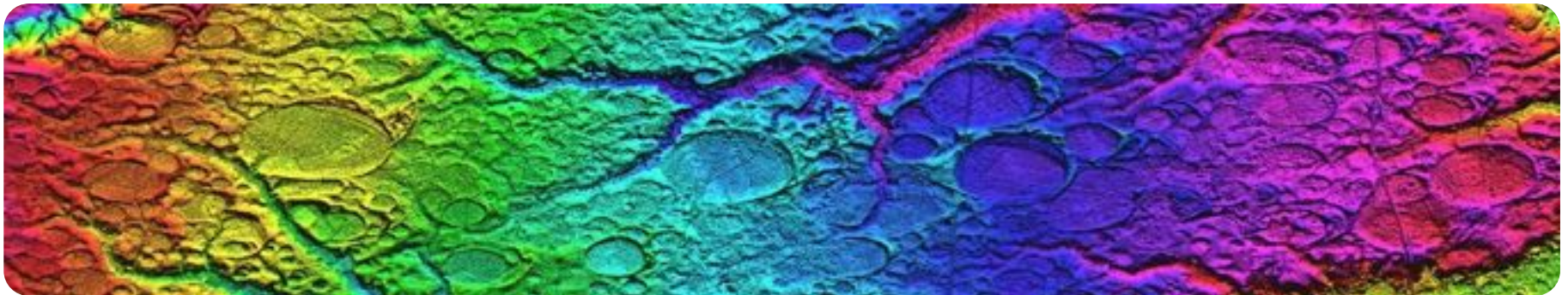# LiDAR IMAGERY EMPLOYED IN CAROLINA BAYS RESEARCH

## Demonstrating Integration with Google Earth Virtual Globe

Abstract No: 176738
**2010 GSA Annual Meeting**
**31 October**
**Denver, Colorado USA**

Michael E. Davias
Jeanette L. Gilbride

# LIDAR IMAGERY EMPLOYED IN CAROLINA BAYS RESEARCH
## Abstract ID#: 176738

Photographs of the Carolina bays have been available from the air since the early 1930's. Those early images sparked extensive research into their genesis, but they reveal only a small part of their unique planforms. Digital elevation maps (DEM) created with today's Laser Imaging and Range Detection (LiDAR) systems accentuates their already-stunning visual presentation, allowing for the identification and classification of even greater quantities of these shallow basins across North America.

Our research was enabled to a large part by the facilities and satellite imagery of the Google Earth (GE) Geographic Information System (GIS). The Global Mapper GIS application was used to generate LiDAR image overlays for visualization in Google Earth, using 1/9 arc-second resolution DEM data from the United States Geological Survey (USGS). Using these facilities, a survey was undertaken to catalogue the extent of Carolina bays, indexed as localized "fields".

Estimations of the bays' numerical quantity extends into the hundreds of thousands, therefore no attempt was made to identify all such landforms; instead each field was selected to be rigorously representative of the distribution in a given locale. The data is primarily used in a geospatial analysis, attempting to correlate the bays' orientations in a triangulation network. Identifying Carolina bays on the costal plain is straight forward, given their solid identification, however bay planforms tend towards a circular presentation in the northern and southern extremes of their geographic extent, presenting challenges. Also challenging is the rougher terrain seen when moving inland. We suspect that access to high resolution LiDAR DEMs in more regions would aid in expanding the bays' identified range.

While there is much research discussing Carolina bays in the east, there are significant quantities of aligned, oval basins in the Midwest. These basins are aligned SW ➔ NE, and are considered to be vital components of the triangulation network. The survey resulted in a catalogue of ~220 fields of Carolina bays, managed in a Keyhole Markup Language (kml) metadata file. The catalogue of LiDAR images is available for interactive visualization using the GE-GIS using the kml file available at http://cintos.org/ge/SaginawKML/Distal_Ejecta_Fields.kmz.

My thanks to those in attendance here, and to the GSA, for the opportunity to share some of the LiDAR  techniques and resources we have applied in researching Carolina bay landforms.  We will also be demonstrating the integration of LiDAR imagery with the Google Earth Virtual Globe, along with sharing a few preliminary results.



Photo Courtesy of
George Howard

So, What is a Carolina bay?  Until 80 years ago, they were simply a scattered collection of swamps and lakes that represented challenges for local farmers and road builders.

 This photograph displays numerous bays under different land uses. Due to their water retention characteristics, the bays' outlines are often easy to see.

# Myrtle Beach, SC
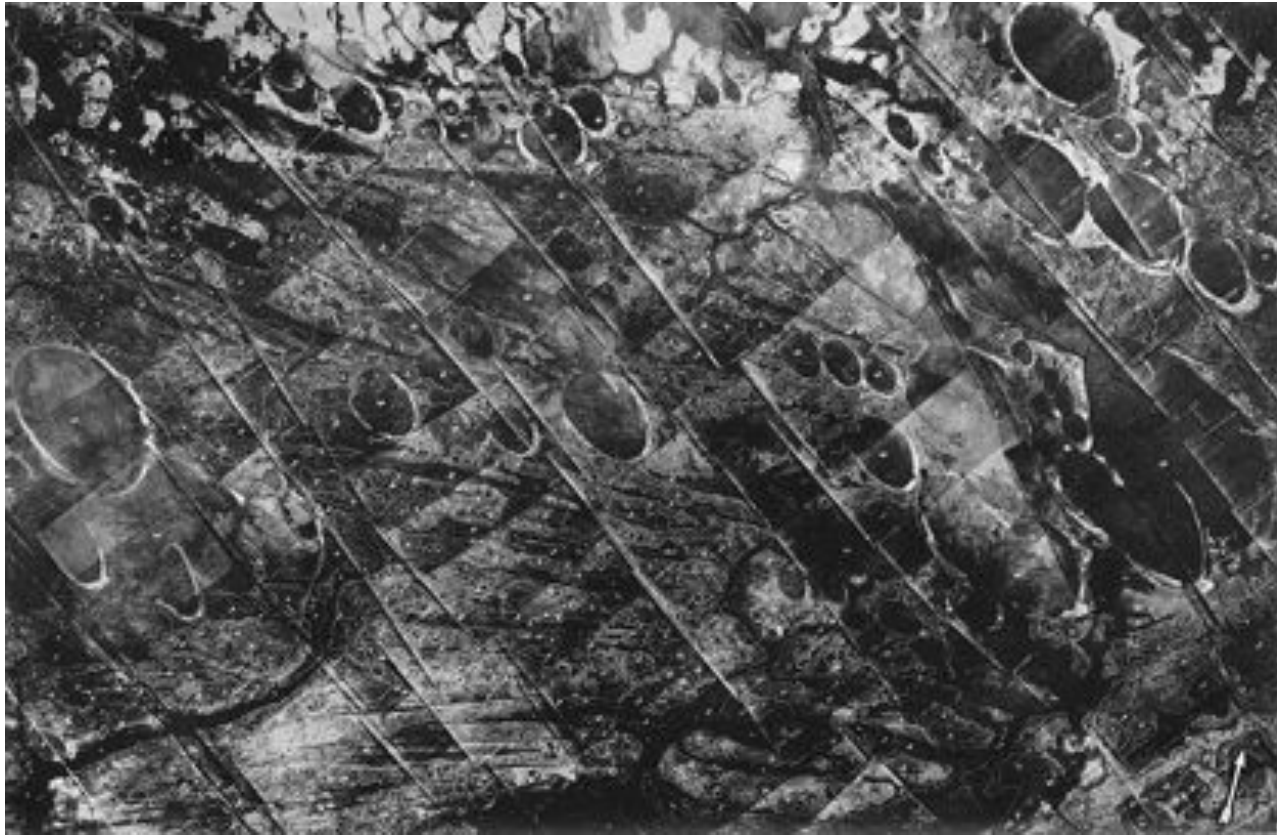


©Fairchild Aerial Surveys for the Ocean Forest Company: Aerial view taken in 1930 (12x8 km)

Since the bays were first visualized in aerial photography of Myrtle Beach in the 1930s, their presence on the landscape has generated controversy as to their geomorphology. Differing from simple parabolic dunes, these landforms universally exhibit a closed circumpheral rim. What would generate shallow ellipsoidal basins, clustered together with a commonly oriented major axis?

# Myrtle Beach, SC
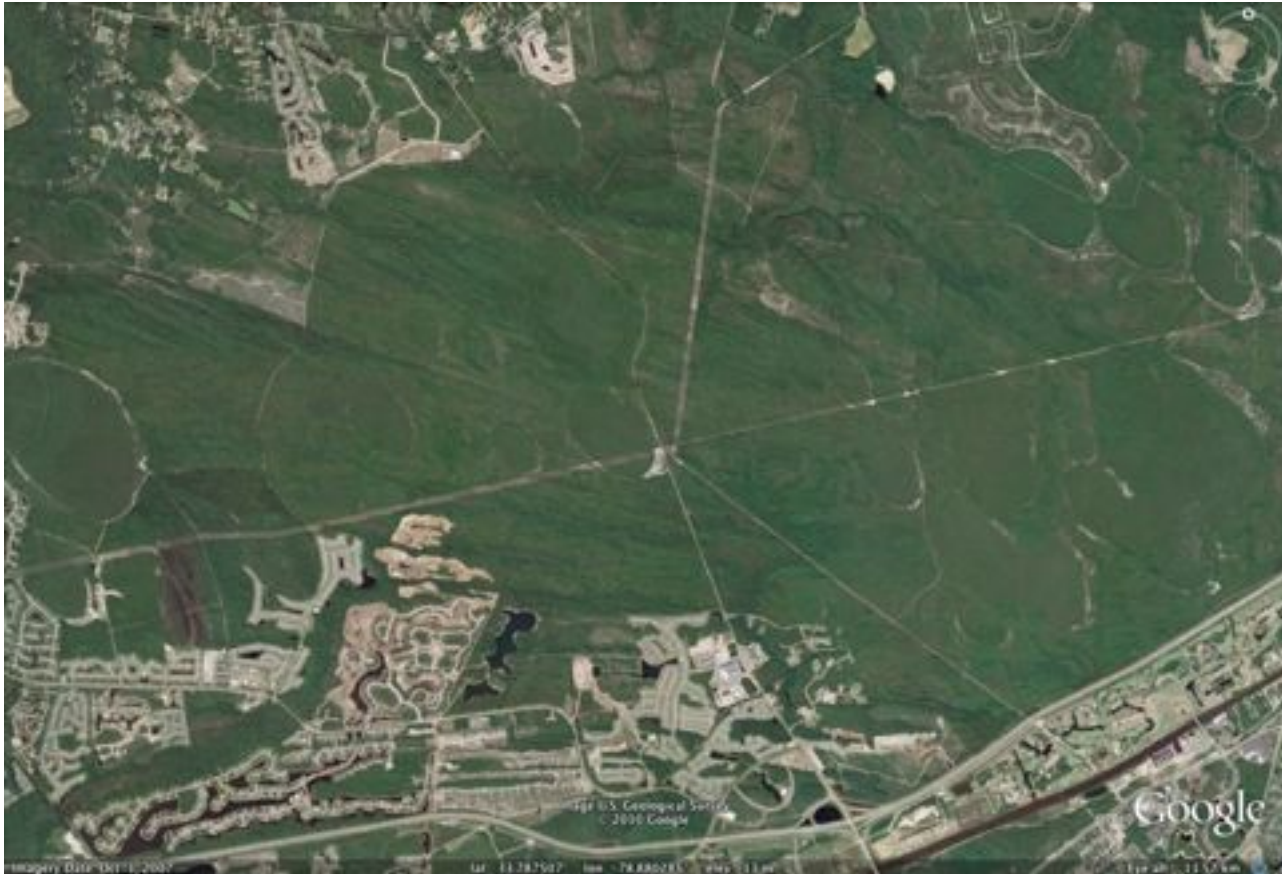


Here we take an original Fairchild Aerial Survey photograph and overlay it on the Virtual Globe, and as we fade out, the current satellite imagery becomes visible. Our goal is to capture multiple planform metrics using remote sensing.

# Myrtle Beach, SC
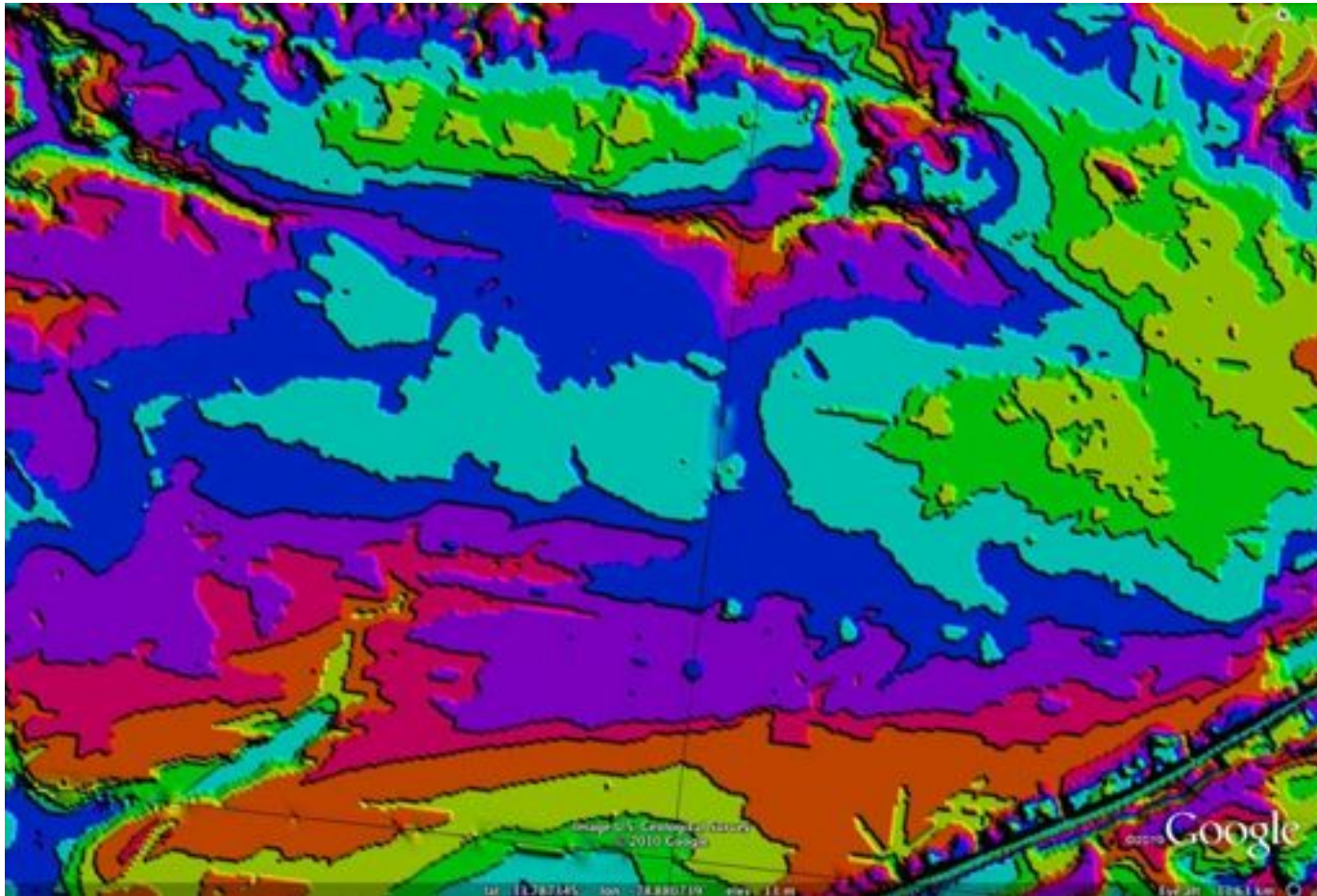


USGS elevation data is of no use here:  the best DEM data offered for Myrtle Beach is 1/3 arc-second, and it looks like this. The original survey seems to be the best!

# GE Imagery (1999), St. Pauls, NC



Here is another example of satellite imagery. While bays and their planforms are visible, it is difficult and imprecise to trace the rims.

# GE Imagery (1999), St. Pauls, NC
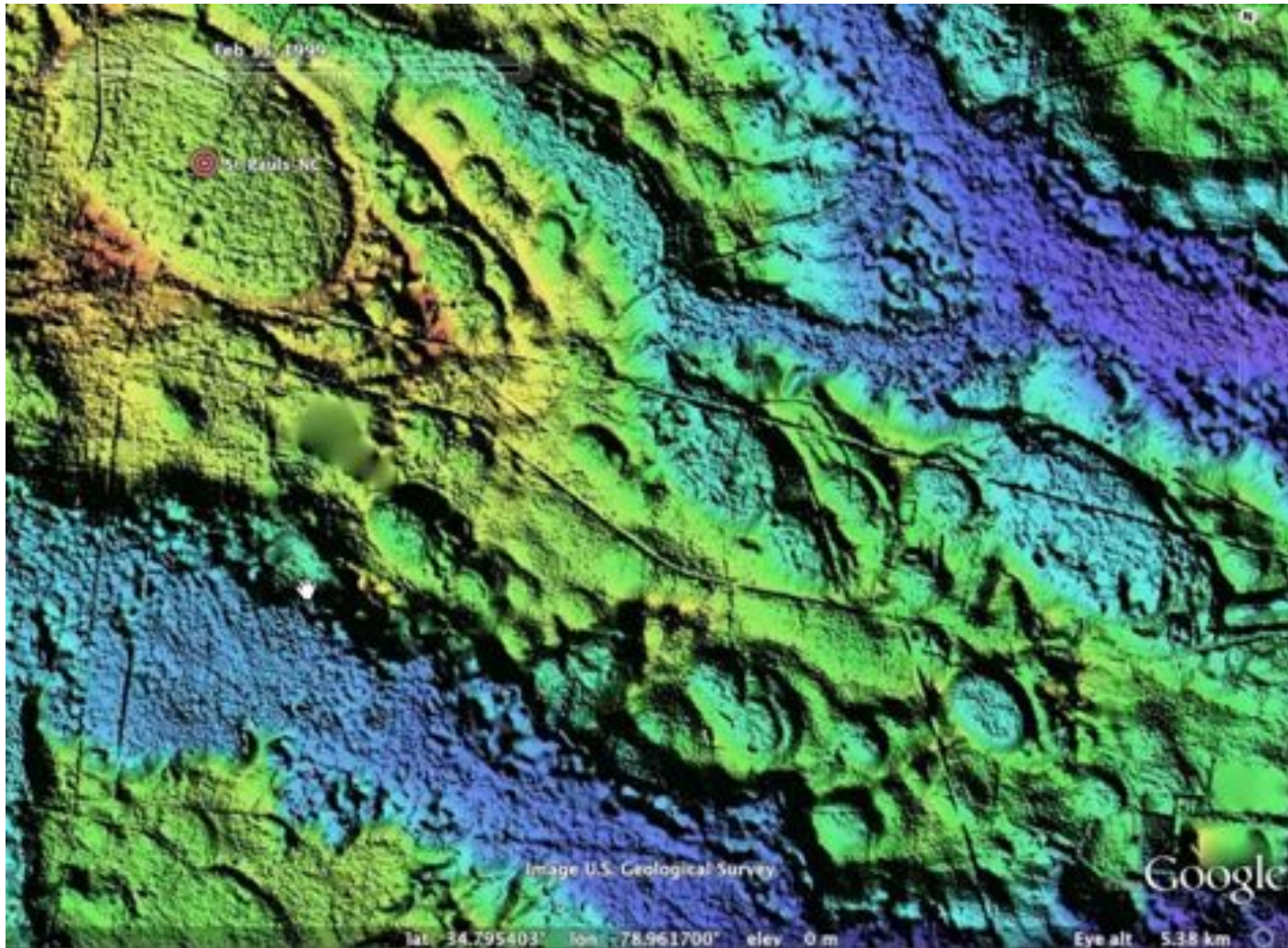


The same are using LiDAR elevation map overlay. We suggest that visual imagery reveals only a small part of their unique planforms.

# GE Imagery Wilmington, NC



In a dense urban landscape, a bay in a park might be noticed

# GE Imagery Wilmington, NC
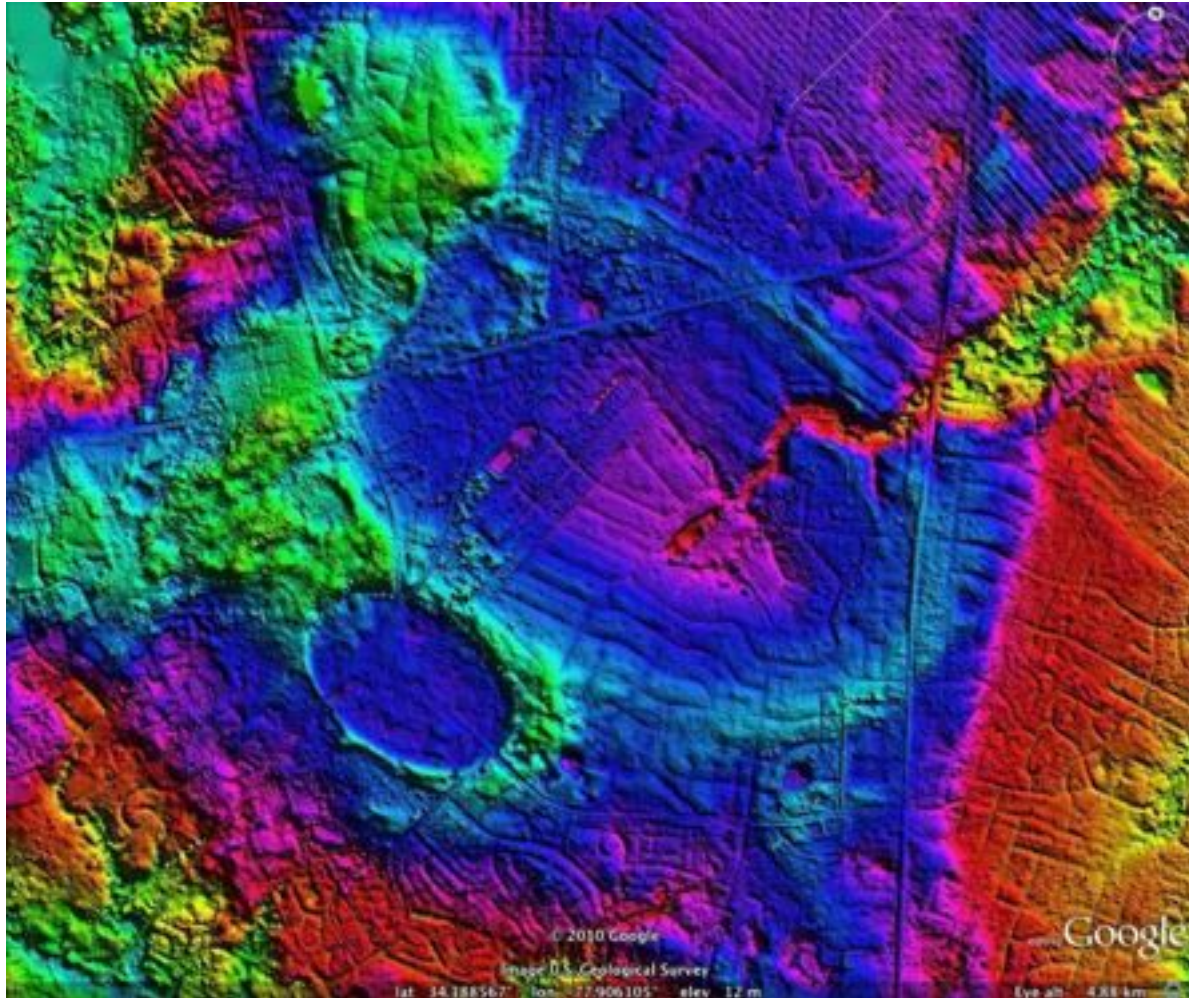


– but that would be overlooking the big elephant in the room.
LiDAR imagery to the rescue !

