A little about myself and the Fulbright Program

DONALD A. 'SKIP' WALKER

University of Alaska Fairbanks
Fulbright Scholar at Masaryk University, Brno

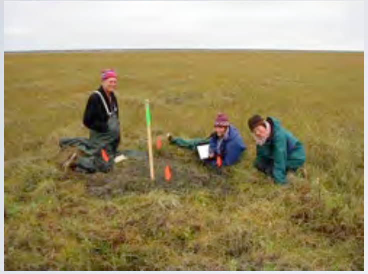
Cross-county skiing at UAF

2010 Joint Russia-U.S. Expedition to Franz Josef Land

Background

- Born in Denver, Colorado, USA, 1945.
- Educated at the Air Force Academy and University of Colorado in Boulder, Colorado (graduated 1972; M.S. 1977; Ph.D. 1981).
- Was married and have one son (18 years old).
- Favorite things to do: Ski, go to natural landscapes anyplace.
- First went to the Arctic in 1969 to work on an oil rig at Prudhoe Bay, Alaska.
- Did my M.S. and Ph.D. as part of the International Biological Programme, Tundra Biome.
- Have worked in the Arctic as a plant ecologist ever since.
- Currently at the University of Alaska Fairbanks.
- Director of the Alaska Geobotany Center.

Main research interests



Examining patterned ground features with graduate students, M. Raynolds, and A. Kade

- Tundra Ecology,
- Vegetation Mapping,
- Quantitative Ecology Methods,
- Geographic Information Systems and Remote Sensing,
- Snow Ecology,
- Biocomplexity of permafrost and patterned ground,
- Landscape Response to Climate Change,
- Disturbance and Recovery of Arctic Ecosystems.

Massive ground-ice erosion at Amderma, Russia

Describing snow structure at Toolik Lake

The Fulbright Scholars Program

Senator J. William Fulbright (1905-1995)

J. William Fulbright

- Prominent American statesman of the 20th century. His political career spanned over thirty years in the U.S. Congress.
- Profound influence on America's foreign policy and his vision for mutual understanding shaped the extraordinary exchange program bearing his name.

Fulbright Scholars Program

- Sponsors U.S. and foreign participants for exchanges in all areas of endeavor, including the sciences, business, academe, public service, government, and the arts.
- Has provided grants to almost 300,000 participants—chosen for their academic merit and leadership potential — with the opportunity to study, teach and conduct research, exchange ideas and contribute to finding solutions to shared international concerns.
- About 800 U.S. faculty and professionals are sponsored annually.

http://www.cies.org/us_scholars/

The Czech Fulbright Commission

Senator J. William Fulbright (1905-1995)

- 2011: 20th anniversary of Czech Fulbright Commission (by a bilateral agreement in 1991).
- Altogether, about 650 Czech grantees and about 550 U.S. grantees have been supported. The number of Czech grantees is higher thanks to a special program called the Fulbright-Masaryk program fully funded by the Czech Ministry of Education and intended for Czech scholars and Ph.D. students to conduct research with an invitation of a U.S. institution.
- 2010-11: 12 U.S. scholars in this academic year (3 of them in Brno). Some of the scholars were here for the fall semester only and they left already).
- Also 4 U.S. research students, 7 teaching assistants, 3 exchange high school teachers and 2 Fulbright-Hays students here. On average, about 25 U.S.-Czech Fulbright grantees each year.

http://www.cies.org/us_scholars/

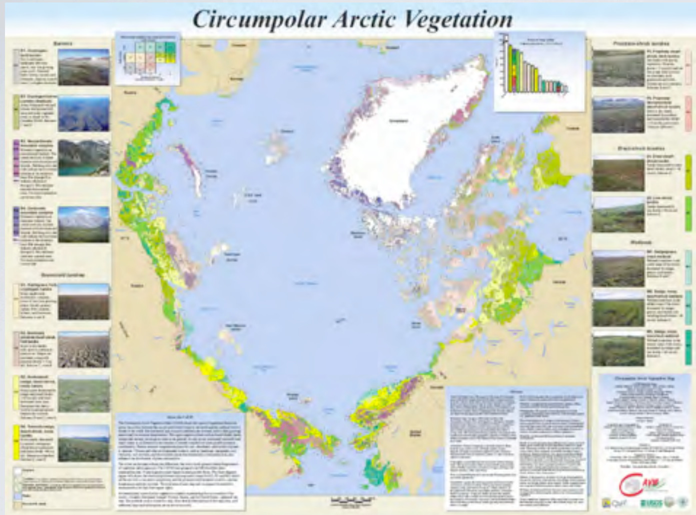
My Fulbright topic: An International Approach to Vegetation Description and Analysis

Photo: Ina Timling.

- Over 300,000 known species of plants and lichens organize themselves into a myriad of plant communities that cover nearly the whole land areas of the Earth.
- These plant communities have tremendous value to humanity for food, medicine, clothing and shelter. Plant communities also have important cultural and spiritual values.
- They help to regulate the Earth's climate and control essential nutrients and other resources including the water in streams and chemical composition of the air.

- Because of plant communities' extraordinary complexity and their essential importance to humans, vegetation scientists have devoted a great deal of energy to describing, classifying and analyzing the plant communities of the Earth.

Why an international approach is needed



- Global climate change has intensified efforts to classify and map the vegetation of the Earth in much more detail than has been done previously.
- Vegetation scientists are now making the first steps from regional vegetation analyses to global analyses of entire biomes that span multiple continents.
- An international approach of describing, naming and analyzing plant communities is needed for a wide variety of purposes.
- Different approaches are used in North America and Europe.

Proposed Activities at Brno

Sampling vegetation, soils, and permafrost monitoring
Amund Ringnes Island, Canada

- Teach Arctic Ecology course.
- Learn the Czech and European approach to vegetation classification and analysis.
- Analyze the vegetation data from the 2010 Joint U.S.-Russia expedition.
- Begin working on a course and/or textbook that would teach the European methods to U.S. students.

Introduction to Arctic Vegetation Ecology: The role of climate, permafrost and topography

Prof. D.A. "Skip" Walker
University of Alaska Fairbanks

Yamal Peninsula, Russia

Course Syllabus

Course calendar:

Week	Topic	Readings*
1	Overview of Arctic Ecosystems	Callaghan et al. 2005. Bliss et al. 1997 Matveyeva et al. 1997
2	Plant to planet mapping of Arctic Vegetation: the Arctic Geobotanical Atlas	Walker, Raynolds et al. 2009 Walker, Raynolds, et al. 2005
3	Loess ecosystems and the Mammoth Steppe: The role of soil pH in Arctic Vegetation	Walker and Everett 2001 Walker, Auerbach et al. 1998
4	Biocomplexity of patterned ground ecosystems: Interrelationships between climate, geomorphology, permafrost, soils, and vegetation	Walker, Epstein et al. 2008
5	Big Oil and Arctic Vegetation: Disturbance and recovery of Arctic vegetation	NRC 2003 (look at whole book, focus on chapter 7) Walker, Forbes et al. 2011
6	Greening of the Arctic: Climate change and circumpolar Arctic vegetation	Bhatt et al. 2010

Syllabus, description and references and other course materials:
http://www.geobotany.uaf.edu/teaching/CzechArcEcol/index

Readings

Bliss, L.C., 1997, Arctic Ecosystems of North America, in Wielgolaski, F.E., ed., Polar and Alpine Tundra: Ecosystems of the World: Amsterdam, Elsevier, p. 551-683.

Callaghan, T. V., et al. 2005.Chapter 7, Arctic tundra and polar desert ecosystems, pp. 243-352, in *Arctic Climate Impact Assessment - Scientific Report*, edited by C. Symon, L. Arris and B. Heal, Cambridge University Press, Cambridge.

Chernov, Y.I., and Matveyeva, N.V., 1997, Arctic ecosystems in Russia, in Wielgolaski, F.E., ed., Polar and Alpine Tundra, Volume 3: Amsterdam, Elvesier, p. 361-507.

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368 pages!!

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Only meant as in-depth supplementary references for serious Arctic students!!

Others should scan the material.

The above references provide a good summary of the known information from the IBP Tundra Biome studies in North America and Russia (Bliss 1997, Chernov and Matveyeva 1997).

Callaghan provides a good overview of the current knowledge with reference to global change.

Most of the lectures will focus on my research.

The Arctic

"There's something about north," he said, "something that sets it apart from all other directions. A person who is heading north is not making any mistake, in my opinion."

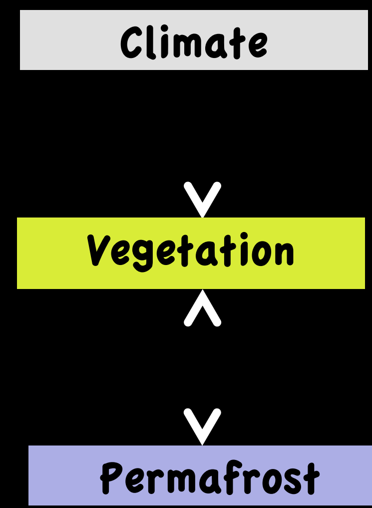
Stuart Little

Goals of the Talk

Controls of Arctic Vegetation:

- Climate
- Permafrost

- Physiography
- Topography
- Microtopography
- Substrate
- History



Think broadly about effects of climate change on vegetation and Arctic ecosystems.

