The effect of scale on the relative importance of climatic variables as drivers of methane flux patterns at an Arctic wet sedge meadow

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Introduction

Arctic wet sedge ecosystems are a significant source of methane (CH_4) to the atmosphere, with an average emission of 100 mg CH_4 m^{-2} d^{-1} across the Arctic (Vourlitis & Oechel, 1997). Due to cold conditions and underlying permafrost, these ecosystems also are large reservoirs of soil organic carbon. High temporal and spatial variability in methane fluxes (F_{CH4}) is often linked to variability in climatic factors such as soil temperature and moisture.

The objective of this study is to identify how the relationships between F_{CH4} and soil moisture and temperature change at different scales. The scale at which these relationships are examined may affect estimates of potential change in F_{CH4} in a warmer climate.

Field site

Sedges, dwarf birch and *Sphagnum* moss characterize the study area. The wet sedge meadow is a fen peatland with palsa-like "shrub islands", collapse scar features, and tussocks within an extensive lawn surface.

Figure 1. Photo of the sedge fen(2017-07-22). The site is located near the Tundra Ecosystem Research Station, 300 km NE of Yellowknife, NT

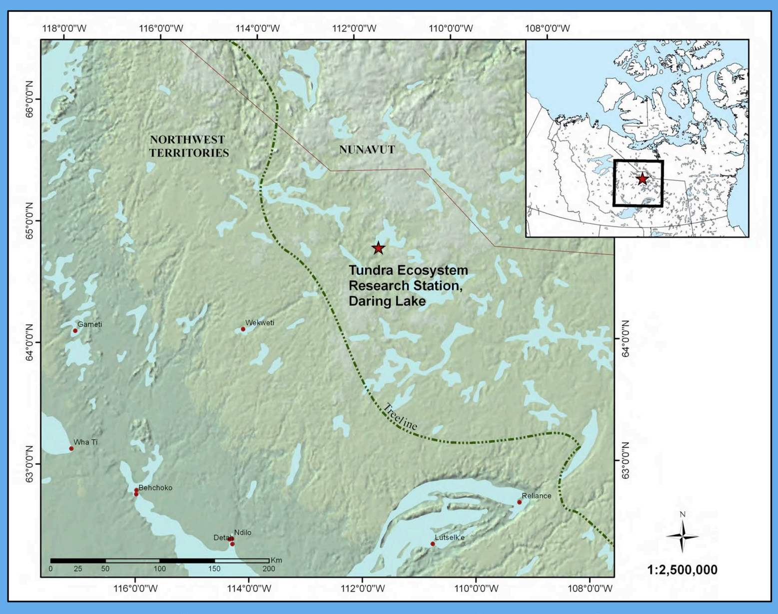


Figure 2. The TERS station in the Northwest Territories, Canada.

