Using the ITEX-AON network to document and understand terrestrial ecosystem change in the New Arctic

Bob Hollister (GVSU –Grand Valley State University)
Steve Oberbauer (FIU –Florida International University)
Craig Tweedie (UTEP –University of Texas at El Paso)
Jeff Welker (UAA –University of Alaska at Anchorage)

Arctic Ecology Program https://www.gvsu.edu/aep

What is the New Arctic?

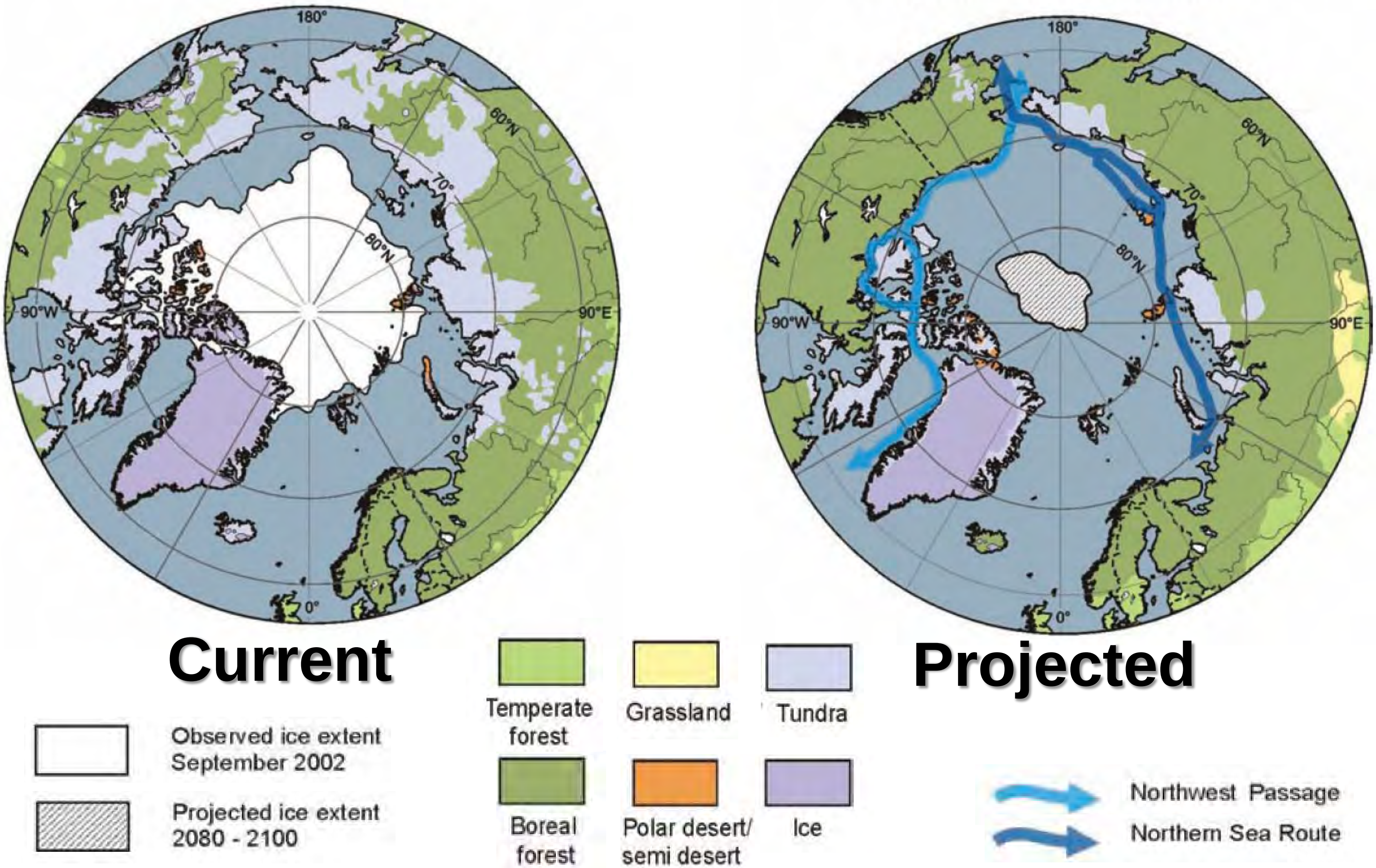
NSF'S 10 BIG IDEAS

Navigating the New Arctic

Establishing an observing network of mobile and fixed platforms and tools across the Arctic to document and understand the Arctic's rapid biological, physical, chemical, and social changes. Current Arctic observations are sparse and inadequate for enabling discovery or simulation of the processes underlying Arctic system change or to assess their environmental and economic impacts on the broader Earth system.

Arctic change will fundamentally alter climate, weather and ecosystems globally in ways that we do not yet understand but that will have profound impacts on the world's economy and security.

What is the New Arctic?

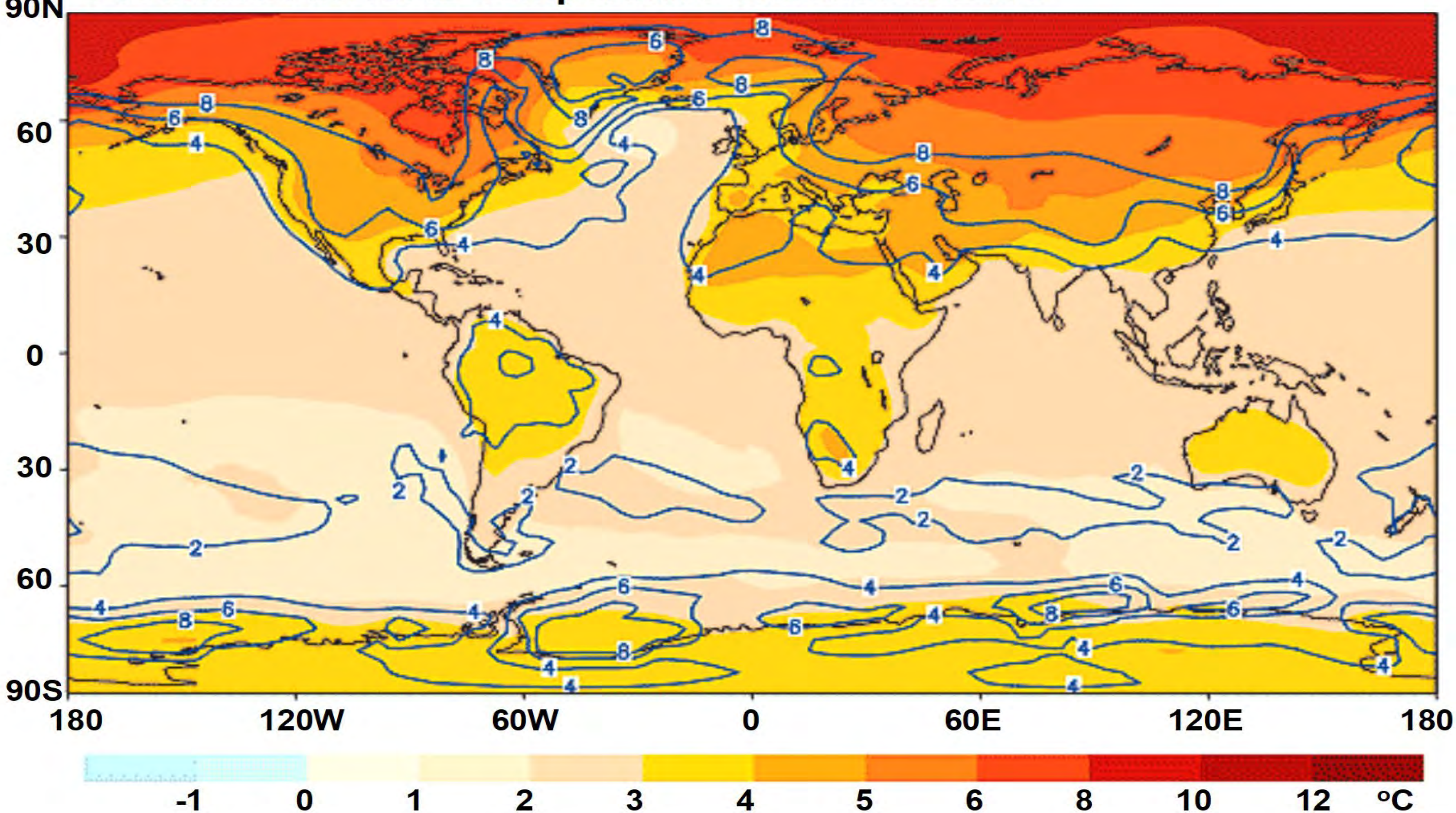


IPCC (Intergovernmental Panel on Climate Change) 2007.

Why?

Warming

Predicted ANNUAL Temperature Increase in 2100



IPCC (Intergovernmental Panel on Climate Change) 2001.
Climate Change 2001: The Scientific Basis

Why?

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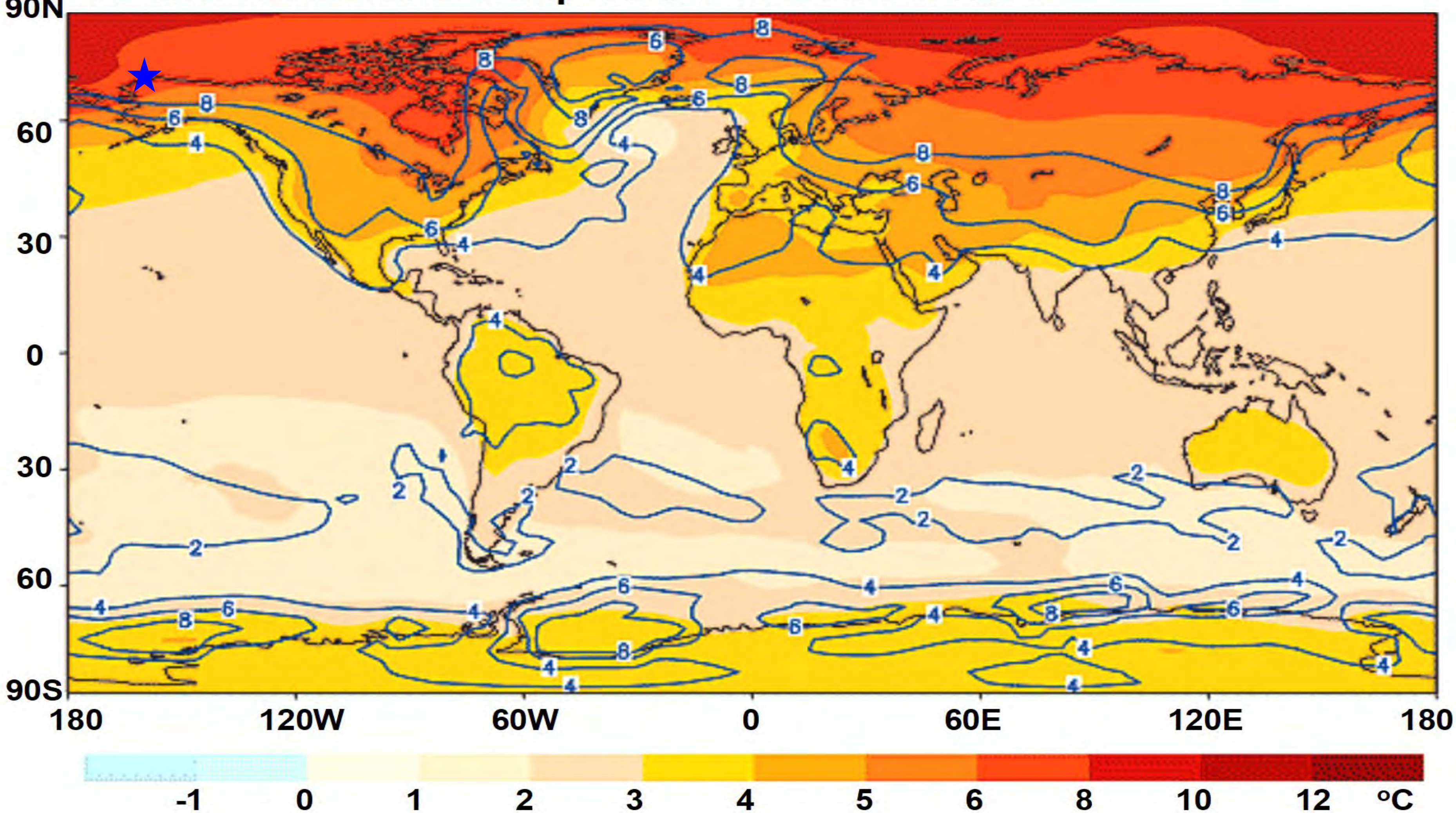
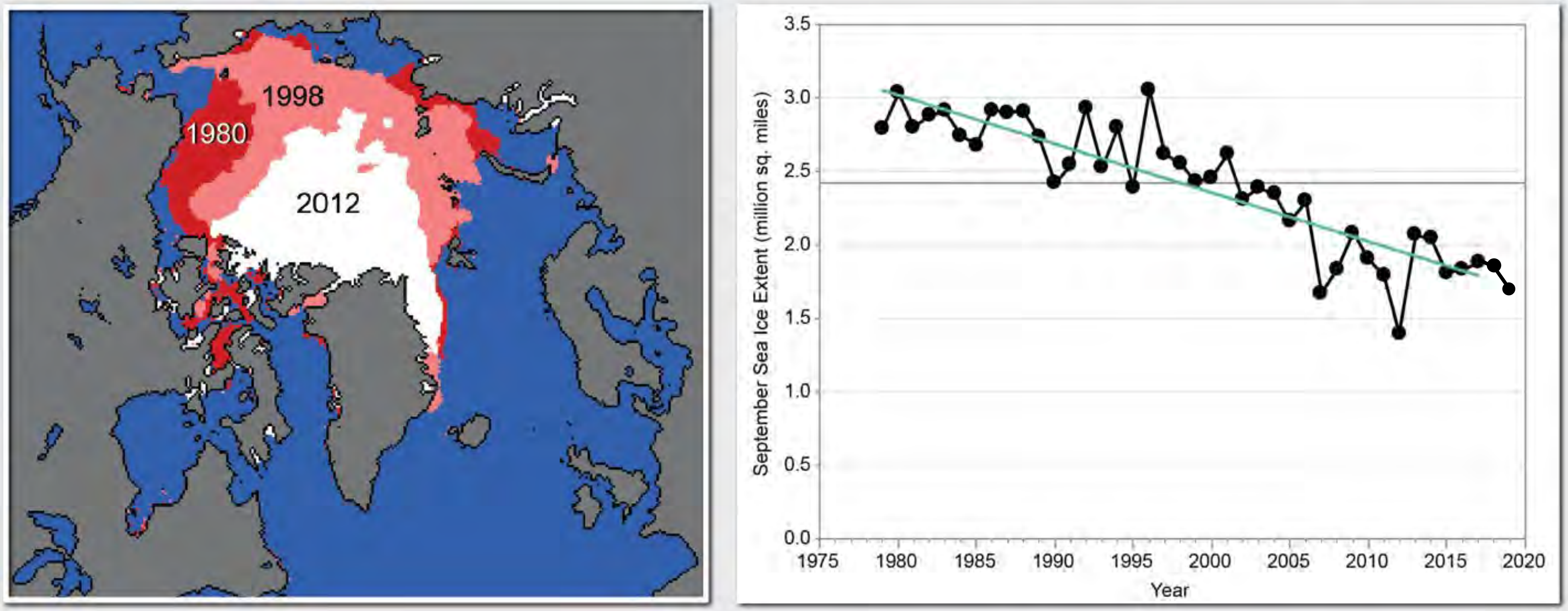


IPCC (Intergovernmental Panel on Climate Change) 2001.
Climate Change 2001: The Scientific Basis

Observed Change

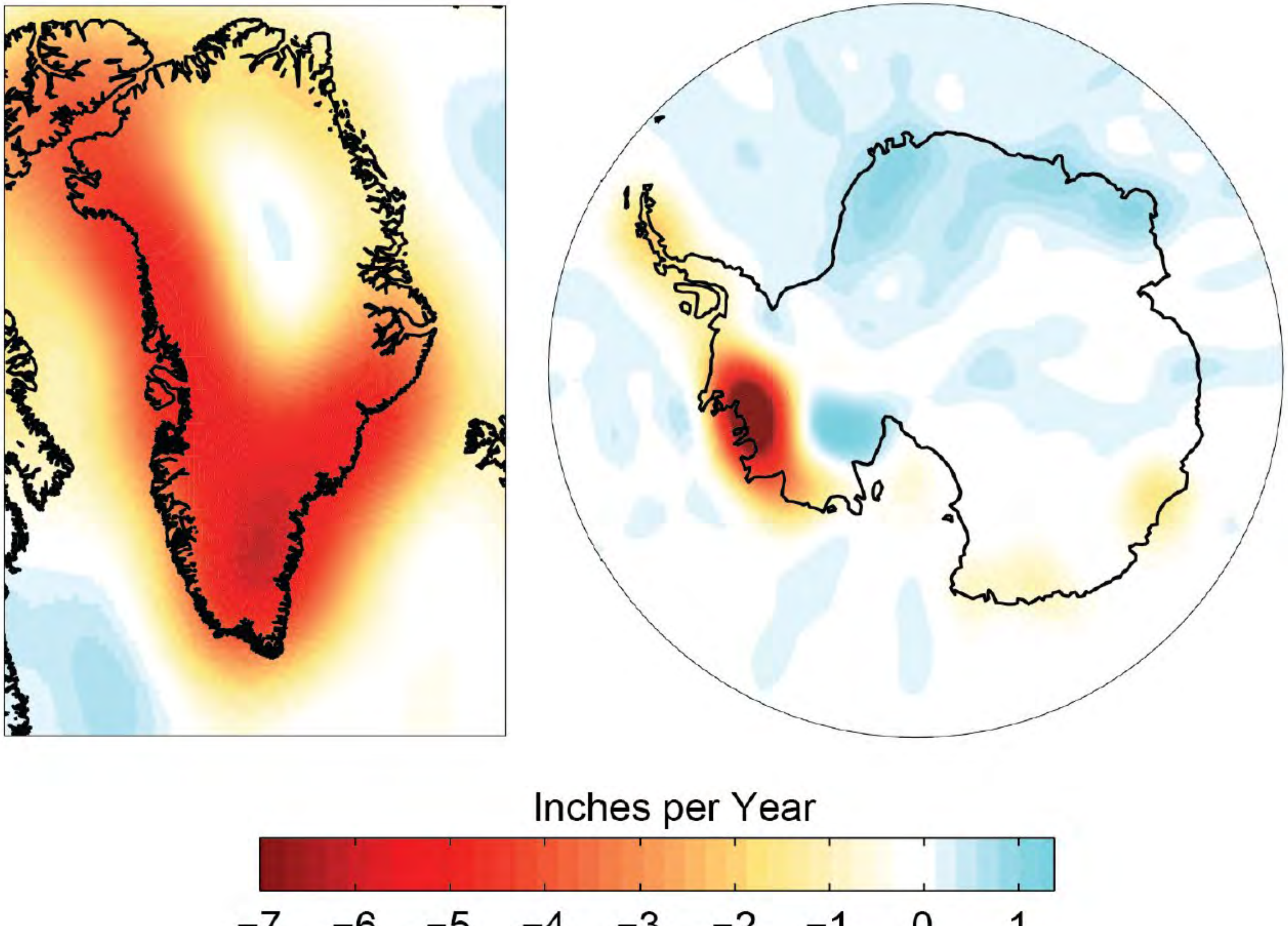
Sea Ice (end of the summer)



