Climate as a Driver of Shrub Expansion and Tundra Greening

Interim Report

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This interim report provides a summary of the research conducted by Dr. Isla Myers-Smith and her work group (Team Shrub) from the University of Edinburgh, Scotland (UK) on Qikiqtaruk - Herschel Island over the summer of 2015.

Premise: Vegetation changes in a warming Arctic

Global warming is changing the environment all over the world, but the changes are particularly pronounced in the Northern Latitudes[1]. The Arctic is warming at twice the rate than the rest of the globe[2] and the higher temperatures associated with longer growing seasons are causing notable changes in the vegetation of the Arctic tundra: the plants are becoming more productive and the tundra is getting "greener"[3,4]. Particularly, shrubs are increasing in height and abundance[5,6] (Figure 1).

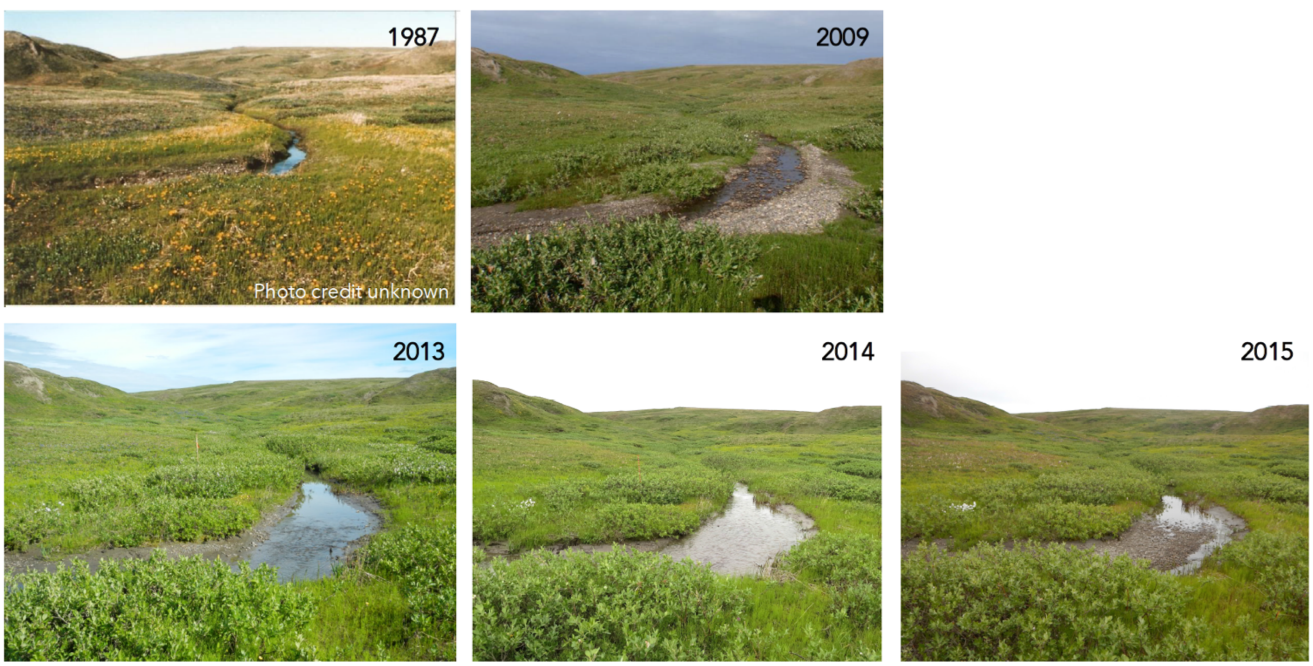


Figure 1: Increase of shrubs in Ice Creek on Qikiqtaruk over the last 28 years shown by repeat photography.

Plants are an essential source of food for the animals living in the tundra, but they also influence microbial activity in the soil and the regional climate by changing snow cover and the reflection of solar light from the landscape[7]. The latter have potentially strong influences on the global climate[7] and the changes in vegetation are therefore of interest to both people living in the Arctic and in the southern latitudes.

