National Mapping Program

# Test of Airborne Radar for Mapping Two Types of Land Cover: Forested Wetland and Perennial Snow or Ice

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U.S. Department of the Interior
Geological Survey
National Mapping Division
Office of Geographic and Cartographic Research

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

# TEST OF AIRBORNE RADAR FOR MAPPING TWO TYPES OF LAND COVER: FORESTED WETLAND AND PERENNIAL SNOW OR ICE

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# TEST OF AIRBORNE RADAR FOR MAPPING TWO TYPES OF LAND COVER: FORESTED WETLAND AND PERENNIAL SNOW OR ICE

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## ABSTRACT

The U. S. Geological Survey has conducted two separate tests of airborne X-band radar images as aids to mapping either (1) Forested Wetland or (2) Perennial Ice and Snow, two cateogires of land cover utilized by the Survey. Most of the attempted measurements proved inconclusive on both land cover types, largely due to ground clutter or lack of contemporaneous collateral information. However, the test with synthetic aperture radar (SAR) images showed promise for detecting the presence of Forested Wetland. Frozen wetland could be detected in a SAR image in contrast to surrounding dry forest and snow-covered rangeland. The Seasat L-Band SAR image was found to be useful in detecting Forested Wetland on a level plain.

## BACKGROUND

The U.S. House of Representatives and the U.S. Senate conference report H.R. 4930 (96th Congress), the Department of the Interior and Related Agencies Appropriations Bill, 1980, stated that the U.S. Geological Survey (USGS) should "begin the use of side-looking airborne radar imagery for topographic and geological mapping, and geological resource surveys in promising areas, particularly Alaska." In response to this

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statement, the Survey purchased airborne X-band [1/] radar imagery that had already been acquired by private aerial survey companies. The investigation described herein was one of many performed by the Survey to evaluate these images for potential applications in Survey activities. In this particular case, it was for the purpose of aiding mapping of Forested Wetland or Perennial Snow and Ice.

The Geological Survey has an ongoing program to map the land use and land cover of the Nation, using aerial photographs as the primary sources of information. Two of the terrain types particularly difficult to interpret accurately are (1) Forested Wetland, as distinguished from dry forest, and (2) Perennial Snow or Ice, which must be measured at the time of minimum area in late summer. For definitions of these two categories, see Anderson and others (1976). Wet ground within Forested Wetland is difficult to see because of the tree canopy when in leaf. Perennial Snow or Ice is commonly in areas of prevailing summer cloudiness, such as high mountains. Because X-band radar energy penetrates clouds and also reflects with sharply different intensities from the surfaces of water, ice, and soil, airborne radar should be helpful for mapping these types of surface conditions. The X-band radar systems, being of relatively high frequency compared to L- or S-band radars, have limited penetration into natural materials of the Earth's surface. For real aperture radar, lower frequency transmissions would have resulted in a wider beam width and a poorer along-track resolution for antennas of a size that could have been mounted on aircraft (American Society of Photogrammetry, 1975, p. 138). Even though airborne X-band radar with shallow look-angle does not penetrate a tree canopy for any significant distance, radar does show differences in vegetation that result from surface conditions, including wetness. The latter phenomenon is little understood, but may result from configuration of branches or water content in the trees. It had already been reported that X-band radars receive a stronger return from wetland forest than from dryland forest in the Mississippi Valley (McDonald and others, 1980, and American Society of Photogrammetry, 1975, p. 154, 997).

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[1/] Frequency band designation by alphabetic format:

| Band | Frequency | Wavelength |
|---|---|---|
| P | 225 - 400.0 MHz | 1.33 - 0.75 m |
| L | 0.4 - 1.5 GHz | 75 - 20.0 cm |
| S | 1.5 - 5.0 GHz | 20 - 6.0 cm |
| X | 5.0 - 12 GHz | 6 - 2.5 cm |
| K | 12 - 36 GHz | 2.5 - 0.83 cm |
| Q | 36 - 46 GHz | 8.3 - 6.5 mm |
| V | 46 - 56 GHz | 6.5 - 5.4 mm |
| W | 56 - 100 GHz | 5.4 - 3.0 mm |
| C | 3.9 - 6.2 GHz | 7.7 - 4.8 cm |

From American Society of Photogrammetry (1975), p. 591.

Film images obtained by using side-looking airborne radar (SLAR), both real aperture radar and synthetic aperture radar (SAR), have been purchased from the MARS Corporation and the Aero Service Corporation. These were off-the-shelf images obtained in radar flights made before the start of this investigation. The radar set used in the real aperture radar (MARS) flight was reported to be a modified version of the APS 94D X-band radar. The type of synthetic aperture radar set used in the Aero Service flight (March 1980) was reported to be a modified Goodyear APQ 102 X-band radar. Because researchers from many specialties within the U.S. Geological Survey had planned to use these films, the dates of the radar flights selected could not always be well-timed for mapping Forested Wetland or Perennial Snow. In this case, the MARS flight was fairly well-timed, the Aero Service flight poorly timed. Both prints and film transparencies were available for these investigations. In this case, the film transparencies were magnified to ease interpretation. To provide collateral information on ground conditions at the time of the radar flights, aerial photographs, Landsat images, Seasat radar images, or recent maps were used.