# Rationale

> ## "No one has yet invented an explanation which will fully account for all the facts observed"
>
> Douglas Johnson, 1942
> *The Origin of the Carolina Bays*

In our opinion, Dr. Johnson's challenge is as valid today as it was 70 years ago!

So, we are *inventing* a novel explanation, where the bays are not nearly as important as the sand strata they are embedded within.

We posit that those sands represent a thin veneer ( up to 10 meters) of pulverized ejecta from a remote cosmic impact. The bays are proposed to be voids in that blanket,

# Bubble Foam



… possibly caused by the deflation of gaseous inclusion in
a foamy slurry: effectively, Popped Bubbles,

# Bubble Foam
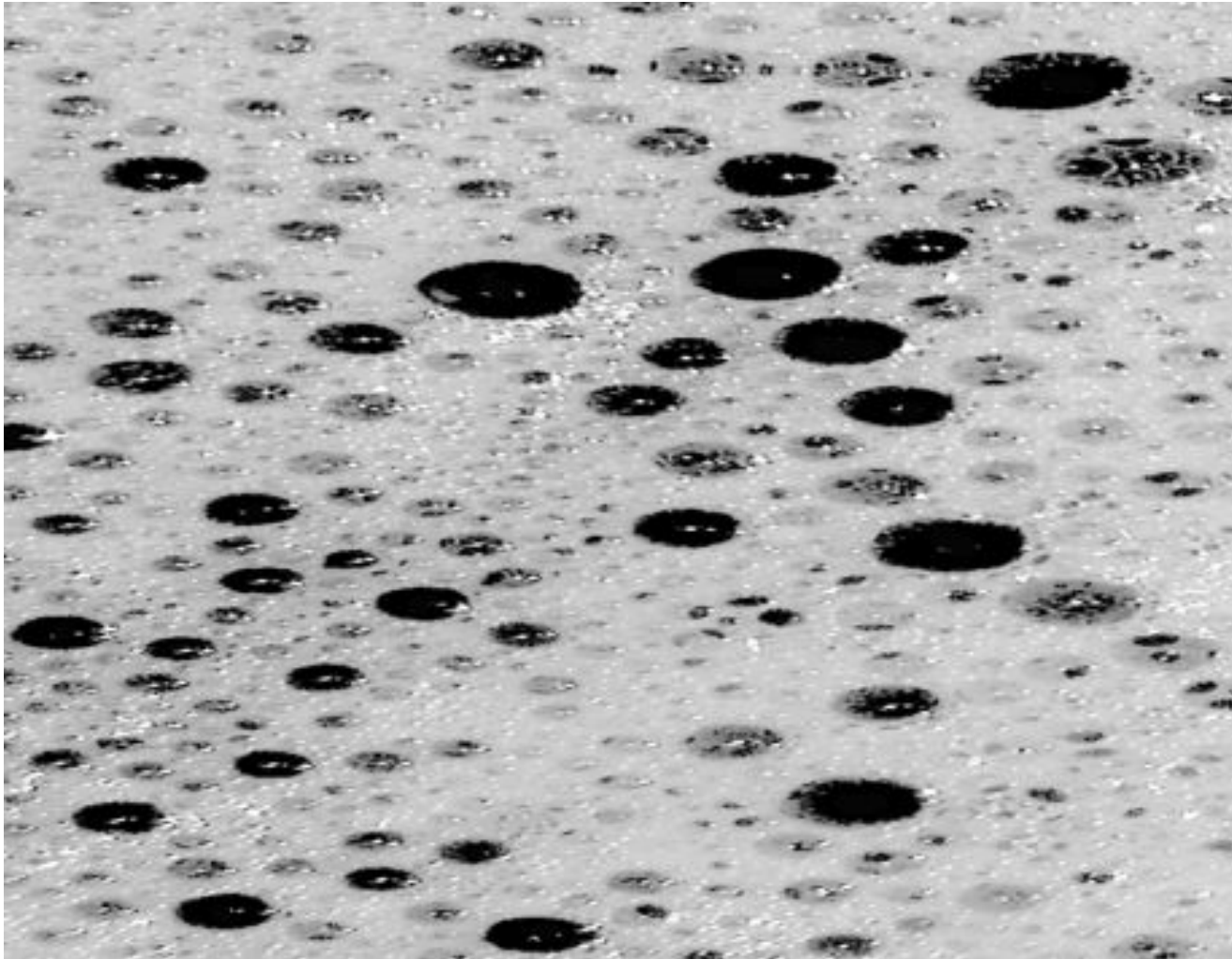


...their elongation perhaps an artifact of the ejecta's arrival vector.

# Research Requirements

- Create Comprehensive Catalogue of Carolina bay landforms
- Triangulation Network requires broad spatial distribution of bays & alignments
- Integrate with Google Earth Virtual Globe



Eyton & Parkhurst (1975)
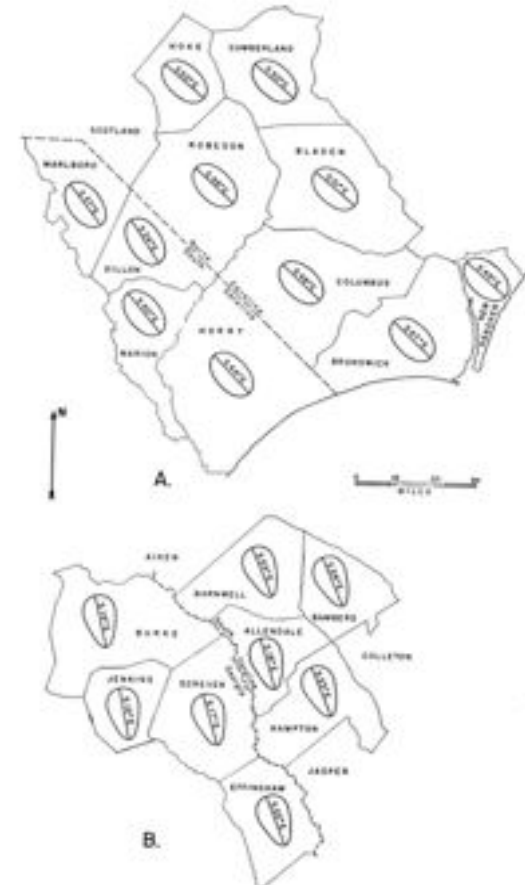


Carolina bay Orientation – Johnson (1942)

Our proposal suggests that straight lines on flat maps may not be the best way to correlate these… instead, we shall apply our data onto a virtual globe.

# Tools & Resources

- USGS 1/9 Arc-second National Elevation Data
- Nebraska Department of Natural Resources LiDAR data
- Global Mapper commercial GIS program
  - Loads many type of data, we use Arc-Grid here
  - Save as JPG or TIFF
  - Save as Keyhole Markup language (KML) data file
- Google Earth loads Global Mapper KML
  - Automatically aligns on virtual globe
  - Allows for capture of planform geospatial metrics

# 1/9 arc second LiDAR-derived Data



Nebraska DNR

Here is the spatial distribution LiDAR-derived data in the areas of interest. We eagerly await similar data for other regions.

USGS NED
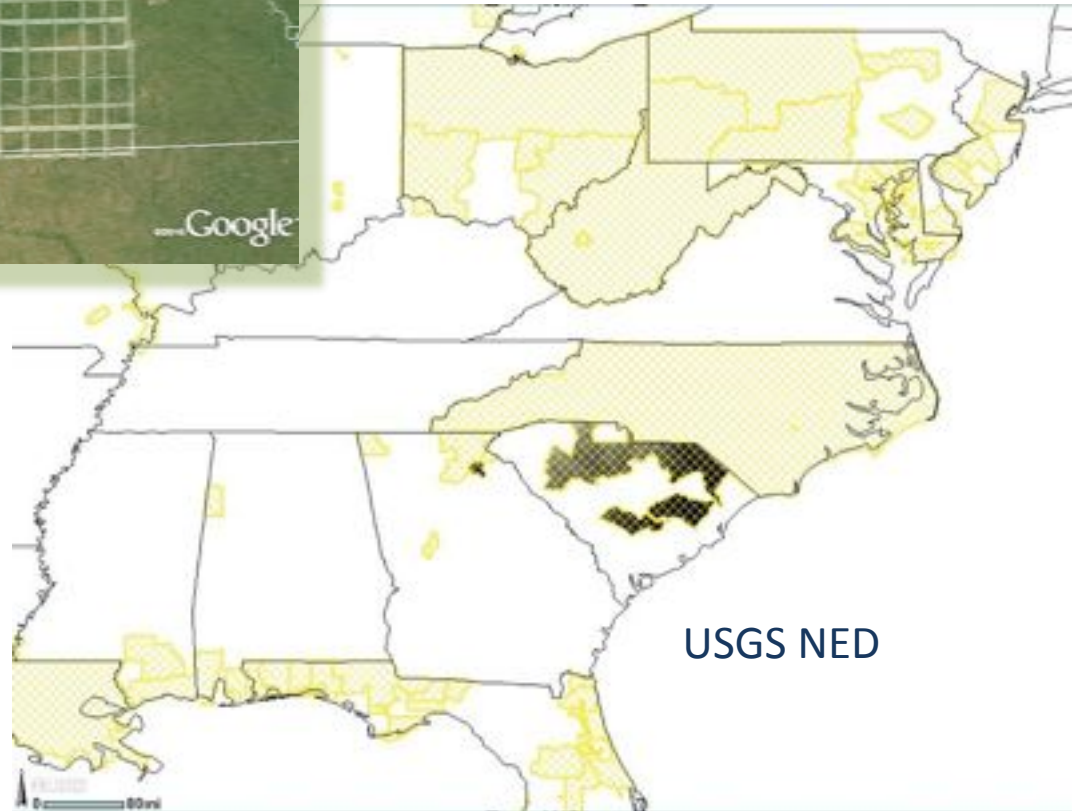
# LiDAR Generation Process – Data Retrieval
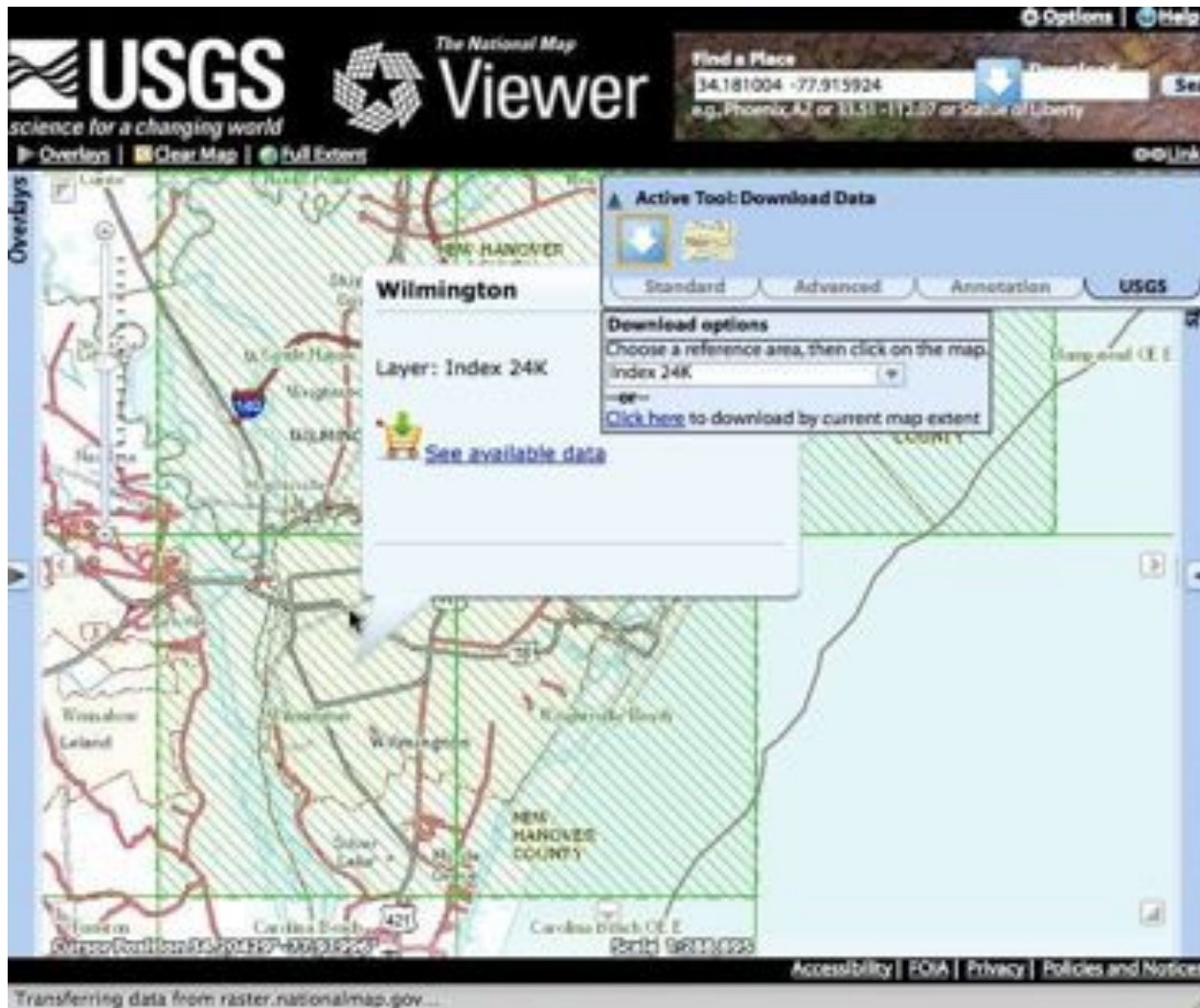


The new USGS National Map application is a wonderful facility.
Enter in latitude, longitude (or a name place) & search.

# LiDAR Generation Process – Data Retrieval
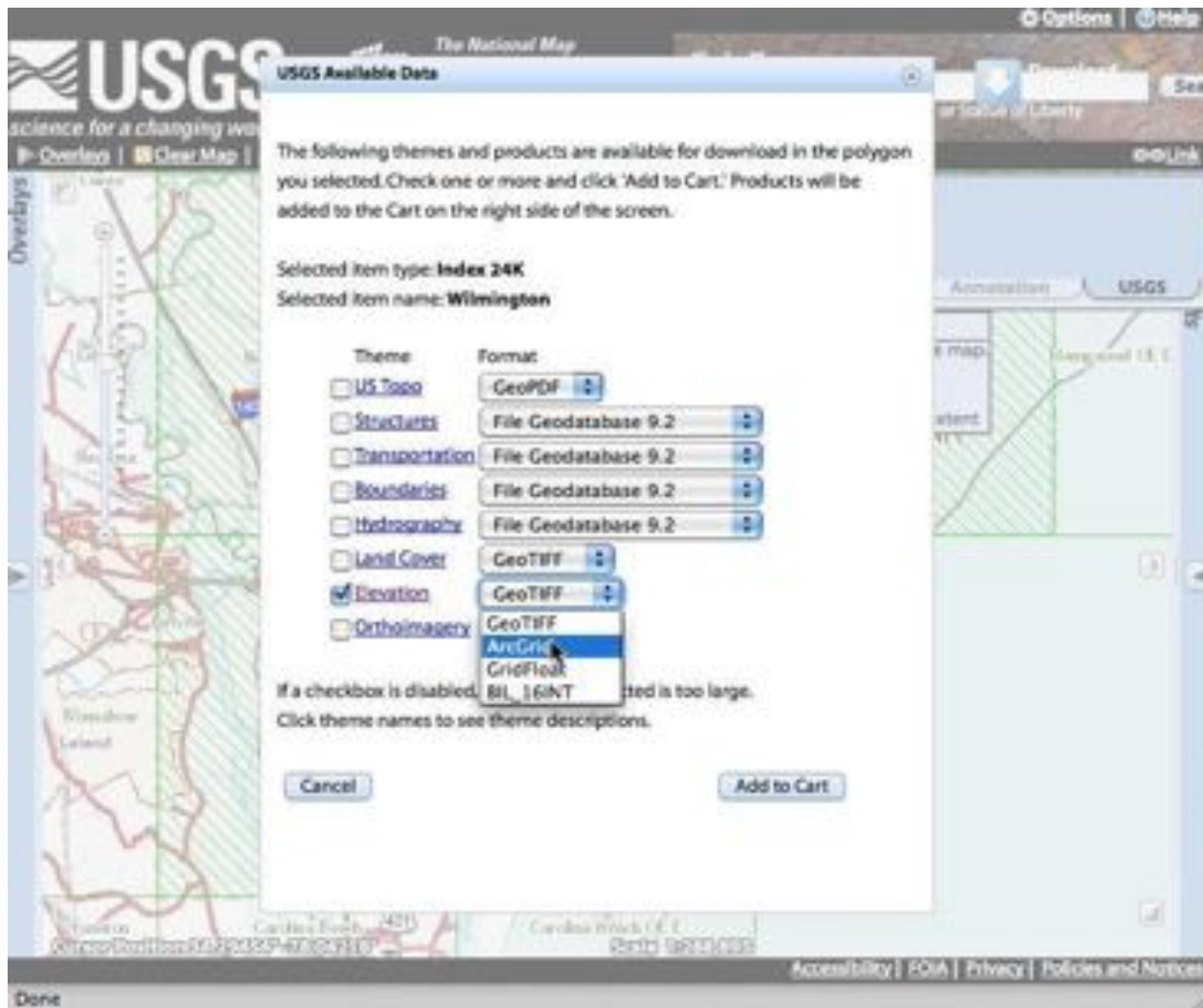


… many options are presented. We are interested in Elevation data, in ArcGrid format, 1/9 arc second where available.

# LiDAR Generation Process – Data Retrieval



Add to the cart and process, and an email is sent with download links.

# LiDAR Generation Process – Global Mapper
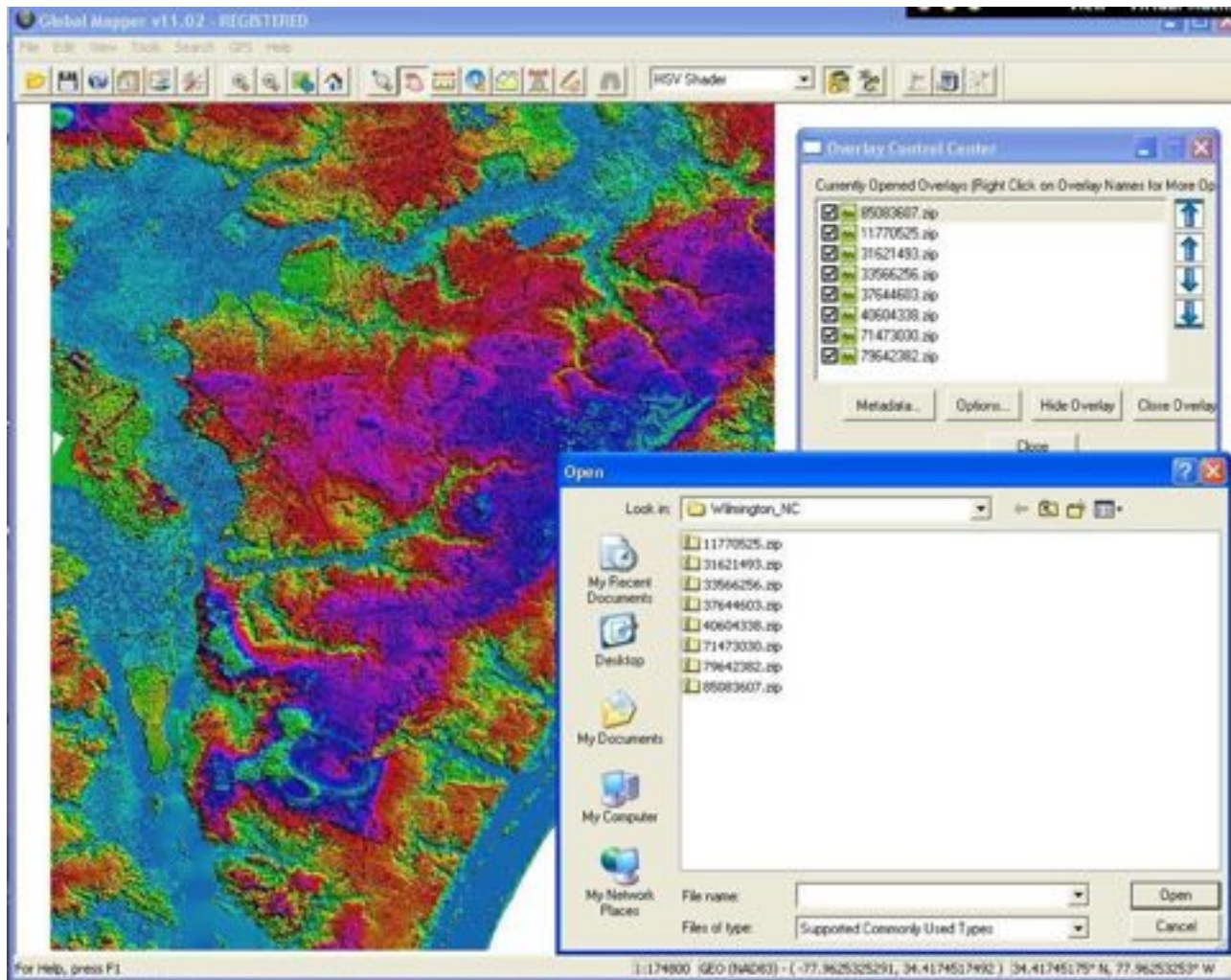


Here, we have loaded eight 24K Quad segments (supplied as zip files) into Global Mapper's interface.

