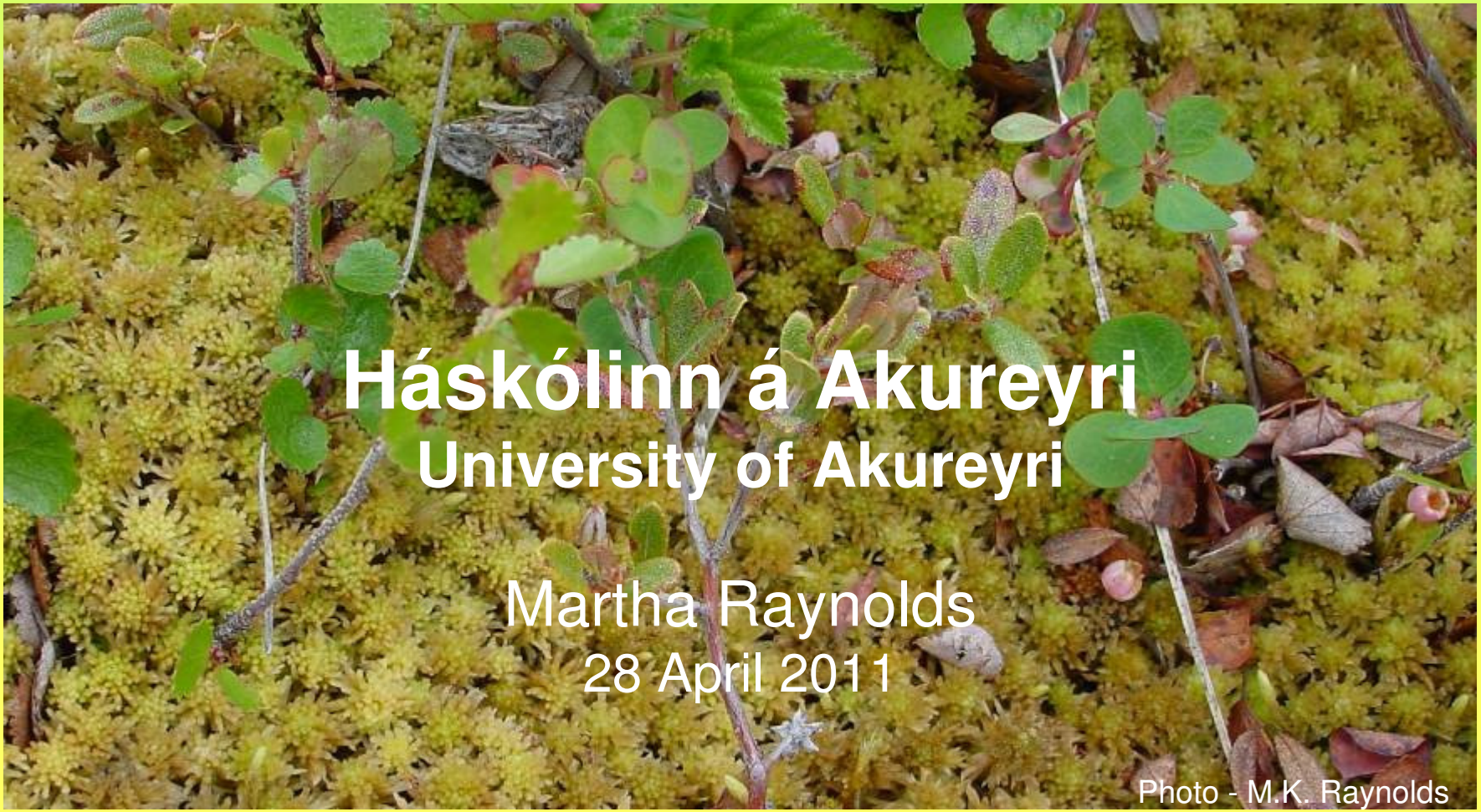
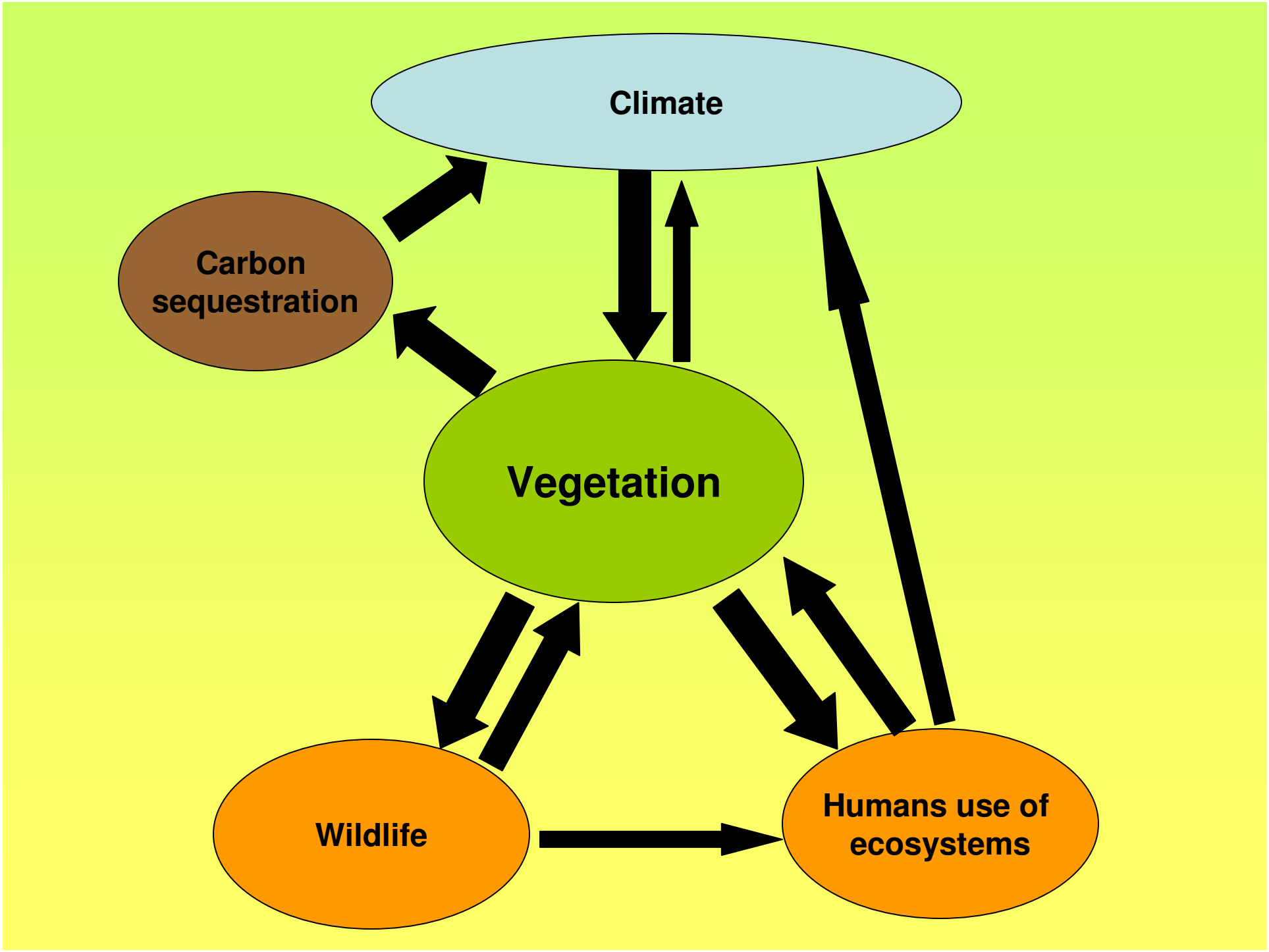
Searching for the response of northern vegetation to climate change

