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Michael E. Davias

Jeanette L. Gilbride

LiDAR-Derived Digital Elevation Maps Of The Delmarva Peninsula And Southern New Jersey Used To Identify Carolina Bay Landforms

Their Planform Shape And Orientation Changes Systematically With Latitude

Acknowledgements
LiDAR data: USGS Seamless Server, College of William & Mary
LiDAR hsv-shaded Imagery: Global Mapper
Virtual Globe Visualization: Google Earth
Placemark Maps, Tables and Graphs: Google Fusion Tables
IDW Plot: ArcGIS, L. Davias

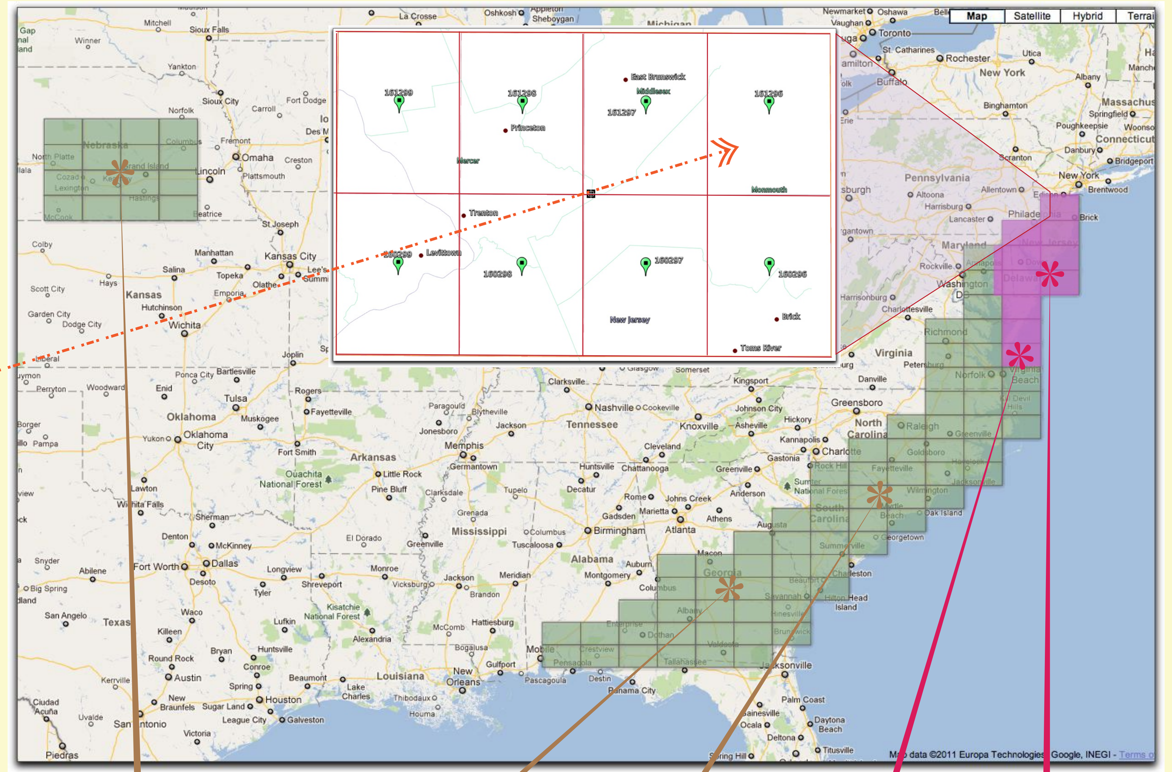
Abstract

The existence of Carolina bay landforms north of the Carolinas has been generally recognized for decades. Recent advances in digital elevation mapping using LiDAR (**Li**ght **D**etection **A**nd **R**anging) technology offer a new perspective on the location and shapes of these shallow basins and their enigmatic circumpheral rims. To support a geospatial survey of Carolina bay landforms within Virginia's Eastern Shore, Maryland, Delaware and New Jersey, we generated hsv-shaded DEMs (Digital Elevation Maps) as KML-JPEG tile sets for visualization. A majority of these DEMs were generated with LiDAR data, while a small subset used USGS 1/3 arc second data. A gentle progression of planform shape is seen on these maps as the viewer moves from south to north. We demonstrate that the planform of most bays identified suggests a very robust correlation to one of two archetypical shapes. These two shapes were engineered into Google Earth overlay elements, which were placed over candidate basins; by manually adjusting the length, width and rotation from North, the shape of the circumpheral bay rim can often be satisfactorily captured. The generic Carolina bay characteristics set includes a pervasive common orientation among neighboring bays. However, as we traverse the coastal plain towards the north, the bays' more-rounded presentation leaves this as a subjective assignment. Using LiDAR-derived imagery, we present our argument for the alignment suggestion that we imbedded in our archetype planform overlays. We demonstrate that when these archetype planforms are overlaid on the basins, their orientation varies systematically by latitude, in a gentle progression similar to that seen further south. The high fidelity LiDAR elevation maps also demonstrates the