The role of non-growing season methane emissions in temperate, boreal, and arctic wetlands and uplands

Claire Treat, PhD

University of Eastern Finland

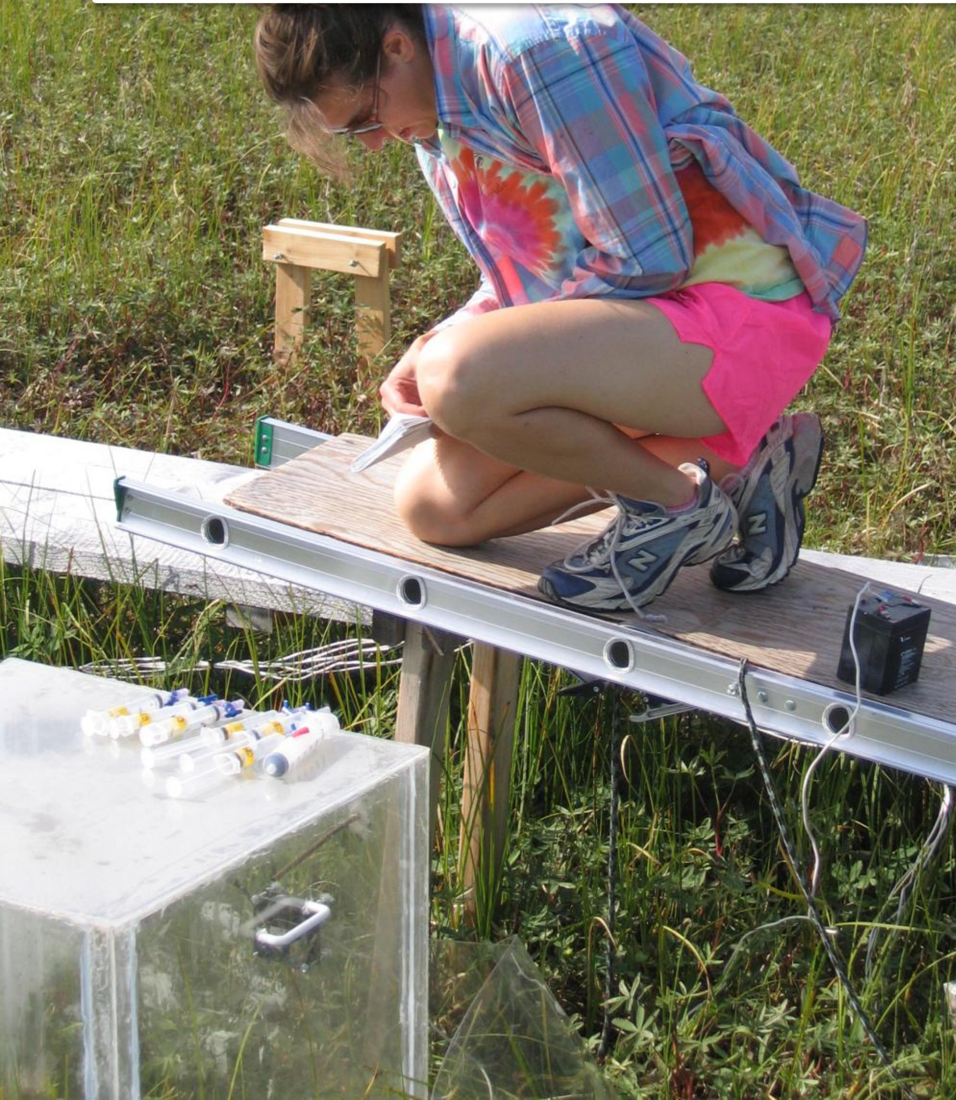
claire.treat@uef.fi, @clairetreat

A. Anthony Bloom, NASA-JPL

Maija E. Marushchak, UEF

Photo: Maija Maruschak

What have we learned in 25+ years of measuring methane?



What have we learned in 25+ years of measuring methane?

REVIEW AND ASSESSMENT OF METHANE EMISSIONS FROM WETLANDS

Karen B. Bartlett and Robert C. Harriss

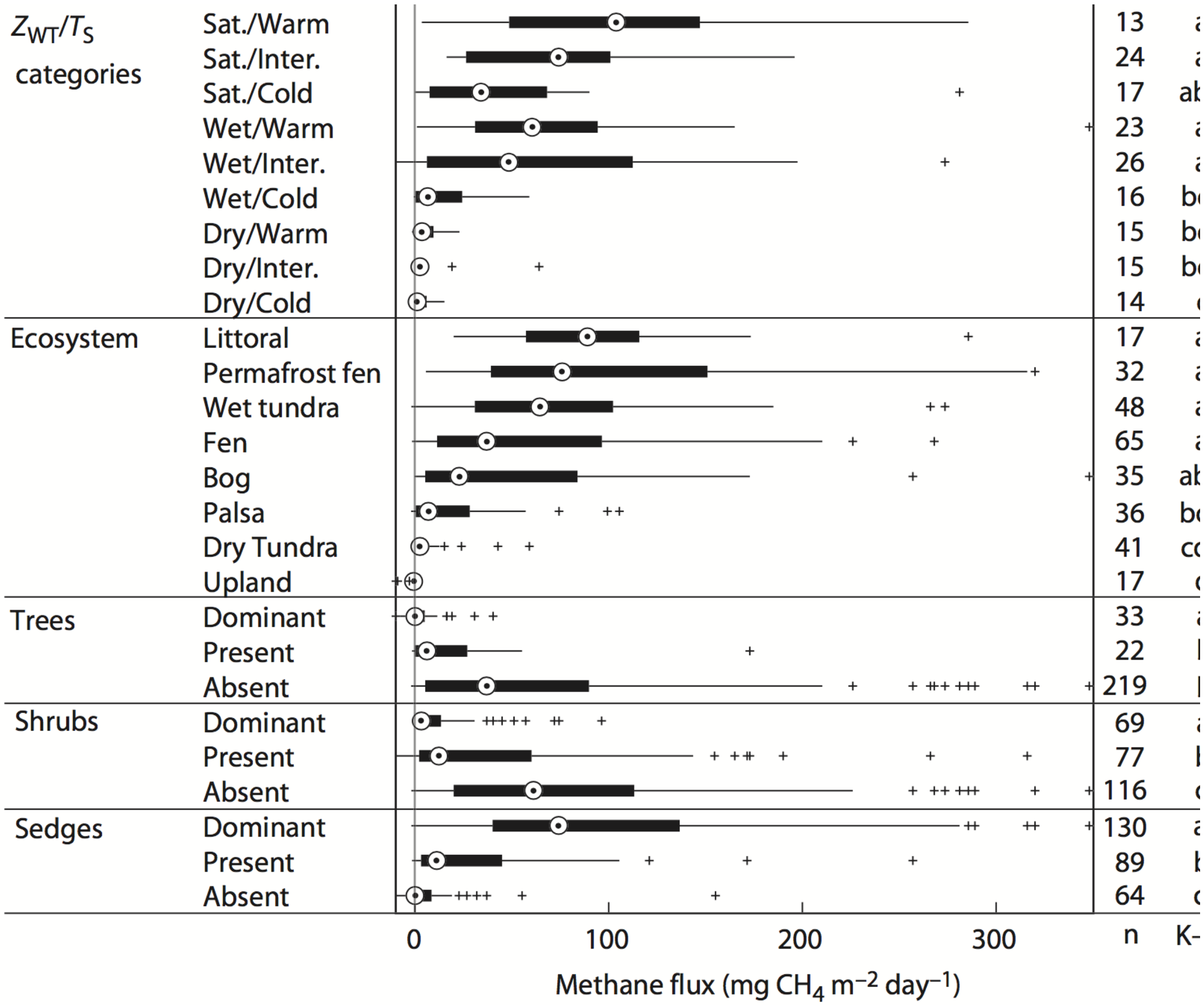
Complex Systems Research Center

area estimates. Further refinement of wetland CH_4 emissions awaits flux measurements from larg
areas currently lacking data, particularly in the tropics and the Siberian Lowlands, more realistic
assessments of seasonal active periods, and accurate, up-to-date habitat classification and
measurement.

