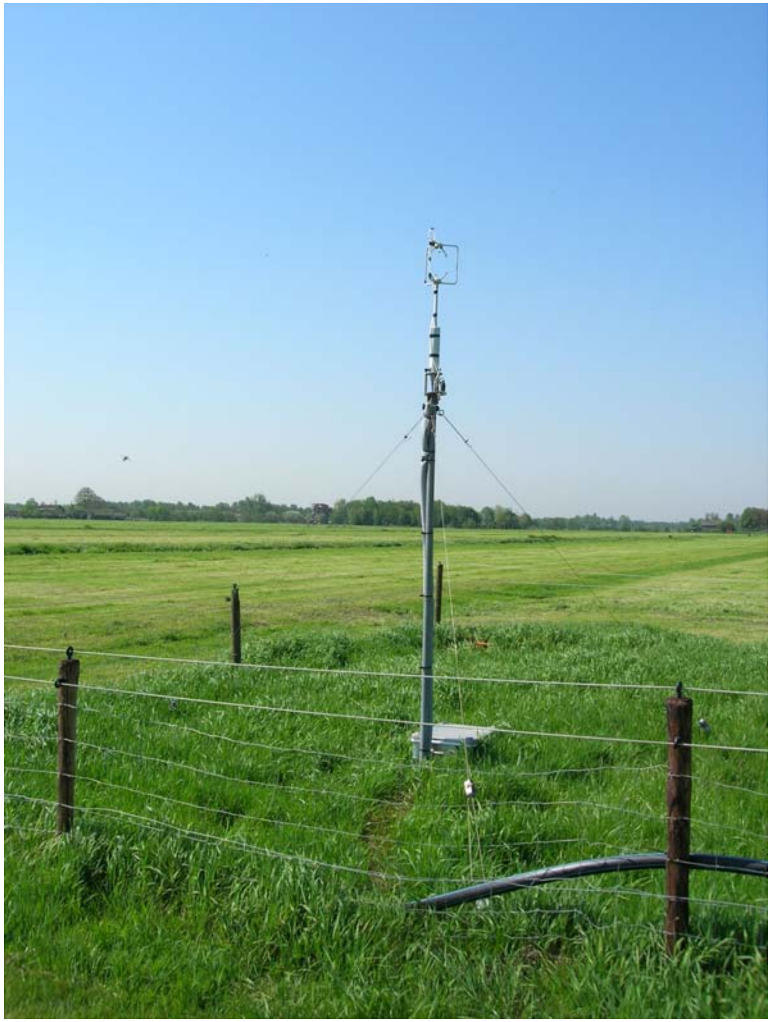
After Reynolds decomposition, integrating over the height and assuming:

- Horizontal homogeneity
- Flat terrain
- Negligible mean vertical wind speed

$$F_{wc} = \underbrace{\int_0^h \frac{\partial \bar{c}}{\partial t} dz}_{\mathrm{St}_{wc}} + \boxed{\underbrace{\overline{w'c'}\big|_{z=h}}_{\mathrm{EC}_{wc}}}$$



