Circumpolar AVHRR Surface Temperature and its Relationship Bioclimate Zones and NDVI

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Overview of Presentation

Two data sets:

- Circumpolar Arctic Vegetation
  Map (CAVM)
- AVHRR surface temperature data

Two comparisons:

- AVHRR temperature of CAVM bioclimate subzones
  - Anomalous areas within subzones
- AVHRR temperature and AVHRR NDVI
  - Anomalous NDVI patterns
  - Comparison with CAVM attributes

Circumpolar Arctic Vegetation

(CAVM Team, 2003)

Plant physiognomy occurring in different Tundra Bioclimate Subzones: A – mosses, liverworts and lichens, B – forbs, C – prostrate dwarf-shrubs, D – non-tussock graminoids, hemiprostrate dwarf shrubs, F – erect dwarf shrubs, G – low shrubs, H – tussock graminoids.

Characteristics of Tundra Bioclimate Subzones

(as developed by Stephen Young (1971), Sylvia Edlund (1990), Arve Elvebakk (1999) and others (CAVM Team, 2003))

Bio-climate Subzone	Mean July Temp (^{o}C)	Summer Warmth Index (^{o}C)	Total phyto-mass (tons/ha)	Net annual production (tons/ha/yr)	# vascular species in flora
A	0-3	< 6	< 3	< 0.3	< 50
B	3-5	6-9	5 - 20	0.2 – 1.9	50 - 100
C	7-9	9-12	10 - 30	1.7 – 2.9	75 -150
D	9-11	12-20	30 - 60	2.9 – 3.9	125 - 250
E	11-13	20-35	50 -100	3.3 – 4.3	200 - 500

Tundra Bioclimate Subzones from the Circumpolar Arctic Vegetation Map (CAVM Team 2003)

Bioclimate
- Subzone A
- Subzone B
- Subzone C
- Subzone D
- Subzone E
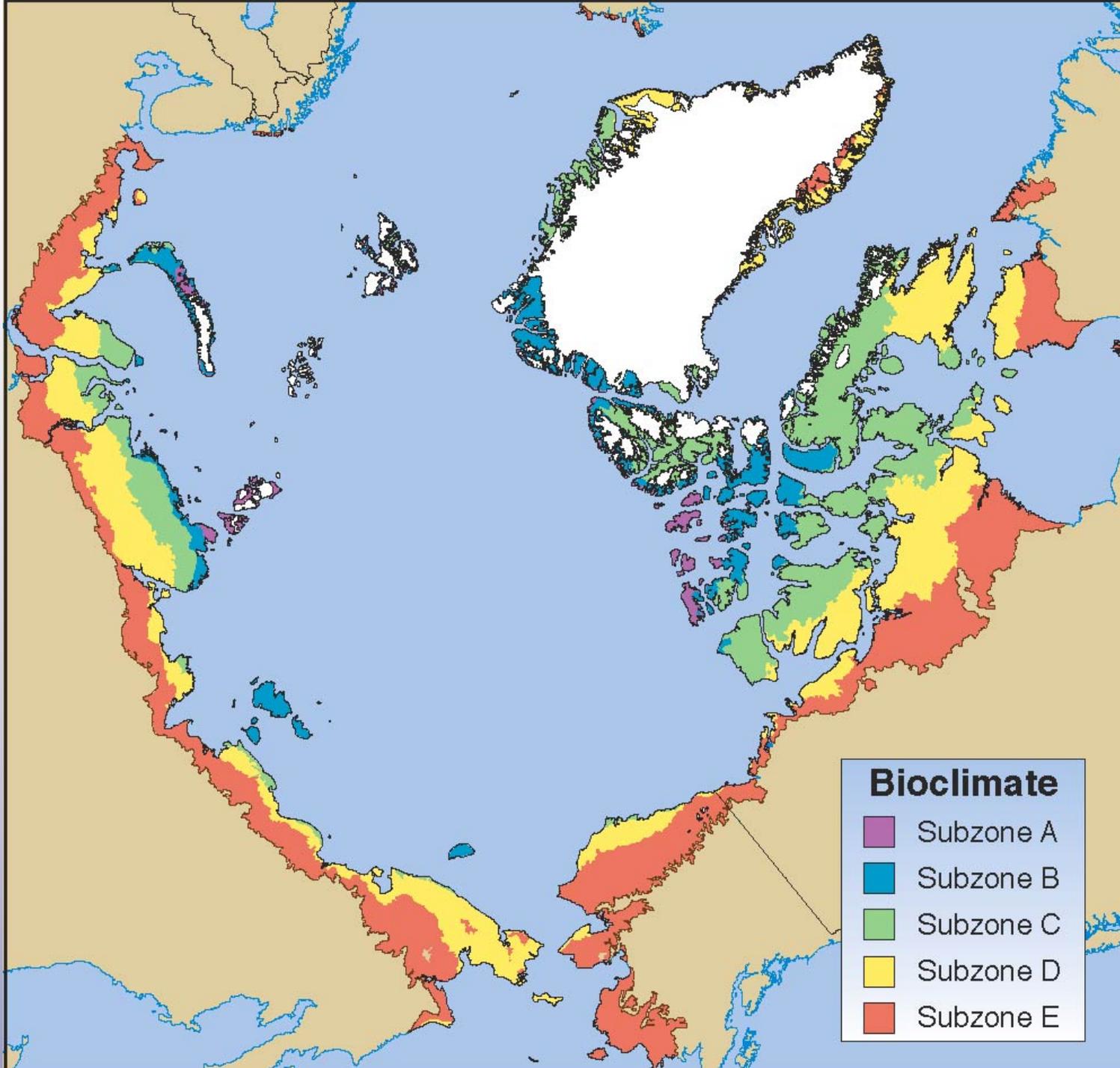
Surface kinetic temperatures calculated from AVHRR 12.5 km pixel data, summarized into monthly means
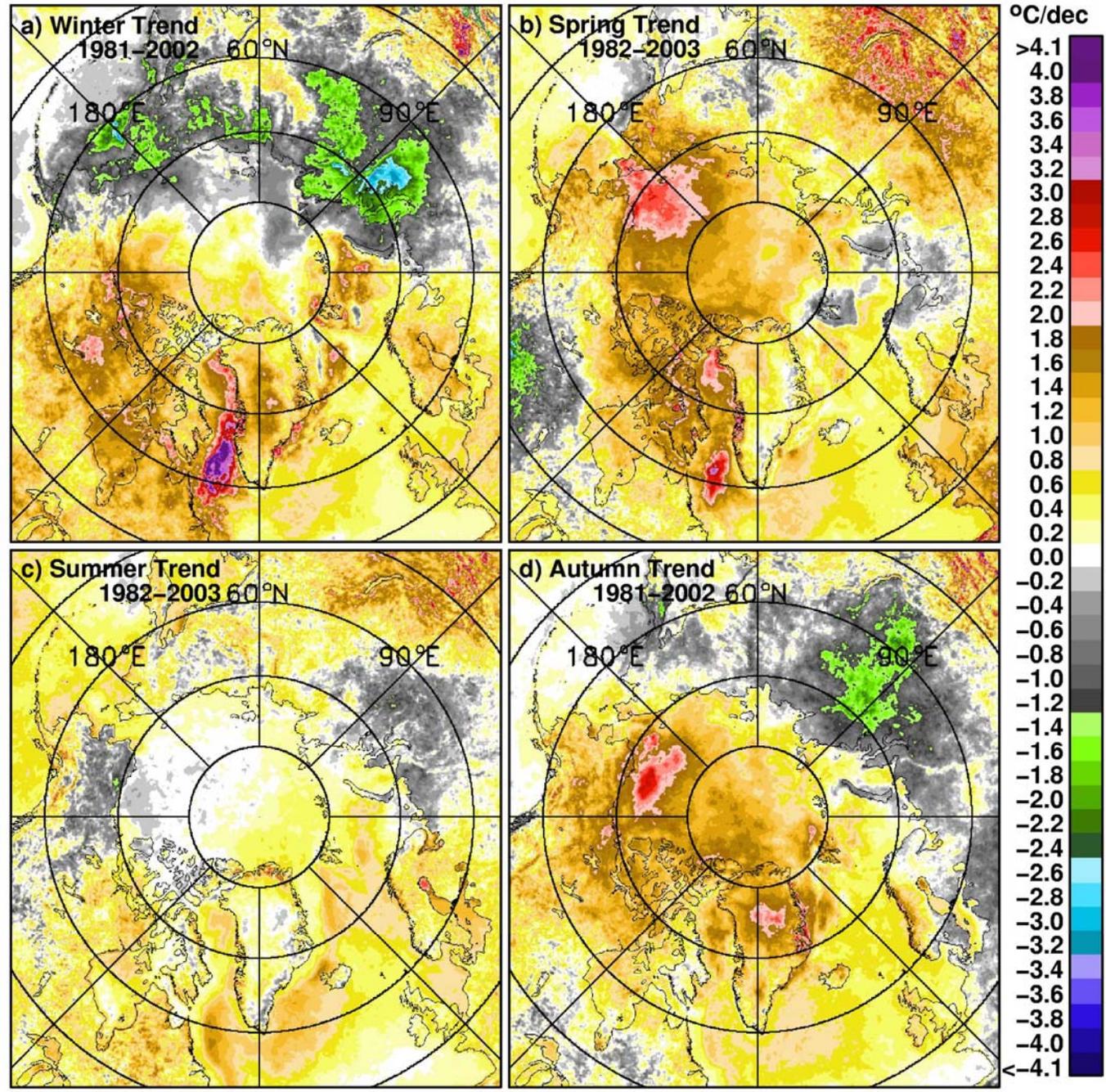
Data from J. Comiso, NASA Goddard

