Wetland Mapping and Monitoring with RADARSAT

Brian Brisco
Noetix Research Inc.
265 Carling Ave
Ottawa, ON
Canada K1S 2E1
Tel: (613) 947-1262
Fax: (613) 947-1385
e-mail:brian.brisco@noetix.on.ca

Terry Pultz
Canada Centre for Remote Sensing
588 Booth Street
Ottawa, ON
Canada K1A 0Y7
Tel: (613) 947-1316
Fax: (613) 947-1385
e-mail: terry.pultz@ccrs.nrcan.gc.ca

ABSTRACT

Wetlands are important components of ecosystems because of their role in the maintenance of environmental quality and bio-diversity. Increasingly, wetlands have been under stress due to drainage activities and subsequent habitat fragmentation. Their importance to a healthy environment and the growing public awareness of their plight has generated the need for effective management approaches to wetland conservation, including the use of remote sensing data. This paper reviews the role of RADARSAT in mapping and monitoring wetlands with examples of research results and studies from North and South America used to support the discussion.

Introduction and Background

Wetlands play an important role in the ecosystem through their influence on the hydrological cycle, as a habitat for flora and fauna, and as a natural cleaning agent for good environmental health. Due to widespread drainage and fragmentation, mostly as a result of the conversion of wetlands to agricultural and urban environments, there is a growing requirement for wetland conservation and sound environmental management. Remote sensing can play an important role in the mapping and monitoring of wetlands (Hardisky et al., 1986; Hess et al., 1990).

Synthetic Aperture Radar (SAR) has several advantages for monitoring wetland conditions. The timely data acquisition capability is important for hydrological monitoring programs. Radar is also very good at mapping water levels and identifying open water, flooded vegetation, and upland areas. In some cases discrimination between wetland vegetation types is possible, especially when combining SAR data with optical data (Li et al., 1995).

This paper will review radar for wetland mapping in general and the use of RADARSAT for this application in detail. The various modes of RADARSAT will be compared and the effects of various environmental conditions like rainfall, freeze/thaw, and season will be discussed. RADARSAT image examples from studies in North and South America are used to illustrate the discussion. Future research requirements to enhance information extraction from SAR data for wetland management purposes are also suggested.

Wetland Applications

Wetlands play a significant role in the functioning of natural ecological processes both within the wetland itself and downstream. Wetlands provide water storage areas for flood attenuation, water quality improvement, wildlife habitat, and surface and groundwater recharge areas essential for maintaining the natural cycles in the terrestrial and aquatic landscapes. Wetland boundaries are not static and are influenced by soil characteristics, natural and human disturbances, drainage and vegetative cover.

Gross et al., (1989) identify wetland mapping and the measurement of biophysical parameters as potential applications of remotely sensed data in wetland investigations. Mapping includes the delineation of wetlands and quantification of the distribution of the various vegetation types within these environments. The biophysical measurements include estimates of the vegetation characteristics such as height, density, percentage of cover, and biomass or productivity.

Kaschiske et al., (1997) present a review of current radar applications for ecological mapping and monitoring of various ecosystems including wetlands. In the case of wetlands, the type and characteristics of the vegetation as well as the conditions of the underlying soil (roughness, moisture content, presence of standing water) are the main target parameters affecting radar backscatter. The ability of microwaves to penetrate a canopy combined with the sensitivity of microwave energy to moisture offers a greater potential for mapping wetland boundaries and monitoring moisture conditions than is possible with multispectral imaging. In addition, the influence of structure and biomass on the radar backscatter make it possible to extract information about vegetation communities in addition to that provided by optical sensors. However, the wetland information content of radar data is also a function of system parameters such as wavelength, incidence angle, polarization and resolution.

RADARSAT Configurations for Wetland Applications

RADARSAT is the most powerful civilian SAR system with flexibility in swath width, incidence angle, and resolution. This, combined with it’s 24 day repeat cycle, gives many options to the applications specialist. This section describes the major implications of each of these parameters for wetland applications.

The resolution of RADARSAT varies from less than 10 meters to 100 meters as the swath width is increased from 50 to 500 km. This has obvious implications in area coverage and in mapping scales achievable with the data. For site-specific applications or mapping requirements at scales larger than 1:50,000 Fine mode data will be required. Obviously, the area coverage and mapping scales are the criteria the user needs to evaluate when choosing the swath width and resolution of the imagery.

