Spatiotemporal variation in recent (2002-2015) browning and greening trends in the Arctic-Boreal Region of western North America:

regional differences, time-series effects, and post-fire trends.

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Larger Context:

Global change

Carbon balance

Process-level understanding

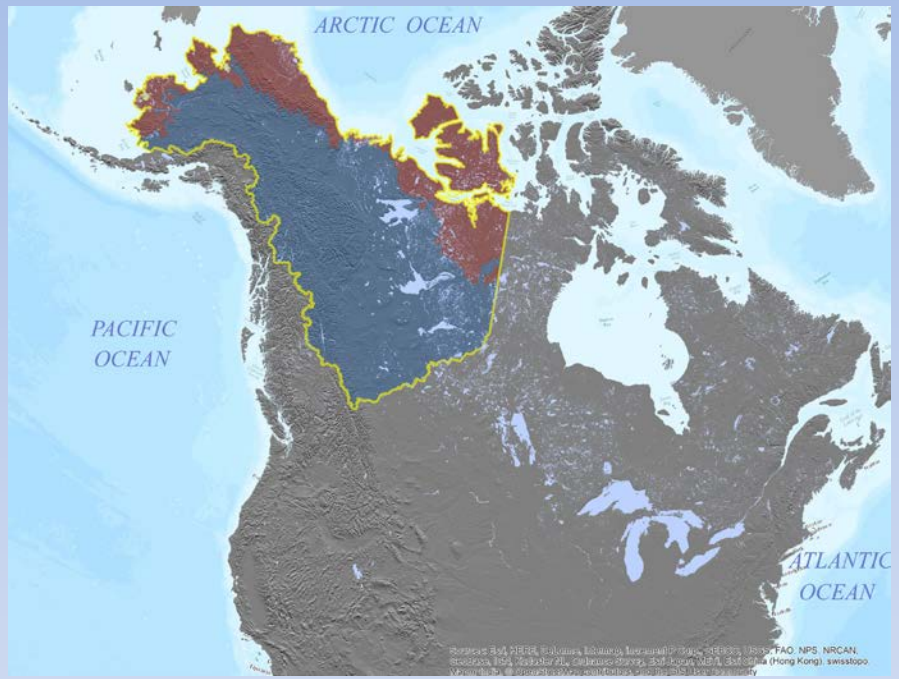
Objectives:

Recent vegetation trends– MODIS

- NDVI greening and browning

Spatial and temporal patterns

- ABoVE Core Region
- Arctic and Boreal
- unburned vs burned



Information from other vegetation indices (VIs)

- NDMI and NDWI
- Tasseled-Cap Brightness (TCB), Greenness (TCG), & Wetness (TCW)

Time-series data:

- 2002-2015 growing season (May 17-Sept 6)
- MODIS (MCD43B4 NBAR) 1-km resolution

Annual Vegetation Indices (**VIs**)

maxNDVI - max Normalized Difference Vegetation Index

NDMI - Normalized Difference Moisture Index

NDWI - Normalized Difference Water Index

TCB - Tasseled Cap Brightness

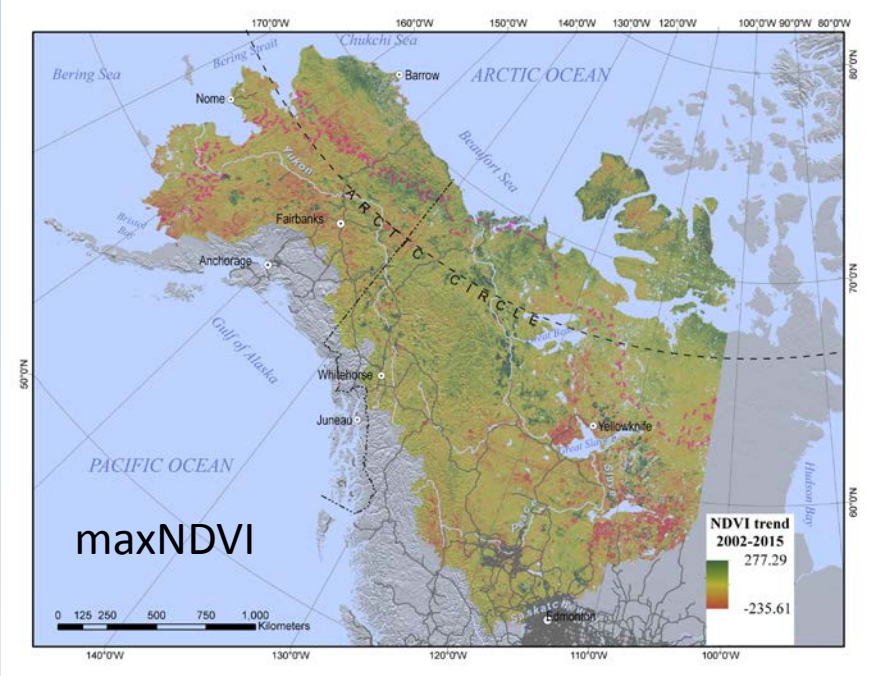
TCG - Tasseled Cap Greenness

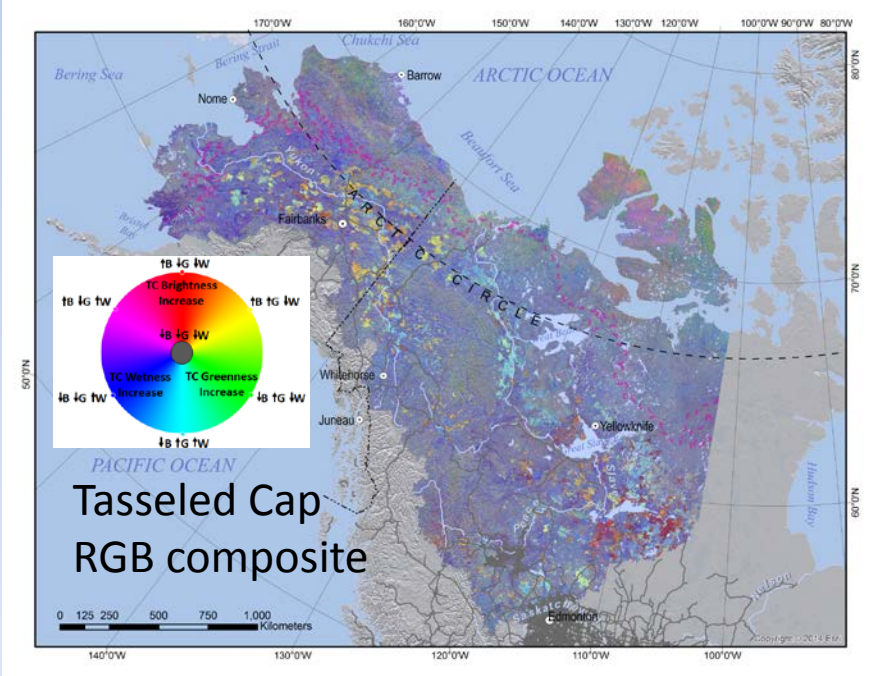
TCW - Tasseled Cap Wetness

VI Trend Analysis

Thiel-Sen Median Slope

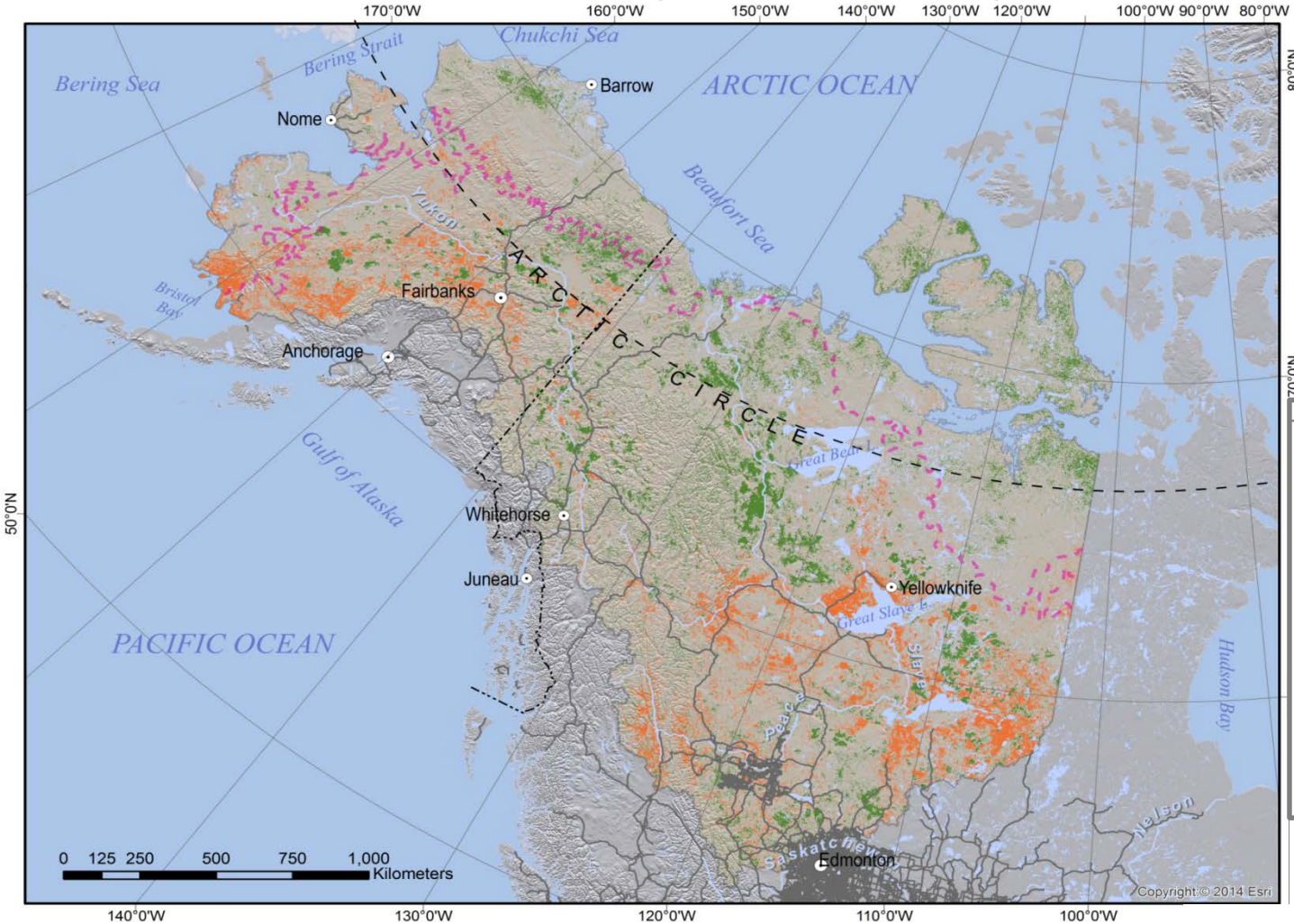
Mann-Kendall significance test at 95% confidence level.

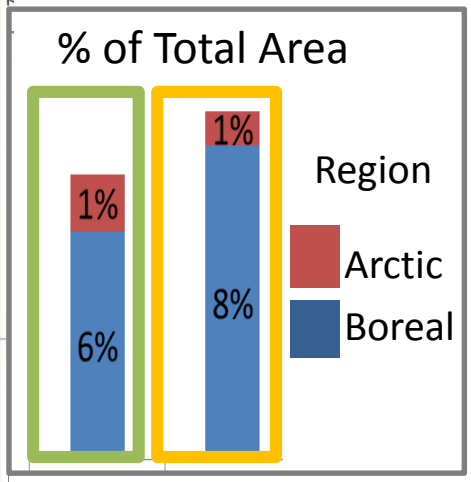




Python, ArcGIS, TerrSet Earth Trends Modeler, ORNL cluster computer

maxNDVI Browning and Greening Trends (2002-2015)





Arctic-Boreal boundary

roads

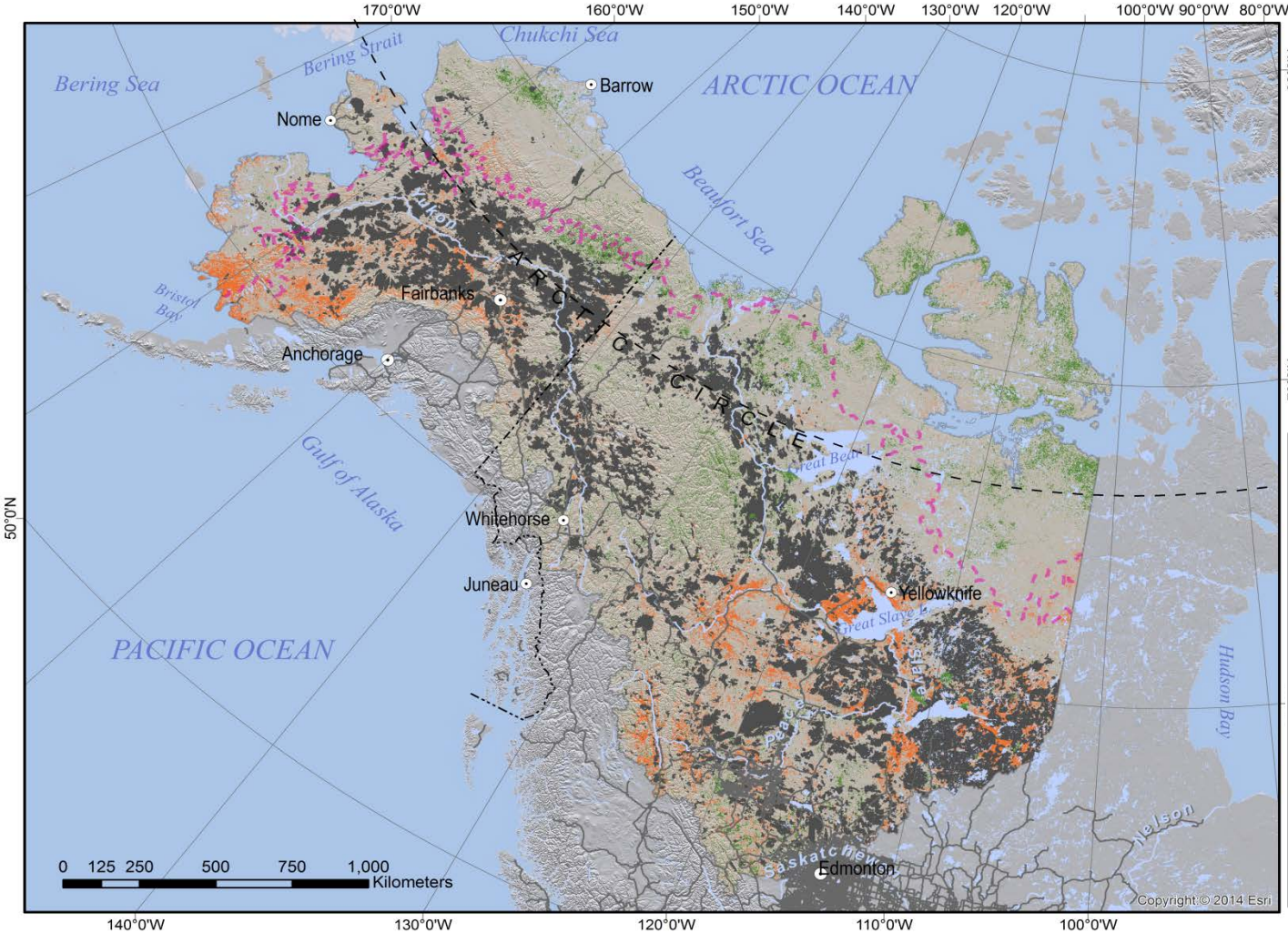
maxNDVI trend

greening

no trend

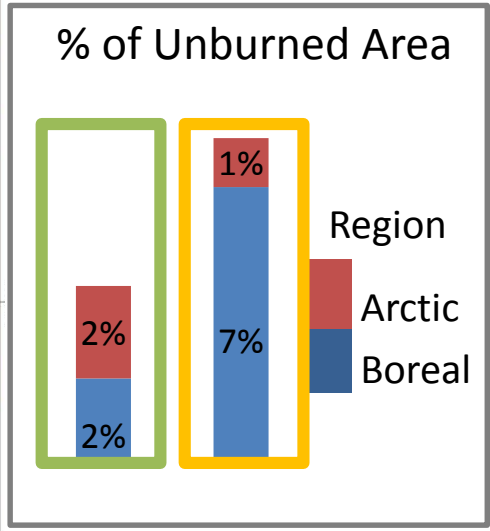
browning

maxNDVI Browning and Greening Trends (2002-2015)



Fire History

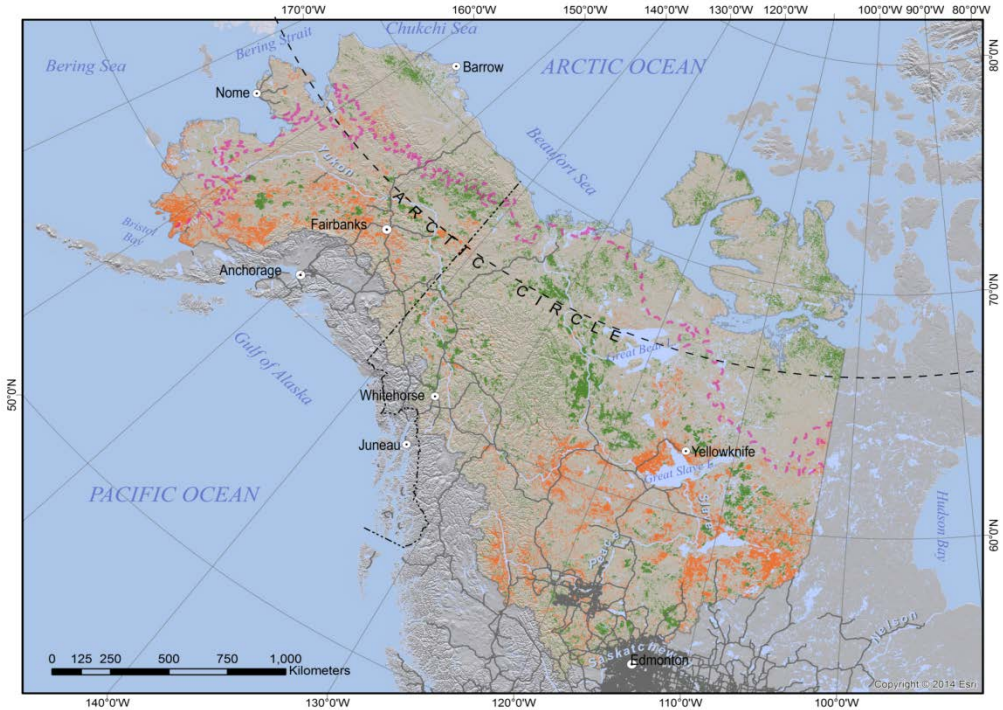
- 30% of the Boreal has burned
- 1.5% of the Arctic has burned

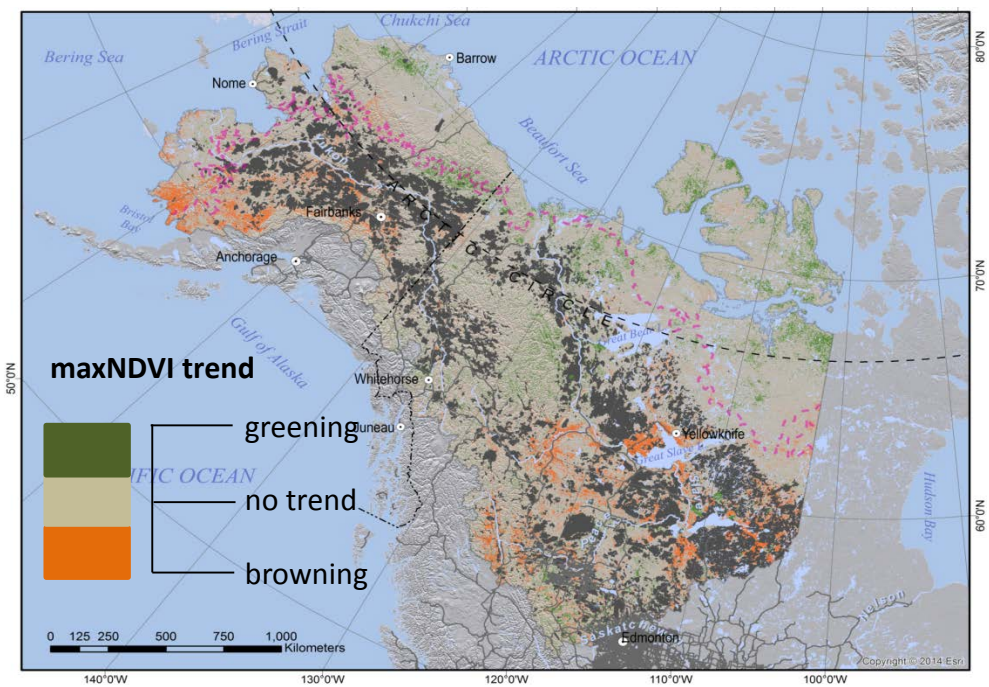


maxNDVI trend

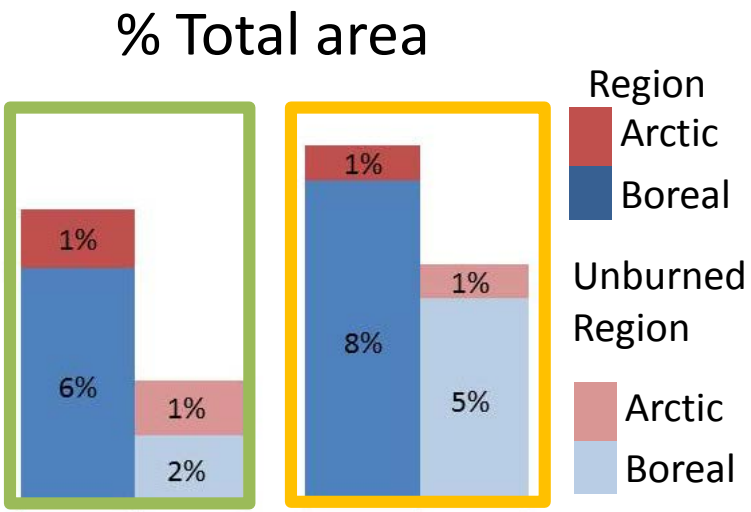
- greening
- no trend
- browning

- Arctic-Boreal boundary
- roads
- burned areas

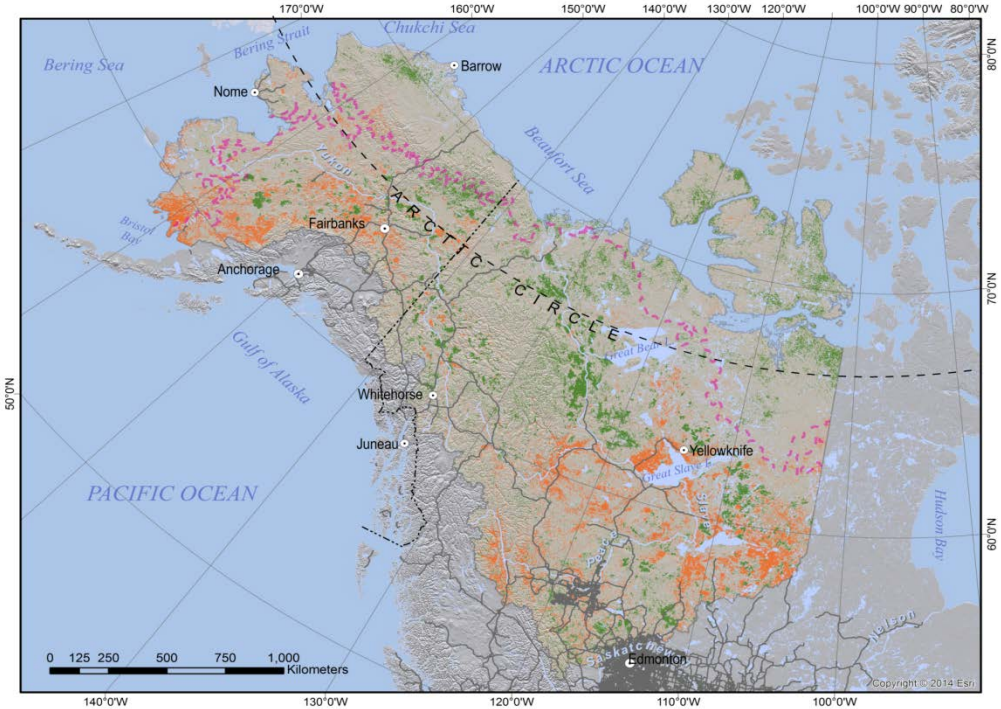


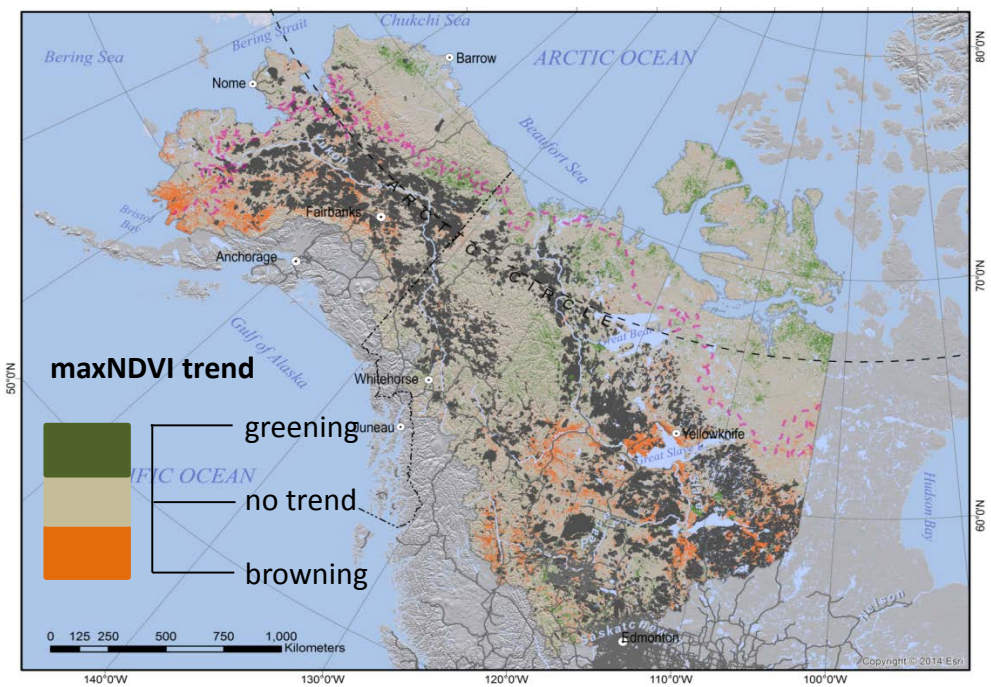


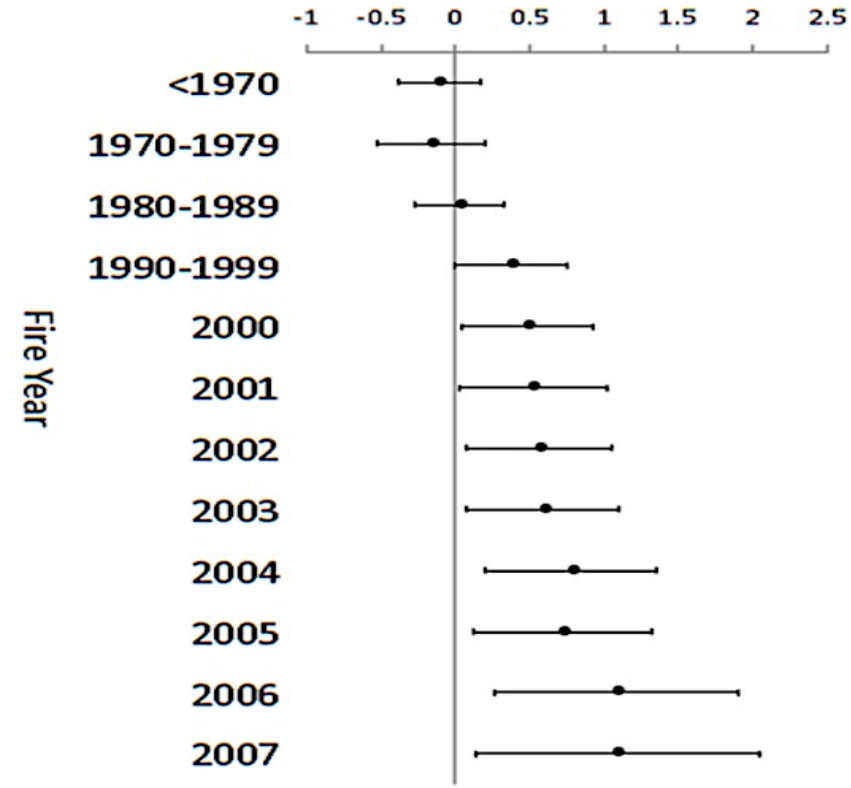
Much of the greening in the Boreal can be attributed to post-fire forest regeneration