Results

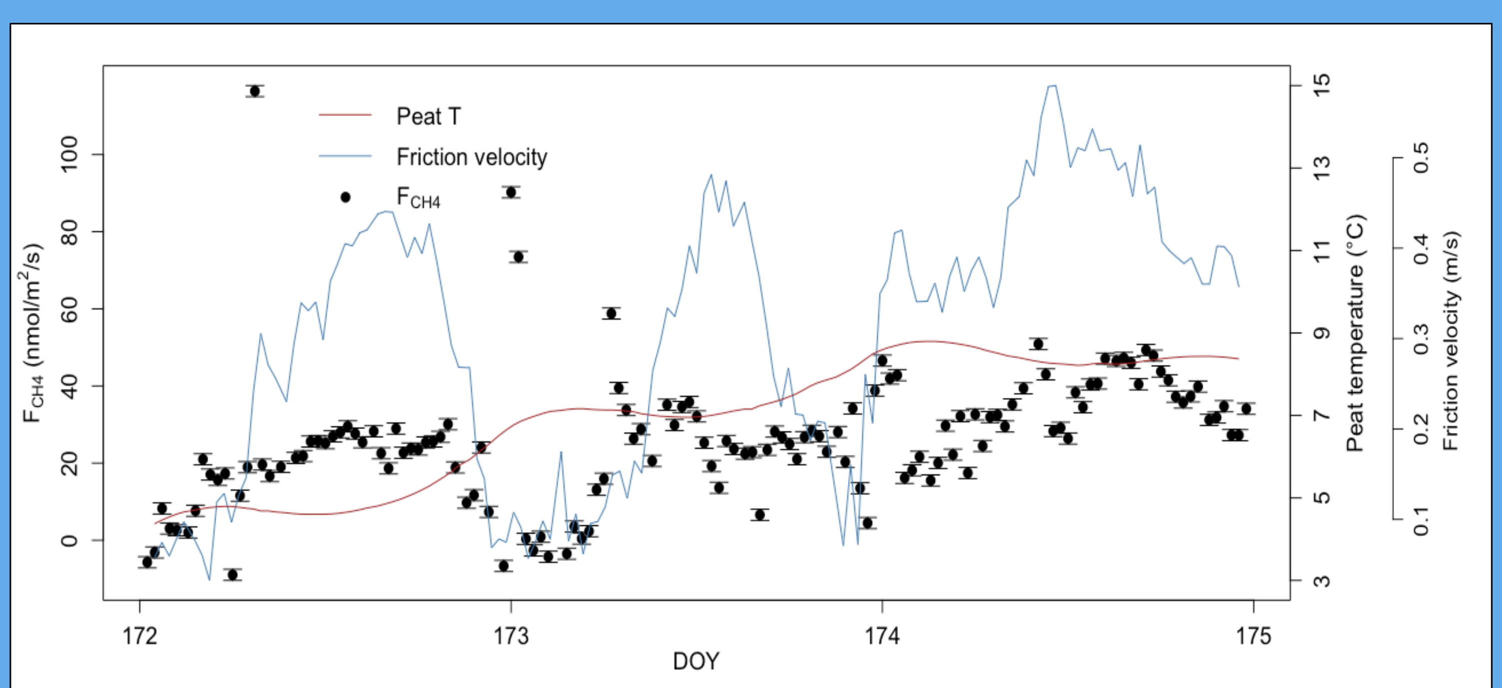
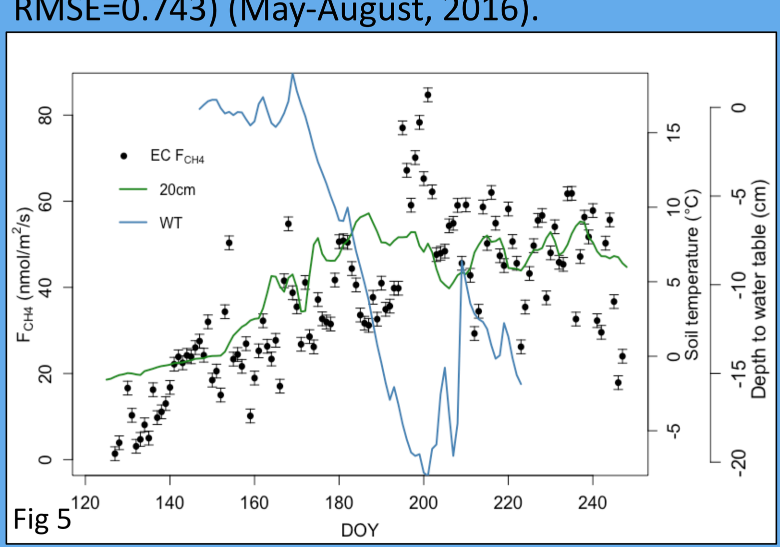
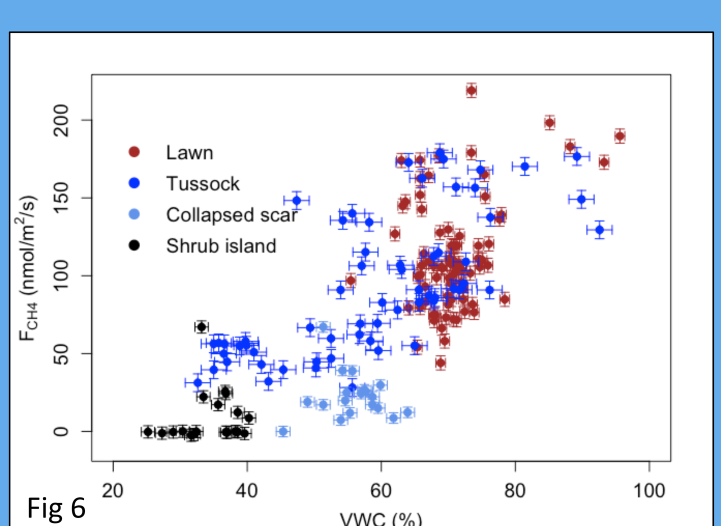