Fourth National Climate Assessment 2018

Observed Change

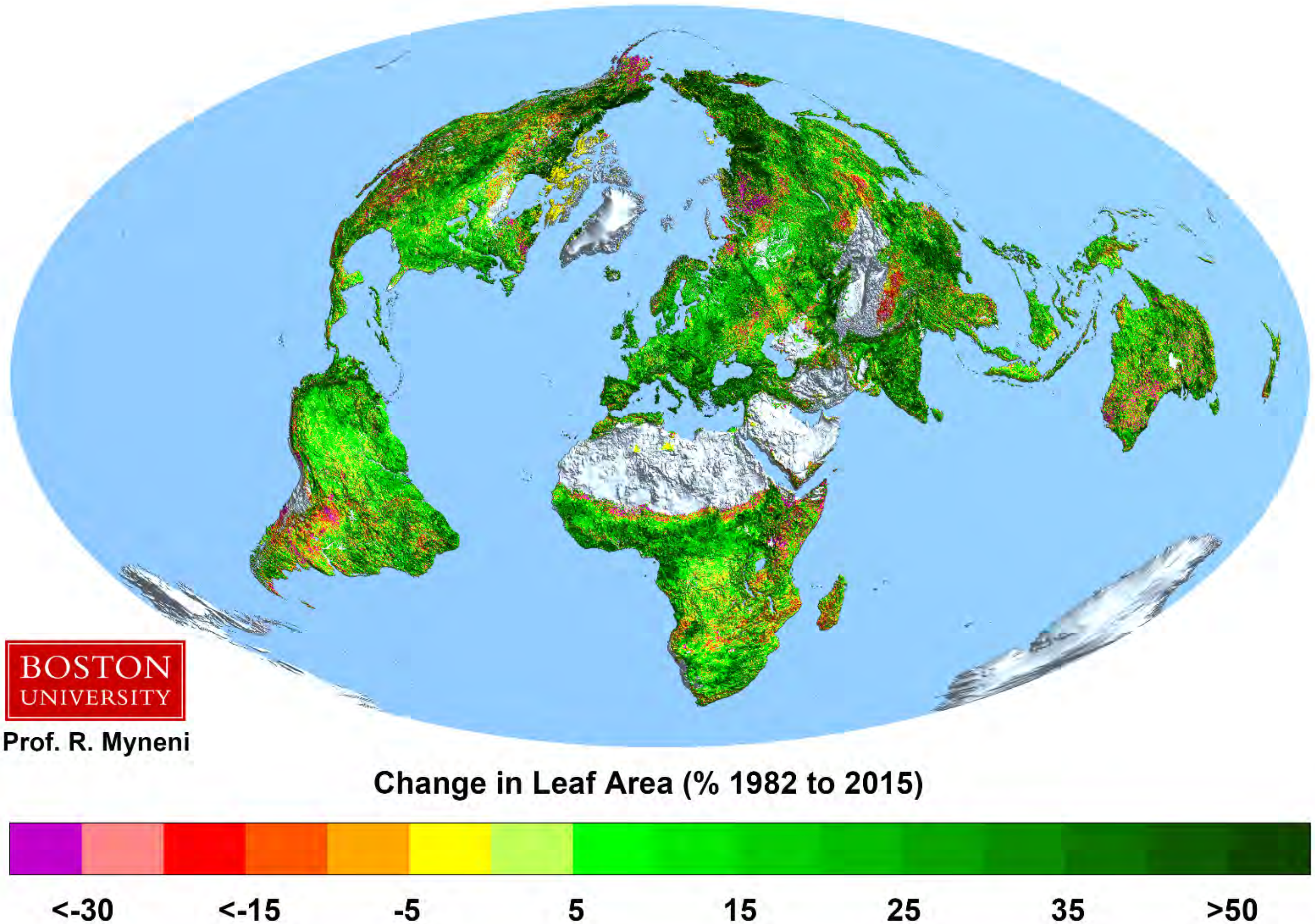
Ice Loss from Greenland & Antarctica



US National Climate Assessment 2014

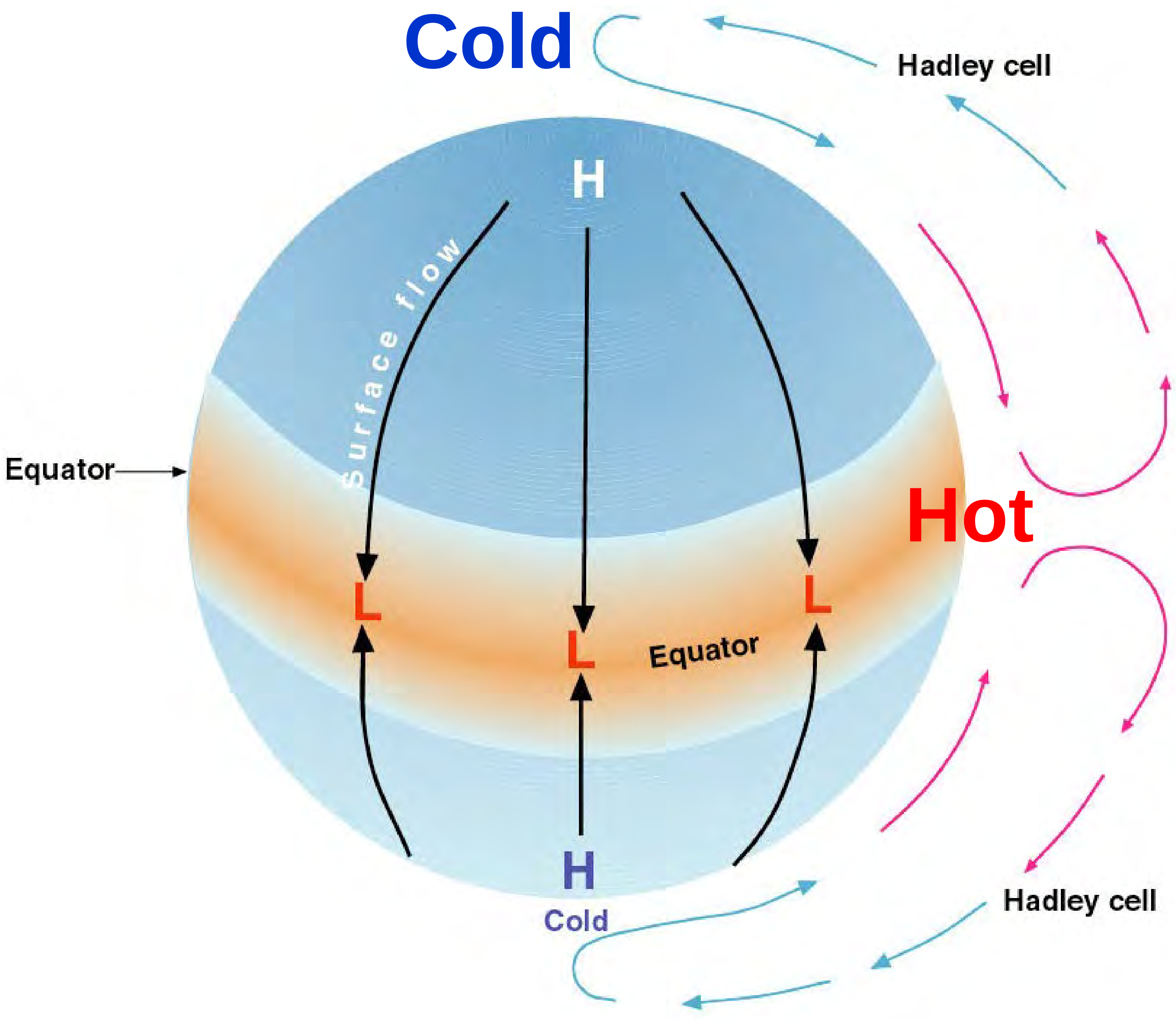
Observed Change

Greening Trend

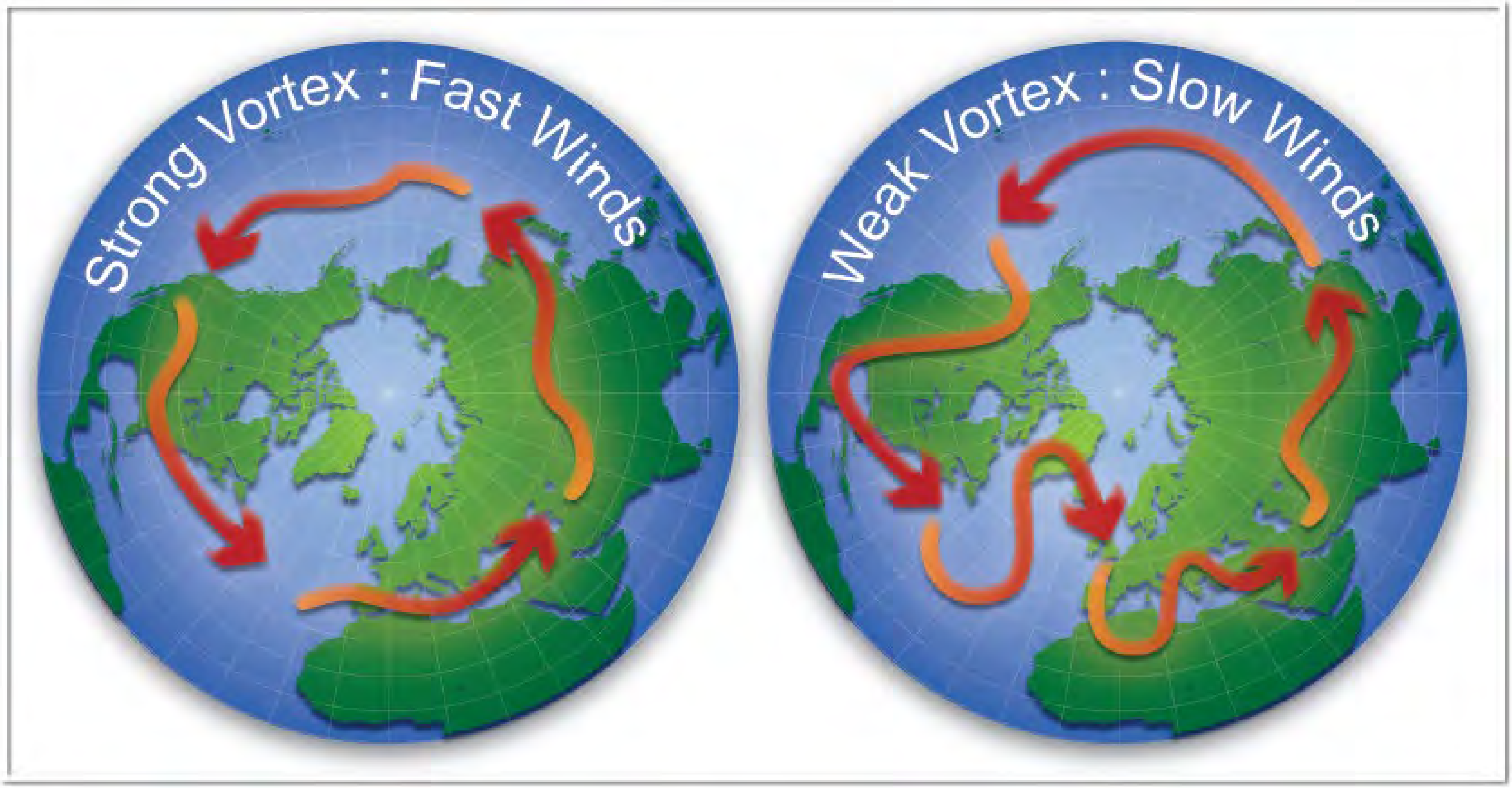


Importance of the Arctic

Simplified Energy Movement

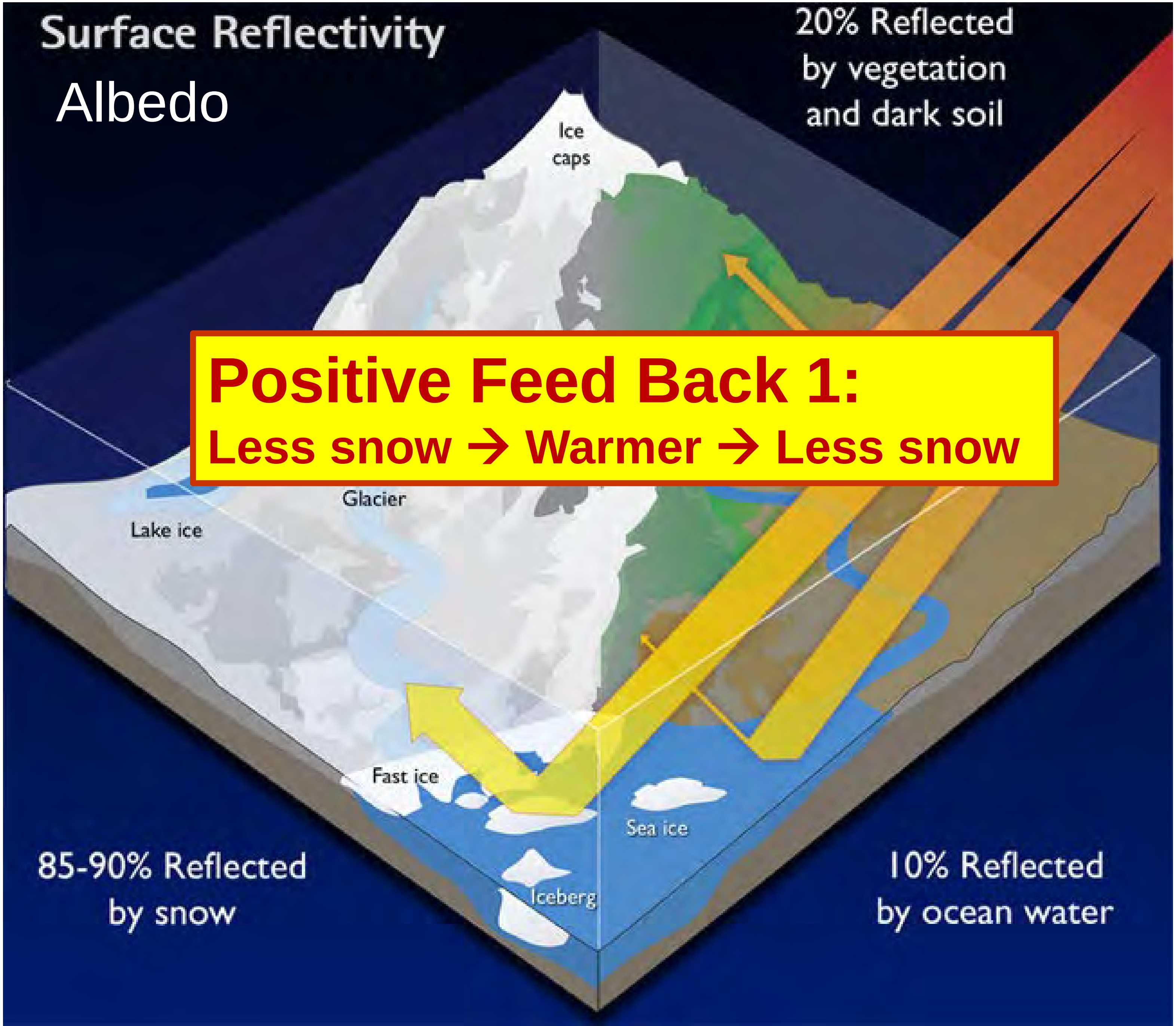


“Polar Vortex”

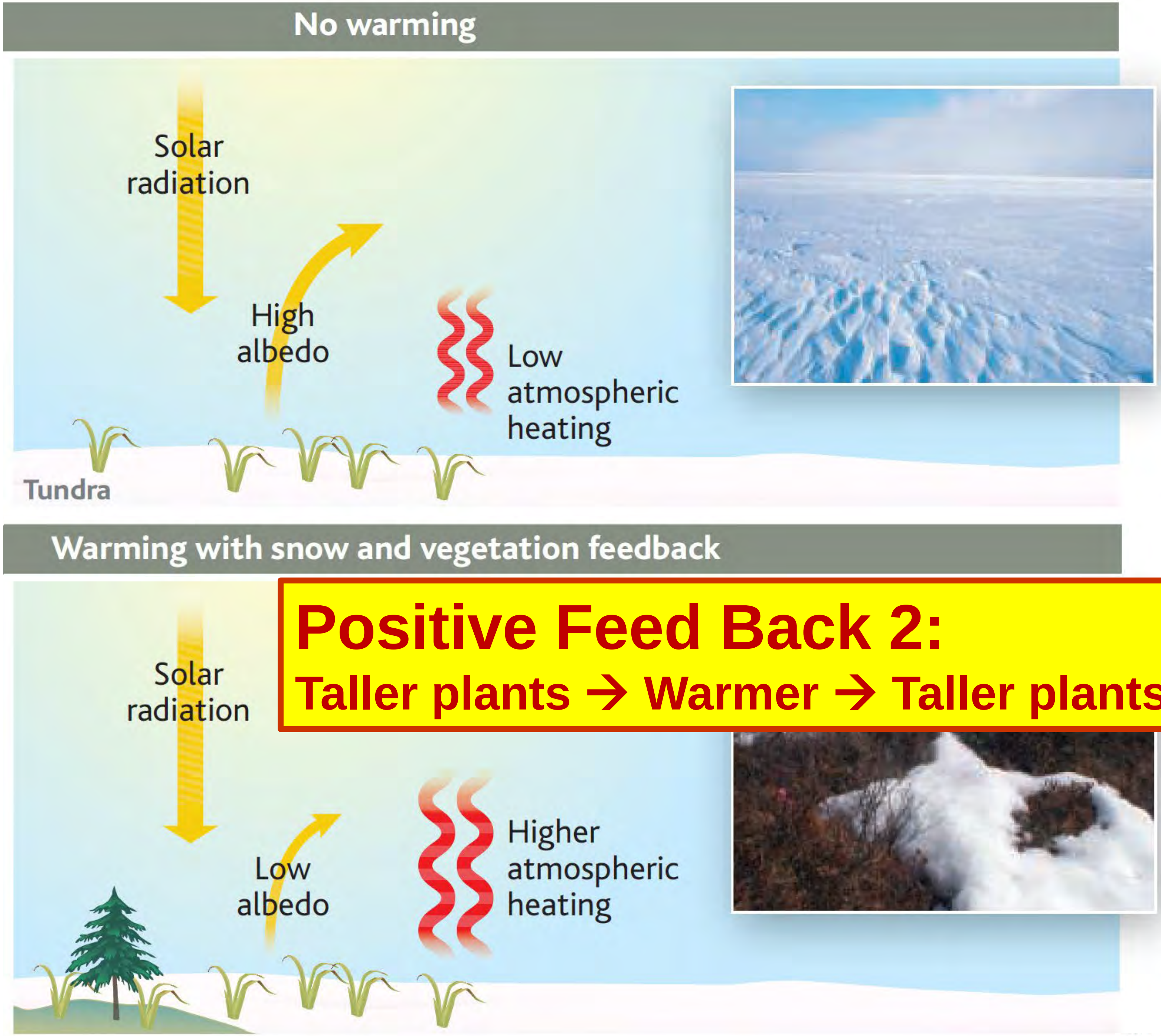


NCADAC v. 11 Jan 2013

Albedo



Positive Feed Back 1:
Less snow → Warmer → Less snow



Positive Feed Back 2:

Taller plants → Warmer → Taller plants

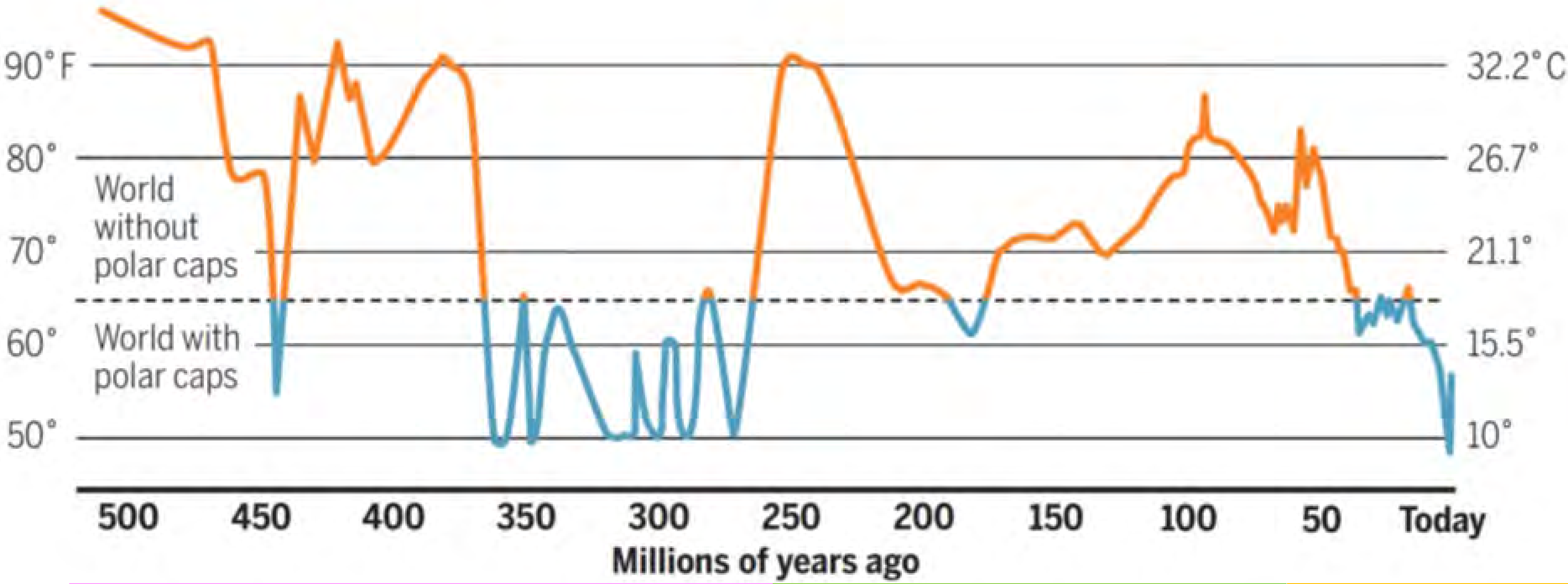
SCIENCE VOL 310 28 OCTOBER 2005

Carbon Release

Positive Feed Back 3:

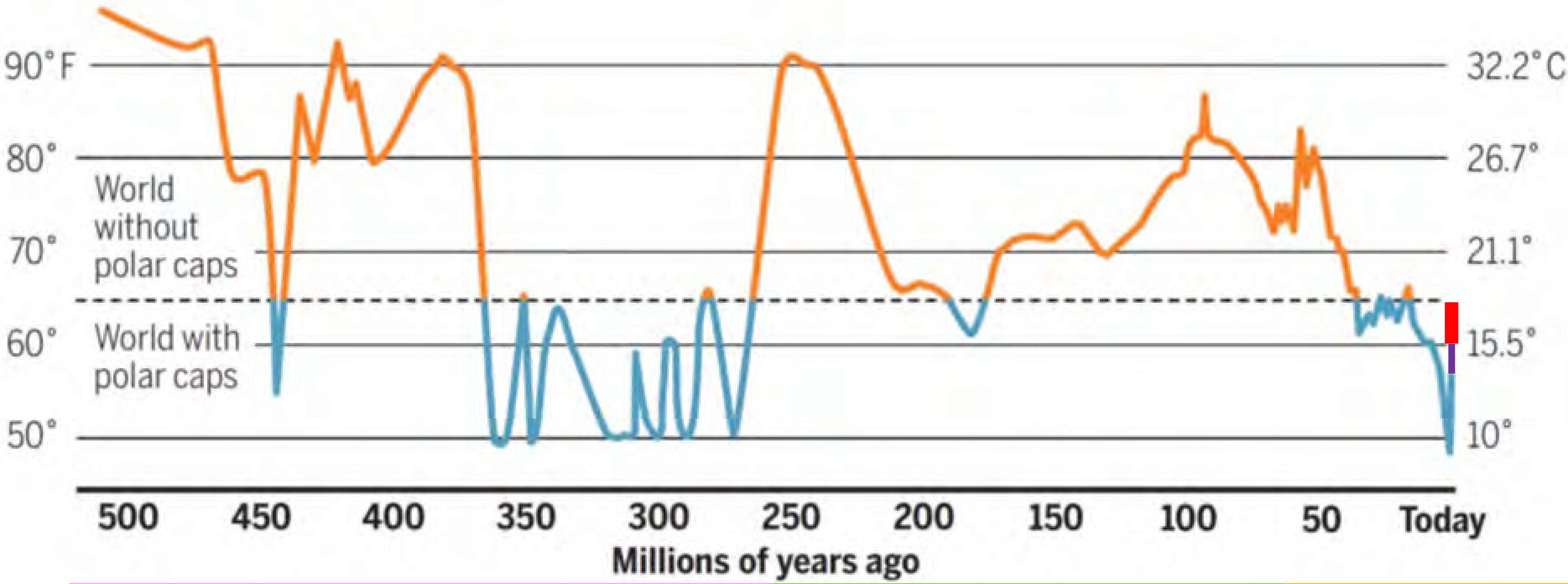
Carbon release→ Warmer → Carbon release

Paleo-Perspective (the world was much warmer)



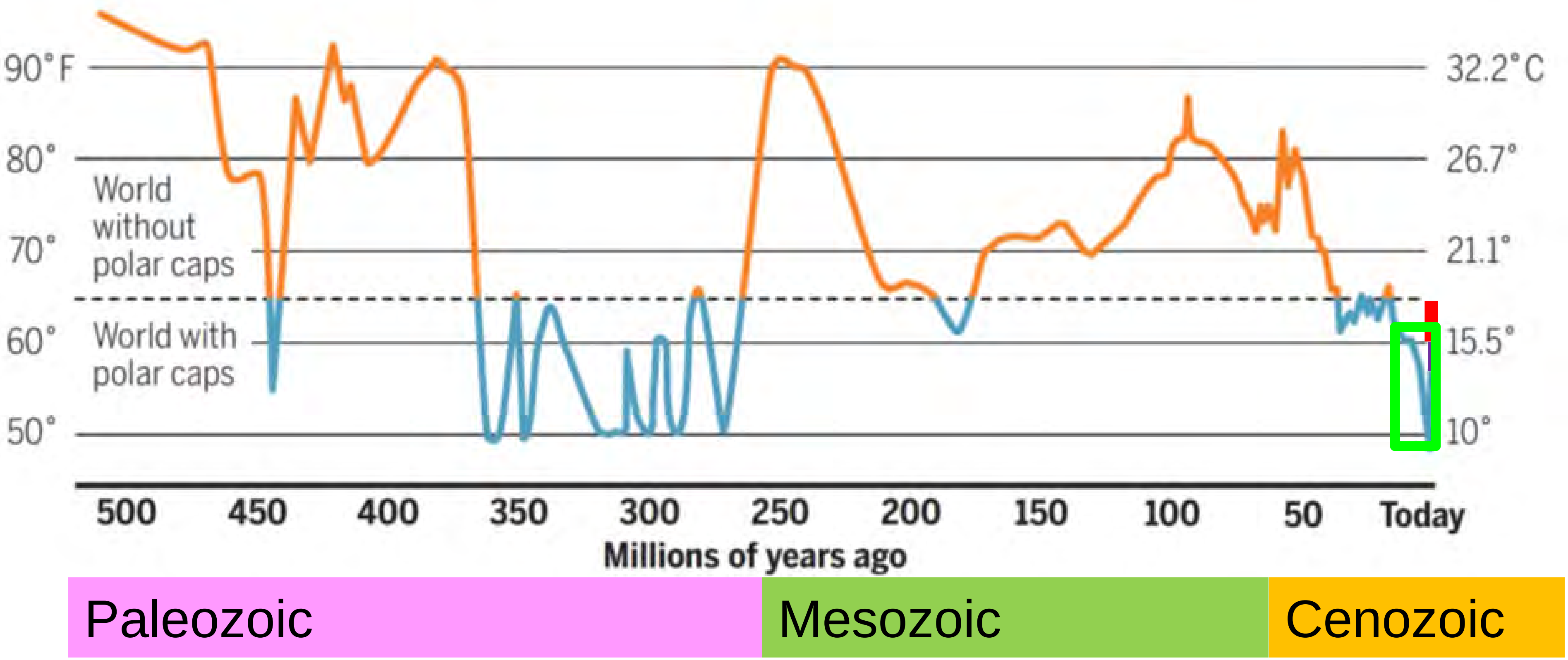
Paleozoic | Mesozoic | Cenozoic

Paleo-Perspective (the world was much warmer)

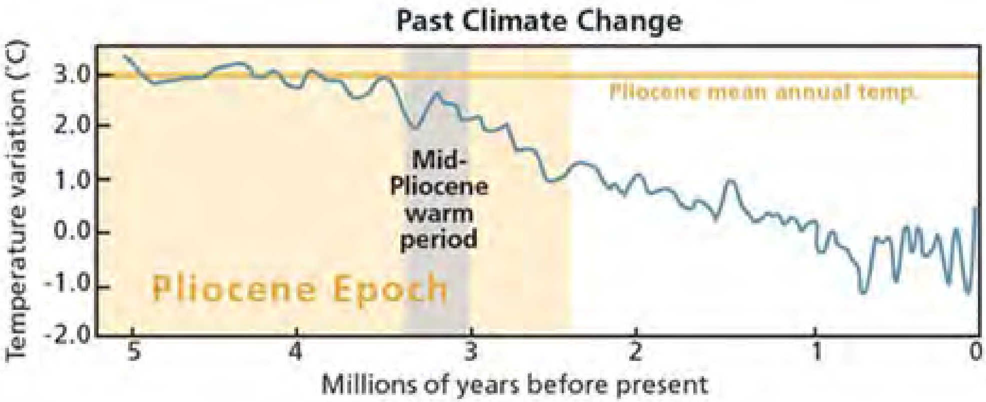


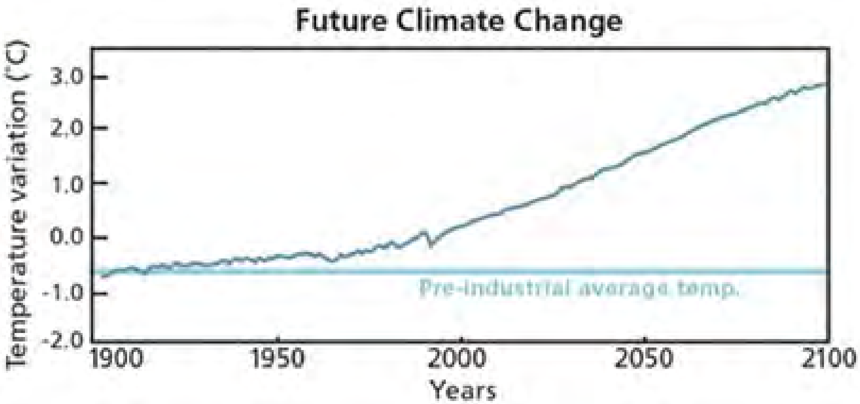
Paleozoic | Mesozoic | Cenozoic

Paleo-Perspective (the world was much warmer)

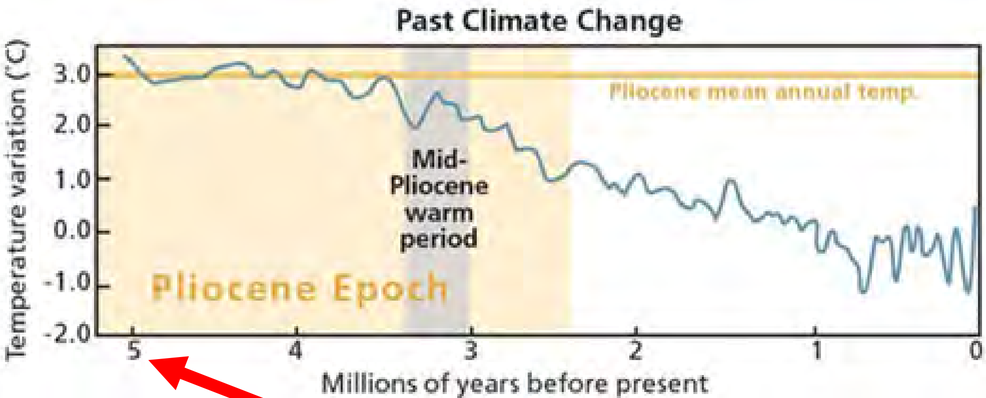


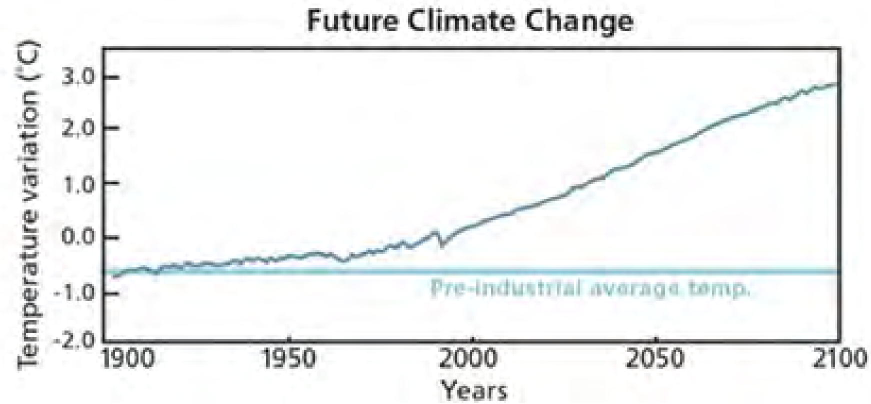
24 MAY 2019 • VOL 364 ISSUE 6442 717 SCIENCE

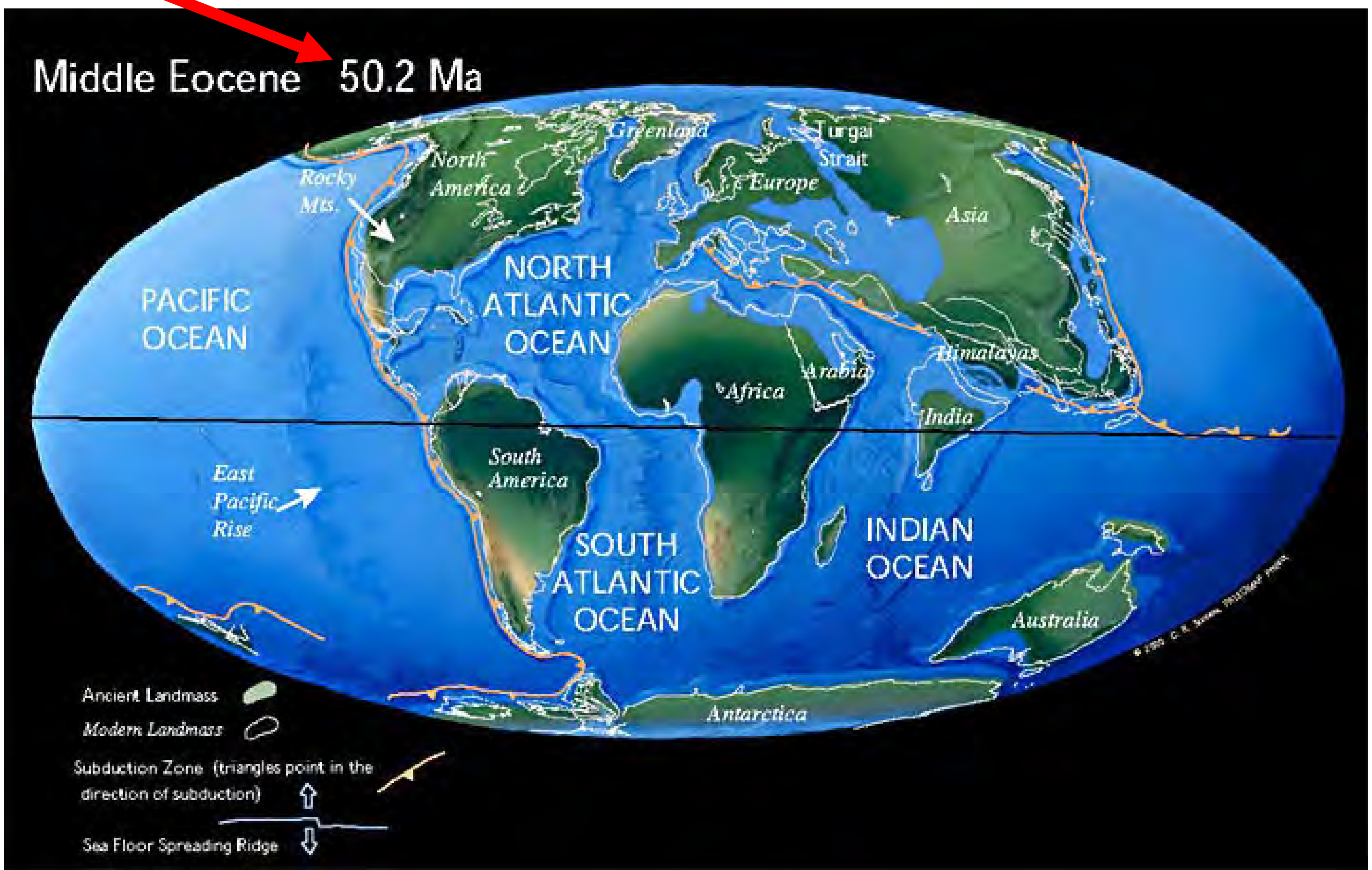




Powel K. 2015. Discover. April:47-53.


