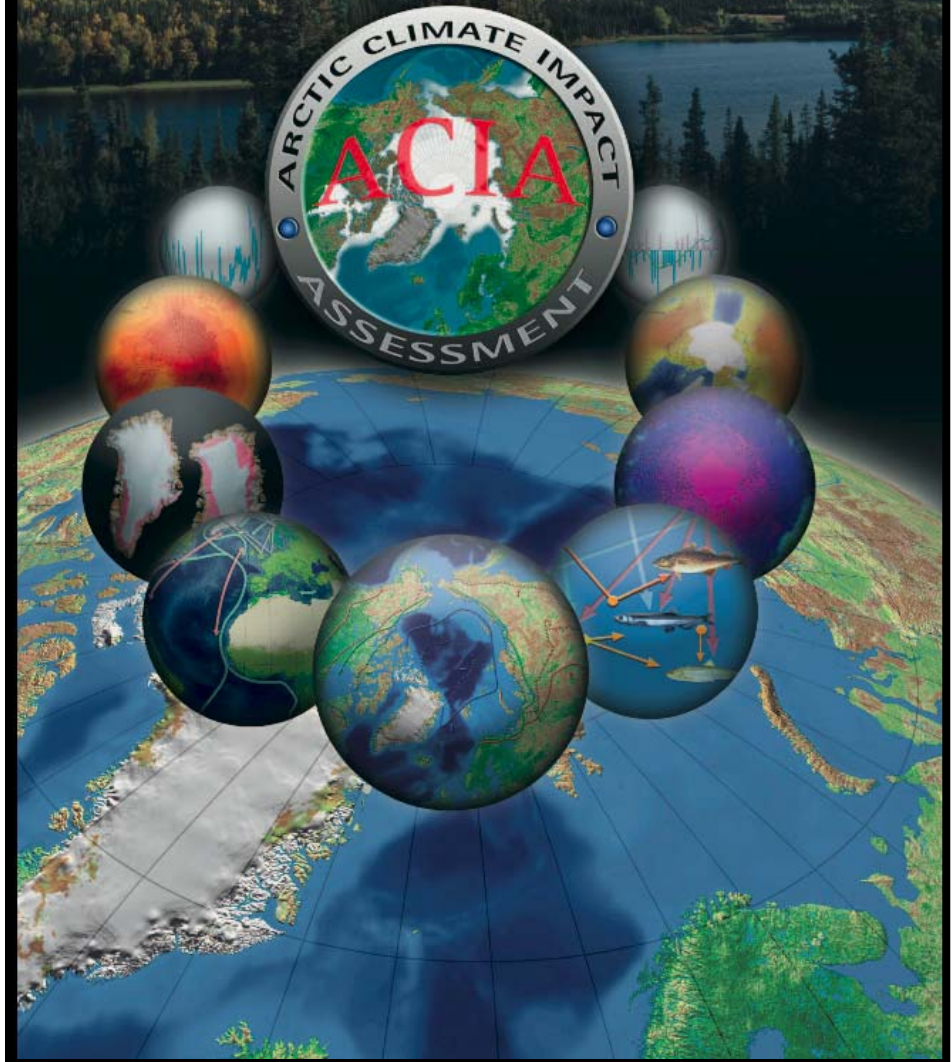


A photograph of a large agricultural field with rows of crops, a tractor, and a mountain range in the background under a cloudy sky. The field is filled with rows of green and reddish-brown plants. A red tractor is visible in the middle ground on the left. In the background, there is a dense line of trees and a large, rugged mountain range with some snow patches. The sky is overcast with grey clouds.

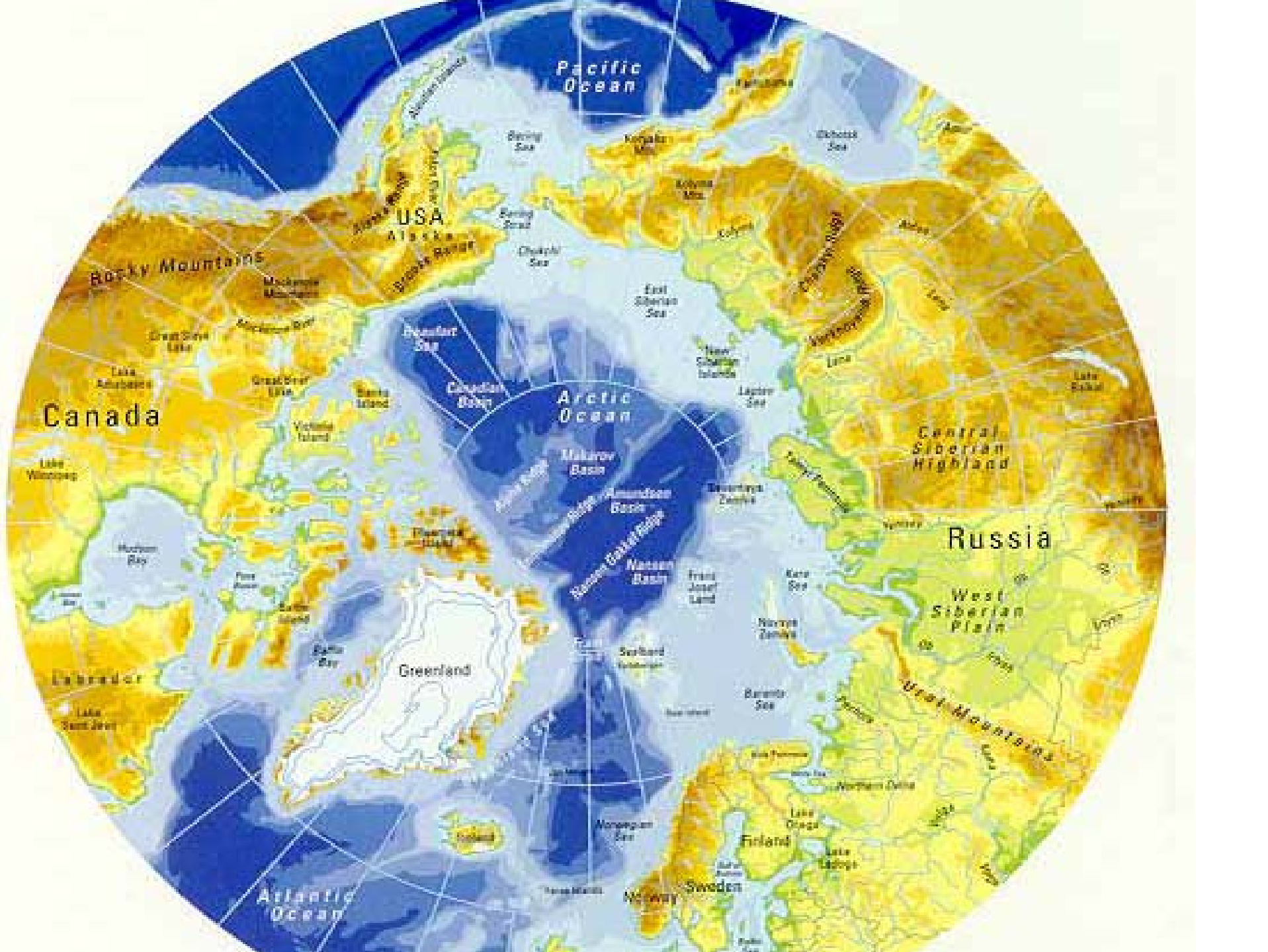
# Climate Change and High Latitude Agriculture

Stephen D. Sparrow, Carol E. Lewis, and Glenn P. Juday

# ARCTIC CLIMATE IMPACT ASSESSMENT







# Current state of Agriculture in Northern Regions



- Large agricultural industries in regions covered by the assessment exist only in Southern Siberia, Northern Alberta, and NE British Columbia
- Pockets of commercial scale agriculture in many areas throughout subarctic region

# Agriculture in the Arctic

- **Cooler areas:**

- potatoes, cool season vegetables, forage crops



- **Warmer areas**

- grains and oilseed crops







## Agriculture in the Arctic

- **Livestock**

- dairy cattle, sheep, goats (declining)
- diversified livestock (reindeer, bison, elk, others)





# Agriculture in Alaska

- Current land in commercial agricultural production
  - ~30,000 acres in crops
    - 74% in perennial hay crops
    - 22% in grain crops
    - 4% in potatoes and vegetables