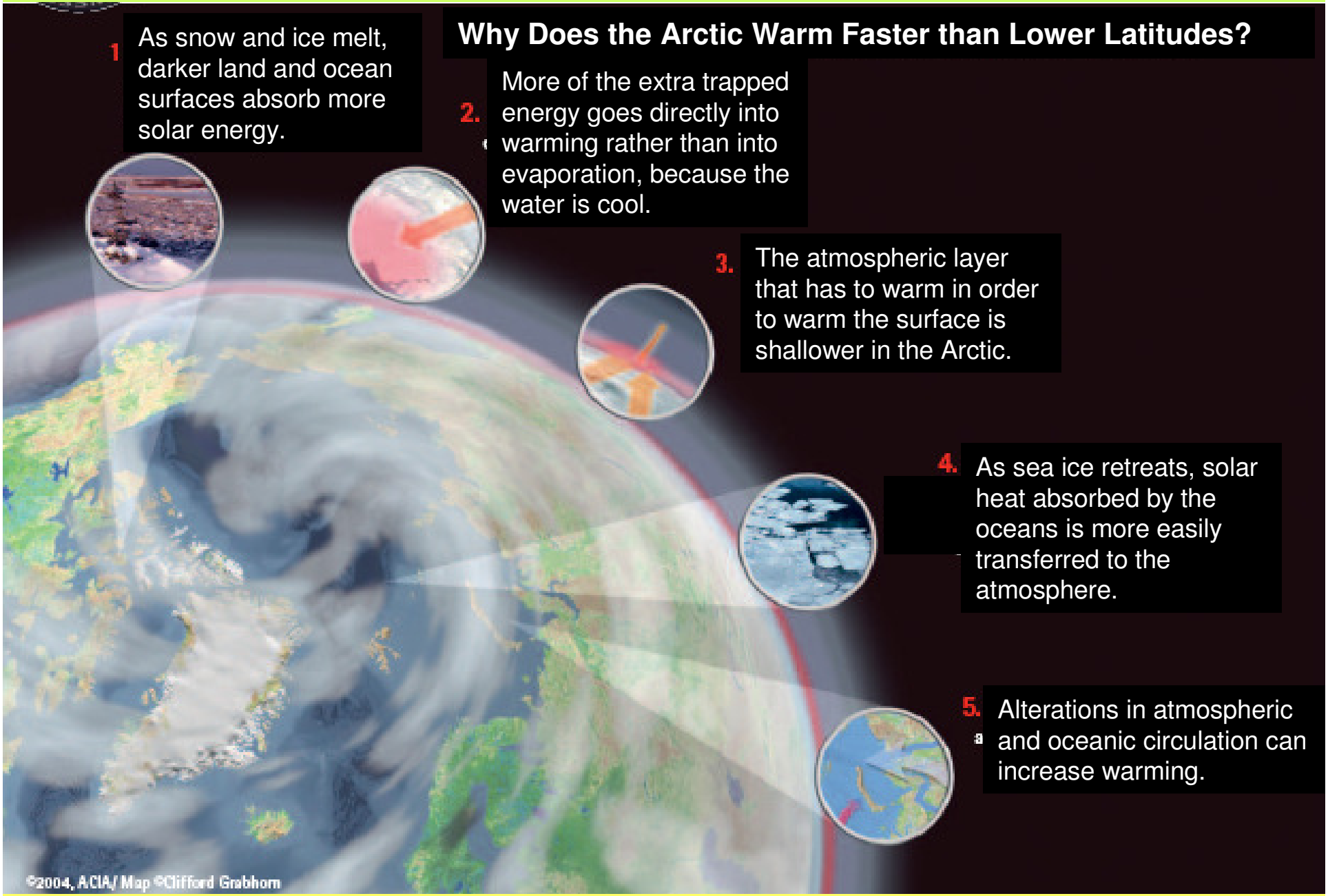



Climate
Carbon sequestration
Vegetation
Wildlife
Humans use of ecosystems

Outline of presentation

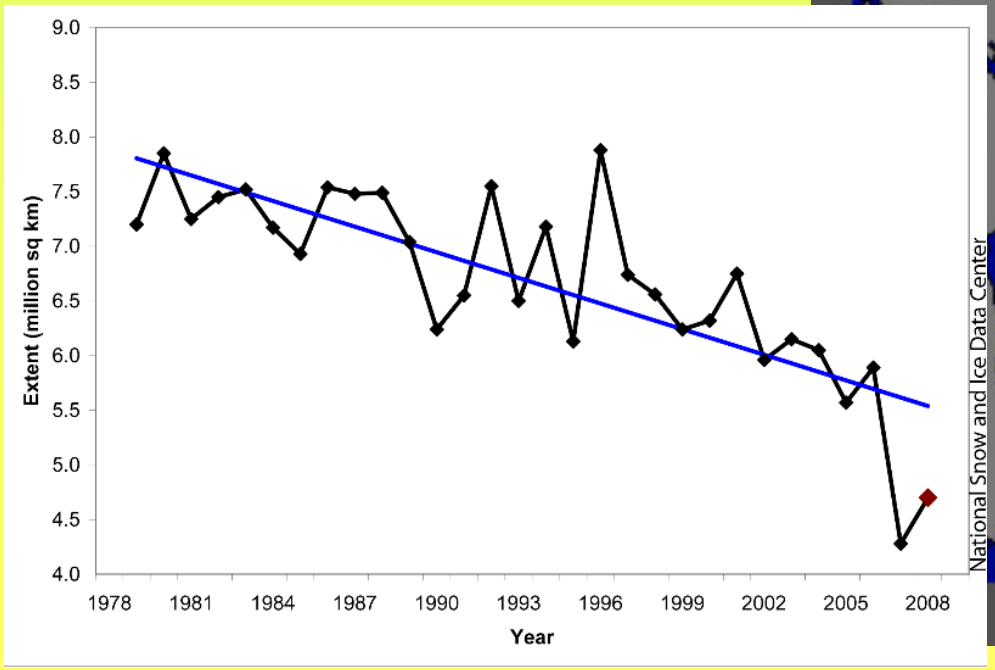
- Overview of climate changes in North
- Natural variation in northern vegetation in response to climate
- Experimental response of vegetation to warming
- Changes in vegetation seen on the ground
- Changes seen from satellite data
- Summary of change in northern vegetation

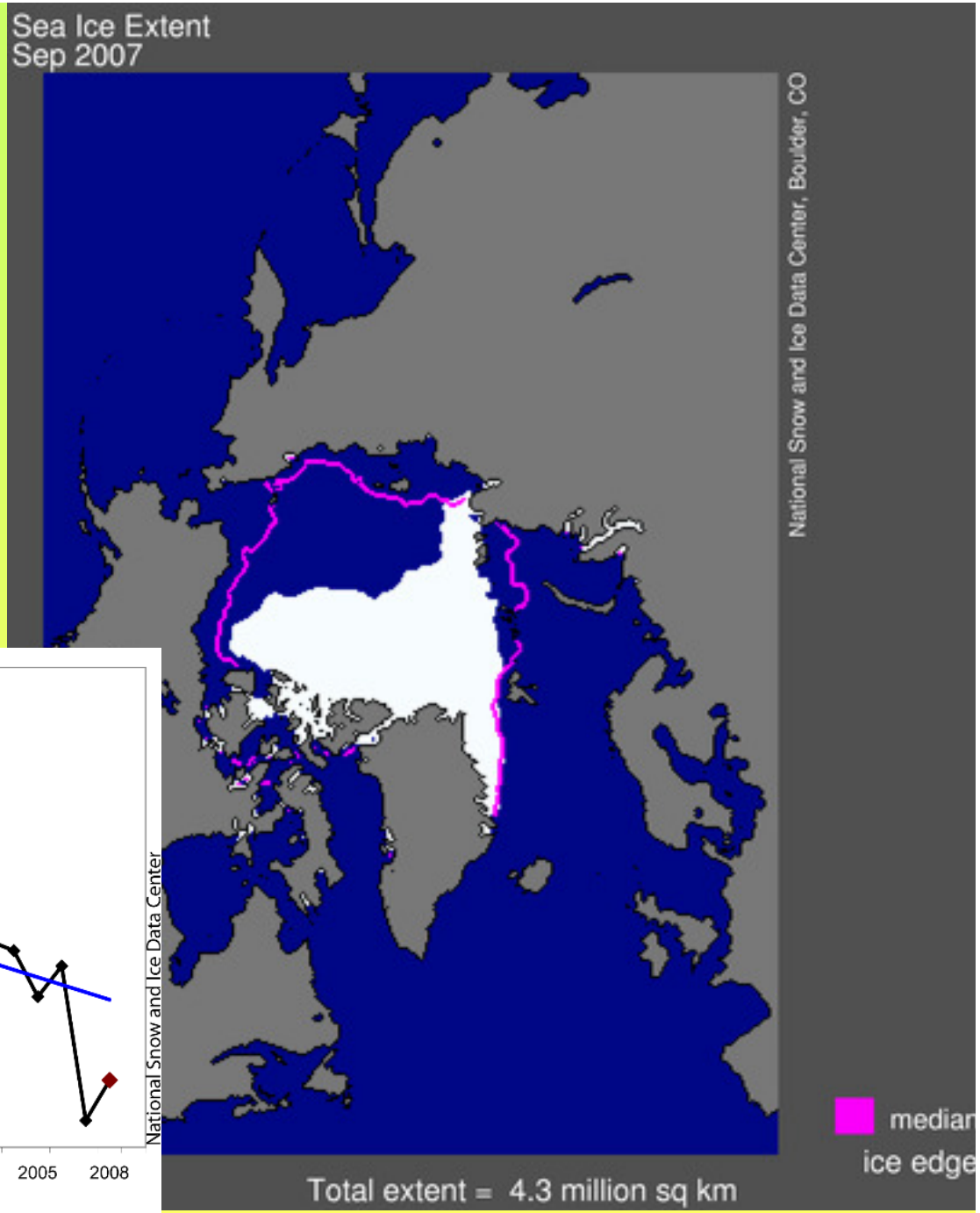
Why Does the Arctic Warm Faster than Lower Latitudes?



