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Eddy covariance-based methane and CO_2 budget of a bog-pine ecosystem in southern Germany

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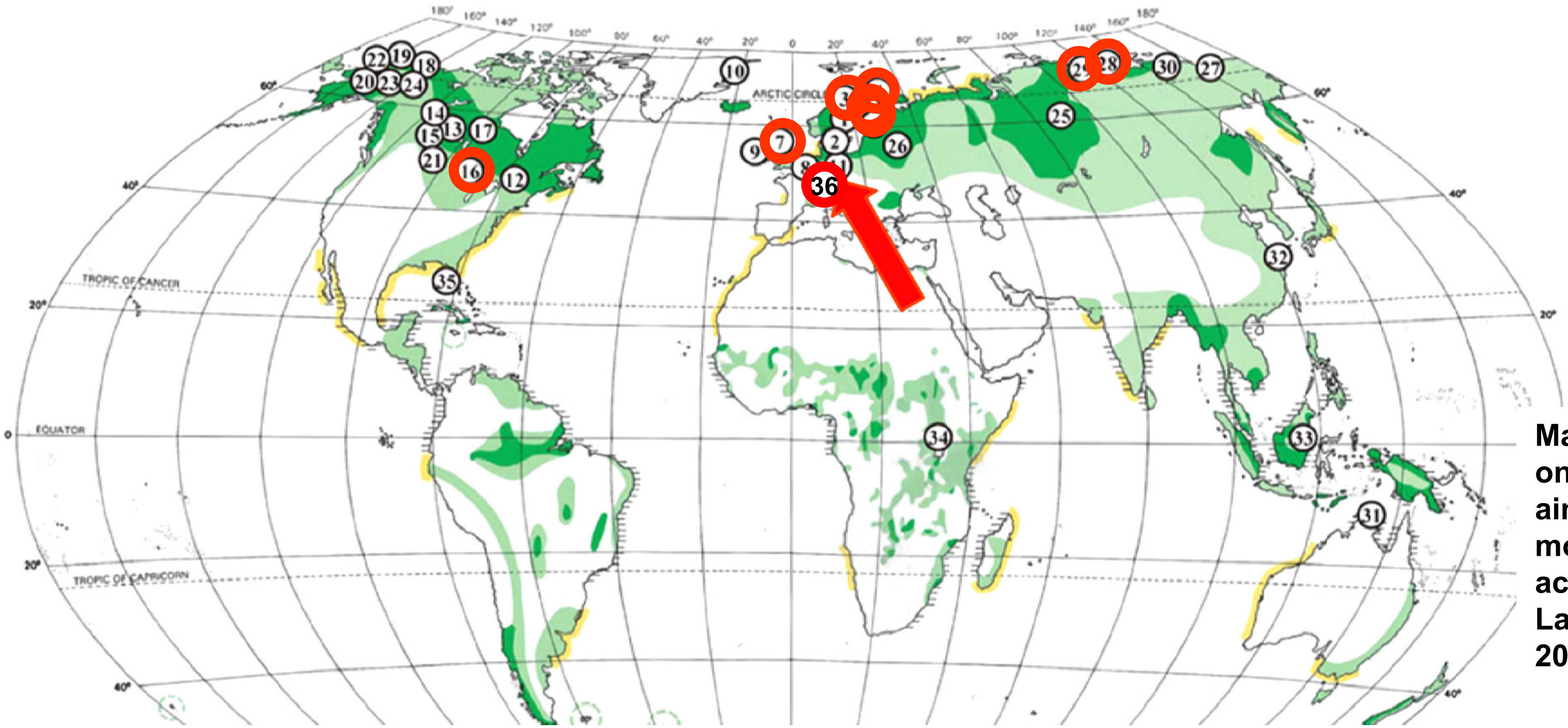
Motivation



Map based on Lappal-ainen 1996; modified according to Laurila et al. 2012

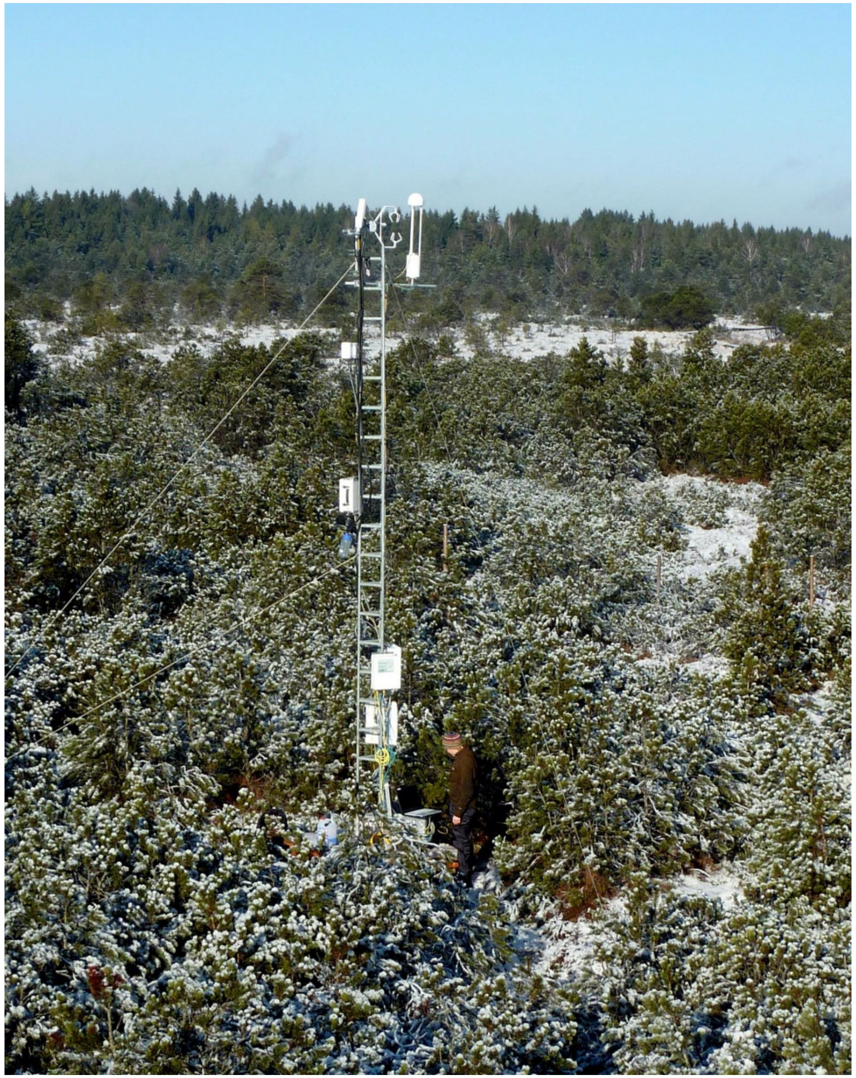
- eddy covariance based carbon exchange studies of peatland ecosystems mostly conducted in **northern regions**