# Agriculture in Alaska

- Current land in commercial agricultural production
  - ~30,000 acres in crops
    - 55% in Tanana Valley
    - 37% in Matanuska/Susitna Valley
    - 9% in Kenai Pen/SW AK



# Potential Arable Land in Alaska



- Study by USDA Soil Conservation Service in 1979 indicated about 20 million acres with soils and climate suitable for cropping



# SOILS WITH AGRICULTURAL POTENTIAL ALASKA

JUNE 1973



ALBERS EQUAL-AREA PROJECTION

### LEGEND

Upland Soils Suitable For Farming

- More Than 50%
- 25-50%

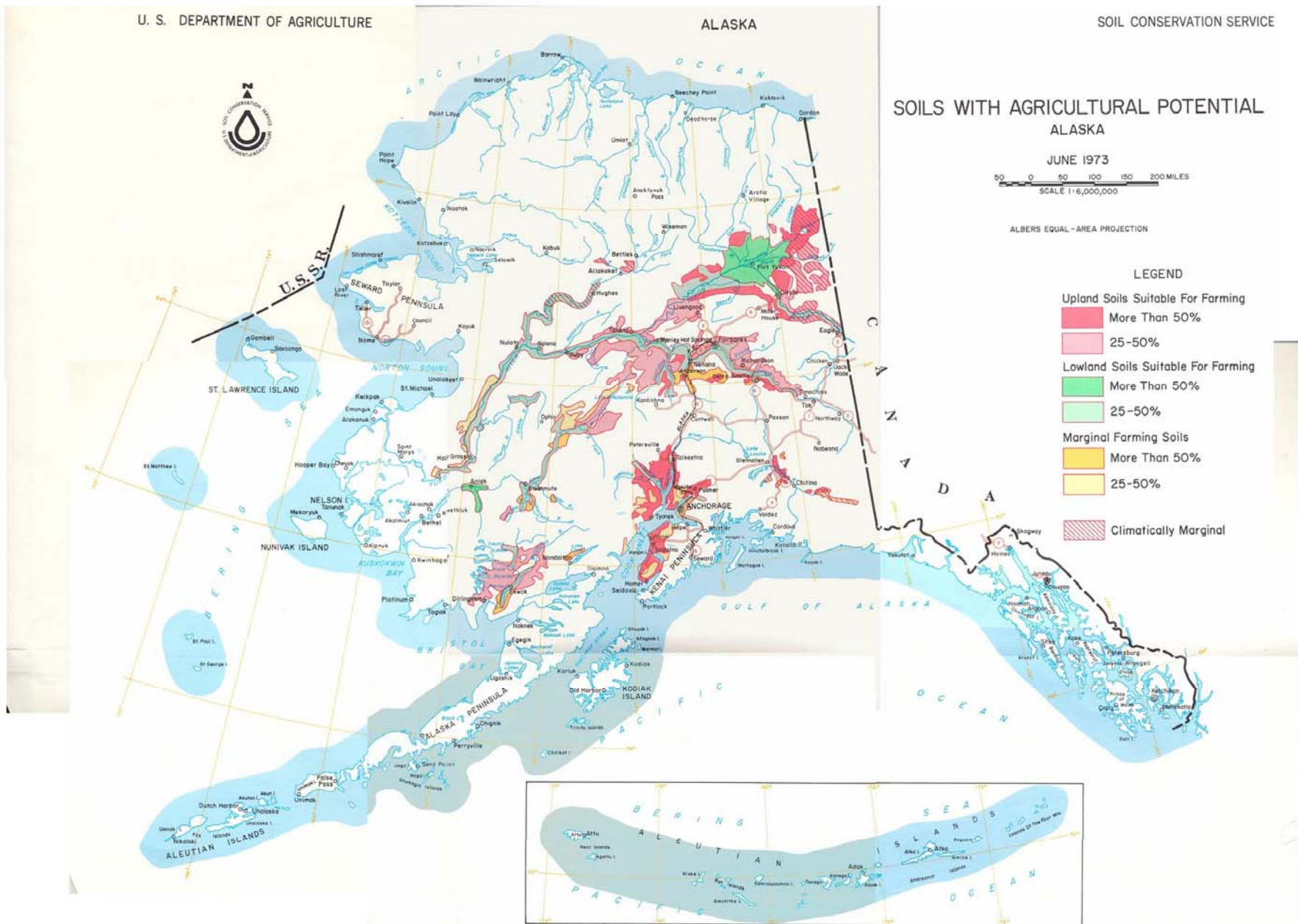
Lowland Soils Suitable For Farming

- More Than 50%
- 25-50%

Marginal Farming Soils

- More Than 50%
- 25-50%

Climatically Marginal

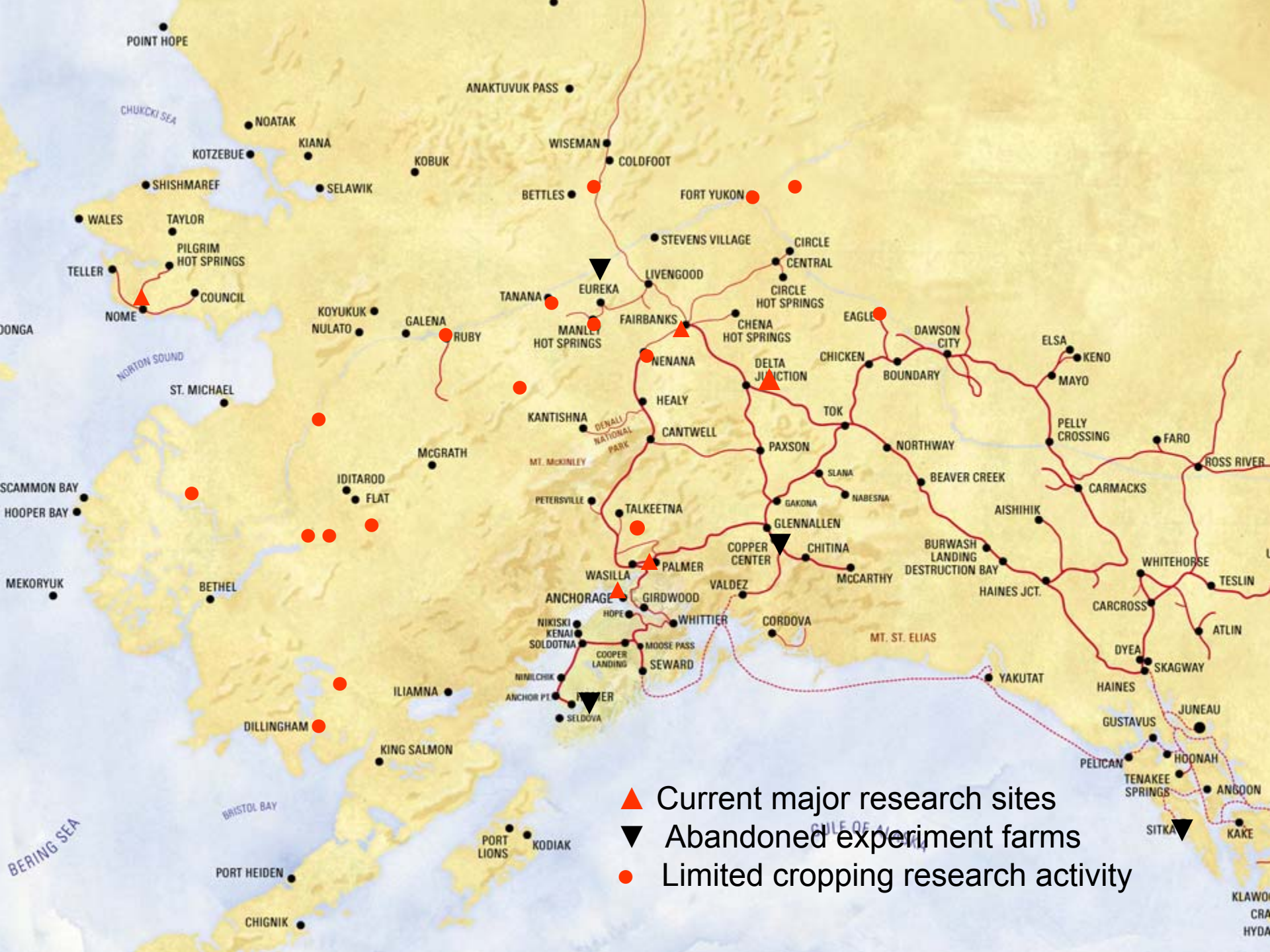


# Alaska Agricultural Potential

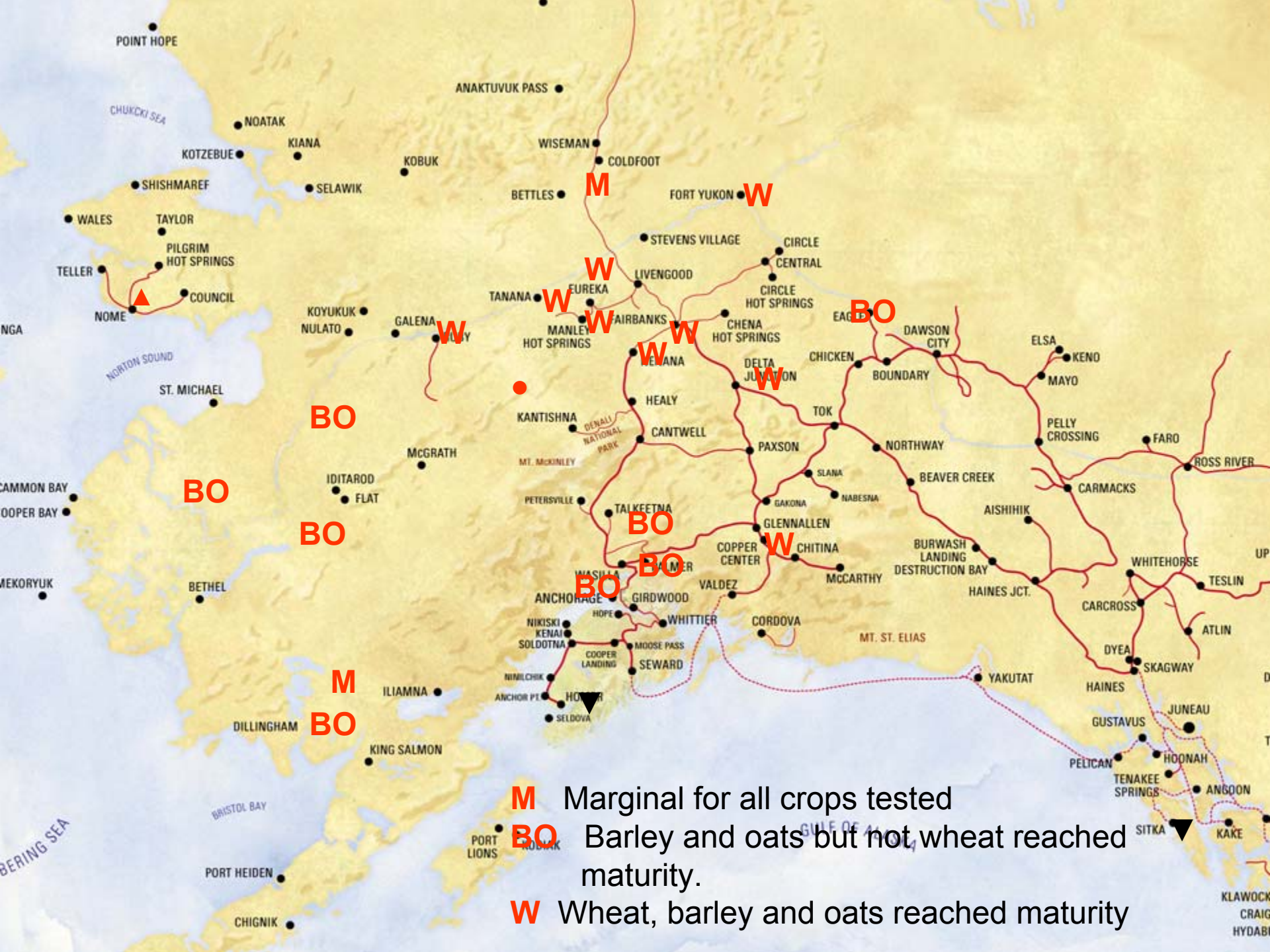


- Trials at remote locations have included mostly small grains (barley, oats, wheat)
- Some research on vegetable crops and potatoes









**M** Marginal for all crops tested

**BO** Barley and oats but not wheat reached maturity.

**W** Wheat, barley and oats reached maturity

# Major constraints to commercial cropping in high latitude regions



- Climate