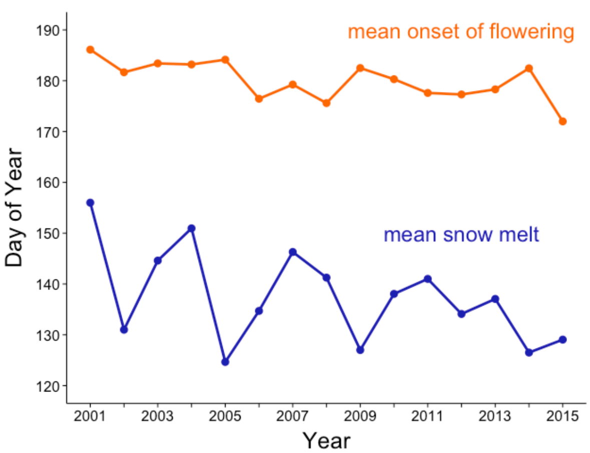
Research on Qikiqtaruk – Understanding vegetation changes
The aim of our research on Qikiqtaruk is to better our understanding of these vegetation changes, their causes and the effect they have on the tundra and the regional climate. To do so we carry out a variety of experiments and surveys, including vegetation monitoring, decomposition experiments and herbivory monitoring.

A large majority of our work forms part of ongoing long-term projects (more than 15 years) that allow us to draw meaningful conclusions of the changes over time. In the far north-west of the Yukon, Qikiqtaruk is at the end of the distribution of large shrubs, which usually would grow further south. The unique setting makes Qikiqtaruk particularly interesting to our research.

Vegetation Monitoring

1. Changes in spring leaf out, flowering and senescence
The Yukon Government Territorial Park rangers have been monitoring the annual date of leaf bud burst, flowering and senescence (autumn leaf fall) for 20 individuals of three plant species on Qikiqtaruk (mountain avens, arctic willow and tussock cottongrass). We're currently analysing the data collected over the last 14 years (2001-2015). Our interim findings show that:

- Arctic willow leaf buds burst earlier in spring and Mountain Avens flowers appear earlier.
- Snow melt seems to govern the dates of leave emergence and flowering in both species.
- No changes in tussock cotton-grass flowering over time.



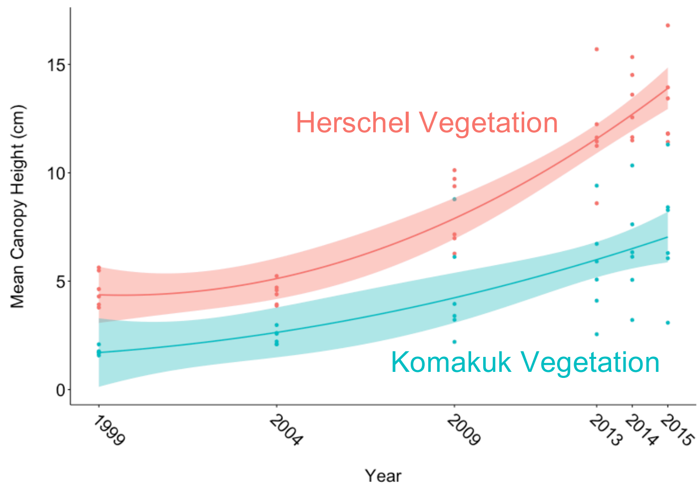


Figure 2: (a) Advancement of snow melt and flowering of Mountain Avens monitored by the Yukon Park Rangers on Qikiqtaruk (Day 121 = May 1, Day 181 = July 1). (b) Increase in vegetation height over time in two patches of tundra on Qikiqtaruk (tussock sedge dominated patch and herb dominated patch).

2. Tundra plant composition and plant height
To find out whether certain plants are becoming more abundant or are increasing in size, we're continuing measurements on the composition of two areas with distinct groups of vegetation common on Qikiqtaruk. The initial measurements were started in 1999, allowing us to look back in time for over 16 years. Combined with the most recent data that we collected in summer 2015, a preliminary analysis shows that:

- Plant height is increasing across the patches of monitored tundra.
- Certain plant species are becoming more abundant including *Eriophorum vaginatum* (cotton grass) and *Salix pulchra* (diamond leaf willow).

3. Plant traits

We collected leaf, seed and stem cuttings from Arctic tundra on Qikiqtaruk. These are used to find out plant characteristics (traits) that indicate different growth strategies and environmental responses between species. These are being examined across the global tundra to look at how they vary and are influenced by the environment.

Initial results indicate that:

- There is very large variation within individuals and species, in some cases larger than the differences between species.
- Some traits, such as height, correlate well with environmental characteristics such as temperature, indicating strong links between how plants grow and their environment.
- Some plant communities are showing changes in their traits as the tundra warms, for example, towards taller canopies. Others are remaining surprisingly stable.

