Influence of ecosystem conditions on permafrost temperature dynamics of the lower Kolyma region

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The resilience and vulnerability of permafrost to climate change depends on complex interactions among topography, water, soil, vegetation, and snow, which allow permafrost to persist at mean annual air temperatures (MAATs) as high as +2°C and degrade at MAATs as low as −20°C. (Jorgenson et al., 2010)

Schematic of common covarying ecosystem components across boreal ecosystems in central Alaska.
SCHEME OF PERMAFROST–LANDSCAPE INTERACTIONS IN THE CONTEXT OF A CHANGING CLIMATE.
DIRECT AND INDIRECT EFFECTS OF VEGETATION ON GROUND THERMAL DYNAMICS
AN EXAMPLE OF SNOW REDISTRIBUTION DUE TO TUSSOCKY MICROTOPOGRAPHY
Left panel: Conductivity of organic (5-10 cm) soil was lower than mineral (20-40 cm). Right panel: The positive relationship between bulk density (low in organic soil) and thermal conductivity.
MAP OF INVESTIGATED AREA, BOREHOLES LOCATION AND RECENT PERMAFROST TEMPERATURE
GOALS

Develop approach for sampling ecological variables alongside permafrost temperature monitoring

Determine and quantify key parameters of ecosystem most important for thermal state of permafrost

Estimate influence of vegetation and soil parameters on the thermal state of permafrost at the lower Kolyma region
TEMPERATURE MEASUREMENTS

Data logger HOBO U-12 with termistors TMC-HD. The set allow to do measurements with resolution 0.004°C and accuracy 0.02°C
Thermal conductivity of soil was measured using the single probe needle sensor. A needle probe inserted horizontally into the soil was heated during 2 minutes and rate of temperature changes was measured. Thermal conductivity was calculated based on the temperature increasing rate.
TERRESTRIAL SURVEY

TREES
Woody debris;
Canopy cover;
Larch biomass;
Snag biomass and density;
Trees per m²

UNDERSTORY
Live biomass;
Overstory deciduous cover;
Understory shrub cover;
Moss & lichens cover;
Herb cover

SOIL
Thaw depth;
Organic layer depth;
C pool in upper 10 and 20 cm
Carbon content;
Soil bulk density and moisture
OMOLON RIVER MOUTH

Terrestrial survey was not conducted yet
OMOLON RIVER MOUTH

MAGT at the 25 m depth (2012) -4.2°C  Positive trend, °C/year 0.063
DUVANNY YAR

Terrestrial survey was conducted in 2012

<table>
<thead>
<tr>
<th>Organic Layer depth (cm)</th>
<th>C pool, 10 cm (g/m²)</th>
<th>C pool, 20 cm (g/m²)</th>
<th>Mineral OS bulk soil density (MS) % (g/cm³)</th>
<th>MS bulk density (g/cm³)</th>
<th>MS moisture GWC</th>
<th>Understory live biomass (g/m²)</th>
<th>Overstory deciduous % Cover</th>
<th>Understory Shrub, % Cover</th>
<th>Moss, Lichen, % Cover</th>
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<tr>
<td>13.8</td>
<td>3483</td>
<td>7913</td>
<td>7.11</td>
<td>0.10</td>
<td>0.61</td>
<td>96.2</td>
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<td>nd</td>
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MAGT at the 25 m depth (2012) -6.1°C  Positive trend, °C/year 0.035
AMBOLIHA

Terrestrial survey was conducted in 2012

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<th>Organic Layer depth (cm)</th>
<th>C pool, 10 cm (g/m²)</th>
<th>C pool, 20 cm (g/m²)</th>
<th>Mineral soil (MS) density (g/cm³)</th>
<th>MS bulk density (g/cm³)</th>
<th>MS moisture</th>
<th>Understory live biomass (g/m²)</th>
<th>Overstory deciduous % Cover</th>
<th>Understory Shrub, % Cover</th>
<th>Moss, % Cover</th>
<th>Lichen, % Cover</th>
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<tr>
<td>0.0</td>
<td>3979</td>
<td>7958</td>
<td>17.4</td>
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<td>0.23</td>
<td>248.1</td>
<td>581</td>
<td>2.9</td>
<td>14.0</td>
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MAGT at the 21 m depth (2012) -5.6°C  Positive trend, °C/year 0.019
PLEISTOCENE PARK

