LIDAR DIGITAL ELEVATION MAPS EMPLOYED IN CAROLINA BAY RESEARCH

NEW VIEW OF THE PIEDMONT'S SURFICIAL GEOLOGY USING GOOGLE EARTH'S VIRTUAL GLOBE

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THE GEOLOGICAL SOCIETY OF AMERICA®

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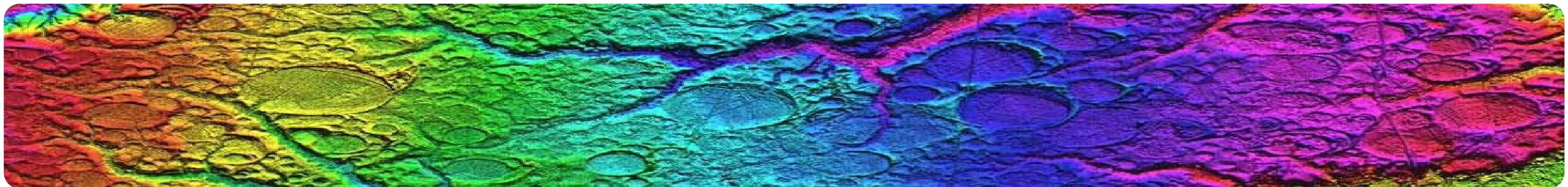

Greetings:

My thanks to those in attendance here, and to the GSA, for the opportunity to share some of the remote sensing techniques and resources we have applied in researching Carolina bay landforms, with emphasis on exploring the region beyond the coastal plain. We will also be demonstrating the integration of LiDAR imagery with the Google Earth Virtual Globe, use of the new Google Fusion Geospatial repository facility, along with sharing a few preliminary observations.

Abstract

Presentation Time: 2:50 PM-3:10 PM

LIDAR DIGITAL ELEVATION MAPS EMPLOYED IN CAROLINA BAY RESEARCH: NEW VIEW OF THE PIEDMONT'S SURFICIAL GEOLOGY USING GOOGLE EARTH'S VIRTUAL GLOBE

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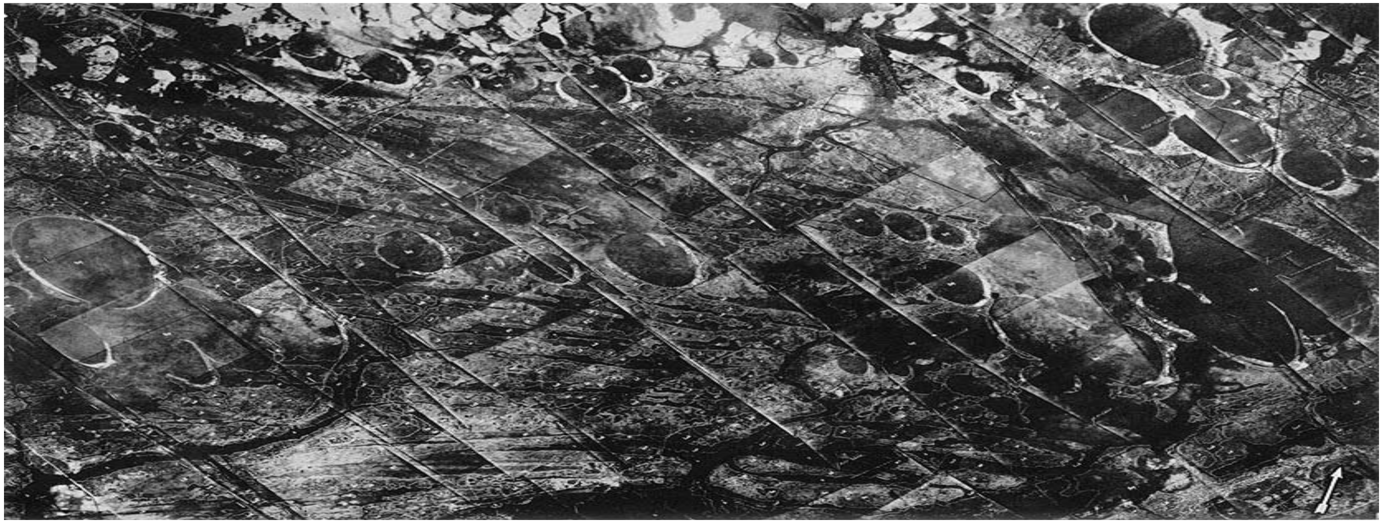
Aerial photographs of the Carolina bays have been available since the early 1930's. Those early images sparked extensive research into their genesis, but they reveal only a small part of their unique planforms. Digital elevation maps (DEM) created with today's Laser Imaging and Range Detection (LiDAR) systems accentuates their already-stunning visual presentation, allowing for the identification and classification of even greater quantities of these shallow basins across the Piedmont and into North America. We suspect that access to high resolution LiDAR DEMs in more regions would aid in expanding the bays' identified range. Our research is enabled to a large part by the facilities of the Google Earth (GE) Geographic Information System (GIS). The Global Mapper GIS application was used to generate LiDAR image overlays for visualization on Google's virtual globe, using 1/9 arc-second resolution DEM data from the United States Geological Survey (USGS). A survey was undertaken to catalogue the full extent of Carolina bays, indexed within USGS 100K Quadrants. Identifying Carolina bays on the costal plain is straight forward, given their characteristic ovoid planform, however bay planforms tend towards a circular presentation in the northern and southern areas of their geographic extent, presenting challenges. Also challenging is the rougher terrain seen when moving inland above the Piedmont. Archetypical planforms specific to each of these regions have been heuristically developed. The LiDAR maps demonstrate that the geomorphological process responsible for creating these depressions supported a rigid adherence to the identified archetype planforms across tens of thousands of instances. GE image overlays of the planforms' geometry are used to capture each bay's location, major & minor axis, elevation, as well as the geospatial orientation of the major axis. The data is intended to support a correlation of the bays' orientations within a 3-D triangulation network.

Photo Courtesy of George Howard

So, What is a Carolina bay?... In other venues, I’d need to to explain that, but not to this particular group of Geologists.

There are numerous bays under different land uses here. Due to their water retention characteristics, the bays’ outlines are sometimes easy to see in photographs.

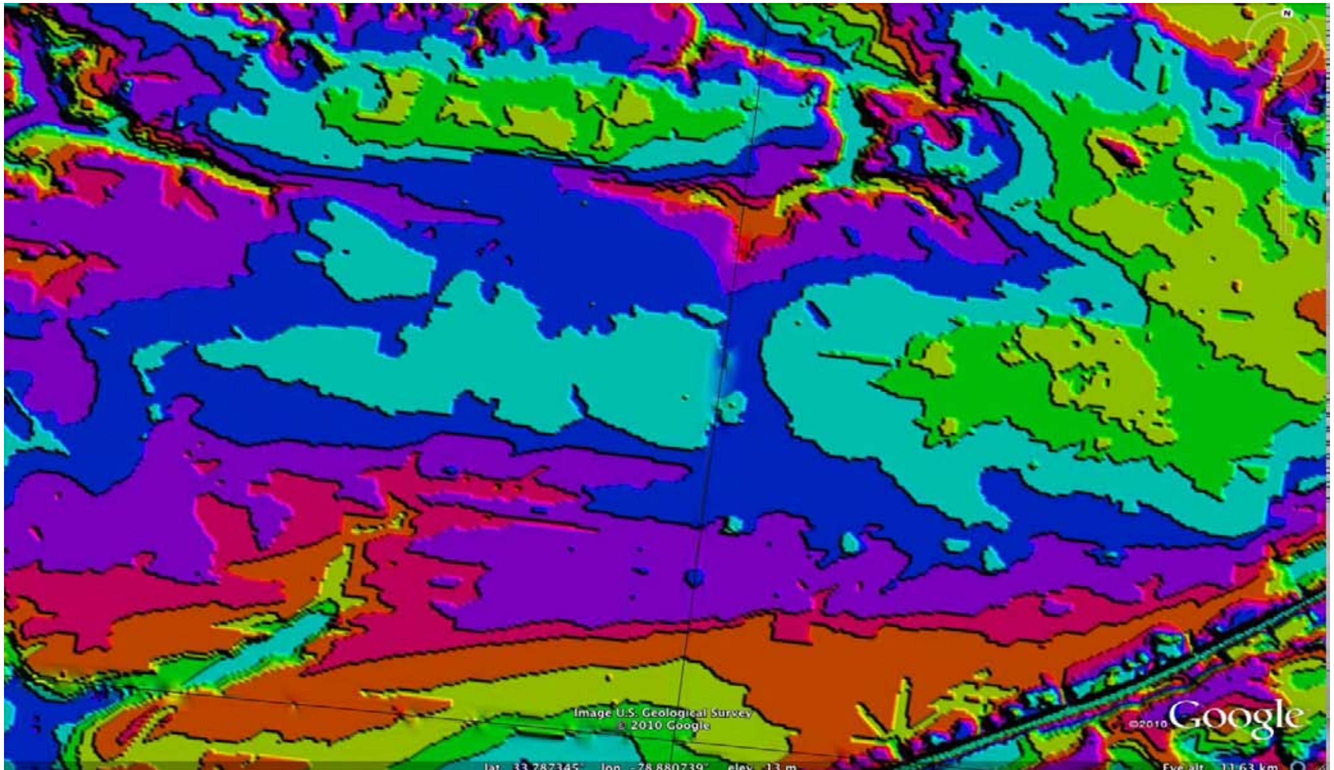
Myrtle Beach, SC



©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? Here we take an original Fairchild Aerial Survey photograph … **CLICK**

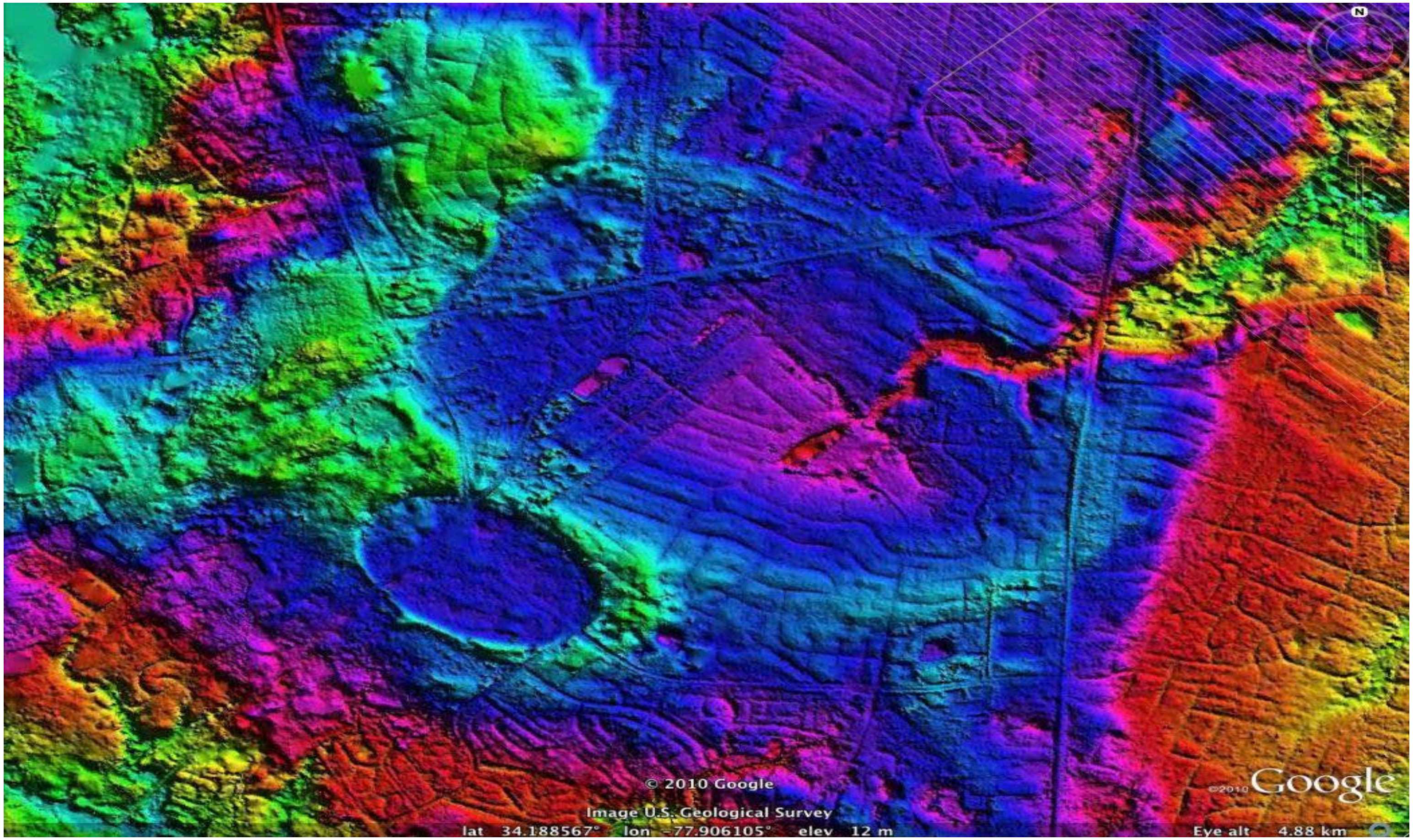
Myrtle Beach, SC



Digital Elevation Map using 1/3 arc-second NED Data

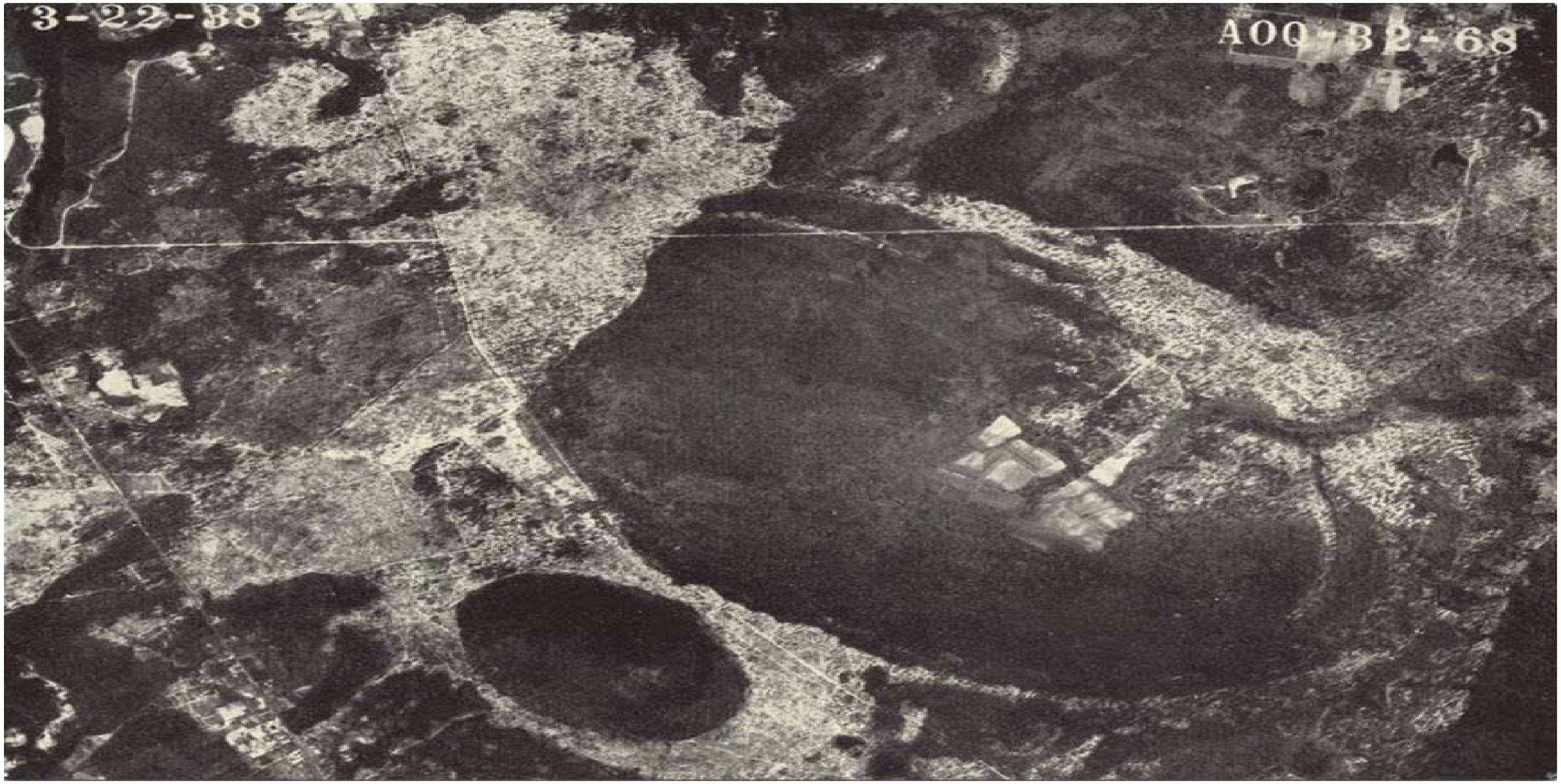
… and overlay it on the Virtual Globe, and as we fade out, the current satellite imagery becomes visible. Our goal is to capture multiple planform metrics using remote sensing. USGS elevation data is of no use here: the best DEM data offered for Myrtle Beach is 1/3 arc-second, and it looks like this.

Wilmington, NC



Here we are in Wilmington! In a this urban landscape, a bay in a park might be noticed – but that would be overlooking the big elephant in the room: **Blythe Ba**y in Glorious LiDAR.

B.D. Wells' Image of Blythe Bay



In 1953, B. W Wells and S.G.Boyce of NC State published a study of Blythe Bay, providing this photo, which was taken in 1938 before the bay's presence was obscured by urbanization.

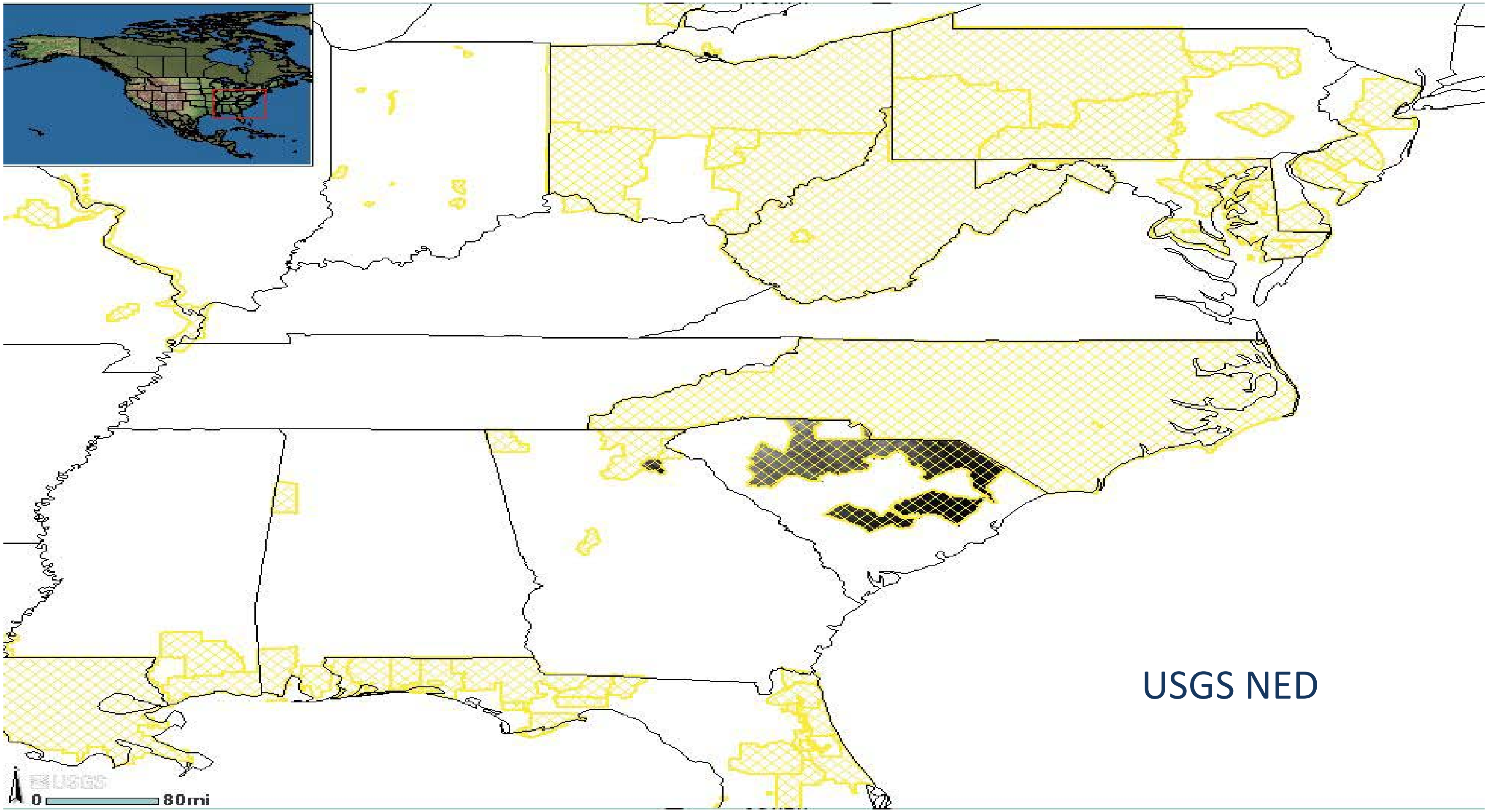
So, hopefully we have made a case for our interest in LiDAR imagery, now lets discuss our research goals and methodologies.

Tools & Resources

- **USGS 1/9 Arc-second National Elevation 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**
  - **Visualization & Satellite Imagery**
    - **Historical Imagery**
  - **Points, Overlays, Line Segments & Polygons**
  - **Allows for capture of planform geospatial metrics**
  - **Loads Global Mapper KML & Automatically aligns on globe**
- **Google Fusion Tables**
  - **Cloud Based**
  - **Geospatial-specific Repository**
  - **Supports Collaborative Projects**

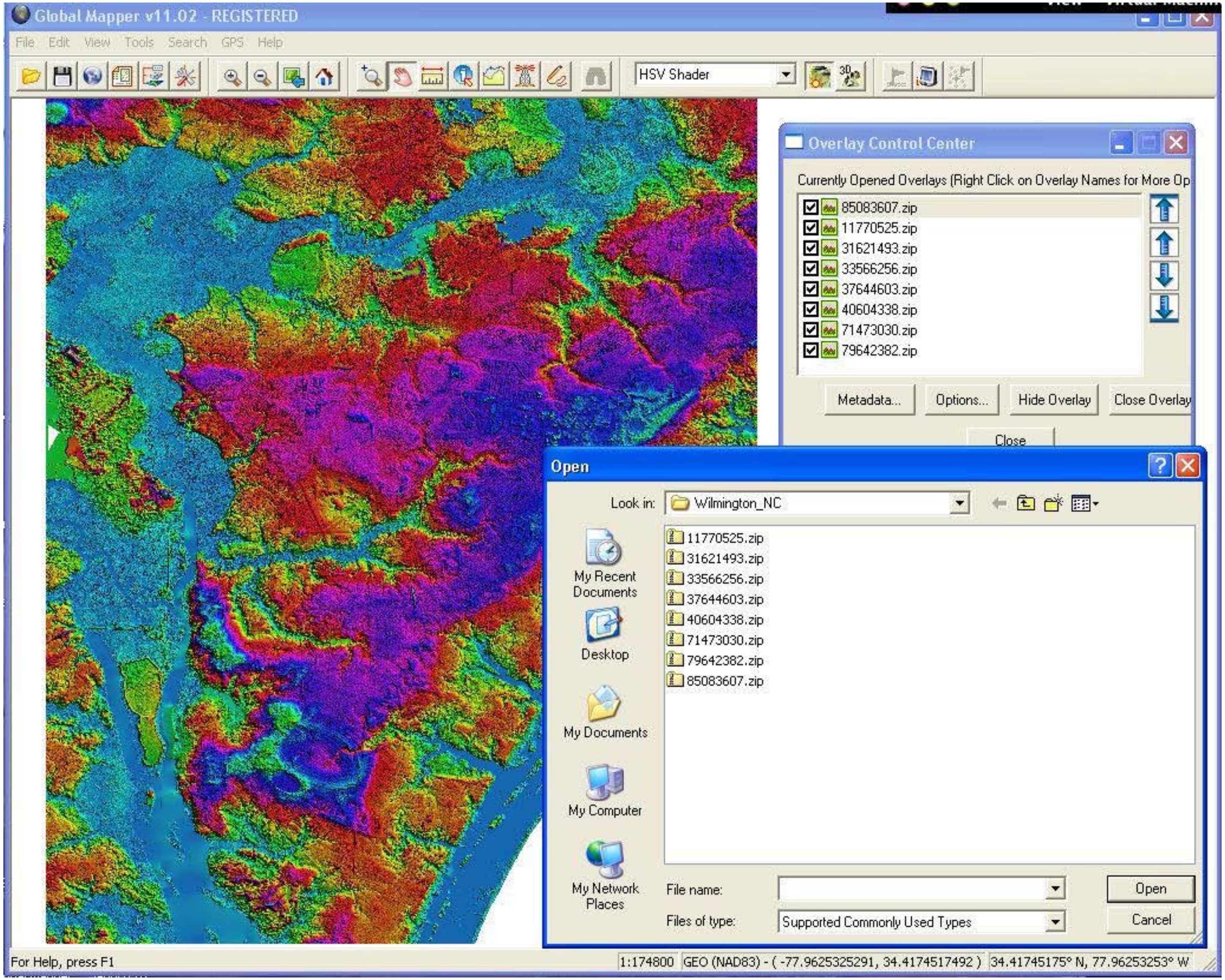
The USGS offers LiDAR-derived elevation data, which were processed in the Global Mapper commercial GIS program and used to create KML-wrapped jpg image. Using various tools within Google Earth, we capture bay geospatial metrics. Google Fusion Tables are used to store this data in the cloud and source data to Google Earth using networked links.