Eddy covariance flux technique: Systematic errors



Sonic anemometer

Wind measurements

Tube connected to QCL

CH_4 measurements

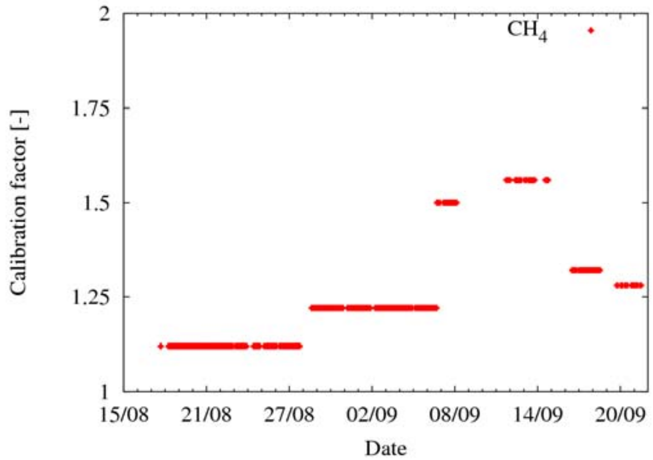
N_2O measurements

$$EC_{wc}^{\mathrm{meas}} = \overline{w'c'}\Big|_{z=h}$$

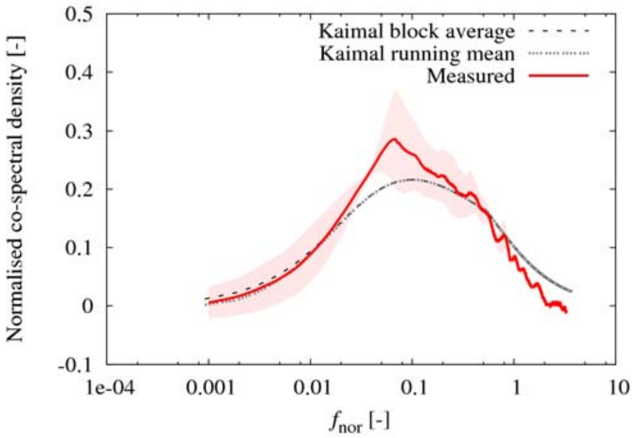
$$= ?$$

$$EC_{wc} = \overline{w'c'}\Big|_{z=h}$$

Eddy covariance flux technique: Systematic errors



Kroon et al., BG, 2007



Kroon et al., AFM, accepted

- Calibrations
- Alignment sonic anemometer
- Low frequency response losses
- High frequency response losses
- Density fluctuations

Rotation algorithm on *u*, *v* and *w*

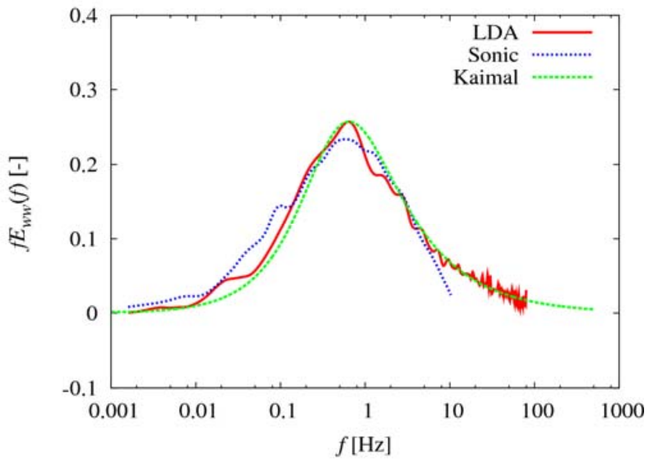
$$\mathrm{EC}_{wc} = \chi_{\mathrm{cal}}\chi_{\mathrm{low}}\chi_{\mathrm{high}}\mathrm{EC}_{wc}^{\mathrm{meas}} + \chi_{\mathrm{cal}}\chi_{\mathrm{Webb}}$$

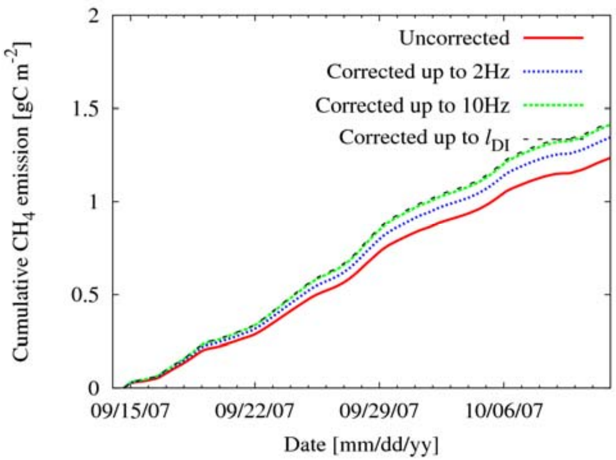
Eddy covariance flux technique: Systematic errors

