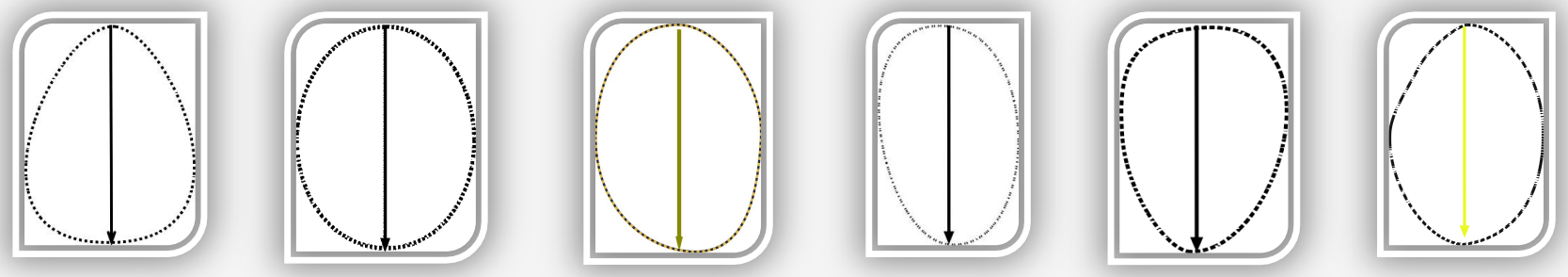
A Taxonomy for Carolina Bay Circumferential Rim Shapes

Findings of Robust Adherence to Several Distinctive Archetype Planforms
Is Supported by LiDAR-derived Digital Elevation Maps



Abstract No:
2013 GSA Meeting
Denver, CO October 30, 2013

Michael E. Davias

Goals of Talk

- **What is a “Carolina bay”**
- **44,000 Individual bays have been measured & documented**
- **Tiled LiDAR DEMs created in Global Mapper for Google Earth**
- **Identify and justify six subtle regional variations as bay taxonomy**
- **Explain Manual Bay Measurements, programmatic processing**
- **Technique applicable to other landform measurement needs**
- **All work product freely available over the Web**

Antioch Bay, NC

Photo: Cameron Davidson, Smithsonian Magazine, September 1997

I would be remiss if I did not address “what is a Carolina bay”. Although the name is applied here to the geological landform, The term was originally applied to the wetland habitats enclosed within those circumpheral quartz sand rims, often filled with Bay trees. This is Antioch Bay, which was the subject of an article in the Smithsonian Magazine, September ‘97. Most bays have been drained, logged and farmed over.

Riddle of the Carolina Bays

BY KEVIN KRAJICK

AS FAST AS SHE CAN MANAGE, SOUTH CAROLINA ZOOLOGY GRAD student Lisa Carswell, 24 years old and five feet tall, is hurdling fallen trees, butting through thick bushes and sprinting in thigh-deep water while grasping a butterfly net that's a lot longer than she is. Her eyes never leave the prey. "C'mere, buddy," she says, suddenly swinging like a major league batter at something small and airborne. Today she might get lucky and perhaps snag a rare insect never seen around here. Maybe even an unknown species. "You never know," she says.

"You never know" is a good motto for the Carolina bays, the locale for her hunt. The confusingly named bays are not ocean inlets; nor are they confined to the Carolinas, though that is where they lie thickest. They are eerie wetland depressions scattered across the Eastern coastal plain from southern New Jersey to northern Florida. Most of them are perfect ovals; they are ringed by ridges of sand as high and dry as their interiors are low and swampy; and all point the same way, northwest to southeast. They have long fueled weird local folklore, bewildered geologists and scared off most everyone else.

Today Carswell is inventorying butterflies, dragonflies and damselflies in bays—the first such study in a region settled for close to 300 years. That's because few biologists want to go in there: bays are often surrounded by, or even filled clear through with, impenetrable walls of shrubs and 12- to 30-foot-

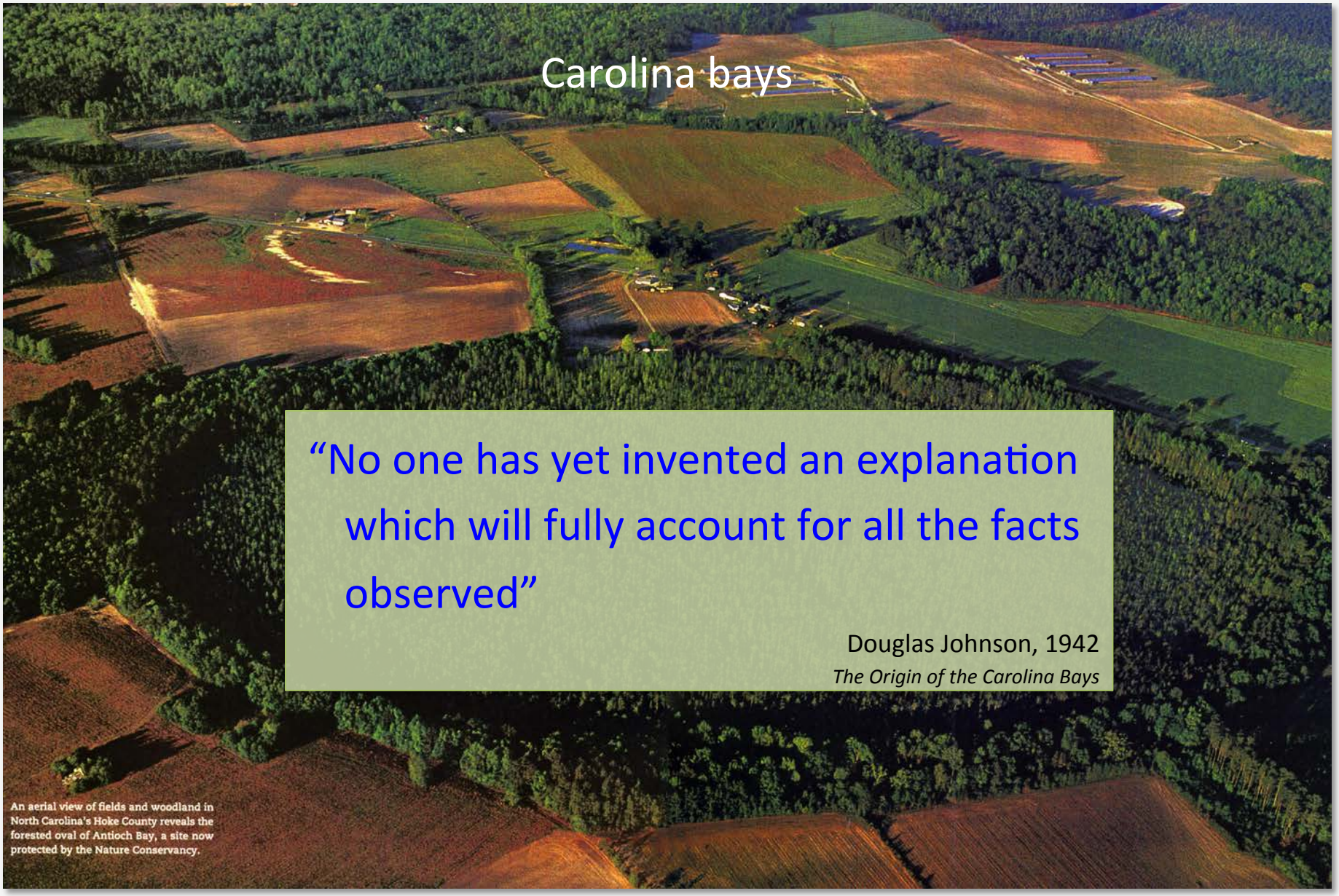
Article by Kevin Krajick, Smithsonian Magazine, September 1997

Riddle of the Carolina bays

Those few remaining in their natural state are National Treasures….
impenetrable enclaves which contain an exotic assortment of flora and fauna.

Photos: Cameron Davidson, Smithsonian Magazine, September 1997

Carolina bays



"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

An aerial view of fields and woodland in North Carolina's Hoke County reveals the forested oval of Antioch Bay, a site now protected by the Nature Conservancy.

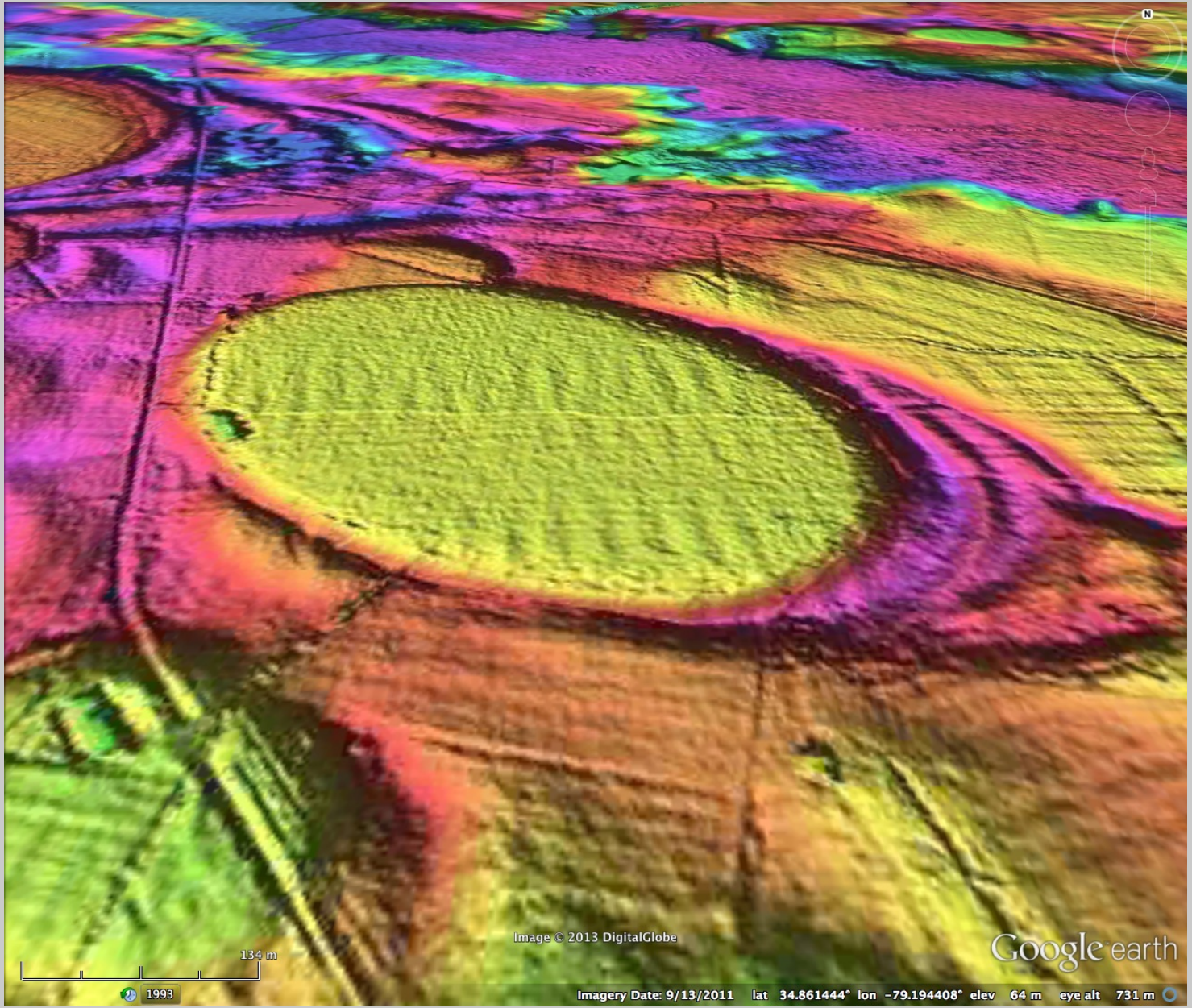
Rasmussen, 1953

"Their very randomness of grouping and scatter demands an explanation. As a statistical phenomenon, they deserve to be studied statistically."

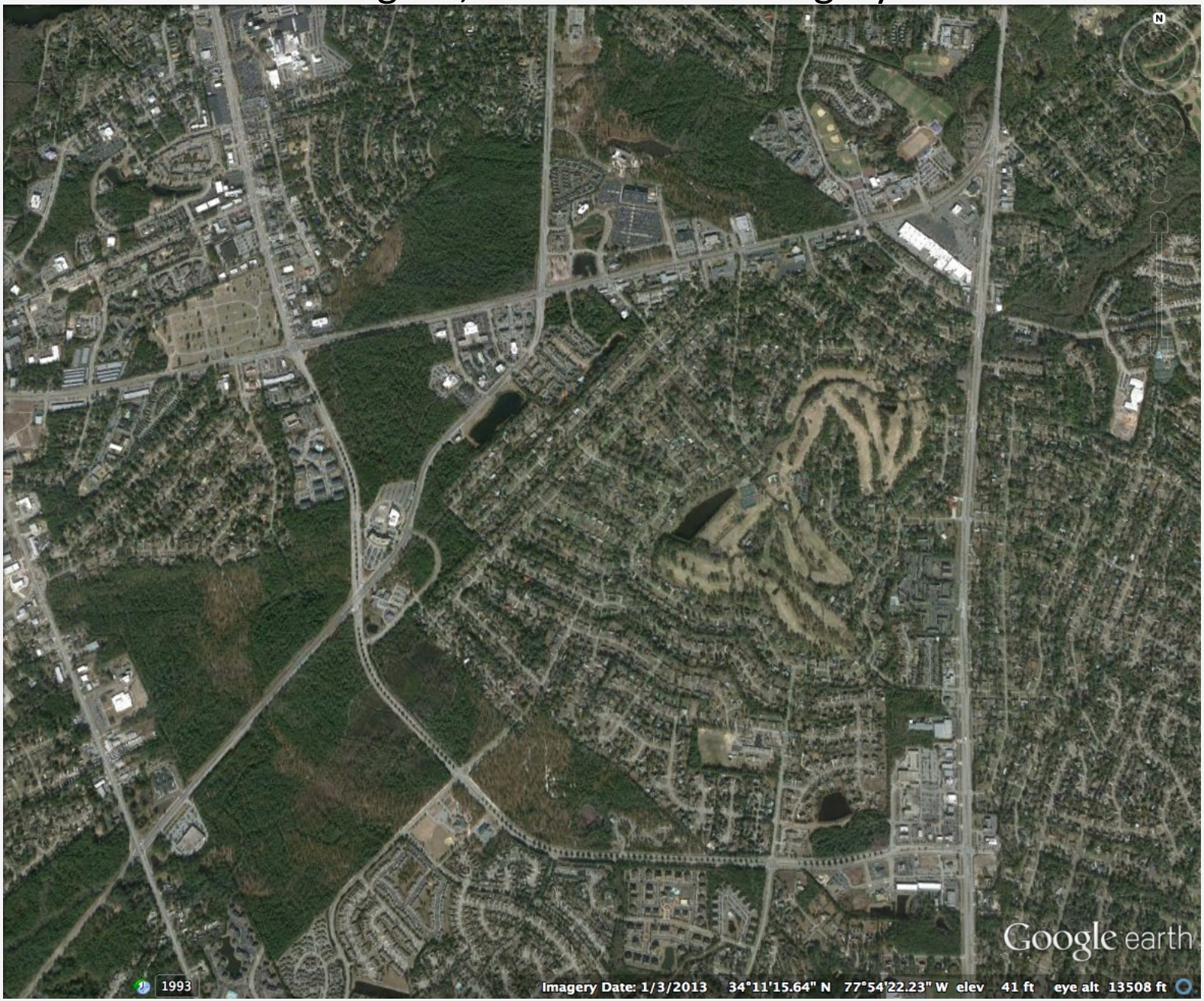
- Shot Patterns & Groupings
- Family Characteristics
  - Planform Shape
  - Orientations
  - Sizes
- Areas of No Basins – why?

W.C. Rasmussen, 1953, *Periglacial Frost-Thaw Basins in New Jersey: A Discussion*, *The Journal of Geology*, Vol. 61, No. 5

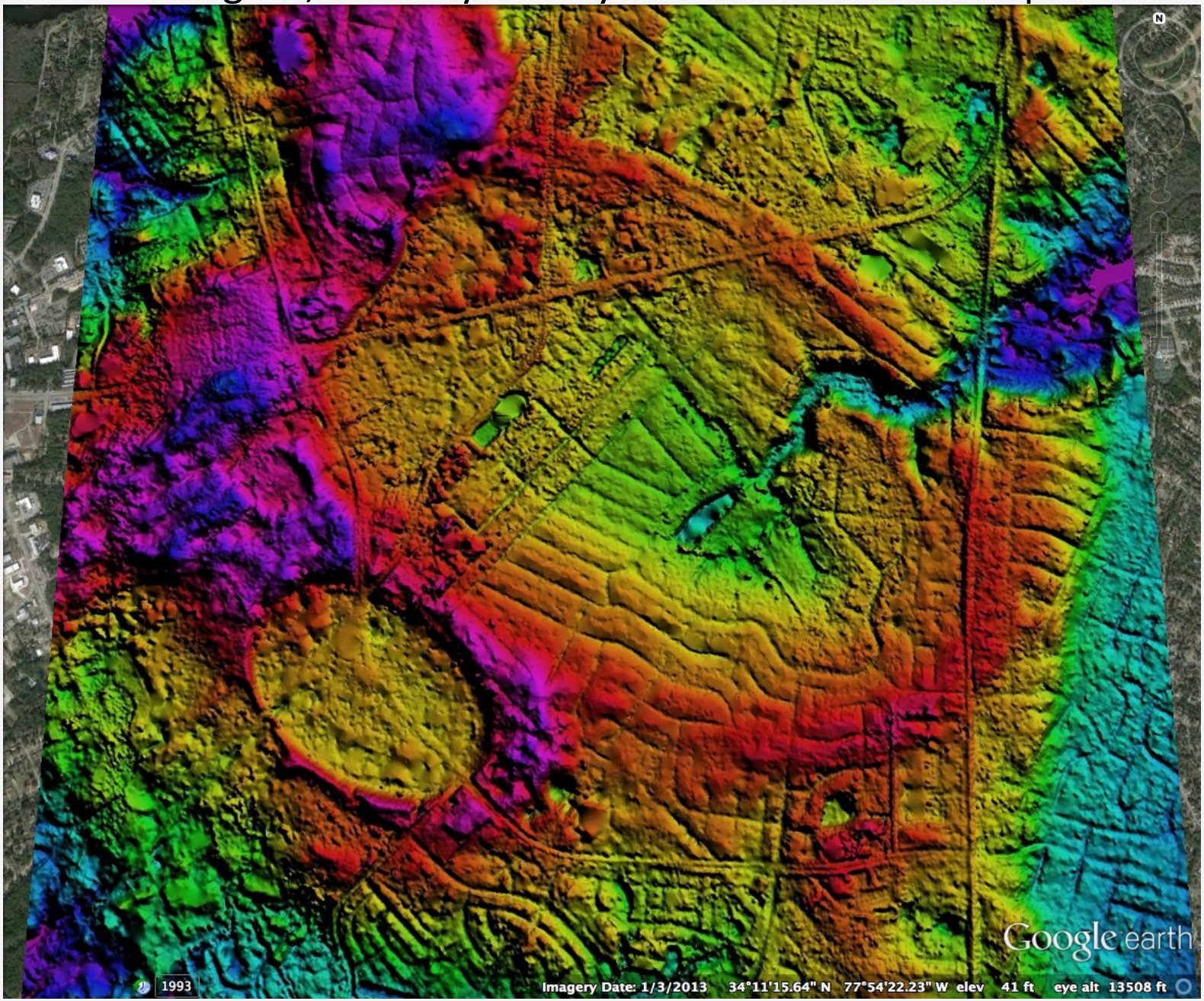
Antioch Bay, NC In LiDAR



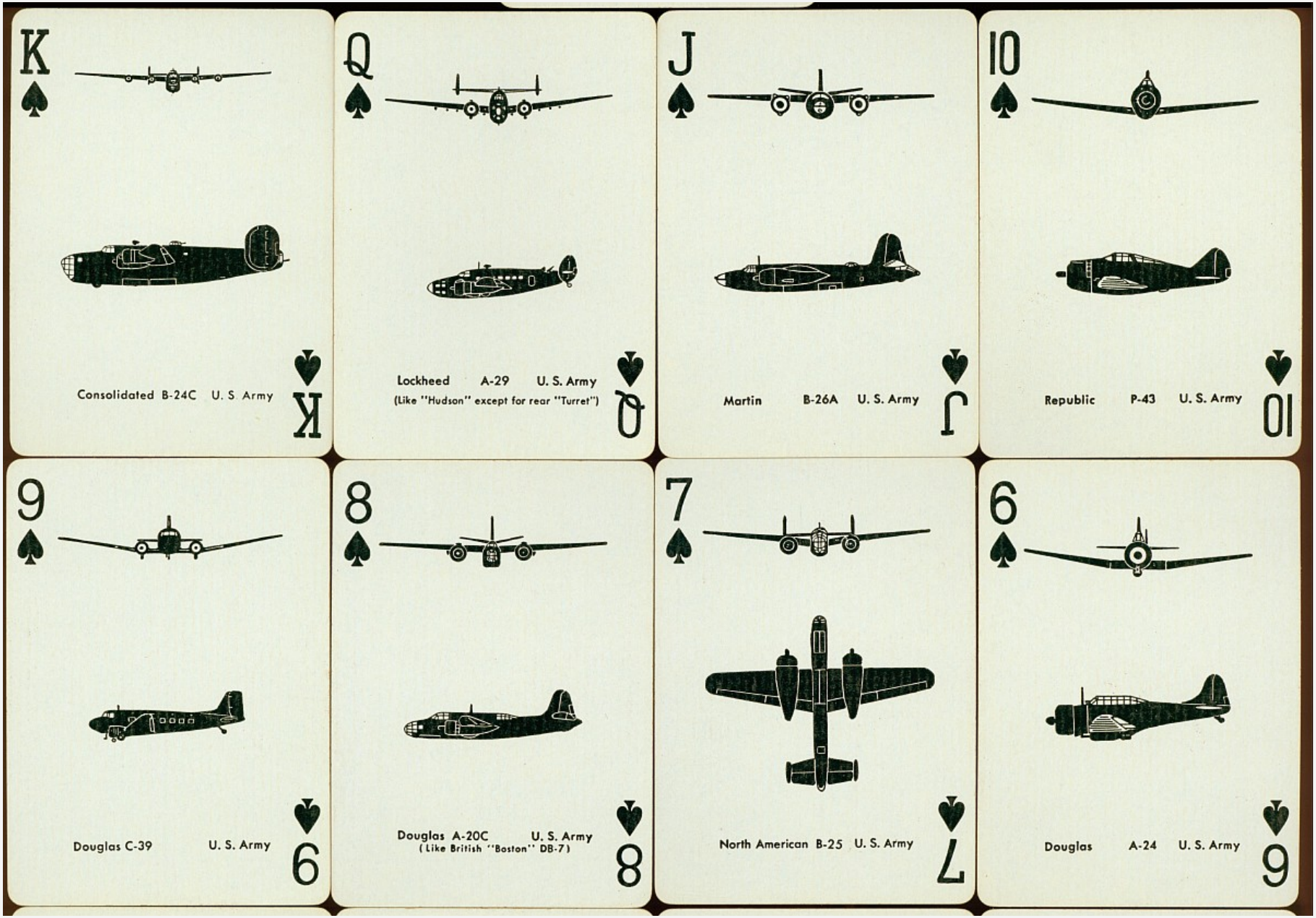
Wilmington, NC in Satellite Imagery



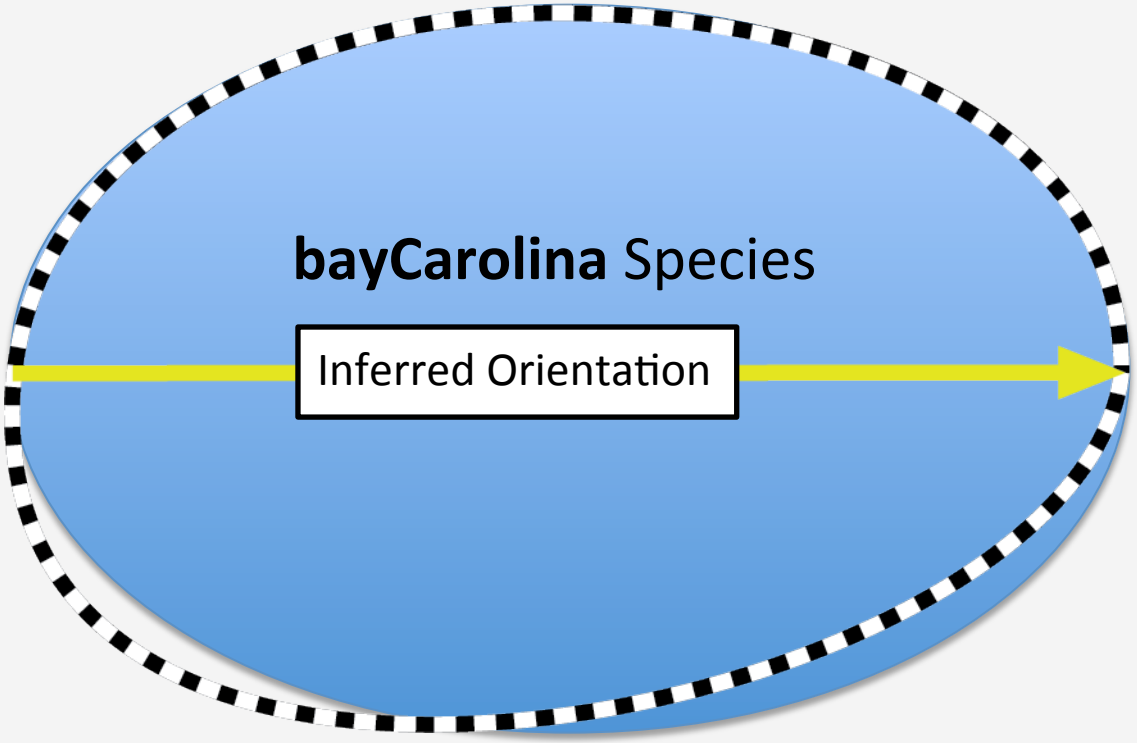
Wilmington, NC - Blythe Bay in LiDAR Elevation Map



