Effects of increased temperature and precipitation on soil biogeochemical processes in Cambridge Bay, Canada

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Permafrost soil

Permafrost is rock or soil that remains at or below freezing for at least two consecutive years.

Frozen peatland soil from the Hudson Bay Lowlands, Canada

Mineral soil sediment deposit in Siberia

Cryoturbated soil from the North Slope of Alaska

(Schuur et al. 2008)

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Source:International Permafrost Association, 1998.
Circumpolar Active-Layer Permafrost System (CAPS), version 1.0.

Distribution of permafrost

22.8 x 10^6 km^2

(23.9% of the Northern hemisphere land mass, Zhang et al. 1999)

SOC storage in permafrost

1035 Pg (billion tons)

(Hugelius et al. 2014)

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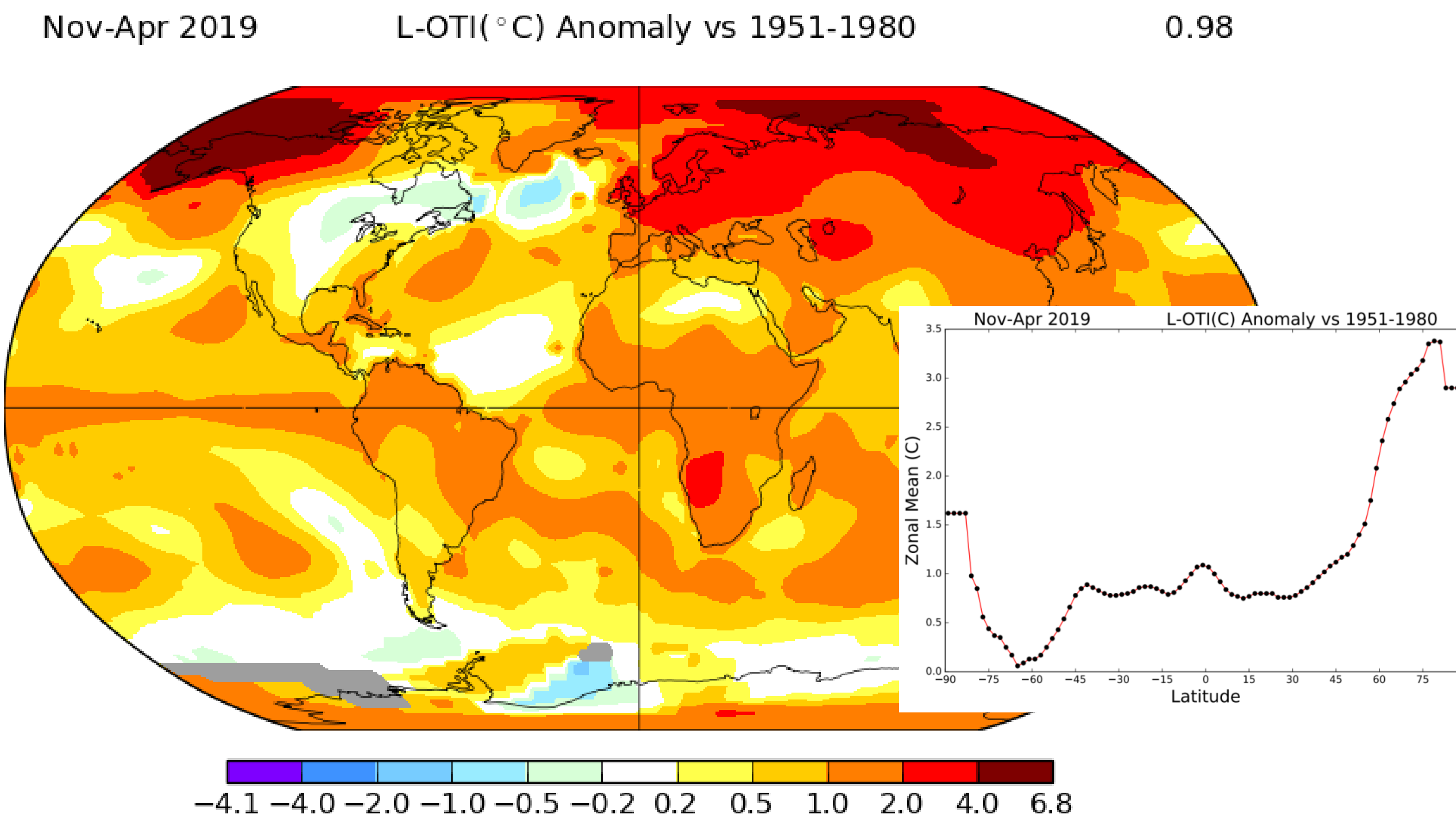
Global surface temperature



Global mean surface temperature change in NH cold season compared with 1951-1980 average

GISTEMP Team(2019) https://data.giss.nasa.gov/gistemp/

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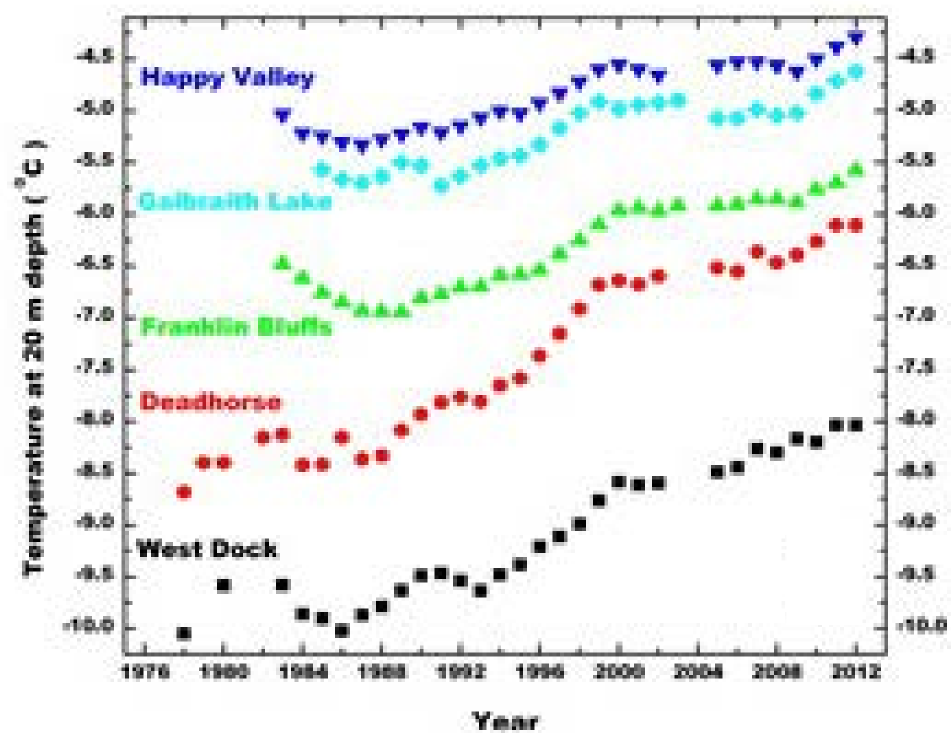
Climate change and its impacts on permafrost soils

- Temperature increase
- Precipitation change
  - 7.5~18.1% increase by 2090
- Thawing, increase active layer depth
  - 15~50% degradation of permafrost until 2050
- Change in a type of ecosystem
  - Tundra area -> Boreal shrubs and trees

(Reviewed by Jahn et al. 2010)



Time series of annual permafrost temperatures measured from north to south across Alaska in the continuous and discontinuous permafrost zones. [From V. Romanovsky, www.arctic.noaa.gov/report12]

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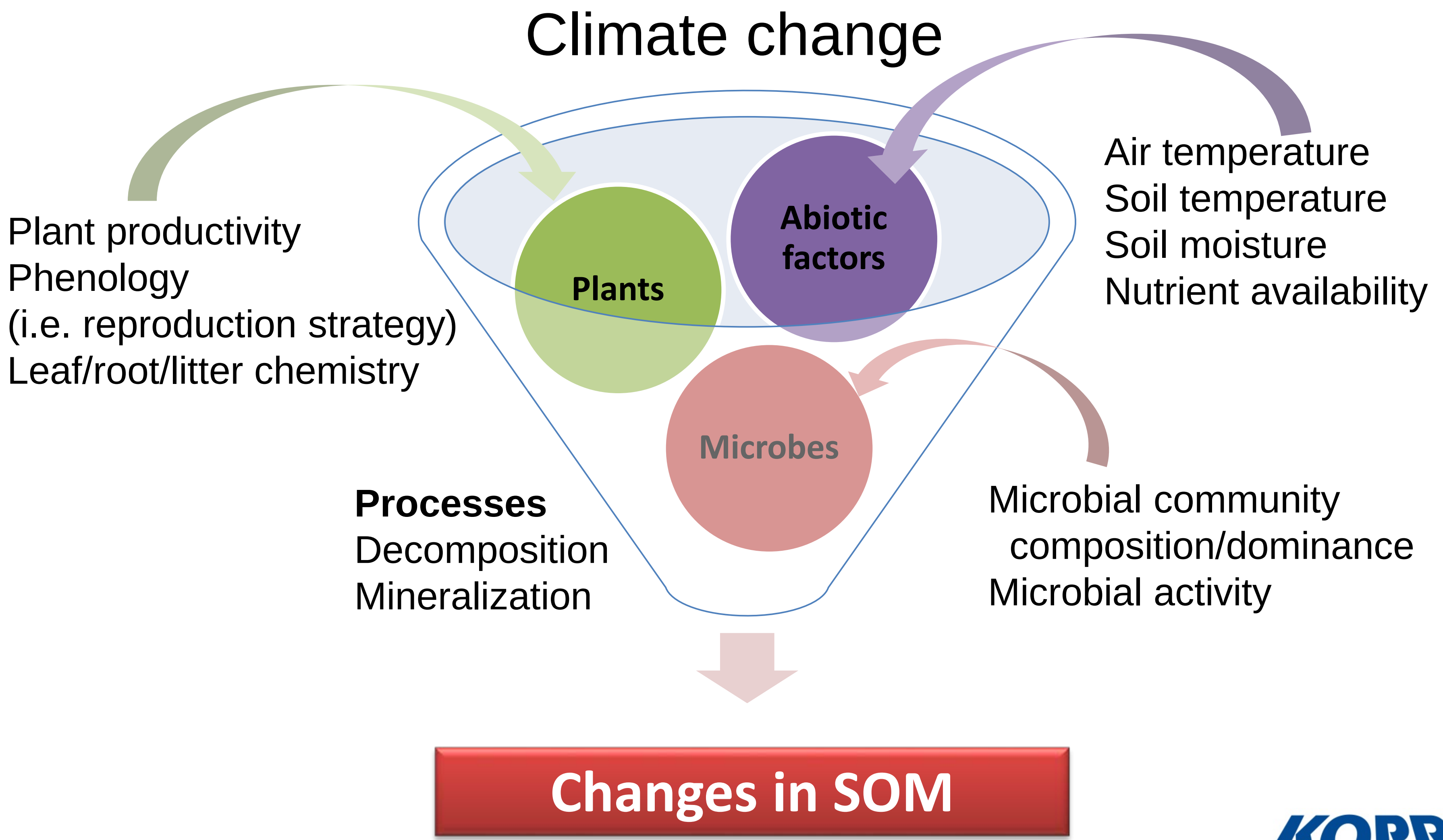
Effects of climate change on SOM