ABSTRACT

The number of emission measurements of methane (CH_4) to the atmosphere has increased greatly in recent years, as recognition of its atmospheric chemical and radiative importance becomes widespread. In this report, we review progress on estimating and understanding both the magnitude of, and controls on, emissions of CH_4 from natural wetlands. We also calculate global wetland CH_4 emissions using this extensive flux data base and the wetland areas compiled and published by Matthews and Fung (1987). Tropical regions (20° N-30° S) were calculated to release 66 $TgCH_4$/yr, 60% of the total wetland emission of 109 Tg/yr. Flux data from tropical wetlands, reported only

Methane flux, 20 Years later….



(NOW with better spatial coverage)

Plot scale methane emissions correlated with:

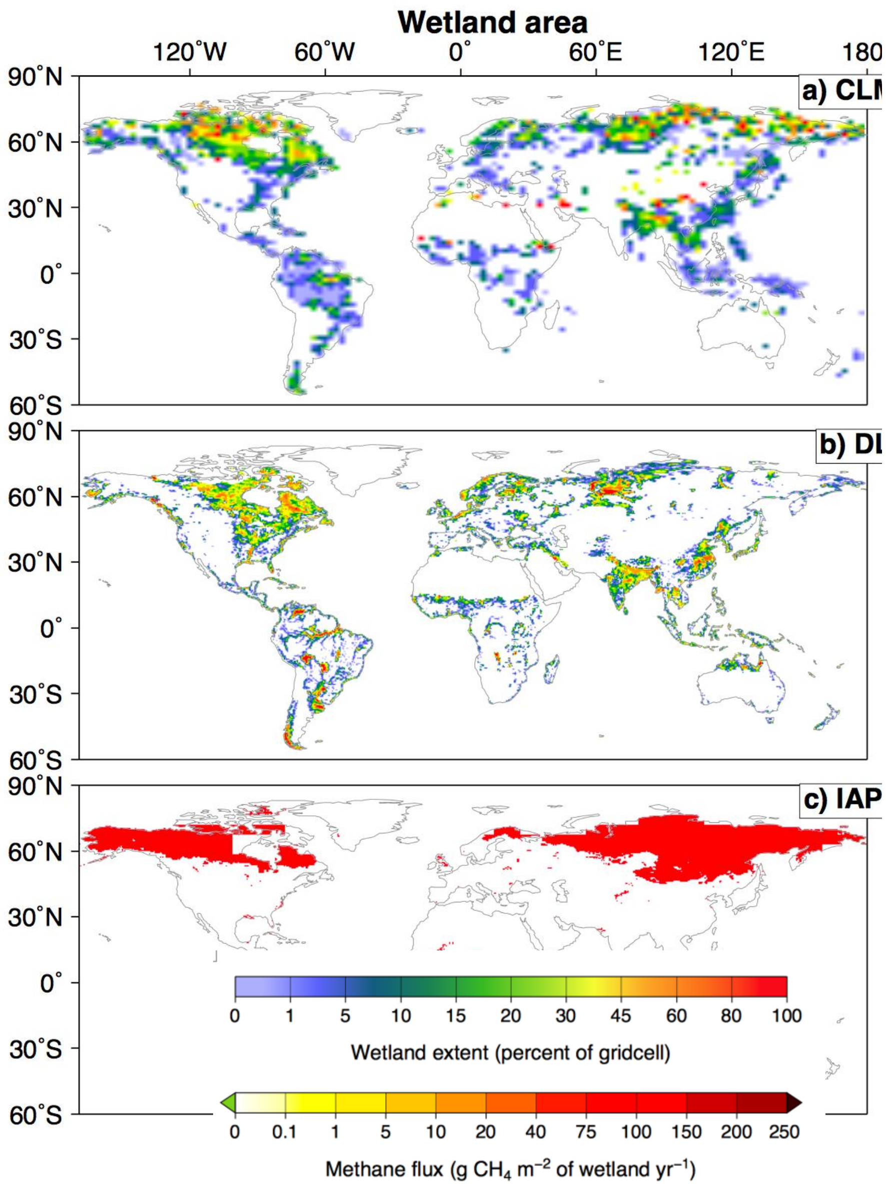
- Water table
- Temperature
- Vegetation
  - Transport
  - Substrate
  - (hydrology)

Relationships are:

- **Non-linear**
- **Spatially variable**

Olefeldt et al. 2013 (GCB)

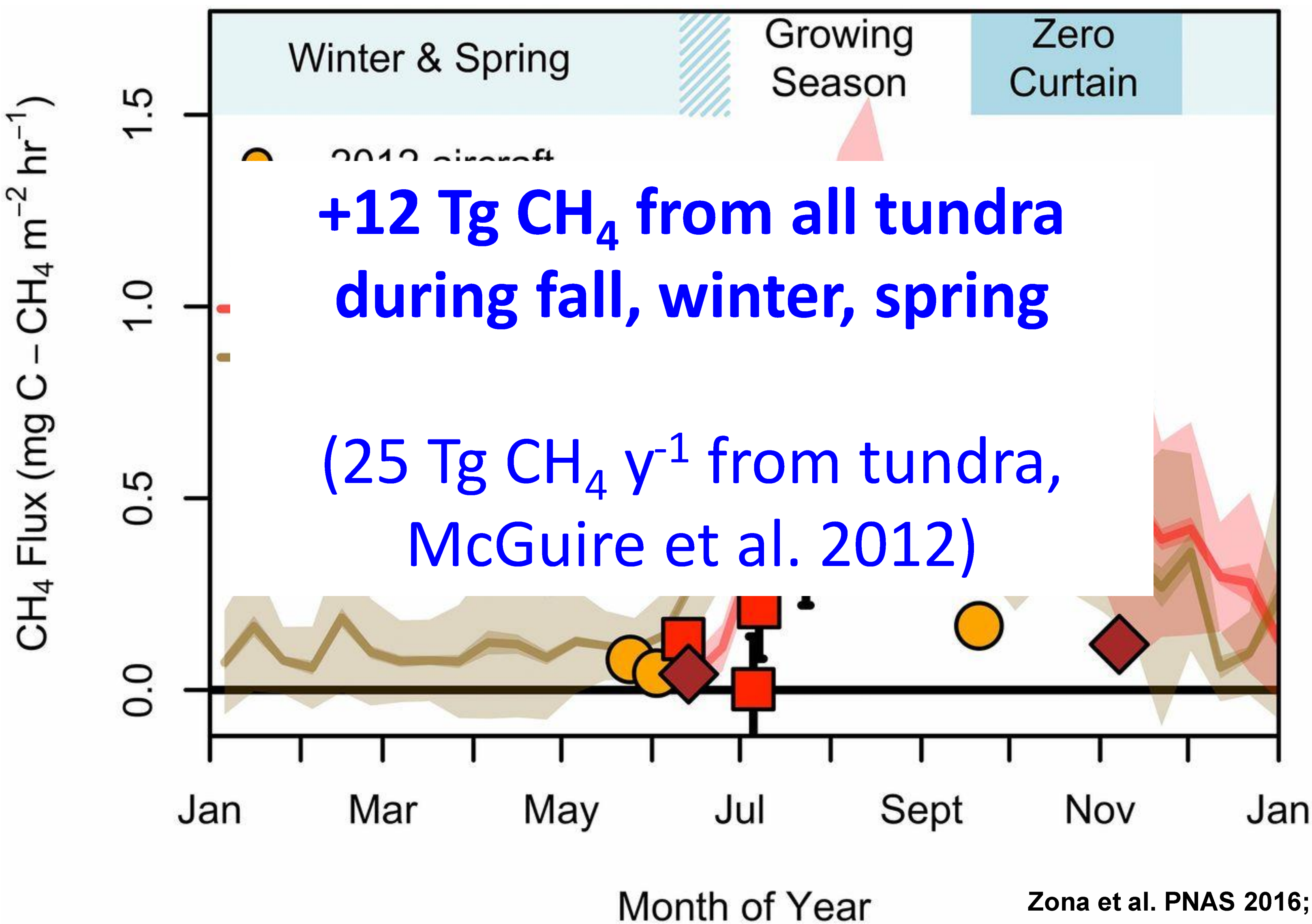
Methane flux, 20 years later



- Have process-based models!
- Wetland extent disagrees among models
  - Underestimates important wetland areas
    - WSL
    - HBL
  - Better maps

Melton et al. (2013)

