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KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

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

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Motivation

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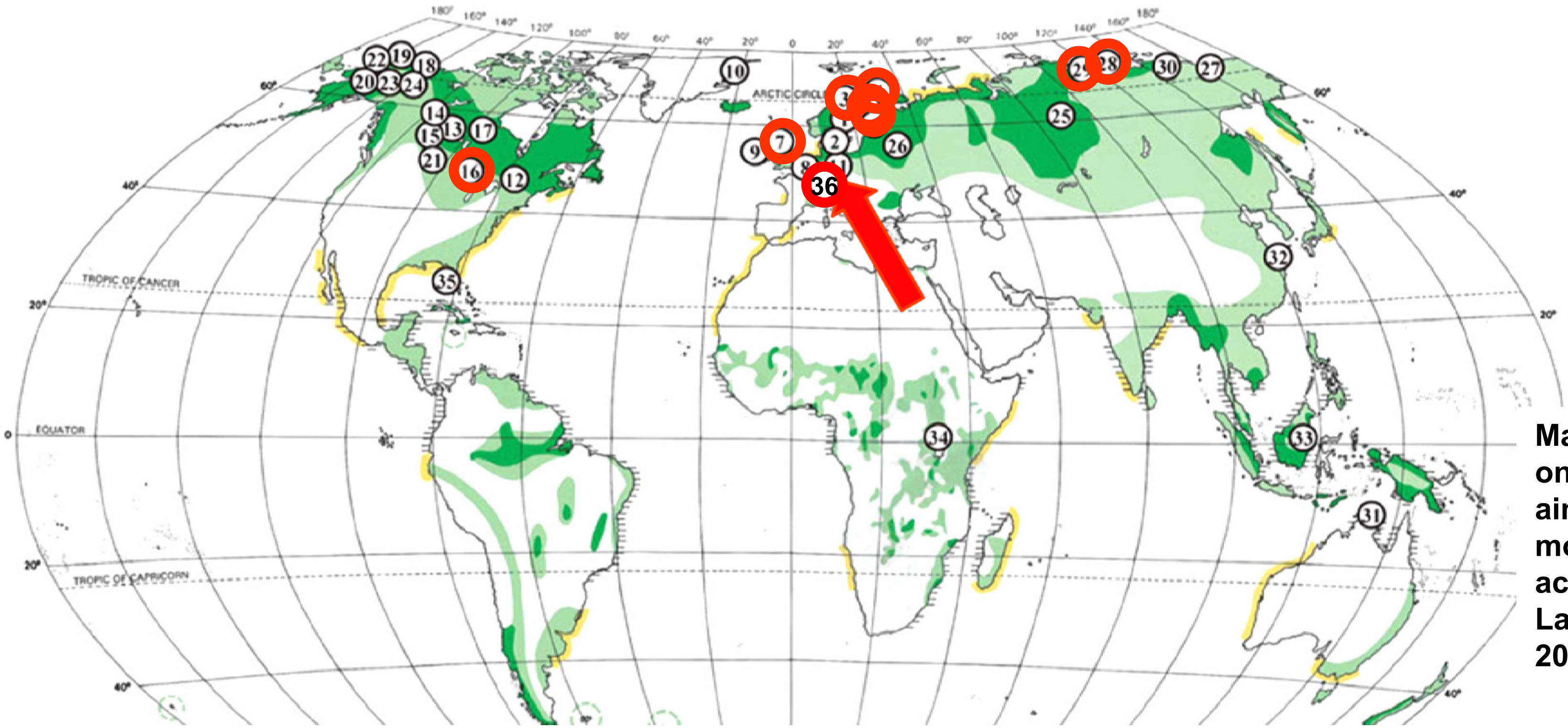


Map based on Lappal-ainen 1996; modified according to Laurila et al. 2012

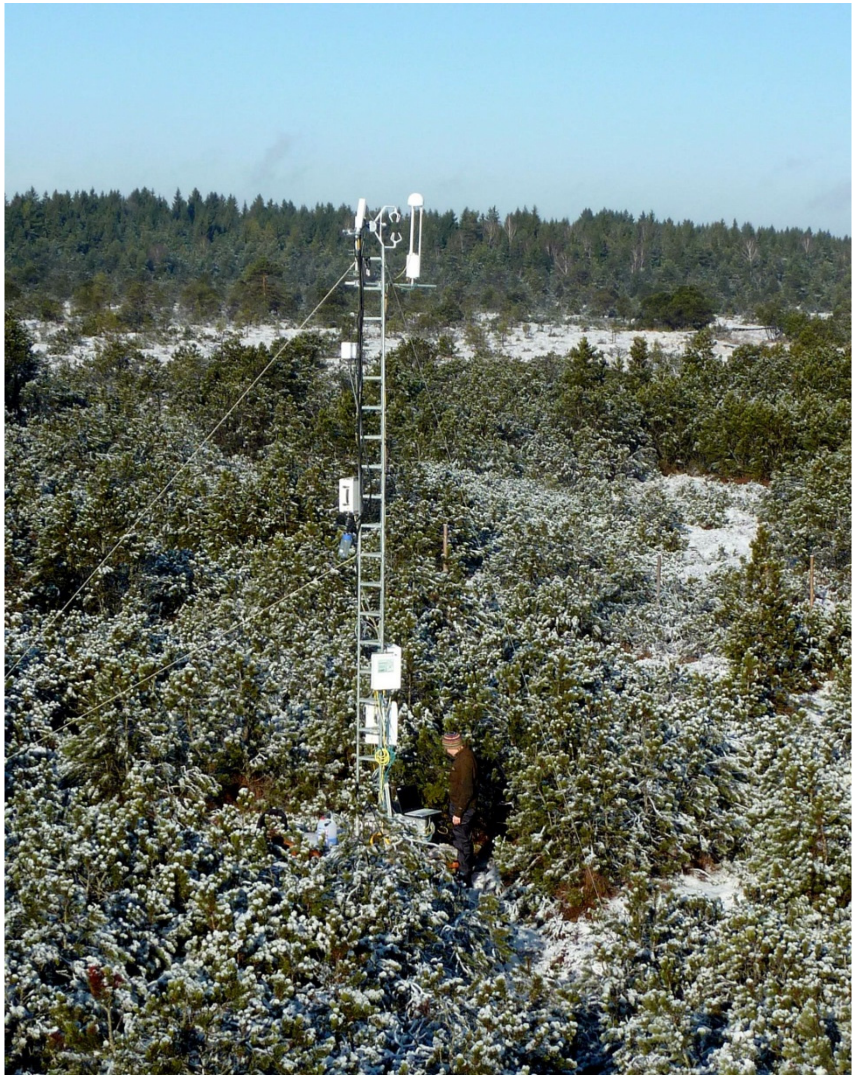
- eddy covariance based carbon exchange studies of peatland ecosystems mostly located in **northern regions**