Arctic Climate Impact Assessment, 2004

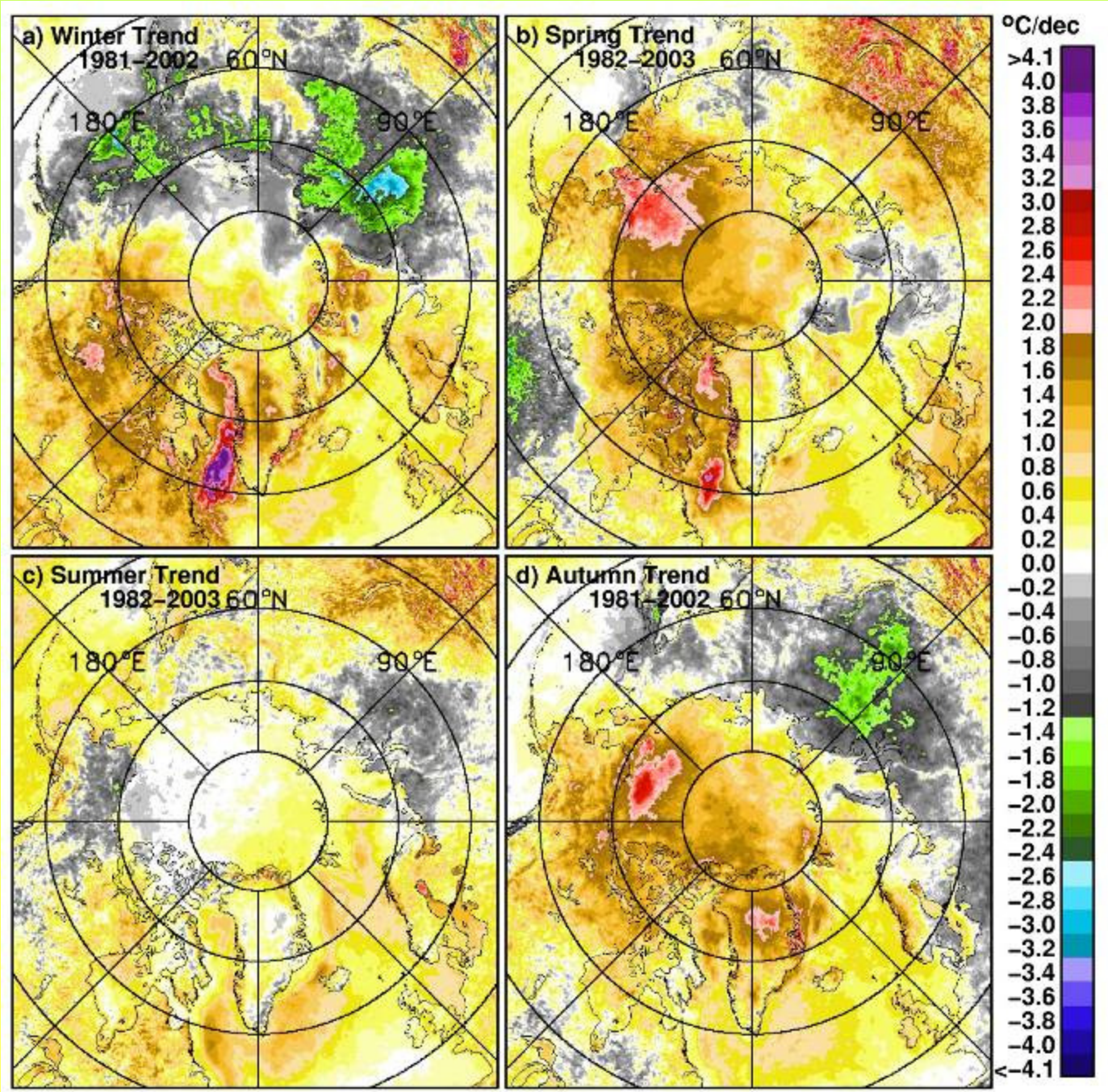
Decreasing Arctic sea ice





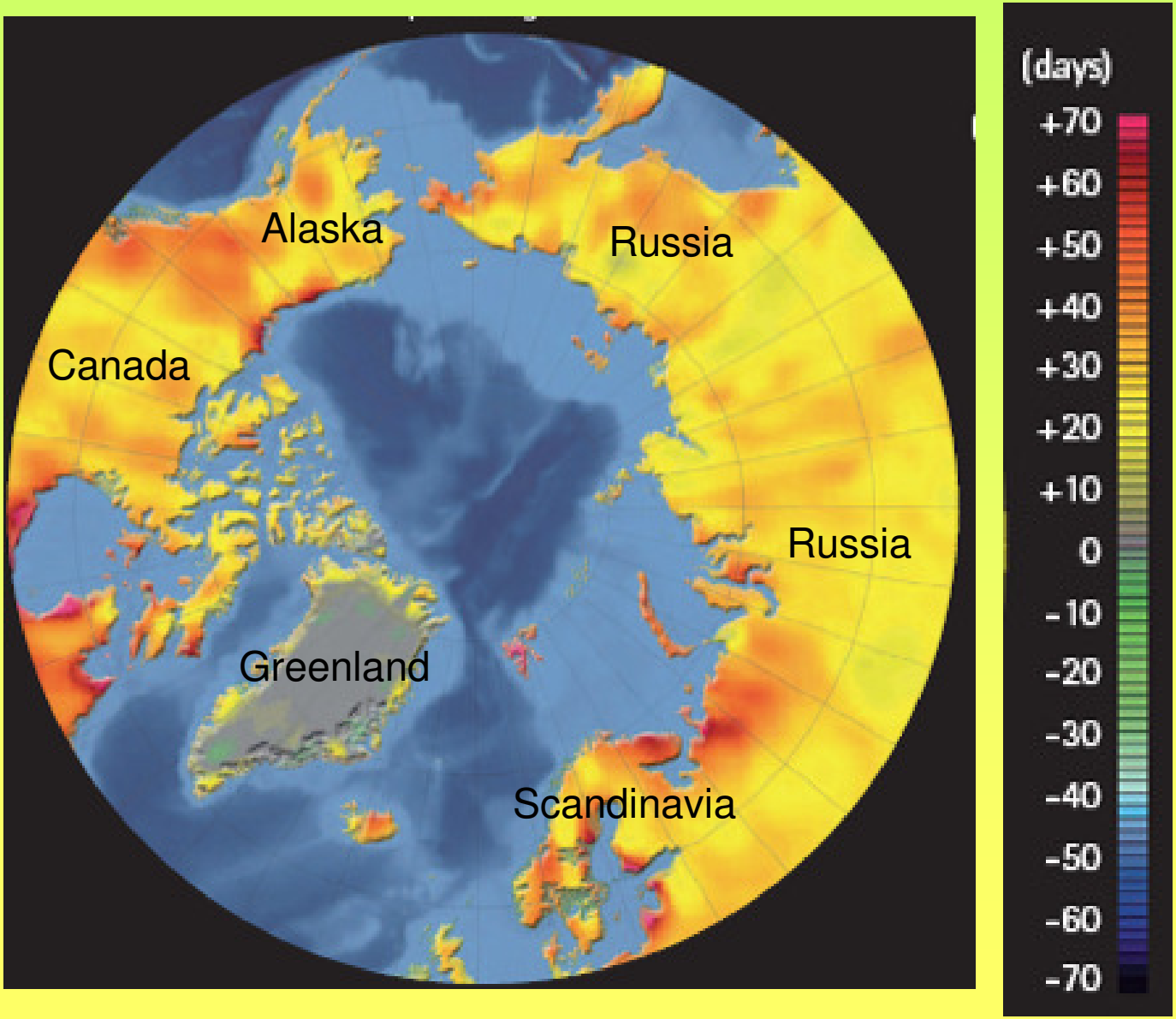
NASA National Snow and Ice Data Center

Seasonal trends in surface temperature 1981-2003



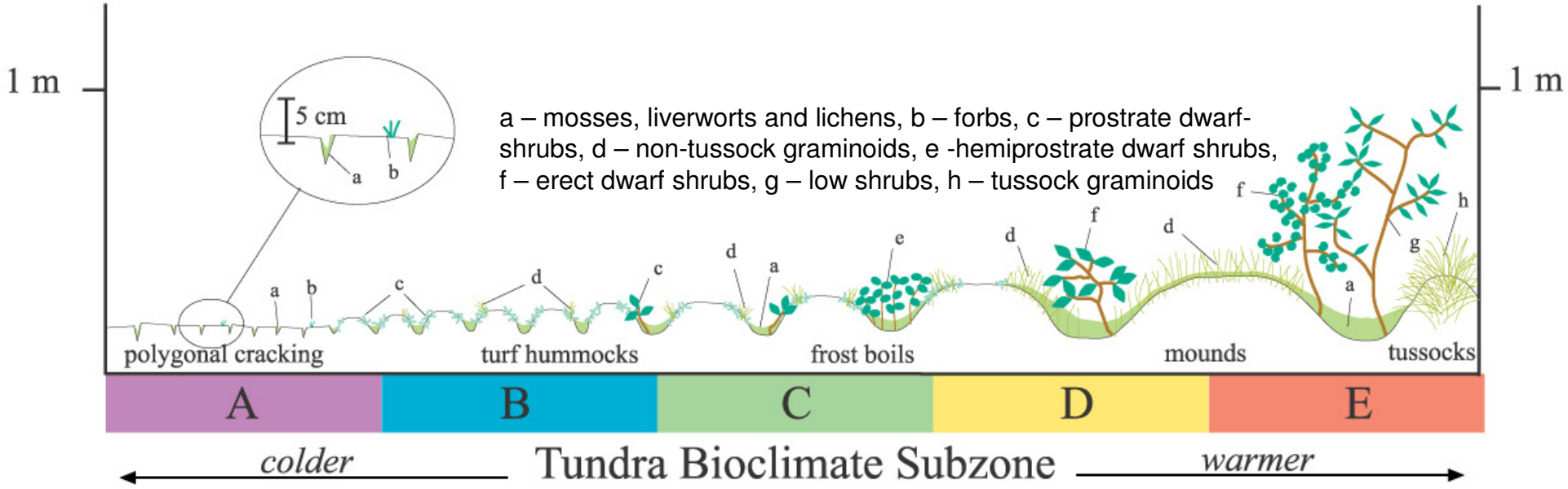
Comiso 2003 J. of Climate

Projected Change in Growing Season Length by 2070-2090 (minimum temperature greater than O°C



Arctic Climate Impact Assessment, 2004


Androsace chamaejasme
Photo - M.K. Raynolds
Rock jasmine



Raynolds et al. 2006 Remote Sensing of Environment

Plant physiognomy occurring in different Tundra Bioclimate Subzones

- A – mosses, liverworts and lichens with some grasses and forbs
- 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

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 (°C)	Vegetation
A	0-3	< 5% cover, < 2 cm tall
B	3-5	5-25 % cover, < 5 cm tall
C	7-9	25-50 % cover, < 15 cm tall
D	9-11	50-80 % cover, < 30 cm tall
E	11-13	80-100 % cover, < 80 cm tall

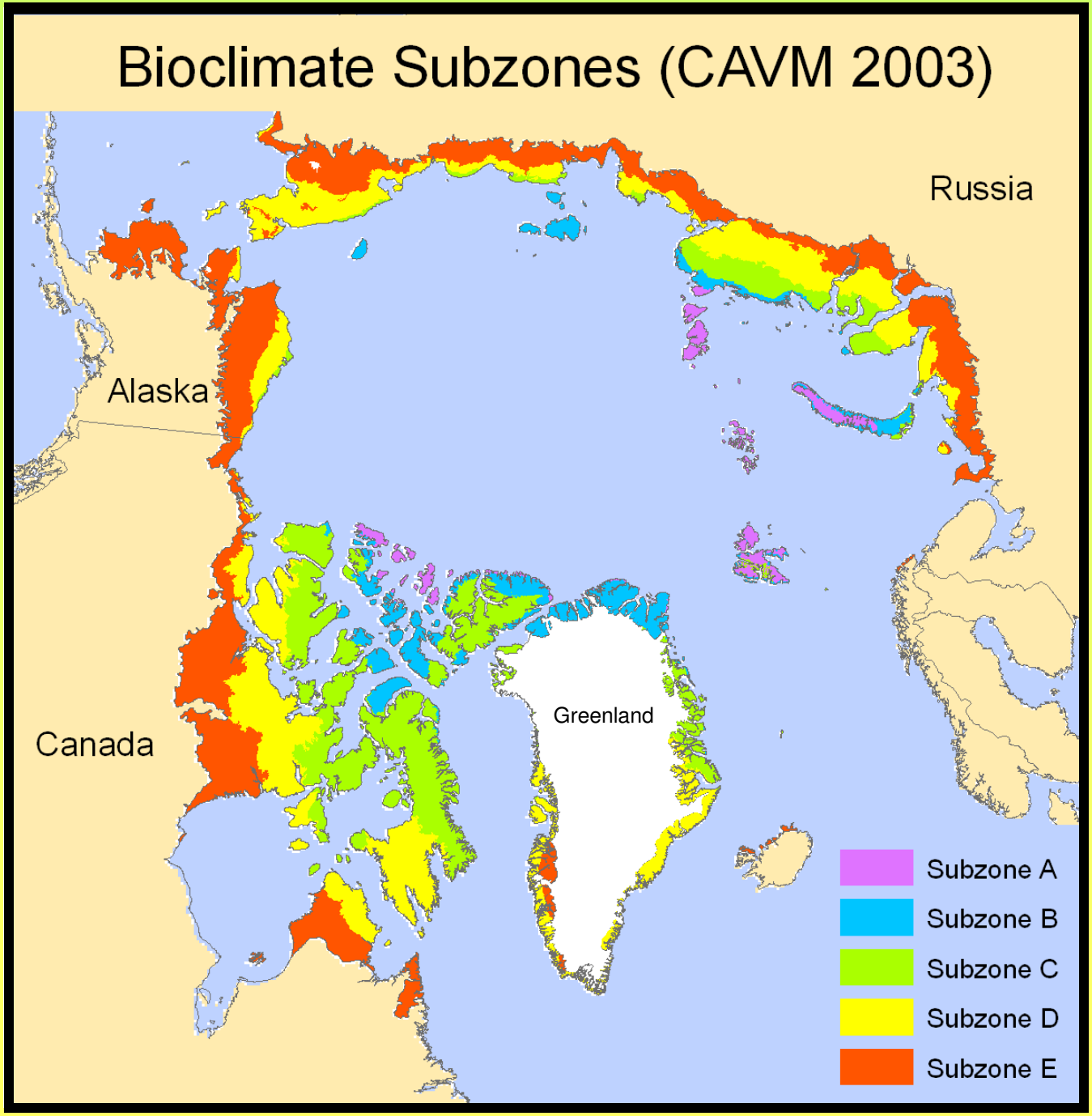
Subzone A, Isachsen, Ellef Ringnes Island

photo by M. K. Raynolds

Subzone E, Sagwon, North Slope Alaska

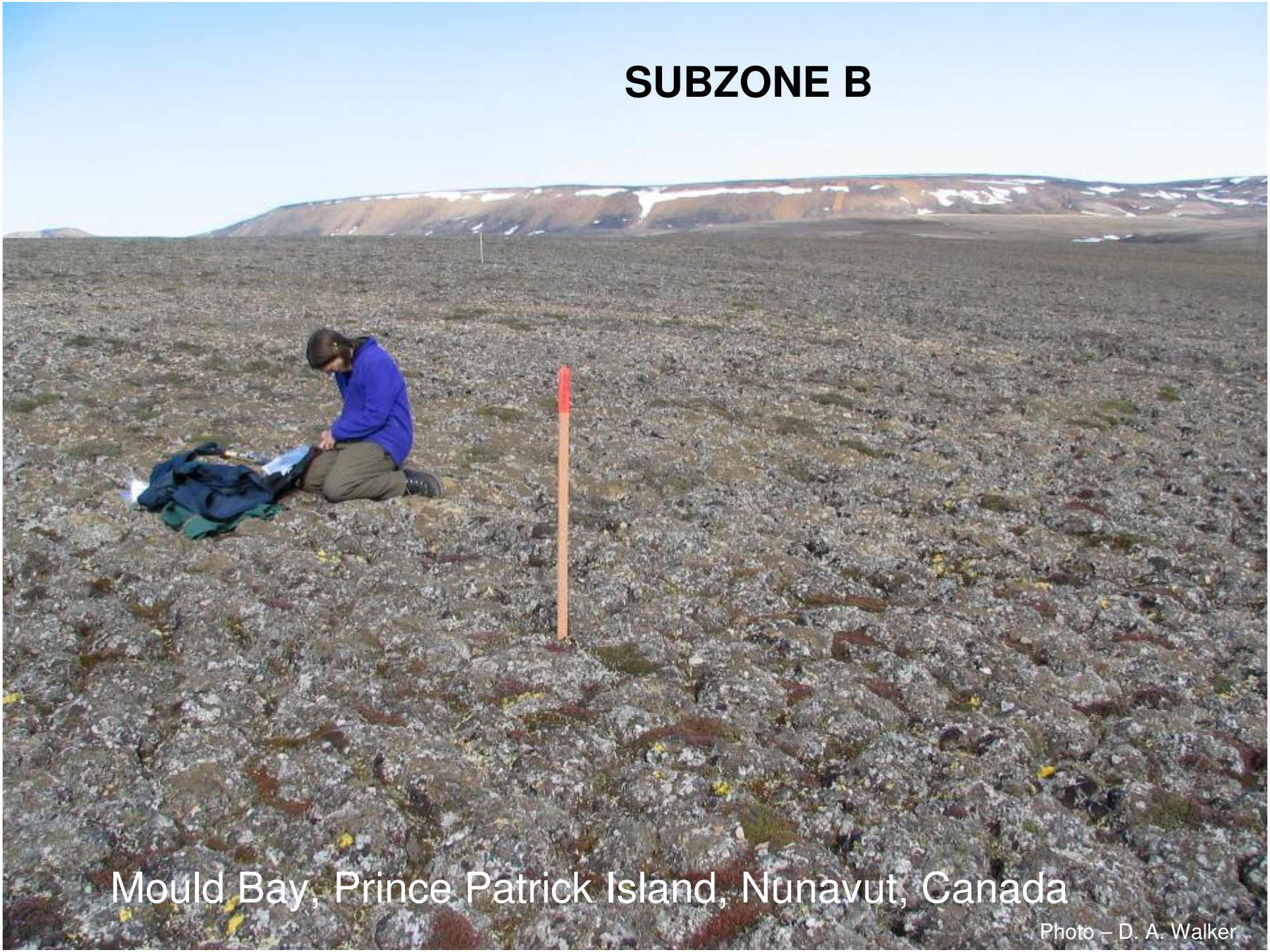
photo by D. A. Walker

Tundra Bioclimate Subzones from the Circumpolar Arctic Vegetation Map



(CAVM Team 2003)


