An approach to represent an orographic terrain in snow modeling

Hilda Harirforoush[1],Steve Aleen[2]

1 Graduated student of Université de Sherbrooke,Department of applied Geomantic

2 Analyste en calcul scientifique, Université de Sherbrooke

Department of Geomatics, University of Sherbrooke, Sherbrooke, Quebec (Canada)

The Centre for research and applications in remote sensing

1 Problematic

Terrain has an essential role in modulating the earth's surface and atmospheric procedures. In fact, the terrain's representation plays a central role in snow modeling. There are various spatial variables with complex relationships that control the snow distribution. Therefore, it is a difficult task to find an adequate continuous function for modeling the snow distribution.

2 Objective

The main objective of this research is to develop and apply an algorithm for assessing the effects of topographic wind sheltering and wind drifting on the snow cover pattern.

3 Hypotheses

The general working hypothesis is that the snow cover at any time depends on the cumulative effects of weather and microclimate factors.

4 Site description

The field area is Schefferville Digital Transect (SDT). It is centered on 54º53'N, 67º08'W, some 30 km northwest of the Schefferville town site north of Quebec –Canada (Granberg and Vachon, 1998). The altitudes range between 465 m and 840 m above sea level. Schefferville represents well the different type of zones (Figure 1).

Figure 1: Study area map

The mean annual air temperature is about -5°C. High wind speeds are common throughout the year, and the annual hours of calm are few. In this windy environment, wind-ablation of the snow cover tends to keep ridge-crests snow free. The snow that blows off the ridge crests accumulate in parts down-wind where it forms deep deposits (Granberg, 1994)

5 Data description

We used four different data sources. Table 1 gives the data studied in this research.

Table 1: Four essential sources of data

N	Source	Description	Data	Spatial resolution and frequency
1	**Satellite**	**U.S. Geological Survey (USGS)**	**Landsat image (blue band)**	**30 m, 16 days**
2	**Meteorological station**	**Schefferville (A)**	**Precipitation, Temperature, Wind...**	**Hourly**
3	**Digital Elevation Model (DEM)**	**Canada Topography Centre**	**Altitude, Aspect, Slope, Curvature**	**20 m**
4	**Digital Vegetation Model (DVM)**	**Landsat image**	**Vegetation density & identification zones**	**30 m**

6 Methodology

The methodology is based on the classification of the study site into three major snow zones as follows:

1) Forest Zone: The effect of the wind on snow cover was considered negligible in this Zone.
2) Lake Zone: The effect of wind is considerable in this Zone. Snow redistribution was determined by the use of a neighbourhood technique. In this zone where neighbours of the central pixel are of equal elevation, the snow eroded from the central pixel is transported to the neighbouring pixel downwind (Figure 2b).
3) Tundra Zone: The Tundra Zone was classified into three sub Zones (I) Sink, (II) Source and (III) Zone influenced by wind as follows:

   I. Sink Zone: Snow is transported to the Sink Zone by wind where it accumulates.
   To determine the “Sink Zone”, a neighbourhood technique was used. If eight neighbours’ elevations are higher than the central pixel and its slope are greater than 5%, the pixel

meets the criterion to be classified as part of a Sink Zone. The snow eroded from windward pixels is transferred to the Sink pixel (Figure 2a).

II. Source Zone: Snow eroded in Source Zones is transported to Sink Zones downwind. To define Source Zone pixels, two criteria were used.

a) If the elevations of the eight neighbouring pixels are lower than that of the central pixel and if the slope is greater than 5%, the pixel is classified as part of a Source Zone. The snow eroded from the Source pixel is transported to the downwind neighbour (Figure 2b).

b) If the elevation of the central pixel is equal to that of its neighbour, the pixel is classified as part of a Source Zone. The snow eroded from the Source pixel is transported to the downwind neighbour (Figure 2b).