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

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

Study 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

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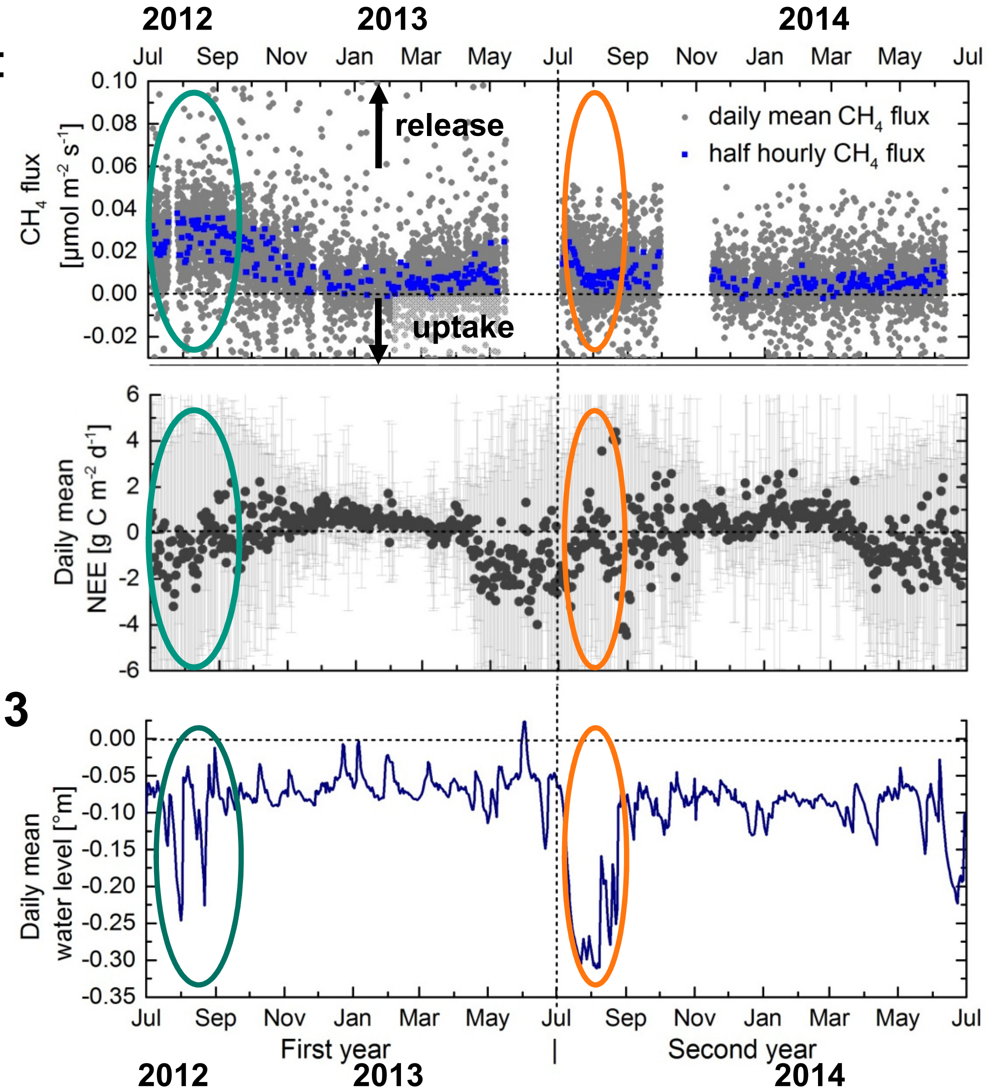
- Measurement period over 2 years:
  from July 2012 to June 2014
- Daily CH_4 release throughout the whole year
- CH_4 exchange is in phase with temperatures

→ CH_4 peak in summer 2012

→ but not on 2013?