Fig 3. 30 min T_{20cm} , EC F_{CH4} and friction velocity (u_*). Daytime F_{CH4}= 2.66(T_{air})+8.21 nmol m^{-2} s^{-1} (R^2=0.92, p<0.001, RMSE=0.833). Daytime F_{CH4} = 166.2 (u_*)-18.6 nmol m^{-2} s^{-1} (R^2=0.93, p<0.001, RMSE=0.743) (May-August, 2016).





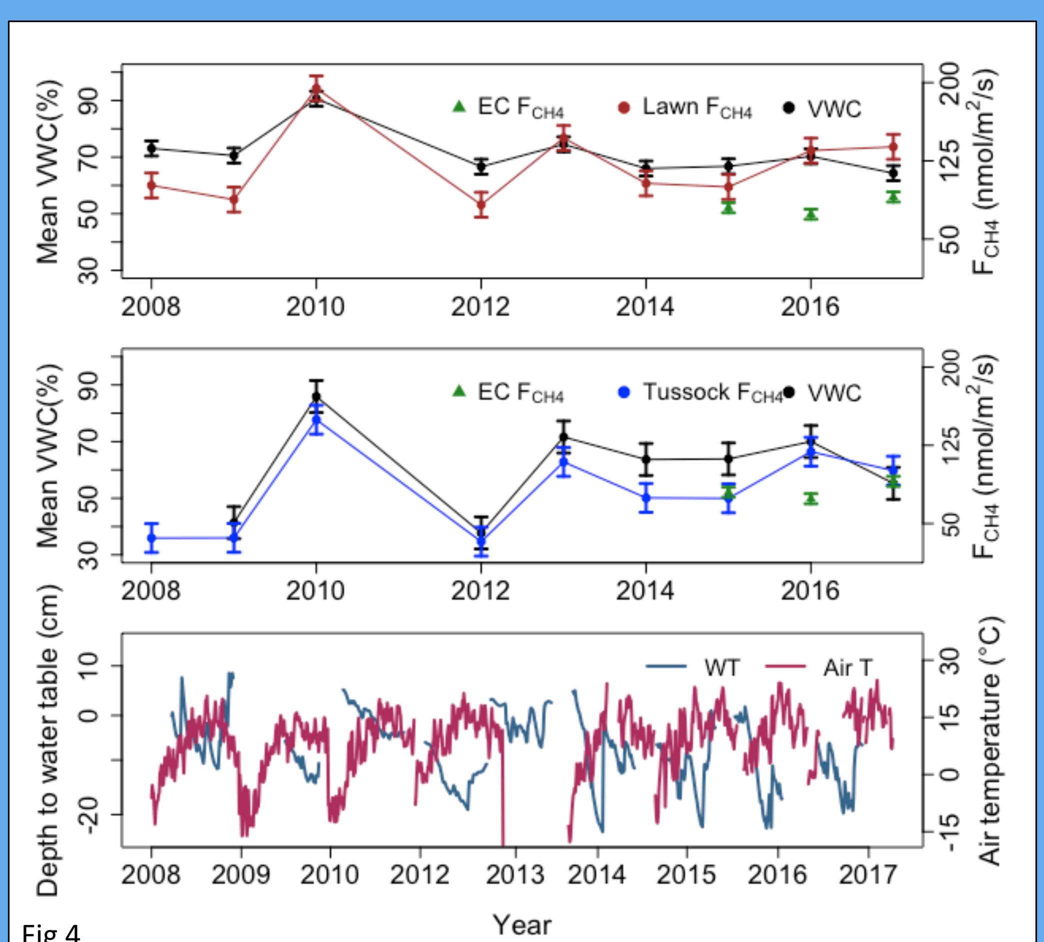


Fig. 4. Yearly mean chamber F_{CH4} for lawn and tussock plots with corresponding peat moisture.
Tussock F_{CH4}=2.3(VWC)-50.7 nmol m^{-2} s^{-1} (R^2=0.81, p<0.01, RMSE=14.96)
Lawn F_{CH4}=3.4(VWC)-117.7 nmol m^{-2} s^{-1} (R^2=0.46, p<0.05, RMSE=22.01)

Fig 5. Average daytime EC F_{CH4} and soil temperatures at 5, 20 and 40 cm depths.
F_{CH4}=3.6(T_{20cm})+19.7 nmol m^{-2} s^{-1} (R^2=0.49, p<0.001, RMSE=12.42) (May-August,2016).

Fig 6. Daily mean chamber F_{CH4} vs soil/peat moisture for different microtopographic features (2008-2017).
log(F_{CH4})=1.03(VWC)+1.03(T_{air})-4.28 nmol m^{-2} s^{-1} (p<0.0001, RMSE =1.70).

Table 1. Summary of the relationships between F_{CH4} and VWC and temperature. Larger circles reflect larger R^2 values and colour indicates positive (red) and negative (blue) relationships. Crosses note when p > 0.05 and/or when R^2 < 0.10.

Peat moisture	Diel	Seasonal	Inter-annual
Plot-level	✖	● (red, small)	● (red, large)
Ecosystem	✖	● (blue)	✖
Soil/air temp.	**Diel**	**Seasonal**	**Inter-annual**
Plot-level	✖	✖	✖
Ecosystem	● (red)	● (red, small)	● (red, large)

Methods

Figure 7. View of 2 of 16 collars where opaque chambers were positioned (left). View from the 3-D sonic anemometer, part of the eddy covariance (EC) instrumentation used to measure 30 minute F_{CH4} (middle). Distant view of the EC system including open-path gas analyzers and anemometer (right). Depth to water table (WTD), 0-20 cm volumetric water content (VWC) , air and peat temperature were also measured.

Acknowledgements