SUBZONE A
Isachsen, Prince Patrick Island, Nunavut, Canada
Photo – M.K. Raynolds

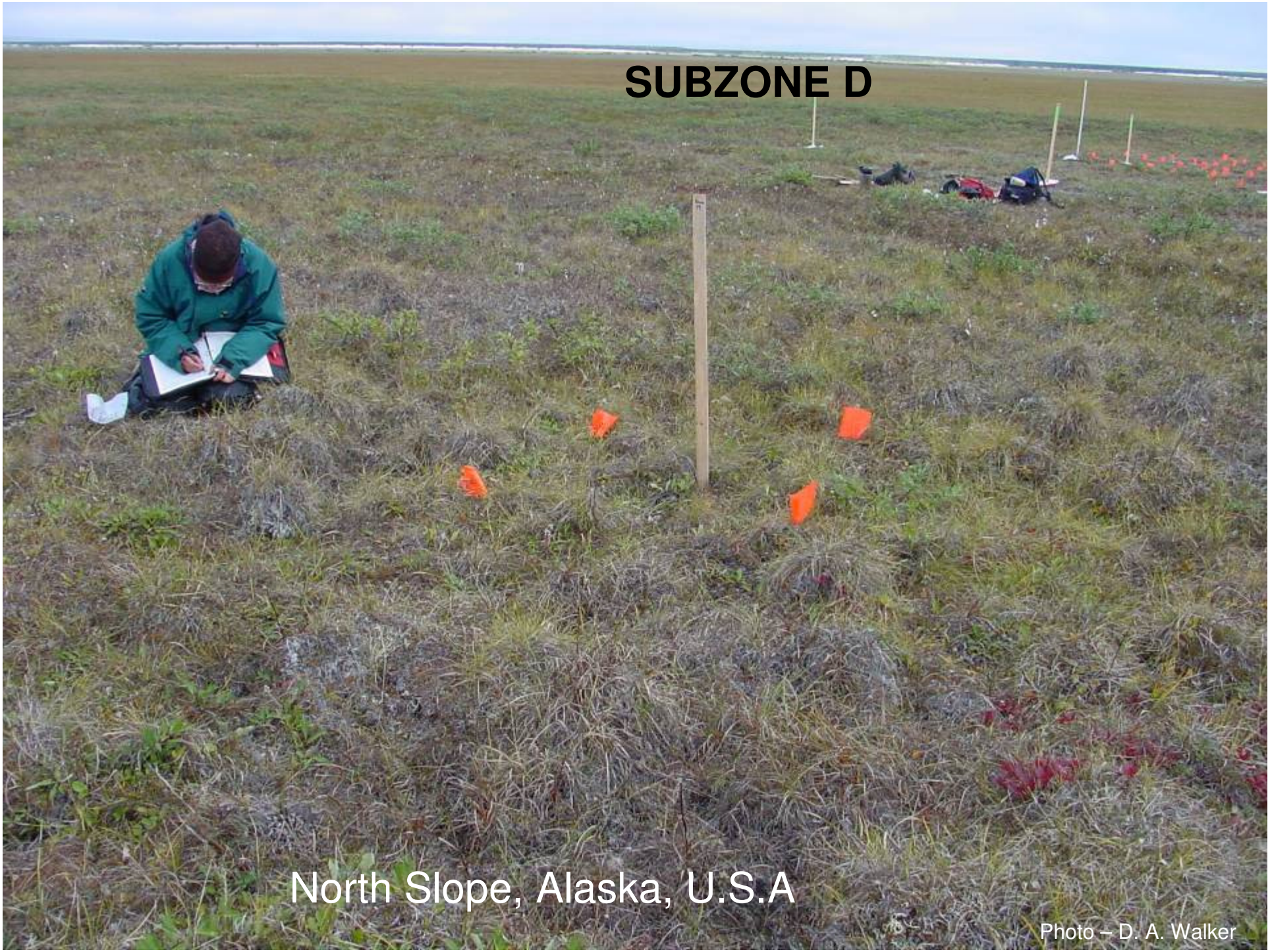

SUBZONE B
Mould Bay, Prince Patrick Island, Nunavut, Canada
Photo – D. A. Walker


SUBZONE B
Mould Bay, Prince Patrick Island, Nunavut, Canada
Photo – D. A. Walker

SUBZONE C

Green Cabin, Banks Island, Nunavut, Canada

Photo – D.A. Walker


SUBZONE D
North Slope, Alaska, U.S.A
Photo – D. A. Walker


SUBZONE E
North Slope, Alaska, U.S.A
Photo – D. A. Walker


BOREAL
Cherskii, Yakutia, Russia
Photo – D. A. Walker


Epilobium latifolium
Photo - M.K. Raynolds
River beauty

Toolik Field Station, North Slope, Alaska

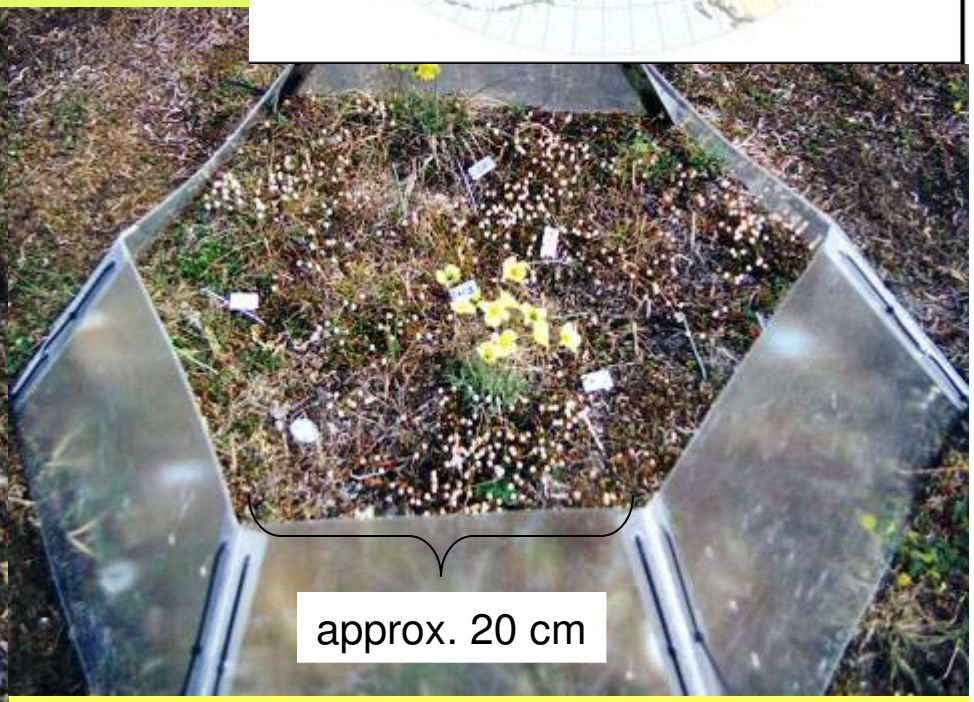
Shrub height (*Betula nana*)

Outside greenhouses	0.5 m
Warmed greenhouse	>1 m
Warmed & fertilized	2 m

The International Tundra Experiment (ITEX)

Community changes in ITEX experiment after 6 years – Walker et al. 2006 PNAS

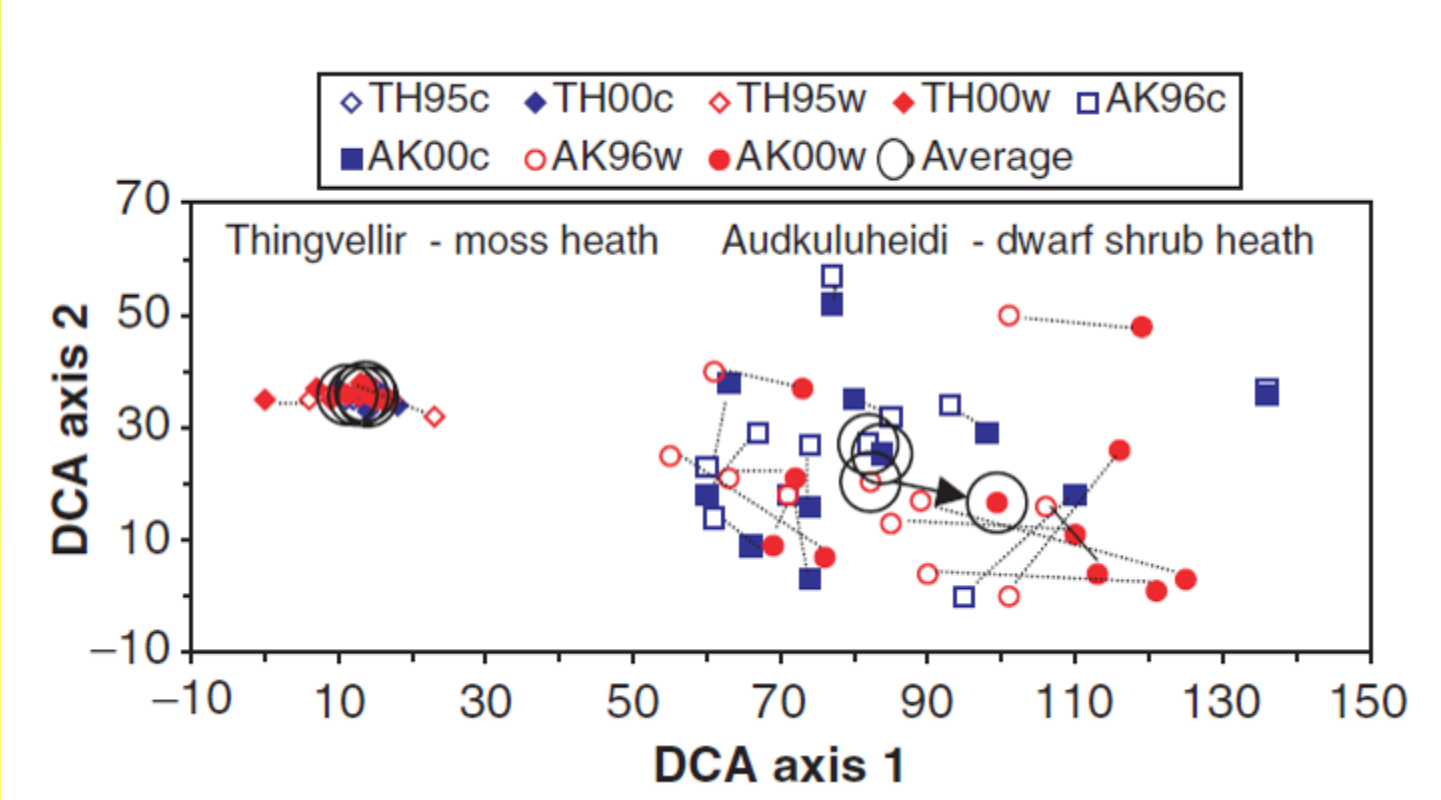
Control



Open-top chamber

Results from Iceland ITEX sites

1995-2000
Þingvellir – no change in moss heath
Auðkúluheiði – changes in shrub heath
•Increase in shrub cover and height (e.g. *Betula nana, Empetrum hermaphroditum*)
•Decrease in moss (*Racomitrium lanuginosum*)



Jonsdottir et al. 2005 Global Change Biology


Dryas octopetala
Photo - M.K. Raynolds
Mountain avens

“The tundra region is projected to shrink by 33 - 44% by the end of this century”

Feng et al 2011. Climate Dynamics, “Evaluating observed and projected future climate changes for the Arctic using the Köppen-Trewartha climate classification”

Does this mean that trees will be galloping across the tundra?