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



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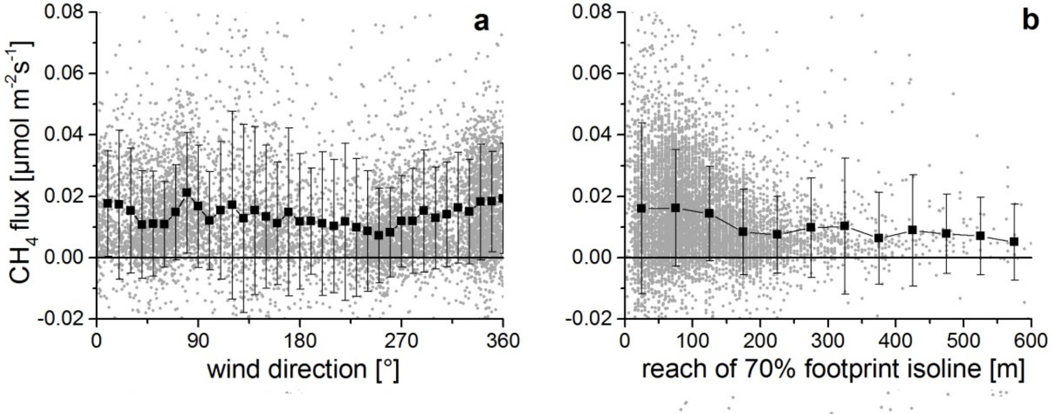
Control Parameters

- 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



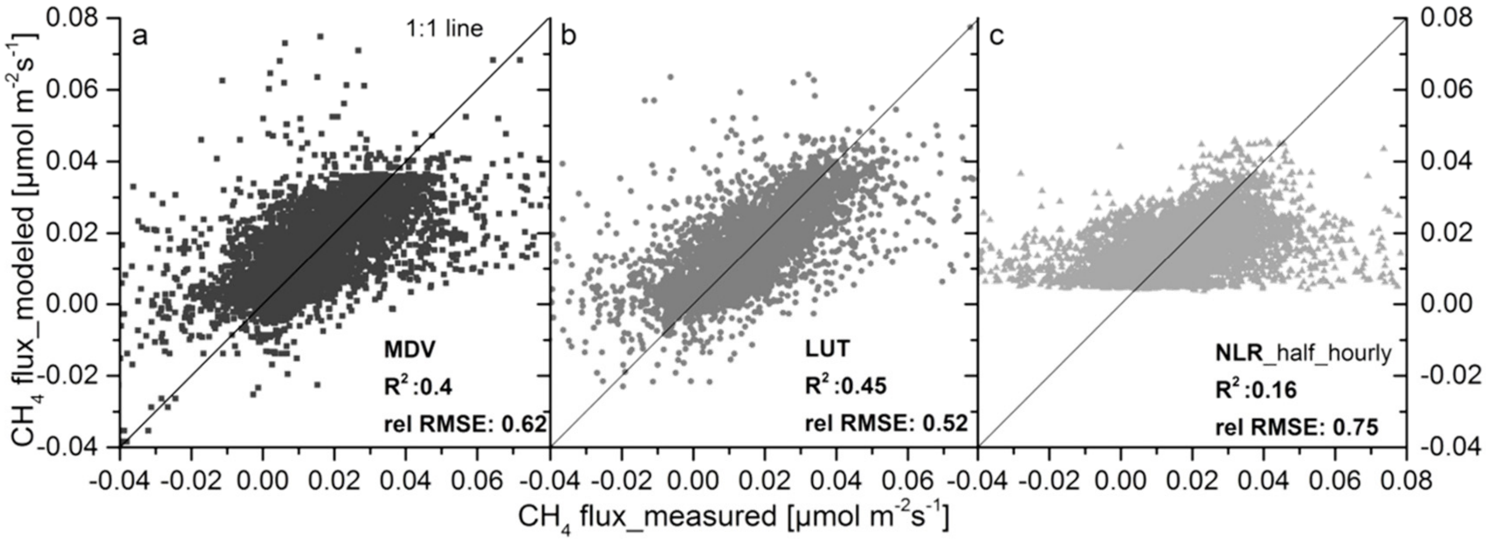
- considering **only CH_4 fluxes at lower water tables** (< -0.12 m):

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

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

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 (maximum 16%)

Methane gap-filling of long data gap

- 3 long data gaps

→ **poor gap filling result**

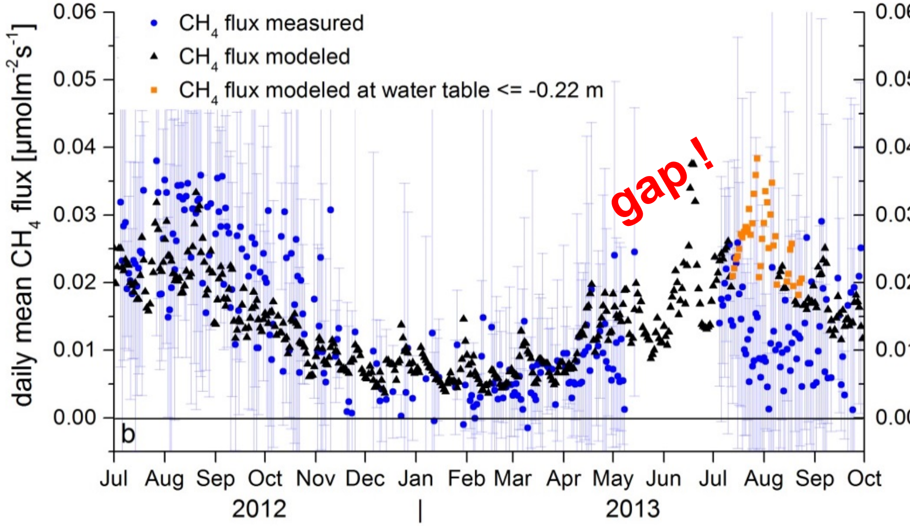
→ gap-filled on **daily** basis: **exponential regression** between daily mean T_{air} and CH_4 flux

