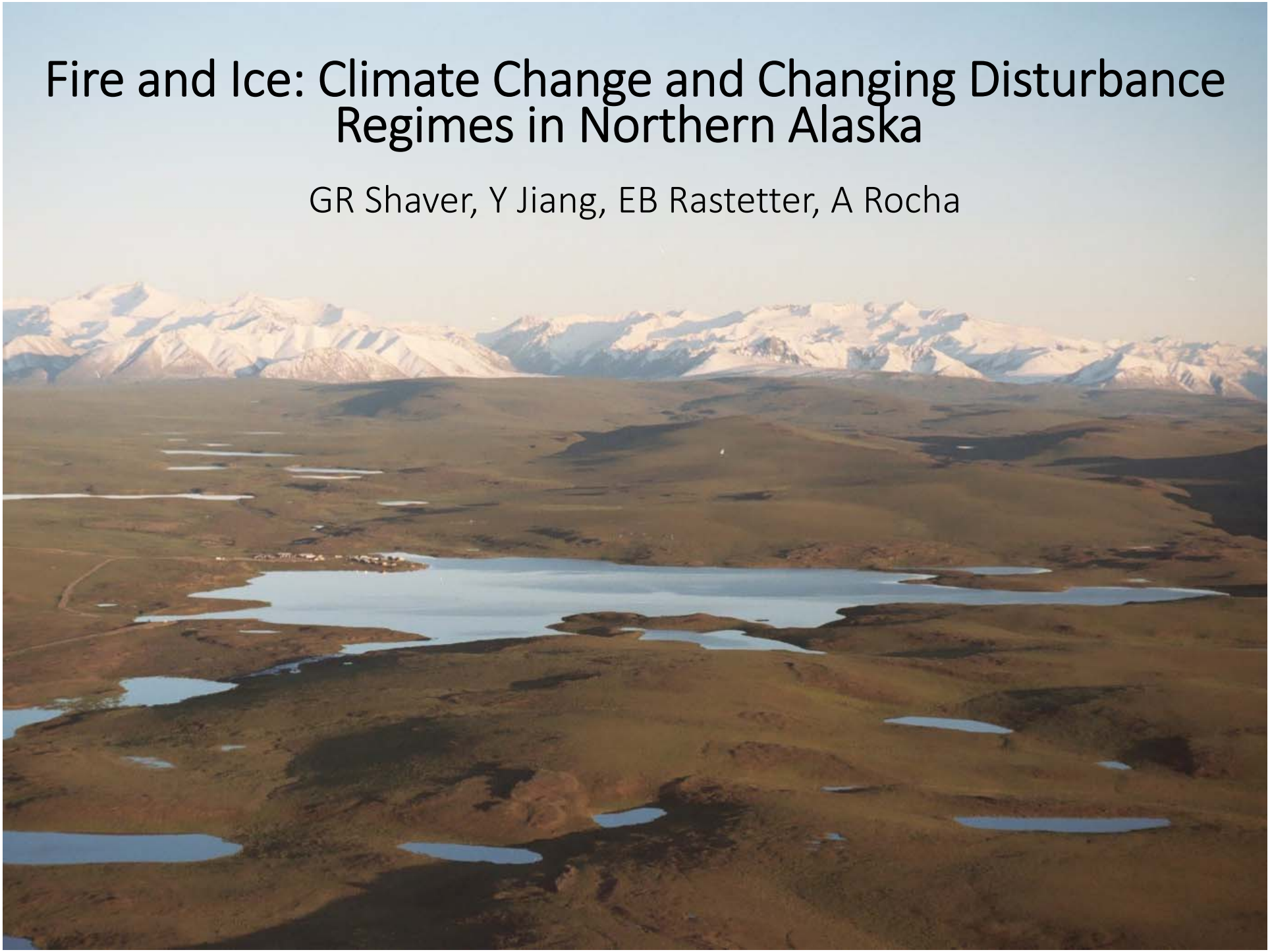
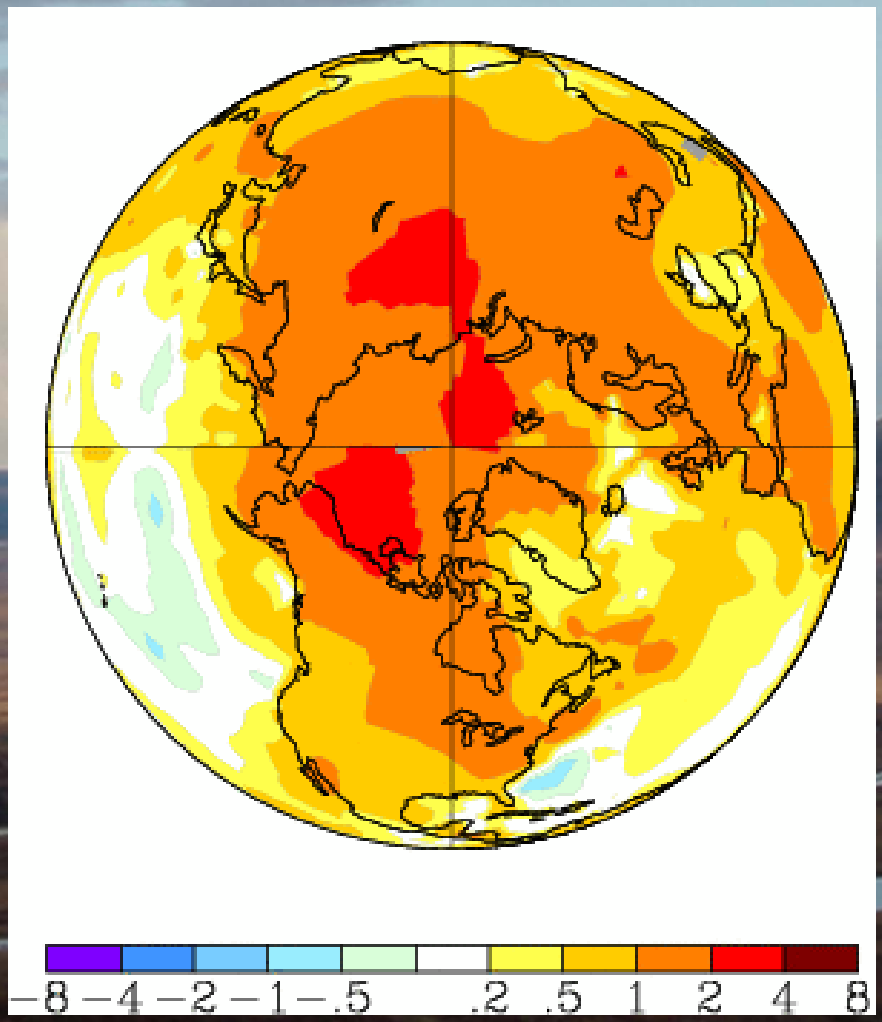
Fire and Ice: Climate Change and Changing Disturbance Regimes in Northern Alaska

GR Shaver, Y Jiang, EB Rastetter, A Rocha

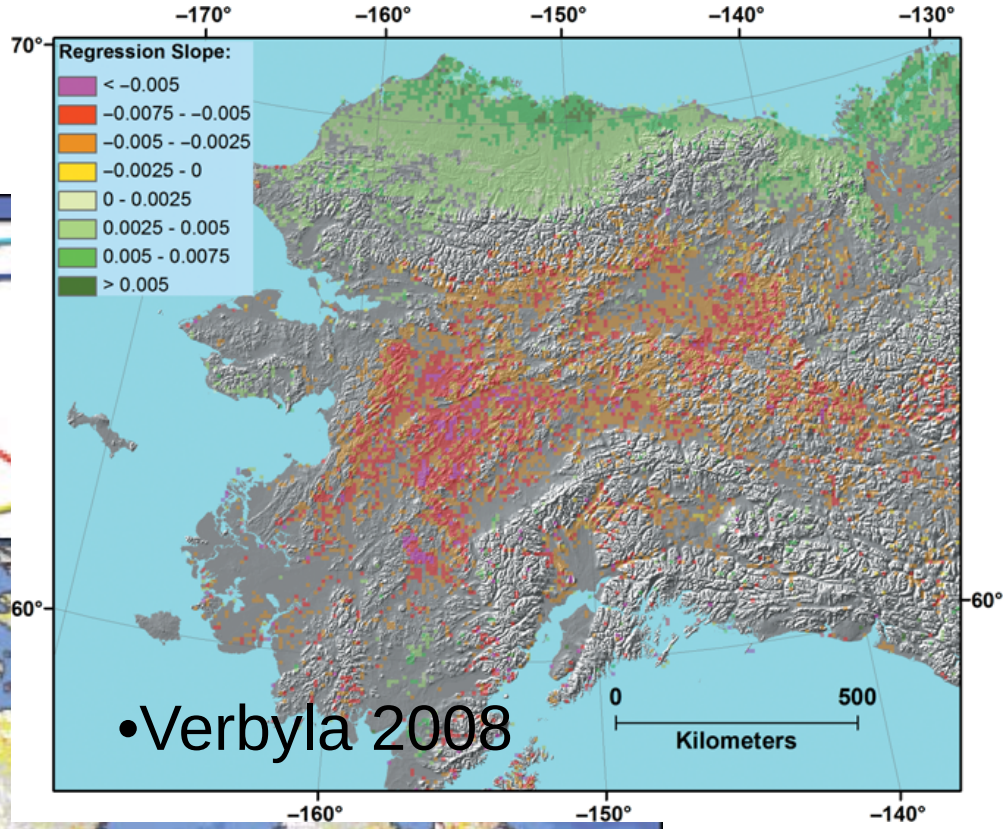


The heat is on!

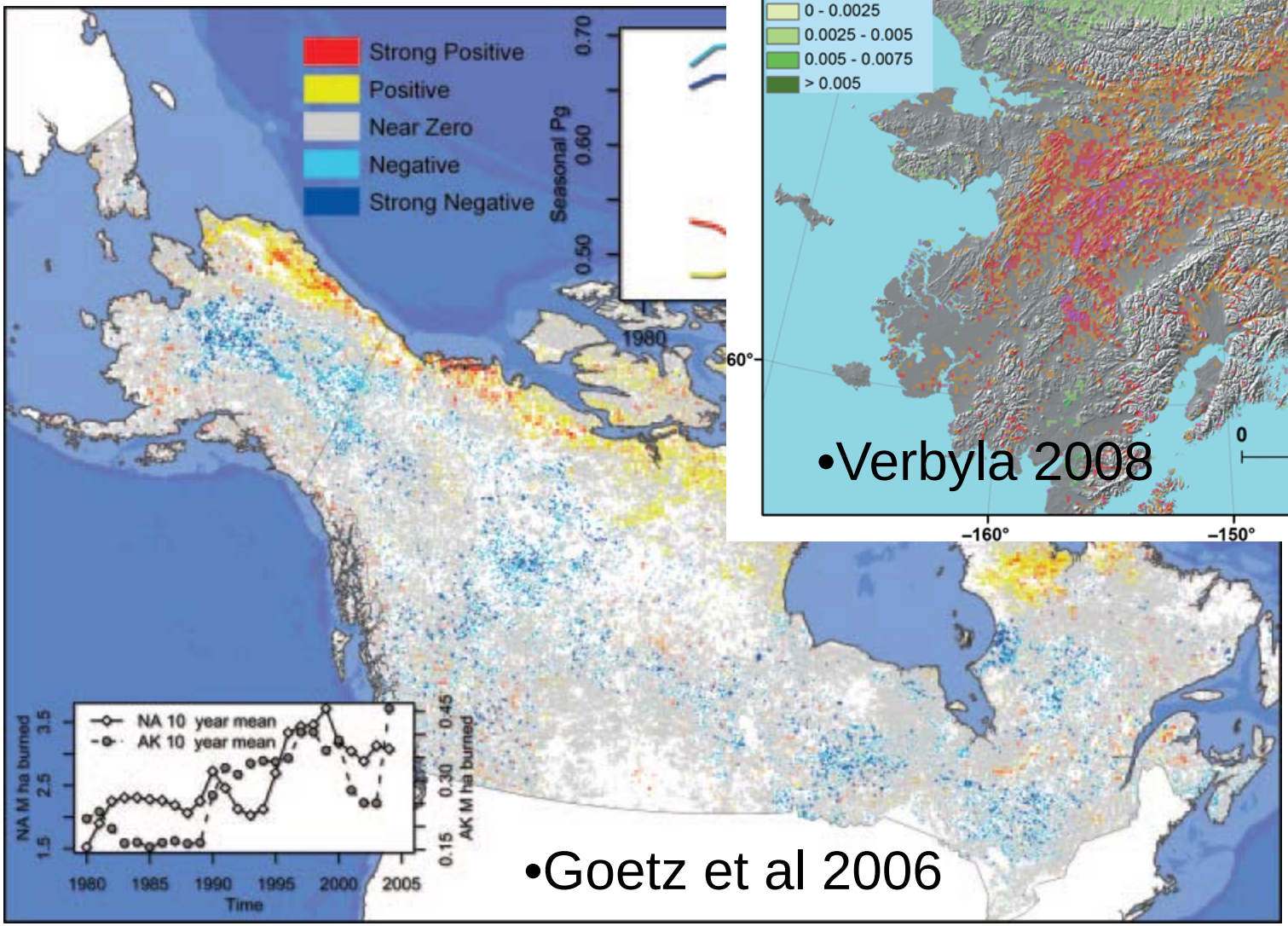
Total change in annual mean surface air temperature (°C), 1958-2007 *[from J. Walsh]*



