MAP REVISION WITH SATELLITE IMAGERY
A POWERFUL ALTERNATIVE

Jean R.R. Gauthier
Director General, Canada Centre for Geomatics
Department of Energy, Mines and Resources, Canada
2144 King Street West, Sherbrooke, Quebec,
Canada
COMMISSION IV

Abstract

The Canada Centre for Mapping (formerly a part of the Surveys and Mapping Branch), EMR, has used Landsat images since 1981 to revise many topographic maps at the scale of 1:250 000 and to monitor changes on 1:50 000 maps. In that relatively short time, one quarter of all the 1:250 000 maps of Canada have been revised with Landsat data and over half of the 1:50 000 maps have been examined. These results, obtained in seven years in a country of 10 millions km^2, are truly remarkable. Since large expanses of Canada have little or no human activity, no changes were found on half of the 1:50 000 maps inspected and only limited changes on most of the remainder. Beside resulting in important savings in aerial photography, the use of Landsat images has proved to be a very economical method of map revision in the Canadian context. More importantly, the use of satellite data has made it possible to better utilize scarce revision resources and thus improve the overall currency of the two map series.

The paper describes briefly the visual method developed by Gregory Geoscience Ltd., a Canadian company, to monitor and revise topographical maps with satellite data, the savings realized, and the plans to use other satellite data such as SPOT.

Résumé

Depuis 1981, le Centre canadien de cartographie (anciennement partie de la Direction des levés et de la cartographie), EMR, révise de nombreuses cartes topographiques à 1:250 000 à l'aide d'images Landsat. Il utilise ces mêmes images afin de suivre l'évolution des cartes à 1:50 000, permettant ainsi de déterminer quand celles-ci doivent être révisées. En ce court laps de temps, on a pu réviser ainsi un quart des cartes à 1:250 000 du Canada et examiner plus de la moitié des cartes à 1:50 000. Obtenus en sept ans dans un pays de 10 millions de km^2, ces résultats sont remarquables. De large étendues du Canada ne subissant pas ou peu d'activité humaine, on a enregistré aucun changement sur la moitié des cartes à 1:50 000 inspectées et seulement peu de changements sur la majorité du reste. Au Canada, l'utilisation des images Landsat s'est révélée être une méthode de révision des cartes topographiques particulièrement économique qui a permis en outre des économies importantes en photographie aérienne. Toutefois, le résultat le plus important a été sans conteste une meilleure utilisation des moyens généralement insuffisants disponibles pour la révision des cartes et, par conséquent, une amélioration notable de la couverture cartographique existante.

L'auteur décrit brièvement la méthode visuelle développée par Gregory Geoscience Ltd., une compagnie canadienne, pour réviser et surveiller l'évolution des cartes topographiques à l'aide d'images satellitaires. Il fait état des économies réalisées et explique les possibilités qu'offriront les prochains satellites d'observation de la Terre, tel SPOT.

1. Introduction

Initially, remote sensing was considered primarily as a means of observing large areas to obtain a better global understanding of natural phenomena. For instance, the synoptic view afforded by satellite images taken hundreds of kilometres above the Earth was and still is particularly useful to geologists in discovering large geological units undiscernible on the ground and not even visible on aerial photographs. For such users, the blurring of small details, a characteristic of the early satellite images, was unimportant and even welcomed as it helped them from being distracted from distinguishing the major components they were looking for. Not surprisingly, satellite data found little application in topographic mapping, which requires the identification and depiction of many small features. Furthermore, the relatively poor positional accuracy of the early satellite images and the lack of stereoscopic capability were other deterrents to their use in topographic mapping.

Nevertheless, four years after the launching of the first satellite of the LANDSAT series, ERTS 1, the Topographical Survey Division of the Surveys and Mapping Branch began investigating the application of the imagery to topographic mapping. E.A. Fleming showed that offshore islands and reservoirs for hydroelectric power generation could be mapped accurately with LANDSAT MSS images (Fleming, 1976; Fleming and Guertin, 1980). In 1978, Gregory Geoscience Ltd., a Canadian company located in Ottawa, was given a government contract to investigate the application of the data for map revision. The results of the research proved successful, demonstrating that new map detail could be reliably positioned in relation to neighbouring features well within the class A NATO standards for 1:250 000 maps[1].