Non-growing season methane flux is non-zero



+12 Tg CH_4 from all tundra during fall, winter, spring

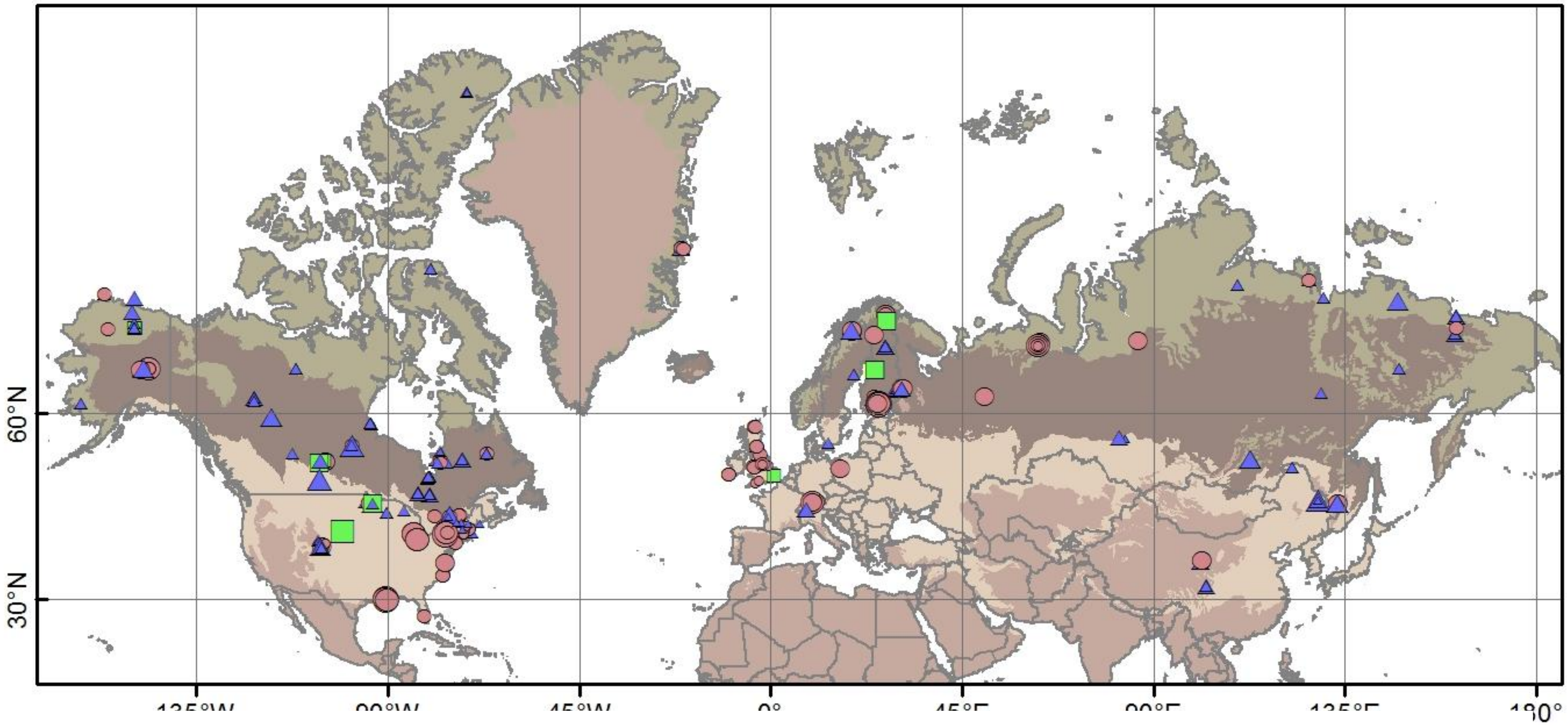
(25 Tg CH_4 y^{-1} from tundra, McGuire et al. 2012)

Zona et al. PNAS 2016;113:40-45

What have we learned in 25+ years of measuring methane?

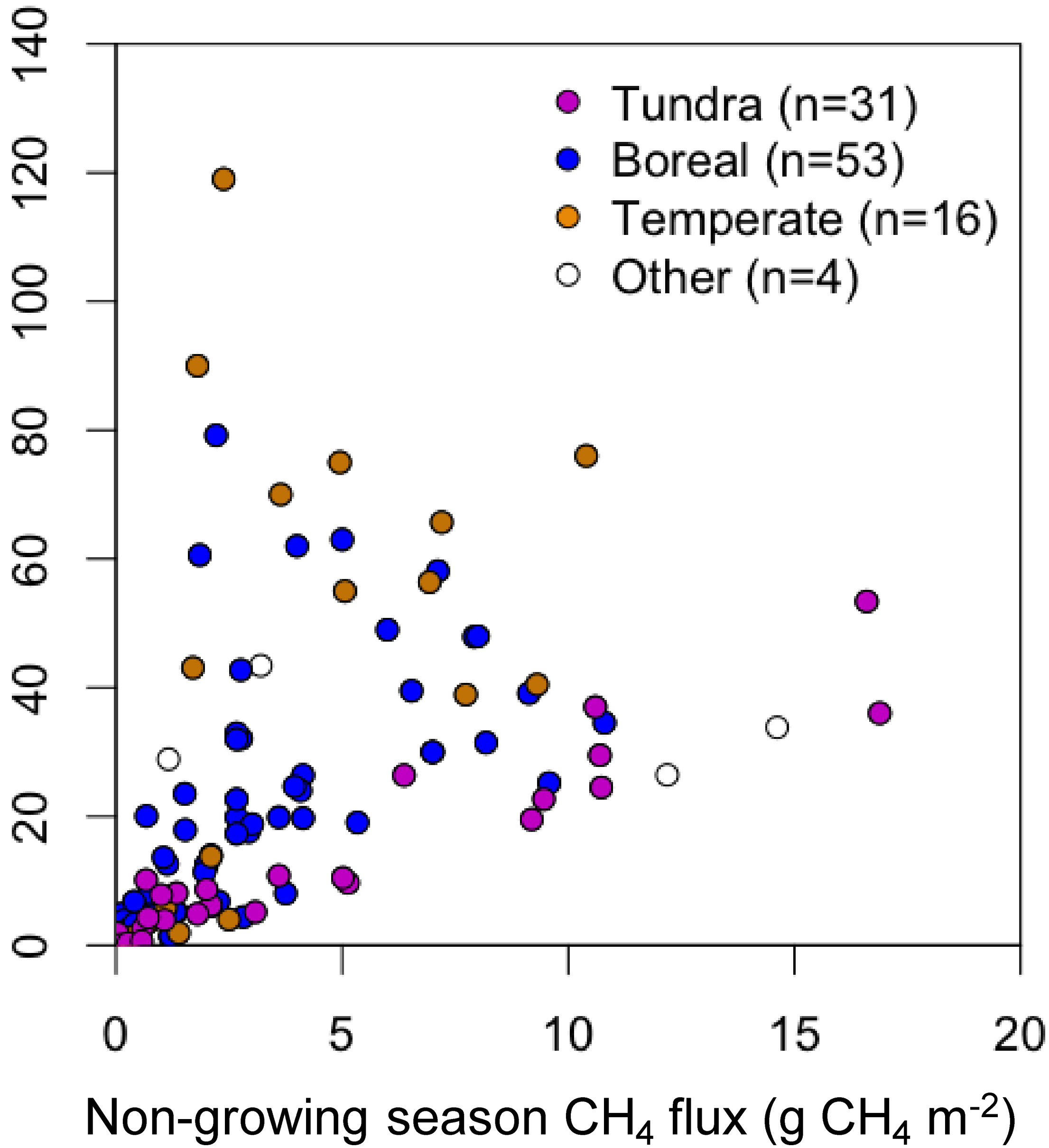
- Improved understanding of methane production, transport, emission during growing season
  - BUT low predictive power for daily emissions with statistical and process models
  - Spatial gaps remain
  - Wetland maps still limiting
  - **Role of non-growing season emissions?**

Methane flux synthesis sites



- Annual emissions, undisturbed sites (circles)
  - 131 measurements, 48 unique sites
- Growing season (>1 msmt/mo, undisturbed)
  - 824 flux-year measurements (microsite x year replicates)
  - 182 unique sites