Some adaptations to cold temperatures and low sun angle

- Long-lived perennials
- Low growth forms
- Slow growing
- Hairy inflorescences common
- Preformed flowers
- Vegetative reproduction common
- Racemes flowering on south-facing sides first
- C_3 photosynthesis
- Low-temperature photosynthesis and respiration
- Large belowground reserves and translocation of reserves to roots in fall
- Long seed survival in soil

Pedicularis lanata flowering on south side of racemes, early June, Prudhoe Bay, AK

Plant adaptations to windblown and snowy environments

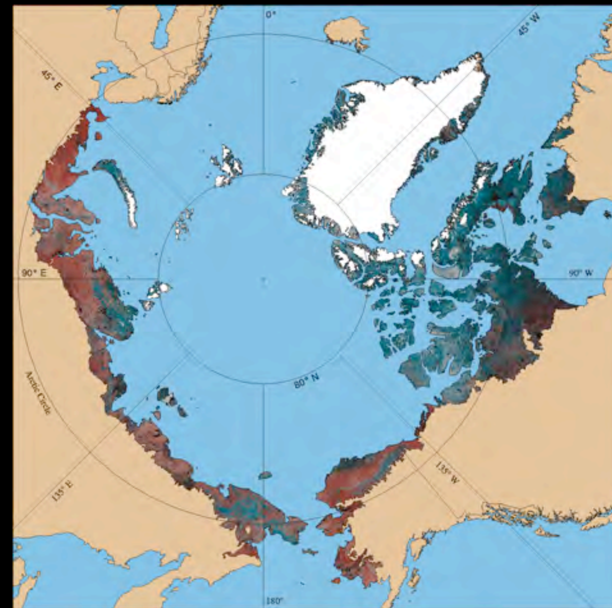
- Wind-blown areas
  - Main limiting factors are drought and physical abrasion.
  - Cushion-plants, and prostrate growth forms
  - Small leaves
  - Lots of attached dead
  - Drought resistance

- Snow beds
  - Main limiting factor is short growing season.
  - Ability to flower quickly at or even before snowmelt
  - Some plants photosynthesize beneath the snow.

Dryas integrifolia, Bundy Fiord,Axel Heiberg Island, Canada

The effect of temperature: Arctic Tundra Bioclimate Zone

- *"Arctic Tundra Zone" = "Arctic Tundra Biome"*
- *A maritime biome defined by its proximity to Arctic sea ice and cold summer and winter temperatures.*
- *Tree line is the southern boundary.*
- *Excludes tundra regions that lack an Arctic flora or an Arctic climate (e.g. Aleutian Islands, most of Iceland).*



CAVM Team 2003

Russian approach to zonation of the Arctic

- *Based on geobotanical subdivisions first proposed in the 1930's (Gorodkov 1935) and modified by Alexandrova Andreev, Sochava and others.*

- *Zones and subzones are characterized by the vegetation and soil that best express the regional climate.*

B.N. Gorodkov (1890-1953)

Arctic Subzones

Subzones (approx. mean July temperatures)

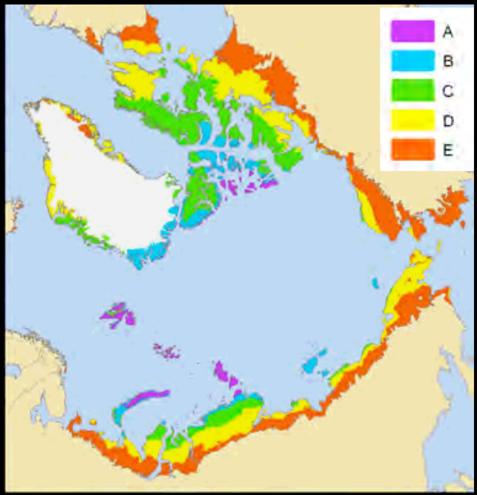
A. Cushion-forb (2-3˚C)

B. Prostrate dwarf-shrub (4-5˚C)

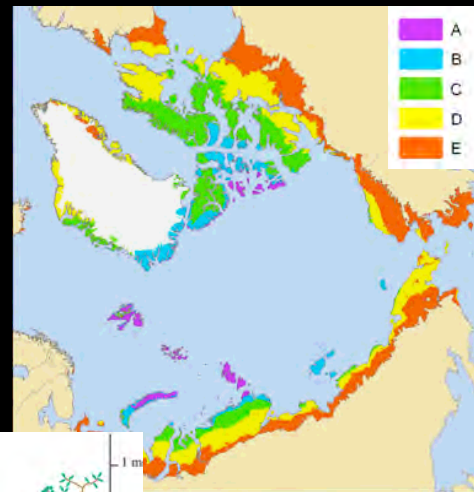
C. Hemiprostrate dwarf-shrub (6-7˚C)

D. Erect dwarf shrub (8-9˚C)

E. Low shrub (10-12˚C)

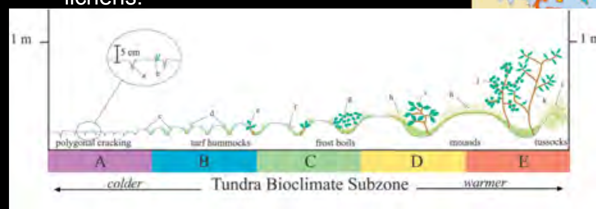


Arctic bioclimate subzones



Dominant Plant Growth Forms in Each Subzone

A – cushion forbs, rushes, grasses, mosses, liverworts, lichens, and cryptobiotic crusts.
B – rushes and prostrate dwarf shrubs with mosses, liverworts and lichens.
C – hemiprostrate and prostrate dwarf shrubs with bryophytes and lichens.
D – sedges, erect and prostrated dwarf shrubs with bryophytes and lichens.
E – tussock sedges, low and erect dwarf shrubs with bryophytes and lichens.



Subzone A: Cushion-forb subzone

Isachsen, Ellef Ringnes Island

- Covers only 2% of the Arctic, mostly in Canada, Mean July temperature 2-3˚C.
- No woody plants.
- Dominance of cushion forbs (*Papaver radicatum, Draba* spp., *Saxifraga* spp.) grasses *(Alopecurus alpina, Dupontia fisheri*), rushes *(Luzula* spp.), mosses, lichens.
- <5% cover of vascular plants on most surfaces.
- <50 vascular plants in local floras.

The “*Papaver* subzone”

Papaver radicatum, Ellesmere Island, Canada

Barren coarse-grained substrates at high elevations

Blacktop Ridge, Ellesmere island

Surprisingly lush vegetation on fine-grained substrates

"The vegetation…is superior to anything that I could have expected in such a latitude...patches of several acres…of as fine a meadow land as could be seen in England."

Captain William Scoresby Jr. 1822
Northeast coast of Greenland

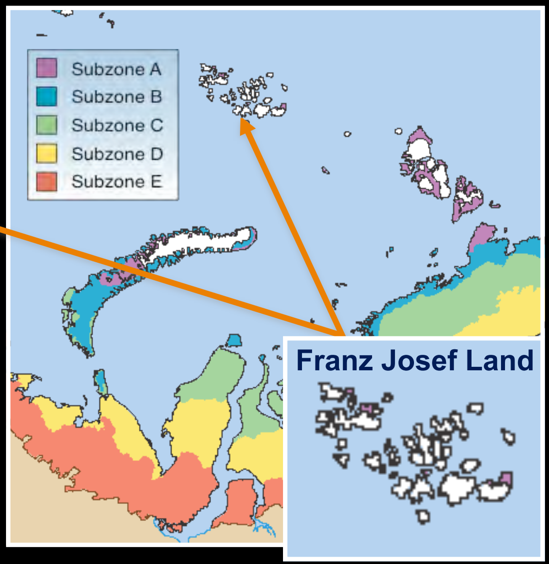
Amund Rignes Island, Subzone A, Canada

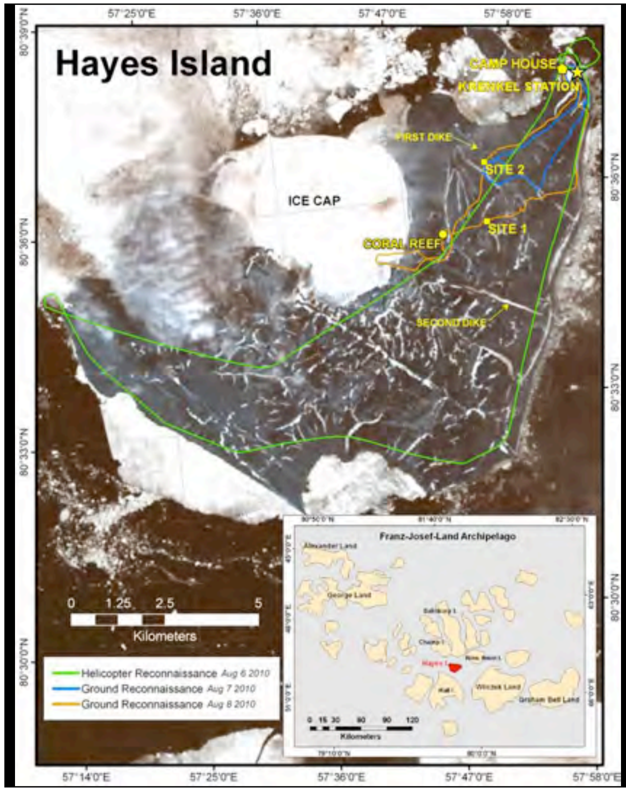
Dominance of cushion forbs

Cerastium arcticum, Saxifraga caespitosa

Franz Josef Land: Bioclimate subzone A

- Subzone A vegetation covers only a small portion of FJL. Most of the archipelago is covered by ice.