The important distinction is that the area with ***Köppen-Trewartha tundra climate classification*** is projected to shrink this quickly

- Forests will not cover 33-44% of tundra by the end of this century

Tree line changes Yukon, Canada

(based on *Picea glauca* tree-ring studies to age trees)

- Tree line elevation and stand density increased significantly during the early to mid 20th century.
- Spruce advanced rapidly on south-facing slopes and tree line rose 65–85 m in elevation.
- Tree line did not advance on north-facing slopes, but stand density increased 40–65%.

Danby & Hik 2007, Journal of Ecology

Comparison of treeline changes in different parts of Alaska

- The mean lag between initiation of recruitment and forest development was estimated at approximately 200 years
- Continued advance of white spruce forests is the most likely future scenario
- Variability due to limitation of spruce establishment in highly permafrost-affected sites, changes in seed dispersal and early establishment, and recent changes in the growth responses of individual trees to temperature.

Lloyd 2005, Ecology

Increase in arctic shrubs

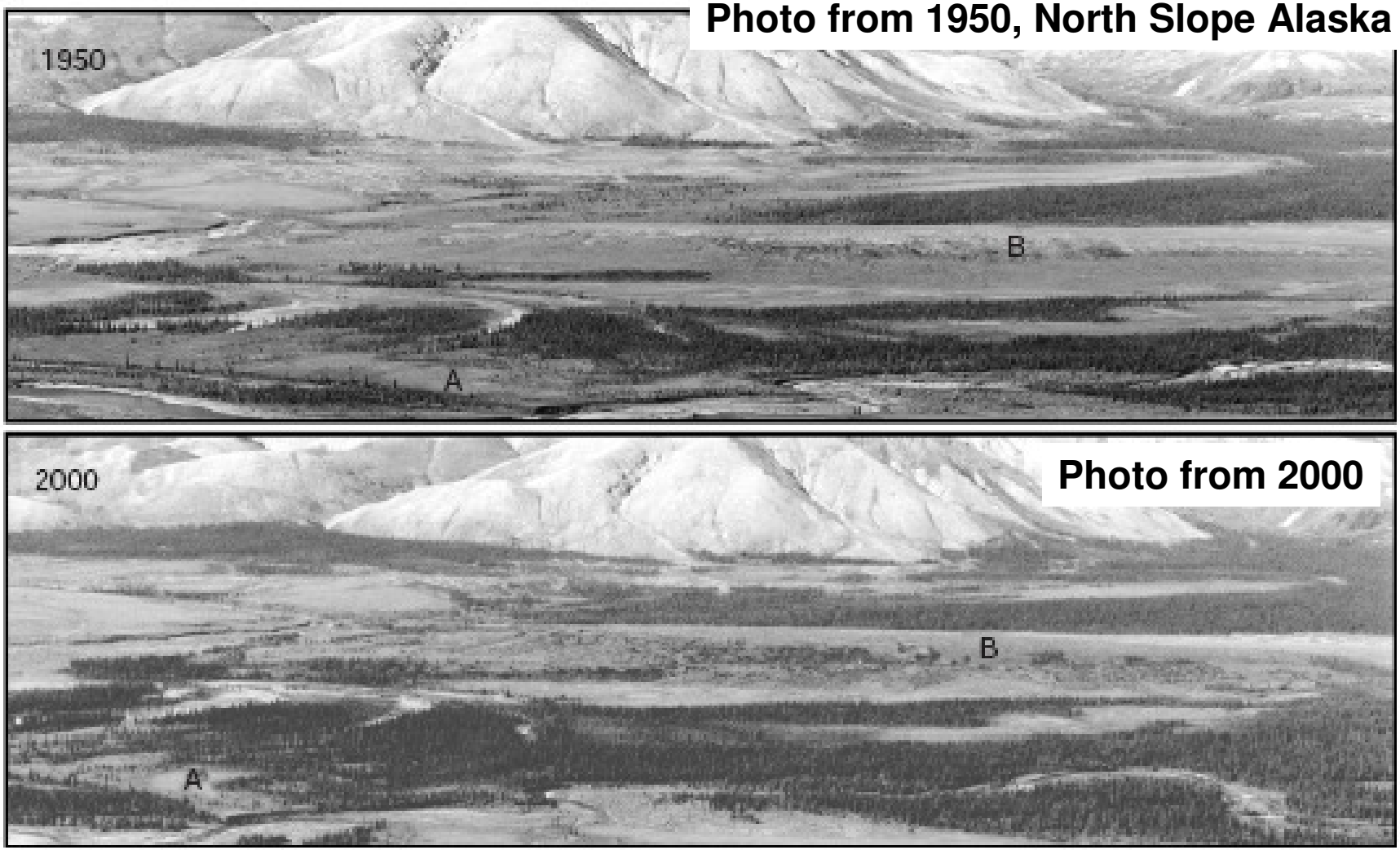


Figure 2 The Kugururok River (N68° 06′, W161° 31′), showing in-filling of spruce stands (A) and increased abundance of shrubs in the middle ground (B); A and B denote the same locations in the old and new photographs.

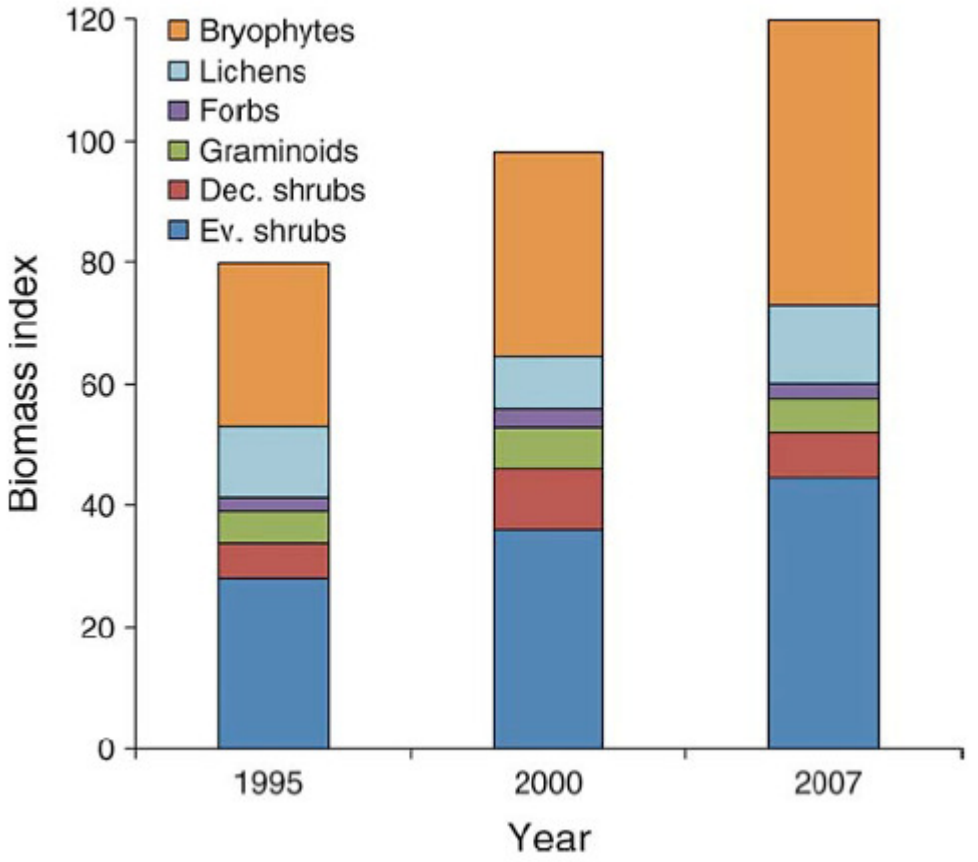
(Sturm et al. 2001)

40 year repeat relevé sampling at Tasiilaq, SE Greenland

- Mires and snowbeds changed most
- Overall minor changes in community composition and cover

Daniels et al. 2010 Applied Vegetation Science

25 year repeat cover & biomass sampling in wet sedge meadow at Alexandra Fiord, Ellesmere Island, Nunavut



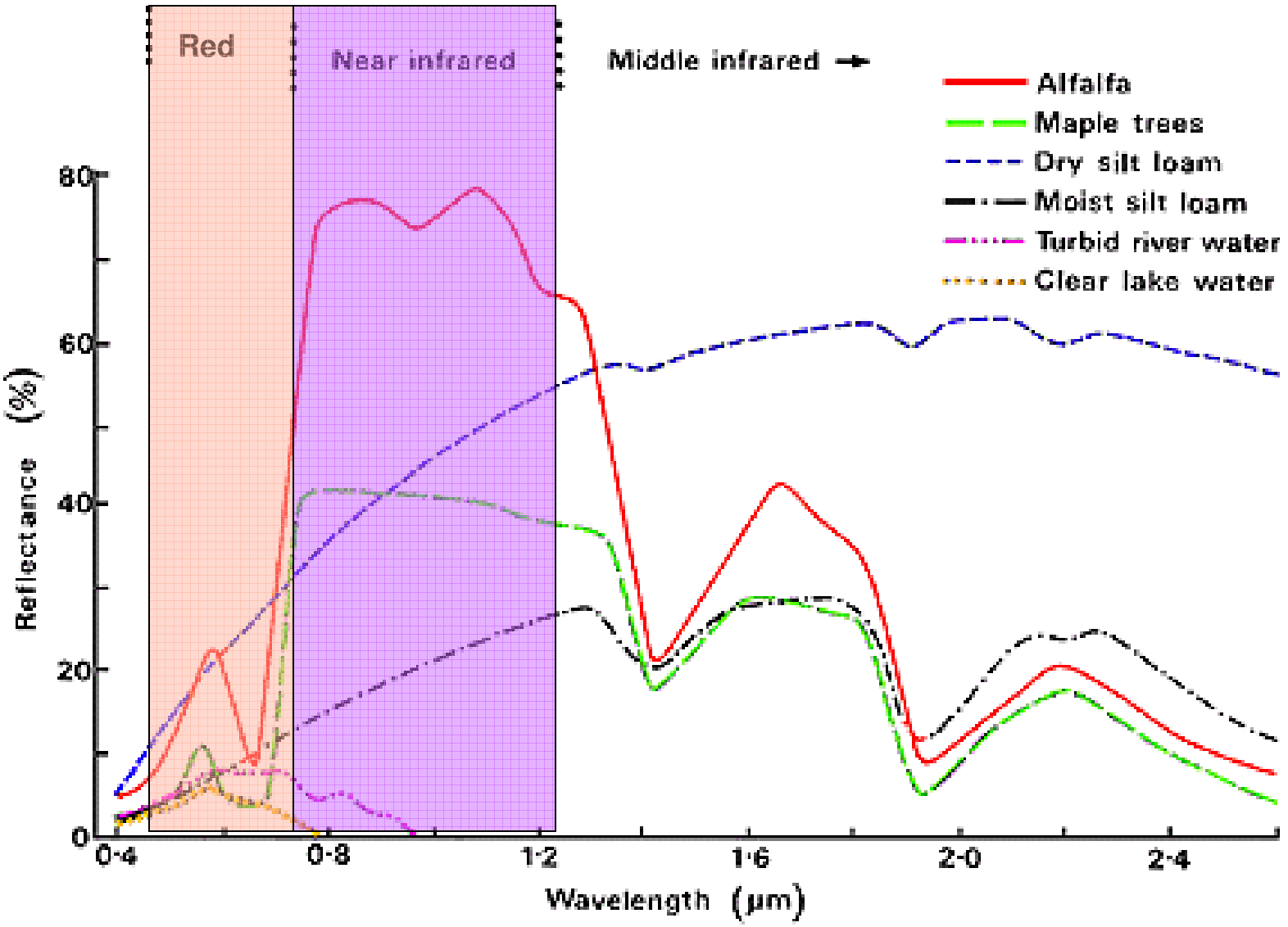
- Increase in aboveground biomass (158%)
- Increase in root biomass increased (67%)
- Increase in rhizome biomass (139%)

