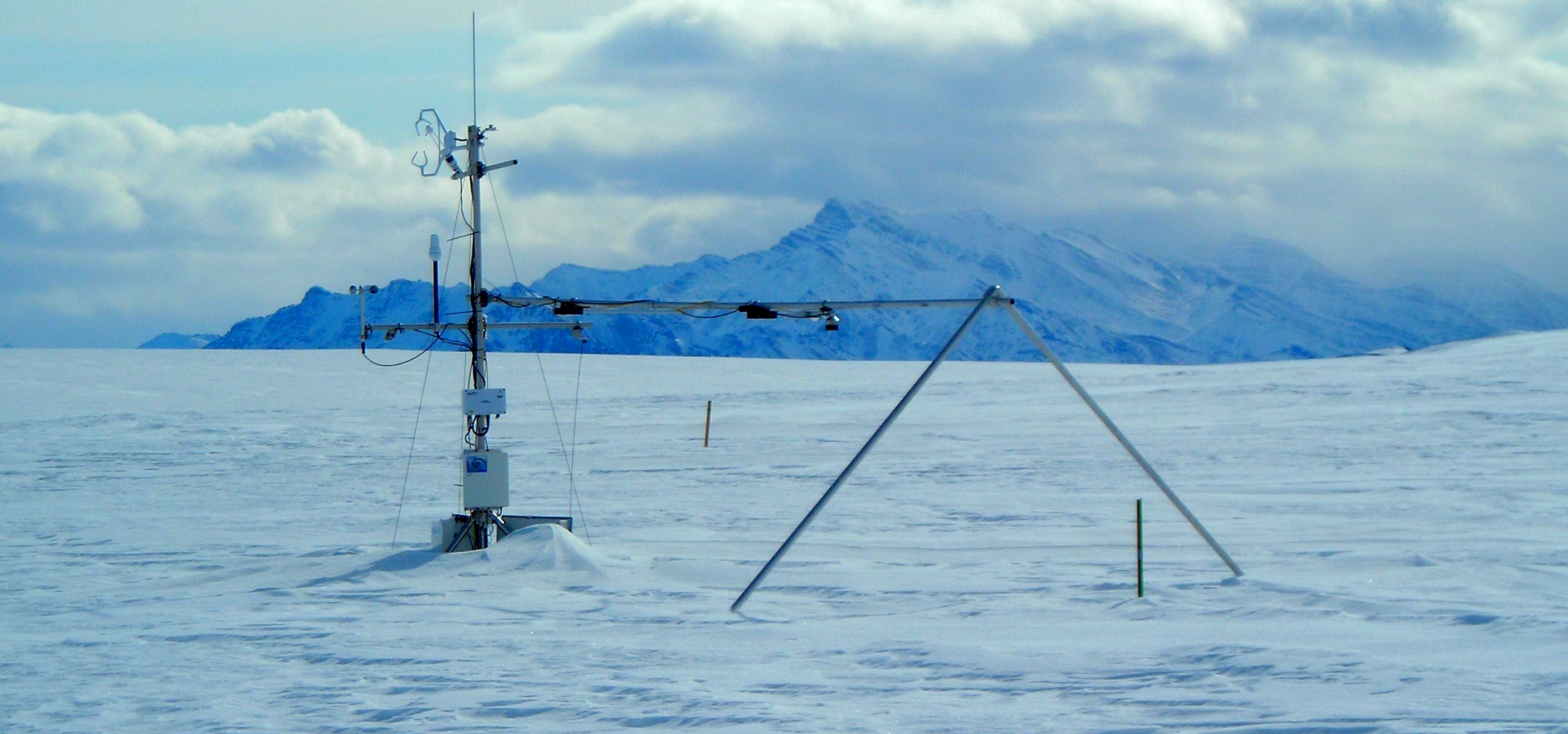
Long-term changes in carbon pools and fluxes in northern Alaska



Eugénie Euskirchen, Syndonia Bret-Harte, Gus Shaver, Colin Edgar, Vladimir Romanovsky, Jessica Cherry

Background

-Tundra ecosystems thought to be CO_2 sources, slight sinks or neutral. Generally, sources of CH_4.

- Detailed descriptions (seasonal, multiyear) of C fluxes at the landscape scale still relatively rare in tundra

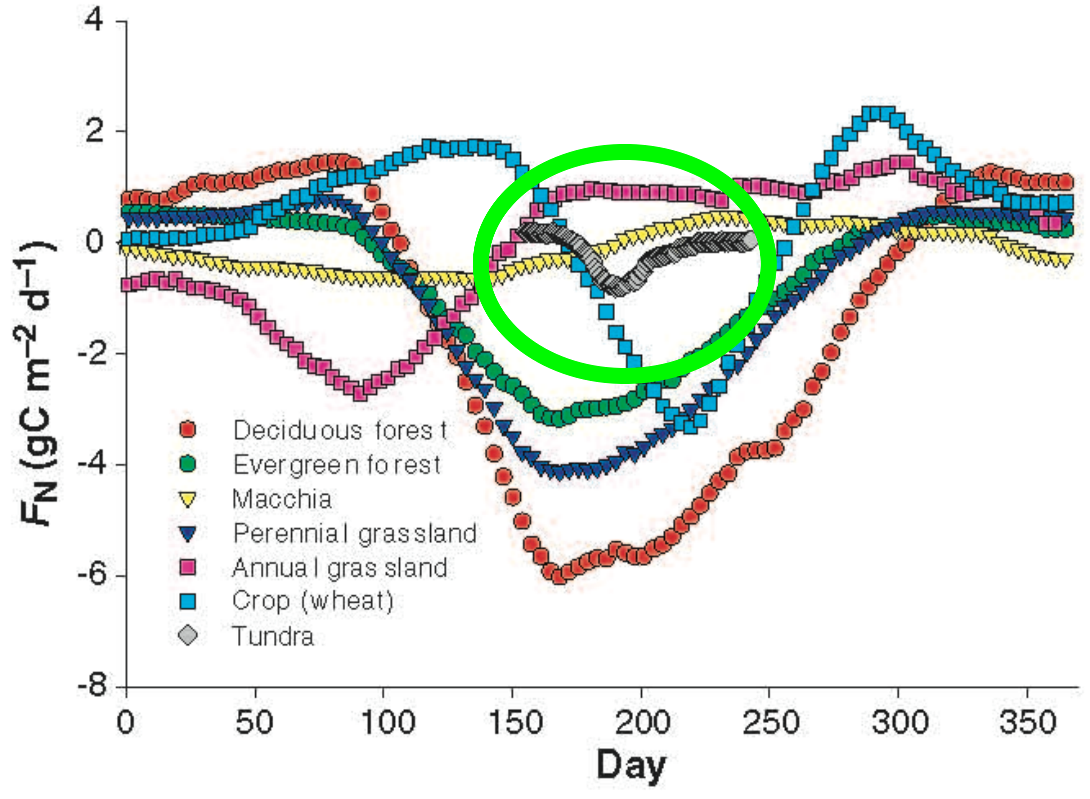
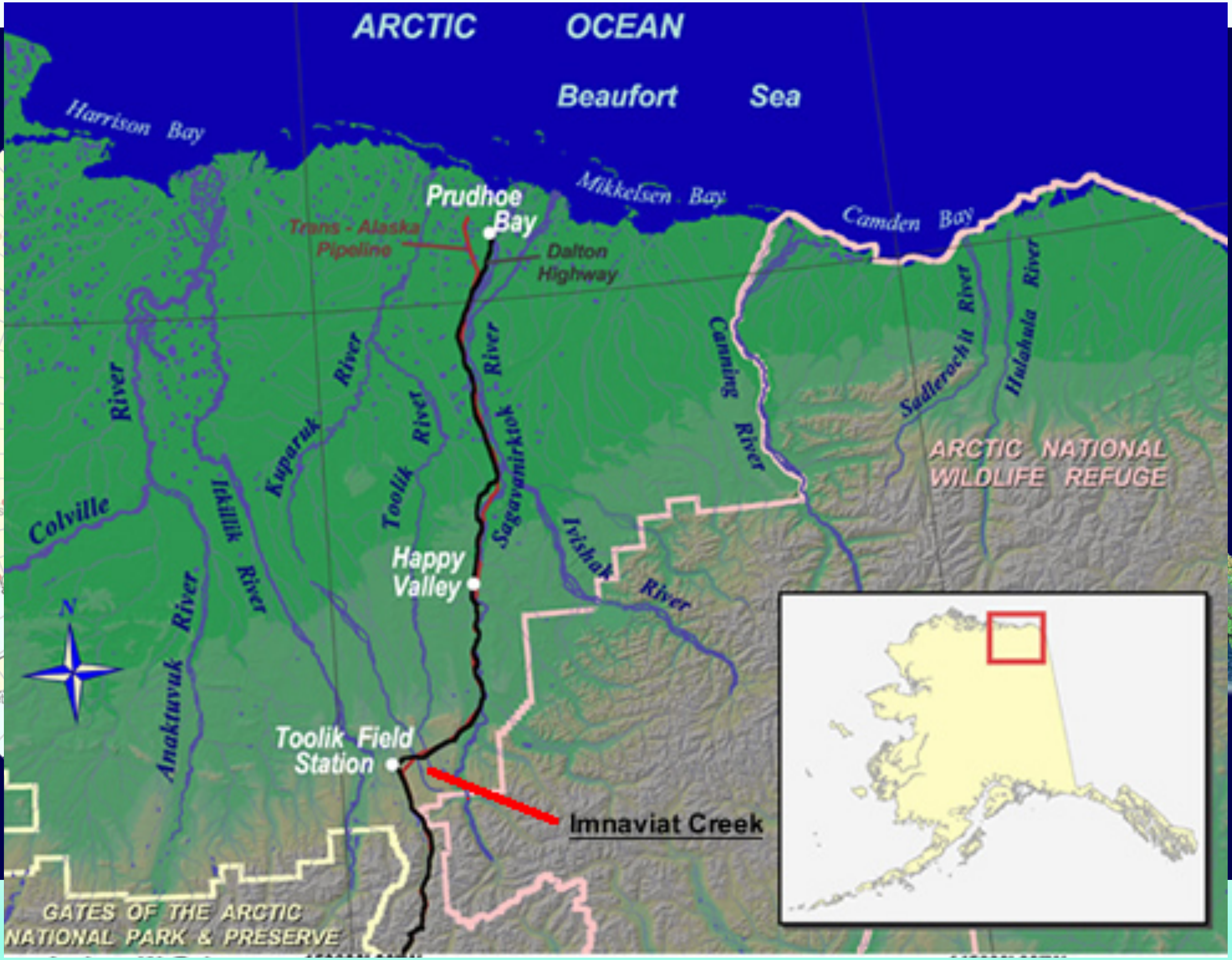


Fig. 2. Seasonal patterns in net ecosystem CO_2 exchange. Adapted from Baldocchi and Valentini (2004).