→ eddy covariance based **methane** exchange is measured only at a few sites

- knowledge about full greenhouse gas (GHG) exchange of **peatland forests** is still lacking (Maljanan et al. (2010))

Measurement Site “Schechenfilz“

- near-natural peat-bog
- pristine peat layer, thickness > 5 m
- bog-pines: ≈ 2 m, different age
- water table depth: -0.06 ±0.04 m
- climate: temperate and humid
  - mean annual air temperature: +8.6 °C
  - annual sum of precipitation: 1127 mm



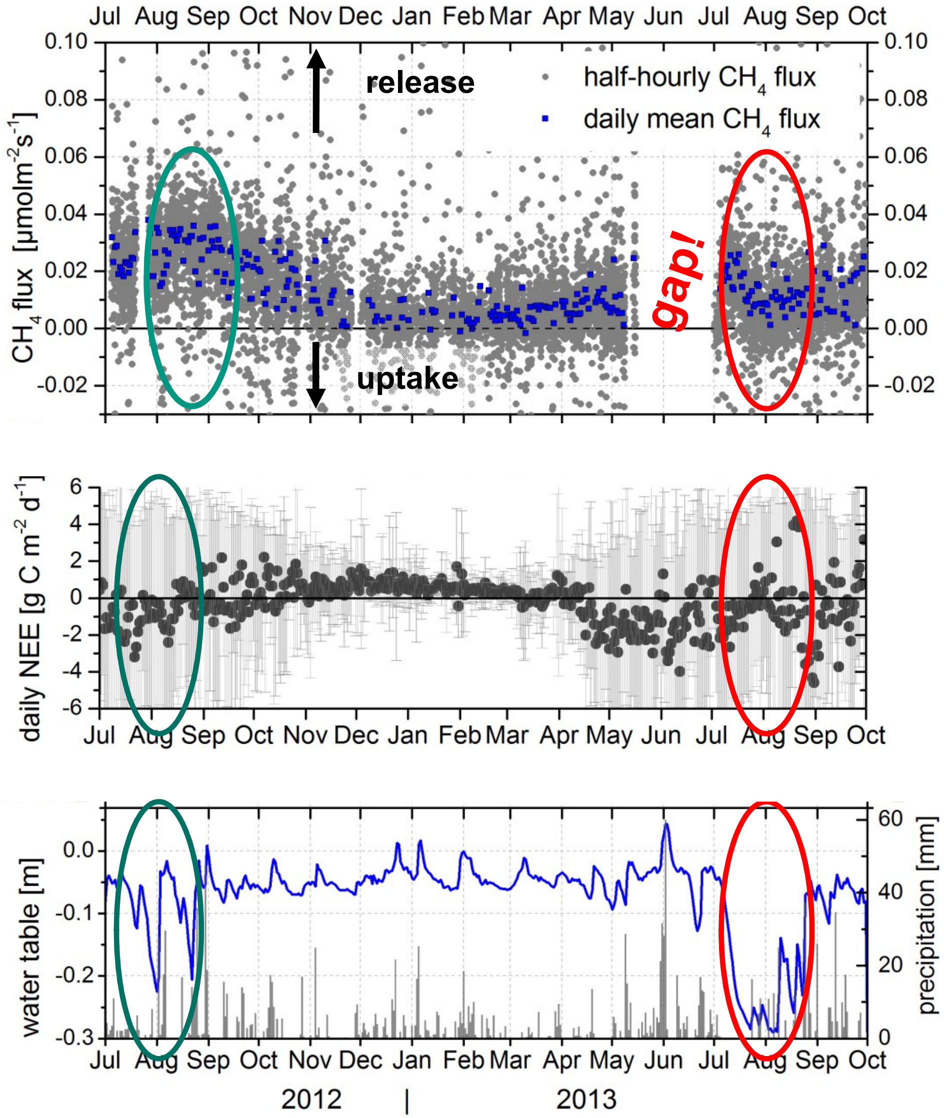
Environmental conditions

- measurement period over 15 months:
  from July 2012 to September 2013
- daily CH_4 release throughout the whole year
- CH_4 exchange is in phase with temperatures

→ CH_4 peak in summer 2012

→ but not on 2013?

