Annual carbon balance of a raised peat bog in New Zealand

Dave Campbell

Jordan Goodrich

Catherine Sturgeon

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Landcare Research
Manaaki Whenua

Wetland restoration programme

- Six year Ministry for Science and Innovation programme *Wetland Restoration* 2010-16
  - Subcontract to Landcare Research
- Fits into "ecosystem functioning" objective
  - Carbon fluxes and balanceof an intact peatland
  - Informs restoration targets for restored peatlands

Presentation objectives

- Annual net ecosystem carbon balance (NECB) at NZ's largest true raised peat bog (year 1)
- Sensitivity of NECB components to environmental drivers

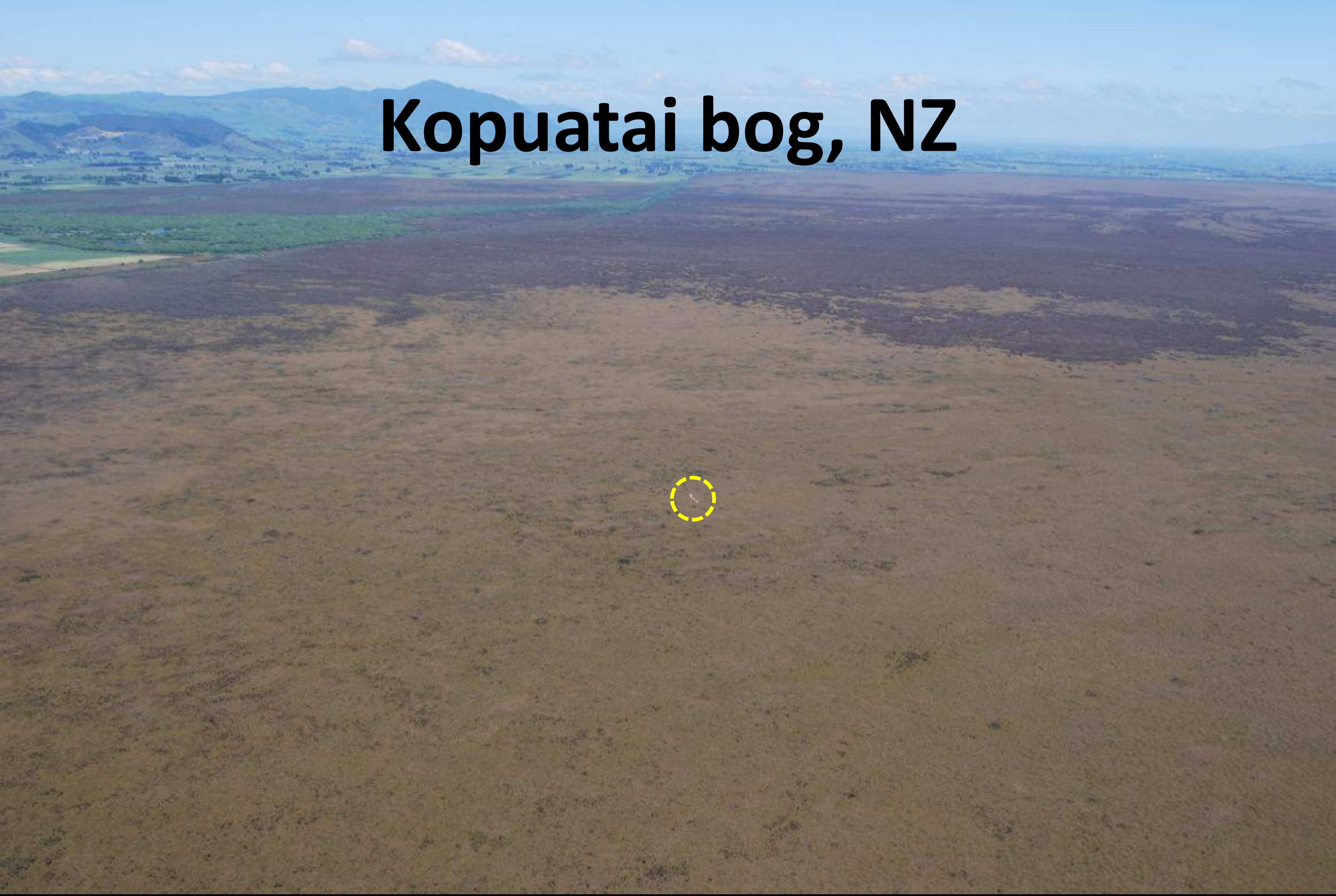
Outline

- Peatlands and carbon
  - Northern hemisphere analogues
- Site description and methods
- Results
  - CO_2 exchange
  - CH_4 exchange
  - Dissolved organic C export
  - One-year NECB

Peatlands and carbon

- Globally large stores of carbon
  - E.g. northern peatlands contain C equivalent to around 1/3 of global soil C store
- Long-term C balance gains over thousands of years
  - Uptakes of CO_2 partially offset by respired CO_2, methane emissions and leached C in runoff
  - Net cooling effect on climate?

Kopuatai bog, NZ



Kopuatai bog

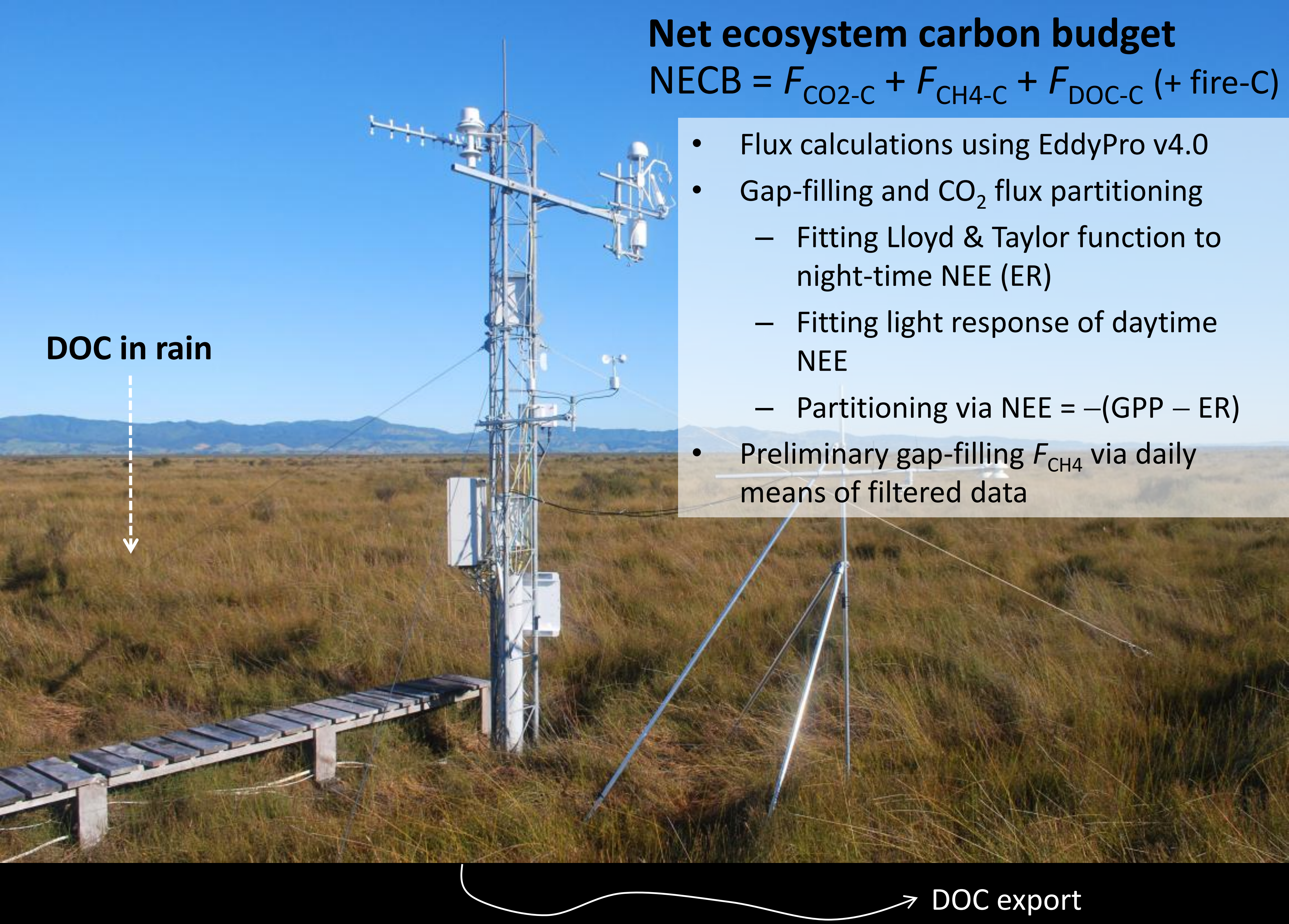
Area >90 km^2
Elevation 2 – 5 m a.s.l.

