Manipulation of Vegetation Canopy and the Effects on Cryoturbation Regime in Alaskan Arctic Tundra

A. Kade, D. A. Walker

Institute of Arctic Biology, University of Alaska Fairbanks, AK 99775

INTRODUCTION

Frost boils are small landforms typical of permafrost regions (Fig. 1) and are caused by differential frost heave (Peterson and Krantz 1998). Once frost boils are formed, they are self-perpetuating in nature. They display tight linkages among vegetation, soil and cryoturbation. Ice-lens formation and the degree of frost heave determine the type of vegetation and quantity of plant biomass that a frost boil can support. Fewer frost-heave disturbances should favor a thicker vegetation mat. In turn, the vegetation mat covering the frost boil should insulate the soil, decreasing heat flux between the soil surface and air, thus decreasing the amount of frost heave.

Fig. 1. Typical frost-boil landscape

Frost boils are highly susceptible to environmental change as they seem to emerge only under certain environmental conditions. A change of vegetation characteristics or a shift in plant functional types on frost boils, possibly caused by global climate change in the near future, could alter the cryoturbation regime and lead to new landscape patterns. The following experiment was designed to investigate the influence of certain vegetation characteristics on cryoturbation activity.

OBJECTIVE

The complex frost-boil ecosystem can be broken down into three major, closely linked components: vegetation, soil, and cryoturbation. The objective of this study was to examine the influence of plant canopy and different plant functional types on the cryoturbation regime of frost boils (Fig. 2).

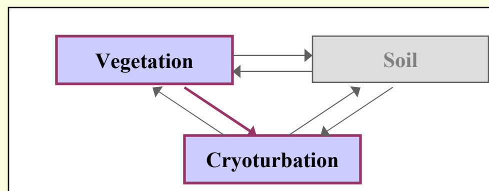

Fig. 2. Major components of the frost-boil system and their interactions.

Following questions were investigated:

- What influence does the lack of plant canopy have on thermal insulation and cryoturbation parameters of frost boils?
- How do vascular plants with an extensive root system *(Eriophorum vaginatum)* affect cryoturbation activity?
- What effect does an insulating moss carpet have on cryoturbation activity?

LOCATION

A field site near Sagwon Hills, Alaska along the Dalton Highway (Fig. 3, Fig. 4) was chosen to experimentally manipulate the vegetation on frost boils. The site is located on the arctic coastal plain, and the vegetation is classified as erect dwarf-shrub tundra (Walker 2000).

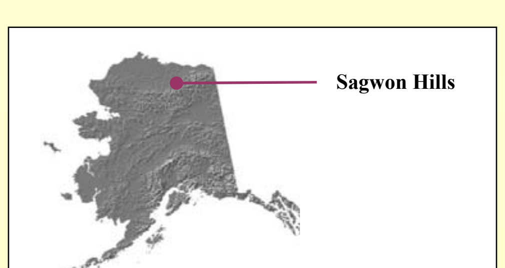

Fig. 3. Map of Alaska, with field site Sagwon Hills.

Fig. 4. View of field site Sagwon Hills.

METHODS

Twenty-eight well-vegetated frost boils in close proximity were selected and an area of 0.5 m^2 at the center of each frost boil received one out of four treatments in July 2002:

Vegetation Removal

Vegetation removal and transplanting *Eriophorum vaginatum* seedlings

Vegetation removal and transplanting a 0.1 m thick moss carpet

Control – no manipulation

We recorded maximum frost heave, maximum thaw depth, soil moisture, soil temperature and soil surface stability over the course of one year (August 2002 – August 2003). We anchored a metal pole at each experimental plot into the permafrost to measure vertical movement of the ground (frost heave), and we pushed a probe through the active layer to determine thaw depth. We recorded volumetric soil moisture of the upper 6 cm of the soil with a ThetaProbe and soil-surface temperature with a digital soil thermometer several times throughout the summer and fall. At each plot, we inserted 25 toothpicks halfway into the soil in July 2002, and the movement of the picks during a one-year period caused by cryoturbation activity served as an indicator for soil-surface stability.

