LIDAR DETECTION OF BELOW-CANOPY CAVE OPENINGS IN THE ANCIENT MAYA KARSTIC LANDSCAPE AROUND CARACOL, BELIZE

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1. INTRODUCTION

The geology of the Yucatán Peninsula consists of a porous limestone shelf that is honeycombed with sinkholes, cenotes, underground streams, lakes, and caverns. It is thought that caves played a significant role in ancient Maya culture [1,2] ca. 2500 BC to 1500 AD. As portals to the Maya underworld, *Xibalbá*, caves served as sacred places of religious and mythological importance in addition to functioning as shelter. They were sites of rituals, ceremonies, burials, and hence often contain ceramics, artwork, architectural modifications, and skeletal remains. However, like many of the monuments found in the Maya polities, cave entrances are often obscured by the dense tropical rainforest vegetation that grew on top of the archaeological features after the sites were abandoned roughly a thousand years ago.

As part of a NASA-funded archaeological prospecting study to use airborne LiDAR to map unknown Maya structures, e.g., temples, causeways, monuments, in a 200 km^2 area around Caracol, Belize, we also identified and measured the dimensions of numerous, vertical surface openings, e.g., cockpits (vertical shafts), collapse dolines (open sinkholes), and chultuns (subterranean storage chambers) in the digital elevation model (DEM). In this presentation, we report our approach and findings.

2. METHODS

2.1 Study Area

Estimated at 170 km^2, Caracol is the largest Maya archaeological site in Belize. Located near the Guatemala border on the Vaca Plateau of the Cayo District (Fig. 1) west of the Maya Mountains, the Caracol landscape consists of rolling karst-defined hills and valleys ranging from ~300 to ~700 m in elevation. At its cultural peak (ca. AD 750), the metropolitan population is estimated to be ~150,000 which makes it one of the most populous cities in the Pre-Columbian world [3]. Since 1950, 23 km^2 have been painstakingly surveyed on the ground.

Fig. 1. Caracol study area in west-central Belize on the Yucatán Peninsula.

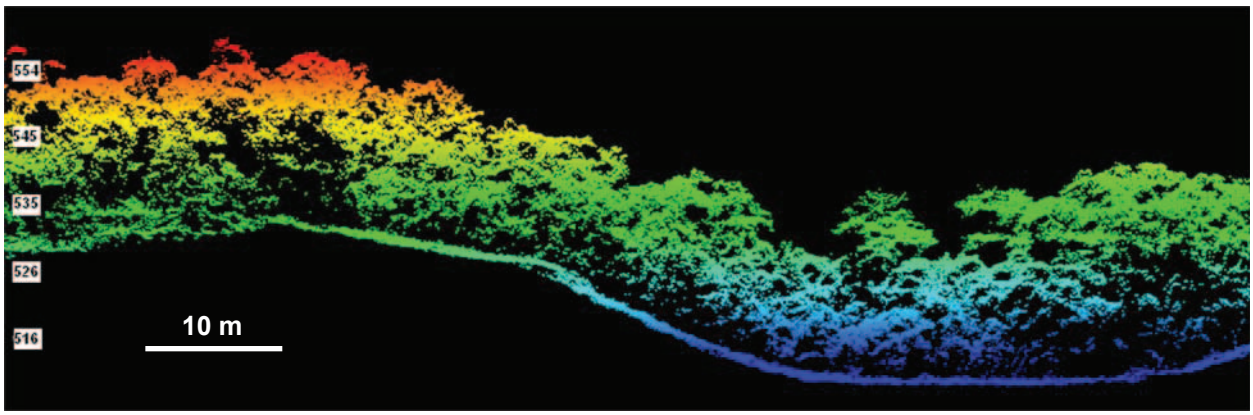

Fig. 2. LiDAR point cloud data profile showing the tropical rainforest canopy and underlying topography. Elevations are in meters above sea level.

2.2 Data Acquisition

The NSF-sponsored National Center for Airbone Laser Mapping (NCALM) LiDAR sensor (an Optech GEMINI ALTM) was flown over western Belize in April 2009. This was done at the end of the dry season when deciduous trees in the lowland/submontane broad-leaved forests had dropped their leaves thereby enhancing laser penetration. Flying a series of north-south and east-west transects, spaced ~260 m apart, 800 m above the ground, the twin-engine Cessna Skymaster covered a 200 km^2 area surrounding the Caracol epicenter. Though ~20 laser pulses/m^2 were fired, only 1.35 points/m^2 on average passed through the 25-30 m tall canopy to the ground surface and were received by the sensor (Fig. 2). From these ground returns, a 1-m horizontal resolution DEM was generated with a vertical accuracy of 5-30 cm.

