The North America and Eurasia Arctic transects:
Using phytosociology and remote sensing to detect vegetation pattern and change

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An International Polar Year initiative

Lecture presentation, European Vegetation Survey 20th Workshop, Rome, Italy, 6-9 April 2011

Major goal of the Greening of the Arctic project:

Link spatial and temporal trends of vegetation greenness observed on AVHRR satellite images to ground observations along both transects.

- ∗Climate
- ∗Vegetation
- ∗Soils
- ∗Permafrost
- ∗Spectral properties

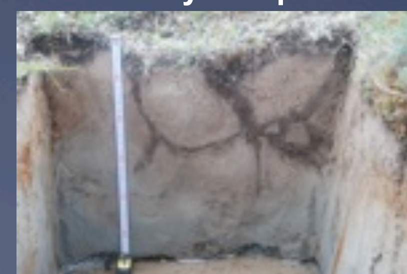

NDVI and LAI


Plant species cover


Active layer depth


Site characterizatiion

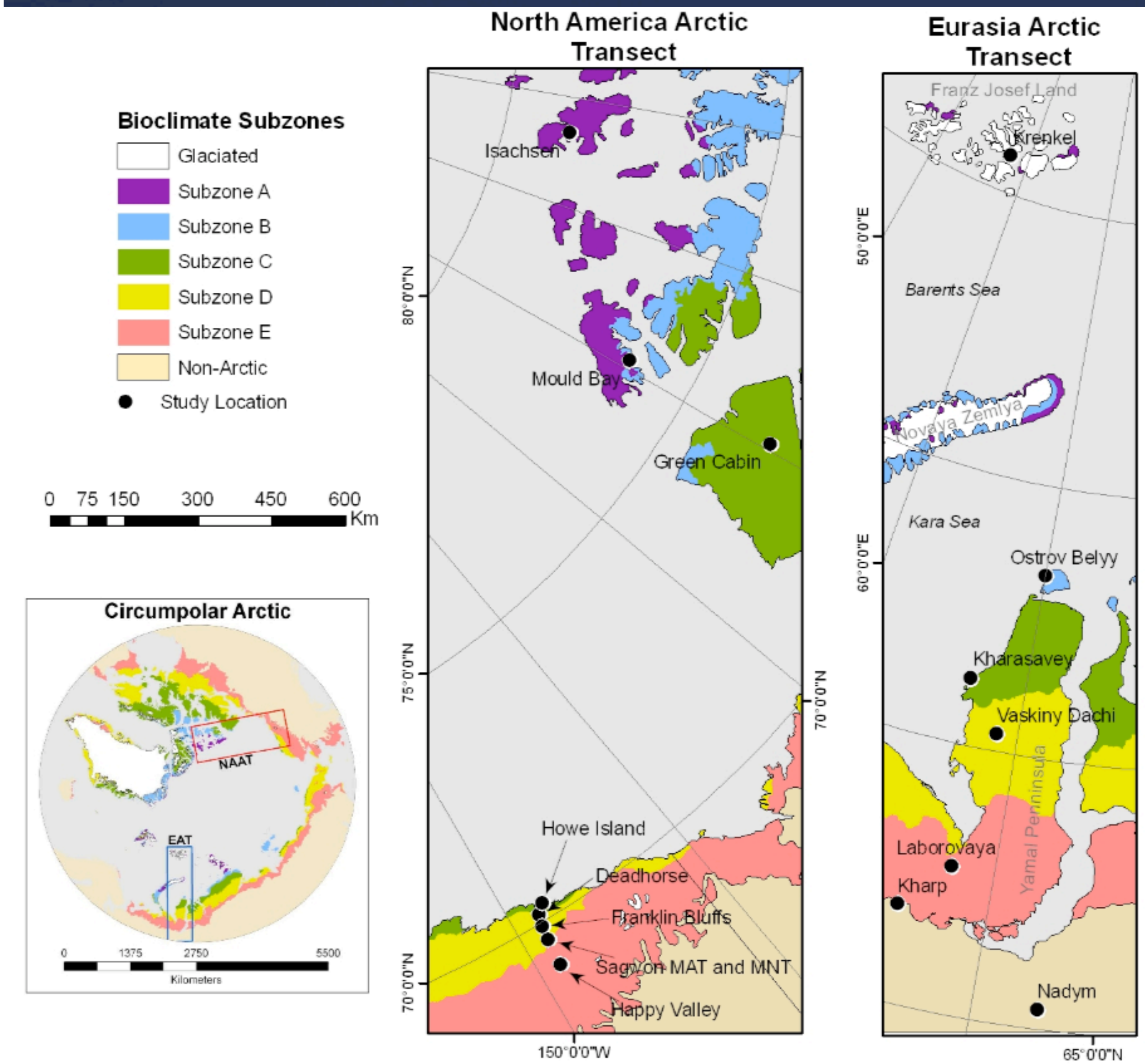

Biomass


Soil characterization


N-factor


Permafrost boreholes

Field studies along two 1800-km Arctic transects



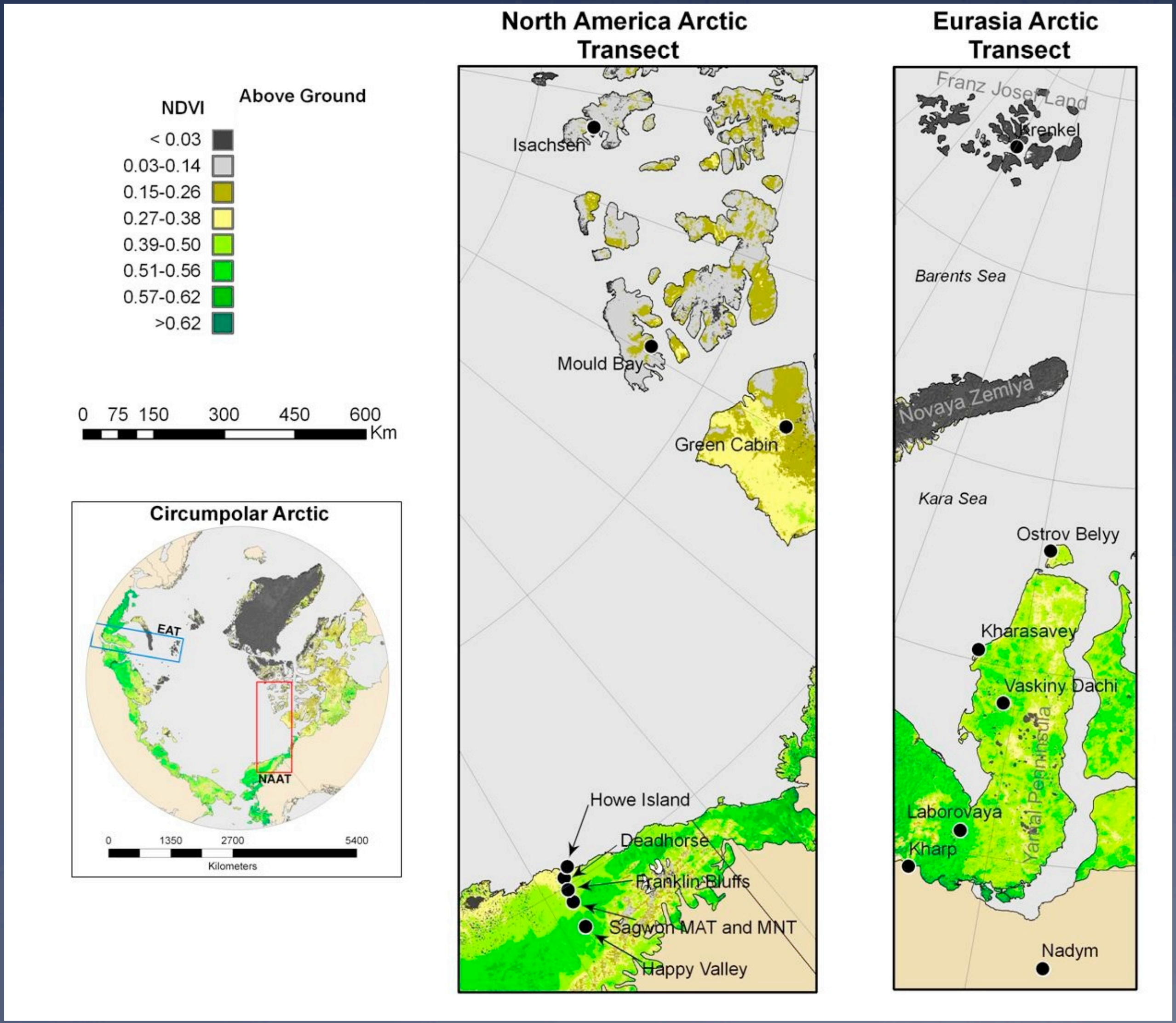
Map by Shalane Carlson, based on CAVM Team (2003)

- **North America Arctic Transect:** 2002-2006 Biocomplexity of Arctic Patterned Ground Ecosystems Project (NSF).
- **Eurasian Arctic Transect:** 2007-2010, Greening of Arctic (NASA).
- Both transects through all five Arctic bioclimate subzones.

Bioclimate Subzones

Sub-Zone	*MJT (˚C)*	*Shrubs*
A	**1-3**	**none**
B	**3-5**	**prostrate**
C	**5-7**	**hemi-prostrate**
D	**7-9**	**erect dwarf**
E	**9-12**	**low**

1-km AVHRR-NDVI patterns for the Arctic along the two transects

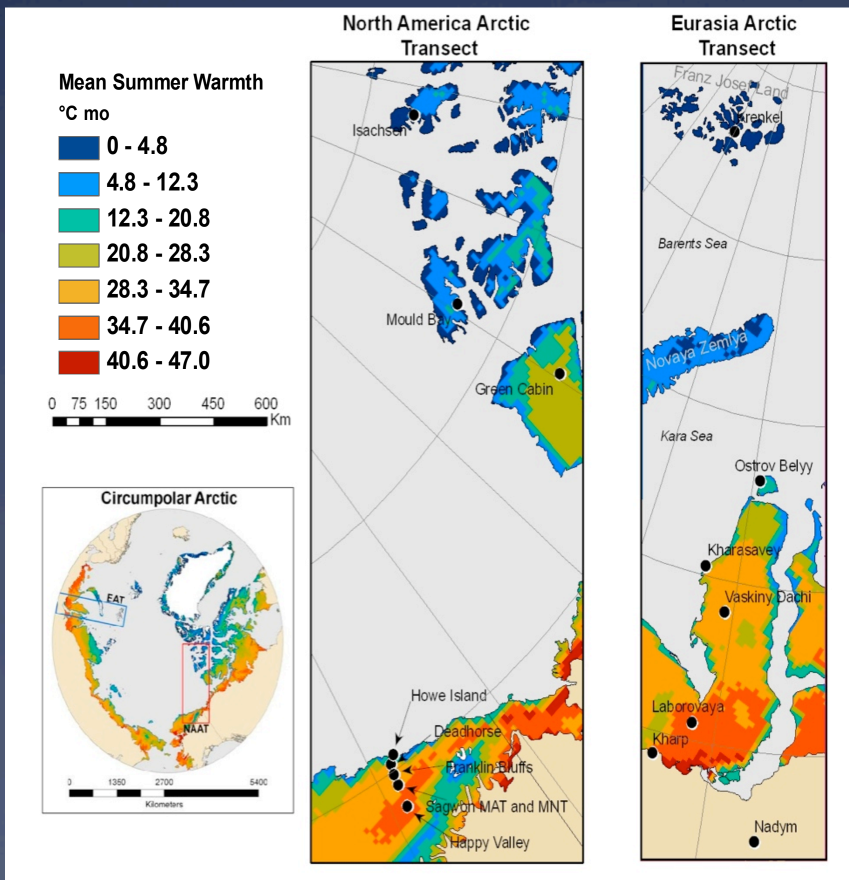


- General pattern of reduced NDVI with higher latitude and elevation.

