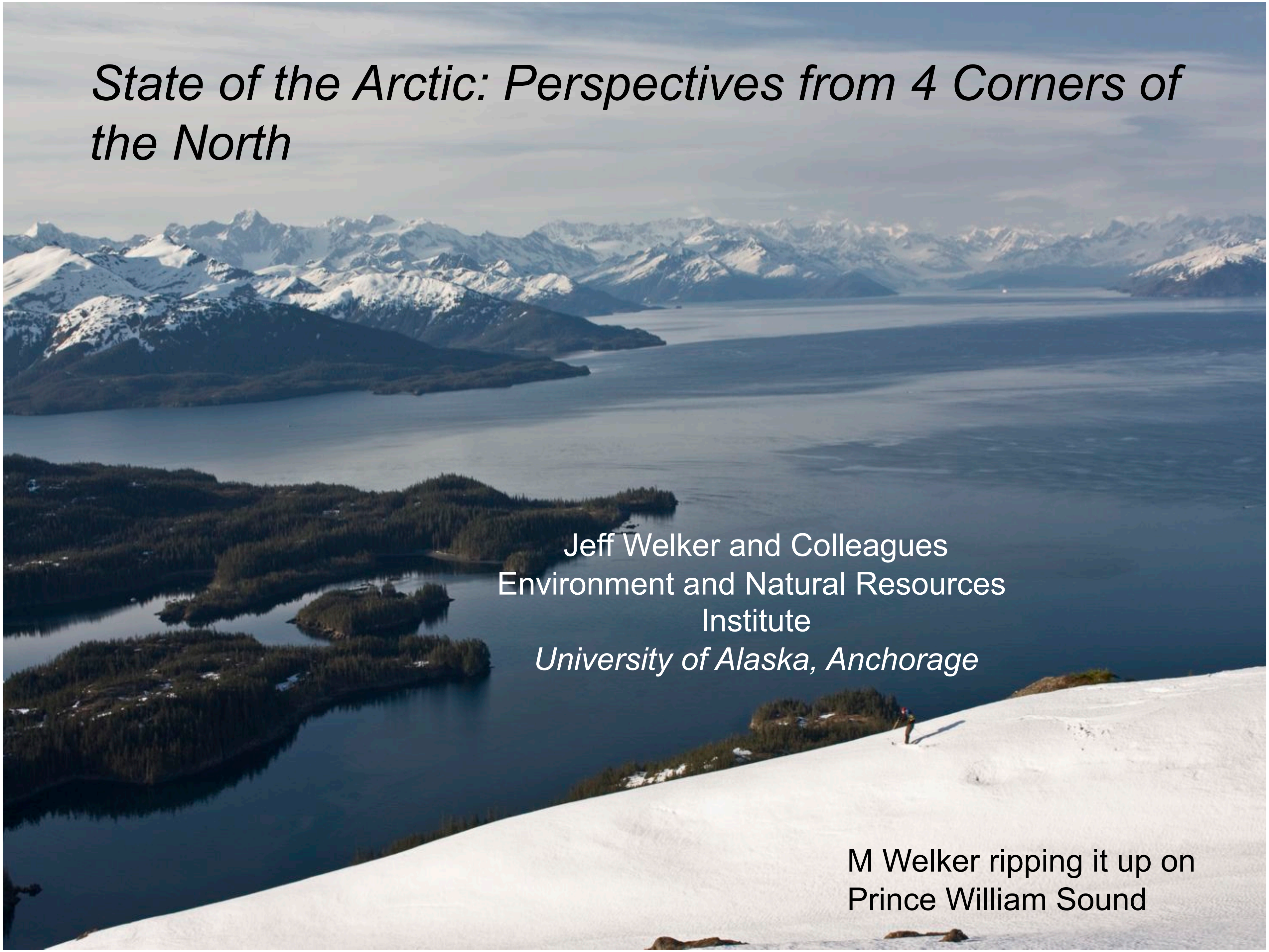
State of the Arctic: Perspectives from 4 Corners of the North



Jeff Welker and Colleagues
Environment and Natural Resources Institute
University of Alaska, Anchorage

M Welker ripping it up on Prince William Sound


Current Status of Polar Regions
INTERNATIONAL POLAR YEAR
2007-2008
Change in the
Polar Regions