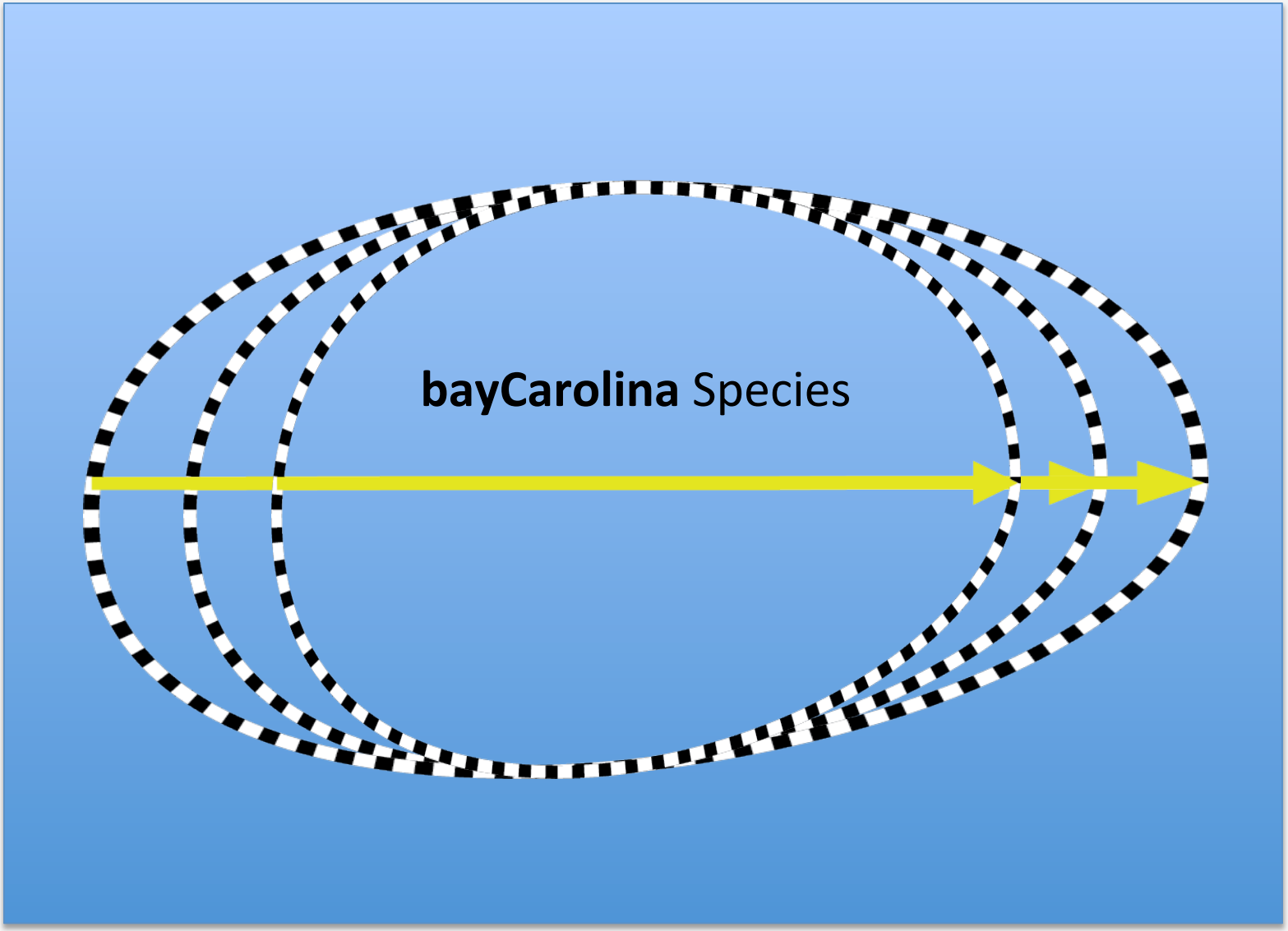
Identification of Species By Silhouette



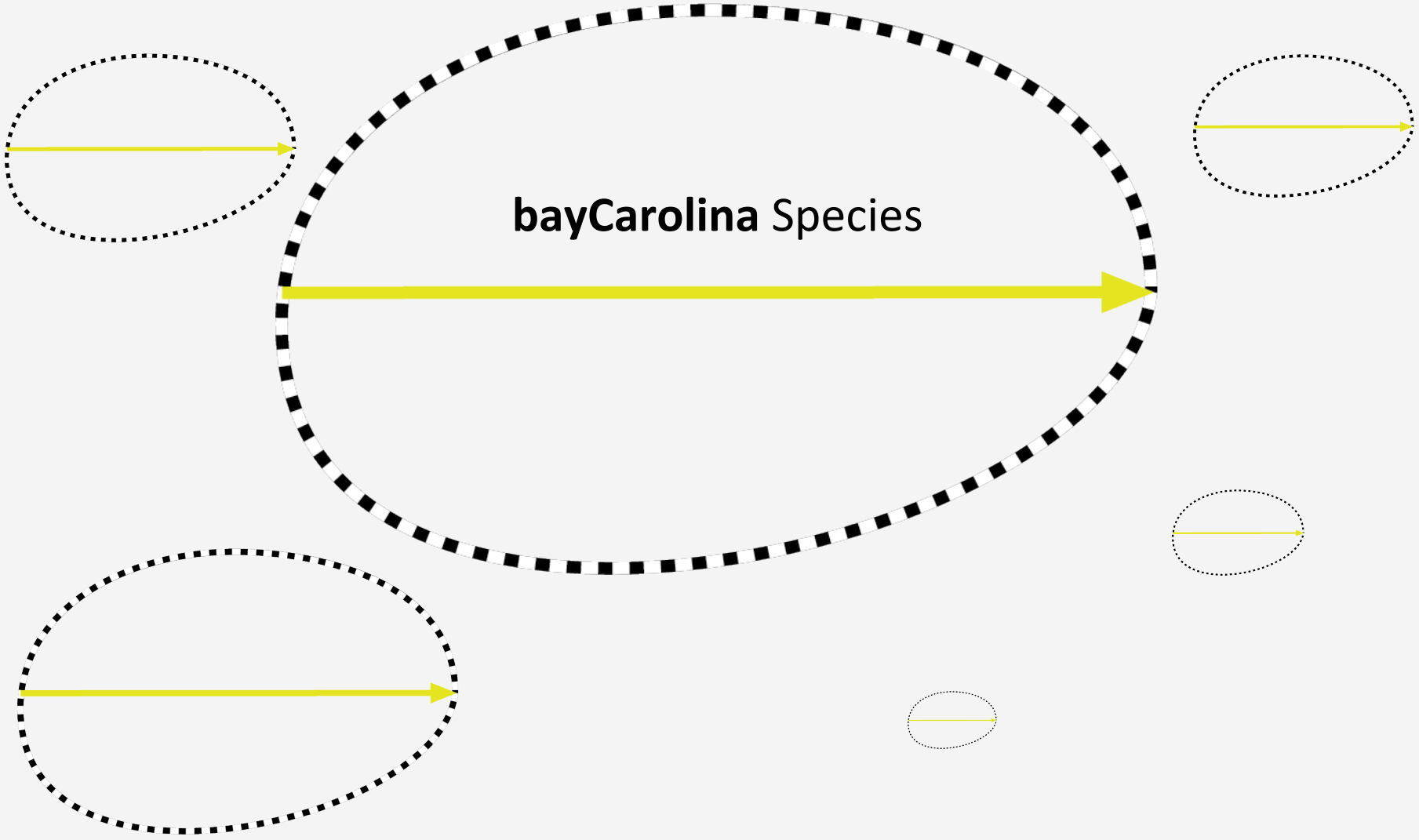
bay Taxonomy



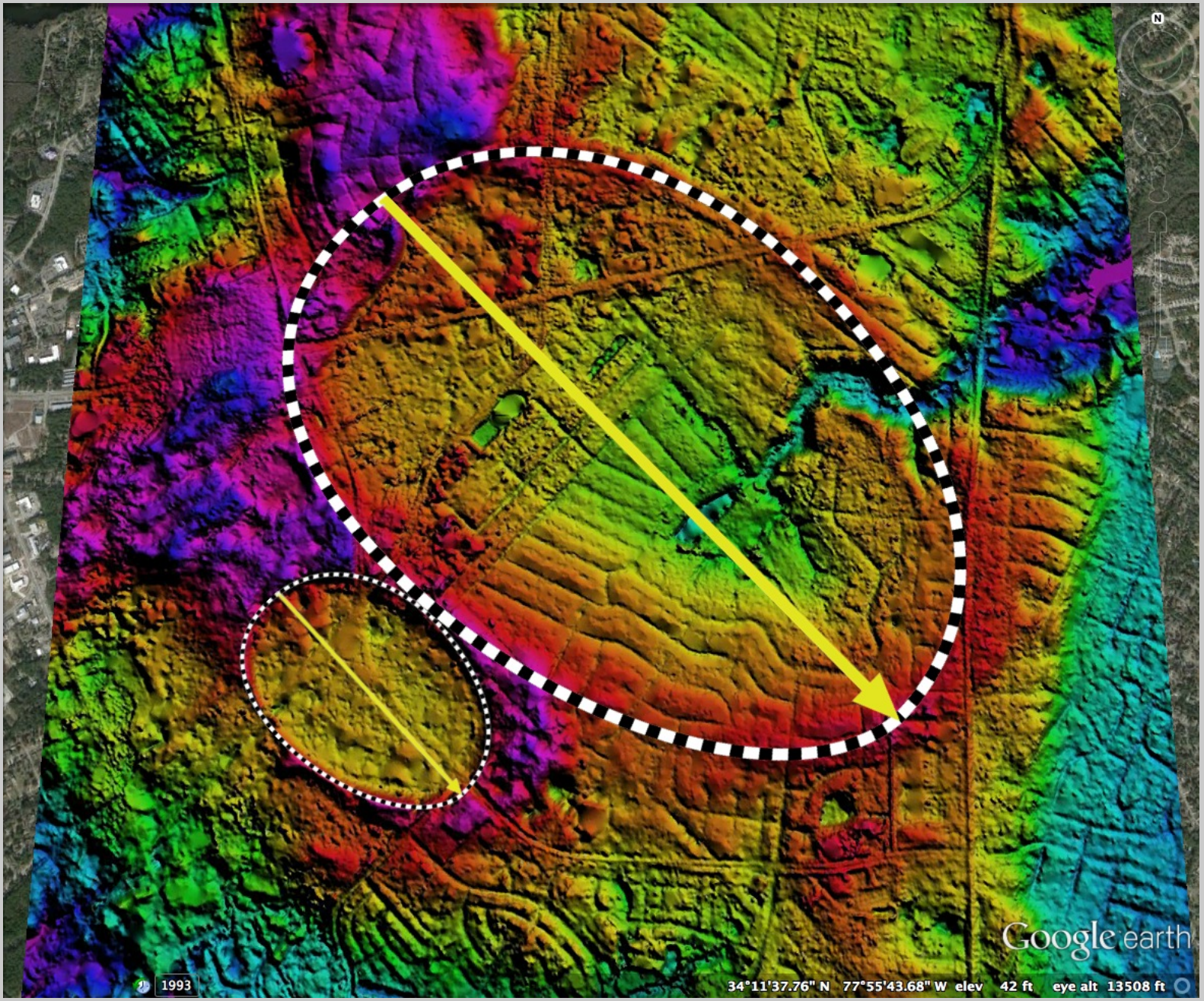
Vary in Eccentricity



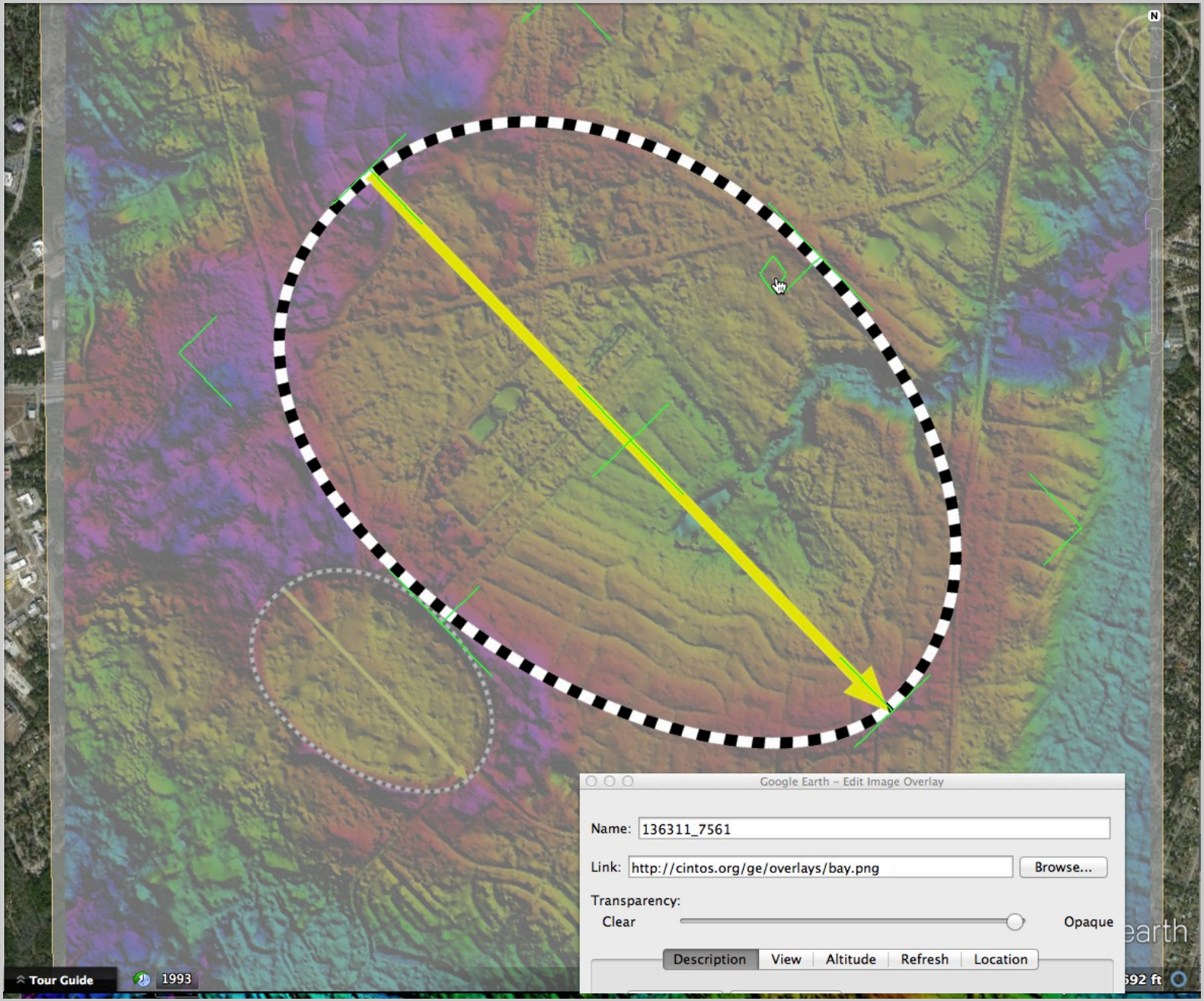
Vary in size



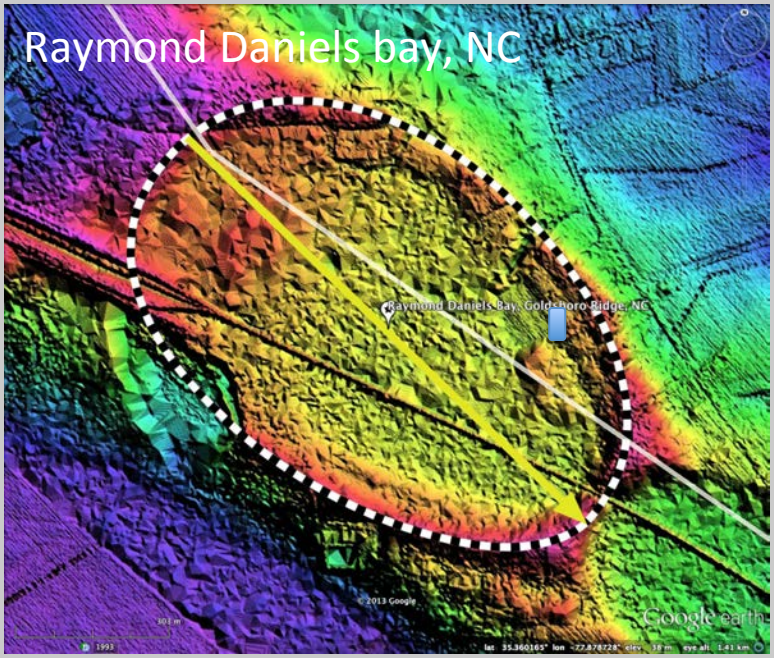
Overlay Placed and Adjusted to Blythe Bay, Wilmington, NC

