A COMPARISON BETWEEN CANADIAN DIGITAL ELEVATION DATA (CDED) AND SRTM DATA OF MOUNT CARLETON IN NEW BRUNSWICK (CANADA)

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ABSTRACT:

Digital elevation models (DEM) are basic part of the information about an area. Knowledge about DEM quality is important for their use in management projects, engineering projects and geomorphologic studies. Errors and imprecision of DEM can impact a lot on the resulting models one makes or uses in a project. It's essential to have accurate topographical information from a DEM.The Centre for Topographic Information (CIT) of Natural Resources Canada produced a particular DEM for the Canada country. These are called Canadian Digital Elevation Data (CDED). The CDED DEM has been used for many types of studies and projects mostly in Canada.The relative accuracy of Canadian Digital Elevation Data of Mount Carleton was assessed using Shuttle Radar Topographic Mission (SRTM) model and profiles/points from Geoscience Laser Altimeter System (GLAS) onboard ICESat. This relative accuracy was examined as a function of surface slope and land cover. Specifically, we analyzed the effect of slope and vegetation type on topographic information (elevation).The particularity of Mount Carleton is that Mount Carleton is the highest mountain in the Maritimes Provinces with the peak at 817 meters and it's heavily wooded. More than 50% of the vegetation is dominated by coniferous trees and the average slope is 5.45° ± 4.72°. Terrain was segmented into three sloping regions (≤ 5°, 5° < slope < 15°, > 15°), and also was segmented to aspect regions, standardized to eight geographical directions.From the correlation between CDED and SRTM, we founded a systematic error of less than 2.0 m in absolute value with a standard deviation of around 16 m. We observed that those values are slope-dependent and the influence of their orientation is not significative. A relative influence is observed for the north directions. The broadleaf is the species which has the highest concentration of errors and the obtained root-mean-square error (RMSE) for SRTM model comparing to CDED fulfill the 16 m RMSE specification mission. ICESat profiles/points used in the study confirmed the good accuracy of CDED.

1. INTRODUCTION

The Canadian Digital Elevation Data (CDED) consists of an ordered array of ground elevations at regularly spaced intervals. The source digital data for CDED at scales of 1:50,000 are extracted from the hypsographic and hydrographic elements of the National Topographic Data Base (NTDB) or various scaled positional data acquired from the provinces and territories (Geobase, 2008). The Customer Support Group at the Centre for topographic information (CIT-Sherbrooke) specifies that the tile reference scheme for CDED models the National Topographic System (NTS) mapping series. That the coverage for each CDED corresponds to half an NTS tile, which means, there is always a western and eastern CDED cell to a whole NTS tile. And that cell coverage varies according to the geographic area. The North American Datum 1983 (NAD83) is used as the reference system for planimetric coordinates. Elevations are orthometric and expressed in reference to mean sea level, Canadian Vertical Geodetic Datum 1928 (CVGD28). For more information about the CDED level 1, see http://www.geobase.ca/doc/specs/pdf/GeoBase_product_specs_CDED_3.pdf.

Beaulieu et al. (2007) assessed the accuracy of a new production of the Canadian Digital Elevation of the North (Canada), using ICESat LIDAR, obtaining, for a group of 21 CDED an accuracy of 0.34 m± 6.22 m – i.e. 10 m at 90% confidence level. Braun A. et al. (2007) evaluated the differences among SRTM data, ICESat data and Alberta Survey Control Markers (ASCMs) elevation data. The ASCM is in good agreement with ICESat, although local terrain effects were not been considered. The effects of snow depth, vegetation, slope, needs to be studied in more detail. Those factors have been considered in the various applications of CDED. The applications on which CDED have been used are not limited to mapping. Considering the multiple uses of DEM data, especially for the use in predictive models, it is important to consider the accuracy of topographic input data that are used (Thompson J.A et al, 2001). CDED should be considered as input data. Accuracy refers to the closeness of an observation to a true value (Maune et al., 2001). Accuracy is computed by a comparison of elevations in the DEM with corresponding known elevations. The root-mean-square error (RMSE) statistic is used to describe the vertical accuracy of a DEM (Eq. (1)), encompassing both random and systematic errors introduced during the production of data (ASPRS, 1990; Maune et al., 2001).

$$RMSE = \sqrt{\frac{(Zi - z'i)\square}{n}} \tag{1}$$

Where Zi is the DEM elevation of a test point, $z'i$, the true elevation and n the number of test points.

