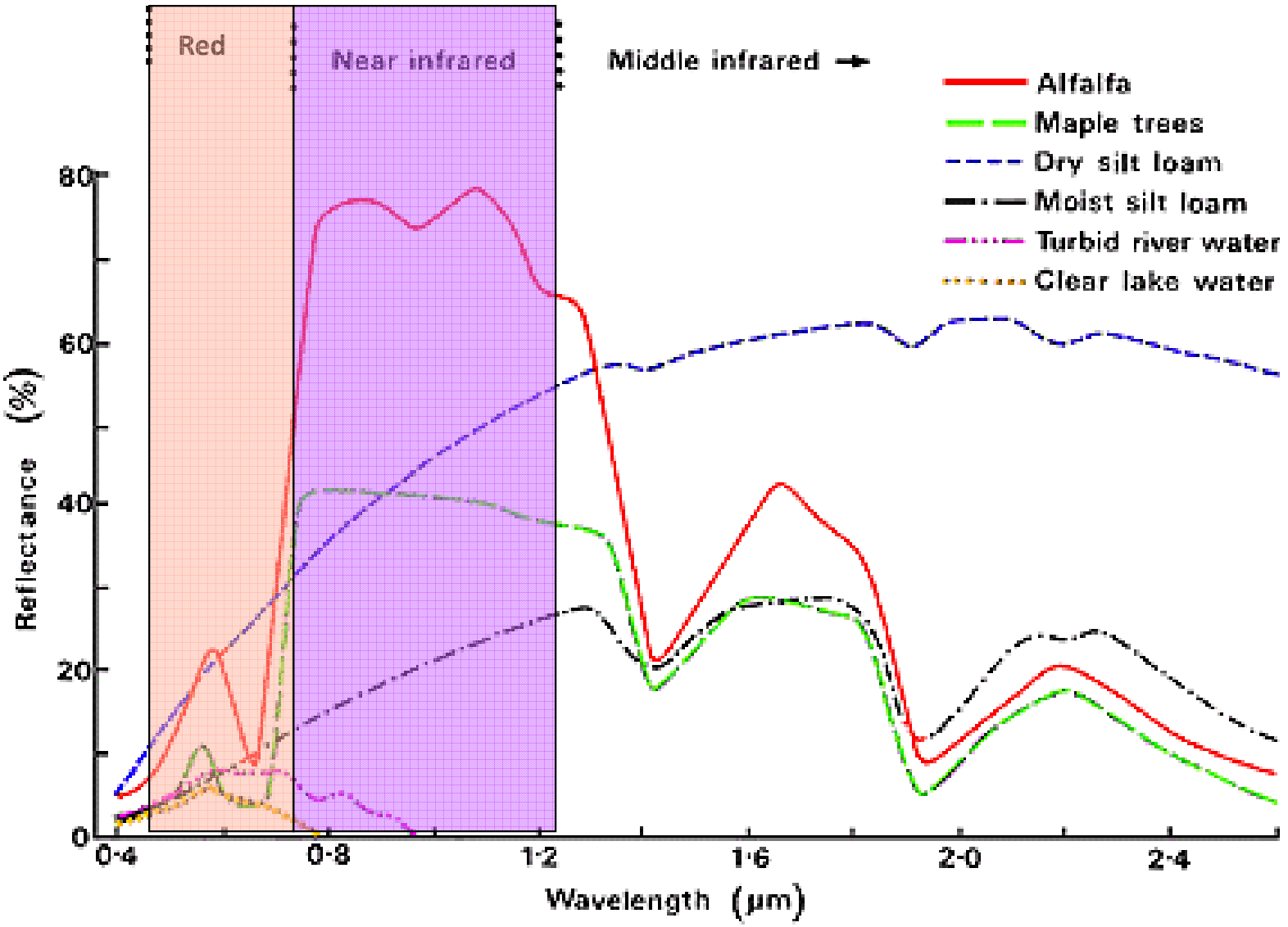
Patterns of change within a tundra landscape: 22-year Landsat NDVI trends in the vicinity of Toolik Field Station, North Slope, Alaska

Martha Raynolds

12th Circumpolar Remote Sensing Symposium

14-18 May, 2012

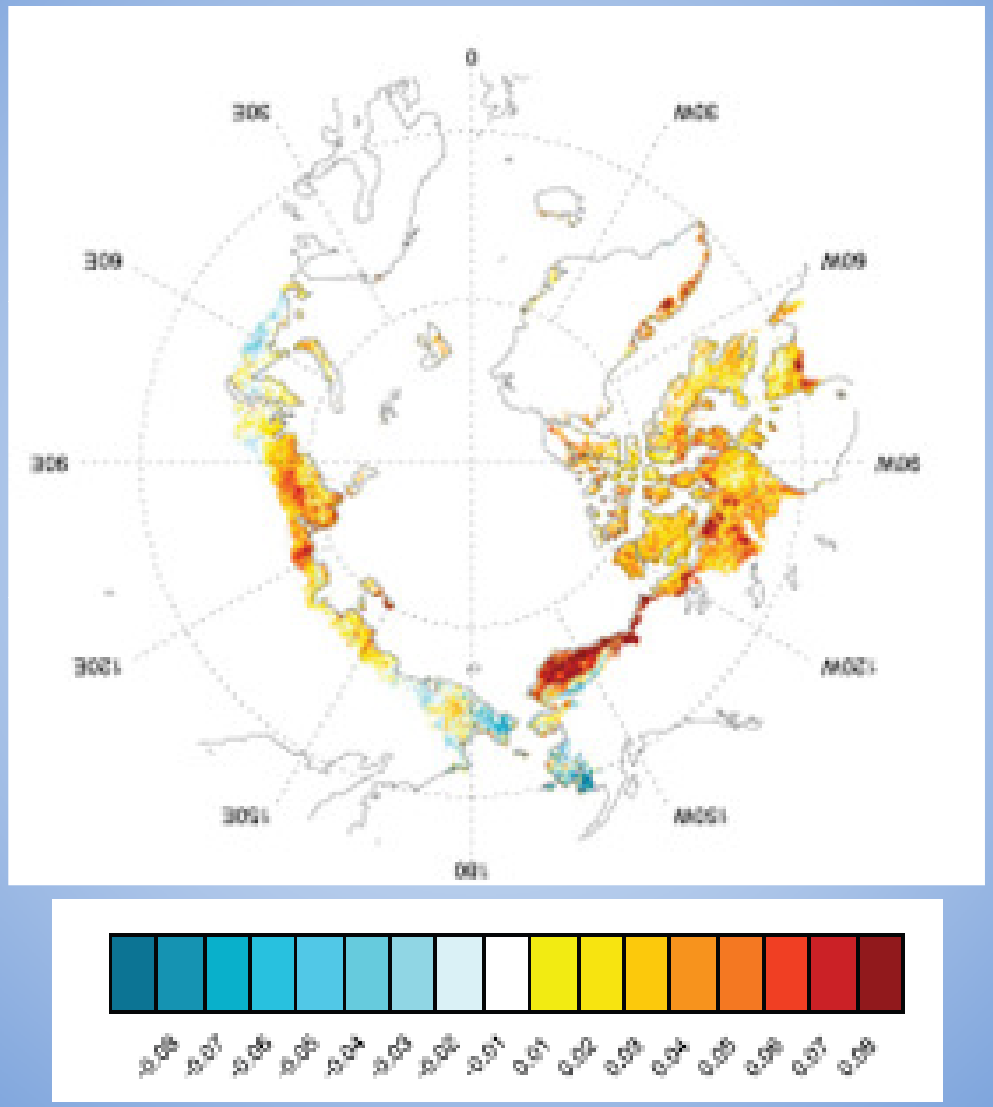
Normalized Difference Vegetation Index, NDVI = $\dfrac{\text{NIR - Red}}{\text{NIR + Red}}$



(http://internet1-ci.cst.cnes.fr:8100/cdrom/ceos1/titlep.htm)

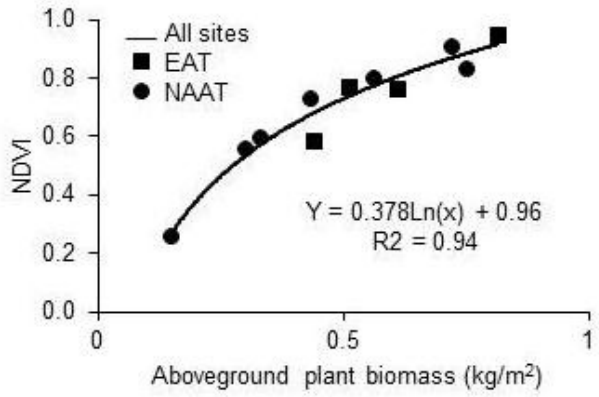
Change in maximum annual value of NDVI, 1982-2008