Mean annual precipitation = 1262 mm
Mean annual temperature = 14.6°C

Net ecosystem carbon budget

$$NECB = F_{CO2\text{-}C} + F_{CH4\text{-}C} + F_{DOC\text{-}C} \text{ (+ fire-C)}$$

- Flux calculations using EddyPro v4.0
- Gap-filling and CO_2 flux partitioning
  - Fitting Lloyd & Taylor function to night-time NEE (ER)
  - Fitting light response of daytime NEE
  - Partitioning via NEE = –(GPP – ER)
- Preliminary gap-filling F_{CH4} via daily means of filtered data



Peatland CO_2 exchange (NEE)

Kopuatai bog, 37°S
M.A.T. = 14.6 °C

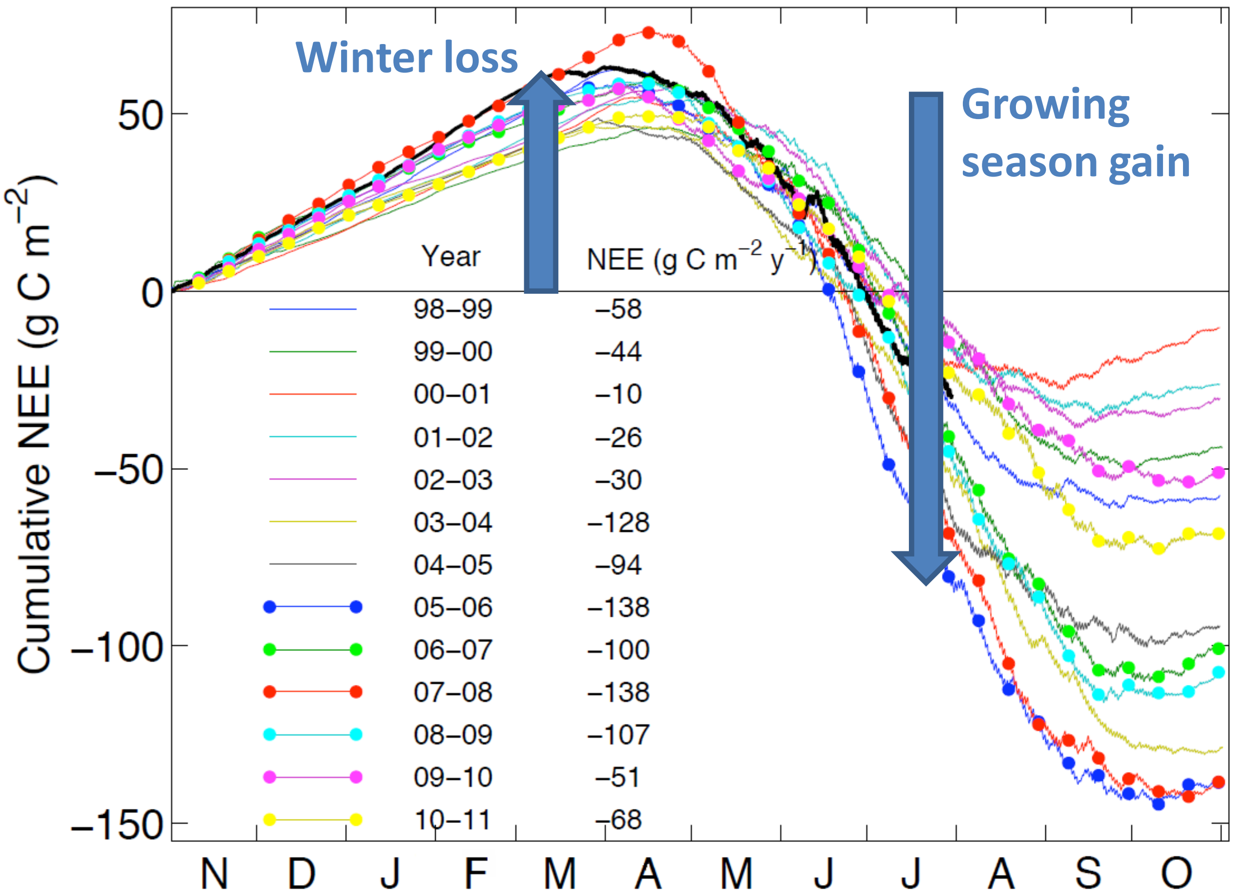
Peat formation via vascular plants

- Mainly wire rush (*Empodisma robustum*)

Mer Bleue bog, Ottawa, 45°N
M.A.T. = 6 °C

Peat formation via mosses

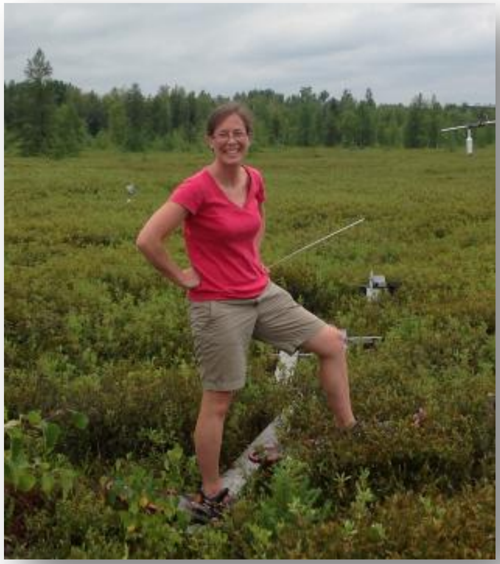
Annual courses of NEE at Mer Bleue bog, Canada



Mean annual sum NEE

−74 gC m^{-2} yr^{-2} (1999-2009)

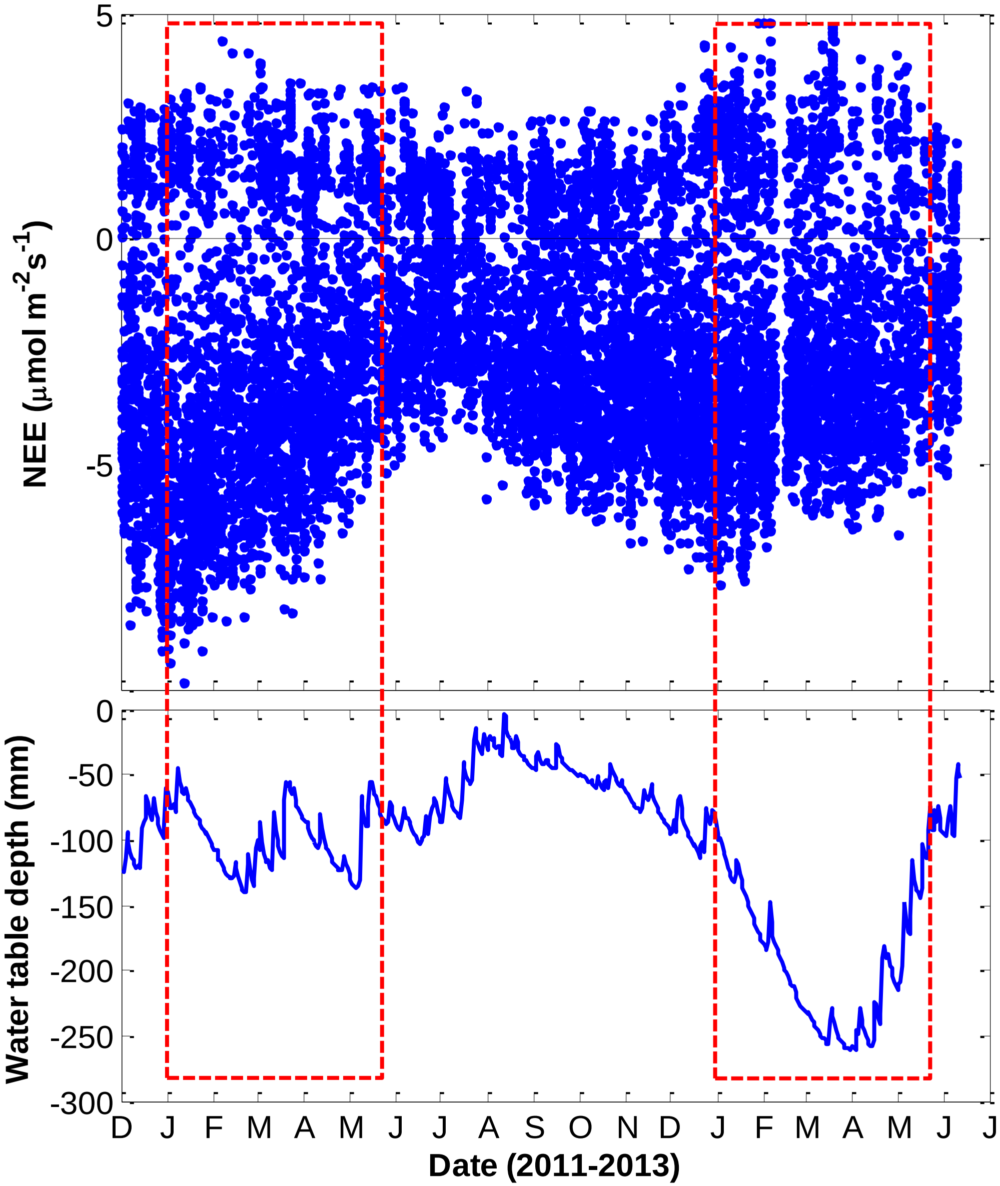
(range −10 to −138 gC m^{-2})



