The Role of Permafrost in Evolution of Terrestrial Ecosystem in Changing Climate at the North Slope of Alaska

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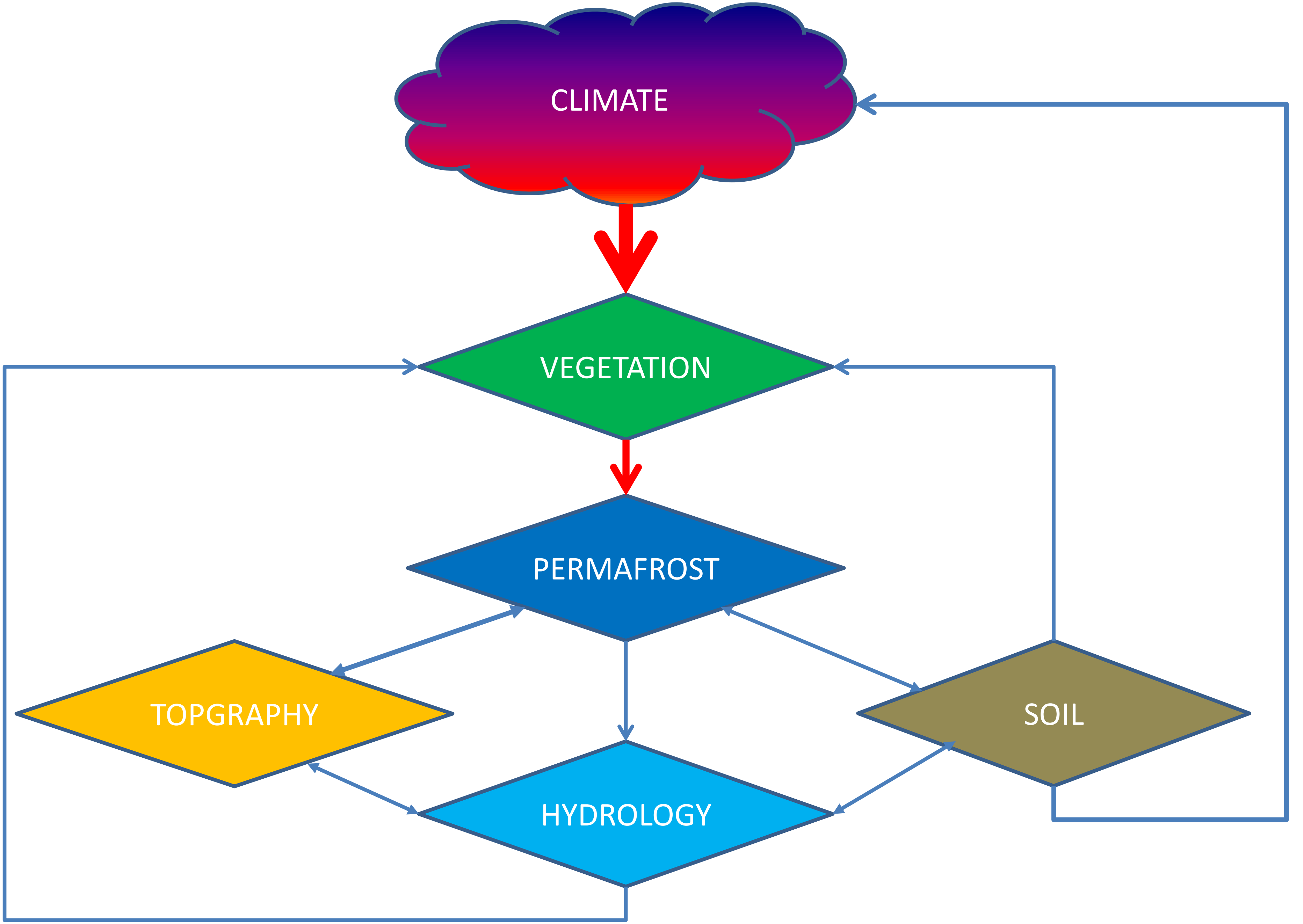
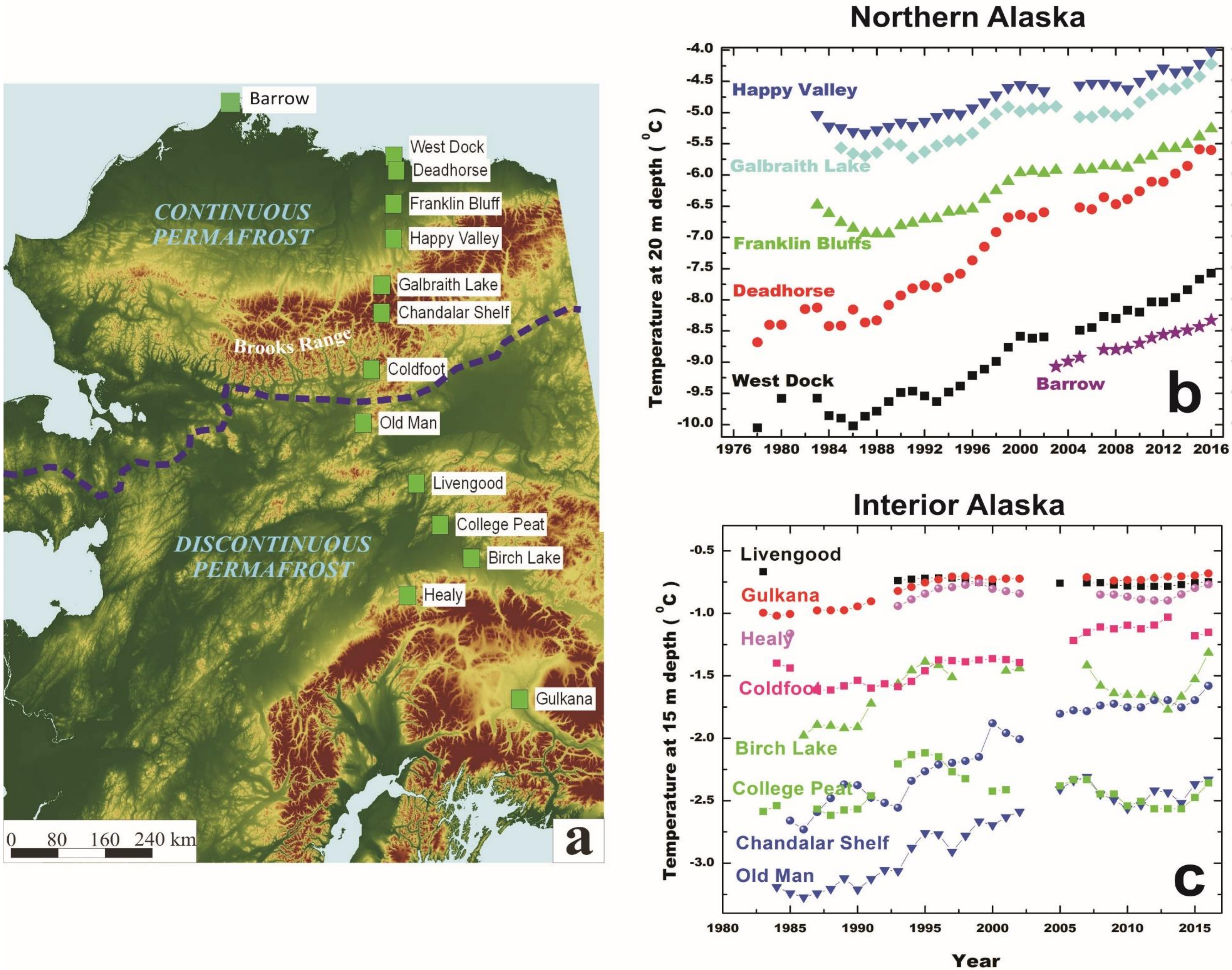
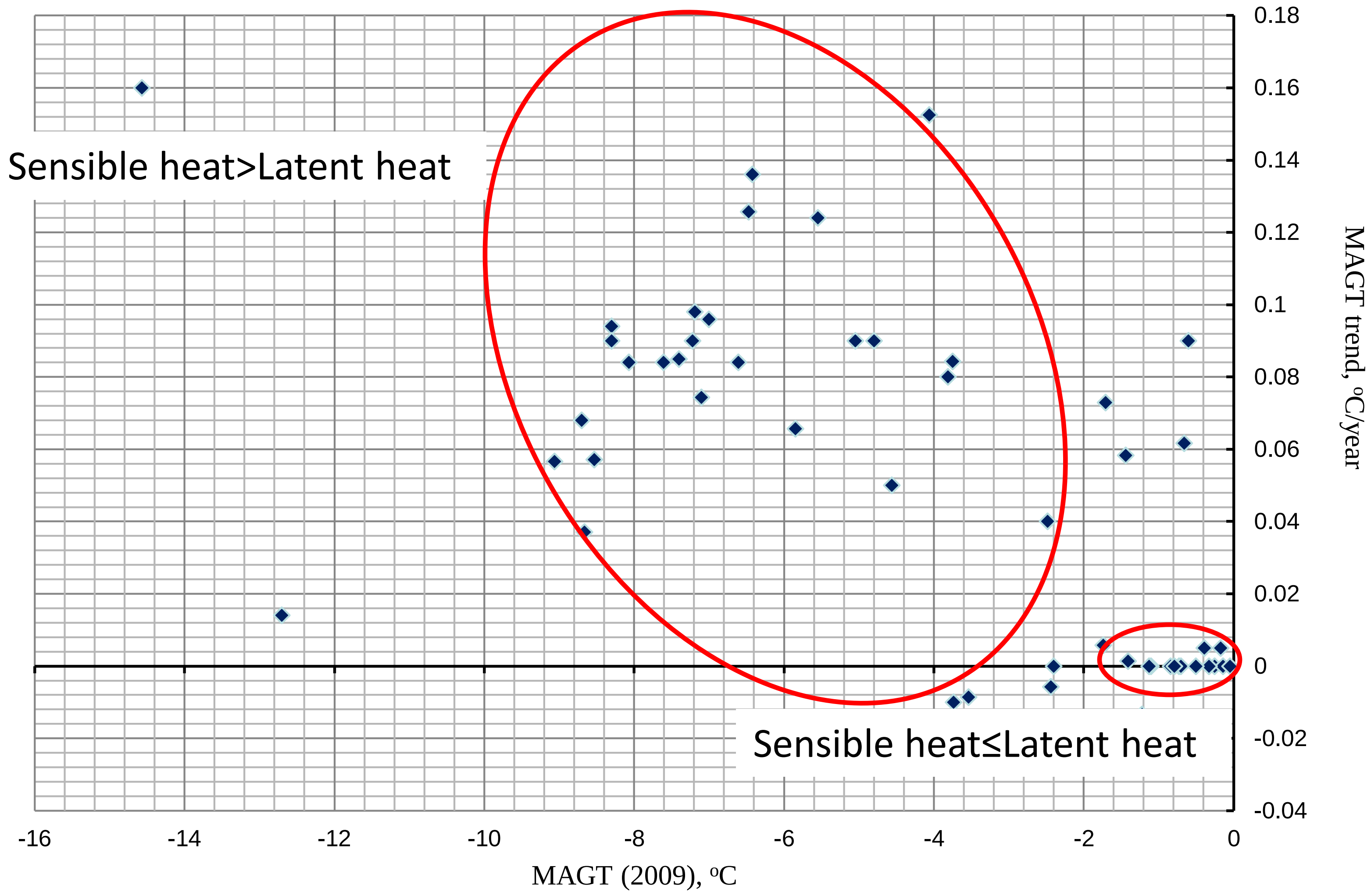
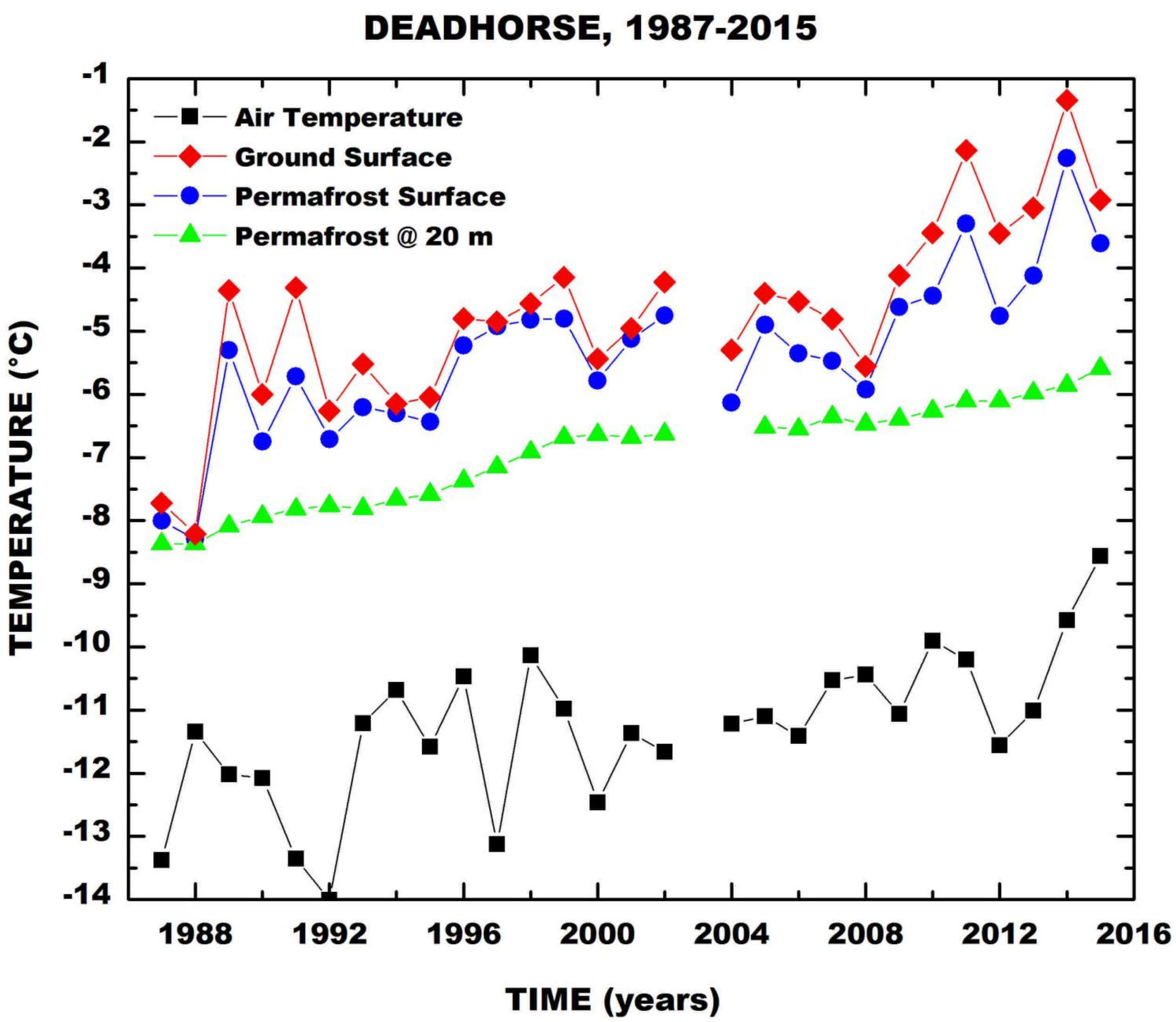
with contribution from ***S.Stuefer, S.Natali and M.Loranty***

