Change Detection Analysis in Wetlands using JERS-1 Radar Data: Tonle Sap Great Lake, Cambodia

Anthony K Milne and Ian J Tapley,
Horizon Geoscience Consulting Pty Ltd
Sydney New South Wales, Australia
Tony.Milne@unsw.edu.au

Abstract- AIRSAR data were collected over the Tonle Sap Great Lake and Angkor regions of Cambodia during the NASA-Australia sponsored PACRIM2 Mission flown in September 2000 and analysed to produce a wetlands vegetation map and to determine flood extent in the TSGL. Archival JERS-1, L-band radar data for the period 1992-98 was available to assess changing environmental conditions brought about by the seasonal variation in water levels associated with flooding and that caused by human occupation and migration. Assessment of the changing environmental conditions was undertaken using three JERS-1 L-band images acquired in 1997. One image was obtained during the dry season in January when water levels associated with the TSGL were changing; one at the end of the dry season in April near to the period of low water in the lake, and the third image in August at the beginning of the next wet season.

Keywords- wetlands; biodiversity; change detection; water resource management.

1. Introduction

The Tonle Sap-Great Lake (TSGL) located in western Cambodia supports one of the most productive and biodiverse freshwater ecosystems in the world. The flow into the TSGL from the Mekong River system during the wet season (July-October) expands its surface area from 250,000 ha to 1.25 Mha inundating large areas of forest and woodlands. These wetlands it turn provide a unique freshwater fish habitat with an annual catch representing 75% of Cambodia's inland fish production and generating an estimated US$70M in income. With the reversal of water flow back into the Mekong River from November on into the dry season, large areas of flooded land on the lakes edge are successively exposed and used for agriculture. In this fertile zone of migrating waters about 48,000 ha are planted with 'receding rice' and another 24,000 ha with other field crops. United Nations Development Program (UNDP) estimates a farm gate value of this agricultural production of US$75M.

Land use as well as environmental conservation planning and natural resource zoning in the TSGL area are intimately linked to the flooding cycles imposed on the lake by the Mekong discharge which governs not only the water levels but also the availability of water at any time.

2. Change detection

An important contribution of remote sensing to environmental analysis is the capacity to monitor changes that occur in surface conditions over time. The process of change is associated with landscape elements being or becoming different, and as such is a function of the time interval involved between the observation dates. Whatever time interval is chosen, however, the change component can only be detected through the processing of two or more discrete data sets. An indication that change has taken place is obtained by comparing the brightness or backscattering values of calibrated, geo-referenced pixel data acquired for the same location on different occasions. To establish the nature and extent of changes that have occurred however requires reference to some existing characterisation or classification of the region being examined. Such baseline data is generally determined at the beginning of the time period involved.

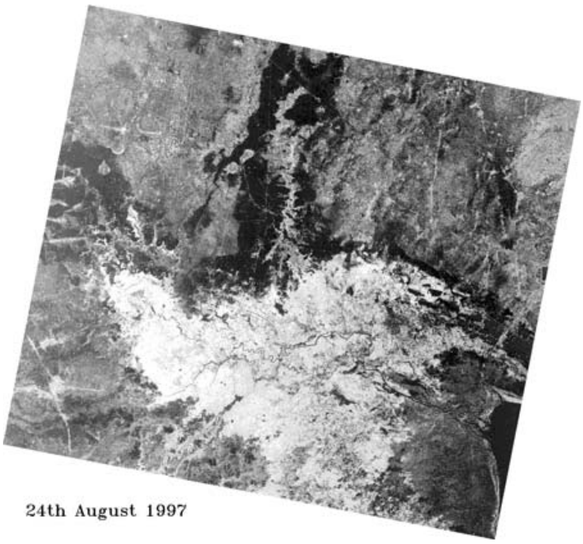
Change detection using remotely sensed data will be useful if (a) the sensor system used provides consistent quality radiometric and geometric data; (b) appropriate processing methods exist to enable the change component to be detected; (c) the nature and extent of the changes detected can be described; and (d) the results can be incorporated into a database in order to judge their long-term significance.

