Global change and arctic systems

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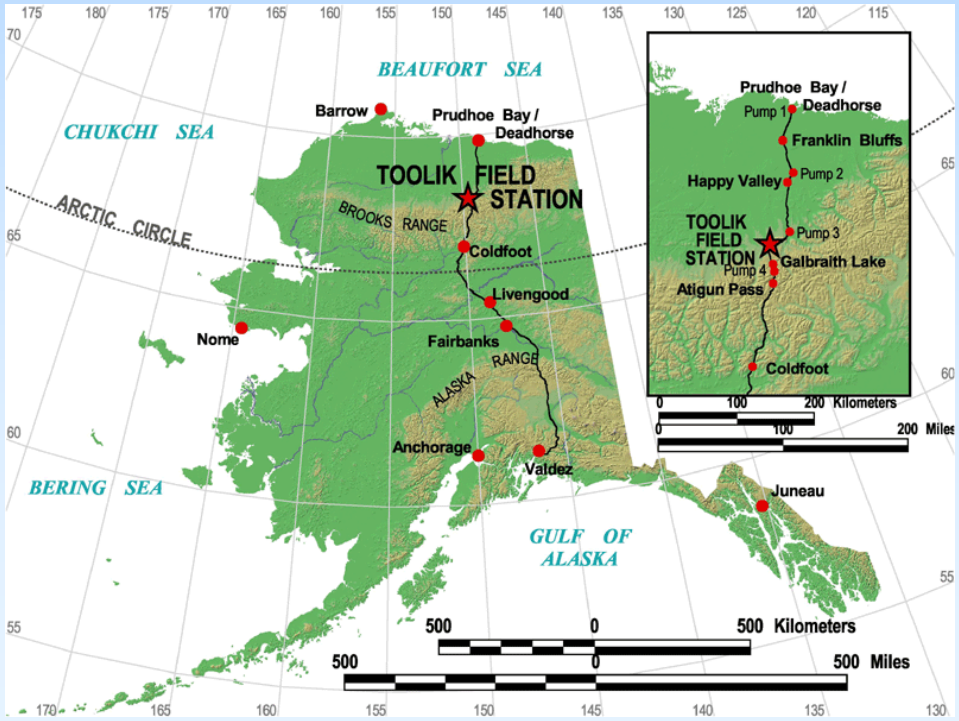
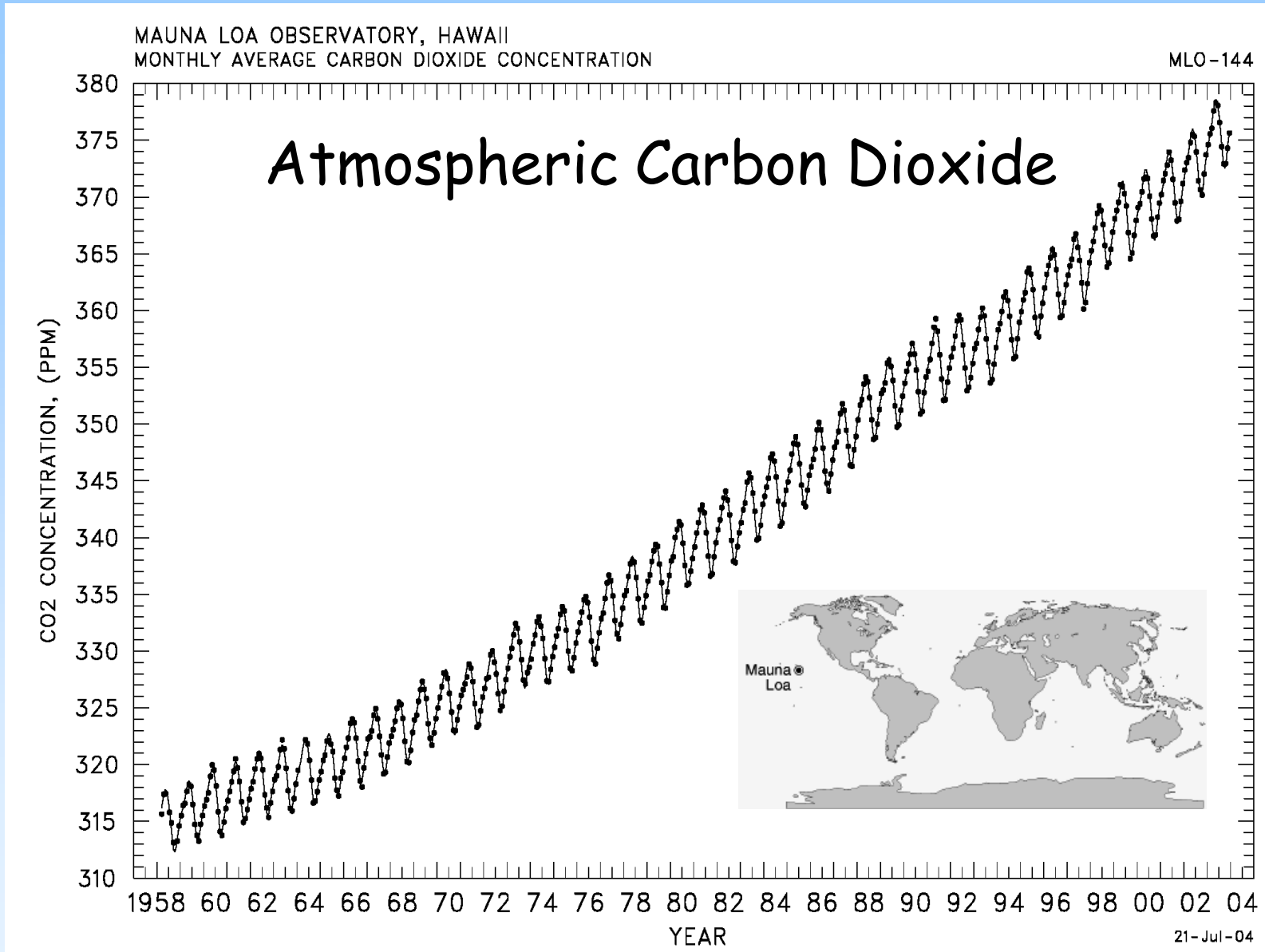
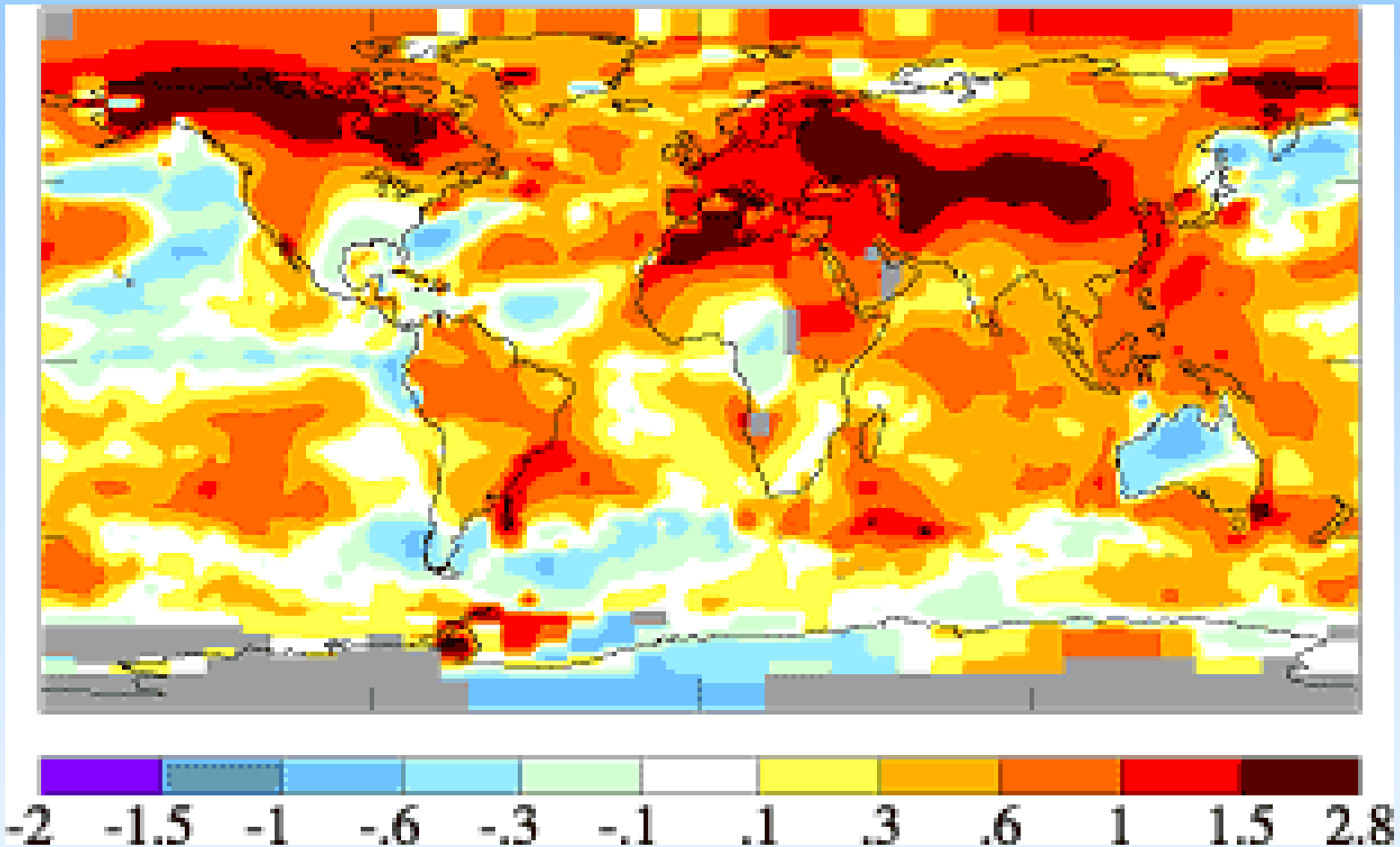
Question