Changes in CO_2 uptake:

-Could see greater uptake as vegetation biomass increases

-Could also see greater release as soil and plant respiration increase



ARCTIC OCEAN
Beaufort Sea
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Camden Bay
Prudhoe Bay
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Ivishak River
Anaktuvuk River
ARCTIC NATIONAL WILDLIFE REFUGE
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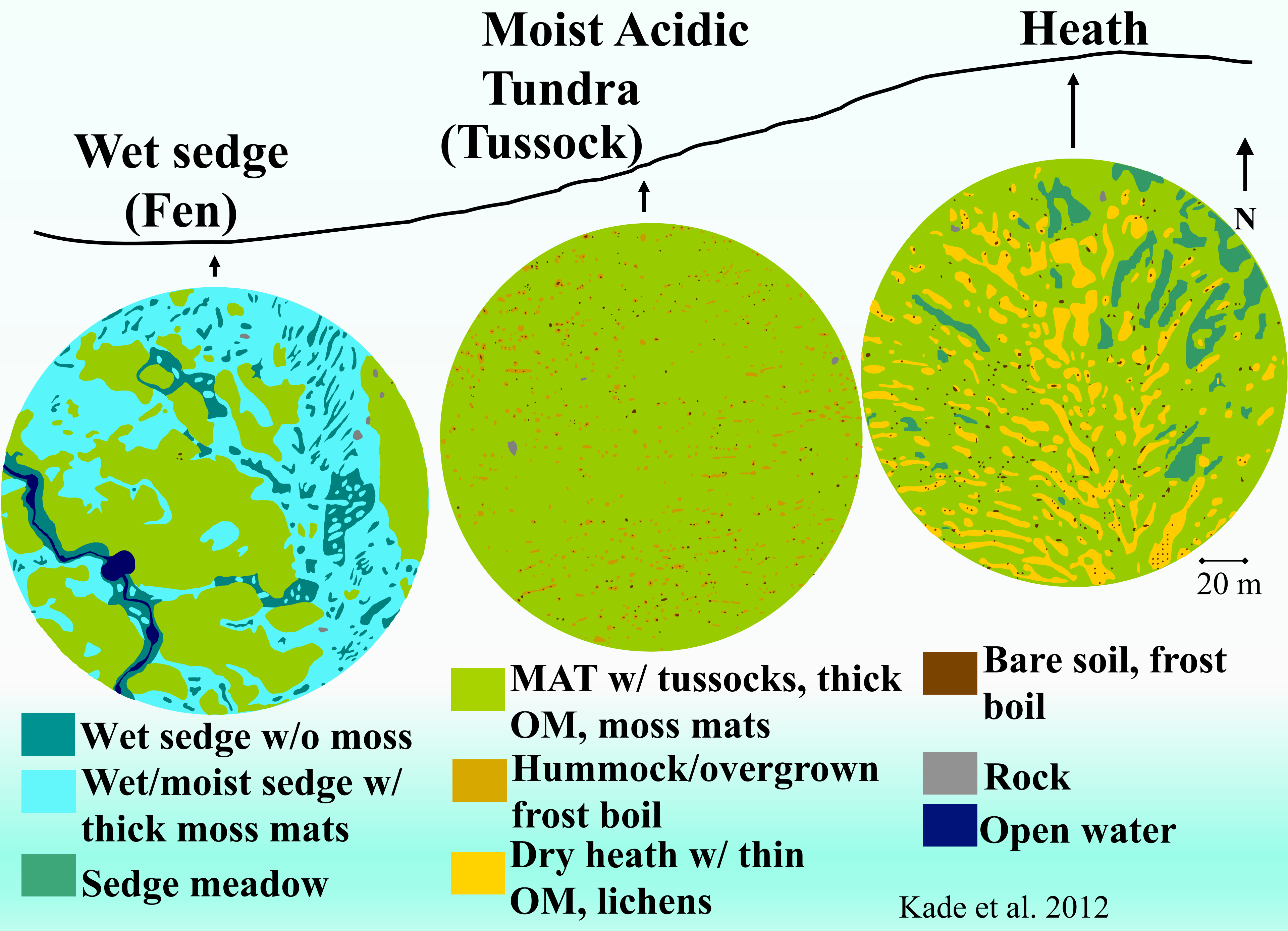
Imnaviat Creek
GATES OF THE ARCTIC NATIONAL PARK & PRESERVE
N

Heath tundra site

Tussock tundra site

Wet sedge tundra site


Moist Acidic Tundra (Tussock)
Heath
Wet sedge (Fen)
N
20 m
Wet sedge w/o moss
Wet/moist sedge w/ thick moss mats
Sedge meadow
MAT w/ tussocks, thick OM, moss mats
Hummock/overgrown frost boil
Dry heath w/ thin OM, lichens
Bare soil, frost boil
Rock
Open water
Kade et al. 2012

Since late 2007, measurements of:

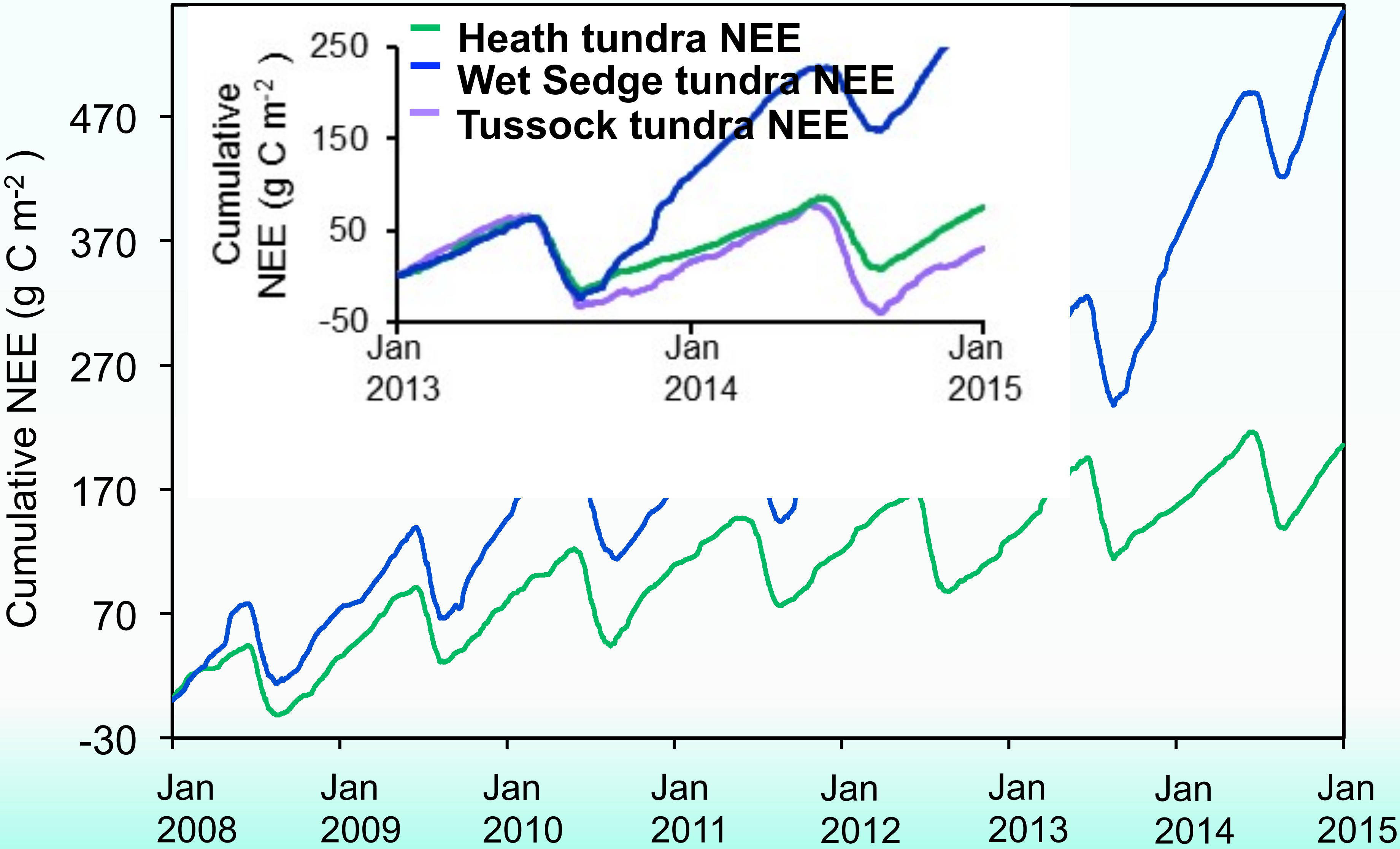
Net Ecosystem Exchange (CO_2 flux) year round at wet sedge and heath sites, April - October at the tussock until 2012

Meteorological & biophysical variables, including soil temperatures in a borehole

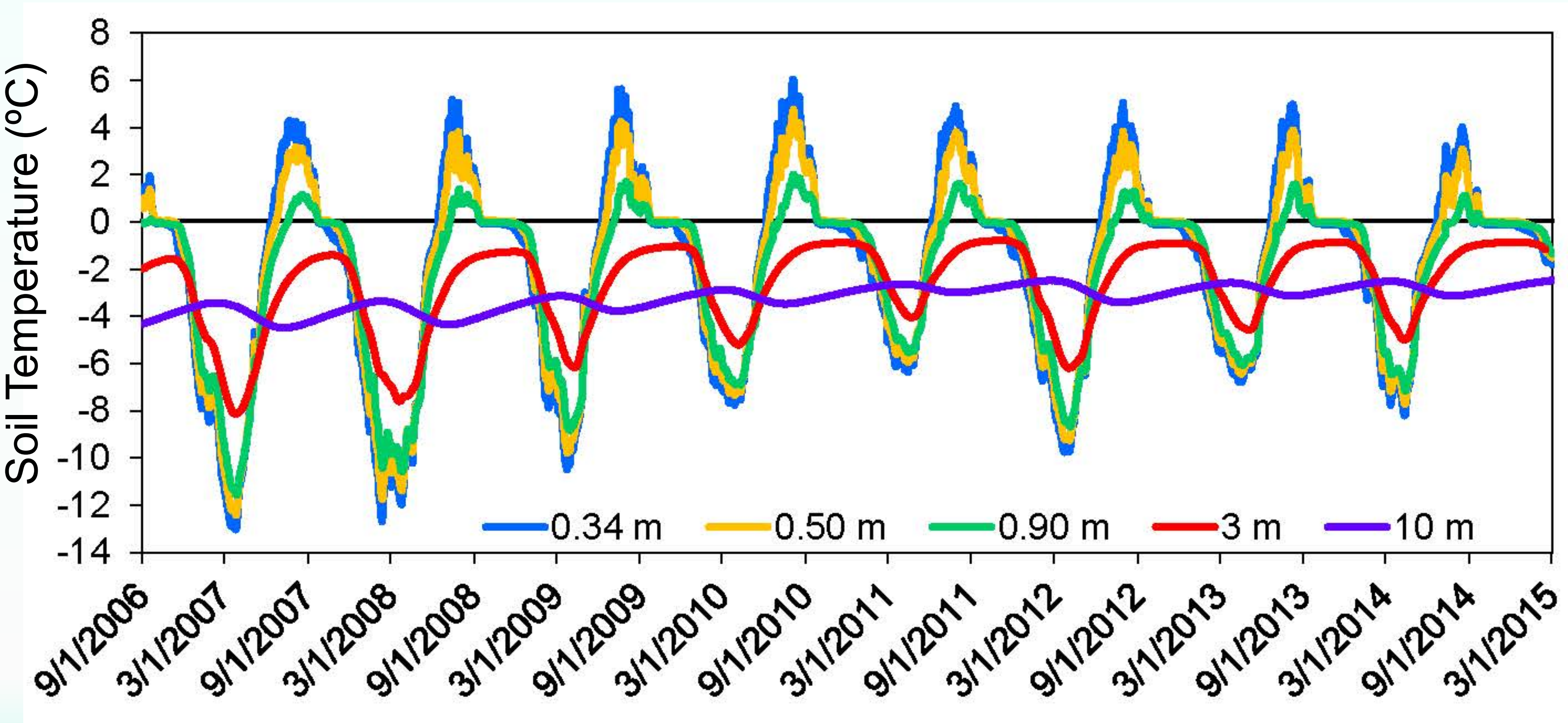
Seasonal methane (CH_4) at the wet sedge

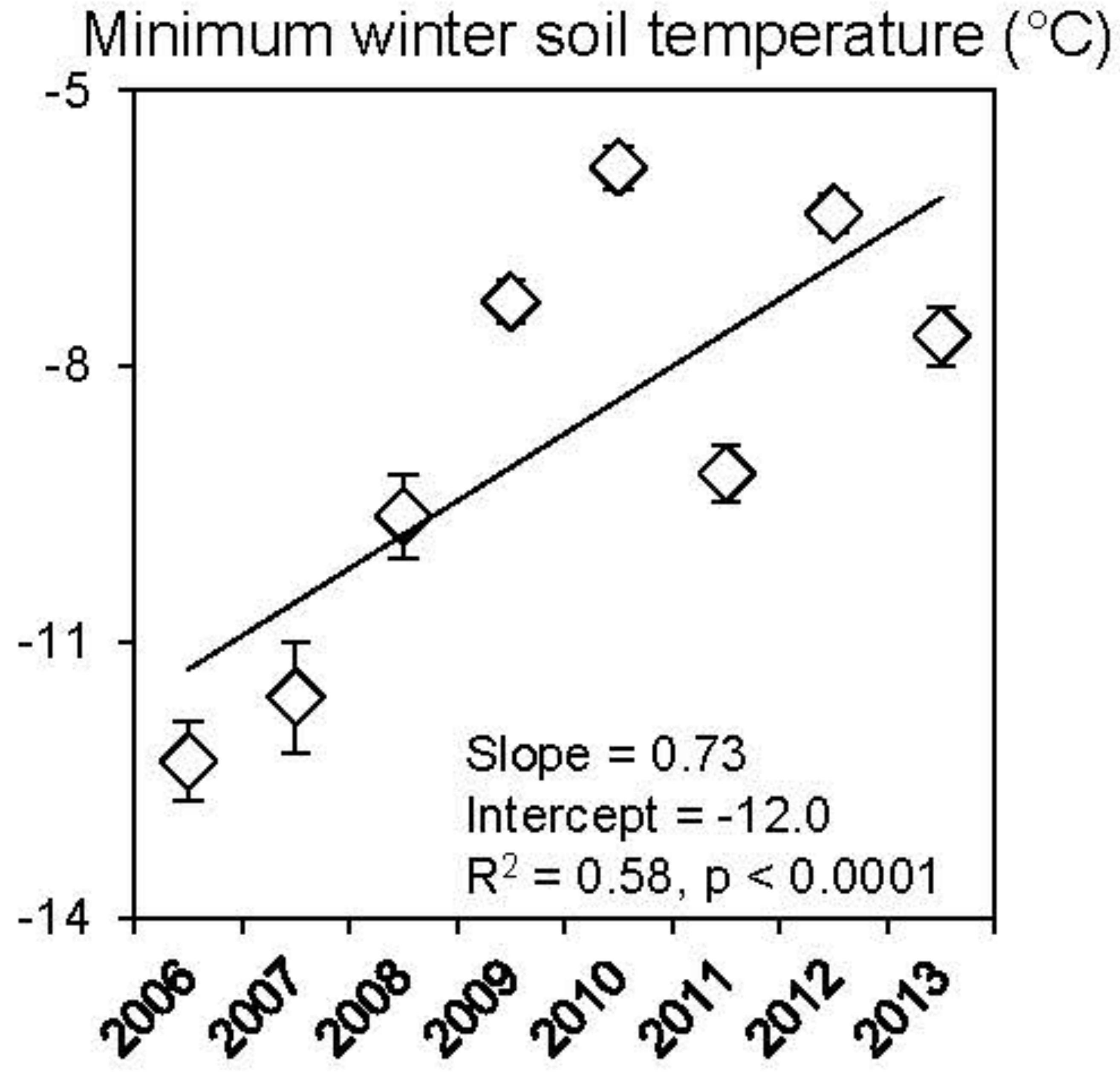
Plant biomass and soil C in each eddy covariance tower footprint

