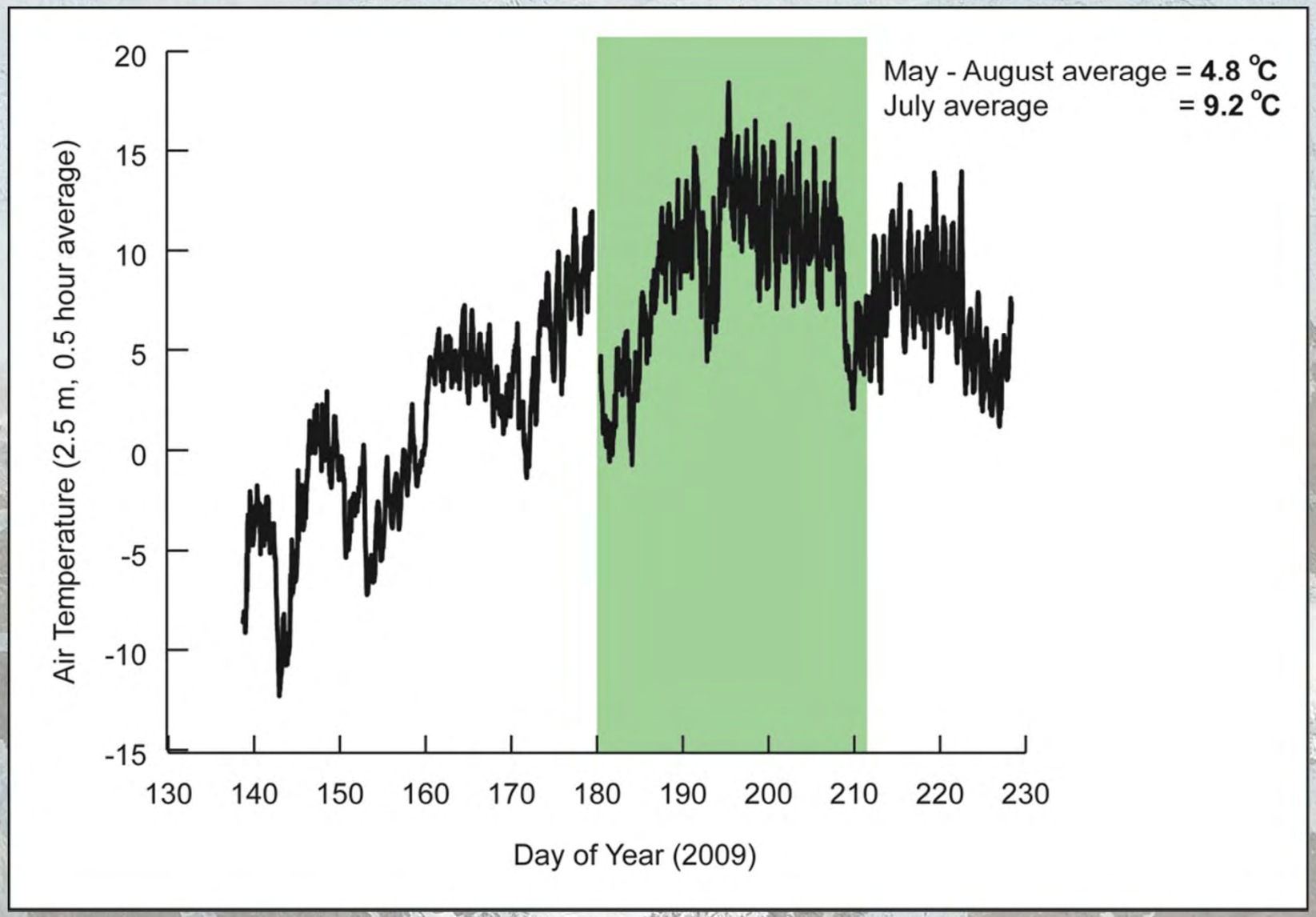
Three Million Year Old Polar Plants

Evidence of a Boreal Forest Ecosystem in the Canadian High Arctic

Joel Barker
Franklin Park Conservatory
11-19-2014

http://visibleearth.nasa.gov/


May - August average = 4.8 °C
July average = 9.2 °C
Air Temperature (2.5 m, 0.5 hour average)
20
15
10
5
0
-5
-10
-15
130
140
150
160
170
180
190
200
210
220
230
Day of Year (2009)

Chamerion latifolium

Dryas octopetela

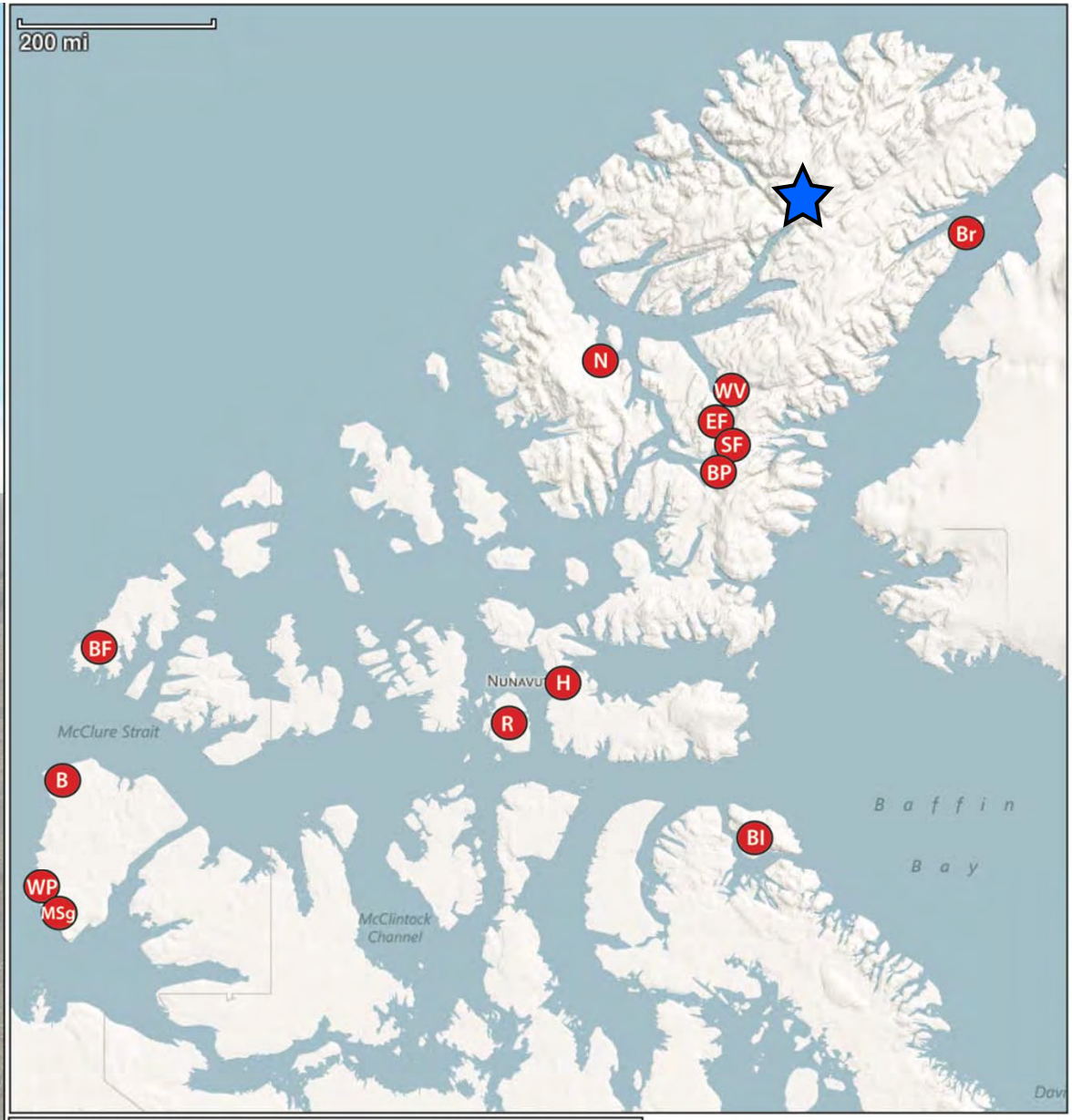
Papaver radicatum

Salix herbacea

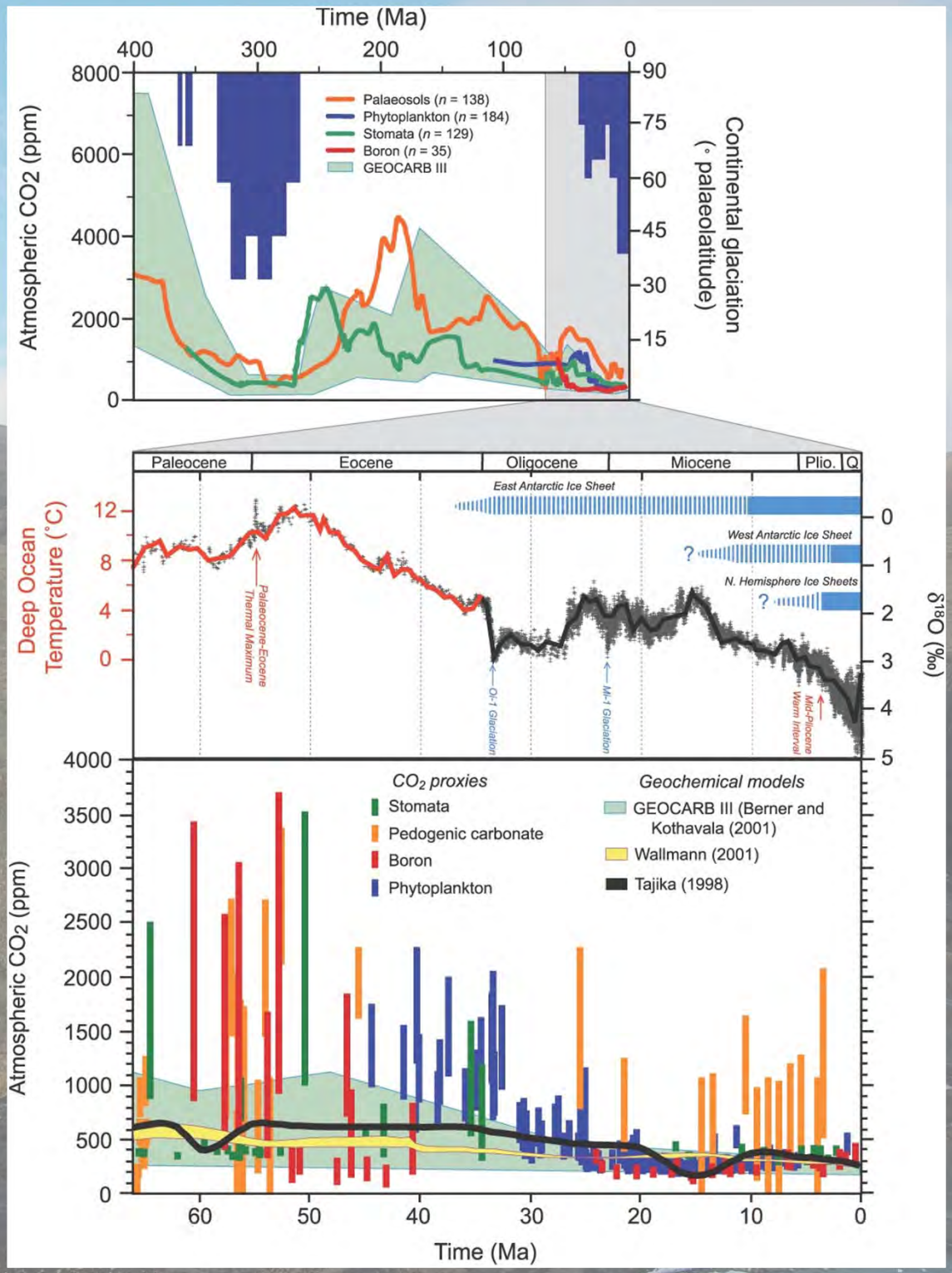
NASA 2012

permineralized (petrified): mineral matrix surrounds and/or replaces organic material

mummified: preserved without mineral replacement or encasement of the organic material