1/9 arc second LiDAR-derived Data



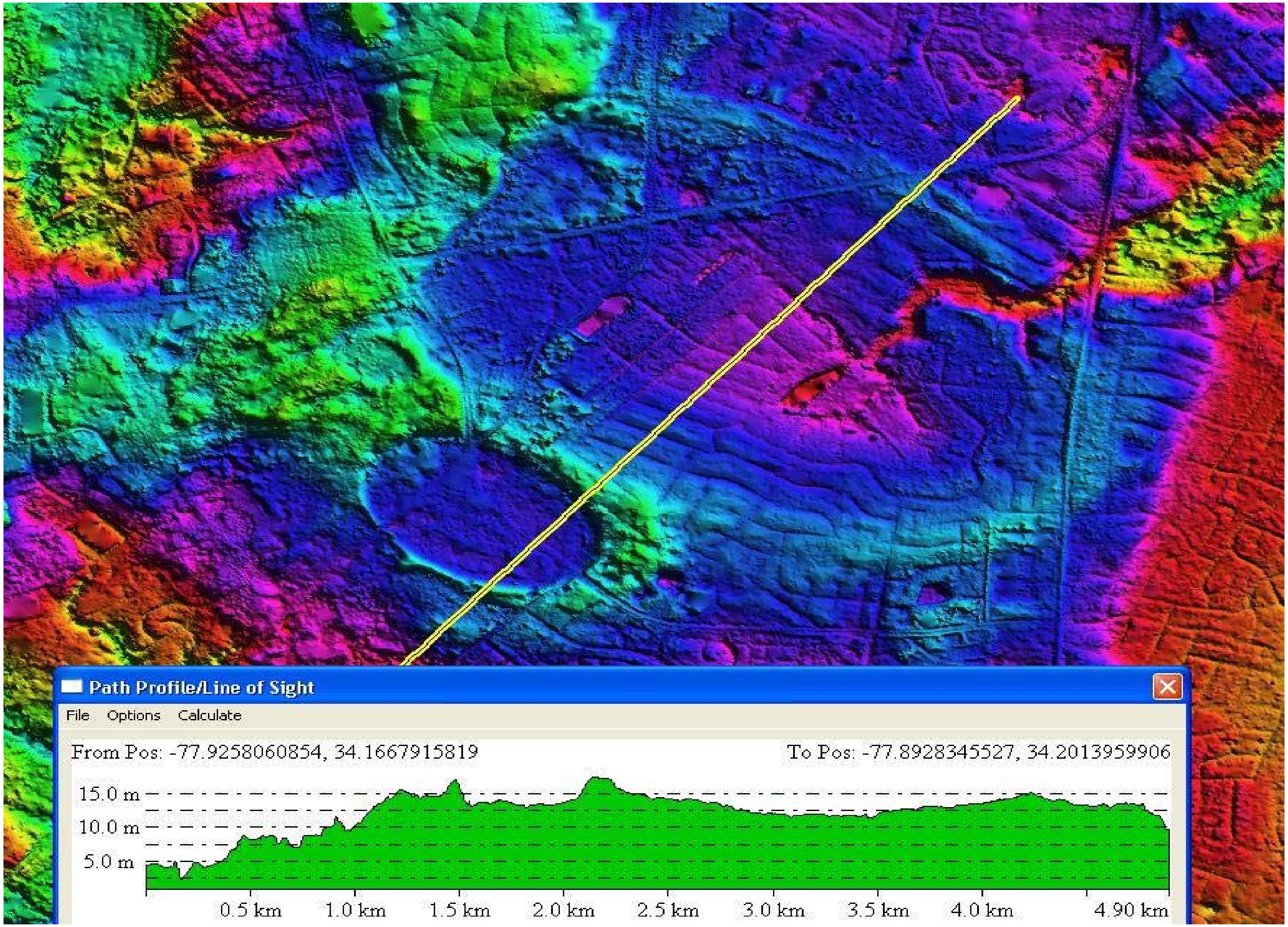
Here is the spatial distribution LiDAR-derived data in the areas of interest. We eagerly await similar data for other regions, such as Georgia, Virginia and the remainder of SC, each of which are in progress.

LiDAR Generation Process



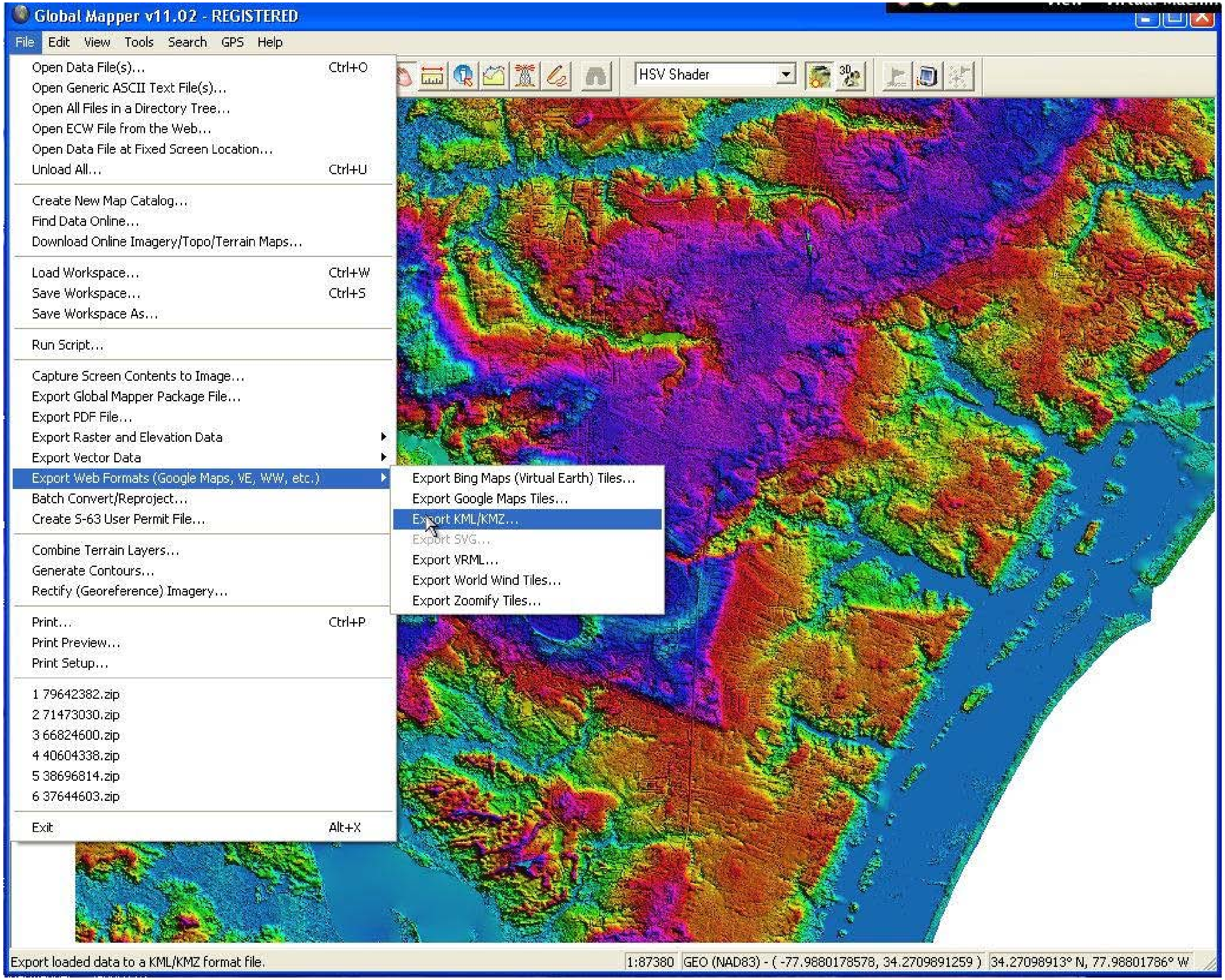
Here, we have loaded several USGS 24K Quad 1/9 arc second data files into Global Mapper's interface for visualization.

LiDAR Generation Process



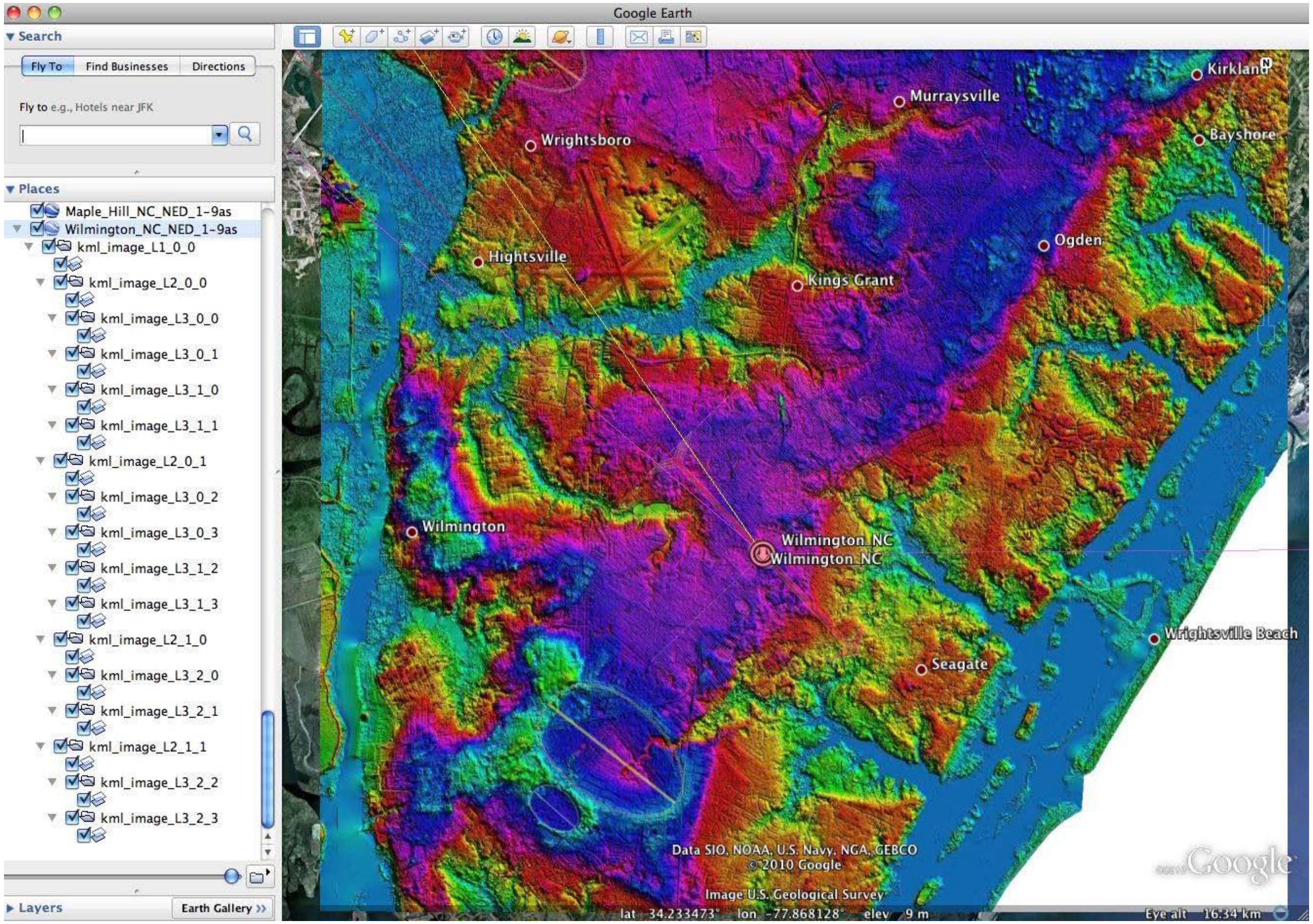
One of Global Mapper's many tools is an elevation profile capability, The 2 kilometer-wide Blythe bay shows only 5 meters of rim relief The imagery is created by driving the hue-saturation value (**HSV**) of each pixel with the elevation value. Our standard method is to use a high gain and 10 to 25x elevation exaggeration

LiDAR Generation Process



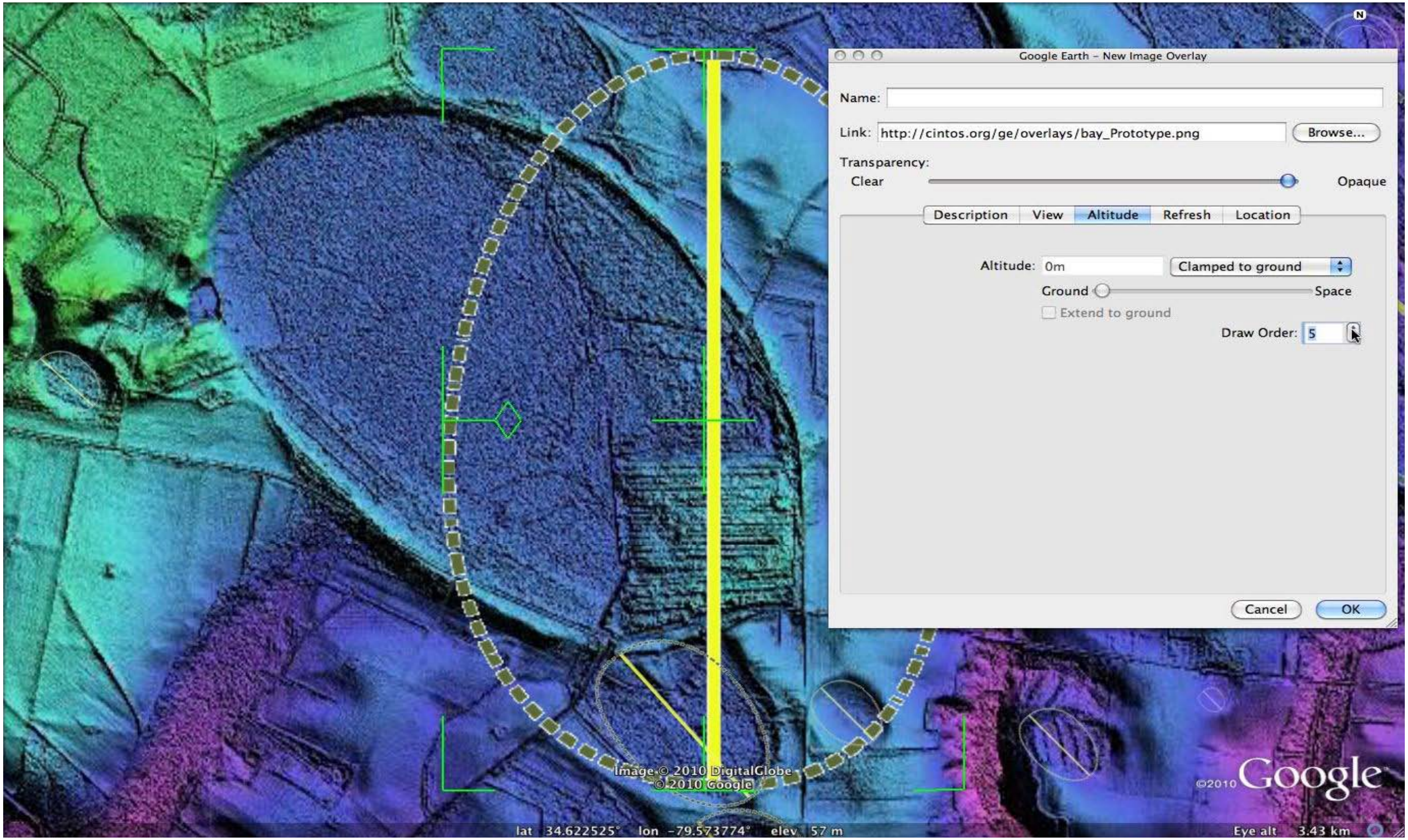
Once we have a scope of LiDAR to define a 100K Quadrant, we proceed with the export of data in a form digestible by Google Earth: - KML

LiDAR Integration with Google Earth



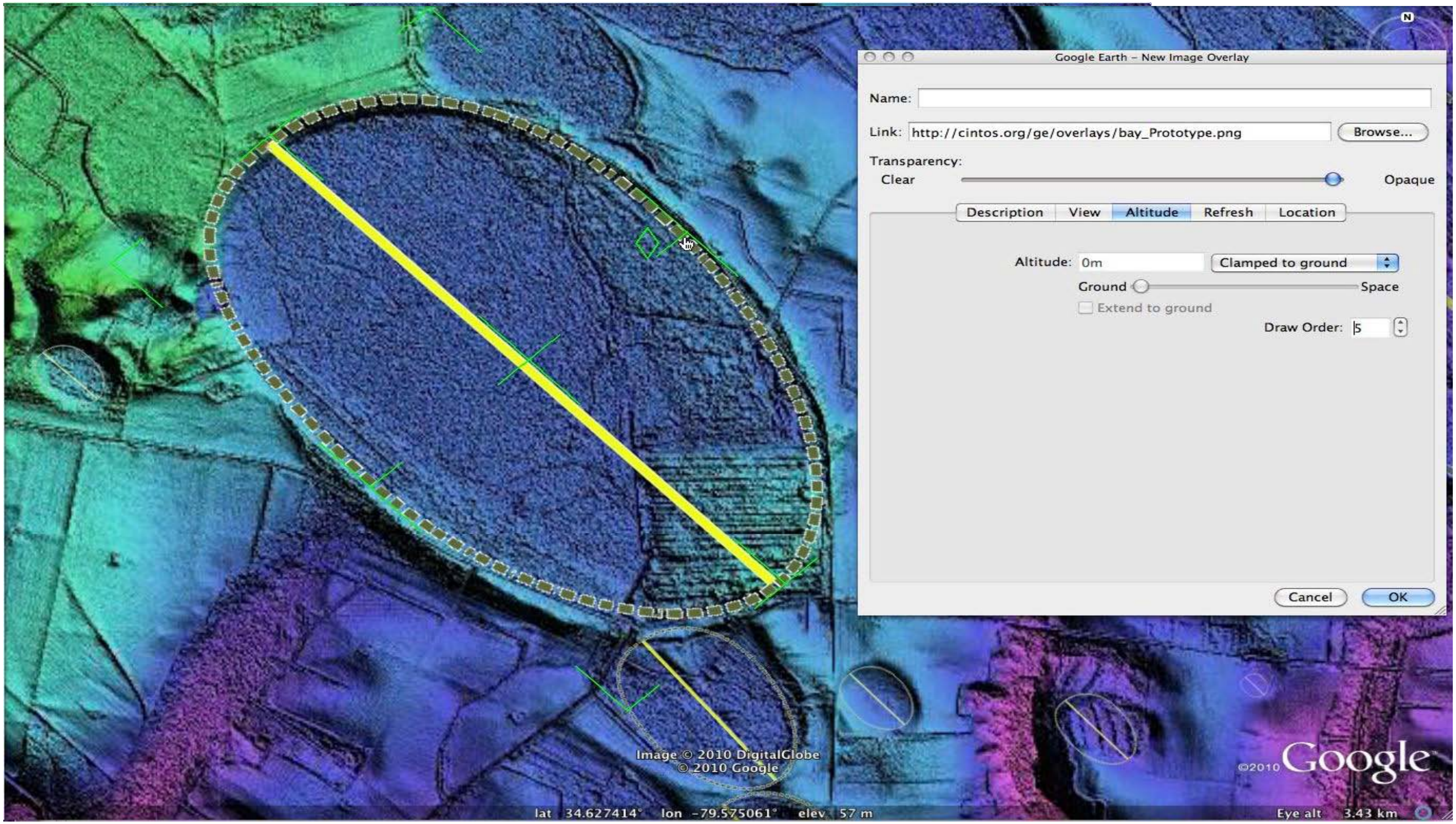
The exported fie is opened in Google Earth, with the Image automatically positioned on the virtual globe. The tree of increasingly detailed image tiles sourced from web links is shown on the left. Thus we only need to load the appropriated data for the area in focus.

Planform – New Image Overlay



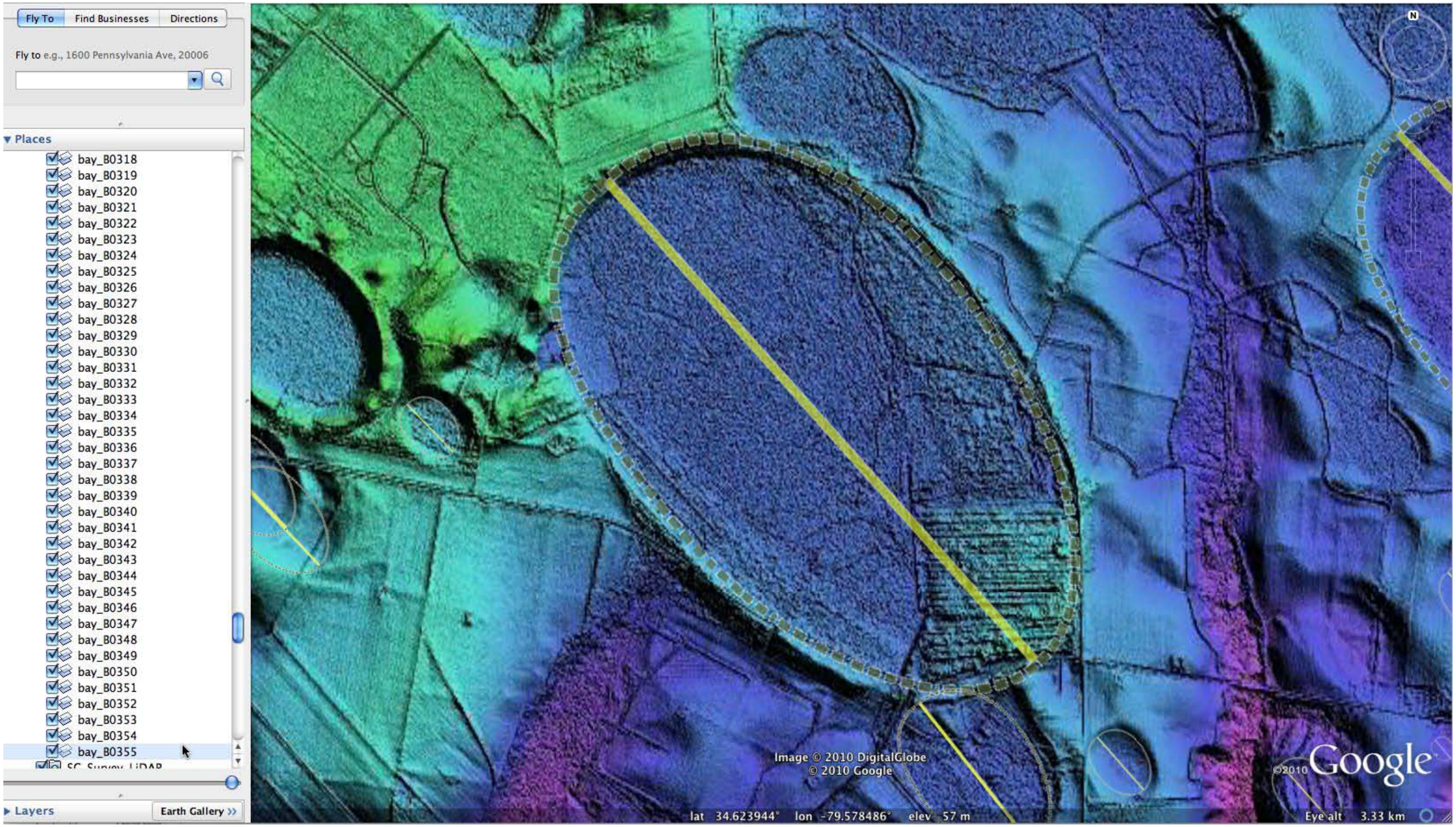
To facilitate our survey of bay metrics, we utilize a Google Earth Overlay element. The overlay is placed over the bay being measured and is rotated manually using the handle -

Planform Overlay



from the default orientation of due north. The overlay is then and sized to the outline of the bay's actual rim using the corner handle.