Hayes Island

- Central part of the FJL Archipelago (inset map).
- 132 km2
- Krenkel hydrometeorological station in NE corner.
- Most of the island is ice free.

Climate for Krenkel Station, Hayes Island

80˚37'N, 58˚3'E, Elev. 21 m

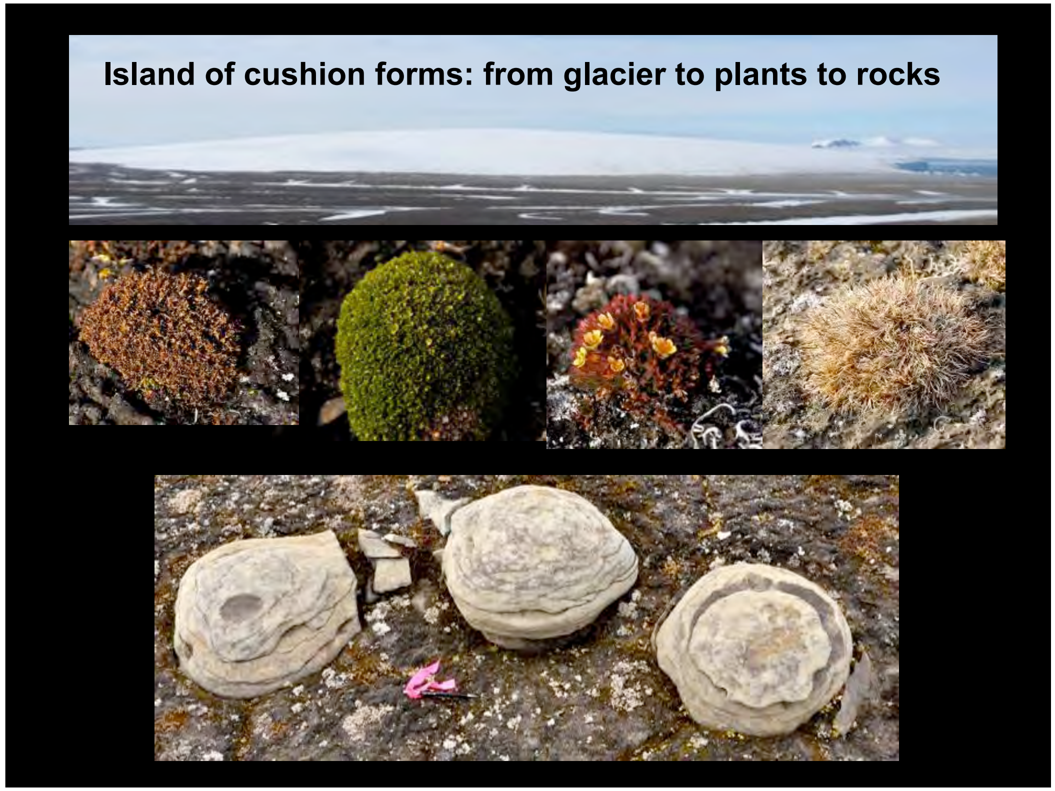
	Unit	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature over 21 years	°C	-12	-22	-23	-23	-18	-8	-1	1	0	-3	-11	-18	-22
Average precipitation over 33 years	cm	28.2	3.6	3.3	2.3	1.8	2.0	1.3	2.3	2.3	3.0	2.3	4.1	3.3
Average wind speed over 19 years	km/h	27.4	30.6	27.4	29.0	29.0	25.7	29.0	19.3	17.7	29.0	29.0	29.0	32.2

- Maritime Arctic climate.
- The mean annual temperature is -12 °C (not that cold compared to Subzone A stations in Canada).
- The absolute recorded extremes are -42 °C and 12 °C).
- Only one month (July) has a mean temperature above freezing and the summer warmth index is 1.1 °C mo (the coldest summer climate in the Arctic).
- Warm Barents Sea strongly affects the winter climate — high winter precipitation.
- Frequent storms, strong winds particularly in winter.


Very Late Phenology
August 7, 2010

Late phenology of plants

Saxifraga oppositifolia (Purple Mountain Saxifrage) only starting to flower Aug 10. This is one of the earliest blooming plants in Alaska tundra.

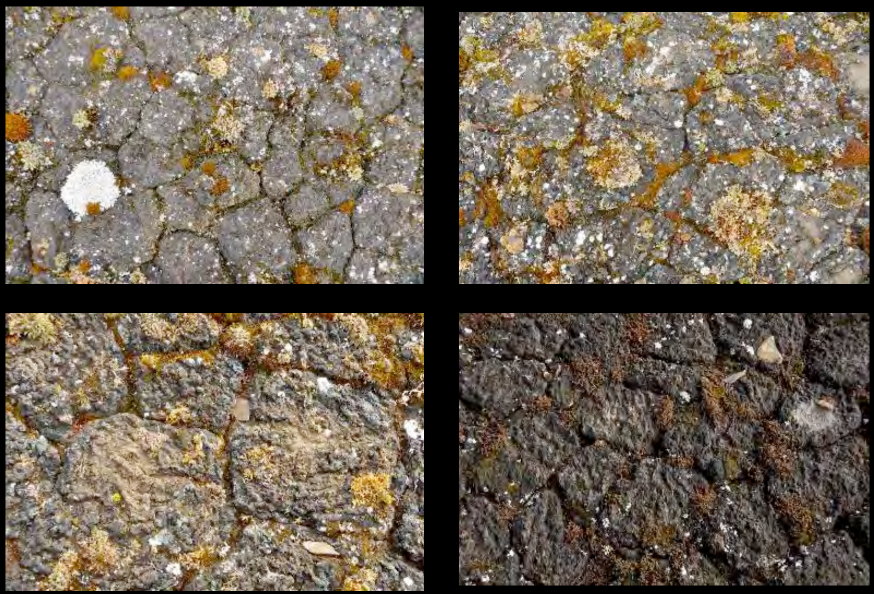

Island of cushion forms: from glacier to plants to rocks

Hayes Island is an excellent example of Tundra Subzone A:

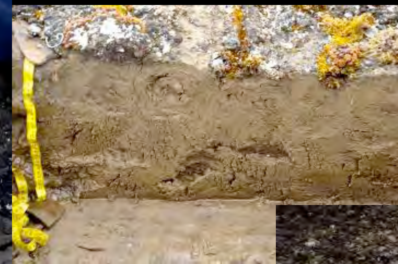
Polar poppy (*Papaver dahlianum* ssp. *polare)*

- "Poppy zone".
- Sparse vascular plant cover and biomass, mainly cryptobiotic soil crusts with scattered cushion lichens, mosses and forbs.
- Vegetation concentrated in cracks between small polygons.
- Low vascular-plant diversity, but relatively high lichen and bryophyte diversity.
- Few graminoid species — grasses (Poacea) and rushes (Juncaceae) are present, but **no sedges** (Cyperaceae).
- **No woody species.**
- **Lack of peaty wetlands**.

Vegetation concentrated in cracks between small polygons



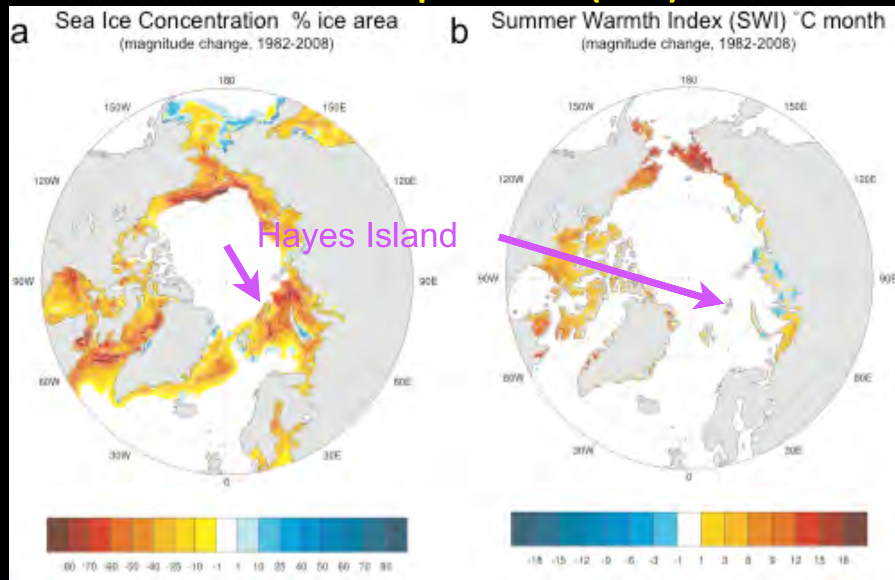
Soils



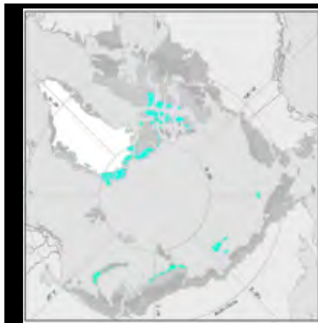
Vertical and horizontal soil pits (Gosha Matyshak):

- Extensive sands. Few areas with truly loamy soils.
- Not much soil horizon development.
- Thin organic horizons occur in cracks between polygons.
- Nearly all soils are wet at shallow depth - even relatively well-drained sites.

