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

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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

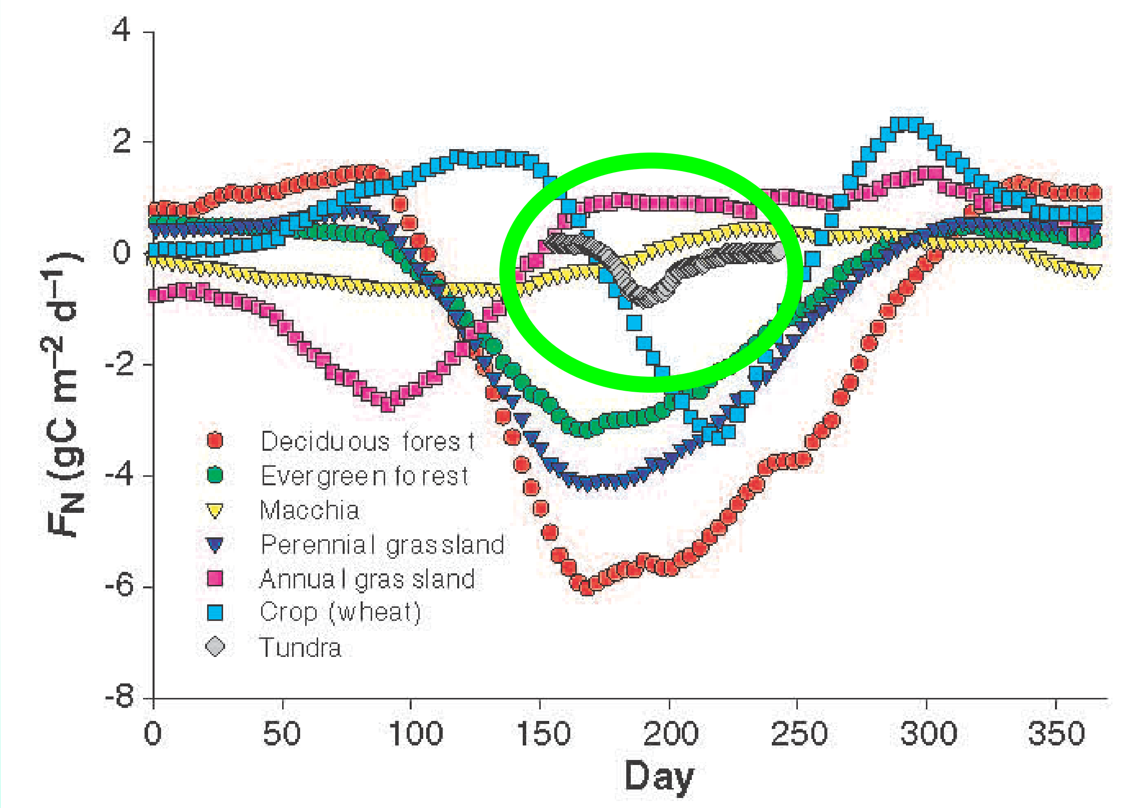
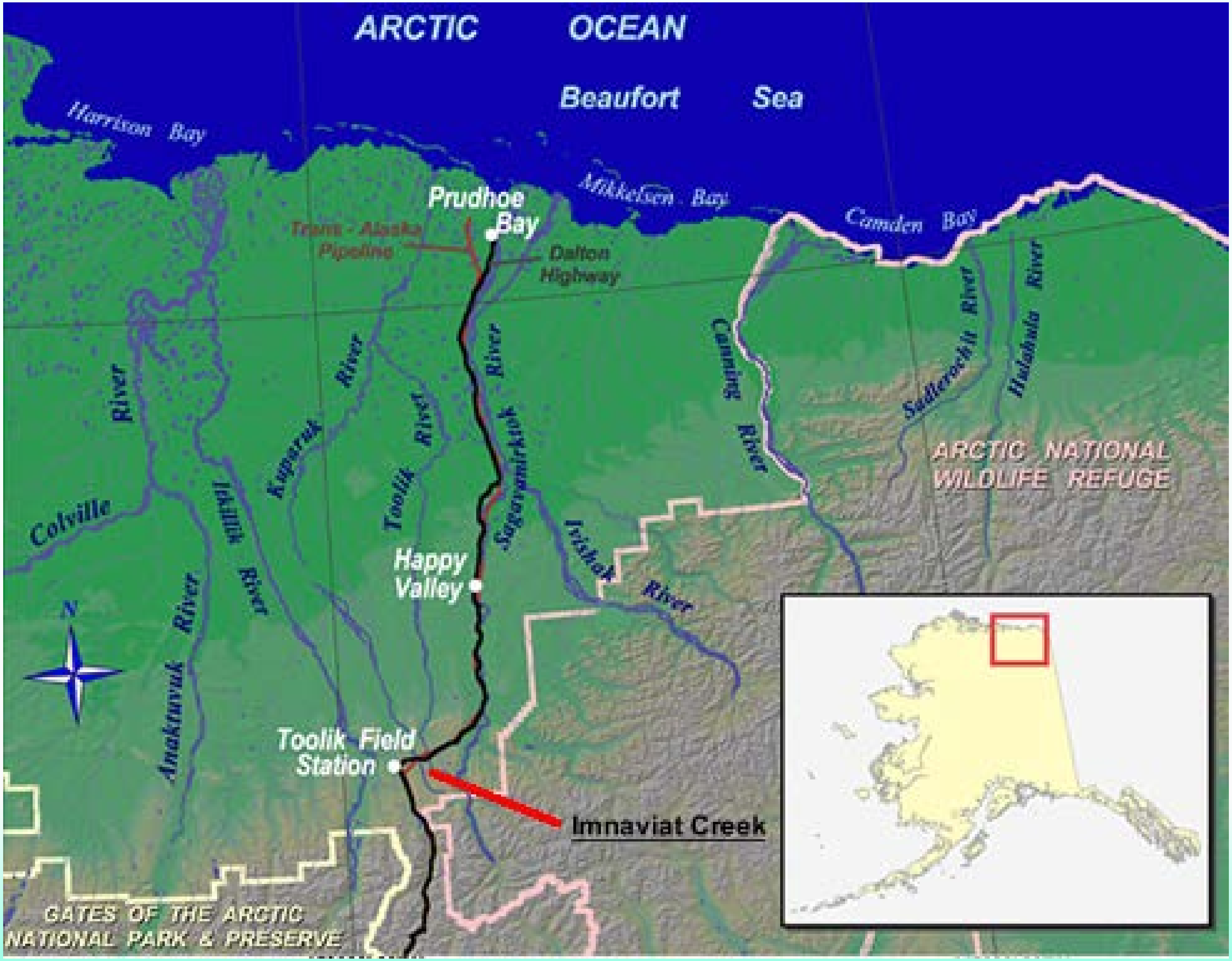


Fig. 2. Seasonal patterns in net ecosystem CO_2 exchange. Adapted from Baldocchi and Valentini (2004).

Changes in CO_2 uptake:

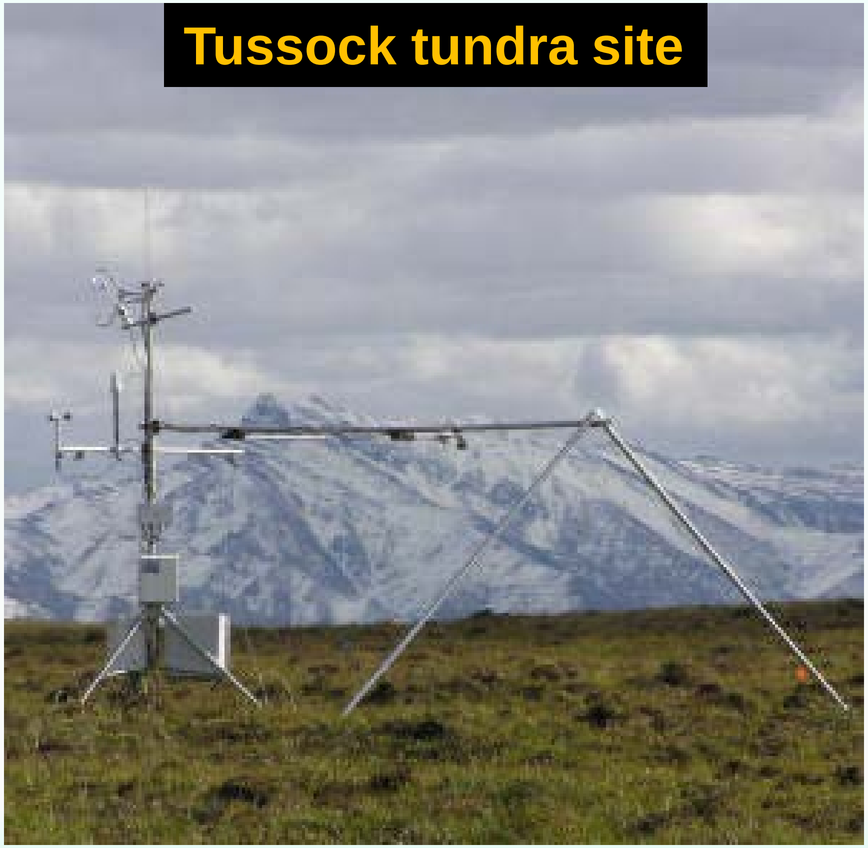
-Could see greater uptake as vegetation biomass increases

-Could also see greater release as respiration increases



ARCTIC OCEAN
Beaufort Sea
Harrison Bay
Mikkelsen Bay
Camden Bay
Prudhoe Bay
Trans - Alaska Pipeline
Dalton Highway
Colville River
Kuparuk River
Toolik River
Sagavanirktok River
Canning River
Sadlerochit River
Hulahula River
Itkillik River
Anaktuvuk River
Ivishak River
ARCTIC NATIONAL WILDLIFE REFUGE
Happy Valley
Toolik Field Station
Imnaviat Creek
N
GATES OF THE ARCTIC NATIONAL PARK & PRESERVE