4. Decomposition

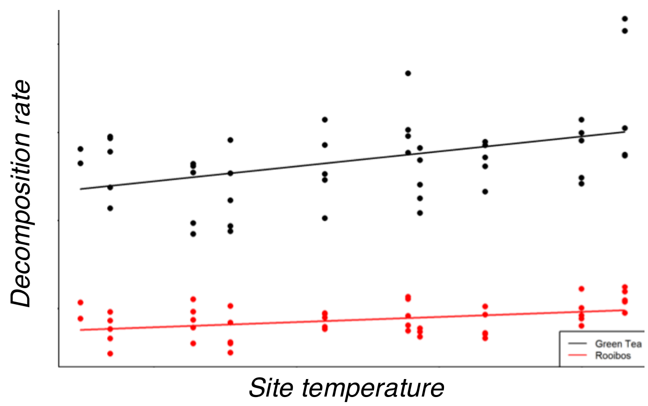
Decomposition is important for transferring nutrients from the plants to the ground. To assess whether different parts of the tundra decompose plant material at different rates we buried tea bags at range of locations across the Qikiqtaruk. These will be recovered in 2016. Doing so will allow us to see if there are large differences in decomposition between different parts of Qikiqtaruk. The same experiment is carried out by our team and collaborators elsewhere around the Arctic allowing us to understand how decomposition speeds vary around the pole. Initial findings from the circumpolar study suggest that:

In 2015 we collected leaves, flowers and stems from common plants on Qiqitaruk. These were buried in a warming common environment for one year in the Kluane Region to investigate differences how quickly different species decompose. This will tell us how the change in plant communities will increase or decrease decomposition rate overall. We also buried tea bags at range of locations to see if there are large differences in decomposition differences between sites. These will be recovered in 2016.

Initial results indicate that:

- Despite changing vegetation, the rate that communities break down has remained stable over the last 25 years.
- Decomposition is different between sites, but this is small compared to the differences between different plant types.