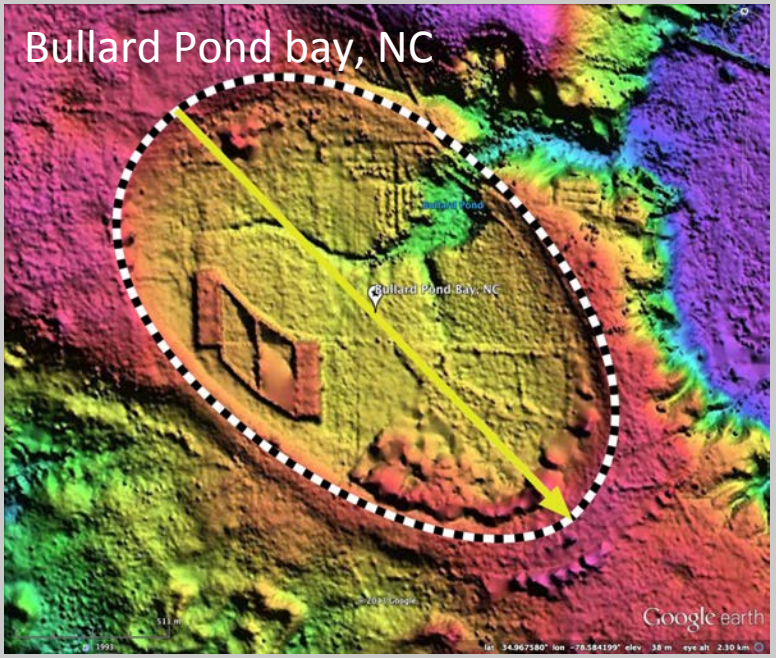


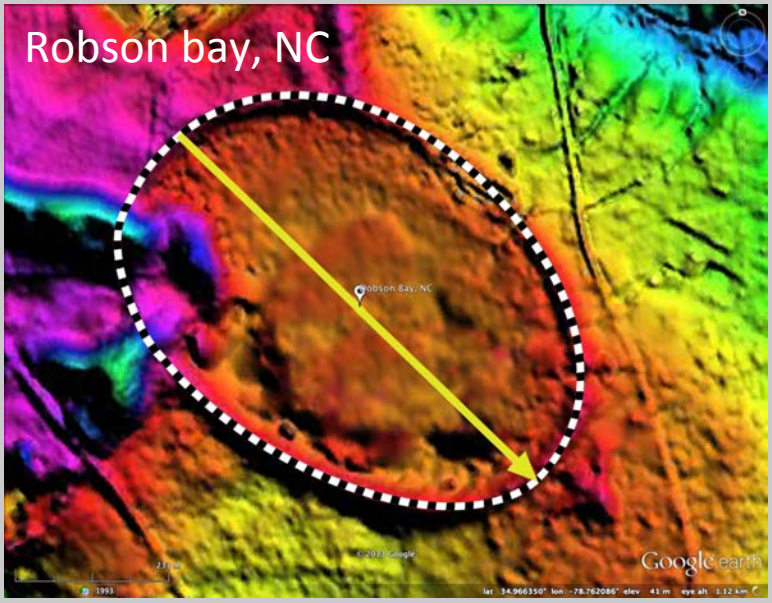
Blythe Bay, Wilmington, NC

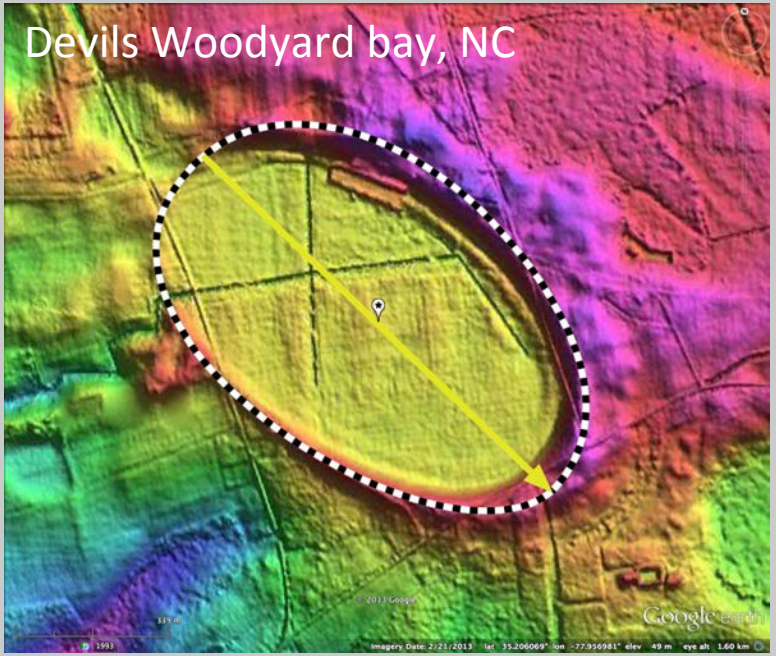


bayCarolina Spiecies

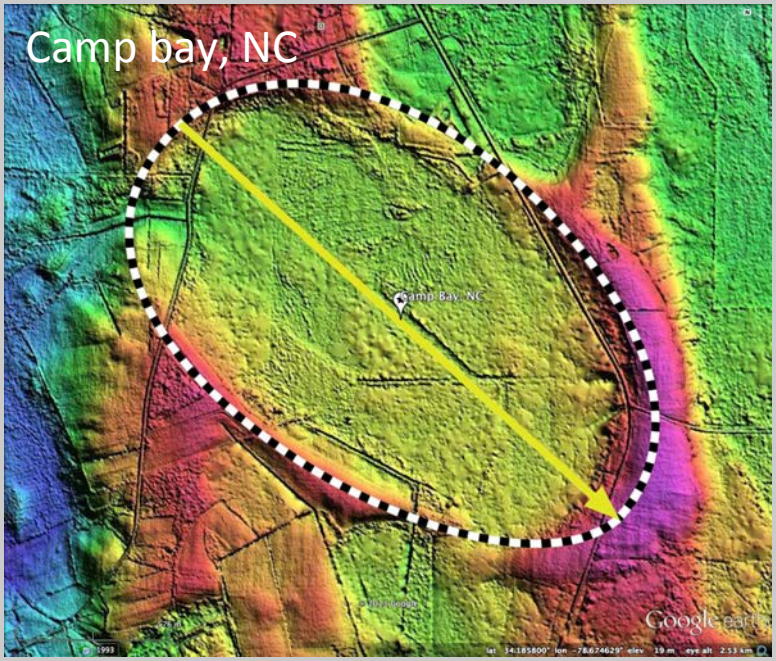


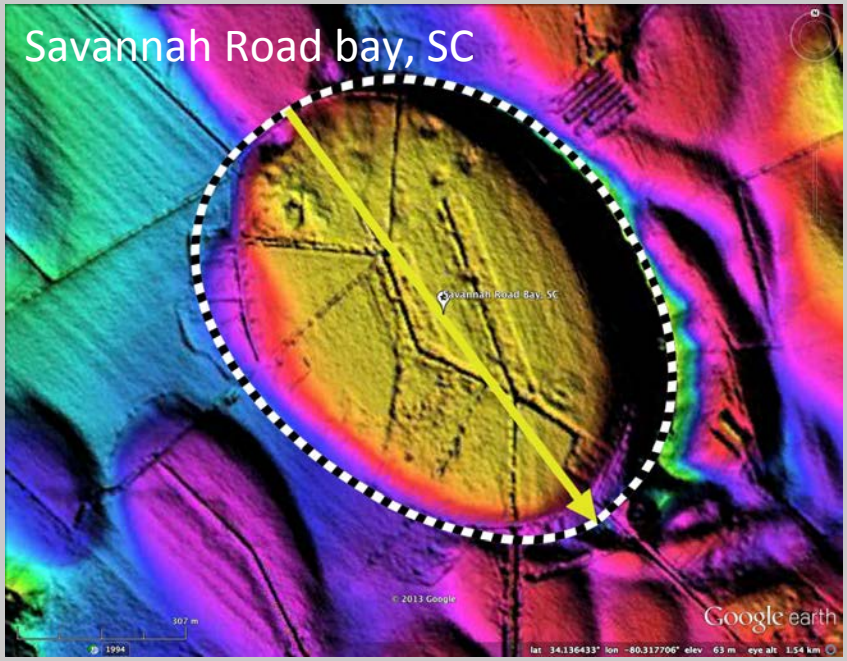


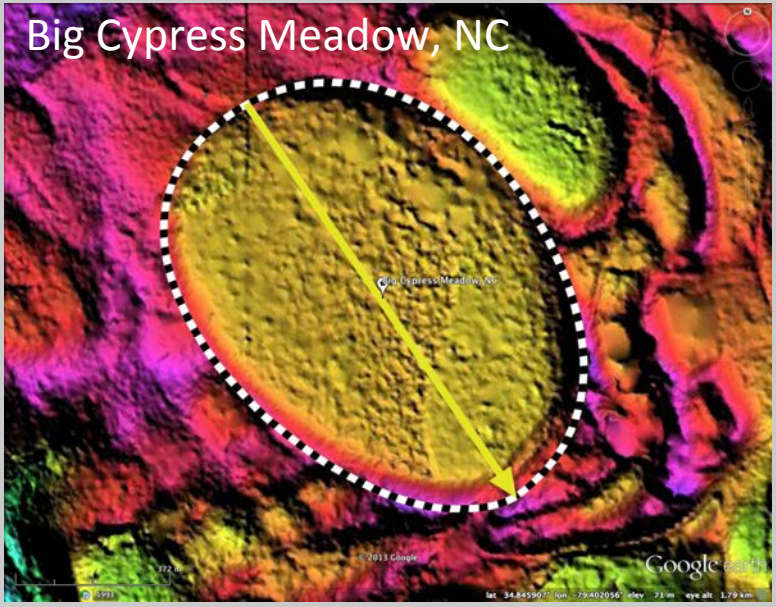


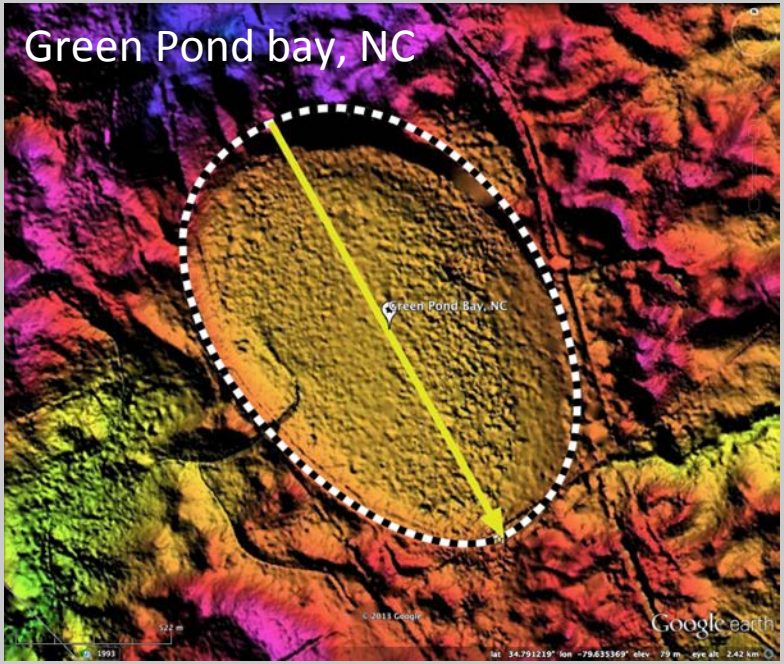


bayCarolina Spiecies

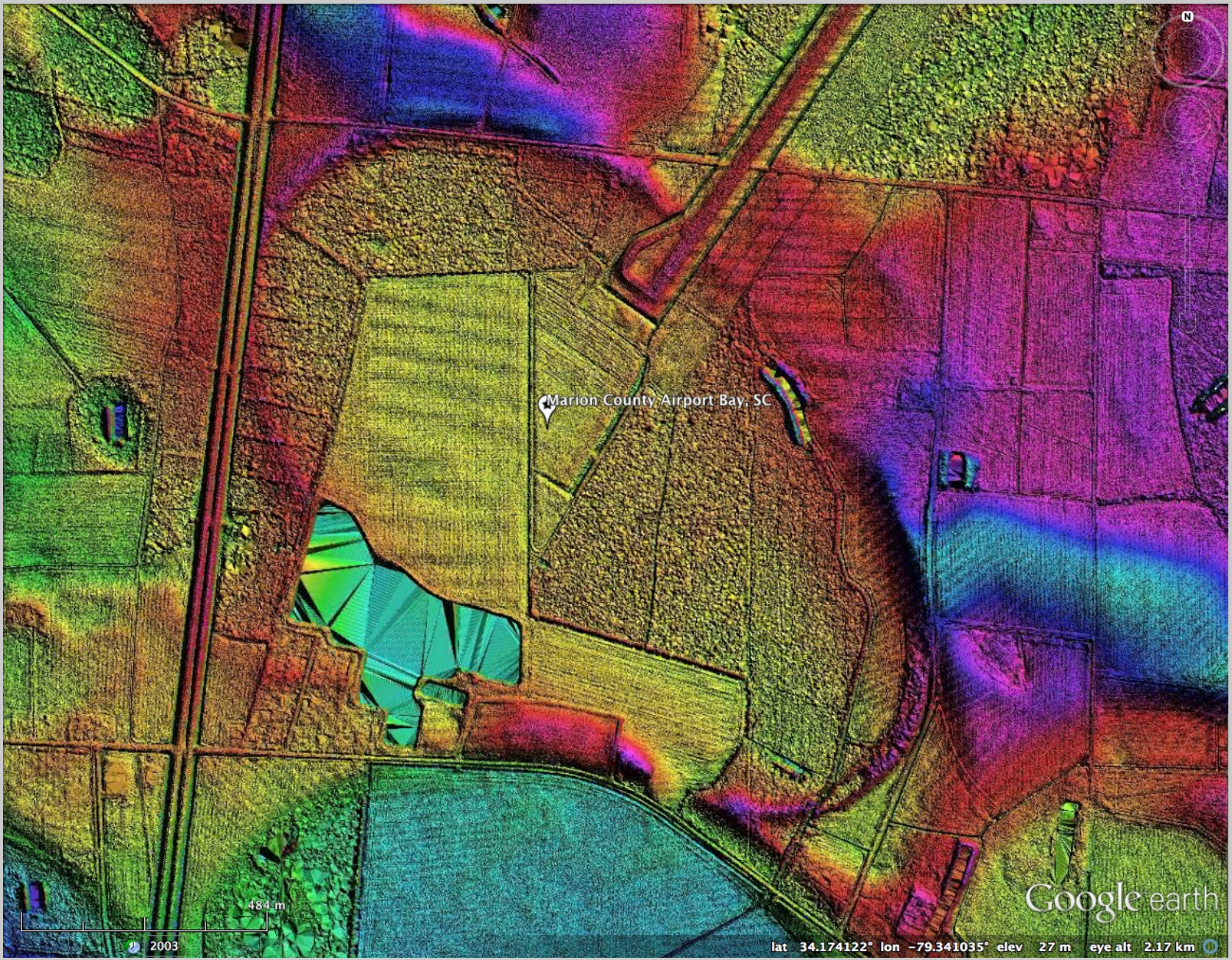




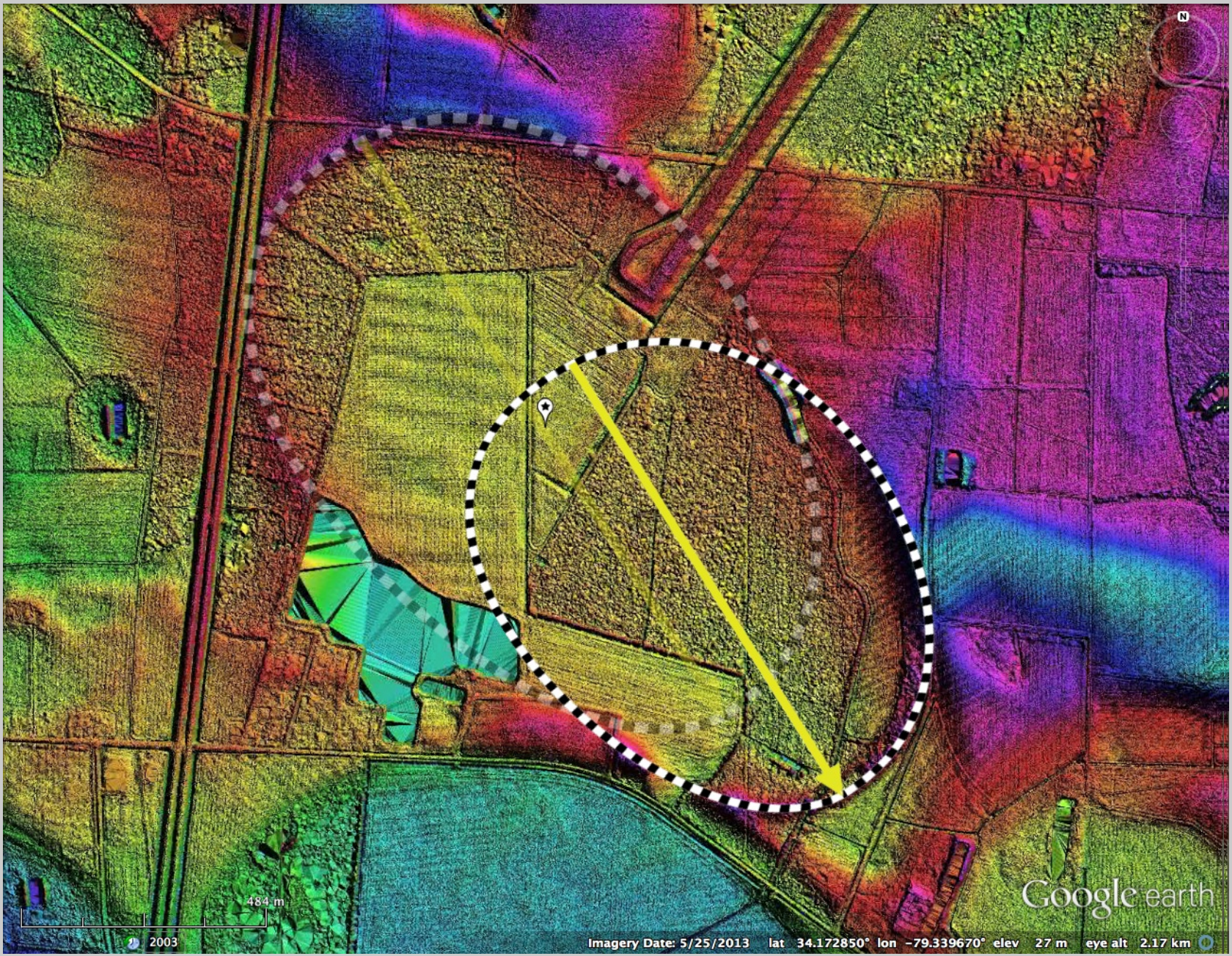




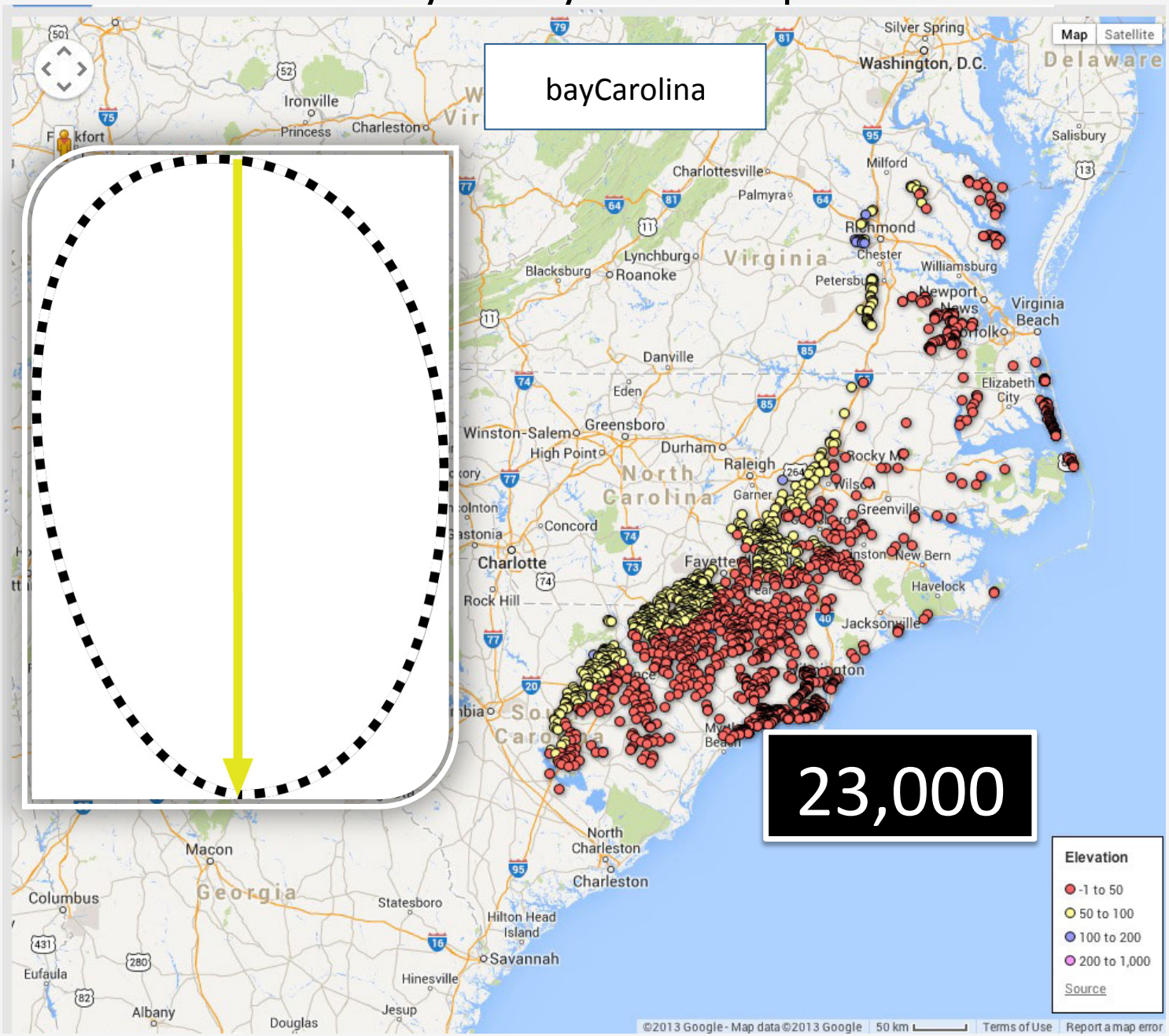
bayCarolina: Marion County Airport bay, SC



bayCarolina: Marion County Airport bay, SC



Territory of bayCarolina species



Two Variations of bay Planforms Identified by Johnson

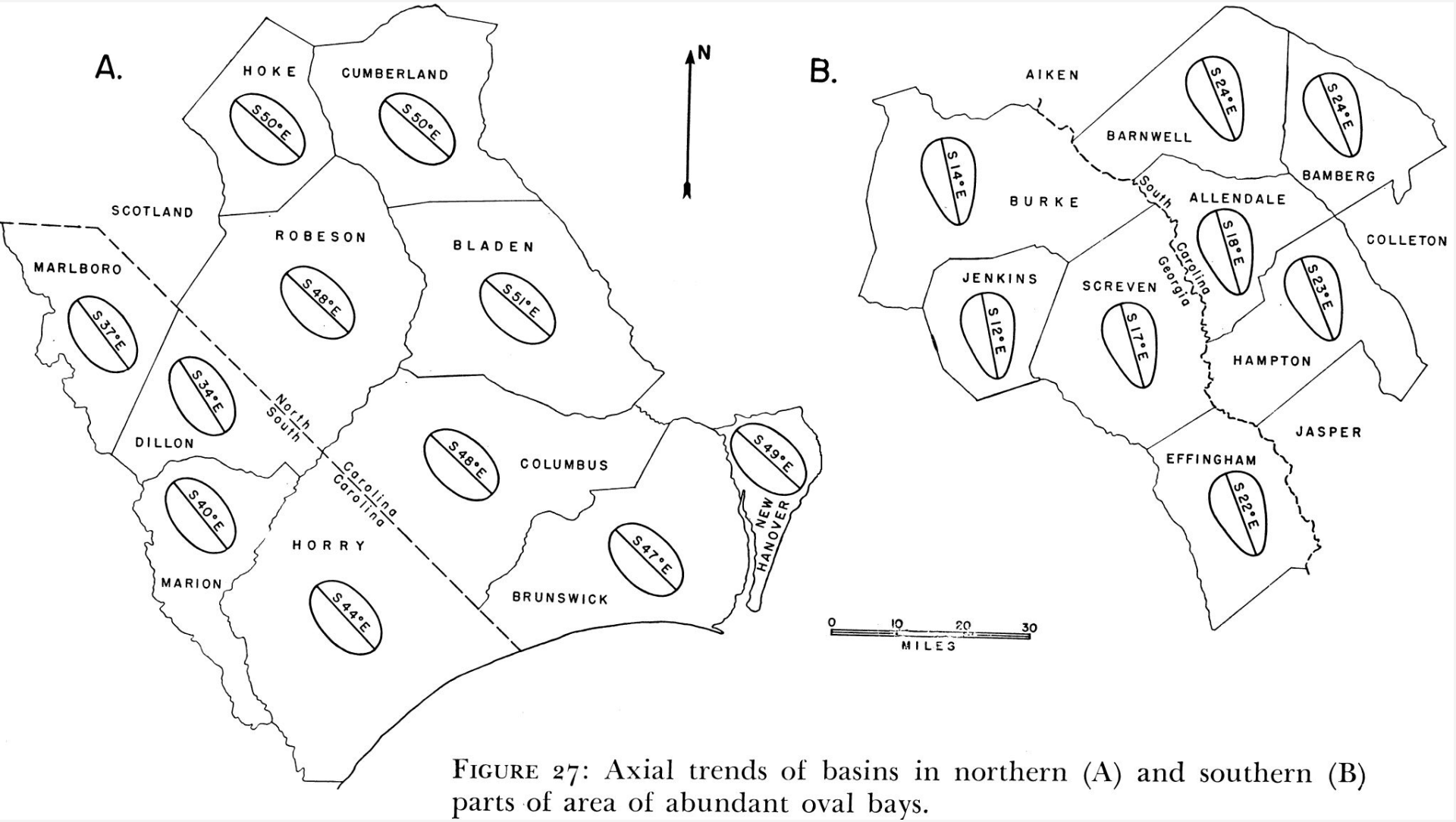
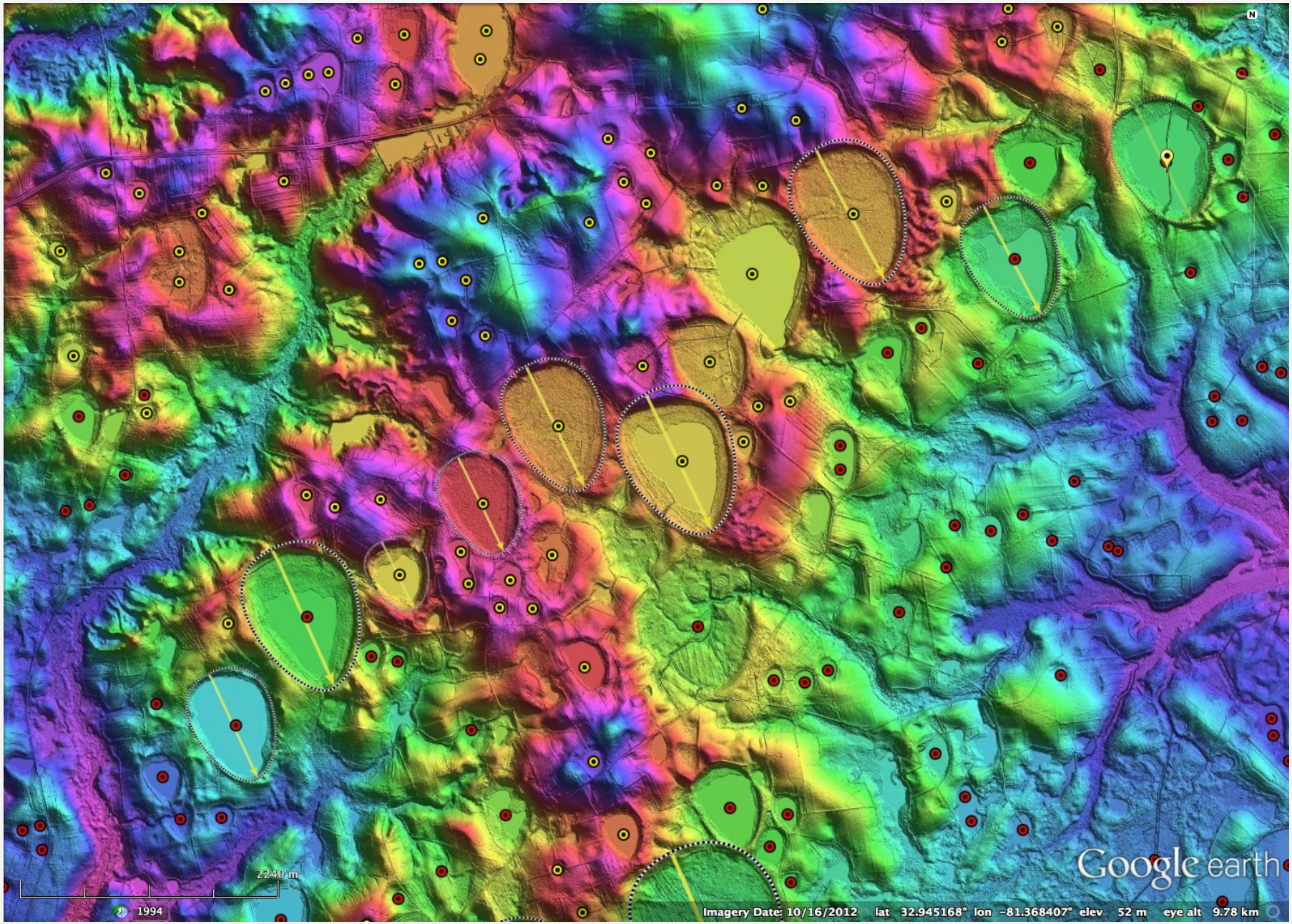


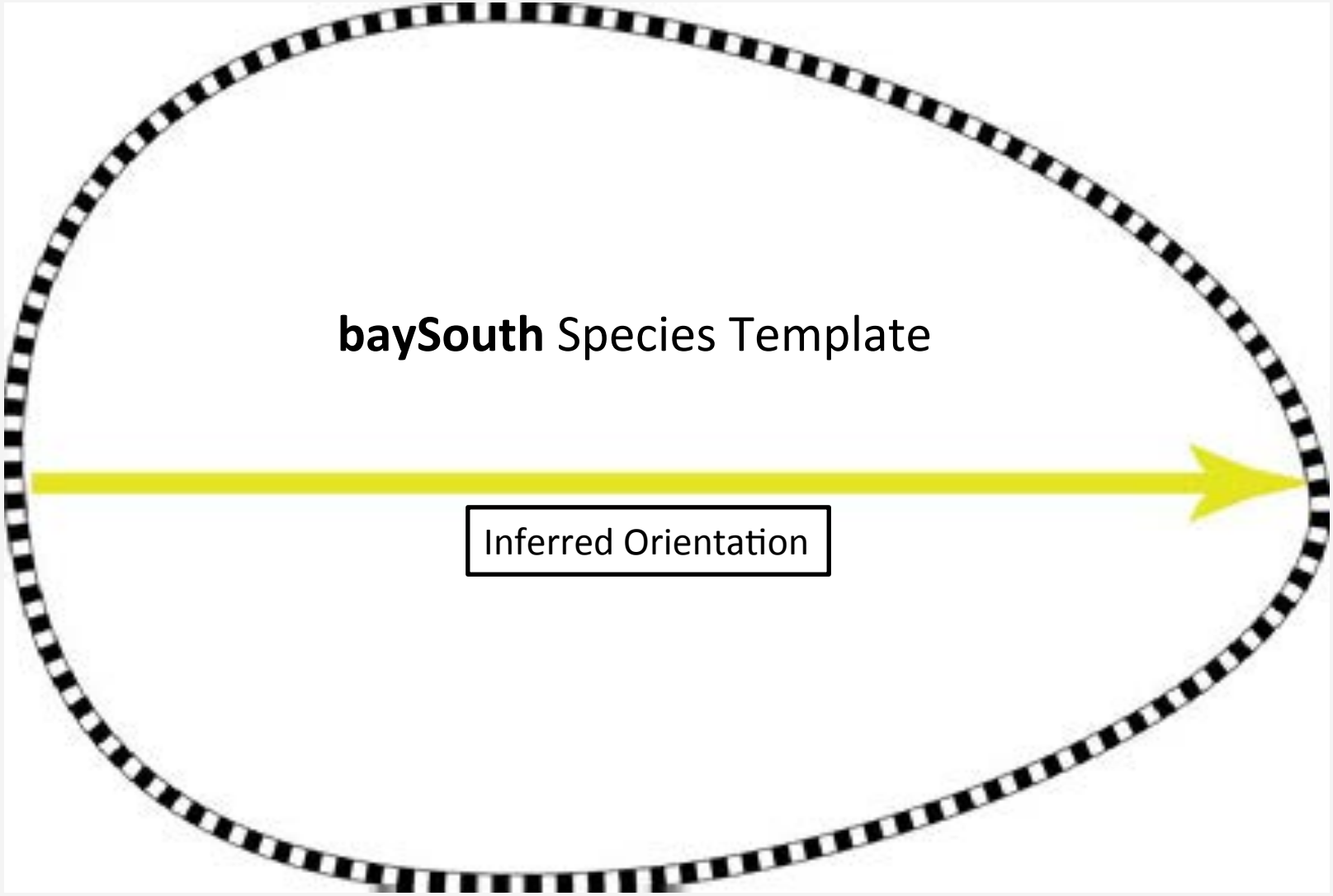
FIGURE 27: Axial trends of basins in northern (A) and southern (B) parts of area of abundant oval bays.