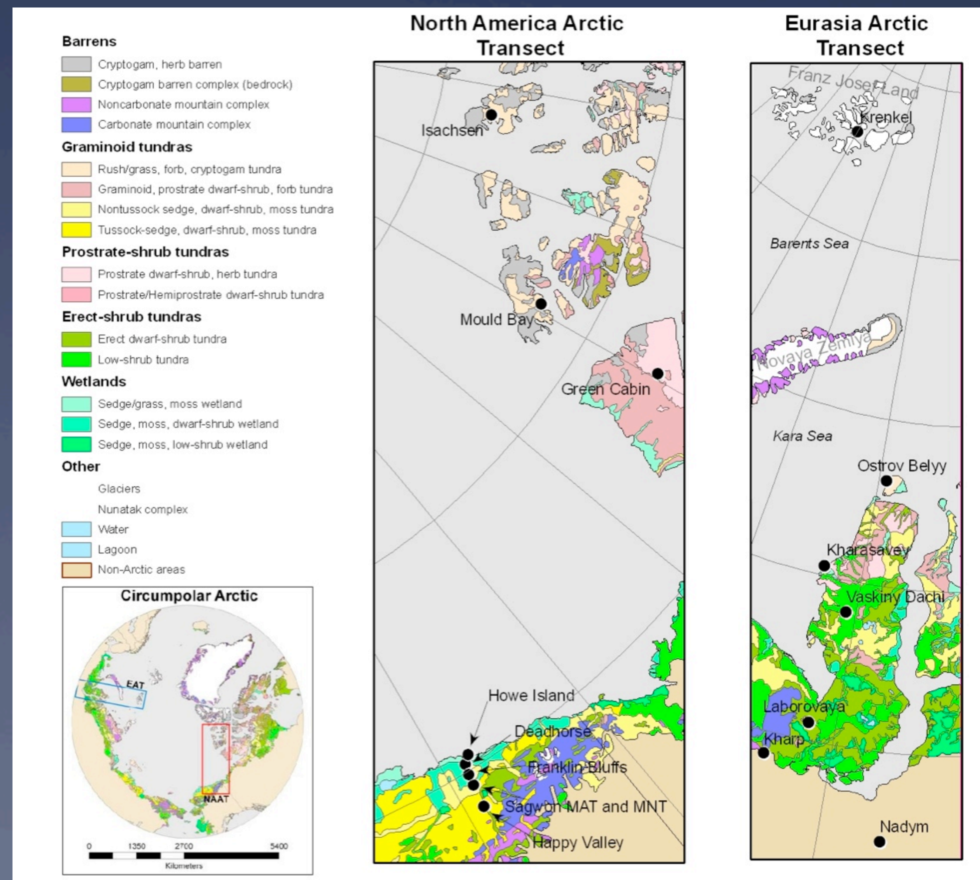
Map by Martha Raynolds & Shalane Carlson

Variation in climate and vegetation along the transects

Summer Warmth Index (AVHRR)



Vegetation (CAVM Team 2003)



Map by Martha Raynolds & Shalane Carlson, based on CAVM Team (2003)

Zonal vegetation along both transects

Eurasia Transect

A - Hayes Island

B - Ostrov Belyy

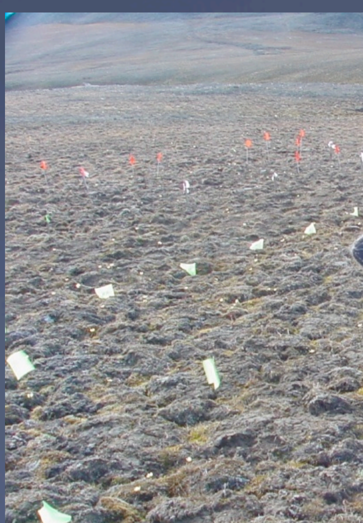
C – Kharasavey

D - Vaskiny Dachi

E - Laborovaya

North America transect

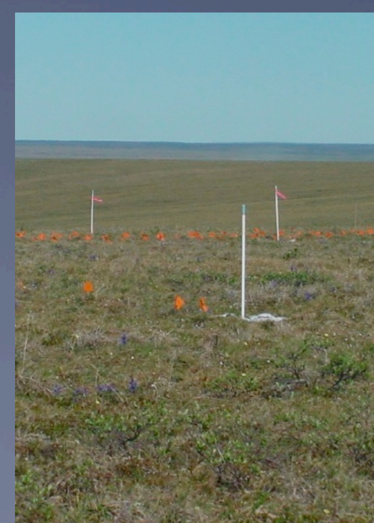
A - Isachsen



B- Mould Bay

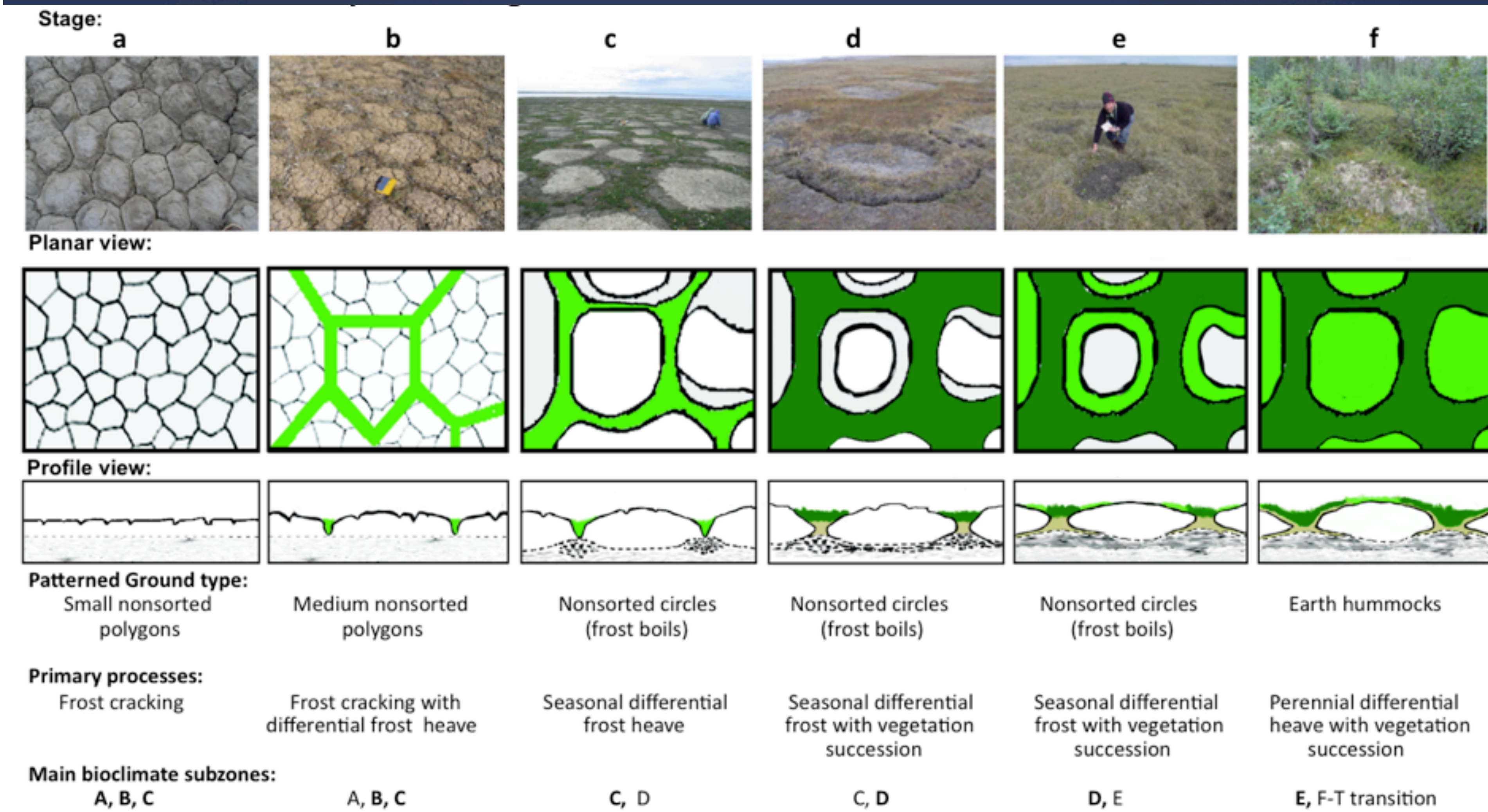
C - Green Cabin

D - Sagwon MNT



E - Happy Valley

North American Arctic Transect: part of a study of biocomplexity of arctic patterned ground



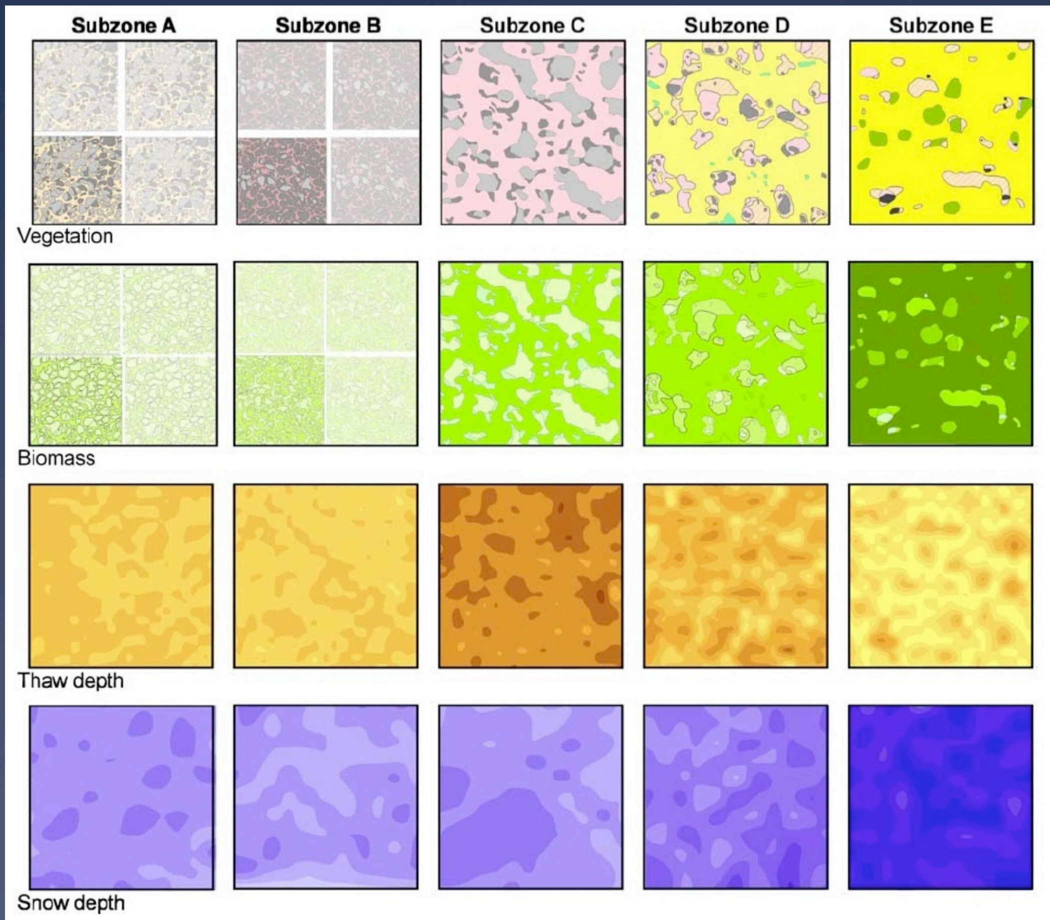
Based on Walker et al. 2011 (in revision). *Applied Vegetation Science.*

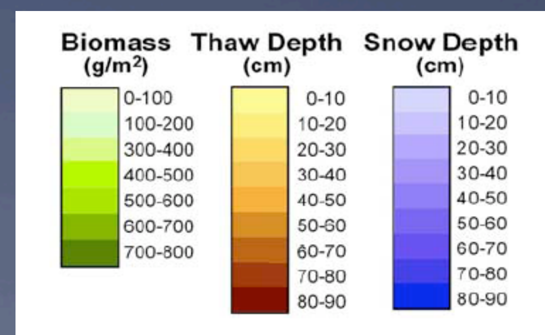
Biocomplexity activities

- CALM Grids
  - Active layer
  - Vegetation
  - Snow
- Climate /permafrost
  - Met station
  - Soil temperatures
  - Frost heave
- Soils
  - Characterization
  - Nitrogen mineralization
  - Decomposition
- Vegetation
  - Classification
  - Biomass
  - Mapping
- Remote sensing
  - NDVI
  - Mapping
- Modeling
- Education

Isachsen, Ellef Ringnes I.