- No change in litter biomass
- No change in diversity measures

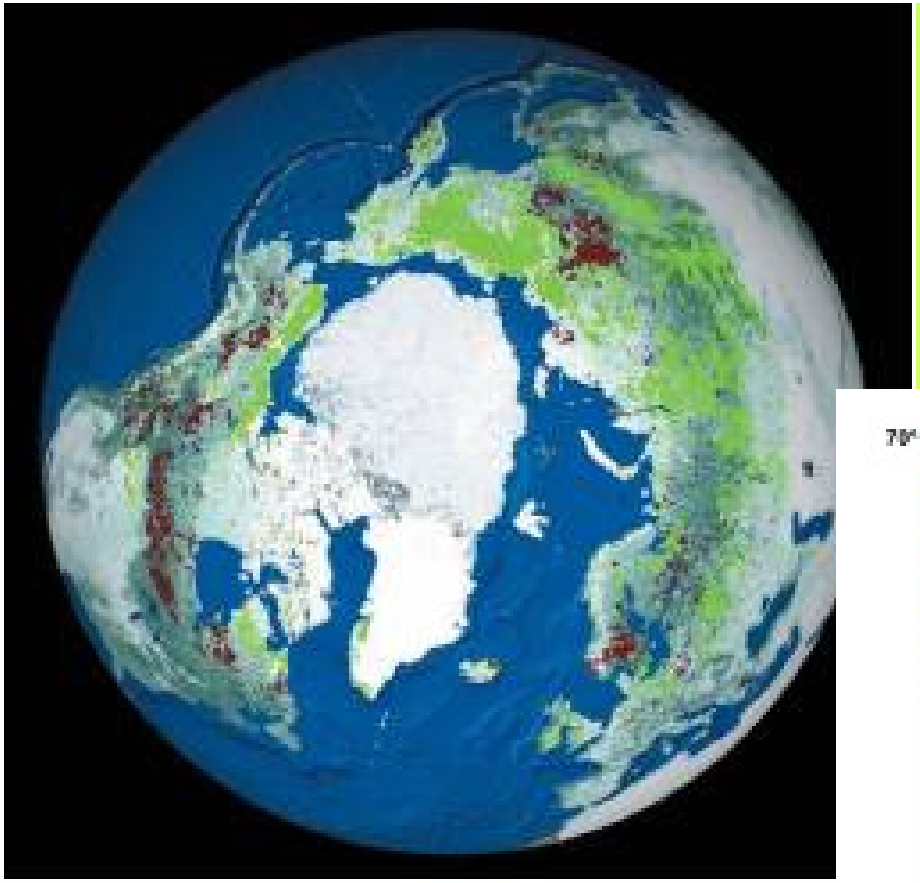
Hudson & Henry 2009 Ecology; Hills & Henry 2011 Global Change Biology


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

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

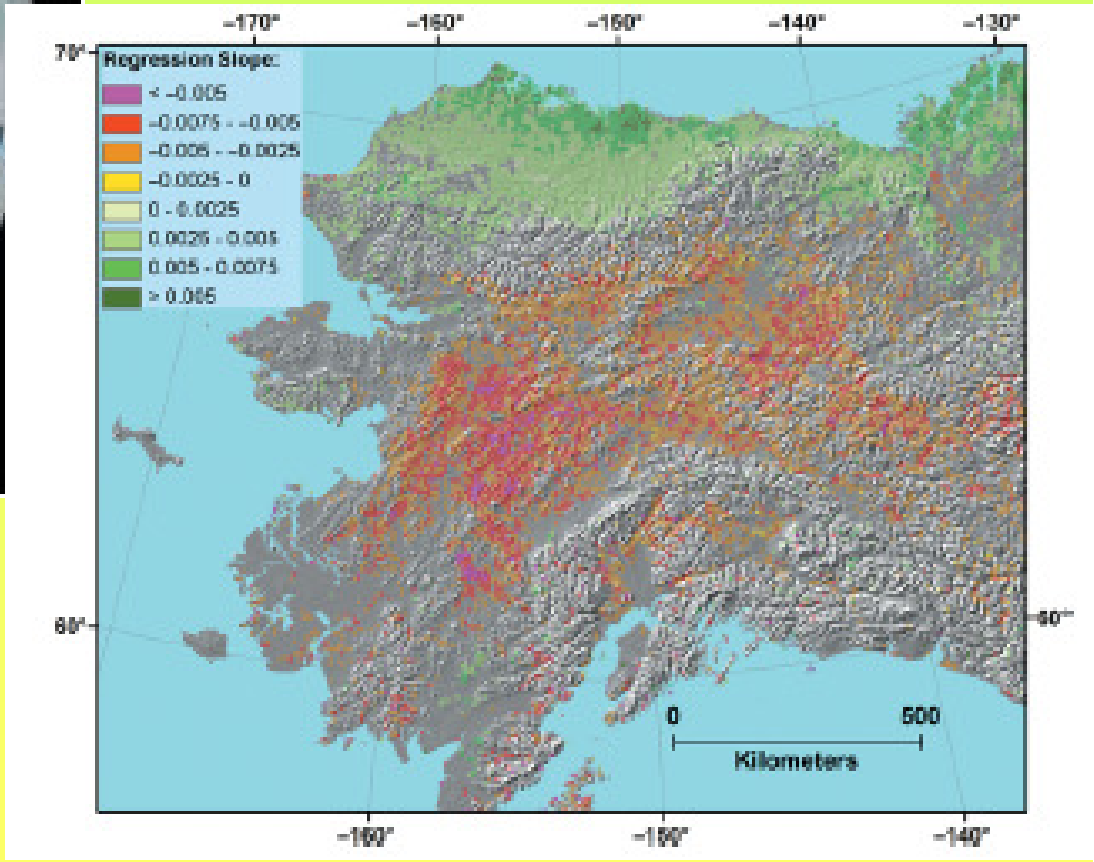


(http://internet1-ci.cst.cnes.fr:8100/cdrom/ceos1/titlep.htm)



Bunn et al. 2007 EOS

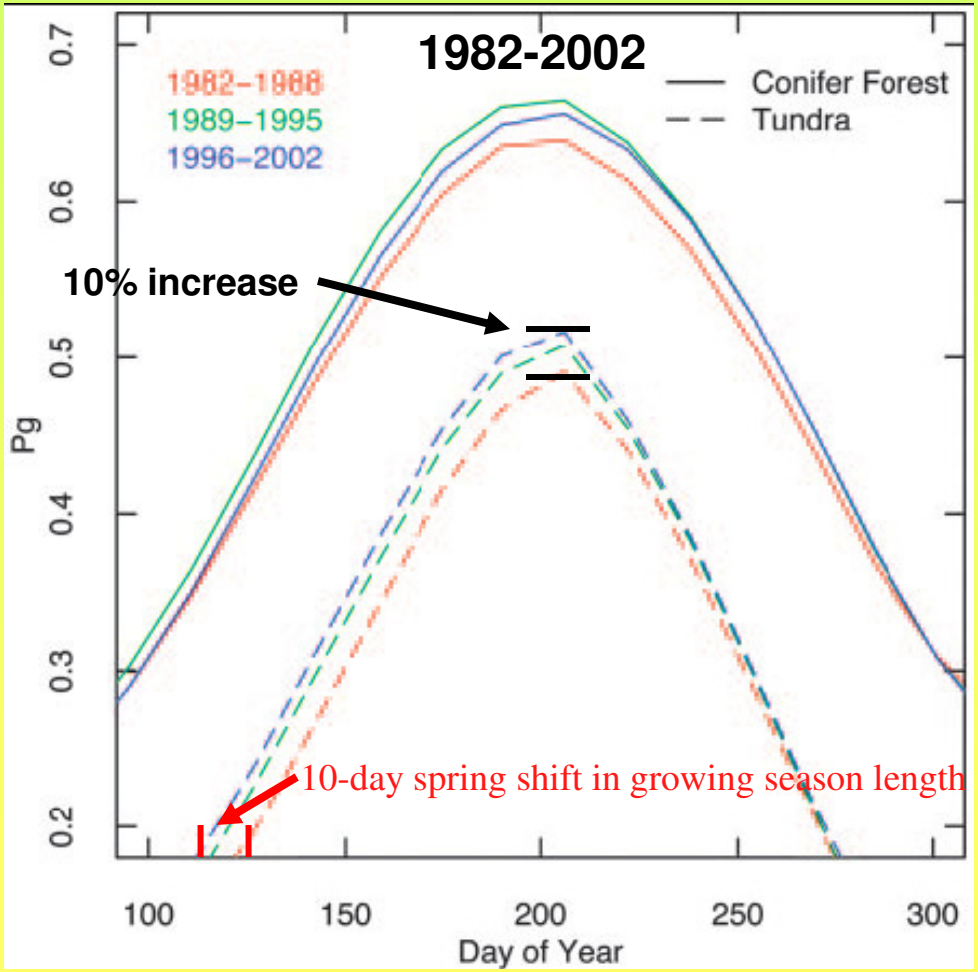
Trends in satellite measures of NDVI 1982-2003