Heath tundra site


Tussock tundra site


Wet sedge tundra site

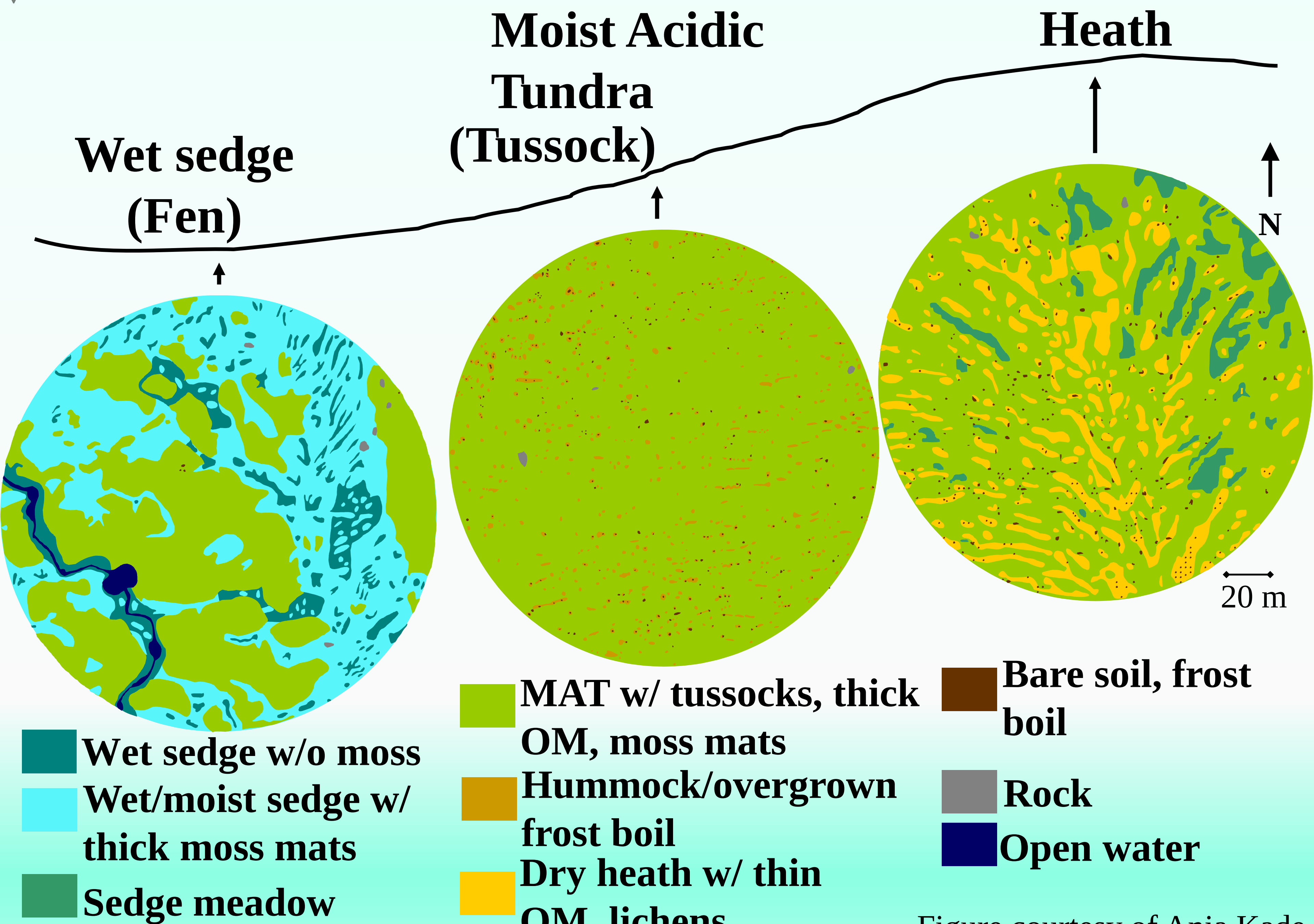
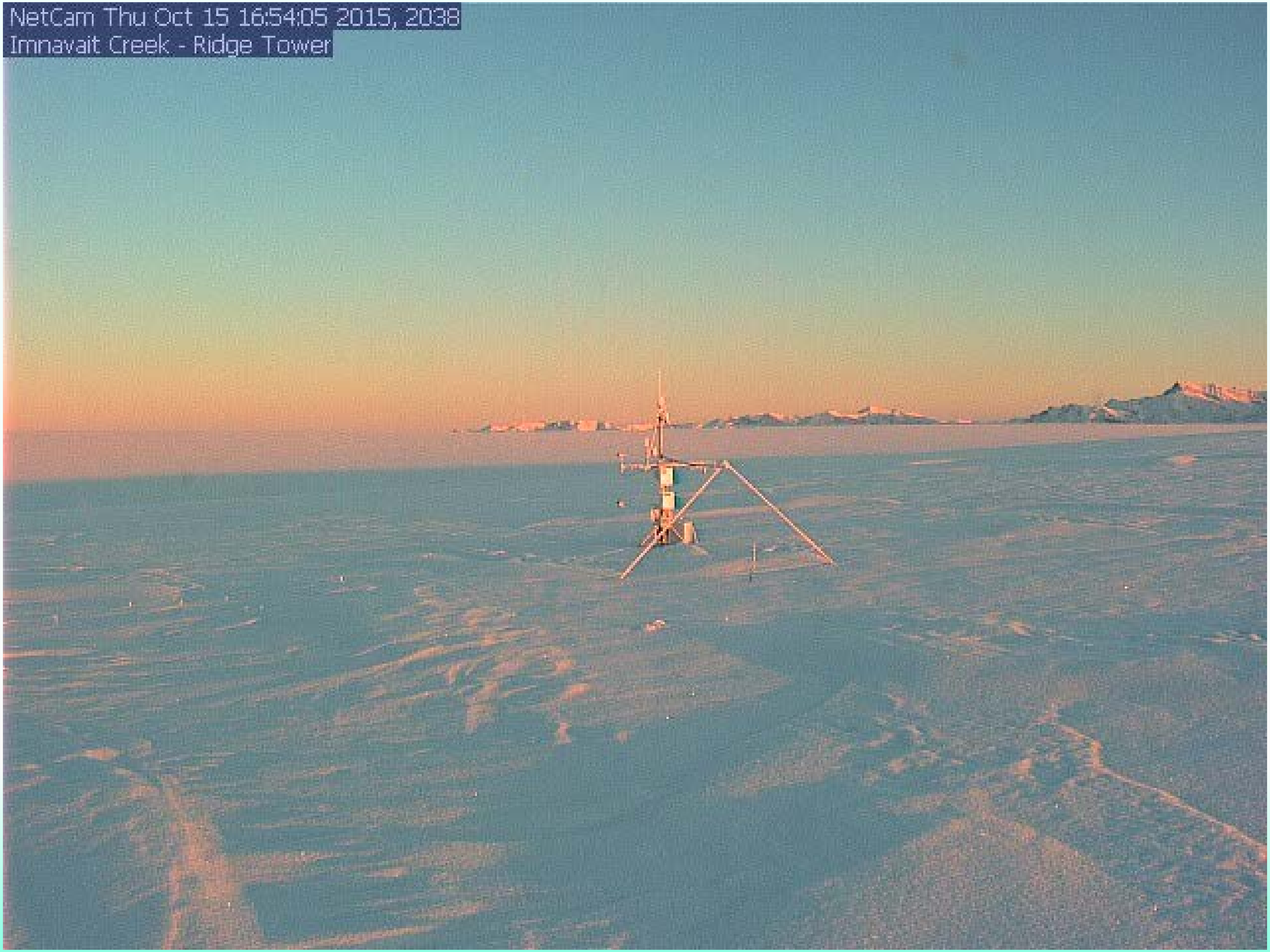


Figure courtesy of Anja Kade



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

Since late 2007, measurements of:

Net Ecosystem Exchange (CO_2 flux) =
Gross Primary Productivity – Ecosystem Respiration

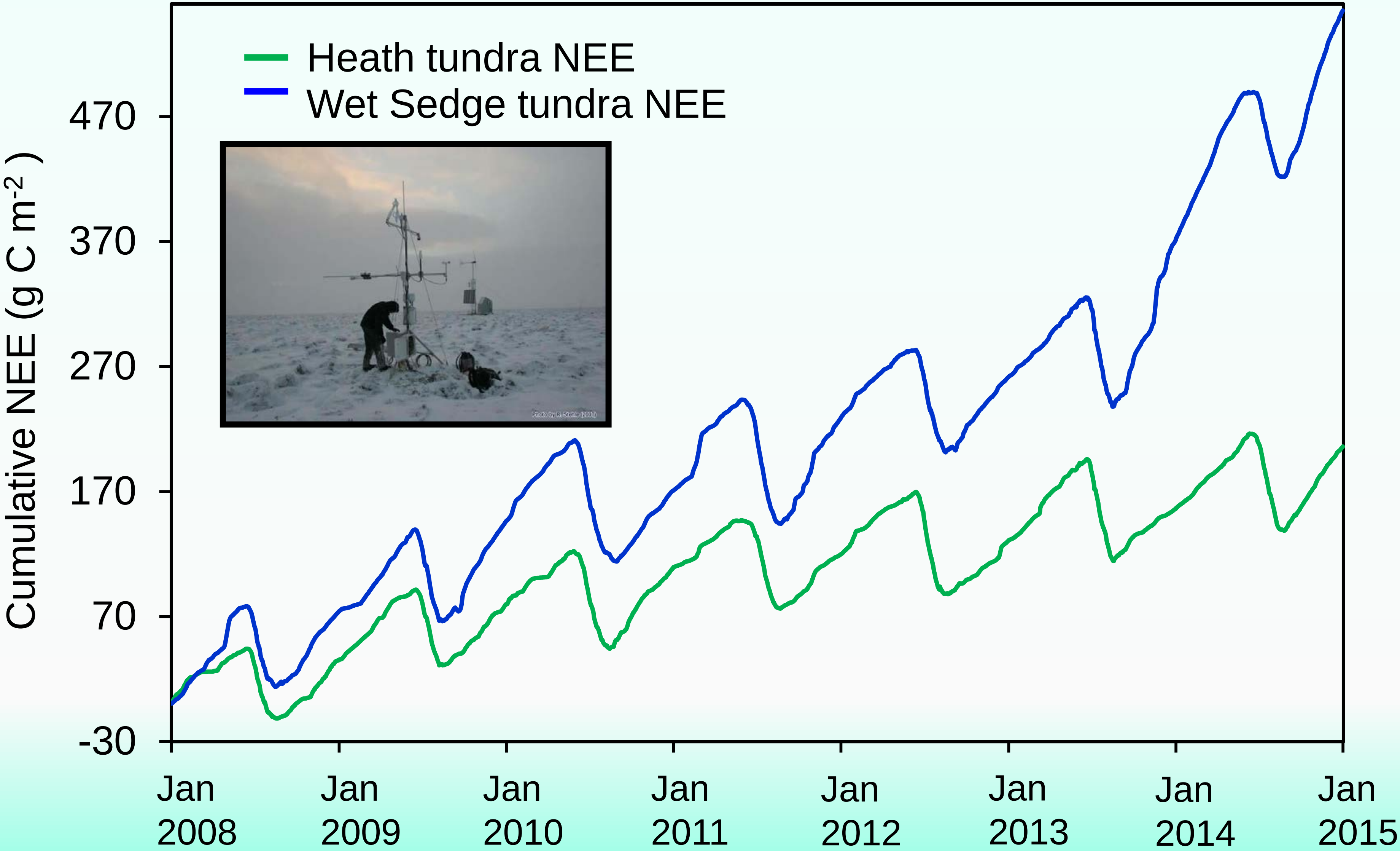
Year round at wet sedge and heath sites, April - October at the tussock until 2012

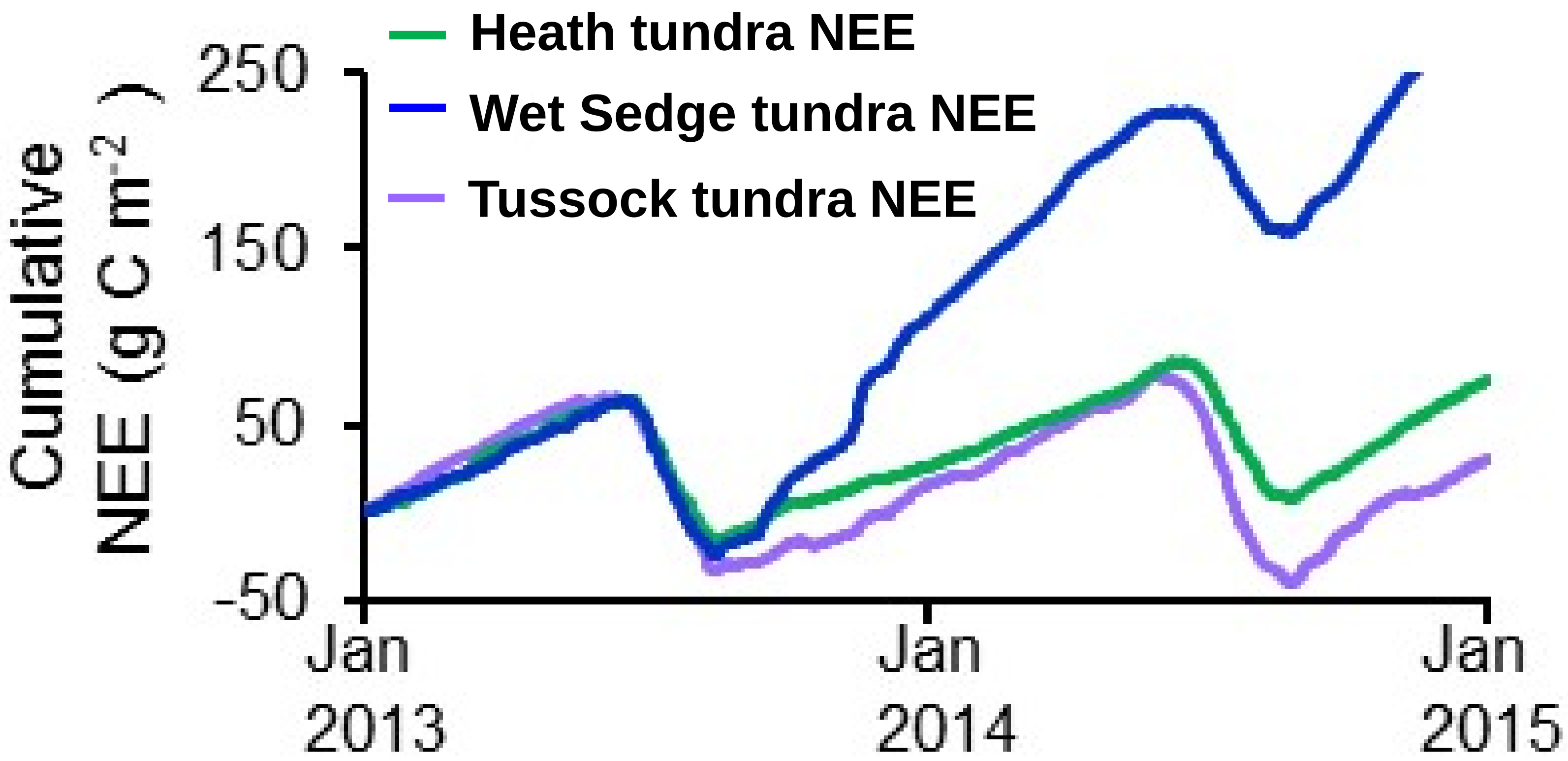
Meteorological & biophysical variables, including soil temperatures in a borehole