pervasiveness of the bay planforms against a backdrop of wind-driven sand sheets and parabolic dune formations across this landscape. All LiDAR maps referenced have been made available on the Internet to support independent research. Likewise, the geospatial database of metrics for 3,500 bays we examined in this region is available from an on-line Google Fusion Table:
`http://www.google.com/fusiontables/DataSource?snapid=S226571PxmB`

Spatial Reference System

The survey is being conducted within ~80 USGS 100K Quadrants shown below. Here, we examine the hsv-shaded LiDAR elevation maps encompassing the states of Virginia (Eastern Shore), Maryland, Delaware and New Jersey, shown in purple below, and detailed in the large map, center.

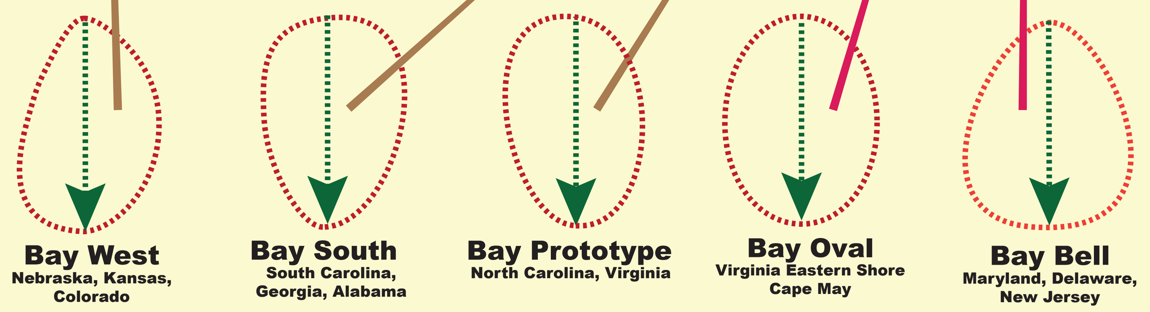
The task of organizing tens of thousands of LiDAR images, as well as the individual Carolina bay metrics and overlay images, required the instantiation of a spatial reference system to generate a convenient (i.e., human recognizable) naming system for unique file names. An arbitrary system was engineered, creating grid cells of 1/4º lat. x 1/4º lon. These represent a reasonable spatial area for our kml-tagged LiDAR overlay tile sets. A USGS 100K Quadrant contains 8 of these grid cells, so we self-name them "Octants". The given name for each Octant is a six-digit number, where the 1st 3 digits represent the count of Octants west of the Grand Meridian, and the 2nd 3 digits represent the count of Octants north of the Equator. These counts are each 3 significant digits across North America, allowing easy conversion back to latitude & longitude, if required.



Octant 161296, in the Trenton USGS Quadrant, is displayed in the upper right of the grid detail on right. A bay is named with the Octant containing its geometric center plus a 4 digit extension, which allows for 10,000 discrete bay locations in each Octant.

5 Archetype Planforms Used In Survey

Five specific bay-type overlays were drawn from archetype Carolina bays. Here, we study the "oval" and "bell" versions, as found in the more northern areas of the bays' extent. We propose that a gentle transition is seen in the shape of bays as the survey extends north from the "prototype" in NC, through the "oval" stage, and finally into the "bell" planform, as shown on left. Fusion table, left, shows count by planform type.