Small landscape maps along climate gradient: 10 x 10 grids





Raynolds, M.K., Walker, D.A., Munger, C.A., et al. 2008. A map analysis of patterned-ground along a North American Arctic Transect. *Journal of Geophysical Research - Biogeosciences. 113:1-18*

Classification of patterned-ground vegetation along the NAAT

Phytocoenologia, 38 (1–2), 23–63
Berlin–Stuttgart, August 22, 2008

Patterned-Ground Plant Communities along a bioclimate gradient in the High Arctic, Canada

by Corinne M. Vonlanthen, Donald A. Walker, Martha K. Raynolds, Anja Kade, Patrick Kuss (Fairbanks, Alaska, USA), Fred J. A. Daniels (Münster, Germany), and Nadezhda V. Matveyeva (St. Petersburg, Russia)

and 1 appendix

circles, non-sorted polygons, and earth hummocks are common ground-surface features in
e caused by a variety of physical processes that occur in permafrost regions including contrac-
t heave. Here we describe the vegetation of patterned-ground forms on zonal sites at three
S transect through the High Arctic of Canada. We made 75 relevés on patterned-ground
gons, earth hummocks) and adjacent tundra (interpolygon, intercircle, interhummock areas)
sified the vegetation according to the Braun-Blanquet method. Environmental factors were
getation data using a nonmetric multidimensional scaling ordination (NMDS). We identified
) *Puccinellia angustata–Papaver radicatum* community in xeromesic non-sorted polygons of
umpolar Arctic Vegetation Map; (2) *Saxifraga–Parmelia omphalodes* ssp. *glacialis* community
lygon areas of subzone A; (3) *Hypogymnia subobscura–Lecanora epibryon* community in
polygons of subzone B; (4) *Orthotrichum speciosum-Salix arctica* community in xeromesic
subzone B; (5) *Cochlearia groenlandica-Luzula nivalis* community in hydromesic earth hum-
(6) *Salix arctica–Eriophorum angustifolium* ssp. *triste* community in hygric earth hummocks
cinellia angustata–Potentilla vahliana* community in xeromesic non-sorted circles and bare
(8) *Dryas integrifolia–Carex rupestris* community in xeromesic intercircle areas and vegetated
(9) *Braya glabella* ssp. *purpurascens–Dryas integrifolia* community in hydromesic non-sorted
10) *Dryas integrifolia–Carex aquatilis* community in hydromesic intercircle areas of subzone
m angustifolium* ssp. *triste–Carex aquatilis* community in hygric intercircle areas of subzone
tion displayed the vegetation types with respect to complex environmental gradients. The first
corresponds to a complex soil moisture gradient and the second axis corresponds to a complex
ate gradient. The tundra plots have a greater moss and graminoid cover than the adjacent
ies. In general, frost-heave features have greater thaw depths, more bare ground, thinner or-
wer soil moisture than the surrounding tundra. The morphology of the investigated patterned
along the climatic gradient, with non-sorted polygons dominating in the northernmost sites
dominating in the southern sites.

xity, Braun-Blanquet classification, Nonmetric Multidimensional Scaling, earth hummocks,
n-sorted polygons.

features, such as circles,
mmocks, are products of
(the patterned-ground ter-
ws Washburn (1980). The
s influences the microscale
tion (e.g. Bliss & Svoboda
nd strongly affects numer-
n properties and processes
4). Previous investigations
round have mainly focused
Washburn 1980), self-or-
round (e.g. Peterson et al.
, and soil relationships (e.g.
studies have addressed the
round (e.g. Wiggins 1951,
& Matveyeva 1997, Mat-
is part of a multidisciplin-

ary analysis of the complex interactions between climate, soils, and vegetation in the formation of these landforms along an 1800-km transect in Alaska and Canada that passes through all five bioclimate subzones of the Arctic Tundra Zone (CAVM Team 2003) (Fig. 1). Kade et al. (2005) described the vegetation along the Low-Arctic Alaskan portion of the transect while this papers describes and analyzes the vegetation along the High Arctic portion in Canada.

The High Arctic of Canada is characterized mainly by dry sparsely-vegetated landscapes with mineral soils, in contrast to the mainly moister well-vegetated landscapes with peaty soils in the Low Arctic (Bliss & Matveyeva 1992). Patterned ground occurs abundantly on nearly all landscapes in the High Arctic. Here we focus on the vegetation of the smaller patterned-ground features that are dominant on flat, primarily zonal sites, although we also include some patterned-ground plant communities in

8/0038–0023 0340–269X/08/0038–0023 $ 18.45

Phytocoenologia	35 (4)	761–820	Berlin–Stuttgart, December 13, 2005

Plant communities and soils in cryoturbated tundra along a bioclimate gradient in the Low Arctic, Alaska

by Anja Kade, Donald A. Walker and Martha K. Raynolds, Fairbanks, Alaska

with 24 figures, 12 tables and 1 appendix

Abstract. Nonsorted circles and earth hummocks are important landscape components of the arctic tundra. Here we describe the vegetation on these frost-heave features at seven study sites along a N-S-transect from the Arctic Ocean to the Arctic Foothills, Alaska. We established 117 relevés in frost-heave features and surrounding tundra and classified the vegetation according to the Braun-Blanquet sorted-table method. We used Detrended Correspondence Analysis to analyze relationships between vegetation and environmental variables. We identified nine communities: *Braya purpurascens-Puccinellia angustata* community (dry nonsorted circles, subzone C); *Dryas integrifolia-Salix arctica* community (dry tundra, subzone C); Salici rotundifoliae-Caricetum aquatilis ass. nov. (moist coastal tundra, subzone C); Junco biglumis-Dryadetum integrifoliae ass. nov. (moist nonsorted circles, subzone D); Dryado integrifoliae-Caricetum bigelowii Walker et al. 1994 (moist tundra, subzone D); *Scorpidium scorpioides-Carex aquatilis* community (wet tundra, subzone D); Cladino-Vaccinietum vitis-idaeae ass. nov. (dry nonsorted circles and earth hummocks, subzone E); Sphagno-Eriophoretum vaginati Walker et al. 1994 (moist tundra, subzone E); and *Anthelia juratzkana-Juncus biglumis* community (wet nonsorted circles, subzone E).

The DCA ordination displayed the vegetation types with respect to complex environmental gradients. The first axis of the ordination corresponds to a bioclimate/pH gradient, and the second axis corresponds to a disturbance/soil moisture gradient. Frost-heave features are dominated by lichens, whereas the adjacent tundra supports more dwarf shrubs, graminoids and mosses. Frost-heave features have greater thaw depths, more bare ground, thinner organic horizons and lower soil moisture than the surrounding tundra. The morphology of frost-heave features changes along the climatic gradient, with large, barren nonsorted circles dominating the northern sites and vegetated, less active earth hummocks dotting the southern sites. Thawing of permafrost and a possible shift in plant community composition due to global warming could lead to a decline in frost-heave features and result in the loss of landscape heterogeneity.

Keywords: biocomplexity, Braun-Blanquet classification, Detrended Correspondence Analysis, earth hummocks, frost heave, nonsorted circles.

1 Introduction

The vegetation and soil patterns in many arctic tundra regions are influenced by the distribution of frost-heave features such as nonsorted circles and earth hummocks (Washburn 1980). Nonsorted circles and earth hummocks form

DOI: 10.1127/0340-269X/2005/0035-0761 0340-269X/05/0035-0761 $ 15.00

Summarized in three papers using the Braun-Blanquet approach.

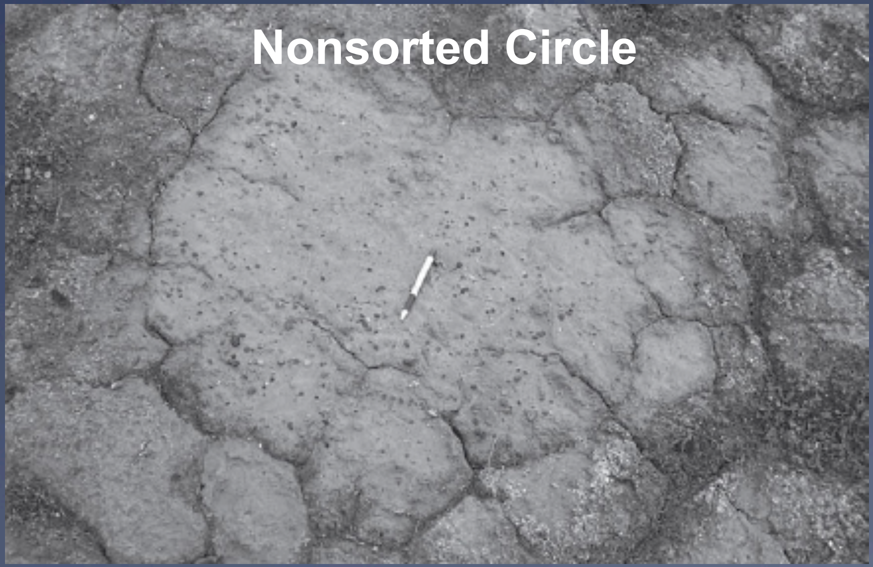
* **Low Arctic:** Kade, A., Walker, D.A., and Raynolds, M.K., 2005, *Phytocoenologia*, v. 35, p. 761-820.

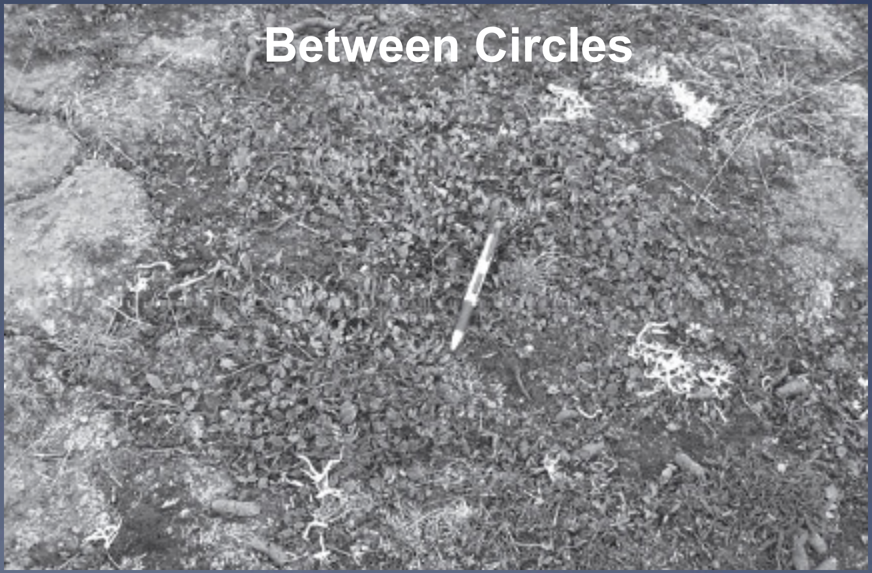
* **High Arctic:** Vonlanthen, C.M., Walker, D.A., Raynolds, M.K., Kade, A., Kuss, H.P., Daniëls, F.J.A., and Matveyeva, N.V., 2008, *Phytocoenologia*, v. 38, p. 23-63.

* **Synthesis:** Donald A. Walker, Patrick Kuss, Howard E. Epstein, Anja N. Kade, Corinne M. Vonlanthen, Martha K. Raynolds & Fred J.A. Daniëls, 2011 (in revsion). *Applied Vegeation Science.*

Studied contrast in vegetation on and between frost features

Deadhorse Subzone C





***Braya purpurascens-Puccinellia angustata* community**

***Dryas integrifolia-Salix arctica* community**

Kade et al 2005

Frost-boil plant communities, soil and site information

Plant communities

Table 3. Class, order, alliance and association or community names and habitats of the cryoturbated tundra in the Alaskan Low Arctic.