D. Johnson, 1942

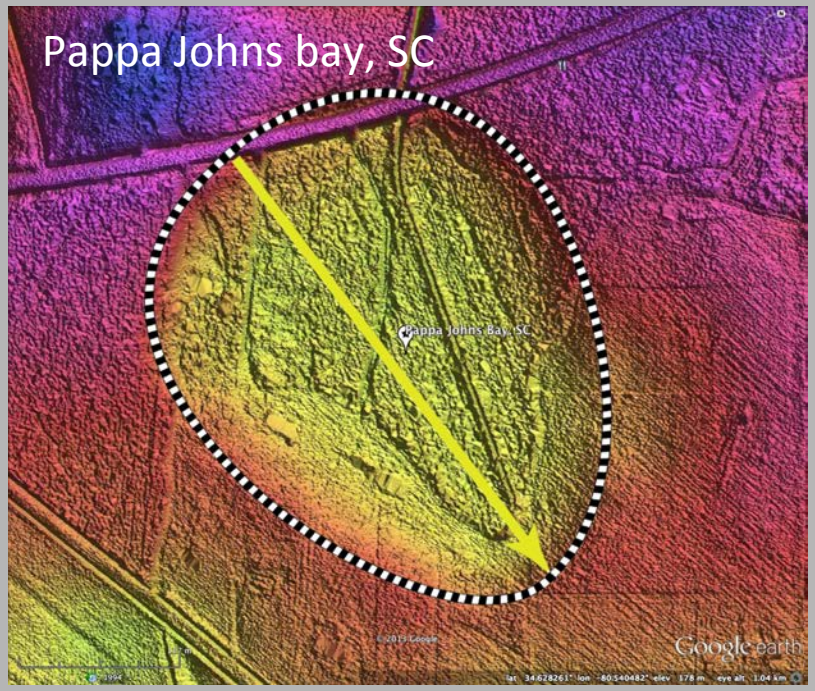
bay South Species Example

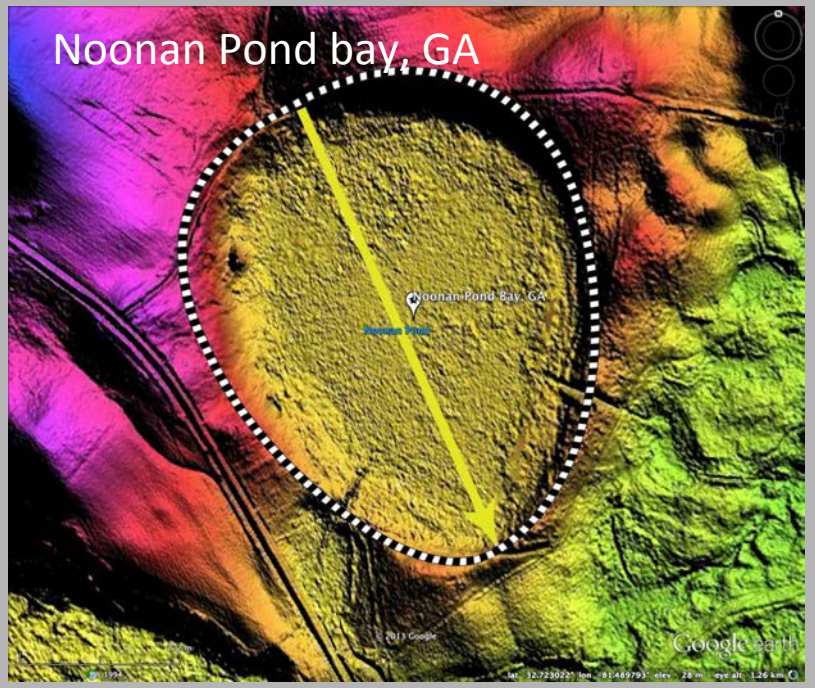


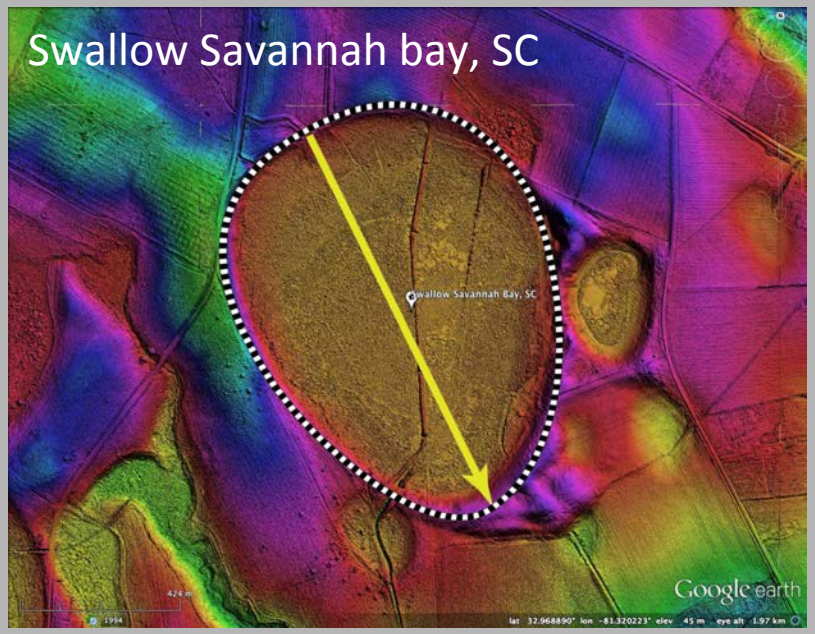
Measurement Overlay Template

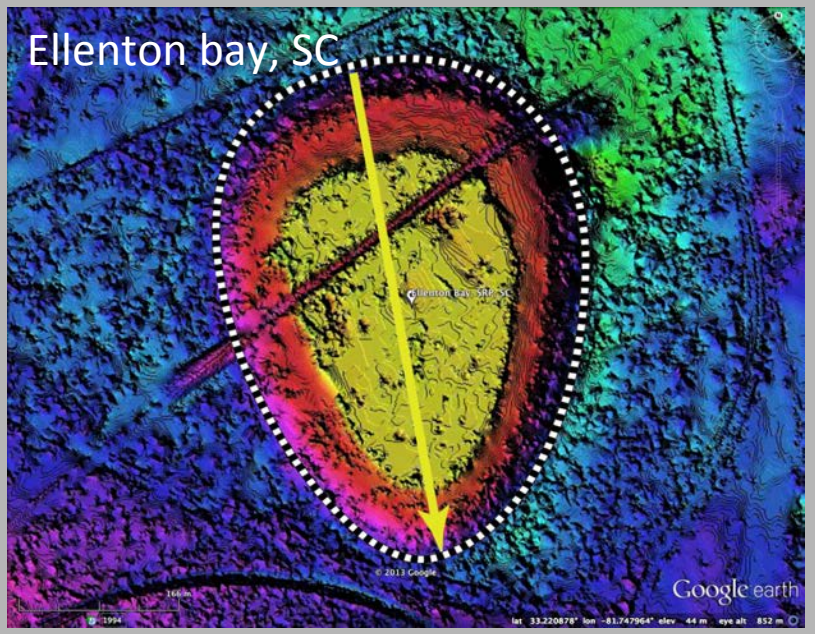


baySouth Species

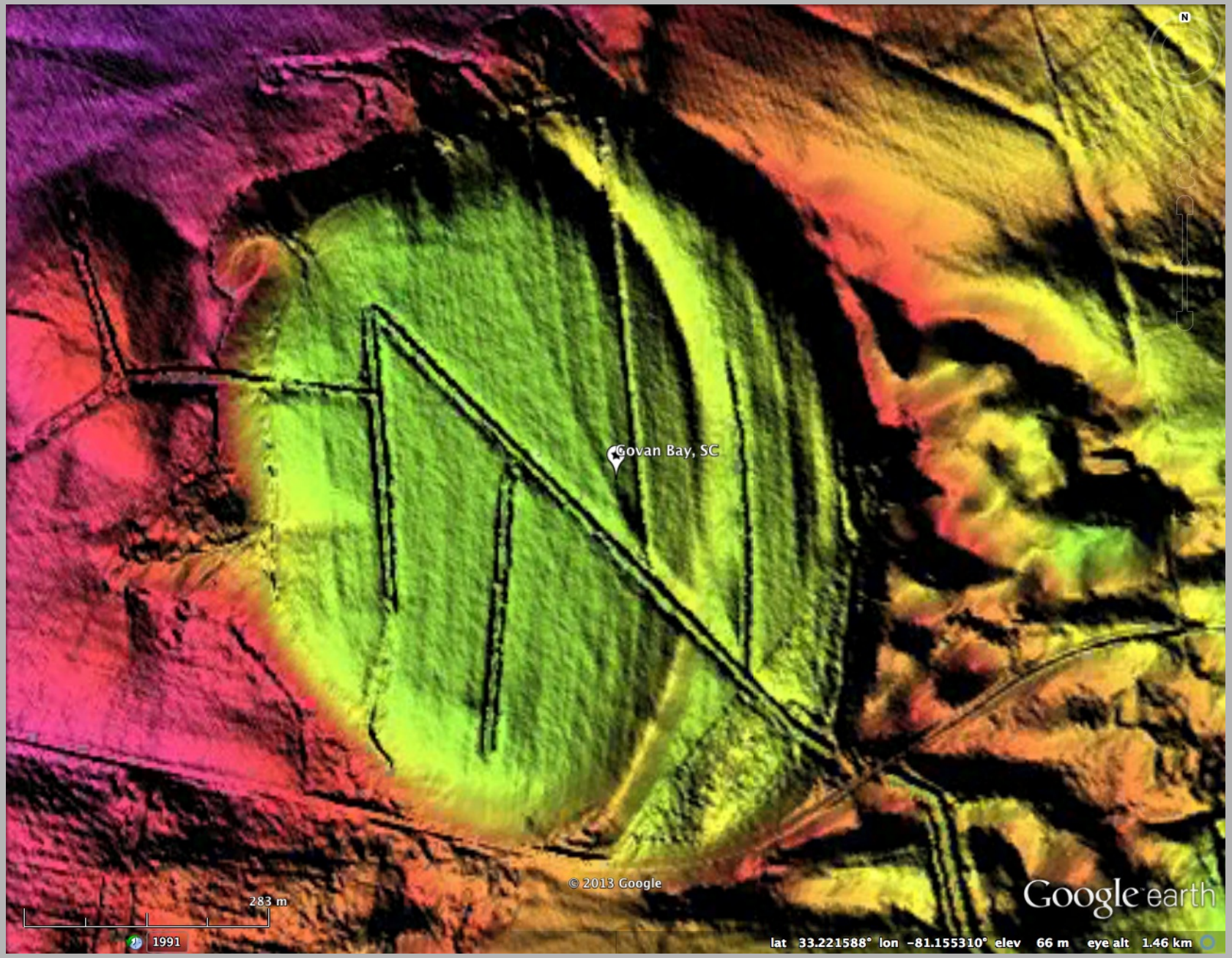




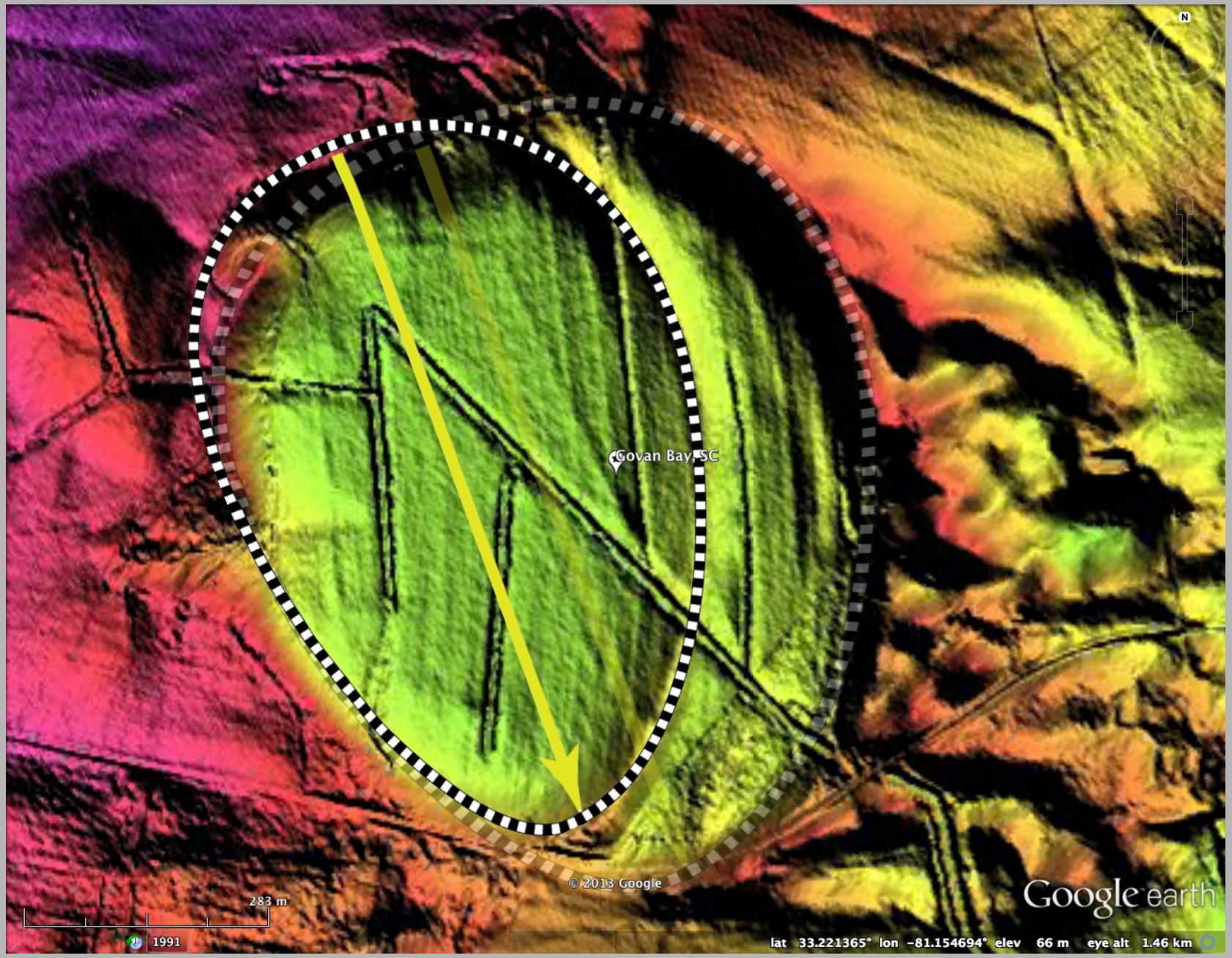




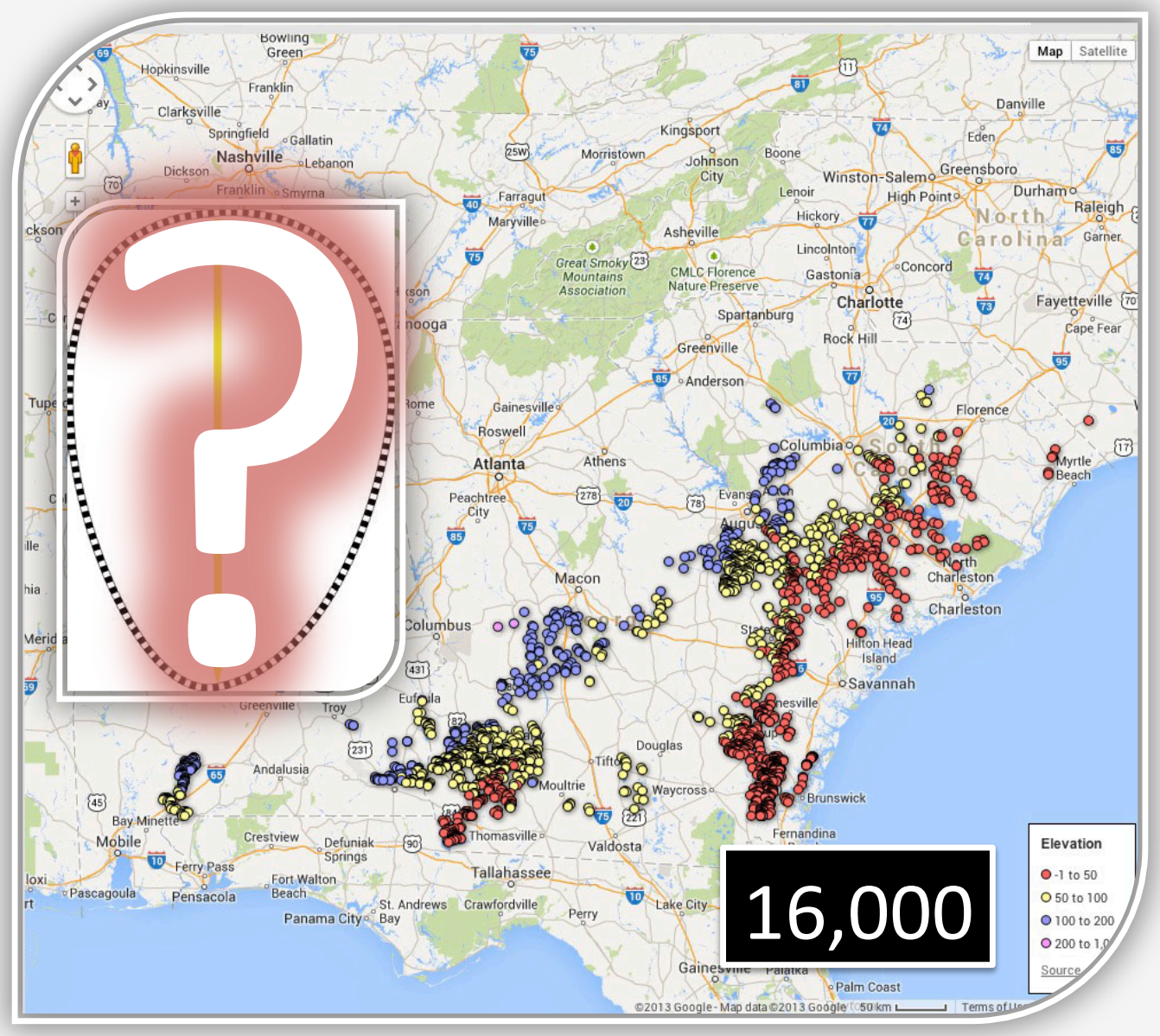
baySouth Govan bay, SC



baySouth Govan bay, SC

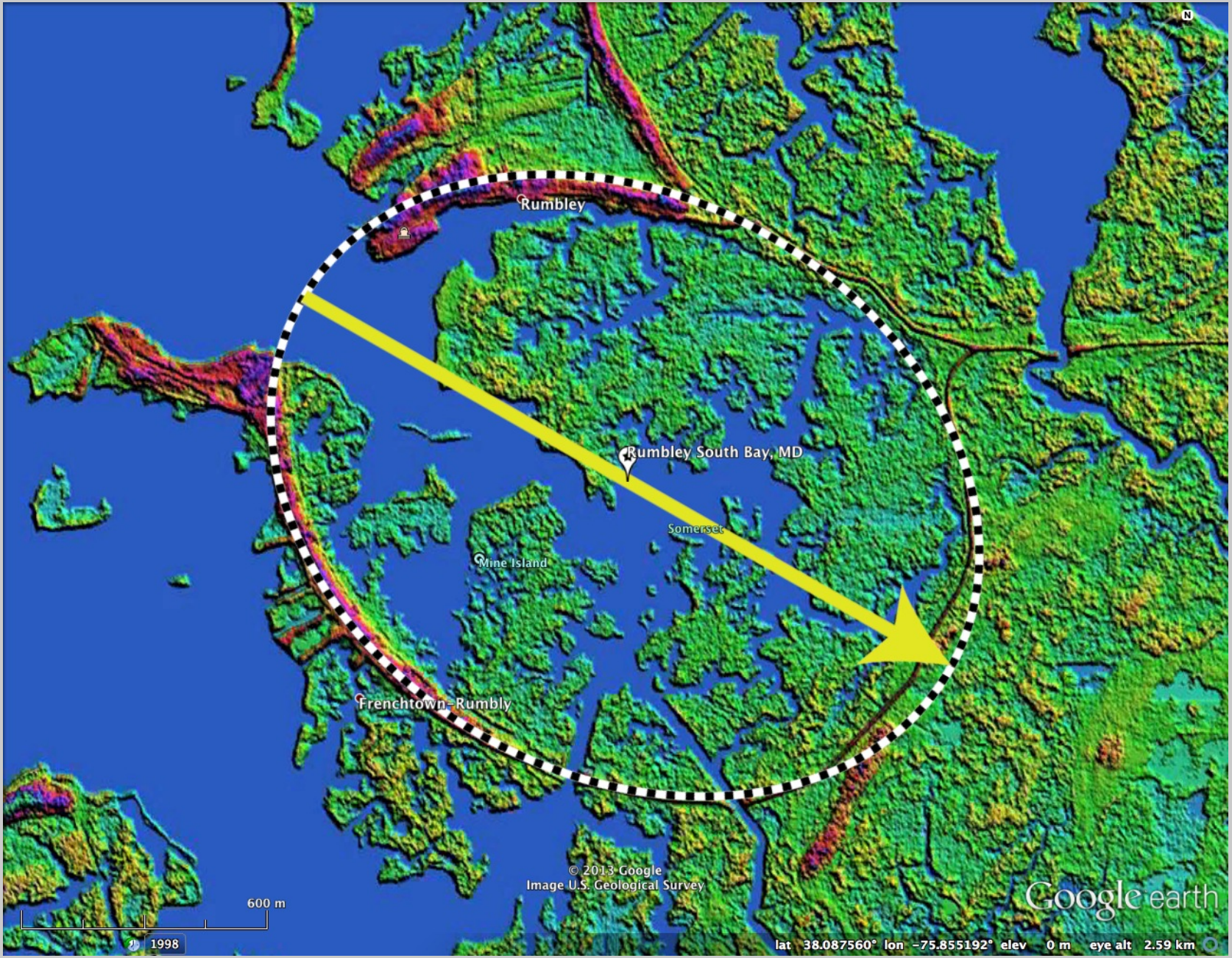


Territory of baySouth species

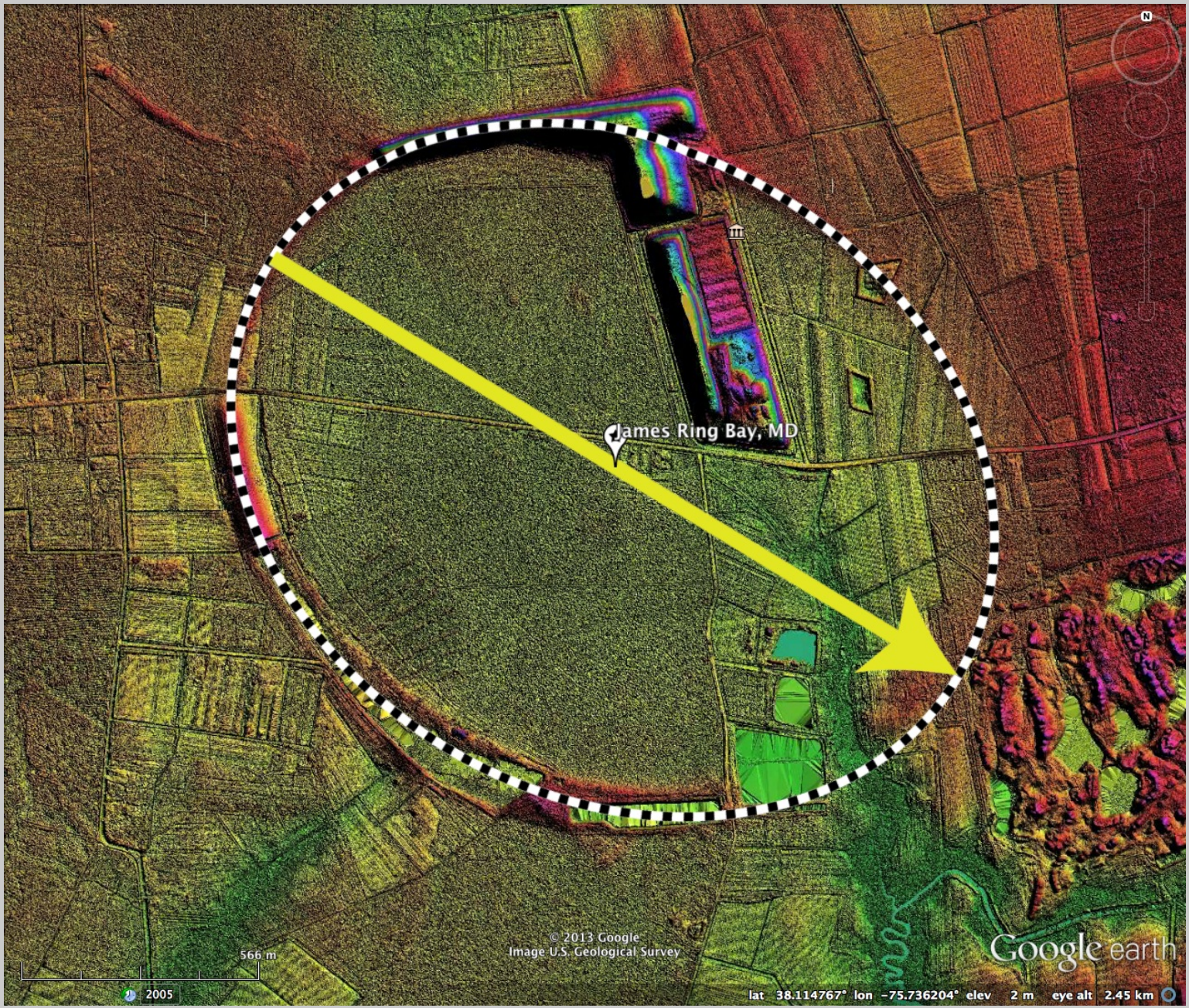


Oval Shape Identified by Cooke in Rumbley, MD

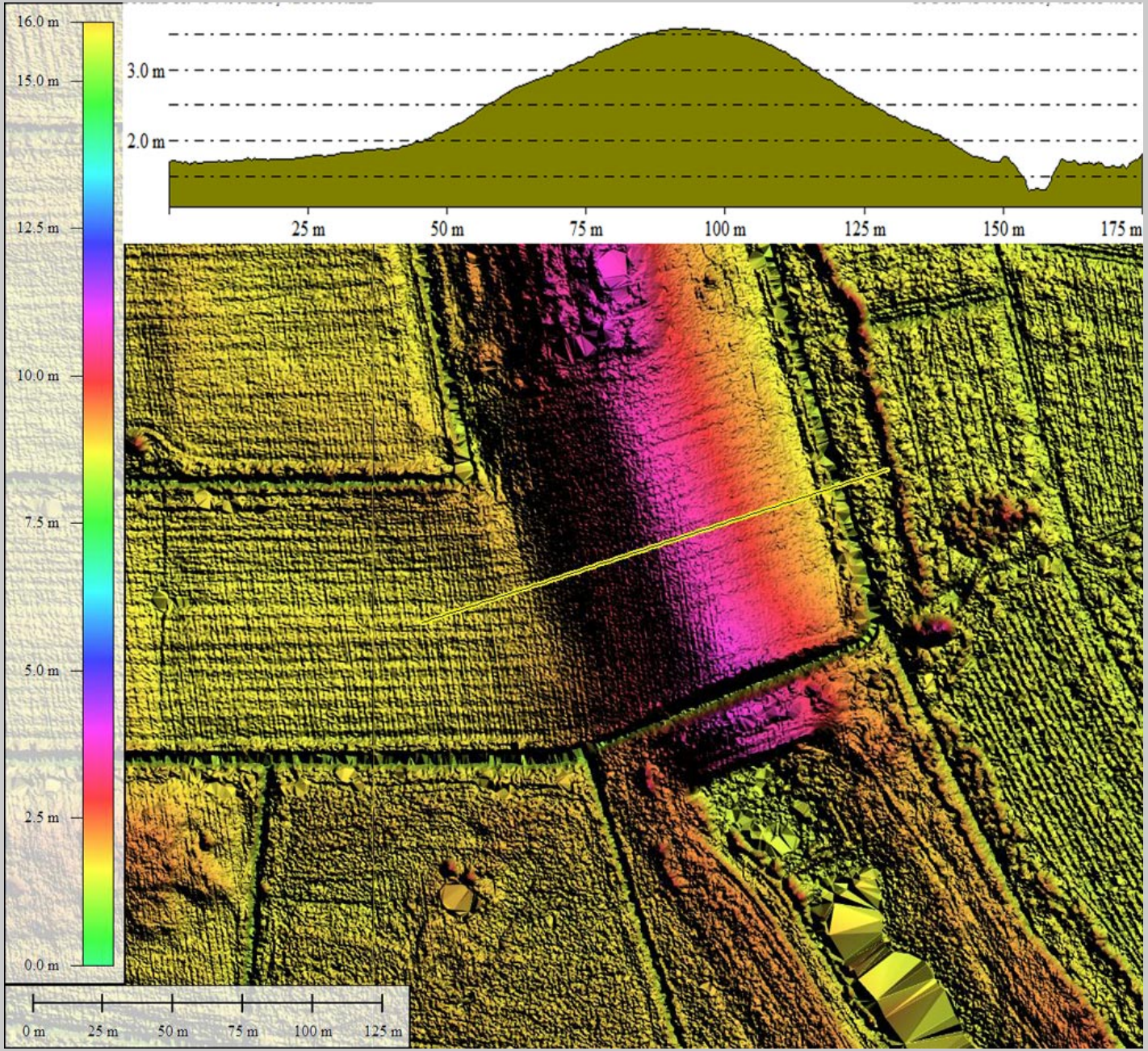
bayOval: Rumbley, MD