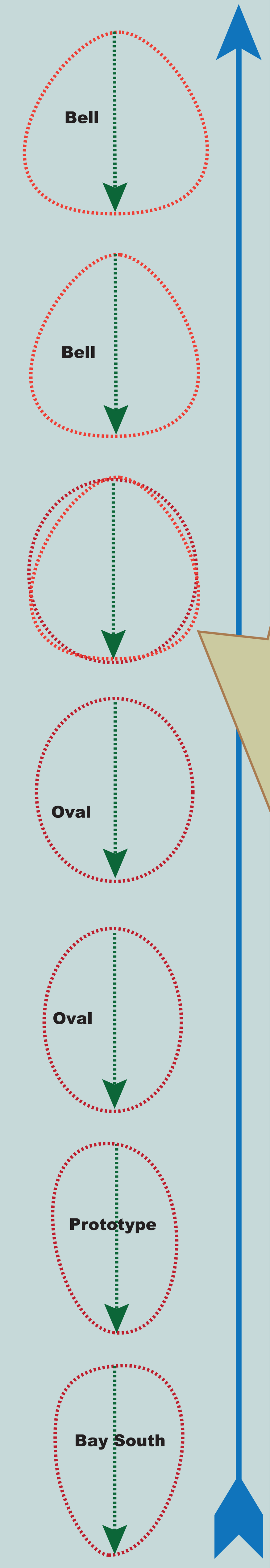


Bays Cintos
File View Edit Visualize Merge
Google Fusion Table Listing
Generated From Table of 25,000 bays using built-in aggregation and averaging features.
Get link Share
Showing aggregate AVERAGE(Eccentricity), AVERAGE(Bearing) by Planform options — 1 - 5 of 5

Planform	Eccentricity AVERAGE	Bearing AVERAGE	Count
West_Prototype	0.6820932642487042	240.63126079447264	579
bay_south_prototype	0.6591936868997841	153.0453055404671	7,364
bay_prototype	0.6981415165230693	141.86584257997646	15,411
bay_oval_prototype	0.6080341047503043	122.23484774665077	821
bayBell_Prototype	0.36842276867827645	120.30391023339341	2,785

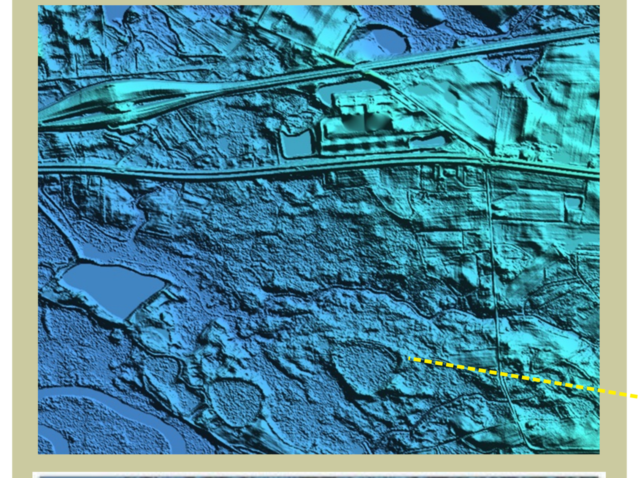
Evolution of Planform Shape

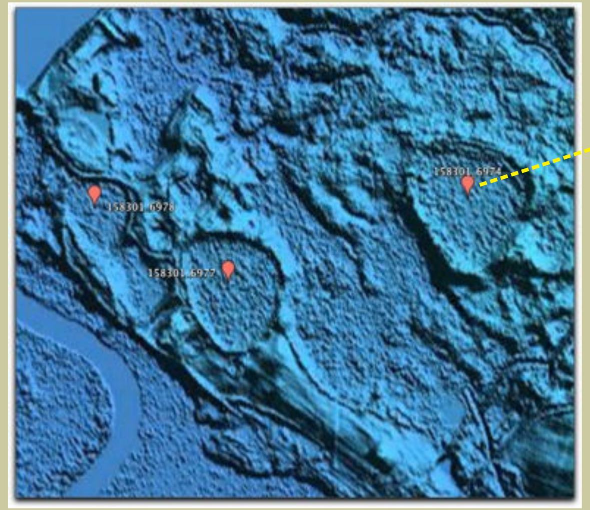
North: Princeton, NJ



South: Alabama

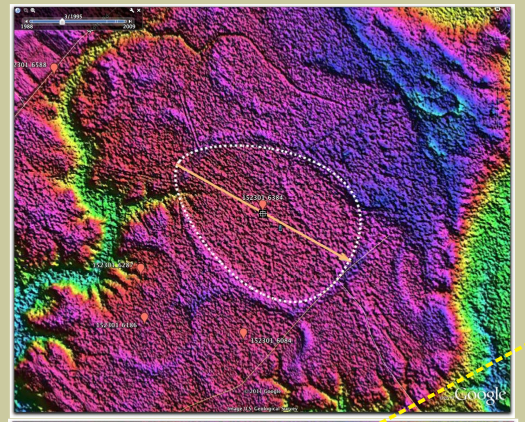
New Jersey, East of Deleware Memorial Bridge