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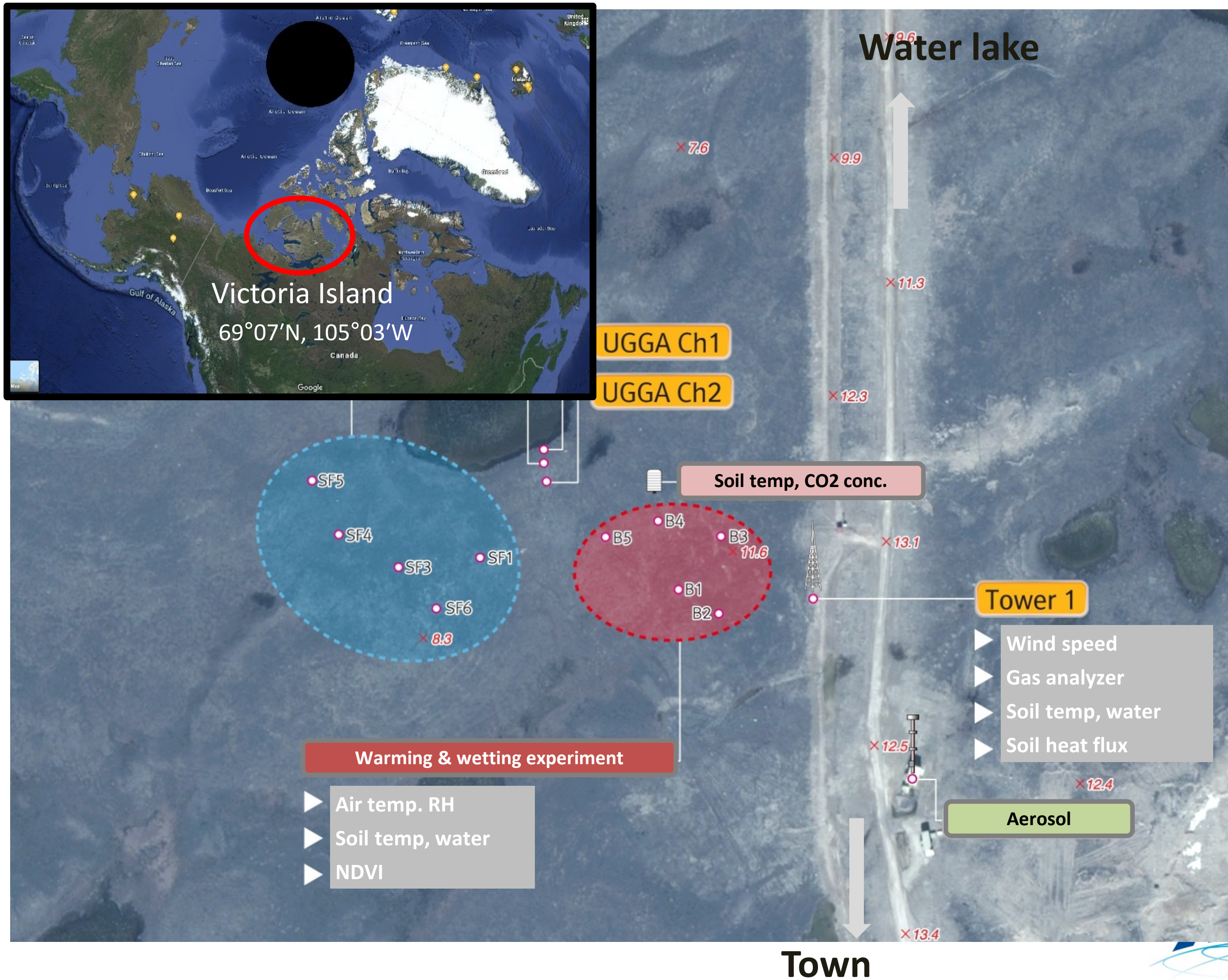
Study site



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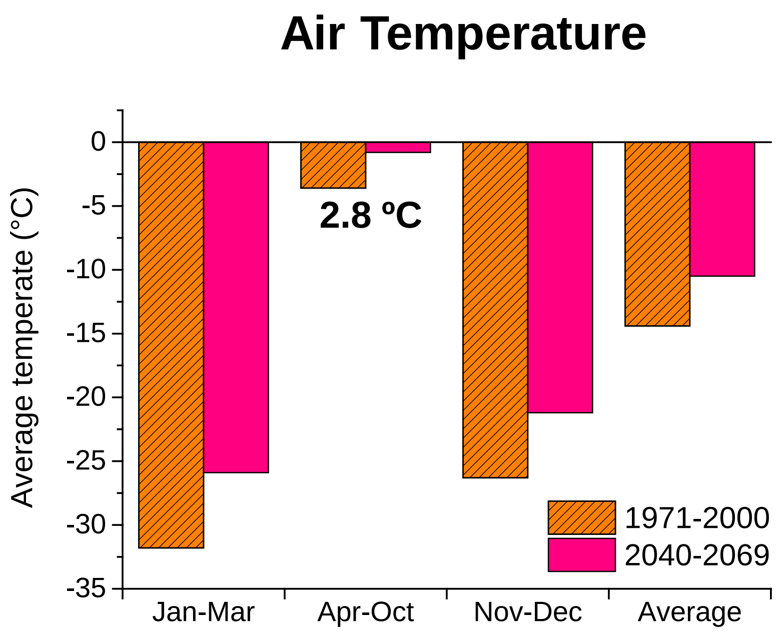
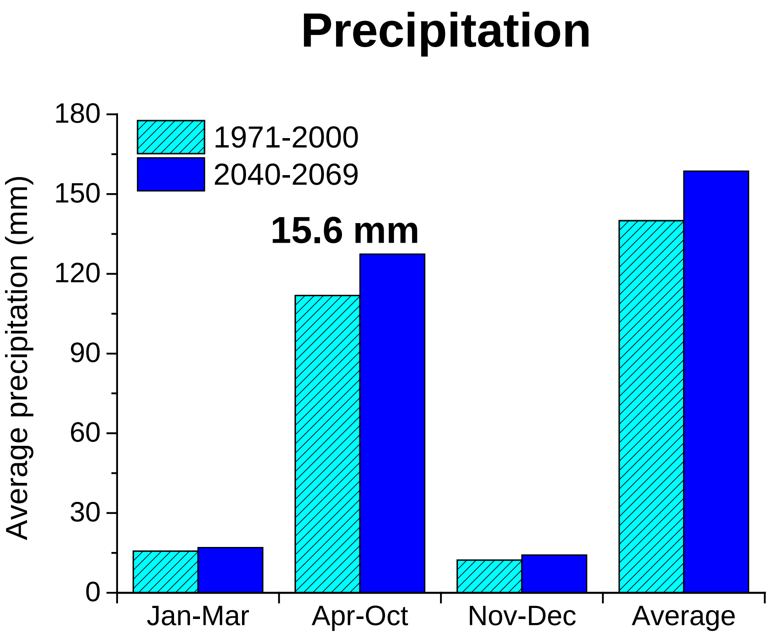
Climate change projections in Cambridge Bay





CGCM1 (Canadian Global Coupled Model) climate prediction

(Bell et al., 2003)

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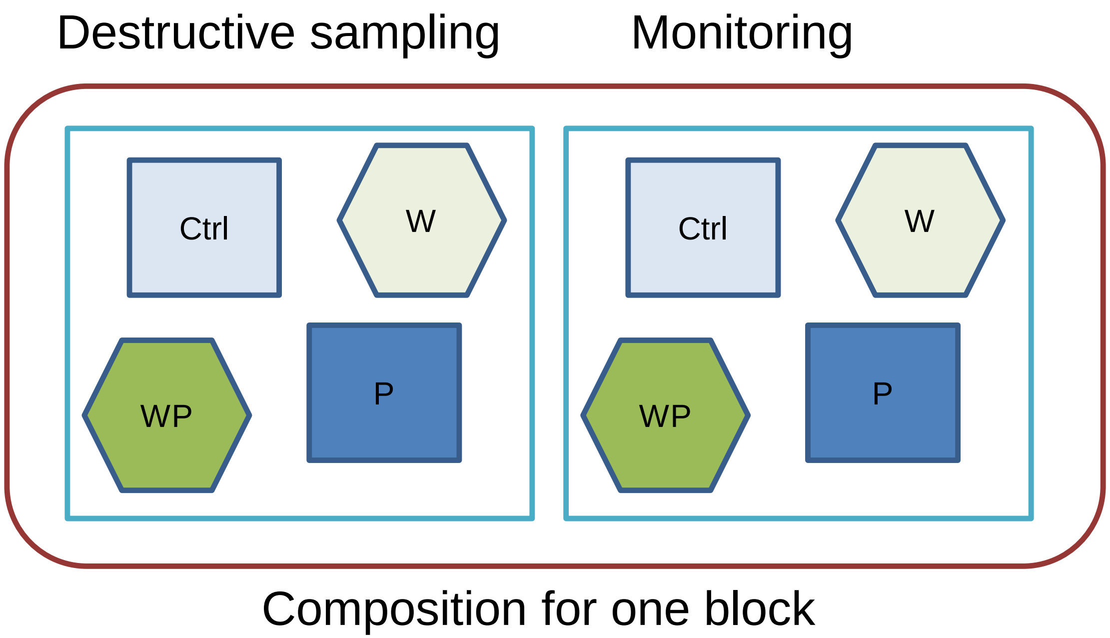
Increased temperature and precipitation



2×2 factorial design with warming & precipitation

Ctrl: control
W: warming
P: increased precipitation

- **Since 2012**
- **Warming by Open Top Chambers (2 m basal diameter)**
- **Precipitation: 2 L/plot/week**
- **OTCs & precipitation operation: July ~ early October**

Warming & watering

Year		OTC Set up	OTC Removal	Warming period (d)	Watering	Added water (L)
2012	1	7/10	10/6	89	7/27, 8/3, 8/10, 8/17, 8/31, 9/7, 9/21	14
2013	2	7/3	10/8	98	7/20, 7/26, 8/9, 8/15, 9/7, 9/13, 9/27 ※ 8/23-9/9 OTC was destroyed due to strong wind	14
2014	3	6/21	9/24	96	6/26, 7/3, 7/10, 7/24, 8/7, 8/14, 8/21, 8/28, 9/11	18
2015	4	6/27	9/24	90	7/3, 7/16, 7/30, 8/6, 8/13, 8/20, 8/27, 9/3, 9/11	18
2016	5	6/20	9/30	103	6/24, 7/1, 7/7, 7/14, 8/4, 8/12, 8/18, 8/25, 9/1, 9/8, 9/15, 9/22	24
2017	6	6/15	9/21	99	6/23, 6/29, 7/7, 7/14, 7/21, 8/4, 8/10, 8/24, 8/31, 9/7	20
2018	7	6/20	9/15	88	6/28, 7/5, 7/12, 7/19, 7/26, 8/2, 8/9, 8/16, 8/23, 8/30, 9/6	22
2019	8	6/22	9/23	94	6/27, 7/4, 7/11, 7/18, 7/25, 8/1, 8/8, 8/15, 8/22, 8/29, 9/5	22

