Uncertainty in CH_4 and N_2O emission estimates from a managed fen meadow using EC measurements

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ECN

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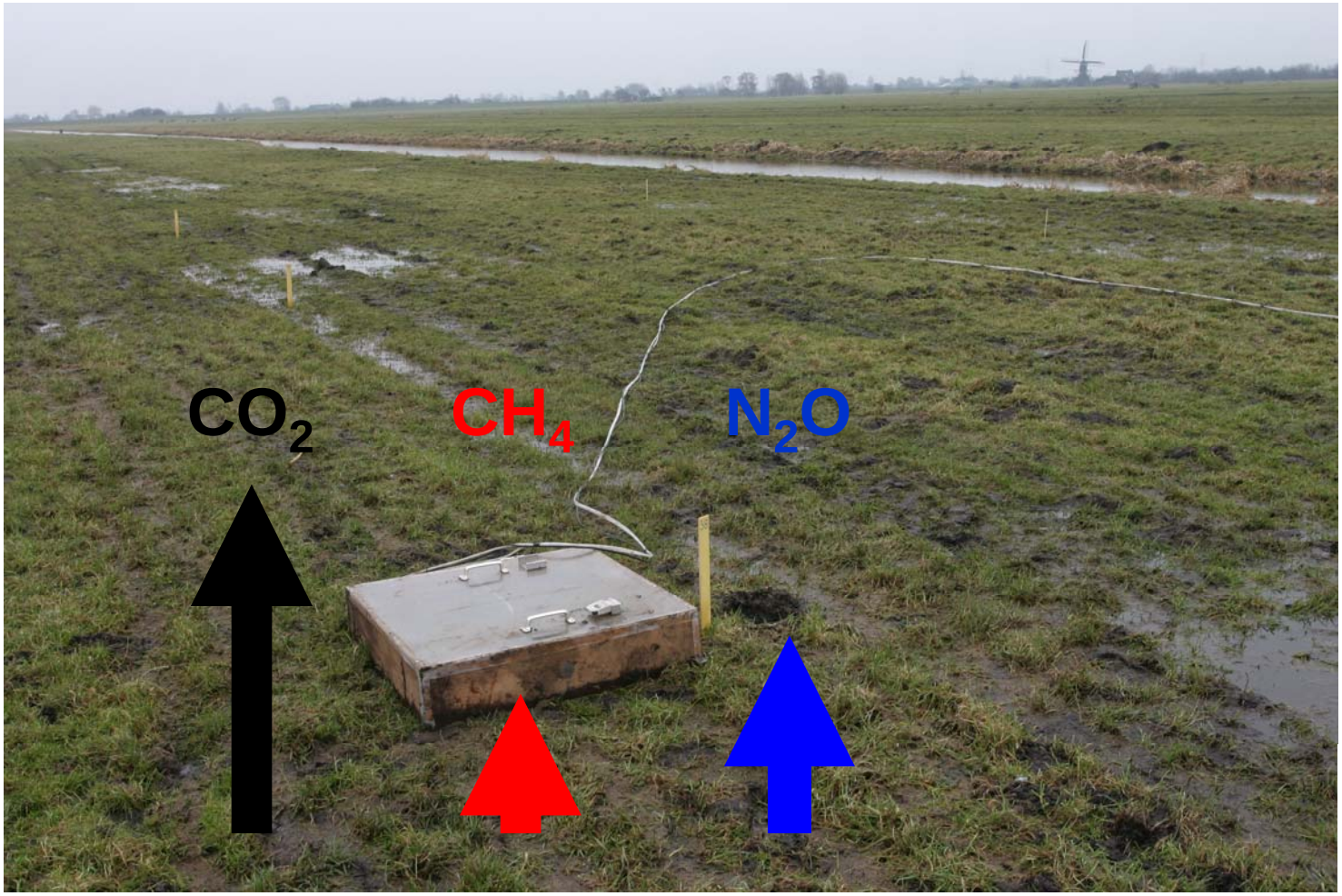
Petra Kroon[1,2], Arjan Hensen[1], Harm Jonker[2], …..

