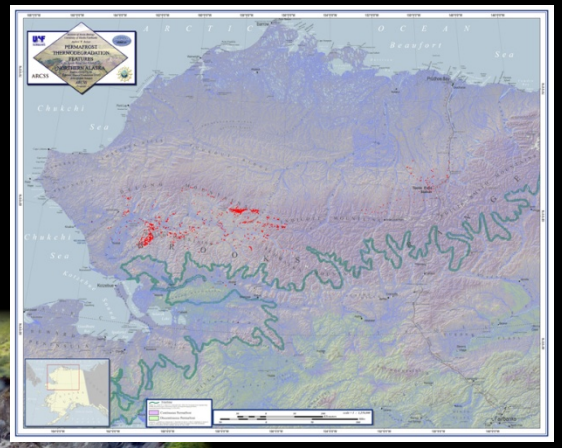
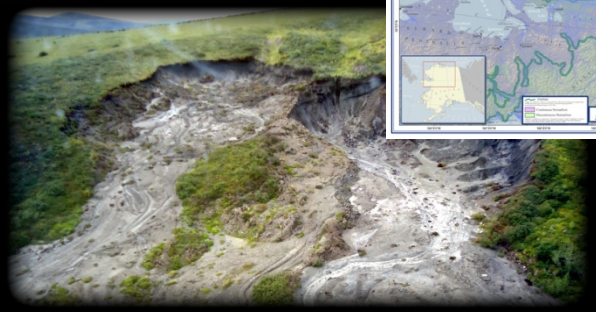
Thermokarst in the Foothills of Northern Alaska:

Timing and Distribution





Andrew W. Balser

Oak Ridge National Laboratory

Jones, J.B.

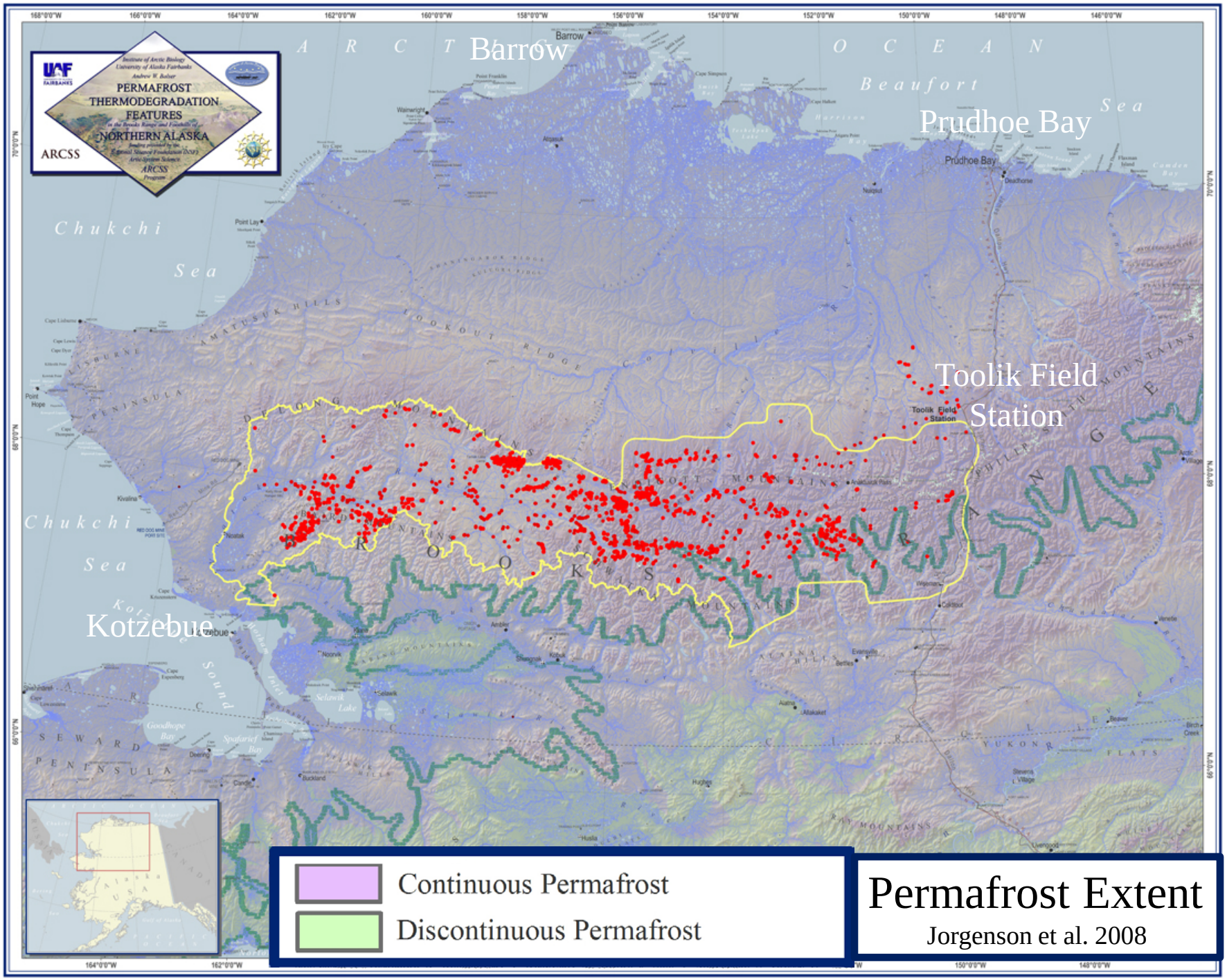
Gens, R.

Jorgenson, M.T.

Walker, D.A.

University of Alaska Fairbanks

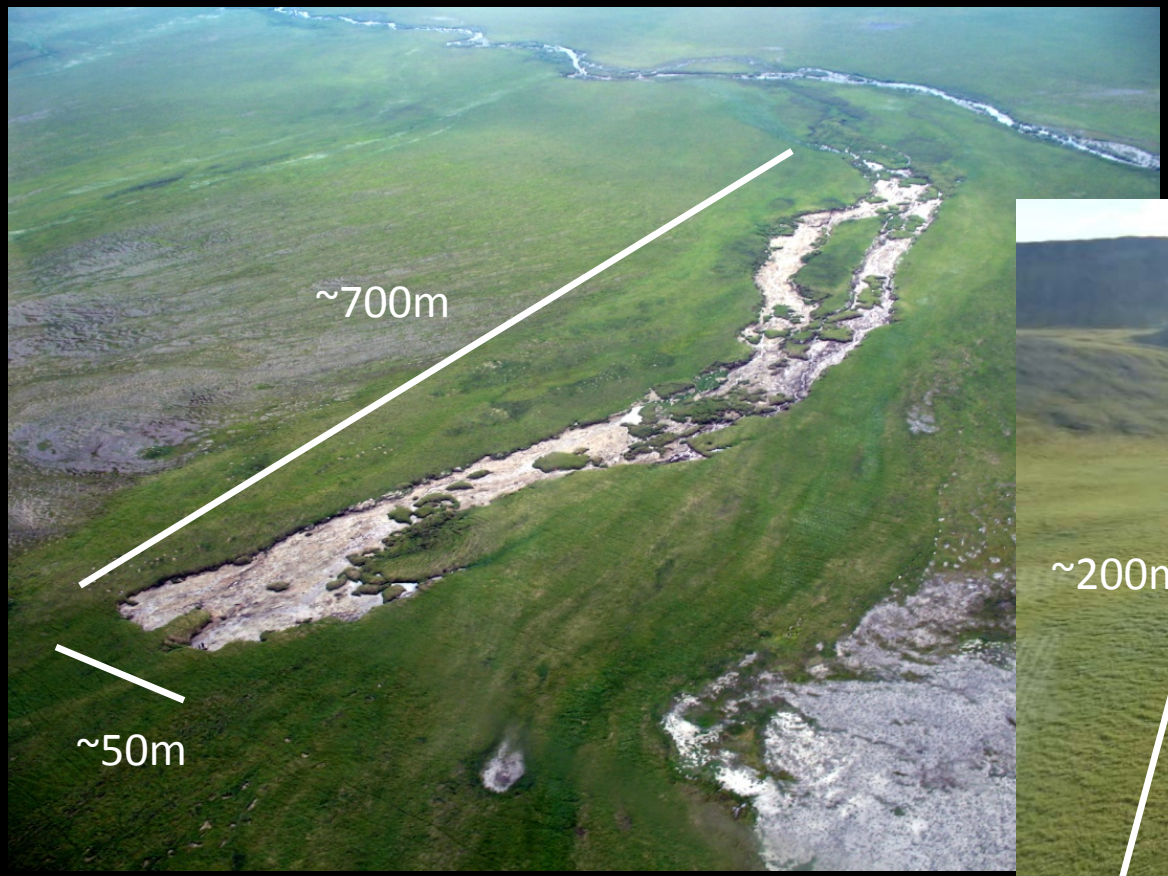
13th International Circumpolar Remote Sensing Symposium - September 8, 2014 - Reykjavík, Iceland

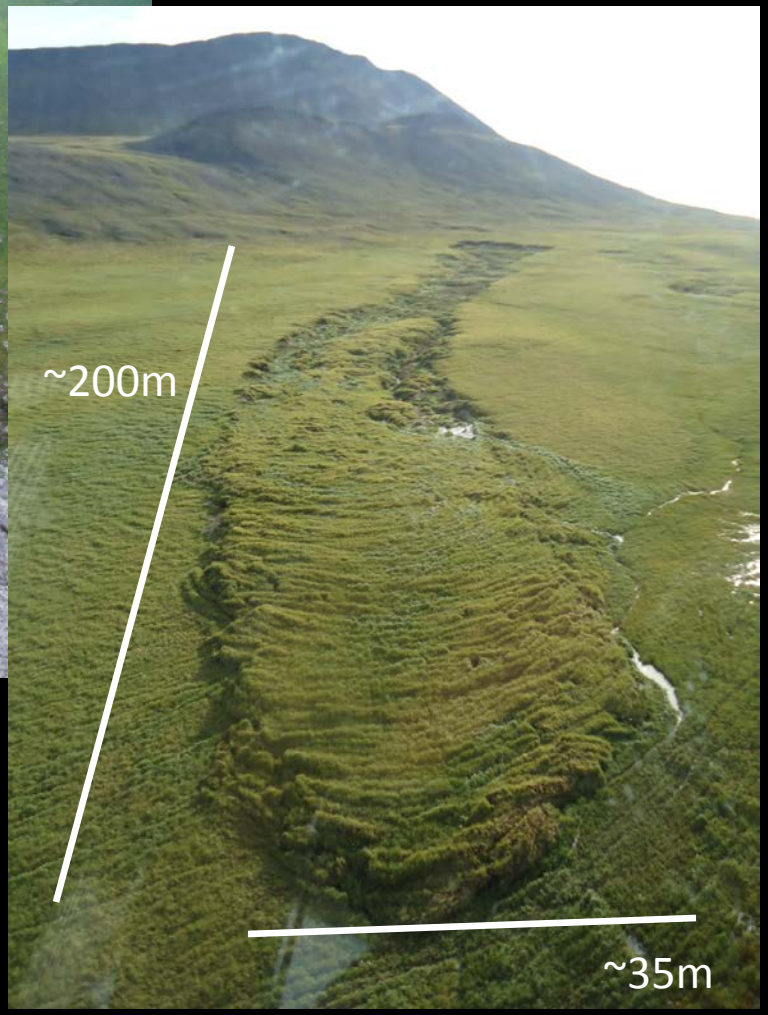


Permafrost Extent

Jorgenson et al. 2008

Active Layer Detachment Slides





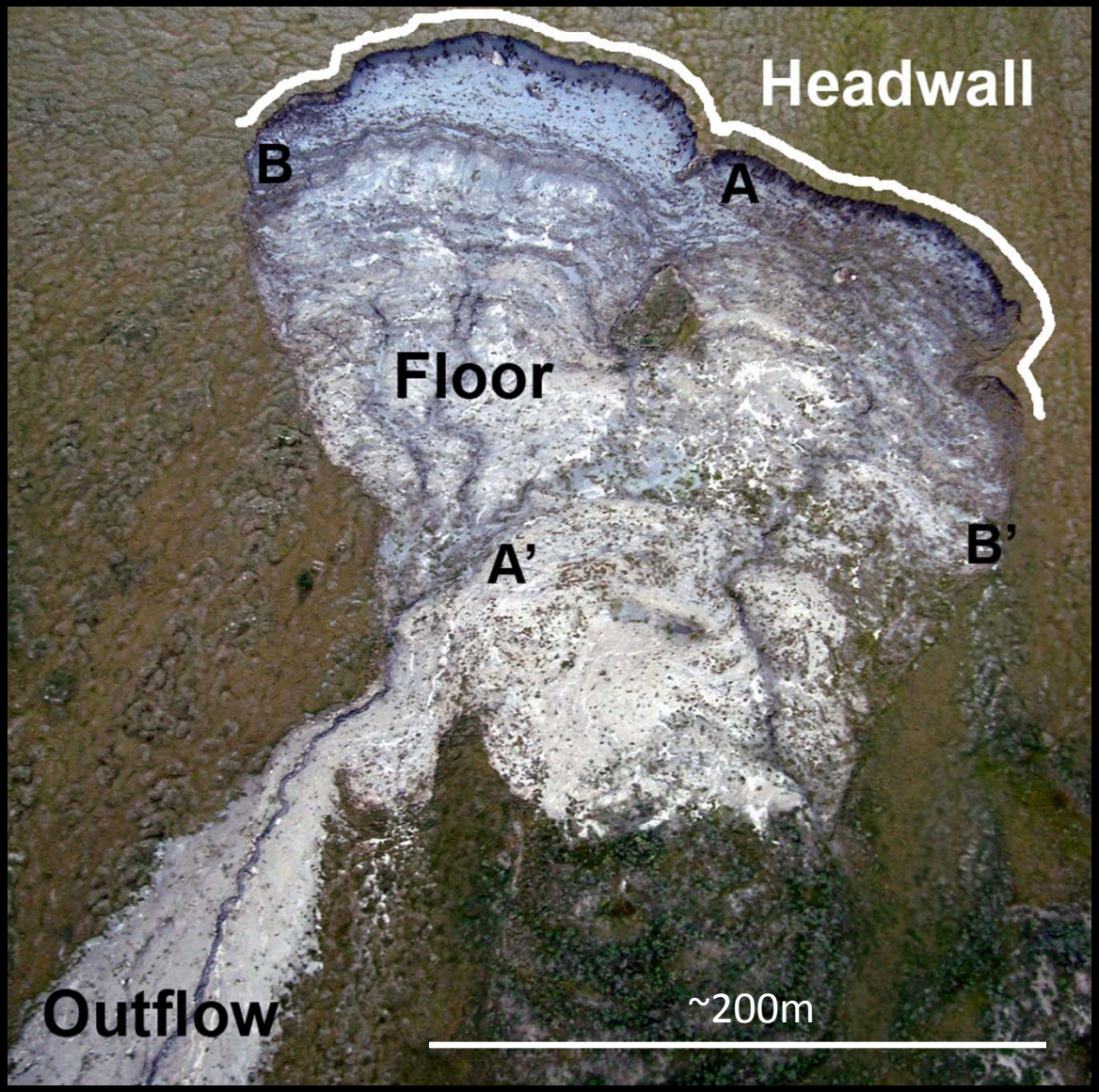
Pore pressure exceeds shear strength

Surficial – top 1 – 2m

Stabilize after 1-2 years (typically)

