Recommendations from GlobeSAR on RADARSAT Operational Modes

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Abstract -GlobeSAR is a highly successful international program designed to transfer technology on Synthetic Aperture Radar (SAR) from Canada to the participating countries and to further develop applications of RADARSAT. While the flexibility in RADARSAT's beam modes and configuration enhances the use of the SAR data for geoscience applications it also adds complexity to the data ordering and selection process. The trade-offs between swath coverage, resolution, number of looks, and incidence angle must all be considered when ordering, processing, and analyzing the data. This paper describes preliminary recornmend8tions for selecting the optimum RADARSAT operating mode for various applications being studied in GlobeSAR. Ancillary data requirements for successful use of the SAR data are also addressed.

I. INTRODUCTION AND BACKGROUND

GlobeSAR is a world-wide Synthetic Aperture Radar (SAR) project led by the Canada Centre for Remote Sensing (CCRS) in co-operation with the Canadian Space Agency (CSA), RADARSAT International Inc. (RSI), and the Canadian International Development and Research Centre (IDRC). The goals of this program are two-fold. One objective is to evaluate the potential of RADARSAT data for resource management in the ten participating countries, ranging from tropical rain-forest areas in south-east Asia to arid conditions in North Africa and in the Middle-East The second objective is to provide technology transfer and human resources development to the participating agencies from the various countries involved in the program. Campbell et al., (1995) provide a more detailed description of the GlobeSAR program.

During the early phase of the program, the various studies being conducted by the research teams have primarily used airborne data acquired by the CV-580 C/X airborne SAR system. Petzinger (1995) provides a description of the GlobeSAR airborne data acquisition program. The airborne data have also been used to simulate Fine Resolution and Standard Mode RADARSAT products for further study and evaluation by the research teams. With the successful launch of RADARSAT in November 1995, the program is now moving towards utilisation of satellite imagery for these applications.
However, the optimal RADARSAT beams and modes must be determined for the various applications in order to meet their respective information requirements and the overall

program objectives. It is also important to assess which complementary data sets will be required to facilitate the subsequent utilisation of RADARSAT data.

This paper will address both of these issues. First of all, significant results will be presented on the analysis of the airborne SAR and simulated RADARSAT products. It is expected that by the time of the symposium presentation there will be several actual RADARSAT datasets available for analysis and comparison. The planned RADARSAT Validation Project (RVP) has identified several key areas from the GlobeSAR program where there is a need to collect data early in the RADARSAT mission to assess the data products. Secondly, recommendations on the modes of operation of RADARSAT will be given for the different applications in the various environments, based on our current understanding. This will include an identification of key ancillary data needed to support the applications. In order to put this work in context, the GlobeSAR project will also be briefly described. Finally, the future activities planned for the final phase of the GlobeSAR program will be outlined to indicate how these recommendations will be evaluated and modified based on the results from this and other RADARSAT validation programs.

II. GLOBESAR PROGRAM DESCRIPTION

The GlobeSAR program was initiated in early 1993 with visits and workshops held in various countries which had expressed interest in participating in the program. During these visits test sites were identified, applications were developed, and contacts were made with local government agencies, universities, and scientists who would then help develop the program. The next few months were devoted to obtaining the flight clearances and other authorisations needed to conduct the airborne data acquisition. In the Fall of 1993, the CCRS CV-580 C/X airborne SAR collected data over 32 research sites in China, Jordan, Kenya, Malaysia, Morocco, Thailand, Tunisia, Uganda, and Vietnam. Tanzania also participated with Uganda and Kenya on their study sites although no airborne SAR data were acquired over Tanzania. Just prior to the airborne data acquisition, workshops on an introduction to radar and on supporting ground data collection were conducted in each country. Ground data were then acquired to support the image analysis for each test site.