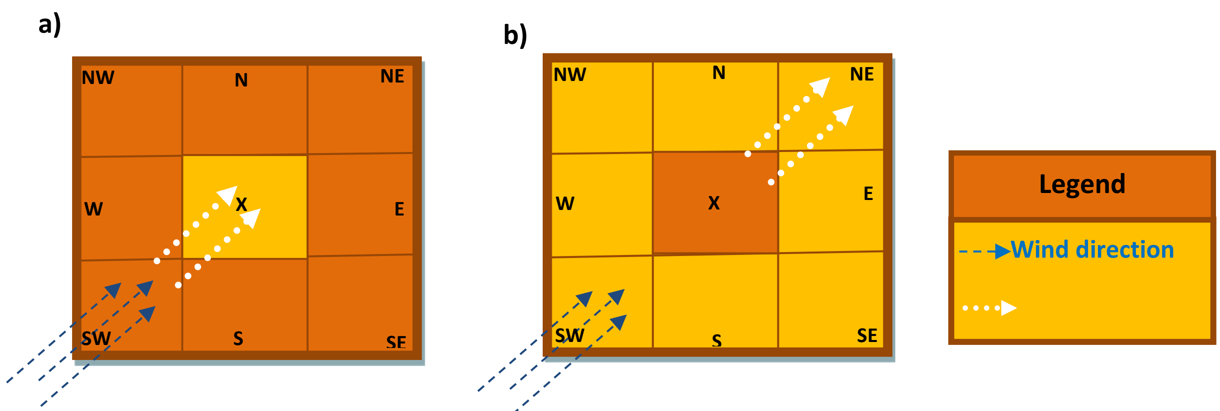

Figure 2: Schematically mechanism of neighbourhood technical a) Sink Zone b) Source Zone

III. Zone influenced by wind: Pixels close to an obstacle such as a mountain (identified by elevation, slope, aspect, curvature) were defined as follows:

a) A Forest pixel neighbour of a Tundra pixel, same is defined as an obstacle.

b) If the elevation of pixel (A) is higher than that of the neighbouring pixel (B) and if the slope of pixel (A) is greater than 5%, the pixel (A) is an obstacle.

The Zone influenced by wind depends on wind direction and aspect and can play a role as Sink Zone or Source Zone (Figure 3) as follows:

a) If (wind direction – aspect) $\geq 45^\circ$ then the Zone will be considered "Sink".

b) If (wind direction – aspect) $\leq 45^\circ$ then the Zone will be considered "Source".

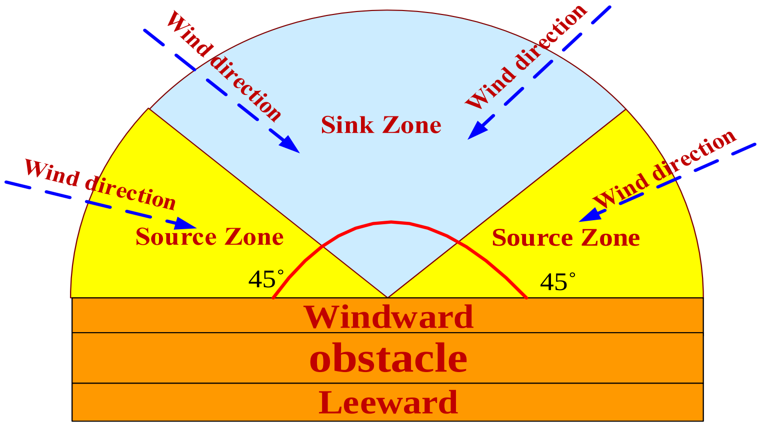

Figure 3: Schematically effect of wind direction and determination Sink Zone and Source Zone near obstacle