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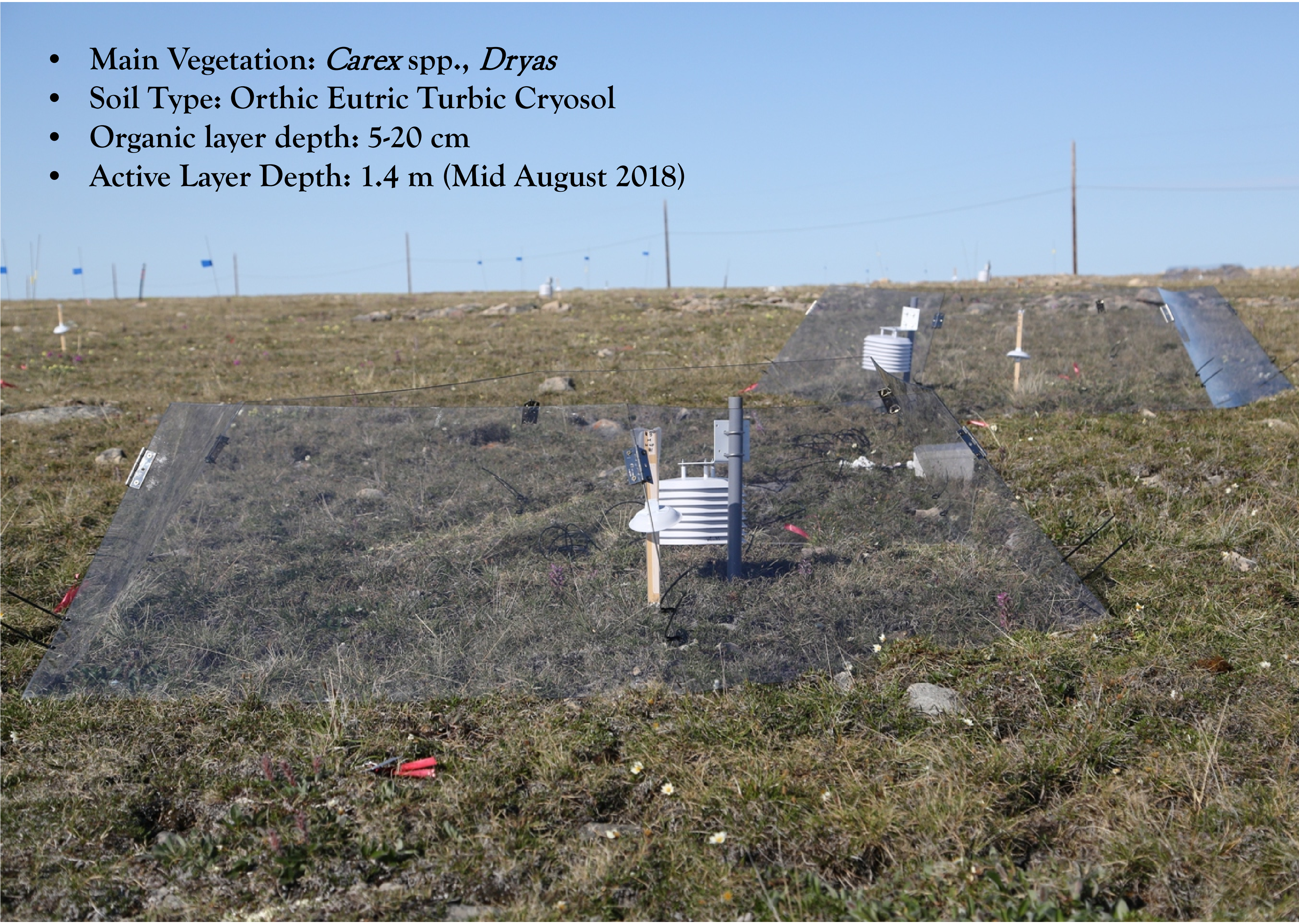
- Main Vegetation: *Carex* spp., *Dryas*
- Soil Type: Orthic Eutric Turbic Cryosol
- Organic layer depth: 5-20 cm
- Active Layer Depth: 1.4 m (Mid August 2018)



Measurements

- **Air and soil environments monitoring** : Air temperature and relative humidity (25 cm), soil temperature and moisture content (5 cm depth)
- **Plant** parameters: Plant species, vegetation coverage, NDVI (normalized difference vegetation index)
- **Soil** properties (Organic, mineral layers)
  - Physical properties: moisture content, bulk density, texture
  - Chemical properties: pH, electrical conductivity, inorganic nitrogen, DOC (quantity and quality)
- **Gas** fluxes: CO_2
- **Soil microbial community** structure (Pyrosequencing) and microbial biomass (Phospholipid fatty acids (PLFA) analysis)
- **Microbial activity**: extracelluar enzyme activity

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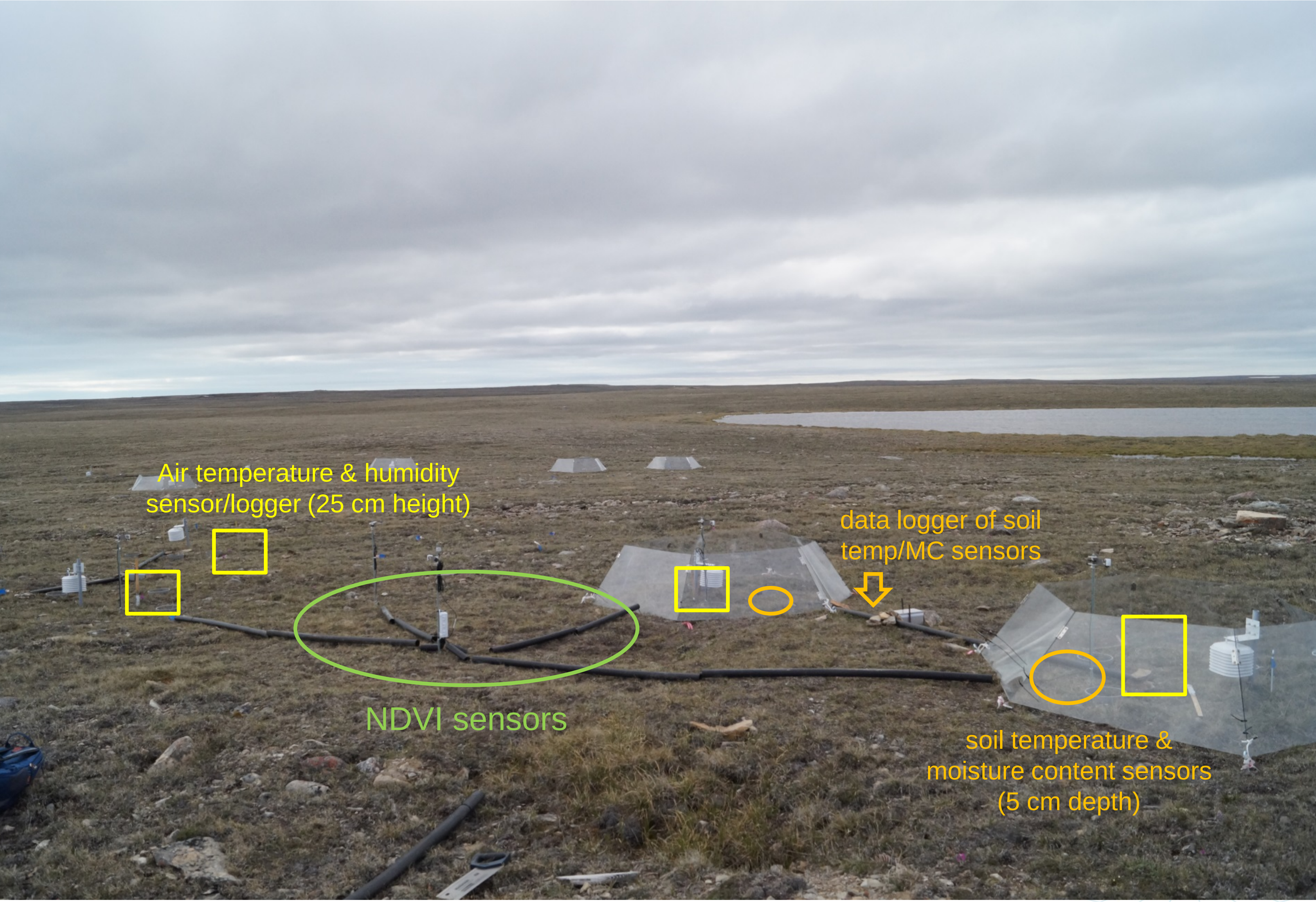
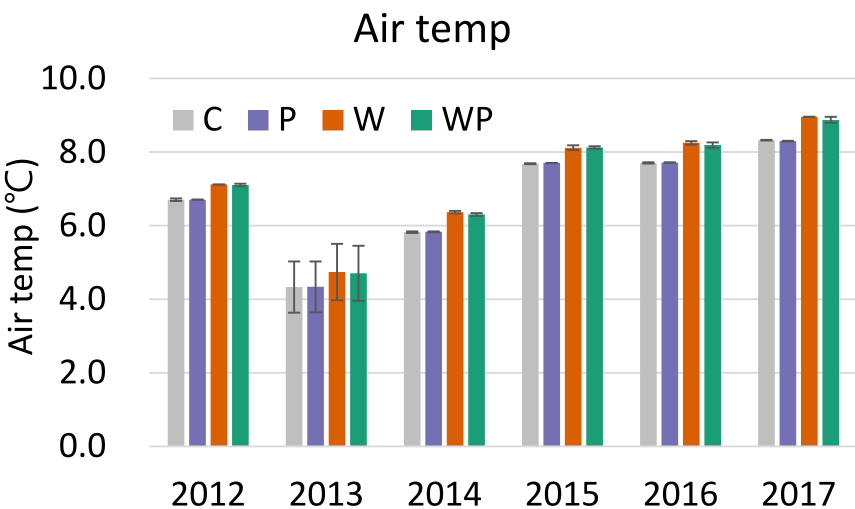
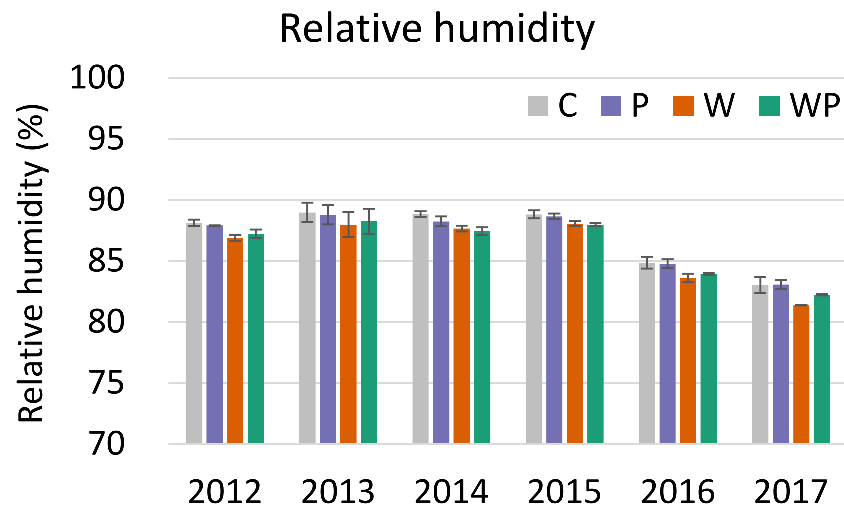