3. JERS-1 composite imagery

Assessment of the changing environmental conditions was undertaken using three JERS-1 (L-band) images acquired during 1997. One image was acquired during the dry season in January when water levels associated with the TSGL were changing; one at the end of the dry season in April near to the period of low water on the lake; and the third image in August during the wet season. All three images are shown in Figure 1.

16th January 1997

14th April 1997



24th August 1997

Fig. 1: Multi-data grey-tone JERS-1 images of TSGL

Two major differences can be noted between the January and the April images. In January, areas adjacent to the immediate TSGL floodplain have a brighter appearance than in April. This results from agricultural activity and crop growing. Also, the wetlands adjoining the western end of Tonle Sap appear darker. This is due to the fact that much of the flooded shrublands are still covered with water in January. By April, however, the water level has fallen in the lake resulting in the emergence of the full canopy layer of trees and shrubs and hence higher backscatter.

The April image most clearly depicts the general landscape differences between bare ground and hayed-off fields which are areas of low backscatter and appear dark-to-black on the image, and the brighter higher backscatter areas of forests and wooded wetlands. Away from the TSGL forests and shrublands the bright linear and circular areas represent tree lined roads and villages and clumps of trees in open fields. The mid-tone areas are representative of areas with scattered trees and shrublands.

The forests and wetlands of the TSGL are areas of high backscatter and appear bright. Within this zone, areas of open water are dark to black depending on the degree of canopy closure and the presence of macrophytes on the surface of the water.

Some major changes are observable in the August image as a result of renewed seasonal flooding. Water has begun flowing down tributaries which drain into the north-western end of the TSGL. Here, dark-black areas clearly define areas cover with water.

As water levels in the TSGL also increase from flow into the lake by way of the Mekong River from May onwards, the shrublands on the eastern end of the wetlands are again covered with water and appear darker. Clearly the surface area of standing water within the wetlands and flooded forests increases at this time.

Figure 2 shows both the nature and the spatial pattern of the change in backscattering taking place and caused by seasonal differences. In Figure 2 (left) the lighter tones represent areas showing major increases in backscatter and the darker areas major decreases between the two dates. Grey or mid-tone patterns may in fact be areas experiencing little or no change. Figure 2 (right) captures the actual change in decibels (dB). The significance of a (+ or -) 4 dB change in backscatter in terms of trying to quantify ecological processes has not been investigated. .