Positive value of NEE = Source of CO_2

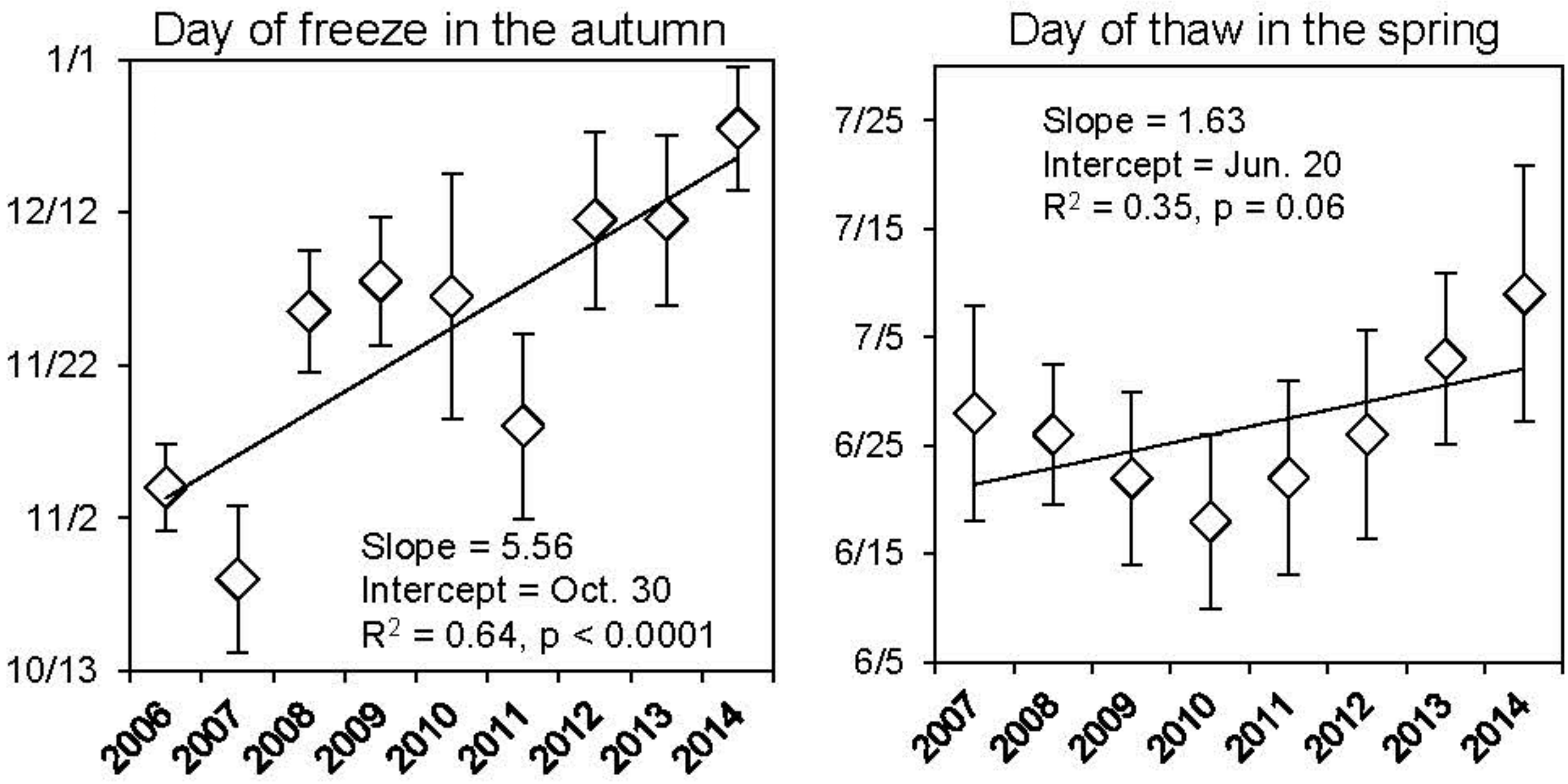


Imnavait Borehole Soil Temperatures

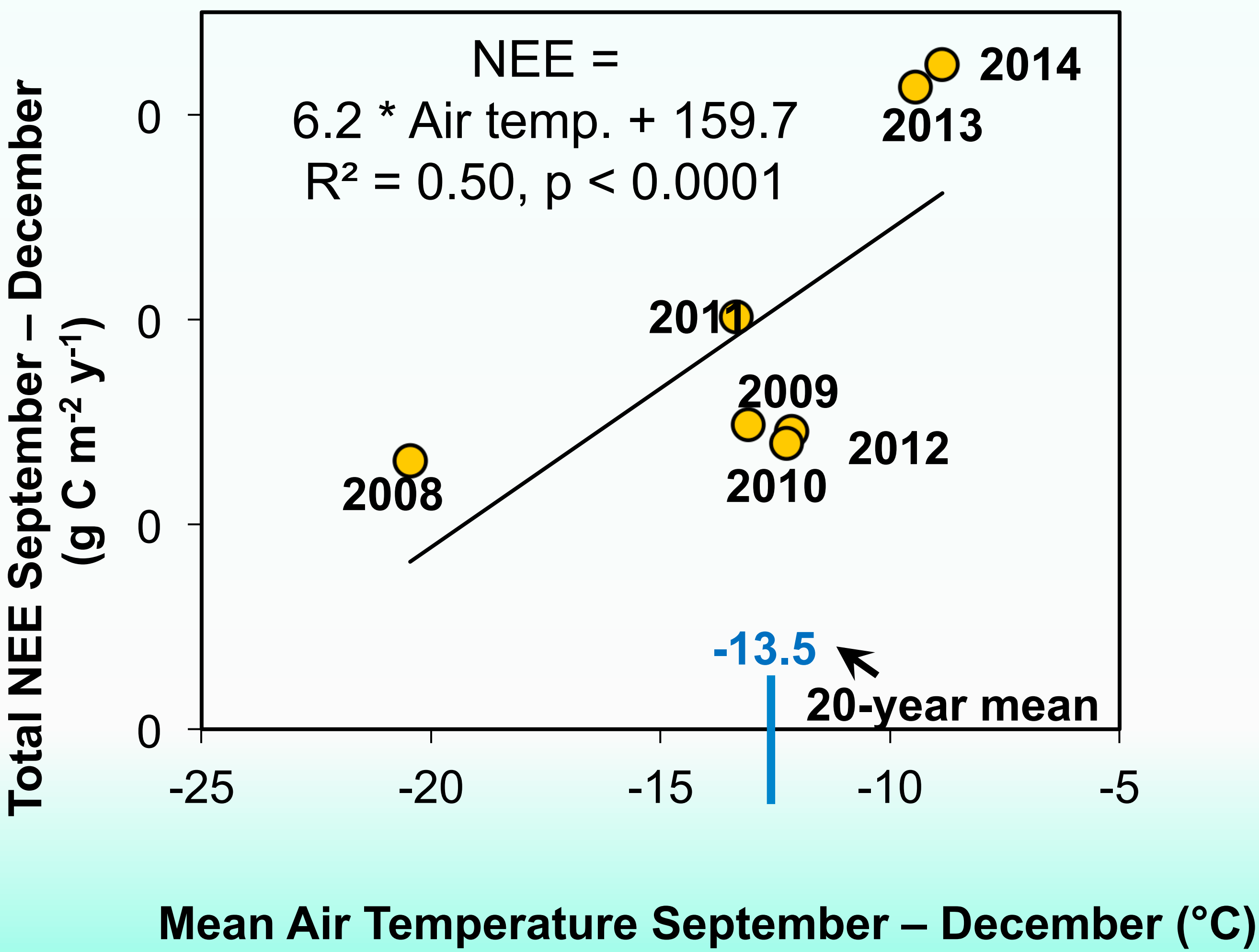


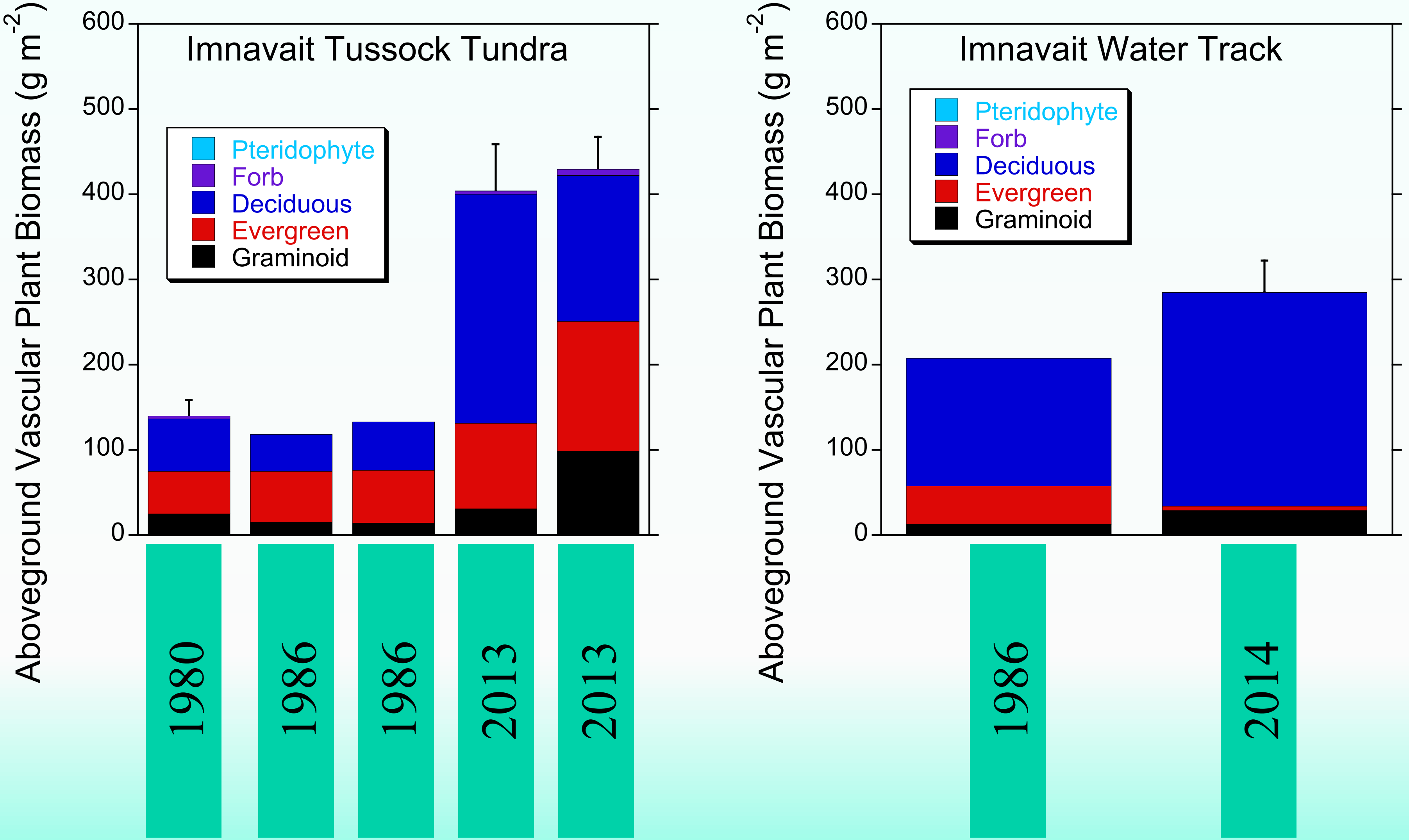


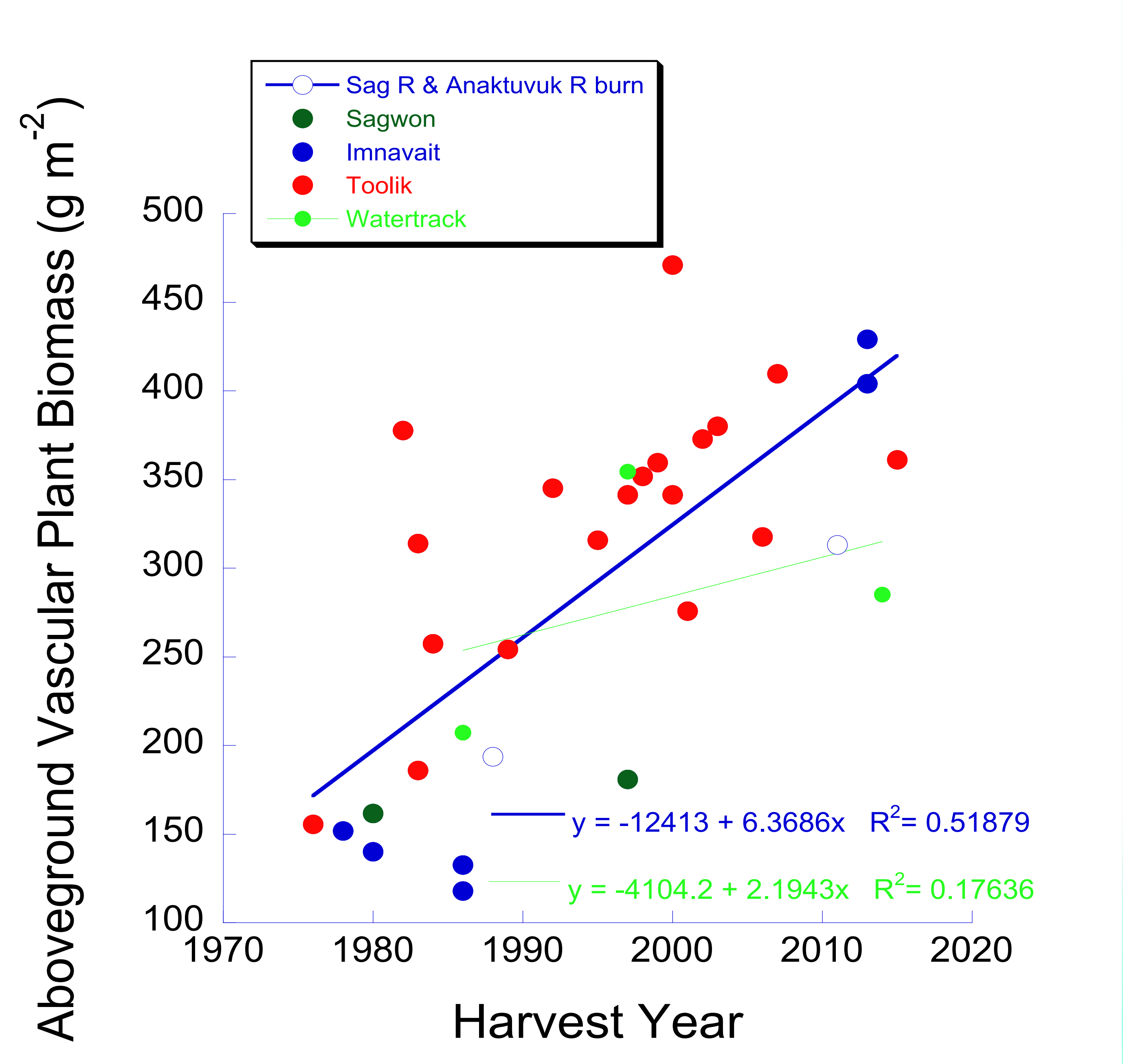
Minimum winter soil temperature (°C)
-5
-8
-11
-14
Slope = 0.73
Intercept = -12.0
R2 = 0.58, p < 0.0001
2006
2007
2008
2009
2010
2011
2012
2013


Day of freeze in the autumn
1/1
12/12
11/22
11/2
10/13
Slope = 5.56
Intercept = Oct. 30
R2 = 0.64, p < 0.0001
2006
2007
2008
2009
