NASA, Remote Sensing and Archaeology: An example from Southeast Louisiana

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NASA Stennis Space Center, located in Mississippi, USA, undertook an archaeological survey of the southeastern Louisiana marshes beginning in 2003. Progress on this activity was severely hampered by the 2005 hurricane season when both Katrina and Rita devastated the study area. In 2008, the NASA team reinitiated the analysis of the project data and that work continues today.

The project was conducted initially in partnership with the U.S. Army, Corps of Engineers New Orleans District and Tulane University. NASA and its partners utilized a wide variety of satellite and airborne remote sensing instruments combined with field verification surveys to identify prehistoric archeological sites in the Southeastern Louisiana delta, both known and still undiscovered. The main approach was to carefully map known sites and use the spectral characteristics of these sites to locate high probability targets elsewhere in the region.

The archaeological activities were conducted in support of Coast 2050 whose stated goals is to sustain and restore a coastal ecosystem that supports and protects the environment, economy and culture of southern Louisiana[1]. As the Coast 2050 report states: "[T]he rate of coastal land loss in Louisiana has reached catastrophic proportions. Within the last 50 years, land loss rates have exceeded 40 square miles per year, and in the 1990's the rate has been estimated to be between 25 and 35 square miles each year. This loss represents 80% of the coastal wetland loss in the entire continental United States."[2] (Figure 1).

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[1] Louisiana Coastal Wetlands Conservation and Restoration Task Force and the WetlandsConservation and Restoration Authority. 1998. Coast 2050: Toward a Sustainable Coastal Louisiana. Louisiana Department of Natural Resources. Baton Rouge, La.
[2] Ibid: 1

Figure 1: Historic cemetery once on land now in open water due to wetland loss.

Among the irreparable damage caused by the loss of wetlands, is the destruction of archaeological sites. This region of Louisiana is formed by ancient and modern deposits of the Mississippi River. Anthropogenic activities like oil production and levee construction aggravate the loss of land caused by natural processes like subsidence.

The region is very difficult to survey using traditional archaeological survey methods due to the presence of numerous waterways, swamps, marshes, and wetlands. The study area includes the Louisiana parishes of Jefferson, LaFourche, Plaquemine and St. Charles. This region has been occupied more or less continuously since about 400 B.C.E.

NASA collected the site files for known archaeological sites located in the four parishes from the Louisiana State Historic Preservation Office. Remote sensing data over 111 known sites were gathered through airborne and orbital missions. A total of sixty-six known prehistoric and historic sites were visited during the field survey. Each of these sites was mapped with differential GPS, taking specific care to create a vector file that best represented the spatial extent of each site. Accurate GPS vectors were needed to derive spectral characteristics of vegetation commonly found at archeological sites and of the shell deposits which are also common constituents of sites in this region. Archaeologists have long been aware that sites in the lowermost Mississippi River delta

are normally associated with specific types of vegetation, specifically live oaks[3] (Figure 2). Using known sites as training sets, we conducted supervised classifications of the entire four parish region to identify high probability targets that based on vegetation and the presence of shell deposits would likely be undiscovered archaeological sites. The process leads to spatial modeling (specifically inductive modeling) where known archaeological sites are used in creating a model to determine the relationships to environmental properties[4].

Figure 2: Typical ground view of archaeological sites in the Louisiana wetlands. The live oak clusters indicate location of prehistoric mounds.

Several types of remotely sensed imagery were used in this project. Landsat TM was employed to develop large scale regional maps identifying landforms where archaeological sites were normally located, these being mostly active and abandoned levees and channels. The geo-referenced TM images also served as the main planning and navigation tools for the field verification surveys.

In addition, NASA Stennis flew its Airborne Terrestrial Applications Sensor (ATLAS) on-board a NASA LearJet (ATLAS Mission 302). This multispectral instrument collected data in 12 channels ranging from 0.45 to 12.2 microns at a GSD of 2.5 m. To improve on the spectral resolution of the ATLAS, NASA employed the services of the Institute for Technology Development (ITD), a Mississippi State organization located at the Stennis Space Center. ITD developed and deployed the Real-time Data Acquisition Camera System (RDACS-3) a 120 band hyperspectral airborne system which collected data at 2m spatial resolution. The RDACS is not a true hyperspectral sensor, but it features some of the advantages of hyperspectral instruments. The RDACS system is an array of three digital cameras mounted underneath a