With the launching of SPOT in 1986, it is our view that, not only will it become possible to revise selected 1:50 000 maps with this new data, but that other topographic applications will be developed for preliminary studies of public works projects such as road location, hydroelectric projects and construction of transmission lines in remote areas.

2. Canada from a Map Maker's Viewpoint

Canadian map makers have always faced unique and often difficult conditions due to the sheer size of the country and its rigorous

[1] For Class A, the planimetric positions of 90% of identifiable features measured on the map must fall within 125 m relative to their true planimetric position referred to the graticule of the map.

climate. With an area of nearly 10 000 000 km^2, Canada, the second largest country in the world, is about forty times larger than the United Kingdom or twenty-seven times the size of Japan. This huge land is populated by only 26 million people largely concentrated in a narrow strip near the United States border. For example, the Yukon and the Northwest Territories, which together represent almost 40 per cent of Canada's area, have less than 75 000 inhabitants. From a map revision point of view, this has important consequences since large expanses with little or no human activity must nevertheless be regularly monitored to ensure the timely mapping of new detail such as mines, roads and transmission lines, especially since they are important land marks in a landscape almost completely devoid of man-made features.

The mantle of cloud enveloping the Earth, an irksome obstacle to most forms of remote sensing in many parts of the world, is futher aggravated in Canada by the snow and ice that cover most of the country, but for a few brief months a year.

Finally, the extent of the forest coverage - approximately 4 400 00 km^2 - is another characteristic of Canada that is worth noting. For most survey work, a dense forest is a handicap. Not so for revision mapping done with satellite data since the contrast between new features and the surrounding woodland makes the features easier to detect and identify.

3. The Map Maintenance Challenge

The fundamental mapping of Canada comprises two topographic series: one at the scale of 1:250 000 and the other at 1:50 000.

3.1. The 1:250 000 Map Series

Initiated in 1948 as a national program and consisting of 917 sheets, the 1:250 000 map series was completed in 1970. Unfortunately, well before that time, many maps of the series were already badly out of date, a situation due mainly to:

(a) the lack of sufficient resources since almost all the Branch mapping effort was directed to the completion of the two series, and

(b) the rapid development of Canada's infrastructure after the Second World War.

The 1:250 000 maps, revised before the use of LANDSAT images, were updated through a combination of expedients such as deriving changes from more up-to-date 1:50 000 maps of the same area or making use of information gathered from various sources. Yet, these methods were never very satisfactory. For instance, it is very unusual for the sixteen 1:50 000 maps that make up a 1:250 000 map to be updated at the same time. Also, the use of information gathered from other sources is limited to instances when only few changes must be made. It is further restricted to cases for which positional information is available that permit the accurate plotting of these changes on the map. Therefore, because of these restrictions, few 1:250 000 maps were revised with these methods, resulting in a serious deterioration of the series, with some maps being as much as thirty years out-of-date as of 1980.

3.2. The 1:50 000 Map Series

The 1:50 000 Canadian map series comprises 12 922 sheets of which 11 000 have been completed. In order to assign scarce revision resources where they were needed the most, a system of revision cycles was designed based on *a priori* assumptions made about the rate of change to be expected for five categories of maps (see Table 1).

While a useful guide, this planning tool was far from perfect, sometimes resulting in the revision of maps with few changes, while others maps, in areas experiencing a sudden burst of economic activity, were overlooked. And to make matters worse, in this instance as well as for the 1:250 000 maps, resources were never sufficient to respect this plan, resulting in a gradual deterioration of the series.

Revision Cycles

Type of Map	Cycle	Number of maps
City and suburban	5 years	230
Rural	10 years	1368
Wilderness	15 years	2764
Arctic and subarctic	30 years	8560

Table 1

Clearly, if Canada were to have met its map maintenance challenge, economical methods would have been required to identify maps most in need of revision and to revise them.