2010
2011
2012
2013
2014
Day of thaw in the spring
7/25
7/15
7/5
6/25
6/15
6/5
Slope = 1.63
Intercept = Jun. 20
R2 = 0.35, p = 0.06
2007
2008
2009
2010
2011
2012
2013
2014

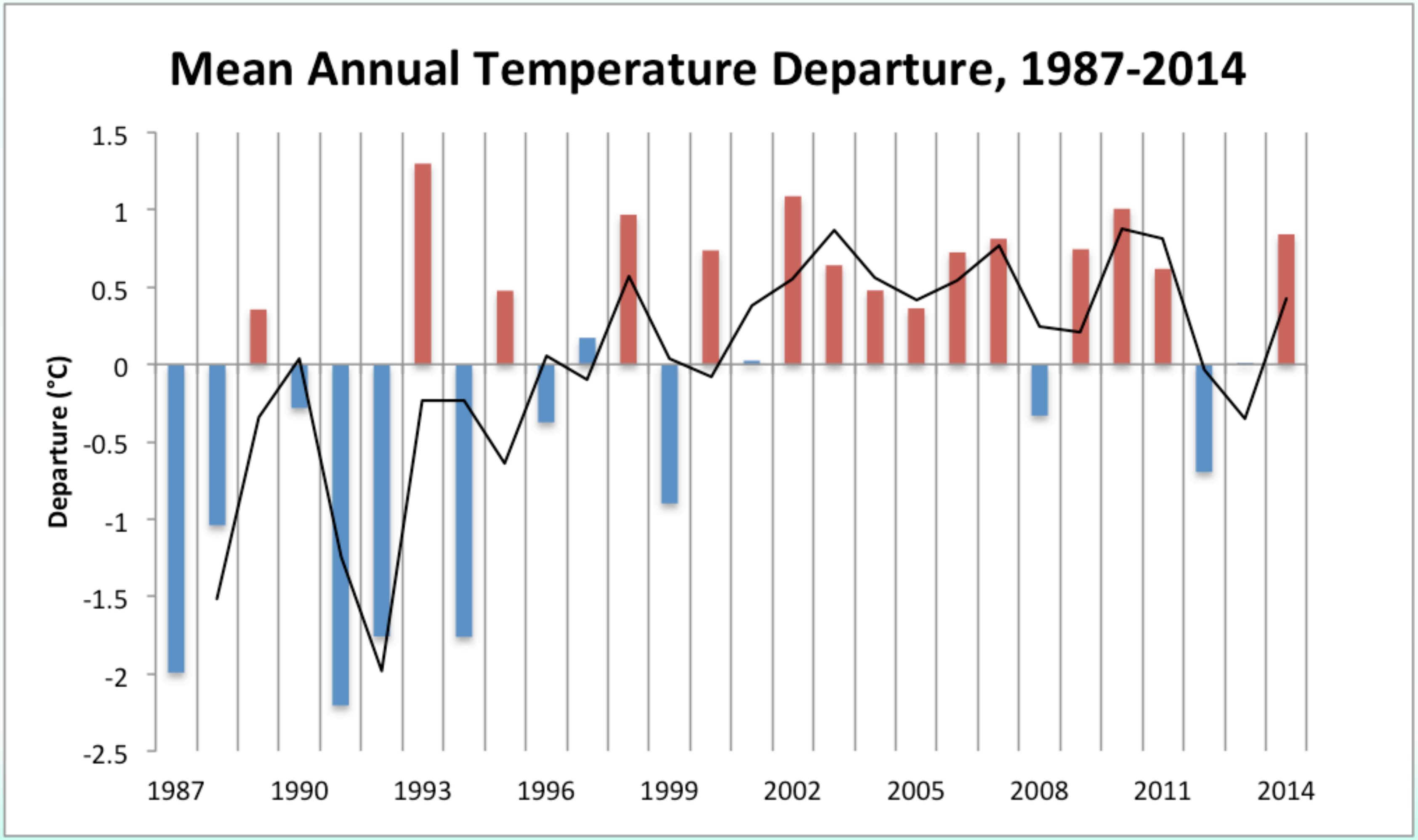
Wet sedge tundra
Late Fall / Early Winter NEE vs. Air Temp.

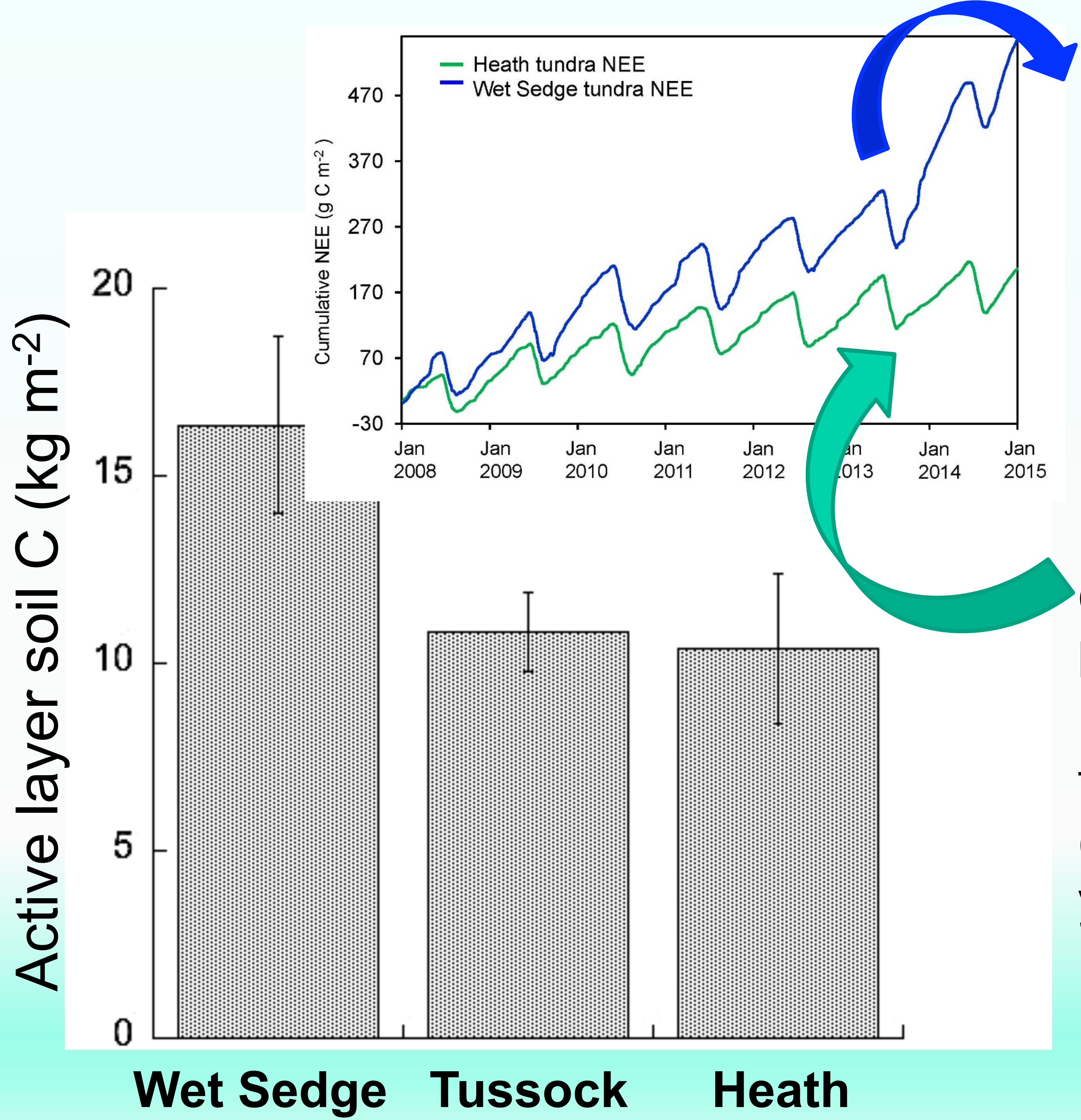



Imnavait Tussock Tundra
Imnavait Water Track
Aboveground Vascular Plant Biomass (g m^{-2})
600
500
400
300
200
100
0
Pteridophyte
Forb
Deciduous
Evergreen
Graminoid
1980
1986
1986
2013
2013
1986
2014