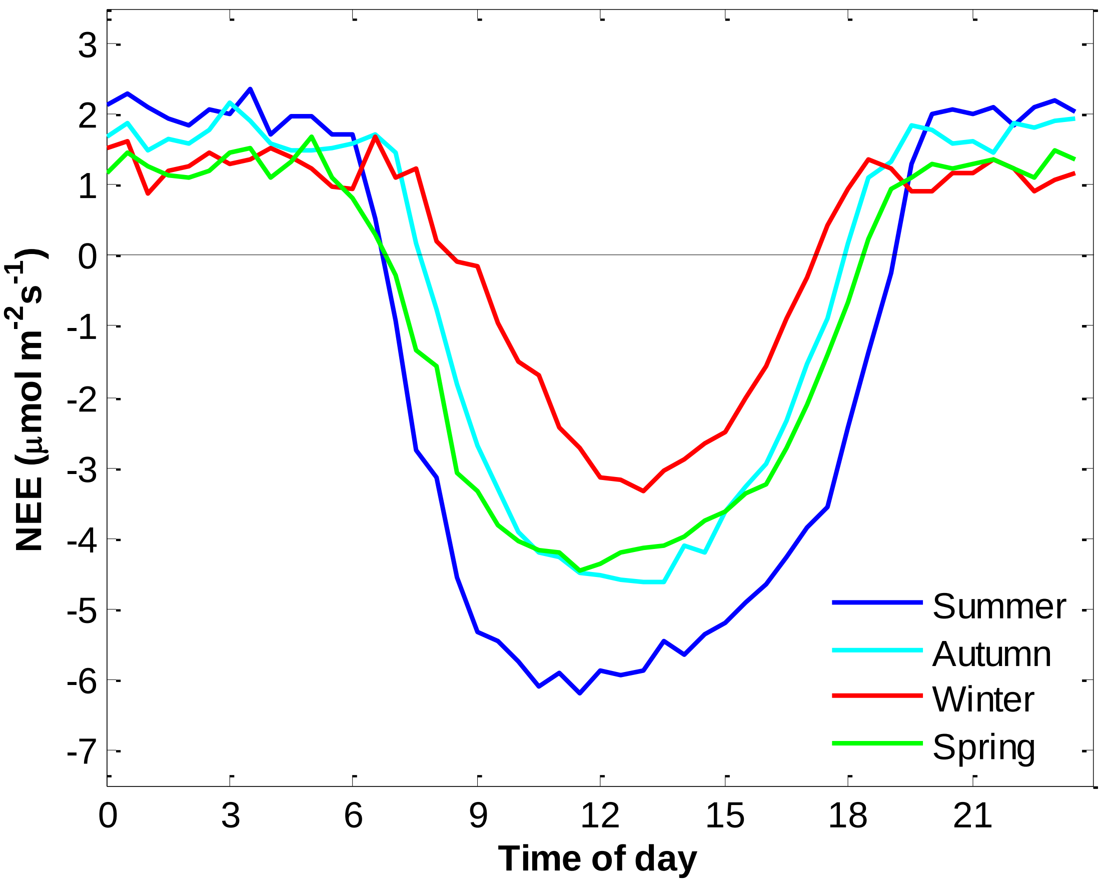
Data from A. Prof. Elyn Humphreys, Carleton University, Ottawa

CO_2 exchange at Kopuatai

Two contrasting summer seasons



Seasonal variation in diel CO_2 exchange



NEE daily mean totals (2012)

Summer : –1.44 gC $m^{-2}day^{-1}$

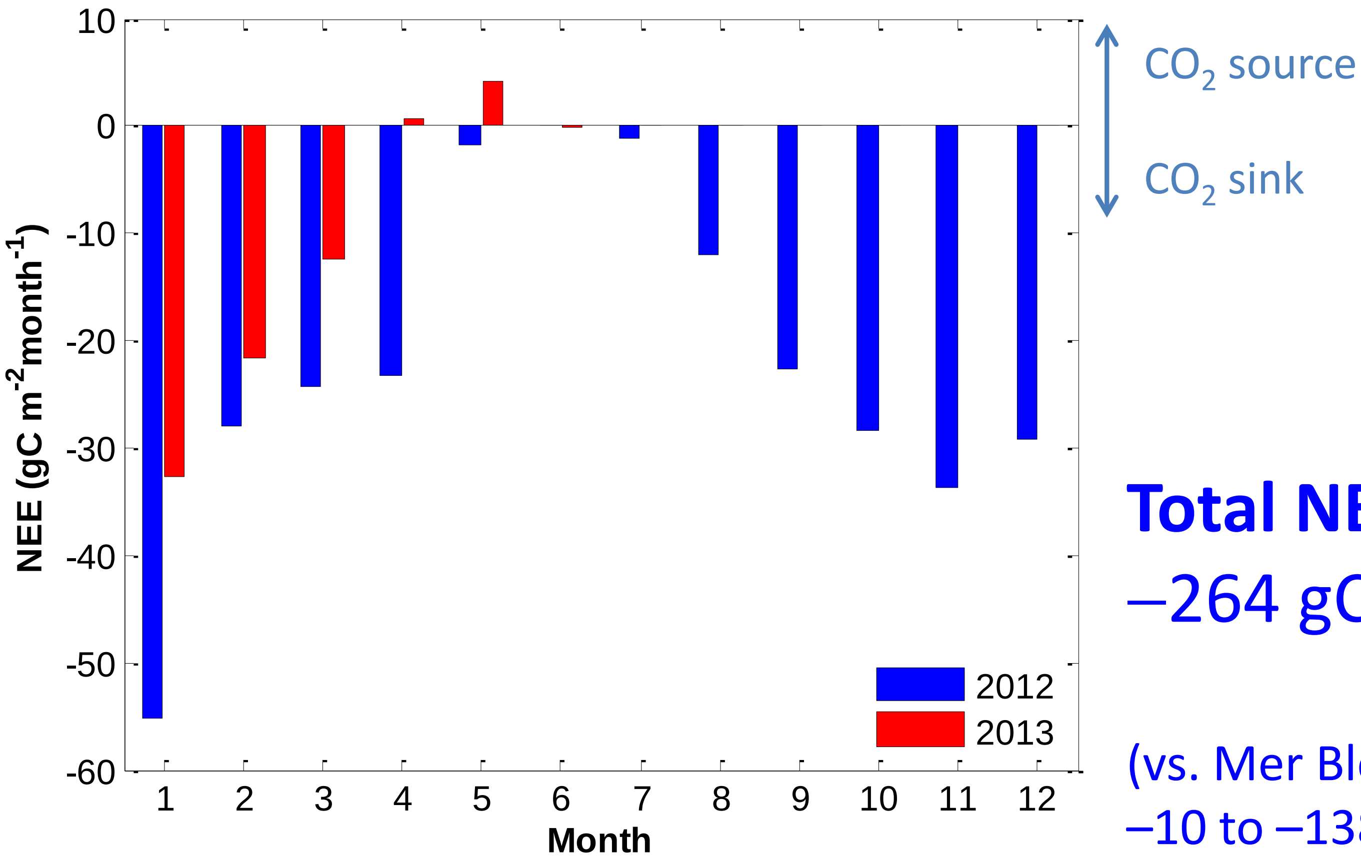
Autumn : –0.51 gC $m^{-2}day^{-1}$

Winter : 0.00 gC $m^{-2}day^{-1}$

Spring: –0.92 gC $m^{-2}day^{-1}$

Growing season 9–10 months
(cf. Mer Bleue 5 -6 months)