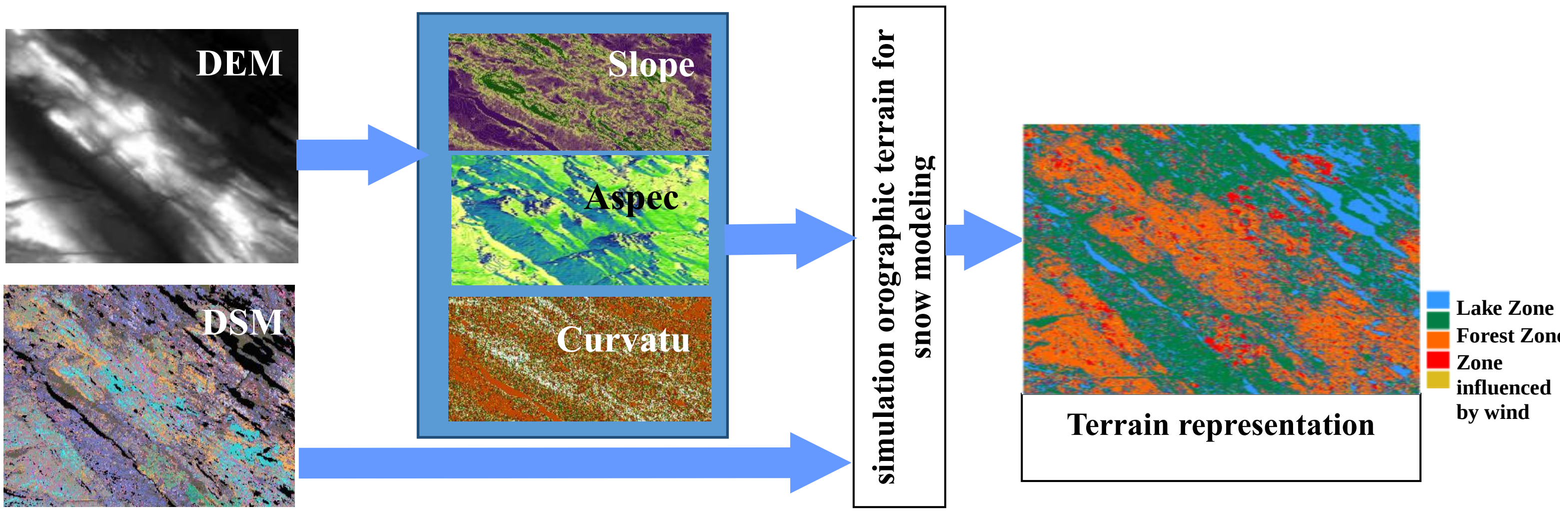

Figure 4 Schematically diagram of methodology

7. Results and Discussion

This terrain model was applied in the Multi-Layer Snow Accumulation Model (MLSAM) over study area.

The results were compared with field observations in the same general area, with snow data from the Schefferville meteorological station and with Landsat images of the same projection as that of the MLSAM output (UTM).

7.1 Patterns of snow accumulation

To evaluate MLSAM results, simulated snow depth distributions were compared to snow depth distributions measured in the field (Granberg, 1975). In 1969 and several subsequent years such distributions were determined for different roughness environments such as recent burn, alpine tundra and closed forest Some are shown by figures 5b, d and f (after Granberg, 1986).