Terrestrial survey was conducted in 2012

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<th>Organic Layer depth (cm)</th>
<th>C pool, 10 cm (g/m²)</th>
<th>C pool, 20 cm (g/m²)</th>
<th>Mineral soil (MS) density (g/cm³)</th>
<th>MS bulk density (g/cm³)</th>
<th>MS moisture % carbon</th>
<th>Understory live biomass (g/m²)</th>
<th>Overstory deciduous % Cover</th>
<th>Understory Shrub, % Cover</th>
<th>Moss, % Cover</th>
<th>Lichen, % Cover</th>
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<td>0.46</td>
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Ground temperature at the 13.5 m depth (2012) -4.7°C  Borehole was drilled in 2012
SHUCHE LAKE

Terrestrial survey was conducted in 2012

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<tr>
<th>Organic Layer depth (cm)</th>
<th>C pool, 10 cm (g/m²)</th>
<th>C pool, 20 cm (g/m²)</th>
<th>Mineral soil (MS) % carbon</th>
<th>OS bulk density (g/cm³)</th>
<th>MS bulk density (g/cm³)</th>
<th>MS moisture</th>
<th>Understory live biomass (g/m²)</th>
<th>Understory deciduous % Cover</th>
<th>Overstory Shrub, % Cover</th>
<th>Understory Moss, % Cover</th>
<th>Lichen, % Cover</th>
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<td>13.8</td>
<td>3107</td>
<td>6161</td>
<td>3.64</td>
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<td>0.94</td>
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<td>1171</td>
<td>53.8</td>
<td>51.5</td>
<td>20.2</td>
<td>5.5</td>
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Ground temperature at the 13.5 m depth (2012) **-2.7°C!!!** Borehole was drilled in 2012
CORRELATION OF PERMAFROST TEMPERATURE AND SOIL PARAMETERS

Carbon pool in upper 10 cm, g/m²

Carbon pool in upper 20 cm, g/m²

Carbon content in mineral soil, %

Mineral soil bulk density, (g/cm³)
CORRELATION OF PERMAFROST TEMPERATURE AND UNDERSTORY PARAMETERS

**Overstory deciduous cover, %**

- Permafrost temperature, °C
- 0.0 10.0 20.0 30.0 40.0 50.0 60.0
- -2.0
- -2.5
- -3.0
- -3.5
- -4.0
- -4.5
- -5.0
- -5.5
- -6.0
- -6.5

**Understory shrub cover, %**

- Permafrost temperature, °C
- 0.0 10.0 20.0 30.0 40.0 50.0 60.0
- -2.0
- -2.5
- -3.0
- -3.5
- -4.0
- -4.5
- -5.0
- -5.5
- -6.0
- -6.5

- Floodplain
- Boreal forest
Alnus
Betula
Salix

Overstory shrubs biomass, g/m²

Amboliha
Pleistocene Park
Shuche lake
Duvanny Yar

Floodplain
Boreal forest
CONCLUSIONS

Temperature of permafrost existing in the same climatic zone can be up to 4°C different in different ecosystems in the investigated area.

Most important factors affecting permafrost temperature are organic layer thickness, TOC in active layer soil, soil bulk density and type and density of understory vegetation.

Increasing of organic content in active layer reduces permafrost temperature and climate impact on its dynamics.

Shrubs influence on permafrost temperature depends on species, so it can work different in different ecosystems.

Based on the current research we would strongly recommend to take in consideration climate induced ecosystem shift (i.e. changes of vegetation structure, increasing of bioproductivity and soil organic carbon accumulation) when doing long-term permafrost dynamics modeling and forecasts.
AKNOWLEDGEMENTS

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