The comparison between CDED level 1 and SRTM data of Mountain DEM over Mount Carleton will be assessed using

SRTM DEM and points/profiles from Geoscience Laser Altimeter System (GLAS) onboard ICESat.

The aim of this paper is to compare the difference between the Canadian Digital Elevation Data (CDED) level 1 and SRTM data over Mount Carleton in New-Brunswick. We will contrast comparisons between CDED and SRTM DEM in the first step of the examination of the difference. In a second step, the comparison will be done between CDED with ICESat's points/profiles. The land cover and the morphology of the relief will be used as additional elements for the comparisons. Three slope classes and eight geographic directions will enable us to perform this vertical assessment. Concerning CDED level 1, we want to reveal as stated by Aguilar Fernando J. and al. (2005), that the slope (morphology) and the land cover (vegetation) have a relative influence impact on the accuracy of a DEM.

2. DATA AND METHODOLOGY

2.1 Study area

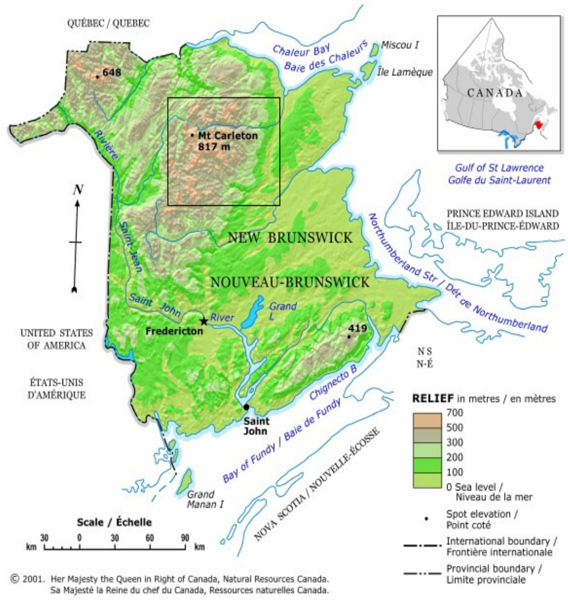

Figure 1: The location of the study area in the New Brunswick province (Natural Resources Canada)

The study area is located in the province of New Brunswick, centered at the coordinates 47°23' N and 66°53' W which corresponds to the position of Mount Carleton. The area covers an area of approximately 36 x 24 km. This mountain is the highest elevation in the Canadian province of New Brunswick, and is also the highest peak in the Canadian Maritime Provinces. With a maximum elevation of 817 meters, it is also one of the highlights of the Canadian portion of the International Appalachian Trail (Figure 1). This region was chosen because of his land cover dominated by various species and his location in the east part of Canada.

2.2 The reference Canadian Digital Elevation Data

The Canadian Digital Elevation Data (CDED) is today available at no cost on http://www.geobase.ca/. The reference CDED used is of level 1. The region of Mount Carleton is included in the 021O07 of the National Topographic Data Base (NTDB) at the scale of 1:50 000. This is a digital terrain model depicting ground elevation in geographic coordinates with spacing of 0.75" x 0.75". For the purpose of future comparison with SRTM model and ICESat points/profiles, it was essential to well prepare the data so that they should be compatible and subject of comparisons. The first step was to convert these DEM from .dem format to .tiff format. The two part of the DEM (East and West) were merged. All studies employing DEM make use of planar coordinates to have the same measurement units for both (x, y) and elevation. The CDED level 1 was provided in geographic coordinates (longitude (λ) and latitude (Φ)); therefore it was necessary to reproject the CDED level 1 to NAD83 UTM zone 19, because the reference of the other data of the study will respect that grid. The software ESRI® ArcMap™ 9.2 was used to conduct the reprojection with the bilinear interpolation resampling method. This option, which performs a bilinear interpolation, determines the new value of a cell based on a weighted distance average of the four nearest input cell centers. When dealing with different datasets resolution, there is often a need of data sampled at one scale to be generalized to other scales. Our aim in the study is to compare three elevation datasets sampled at different scales (spatial resolutions). The pixel size of the CDED level 1 was 19.56 m after the reprojection. Finally, from the 1201 x 1201 grid, we obtained a new one with 455 columns and 304 rows. The elevation range point is from 242 to 808 m. These elevations are orthometric and expressed in reference to mean sea level (Canadian Vertical Geodetic Datum 1928 (CVGD28)). In order to compare the three datasets, the reference CDED level 1 will be subject of an aggregated pixel size, matching the dimensions of the SRTM grid for example.