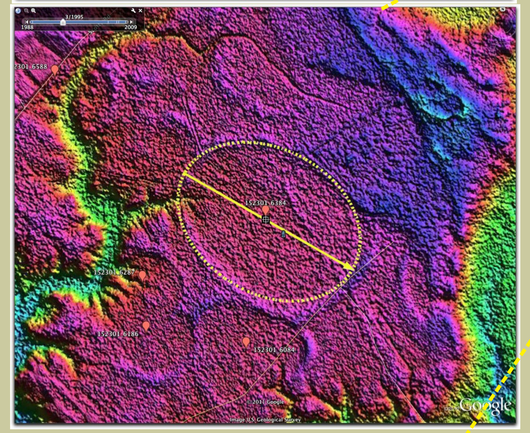


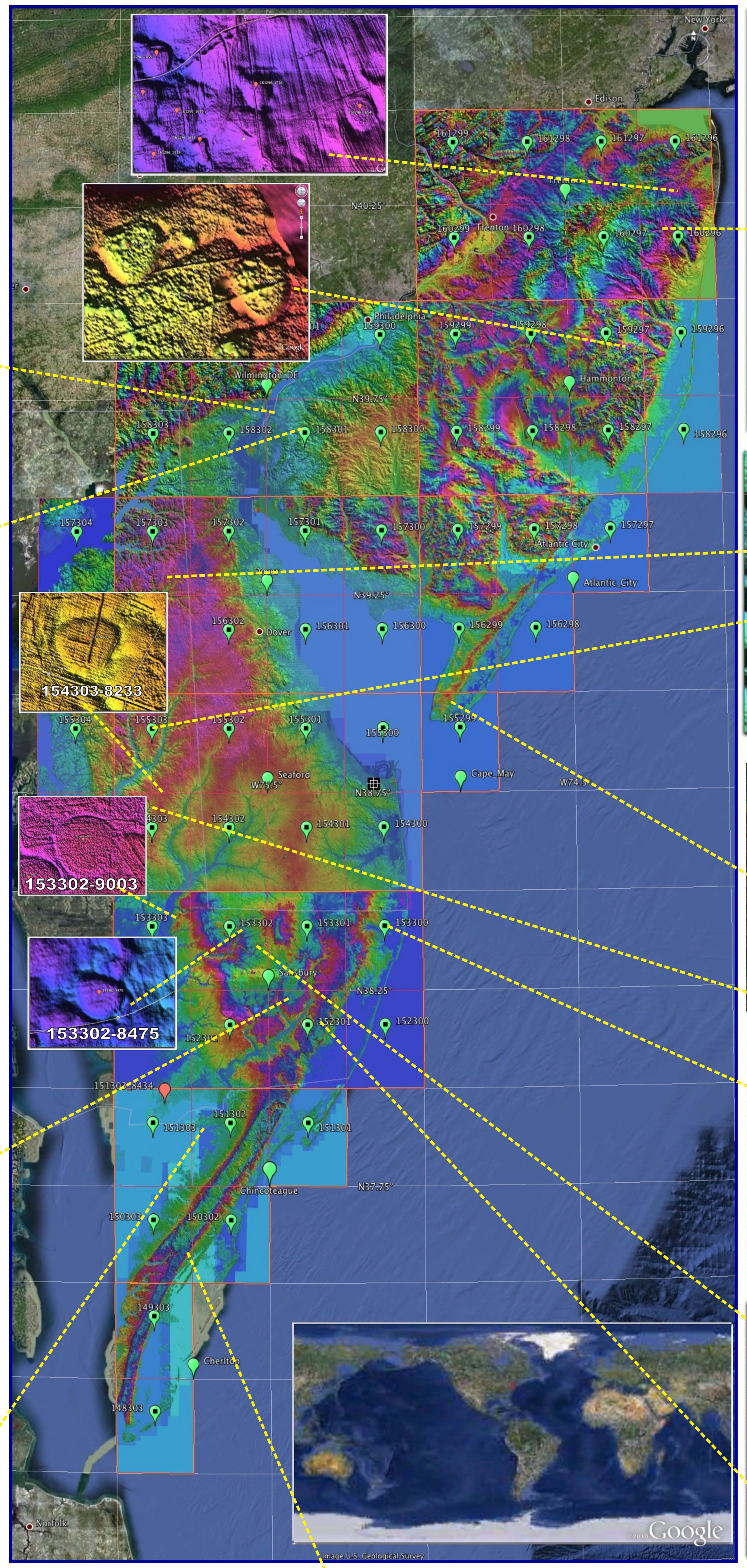


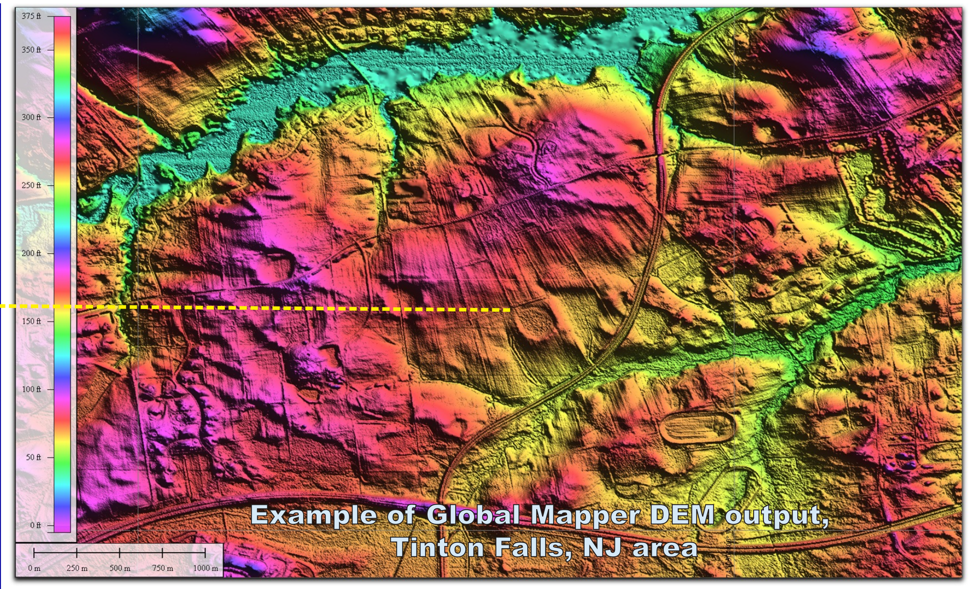
Transition Bay 152301_6384

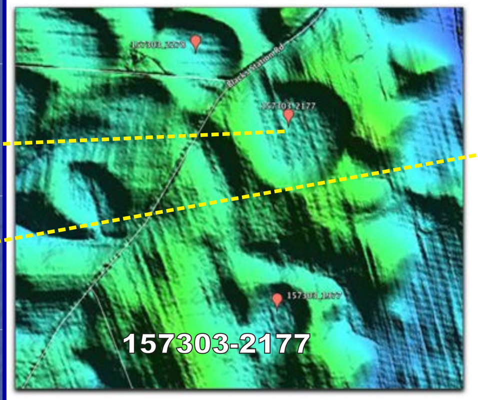
Neither Planform is Perfect Fit