Winter is key to vegetation change

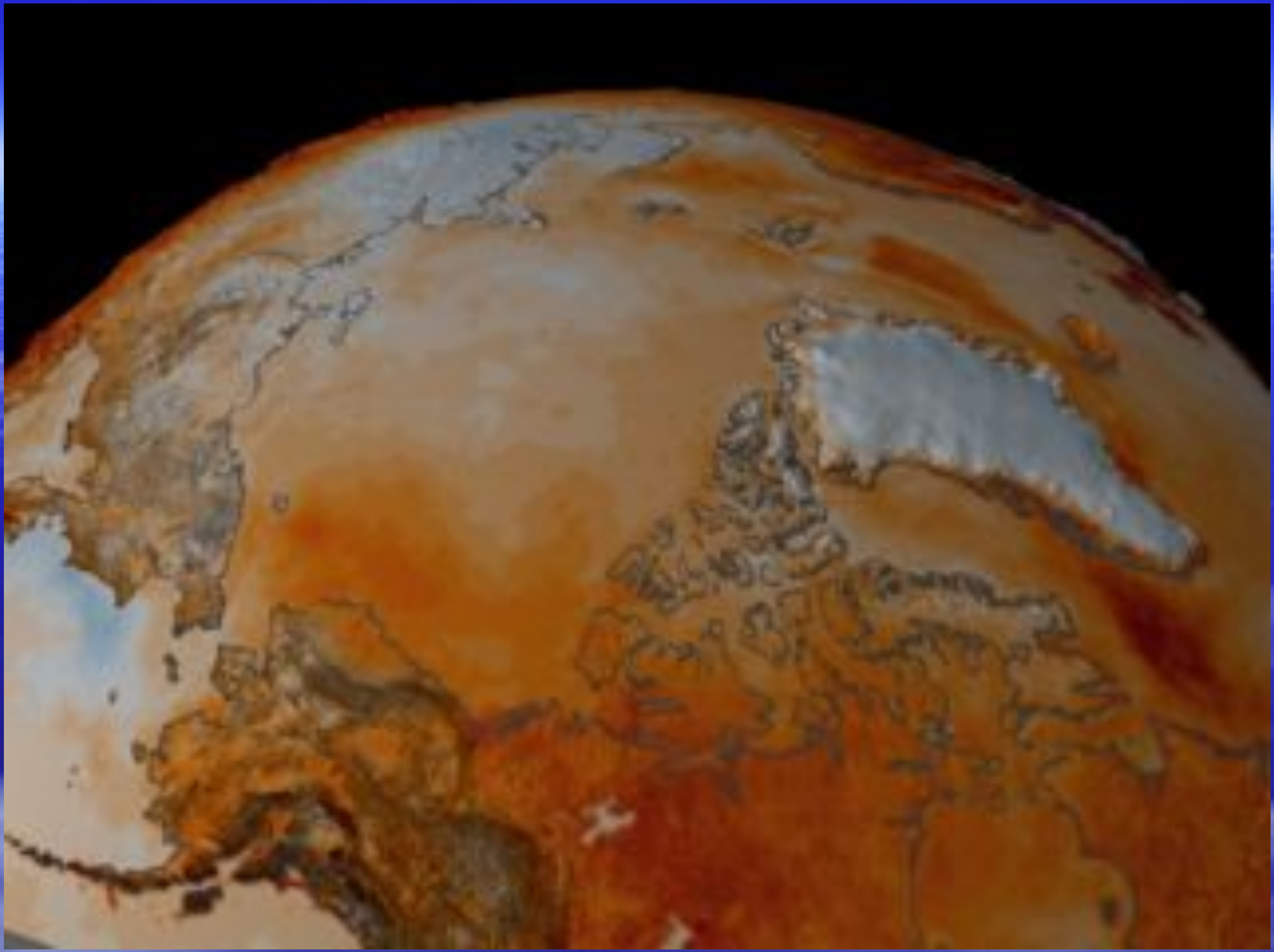

Herbivores modify biogeochemical responses to warming


High Arctic C cycling is more important than we thought

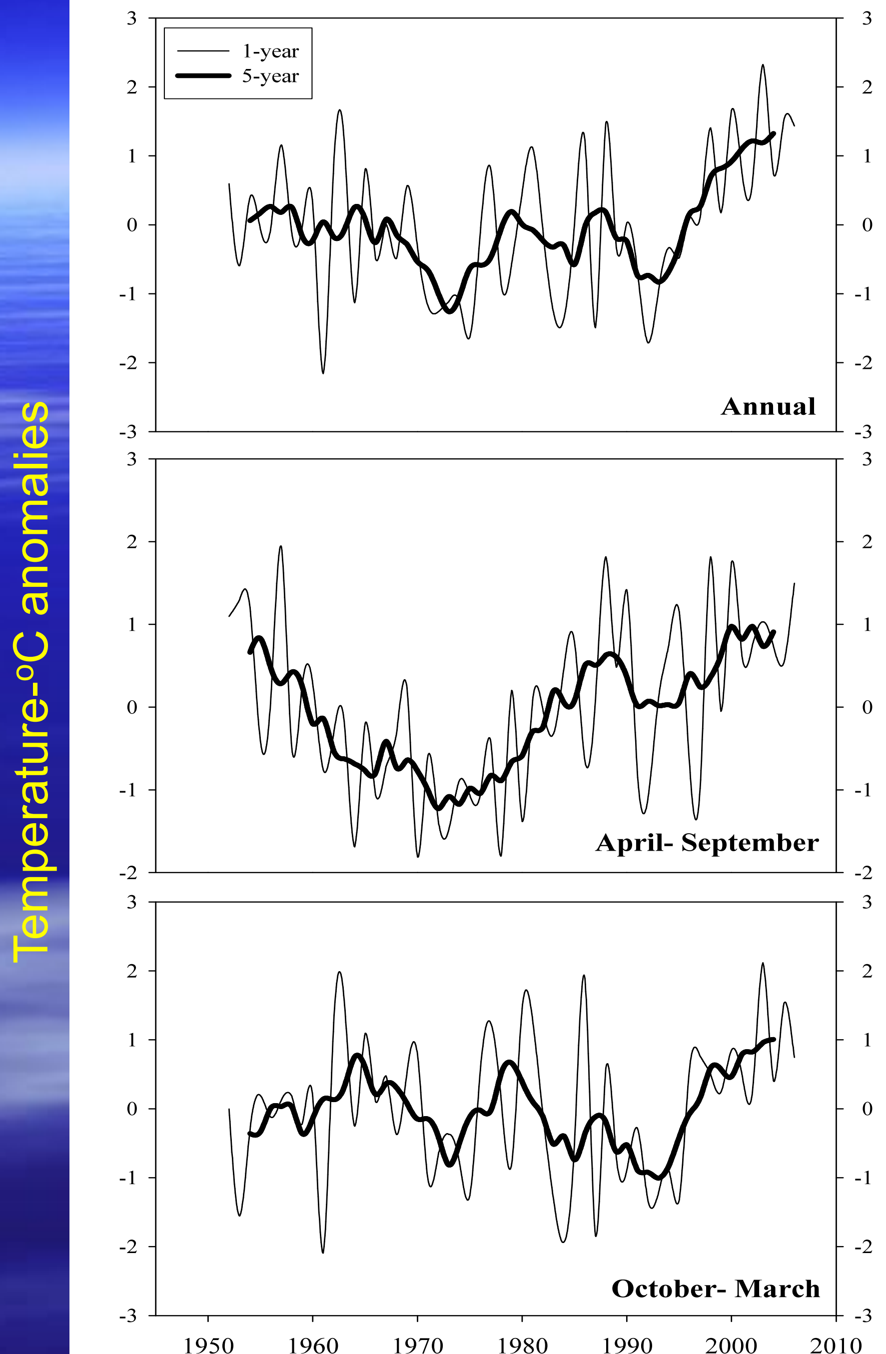

Thawing permafrost may be an important source of water for northern plants

Overview

- **Background**
  - **Changing climates in the north & IPY Efforts**
- **Perspectives from the Four Corners**
  - **Winter**
    - **Year-long considerations and fall-winter transitions**
    - **Controls on vegetation change**
    - **Snow arrival and spring vegetation growth**
  - **Herbivores in the Arctic-controllers and responders**
    - **Climate warming interactions**
  - **High Arctic C cycling**
    - **Temperature and water controls on CO_2 exchange**
    - **Soil C pools and recalibrations of Arctic C pools**
    - **Ancient C-modern C cycle interactions**
  - **Ecohydrology and change**
    - **Water sources in boreal and tundra systems**
    - **Feedbacks to atmospheric water vapor-the forgotten greenhouse**
- **Summary**

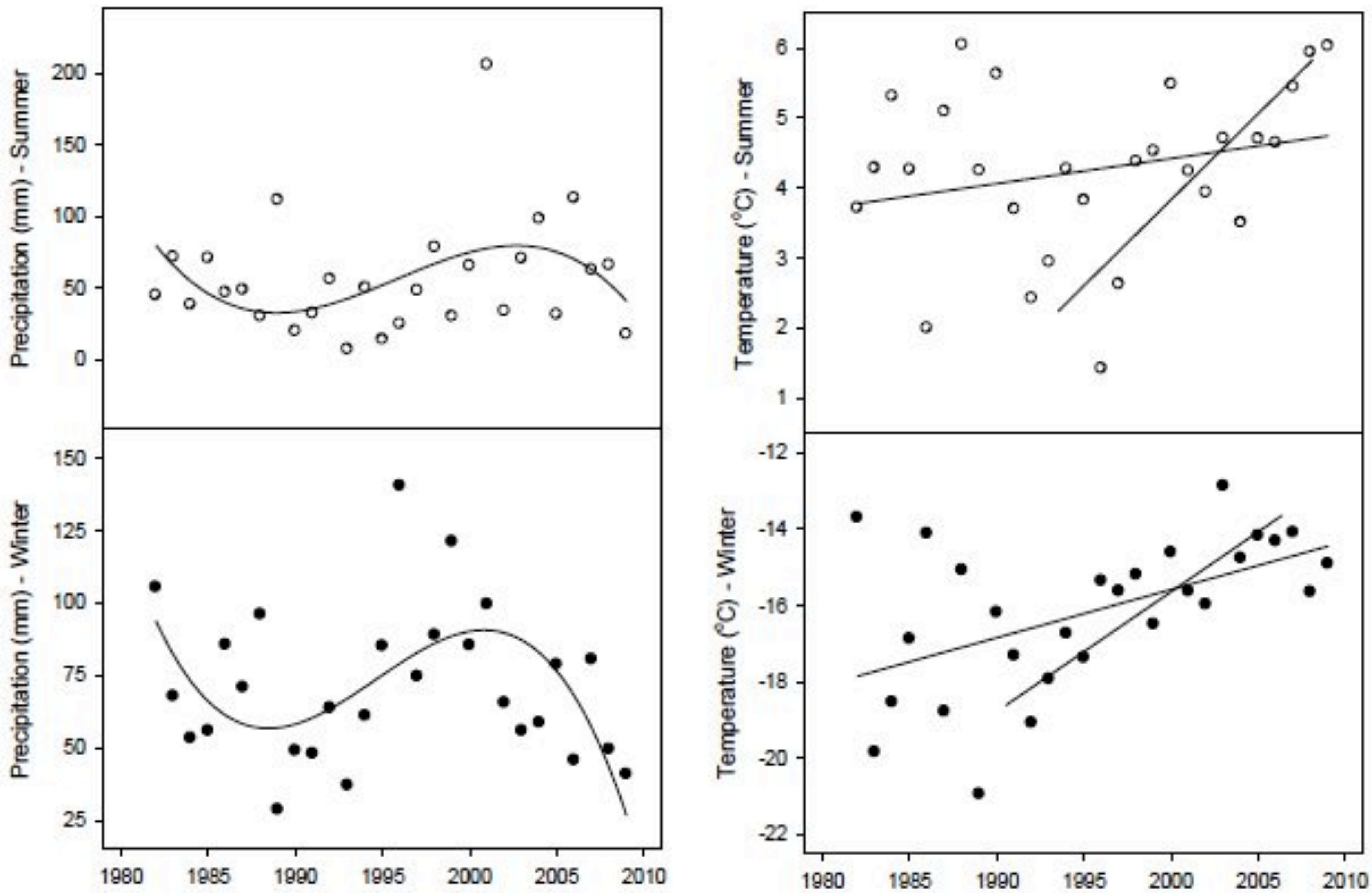


The Arctic is changing and is
warming in many locations



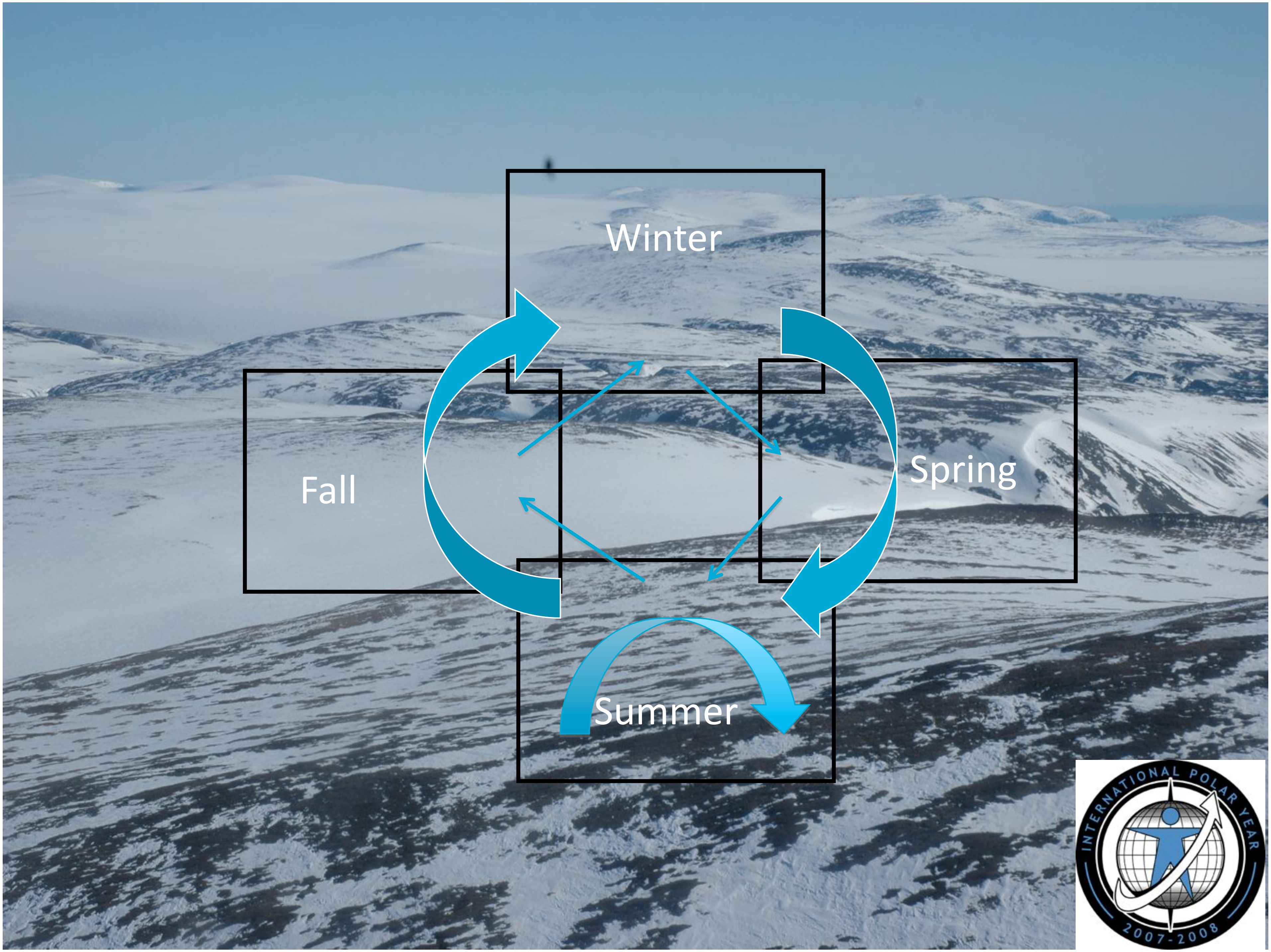
Warming in NW Greenland has been pronounced since the early 1990's proceeded by cool periods in the 1970's and in the late 1980's