2.3 SRTM data

The Shuttle Radar Topographic Mission (SRTM) successfully collected Interferometric Synthetic Aperture Radar (IFSAR) data over 80% of the landmass of the Earth between 60ºN and 56ºS latitudes during an 11-day Space Shuttle mission in February 2000. This mission has created an unparalleled data set of global elevations that is freely available for modeling and environmental applications. There are two SRTM products in raster format: The 30 m (1") spatial resolution and 90 m (3") data which is available globally (80% of the Earth surface). The 30 m data is available only for the USA territory.

Many homepages provided these data for example at ftp://e0srp01u.ecs.nasa.gov and http://seamless.usgs.gov/. The SRTM data used in our study provided from http://srtm.csi.cgiar.org.They are derived from the USGS/NASA SRTM data and distributed in decimal degrees and datum WGS84 (Jarvis A., H.I. Reuter, Nelson, E. Guevara, 2006). Since these data were provided in geographical WGS84 system, therefore it was necessarily to reproject them in NAD83 UTM 19, to respect the datum of the reference CDED level 1. For this operation bilinear interpolation method was used. The spatial resolution was maintained. The vertical datum is mean sea level as determined by the same WGS84 Earth Gravitational Model (EGM 96) geoid. The Elevation range point here is between 233 and 794 m.

2.4 ICESat data

ICESat (Ice, Cloud, and Land Elevation Satellite) launched 12 January 2003, as part of NASA's Earth Observing System, is a satellite mission for measuring ice sheet mass balance, cloud and aerosol heights, as well as land topography and vegetation characteristics (Zwally et al. 2002 and Schutz et al. 2005). These measures are accomplished using the Geoscience Laser Altimeter System (GLAS) combined with precise orbit determination. The GLAS instrument was designed with three lasers, but only two are being used. One laser will operate at a time with the shot repetition rate of 40 Hz. Every shot is about 70 m and each footprint is separated along-track by 172 m intervals. In the best conditions the accuracy of ICESat derived elevations is sub-decimetres (Fricker et al. 2005).

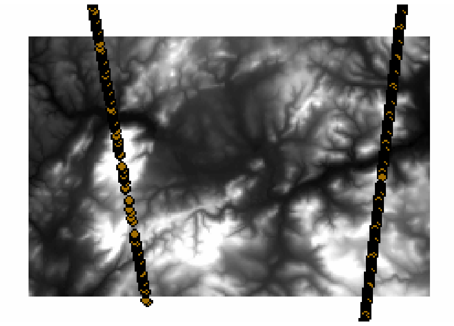

Figure 2: Profiles ICESat over CDED

The GLAS instrument, based on the principle of lidar, measures accurately how long it takes for photons from laser to pass through the atmosphere to the surface or clouds and return through the atmosphere.

The ICESat data (Figure 2) used in our study is extracted with the NSIDC GLAS Altimetry elevation extractor (NGAT) which is provided on the GLAS homepage http://nsidc.org/data/icesat/. The NGAT tool extracts elevation and geoid data from GLAS altimetry products. Among the 15 GLAS data product, we used GLAS/ICESat L2 Global Land Surface Altimetry data, specifically GLA14. From the same tool, we obtained outputs latitude, longitude, elevation and geoid in ASCII columns. The GLA14 (version 26) is from laser 3A which provided the best accuracy among the measurements (personal communication with David Korn, GLAS team). For the fact that ICESat elevation data are referenced according to the TOPEX/Poseidon–Jason ellipsoid (Schutz et al. 2005), and for the purpose of comparisons with CDED level 1 and SRTM data, these data have to be transformed into orthometric heights according to Canadian Geodetic Vertical Datum of 1928 (CGVD28) with the NAD83 UTM zone 19. The data used are those of the laser L3A corresponding to the period from 03 October 2004 to 08 November 2004. We used bilinear interpolation method to make that each point ICESat will be coinciding with the corresponding CDED level 1 location. Because of the existence of false elevation resulting from clouds or valley fog, ICESat points have to be filtered. We rejected all value of elevation showing a difference between the interpolated CDED elevation and the ICESat elevation above 50 m.