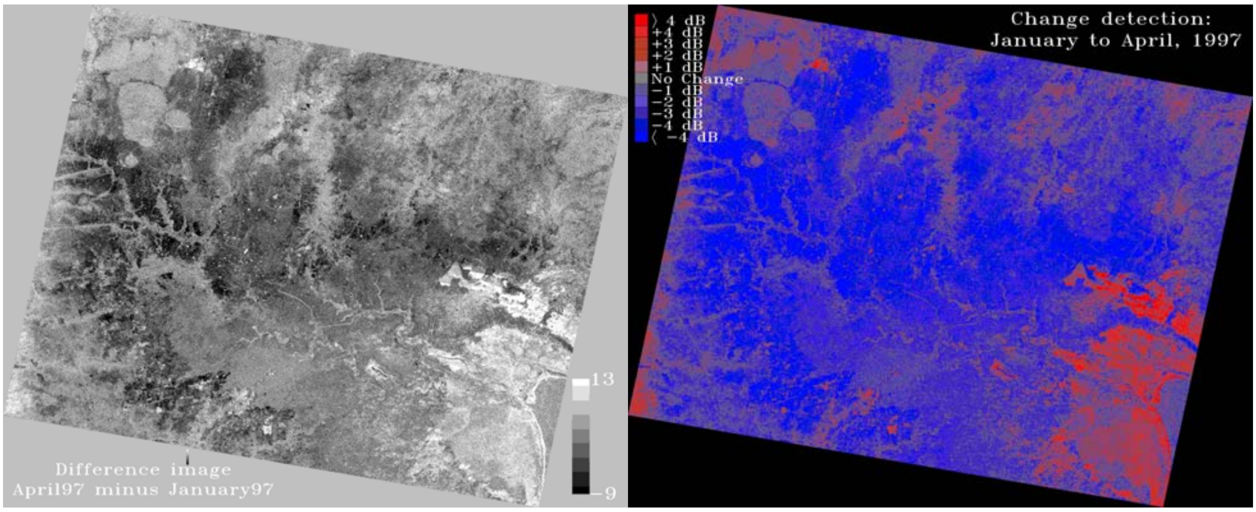


Fig. 2: Band difference (Left) and change detection (Right) images from January and April 1997.

Figure 3 shows a colour composite change image compiled by combining the January image (red); April image (green) and the August image (blue). In this context**, red-orange** colours show areas that had a higher backscatter in January than in April or August; **green** colours a higher backscatter in April than in either August or January; and **blue** colours, a higher backscatter in August than in January or April. Bright and dark areas represent surfaces that have changed little in backscatter during the year, with high backscatter shown in **white** and low backscattering regions in **black**. Also shown in Figure 3 are the locations of four sub-areas two of which are discussed below.