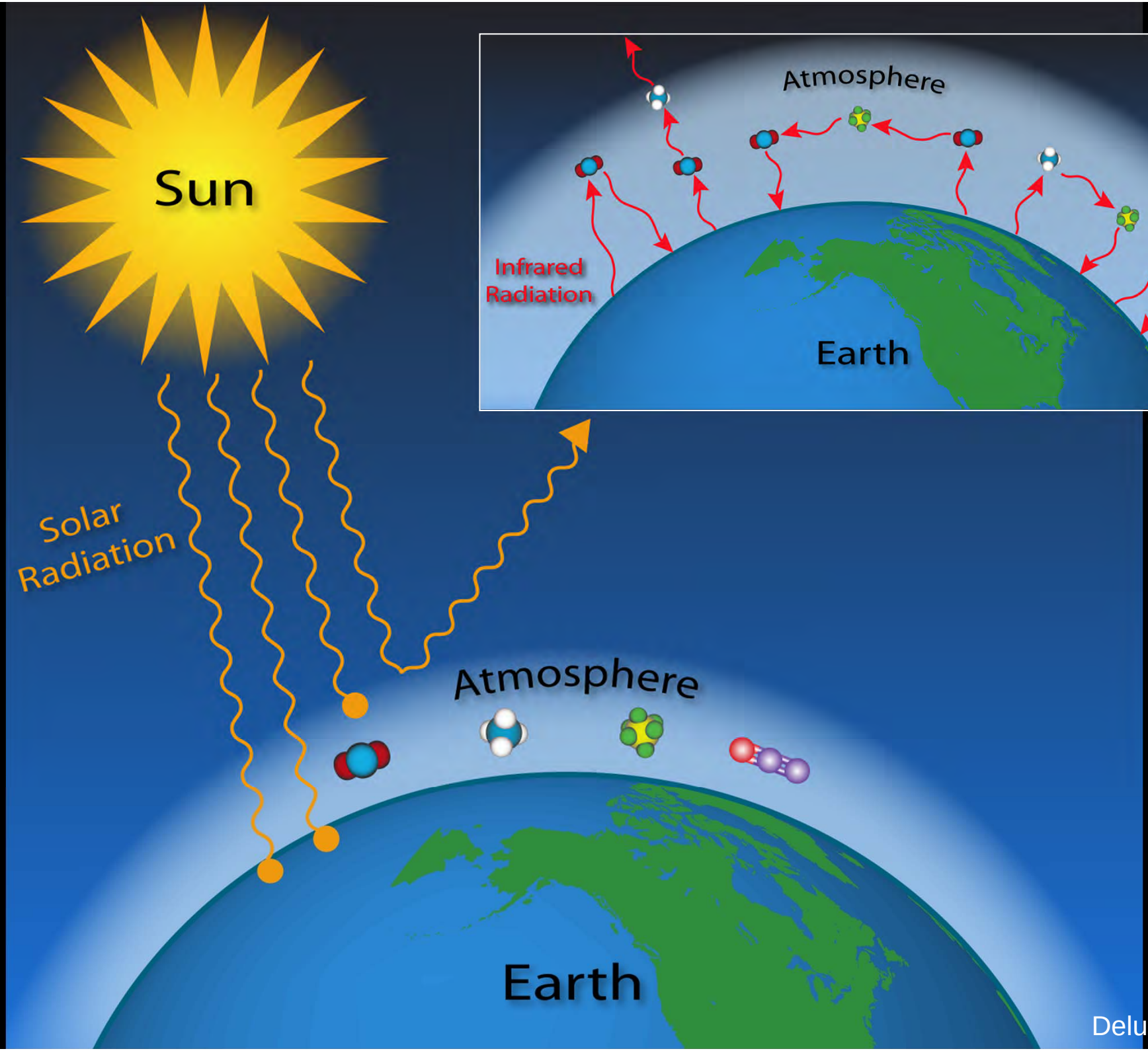


B = Ballast Brook Formation	Middle Miocene
BF = Beaufort Formation	Pliocene
BI = Bylot Island	Pliocene
BP = Beaver Pond Locality	Pliocene
Br = Brainard's Fossil Forest	Lower Tertiary
EF = Expedition Formation	Early - Middle Paleocene
H = Haughton Astrobleme	Miocene
MSg = Mary Sachs Gravel	Miocene
N = Napartulik	Middle Eocene
R = Resolute	Late Oligocene
SF = Strathcona Fiord	Middle Paleocene
WP = Worth Point	Late Tertiary
WV = Wolf Valley	Late Tertiary

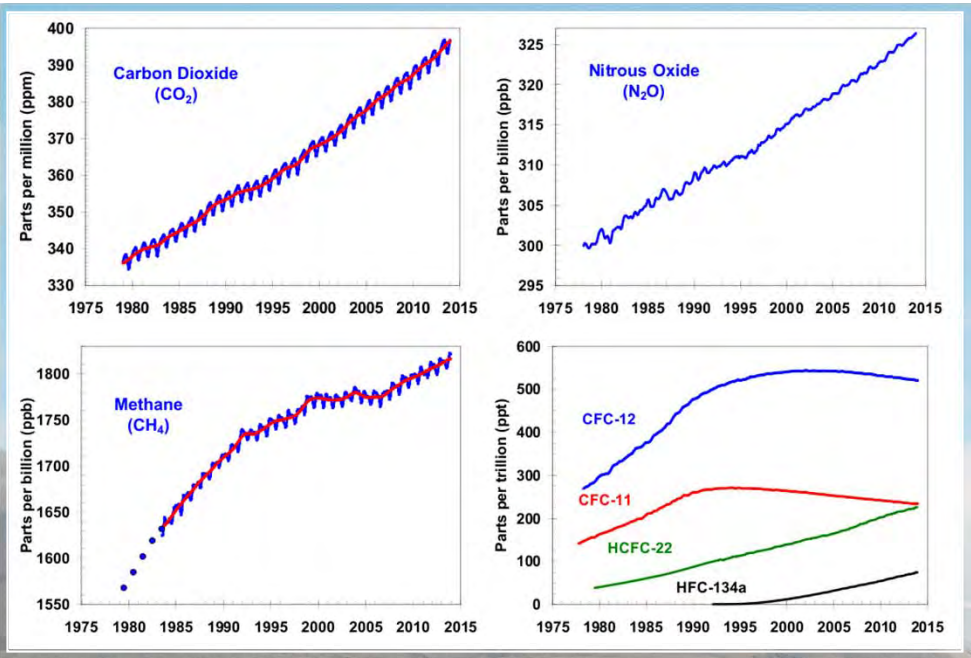

Time (Ma)
Atmospheric CO2 (ppm)
Continental glaciation (° palaeolatitude)
Palaeosols (n = 138)
Phytoplankton (n = 184)
Stomata (n = 129)
Boron (n = 35)
GEOCARB III
Paleocene
Eocene
Oligocene
Miocene
Plio.
Q
East Antarctic Ice Sheet
West Antarctic Ice Sheet
N. Hemisphere Ice Sheets
Deep Ocean Temperature (°C)
δ18O (‰)
Palaeocene-Eocene Thermal Maximum
Oi-1 Glaciation
Mi-1 Glaciation
Mid-Pliocene Warm Interval
CO2 proxies
Stomata
Pedogenic carbonate
Boron
Phytoplankton
Geochemical models
GEOCARB III (Berner and Kothavala (2001)
Wallmann (2001)
Tajika (1998)
Atmospheric CO2 (ppm)
Time (Ma)