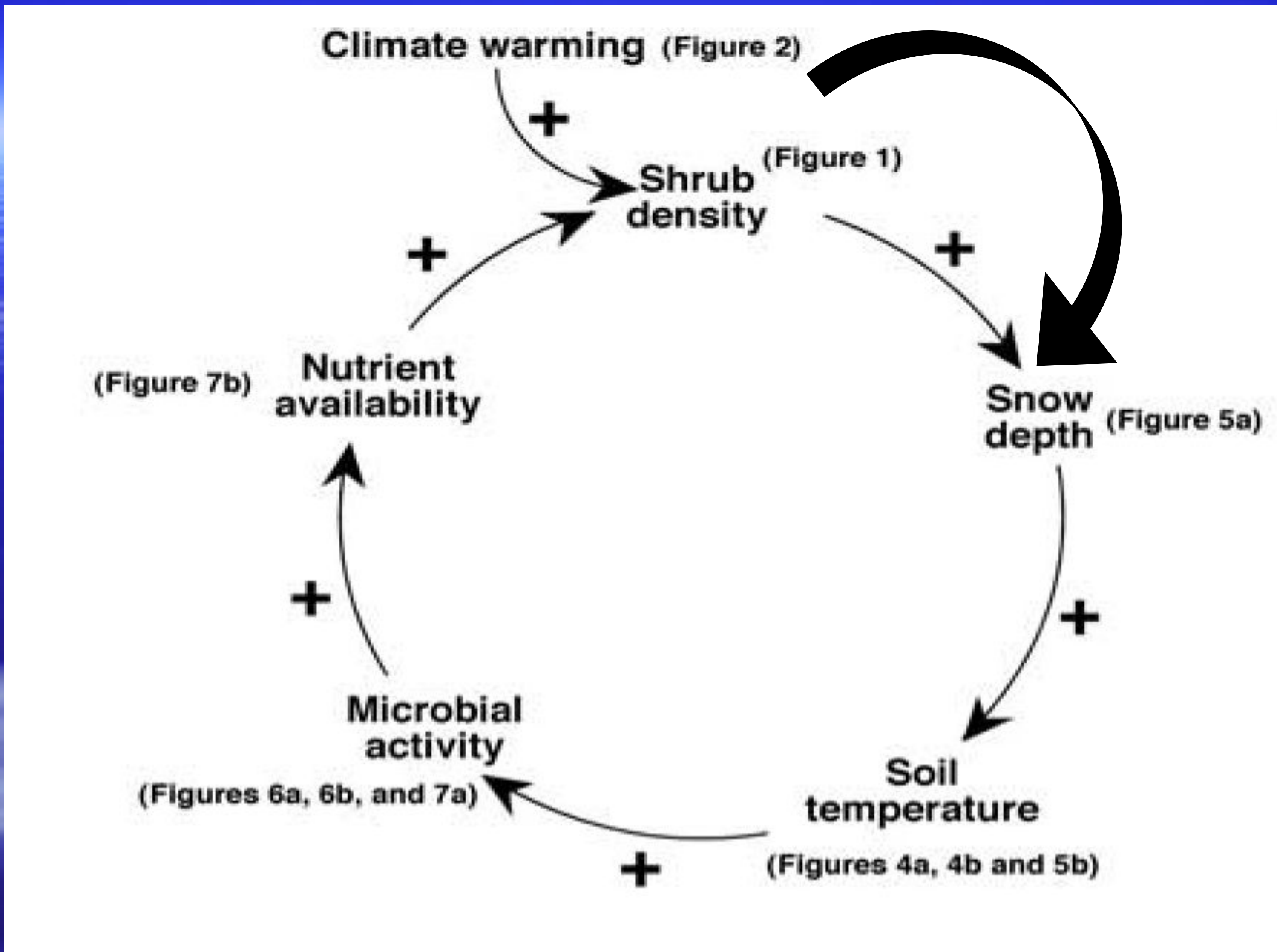
Recent Precipitation and Temperatures in NW Greenland




Thule, NW Greenland

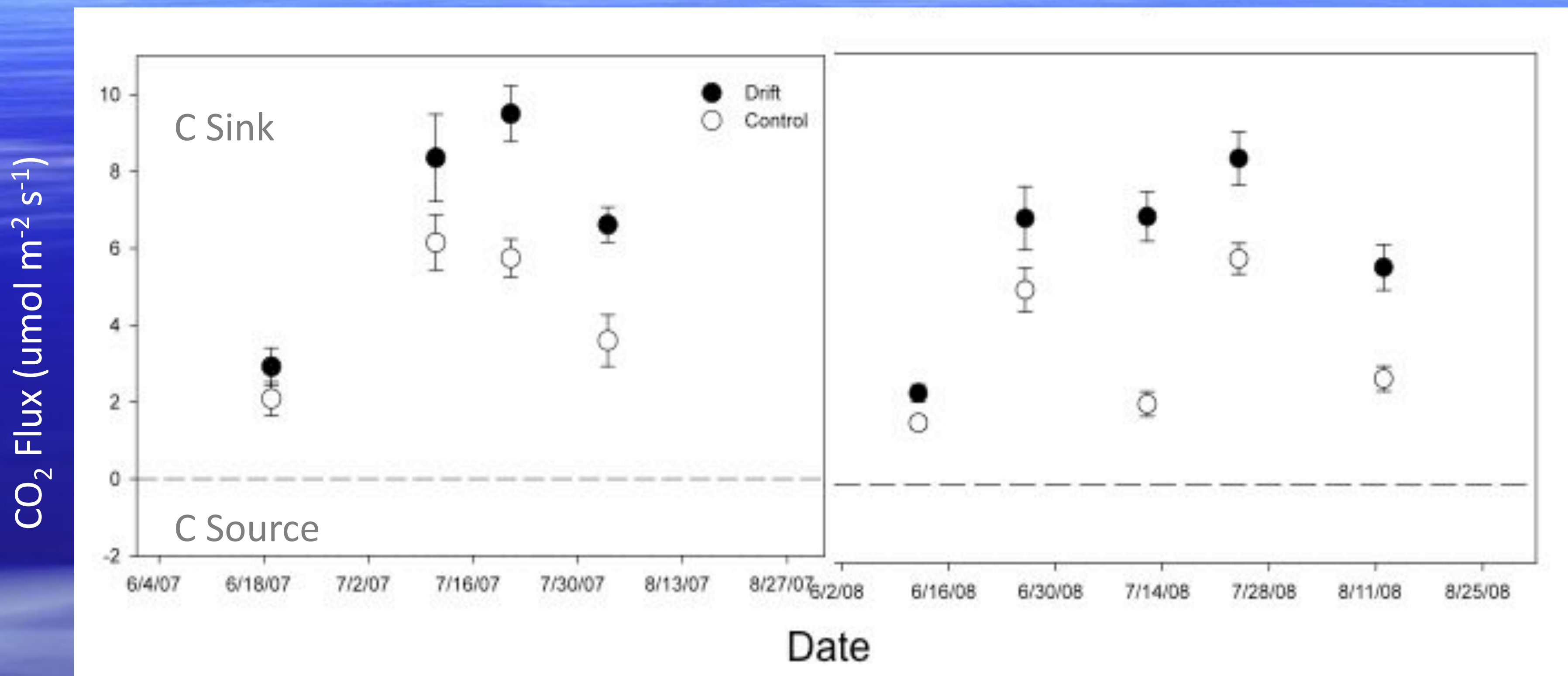

Toolik Lake, Alaska


Winter
Fall
Spring
Summer
INTERNATIONAL POLAR YEAR
2007-2008



Fahnestock et al. 1998, 1999, Schimel et al. 2004, Sturm et al. 2005, Welker et al. 2005

Net Ecosystem Exchange



Intermediate increases in snow leads to stronger net CO_2 sink activity-greater C sequestration