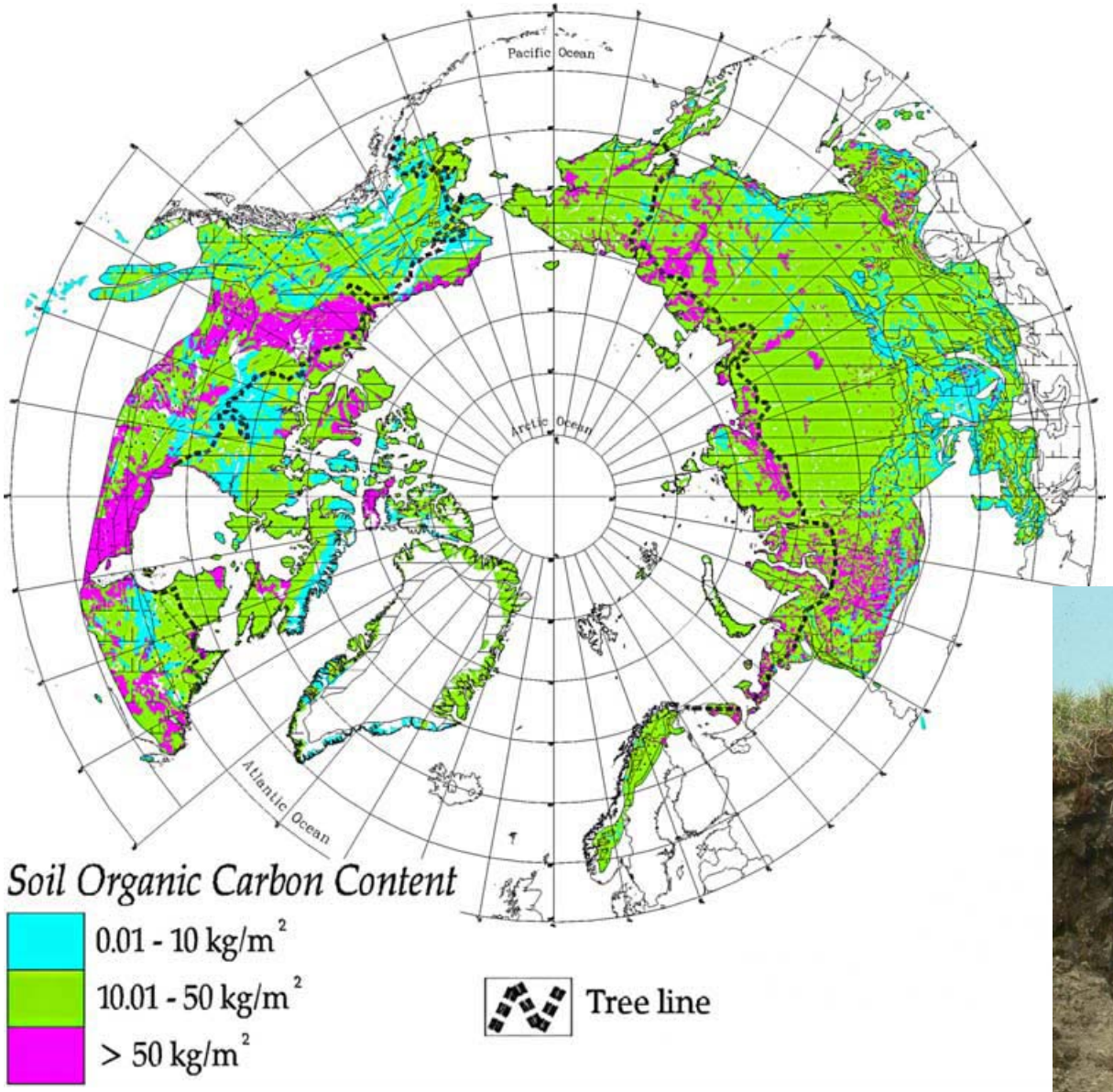
The Greening and the Browning of the Arctic and Boreal regions



•Verbyla 2008



•Goetz et al 2006

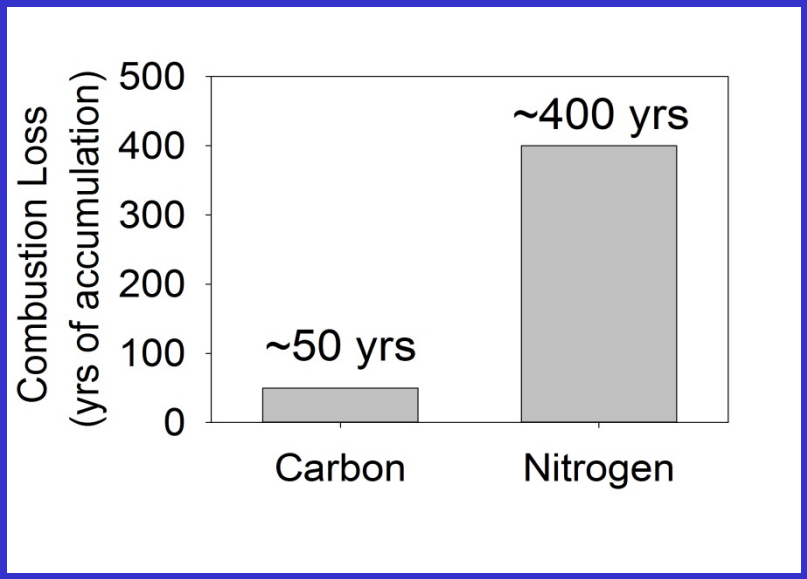


Soils underlain by permafrost contain almost 1700 Pg C, about 50 % of all soil C and >2x that held in the atmosphere

Something new on the horizon….

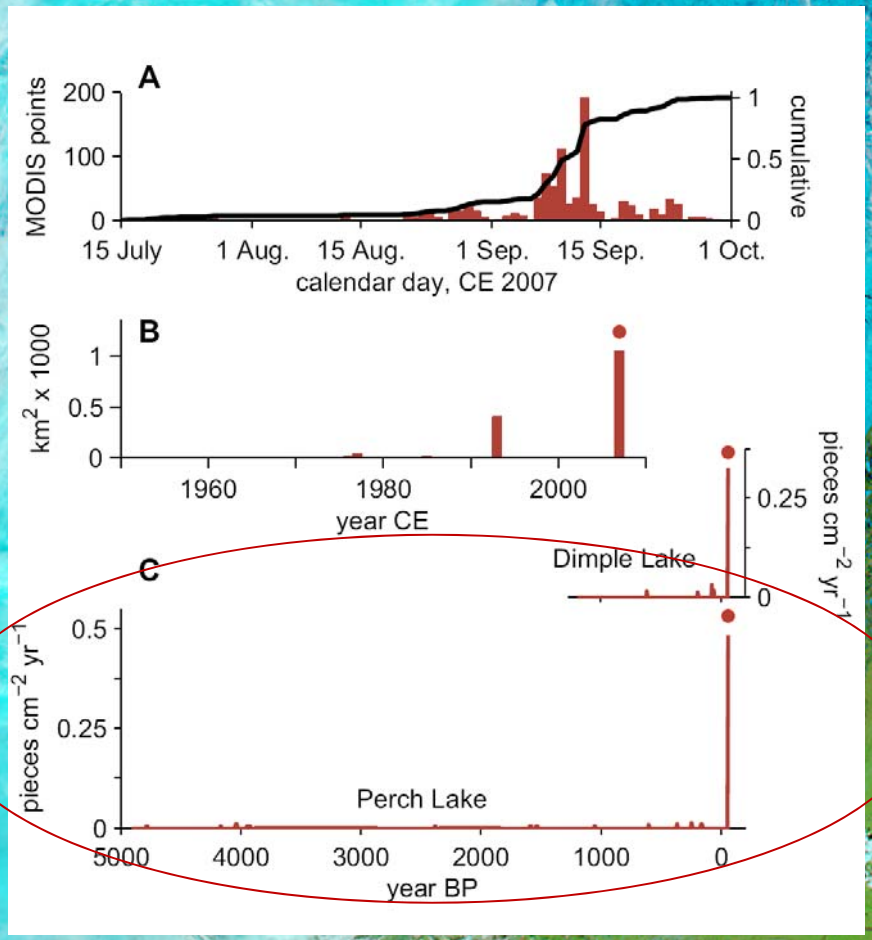
Why are tundra fires important?

Fire



Large Carbon and Nutrient losses during combustion

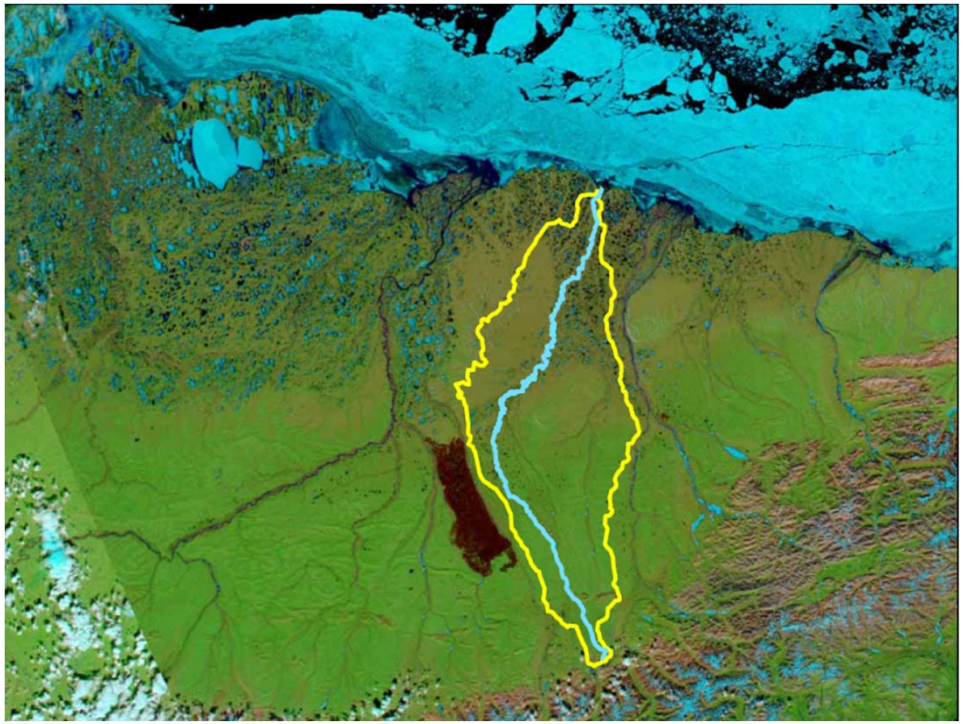
Anaktuvuk River Burn, MODIS, early June 2008



Hu et al. 2010: no fires in this area for past 5000 y

COMBUSTION LOSSES VS ANNUAL NEE OF KUPARUK BASIN:

C loss by combustion was
~2.16 Tg over 1039 km2
(measured by Mack et al 2011)



Annual NEE of the Kuparuk R. catchment: 0.218 Tg net C LOSS (measured 1995-96 by Oechel et al. 2000) or 0.23 Tg net C GAIN (modeled 1980-2100 by McGuire et al. 2000) in 9200 km2.