  - Low heat energy
  - Short growing seasons
  - Water deficits
  - Unfavorable winter climates for survival of perennial crops
- Infrastructure
  - Lack of roads, ports, etc.



# Major constraints to commercial cropping in high latitude regions



- Economics
- Current land ownership/management
- Government policy?

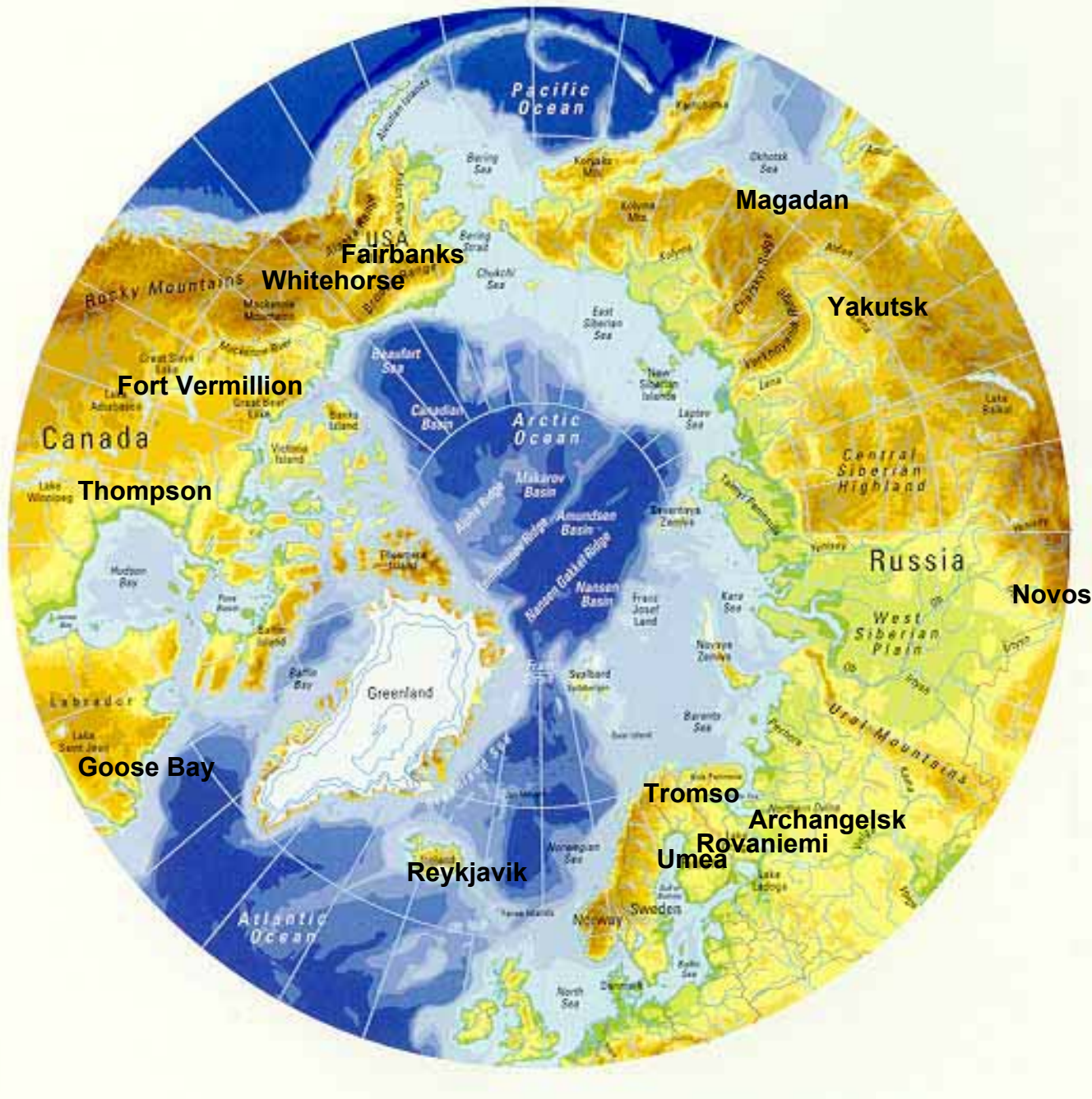
**How will climate warming likely affect agricultural potential in the circumpolar region and especially in Alaska?**





- We used projections from 5 climate models to analyze likely effects of climate change on potential for production of several crops at 14 locations in Circumpolar North
- Focused mostly on crop production rather than livestock







# Approach

- Selected 12 crops representing livestock feed, human food, and oilseed crops.
  - Focused mainly on annual crops
- Selected crops which are currently grown in at least part of the region.
- Used growing degree days (accumulated heat energy during growing season) to assess suitability for given annual crop species.