2.5 EOSD data

The Earth Observation for Sustainable Development (EOSD) of forest is a joint program between Canadian Forest Service (CFS) and Canadian Space Agency to develop a forest monitoring system for Canada. Land Cover are mapped for the forested area of Canada based on Landsat-7 Enhanced Thematic Mapper (ETM+) data acquired by the Centre for Topographic Information (CIT). The EOSD data was obtained from http://www2.saforah.org:7700/. EOSD data and products are freely available to the public and accessible. They are already referenced to the NAD83 UTM zone 19 and the resolution is 25 m in raster format. This spatial resolution has been brought to the one of SRTM model through an aggregated pixel resample size. The vegetation over of the study area is dominated by more than 50% of coniferous trees.

3. RESULTS

3.1 The image's difference and Interpretation

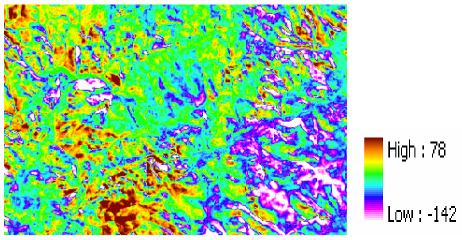

Figure 3: The difference image

This is the reference CDED level 1 minus SRTM model. The error (elevation difference: CDED level 1 minus SRTM model) per grid point is computed with the raster calculator tool of the ArcMap 9.2 tools bar menu. The error range varies from - 142 to 78 m (Figure 3). The following spatial patterns are interpreted in the error image:

(i) From the CDED (Figure 2), high frequency errors location (residual anomalies) are evident on mountain features while the phenomenon is less evident in plane area; (ii) Mountains are located in the SE, S and SW and the highest error values are concentrated on those regions; (iii) General mean is -1.2 m and standard deviation is 15.6 m. (iv) The error's histogram indicated that anomalies values are less. For statistical purpose, those values have been filtered.

The strategy for terrain segmentation is justified by the fact that high frequency errors are located on the mountain feature. The study area is therefore divided into three slope classes: (a) Plane regions for slope ≤ 5º, (b) the medium sloping regions where slope is > 5º and < 15º and (c) the highest sloping areas with slope > 15°

3.2 Terrain segmentation

Slope is a calculation of the maximum rate of change across the surface, either from cell to cell in the gridded surface like in our study or of a triangle in a TIN (Maune. F et al. 2001). If the partial derivatives of elevation (Z) along the East (x) and the North (y) directions are known then slope and the slope pointing orientation (aspect) are computed from the Eqs. (2) and (3) (Burrough, 1987 and Miliaresis. G et al. 2005).

$$Slope = \sqrt{\left(\frac{dZ}{dx}\right)^2 + \left(\frac{dZ}{dy}\right)^2} \quad (2)$$

$$Aspect = \arctan\left(\frac{-dZ/dy}{dZ/dx}\right) \quad (3)$$

Slope is often calculated as either percent or degree of slope. In our study, slope was expressed in degrees while aspect was standardized to the eight geographical directions (N, NE, E, SE, SW, W, NW) defined in raster/grid representations. Aspect identifies the steepest downslope across a surface. Dymond et al. (1995) defined aspect as elementary terrain units composed by adjacent pixels with the same aspect pointing direction. The software ArcMap gives the measures clockwise in degree from

0 (due north) to 360 (again due north). The value of each location in an aspect dataset indicates the direction the surface slope faces. The slope is presented in Figure 4 and the aspect regions defined from the reference CDED level 1 are by geographic directions.