Past Climate Change
Temperature variation (°C)
3.0
2.0
1.0
0.0
-1.0
-2.0
Pliocene mean annual temp.
Mid-
Pliocene
warm
period
Pliocene Epoch
5
4
3
2
1
0
Millions of years before present


Future Climate Change
Temperature variation (°C)
3.0
2.0
1.0
0.0
-1.0
-2.0
Pre-industrial average temp.
1900
1950
2000
2050
2100
Years


Middle Eocene 50.2 Ma
Greenland
Turgai
Strait
North
America
Rocky
Mts.
Europe
Asia
PACIFIC
OCEAN
NORTH
ATLANTIC
OCEAN
Himalayas
Arabia
Africa
India
South
America
East
Pacific
Rise
SOUTH
ATLANTIC
OCEAN
INDIAN
OCEAN
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the
direction of subduction)
Sea Floor Spreading Ridge

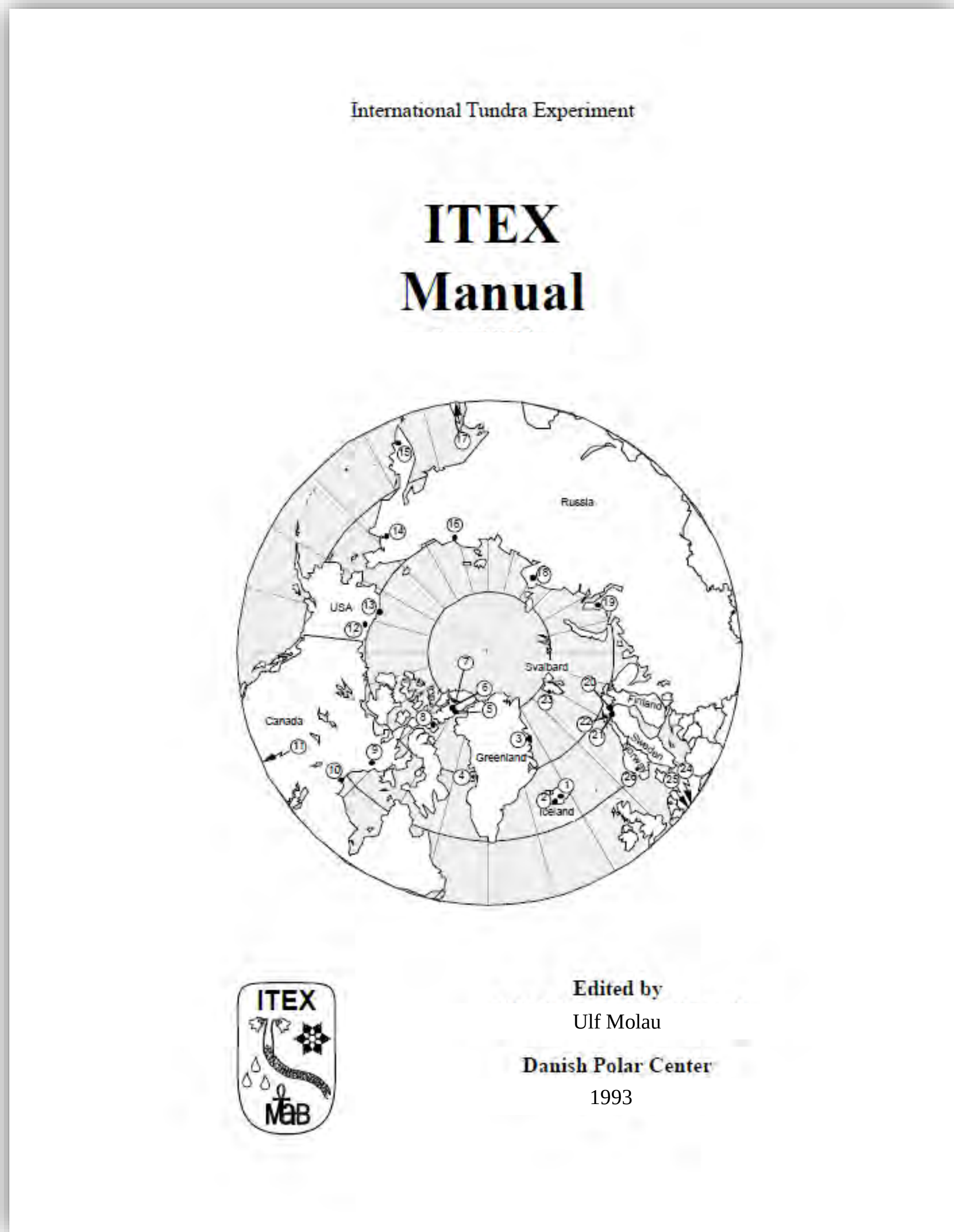
What is ITEX?

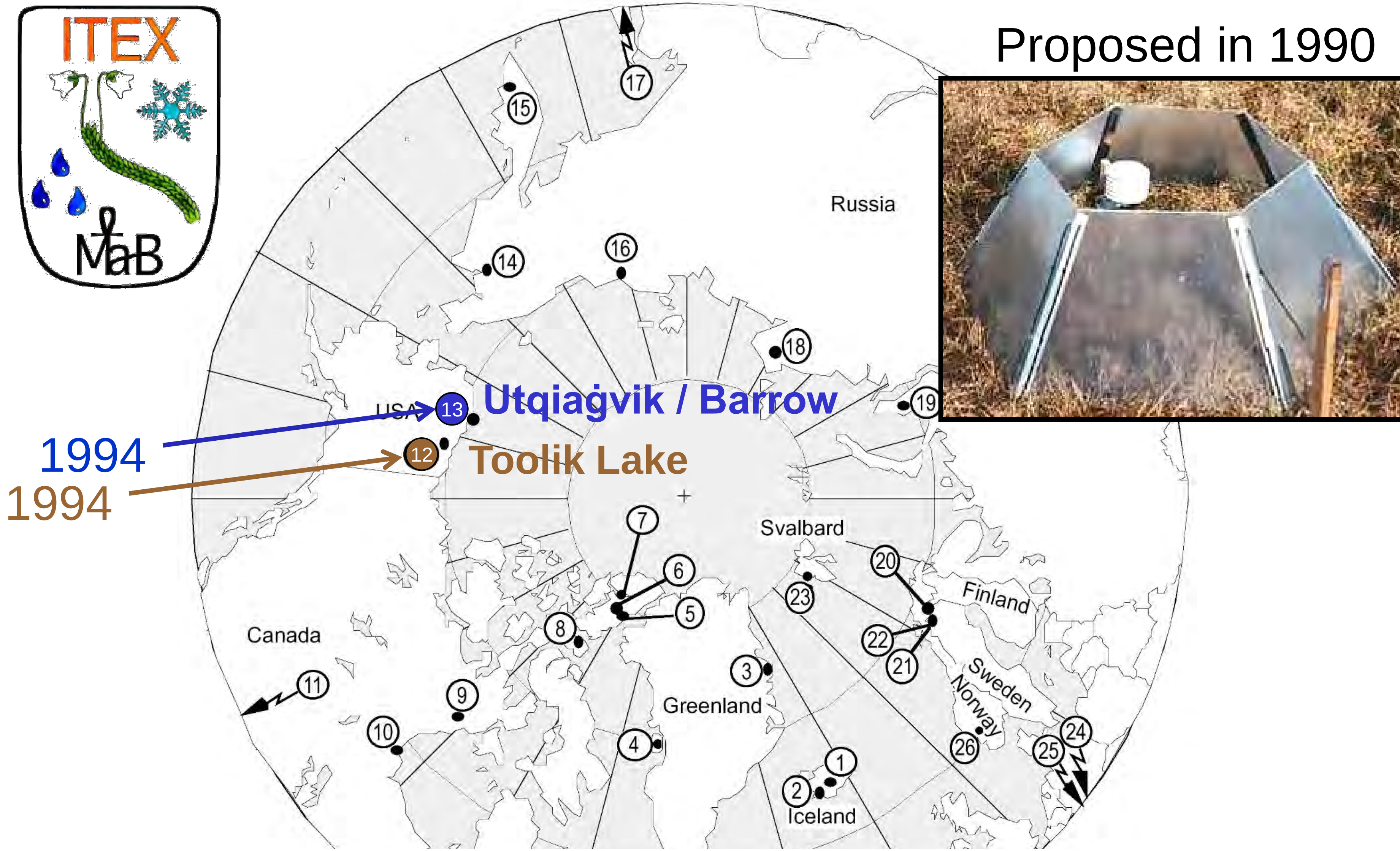
Ecologists Collaborating to Document the Impacts of Climate Change on Plants

International **T**undra **Ex**periment

1990

Collaborators agreed upon Common Protocols



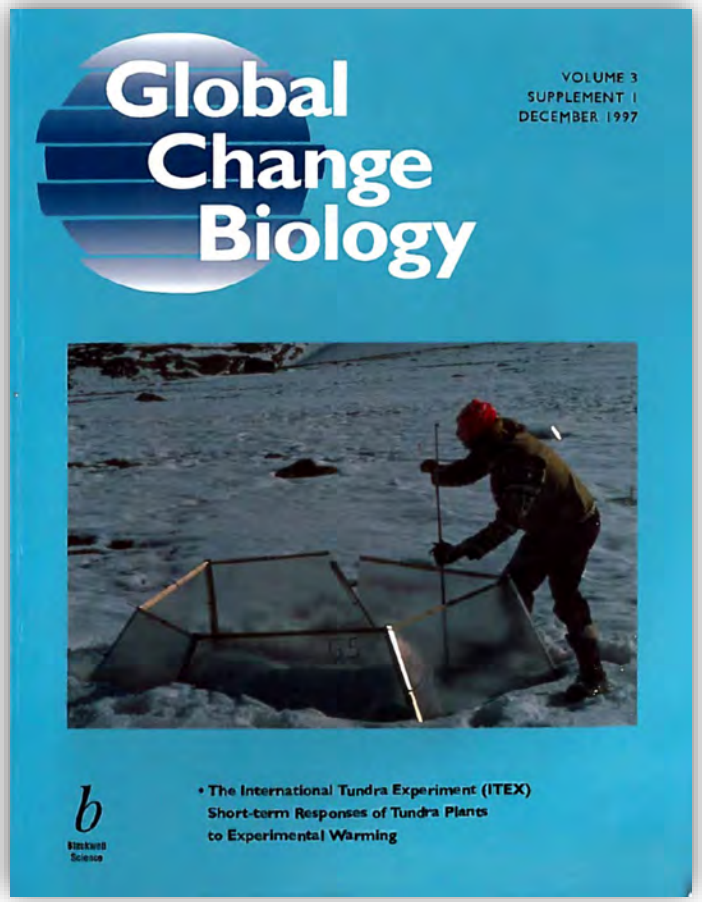


Proposed in 1990

The original **International Tundra Experiment** sites

agreed on a common warming manipulation
to simulate climate change

Special Issue 1997
GCB 3(Suppl. 1)



1 Overall Synthesis
15 cross site comparisons

Lots of Papers comparing Plant Response across sites

Global Change Biology
Volume 3, Supplement 1, December 1997

ITEX

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D. F. Murray

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A. Stenström a... ...sdóttir

97 Respon... variation and e... tundra plant ...ns: *Cassiope* ...*alis*

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ITEX Synthesis
Phenology & Growth

Arft et al. 1999
Ecological Monographs 69(4):491-511


Ecological Monographs, 69(4), 1999, pp. 491–511

RESPONSES OF TUNDRA PLANTS TO EXPERIMENTAL WARMING: META-ANALYSIS OF THE INTERNATIONAL TUNDRA EXPERIMENT

A. M. Arft,[1] M. D. Walker,[1,22] J. Gurevitch,[2] J. M. Alatalo,[3] M. S. Bret-Harte,[4] M. Dale,[5] M. Diemer,[6] F. Gugerli,[7] G. H. R. Henry,[8] M. H. Jones,[9] R. D. Hollister,[10] I. S. Jónsdóttir,[11] K. Laine,[12] E. Lévesque,[13] G. M. Marion,[14] U. Molau,[3] P. Mølgaard,[15] U. Nordenhäll,[3] V. Raszhivin,[16] C. H. Robinson,[17] G. Starr,[18] A. Stenström,[3] M. Stenström,[3] Ø. Totland,[19] P. L. Turner,[1] L. J. Walker,[10] P. J. Webber,[10] J. M. Welker,[20] and P. A. Wookey[21]

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...Hole, Massachusetts 02543 USA
..., Alberta T6G 2E9, Canada
...sity Park, Miami, Florida 33199 USA
...007 Bergen, Norway
...mie, Wyoming 72801 USA
...gham, Surrey TW20 0EX, UK

Abstract. The International Tundra Experiment (ITEX) is a collaborative, multisite experiment using a common temperature manipulation to examine variability in species response across climatic and geographic gradients of tundra ecosystems. ITEX was designed specifically to examine variability in arctic and alpine species response to increased temperature. We compiled from one to four years of experimental data from 13 different ITEX sites and used meta-analysis to analyze responses of plant phenology, growth, and reproduction to experimental warming. Results indicate that key phenological events such as leaf bud burst and flowering occurred earlier in warmed plots throughout the study period; however, there was little impact on growth cessation at the end of the season. Quantitative measures of vegetative growth were greatest in warmed plots in the early years of the experiment, whereas reproductive effort and success increased in later years. A shift away from vegetative growth and toward reproductive effort and success in the fourth treatment year suggests a shift from the initial response to a secondary response. The change in vegetative response may be due to depletion of stored plant reserves, whereas the lag in reproductive response may be due to the formation of flower buds one to several seasons prior to flowering. Both vegetative and reproductive responses varied among life-forms; herbaceous forms had stronger and more consistent vegetative growth responses than did woody forms. The greater responsiveness of the herbaceous forms may be attributed to their more flexible morphology and to their relatively greater proportion of stored plant reserves. Finally, warmer, low arctic sites produced the strongest growth responses, but colder sites produced a greater reproductive response. Greater resource investment in vegetative growth may be a conservative strategy in the Low Arctic, where there is more competition for light, nutrients, or water, and there may be little opportunity for successful germination or seedling development. In contrast, in the High Arctic, heavy investment in producing seed under a higher temperature scenario may provide an opportunity for species to colonize patches of unvegetated ground. The observed differential response to warming suggests that the primary forces driving the response vary across climatic zones, functional groups, and through time.

Key words: *arctic tundra; experimental warming; global change; global warming; International Tundra Experiment; ITEX; meta-analysis; plant response patterns; spatiotemporal gradients; tundra plants.*

Manuscript received 29 June 1998; revised 31 December 1998; accepted 5 January 1999; final version received 29 January 1999.

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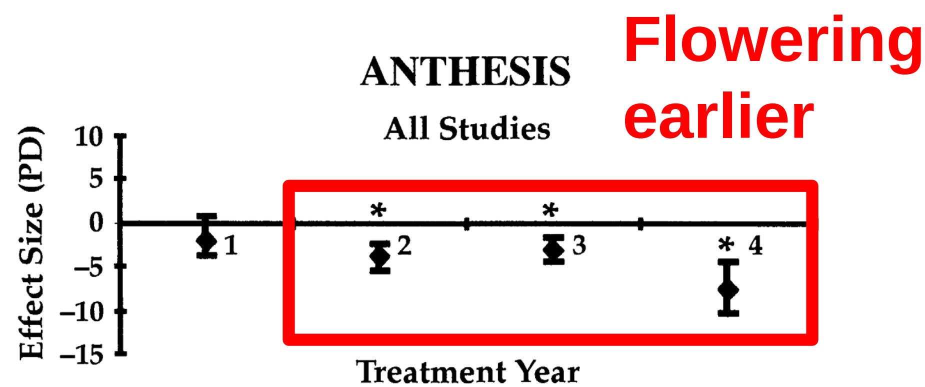

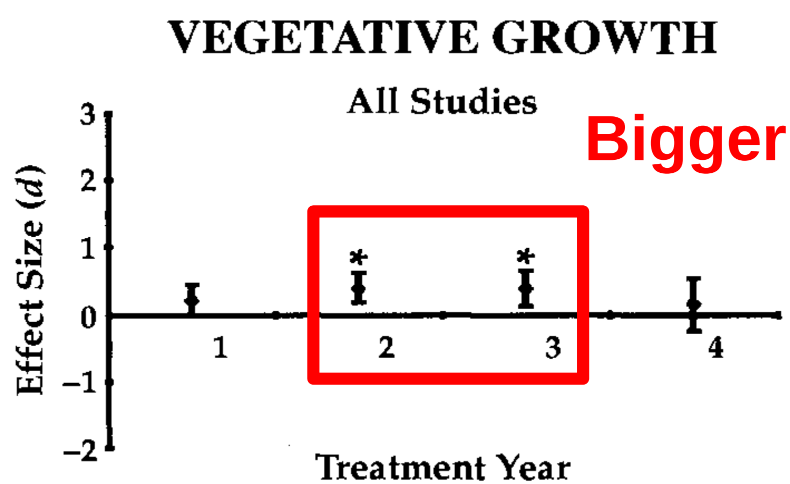

ITEX Synthesis Community Change

Walker et al. 2006
PNAS 103(5): 1342-46

Plant community responses to experimental warming across the tundra biome

Marilyn D. Walker[a], C. Henrik Wahren[b], Robert D. Hollister[c], Greg H. R. Henry[d,e], Lorraine E. Ahlquist[f], Juha M. Alatalo[g], M. Syndonia Bret-Harte[h], Monika P. Calef[h], Terry V. Callaghan[i], Amy B. Carroll[a], Howard E. Epstein[j], Ingibjörg S. Jónsdóttir[k], Julia A. Klein[l], Borgþór Magnússon[m], Ulf Molau[g], Steven F. Oberbauer[f], Steven P. Rewa[n], Clare H. Robinson[o], Gaius R. Shaver[p], Katharine N. Suding[q], Catharine C. Thompson[r], Anne Tolvanen[s], Ørjan Totland[t], P. Lee Turner[u], Craig E. Tweedie[v], Patrick J. Webber[w], and Philip A. Wookey[x]

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[f]Department of Biological Sciences, Florida I
Göteborg, Sweden; [h]Institute of Arctic Biolo
[j]Department of Environmental Sciences, Uni
Norway; [l]Natural Resource Ecology Laborato
Box 5320, 125 Reykjavik, Iceland; [n]Departme
London, Franklin-Wilkins Building, London
[q]Department of Ecology and Evolutionary B
WA 98362; [s]Finnish Forest Research Institute
Resource Management, Norwegian Universi
of Colorado, Boulder, CO 80309; [v]Departme
Boulevard, El Paso, TX 79968-0513; [w]Depart
Environmental Sciences, University of Stirlin

Edited by F. Stuart Chapin III, University of A

Recent observations of changes in some tundra ecosystems appear to be responses to a warming climate. Several experimental studies have shown that tundra plants and ecosystems can respond strongly to environmental change, including warming; however, most studies were limited to a single location and were of short duration and based on a variety of experimental designs. In addition, comparisons among studies are difficult because a variety of techniques have been used to achieve experimental warming and different measurements have been used to assess responses. We used metaanalysis on plant community measurements from standardized warming experiments at 11 locations across the tundra biome involved in the International Tundra Experiment. The passive warming treatment increased plant-level air temperature by 1–3°C, which is in the range of predicted and observed warming for tundra regions. Responses were rapid and detected in whole plant communities after only two growing seasons. Overall, warming increased height and cover of deciduous shrubs and graminoids, decreased cover of mosses and lichens, and decreased species diversity and evenness. These results predict that warming will cause a decline in biodiversity across a wide variety of tundra, at least in the short term. They also provide rigorous experimental evidence that recently observed increases in shrub cover in many tundra regions are in response to climate warming. These changes have important implications for processes and interactions within tundra ecosystems and between tundra and the atmosphere.

arctic and alpine ecosystems | biodiversity | climate change | vegetation change

Detecting biotic responses to a changing environment is essential for understanding the consequences of global climate change (1–4). Shifts in the composition and abundance of plant species will have important effects on ecosystem processes, including net primary production and nutrient cycling, and on organisms at all trophic levels (5). Vegetation changes are expected to be large in tundra regions (1, 4, 6) in response to predicted warming, although the variability in tundra vegetation at local and regional scales makes it difficult to predict these changes. Arctic regions have been warming since the mid-1800s (7), but the warming has accelerated in recent decades (1, 7, 8) and is expected to continue throughout this century (1, 4). Model projections show that the warming could result in the loss of as much as 40% of the current tundra area by the year 2100 as it is replaced by boreal forest (1). Observational studies have found that leaf-out is earlier (9) and shrub cover has increased in areas such as northern Alaska (10). Many observed biotic changes are consistent with expected responses to increasing temperature (11, 12); however, experimental warming provides a direct test of the effect of temperature on plant communities.