- Growing degree day (GDD) is the average daily temperature minus base temperature
- Example : for base temperature = 5°C

Daily high = 20°C, low = 10°C

$$\text{GDD} = 15 - 5 = 10$$





- GDD often used as indicator of crop growth rates, time to maturity, and yields
- Limitations:
  - GDD requirement for given plant species varies with growth stage and crop cultivar
  - Base temperature for growth varies with crop species, growth stage, and crop cultivar
  - GDD requirement varies with degree of environmental stress and with photoperiod



- Limitations:
  - Limited data for GDD requirements for some crops
  - Limited data for GDD requirements at high latitudes

# GDD requirements for selected food crops to reach maturity



Crop	GDD (5°C base)
Dry beans	1100-1500
Peas (for green processing)	700-800
Dry peas	800-1150

# GDD requirements for selected feed or oil crops to reach maturity



Crop	GDD (5°C base)
Spring wheat	1000-1200
Canola	950-1050
Barley	700-900



# GDD requirements for selected forage crops reach harvest stage



Crop	GDD (5°C base)
Alfalfa	350 -450
Red clover	450
Timothy	350 - 450

# Current GDD at select locations



Location	GDD (5°C base)
Fairbanks	1116
Big Delta	1007
Tromso	496
Novosibirsk	1426



- Determined potential moisture deficits or surpluses by subtracting projected evapotranspiration from projected precipitation.



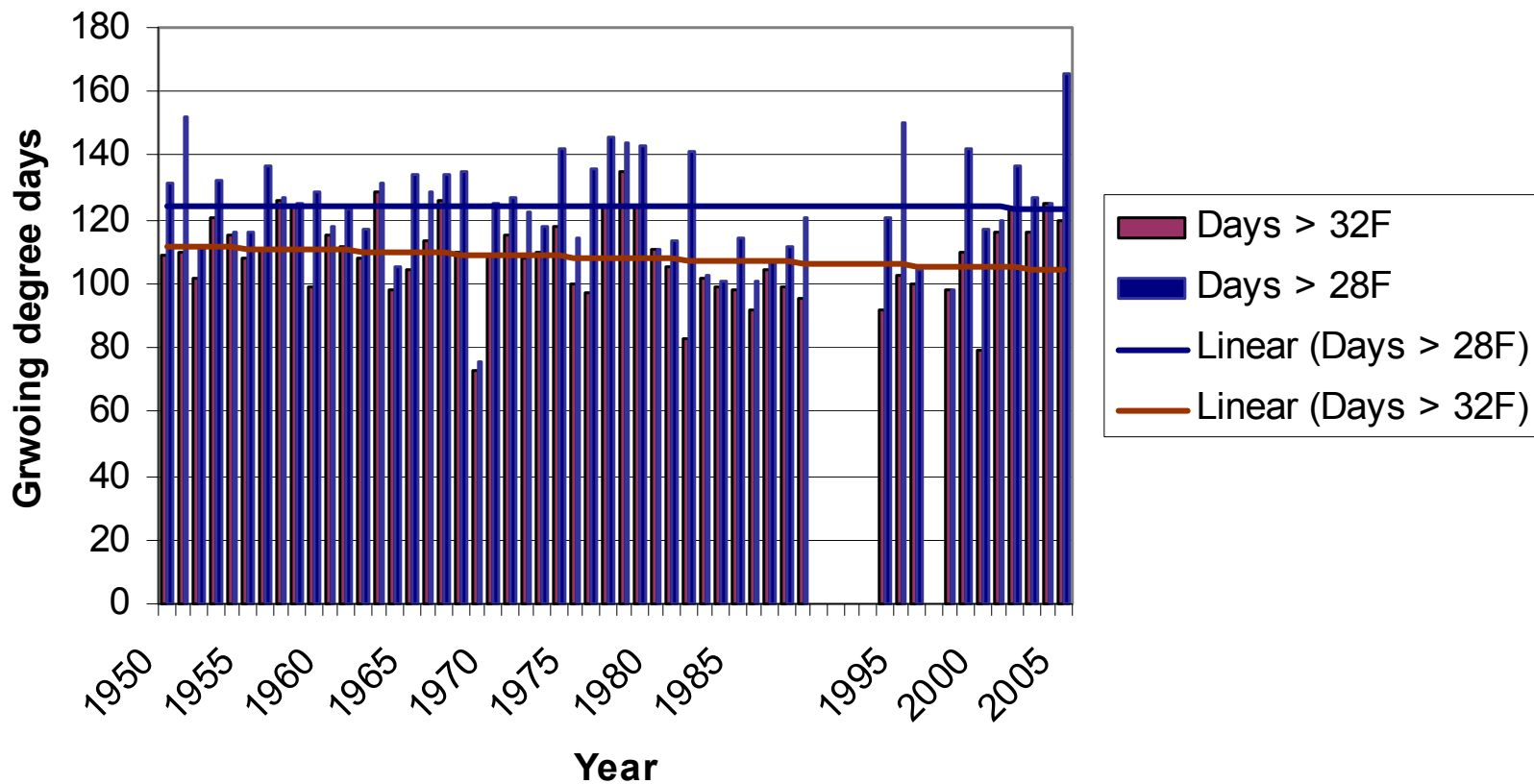
- Used three 20 year time periods from 2011 until 2090 for evaluation.
- Used lowest and highest projection for GDD and moisture deficit for each location.