Monthly sums of NEE



Total NEE 2012

–264 gC m^{-2} $year^{-1}$

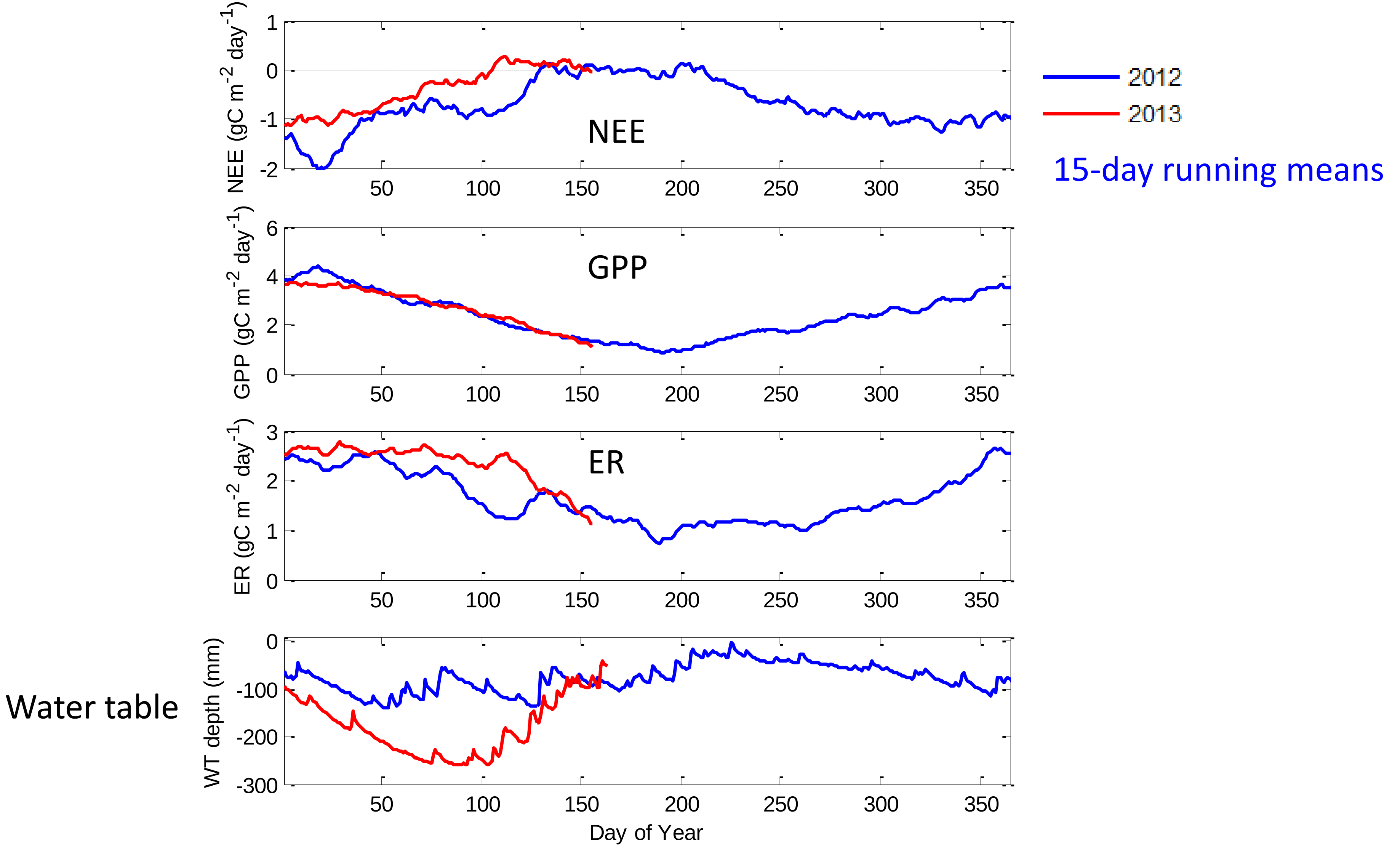
(vs. Mer Bleue range –10 to –138 gC m^{-2})