Trends of Circumarctic sea ice and summer land temperatures (SWI)



Bhatt et al. 2010. *Earth Interactions*



Subzone B: Prostrate dwarf-shrub subzone

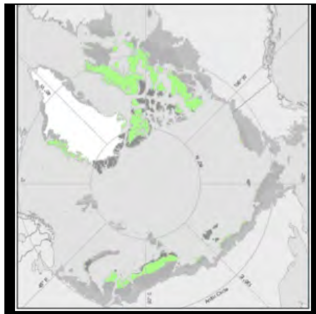
- Mean July temperature 3-5˚ C.
- Prostrate dwarf shrubs (e.g. *Salix arctica, Dryas integrifolia*) are abundant, Rushes (*Luzula*) are dominant on mesic surfaces.
- 5-50% cover of plants on zonal surfaces.
- 75-125 plant species in local floras.

Luzula confusa tundra at Mould Bay, Prince Patrick Island, Canada

Subzone B: "The *Dryas* subzone"

Coastal Arctic Alaska: Subzone B

West Dock, Prudhoe Bay, AK



Subzone C: Hemi-prostrate dwarf-shrub subzone

Mean July temperature: 5-7 °C.

- Dominant plant growth forms: Hemi-prostrate dwarf shrubs, sedges.
- 75-150 vascular plant species in local floras.

Thompson River vicinity, Banks Island, Canada

Subzone 3: "the *Cassiope* subzone"

- *Cassiope abundant* in snowbeds in areas of nonacidic soils.
- Abundant on mesic surfaces in areas of acidic soils.

Cassiope tetragona, photo by Dave Murray.

Subzone C: Hemiprostrate dwarf-shrub subzone

- Mean July temperature 5-7˚ C.
- The hemiprostrate dwarf shrub.*Cassiope Tetragona is* abundant (but on nonacidic substrates, only in snowbeds).
- 5-50% cover of plants on zonal surfaces.

East Wind Lake, Ellesmere Island

Typical Subzone 3 toposequence, northern Canada

Ellesmere Island, East Wind Lake vicinity

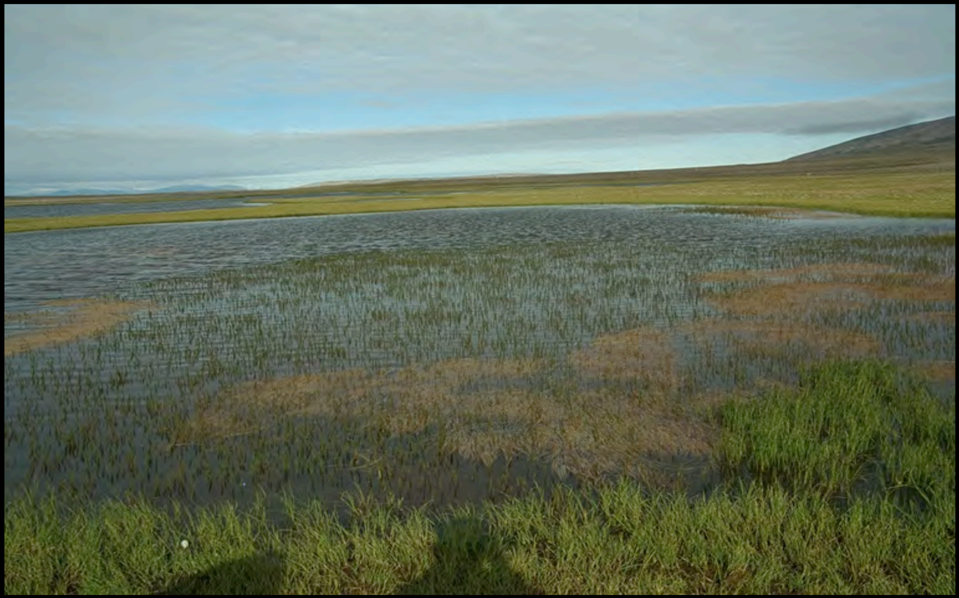
1. Hill crest: Dry barrens with scattered forbs, sedges, lichens

2. Upper backslope: Dry polygons and stripes with *Dryas*

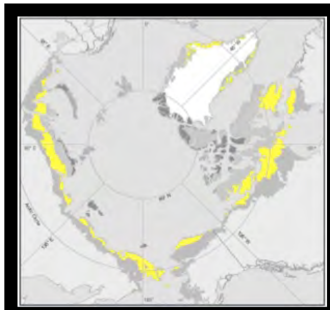
3. Lower backslope: Zonal vegetation, *Cassiope tetragona* community

4. Footslope: Wet meadow

Subzone C: Well developed wetlands in lowlands



East Wind Lake vicinity, Ellesmere Is.: *Hippuris vulgaris, Pleuropogon sabinii, Carex aquatilis*



Subzone D: Erect dwarf-shrub subzone

- Mean July temperature 7-9 ˚C
- Extensive peat development
- 50-80% cover of plants on zonal surfaces
- 150-250 plant species in local floras

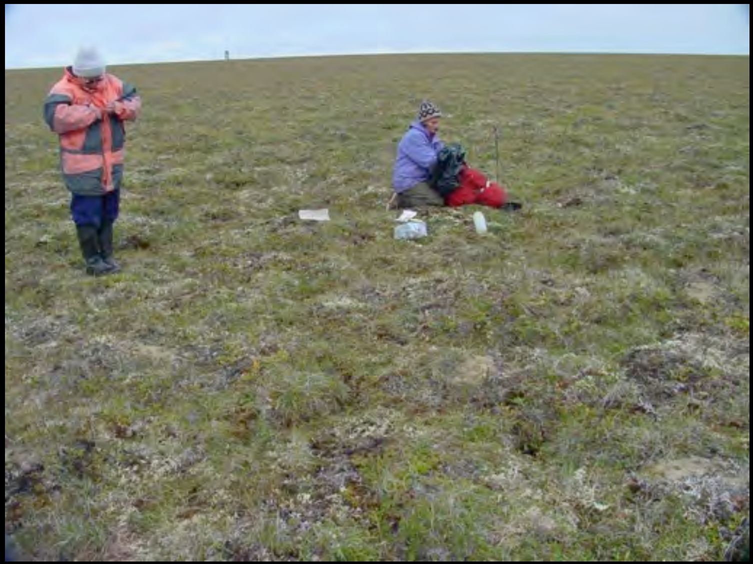
Cambridge Bay vicinity, Victoria Island

Subzone D: “*Betula* subzone”

- Northern limit of *Betula nana/exilis*
- Erect dwarf shrubs (<40 cm common in open tundra),
- Low shrubs (up to 2m) along streams
- Extensive peat development
- 50-80% cover of plants on zonal surfaces
- 150-250 plant species in local floras

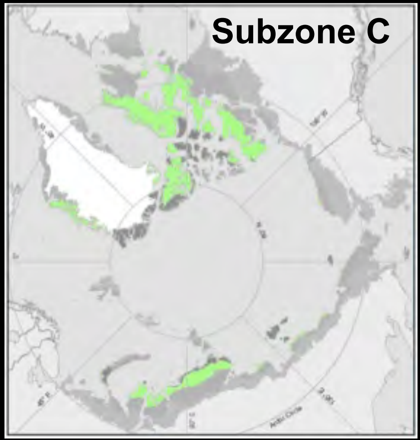
Betula nana, Photo: Hordur Kristinsson

Mesic Subzone D tundra near the mouth of the Kolyma River, Russia

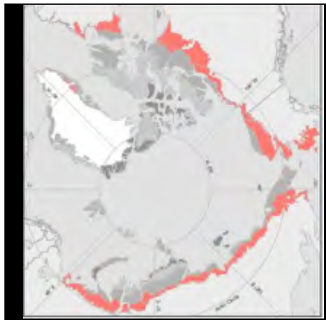


- Abundance of non-sorted circles (frost boils).
- Peaty tundra with thick moss between the circles.

Subzone C-D boundary



- Separates High (subzones A, B, C) and Low Arctic (subzones D, E) (Bliss).
- Hyperarctic and Hypoarctic (Yurtsev).
- Northern limit of many hypoarctic taxa such as *Vaccinium, Ledum, Betula, Arctous*.
- Separates mainly mineral zonal soils north of the boundary from mainly peaty soils to the south.



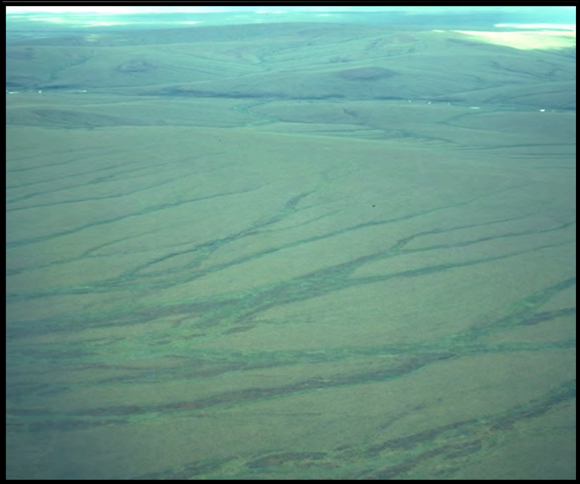
Subzone E: Low-shrub subzone

- Mean July temperature 10-12˚ C.
- Low and tall shrubs common along streams.
- Extensive acidic peat development.
- 80-100% cover of plants on zonal surfaces.
- 200-450 plant species in local floras.