High frequency response correction:

$$\chi_{\text{high}} = \frac{\int_0^\infty E_{wc}(f)df}{\int_0^\infty T_{\text{high}}(f)E_{wc}(f)df}$$

Kroon et al., AFM, accepted





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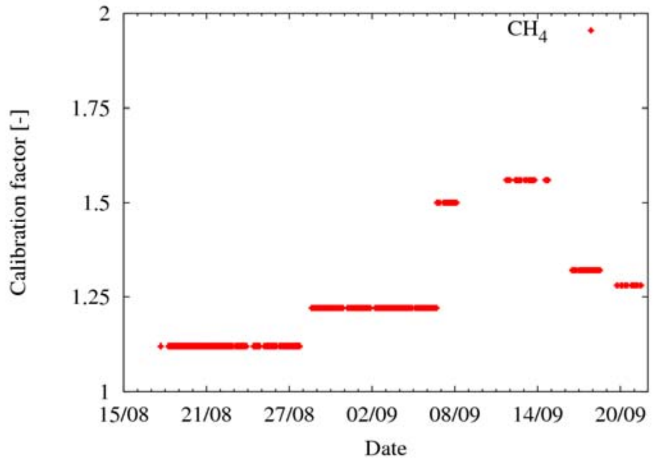

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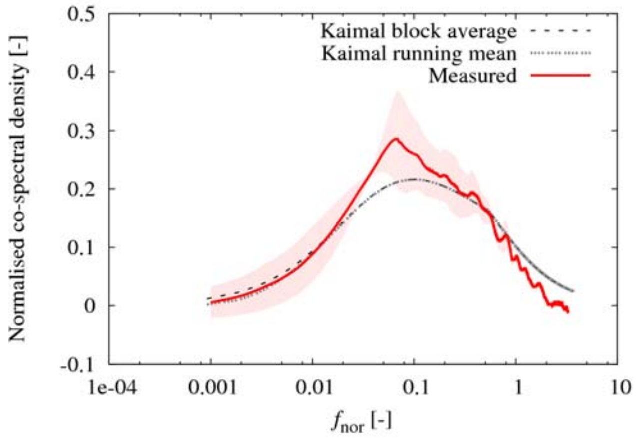

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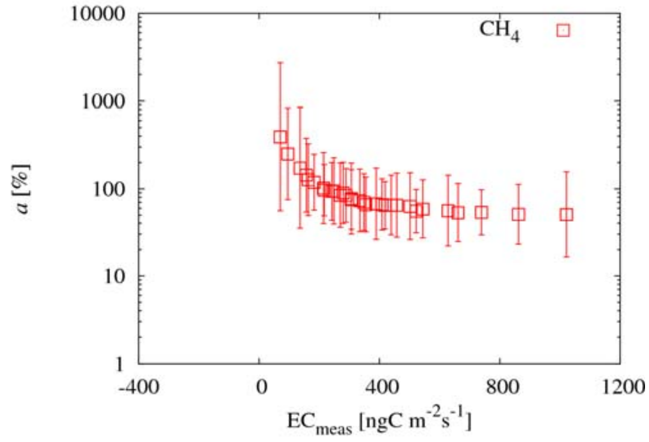
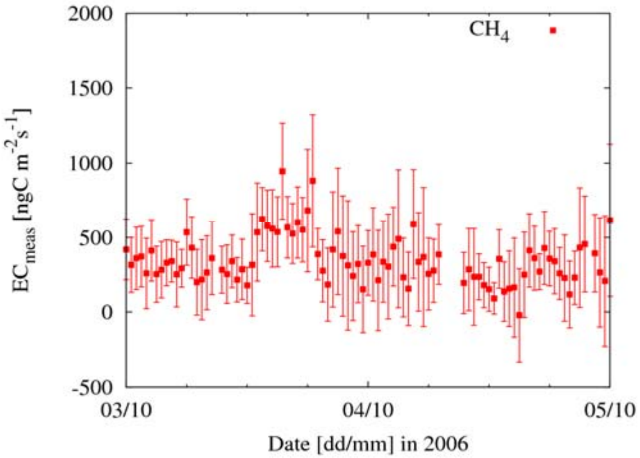
$$\mathrm{EC}_{wc} = \chi_{\mathrm{cal}}\chi_{\mathrm{low}}\chi_{\mathrm{high}}\mathrm{EC}_{wc}^{\mathrm{meas}} + \chi_{\mathrm{cal}}\chi_{\mathrm{Webb}}$$