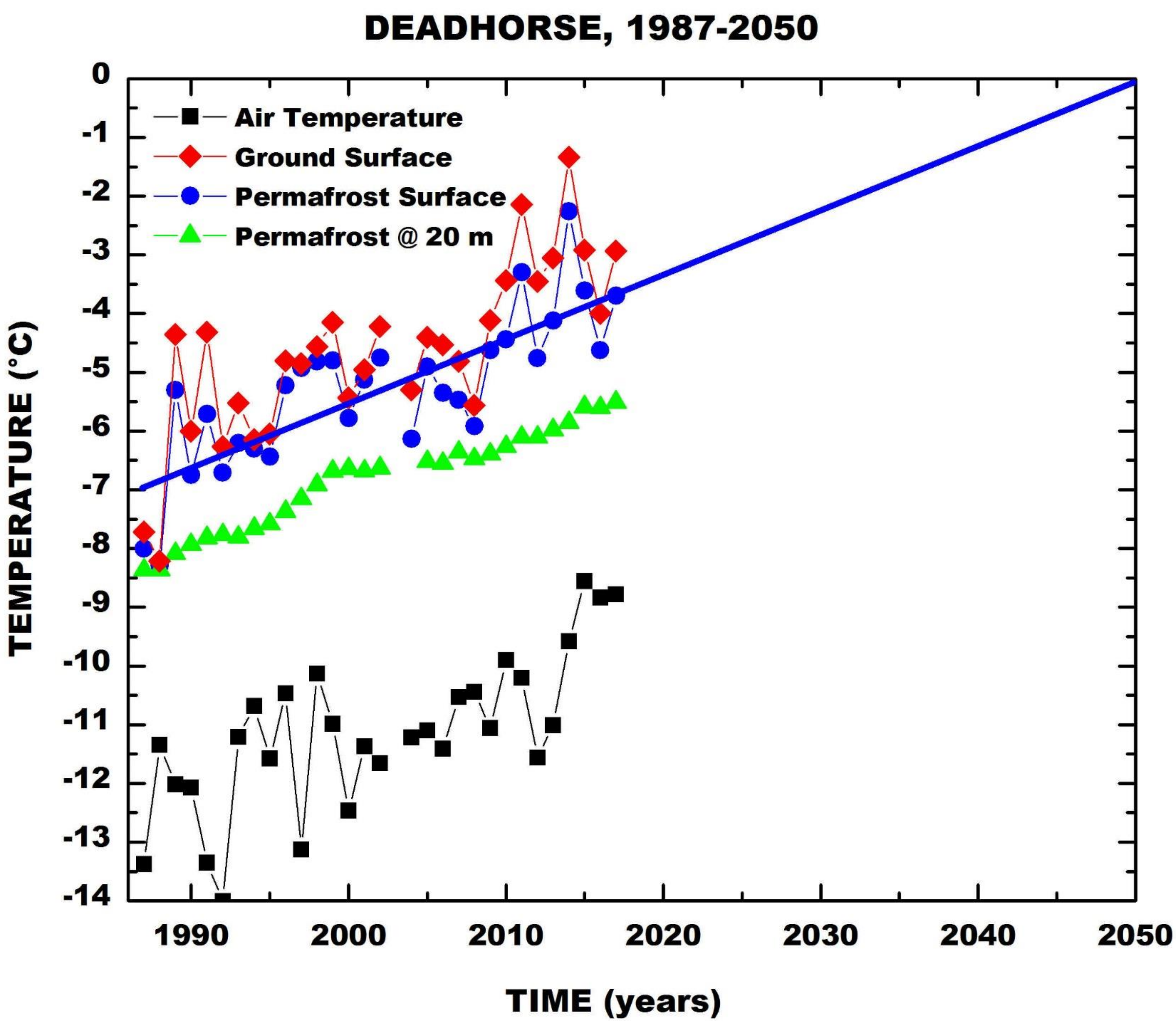

CLIMATE
VEGETATION
PERMAFROST
TOPGRAPHY
SOIL
HYDROLOGY


Barrow
West Dock
Deadhorse
Franklin Bluff
Happy Valley
Galbraith Lake
Chandalar Shelf
Coldfoot
Old Man
Livengood
College Peat
Birch Lake
Healy
Gulkana
CONTINUOUS PERMAFROST
DISCONTINUOUS PERMAFROST
Brooks Range
0 80 160 240 km
a
Northern Alaska
Happy Valley
Galbraith Lake
Franklin Bluffs
Deadhorse
West Dock
Barrow
b
Temperature at 20 m depth (^{0}C)
-4.0
-4.5
-5.0
-5.5
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
-9.0
-9.5
-10.0
1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016
Interior Alaska
Livengood
Gulkana
Healy
Coldfoot
Birch Lake
College Peat
Chandalar Shelf
Old Man
c
Temperature at 15 m depth (^{0}C)
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
1980 1985 1990 1995 2000 2005 2010 2015
Year

