Monitoring the Seasonal Ground freezing in the Northern Quebec Tundra using Active and Passive Microwave.

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INTRODUCTION

This study conducted in the framework of the International Polar Year and "*Variability and Change in the Canadian Cryosphere* - A Canadian Contribution to "State and Fate of the Cryosphere" project under the leadership of Environment Canada (EC). The objective is to follow the seasonal ground freezing in the Northern Quebec tundra region (Nunavik) using passive and active microwave data. The continuous acquisition of spatial data in the microwave can follow a daily soil conditions (humidity), moisture content of vegetation and water equivalent of snow. Cloud cover does not influence this technique [1, 3]. The seasonal freeze-thaw cycle is a major phenomenon in the climate system and plays an important role in ecosystem functioning [3] by influencing the rate of photosynthesis and respiration of the vegetation [6], reducing evaporation, reducing the penetration of water into the soil and altering surface runoff [4]. The freezing of the soil is, in fact, the freezing of water in soil pores. The speed at which the frost is spread in soil depends on its physical properties (texture, porosity); its water content, weather (the air temperature, the presence of snow and its thickness) and land cover [3]. Knowing when the ground begins to freeze and the duration of the frost season leads to a better understanding of ecosystems [3]. The objectives of this study are:

1. Perform a spatiotemporal analysis using AMSR-E data to better understand the seasonal variation of soil freezing;
2. Evaluate the impact of snow cover and the effects of land cover use on the brightness temperatures extracted data AMSR-E;
3. Develop an algorithm to map the seasonal freezing of soil through the combined use of passive microwave and active microwave data.

METHODS

- **AMSR-E** « *Advanced Microwave Scanning Radiometer for Earth Observing System* »

After a first analysis of the different algorithms available, two algorithms were selected to generate maps of frozen ground from AMSR-E data. The AMSR-E data are from fall 2007 to the present. Cloud cover, aerosol effect, and atmospheric conditions influence little the microwave signal. Therefore, we proposed to use the Royer [5] algorithm to determine the presence of snow on Nunavik by AMSR-E images. The majority of treatments performed on these images were made on ArcGIS using Python programming language.

For summer 2008, two parameters, the threshold (*th*) and the gradient of the spectral emissivity ($\Delta\varepsilon_{norm}$) are calculated from July 26, 2008 to September 8, 2008 because we consider that these are the days without snow in Nunavik. According to previous study, if the gradient of the spectral emissivity of a pixel is below the threshold, it means the presence of snow. Then, the days with snow are those for which $\Delta\varepsilon_{norm} < th$ - 2 sigma. These values are used to identify the presence of snow on the ground from October 10 to December 10, 2008. The presence of snow and its properties such as thickness and humidity influence the emissivity. Figure 1 shows the variation of emissivity normalised according to the presence of snow in fall 2008 [5].

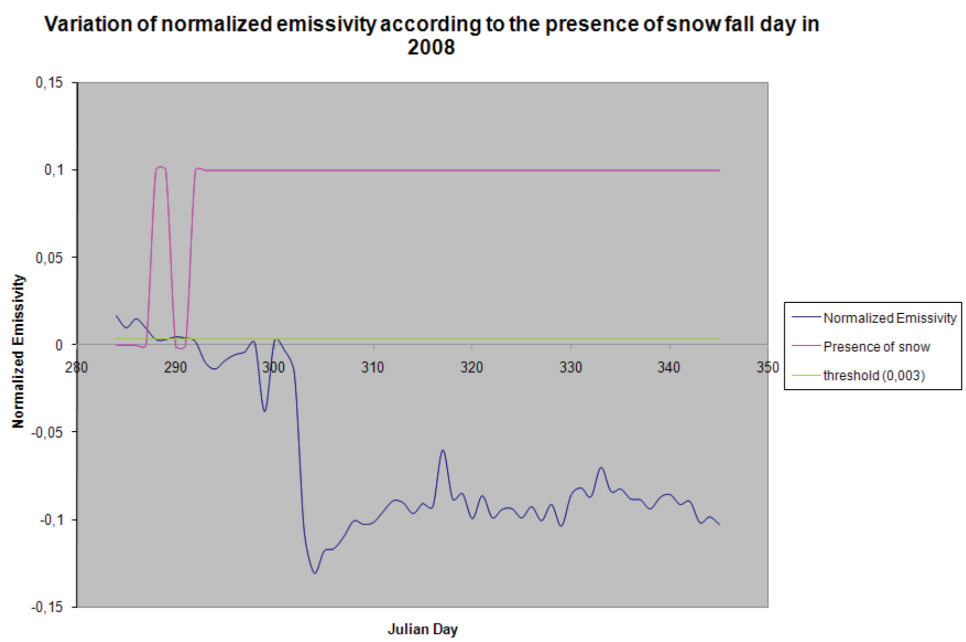

Figure 1: Variation of normalized emissivity according to the presence of snow fall day in 2008.