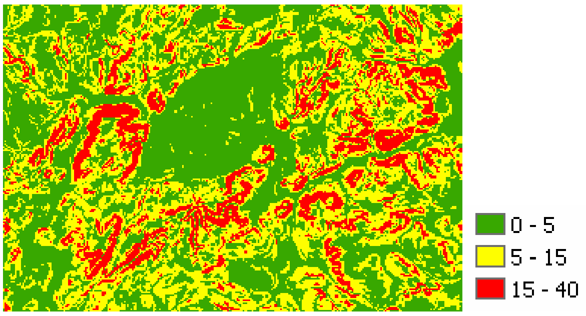

Figure 4: Slope classes of the reference CDED level 1

3.3 Land cover classes

Claudia C. Carabajal and David J.Harding. (2005) were among the first to evaluate the influence of the vegetation on digital elevation models. Canada's forests are vast–nearly 50% of the total landmass of the country (Natural Resources Canada, 2001). The EOSD data used are represented by many classes. All the classes were not used. The main classes were considered. Those are: Coniferous, broadleaf, mixedwood and herbs. The distribution of the species, dominated by coniferous-open justifies the adoption of such classes. We combined coniferous-sparse, coniferous open and coniferous dense to form the class of coniferous. The same idea was used to create the broadleaf and mixedwood classes. The herbs class was maintained.

3.4 Error Statistics

Statistics are computed for the differences between CDED level 1 and SRTM model per each segmented terrain classes as for the study area. Several descriptive statistic measures were employed, among which the mean, the standard deviation for the both the error and the absolute value. We determined also the root-mean-square error (RMSE). If RMSE is normally distributed then, we can compute the linear error (LE) at 95% confidence level (Maune et al. 2001). This indicates that the 95% of CDED level 1 points represent the true value with |error| < LE. LE = 1.96 * RMSE. Also from Maune et al. (2001), the contour interval (CI) is related to RMSE by the relation: C.I = 3.2898 * RMSE. After normalizing the distribution of all the differences by filtering. on the base of three times the standard deviation we, respectively computed the LE and CI. All the results obtained are presented in table 1. The same statistics were made for the four species of the land cover (Table 2). The influence of the slope was removed since we considered only the first slope classe (Slope ≤ 5°); we filtered the other slope classes.

Statistics	**Land cover classes**			
	Herbs	Broadleaf	Coniferous	Mixedwood
Accuracy				
RMSE	**9,0**	**12,7**	**10,7**	**12,0**
LE	17,7	24,8	20,9	23,6
CI	29,7	41,7	35,0	39,5
No of points	25	4412	33527	3460
Percentage	100 %	99,10 %	99,30 %	99,10 %
Error				
Minimum	-13,0	-37,0	-35,0	-37,0
Maximum	22,0	42,0	31,0	39,0
Mean	**-1,5**	**2,8**	**-1,8**	**1,4**
S.D	9,2	13,0	10,8	12,1
|Error|				
Mean	**7,7**	**10,3**	**8,2**	**9,4**

Tableau 2: Differences in function of land cover in meters between CDED and SRTM

Concerning statistics on ICESat's points/profiles, the skewness which characterizes the degree of asymmetry of a distribution around its mean and the kurtosis which describes the relative peakedness or flatness of a distribution compare with the normal distribution were added to the statistics presented in table 2. ICESat data were filtered to remove samples that might have been contaminated by cloud cover or other atmospheric interference. Figure 5 below presents that correlation between CDED level 1 and ICESat.