RESULTS

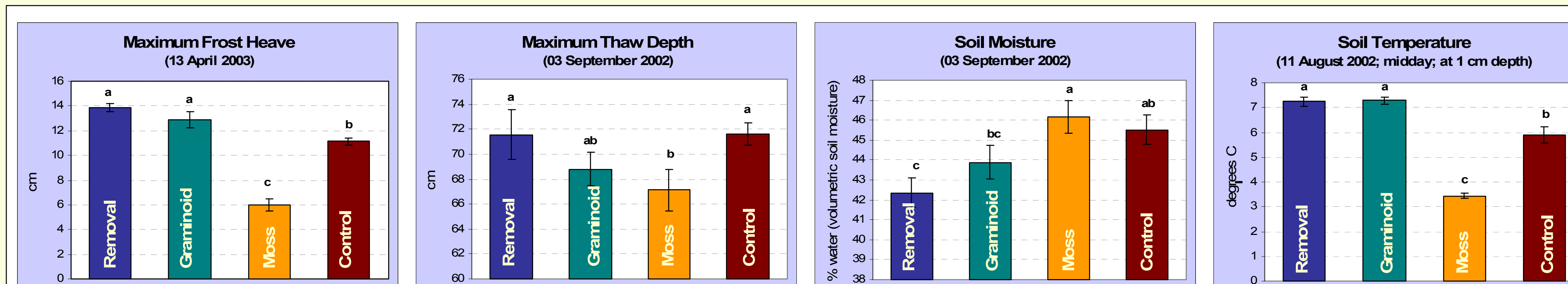

Fig. 5. Maximum frost heave (cm), maximum thaw depth (cm), volumetric soil moisture (%) and soil-surface temperature (ºC) for vegetation removal, graminoid, moss and control plots at Sagwon Hills, Alaska.

Maximum frost heave was increased by the bare and graminoid treatments by about 2 cm with respect to the control plots, and was decreased by the moss treatment by about 6 cm (Fig. 5). Thaw depth was significantly reduced by the moss treatment by almost 5 cm, whereas the other treatments did not change thaw depths when compared to the control. The moss plots exhibited wetter soils (46%) than the bare plots (42%) and graminoid plots (44%), but only the bare plots differed significantly from the control plots (45%). Soil-surface temperature increased by about 1.5ºC in the bare and graminoid plots when compared to the control plots, and decreased 2.5ºC in the moss plots.

The position of each toothpick was categorized as either "straight", "tilted" or "expelled" after one year (Fig. 6). Bare plots showed a high percentage of expelled toothpicks (89%) and a low percentage of straight toothpicks (5%). Graminoid plots also exhibited many expelled toothpicks (63%), but had a larger fraction of tilted (14%) and straight toothpicks (23%) than the bare plots. In contrast, most toothpicks were still straight in the moss treatments (89%) and in the control treatments (85%), and only a small fraction of toothpicks were tilted or expelled. The soil surface was generally protected against soil movement at the moss and control plots, whereas bare plots showed a high degree of soil-surface instability.

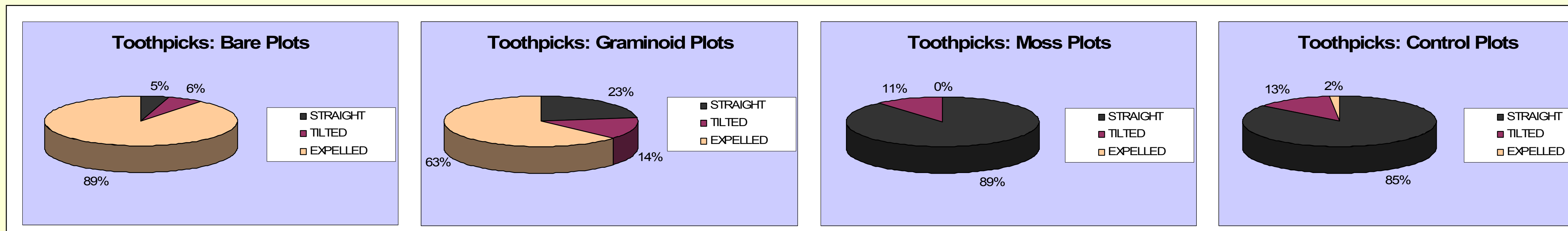

Fig. 6. Percent straight, tilted and expelled toothpicks in bare, graminoid, moss and control plots. Toothpicks were inserted halfway into the soil and their position was recorded after a one-year time period.

DISCUSSION

Preliminary results suggest that cryoturbation activity is closely linked to the properties of the vegetation canopy: Moss treatments insulated the soil, leading to decreased frost heave, thaw depth and soil-surface temperature and increased soil-surface stability. In contrast, vegetation removal seemed to increase heat flux between the air and soil, resulting in increased frost heave and soil-surface temperature and decreased soil moisture and soil-surface stability. Graminoid transplants had a similar effect on cryoturbation activity, although the effect was less pronounced. The influence of vegetation properties on the upper portion of the soil is apparently an important player affecting the overall cryoturbation regime. A possible shift to a thicker, moss-rich vegetation type facilitated by global climate change might result in less cryoturbation activity and slow "dying-off" of frost boils in this climatic subzone.

REFERENCES

Peterson, R. A. and W. B. Krantz. 1998. *A linear stability analysis for the inception of differential frost heave*. Proceedings of the Seventh International Conference on Permafrost, Yellowknife, Canada. University of Laval, Toronto, Canada.

Walker, D.A. 2000. Hierarchical subdivision of arctic tundra based on vegetation response to climate, parent material, and topography. *Global Change Biology* 6: 19-34.

Walker, D. A., H. E. Epstein, W. G. Gould, W. B. Krantz, R. Peterson, C. L. Ping, V. E. Romanowsky and M. D. Walker. 2001b. Biocomplexity associated with biogeochemical cycles in arctic frost boil ecosystems. Research proposal funded under NSF award OPP-0120736.

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