The real aperture film images were obtained in August 1979 over the western part of the State of Washington as shown in the orientation map (figure 1). The date was good for study of perennial snow and at least acceptable for wetland study.

The synthetic aperture radar images purchased from Aero Service were made during a flight in March 1980 over the northern Rocky Mountain overthrust belt in Montana and Idaho as shown in the orientation map (figure 2).

The general problem of mapping Perennial Snow and Ice is less difficult than wetland mapping inasmuch as multispectral scanner (MSS) or return beam vidicon (RBV) data from the Landsat satellite are available for late summer scenes of most parts of the 50 States and could aid snowline mapping.

## MAPPING OF FORESTED WETLANDS

Under the land use and land cover classification system used by USGS, wetland forest is distinguished from dryland forest in that hydrophytic vegetation usually is established. Forested Wetland includes seasonally flooded bottomland hardwoods, mangrove swamps, shrub swamps, and wooded swamps around bogs.

Existing maps (U.S. Geological Survey, 1977a) of land use and land cover for Western Washington show areas of Forested Wetland or swamp in numerous valleys on the west side of the Olympic Peninsula. These forested wetland patches, which in this particular case are commonly surrounded by drier forest, were originally mapped from aerial photographs. Climatic maps in the National Atlas of the United States indicate that this area has over 240 days of rain each year (U.S. Geological Survey, 1970). The real

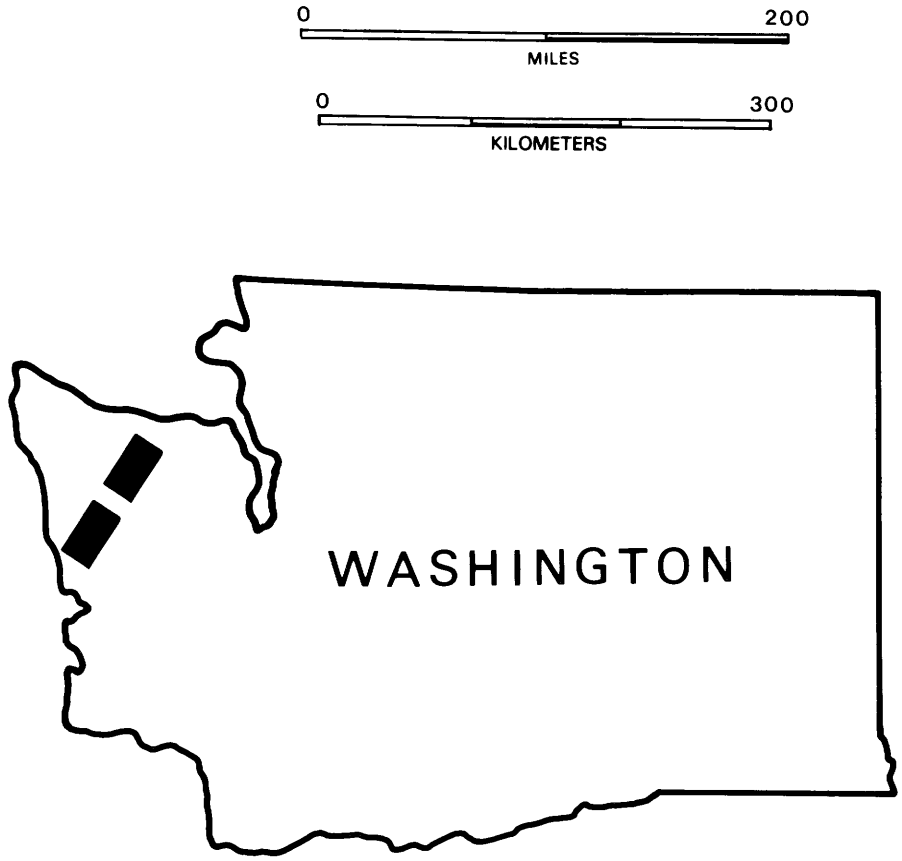


Figure 1.--Orientation map of the State of Washington. The two test sites, shown in black, are west of Puget Sound. These sites were chosen because USGS land use and land cover mappers report that the northern test site contains Perennial Snow or Ice cover on the Olympic Mountains and the southern site contains Forested Wetlands (U.S. Geological Survey, 1977a).