- **water table drawdown event in summer 2013**
  - → **carbon oxidation**
  - **reduced CH_4 emissions**
  - **reduced net CO_2 uptake**



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Garmisch-Partenkirchen

Control Parameters

- no clear influence of **spatial heterogeneity** on CH_4 exchange
- **increase** of CH_4 emissions with **increasing temperature**

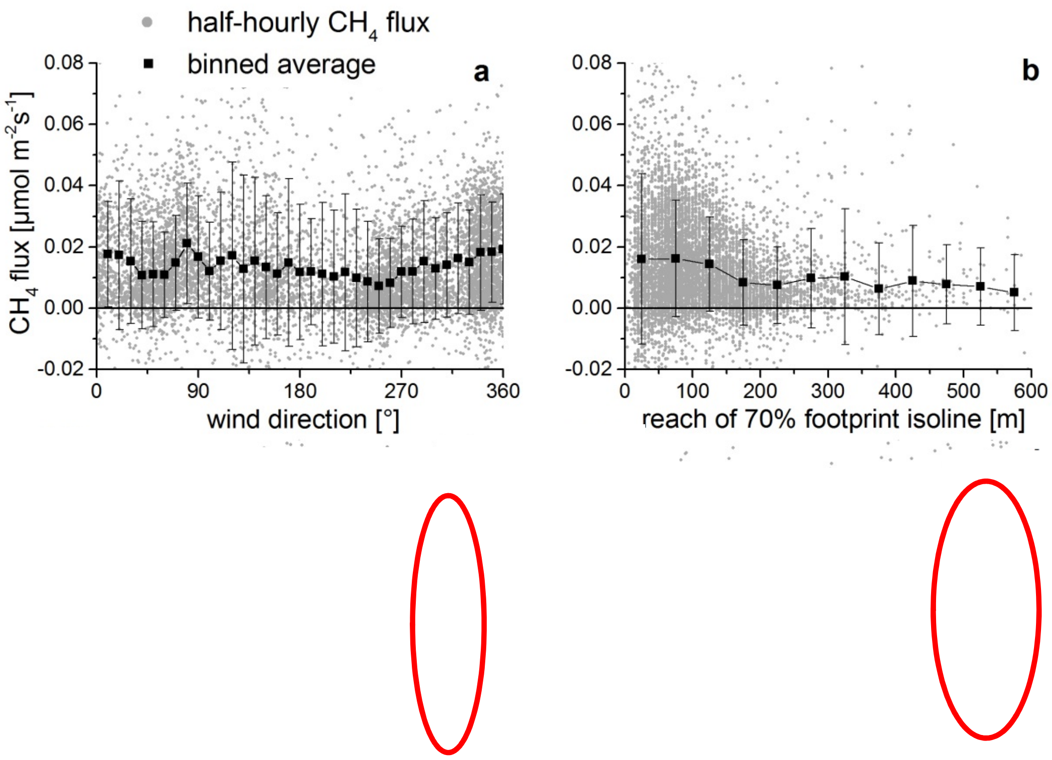
→ but not at high temperatures ?!?

- no obvious dependence on **water table** variations

- considering **only CH_4 fluxes at lower water tables** (< -0.12 m):

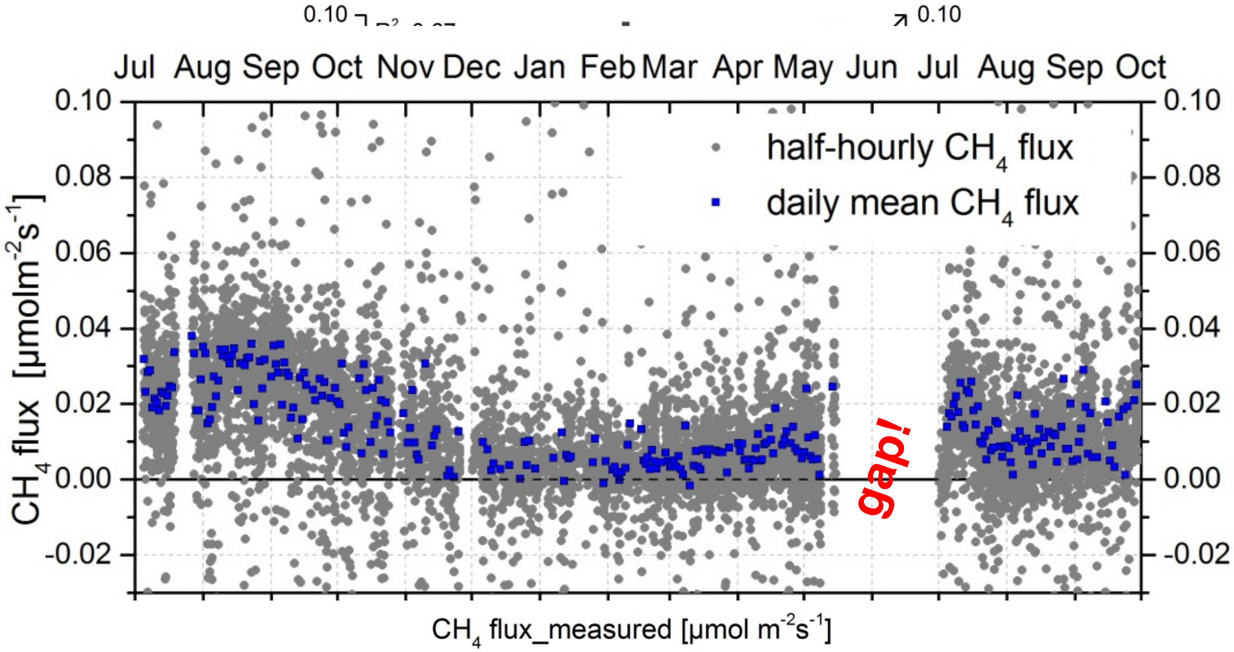
→ CH_4 emissions **reduced** and **independent** of environmental control

→ **methane exchange: mostly temperature controlled, except for periods of low water table**



Methane gap-filling of half hourly fluxes

- examined three different methods:
  - 1) Mean daily variation
  - 2) Non-linear regression
  - 3) Look-up table
- best fit by **look-up table** method
- based on $T_{air,}$ PAR, water table depth, reach of the 70% footprint isoline