Overlay Given a Name



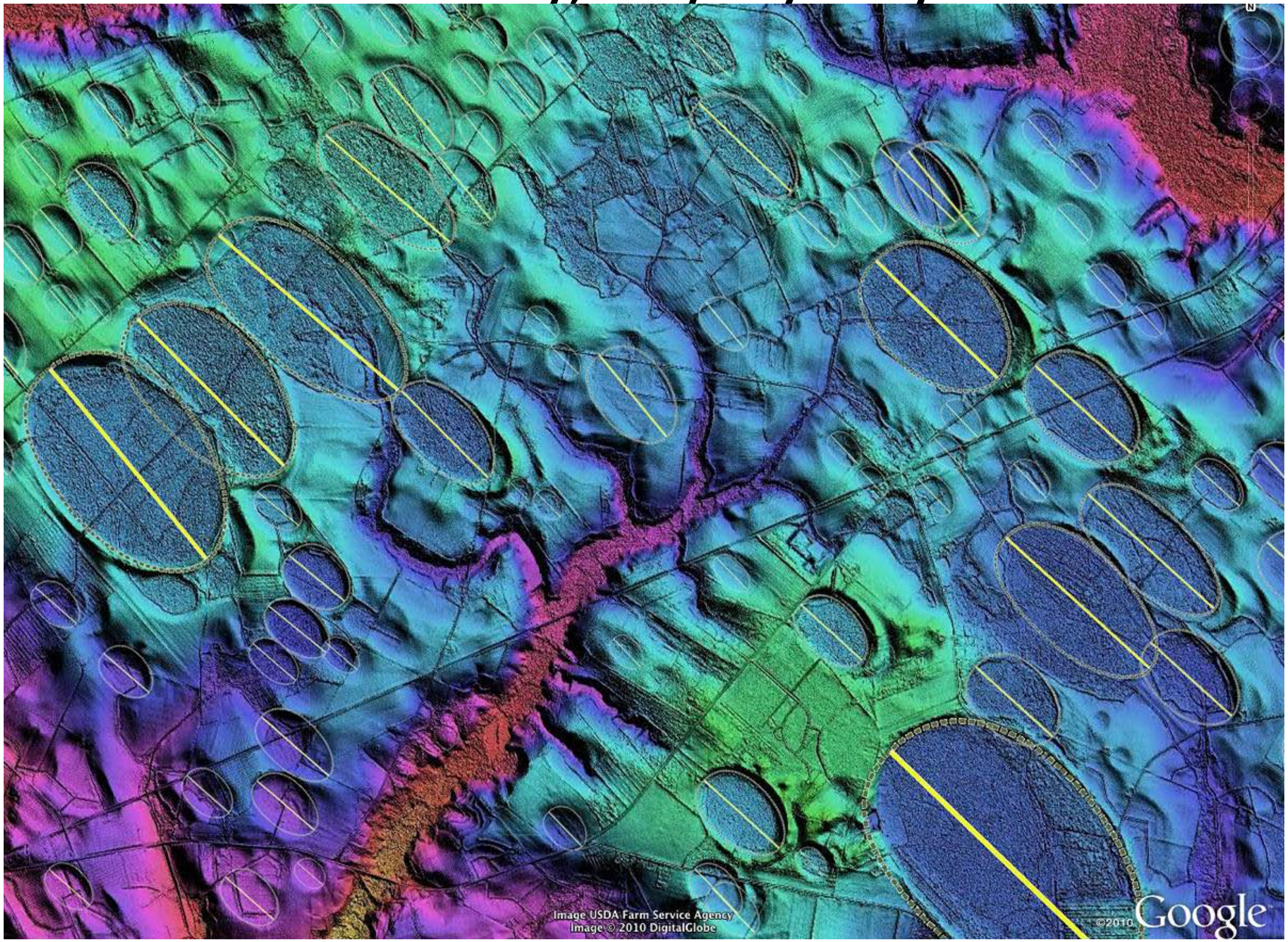
With a bit of fine tuning, a very snug fit is usually obtained, and it appears in the object directory on the left. The entire folder of overlays is copied out to process. The copied data it is comprised of a text in the Keyhole Markup Language (**KML**).

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>

Pasting this in a text editor, we see the overlay format carries information: The bounding box's latitude and longitude yields the length of the major and minor axis and an estimate the bay's surface area. The rotation angle of the overlay from due north documents the bay's orientation.

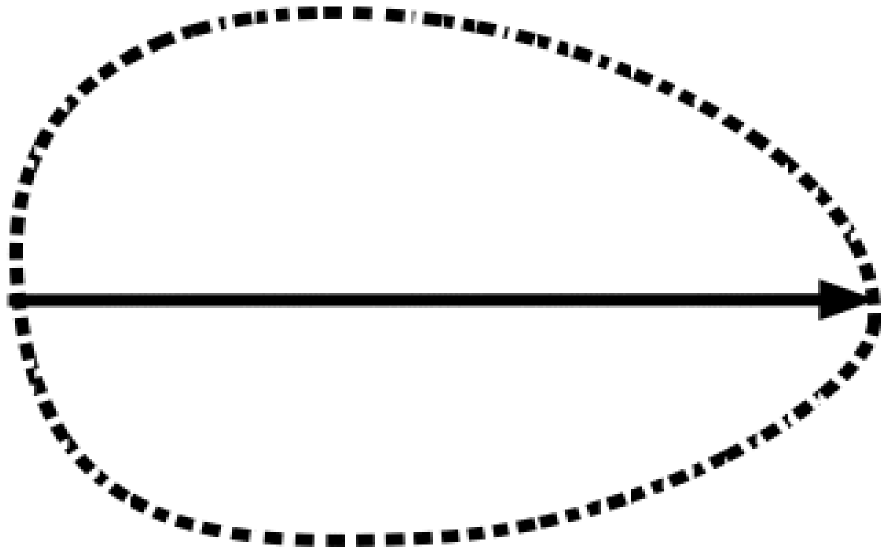
Survey, bay-by-bay



Our survey currently includes metrics from about 20,000 individual bays. My confidence in our working hypothesis waxes and wanes, but when you drop in these planforms by the hundreds, and they all match perfectly, its is quite a satisfying task …

Criteria for Identification as a Carolina Bay

- Found Amongst Collection Of Similar Landforms
- Exhibit A Closed Circumferal Rim
- Satellite Imagery Supported By LiDA As A Basin
- Planform Fits Archetype For Locale



Here are some of our criteria for determining if a basin is a Carolina bay. They should not be singularities in the area, their rims should be closed, or at least a significant hint that a closed rim exists, if we are primarily using satellite imagery for selection, there should be support by DEM data to insure it is a depression. And finally, it should conform to one of our planform overlays, such as the one shown here **Click** , which is the Archetype. It is not a true oval, but is slightly "twisted", or "skewed". We have documented 13,000 such bay. **Click** To the south, the slightly pointed planform shown here is used, with 3500 documented so far.

Criteria for Identification as a Carolina Bay

- Planform Fits Archetype For Locale

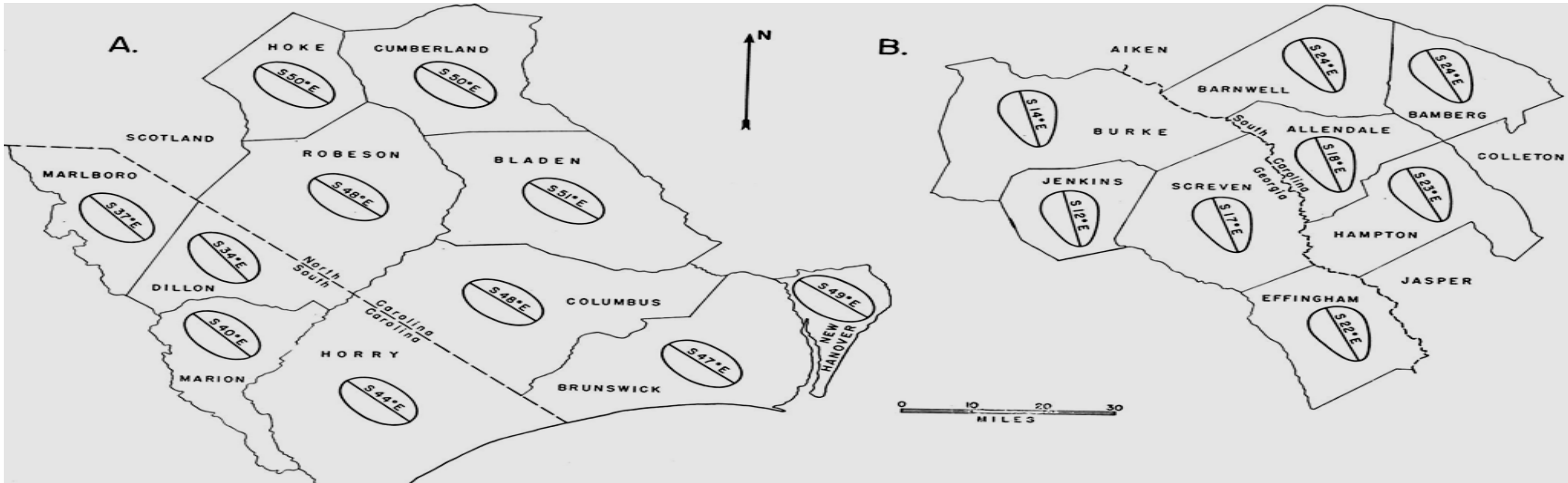
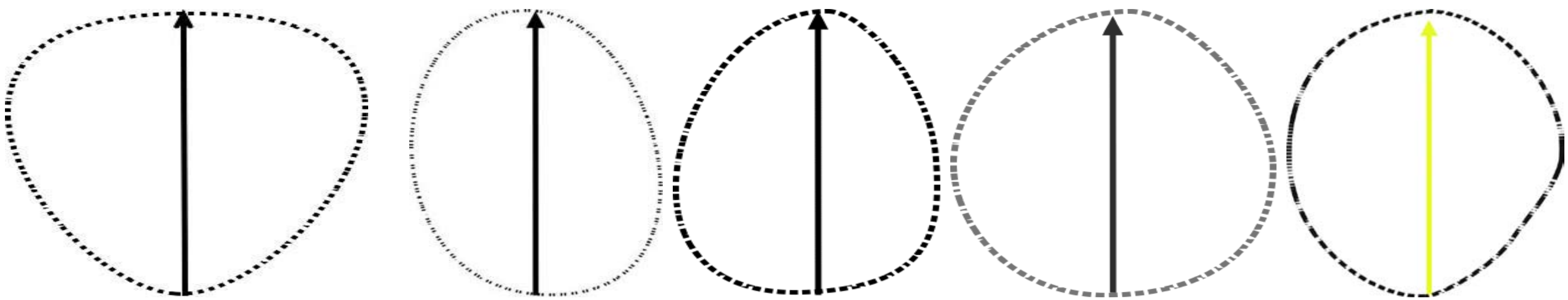


FIGURE 27: Axial trends of basins in northern (A) and southern (B) parts of area of abundant oval bays.

Douglas Johnson documented his version of these two bay types in his book *The Origins of the Carolina Bays*, and we note them in the same general areas. Obviously there is a gently transformation from one style to the other, as the bays are found to exists on a near-continuum across the region.

Criteria for Identification as a Carolina Bay

- Found Amongst Collection Of Similar Landforms
- Exhibit A Closed Circumferal Rim
- Satellite Imagery Supported By LiDAR/DEM As A Basin
- Planform Fits Archetype For Locale



Locale	MD, DE, NJ	NC, SC	SC, GA	GA, AL	Nebraska
Quantity	2,000	13,000	3,500	1000	500
Eccentricity	0.39	0.71	0.69	0.59	0.68

Both these types show a mean eccentricity of about 0.7. All bays we discuss today will be of these two types, but we interpret the planforms of bays in other areas to also vary slightly.
In Georgia and further west, we see an even fatter shape, 1000. In the northern areas of the coast we also see a squatter shape, but inverted from the last one: 2000. Finally, out west in Nebraska, we suggest a shape with one flattened side, similar to the eastern archetype : 500 of those are in the survey.

Google Fusion Table

Google fusion tables **example** Cintos

Discussions (0) | Get link | Share

File View Edit Visualize Merge

Filter | Aggregate | Choose columns

Elevation > 100.64

Elevation < 120.55

Add condition

Apply | Clear filter

Current view: **[Elevation > 100.64&Elevation < 120.55]** - Hide options

1 - 100 of many Next »

Cell: (139315_0236 | Name)

Curent Cell value: 139315_0236

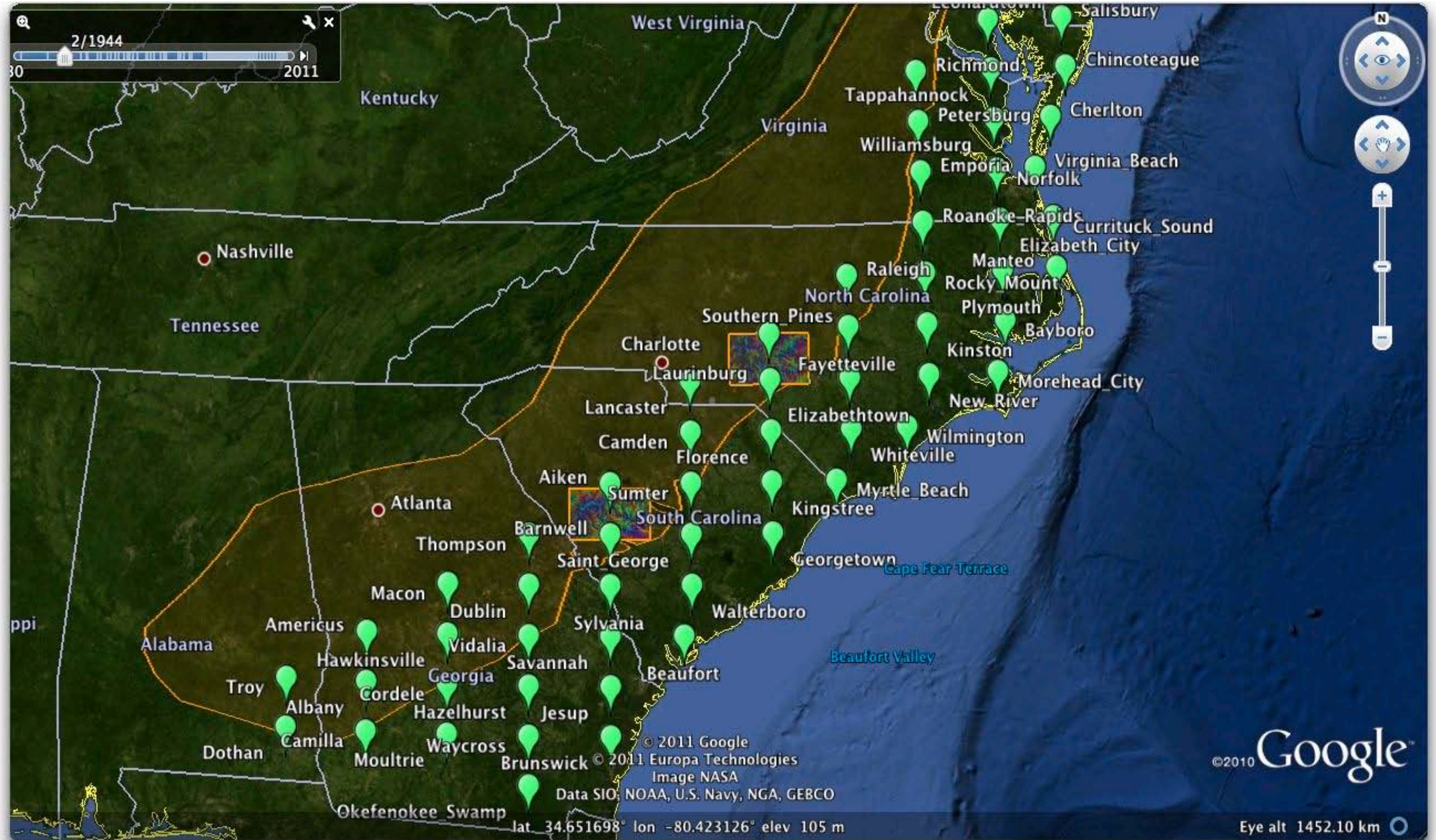
Your comment ...

Save comment

Name	Octant	Latitude	Longitude	Eccentricity	Bearing	Elevation	Planform	effectiveDiameter
150310_0332	150310	37.50939	-77.58233	0.646	138.6	100.82	bay_prototype	653.973
128334_9449	128334	32.23713	-83.62361	0.704	162.6	100.93	bay_south_prototype	265.828
142314_4145	142314	35.60344	-78.61343	0.734	148.16	101.28	bay_prototype	205.91
150310_8830	150310	37.72016	-77.57718	0.663	132.93	101.58	bay_prototype	175.534
129333_4477	129333	32.36214	-83.44294	0.53	159.94	101.61	bay_south_prototype	306.952
126337_9579	126337	31.73951	-84.44791	0.704	166.07	101.82	bay_ga_prototype	380.483
134324_3379	134324	33.58466	-81.19884	0.8	159.04	101.87	bay_south_prototype	715.964
129334_2623	129334	32.31617	-83.55751	0.577	160.58	101.98	bay_south_prototype	842.287
129334_2623	129334	32.31617	-83.55751	0.577	160.58	101.98	bay_south_prototype	842.287
[illegible]	[illegible]	33.38429	-81.39505	0.785353452	155.85	101.99	bay_south_prototype	334.731
[illegible]	[illegible]	31.72087	-84.48147	0.554	159.8	101.99	bay_ga_prototype	411.974
[illegible]	[illegible]	35.75517	-78.3385	0.56	137.54	102.0	bay_prototype	352.155
[illegible]	[illegible]	33.39292	-81.48513	0.724137931	158.96	102.09	bay_south_prototype	244.626
[illegible]	[illegible]	33.06881	-82.17541	0.512	162.86	102.15	bay_south_prototype	537.847
[illegible]	[illegible]	35.75259	-78.3398	0.582	137.55	102.23	bay_prototype	189.487
143313_0235	143313	35.75705	-78.33879	0.625	137.54	102.27	bay_prototype	409.649
126339_2615	126339	31.56527	-84.78965	0.533	163.97	102.36	bay_ga_prototype	410.115
132329_1756	132329	33.04446	-82.39152	0.623	156.2	102.39	bay_south_prototype	1,199.429
133325_5560	133325	33.38812	-81.40184	0.735597048	154.06	102.42	bay_south_prototype	262.939
133325_5560	133325	33.38812	-81.40184	0.735597048	154.06	102.42	bay_south_prototype	262.939
126337_9577	126337	31.73941	-84.44474	0.667	166.07	102.42	bay_ga_prototype	627.747

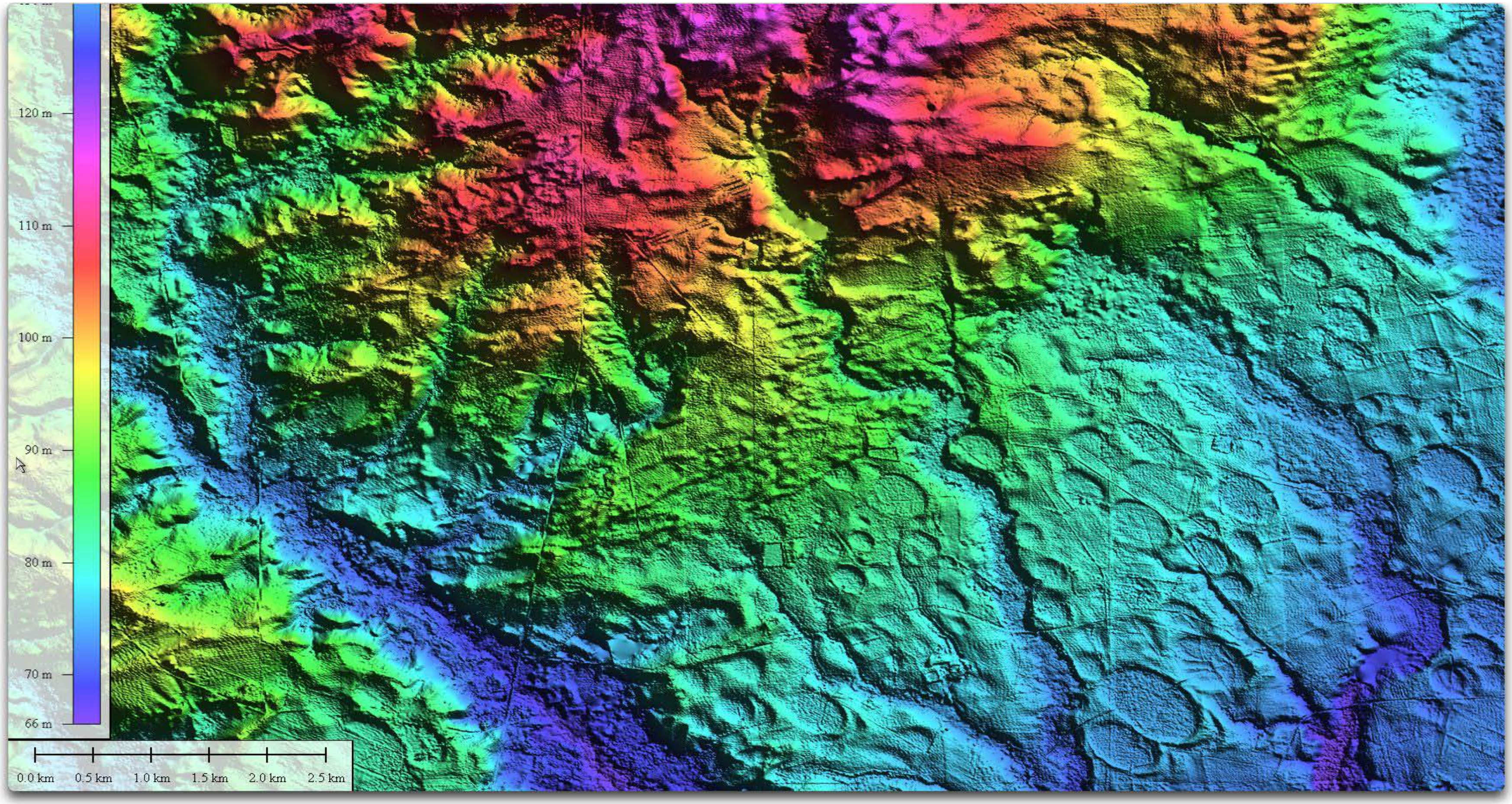
Our collection of fitted bay overlays are programmatically processed into table entries which are placed in an on-line Google Fusion Table. Our goal is to catalogue 50,000 unique bays.