(photos: Noatak Basin, 2006)

Retrogressive Thaw Slumps



Large & Deep

Depth ~ 14m

(@ headwall scarp)

A – A' = 181m

B – B' = 287m

Years to Decades

Headwall Retreat

1 to 10+ m/yr

(photo: Noatak Basin, 2011)

Questions:

When do they initiate?

- triggered by weather events? (pulse)
- distributed evenly through the years? (press)

Where might they occur?

- which terrain is suitable?

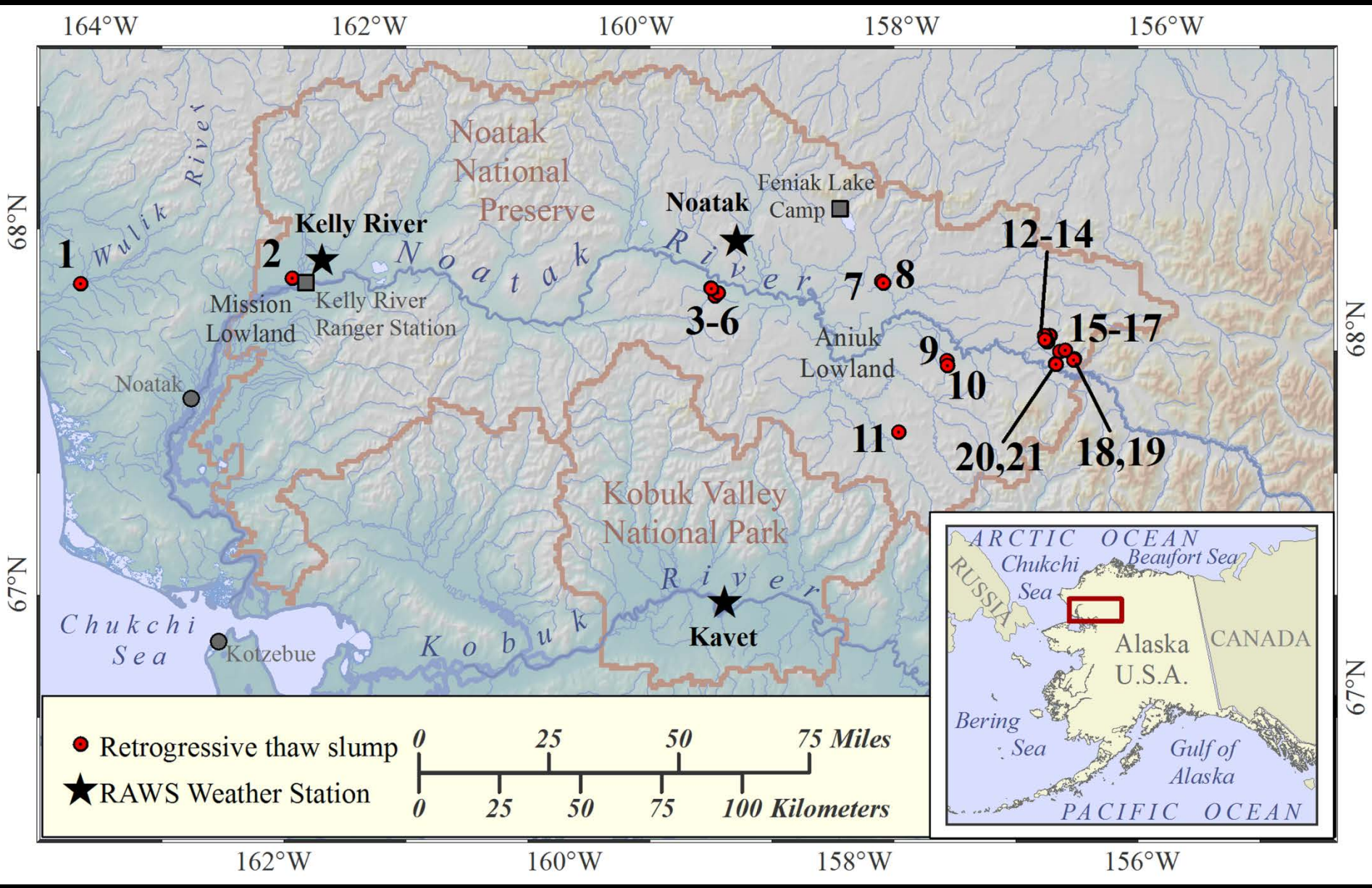
Questions:

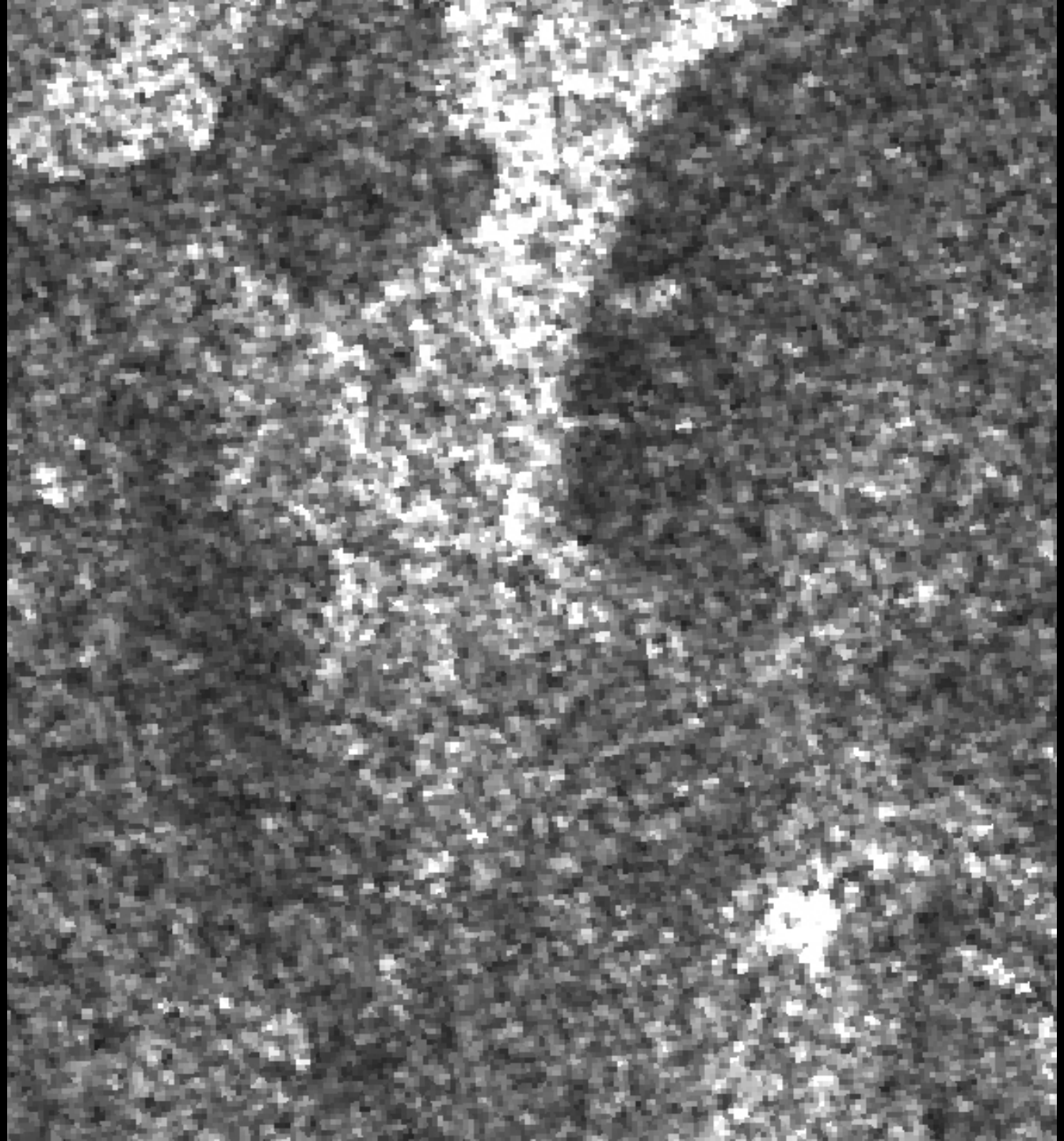
When do they initiate?

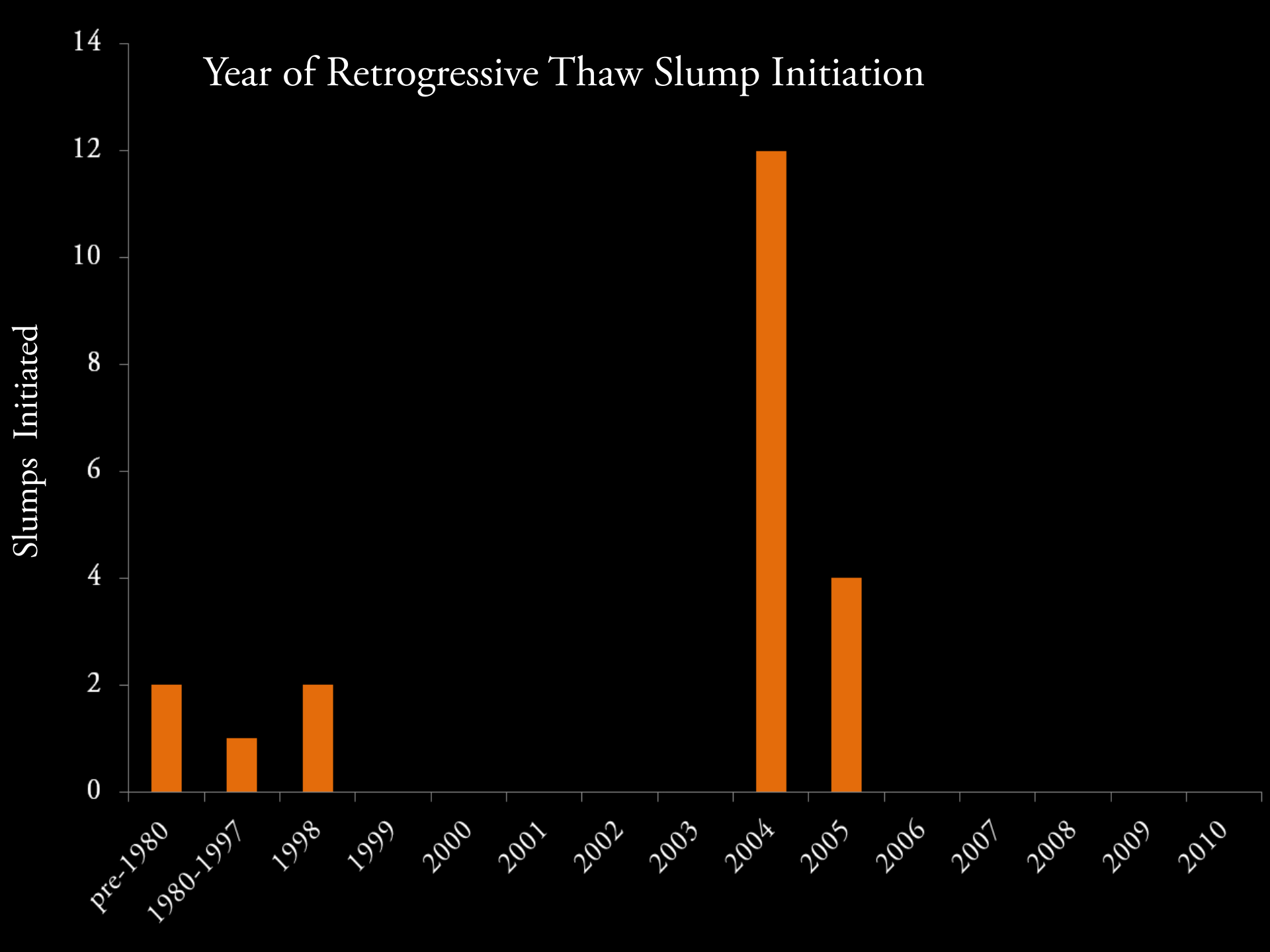
- triggered by weather events? (pulse)
- distributed evenly through the years? (press)