The next few months were devoted to data documentation, processing, RADARSA T product simulation, and data distribution. In the late spring and summer of 1994, the various countries were revisited and workshops conducted on advanced radar concepts, radiometric and geometric correction to SAR data, and information extraction. Major applications were also reviewed, in general, followed by detailed discussion on study plans for local applications. During this visit, image analysis software developed by Canadian companies (PCI and Atlantis Scientific) was installed and hands-on training provided. These workshops were followed by regional meetings held in Bangkok, Amman, and Beijing where results were presented by the various study teams. During these regional meetings, and through follow up visits to each country, plans for actual RADARSAT data acquisition and analysis were developed during 1995. With the launch of RADARSAT on November 4, 1995 the final phase of the program is ready to begin.

III. APPLICATIONS REVIEW AND RADARSAT RECOMMENDATIONS

Due to space constraints in this publication the following discussion is quite brief and is only meant to highlight the most promising applications and make preliminary recommendations on RADARSAT modes and beam choices. A more detailed GlobeSAR application review can be found in Brown et al., (1995) with specific studies described in detail in the proceedings of the various regional meetings.

A. *Agriculture*

One of the most promising applications in agriculture for RADARSAT will be wetland rice mapping and monitoring (Brisco et al., 1995). The characteristic dark signature of flooded paddies followed by increased radar backscatter as the crop grows and develops offers the ability to monitor rice growth using multi-temporal imagery. The underlying water surface tends to simplify the scattering process as little or no direct surface backscatter is included in the total backscatter. For dryland crops, the soil contribution makes it more difficult to extract crop canopy information. The larger angles have repeatedly been shown to be superior for this type of application and due to the fragmented land cover Fine mode data may be required. Larger incidence angles (i.e., greater than 40 degrees) eliminate or reduce row direction effects which often reduces the accuracy of identification or monitoring applications. For regional studies and areas of larger field size Standard mode or even Wide mode data may be preferred, but once again at larger incidence angles. GIS layers on land cover and field boundaries will facilitate the identification and mapping applications. Ancillary data on weather conditions and yield models for integrating the remotely sensed data within the GIS will be needed to obtain final productivity estimates.

Soil moisture estimation is also a very promising RADARSAT application as the very high dielectric constant of water at microwave frequencies (approximately 70) causes a significant increase in radar backscatter as water is added to the soil (which has a dielectric value of from 3-5). The information extracted from the SAR data can be used in many applications such as yield estimation in agriculture, or distributed watershed modelling in hydrology. The results have demonstrated that the smaller incidence angles are preferred for this application, as the vegetation and soil roughness error sources .are reduced with this approach. This implies Standard mode beams 1 and 2 as the preferred RADARSAT configuration, although once again more regionally orientated applications may make use of the Wide or even ScanSAR modes. GIS overlays of soil type, land cover, topography, etc. will benefit this approach as will suitable models for each particular application.

B. *Archaeology*

Remnants of archaeological sites will often appear as man-made patterns on SAR images. Northern Thailand has a number of ancient moated cities which are now agricultural areas or larger urban centres. Often the moats of these cities and the associated canals that led to them, are still visible or detectable with SAR, even though some canals have been filled. It is archaeologically important to locate the ancient canals as they testify to the chronological evolution of that area and to the extent of development. Archaeological features are linked to the geomorphology of the area, which will dictate the preliminary appearance of RADARSAT data. The larger angle Standard mode beams will be most useful for this application. In addition, the GlobeSAR simulations indicated that Fine mode data will be an asset in detecting and adding to the archaeological inventory. Additional investigations of smaller incidence angle data will assess its potential for ancient canal mapping, which can be identified through soil moisture effects.

C. *Coastal zones*

The coastal zone includes the marine and terrestrial near shore area. Its assessment and monitoring is crucial in matters of sovereignty, environmental monitoring and protection, and hazard mitigation. Sensitive areas, such as mangrove forests, are protected in most countries as they are threatened by human activities and by tropical storms which erode coastlines. The expanding shrimp farming industry requires a near-shore salty or brackish water environment, an ecosystem similar to that of mangroves, which results in a monitoring requirement to prevent encroachment into these forested areas. RADARSAT Fine and Standard mode data are being acquired for those types of studies. Preliminary results from analysis of airborne SAR data and RADARSAT simulations suggest that beyond 300, incidence angle variations will not have a significant impact on interpretability of the data for primary landuse. Instead, a combination of several Standard mode beams may be used to obtain timely spatial coverage.