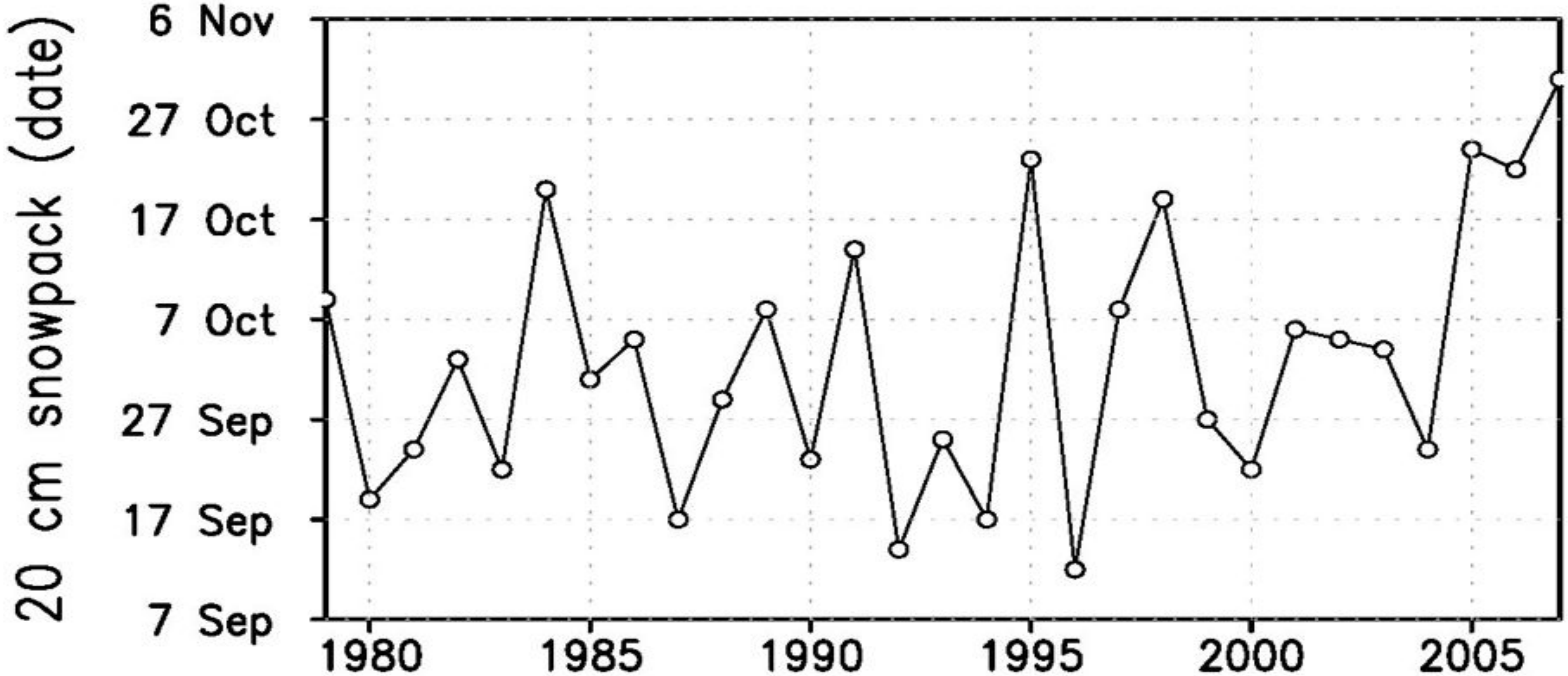
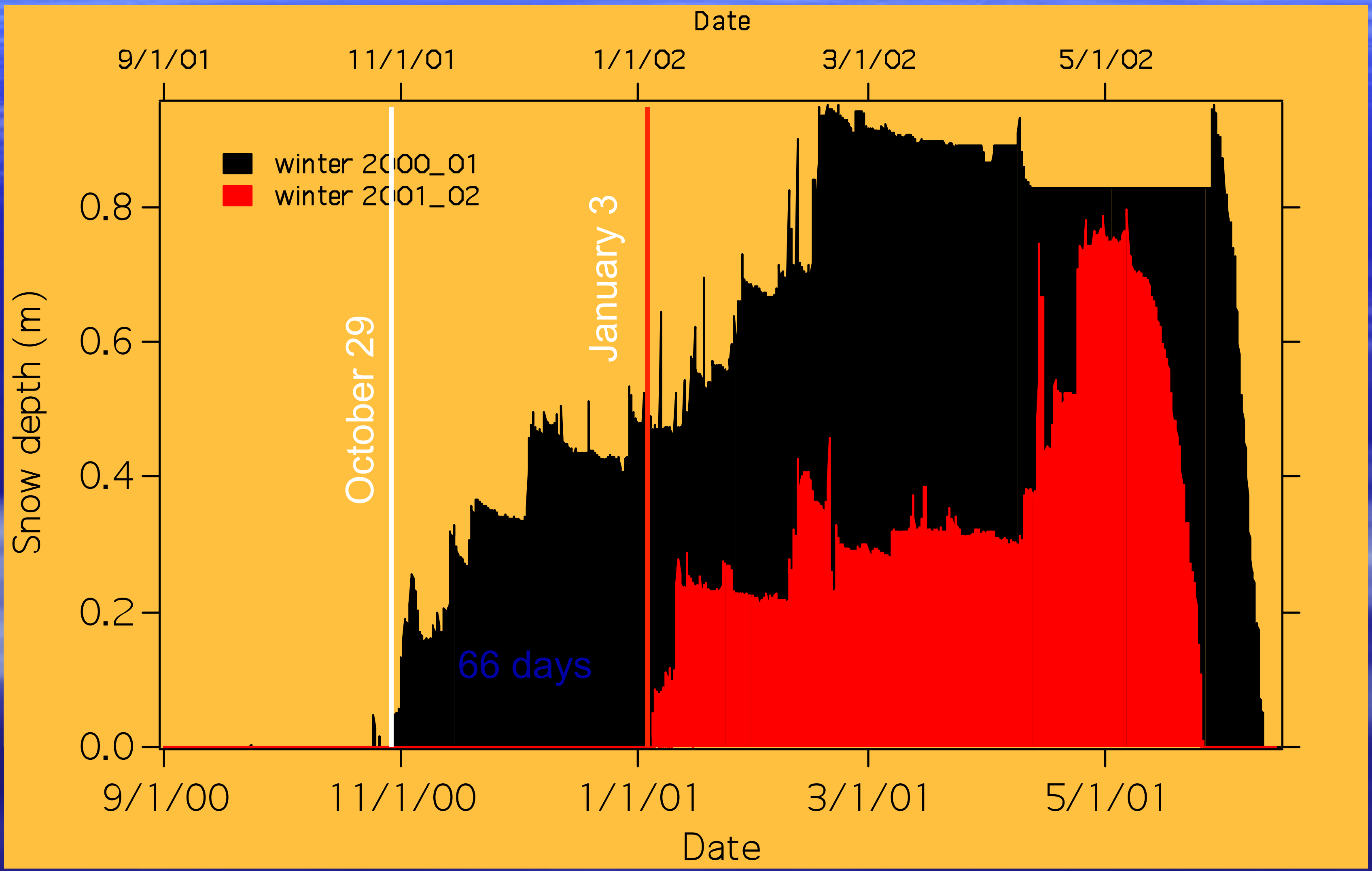


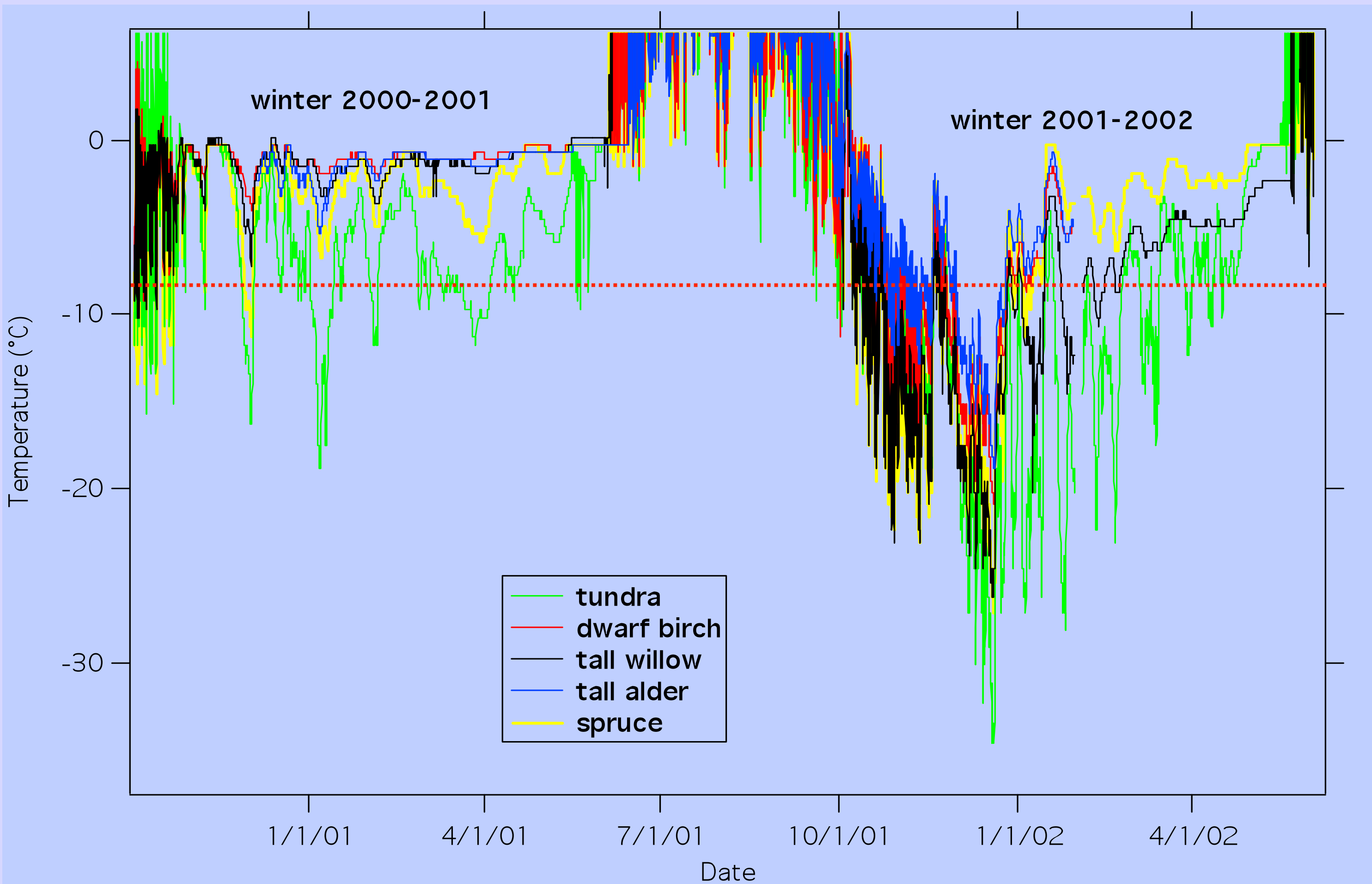
Figure 2. The arrival of 20 cm deep snow at Toolik Lake. Calculated using SnowModel (Liston and Elder 2006a,b) for 1979-2007.

The way winter comes to the Arctic-permanent snow pack arrival dates vary and can have important consequences for ecosystem function

Seward Peninsula
2000-2002: Two very different snow histories



Variation in ground temperatures due to late, shallow snowpack in 2001-2002.



Herbivory in winter

Timing of snow pack development and browsing interactions

Early snow pack

Abiotic

Warmer soils

↓

Higher winter N and C mineralization-greater shrub growth in summer

↓

Larger shrub canopies, reduced graminoids, reduced soil C storage-

↓

Increases in winter and summer albedo? Feedbacks?