RADARSAT provides data with incidence angles ranging from 20 to 50 degrees as well as extended high and low beams providing data at steeper and shallower angles. This allows the user to choose an angle of observation most suited to their objectives. In general, steep angles (less than 30 degrees) provide more penetration and subsequently more information about surface soil moisture for hydrology modelling applications. This increased penetration can also enhance the double bounce scattering of flooded forests which then helps map inundated vegetation during flood events or as a function of the seasonal changes in water level. Shallow angle data is more suitable for discriminating between different types of upland vegetation surrounding the wetlands and between different wetland vegetation associations like various sedge, grass, and rush communities. In windy conditions the shallow angle data also enhances mapping surface flooding due to the bigger difference in radar backscatter between land and wind-roughened water at these incidence angles.

Seasonal changes in the wetlands are very easy to monitor with RADARSAT, or to use in planning for data acquisition purposes. The 24 day repeat cycle with the numerous beam positions and swath coverages gives many different viewing opportunities. This allows the user to either plan a temporal sequence to capture the seasonal changes or to develop an acquisition plan for getting the data during the season of interest.

RADARSAT Examples

Due to the page limitations in these proceedings it was decided not to present the image examples nor describe in detail the results from the various studies in this publication. The imagery will be presented at the symposium while the following section provides a brief description of the sites and the studies from which the examples are extracted. References are provided to provide the reader a source for more detailed information.

The Ottawa area has served as a test site for a number of hydrology and landcover mapping studies (Cihlar et al.,1992; Crevier et al., 1996; Pultz and Crevier, 1996) and thus many RADARSAT scenes are available for analyses. The wetlands in this region are mostly swamps with limited marsh, bog, and open-water macrophytic wetland vegetation communities. Although these wetlands are identifiable at all incidence angles investigated they are more easily identified at steeper angles. Environmental conditions, especially freeze/thaw effects on the snow cover and the height of the water table during flood events, also have marked effects on the wetland signatures. In most cases wet snow and high water tables enhance mapping the swampy wetlands in this region.

RADARSAT's utility for mapping the wetlands of the Long Island area of New York is being investigated by Henderson et al, 1998a & 1998b. In this region there has been evidence that the shallower angles of RADARSAT are preferred for mapping the various wetland and upland vegetation communities. The fragmented areas of Palustrine and Estuarine Emergent wetland classes are better separated at the shallower angles. Fine mode is also required because of the small size of many of the wetlands and the fragmented land cover. These studies also further demonstrate the synergism of fusing optical and SAR data for landcover mapping applications.

The Amazonian region of Brazil is being intensively imaged by RADARSAT due to the interest in mapping and monitoring this vast tropical rainforest. Costa et al., 1997 have shown how temporal RADARSAT data can be used to map the floodplain vegetation as well as the progress in the growth of aquatic macrophytes. This is related to water level changes due to the wet versus dry season distribution of rainfall and is useful information to both the hydrologist and the environmentalists.

Willow and poplar plantations are very important to the local economy in the Parana River delta region of Argentina where the resulting pulp is mostly used for paper production. A GlobeSAR-2 project (Brisco et al., 1997) is evaluating the information content of RADARSAT for mapping these plantations as well as for mapping the other wetland vegetation communities which are ecologically important to the delta region (Milovich et al., 1998; Kandus et al., 1998). Results have demonstrated that the steeper incidence angles are preferred for separating the forest plantations from the other wetland vegetation. Fires, caused by careless human activities, also cause a decrease in the backscatter of the sedge and rush vegetation associations which can cause confusion with the forested regions. Fortunately, this effect appears to be temporary which implies that it will not create severe problems for the forest management while providing useful monitoring information for the environmentalist.

Concluding Remarks

RADARSAT data have been used to provide useful information for many applications in hydrology including wetland mapping and monitoring. Vegetation discrimination, water level estimation, flood mapping, and monitoring environmental effects and disturbances have all been demonstrated. The flexibility of RADARSAT's data collection capabilities, including both it's "all-weather" capability and it's multiple modes and beam positions, enhance many of these applications but must be considered in developing a data acquisition plan.