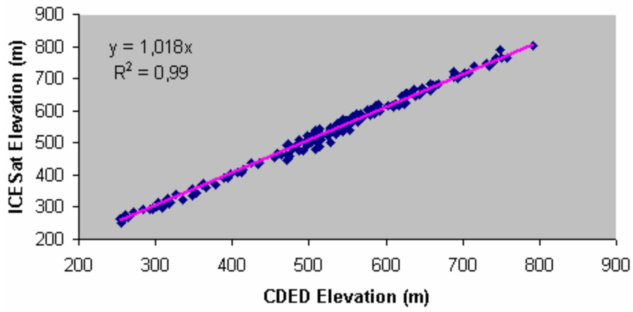

Figure 5: Correlation between CDED level 1 and ICESat data

3.4.1 Altitude Error distribution

The altitude errors (differences) between CDED level 1 and SRTM model are respectively in the range – 50 to 47 m, while the standard deviation of the altitude is 15.6 m. In the following, it is examined if the difference in mean error is statistically significant for CDED level 1 versus SRTM model. For this, the first task is to determine the equality of sample variances. We used the R software; R. Version 2.6.2 (2008-02-08). The observed F-Statistic equals to 0.9968 for CDED level 1 versus SRTM model. With a p-value of 0.5541 at 95% confidence interval, the true ratio of variances is not equal to 1. In this case it was not possible to presume the equality of variances. This indicates that the means errors of both DEM are significantly different.

Statistics	Study area	Slope classes			Aspect regions							
		Slope <5°	5° < Slope ≤ 15°	Slope >15°	E	NE	N	NW	W	SW	S	SE
Accuracy												
RMSE	**15,6**	**11,2**	**16,2**	**23,8**	**13,0**	**14,8**	**14,1**	**12,3**	**11,7**	**12,5**	**13,1**	**12,2**
LE	30,5	22,0	31,7	46,7	25,4	29,0	27,6	24,1	22,8	24,5	25,7	23,8
CI	51,2	36,9	53,2	78,4	42,7	48,7	46,4	40,5	38,3	41,0	43,2	40,0
No of points	137519	49763	71645	16396	16819	15521	15037	18071	17917	17212	18121	18021
Percentage	94,4%	99,4%	99,8%	99,7%	99,8%	99,7%	99,2%	99,4%	99,5%	99,5%	99,5%	99,5%
Error												
Minimum	-50,0	-35,0	-50,0	-80,0	-56,0	-61,0	-60,0	-44,0	-29,0	-29,0	-32,0	-35,0
Maximum	47,0	34,0	49,0	64,0	35,0	29,0	32,0	37,0	43,0	48,0	49,0	39,0
Mean	**-1,2**	**-0,5**	**-0,5**	**-6,5**	**-8,4**	**-15,3**	**-13,3**	**-3,4**	**6,7**	**9,4**	**8,3**	**2,0**
S.D	15,6	11,2	16,2	24,7	15,5	21,3	19,4	12,8	13,4	15,6	15,5	12,3
|Error|												
Mean	12,1	8,6	12 ,9	20,2	11,8	17,1	15,4	9,9	10,5	12,3	12,2	9,6

Tableau 1: Statistics for the error (reference CDED level 1 minus SRTM model

Statistics	CDED/ICESat	SRTM/ICESat
Mean	**-9,1**	**-4,8**
S.D	12,7	14,9
RMSE	**12,7**	**14,8**
|Error|	12,7	11,3
Kurtosis	0,094	0,701
Skew	0,363	-0,430
Min	-40,8	-46,2
Max	27,6	36,3
N. Points	175	174