USGS 100K Quads Under Review



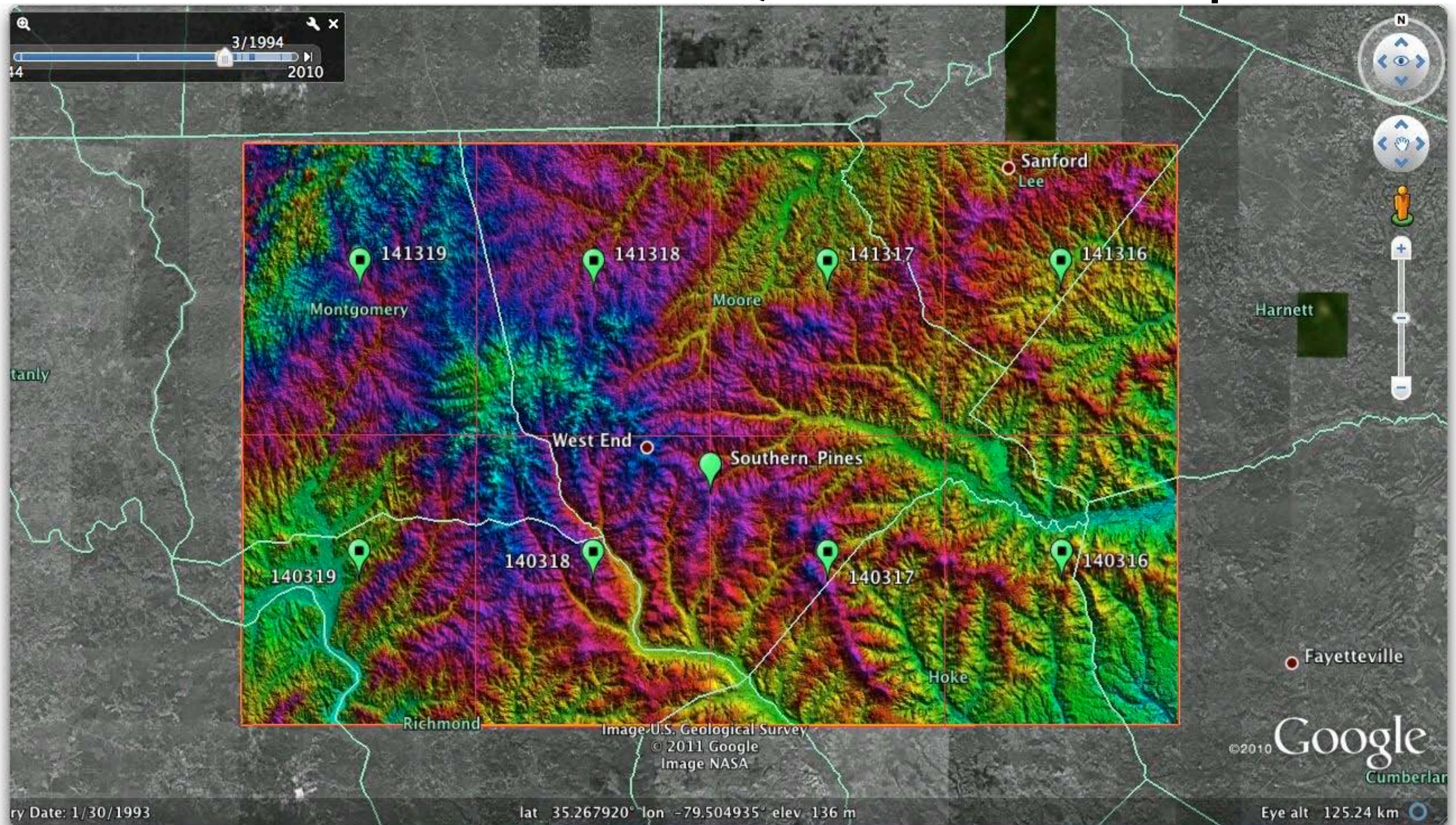
Our survey encompasses these 100K Quads on the East Coast. Where 1/9 arc sec data is unavailable, we have produced 1/3 arc sec hsv shaded Digital Elevation Maps, Our goal here today is to discuss the possible existence of bays above the coastal Plain.

Laurinburg Transition to Southern Pines



Let's start on the coastal plain within the Laurinburg Quad. Elevation rises from 65 meters to over 120 meters. We see bays being formed on a continuum at elevations up to 90 meters. Then: sand dunes! as we go deeper towards the Piedmont, the local relief becomes complex. So, regardless of geomorphology, we propose that the bays – as we know them – could not exist on uneven surfaces.

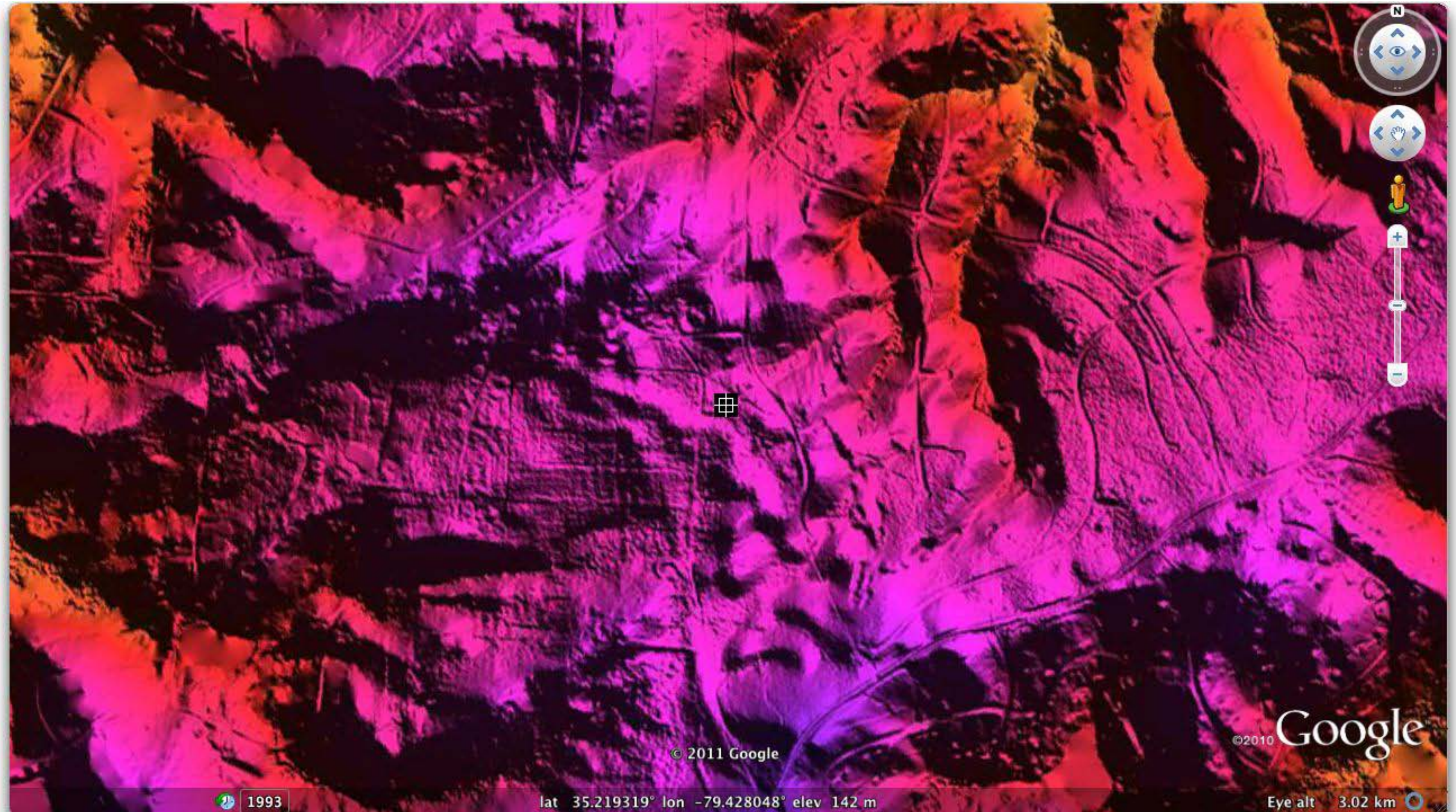
Southern Pines Quad LiDAR Map



Directly North, we enter the Southern Pines Quadrant. The virtual globe displays our LiDAR tiled elevation map overlays. Each of the eight survey segments shown encompasses a quarter degree grid- which we call an **Octant**. We currently have LiDAR sets for 375 Octants, for about ½ of our survey area. We subdivide each octant into a 1000 x 1000 grid, allowing us to uniquely name up to 10,000 bays in each of these eight Octants.

Sand Dunes on Hilltops

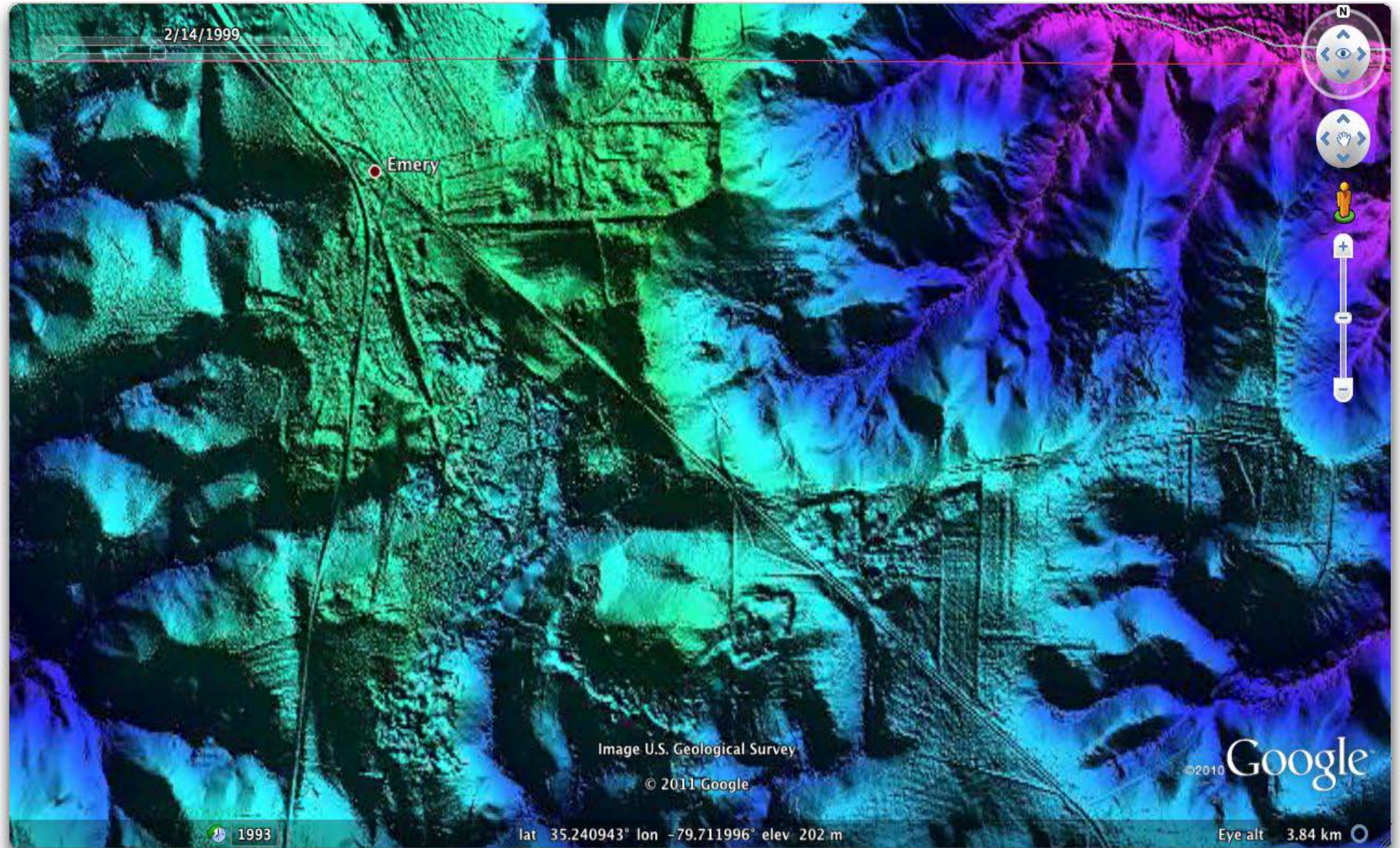
Pinehurst, NC



Moving into Southern Pines using Google Earth and our LiDAR overlays, we see what appears to be a large volume of surficial sand that often is expressed in dune formations.

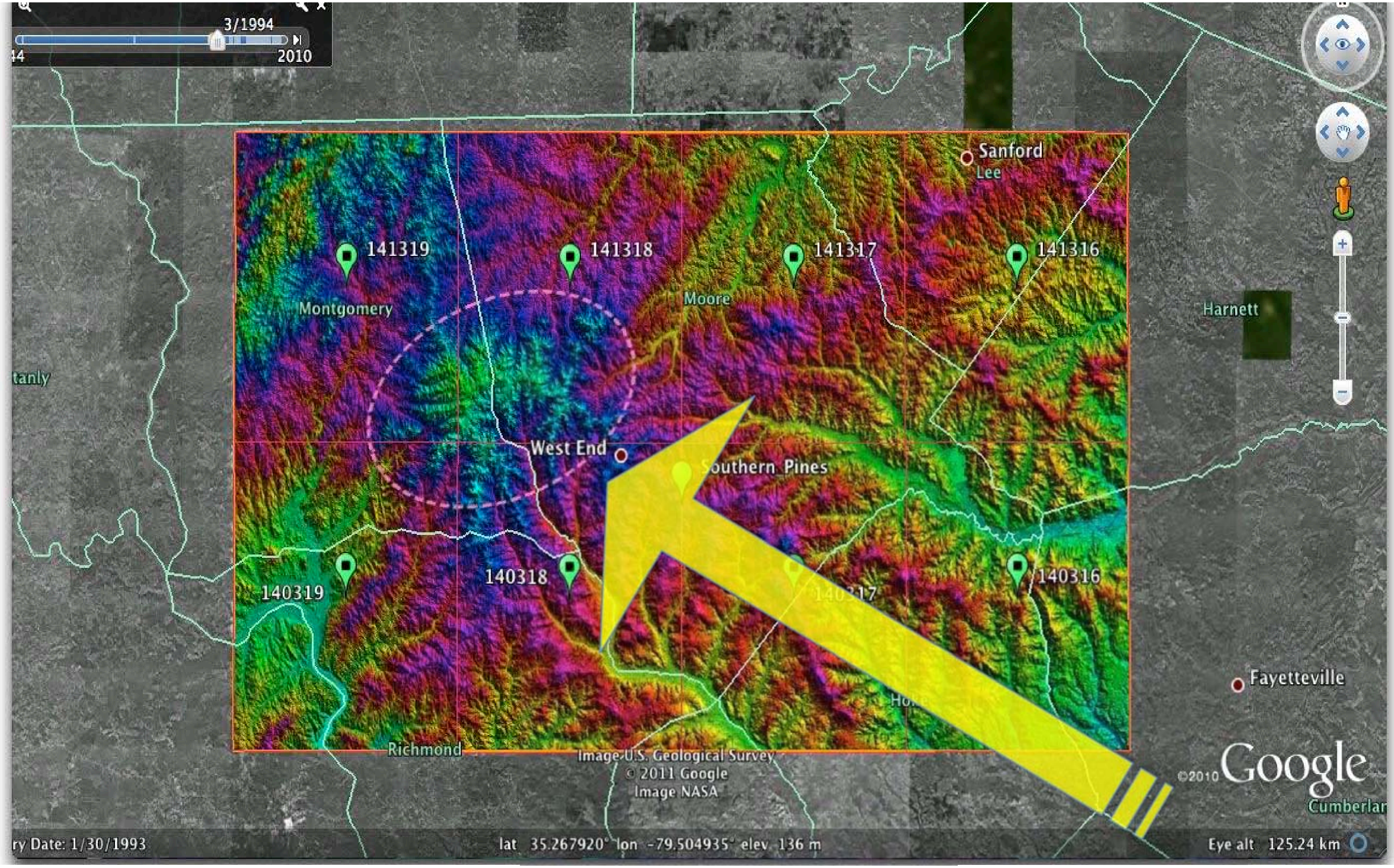
Sand Quarries on Hilltops

Emery, NC



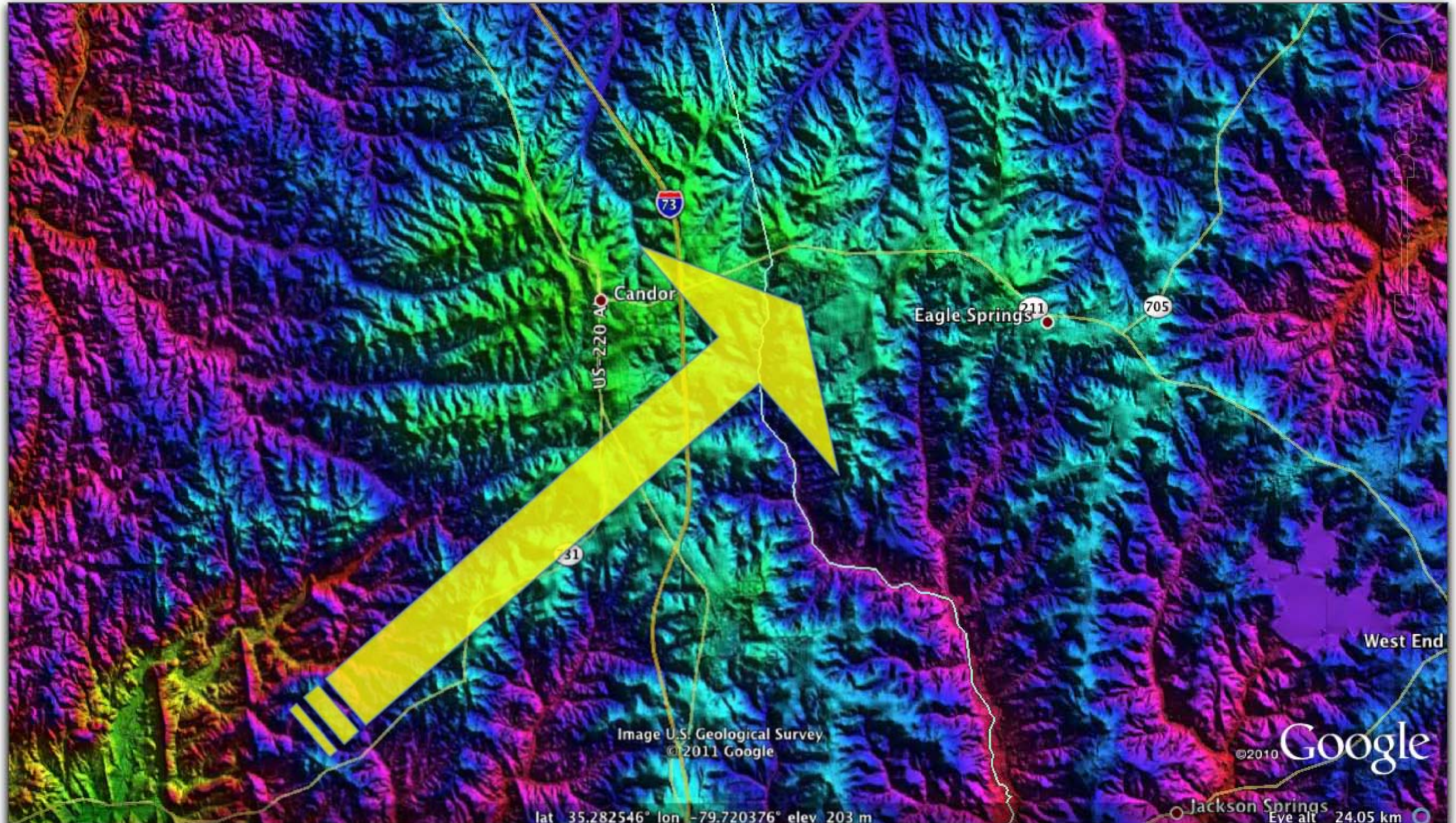
Emery Mines. Interestingly, the sand mining activities are not taking place along the drainage basins, but up on these smooth hilltops.