Substantial non-growing season CH_4



Substantial flux

- ~0 to 15 g m^{-2}
- Magnitudes differ among biomes

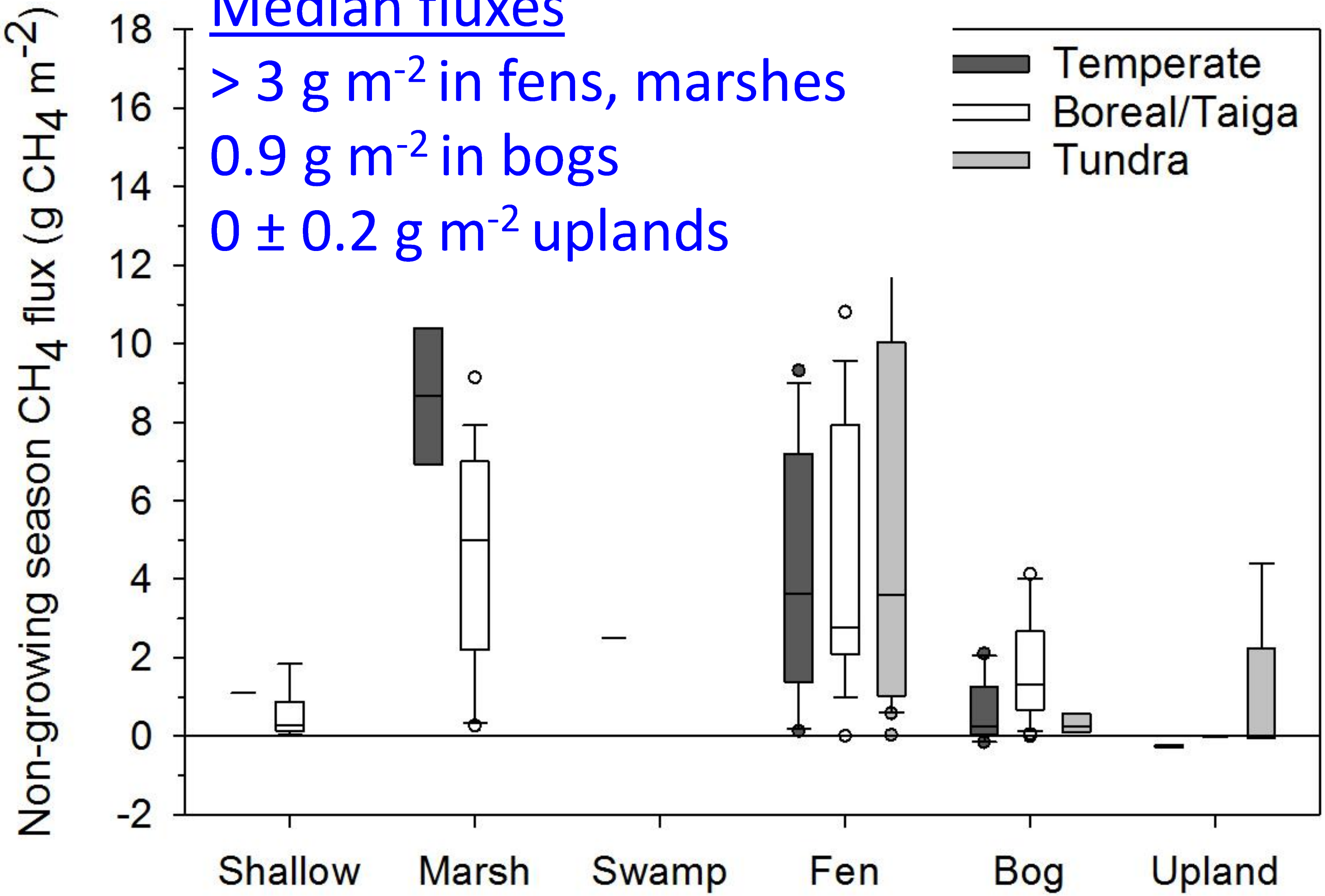
Substantial non-growing season CH_4

Median fluxes

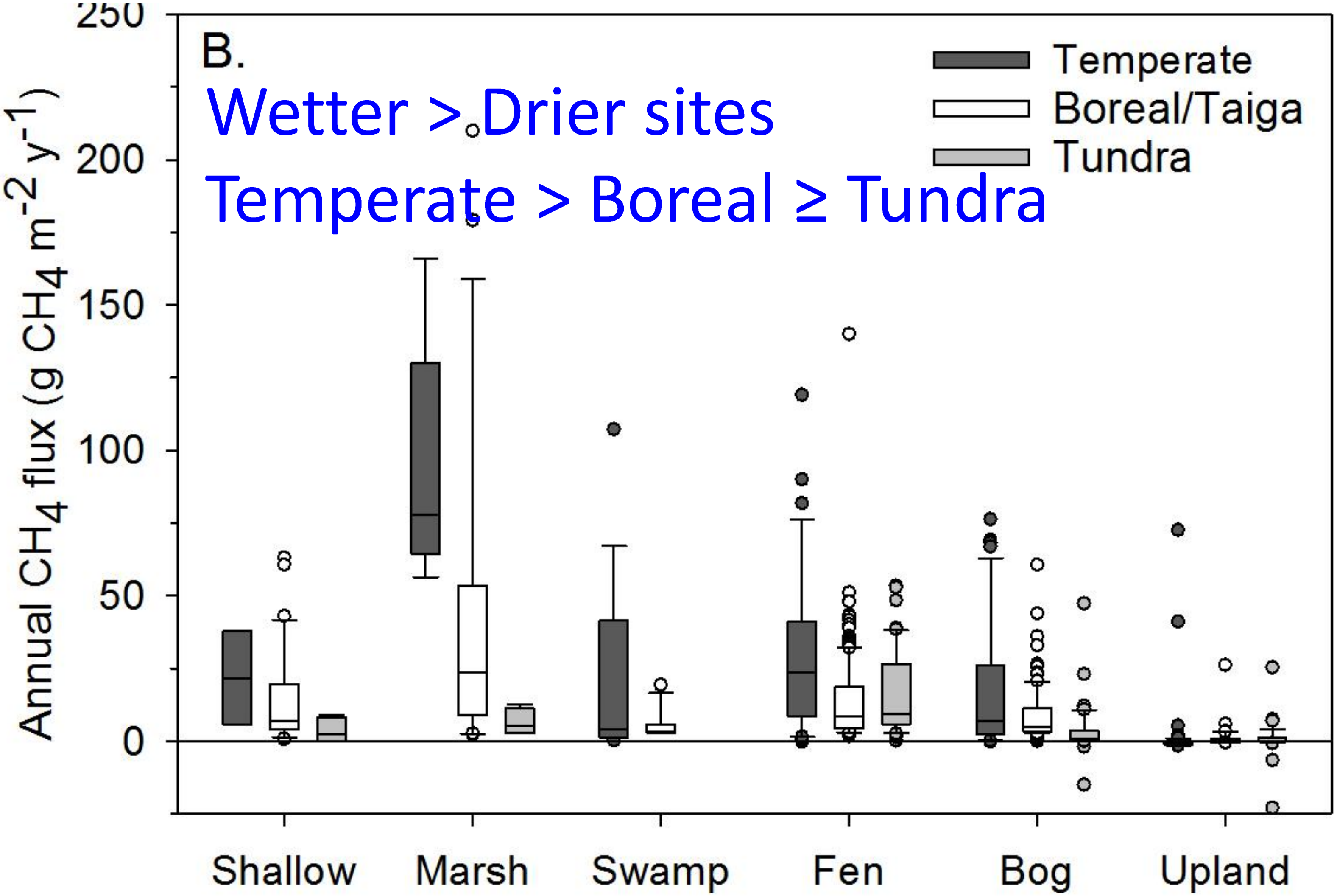
> 3 g m^{-2} in fens, marshes

0.9 g m^{-2} in bogs

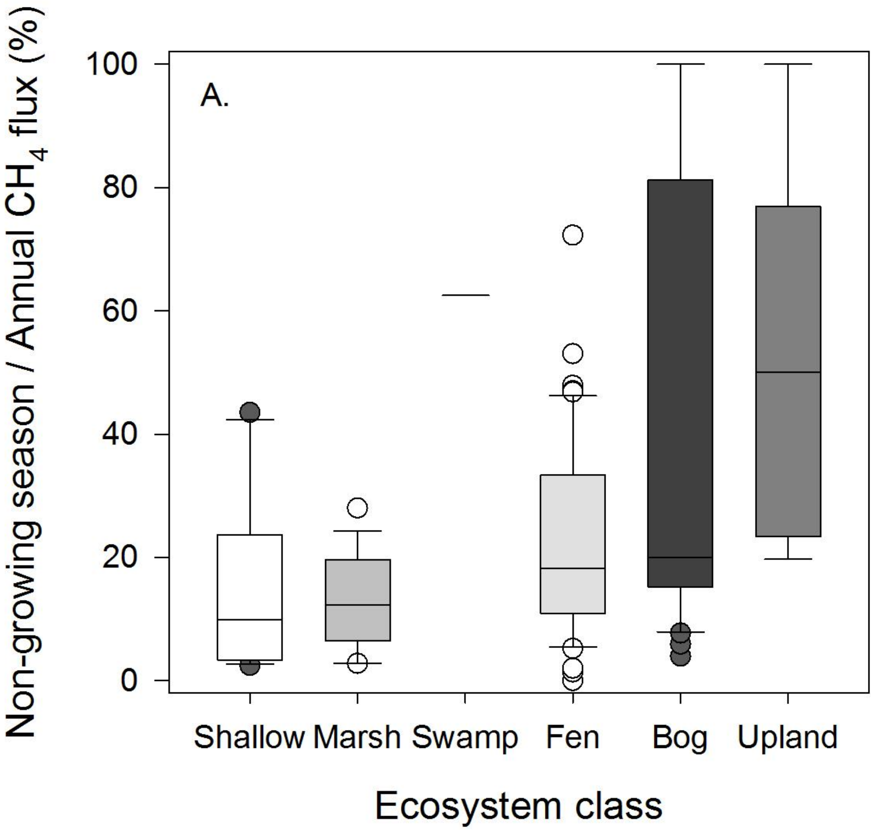
0 ± 0.2 g m^{-2} uplands



Annual CH_4 flux: Type x Biome



How much of annual CH_4 flux is during non-growing season?

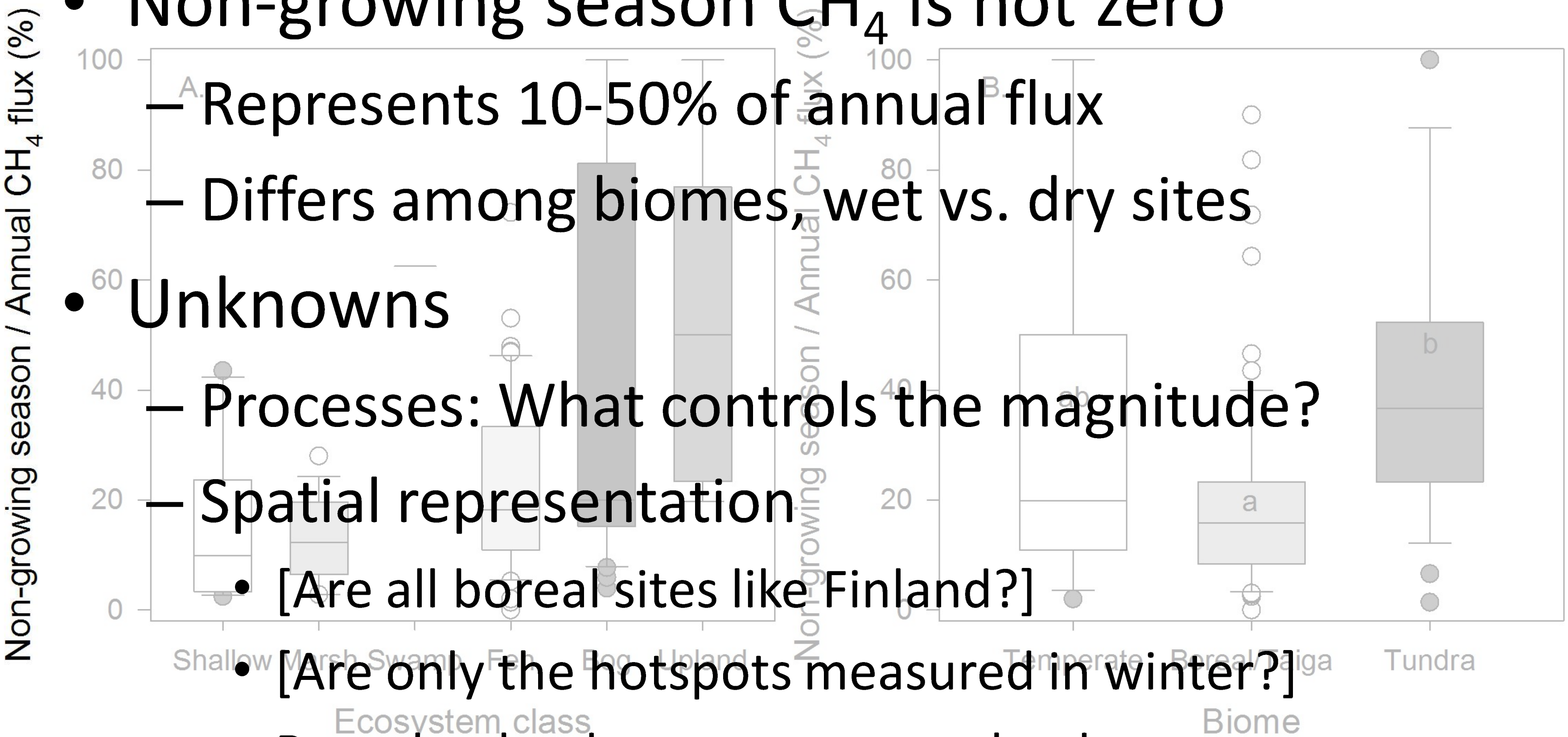


Drier > Wetter