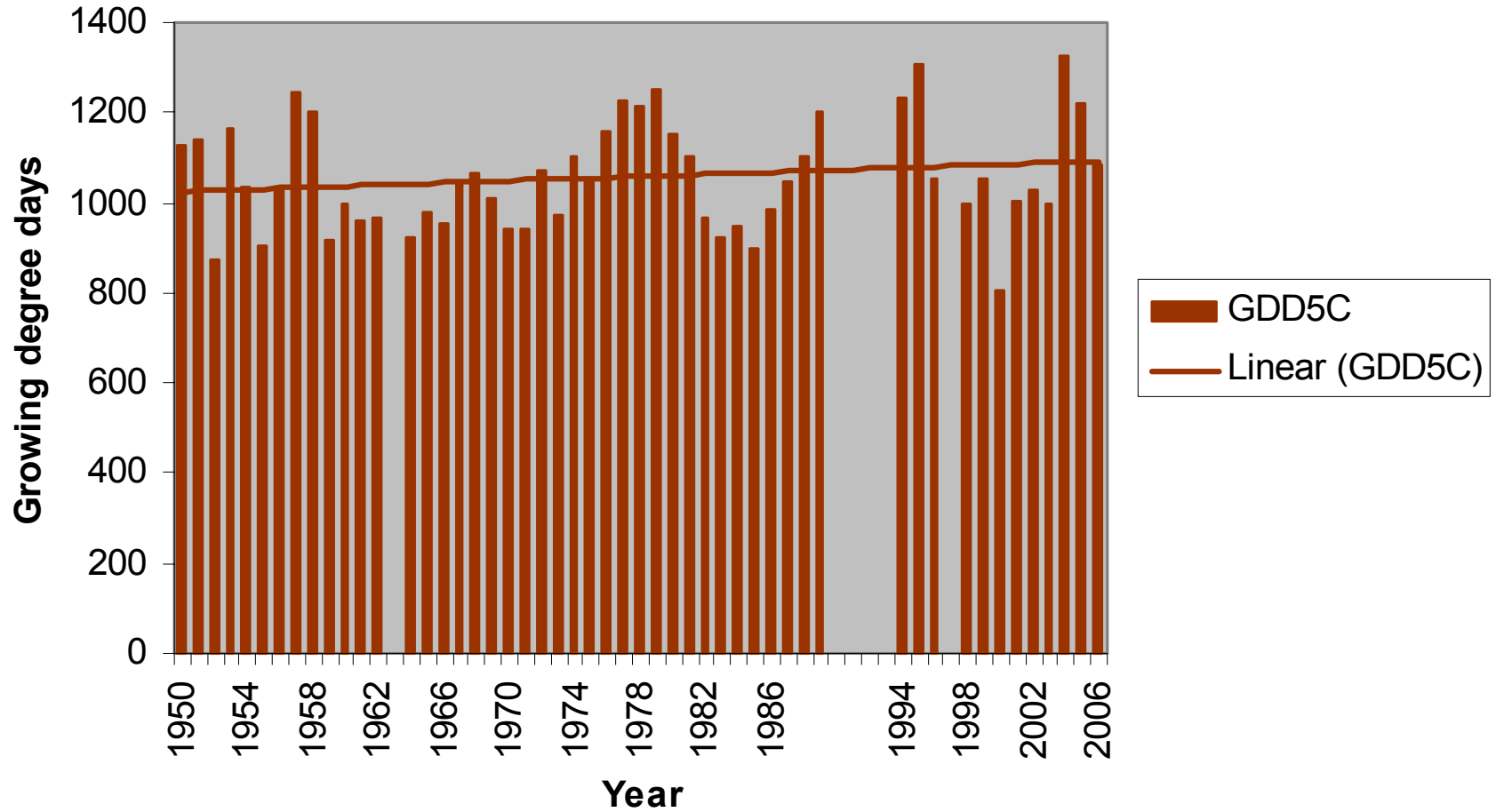


- A quick look at current and recent (50 ybp) climate in central AK

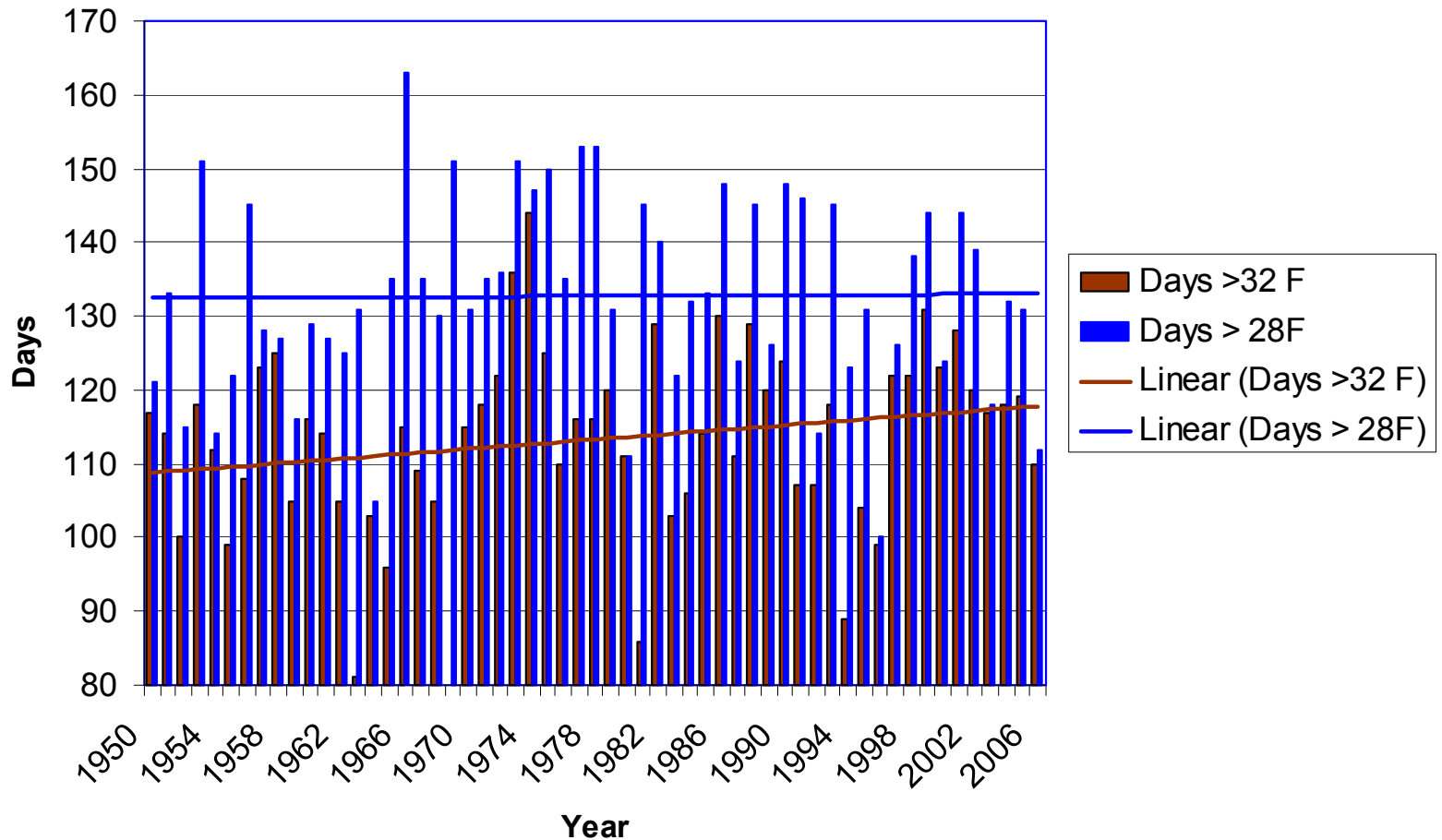
## Growing season length based on 32 degrees F and 28 degrees F at Big Delta, Alaska