Search For Areas of Smother Relief



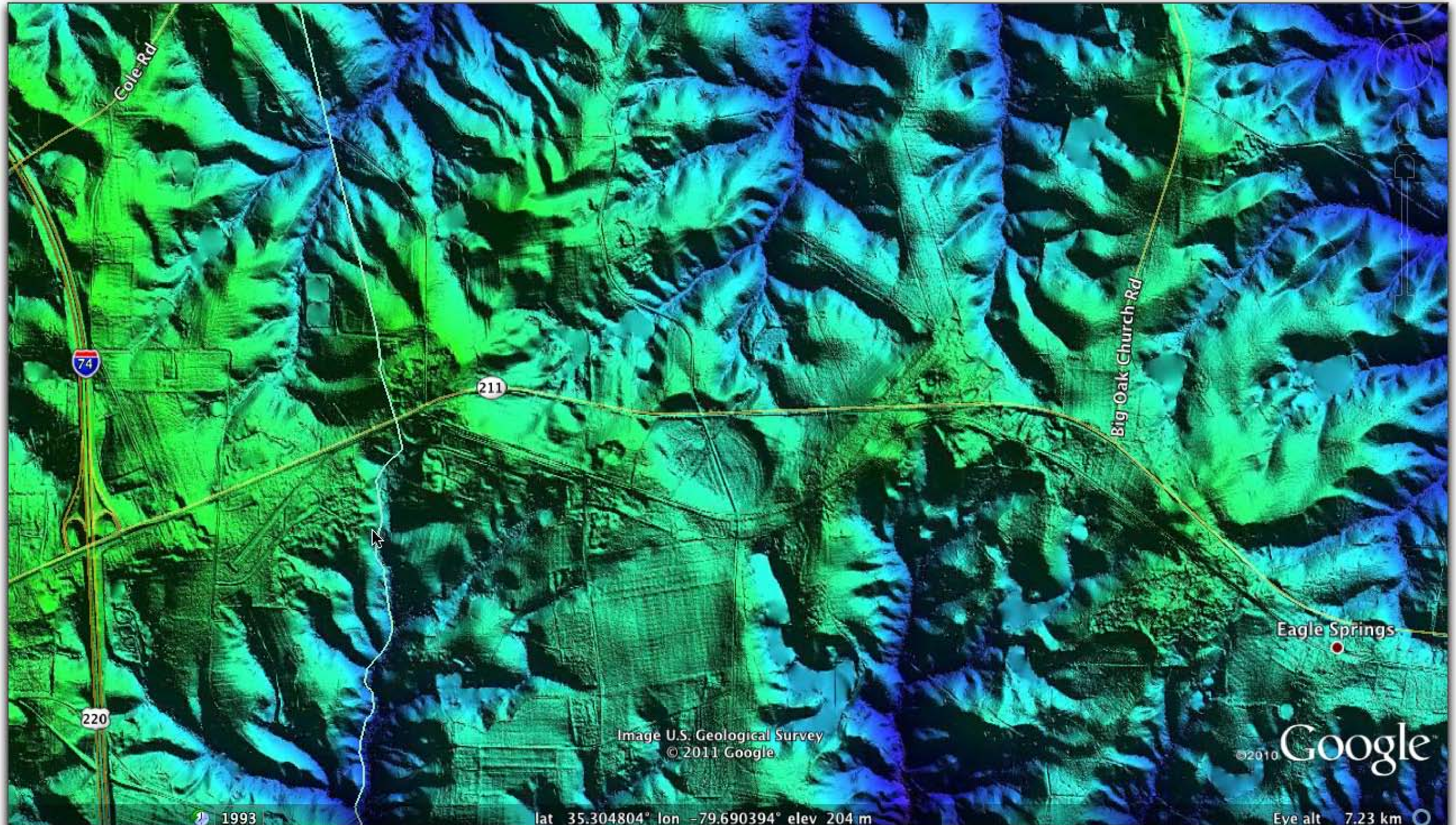
Lets look at this broad elevated area which looks to be a bit smother

Southern Pines Smooth Area



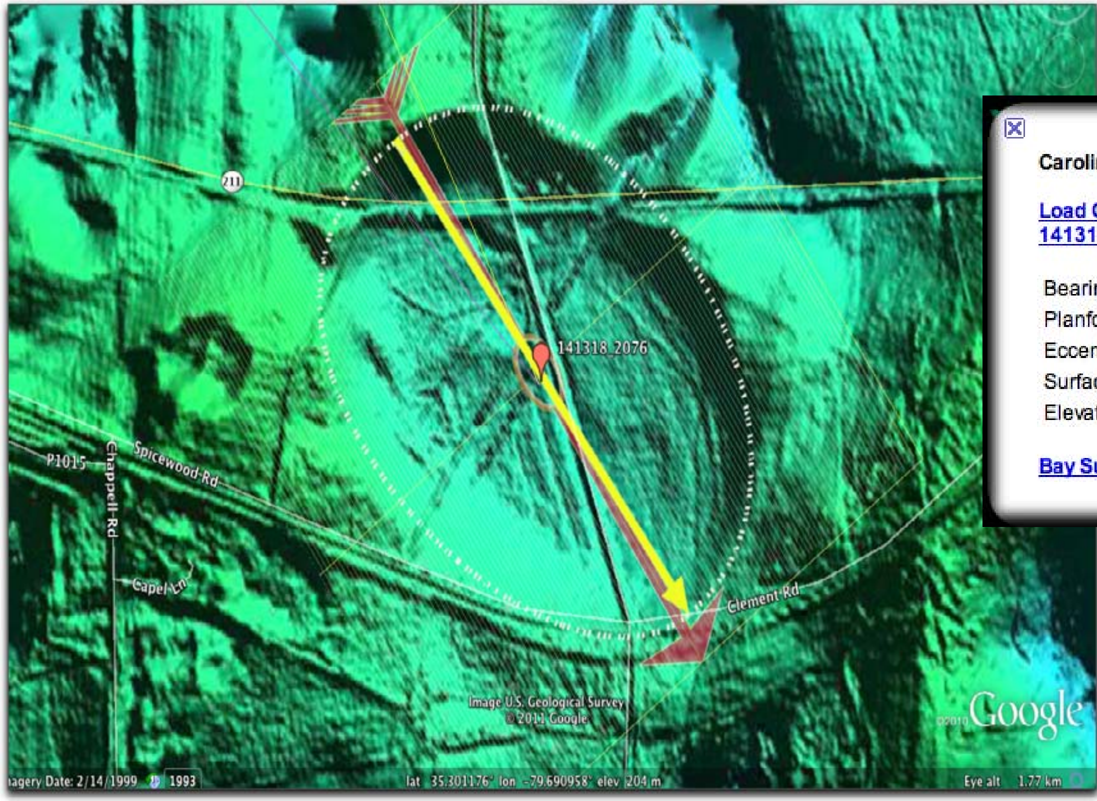
Zooming **Click** in we note a oval landform

Eagle Springs, NC Locale



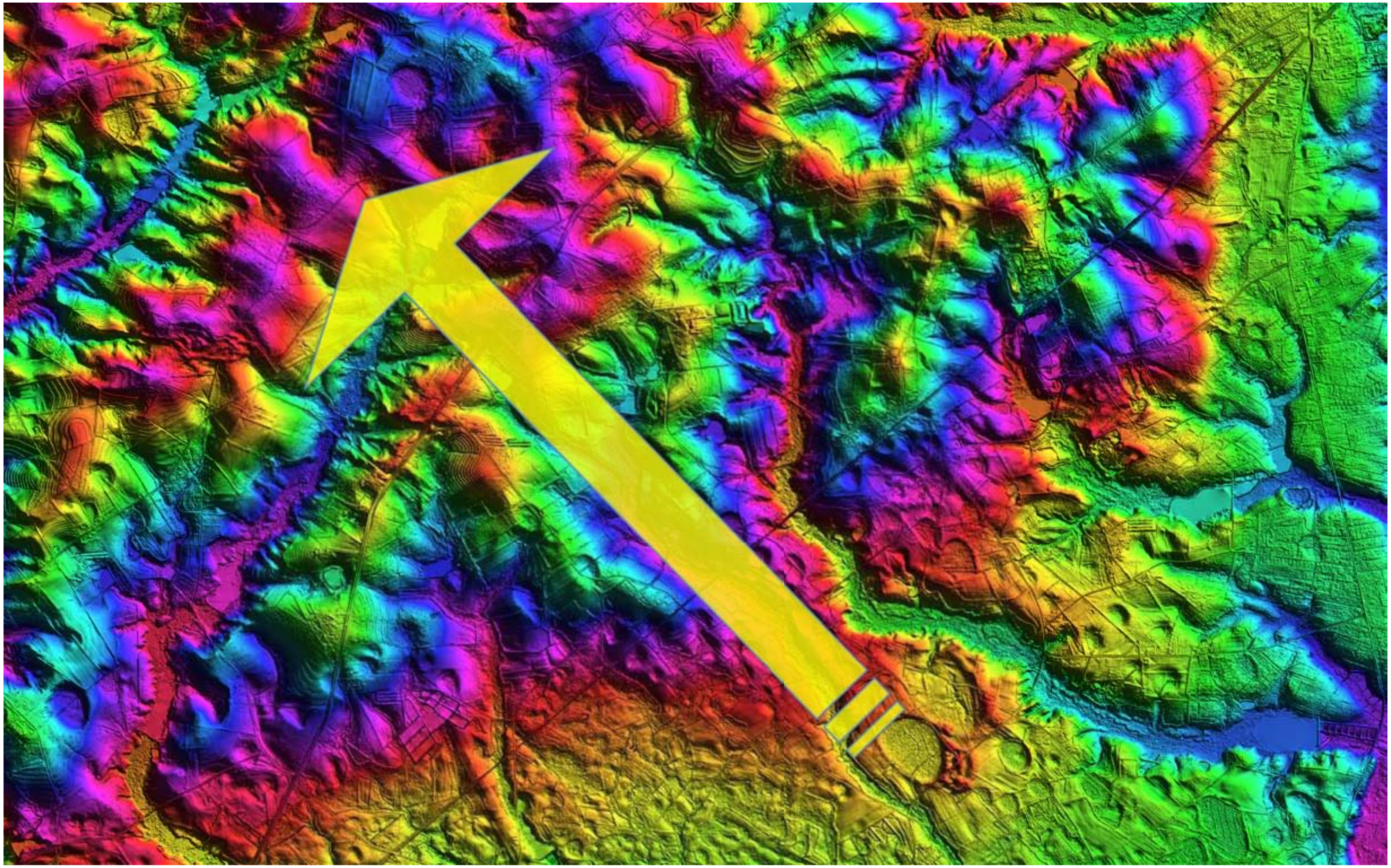
This is the just west of Eagle Springs, NC.

Eagle Spring Bay – Serendipity?



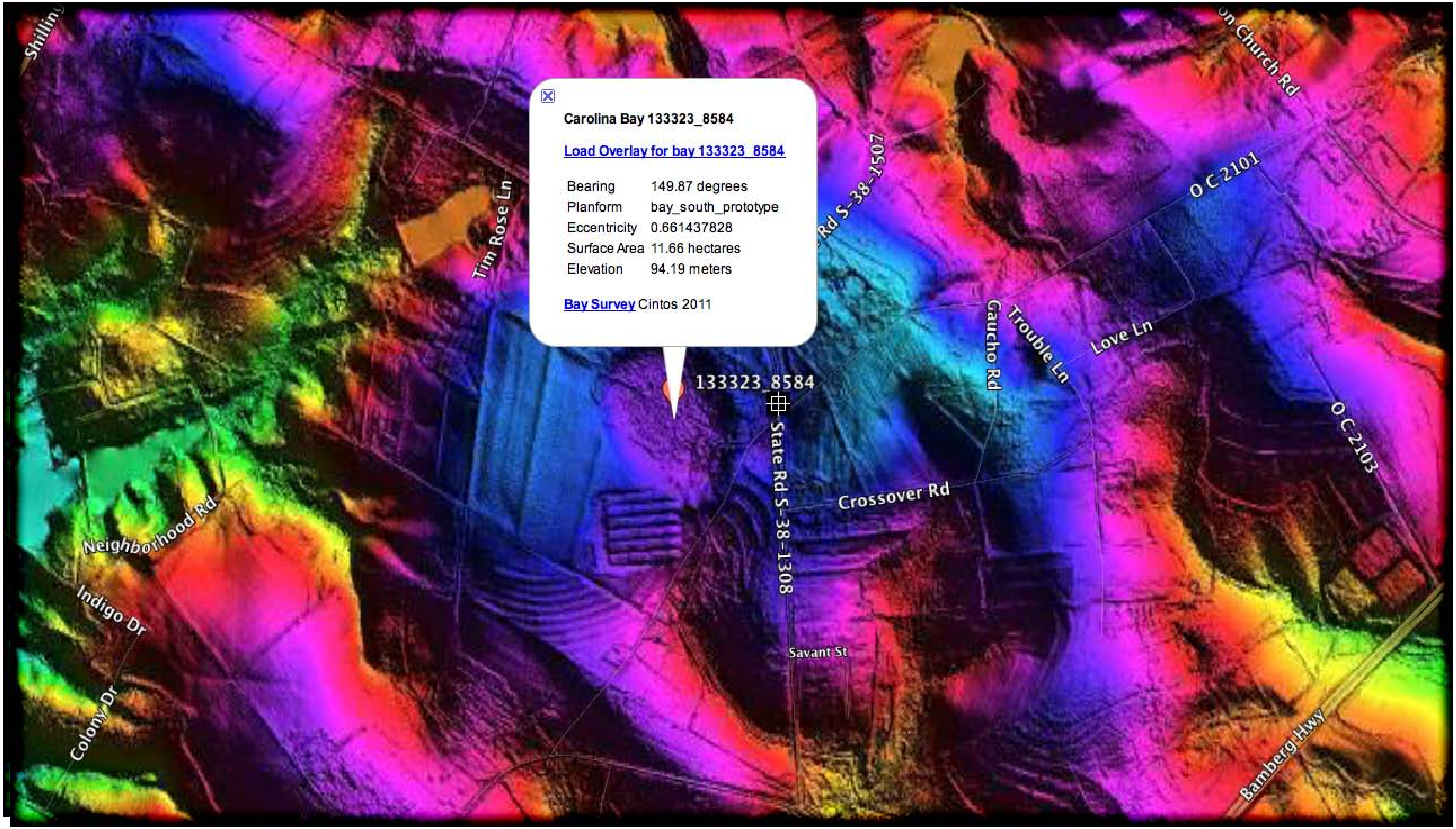
4-slides: Using the Google Earth Historical imagery, we first attempt to fit a planform overlay into the basin. We have engineered an analytical calculator to generate proposed bay orientations at any given location across the US as shown with this red arrow. **Metrics discussed.** Now, we have been informed by an experienced NC geologist that this is NOT a Carolina bay, but a simply a case of serendipity.. In any case, this is a singularity, so we would need to find a denser collection of landforms to make any case for bays in the above the coastal plain.

Transition from St. Paul to Aiken



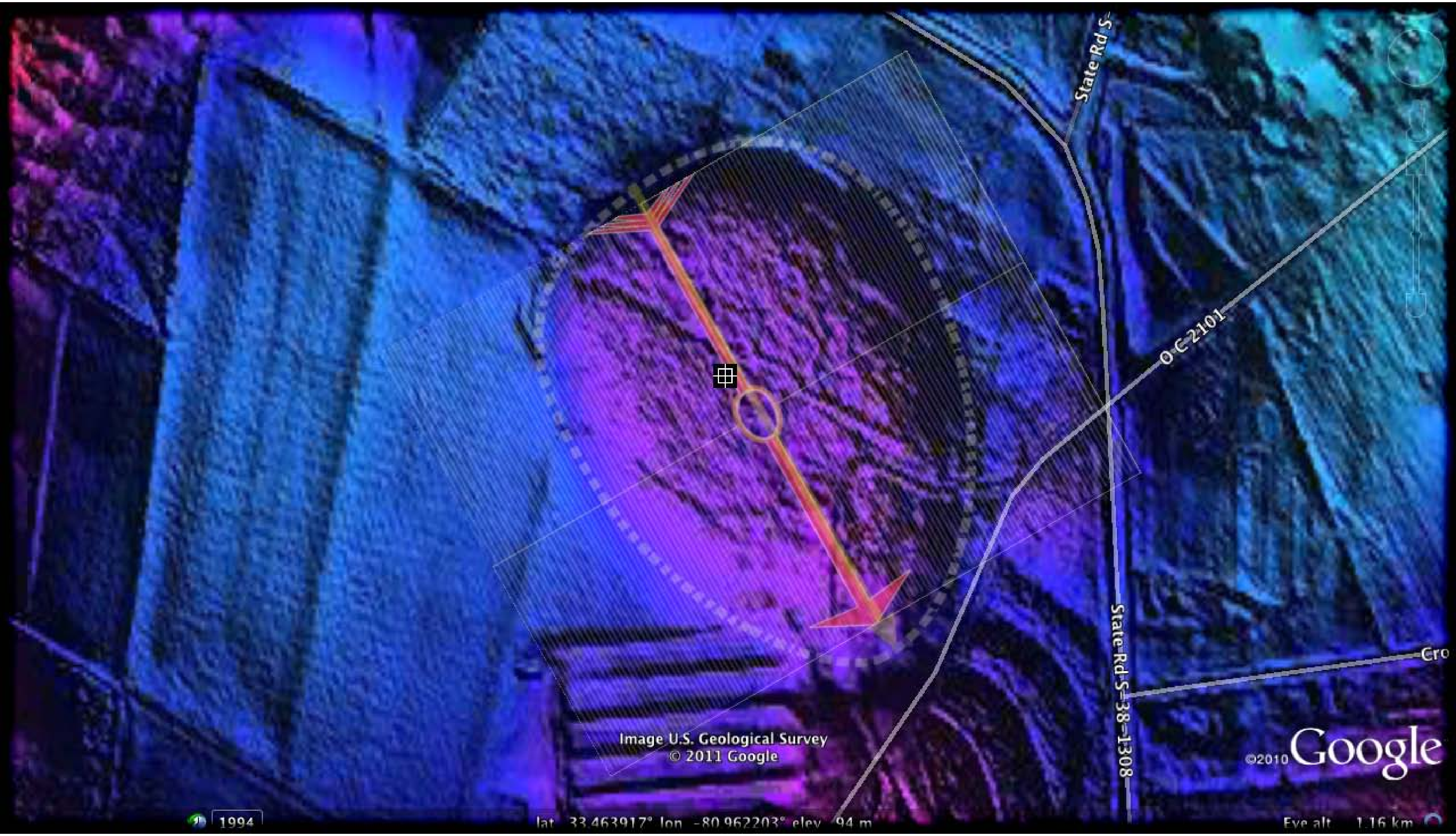
Now let's look at this LiDAR showing the transition up from the coastal plain in the St Paul quadrant. Once again, we see the bays diminish as the terrain become more complex. But here's a bay-shaped landform further up, but again located in a smooth hill-top setting.

Detail of Bay @ 94m AMSL



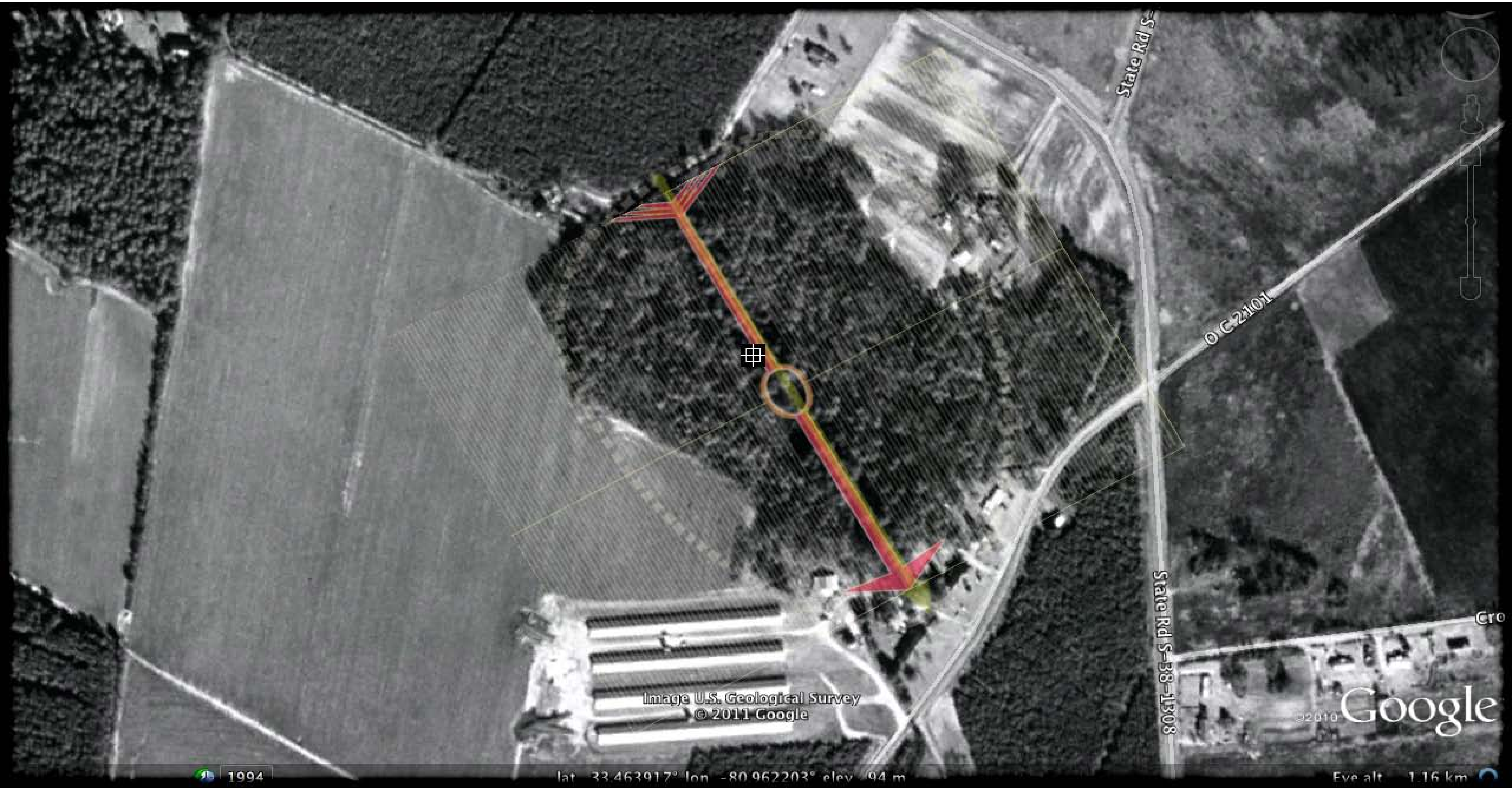
94 meters up. Looks like a Carolina bay to me …

Detail of Bay @ 94m AMSL



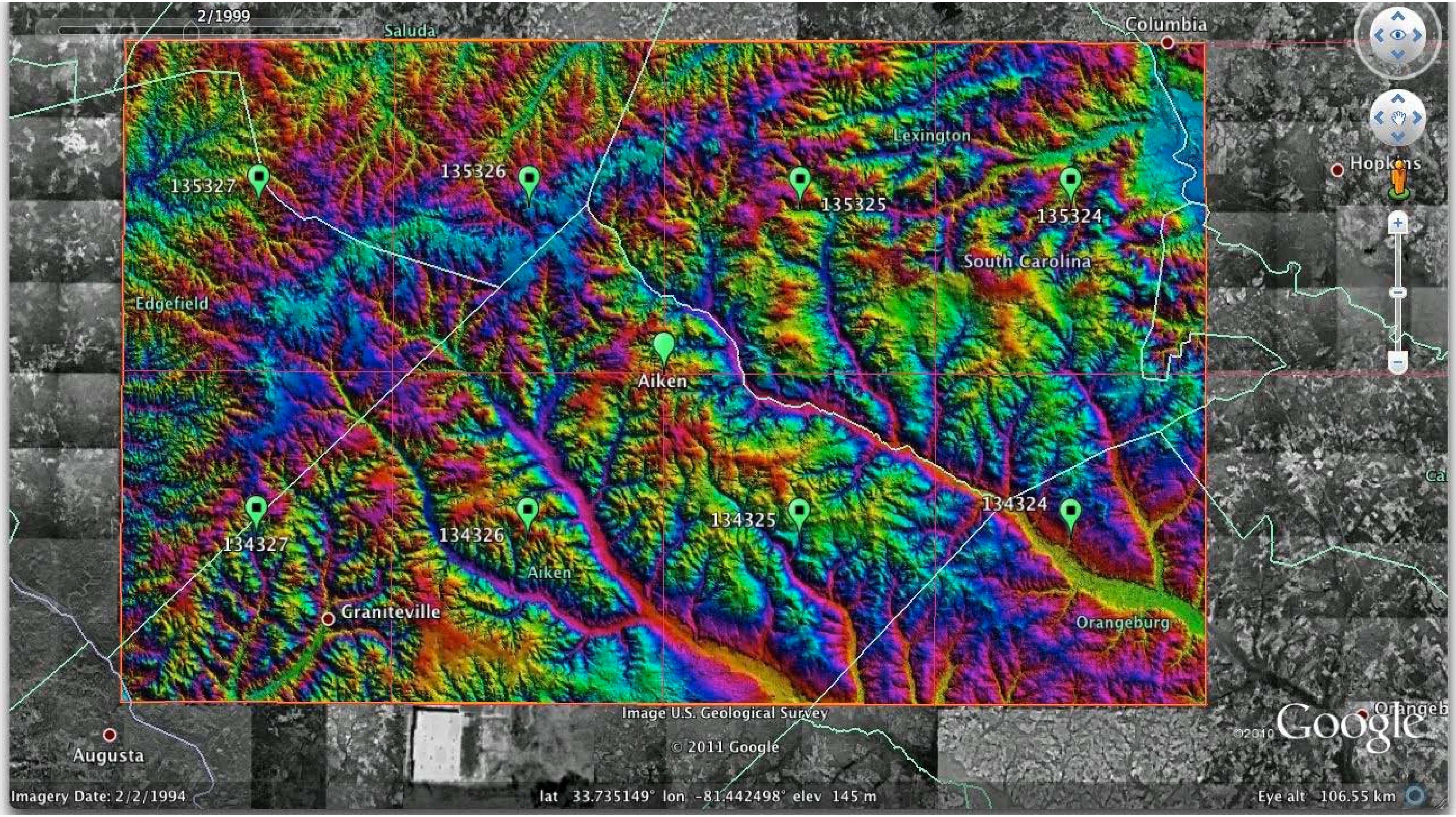
This conforms well to the second bay profile, and is dead on our model's predicted orientation.