After applying corrections 30 min fluxes can increase by even more than 100%!

Eddy covariance flux technique: Uncertainties



Kroon et al., AFM, accepted



Kroon et al., AFM, accepted

Random uncertainty in correction algorithms

Other random uncertainties:

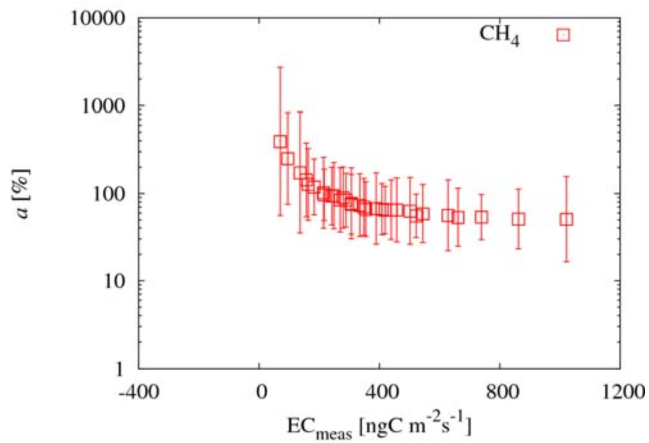
- Drift and precision in instruments
- One-point sampling

90% of 30 min EC flux uncertainty is caused by one-point uncertainty!

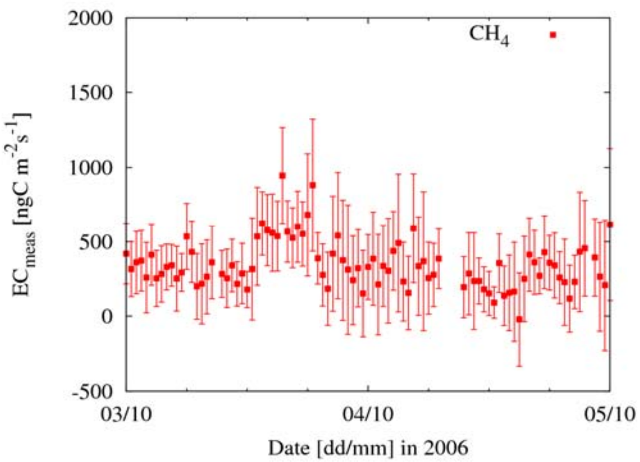
$$u_{\mathrm{op}} = \sqrt{\frac{2}{M}}\sigma_{w'c'} = \sqrt{\frac{20z}{TU}}\sqrt{\overline{(w'c')^2} - \left(\overline{w'c'}\right)^2}$$