Seasonal methane (CH_4) at the wet sedge

Measurements of plant biomass and soil carbon

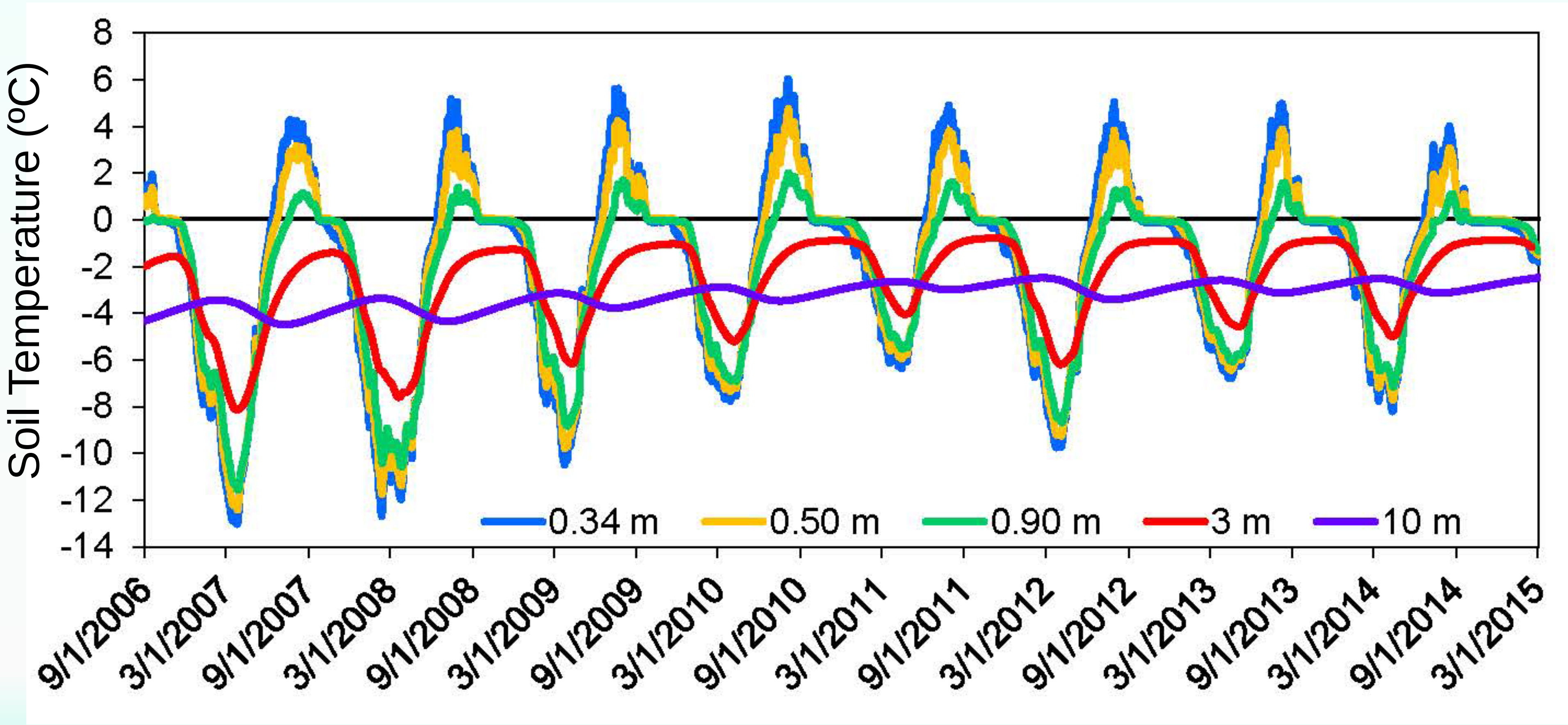
Positive value of NEE = Source of CO_2

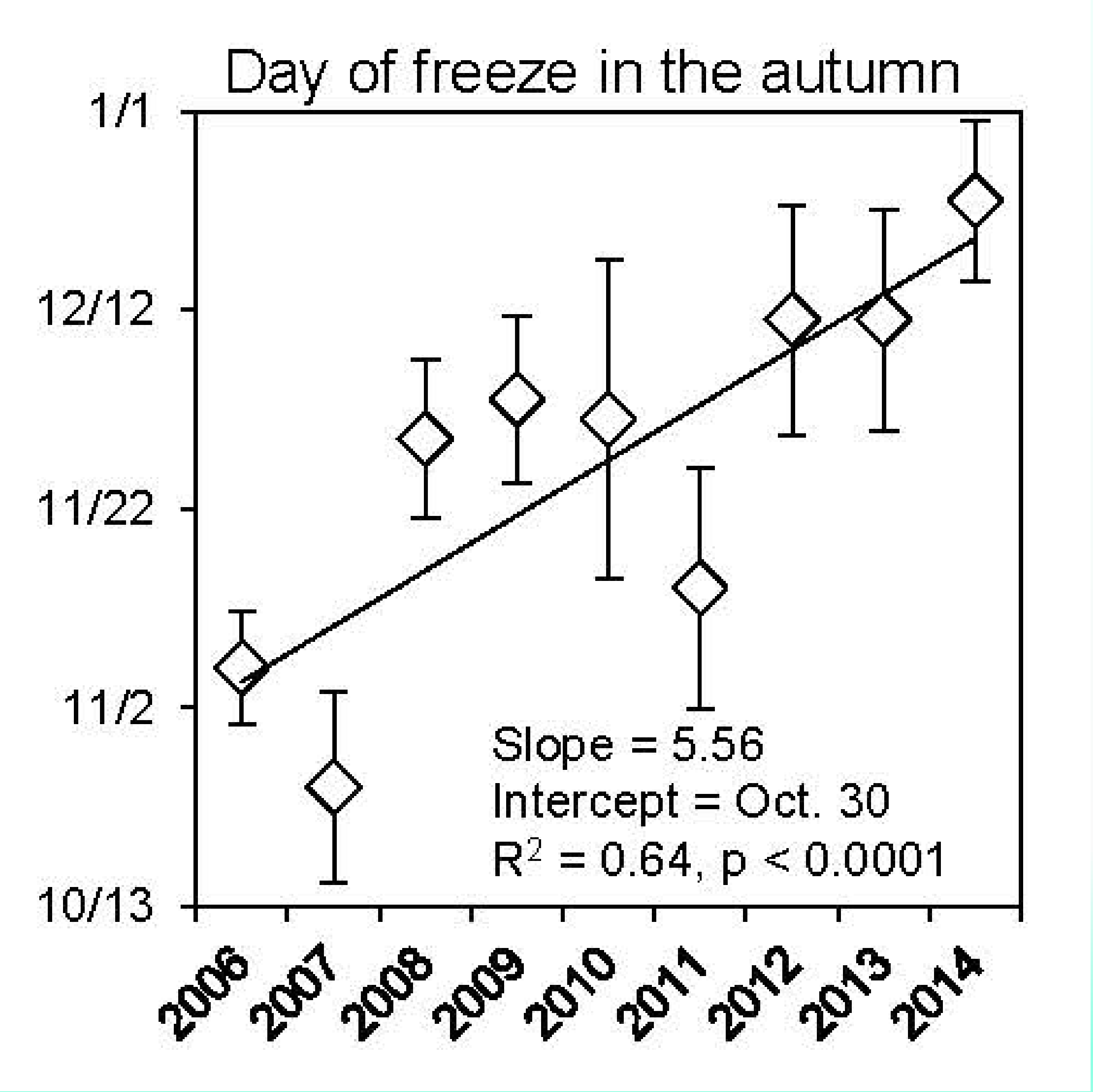


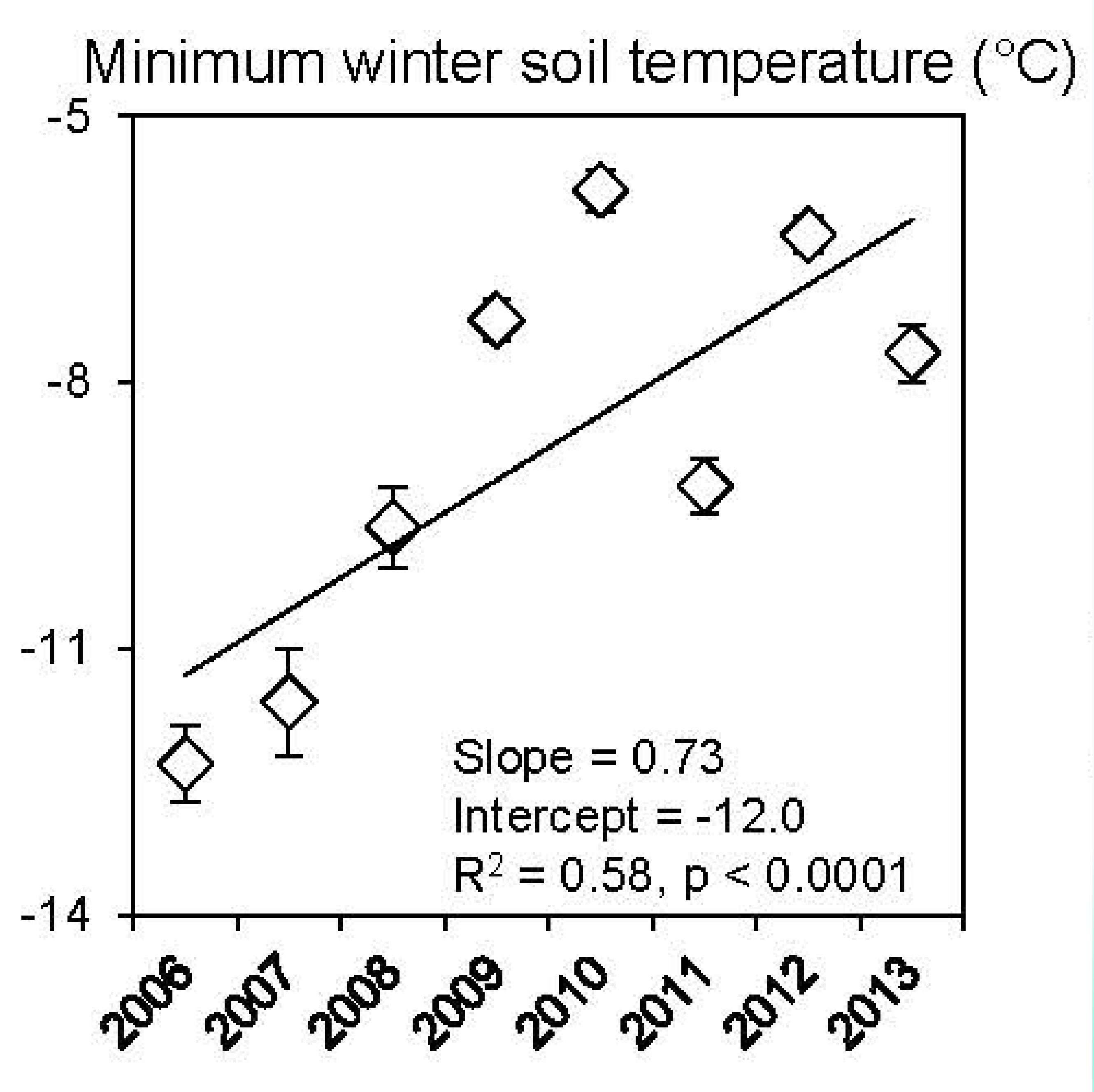


Positive value of NEE = Source of CO_2

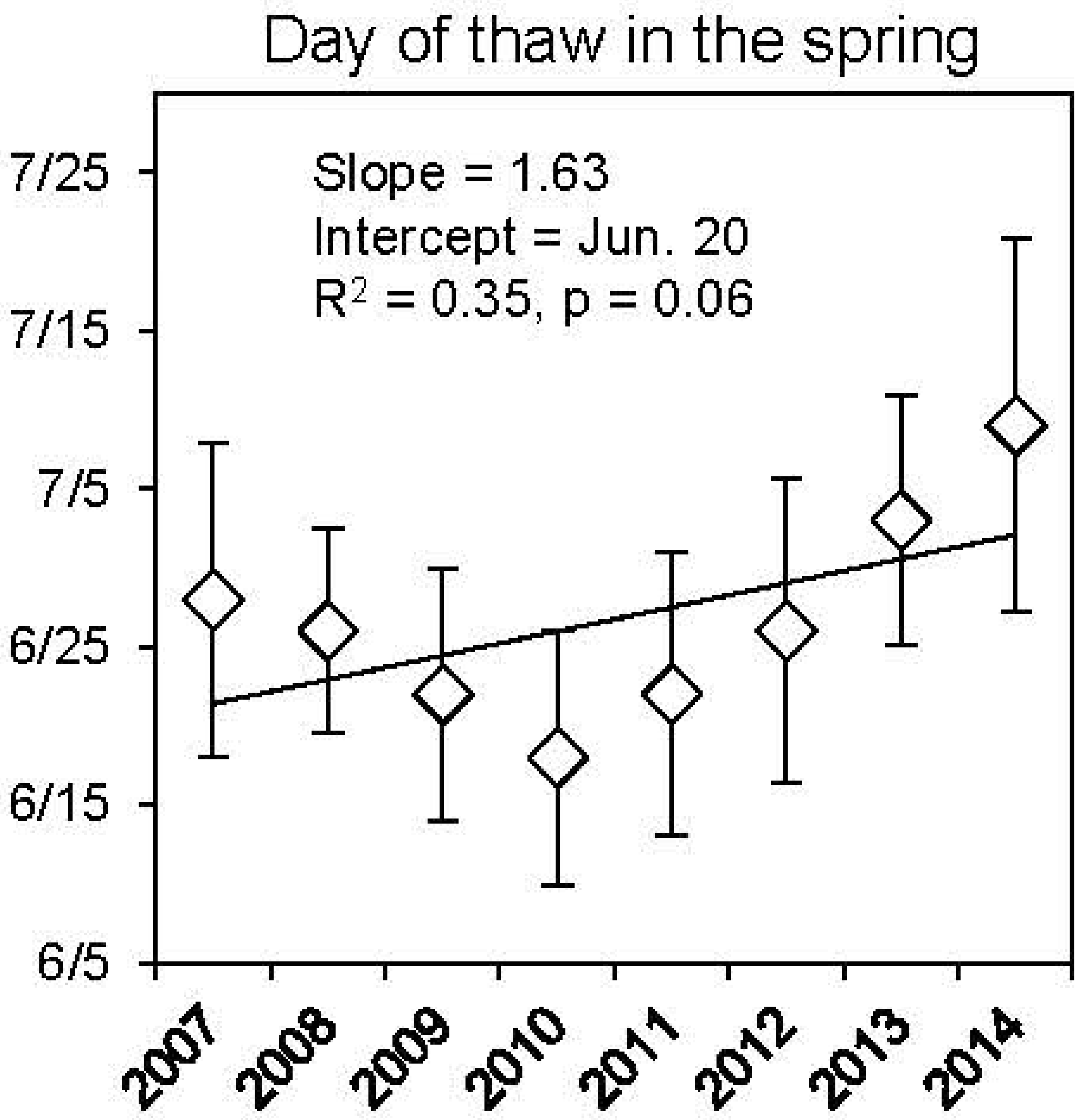
Imnavait Borehole Soil Temperatures



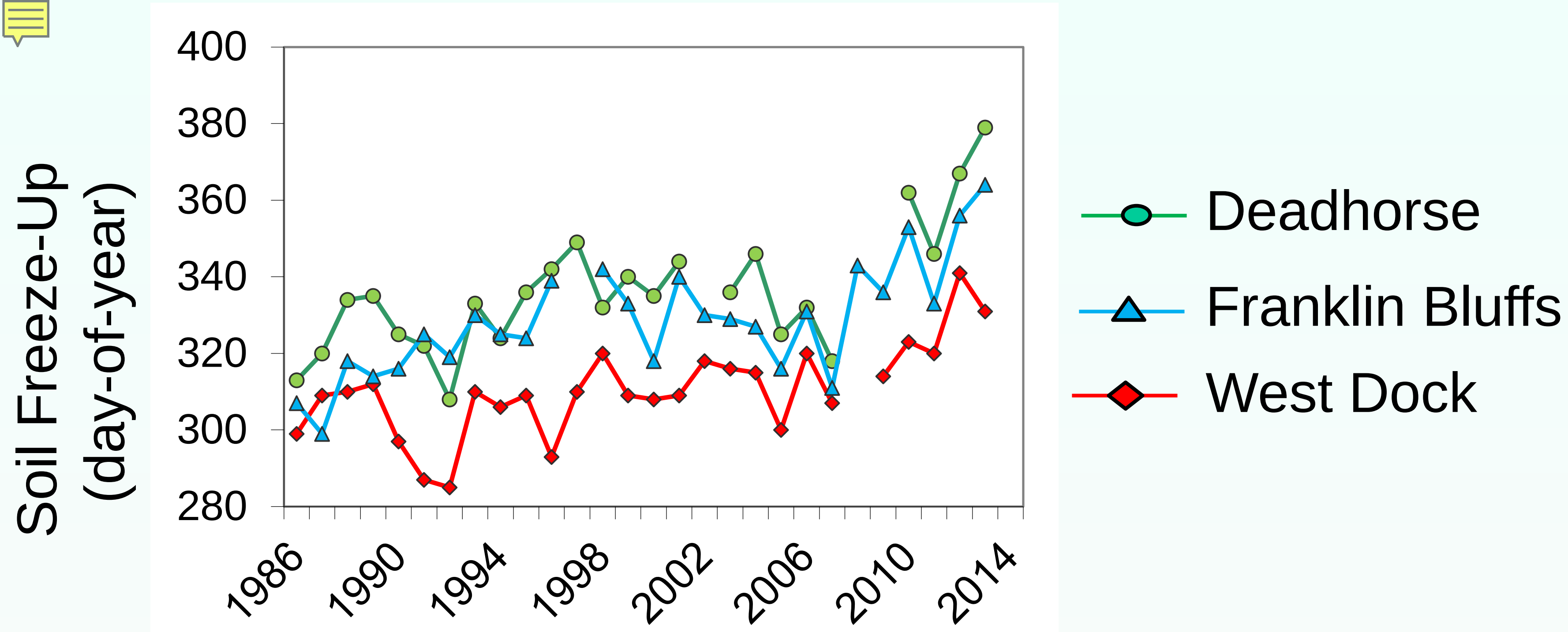

Day of freeze in the autumn
1/1
12/12
11/22
11/2
10/13
2006