Detail of Bay @ 94m AMSL



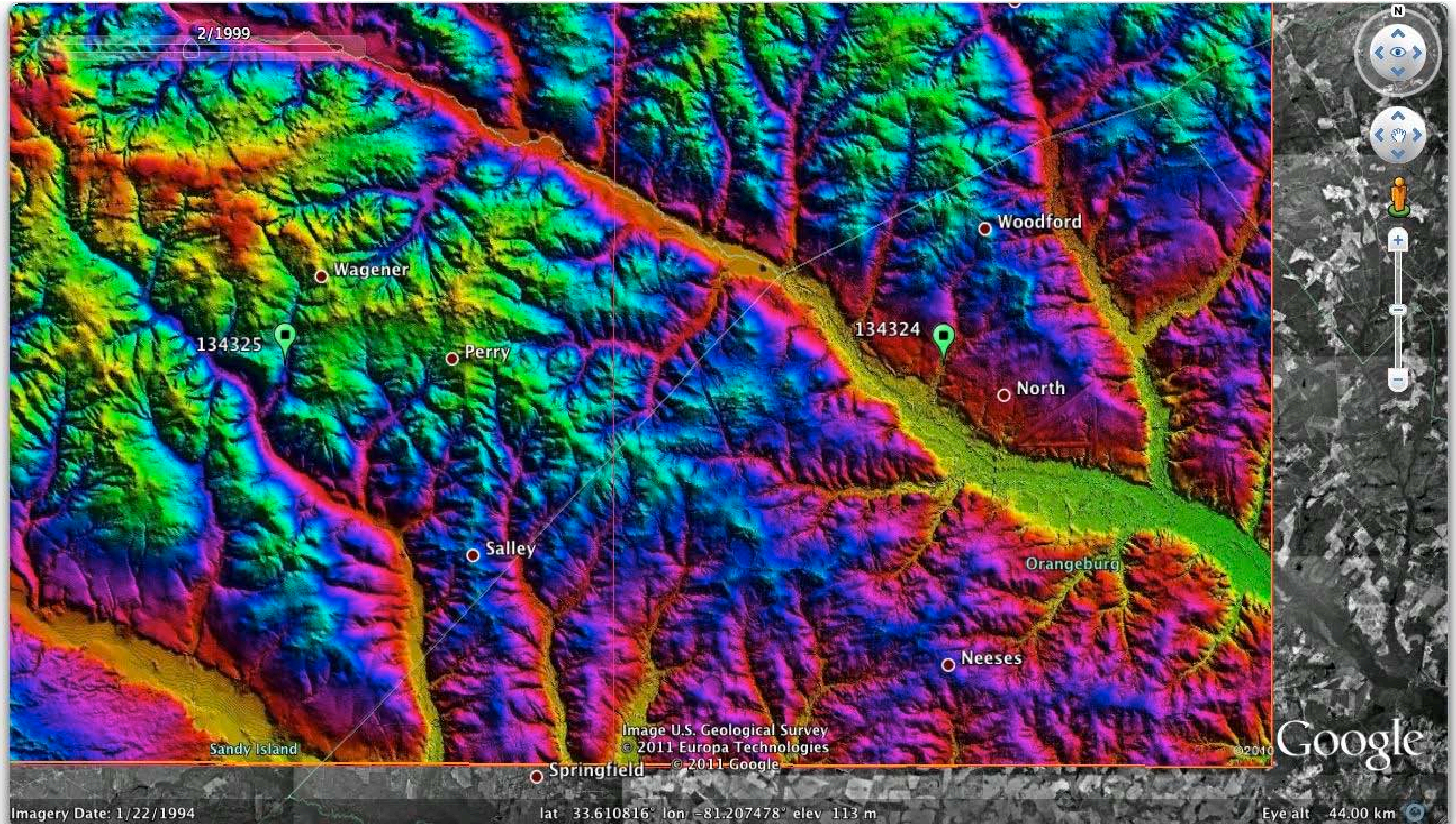
Satellite View. While this meets our criteria for a bay, it is at too low an elevation to qualify as "On the Piedmont".

Searching the Aiken Quad



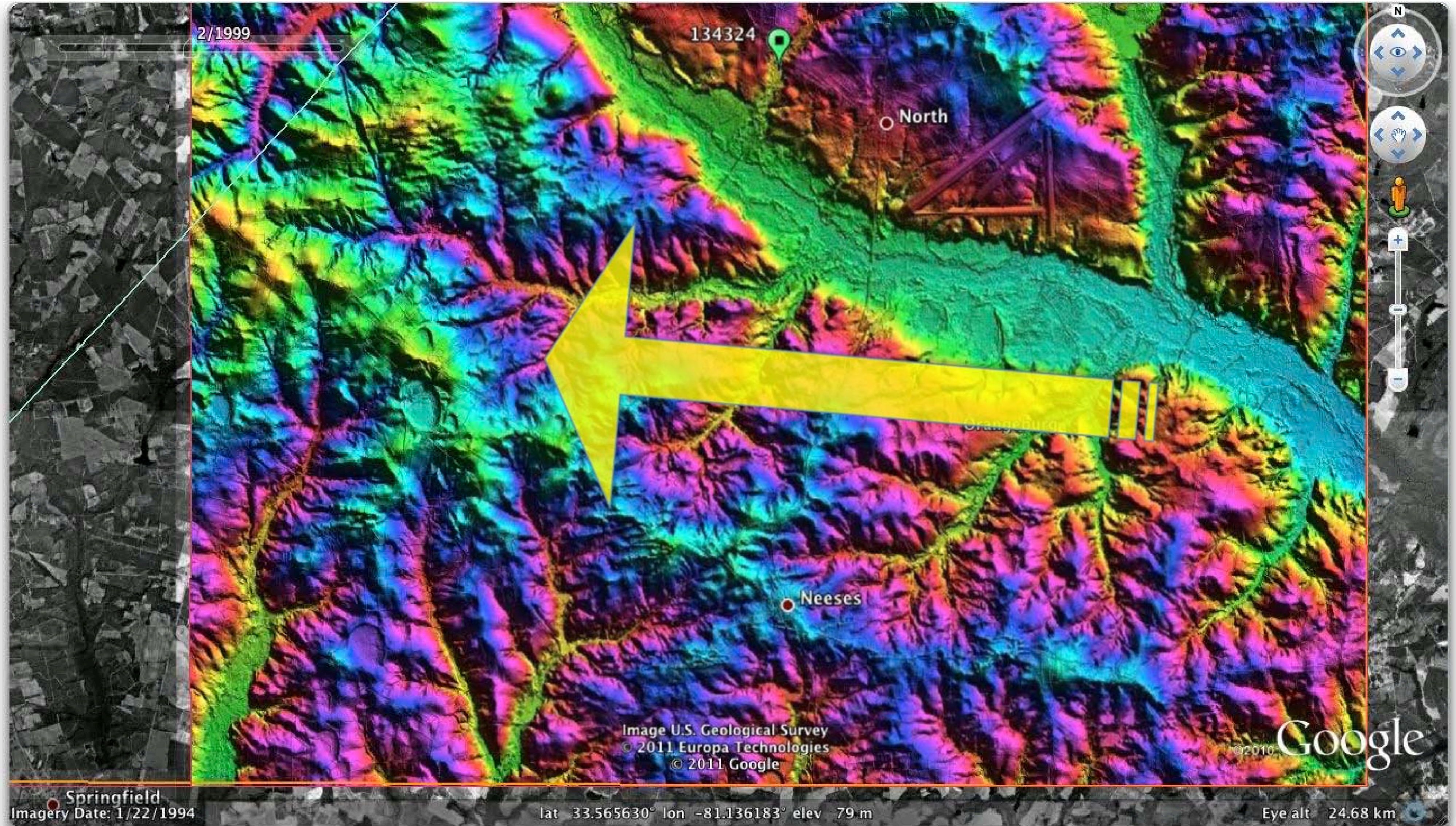
Let's look at the Aiken Quad, just to the north.

Searching the Aiken Quad @110m



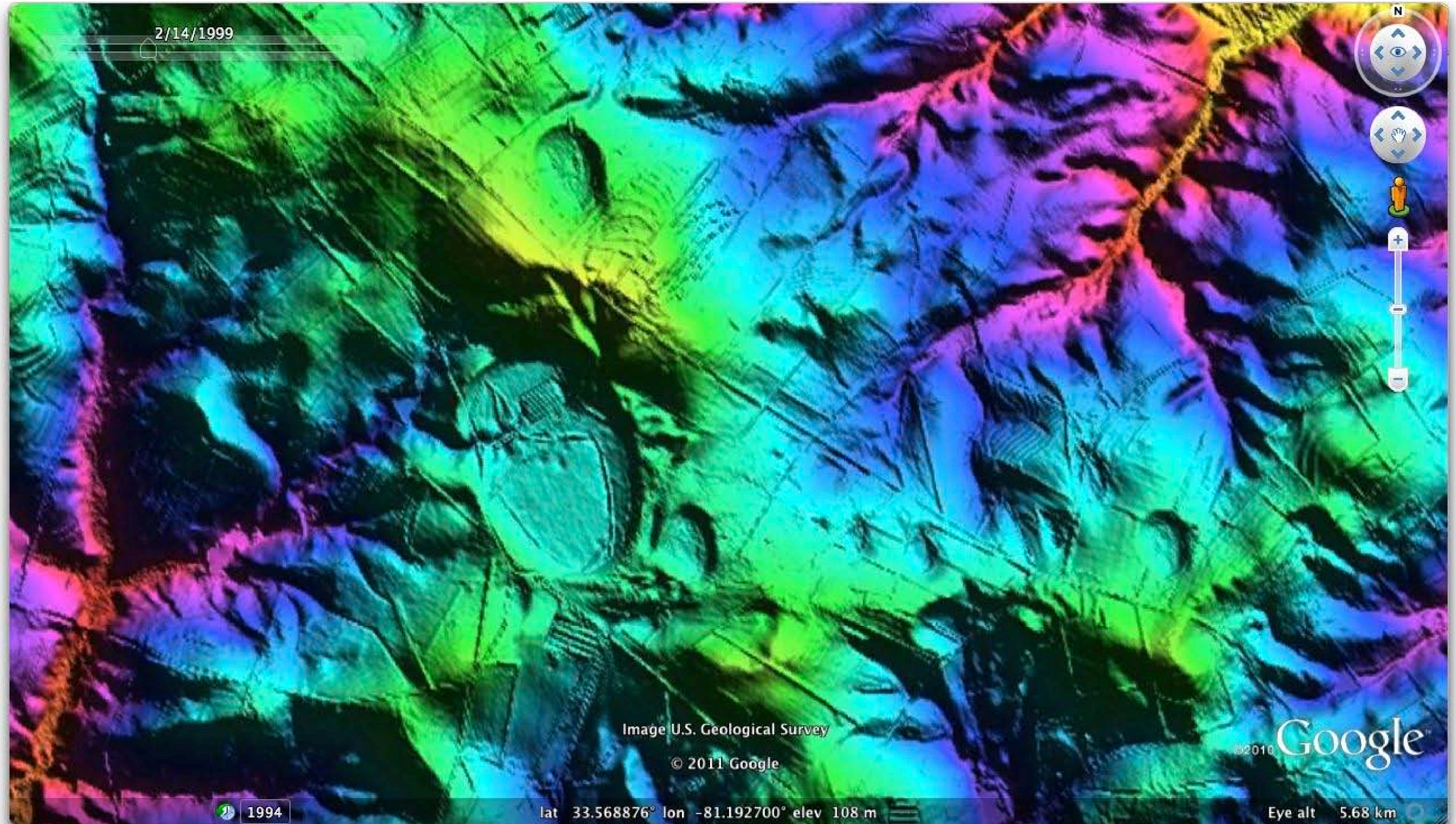
Zoom in, looking for smooth hill tops.

Searching the Aiken Quad @110m



Octant 134324

Searching the Aiken Quad @110m

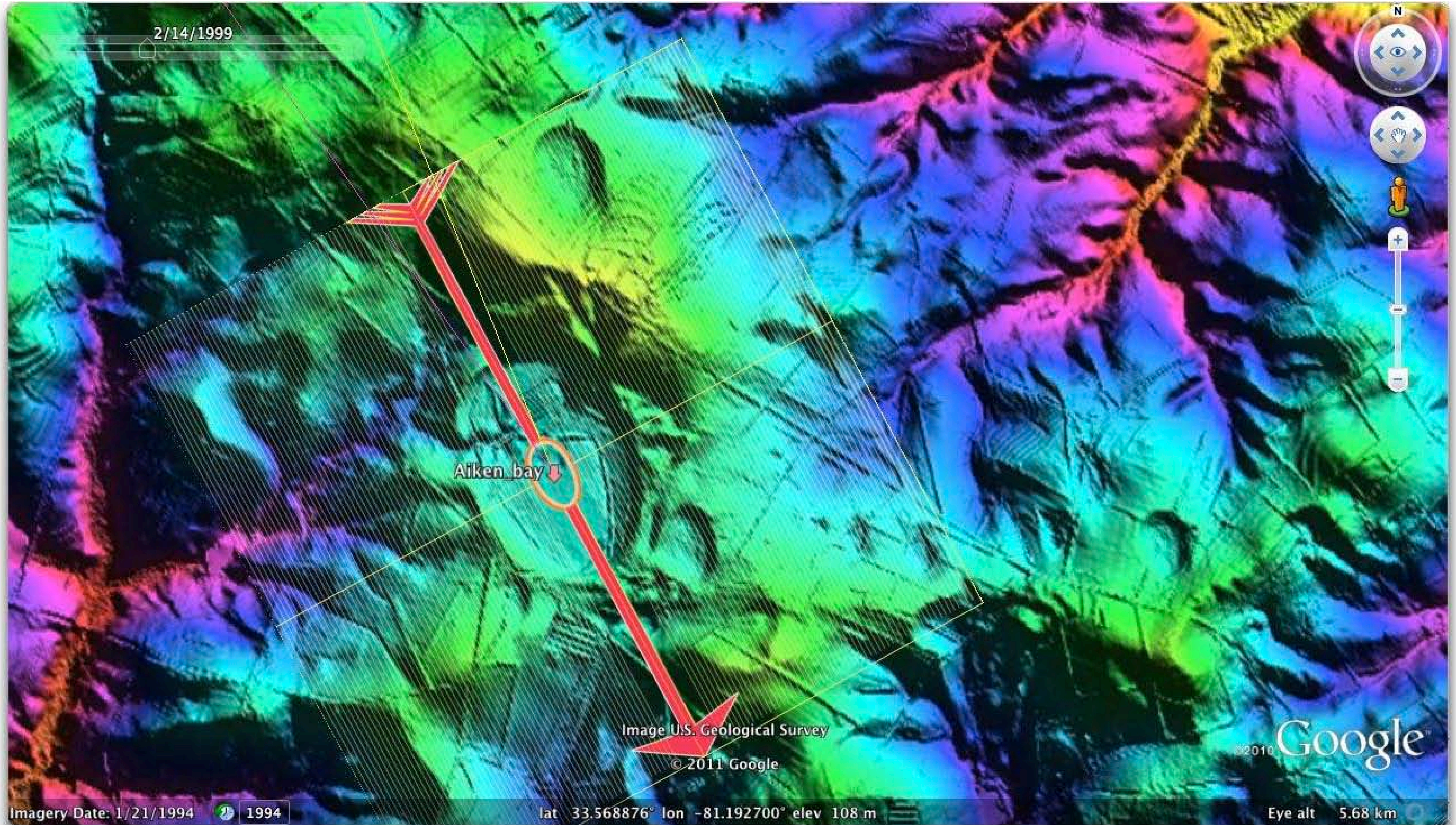


Ah! Multiple bays… at 110 m , Now we are getting somewhere!

Searching the Aiken Quad @110m

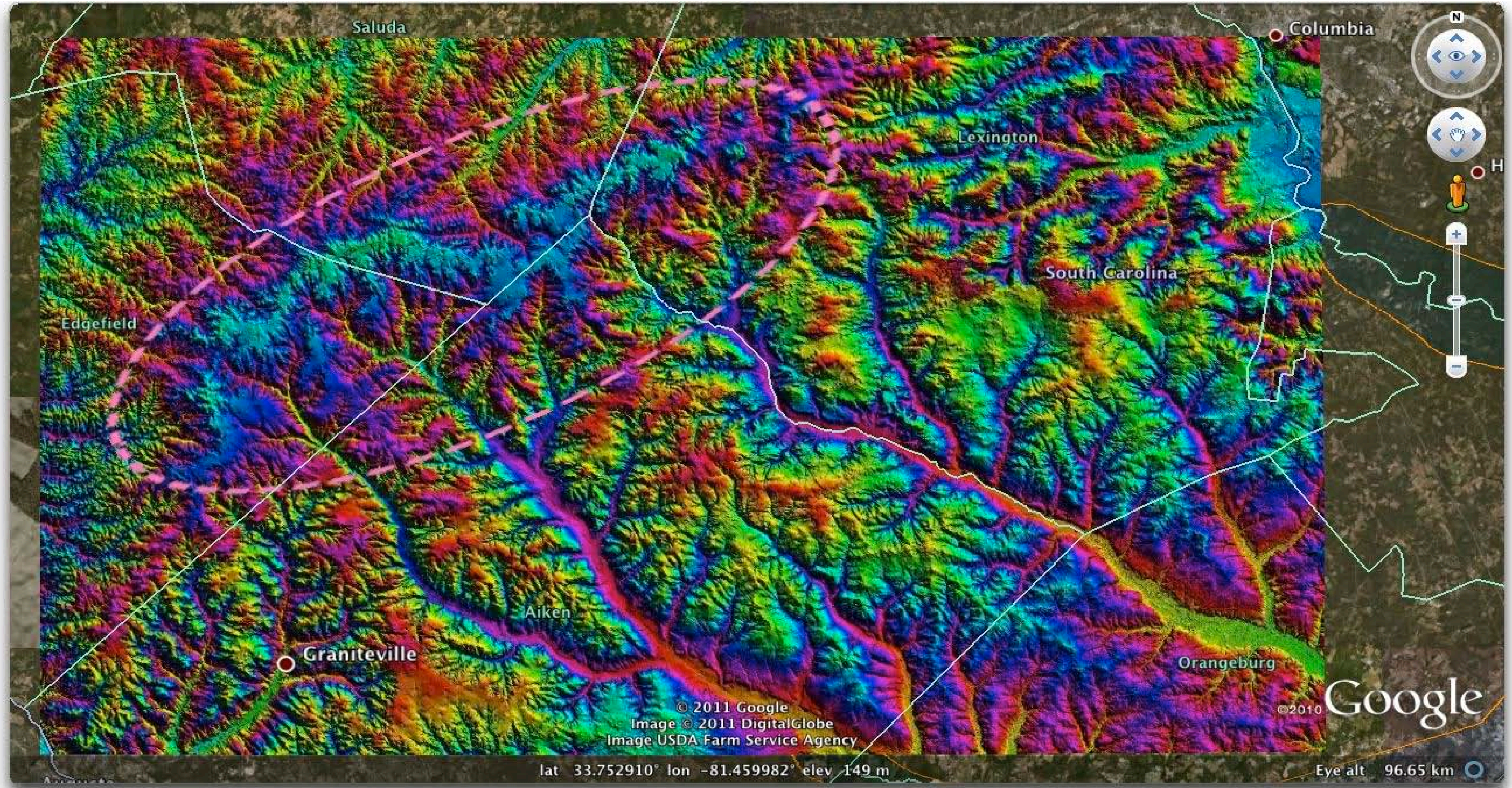
Can't see much in the satellite imagery…

Searching the Aiken Quad @110m



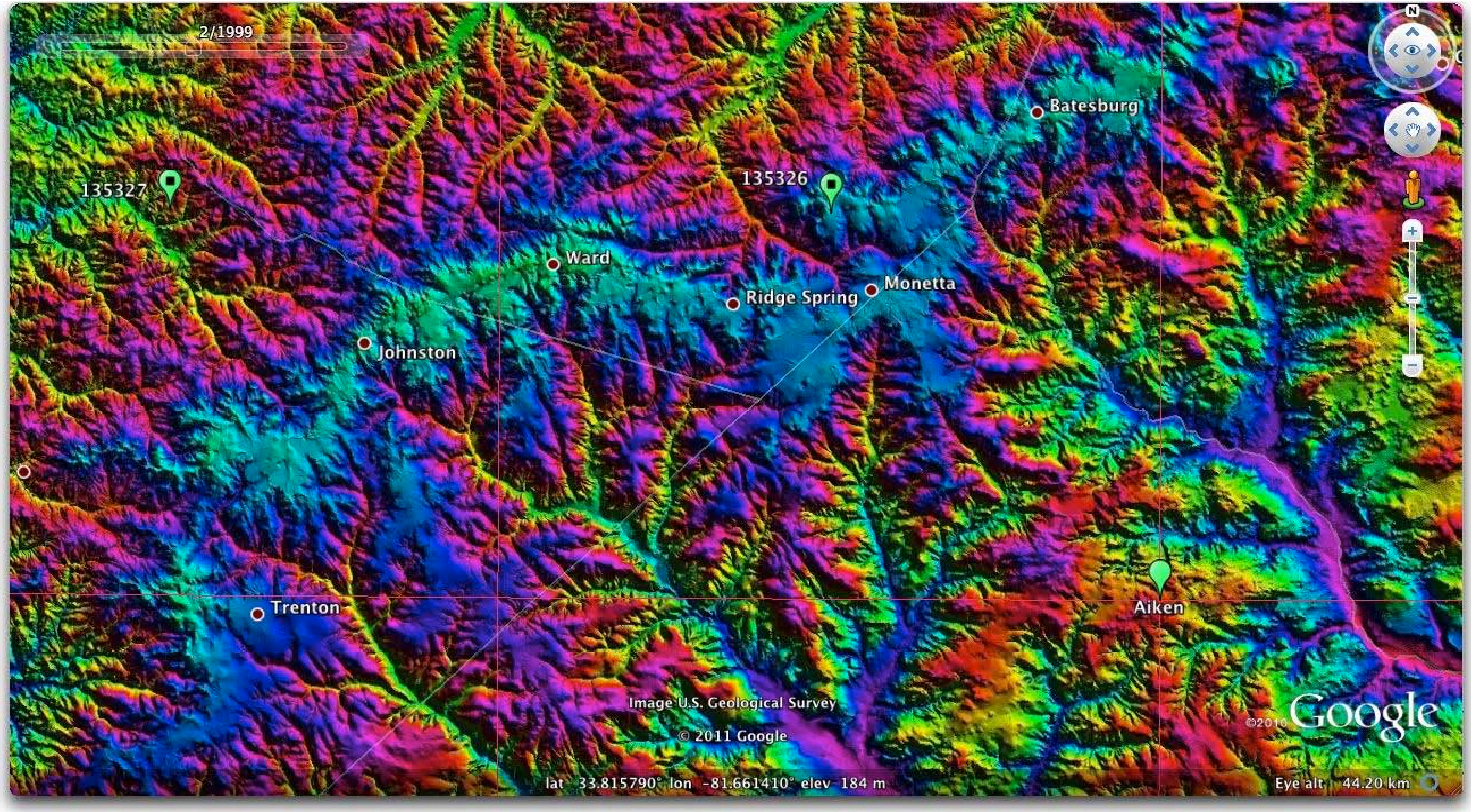
Good match on the predicted orientation

Searching Aiken Quad – Ridge Spring



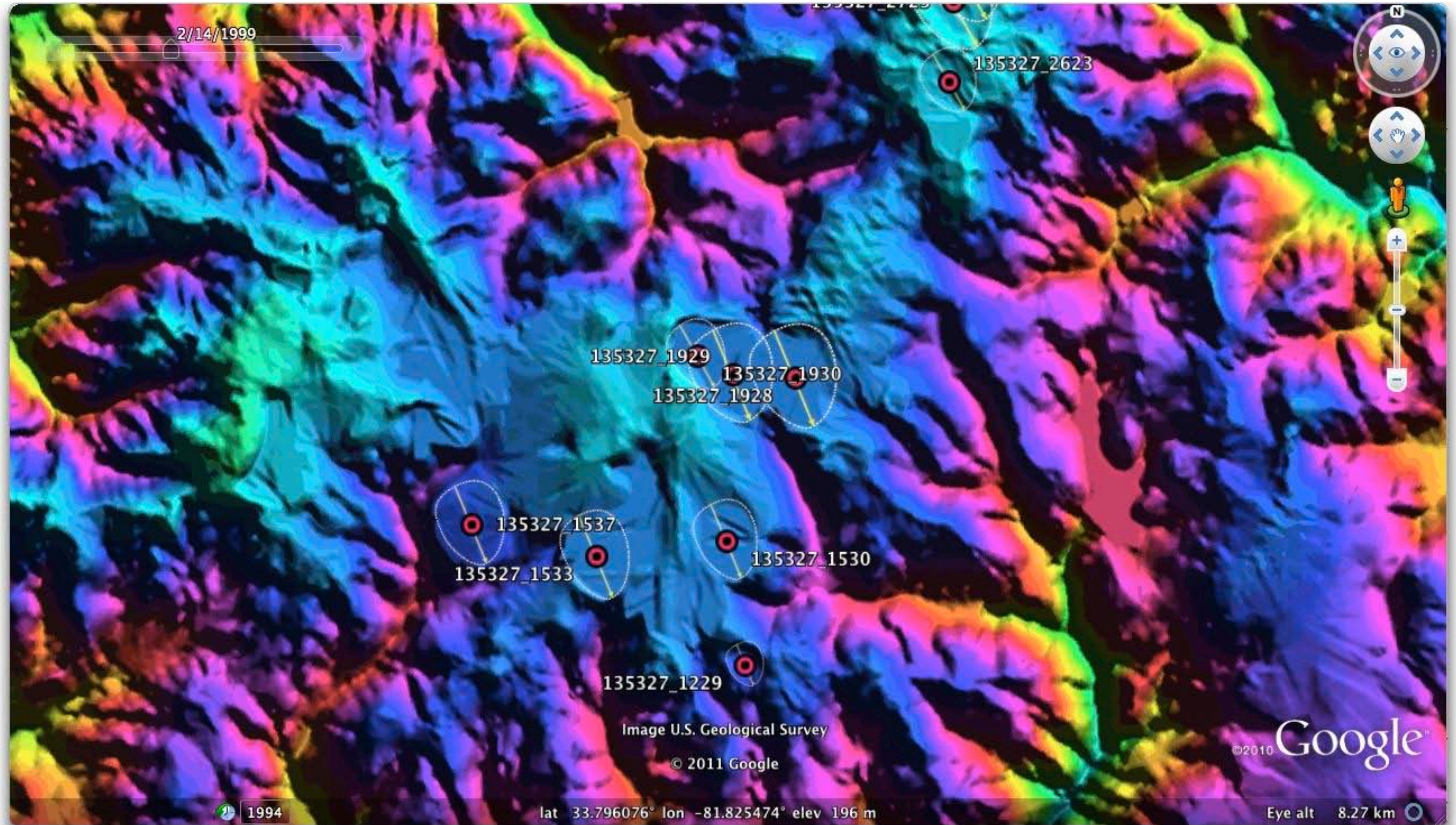
Now lets look at what seems to be a broad expanse of smooth hill tops in the northwest area of the Aiken Quad.

