Analysis of the Interactions Between Snow and Shrub Ecosystem of the Taiga in Nunavik

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ABSTRACT

Many recent articles have shown that the growth of vegetation increases under a warming climate since the last 30 to 40 years in high latitudes. In particular, the shrub vegetation appears to develop itself throughout the transition zone between tundra and taiga. The feedback of the vegetation on snow could affect the properties of snow cover, notably snow albedo as clearly shown by climate models. Shrubs can also accelerate the melt of snow in spring when branches start protruding through the snow, but in return the shade effect of shrubs on snow can decrease the snow melt. Furthermore, the vegetation has the capacity to trap the snow ("trapping effect") creating a barrier against wind. Thus what will be the final impact between these opposite effects (trapping and shadowing vs accelerated melting)?

The general objective of this research is to better characterize and quantify the impact of the shrubs on the evolution of snow in this transition zone in Nunavik from satellite remote sensing and *in-situ* measurements. The research is focalized on the region of Umiujaq and the James Bay area. Snow depth has been measured on many transects over different land covers. These have managed to prove the existence of trapping effect in the transition zone. A total of 7 transects were done in Umiujaq over 6 km and 8 more in the James Bay area over 4km. Data analysis using PLEIADE images are in progress and should bring significant results as well. Normalized difference snow index using Landsat images have been analyzed to see the difference in melt throughout different types of land cover and a slight difference has been shown between these zones.
Keywords : Snow Remote Sensing, snow depth, trapping effect, shadow fraction, thermal radiance

INTRODUCTION

The effect of vegetation on snow is a subject that is not well characterized yet. Snow is an important input in the hydrological systems in the polar parts of the world. Vegetation gets scarce as we move further north, but the warming climate makes the proliferation of vegetation possible. Vegetation can lead to deeper snow through wind trapping effect, accelerate snow melt from radiative transfer or decelerate the melt by shadowing effect. These effects can modify snow cover in many ways throughout the accumulation period during the winter as well as the melting period in spring.

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The evolution of snow throughout the land can affect the atmospheric circulation, permafrost formation, soil hydrology, flora growth as well as access to nutrients for the fauna. Furthermore, the high albedo of snow influences the radiative balance between ocean, earth and atmosphere. The understanding and characterization of the effects of vegetation on snow would bring a better understanding of snow cover evolution on arctic regions that are changed under warming climate.

OBJECTIVES

The general goal of this research is to characterise and quantify the impact of shrubs on snow cover dynamic in regards to an uncovered soil in Nunavik using Satellite remote sensing, models and in-situ measurements. This goal brings in two main objectives. First, develop a new approach allowing snow depth retrievals using high resolution visible imagery. And second, to determine if vegetation either accelerates or decelerates spring melt by determining the relative impact of trapping effect, shadow effect and thermal radiance.

STUDY SITE

The Tasiapik Valley situated in Umiujaq in Nunavik, Quebec (Figure 1). It holds a microclimate created by the warm air coming from Lake Guillaume which is being trapped by the high walls of the valley. This micro climate is important for this research as we have different land covers over a small (12km^2) area. The land cover consists of naked ground, short shrubs, high shrubs (*betula grandulosa*) and a forested area of spruce. There are two weather stations on site which measure snow in detail and weather in general. More than 500 mm of precipitation reach the valley every year. The snow depth has been measured at over 200 cm at some places along the valley.

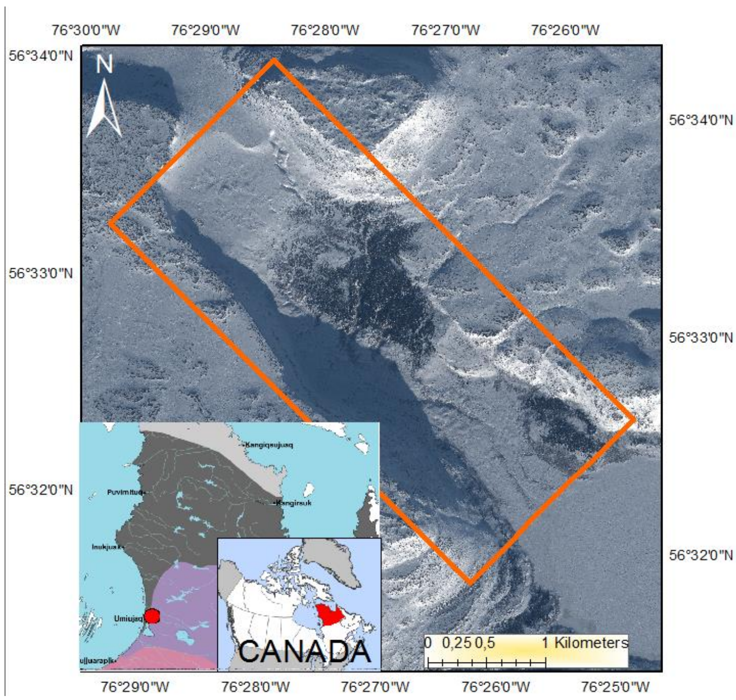

Figure 1. The Study site in Umiujaq, Québec, called the Tasiapik Valley. Background map: Pléiades image from January 29th 2014