IPCC, 2007

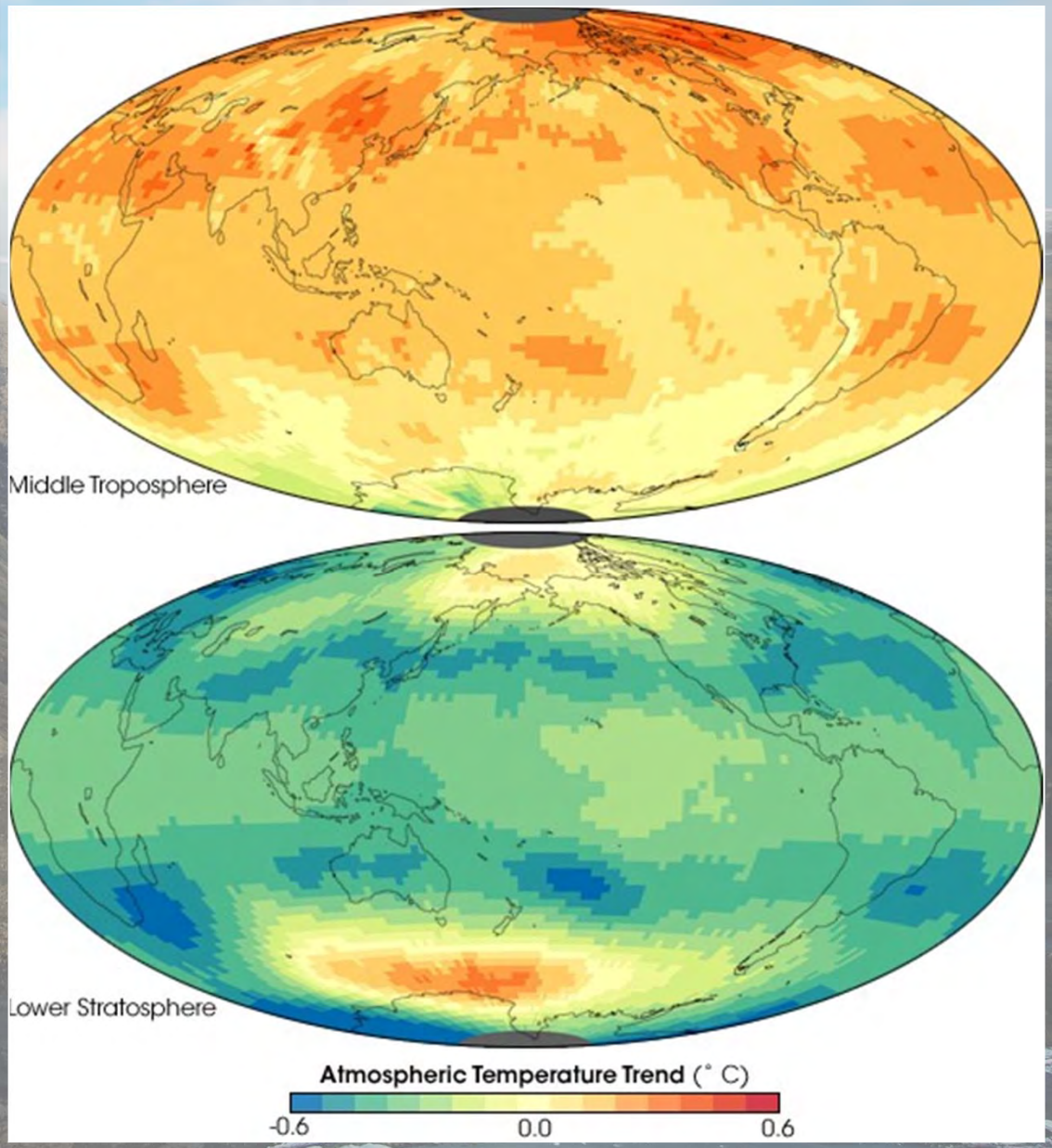
NASA, 2010



Deluisi, NOAA



NOAA, 2013

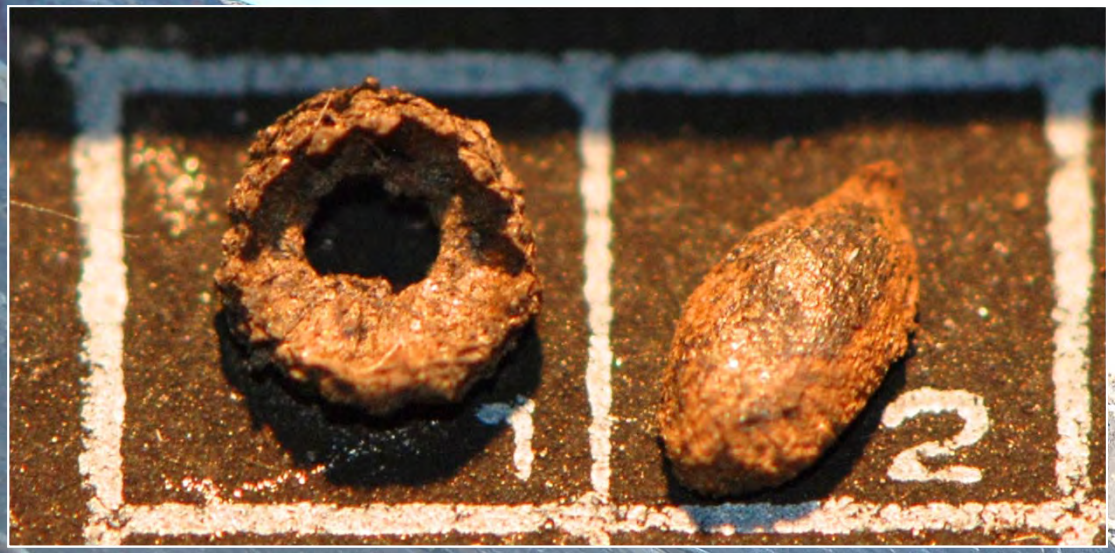


NASA, 2007

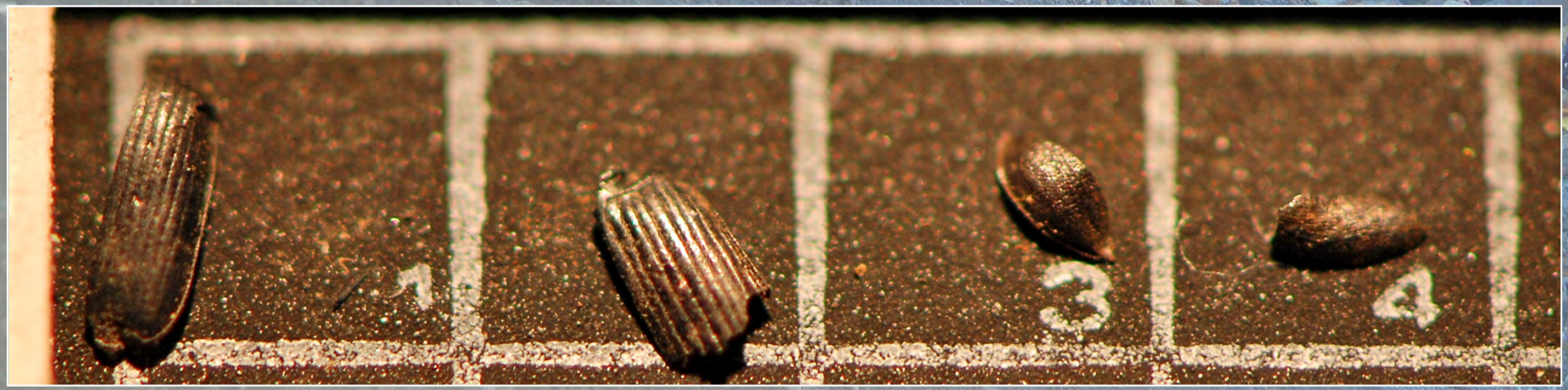
1960

2010

Nikon


1
2

38
39
41
42

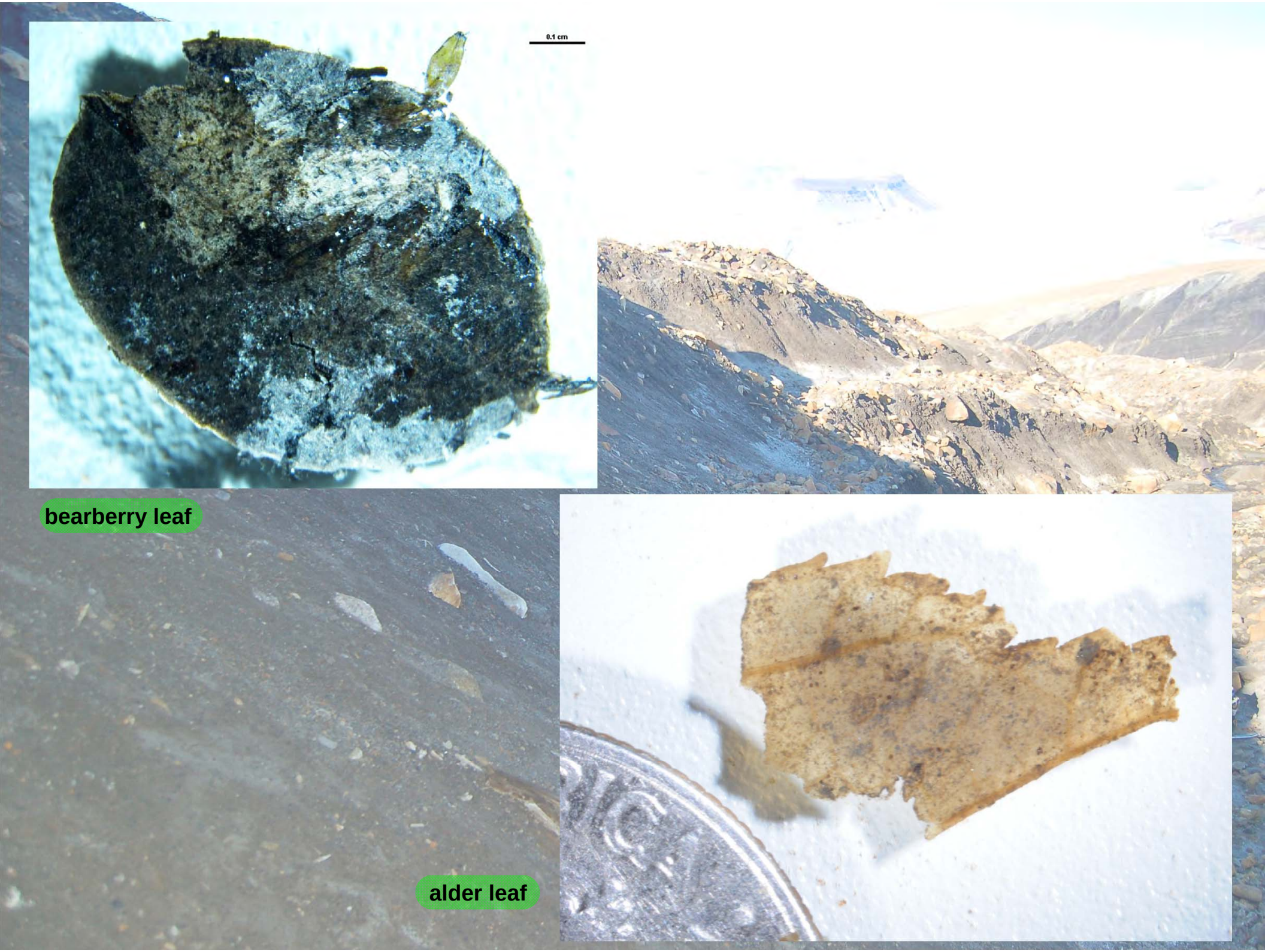

1
3
4

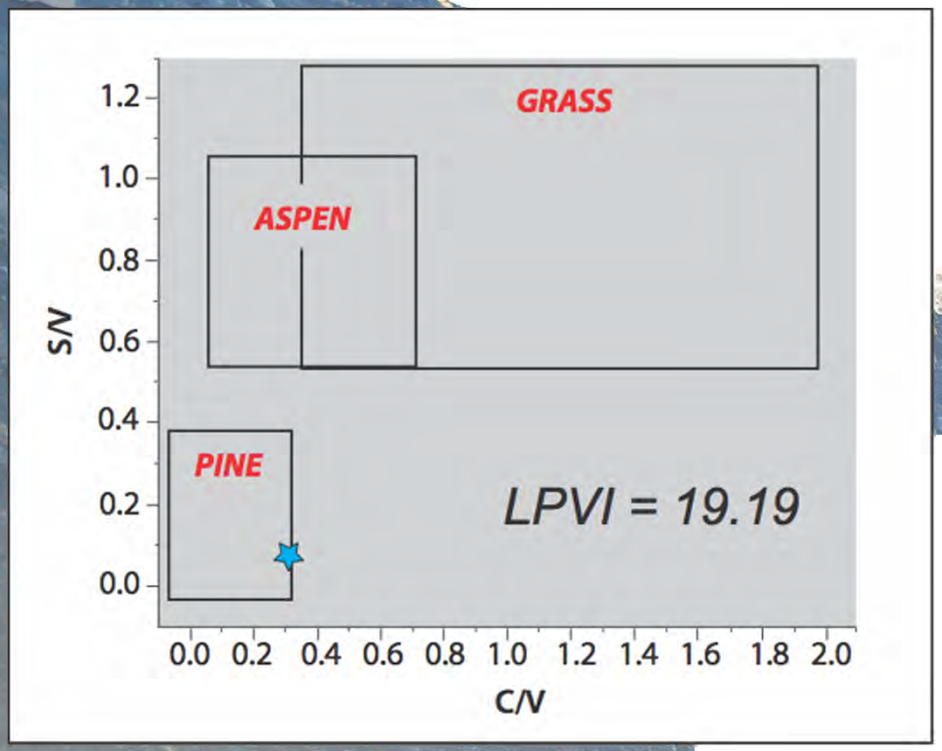
alder seed

birch bract

5-needle pine

larch cone

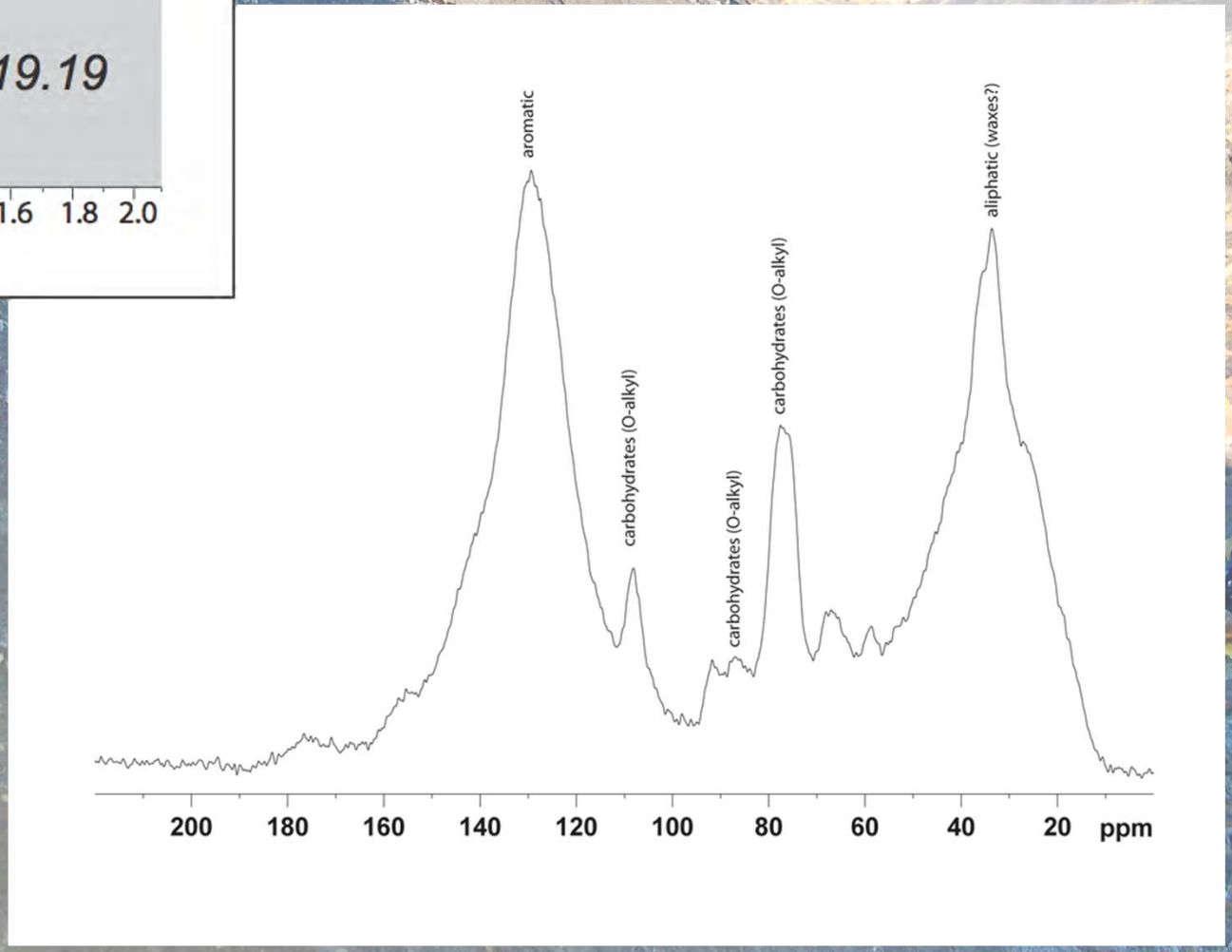

0.1 cm
bearberry leaf
alder leaf



C/V: cinnamyl/vanillyl monomers

S/V: syringyl/vanillyl monomers

LPVI: lignin phenols vegetation index



		comment	interpretation
Wood Identification	*Betula* (birch) *Larix* (larch) *Picea* (spruce) *Pinus* (pine)	 **>76 years old** **>87 years old**	**mixed boreal forest**
Leaf identification	*Larix* (larch) *Picea* (spuce) *Pinus* (pine) *Alnus* (alder) *Rhododendron* *groenlandicum* (labrador tea) *Arctostaphylos* *uva ursi* (bearberry)		**mixed boreal forest, water available**
Insect Identification	Coleoptera (beetles and weevils) - *Plateumaris nitida* - *Aspidoglossa subangulata* - at least 6 others...		**water available**
Palynology	*Picea* (spruce) *Pinus* (pine) *Abies* (fir) *Alnus* (alder) *Betula* (birch) *Tsuga* (hemlock) *Ericaceae* (heath)	**abundant** **abundant** **common** **rare** **rare** **single grain** **single grain**	**mixed boreal forest, water available**

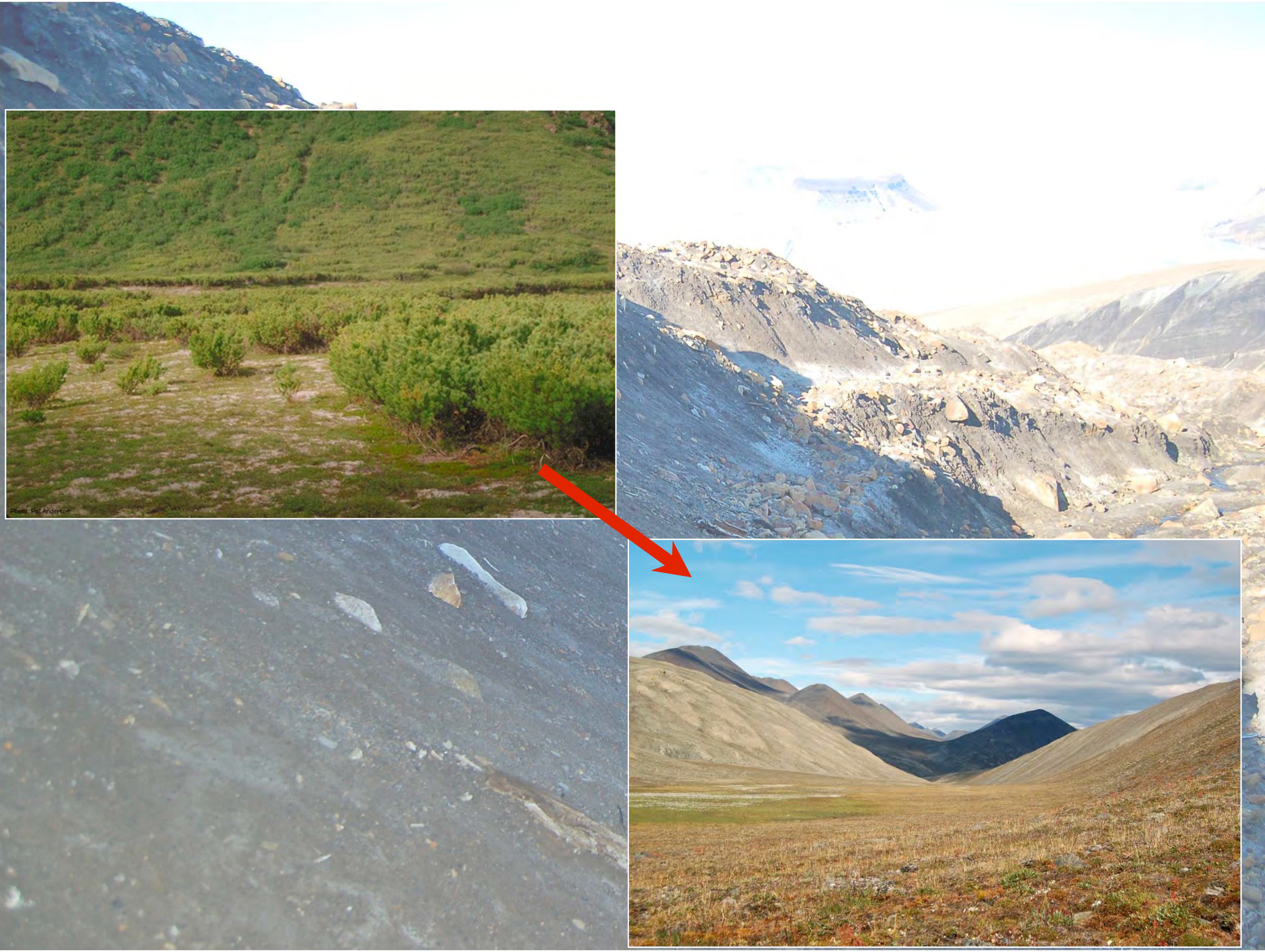
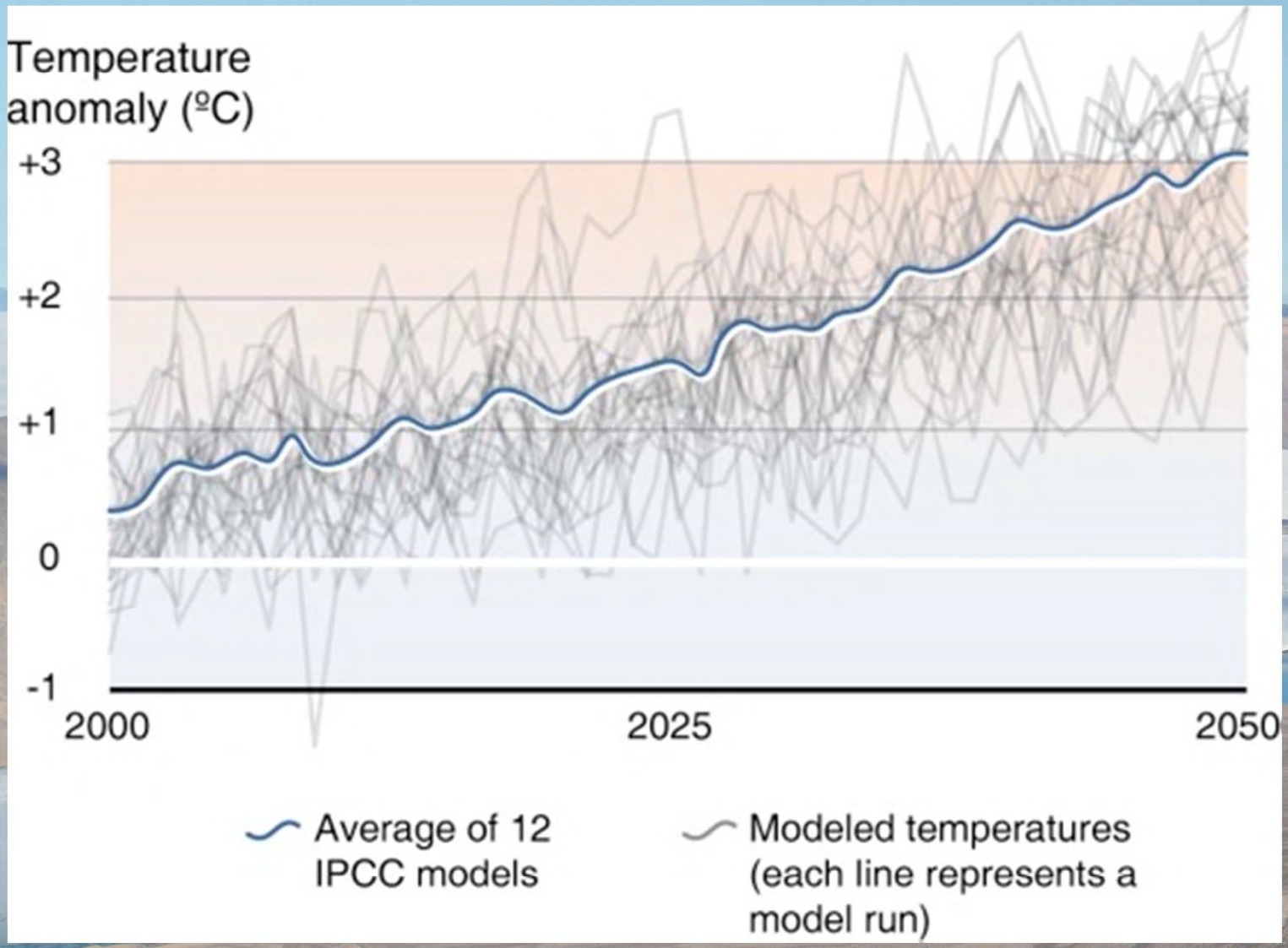