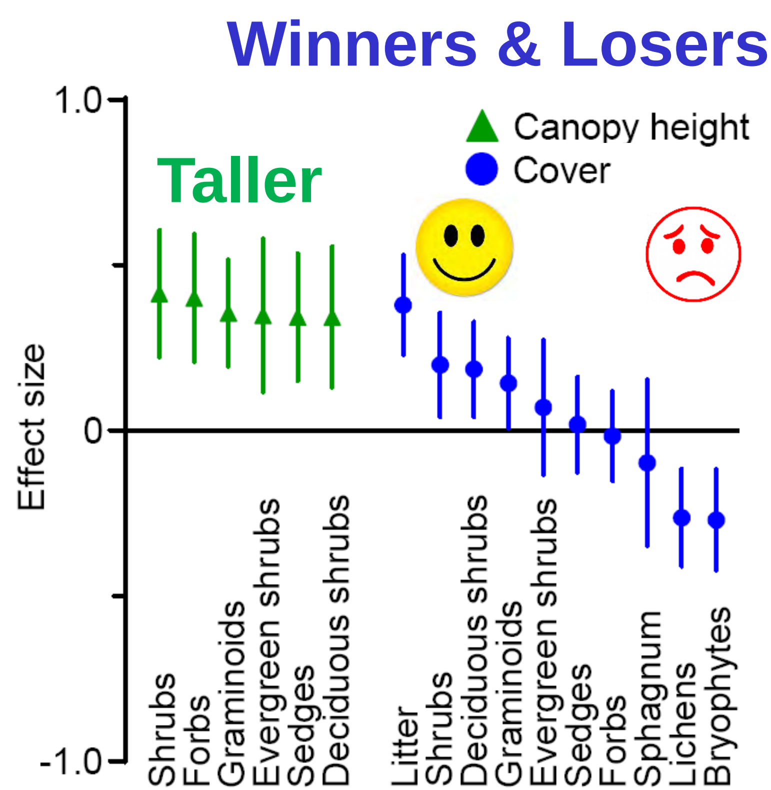
Over the past two decades, experimental studies have shown that tundra plants can respond strongly to environmental manipulations, including warming (e.g., refs. 13–16), and there have been a few syntheses of these studies (17–20). However, most of the previous studies were conducted at single sites for relatively short periods using methods unique to the study. The restricted geographic coverage, short duration, and variability in experimental design hinder the general conclusions from syntheses of these studies. These shortcomings were highlighted in the recent synthesis of responses of arctic terrestrial ecosystems to climate change completed for the Arctic Climate Impact Assessment (1), which recommended better coordination of research throughout the Arctic. Here, we report whole plant community results from standardized warming experiments conducted at 11 locations throughout the tundra biome (Fig. 1). The studies are part of the International Tundra Experiment (ITEX), which is a network of arctic and alpine sites throughout the world where experimental and observational studies have been established by using standardized protocols to measure responses of tundra plants and plant communities to increased temperature (16, 17, 21–28). The use of standardized protocols helps to ensure data are comparable among sites and increases the strength and reliability of conclusions based on analyses of the data. In a previous synthesis of short-term plant responses at ITEX sites (17), we found that graminoid and forb species showed the strongest growth responses to experimental warming, and these were greatest in the

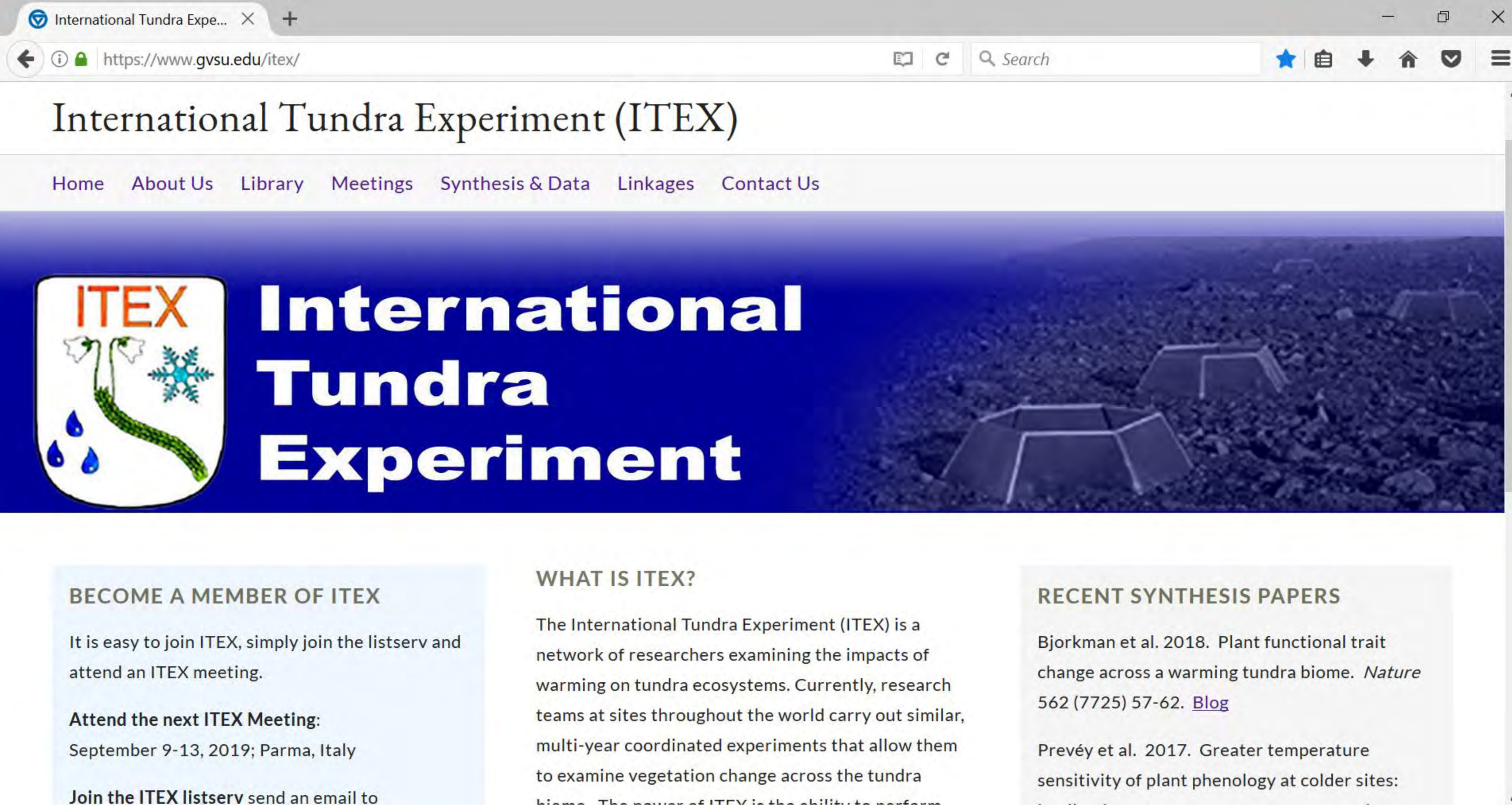
Conflict of interest statement: No conflicts declared.

This paper was submitted directly (Track II) to the PNAS office.

Abbreviation: ITEX, International Tundra Experiment.

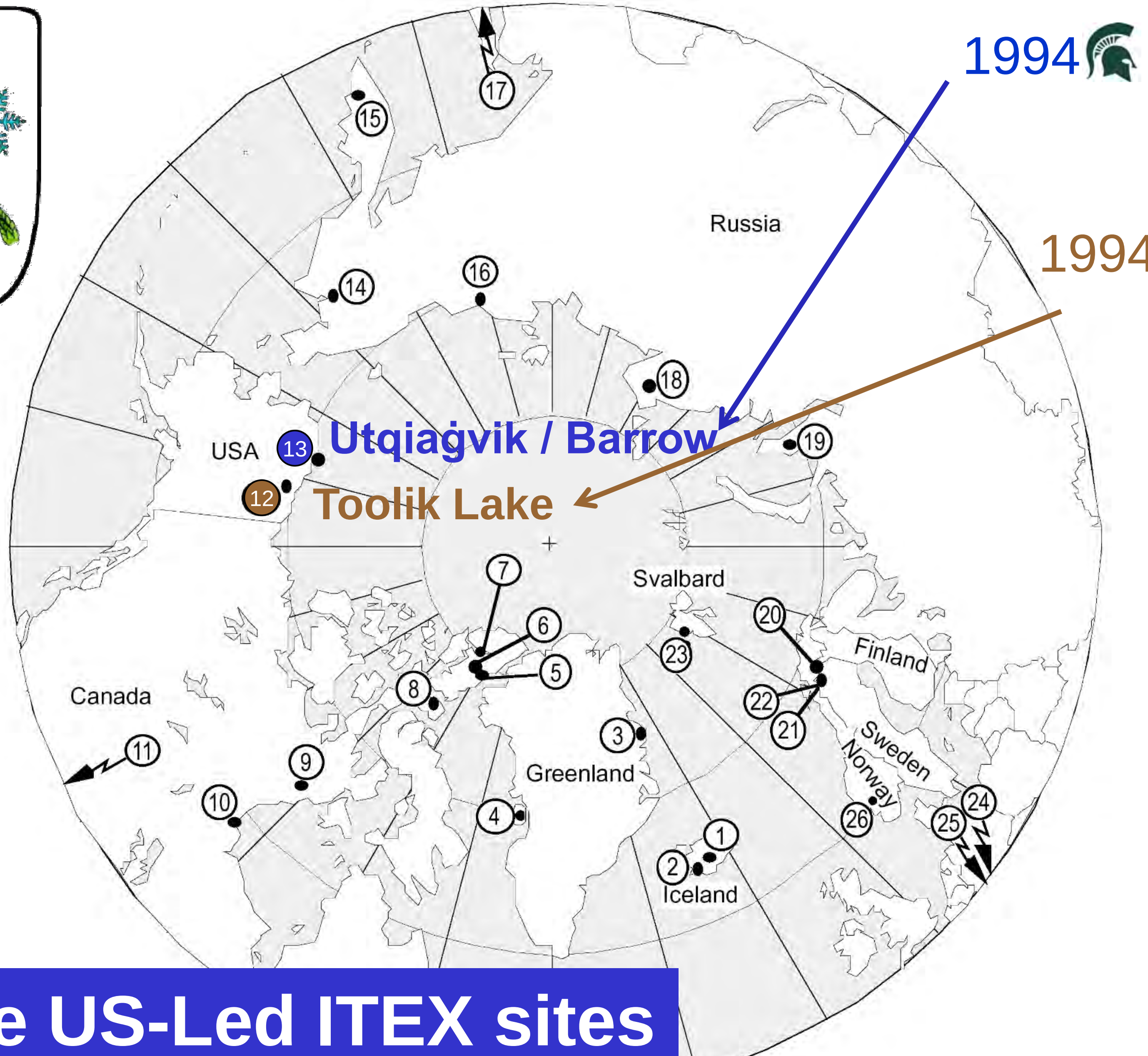
[e]To whom correspondence should be addressed. E-mail: ghenry@geog.ubc.ca.





SEE More Details on ITEX at the Webpage

Bottom line: Long history of success



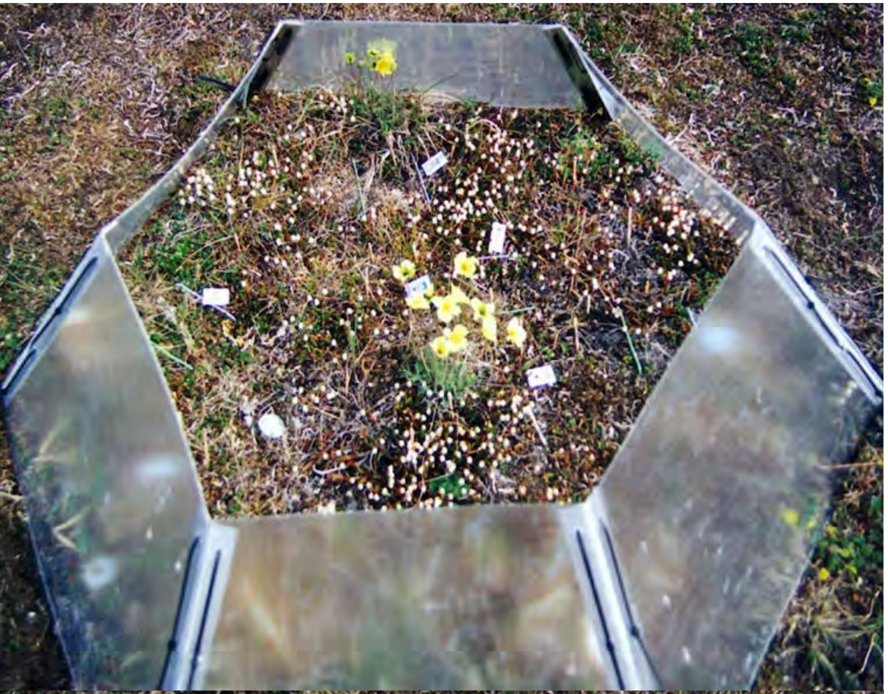
The US-Led ITEX sites

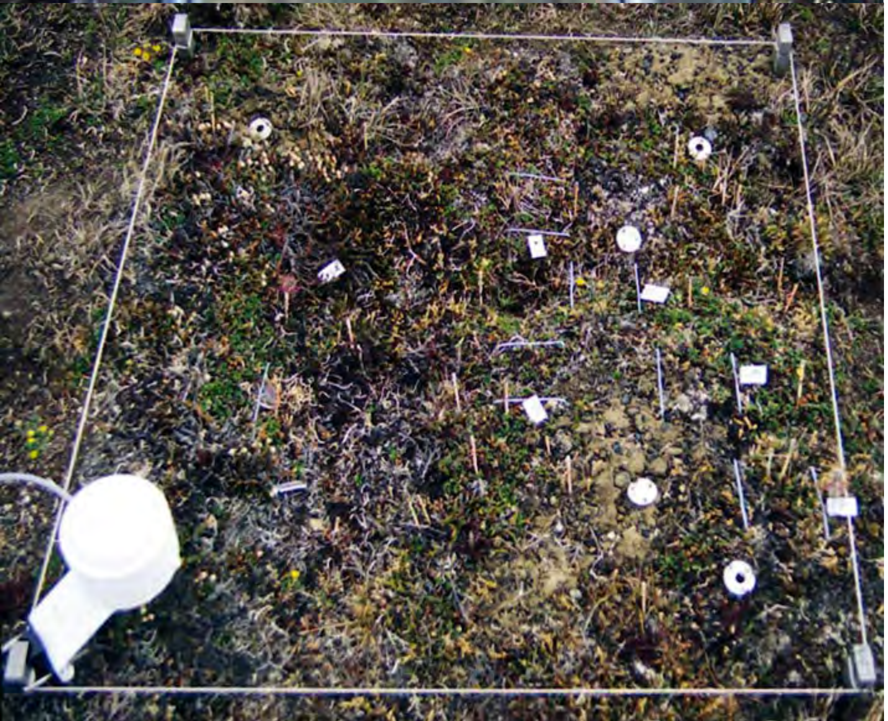
The original International Tundra Experiment sites

Plant Measures

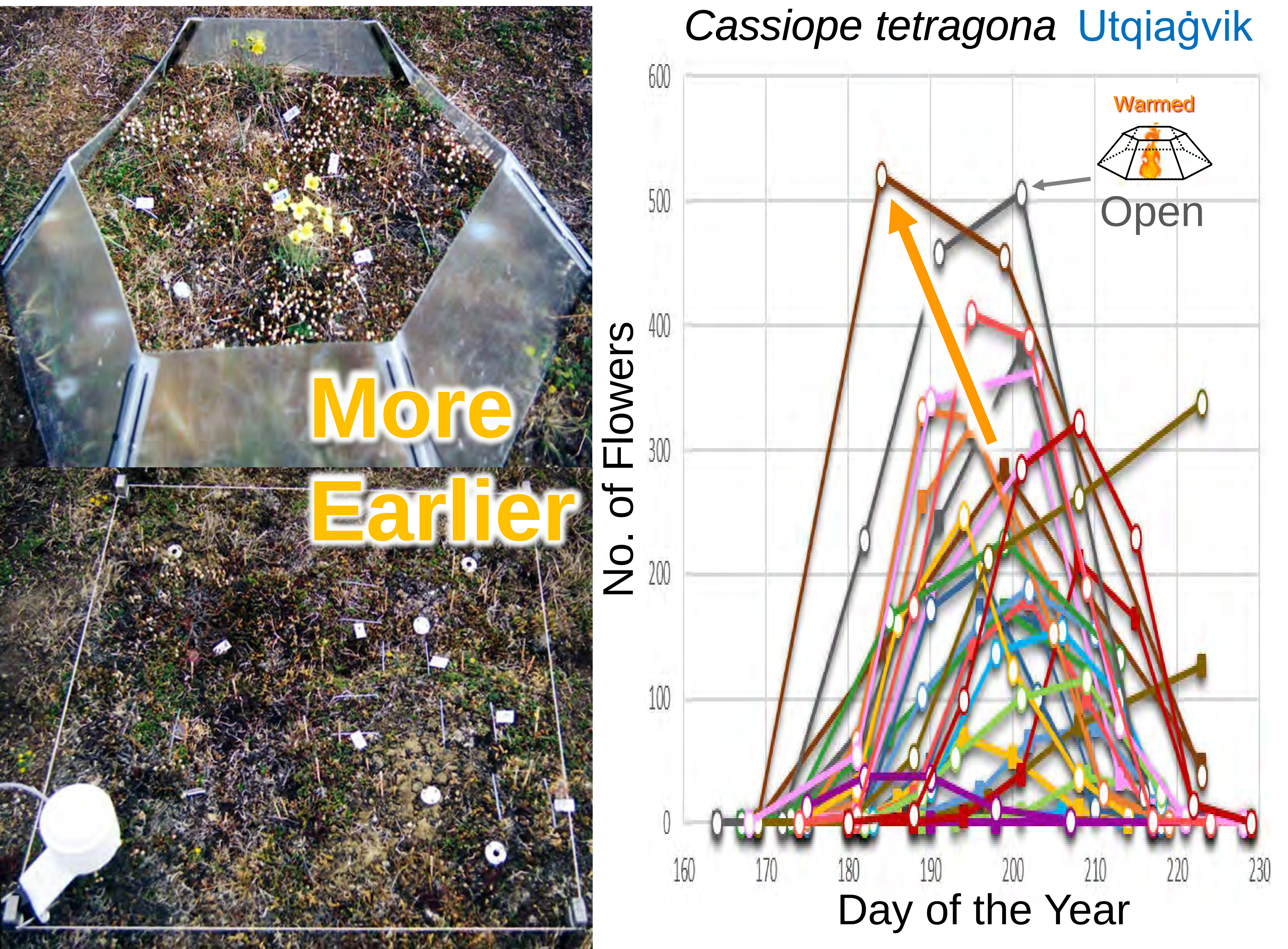
- Plant phenology
- Plant growth
- Plant reproduction