To determine the soil freezes from AMSR-E images, the spectral gradient of the brightness temperature and the corrected brightness temperature at 37 GHz were calculated from October 10 to December 10, 2008 [3]. Subsequently, we checked the following conditions to identify the soil freezes for each pixel and for each day:

1. GTVP (K/GHz) <0 ;
2. $T_{b37GHzV}(K) < 247K$

- **RADARSAT**

RADARSAT-1 and RADARSAT-2 are active and high resolution microwave sensors. RADARSAT images were also acquired in fall and winter 2008 and 2009. They can determine the influences of the presence of snow on the ground (freezing soil surface) but also, indirectly, on the brightness temperature [2, 5]. Those data are used to validate the mapping of frozen ground and calibrate our AMSR-E results. The use of SAR images allow us to obtain more detailed information on the freezing ground depending on the land cover and on the presence of dry snow. The determination of the snowmelt period could also be derived from SAR images [5].

Freezing ground is determined using a threshold approach [2, 4]. The threshold (backscattering coefficient) could be different for different land cover and type of soil [2]. Lagacé [4] showed also that the backscattering coefficient decreased gradually during the period of freezing and that the type of land could have an impact on the amount and timing of this decline in backscatter. Then, a method is developed to integrate RADARSAT imagery (high resolution) in the mapping.

- **In situ measurements**

In situ measurements are collected from the Center for Northern Studies (CEN-SAON) meteorological network (air, soil temperature). Additional sensors to measure surface soil temperature in different landscapes were also installed near Kuujjuaq in September 2007 and data were recovered from five sensors in September 2009.

PRELIMINARY RESULTS

Figure 2 shows two maps of soil freezing (November 10 and December 5 2008). Generally, the maps are generated for the freezing season (2007-2008) and (2008-2009). According to our results, the soil freezing starts from North West to South East.

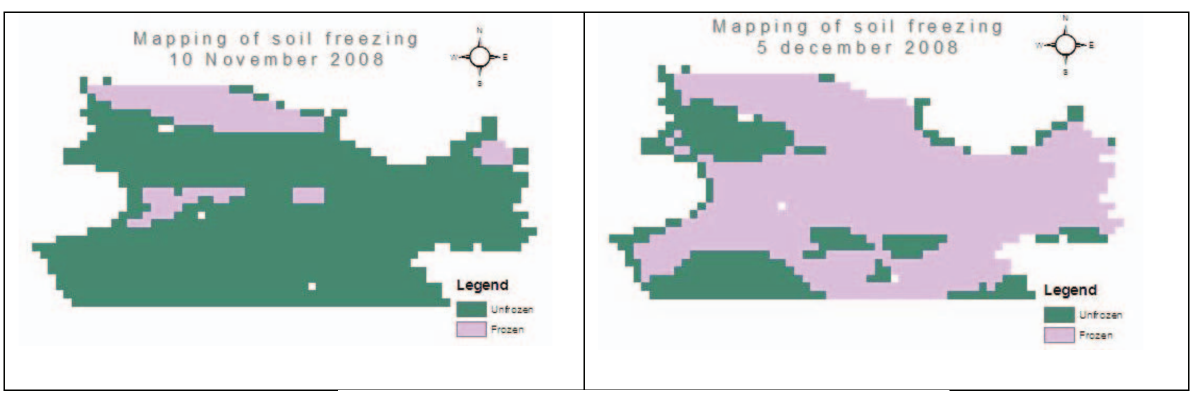

Figure 2: Mapping of frozen ground from AMSR-E images.

CONCLUSION

Data and maps provided by this research will be used to evaluate the performance of freezing ground estimation in Regional Climate Models. They will also allow northern communities to know the variations of the freezing period of one year to another. Furthermore, the methodologies and knowledge developed on frozen ground monitoring in a sub-arctic area could use for the NASA new mission SMAP (to be launch in the 2014-2015 time frame). SMAP instrument includes a radiometer and Synthetic Aperture Radar operating at L-band (1.20-1.41 GHz). SMAP will improve the frozen soil mapping progress because of its capability to make coincident measurements of surface emission and backscatter, and with the ability to sense the soil conditions through moderate land cover. Furthermore, the instrument measurements will be analyzed to yield estimates of soil moisture and freeze/thaw state. The accuracy, resolution, and global coverage of SMAP soil moisture and freeze/thaw measurements make possible a systematic updating of frozen ground maps and monitoring the seasonal freeze/ thaw cycle [7].

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7. http://smap.jpl.nasa.gov/