Ship detection and tracking from SAR data offers potential solutions to illegal shipping and fishing. This is an instance where the steerable beam of RADARSAT is a great asset by providing timely information and more useful large incidence angle data. Ancillary data on wind and wave conditions and shipping lanes will facilitate ship detection applications. Oil spill detection and extent mapping is another promising application being investigated under the GlobeSAR and RADARSAT Application and Development Research Opportunity (ADRO) projects. The RADARSAT beams acquired at smaller incidence angles and the Fine resolution mode can be important tools in evaluating the extent of spills and the potential environmental impact.

The detection and mapping of ocean features represent the final discipline in coastal zone monitoring. Radar data has proven its usefulness in this field with airborne SAR and data from the ERS-l satellite. Though not a common GlobeSAR activity, it is being evaluated by Malaysian scientists and will be further investigated by various participants under ADRO projects. The results have shown that these features can be detected using Standard mode data, especially at the smaller incidence angles. More detailed studies may require Fine mode data while regional investigations can make use of the Wide mode products.

D. *Forestry and Land Cover Mapping*

General land cover mapping at the primary level (i.e., forest, water, urban, agriculture, etc.) is quite effective with SAR data and in most cases the larger incidence angles are preferable. The appropriate mode of RADARSAT will depend on the area of interest and the desired mapping scale. In areas of rugged topography, a DEM will be needed to account for variations in local incidence angle, which is the first-order parameter governing radar brightness. Other ancillary data, especially visible and infra-red data from the optical satellites, combines synergistically with the SAR data to improve identification accuracy. Texture is also very useful in SAR interpretation for separating natural from cultural vegetation types, as the randomness of the natural vegetation generates rougher textural signatures.

SAR data has been shown to be very useful for monitoring clear cuts, forest regeneration, and infrastructure developments (i.e., roads and buildings). In general the shallower angles are preferred for these applications, and in some cases the higher resolution Fine mode data may be required to accurately identify the location and size of the feature(s) of interest. Due to the all-weather day or night capabilities of SAR data collection, RADARSAT will be very useful for change detection approaches to support these applications. The information content at C-band is low for forest-type mapping and biomass estimation. However, the data can be used synergistically with other data (including other SAR frequencies and polarizations) to improve forest mapping capabilities. The longer wavelengths, such as p- and L-band, are more suitable for these applications.

E. *Geology*

Geological applications of SAR data are well proven and many have successfully integrated information layers of mapping agencies and exploration companies. The primary objective of a mapping / exploration exercise is the recognition of physical structures expressed in SAR images. Second-order information is extracted from SAR texture analysis, revealing terrain attributes and extent of domains related to general geological units. The physical features expressed in SAR imagery are directly related to structural geology (e.g., faults, synclines/anticlines), extent of lithological units, and erosion and weathering patterns. In tropical areas, boundaries between resistant and recessive units are frequently visible due to erosional escarpments at their contacts, which correspond to changes or gaps in the forest canopy. High precipitation rates and warm temperatures facilitate chemical weathering of bedrock and the pattern of erosion seen from SAR data can be a diagnostic indicator of rock types. SAR imagery was successfully used to trace bedding and update existing maps in tropical forested areas. Fold axes were mapped and the principal phases of folding were easily recognized. The airborne data used in GlobeSAR confirmed that acquisition at high incidence angles gave optimal results in rugged terrains such as those of Sarawak, Malaysia and Cao Bang, Vietnam. Gold deposits associated with shear zones were identified in China, Malaysia, and Vietnam from the SAR data. Although the locations of these deposits were previously known, these projects demonstrated the use of SAR data for gold exploration in tropical environments. The use of RADARSAT simulations indicated that resolution and data quality were appropriate to successfully update geological maps at a scale of 1:50,000 using Fine mode and 1:100,000 using Standard mode. On-going work with RADARSAT data will verify these findings and assess the value of ScanSAR Narrow data for regional mapping. Through all GlobeSAR projects, the role of data fusion to increase interpretability and synergism of all data sets was confirmed and emphasized.