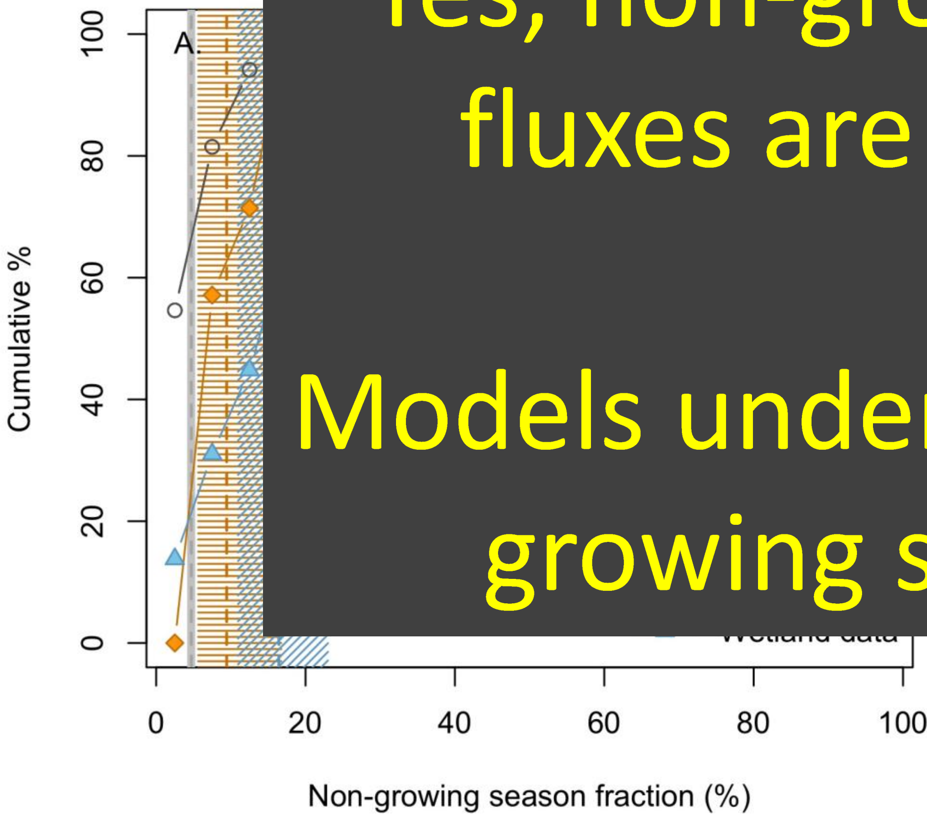
Tundra > Temperate > Boreal wetlands

Substantial non-growing season CH_4

- Non-growing season CH_4 is not zero
  - Represents 10-50% of annual flux
  - Differs among biomes, wet vs. dry sites
- Unknowns
  - Processes: What controls the magnitude?
  - Spatial representation
    - [Are all boreal sites like Finland?]
    - [Are only the hotspots measured in winter?]
    - Boreal uplands, temperate wetlands
  - **How much does non-growing season flux matter globally?**



Does non-growing season flux matter?