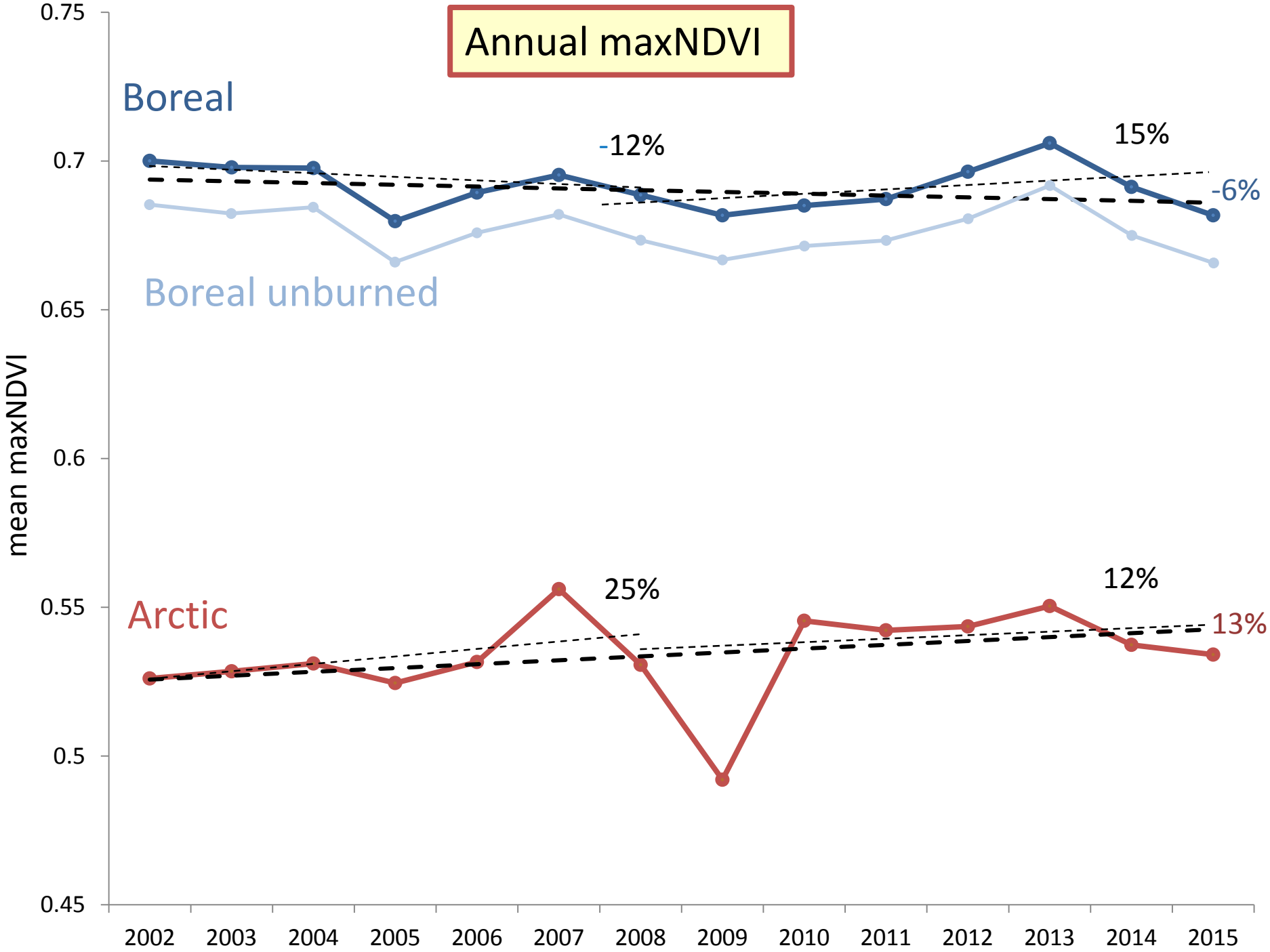


Average post-burn NDVI trend








Annual maxNDVI
Boreal
Boreal unburned
Arctic
-12%
15%
-6%
25%
12%
13%
mean maxNDVI
0.75
0.7
0.65
0.6
0.55
0.5
0.45
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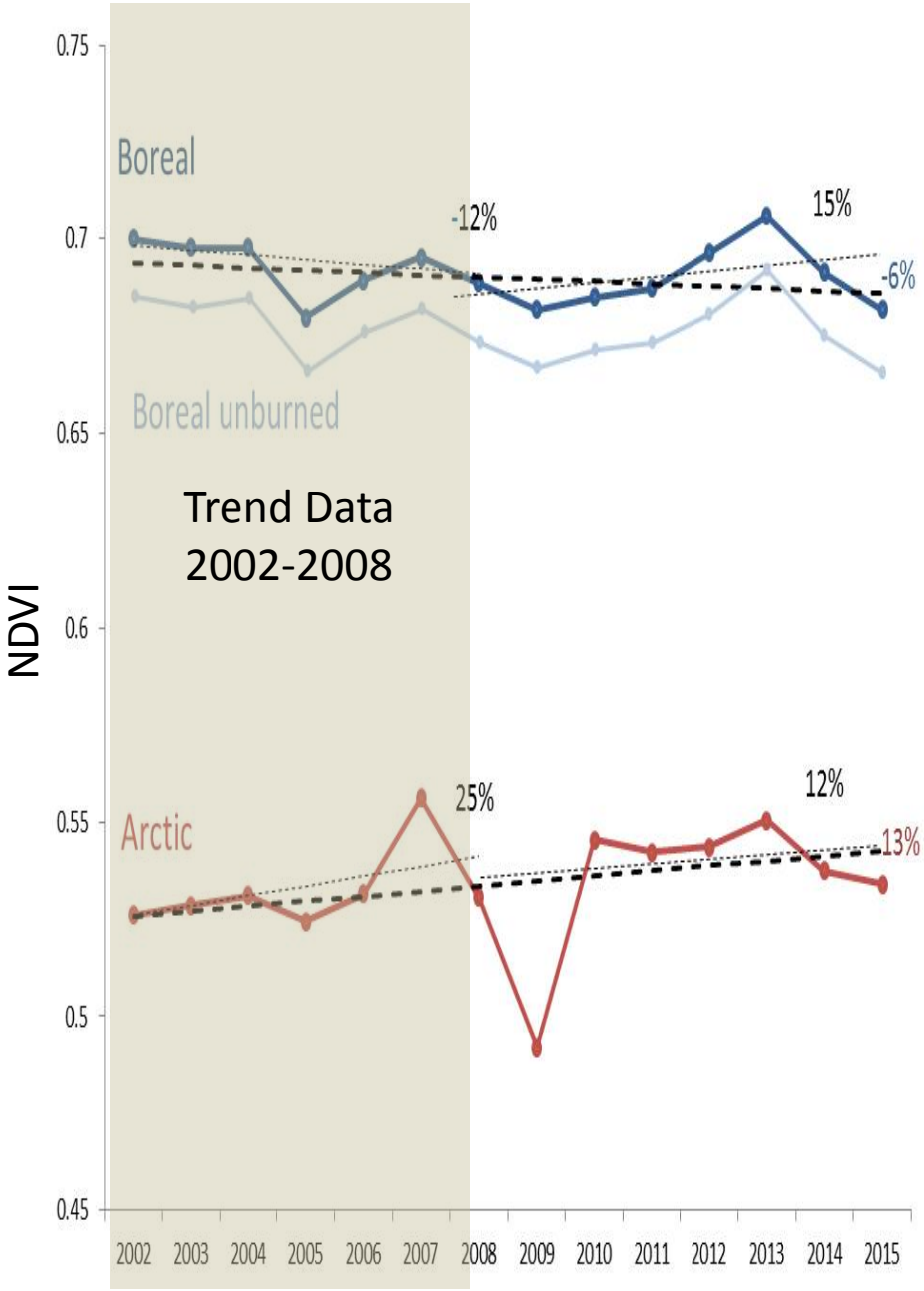
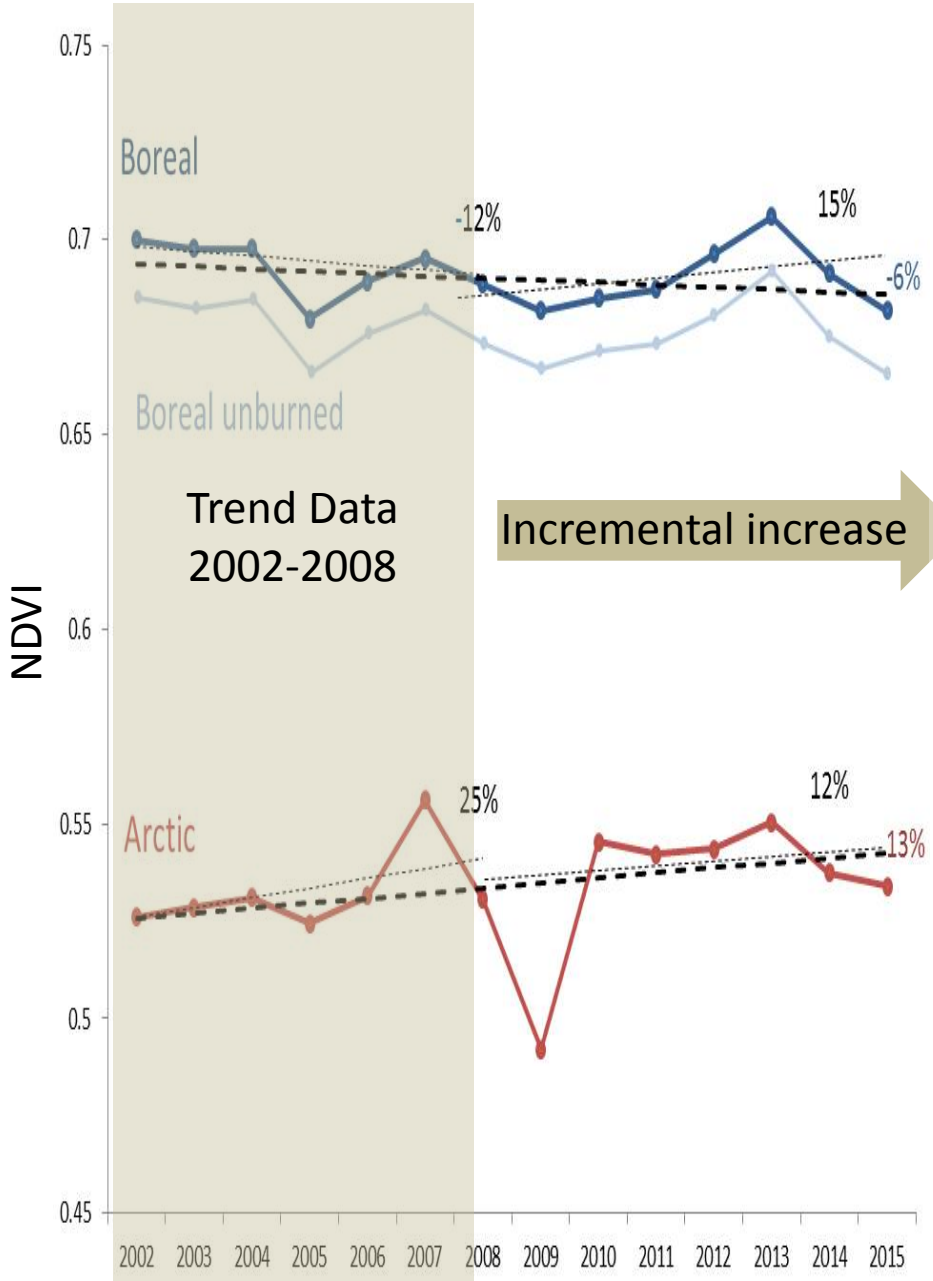
2015

Time-series matters:

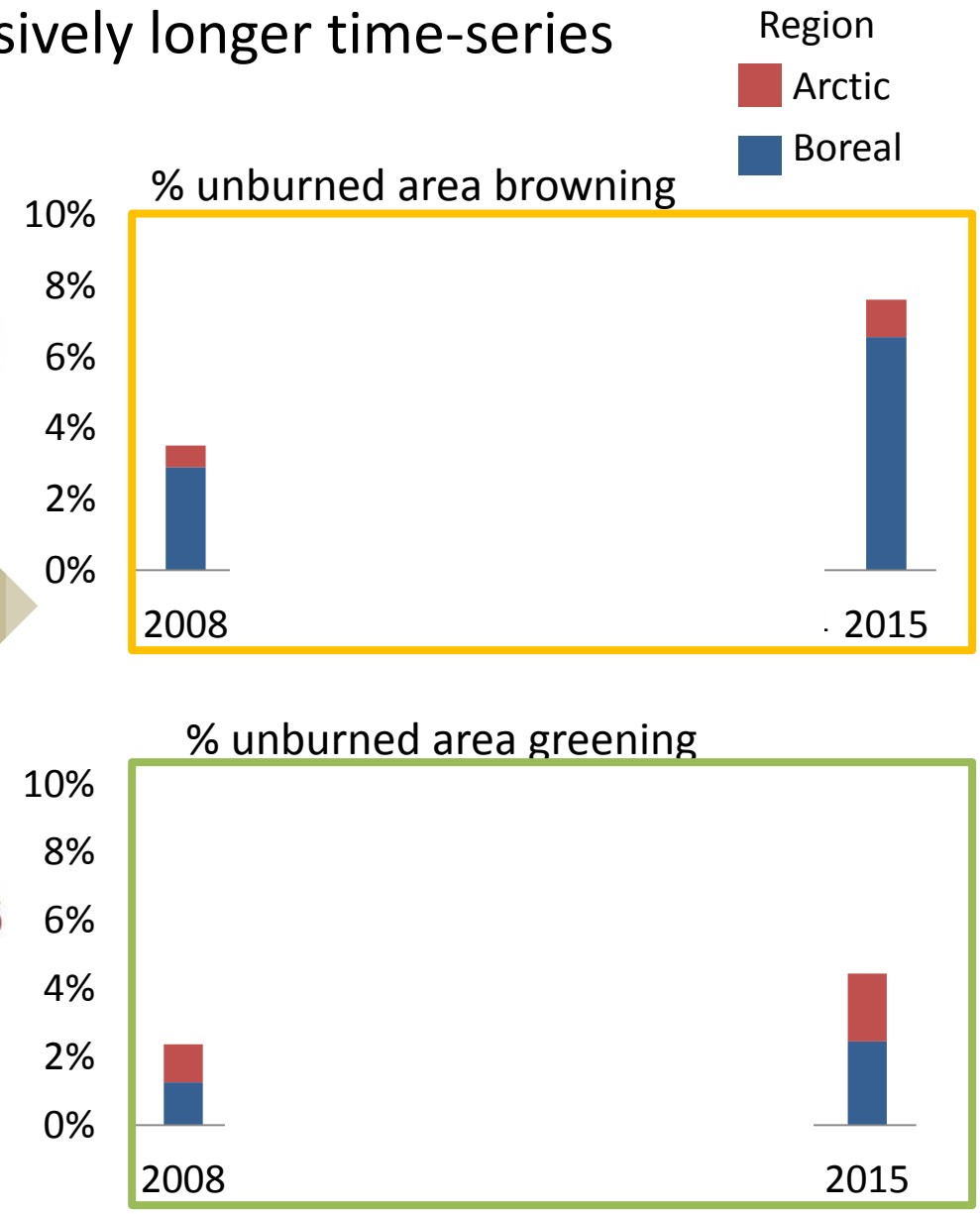


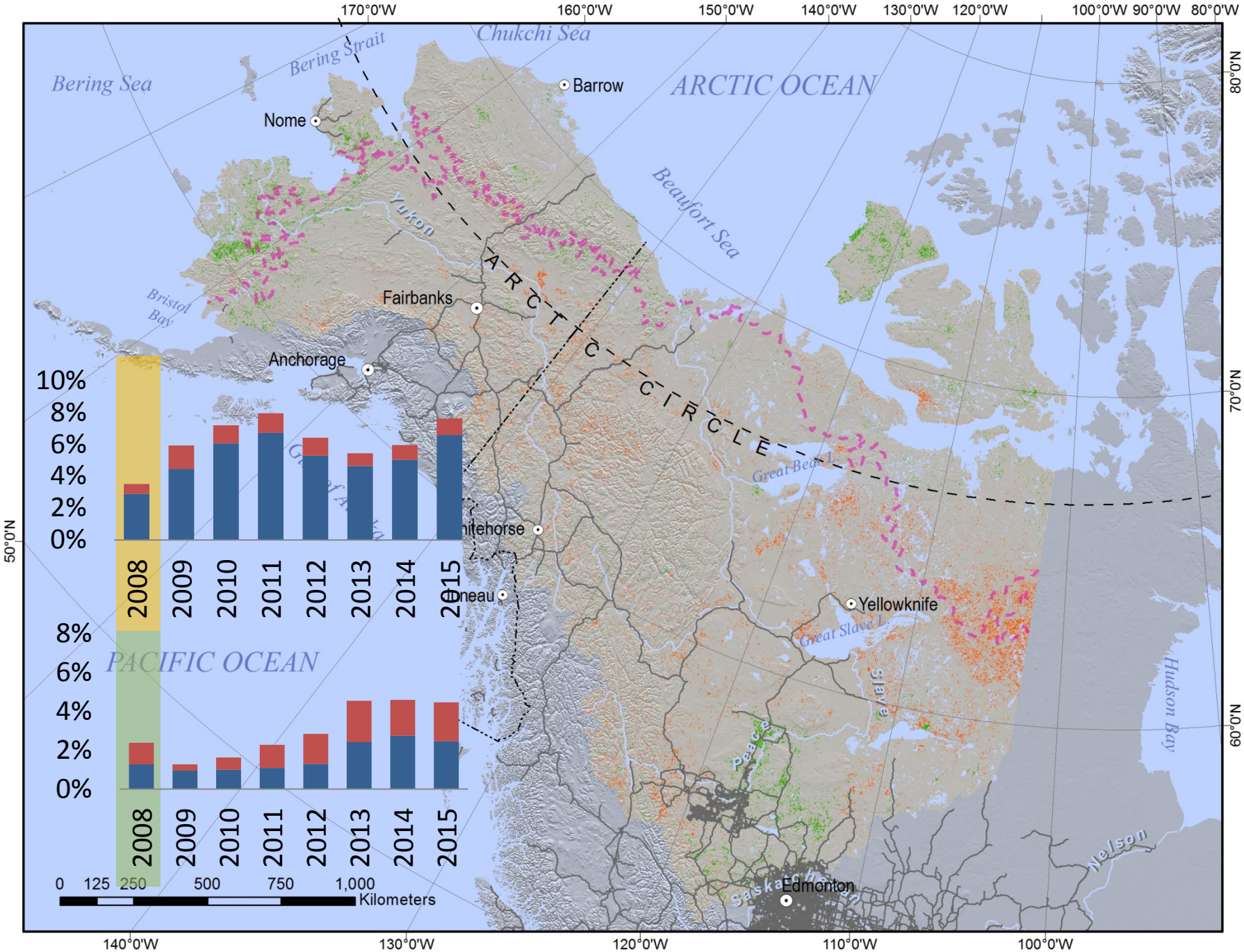
Time-series matters:
considering progressively longer time-series