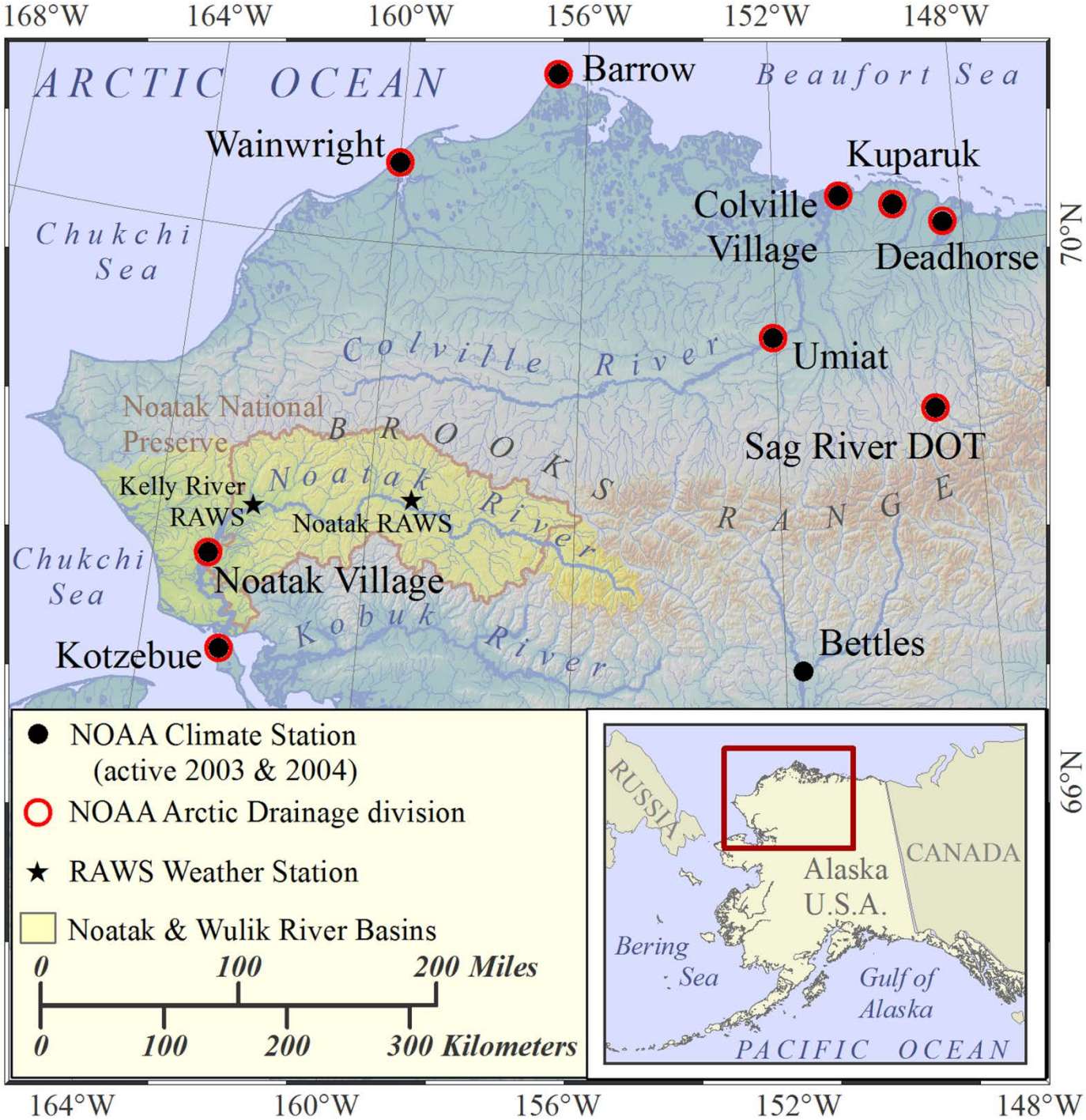
Where might they occur?

- which terrain is suitable?

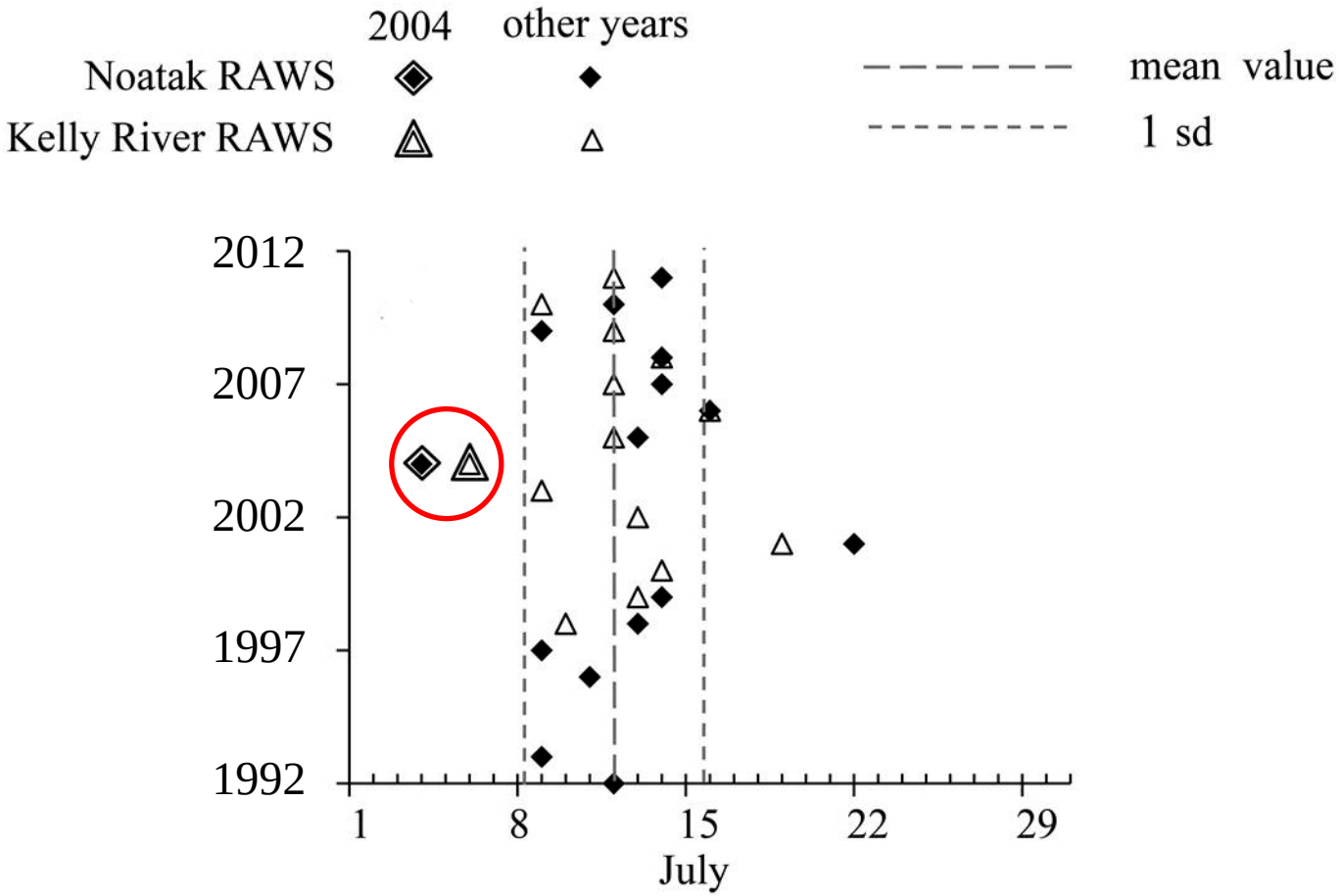

164°W
162°W
160°W
158°W
156°W
68°N
67°N
Noatak National Preserve
Kobuk Valley National Park
Wulik River
Noatak River
Kobuk River
Chukchi Sea
Kelly River
Noatak
Feniak Lake Camp
Mission Lowland
Kelly River Ranger Station
Aniuk Lowland
Kotzebue
Kavet
1
2
3-6
7
8
9
10
11
12-14
15-17
18,19
20,21
Retrogressive thaw slump
RAWS Weather Station
0 25 50 75 Miles
0 25 50 75 100 Kilometers
ARCTIC OCEAN
Beaufort Sea
Chukchi Sea
RUSSIA
Alaska U.S.A.
CANADA
Bering Sea
Gulf of Alaska
PACIFIC OCEAN

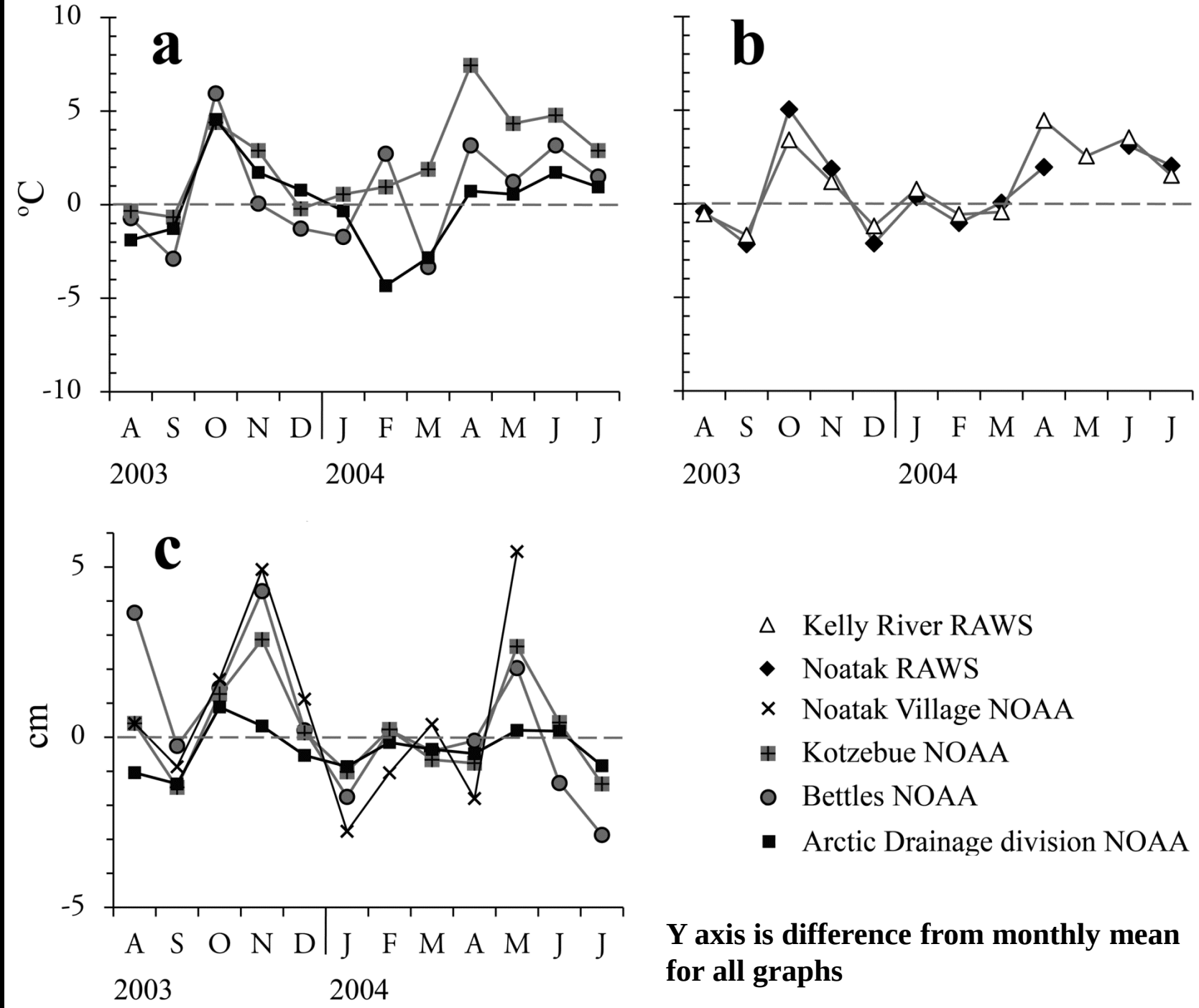



Year of Retrogressive Thaw Slump Initiation
Slumps Initiated
0
2
4
6
8
10
12
14
pre-1980
1980-1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


168°W
164°W
160°W
156°W
152°W
148°W
70°N
66°N
ARCTIC OCEAN
Beaufort Sea
Barrow
Wainwright
Kuparuk
Colville Village
Deadhorse
Chukchi Sea
Colville River
Umiat
Noatak National Preserve
BROOKS RANGE
Sag River DOT
Kelly River RAWS
Noatak RAWS
Noatak River
Noatak Village
Kobuk River
Kotzebue
Bettles
NOAA Climate Station (active 2003 & 2004)
NOAA Arctic Drainage division
RAWS Weather Station
Noatak & Wulik River Basins
0 100 200 Miles
0 100 200 300 Kilometers
RUSSIA
CANADA
Alaska U.S.A.
Bering Sea
Gulf of Alaska
PACIFIC OCEAN

