Assessing forest change associated with sediment modifications for large tropical estuaries using ALOS PALSAR data

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Abstract
It is believed that recent hydrological modifications of various large rivers of the tropics may be impacting estuarine vegetation, namely mangrove forests. In this study we outline the proposed objectives of our ALOS project with the intent to eventually model long term in situ hydrological records with dynamic changes in these forested wetlands as observed using ALOS data. In this paper we focus on one of the four selected study sites, the Teacapán-Agua Brava-Las Haciendas estuarine-mangrove complex. Specifically we explore the current controversy regarding the use of optical satellite data to monitor the mangroves of this system and we discuss the more recent attempts to employ older space-borne SAR data for mangrove mapping and for biophysical parameter estimation. Finally, we discuss the potential advantages of ALOS data for accurate monitoring of mangrove forest change associated with recent hydrologic modifications of large rivers of the tropics.

Keywords: ALOS, large rivers, tropics, mangroves, hydrologic change, reservoirs, monitoring.

1. INTRODUCTION

Water and sediment discharge from large rivers of the tropics have been changing dramatically due to human and climate induced changes within the river basins. One particular concern is the reduction of sediments to estuaries resulting from upland hydrologic diversion projects such as small impoundments and reservoirs. In our proposal we wish to utilize ALOS data in conjunction with field data to model impacts on estuary vegetation, specifically mangroves. We aim to develop relationships between the health of the mangroves and water and sediment discharge changes. This investigation involves three objectives; (1) to assess whether ALOS PALSAR data can be used to monitor the health for these coastal forests by applying various classification procedures including the use of polarimetric decomposition techniques (2) to examine the relationships between the various backscattering coefficients (HH, HV, VV), the co- and cross-polarization ratios and the co-polarized channel phase difference with various biophysical parameters of these forests (e.g. stem density, LAI) (3) to incorporate these data with hydrological data in modeling experiments so as to predict rates of degradation resulting from projected sediment fluxes. Data are currently being examined from four large estuaries, two in Asia and two in the Americas. Using one of the proposed study sites, the Teacapán-Agua Brava-Las Haciendas estuarine-mangrove complex, the goal of this paper is to provide a brief overview of the controversy regarding the use of various sources of satellite data for monitoring mangrove change, to discuss previous attempts using older SAR platforms, and to briefly discuss the potential benefits from the application of ALOS data with long term in situ data
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2. STUDY AREA

The Teacapán-Agua Brava-Las Haciendas estuarine-mangrove complex is considered one of the largest estuarine mangrove forests on the Pacific coast of the Americas (Fig. 1). The black mangrove (*Avicennia germinans*) and the white mangrove (*Laguncularia racemosa*) dominate in the north and south section of the system, respectively. Large red mangrove (*Rhizophora mangle*) can be found along the edges of the lagoons and estuaries and, in the south section, can form homogeneous islands. Recent studies [1] [2] [3] employing optical satellite imagery report that this system has experienced considerable degradation. As a result, various conditions of mangrove can be found including healthy tall mangrove, healthy mangrove, poor condition mangrove and dead stands (Fig. 2b). It has been suggested by both scientists and local inhabitants [4] that hydrologic changes, elevated salinity levels in particular, have resulted in the observed condition of the mangroves. Specifically, the construction of the Cuautla canal, opened in 1971, is considered one of the major culprits.