METHOD

The data used for this research consists of a compilation of images from a variety of satellites. We have acquired 2 winter images from Pléiades which have a spatial resolution of 50cm. These images are used to measure snow depth with a new algorithm using tree shadow fraction. To validate this algorithm in-situ measurements of snow depth have been performed at the given dates of the images. Using a tool called the magnaprobe a maximum of snow depth data have been measured. By figure 2 we now know that it is only necessary to measure snow depth for ±30m in each zone (Clark et al. 2011). A classification of vegetation was made possible by the work of Provencher-Nolet et al. (to be published). This classification determines the land cover type in the valley and is of great help for the study. 19 Landsat images have been acquired to study the change in NDSI over the year. We can study snow melt using this technique to determine if snow melt is different depending on land cover. The data from the two weather stations will help us determine the cause of the change in snow depth. During our in-situ measurements we also did a number of snow pits with which we studied snow density, grain size and snow temperature at different places across the valley. This data is important to characterize the response of snow to the vegetation. Figure 3 presents the method used in a schematic way.

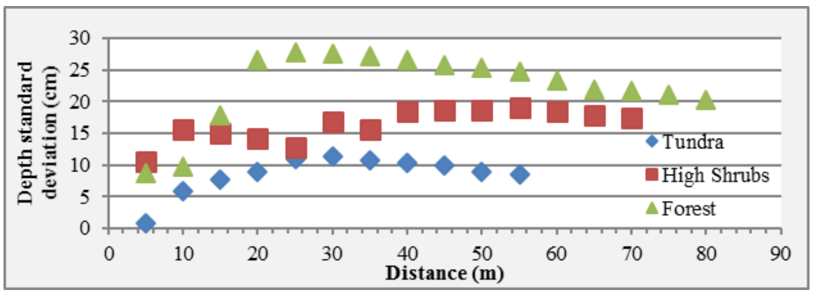

Figure 2. Representativeness length of MagnaProbe transects

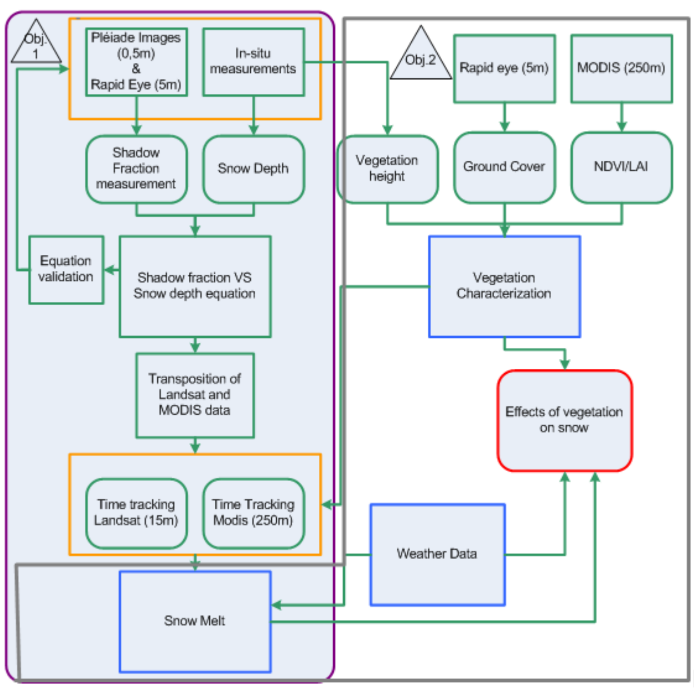

Figure 3. Schematic view of the method used

RESULTS AND DISCUSSION

To characterize the effects of vegetation on snow cover, we have measured the snow depth on different zones of the valley at 2 different times during the winter. The first time was at the end of January 2014 and the second at the end of February. With figure 4a and 4b, we can observe the difference of snow depth across the valley according to the land cover zones. With data from the weather stations we can analyze the difference of snow depth between the two dates. An event of strong winds would prove the importance of trapping effect in the high shrub area and in isolated spruce areas. Future analysis of this data will imply creating a classification map of tree shadow using the two Pléiades images. This classification will be used to measured tree shadow fraction. With this data a link will be made between tree shadow fraction and snow depth. Our validation will be made using the information from figure 3a and 3b, comparing known snow depth with shadow fraction. The goal here would be to be able to determine snow depth if another very high resolution image was acquired.