Photo: Pal Anderson

Forest Age

- no *Metasequoia* pollen → < 5 Ma
- we have a forest → > 2.5 Ma

Between 2.5 - 5 Ma
PLIOCENE

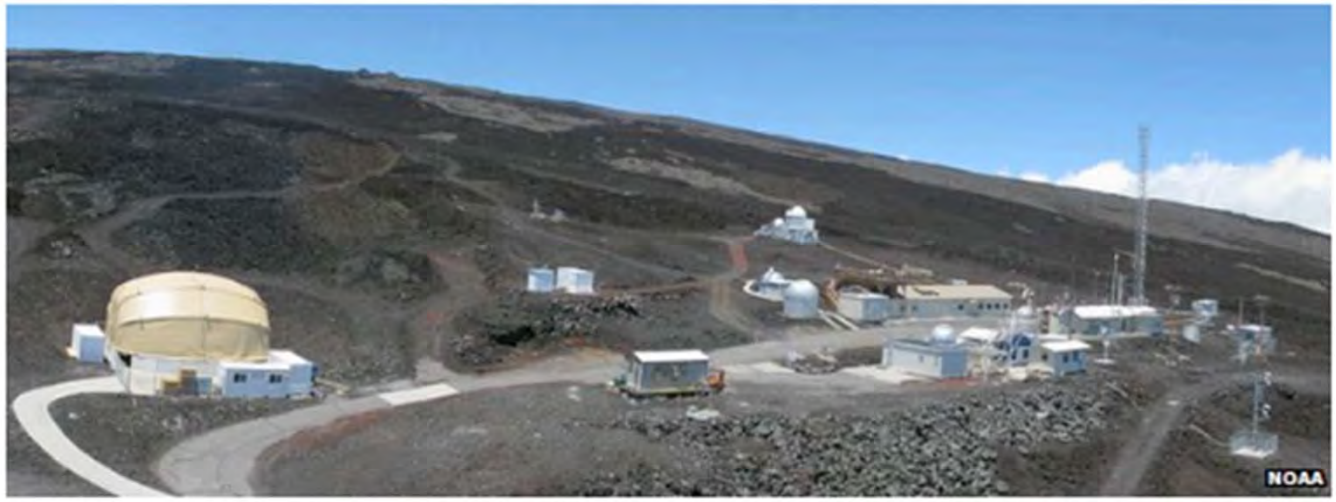


Source: GRID Arendal 2002

10 May 2013 Last updated at 11:39 ET

Share

Carbon dioxide passes symbolic mark



Key measurements are made on top of the Mauna Loa volcano

Carbon dioxide levels in the atmosphere have broken through a symbolic mark.

Daily measurements of CO_2 at a US government agency lab on Hawaii have topped 400 parts per million for the first time.

The station, which sits on the Mauna Loa volcano, feeds its numbers into a continuous record of the concentration of the gas stretching back to 1958.

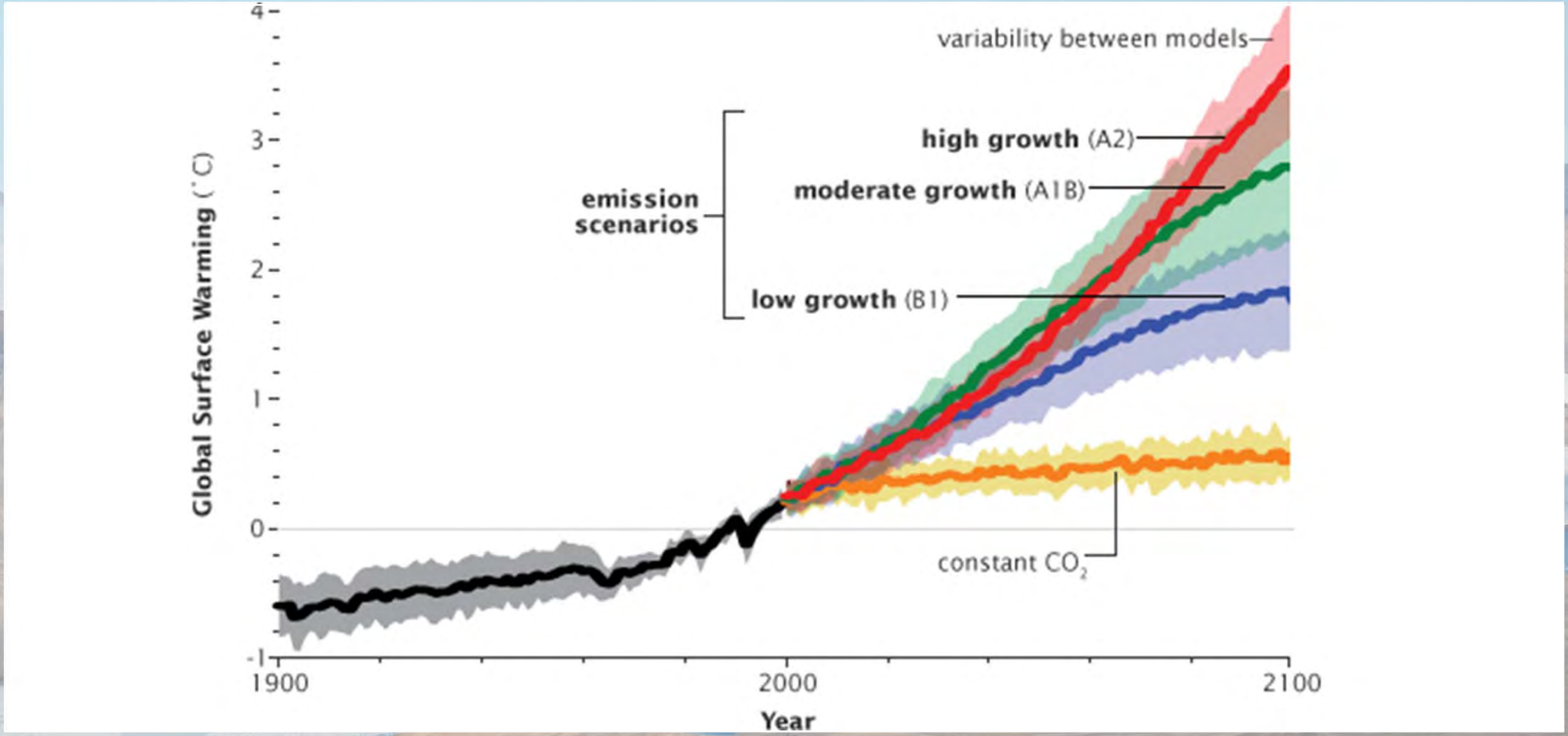
The last time CO_2 was regularly above 400ppm was three to five million years ago - before modern humans existed.

Scientists say the climate back then was also considerably warmer than it is today.

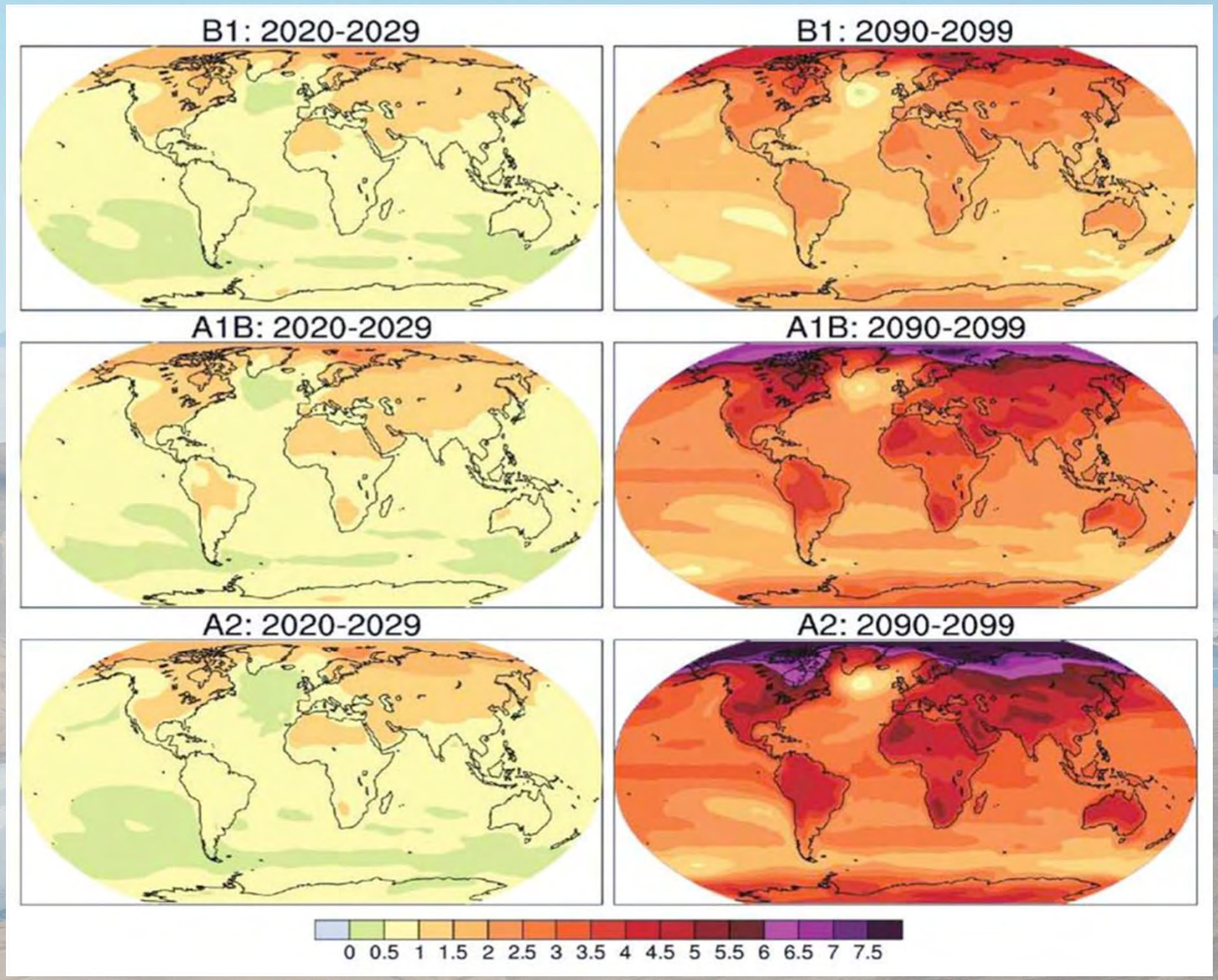
Related Stories

- 50 years on: The Keeling Curve legacy
- UN warning as emissions gap grows
- Carbon emissions 'defer Ice Age'

BBC News


variability between models
high growth (A2)
moderate growth (A1B)
emission scenarios
low growth (B1)
constant CO_2
Global Surface Warming (°C)
4
3
2
1
0
-1
1900
2000
2100
Year