$$= a\mathrm{EC}_{wc}^{\mathrm{meas}}$$

Eddy covariance flux technique: Uncertainties



Kroon et al., AFM, accepted



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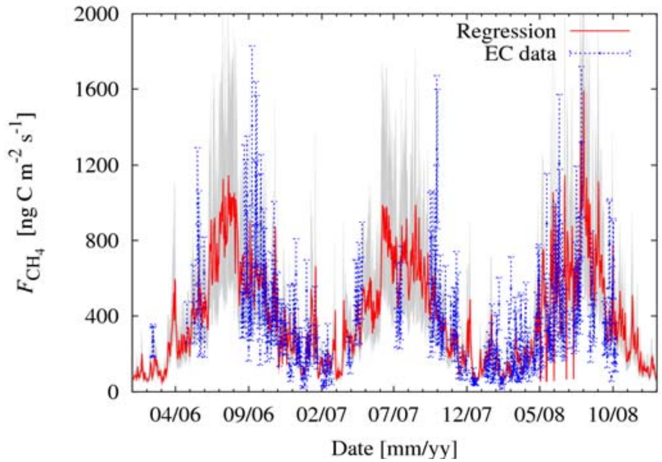
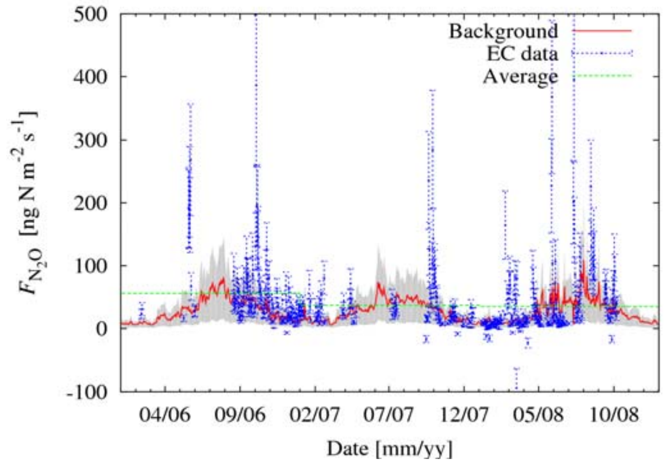
Uncertainty in a 30 min flux can be much larger than 100%; however it decreases with $1/\sqrt{N}$.

Annual field emission: CH_4 and N_2O emissions





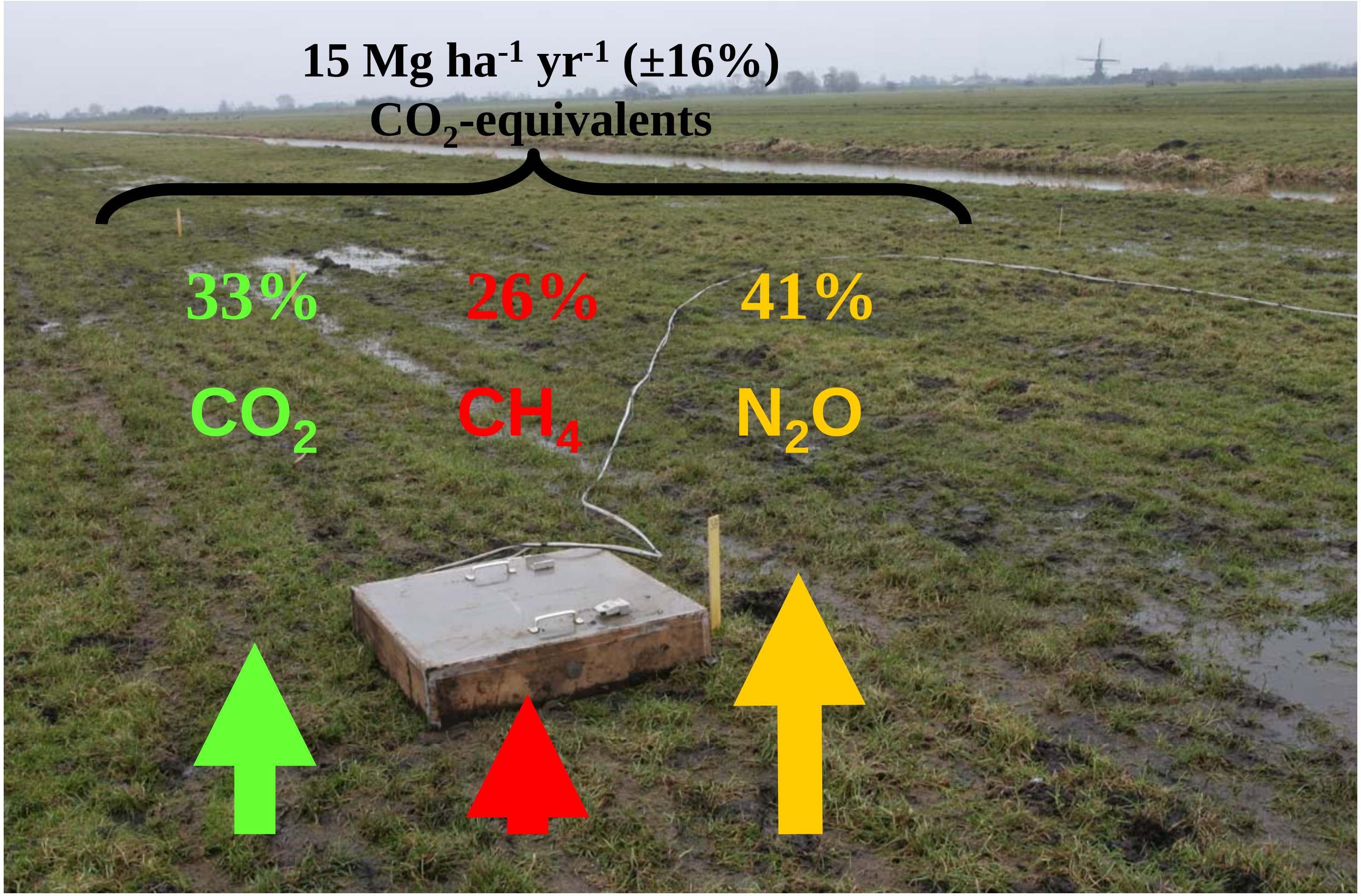
Average annual emissions over 2006 – 2008