How can long-term research inform our understanding of how terrestrial arctic carbon balance will respond to climate warming?



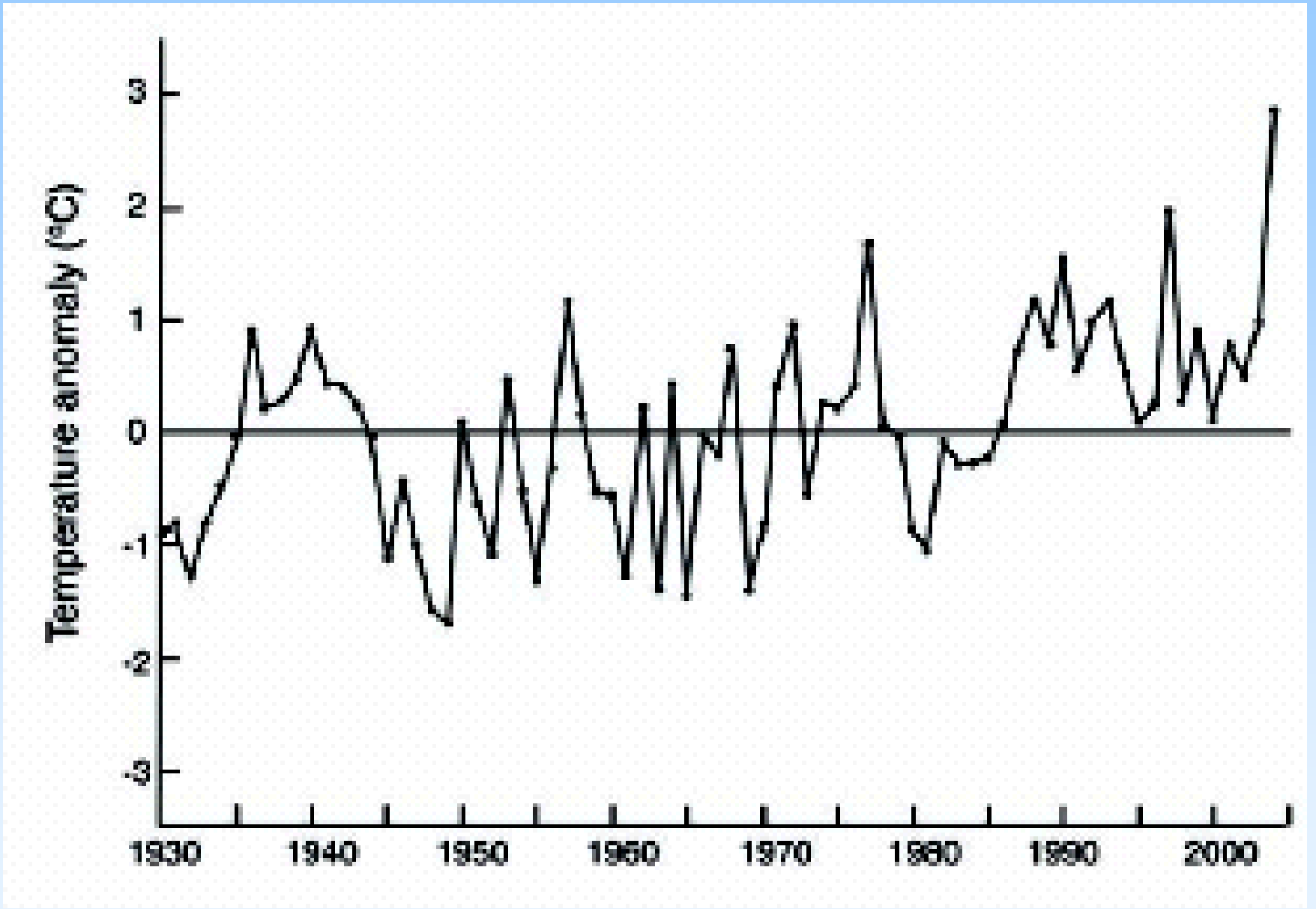

MAUNA LOA OBSERVATORY, HAWAII
MONTHLY AVERAGE CARBON DIOXIDE CONCENTRATION
MLO-144
Atmospheric Carbon Dioxide
CO2 CONCENTRATION, (PPM)
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
1958 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04
YEAR
21-Jul-04
Mauna Loa

Mean global surface T anomalies, 2005



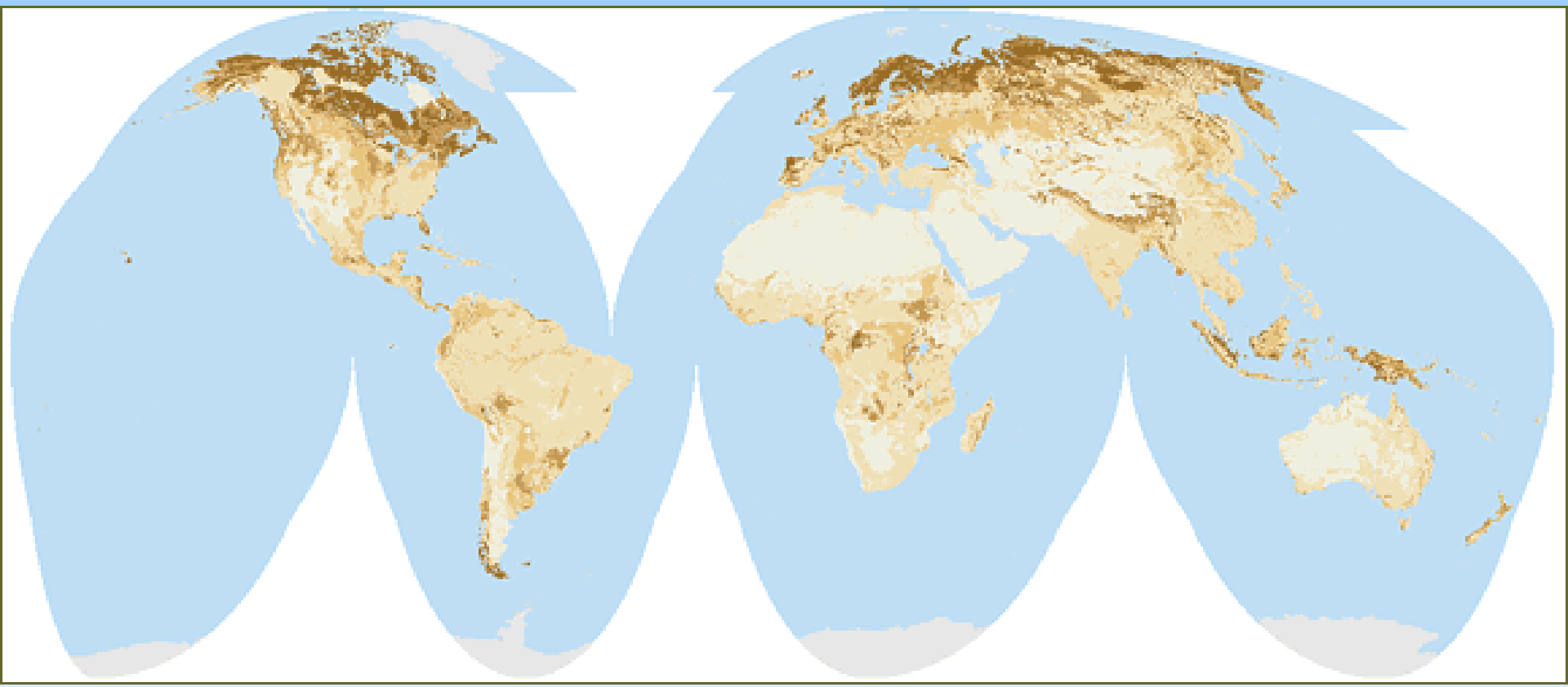
http://www.giss.nasa.gov/research/observe/surftemp/