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[3] Neuman 1976; Neuman and Byrd 1980
[4] Braland, Malinda (2007) *GIS Predictive Model for Locating Archaeology Sites in South Louisiana.* Master Thesis, University of Southern Mississippi.

singleengine airplane. Each camera is fitted with a filter that determines the wavelength sensitivity of the camera. In other words, the wavelength and width of the three bands may be chosen for each flight, based on the needs of each mission. During this project, NASA requested data collection in 10 nm wide bands within the green, red and near-IR wavelengths. These regions of the EM were deemed *a priori* to be the most diagnostic for identifying vegetation and shell deposits. In addition, IKONOS imagery was purchased over the project area and together with the ATLAS data provided the most useful information for identifying high probability locations.

Two other sensors were initially targeted for delivering data. These included NASA's AVIRIS (Airborne Visible InfraRed Imaging Spectrometer) a hyperspectral airborne instrument that delivers calibrated images of the upwelling spectral radiance in 224 contiguous spectral channels. Although the data was excellent, mission restrictions prevented statistically significant coverage of the region. The AVIRIS data therefore, was only incorporated over those few localities where it was already available in the archives.

While hyperspectral data proved more useful in deconvoluting the spectral signals (pixel unmixing) associated with the vegetation communities that characterized archaeological sites, the spectral response curves for shell middens were clearly identifiable in multispectral ATLAS and IKONOS data. In fact, the live oaks which are the most diagnostic plant on archaeological sites were also clearly identifiable spectrally in multispectral data. Consequently, due to the greater ease associated with storing, manipulating and processing multispectral data, these type data were preferred throughout the project.

Sixty-nine known sites were relocated in the field. Remotely sensed data from these sites confirmed (and quantified) what was generally already known: all sites were being rapidly destroyed by the loss of wetlands. Channel construction, salt water intrusion and natural subsidence are taking a heavy toll on these cultural resources.

In addition, analysis of specified spectral response curves identified 23 high probability localities ten of which were visited by the field crews before the hurricanes ended the in situ verification process. Of these ten, six turned out to be new archaeological sites.

Two additional important discoveries were made through the use of remote sensing. First it was determined that mound sites from the Plaquemine period (~A.D. 1000-1500) were originally arranged in specific patterns namely in groups of four mounds equally spaced and oriented along the four cardinal directions. Due to subsidence, several of the mounds in these patterns were no longer visible in the field but retained a characteristic signal in the remotely sensed data. This is most evident at the Buras Mound site and at the Bayou Robinson Mound site, both in Plaquemines Parish (Figure 3 and Figure 4).
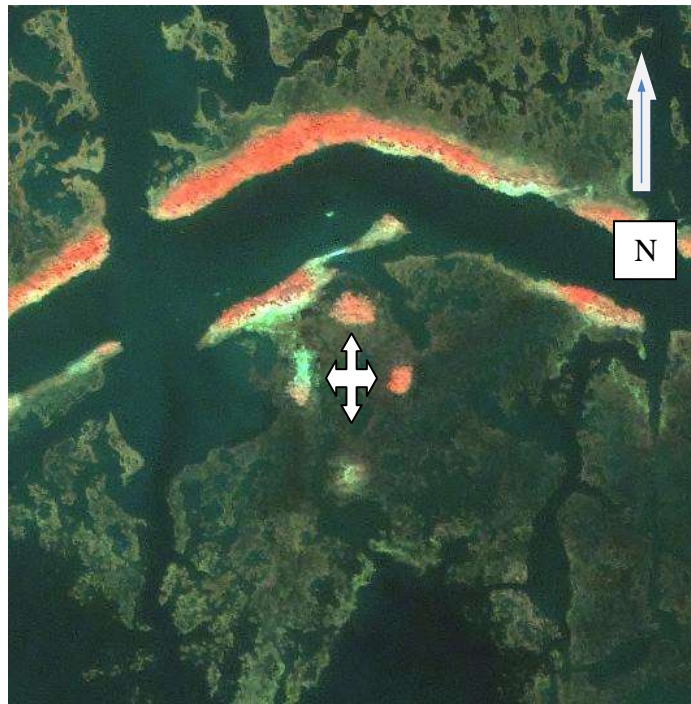