Kuparuk River, Northern Alaska

Subzone E: Peaty landscapes

- Paludified hillslopes with *Sphagnum* and peat
- Water tracks and well-developed drainage systems
- Dominance of common boreal-forest shrubs (e.g., *Betula, Ledum, Vaccinium, Empetrum, Salix* spp.)



Water tracks, Arctic Foothills, northern Alaska

Subzone E: the "*Alnus* zone"

- Well-developed shrublands develop on warmer soils with no or very deep permafrost.

Extensive tussock-tundra in unglaciated areas of Beringia

- Common in areas with ice-rich permafrost with shallow active layers.

Beringian land bridge

- Sea level about 90 m lower 19,000 years ago.
- Continental-sized land bridge with colder, drier climate than present.
- Land bridge flooded about 14,400 years ago.

From Hopkins et al., 1982

Number of species in different taxa in local floras and faunas along the bioclimate gradient, Taimyr Peninsula, Russia

	High Arctic		Low Arctic	
Subzone	A	B/C	D	E
Vascular plants	57	96	239	241
Spiders	2	9	19	?
Springtails	12	29	62	96
Bugs	0	1	4	12
Beetles	2	9	35	68
Birds	9	32	47	50
Mammals	3	6	8	15

(modified from Chernov and Matveyeva 1997)

Effect of temperature on northern limit of species: Young's (1971) floristic zones

Zone	SWI (˚C)	Size of flora
1	<6	<50
2	6-11	75-125
3	12-19	125-250
4	20-35	250-500

SWI = sum of the mean monthly temperatures >0˚C.

- Temperature is the primary variable controlling the diversity and productivity of tundra.
- Young divided the Arctic into four floristic zones based on the total amount of summer warmth.
- Along this gradient, there is a roughly a 5-fold increase in the amount of available summer heat above freezing, and 10-fold increase in number of plant species in regional floras.

Permafrost

- Permanently frozen ground
- Defined exclusively on the basis of temperature (below 0˚C all year for at least 2 years).
- Independent of soil texture, water content, or lithologic character.

Yedoma deposit, Yakutia, Russia
Photo Washburn 1980

Distribution of permafrost

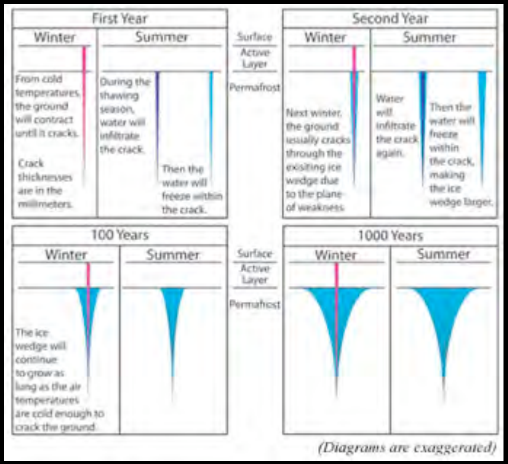
- **Continuous**: permafrost nearly everywhere
- **Discontinuous**: Large areas mainly on south-facing slopes without permafrost.
- **Sporadic**: Large areas with permafrost, mostly in wetlands and bogs.
- **Isolated**: Mostly in alpine areas.

Patterned ground: ice-wedge polygons

Prudhoe Bay vicinity, Alaska

Ice wedge

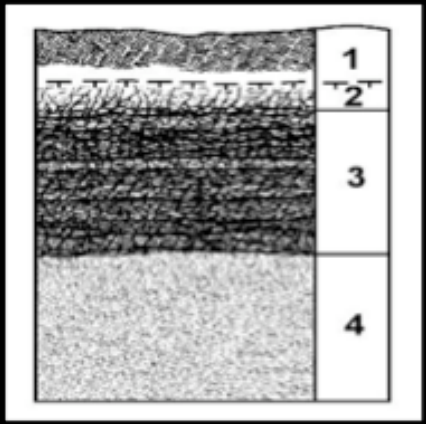
Photo: Washburn 1980



From: U.S. Army CRREL Permafrost Tunnel website: http://permafrosttunnel.crrel.usace.army.mil/permafrost/massive_ice.html.

Active layer

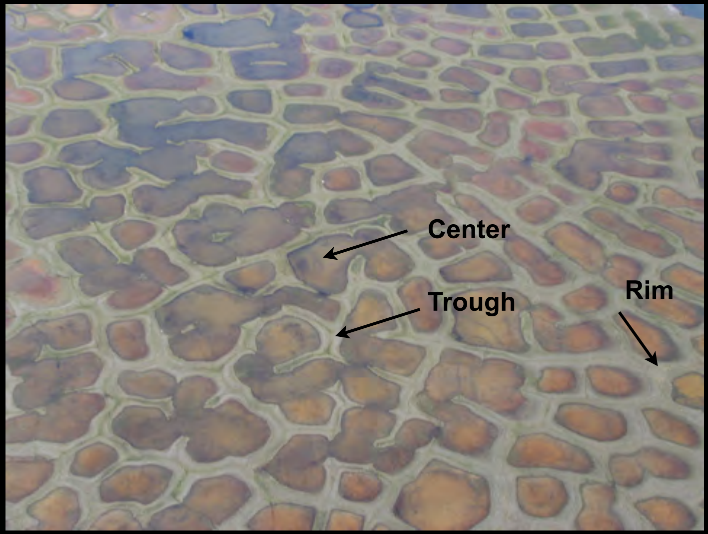
- The layer of soil that thaws in the summer and freezes each autumn.



From French and Shur (2010)

- *1 – Active layer (zone of annually thawed soil).*
- *2 – Transient layer (which is frozen in some summers and thawed in others and defines variation in the active layer depth in the contemporary climate).*
- *3 – Intermediate layer (ice-rich and organic-rich zone at the top of permafrost, which is slowly aggrading, i.e. increasing in thickness and moving upward due to organic-matter accumulation and changing microenvironment).*
- *4 – Original permafrost.*

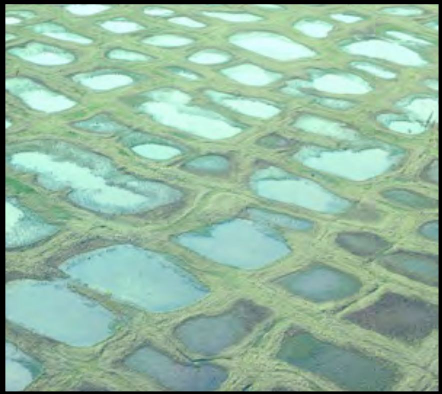
Low-centered ice-wedge polygons



- Centers: wet tundra or water.
- Rims: moist tundra, soil displaced by the ice wedge.
- Troughs: wet cracks between rims, position of ice wedge

Thermal contraction-crack analogue: desiccation cracks

Vegetation patterns associated with ice-wedge polygon terrain



Low-centered polygons,
Kuparuk River Delta, Alaska

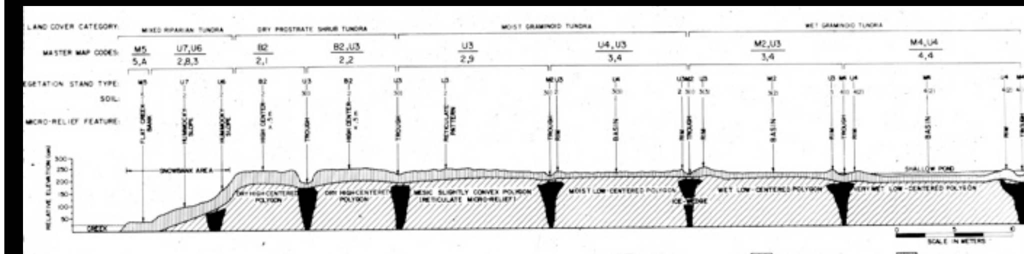
Friophorum angustifolium,
in troughs of flat-centered polygons,
Arctic Foothills, Alaska

High centered polygons formed by enhanced drainage of low-centered polygons

http://en.wikipedia.org/wiki/File:Melting_pingo_wedge_ice.jpg

Ice wedges in relation to microtopography

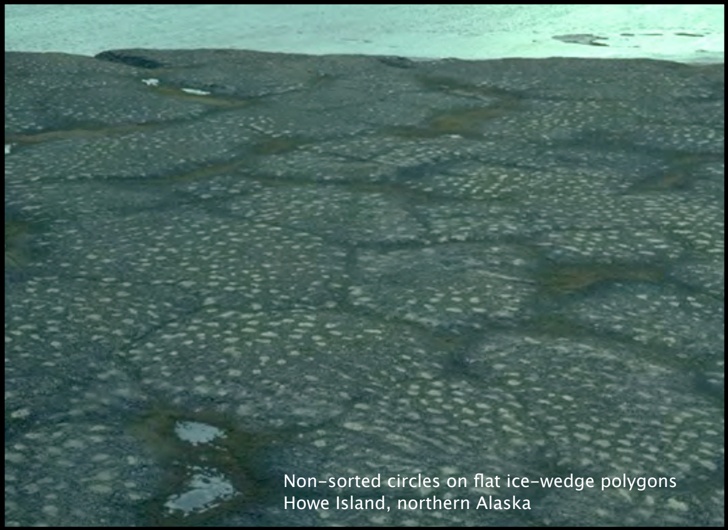
Idealized cross section through ice-wedge polygons showing the position of the ice-wedge in relation to microtopographic elements