Mean arctic surface T anomalies



Chapin et al. 2005

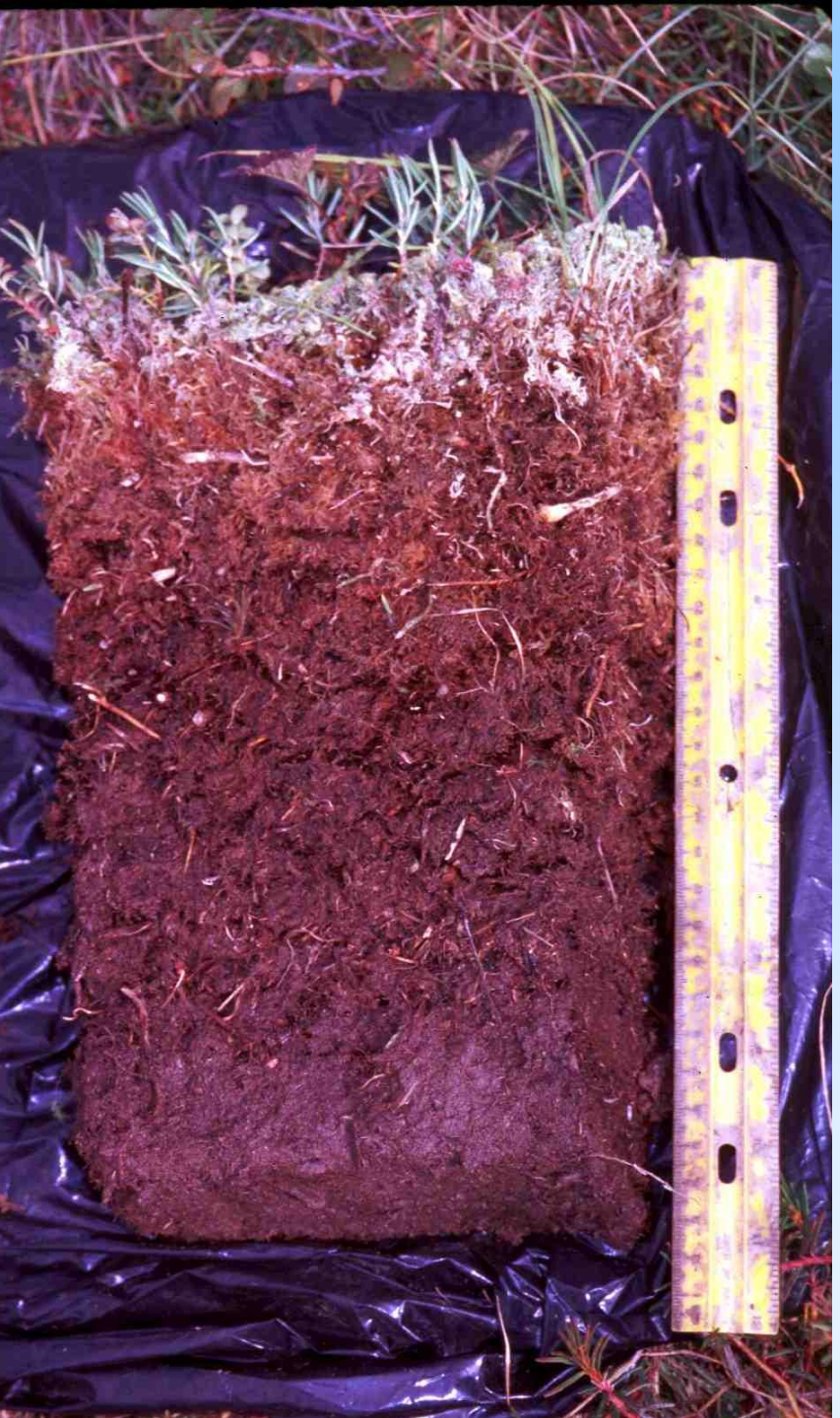
Global Soil Carbon Storage



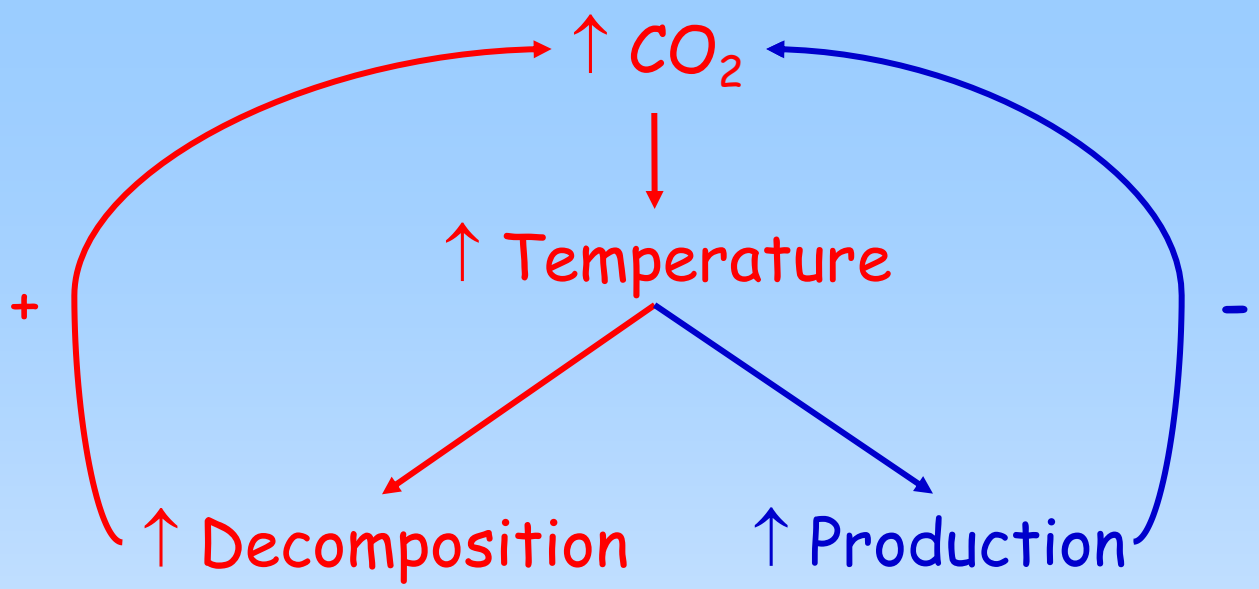
Carbon Storage
metric tons / ha

1-50
51-100
101-150
151-300
> 300
No data

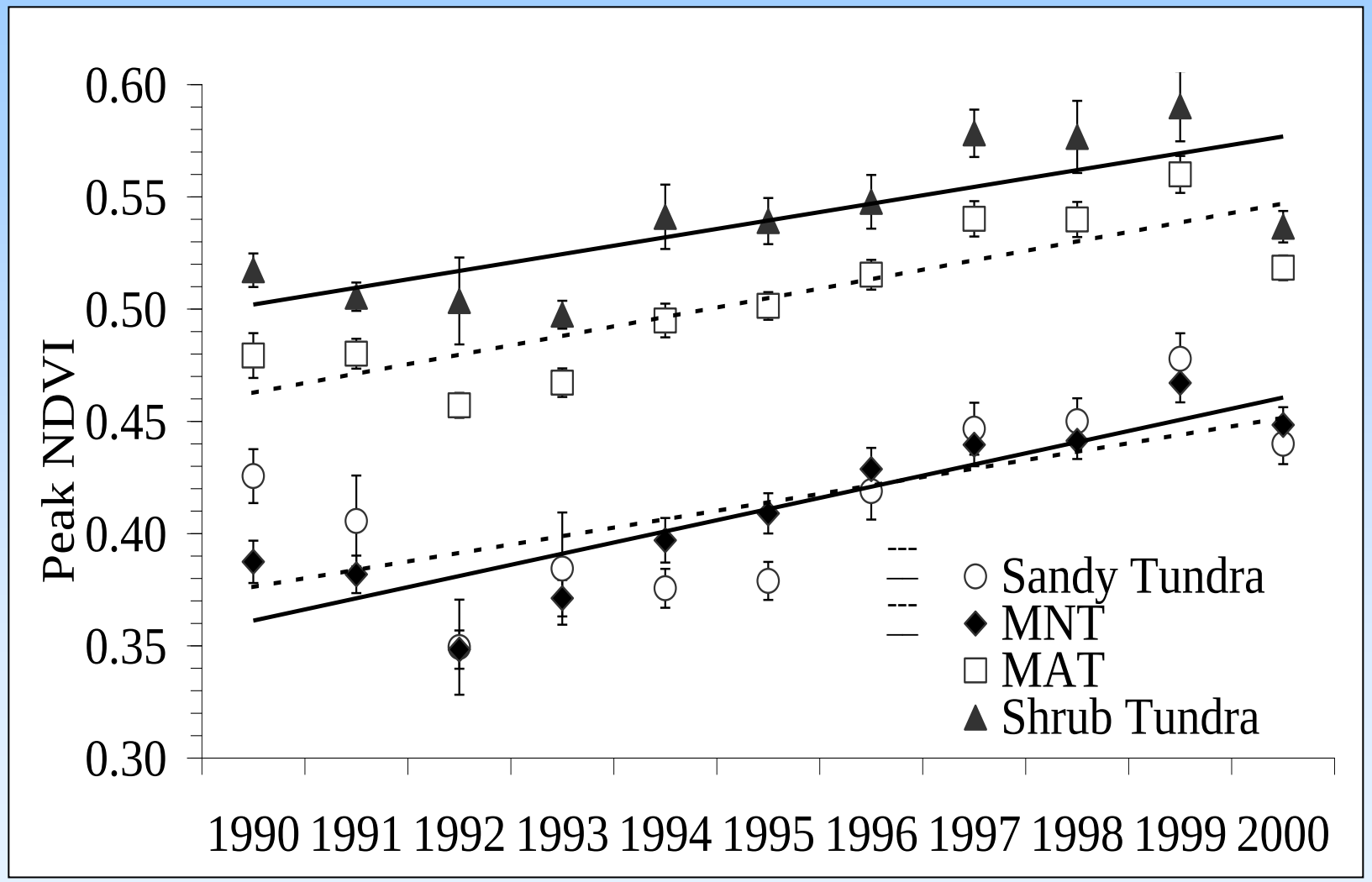
earthtrends.wri.org



- 40% of the global soil C pool resides in high latitude ecosystems.