Trend Data
2002-2008

Incremental increase

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Bristol Bay
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Great Bear L.
Whitehorse
Juneau
Yellowknife
Great Slave L.
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Saskatchewan
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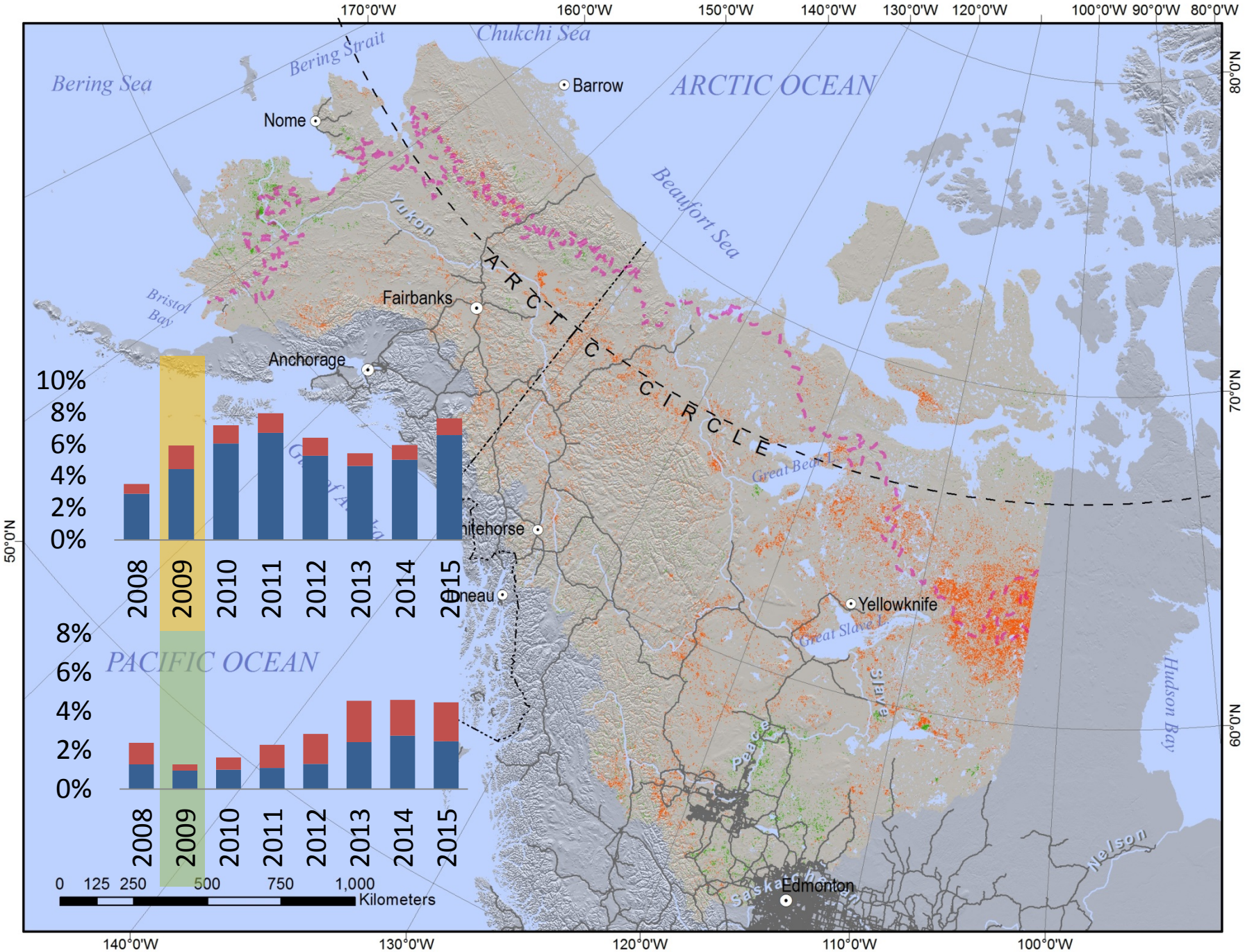
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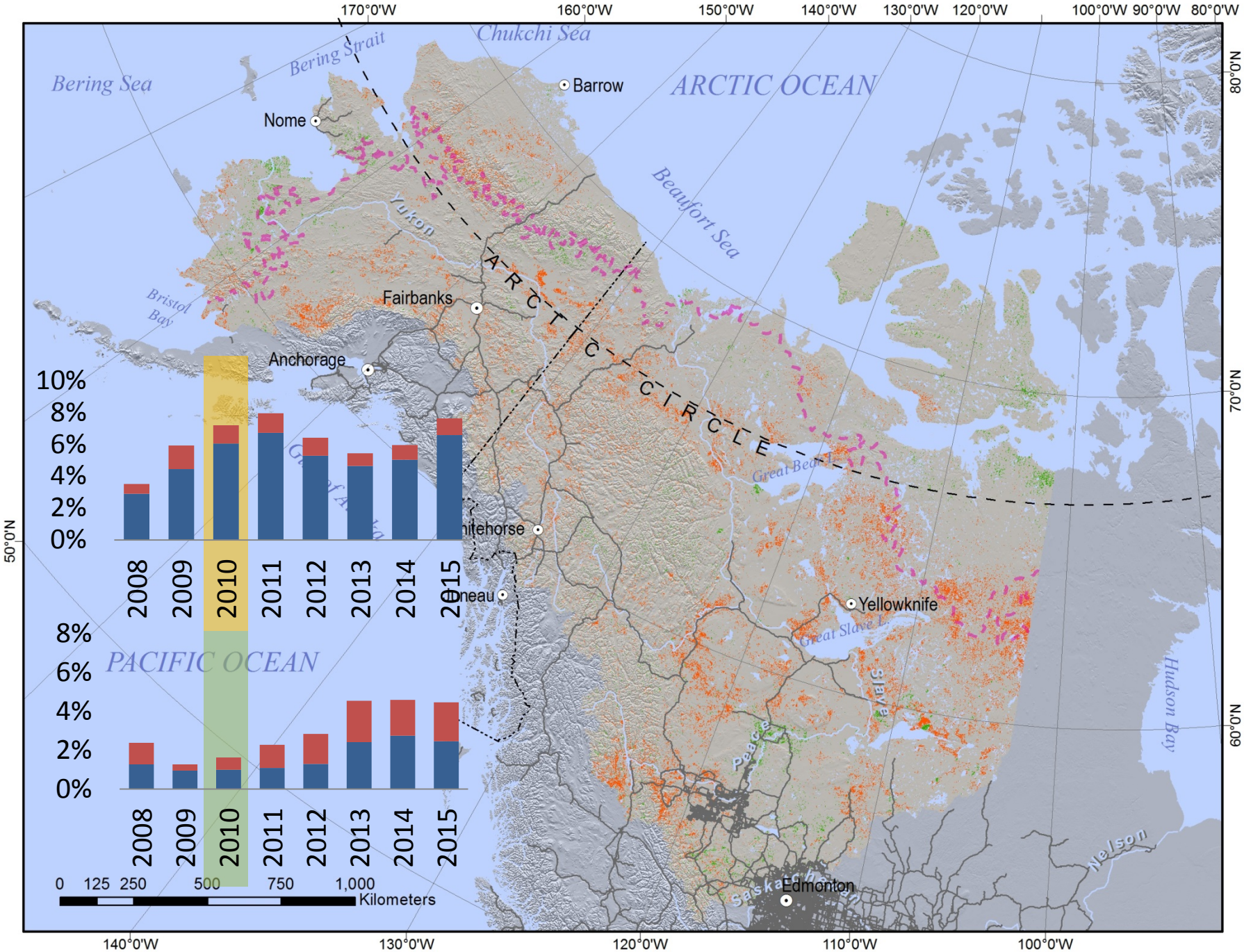
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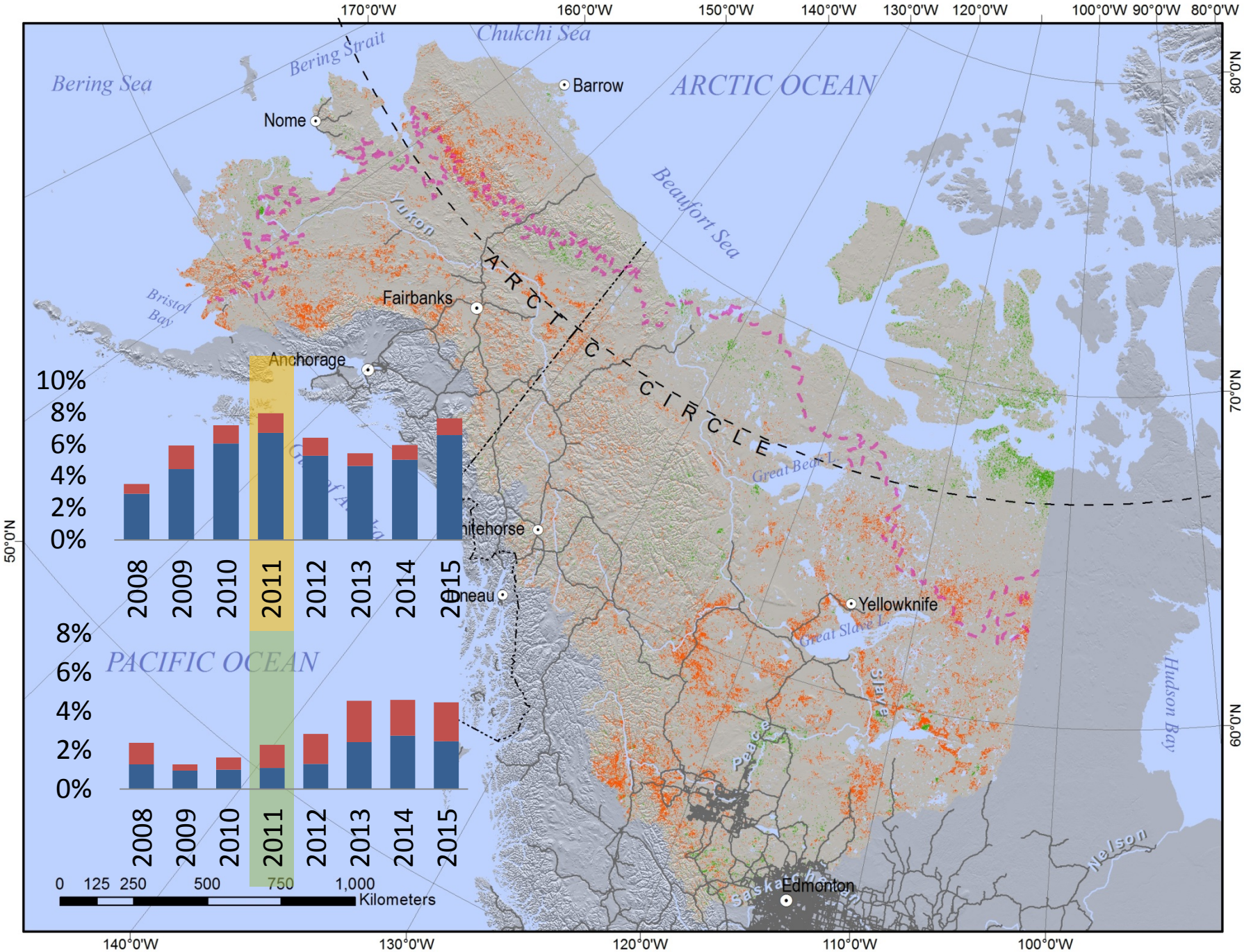
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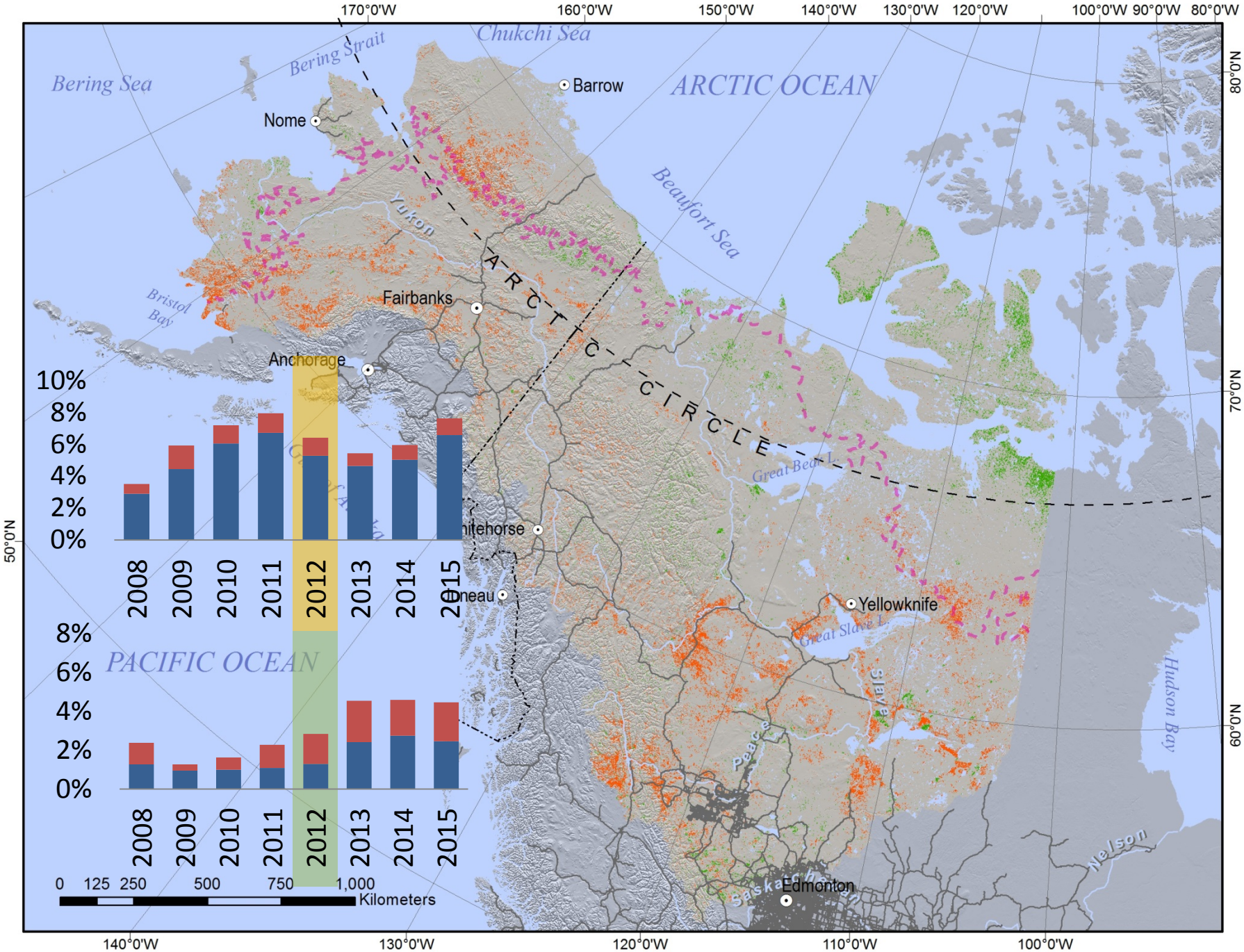
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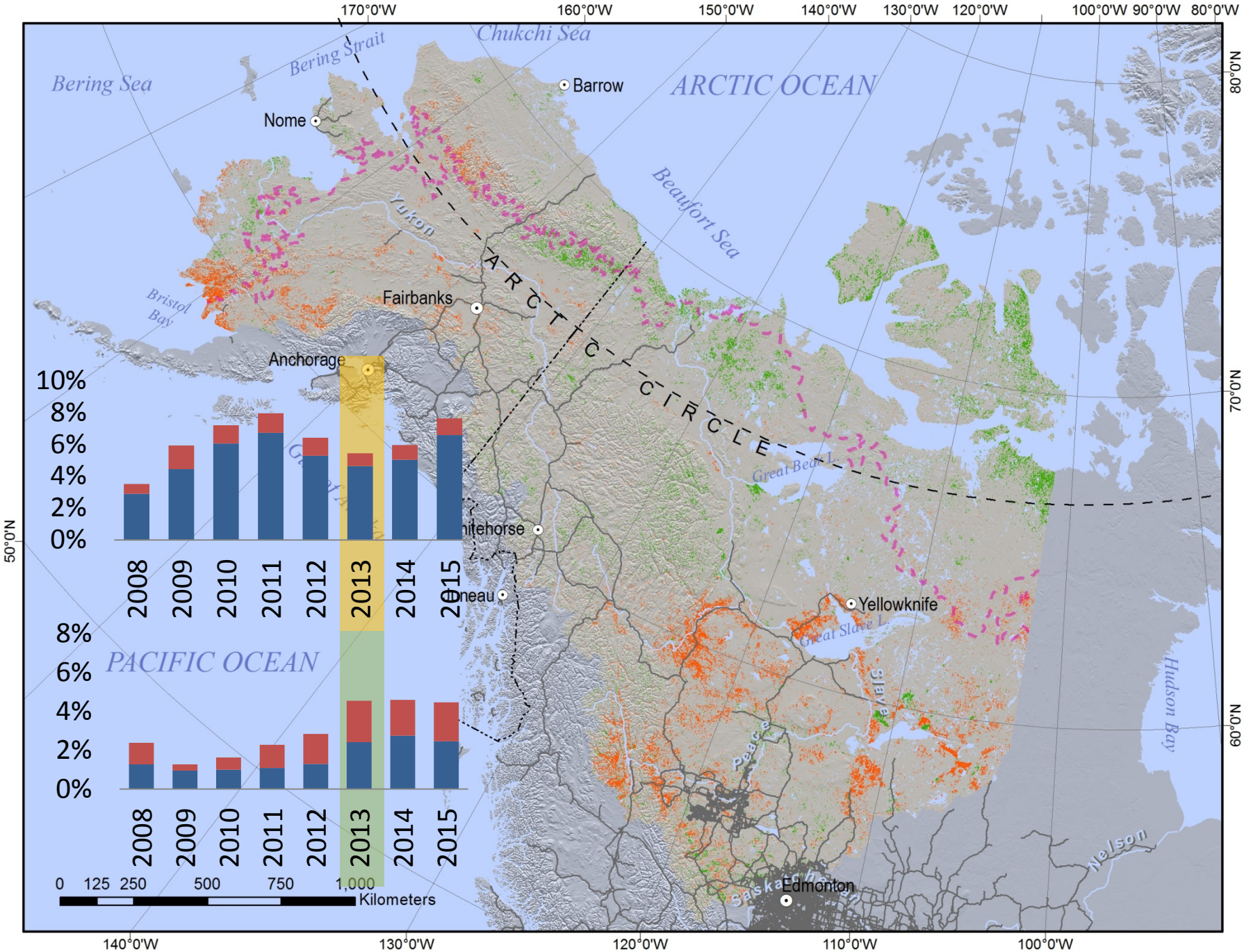
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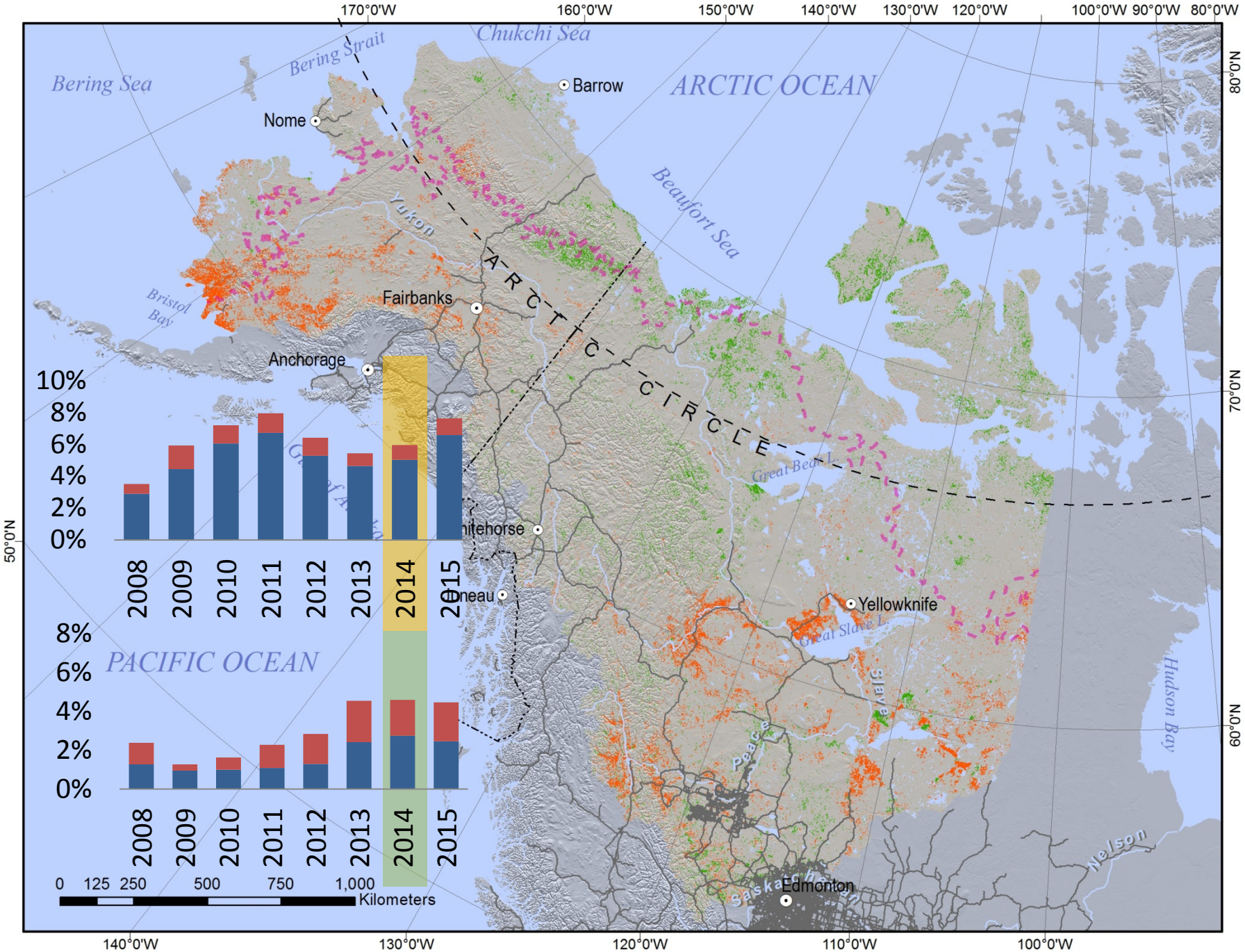
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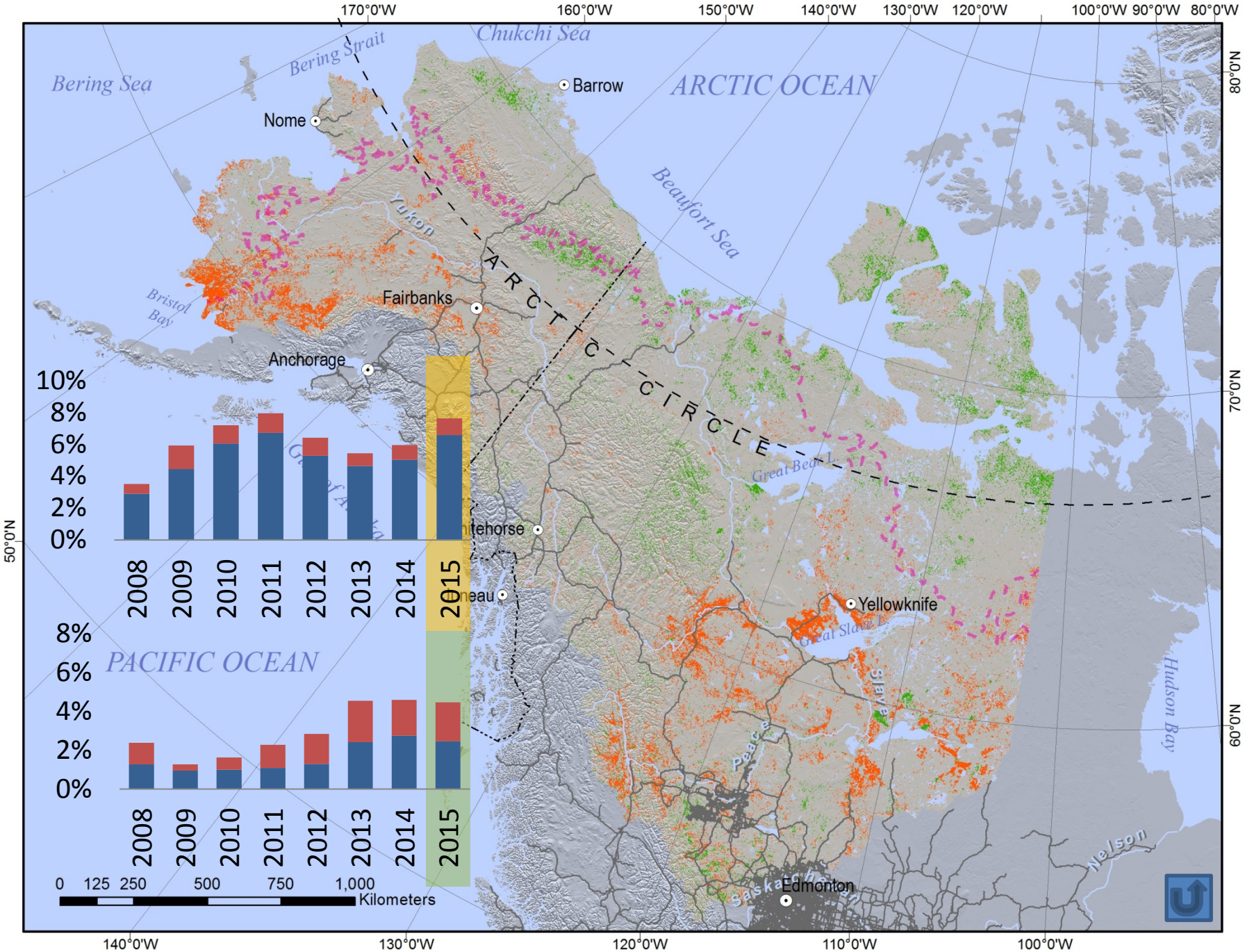
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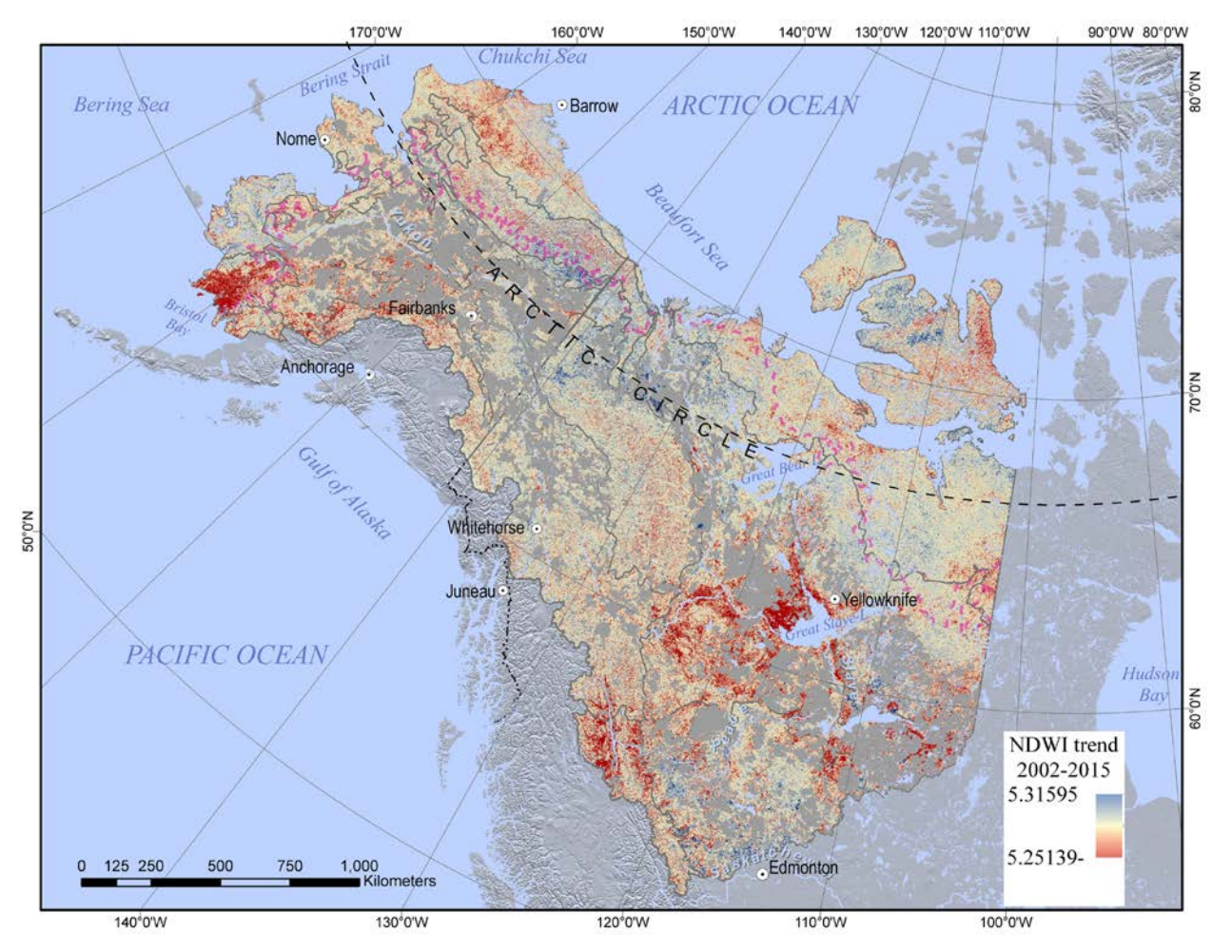
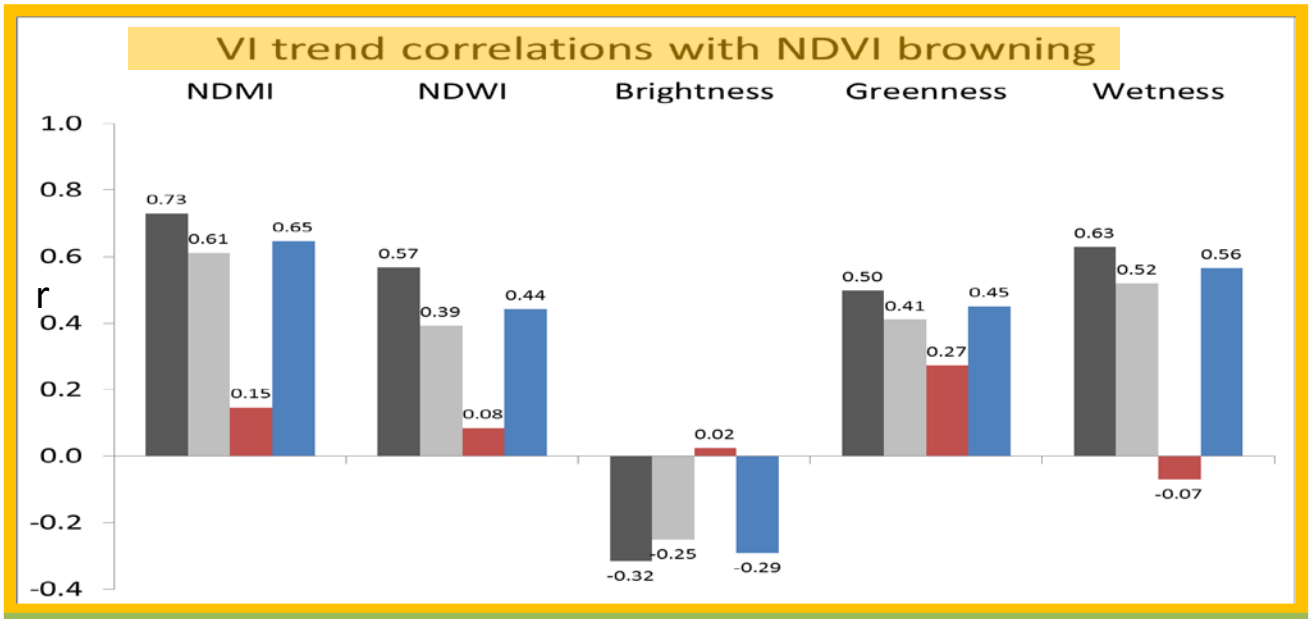
How can we learn more about these changes?

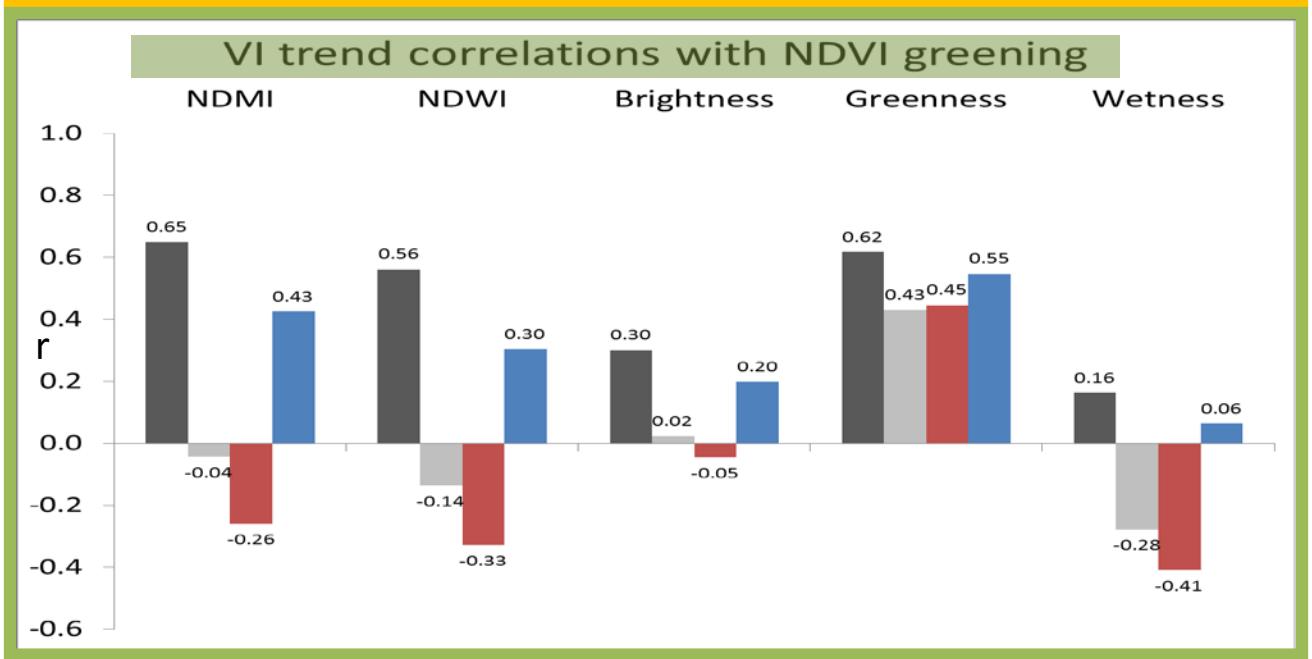
Look at what is happening with other indices…



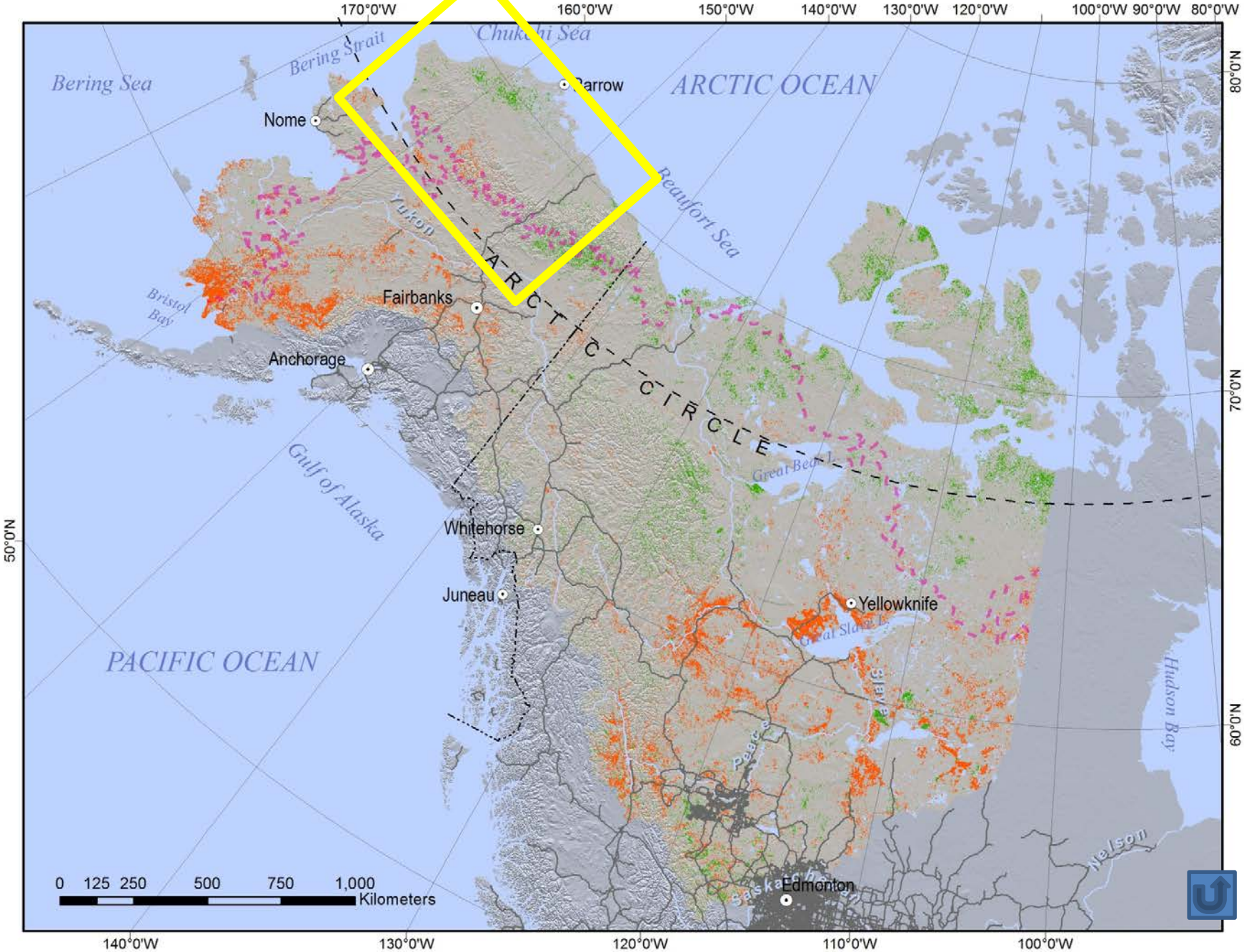
NDVI Browning and Greening correlations (r) with other VIs

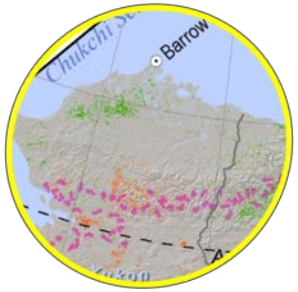
- burned areas
- unburned areas
- arctic unburned
- Boreal unburned





