Physico-Chemical Characterization of Arctic Low Centered Polygonal Microtopographs

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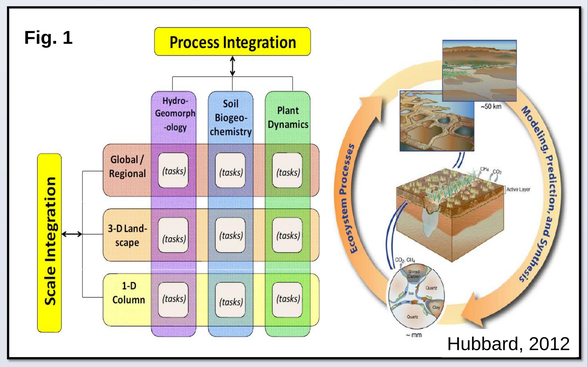
Introduction

- Estimate of soil organic C pool in permafrost regions amount to about 1672 Pg carbon (Tarnocai et al., 2009)
- Permafrost is rapidly warming and thawing with a resulting thickening of active layer and previously frozen old soil carbon being converted and released as CH_4 and CO_2
- Permafrost degradation can lead to dramatic changes in ecosystem structure and function (Graham et al., 2012)
- Central focus of the U.S. DOE Next-Generation Ecosystem Experiments (NGEE Arctic) is to advance understanding of processes and prediction of ecosystem-climate feedbacks in the rapidly changing Arctic tundra ecosystems
- This study presents the physico-chemical characteristics of soils in one of the three intensive sites of permafrost degradation – the Low-Centered Polygons located at the Barrow Environmental Observatory, Barrow, Alaska

Overarching Goals of NGEE

- Elucidate permafrost thaw-degradation and feedback effects on the climate system at different landscape scales
- Development of a process-rich ecosystem model (Fig. 1)

Fig. 1



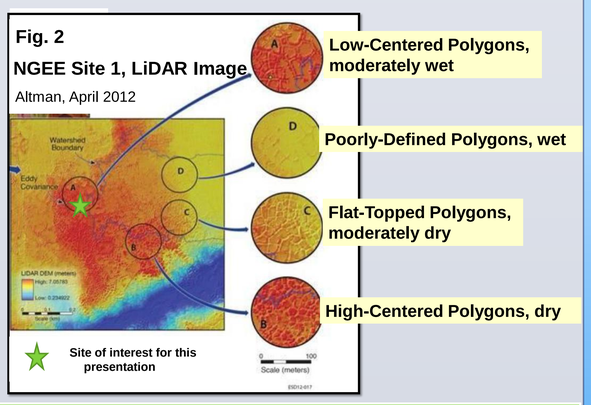
Hubbard, 2012

NGEE Study Sites and Soil Sampling

Fig. 2

NGEE Site 1, LiDAR Image

Altman, April 2012



Permafrost sampling with hydraulic SIPRE auger, April '12

Graham, 2012

PhysicoChemical Characterization of the Low-Centered Polygons (LCP)

Methods

- Intact soil cores from two microtopographic location, viz. the Center, Ridge and Trough of the Low-Centered Polygons (LCP) were collected in April, 2012 and sectioned into organic horizon, active layer, and permafrost
- Soil pH was determined in nanopure (np) water using 1:5 (w/v) ratio
- Gravimetric water content was determined by loss of weight on drying at 105 °C for 24 h
- Inorganic anion analyses was done from de-ionized water extracts (1:50) using Ion Chromatography (DX-120)
- Total C and N were determined using LECO C/N analyzer
- Fe(II) was determined from anoxic 2 M KCl extract (1:5, w/v) extraction using O-phenanthroline chromophore and quantified using spectrometry at 510 nm
- Soil microcosms were constructed and incubated at 4 and 10 °C, respectively for 75 days and CH_4 flux measured with Agilent GC/FID 6890

