Airborne Lidar Applications Overview

Presented by John Brock

“Nuts and Bolts”

FIRST, A FEW DEFINITIONS …

Lidar:

- "*Li*ght *d*etection *a*nd *r*anging"
- Laser-based radar
- A beam of laser light is used to
- measure distance

USGS

Lidars mounted on aircraft scan the distance to the ground

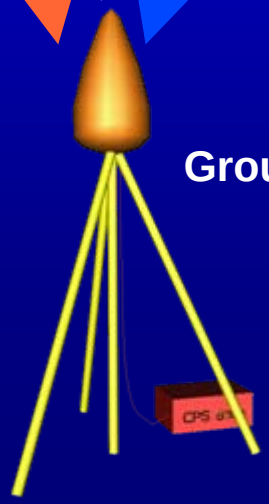
These distance measurements are transfomed to measurements of the elevations or “shape” of the ground

Mobile GPS Receiver

- Kinematic differential GPS aircraft positioning.
- Uses the difference in the dual frequency (L1, L2) carrier phase-derived ranges for the BS and aircraft.
- Provides aircraft position at submeter accuracy.

Typical Airborne DGPS Relative Positioning Errors:

Error Source	Error for 50 Km Baseline (m)
Orbital	0.05
Ionospheric	0.05 – 0.50
Tropospheric	0.10
Signal Multipath	0.05
Receiver Noise	<0.025
Total Error	**0.1 – 0.5** (Maune, 2001)



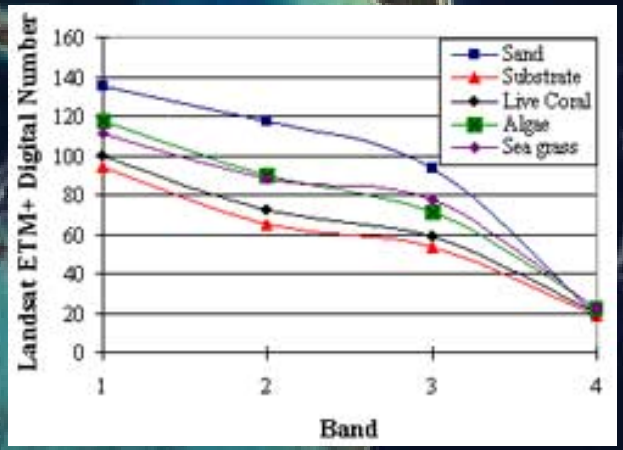
GPS
Ground Station

Spectral (Color) Imaging:

Panchromatic: captures just a single b+w band

Multispectral: captures > 2 color bands simultaneously

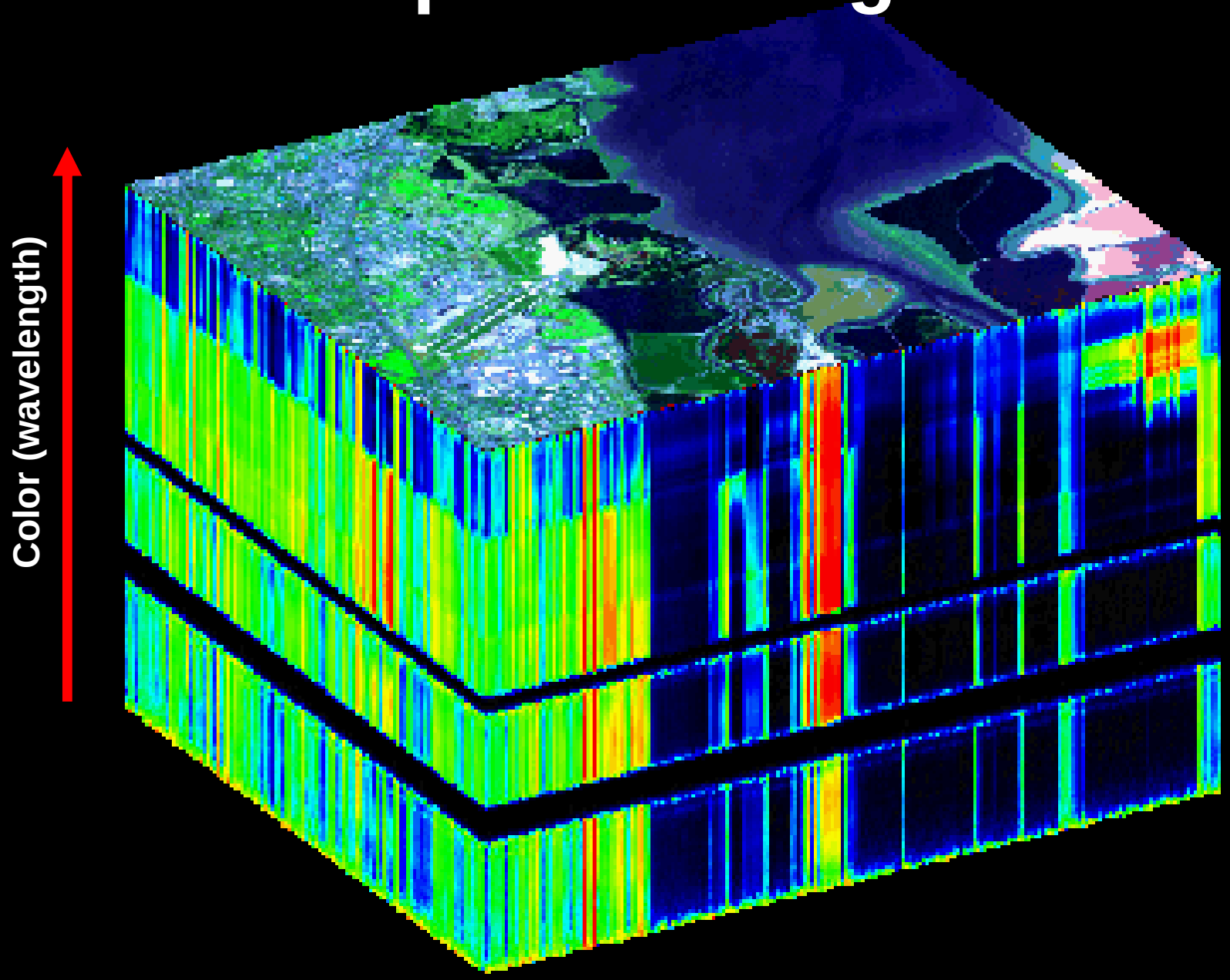
Hyperspectral: captures many color bands



USGS

Space Imaging

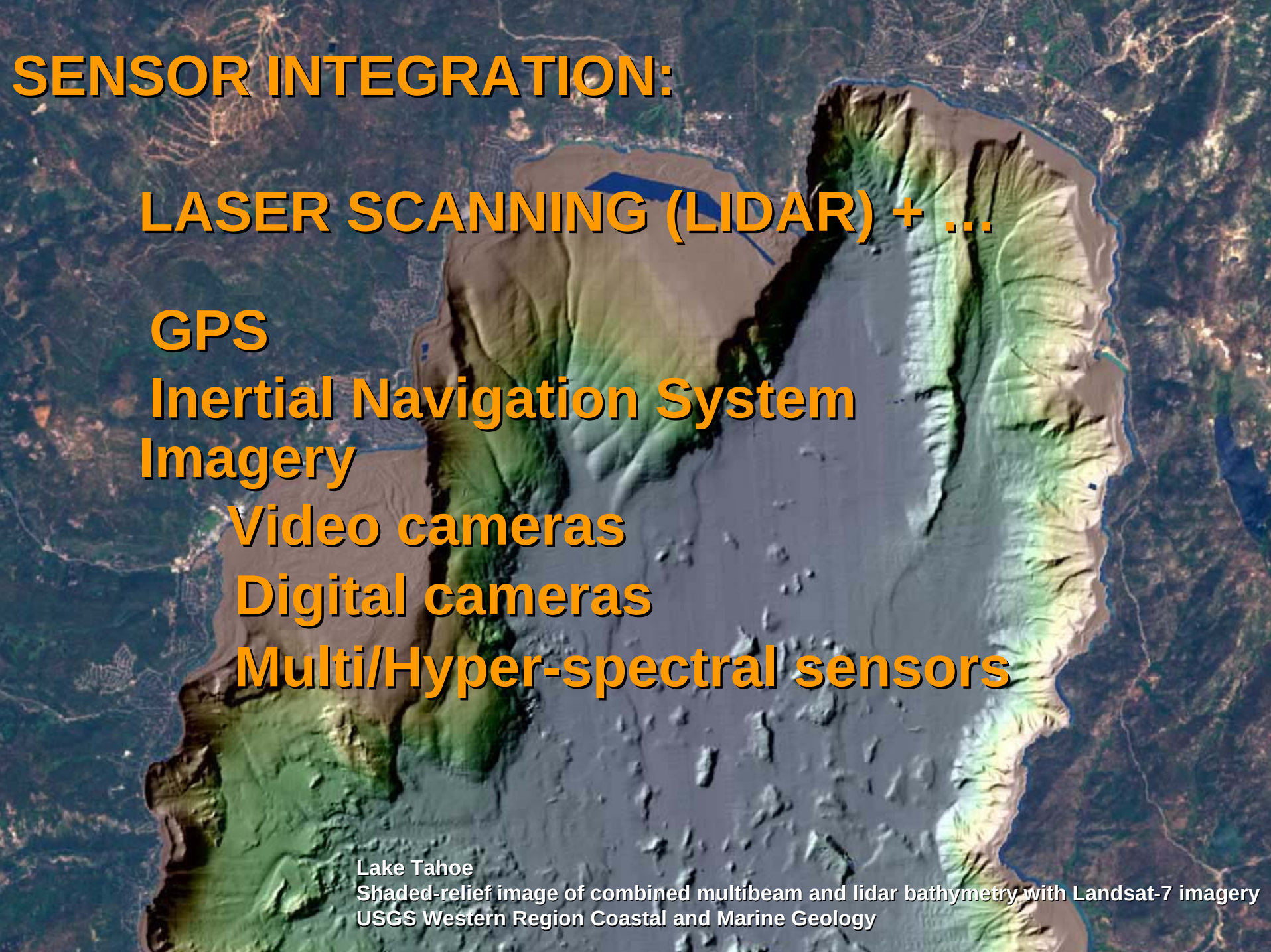
“The Spectral Image Cube”