Tableau 3: Error of ICESat points versus CDED level 1 and SRTM

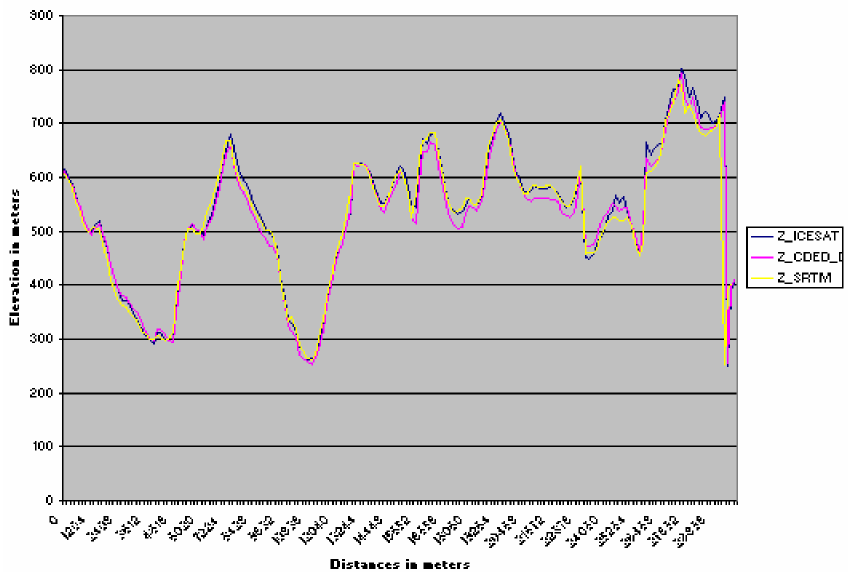

Figure 6: ICESat's profiles over Mount Carleton

3.4.2 Slope errors and aspect regions

The results obtained for the three classes showed that the differences between CDED level 1 and SRTM model are slope-dependent. There is for example a difference of 12.6 m between the slope classes (slope < 5° and slope > 15°). The various values of linear error (LE) are also slope-dependent. The RMSE of 16.2 m corresponds to the major part (71645 points) of the mountain for the slope comprises between 5° and 15°. In all cases |Error| < LE. This indicates that 95% of CDED level 1 points represent the true value. Less than 2% of points were removed for the statistical purposes.

Concerning the differences in function of directions between CDED level 1 and SRTM model, less than 1% of points were eliminated and the distribution of points per direction is relatively similar with an average of 17090. Even though the |Error| < LE, we observed a little significant difference among the 8 directions. The northern directions presented the highest differences (NE and N).

3.4.3 Land cover errors

Error computations were made using respectively herbs class, broadleaf class, coniferous class and mixedwood class. While showing that |Error| < LE, the broadleaf species presented the highest difference value (12.7 m). This is followed by mixedwood and coniferous species. The large range difference is from -37.0 to 42.0 m for the broadleaf species. The number of points with herbs species was to low (25).

Considering that for topographic maps of scale 1: 250 000, the contour interval (CI) is equals to 100 m; we obtained less than the half of this value for all the four species.

4. DISCUSSION

According to the CDED level 1 – CGIAR-CSI SRTM, errors which were operationally defined as discrepancies between elevation from CDED level 1 and corresponding location on SRTM model, we obtained an RMSE of 15.6 which is inferior to the specified 16 m of the original SRTM. Only 5.6% of points, considered as gross errors were removed. At 95% confidence interval, since |Error| < LE, the large range from -50.0 to 47.0 m explain the existence of large errors between CDED level 1 and SRTM data. A mean error of 12.1 m indicates that SRTM is above CDED level data which is normal (Gorokhovich Y. et Voustianiouk A.; 2006, Beaulieu. 2007). A linear regression conducted on CDED level 1 and SRTM data indicated a high level of correlation with $R^2 = 0.99$ and linear regression equation which is $y = 0.99x + 5.46$.

Concerning slope and aspect influence on CDED level 1 comparison, analysis revealed significant difference between CDED level 1 and SRTM when measurements were performed on terrain characterized by slope values greater than 5°. Indeed, in our study, the mean error is more than 12 times higher for slope values which are exceeding 15° (-6.5 m in table 1). It's also important to indicate that the range error is very large for slope exceeding 5°. The range from -80.0 to 64 m corresponds to the slope higher than 15°. Sun et al. (2006) confirm that there is an impact of sloping regions on SRTM data. This can be explained by the interferometrric measurements process during the SRTM mission (foreshortening, layover and shadow). Aspect of the terrain was found to have a relative influence on the accuracy in our study. From the aspect regions distribution and Table 1, the highest values are for the NE and N directions. The study area is sloping more towards the SW and NE directions. This observation is an agreement to the value obtained which is from 12.5 m (SW) to 14.8 m (NE). The overall accuracy (RMSE) approaches 15 m and so the 16 m specification for the SRTM mission is fullfield. Considering the average of points which is 17090 among the eight directions, we will indicate only the relative directional dependency of the vertical accuracy. For all the terrain classes, CI is less than 100 m (Table 1) and so the 100 m contour line specification for topographic maps of 1: 250 000 is fullfield (Lang and Welch, 1999).