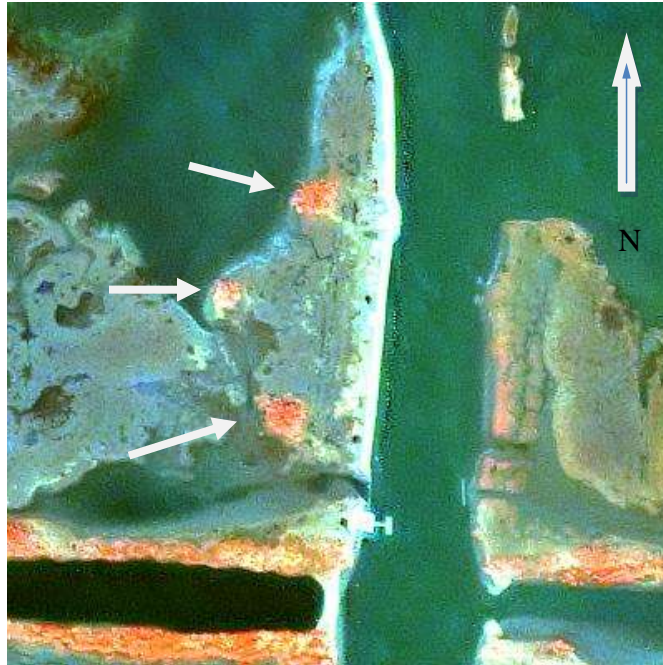Figure 3 IKONOS Buras Mounds; arrows point to mounds oriented along cardinal directions

Figure 4: IKONOS Image, Bayou Robinson, RGB; arrows indicate mounds; eastern mound destroyed by dredging but evidence still present along the shell beach in the form of artifacts and charcoal

The other interesting discovery derived from the analysis of the remotely sensed images was a previously unknown "causeway" leading from Bayou Grand Cheniere to a 12 mound complex known as the Bayou Grand Cheniere site (16PL159). This site consists of 11 mounds grouped together to form a circle and a 12th mound located southeast of the main group. One conical mound in the group is approximately 60 feet (18.3 meters). All twelve mounds are covered by live oaks (*Quercus virginiana*) and yaupon holly (*Ilex vomitoria*) (Figure 5). The site was first explored in 1926 by Henry Collins[5] but had remained unvisited and unexplored until the early 21st century. Remotely sensed data from the RDACS system was used to accurately map the site and to identify the vegetation through spectral analysis. While conducting this latter analysis, we noted a linear feature extending from the site to the bayou (Figure 6). Repeated field surveys failed to identify it on the ground, even after it was noted on the imagery. In the imagery,

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[5] Collins, Henry B. 1927 Archaeological and anthropometrical work in Mississippi. Explorations and Fieldwork of the Smithsonian Institution, 1926. Smithsonian Miscellaneous Collection volume 78.