# LiDAR Generation Process – Global Mapper
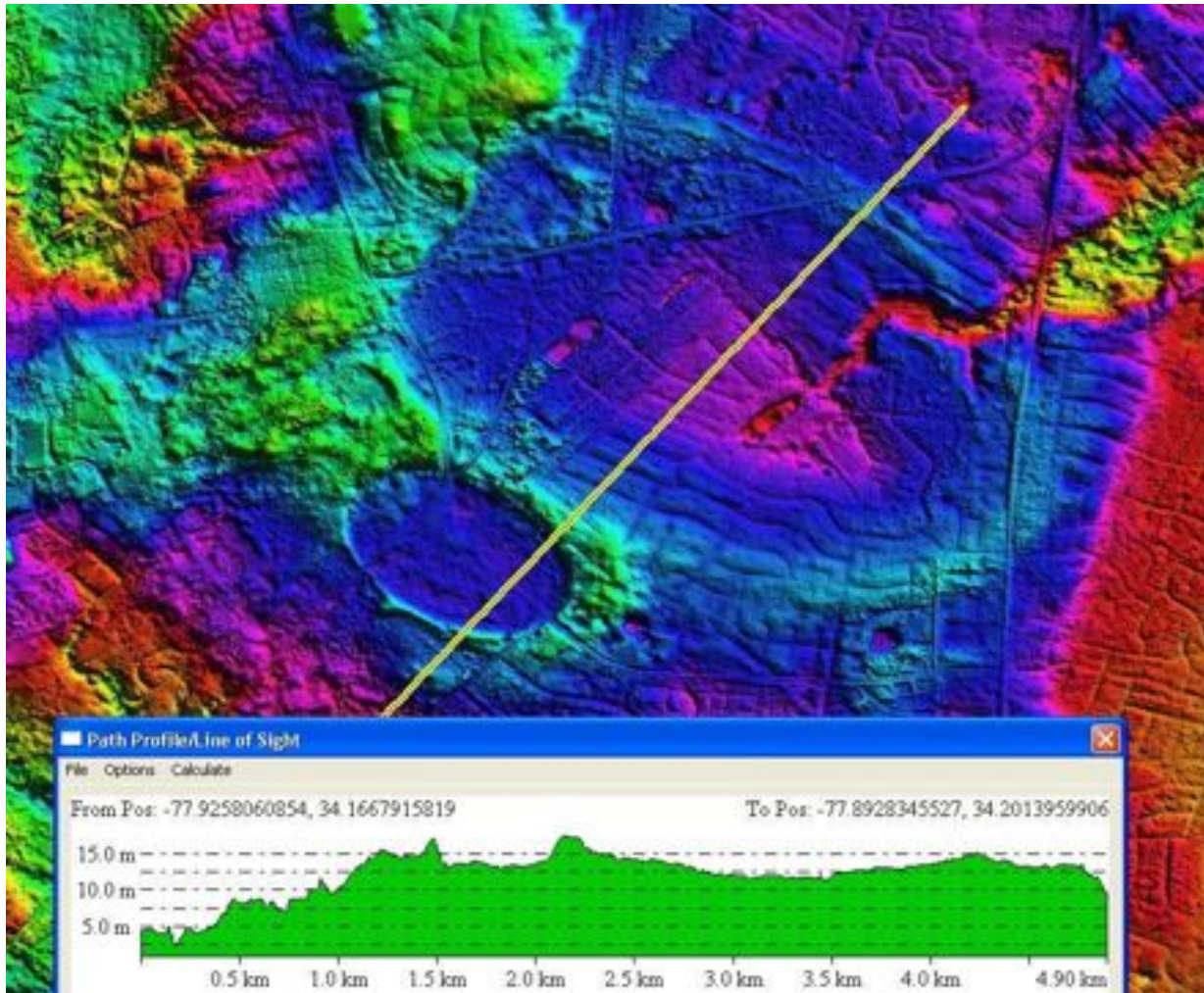


One of Global Mapper's many tools is an elevation profile capability,
The 2 kilometer-wide bay has only 5 meters of rim relief… FL AT

# Elevation Profiles
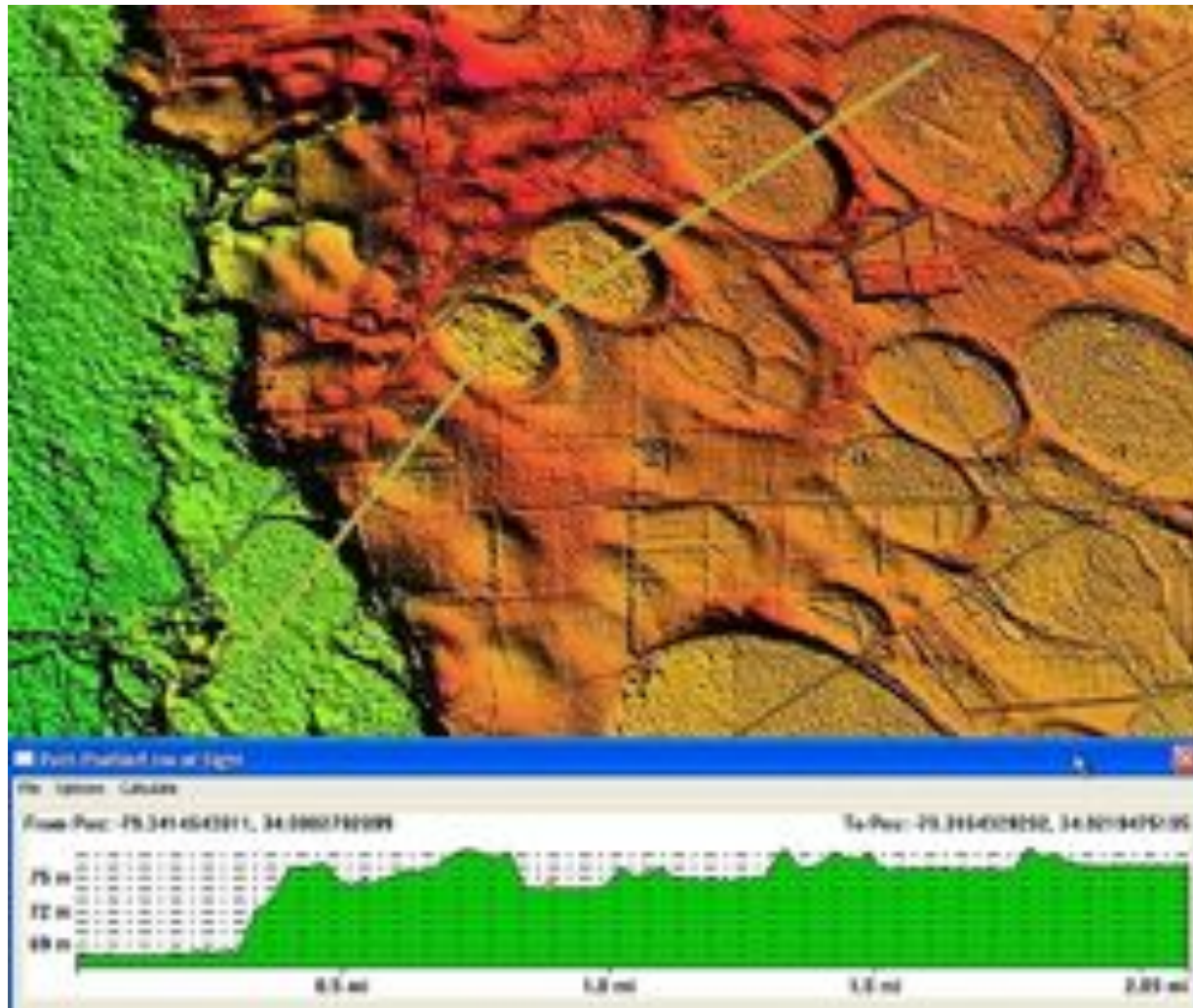


We have used the profile tool to show the diverse elevations that bays occur at, even over relatively short distances. Our proposed blanket would have merely draped over antecedent terrain. Note the bay planforms on the valley floor, lower left.

# Nebraska Bays Elevation Profile

## ~ 10 m rim height on 2 km bay



AMSL     515 m              510 m           506 m        505 m
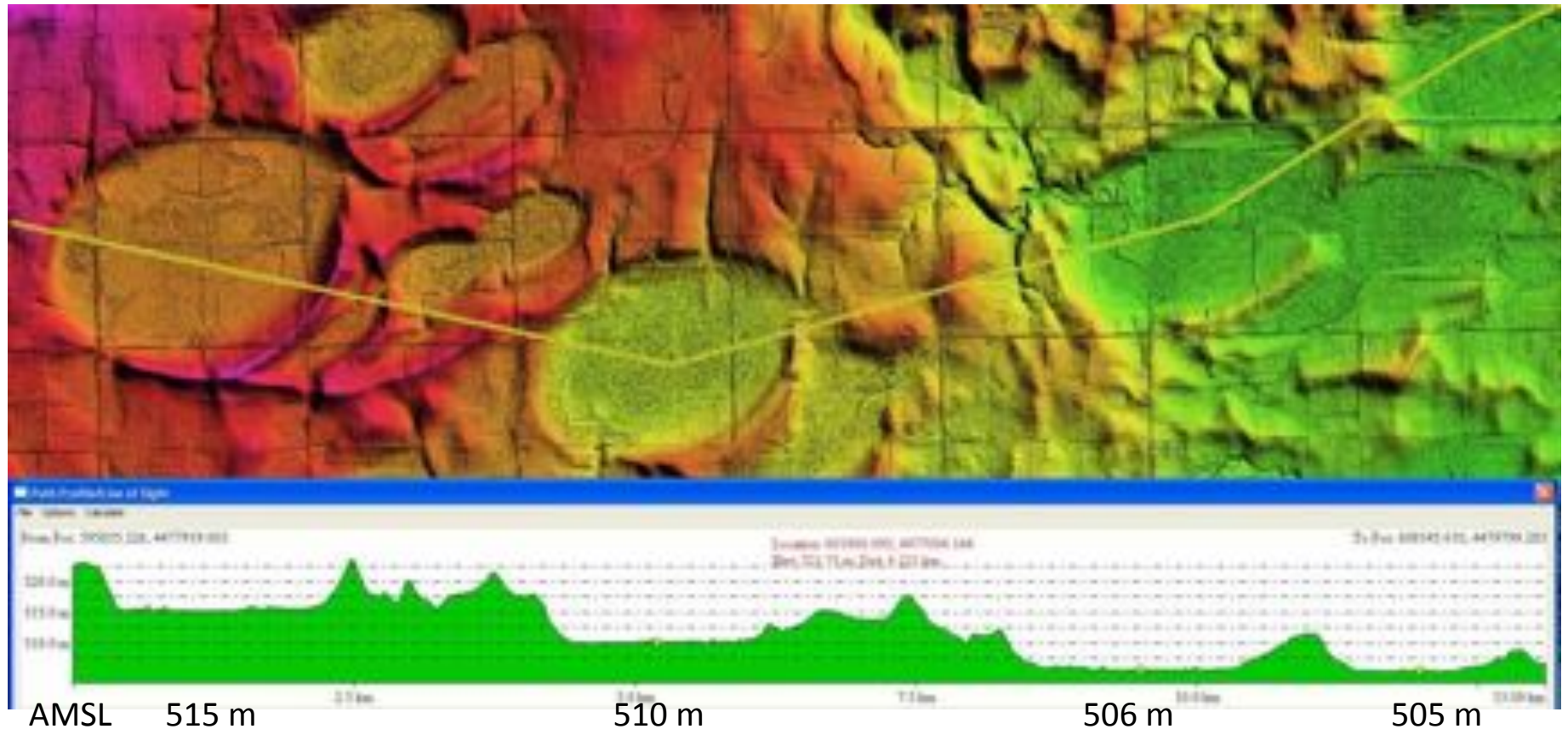
William Zanner identified ancestral basins in Nebraska similar to the Carolina bays. He proposed these to be the controlling structure underlying many meters of late Wisconsinan loess.  In the LiDAR, the basins jump out. We have identified hundreds of these in the Midwest.