Methane gap-filling of long data gap

- long data: gap filled on **daily basis**

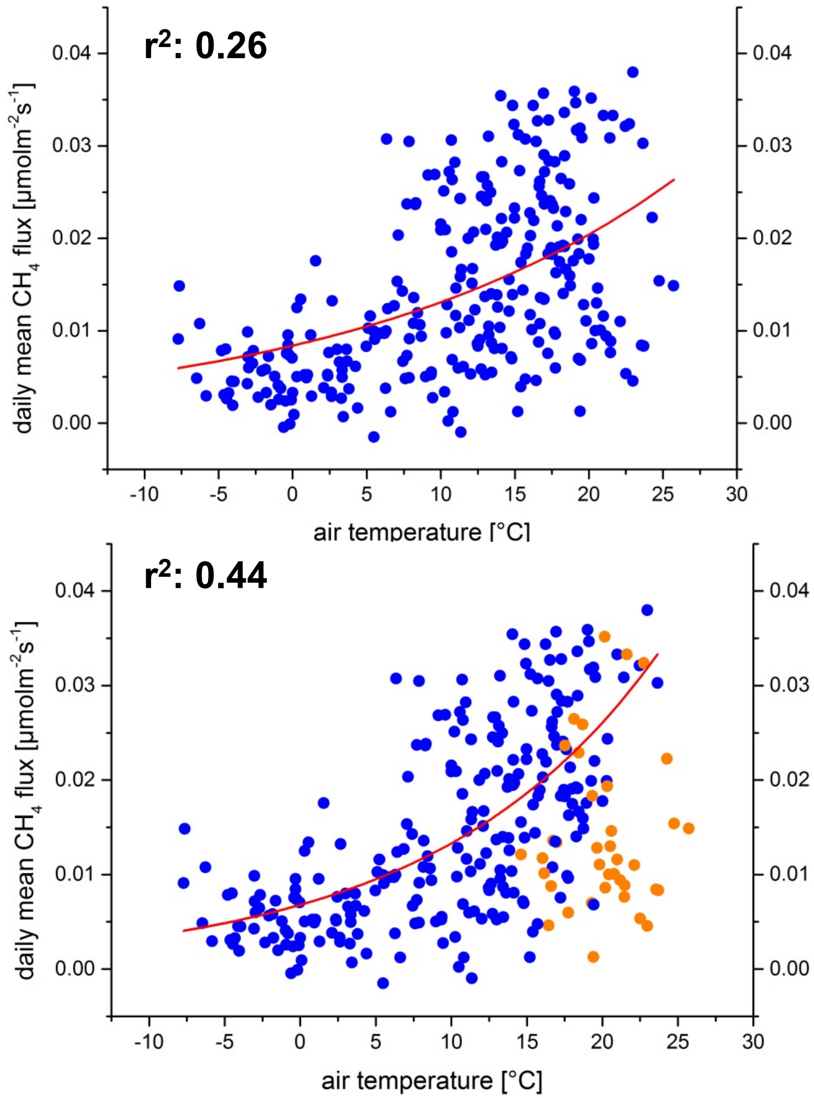
→ **exponential regression** between daily mean T_{air} and CH_4 flux

→ $F_{CH_4} = a \cdot \exp(T_{air} \cdot b)$

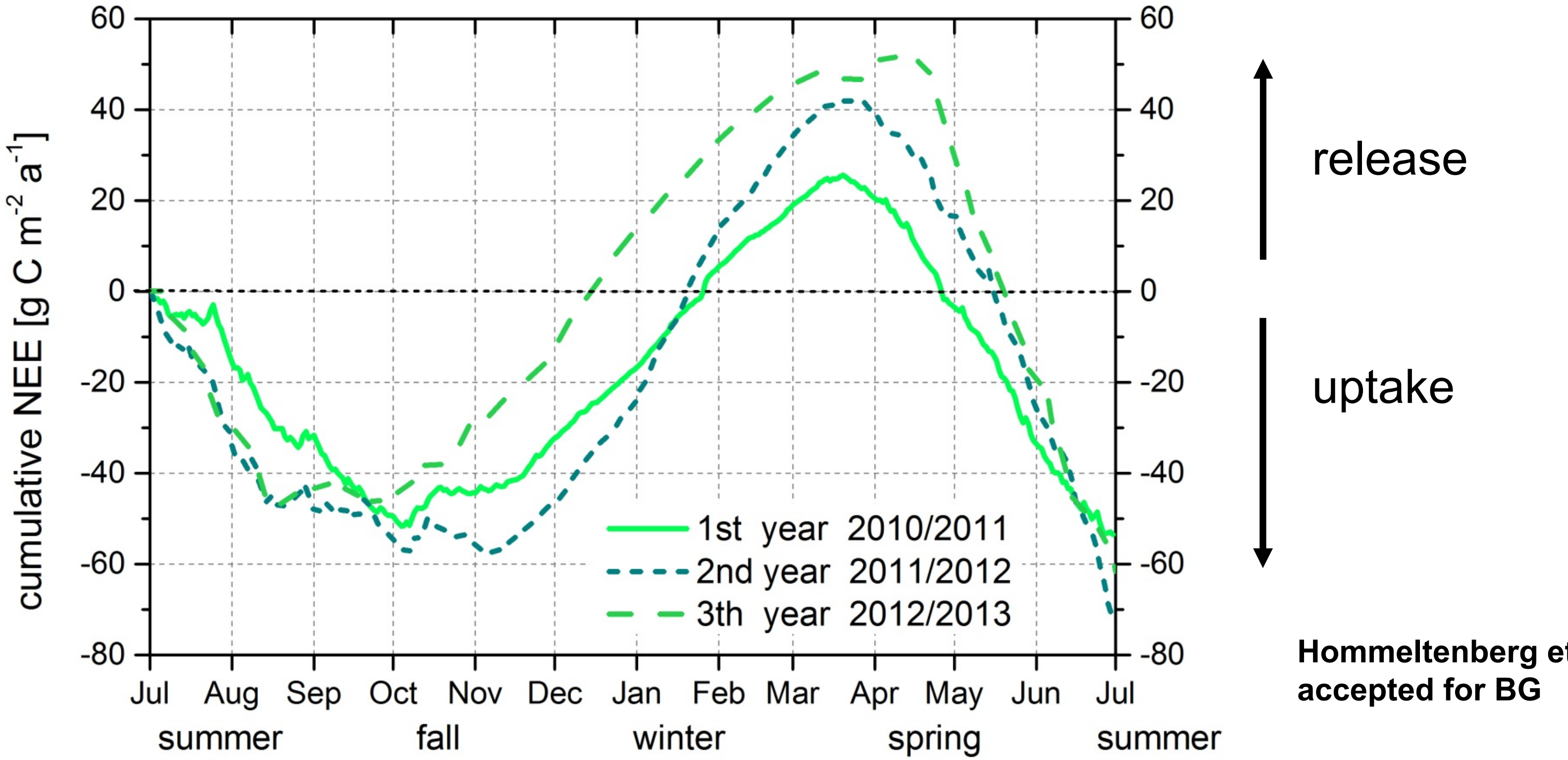
- improvement: excluding CH_4 fluxes, measured during **drought** period in summer 2013