OR: Fire released as much CO2 to the atmosphere as annual NEE of ~10 Kuparuk R. watersheds in ~10% of the area of one Kuparuk R. watershed

The US B-53 Nuclear Bomb

Explosive yield ~9 Megatons

1 Megaton = 4.2×10^{15} Joules

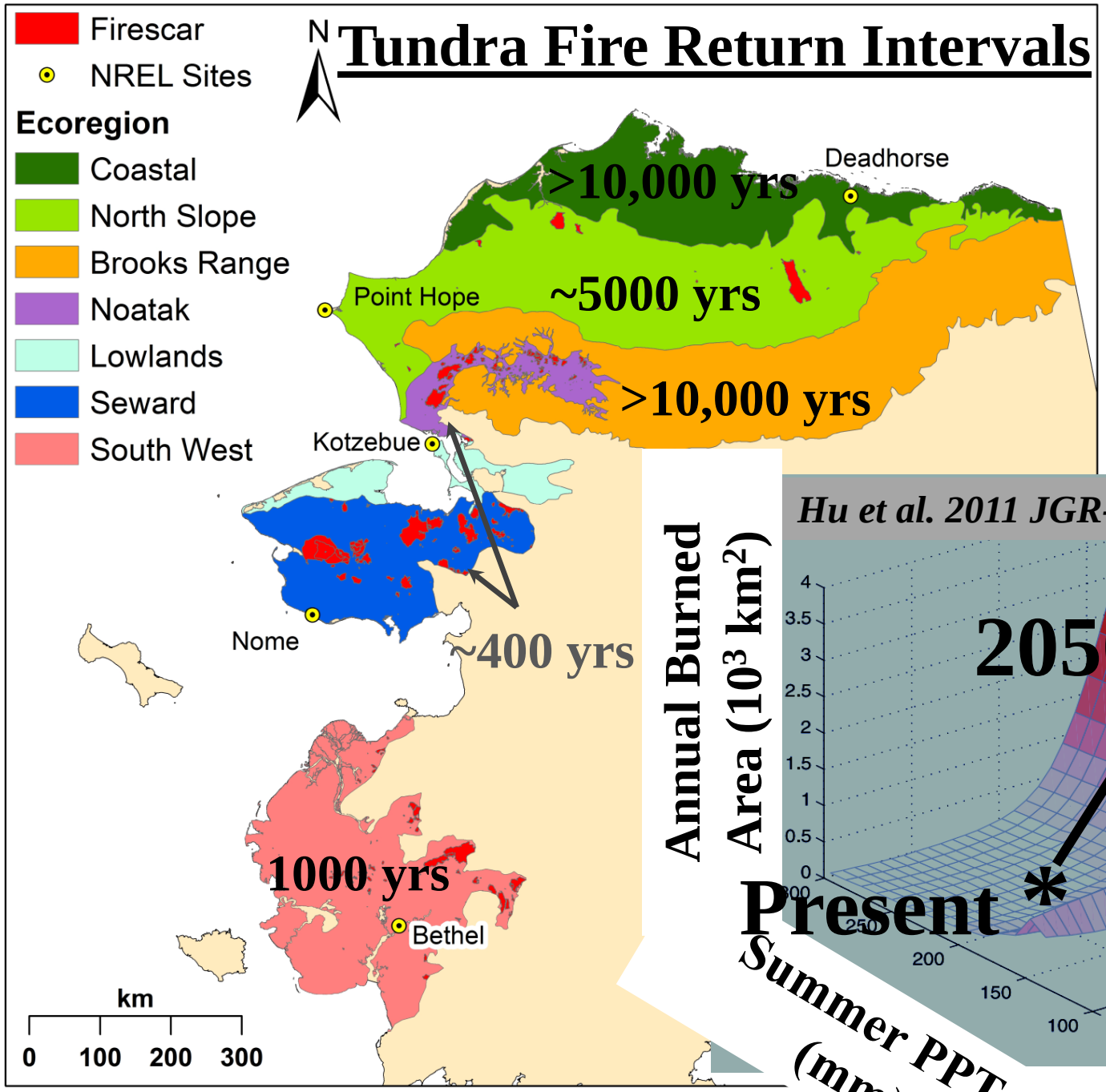
The Anaktuvuk River Burn

Energy released by combustion of organic matter

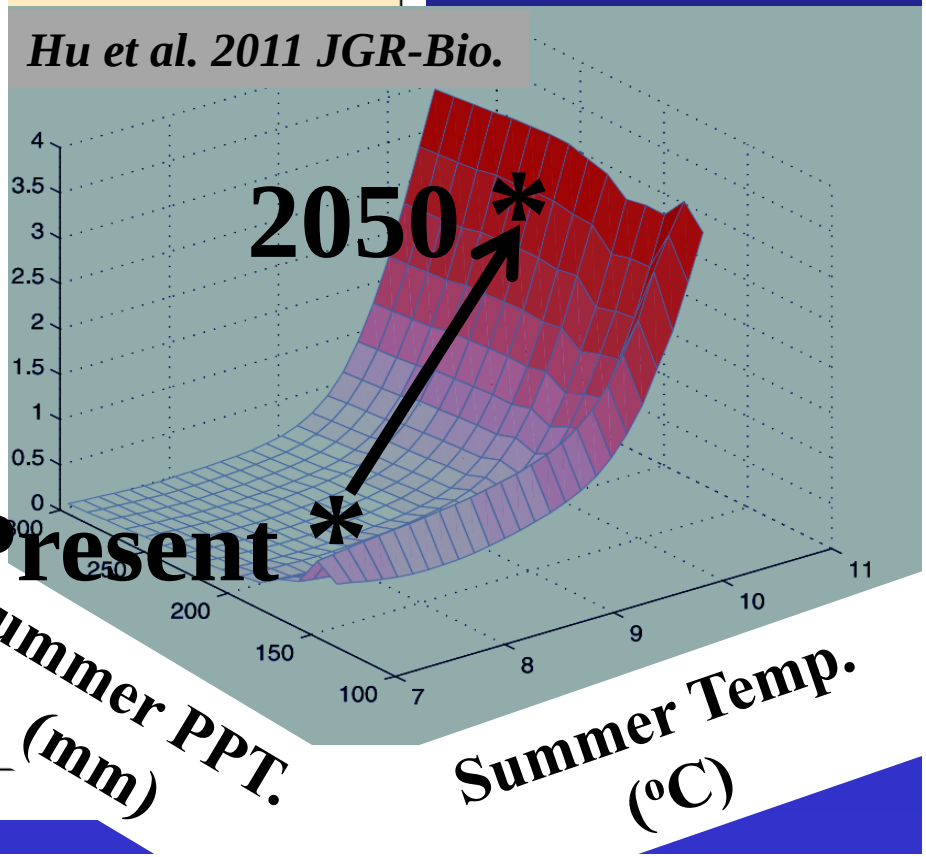
~93×10^{15} Joules, equivalent to

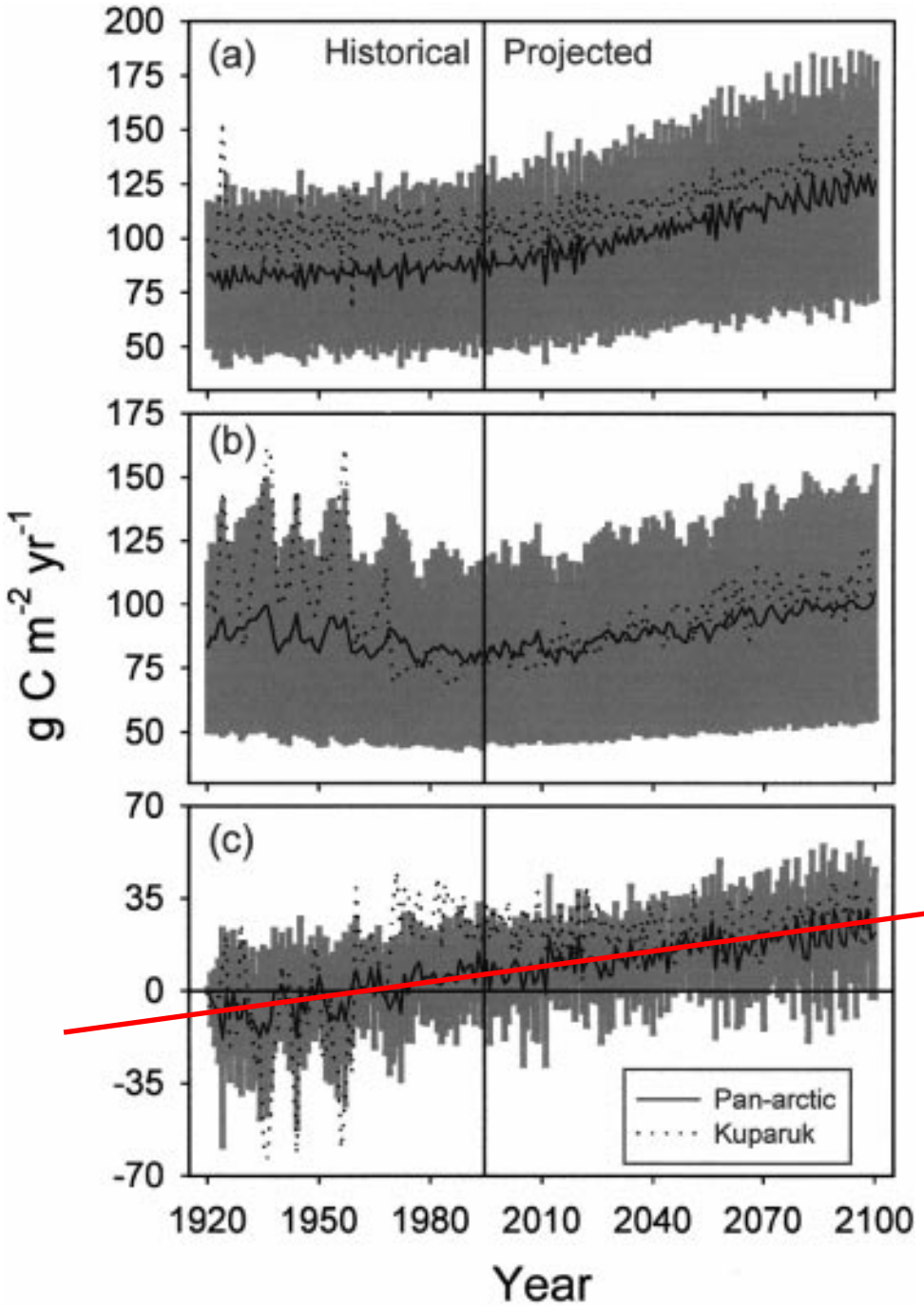
~22 Megatons TNT

Tundra Fire Return Intervals



- Fire return intervals vary by orders of magnitude.
- Tundra fires sensitive to temp.





GPP

R_E

NEP

McGuire et al. 2000:

NEP of PanArctic tundra varies from -30 to +40 g C/m^2/y,

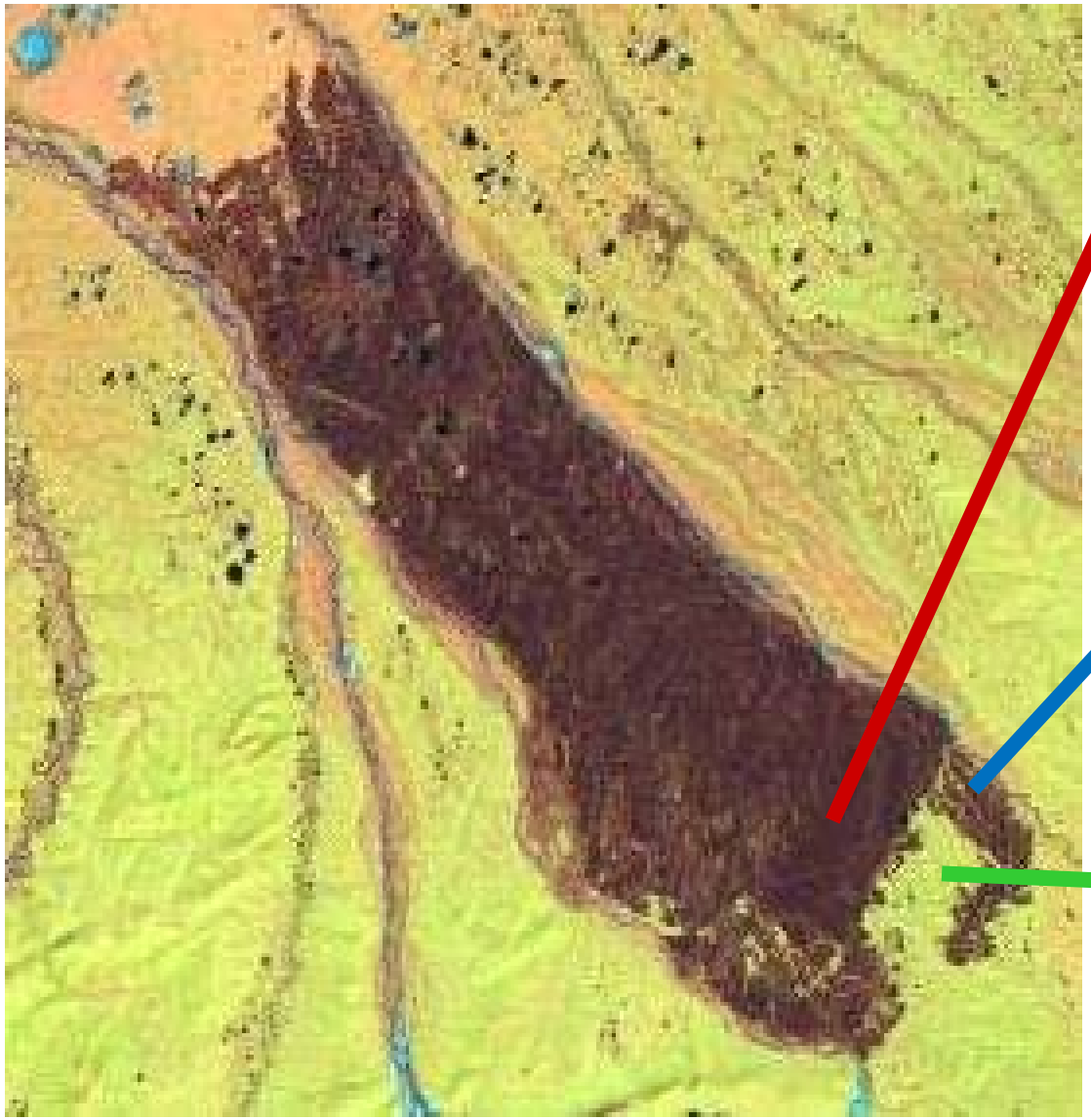
NEP of Kuparuk watershed is currently ~15-25 g C/m^2/y