Cassiope tetragona Utqiaġvik



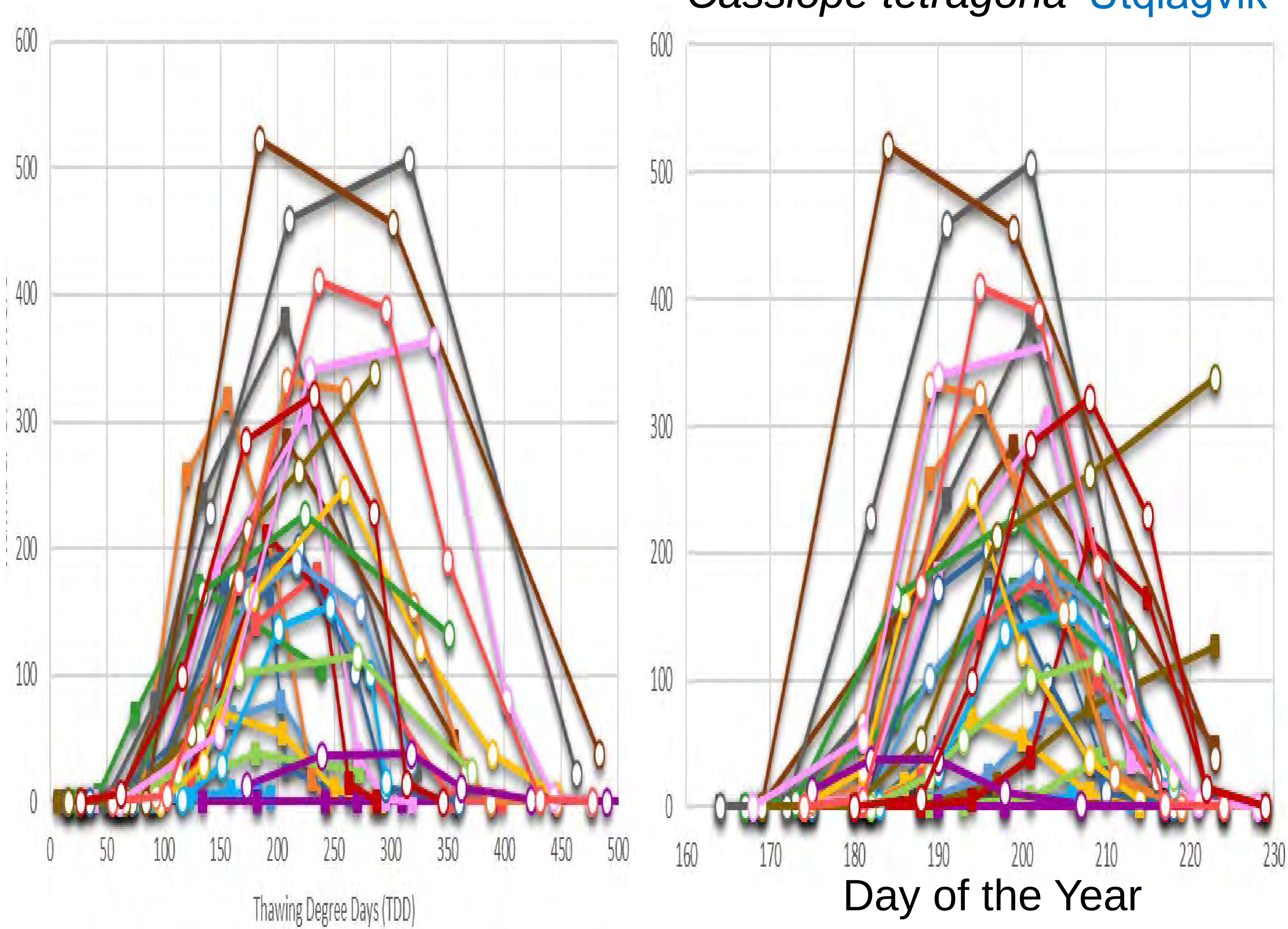


No. of Flowers

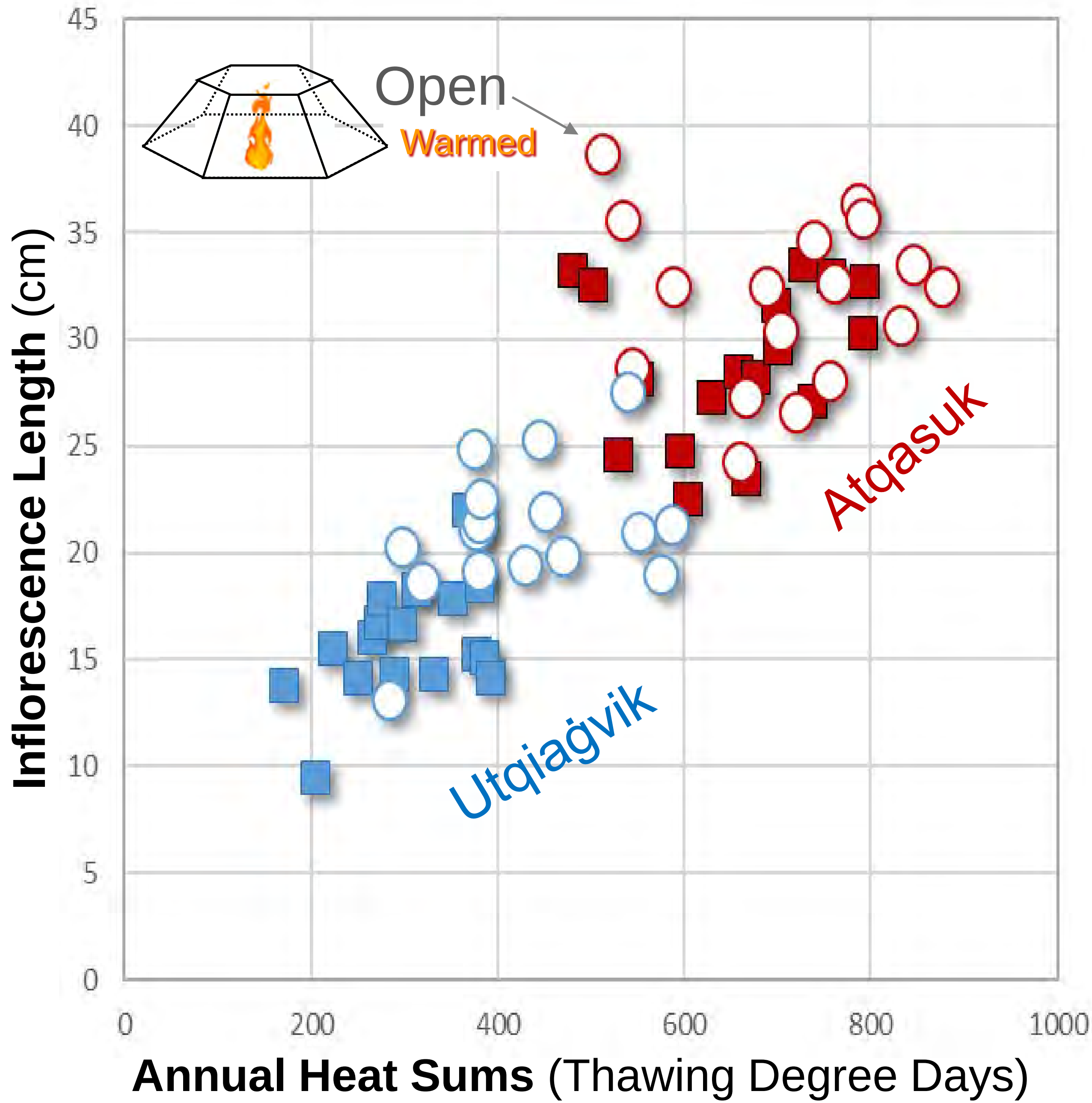


More
Earlier
Cassiope tetragona Utqiaġvik
Warmed
Open
No. of Flowers
0
100
200
300
400
500
600
Day of the Year
160
170
180
190
200
210
220
230

Cassiope tetragona Utqiaġvik

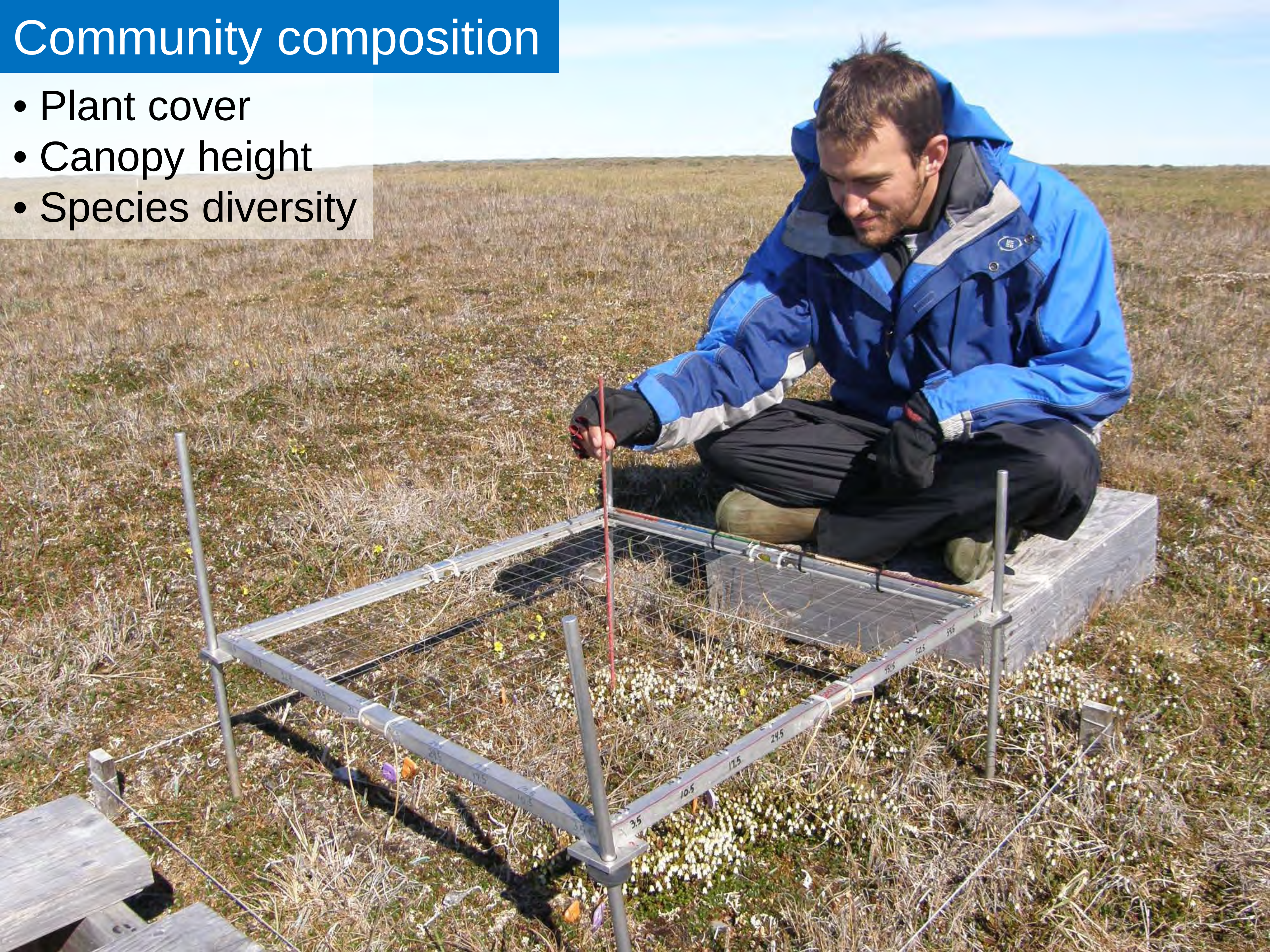


Plant size (*Carex aquatilis*)

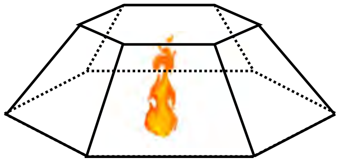


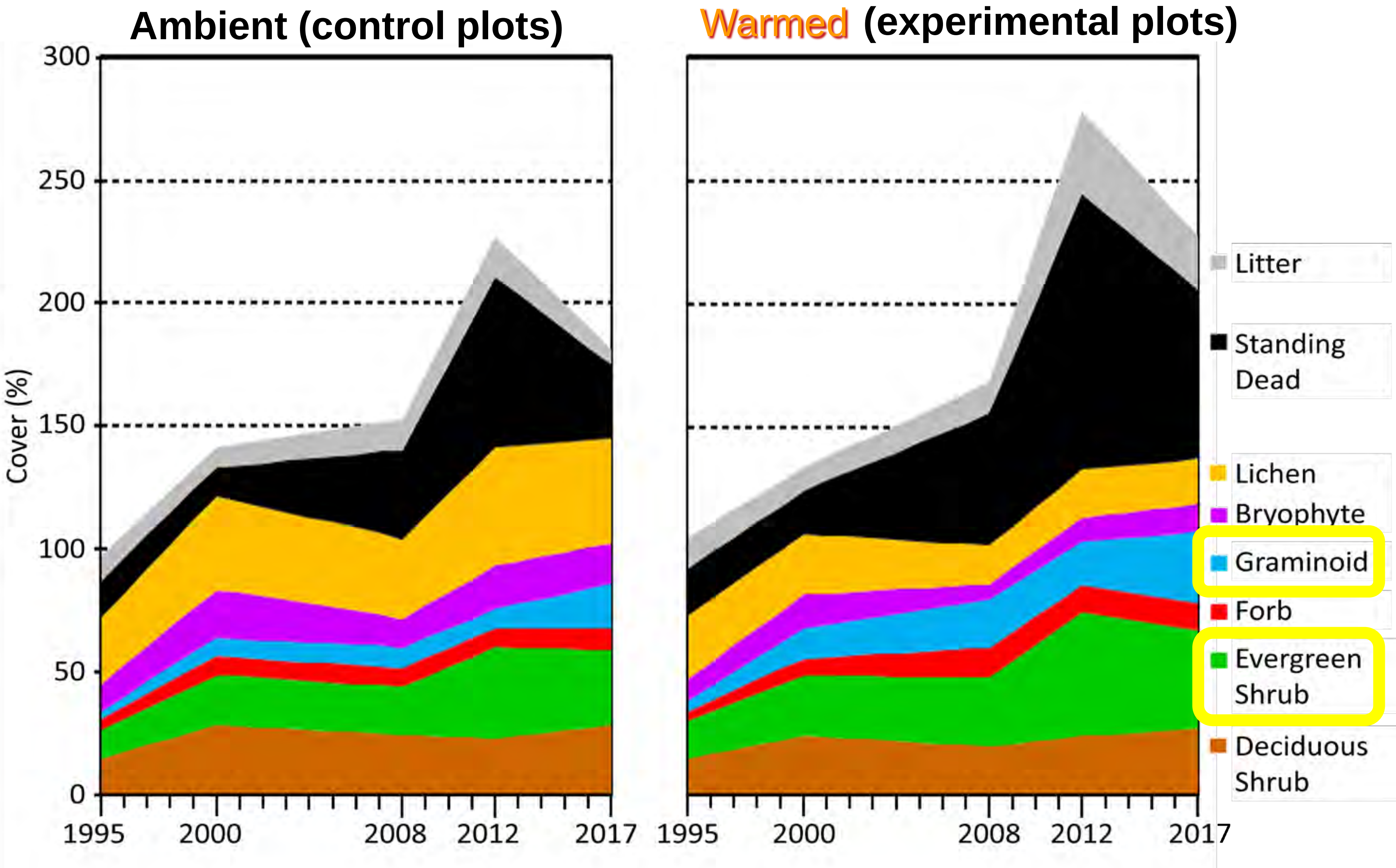
Community composition

- Plant cover
- Canopy height
- Species diversity



Utqiaġvik Dry Site



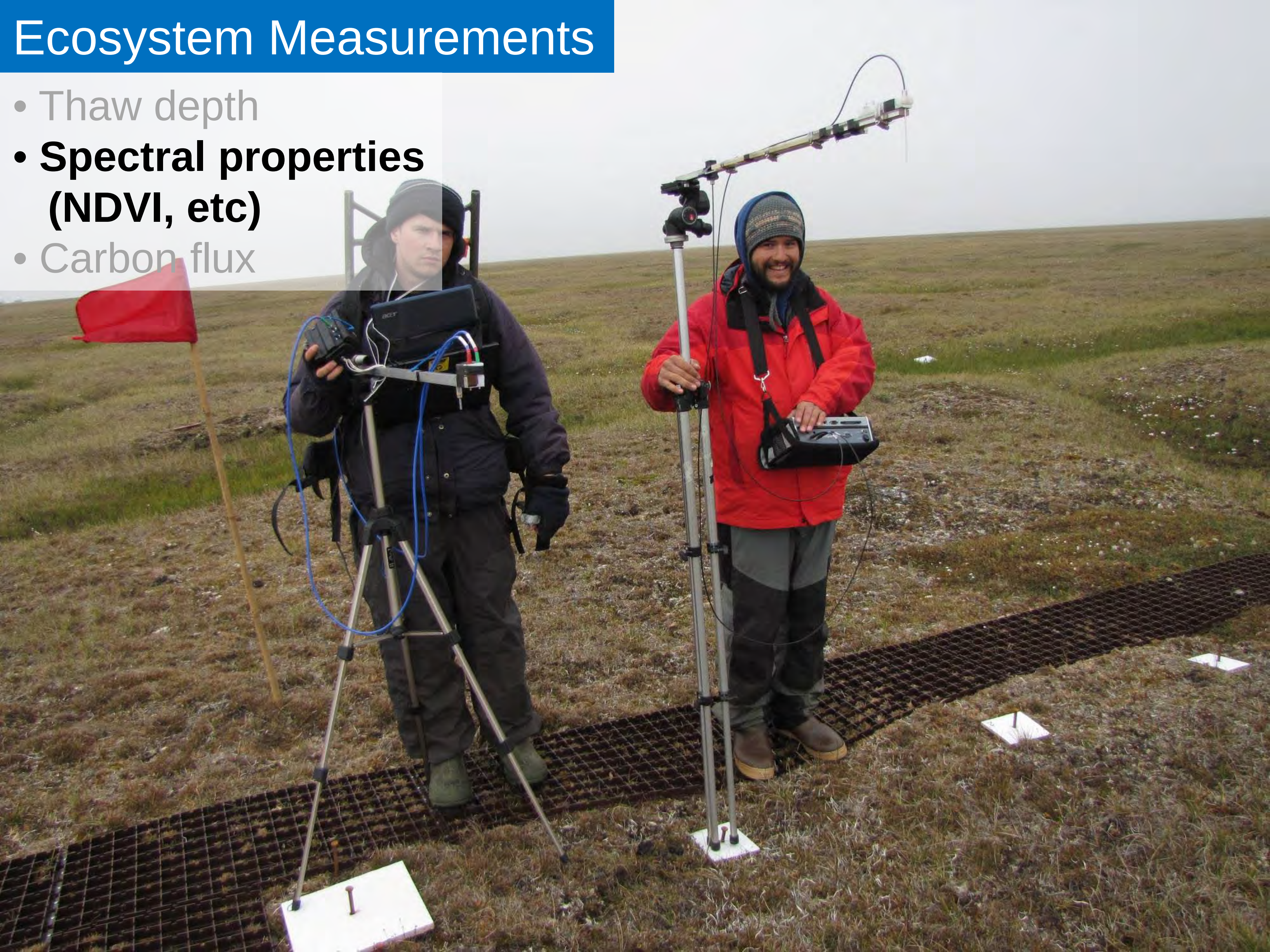


Ecosystem Measurements

- **Thaw depth**
- Spectral properties (NDVI, etc)
- Carbon flux

Ecosystem Measurements

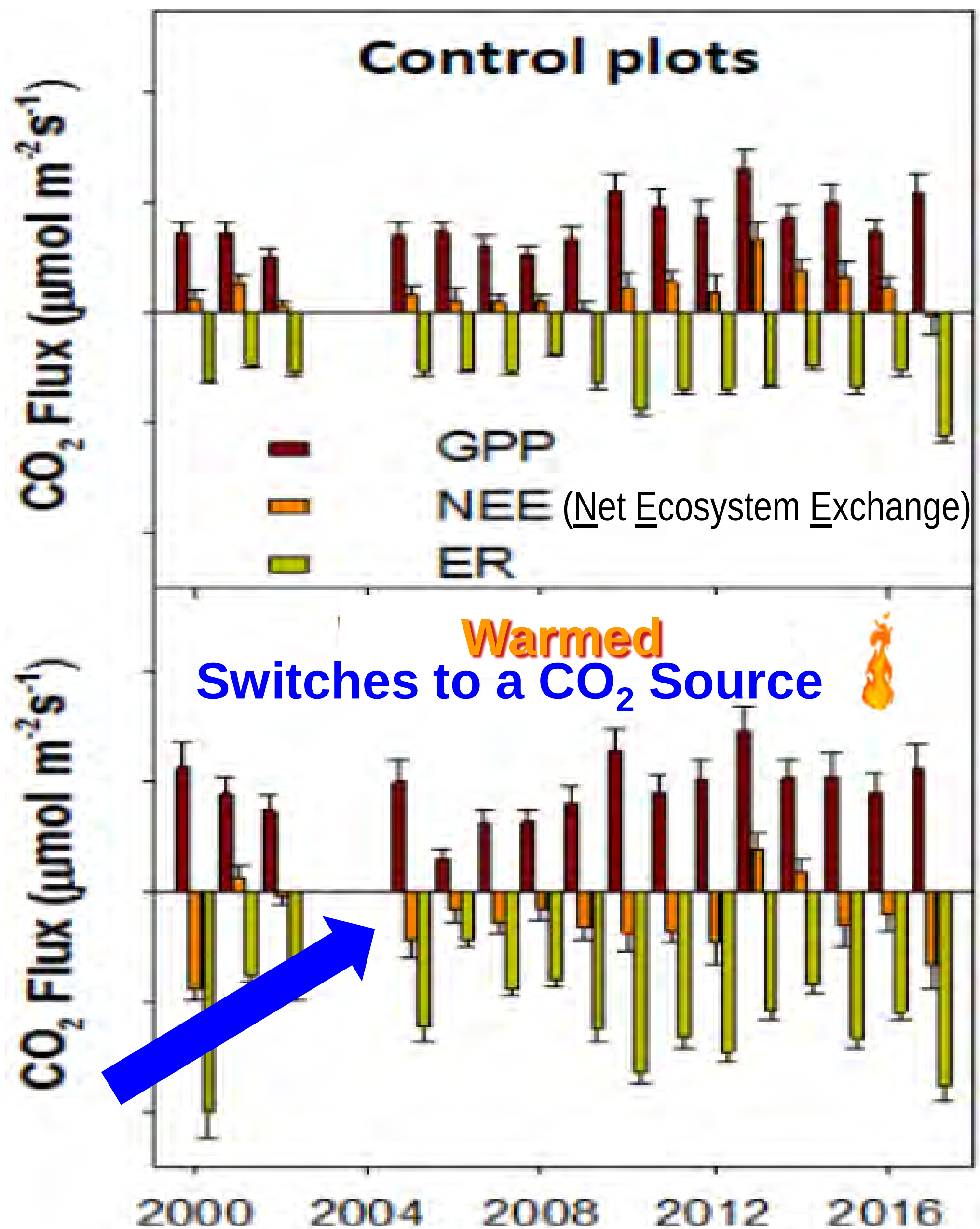
- Thaw depth
- **Spectral properties (NDVI, etc)**
- Carbon flux



Ecosystem Measurements

- Thaw depth
- Spectral properties (NDVI, etc)
- **Carbon flux**

Utqiaġvik Dry Site



What is ITEX-AON?