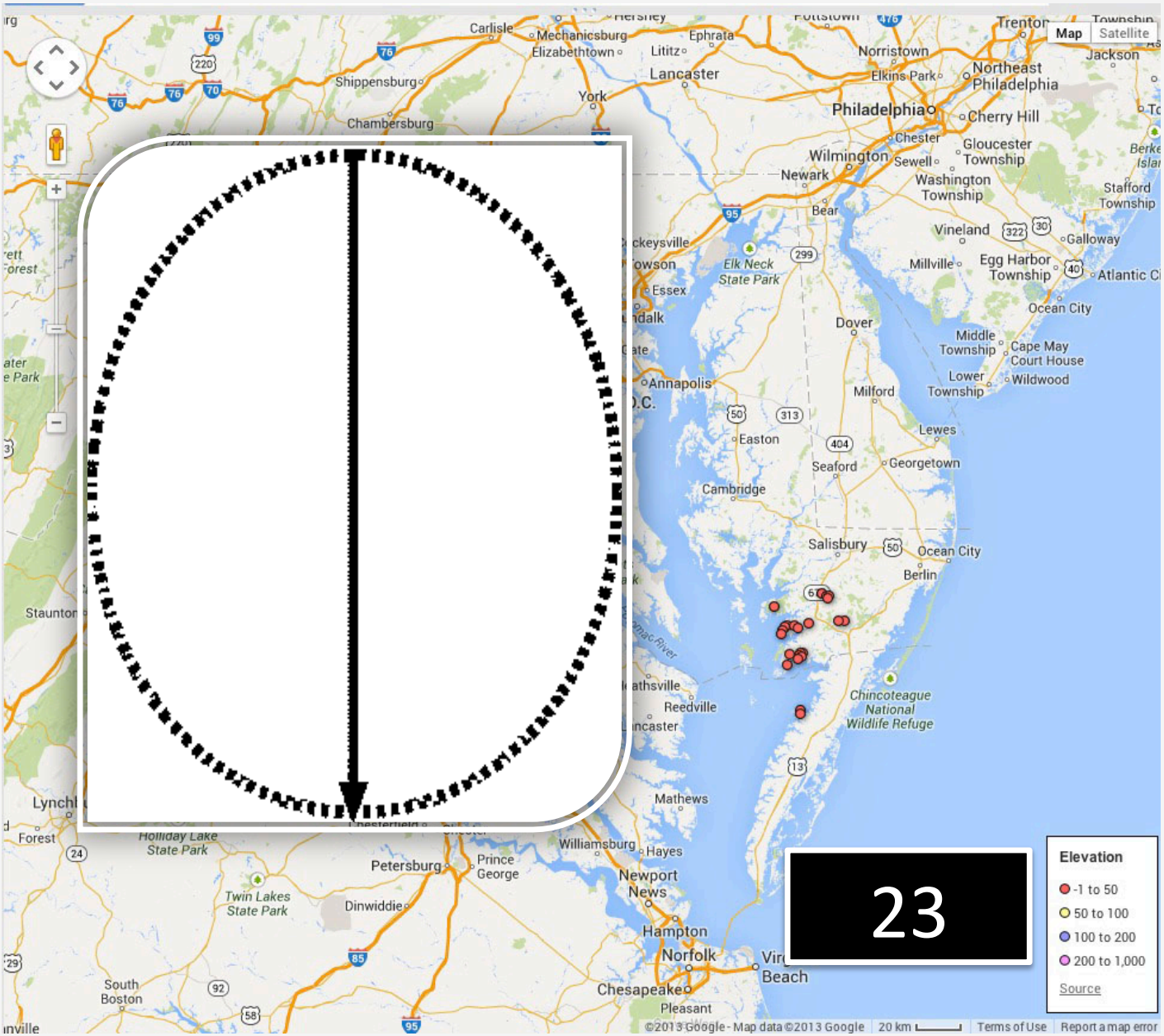
bayOval: James Ring Bay MD



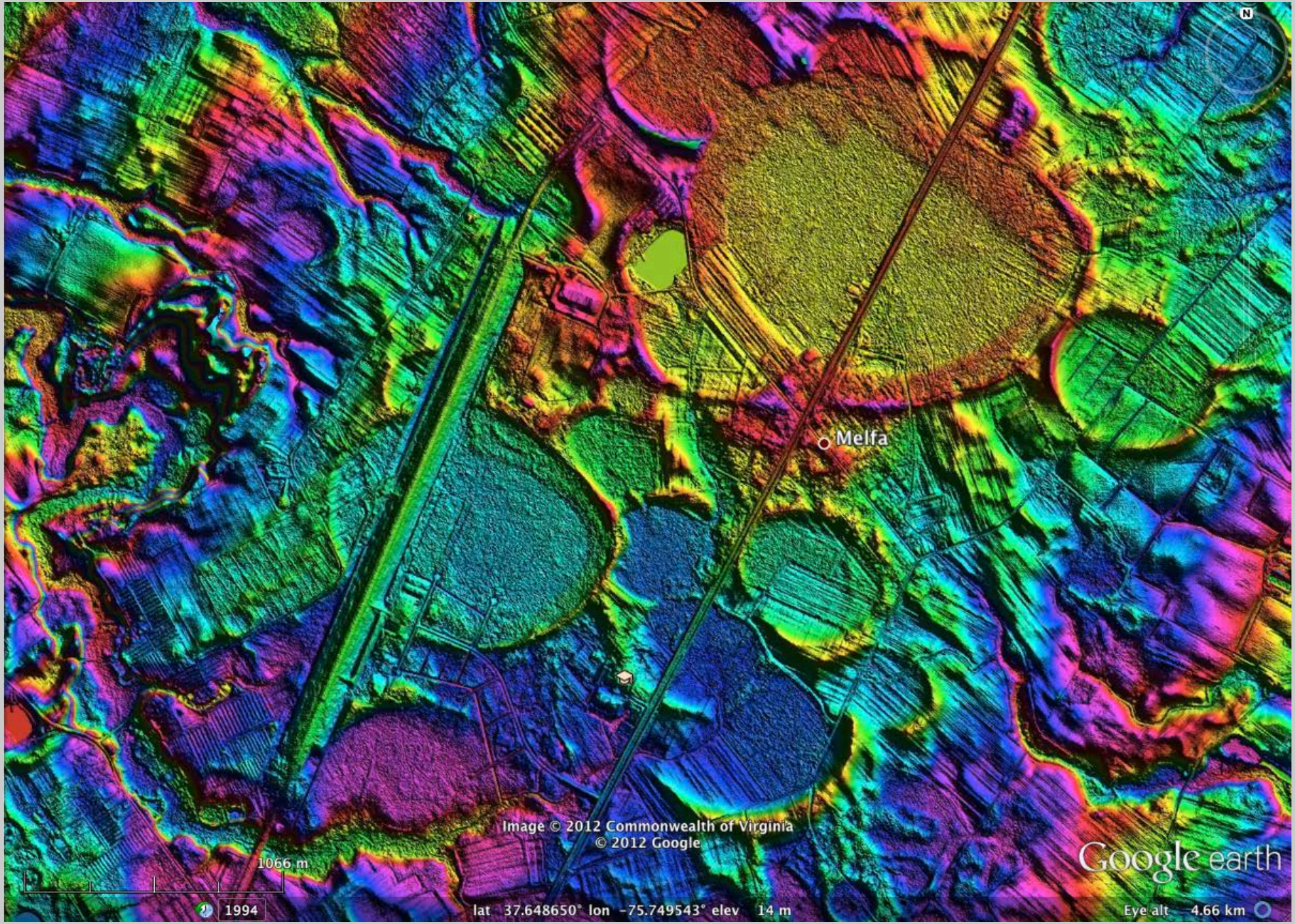
bayOval: James Ring Bay MD



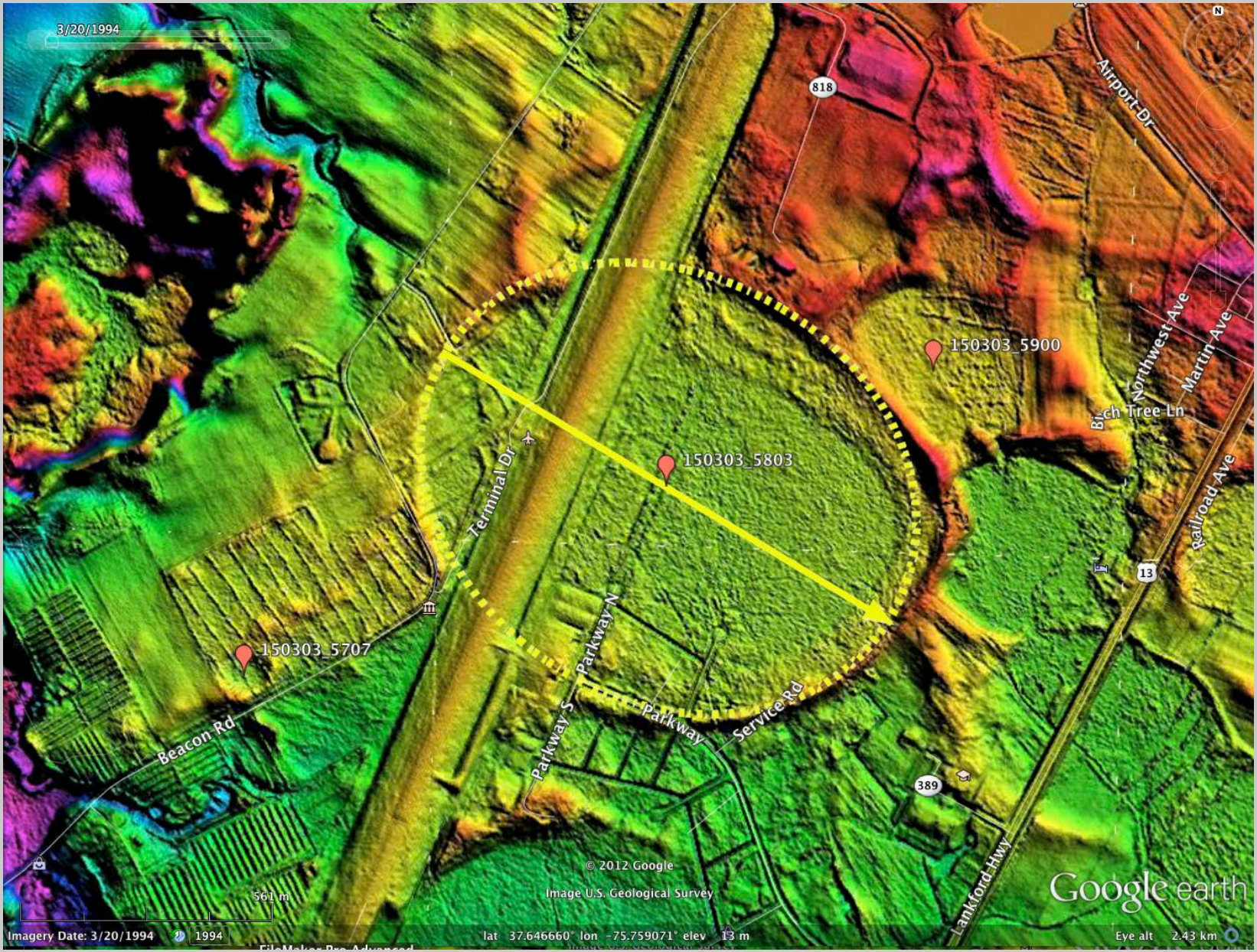
Territory of bayOval species



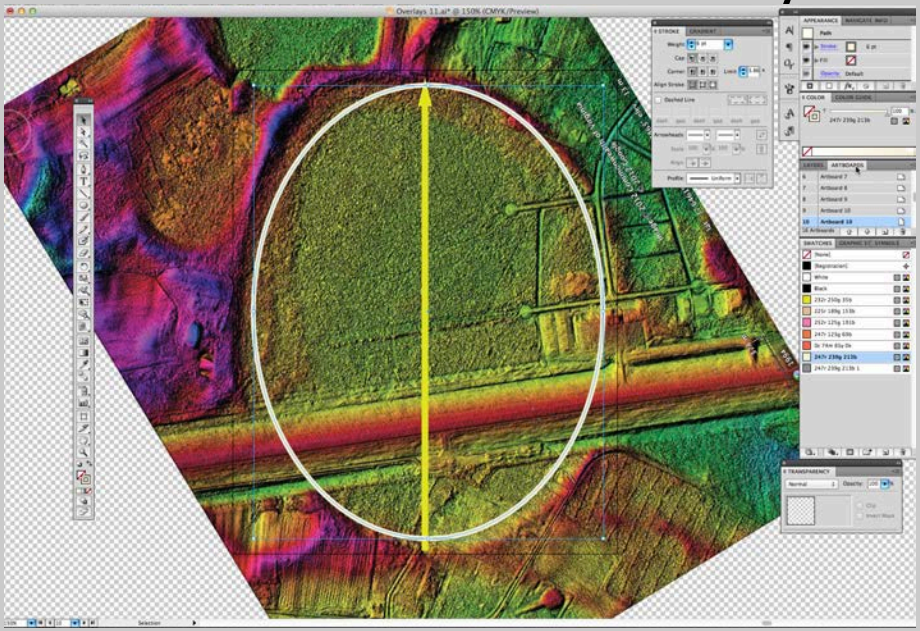
VA 10 ft LiDAR DEM

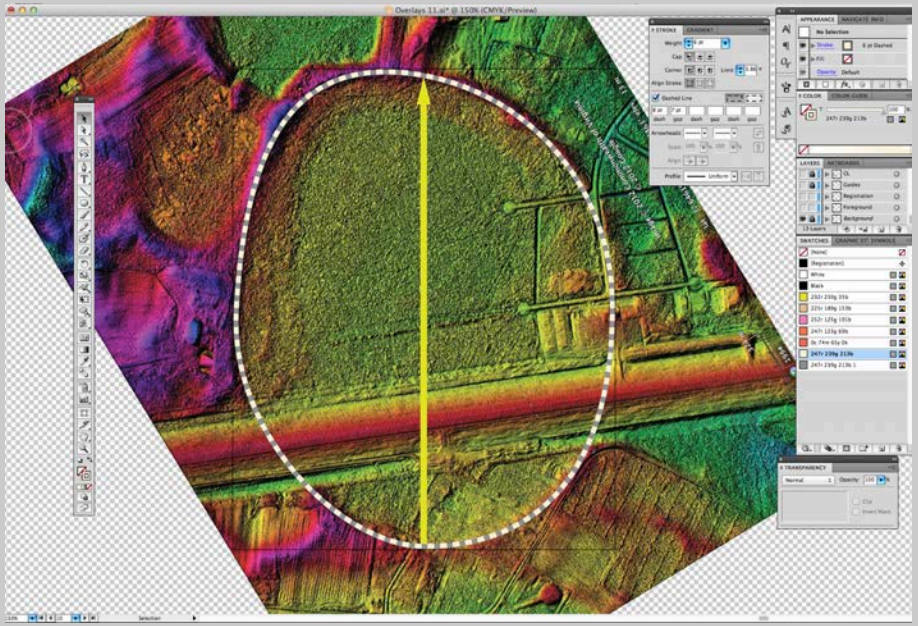


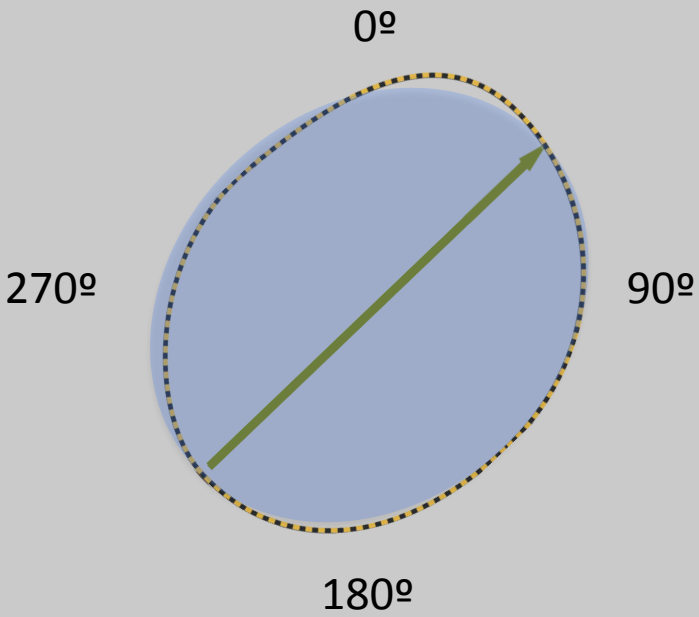
Surveyed Bay Template in Google Earth

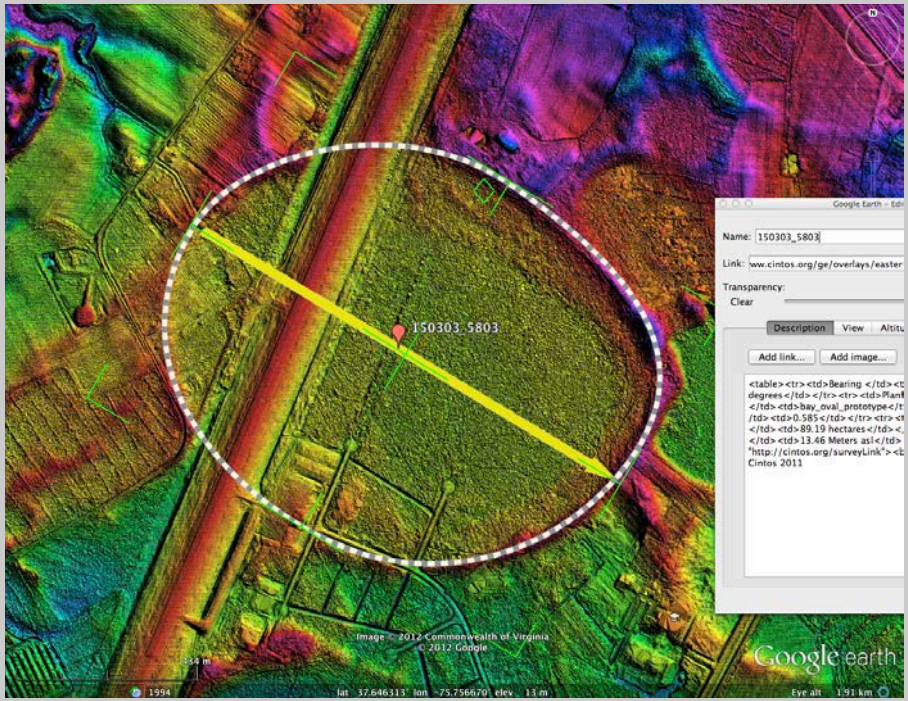


GroundOverlay Created in Illustrator









Keyhole Markup Language Data in GroundOverlay

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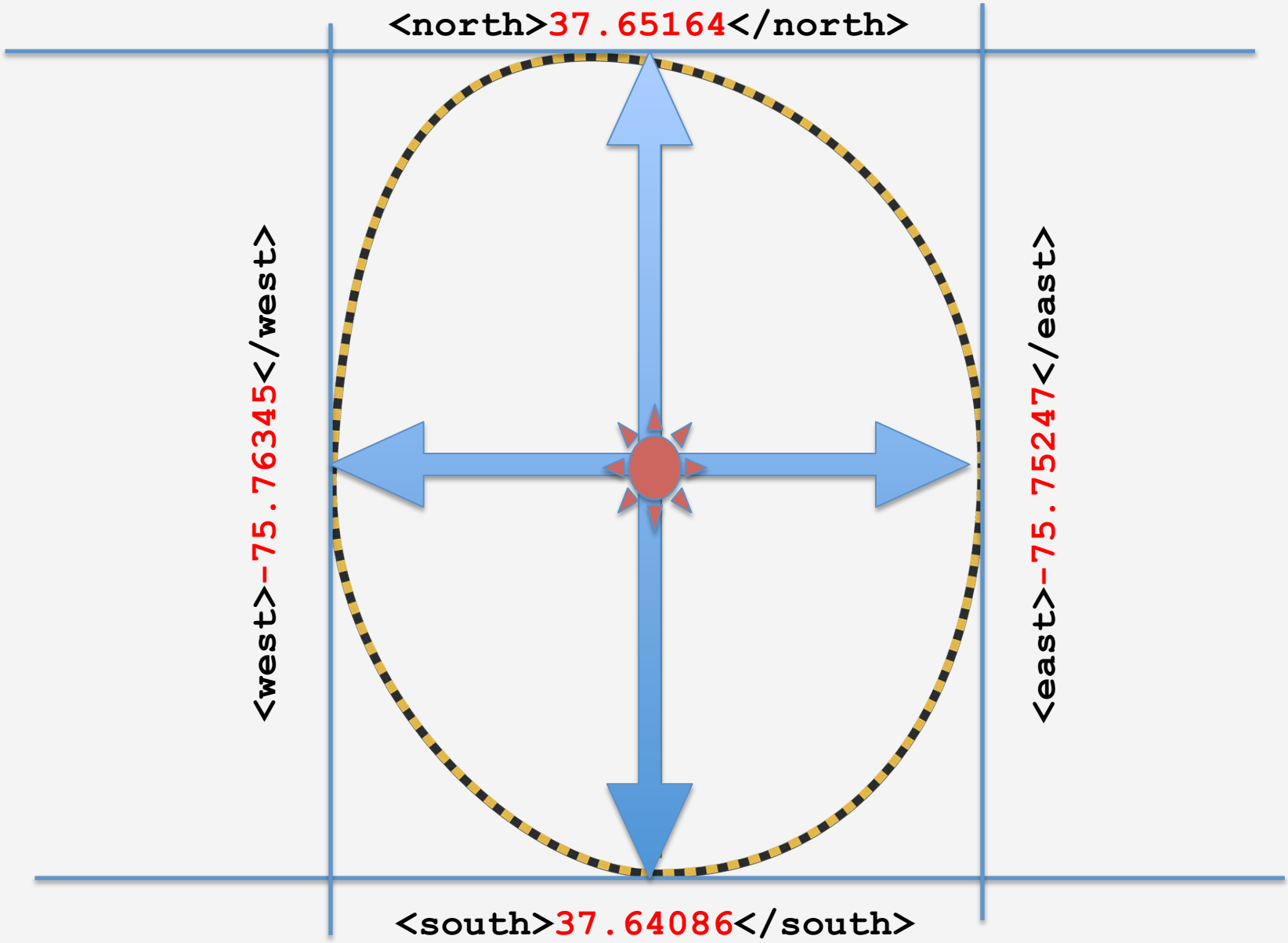
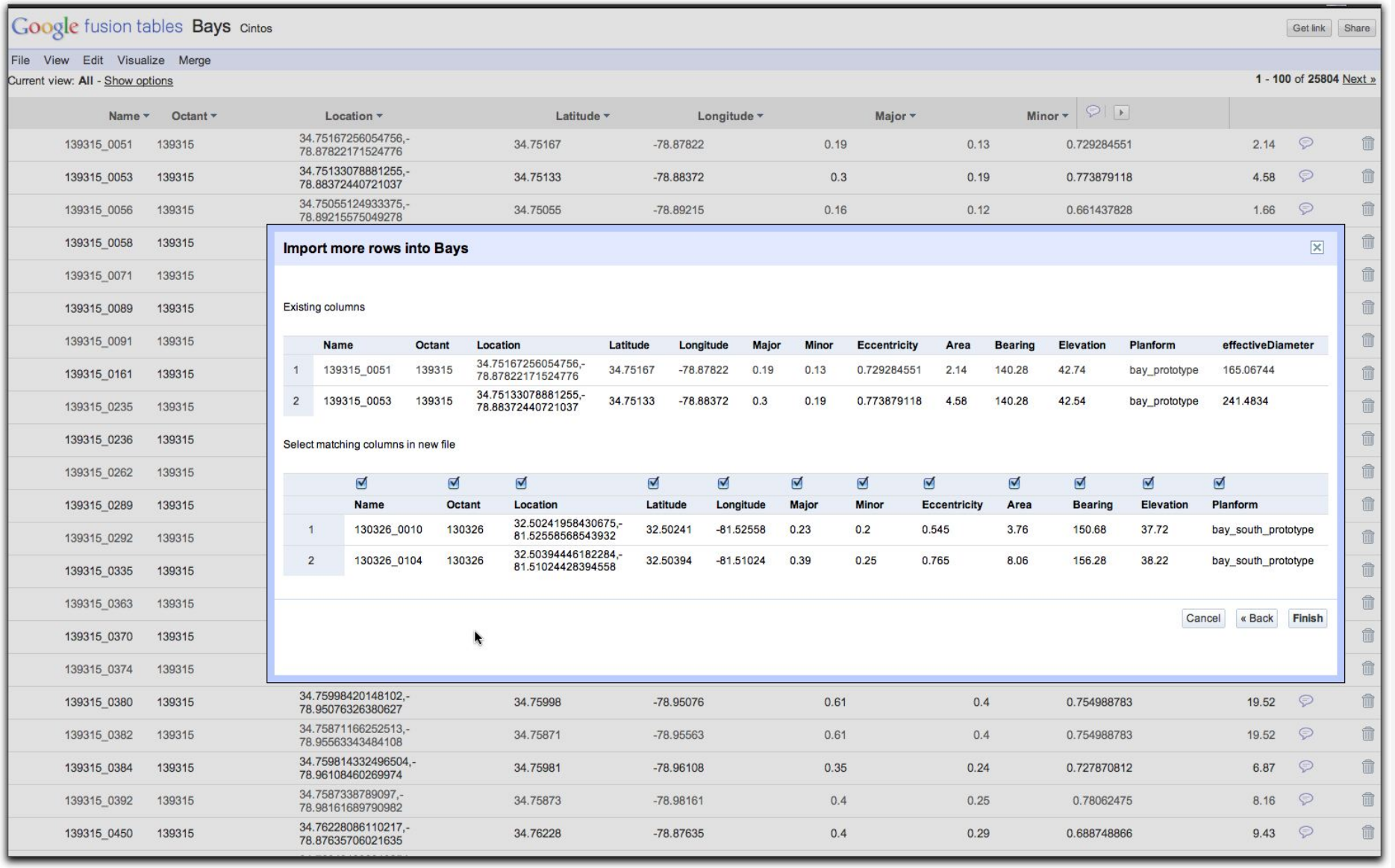
GroundOverlay LatLonBox Computations