Change in NEP due to climate change is ~0.3 g C/m^2/y

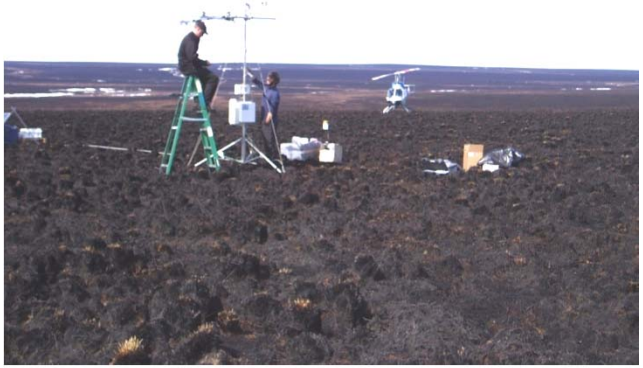
2007 Anaktuvuk River Fire

Area burned : 1039 km2

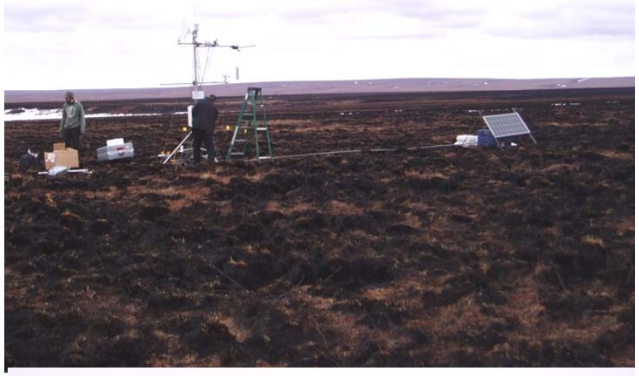
C released : ~2.16 Tg



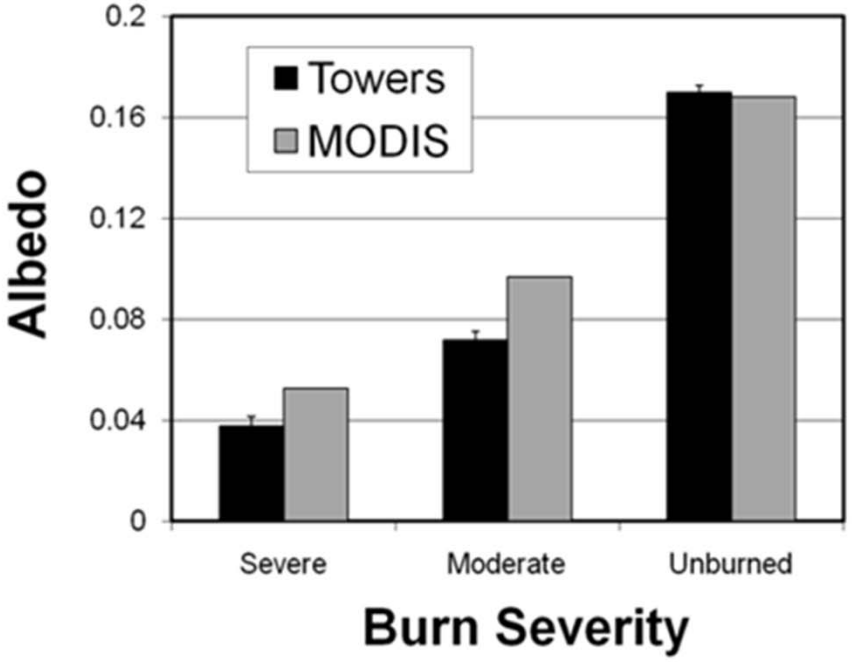
Severe

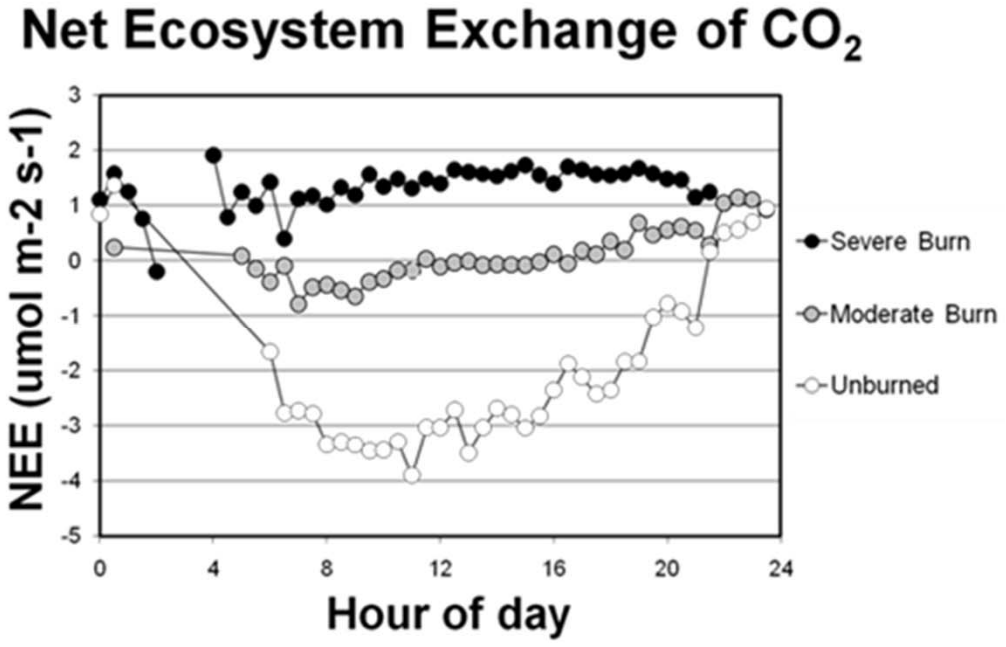


Moderate



Unburned


Albedo
0.2
0.16
0.12
0.08
0.04
0
Towers
MODIS
Severe
Moderate
Unburned
Burn Severity


Net Ecosystem Exchange of CO_2
NEE (umol m-2 s-1)
3
2
1
0
-1
-2
-3
-4
-5
0
4
8
12
16
20
24
Hour of day
Severe Burn
Moderate Burn
Unburned