2007
2008
2009
2010
2011
2012
2013
2014
Slope = 5.56
Intercept = Oct. 30
R^2 = 0.64, p < 0.0001

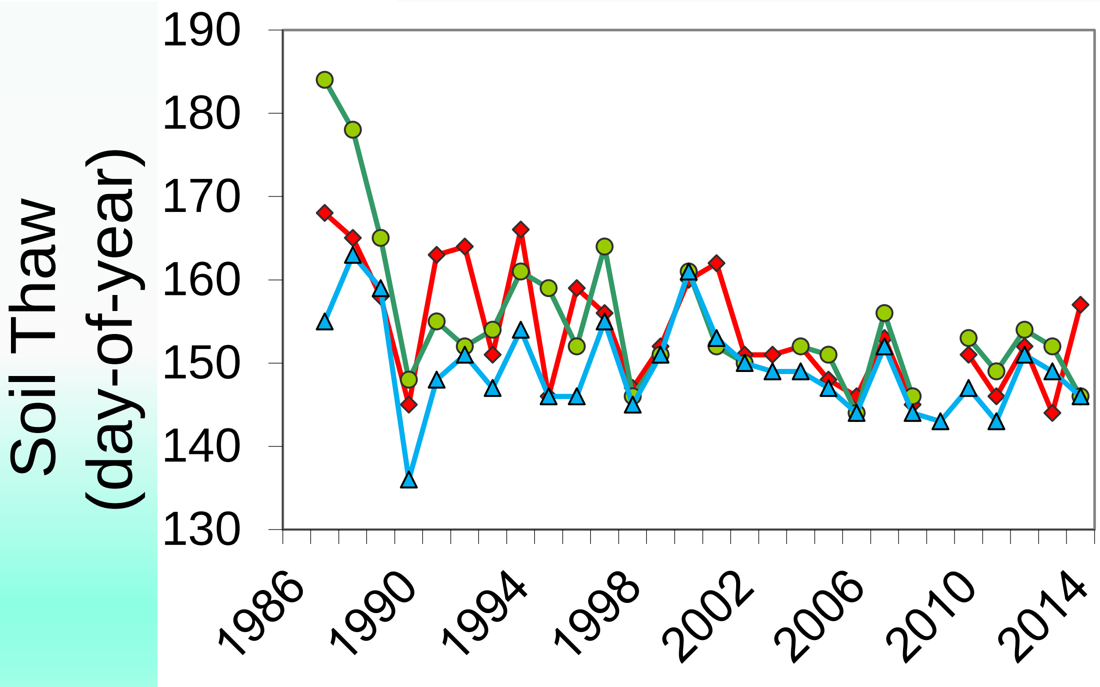


Minimum winter soil temperature (°C)
-5
-8
-11
-14
2006
2007
2008
2009
2010
2011
2012
2013
Slope = 0.73
Intercept = -12.0
$R^2 = 0.58$, $p < 0.0001$

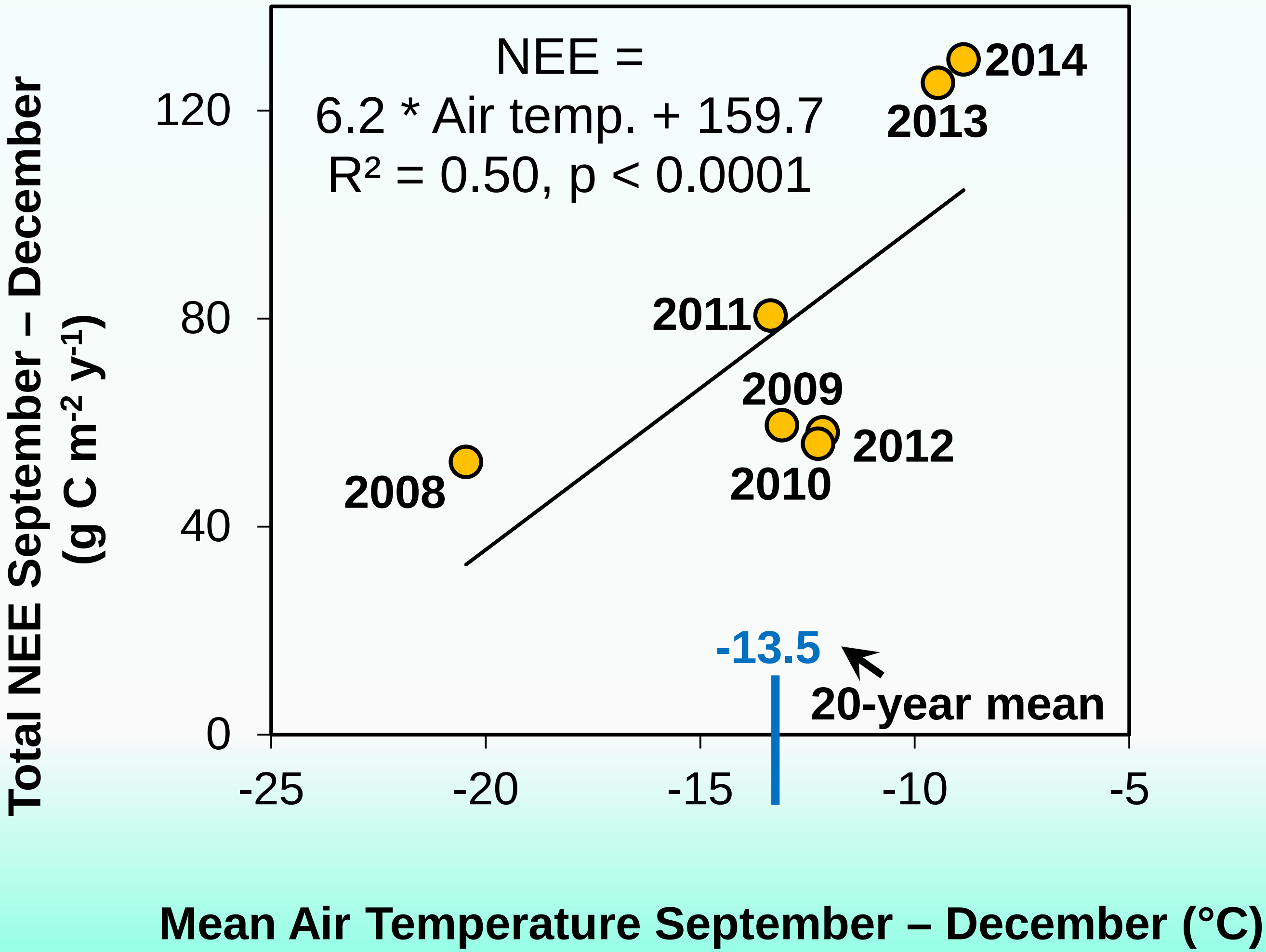


Day of thaw in the spring
Slope = 1.63
Intercept = Jun. 20
R2 = 0.35, p = 0.06
7/25
7/15
7/5
6/25
6/15
6/5
2007
2008
2009
2010
2011
2012
2013
2014