Mean July Temperature (MJT) from AVHRR data
ten year average (1982-1991) of monthly mean July temperatures (^{o} C)

Colored according to CAVM Bioclimate Subzones A - E

	< 2 C
	A: 2 - 5
	B: 5 - 7
	C: 7 - 9
	D: 9 - 11
	E: 11 - 14
	> 14 C

Mean July Temperature
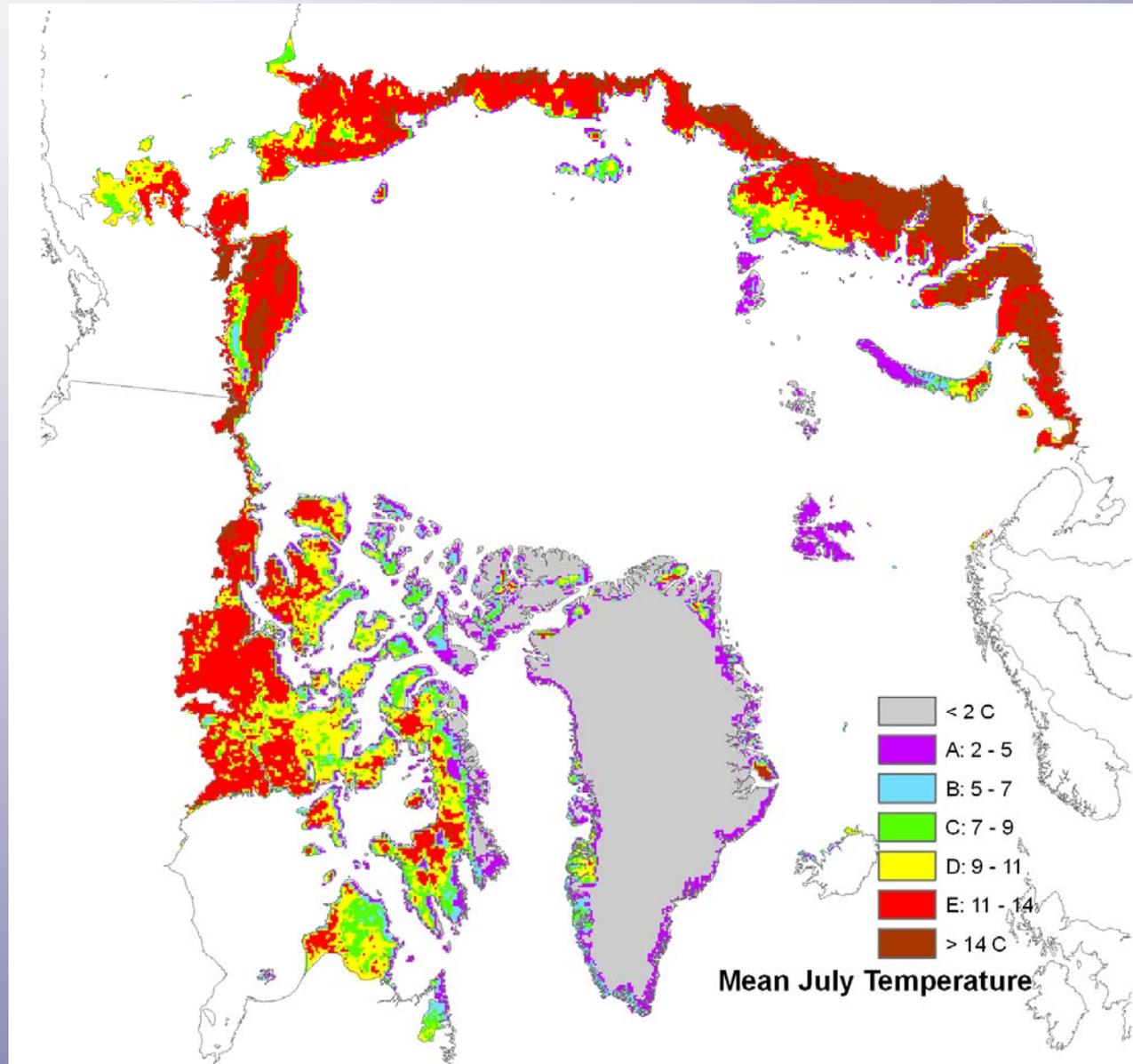
Summer Warmth Index (SWI) from AVHRR data:
ten year average (1982-1991) of sum of monthly means above 0° C

Colored according to CAVM Bioclimate Subzones A - E

Summer Warmth Index

- 0
- A: < 8
- B: 8 - 13
- C: 13 - 18
- D: 18 - 28
- E: 28 - 45
- > 45
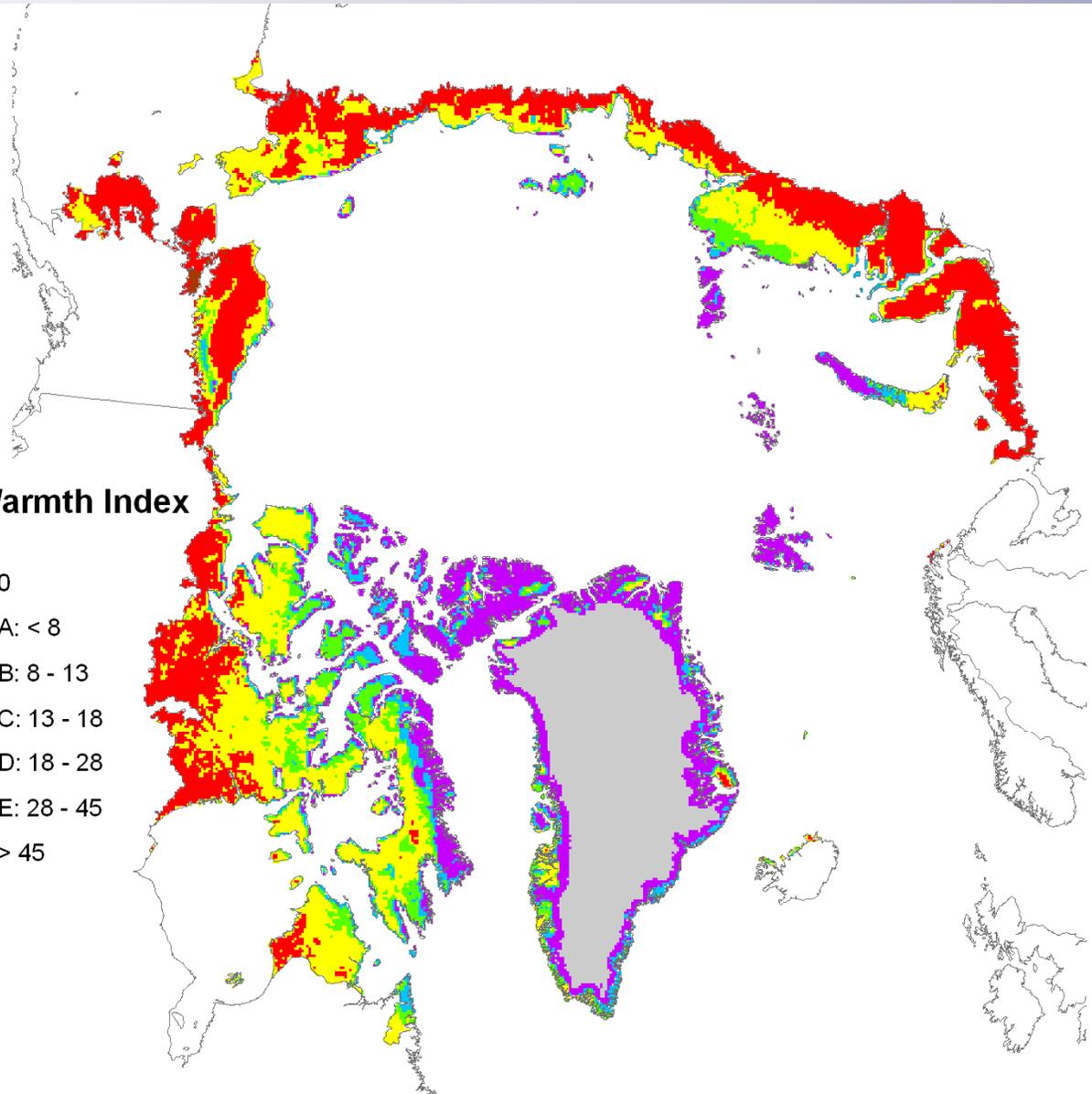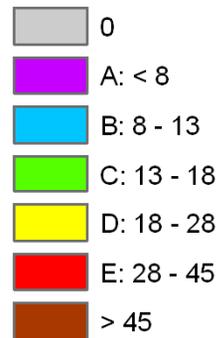
Mean AVHRR surface temperature, summarized by bioclimate subzone as mapped by the CAVM

