Evaluating RADARSAT Stereoscopic Pairs For DEM Generation

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DEM generated from RADARSAT images are evaluated. Results show that the only parameter that has a significant impact on the precision is the type of the relief: 20-25 m and 35-40 m with 90% of confidence for low and moderate relief respectively, whatever the stereo-pair. It also shows that the base-to-height ratio is not a good indicator for predicting the accuracy with SAR stereo-images.

INTRODUCTION

Numerous research has assessed the radar stereo-viewing these last twenty years. The more interesting results can be summarized as follows:

1. Ref. [1] found that optimum intersection angles are about 40-45°;
2. Ref. [2] showed that the best subjective impressions were obtained with shallow viewing angles (50-70°) and at an intersection angle of 20°;
3. Ref. [3] showed that accuracy does not necessarily improves with increasing intersection angle;
4. Ref. [4] noted that a higher ground resolution does not necessarily lead to higher height accuracy;
5. Better results are more consistently achieved with opposite-side stereo-viewing [4, 5]..

These reported results are inconsistent, and practical experiments do not support theoretical expectations, especially in rough topography. Theoretical modeling accounts only for the geometric error propagation and not for the radiometric image content. Since radiometric disparities have more impact on radar than on visible imagery, the different geometric and radiometric should be addressed for a better and more consistent stereo-viewing evaluation

RADARSAT's many beam modes offer a variety of stereoscopic configurations (Fig.1) of a given location that are very different in terms of geometry and radiometry. Under the Applications and Research Opportunity (ADRO) program sponsored by the Canadian Space Agency the goal was to evaluate the parameters which affect the geometry of RADARSAT data for stereoscopic applications. The following parameters: resolution, look angle, intersection angle, radiometry, speckle and terrain relief were compared for DEM production. Using different stereoscopic pairs DEM were extracted from two sub areas: one with low relief (slopes of 0° -10°), the other with moderate relief (slopes of 10°-25°).

DEM EXTRACTION FROM RADARSAT STEREO-PAIR

Large geometric and radiometric disparities on the stereo pair hinder stereo viewing and precise stereo plotting. As a reduction of one disparity could compensate for the other disparity, a compromise has to be reached between a better stereo viewing (small radiometric differences) and a stronger stereo geometry and plotting (large parallax). But, Fig. 1 shows well that the traditional base-to-height ratio (B/H) uses for predicting and evaluating DEM quality from visible stereo-images is not valid for radar stereo-images

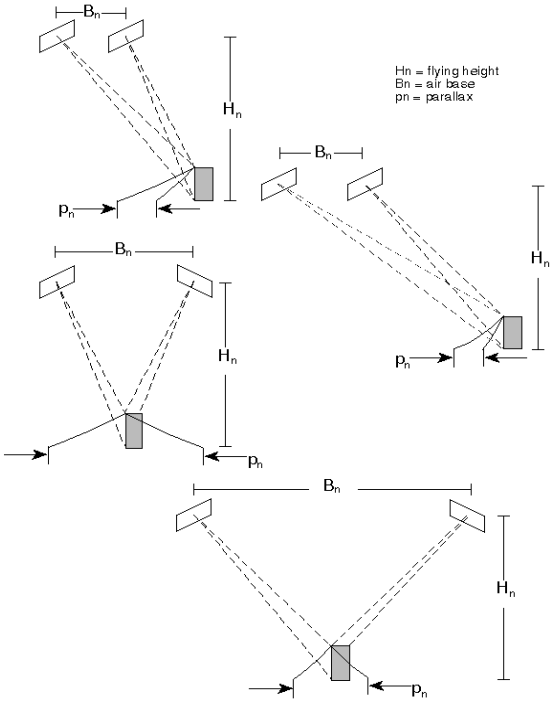

Fig.1,: Different stereo-configurations (B/H) with RADARSAT data

In general, the compromise for any type of relief is to use a same-side stereo-pair reducing both disparities.

Unfortunately, it does not maximize the full potential of stereo radar for each study site and relief. The compromise to minimize the radiometric disparities and to maximize the geometric disparities has thus to take into account the terrain and its relief [5]. Consequently, the solution should be found between the two extreme stereo-configurations.

EXPERIMENT

The test area comprises two 1:50,000 map sheets (Sherbrooke, Quebec, Canada) covering a land area of about 26 km by 40 km with 350-m maximum elevation difference. The checked DEM was derived from the 10-m contour lines from the 1:50,000 map with an accuracy of 5 m. The RADARSAT images are:

1. 4 fine mode images , ascending orbit (F1 et F5) and descending orbit (F2 et F4);

2. 6 standard mode images, descending orbit (S1, S4 et S7) and ascending orbit (S2, S5 et S7); and

3. 2 extended mode images, descending orbit (EH3 and EH6).

These images are in ground range and orbit oriented with 6.25-m and 12.5-m pixel spacing for the fine mode and the other modes, respectively.