→ 77% of the daily CH_4 variation could be explained by T_{air}

→ drought period and data –gap did not overlap



Annual budgets of CO_2



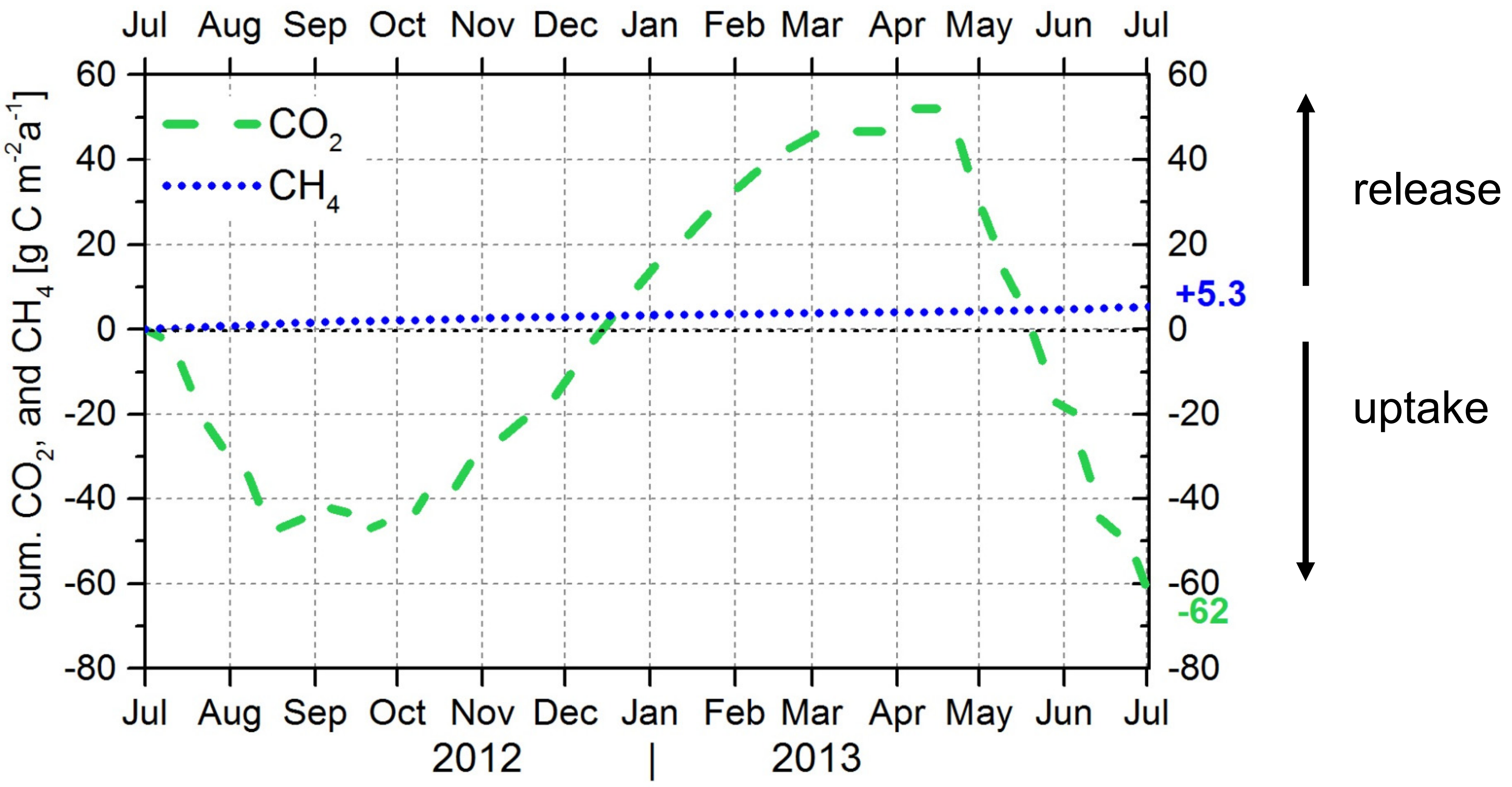
Hommeltenberg et al. 2014, accepted for BG

- **fairly stable net CO_2 uptake between -53 ±28 and -73 ±38 g C m^{-2} a^{-1}**

