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The affects of look direction on the interpretation of side-looking airborne radar imagery

by

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Introduction

An investigation into the effects of look direction and mosaicking on the interpretation of side-looking airborne radar (SLAR) was performed as a part of the U.S. Geological Survey Radar Project which began in November, 1979. The project was a result of the House/Senate conference report on HR-4930 (96th congress), the Department of Interior and Related Agencies Appropriations bill, 1980, which required a reappropriation of $2,000,000.00 "to begin the use of side-looking airborne radar imagery for topographic and geologic mapping, and geological resource surveys in promising areas, particularly Alaska" (Moore, 1981).

The study area was the $1^{o}x3^{o}$ Ikpikpuk River quadrangle in northern Alaska. This quadrangle was one of four north slope quadrangles for which imagery was available. The southern portion of the quadrangle consists of east-west trending ridges with elevations of up to 1600 feet. The northern half of the area is a coastal plain which gently slopes from a maximum elevation of about 400 feet to a minimum of 200 feet in the northernmost part of the quadrangle. This area is covered with glacial lakes.

Real aperture X-band radar in two look directions was provided by Mars, Inc., and made available as both strips and mosaics at a scale of 1:250,000. Mars, Inc., considers relief, slope angles and general geologic structural grain when choosing flight line directions and flight altitude. Choosing altitude, depression angle, and flight line orientations most suited to each region reduces the amount of shadowing and optimizes information available (MARS, 1976). Contract requirements for this project stated that while depression angles and flight altitudes should be chosen to maximize information content, multiple altitudes and depression angles within a single mosaic should be minimized or eliminated.

North-look (Fig. 1) and south-look (Fig. 2) directions were chosen so that illumination was perpendicular to the major topographic features of the area. The design of the radar equipment is such that the two look directions are 180^{o} apart, and two adjacent swaths of opposite look direction are imaged simultaneously. Mosaics were prepared by MARS primarily from the mid-range portions of the radar strips. The published U.S. Geological Survey topographic map of Ikpikpuk River quadrangle was used for control. Contract requirements stated that distance errors across the entire quadrangle between points of approximately the same elevation were not to exceed 1600 meters.

Method

Drainage nets were prepared from both the north-look and south-look mosaics (Figs. 3 & 4) as well as from some of the individual radar strips so that the influence on interpretation from look direction and from splicing the strips together for mosaicking could be examined. Drainage was chosen for analysis because it provided a consistent feature present over a large area. Of all the quadrangles available, Ikpikpuk River contained the largest area in which drainage was easy to define. All features identified as drainage were drawn. Areas where tonal variation was slight and interpretation uncertain were represented as dashed lines on the original drainage nets, but they have been excluded here for ease of reproduction. In addition, an overlay of mosaic join lines was prepared for each of the mosaics.

In order to compile the most complete drainage map possible from the radar images, information available on only one look direction was added to the map drawn from the opposite look direction. Streams visible only on the original radar strips were also added. All streams added to the original drainage maps are shown as dotted lines.

The drainage nets were each overlain with an outline of the major drainage divides so that the relationship between look direction and local topography could be examined. Where regional slope was toward the north the north look direction provided more detail than the south look. Where regional slope was toward the south, the south look direction more strongly enhanced fine features. Slopes facing directly into the illumination appeared washed out due to the large amount of backscatter from surfaces oriented normal to the incident illumination (Fig. 5). Backslopes, however, showed much more detail from smaller features casting shadows. As the depression angle approached the grazing angle, longer shadows were cast, emphasizing subtle features. If the depression angle were too low relative to the local terrain, large areas of total shadow would have resulted and obscured information.