- High latitude soil C pool ≈ 0.5 x atmospheric C pool.
- Warming will increase decomposition of soil organic matter and release of soil C.


↑ CO_2
↑ Temperature
+
-
↑ Decomposition
↑ Production

Satellite images show evidence of "arctic greening"



Jia et al. 2005

Shrub density has increased

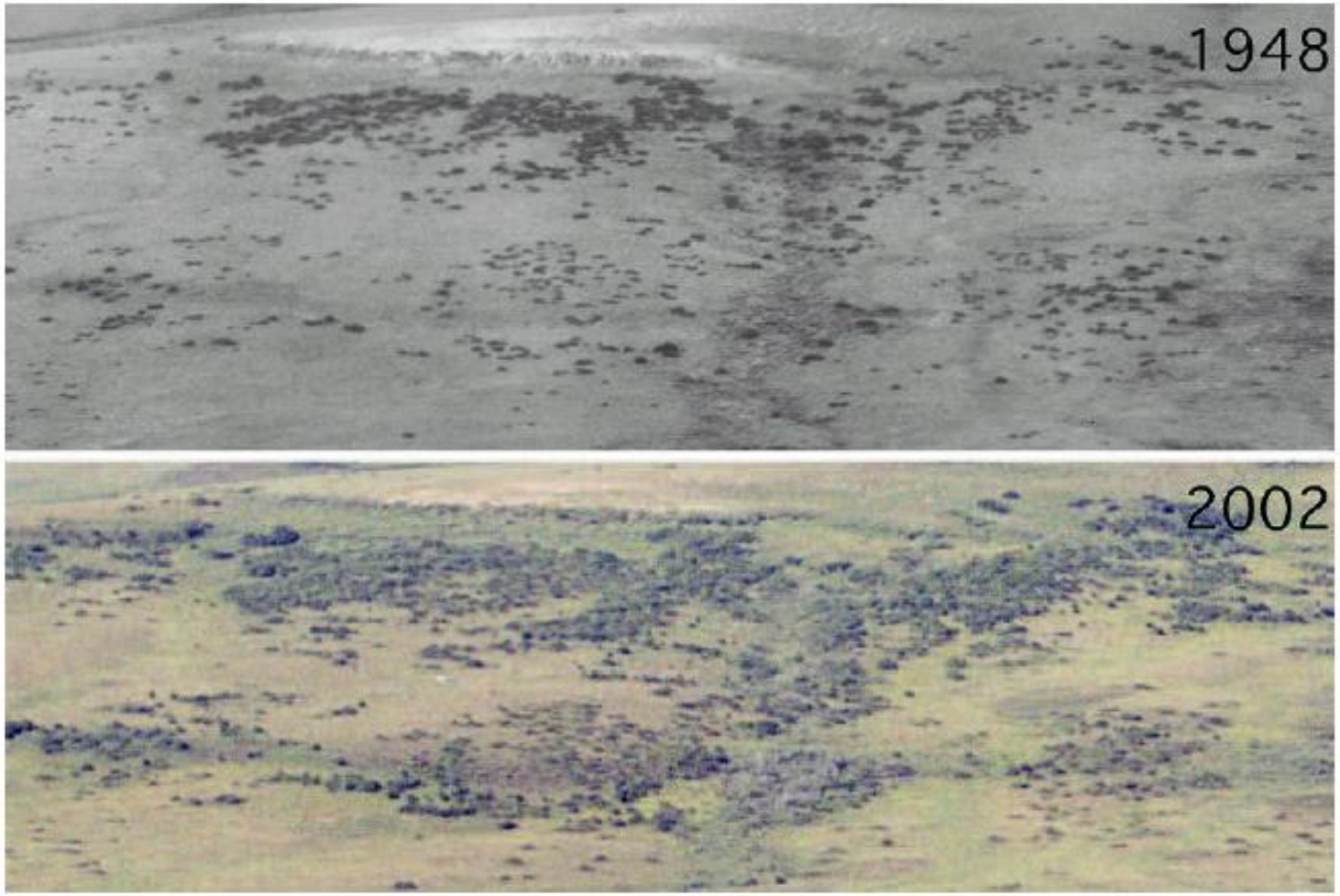
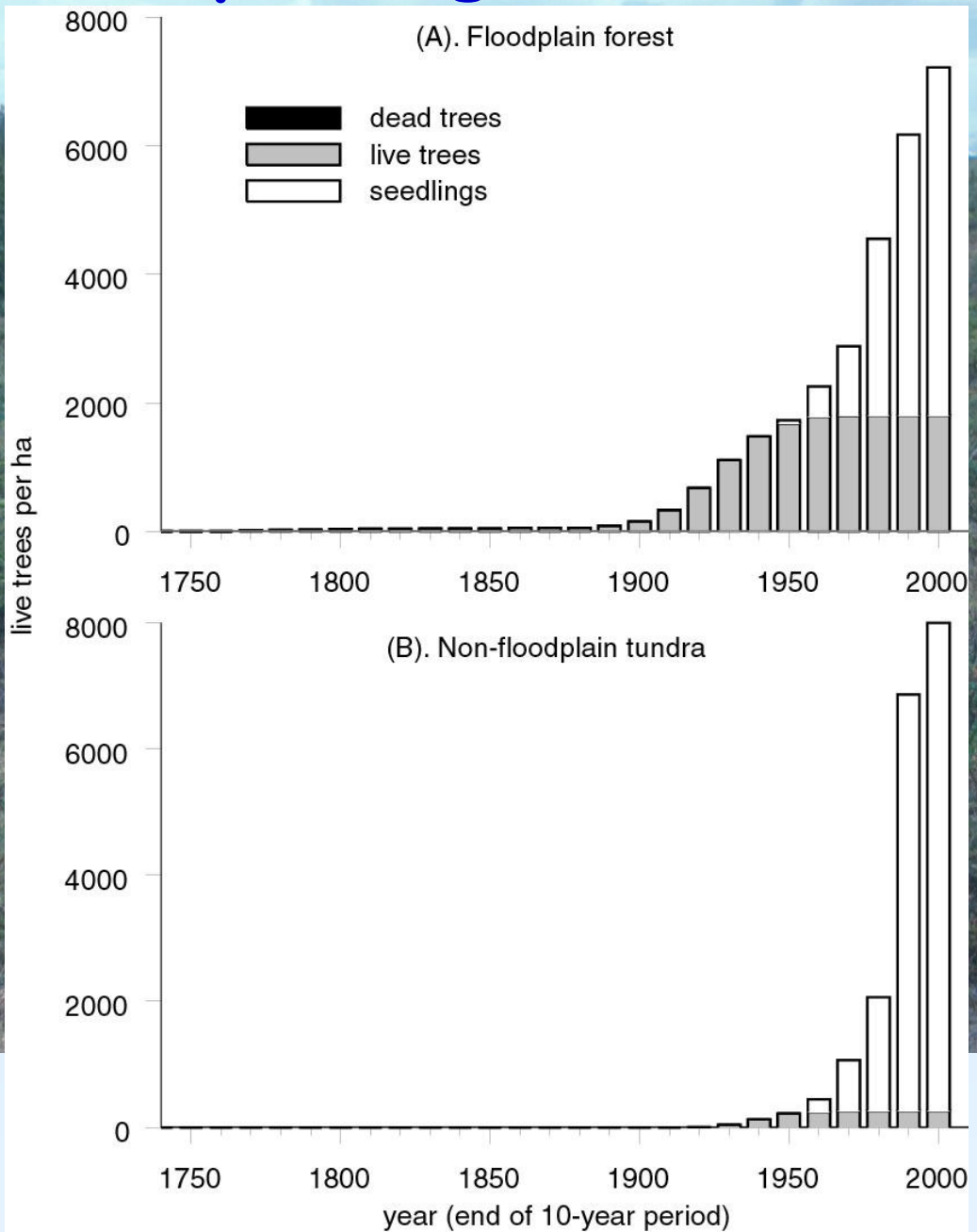