Loading Fusion Table: Carolina Bay Geospatial Survey



Name	Octant	Location	Latitude	Longitude	Major	Minor	Eccentricity	Area	Bearing	Elevation	Planform	effectiveDiameter
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139315_0053	139315	34.75133078881255,-78.88372440721037	34.75133	-78.88372	0.3	0.19	0.773879118	4.58	140.28	42.54	bay_prototype	241.4834
139315_0056	139315	34.75055124933375,-78.89215575049278	34.75055	-78.89215	0.16	0.12	0.661437828	1.66				
139315_0058	139315											
139315_0071	139315											
139315_0089	139315											
139315_0091	139315											
139315_0161	139315											
139315_0235	139315											
139315_0236	139315											
139315_0262	139315											
139315_0289	139315											
139315_0292	139315											
139315_0335	139315											
139315_0363	139315											
139315_0370	139315											
139315_0374	139315											
139315_0380	139315	34.75998420148102,-78.95076326380627	34.75998	-78.95076	0.61	0.4	0.754988783	19.52				
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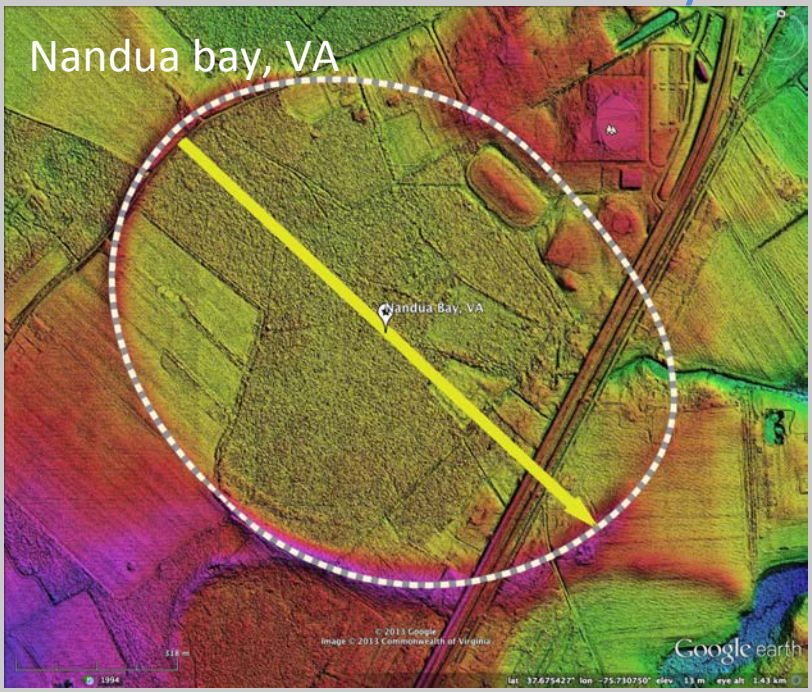
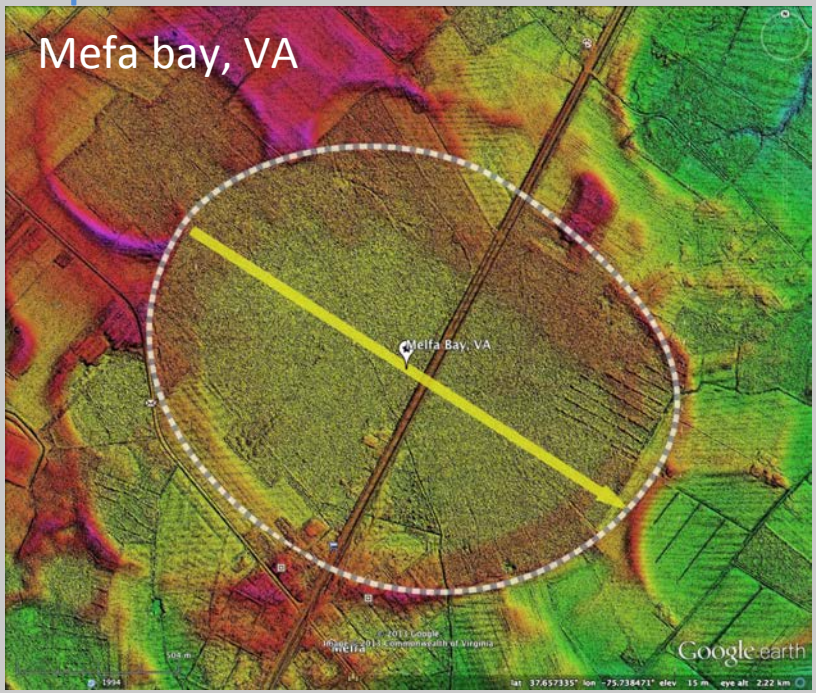
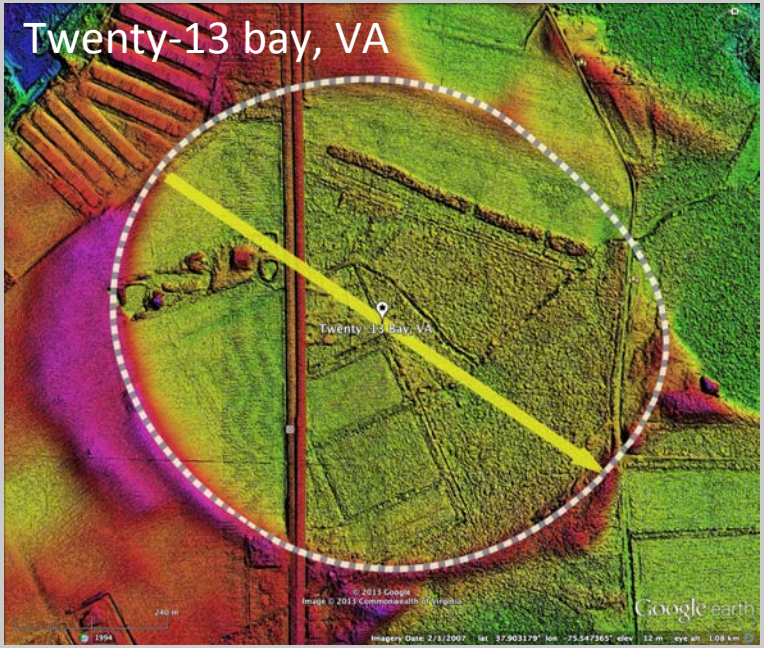
139315_0384	139315	34.759814332496504,-78.96108460269974	34.75981	-78.96108	0.35	0.24	0.727870812	6.87				
139315_0392	139315	34.7587338789097,-78.98161689790982	34.75873	-78.98161	0.4	0.25	0.78062475	8.16				
139315_0450	139315	34.76228086110217,-78.87635706021635	34.76228	-78.87635	0.4	0.29	0.688748866	9.43				

	Name	Octant	Location	Latitude	Longitude	Major	Minor	Eccentricity	Area	Bearing	Elevation	Planform
1	130326_0010	130326	32.50241958430675,-81.52558568543932	32.50241	-81.52558	0.23	0.2	0.545	3.76	150.68	37.72	bay_south_prototype
2	130326_0104	130326	32.50394446182284,-81.51024428394558	32.50394	-81.51024	0.39	0.25	0.765	8.06	156.28	38.22	bay_south_prototype

bayShore Species

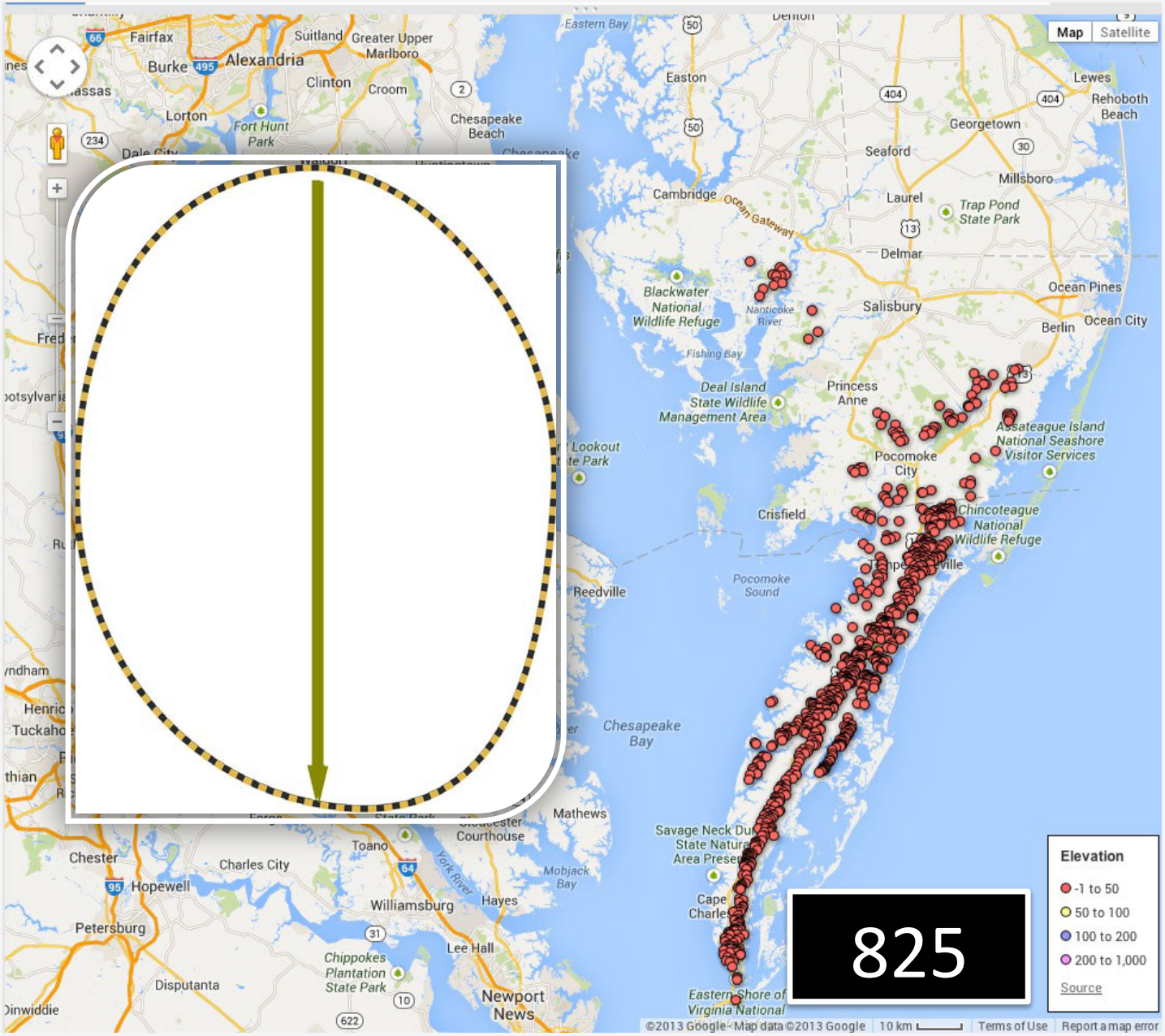




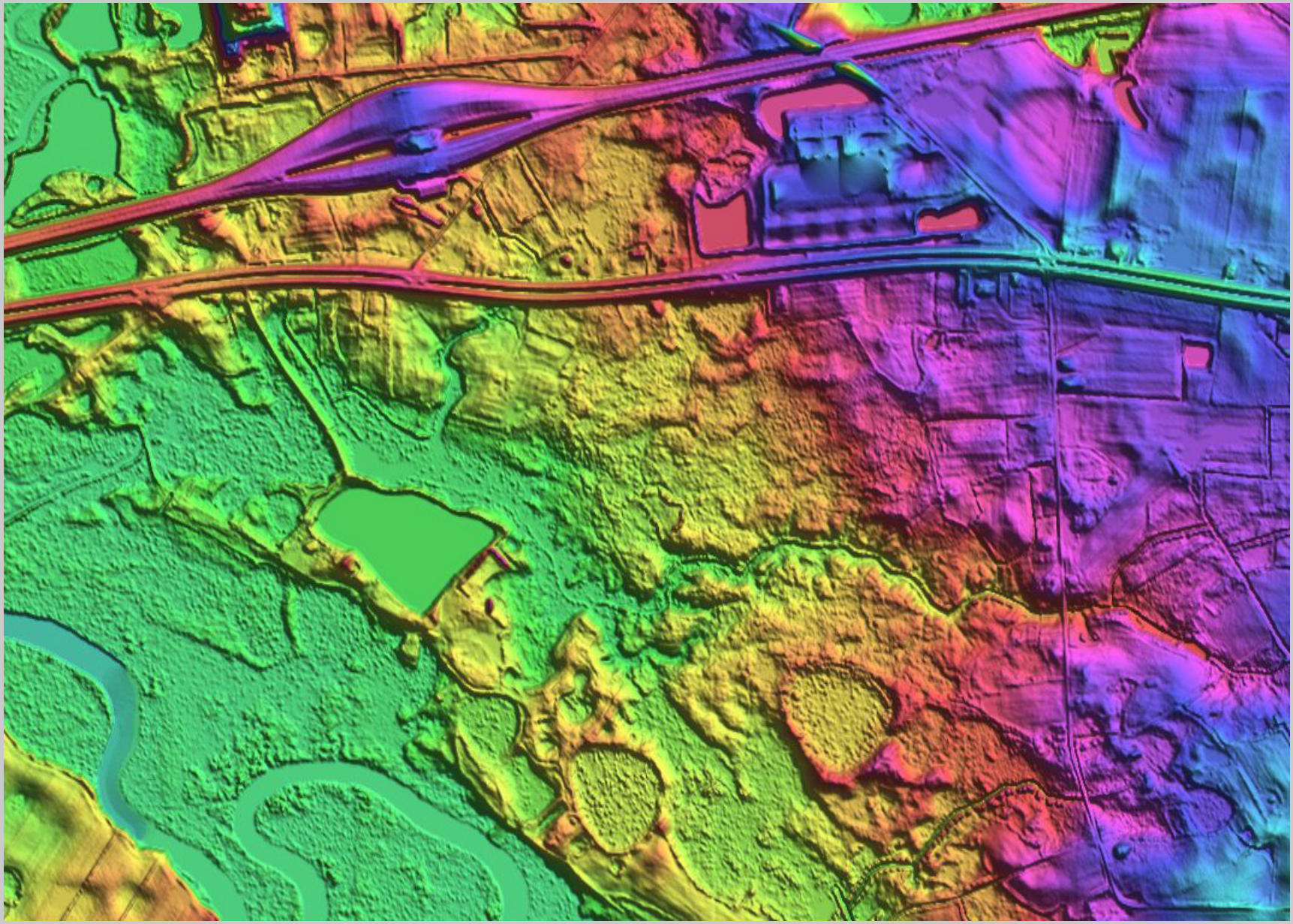


Twenty-13 bay, VA

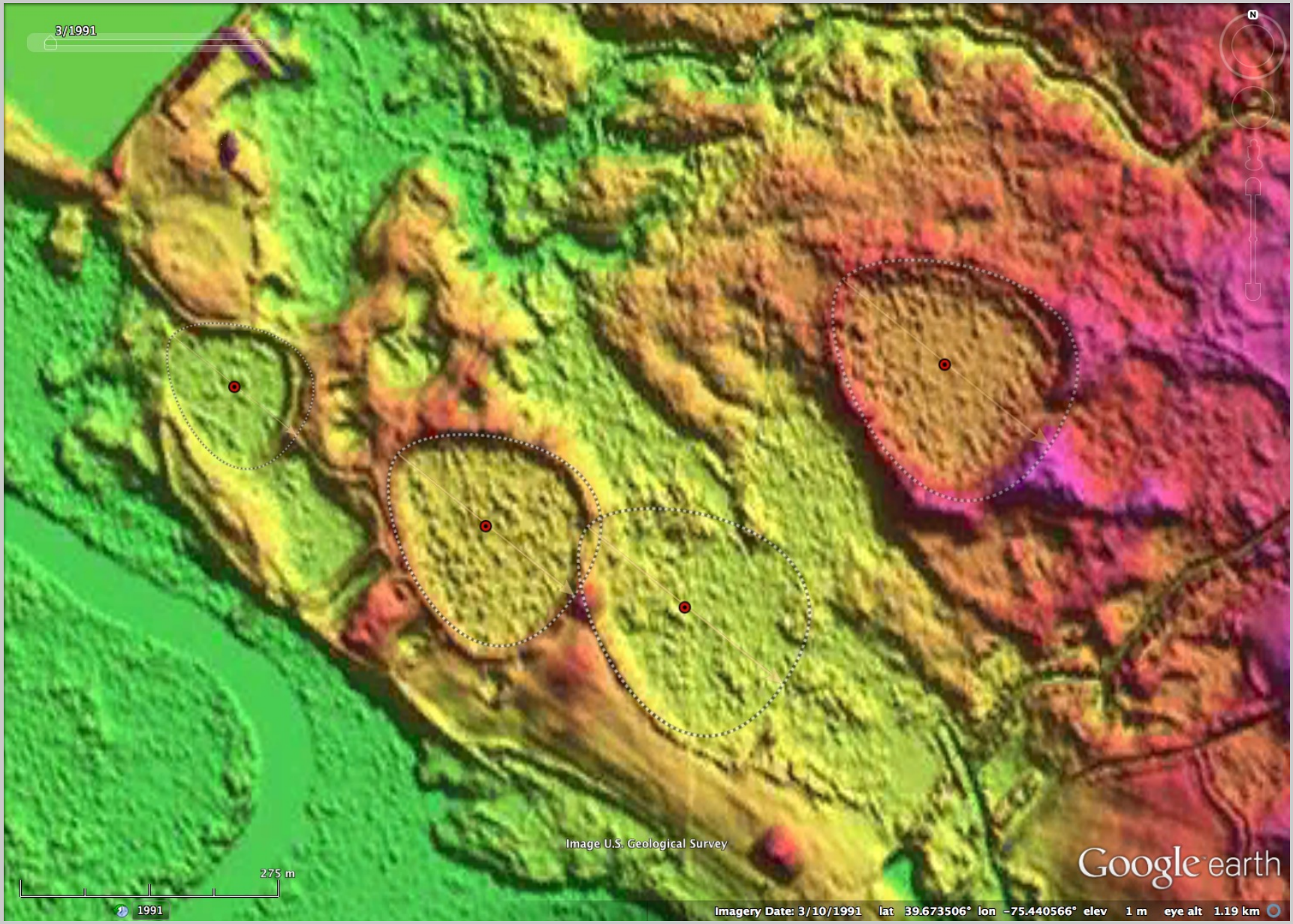
Territory of bayShore species



bayBell Delaware Memorial Bridge, NJ side



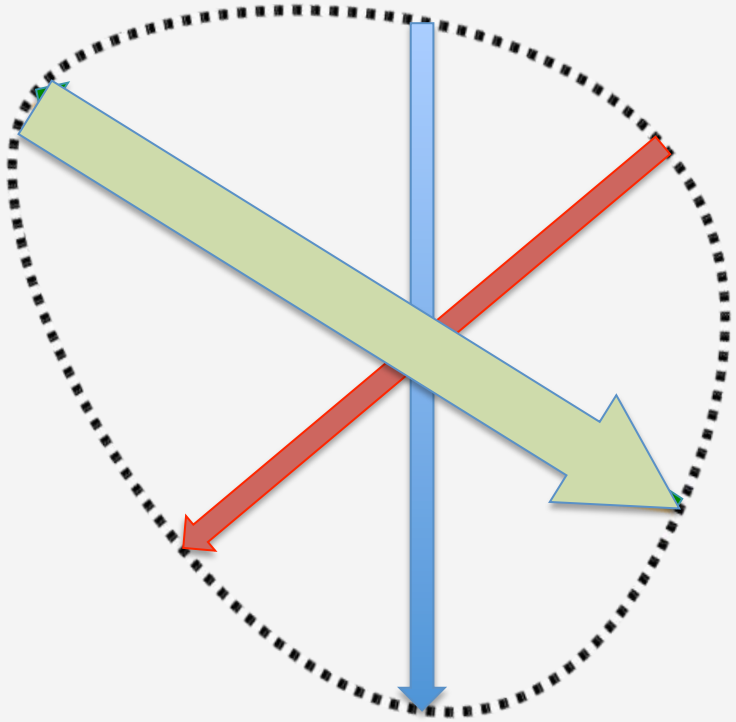
bayBell Delaware Memorial Bridge, NJ side



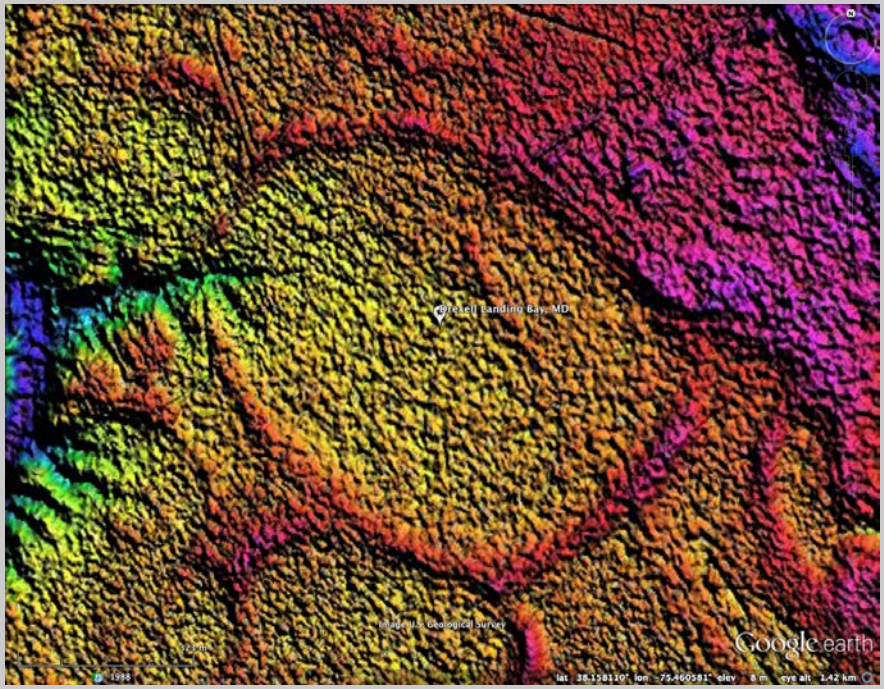
Look at a “bay” in NJ & DelMarVa

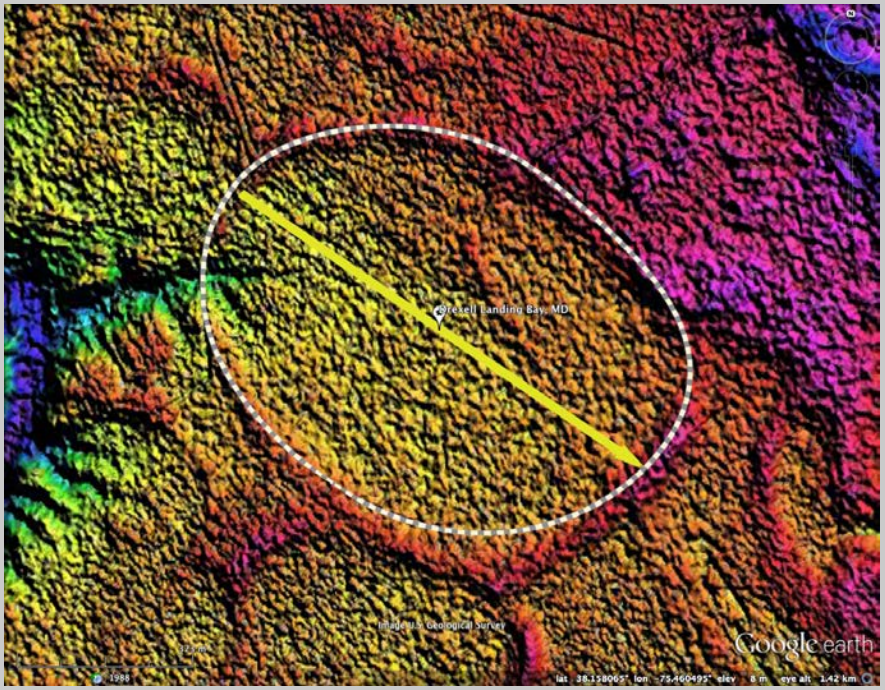
- Looks like baySouth rotated 180º
- Robust adherence to shape seen MD to NJ
- Orientation in Question

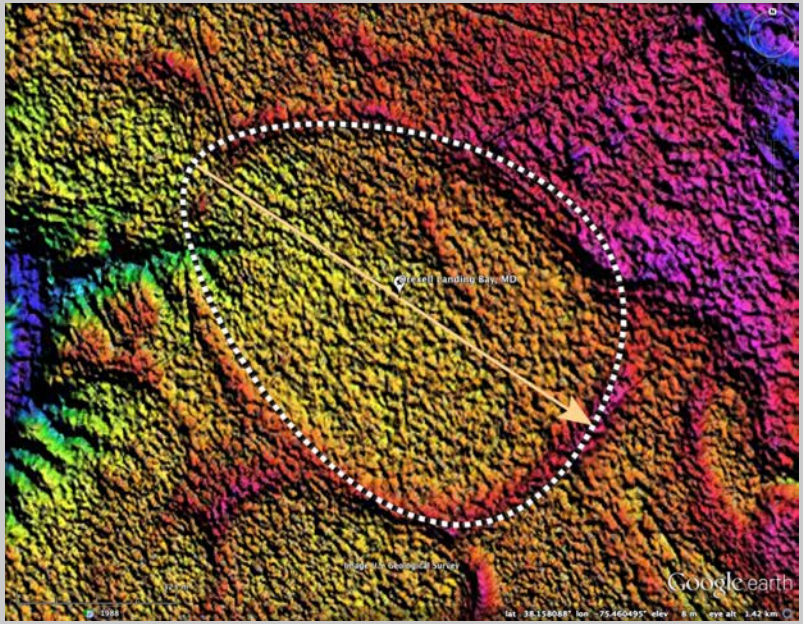
Taxonomy “bayBell”