Air temperature & humidity
sensor/logger (25 cm height)
data logger of soil
temp/MC sensors
NDVI sensors
soil temperature &
moisture content sensors
(5 cm depth)

Environmental data





Air temp	Warming*Wetting	Warming only
Warming	***	***
Wetting	n.s.	-
W*W	n.s.	-
random	(slope) block, year	(slope) block, year

RH	Warming*Wetting	Warming only
Warming	***	***
Wetting	n.s.	-
W*W	***	-
random	(slope) block, year	(slope) block, year

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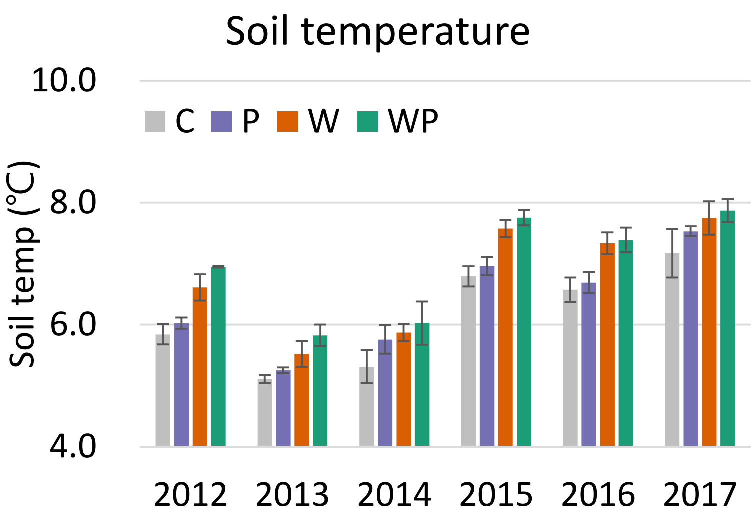
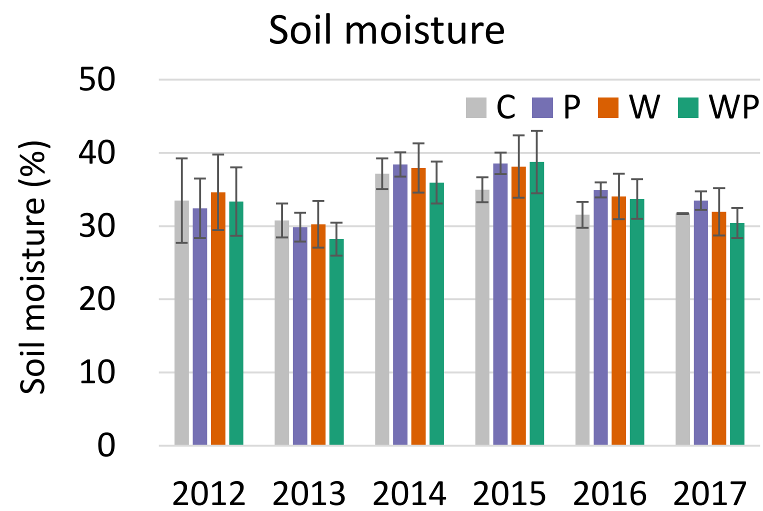
Environmental data





Soil temp	Warming*Wetting	Warming only
Warming	***	***
Wetting	n.s.	-
W*W	n.s.	-
random	(slope) year	(slope) year

Moisture	Warming*Wetting	Warming only
Warming	n.s.	n.s.
Wetting	n.s.	-
W*W	n.s.	-
random	(slope) block, year	(slope) block, year

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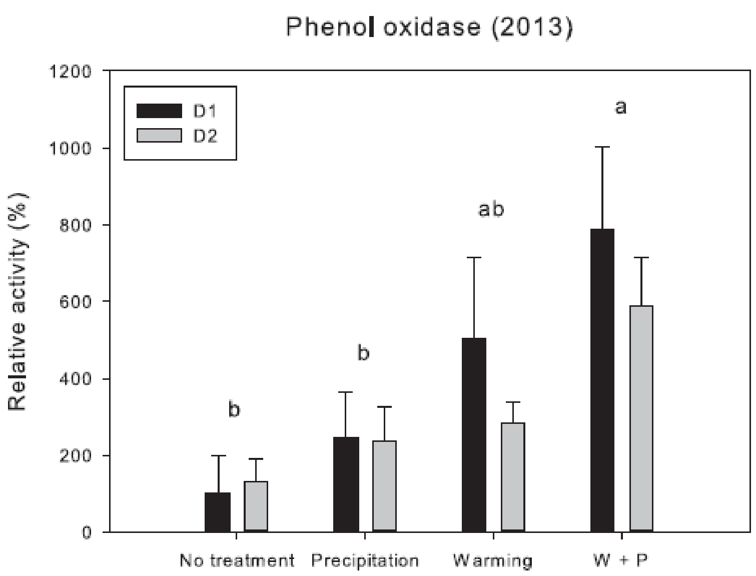
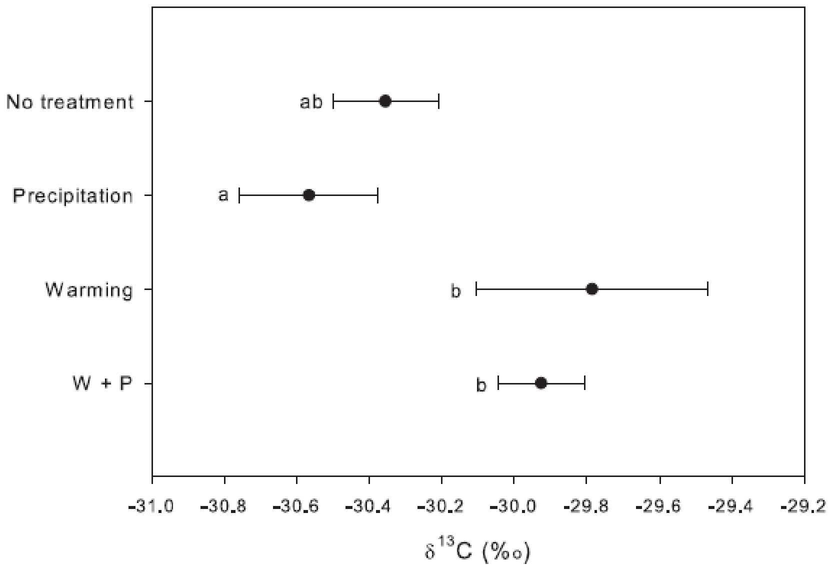
Short-term responses

- Effects of warming (after 1.5 year of manipulation)
  - Increased inorganic N content
  - Enzyme activity: increased phenol oxidase activity
  - Vegetation: drought stress

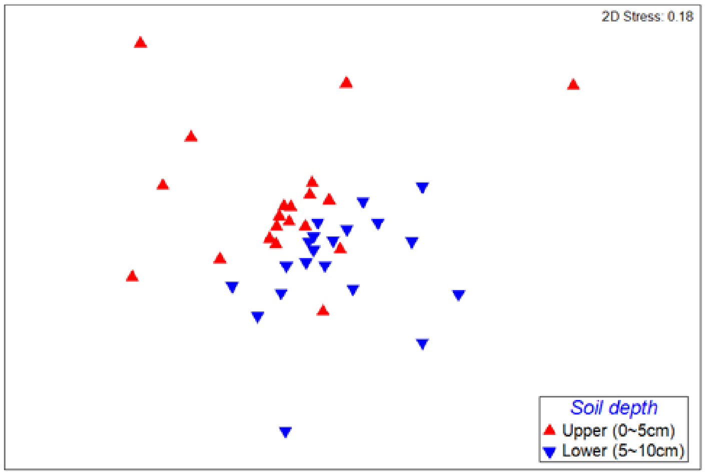
(Seo et al., 2015)

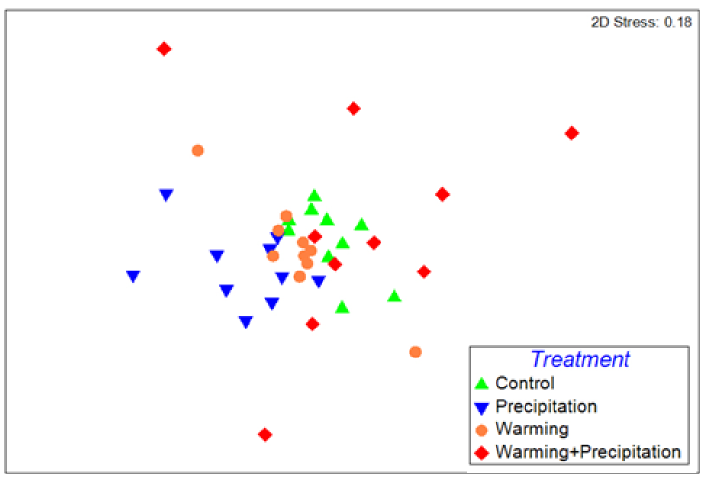




Short-term responses

Bacterial community





- PERMANOVA results
  Block, treatment, depth showed significant differences
- *post hoc* pairwise t-test
  Significant difference between control and precipitation plots

Groups	t	P (perm)	Unique perms	P (Monte Carlo)
C vs. P	1.197	**0.003**	7175	0.1417
C vs. W	1.085	0.048	7093	0.3107
C vs. W+P	1.104	0.007	7106	0.2674
P vs. W	1.140	0.015	7150	0.2152
P vs. W+P	1.163	0.012	7183	0.183