→ slow growing bog pines

→ suppressed organic matter decomposition

Annual budget of CH_4



- minor methane emissions

→ minor contribution to the annual net carbon balance

Annual budget of GWP

- methane: 25 times stronger GWP than CO_2

→ considerable reduction of CO_2 uptake induced climate cooling

- N_2O fluxes are negligible at nutrient poor, natural peatland sites

→ **small greenhouse gas sink**

→ overall GWP of -50 g C [CO_2-eq] $m^{-2}a^{-1}$

	Carbon balance (g C $m^{-2}a^{-1}$)		GWP-balance (g C [CO_2-eq] $m^{-2}a^{-1}$)
CO_2	-62	=	**-226**
CH_4	+5.3	=	**+176**
Balance	**-57**		**-50**

Reduction of 80%

Conclusions

- natural temperate bog-pine ecosystem: **stable net CO_2 sink** and a **minor CH_4 source**

→ **small greenhouse gas sink** (GWP: -50 g C [CO_2-eq] $m^{-2}a^{-1}$)

- wet soil conditions: Methane fluxes **mostly temperature controlled**
- aerated soil conditions: reduced methane emissions, independent of environmental control

- During observation period mean annual air temperature almost equals the long-term average

→ observed methane balance is likely within the usual range

There is still a long way to go!

- uncertainties
- what is the role of the trees?
- climate variability
- ….

Thanks for your attention

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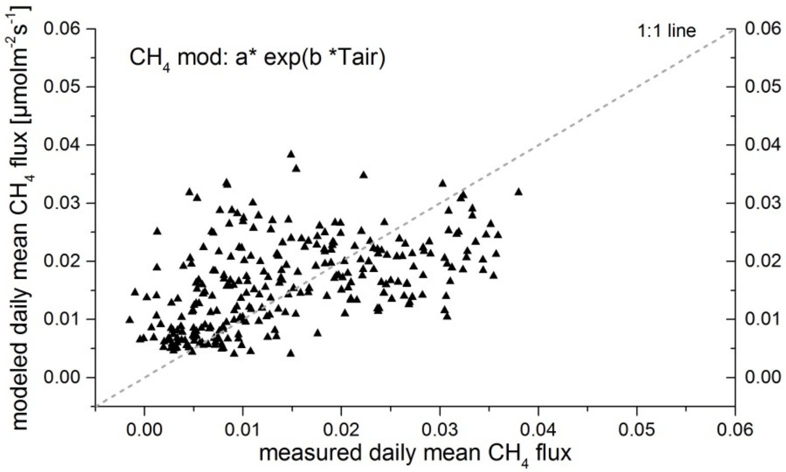
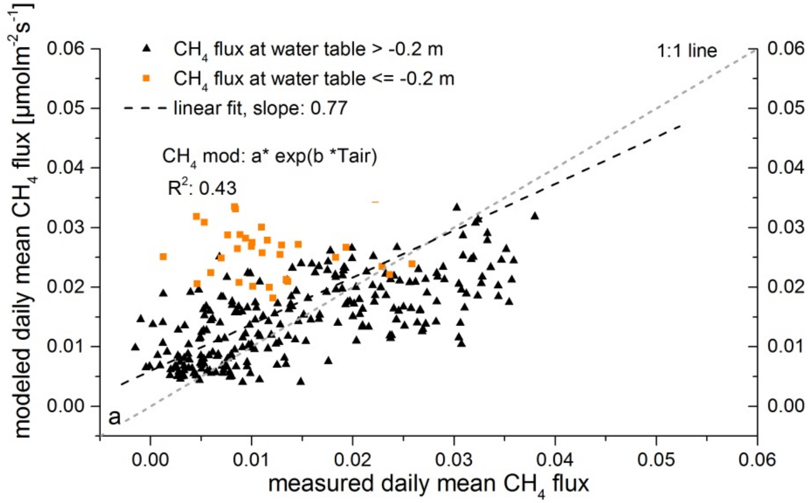
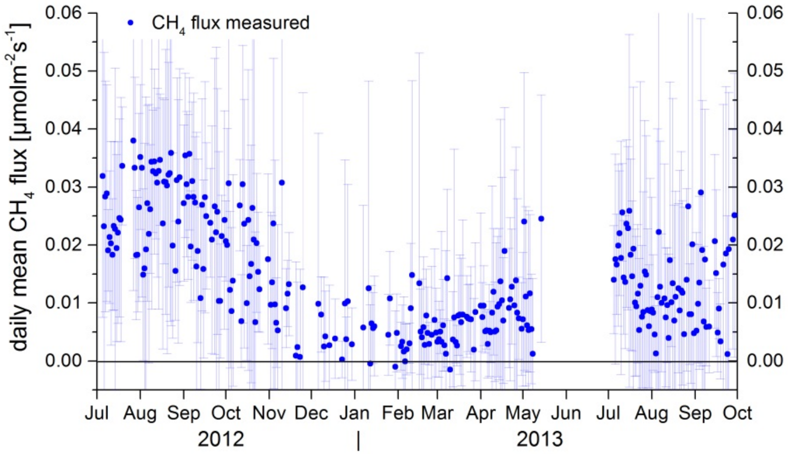
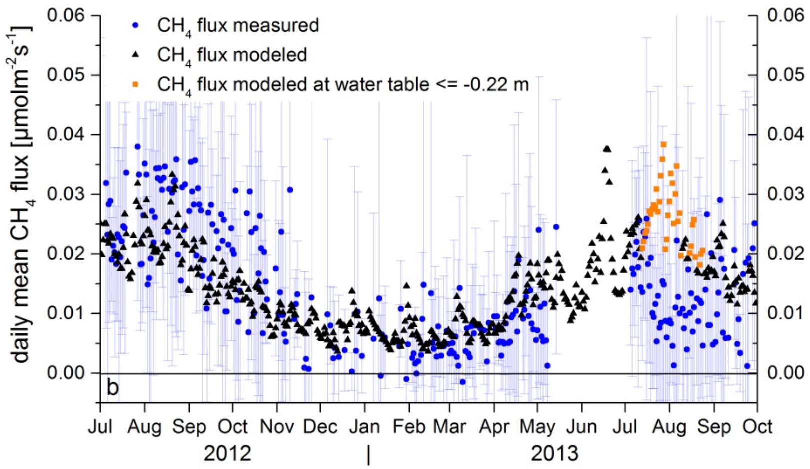
Appendix


