# Using drones to understand Arctic greening: How does phenology respond to climate and what are the implications for tundra vegetation change?

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**Short Summary:** This PhD project will explore the importance of climate in explaining changing plant phenology and vegetation in Arctic tundra ecosystems.
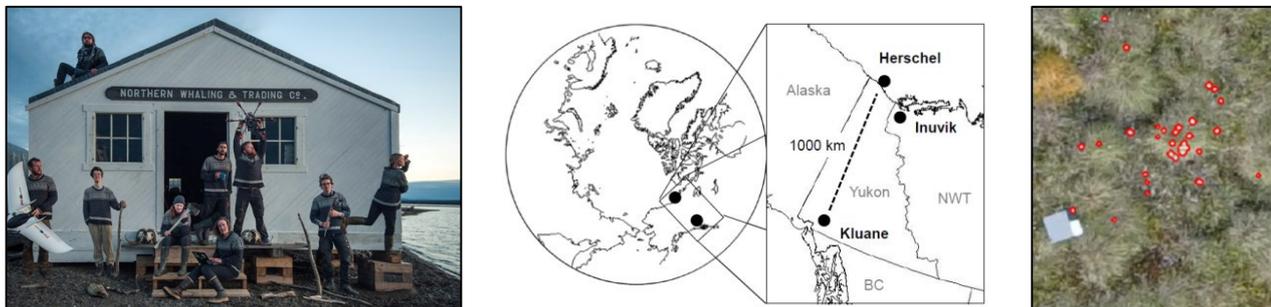
Figure 1. Team Shrub in 2016, a map of the field locations in the Canadian North and a drone image with flowers identified using image analysis.

**Project background:** Global climate change has been identified as a serious threat that is having profound impacts on terrestrial Arctic systems, including altering tundra plant communities. Though recent evidence indicates widespread vegetation change around the tundra biome, we still have a very limited understanding of how plant growth and plant phenology are controlled directly by climate versus indirectly through interactions with other biological or environmental factors.

**Aims:** This PhD research project will use long--term records of plant phenology, phenocam imagery (time lapse photography) and remotely--sensed drone data to test the factors best explaining variation in plant phenology including flowering abundance across the landscape and over time. The project will test fundamental global change research questions and help to develop common protocols that can be applied across Arctic tundra sites to capture vegetation change from phenocam networks and drone data collection. The PhD student will gain skills in operating drone systems, image analysis, hierarchical modelling and will contribute to international data synthesis. The PhD programme will interface with international collaboration as a part of the Shrub Hub, International Tundra Experiment (ITEX), sTUNDRA and newly formed Drone Ecology research networks and will provide opportunities for the recruited student to develop their own targeted research questions within a larger project.

**Key Research Questions:** This project will explore the overall hypothesis that climate is the primary driver of recent vegetation change in tundra ecosystems by exploring records of flowering phenology. This PhD project will address three specific factors influencing the climate response of tundra plants that remain little explored:
1. How does flowering phenology and reproductive effort of sedge tussocks (*Eriophorum vaginatum*) and avens (*Dryas integrifolia*) vary over time and across the landscape in relation to climate, microsite conditions and experimental warming?
2. Do data observed at different spatial scales and temporal frequencies influence the climate-phenology/reproductive effort relationships detected?
3. Do sites that demonstrate greater climate--sensitivity of phenology, reproductive effort and reproductive success (fitness) demonstrate greater cover change over time for tundra key species across the tundra biome?

**The Student:** We aim to recruit an enthusiastic, highly motivated and quantitative student with a background in ecology, environmental sciences, ecoinformatics or a related discipline.
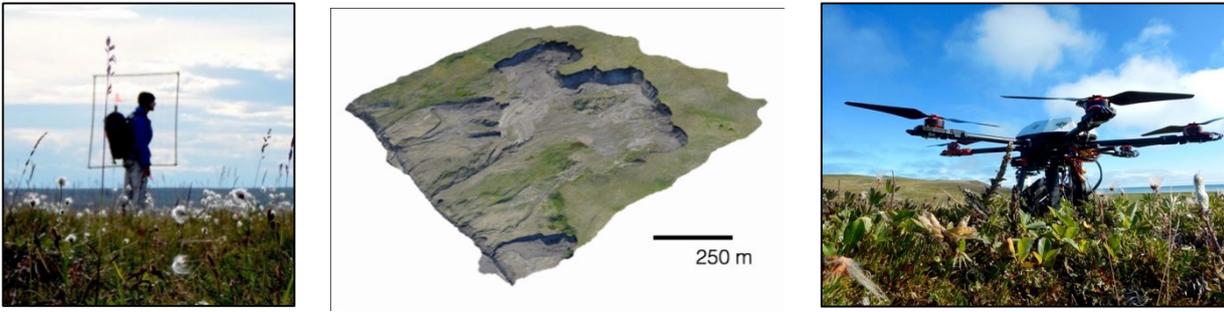
Figure 2. Images of ecological and drone--based monitoring and a 3D structural model produced from drone imagery.

**Project Description and Methodology:** This PhD project will consist of three mutually--supportive research directions: 1) integration of drone, phenocam, ecological monitoring data and experiments, 2) analysis of patterns and processes across scales contributing to the development of cross--site data collection protocols, and 3) synthesis of ecological datasets and international collaboration. You will have access to datasets of drone, ecological monitoring and phenocam data from our Qikiqtaruk field site;; plant phenology and cover change from sites around the tundra biome and the opportunity to conduct multisite tundra synthesis or to establish new experiments. The student will have significant scope to develop their own research ideas within these three research themes. Opportunities also exist to explore other aspects of tundra disturbance such as active layer thaw depths, cryoturbation processes and retrogressive thaw slumps. The project will involve fieldwork in the Western Canadian Arctic, on Qikiqtaruk -- Herschel Island and in the Kluane Region of the Yukon Territory. The project will also involve collaboration with scientists across the Shrub Hub, sTundra and ITEX networks. Opportunities exist for extended visits with collaborators and participation in international conferences. The fieldwork involves coordination and collaboration with other research teams and local northern communities.

**Training and Facilities:** A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. The recruited student will gain skills in plant ecology, climate change science, experimental design, statistical analysis including hierarchical modelling in a Bayesian framework, image analysis including structure--for-motion photogrammetry, data management including using GitHub, science communication and field logistics. In addition, the student will develop expertise in the safe operation of drones for geoscience applications, supporting by in--house training by the supervisory team and the University of Edinburgh's Airborne Geoscience Facility. The project links to NERC--funded research on tundra vegetation change, data synthesis funded by the German Synthesis Centre for Biodiversity Science, and the research programmes of collaborators in the US, Canada and Germany. The recruited student will join a vibrant tundra plant ecology research group at the University of Edinburgh and will interact with plant ecologists and climate change scientists in the School of GeoSciences and Biological Sciences and through the Edinburgh Ecology Network.

**Future Opportunities:** This PhD training will provide many opportunities to pursue a research or applied career in ecology. The supervisory team will provide excellent training, career development and mentorship of relevance to career paths in the UK, Europe and internationally. The lead supervisor, Dr. Isla Myers--Smith, has built a dynamic research team including PhD students, postdocs, visiting researchers and under--graduate students (http://teamshrub.wordpress.com/). Additionally, through the scientists involved in sTundra, the ShrubHub and ITEX networks, the student will develop extensive network of tundra ecologists across continents.


Figure 3. Opportunities exist to conduct field research in the Yukon Territory