4. Revision of Topographic Maps with LANDSAT Images

Fortunately, as we mentioned earlier, by the end of the last decade, research had shown that many 1:250 000 maps could have been updated with LANDSAT MSS images resulting in the creation of an operational revision program of maps of this scale.

4.1. Operational Techniques

The techniques employed for the revision of the 1:250 000 maps and the detection of changes on the 1:50 000 maps have already been described in detail in other publications (Gregory *et al.*, 1986; Turner *et al.*, 1986). Therefore, only an outline will be given here.

The 1:250 000 map revision includes the following five major steps.

Step 1 Image Selection
Carried out by experienced interpreters, this is a critical step to the success of the process since many new features must be detected and correctly identified using as few images as possible.

Step 2 Feature Detection and Identification
Two key procedures characterize this step:
-the detection and identification of the new features is carried out visually on PROCOM 2 using standard photointerpretative procedures (Gregory *et al.*, 1982);
-compilation of the changes for the 1:250 000 scale is carried out on the latest edition of the 1:50 000 maps of the area. This presents two advantages: first, working at a larger scale facilitates the interpretation and results in higher positional accuracy of the new details; and, second, the 1:50 000 maps are usually more up-to-date than the corresponding 1:250 000 maps, thus reducing the work to be done.

Step 3 Verification
Unindentified changes are verified in one of two ways:
-office verification. Whenever possible, in order to save time and money, existing documents such as maps from other sources and professional journals are used to check the identity of the new features;
-field verification. If necessary, the interpreter flies over the area in a small plane to verify remaining unidentified features.

Step 4 Quality Control

Step 5 Cartographic Revision
The new information obtained from the Landsat images is then combined with other data such as new names and boundary changes using standard cartographic techniques to produce the revised 1:250 000 map.

The 1:50 000 change detection is carried out in the same manner except that steps 3 and 5 are omitted.

4.2. Results

So far, Landsat images have been used to monitor over half of the 10 500 existing 1:50 000 maps (see Figure 1), and to revise almost one quarter of the 917 maps of the 1:250 000 series (see Figure 2) as indicated in Table 2.

Map Scale	Purpose	Mode	Number of Maps
1:50 000	Change	Contract	3765
1:50 000	detection	In-house	700
	TOTAL		4465
1:250 000	Revision	Contract	204
1:250 000	"	In-house	9
	TOTAL		213