1. ECN, the Netherlands ; 2. TU Delft, the Netherlands

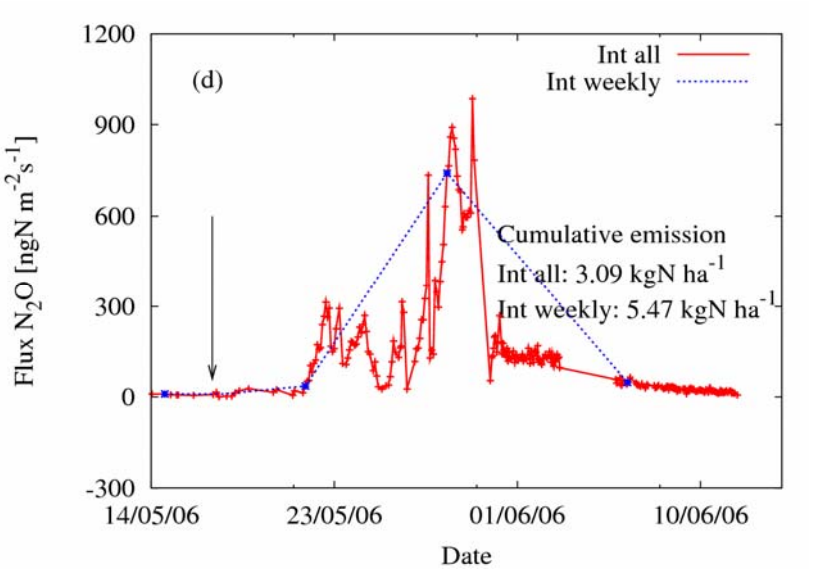
Background: GHG emissions from a managed fen meadow



Background: Lack of accurate annual sums

Due to temporal variation

Managed site in Reeuwijk in the Netherlands



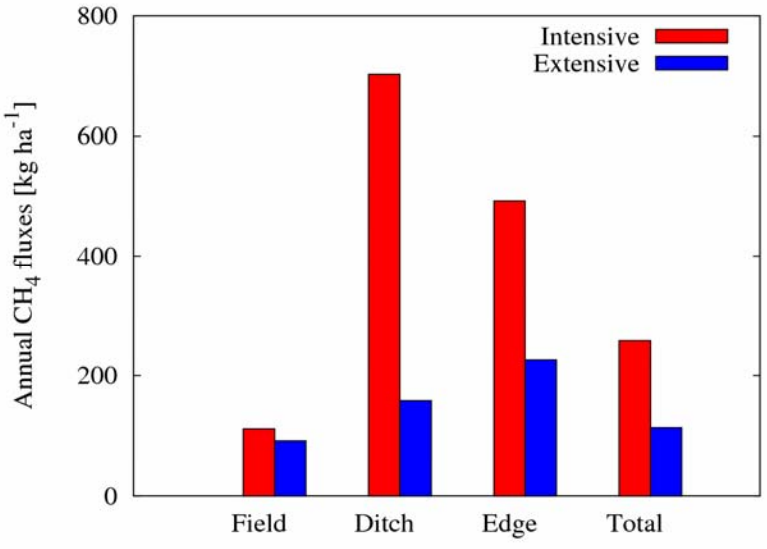
(Kroon et al., 2008)

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

Background: Lack of accurate annual sums

Due to spatial variation

Top view Reeuwijk site in the Netherlands



(Based on Schrier et al., 2008)