Undescribed unit
- Braya purpurascens-Puccinellia angustata comm.
  - Nonsorted circles and small polygons; dry nonacidic tundra; subzone C

C. Carici rupestris-Kobresietea bellardii Ohba 1974
- O. Kobresio-Dryadetalia (Br.-Bl.1948) Ohba 1974
  - A. Dryadion integrifoliae Ohba ex Daniëls 1982
    - Dryas integrifolia-Salix arctica comm.
      - Stable, dry nonacidic tundra; subzone C
    - Junco biglumis-Dryadetum integrifoliae ass. nov.
      - Nonsorted circles; moist nonacidic tundra; subzone D
    - Dryado integrifoliae-Caricetum bigelowii Walker et al. 1994
      - Stable, moist nonacidic tundra; subzone D

C. Scheuchzerio-Caricetea nigrae (Nordh. 1936) Tx. 1937
- O. Scheuchzerietalia palustris Nordh. 1936
  - A. Caricion lasiocarpae Vanden Berghen ap. Lebrun et al. 1949
    - Salici rotundifoliae-Caricetum aquatilis ass. nov.
      - Stable, moist nonacidic coastal tundra; subzone C
    - Scorpidium scorpioides-Carex aquatilis comm.
      - Stable, wet nonacidic tundra; subzone D

C. Loiseleurio-Vaccinietea Eggler 1952
- O. Rhododendro-Vaccinietalia Br.-Bl. ap. Br.-Bl. & Jenny 1926
  - (A. Loiseleurio-Diapension (Br.-Bl. Et al. 1939) Daniëls 1982?)
    - Cladino-Vaccinietum vitis-idaeae ass. nov.
      - Nonsorted circles and earth hummocks; moist acidic tundra; subzone E
    - Sphagno-Eriophoretum vaginati Walker et al. 1994
      - Stable, moist acidic tundra; subzone E

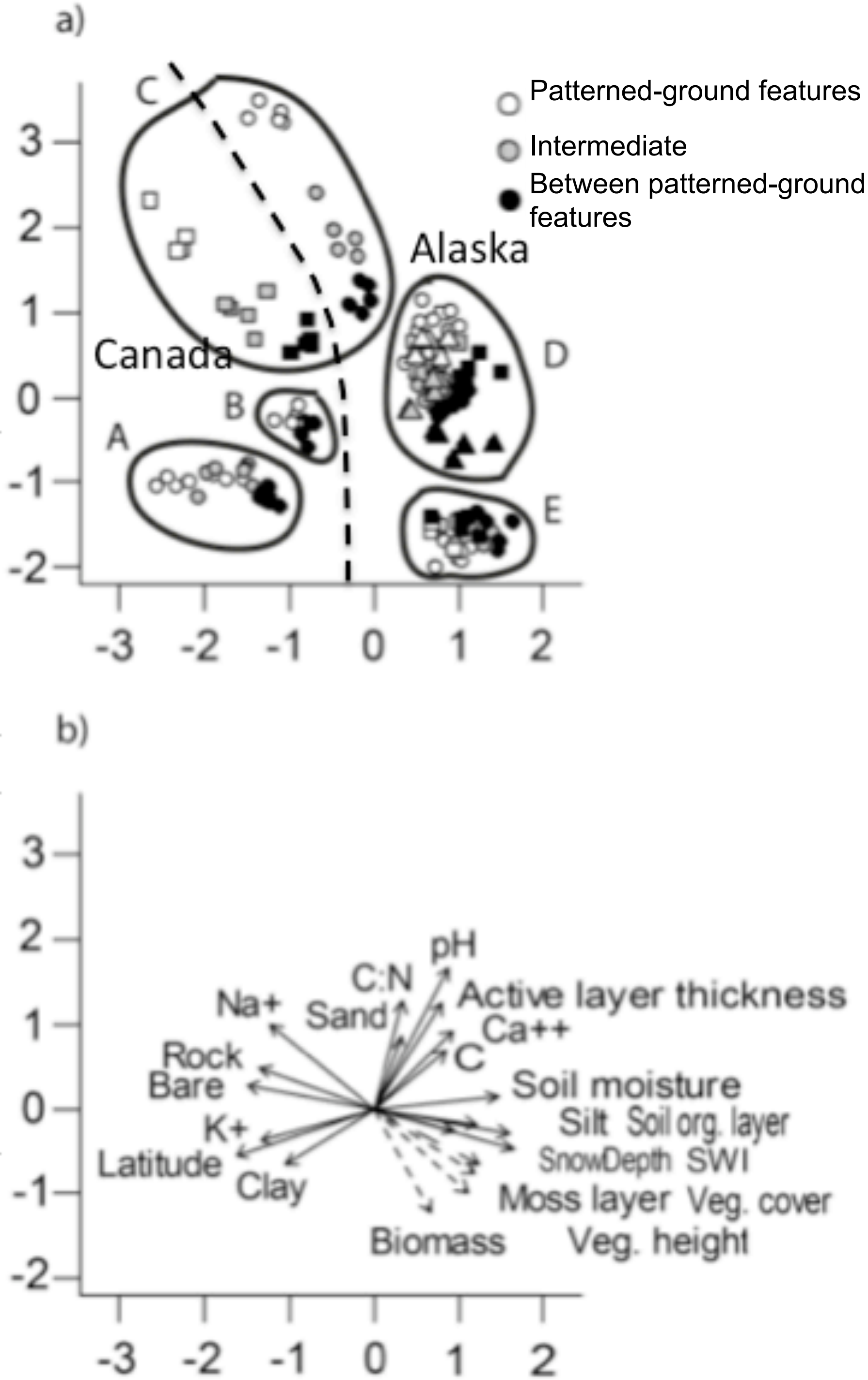
C. Salicetea herbaceae Br.-Bl. 1947
- O. Salicetalia herbaceae Br.-Bl. 1926
  - A. Saxifrago-Ranunculion nivalis Nordh. 1943 emend. Dierß. 1984
    - Anthelia juratzkana-Juncus biglumis comm.
      - Nonsorted circles; moist acidic tundra; subzone E

Soil and site data

Table 1. Environmental variables and soil physical and chemical properties for the plant associations and communities of the cryoturbated tundra. Mean with standard error in parentheses.

	Braya purpurascens-Puccinellia angustata comm.	Dryas integrifolia -Salix arctica comm.	Salici rotundifoliae - Caricetum aquatilis ass.	Junco biglumis -Dryadetum integrifoliae ass.	Dryado integrifoliae - Caricetum bigelowii ass.	Scorpidium scorpioides - Carex aquatilis comm.	Cladino-Vaccinietum vitis - idaeae ass.	Sphagno-Eriophoretum vaginati ass.	Anthelia juratzkana -Juncus biglumis comm.
Thaw depth (cm)	79.4 (1.1)	65.0 (1.4)	28.0 (0.3)	88.1 (1.4)	64.9 (1.9)	70.0 (1.8)	60.3 (0.9)	33.6 (1.6)	59.8 (1.9)
Snow depth (cm)	8.1 (2.0)	13.3 (2.7)	19.2 (2.6)	27.0 (1.9)	39.8 (2.5)	58.6 (7.4)	39.7 (4.6)	60.1 (4.4)	63.2 (0.9)
O-horizon depth (cm)	0.0 (0.0)	0.4 (0.2)	26.8 (1.2)	0.2 (0.1)	15.3 (1.5)	25.4 (0.9)	6.4 (1.6)	11.9 (1.0)	0.0 (0.0)
Bare soil (%)	55.0 (11.8)	0.0 (0.3)	0.1 (0.1)	26.3 (4.8)	0.3 (0.2)	2.4 (1.1)	0.0 (0.0)	0.0 (0.0)	10.6 (4.2)
Soil moisture (vol.-%)	28.3 (2.9)	37.3 (2.6)	47.1 (0.4)	39.2 (0.9)	45.2 (2.5)	49.0 (1.9)	35.8 (1.6)	44.1 (1.3)	41.8 (3.3)
Bulk density (g/cm^3)	1.11 (0.04)	0.79 (0.03)	0.82 (0.02)	1.35 (0.04)	1.23 (0.07)	1.34 (0.04)	0.95 (0.05)	1.07 (0.04)	1.13 (0.04)
Sand content (%)	52.1 (3.3)	65.3 (2.3)	36.8 (1.6)	44.9 (2.7)	45.3 (3.3)	43.3 (2.7)	29.8 (1.4)	33.4 (1.9)	28.6 (1.9)
Silt content (%)	31.8 (2.3)	30.1 (2.6)	45.7 (2.0)	34.9 (2.6)	40.8 (3.0)	46.6 (5.8)	44.4 (1.1)	44.9 (1.1)	43.6 (1.5)
Clay content (%)	16.1 (3.9)	4.6 (0.8)	17.5 (2.2)	20.2 (0.6)	13.9 (1.2)	10.1 (3.2)	25.8 (0.8)	21.7 (1.8)	27.8 (1.8)
Soil pH	8.3 (0.1)	7.9 (0.1)	6.5 (0.1)	8.1 (0.1)	7.9 (0.1)	7.7 (0.1)	5.0 (0.1)	5.3 (0.1)	5.2 (0.1)
Total C (%)	4.77 (0.31)	6.30 (0.24)	5.34 (0.11)	5.1 (0.21)	5.78 (0.26)	5.42 (0.83)	3.73 (0.39)	3.46 (0.28)	2.68 (0.55)
Total N (%)	0.11 (0.01)	0.18 (0.03)	0.19 (0.02)	0.18 (0.01)	0.29 (0.03)	0.26 (0.05)	0.21 (0.02)	0.21 (0.02)	0.15 (0.04)
Available Ca^{2+} (me/100g)	39.8 (1.4)	48.3 (1.8)	22.0 (0.8)	67.3 (6.7)	53.2 (2.7)	40.6 (8.3)	5.4 (0.9)	9.2 (0.5)	6.0 (0.9)
Available Mg^{2+} (me/100g)	2.35 (0.12)	1.78 (0.15)	1.14 (0.08)	1.7 (0.18)	1.86 (0.21)	1.20 (0.12)	0.76 (0.10)	1.59 (0.07)	1.07 (0.11)
Available K^+ (me/100g)	0.18 (0.01)	0.14 (0.02)	0.11 (0.01)	0.12 (0.01)	0.18 (0.02)	0.18 (0.02)	0.10 (0.01)	0.07 (0.01)	0.08 (0.01)
Available Na^+ (me/100g)	3.18 (0.61)	0.32 (0.14)	1.42 (0.10)	0.05 (0.01)	0.06 (0.01)	0.06 (0.01)	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)

Kade et al. 2005, Plant communities and soils in cryoturbated tundra along a bioclimate gradient in the Low Arctic, Alaska. *Phytocoenologia*, 35: 761-820.



Ordination of zonal patterned ground vegetation: controlling environmental gradients

- **NMDS ordination.**
- **Clear gradient of vegetation response to cryoturbation within each subzone and clear floristic separation between subzones.**
- **But no clear overall controlling factors for the whole data set.**
- **Floristic separation between Alaska and Canada portions of the gradient due to different floristic provinces, and substrate differences.**

Walker et al. 2011 in revision. *Applied Vegetation Science.*

A few of the conclusions from the NAAT vegetation studies

1. Vegetation is the principal factor affecting thermal differentials between the centers and margins of small patterned-ground features and strongly affects the types of patterned ground features that are dominant within zonal Arctic landscapes.

2. Recognizing characterizing and classifying the small-scale plant communities within respective microhabitats was essential for understanding the biological and physical controls of patterned-ground morphology.

3. The zonal patterned-ground vegetation complexes (combined microhabitats) were useful for landscape and regional-level comparisons, such as comparison of floristic richness in zonal landscapes, or for extrapolation of information collected at plot scales (such as biomass and NDVI) to larger regions.

The Eurasian Arctic Transect:

- Part of an IPY study to examine the linkages between changing Arctic sea-ice conditions, summer land temperatures, and vegetation
- 2010 expedition to Hayes Island, Franz Josef Land, completed parallel transect studies in North America and Eurasia.

High-ice Permafrost Landscapes of the Yamal Peninsula

1. Extensive nutrient-poor surface sands with lichens that are easily overgrazed by reindeer.

2. Underlain by permafrost with massive pure ice.

3. Extensive landslides are rapidly eroding the landscape.

4. This exposes salt-rich and nutrient-rich clays.

5. Complex vegetation succession process that results in willow-shrub tundra and much greener vegetation in the eroded valleys.