Table 2

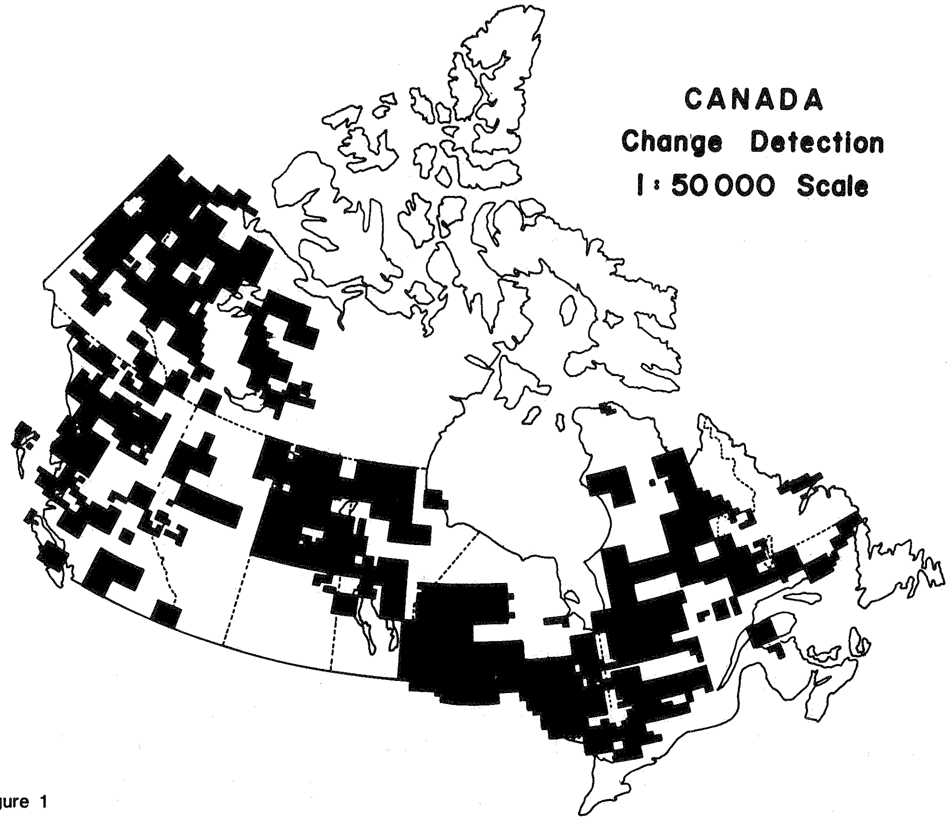

Figure 1

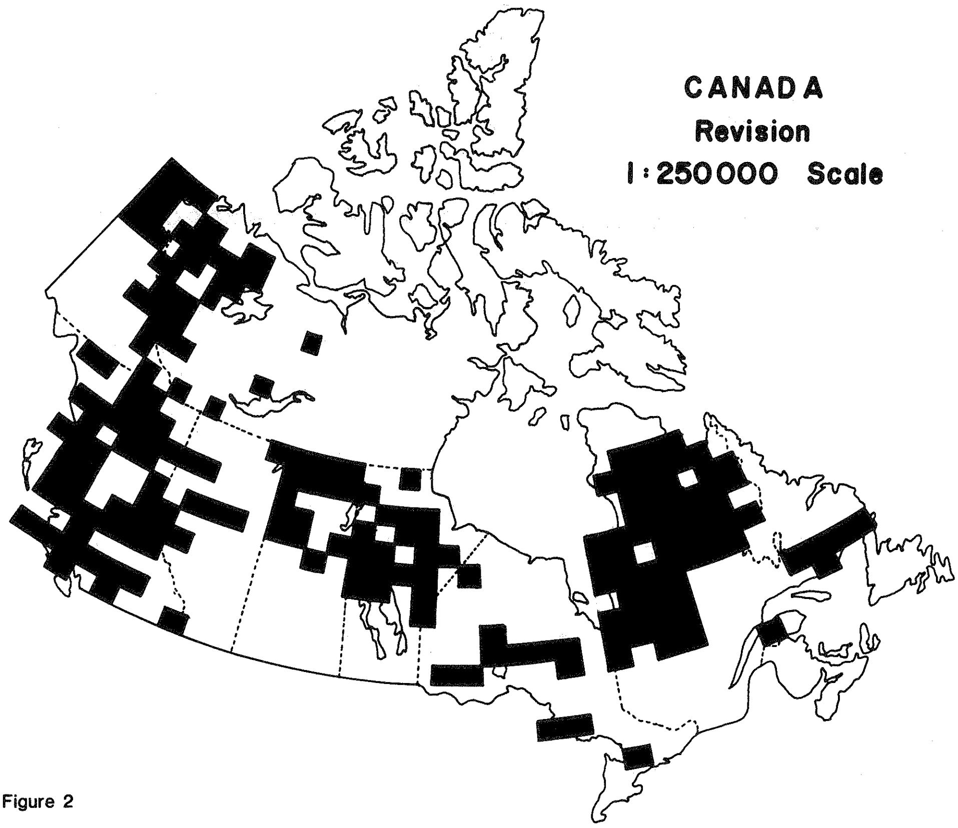

Figure 2

It is quite remarkable that these results were achieved at very reasonable costs in a very short time. In theory, savings realised are considerable since it would take about $30 000 (Can) to update one map with newly flown, small scale photography[1] while the average cost with LANDSAT images has been only $ 5000 (Can). Theoretical savings so far are in the order of five million dollars. However, in practice, because of the cost, 1:250 000 maps were never updated in this manner. Since the other revision methods were inadequate, it is therefore fair to say that the use of satellite data has made it possible to revive an important Canadian map series that was slowly becoming obsolete.