Searching Aiken Quad – Ridge Spring



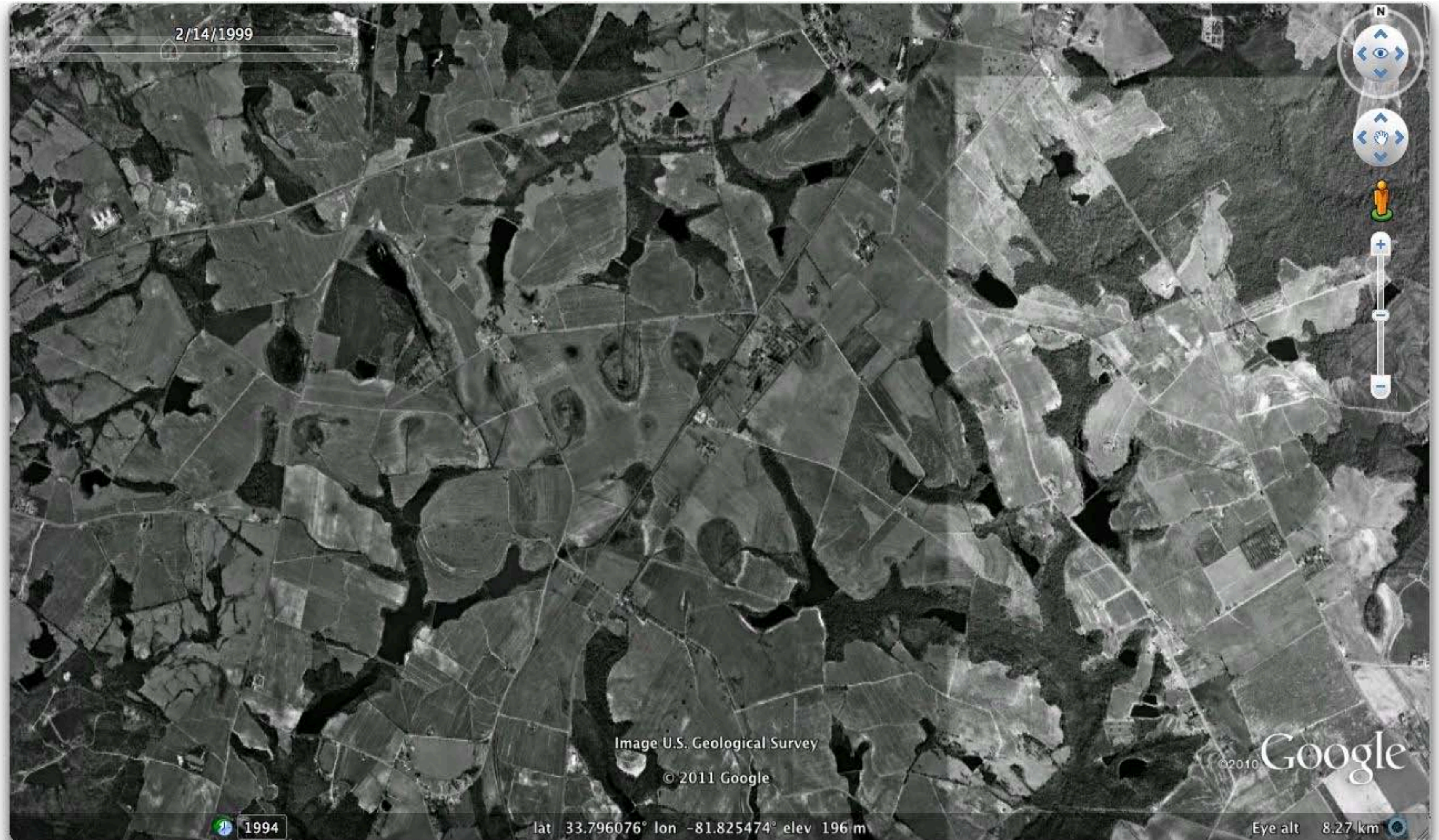
Let's call this Ridge Spring Ridge, after the town in the middle of it.

Western Ridge Spring Locale



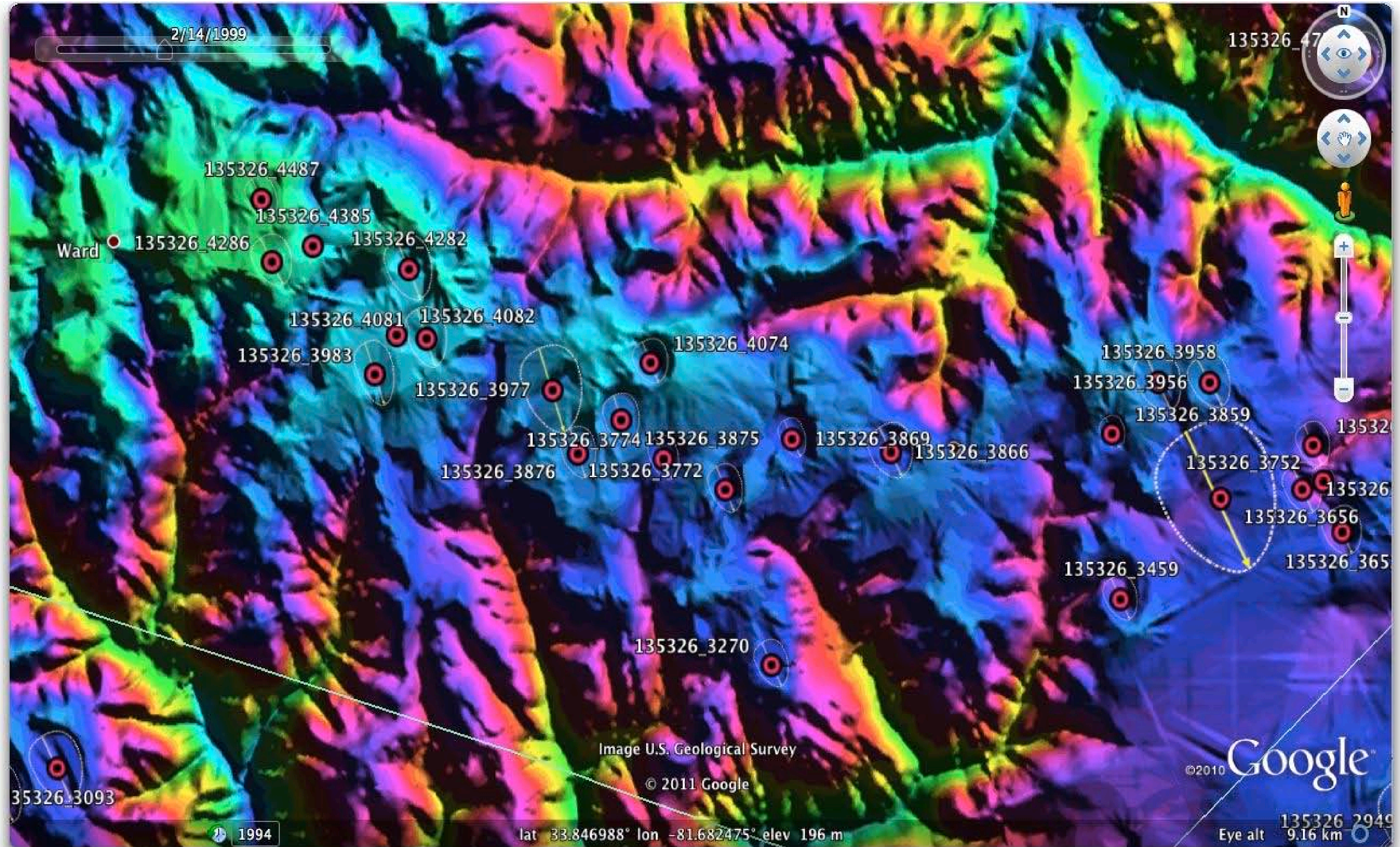
Only 1/3 arc second USGS NED data here, but the bays are discernable – at least to my biased eye…

Western Ridge Spring Locale



And there is supportive satellite imagery

Central Ridge Spring Locale



Another area a bit to the east along the Ridge ....

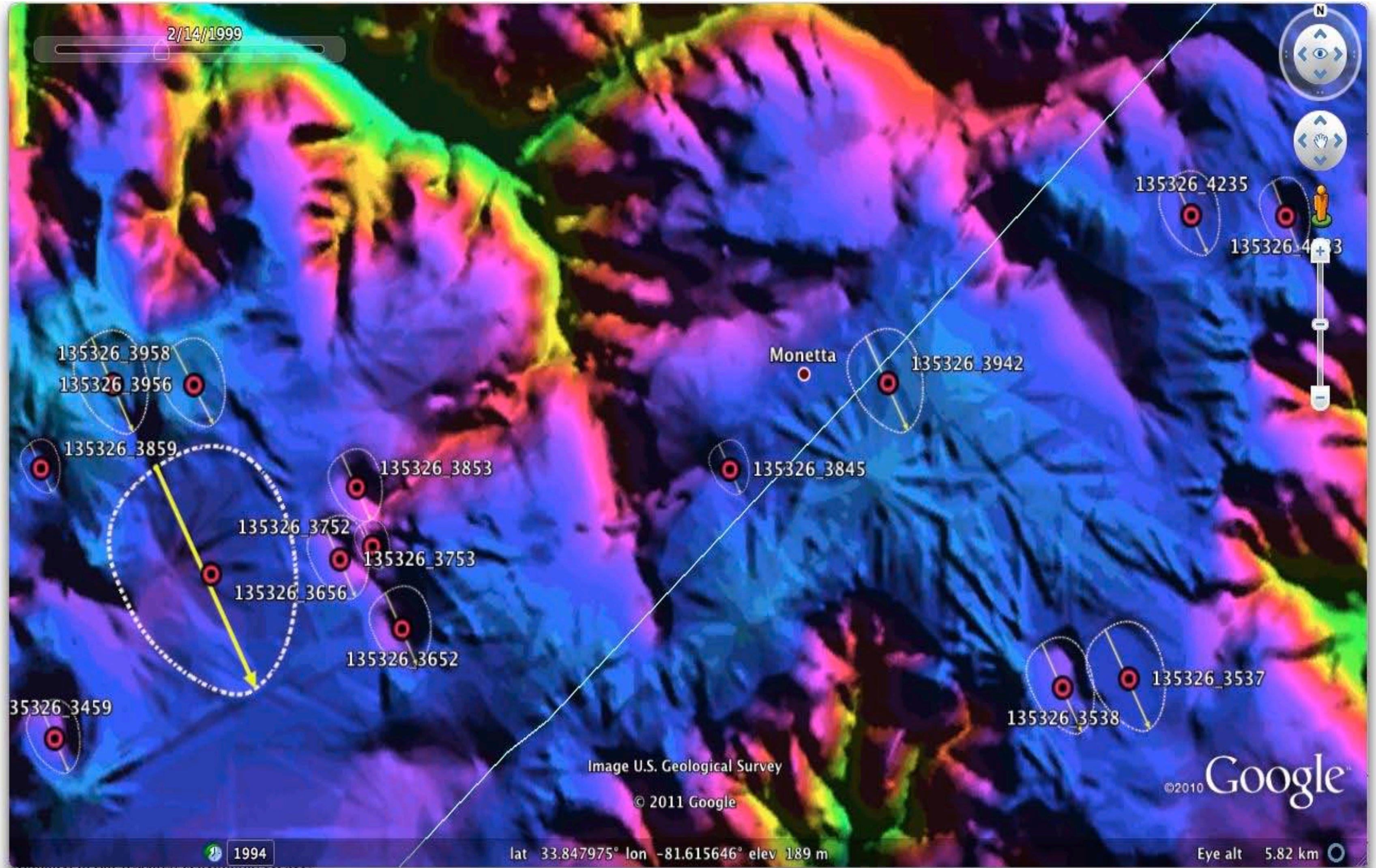
Central Ridge Spring Locale

Again, support in the visual imagery..

Central Ridge Spring Locale

Detail from previous slide area

Eastern Ridge Spring Locale

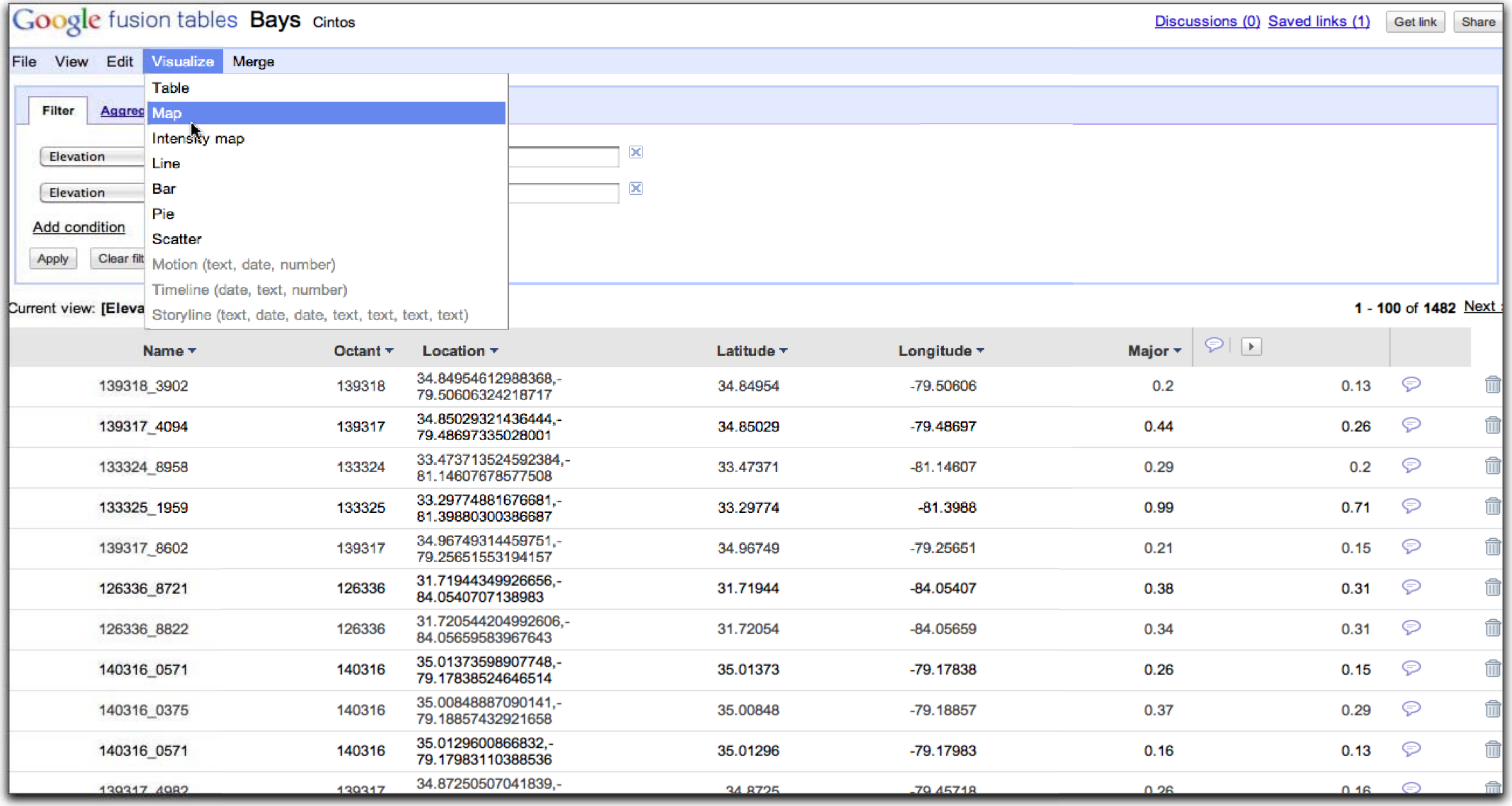


Further east along the ridge

Not LiDAR-quality, but even this suggests closed depressions

Eastern Ridge Spring Locale

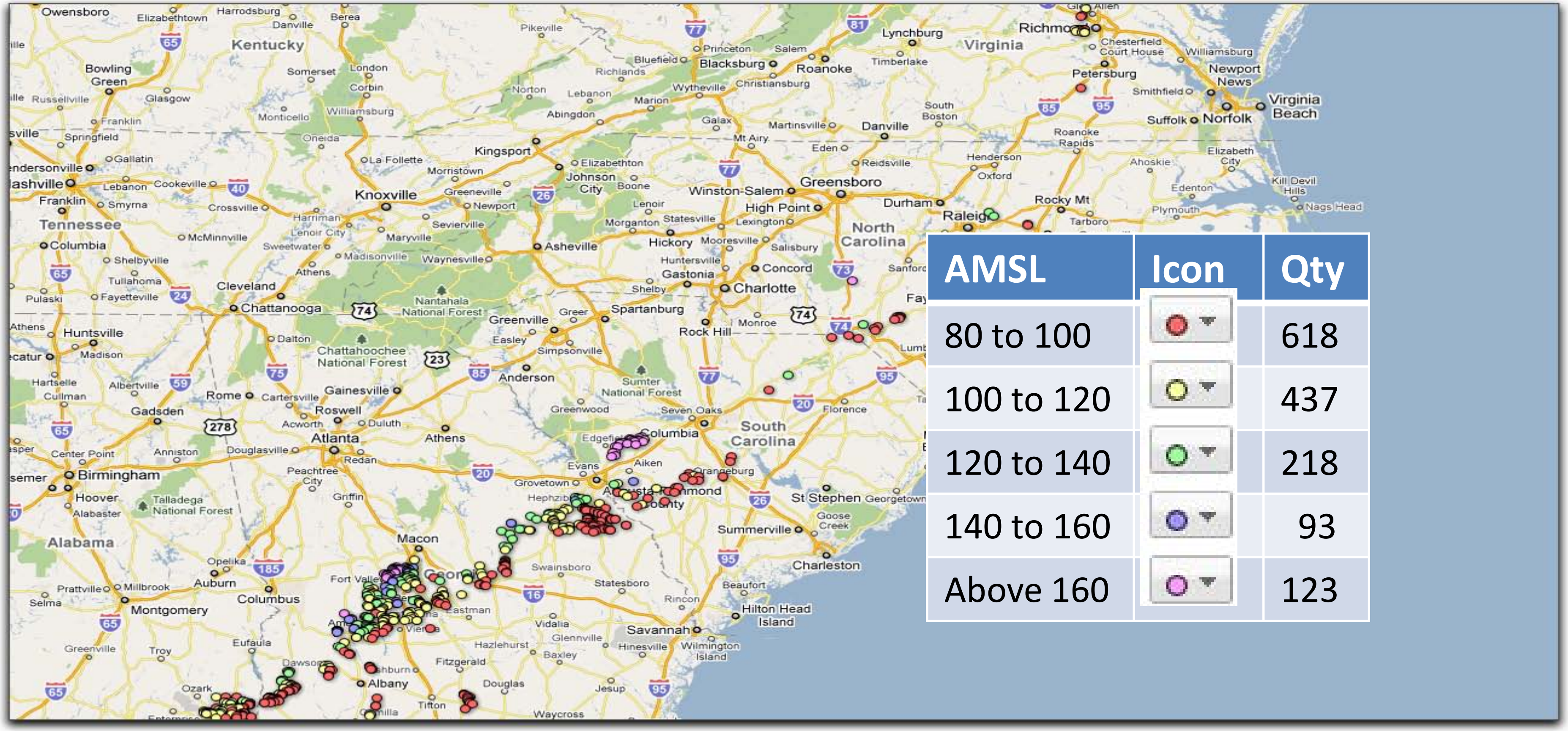
Fusion Table Search – Bays Above 80 m



Name	Octant	Location	Latitude	Longitude	Major	
139318_3902	139318	34.84954612988368,-79.50606324218717	34.84954	-79.50606	0.2	0.13
139317_4094	139317	34.85029321436444,-79.48697335028001	34.85029	-79.48697	0.44	0.26
133324_8958	133324	33.473713524592384,-81.14607678577508	33.47371	-81.14607	0.29	0.2
133325_1959	133325	33.29774881676681,-81.39880300386687	33.29774	-81.3988	0.99	0.71
139317_8602	139317	34.96749314459751,-79.25651553194157	34.96749	-79.25651	0.21	0.15
126336_8721	126336	31.71944349926656,-84.0540707138983	31.71944	-84.05407	0.38	0.31
126336_8822	126336	31.72054420499260 6,-84.05659583967643	31.72054	-84.05659	0.34	0.31
140316_0571	140316	35.01373598907748,-79.17838524646514	35.01373	-79.17838	0.26	0.15
140316_0375	140316	35.00848887090141,-79.18857432921658	35.00848	-79.18857	0.37	0.29
140316_0571	140316	35.0129600866832,-79.17983110388536	35.01296	-79.17983	0.16	0.13
139317_4982	139317	34.87250507041839,-	34.8725	-79.45718	0.26	0.16

This is the Fusion table user interface, viewed in your standard web browser. Here we have searched for and found 1492 bays over 80 m **CLICK** We select Visualize>Map.