Herbivores

Reduced winter forage availability

↓

Increases cratering, more energy expenditure, poorer forage quality

↓

Nutritional deficits, reductions in fecundity

↓

Subsistence harvesting reduced

Late snow pack

Abiotic

Colder soils

↓

Lower winter C & N mineralization-reduced shrub growth

↓

Smaller shrub canopies, increased graminoid and lichen growth, increased soil C storage

↓

Decreases in winter & summer albedo? Feedbacks?

Herbivores

Greater winter forage availability

↓

Reduced cratering, reduced energy expenditure-

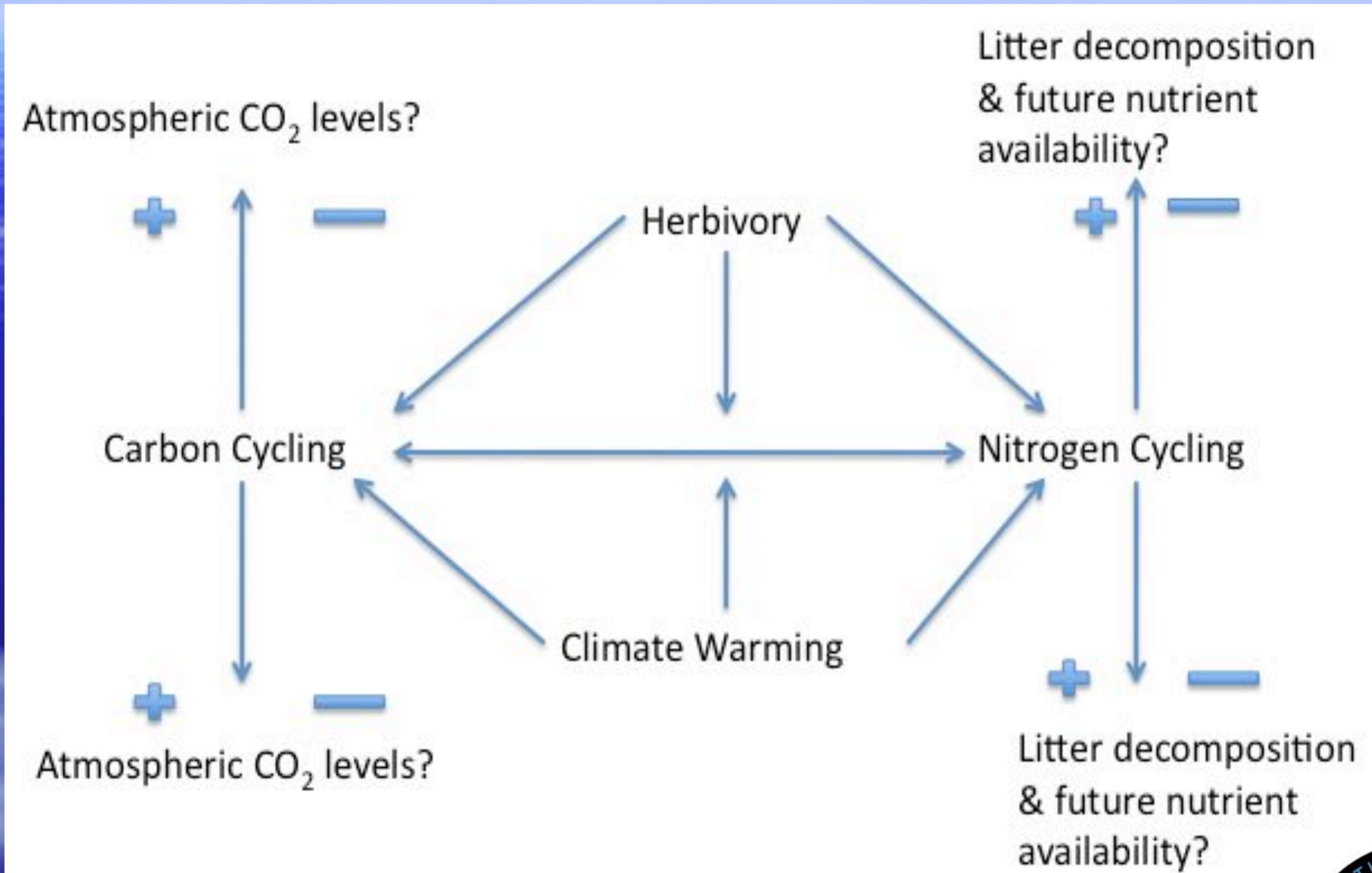
↓

Higher forage quality, increases in fecundity

↓

Subsistence harvesting increased

INTERNATIONAL POLAR YEAR 2007-2008



Atmospheric CO_2 levels?
Litter decomposition & future nutrient availability?
+
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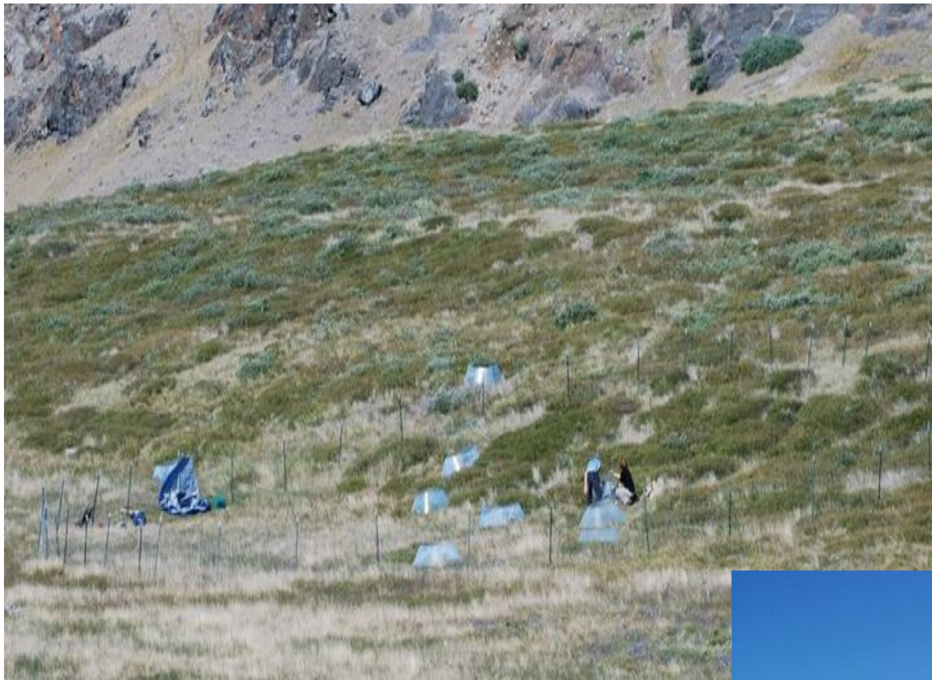
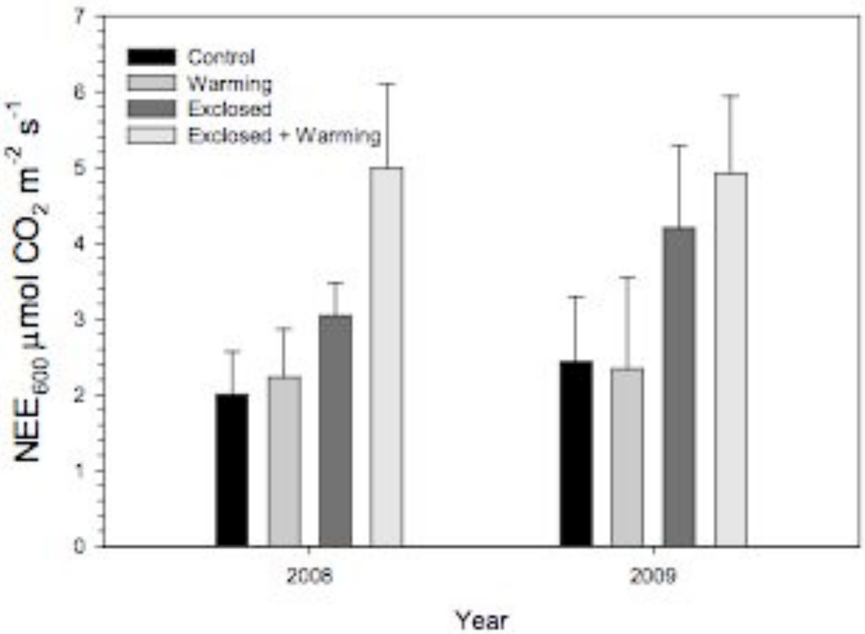
Herbivory
Carbon Cycling
Nitrogen Cycling
Climate Warming
Atmospheric CO_2 levels?
Litter decomposition & future nutrient availability?



Measurements:
CO_2 flux-NEE, GEP, RE
Vegetation canopy traits
Plant leaf C&N,
Soil C & N
Vegetation phenology
Soil Moisture

Treatments: Exclosed-ambient and warmed, Grazed-ambient and warmed: started in 2003

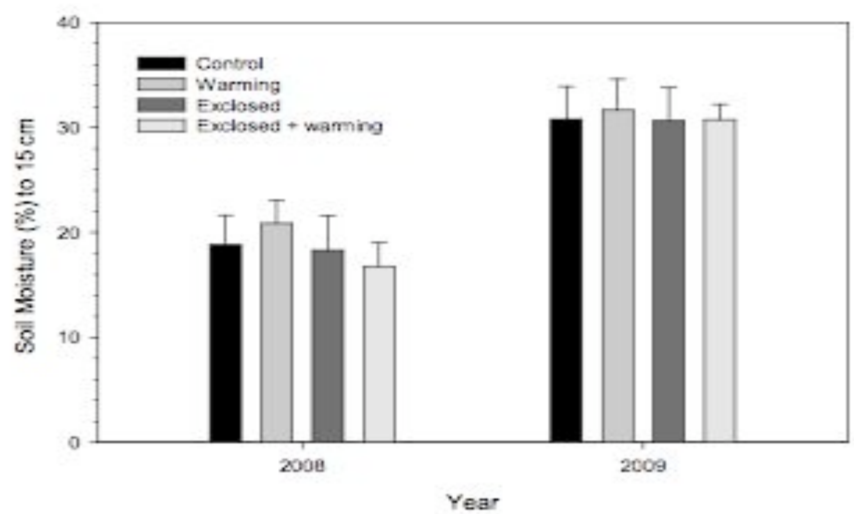
NEE (normalized to 600 μmol photons $m^{-2} s^{-1}$) at peak season for both years

