Geospatial landform mapping using HRTdems integrated into a virtual globe, M.E. Davias, Cintos Research, 1381 Hope St, Stamford, CT 06907, michael@cintos.org

Introduction: While not an issue on other terrestrial surfaces, Earth's biotic cover can easily obfuscate the presence of enigmatic landforms. LiDAR-generated high-resolution topographic digital elevation models (HRTdems) reveal the true geological terrain. A protocol is introduced which uses Global Mapper GIS (GM) and Google Earth (GE) virtual globe to enumerate a collection of landforms and document their spatial measurements and distribution. An extensive seamless false-color elevation model has been assembled and integrated into Google Earth for display, superimposed as image overlays in place of satellite imagery. Google Earth design elements such as placemarks and image overlays are leveraged for indexing and measuring landforms subjectively matching an archetype planform template. Metadata from those features are extracted as text and processed to populate a geospatial database. The protocol may be useful on other planetary virtual globes that use keyhole markup language (kml).

Rationale: The Carolina bays of North America (Cbays) are recognized in remote sensing as oriented ovoid basins since the 1930s. A series of research explorations of Cbays during the 1970's led to a finding that the bays were formed during the *deposition* of the allochthonous sediments they are expressed within [1]. Mechanism for deposition available in that era (marine, estuarian, fluvial, glacial and eolian) provided ambiguous solutions, as each had significant contradictions. The sediments hosting the Cbays are nonfossiliferous and rest upon well-dated marine terraces, yet today are only constrained as "post-Miocene", being older than ^{14}C or OSL can resolve.

To better understand Cbay geomorphology, a comprehensive survey was undertaken to elucidate Cbay spatial distributions, sizes, planforms, and orientations, employing innovative 21st century technology [2].

Methods: GE's virtual globe is leveraged for identifying and measuring Cbays using HRTdems retrieved from purpose-built cloud services.

HRTdems are assembled from LiDAR point-clouds into USGS 1ºx1º quadrant seamless bare-earth elevation models using GIS tools. Elevation values are boosted 20x to enhance hill shading and encoded using a 10m-range cyclic color ramp. The resulting imagery helps elucidate the fine Cbay relief features on level terrain. The *HRTdems* are rendered at 1.5m spatial resolution into 16 discrete 15' quadrants indexed with the location's 3-digit modulo 15' offset northerly and 3-digit modulo 15' offset westerly as a 6-digit name.

Ovoid planform archetypes diverging from ellipses by subtle stylistic markers have been matched to Cbay planforms. The survey has identified six, each found applicable to a specific region of the spatial distribution. For use as a measurement graticule in GE, archetypes are rendered as a png files with transparent white space.

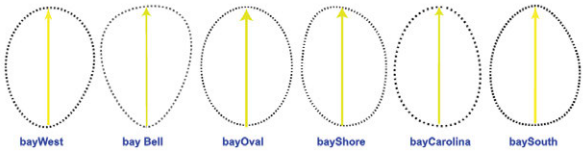


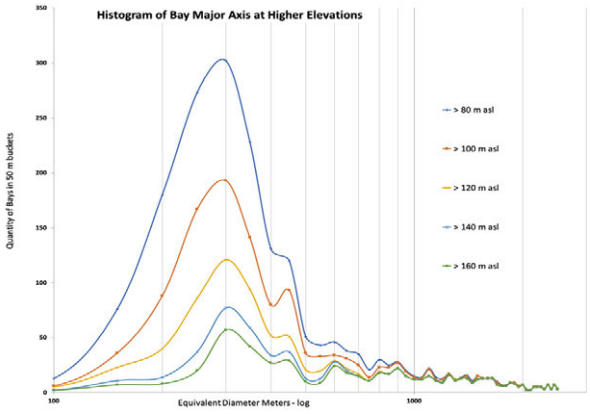
Image Overlays are GE elements used to visualize the archetypes, and are instantiated using an xml-like *kml* structure which incorporates the url of the image, the Cartesian values of the *bounding box* of the image as viewed "north up", and a *rotation* value of the image's placement on the virtual globe. To measure a Cbay, one of the 6 archetype templates is positioned in GE, and the editing mode *handles* are used to fine-tune the length, width and rotation to achieve a subjective best-fit match to the rim as expressed in the HRTdems. The overlay's kml is extracted from GE as a text file.

A Java Application processes the overlay kml to compute the Cbay's length (major axis), width (minor axis) and a location centroid using simple trig operating on the bounding box latitude/longitude values. It also generates the Cbay's clickable placemark that includes a pop-up displaying the metrics, and a TSV-formatted input string used to populate a database entry. Cbays measured within a 15' quad acquire a numeric index name based on its 15' quad, plus a 4-digit index for a format yyyxxx-zzzz, for 10,000 entities per 15' quad.

Regionalization and Network Links are implemented in GE to efficiently trigger the download of images and data from the cloud; as the viewer zooms in from a global view, increasingly detailed facets of the survey are visualized. Each 15' quad's HRTdem is built as a regionalized tile set using network links to deliver map imagery to GE at an optimum resolution for the user's current field-of-view. GE presentation of Cbays is triaged by major axis, and regionalized in the kml at the 15' quad level to trigger a network link for the largest 10%, then next largest 40%, and smallest 50% based on field-of-view, minimizing cpu and network resources, while allowing for geospatial searches of the top 10% of Cbays within wide field views. GE's visualization of the survey is invoked by loading a small kmz file [3], which accesses 250 Gb of data on a cloud-based server. Only a small percentage is retrieved for a given field-of-view, yielding a reactive screen with reasonable network load.