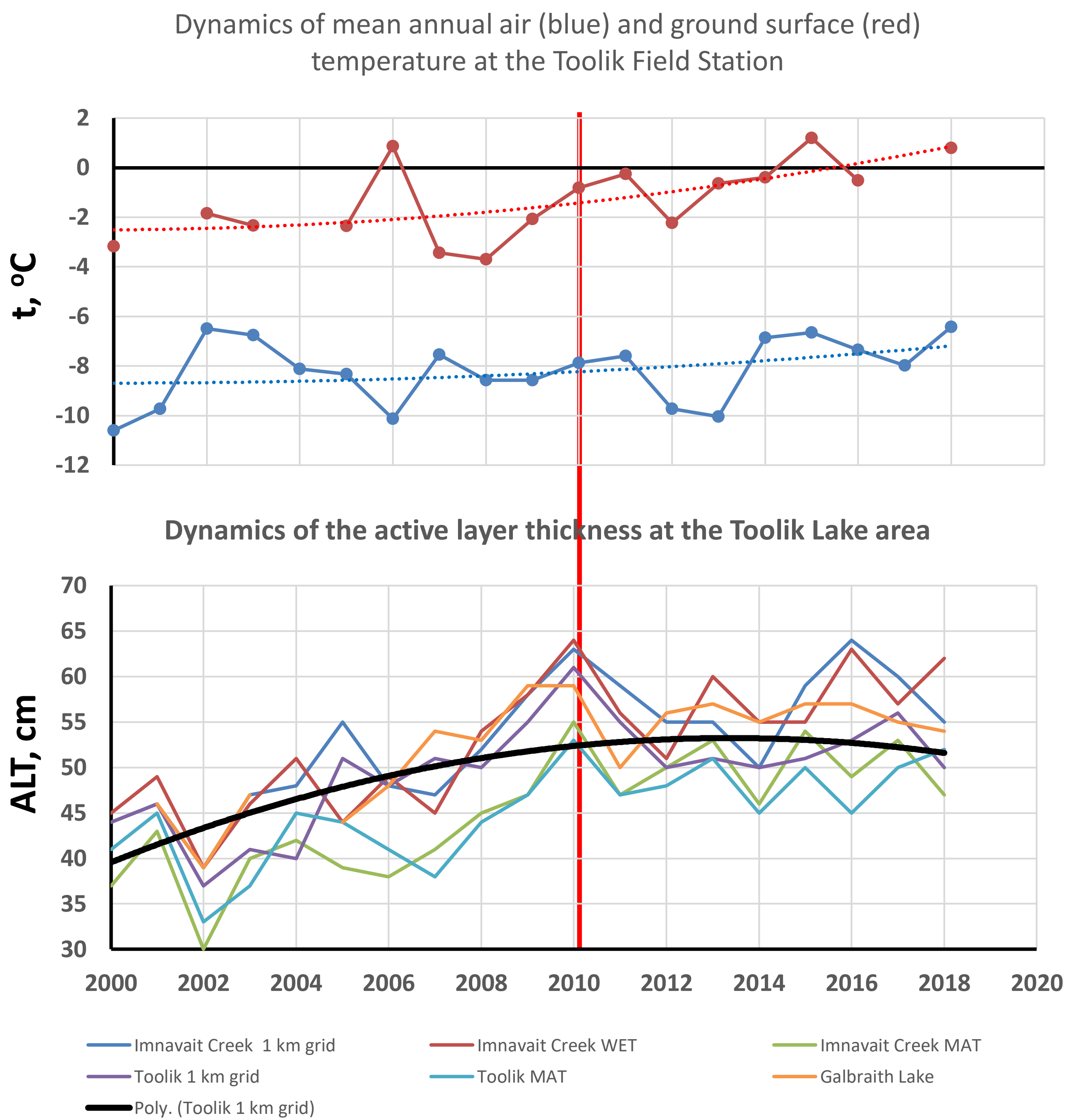
CORRELATION OF MEAN ANNUAL GROUND TEMPERATURE VALUES AND ITS TRENDS DURING 2010-2015 IN ALASKA




DEADHORSE, 1987-2015
Air Temperature
Ground Surface
Permafrost Surface
Permafrost @ 20 m
TEMPERATURE (°C)
TIME (years)
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
1988
1992
1996
2000
2004
2008
2012
2016



DEADHORSE, 1987-2050
Air Temperature
Ground Surface
Permafrost Surface
Permafrost @ 20 m
TEMPERATURE (°C)
TIME (years)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
1990
2000
2010
2020
2030
2040
2050


Dynamics of mean annual air (blue) and ground surface (red) temperature at the Toolik Field Station
t, ºC
2
0
-2
-4
-6
-8
-10
-12
Dynamics of the active layer thickness at the Toolik Lake area
ALT, cm
70
65
60
55
50
45
40
35
30
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Imnavait Creek 1 km grid
Imnavait Creek WET
Imnavait Creek MAT
Toolik 1 km grid
Toolik MAT
Galbraith Lake
Poly. (Toolik 1 km grid)