AVHRR 8-km
GIMMS data



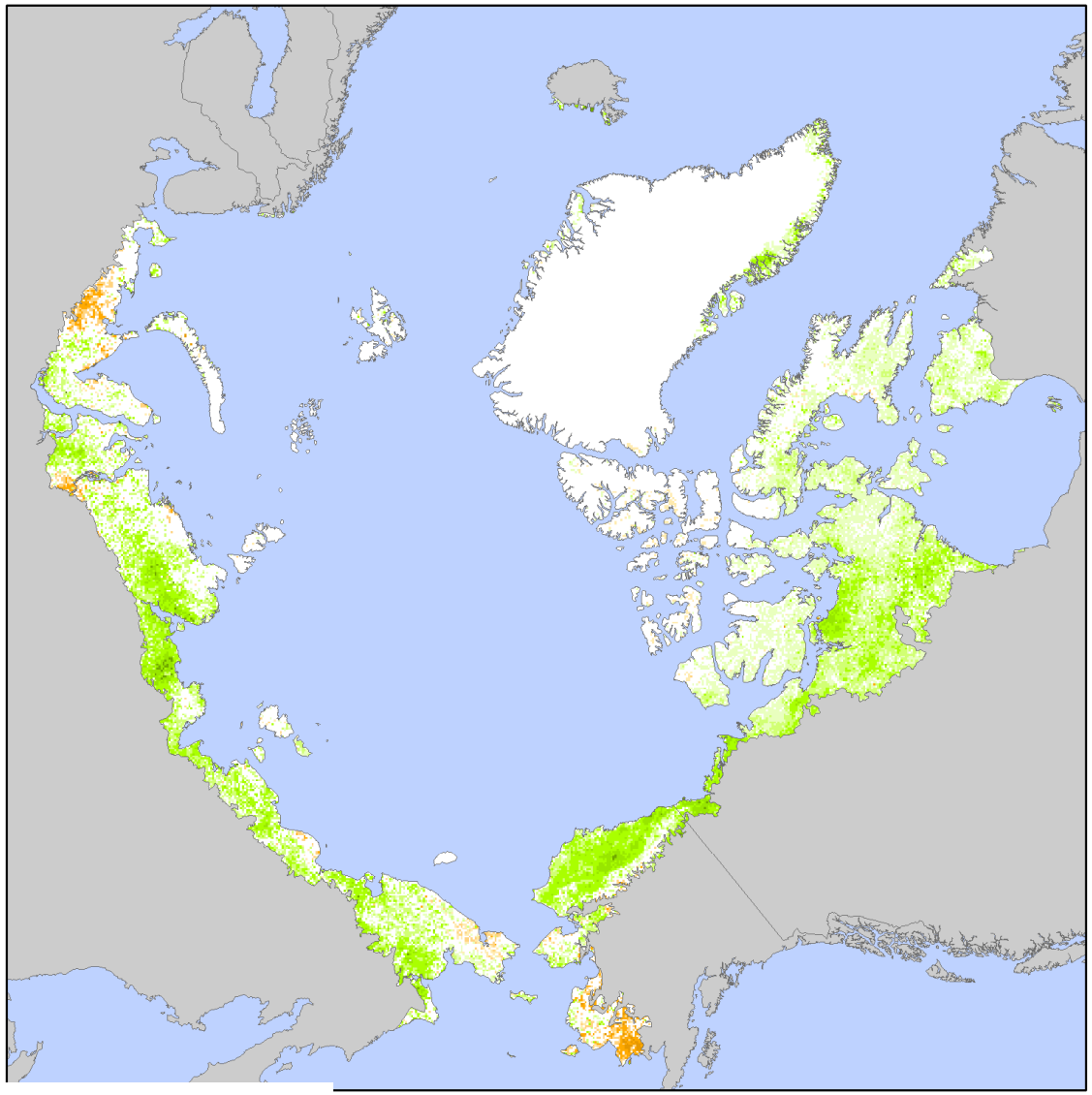
Bhatt et al. 2010, Earth Interactions

Changes in aboveground plant biomass

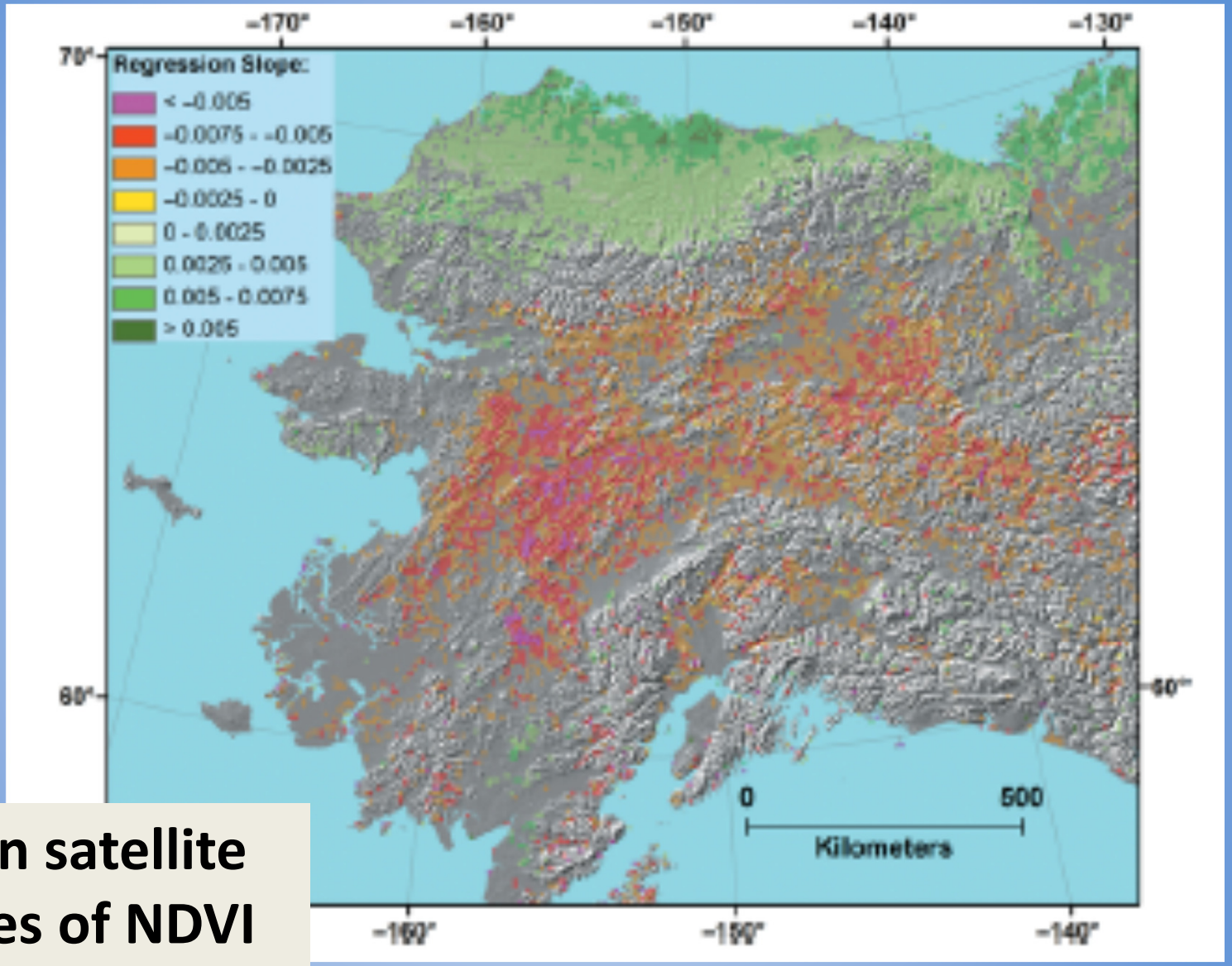


Change in phytomass 1982-2010
kg/m2/yr
sign trend, p < 0.05

- < -0.01
- -0.01 - -0.005
- -0.005 - -0.0025
- -0.0025 - 0
- 0 - 0.0025
- 0.0025 - 0.005
- 0.005 - 0.01
- 0.01 - 0.015
- 0.015 - 0.02
- > 0.02
- No sign. change



Epstein et al. 2011, Environmental Research Letters



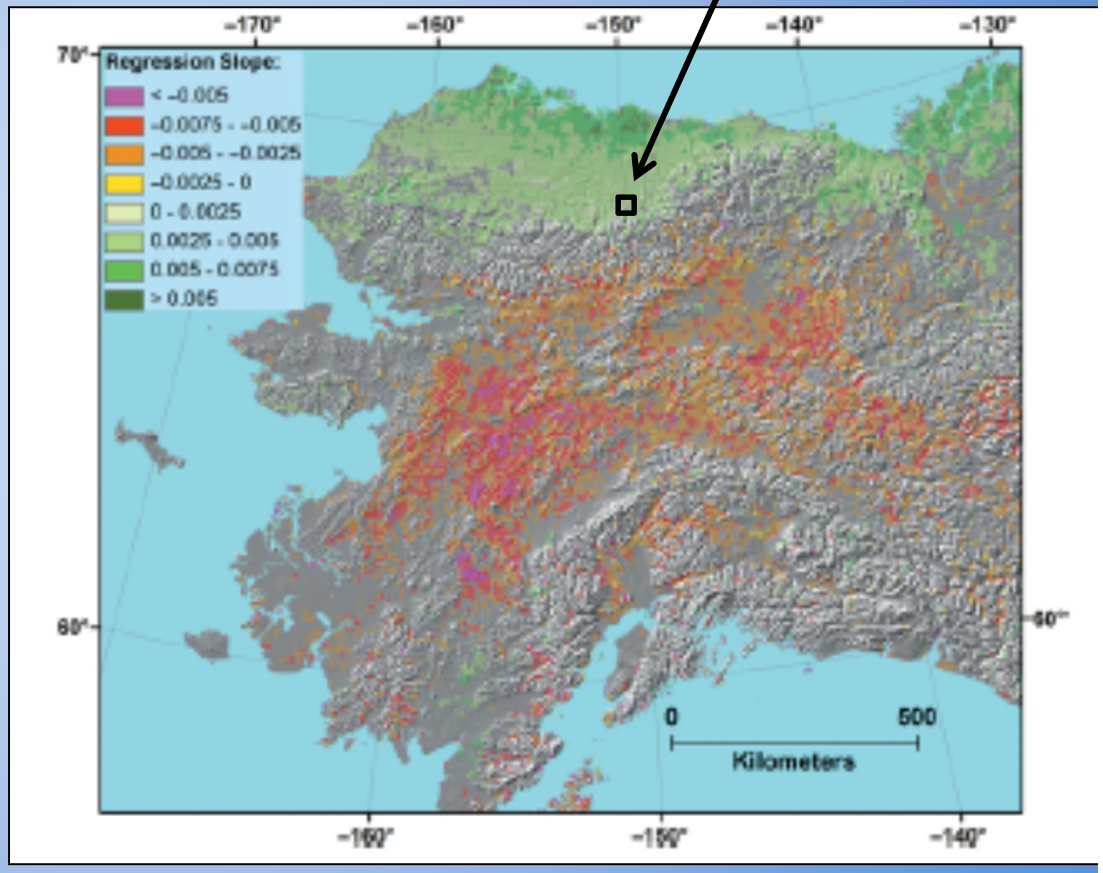
Trends in satellite measures of NDVI 1982-2003

Verbyla 2008 ,Global Ecology & Biogeography

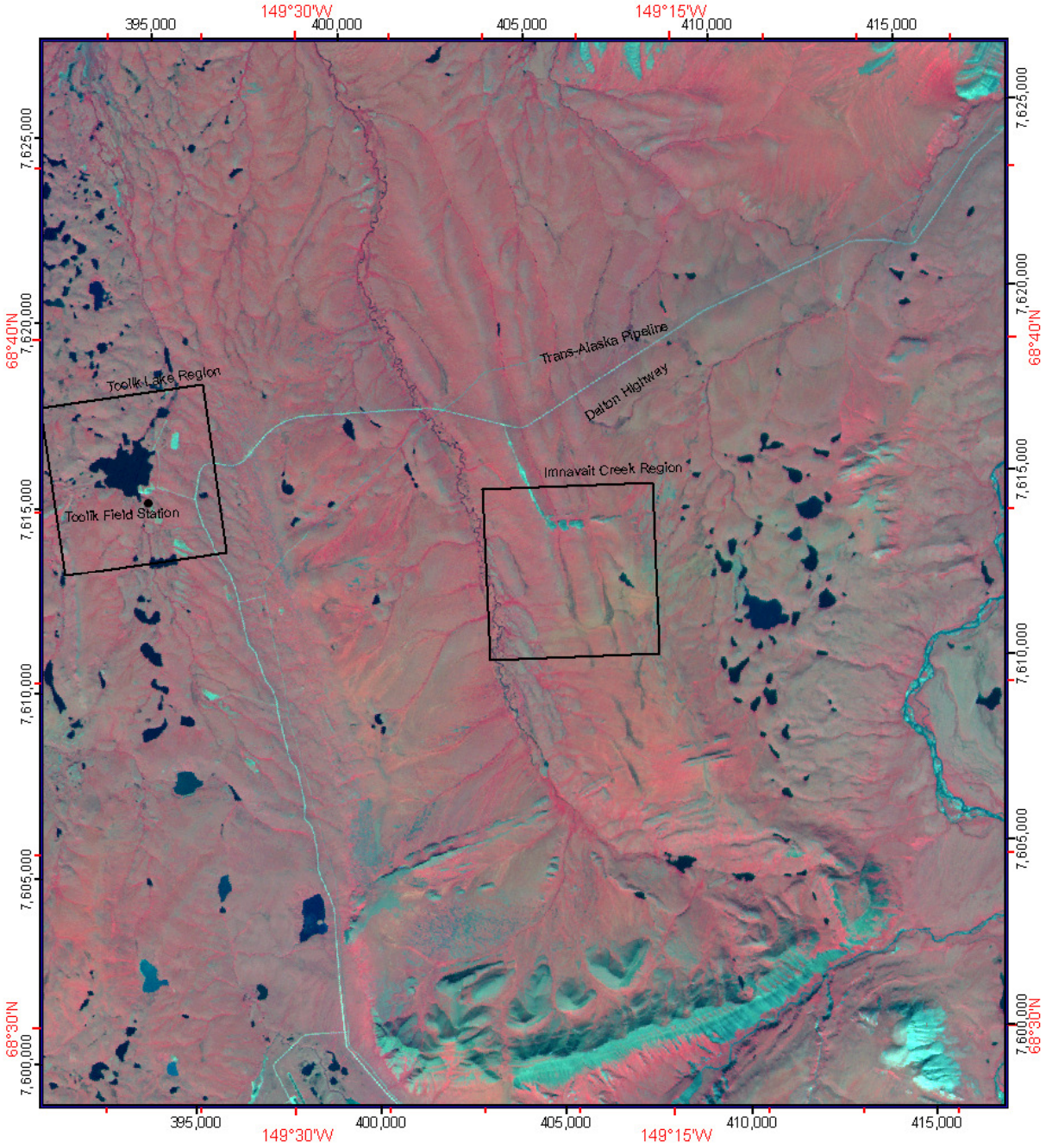
Going from the subcontinent scale to the landscape scale

AVHRR 8-km
GIMMS data

LANDSAT TM or ETM+ data
30-m pixels

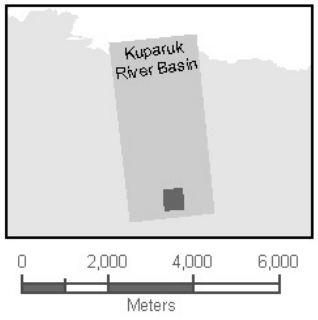


Verbyla 2008, Global Ecology & Biogeography



Upper Kuparuk River Region
False-Color Infrared Image

Derived from
SPOT 20-m data
collected on
28 July 1989



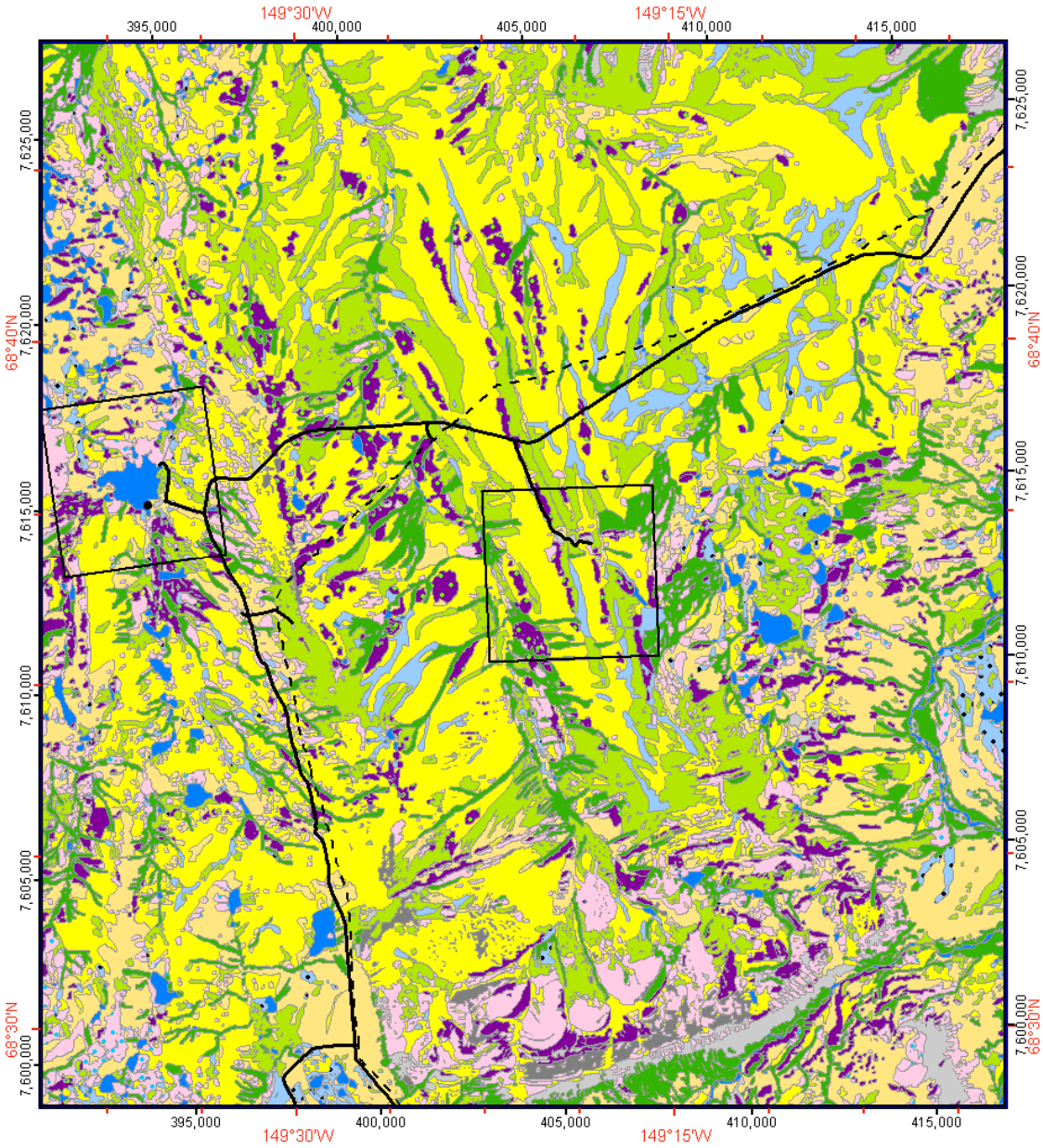
Derived from: Walker, D.A. and H.A. Maier. 2008. Vegetation in the Vicinity of the Toolik Field Station, Alaska. Biological Papers of the University of Alaska, No. 28. Institute of Arctic Biology, Fairbanks, AK.