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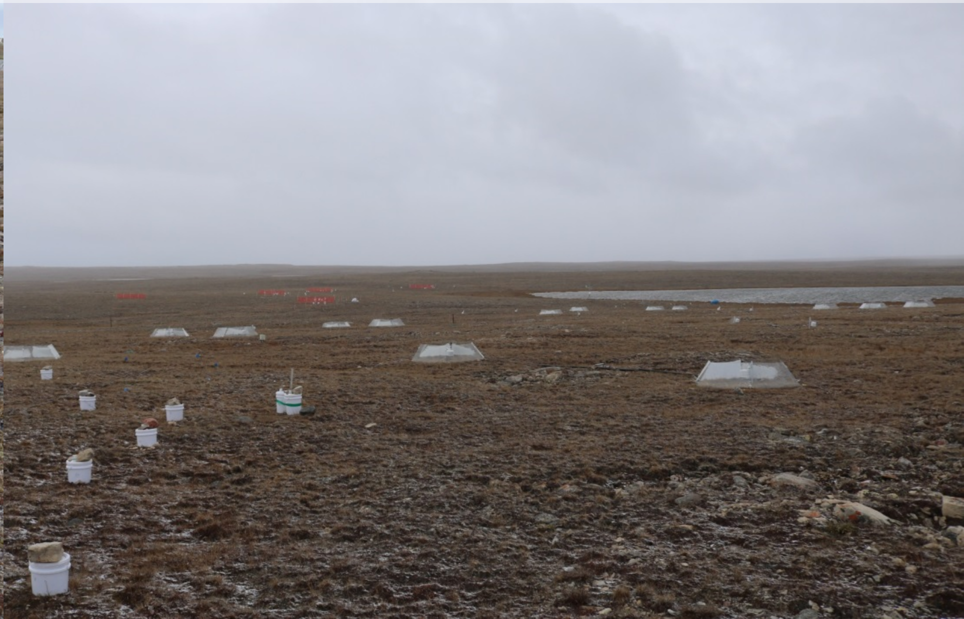
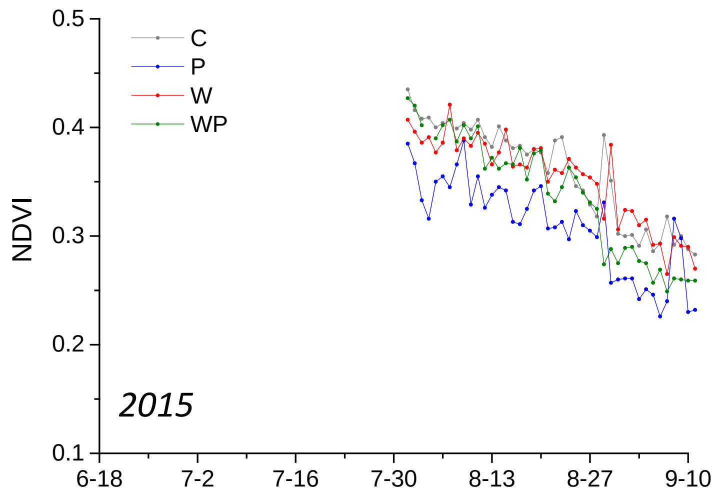
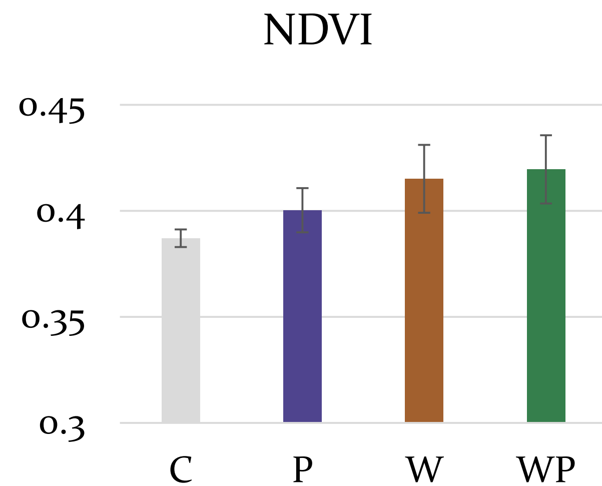
After 7-8 years



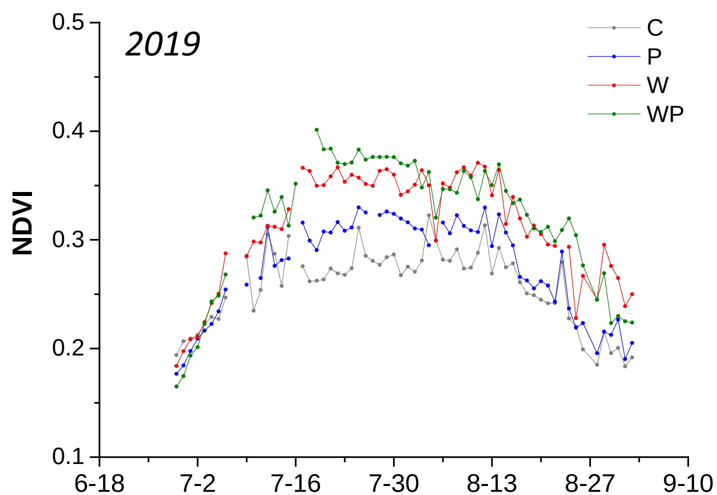
Plant responses

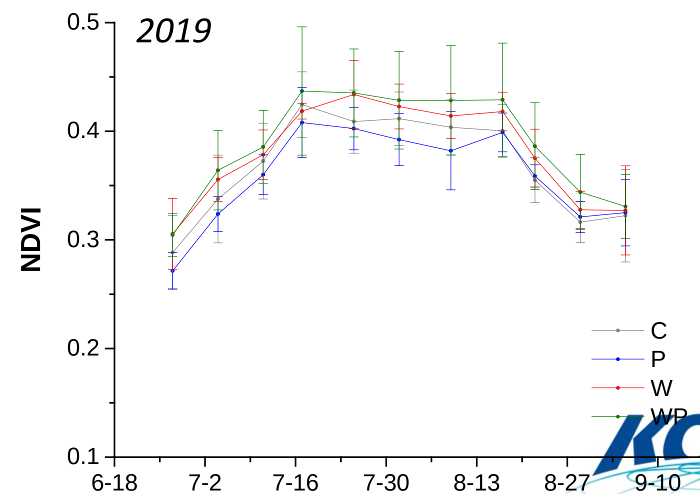
Normalized Difference Vegetation Index





Measured on Jul 28, 2018





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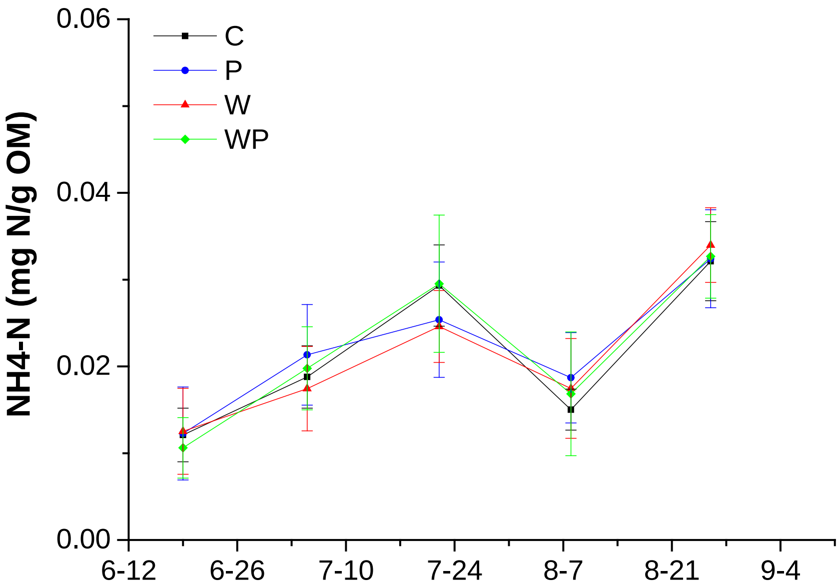
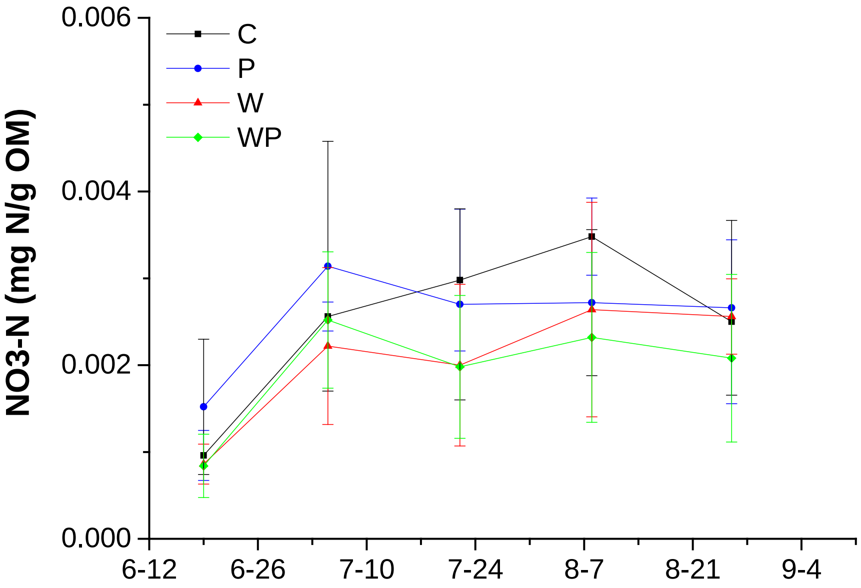
Soil responses





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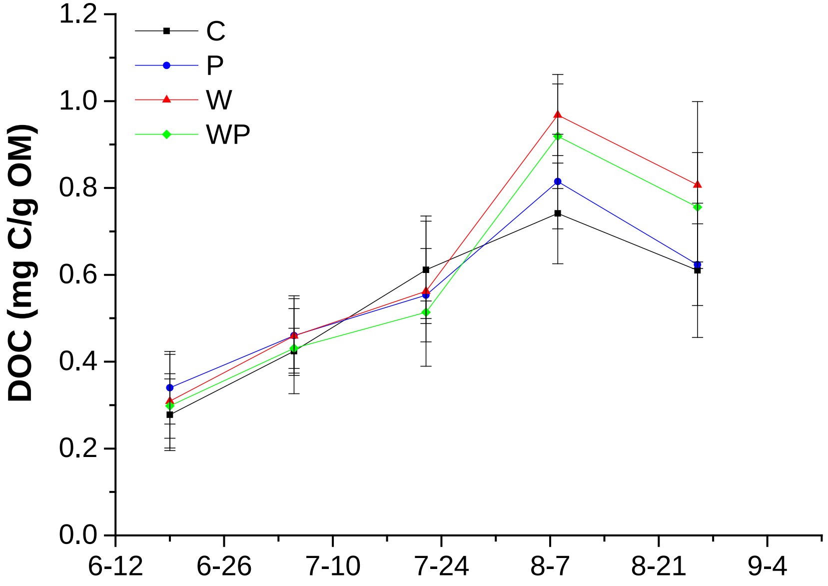
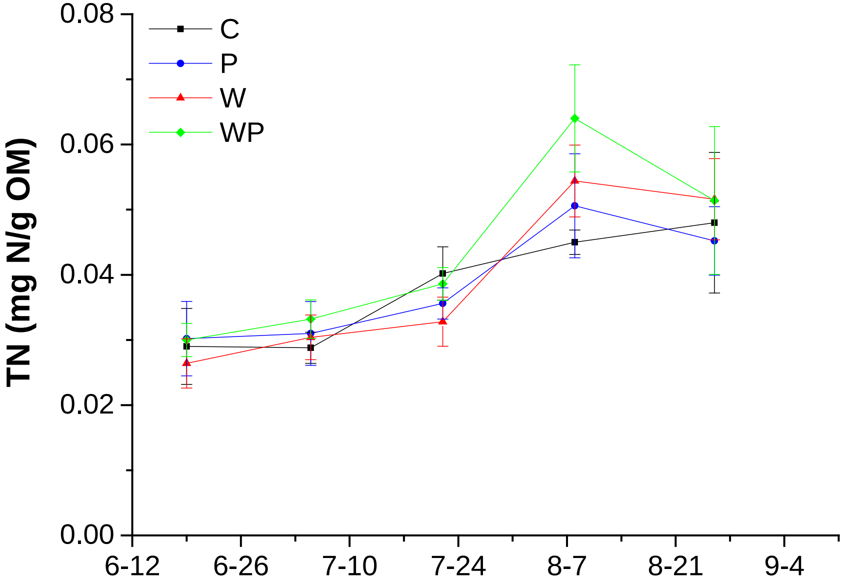
Soil responses