2005

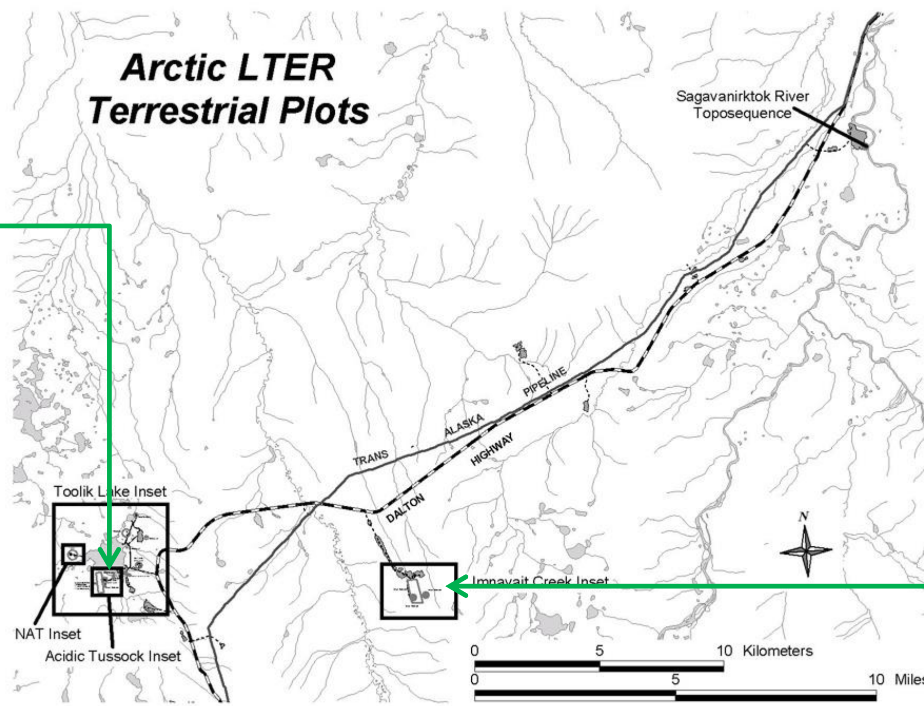

2013


2005


2013

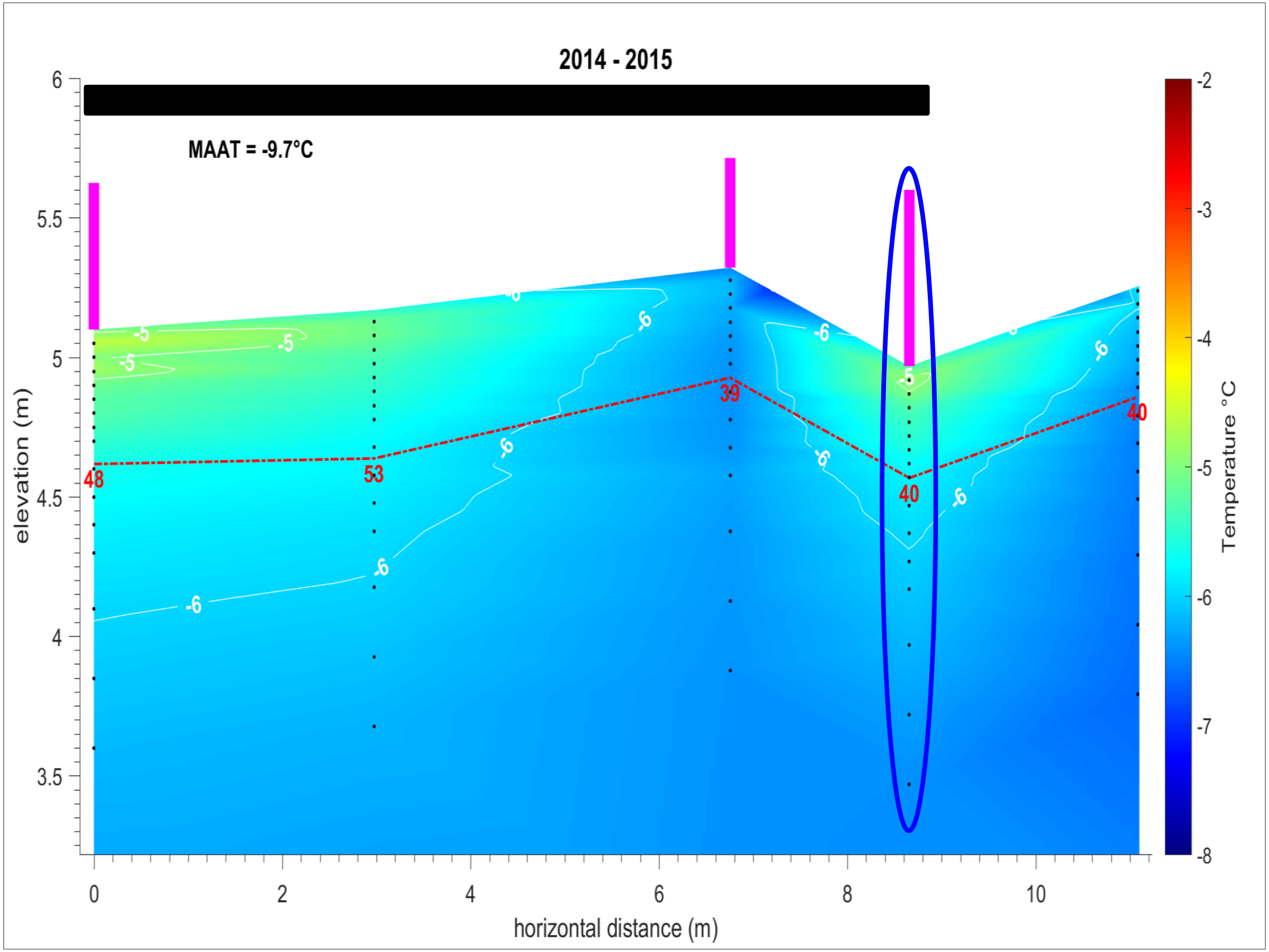
CONTENT OF GREENGOUSE GASES IN THE FROZEN SOILS AT THE TOOLIK LAKE STATION

					CO2			CH4	
Sampling site	Sample depth	Weight of sample, gr	Gravimetric soil moisture	ml per kg of wet soil	ml per kg of dry soil	concentration in pore solution, %	ml per kg of wet soil	ml per kg of dry soil	concentration in pore solution, %
Imnavait creek tower (wet)	25-30 cm (active layer)	42.8	3.53	30.57	138.44	0.0317	0.51	2.32	0.0005
	62-67 cm (permafrost?)	42.5	2.16	48.25	152.71	0.1069	4.24	13.41	0.0094
Near the tussock acidic tundra plots	intertussock 2	29.2	1.44	48.54	118.41	0.0746	0.01	0.02	0.0000
	tussock 1	30.6	0.74	31.99	55.69	0.0482	5.76	10.03	0.0087
	tussock 2	29.7	0.66	55.92	92.70	0.1350	0.58	0.97	0.0014