Median Date of Thawing Index





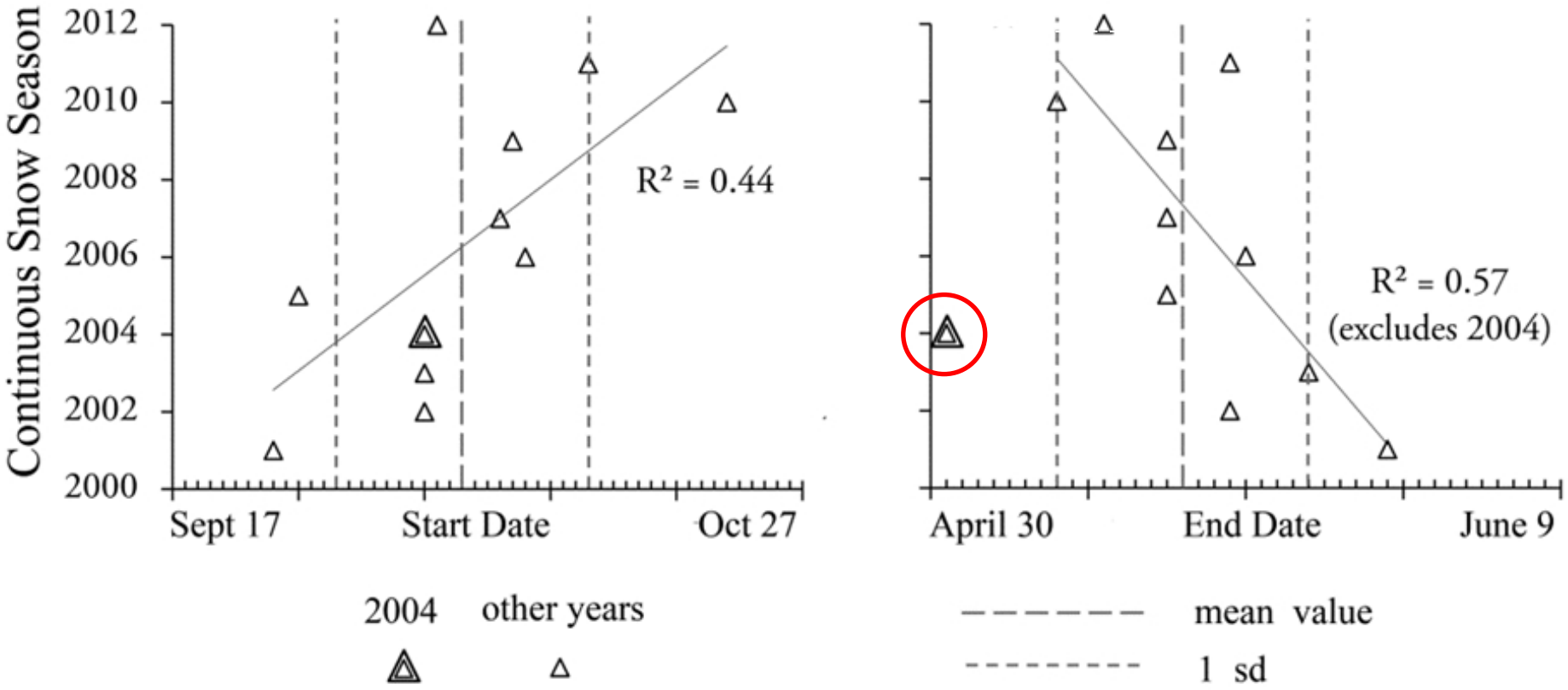
Y axis is difference from monthly mean for all graphs

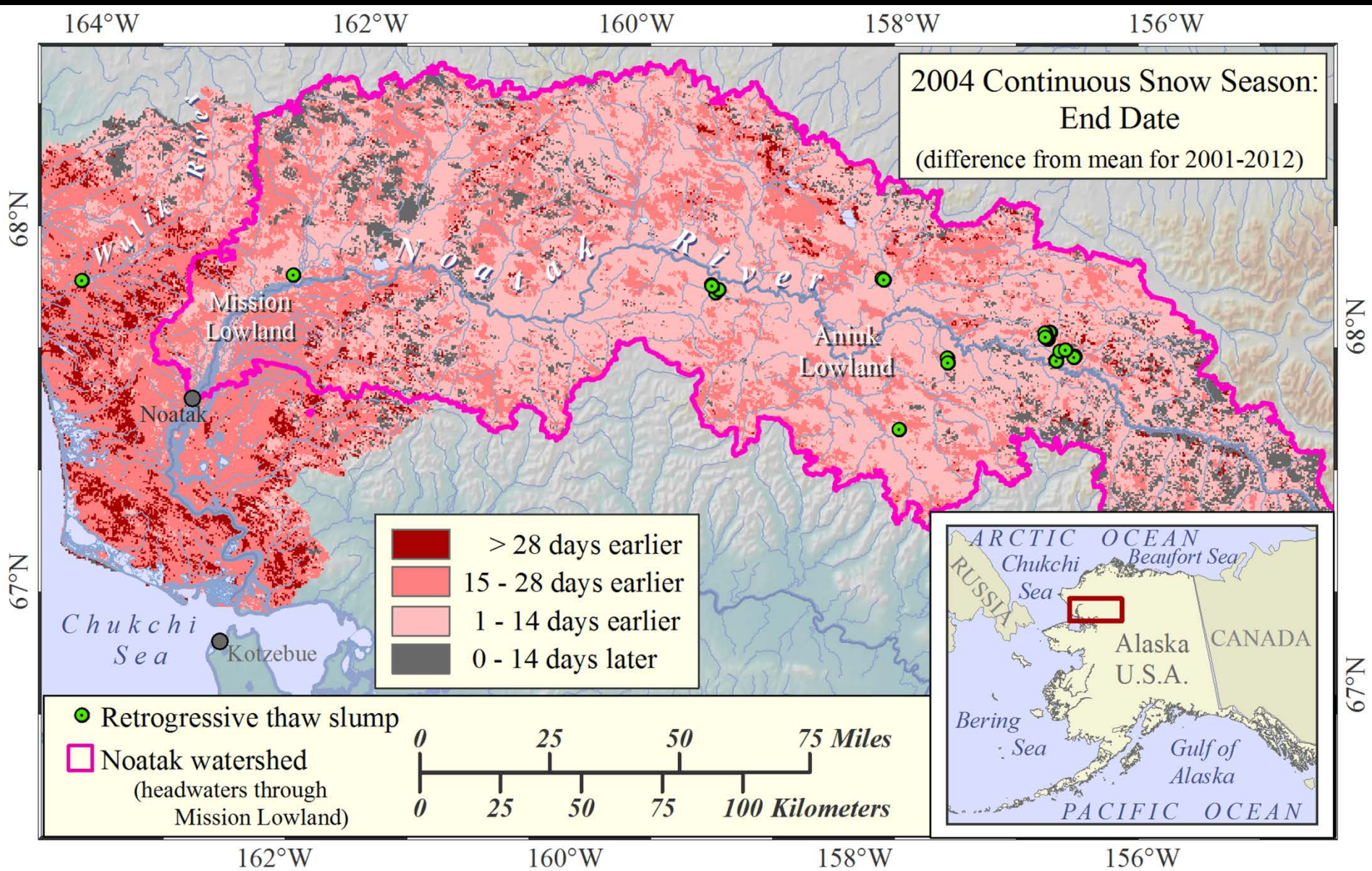
May 2004 precipitation at the NOAA and RAWS stations in the study area
+ includes record rainfall

	May 2004		
	5/6 to 5/11	5/22 to 5/24	total
	cm	cm	cm
Kotzebue NOAA	2.2	0.58	3.5 +
Kelly River RAWS	**3.9**	**2.8**	**8.1**
Noatak Village NOAA	**3.5**	**1.8**	**6.9**
Noatak RAWS	N/A	N/A	N/A
Bettles NOAA	1.2	0.2	4.2

Snow Seasons in the Noatak Basin

(from MODIS Snow Metrics 2001-2012)




2004 Continuous Snow Season: End Date
(difference from mean for 2001-2012)
164°W
162°W
160°W
158°W
156°W
68°N
67°N
Walik River
Noatak River
Mission Lowland
Noatak
Aniuk Lowland
Chukchi Sea
Kotzebue
> 28 days earlier
15 - 28 days earlier
1 - 14 days earlier
0 - 14 days later
Retrogressive thaw slump
Noatak watershed
(headwaters through Mission Lowland)
0 25 50 75 Miles
0 25 50 75 100 Kilometers
ARCTIC OCEAN
Beaufort Sea
Chukchi Sea
RUSSIA
Alaska U.S.A.
CANADA
Bering Sea
Gulf of Alaska
PACIFIC OCEAN

Anomalous weather early in the thaw season:

- Sun angles are highest
- Duration of daylight is longest
- Cloud cover is minimal (typically)
- Before bud burst (mostly)

- Increased incident solar radiation to the surface
- Accelerated rate of thaw front advance – with the rest of the thaw season still to come

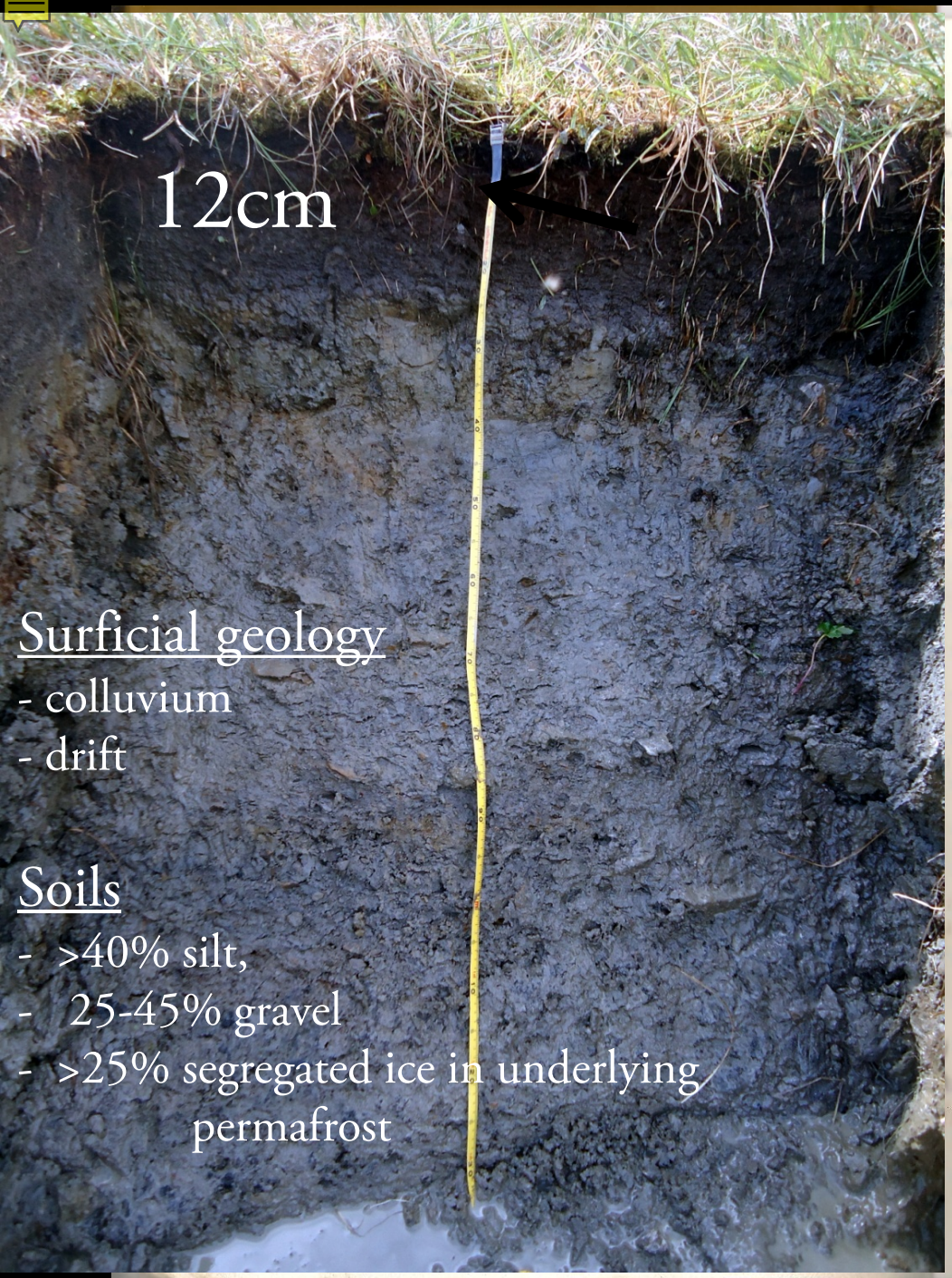
Questions:

When do they occur?

- associated with weather events?
- evenly through the years?

Where might they occur?

- how much landscape is susceptible?