www.ArcticAtlas.org


Pedicularis sudetica
Lousewort

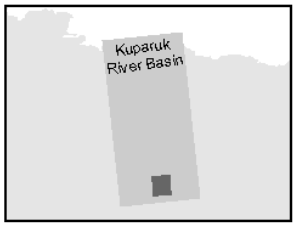
Geobotanical mapping layers available for analysis

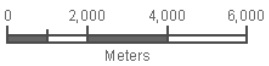
- **Vegetation type**
- **Glacial geology**
- **Surficial geology**
  - type of deposit: glacial till, alluvial, collluvial, etc.
- **Surficial geomorphology**
  - patterning: water tracks, high-centered polygons, etc.



Upper Kuparuk River Region Vegetation

- Barrens
- Lichens on rocks
- Partially vegetated barrens
- Tussock-sedge, dwarf-shrub, moss tundra
- Nontussock sedge, dwarf-shrub, moss tundra
- Sedge, moss tundra (poor fen)
- Sedge, moss tundra (fens)
- Water and herbaceous marsh
- Prostrate dwarf-shrub, forb, fruticose-lichen tundra (acidic)
- Prostrate dwarf-shrub, sedge, forb, fruticose-lichen tundra (nonacidic)
- Hemi-prostrate dwarf-shrub, fruticose-lichen tundra
- Hemi-prostrate and prostrate dwarf-shrub, forb, moss, fruticose-lichen tundra
- Dwarf- to low-shrub, sedge, moss tundra
- Low to tall shrublands
- Toolik Lake Research Area
- Imnavait Creek Research Area
- Roads
- Pipeline

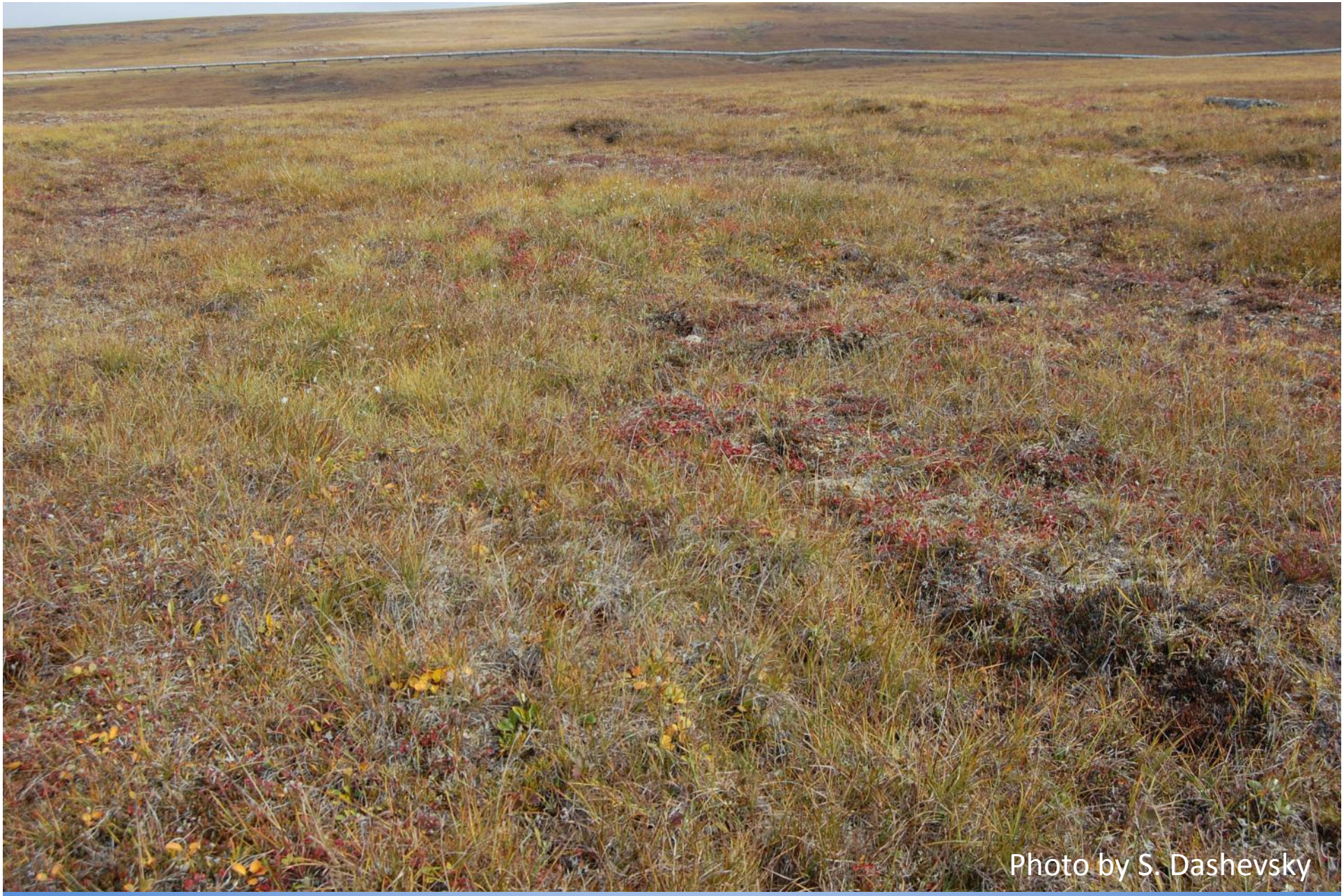




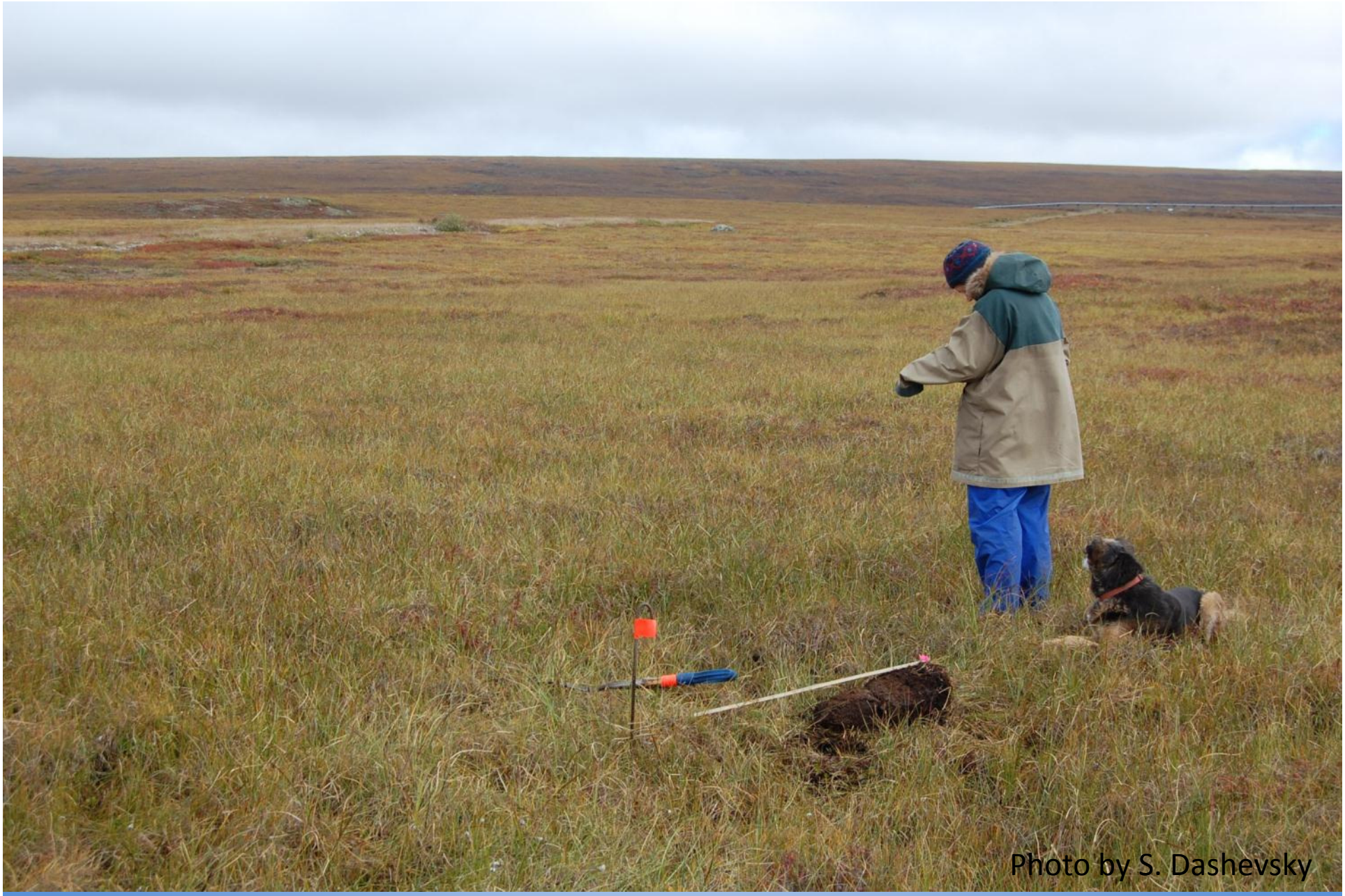
Derived from: Walker, D.A. and H.A. Maier. 2008. Vegetation in the Vicinity of the Toolik Field Station, Alaska. Biological Papers of the University of Alaska, No. 28. Institute of Arctic Biology, Fairbanks, AK