Beginning in 2009

ARCTIC OBSERVING NETWORK

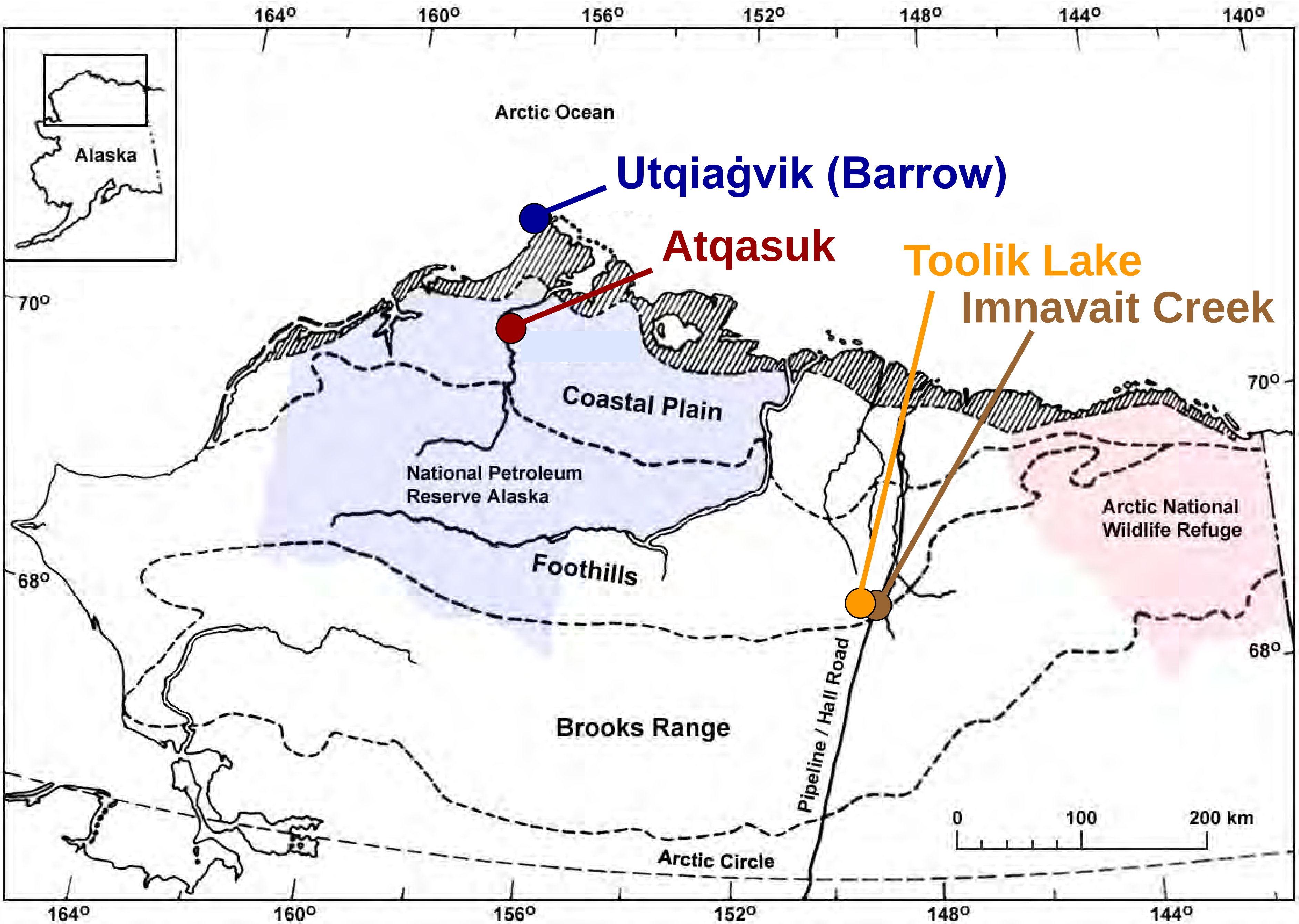
Arctic Observatory Network

Title: NNA: Collaborative Research: Using the ITEX-AON network to document and understand terrestrial ecosystem change in the New Arctic.

Funding: National Science Foundation

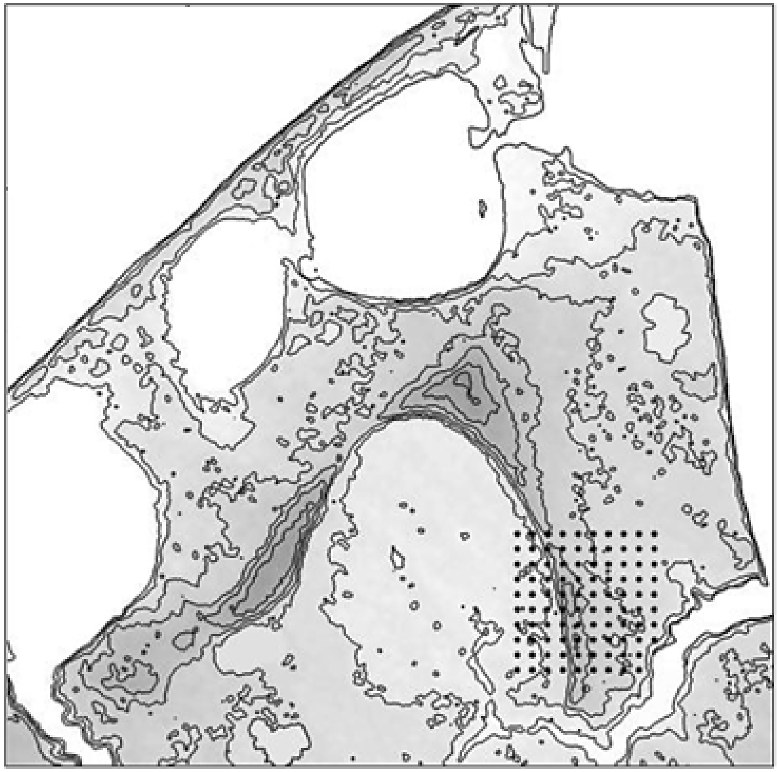
Institutions:

GVSU, Grand Valley State University
FIU, Florida International University
UTEP, University of Texas at El Paso
UAA, University of Alaska at Anchorage



164° 160° 156° 152° 148° 144° 140°
Alaska
Arctic Ocean
Utqiaġvik (Barrow)
Atqasuk
Toolik Lake
Imnavait Creek
70°
Coastal Plain
National Petroleum
Reserve Alaska
Arctic National
Wildlife Refuge
Foothills
68°
Brooks Range
Pipeline / Hall Road
0 100 200 km
Arctic Circle

Utqiaġvik (Barrow)

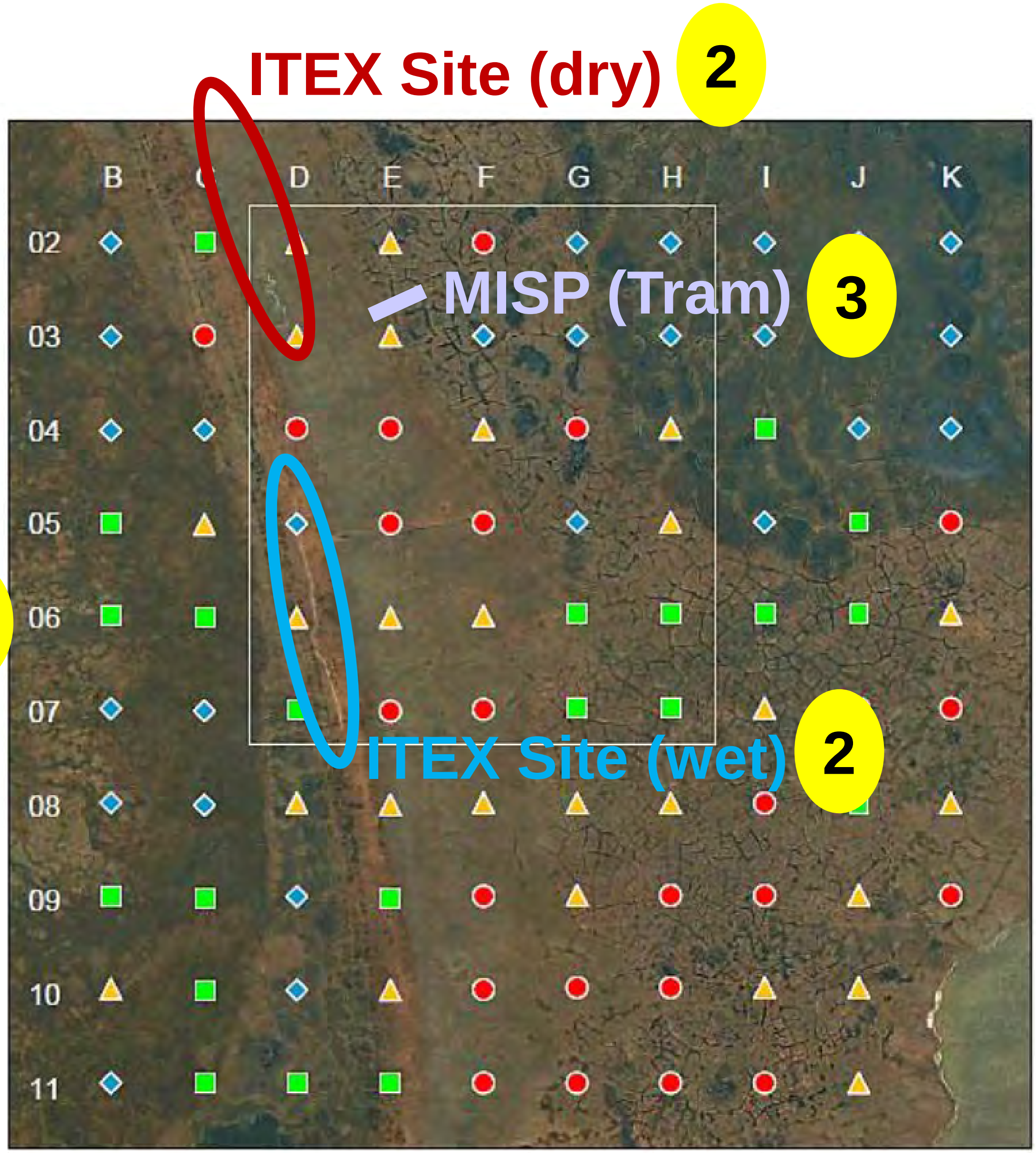


ARCSS Grid

Arctic System Science

100 meters between plots

1

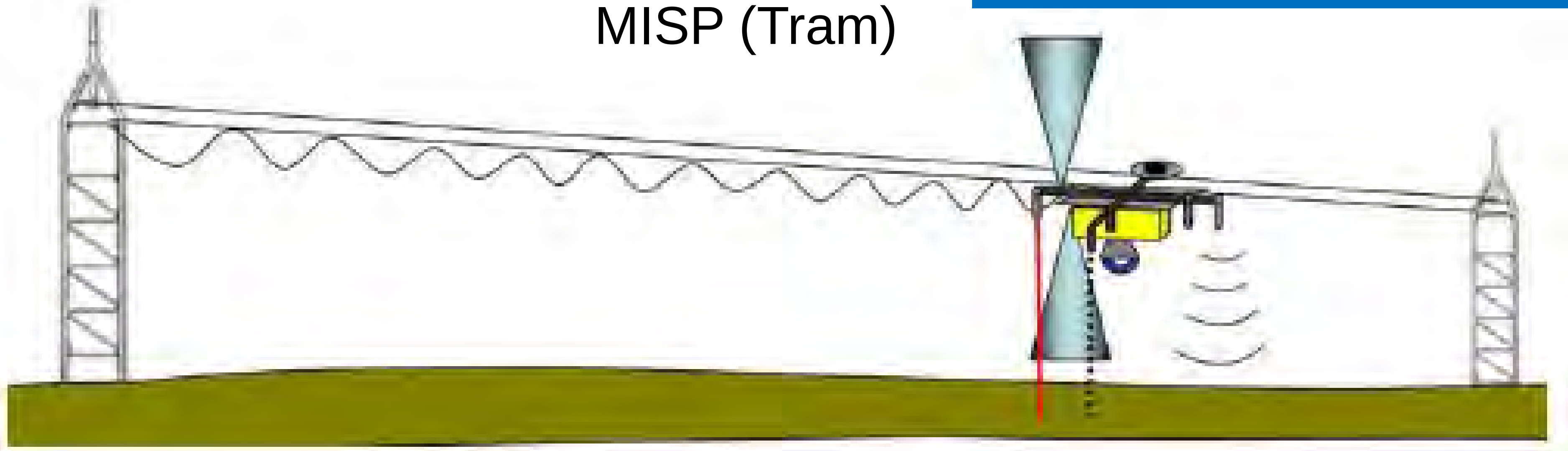


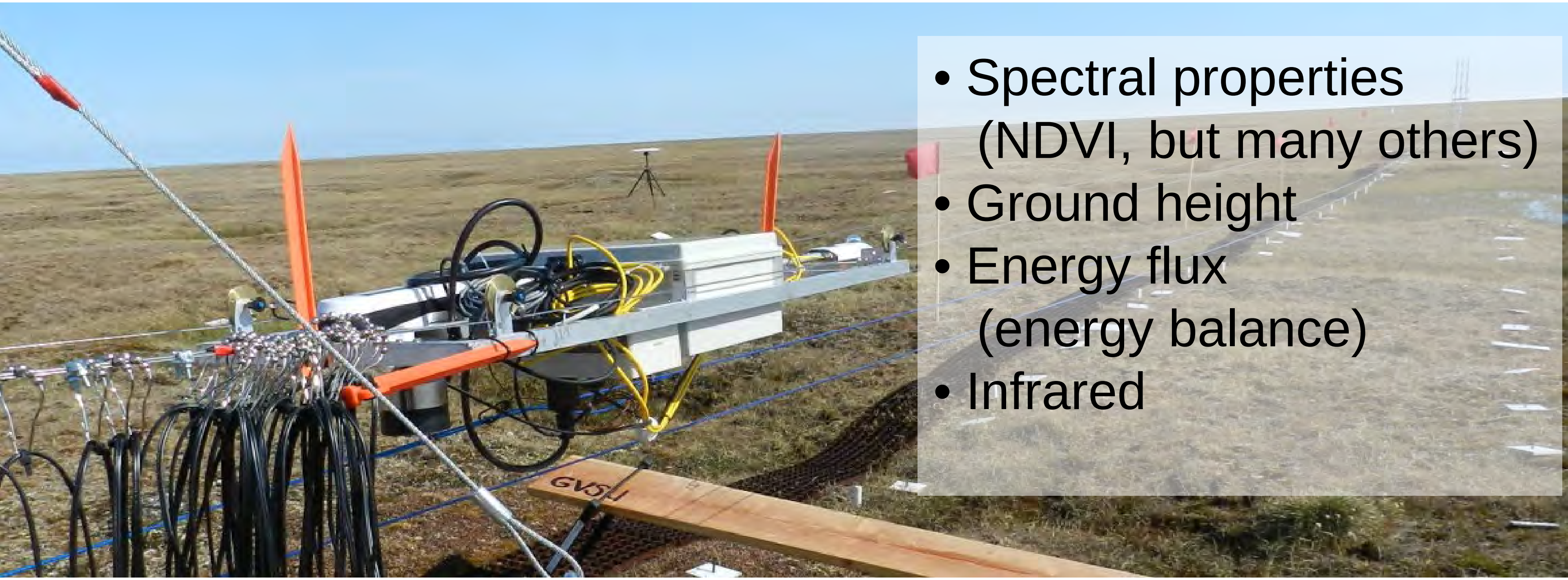
Community Type
- Dry
- Dry-moist
- Moist
- Wet

Mobile Instrumented Sensor Platform

Automated Sampling

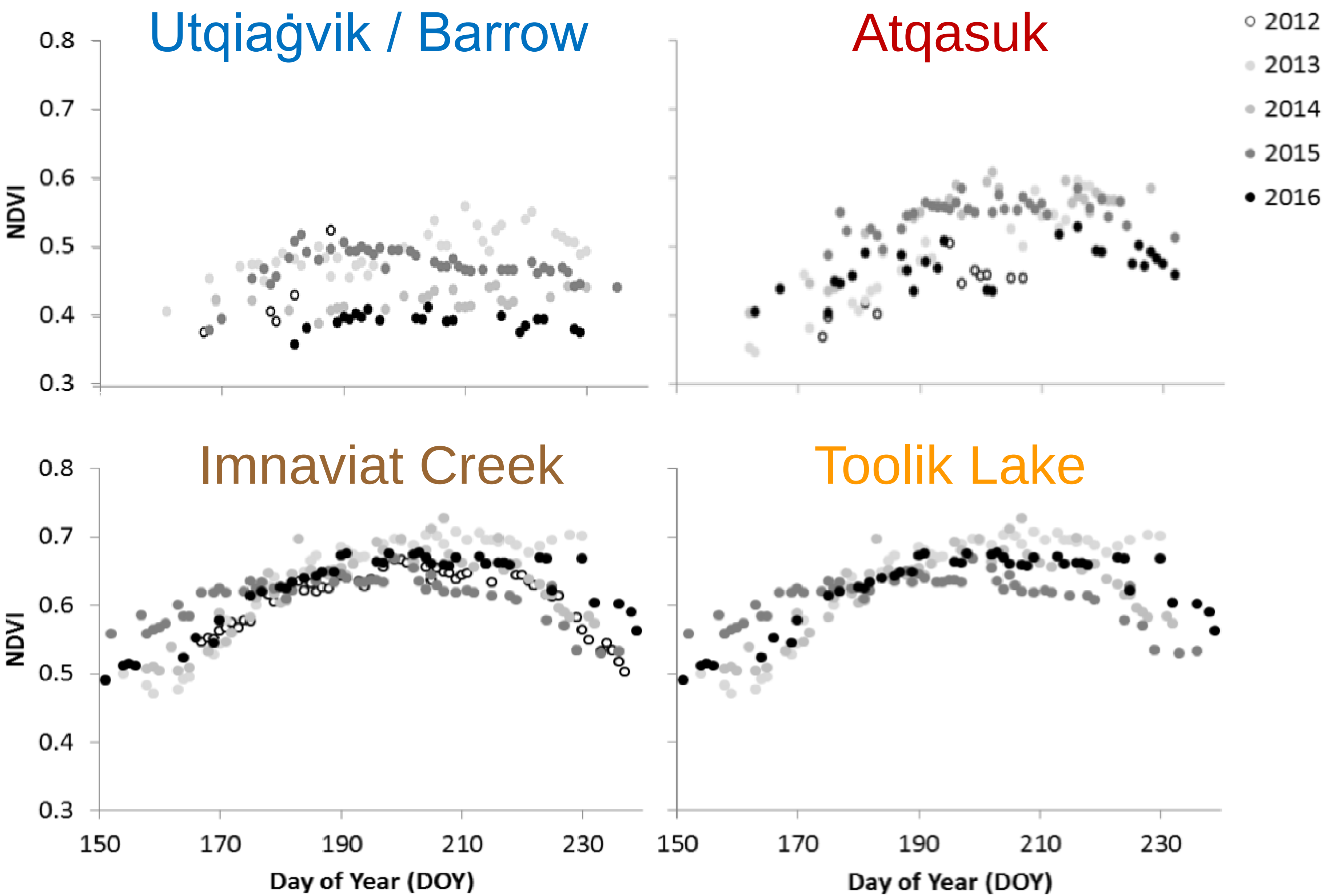
MISP (Tram)