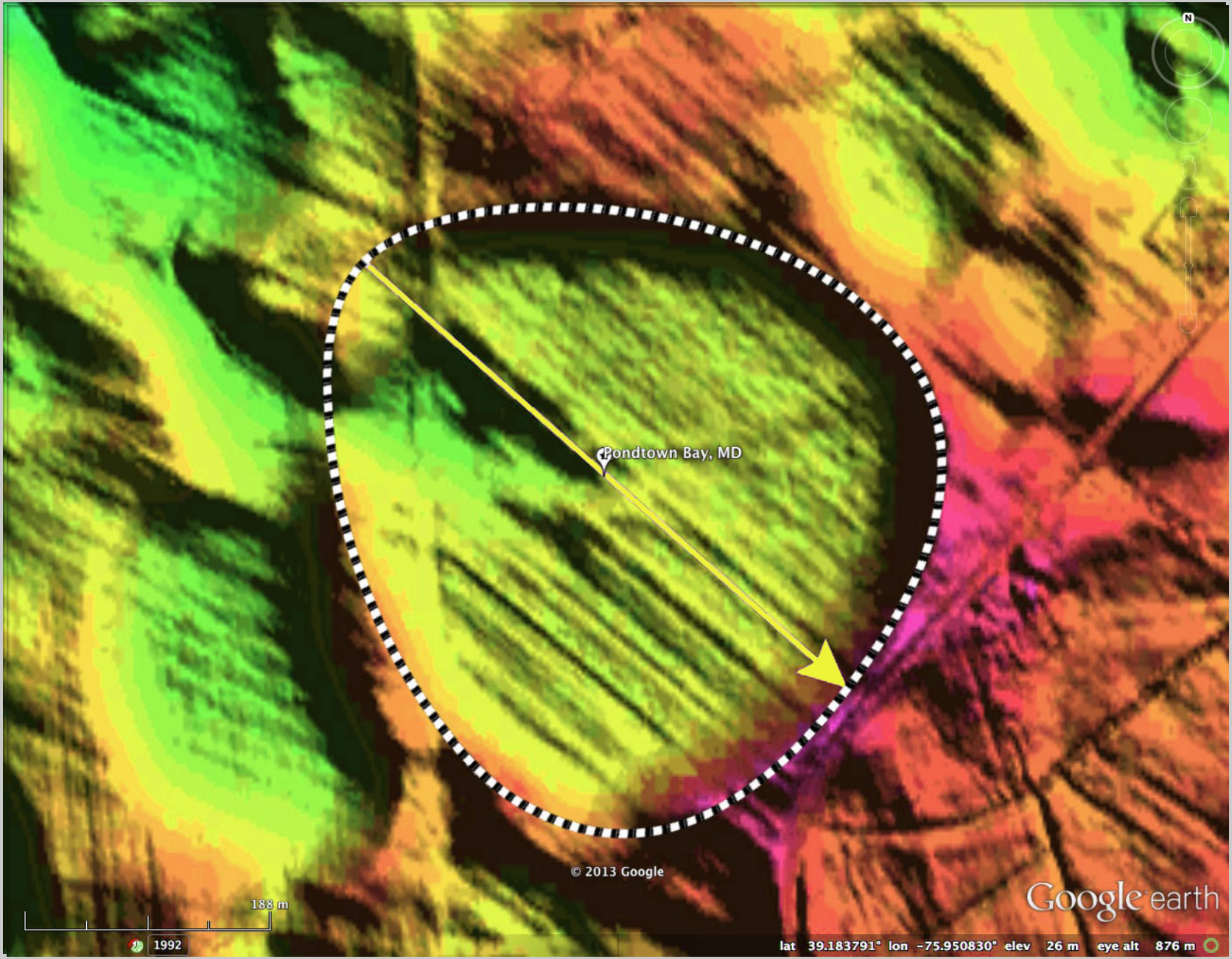
bayBell Drexel Road bay, MD





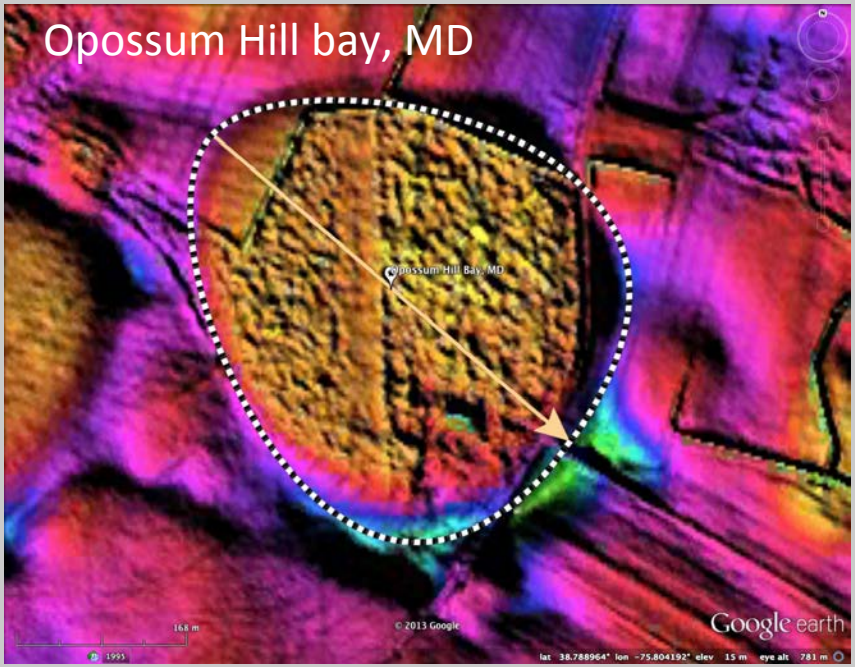


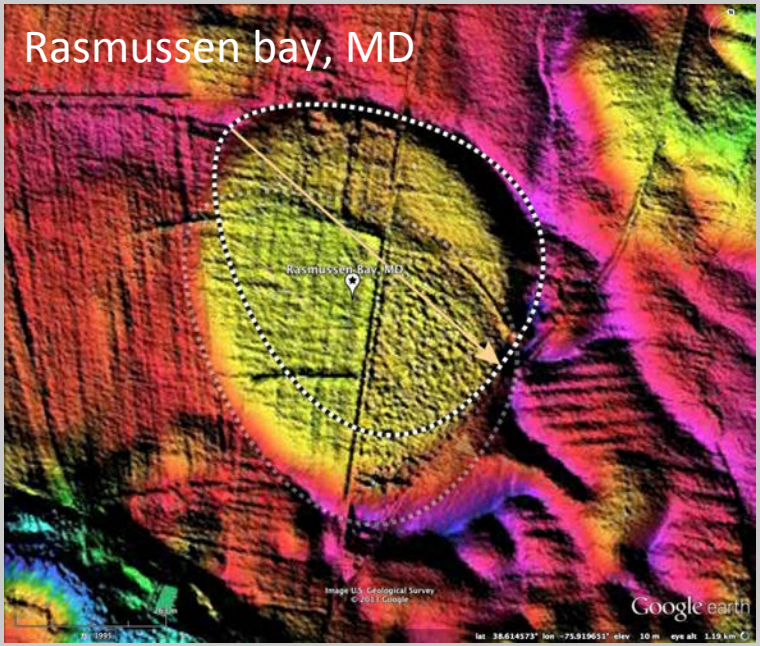
bayBell Pondtown bay, MD



bayBell

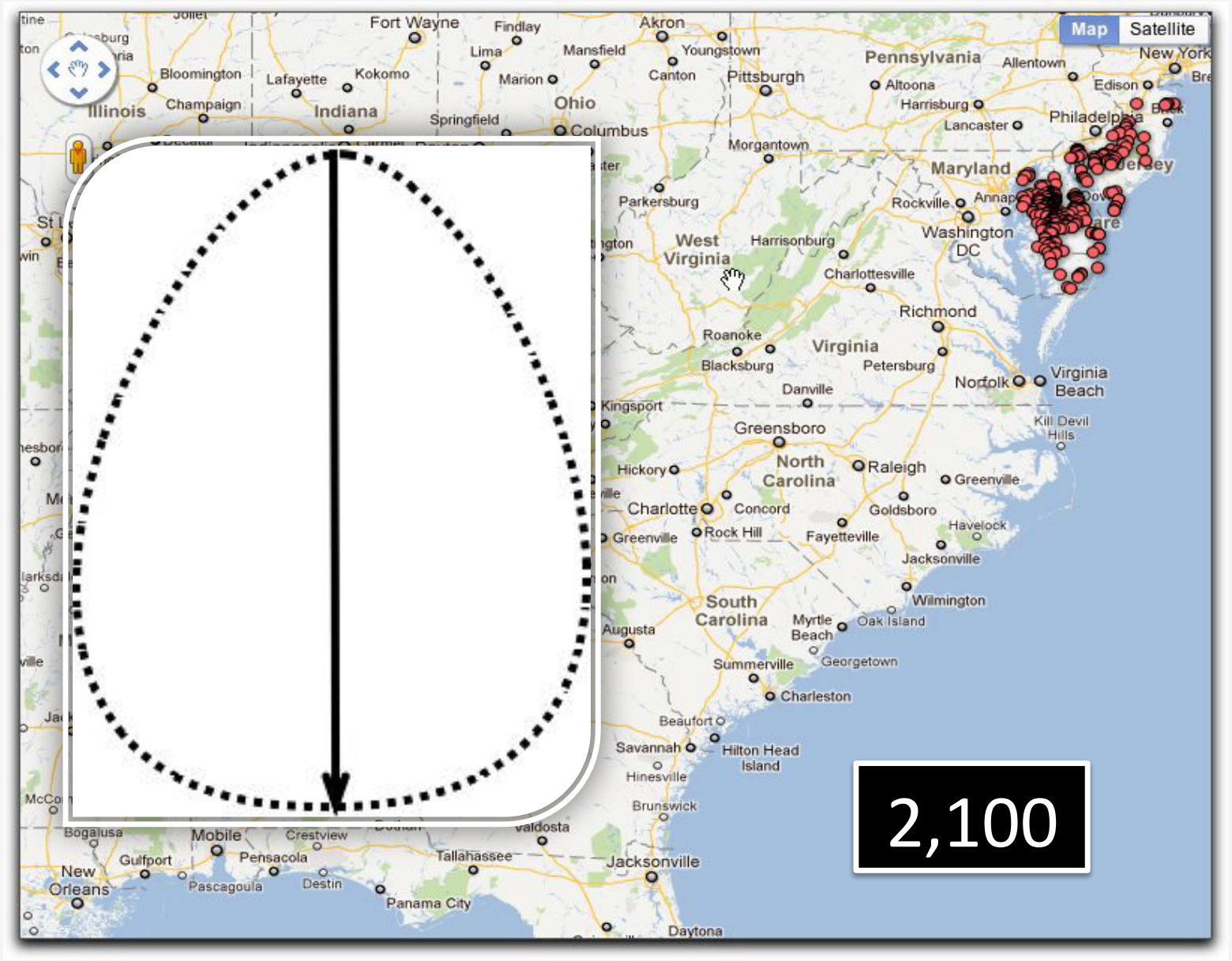

Fox Hunter bay, DE
Fox Hunter Bay, DE
Google earth


Opossum Hill bay, MD
Opossum Hill Bay, MD
© 2013 Google
Google earth


Rasmussen bay, MD
Rasmussen Bay, MD
Image U.S. Geological Survey
Google earth


Archertown bay, NJ
Archertown Bay, NJ
© 2013 Google

Territory of bayBell species



Nebraska From the Air: Rainwater Basins

Nebraska Rainwater Basins

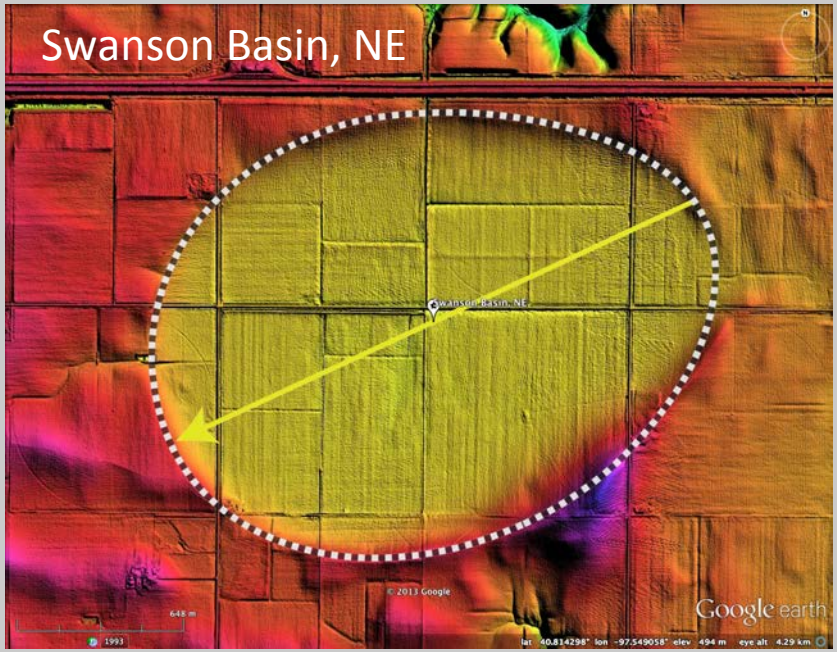
Unlike the Carolina bays, the oval Rainwater basins are the surface expression of elliptical depressions developed in fluvial sands and gravels buried by a blanket of several meter-thick loess.

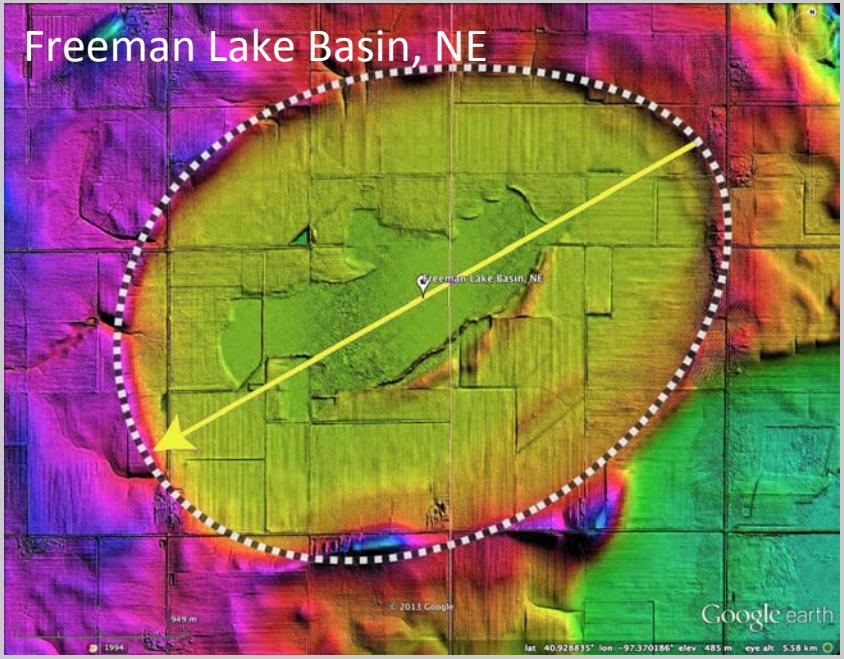
These basins are palimpset landforms created by the draping of a younger loess blanket over these underlying depressions .

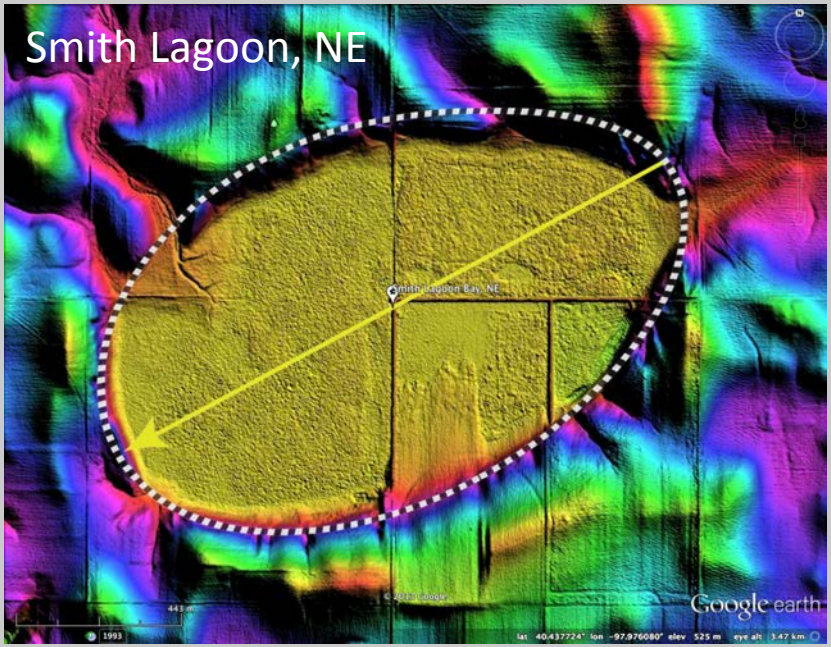
- Zanner and Kuzila 2001

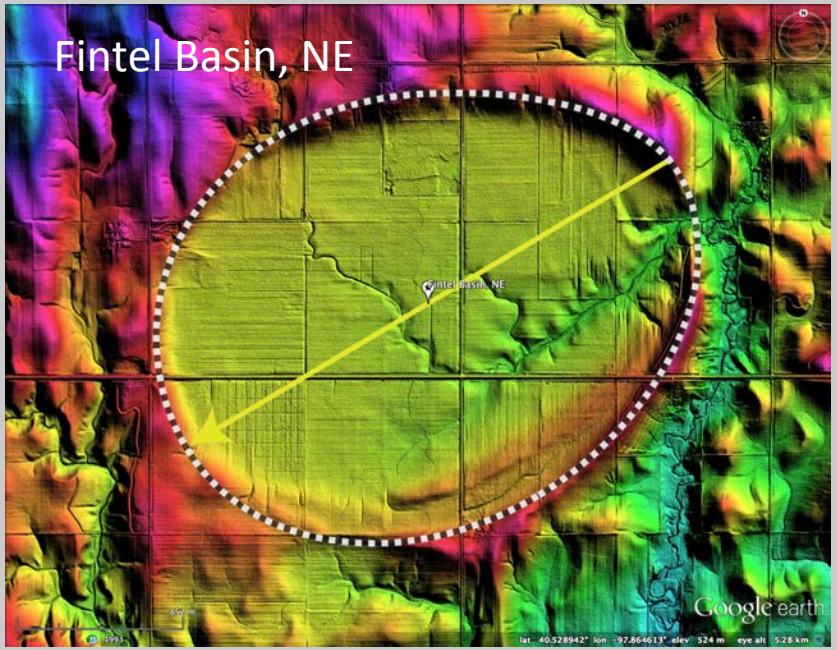
Do they qualify as another Species of Carolina Bays?

bayWest

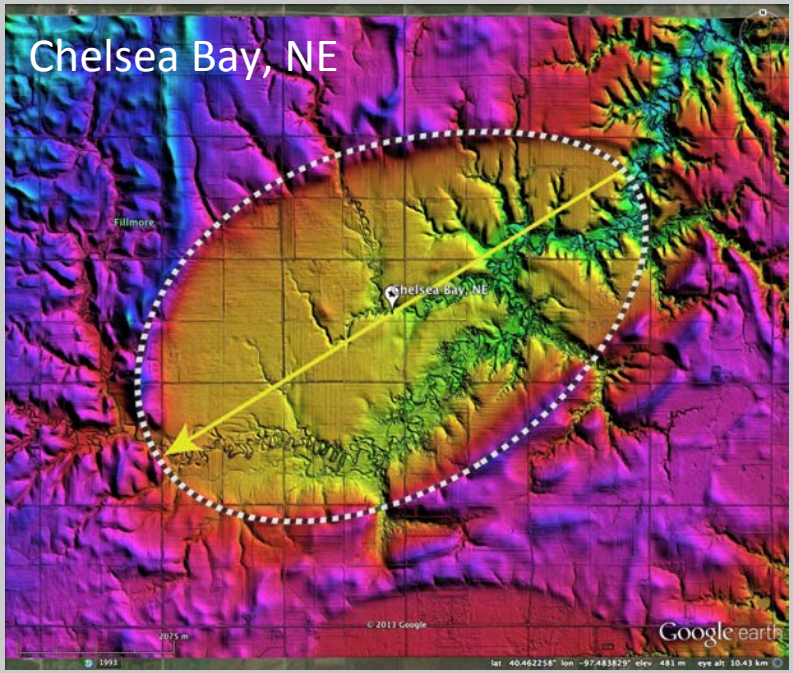

Swanson Basin, NE
Google earth

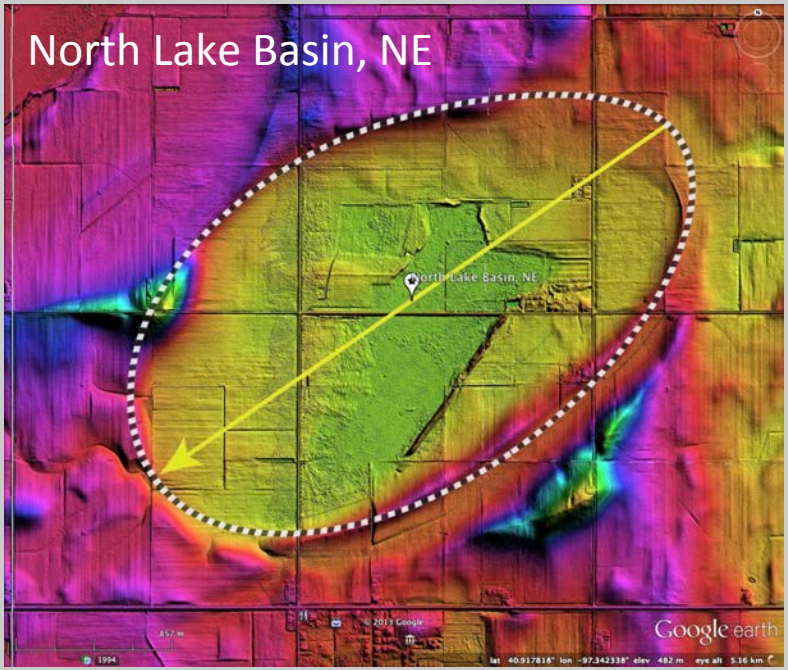

Freeman Lake Basin, NE
Google earth

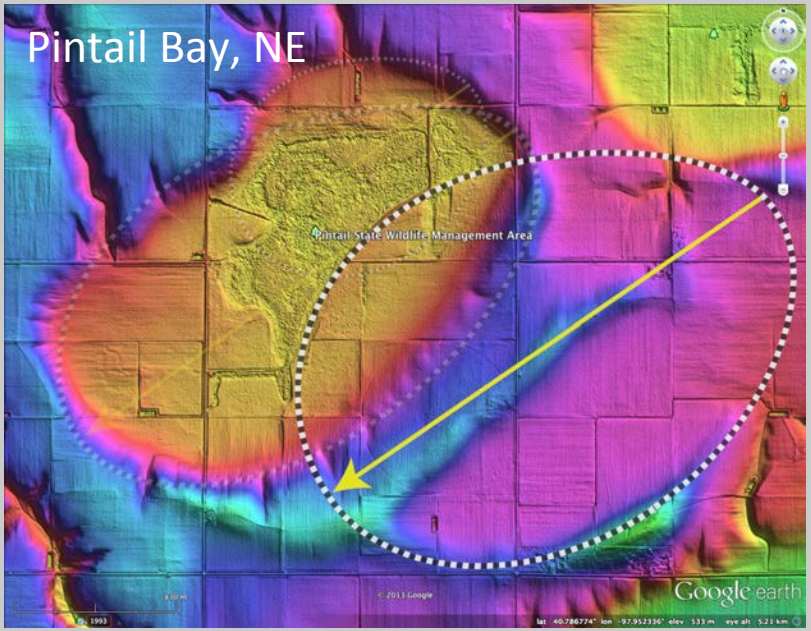

Smith Lagoon, NE
Google earth

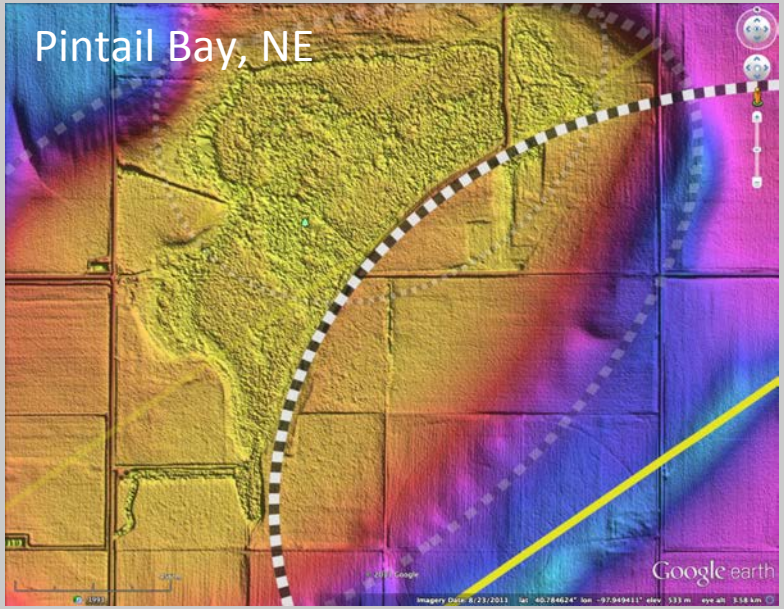

Fintel Basin, NE
Google earth

bayWest

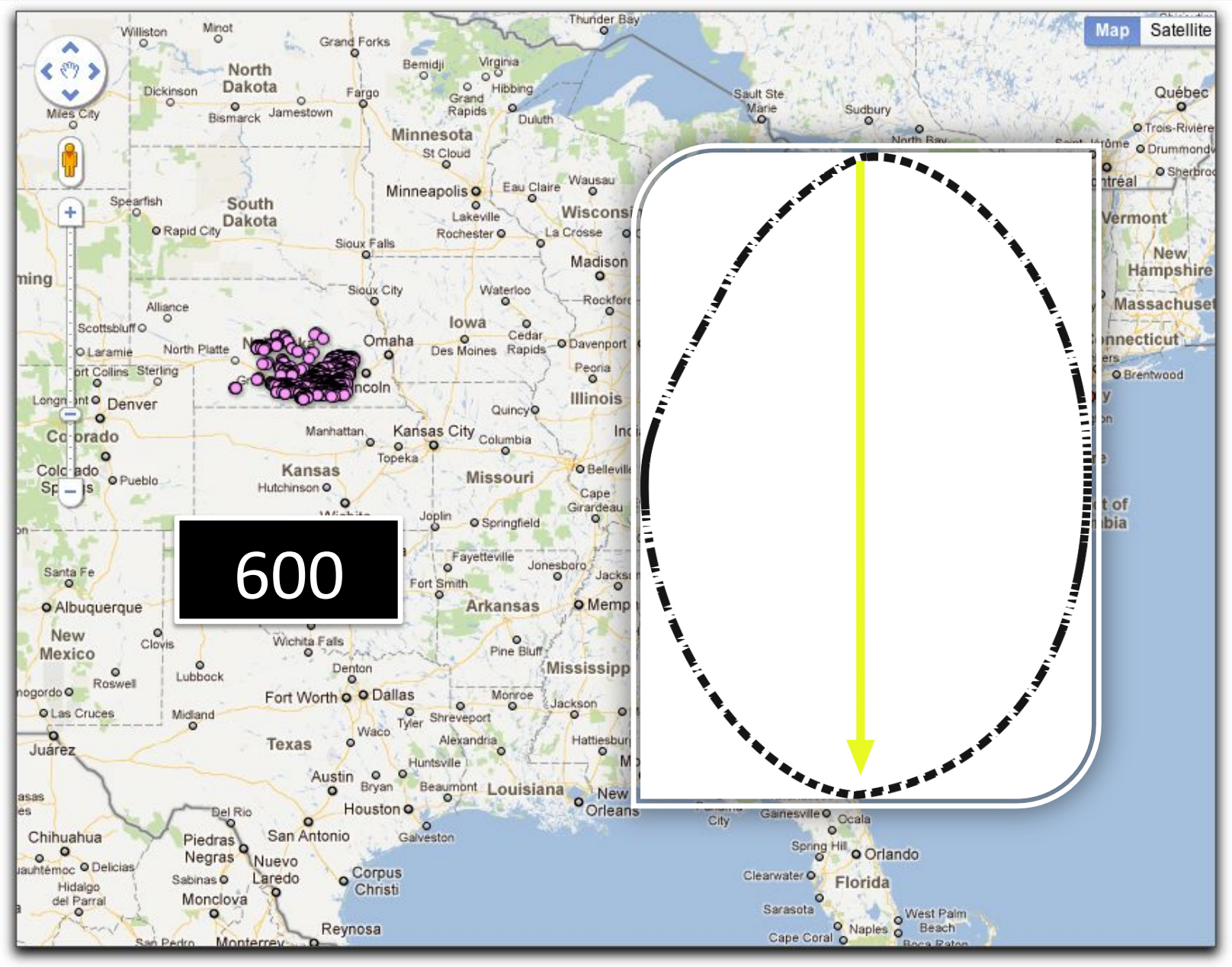

Chelsea Bay, NE
Fillmore
Chelsea Bay, NE
Google earth


North Lake Basin, NE
North Lake Basin, NE
Google earth


Pintail Bay, NE
Pintail State Wildlife Management Area
Google earth

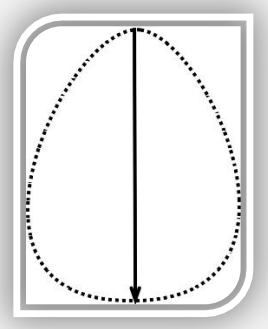
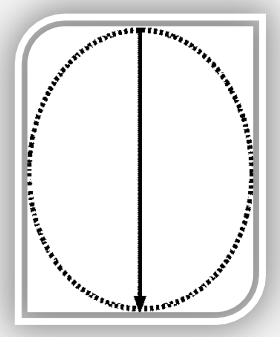
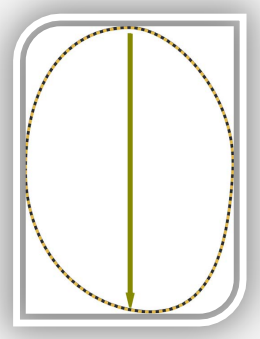
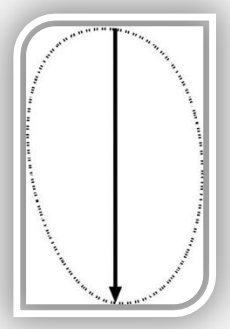
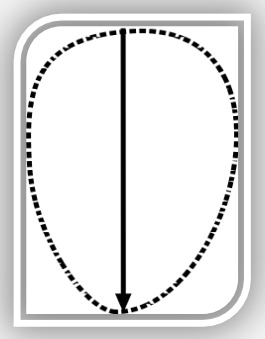
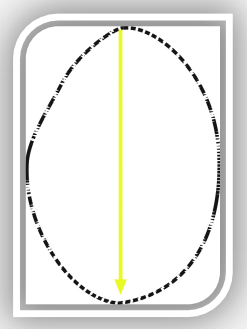