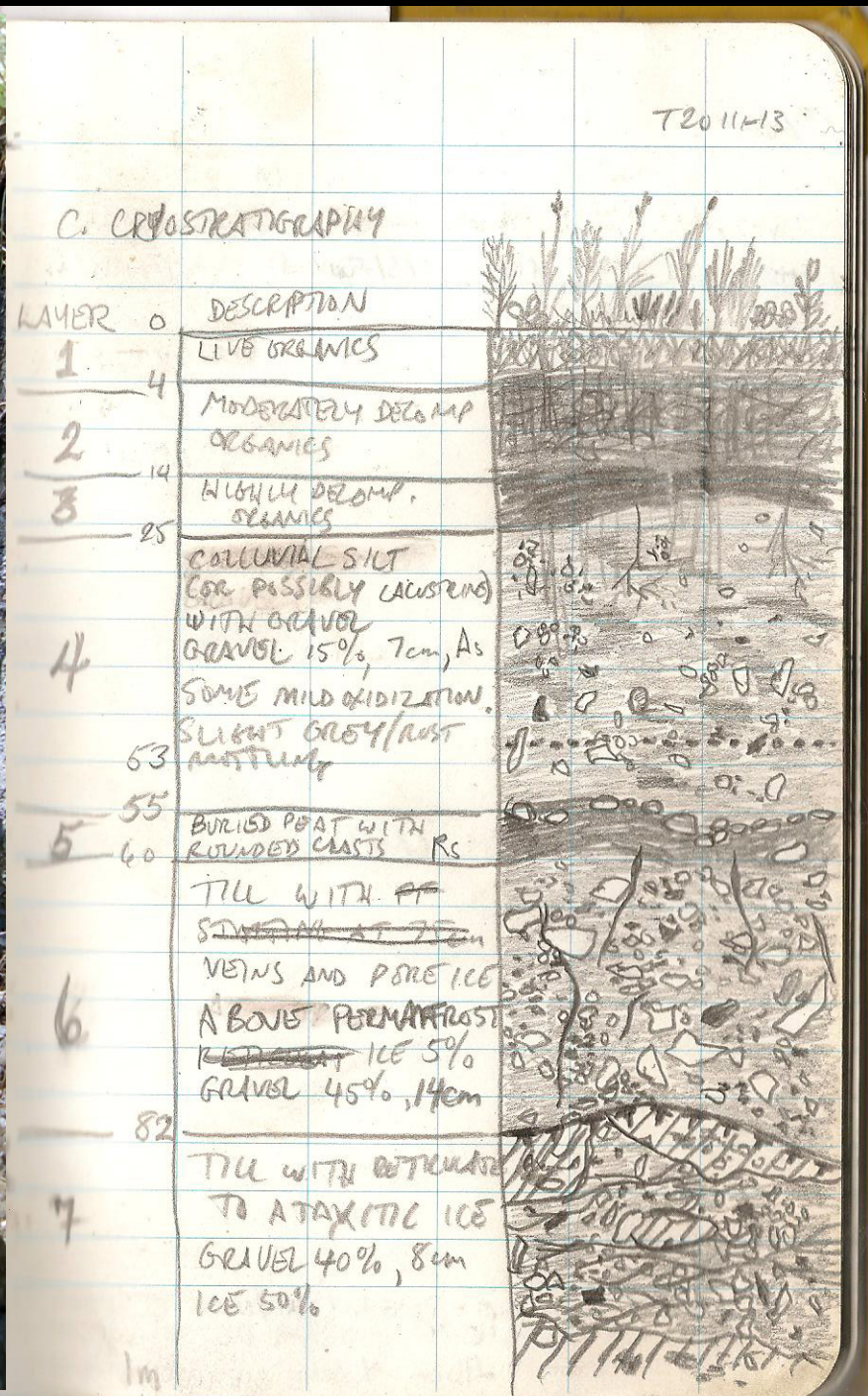


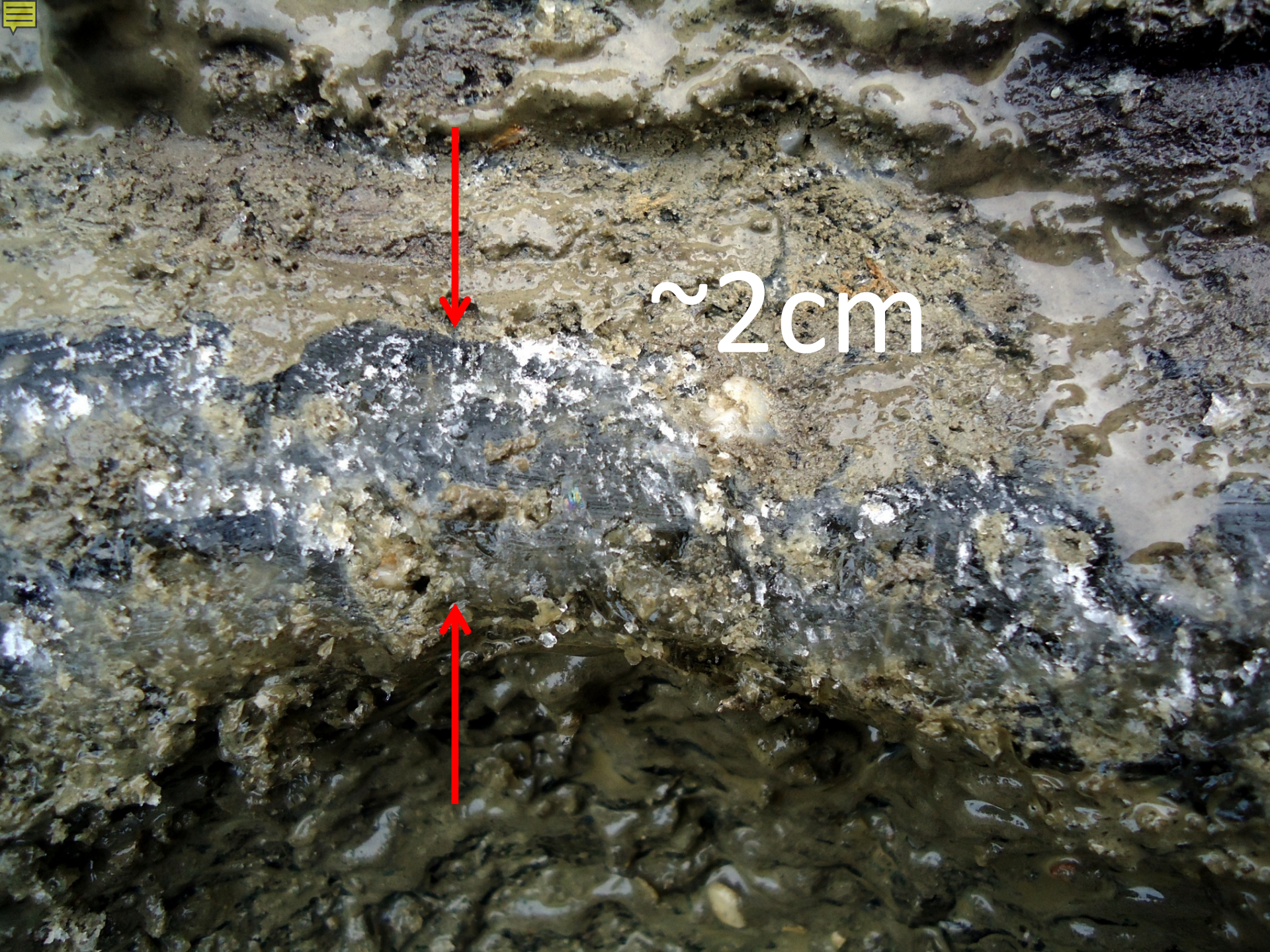
Surficial geology

- colluvium
- drift

Soils

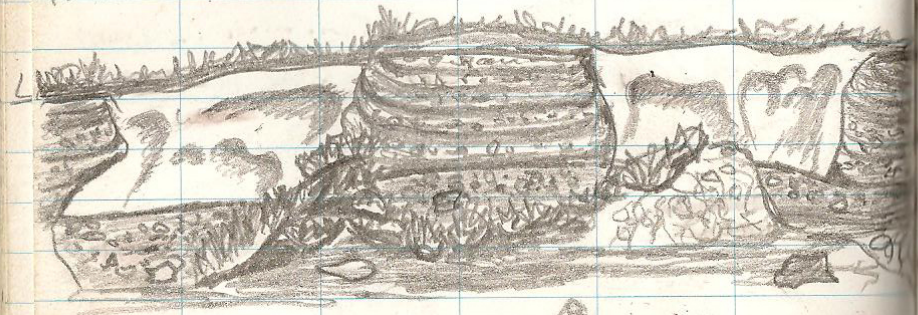
- >40% silt,
- 25-45% gravel
- >25% segregated ice in underlying permafrost

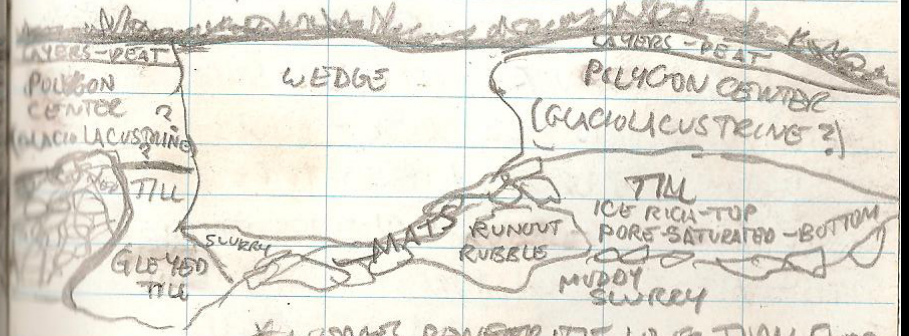



~2cm

7/31/14

T2011-12 SCHEMATIC OF CENTRAL HEADWALL AND PANORAMA



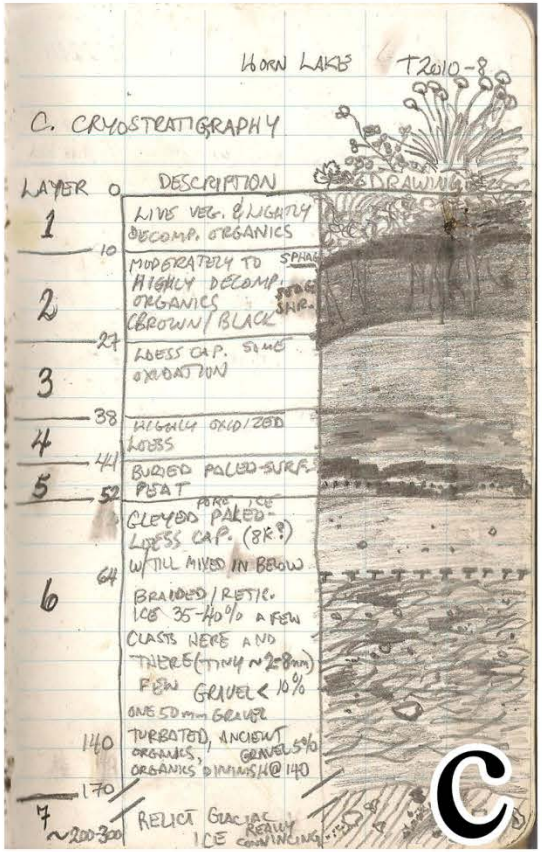


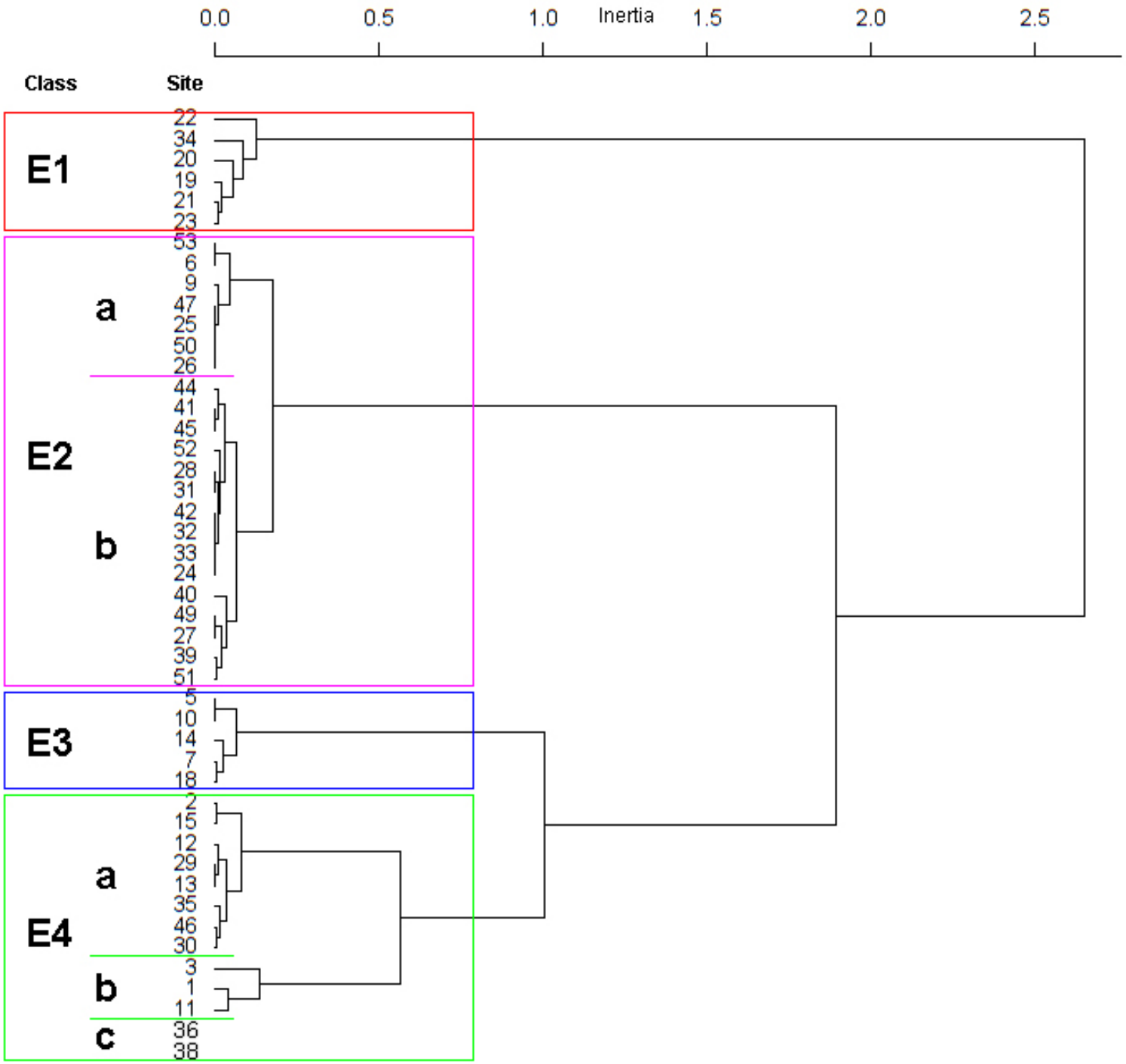
* WEDGES PENETRATE LOWER THAN FLOOR OF TK
* BASAL TILL ALMOST SLIMY WHEN SCRAPED IT'S SO ICE-RICH (PORE)