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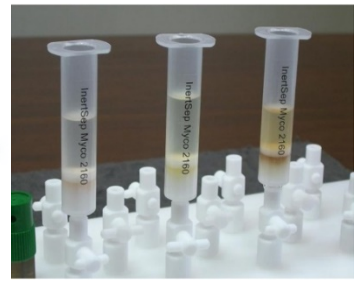
DOM analysis procedure using 15 Tesla Fourier transform ion cyclotron resonance (FT-ICR) mass spectrometry

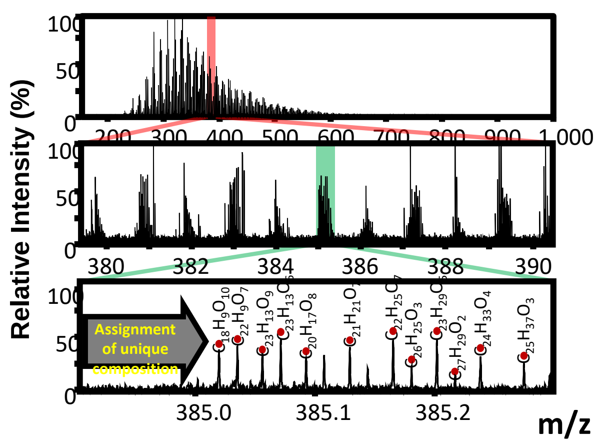
Soil sampling & hand-shacking

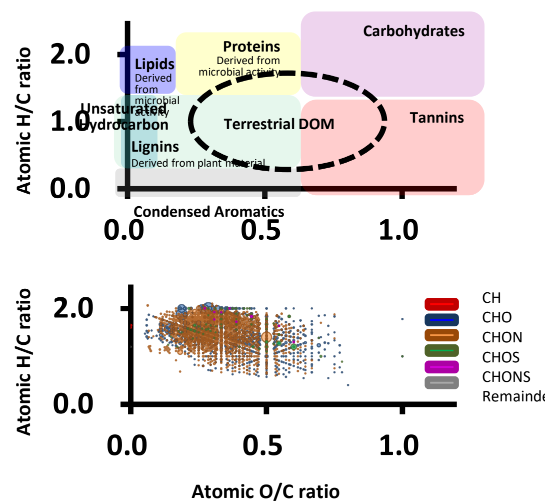
Extraction with ultra pure water



Solid Phase Extraction

15T FT-ICR MS analysis





Chemical composition of DOM (Frequency-based)

Date	Trt	Tot. Peak	CHO	CHON	CHOS	CHONS
6-28	C	1977	69.3	29.4	0.3	0.9
	W	2014	71.3	27.5	0.2	0.8
7-14	C	1926	69.5	29.7	0.1	0.6
	W	1975	72.8	26.3	0.0	0.6
7-31	C	1918	66.3	32.8	0.0	0.8
	W	2161	63.6	35.5	0.2	0.8
8-17	C	1547	74.9	23.0	0.8	1.1
	W	1708	76.9	21.3	0.5	1.0
9-2	C	1821	73.5	24.6	0.4	1.2
	W	1890	70.7	26.9	0.8	1.4

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Chemical composition of DOM (Intensity-based)

Date	Trt	CHO	CHON	CHOS	CHONS	CHNS
6-28	C	80.4	18.4	0.2	1.0	0.0
	W	76.3	15.7	7.2	0.7	0.1
7-14	C	79.6	19.6	0.1	0.6	0.1
	W	82.5	16.9	0.0	0.5	0.1
7-31	C	78.7	20.5	0.0	0.8	0.0
	W	76.9	22.1	0.1	0.9	0.0
8-17	C	82.9	15.3	0.7	1.0	0.1
	W	87.1	11.5	0.4	0.8	0.1
9-2	C	84.2	14.1	0.2	1.3	0.1
	W	84.7	13.0	1.1	1.2	0.1

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Molecular class distributions of the assigned formulas

Date	Trt	Lignin	Cond. aromatics	Tannin	Carbo-hydrate	Unsat. hydroC	Lipids	Protein
6-28	C	84.3	4.5	2.6	0.2	0.5	7.6	0.4
	W	79.2	4.4	4.2	0.1	0.1	11.7	0.3
7-14	C	82.6	5.9	4.1	0.0	0.1	6.1	1.2
	W	81.8	5.7	3.6	0.0	0.0	8.0	0.8
7-31	C	83.2	3.4	2.3	0.0	0.1	9.6	1.3
	W	86.1	2.4	2.7	0.4	0.1	6.5	1.8
8-17	C	84.1	3.9	2.0	0.3	0.1	6.7	2.9
	W	81.4	3.0	2.0	0.2	0.0	12.7	0.6
9-2	C	84.6	4.0	2.0	0.3	0.1	8.0	1.0
	W	89.3	2.3	1.4	0.4	0.1	5.9	0.4

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Summary

- In a short term, warming combined with precipitation increased the activity of phenol oxidase
- Warming induced drought stress in vegetation
- After 7-8 years, warming slightly increased the activity of vegetation
- Warming significantly increased DOC contents at the end of growing season
- Chemical compositions of DOM did not significantly vary with either plant phenology or warming treatment

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- Funding: National Research Foundation of Korea funded by the Korean Government
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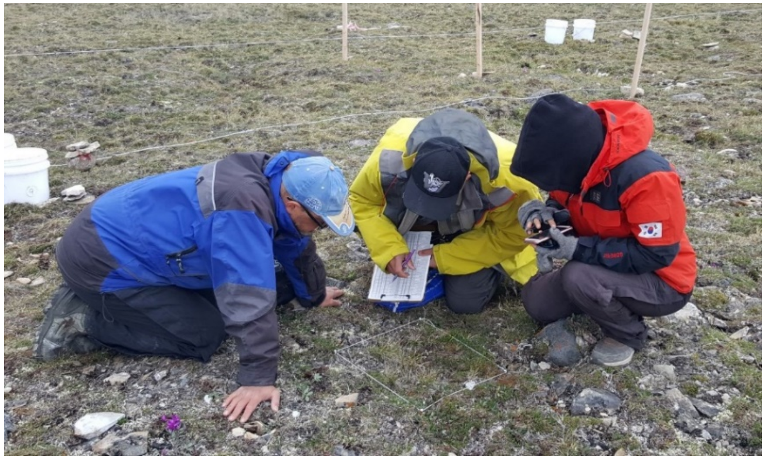
- POLAR (Canadian High Arctic Research Station) staffs
- Lab work: Sujeong Jung

Rick, Aaron, Sandi



Johann Wagner & Serguei Ponomarenko

Donald McLennan

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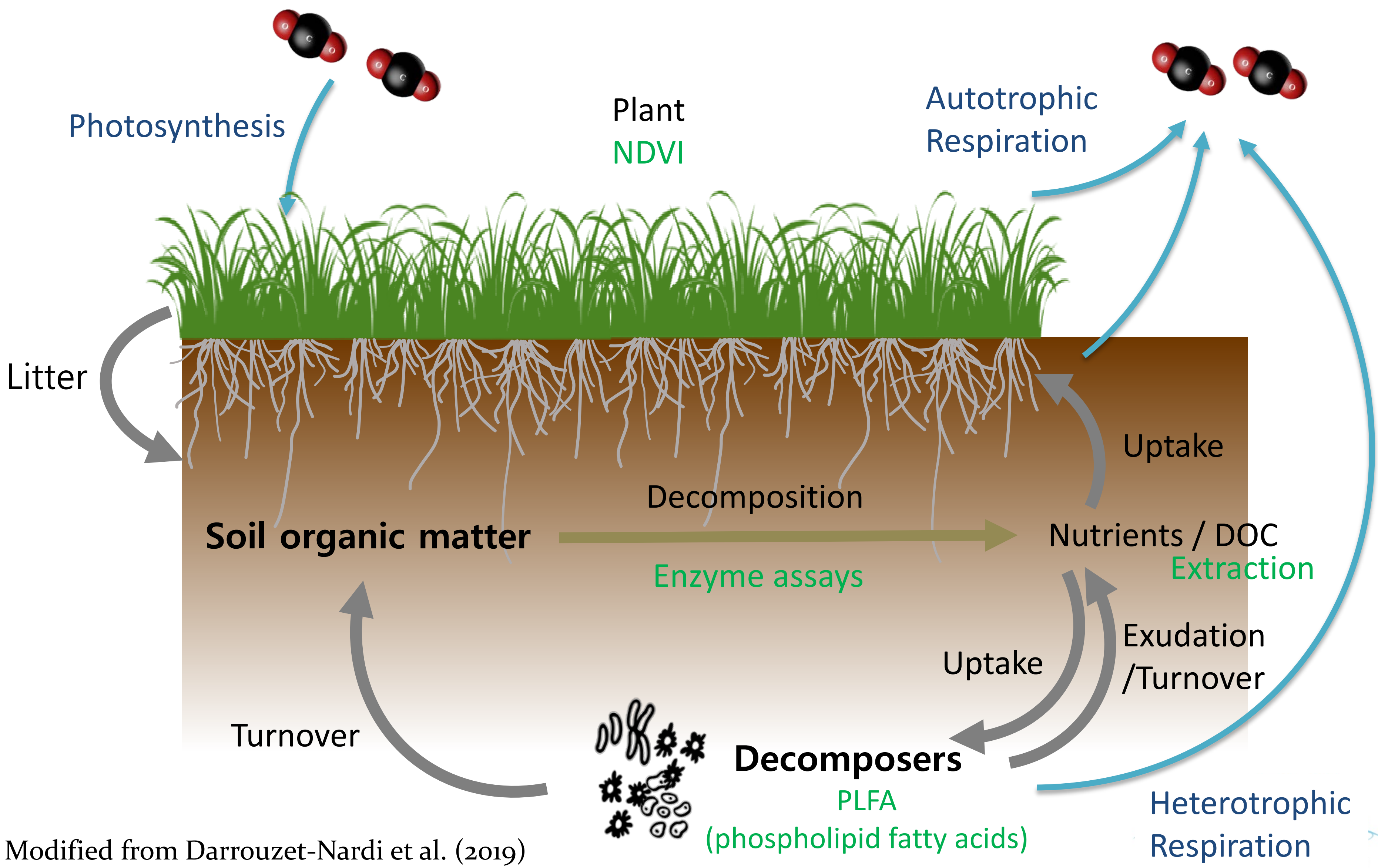
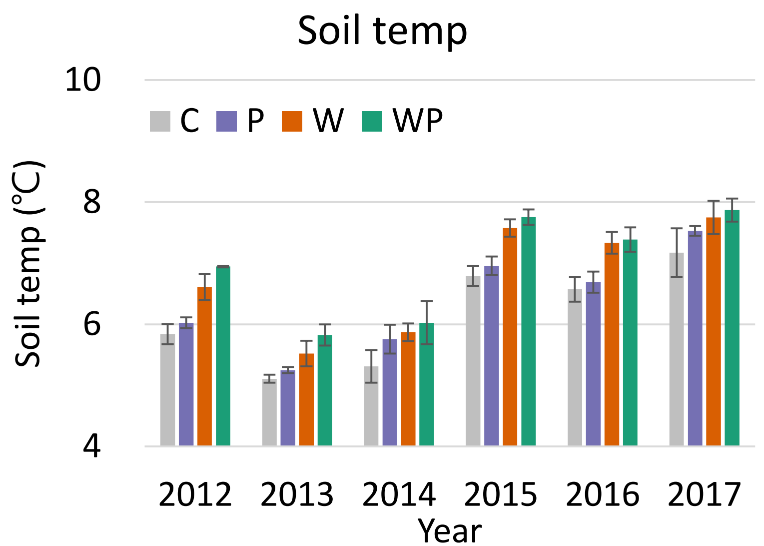
Thank you!
Quana!