however, the feature is clearly visible and represents the first evidence of a prehistoric "causeway" in this region.
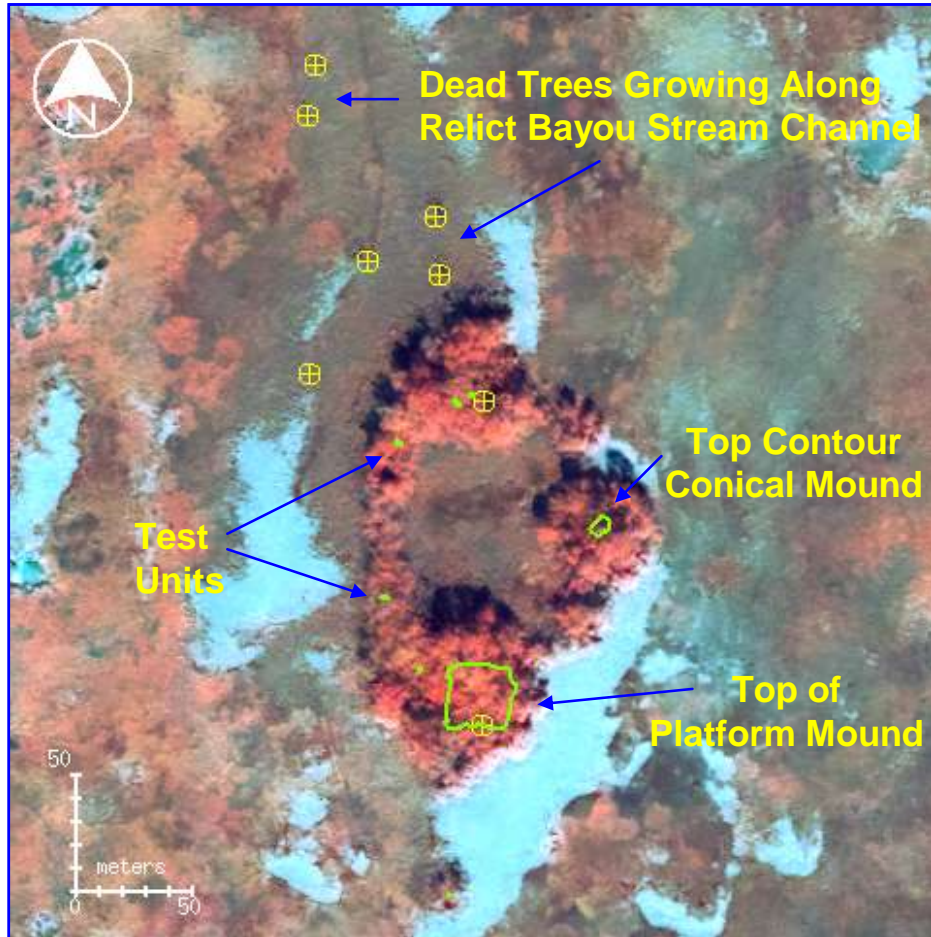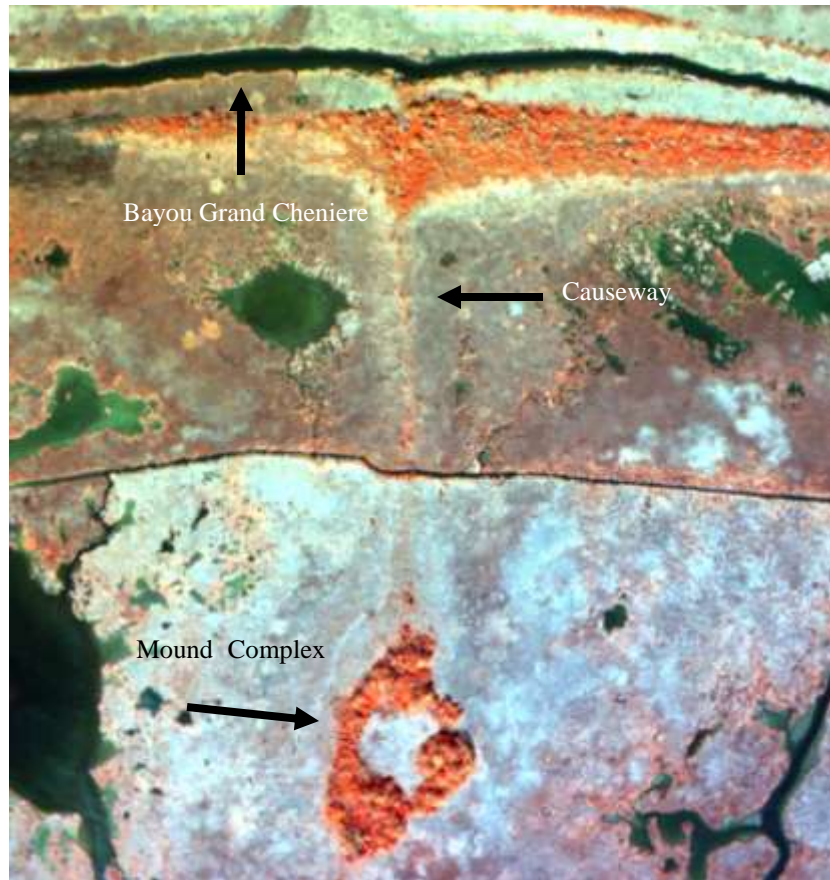

Figure 5: RDAC imagery showing GPS vectors

Figure 6: Bayou Grand Cheniere Site showing 'causeway", Bayou Grand Cheniere and the 12 mound complex; RDAC image, G,R,NIR

Analysis of the data continues today. Funding for further field work is not available at this time but NASA scientists continue to analyze the remotely sensed data and making it available to universities in the hope that more validation of the predictive model derived from this project will occur in the near future.