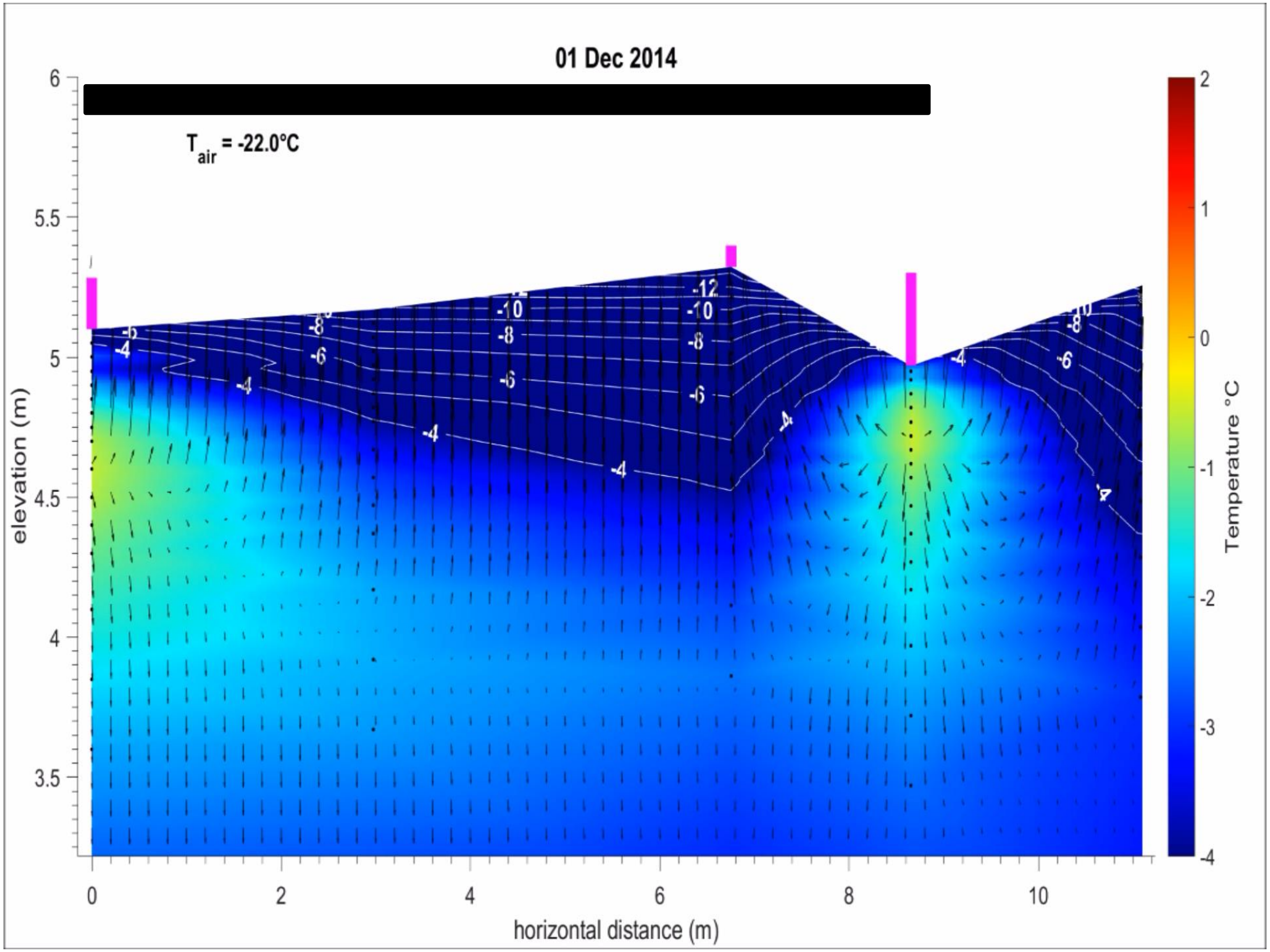
Mean Annual Ground Temperature

Walled Polygon



Credited by W.Cable

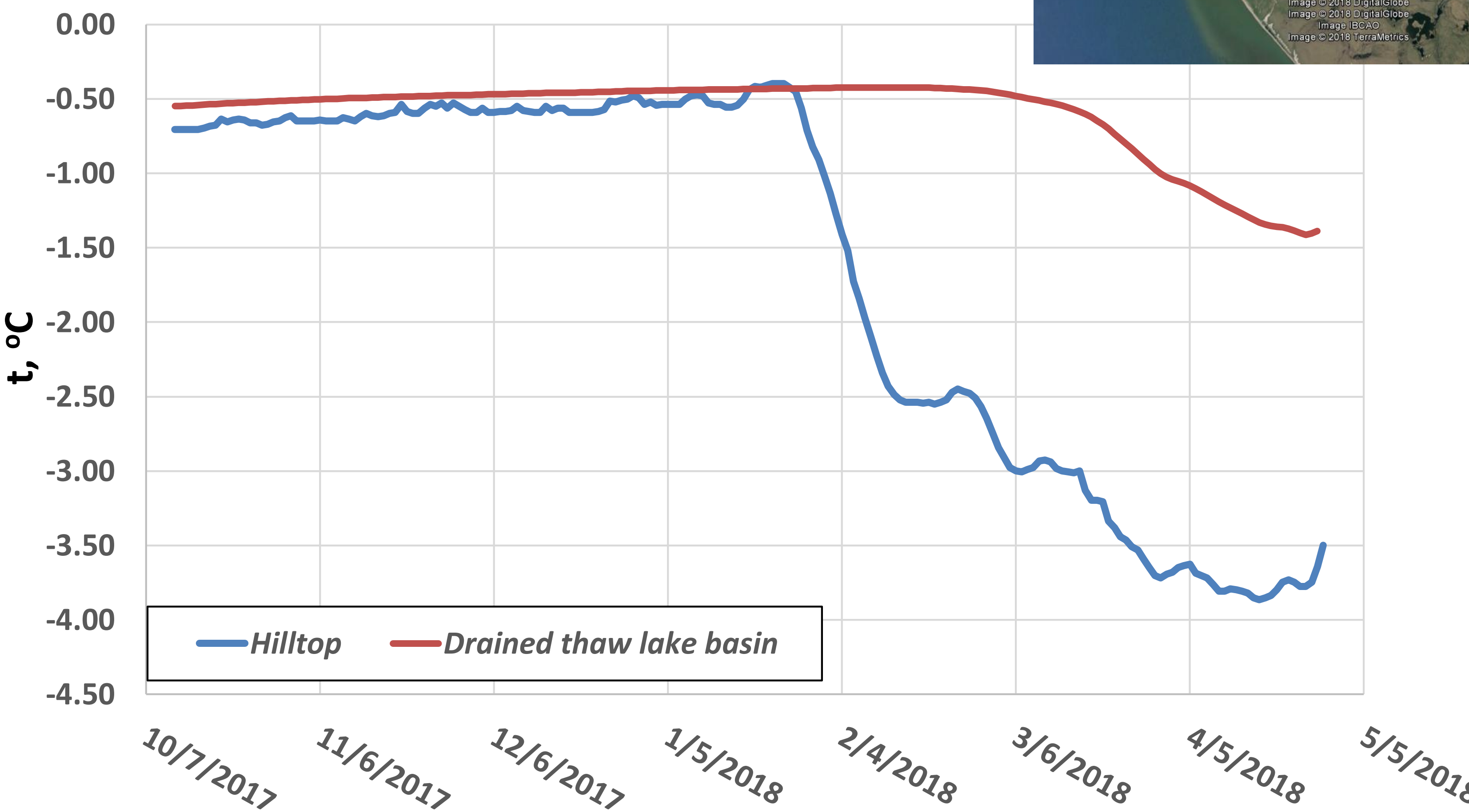
Walled Polygon, 2D Thermal Dynamics



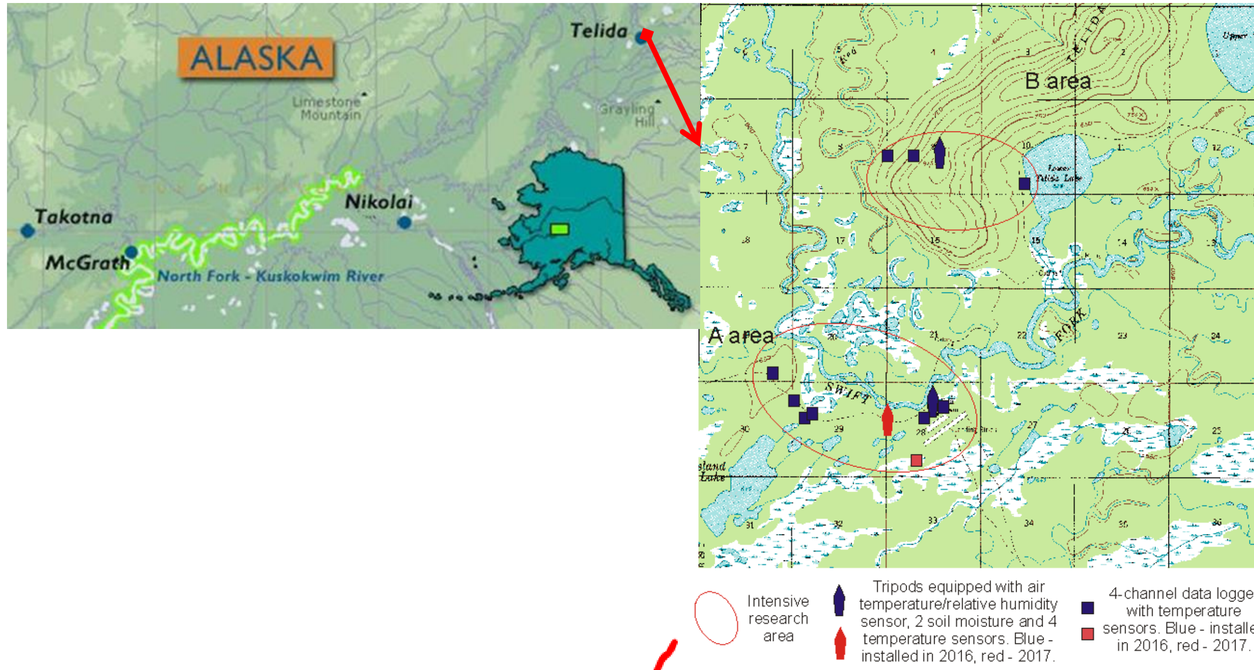
*arrows show the direction and magnitude of the temperature gradient

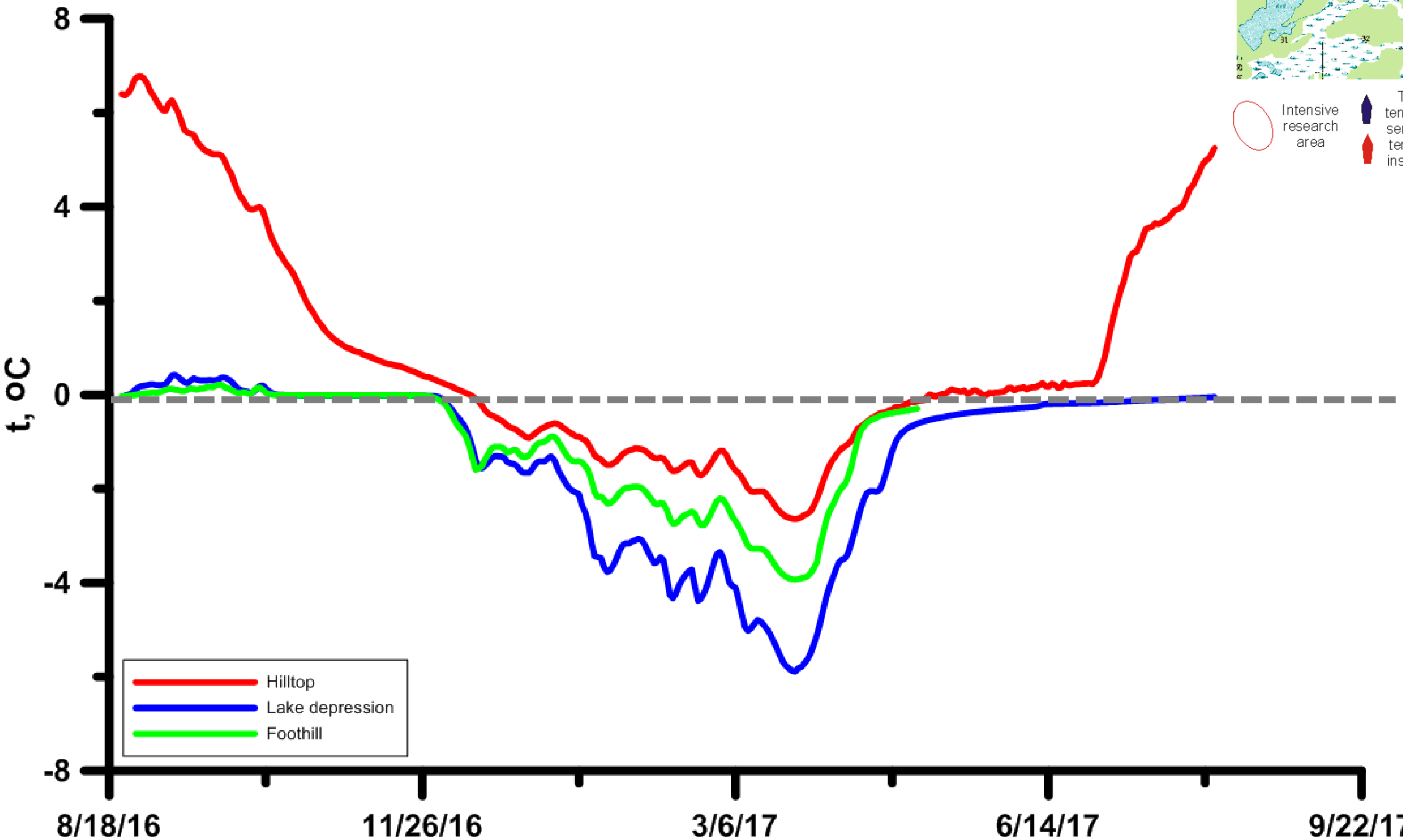
Credited by W.Cable

Ground temperature dynamics at the depth of 4' (permafrost table) in vicinity of the city of Kotzebue (tundra biome)



Dynamics of ground temperature at the depth of 50 cm at the different geomorphological levels in the boreal forest zone

