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

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What is the New Arctic?

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?

Current

Projected

IPCC (Intergovernmental Panel on Climate Change) 2007.
Why?

Predicted ANNUAL Temperature Increase in 2100

Why?

Predicted ANNUAL Temperature Increase in 2100

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

Sea Ice (end of the summer)
Observed Change

Ice Loss from Greenland & Antarctica
Observed Change

Greening Trend

Change in Leaf Area (% 1982 to 2015)
Importance of the Arctic
Simplified Energy Movement

Cold

Hot

Equator

Surface flow

Hadley cell

Hadley cell
“Polar Vortex”
Positive Feed Back 1:
Less snow $\rightarrow$ Warmer $\rightarrow$ Less snow
Positive Feed Back 2:
Taller plants → Warmer → Taller plants
Carbon Release

Positive Feed Back 3: Carbon release $\rightarrow$ Warmer $\rightarrow$ Carbon release
Paleo-Perspective (the world was much warmer)

![Graph showing temperature changes over millions of years, with different eras labeled: Paleozoic, Mesozoic, Cenozoic.]
Paleo-Perspective (the world was much warmer)

The chart illustrates temperature changes over millions of years, with distinct sections for the Paleozoic, Mesozoic, and Cenozoic eras. The graph shows temperature fluctuations, with a notable reduction in polar caps over time.
Paleo-Perspective (the world was much warmer)
Past Climate Change

- Mid-Pliocene warm period
- Pliocene mean annual temp.

Future Climate Change

- Pre-industrial average temp.

What is ITEX?

Ecologists Collaborating to Document the Impacts of Climate Change on Plants

International Tundra Experiment

1990
Collaborators agreed upon Common Protocols
The original International Tundra Experiment sites agreed on a common warming manipulation to simulate climate change.
1 Overall Synthesis
15 cross site site comparisons

Lots of Papers comparing Plant Response across sites
Responses of tundra plants to experimental warming: meta-analysis of the international tundra experiment


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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 data 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, followed by arctic sites produced the greatest 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.

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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 meta-analysis 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.

It is not possible to determine 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 is expected to increase 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 and ecosystems respond strongly to experimental 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 compiled 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...
International Tundra Experiment (ITEX)

WHAT IS ITEX?

The International Tundra Experiment (ITEX) is a network of researchers examining the impacts of warming on tundra ecosystems. Currently, research teams at sites throughout the world carry out similar, multi-year coordinated experiments that allow them to examine vegetation change across the tundra biome. The power of ITEX is the ability to perform

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

Utqiagvik
Cassiope tetragona Utqiagvik

More

Earlier

No. of Flowers

Day of the Year

Warmed

Open
Cassiope tetragona  Utqiagvik
Annual Heat Sums (Thawing Degree Days)

Inflorescence Length (cm)

Plant size (*Carex aquatilis*)

- Open
- Warmed

- Utqiagvik
- Atqasuk
Community composition

- Plant cover
- Canopy height
- Species diversity
Utqiagvik Dry Site

Ambient (control plots) vs. Warmed (experimental plots)

- Cover (%)
- Litter
- Standing Dead
- Lichen
- Bryophyte
- Graminoid
- Forb
- Evergreen Shrub
- Deciduous Shrub
Ecosystem Measurements

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

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Ecosystem Measurements

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

Utqiagvik Dry Site

(Net Ecosystem Exchange)

Warmed Switches to a CO₂ Source

CO₂ Flux (µmol m⁻² s⁻¹)

GPP
NEE
ER

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

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Institutions: GVSU, Grand Valley State University
FIU, Florida International University
UTEP, University of Texas at El Paso
UAA, University of Alaska at Anchorage
Utqiagvik (Barrow)

1. ARCSS Grid
   Arctic System Science
   100 meters between plots

2. ITEX Site (dry)
3. MISP (Tram)

Community Type:
- Dry
- Dry-moist
- Moist
- Wet
Mobile Instrumented Sensor Platform
MISP (Tram)

Automated Sampling

- Spectral properties (NDVI, but many others)
- Ground height
- Energy flux (energy balance)
- Infrared
Season NDVI (greenness) Change (whole transect)

- **Utqiavik / Barrow**
- **Atqasuk**
- **Imnaviat Creek**
- **Toolik Lake**
Speculation

Because Green-up and senescence rates respond to temperature

Because Green-up and senescence rates respond to temperature.

![Graph showing changes in NDVI with Warming and Longer Green Season](image)
Use a vegetation map to estimate the occurring across the region based on the contribution of each community type.
Satellite Kite or Drone

SSI KAP T-LiDAR

Elevation

3.1 m
2.6 m
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

ITEX Site
MISP or Tram (Mobile Instrumented Sensor Platform)

ITEX-AON network

Document & Understand Ecosystem Change

Old Carbon

ITEX Site

ARCSS Grid (Acting from science every 100m)
People that made this work possible

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