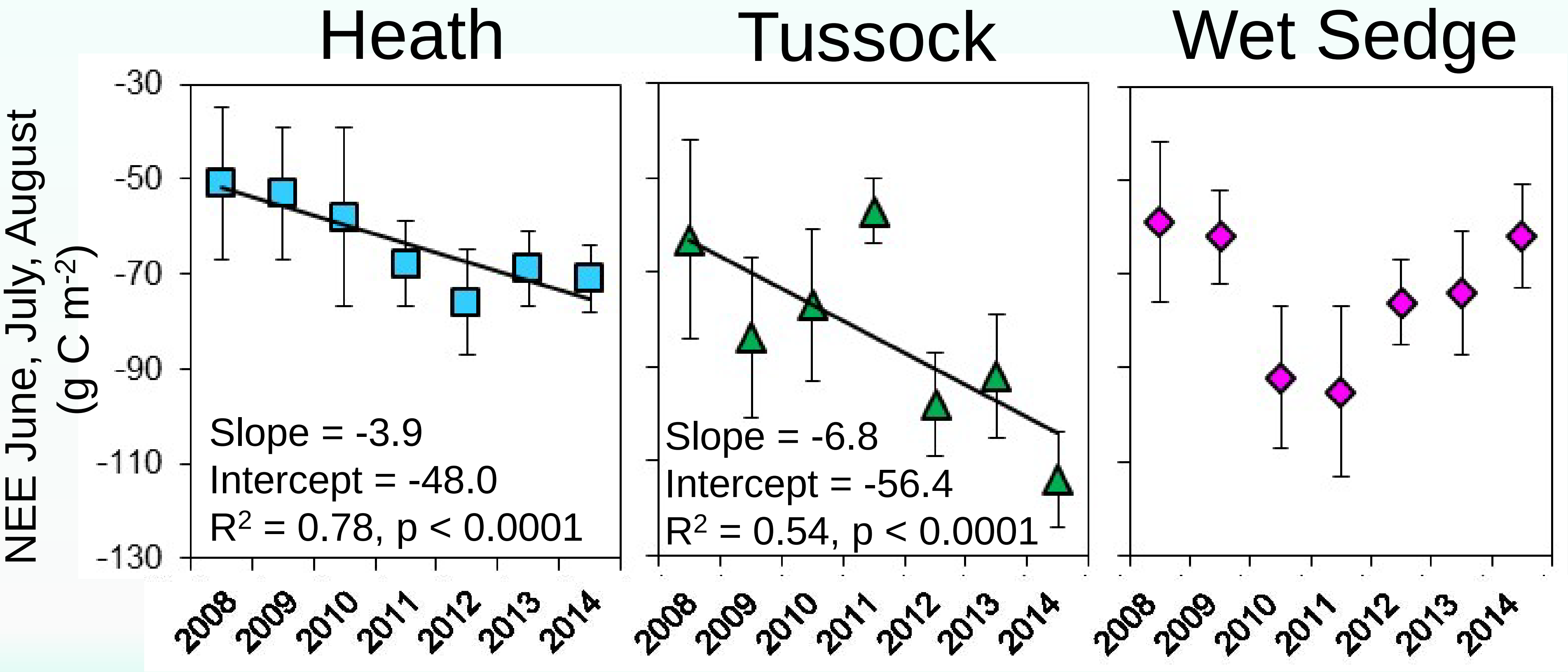

Soil Freeze-Up
(day-of-year)
400
380
360
340
320
300
280
1986
1990
1994
1998
2002
2006
2010
2014
Deadhorse
Franklin Bluffs
West Dock


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

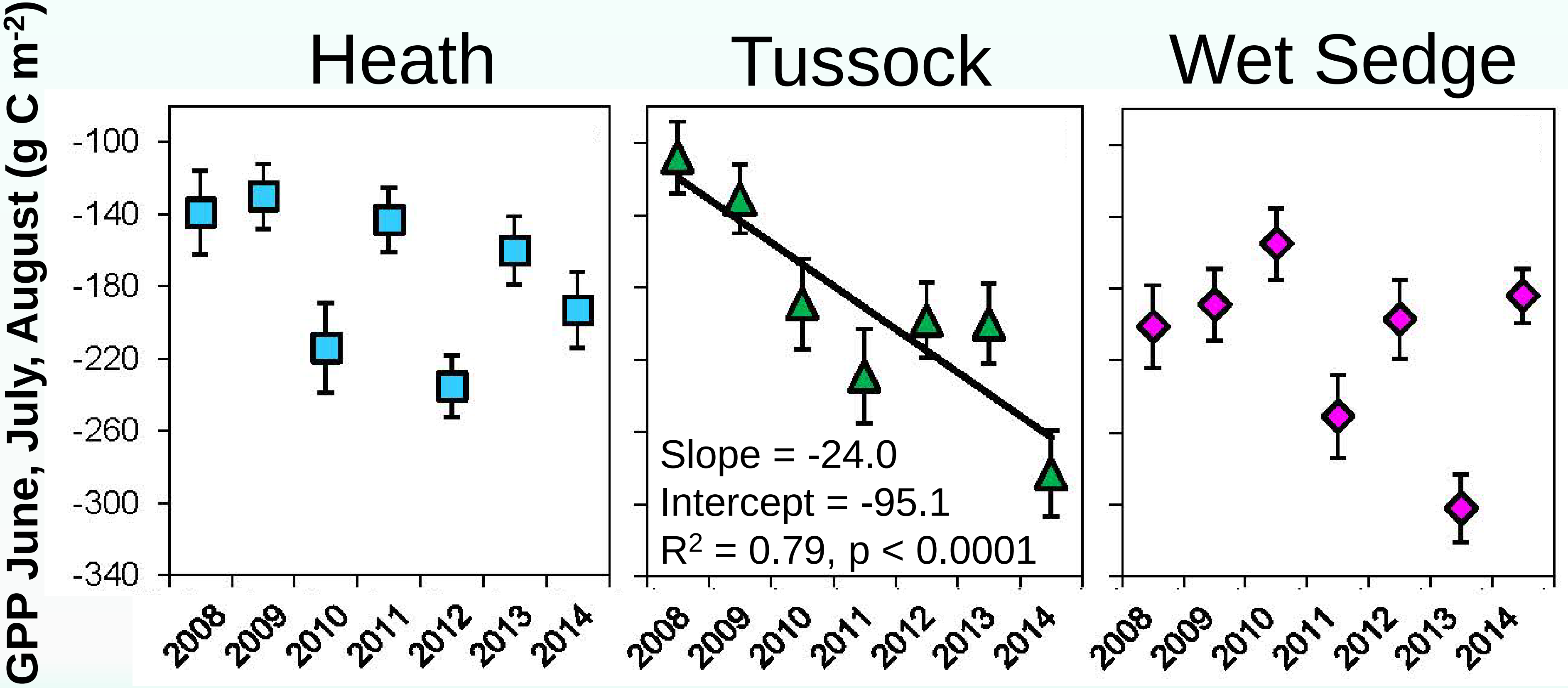
Wet sedge tundra
Late Fall / Early Winter NEE vs. Air Temp.



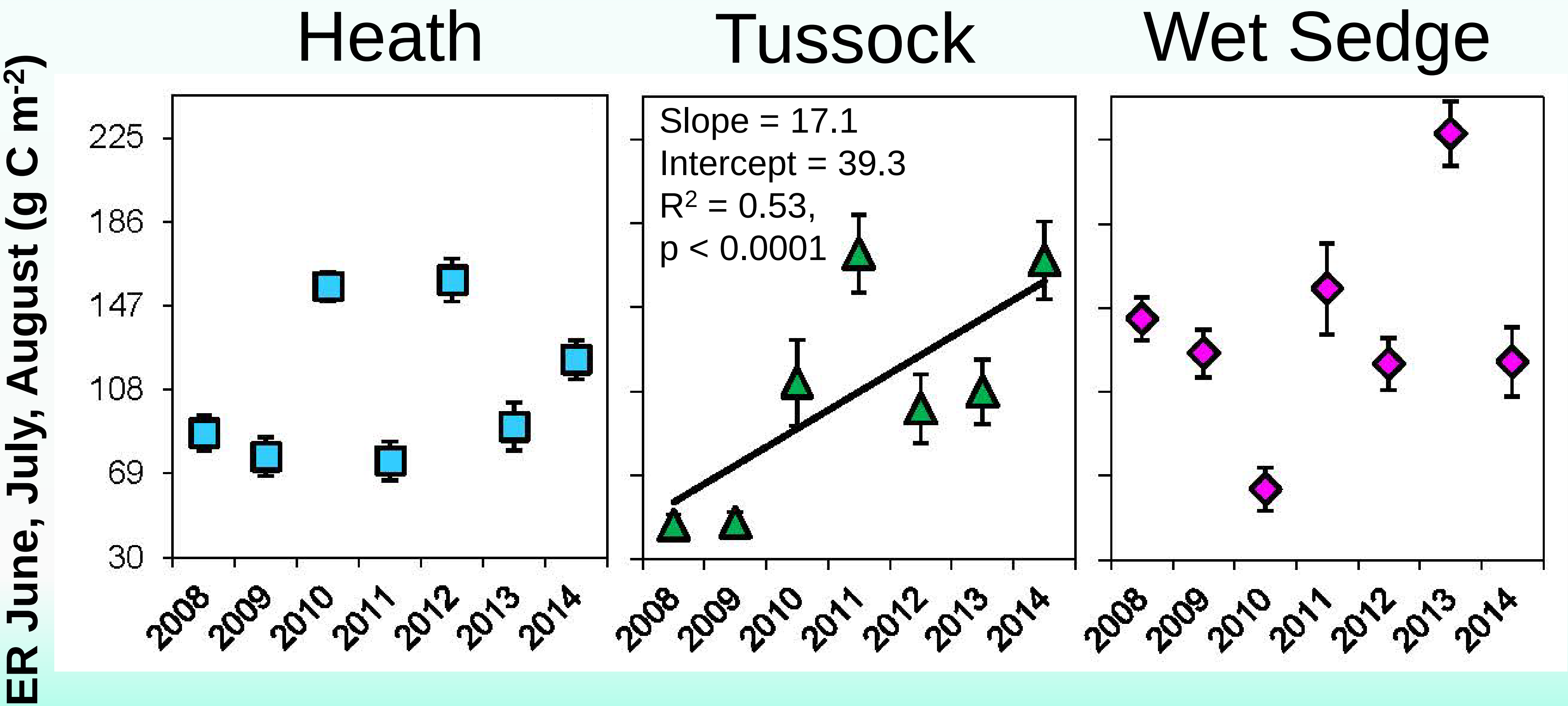
Summer NEE Trends
(negative value = uptake)