With respect to the 1:50 000 monitoring program, it is worth noting that no change was found on 1017 of the 4465 maps inspected. Since, on one hand, the average cost of inspection of a 1:50 000 map with Landsat images is $ 250 (Can) and, on the other hand, the average cost of aerial photography per 1:50 000 map is $ 2800 (Can), one can deduce that the use of Landsat data resulted in potential savings of approximately $ 2500 (Can) per 1:50 000 map or $ 2.5 million since the beginning of the change detection program.

In addition to pinpointing maps with no change, Landsat permits a more rational planning of revision photography in cases where changes on a map are limited (e.g. to a new road, a new mine or a new transmission line). In such cases, a single line of photographs is usually sufficient to compile the new feature on the old map. We estimate that a further eventual saving of about $ 2.5 million ensue from this use of Landsat images.

Since 1980, the overall benefit derived from using Landsat for the revision of the two map series can therefore be estimated to be approximately $ 10 million. A further important, but nonmeasureable benefit, results from being able to better direct scarce revision resources and thus improve the overall currency of the two series.

4.3. Advantages of LANDSAT for the Maintenance of the Series

LANDSAT images have several advantages for the revision of topographical maps. Each image covers quite a large area (27 000 km^2), which is equivalent to about two 1:250 000 maps of the Canadian National Topographic System (NTS). This, of course, depends on the latitude since NTS map edges conform to the geographical grid. For the sake of comparison, it is interesting to note that approximately 40 aerial photographs at the scale of 1:125 000 or 6 SPOT images would be required to cover an average 1:250 000 map.

Finally, a relatively low cost per unit area, a regular and repetitive coverage, a sufficient resolution and accuracy to permit

---

[1] $ 18 000 (Can) for photography at 1:125 000 scale taken with a super wide angle camera at an altitude of 11 000 m and $ 12 000 (Can) for compiling the changes.

the expeditious identification and positioning of new features are other important factors that work in favour of the use of Landsat images for the revision of small scale topographic maps.

5. Future Topographic Applications of Satellite Data

5.1. Use of SPOT Images for the Revision of 1:50 000 and 1:250 000 Maps

With the launching of the French satellite SPOT on February 22, 1986, a new type of data is now available for the maintenance of topographical maps. Experiments carried out at the Institut Géographique National of France with SPOT simulations indicated that new map details could be accurately positioned with SPOT images but could not always be correctly identified. The conclusion was, therefore, that SPOT images were, by themselves, inadequate for the revision of the 1:100 000 and the 1:250 000 maps of France[1,2].

While these observations may be valid for heavily developed and densely populated countries such as France, the increased resolution and planimetric precision of SPOT images will probably permit their use for the revision of many 1:50 000 maps of Canada, particularly those in wooded areas with little man-made features. Quite obviously, point detail (buildings, small bridges, etc...) cannot be reliably seen and identified on SPOT images, but this limitation is of little consequence in areas where most changes are large linear or area features (roads, pipelines, reservoirs, etc.) and where buildings are uncommon and usually associated with clearings or other features such as landing strips and mines.

It is also likely that the better resolution of SPOT images will make it possible to extend this technique to the revision of 1:250 000 maps of regions such as the Canadian Prairies and of urban areas of moderate density.

5.2. Other Potential Topographic Applications of Satellite Data

Besides the revision of maps, other topographic applications of satellite data can be envisaged now that we have early results of stereoscopic measurements performed on analytical plotters with SPOT images.

The SPOT acceptance tests of 60 stereo pairs carried out between March and December of 1986 on a TRASTER analytical plotter by the Institut Géographique National of France, using 31 SPOT images,

---

[1] La principale conclusion qui se dégage de cet essai, est que l'image SPOT apparait <u>très nettement insuffisante</u> pour permettre, <u>à elle seule</u>, la révision d'une carte au 1:100 000 aussi dense que le 1:100 000 de France (Planques, 1984, premier compte-rendu).