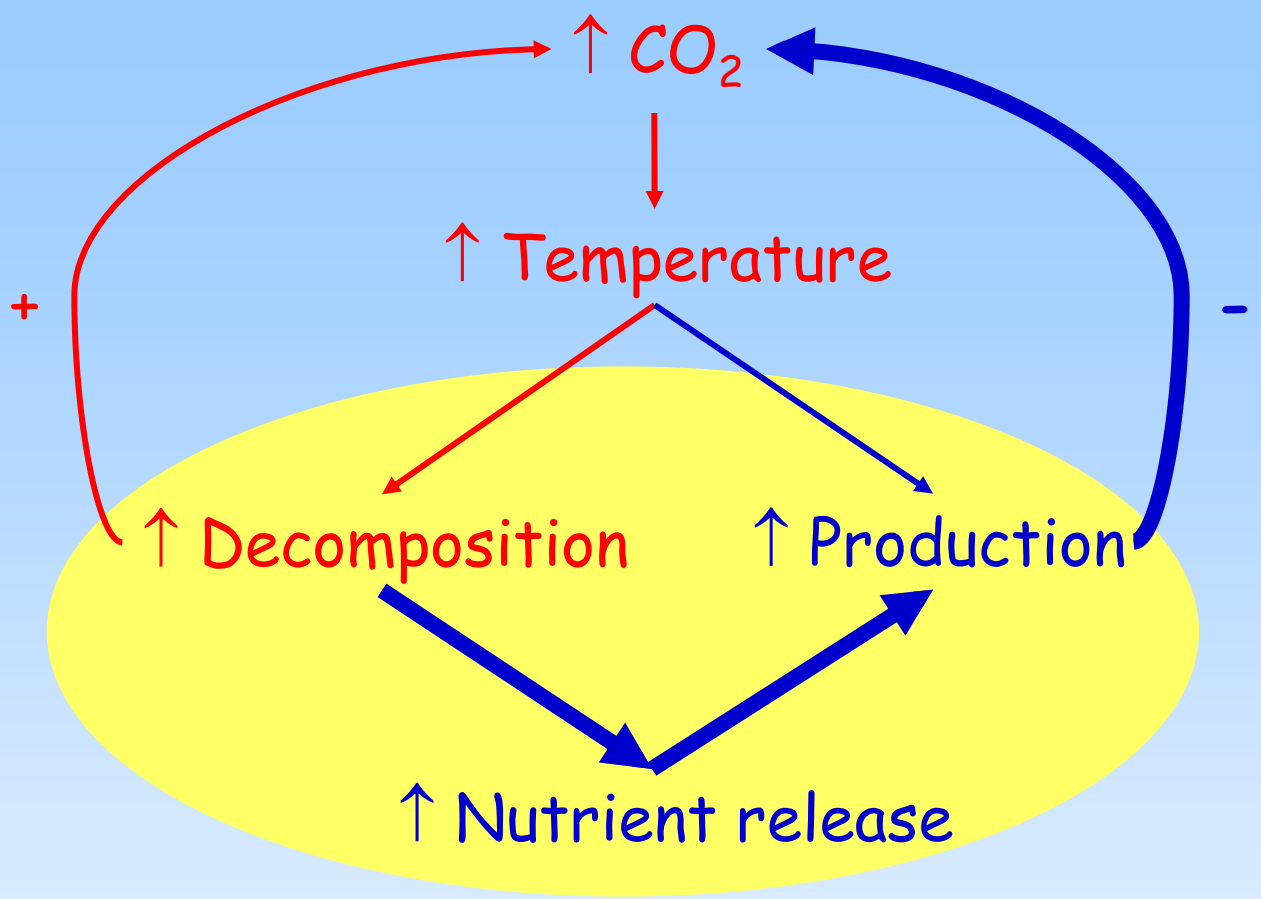
Figure 1. Increasing abundance of shrubs in arctic Alaska. The photographs were taken in 1948 and 2002 at identical locations on the Colville River (68° 57.9' north, 155° 47.4' west). Dark objects are individual shrubs 1 to 2 meters high and several meters in diameter. Similar changes have been detected at more than 200 other locations across arctic Alaska where comparative photographs are available. Photographs: (1948) US Navy, (2002) Ken Tape.