Sag R & Anaktuvuk R burn
Sagwon
Imnavait
Toolik
Watertrack
Aboveground Vascular Plant Biomass (g m-2)
500
450
400
350
300
250
200
150
100
1970
1980
1990
2000
2010
2020
Harvest Year
y = -12413 + 6.3686x R2= 0.51879
y = -4104.2 + 2.1943x R2= 0.17636

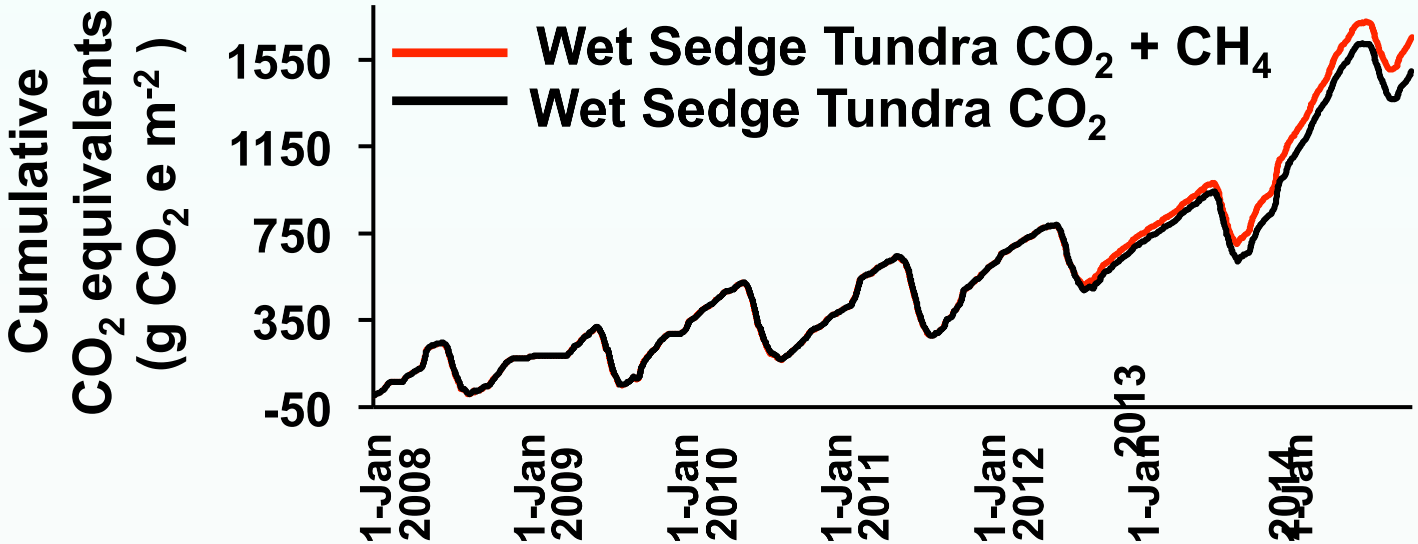

Mean Annual Temperature Departure, 1987-2014
Departure (°C)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014

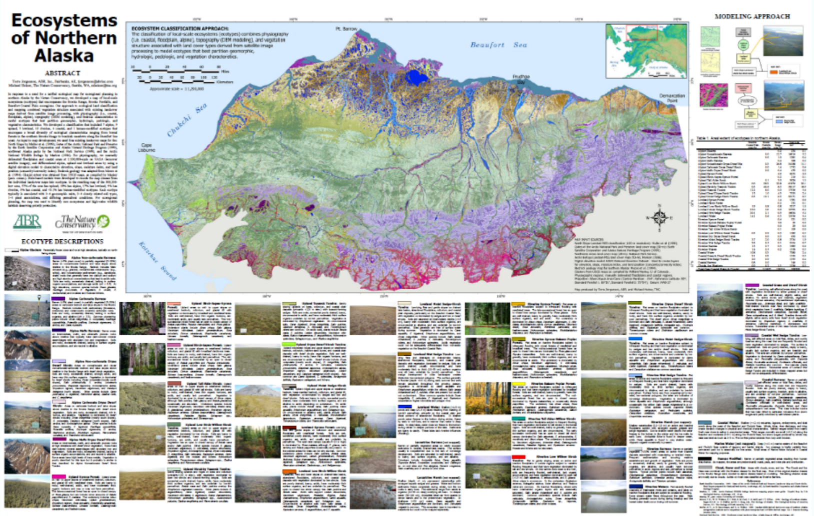


Loss of 554 g C m^{-2} in the wet sedge tundra = 3.6% of the total soil C stocks (0.5% per year)

Loss of 205 g C m^{-2} in the heath tundra = 1.9% of the total C stocks (0.3% per year)

(Positive Value = CO_2 e Release)





Heath → 43,000 km²

Tussock (graminoid) → 74,000 km²

Wetland / Wet sedge → 30,000 km²

= 147,000 km²

Arctic tundra land area in Alaska: 300,000 km²

2012-2014

Vegetation type	Area (km²)	Total NEE (g C m⁻²)	Spatially scaled NEE (Tg C)
Heath tundra	42,552	75 ± 33	3.2 ± 1.4
Tussock tundra	74,716	30 ± 17	2.3 ± 1.3
Wet sedge tundra	30,027	293 ± 39	8.8 ± 1.2
Total of all three	147,295	399 ± 97	14.7 ± 3.8
Tussock tundra	290,000	30 ± 17	8.8 ± 4.9

Conclusions:

-These tundra ecosystems appear to be CO_2 sources over the long-term

-Wet sedge tundra is a strong source of CO_2 in recent years with warmer late fall/ early winter

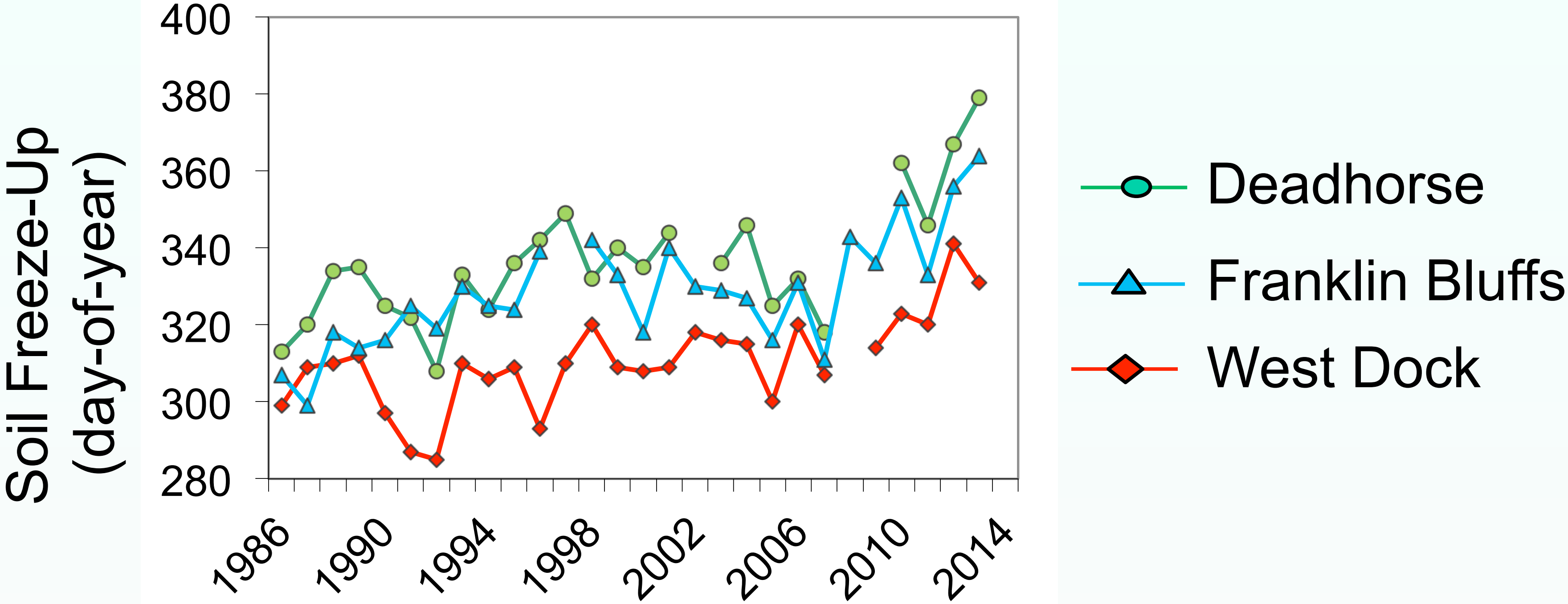
-CH_4 emissions at the wet sedge added a small component to the annual carbon emissions

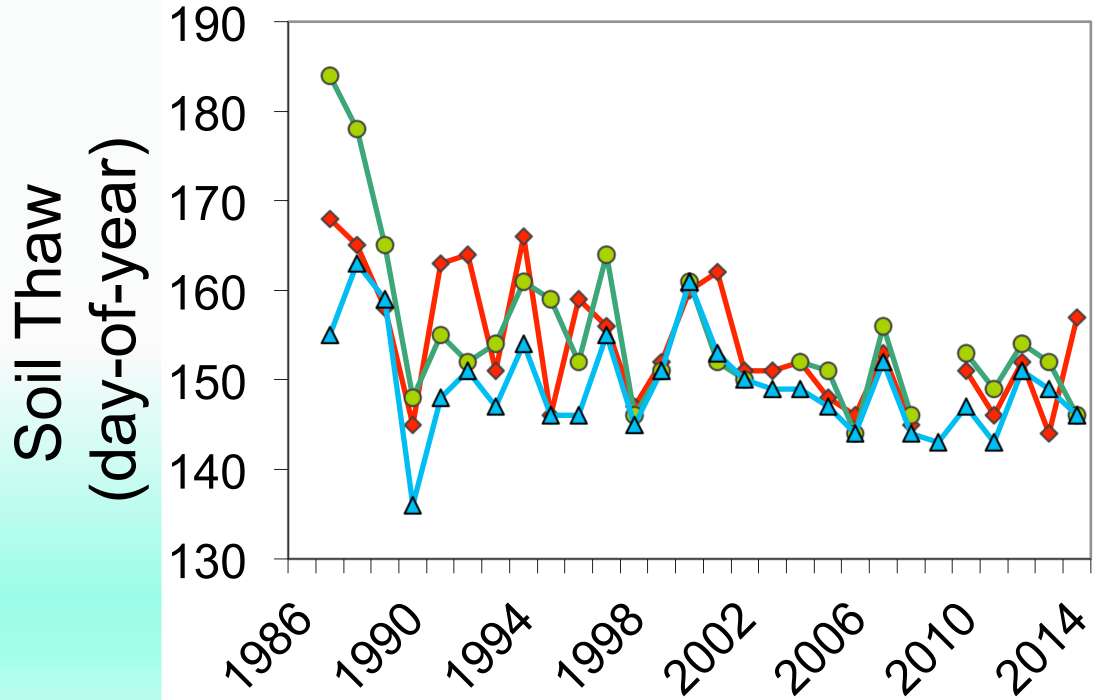
-Tussock tundra biomass appears to have increased substantially over the last 40 years; this is consistent with a modest fertilization effect as permafrost warms and soil organic matter is decomposed