SENSOR INTEGRATION:

LASER SCANNING (LIDAR) + ...

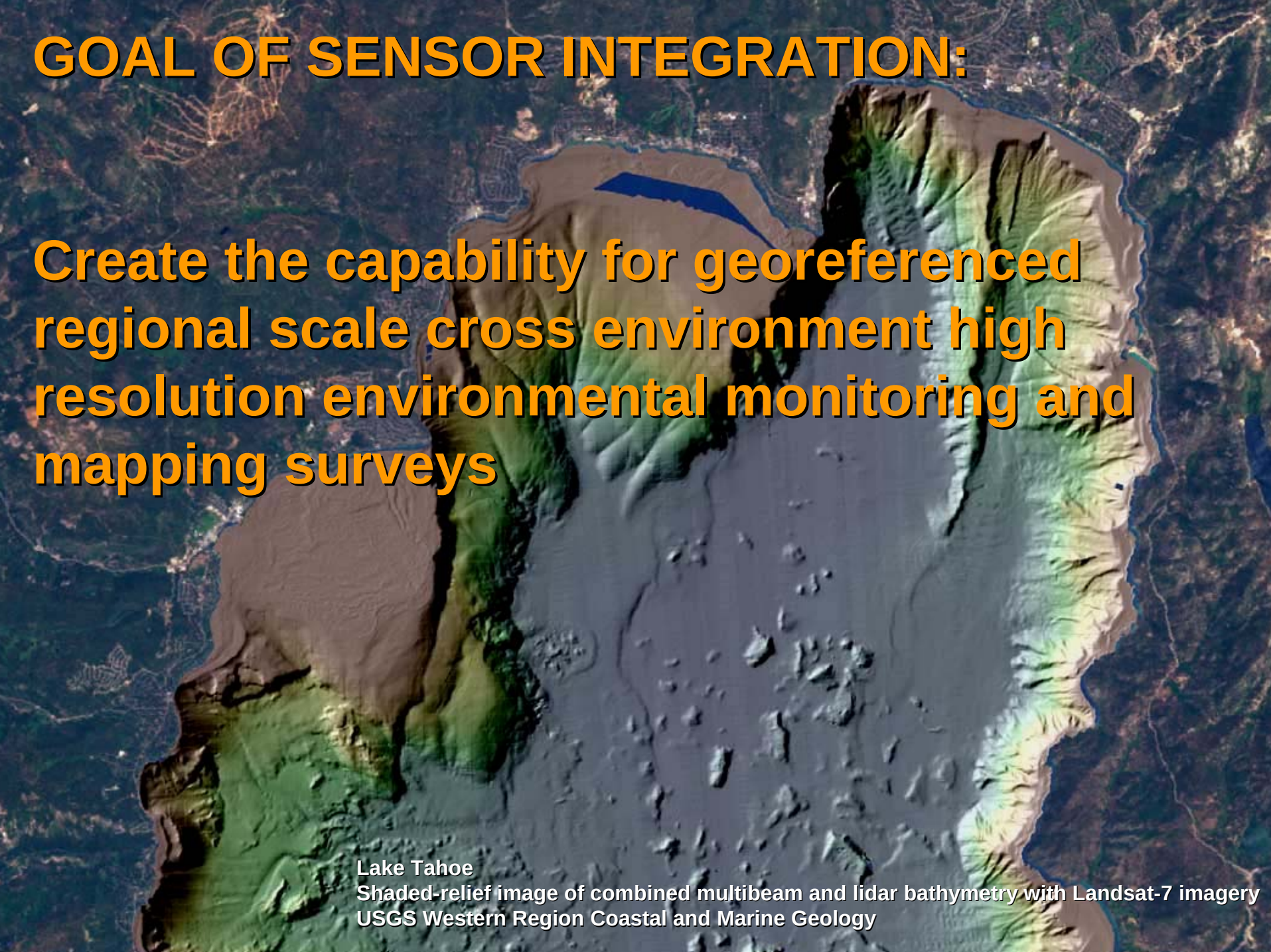
- GPS
- Inertial Navigation System
- Imagery
  - Video cameras
  - Digital cameras
  - Multi/Hyper-spectral sensors



Lake Tahoe
Shaded-relief image of combined multibeam and lidar bathymetry with Landsat-7 imagery
USGS Western Region Coastal and Marine Geology

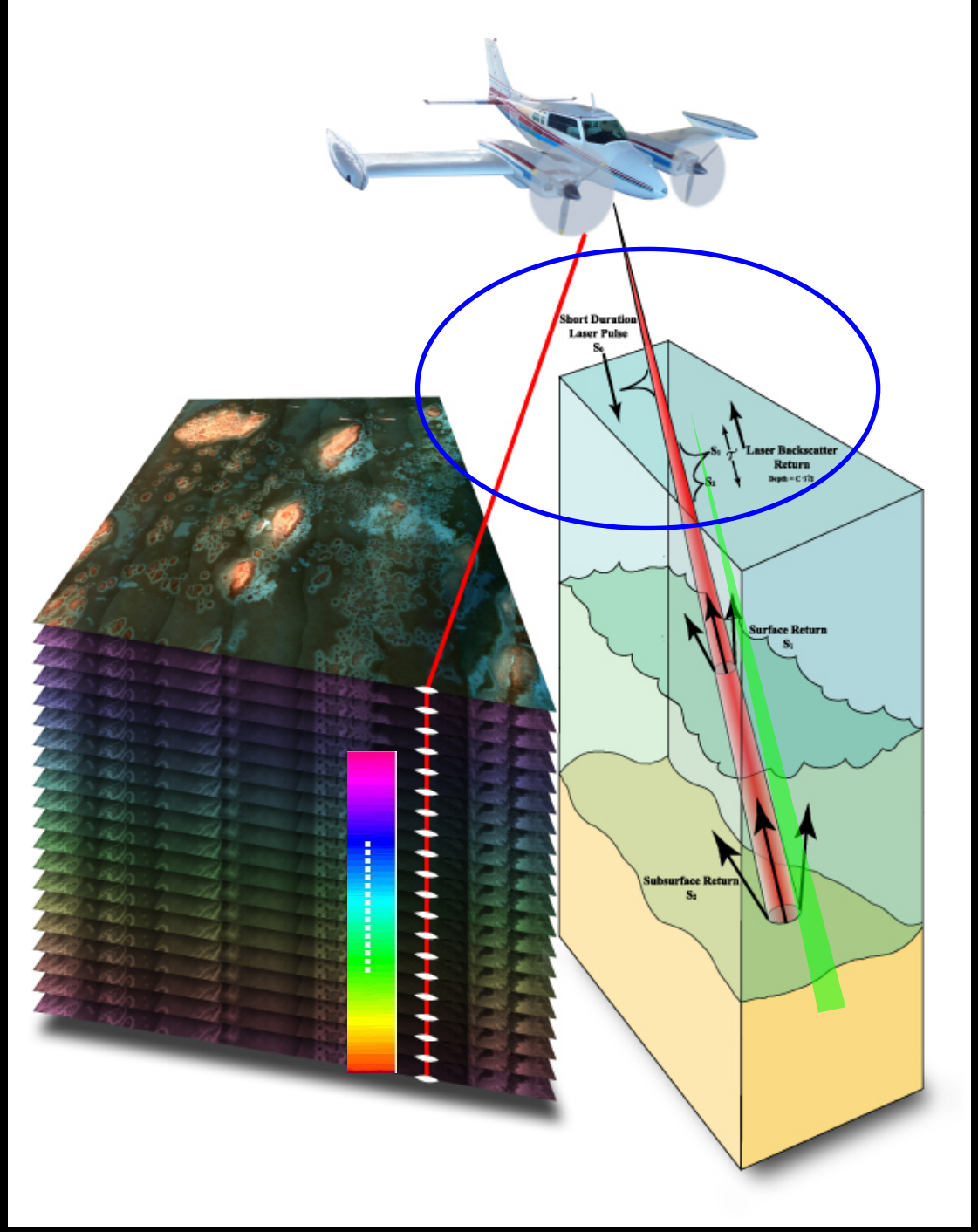
GOAL OF SENSOR INTEGRATION:

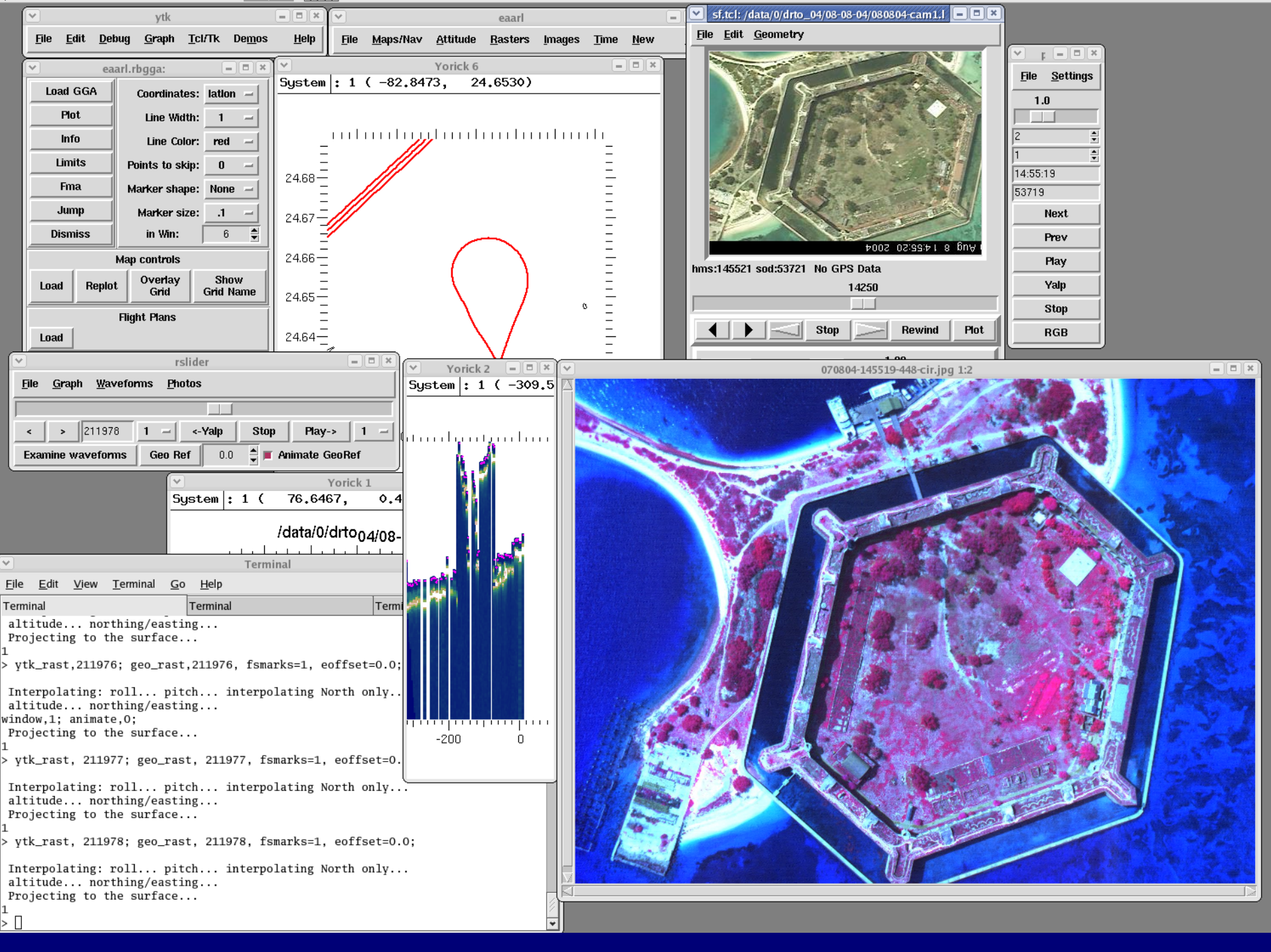
Create the capability for georeferenced regional scale cross environment high resolution environmental monitoring and mapping surveys



Lake Tahoe
Shaded-relief image of combined multibeam and lidar bathymetry with Landsat-7 imagery
USGS Western Region Coastal and Marine Geology