	Static chamber	Eddy covariance
CH_4 [kg CH_4 ha^{-1} yr^{-1}]	170 (±32%)	165 (±13%)
N_2O [kg N_2O ha^{-1} yr^{-1}]	NA	20 (±34%)

Kroon et al., Eur. J. Soil Sci., submitted; Schrier-Uijl et al., Plant and Soil, accepted

Thus, EC flux measurements can contribute to more accurate annual estimates of CH_4 and N_2O!

Annual field emission: Total GHG field balance



Kroon et al., Eur. J. Soil Sci, submitted; Veenendaal et al., BG, 2007

Conclusions

• The annual field emission estimates of CH_4 and N_2O are very uncertain.

• Corrections should be applied for the systematic errors in EC flux measurements.

• There are many uncertainties in EC flux measurements.

• The uncertainty in a 30 min EC flux measurement can be even larger than 100%.

• Assuming 100% data coverage, the uncertainty of a monthly EC flux average can be smaller than 10%.

• The total field emission is estimated at 15 Mg ha^{-1} yr^{-1} CO_2-equivalents (41% due to N_2O); however the emission will increase by more than 250% when biomass removal and farm based emissions are included.

Thanks to …

Reeuwijk-team

Cabauw-team

BSIK-team

LDA-team

- Arjan Hensen (ECN)
- Hans van 't Veen (ECN)
- Alex Vermeulen (ECN)
- Pim van den Bulk (ECN)
- Piet Jongejan (ECN)
- Rob Rodink (ECN/TU)
- Harm Jonker (TU)
- Erwin de Beus (TU)
- Adriaan Schuitmaker (TU)
- Huug Ouwersloot (TU)
- Mark Tummers (TU)
- Fred Bosveld (KNMI)
- Arina Schrier (WUR)
- Elmar Veenendaal (WUR)
- Dimmie Hendriks (VU)
- Mark Zahniser (Aerodyne)
- ….

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climate changes spatial planning

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