IPCC, 2007


B1: 2020-2029
B1: 2090-2099
A1B: 2020-2029
A1B: 2090-2099
A2: 2020-2029
A2: 2090-2099
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5

IPCC, 2007

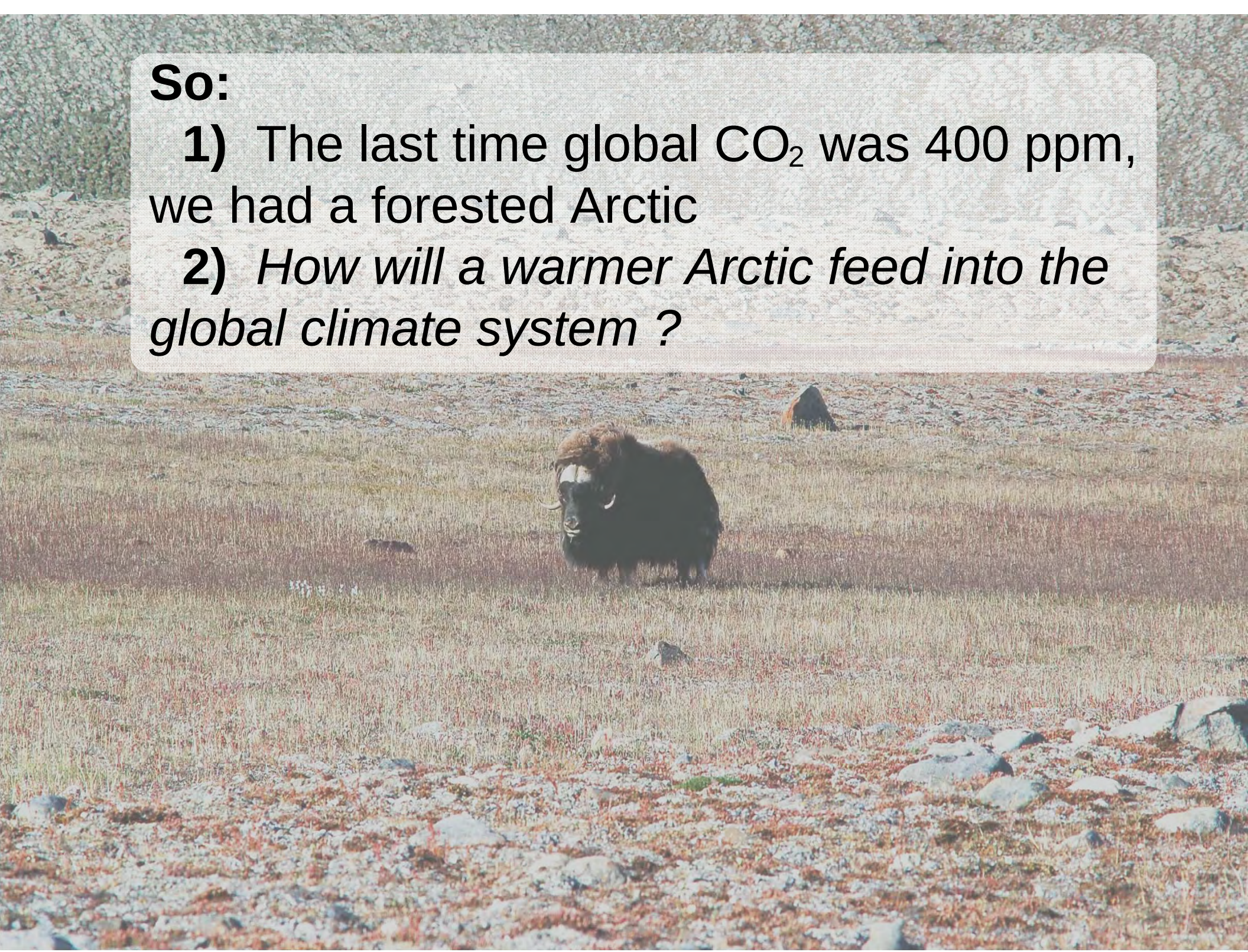
So:

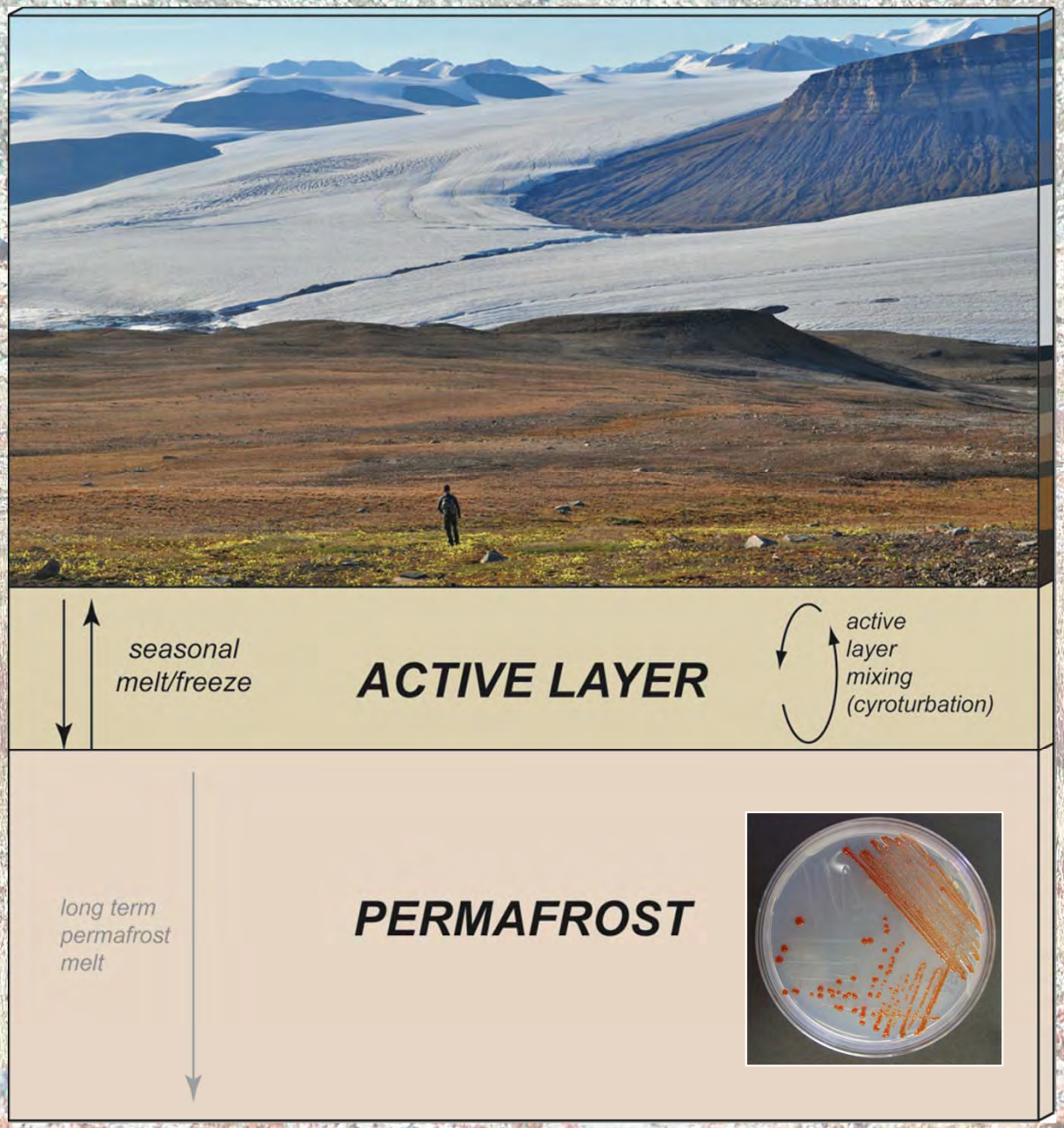
1) The last time global CO_2 was 400 ppm, we had a forested Arctic

So:

1) The last time global CO_2 was 400 ppm, we had a forested Arctic

2) *How will a warmer Arctic feed into the global climate system ?*




seasonal
melt/freeze
ACTIVE LAYER
active
layer
mixing
(cyroturbation)
long term
permafrost
melt
PERMAFROST

CO_2 flux

High stocks of soil organic carbon in the North American Arctic region

CHIEN-LU PING[1]*, GARY J. MICHAELSON[1], MARK T. JORGENSON[2], JOHN M. KIMBLE[3], HOWARD EPSTEIN[4], VLADIMIR E. ROMANOVSKY[5] AND DONALD A. WALKER[6]

[1] Agriculture and Forestry Experiment Station, University of Alaska Fairbanks, 533 E. Fireweed, Palmer, Alaska 99645, USA
[2] Alaska Biological Research, Box 80410, Fairbanks, Alaska 99708, USA
[3] Professional Soil Scientist, 151 East Hill Church Road, Addison, New York 14801, USA
[4] Department of Environmental Sciences, University of Virginia, PO Box 400123, Charlottesville, Virginia 22904, USA
[5] Geophysical Institute, University of Alaska Fairbanks, PO Box 755780, Fairbanks, Alaska 99775, USA
[6] Institute of Arctic Biology, University of Alaska Fairbanks, PO Box 757000, Fairbanks, Alaska 99775, USA
*e-mail: ffcp@uaf.edu

The Arctic soil organic-carbon pool is a significant, but poorly constrained, carbon store. The most cited pool size estimates are based on a study that severely undersamples Arctic soils, with only five out of the 48 soils examined actually from the Arctic region. Furthermore, previous measurements have been confined to the top 40 cm of soil. Here, we present 1-m-deep measurements of soil organic carbon obtained at 117 locations in the North American Arctic region. To this dataset we add previously published measurements to generate a total sample size of 139 North American Arctic soils. We show that soil organic-carbon stores are highly dependent on landscape type, being highest in lowland and hilly upland soils, where values average 55.1 and 40.6 kg soil organic carbon m^{-2} respectively, and lowest in [illegible] 3.4 and 3.8 kg soil organic carbon m^{-2} respectively. Extrapolating our measure[illegible] estimate that the total organic carbon pool in North American Arctic soils, together with the average amount of carbon per unit area, is considerably higher than previously thought. Our estimates of the depth distribution and total amount of organic carbon in North American Arctic soils will form an important basis for studies examining the impact of climate warming on CO_2 release in the region.

55.1 and 40.6 kg soil organic carbon m^{-2}

Nature Geoscience (2008)

Table 1 Average SOC stores for the landscape units[20] of the North American Arctic. The data set is given in Supplementary Information.

Landscape unit*	n †	Active layer: Organic enriched surface horizons	Active layer: Subsurface horizons (to permafrost)	Permafrost: Upper permafrost to 1 m depth	Total: To 1 m
		kg SOC m^{-2}			
Lowlands	54	15.1	14.1	25.9	55.1
Std(range)		14.5(2.1–51.9)	12.9(0–47.8)	15.8(1.5–68.1)	18.9(14.3–95.0)
% of total		27	26	47	
Uplands	76	7.5	18.2	15.0	40.6
Std(range)		11.6(0.1–63.5)	13.1(0–57.6)	13.6(0–53.0)	22.7(6.0–104.3)
% of total		18	45	37	
Rubblelands	5	0.8	2.1	0.5	3.4
Std(range)		2.1(0.1–3.7)	2.8(0.1–6.6)	1.1(0–2.4)	3.5(0.3–9.0)
% of total		23	62	15	
Mountains	4	0.7	3.1	0.0	3.8
Std(range)		0.5(0–1.3)	1.6(1.6–5.3)	(0)	1.8(1.6–6.1)
% of total		18	82	0	
Ave. wtd‡		6.8	14.9	13.1	34.8
% of total		20	42	38	

*Lowlands were soils in CAVM units W1–3, uplands were in units B1, G1–4, P1–2 and S1–2, rubbleland soils were in unit B2, and mountains were in units B3–4 (ref. 20).

† n = number of soil profiles averaged for the landscape unit.

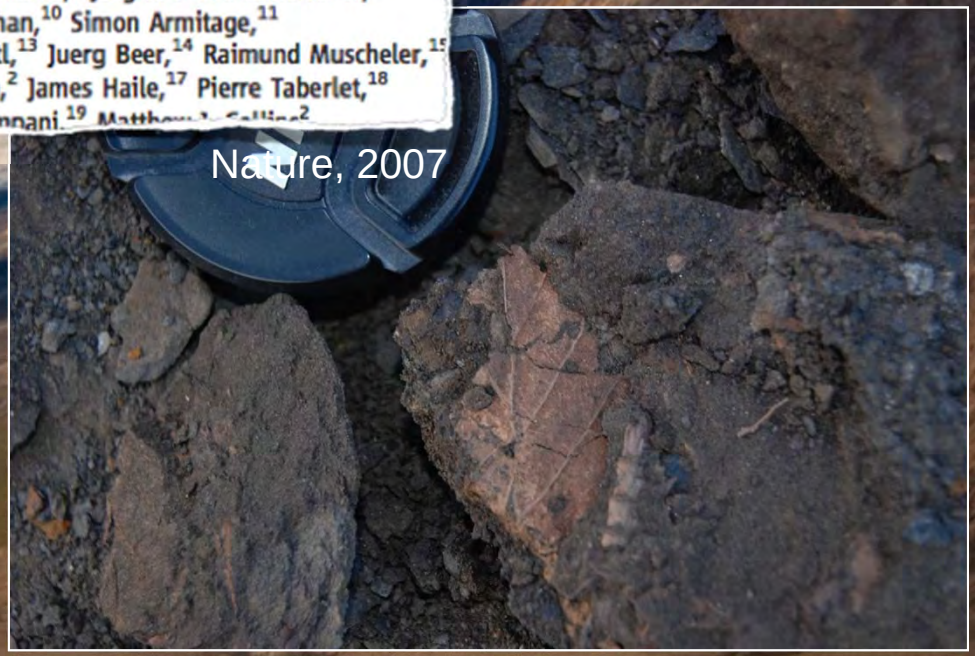
‡ Averaged using relative areas of each landscape unit in the North American Arctic (ref. 20).