Results

Low Centered Polygon – Microtopography Soil Horizonation

Fig. 3

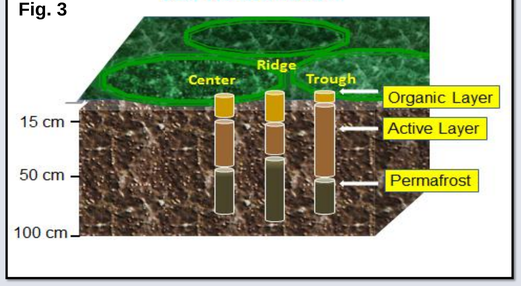


Table 1: Soil Solution and Pore Water pH

Soil Horizon	Low Centered Polygon						High Centered Polygon
	Center		Ridge		Trough		
	pH_{soil} (1:5, w/v)	Pore Water (to depth 47 cm)	pH_{soil} (1:5, w/v)	Pore Water (to depth 40cm)	pH_{soil} (1:5, w/v)	Pore Water (to depth 55 cm)	pH_{soil} (1:5, w/v)
Organic layer	4.5 (0.021)	6.2	4.99 (0.017)	5.93	na*	5.79	5.33 (0.01)
Active Layer	4.95 (0.002)		4.85 (0.026)		4.53 (0.002)		5.62 (0.15)
Permafrost	5.35 (0.002)		4.94 (0.024)		na*		5.33 (0.09)

Fig. 4: Fe(II) Concentration in Pore Water & Soil Extracts

Pore Water Fe (II) Concentration			
	LCP-Center	LCP-Ridge	LCP-Trough
Depth (cm)	47	40	55
Fe(II) ppm	37.5	5	26.25

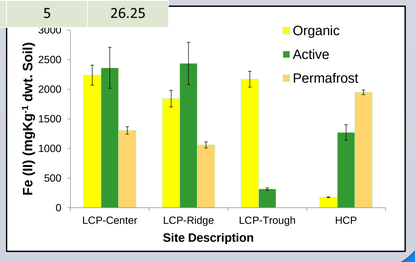


Fig. 5: Total C Concentration and C:N Ratio

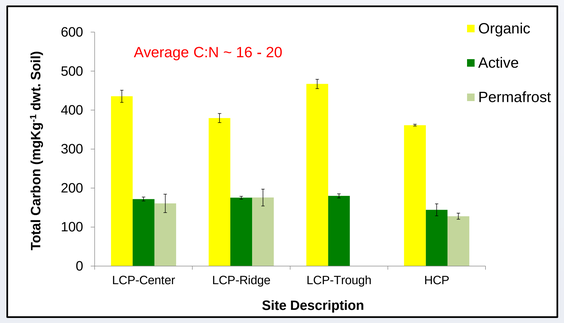


Fig. 6: Soil Anion Concentration & Water Content

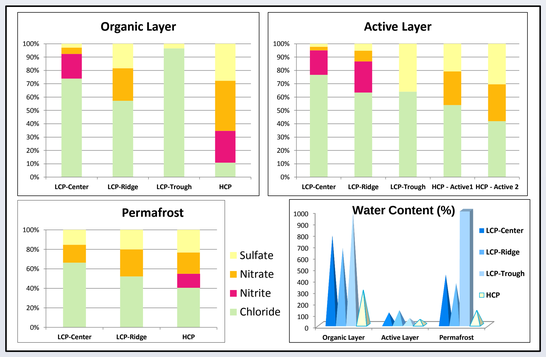


Fig. 7.1: Effect of Soil Warming on Methane Emission Rates in Organic Horizon

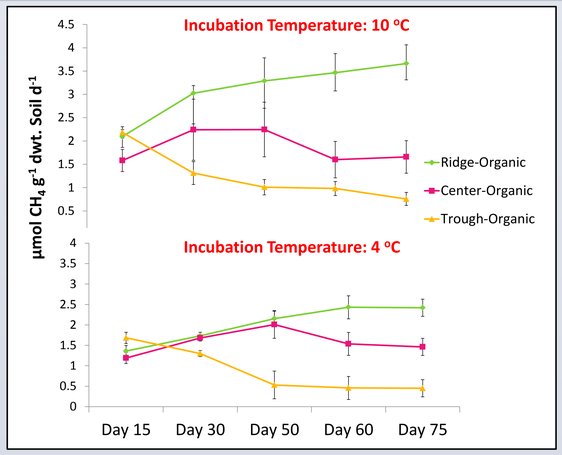


Fig. 7.2a: Effect of Soil Warming on Methane Emission Rates in Active Layer & Permafrost