Airborne lidar scanning and be integrated with multi- or hyperspectral scanning

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Flight Plans
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Terminal
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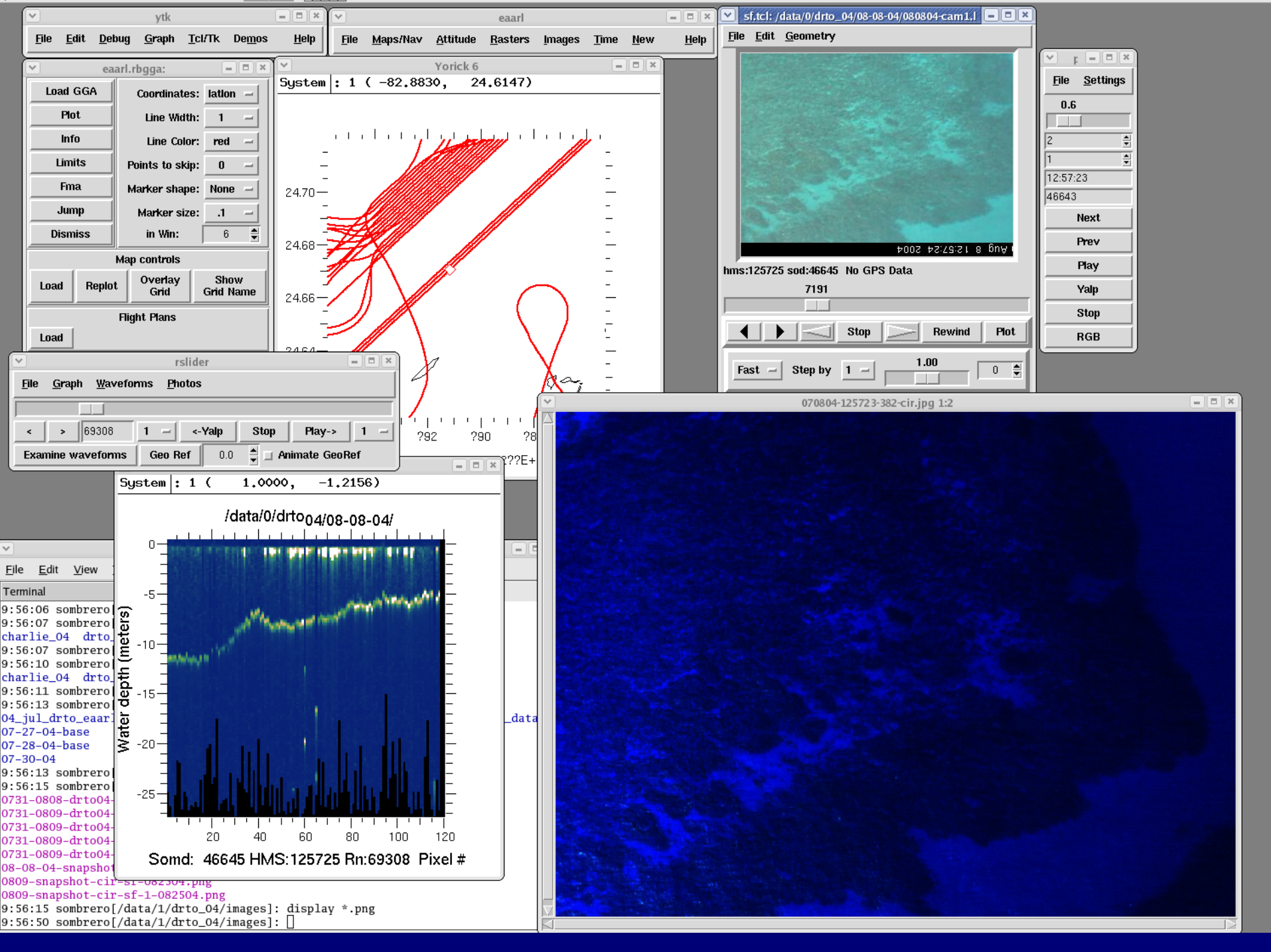
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Coordinates: latlon
Line Width: 1
Line Color: red
Points to skip: 0
Marker shape: None
Marker size: .1
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Map controls
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Replot
Overlay Grid
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Flight Plans
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Water depth (meters)
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File Edit View
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9:56:10 sombrero
charlie_04 drto
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07-27-04-base
07-28-04-base
07-30-04
9:56:13 sombrero
9:56:15 sombrero
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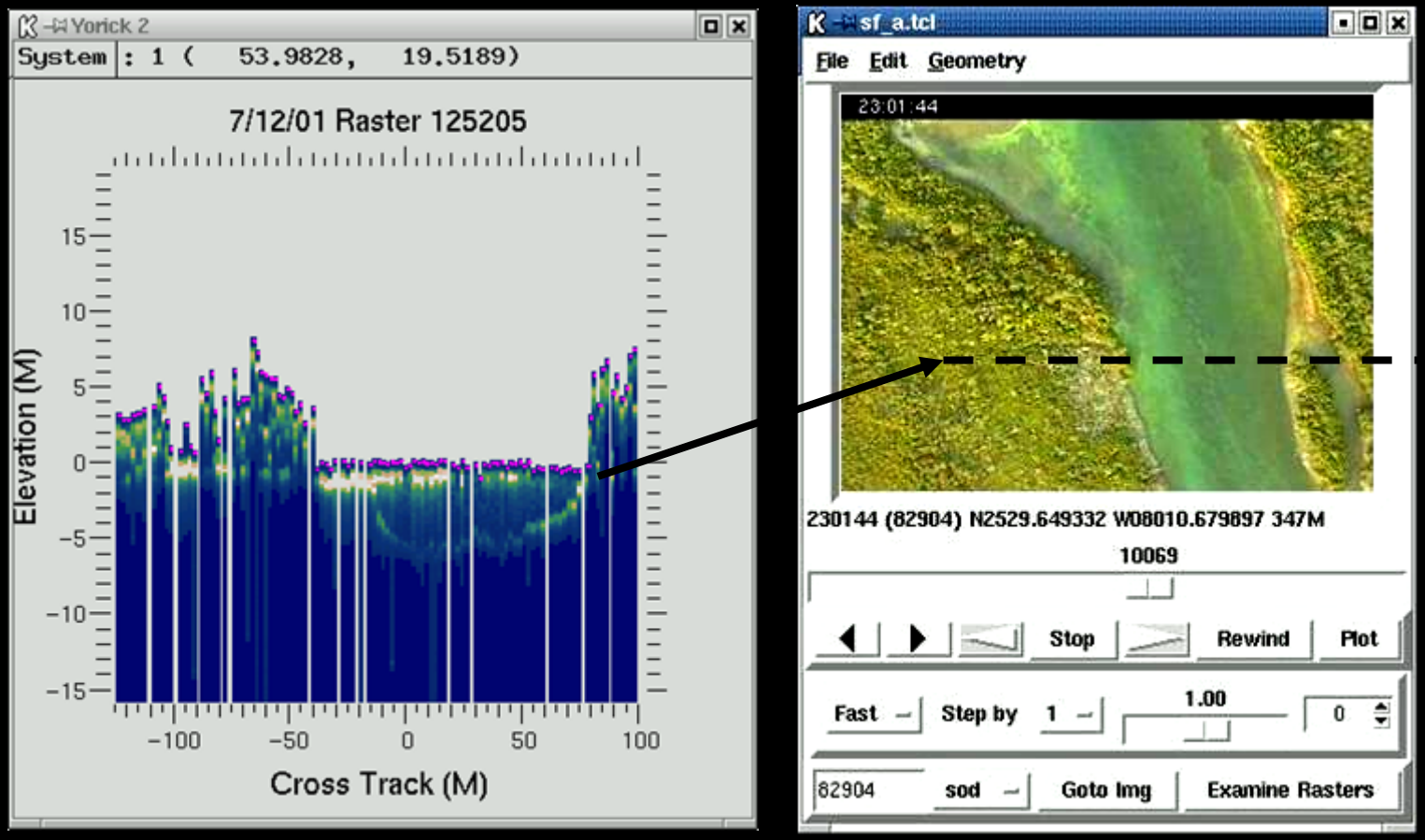
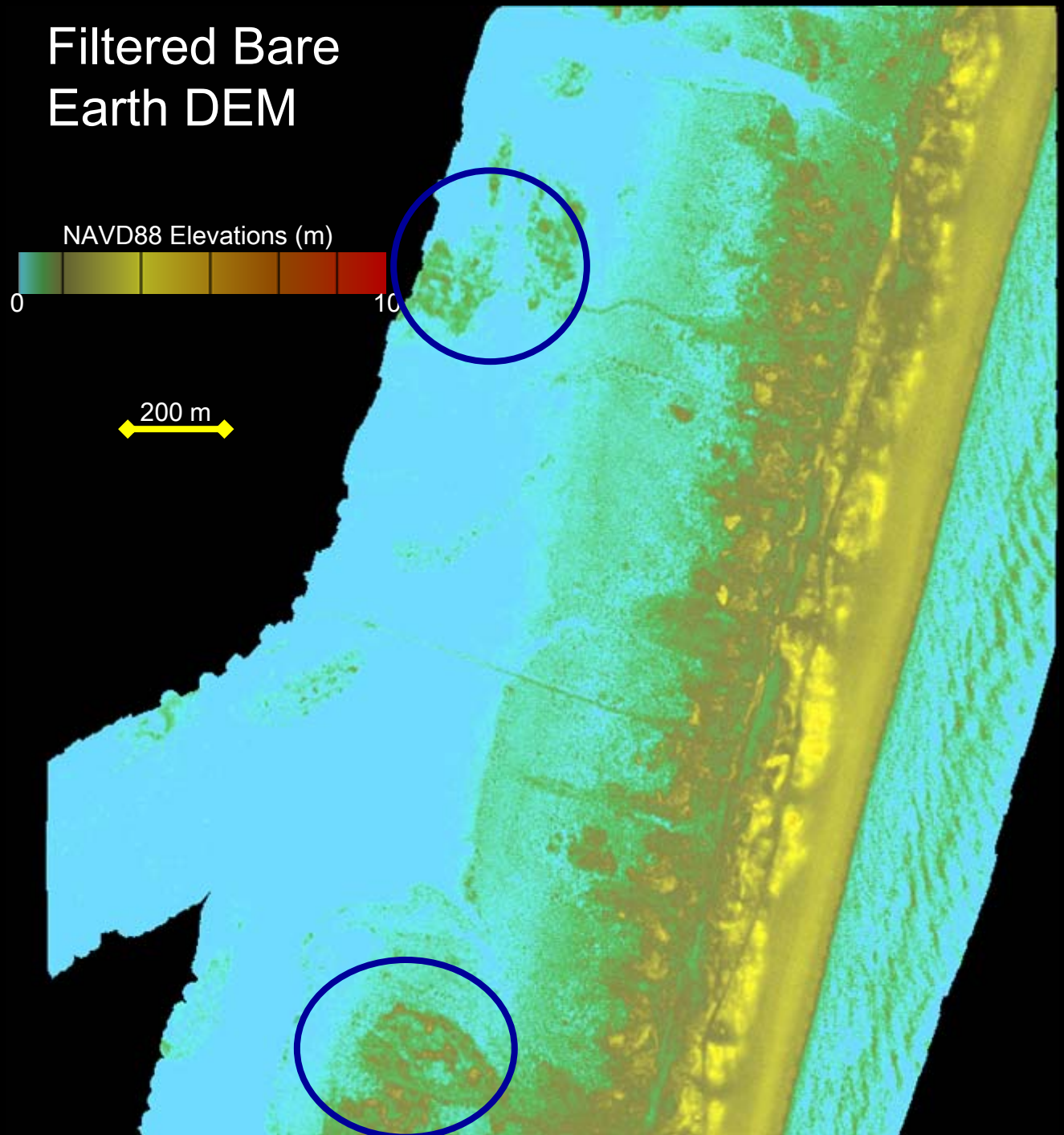
Cross Environment Coastal Lidar Surveying:



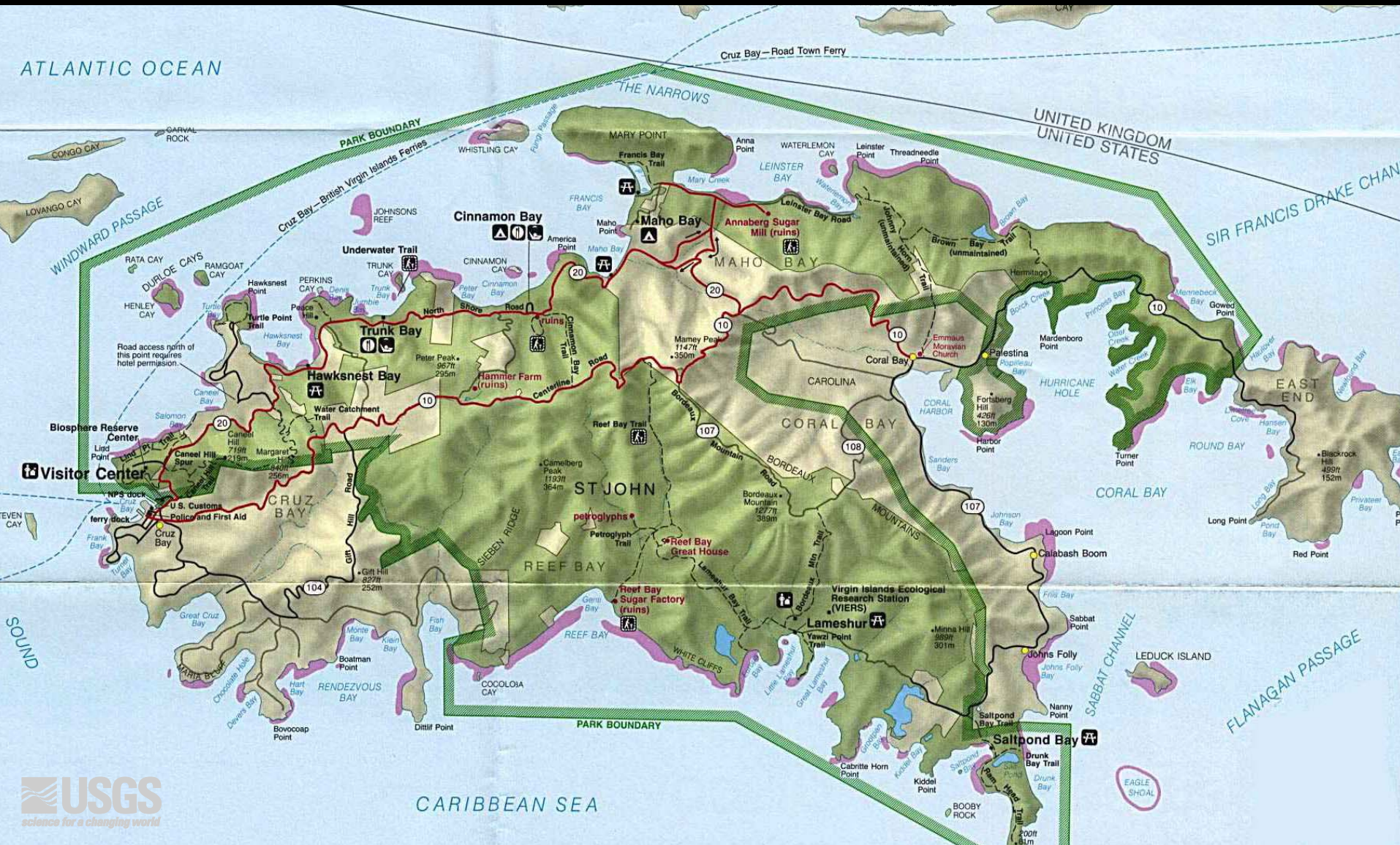
EAARL Raster, Sand Cut, Florida Keys

Filtered Bare Earth DEM

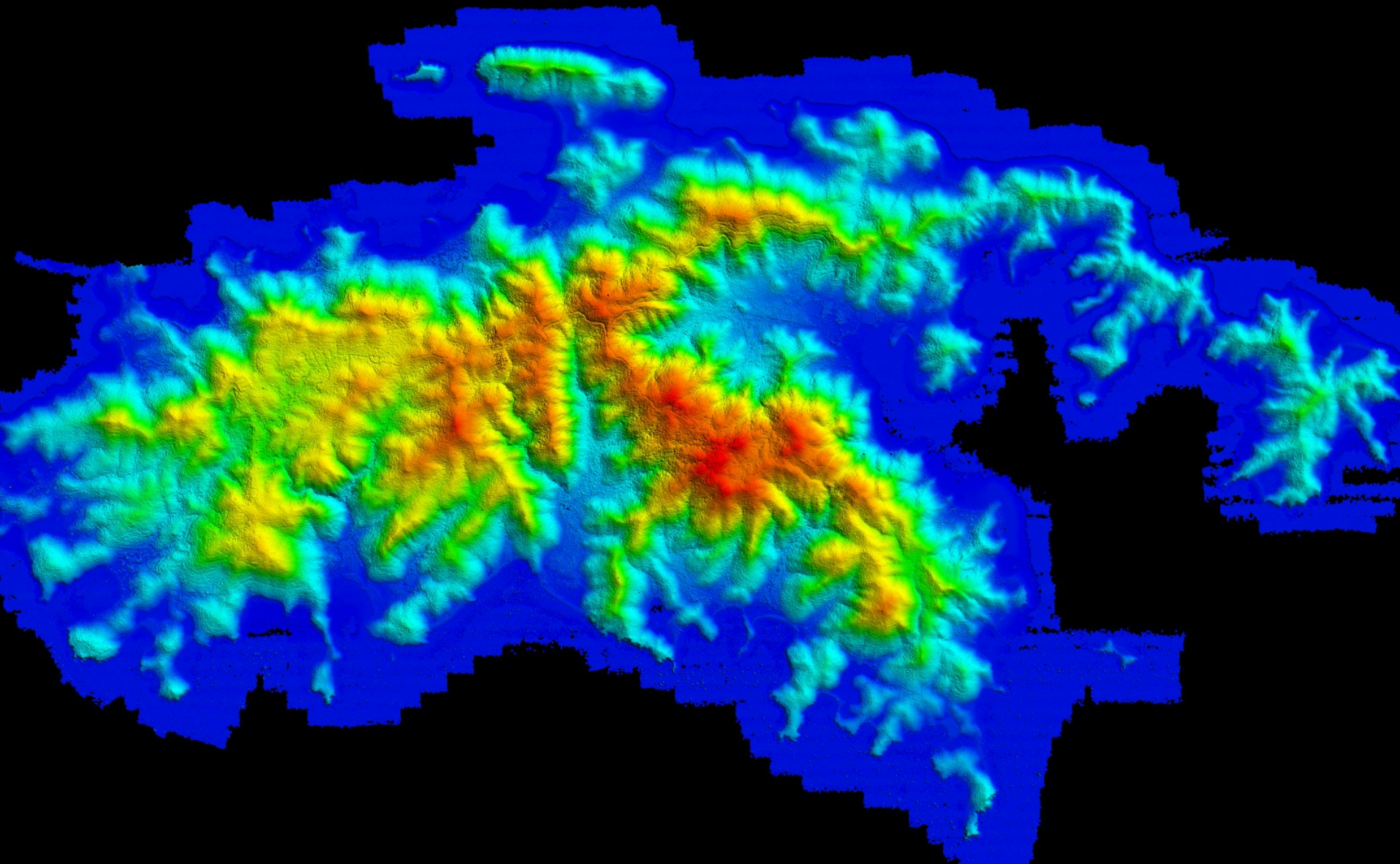


Lidar Applications

BASELINE TOPOGRAPHIC MAPPING
Results for St. John, USVI

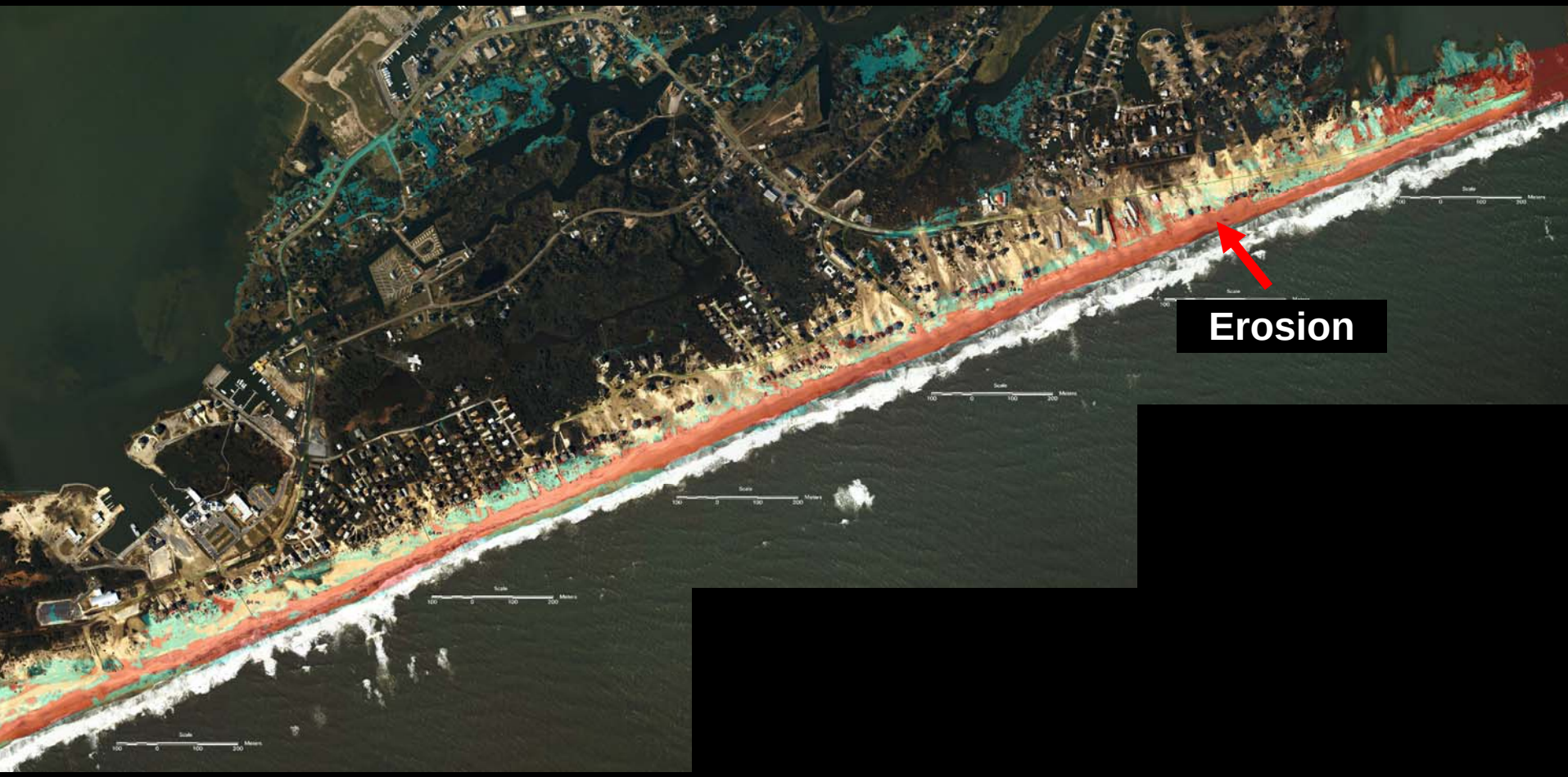