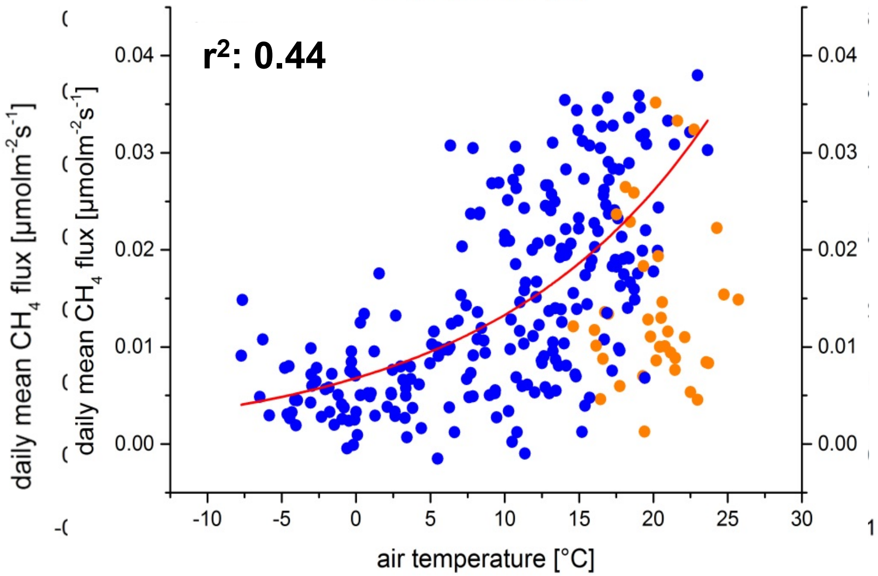
→ $F_{CH4} = a*\exp(T_{air}*b)$

- 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}

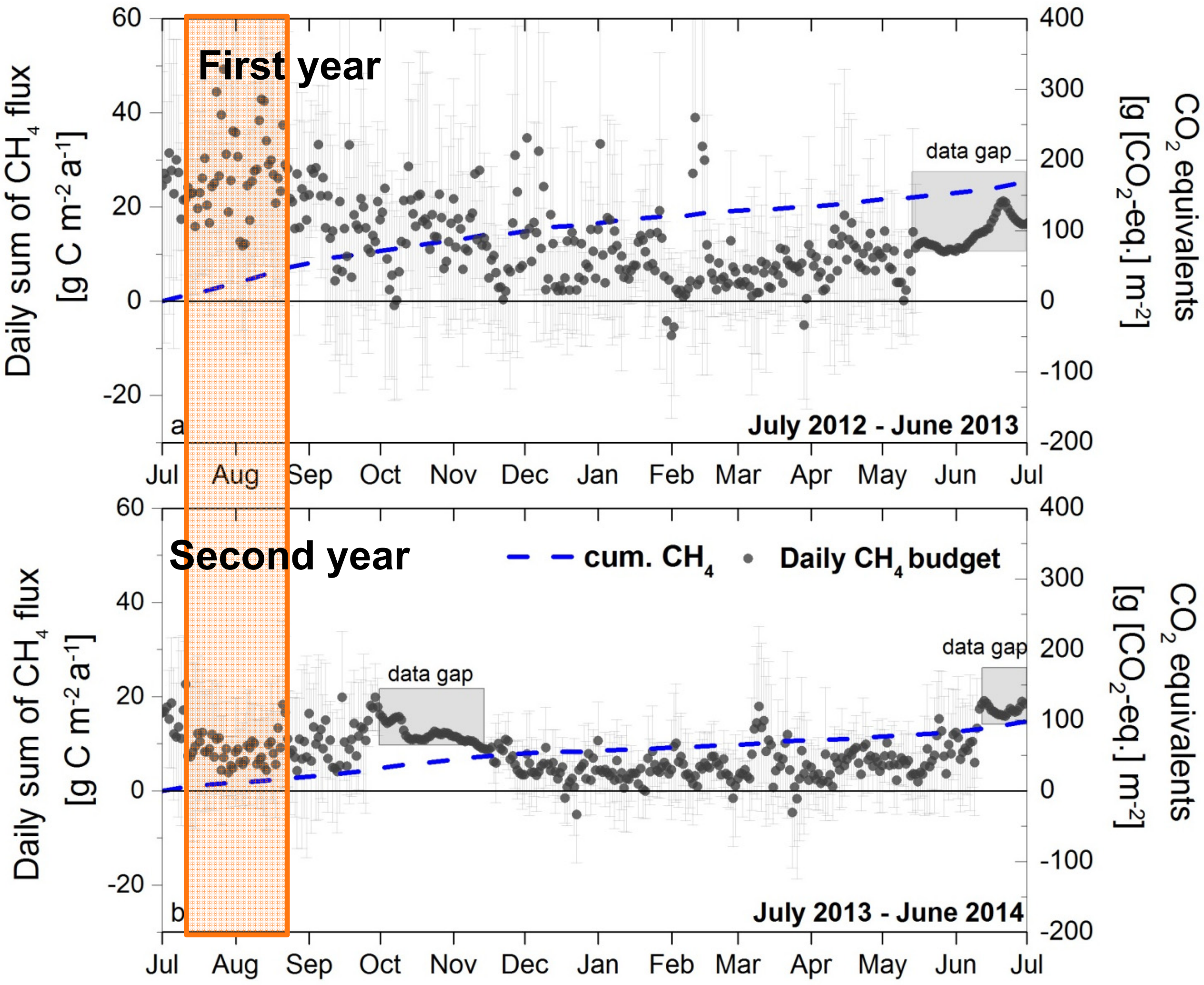
→ drought period and data –gap did not overlap