Northern Alaska





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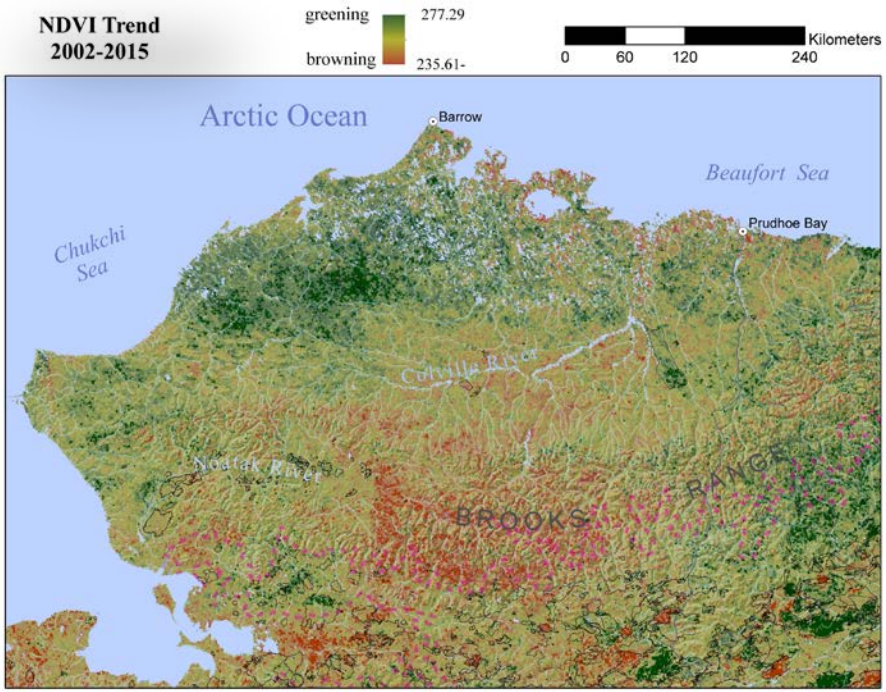
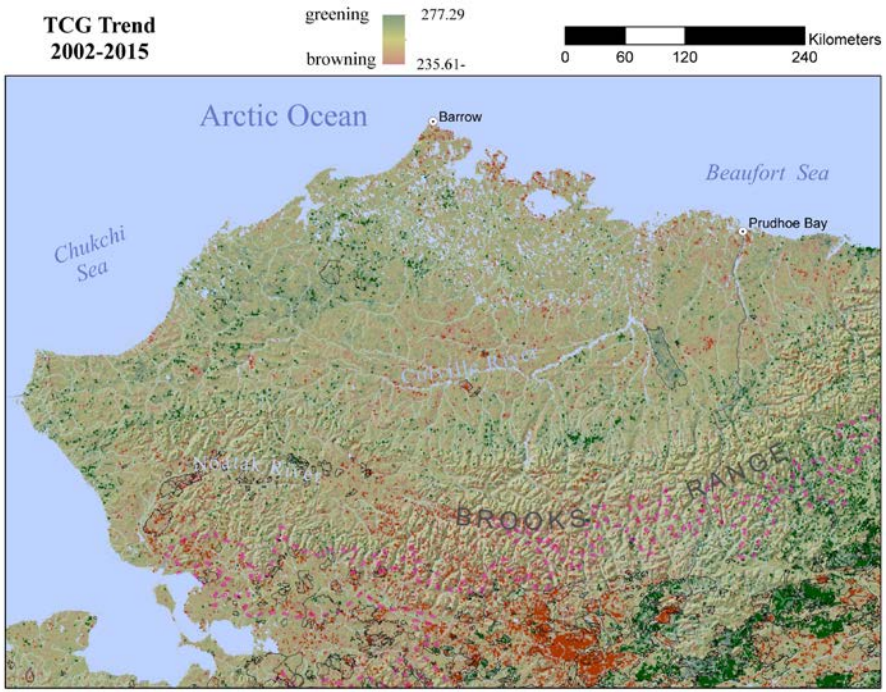
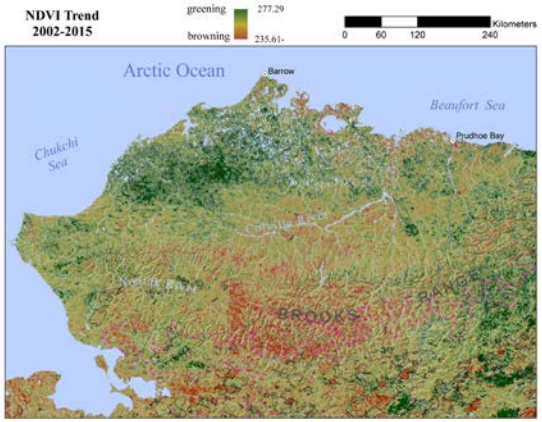
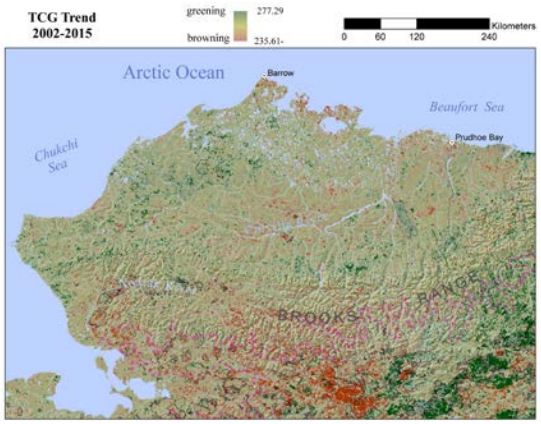
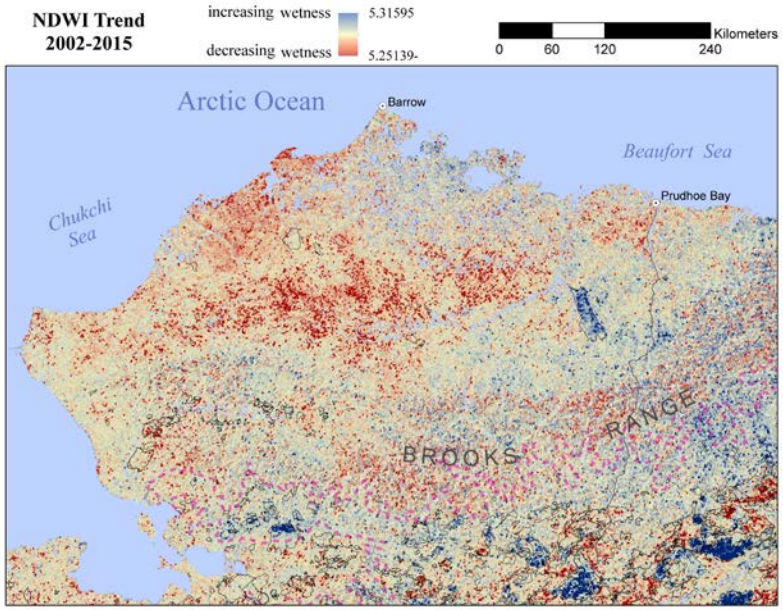


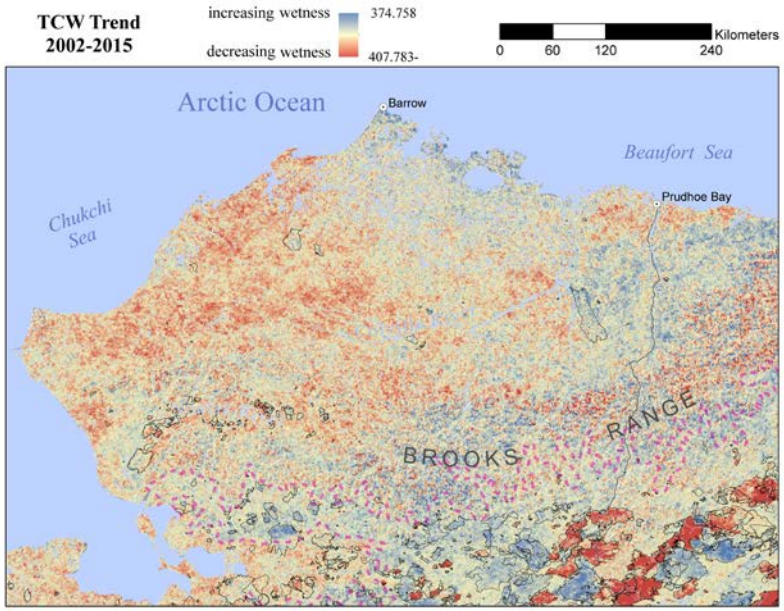


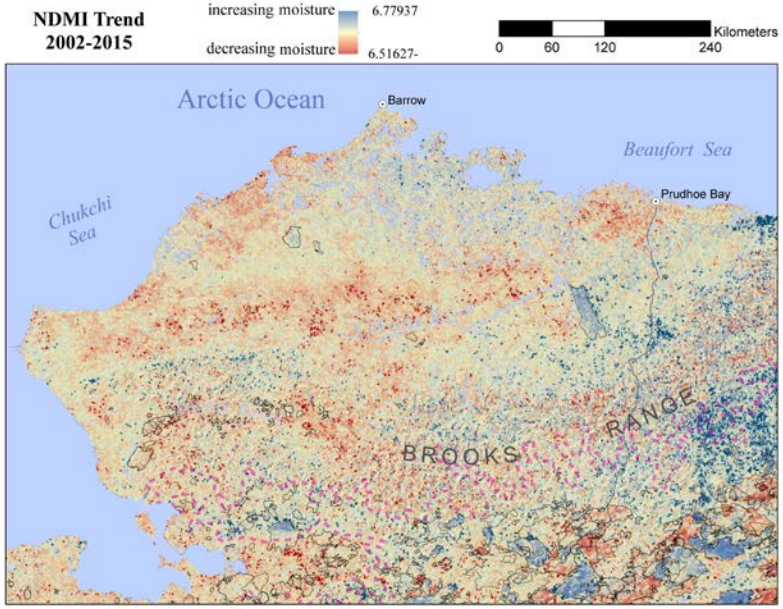
Northern Alaska

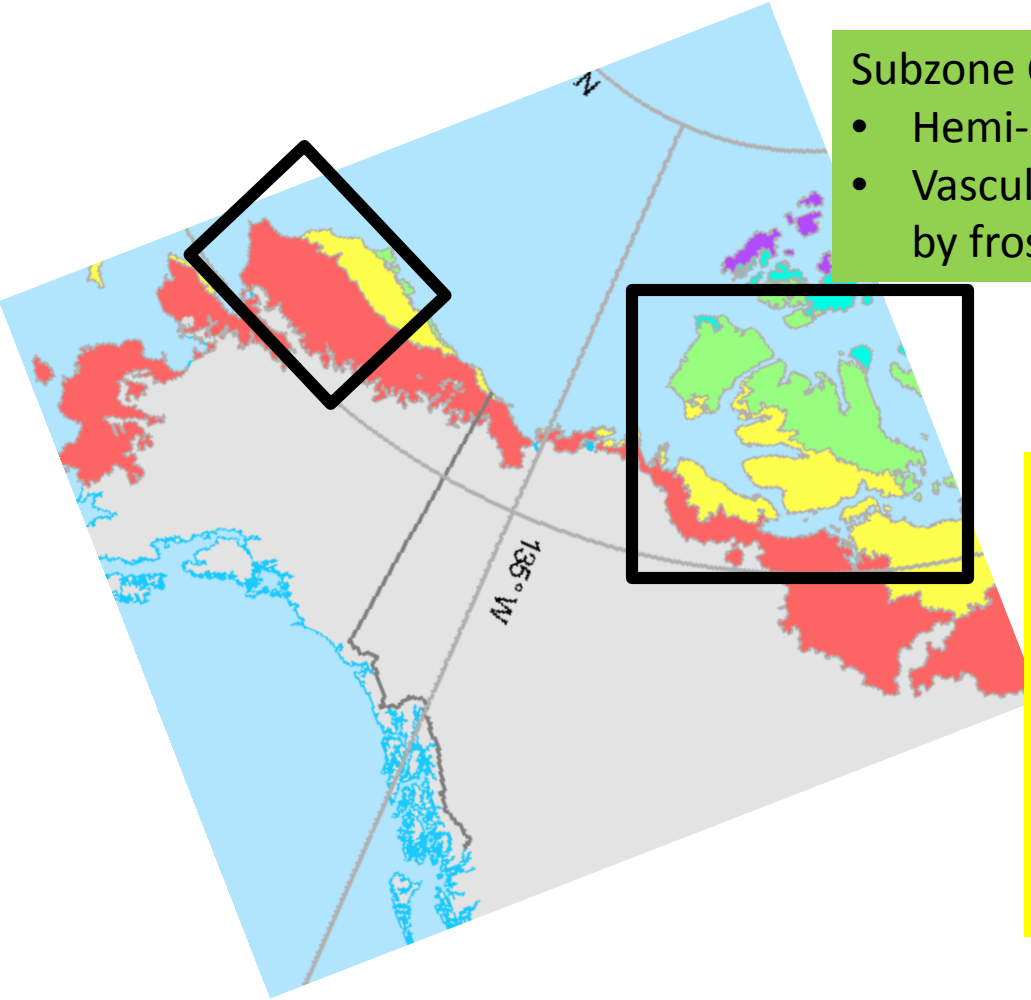






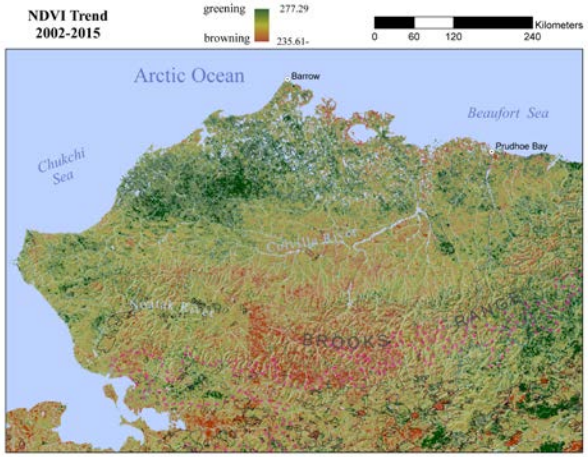






Subzone C:

- Hemi-prostrate dwar
- Vascular plant cover
  by frost scars and oth



Subzone D:

- Erect dwarf shrubs, sedges, mosses
- plants have regional variation with some boreal forest species
- Low shrubs occur along streams.
- Patches of bare soil caused by nonsorted circles, stripes, and a variety of other periglacial features.

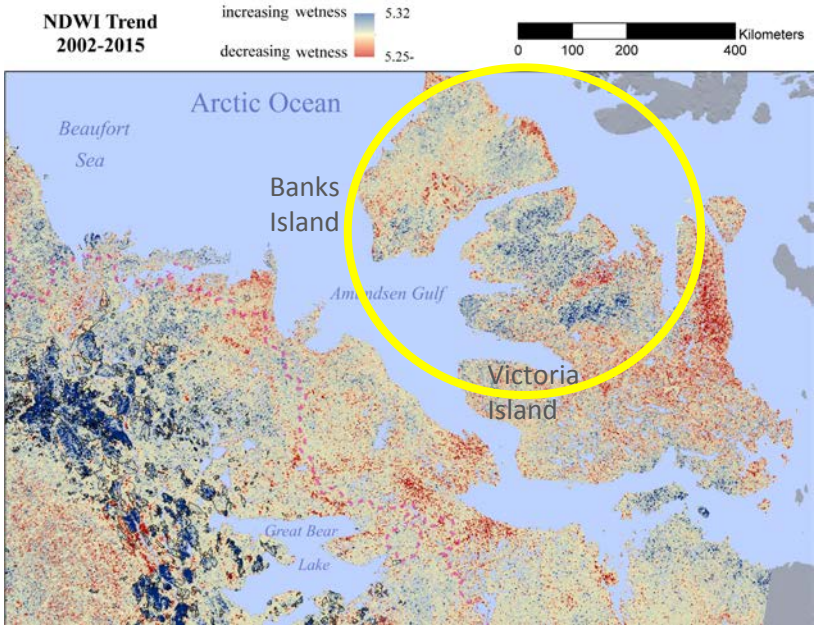
Subzone E:

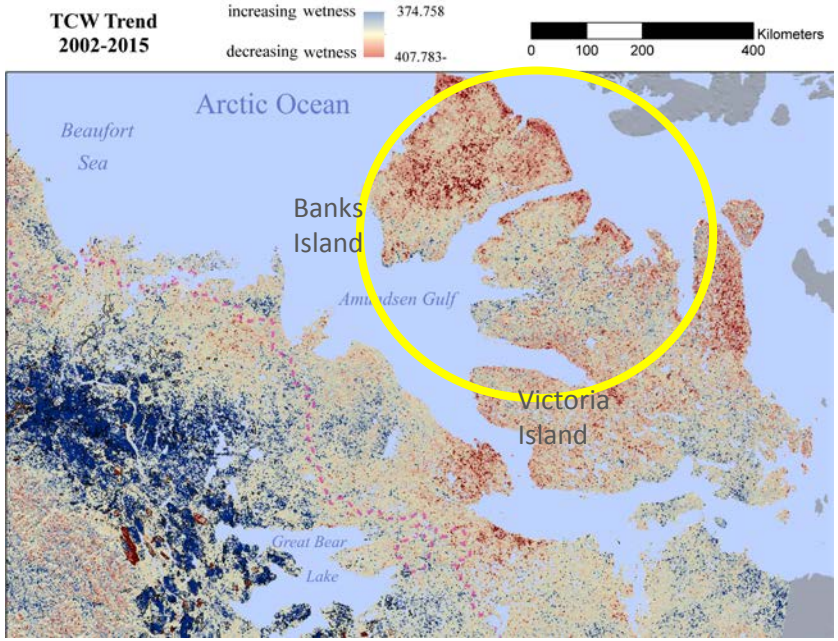
- Low shrubs, tussock sedges, mosses
- Low and tall shrubs are abundant in most watercourses.
- Tundra-Taiga transition zone at southern edge.

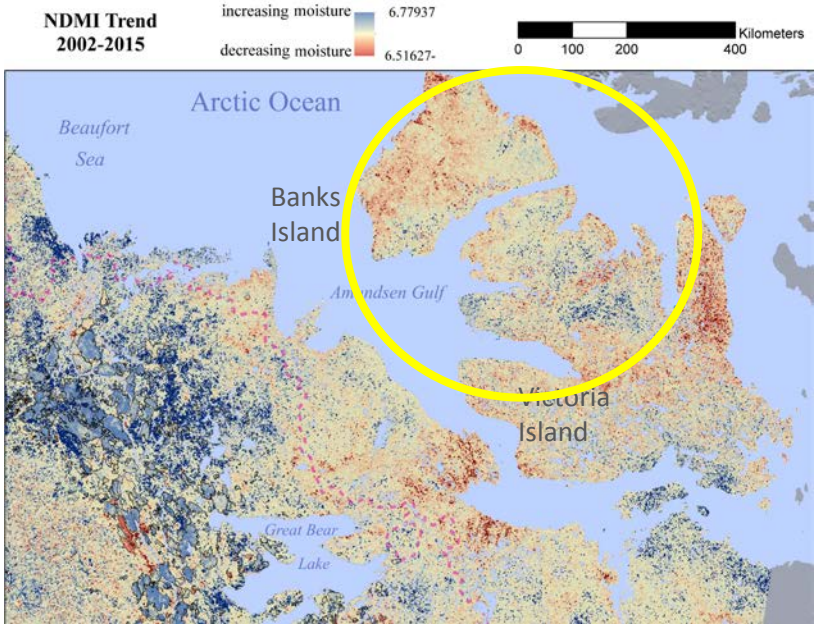
Canadian Arctic Bioclimate Subzone C, D, & E

NDVI Trend
2002-2015
greening
277.29
browning
235.61-
Kilometers
0 100 200 400
Arctic Ocean
Beaufort
Sea
Amundsen Gulf
Great Bear
Lake

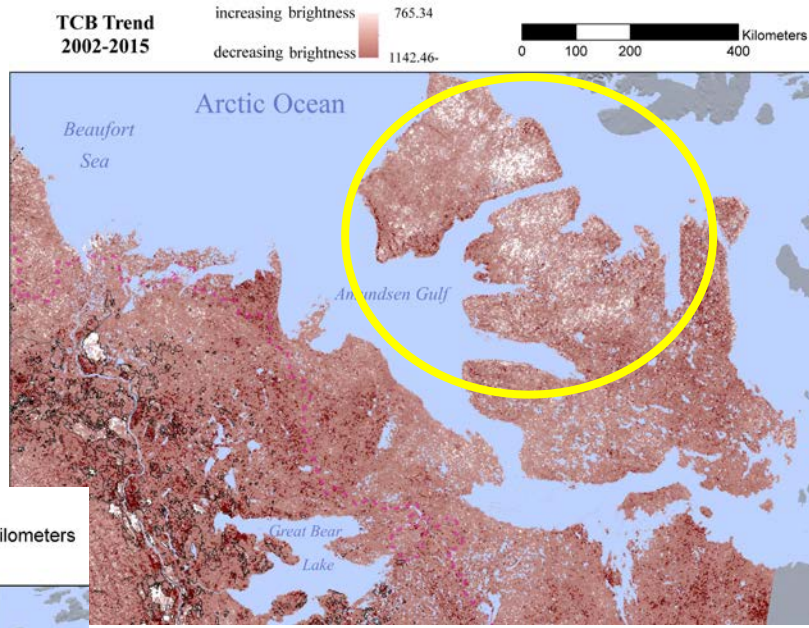
TCG Trend
2002-2015
greening
277.29
browning
235.61-
Kilometers
0 100 200 400
Arctic Ocean
Beaufort
Sea
Amundsen Gulf
Great Bear
Lake

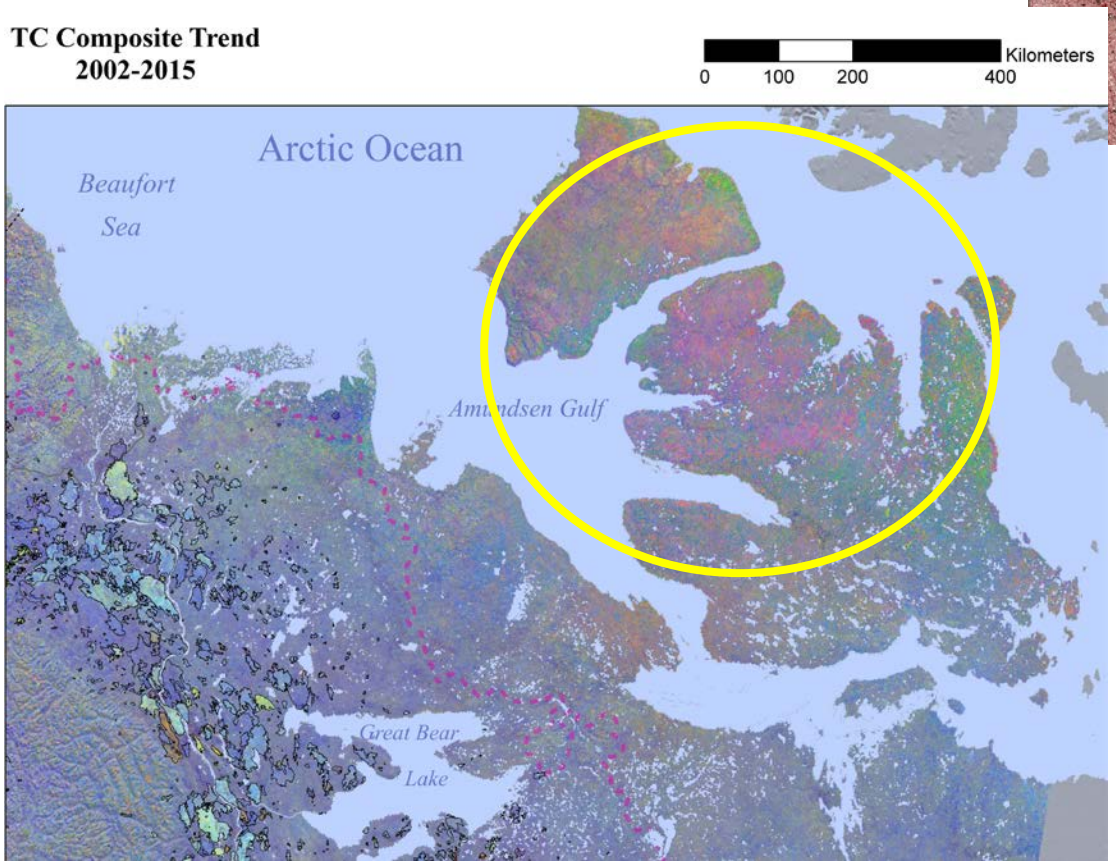

NDWI Trend
2002-2015
increasing wetness
5.32
decreasing wetness
5.25-
Kilometers
0 100 200 400
Arctic Ocean
Beaufort
Sea
Banks
Island
Amundsen Gulf
Victoria
Island
Great Bear
Lake


TCW Trend
2002-2015
increasing wetness
374.758
decreasing wetness
407.783-
Kilometers
0 100 200 400
Arctic Ocean
Beaufort
Sea
Banks
Island
Amundsen Gulf
Victoria
Island
Great Bear
Lake

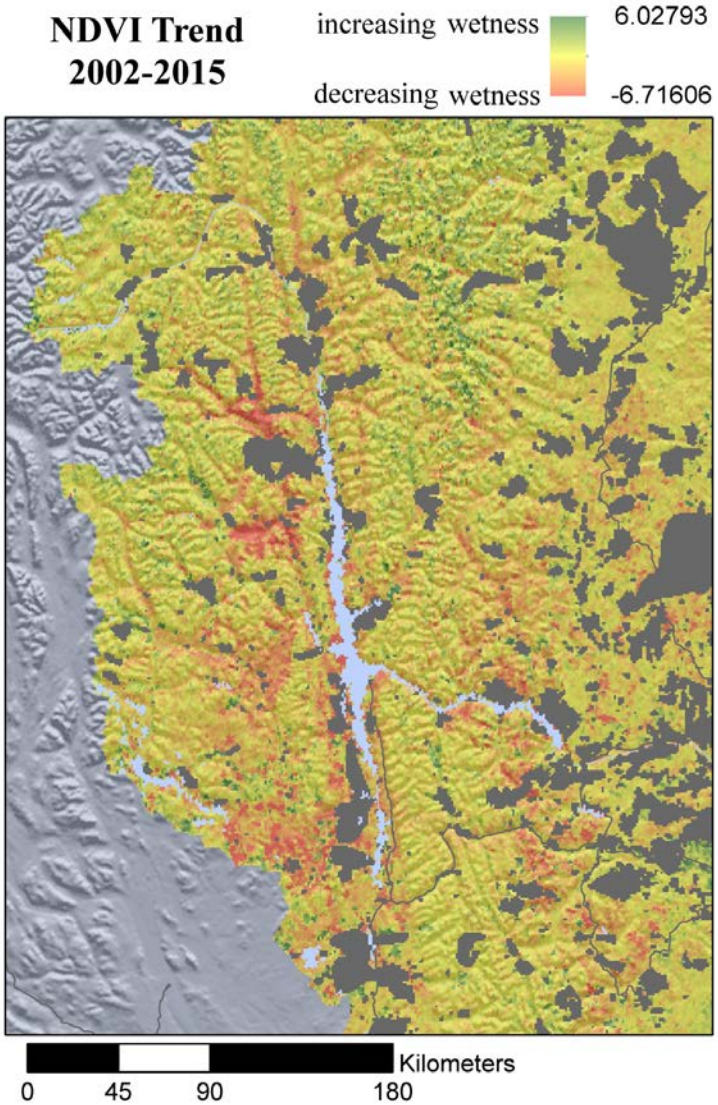

NDMI Trend
2002-2015
increasing moisture
6.77937
decreasing moisture
6.51627-
Kilometers
0 100 200 400
Arctic Ocean
Beaufort
Sea
Banks
Island
Amundsen Gulf
Victoria
Island
Great Bear
Lake

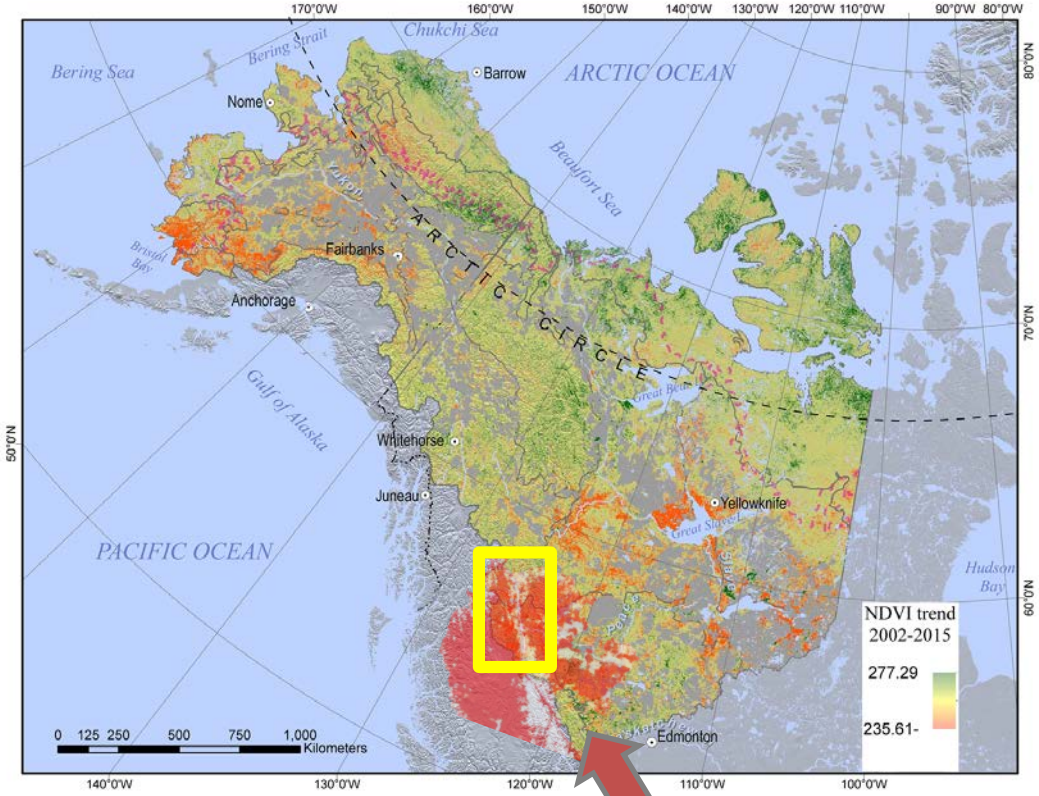
NDVI Trend
2002-2015
greening
browning
277.29
Kilometers
0
100
200
400
Arctic Ocean
Beaufort
Sea
Amundsen Gulf
Great Bear
Lake


TCB Trend
2002-2015
increasing brightness
decreasing brightness
765.34
1142.46
Kilometers
0
100
200
400
Arctic Ocean
Beaufort
Sea
Amundsen Gulf
Great Bear
Lake