Ping et al., 2008

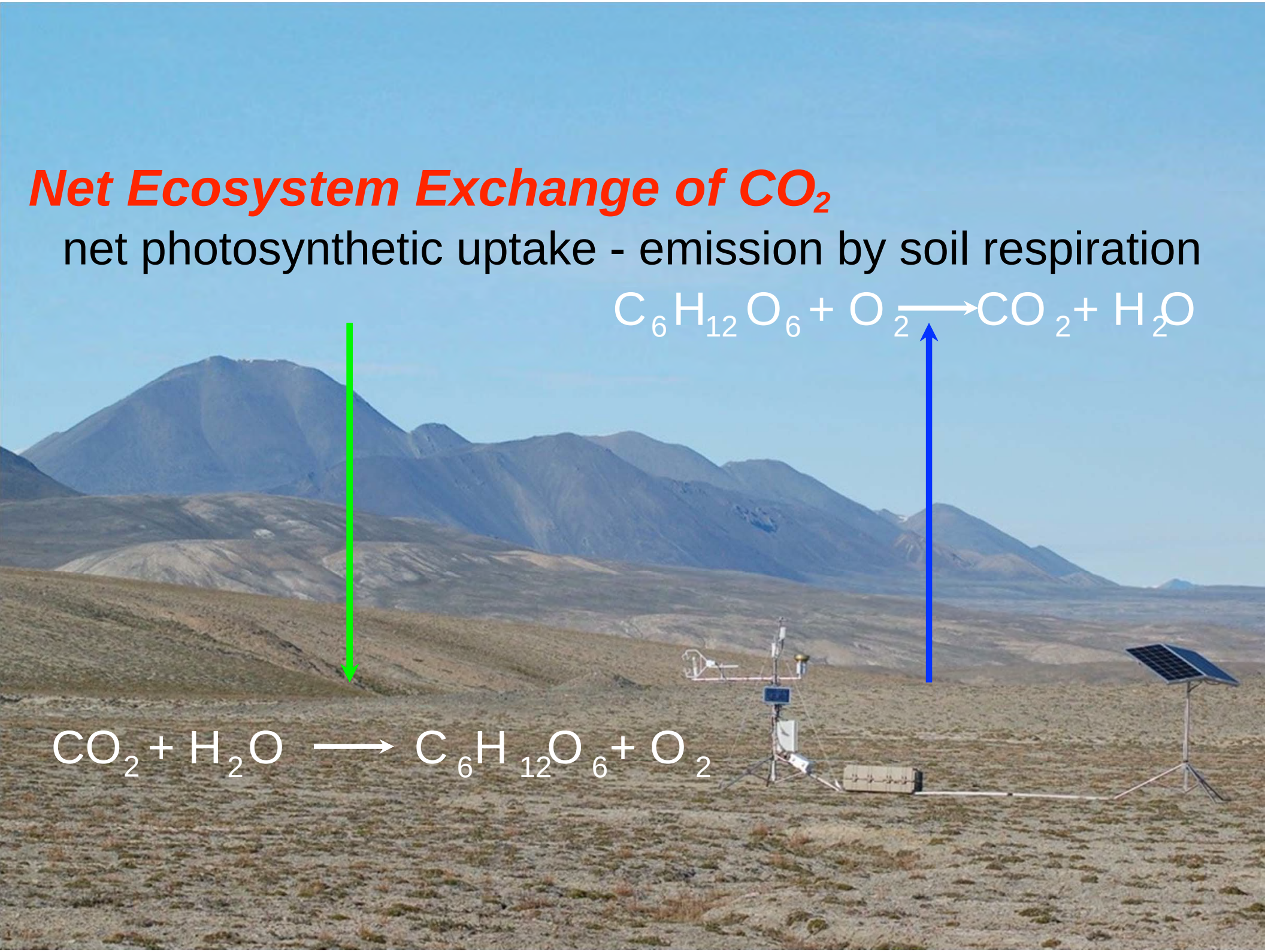
cultivated soil in Ohio = ~ 5.5 kg SOC m^{-2}

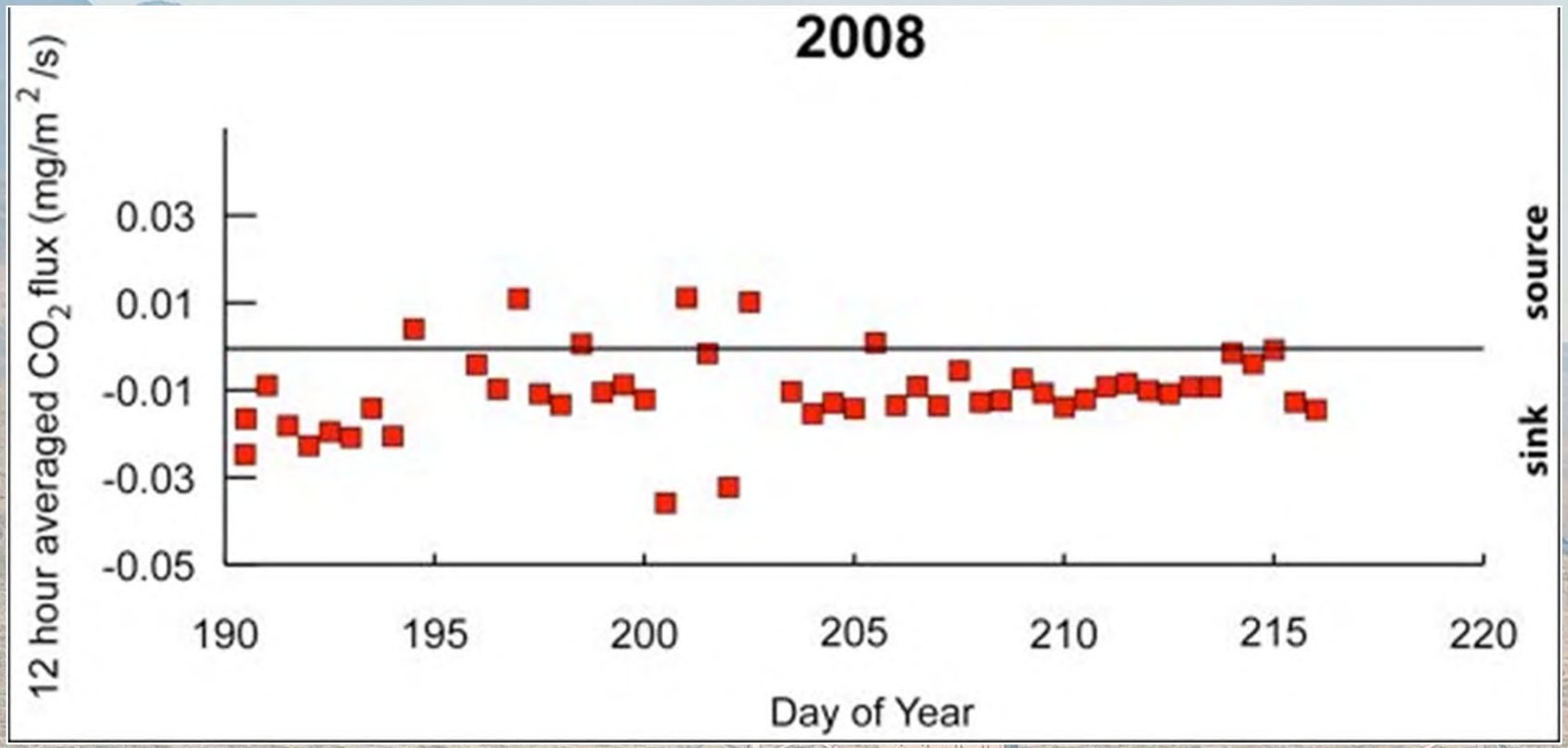
Ancient Biomolecules from Deep Ice Cores Reveal a Forested Southern Greenland

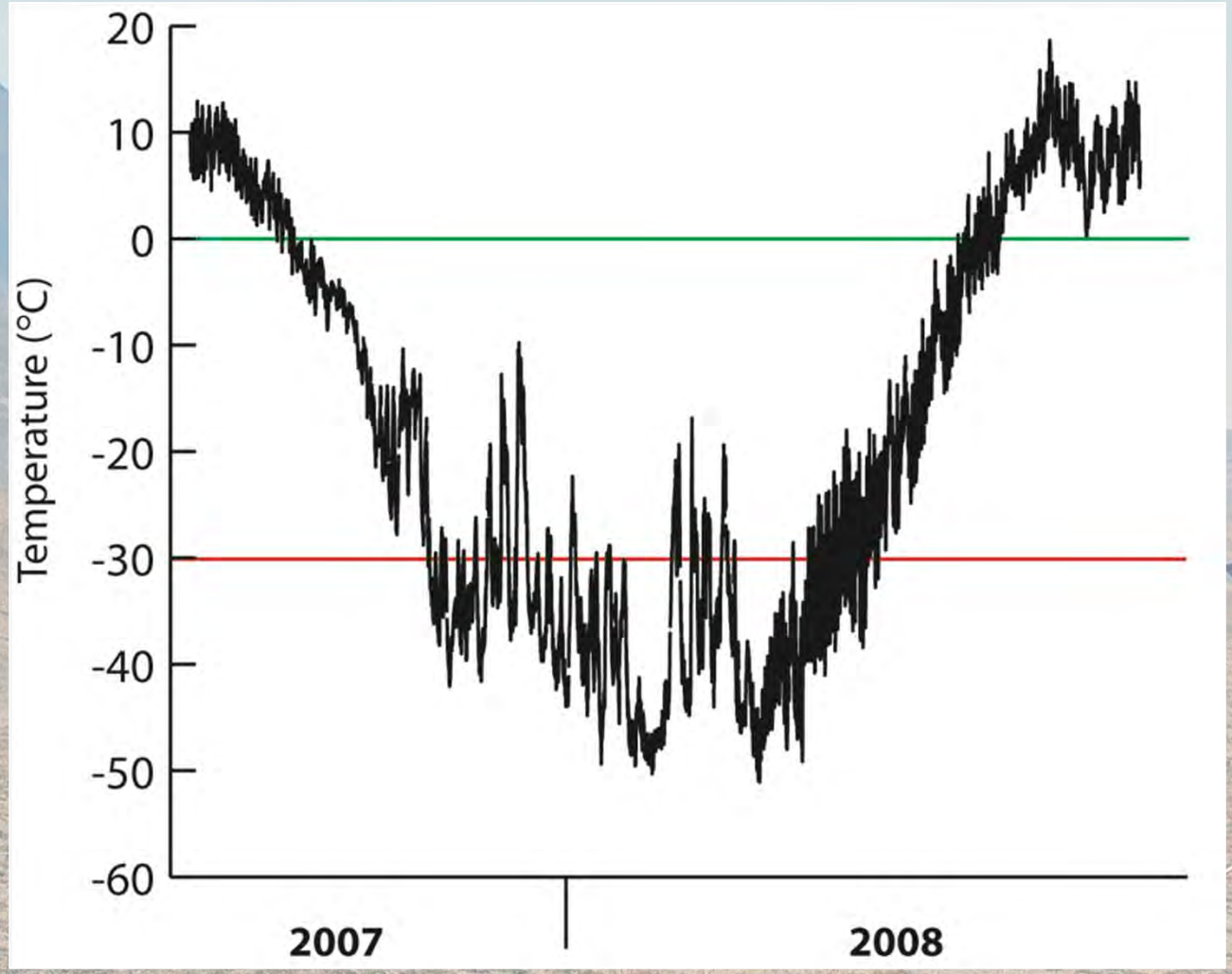
Eske Willerslev,[1*] Enrico Cappellini,[2] Wouter Boomsma,[3] Rasmus Nielsen,[4] Martin B. Hebsgaard,[1] Tina B. Brand,[1] Michael Hofreiter,[5] Michael Bunce,[6,7] Hendrik N. Poinar,[7] Dorthe Dahl-Jensen,[8] Sigfus Johnsen,[8] Jørgen Peder Steffensen,[8] Ole Bennike,[9] Jean-Luc Schwenninger,[10] Roger Nathan,[10] Simon Armitage,[11] Cees-Jan de Hoog,[12] Vasily Alfimov,[13] Marcus Christl,[13] Juerg Beer,[14] Raimund Muscheler,[15] Joel Barker,[16] Martin Sharp,[16] Kirsty E. H. Penkman,[2] James Haile,[17] Pierre Taberlet,[18] M. Thomas P. Gilbert,[1] Antonella Casoli,[19] Elisa Campani,[19] Matthew J. Collins[2]