Annual methane budget

- Continuously increasing methane budget
- Annual methane exchange +5.3 and +3 g C m^{-2} a^{-1} (= +176 and +100 g C [CO_2-eq] $m^{-2}a^{-1}$)
- Difference mostly caused by drought event in summer 2013



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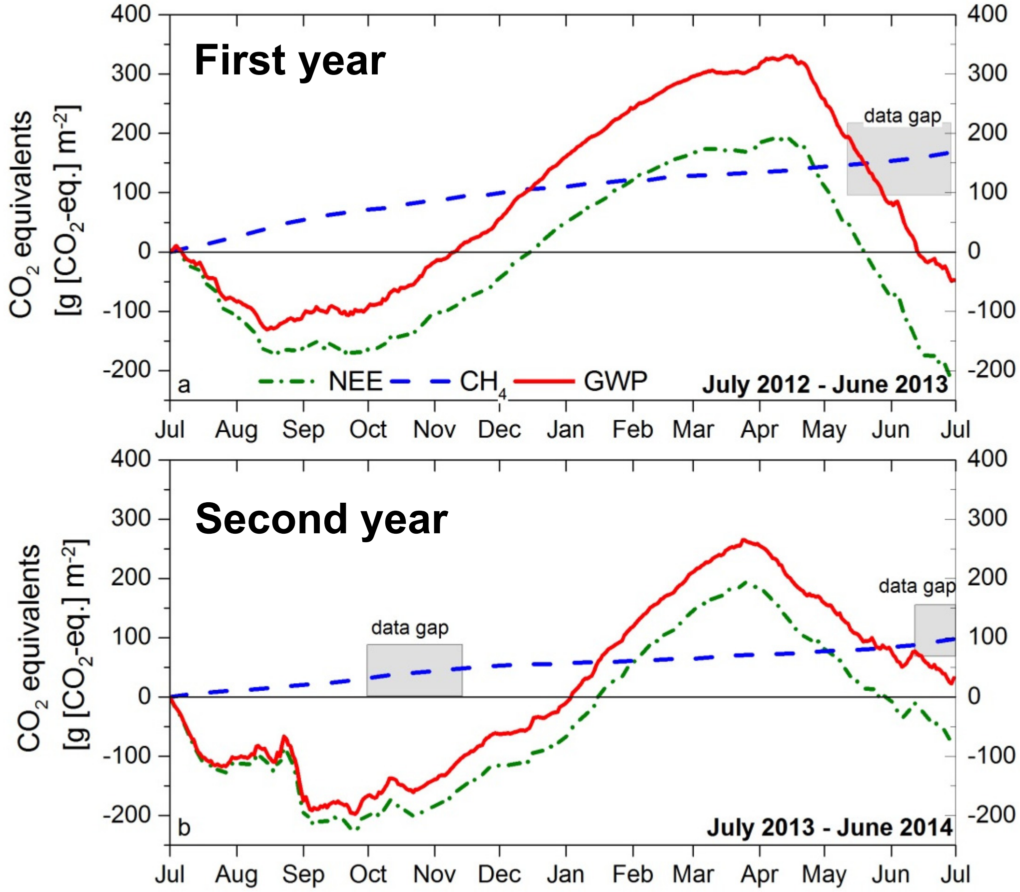
Annual GHG budget

- N_2O fluxes are negligible at nutrient poor, natural peatland sites
- Methane: 25 times stronger GWP than CO_2