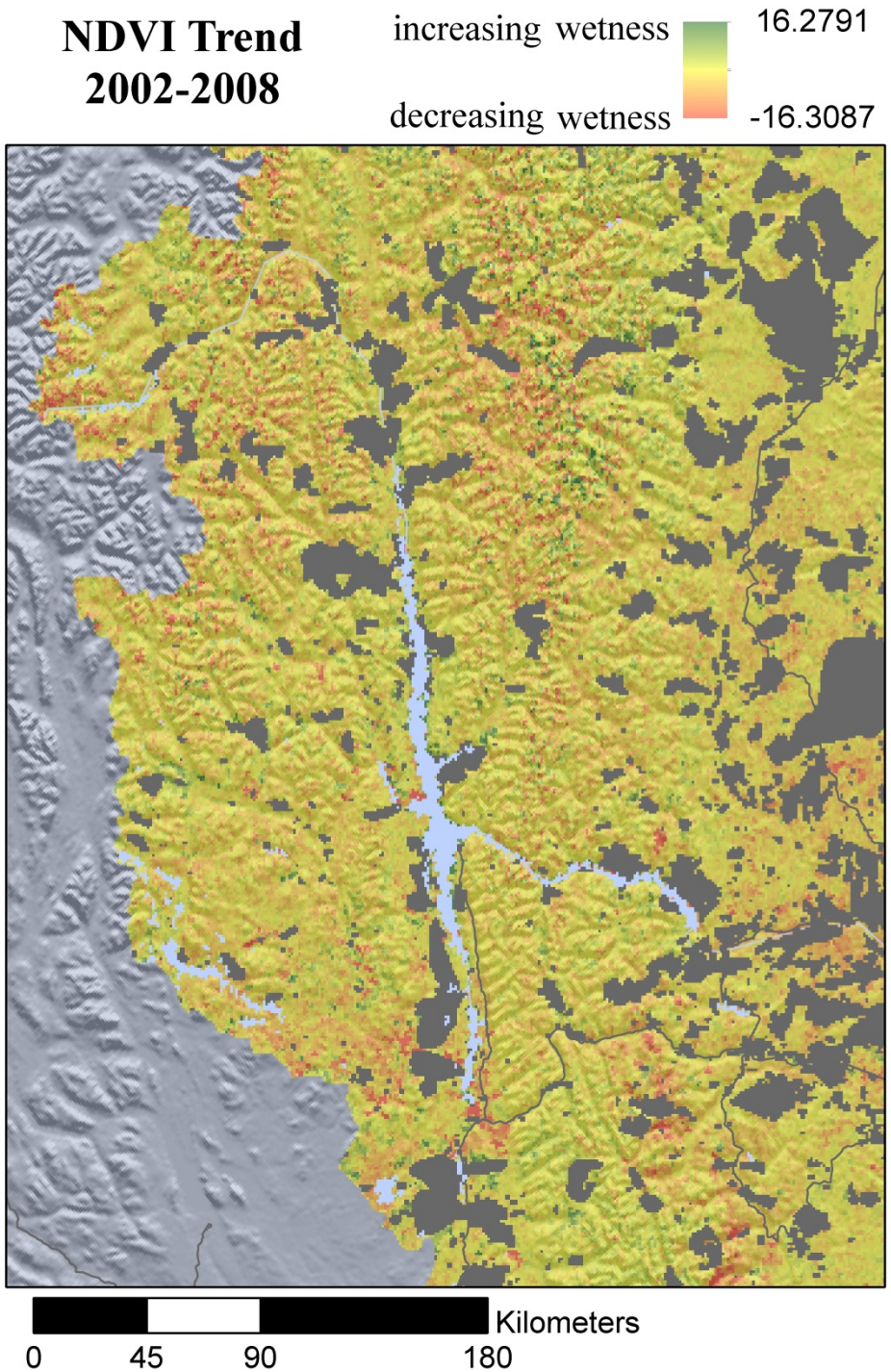

TC Composite Trend
2002-2015
Kilometers
0
100
200
400
Arctic Ocean
Beaufort
Sea
Amundsen Gulf
Great Bear
Lake

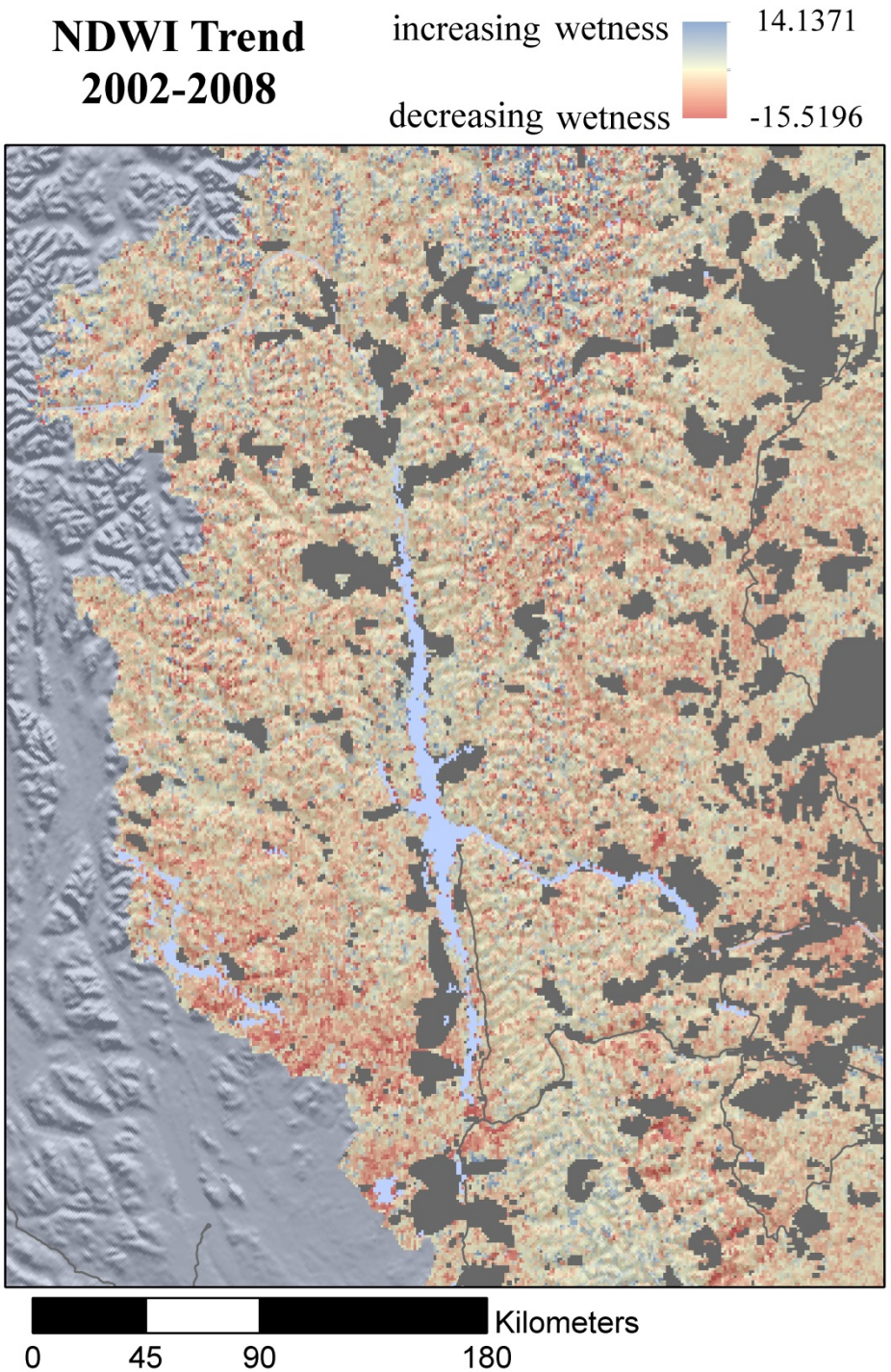
Target known processes: insect outbreaks

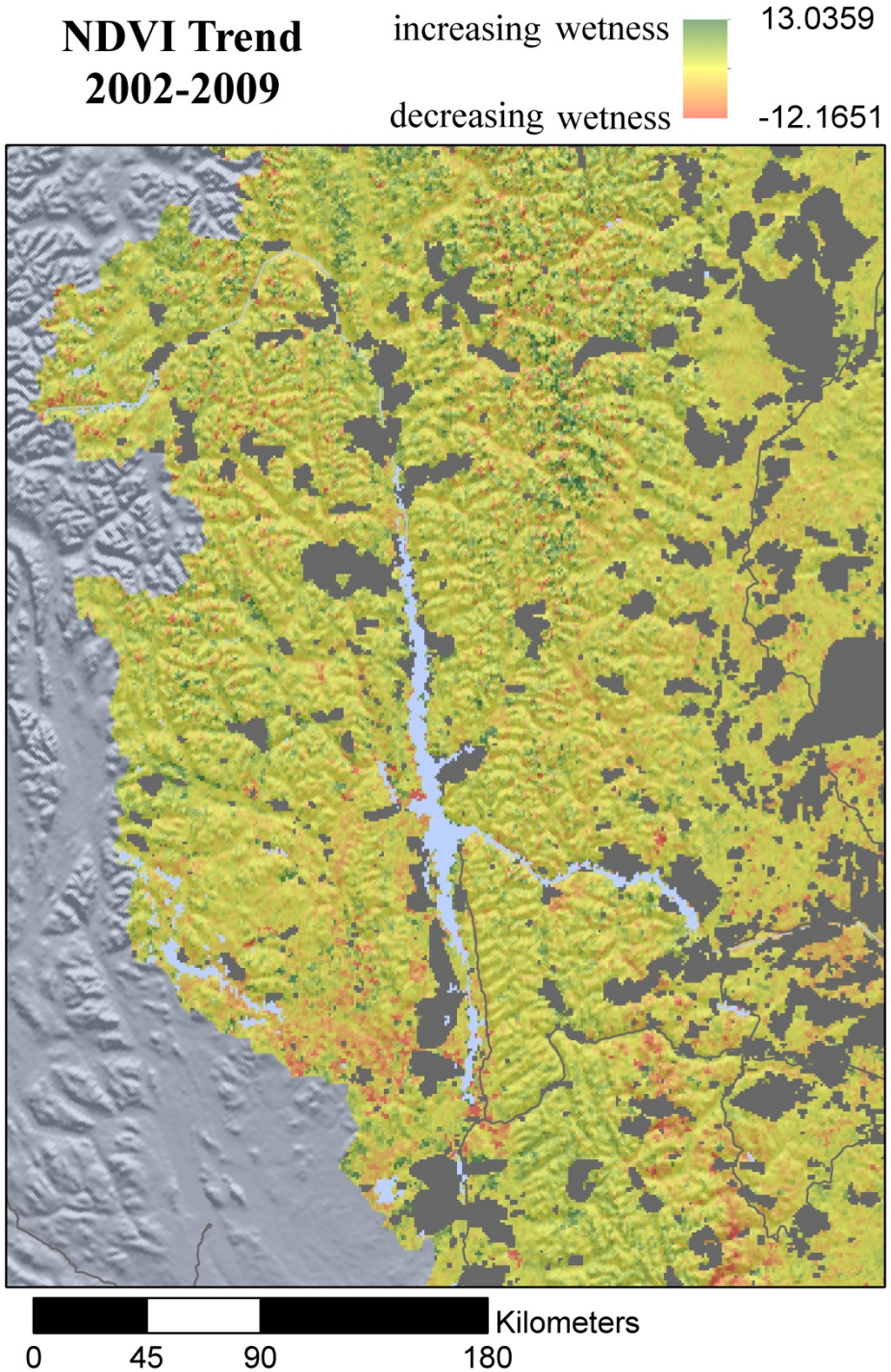


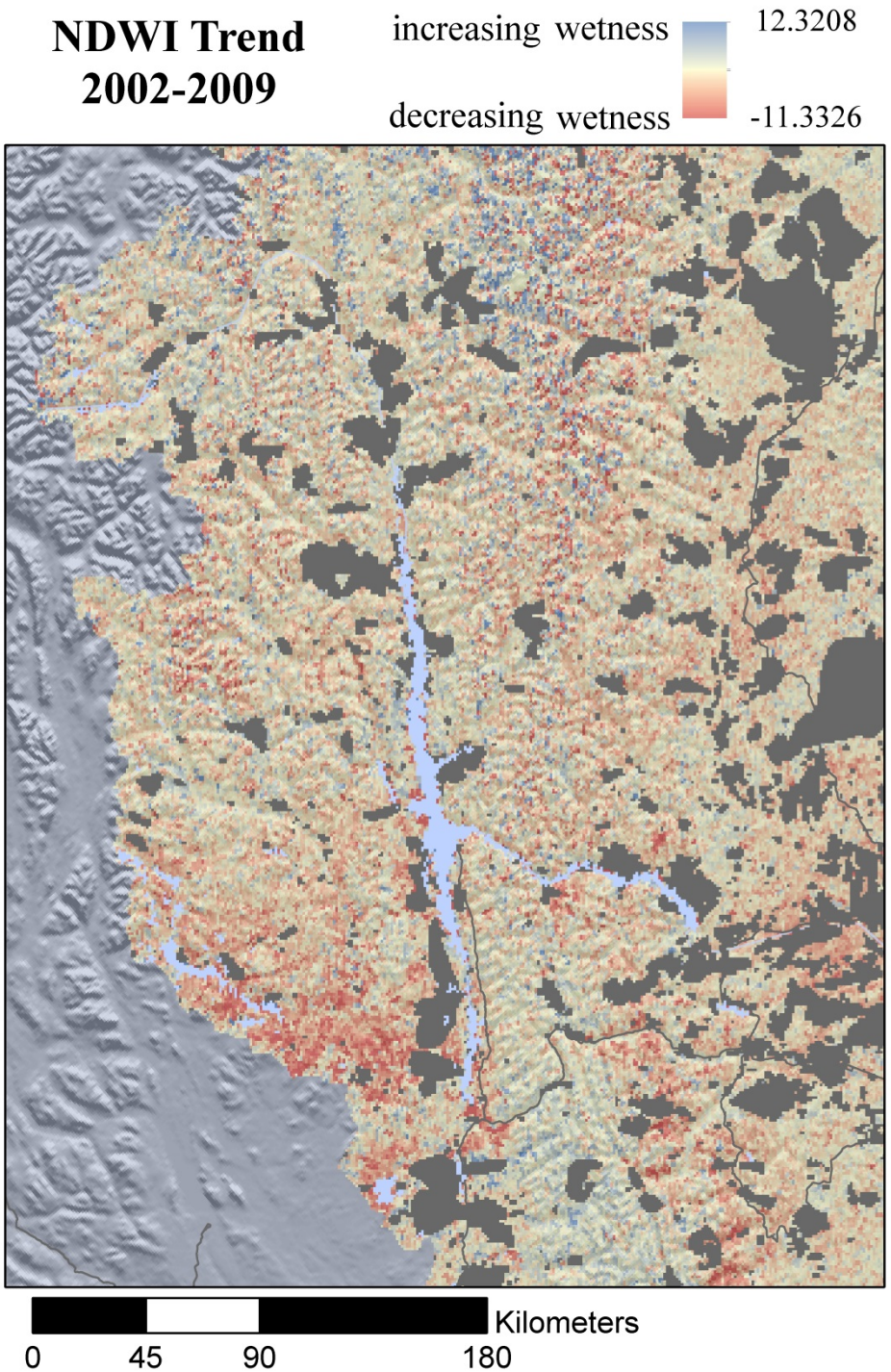


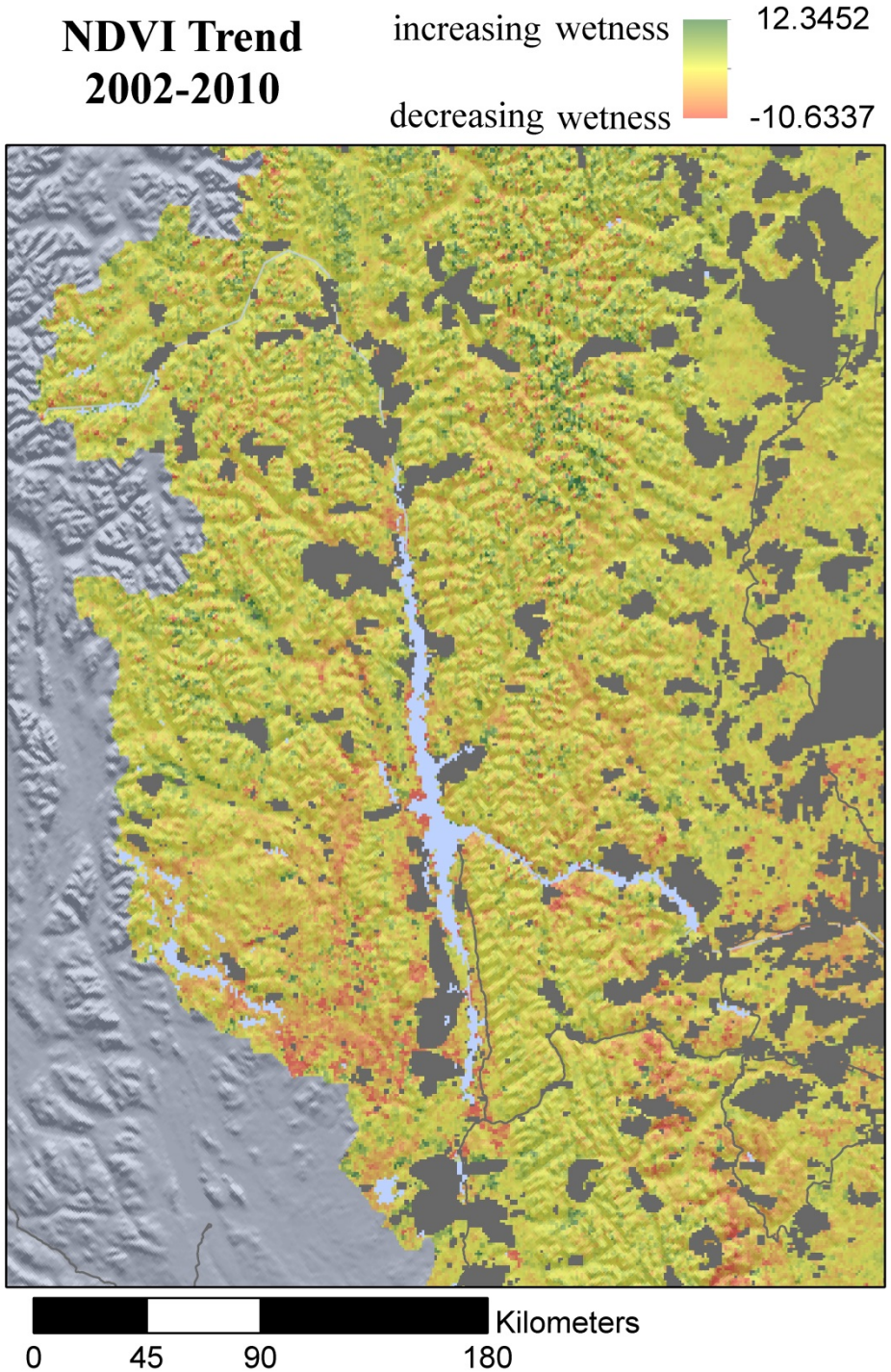
Observed presence of mountain pine beetle from 1999 to 2012.
Natural Resources Canada

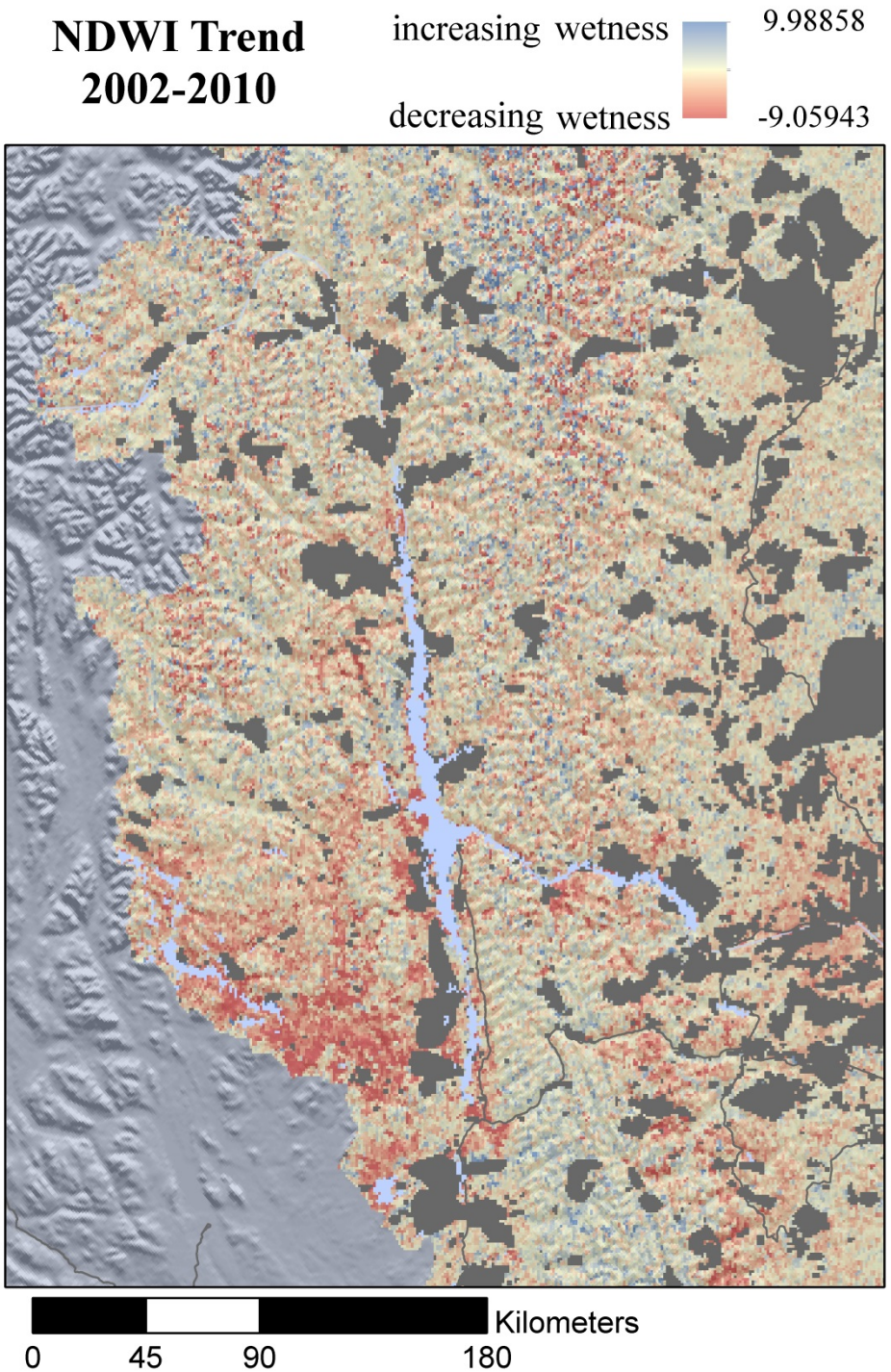

NDVI Trend
2002-2008
increasing wetness
16.2791
decreasing wetness
-16.3087
Kilometers
0
45
90
180

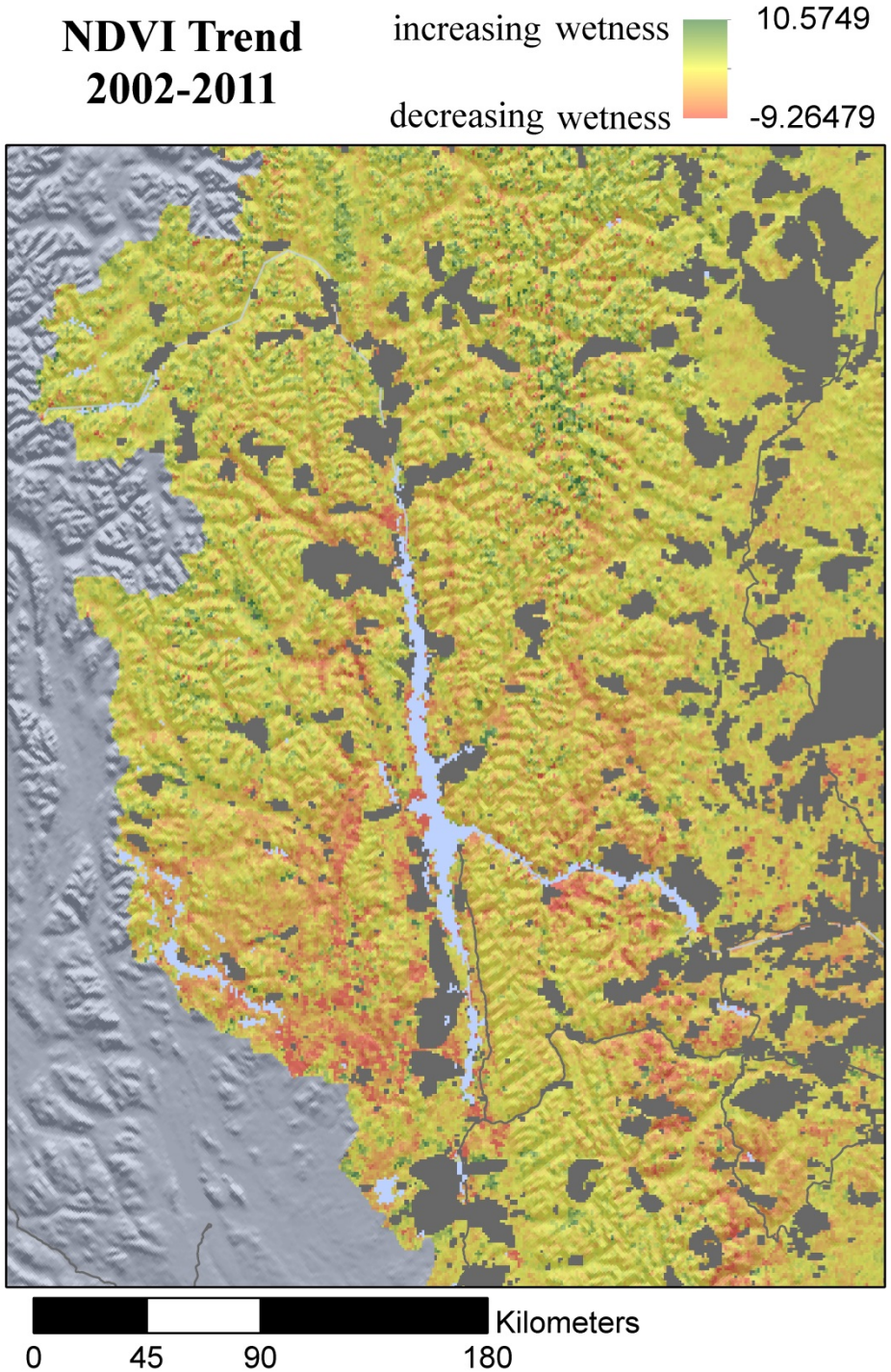

NDWI Trend
2002-2008
increasing wetness
14.1371
decreasing wetness
-15.5196
Kilometers
0
45
90
180

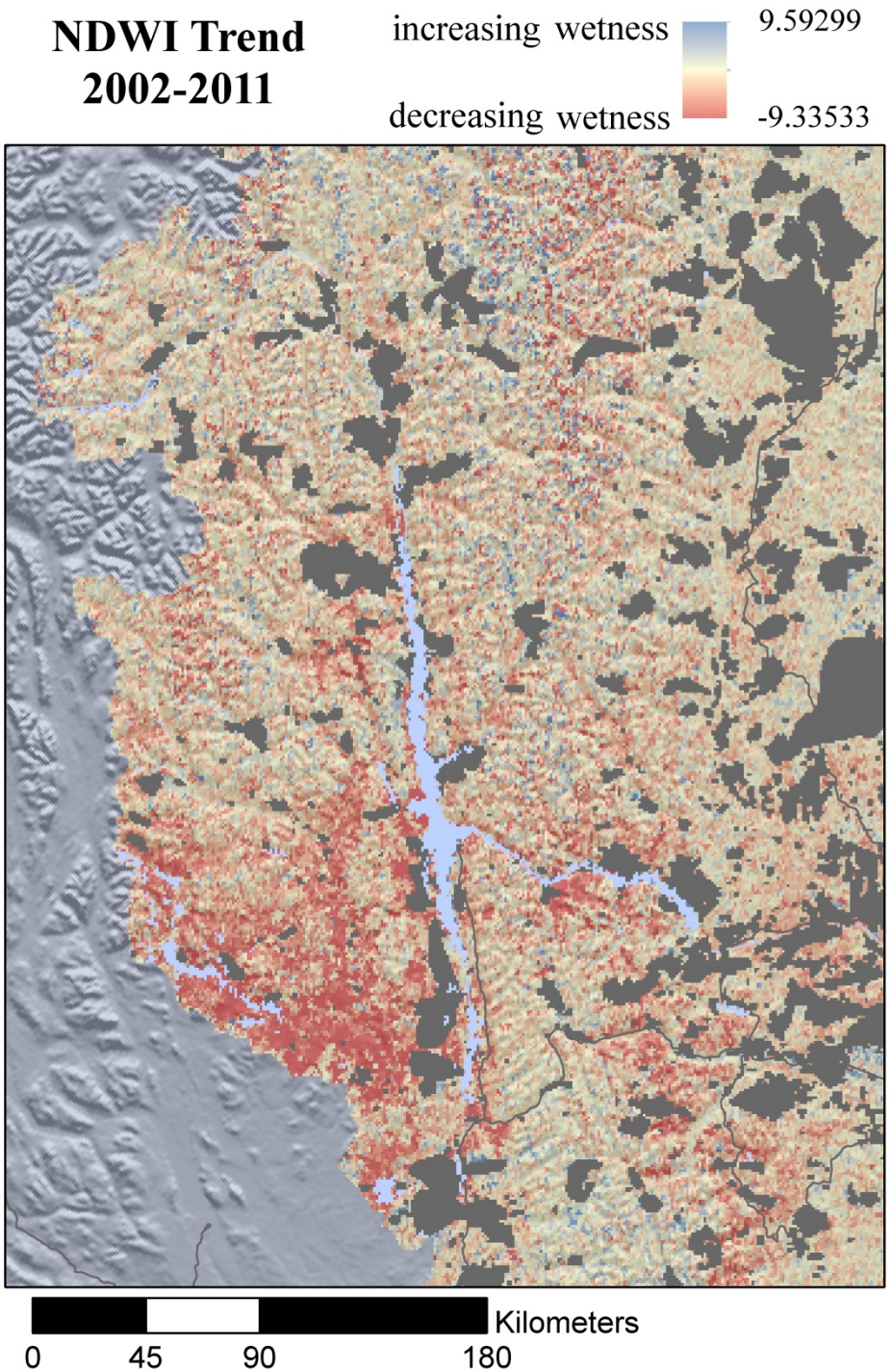

NDVI Trend
2002-2009
increasing wetness
13.0359
decreasing wetness
-12.1651
Kilometers
0
45
90
180