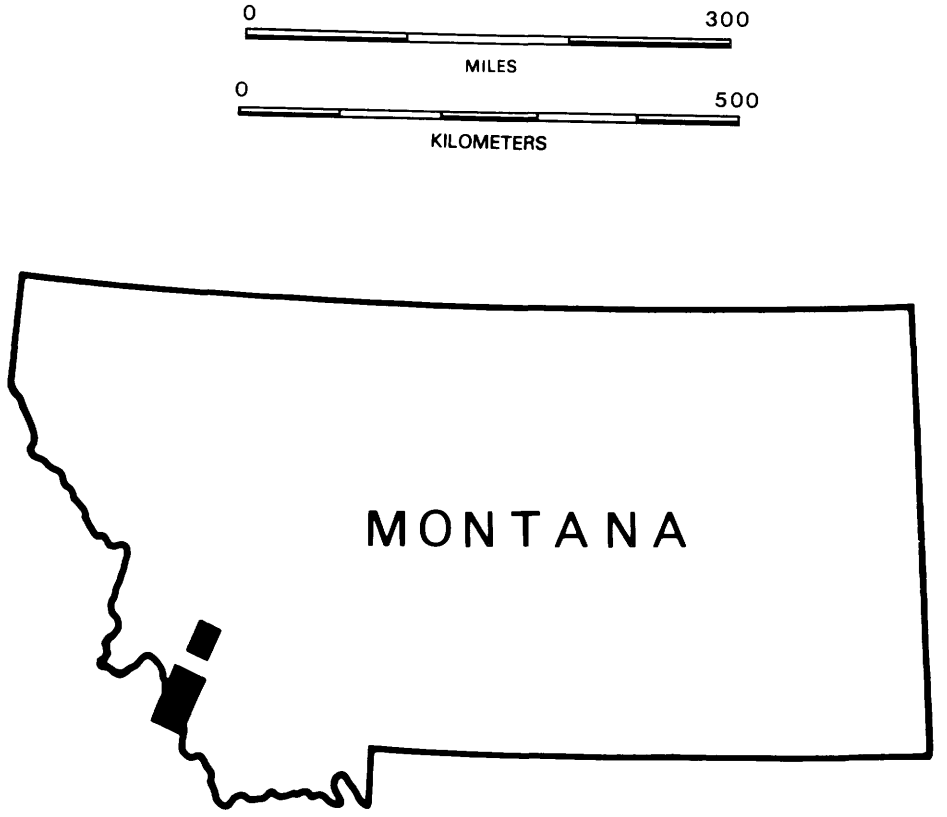


Figure 2.--Orientation map showing the location of test sites on the Montana/Idaho border. The southern site contains Perennial Snow or Ice in the Bitterroot Range; the northern site contains Forested Wetlands at the western edge of the Big Hole Valley.

aperture radar images were obtained during a flight conducted in summer, the least rainy season. In any event, a radar signature distinguishing Forested Wetland from other cover types was absent in an image taken August 24, 1979. High intensity radar reflections from steep slopes tended to mask out reflections from vegetation or wet soils (figure 3).

The northern Rocky Mountain overthrust belt is prevailingly arid or semi-arid except in the higher mountains. However, there is at least one large level area with many Forested Wetlands shown on USGS topographic maps (Ajax Ranch and Isaac Meadows, Montana, USGS 7.5-minute quadrangles). This relatively level area is located along the west side of the Big Hole Valley in Montana at elevations of 6,600 to 6,800 feet. Here, mountain streams flow onto the semiarid valley floor and supply water to Forested and Nonforested Wetlands [2/] in complex intermixture. Unfortunately, the flights with the synthetic aperture radar were made in the winter season when the entire area was snow covered or frozen. Nevertheless, the frozen wetlands are distinguishable from surrounding dryland because of the wetland's strong radar return, appearing light gray in the image. Separation of Forested from Nonforested Wetland is difficult in this radar scene, but this can be overcome by supplementing the radar image with aerial photographs or Landsat images (figure 4).

During our search for collateral information, we have discovered that the Seasat L-Band synthetic aperture radar was often effective as an aid in discriminating Forested Wetland from dry forest on level coastal plains, such as the Delaware-Maryland-Virginia (Delmarva) Peninsula east of Chesapeake Bay. The Forested Wetland known to occupy the flood plain of the Pocomoke River stands out as a white strip in the radar image (dated September 25, 1978) compared to the dry forest which appears gray, and the grassy marsh which appears black. This pattern of high radar reflection closely agrees with the Forested Wetland pattern shown on an existing map of land use and land cover (U.S. Geological Survey, 1977b) (figure 5).

This finding agrees with results of investigations performed independently by D. W. Mooneyhan (1979) at NASA's Slidell, Louisiana facility and by Professor Harold MacDonald and others (1980) at the University of Arkansas, all of whom were working in test sites in or near the lower Mississippi Valley. McDonald believed that the strong radar reflection was due to wet ground around the trees. However, the Pocomoke image was obtained during a long dry period when stream runoff had dropped to a very low flow condition.

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[2/] The word "marsh" is also used to designate Nonforested Wetland.