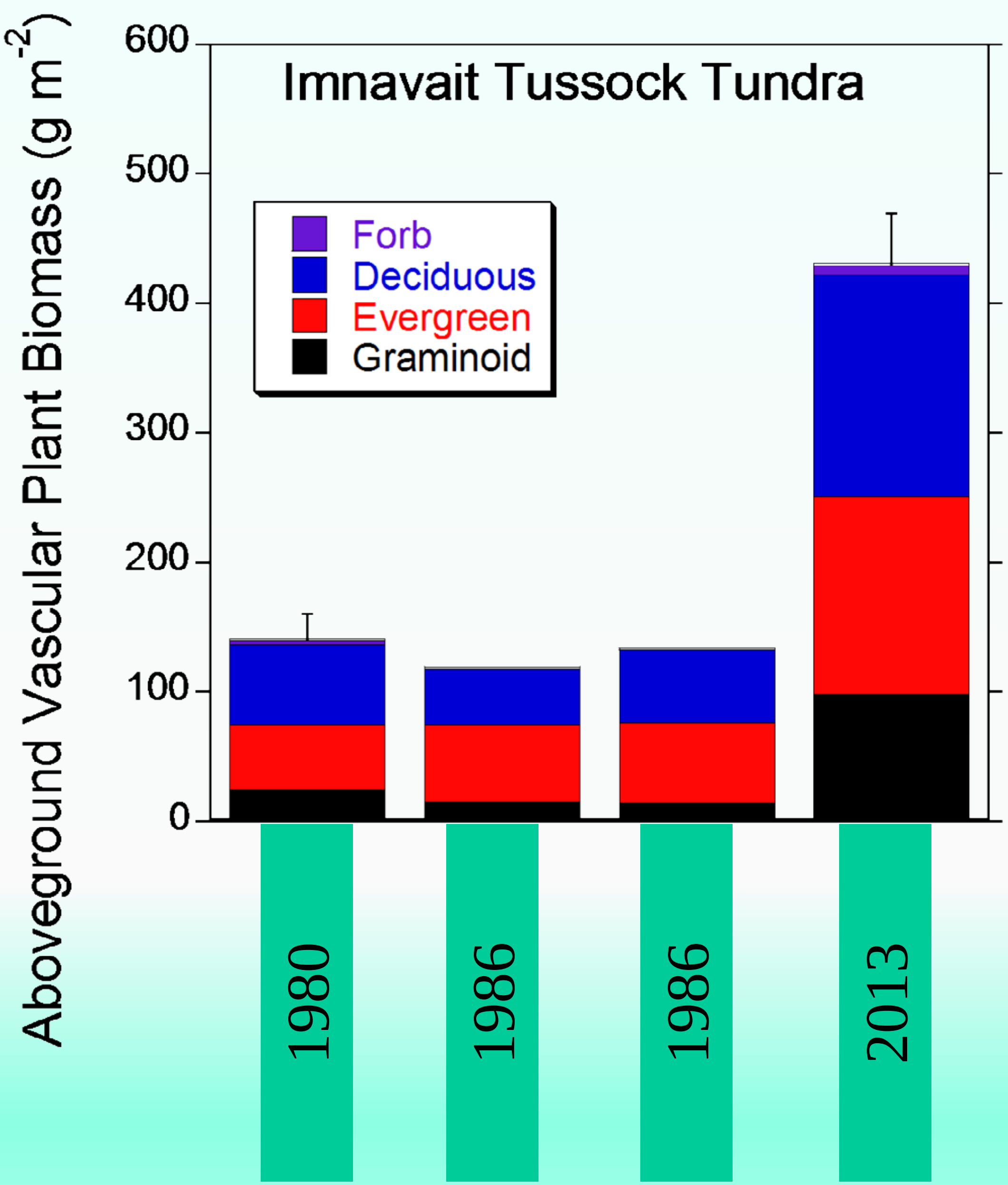


Summer GPP Trends (negative value = uptake)

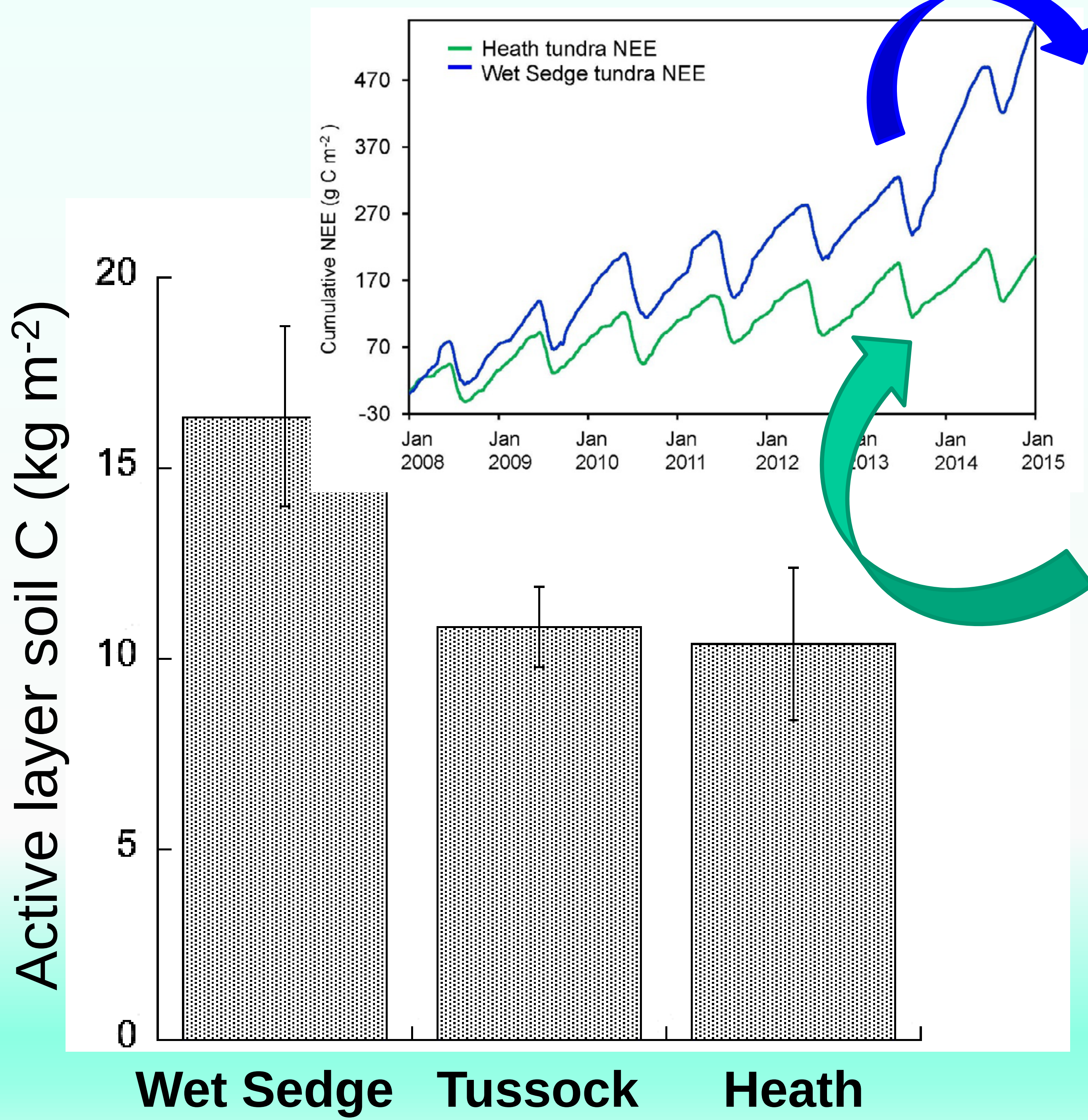


Summer Ecosystem Respiration (ER) Trends (positive value = release)





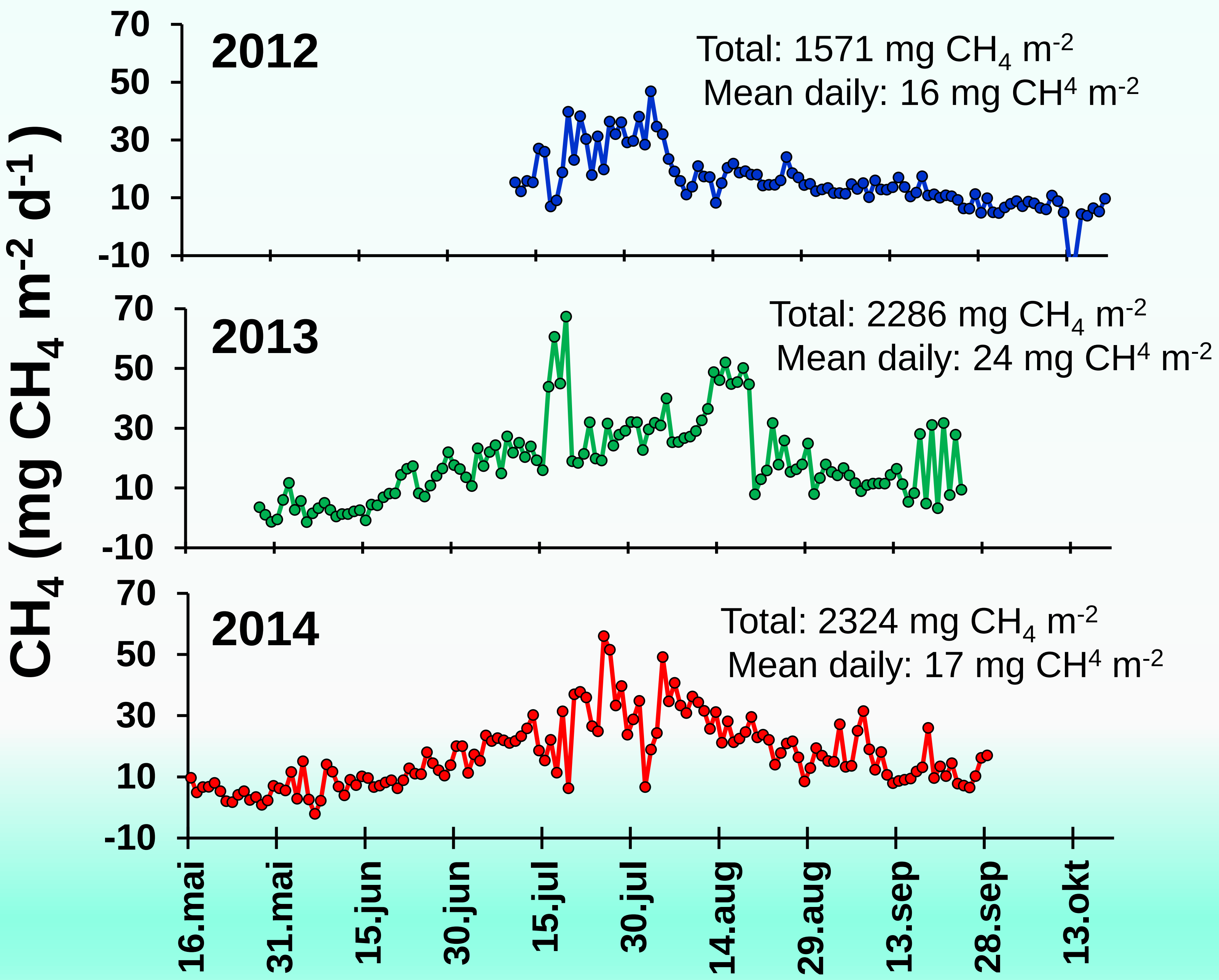
Imnavait Tussock Tundra
Aboveground Vascular Plant Biomass (g m-2)
600
500
400
300
200
100
0
Forb
Deciduous
Evergreen
Graminoid
1980
1986
1986
2013



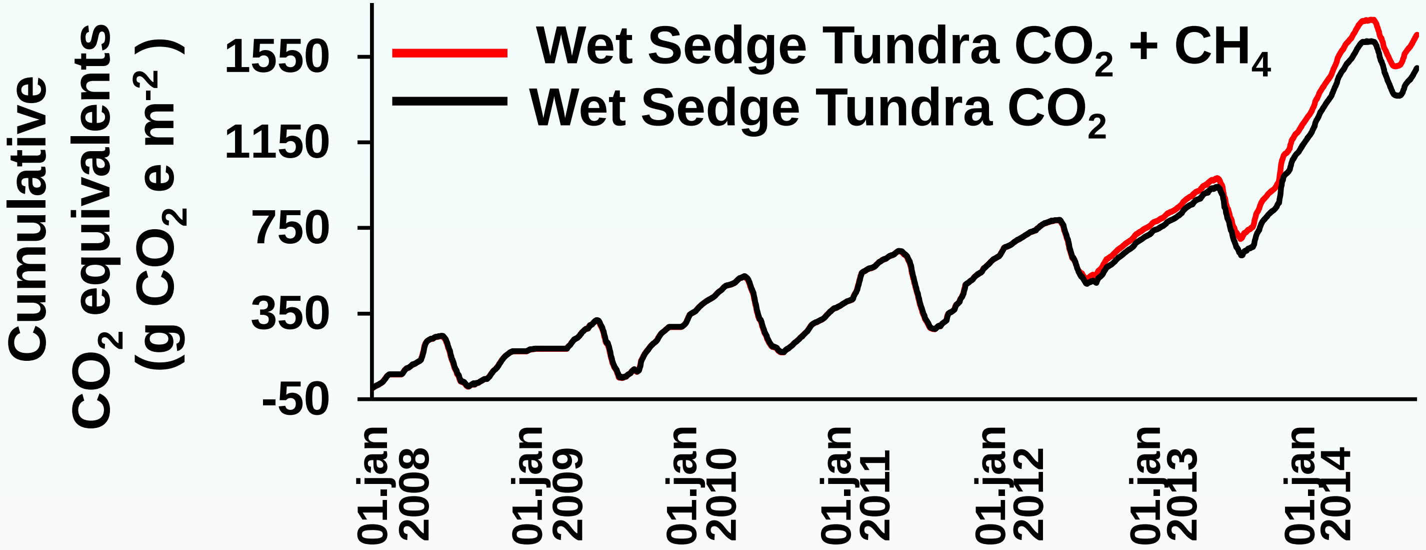
Loss of 554 g C m^{-2} in the wet sedge tundra = 3.6% of the total soil C stocks (0.5% per year)

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

Wet sedge tundra: Methane flux



(Positive Value = CO_2 e Release)