To analyse the melt in the different land cover zones, 19 Landsat images were manipulated using PCI geomatica. The Normalized Difference Snow Index (NDSI) was measured in each zone. The mean value of NDSI was kept as the NDSI value for each zones. In figure 5, we can see the evolution of snow cover throughout the valley. We can notice that NDSI in tundra is generally higher throughout the year. It also seems that the tundra and isolated spruce zones are melting slower than the two other zones. This could possibly be explained by radiative transfer between snow and a bigger vegetation cover. The shadowing effect is still not clear.

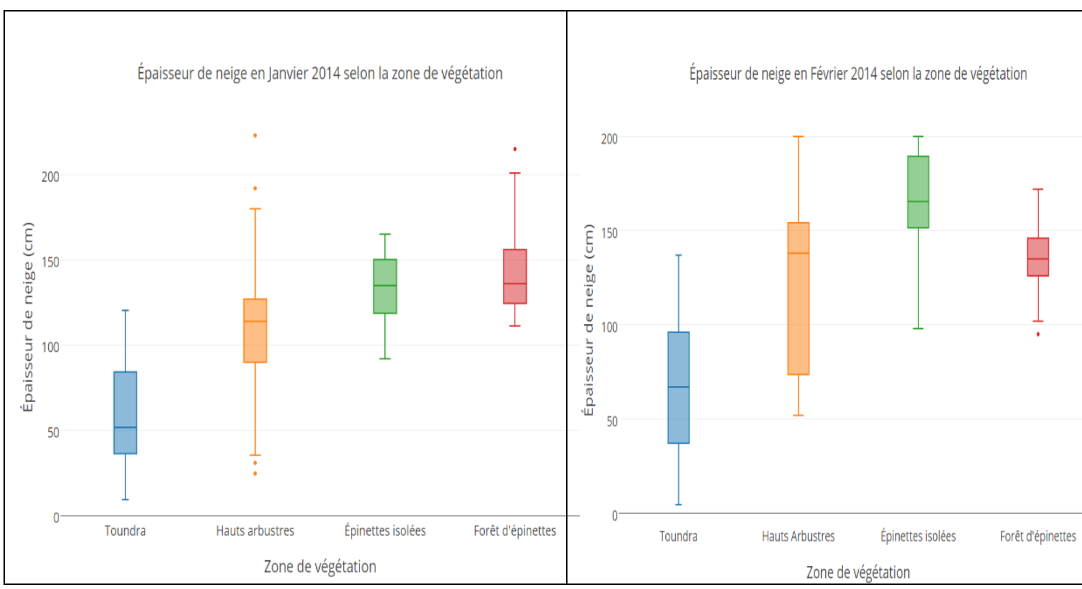

Figure 4. a) Snow depth in the different land cover zones in January 2014. b) Snow depth in the different land cover zones in February 2014

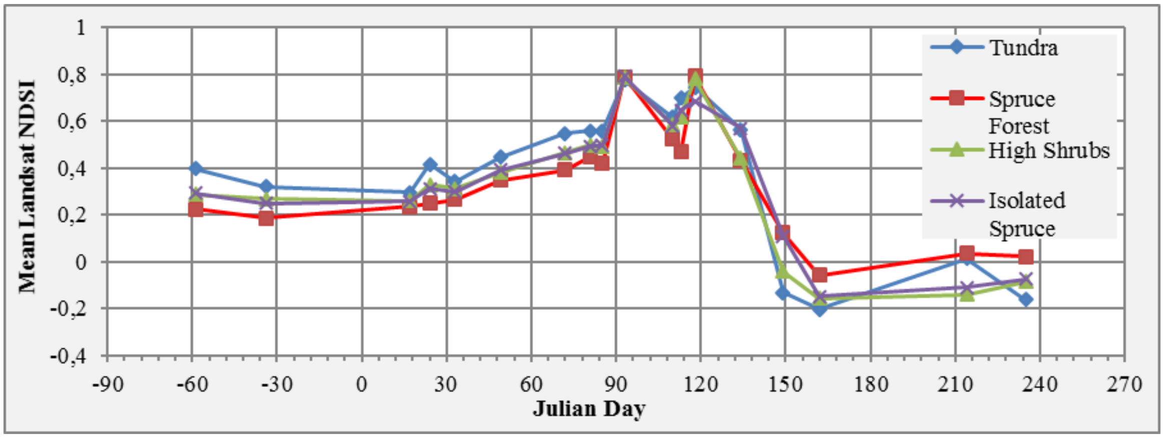

Figure 5. Change in Normalized Difference Snow Index (NDSI) with the day of the year

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