→ but considerable reduction of the CO_2 uptake induced climate cooling effect



Negative radiative forcing GWP: -50 g C [CO_2-eq] $m^{-2}a^{-1}$

Positive radiative forcing GWP: +32 g C [CO_2-eq] $m^{-2}a^{-1}$

Natural bog-pine ecosystem is climate neutral

Annual GHG budget

- Lower methane emissions, but also lower CO_2 uptake in the second year

→ GHG source

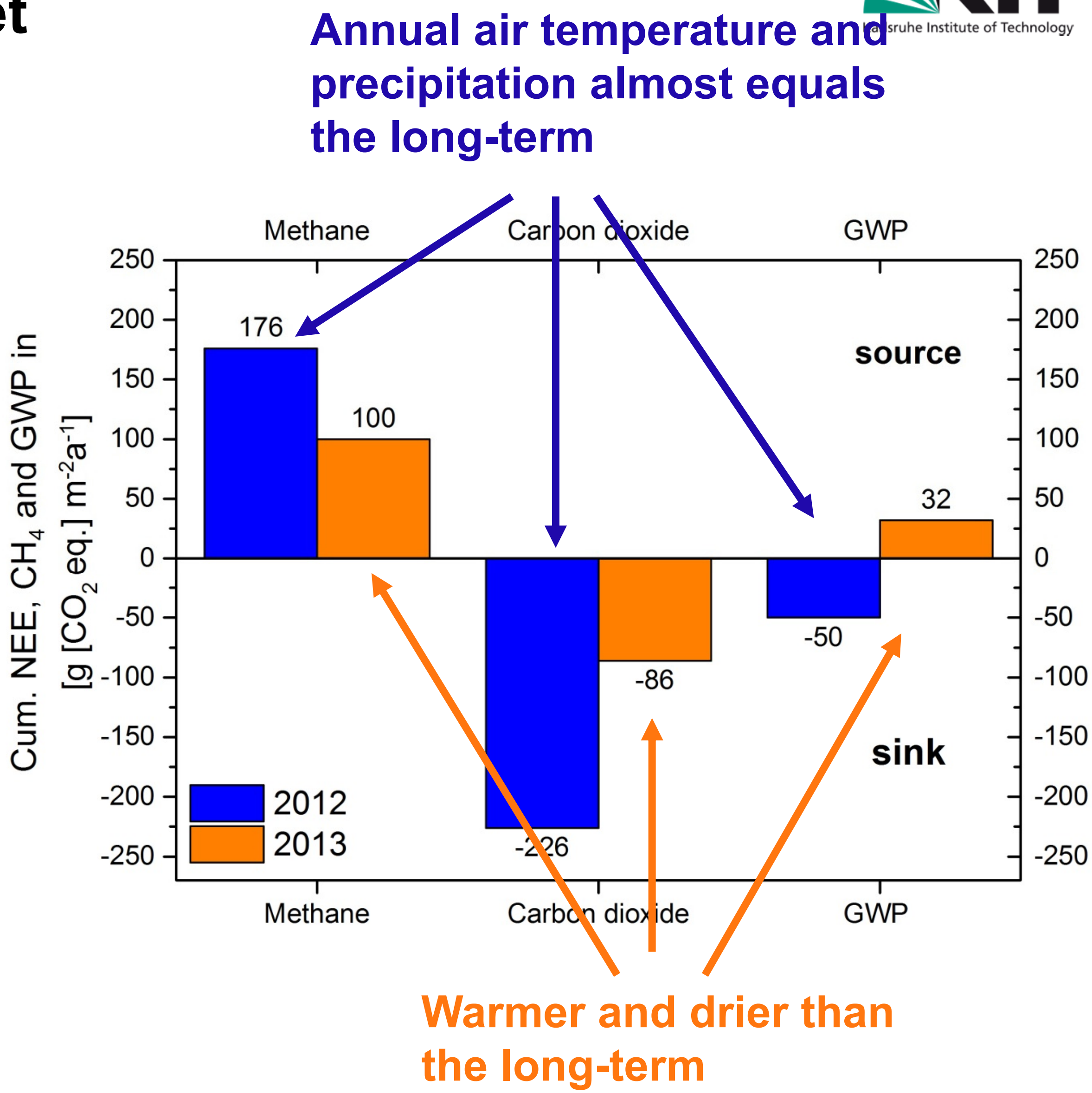
- Second measurement period:

→ warmer and drier than the long-term

→ Lower water level

→ less methane emissions but more respiration

→ Conditions of the first year were more typical



Conclusions

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

→ **Climate neutral** (-50 g C [CO_2-eq] $m^{-2}a^{-1}$; +32 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 the first measurement 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

Methane gap-filling of long data gap

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

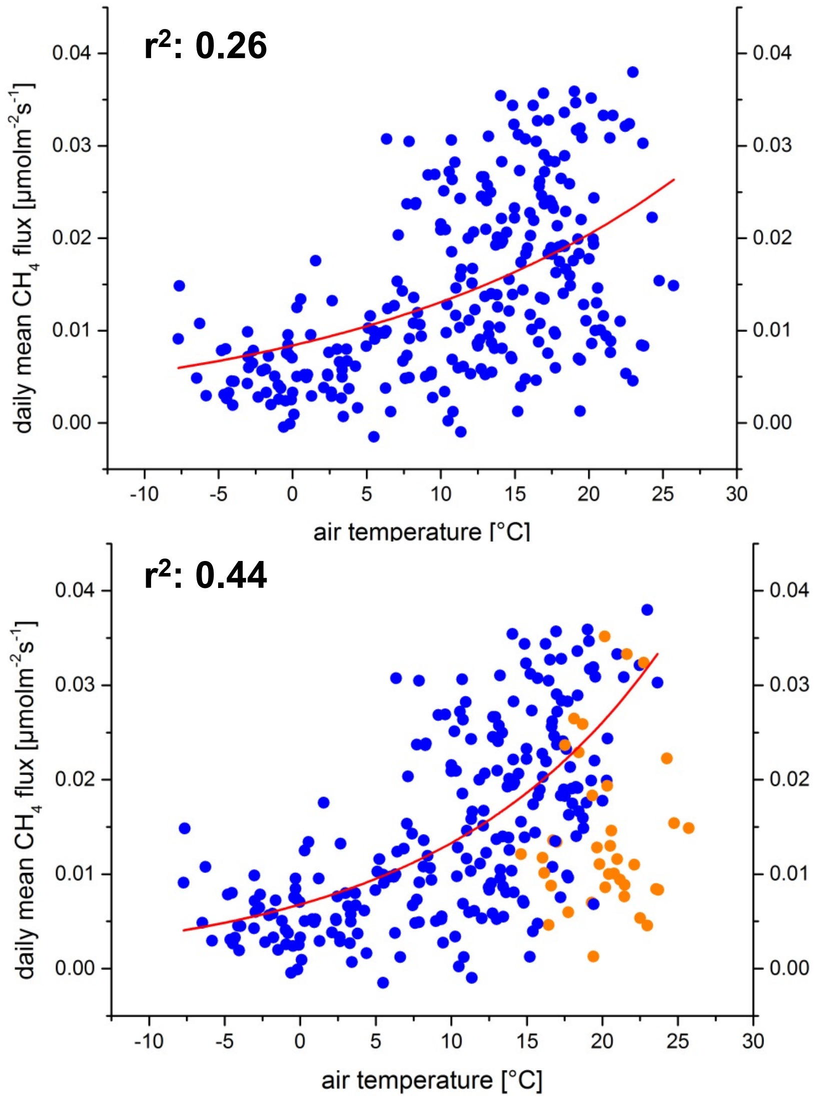
→ **exponential regression** between daily mean T_{air} and CH_4 flux