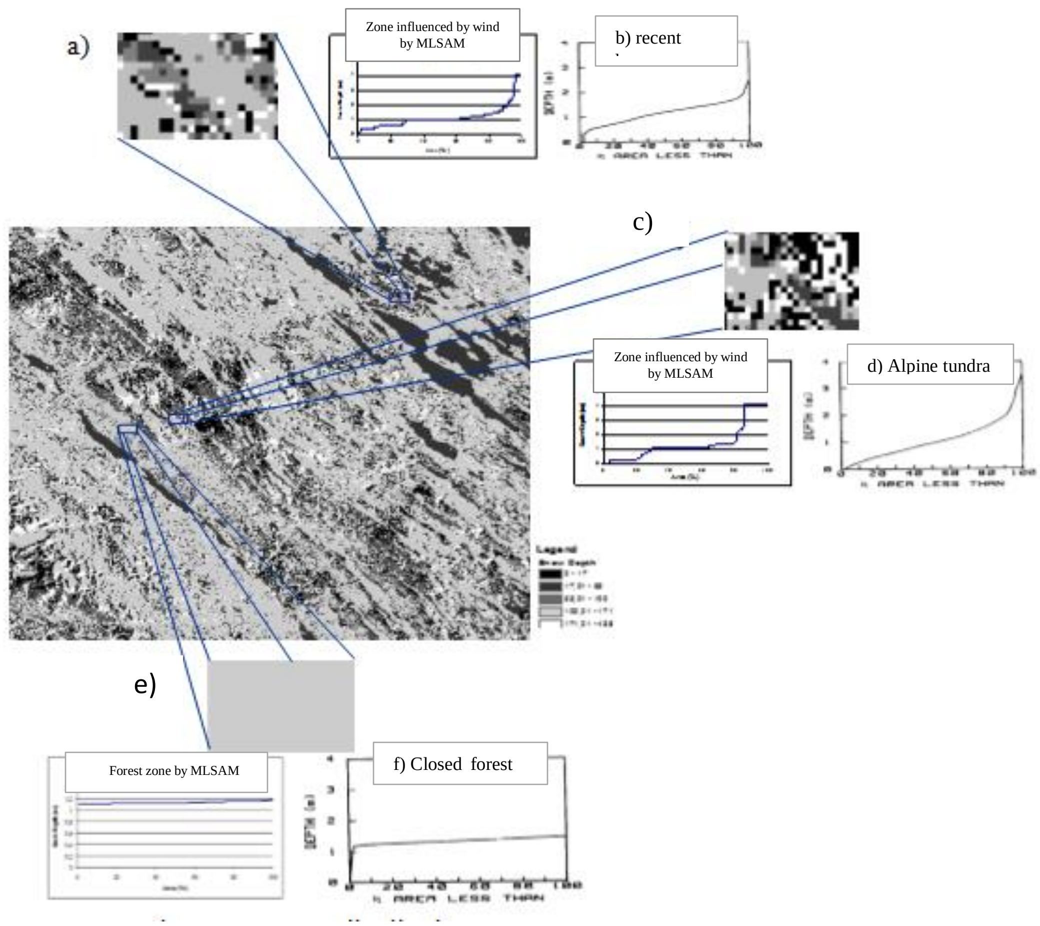

Figure 5 Snow map distribution

Figure 5 depicts the distribution of snow depths in recent burn (Figure 5a), alpine tundra (Figure 5c) and forest (Figure 5e). Comparing the distribution to figures 5a, c and e respectively shows a good general likeness with fairly uniform snow depth in cover types.

7.2 Comparison of simulated and observed snow cover patterns

Figures 6(a) and 6(b) show the snow cover mapping simulated by the MLSAM and Landsat image. There is good agreement between snow cover mapping and landsat image.

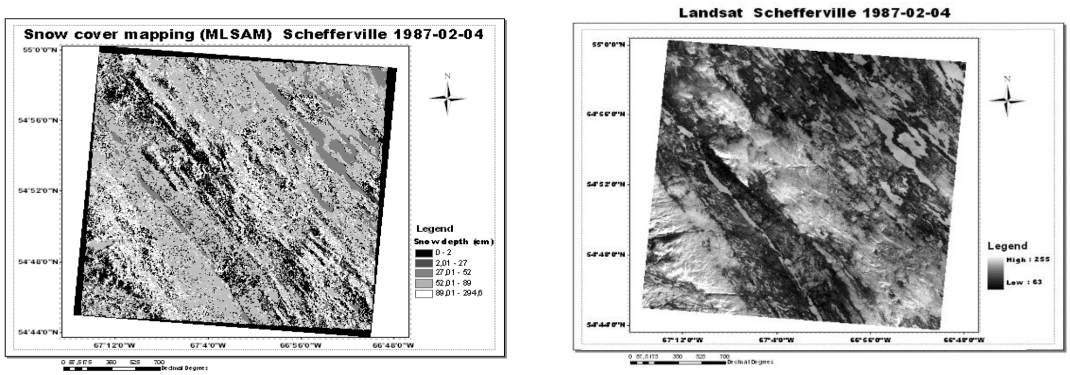

Figure 6 a) Snow-cover mapping using MLSAM b) Snow-cover mapping by landsat image (1987-02-04)

Conclusions

A new algorithm has been developed and presented to reflect the relationships between the factors controlling the spatial variability of snow accumulation. It is based on climatological conditions as well as topographic and environmental conditions.

The algorithm has been used in a Multi-Layer Snow Accumulation Model. The result shows an acceptable agreement with the field measures results. Therefore, the new algorithm has a good potential to be used in snowmelt and equivalent snow water models.

References

Granberg, H.B. and Vachon, P.W. 1998: Delineation of Discontinuous Permafrost at Schefferville Using RADARSAT in Interferometric mode. Permafrost - Seventh International Conference, Yellowknife, NWT, 23-27 June 1998, p. 341-345.

Granberg, H.B. 1994: Mapping heat loss zones for permafrost prediction at the northern/alpine limit of the Boreal forest using high resolution C-band SAR. Remote Sensing of Environment, Vol. 50, p. 280-286.

Granberg, H.B., 1986: Role of seasonal snow cover in forest regeneration. Symposium Work shop climate applications in forest renewal and forest production. p. 97-106

Granberg, H.B., 1975: Snow in different roughness zones at Schefferville: its character and hydrologic significance. Eastern snow conference, February 6-7 1975, p. 108-125.