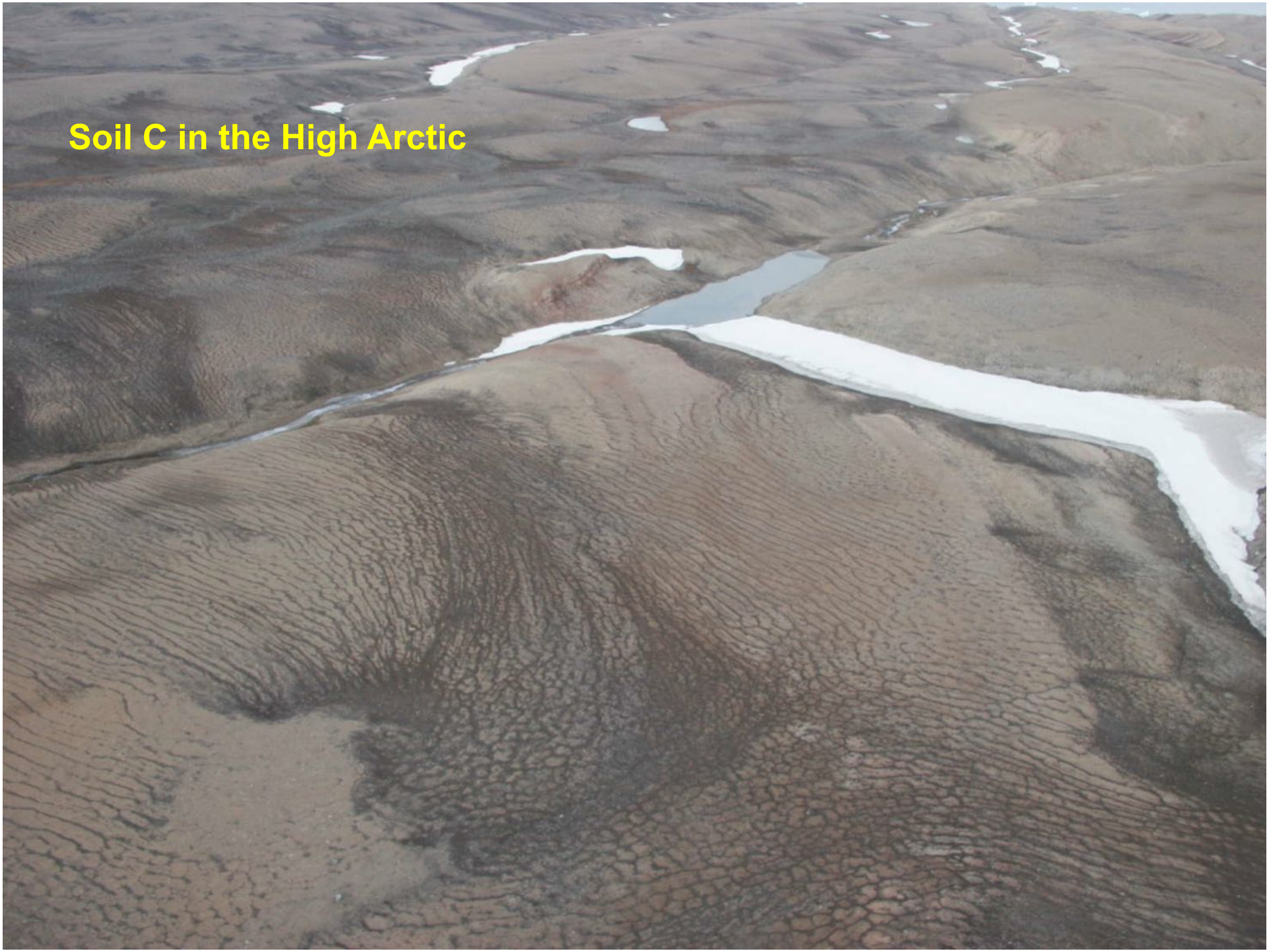


Warming response is muted when herbivores are present and are stronger in dry vs. wet years

The uncertainty is however, the extent to which grazers effect belowground processes, and the effects on the synchrony of growth between roots and shoots

Interannual comparison of soil moisture at peak season (mid-July)




Soil C in the High Arctic

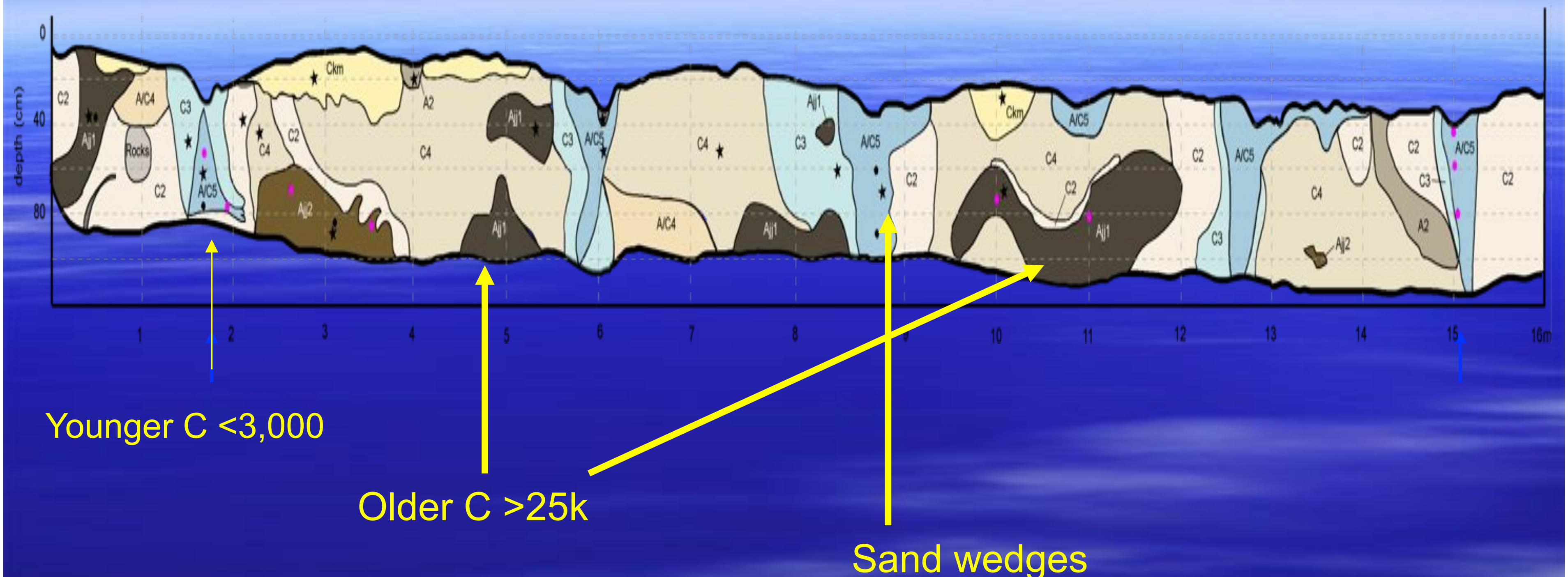
Soil Carbon Pool Reassessment of the High Arctic

Vegetation type	Bliss and Matveyeva (1992)			Horwath and Sletten (this work)	
	Area (10^6 km^2)	O.M. (kg/m^2)	SOC (Pg)	Organic Carbon (kg/m^2)	SOC (Pg)
Polar semidesert	1.005	2.19	0.978	8.72	8.68[a]
Polar desert	0.847	0.046	0.017	2.52	2.13[a]
Mire	0.132	23.36	1.358	29.8	3.93[a]
Total			2.35		14.74

~ 8 X more carbon estimated for High Arctic Systems

Trenching of polar stripe area for detailed soil carbon studies

Polar strip formation, soil carbon distribution and ages (^{14}C dating)



- Vegetated troughs are filled with sand, indicating importance of aeolian processes formation and stabilization

- Soil C ages increase with depth in sand wedges

- Older soil C found in pockets that appear to have undergone cryoturbation

- Two distinct pools of carbon – younger “active” and older “preserved”


Key Questions
What are the magnitudes of soil respiration over the summer in polar stripe landscapes?
Is there evidence that the older soil carbon is contributing to the total soil C efflux?