Verbyla 2008 Global Ecology & Biogeography

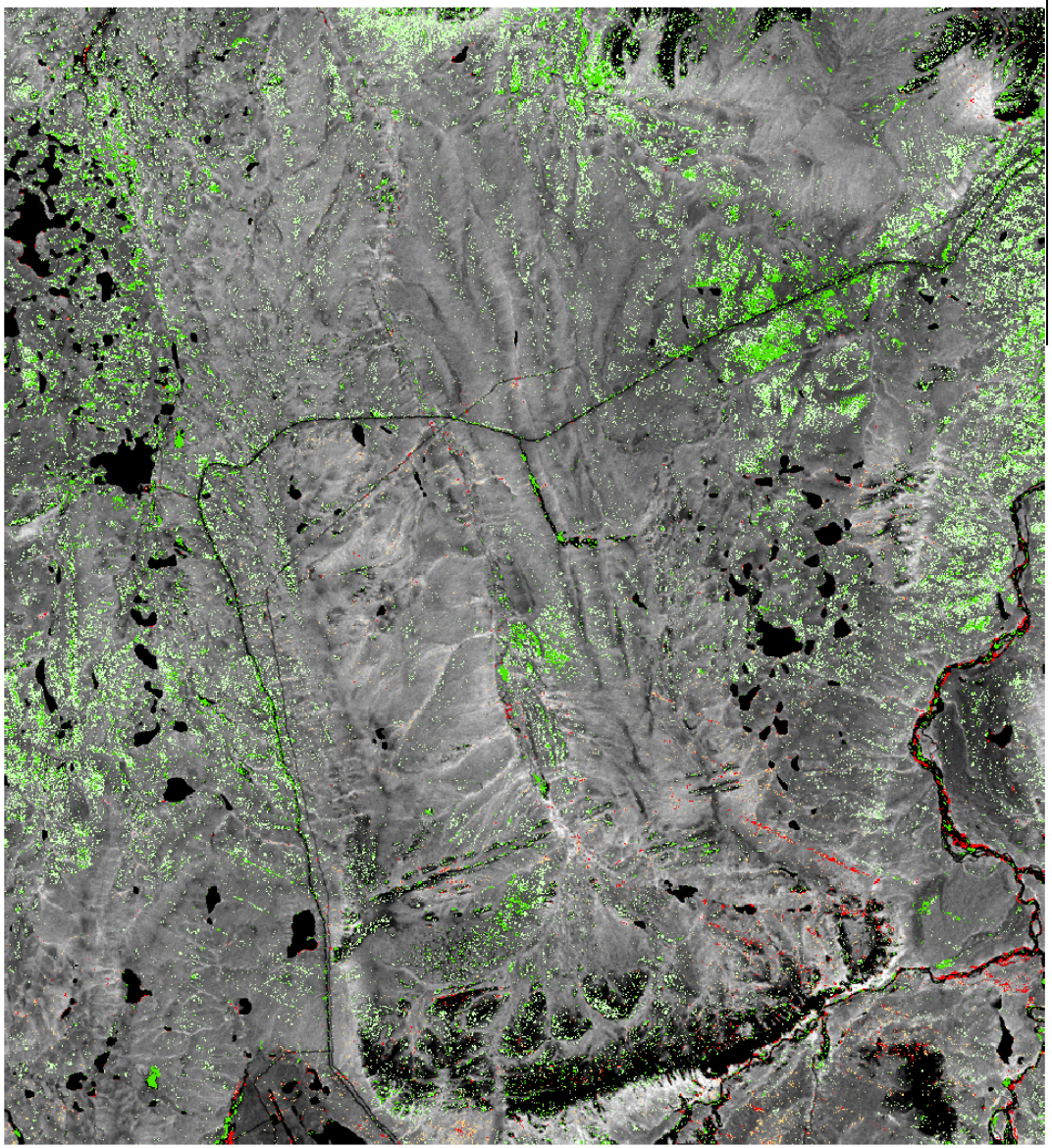
The spring season has started earlier and there is more tundra vegetation

- Separated forested and tundra regions, broken down by six-year intervals.
- The forested areas show a recent decline
- Tundra regions have shown a continued increase and a 10-day shift toward earlier onset of greening.
- There is no corresponding shift in the end of the greening period.



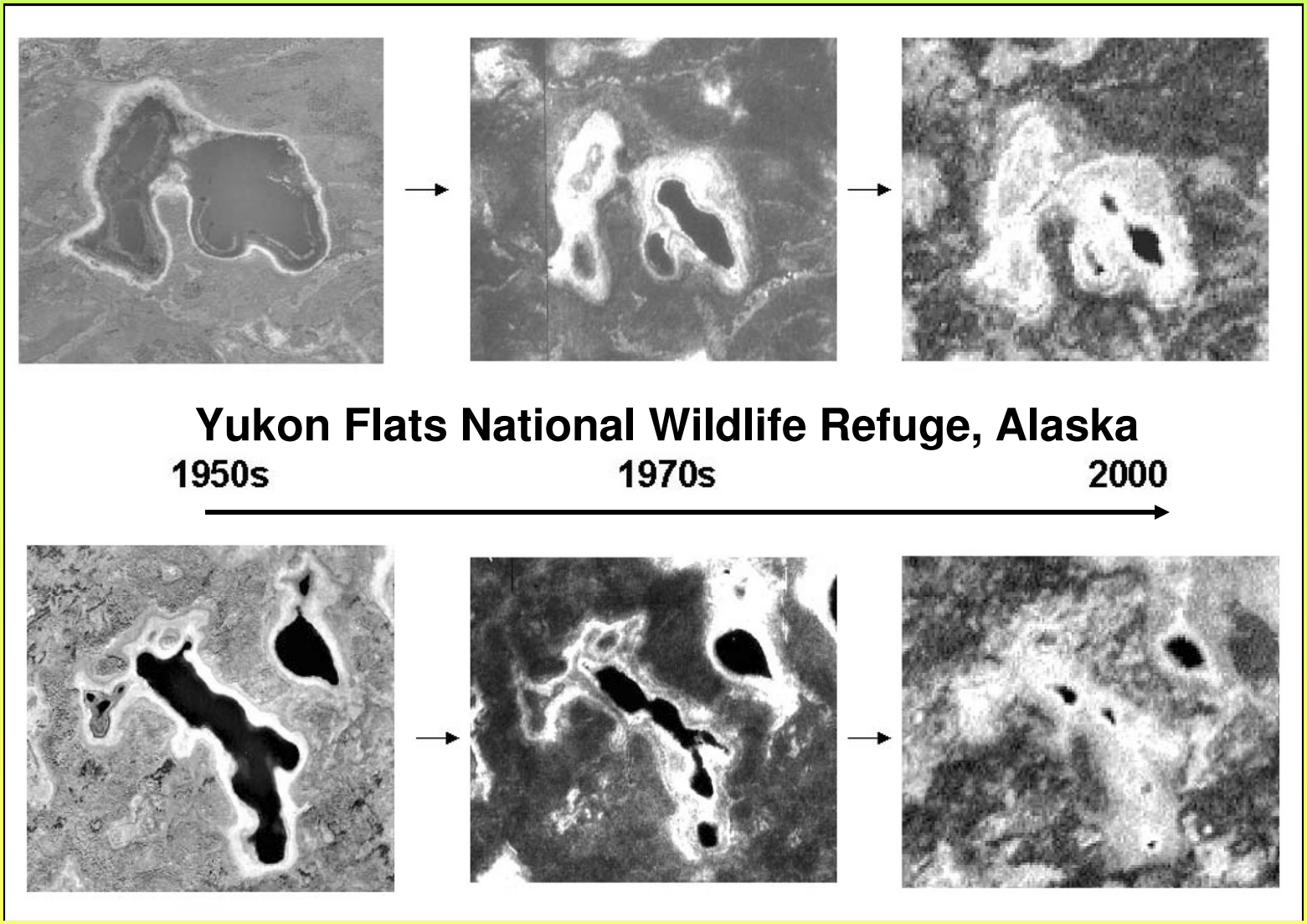
Goetz et al. 2005. Proc. Natl. Academy of Sciences

Upper Kuparuk River Basin, North Slope, Alaska



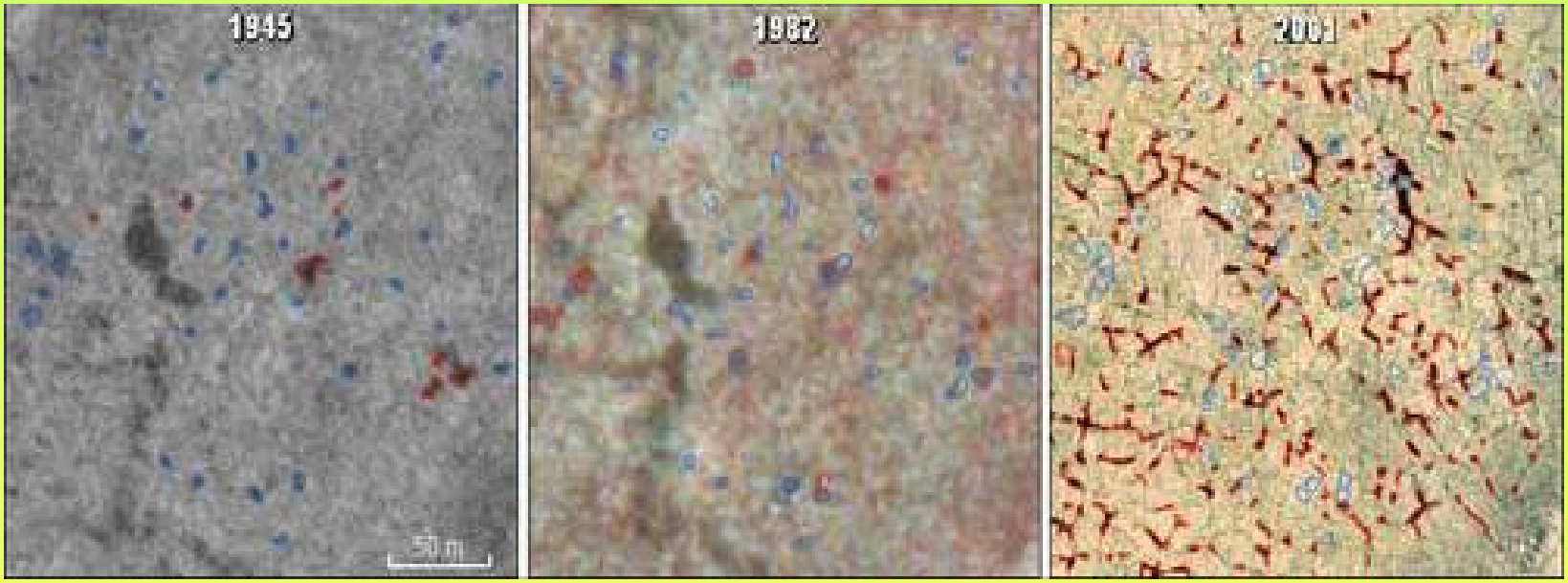
Northern Alaska Landsat study of change in vegetation index 1985-2007 (22 years)