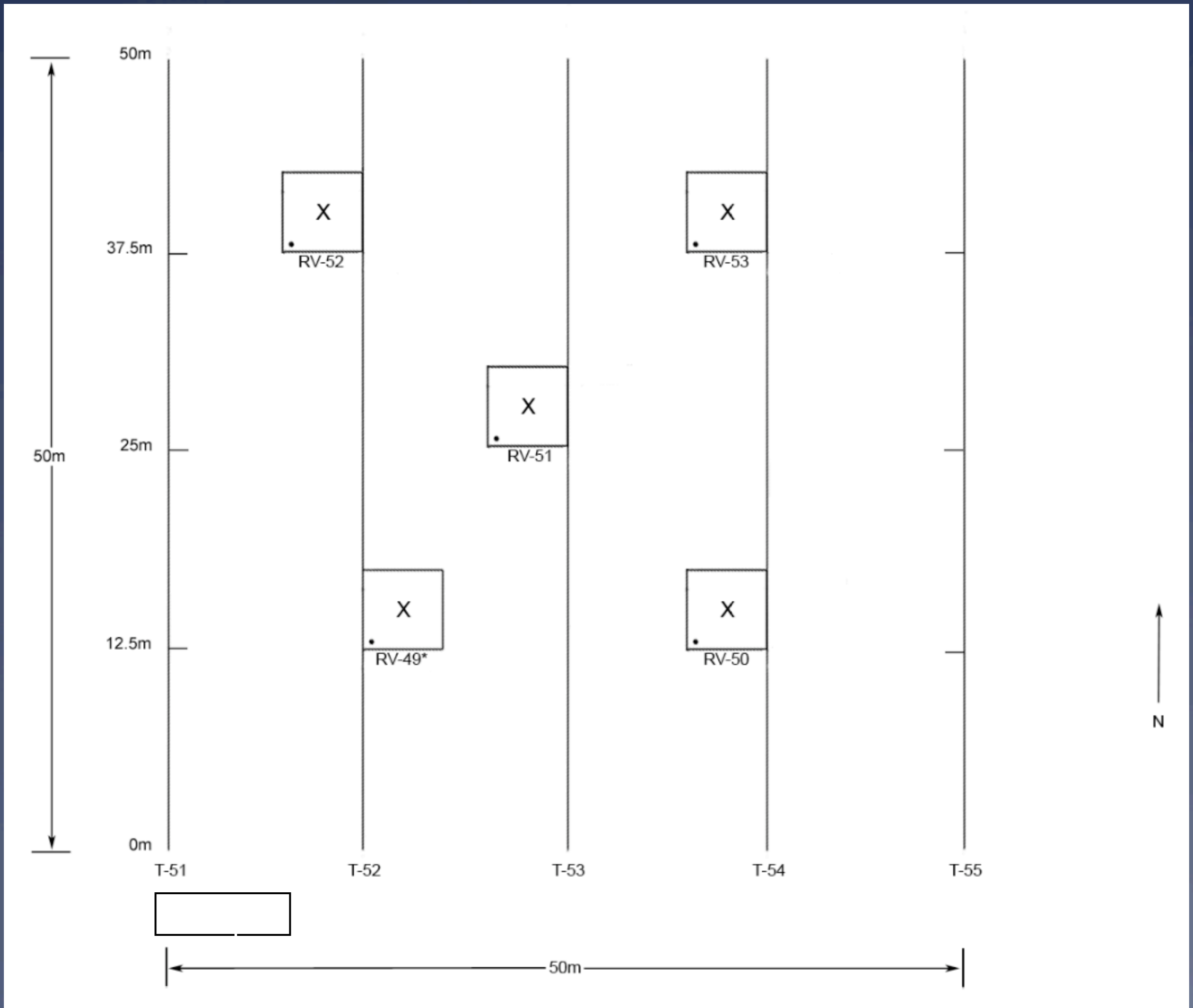
Photos: D.A. Walker and M. Liebman (upper right)

Reindeer effects on greenness patterns:

- **Effects on reindeer on NDVI are unknown at present because of lack of control areas to study the effects (exclosures).**
- **Potential major effect in sandy areas.**

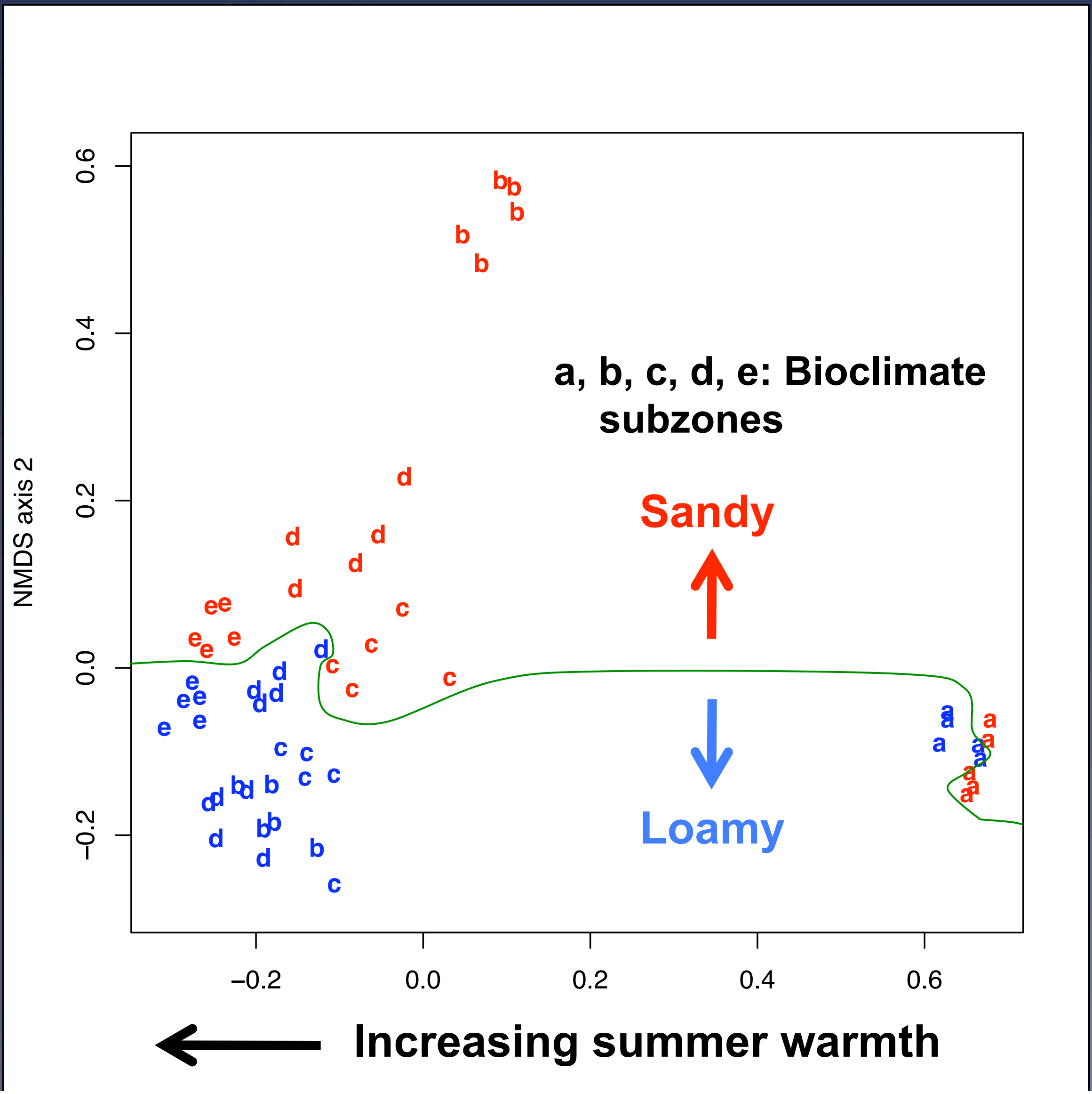
Photos: Bruce Forbes.

Typical layout of transects and plots at each EAT site



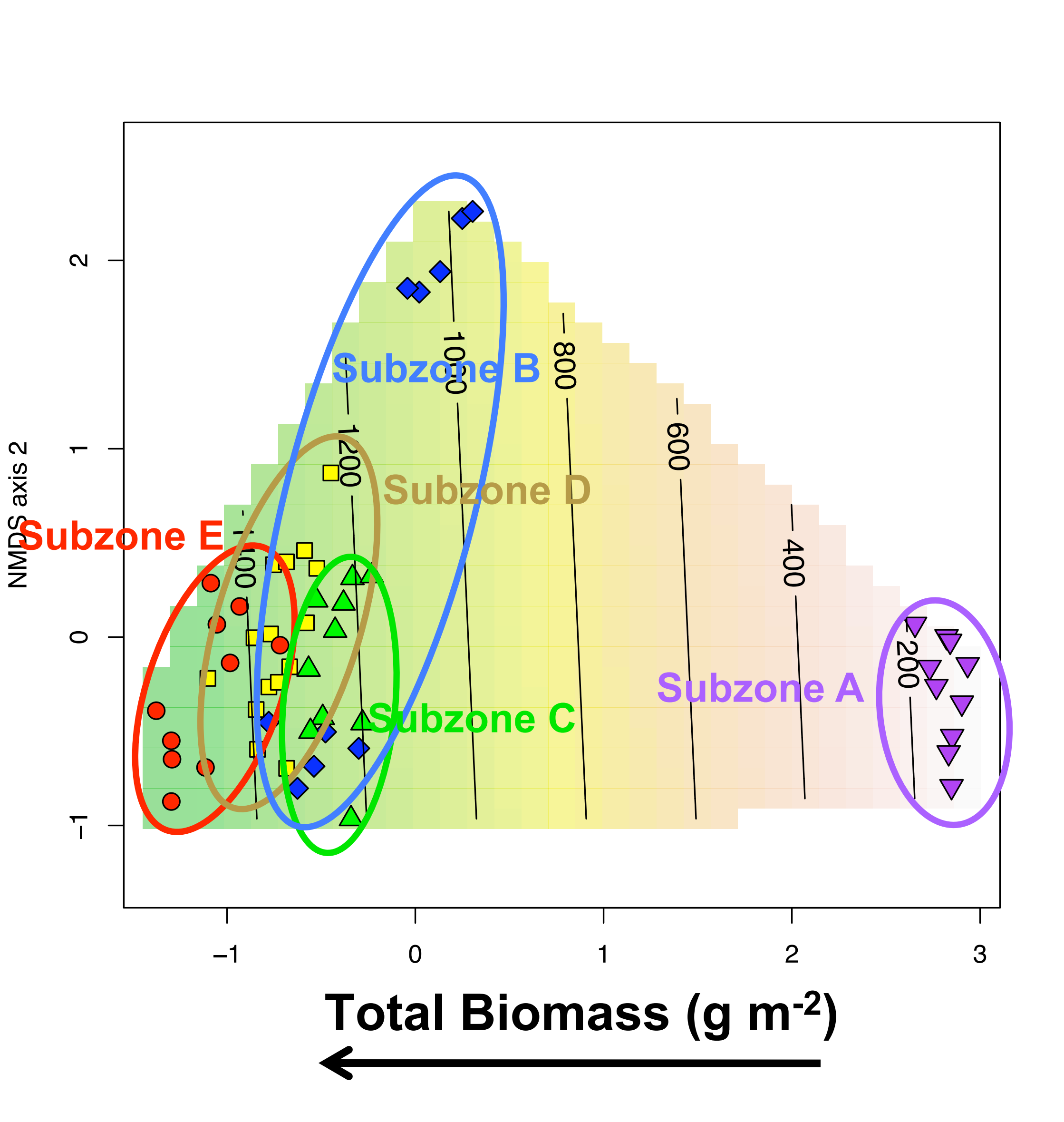
- Sampled loamy and sandy sites within each subzone.
- Five 50-m transects
- Five 5 x 5-m plots (relevés)
- Biomass harvests in each plot (x)
- iButtons for n-factor in corner of each plot (•)
- Soil pit in SW corner

NMDS Ordination of all EAT study plots based on floristic similarity

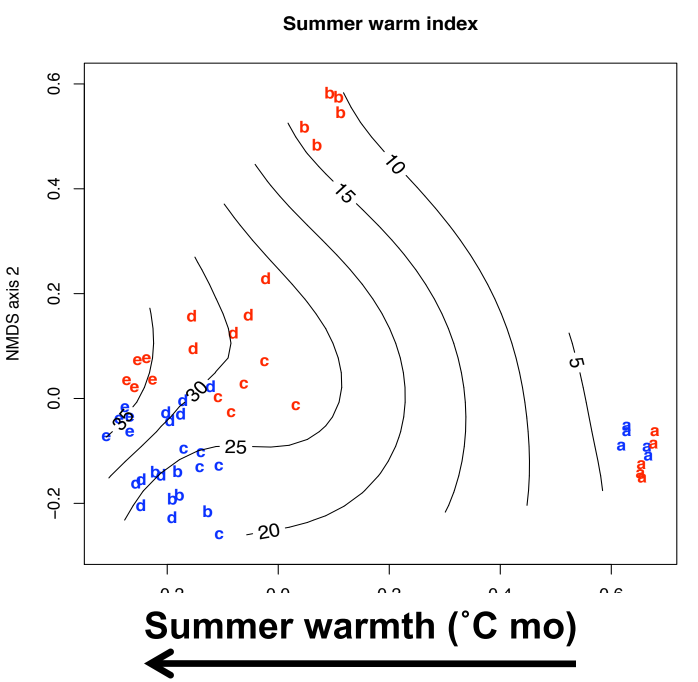


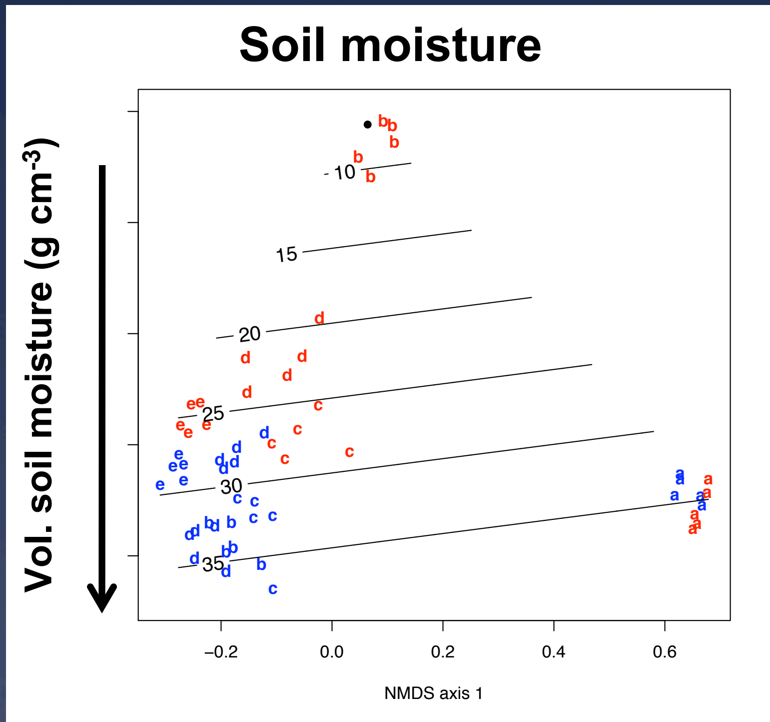
- Subzone A floristically distinct from the rest of the gradient.
- Plots organized along the Axis 1 by summer warmth, and along the second axis by soil texture, reflecting the sampling strategy.