About 1,000 elevation points per DEM for each stereo-pair were interactively extracted from the two sub areas using a PC-based radar softcopy stereo-workstation. These elevation points were then directly compared to the checked DEM without any interpolation. Results are presented in Table 1.

DISCUSSION

The table shows that the only parameter that has a significant impact on the precision of the DEM is the type of relief. The greater the variation between two viewing angles (S1-S7 versus S1-S4 or S4-S7), the more the quality of the stereoscopic fusion deteriorated. This cancels out the advantage obtained from the better stereo viewing geometry.

Table 1. Results of the DEM extraction for the different RADARSAT stereo-images

Stereo pair	Beam mode	Resolution	Look angles	Intersection angle	Statistics for each 1,000 elevation points					
					Type of relief	Std. dev. 71%	LE90 90%	Bias	Extreme Min:	values : Max:
F1 asc	Fine	9m x 8m	37°- 40°	8°	***Low***	***12,6 m***	***21m***	***-7,2m***	***-44,6m***	***42,6m***
F5 asc	Fine	7m x 8m	45°- 48°		Moderate	23,3m	39m	-5.5m	-78,5m	70,7m
S4 desc	Standard	26m x 27m	34° - 40°	10°	***Low***	***15,2m***	***24m***	***7,8m***	***-36,4m***	***53,8m***
S7 desc	Standard	20m x 27m	45°- 49°		Moderate	20,8m	35m	1,4m	-58,8m	74,9m
S7 desc	Standard	20m x 27m	45°- 49°	11°	***Low***	***16,1m***	***26m***	***-1,4m***	***-49,1m***	***46,6m***
H6 desc	Extended	17m x 27m	57° - 59°		Moderate	25,4m	42m	8,6m	-78,8m	86,1m
S1 desc	Standard	29m x 27m	20° - 27°	13°	***Low***	***13,1m***	***20m***	***3,4m***	***-48,7m***	***51,3m***
S4 desc	Standard	26m x 27m	34° - 40°		Moderate	23,3m	37m	11,7m	-43,0m	82,2m
S4 desc	Standard	26m x 27m	34° - 40°	15°	***Low***	***14,4m***	***23m***	***2,34m***	***-32,9m***	***45,73m***
H3 desc	Extended	18m x 27m	51°- 55°		Moderate	22.7m	37m	0.4m	-69.1m	74.4m
S7 asc	Standard	20m x 27m	45°- 49°	17°	***Low***	***12,8m***	***21m***	***-2,4m***	***-40,5m***	***36,4m***
S2 asc	Standard	24m x 27m	24° -31°		Moderate	25,2m	41m	6,3m	-94,5m	69,9m
S1 desc	Standard	29m x 27m	20° - 27°	22°	***Low***	***13,8m***	***22m***	***6,9m***	***-36,9m***	***56,9m***
S7 desc	Standard	20m x 27m	45°- 49°		Moderate	25,0m	41m	9,3m	-68,2m	88,6m
F4 desc	Fin	8m x 8m	43°- 46°	89°	***Low***	***8,8m***	***12m***	***-5,6m***	***-27,7m***	***21,8m***
F5 asc	Fin	7m x 8m	45°- 48°		Moderate	28,2m	47m	11,7m	-66,1m	109,7m
F4 filter	Fin desc.	8m x 8m	43°- 46°	89°	***Low***	***8,8m***	***14m***	***-7,8m***	***-30,0m***	***28,1m***
F5 filter	Fin asc.	7m x 8m	45°- 48°		Moderate	26,8m	44m	6,5m	-97,0m	114,3m

On the other hand, although a higher resolution (F1-F5) produced a better quality image, it did not change the precision of the stereoscopic plotting for a given configuration (e.g. intersection angle) when compared to a lower resolution (S4-S7). Furthermore, although the speckle degrades a little the stereoscopic viewing, it does not create confusion and error in the stereo plotting. The only consistency is achieved with opposite side (F4-F5) versus same side (F1-F5) stereo-images.

These results do not correspond to theoretical predictions of error propagation. In practice, error propagation modelling has some severe limitations because it is purely geometric and does not take into account the radiometric content of images. Furthermore, same side stereo-pairs with steep (S1-S4) or shallow (S4-S7) look angles generate about the same B/H (Table 1), but the elevation parallaxes are larger with steep look angles (Fig.1). In the same way with opposite side stereo-pairs, smaller is the B/H (steep angles) larger is the elevation parallaxes (Fig. 1). Consequently, B/H is no more a valid parameter to predict and evaluate the elevation error with SAR stereo-images.

CONCLUSIONS

Since RADARSAT can collect imagery from different look directions), beam positions (steep, shallow) and modes (low and high incidences, fine, standard), at different resolutions (one or four looks) many stereo configurations on the same study site with various geometric and radiometric characteristics can be generated for DEM extraction. Results with different stereo-pairs show that (i) the B/H ratio is not a good indicator for DEM accuracy, and (ii) the relief is the major parameter that a significant impact on DEM accuracy.

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