# Growing degree days (base 5C ) at Big Delta, Alaska

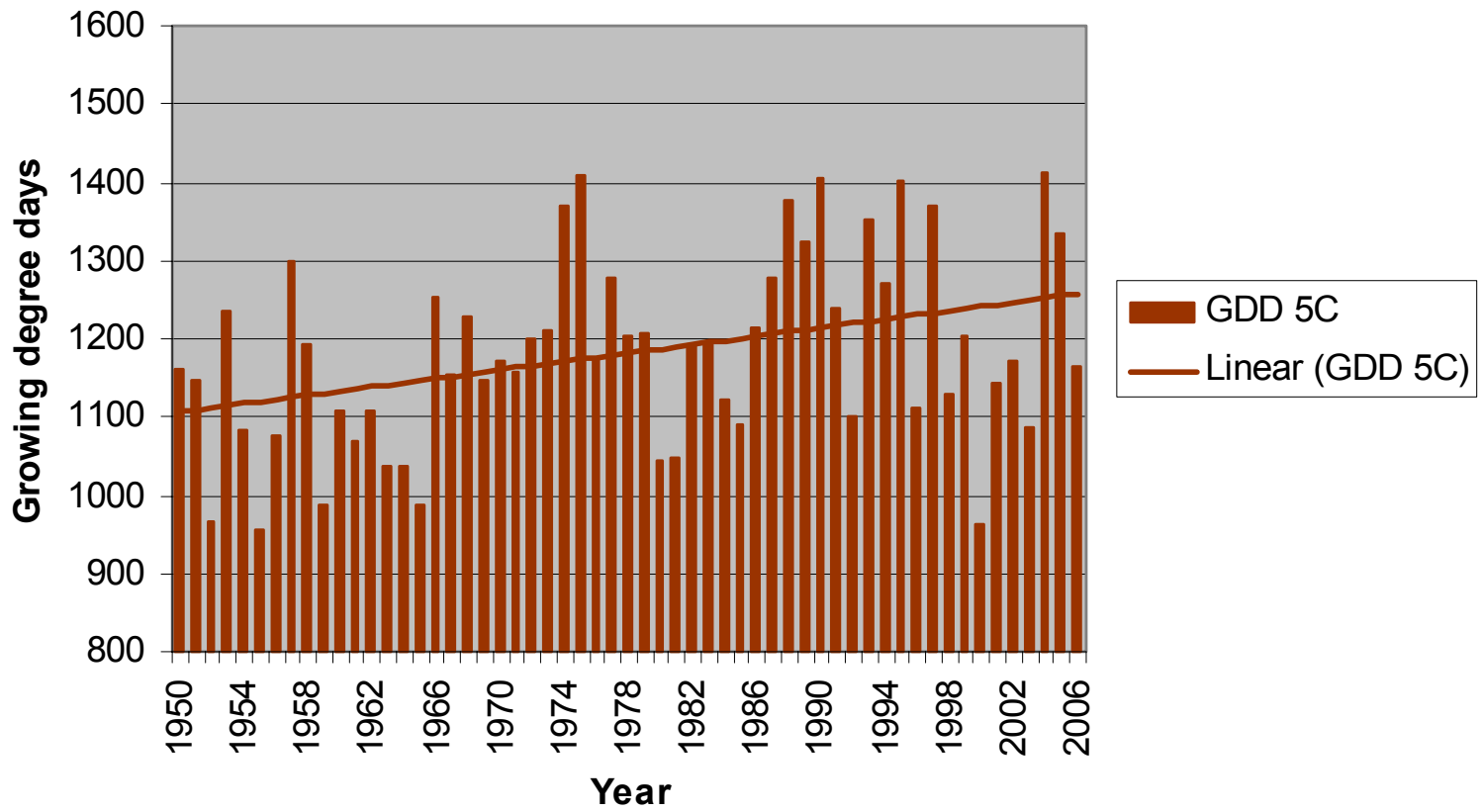


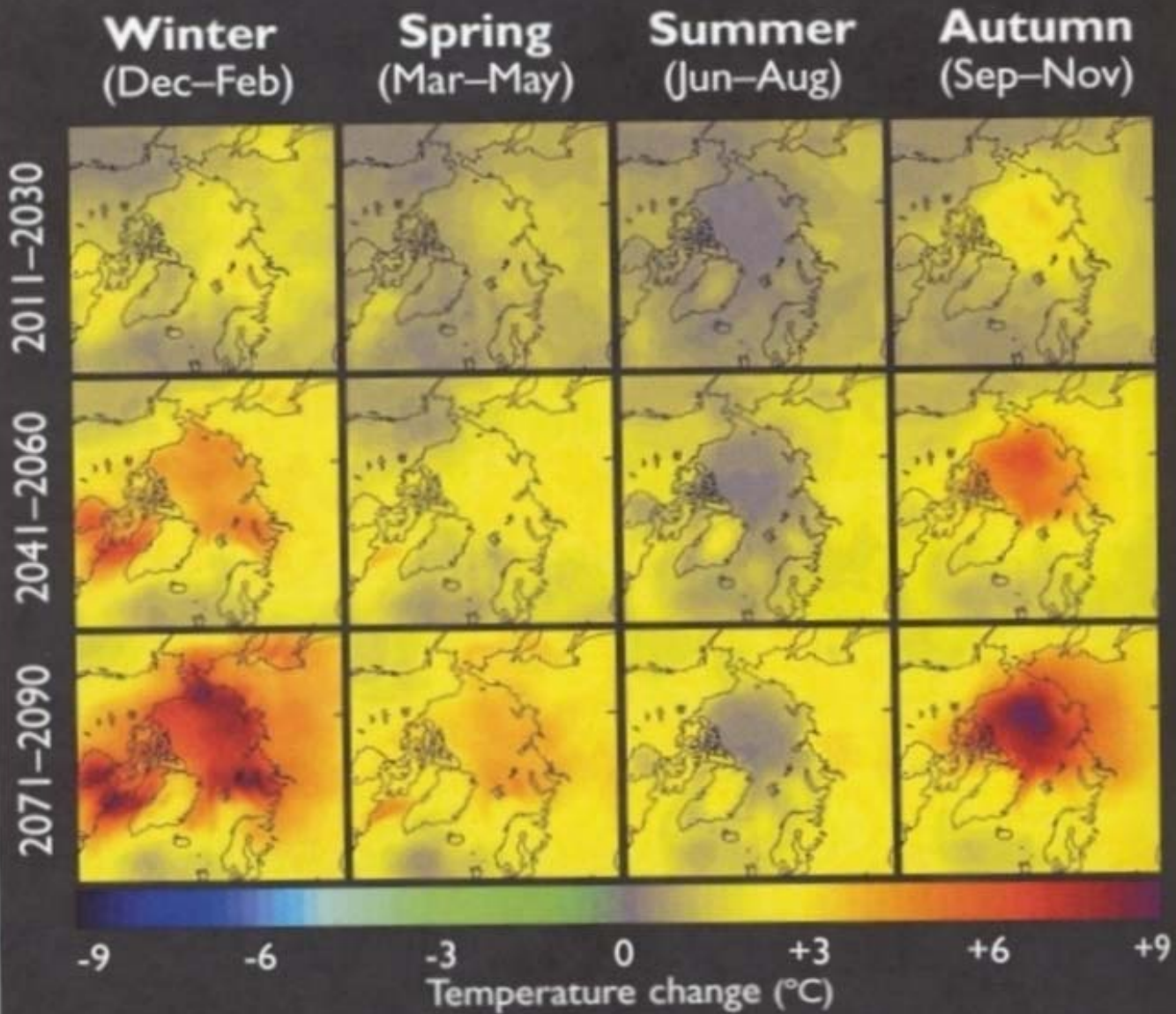
## Growing season length based on 32 degrees F and 28 degrees F at Fairbanks, AK





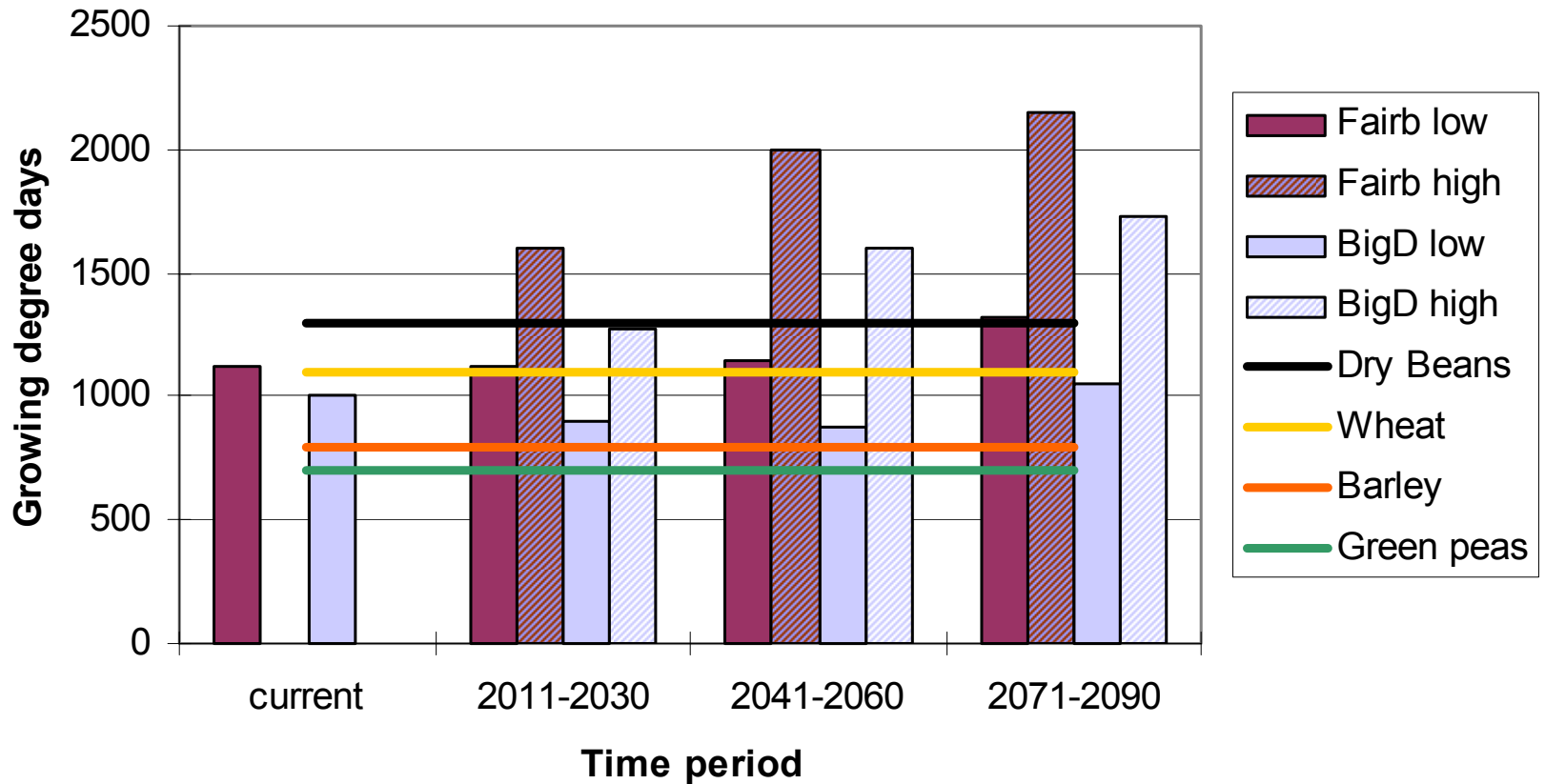
## Growing degree days (5 C) at Fairbanks, Alaska