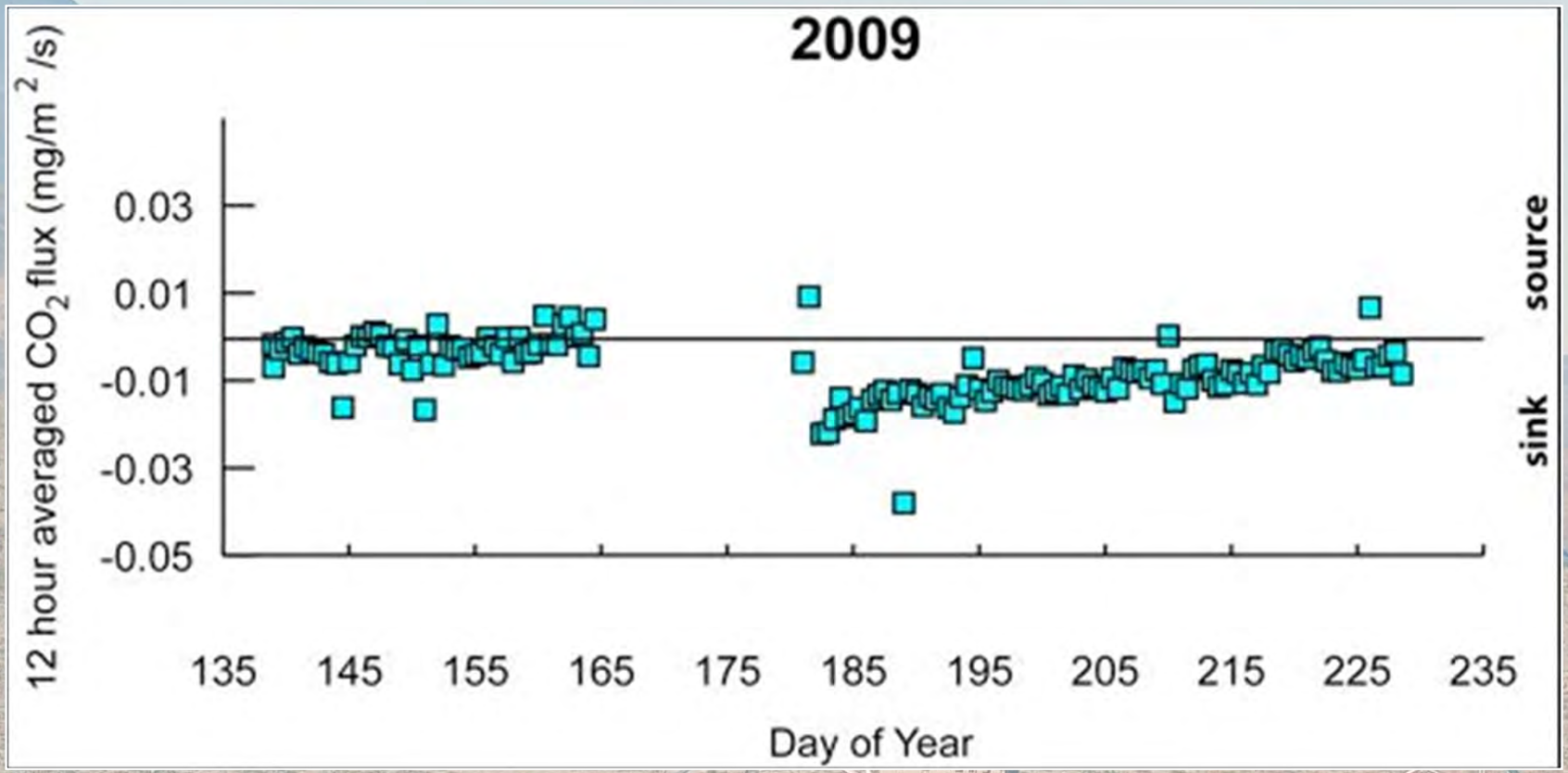


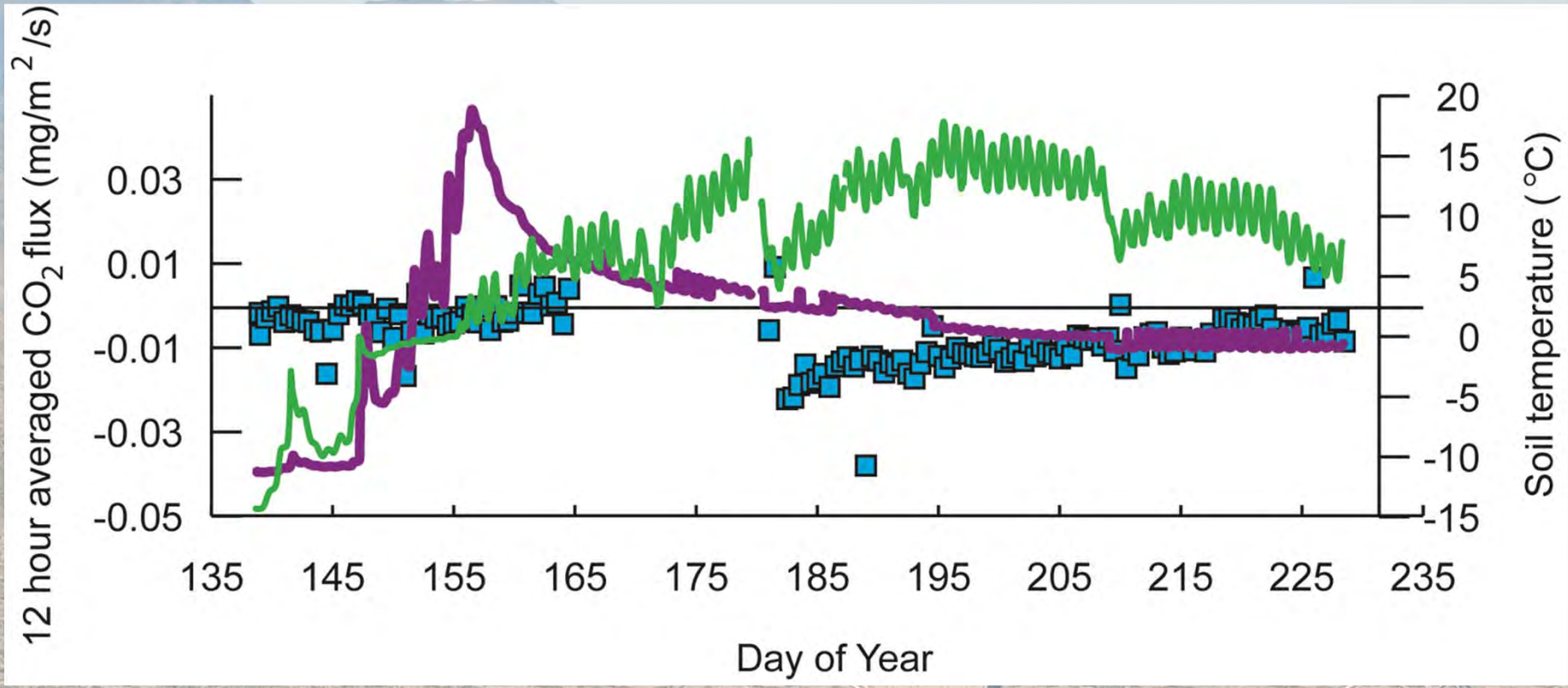
Nature, 2007

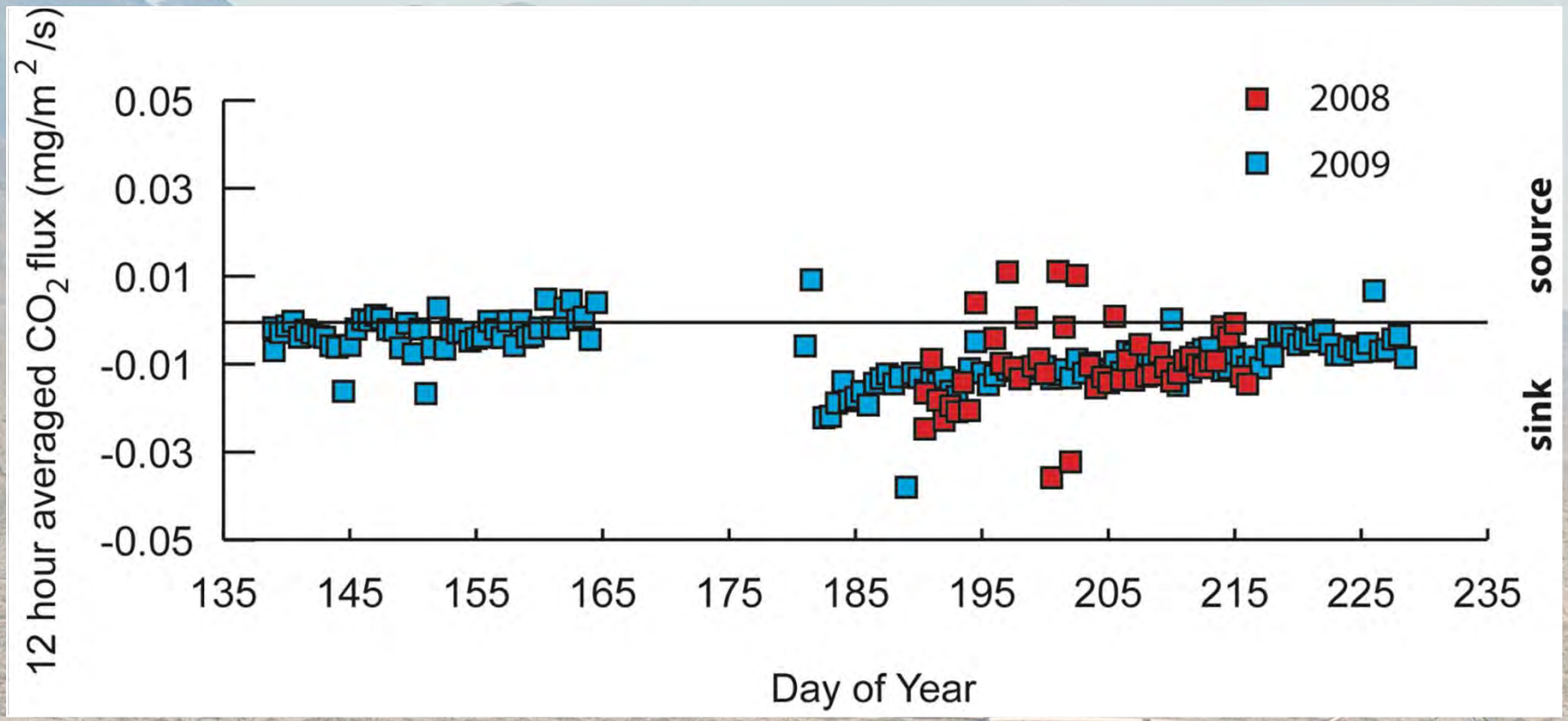

Net Ecosystem Exchange of CO_2
net photosynthetic uptake - emission by soil respiration
$C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O$
$CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$

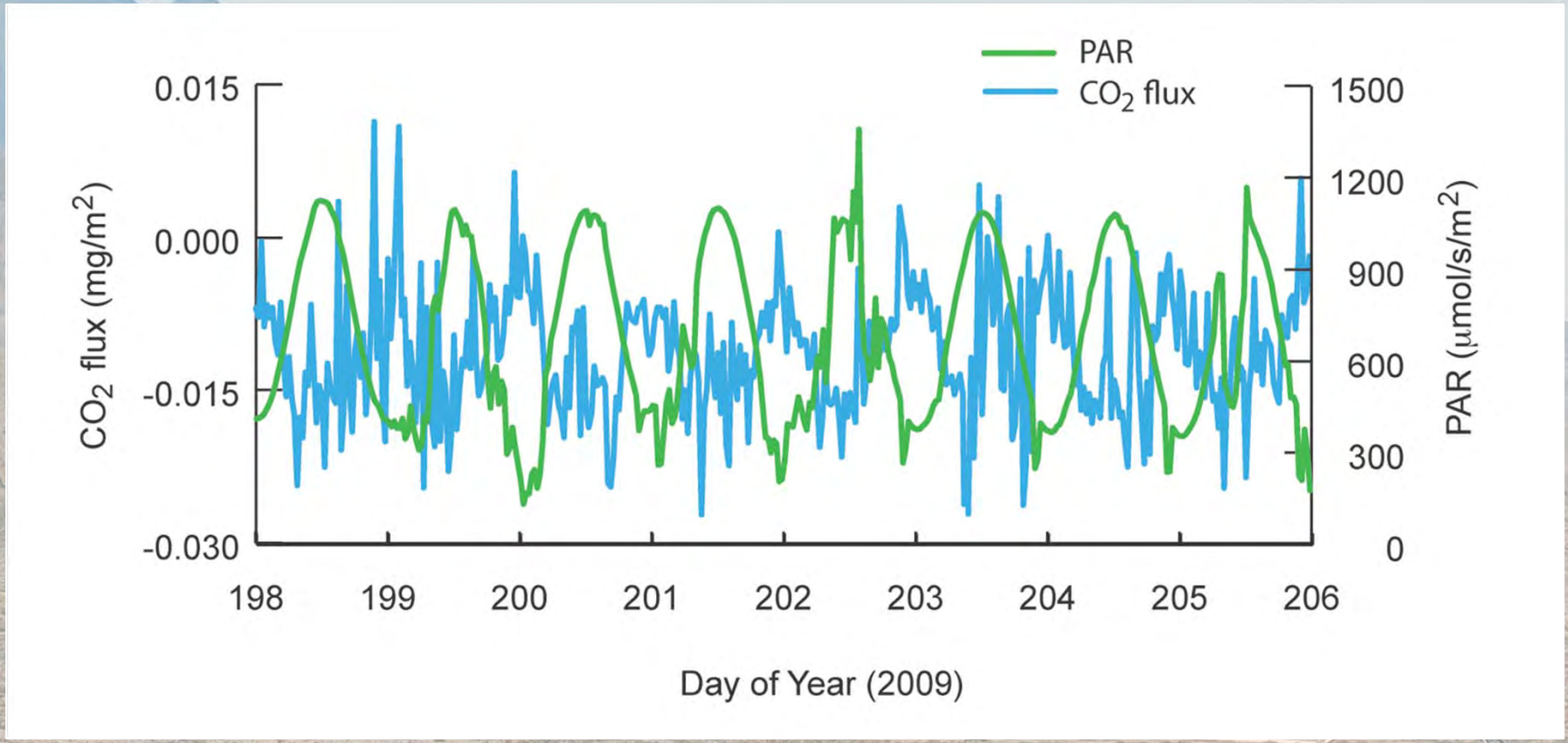

2008
12 hour averaged CO_2 flux (mg/m^2/s)
0.03
0.01
-0.01
-0.03
-0.05
190
195
200
205
210
215
220
Day of Year
source
sink


20
10
0
-10
-20
-30
-40
-50
-60
Temperature (°C)
2007
2008

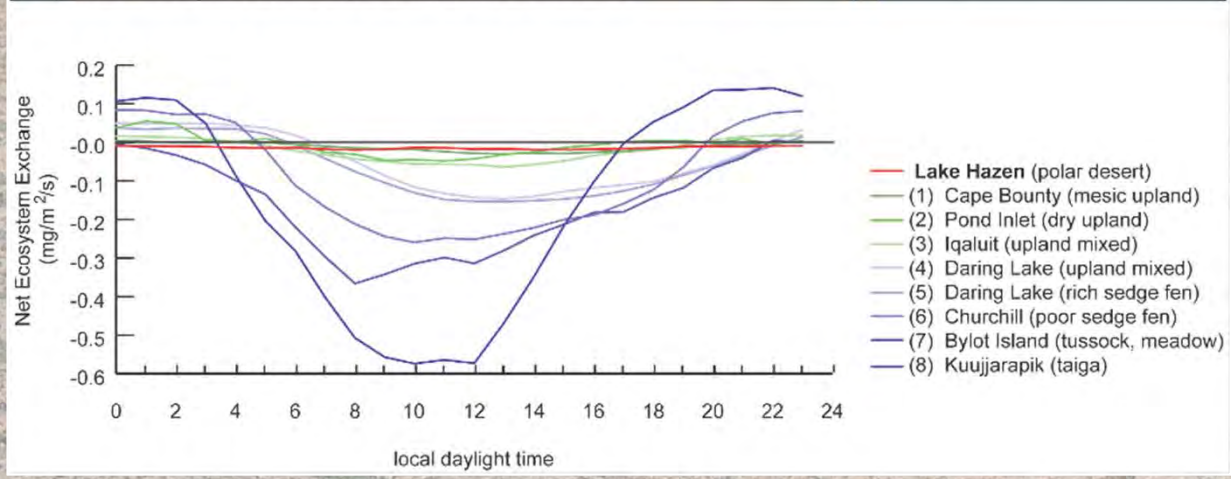

2009
12 hour averaged CO_2 flux (mg/m^2/s)
0.03
0.01
-0.01
-0.03
-0.05
135
145
155
165
175
185
195
205
215
225
235
Day of Year
source
sink