# Nebraska Bays – Rainwater Basins
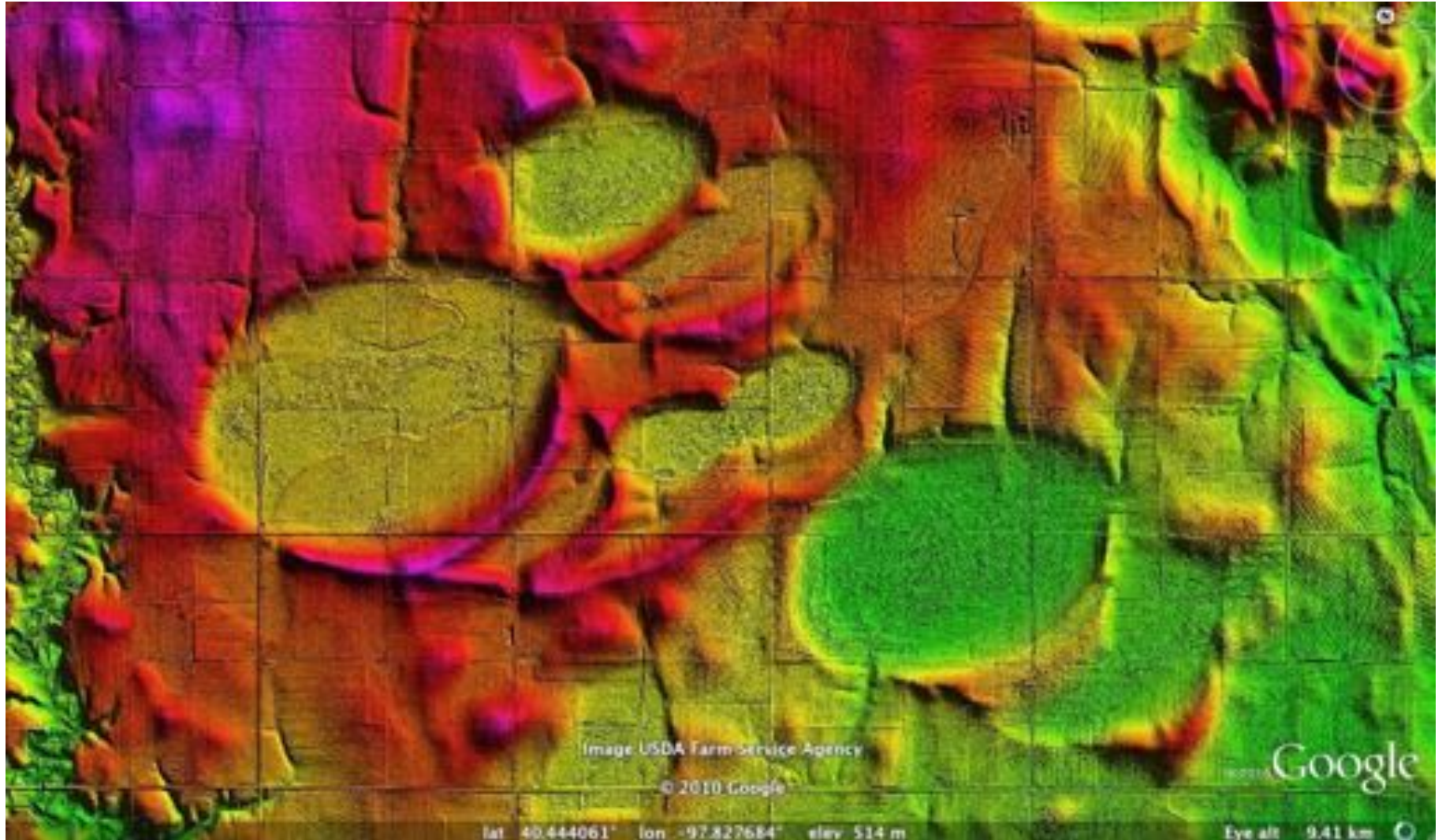


Basins visualized with LiDAR vs Satellite imagery

# Nebraska Bays – Rainwater Basins



Basins visualized with LiDAR vs Satellite imagery

# LiDAR Generation Process
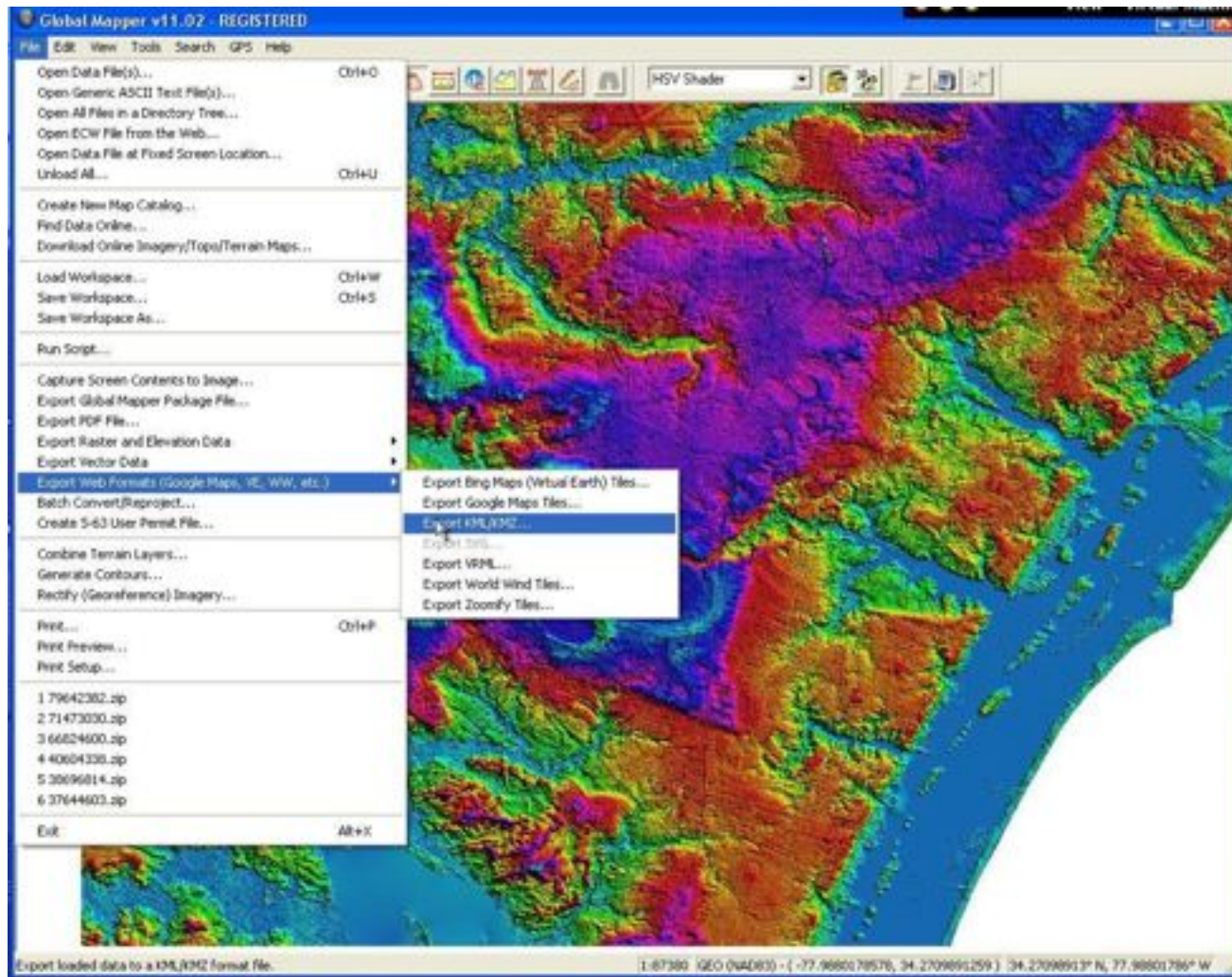


Once we have a scope of LiDAR to define a "field" of bays, we proceed with the export of data in a form digestible by Google Earth: - KML
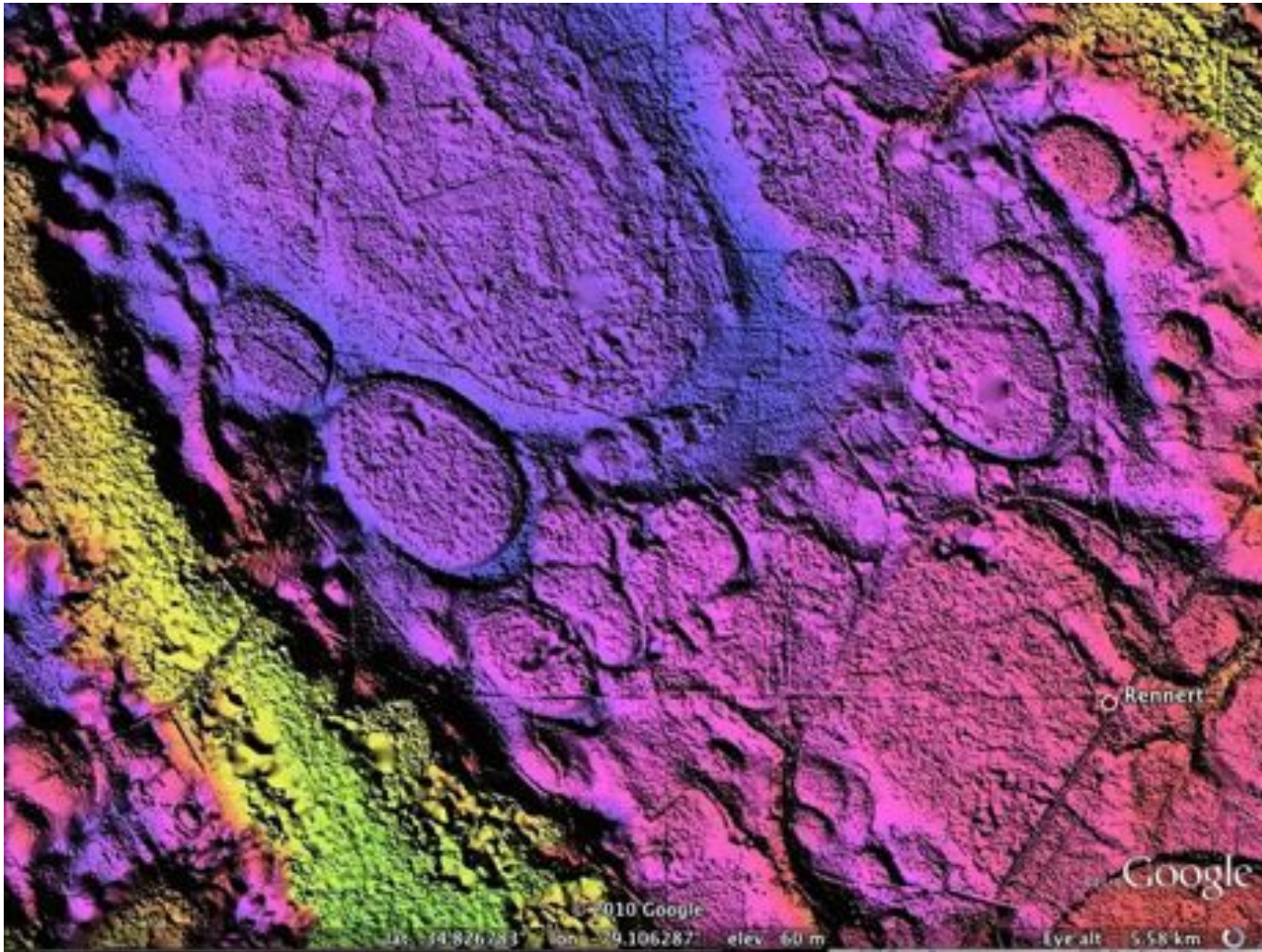
# LiDAR Integration with Google Earth
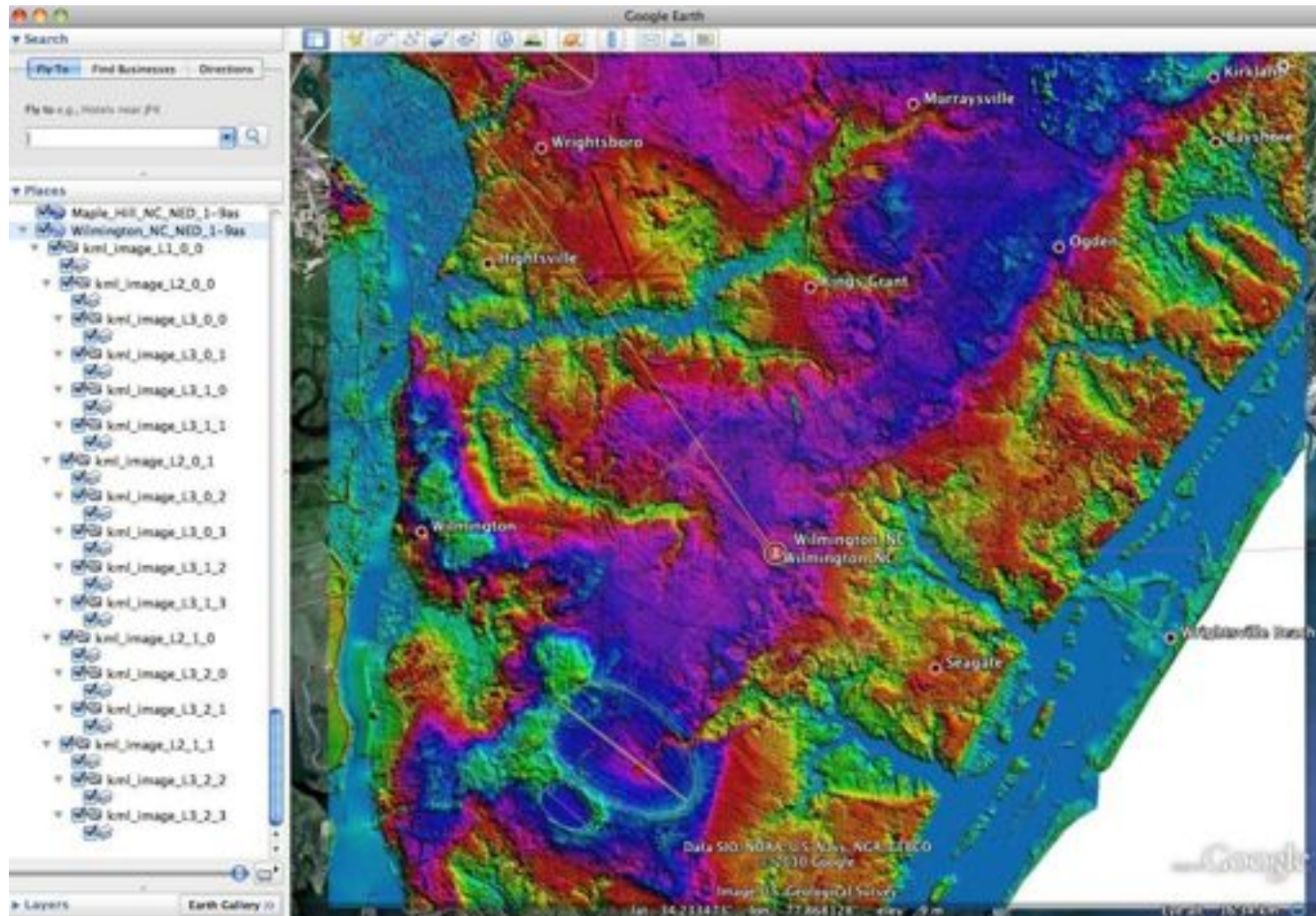


The exported fie is opened in Google Earth, with the Image automatically positioned on the virtual globe. The tree of increasingly detailed image tiles is shown on the left.
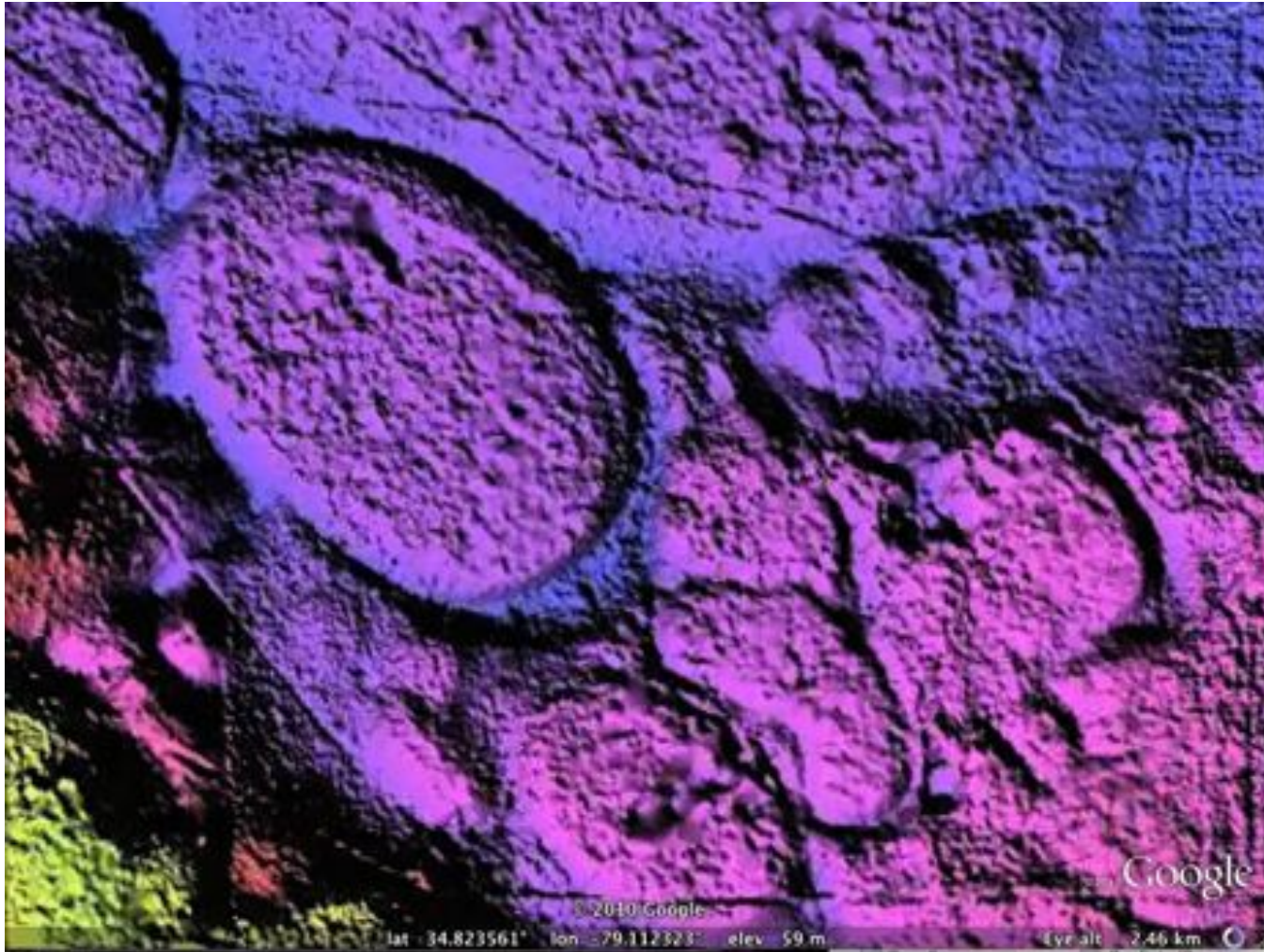
# LiDAR Overlay KML in Google Earth
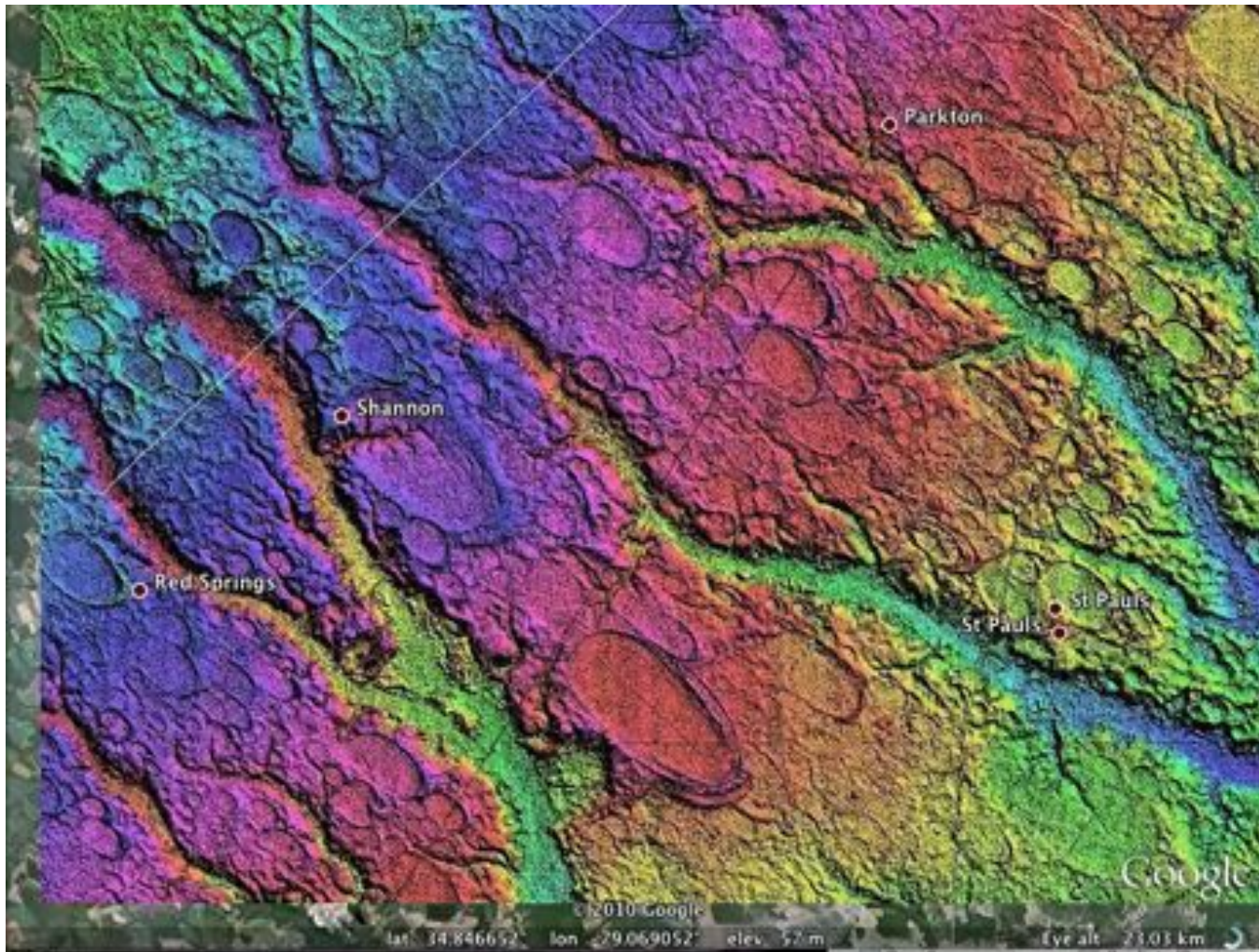


This LiDAR imagery covers 600 square km surrounding Rex, NC.

# LiDAR Overlay KML in Google Earth



As we zoom in, we see the increasing detail provided by the tiling tree. The crisp planform viewed here is the Archetype of bays in the Carolinas.
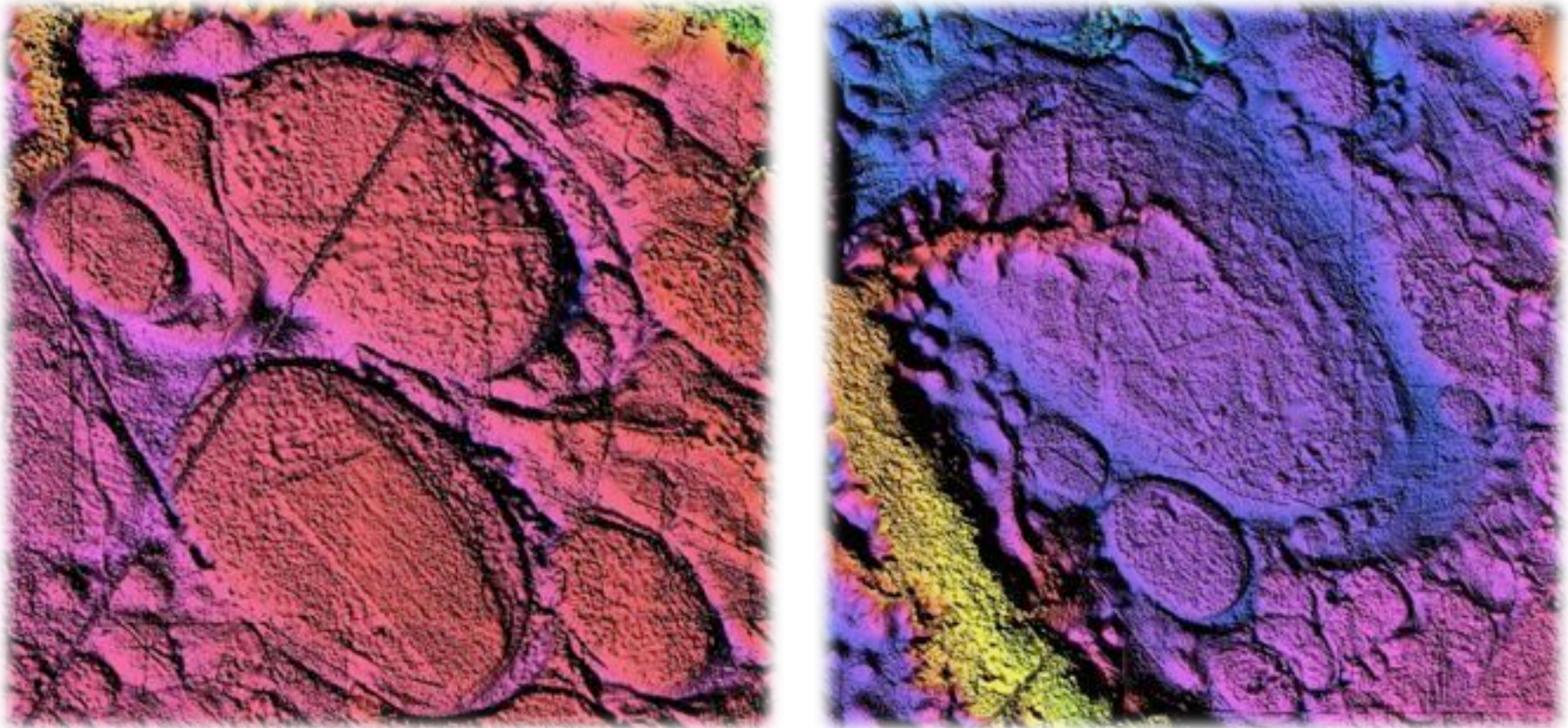
# LiDAR Overlay KML in Google Earth



They are not pure ovals, as they have one flattened side and a built-up rim on the Southeast end.

# LiDAR Overlay KML in Google Earth



Here is the same landscape seen in Google Earth imagery. Flipping back and fourth, it is easy to see the value of LiDAR..

# Blanket Artifacts – Daughter Bubbles



Now, let's look at some of the interesting planform features we have visualized using these LiDAR maps. This juxtaposition of adjacent bays is what might be termed "daughter bubbles": small bays at the southeastern end of a large bay….

# Antecedent Channels
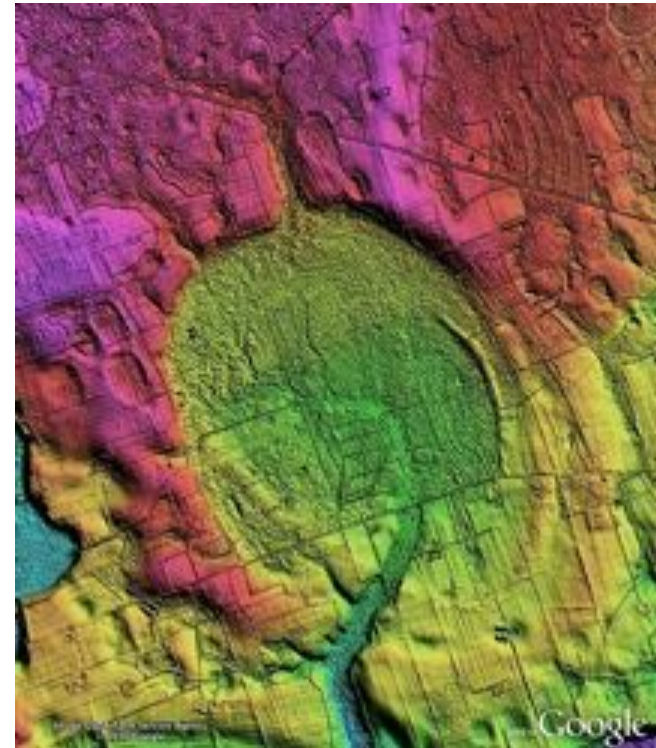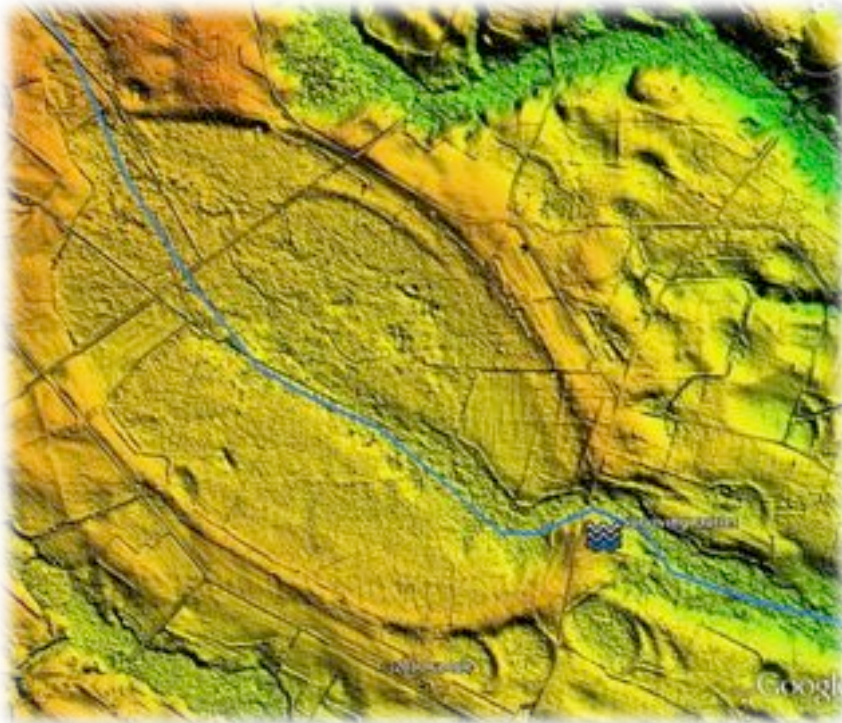


Douglas Johnson comfortably dismissed direct impact theories using numerous observations. Among them was that antecedent drainage channels clearly survived across the planform of many bays. As such, it was impossible for the bay to have been carved out by an excavating event. But a blanketing event would allow those channels to map through.