[2] Ici encore, l'image SPOT apparait comme insuffisante pour permettre, à elle seule, la révision du 1:250 000 de France (Planques, 1984, deuxième compte-rendu).

yield a standard error of about 6 m in X, Y and Z (IGN, 1986)[1]. These results agree with those obtained at the Photogrammetric Research Laboratory of the National Research Council of Canada on the Anaplot. The X and Y RMS values for the residuals on about 80 check points for a single panchromatic SPOT image range between 6.7 and 8.2 m depending on the control configuration and the transformation (van Wijk, 1987).

These remarkable results indicate that SPOT data could be used for the preliminary studies of large public work projects such as route location and hydroelectric development projects particularly in areas with little or no man-made features. The topographic products that could be employed for these applications could be either standard cartographic maps produced on analytical plotters equipped with appropriate software or a combination of Digital Elevation Models and precision-geocoded or rectified images. Only experience will tell whether the use of satellite data for such purposes is more economical and more practical than conventional photogrammetry.

6. Conclusion

Canada has often benefited more than most countries from the development of new technologies in surveying and mapping. The succesful use of LANDSAT images for the revision of the country's two fundamental map series is therefore no exception. There is little doubt that, without this technological breakthrough or the improbable addition of new resources, the 1:250 000 map of Canada would have continued to deteriorate to the point where a good number of maps of that series would have been of little use to many users. Thanks to the use of LANDSAT data, many 1:250 000 maps are being updated and the situation is rapidly being corrected. As for the 1:50 000 map, LANDSAT has permitted the deployment of scarce resources where there are needed the most for the maintenance of the series.

Earth observation satellites are a welcome addition to the array of modern tools already available to surveyors and map makers.

7. References

Fleming, E.A., 1976. The Use of Satellite Photography in the National Topographic Mapping Program of Canada, *Proc. 13th Congress of ISP,* Commission IV, Helsinki.

Fleming, E.A.and F.E. Guertin, 1980. The Determination of the Geographical Position of Isolated Islands Using Digital Image Correction System for Landsat MSS Imagery, *Proc. 14th Congress of ISP,* Commission IV, Hamburg.

Gregory, A.F., H.D. Moore and A.M. Turner, 1982. PROCOM: A Cerebral System for the Analysis of Landsat and Collateral Data

---

[1] X = 8.0 m, Y = 6.6 m, Z = 7.1 m. However, these results were obtained with a mix of images, some of which less than perfect (some snow and thin clouds). When only good images are used, the accuracy is improved somewhat: X = 6.46 m, Y = 4.69 m, Z = 5.83 m.

at Scales up to 1:50 000, *Proc. of ISPRS Commission II Symposium,* Vol. 24-II, Ottawa, pp. 237-247.

Gregory, A.F. and H.D. Moore, 1986. Economical Maintenance of a National Topographic Data Base Using Landsat Images, *Photogrammetric Engineering and Remote Sensing,* Vol. 52, No. 4, April 1986, pp. 519-524.

Institut Géographique National, 1986. Recette en vol/Stéréoscopie, *Unpublished Report,* IGN, France, December 10,.1986.

Planques, P., 1984. Etudes des possibilités de révision à l'aide d'images SPOT (premier compte-rendu), *Unpublished Report,* Service des Cartes aux moyennes échelles, Institut Géographique National, France.

Planques, P., 1984. Etudes des possibilités de révision à l'aide d'images SPOT (deuxième compte-rendu), *Unpublished Report,* Service des Cartes aux moyennes échelles, Institut Géographique National, France.

Turner, A.M.and D.R. Stafford, 1986. Operational Revision of National Topographic Maps Using Landsat Images - The Canadian Experience, *Proceedings, Commission IV Symposium on "Mapping and Modern Imagery",* ISPRS, vol. 26, part 4, Edinburgh.

van Wijk, 1987. Geometric Evaluation of SPOT Imagery - Initial Results, *Proceedings, Colloquium on Topographic Applications of SPOT,* Ottawa, May 28 & 29, 1987.