CH4 mod: a* exp(b *Tair)
1:1 line
modeled daily mean CH4 flux [µmolm-2s-1]
measured daily mean CH4 flux


CH4 flux at water table > -0.2 m
CH4 flux at water table <= -0.2 m
linear fit, slope: 0.77
CH4 mod: a* exp(b *Tair)
R2: 0.43
1:1 line
a
modeled daily mean CH4 flux [µmolm-2s-1]
measured daily mean CH4 flux


CH4 flux measured
daily mean CH4 flux [µmolm-2s-1]
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
2012
2013


CH4 flux measured
CH4 flux modeled
CH4 flux modeled at water table <= -0.22 m
b
daily mean CH4 flux [µmolm-2s-1]
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
2012
2013

Appendix

	CH_4	CO_2	Total
Carbon-balance ($gC\ m^{-2}\ a^{-1}$)	+5.3	-62	-56.7
	*1.33	*3.66	
in $gCH_4\ m^{-2}\ a^{-1}$ and $gCO_2\ m^{-2}\ a^{-1}$	+7.0	-226	
	*25		
GWP_{100}-balance (gCO_2 eq.$m^{-2}\ a^{-1}$)	+176	-226	-50

Molar mass

C: 12 $g*mol^{-1}$

H: 1 $g*mol^{-1}$

O: 16 $g*mol^{-1}$

CH_4: 16 $g*mol^{-1}$

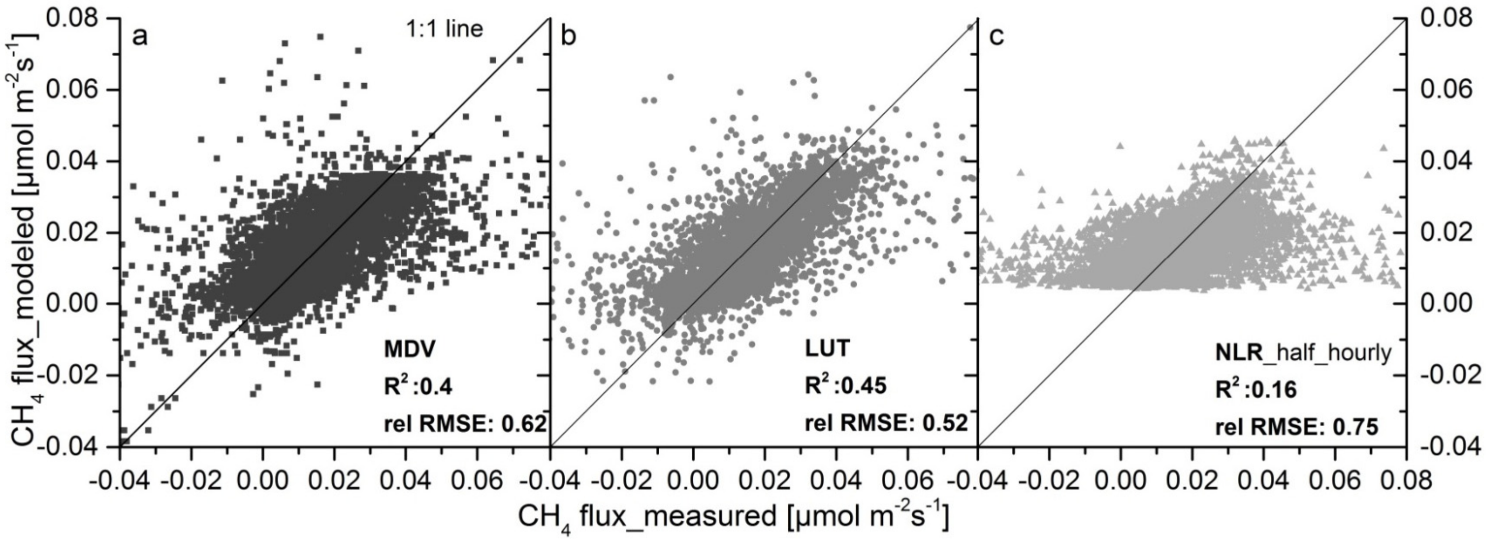
CO_2: 44 $g*mol^{-1}$

gC-CH_4 in gCH_4= 16 $g*mol^{-1}$ / 12 $g*mol^{-1}$
gC-CO_2 in gCO_2= 44 $g*mol^{-1}$ / 12 $g*mol^{-1}$