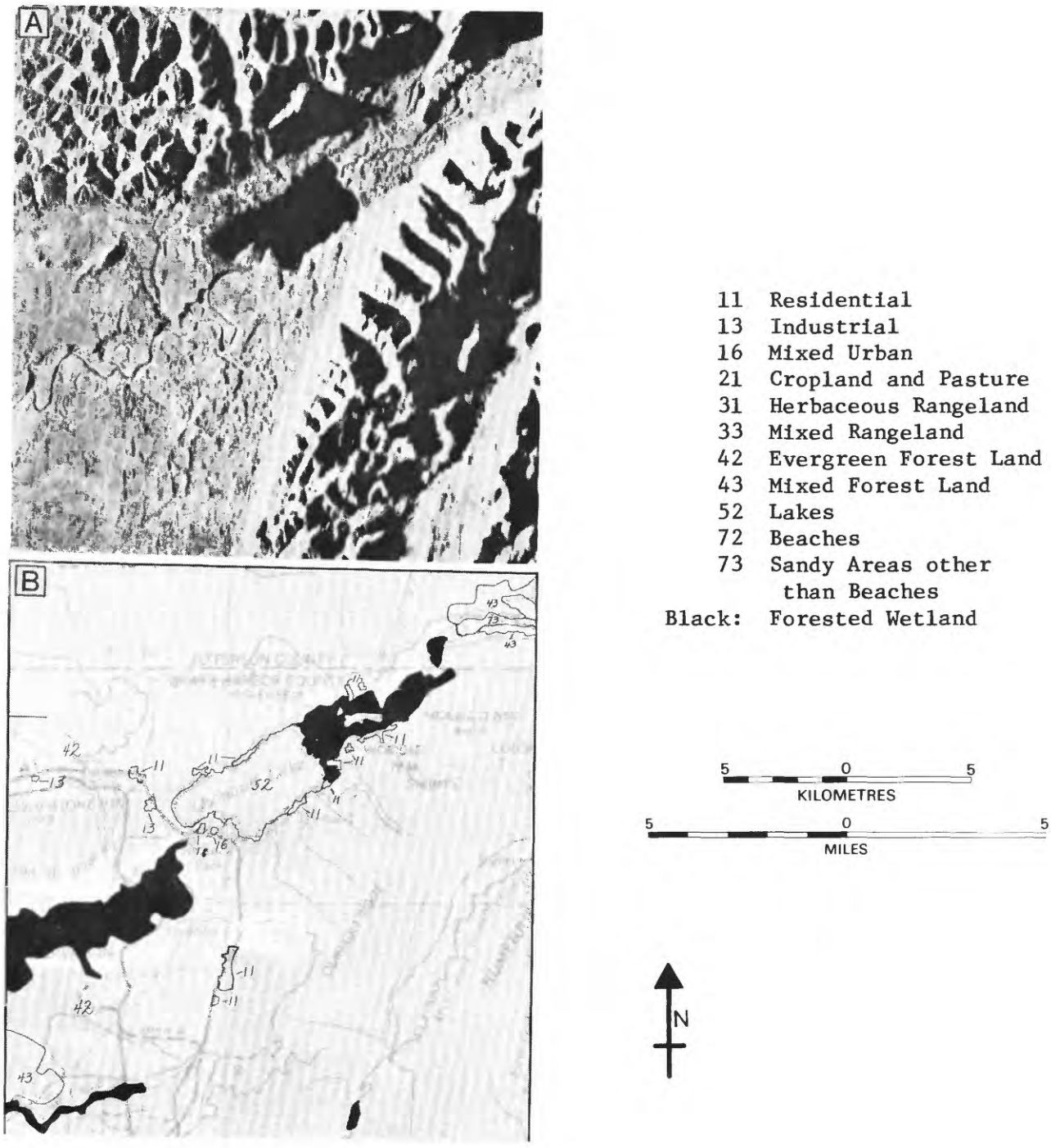



Figure 3.--Comparison of side-looking radar image (A) with existing map of land use and land cover (B), on which Forested Wetland is shown in solid black, fails to reveal any agreement in wetland boundary that could aid in map compilation for this part of Olympic Peninsula in Washington. The numbers on the map represent other categories of land use and land cover.