3. CURRENT SATELLITE MONITORING APPROACHES

3.1. Optical sensors

Reference [1] employed a time series of Landsat TM data,

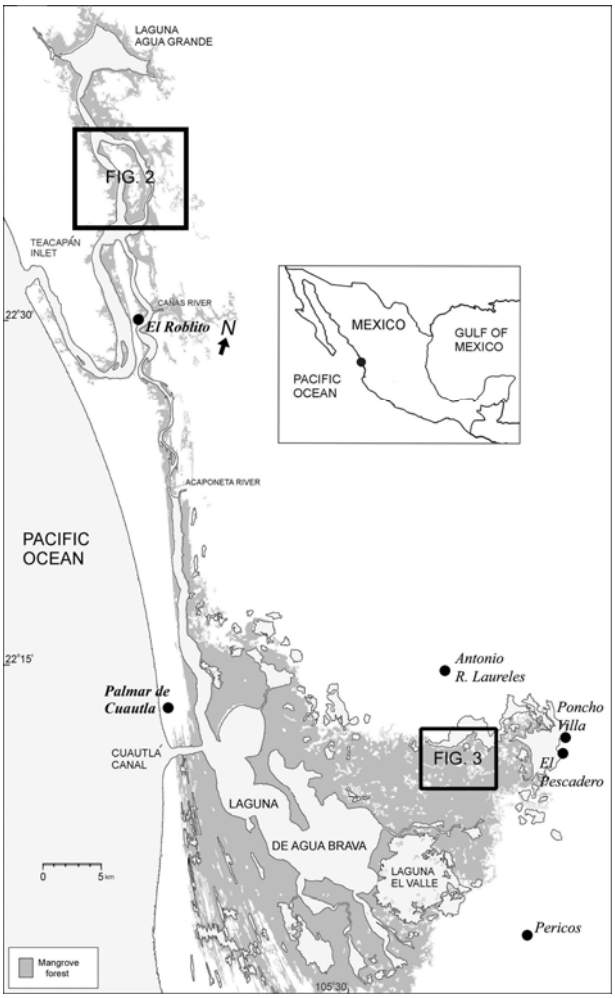

Figure 1. The Teacapán-Agua Brava-Las Haciendas estuarine-mangrove complex of the Mexican Pacific.

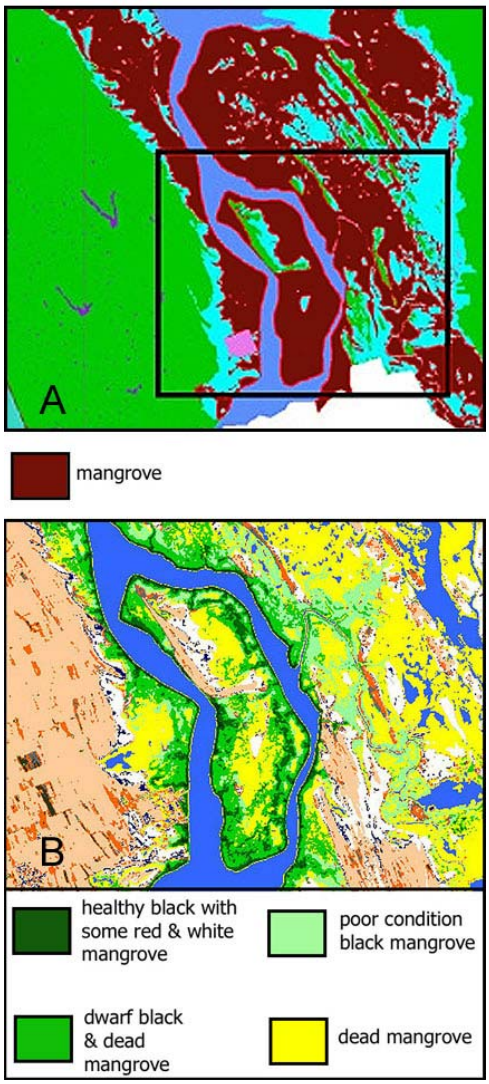

Figure 2. Comparison of Landsat ETM mangrove classifications employed by (A) reference [6] (modified from DUMAC, 2005) and by (B) reference [7] for Isla la Palma, Sinaloa, Mexico.

1986-1999, to map the extent of mangrove degradation occurring in the study area. The classification of the mangroves did include the four conditions previously mentioned. References [2] and [3] used higher resolution IKONOS data to map the extent of Leaf Area Index values estimated for a small region within this system, namely east of the Agua Brava Lagoon. Although these aforementioned reports all indicated a degraded state, recent studies [5] [6], using newer Landsat ETM data, for the northern section, reported that the extent of mangrove was increasing. These studies did not consider the condition of the mangroves, employing only one mangrove class. Reference [7] reclassified the mangroves of the system using a more recent 2005 Landsat ETM data and the mangrove classification that considered the four conditions present. It is apparent from Fig. 2 that the state of the mangrove differs given the two different mangrove classification approaches (i.e. one versus four mangrove classification). Reference [7] did report an overall classification accuracy of only 63% for the mangroves with the majority of error resulting from misclassifications amongst the dead mangrove, the shallow water and the saltpan classes.

3.2. SAR sensors

In addition to the optical data, reference [7] also examined the use of Envisat ASAR data to map the mangroves. Specifically, four scenes of dual-polarized data at two incidence angles were analyzed individually and in combination. The highest achieved overall accuracy with the C-band data was 45%. Unlike the optical data, the dead mangroves were easily distinguished from the saltpans and the shallow water. The majority of confusion occurred amongst the two healthy mangrove classes (short and tall) which were also often misclassified with the palm forest class, the other terrestrial forest class and the agricultural class.