25 times large GWP of CH_4

Methane gap-filling of half hourly fluxes

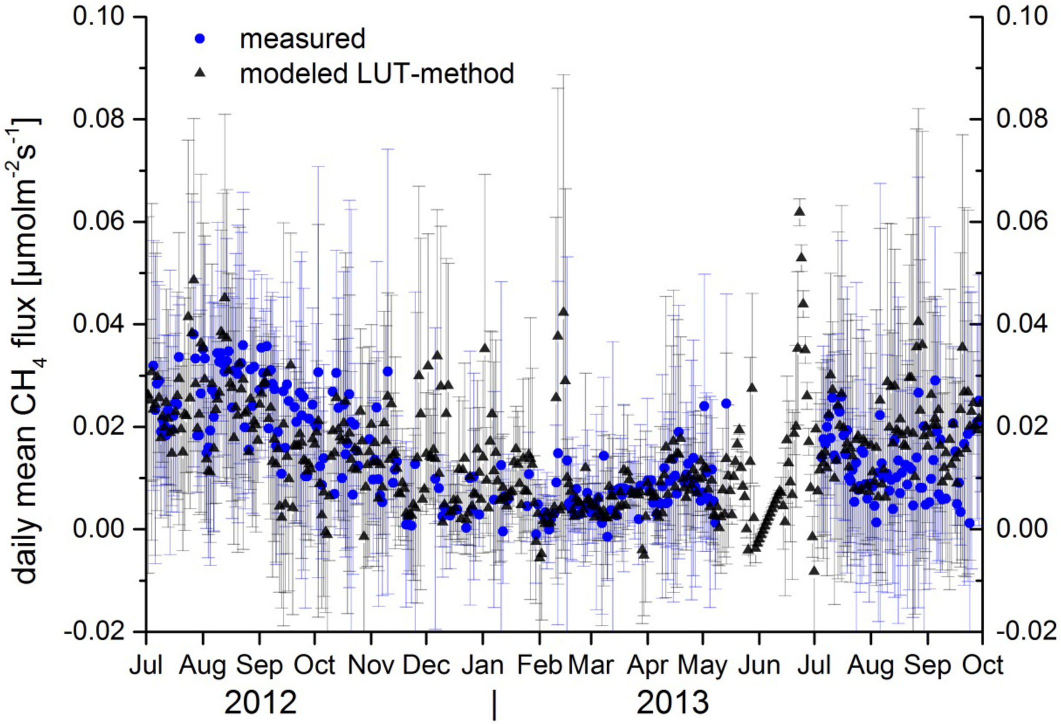
- Examined three different methods:
  - a) Mean daily variation (**MDV**)
  - b) Look-up table (**LUT**), based on T_{air}, PAR, water table depth, reach of the 70% footprint isoline
  - c) Non-linear regression (**NLR**): $F_{CH_4} = a * \exp(T_{air} * b)$



→ **LUT-method fits best**

→ Minor influence of chosen method to annual net CH_4 exchange (range between ±0.5 g C m^{-2} a^{-1} or 16%)

LUT



measured
modeled LUT-method
daily mean CH_4 flux [µmolm^{-2}s^{-1}]
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
2012 | 2013

Methane gap-filling of long data gap

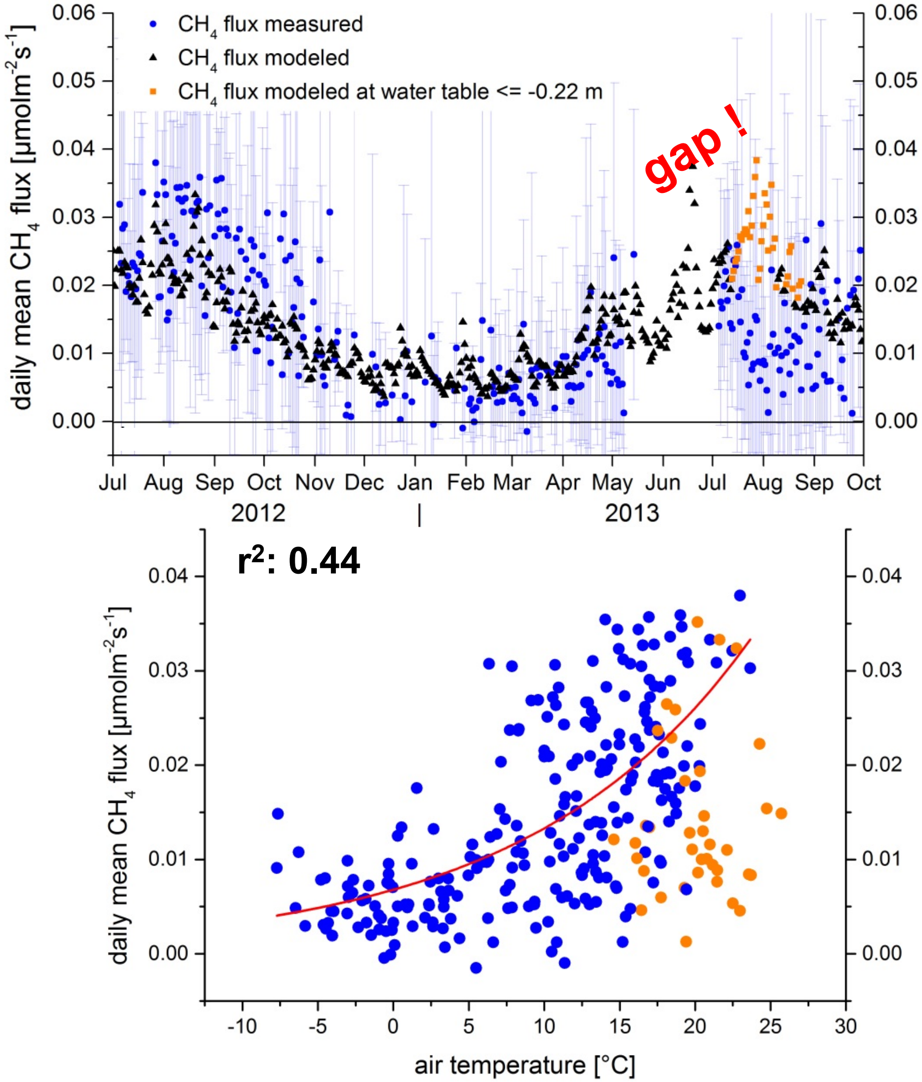
- Long data gap of 7 weeks

→ gap-filled on **daily** basis by exponential regression between daily mean CH_4 flux and T_{air}

→ F_{CH4}= a*exp (T_{air}*b)

- Improvement: excluding CH_4 fluxes, measured during the **drought** period in summer 2013

→77% of the daily CH_4 variation could be explained by T_{air}



Footprint climatology