On the north look drainage map (Fig. 3), many additions to the stream pattern were made from the south look mosaic in area "B"; however, notably fewer additions were made in area "A", which is a backslope relative to the look direction. On Figure 4, the bias from look direction is even more pronounced. Only three stream segments could be added from the north look mosaic in area "B", whereas in area "A" numerous additions were made. This example clearly demonstrates the increased information available from optimally-oriented backslopes than from slopes facing into the look direction. Examining figures 3 and 4 revealed further that the boundaries of areas of different information content followed the major changes in slope over the whole mosaic.

In some areas the effect of look direction was so strong that entirely different drainage patterns were drawn from the two mosaics (Figs. 3 & 4, C and D), or large portions of the stream network were completely omitted when traced from only one mosaic (Figs. 3 & 4, E).

The locations of the mosaic join lines relative to drainage divides and the portion of each strip used to create the mosaics commonly created apparent textural changes. In the mosaicking process, mid to far range portions of some strips were adjoined to the near range portion of the adjacent strip. Generally, more detail can be perceived on the far range than on the near range parts of radar strip imagery (MacDonald, 1969). The abutment of different portions of the strips created what appeared to be textural differences occurring along those mosaic joins. When the mosaic line coincided with a major drainage divide, the bias caused by look direction which was discussed earlier enhanced the apparent variation in texture.

Examples of these changes across join lines are outlined on Figure 1 (areas I and J) and on Figure 2 (areas F, G and H). The radar strip from which the northern half of area G was taken (Fig. 6) does not show the change that appears on the mosaic. Without careful examination of join line placement and comparison to the original radar strip, one might incorrectly interpret these textural variations as geomorphic or geologic boundaries, when they are actually artifacts created by the mosaicking process.

The geometric fidelity of the images met contract requirements, but the magnitude of distortion made properly locating corresponding features on opposite look directions difficult. Overlaying the two drainage nets by matching corner ticks resulted in streams being out of registration by up to 1 km, with an average misplacement of approximately .4 km. Upon comparison to the published 1:250,000 topographic map of the quadrangle, each drainage net was still out of registration, but to a lesser degree.

Local errors were often much greater than the mean error. For example, when major streams were overlain near K (Figs. 3 and 4), streams in the vicinity of L were mislocated by a maximum of about 1.75 km. The maximum displacement found on any single radar strip was about 1 km. Additionally, it was found that neither the amount nor the direction of displacement followed any pattern. Placing the traces of join lines over the mosaics revealed that much of the poor geometric fidelity could be attributed to artifacts from mosaicking. At M and N, streams could not be properly traced across join lines. Streams were found to be offset by up to 1.5 km at mosaic boundaries.

Conclusions

This study demonstrates the need for extreme caution when using radar imagery for detailed topographic and geologic investigation. Although the synoptic view offered by mosaics may be desired, the ambiguities and geometric distortion created by the mosaicking process must be carefully considered.

Because the amount of detail perceived on each drainage net is strongly dependent upon the illumination direction and depression angle and its relation to regional slope, multiple look directions are essential. More detailed information is available from areas of backslope due to the near grazing angle incidence on the backslope and the large backscatter from the foreslope. The interpretation of textural changes and judging their validity solely from mosaics is difficult due to the difference in information content available from near versus far range radar. Additionally, some detail may be visible only on original radar strips. Unfortunately, transferring data from one source to another is problematic because of distortion which is both inherent in radar and created on the mosaics. Due to the abundance of these artifacts, interpretation of radar mosaics should not be attempted without the use of original strip imagery or without careful consideration of join line locations.

References

MacDonald, H. C., Kirk, J. N., Dellwig, L. F., and Lewis, A. J., 1969, The influence of radar look-direction on the detection of selected geological features in Proceedings of the Sixth International Symposium on Remote Sensing of Environment, v. 1, p. 637-650

Moore, G. K., and Sheehan, C. A., 1981, Evaluation of radar imagery for geologic and cartographic applications, U.S. Geological Survey Open File Report 81-1358, 37 p.

Motorola Aerial Remote Sensing, Inc., 1976, An application of side-looking airborne radar for surveying geology and natural resources potential, 27 p.