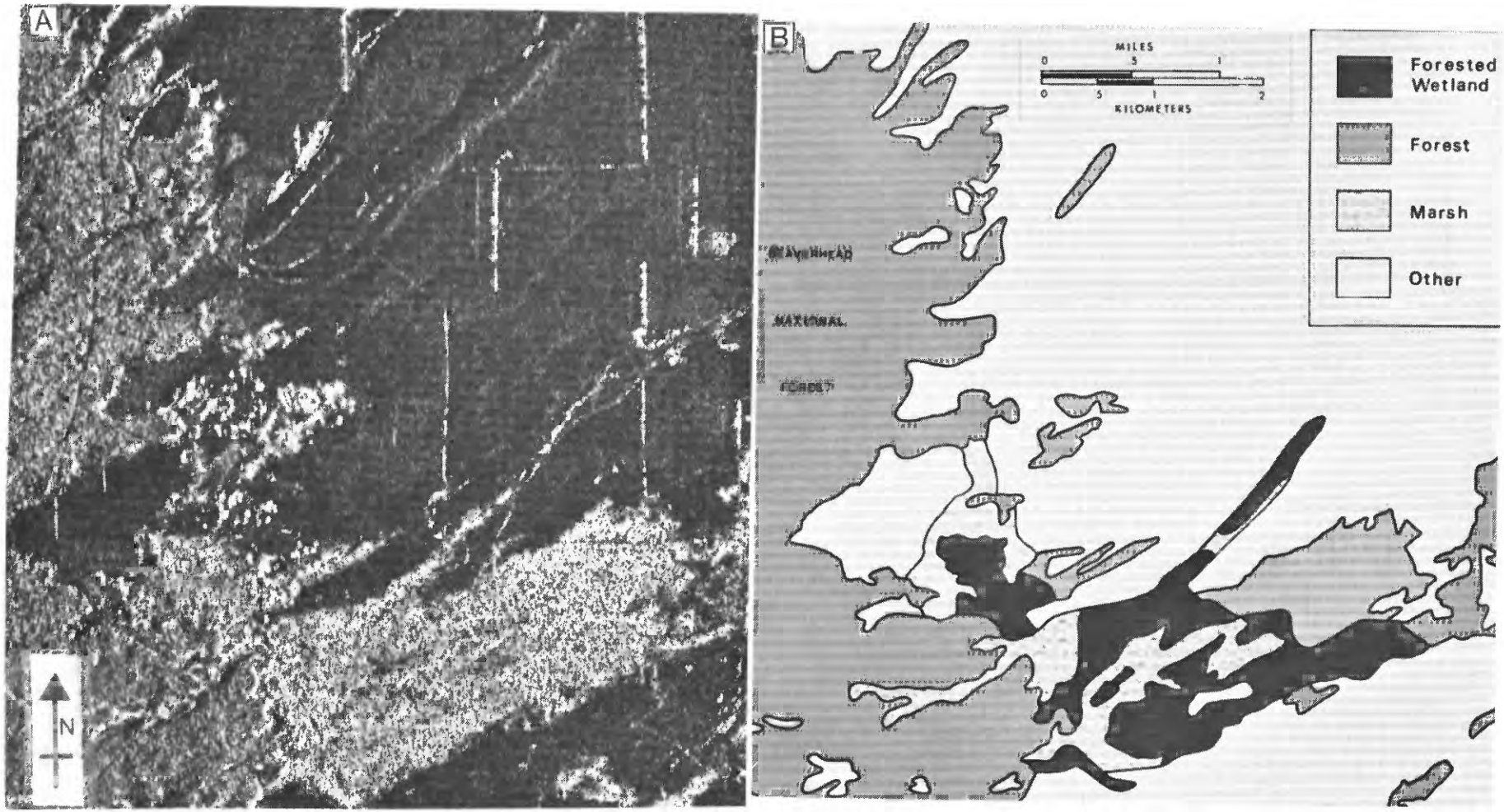
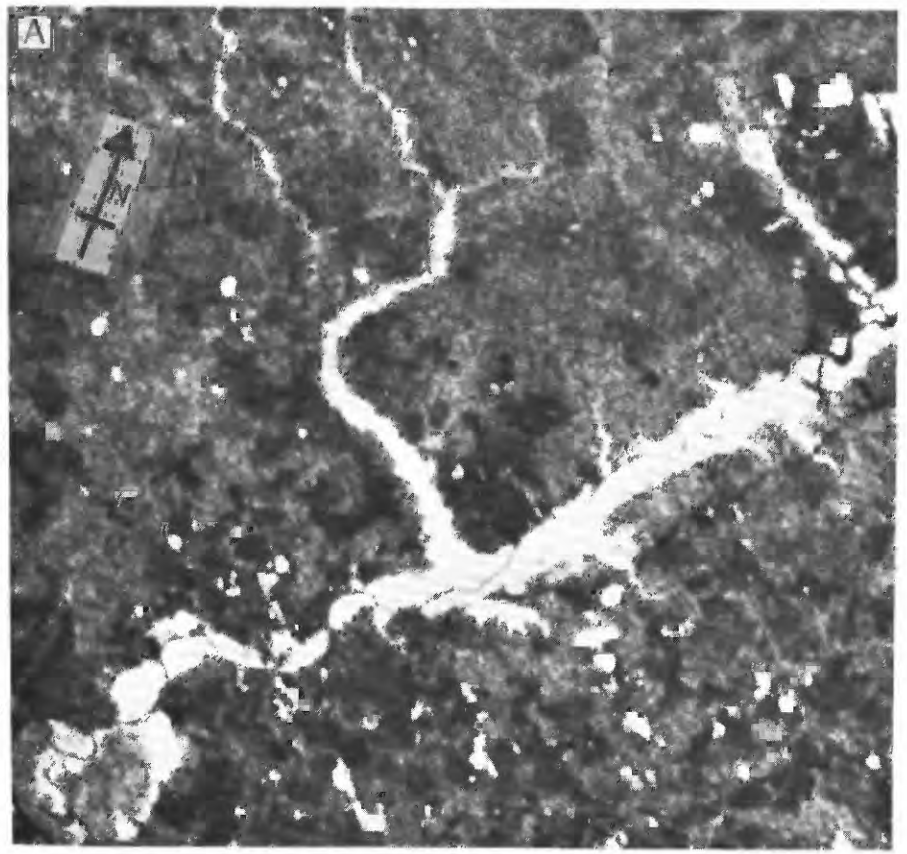
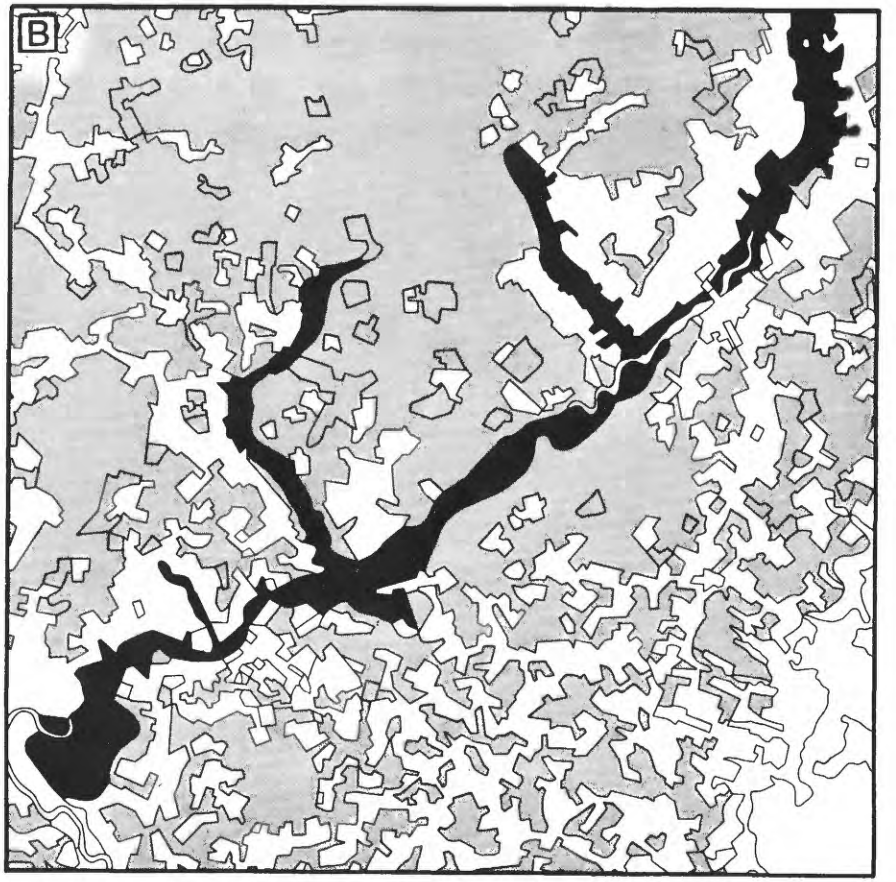