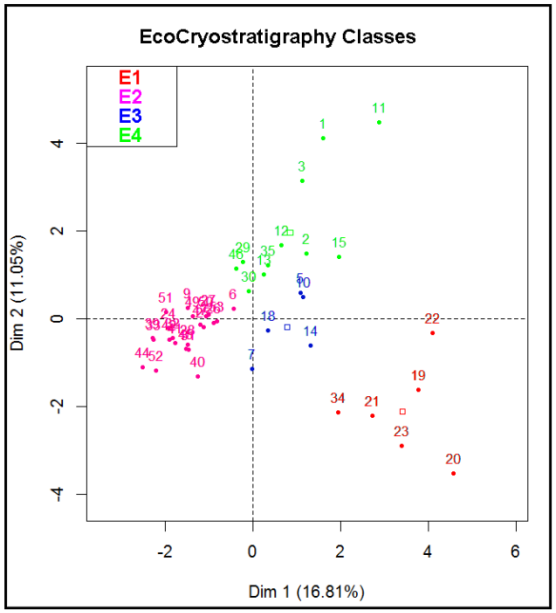
JUST ACROSS SMALL RIVER VALLEY FROM id1A TERMINAL MORAINE (~1 MILE FROM MORAINE CREST) T2011-12 APPEARS TO HAVE A TILL BASE (OBVIOUS UNIFORM DIAMICTOUS GREY, SILT RICH) WITH SUPER-SATURATED PORE ICE. TOP SECTION OF BASAL TILL HAS 25-200cm OF ATAXITIC (>65%) ICE. SEVERAL MORE LAYERS MAY BE TILL OR VERY PROXIMAL GLACIOLACUSTRINE, OR MAYBE GLACIOFLUVIAL OUTWASH. PREDOMINANTLY BEDDED (0.4-1.2cm LENSES) INTERSPERSED WITH 4-10cm THICK ICE BEDS (GIVING THE STRIATED APPEARANCE IN HEADWALL. TOP ~1m HAS SOME OBVIOUS PROXIMAL AND DISTAL GLACIOLACSTRINE WITH PEAT INTERLAIN. SOME PLACES SHOW ~20cm LOESS CAP UNDER LIVING VEGETATION. SOME PLACES SHOW PROMINENT SORTING OF ROUNDED CLASTS / SILT.

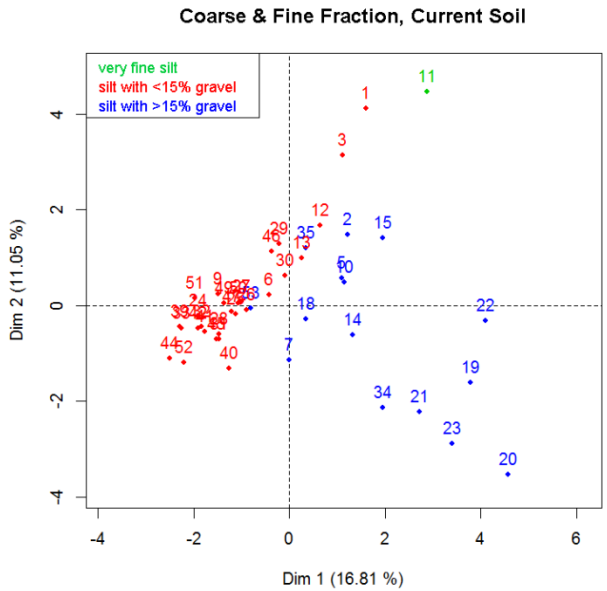
a

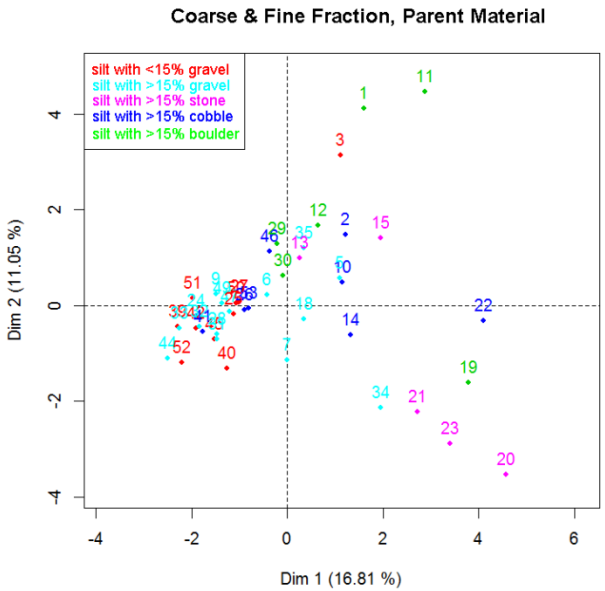
b

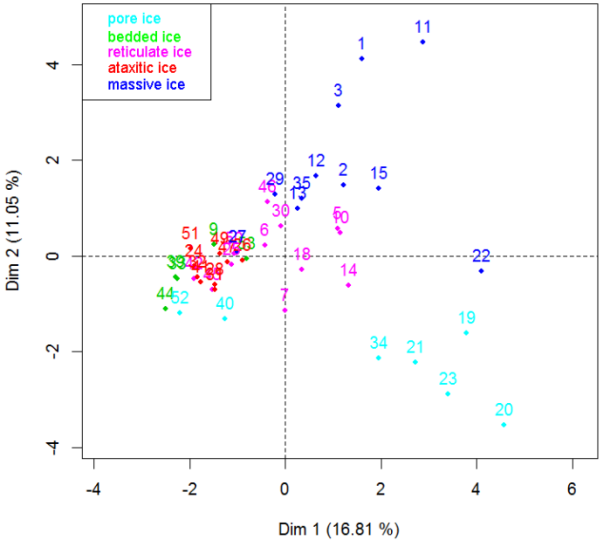

HORN LAKE T2010-8
C. CRYOSTRATIGRAPHY
LAYER 0 DESCRIPTION
DRAWING
1
LIVE VEG. & LIGHTLY DECOMP. ORGANICS
10
MODERATELY TO HIGHLY DECOMP. ORGANICS BROWN/BLACK
SPHAG
27
2
LOESS CAP. SOME OXIDATION
3
38
HIGHLY OXID/ZED LOESS
4
41
BURIED PALEO-SURF. PEAT
5
52
CLEYED PALEO-LOESS CAP. (8K?) W/TILL MIXED IN BELOW
64
6
BRAIDED/RETIC. ICE 35-40% A FEW CLASTS HERE AND THERE (TINY ~2-8mm) FEW GRAVEL < 10%
ONE 50mm GRAVEL
140
TURBATED, ANCIENT ORGANICS, GRAVEL 5%
170
7
~200-300
RELICT GLACIAL ICE
C

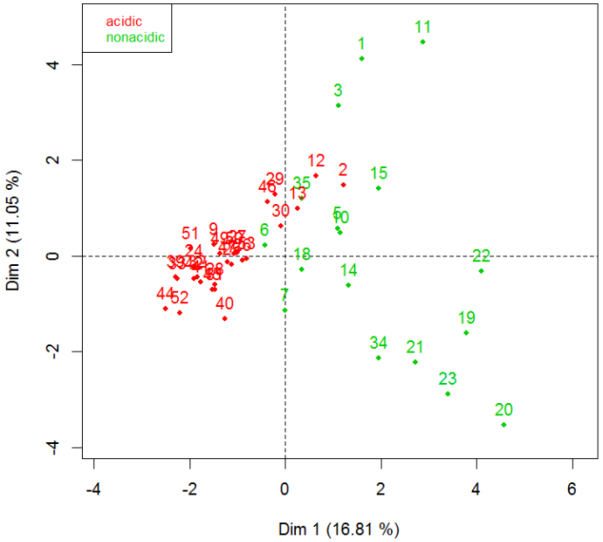

0.0
0.5
1.0
Inertia
1.5
2.0
2.5
Class
Site
E1
22
34
20
19
21
23
E2
a
53
6
9
47
25
50
26
b
44
41
45
52
28
31
42
32
33
24
40
49
27
39
51
E3
5
10
14
7
18
E4
a
2
15
12
29
13
35
46
30
b
3
1
11
c
36
38

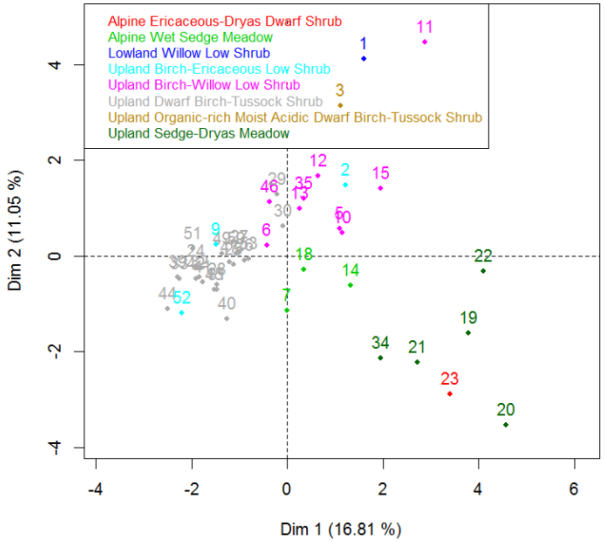

EcoCryostratigraphy Classes
E1
E2
E3
E4
Dim 1 (16.81%)
Dim 2 (11.05%)


Coarse & Fine Fraction, Current Soil
very fine silt
silt with <15% gravel
silt with >15% gravel
Dim 1 (16.81 %)
Dim 2 (11.05 %)

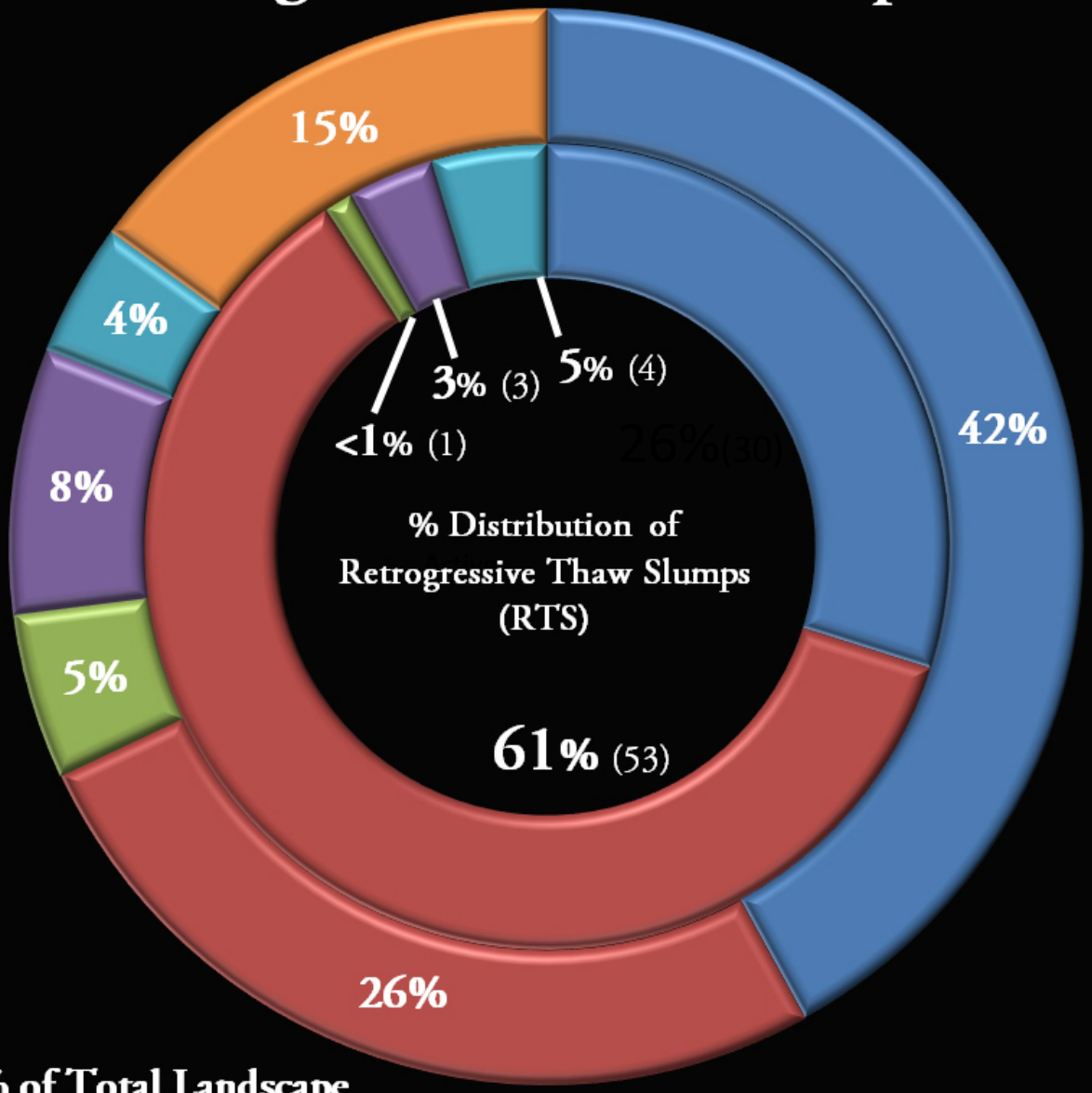

Coarse & Fine Fraction, Parent Material
silt with <15% gravel
silt with >15% gravel
silt with >15% stone
silt with >15% cobble
silt with >15% boulder
Dim 1 (16.81 %)
Dim 2 (11.05 %)