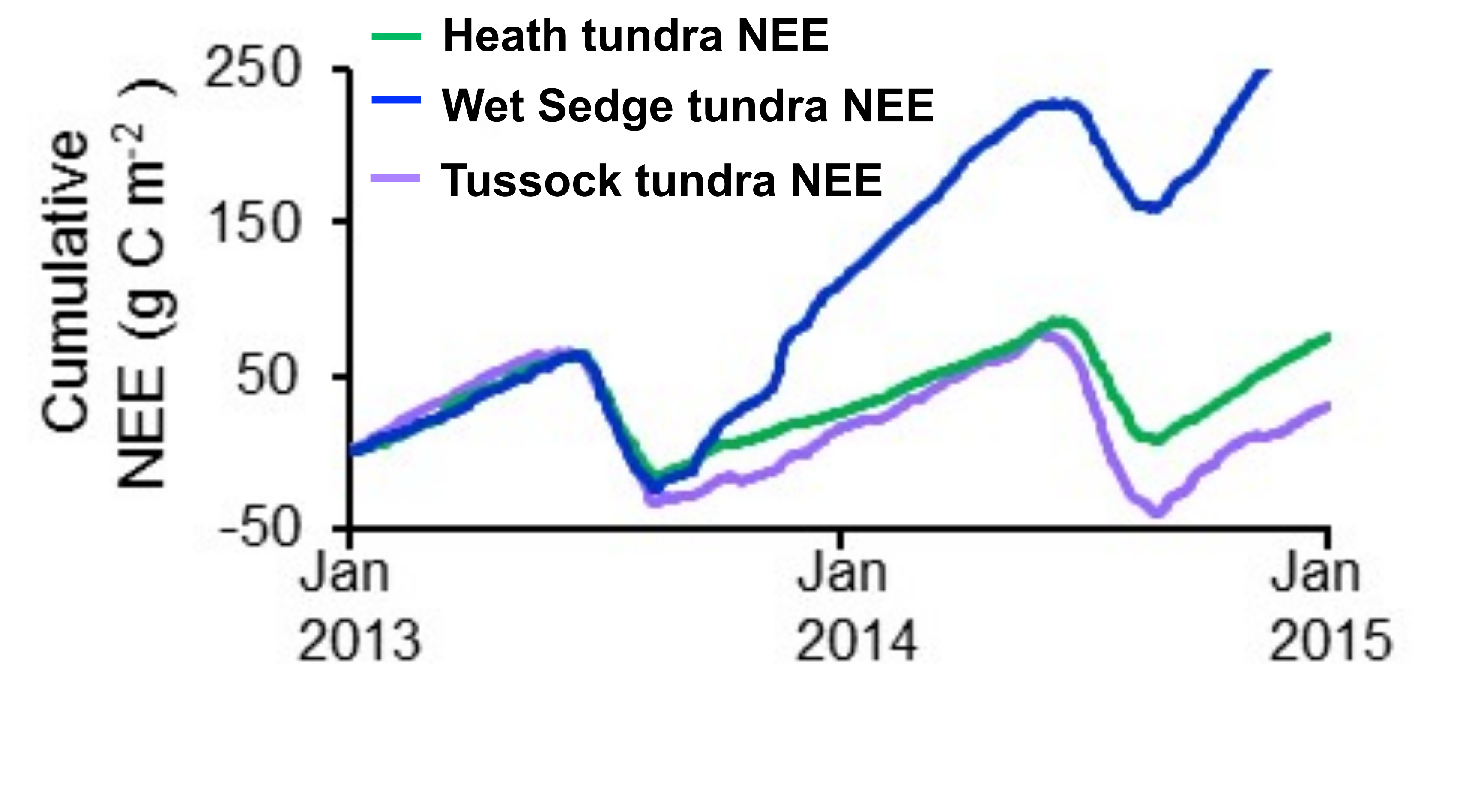
-Important to take into account landscape heterogeneity and interannual variability

-It is not clear whether the rates of loss seen here will be sustained over the longer term

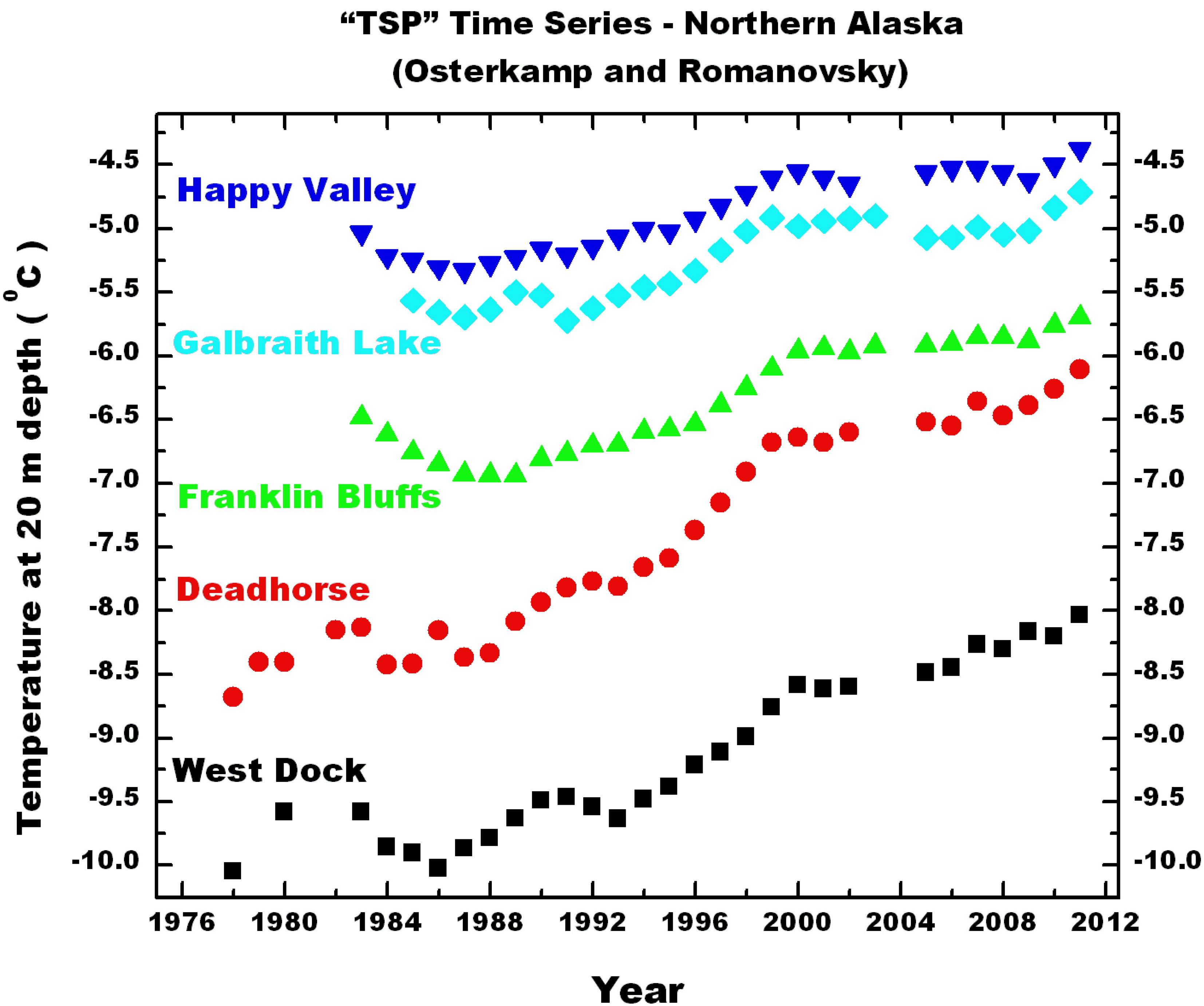
-It would be helpful to continue observations here


Soil Freeze-Up (day-of-year)
400
380
360
340
320
300
280
1986
1990
1994
1998
2002
2006
2010
2014
Deadhorse
Franklin Bluffs
West Dock


Soil Thaw (day-of-year)
190
180
170
160
150
140
130
1986
1990
1994
1998
2002
2006
2010
2014

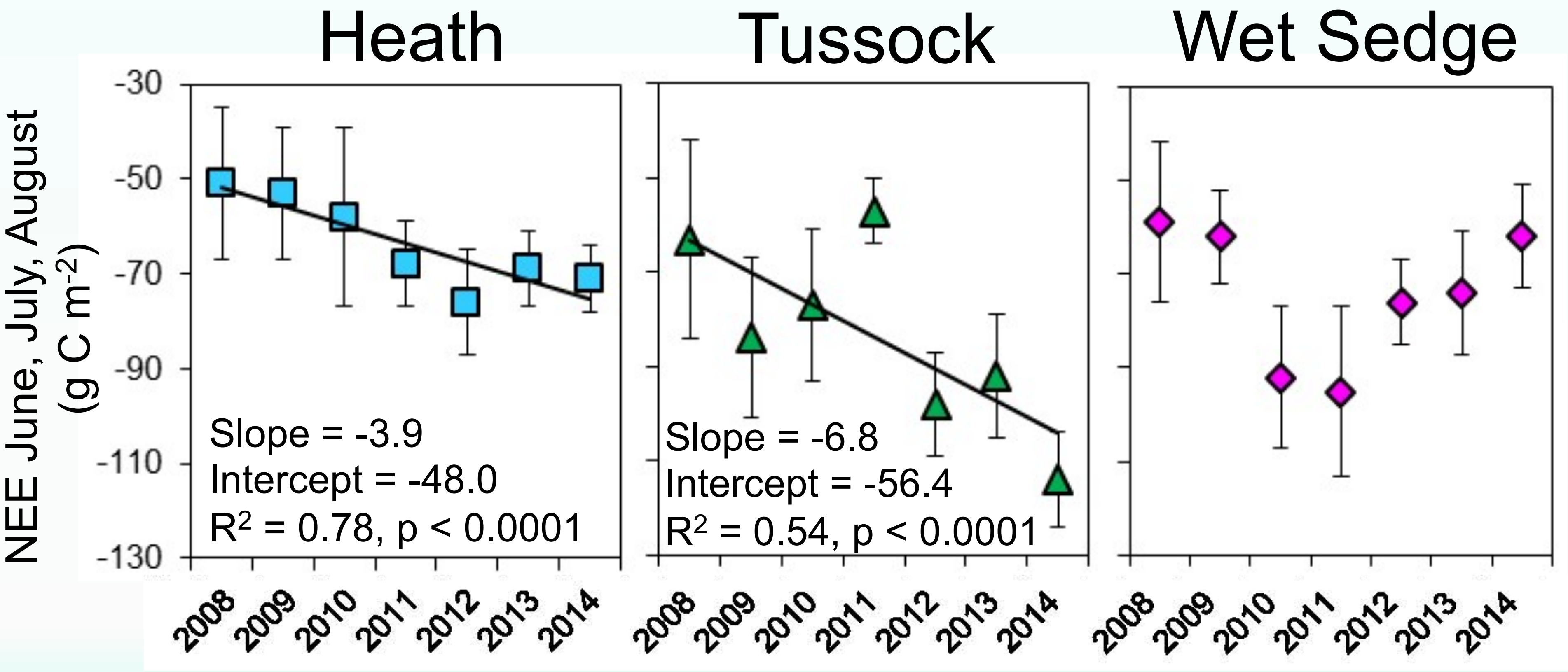


Positive value of NEE = Source of CO_2

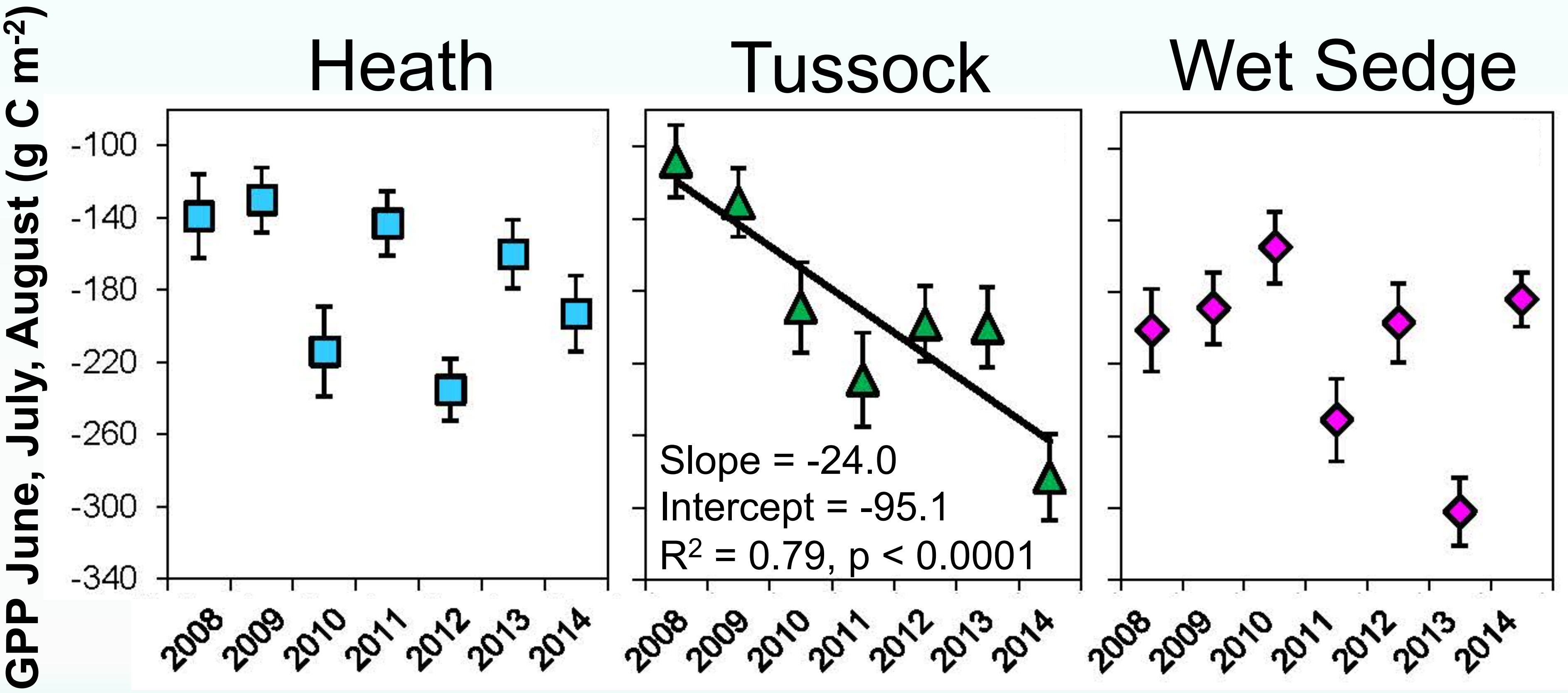


"TSP" Time Series - Northern Alaska
(Osterkamp and Romanovsky)
Happy Valley
Galbraith Lake
Franklin Bluffs
Deadhorse
West Dock
Temperature at 20 m depth (^{0}C)
Year
-4.5
-5.0
-5.5
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
-9.0
-9.5
-10.0
1976
1980
1984
1988
1992
1996
2000
2004
2008
2012