Walker et al. 1980

Schematic of an actual 300-m trench through ice-wedge polygons showing the areas of massive ground ice (blue)

Patterned ground



Non-sorted circles on flat ice-wedge polygons
Howe Island, northern Alaska

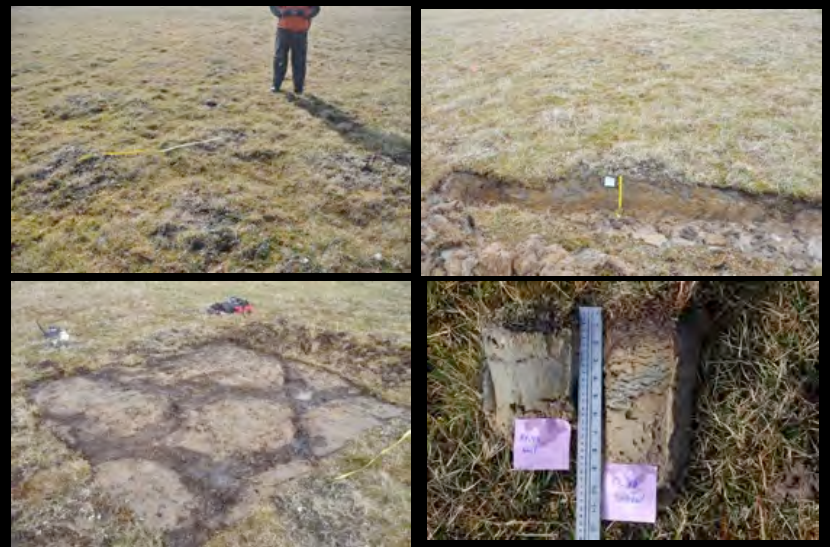
Non-sorted circles

- 1-3 m diameter circles caused by frost heave.
- Ubiquitous feature of landscapes in northern tundra areas.
- Result in patchy landscapes,

Aerial photo: Nonsorted circles, southern Yamal Peninsula, Subzone E.
Insert: Prudhoe Bay, AK, subzone D.

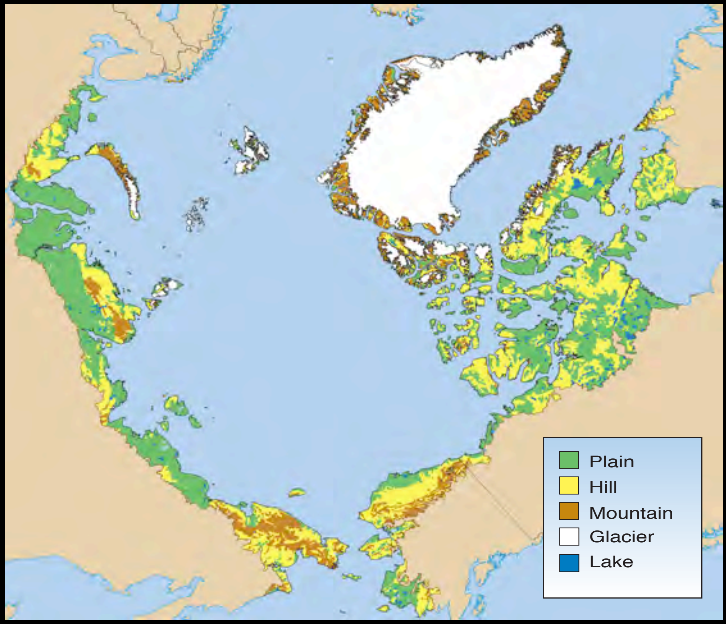
Soils of nonsorted circles

- Thinner O horizons
- 10-20 cm of heave within the frost boils, compared to less than 5 cm between the boils.
- Fewer plants
- Greater heat flux
- Deeper active layers
- Carbon sink



Ostrov Belyy, Russia, Subzone B/C

The effects of topography: Major Physiographic Units



Plains and plateaus

Areas that are covered by deep glacial, alluvial or marine deposits.

Major areas:

- Northern Alaska Y-K delta,
- Western Canada,
- Most of Russian Arctic

Arctic coastal plain, northern Alaska

Folded mountains

Tectonically uplifted regions.

Major regions:

- Brooks Range, Seward Peninsula, Alaska;
- Northern Canada
- Northern Greenland
- Urals and Chukotka in Russia

Phillip Smith Mountains, Brooks Range, Alaska

Shields

- Predominantly glaciated areas that have been eroded down to the Precambrian bedrock.
- Rugged uplands, rock surfaces, spectacular fjords, and deranged drainages.
- Major areas:
  - Eastern Canada,
  - Most of Greenland,
  - Scandinavia

Canadian Shield, Daring Lake vicinity, Northwest Territories, Canada

Effects of topography: Toposequences

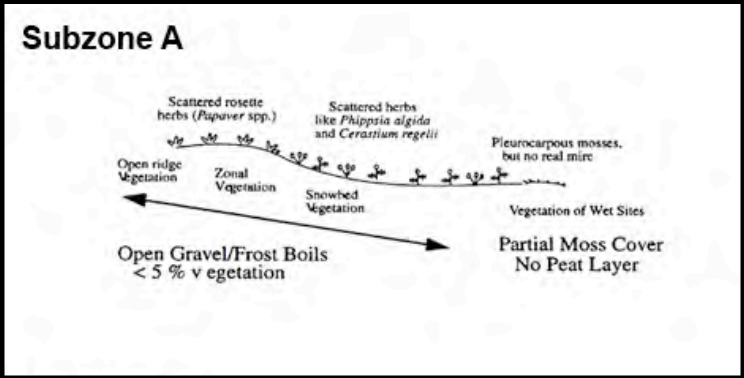
Imnavait Creek, Subzone E, northern Alaska

Toposequence or “catena”

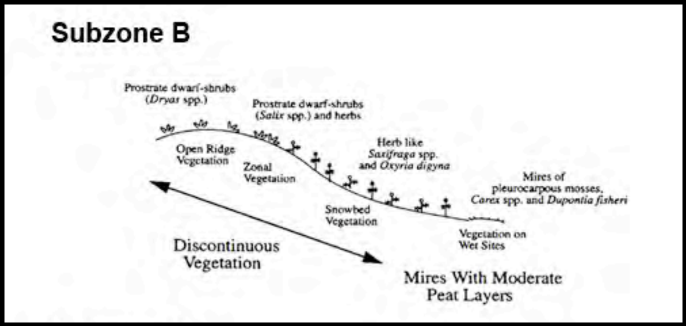
Catena (from Latin: “Chain”)

- “…a mapping convenience…a grouping of soils which while they fall wide apart in a natural system of classification on account of fundamental and morphological differences, are yet linked in their occurrence by conditions of topography and are repeated in the same relationship to each other wherever the same conditions are met with” (Milne 1935) cited in (Warkentin 2006).
- = Hill slope gradient, mesotopographic gradient (Billings 1973), ecohydrological gradient (de Molenaar 1987), synthetic alpine slope model (Burns and Tonkin 1982)

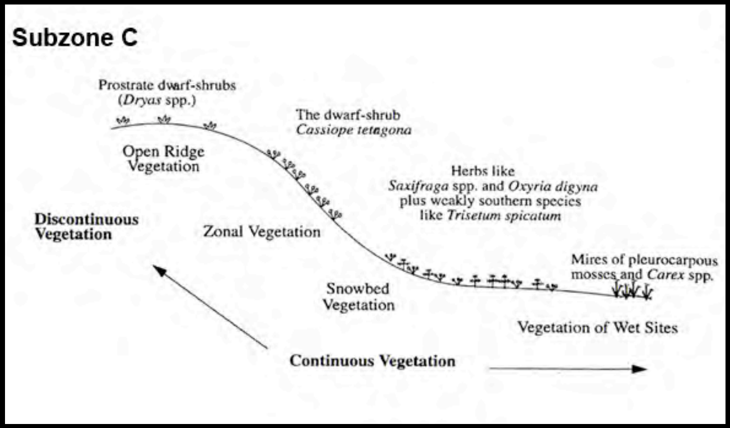
Idealized toposequences in each subzone (based on Elvebakk 1999)



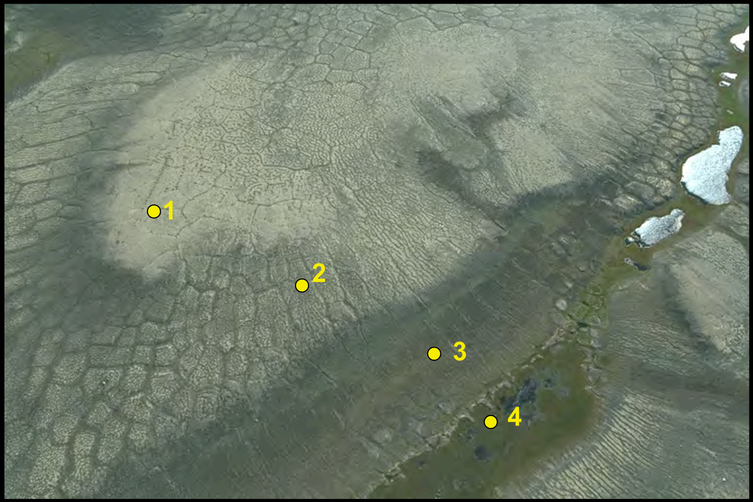
Idealized toposequences in each subzone (based on Elvebakk 1999)