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Summary

Soil temperature relationships: Anaerobic decomposition is expected to increase with peat/soil temperature as reaction rates and microbial activity increase. For all temporal scales, warmer temperatures were associated with greater EC F_{CH4}. Weekly chamber F_{CH4} did not experience the same temperature range potentially explaining why we did not see the same response. Diel trends in EC F_{CH4} were associated with temperature and friction velocity, as the EC method requires sufficient turbulence. In contrast, an overnight set of chamber F_{CH4} showed little trend (data not shown).

Soil moisture relationships: Wetter soils are expected to increase F_{CH4} by inhibiting the oxidation of CH_4 , by increasing substrate and microbes in anaerobic conditions, and hosting plants with aerenchyma. Diel scale VWC variations are negligible. However, plot-level F_{CH4} was positively correlated to VWC over the season, among years and among plots. In contrast, falling WTD coincided with increased EC F_{CH4}. Treat et al. (2007) and Moore et al. (2011) describe how changes in hydrostatic pressure gradients associated with falling WT may result in CH_4 degassing. In addition, early season high WT coincides with cold soils limiting CH_4 production.

Conclusions: This study shows how the relationships among temperature, VWC, WT and F_{CH4} are not necessarily common among different spatial and temporal scales as the relative importance of CH_4 production, transport and storage processes varies among these scales.

Figure 8. Various views of the TERS wet sedge meadow study site. Students Caitlyn Proctor and Emma Riley performing chamber measurements (bottom right).

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Photo credit: Claire Elliot (banner) & Mike Treberg