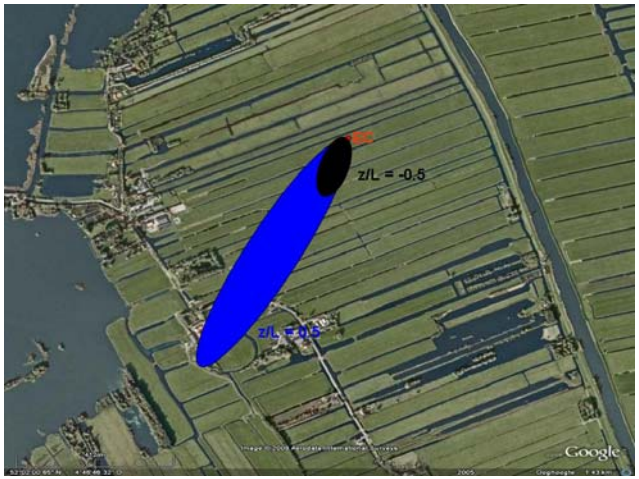
Background: Measurement techniques

Chamber

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

Eddy Covariance

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



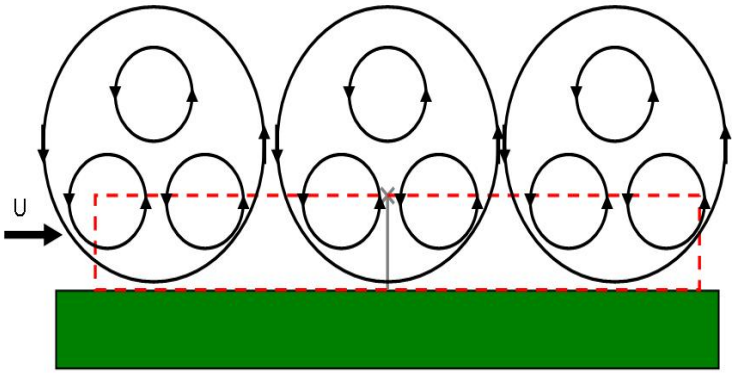
Background: Measurement techniques

Chamber

Eddy Covariance

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

Eddy covariance flux theory



Tracer conservation equation

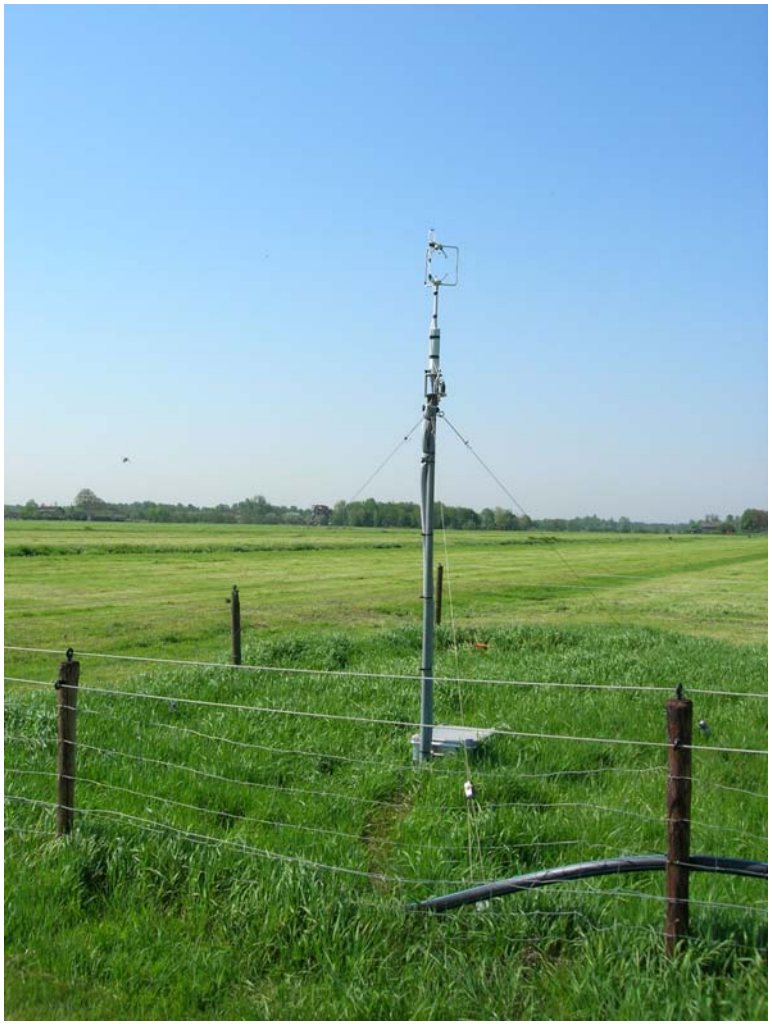
$$\underbrace{\frac{\partial \bar{c}}{\partial t}}_{I} + \cancel{\underbrace{\bar{u}\frac{\partial \bar{c}}{\partial x} + \bar{v}\frac{\partial \bar{c}}{\partial y}}_{II}} + \cancel{\underbrace{\bar{w}\frac{\partial \bar{c}}{\partial z}}_{III}} + \cancel{\underbrace{\frac{\partial \overline{u'c'}}{\partial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

After Reynolds decomposition, integrating over the height and assuming:

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

$$\underbrace{\int_0^h S_c\,dz}_{NEE} = \underbrace{\int_0^h \frac{\partial \bar{c}}{\partial t}\,dz}_{Storage} + \underbrace{\overline{w'c'}\big|_{z=h}}_{\approx F_c}$$