Pintail Bay, NE
Google earth

Territory of bayWest species

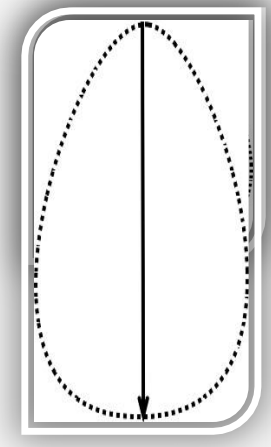
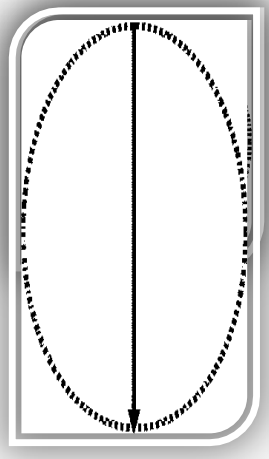
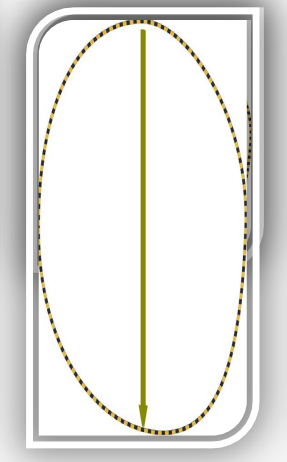
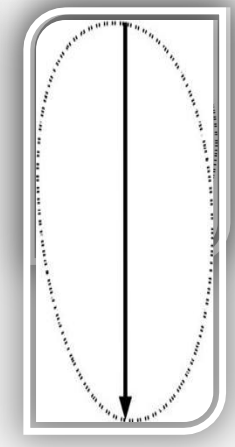
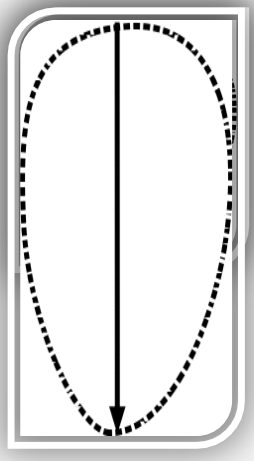
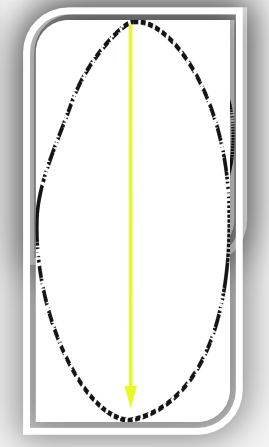


Taxonomy of landform Genus “Carolina Bay”

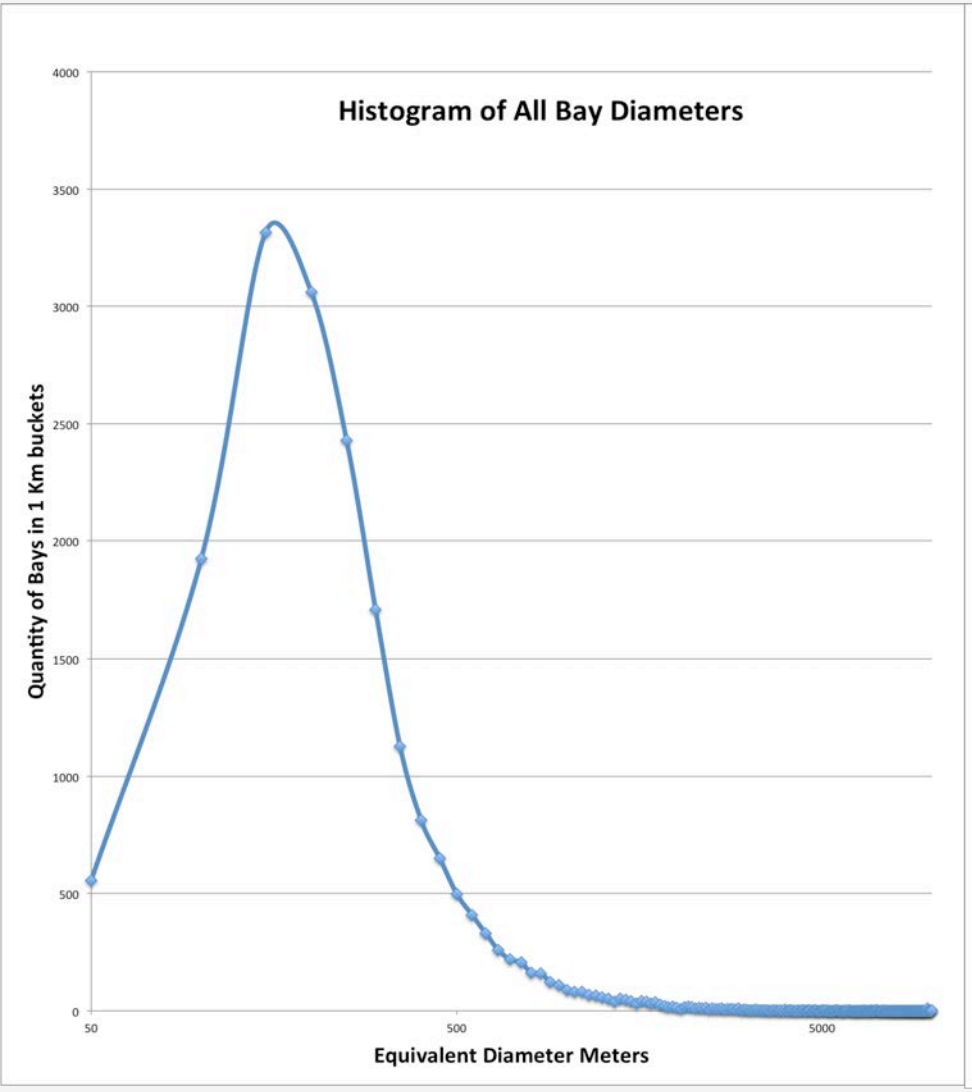
- Six tightly constrained archetypes as Species

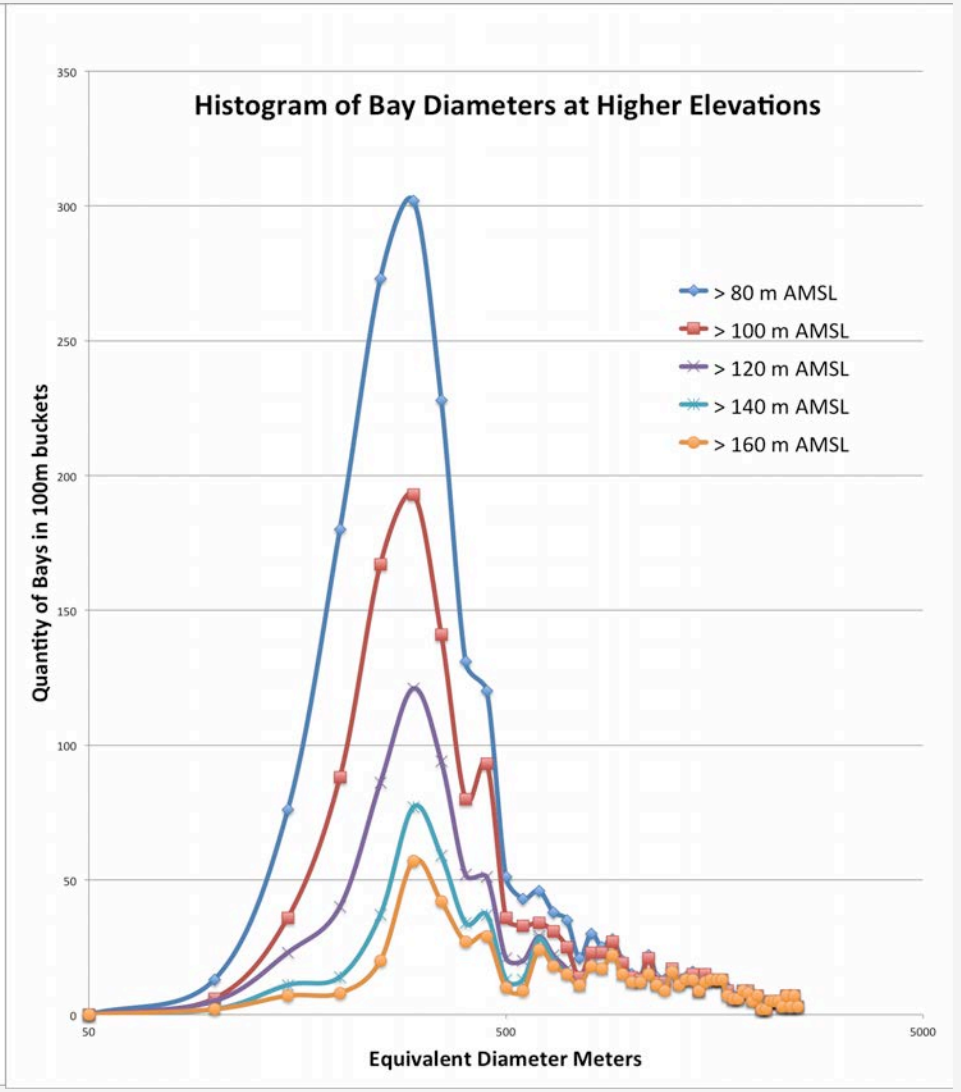







- Bell Oval Shore Carolina South West

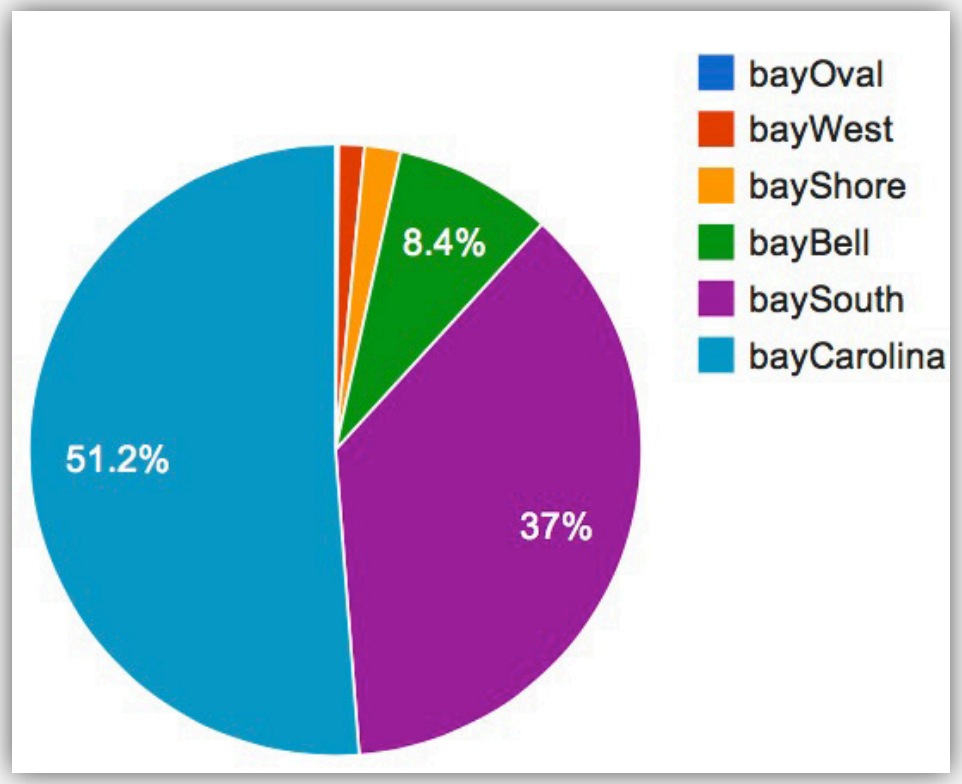
Bay Sizes Exhibit Log-Normal Distribution



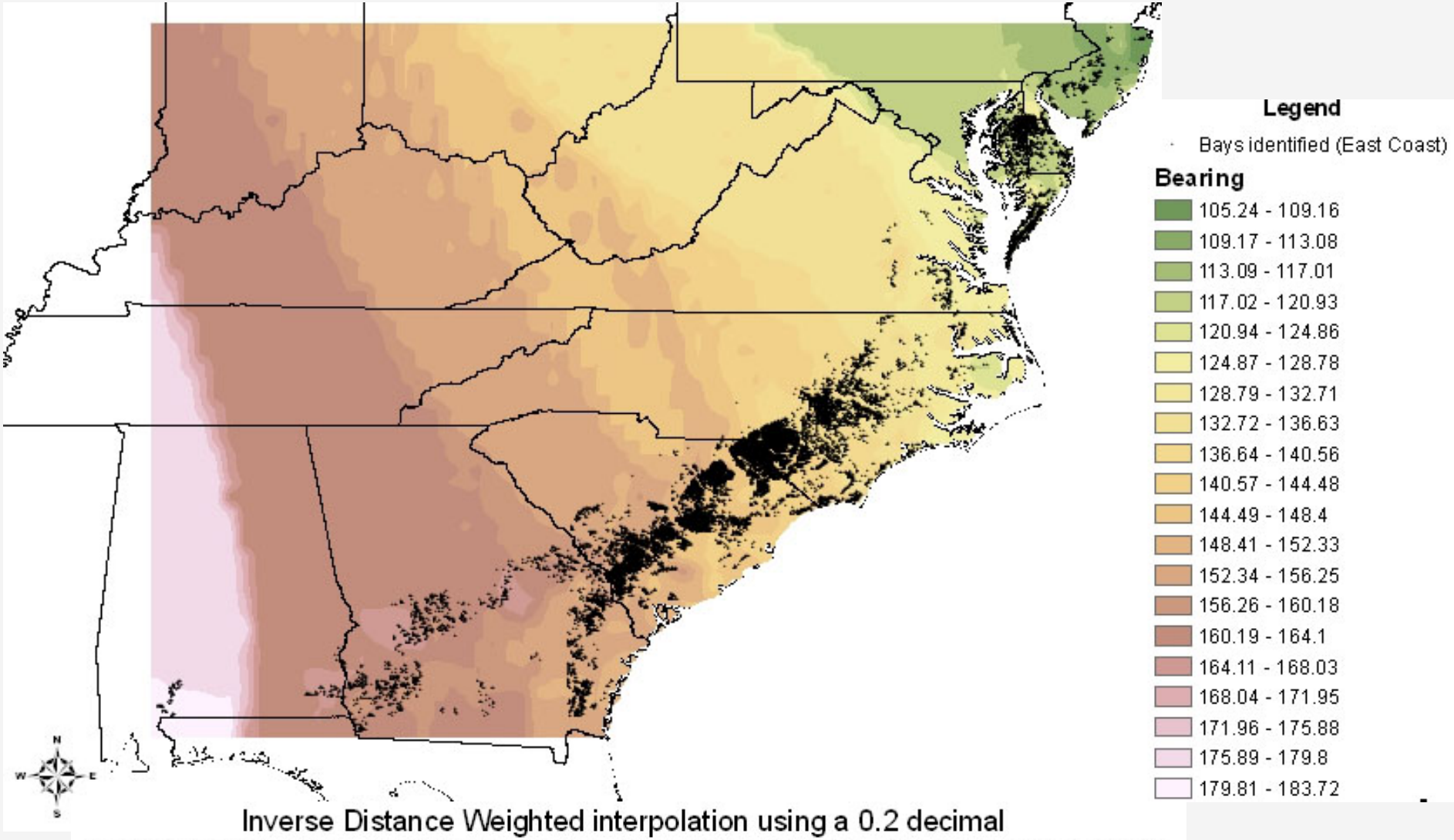


Fusion Tables: Metrics by Species

Planform	count	Major Axis Avg	Eccentricity Avg	Area Avg
bayOval	73	0.60	0.51	54.80
bayWest	592	1.52	0.68	190.90
bayShore	829	0.53	0.61	26.48
bayBell	3641	0.23	0.36	5.67
baySouth	16102	0.33	0.63	11.83
bayCarolina	22316	0.39	0.69	17.59



Bays and Bearings



Inverse Distance Weighted interpolation using a 0.2 decimal degree search radius, minimum 3 points, and output grid size of 0.2 decimal degrees.

Clockwise Rotation of ~75º from NJ through Alabama

Expanding Genus Carolina Bay Taxonomy

- Species identified by Bay Shape ✔
- Orientation ✔
- Rim Expression
  - Raised
  - Pediment
  - Combination
- Singleton, Paired or Merged?
- Closed Hydrology or Naturally Drained?

Some Open Questions For Future Work

- How many total bays exist?
- How were the bays were created? … novel speculation?
- What is the provenance of the 99% pure quartz rim sands?
- Do the orientations suggest a triangulation network focus?
- What drives the variations in species across the range of bays?

Applicability of Technique

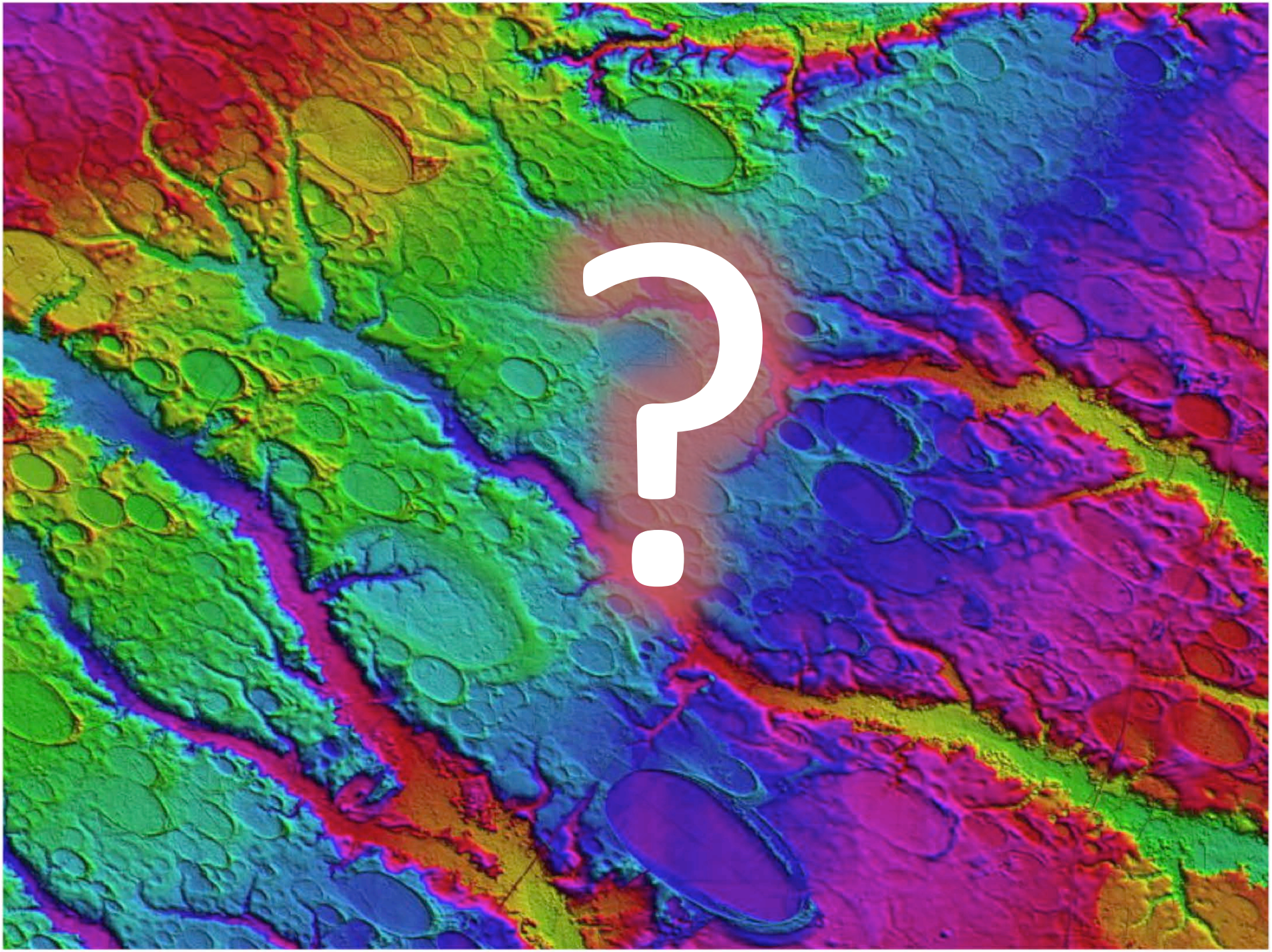
- Landforms which present archetypal planforms
- Landforms present in large range of scale
- Landforms resolvable at the surface using remote sensing

To Learn More

- ✓Google search: Carolina Bay Survey
- ✓Google search: Carolina bay of the day
- ✓Web site: http://CINTOS.ORG

Carolina Bay Survey Tools & Resources

- 1/9 Arc-second Elevation Data
  - USGS Seamless Server
  - NOAA Digital Coast
  - Nebraska DNR
  - College of William & Mary
- Global Mapper commercial GIS program
  - Generates hsv-shaded DEMs from bare earth LiDAR elevation data
  - Exported as Keyhole Markup language (KML) tiled data files
- Google Earth
  - Visualization
  - Google Earth loads Global Mapper Imagery & aligns on virtual globe
  - Tools to capture bay geospatial metrics
- Google Fusion Tables
  - Cloud Based Geospatial Repository
  - Statistical Data Analysis
  - Network Linked Data Provider



A Taxonomy for Carolina Bay Circumferential Rim Shapes

Findings of Robust Adherence to Several Distinctive Archetype Planforms Is Supported by LiDAR-derived Digital Elevation Maps

Aerial photographs of Carolina bays taken in the 1930's sparked the initial research into their geomorphology. High resolution Digital Elevation Maps (DEMs), using Light Detection And Ranging (LiDAR) remote sensing data, accentuate the visual presentation of these aligned ovoid shallow basins by elucidating their robust circumferential rims. To support a geospatial survey of Carolina bay landforms in the continental USA 400,000 km2 of hsv---shaded Digital Elevation Maps (DEM) have been generated with LiDAR---derived data. Here, the DEM generation process and subsequent integration as KML---JPEG tile sets into Google Earth for visualization is demonstrated. While the generic Carolina Bay planform is considered ovoid, the survey has documented a small number of subtle yet distinctive regional variations in Bay shape, which are documented here as six archetype planform templates and offered as taxonomy for Bay shape. The measurement protocol involves placing a matching template as a PNG image overlay onto the virtual globe, then sizing and rotating it so that it satisfactorily represents an individual Carolina bay's rim. The resulting overlay data element is extracted from Google Earth's object directory and programmatically processed to generate metrics such as geographic location, elevation, surface area, and major axis spatial orientation. Over 40,000 distinct Carolina bays have been measured using the methodology described, demonstrating their robust adherence to the taxonomy. The resulting data is resident in Google's Fusion geospatial data repository facility, through which these bay metrics are made publically accessible, both in tabular form and in situ on the Google Earth virtual globe. Preliminary findings from the survey are discussed, such as how the spatial orientation of the ovoid's major axis varies systematically by latitude and longitude across the USA. The availability of this detailed spatial dataset may assist in explaining the geomorphology of these enigmatic landforms. The processes demonstrated here may find applicability to geospatial analysis of other landforms on Earth and the planets. T91. Geological and Geomorphological Applications of Digital Terrain Analysis Disciplines: Geoinformatics; Remote Sensing/Geographic Info System; Geomorphology Advocates: Carlos Henrique Grohmann; Christopher J. Crosby Digital terrain data provide insight into Earth's topography, allowing quantification of processes and spatial relationship of features. We welcome contributions highlighting advances in methods, algorithms, and applications of digital terrain analysis to geology and geomorphology.