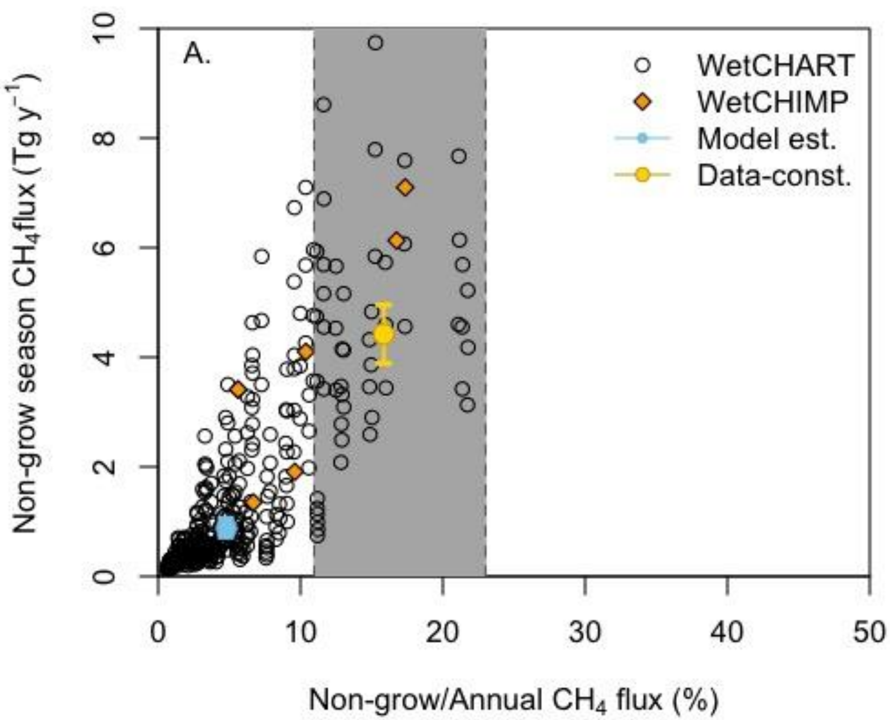
Yes, non-growing season fluxes are important.

Models underestimate non-growing season flux

Data > Model
(Data: More CH_4 during winter)

Does non-growing season flux matter?

40-60° N



Constrained = 4.4 Tg CH_4 + 3.5 Tg CH_4 NGS

If we assume models that can accurately represent the seasonal distribution are probably “more right” than models that can’t, then we can constrain models with data.

Does non-growing season flux matter?

Data-constrained models:

Wetland emits = 40 Tg CH_4 y^{-1}

+ 10 Tg CH_4 y^{-1} (+ 30%)

+Winter = 30-50%

+ 7 Tg CH_4 annually

+ 50% during winter

What have we learned in 25+ years of measuring methane?

of efforts are frequently not possible in more remote, globally significant wetlands. Northern wetlands (north of 45° N) were calculated to release a total of 38 $TgCH_4$/yr (34% of total flux); 34 Tg/yr from wet soils and 4 Tg/yr from relatively dry tundra. These latitudes have been the focus of

REVIEW AND ASSESSMENT OF METHANE EMISSIONS FROM WETLANDS

Karen B. Bartlett and Robert C. Harriss

Wetland flux, 40° N

Data-constrained models

40 ± 5 Tg CH_4 y^{-1}

emissions using this extensive flux data base and the wetland areas compiled and published by Matthews and Fung (1987). Tropical regions (20° N-30° S) were calculated to release 66 $TgCH_4$/yr, 60% of the total wetland emission of 109 Tg/yr. Flux data from tropical wetlands, reported only

Conclusions

- Non-growing season emissions important to annual methane budget
  - 10-50% of annual methane flux
  - Temperate sites, boreal uplands?
  - Processes?
- Useful for model benchmarking
  - Non-growing season fraction scalable
  - NGS Frac. underestimated by many models
  - 30% higher annual CH_4 emissions
    - + non-growing season emissions
    - + growing season emissions