Errors and uncertainties in EC flux measurements



Sonic anemometer

Wind measurements

Tube connected to QCL

CH_4 measurements

N_2O measurements

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

$$= ?$$

$$\tilde{\tilde{F}}_c = \overline{w'c'}\Big|_{z=h}$$

Errors and uncertainties in EC flux measurements

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

Uncertainties

- Drift in instruments (R)
- Precision of instruments (R)
- One point sampling (R)
- Alignment sonic anemometer (S)
- Calibrations (S)
- Low frequency response losses (S)
- High frequency response losses (S)
- Delay time determination (S/R)

$$\tilde{\tilde{F}}_c = \chi_{cal}\chi_{low}\chi_{high}F_c + \chi_{Webb}$$

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

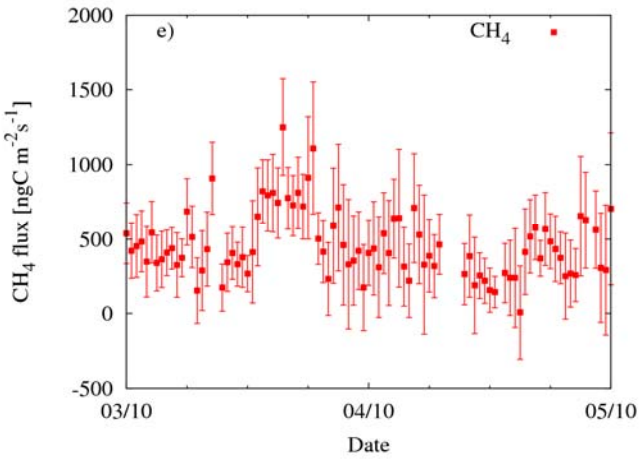
Uncertainty in 30 min EC flux measurement

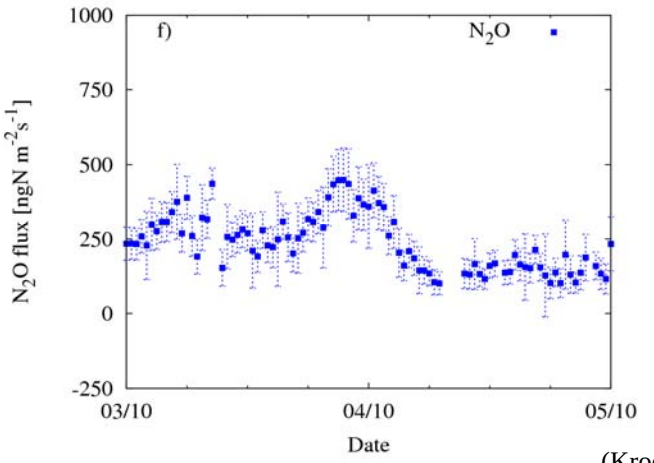
Estimated relative uncertainty $u\left(\tilde{\tilde{F}}_c\right)$

Averaging period	CH_4		N_2O	
	U=1 ms^{-1}	U=10 ms^{-1}	U=1 ms^{-1}	U=10 ms^{-1}
30 min	142%	48%	269%	87%
Day	22%	11%	40%	15%
Month	10%	9%	12%	8%
3 months	9%	9%	9%	8%

Dominated by random uncertainty due to one point sampling

$$u_{op} = aF_c = \sqrt{\frac{20z}{TU}\left|\frac{\overline{(w'c')^2}}{\left(\overline{w'c'}\right)^2} - 1\right|}F_c$$ (Businger, 1986)





(Kroon et al., submitted)