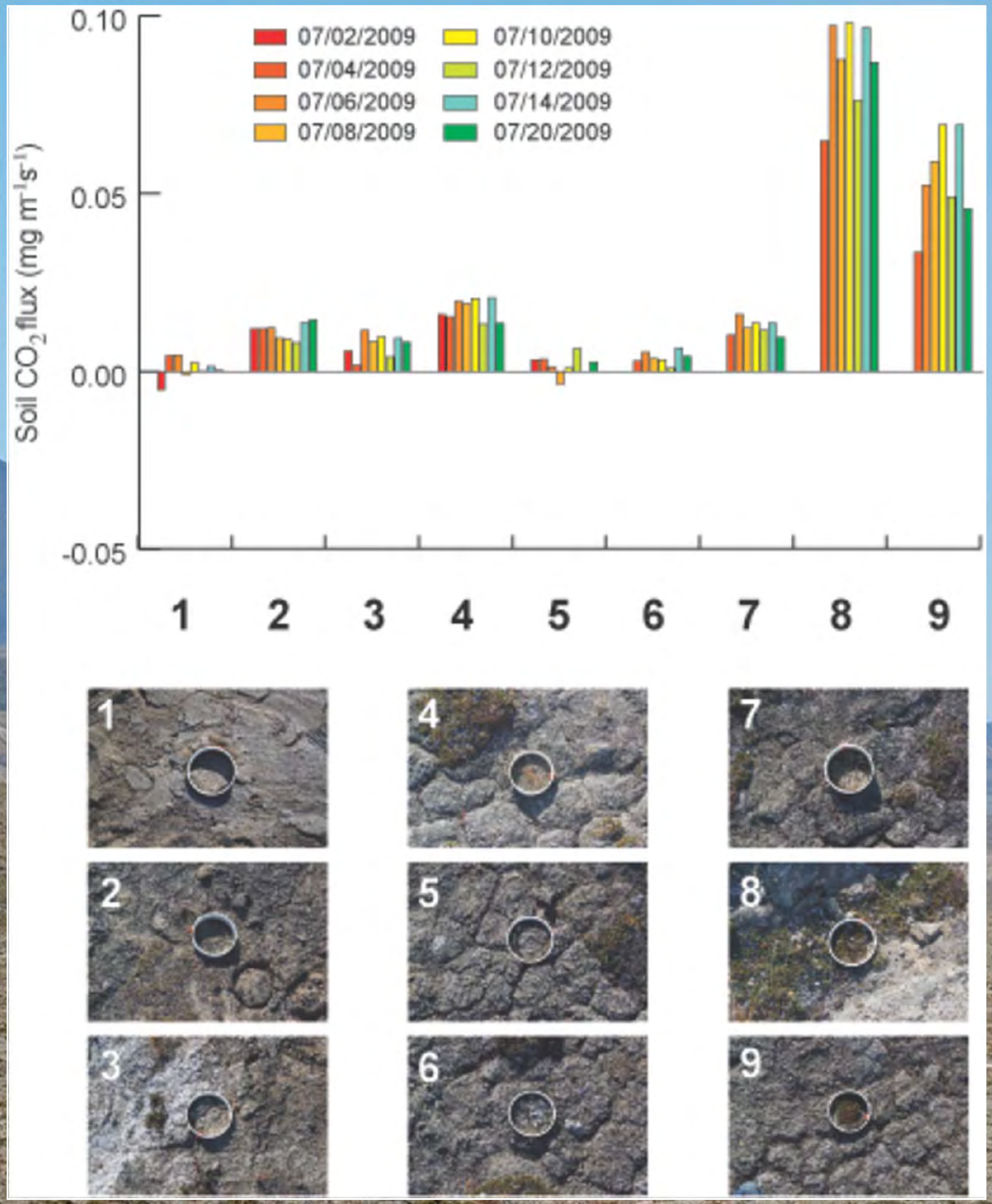

12 hour averaged CO_2 flux (mg/m^2/s)
0.03
0.01
-0.01
-0.03
-0.05
135
145
155
165
175
185
195
205
215
225
235
Day of Year
20
15
10
5
0
-5
-10
-15
Soil temperature (°C)


12 hour averaged CO_2 flux ($mg/m^2/s$)
0.05
0.03
0.01
-0.01
-0.03
-0.05
135
145
155
165
175
185
195
205
215
225
235
Day of Year
2008
2009
source
sink


PAR
CO_2 flux
0.015
0.000
-0.015
-0.030
CO_2 flux (mg/m^2)
1500
1200
900
600
300
0
PAR (μmol/s/m^2)
198
199
200
201
202
203
204
205
206
Day of Year (2009)

Canada's National Parks
National Parks / National Park Reserves
National Marine Conservation Areas
© 2007. Her Majesty the Queen in Right of Canada, Natural Resources Canada.
North Pole
Polar Ice
Arctic Ocean
Russia
Alaska (USA)
Bering Strait
Norwegian Sea
Norway
Greenland Sea
UK
Iceland
Kalaallit Nunaat (Grønland) (Denmark)
Quttinirpaaq
Baffin Bay
Davis Strait
Labrador Sea
Atlantic Ocean
Pacific Ocean
Scale
300 0 300 600 900 km
atlas.gc.ca
Yukon
Kluane
Northwest Territories
Nahanni
Nunavut
Ivvavik
Aulavik
Vuntut
Tuktut Nogait
Ukkusiksalik
Auyuittuq
Ungava Bay
Torngat Mountains
Newfoundland and Labrador
Terra Nova
Gros Morne
Mingan Archipelago
Forillon
Cape Breton Highlands
Prince Edward Island
Kejimkujik
Hudson Bay
James Bay
Quebec
Ontario
Manitoba
Saskatchewan
Alberta
British Columbia
Wood Buffalo
Wapusk
Riding Mountain
Prince Albert
Grasslands
Waterton Lakes
Jasper
Elk Island
Banff
Glacier
Mount Revelstoke
Yoho
Kootenay
Gulf Islands
Pacific Rim
Gwaii Haanas
Saguenay–St Lawrence
La Mauricie
Kouchibouguac
Fundy
PEI
NB
NS
(FR)
Pukaskwa
Fathom Five
Georgian Bay Islands
St Lawrence Islands
Bruce Peninsula
Lake Superior
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
Point Pelee
United States of America
NS = Nova Scotia
NB = New Brunswick
PEI = Prince Edward Island


Net Ecosystem Exchange (mg/m²/s)
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0 2 4 6 8 10 12 14 16 18 20 22 24
local daylight time
Lake Hazen (polar desert)
(1) Cape Bounty (mesic upland)
(2) Pond Inlet (dry upland)
(3) Iqaluit (upland mixed)
(4) Daring Lake (upland mixed)
(5) Daring Lake (rich sedge fen)
(6) Churchill (poor sedge fen)
(7) Bylot Island (tussock, meadow)
(8) Kuujjarapik (taiga)


0.10
0.05
0.00
-0.05
Soil CO_2 flux (mg $m^{-1}s^{-1}$)
07/02/2009
07/04/2009
07/06/2009
07/08/2009
07/10/2009
07/12/2009
07/14/2009
07/20/2009
1
2
3
4
5
6
7
8
9

So:

1) **Currently, the Arctic is a sink for CO_2**
2) The Arctic is warming
3) Evidence of past forested Arctic under conditions similar to today, and predicted for next 100 years
4) Will Arctic continue to function as a sink ?
   a) will the sink increase with increased leaf area ?
5) Will Arctic warming increase soil respiration enough that it becomes the dominant process ?

So:

1) Currently, the Arctic is a sink for CO_2

2) **The Arctic is warming**

3) Evidence of past forested Arctic under conditions similar to today, and predicted for next 100 years

4) Will Arctic continue to function as a sink ?

a) will the sink increase with increased leaf area ?

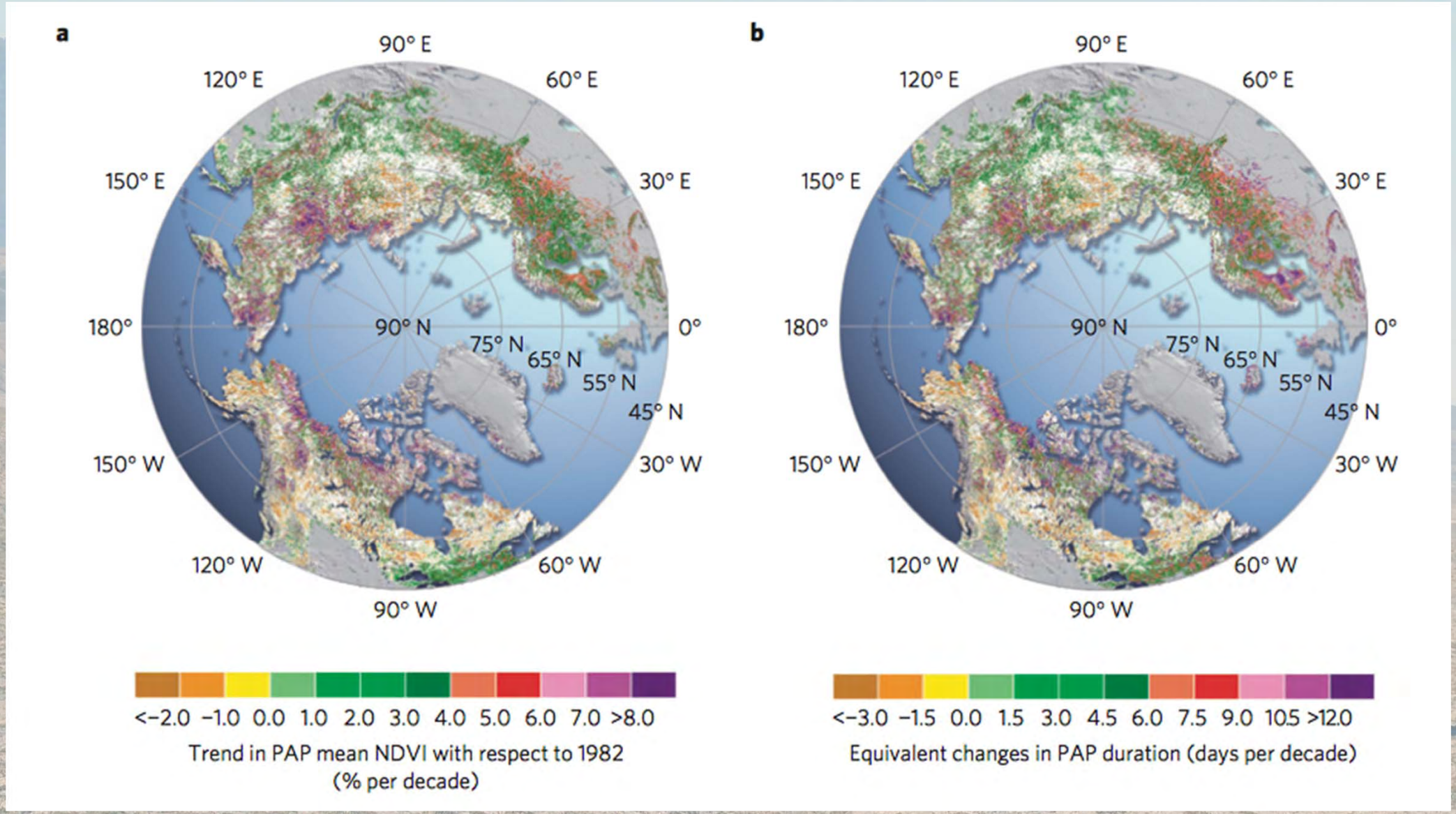
5) Will Arctic warming increase soil respiration enough that it becomes the dominant process ?

So:

1) Currently, the Arctic is a sink for CO_2
2) The Arctic is warming
3) **Evidence of past forested Arctic under conditions similar to today, and predicted for next 100 years**
4) Will Arctic continue to function as a sink ?
   a) will the sink increase with increased leaf area ?
5) Will Arctic warming increase soil respiration enough that it becomes the dominant process ?

So:

1) Currently, the Arctic is a sink for CO_2
2) The Arctic is warming
3) Evidence of past forested Arctic under conditions similar to today, and predicted for next 100 years
4) **Will Arctic continue to function as a sink ?** ***Will the sink increase with increased leaf area ?***
5) Will Arctic warming increase soil respiration enough that it becomes the dominant process ?


a
90° E
120° E
60° E
150° E
30° E
180°
0°
90° N
75° N
65° N
55° N
45° N
150° W
30° W
120° W
60° W
90° W
<−2.0 −1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 >8.0
Trend in PAP mean NDVI with respect to 1982
(% per decade)
b
90° E
120° E
60° E
150° E
30° E
180°
0°
90° N
75° N
65° N
55° N
45° N
150° W
30° W
120° W
60° W
90° W
<−3.0 −1.5 0.0 1.5 3.0 4.5 6.0 7.5 9.0 10.5 >12.0
Equivalent changes in PAP duration (days per decade)

Xu et al., 2013

So:

1) Currently, the Arctic is a sink for CO^2
2) The Arctic is warming
3) Evidence of past forested Arctic under conditions similar to today, and predicted for next 100 years
4) Will Arctic continue to function as a sink ? Will the sink increase with increased leaf area ?
5) **Will Arctic warming increase soil respiration enough that it becomes the dominant process ?**

Thank you