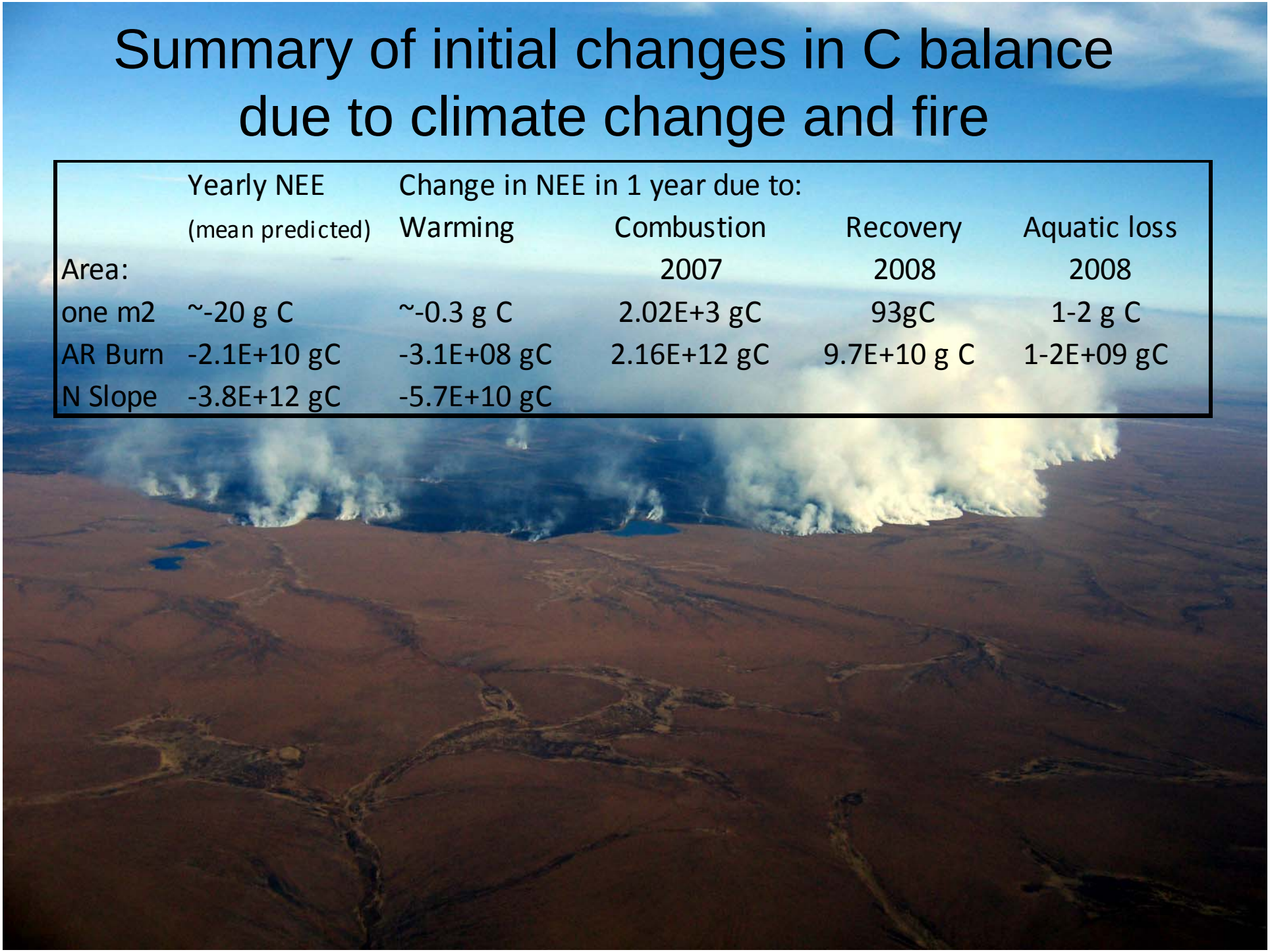
Unburned Tundra, 4 July

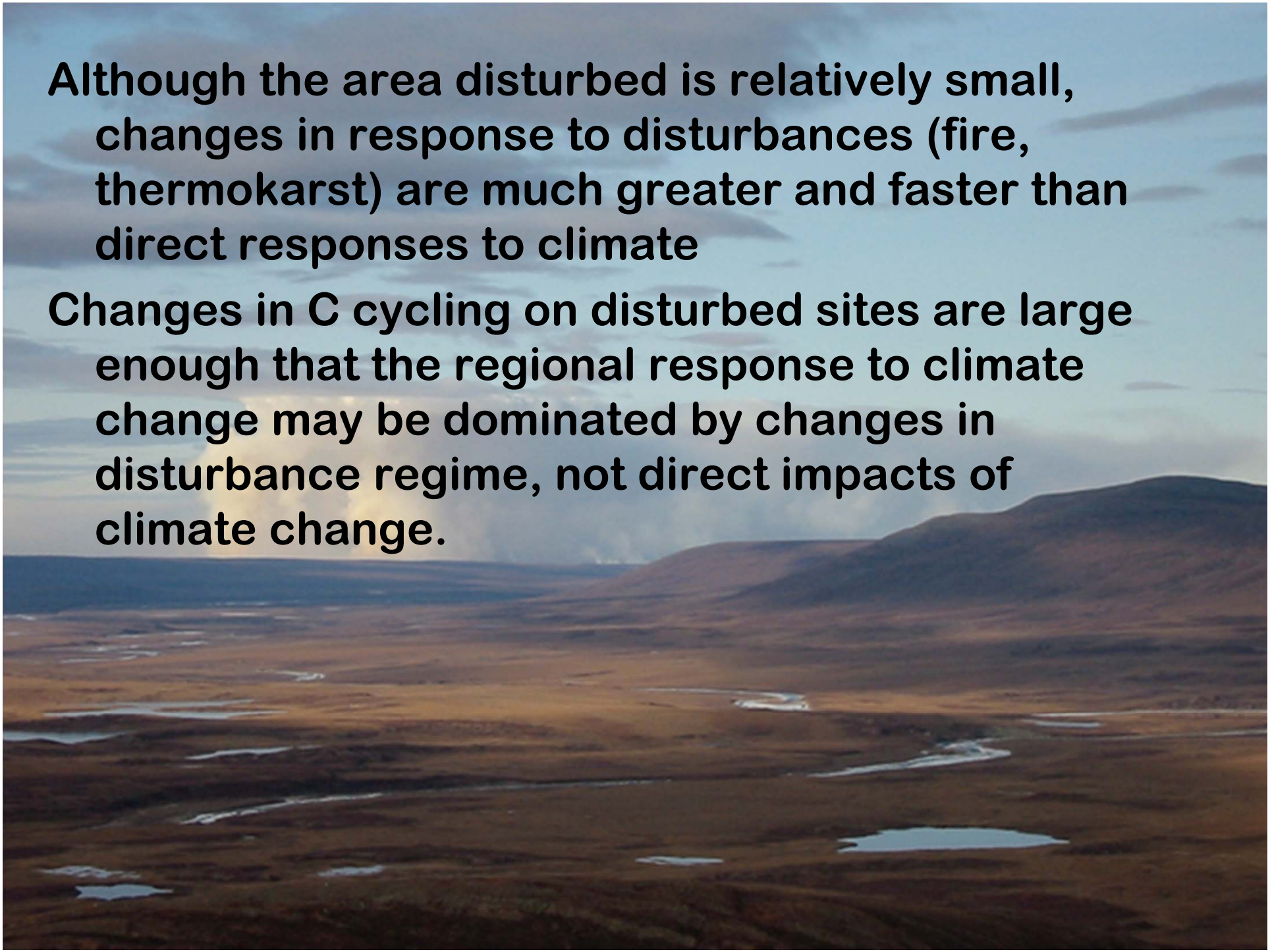
Severe Burn, 31 May

Severe Burn, 4 July

Summary of initial changes in C balance due to climate change and fire

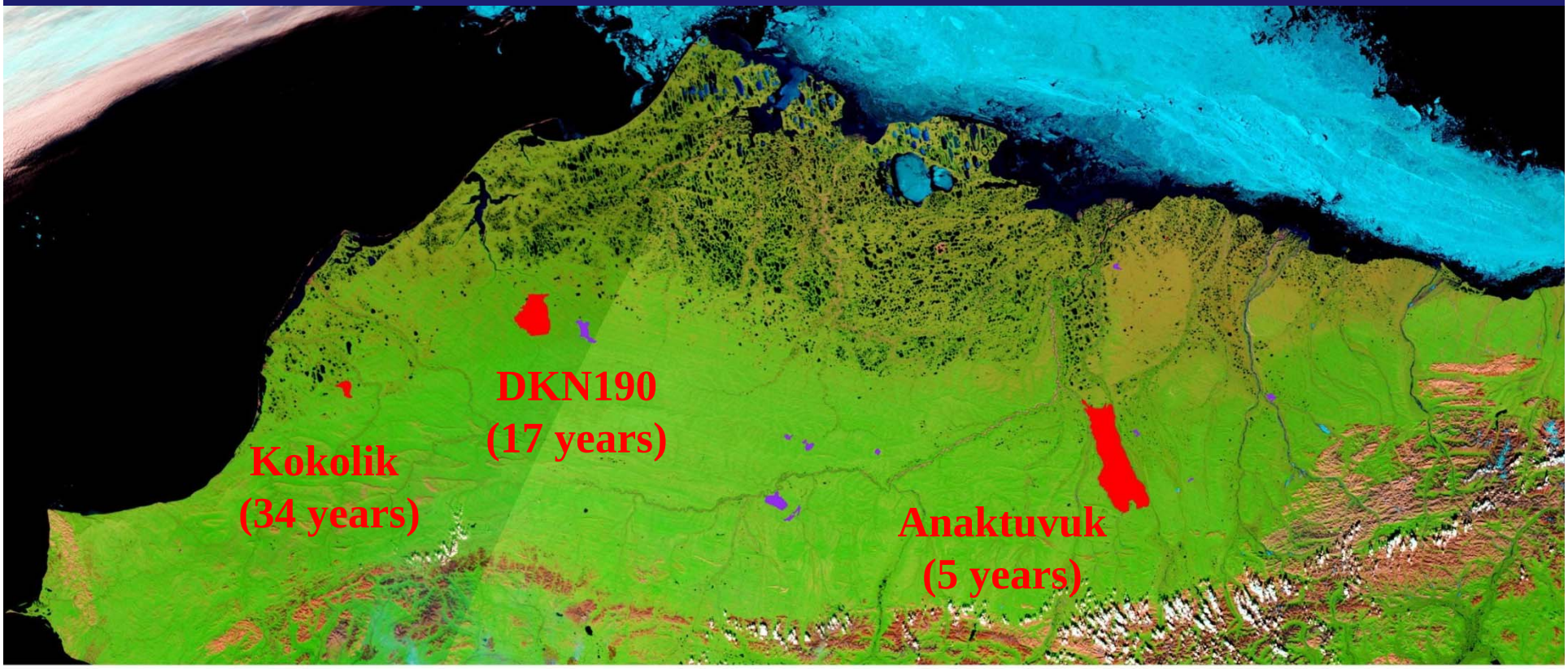
	Yearly NEE (mean predicted)	Change in NEE in 1 year due to: Warming	Combustion	Recovery	Aquatic loss
Area:			2007	2008	2008
one m2	~-20 g C	~-0.3 g C	2.02E+3 gC	93gC	1-2 g C
AR Burn	-2.1E+10 gC	-3.1E+08 gC	2.16E+12 gC	9.7E+10 g C	1-2E+09 gC
N Slope	-3.8E+12 gC	-5.7E+10 gC			

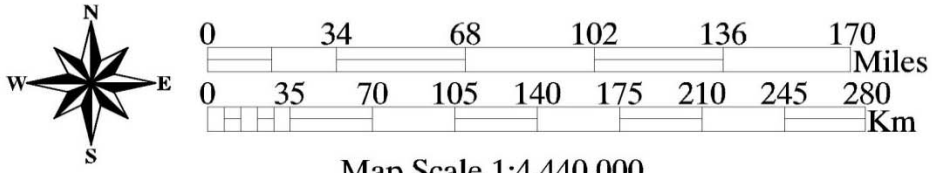




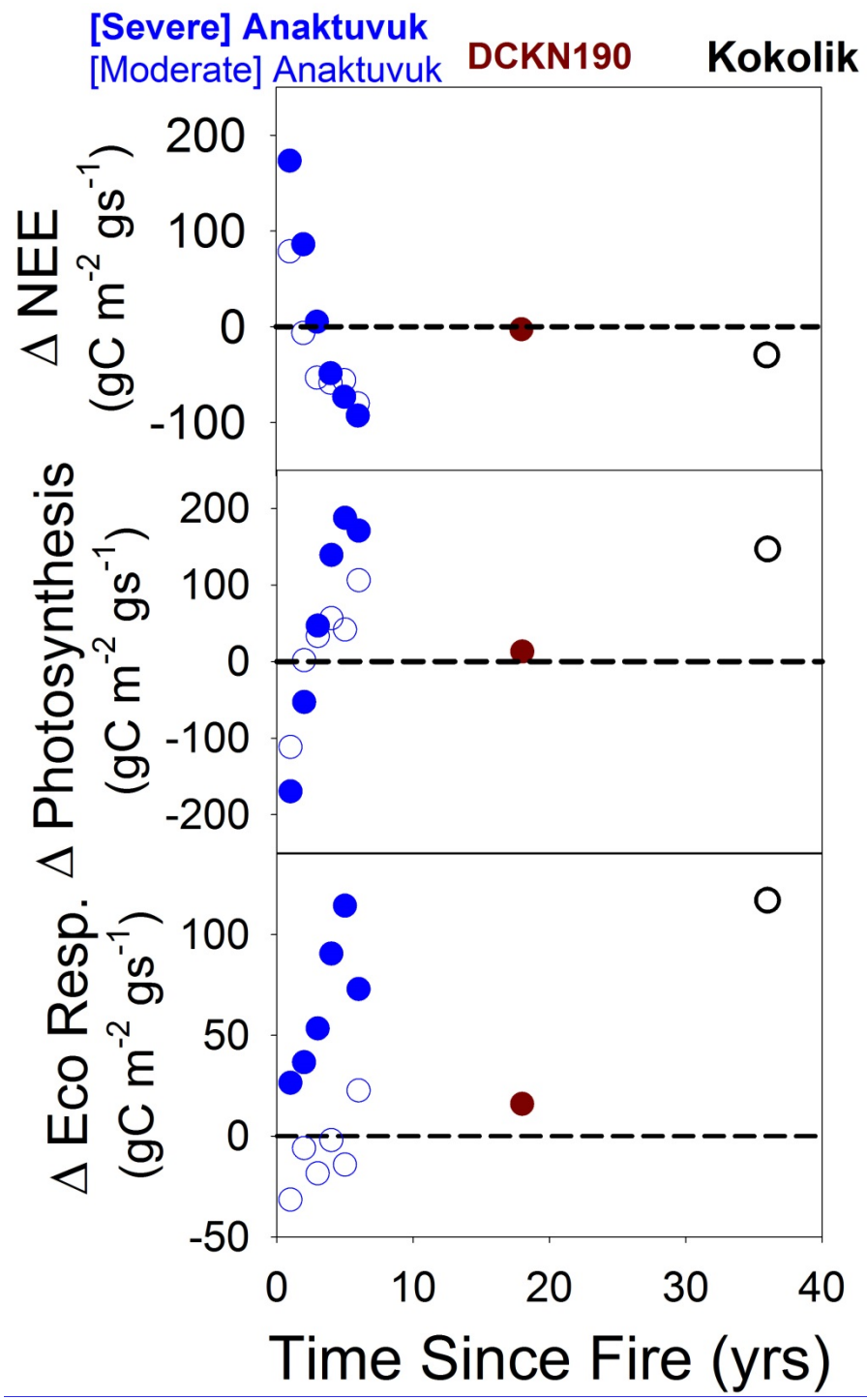
- Although the area disturbed is relatively small, changes in response to disturbances (fire, thermokarst) are much greater and faster than direct responses to climate
- Changes in C cycling on disturbed sites are large enough that the regional response to climate change may be dominated by changes in disturbance regime, not direct impacts of climate change.