F. *Geomorphology*

Geomorphology is the study of landforms, of their surface expression, of surficial deposits and their genesis. As such, the first-order interaction and backscatter of microwaves with terrain will be closely tied to the geomorphology of the area. The GlobeSAR data in all countries were classified into geomorphologic classes such as flood plains, terrace, erosional valleys, dissected highlands, solution depressions, etc. The geomorphologic information provided by the SAR data is often useful in determining and explaining landuse and agricultural practices. For example, under given environmental conditions, gently undulating topography is easily identified in SAR imagery by the dryer (darker) crest and wetter (brighter) trough. RADARSAT investigations require incidence angle analysis to determine optimal information content for various terrain types. Features tied to soil moisture effects may be best mapped using steep incidence angles, whereas those marked by topographic or roughness attributes may be best highlighted by mid- to high-incidence angles. The study of RADARSAT simulations suggested that Standard Mode data were best suited to extract and study the geomorphologic features.

G. *Hydrology*

Soil moisture and distributed watershed modelling was discussed in the agricultural section. Other notable hydrology applications include flood mapping, hydrology network mapping, and wetland identification and monitoring. Due to the specular nature of radar backscatter from water bodies, which creates a very dark image, the hydrology network and the presence of standing water is easy to map. This is best done at the larger angles as the contrast with the land targets is maximized. The enhanced backscatter from flooded vegetation further enhances the ability to map floods and the hydrology network. The choice of mode (Standard, Fine, Wide, etc.) depends on the area flooded or the area to be mapped and what scale is desired. For many applications the Wide beam mode may offer the best compromise between swath width and resolution. As with most other applications a GIS overlay of water boundaries, land cover, etc., will benefit the approach.

Due to the sensitivity of radar backscatter to moisture variations in both soil and vegetation, wetlands can be readily identified on SAR images. The larger incidence angles are preferred with the choice of mode dependent on scale and land cover fragmentation issues. The use of GIS overlays and ancillary data, such as optical imagery, further enhances classification abilities. Due to the seasonal variations which most wetlands experience, the use of multi-temporal RADARSAT data is particularly useful for this application.

IV. RADARSAT VALIDATION

RADARSAT scenes will be acquired of the GlobeSAR test sites using various modes and beams to validate and further refine these recommendations. RVP, ADRO, and the GlobeSAR program activities will be coordinated by CCRS, with input from RSI and CSA, in order to evaluate the various applications and provide more details on the preferred RADARSAT configuration. The participating agencies and scientists from the GlobeSAR countries will continue to conduct ground data acquisition programs to support the analysis and interpretation of the data. The results from these various programs will be presented at various meetings and symposiums in the future.

V. SUMMARY

The steerable beams of RADARSAT and the different modes of operation combine to give a flexibility in data products which enhances the use of the data for various geoscience applications. This requires the user to consider trade-offs in swath width, resolution, number of looks, and incidence angle before selecting and processing SAR data. While this paper provides some general guidelines to this approach from an applications perspective, the RVP, ADRO, and GlobeSAR programs will all contribute to a better understanding of these issues. The GlobeSAR test sites will all be imaged by RADARSAT during 1996 using a coordinated plan of data acquisition to acquire a variety of beam and mode products for evaluation. This will allow a refinement of the recommendations made above.

VI. REFERENCES

Brisco, B., R.J. Brown, G. Staples, and D. Nazarenko, 1995, "Potential Rice Identification and Monitoring with RADARSAT", Proceedings of 17th Canadian Symposium on Remote Sensing, Saskatoon, Saskatchewan, June 13-15, pp. 474-479.

Brown, R.J., M.A D'Iorio, and B. Brisco, 1995, "GlobeSAR Application Review", Geocarto International. Vol. 10(3), pp. 19-32.

Campbell, F.H.A, R.A Ryerson, and R.J. Brown, 1995, "GlobeSAR: A Canadian Radar Remote Sensing Program", Geocarto International Vol. 10(3), pp. 3-8.

Petzinger, F.C., 1995, "GlobeSAR: The CCRS Airborne SAR in the Era of RADARSAT", Geocarto International. Vol. 10(3), pp. 9-18.