Jan – April total NEE

2012: –131 gC m^{-2}

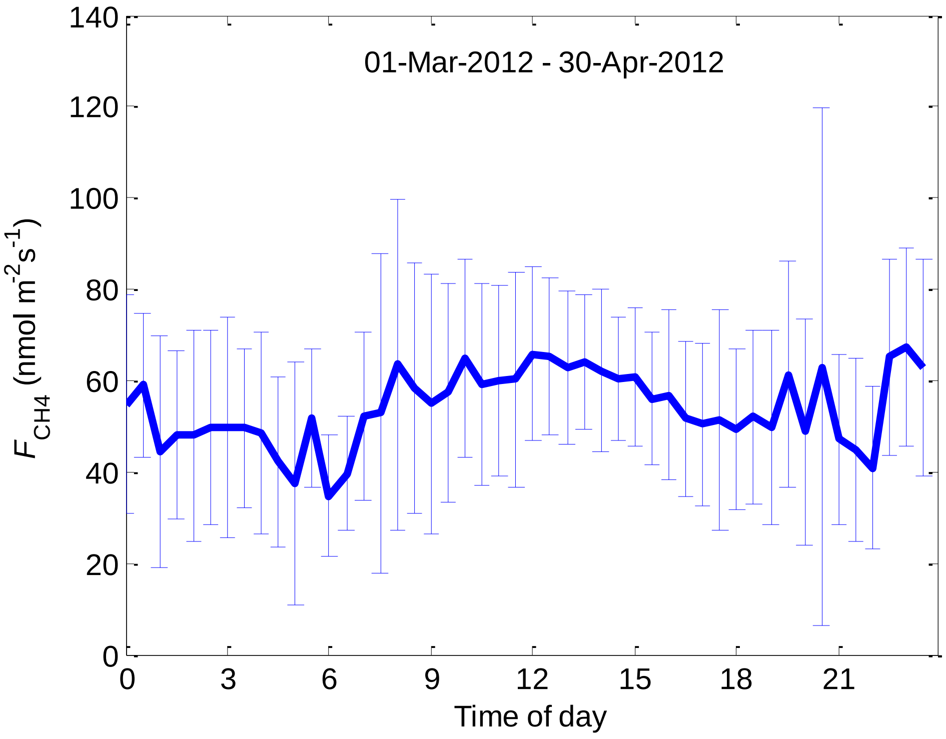
2013: –66 gC m^{-2}

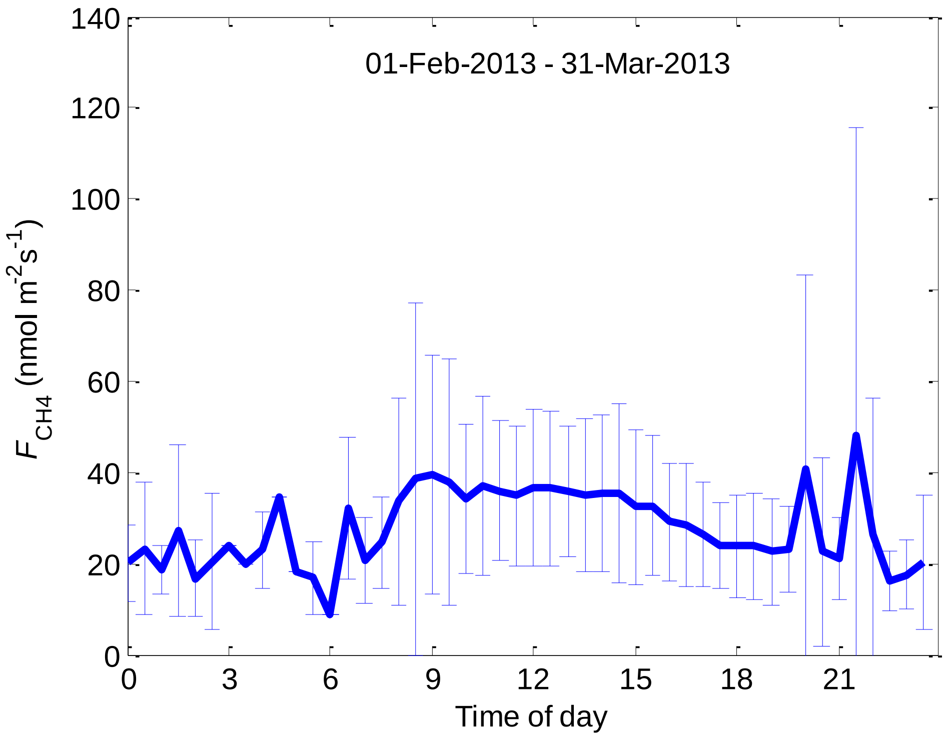
Importance of the water table



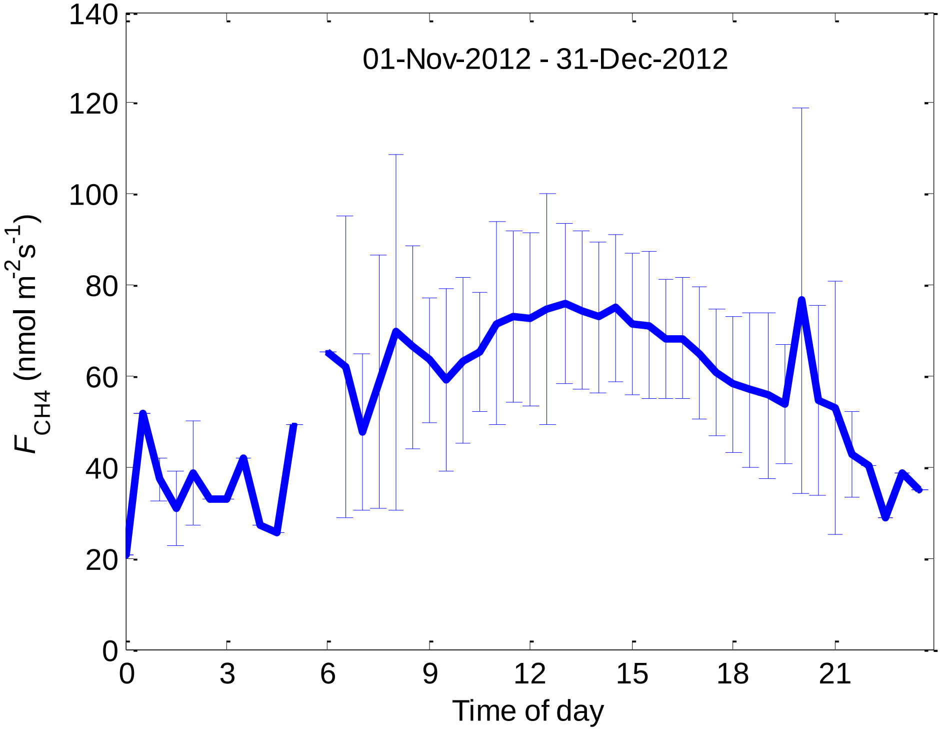
Methane flux, F_{CH4}

Little diurnal variation in F_{CH4}





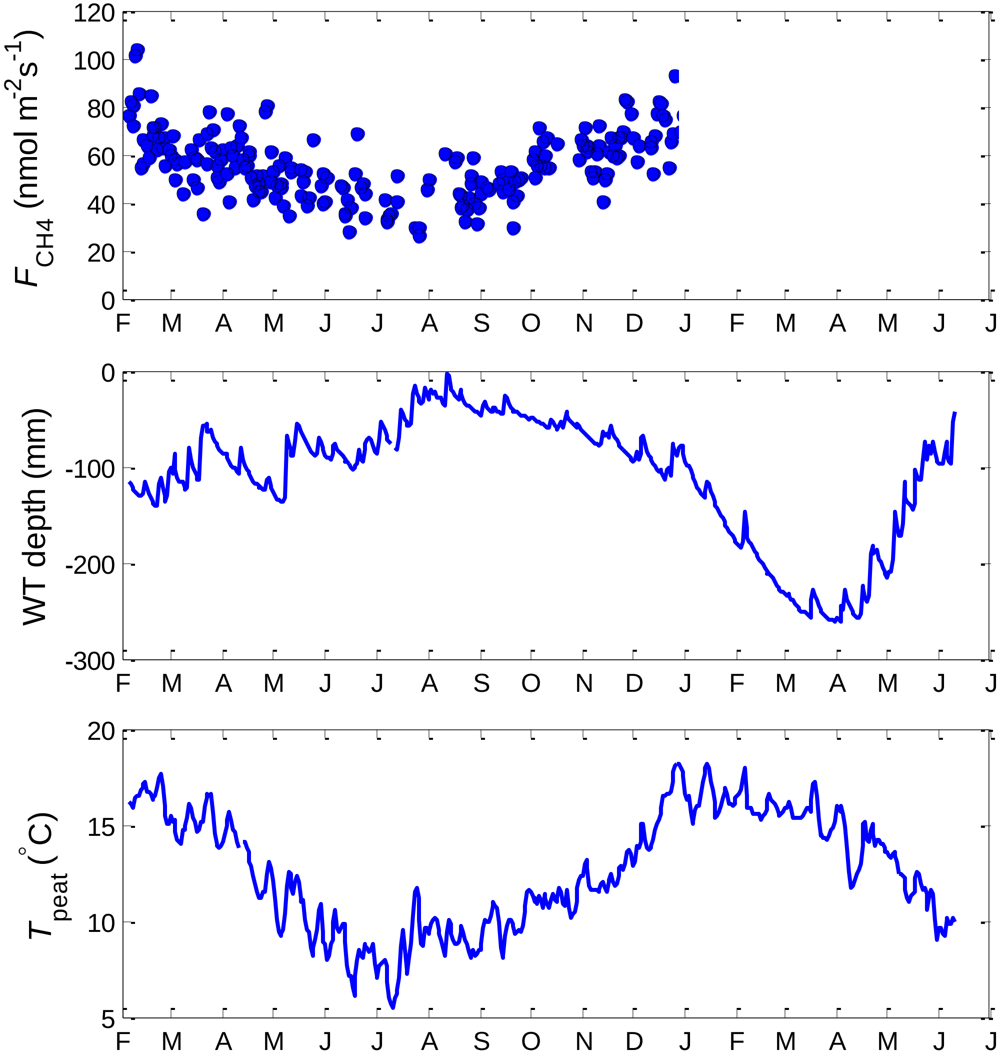
But…

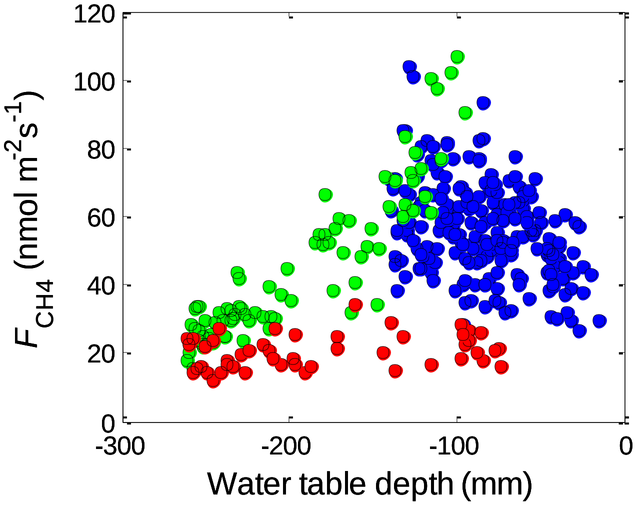


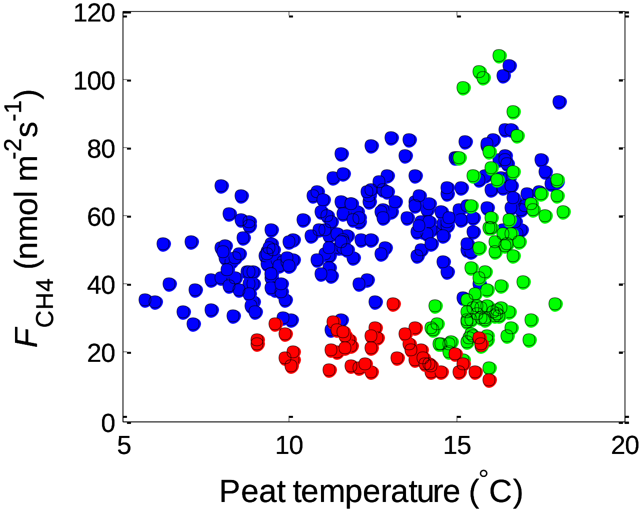
Evidence for plant-mediated CH_4 transport?

Controls on F_{CH4}

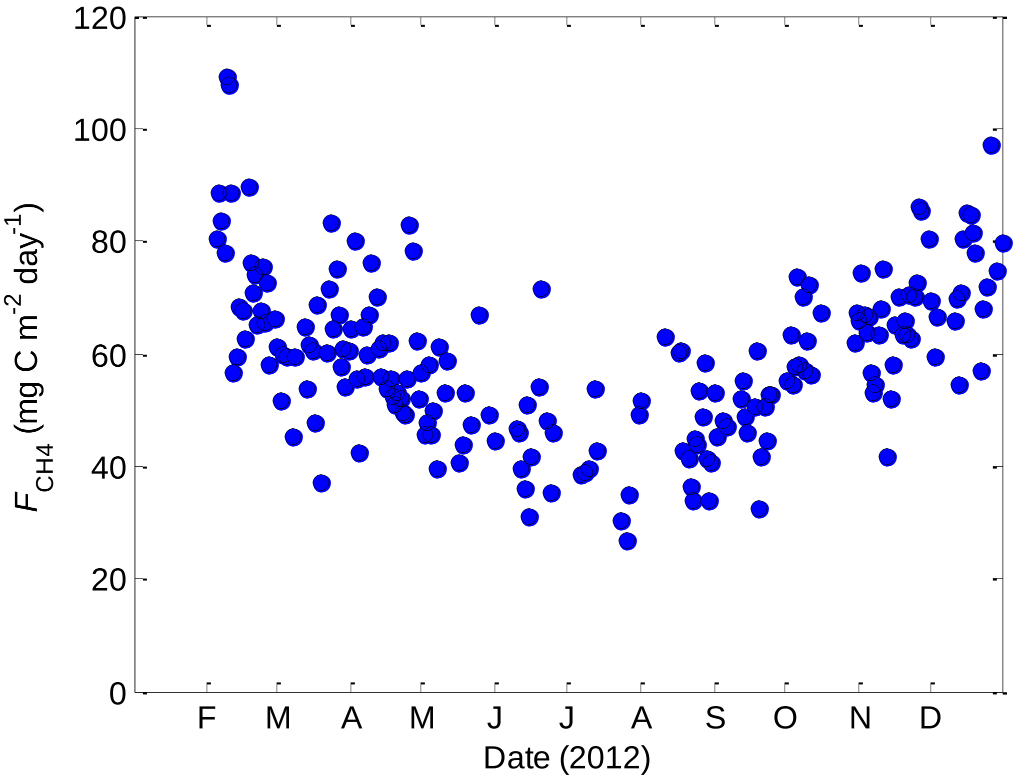
Daily means







Estimated annual F_{CH4}



Daily mean

59.4 mg C m^{-2} day^{-1}

Annual total

21.7 g C m^{-2} year^{-1}

Dissolved organic C export method

- Spatial, depth and temporal sampling of DOC in peat pore water
- Monthly water export calculation via water balance:

$$Q = P - E - \Delta S$$

P = precip.; E = evap.; ΔS = change in stored water

$\Delta S = Y \times \Delta \mathrm{WT}$ (Y = peat specific yield; WT = water table depth)

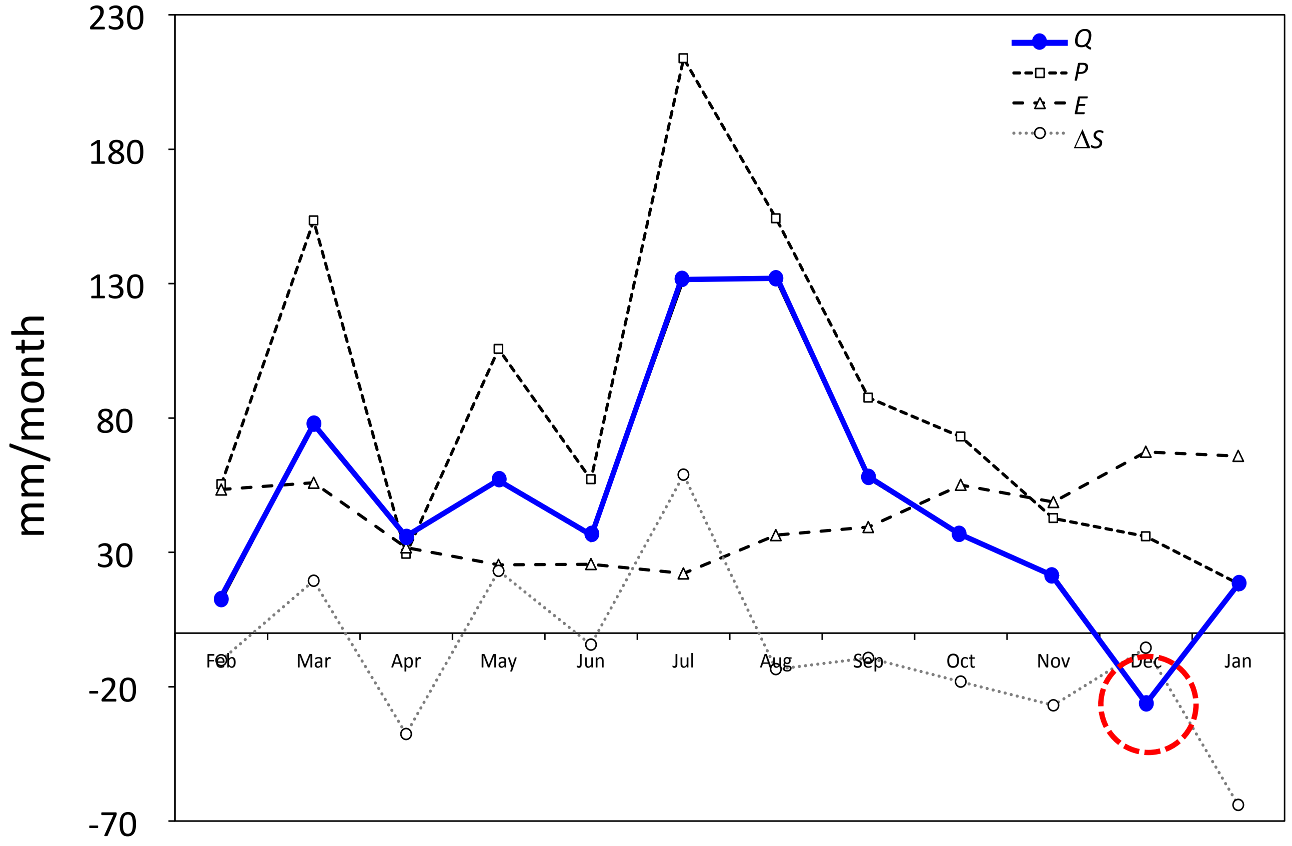
- Monthly flux of DOC:

$$F_{\mathrm{DOC}} = Q \times C_{\mathrm{DOC}}$$

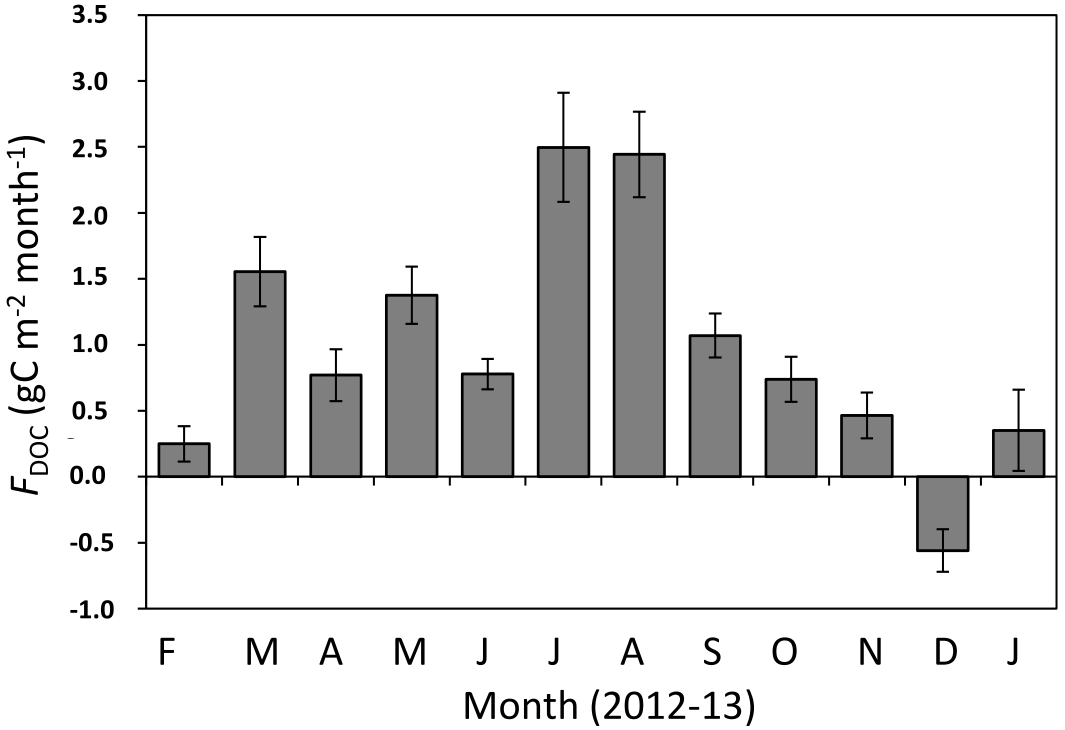
(C_{DOC} = monthly mean DOC concentration)

- F_{DOC} uncertainty estimated
- F_{DOC} calculated with and without rainwater DOC input

DOC export – water balance



DOC export



Annual DOC export

11.7 ± 0.82 (gC m^{-2} year^{-1})
or, accounting for rain input of DOC:
10.5 ± 1.17 (gC m^{-2} year^{-1})

Annual net ecosystem C balance

$$NECB = F_{CO2\text{-}C} + F_{CH4\text{-}C} + F_{DOC\text{-}C}$$

$$NECB = 264 - 22 - 11 \ \text{gC m}^{-2}\ \text{yr}^{-1}$$
$$= 231 \ \text{gC m}^{-2}\ \text{yr}^{-1}$$

= 10.8 times larger than 6-year mean NECB reported for Mer Bleue bog, and 2.6 times larger than greatest [1]

[1]Roulet et al. (2007) *Global Change Biology* 13: 397–411

Summary

- Annual NEE for 2012 was 190% greater than the largest recorded from an analogous Canadian bog.
  - length of growing season seems to explain this
  - (ecosystem light response and respiration parameters are similar to northern hemisphere analogues)
- NEE sensitive to summertime water table position
  - major driver of inter-annual variability?
- Drivers of CH_4 fluxes seem to alternate: temperature (winter) and water table (dry summer)
- NECB was very large cf. N. Hem. analogues
  - How variable is it inter-annually?
  - How does it compare to long-term C accumulation rates?