Summer Warmth Index

Mean July Temperature
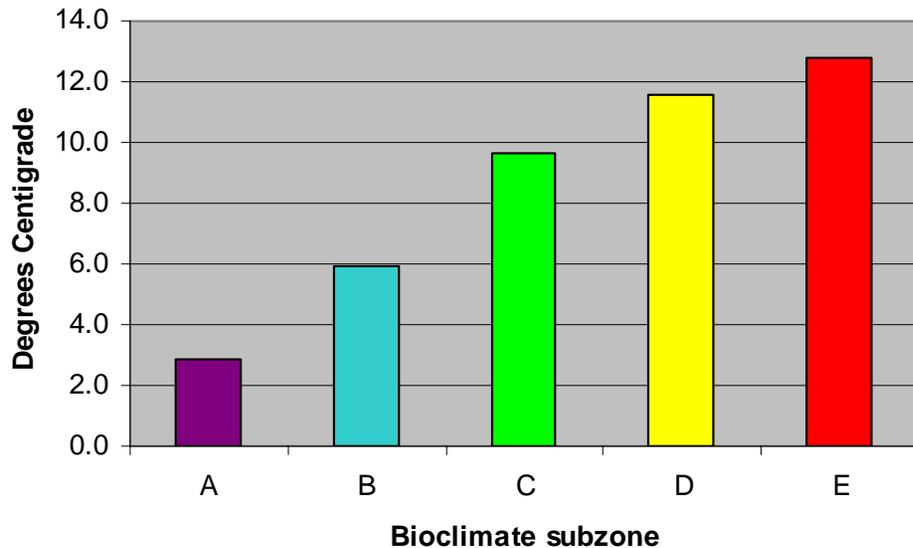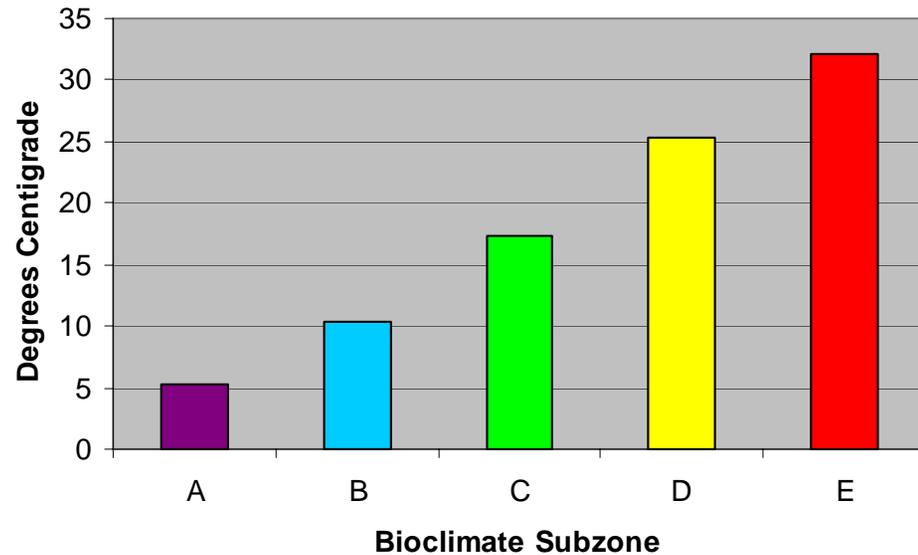
*Zone mean temperatures are buffered 1 pixel from coast to avoid including ocean data, and exclude areas mapped as mountains, glaciers and waterbodies.

Comparison between mean daily air temperatures measured at East Kuparuk (Franklin Bluffs) and surface temperatures retrieved from Modis on Terra at day overpass from 10 AM to 2 PM
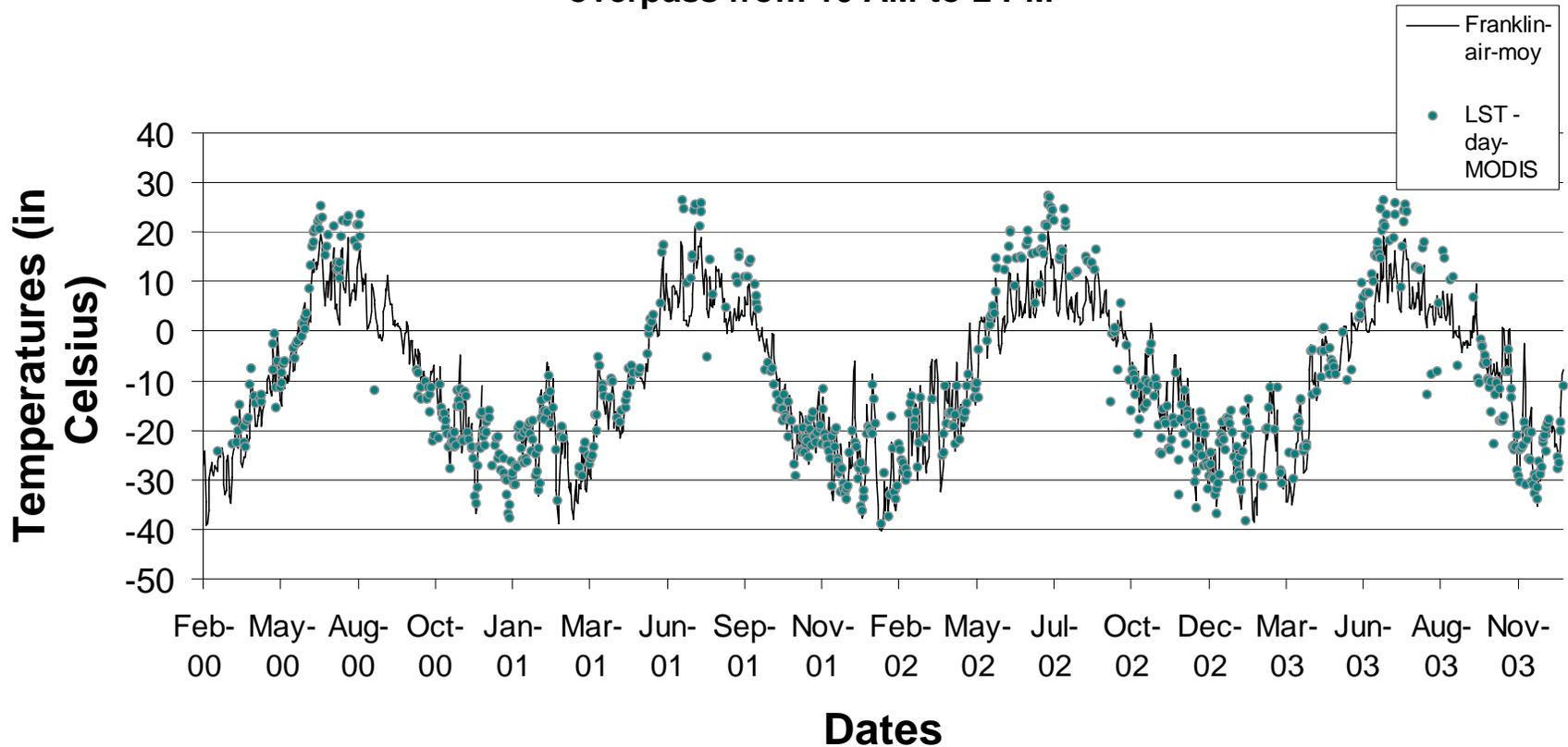
Correction factor needed between:
- kinetic surface temperature calculated from AVHRR satellite data
- air temperature at 1.5-2 m elevation measured at weather stations

Summer Warmth Index calculated from AVHRR surface temperature data, summarized by bioclimate subzone as mapped by the CAVM.