Measuring and Sampling of CO_2

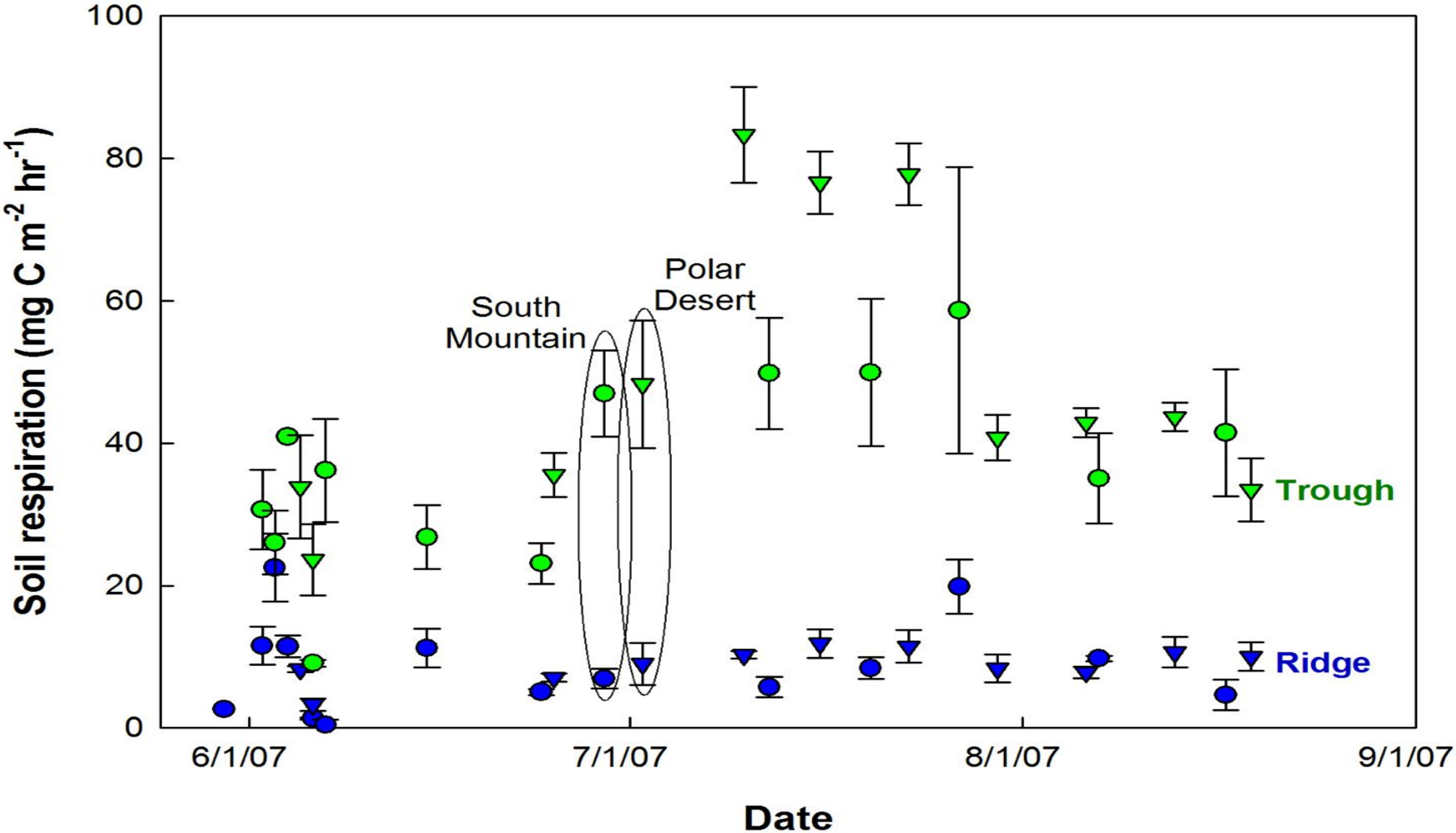
Rate of CO_2 flux from the Soil Surface (Soil Respiration)

Storage of air samples

Canister

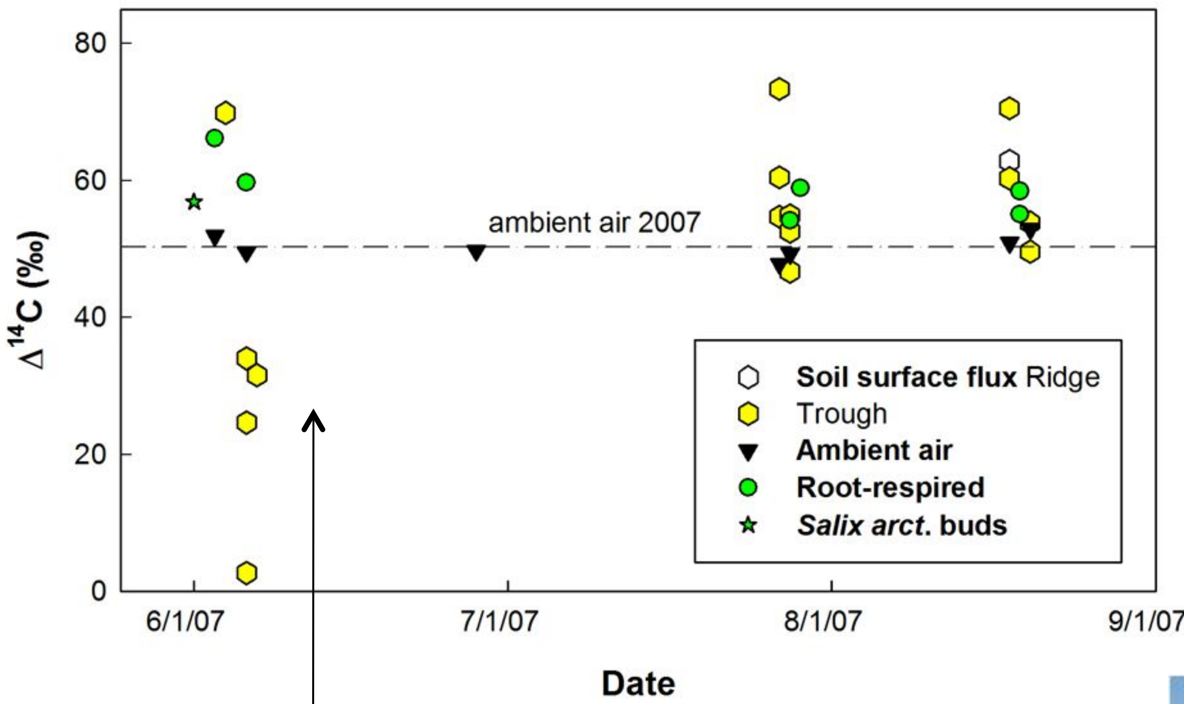
Soil Probes

[CO_2]- Depth Profiles



Soil CO_2 efflux rates (respiration) are 8x higher on vegetated troughs than barren ridges and show a strong seasonal pattern

Delta ^{14}C of respired CO_2 from polar stripe landscapes

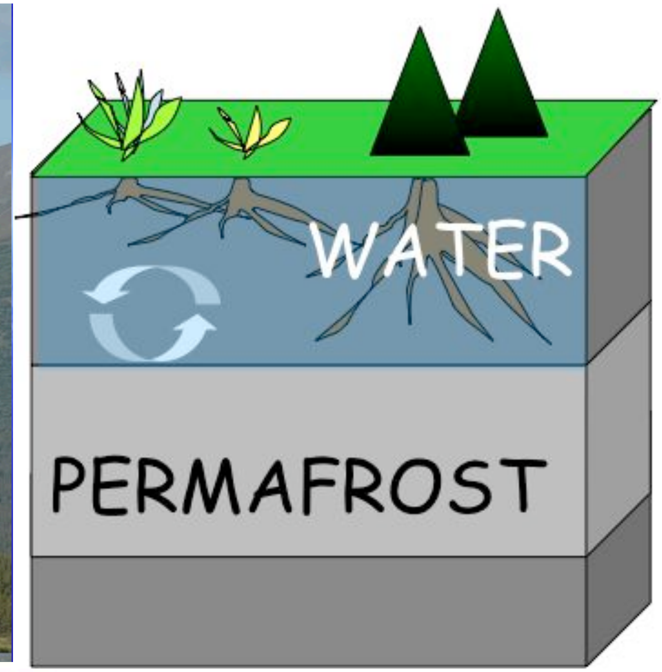


Efflux of older soil C is detectable before leaf out when the signal becomes swamped by fresh C from recent photosynthesis and root exudation