Idealized toposequences in each subzone (based on Elvebakk 1999)



Typical Subzone C toposequence, Banks Island, Canada



Ellesmere Island, East Wind Lake vicinity

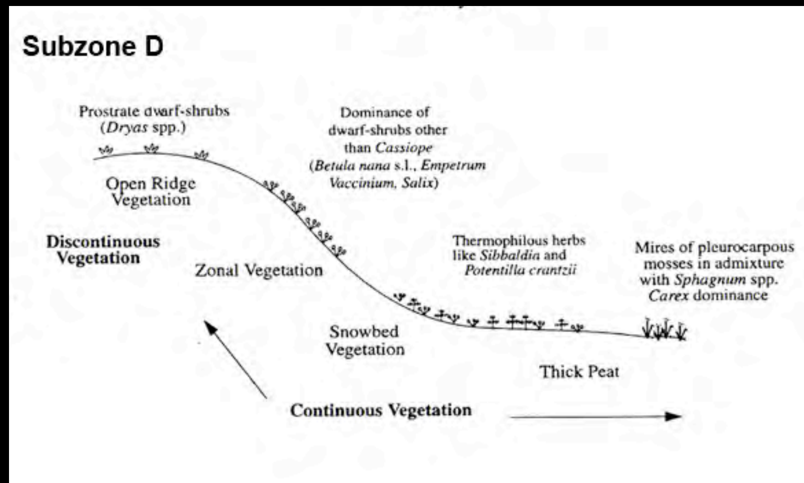
1. Hill crest: Dry barrens with scattered forbs, sedges, lichens

2. Upper backslope: Dry polygons and stripes with *Dryas*

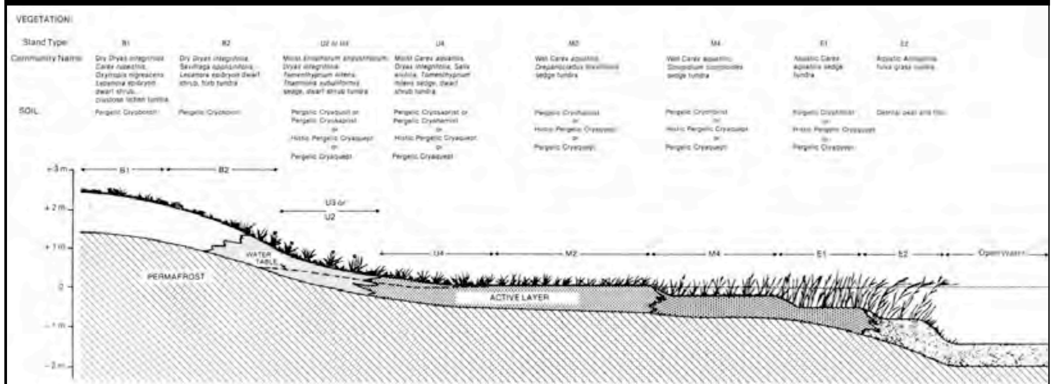
3. Lower backslope: Zonal vegetation, *Cassiope tetragona* community

4. Footslope: Wet meadow

Idealized toposequences in each subzone (based on Elvebakk 1999)

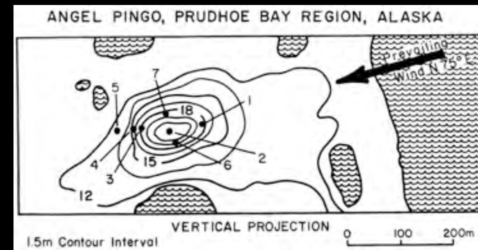


Subzone D, Toposequnce, Prudhoe Bay, Ak



Walker and Everett, 1991

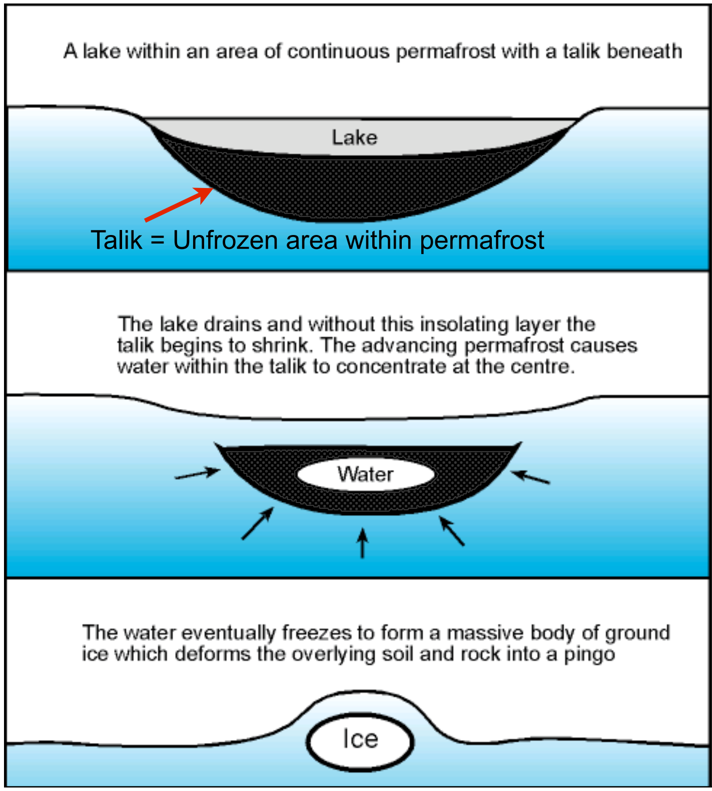
Pingo Toposequences, Subzone D, on gravelly pingos, northern Alaska



1. ENE wind-exposed crest.
2. Summit (usually site of animal dens and bird perches),
3. Dry leeward side above the snowbank,
4. Middle of snowbank on leeward side (well drained),
5. Bottom of snowbank at leeward base of pingo (poorly drained),
6. South slope,
7. North slope. Sites 2, 3, 4 and 5 formed a toposequence (M.D. Walker 1990).

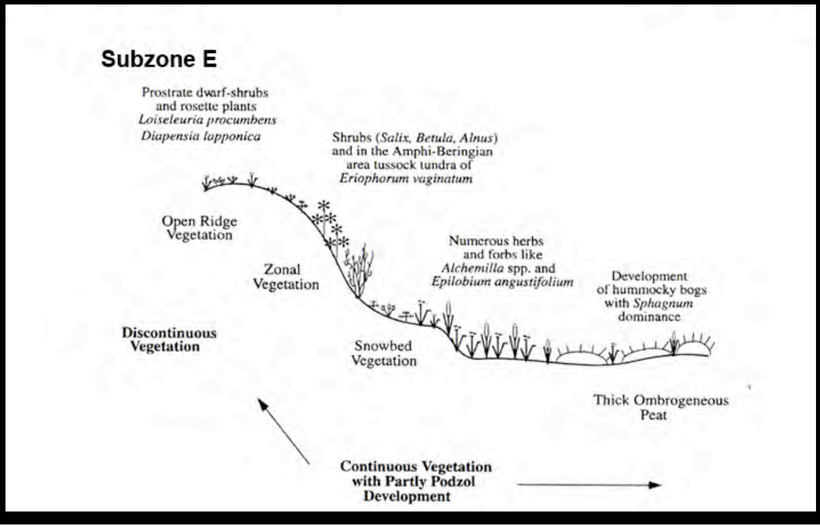
Walker, DA et al. 1985. Pingos of the Prudhoe Bay area, Alaska. AAR 17: 321-336

Closed-system Pingo formation

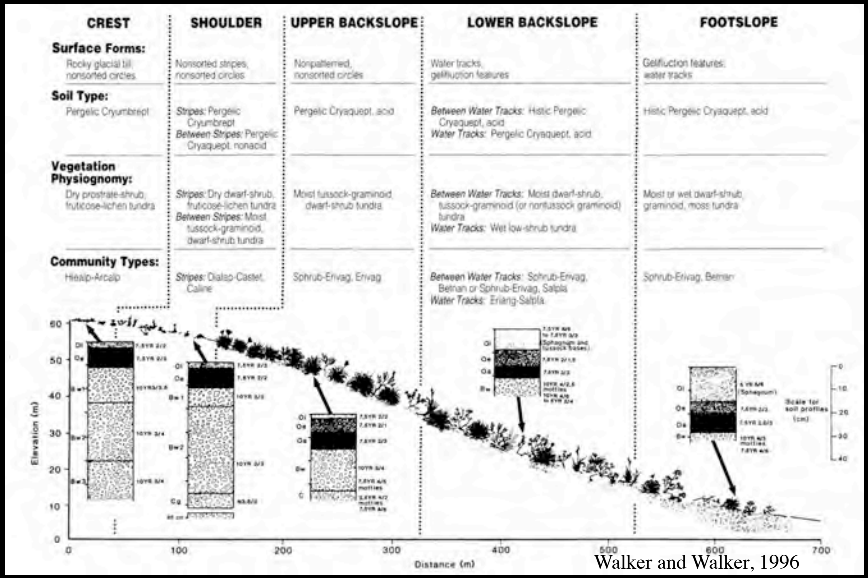


Courtesy: British Society for Geomorphology

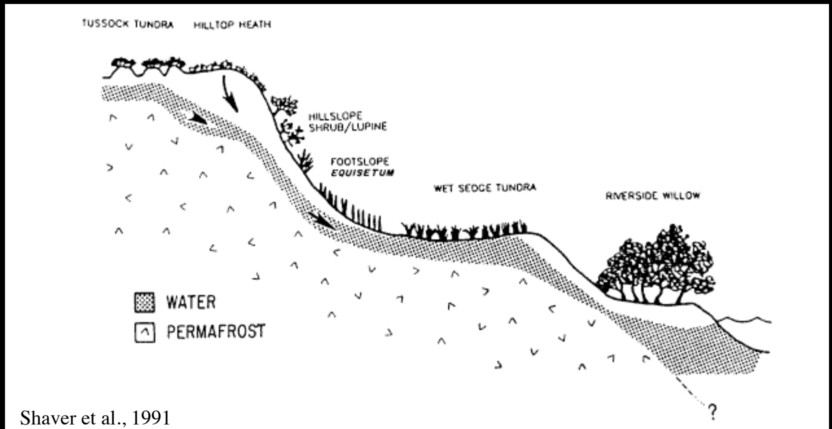
Idealized toposequences in each subzone (based on Elvebakk 1999)