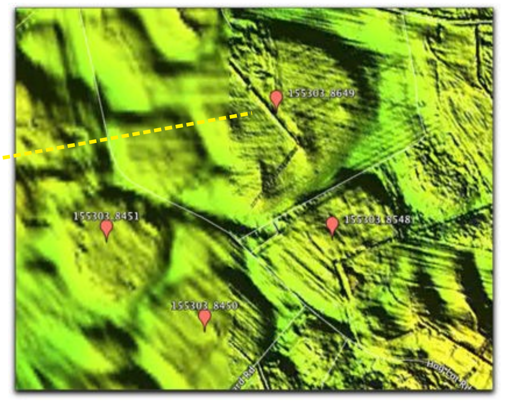


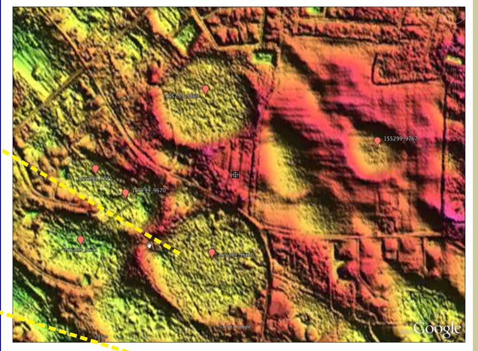






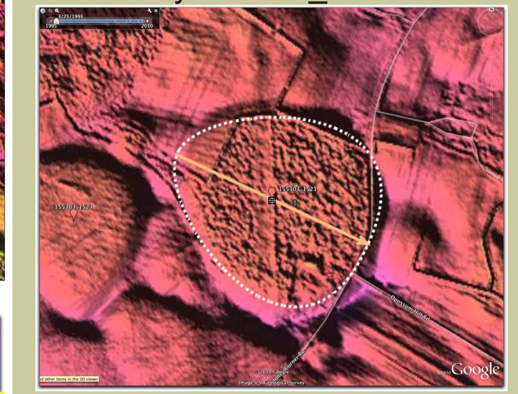




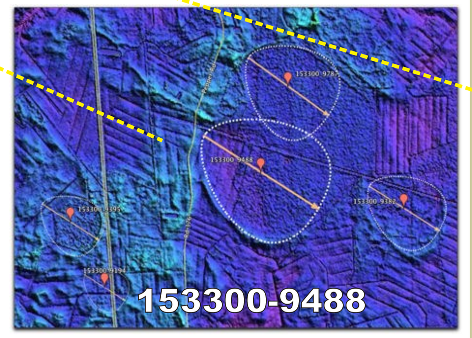


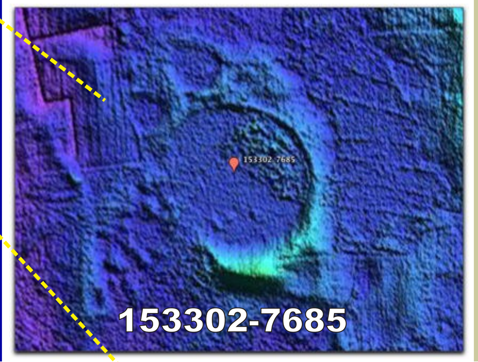
LiDAR vs Satellite Imagery