Digital Elevation Model for St. John, USVI



Long Term Coastal Erosion

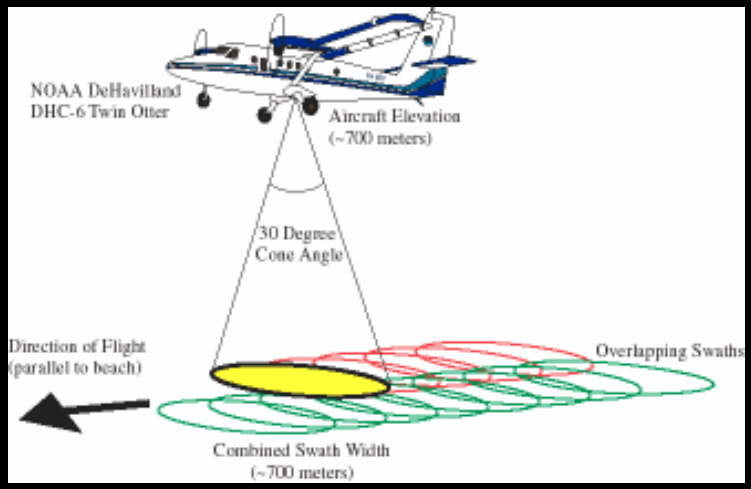
Changes in Beaches and Dunes

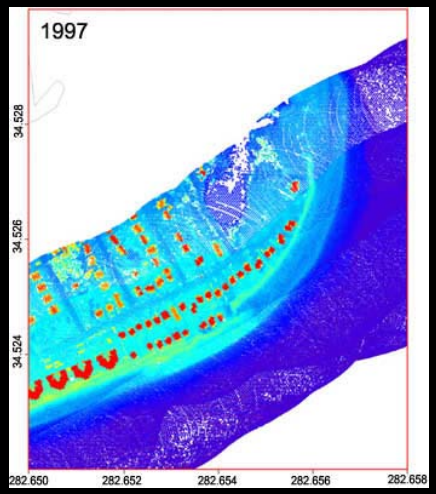


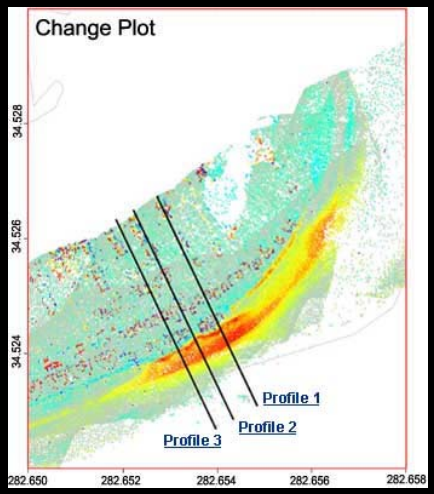
A. Sallenger

STORM IMPACTS
Hurricane Bonnie, August 1998