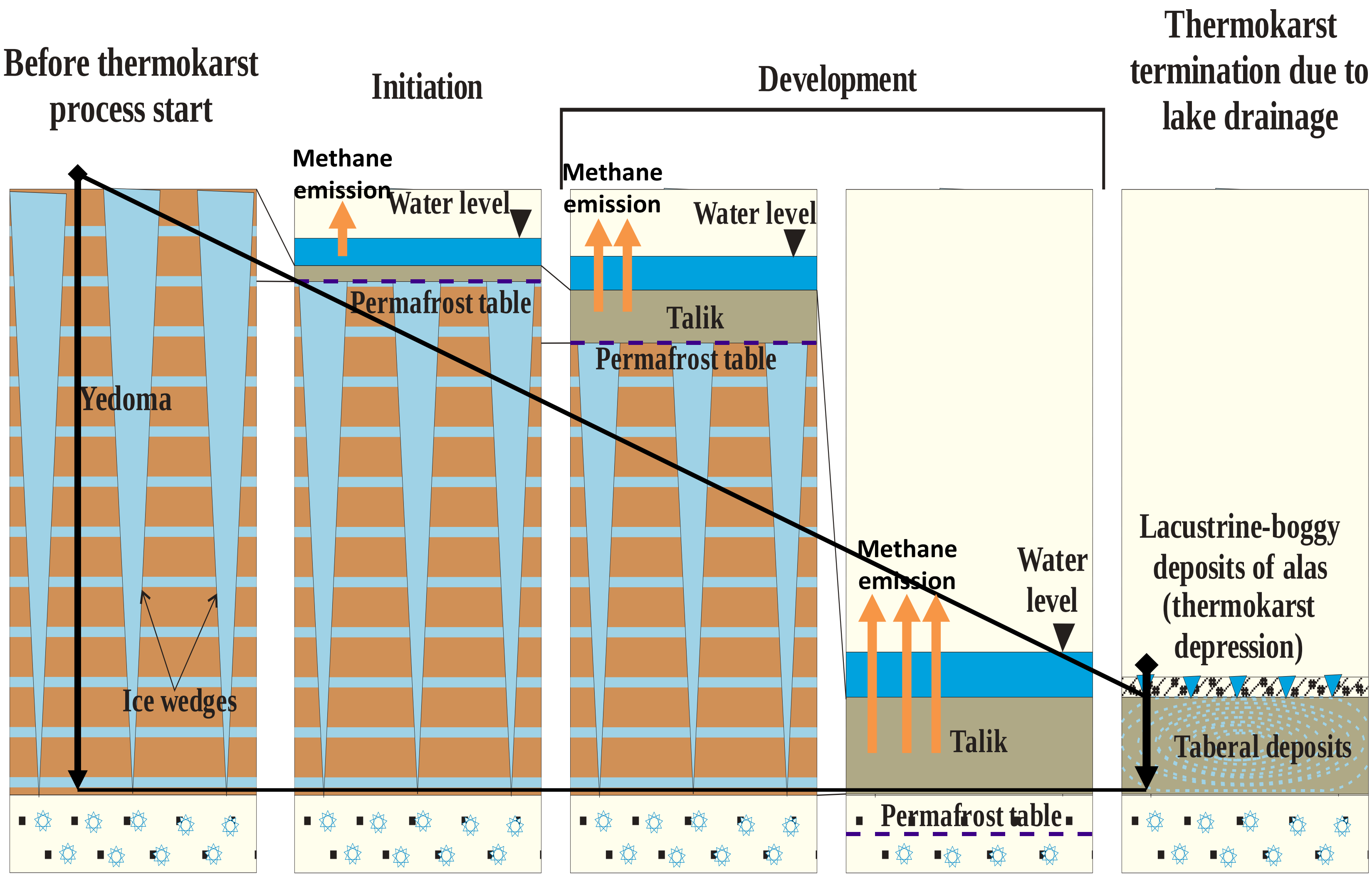




TAKE HOME MESSAGE!

Under current conditions p**resence of the massive ice** (especially unevenly distributed) close to the bottom of active layer might be **more important** for the dynamics of the thermal state of permafrost **than long-term climatic trend**.

Subsidence of the ground surface due to melting of ground ice caused by short-term changes of surface energy balance will affect snow redistribution and thus intensify permafrost warming, trigger development of the process of thermokarst and initiate increasing of methane emission into atmosphere.



Scheme of thermokarst process development .

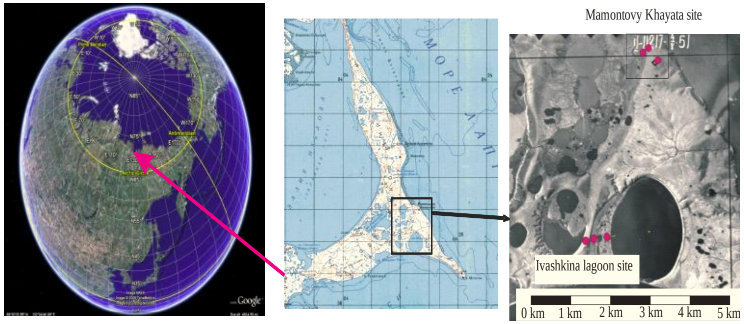
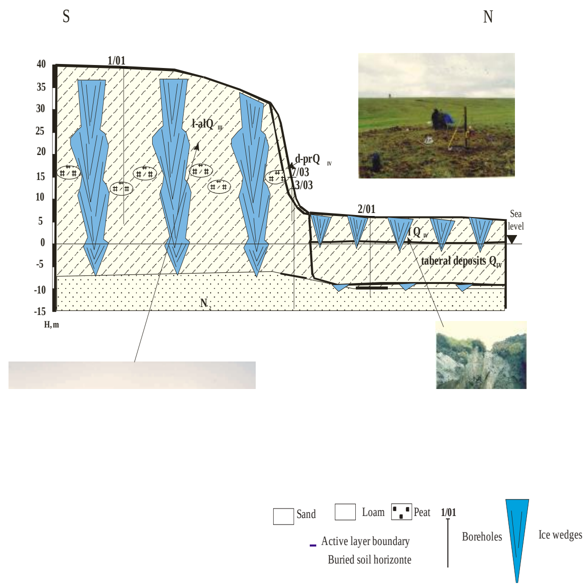
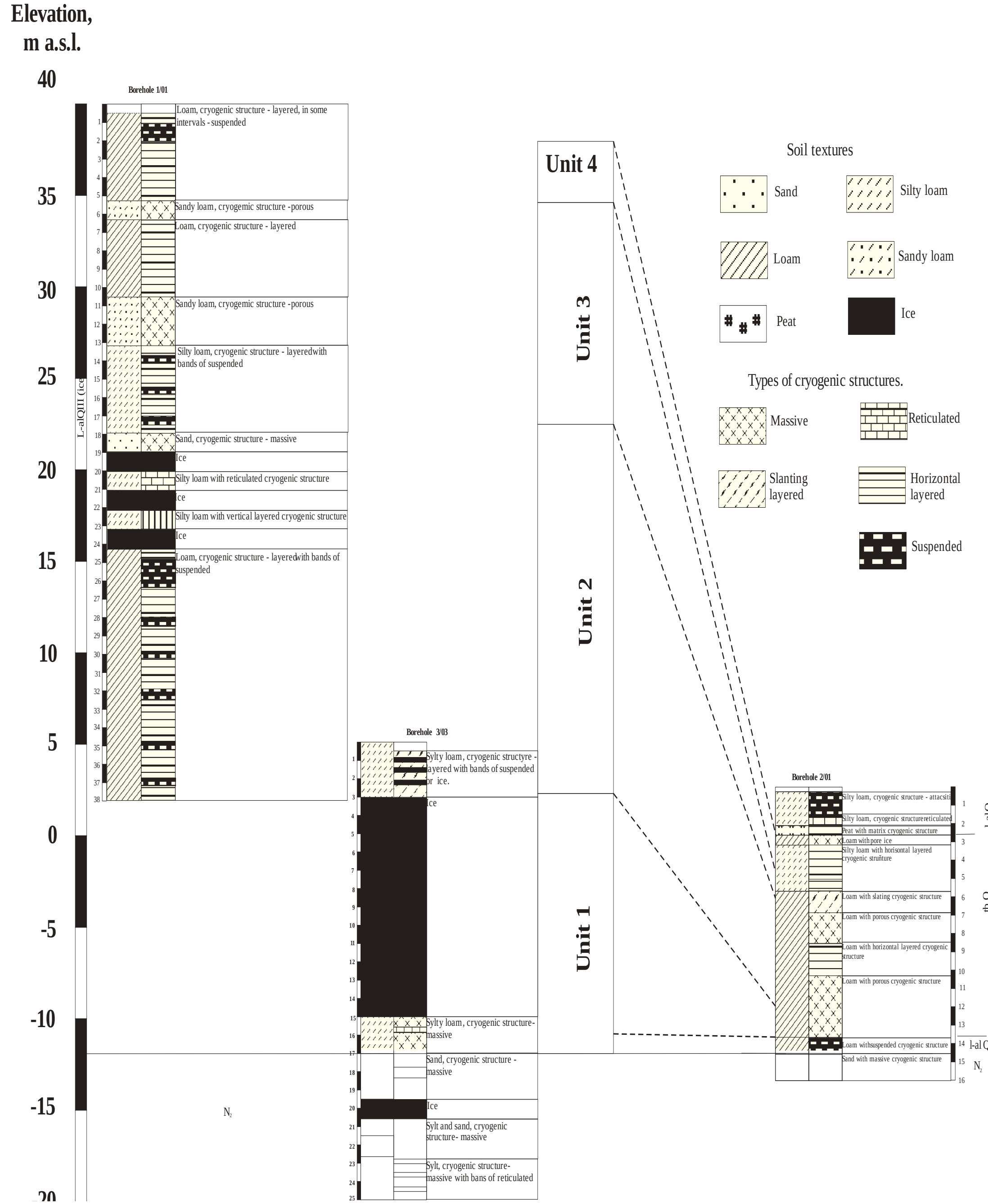