Brackets indicate range estimated by CAVM for subzone.

Summer Warmth Index

Degrees Centigrade (y-axis): 0, 5, 10, 15, 20, 25, 30, 35

Bioclimate Subzone (x-axis): A, B, C, D, E
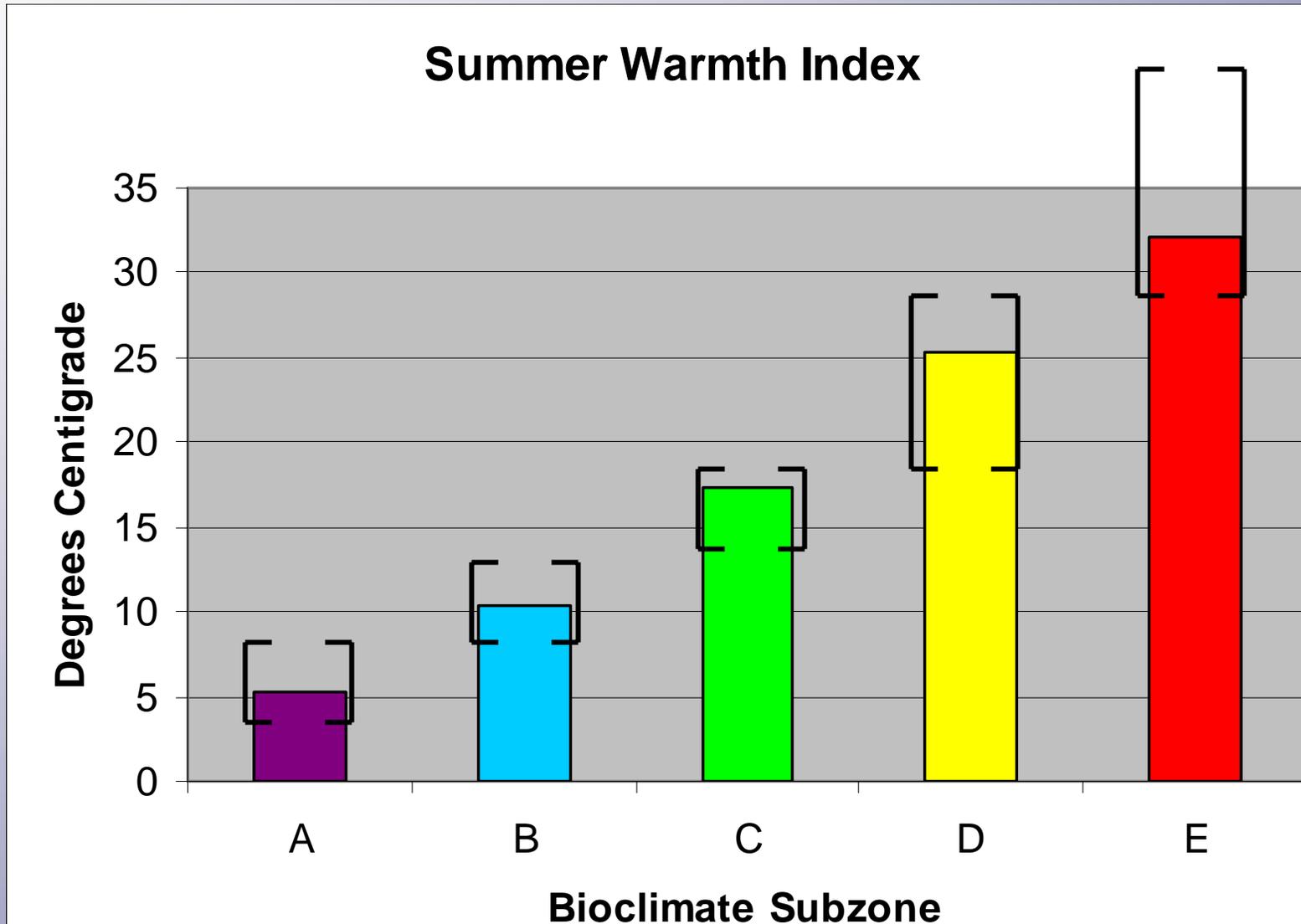
AVHRR Summer
Warmth Index (SWI)
compared to CAVM
zonal range.
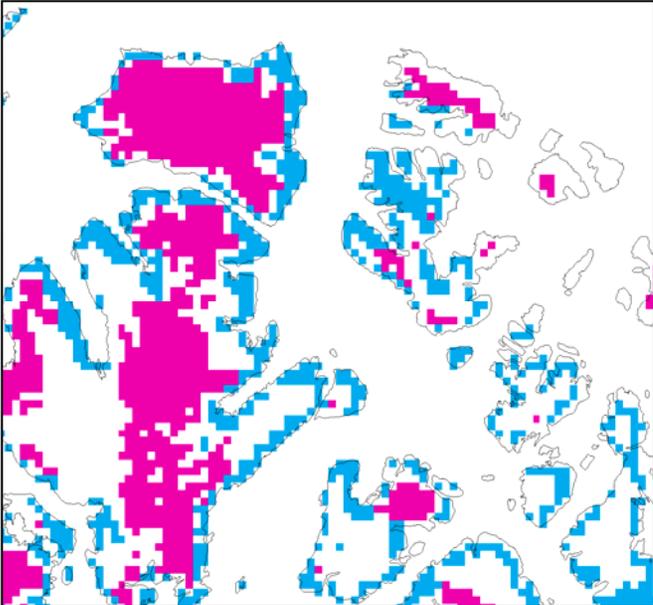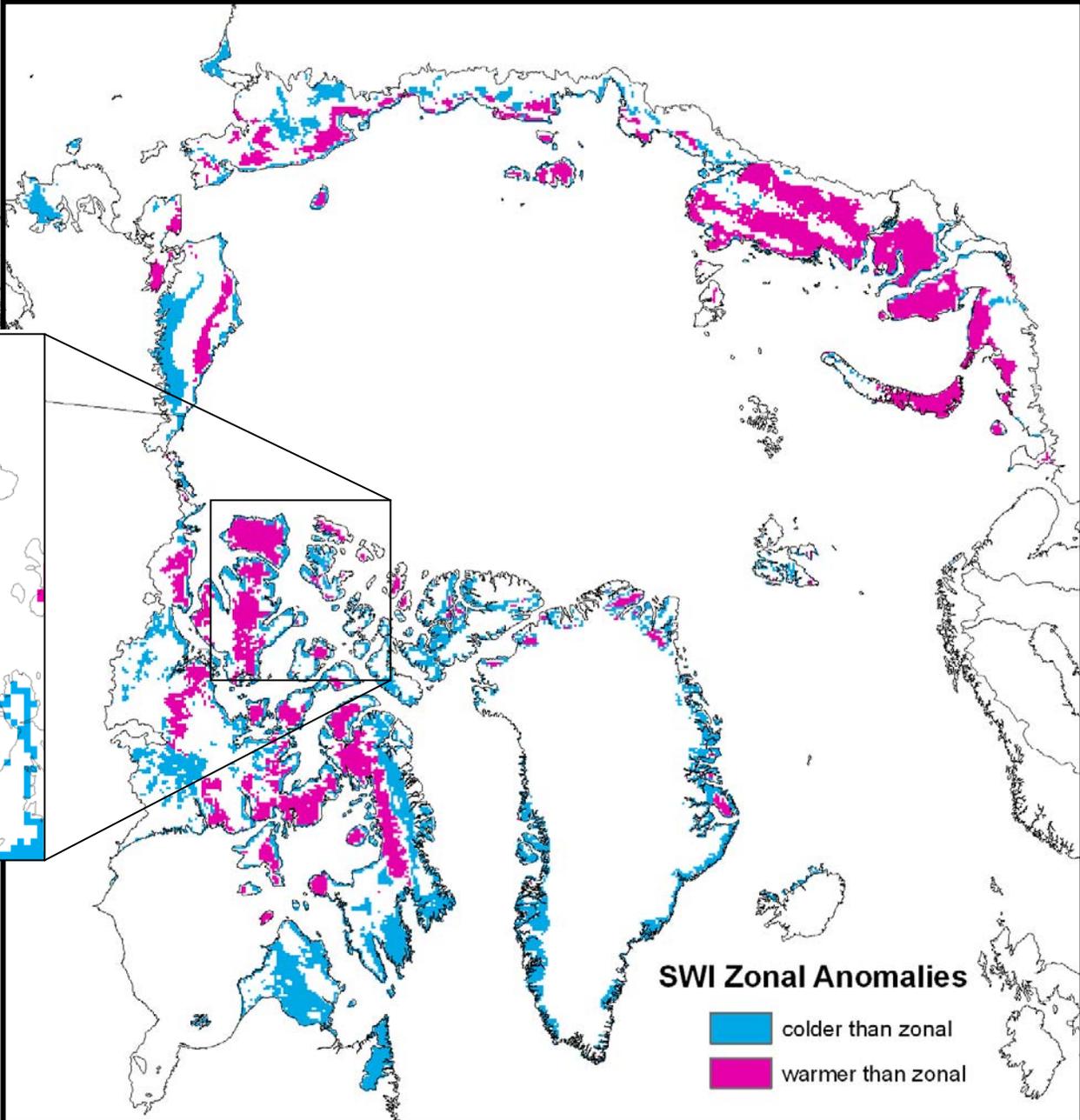
Areas colder than
mapped subzone are
blue, warmer than
mapped are pink.