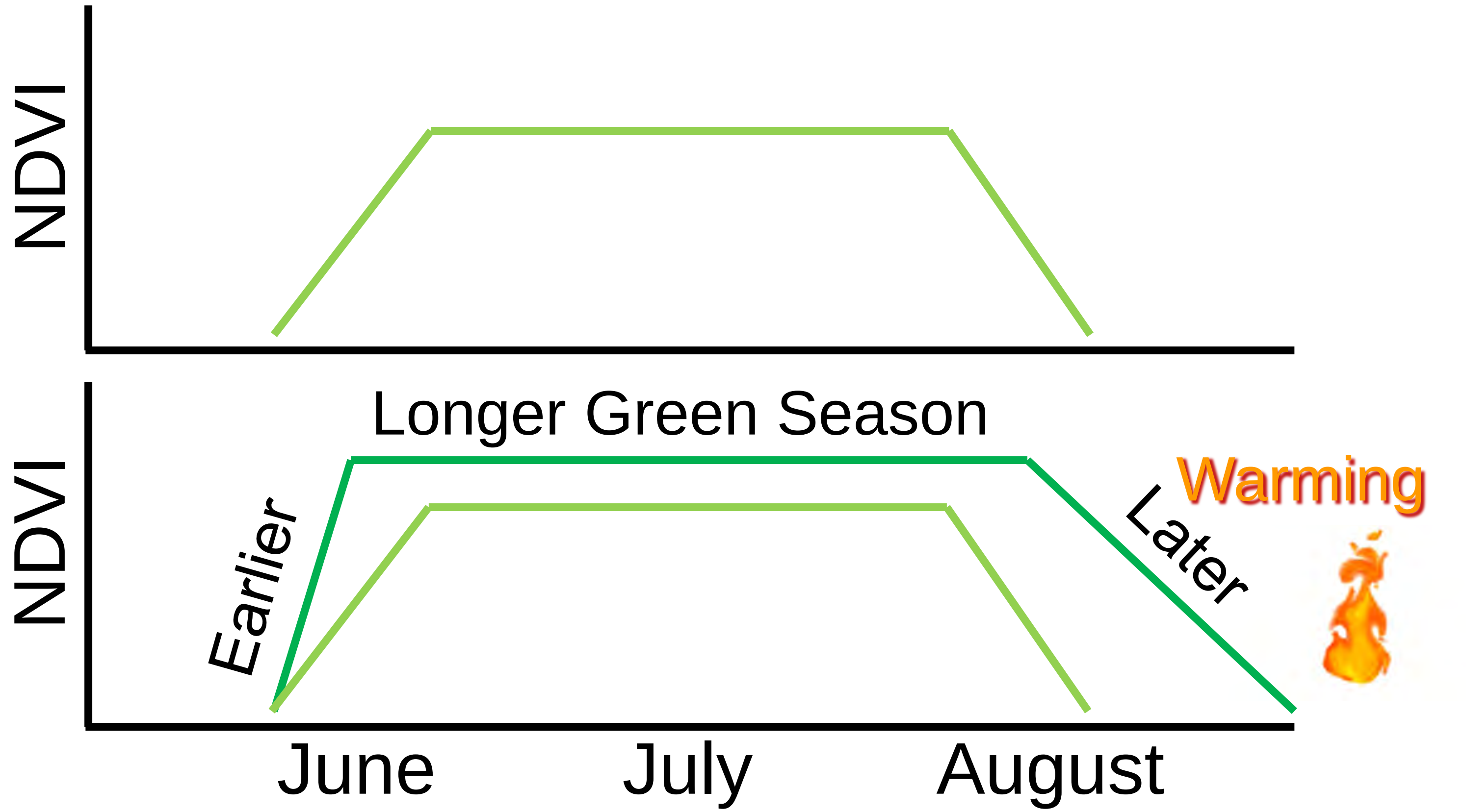
- Spectral properties (NDVI, but many others)
- Ground height
- Energy flux (energy balance)
- Infrared

Season NDVI (greenness) Change (whole transect)



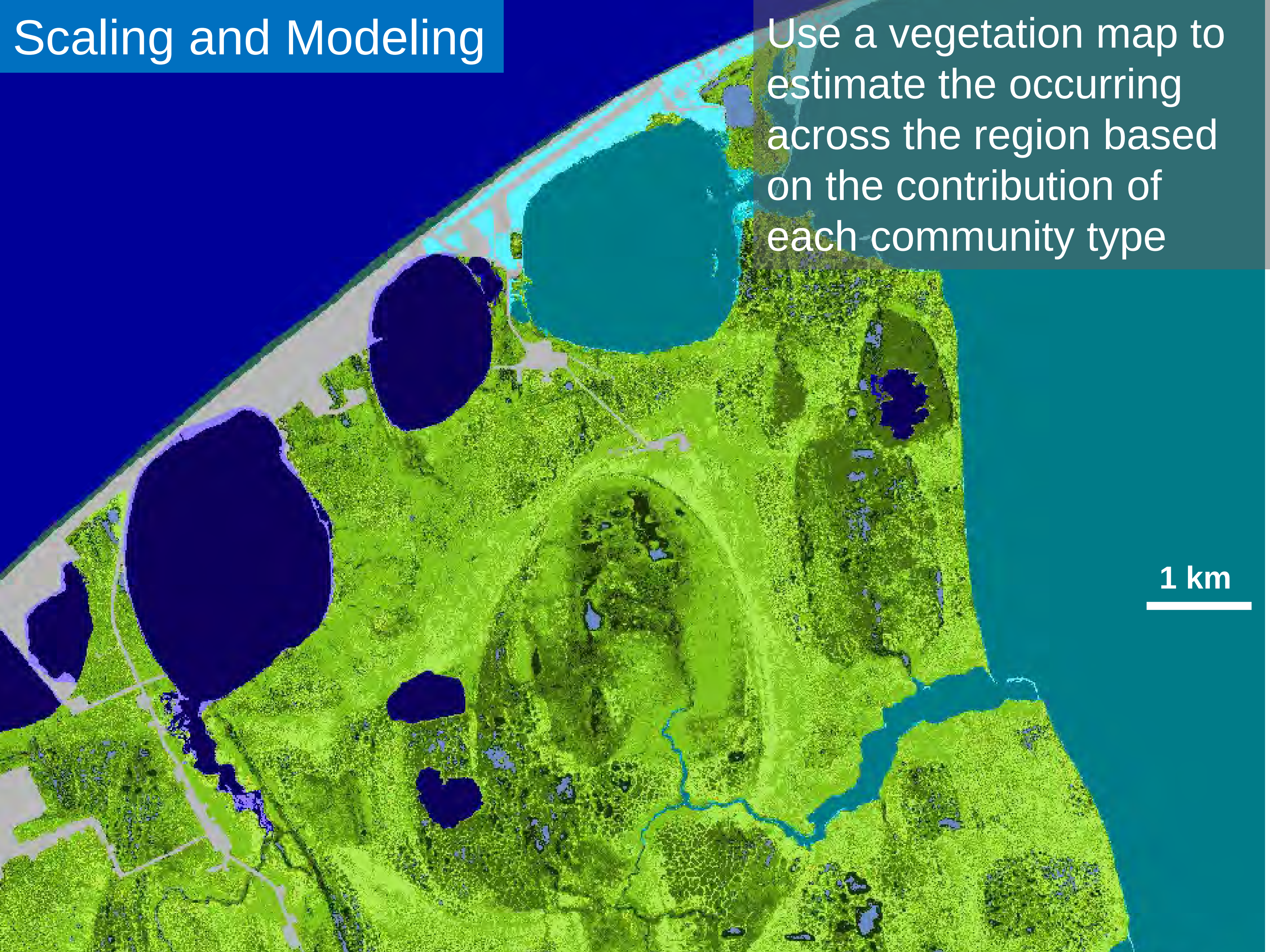
Speculation

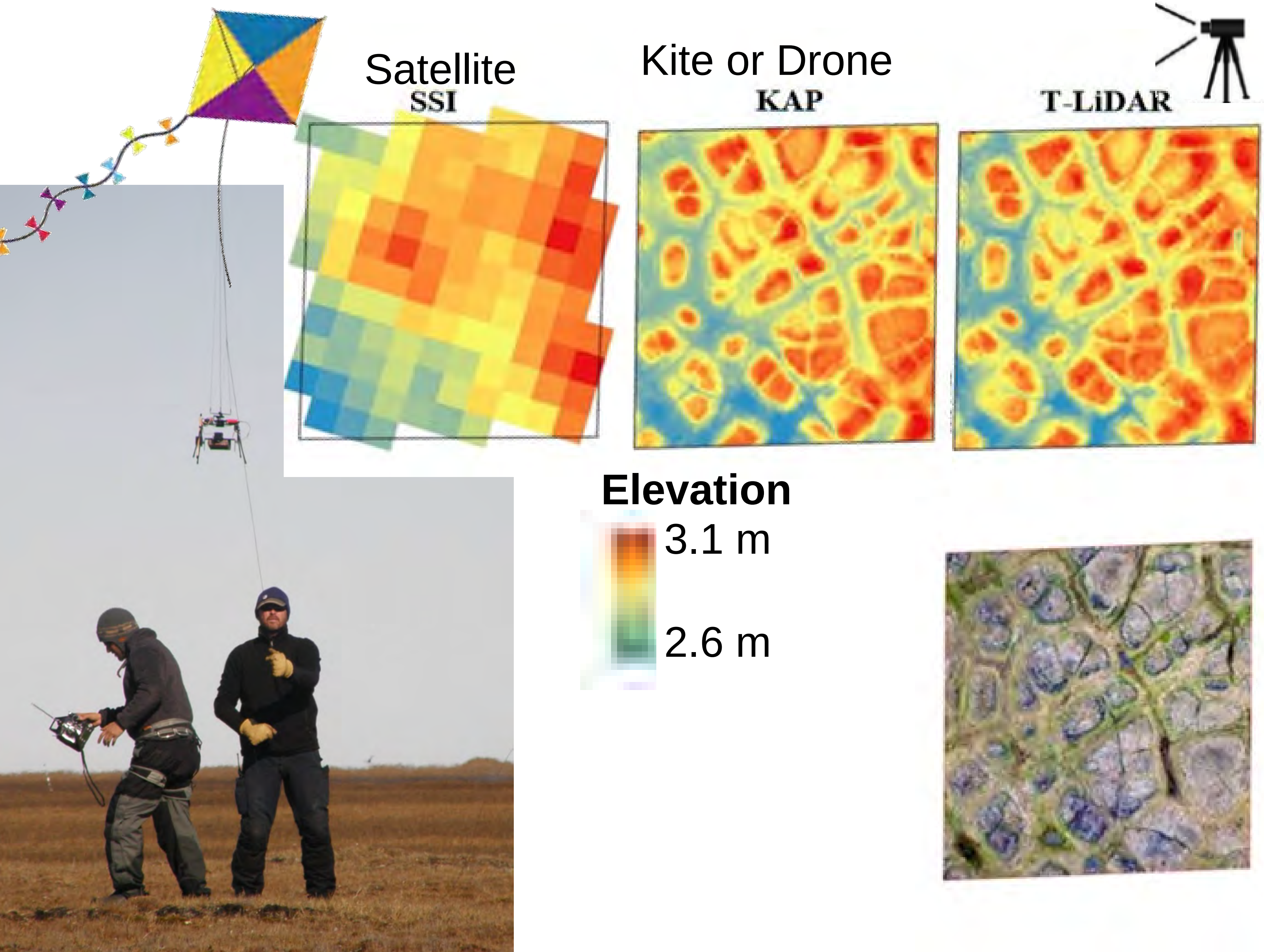
Because Green-up and senescence rates respond to temperature



Scaling and Modeling

Use a vegetation map to estimate the occurring across the region based on the contribution of each community type



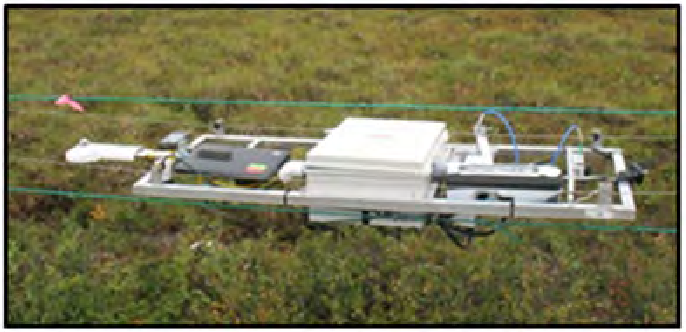

Satellite
SSI
Kite or Drone
KAP
T-LiDAR
Elevation
3.1 m
2.6 m

Phenocams

Plot scale vegetation assessment

-Highly precise

-Time and labor intensive



Mobile Instrumented Sensor Platform (MISP)

-Highly precise

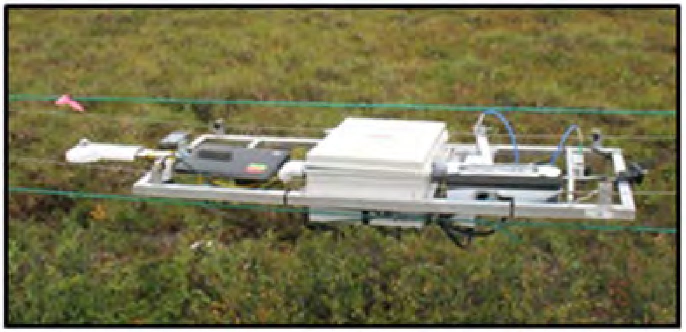
-Less labor intensive

-High spatial and temporal resolution

+ Experiments and one-time measurements designed at understanding process

Plot scale vegetation assessment

-Highly precise
-Time and labor intensive



Mobile Instrumented Sensor Platform (MISP)

-Highly precise
-Less labor intensive
-High spatial and temporal resolution

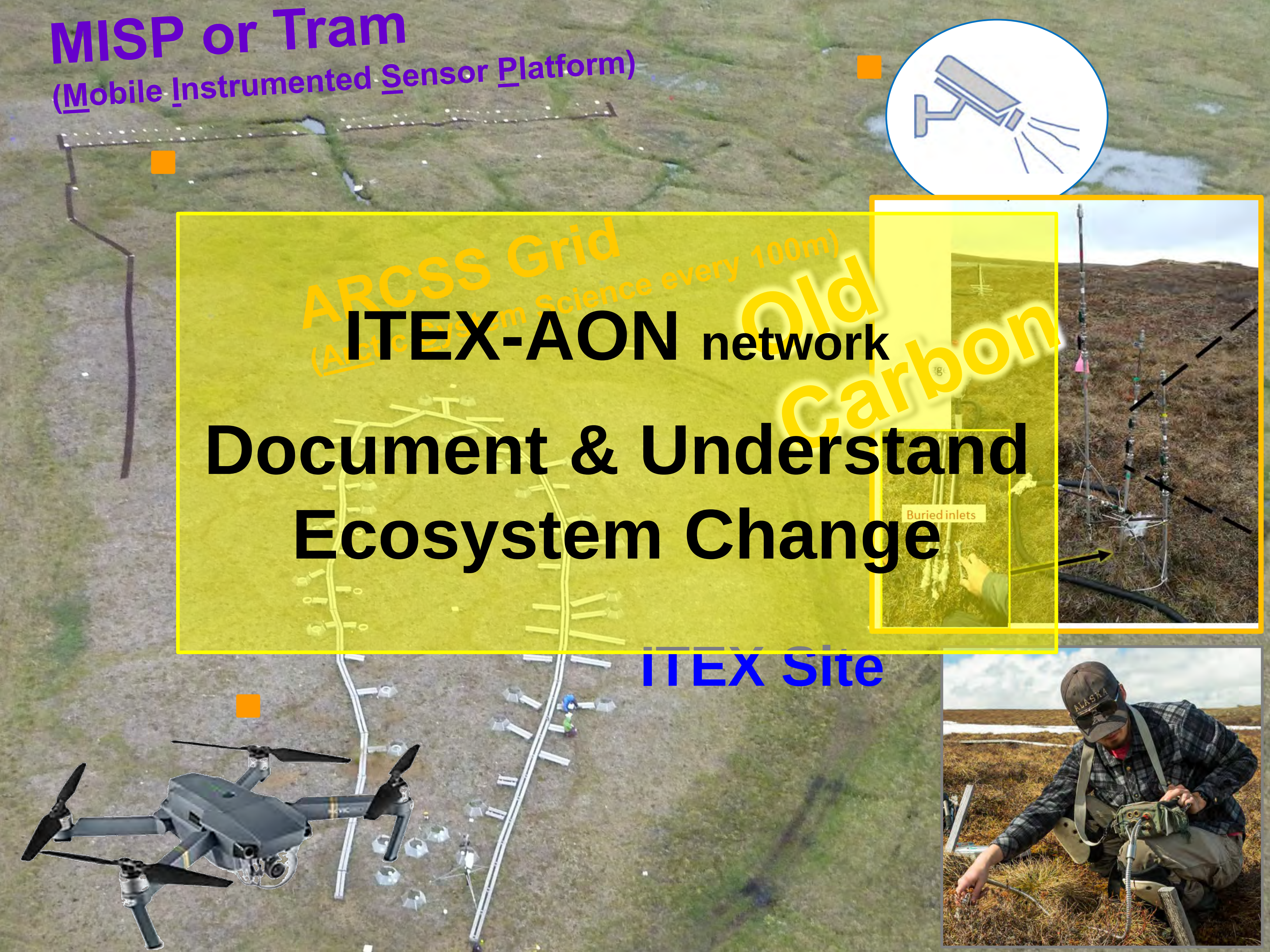
Satellites imagery

-Large scale monitoring
-Low spatial and temporal resolution

Need to Do!

- **Continue ecosystem monitoring**
  (essentially all the examples above)
- Focus on **understanding** observed changes
  (identify the processes driving the observed changes)
- **Integrate** across data types (and institutions)
- **Scale** observations


MISP or Tram
(Mobile Instrumented Sensor Platform)
ARCSS Grid
(Arctic System Science every 100m)
Old Carbon
Buried inlets
ITEX Site


MISP or Tram
(Mobile Instrumented Sensor Platform)
ARCSS Grid
(Arctic System Science every 100m)
Old Carbon
ITEX-AON network
Document & Understand Ecosystem Change
Buried inlets
ITEX Site

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