Several areas where additional research is needed to more fully develop the use of SAR data for wetland mapping applications are also identified. Environmental effects need additional study and quantification so the methodology for correcting for these effects, as well as for using the resulting change in information content, can be developed. The same can be said for the effects of incidence angle. Further development of data integration methodologies will also enhance the use of the information derived from RADARSAT or other SAR sensors. With many counties having future plans for polarimetric and/or multi-frequency satellite SAR systems, including RADARSAT-2, continued research on the frequency and polarization (including phase) dependence of radar backscatter from wetlands is also needed.

References

Brisco, B., M.J. Manore, R.J. Brown, M.A. D'Iorio, and F.H.A. Campbell, 1997, "GlobeSAR-2 RADARSAT Applications Review", Proceedings of Geomatics in the Era of RADARSAT (GER'97), Ottawa, Canada, May 25-30, 1997.

Cihlar, J., T.J.Pultz, A.L.Gray, 1992, "Change Detection with Synthetic Aperture Radar", International Journal of Remote Sensing, Vol.13, No.3, pp. 401-414.

Costa M. P. de F. , Novo E. M.L. de M. , Mitsuo II F. , Ballester M.V. , Ahern F, 1997, "Classification of Floodplain Habitats (Lago Grande, Brazilian Amazon) with RADARSAT and JERS-1 Data", Proceedings of Geomatics in the Era of RADARSAT (GER'97), Ottawa, Canada, May 25-30 , 1997.

Crevier, Y., T.J.Pultz, T.I.Lukowski, T.Toutin, 1996, "Temporal Analysis of ERS-1 SAR Backscatter for Hydrology Applications", Canadian Journal of Remote Sensing, Vol.22, No.1, pp.65-76.

Gross M.F, Hardisky, M.A., and Klemas V. 1989, "Applications to coastal wetlands vegetation", in Theory and Applications of Optical Remote Sensing, Asrar G. (Ed.), John Wiley & Sons, Wiley Series in Rem. Sensing, Toronto, Ch. 11, pp.474-490.

Hardisky, M.A., M.F. Gross, and V. Klemas, 1986, "Remote Sensing of Coastal Wetlands", Bioscience, Vol. 36, No. 7, pp. 453-460.

Henderson, F.M., T.F. Hart, R. Chasan, and J. Portolese, 1998a, "Analysis of Optical-SAR Data Fusion and Merged Data Set Procedures in Highly Developed Urbanized Coastal Environments", to appear in Proceedings of IGARSS'98, Seattle, Washington, June 1-5.

Henderson, F.M., T.F. Hart, B. Heaton, and R. Chasan, 1998b, "Spectral Separability and Composition of Coastal Wetlands using SAR and Fused Optical-SAR Data Sets", to appear in Proceedings of IGARSS'98, Seattle, Washington, June 1-5.

Hess, L.L., J.M. Melack, and D.S. Simonett, 1990, "Radar Detection of Flooding Beneath the Forest Canopy: A Review", International Journal of Remote Sensing, Vol. 11, No. 7, pp. 1313-1325.

Kandus, P., H. Karszenbaum, L. Fulla, and J. Milovich, 1998, “Imágenes SAR/RADARSAT del Bajo delta del Rio Paraná Argentina, Parte II: Análisis de los factores ambientales que determinan las caracteristicas de la señal retrodispersada”, GlobeSAR 2 Mid-Term Symposium: RADARSAT Applications in Latin America, Cartagena, Colombia, April 20-24.

Kasischke, E., S. et al.,1997, "The use of Imaging Radars for Ecological Applications -A Review", Remote Sensing of Environment, Vol. 59 : 141-156.

Li, C., B. Brisco, R.J. Brown, J. Wang, and J. McDonald, 1995, "SAR/TM Wetland Identification in the Lake St. Clair Delta", Proceedings of the 17th Canadian Symposium on Remote Sensing, June 13-15, Saskatoon, Saskatchewan, pp. 60-65.

Milovich, J.A., L.A. Frulla, H. Karszenbaum, and P. Kandus, 1998, "Análisis de imágenes SAR/RADARSAT del Bajo delta del Rio Paraná, Argentina, Parte I: Seleccion y verificacion de procedimientos de pre-procesamiento y procesamiento", GlobeSAR 2 Mid-Term Symposium: RADARSAT Applications in Latin America,Cartagena, Colombia, April 20-24.

Pultz, T.J., Yves Crevier, 1996, "Early Demonstration of Radarsat for Applications in Hydrology", Third International Workshop on Applications of Remote Sensing in Hydrology, Greenbelt, Maryland. October 16-18, pp.271-282.