Subzone E, Imnavait Creek, Ak toposequence



Subzone E, Sagavanirktok River Toposequnce



Shaver et al., 1991

Imnavait Creek: hill crest

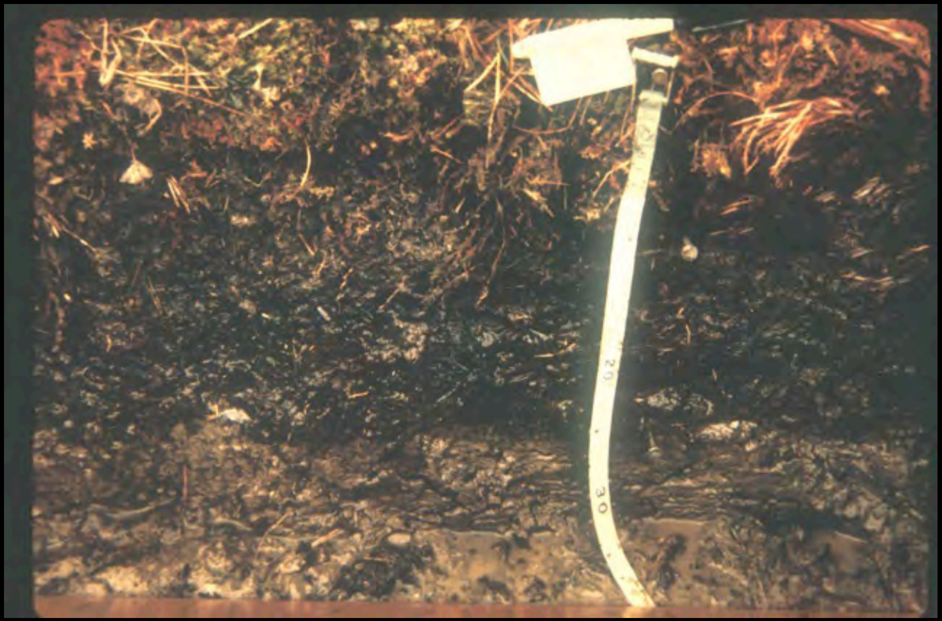
Hill crest soil: Pergelic Cryochrept

Imnavait Creek: backslope vegetation

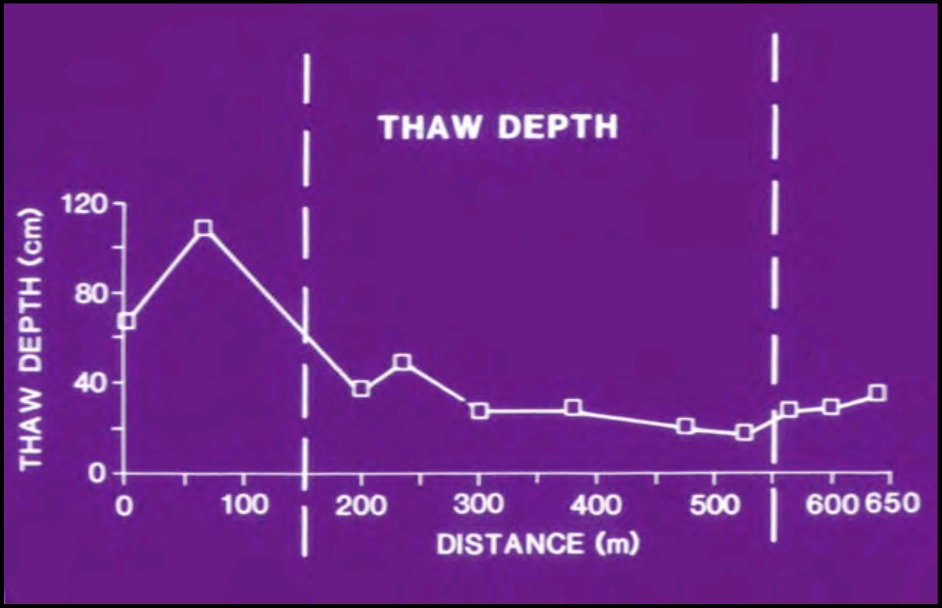
Backslope soil: Pergelic Cryaquept

Imnavait Creek: toe slope vegetation

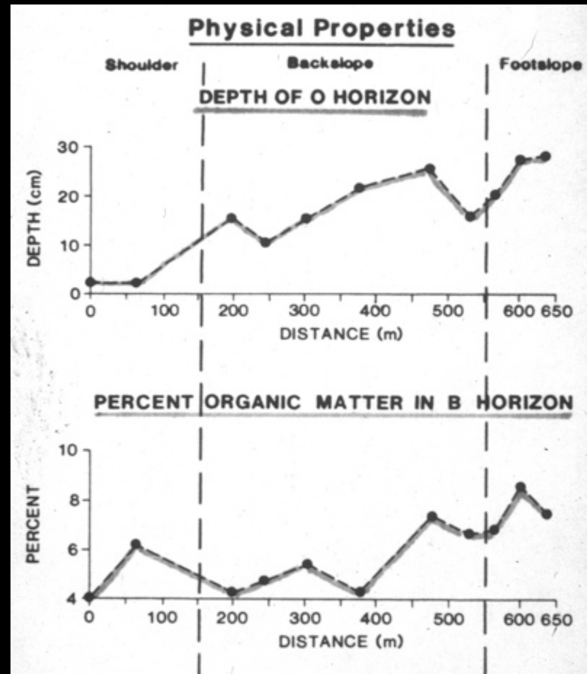
Toeslope soil: Histic Pergelic Cryaquept



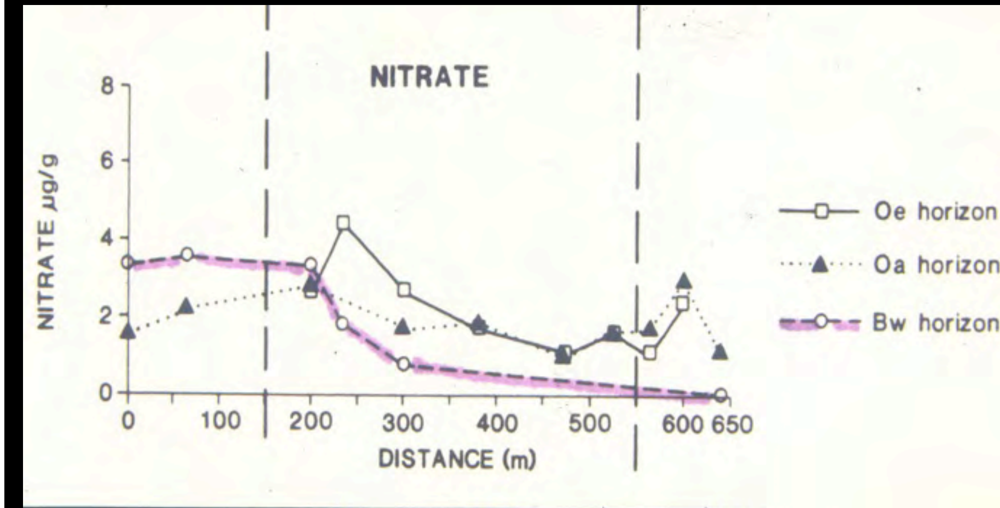
Trends in active layer depth



Trends in organic matter



Trends in nitrate



General trends in soil properties downslope in the Low Arctic, Subzone E, acidic tundra on ice-rich permafrost

- Increasing
  - Depth of O horizon
  - Depth of the A horizon
  - Percent clay in the B horizons
  - Soil moisture
  - Ice content in permafrost
- Decreasing
  - Active layer thickness
  - Soil pH (opposite to pattern in temperate regions due to organic soils)
  - Soil nutrients (opposite to pattern in temperate regions due to organic soils)

Take-home points

- The Arctic is every bit as diverse as other global biomes in terms of terrain, climate and productivity variation.
- The primary control of vegetation production and diversity is temperature.
- Along the Arctic climate gradient there is about 10x increase in mean July temperature, a 10x increase in vegetation productivity and total biomass, and a 10x increase in total species richness.
- The Arctic is divided in 5 bioclimate subzone. The clearest trend along the climate gradient is the stature of woody plants.
- Permafrost is a unique feature of the tundra biome that has large effects on soil temperature, soil moisture, and microtopography.
- Topographic gradients (toposequences) of vegetation vary with bioclimate subzone.