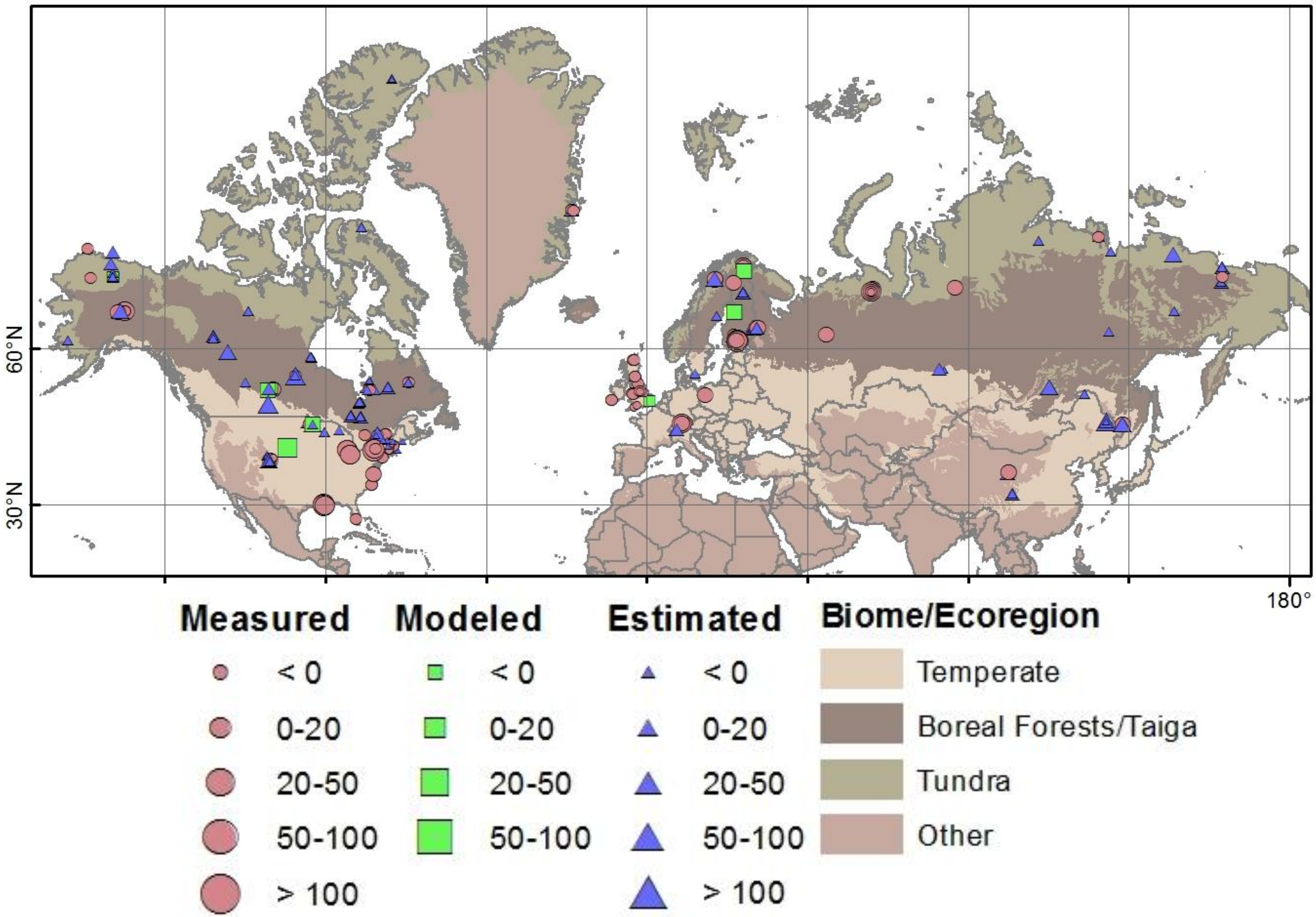
Photo: Maija Maruschak

Acknowledgments

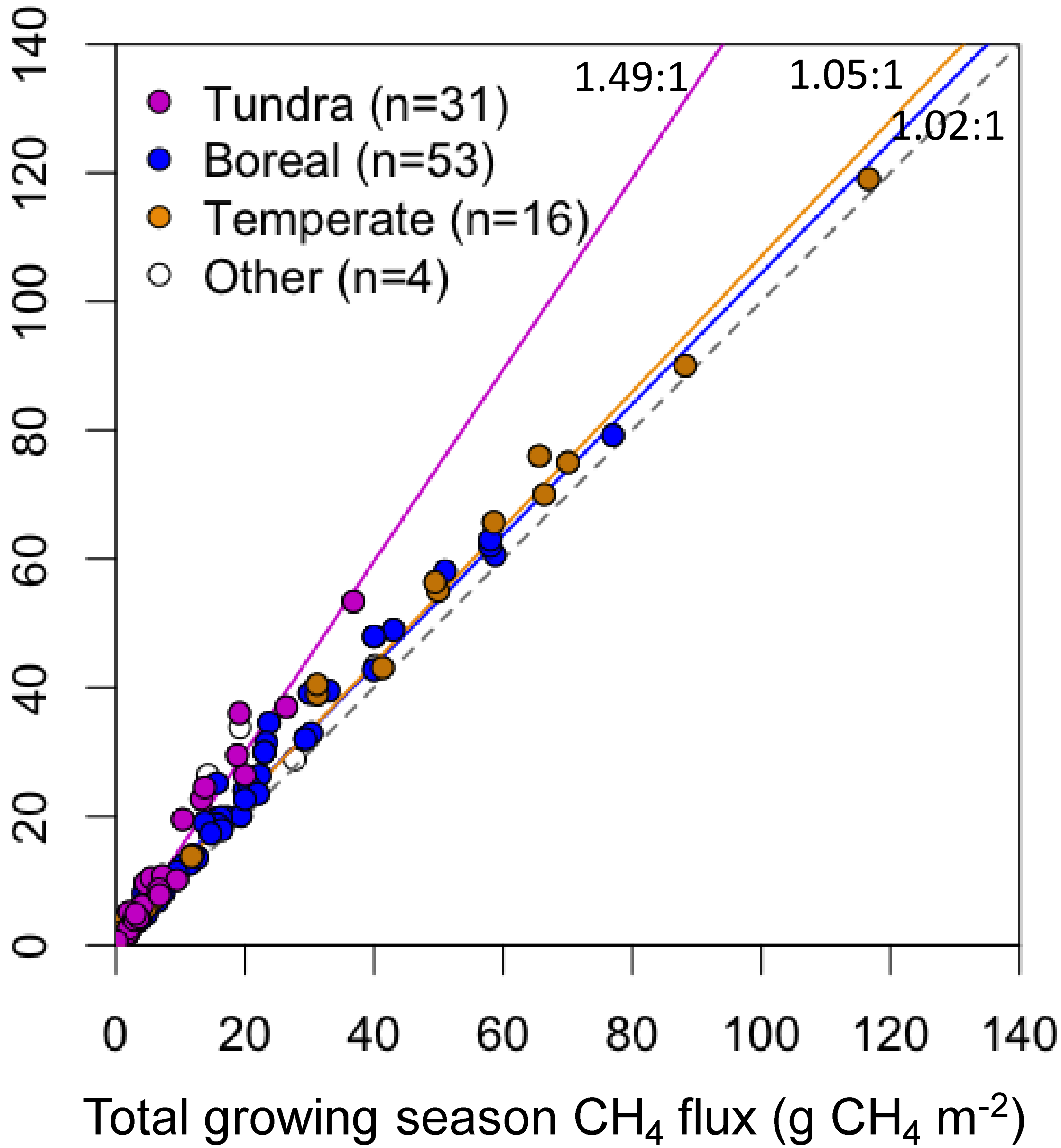
- CAPTURE, Academy of Finland & NSF P2C2
- Data: Carolina Voigt, Avni Malhotra
- Jill Bubier, Sari Juutinen, Sue Natali, Alison Hoyt