SWI Zonal Anomalies

colder than zonal

warmer than zonal

Possible reasons for difference shown on map of anomalies:

1. Problems with the mapping of the bioclimate subzones
   - Cooler areas due to increased elevation
   - Errors due differences in scale of mapping vs. pixels
   - Other mapping errors

2. Problems with the temperature data

3. Changes in climate, where vegetation has not yet had time to adapt to climate changes

c) Summer Trend 1982–2003 60°N

180°E 90°E

°C/dec
>4.1
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
−1.8
−2.0

SWI Zonal Anomalies
colder than zonal
warmer than zonal

Trends in summer surface temperatures in the Arctic derived from AVHRR data

AVHRR Summer Warmth Index (SWI) compared to CAVM zonal range
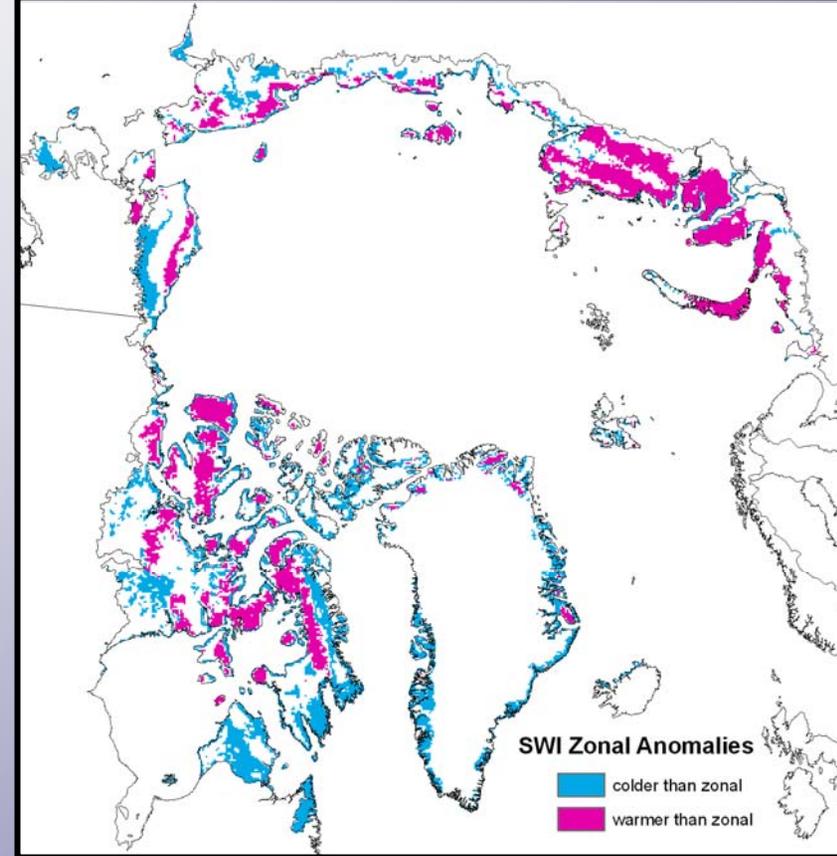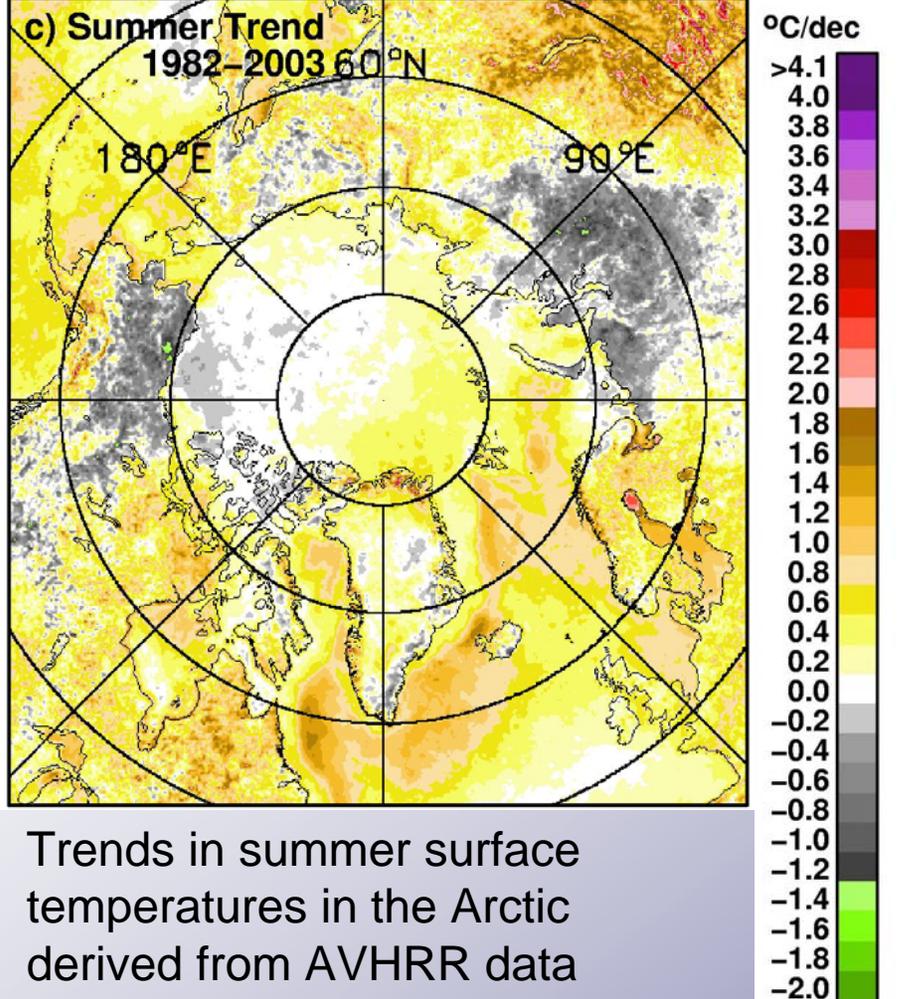
No evidence of warming climate as would be indicated by correlation between trend in summer temperatures and anomaly map.