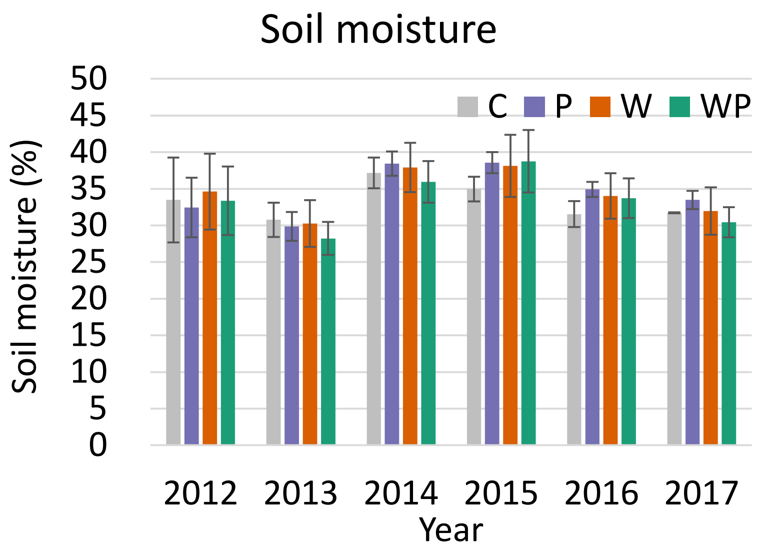
Soil Organic Matter (SOM)



Modified from Darrouzet-Nardi et al. (2019)

OTC period





Soil temp	Warming*Wetting	Warming only
Warming	***	***
Wetting	n.s.	-
W*W	n.s.	-
random	(slope) year	(slope) year

Moisture	Warming*Wetting	Warming only
Warming	n.s.	n.s.
Wetting	n.s.	-
W*W	n.s.	-
random	(slope) block, year	(slope) block, year

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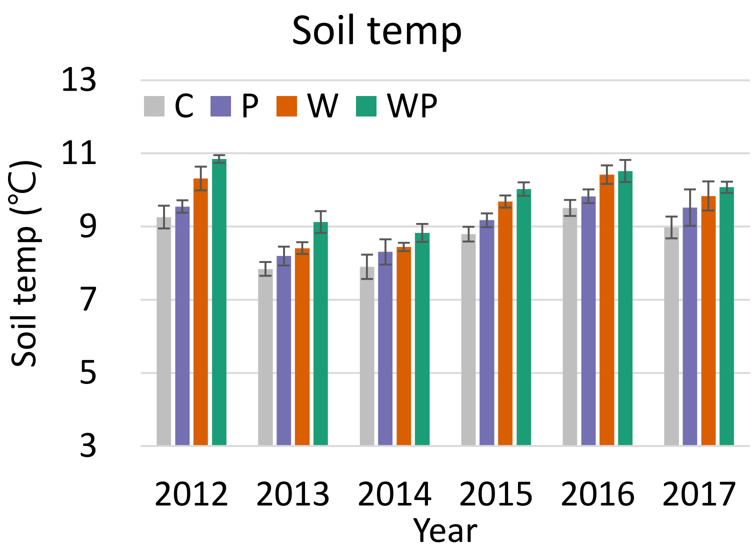
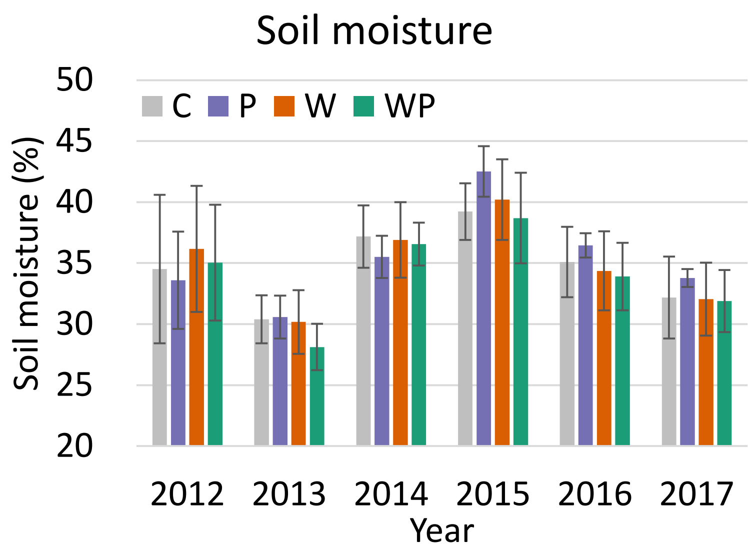
July





Soil temp	Warming*Wetting	Warming only
Warming	***	***
Wetting	***	-
W*W	n.s.	-
random	(slope) year	(slope) year

Moisture	Warming*Wetting	Warming only
Warming	n.s.	n.s.
Wetting	n.s.	-
W*W	n.s.	-
random	(slope) block, year	(slope) block, year

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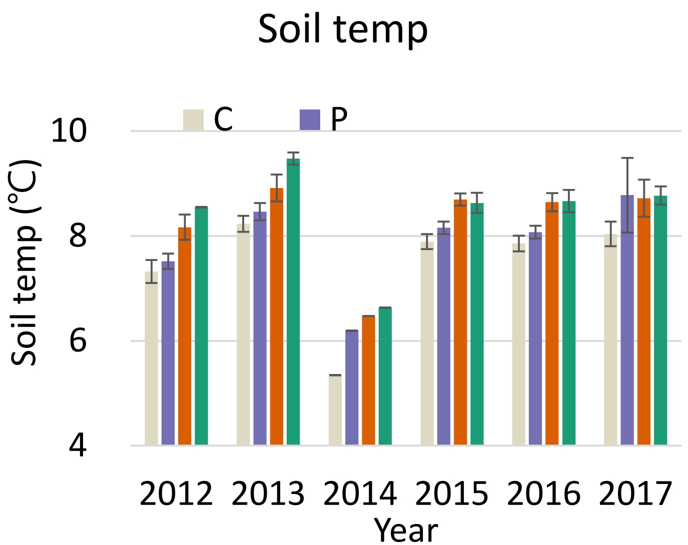
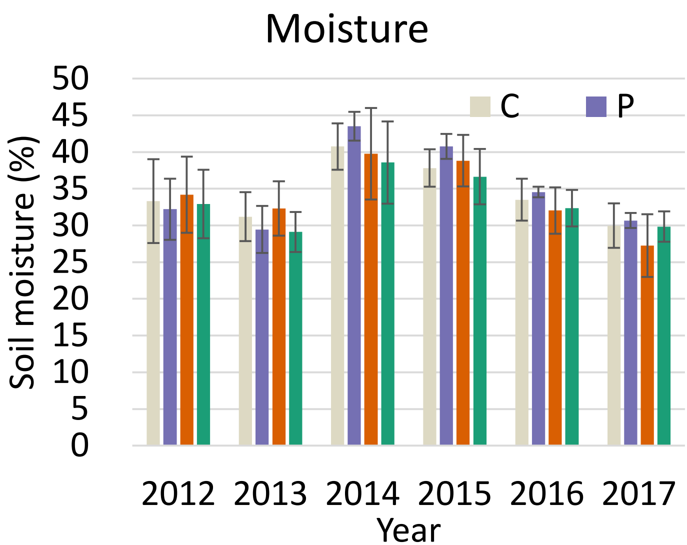
August





Soil temp	Warming*Wetting	Warming only
Warming	***	***
Wetting	**	-
W*W	n.s.	-
random	(slope) year	(slope) year

Moisture	Warming*Wetting	Warming only
Warming	n.s.	n.s.
Wetting	n.s.	-
W*W	n.s.	-
random	(slope) block, year	(slope) block, year

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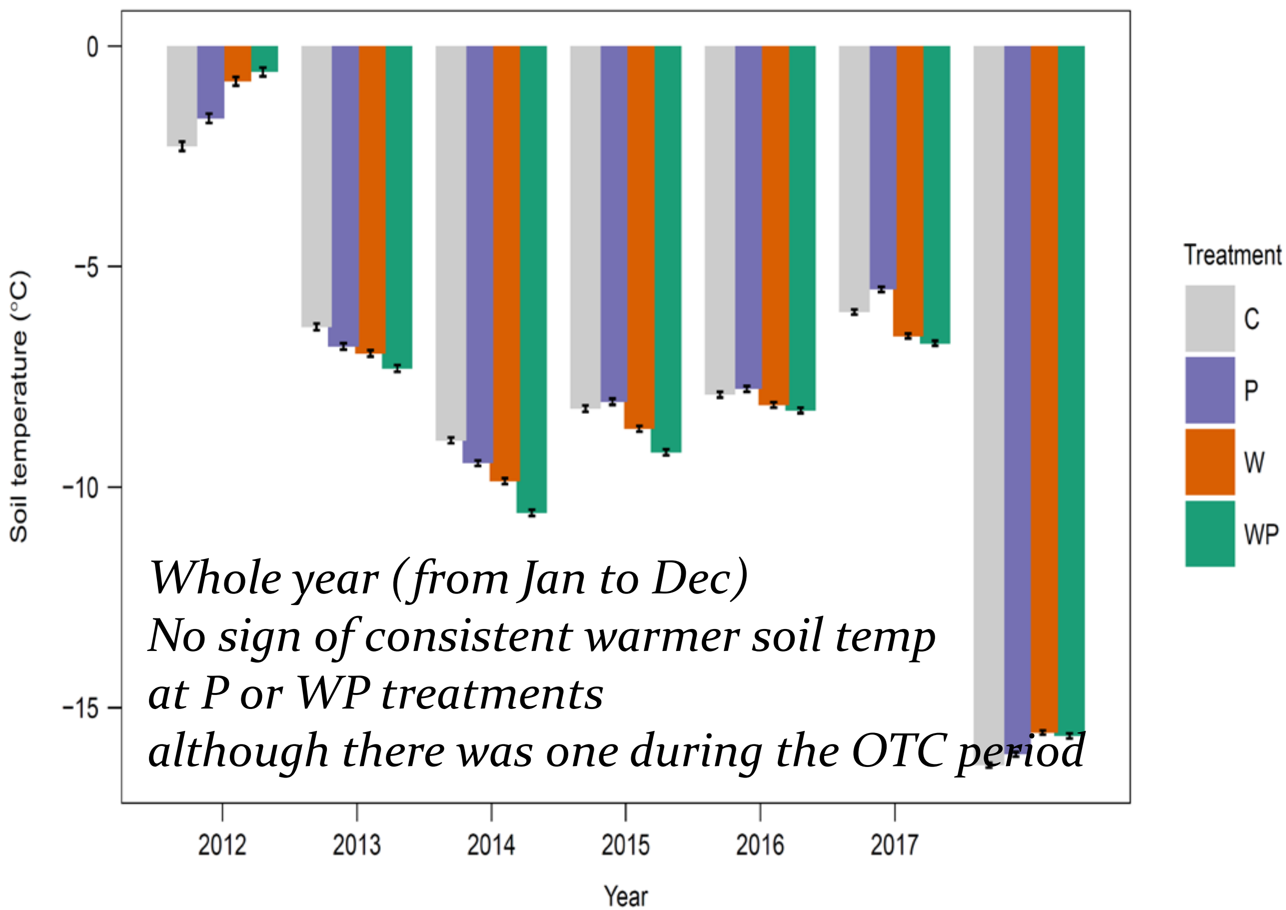
Wetting → soil temp rise in Jul and Aug