→ $F_{CH_4} = a*\exp(T_{air}*b)$

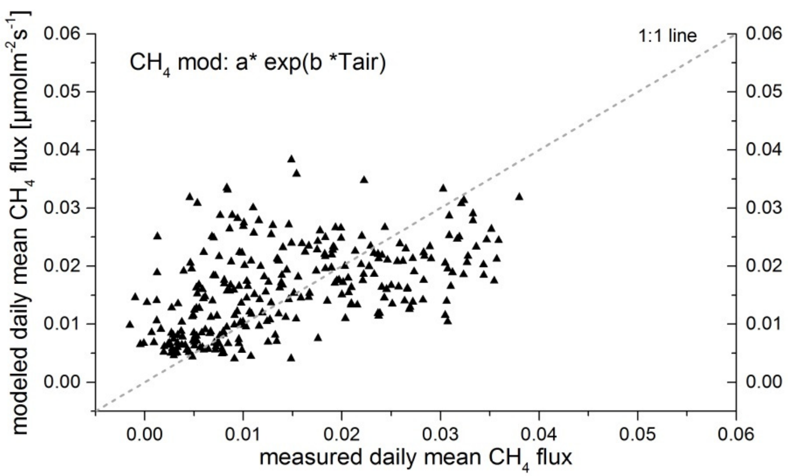
- improvement: excluding CH_4 fluxes, measured during **drought** period in summer 2013

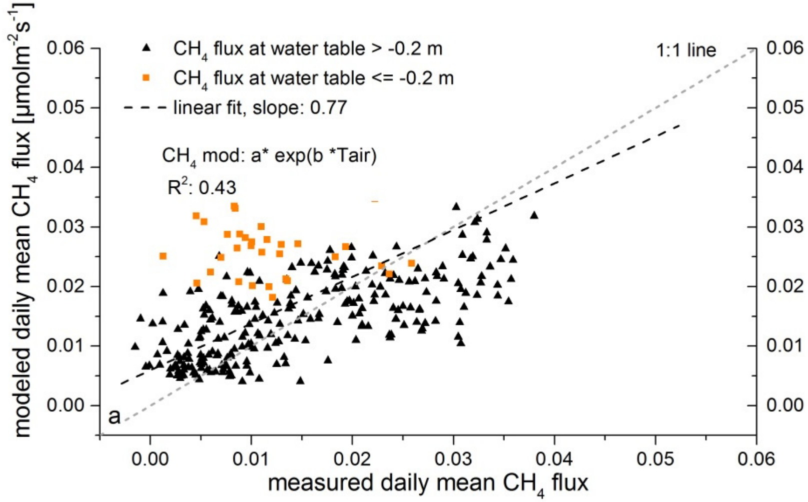
→ 77% of the daily CH_4 variation could be explained by T_{air}

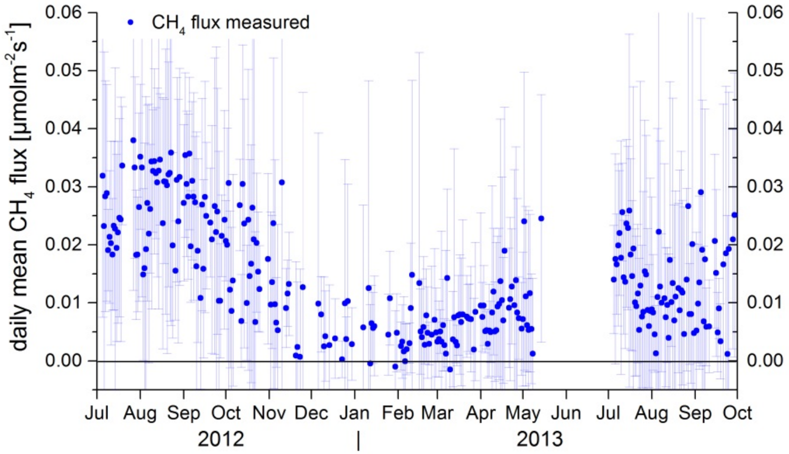
→ drought period and data –gap did not overlap

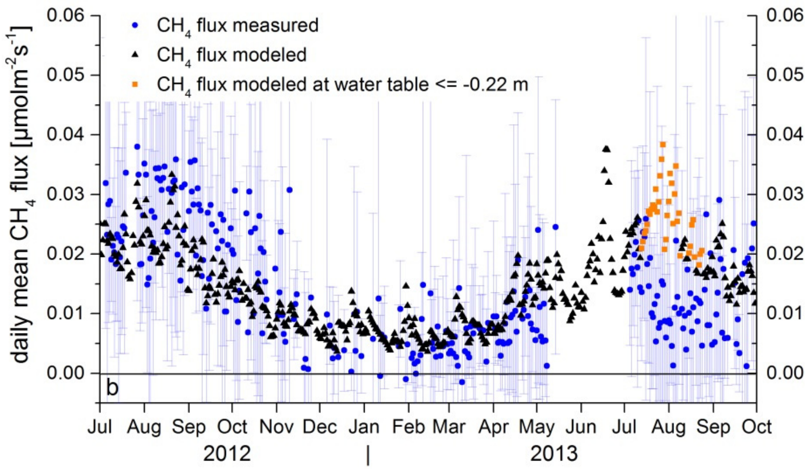


Appendix


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
1:1 line
CH4 mod: a* exp(b *Tair)
R2: 0.43
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