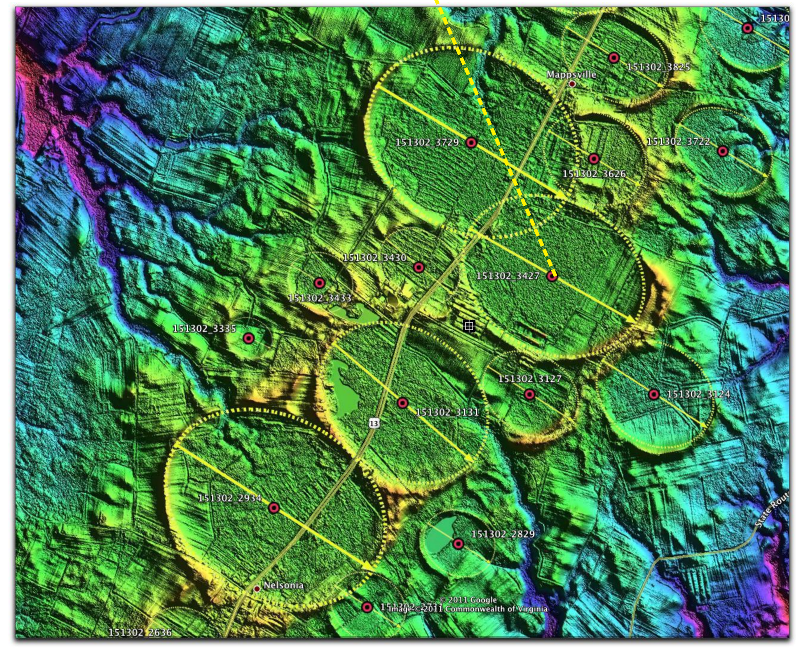
bay 155305_1521



LiDAR maps are presented here as hsv-shaded DEMs integrated as overlay tile sets in Google Earth. Comparisons with Satellite imagery demonstrates value of high resolution DEMs.