Figure 4.--Comparison of airborne synthetic aperture radar (SAR) image (A) with map of wetland, rangeland, and dry forest areas drawn from the topographic map (Ajax Ranch) of Big Hole Basin, Montana (B) reveals that frozen wetland (forested plus nonforested) may be distinguished from surrounding dryland because of stronger radar return in this wintertime (March 1980) scene. The radar was pointing due west which caused the north-south fence lines to appear as straight white lines on the image.

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5 0 5
KILOMETERS

5 0 5
MILES

FORESTED WETLAND

FORESTED LAND

Figure 5.--Comparison of Seasat synthetic aperture radar image (A) with an existing map of land cover with Forested Wetland shown in black (B) reveals a similarity in an easily seen pattern. The radar return from this Forested Wetland is very intense, i.e., white. The area shown is the lower Pocomoke River Valley east of Chesapeake Bay in Maryland (U.S. Geological Survey, 1977b).

## MAPPING OF PERENNIAL SNOW OR ICE

Areas of Perennial Snow or Ice exist in several places within the radar images of western Washington purchased from MARS Corporation. Unfortunately, these snowfields existed only on mountains where the steep western slopes reflected so much of the side-looking radar pulse that it completely masked the differences between snow/ice and soil (figure 6).

The attempt to delineate snow or ice using the synthetic aperture radar images was handicapped because these images were obtained during a wintertime flight over the northern Rockies when all of the higher areas tend to be snow covered. The exact limits of the snowfields at time of flight were not known. Aerial photographs or satellite images of the area were unavailable from the same date. Snow cover above timberline shown in a Landsat image, obtained earlier that winter, was not visible in the radar image. Again, the high relief causes masking clutter in many areas, including radar distortion due to a combination steep look-angle and steep slope (figure 7). The Montana test had been started before the date of the radar images became known; it is reported on here only to point up the problem of having one radar mission serve many investigations.