Strum et al. 2005

Forests are expanding



Lloyd and Fastie, In press



Soil C:N = 15

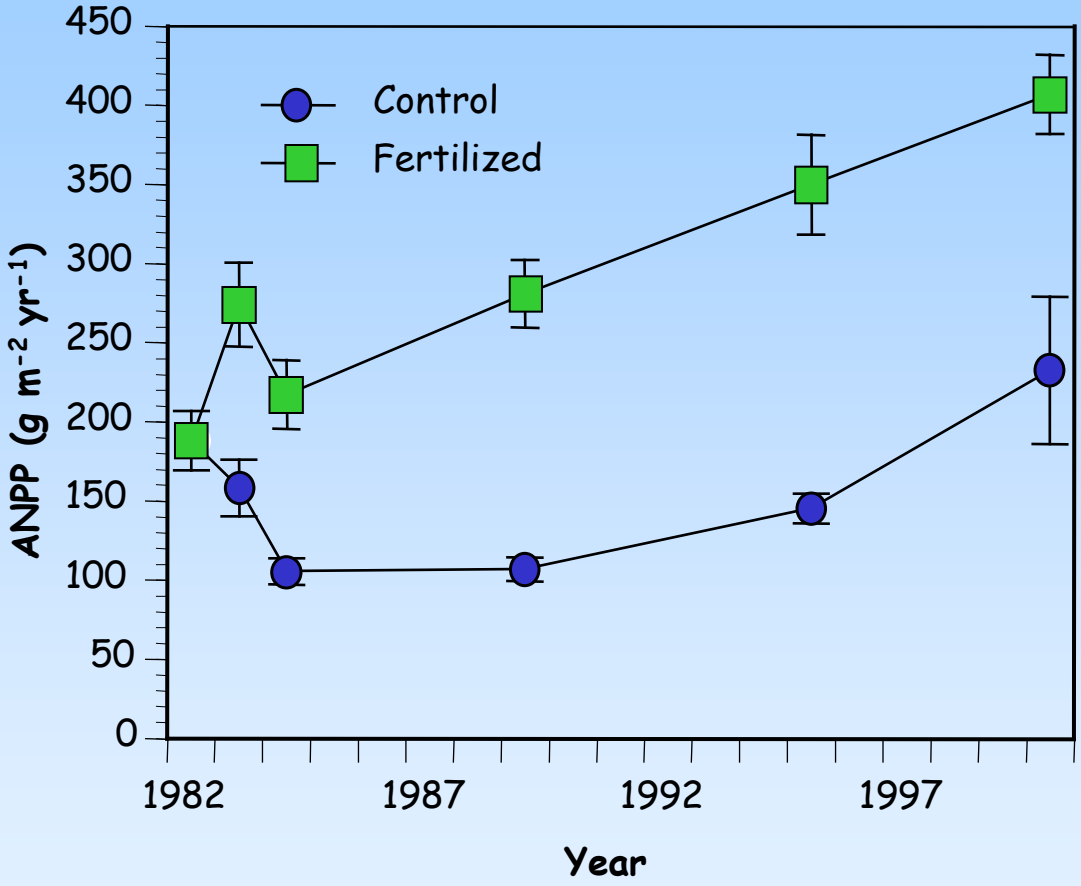
Plant C:N = 30-45+

Store more C in plants than soil

"Historic" fertilization experiment

- 10 gN and 5 $gP \cdot m^{-2} \cdot yr^{-1}$ added to replicate plots of tussock tundra since 1981
- Vascular ANPP and total above ground biomass by destructive harvests, 1981-1995
- Total ecosystem C and N pools, 2000

Effect of fertilization on aboveground net primary productivity

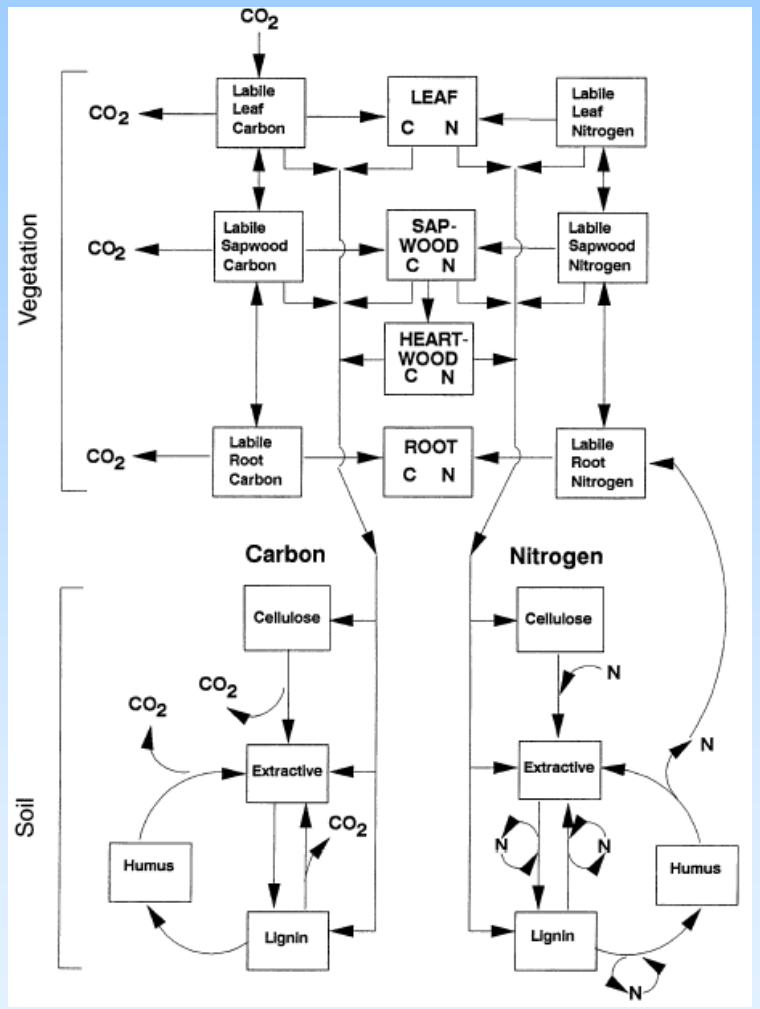


Cumulative vascular ANPP over 20 years (g m^{-2}):