Full data set: Axis 1: Complex biomass / summer-warmth gradient

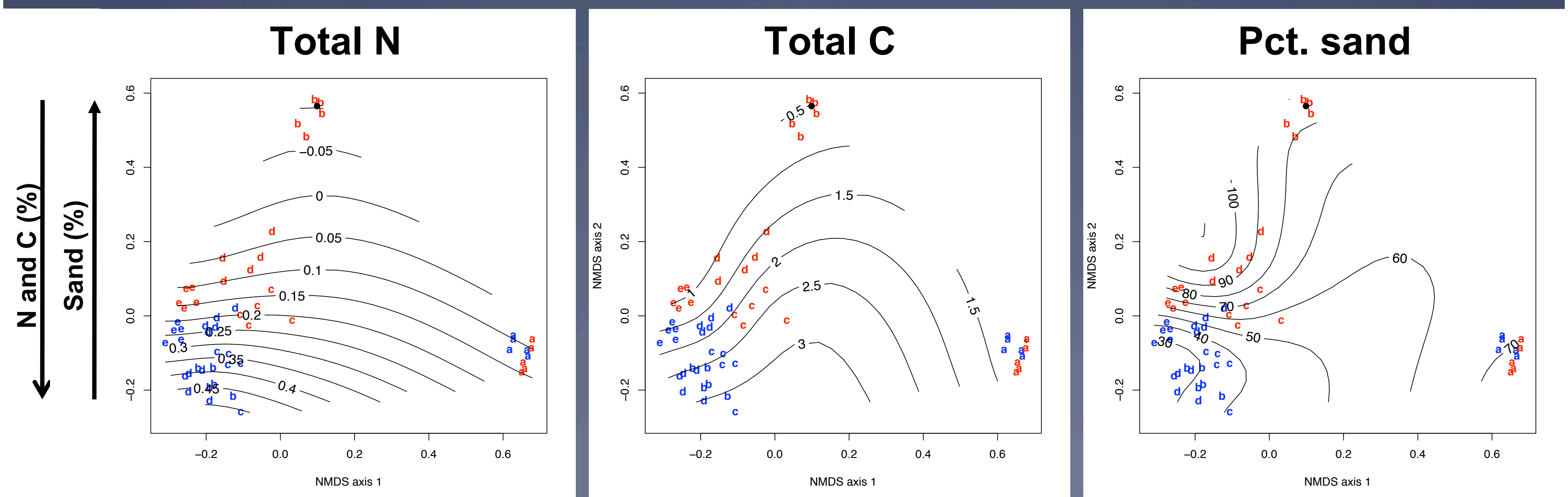


- **Axis 1 most strongly correlated with total biomass.**
- **Also, summer warmth, NDVI, LAI, disturbance, active layer thickness, species richness.**

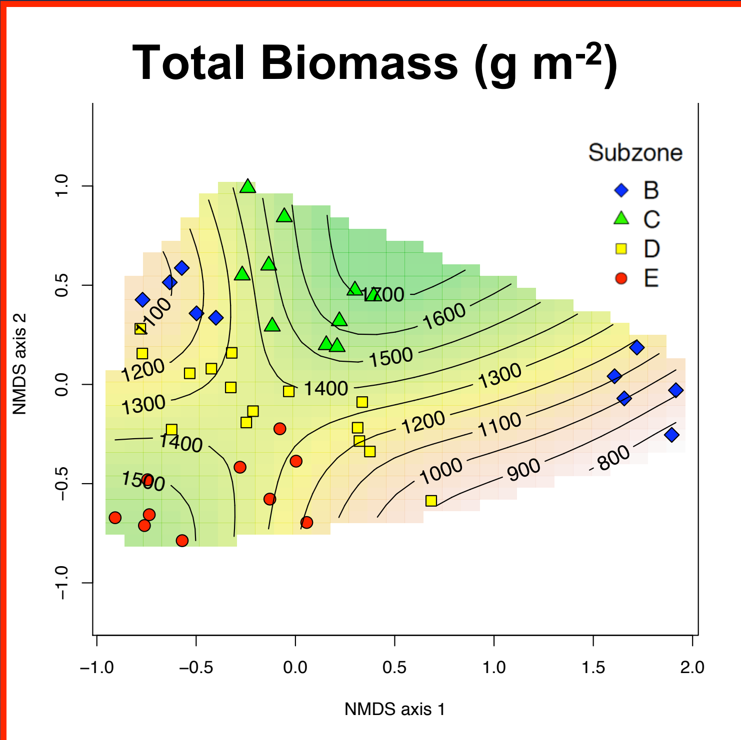


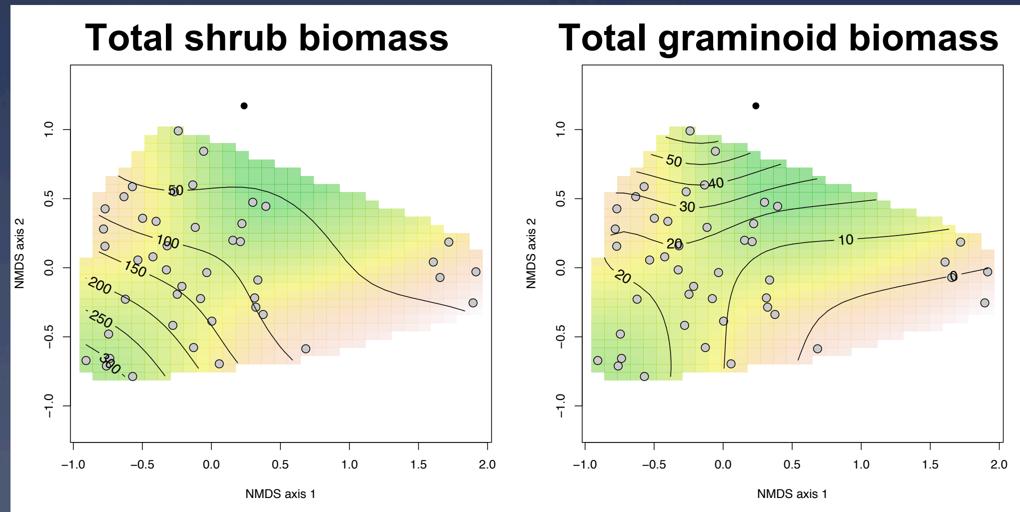


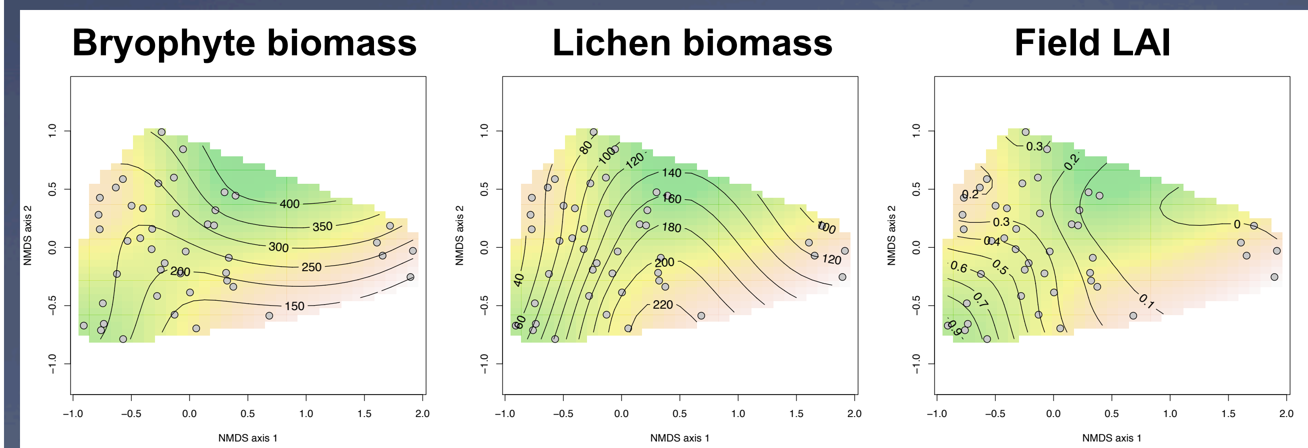
Full data set: Axis 2: Complex soil moisture, soil texture, N, organic matter gradient

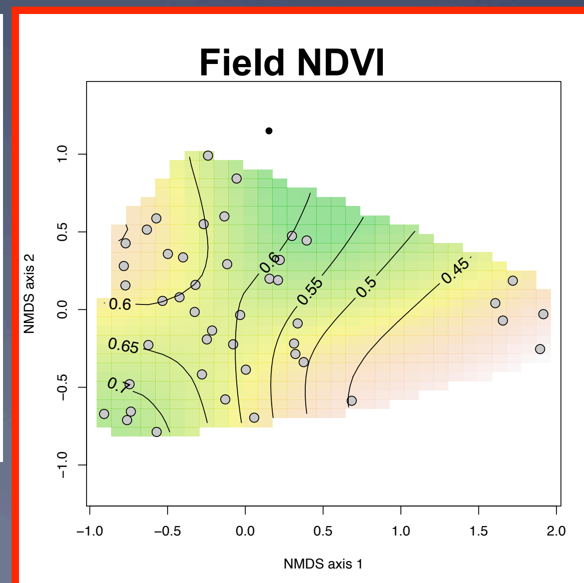


Biomass space: Yamal plots only (excluding FJL)









- **Field NDVI is most strongly correlated to total biomass.**

Toward a synthesis of the two transects

Although the research along the two transects had different objectives. There is a common primary data set from both transects:

1. **Vegetation, soils, and site factors from zonal vegetation along the complete Arctic bioclimate gradient.**
2. **Ground measurements of key plant productivity variables: biomass, LAI, and NDVI.**
3. **A circumpolar remote-sensing data set that contains vegetation, land temperatures, and NDVI data for both transects and changes in NDVI since 1982.**

This allows us to compare the spatial and temporal trends in vegetation, biomass, and NDVI between the two transects in response to ongoing changes in climate and land-use.