Permafrost Primary Cryostructures
pore ice
bedded ice
reticulate ice
ataxitic ice
massive ice
Dim 1 (16.81 %)
Dim 2 (11.05 %)


Acidic / Nonacidic
acidic
nonacidic
Dim 1 (16.81 %)
Dim 2 (11.05 %)


Ecotype
Alpine Ericaceous-Dryas Dwarf Shrub
Alpine Wet Sedge Meadow
Lowland Willow Low Shrub
Upland Birch-Ericaceous Low Shrub
Upland Birch-Willow Low Shrub
Upland Dwarf Birch-Tussock Shrub
Upland Organic-rich Moist Acidic Dwarf Birch-Tussock Shrub
Upland Sedge-Dryas Meadow
Dim 1 (16.81 %)
Dim 2 (11.05 %)

Retrogressive Thaw Slump Distribution

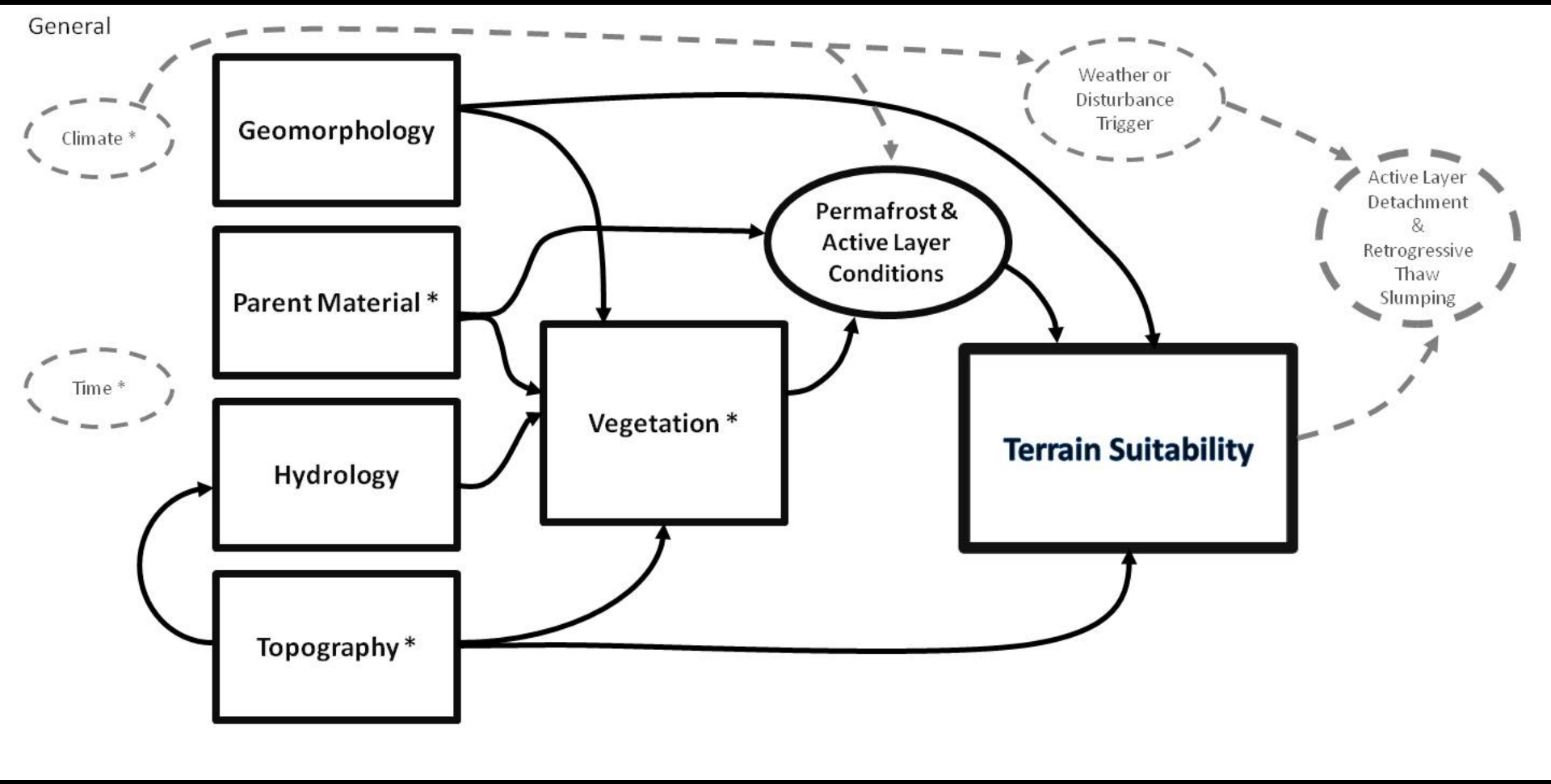


Lithology

- Sedimentary Complex
- Glaciolacustrine
- Mafic
- Glacial
- Alluvial
- Other

% of Total Landscape
- Lithology -

Base SEM Diagram - Conceptual

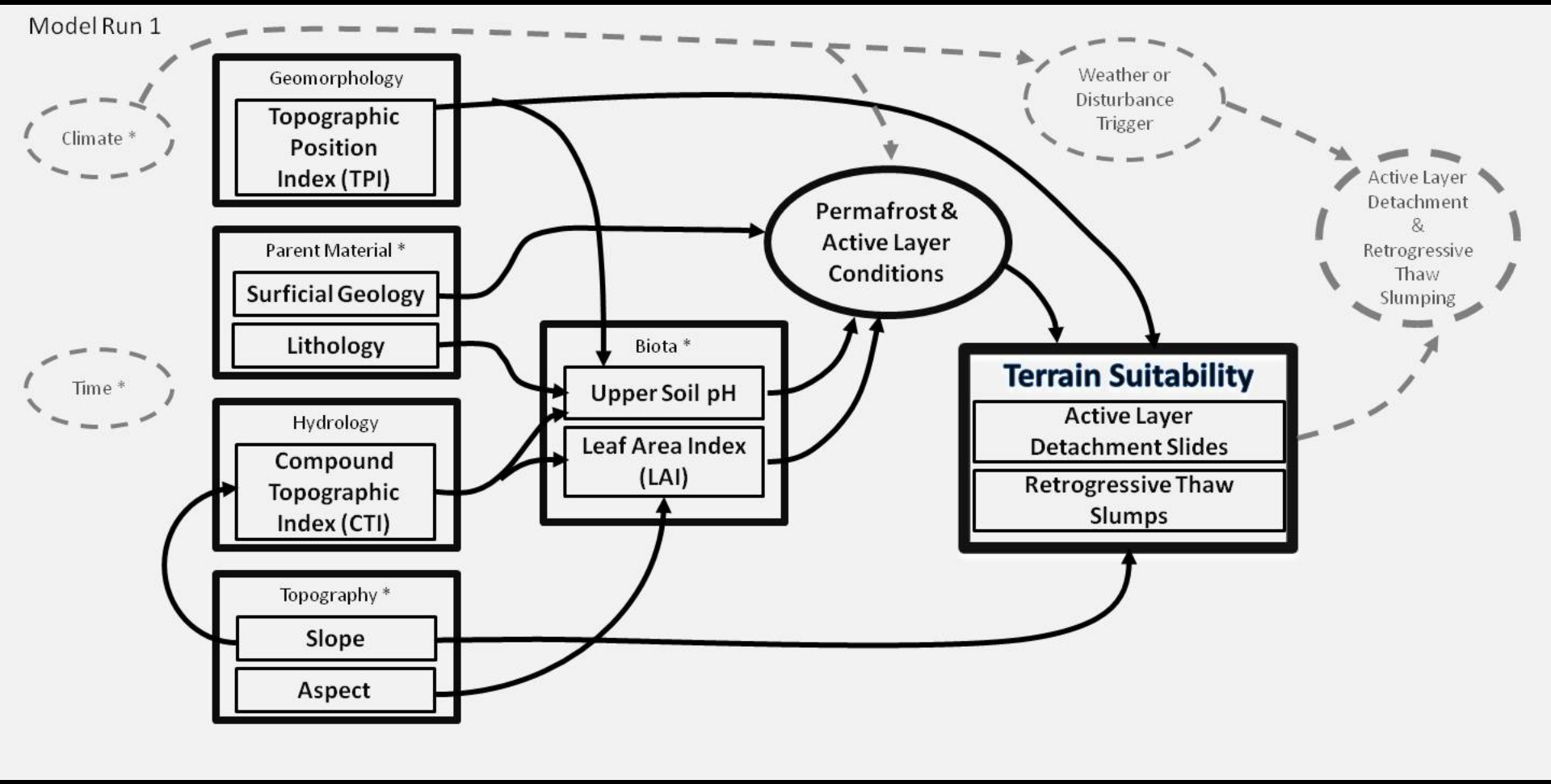


* = State Factor

Observed

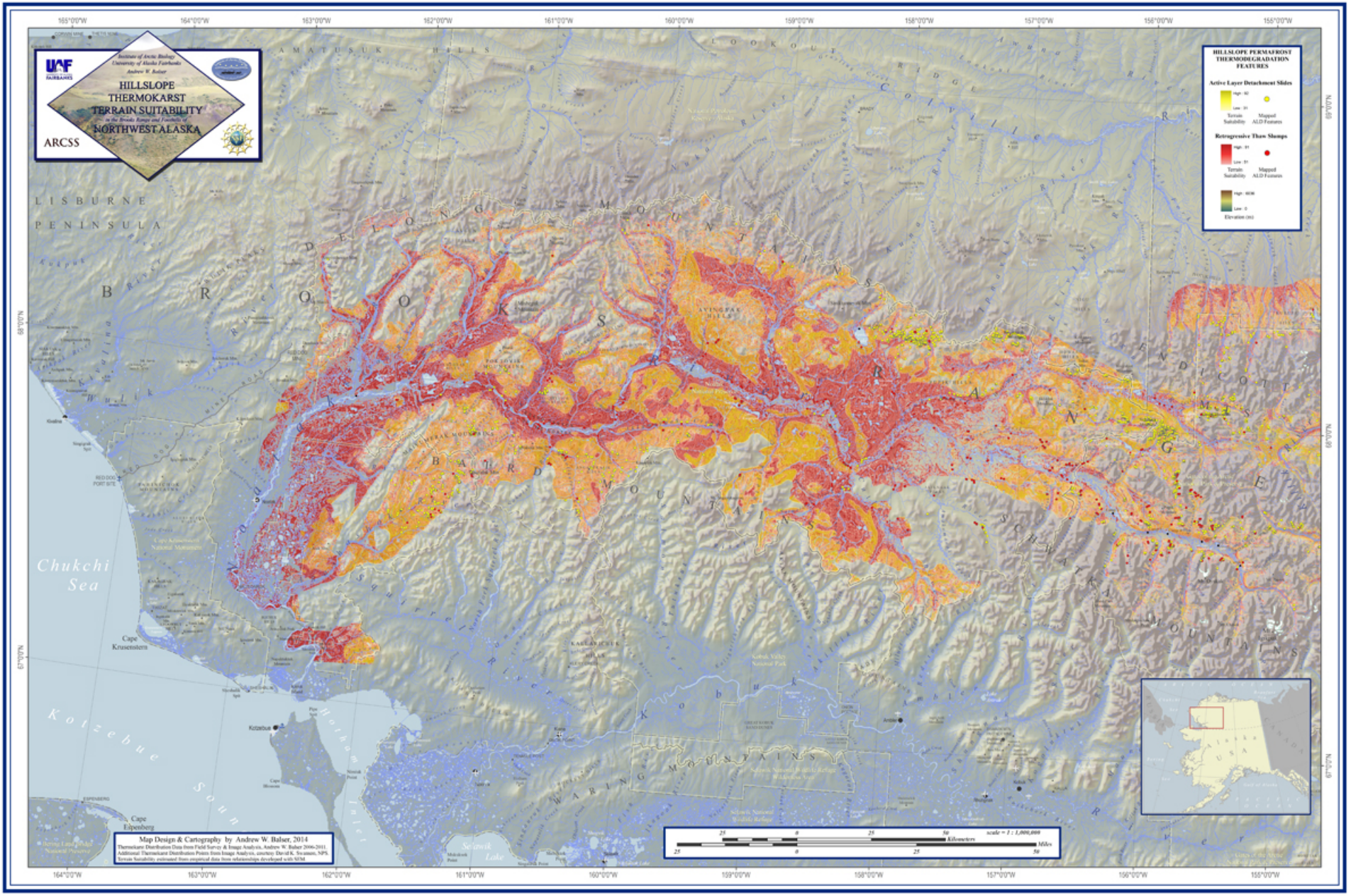
Latent

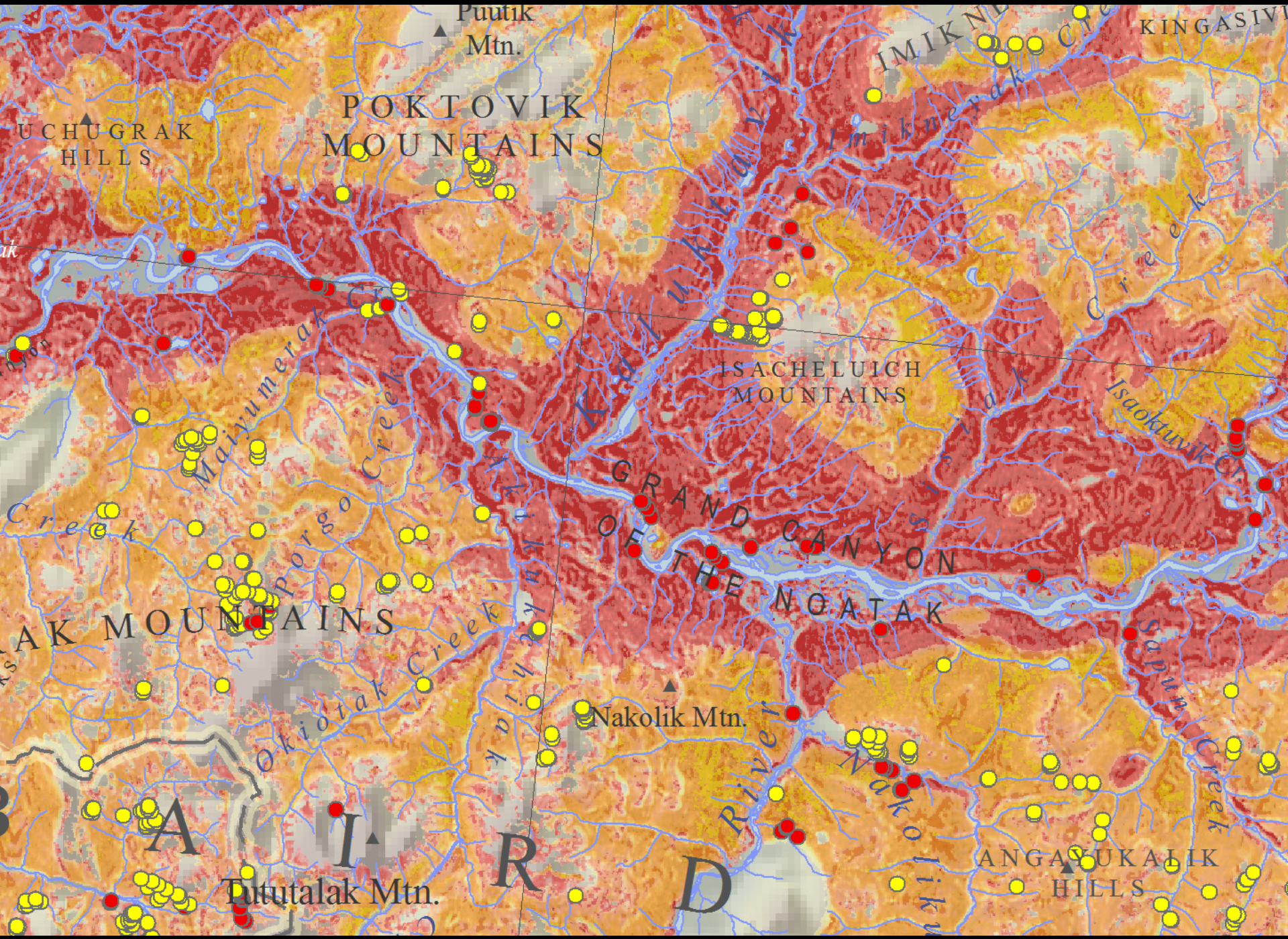
SEM Diagram - Computational



Observed

Latent


Institute of Arctic Biology
University of Alaska Fairbanks
Andrew W. Balser
HILLSLOPE
THERMOKARST
TERRAIN SUITABILITY
in the Brooks Range and Foothills of
NORTHWEST ALASKA
ARCSS
HILLSLOPE PERMAFROST THERMODEGRADATION FEATURES
Active Layer Detachment Slides
Retrogressive Thaw Slumps
Terrain Suitability