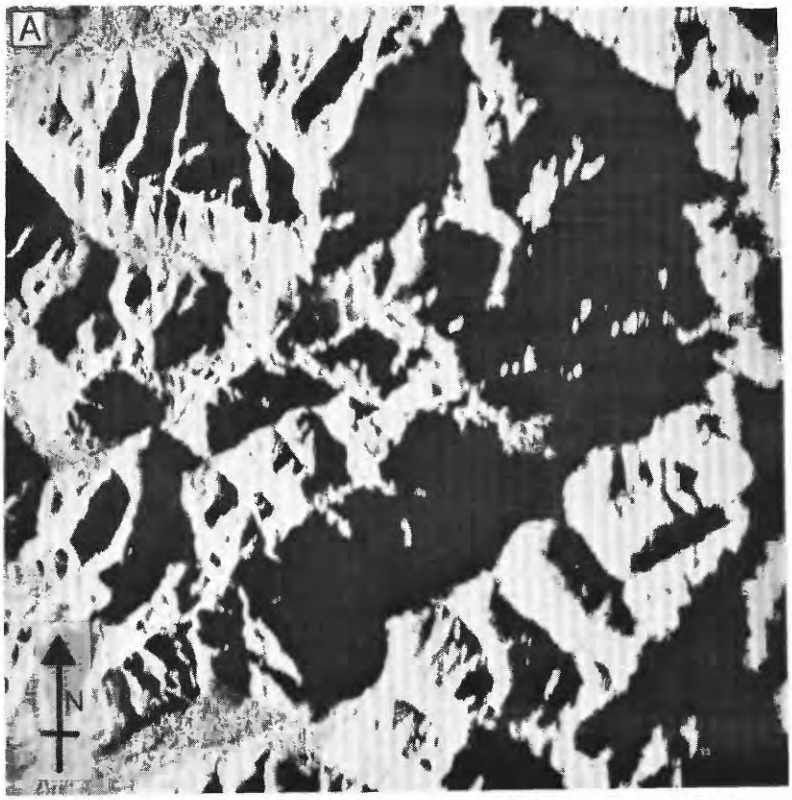
Past studies have shown K-band SLAR to be somewhat effective for detecting patches of snow (American Society of Photogrammetry, 1975 p. 1034). Attempts were made to utilize synthetic aperture radar images from the Seasat satellite, but interpretation of these did not reveal recognizable snow patterns in summer scenes over either Washington or Montana.

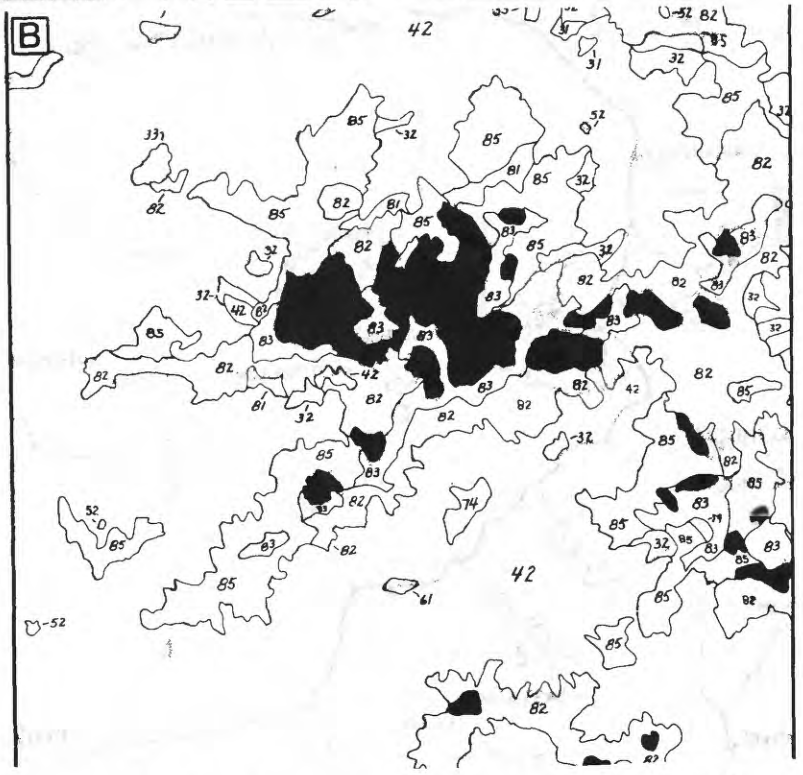
## SUMMARY OF FINDINGS

The tests of the utility of airborne X-band radar images for compiling maps of Forested Wetland or Perennial Snow or Ice were generally inconclusive. This was largely because the radar missions had been flown in seasons that were not ideal for this purpose and were over terrain where high topographic relief created too much radar clutter to allow subtle hydrologic differences to be detected.

If SLAR is used for this type of testing in the future, it should be used over flat terrain during late summer for delineation of Perennial Snow or Ice and during the spring thaw for detection of Forested Wetland. K-band, not X-band radar should be used to delineate snow cover.

Goodyear SAR radar did detect frozen wetland in Montana--giving a different return from adjacent dry forest and rangeland that was also snow covered. Interpretation of the images from the L-band synthetic aperture radar (SAR) that was mounted in Seasat--and similar to those likely to be used in future satellites and space shuttles--showed that SAR with a steep look-angle was able to detect Forested Wetland in a nearly level plain along the Atlantic seaboard.