Synoptic tables for NAAT and EAT

Only a few taxa were diagnostic for the same subzone along both transects:

Subzone A:
Cerastium arcticum
Draba subcapitata
Saxifraga cernua

Subzone E:
Betula nana/exilis
Empetrum nigrum
Salix phylicifolia/ pulchra

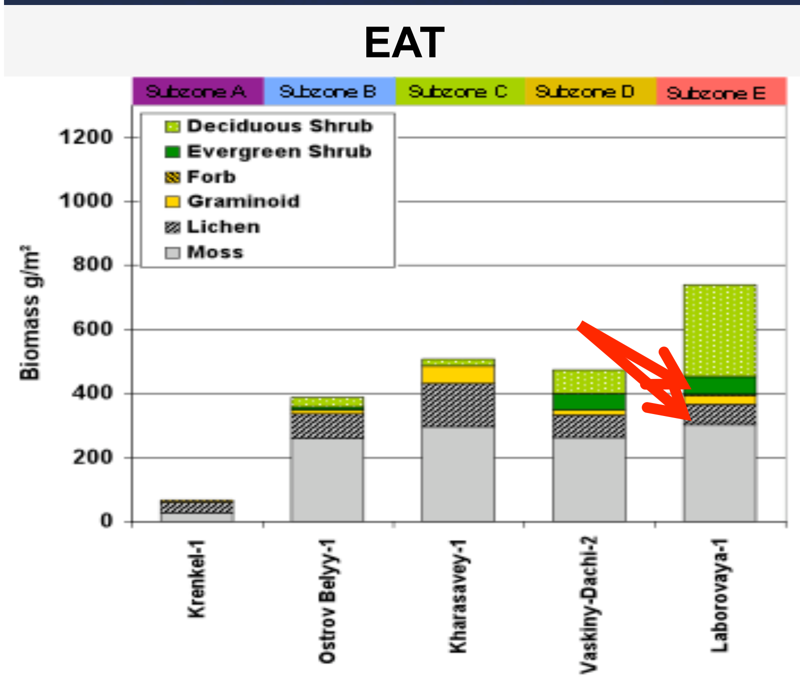
But many more for the broader High Arctic, Low Arctic groups of subzones.

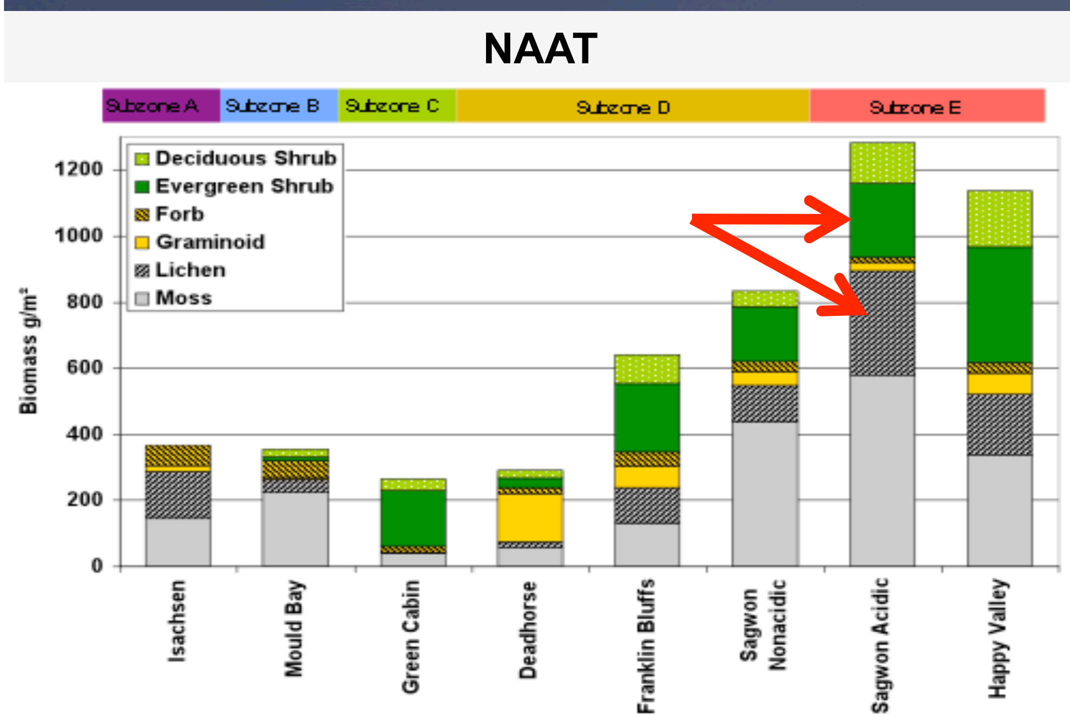
NAAT

No. of relevés:		21	10	29	62	25
No. of species:		142	79	108	226	108
Diagnostic taxa for subzone A:						
Pertusaria octomela	L	90	0	0	0	0
Psoroma hypnorum	L	86	0	0	0	4
Rinodina terrestris	L	76	0	0	0	0
Draba oblongata	V	95	0	24	0	0
Draba subcapitata	V	71	0	0	0	0
Cardamine bellidifolia	V	67	0	0	0	0
Poa alpigena	V	67	0	0	0	0
Ranunculus sabinei	V	67	0	0	0	0
Saxifraga cernua	V	76	30	0	0	0
Cerastium arcticum	V	76	30	0	0	0
Rinodina turfacea	L	86	20	0	6	4
Racomitrium panschii	B	71	20	0	0	0
Peltigera didactyla	L	71	0	0	3	0
Syntrichia ruralis	B	90	50	21	0	0
Fuscopannaria praetermissa	L	62	0	0	0	0
Puccinellia cf. andersonii	V	62	0	0	0	0
Lecidella wulfenii	L	62	0	0	0	0
Caloplaca ammiospila	L	62	10	0	0	0
Festuca brachyphylla	V	57	0	0	0	0
Schistidium frigidum	B	57	0	0	0	0
Protopannaria pezizoides	L	57	0	0	0	0
Megalaria jemtlandica	L	52	0	0	0	0
Stereocaulon rivulorum	L	48	0	0	0	0
Tetramelas insignis	L	48	0	0	0	0
Schistidium papillosum	B	52	20	0	0	0
Ochrolechia inaequatul	L	57	10	0	3	4
Candelariell terrigena	L	43	0	0	0	0
Megaspora verrucosa	L	67	30	21	2	0
Caloplaca cerina	L	52	20	3	2	0
Peltigera canina	L	43	0	0	2	0
Rinodina olivaceobrunn	L	38	0	0	0	0
Sticta arctica	L	38	0	0	0	0
Ochrolechia cf. inaequatula	L	38	0	0	0	0
Cladonia pyxidata	L	62	0	0	13	8
Diagnostic taxa for subzone B:						
Oxyria digyna	V	0	90	0	0	0
Potentilla hyparctica	V	57	100	0	0	0
Orthotrichum speciosum	B	5	70	0	0	0
Luzula nivalis	V	33	90	0	0	16
Festuca hyperborea	V	0	60	0	0	0
Draba sp.	V	0	70	21	0	0
Parrya arctica	V	0	80	41	0	0
sterile black crust	L	0	50	0	0	0
Lecidea ramulosa	L	0	50	0	0	0
Bryum rutilans	B	0	50	0	2	0
Didymodon rigidus var.. icmadophila	B	43	80	17	5	0
Ctenidium procerrimum	B	0	80	48	6	0
Mnium thomsonii	B	0	40	0	0	0
Diagnostic taxa for subzone C:						
Puccinellia angustata	V	0	0	55	0	0
Braya glabella ssp. purpurascens	V	0	0	48	2	0
Oxytropis borealis	V	0	0	38	0	0
Diagnostic taxa for subzone D:						
Eriophorum angustifolium ssp. triste	V	0	0	0	100	0
Carex membranacea	V	0	0	0	81	0
Cardamine digitata	V	0	0	0	73	0
Salix reticulata	V	0	0	0	68	0
Equisetum variegatum	V	0	0	0	65	0
Hypnum bambergeri	B	0	0	14	79	0
Carex capillaris	V	0	0	0	56	0
Thamnolia subuliformis	L	0	0	28	89	4
Tofieldia pusilla	V	0	0	0	50	0
Pedicularis lanata	V	0	0	0	58	8
Arctous rubra	V	0	0	0	48	4
Astragalus umbellatus	V	0	0	0	40	0
Equisetum arvense	V	0	0	0	40	0
Pedicularis capitata	V	0	0	0	44	4
Carex scirpoidea	V	0	0	0	35	0
Catoscopium nigritum	B	0	0	0	35	0
Papaver macounii	V	0	0	0	35	0
Diagnostic taxa for subzone E:						
Betula nana	V	0	0	0	0	100
Vaccinium vitis-idaea	V	0	0	0	2	100
Cladina rangiferina	L	0	0	0	0	84
Petasites frigidus	V	0	0	0	0	84
Dicranum elongatum	B	0	0	0	5	92
Cladina arbuscula	L	0	0	0	0	76
Empetrum nigrum	V	0	0	0	3	80
Cladina stygia	L	0	0	0	0	64
Cladonia amaurocraea	L	0	0	0	6	72
Sphenolobus minutum	B	14	0	0	3	80
Aulacomnium turgidum	B	48	0	0	15	100
Hylocomium splendens	B	14	10	14	15	96
Cassiope tetragona	V	0	0	0	31	96
Pedicularis lapponica	V	0	0	0	0	52
Salix pulchra	V	0	0	0	0	52
Pleurozium schreberi	B	0	0	0	2	52
Cladonia fimbriata	L	0	0	0	2	52
Dactylina arctica	L	0	0	3	31	92
Dicranum acutifolium	B	5	0	0	3	56
Dicranum groenlandicum	B	0	0	0	0	40
Peltigera leucophlebia	L	29	0	0	5	64
Cetraria laevigata	L	0	0	0	3	44
Peltigera malacea	L	0	0	0	2	40
Sphagnum warnstorfii	B	0	0	0	0	36

EAT

No. of plots			10	10	10	15	10
Species		Freq.					
Diagnostic taxa for subzone A:							
Cochlearia groenlandica	V	10	100	.	.	.	.
Stellaria edwardsii / crassipes	V	10	100	.	.	.	.
Phippsia algida	V	10	100	.	.	.	.
Orthothecium chryseon	B	10	100	.	.	.	.
Lecidea ramulosa	L	10	100	.	.	.	.
Papaver dahlianum ssp. polare	V	10	100	.	.	.	.
Cladonia pocillum	L	11	100	10	.	.	.
Draba subcapitata/micropetala	V	9	90	.	.	.	.
Cerastium arcticum	V	9	90	.	.	.	.
White crust	L	12	100	.	20	.	.
Cetrariella delisei	L	13	100	.	.	13	10
Cerastium regelii	V	8	80	.	.	.	.
Solorina bispora	L	7	70	.	.	.	.
Saxifrage cespitosa	V	7	70	.	.	.	.
Cirriphyllum cirrosum (= Brachythecium c	B	7	70	.	.	.	.
Fulgensia bracteata	L	7	70	.	.	.	.
Distichium capillaceum	B	9	80	10	.	.	.
Pohlia cruda	B	9	80	10	.	.	.
Black crust	L	16	100	.	.	40	.
Cetraria aculeata	L	6	60	.	.	.	.
Bryum rutilans	B	6	60	.	.	.	.
Encalypta alpina	B	6	60	.	.	.	.
Saxifraga cernua	V	8	70	.	10	.	.
Bryum sp.	B	8	70	10	.	.	.
Polytrichastrum alpinum	B	18	100	20	20	27	.
Saxifraga oppositifolia	V	5	50	.	.	.	.
Gowardia arctica	L	5	50	.	.	.	.
Cratoneuron curvicaule	B	5	50	.	.	.	.
Bryoerythrophyllum recurvirostrum	B	7	60	10	.	.	.
Protopannaria pezizoides	L	6	50	.	.	7	.
Ditrichum flexicaule	B	11	70	30	.	7	.
Campylium cf. arcticum	B	4	40	.	.	.	.
Bartramia ithyphylla	L	4	40	.	.	.	.
Niphrotrichum panschii	L	4	40	.	.	.	.
Cladonia symphycarpia	L	4	40	.	.	.	.
Stereocaulon rivulorum	L	4	40	.	.	.	.
Myurella julacea	B	4	40	.	.	.	.
Diagnostic taxa for Subzone B:							
Blepharostoma trichophyllum	B	6	.	50	.	7	.
Polytrichum piliferum	B	6	.	50	.	7	.
Solorina crocea	L	4	.	40	.	.	.
Dianostic taxa for subzone C:							
Tephroseris atropurpurea	V	10	.	.	90	7	.
Peltigera aphthosa	L	9	.	10	80	.	.
Dicranum laevidens	B	18	.	.	100	20	50
Peltigera canina	L	7	.	.	60	7	.
Luzula confusa	V	18	.	60	100	13	.
Lophozia ventricosa	L	22	.	.	100	53	40
Lichenomphalia hudsoniana	L	6	.	.	50	7	.
Dianostic taxa for subzone D:							
Cladonia chlorophaea	L	7	.	.	.	47	.
Vaccinium vitis-ideae	V	25	.	.	20	100	80
Dianostic taxa for subzone E:							
Salix phylicifolia	V	12	.	.	.	13	100
Vaccinium uliginosum	V	13	.	.	.	20	100
Pedicularis labradorica	V	8	.	.	.	.	80
Pleurozium schreberi	B	8	.	.	.	7	70
Empetrum nigrum	V	14	.	.	.	33	90
Eriophorum vaginatum	V	18	.	.	.	53	100
Asahinea chrysantha	L	6	.	.	.	.	60
Betula nana	V	21	.	.	.	73	100
Ledum palustre	V	11	.	.	.	27	70
Petasites frigidus	V	4	.	.	.	.	40
Pedicularis cf. lapponica	V	6	.	.	10	.	50
Flavocetraria nivalis	L	19	.	.	50	33	90