Note that one channel exits at the thickest section of the rim, another of Johnson's observations. Daughter bubbles are again present along the Southeast end.
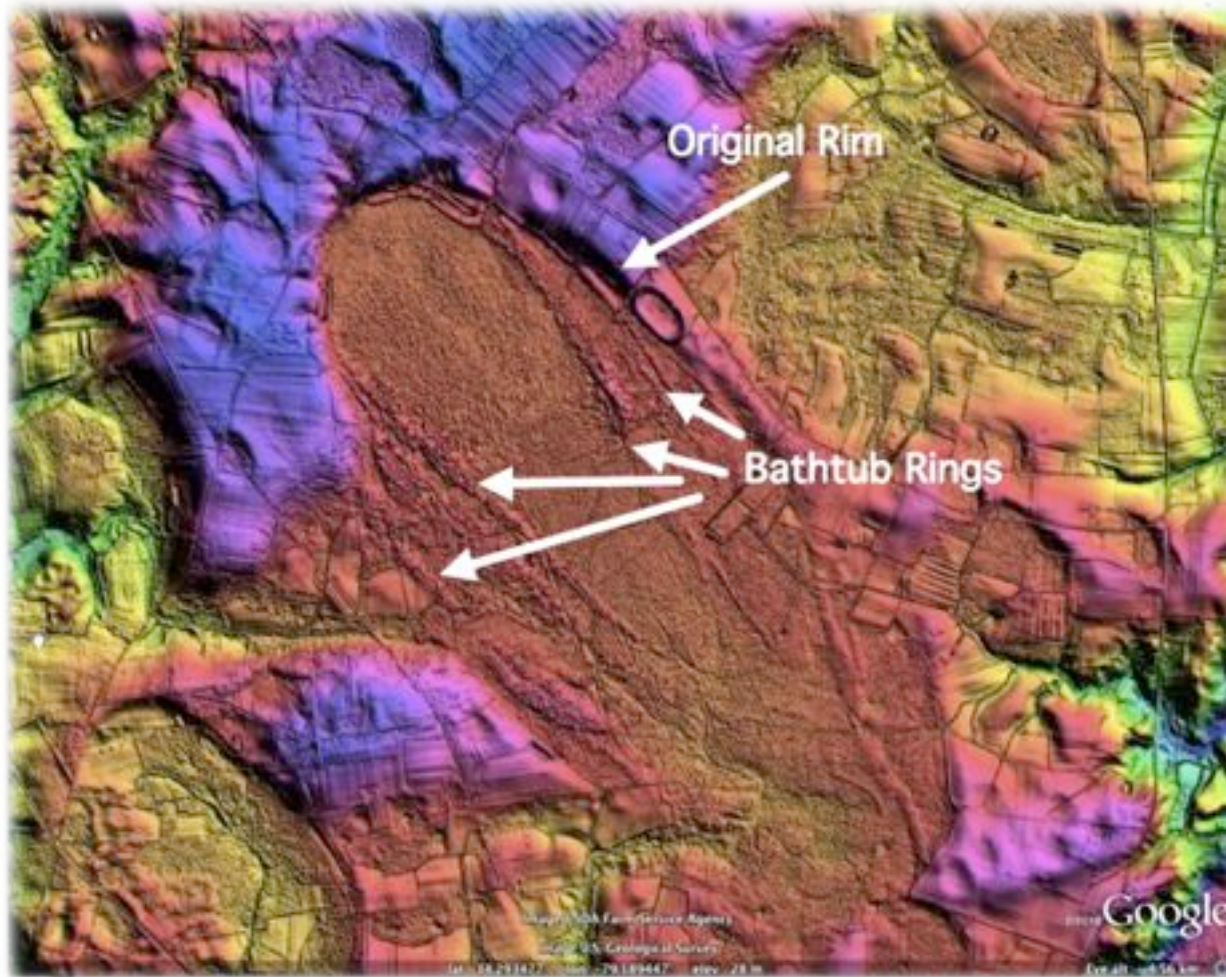
# Double-bay Wall
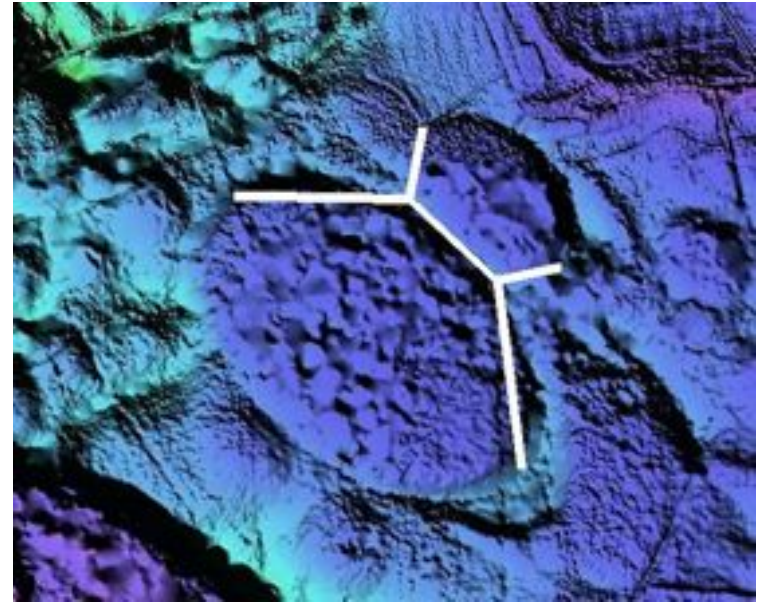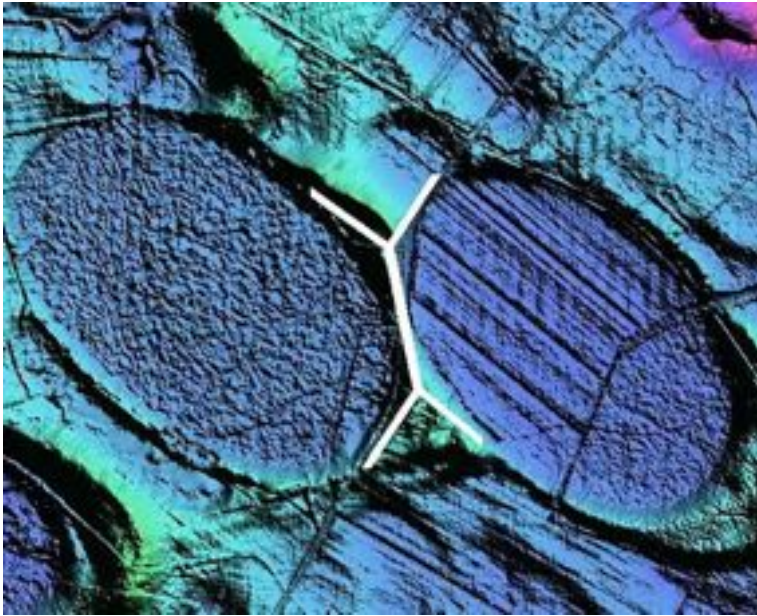




Occasionally, we find the bays in a paired arrangements.  Sometimes (as noted by Johnson), there is no intervening rim. We suggest this is mimicking the common bubble wall network geometry. The walls should ideally meet at 120º angles, if these were indeed "bubbles".
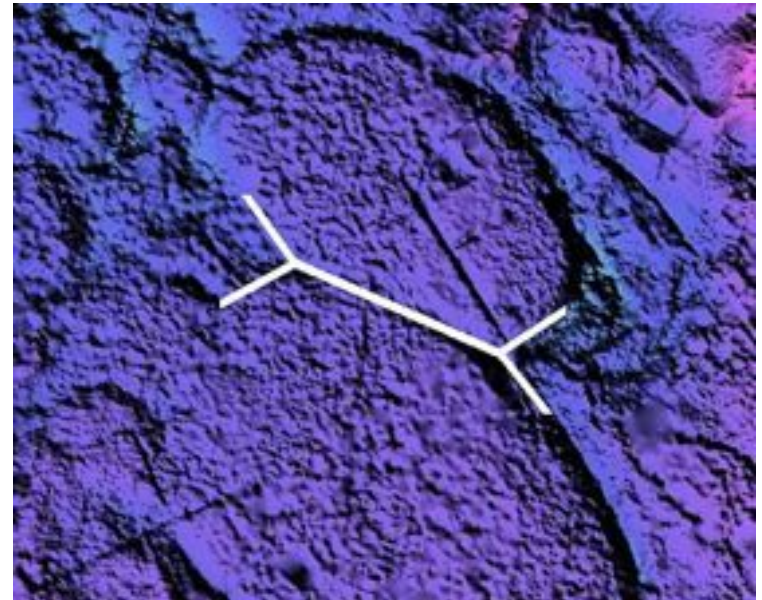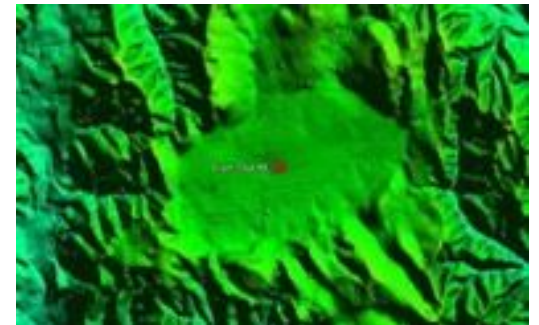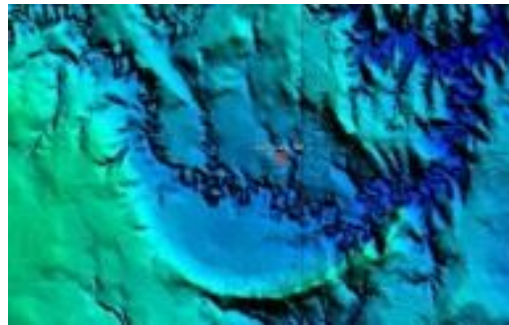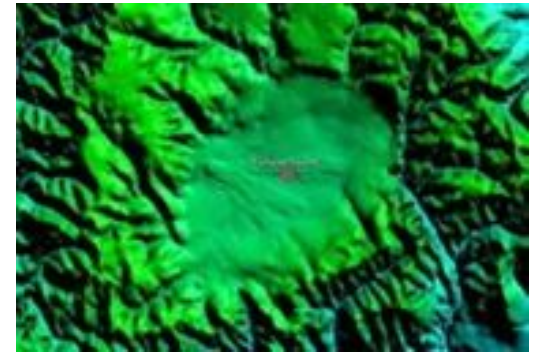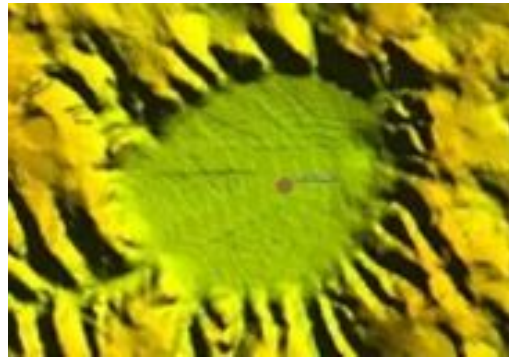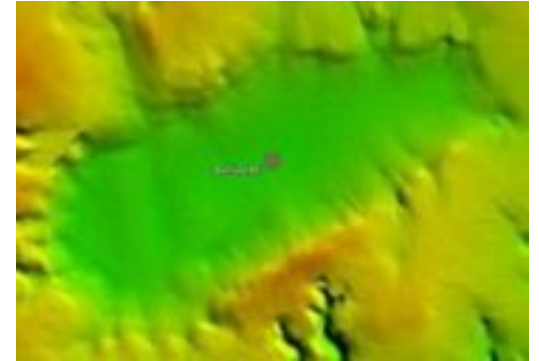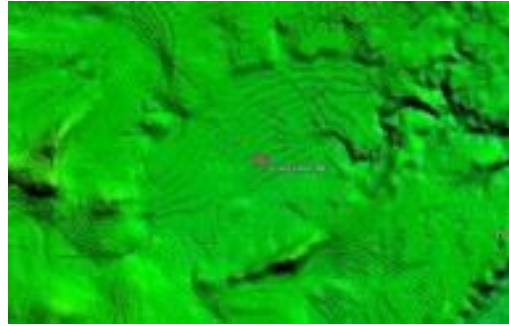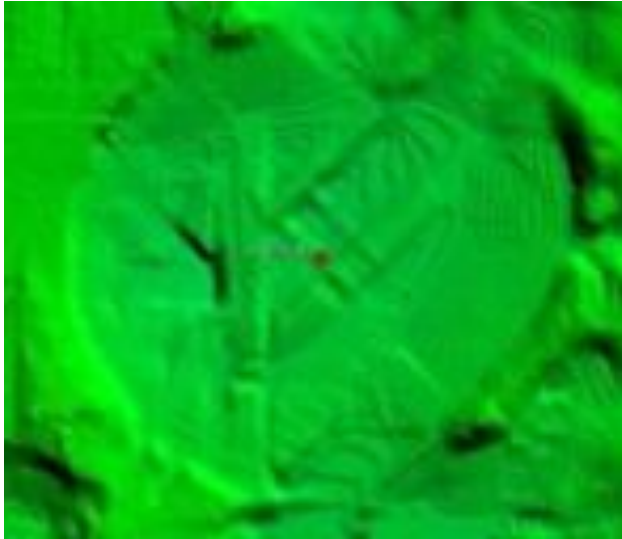
# Lacustrine Bathtub Rings



It would be expected that larger basins would host bodies of water. Occasionally we see artifacts considered by us to be "bathtub rings"- concentric rings within a bay rim, formed as the enclosed lake level receded. Correctly dating this assemblage would require discriminating between the two regimes of deposition.
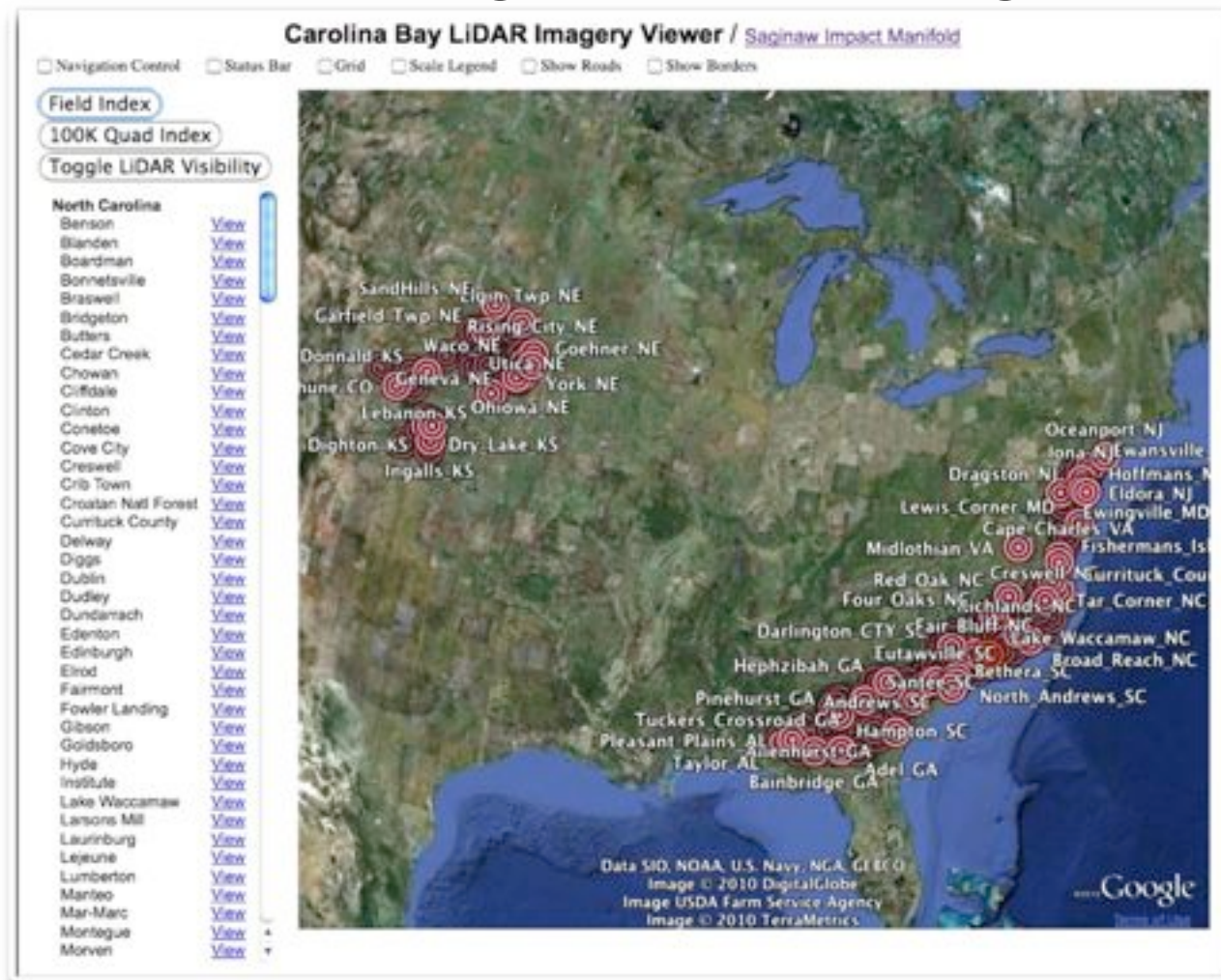
# Nebraskan Bays

# Round & Squashed Bays
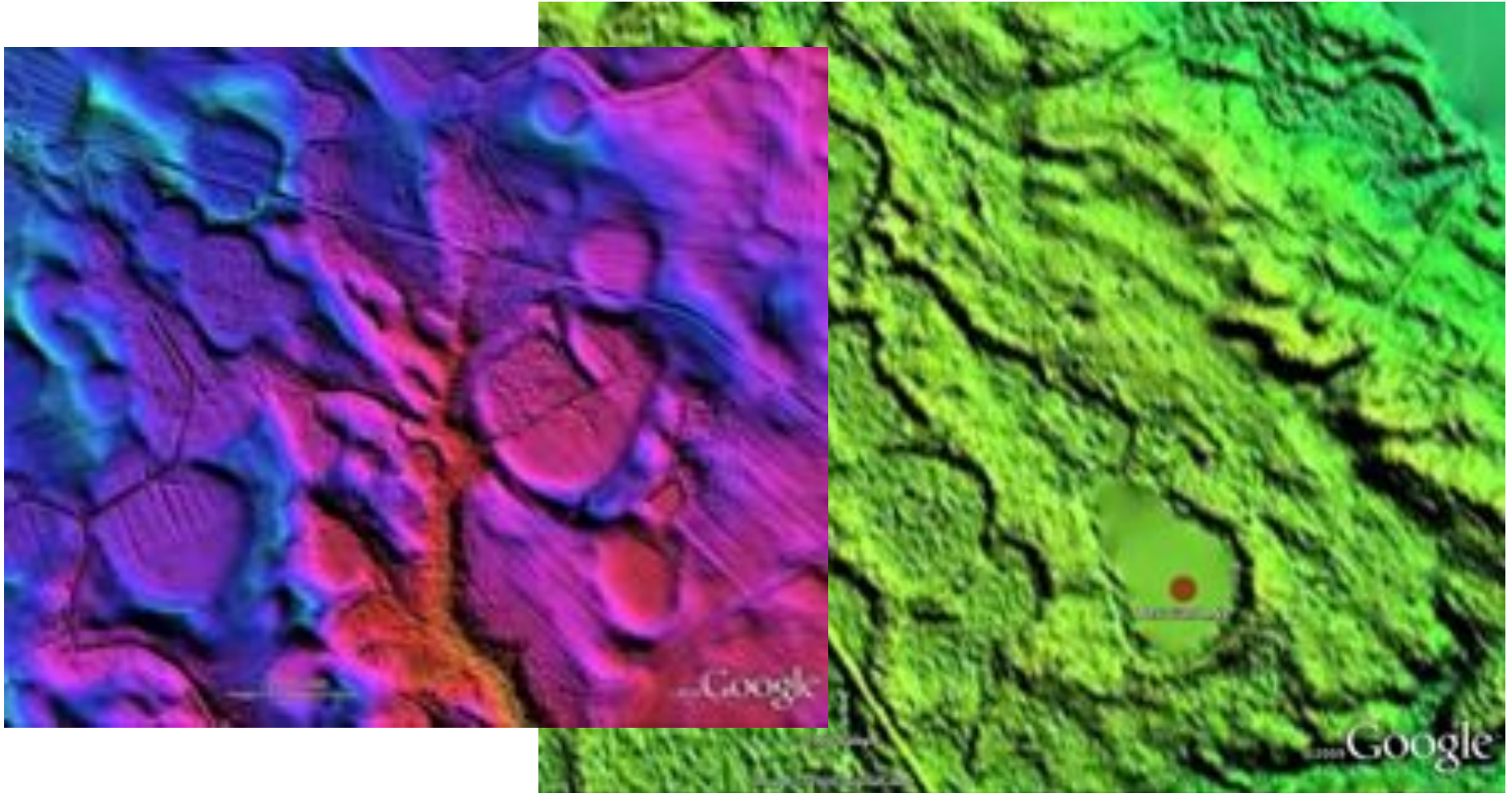


Here are LiDAR representations of bays in Maryland, Delware and New Jersey.  We propose these continue to be flowing in from the upper left (north-west), but are visualized as 'squashed" and abruptly halted. Challenging for our triangulation network, no doubt.