Acknowledgements

Bev Clarkson, Landcare Research

Department of Conservation

Murray and Angela Brewster

The University of Waikato

Ngati Hako o Hauraki

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Landcare Research
Manaaki Whenua

GHG budget for Kopuatai bog

CO_2
264 gC m^{-2}
= 970 gCO_2 m^{-2}

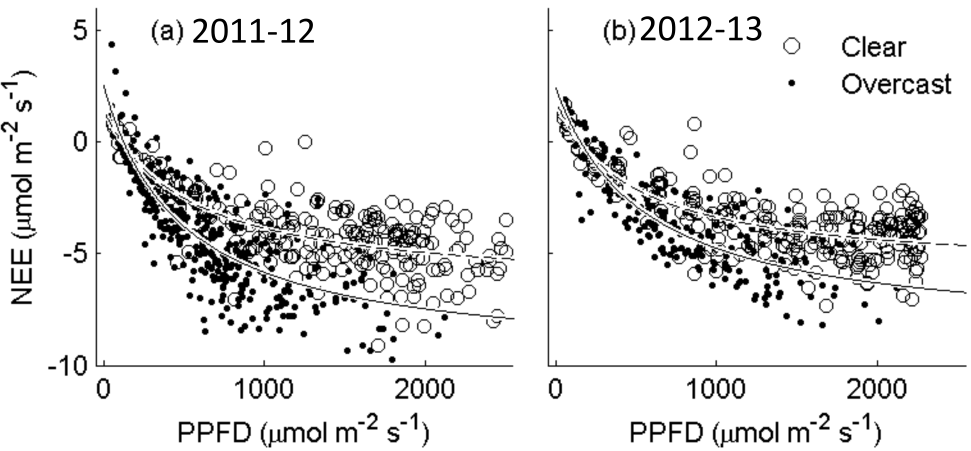
CH_4
22 gC m^{-2}
= 29 gCH_4 m^{-2}

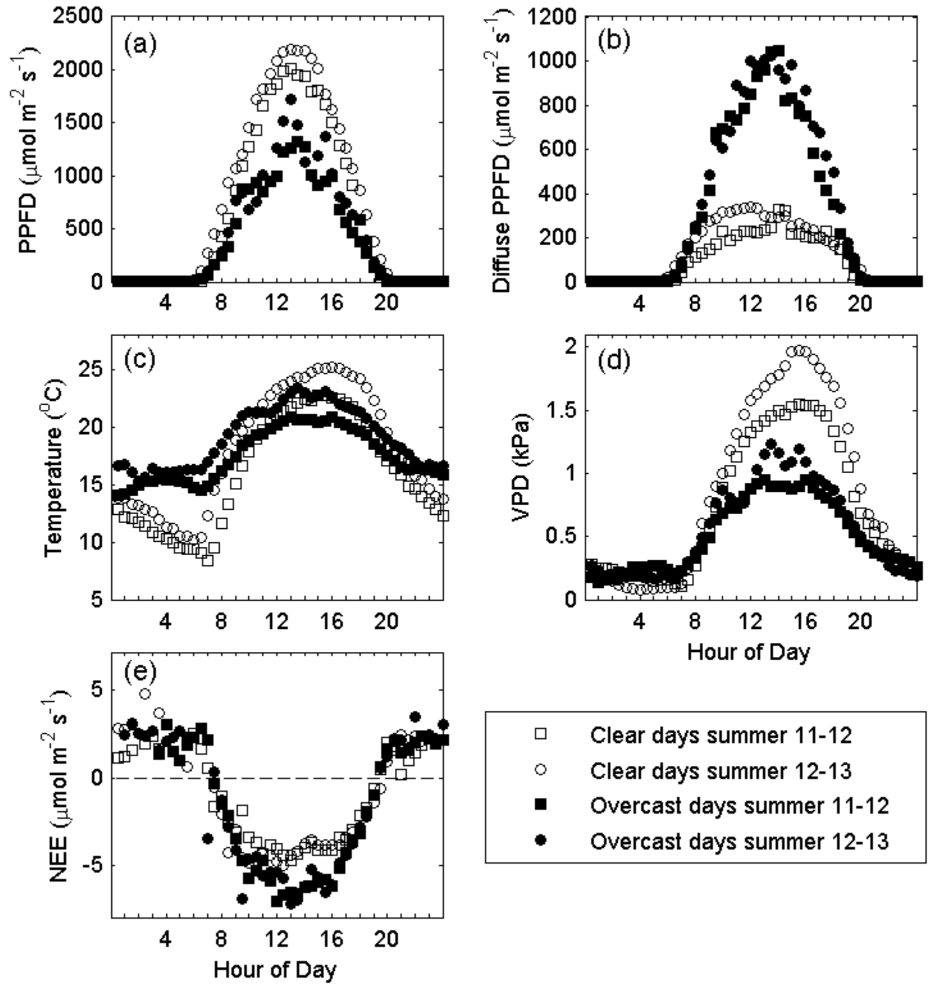
DOC (assume converted to CO_2)
11 gC m^{-2}
= 40 gCO_2 m^{-2}

$$\text{GWP} = -970 + (29\times25) + 40 \text{ gCO}_2\text{-e m}^{-2}$$
$$= -205 \text{ gCO}_2\text{-e m}^{-2} \text{ (GHG sink)}$$