Ecosystems of Northern Alaska

ABSTRACT

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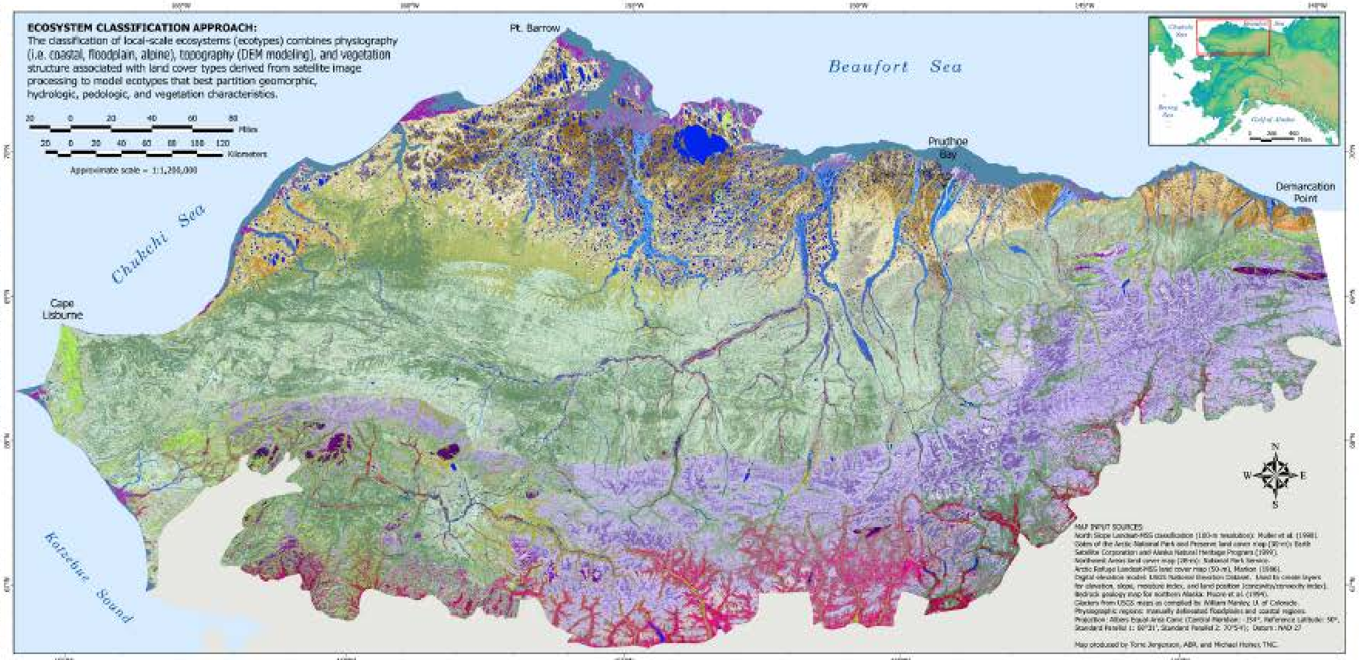
Michael Heiner, The Nature Conservancy, Seattle, WA, mheiner@tnc.org

In response to a need for a unified ecological map for ecoregional planning in northern Alaska by the Nature Conservancy, we developed a map of local-scale ecosystems (ecotypes) that encompasses the Brooks Range, Brooks Foothills, and Beaufort Coastal Plain ecoregions. Our approach to ecological land classification and mapping combined vegetation structure associated with existing landcover maps derived from satellite image processing, with physiography (i.e., coastal, floodplain, alpine), topography (DEM modeling), and bedrock characteristics to model ecotypes that best partition geomorphic, hydrologic, pedologic, and vegetative characteristics. We developed a classification that included 7 alpine, 9 upland, 5 lowland, 10 riverine, 4 coastal, and 1 human-modified ecotypes that encompass a broad diversity of ecological characteristics ranging from boreal forests in the southern Brooks Range to brackish meadows along the Beaufort Sea coast. As input to map development, we used four existing landcover maps for the North Slope by Muller et al. (1999), Gates of the Arctic National Park and Preserve by the Earth Satellite Corporation and Alaska Natural Heritage Program (1999), northwest Alaska parks by the National Park Service (1999), and the Arctic National Wildlife Refuge by Markon (1986). For physiography, we manually delineated floodplains and coastal areas at 1:100,000-scale on NASA Geocover satellite imagery, and differentiated alpine, upland and lowland areas by using a digital elevation model to characterize elevation, slope, moisture index, and land position (concavity/convexity index). Bedrock geology was adapted from Moore et al. (1994). Glacial extent was obtained from USGS maps, as compiled by Manley (pers. comm.). Rule-based models were developed to recode the map classes from the individual landcover maps into ecotypes. In the resulting map of the 300,200-km² area, 55% of the area has upland, 18% has alpine, 17% has lowland, 9% has riverine, 3% has coastal, and <0.1% has human-modified ecotypes. Each ecotype typically is associated with 3–4 geomorphic units, 3–4 closely related soil types, 3–5 plant associations, and differing permafrost conditions. For ecoregional planning, the map was used to identify rare ecosystems and high-value wildlife habitats deserving priority protection.

ABR

The Nature Conservancy

ECOTYPE DESCRIPTIONS



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

MAP INPUT SOURCES

MODELING APPROACH

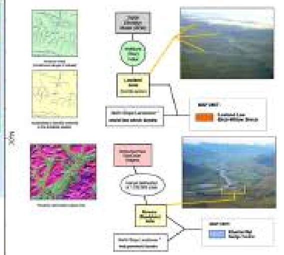
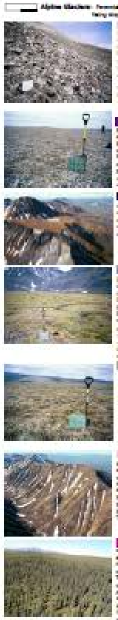


Table 1. Areal extent of ecotypes in northern Alaska.



Alpine Non-carbonate Barrens

Alpine Carbonate Barrens

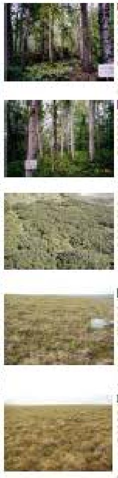
Alpine Mafic Barrens

Alpine Non-carbonate Dryas Dwarf Shrub

Alpine Carbonate Dryas Dwarf Shrub

Alpine Mafic Dryas Dwarf Shrub

Upland Spruce Forest



Upland Birch-Aspen-Spruce Forest

Upland Birch-Aspen Forest

Upland Tall Alder Shrub

Upland Low Birch-Willow Shrub

Upland Shrubby Tussock Tundra

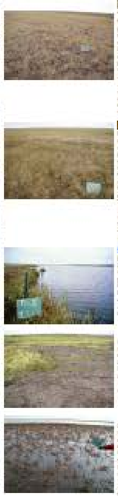
Upland Tussock Tundra

Upland Dryas Dwarf Shrub Tundra

Upland Moist Sedge-Shrub Tundra

Lowland Spruce Forest

Lowland Low Birch-Willow Shrub



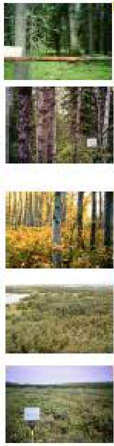
Lowland Moist Sedge-Shrub Tundra

Lowland Wet Sedge Tundra

Lowland Water

Lacustrine Barrens

Lacustrine Marsh



Riverine Spruce Forest

Riverine Spruce-Balsam Poplar Forest

Riverine Balsam Poplar Forest

Riverine Tall Alder-Willow Shrub

Riverine Low Willow Shrub

Riverine Dryas Dwarf Shrub

Riverine Moist Sedge-Shrub Tundra

Riverine Wet Sedge Tundra

Riverine Marsh

Riverine Barrens

Riverine Waters

Coastal Grass and Dwarf Shrub Tundra

Coastal Wet Sedge Tundra

Coastal Barrens

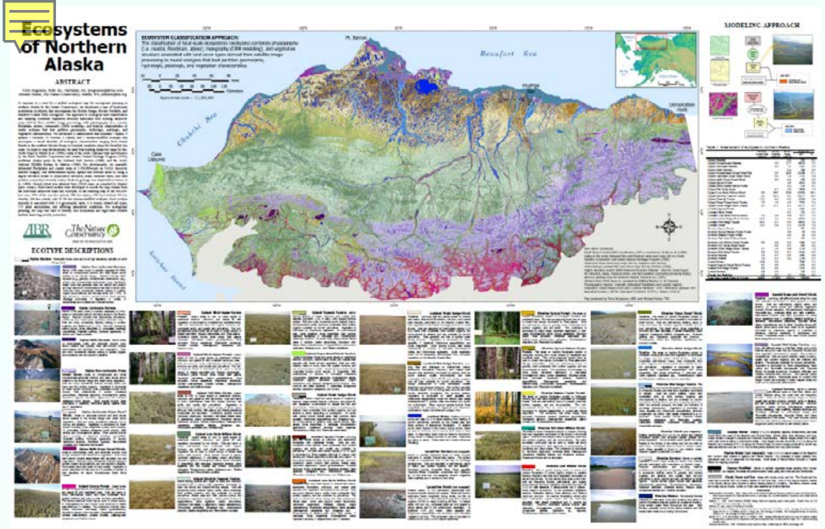
Coastal Water

Marine Water

Human Modified

Cloud, Snow and Ice

References



Heath

Tussock (graminoid)

Wetland / Wet sedge

43,000 km^2

74,000 km^2

30,000 km^2

= 147,000 km^2

Arctic tundra land area in Alaska: 300,000 km^2

2012-2014

Vegetation type	Area (km^2)	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

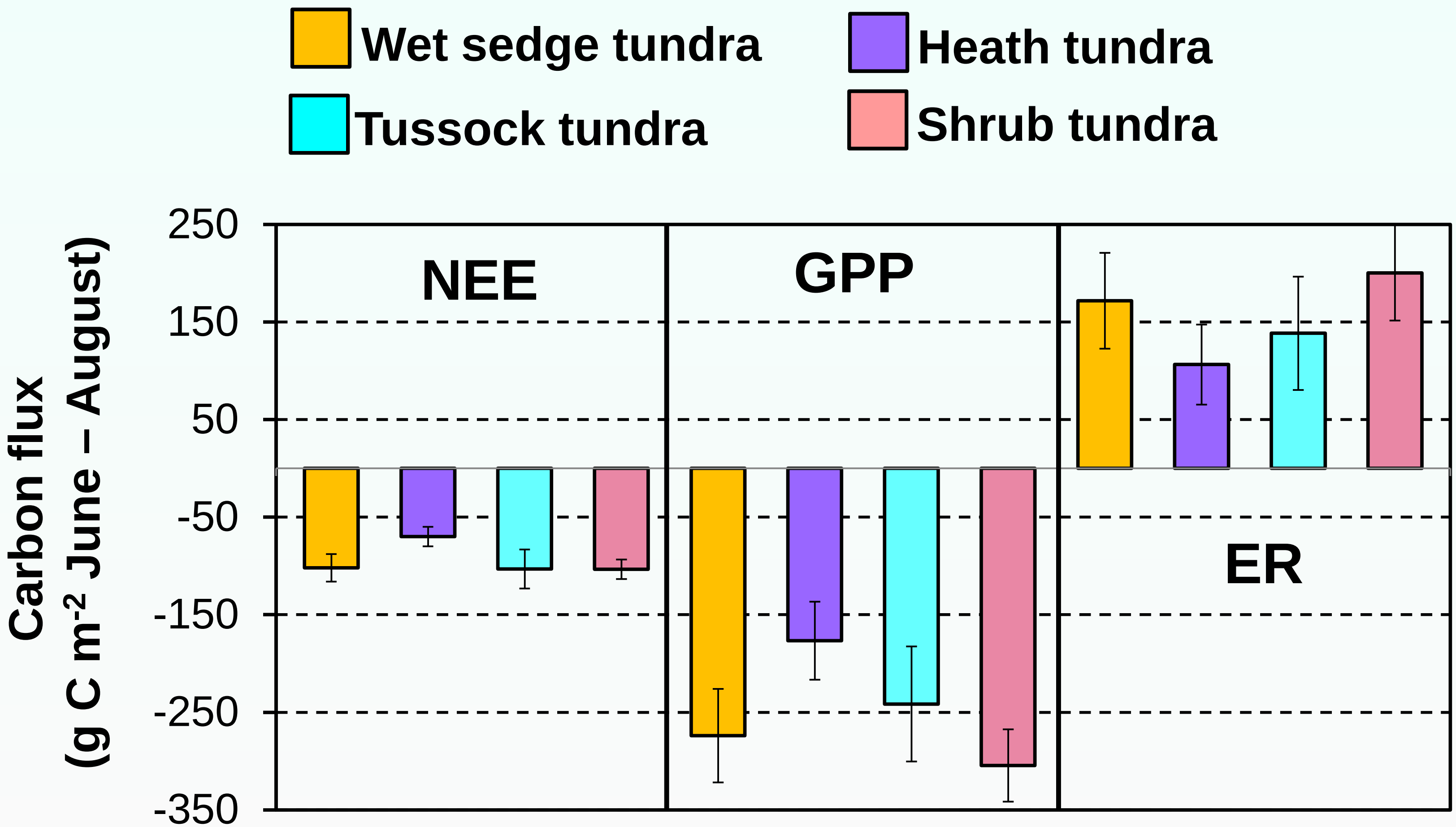
Conclusions:

-Important to take into account landscape heterogeneity and interannual variability

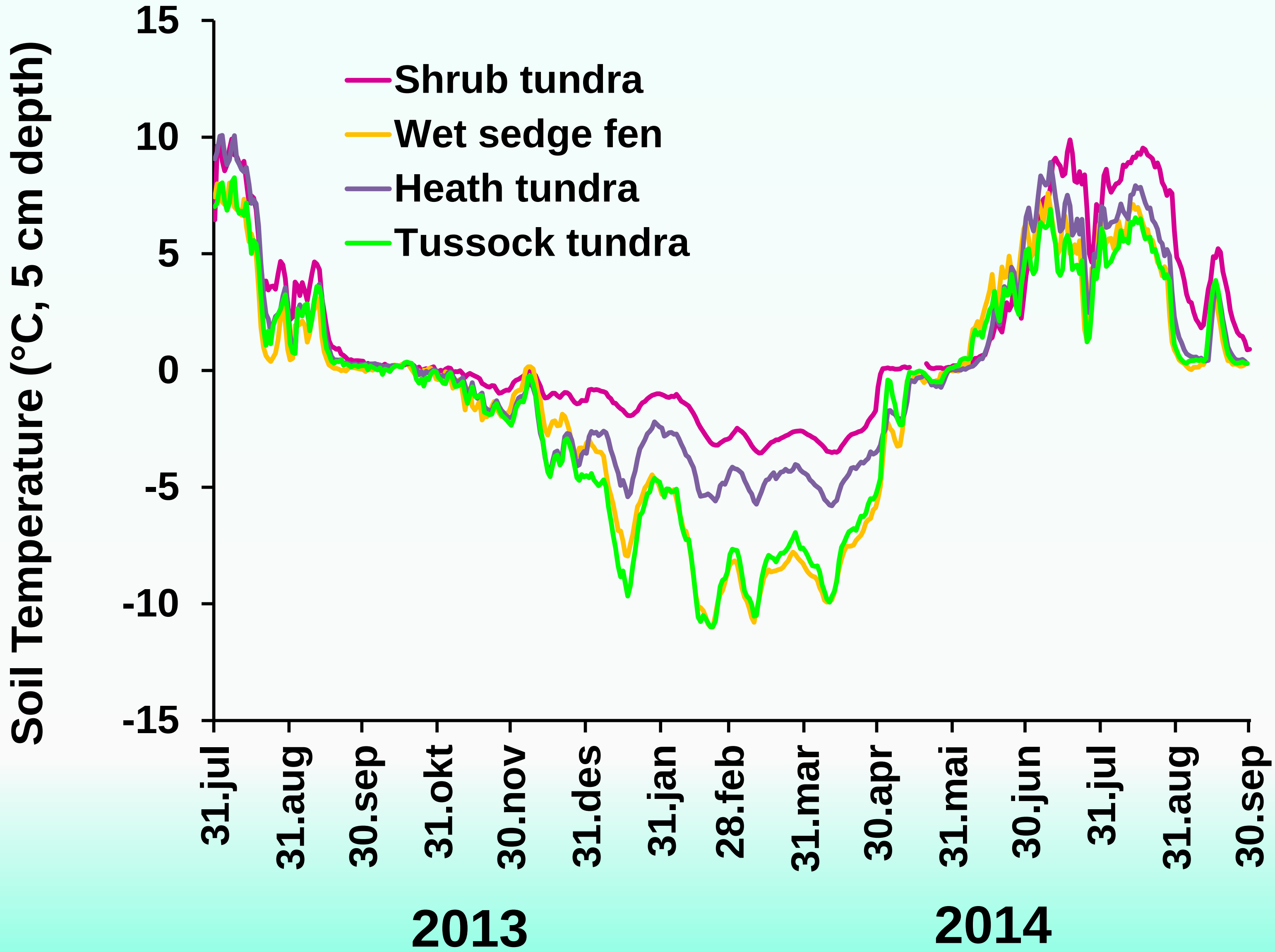
-Wet sedge tundra a greater source of CO_2 in recent years with warmer late fall/ early winter

-CH_4 emissions at the wet sedge added a small component to annual CO_2 equivalent emissions

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

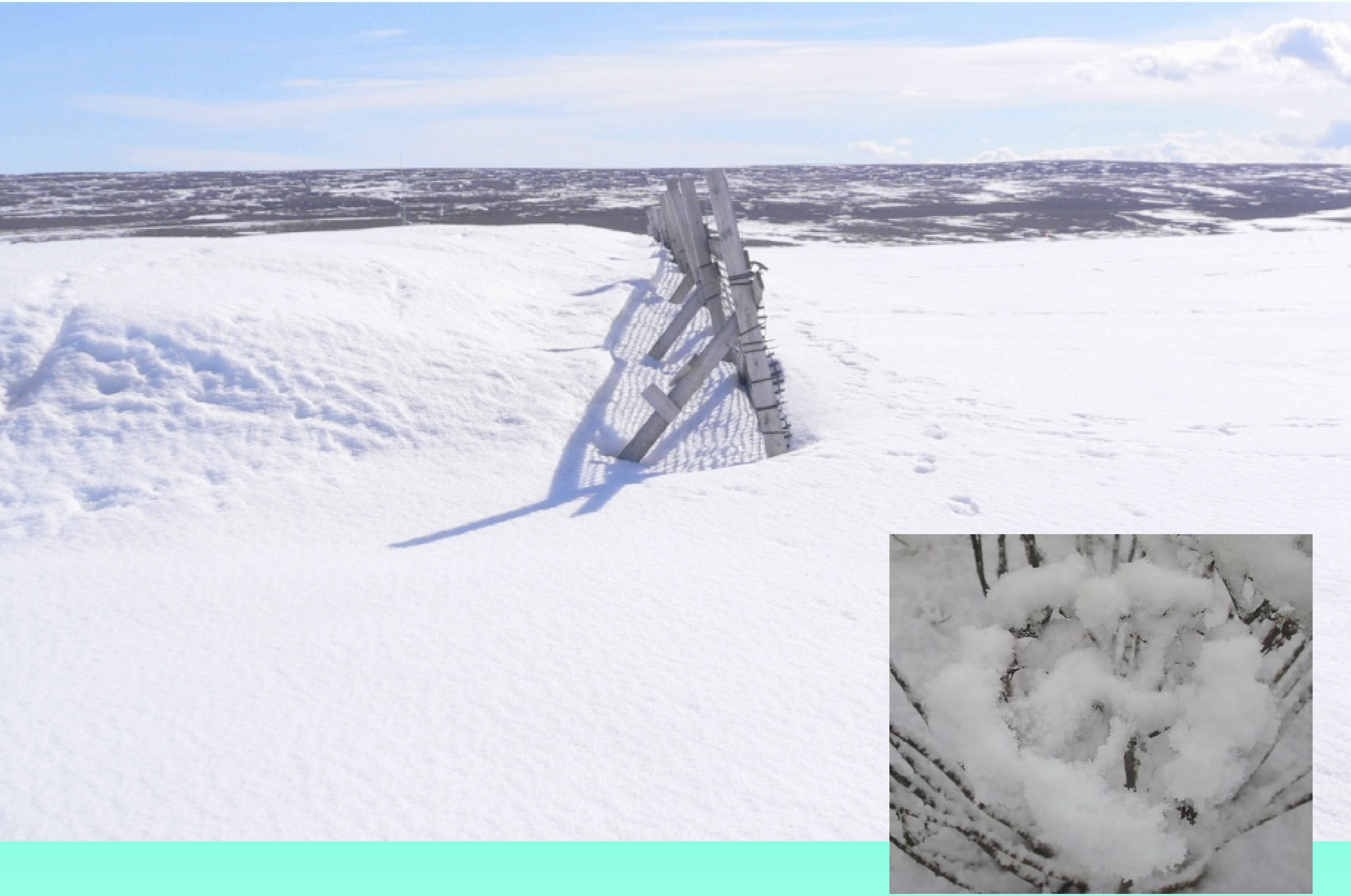


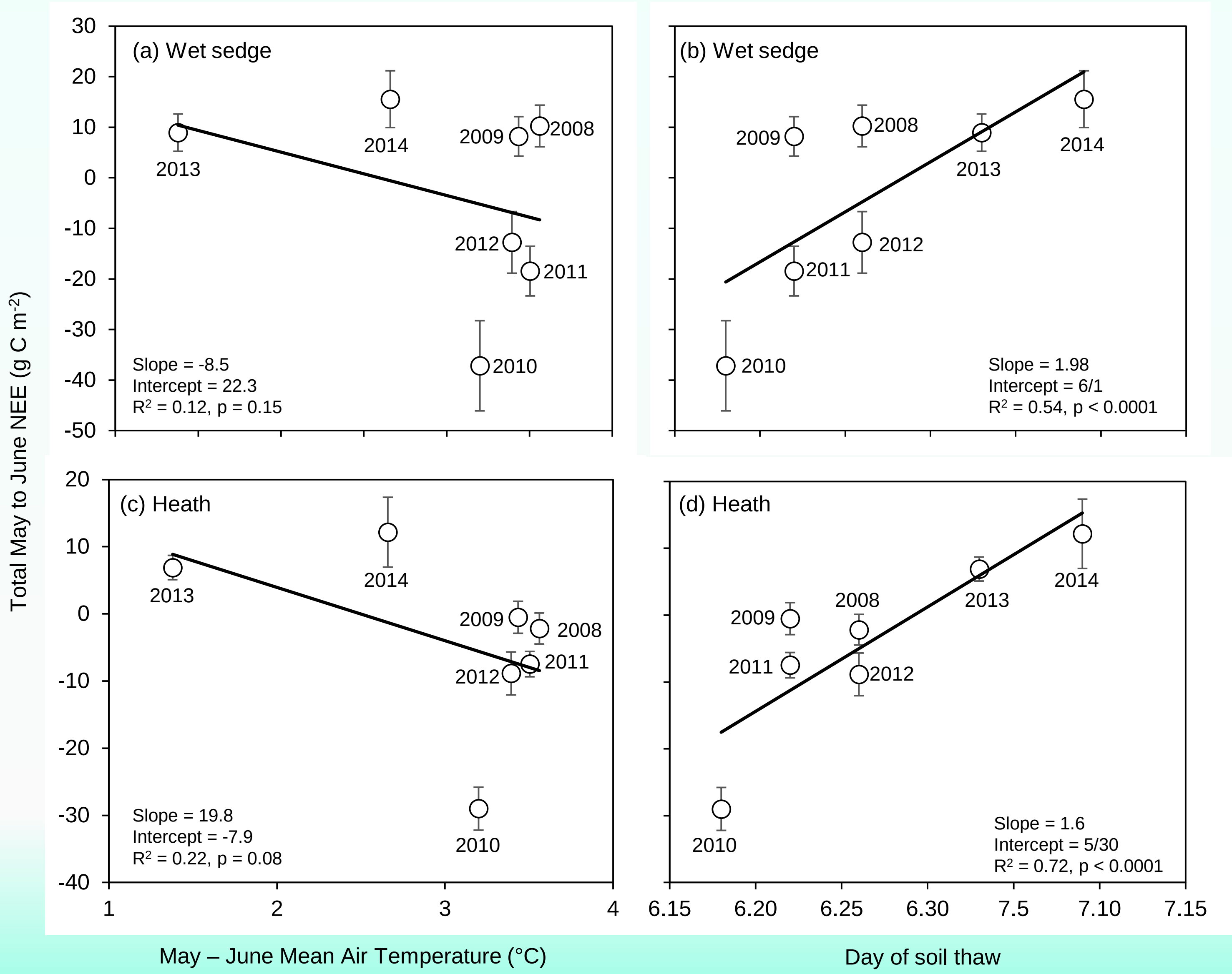
Data from 2013 – 2014 (n =2)



Soil Temperature (°C, 5 cm depth)
15
10
5
0
-5
-10
-15
Shrub tundra
Wet sedge fen
Heath tundra
Tussock tundra
31.jul
31.aug
30.sep
31.okt
30.nov
31.des
31.jan
28.feb
31.mar
30.apr
31.mai
30.jun
31.jul
31.aug
30.sep
2013
2014

Winter shrub albedo





Supplementary Figure 2