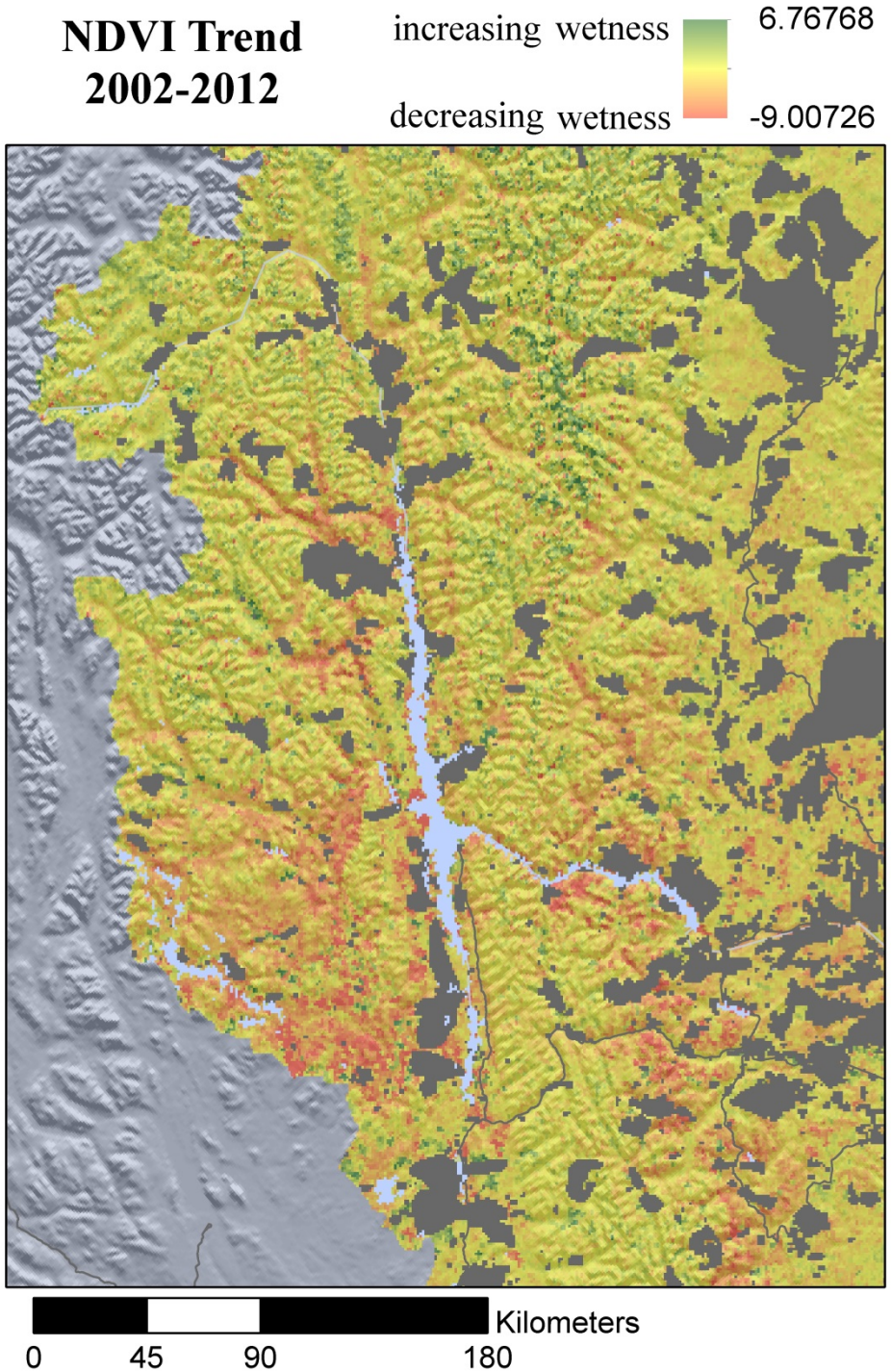

NDWI Trend
2002-2009
increasing wetness
12.3208
decreasing wetness
-11.3326
Kilometers
0
45
90
180

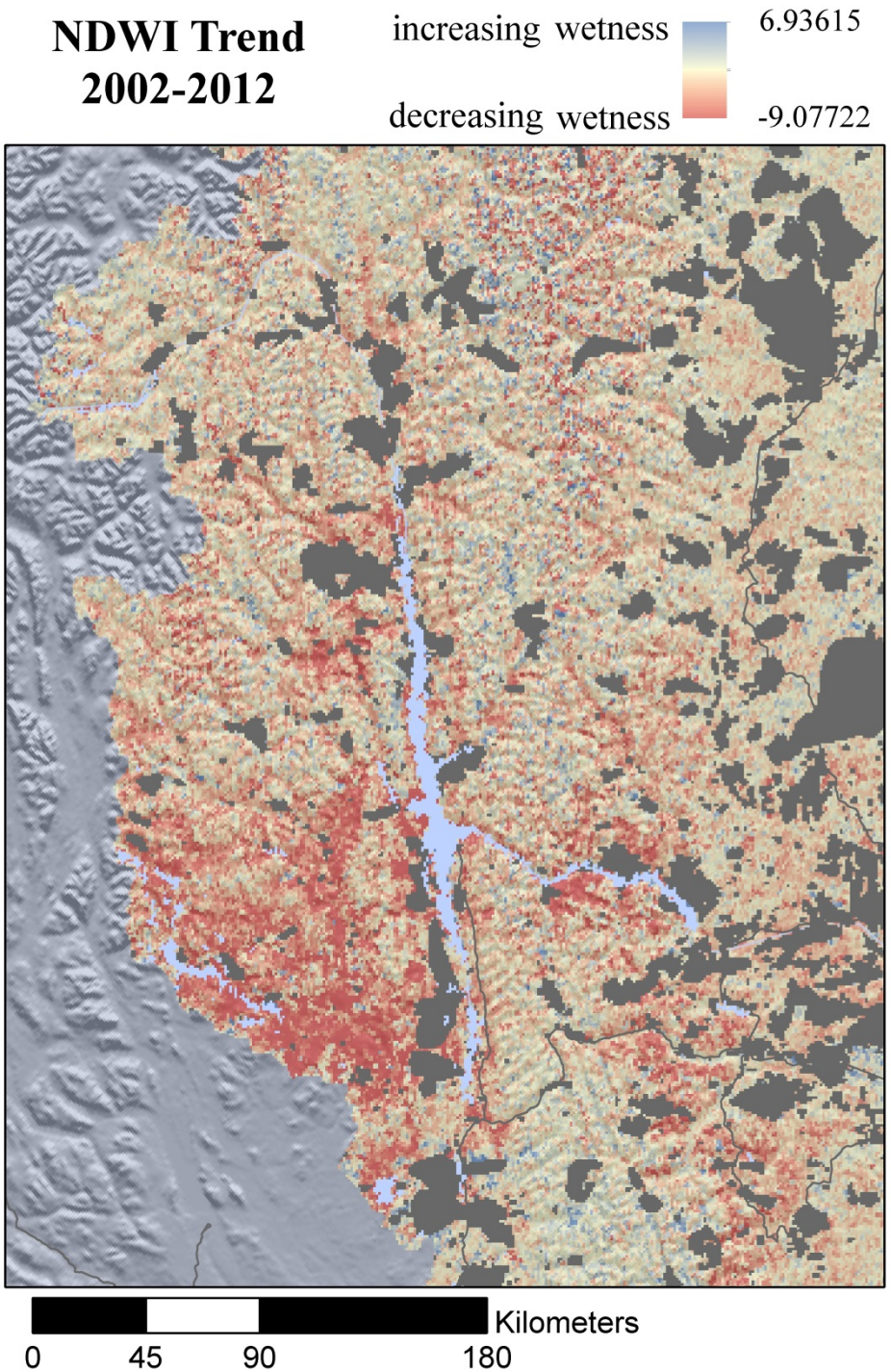

NDVI Trend
2002-2010
increasing wetness
12.3452
decreasing wetness
-10.6337
Kilometers
0
45
90
180

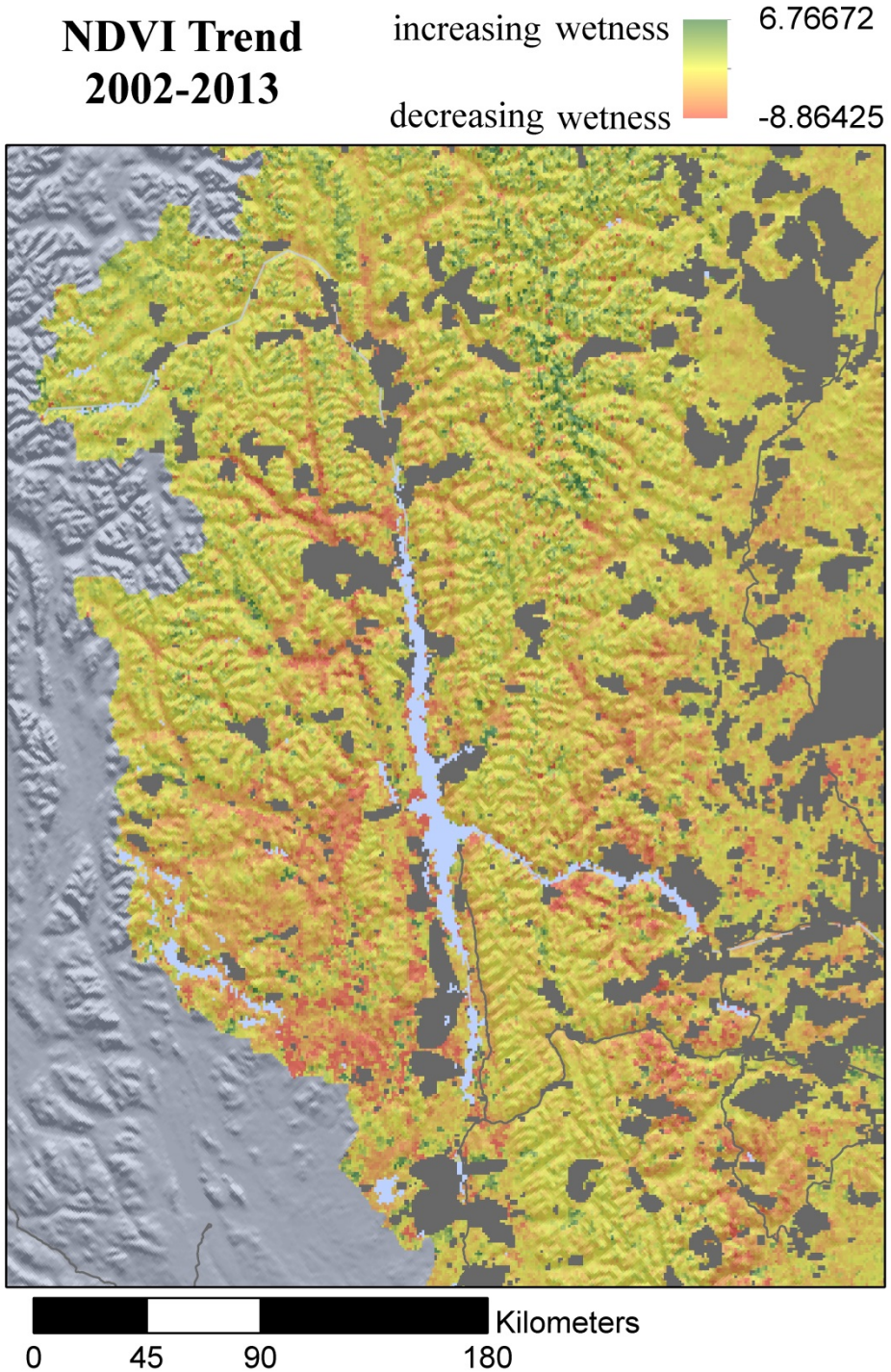

NDWI Trend
2002-2010
increasing wetness
9.98858
decreasing wetness
-9.05943
Kilometers
0
45
90
180

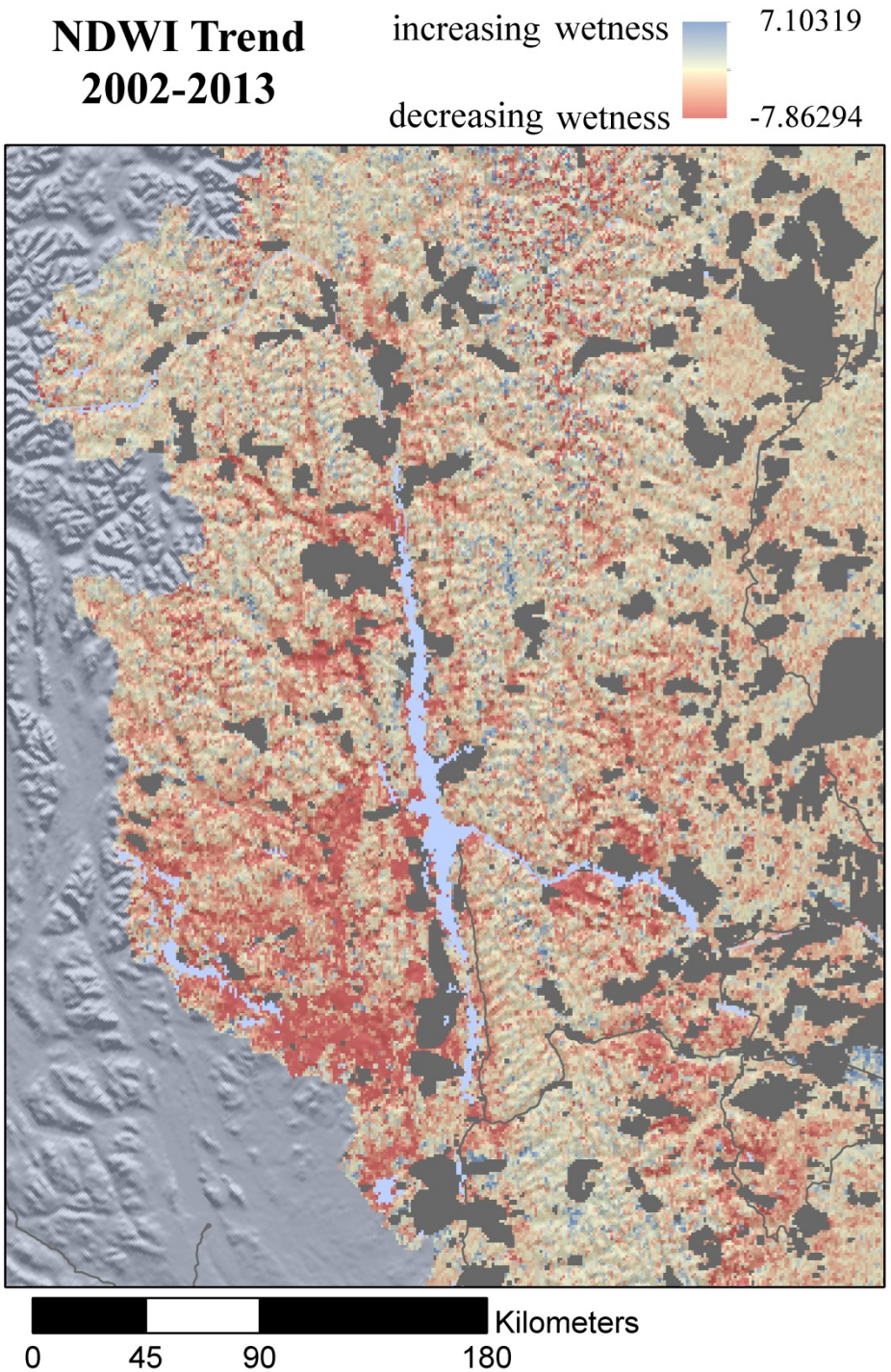

NDVI Trend
2002-2011
increasing wetness
10.5749
decreasing wetness
-9.26479
Kilometers
0
45
90
180

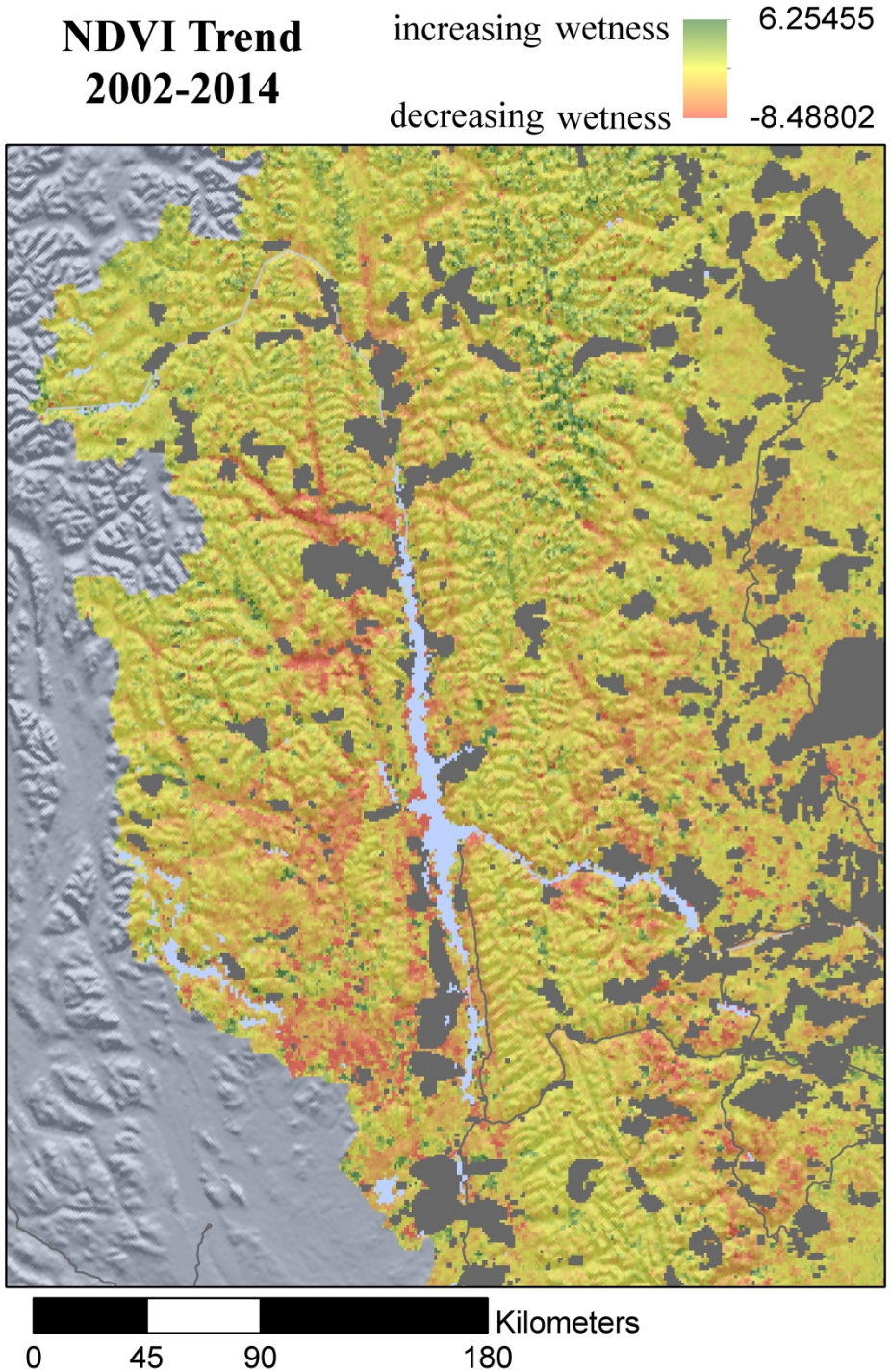

NDWI Trend
2002-2011
increasing wetness
9.59299
decreasing wetness
-9.33533
Kilometers
0
45
90
180


NDVI Trend
2002-2012
increasing wetness
6.76768
decreasing wetness
-9.00726
Kilometers
0
45
90
180


NDWI Trend
2002-2012
increasing wetness
6.93615
decreasing wetness
-9.07722
Kilometers
0
45
90
180


NDVI Trend
2002-2013
increasing wetness
6.76672
decreasing wetness
-8.86425
Kilometers
0
45
90
180


NDWI Trend
2002-2013
increasing wetness
7.10319
decreasing wetness
-7.86294
Kilometers
0
45
90
180


NDVI Trend
2002-2014
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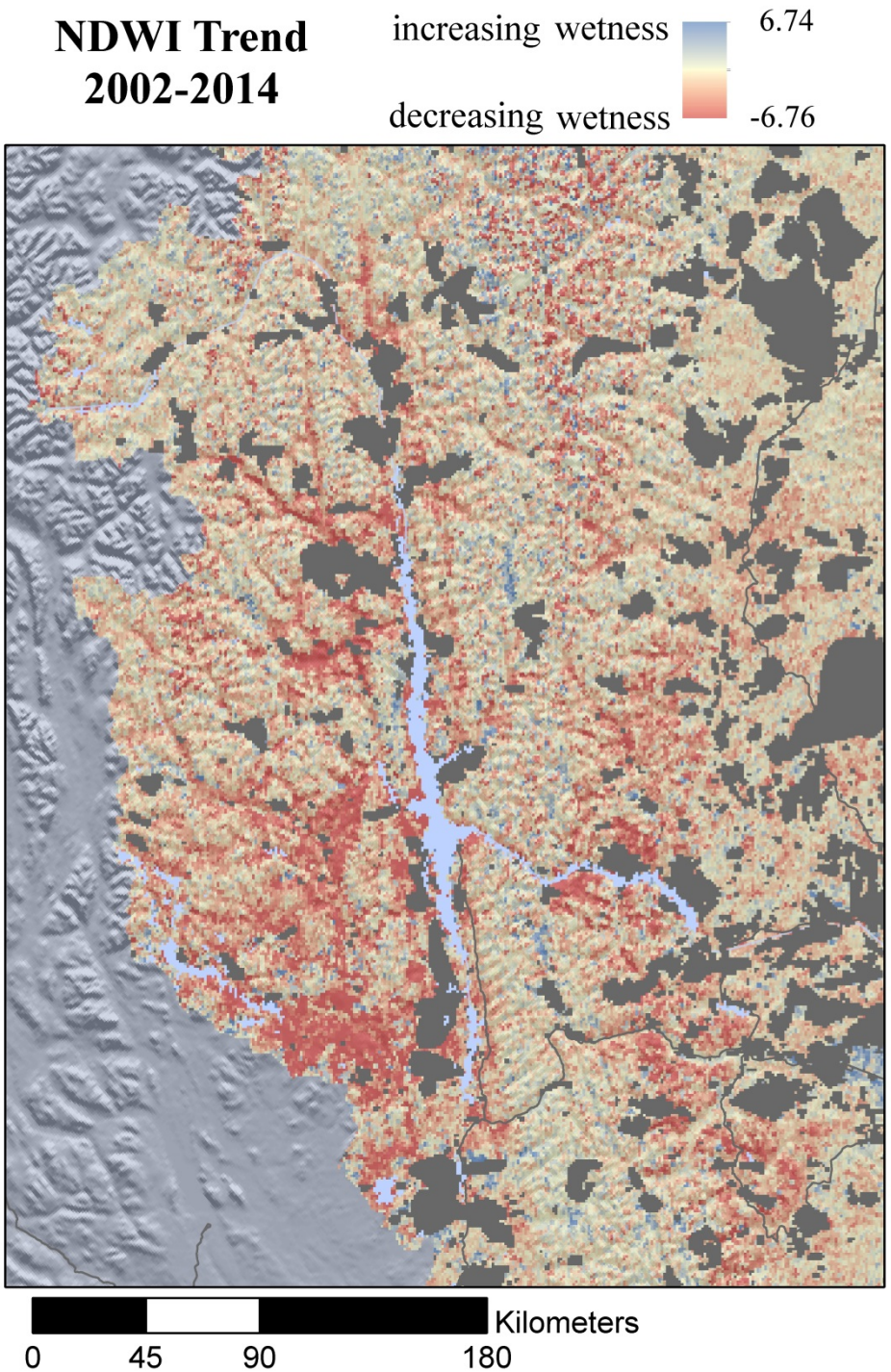
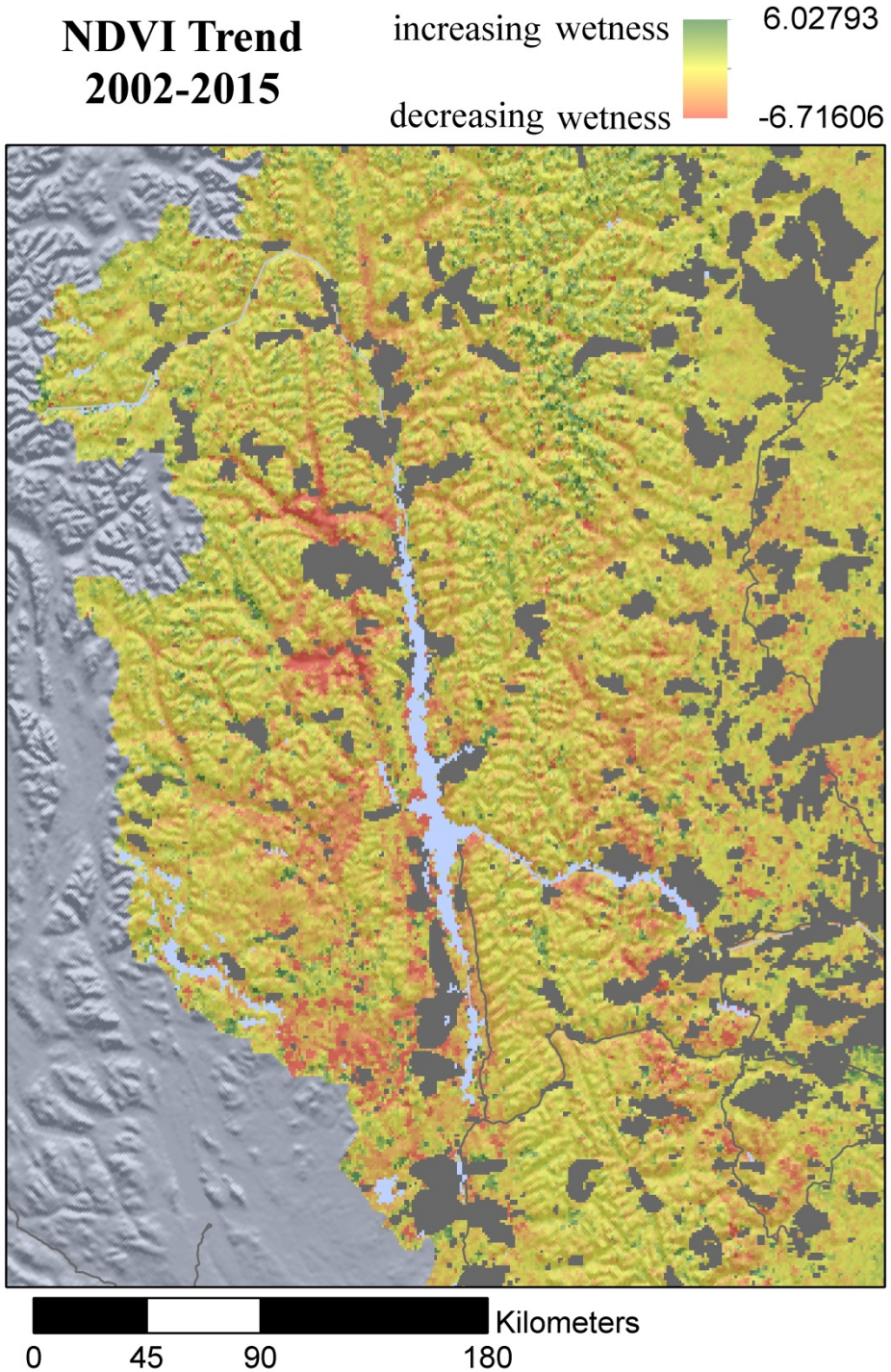
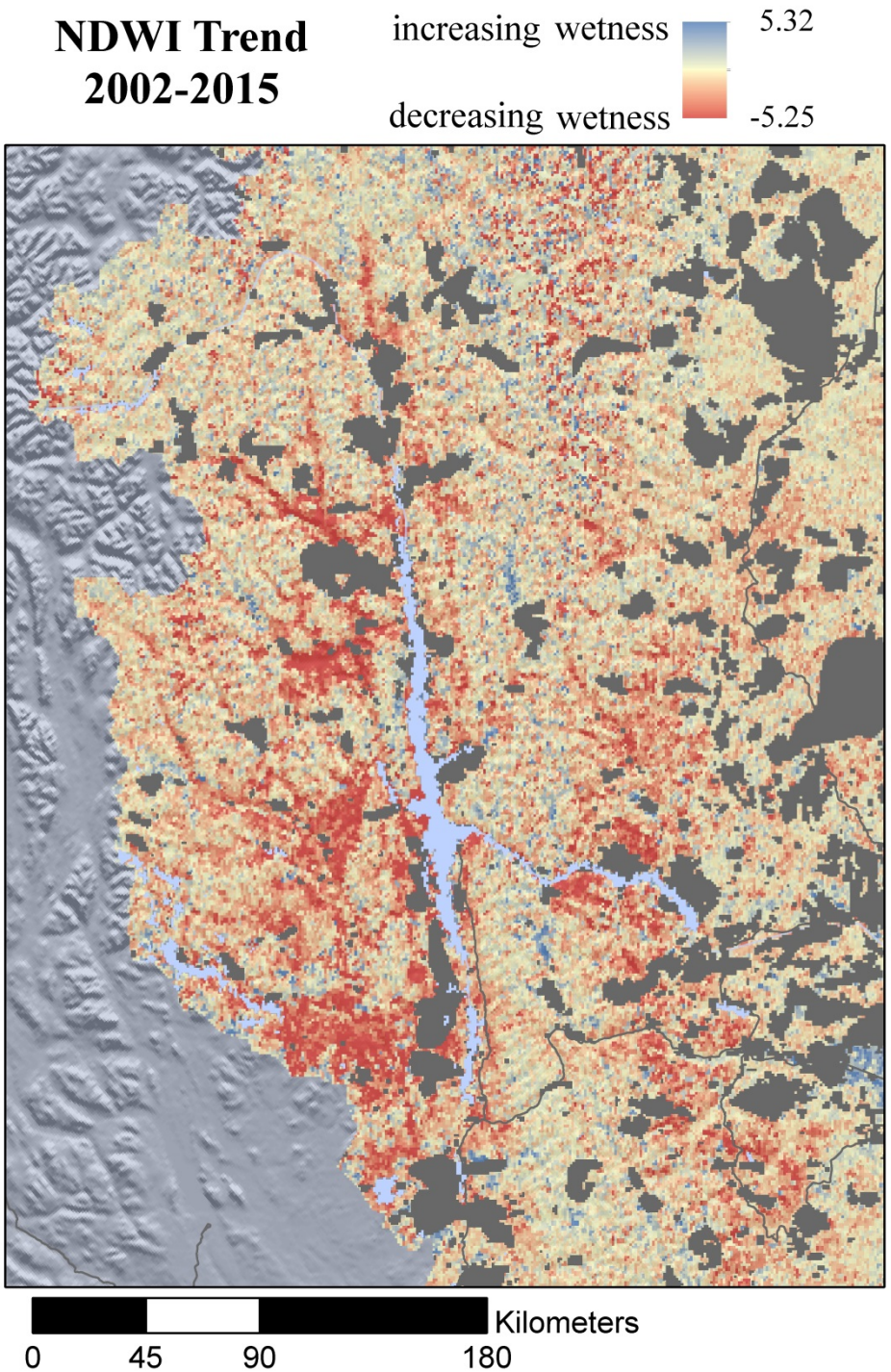
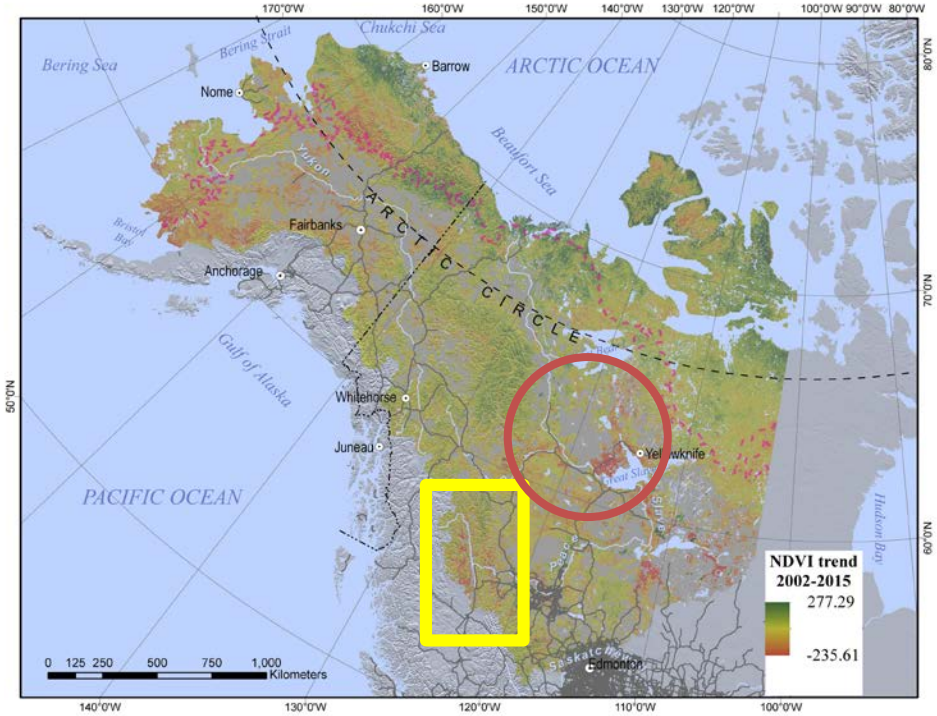
decreasing wetness
-8.48802
Kilometers
0
45
90
180