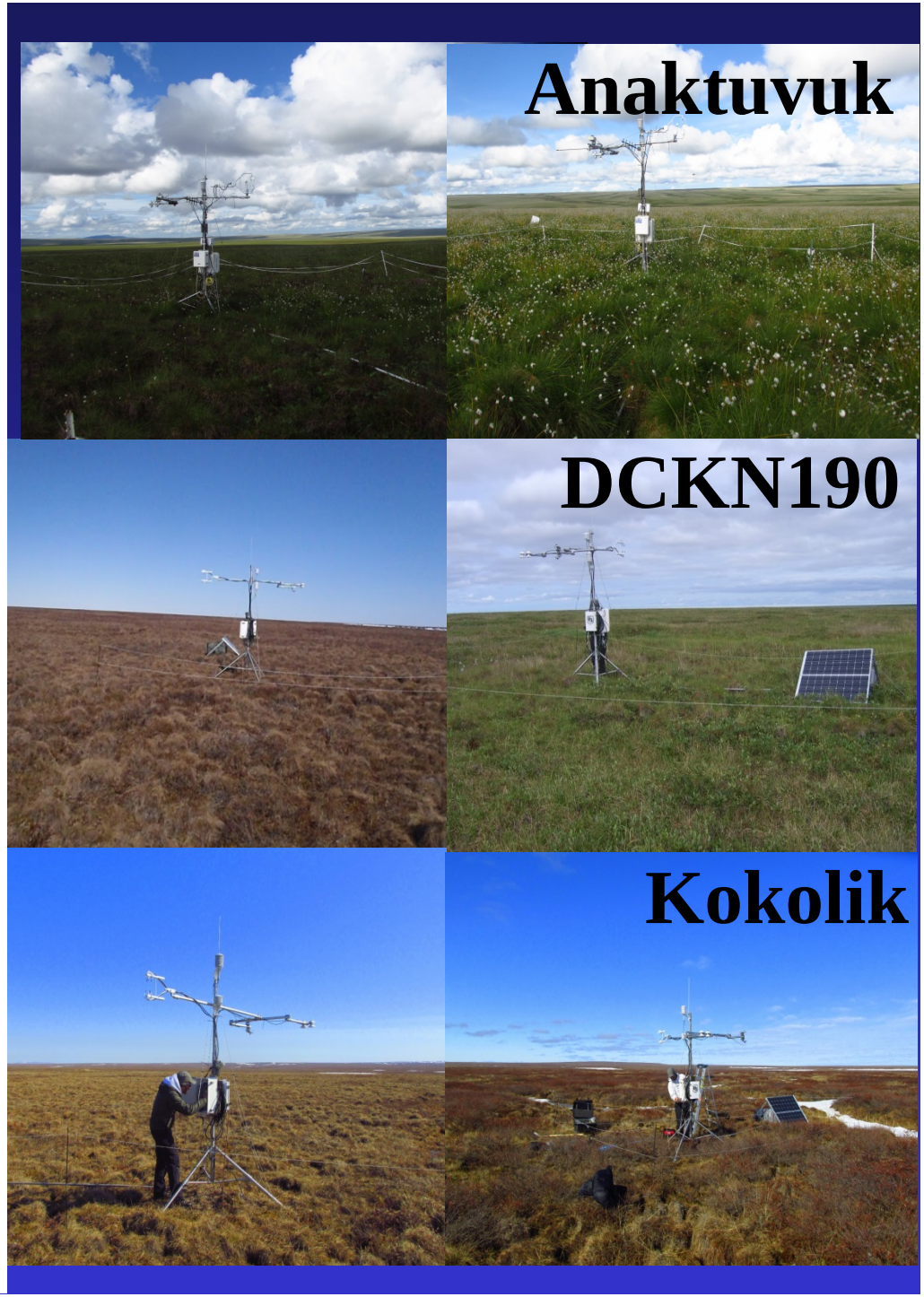
What are the long-term impacts of fire?

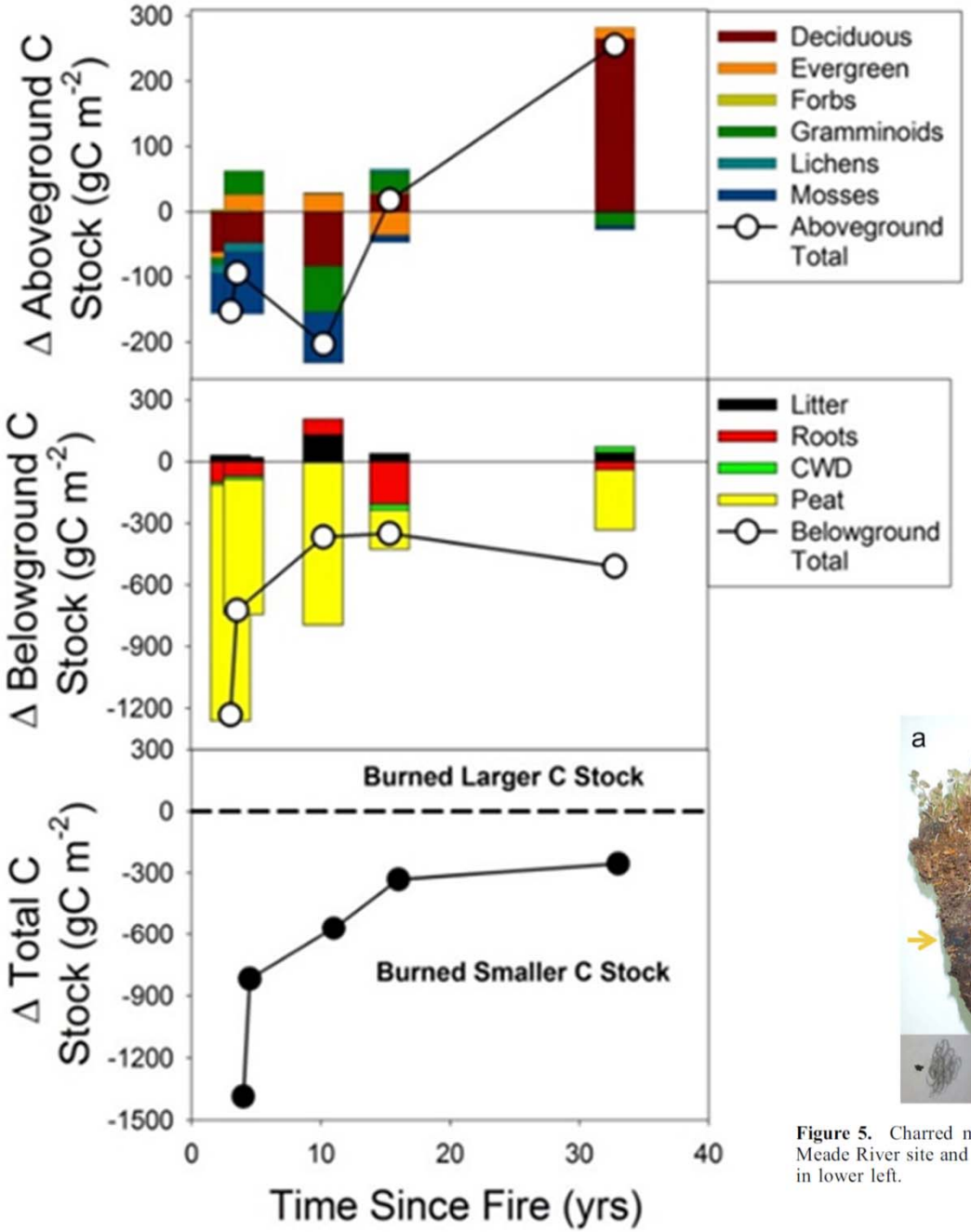




Map Scale 1:4,440,000


[Severe] Anaktuvuk
[Moderate] Anaktuvuk
DCKN190
Kokolik
Δ NEE (gC m-2 gs-1)
Δ Photosynthesis (gC m-2 gs-1)
Δ Eco Resp. (gC m-2 gs-1)
200
100
0
-100
-200
50
-50
0
10
20
30
40
Time Since Fire (yrs)


Anaktuvuk
DCKN190
Kokolik



Carbon stocks on the ground follow predictions of NEE model first 35 years

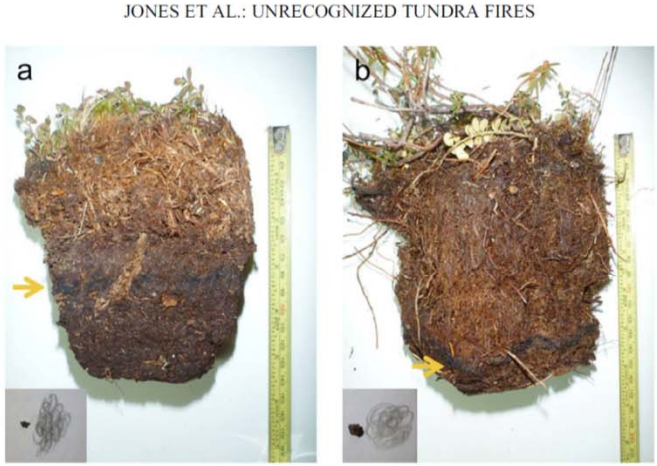
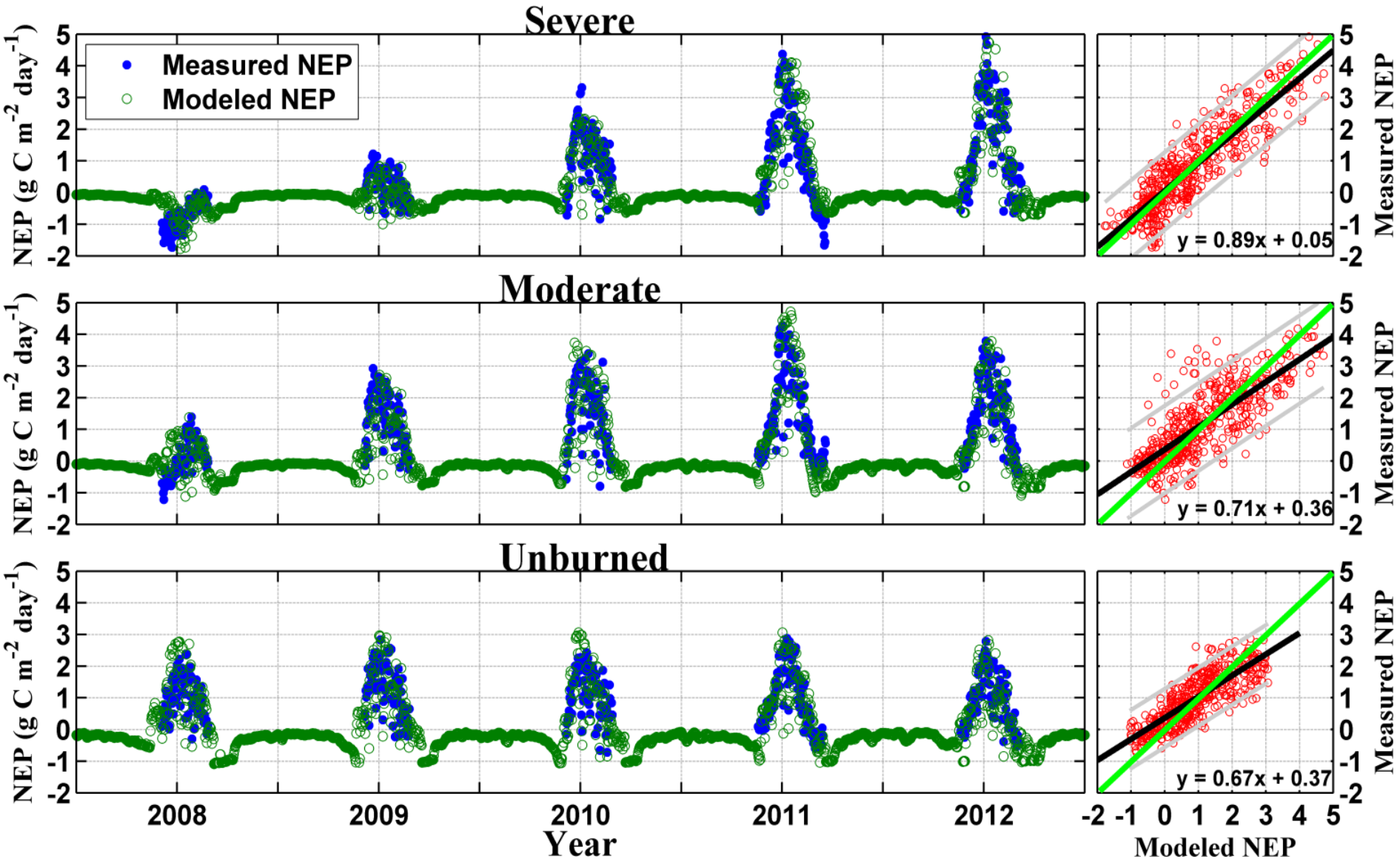
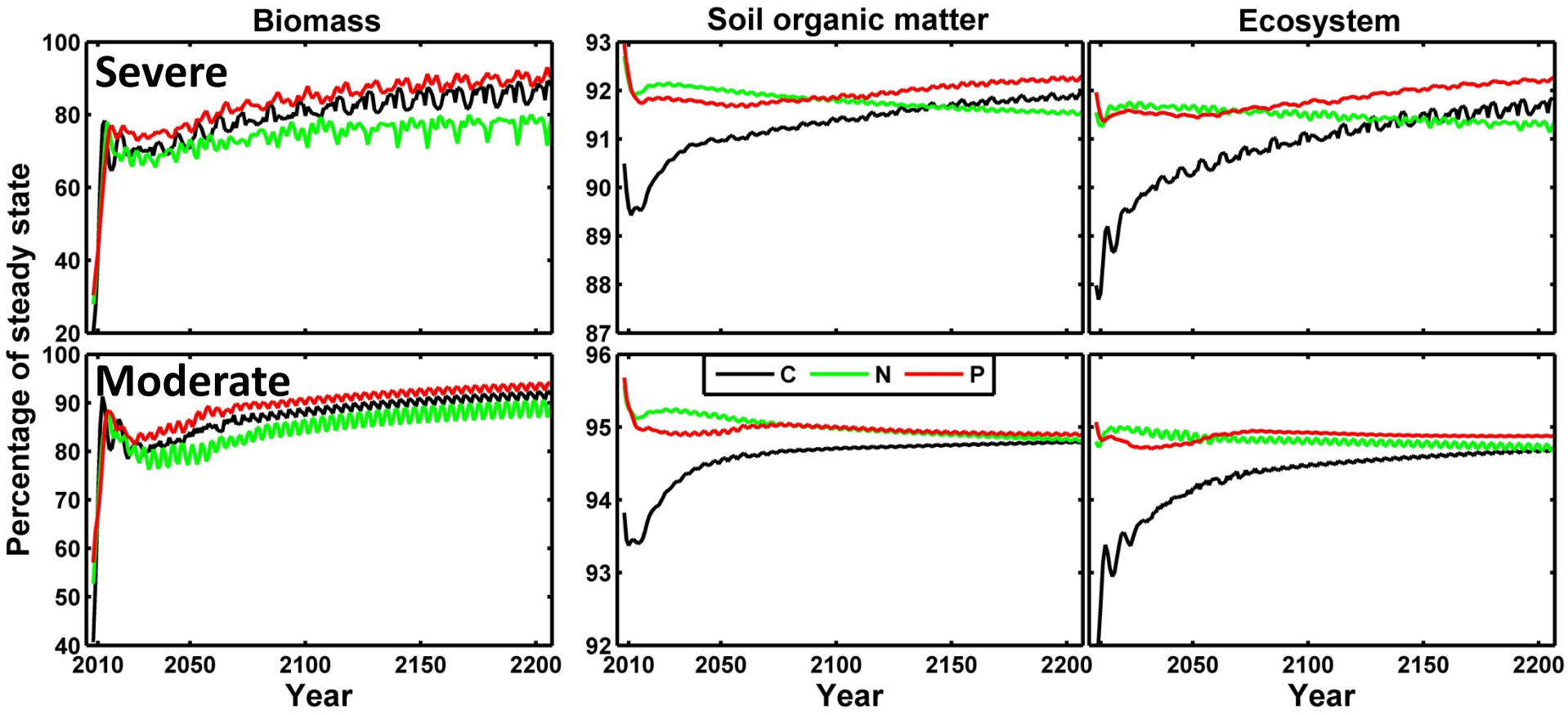