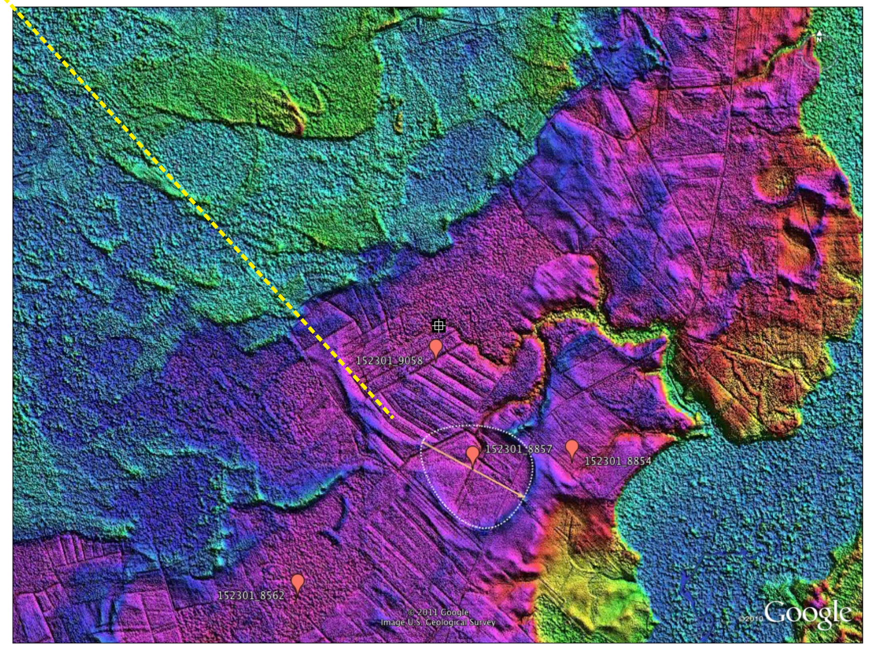




Dunes & Bays

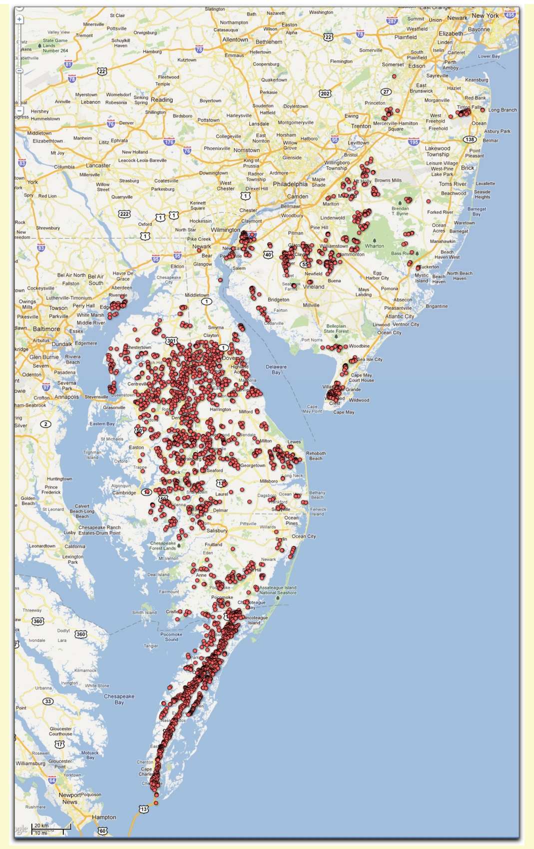
Right, extensive sheets of sand are seen migrating across Maryland as parabolic dunes. Existing Carolina bays present a significantly different and characteristic shape.

Left, over 700 oval bays are seen across Virginia's Eastern Shore



Google Fusion Tables

The Survey utilizes Google's Fusion Table geospatial database system as an on-line repository. Measured bays are represented as a row in a table, and can be visualized as a placemark on a browser-based map. Fusion can generate custom pop-up balloons for reference when a placemark is clicked. Here, we supply several metrics for the selected bay, along with a hyperlink to retrieve the bay overlay for viewing within the user's Google Earth desktop instance.



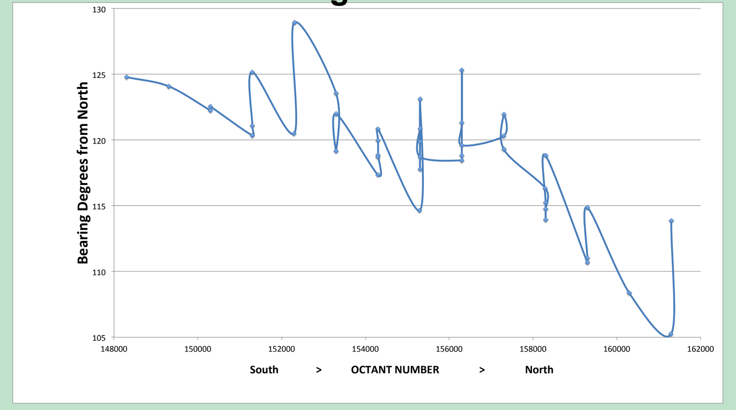
`google.com/fusiontables/DataSource?snapid=S258711wucT`