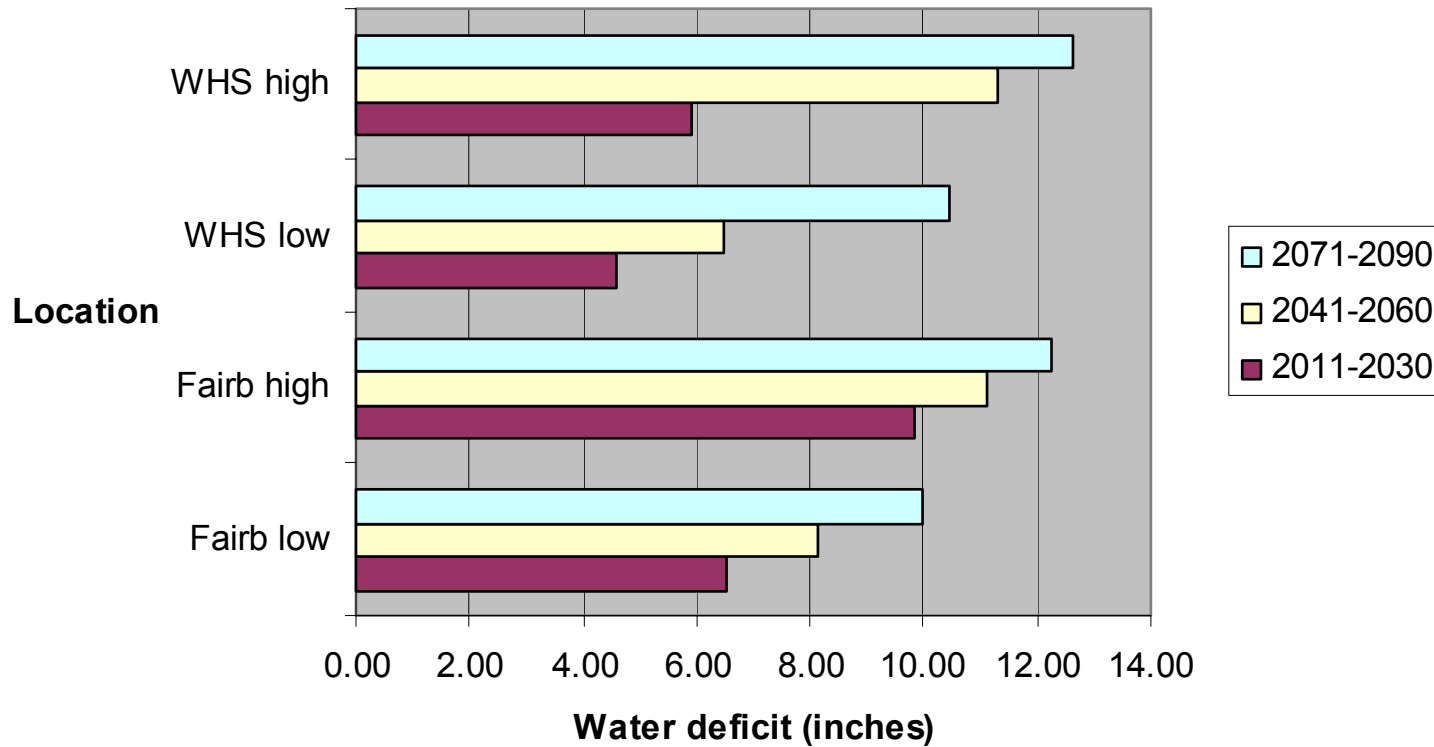


**Fig. 4.16.** Seasonal changes in surface air temperature averaged over the five ACIA-designated B2 projections. Top: 2011–2030; middle: 2041–2060; bottom: 2071–2090.

## Projected growing degree days (5C base) at Fairbanks (Fairb) and Big Delta (BigD), Alaska



## Projected potential water deficits at Fairbanks (Fairb) and Whitehorse (WHS)





# What can we conclude about potential for agriculture in a warmer boreal region?



- Crop production could advance northward throughout the century
- Many crops now suitable only for warmer parts of the boreal region may become suitable as far north as the Arctic Circle
- Crop yields are likely to increase due to suitability of longer-season, higher yielding varieties
- Water stress may become an important factor in many areas, and irrigation may be necessary to produce good yields

# What can we conclude about potential for agriculture in a warmer boreal region?



- Yields of perennial forage crops may increase because warmer, longer growing seasons will allow more harvests
- Warmer winters could allow crops less hardy perennial crops to move northward, but increased winter thaws may negate this potential effect

# Some important variables not considered



- Extreme storm events
- Winter conditions (especially important for perennial crops)



# Other Potential Effects

- Pests (plant diseases, insects, weeds) would likely increase under a warmer climate
  - No detailed analysis
  - Not likely to offset potential yield increases or potential for new crops if proper control measures are used
  - Could have severe local effects





# Other Potential Effects

- CO<sub>2</sub> fertilization effect
  - May result in yield increases, but little research on CO<sub>2</sub> enrichment effects on crops at high latitudes, thus difficult to forecast
- Changes in worldwide food costs
- Changes in available shipping lanes