Database. Measured and derived metrics for Cbays are publicly accessible as a tab-separated text file [4]. Each record contains a plain-text kml-coded GE *folder* element containing a centroid placemark and the archetype image overlay element for that Cbay, which enables the results of ad-hock and automated queries to be displayed in context on the virtual globe.

Results: An example histogram using survey data advises that the size distributions of Cbays remain strikingly similar regardless of elevation above sea level, while Cbay count drops as elevation increases.



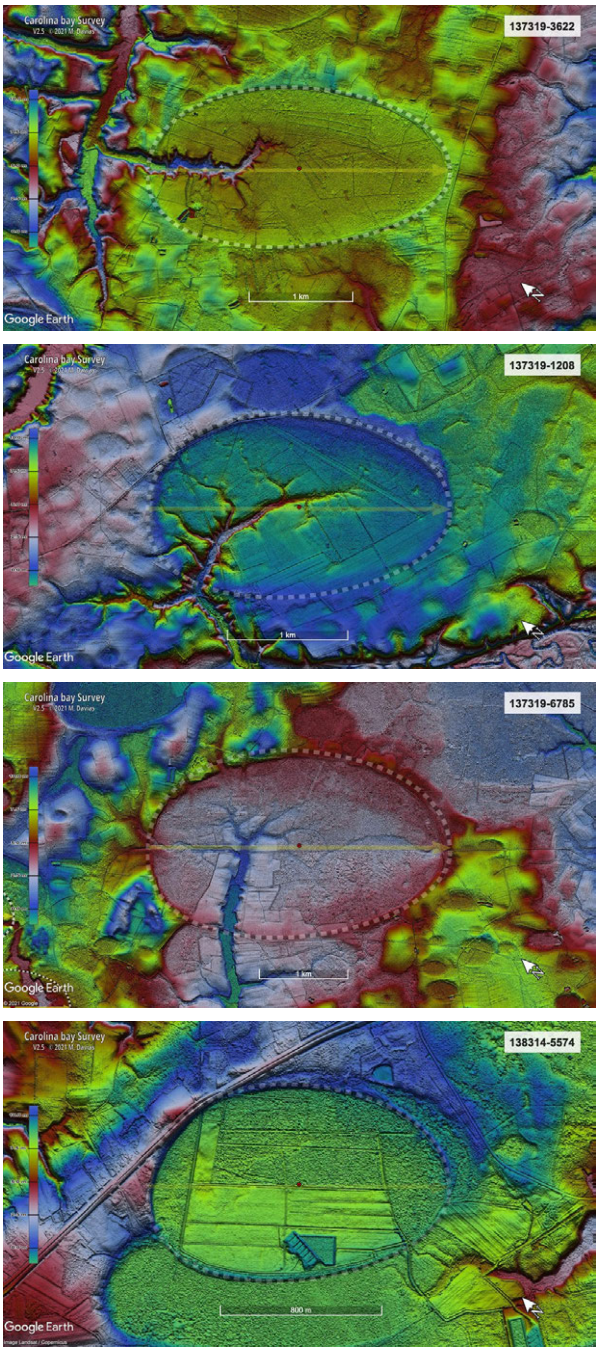
Cbays are the manifestations of hydraulically closed circumferential embankments, typically unremarkable to the unaided eye. HRTdems reveal that those arcuate embankments track precisely to ovoid archetypes across many kilometers, elucidating a robust correlation of the finely-scribed bay rim and the template, which varies only by scale and eccentricity. The persistent imprint may denote densified lithology in the rim asserts its topographical expression through differential erosion.

To facilitate viewing the rim's trace under the template (which often obfuscates the crisply-defined rim), the overlay can be toggled on & off or faded using the GE DOM controls. In addition, an interactive web-browser facility containing HRTdems of ~250 bays [5] allows the overlay to be manipulated using a "before-after" manual slider. Four example GE screen shots are provided on the right, featuring templated Cbays normalized for size and orientation. Double-clicking a Cbay's overlay in GE's DOM will orientate the display to this composition, optimized for a 16:9 aspect ratio.

Inspection of 55k Cbays suggests they are not wispy gradualistic basins, but rather are deeply imbedded into the landscape, and perhaps catastrophic in nature.

Future goals: Dating only the sporadic dusting of surficial eolian sediments atop Cbay rims may lead to erroneous formation dates. The allochthonous sediment deposition are better constrained with deep (10-20 m) corings of Cbay rims to gain $^{10}Be/^{26}Al$ burial dating at their contact with dateable subjacent fossiliferous units.

Normalized Carolina bay HRTdems: Maps are hyperlinked for interactive full-screen display in a common web browser, loading from cloud-based facility. Slider allows rolling template on and off [5].



References:

[1] Gamble, E., Daniels, R. and Wheeler, W. (1977) *Southeastern Geo, V18 no4* 199–212

[2] Davias, M.(2013), Carolina Bay Rim Taxonomy

[3] Google Earth survey: cintos.org/CbaySurveyKMZ

[4] Survey data: cintos.org/CbaySurveyTSV.zip

[5] Interactive website: planform.cintos.org