Observations & Results

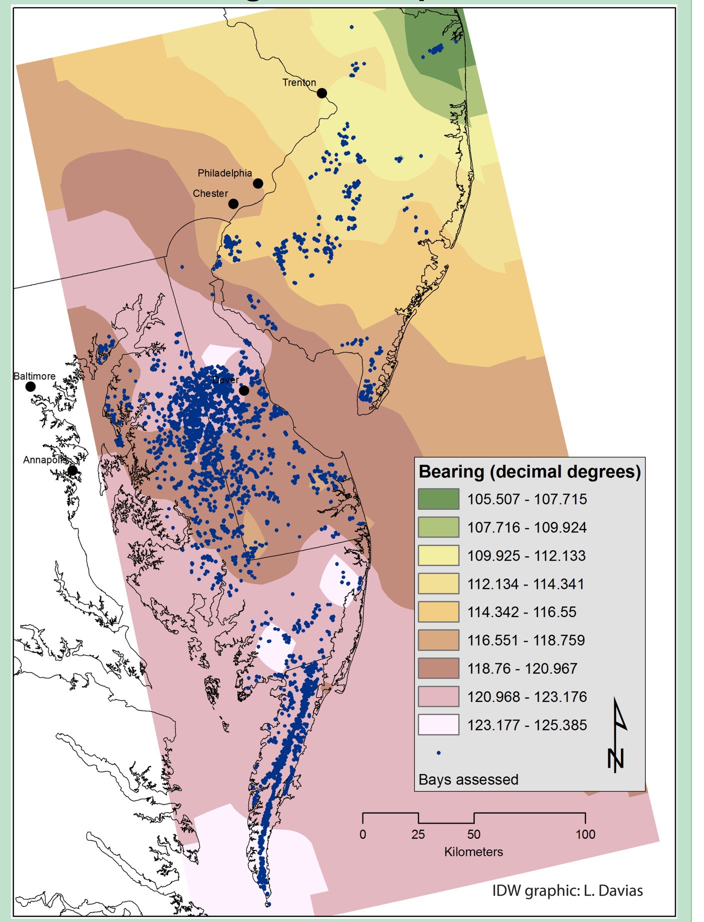
Carolina bay landforms identified north of the Carolinas are considered by many workers to posses orientations not correlating with the NW ➡ SE orientation of those further south. We propose that such assessments were based on the visualization of lakes and wetlands within these depressions, which often do not represent the planform of the depression's rim. With the availability of today's LiDAR elevation data, the bay outlines can be interrogated with a fidelity not previously available. Using a survey of ~3,500 probable Carolina bays, we show that there is a gentle evolution of planform shapes - from elongated ovals to the squat "bayBell" - can be seen across the landscape from Virginia to New Jersey. When the bay planform is viewed as a robust set of related shapes, we show that the orientation of these basins also changes systematic with latitude and longitude, rotating counter-clockwise as the region is traversed from south to north or west to east. Such progression is similar to (and on a continuum with) the rotation seen while traversing the more southerly Carolina bays. An alternative interpretation suggests that the bay alignment changes suddenly in a clockwise direction to yield a NNE ➡ SSW alignment. We show here that the LiDAR does not support such a sudden shift.

The charts below display the progression of orientations seen within the VA/MD/DE/NJ area.

Bearing vs Octant



Bearing IDW Interpolation



Evaluation of this data, when combined with similar data from other North American Carolina bays, may enable triangulation to a putative cosmic impact site implicit in a catastrophic mechanism for bay generation. The bays are clearly not primary or secondary impact craters, as shown by their shallow planforms (and numerous other facets). We instead speculate that they are surface defects (popped bubbles) embedded in a sheet of distal ejecta, distributed as a superheated slurry of pulverized silicate (sand) & water along an annulus surrounding the impact site.

LiDAR elevation map tiles utilized in this research are available on-line for integration with Google Earth, using the starter index KMZ file:
`http://www.cintos.org/ge/survey/SurveyTiles.kmz`

A table of metrics for 27,000 bay candidates in the Survey can be exported as a .csv file from:
`http://www.google.com/fusiontables/DataSource?dsrcid=396383`