Differences in vegetation and thaw depths of frost boils and inter-boils of acidic and non-acidic tundra

A Research Experience for Undergraduates (REU) Project

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Introduction

Frost boils are small patterned ground formations created by the formation of ice lenses and frost heave. A contrast can be seen between frost boils and inter-boil areas. Disturbance created by cryoturbation results in less vegetation on frost boils as compared to inter-boils. Well developed frost boils are sparsely vegetated by mosses and lichens. Prostrate dwarf shrubs, sedges and an overall greater amount of biomass characterize inter-boils. Differences are also observed in boil and inter-boil areas on different parent material. The purpose of this project was to study the differences in vegetative characteristics (biomass, leaf area index and normalized difference vegetation index) and thaw depth between 1) frost-boil and inter-boil areas and 2) moist acidic and moist non-acidic tundra. The insulative properties of a heavy biomass layer (especially from moss) can affect seasonal thawing. The central hypothesis of this project was that vegetative differences between boil and inter-boil areas and between acidic and non-acidic tundra are the primary controlling factors on active layer thickness (thaw depth). Secondly, we hypothesized that a smaller amount of biomass would result in greater summer thawing.

Acidic Boil

Acidic Inter-boil

Methods

Study sites: Sagwon, along the North Slope near Prudhoe Bay, Alaska

	Moist Acidic Tundra	Moist Non-acidic Tundra
Boil	3 plots	3 plots
Inter-boil	3 plots	3 plots

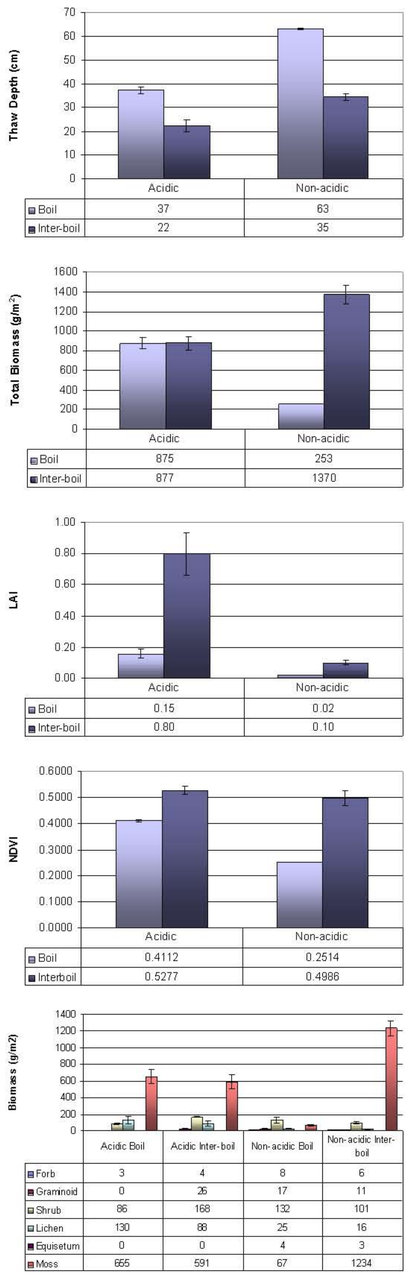
Thaw depth was measured by pushing a thaw probe into the ground until reaching a solid layer of frozen soil below. Three thaw depth measurements were taken on each plot in late July (July 19-20).

Biomass: One 20 x 50 cm biomass clipping was taken from each plot. All live vegetation was collected and sorted by functional group: lichens, moss, forbs, shrubs, equisetum and graminoids. Samples were then dried and weighed. All biomass was clipped July 11-31, during peak season.

Leaf Area Index (LAI) was measured with an LI-COR LAI-2000 Plant Canopy Analyzer. This instrument quantifies plant canopy cover by calculating the difference in diffuse radiation above and below the canopy (ATLAS 2000). A control reading was taken from above the canopy and four measurements were taken from below the canopy, just above the moss layer. From this, a mean LAI value was calculated for each plot. LAI was measured July 19, during peak season.

Normalized Difference Vegetation Index (NDVI) was used as a measure of "greenness." NDVI is the difference between the near-infrared channels (NIR = 0.76 - 0.0 µm) and the red channels (R = 0.63 - 0.69 µm). The NIR radiation is strongly reflected by healthy vegetation; whereas red light is absorbed for photosynthesis. The differences in these channels is normalized by their sum to account for the effects of slope and shadows which can change the total light conditions, such that NDVI = (NIR - R)/(NIR + R).
NDVI was measured July 18, during peak season, using a PS-II instrument made by Analytical Spectral Devices, Inc.

Note: two of the non-acidic boils were not sampled for NDVI and LAI.



Results and Discussion

- Non-acidic boils have significantly* less total biomass than non-acidic inter-boils (253 g/m^2 vs. 1370 g/m^2, respectively) and deeper thaw depth (63 cm vs. 35 cm, respectively).
- For acidic tundra, however, there was no correspondence between biomass and thaw depth. Biomass on acidic frost-boil and inter-boil plots were about the same (875 g/m^2 and 877 g/m^2, respectively), yet acidic boils had nearly twice as much thaw compared to inter-boil areas (37 cm and 22 cm, respectively).
- Acidic boils have significantly* more biomass than the non-acidic boils (875 g/m^2 and 253 g/m^2, respectively) and a significantly* shallower thaw depth (37 cm and 63 cm, respectively).
- Non-acidic inter-boils have significantly* more biomass than acidic inter-boils (1370 g/m^2 vs. 877 g/m^2, respectively) but have a significantly* deeper thaw depth than acidic inter-boils (35 cm vs. 22 cm, respectively).
- Moss biomass between acidic boils and inter-boils were similar (655 g/m^2 and 591 g/m^2, respectively), yet significant** differences were seen between non-acidic boils and inter-boils (67 g/m^2 and 1234 g/m^2, respectively), acidic and non-acidic boils (655 g/m^2 and 67 g/m^2, respectively), and between acidic and non-acidic inter-boils (591 g/m^2 and 1234 g/m^2, respectively).

*at 95% confidence interval
**at 90% confidence interval

Non-acidic Boil

Non-acidic Inter-boil

Conclusions

1) There was generally deeper thaw on frost boils than on inter-boil areas, and on non-acidic compared to acidic parent material.

2) However, there is not a general inverse correspondence between biomass and thaw depth that was expected.

3) Unmeasured variables that may help explain such discrepancies include thickness and density of the organic layer (biomass only measures "live" material) and variations in physical properties of the soil, such as soil moisture and soil texture.

4) No good correlation was found between LAI, NDVI and biomass.
   - LAI measures leaf canopy, but does not account for moss, as the instrument is placed above the moss layer when readings are taken.
   - Differences between the acidic and non-acidic plant composition may point to why NDVI readings do not give much connection to biomass data.

5) The effects of variations in moss biomass must be further addressed.

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Literature Cited:
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