Raynolds et al. 2010 Am. Geophys. Union



Riordan et al. 2006 J. Geophysical Research

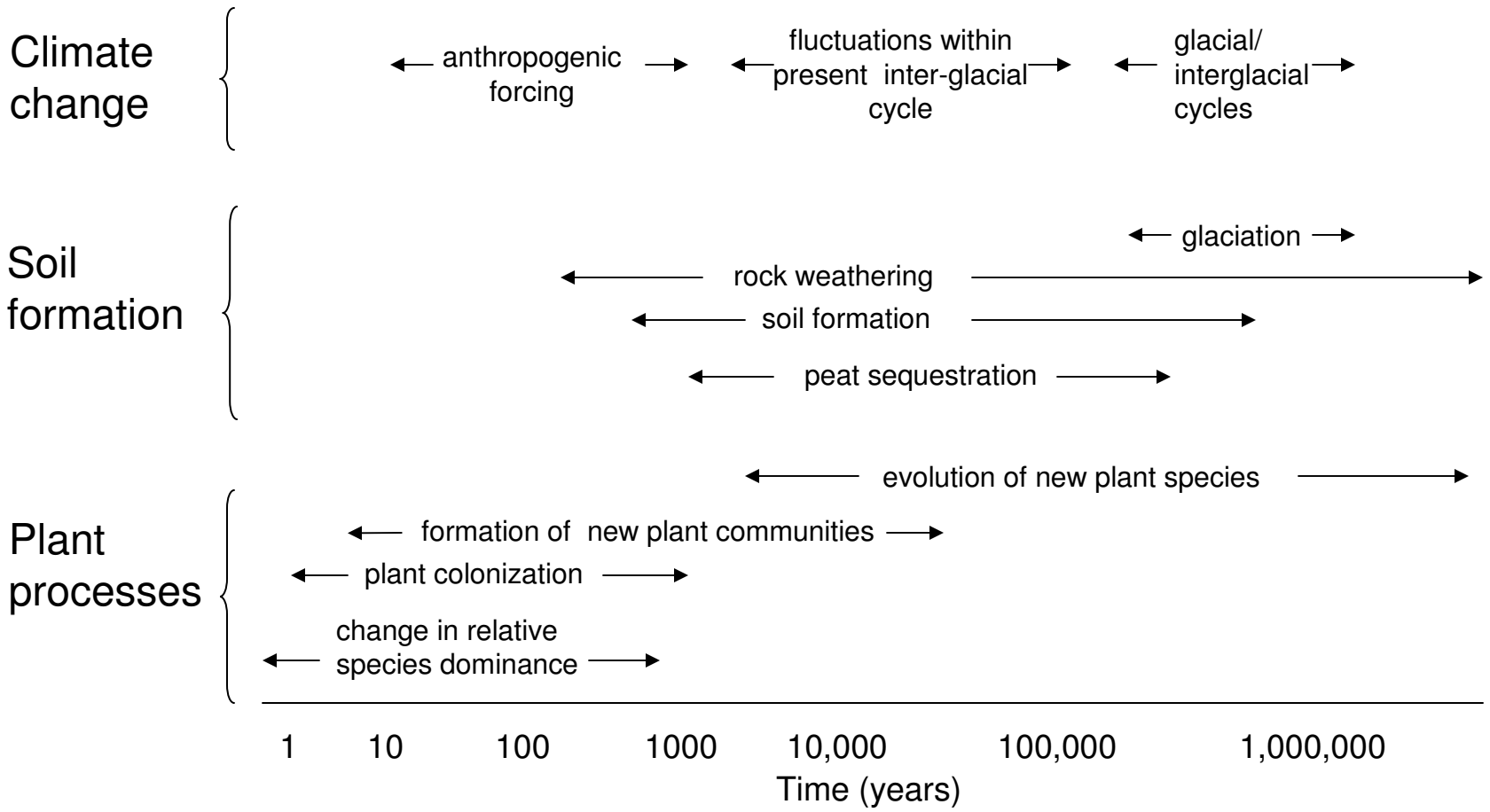
Shrinking lakes in areas of discontinuous permafrost



Jorgenson et al. 2006 Geophysical Research Letters

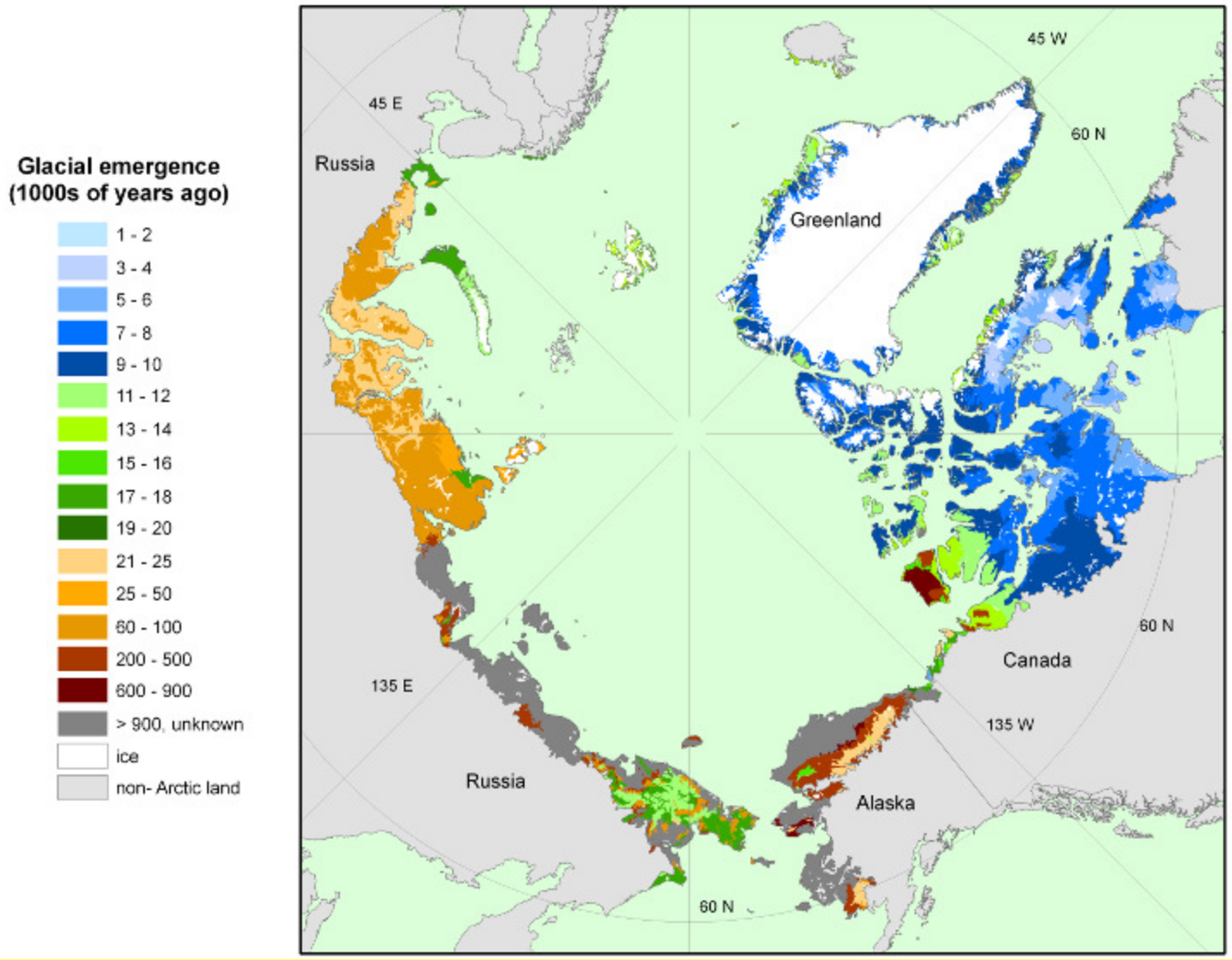
Increasing surface area of water in areas of continuous permafrost


Andromeda polifolia
Bog rosemary
Photo - M.K. Raynolds



Raynolds et al. 2009 Canadian J. of Remote Sensing

Time scale of different processes affecting arctic plant community development



Raynolds et al. 2009 Canadian J. of Remote Sensing

Conclusion of analysis of effects of glaciation on tundra vegetation: Vegetation still responding to glaciations, with plant biomass increasing with time since deglaciation

Trends in NDVI with landscape age

- 0 – 3 000 years
  - rapid initial rise of NDVI with colonization

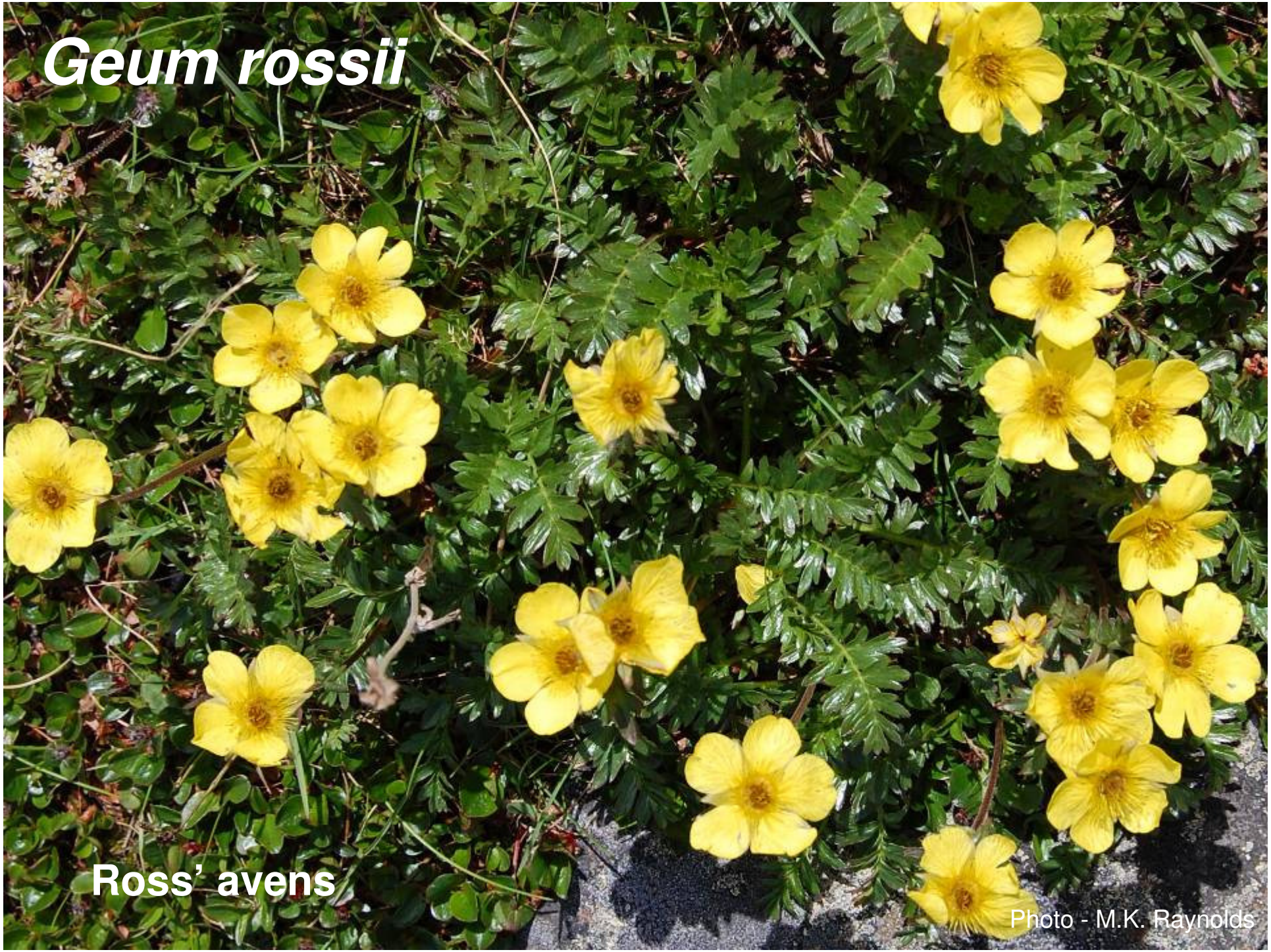
  Pollen and plant fossil data corroborate rapid recolonization rates (Brockmann *et al.* 2003 *Taxon*) and changes in plant communities with glacial cycles (Bigelow *et al.* 2003 *J. Geophys. Research*).

- 3 000 – 14 000 years
  - leveling off of NDVI with peatland development

  Dating of peatlands show rapid initiation 2 000 - 4 000 years after deglaciation (MacDonald 2006 *Science*). Paludification process.

- 14 000 – 20 000 years
  - rise of NDVI with soil & landscape maturation

  Development of soil horizons (Birkeland 1978 *Arctic & Alpine Res.*), infilling of lakes (Campbell *et al*. 1997 *Ecoscience*)


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


Climate-related disturbance
•permafrost thawing
•fire
•insects & disease
Landslide in Denali Park, Alaska
Photo - M.K. Raynolds

Anaktuvuk River tundra fire,
summer 2007 – burned 1000 km^2
North Slope, Alaska

Photo - A. Rocha

Photo - A. Rocha

Defoliation of alders (*Alnus incana* subsp. *tenuifolia*) by the European green alder sawfly in central Alaska

Conclusions

- Vegetation response to climate change is not uniform throughout the north
  - Climate change is variable
  - Initial conditions are variable
- Rate of change is relatively slow from human time perspective
- More rapid changes occur from disturbance


Takk Fyrir!
Questions?
Photo - M.K. Raynolds