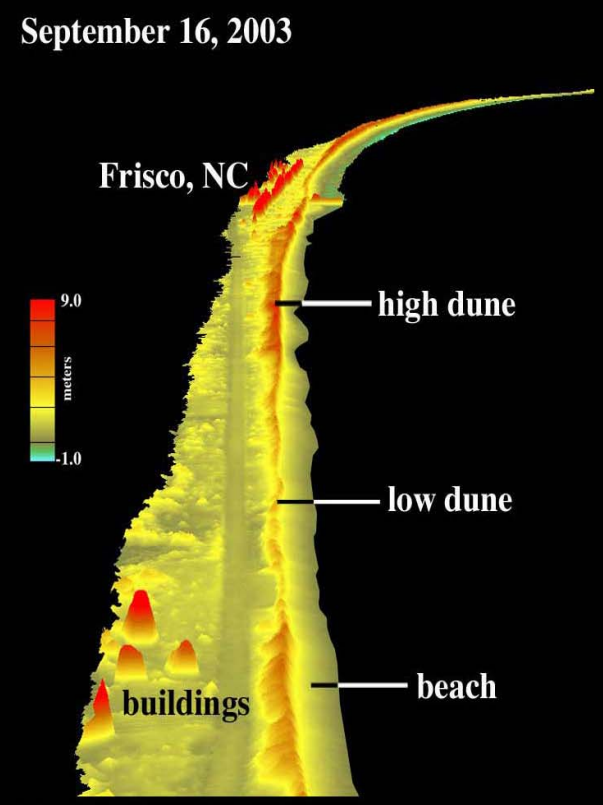
A. Sallenger







STORM IMPACTS
Hurricane Isabel, September, 2003



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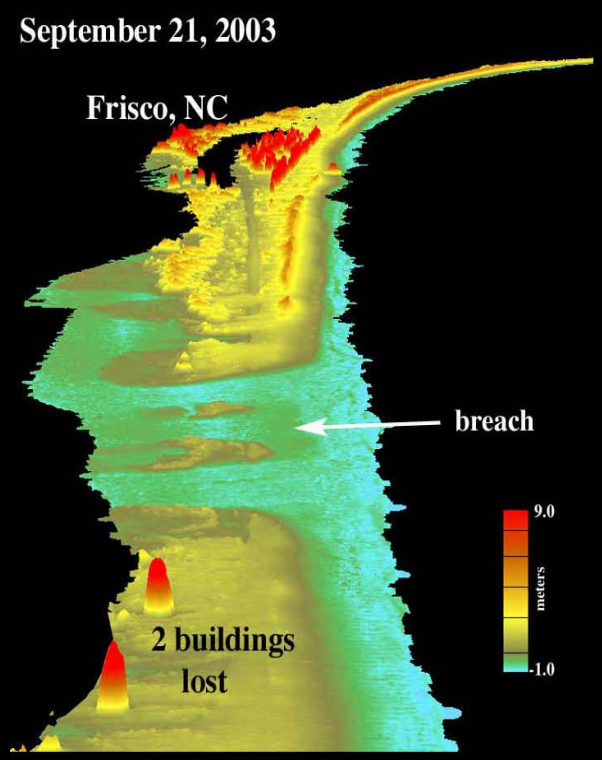
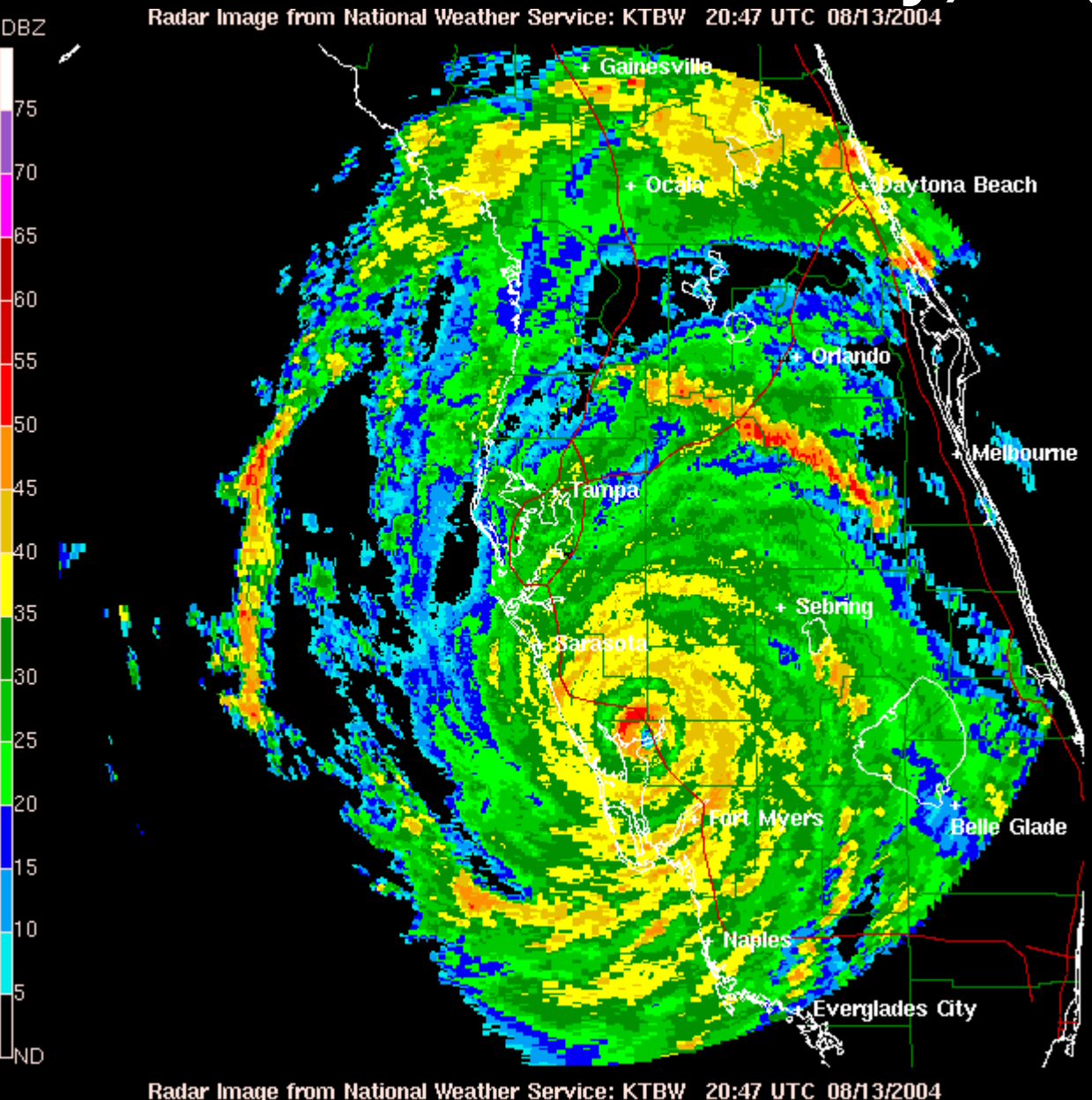
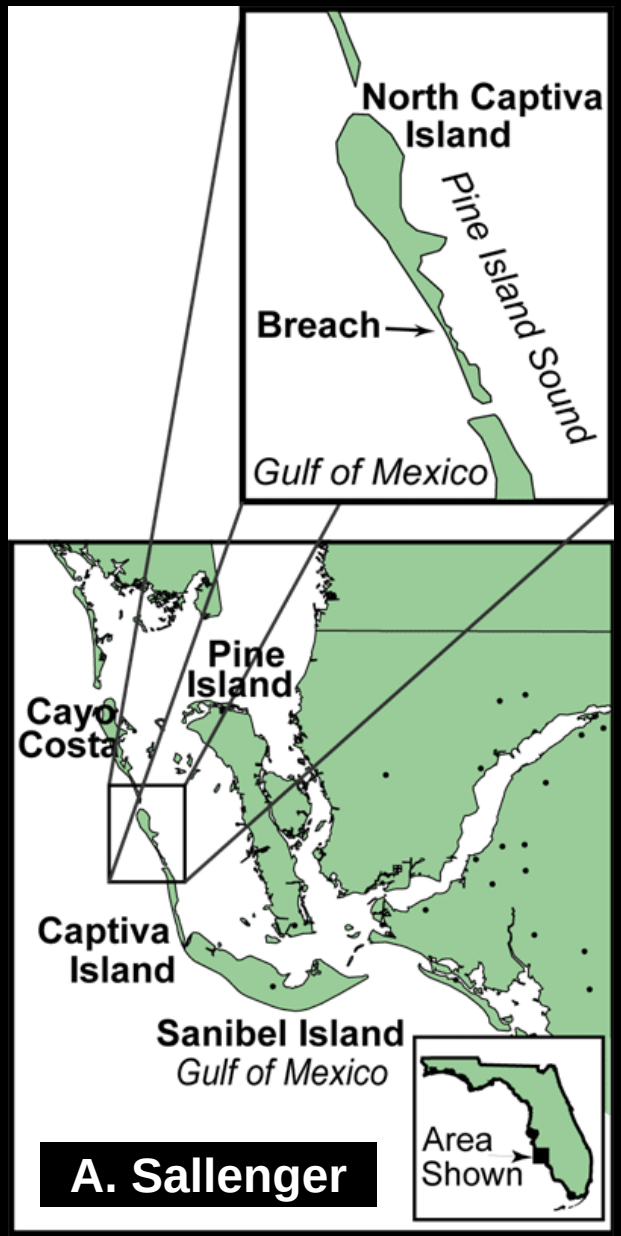