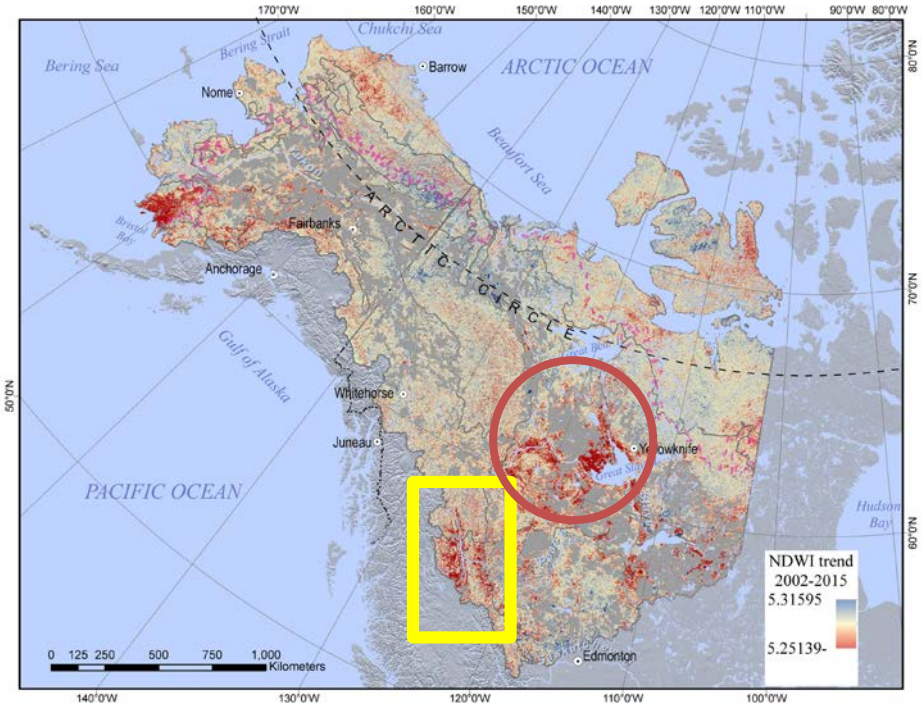

NDWI Trend
2002-2014
increasing wetness
6.74
decreasing wetness
-6.76
Kilometers
0
45
90
180


NDVI Trend
2002-2015
increasing wetness
6.02793
decreasing wetness
-6.71606
Kilometers
0
45
90
180


NDWI Trend
2002-2015
increasing wetness
5.32
decreasing wetness
-5.25
Kilometers
0
45
90
180

NDWI trends can be useful for monitoring and measuring insect outbreaks.





The pine beetle continues to move northwards and in 2012 was reported north of 60° latitude in the Northwest Territories for the first time.

Link observed changes to ecological and geophysical processes

We can formulate and hone hypotheses explaining observed trend trajectories.

Improved ability to model and predict future trends in a climate change scenario.

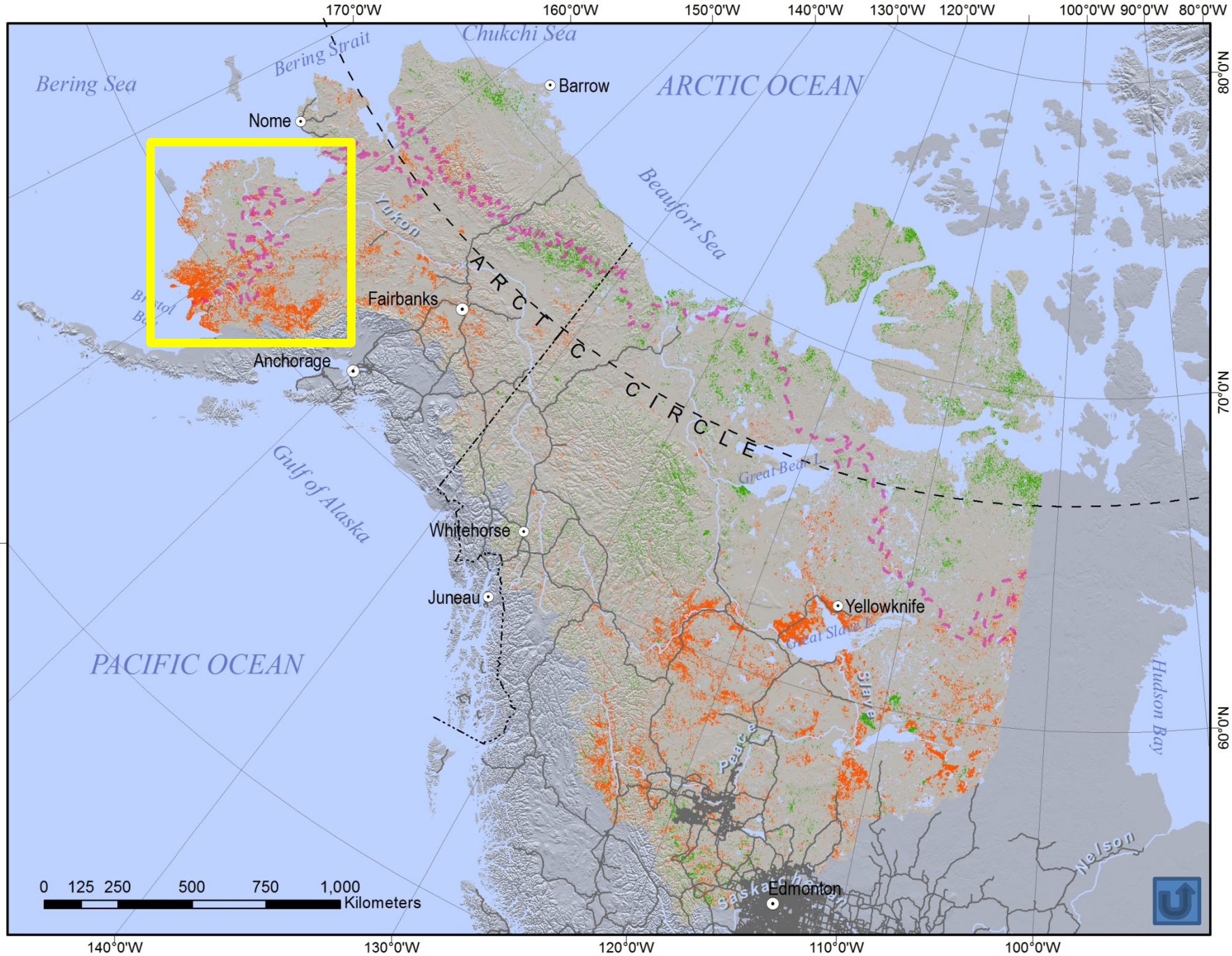
Particularly relating to the fate of carbon.

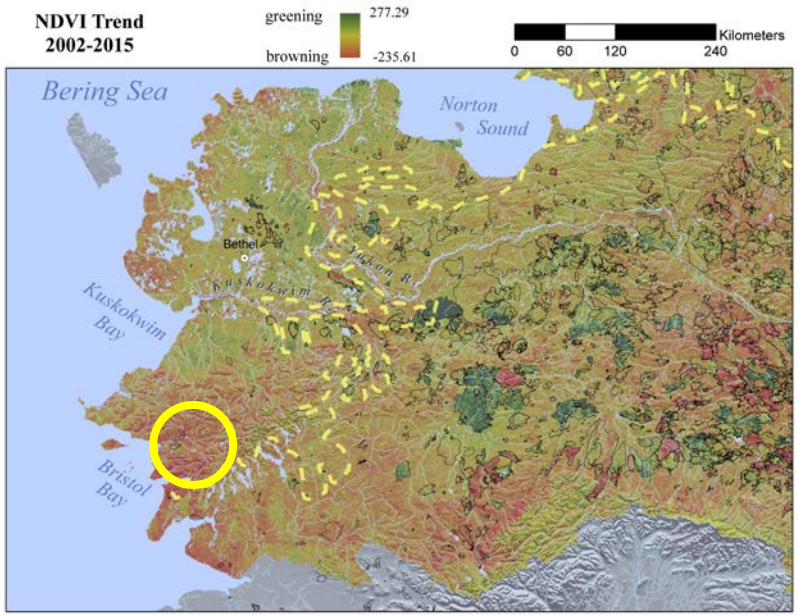
Thank You!

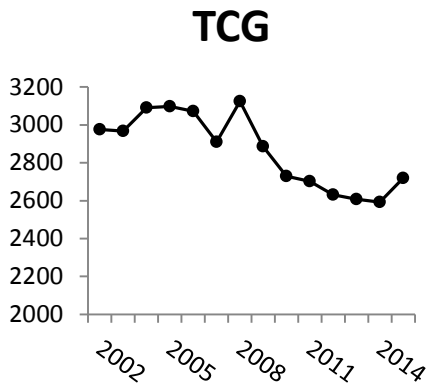
Questions?

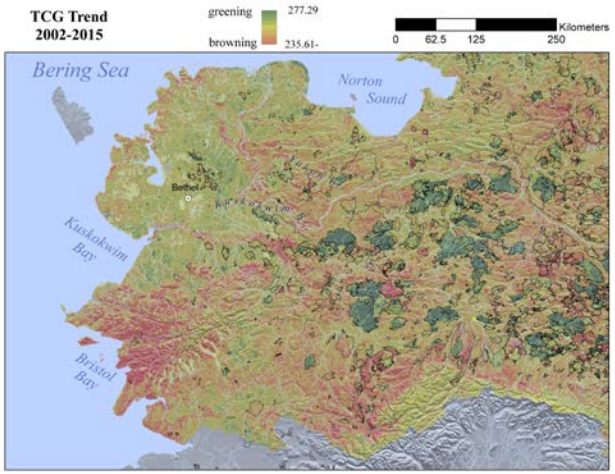
Acknowledgements

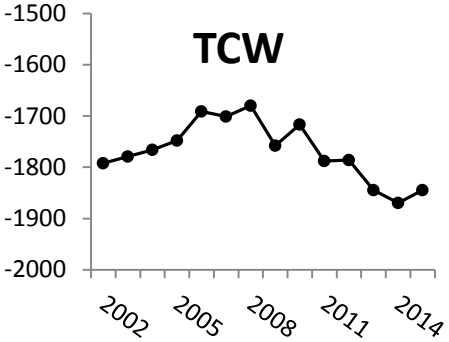
This work is supported by a Department of Energy (DOE) Early Career Award (DOE-BER #3ERKP818)

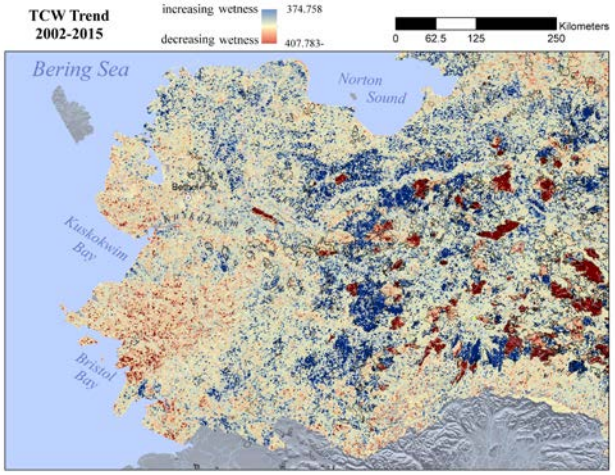

170°0'W
160°0'W
150°0'W
140°0'W
130°0'W
120°0'W
100°0'W
90°0'W
80°0'W
80°0'N
70°0'N
60°0'N
50°0'N
Bering Sea
Bering Strait
Chukchi Sea
ARCTIC OCEAN
Barrow
Nome
Beaufort Sea
Yukon
ARCTIC CIRCLE
Fairbanks
Anchorage
Gulf of Alaska
Great Bear L.
Whitehorse
Juneau
Yellowknife
Great Slave L.
PACIFIC OCEAN
Slave
Hudson Bay
Peace
Nelson
Edmonton
0 125 250 500 750 1,000
Kilometers
140°0'W
130°0'W
120°0'W
110°0'W
100°0'W

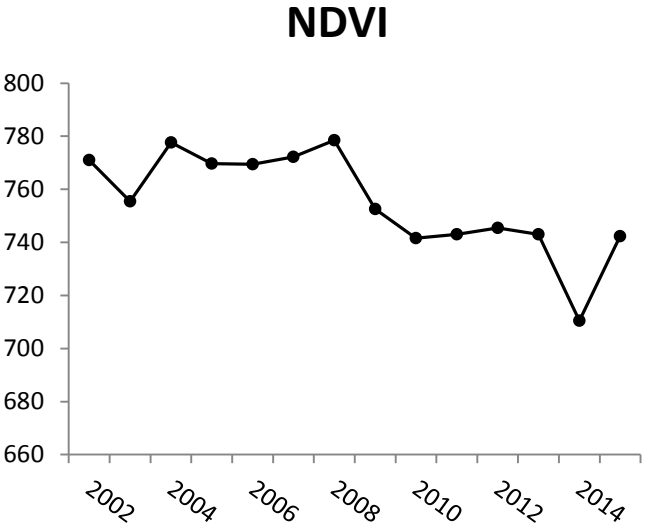

NDVI Trend
2002-2015
greening
277.29
browning
-235.61
Kilometers
0 60 120 240
Bering Sea
Norton Sound
Bethel
Kuskokwim Bay
Bristol Bay

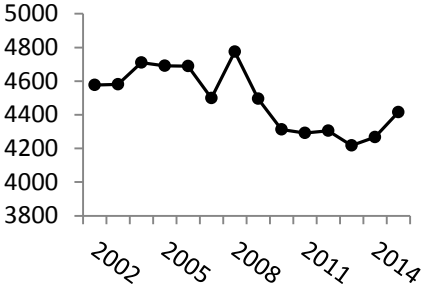

TCG
3200
3000
2800
2600
2400
2200
2000
2002
2005
2008
2011
2014

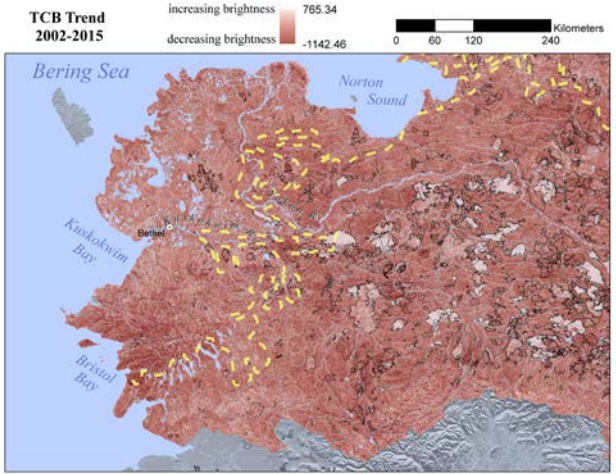

TCG Trend
2002-2015
greening
277.29
browning
-235.61
Kilometers
0 62.5 125 250
Bering Sea
Norton Sound
Bethel
Kuskokwim Bay
Bristol Bay

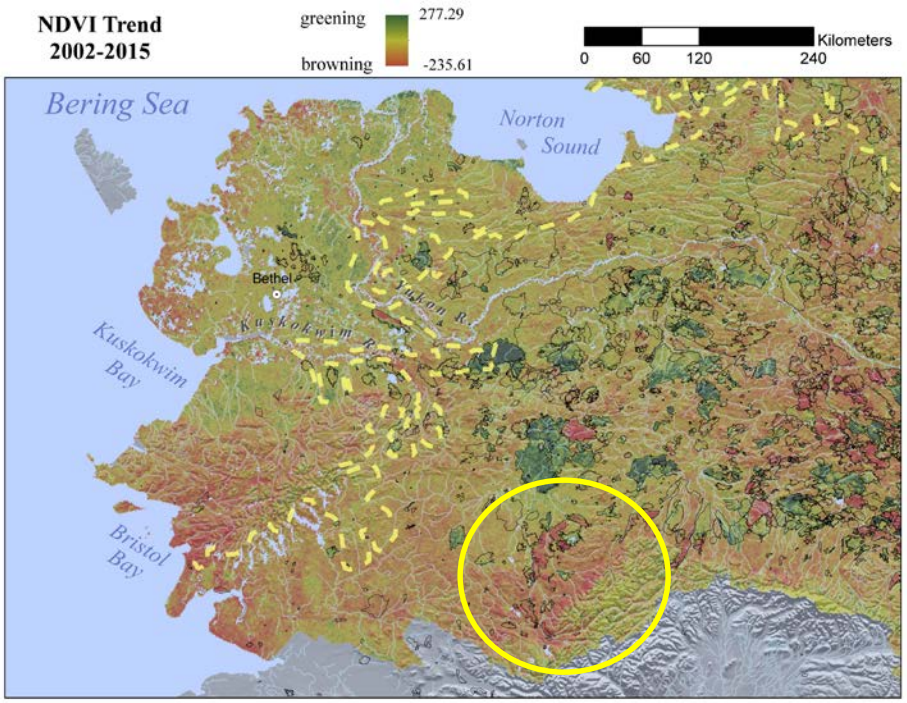

TCW
-1500
-1600
-1700
-1800
-1900
-2000
2002
2005
2008
2011
2014

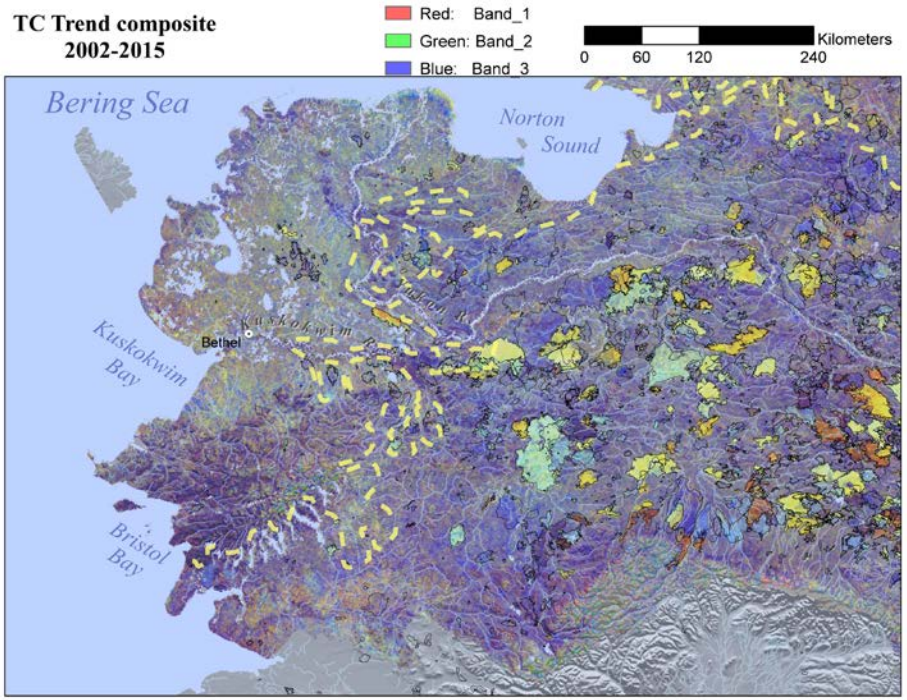

TCW Trend
2002-2015
increasing wetness
374.758
decreasing wetness
-407.783
Kilometers
0 62.5 125 250
Bering Sea
Norton Sound
Kuskokwim Bay
Bristol Bay

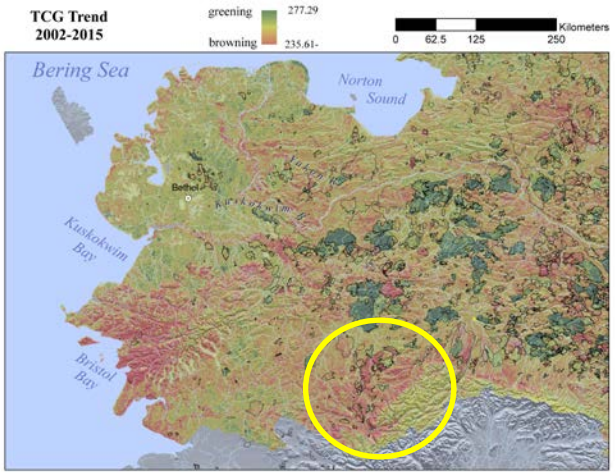

NDVI
800
780
760
740
720
700
680
660
2002
2004
2006
2008
2010
2012
2014

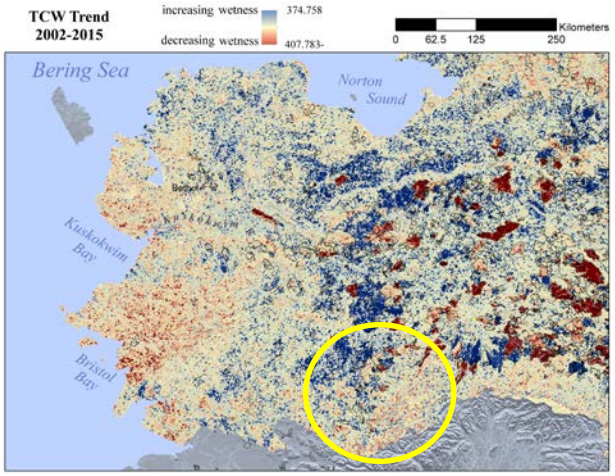

TCB
5000
4800
4600
4400
4200
4000
3800
2002
2005
2008
2011
2014

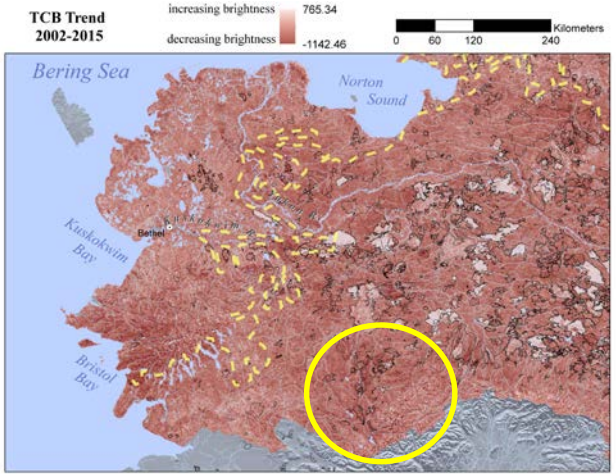

TCB Trend
2002-2015
increasing brightness
765.34
decreasing brightness
-1142.46
Kilometers
0 60 120 240
Bering Sea
Norton Sound
Bethel
Kuskokwim Bay
Bristol Bay


NDVI Trend
2002-2015
greening
browning
277.29
-235.61
0 60 120 240
Kilometers
Bering Sea
Norton Sound
Bethel
Kuskokwim R.
Yukon R.
Kuskokwim Bay
Bristol Bay


TC Trend composite
2002-2015
Red: Band_1
Green: Band_2
Blue: Band_3
0 60 120 240
Kilometers
Bering Sea
Norton Sound
Bethel
Kuskokwim R.
Yukon R.
Kuskokwim Bay
Bristol Bay


TCG Trend
2002-2015
greening
browning
277.29
235.61-
0 62.5 125 250
Kilometers
Bering Sea
Norton Sound
Bethel
Kuskokwim Bay
Bristol Bay


TCW Trend
2002-2015
increasing wetness
decreasing wetness
374.758
407.783-
0 62.5 125 250
Kilometers
Bering Sea
Norton Sound
Kuskokwim Bay
Bristol Bay


TCB Trend
2002-2015
increasing brightness
decreasing brightness
765.34
-1142.46
0 60 120 240
Kilometers
Bering Sea
Norton Sound
Bethel
Kuskokwim Bay
Bristol Bay