GWP = global warming potential
GWP_{CO2} = 1
GWP_{CH4} = 25

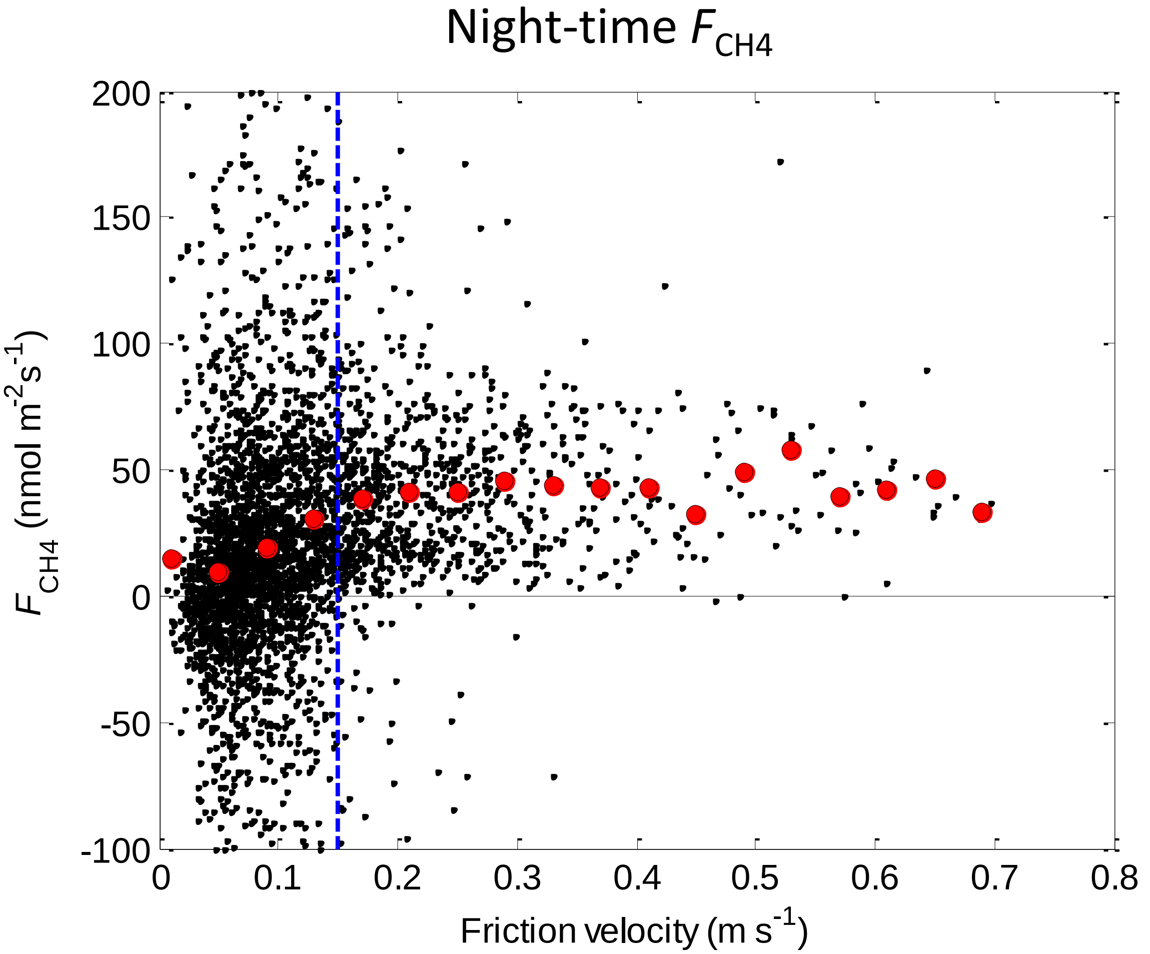
Effect of light quality on NEE



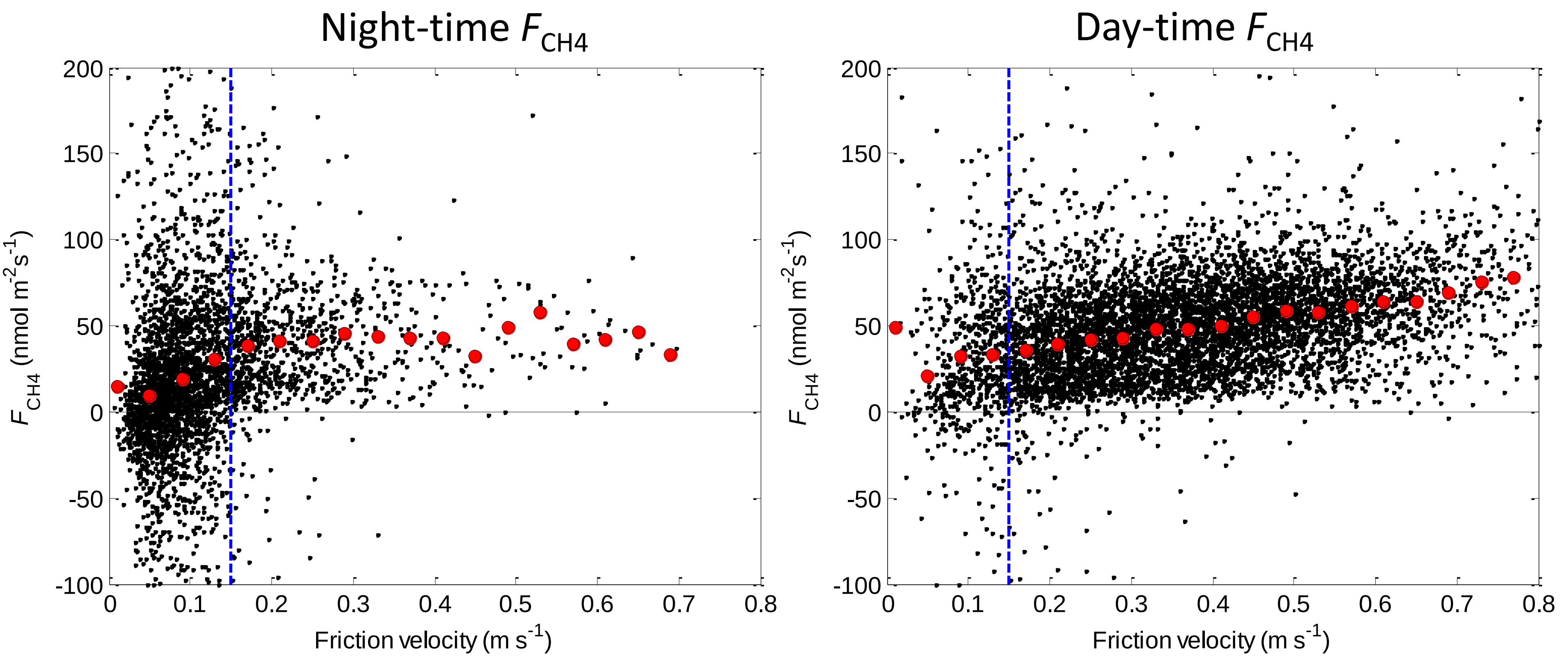


Goodrich, J. *et al.* Changes in photosynthetic capacity and radiation use efficiency lead to increases in net CO_2 uptake during overcast conditions at a southern hemisphere peatland. (in prep. for submission to *Agric. For. Meteorol.*).

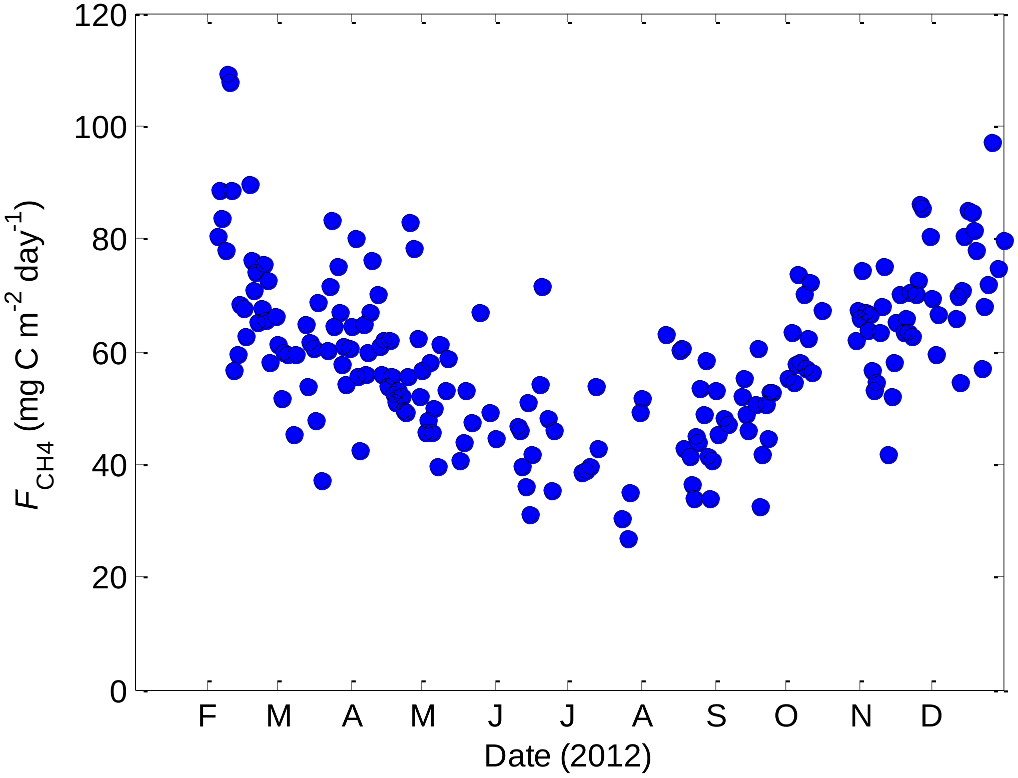
Threshold turbulence for F_{CH4}



Threshold turbulence for F_{CH4}



Estimated annual F_{CH4}

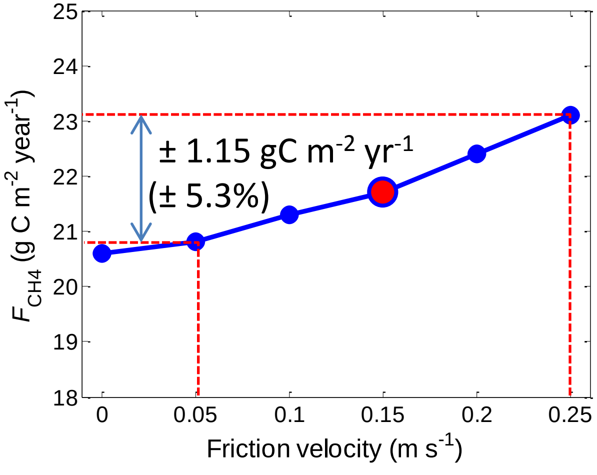


Daily mean

59.4 mg C m^{-2} day^{-1}

Annual total

21.7 g C m^{-2} year^{-1}



Broad research goals

- To describe the annual net ecosystem carbon budget (NECB) at NZ's largest true raised peat bog
- Determine the sensitivity of NECB components to environmental drivers
- Provide a baseline of "normal" peatland C exchange processes to inform restoration efforts, and to contrast with agricultural peatlands in the region

EC methods

- Open path sensors
  - LI-7500 for CO_2/H_2O
  - LI-7700 for CH_4
- Flux calculations using EddyPro v4.0
- Fluxes rejected when u_* below threshold value
- Gap-filling and CO_2 flux partitioning
  - Fitting Lloyd & Taylor function to night-time NEE (ER)
  - Fitting light response of daytime NEE
  - Partitioning via NEE = –(GPP – ER)
- Preliminary gap-filling F_{CH4} via daily means of available data

Acknowledgements

- Bev Clarkson, Landcare Research
- Department of Conservation
- Murray and Angela Brewster
- The University of Waikato