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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}

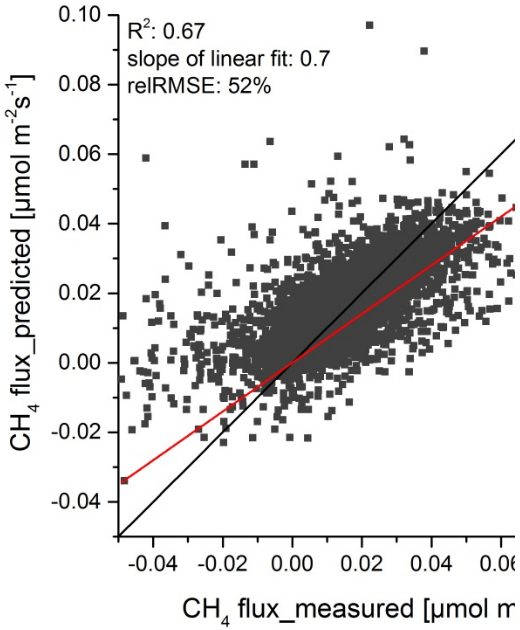
CO_2: 44 g*mol^{-1}

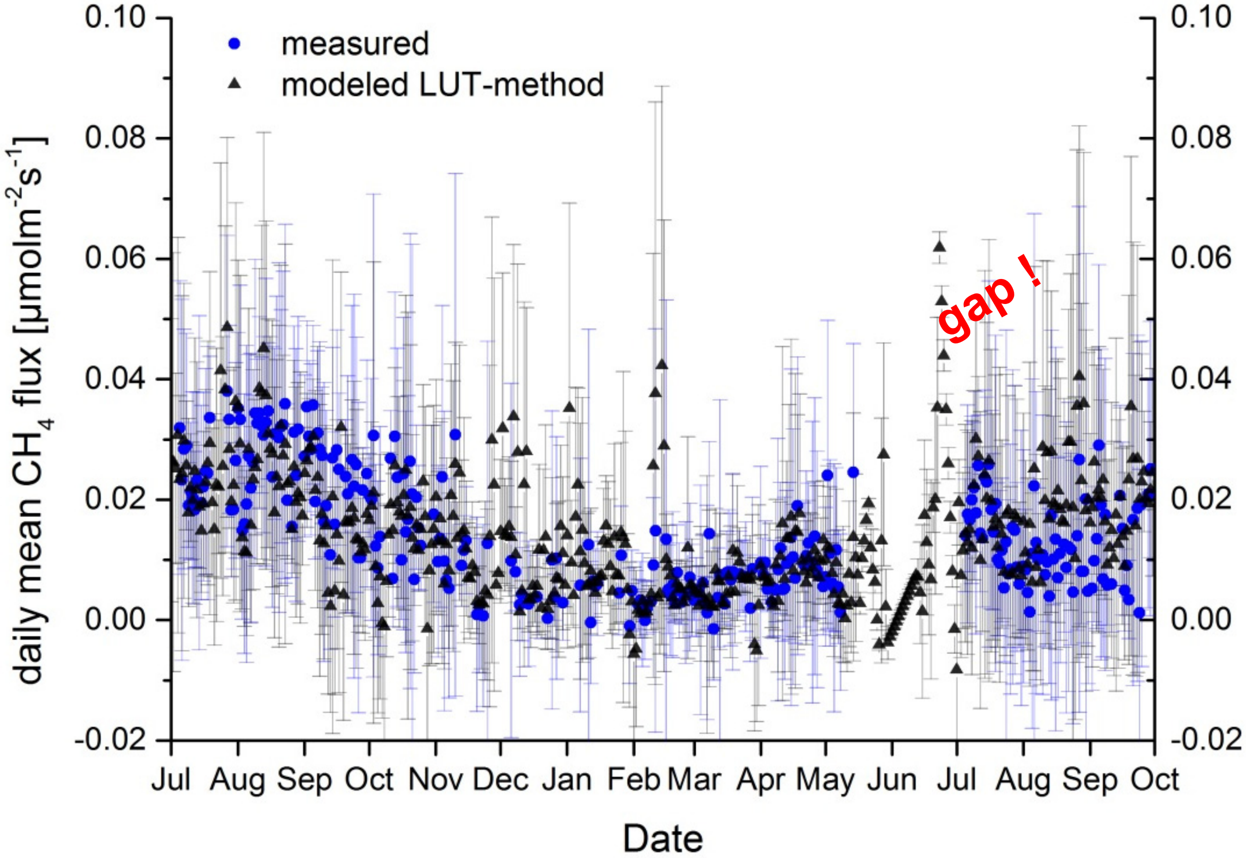
gC-CH_4 in gCH_4= 16 g*mol^{-1} / 12 g*mol^{-1}
gC-CO_2 in gCO_2= 44 g*mol^{-1} / 12 g*mol^{-1}

25 times large GWP of CH_4

Methane gap-filling of half hourly fluxes

- Look-up table:
- based on $T_{air,}$ PAR water table depth, of the 70% footprir isoline





Footprint climatology