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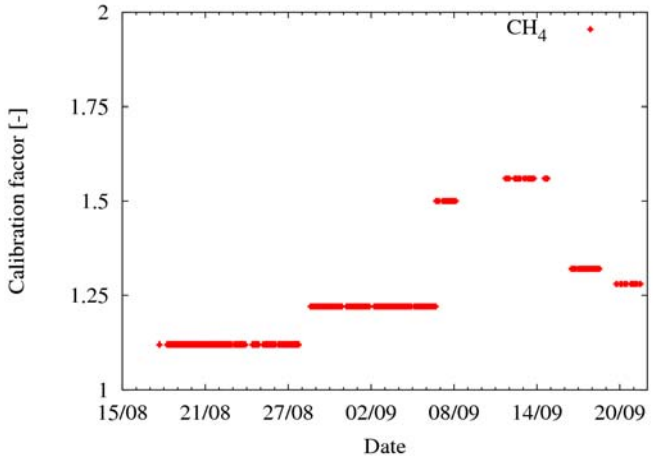
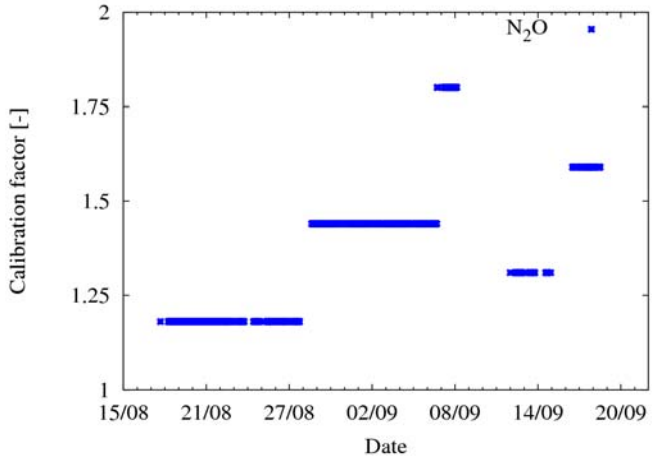
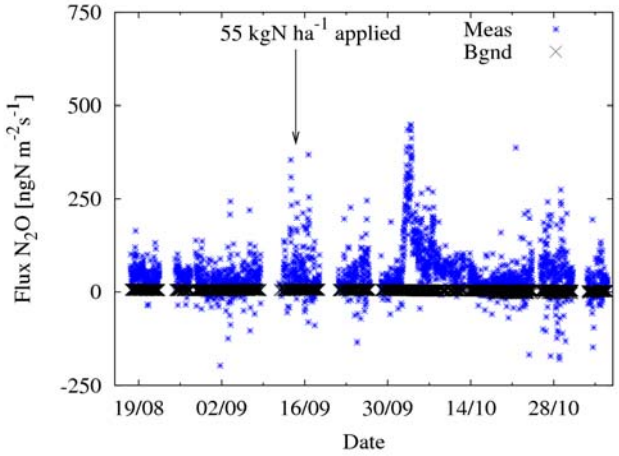
→ Dominated by systematic uncertainty due to calibration

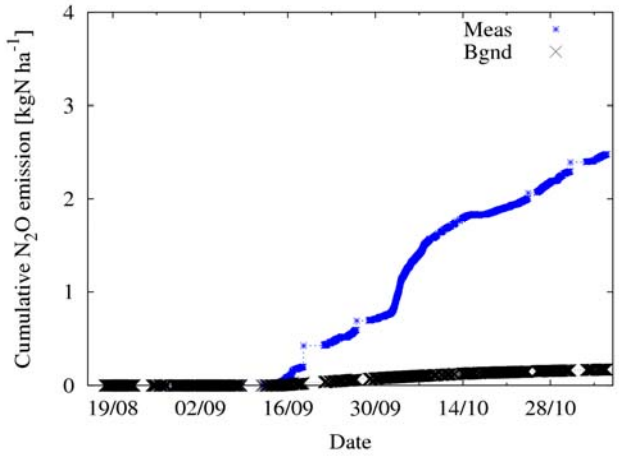




(Kroon et al., 2007)

Uncertainty in emission coefficient





Background emission

- $F_{bgnd}=f(T_{soil})$ (Flechard et al., 2007)

Emission factor

$$EF_i = \frac{F_{meas} - F_{bgnd}}{kN_{fert}} x100\%$$ (IPCC, 2001); (Flechard et al., 2007)

Uncertainty in emission factor

$$u(Y) = \sqrt{\sum_{i=1}^{n} \left(u(x_i) \frac{\partial Y}{\partial x_i} \right)^2}$$

$$\frac{u(F_{meas})}{F_{meas}} = 0.09; \frac{u(F_{bgnd})}{F_{bgnd}} = 0.05;$$

$$\frac{u(k)}{k} = 0.05; \frac{u(N_{fert})}{N_{fert}} = 0.10.$$

$$5.2\% \pm 0.8\%$$

Uncertainty due to e.g. storage and advection are not included!!

Thus …

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

Yes!!

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)
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- Arina Schrier (WUR)
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- Mark Zahniser (Aerodyne)
- Elmar Veenendaal (WUR)
- ….

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