# LiDAR Integration with Google Earth



LiDAR imagery has been generated for our catalogue of 250 "fields", each typically containing dozens to hundreds of bays. The catalogue is available for you to view on line using a web browser with a Google Earth "Plug-in", although the same imagery is available for you in the Google Earth Application, if you prefer. See http://cintos.org/LiDAR
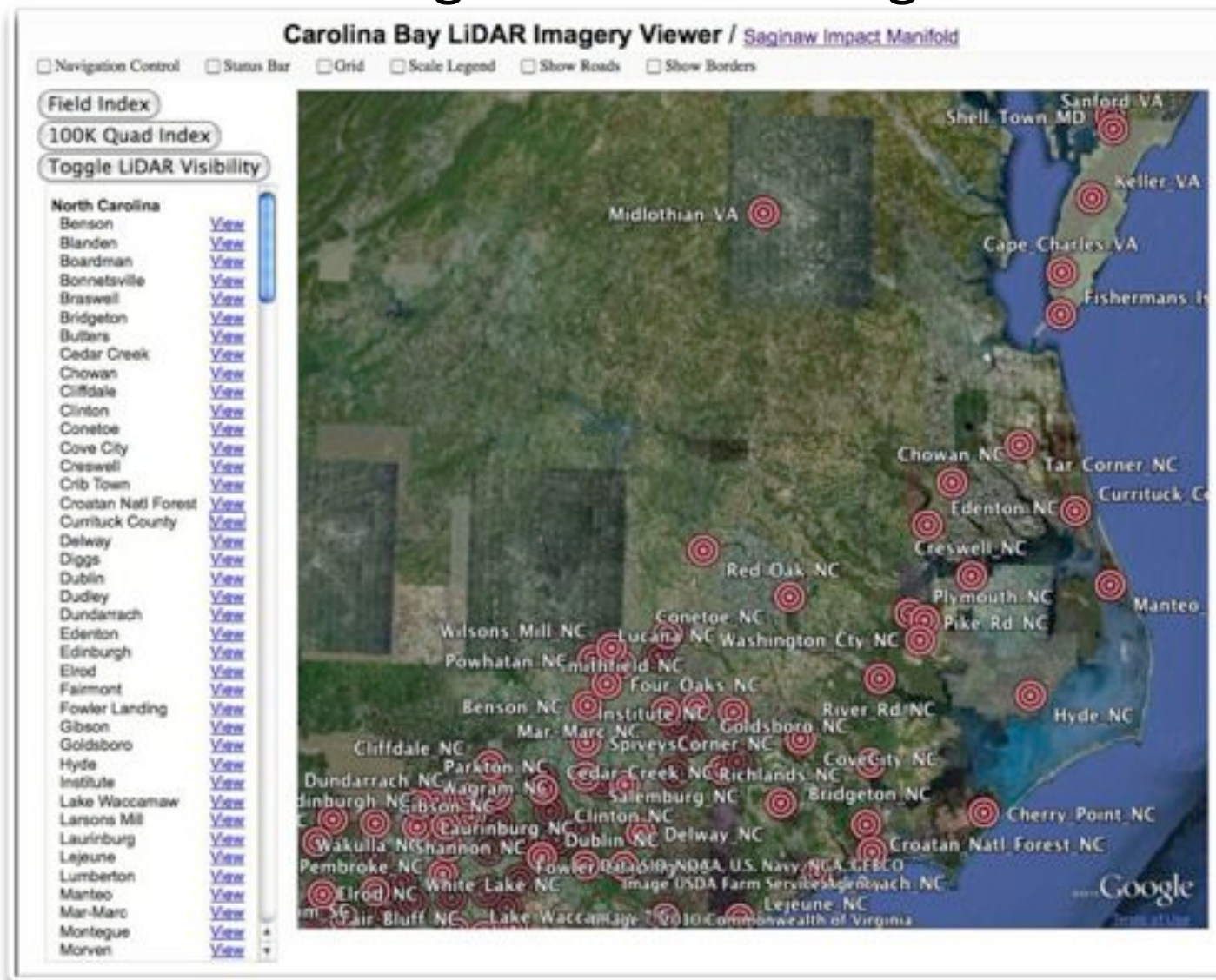
# LiDAR Integration with Google Earth



As the LiDAR Loads, the virtual globe rotates and zooms to put the KML overlay into focus

# LiDAR Integration with Google Earth
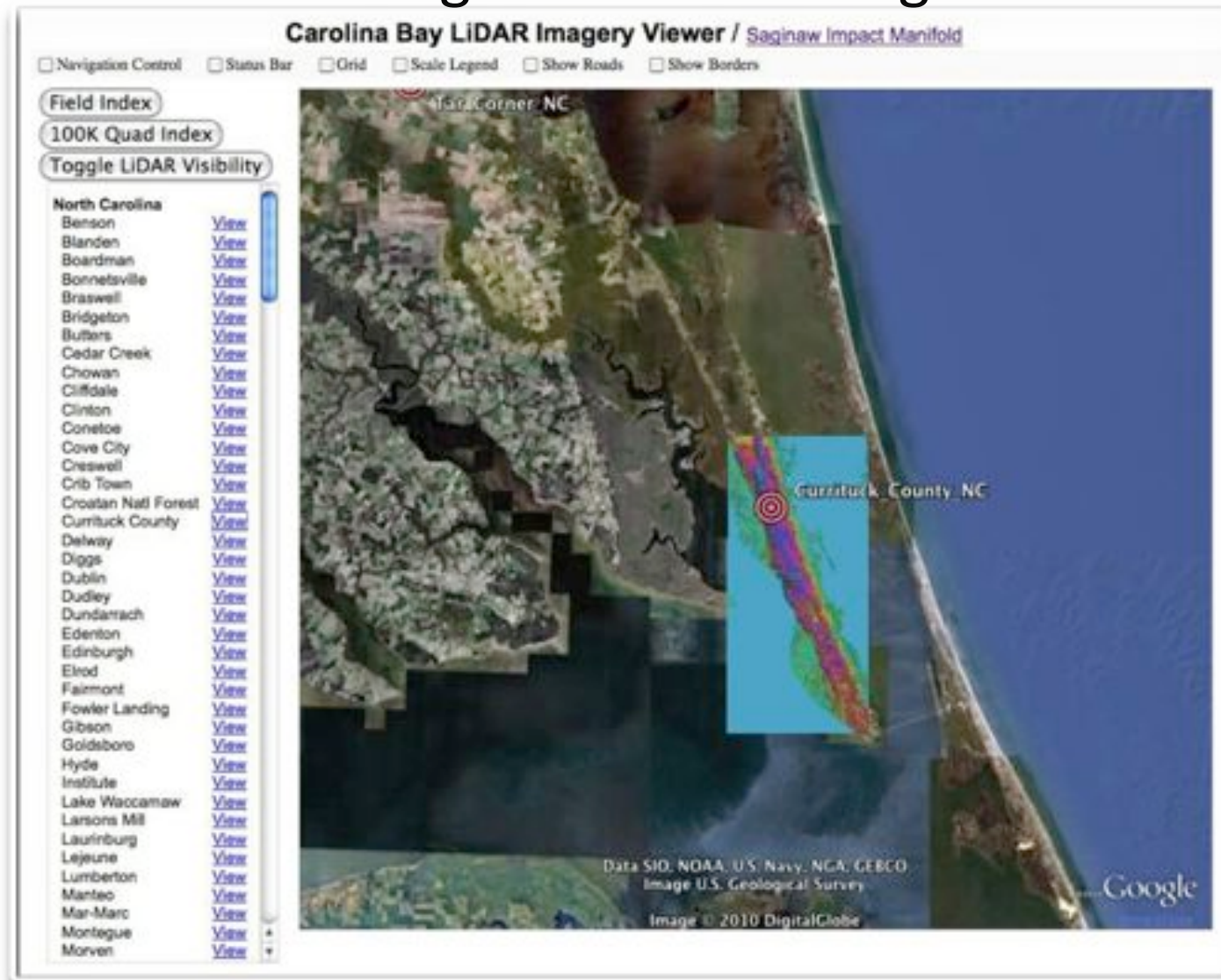


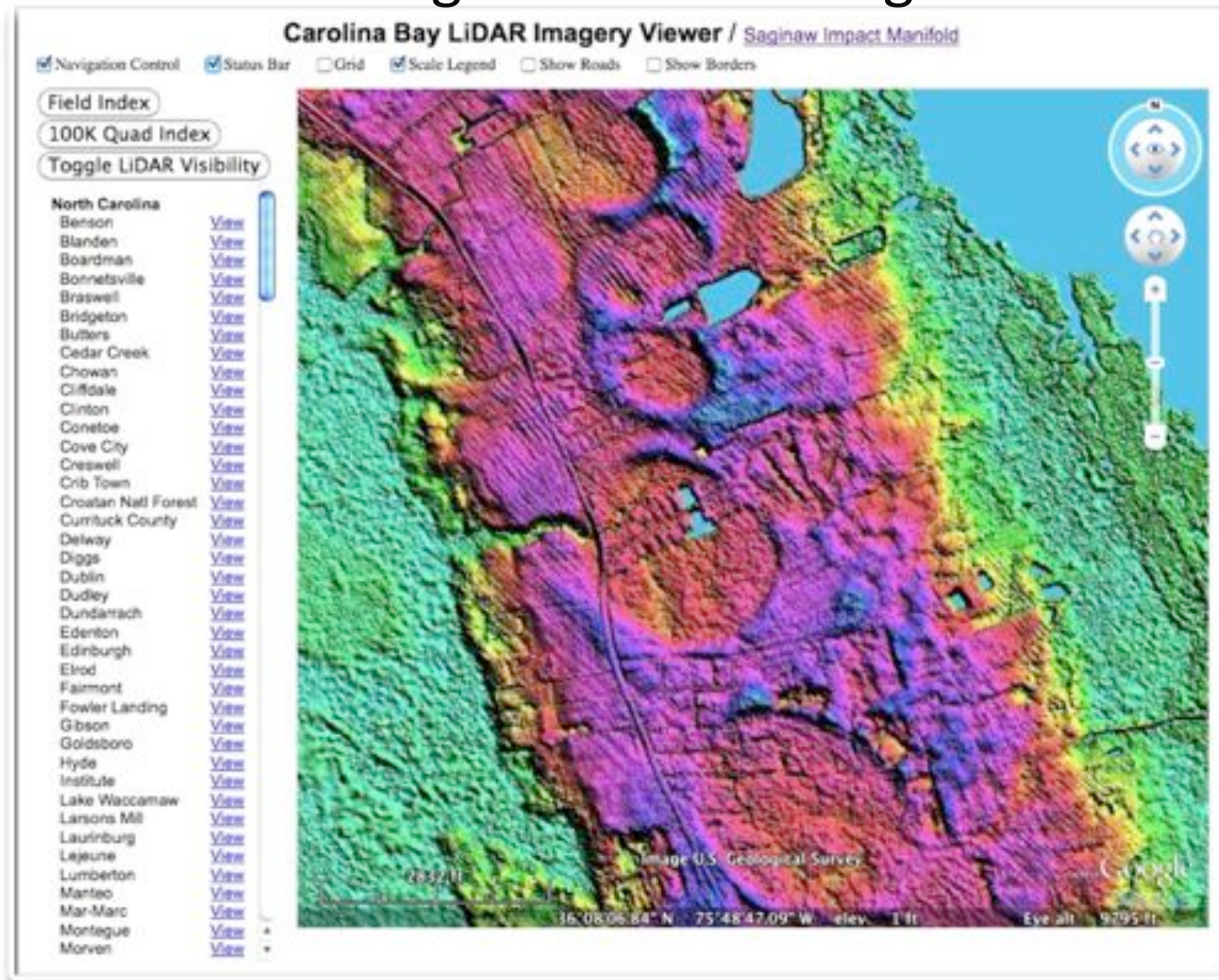As the LiDAR Loads, the virtual globe rotates and zooms to put the KML overlay into focus

# LiDAR Integration with Google Earth



As the LiDAR Loads, the virtual globe rotates and zooms to put the KML overlay into focus
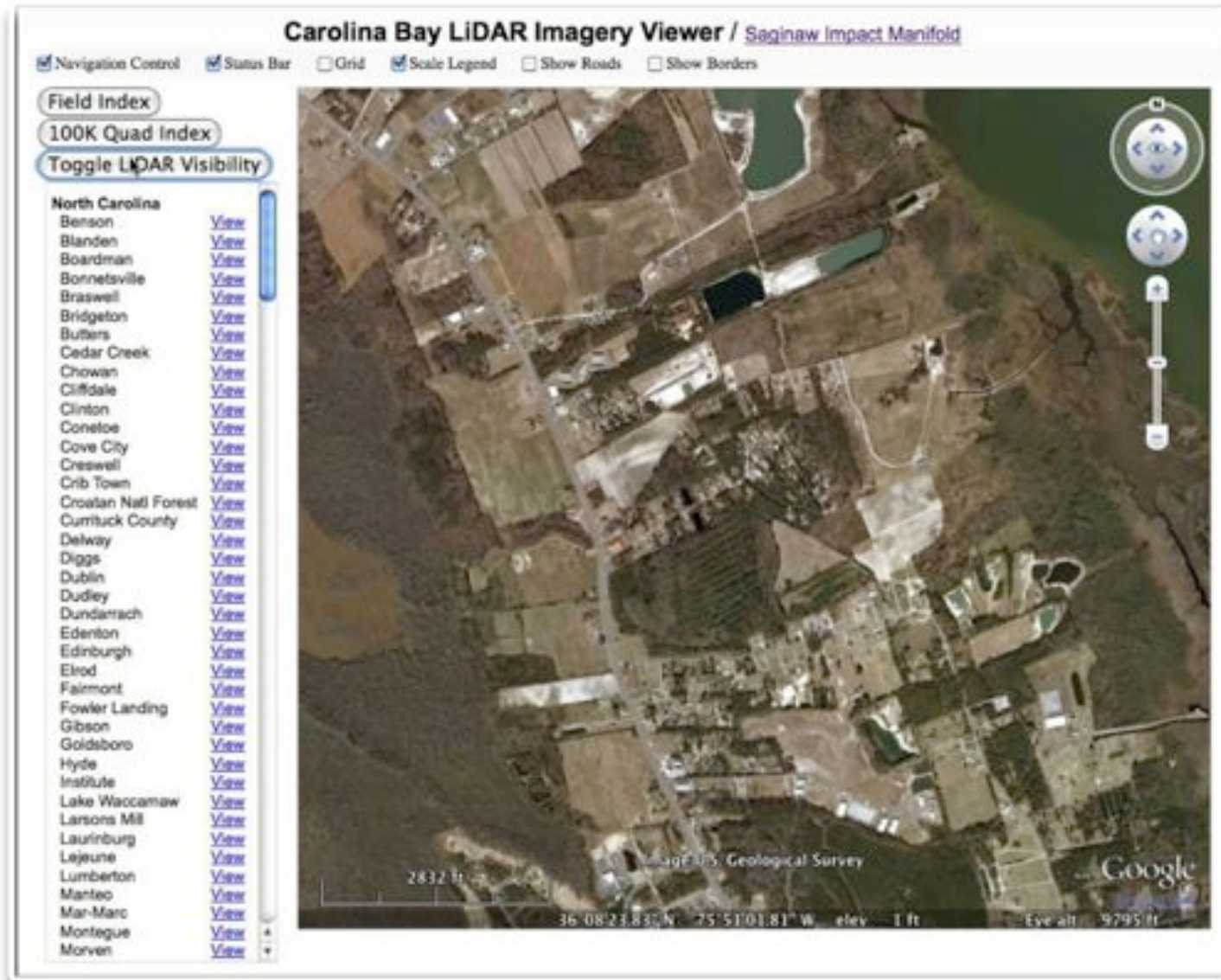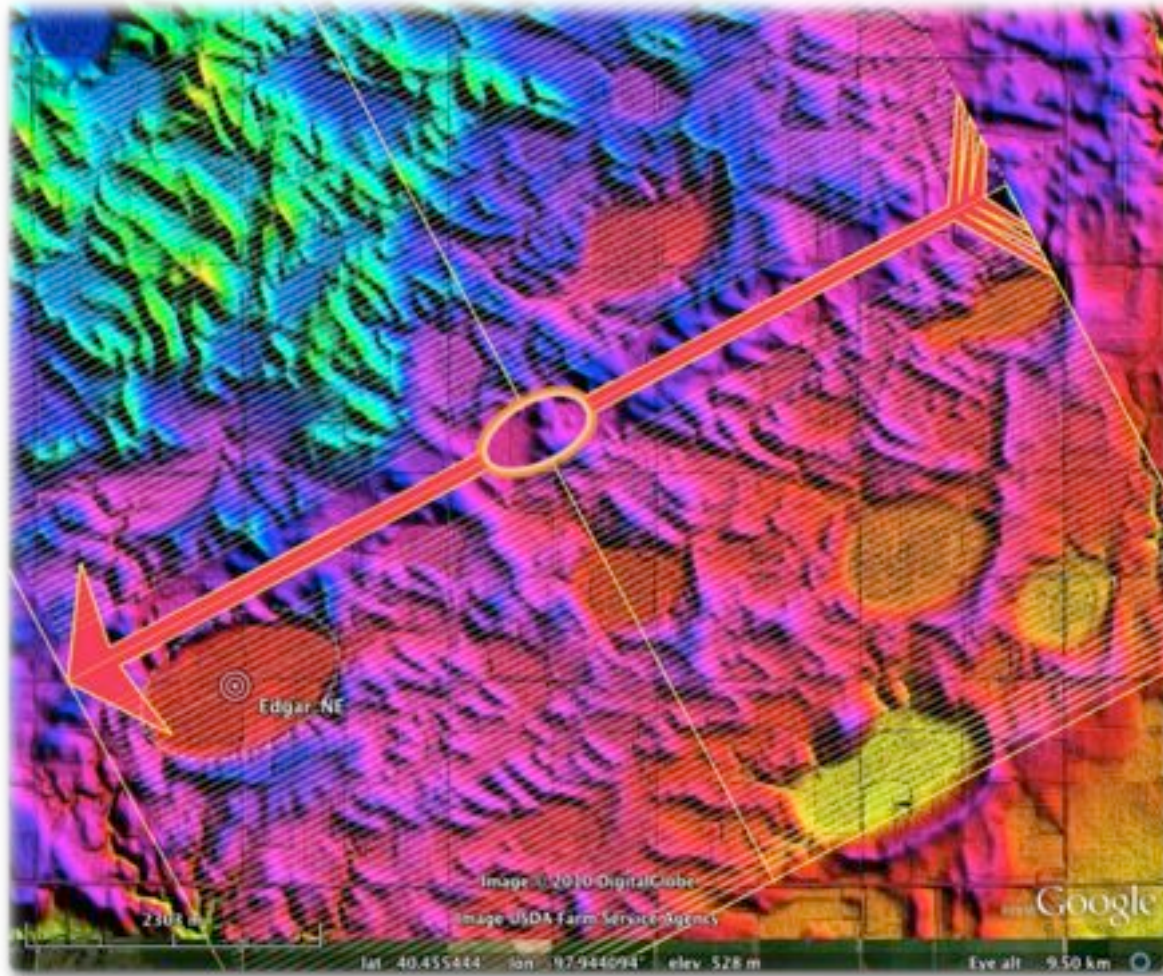
# LiDAR Integration with Google Earth



A "Toggle" button allows turning off the overlay to display the Google Earth satellite imagery., where the bays are often hard to visualize.

# Capturing Alignment with Overlay



To capture the orientation of an entire field of bays, we position a transparent overlay on the virtual globe, and using the edit controls, size it and rotate it to best represent the prevailing orientation. This example, from the area around Edgar, Nebraska, also demonstrates how linear dunes are slowly filling the basins from the northwest.

# Planform – New Image Overlay
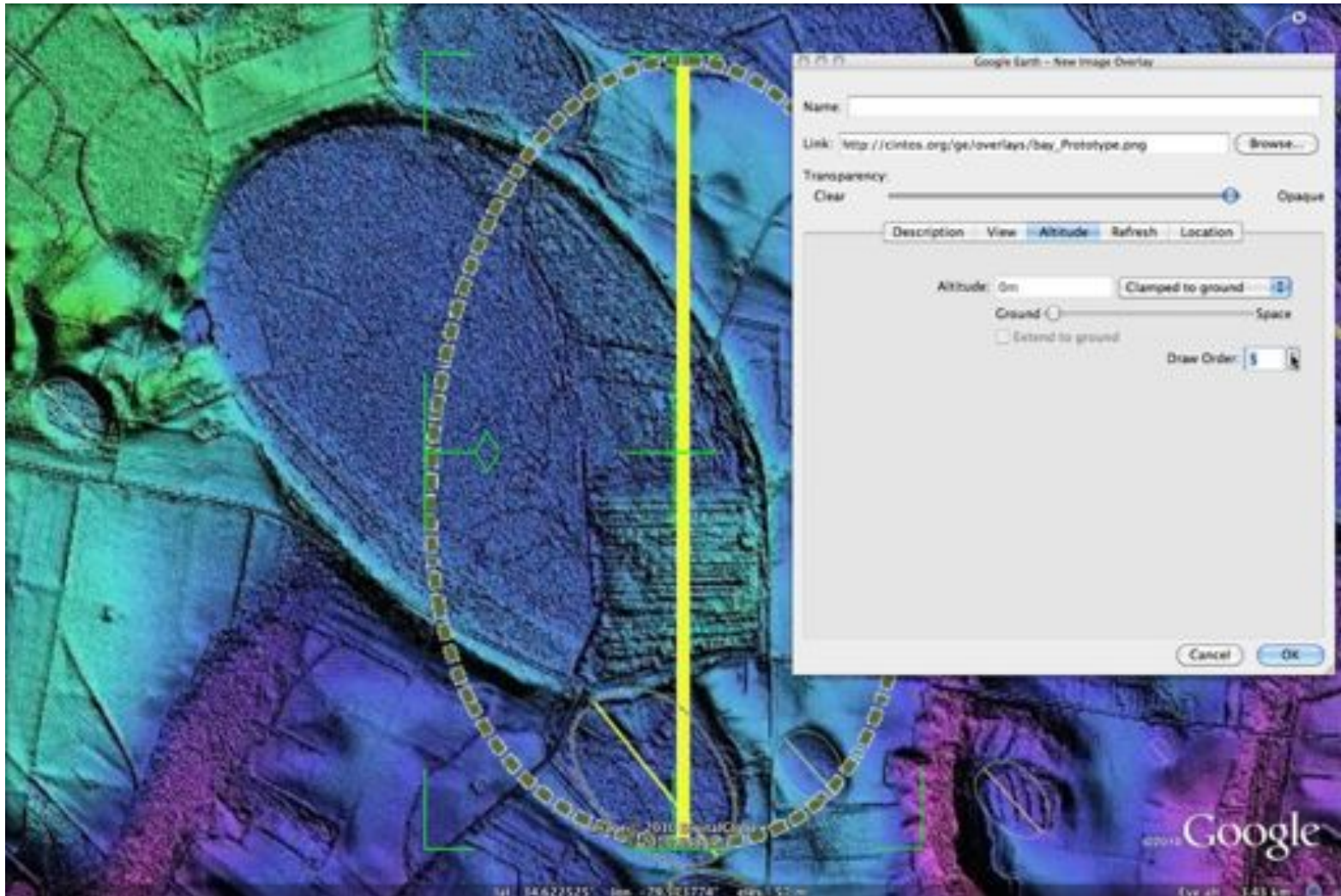


An individual bay's orientation can similarly be captured - here using an overlay representing the archetype central Carolina bay planform. Default orientation is due north.