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Wetting → soil temp rise in Jul and Aug

- No difference in air temp induced by wetting
- Difference in soil temp induced by wetting, avr 0.3 degC in Jul & Aug
- Sensor accuracy: 0.21 – 0.25 degC, resolution: 0.02 – 0.03 degC

OTC, avr	C	P	W	WP
Air temp	6.96	6.97	7.48	7.43
RH	86.87	86.65	85.61	85.91
Soil temp	6.11	6.28	6.78	6.97
Moi	32.83	34.48	35.22	33.65

July, avr	C	P	W	WP
Air temp	10.14	10.16	10.81	10.78
RH	82.16	81.98	80.66	80.88
Soil temp	8.68	9.05	9.52	9.88
Moi	35.22	35.60	35.64	34.58

Aug, avr	C	P	W	WP
Air temp	8.71	8.73	9.20	9.18
RH	86.00	85.71	84.64	84.90
Soil temp	7.47	7.80	8.27	8.44
Moi	35.30	35.25	35.38	34.98

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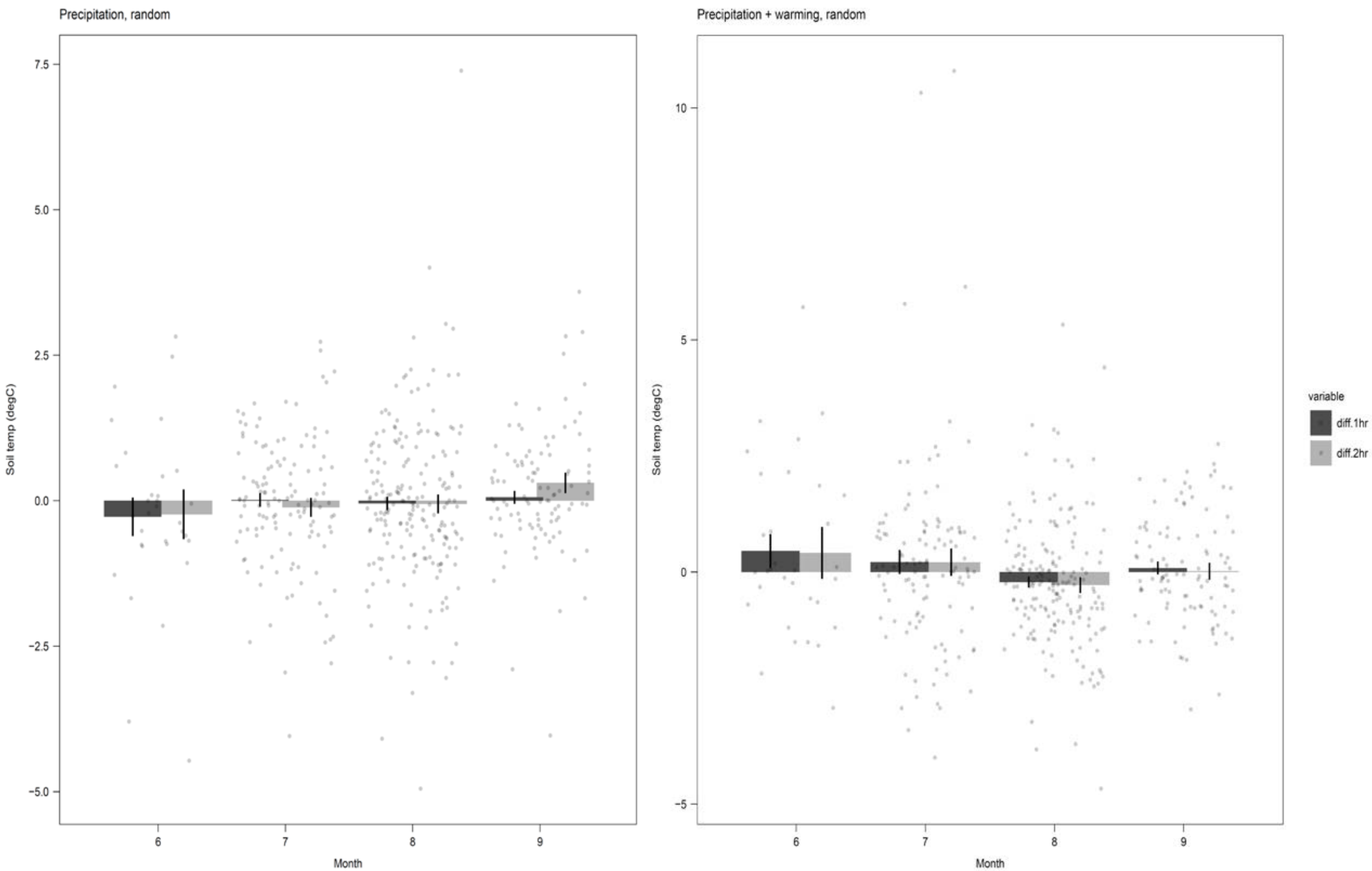
Wetting → soil temp, random sampling



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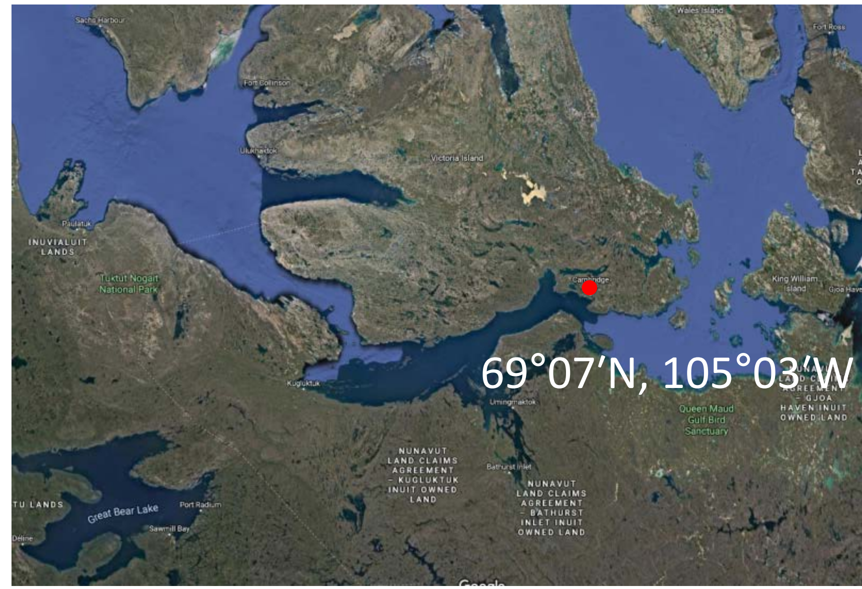
30
60
70
80

Study site



Southeast coast of Victoria Island, Nunavut

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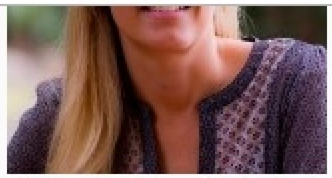
Associate Professor Kerrylee Rogers is a coastal ecogeomorphologist and recent ARC Future Fellow in the School of Earth, Atmospheric and Life Sciences at the University of Wollongong (UOW). Between 2005, when she graduated with PhD from UOW, and 2012 she was appointed as an environmental scientist with the New South Wales Government, before returning as a research associate at UOW in 2012. *[full biography]*



1100-1130	**Morning Tea & Exhibition** | *Gallery Level 1*		
	Concurrent Session A		
Room	**Stream 1 | *Ballroom A***	**Stream 2 | *Ballroom B***	**Stream 3 | *Ballroom C***
Theme	C sequestration – opportunities, costs, trade-offs	Ecological significance and function of SOM	Blue carbon
Chair	Mike Beare & Elaine Mitchell	Brian Wilson & Liz Coonan	Di Allen & Christina Asanopoulos
1130-1144	Full inversion tillage offers opportunity for increased C sequestration, implications and agronomic effects *Dr Sam McNally*	Abiotic nitrogen immobilization affect organic matter composition and stoichiometry *Professor Johannes Lehmann*	Investigating the relationship between soil organic carbon and age in temperate blue carbon ecosystems *Christina Asanopoulos*
1145-1159	Dynamics of residue 13C and 15N at various depths in diverse soils *Dr Monika Gorzelak*	Convergence and divergence of carbon pathways by soil organic matter formation *Professor Yakov Kuzyakov*	Laboratory capacity for the analysis of Soil Organic Matter in Pacific Island Region and the Blue Carbon Initiative *Dr Vincent Lal*
1200-1214	Carbon sequestration opportunity in South Australian sandy soils with subsoil clay addition *Dr Amanda Schapel*	SOM chemistry and its relationship to water retention and hydraulic conductivity in Canadian and Australian peat soils *Anne Yusuf*	Microbial uptake kinetics of dissolved organic carbon (DOC) compound groups from river water and sediments *Dr Helen Glanville*
1215-1229	Intensification of no-till agricultural systems: An opportunity for carbon sequestration *Dr Rodrigo Nicoloso*	Effects of increased temperature and precipitation on soil biogeochemical processes in Cambridge Bay, Canada *Dr JiYoung Jung*	Nutrient enrichment induces a shift in dissolved organic carbon (DOC) metabolism in oligotrophic freshwater sediments *Francesca Brailsford*
1230-1244	Forest conversion effects on SOM composition: Disentangling effects of parent material and litter input chemistry *Olaf Brock*	Impacts of residue quality and N input on aggregate turnover using the combined 13C natural abundance and rare earth oxides as tracers *Professor Xinhua Peng*	Predicting the carbon and nitrogen contents in soil from blue carbon environments using infrared spectroscopy *Dr Jeff Baldock*
1245-1259	*Cancelled presentation*	Is paddy-rice system a better niche for carbon sequestration? *Dr Ashim Datta*	The crucial role of organic carbon availability in driving geochemical cycles in wetland and floodplain soils