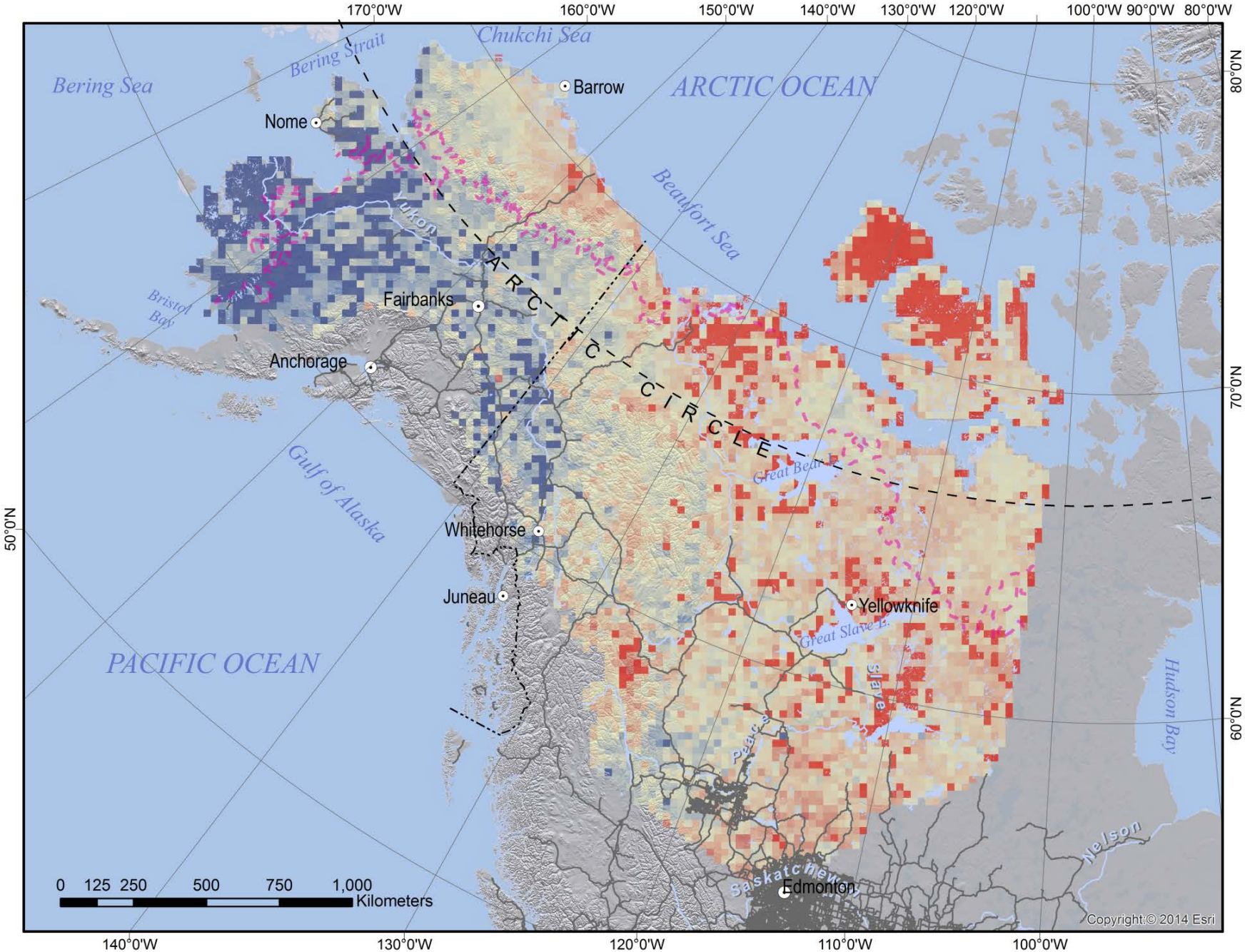
Vegetation Indices

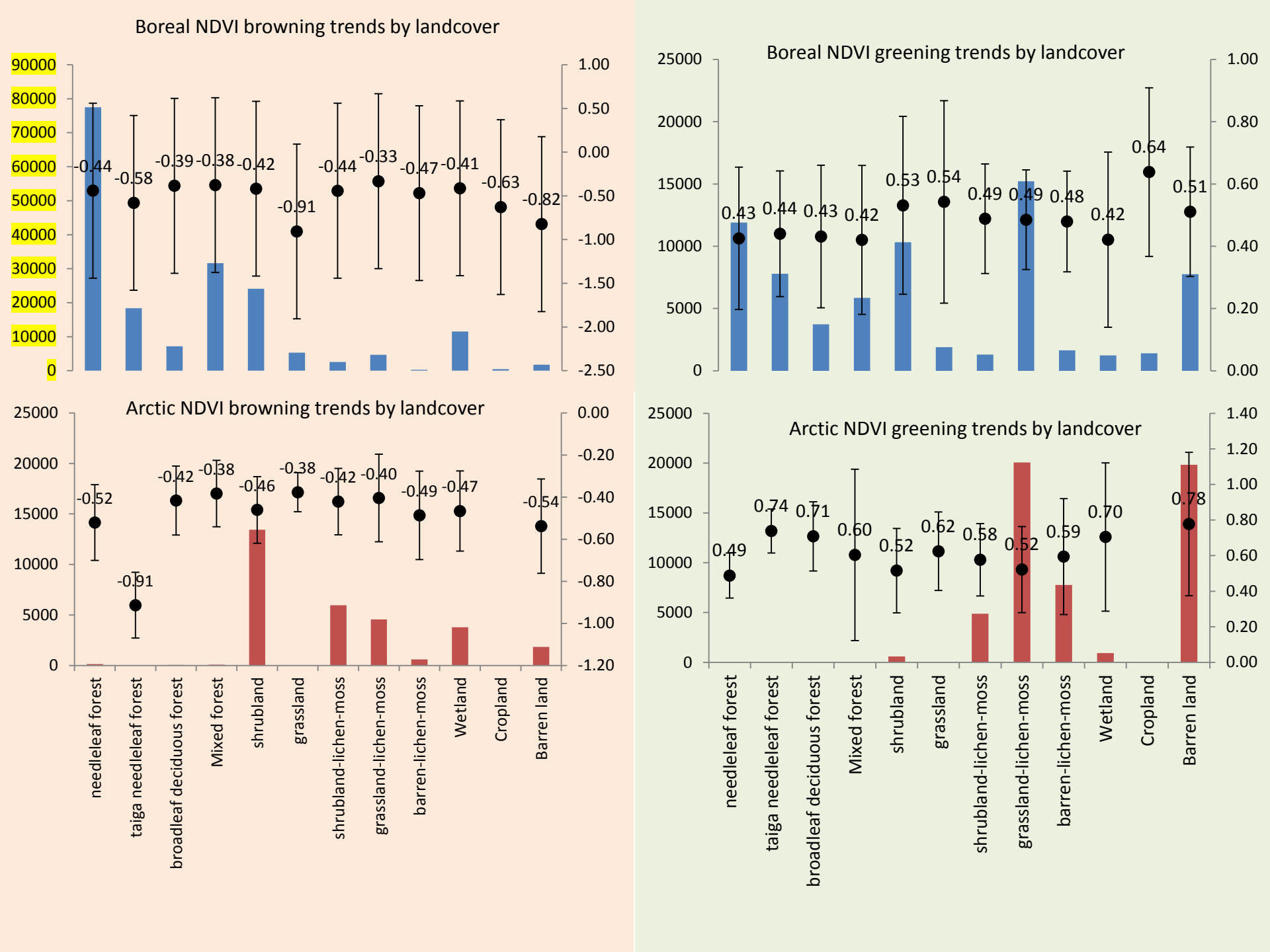
NDVI	photosythetic activity	$\frac{NIR - Red}{NIR + Red}$	$\frac{Band\ 2 - Band\ 1}{Band\ 2 + Band\ 1}$
NDMI	soil moisture	$\frac{NIR - SWIR_{1640}}{NIR + SWIR^{1640}}$	$\frac{Band\ 2 - Band\ 6}{Band\ 2 + Band\ 6}$
NDWI	standing water	$\frac{NIR - SWIR_{1240}}{NIR + SWIR^{1240}}$	$\frac{Band\ 2 - Band\ 5}{Band\ 2 + Band\ 5}$

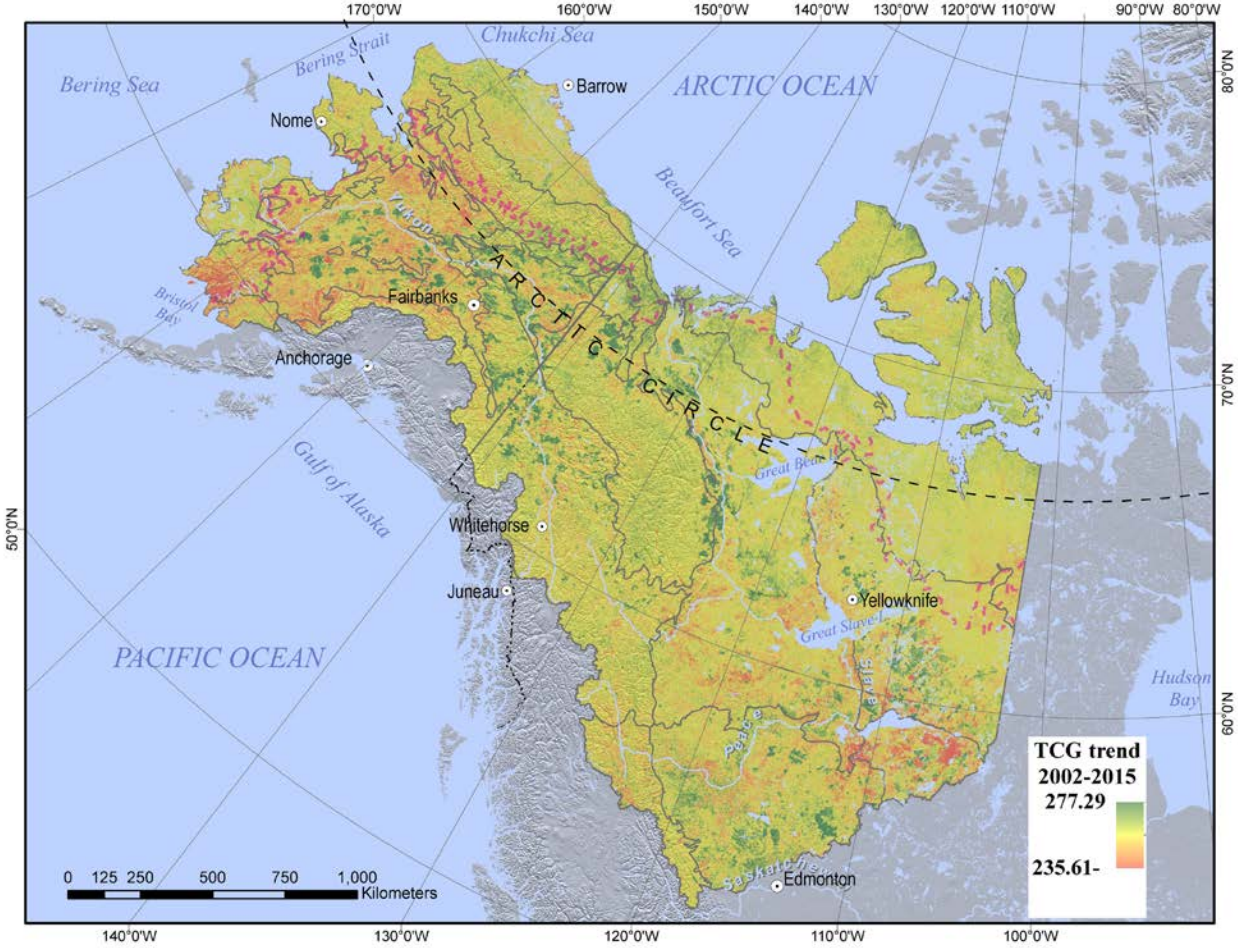
Tasseled-cap = (C1 * band1)+ (C2 * band2)+ (C3 * band3)+(C4 * band4)+ (C5 * band5)+ (C7 * band7)

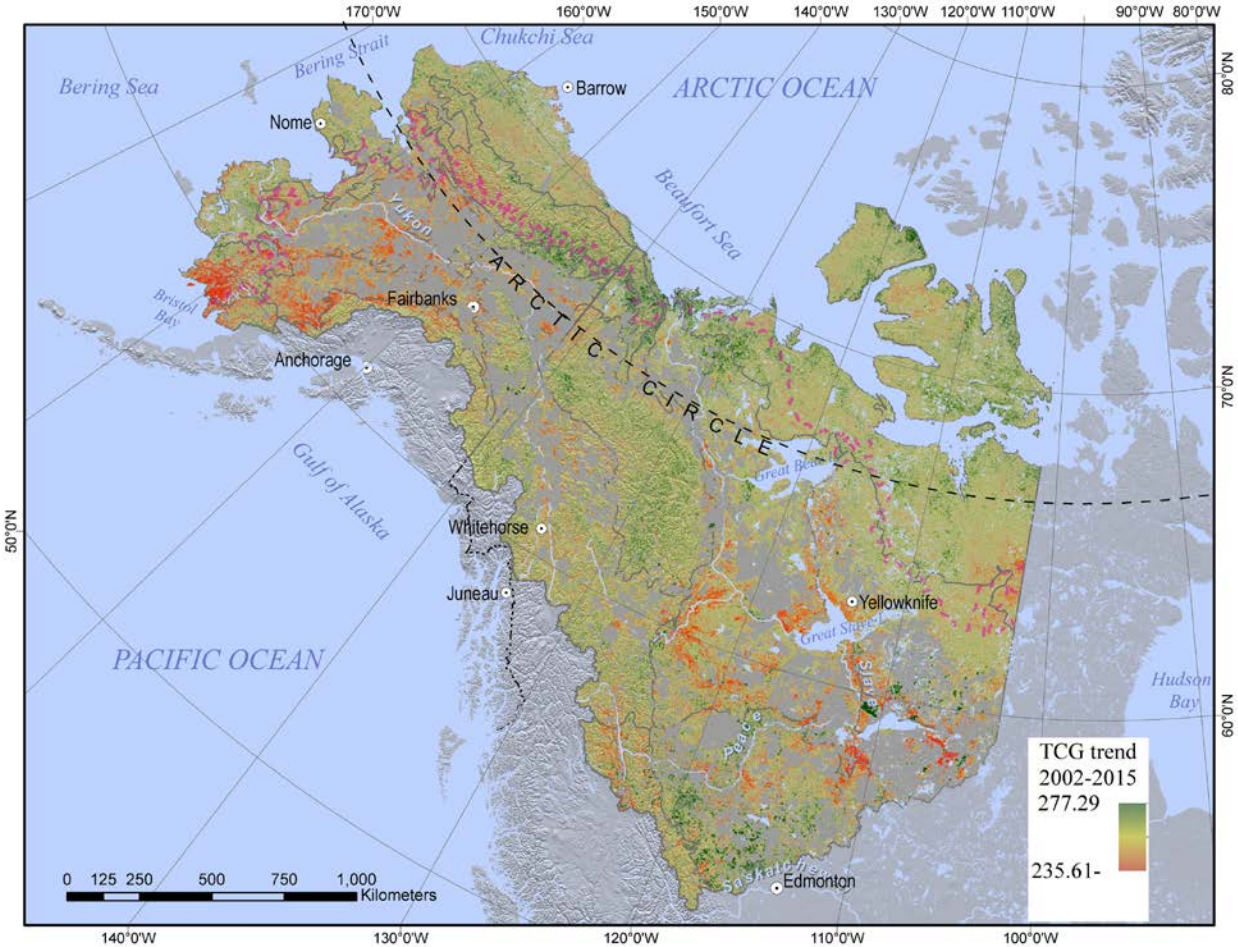
Band		band1	band2	band3	band4	band5	band6	band7
MODIS(nm)		620-670	841-876	459-479	545-565	1230-1250	1628-1652	2105-2155
Brightness	bare ground albedo	0.4395	0.5945	0.2460	0.3918	0.3506	0.2136	0.2678
Greenness	vegetation greenness	-0.4064	0.5129	-0.2744	-0.2893	0.4882	-0.0036	-0.4169
Wetness	soil & canopy moisture	0.1147	0.2489	0.2408	0.3132	-0.3122	-0.6416	-0.5087

Summer Warmth Index trends 2002-2012




Boreal NDVI browning trends by landcover
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-0.44
-0.58
-0.39
-0.38
-0.42
-0.91
-0.44
-0.33
-0.47
-0.41
-0.63
-0.82
Boreal NDVI greening trends by landcover
25000
20000
15000
10000
5000
0
1.00
0.80
0.60
0.40
0.20
0.00
0.43
0.44
0.43
0.42
0.53
0.54
0.49
0.49
0.48
0.42
0.64
0.51
Arctic NDVI browning trends by landcover
25000
20000
15000
10000
5000
0
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
-1.20
-0.52
-0.91
-0.42
-0.38
-0.46
-0.38
-0.42
-0.40
-0.49
-0.47
-0.54
Arctic NDVI greening trends by landcover
25000
20000
15000
10000
5000
0
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.49
0.74
0.71
0.60
0.52
0.62
0.58
0.52
0.59
0.70
0.78
needleleaf forest
taiga needleleaf forest
broadleaf deciduous forest
Mixed forest
shrubland
grassland
shrubland-lichen-moss
grassland-lichen-moss
barren-lichen-moss
Wetland
Cropland
Barren land


170°0'W
160°0'W
150°0'W
140°0'W
130°0'W
120°0'W
110°0'W
90°0'W
80°0'W
80°0'N
70°0'N
60°0'N
50°0'N
140°0'W
130°0'W
120°0'W
110°0'W
100°0'W
Bering Sea
Bering Strait
Chukchi Sea
ARCTIC OCEAN
Beaufort Sea
Barrow
Nome
Yukon
ARCTIC CIRCLE
Bristol Bay
Fairbanks
Anchorage
Gulf of Alaska
Great Bear
Whitehorse
Juneau
Yellowknife
Great Slave
PACIFIC OCEAN
Hudson Bay
Peace
Athabasca
Saskatchewan
Edmonton
0 125 250 500 750 1,000
Kilometers
TCG trend
2002-2015
277.29
235.61-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Bering Sea
Bering Strait
Chukchi Sea
ARCTIC OCEAN
Barrow
Nome
Beaufort Sea
Yukon
ARCTIC CIRCLE
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Gulf of Alaska
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Juneau
Yellowknife
Great Slave
PACIFIC OCEAN
Hudson Bay
Peace
Saskatchewan
Edmonton
TCG trend
2002-2015
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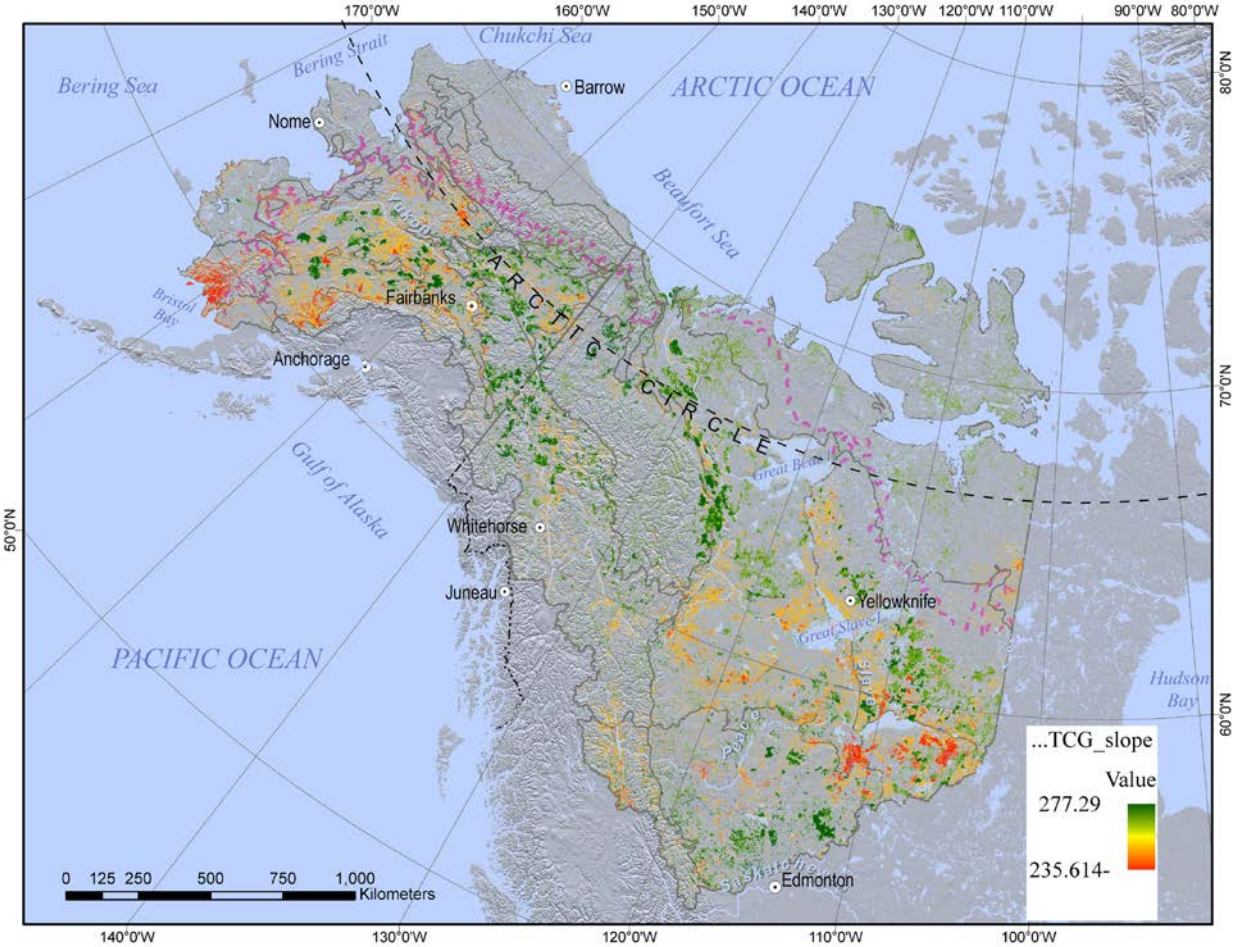
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Bering Sea
Bering Strait
Chukchi Sea
ARCTIC OCEAN
Barrow
Nome
Beaufort Sea
Yukon
ARCTIC CIRCLE
Bristol Bay
Fairbanks
Anchorage
Gulf of Alaska
Great Bear
Whitehorse
Juneau
Yellowknife
Great Slave L.
PACIFIC OCEAN
Hudson Bay
Peace
Slave
Saskatchewan
Edmonton
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Kilometers
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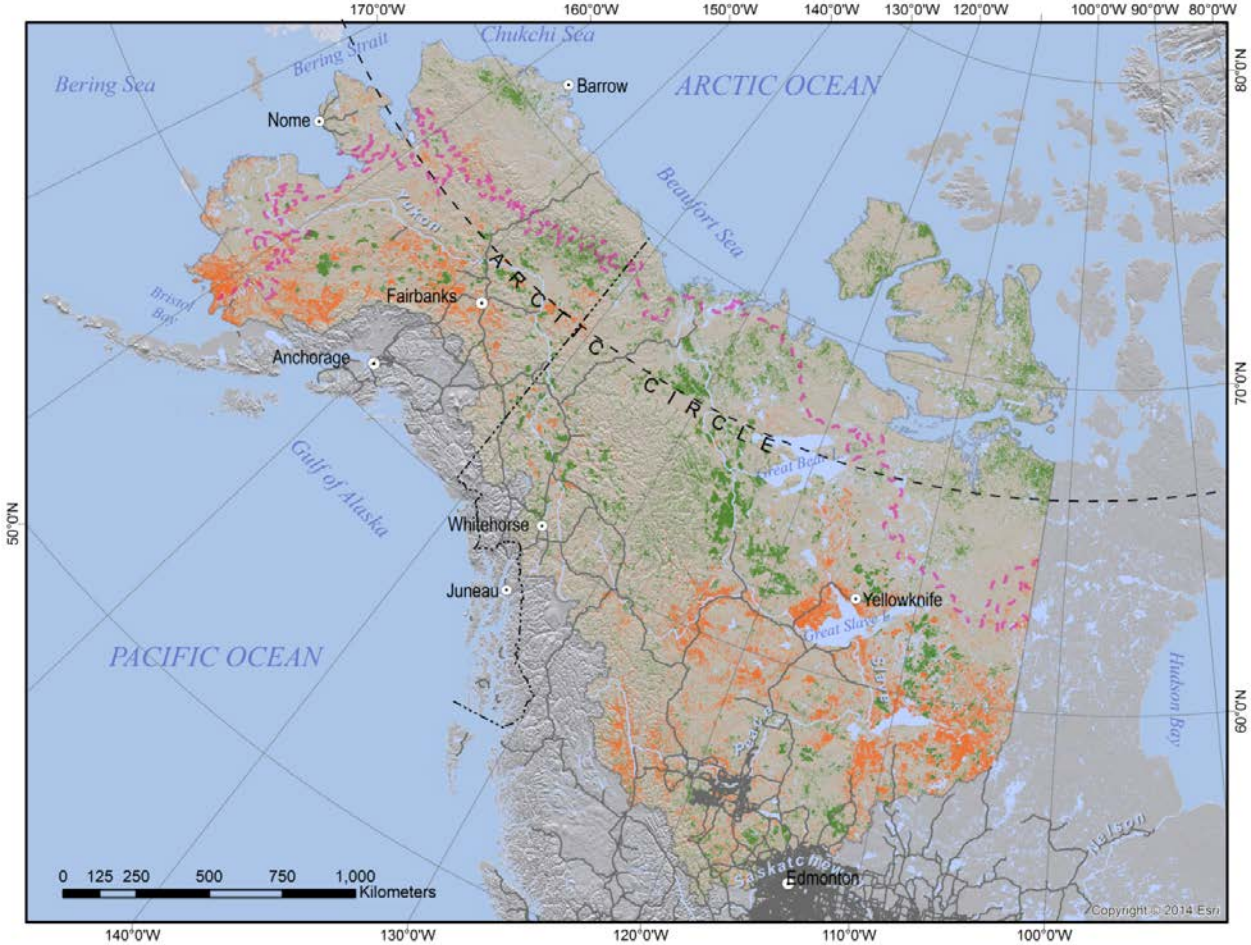
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Bering Sea
Bering Strait
Chukchi Sea
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Gulf of Alaska
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Juneau
Yellowknife
Great Slave
PACIFIC OCEAN
Hudson Bay
Nelson
Saskatchewan
Edmonton
0 125 250 500 750 1,000
Kilometers
Copyright © 2014 Esri
140°0'W
130°0'W
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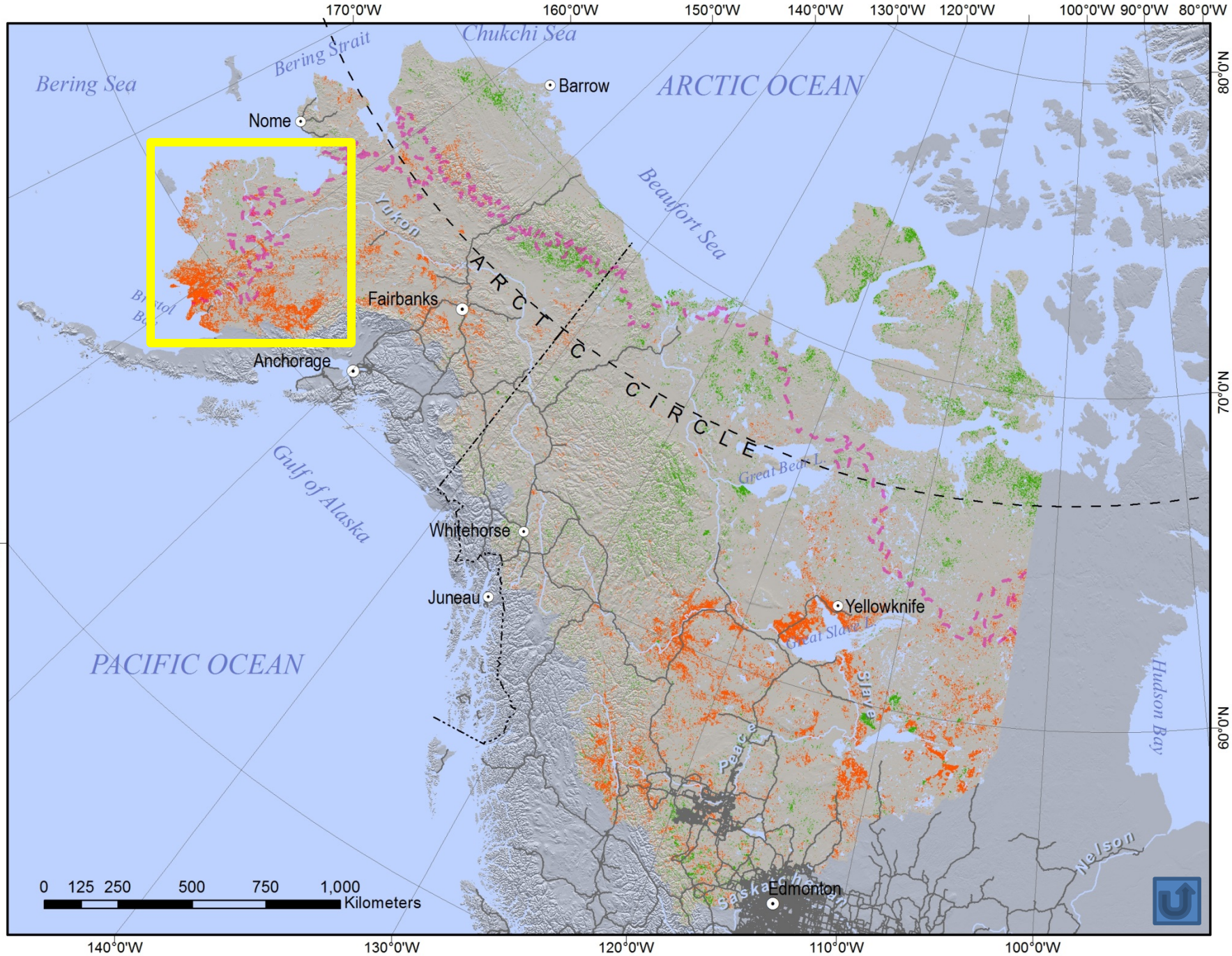
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