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ANALYSIS OF SYNTHETIC APERTURE RADAR IMAGERY

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1.0 BACKGROUND & SUMMARY

1.0 Background

This study is directed toward demonstrating the capability of radar systems to recognize contrasts between watersheds with different runoff potential. Synthetic aperture radar (SAR) data were collected by the Environmental Research Institute of Michigan (ERIM) using their aircraft system over watersheds in central Oklahoma. In addition, the Jet Propulsion Laboratory of Pasadena, California furnished L-band radar data with this same study. These data are to be analyzed to determine if the radar response of the longer wavelength in the microwave region, L-band and/or X-band, can be related to the runoff coefficient used in the Soil Conservation Service (SCS) watershed runoff equation.

It was proposed that the SAR data should be provided by ERIM on film strips and the density measurements of the film would be examined to determine if conventional hydrologic parameters could be detected in the data. Watershed drainage areas for the selected watersheds having extensive historical records of rainfall and runoff were to be mapped to identify the radar data within the watershed boundary.

The average density of strips of data representing a narrow range of angles off nadir were to be modified to correct for differences in radar power. An average modified return was to be compared to watershed runoff coefficients derived from the rainfall and runoff data. The work required to complete this study was envisioned as three related tasks.

1. Locate the specific watersheds on the four channels of SAR imagery. The four channels are the like and cross polarized returns at X and L-bands.

2. Determine the average values in a relative sense of the backscatter coefficients for these watersheds. If possible, the effect of the varying nadir angle on the scattering coefficient will also be determined.

3. Correlate the observed scattering coefficient with known watershed parameters for these watersheds and with ground observations made at the time of the flight.

1.2 Summary

Radar images from watershed areas in central Oklahoma collected by ERIM and JPL were provided as film products for L and X-band frequencies. Qualitative assessment of the film indicated that drainage patterns and water under vegetation could be identified in L-band data. Influence of land slopes and apparent irregularities in response across track may limit measurement of the other watershed parameters such as soil moisture or vegetative cover. Study of the digitized radar return indicated that the JPL like polarized L-band data may be related to the SCS watershed runoff coefficient. This relationship could not be verified in the ERIM data.

Development of digital radar systems with internal and external calibration that can be operated without a radome is suggested. The necessity for either a rectified image or a constant angle imager would also be required before this system could become operational.

2.0 ACCOMPLISHMENTS, PROBLEM AREAS, AND RECOMMENDATIONS

2.1 Accomplishments and Problem Areas

To accomplish the objectives of this study, data from both the Jet Propulsion Laboratory (JPL) and the ERIM L-band system were collected over watersheds near Chickasha, Oklahoma. The ERIM system was flown over the watersheds on November 11, 1975 and the JPL system was flown on January 6, 1976. These data have been received as film and isolated sections of the data have been furnished in digital form. Three different systems have been used to digitize the data, namely the General Electric Image 100 and the JPL PDP, both of which were used to digitize the image film. An ERIM system which digitizes the output of the optical correlator was used on some of the original ERIM data.

Only the like polarized (HH) data were available from the JPL L-band system for this study. This system was flown at approximately 30,000 feet altitude. Two passes were flown over the eastern portion of the watershed study area and one pass over the western portion. Four small watersheds representing high and low runoff areas were imaged in one pass over the eastern area. Imagery from passes over the Mississippi-Arkansas flight path and a westerly pass in western Oklahoma and Texas were also furnished by JPL.

The ERIM X and L-band system was flown at approximately 12,000 feet altitude providing data from four passes on the eastern end of the study area and two passes on the western side. These data provide good coverage of a number of watersheds that have extensive records including the same four mentioned previously. The like and cross polarized data for both frequencies were reduced to film products by ERIM. A small portion of these data were digitized covering the most significant watersheds.

The film products from both flights were examined and some qualitative observations were made. The most obvious watershed characteristic from the film is the definition of drainage patterns particularly in the Great Plains area. Drainage patterns in relatively flat, large alluvial areas along major rivers are not as well defined near nadir as those imaged at far angles. The L-band images from both systems do not appear to be influenced as much by differences in density of dormant vegetation as the X-band images are. Areas of water even under moderate vegetation are detectable in the L-band data. Open bodies of water were best defined by X-band like polarized data.

Subtle differences due to differences in soil moisture may be present in the film, but if present they are completely overwhelmed at far angles from nadir by the influence of land slopes. Extreme differences in scattering of L-band energy in the timber and the extremely rough gullies make these areas predominant on the film.