In addition to qualitative mapping of the mangrove forests, two studies [8] [9] have also examined the relationship of C-band space-borne SAR backscatter, both Envisat ASAR and RadarSat-1 fine beam mode, with

mangrove forest biophysical parameter data including Leaf Area Index (LAI), mean height, mean DBH, basal area and stem density. Specifically, these studies have focused on the monitoring of the white mangrove (*L.racemosa*) which is the species of mangrove most impacted by the changes and also the species most depended upon by the local inhabitants [10]. With the coarser spatial resolution Envisat ASAR data, significant relationships were only found between backscatter and LAI and mean height using the cross-polarized data [8]. It is believed that the inability of the co-polarized data to differentiate between the healthy mangrove stands and the dead mangrove stands (LAI = 0) is the result of equally high backscatter resulting from scattering from crown volume and trunk-ground double bounce, respectively (Fig. 3). However, reference [9] did show that with a higher spatial resolution C-band sensor, RadarSat-1 fine beam, a significant relationship between co-polarized backscatter and LAI could be observed but at a lower level of accuracy.

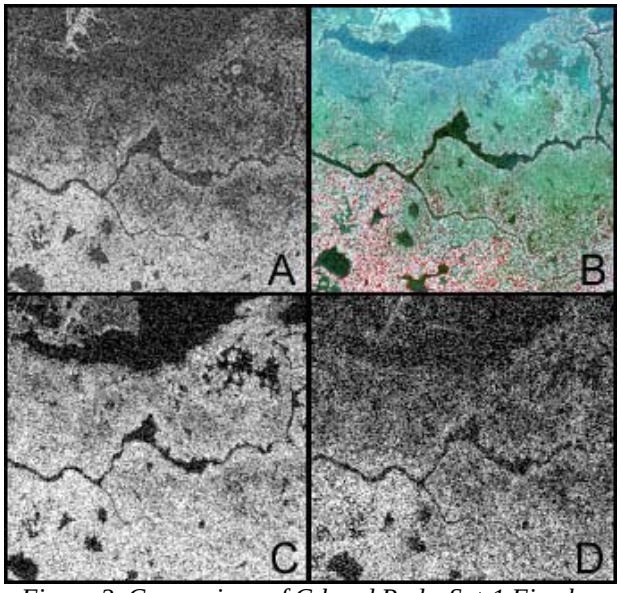

Figure 3. Comparison of C-band RadarSat-1 Fine beam (A), C-band Envisat ASAR co-pol hh (C), Envisat ASAR cross-pol hv (D) backscatter and an (B) enhanced IKONOS false color composite (4, 3, 2) for a degraded section of Laguncularia racemosa mangrove within the Teacapán-Agua Brava-Las Haciendas estuarine-mangrove complex. Note the expanse of dead mangrove at the top of each scene.

4. DISCUSSION & ANTICIPATED RESULTS

Given the aforementioned studies on the Teacapán-Agua Brava-Las Haciendas estuarine-mangrove complex, which are often conflicting, it is apparent that this system requires an accurate method for monitoring the condition of the mangroves in response to continued hydrologic modifications. With regards to qualitative mapping, if polarimetric data are available, we believe that the classification of the polarimetric data using decompositions of the scattering matrix would be the ideal for mapping the extent of degradation occurring in these forests. Specifically, we expect that each condition of the mangroves (e.g. dead, poor condition) would reflect unique scattering mechanisms thus allowing an accurate classification of such forests. However, it is also anticipated that the dual-polarized data, used in conjunction with AVNIR-2 data, can improve classification procedures. Given the longer wavelength in comparison to C-band, which saturates early, we believe ALOS will better manage the separation of the healthier vegetation including terrestrial forests. As for mangrove biophysical parameter estimation, we anticipate some significant coefficients of determination between these data and polarizations, the cross-polarization ratio and co-polarized phase difference. For dual-polarization data only, we also believe the cross-polarized data by itself could be useful for predicting, in particular, LAI for highly variable mangrove forests that have been degraded. We anticipate that the health of mangroves has been deteriorating in all of the three other study areas proposed and in some cases the extent of mangrove cover has been shrinking as a result of dramatic or sudden sediment decline due to, say, reservoir construction. We aim to develop relations between the condition of the mangroves (e.g. healthy, poor, dead) and disturbances of large river drainage systems in term of water and sediment discharge changes. It is also anticipated that we could use the relations to predict future trajectory of the mangroves as affected by the projected water and sediment changes.

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