www.ArcticAtlas.org

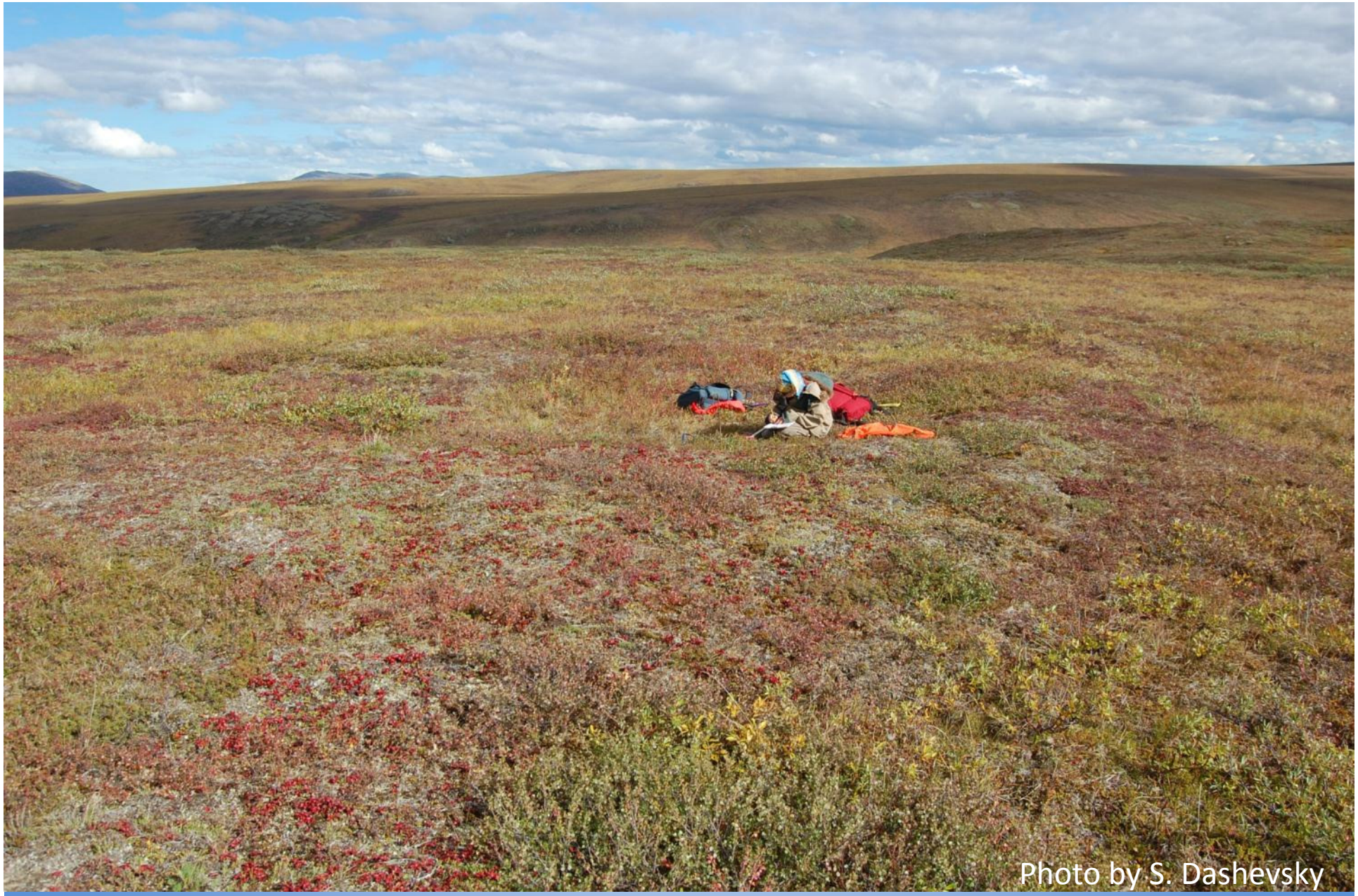
Tussock sedge, dwarf-shrub, moss tundra



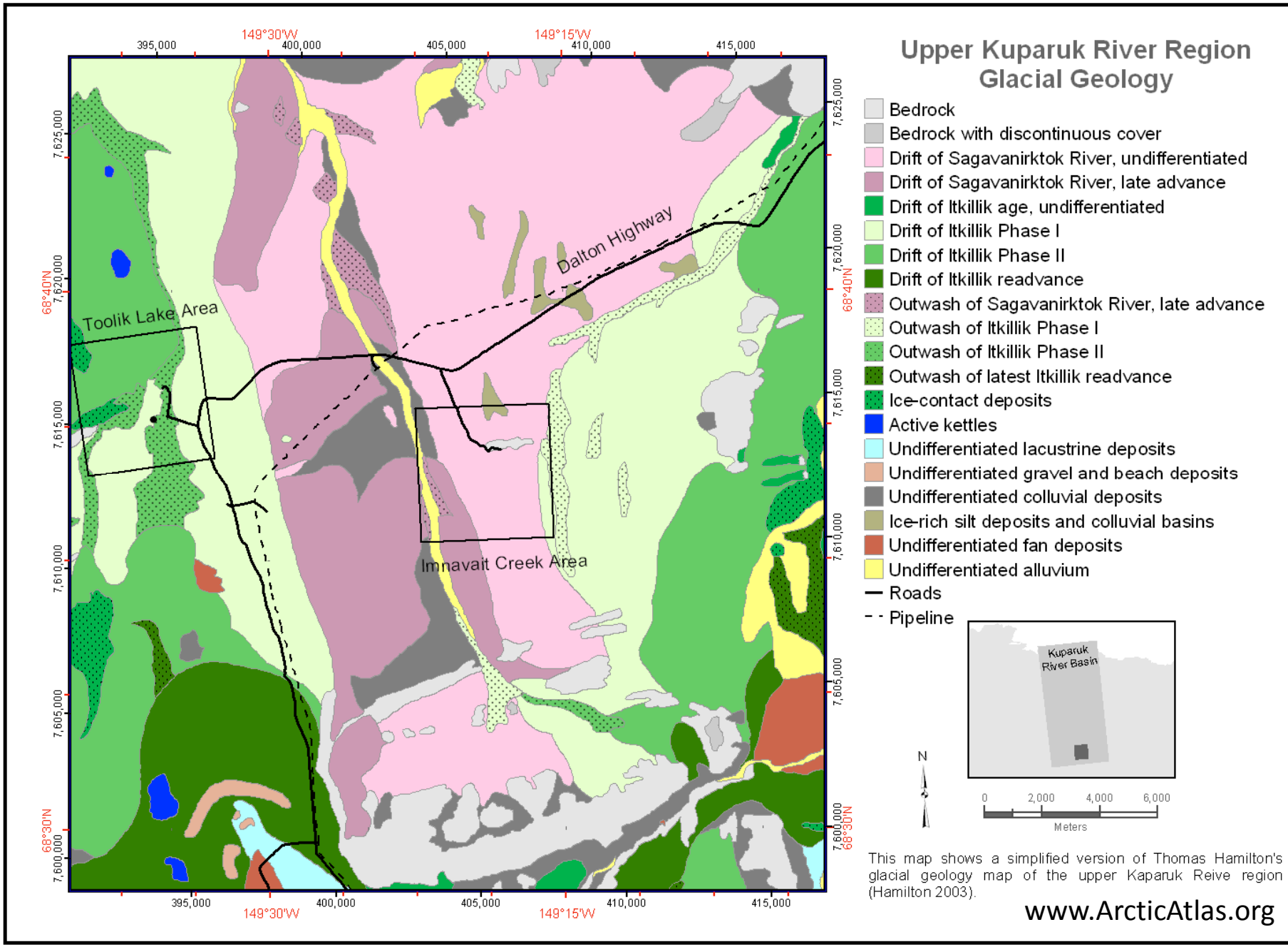
Non-tussock sedge, dwarf-shrub, moss tundra

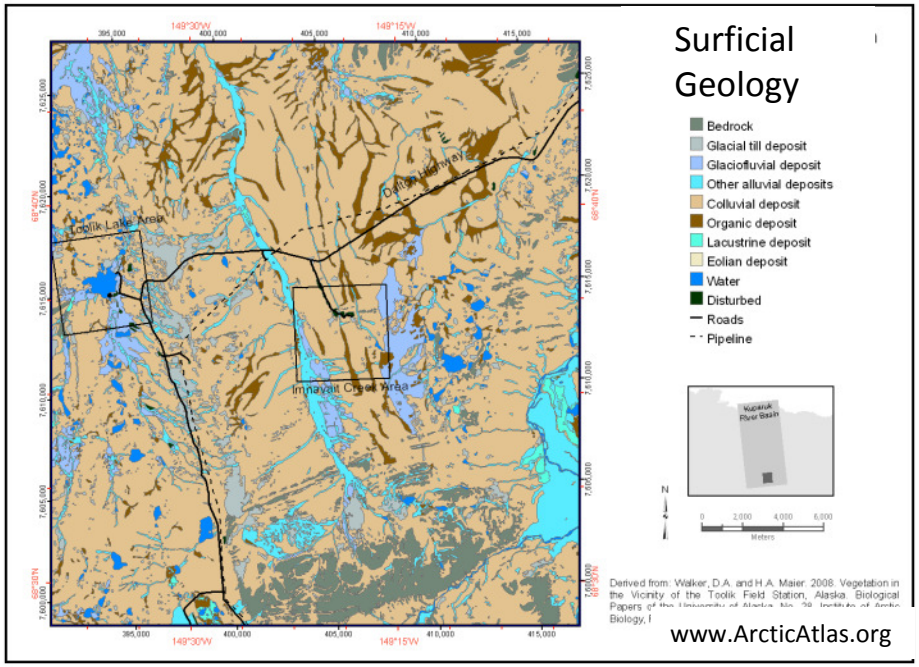


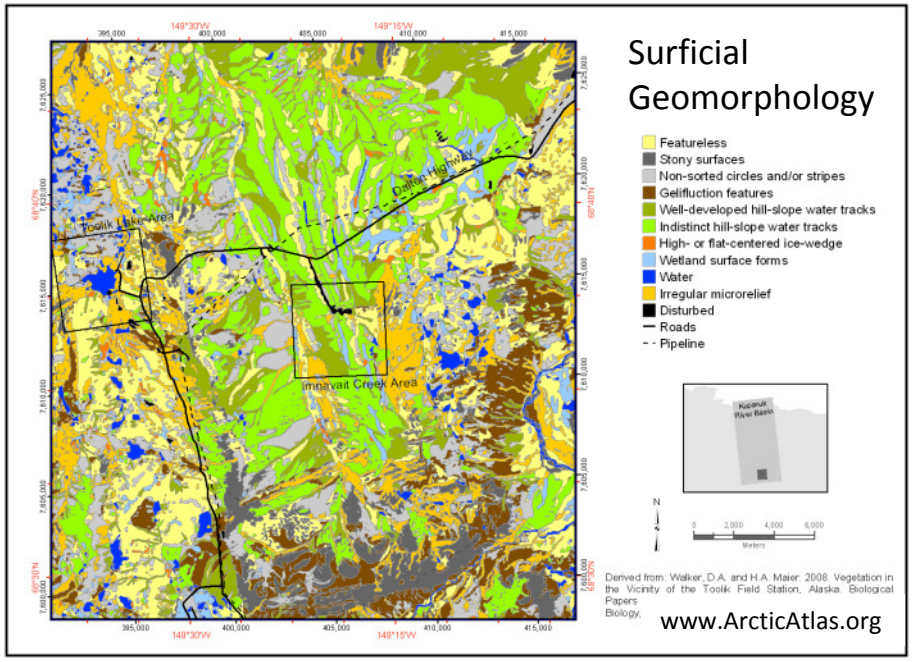
Sedge, moss tundra (Fen)

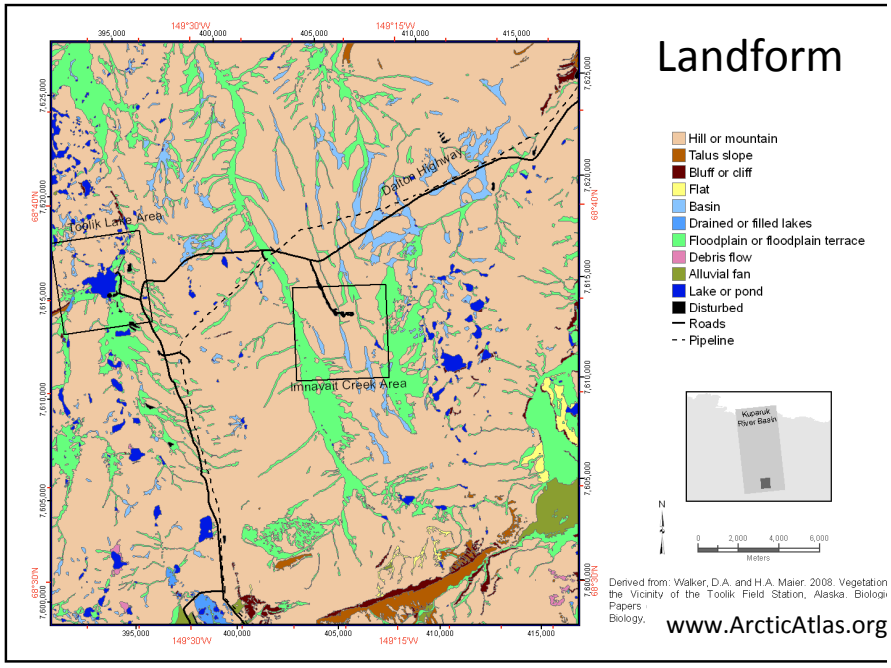


Prostrate dwarf-shrub, forb, fruticose lichen tundra (acidic)


Upper Kuparuk River Region
Glacial Geology
Bedrock
Bedrock with discontinuous cover
Drift of Sagavanirktok River, undifferentiated
Drift of Sagavanirktok River, late advance
Drift of Itkillik age, undifferentiated
Drift of Itkillik Phase I
Drift of Itkillik Phase II
Drift of Itkillik readvance
Outwash of Sagavanirktok River, late advance
Outwash of Itkillik Phase I
Outwash of Itkillik Phase II
Outwash of latest Itkillik readvance
Ice-contact deposits
Active kettles
Undifferentiated lacustrine deposits
Undifferentiated gravel and beach deposits
Undifferentiated colluvial deposits
Ice-rich silt deposits and colluvial basins
Undifferentiated fan deposits
Undifferentiated alluvium
Roads
Pipeline
Toolik Lake Area
Imnavait Creek Area
Dalton Highway
149°30'W
149°15'W
395,000
400,000
405,000
410,000
415,000
7,625,000
7,620,000
7,615,000
7,610,000
7,605,000
7,600,000
68°40'N
68°30'N
Kuparuk River Basin
N
0
2,000
4,000
6,000
Meters
This map shows a simplified version of Thomas Hamilton's glacial geology map of the upper Kaparuk Reive region (Hamilton 2003).
www.ArcticAtlas.org


Surficial Geology
Bedrock
Glacial till deposit
Glaciofluvial deposit
Other alluvial deposits
Colluvial deposit
Organic deposit
Lacustrine deposit
Eolian deposit
Water
Disturbed
Roads
Pipeline
Toolik Lake Area
Imnavait Creek Area
Dalton Highway
Kuparuk River Basin
N
0 2,000 4,000 6,000
Meters
Derived from: Walker, D.A. and H.A. Maier. 2008. Vegetation in the Vicinity of the Toolik Field Station, Alaska. Biological Papers of the University of Alaska, No. 29. Institute of Arctic Biology, I
www.ArcticAtlas.org