Burying alpine plant litter in specially prepared beds

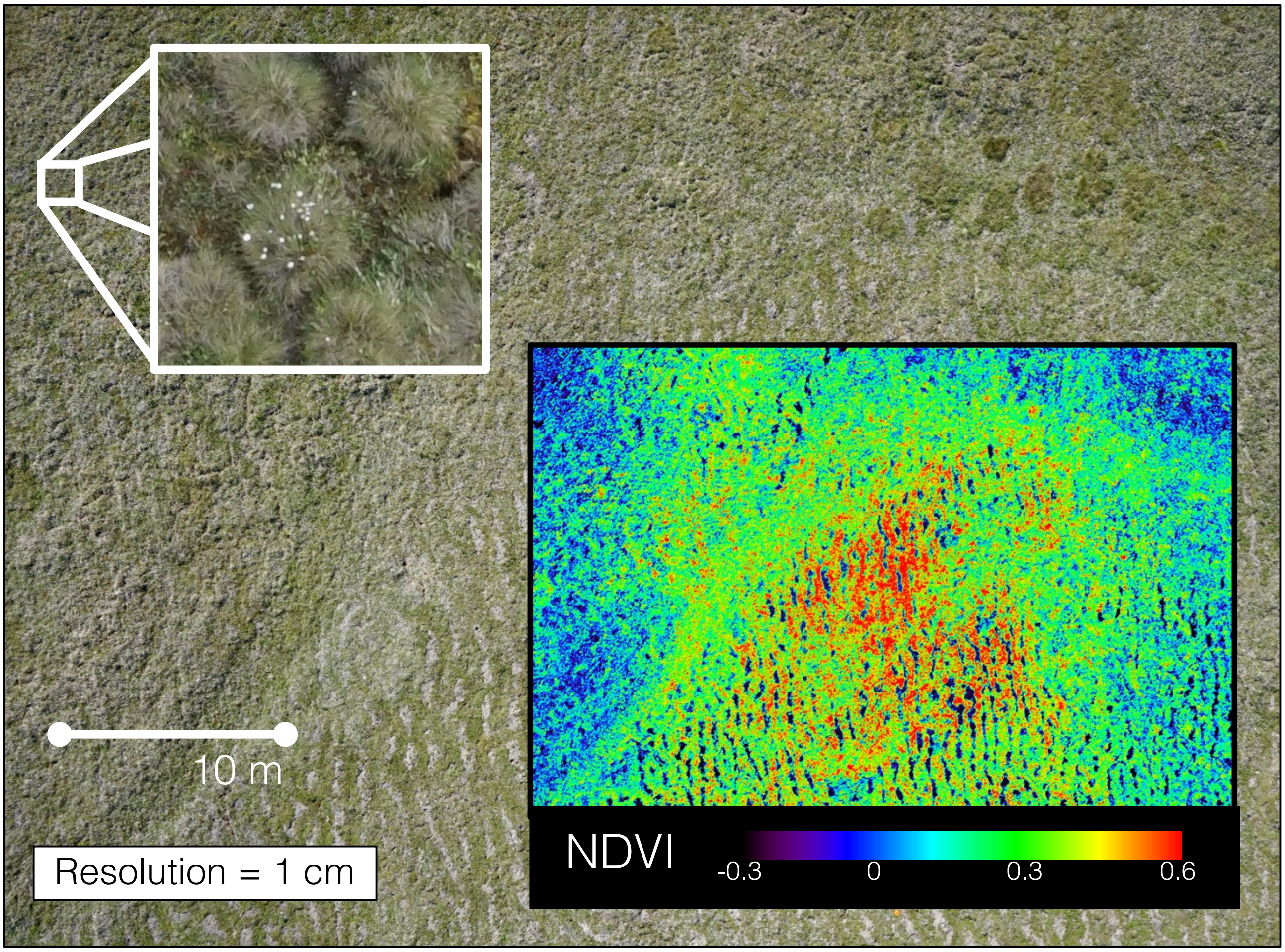


Tea decomposes faster at warmer sites, but green tea rots much faster than red tea

5. Mapping landscape vegetation with drones

Much of our understanding of changes in the tundra vegetation across regions and around the pole comes from satellite data. However, the satellite images are coarse compared to our fine-scale observations on the ground. In summer 2015, we successfully piloted the use of drones to obtain the same type of imagery that the satellites take at a much higher resolution:

- Areal imagery obtained with drones tracks vegetation greenness over the growing season (spring green-up to fall senescence).

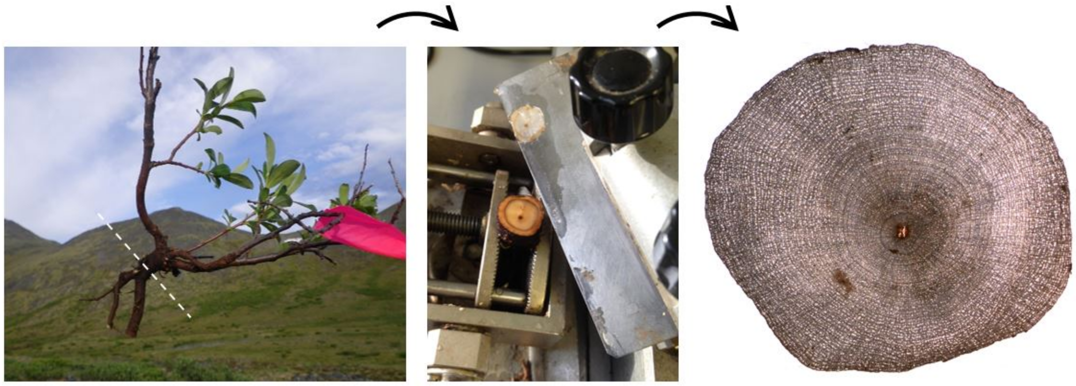


Imagery of the Herschel and Komakuk vegetation types on Qikiqtaruk and NDVI imagery of the "greenness" of the tundra. Areas that are very green and have lots of plant biomass are indicated as red in this figure and areas that have no plants – bare ground are indicated as black.

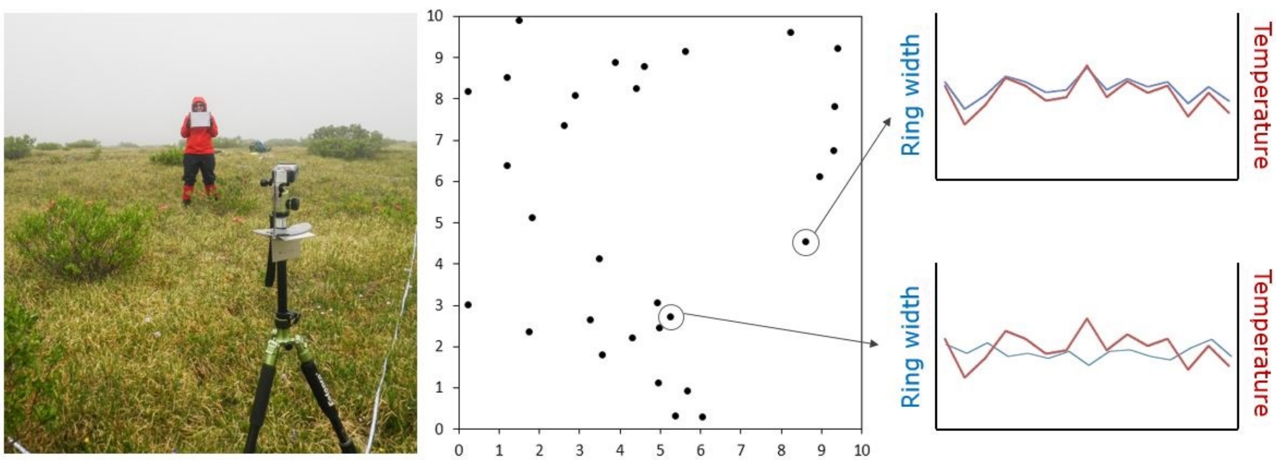
6. Competition and climate sensitivity of shrubs on Qikiqtaruk