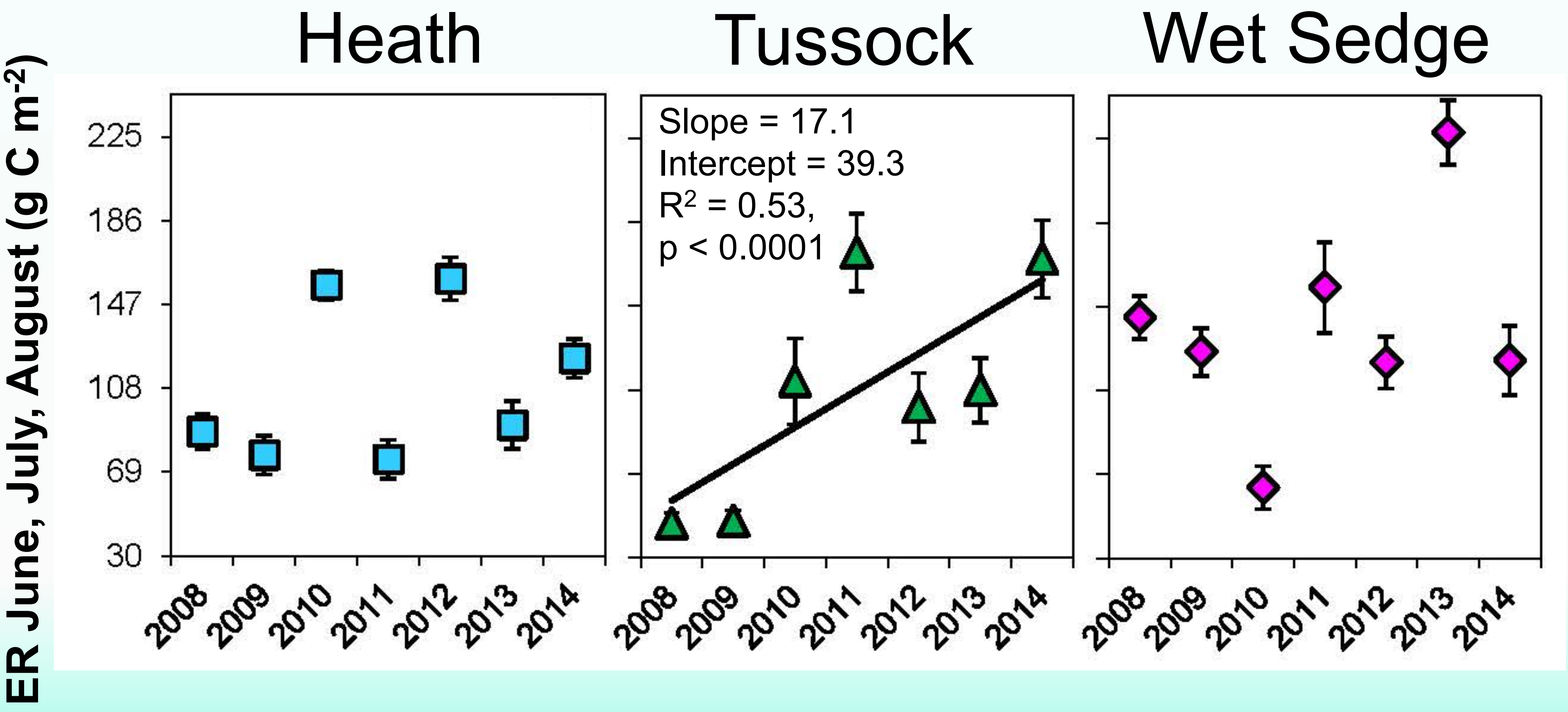
Summer NEE Trends (negative value = uptake)

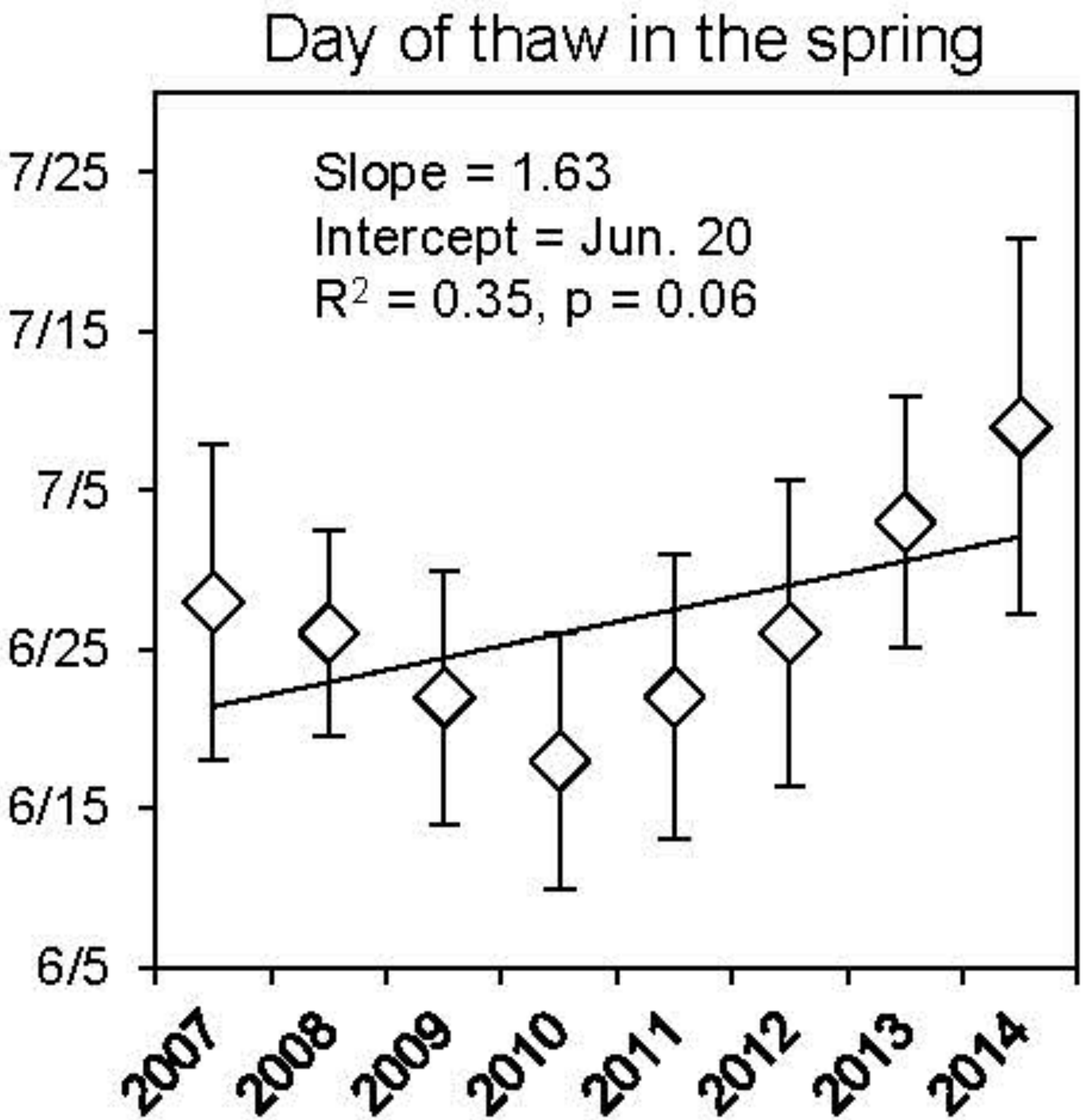


Summer GPP Trends (negative value = uptake)



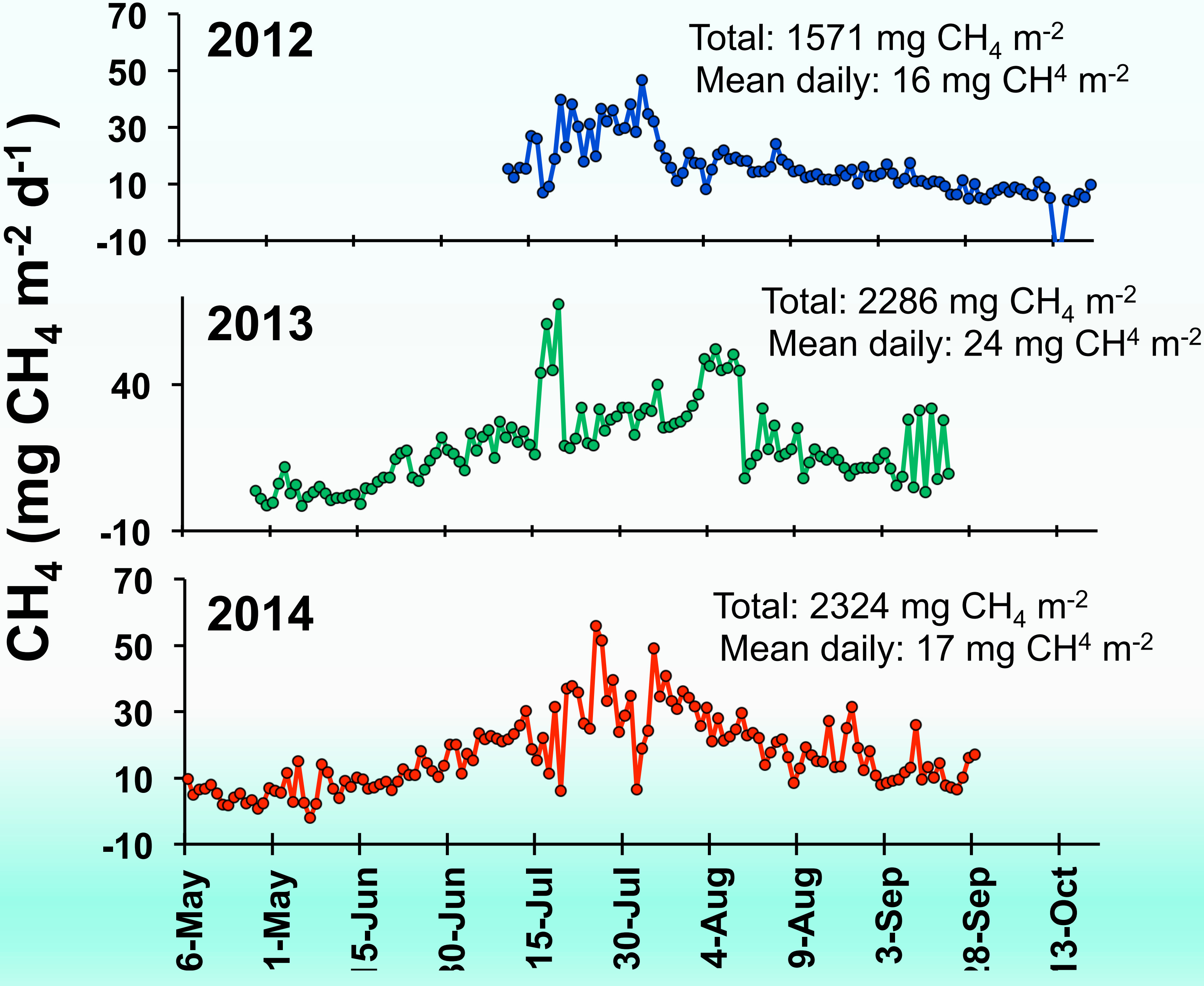
Summer Ecosystem Respiration (ER) Trends (positive value = release)