Surficial Geomorphology
Featureless
Stony surfaces
Non-sorted circles and/or stripes
Gelifluction features
Well-developed hill-slope water tracks
Indistinct hill-slope water tracks
High- or flat-centered ice-wedge
Wetland surface forms
Water
Irregular microrelief
Disturbed
Roads
Pipeline
Toolik Lake Area
Imnavait Creek Area
Dalton Highway
Kuparuk River Basin
N
0 2,000 4,000 6,000
Meters
Derived from: Walker, D.A. and H.A. Maier. 2008. Vegetation in the Vicinity of the Toolik Field Station, Alaska. Biological Papers
Biology,
www.ArcticAtlas.org

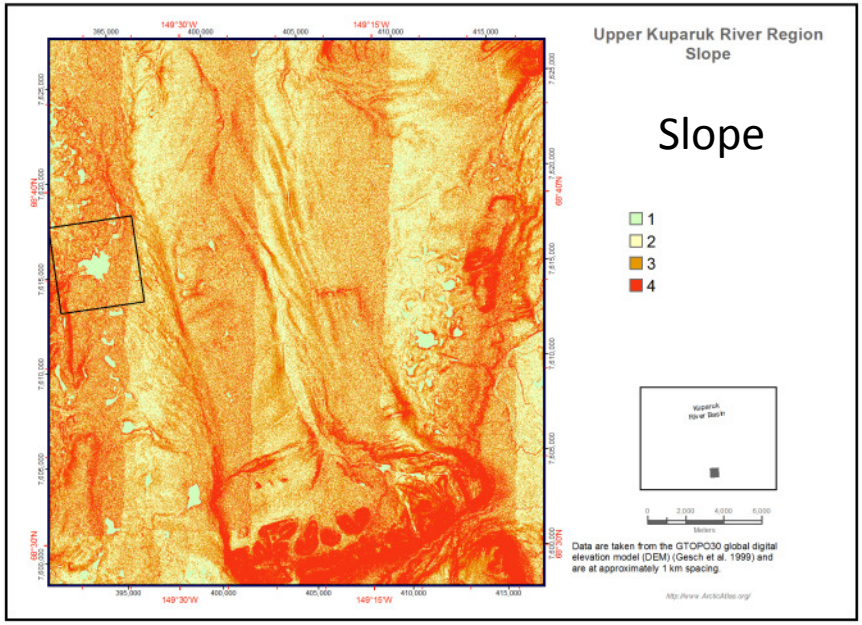

Landform
Hill or mountain
Talus slope
Bluff or cliff
Flat
Basin
Drained or filled lakes
Floodplain or floodplain terrace
Debris flow
Alluvial fan
Lake or pond
Disturbed
Roads
Pipeline
Toolik Lake Area
Imnavait Creek Area
Dalton Highway
Kuparuk River Basin
N
0 2,000 4,000 6,000
Meters
Derived from: Walker, D.A. and H.A. Maier. 2008. Vegetation
the Vicinity of the Toolik Field Station, Alaska. Biologi
Papers
Biology,
www.ArcticAtlas.org

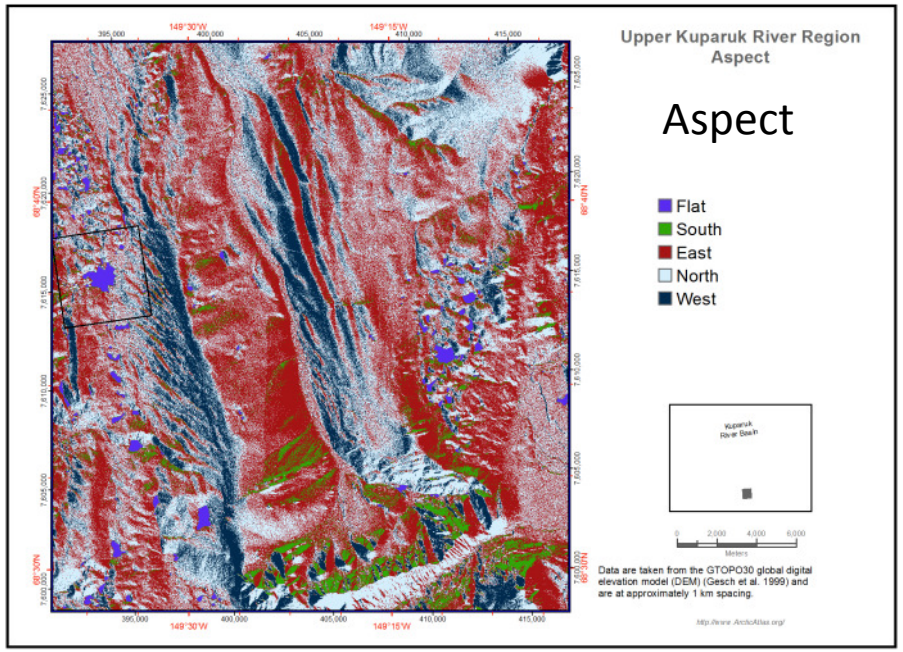
SAR Radar data DEM-derived layers available for analysis

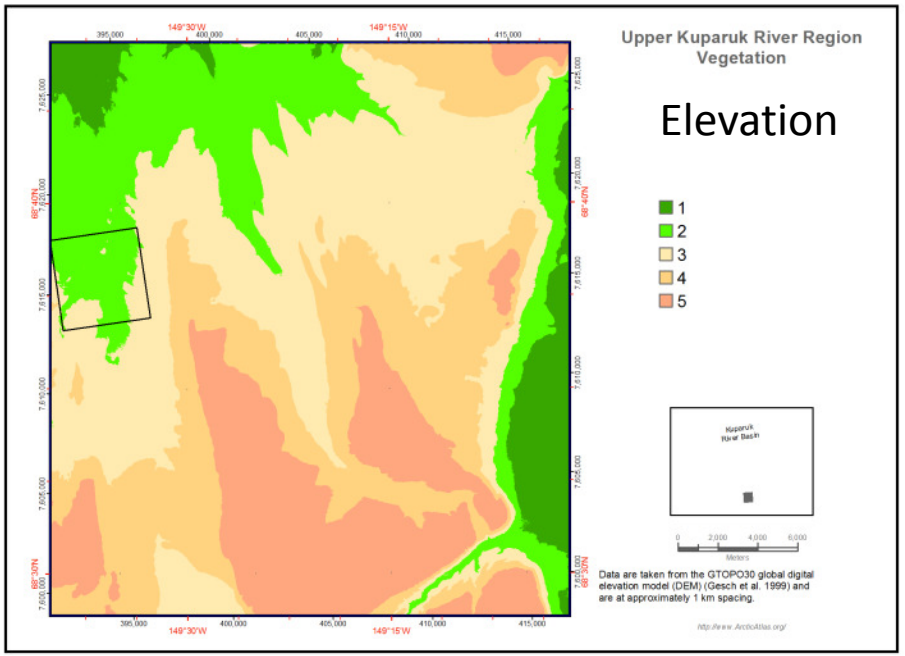
- **Slope**
- **Aspect**
- **Elevation**

Data from Matt Nolan's Digital Elevation Model (DEM) for the Kuparuk River Basin acquired from Star3i, Interferometric Synthetic Aperture Radar (InSAR)
5-m spatial resolution

http://www.drmattnolan.org/olderprojects/kuparuk/kupdem/index.html


Upper Kuparuk River Region
Slope
Slope
1
2
3
4
Kuparuk River Basin
0 2,000 4,000 6,000
Meters
Data are taken from the GTOPO30 global digital elevation model (DEM) (Gesch et al. 1999) and are at approximately 1 km spacing.
http://www.ArcticAtlas.org/


Upper Kuparuk River Region
Aspect
Aspect
Flat
South
East
North
West
Kuparuk River Basin
0 2,000 4,000 6,000
Meters
Data are taken from the GTOPO30 global digital elevation model (DEM) (Gesch et al. 1999) and are at approximately 1 km spacing.
http://www.ArcticAtlas.org/


Upper Kuparuk River Region
Vegetation
Elevation
1
2
3
4
5
Kuparuk River Basin
0 2,000 4,000 6,000
Meters
Data are taken from the GTOPO30 global digital elevation model (DEM) (Gesch et al. 1999) and are at approximately 1 km spacing.
http://www.ArcticAtlas.org/


Arctic mountain heather
Cassiope tetragona
Photo - M.K. Raynolds

Landsat data processing steps

1. Acquire Landsat data (1985, 1989, 1995, 1999, 2004, 2007, 2009)

1. Clip Landsat scenes to study area

2. Calculate radiance , reflectance and NDVI for Landsat data

3. Choose best year (1985) and radiometrically correct Band 3 and Band 4 data from other years to reference data

4. Recalculate NDVI using radiometrically corrected band data

5. Mask out water, clouds, shadows, Landsat 7 gaps

6. Calculate linear regression of pixels to determine NDVI trend

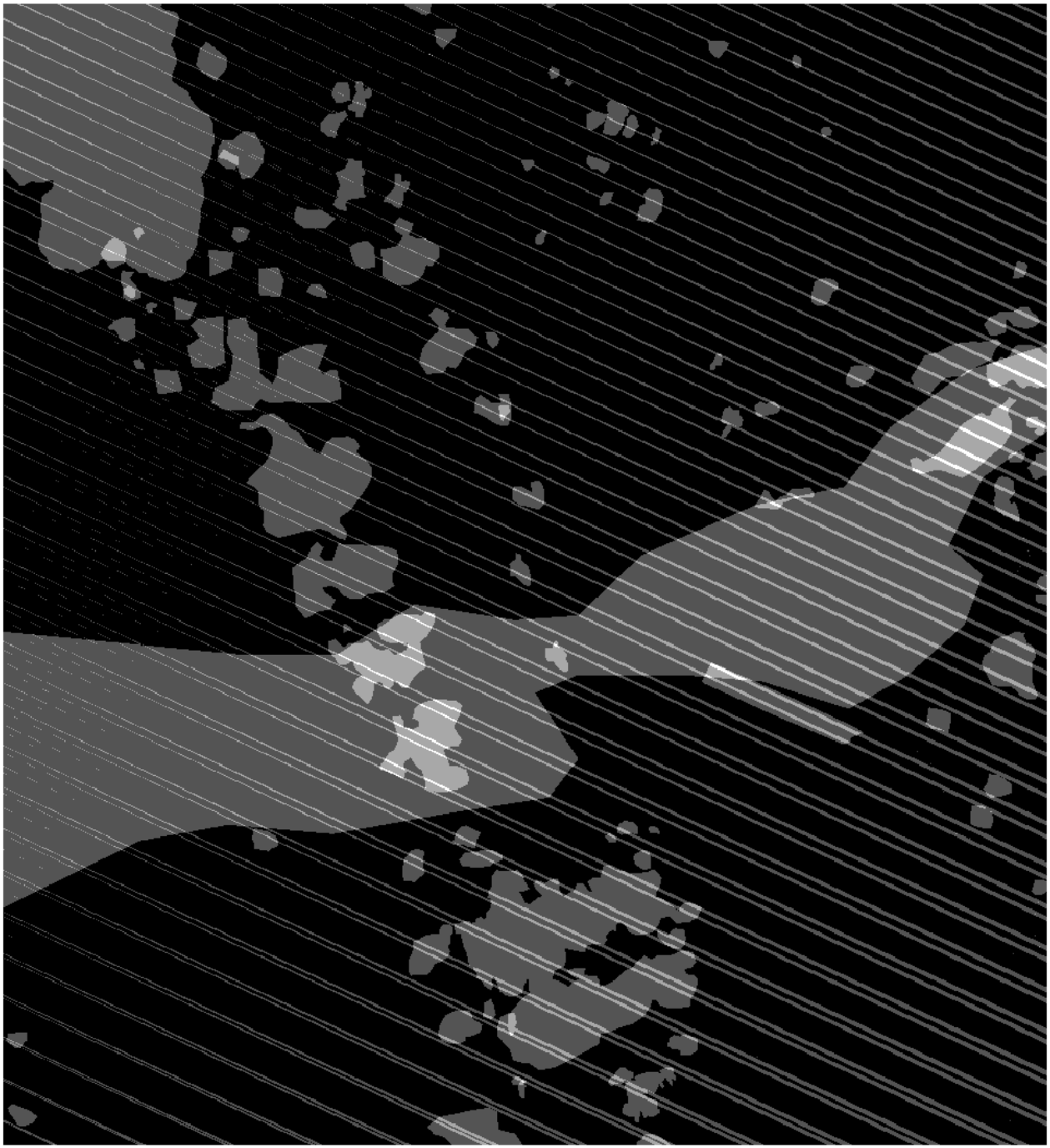
7. Co-register ancillary maps to Landsat and DEM

Select best Landsat scenes available on GLOVIS for study area

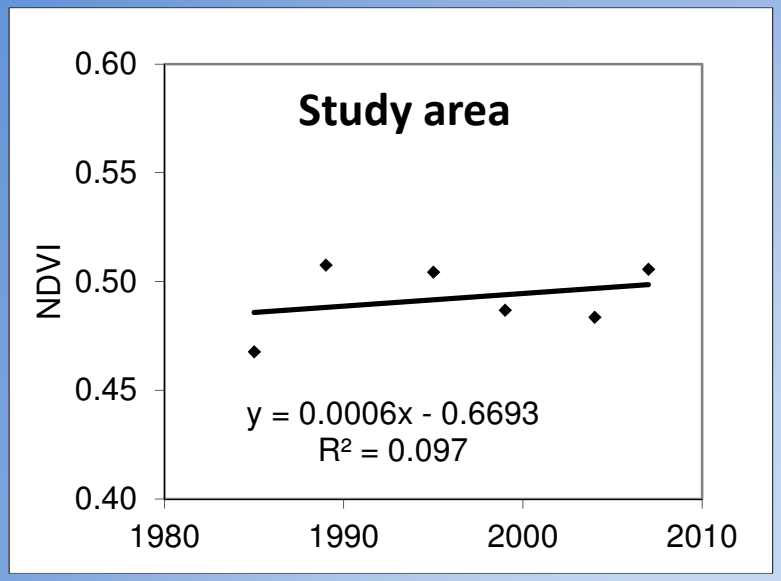
Selection criteria:

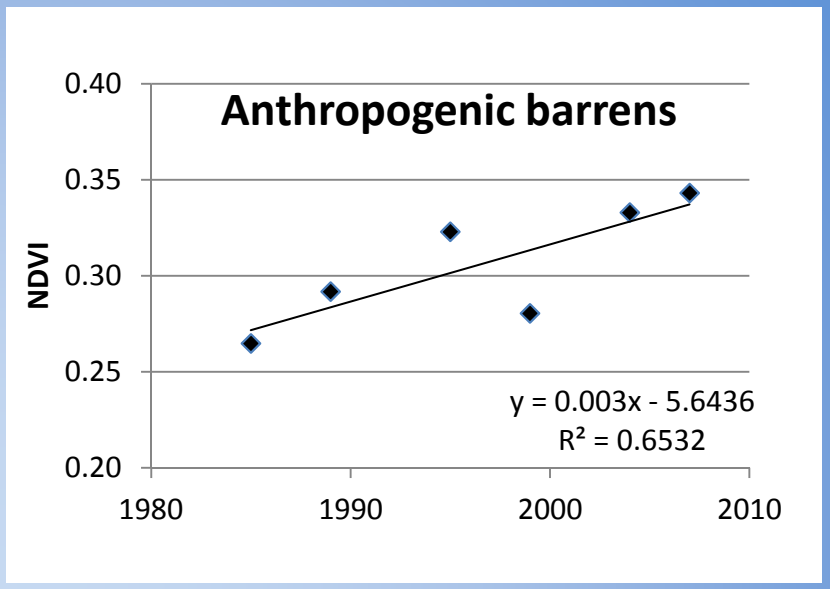
- only TM or ETM+ data (earlier MS scenes were too poor quality)
- Late July to early August for maximum NDVI
- Minimal cloud cover in that portion of scene
- Minimize effect of banding in Landsat 7 data

Date	Satellite	Resolution	SCENE - Glovis ID	Path, Row	Cloud cover	Download
8/4/1985	L5-4 TM	30 m	LT50730121985216XXX07	073 012	Clear	download
7/29/1989	L5-4 TM	30 m	LT40740121989210XXX02	074 012	Clear	dowload
8/9/1995	L5-4 TM	30 m	LT50720121995221XXX00	072 012	Small puffs in NW	download
8/3/1999	L7 SLC on	30 m	LE70730121999215AGS00	073 012	maybe small puff in NW	download
8/16/2004	L7 SLC off	30 m	LE70730122004229EDC02	073 012	Clear	order
8/9/2007	L7 SLC off	30 m	LE70730122007221EDC00	073 012	Totally clear over Toolik	download

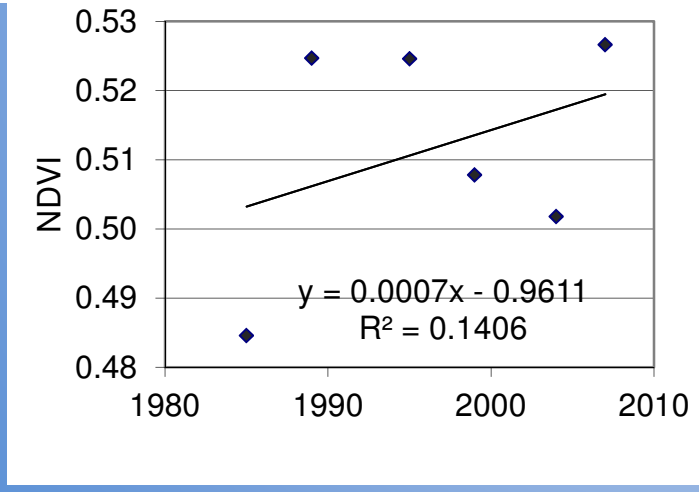

Number of years of data
3
4
5
6

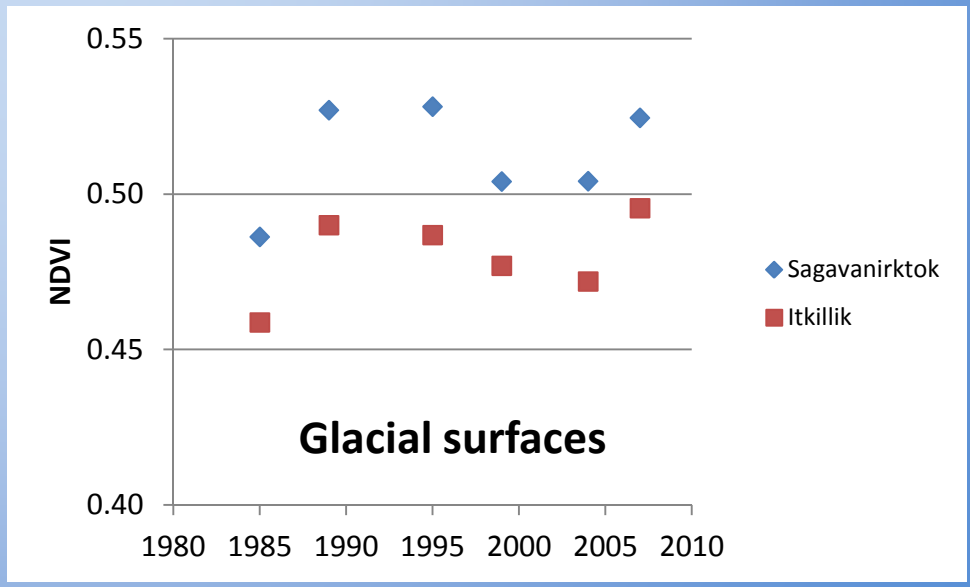
NDVI values for different categories over study period



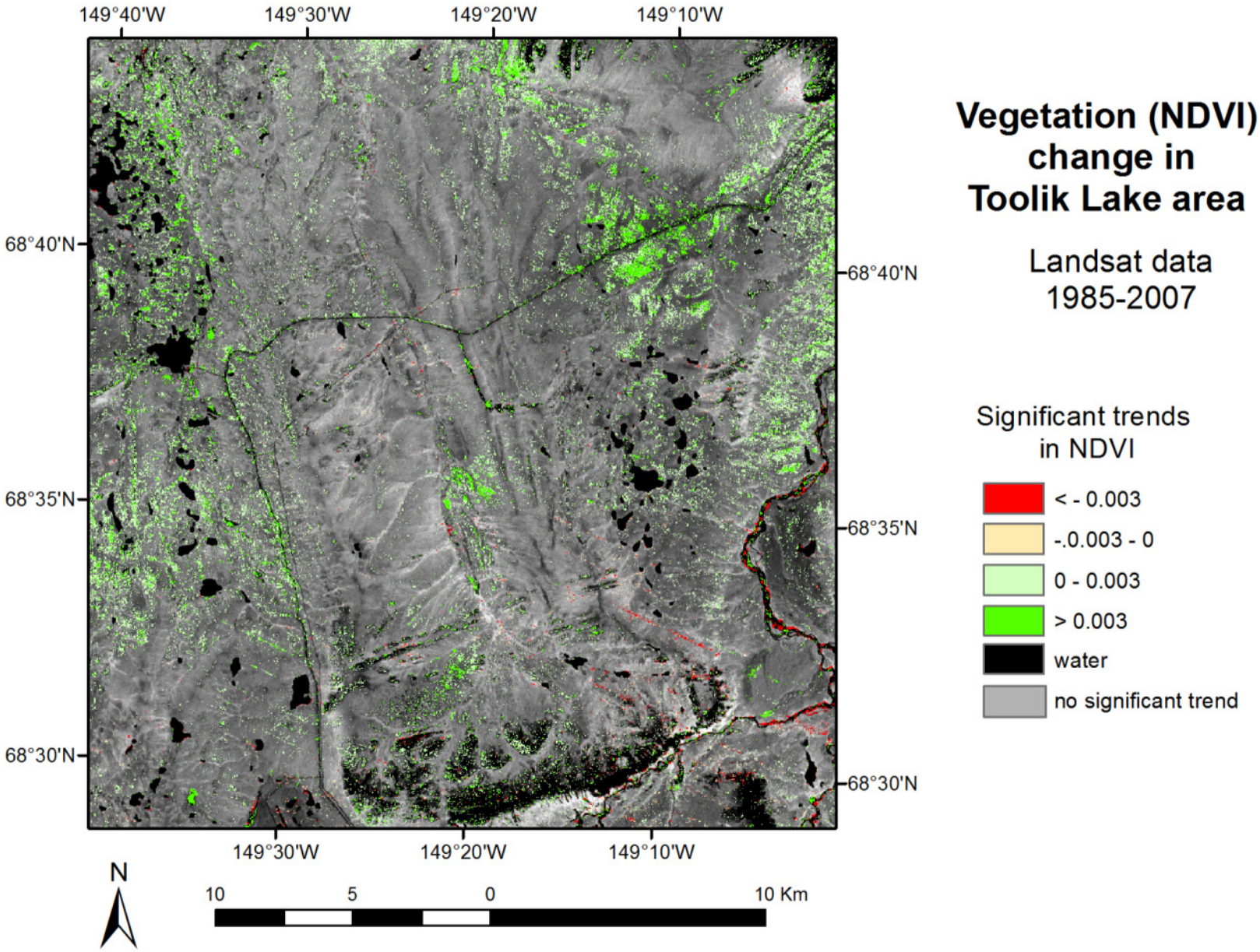


Tussock sedge, shrub, moss tundra



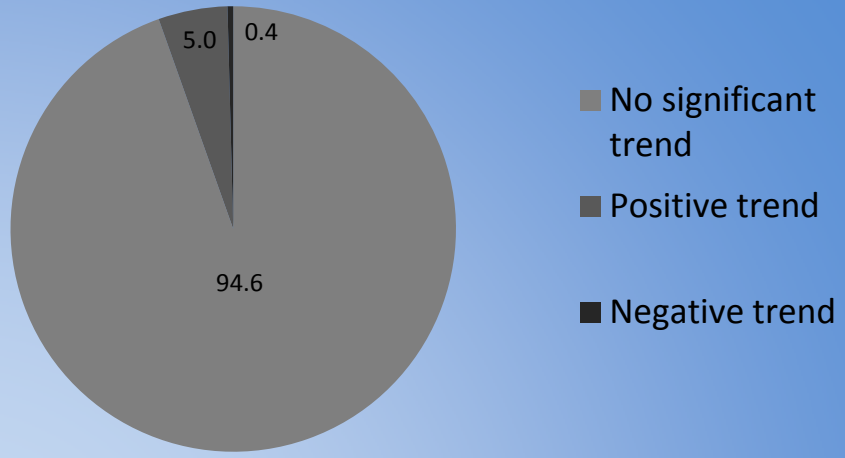


Results of pixel-based regression analysis, p < 0.1



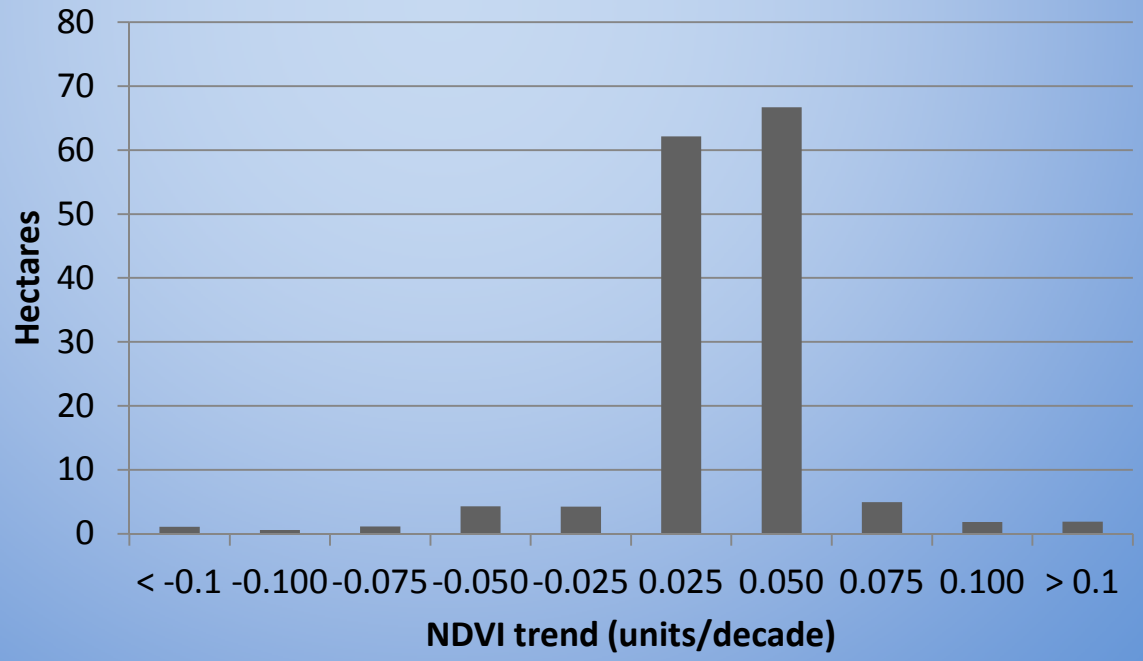
Summary of all pixels in study area

Significant trend in NDVI, $p < 0.05$



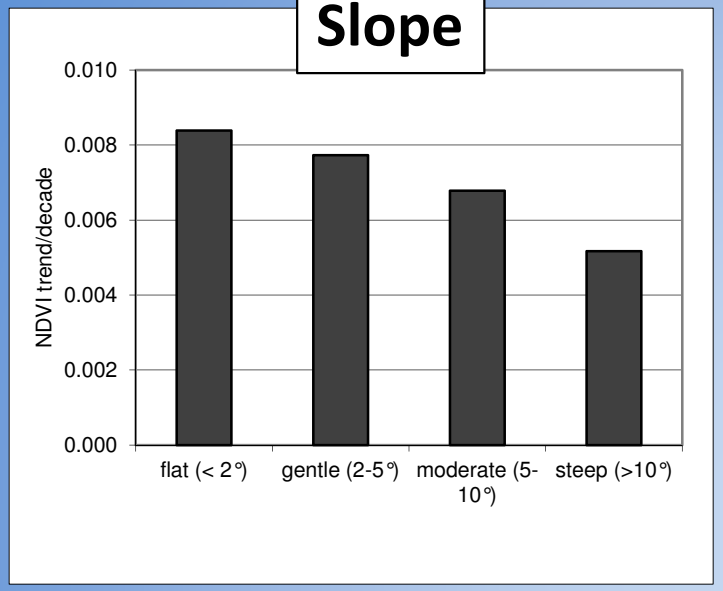
At $p < 0.1$
10% positive trend
1% negative trend
89% no trend