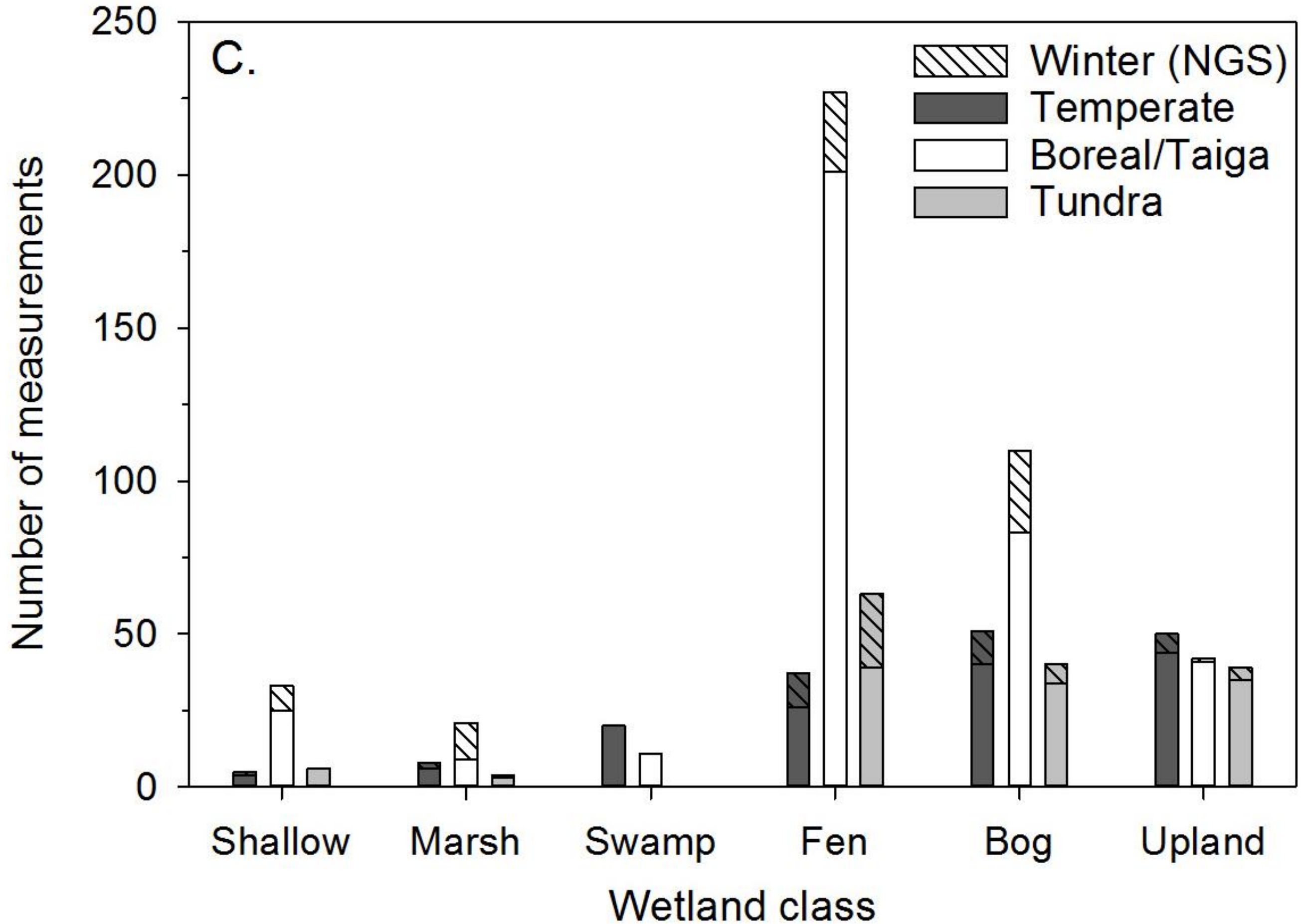
Photo: Maija Maruschak

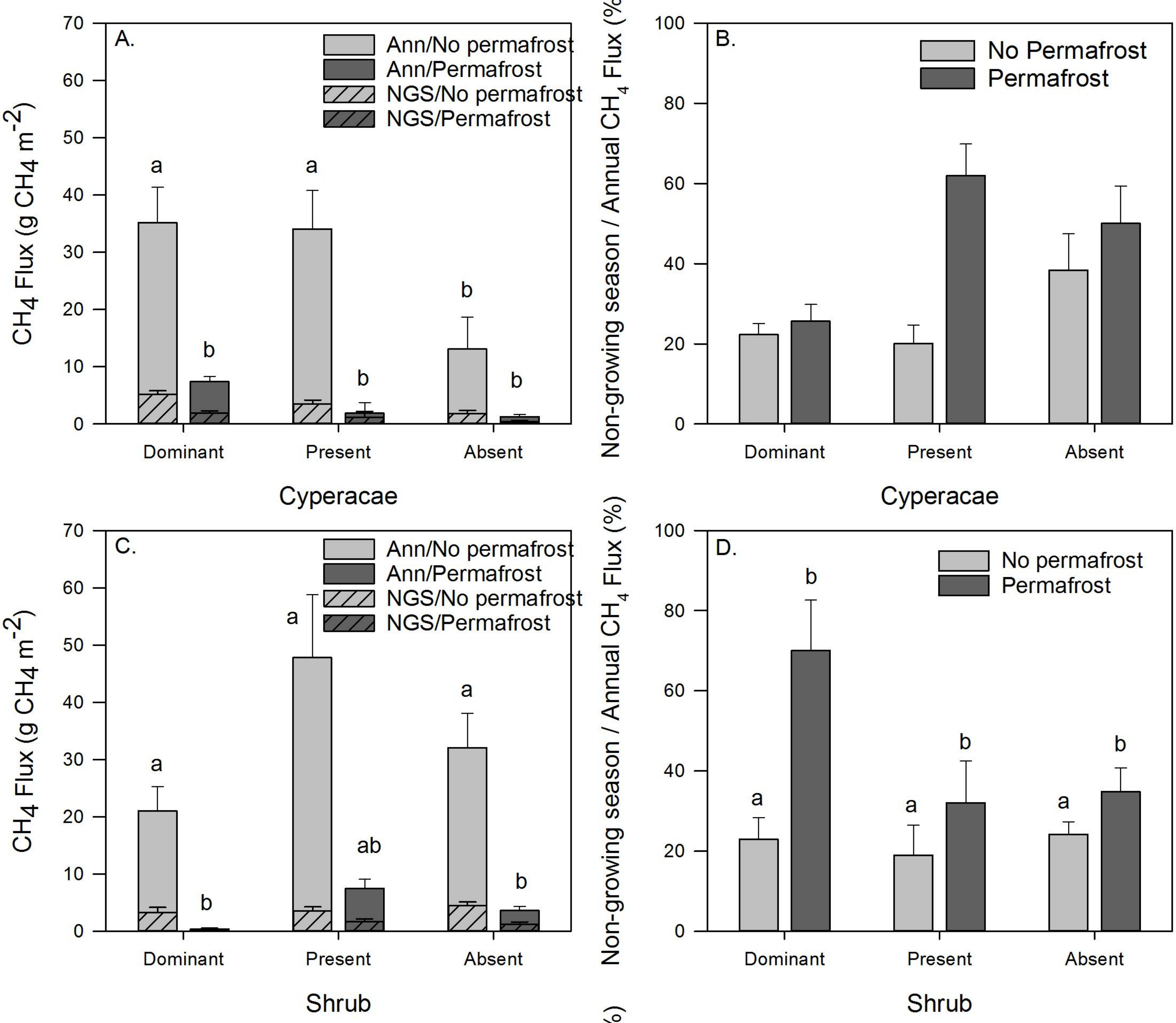
Methane flux synthesis sites

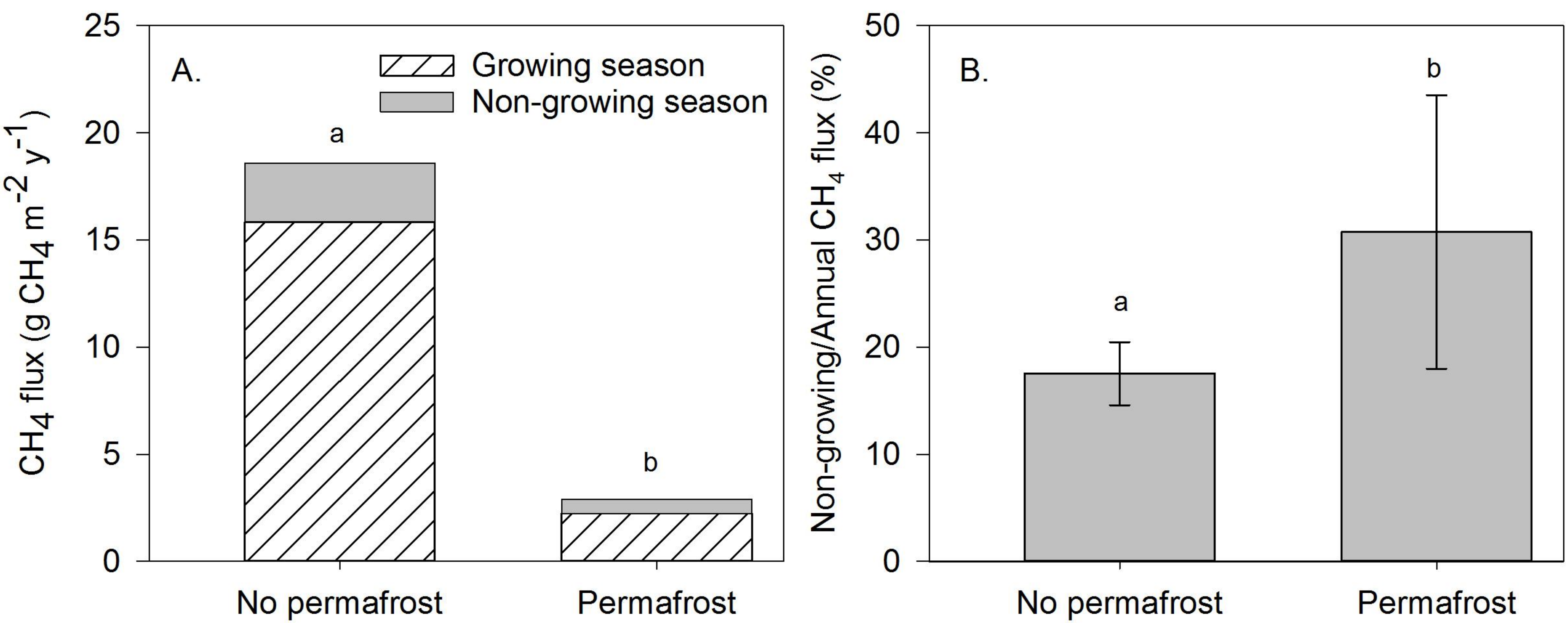


Substantial non-growing season CH_4




C.
Winter (NGS)
Temperate
Boreal/Taiga
Tundra
Number of measurements
0
50
100
150
200
250
Shallow
Marsh
Swamp
Fen
Bog
Upland
Wetland class


A.
Ann/No permafrost
Ann/Permafrost
NGS/No permafrost
NGS/Permafrost
CH4 Flux (g CH4 m-2)
Dominant
Present
Absent
Cyperacae
B.
No Permafrost
Permafrost
Non-growing season / Annual CH4 Flux (%)
Cyperacae
C.
Shrub
D.
No permafrost
Permafrost
Shrub



A.
Growing season
Non-growing season
CH_4 flux (g CH_4 m^{-2} y^{-1})
25
20
15
10
5
0
a
b
No permafrost
Permafrost
B.
Non-growing/Annual CH_4 flux (%)
50
40
30
20
10
0
a
b
No permafrost
Permafrost

Methane flux, as summarized by Blodau in 2002….

Also on smaller spatial and temporal scales, little of the variation in CH_4 exchange rates can be explained by water table levels, peat temperature, and other variables (Kettunen et al. 1996; Bellisario et al. 1999; Moore et al. 1994; Shannon and White 1994). This is probably a consequence of the interaction among production, consumption, storage, and transport of gases in the peat. On time-scales of weeks to months, equilibrium among these processes might not be reached when environmental controls vary. It can therefore be hypothesized that biogeochemical process rates in the peat are to a varying degree decoupled from fluxes to the atmosphere. This would explain why fluxes measured in field studies were

- Little variance in CH_4 flux explained at small temporal and spatial scales
- CH_4 flux is decoupled from production due to time lags in process rates, storage, and transport
- Cumulative CH_4 flux more easily predicted

120 Environ. Rev. Vol. 10, 2002

decoupled from controls on CH_4 production (Kettunen et al. 1996; Bellisario et al. 1999; Moore et al. 1994; Shannon and White 1994). It also explains that better correlation between environmental variables and CH_4 exchange rates have been obtained by cumulating exchange rates of CH_4 (e.g., Moore et al. 1998), which eliminates time lags in process rates, storage, and transport effects.