Part II

Polar bear
hand & foot

My
hand

NDVI

⬜	< 0.03
🟪	0.03 - 0.14
🟦	0.14- 0.26
🟩	0.26 - 0.38
🟩	0.38- 0.5
🟨	0.5 - 0.56
🟧	0.56 - 0.62
🟥	> 0.62
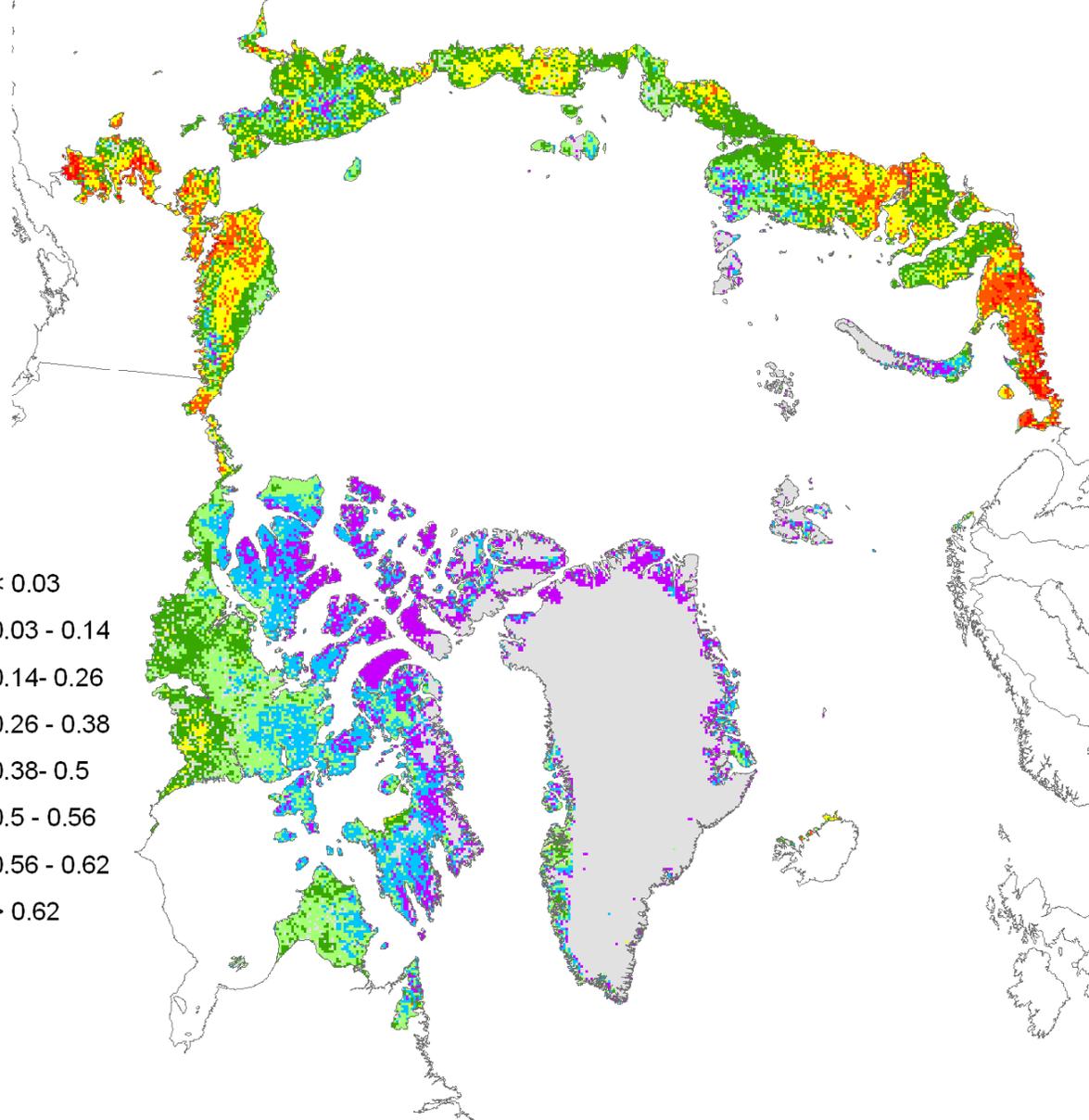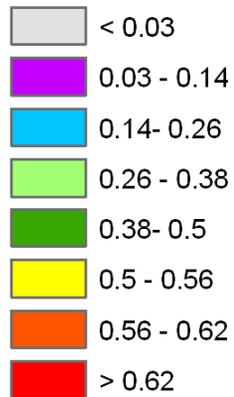
Maximum NDVI from AVHRR data 1993 & 1995 from the
Circumpolar Arctic Vegetation Map (CAVM Team, 2003)
Normalized Difference Vegetation Index = (NIR − R) / (NIR + R)

Regression of Mean July Temperature (MJT) and Summer Warmth Index (SWI) against NDVI (approx.100 random points) for 1993 & 1995