Mapped ALD Features
Elevation (m)
LISBURNE PENINSULA
Chukchi Sea
Kotzebue Sound
Cape Krusenstern
Kotzebue
Cape Espenberg
Map Design & Cartography by Andrew W. Balser, 2014
Thermokarst Distribution Data from Field Survey & Image Analysis, Andrew W. Balser 2006-2011.
Additional Thermokarst Distribution Points from Image Analysis, courtesy: David K. Swanson, NPS.
Terrain Suitability estimated from empirical data from relationships developed with SEM.
scale = 1 : 1,000,000
Kilometers
Miles


Puutik Mtn.
POKTOVIK MOUNTAINS
UCHUGRAK HILLS
IMIKNERAK CREEK
KINGASIVI
Imiknerak
ISACHELUICH MOUNTAINS
Isachelukpuk Creek
Isaokuvik Creek
Maiyumerak Creek
Porgo Creek
Okiotak Creek
GRAND CANYON OF THE NOATAK
AK MOUNTAINS
Nakolik Mtn.
Nakolik River
Sapuni Creek
ANGAYUKALIK HILLS
Tututalak Mtn.
A I R D

Conclusions

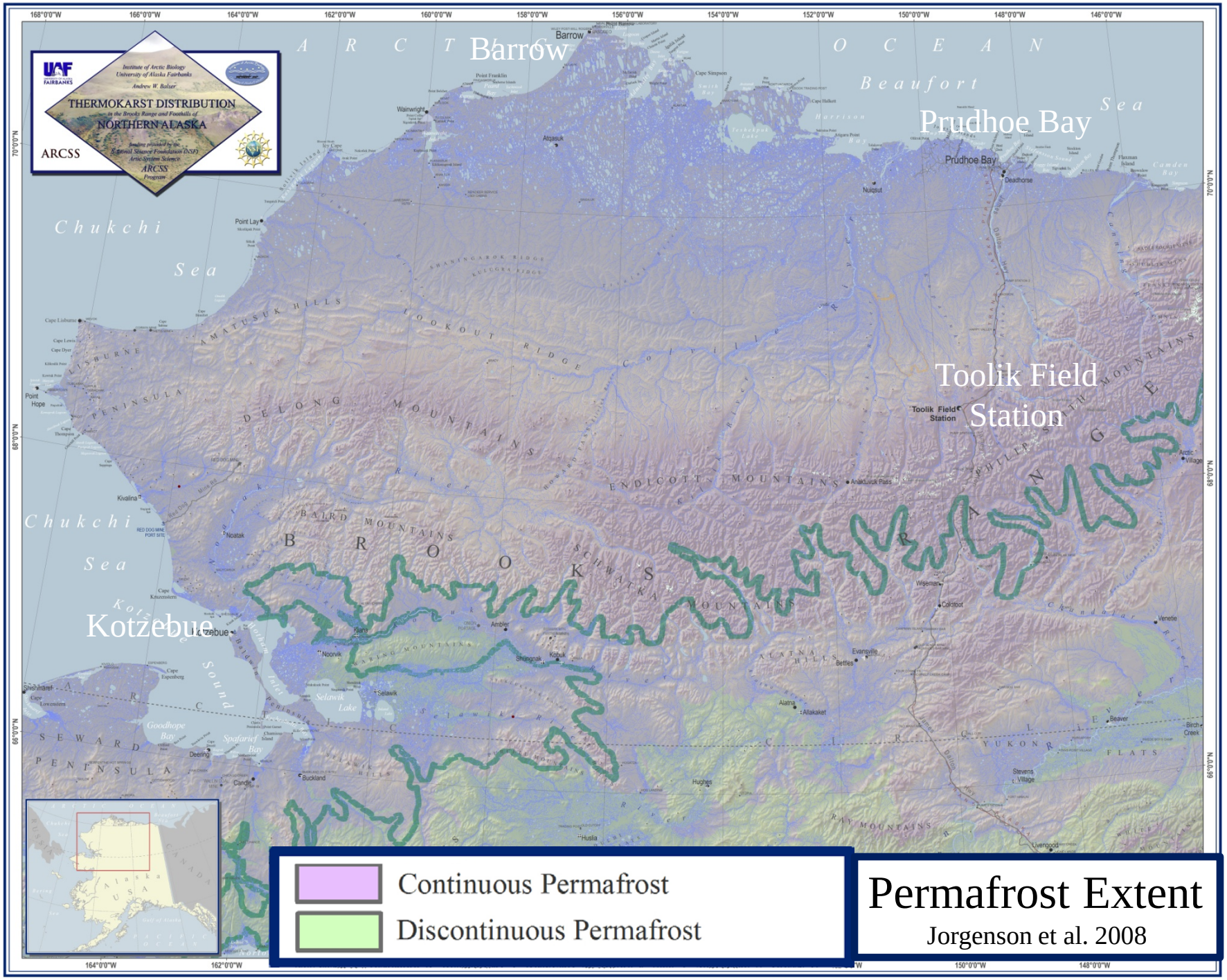
Pulse vs. Press

- Pulse - initiation
- Press - preconditioning agent

Consistent landscape properties

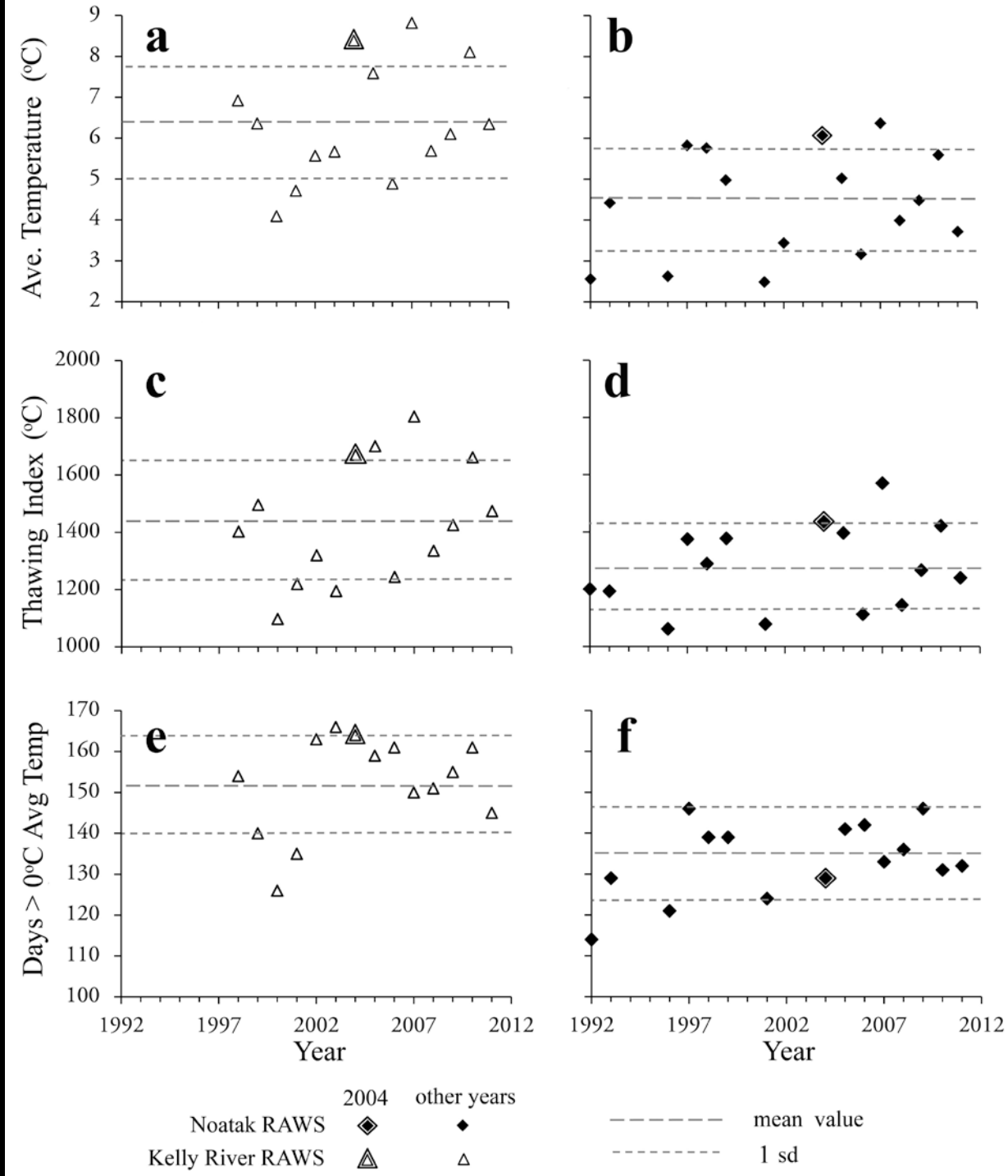
Low-arctic foothills may contain substantial suitable terrain

Questions?



Permafrost Extent

Jorgenson et al. 2008


a
b
c
d
e
f
Ave. Temperature (ºC)
Thawing Index (ºC)
Days > 0ºC Avg Temp
Year
Year
2004
other years
Noatak RAWS
Kelly River RAWS
mean value
1 sd