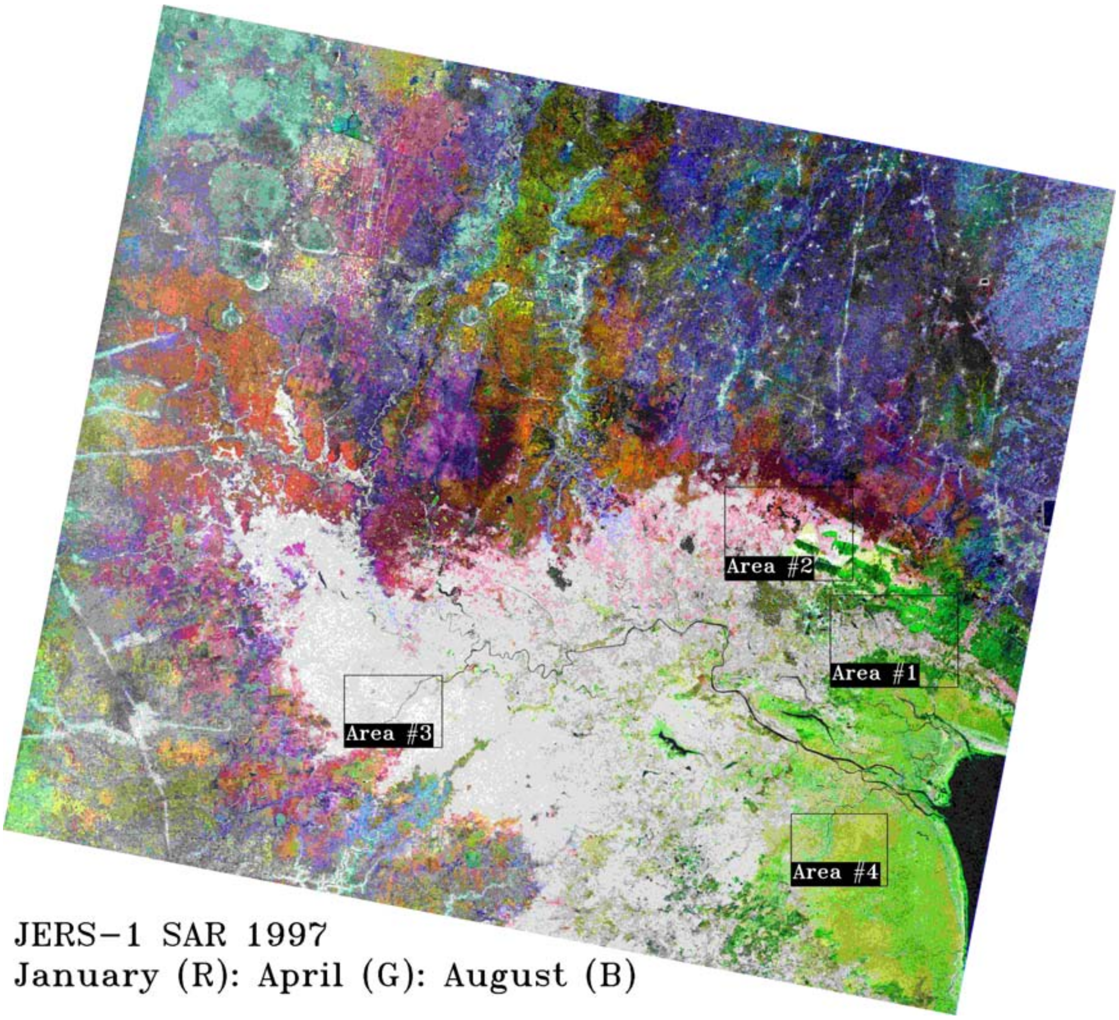


Fig. 3: Colour composite JERS-1 image for January, April and August (as RGB), showing location of sub-areas 1 to 4.

A number of observations can be made about the patterns recognisable within the flooded forest-wetland zone of the TSGL in this composite image. They include:

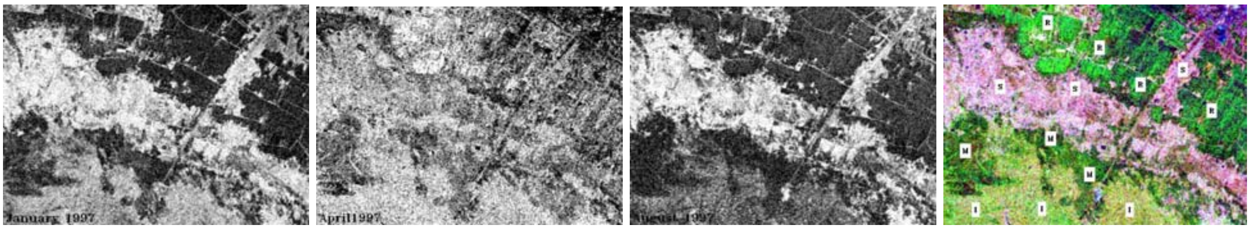
- the extent and boundary of the forest-wetlands region is clearly defined;
- the bright areas mark the location of forest and woodlands with or without an enhanced response due to the presence of water under trees;
- red hues on the northern side of Steng Sangher suggest the northern areas are flooded for longer periods into the dry season than the south. This is on the assumption that a higher backscatter in January than April is the result of flooding beneath tree cover;
- uniform bright areas indicate little change in backscatter from one date to the next;
- green areas within the forested zone and away from the wetlands on the margins of the lake represent areas still flooded in April. Together with the wetlands and areas of open standing water, they appear to mark the approximate boundary between permanent and seasonally flooded landscapes;
- areas of cyan and blue along the main rivers and adjacent tributaries show forests inundated as a result of floodwaters entering the system from the north and north-west in August as the result of rainfall;
- permanent areas of open water are black and clearly identifiable;
- yellow-coloured areas near the mouth of the rivers flowing into the TSGL are the result of higher backscattering in both January and April than August and suggest the presence of some taller trees or trees with a more dense canopy than exists to the south east. With falling water levels exposed trunks or canopies will result in higher backscattering;
- the irregular shaped black areas in the wetlands south-west of Siem Reap are areas of standing water covered with varying densities of macrophytes and appear to represent areas where wetland trees have been cleared;
- a semi-circular shaped band of uncleared shrubland separates the recessional rice fields from the flooded wetlands on the northern side of the TSGL (see Figures 4 and 5 below); and
- clearings in the shrublands for individual rice-fields on the edge of the floodplain are discernible in the composite image.