NDVI

MJT

$y = 0.0367x - 0.058$
$R^2 = 0.5737$

SWI

$y = 0.0127x - 0.0192$
$R^2 = 0.6583$

Degrees Centigrade
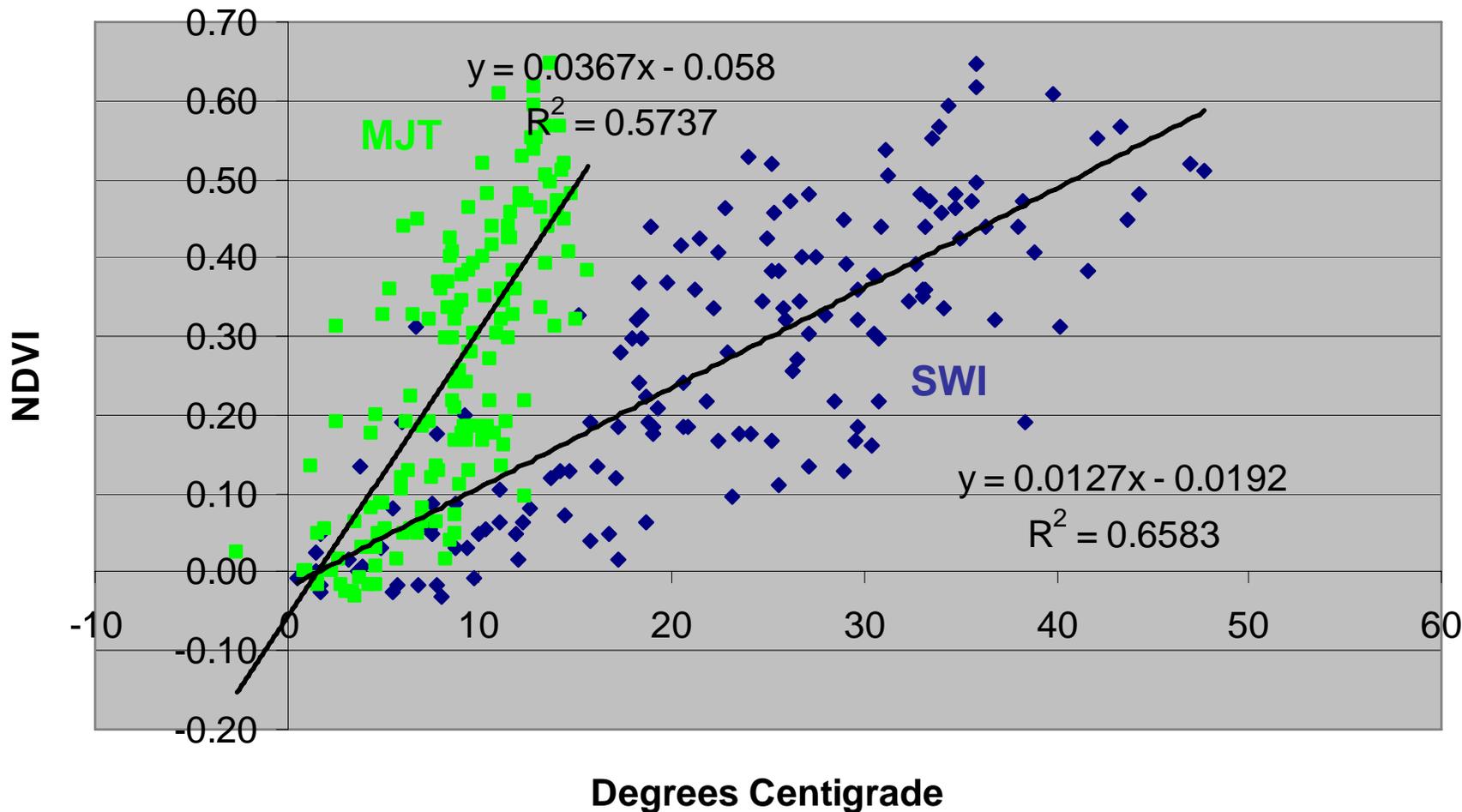
AVHRR Summer Warmth Index (SWI) compared to expected NDVI value as calculated by regression equation.
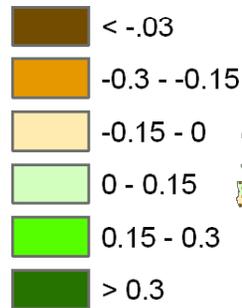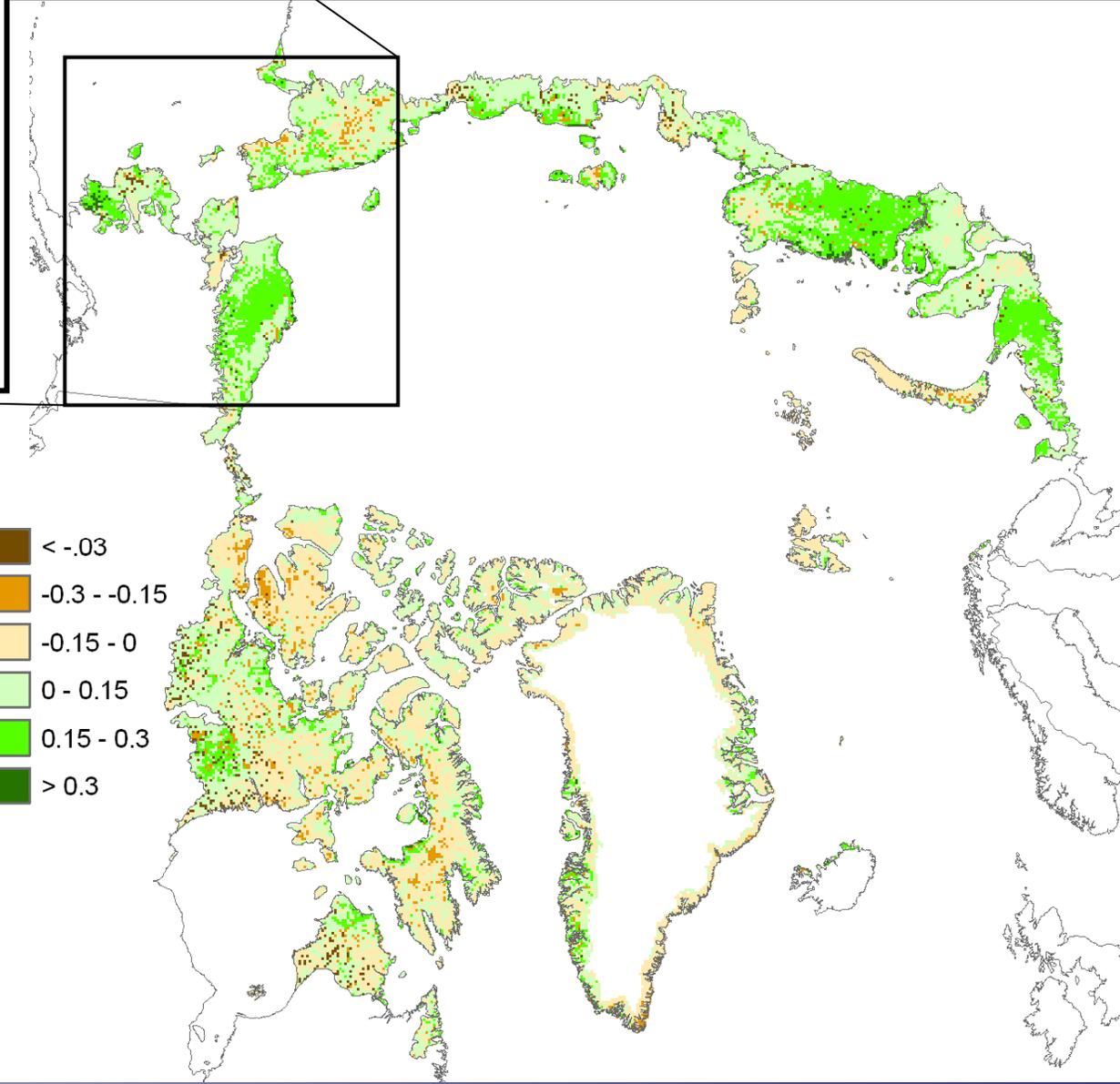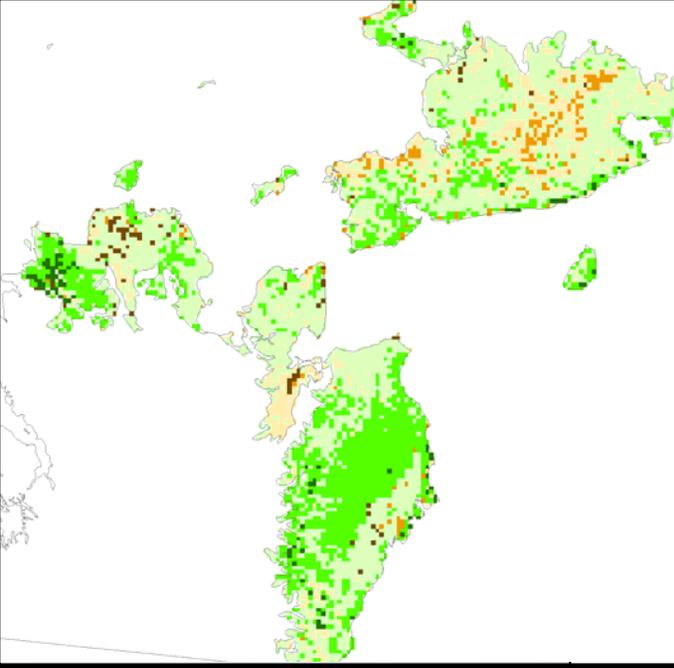
Areas with less NDVI than expected are brown, areas with more NDVI than expected are green.

	< -.03
	-0.3 - -0.15
	-0.15 - 0
	0 - 0.15
	0.15 - 0.3
	> 0.3

Charts of anomalies between AVHRR Summer Warmth Index (SWI) and expected NDVI value as calculated by regression equation.
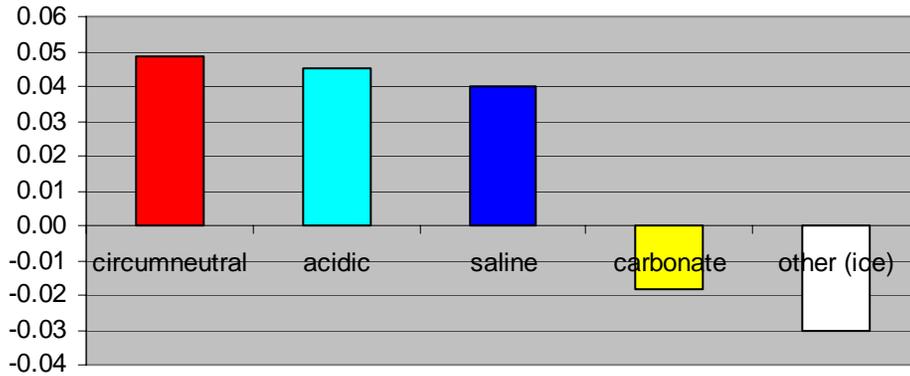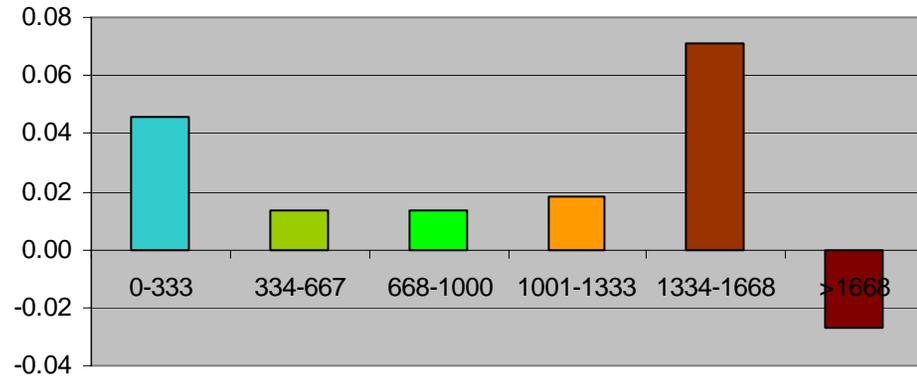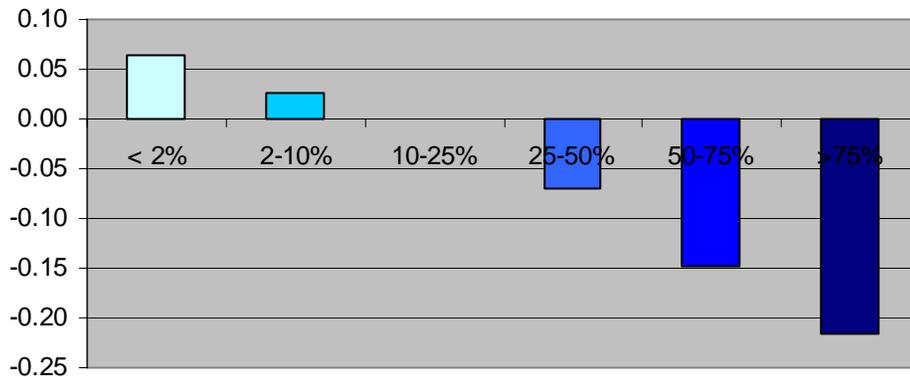
CAVM attribute classes with more NDVI than predicted by the equation are above zero, classes with less NDVI than predicted are below zero.