2.3 Data Processing

We visually surveyed a hillshaded version of the DEM and applied a pit detection algorithm to the original DEM to identify vertical openings below the ground surface. The algorithm determined the elevation range in a 9 m x 9 m window around the focal raster. Depressions, ≥10 m in each 81 m^2 block, were denoted.

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3. RESULTS AND DISCUSSION

There has been an ongoing effort to apply thermal remote sensing to locate caves in west-central Belize using LANDSAT Thematic Mapper [4]. But given the somewhat coarse resolution (30 m) with respect to most cave openings and the existing problem of obfuscation by the canopy, it seems that this may not be a fruitful avenue. LiDAR has been used to survey depressions in karst terrain to identify potential sinkholes [5] and render below-canopy topography, but as far as we know, this may the first use of it to identify cave openings.

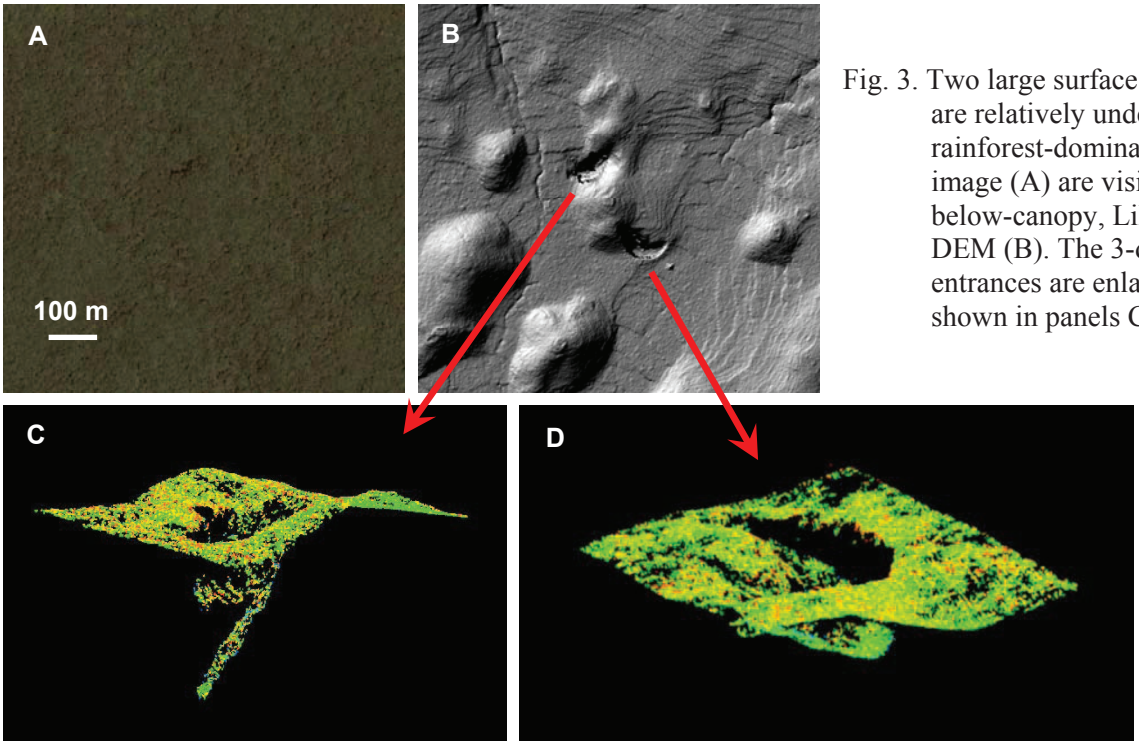

Fig. 3. Two large surface openings that are relatively undetectable in the rainforest-dominated IKONOS image (A) are visible in the below-canopy, LiDAR-derived DEM (B). The 3-dimensional entrances are enlarged and shown in panels C and D.

In the 200 km^2 area, from the visual assessment and block statistics, 131 potential cave openings and 99 depressions ≥10 m were identified, respectively. Of these, 60 were coincident. Several of these will be verified during the Spring 2010 field season. Entrances range from several to >50 m wide with vertical shafts more than 75 m deep (Fig. 3). In the vicinity of Caracol, a couple dozen caves and chultuns have been previously located and explored yielding a wealth of Maya archaeological data [6,7]. Some of these known sites correspond to openings that we identified using these techniques. Others with smaller or horizontal openings were undetected. However, most of the entrances found in this study have not been previously documented and will require speleological/geological/archaeological reconnaissance to assess if they were open at the time of the Maya occupation and if so, in what capacity were the caves used.

4. ACKNOWLEDGMENTS

This research was funded by NASA Space Archaeology Grant #NNX08AM11G and through the University of Central Florida - University of Florida Space Research Initiative. We appreciate the encouragement of Holley Moyes and Jaime Awe and the expertise of the NCALM group, Ramesh Shrestha, Clint Slatton, Bill Carter, and Michael Sartori, which made this research possible.

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