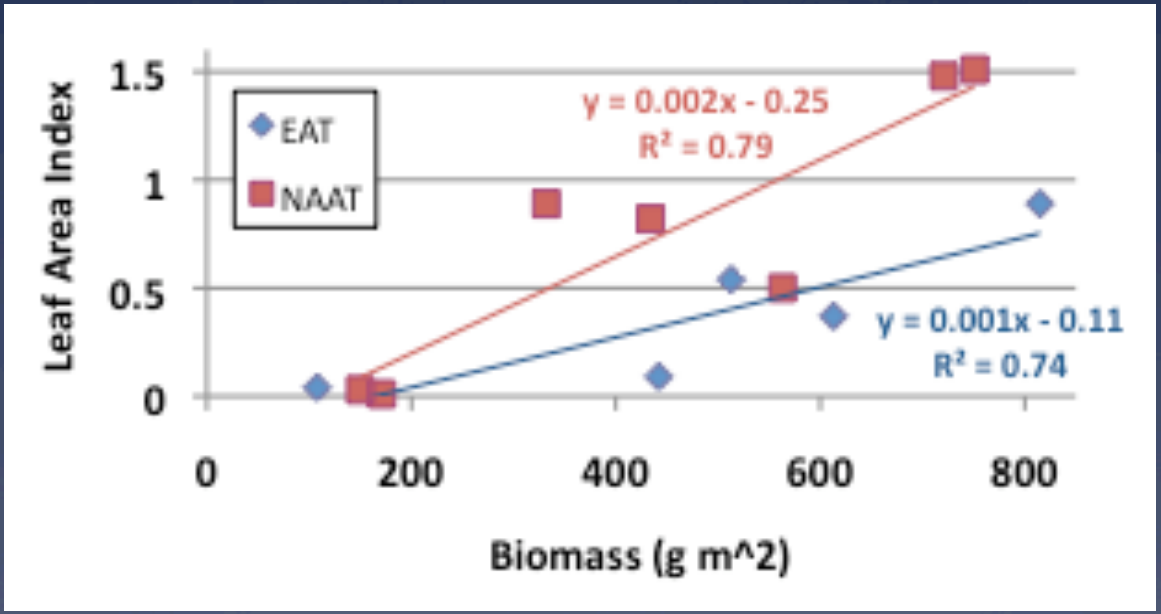


Plot-level biomass trends along EAT and NAAT

***Compared to NAAT, EAT has*:**

- **Less biomass in subzone A (Wetter, much colder).**
- **More biomass in subzone C, (Wetter, unglaciated landscape along the EAT.)**
- **Much more biomass in subzone E.**
- **Fewer evergreen shrubs and lichens. (Reindeer?)**

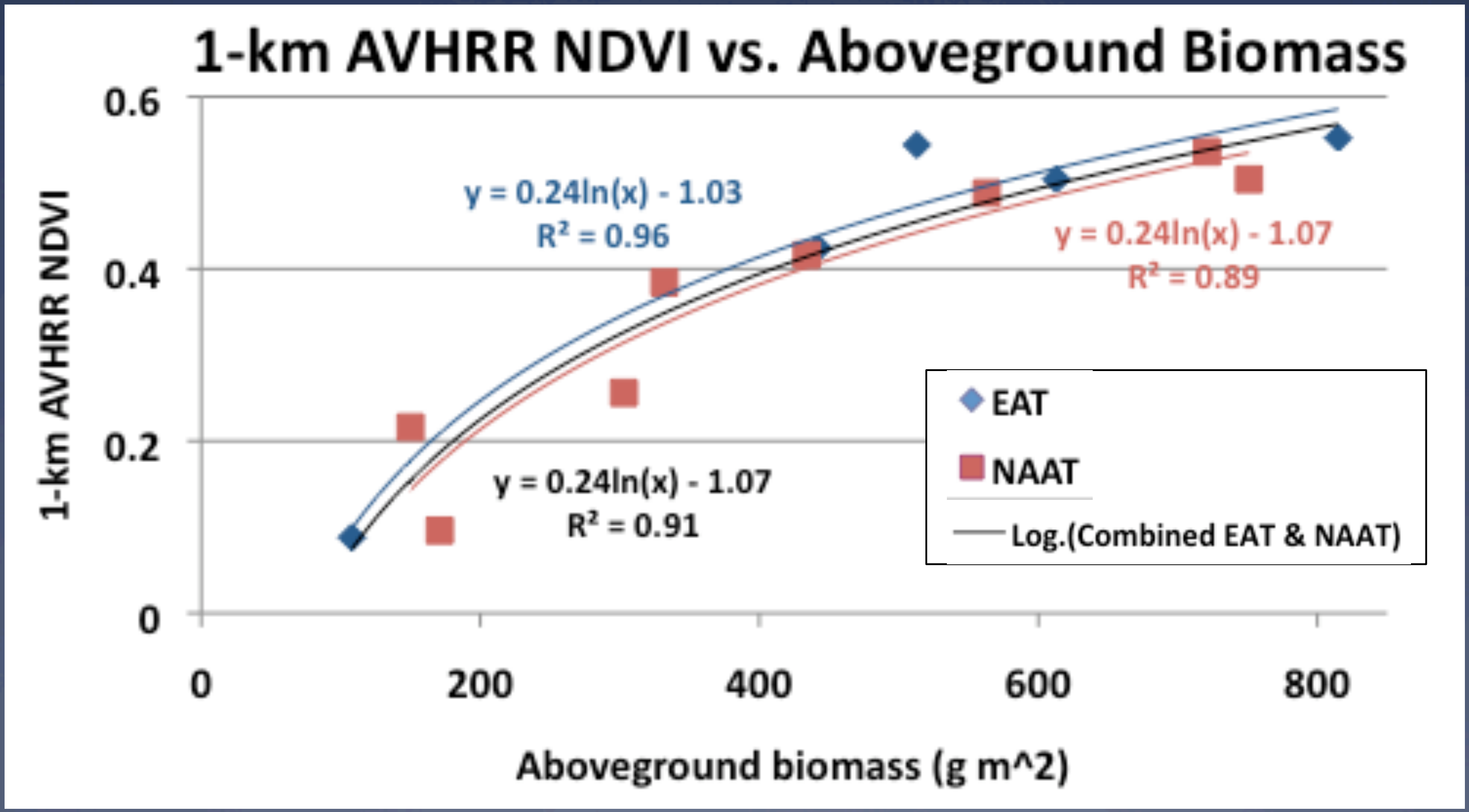
Comparison of EAT and NAAT Leaf Area Index vs. Biomass



- An equivalent amount of biomass has consistently much higher LAI values along the NAAT than along the EAT and the difference increases at higher biomass values.

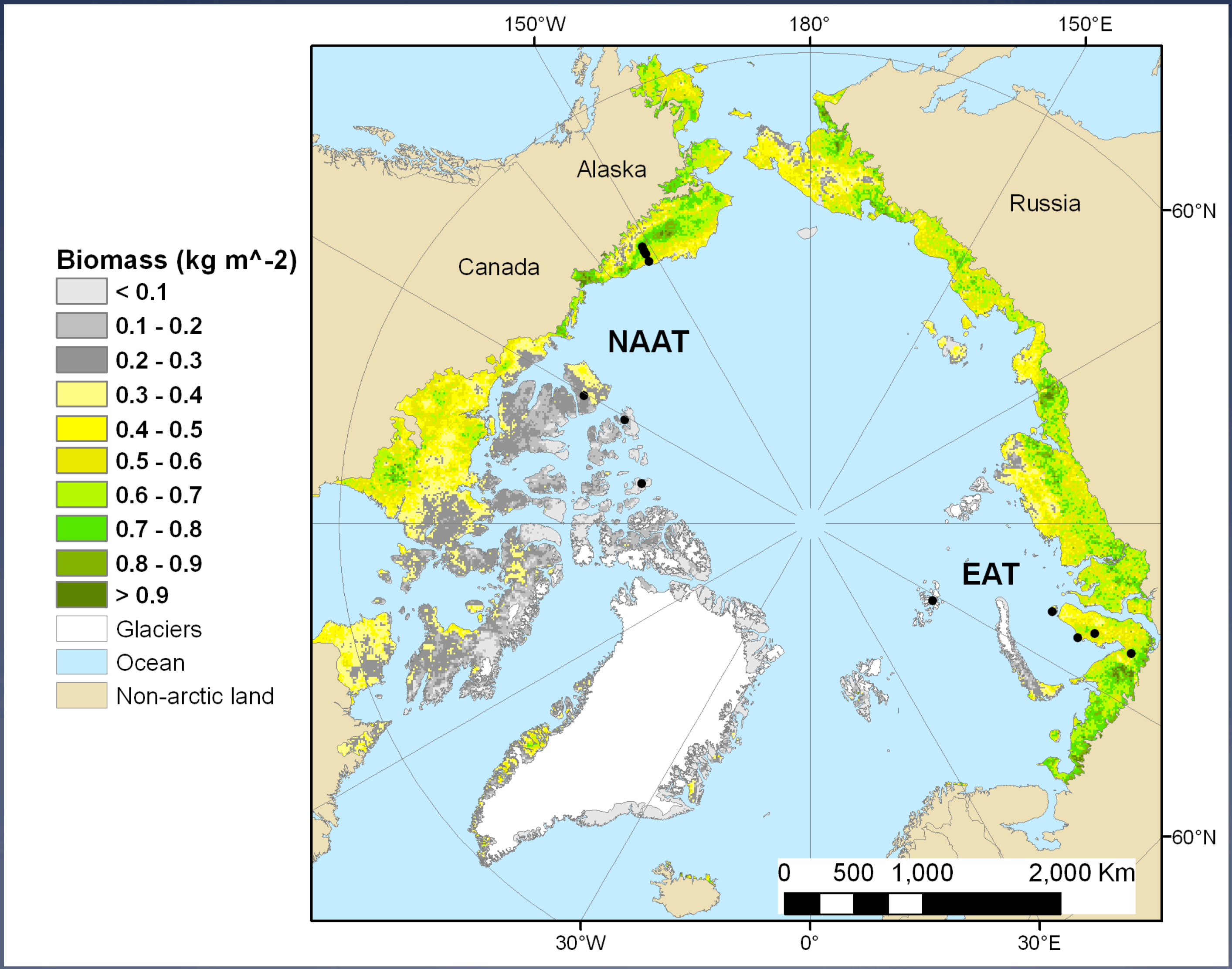
- Reflects the different structure of the vegetation along the two transects. Higher proportion of the total biomass is non-green along the NAAT (more wood, standing dead, hairy leaves, brown moss, evergreen shrubs and lichens).

Almost identical correlation between AVHRR NDVI and biomass along the two transects



Raynolds et al. 2011 submitted. *Geophysical Research Letters*.

Circumpolar aboveground biomass derived from NDVI



Raynolds et al. 2011 submitted, Geophysical Research Letters

Conclusions

1. There are broad similarities in community composition and structure between North America and Eurasia transects, but also major differences related to different disturbance regimes, geology, and precipitation patterns.
2. The Eurasia transect is much more homogeneous in the middle part of the transect (subzones B, C, D) than the NAAT.
3. Based on these data, it is not possible to define distinct zonal plant communities, except at the ends of the gradient in Subzones A and E, which are similar on both transects. The middle parts of the gradients have few good diagnostic taxa.
4. Ordination analysis reveals strong relationships between field-NDVI and total live biomass.
5. There is also a very strong correlation between AVHRR NDVI and zonal landscape-level biomass, that is nearly identical along both transects, which gives us good confidence in the biomass of zonal sites as depicted on our biomass map of the Arctic.
6. This study has shown the feasibility of studying and monitoring zonal landscape-level biomass and NDVI across the full Arctic bioclimate gradient.

Collaborations

Institutions:

- University of Alaska
- University of Virginia
- Earth Cryosphere Institute (RAS),
- Arctic Centre, Rovaniemi
- Agriculture and Agri-Foods, Canada
- University of Münster
- Masaryk University, Brno

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Synthesis data analysts: Patrick Kuss, Martin Kopecky and JJ Frost