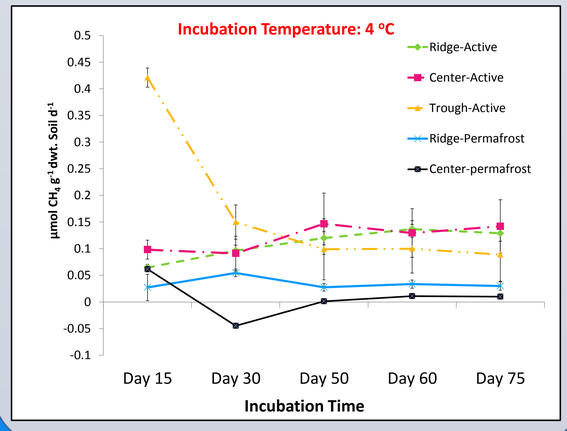
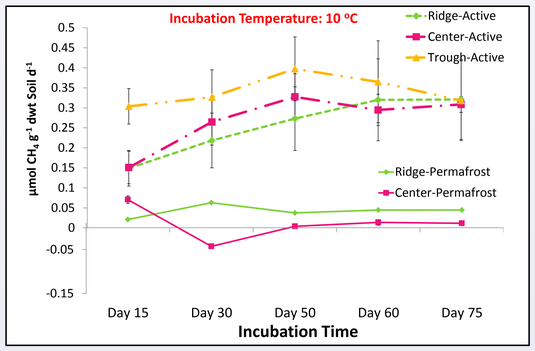


Fig. 7.2b: Effect of Soil Warming on Methane Emission Rates in Active Layer & Permafrost



Key Observations

- Organic horizons had the lowest mean pH values (4.5) with no significant difference between the microtopographies
- Mean gravimetric water content (θ_g= 8.4 $gH_2O\ g^{-1}$ dry soil) was significantly higher in the organic horizons of the trough and the highest mean organic carbon (43.5 %) was observed in the organic horizons at the center of the low-centered polygons
- Mean pH (5.2) and θ_g (3.65 $gH_2O\ g^{-1}$ dry soil) of the permafrost was higher than those for active layer (pH= 4.93,θ_g=0.99 $gH_2O\ g^{-1}$ dry soil)
- C:N ratio ranged from 19 – 20 with no difference between the horizons and microtopographic sites
- Fe(II) concentrations were significantly lower in the permafrost than in the organic and active layers – organically bound Fe ?
- Temperature activation (at 10 °C) of dormant microbial cells and plant roots could account for the ~ 10 fold higher CH_4 emission rates in the Organic layer compared to the Active layer and Permafrost
- Decline in CH_4 emission rates with time in the Organic layers of the LCP-Center and Trough at the higher incubation temperature (10 °C) suggests distinctive differences in C decomposition mechanisms at these sites compared to the LCP-Ridge
- Importance of Fe in respiration has implications for the impact of a warmer Arctic: a deeper thaw would provide more contact with the mineral layer, allowing a higher Fe availability– Ridge Active layer showed significantly higher Fe(II) than the Permafrost

Future Directions

- Enzyme studies to determine effects of soil warming on C and N mineralization rates, microbial Carbon Use Efficiencies
- Investigate and understand associations of Fe(II) and Fe(III) in the organic and mineral fractions using chemical and imaging techniques
- Explore the lower and Zero methane emission rates in the Active layer and Permafrost, respectively, possible by dissimilatory Fe(III) reduction in ice-wedge induced microtopographic soil chemistry
- Determination of C pools and characterization of soil organic matter

References

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