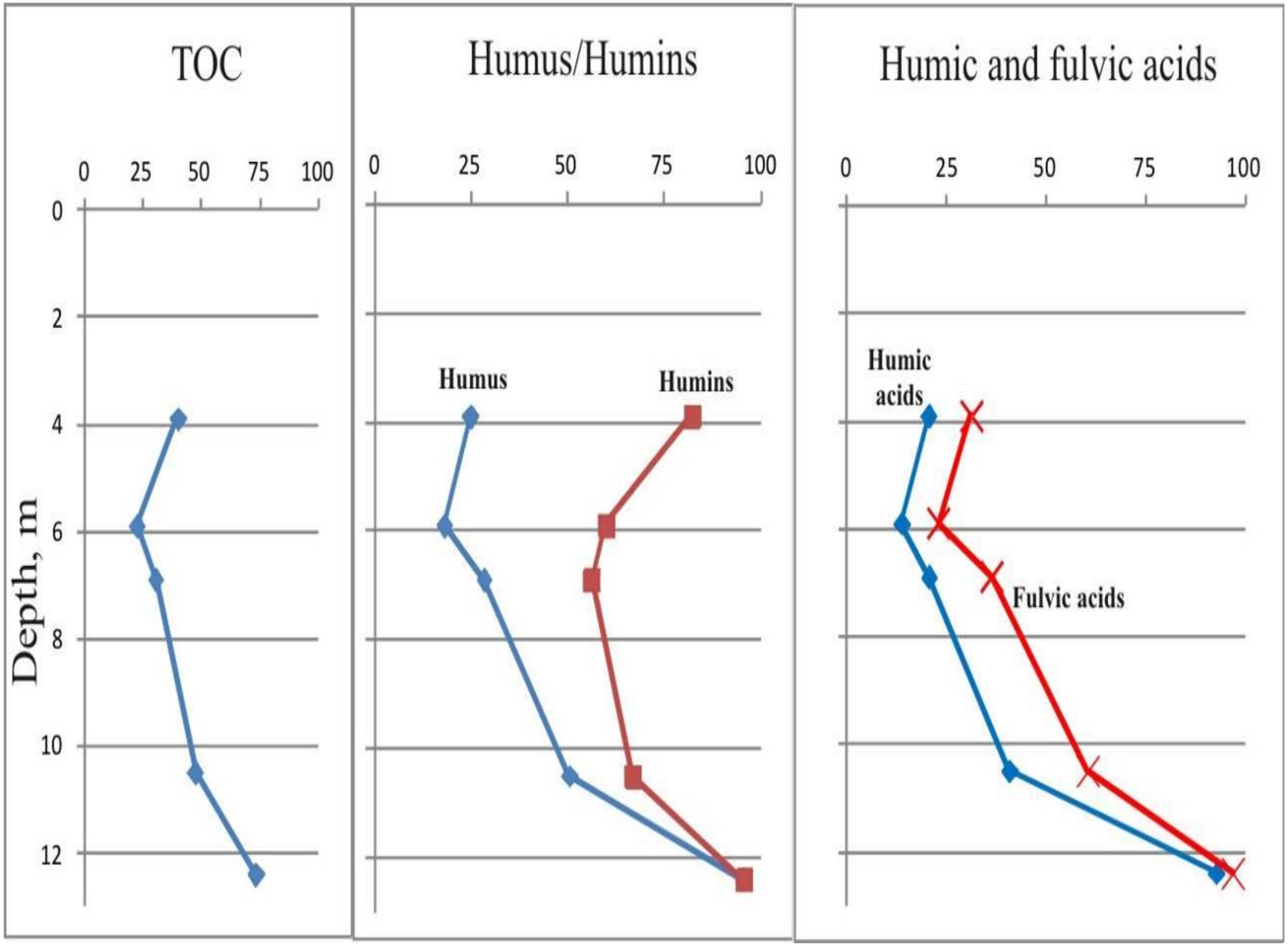
Figure 1. Investigation area and borehole locations.



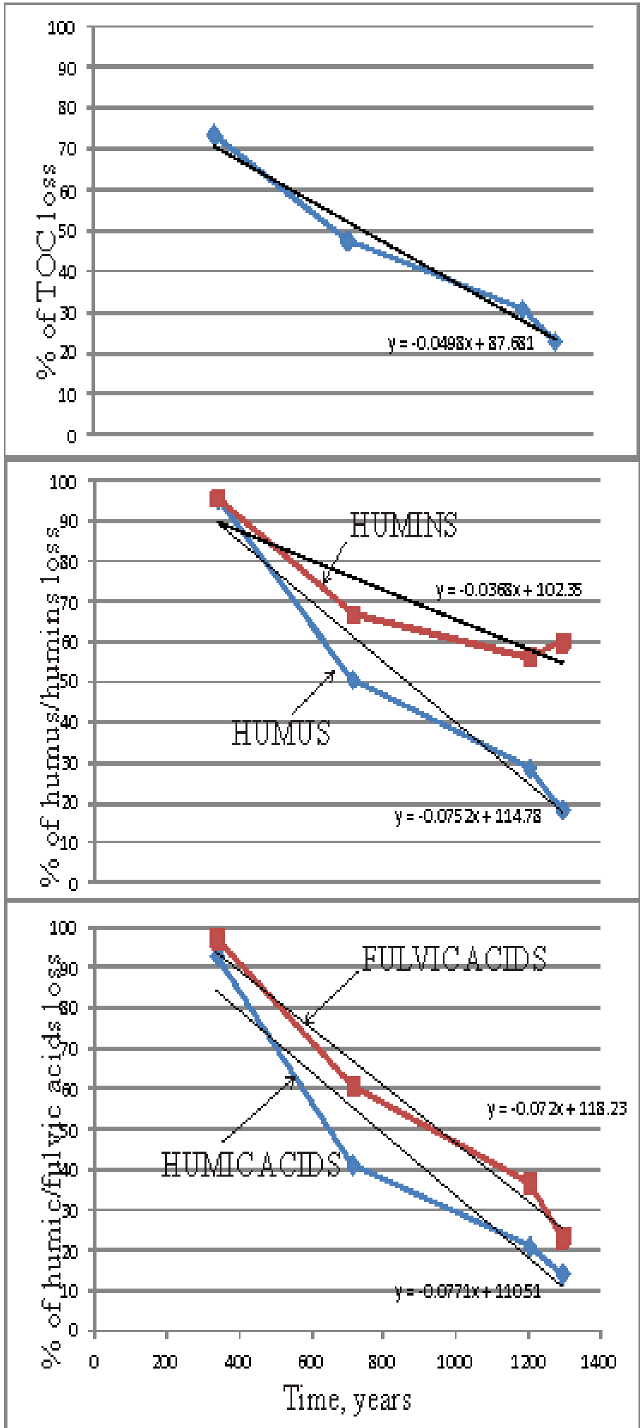


Average values of TOC, humus content and its fractions of main stratigraphic units of Yedoma and corresponding parts of taberal deposits layer (% of sample weight).

YEDOMA						TABERAL DEPOSITS					
	TOC	**Humus**	**Humins**	**Humic acids**	**Fulvic acids**	**Depth, m**	**TOC**	**Humus**	**Humins**	**Humic acids**	**Fulvic acids**
Unit 4	3.57	0.55	1.58	0.27	0.28	3.9	1.43	0.5	0.93	0.25	0.25
Unit 3	3.41	1.56	1.86	0.83	0.73	5.9	0.77	0.28	0.49	0.12	0.17
Unit 2	2.07	0.76	1.32	0.39	0.37	6.9	0.63	0.22	0.42	0.08	0.14
						10.5	0.98	0.38	0.6	0.16	0.22
Unit 1	1.35	0.5	0.84	0.21	0.29	12.4	0.99	0.48	0.51	0.2	0.28



Changes of TOC and main humification parameters in taberal deposits (percentage of original values in Yedoma) for borehole 2_01.



Changes of TOC (upper plot), humus and humins (middle plot) and humic/fulvic acids (lower plot) in taberal deposits relatively original values depending on the time of talik existence.

Most upper layer of taberal deposits had not been taken in account due to assumed "contamination" with young organics form the Holocene lacustrine deposits.

<u>Average rates of **TOC** depletion under this particular lake can be estimated as **0.05% per year, humus - 0.075% per year; humins - 0.037% per year, humic** and **fulvic acids - 0.077 and 0.072% per year** correspondingly.</u>

POTENTIAL FUTURE RESEARCH TOPICS

Cryostratigraphy.

Goal: Collect information for better understanding of potential consequences of permafrost degradation.

Objectives: Mapping of spatial variability of distribution of ground ice at the permafrost table;
Estimation of quantity and quality of SOM potentially available to be involved into biogeochemical cycle;
Understanding of the effect of cryogenic process on SOM transformation.

Monitoring.

Goal: Estimate response of coupled permafrost-vegetation system to the changing climate.

Objective: Complement program of observations on the existing permafrost monitoring network with ecological and hydrological studies to understand changes in magnitude of the vegetation impact on permafrost response to climate changes and feedback from the process of permafrost degradation to ecosystems.

COMPLEX OBSERVATIONS

Collaborative Research: Vegetation And Ecosystem Impacts On Permafrost Vulnerability

(NSF award 1417908/1417700/1417745)