Hodgson et al. (2002) indicate that the land cover on the terrain can have a profound impact on the accuracy of a DEM. From EOSD data, we computed the statistics for four species of the land cover of Mount Carleton. The obtained RMSE of 12.7 m for the broadleaf species which is not dominated the study area (coniferous is more than 55%) is inferior to the overall accuracy of the study area which is 15.6 m. To well evaluate the impact of the vegetation on the difference between CDED level 1 and SRTM data, we excluded all slope above 5° on the statistics for the four species. There is not any correlation between the maximum range difference and the number of points (Table 2). From the same table, the broadleaf's species concentrated the maximum of difference. There is an influence of broadleaf species on the comparison of CDED versus SRTM. Less than 1% of points were filtered for the statistical purposes and since the |Error| < LE in the three cases, the confidence interval is 95%. Due to the fact that, the number of herbs points was to low, statistically, we did not consider this species. The overall average of the root-mean-square error (RMSE) of 11.8 m can be considered as the height of the canopy. Carabajal et al. (2005) confirmed that SRTM data give the height of canopy.

From the 1006 points of laser 3A and after removing points that might have been contaminated by cloud or other atmospheric interference (more than 50 m above the difference) and points which are not intersecting CDED level 1 (values equal to – 9999), only 175 points remained and have been used to statistically analyze the accuracy of CDED level 1 versus ICESat profiles/points and versus SRTM model (CGIAR-CSI SRTM). The RMSE obtained is 12.7 m between CDED and ICESat (Table 3); this value is inferior while comparing CDED and SRTM (15.6 m). Zwally et al. (2002) demonstrated that today laser altimetry provides unprecedented level of accuracy and in good conditions, the vertical accuracy of ICESat measurements can be less than 20 cm. Because of this, ICESat measurements can be used as validation data while analyzing the accuracy of CDED level 1. When considering the means of the results obtained, with the value of -4.8 m, SRTM is more near to ICESat than CDED level 1. Harding et al. (2005) have shown that SRTM is above and close to ICESat. Both ICESat and SRTM are affected by the vegetation, but in different manner. The ICESat's profiles on Figure 6 better explain the similarity on the tendency of the various profiles. We computed the most common measure of correlation which is the Pearson Product Moment Correlation (called Pearson's correlation for short). The results obtained confirmed the positive correlation between CDED level 1 and ICESat with $r = 0.996$ and this correlation is significantly at 0.01 (bilateral).

5. CONCLUSION

The goal of this paper was to compare the Canadian Digital Elevation Data (CDED) level 1 with SRTM data, specifically over Mount Carleton in New-Brunswick (Canada). The difference between CDED level 1 and SRTM data of Mount Carleton is described as follows: Mean error -1.2 ± 15.6 m, absolute error 12.1 m, RMSE 15.6 m, CI 51.2 m, LE 30.5 m with 95% of the points to present difference with the range [-50.0, 47.0 m]. We founded that vertical accuracy is terrain class dependent. Accuracy particularly suffers on terrain with slope values higher than 15°. High errors of CDED level 1 are not typical of sloping regions. Aspect of the terrain influences both the magnitude and the sign of errors in the difference between CDED level 1 and SRTM data. But statistically, limited to our study area, we can only mention the relative concentration of errors in the NE and N directions. The obtained results proved that the error is relatively geographic dependent in NE, N directions and minimized in the other directions. Like other DEM, CDED are slope-dependent. Mostly for SRTM model, their accuracy vary in function of the specific vegetation type (Miliaresis G.C et al. 2005). The role of vegetation was also assessed in our study. It is shown that in the geographic area studied, vegetation covers uniformly (various species) 36 x 24 km. Differences are concentrated on broadleaf and there is not a correlation between the percentage of dominant species and large range difference. The highest RMSE of 12.7 m among species is for broadleaf class which is not dominant in the study area. Assessment of the impact of the vegetation was made using SRTM (CGIAR-CSI SRTM) and ICESat data. Both SRTM and ICESat are subject of the influence of the vegetation. We observed that SRTM is much closed to ICESat, but the RMSE of 12.7 m confirm the accuracy of ICESat data versus CDED level 1. The Pearson's correlation between ICESat and CDED level 1, the tendency of the ICESat'profiles indicated that data investigated in our study is reliable.

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