Apart from the forest-wetlands, regional patterns can also be interpreted from the composite image. The **red-orange** areas show the extent of agricultural activity that was occurring around January but was completed by April. The **magenta** colours suggest more moist surfaces (but not flooded) in January and August. **Blue** colours depict areas with higher backscatter in August that in either January or April and are found mostly on the higher ground outside the floodplain.

4. Sub-area case studies

The following examples are included to show the versatility of using a multi-date satellite derived dataset.

Figure 4 shows a sub-set of the radar images for January, April and August 1997 together with a colour composite image of Sub-area 1. Four cover classes have been identified and include macrophytes (M), inundated forest (I), shrublands (S) and recession rice-fields (R). A time series spectral plot of the changes in backscatter for these cover types in January, April and August is included which indicates that the four cover classes can be detected and separated in each image and have distinct spectral curves when viewed over time.

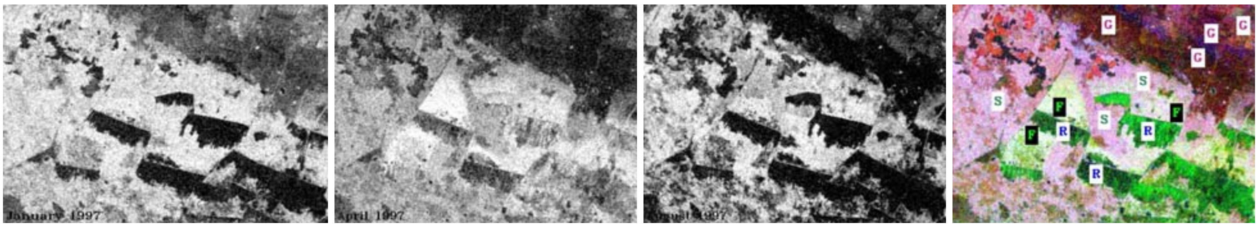


January April August

Fig. 4: Sub-area 1, grey-tone images for January, April and August 1997, and 3-date colour composite (as RGB)

What is evident in the composite image is the clear boundary between the recession rice-fields and the permanently flooded macrophytes and forest which is marked by an arc of uncleared shrubland.

Figure 5 shows the radar images of Sub-area 2 for January, April and August along with time-series spectra backscatter curves for four cover types in an area of shrubland west of Siem Reap that in 1997 was undergoing clearing and conversion to individual rice fields. Later images show this region has been transformed into much



January April August

Fig. 5: Sub-area 2, grey-tone images for January, April and August 1997, and 3-date colour composite (as RGB)

larger and consolidated field patterns for recessional rice growing. Under this practice water is stored upslope behind bunds in areas of uncleared shrubland and then gravity fed into the long rectangular-shaped fields, downslope of the bunds as required. Brightness changes depict different water levels below the shrublands. This is a further demonstration that with multi-date imagery it is possible to separate out land cover types and monitor changes in land use practices.

5. Conclusions

While the interpretations presented above may be regarded as subjective, they are in fact based on microwave theory that stems from the known backscattering characteristics of different surface materials and from the employment of a calibrated radar system in which the radiometric and geometric characteristics are known to be constant between acquisition dates. They are also consistent with the broad climatic-hydrological changes that are known to exist and with land practices documented for the region.

The study clearly demonstrates the high information content that can be obtained from L-band satellite coverage while at the same time showing that adequate characterisation and description of the ecological conditions or the production of an accurate land cover map cannot be obtained from single-date imagery.

In this high change environment, seasonal differences preclude the production of a satisfactory land cover map from a single date image. The highly complex and changing ecological conditions exhibited mean that any baseline mapping must take into account seasonal change.

The information obtained in a time-series imagery such as presented here shows the potential for using L-band radar to discriminate between different surface types and landscape components and to provide information for bio-physical process analysis.

The information obtained in time-series analysis of JERS-1 and hopefully its successor ALOS-PALSAR (due for launch in September 2005), shows the potential for using L-band radar to discriminate between different surface types and landscape components and to provide information for bio-physical process studies in wetland environments.

Acknowledgements

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