C=2537

F=5506

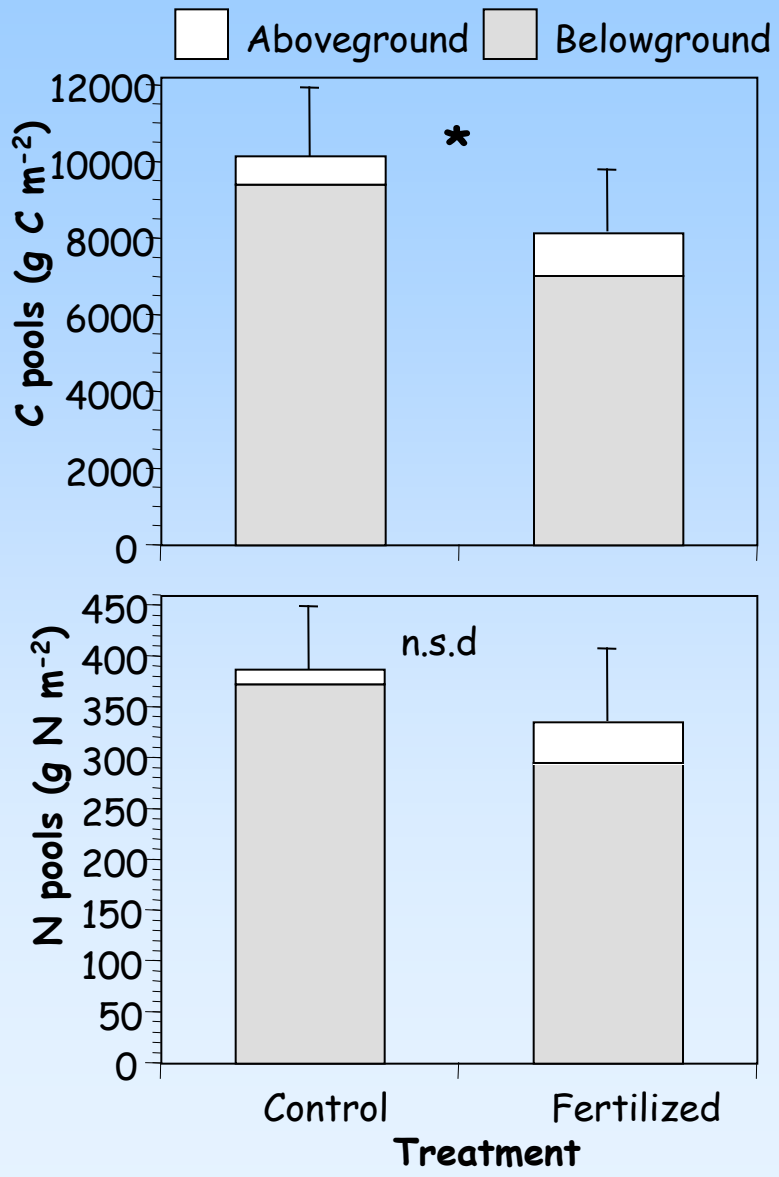
Simulated Change in C Storage



ΔC pools

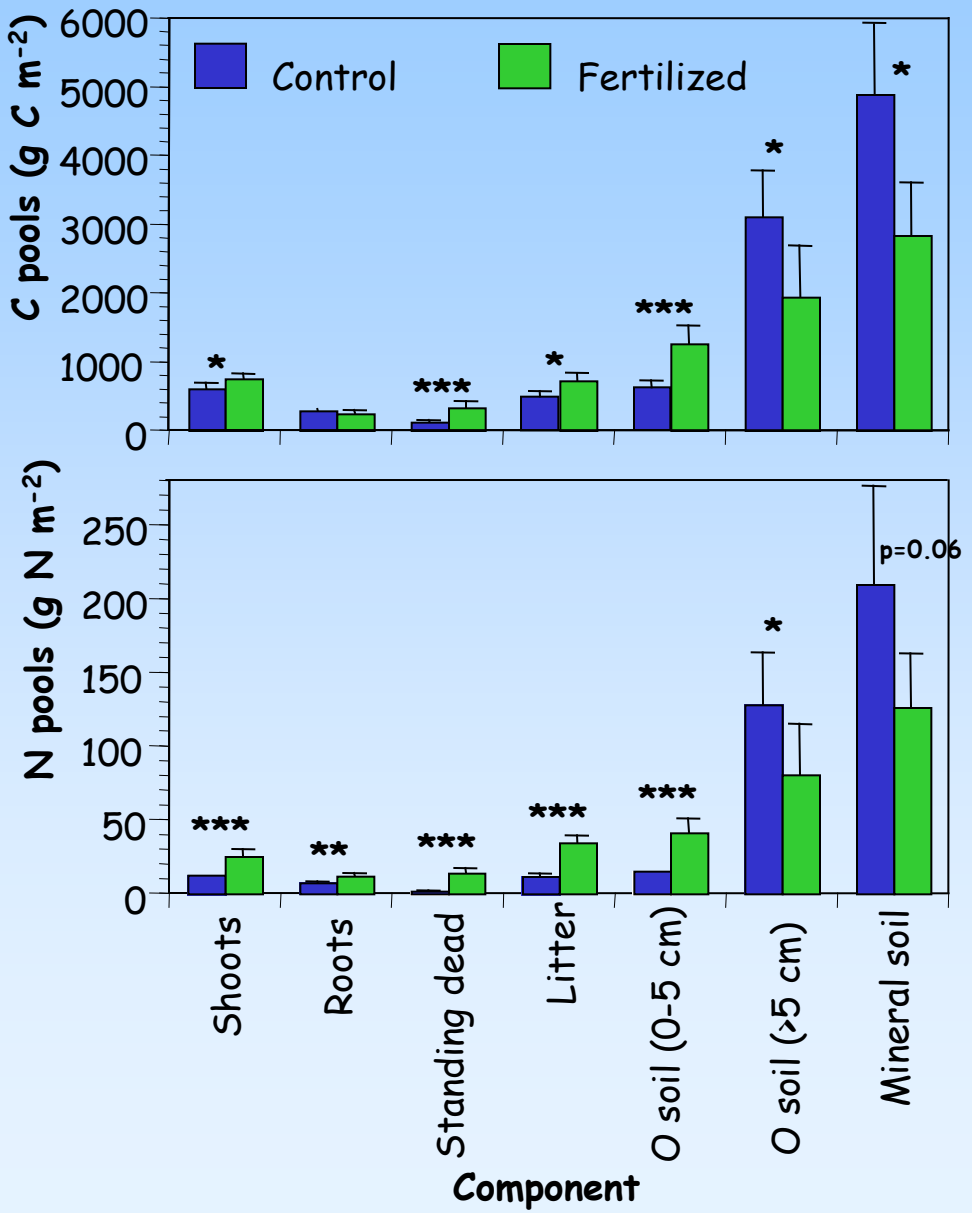
	(g C/m²)
Year 3	
Plant C	80
Soil C	19
Ecosystem C	**99**
Year 9	
Plant C	261
Soil C	212
Ecosystem C	**473**

Ecosystem C and N pools after 20 years



- Net decrease in total ecosystem C storage of ~2 kg C/m^2
- No net effect on total N storage despite addition of 200g N/m^2

Ecosystem C and N pools after 20 years



- Plant and surface soil C and N pools <u>increased</u>

BUT

- Deep organic and mineral soil C and N pools <u>decreased</u>

Fertilization caused a net loss of 2 kg C/m^2 over 20 years…How?

C storage = inputs - outputs

= Plant NPP – decomposition

Decreased production

or

Increased C loss?

Fertilization reduced deep soil C pools by:

~~H1. Decreasing total production through~~

~~a. Decreased root allocation~~

~~b. Decreased moss production~~

H2. Increasing decomposition/C loss through

~~a. Increased litter quality~~

<30% b. Changes in the environment for decomposition

\+ c. Alleviation of nutrient limitation to decomposers

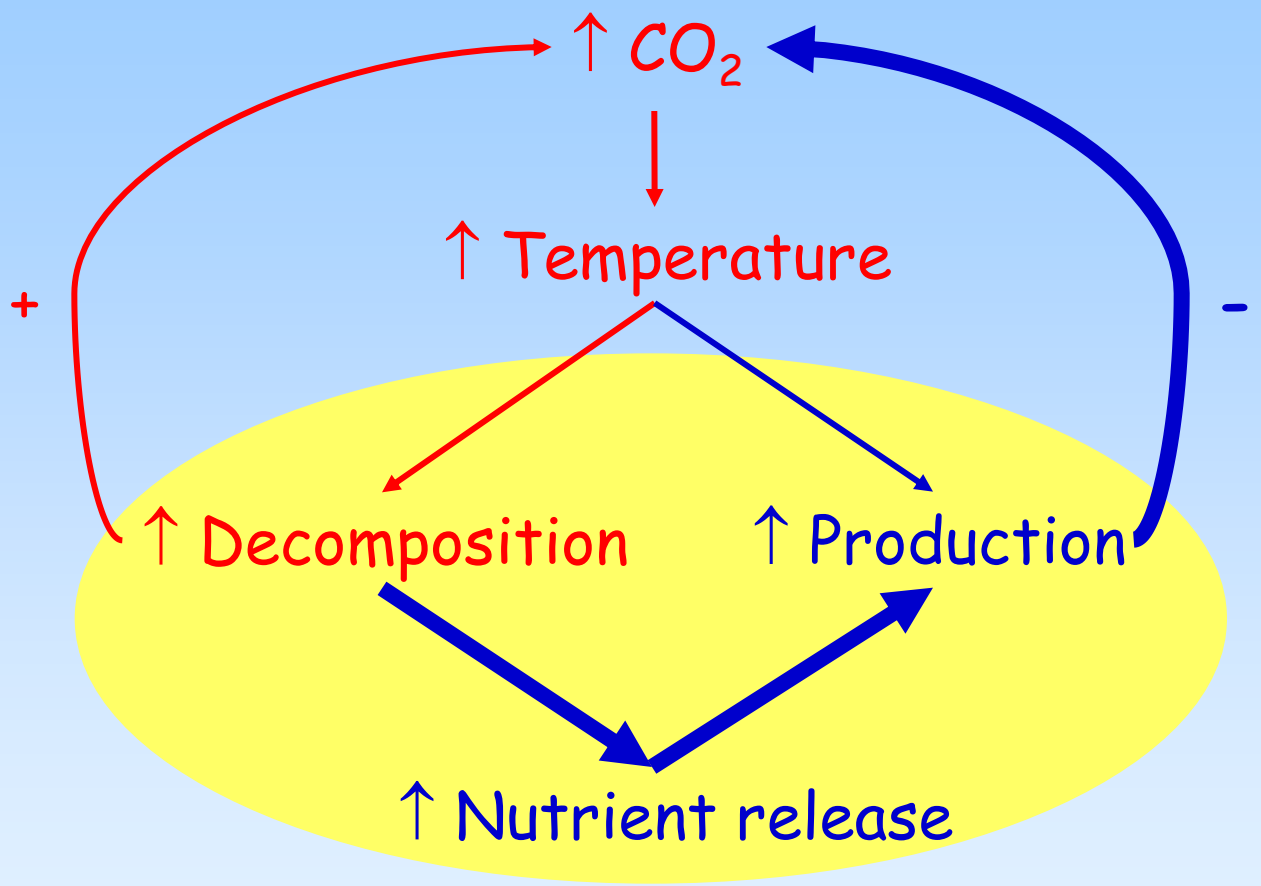
\+ d. Changes in belowground community dynamics