Figure 5. Charred material preserved in soil column. Example of soil plugs taken from the (a) Meade River site and the (b) Ketik River site. Arrows depict charred horizon and smear tests shown in lower left.

Insights from Modeling NEE

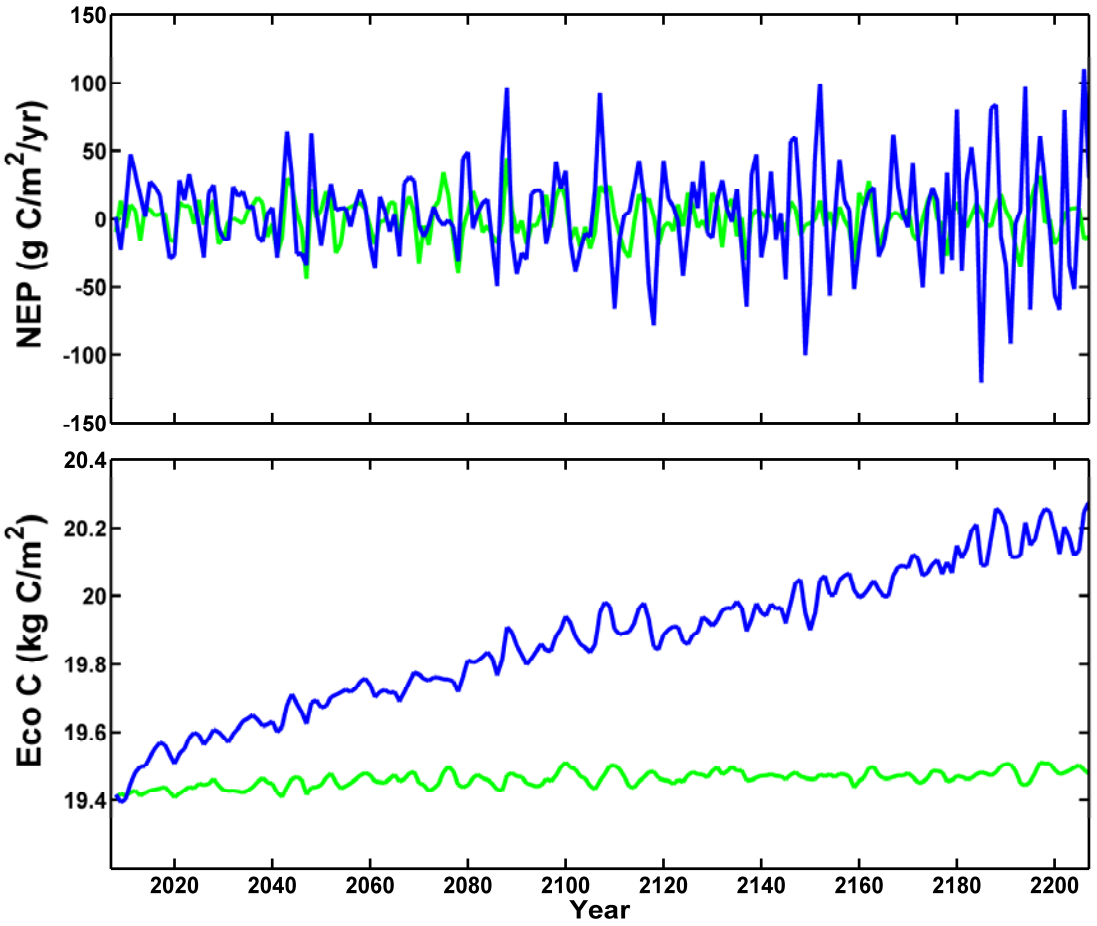


Long-term Recovery from Fire



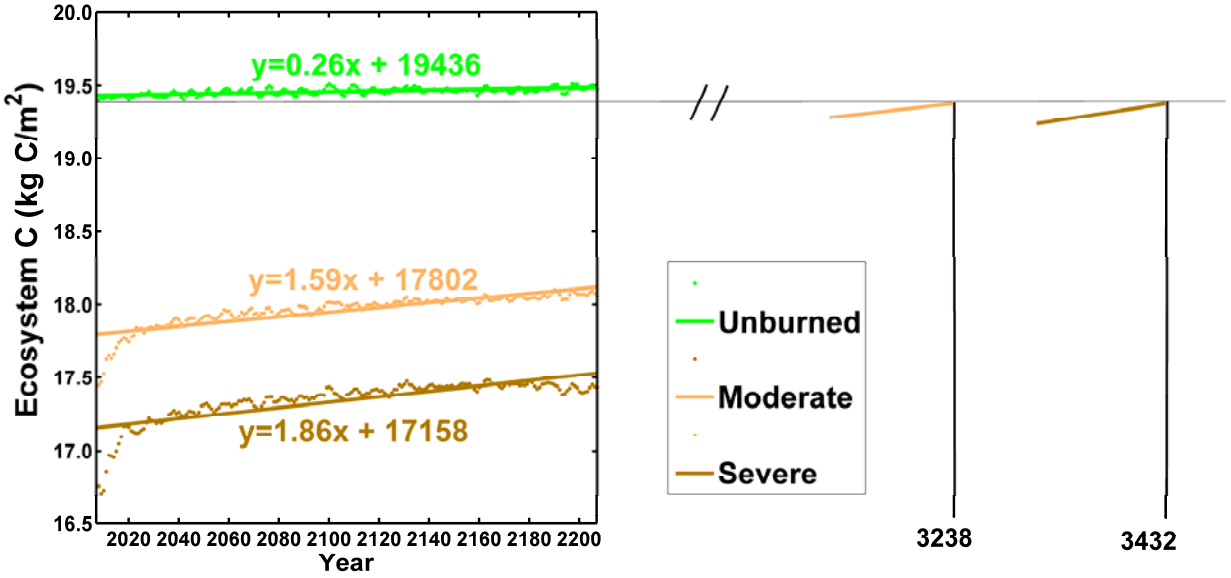
Long term recovery of C stocks is limited by slower recovery of N and P stocks

Current (stable) climate versus IPCC B1 climate (warmer, wetter, higher CO2)

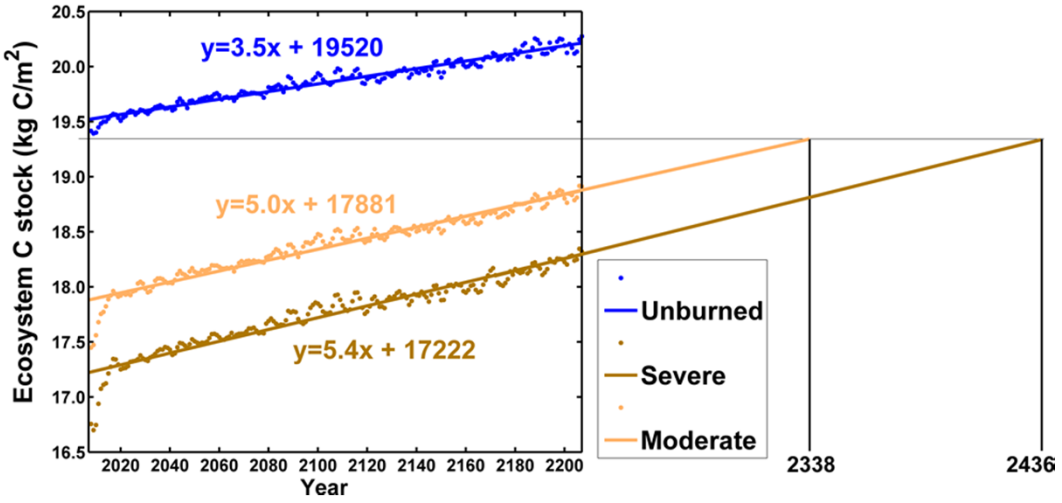


With a gradually warming (IPCC B1) climate, NEP is more variable but C accumulates at 3-4 g C m^{-2} y^{-1}

Under current climate, C accumulates very slowly (<1 g C m^{-2} y^{-1})

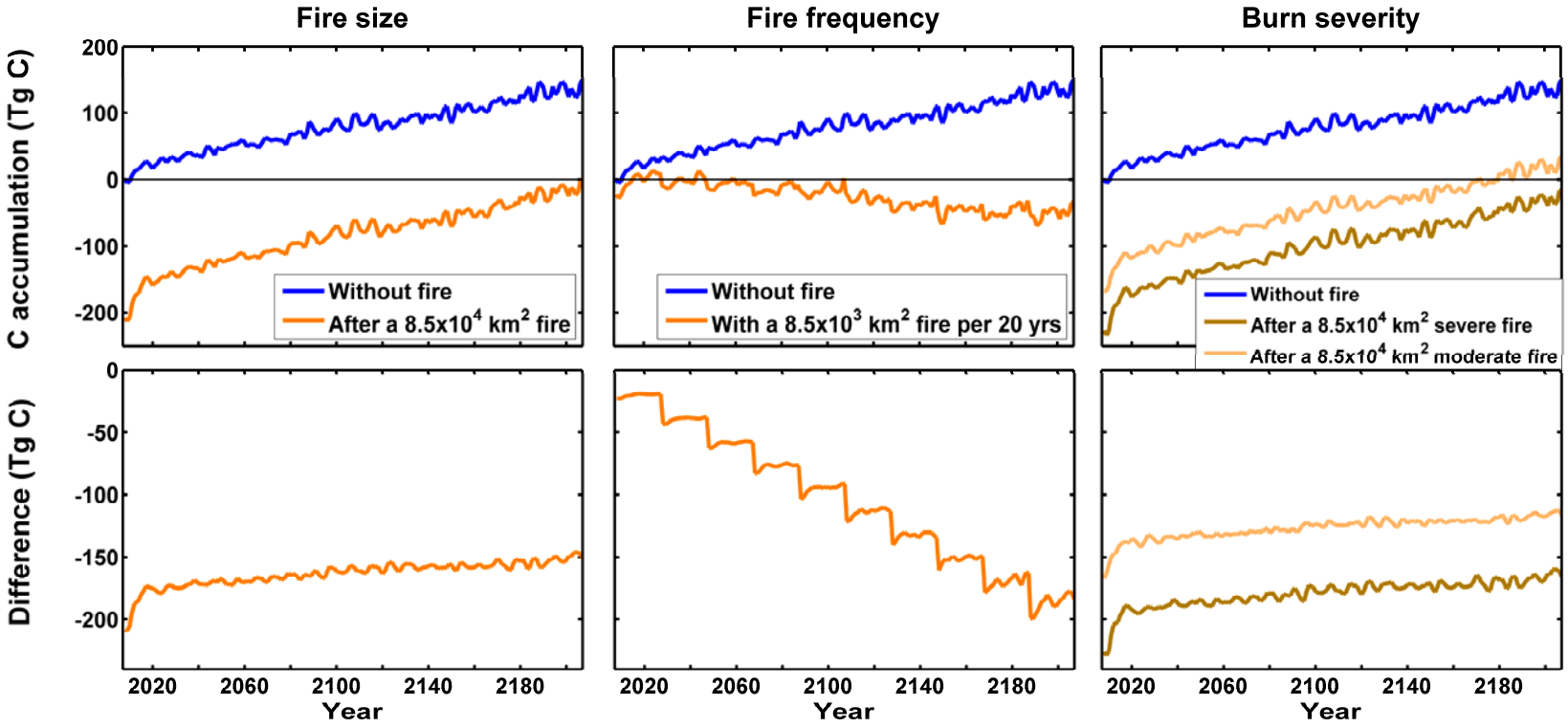


Under current climate it would take 1200-1500 years to recover to pre-burn C stock