Distribution of pixels with significant NDVI trends, p < 0.05

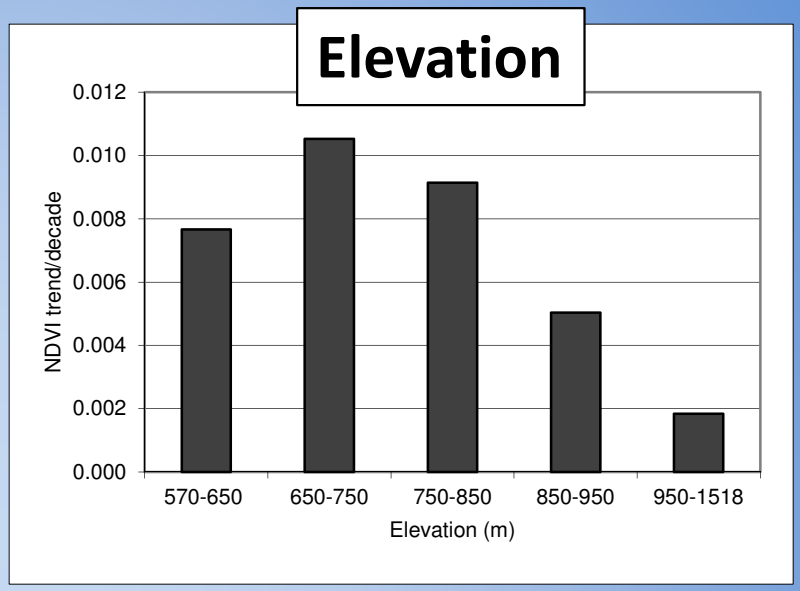


NDVI trends for different categories

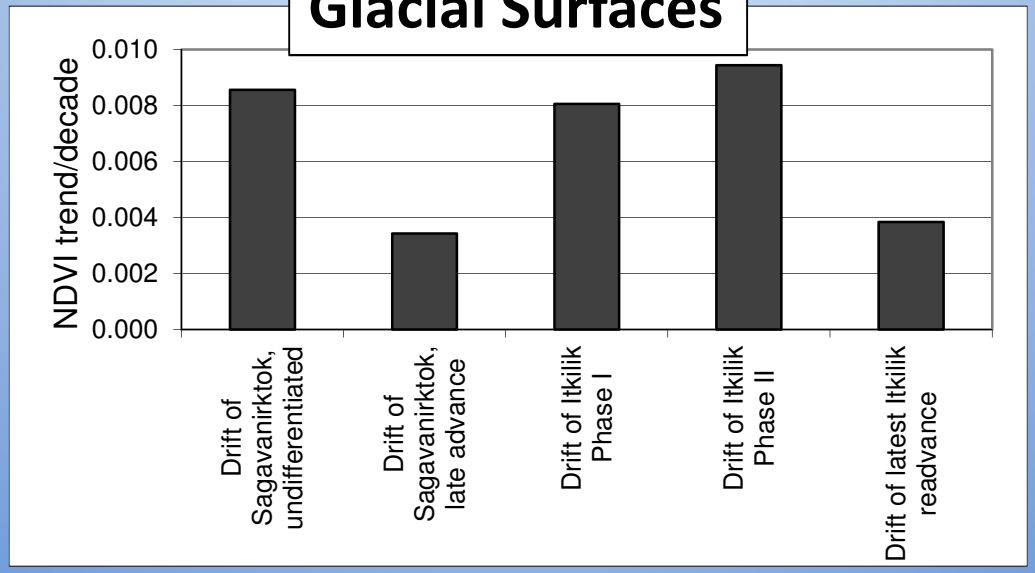
Slope

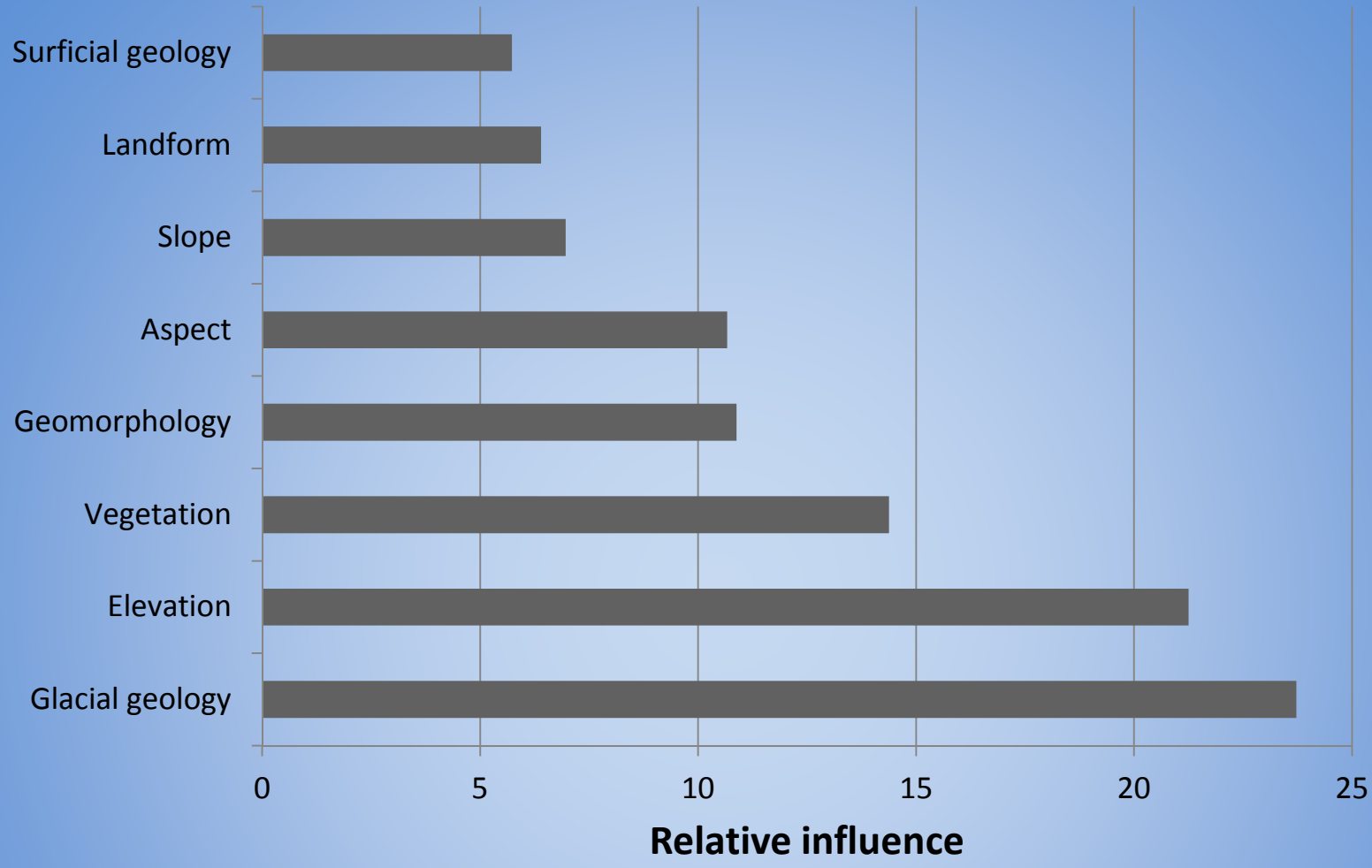


Elevation



Glacial Surfaces

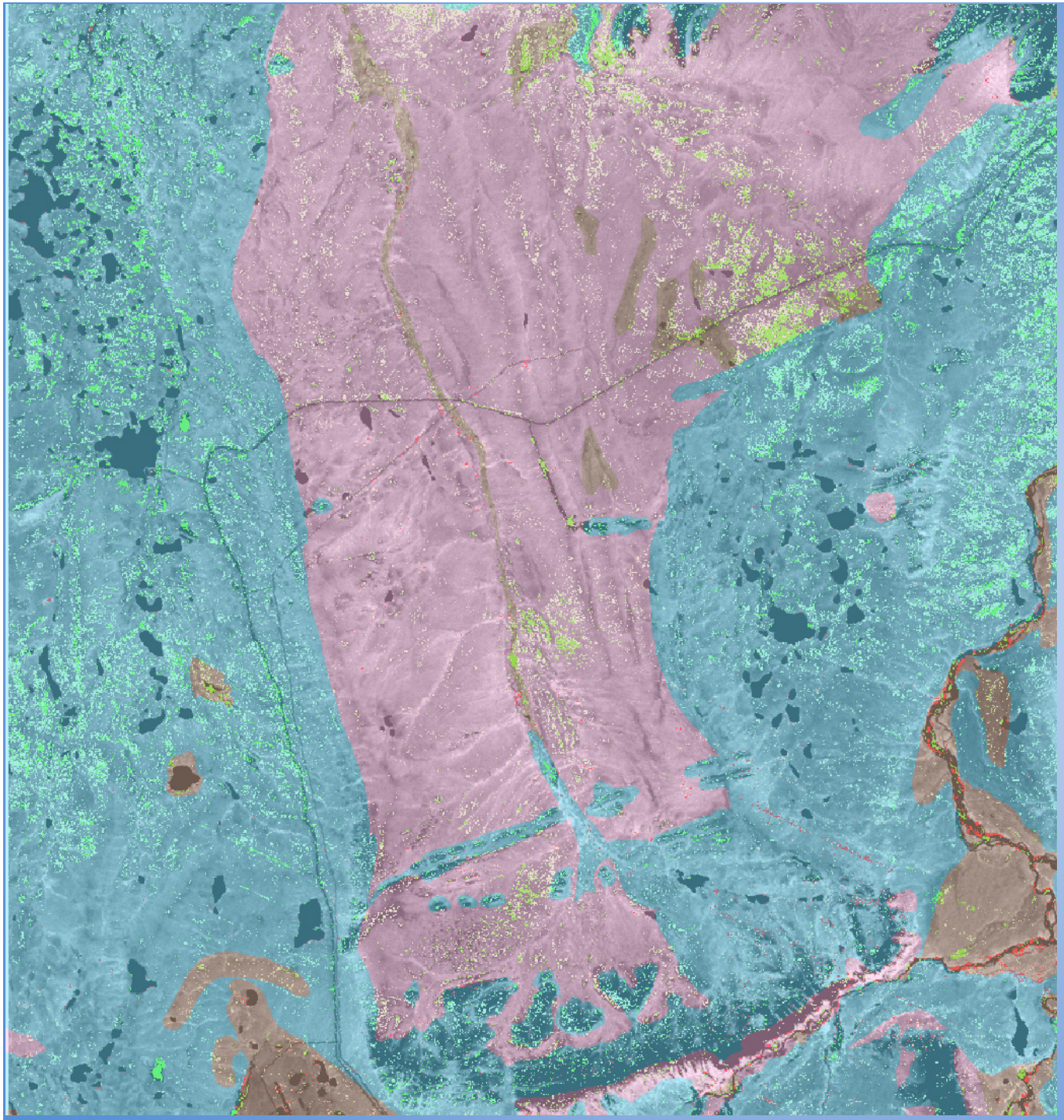




Relative Influence of Variables on NDVI Trends

Regression tree analysis of all pixels in study area


Geum rossii
Ross' avens
Photo - M.K. Raynolds

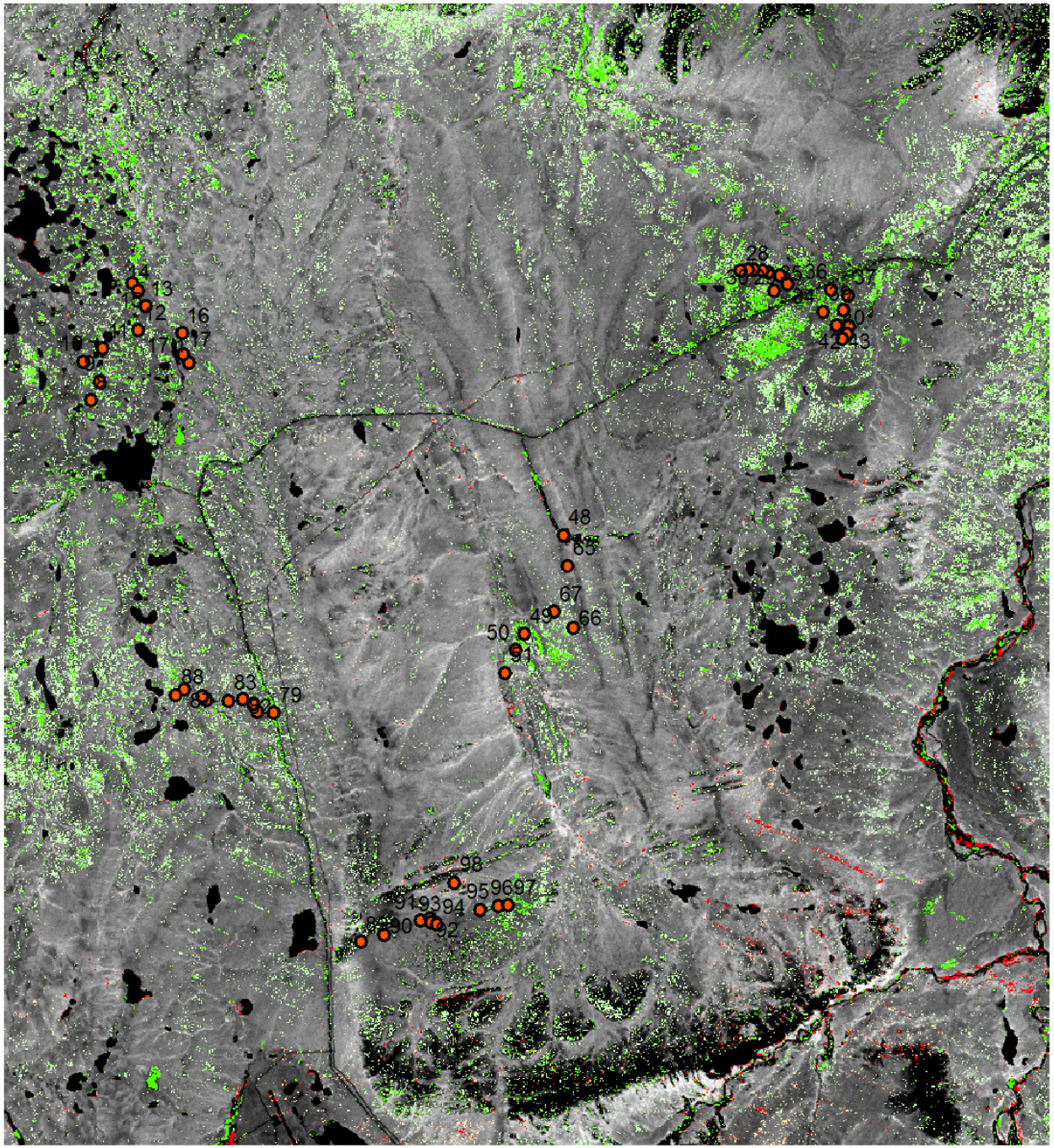


Different patterns of greening on surfaces of different glacial ages

Pink – older, Sagavanirktok glaciation (mid-Pleistocene)

Blue – younger, Itkillik glaciation (late Pleistocene

Gray – recent deposits



Ground sampling locations, August 2011

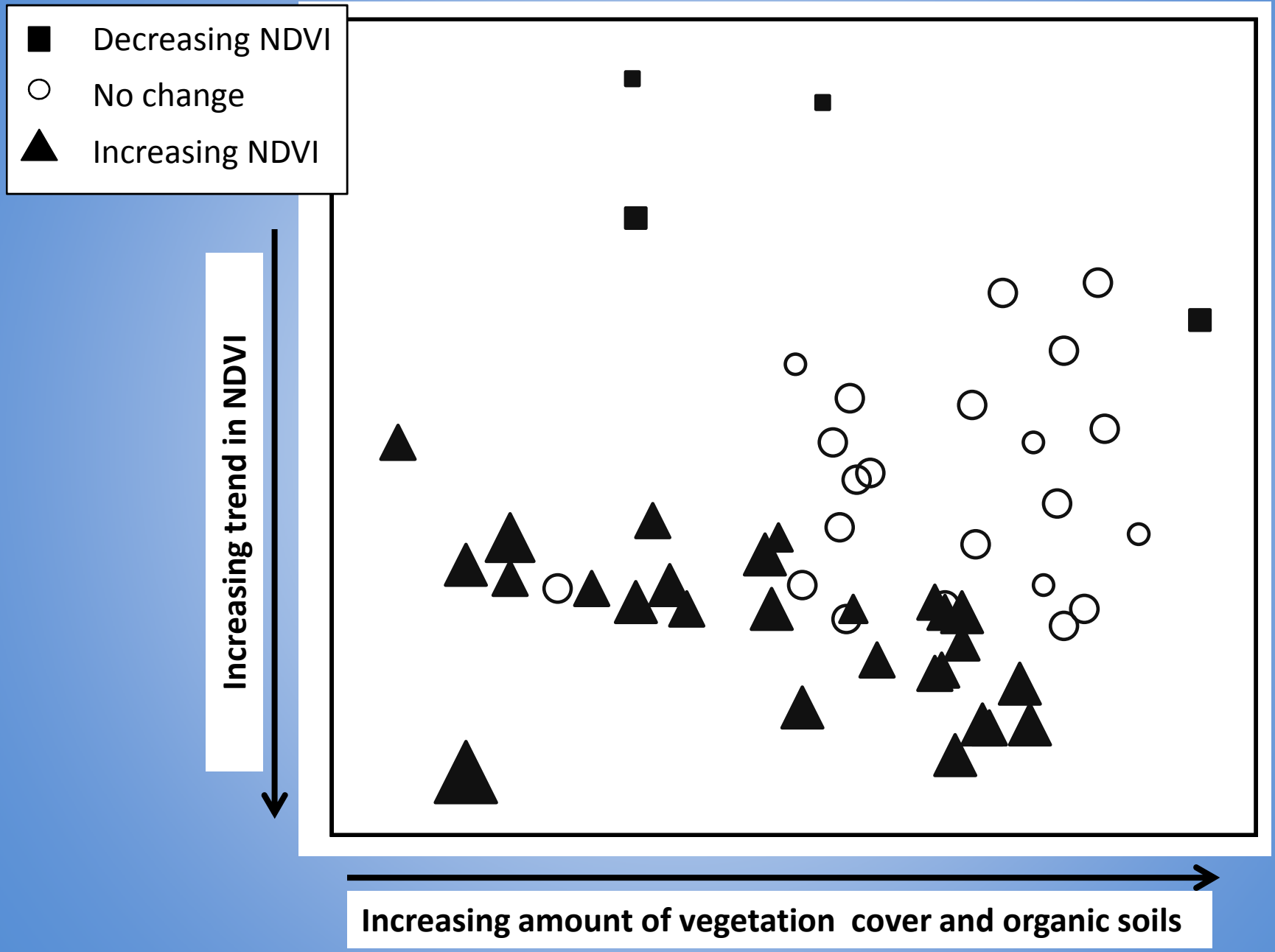
Ground data collected

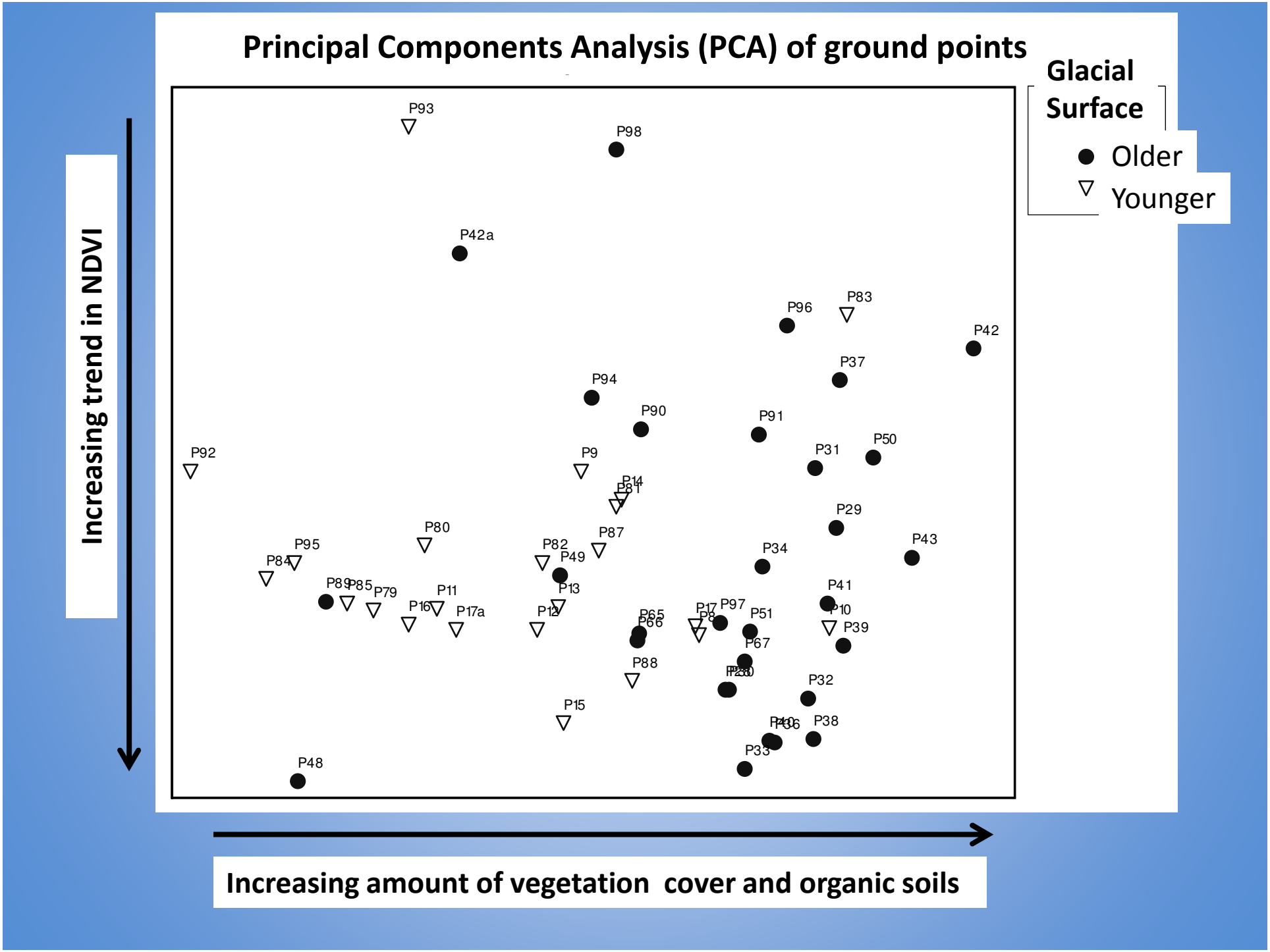
- Latitude, longitude
- Slope, aspect, topographic position
- Landform, presence of patterned ground and snowbanks
- Any evidence of permafrost degradation or other recent landscape changes.
- Ground cover - % live and dead vegetation, water, bare soil and rocks
- Vegetation cover - % cover of different plant lifeforms
- Species cover of dominant plants
- Soil characteristics
    - Thickness of live moss, dead moss, peat, A and B horizons
    - Active layer depth
    - Soil moisture
    - Soil texture

Ground observations

- Boundaries between NDVI trends coincided with changes in vegetation types and landform
- Areas of decreasing NDVI were discrete locations with obvious changes e.g. erosion, killed vegetation.