Density measurements of the film were made in selected fields near rain gauge location. In most locations at least one field of winter wheat, one of bare soil and one of pasture were measured. These locations were then separated into groups representing a narrow range of incident angles. An attempt was then made within each group to relate film density to antecedent soil moisture. Care had been taken to modify one film strip to match the other by ratioing the density from the density wedges. The modification for differences in antecedent conditions over the gauged area did not represent a large range of moisture values. This effort was abandoned after no significant relation was detected on plots of density for a specific cover (wheat, bare soil, native grass) versus antecedent precipitation.

From the study of the film and the density measurements it became obvious that corrections in the data for differences in power due to the direction and/or irregularities in the radar pattern must be made before these images can be of maximum value. The configuration of the SAR image also limits the accurate selection of data in the area representing small angles off nadir.

Watersheds within the portion of the digitized data from both the ERIM and JPL systems were generally large. All look angles from nadir to 60^{o} from nadir were represented in most of the large watersheds. An attempt was made to average large numbers of data points along track to derive a set of values that could be used to normalize the image. These efforts failed to correct the data to our satisfaction. Four small watersheds were viewed at approximately 40 to 45 degrees from nadir on the JPL data. Average digital values for each watershed after slicing out data identified as timber appears to be inversely related to the SCS watershed runoff coefficient.

Watershed Number	Watershed Runoff Coefficient	Average L-band Digital Data
R5	45.4	126.5
R6	53.6	131.4
R7	75.8	90.6
R8	77.4	78.7

The above results could not be compared to data from ERIM since the same small watersheds fall on a portion of the film that appears biased by irregularities in the antenna pattern. Correlation of values representing backscatter with the watershed runoff coefficients for the larger drainage areas appears unreasonable until adequate correction of this data is possible.

A number of measurements of the antenna power pattern at specific angles were available from ERIM. In addition, ERIM estimated the average relative antenna power pattern for each strip of the image representing one tenth of the total image width. These values now do not seem adequate to correct the data. An area of the Seasat Marineland radar data over water taken with the same system is now being digitized to provide a better estimate of the average curve across track that can be fitted to the calibrated point measurements.

At the present time JPL has no measured values to use as a basis for correction of the differences in power across the beam for their system. The images produced for the like polarized data taken by the JPL system do appear free from local differences in the antenna power. At the present time an adequate adjustment for the digital values has not been determined for either set of data.

2.2 Recommendations

As a result of the findings noted above, there have been several conversations with equipment designers and data processors at both JPL and ERIM concerning how the data are collected and processed. From discussions with the microwave hardware engineers and water resources "users", several important points bearing on microwave applications in earth resources problems have become evident.

First is the fact that users in both hydrology and agricultural areas will require first generation repeatable digital values representing each resolution element. Even though the optical processor may be fast and inexpensive to operate, it does not allow production of first generation digital data. Since we will be requiring digital data from the spaceborne systems it only seems reasonable to adopt the aircraft systems to produce digital output. The risk of reaching erroneous conclusions using second or third generation data might jeopardize a basically sound system.

Secondly, it appears fruitless to fly any radar for hydrologic or agricultural applications until the power distribution of the antenna has been measured. These systems will also need some means of internal calibration in order that we can be assured that the system does not change from flight to flight.

Third, there appears to be some possibility that the ERIM L-band pattern may be influenced by the radome. The JPL system is not transmitting or receiving through a radome, and it produced a more uniform image. When a radar operates from space it will be on a stable platform without a radome and therefore it is reasonable that the aircraft system should be designed to operate under similar circumstances.

Fourth, if the side-looking radar is to be used as the test imager, adequate rectification of the image should be provided. The most acceptable image to the water resources or agricultural user, however, would be provided by a constant angle imager similar to the Passive Microwave Imaging System.

These observeations are presented to offer constructive adjustment of the present microwave experiment plans. Some adjustment in emphasis may be needed to get the most effective results from application experiments. Hopefully, these suggestions will aid in developing acceptable data products for the user.

2.3 Accomplishments Expected During Remainder of Contract

When adequate background data are received from ERIM, a correction will be developed and applied to the existing digital data. This correction should compensate for differences in the radar pattern. The corrected data will be reformatted on tape for display on the Image 100. Watershed areas will be outlined on the display and averaged digital values will be calculated and compared with runoff coefficients for these watersheds.

3.0 SIGNIFICANT RESULTS AND PRESENTATIONS

3.1 Significant Results

1. Average radar response for the JPL L-band like polarized system appear to be related to the watershed runoff coefficients when the viewing angle is approximately 42° off nadir.

2. Four requirements for radar systems used to verify applications of active microwave for water resources have been identified.

(a) First generation digital data will be required.

(b) The radar should be calibrated both internally and externally.

(c) New systems should avoid the use of radomes.

(d) Images should be geometrically rectified prior to delivery to the user.

3.2 Presentations

None.