Shrub expansion rates vary from site to site and among species, because non-climatic factors also control vegetation dynamics. One factor that could mitigate the climate response of shrubs is competition for resources such as water and nutrients. This is supported by studies at the treeline, but has never been tested on tundra vegetation. We therefore aim to determine whether competition alters the climate sensitivity and the expansion potential of shrub communities in the Canadian Arctic. More specifically, our objective is to investigate how the climate response of shrubs vary according to the number, size and proximity of competitors.

1. Shrubs are mapped in 10 m x 10 m plots
2. Shrubs are sampled and processed to measure the growth rings
3. Growth rings are linked to local temperatures and the climate response of each individual is examined in function of its neighbours.



Preparation of samples for growth-ring analysis Preparation of samples for growth-ring analyses, from sampling (left) to preparation of thin sections (center) that can be photographed under the microscope (right). Growth rings can then be measured on the computer.



Sampling of shrubs to estimate the importance of competition on the climate sensitivity of growth Field mapping of shrubs in a 10 m x 10 m plot (left), the resulting map (centre), and expected climate-growth relationships (right). Isolated individuals that are not competing for resources are expected to have a more consistent growth response to variations in temperature (upper right) than shrubs that are competing with their neighbours (lower right). Isolated shrubs that are not competing for resources are expected to have a more consistent response to variation in temperature than shrubs that have many competitors around.

In 2015, we mapped and sampled 6 plots on Qikiqtaruk. These are part of a larger sampling efforts with 17 other plots located in the Kluane Region of the Yukon, in Umiujaq (QC) and in Salluit (QC). The growth rings are currently being counted and measured. The width of the rings will be linked to local climate data to determine how strongly growth is influenced by climate. This sensitivity will then be linked back to the spatial data, which will tell us if an individual with many neighbours responds less to warming than an isolated individual. Samples are currently being processed and preliminary results are expected in the spring 2016. The completion of this project is expected in 2017.

7. Carbon stored in tussock tundra

The arctic landscape is projected to change from a tussock- to a shrub-dominated tundra with ongoing climate warming. The carbon stored in the tussock landscape is presently poorly quantified and the fate of these carbon stores, in the event of tussock loss, is largely unknown. Tussocks change their soil microenvironment and a vegetation community shift may have indirect effects on the soil carbon stocks as well.

As a part of the Carbon in Arctic Tussock Tundra (CATT) Network, lead by Adrian Rocha, Notre Dame University, Team Shrub carried out the CATT protocol to help quantify arctic tussock carbon stores. Data and samples were sent to Rocha's team for further analysis.

8. Herbivory monitoring

One of the reasons that plants such as shrub species could be increasing in tundra ecosystems might be a reduction in the number of animals feeding on those plants over time. Though large mammal populations of caribou and muskox have been relatively stable on Qikiqtaruk over the past 15 years (*Pers. Comm.* Herschel Island – Qikiqtaruk Territorial Park Rangers, Cameron Eckert), we do not know the exact impact of herbivores in the area where the long-term ecological monitoring occurs on the island over time.

In order to assess the role of herbivory, animals eating plants at these sites, we surveyed for animal sign such as feces, nests, wool (qiviat), and leaf damage from animals such as caribou, muskox, lemmings, ptarmigan and insects. We have been conducting these protocols over the past couple of years to contribute to assessments of herbivore densities and impacts on plant communities around the tundra biome coordinated by the Herbivory Network (http://herbivory.biology.ualberta.ca/).

Additional information:

Team Shrub at the University of Edinburgh https://teamshrub.wordpress.com/
The Tundra Tea Bag Experiment https://tundratea.wordpress.com/
The Global Tea Bag Index www.decolab.org/tbi
Herbivory Network http://herbivory.biology.ualberta.ca/