THERMAL CONDUCTIVITY MEASUREMENTS

TERRESTRIAL SURVEY

Canopy cover;
Tree biomass;
Snag biomass and density
Trees per m

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

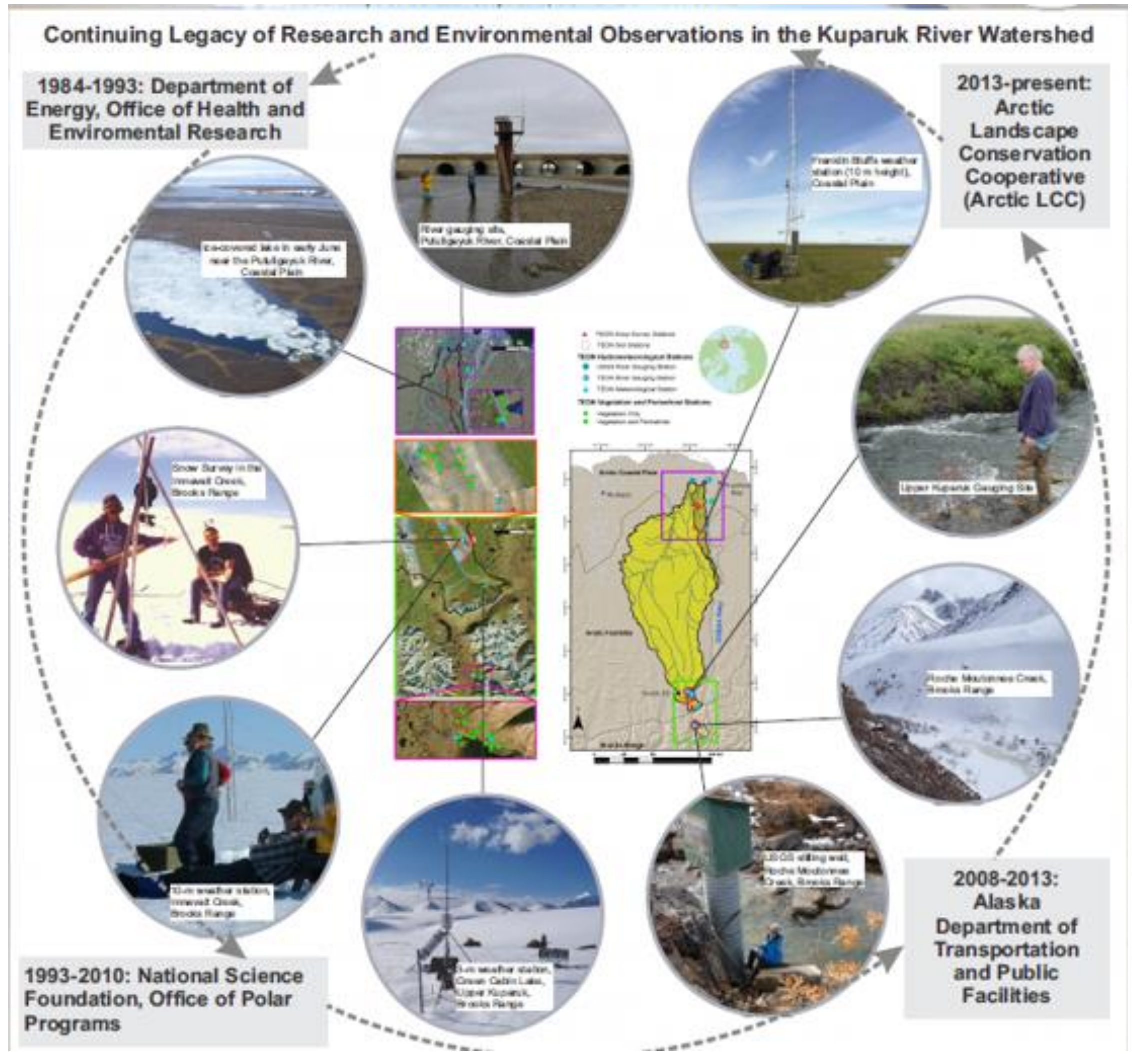
SOIL
Thaw depth;
Organic layer depth;
Carbon content in organic and mineral layers;

Soil bulk density and moisture

COMPLEX OBSERVATIONS

Terrestrial Environmental Observing Network (TEON) – the Kuparuk River, Alaska's Arctic, USA

The project is funded by Arctic Landscape Conservation Cooperative (Arctic LCC), U.S. Fish and Wildlife Service. The long-term Kuparuk network was established in 1984 by the WERC research group lead by Prof. Douglas Kane (UAF). The vegetation observations are conducted by the USFWS Arctic Refuge (Janet Jorgenson, Katie Ordnahl, Robert Lieberman), permafrost observations are made by the UAF GI Permafrost Laboratory (Vladimir Romanovsky, Bill Cable), soils are studied by USDA-Natural Resources Conservation Service (Nathan Parry) and data modelling is performed by the USGS Alaska Science Center (Dennis Walworth).



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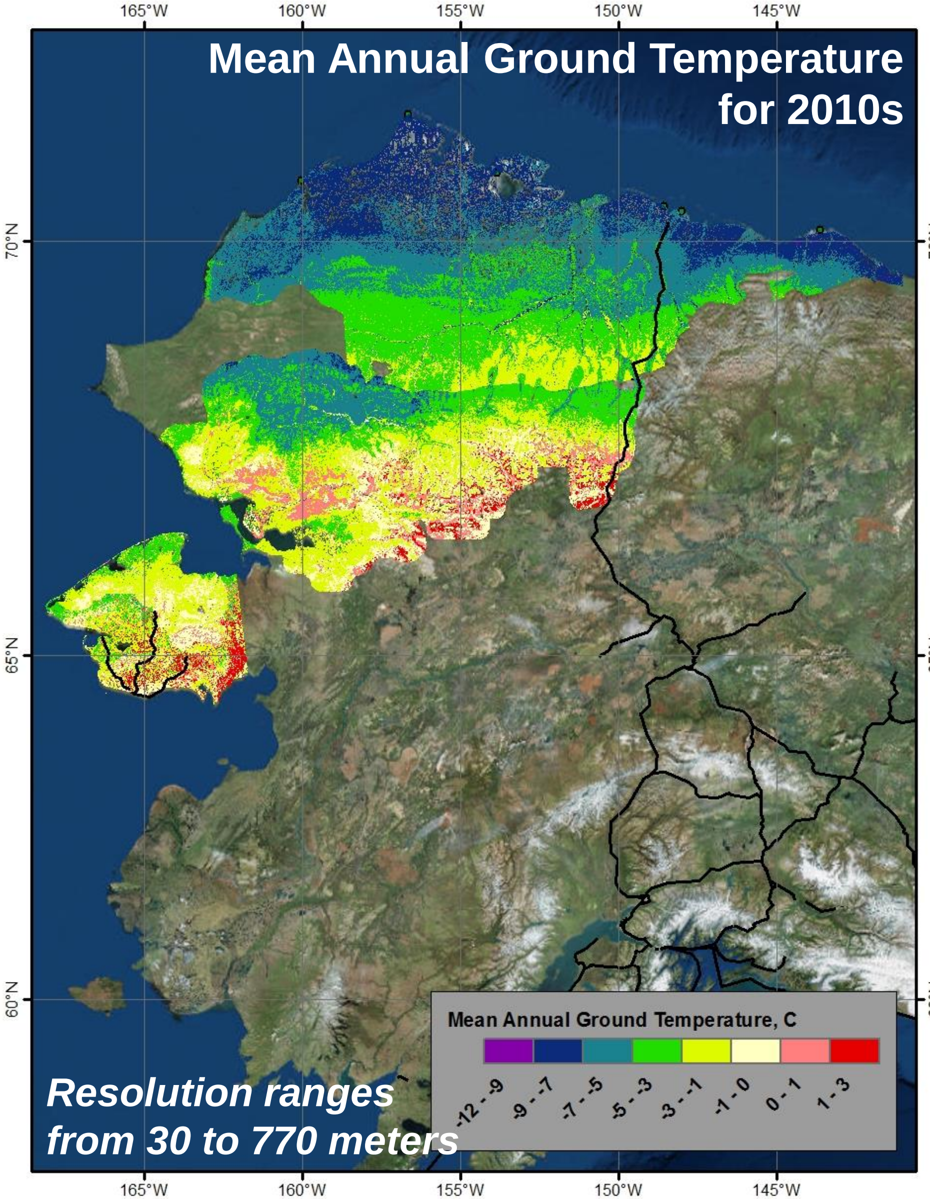
Modeling.

Goal: Forecast of the future changes of permafrost distribution and thermal state under various scenarios of climate changes.

Objective: Development and improvement of high-resolution coupled models of permafrost.

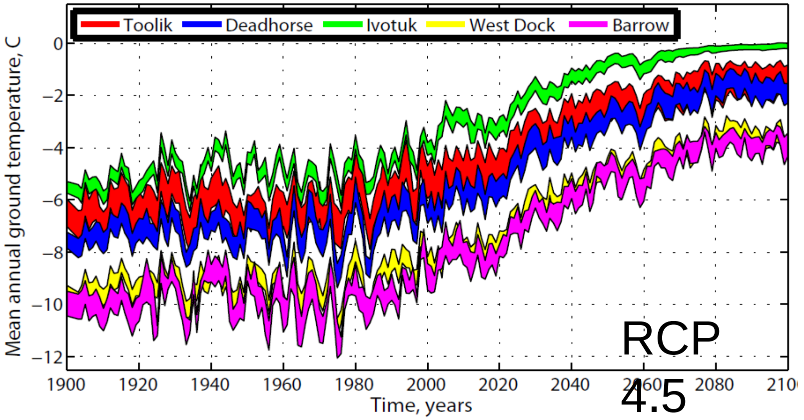
High-resolution temperature modeling



Results are available on-line at

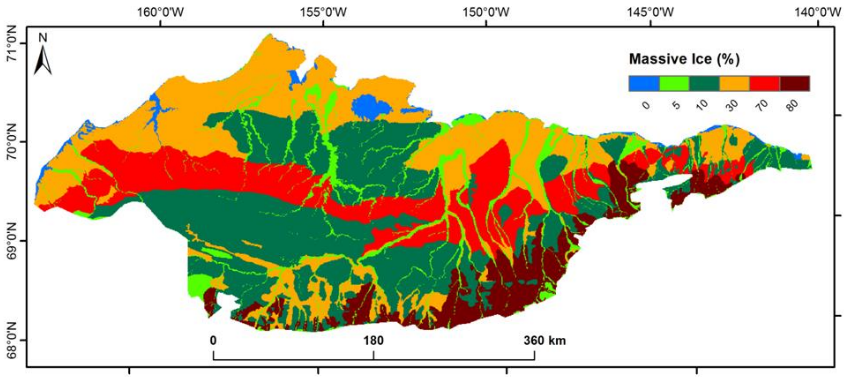
http://permamap.gi.alaska.edu

Projections of the ground temperature



Potential ground surface subsidence

Ice content along the North Slope of Alaska



Modeled potential thaw settlement between 2000 and 2090 years from