# Planform Overlay
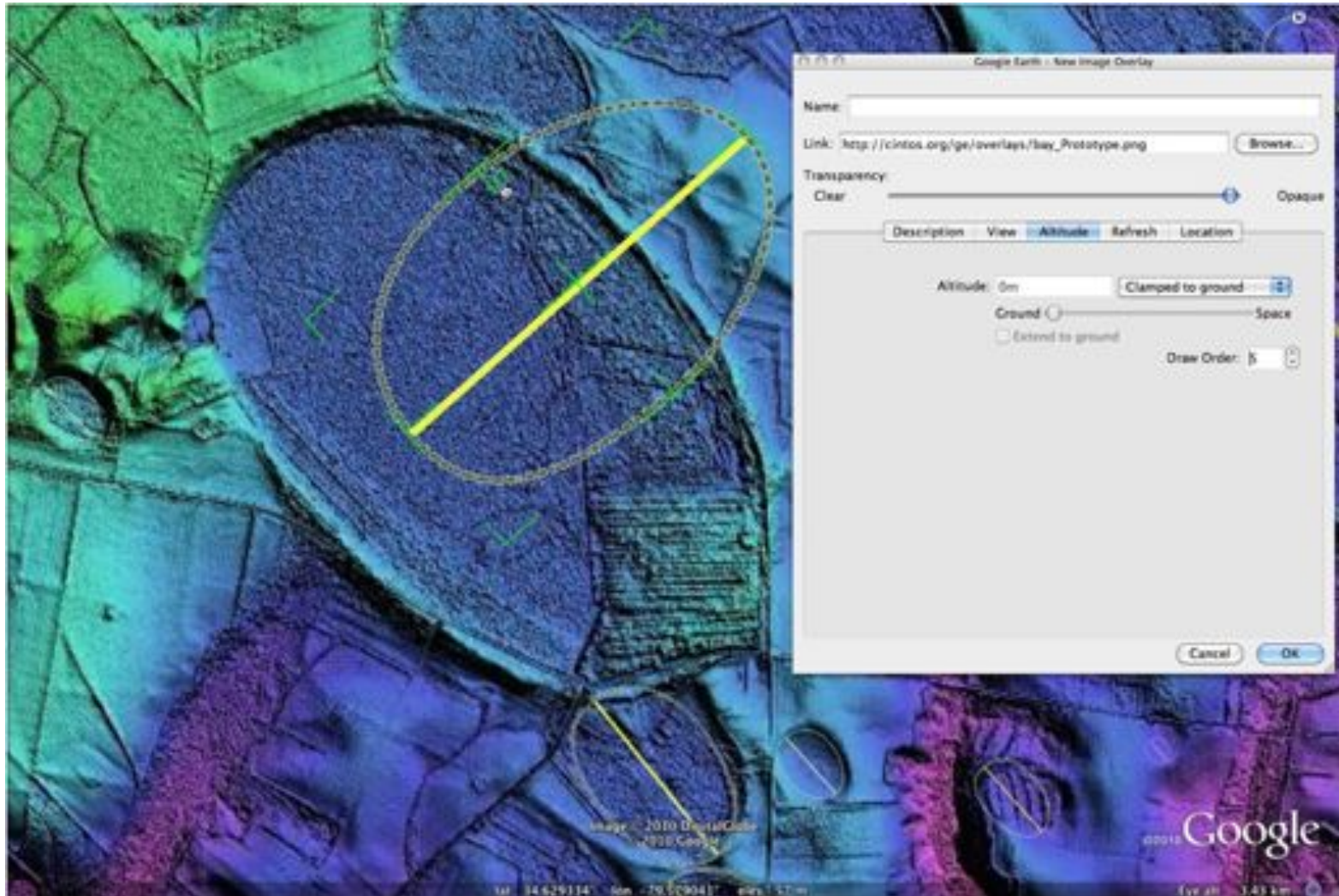


The overlay is rotated and sized to the outline of the bay's actual rim.
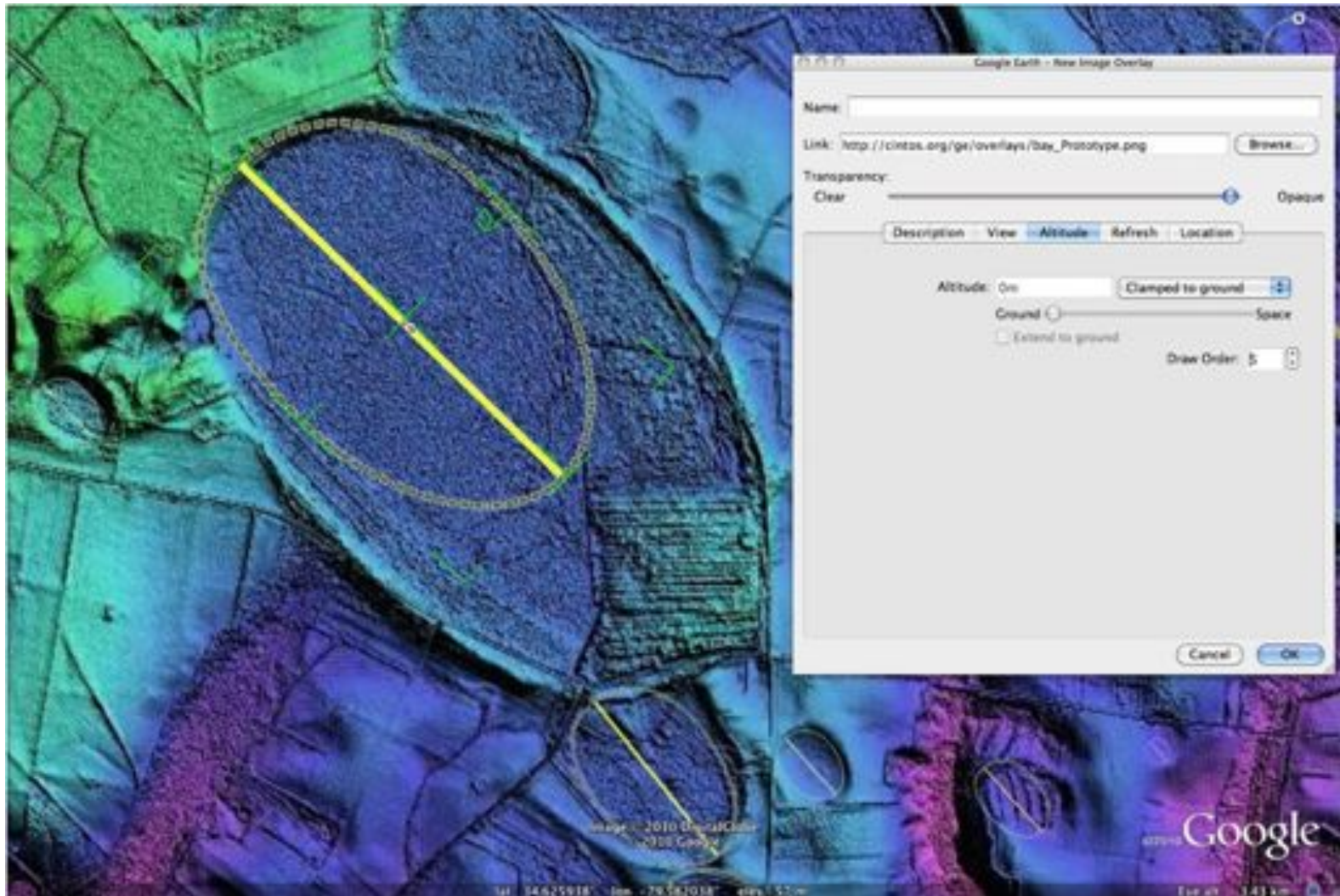
# Planform Overlay



The overlay is rotated and sized to the outline of the bay's actual rim.
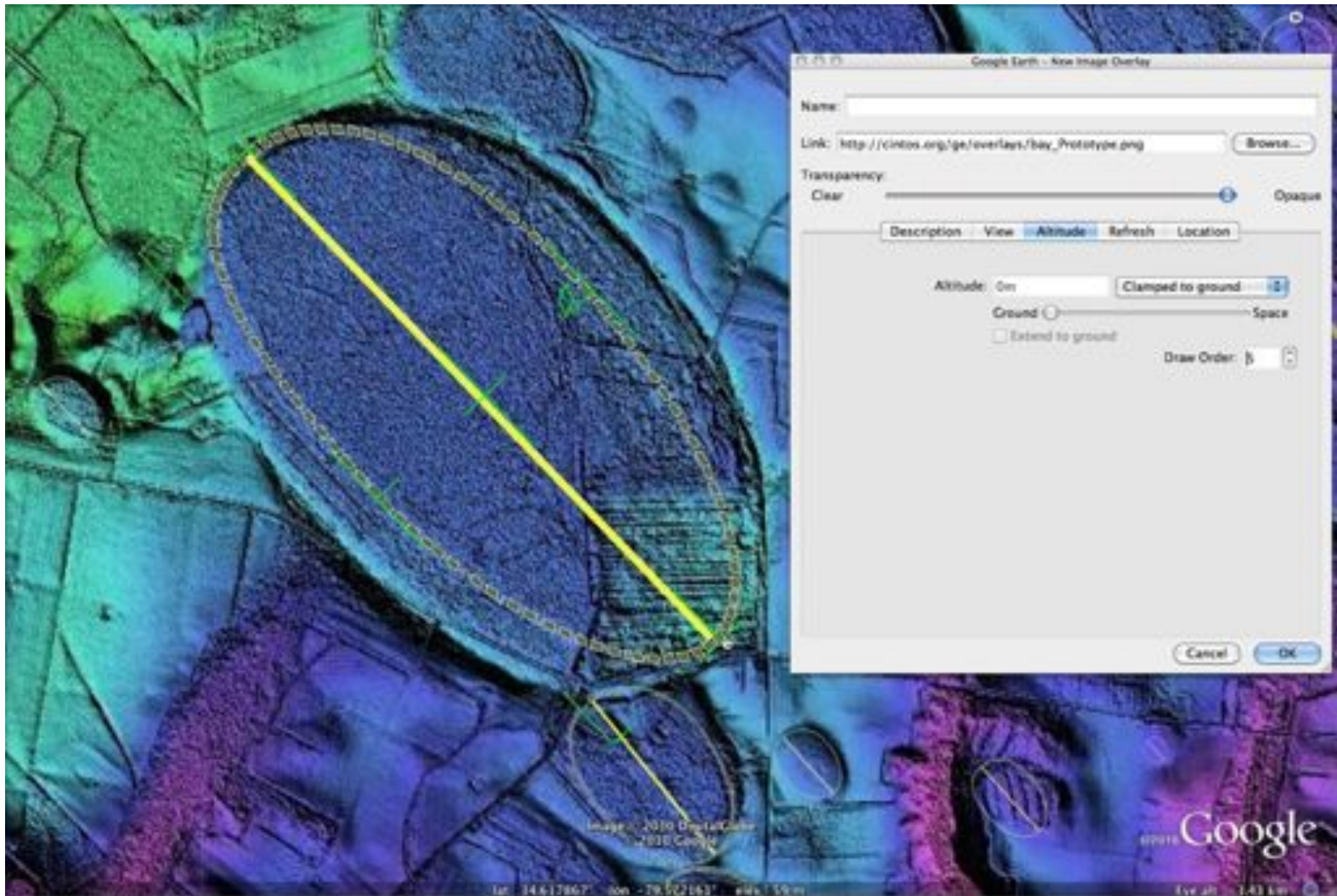
# Planform Overlay



Orientation of bays is tightly constrained in any give area.

# Planform Overlay
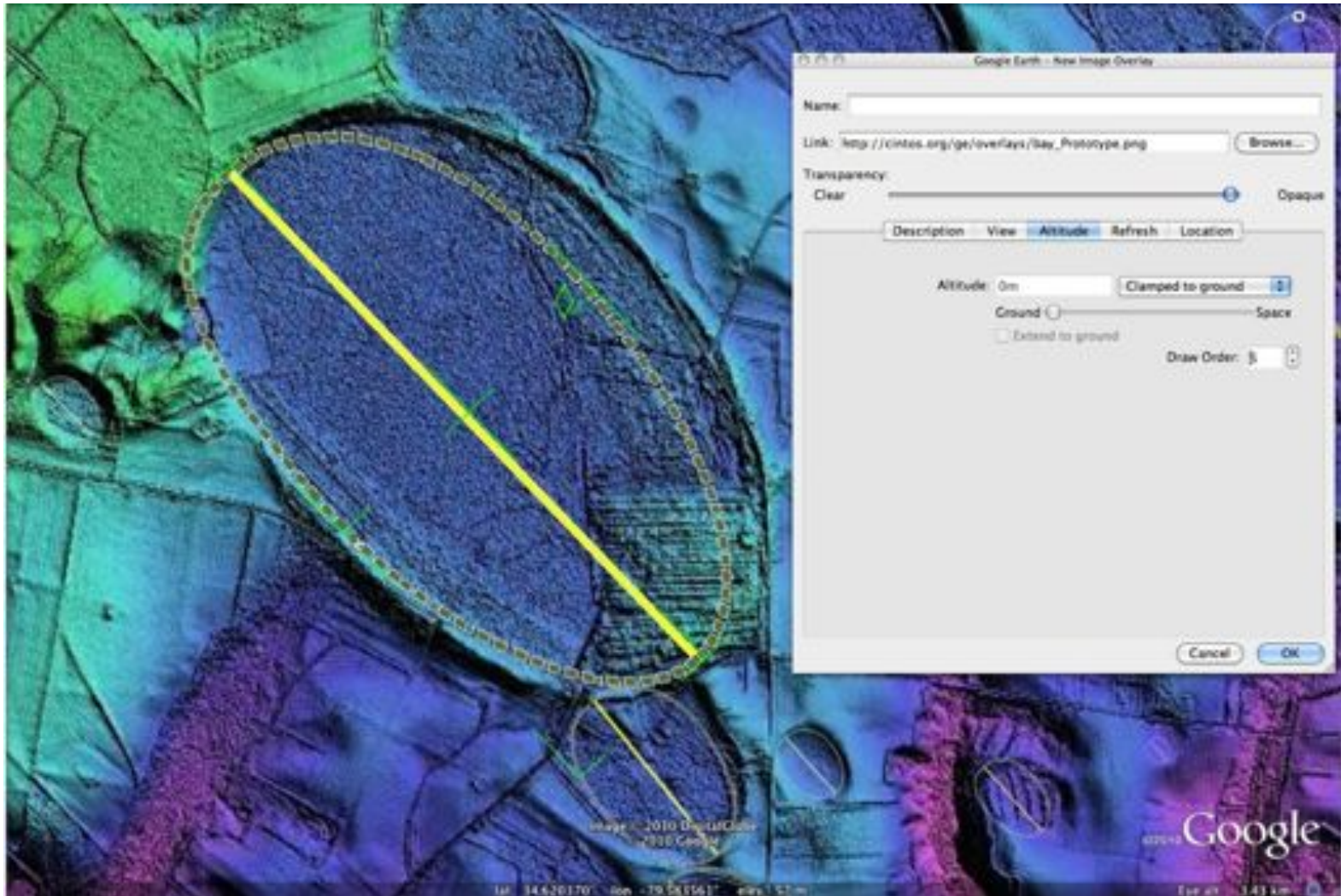


We note that there are tens of thousands of bays which are crisply represented by this particular overlay. "Cookie Cutter" geomorphology.

# Planform Overlay
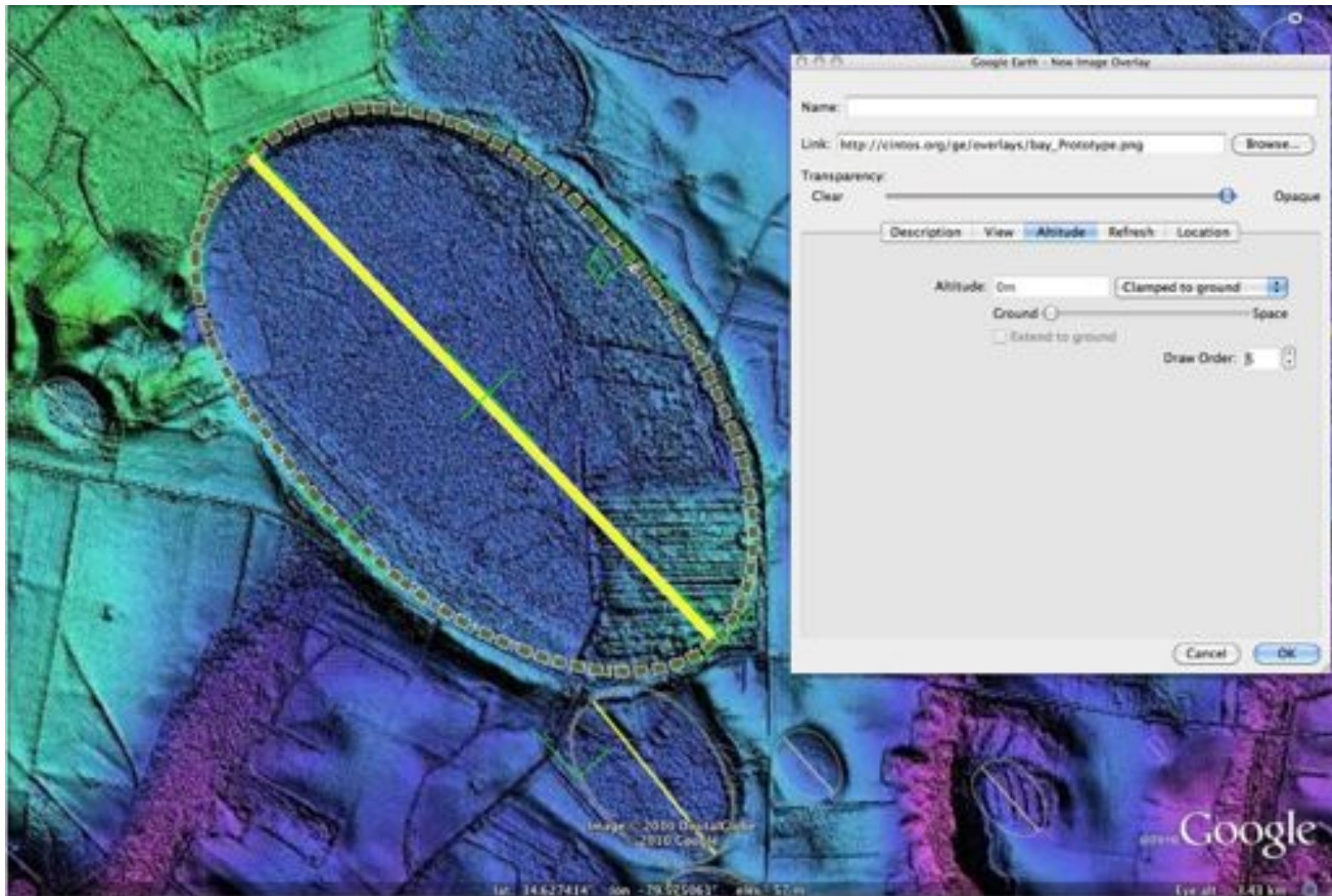


Spatial sizes vary considerably. Length/width ratio tightly constrained.

# Overlay Given a Name
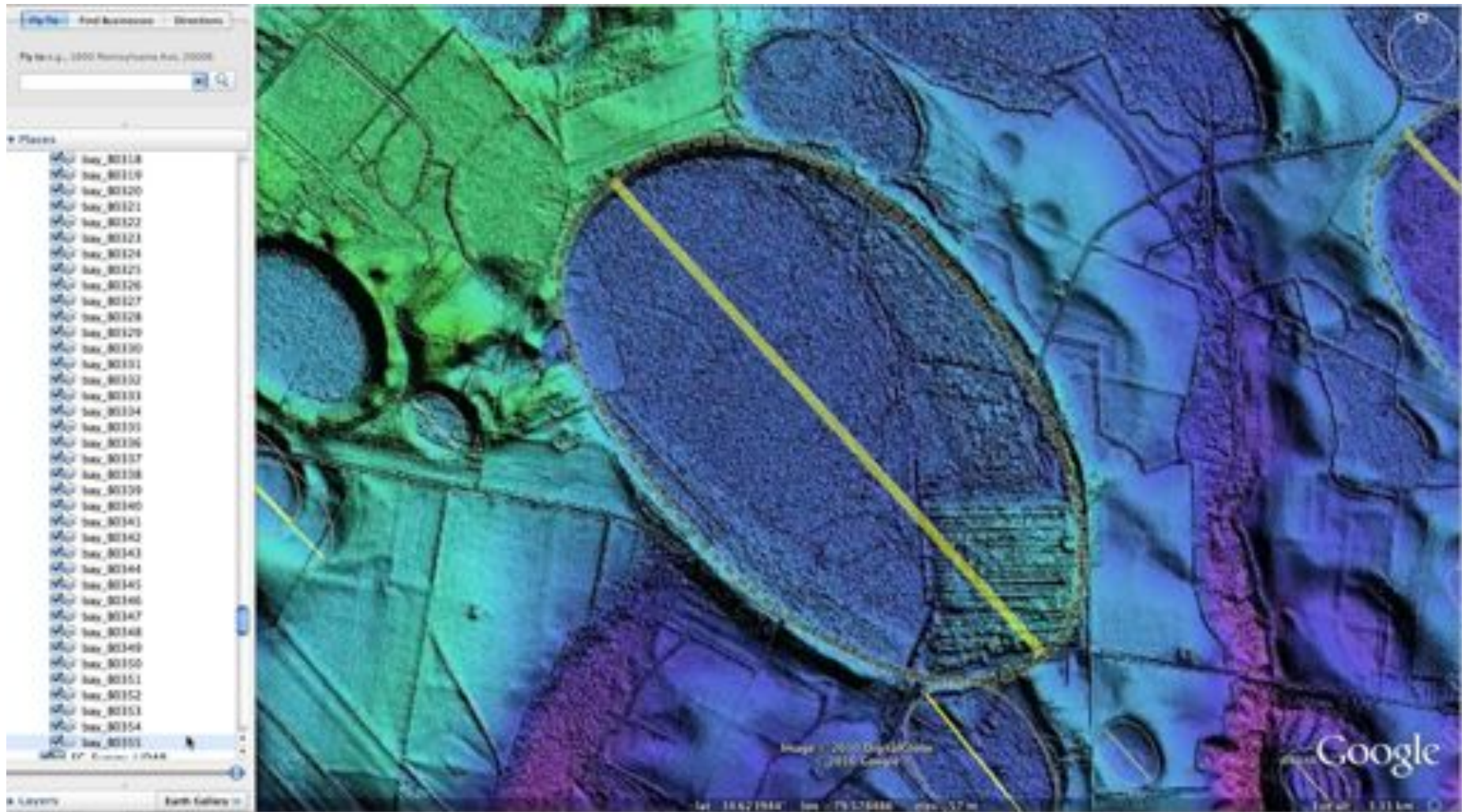


With a bit of fine tuning, a very snug fit is obtained! We give the overlay a name, and it appears in the object directory. That object can be copied, as it is comprised of a series of meta data elements in the kml text format.

# KML Meta Data in Overlay

- <GroundOverlay>
- <name>bay_B0355</name>
- <Icon>
- <href>http://cintos.org/ge/overlays/bay_Prototype.png</href>
- <viewBoundScale>0.75</viewBoundScale>
- </Icon>
- <LatLonBox>
- <north>34.63252148936107</north>
- <south>34.61506906232364</south>
- <east>-79.57293257637467</east>
- <west>-79.58581679997867</west>
- <rotation>-135.2369396039304</rotation>
- </LatLonBox>
- </GroundOverlay>

Placing this in a text editor, we see the overlay carries information which can be extracted: from the bounding box latitudes and longitudes we can calculate the length of the major and minor axis as well as the general bay surface area. The rotation angle from due north is given directly.