- On younger surfaces, areas of increase were on dry, partially vegetated ridges. Areas with no change were more moist, continuously vegetated.
- On older surfaces, areas of increase were usually tussock tundra. Moister drainage areas showed no change.

Principal Components Analysis (PCA) of ground points




Principal Components Analysis (PCA) of ground points
Glacial Surface
Older
Younger
Increasing trend in NDVI
Increasing amount of vegetation cover and organic soils
P93
P98
P42a
P96
P83
P42
P37
P94
P90
P91
P50
P92
P9
P31
P14
P81
P29
P80
P87
P43
P95
P82
P49
P34
P84
P13
P41
P89
P85
P79
P11
P16
P17a
P12
P65
P66
P17
P97
P51
P10
P39
P67
P88
P32
P15
P38
P33
P48

Tussock tundra vegetation type that most commonly showed increases on older, Sagavanirktok glacial surfaces

Photo by S. Dashevsky

Photo by S. Dashevsky

Prostrate-shrub tundra vegetation type that most commonly showed increases on younger, Itkillik glacial surfaces

Conclusions

- Increase in NDVI is not homogenous at finer spatial resolution
  - 5% of the area responsible for increase in NDVI
- Decreases in NDVI related to specific disturbance events
- Boundaries between NDVI trends coincided with changes in vegetation types and landform
- Patterns of NDVI change are different on landscapes of different glacial ages
  - Younger glacial surface - more scattered greening on partially vegetated areas.
  - Older glacial surfaces – discreet areas of change, possibly due to increased nutrient availability from melting of ice-rich soils.
- Increased NDVI was not concentrated in shrubby areas


Kiitos!
Questions?


Epilobium latifolium
Photo - M.K. Raynolds
River beauty