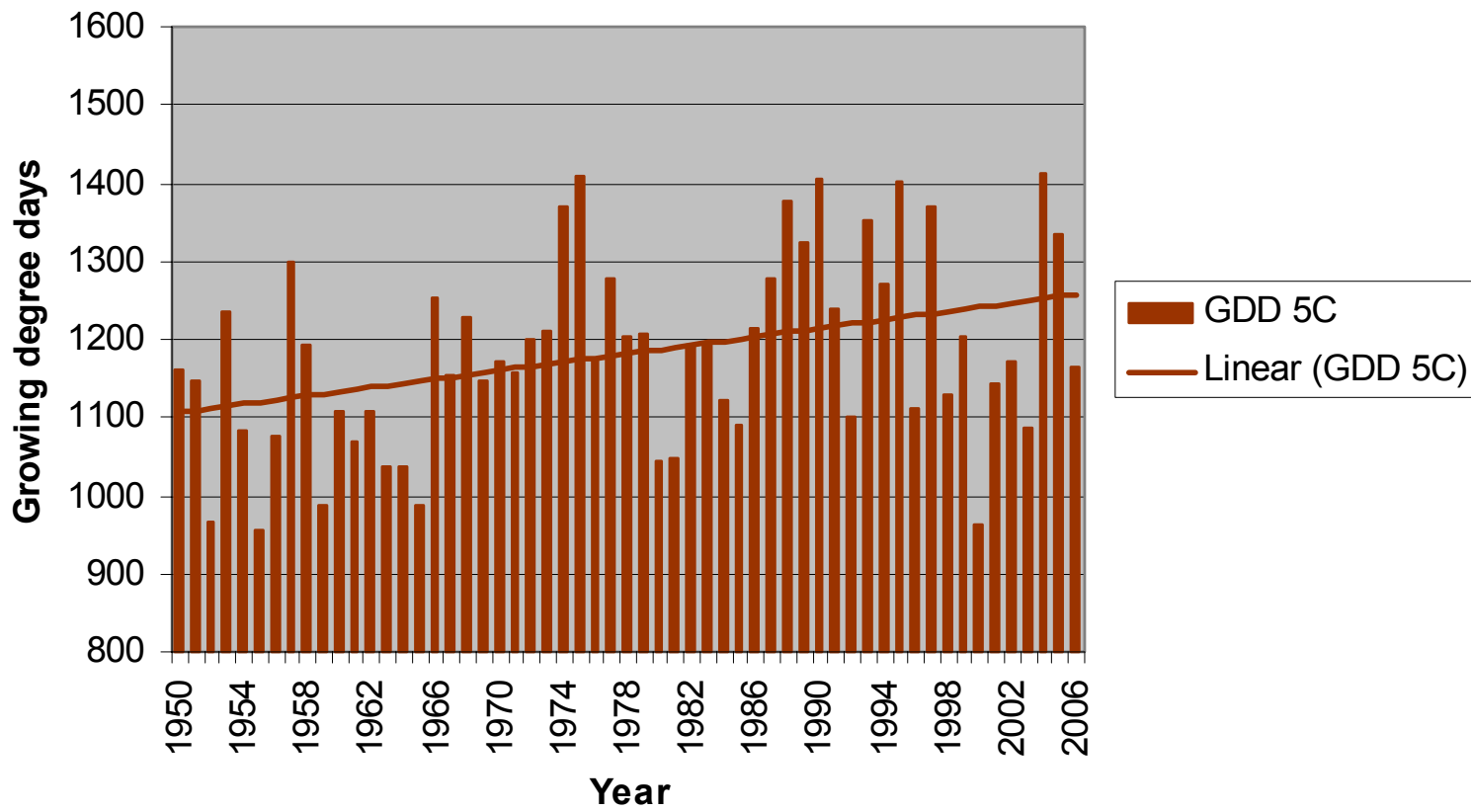


# The Future

- Remoteness and lack of infrastructure likely to remain major limiting factors for commercial agricultural development in most northern regions in near future
- Government policies regarding agriculture and perhaps trade will likely have very large influence on occurrence and rate of agricultural development in the north
- Farmers perception of risk and rate of adaptation could be important



### Growing degree days (5 C) at Fairbanks, Alaska



# Speed of Adoption of Some Major Adaptation Measures



Adaptation	Adjustment time (Yrs)
New variety adoption	3-14
New variety development	8-15
New crop adoption	15-30
Tillage systems	10-12
Major new infrastructure (e.g. dams)	Up to 50

## Suppose the climate cools significantly over the next 25 – 50 years



- Unless cooling is severe, total area of potentially arable land in AK not likely to change much
- Wheat and Canola would become less feasible as potential economic crops
- Barley and cool season vegetables likely to remain viable crops in most areas



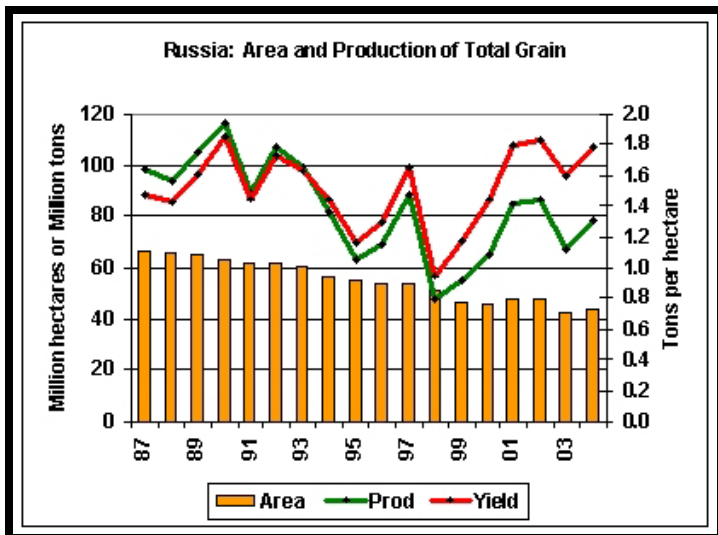


● Questions?



# Agriculture and Climate Scenarios

- **Rising temperatures very likely (almost certain) to enable crop production further north.**
- **Crops now only suitable in warmest parts become possible northward to Arctic Circle or further north.**
- **Average annual yield of farms likely to increase at lower levels of warming.**
  - **higher yielding crop varieties become practical**
  - **lower probabilities of limiting low temperatures**

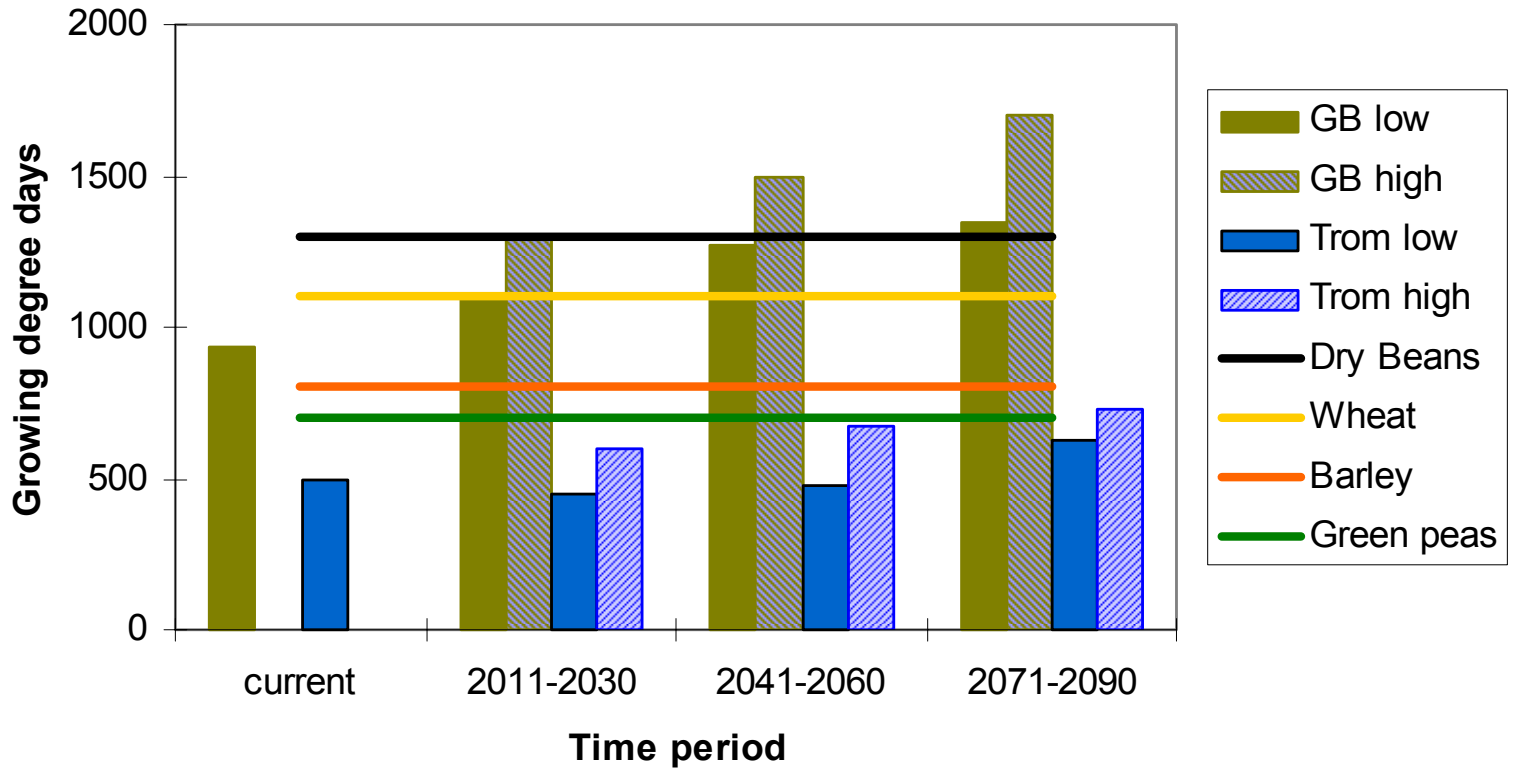


# Other possible approaches



- Use crop/climate modeling
  - Limited data for crops of interest, especially at high latitudes.
  - Lack of crop modeling expertise

## Projected growing degree days (base 5C) at Goose Bay (GB) Canada and Tromso (Trom), Norway



## Projected water deficits at Goose Bay GB), Canada and Tromso (Trom), Norway