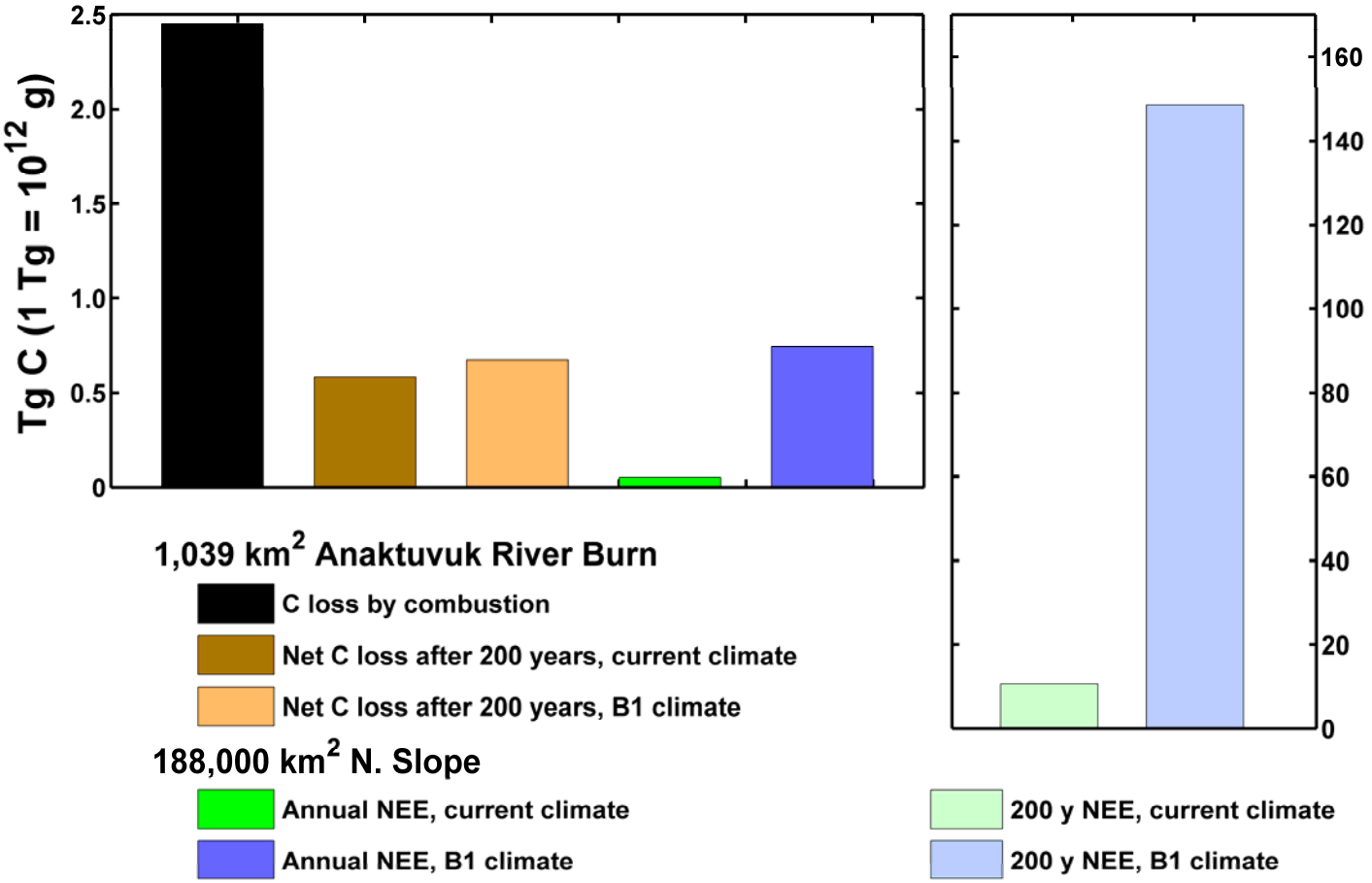


With a warmer, wetter, higher-CO2 (B1) climate it would take 300-500 years to recover to pre-burn C stock

How much wildfire would it take to cancel long term effects of climate change on North Slope C stocks ?



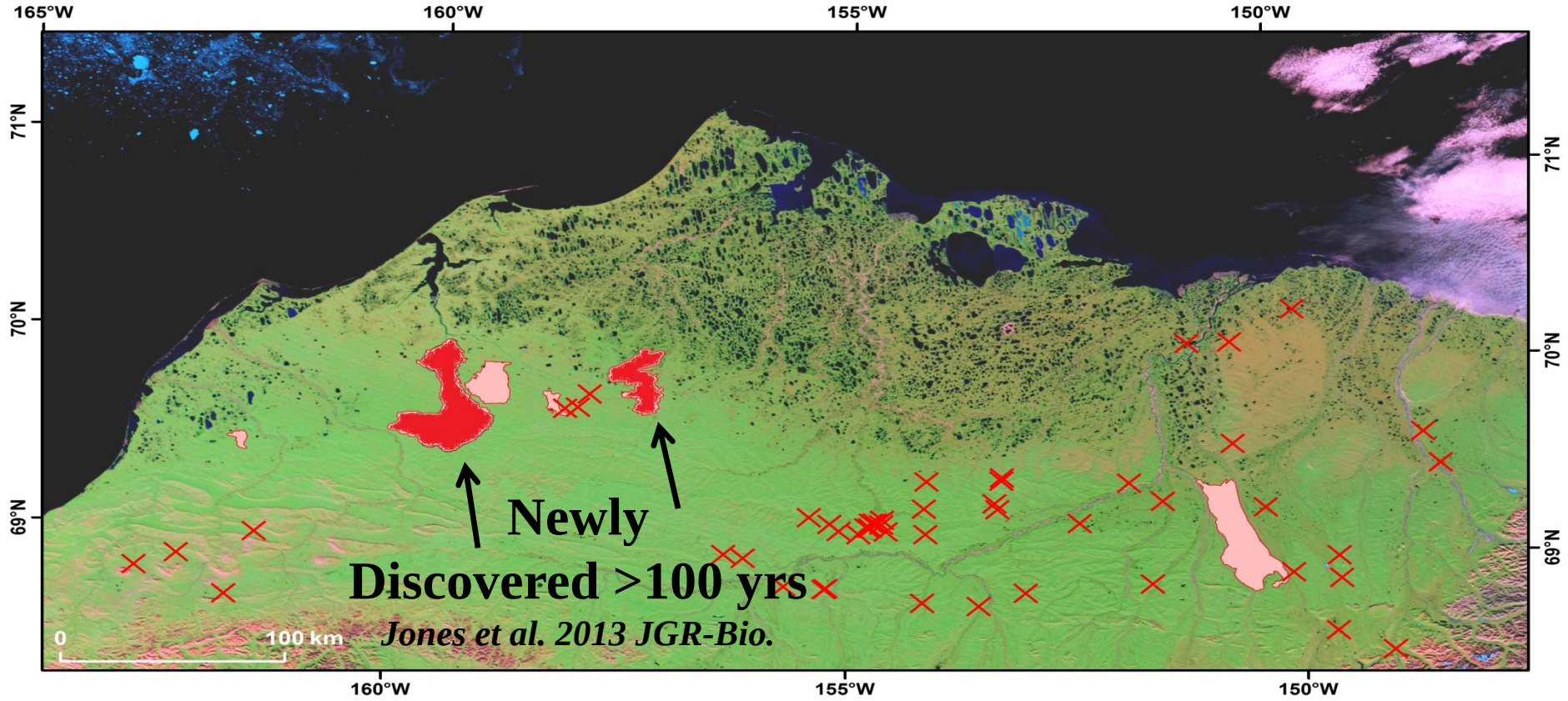
Wildfire vs Climate Change: Which has a greater effect on C balance?



Wildfire and Climate Change

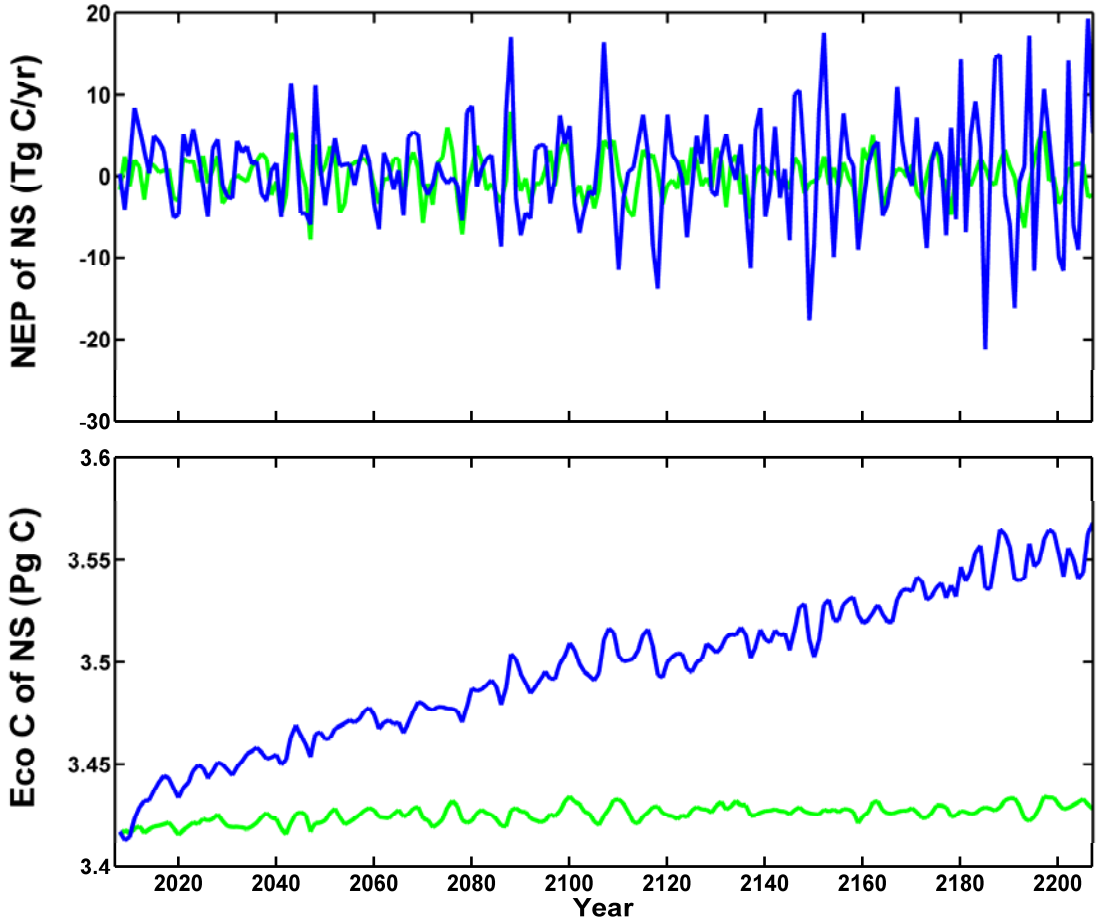
- Combustion losses may dominate regional C balance in year of burning
- Large swings in C balance in recovering burns may dominate local C balance 1-2 decades after fire
- Initial C losses by combustion are not recovered because N and P losses limit C recovery
- Short term effects of climate change on C balance are small relative to combustion losses and initial changes in NEE as vegetation recovers
- Longer term (200 y) changes in C balance are dominated by changes in climate and interactions with N and P inputs and turnover

NEXT PROBLEM: What is the background rate of burning?



THE END

Figure 5. Charred material preserved in soil column. Example of soil plugs taken from the (a) Meade River site and the (b) Ketik River site. Arrows depict charred horizon and smear tests shown in lower left.


NEP of NS (Tg C/yr)
20
10
0
-10
-20
-30
Eco C of NS (Pg C)
3.6
3.55
3.5
3.45
3.4
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
Year