12 Commercial and Services
31 Herbaceous Rangeland
33 Mixed Rangeland
42 Evergreen Forest Land
51 Streams
52 Lakes
61 Forested Wetland
81 Shrub and Brush Tundra
82 Herbaceous Tundra
83 Bare Ground Tundra
85 Mixed Tundra
Black: Perennial Snow or Ice

5 0 5
KILOMETRES
5 0 5
MILES

Figure 6.--Comparison of side-looking airborne radar image (A) with map of Perennial Snow/Ice (shown as solid black areas) for western Olympic Mountains, Washington (B). The intense reflection of the radar energy from the steep western slopes completely masks the summer snowline. The code numbers on the map represent other categories of land cover.

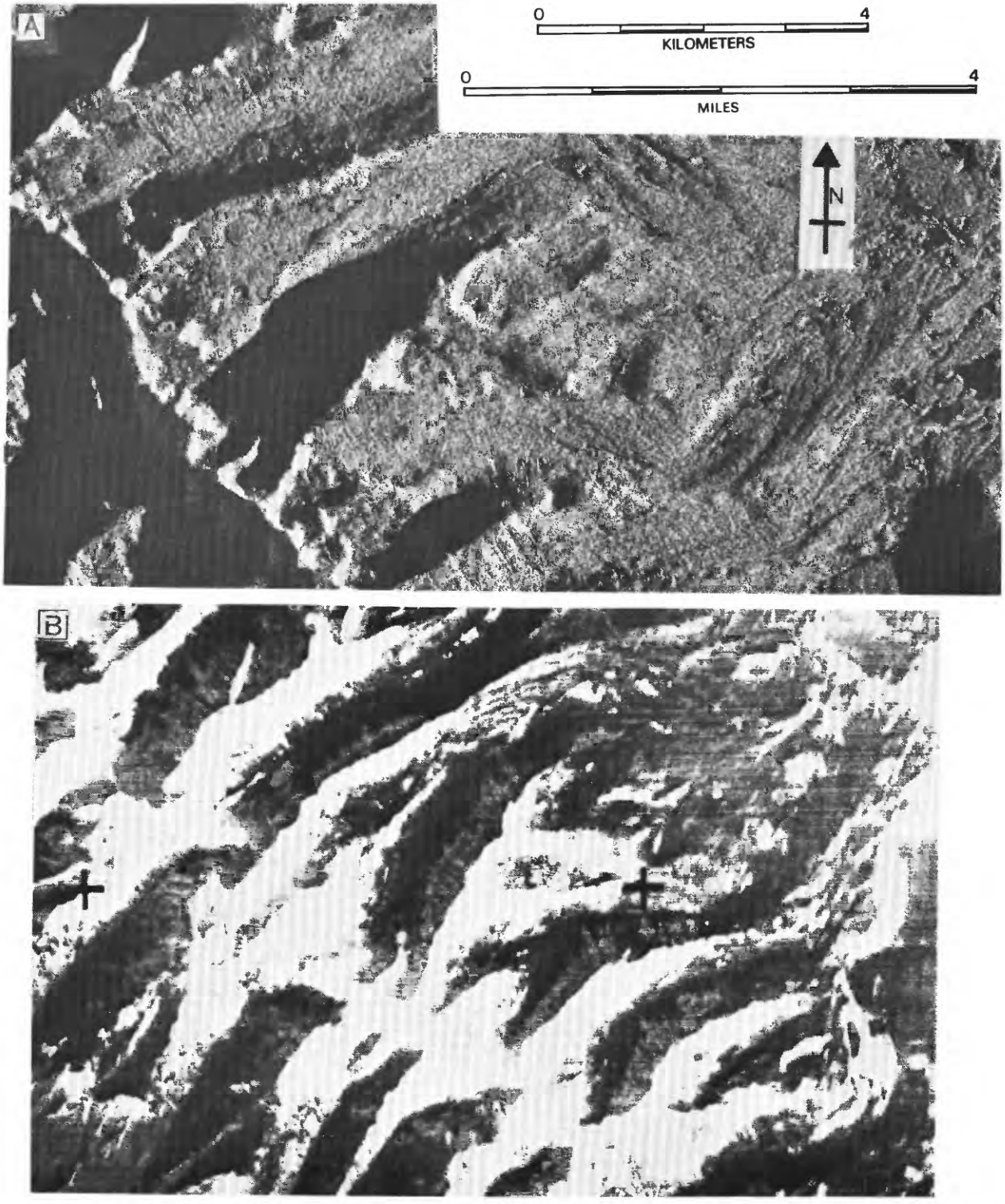



Figure 7.--Comparison of airborne synthetic aperture radar image (A) with Landsat image (B) shows some similarity in ridgeline in the Bitterroot Mountains of Montana/Idaho. In both cases, the area has complete snow cover in the winter. The radar energy reflects off east facing slopes revealing a speckled pattern which probably in this case represents the reflection from forest trees, but which may also be technological speckling common with SAR. The white in the Landsat image is exposed snow cover, mostly above timberline.

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