Floristic provinces
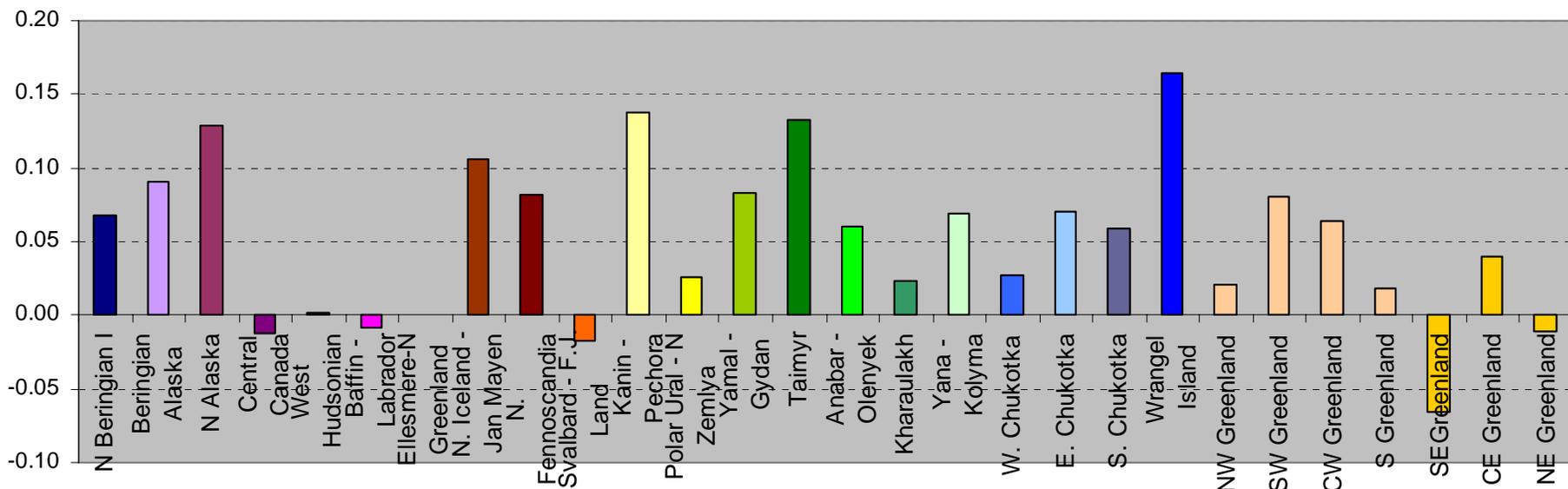
Vegetation types
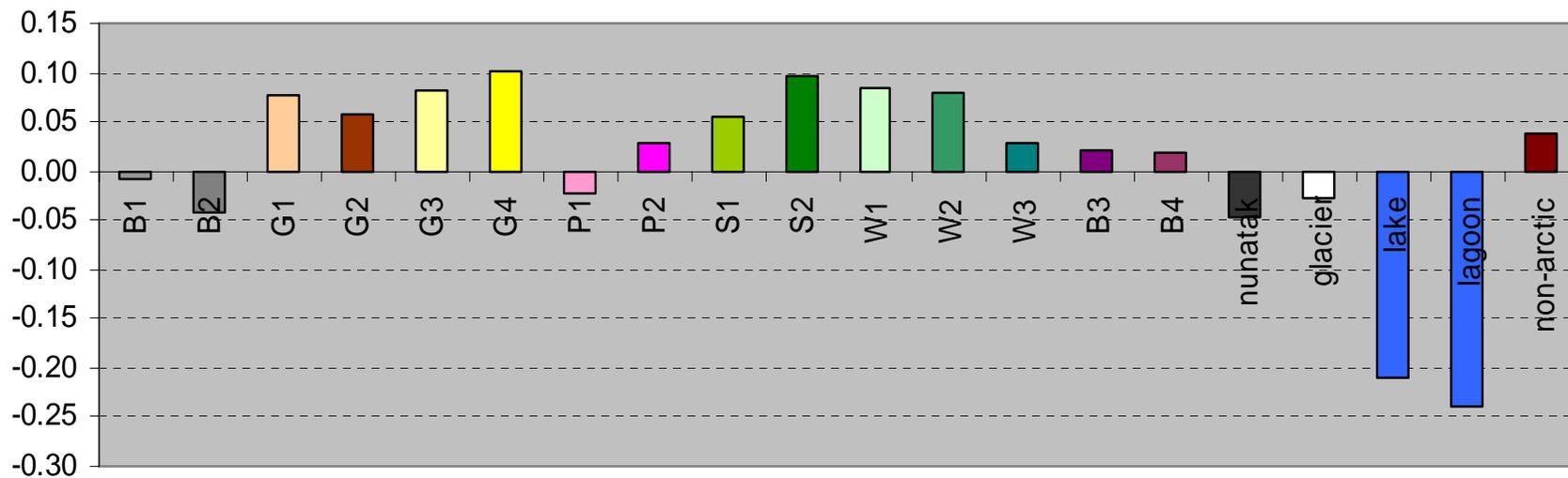
Summary

Analysis of AVHRR kinetic surface temperature data and CAVM bioclimate subzones
- Good correspondence between means
- Can be improved by using temperature data to map refine resolution of bioclimate subzones, particularly for islands
- Some areas that do not correspond need further investigation

Analysis of AVHRR kinetic surface temperature data and AVHRR NDVI
- Positive relationship between surface temperature and NDVI
- Areas with higher than expected NDVI include:
    Shrubby hills
    Productive coastal areas
- Areas with lower than expected NDVI include:
    Glaciated areas
    Carbonate substrates
    High mountains
    Lakes

Acknowledgements

- Josefino Comiso for his data and advice
- Dave Verbyla & Hilmar Maier for help reading temperature data into ArcMap
- Vladimir Romanovsky for discussion about estimating ground surface temperature from air temperature
- Sam Dashevsky his review of this presentation

Citations

Edlund, S. A., 1990: Bioclimatic zones in the Canadian Arctic Archipelago. *In* Harrington, C. R. (ed.), *Canada's missing dimension - science and history in the Canadian Arctic Islands*. Ottawa: Canadian Museum of Nature, 421-441.

Elvebakk, A., Elven, R., and Razzhivin, V. Y., 1999: Delimitation, zonal and sectorial subdivision of the Arctic for the Panarctic Flora Project. *In* Nordal, I. and Razzhivin, V. Y. (eds.), *The Species Concept in the High North - A Panarctic Flora Initiative*. Oslo: The Norwegian Academy of Science and Letters, 375-386.

Comiso, J. C., 2003: Warming trends in the Arctic from clear sky satellite observations. *Journal of Climate,* 16: 3498-3510.

CAVM Team, 2003: Circumpolar Arctic Vegetation Map, scale 1:7 500 000, *Conservation of Arctic Flora and Fauna (CAFF) Map No. 1*. Anchorage, Alaska: U.S. Fish and Wildlife Service.

Raynolds, M. K., Walker, D. A., and Maier, H. A., 2006: Alaska Arctic Tundra Vegetation Map. Scale 1:4,000,000, *Conservation of Arctic Flora and Fauna Map No. 2*. Anchorage, AK: U.S. Fish & Wildlife Service.

Young, S. B., 1971: The vascular flora of St. Lawrence Island with special reference to floristic zonation in the Arctic Regions. *Contributions from the Gray Herbarium,* 201: 11-115.

Questions?

Conclusions

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