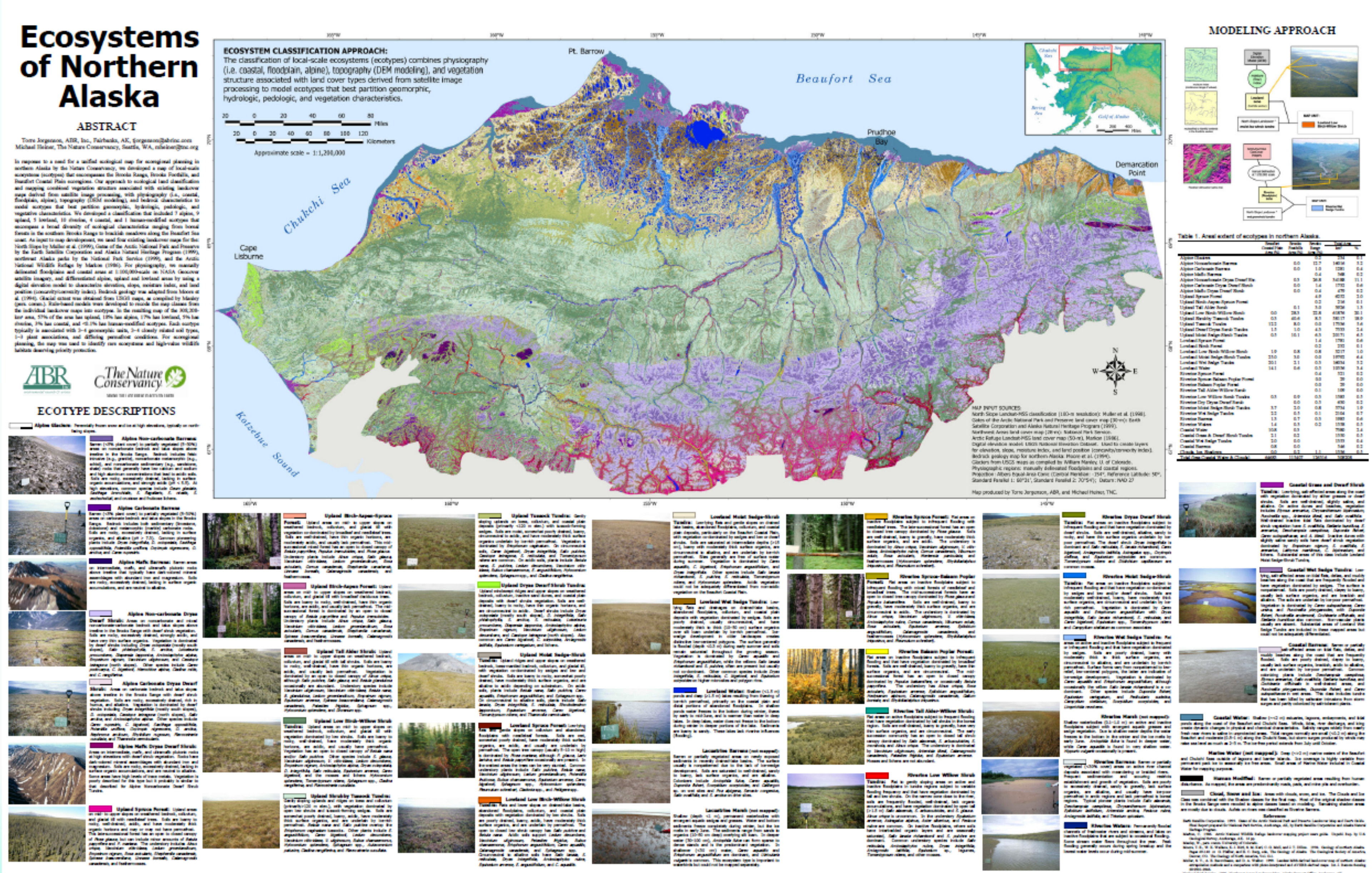


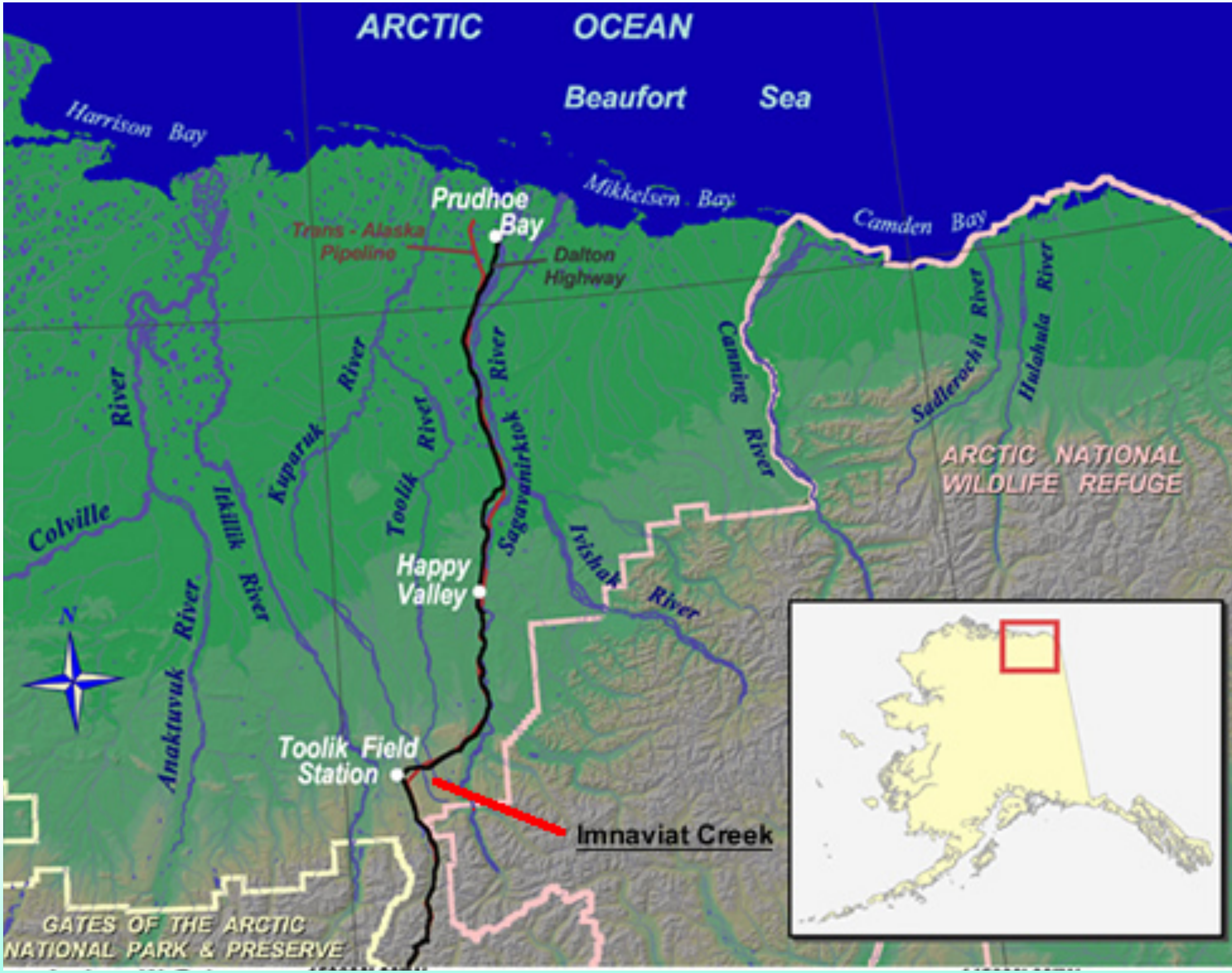


Day of thaw in the spring
Slope = 1.63
Intercept = Jun. 20
R2 = 0.35, p = 0.06
7/25
7/15
7/5
6/25
6/15
6/5
2007
2008
2009
2010
2011
2012
2013
2014

Wet sedge tundra: Methane flux




Ecosystems of Northern Alaska
ABSTRACT
ECOSYSTEM CLASSIFICATION APPROACH:
The classification of local-scale ecosystems (ecotypes) combines physiography (i.e. coastal, floodplain, alpine), topography (DEM modeling), and vegetation structure associated with land cover types derived from satellite image processing to model ecotypes that best partition geomorphic, hydrologic, pedologic, and vegetation characteristics.
Approximate scale = 1:1,200,000
Pt. Barrow
Beaufort Sea
Chukchi Sea
Cape Lisburne
Prudhoe Bay
Demarcation Point
Kotzebue Sound
MODELING APPROACH
Table 1. Areal extent of ecotypes in northern Alaska.
ECOTYPE DESCRIPTIONS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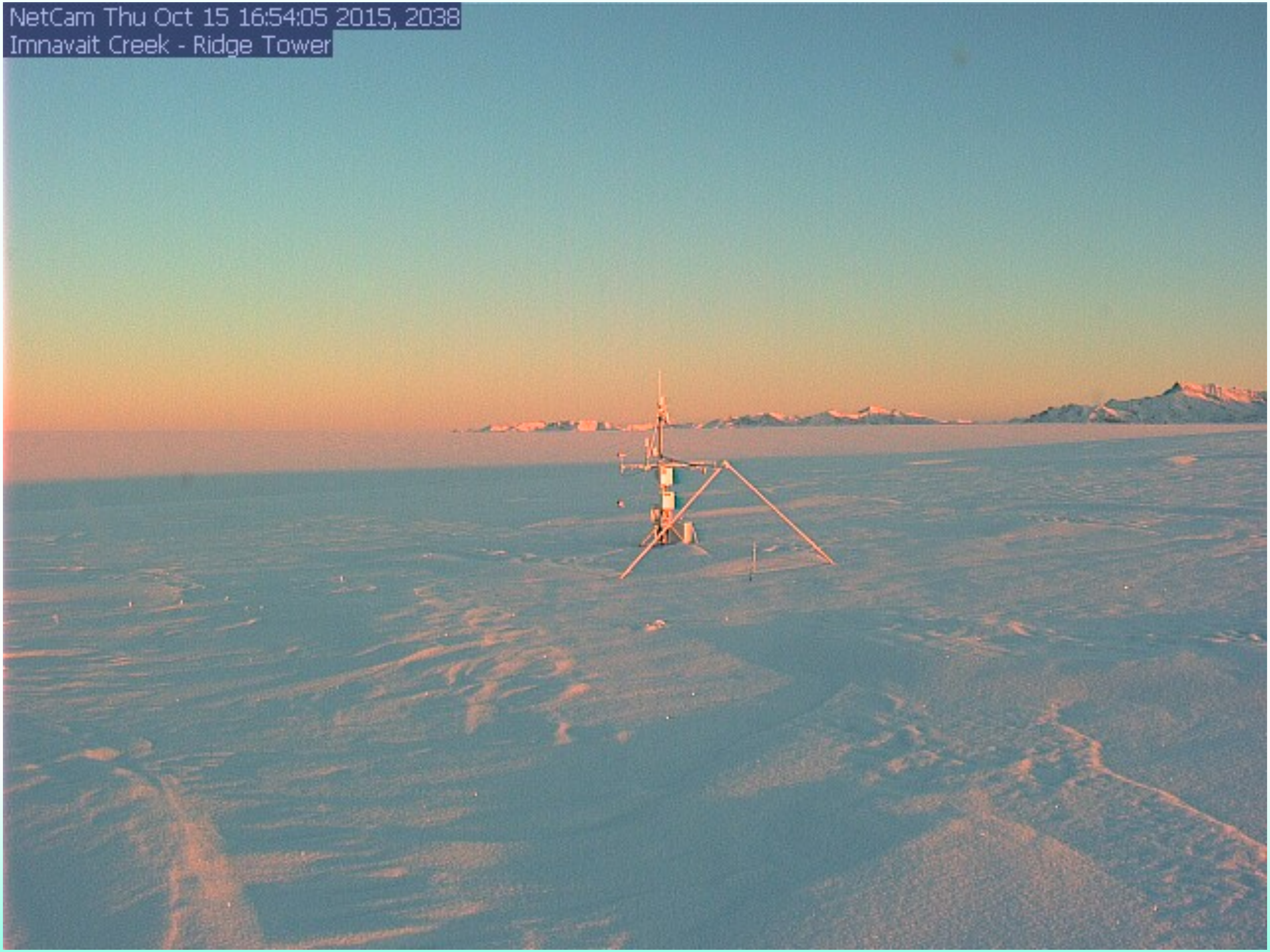

http://aon.iab.uaf.edu/AON_Home.html

Measurements of plant biomass and soil carbon