Extensive Set of Bays Found Above 80 m



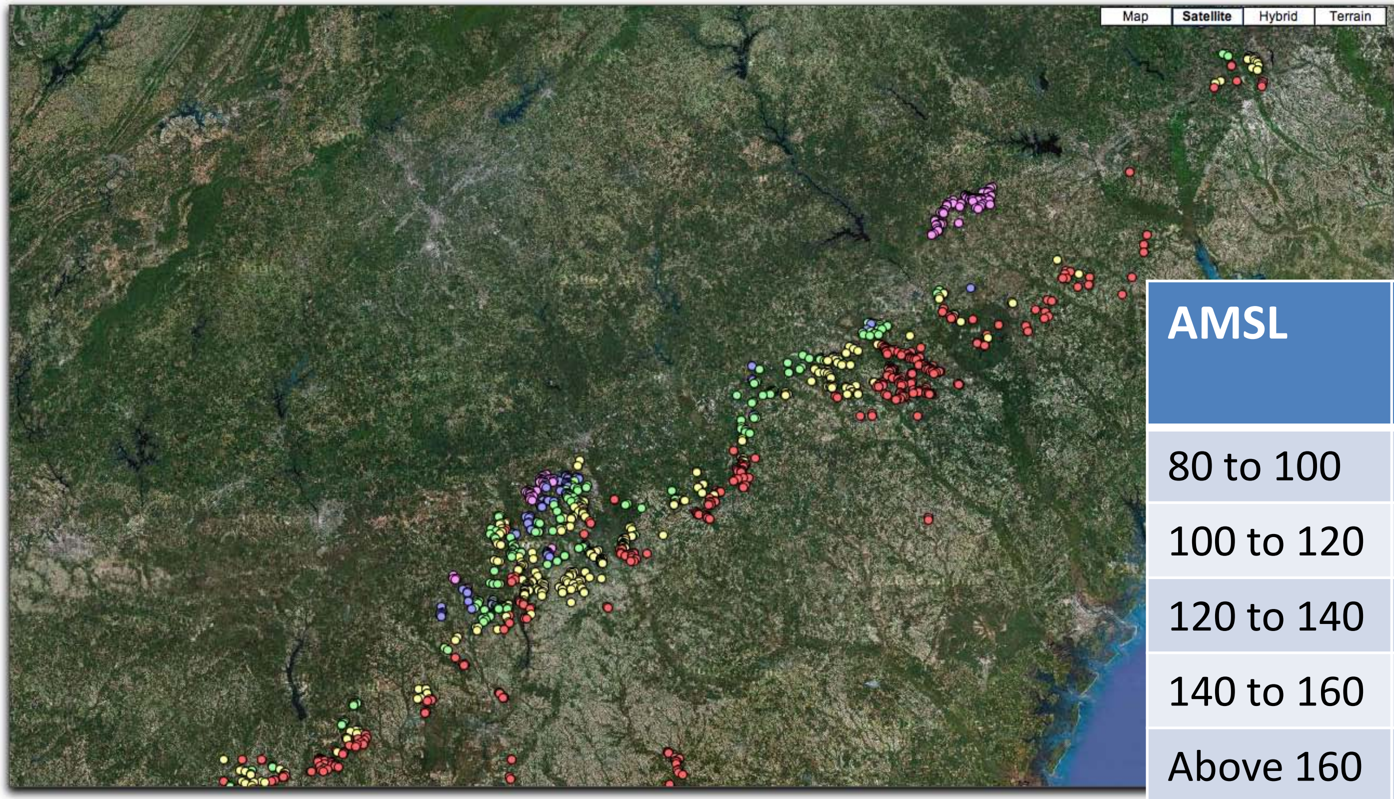
AMSL	Icon	Qty
80 to 100		618
100 to 120		437
120 to 140		218
140 to 160		93
Above 160		123

Results from Fusion Table; elevation > 80m,
http://google.com/fusiontables/DataSource?snapid=166010

And we get a nice map of the selected bay data. We have edited the icon styles to correspond to 20 meter ranges of elevation, as shown in the legend.

Using Fusion Map Visualization

Results from Fusion Table; elevation > 80m,
http://google.com/fusiontables/DataSource?snapid=166010

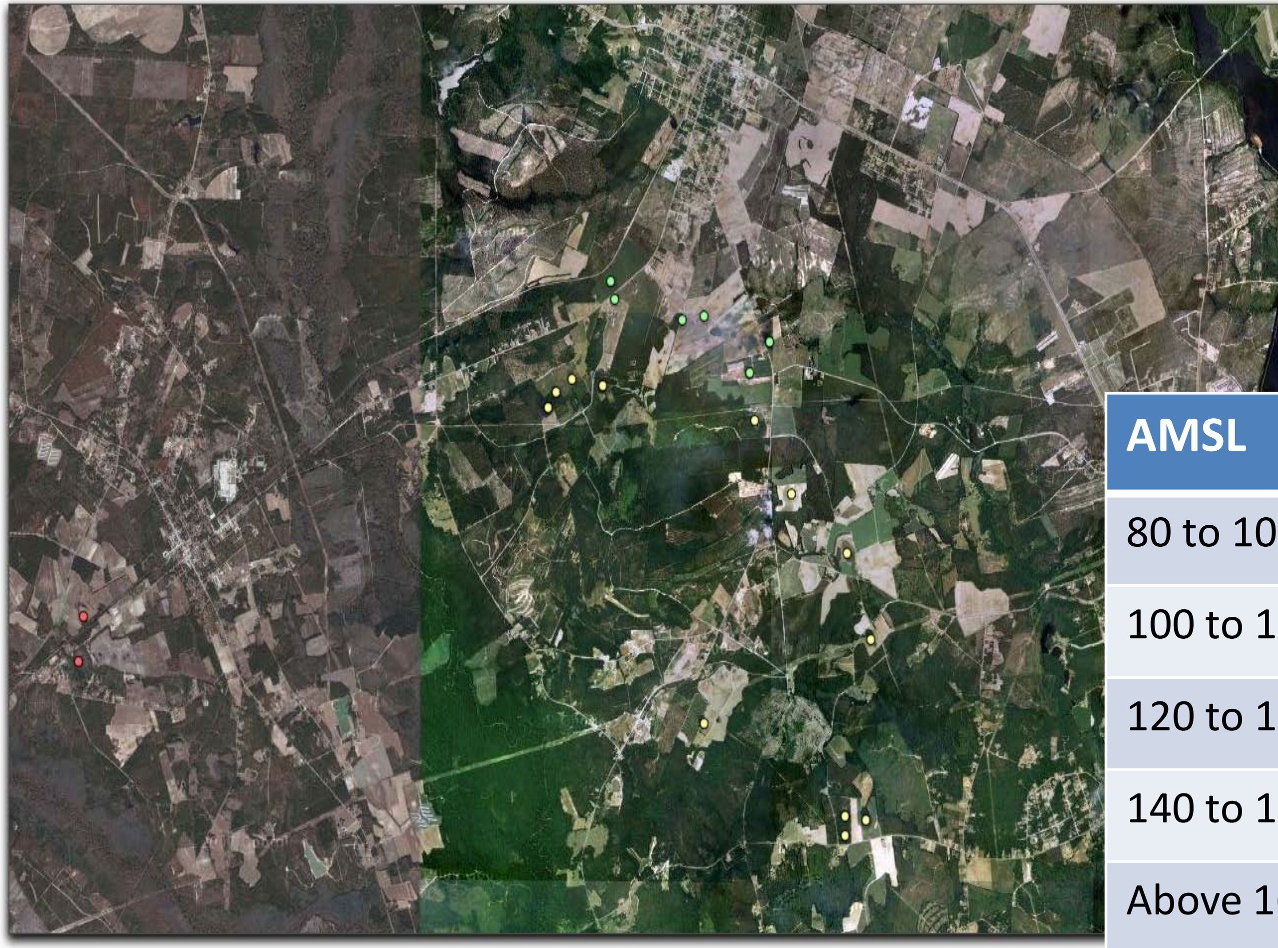


AMSL	Icon	Qty
80 to 100		618
100 to 120		437
120 to 140		218
140 to 160		93
Above 160		123

Instead of the map view, we can select Satellite in the upper right… The Fusion facility will only show 500 total placemarks at a time to keep from cluttering the view, but as you zoom in..

Using Fusion Map Visualization

Results from Fusion Table; elevation > 80m,
http://google.com/fusiontables/DataSource?snapid=166010



AMSL	Icon	Qty
80 to 100		618
100 to 120		437
120 to 140		218
140 to 160		93
Above 160		123

The individual placemarks become resolved. We are zooming in on one of the Yellow Placemarks, 100 to 120 m elevation.

Using Fusion Map Visualization

Zoom. Selecting the Placemark, you get a popup with bay metrics from the cloud repository; this is just shy of 120 meters, a value provided by the USGS using a web query during our processing of this bay's overlay. And you can retrieve that overlay for viewing in the Google Earth Application by clicking on the highlighted link in the balloon. Note that you are still in the Fusion table visualization tool in your web browser.

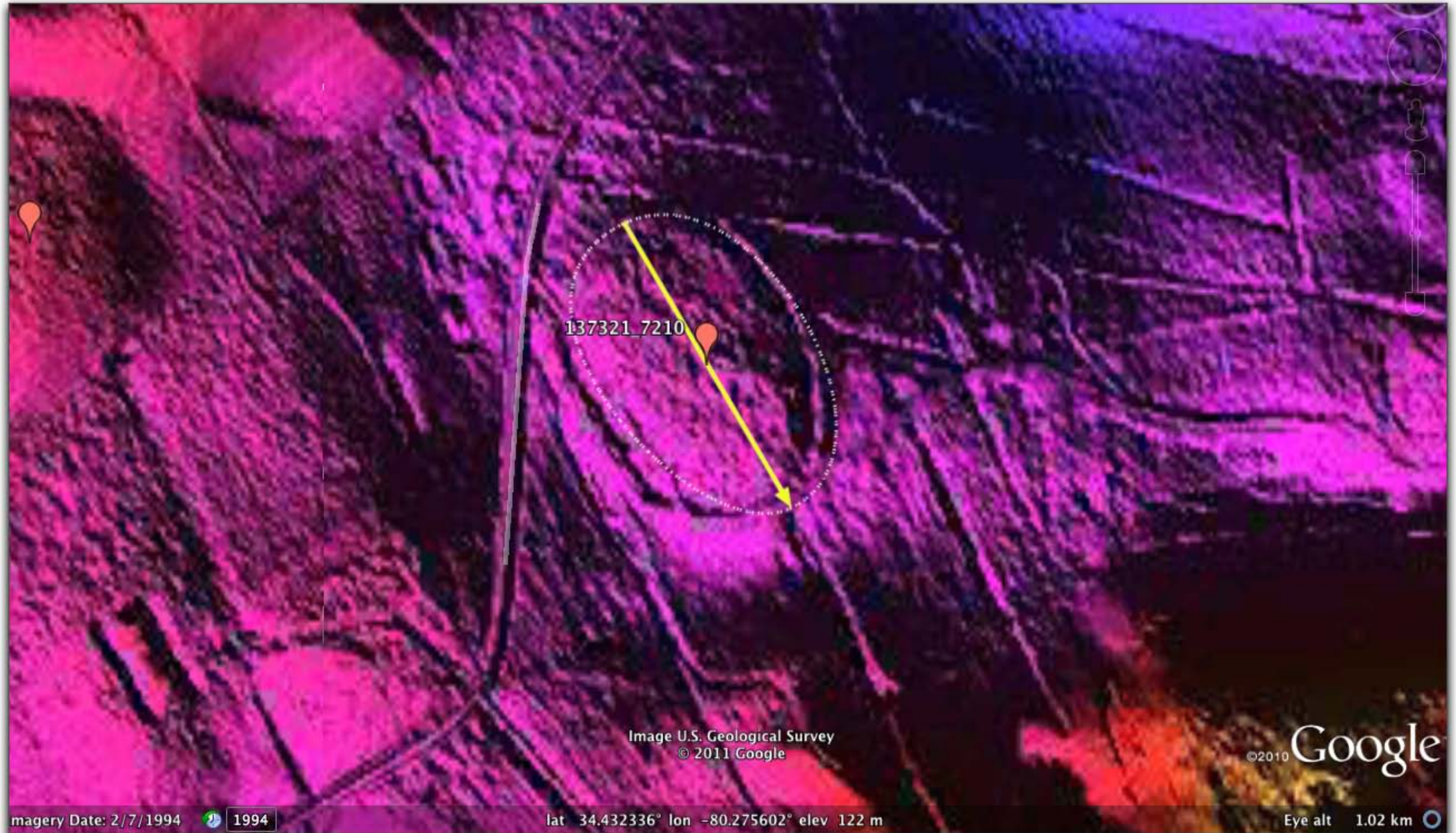
Loaded Bay Overlay Into Google Earth

By selecting the link, we switch to the Google Earth application and are brought to the bay's location on the GE virtual globe, with the overlay in place as we had positioned it during the survey capture. Historic Imagery view 2/7/1994

Results from Fusion Table; elevation > 80m,
http://google.com/fusiontables/DataSource?snapid=166010

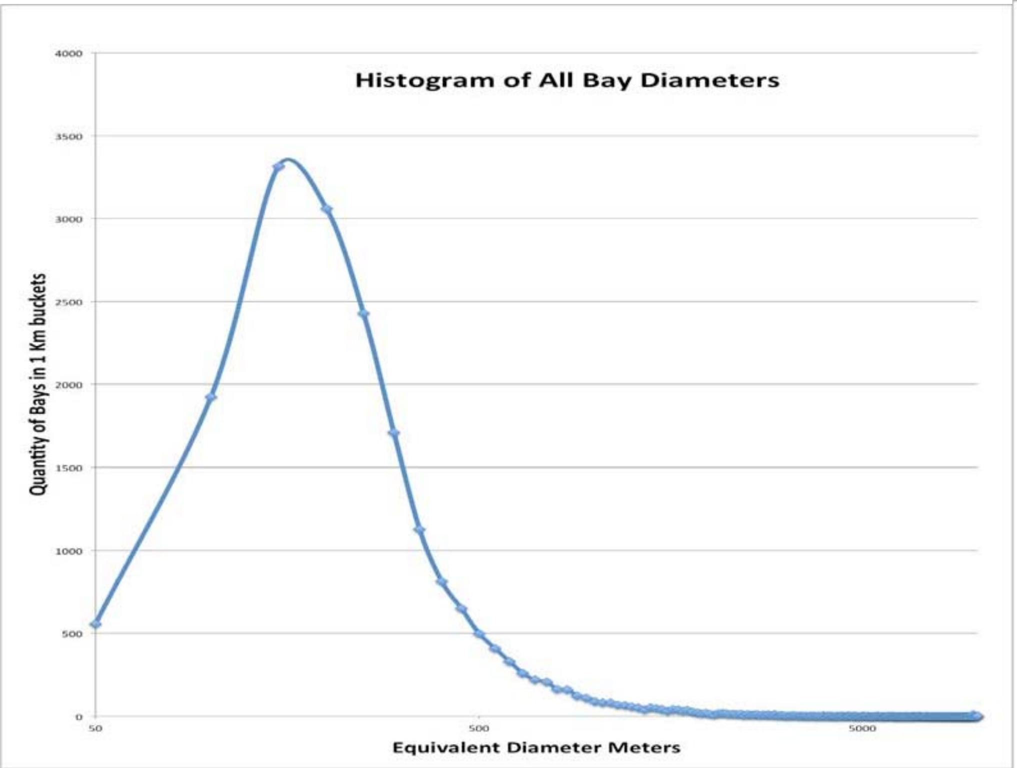
Loaded Bay Overlay Into Google Earth

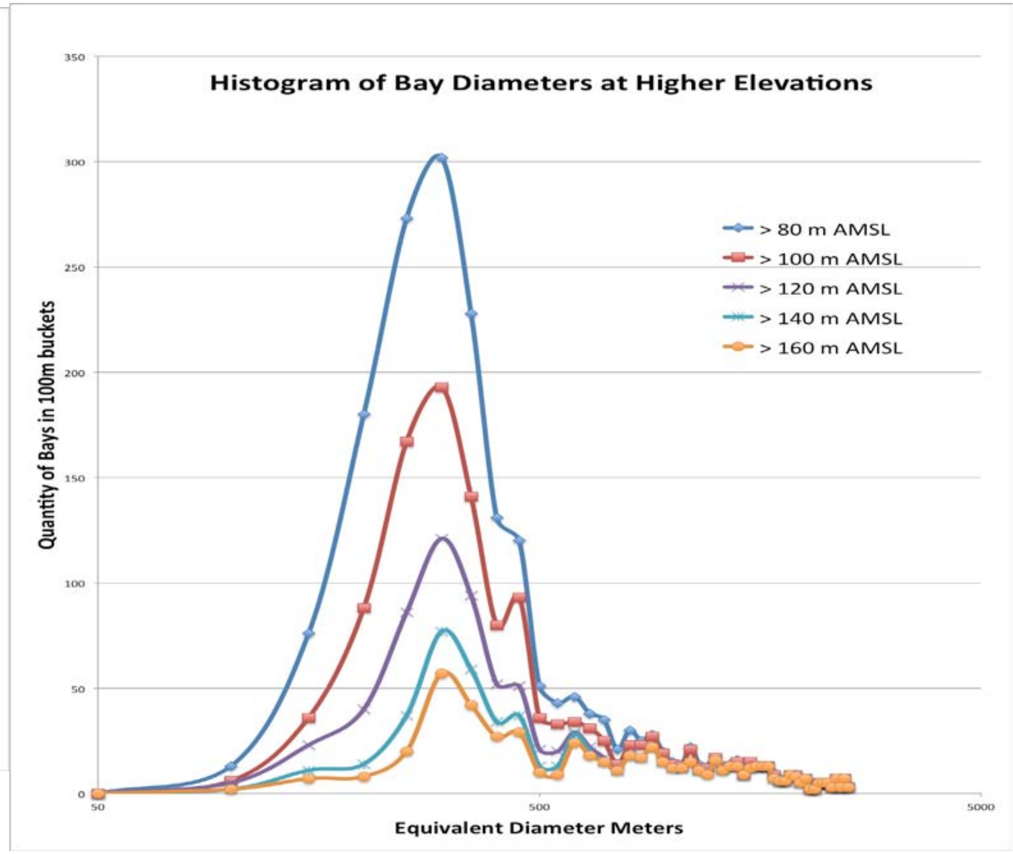
Results from Fusion Table; elevation > 80m,
http://google.com/fusiontables/DataSource?snapid=166010



And, here is the LiDAR View

Bay Sizes Exhibit Log-Normal Distribution





On your left is a histogram of all bay sizes in the survey , exhibiting a classic log normal distribution. Contrasted on the right is the log-normal distribution of bays found above 80 m in five ranges. We suggest this statistically associates each of these groups with the main body of bays. i.e., one common geomorphology. And what is that exactly? Who knows!

Bubble Sizes Exhibit Log-Normal Distribution

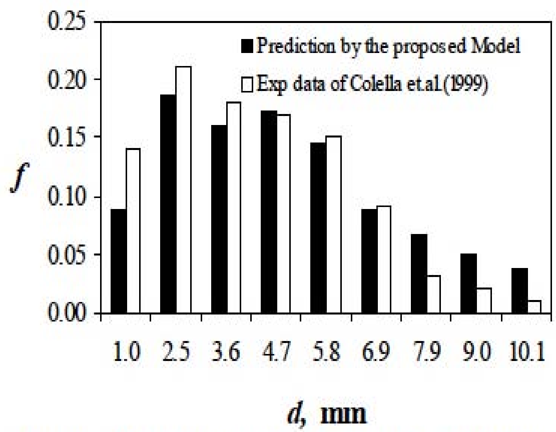


Fig 3. Comparison of the model with the experimental data of Collela et.al. (1999) for velocity 0.59 cm/s.

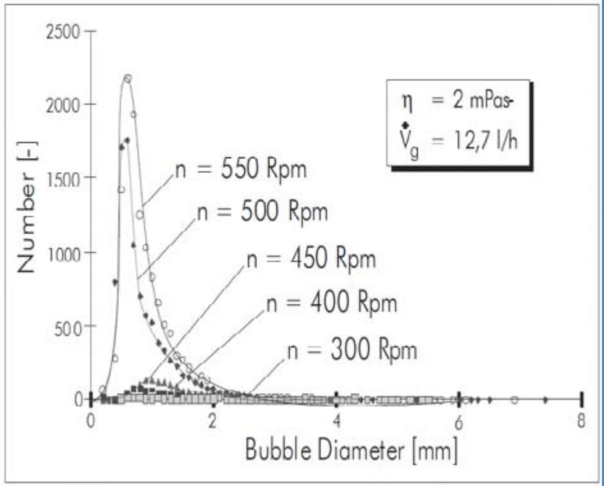


Fig. 4 : Bubble size distributions for different impeller speeds

One of natural phenomena commonly know to follow a log-normal distribution is bubbles.

Here are three examples of experimental results demonstrating this.

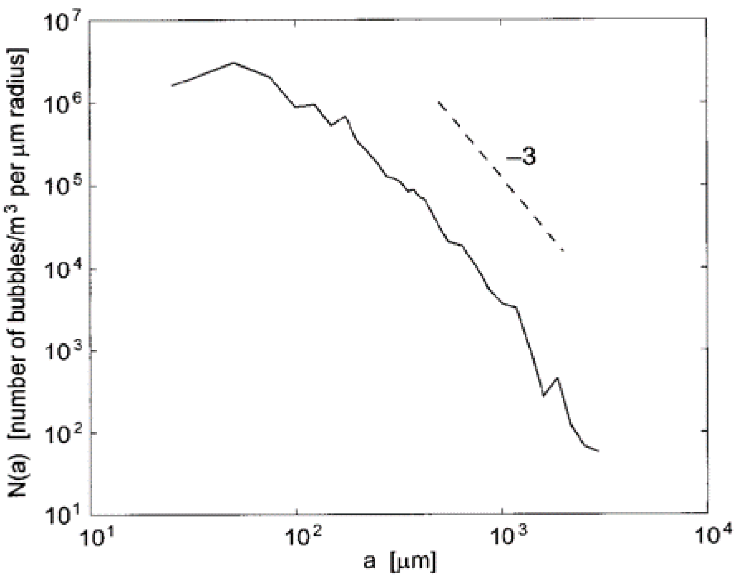


FIG. 1. The bubble size spectrum $N(a)$ in a breaking wave in the surf zone [redrawn from Deane (1997) with correction for a factor of 2 error in the original plot (G. Deane 1999, personal communication)]. The dashed line is proportional to a^{-3}.

1. *A Numerical Model For Bubble Size Distribution In Turbulent Gas-liquid Dispersion ,* M. A. K. Azad and Sultana R. Syeda
   Journal of Chemical Engineering, IEB. Vol. ChE. 24, 2006

1. *Bubble Size Distribution In An Aerated Stirred Vessel,* Dipl.-Ing. O. Feldmann, Prof. Dr.-Ing. Dr.-Ing. E.h. F. Mayinger

2. The Connection between Bubble Size Spectra and Energy Dissipation Rates in the Upper Ocean, 1999, Chris Garrett, Ming Li And David Farmer

Observations

- Bays exhibit tightly constrained planform shapes
- Bays exhibit log-normal size distribution
- Alignments correlate to our analytical model
- Metrics of Bays >100m elevation correlate to those on Costal Plain
- Topographic Relief Might Control Bay Formation/Persistence
  - Relief less than rim height required maintain a basin
  - Areas of higher relief result in simple sand blanket?
- Survey is Remote Sensing Based Only
  - Ground-proofing efforts are non-existent

Next Steps

- Source additional LiDAR data & generate DEMs
- Identify & Document additional 30,000 bays
- Capture additional data for each bay
- Provide for rating system

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. Our review of the current literature about bay rim sand has identified a common observation that the strata of coarse sand is ambiguous as to weather it was deposited by wind or water. We encourage others to consider evaluation of the bay rim sand in the context of our proposed deposition method.

Summary

- Integrated ~ 500 LiDAR DEM images into Google Earth
- Captured Individual bay Metrics
  - Location (Latitude & Longitude to six decimal places)
  - Major & Minor Axis: yields Area & Eccentricity
  - Orientation
- Identified and Documented ~ 20,000 Individual Bays
- Identified ~1500 bays above 80 m AMSL
- Integrated Results into Google Fusion Repository
  - Cloud-based
  - Collaborative access

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

Thank you for your attention!