# Survey, bay-by-bay
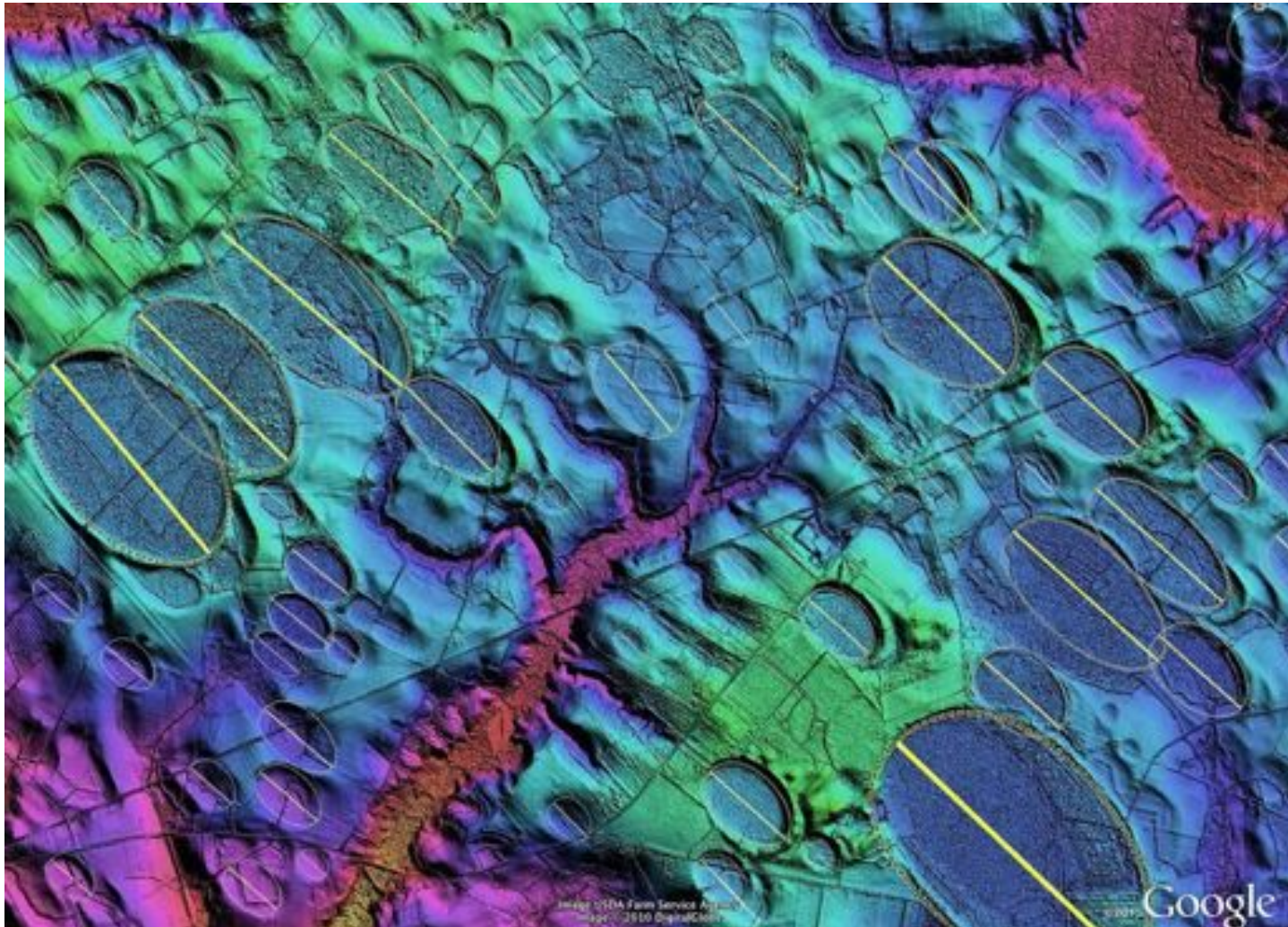


A survey has been undertaken to attempt the identification and planform capture from all identified Carolina bays.

# Meta Data Processed into Spreadsheet

| Name | Axis | Axis | Ratio | Area | Latitude | Longitude | Bearing |
|---|---|---|---|---|---|---|---|
| bay_A00031 | 0.0771 | 0.0651 | 1.1843 | 0.3938 | 34.6149 | -79.5588 | 138.15 |
| bay_A00075 | 0.1278 | 0.0949 | 1.3470 | 0.9521 | 34.5950 | -79.5457 | 143.48 |
| bay_A00024 | 0.1279 | 0.1046 | 1.2226 | 1.0506 | 34.6041 | -79.5803 | 141.25 |
| bay_A00023 | 0.1380 | 0.1122 | 1.2300 | 1.2160 | 34.6057 | -79.5814 | 138.57 |
| bay_A00068 | 0.1559 | 0.0999 | 1.5599 | 1.2238 | 34.5640 | -79.5532 | 143.48 |
| bay_A00069 | 0.1559 | 0.0999 | 1.5598 | 1.2238 | 34.5616 | -79.5408 | 143.48 |
| bay_A00076 | 0.1572 | 0.1043 | 1.5076 | 1.2880 | 34.5971 | -79.5390 | 143.48 |
| bay_B0081 | 0.1647 | 0.1037 | 1.5887 | 1.3416 | 34.7264 | -79.6825 | 141.09 |
| bay_A00057 | 0.1636 | 0.1053 | 1.5542 | 1.3532 | 34.5620 | -79.5183 | 142.44 |
| bay_B0296 | 0.1515 | 0.1177 | 1.2872 | 1.4001 | 34.6431 | -79.6113 | 134.66 |
| bay_A00054 | 0.1672 | 0.1086 | 1.5394 | 1.4272 | 34.5804 | -79.5223 | 142.44 |
| bay_B0113 | 0.1578 | 0.1250 | 1.2617 | 1.5491 | 34.6799 | -79.5285 | 136.58 |

A Java program is used to parse a folder of bay overlays and generate metrics in tab delimited format for use in a spreadsheet. Here is a range of bays sorted by surface area

# Survey Graphs
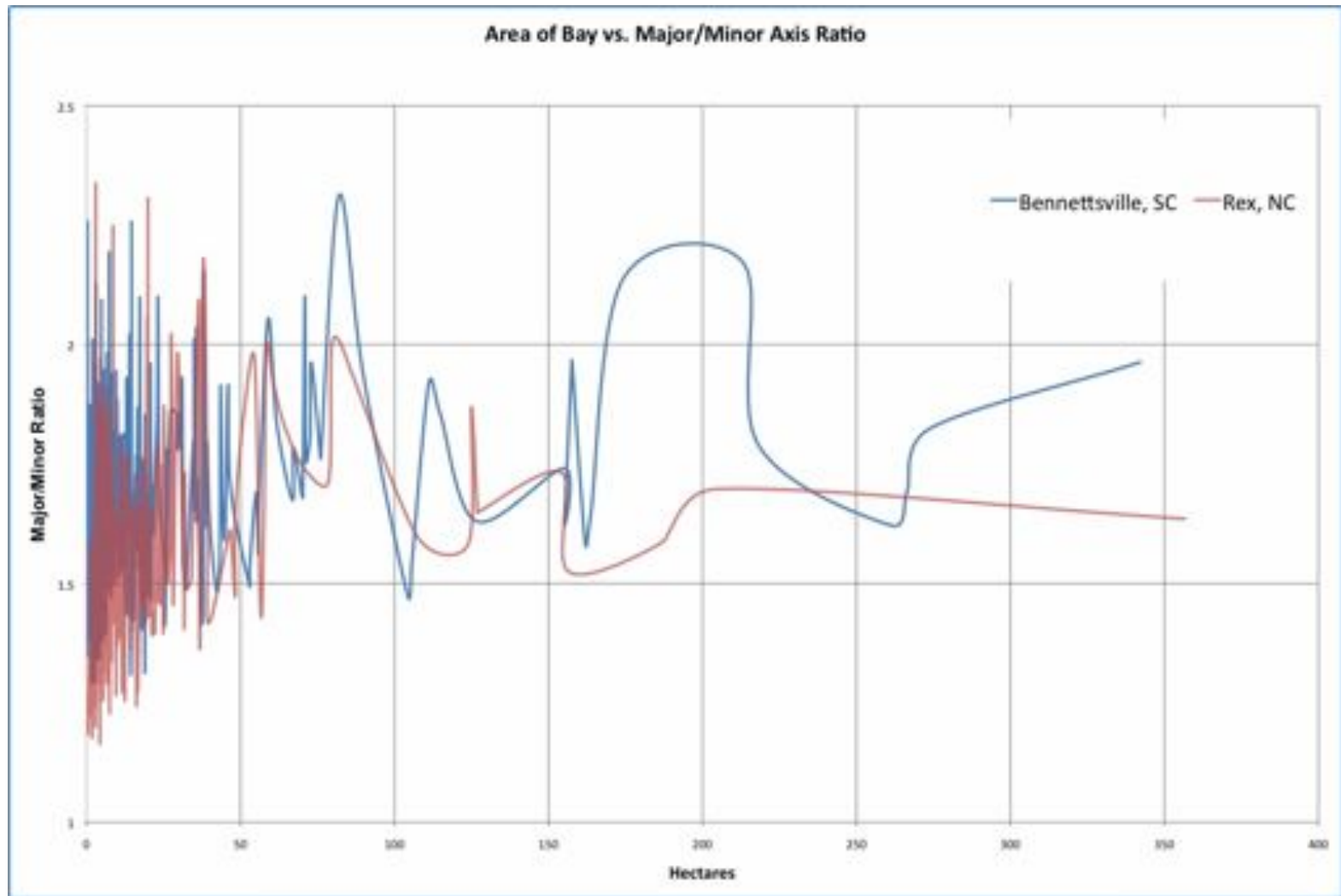


Here is a graph generated using results from two regions– representing a total of about 900 bays. Clearly the Major/minor axis ratio is tightly constrained, even across the full range of bay sizes from 1 hectares out over 300

# Survey Graphs



This histogram shows the quantity of bays by surface area.
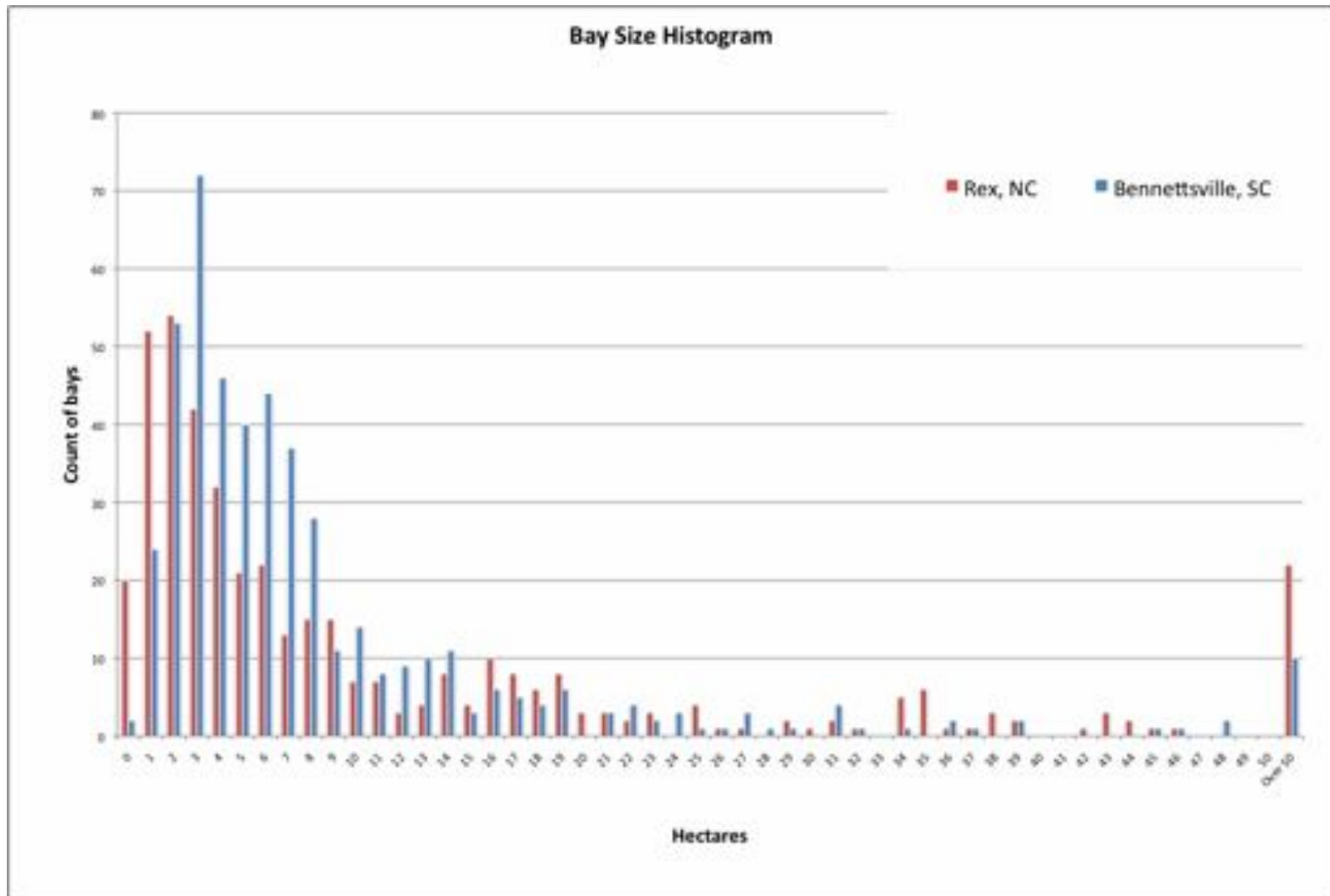
# Geospatial Distribution Test

Graphic displays geospatial extent of bays in survey, and a graph of flight distances from our proposed impact site.
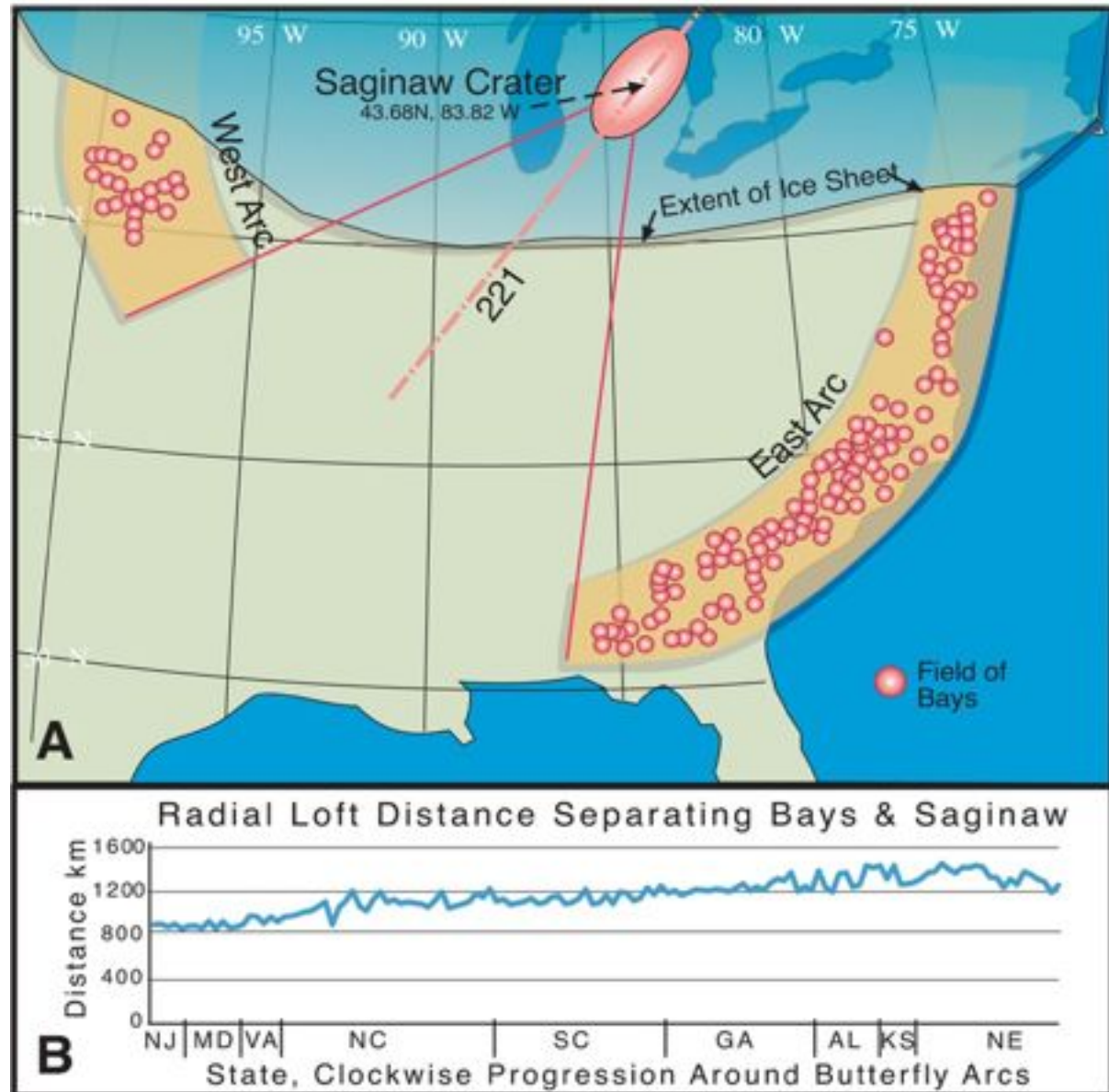
# Summary

- Integrated LiDAR DEM images into Google Earth
- Identified and Documented ~ 250 *Fields* of Bays
  - Locations
  - Inferred Arrival Bearings
  - LiDAR Imagery
- Captured Individual bay Metrics
  - Location
  - Major & Minor Axis
    - Size
    - Elongation ratio
  - Orientation
- Correlated Alignments using Java Calculator

Our work gives us to a better sense of the hypothesis's merit, but accomplishing the necessary ground-proofing will require skills and efforts well beyond our capabilities. We encourage others to consider evaluation of the bay rim sand in the context of our proposal.

Thank you for your attention!

# Rex, NC Area LiDAR
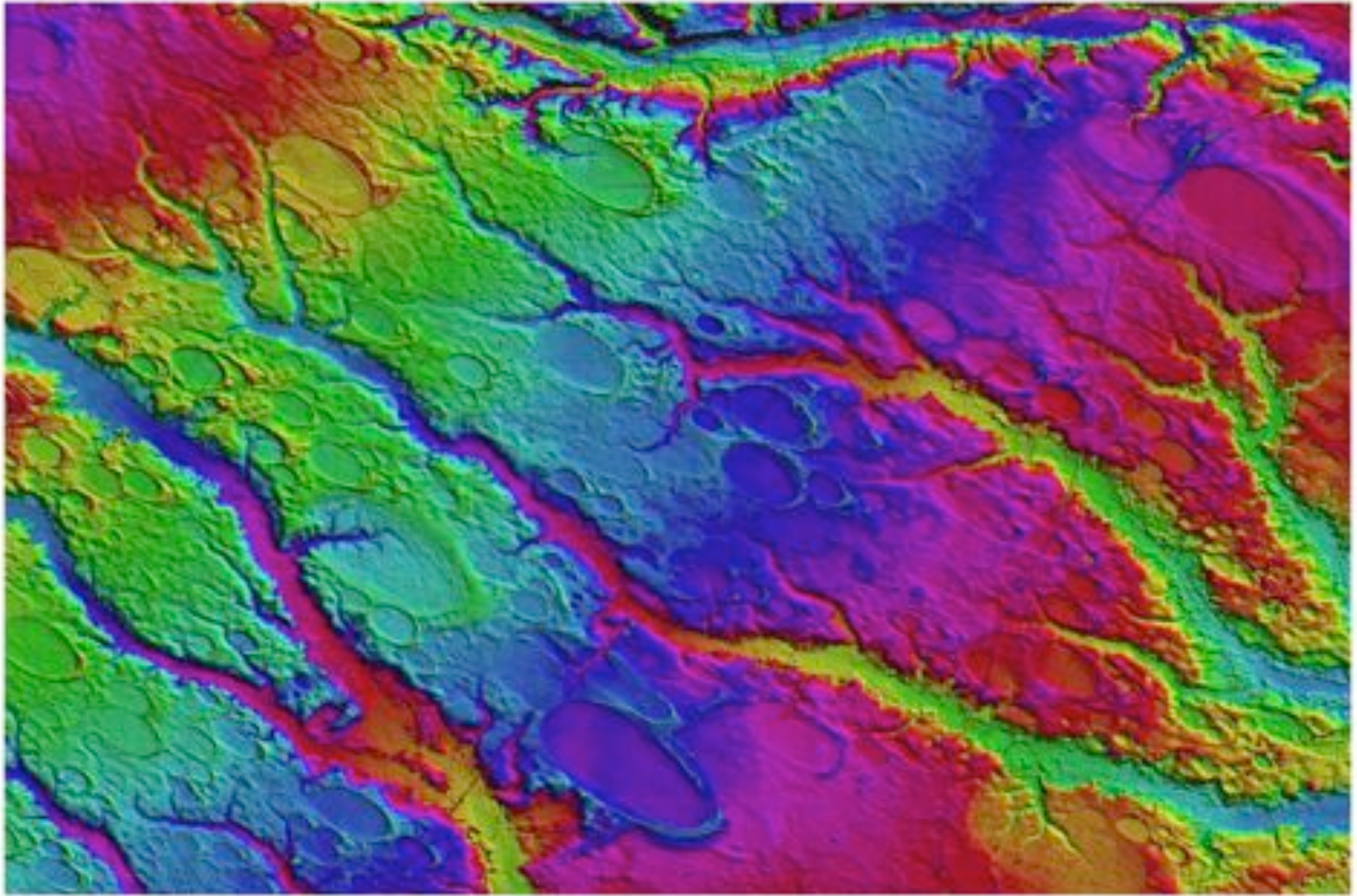


Abstract Geological Image category winner, Meeting's Photography Exhibition.