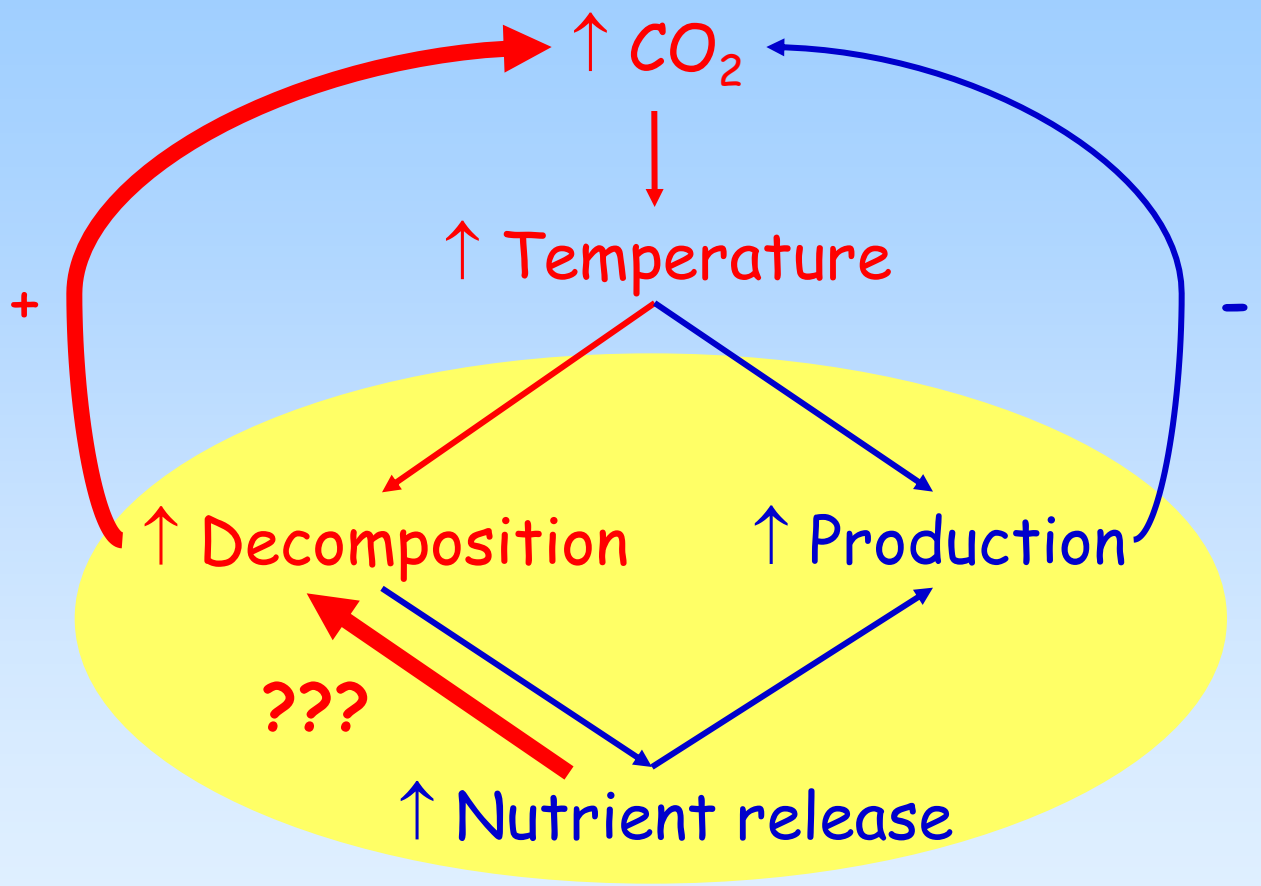
How does this experiment compare to climate warming?

- Gross N release by warming may be similar in magnitude
  - R_h = total plant production = 150 g C m^{-2} yr^{-1}
  - Q_{10} of R_h = 2
  - SOM C:N = 26
  - Then a 3 – 7° C increase in T = 7 – 9.4 g N m^{-2} yr^{-1}

How does this experiment compare to climate warming?

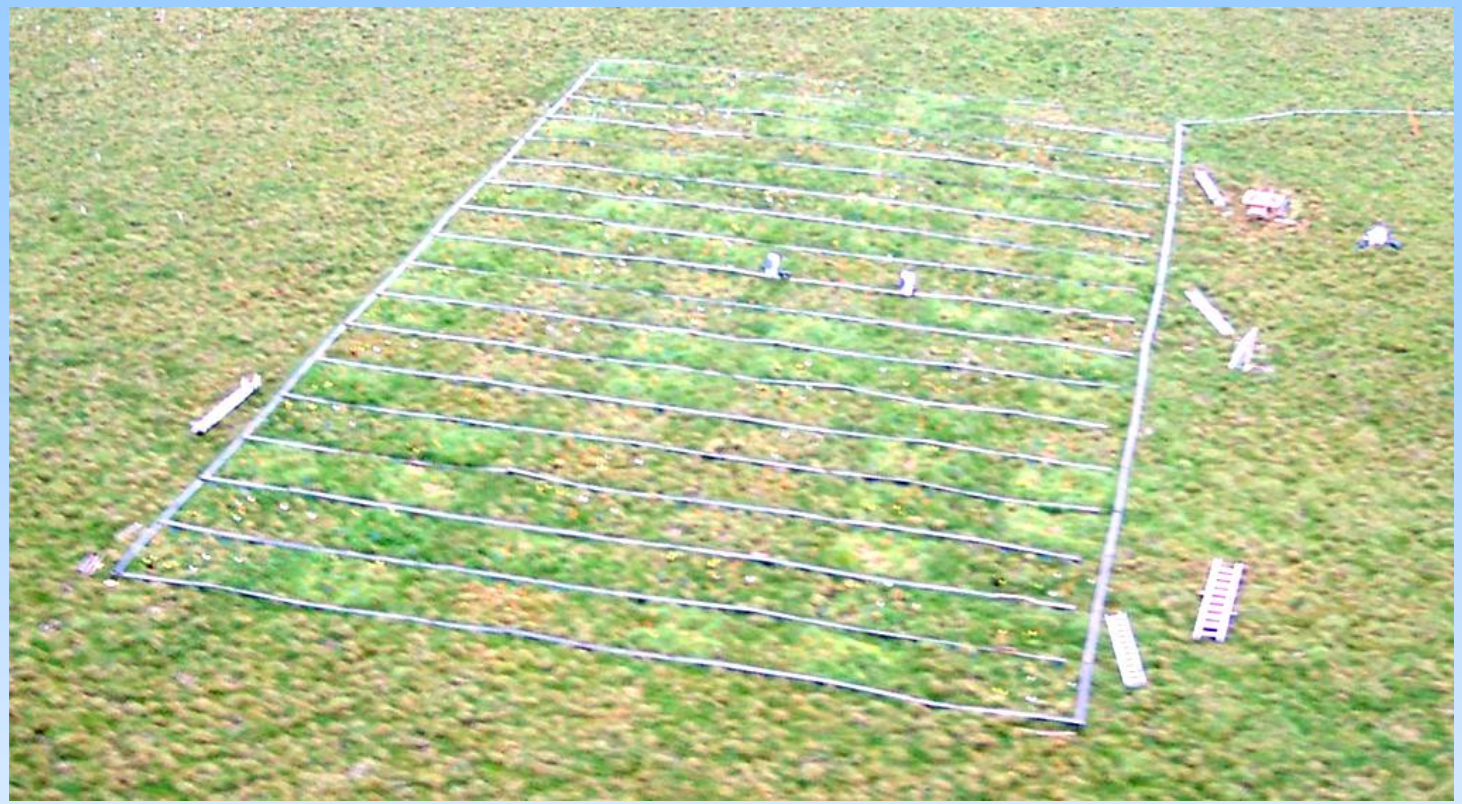
- Gross N release by warming may be similar in magnitude
- Naturally occurring shrub tundra has less soil C despite more biomass and ANPP
- Other signals of climatic change have positive effects, making interactive amplification of C loss likely


↑ CO_2
↑ Temperature
+
-
↑ Decomposition
↑ Production
↑ Nutrient release


↑ CO_2
↑ Temperature
+
-
↑ Decomposition
↑ Production
???
↑ Nutrient release


Laurie Carr, TREC 2004

The "species" removal experiment



Treatments: removal with and without fertilization

Removals:
- *Betula nana*
- *Ledum palustre*
- *Betula* and *Ledum*
- Moss
- *Betula*, *Ledum*, and Moss
- All deciduous shrubs
- All canopy shrubs

Figure 5. A shrub patch that has created a snowdrift in and downwind of the patch. The snow on the tundra behind the patch was about one-fifth as deep as the drift. Photograph: Matthew Sturm.

Strum et al. 2005

Acknowledgements

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The many pluckers and grinders in my lab…

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