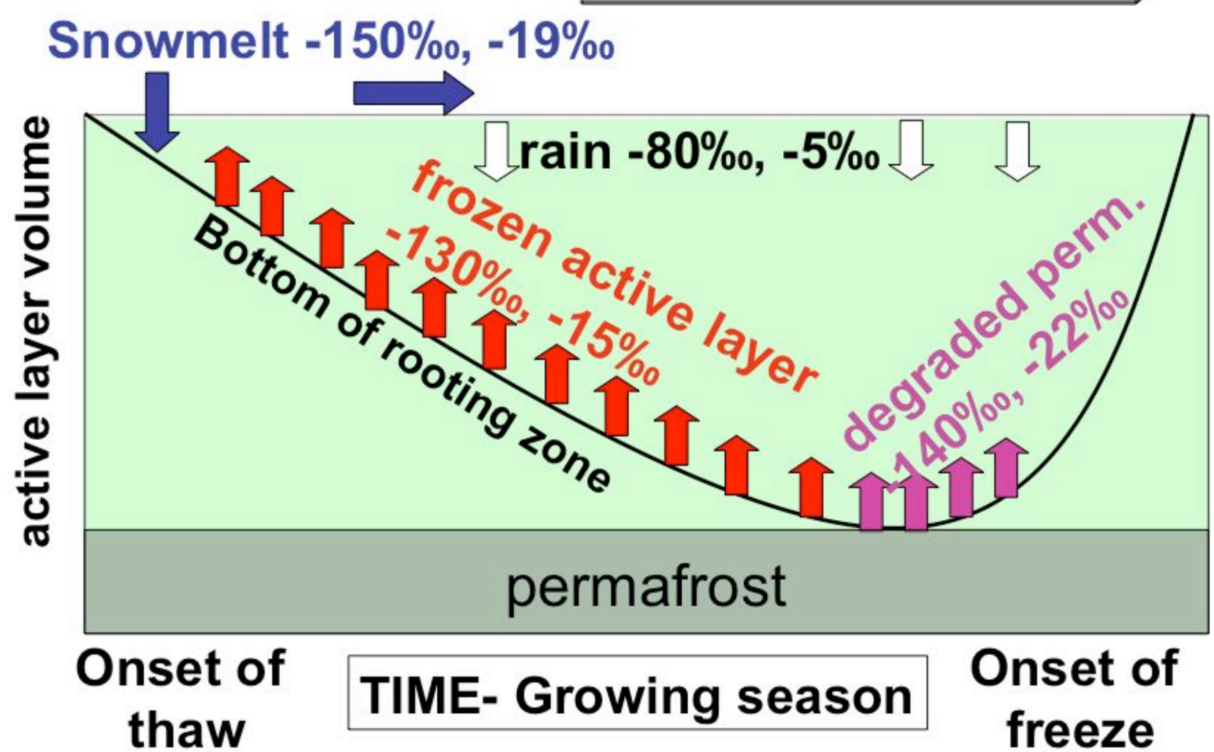
Leaf out

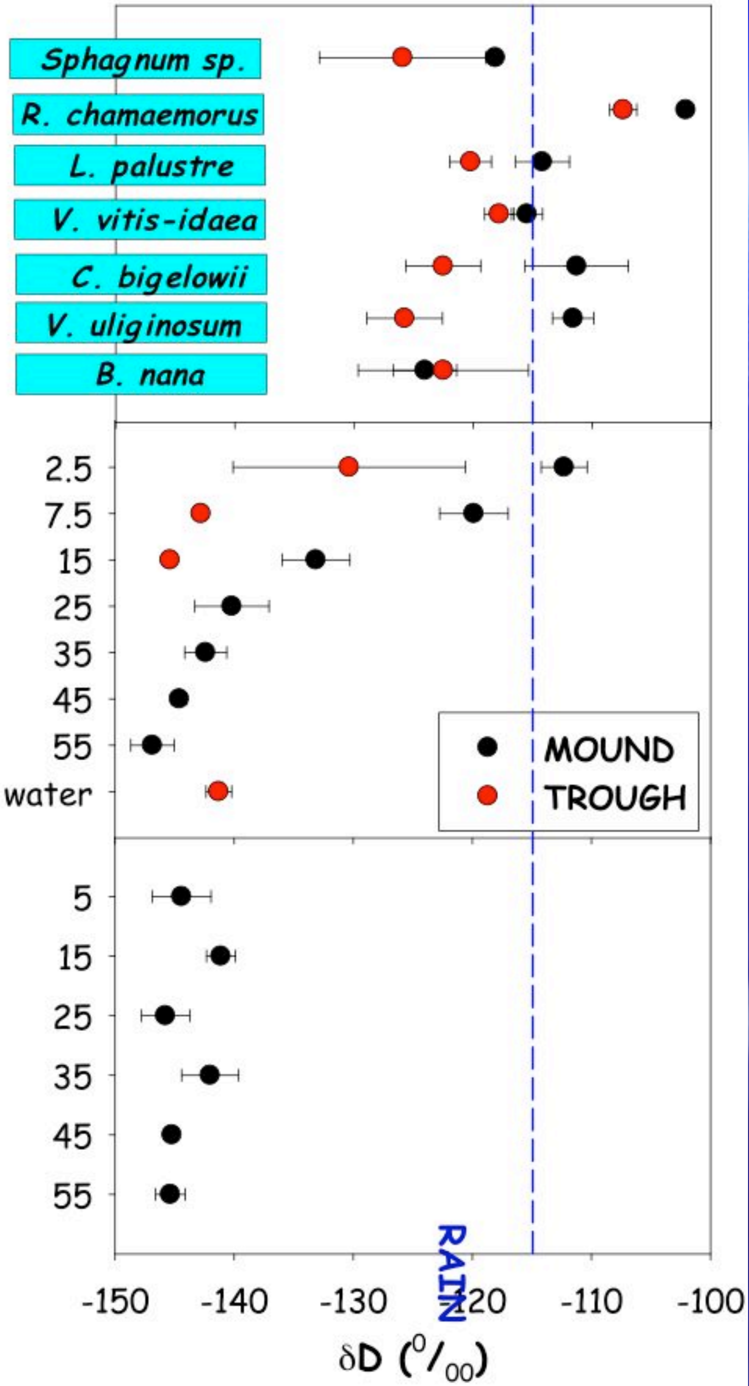
How will older soil C efflux respond to climate warming with and without added summer water?

Permafrost and Ecohydrology



Thawing permafrost may become an important water source for boreal and arctic plants-leading to: vegetation change and changes in the patterns and magnitudes of transpiration





Plant use of rain and deep water vary between life forms, the δD values of water in the active layer becomes progressively depleted from the surface to the bottom of the active layer/top of the permafrost.

Uncertainty-how do water sources vary between wet and dry years and as permafrost thaws, will "old" water become an important water source for all species?

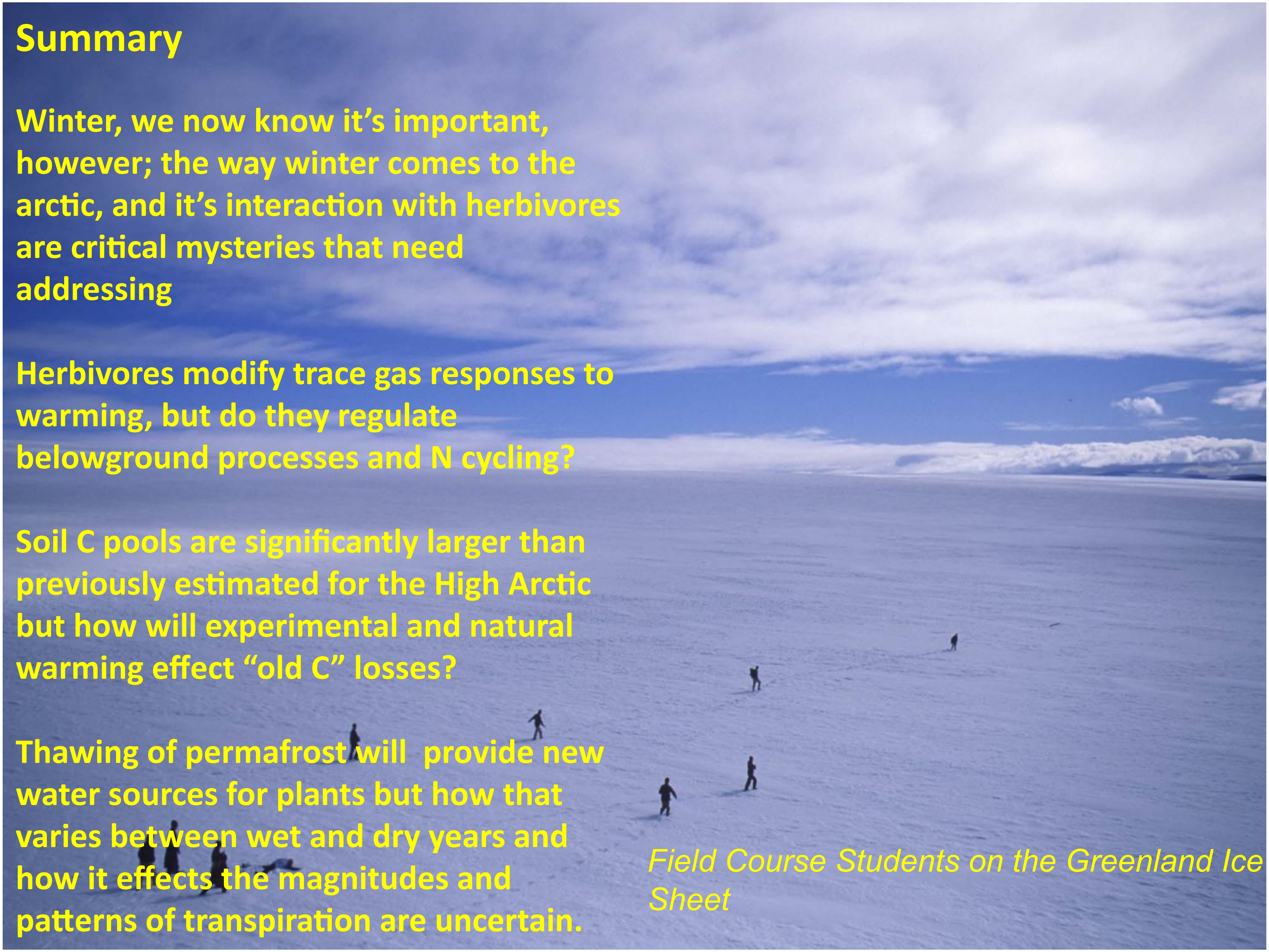
Summary

Winter, we now know it's important, however; the way winter comes to the arctic, and it's interaction with herbivores are critical mysteries that need addressing

Herbivores modify trace gas responses to warming, but do they regulate belowground processes and N cycling?

Soil C pools are significantly larger than previously estimated for the High Arctic but how will experimental and natural warming effect "old C" losses?

Thawing of permafrost will provide new water sources for plants but how that varies between wet and dry years and how it effects the magnitudes and patterns of transpiration are uncertain.



Field Course Students on the Greenland Ice Sheet

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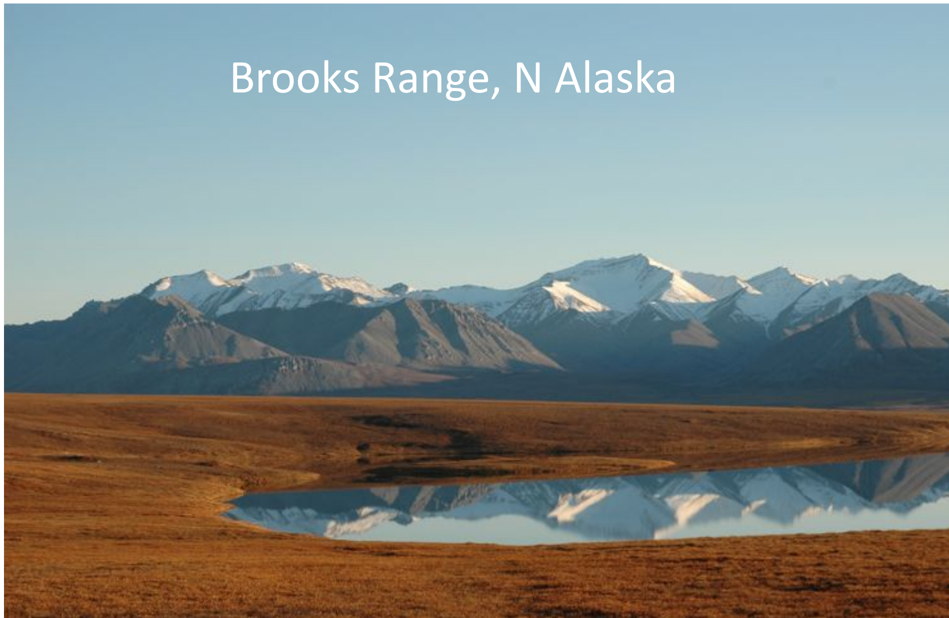
Co Authors: P Sullivan, J Cable, C Czimczik, E Post, S Cahoon, H Steltzer, J Schimel, R Sletten, B Hallet, B Hagedorn, B Sharp, M Rogers, S Arnes

Alyeska in March

Ripping the Aly pow


Brooks Range, N Alaska


West Central Greenland


NW Greenland