AFTER

A. Sallenger

STORM IMPACTS
Hurricane Charley, August, 2004

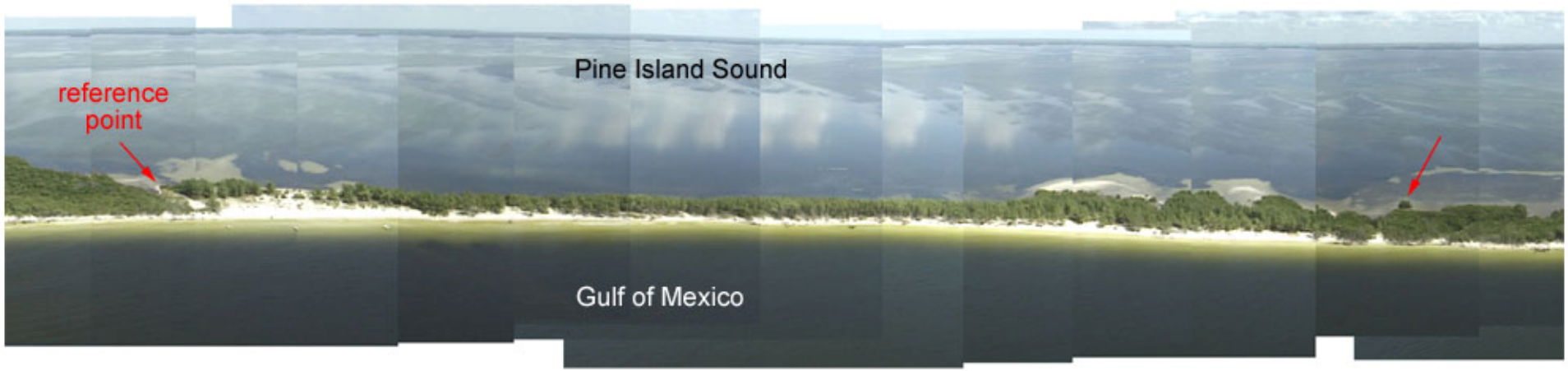




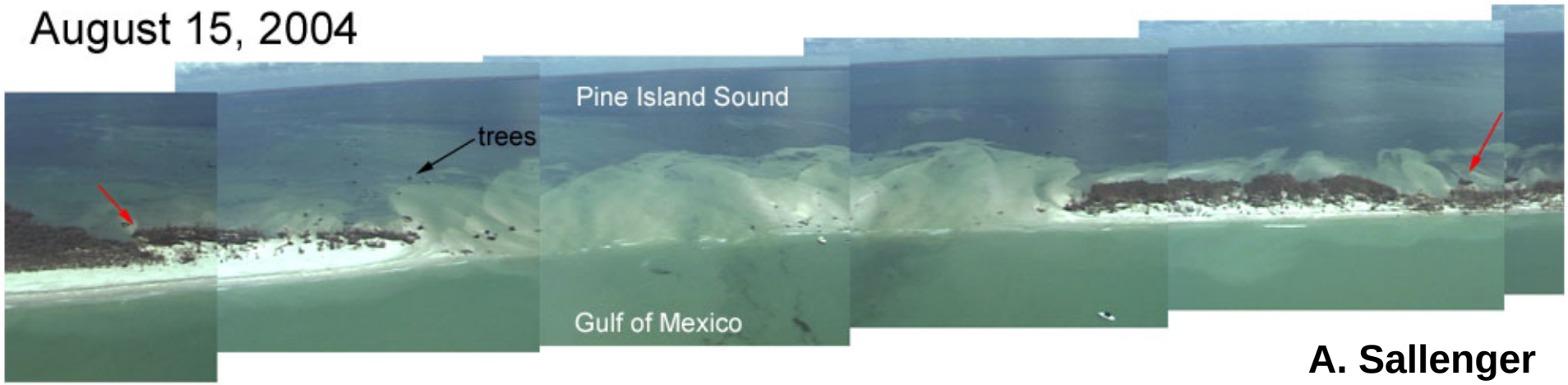
A. Sallenger

STORM IMPACTS
Hurricane Charley, August, 2004

North Captiva Island, FL
September 29, 1999

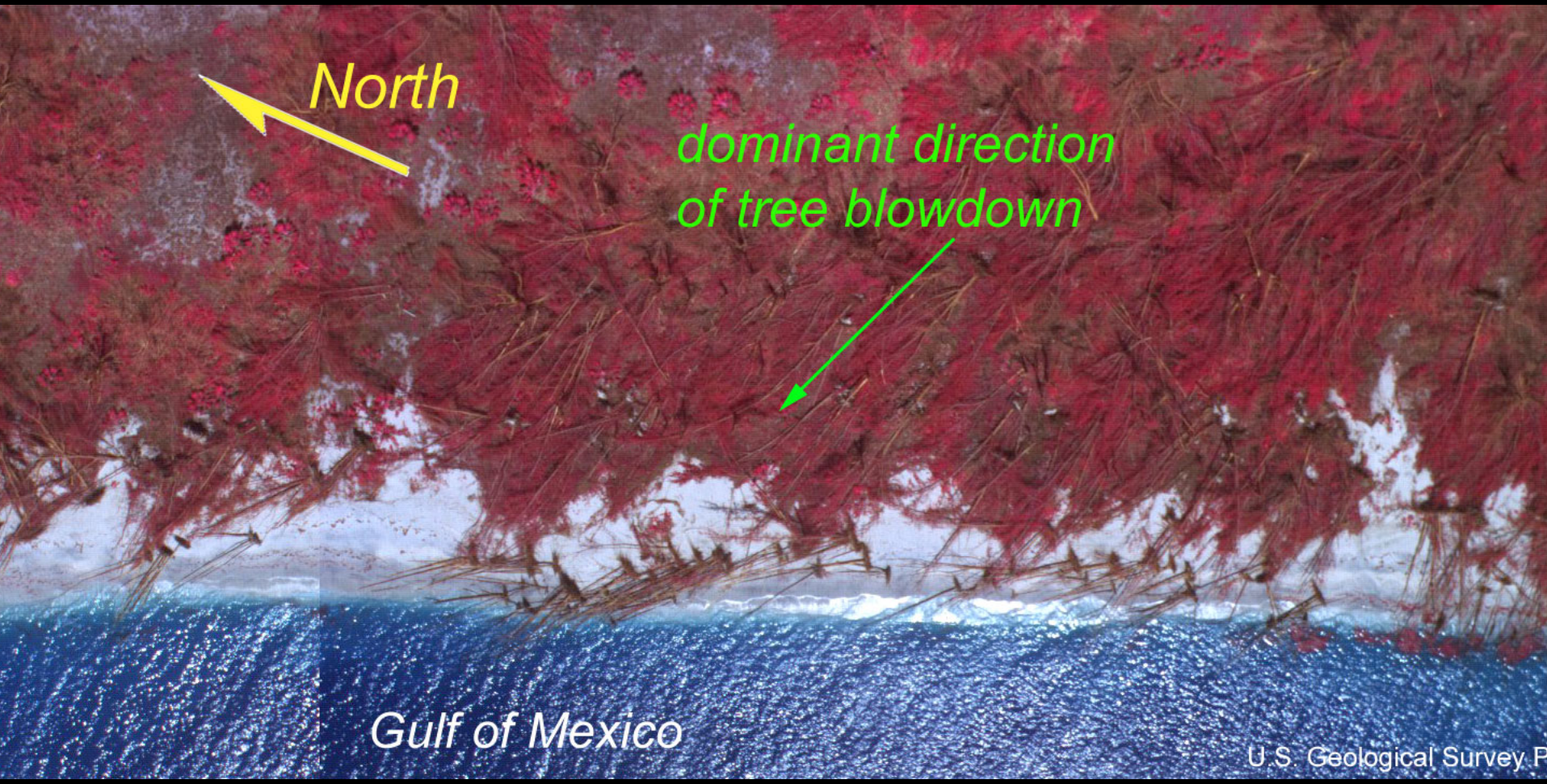


August 15, 2004



A. Sallenger

Color Infrared Image Acquired by NASA EAARL on August 17, 2004



USGS

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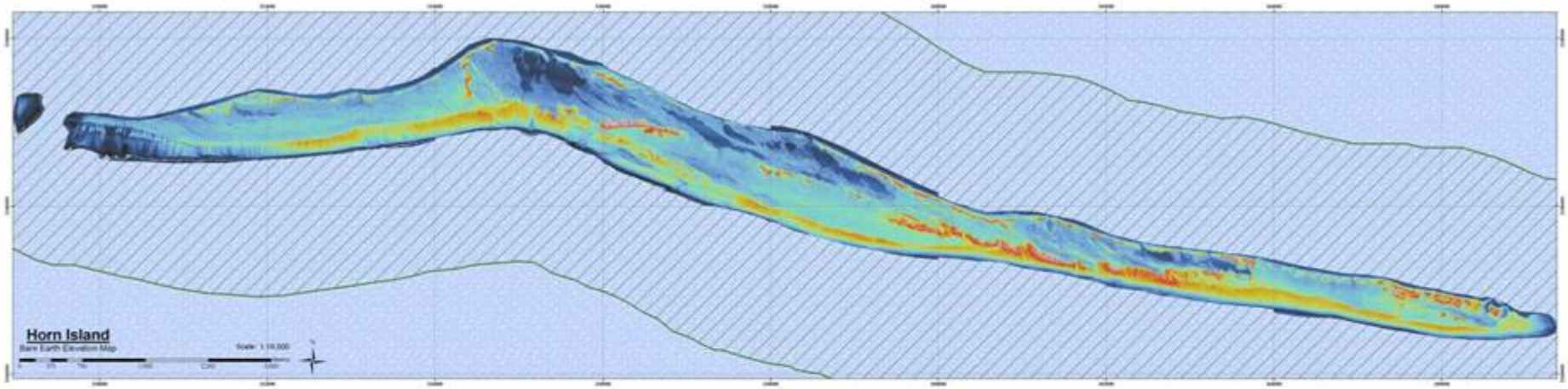
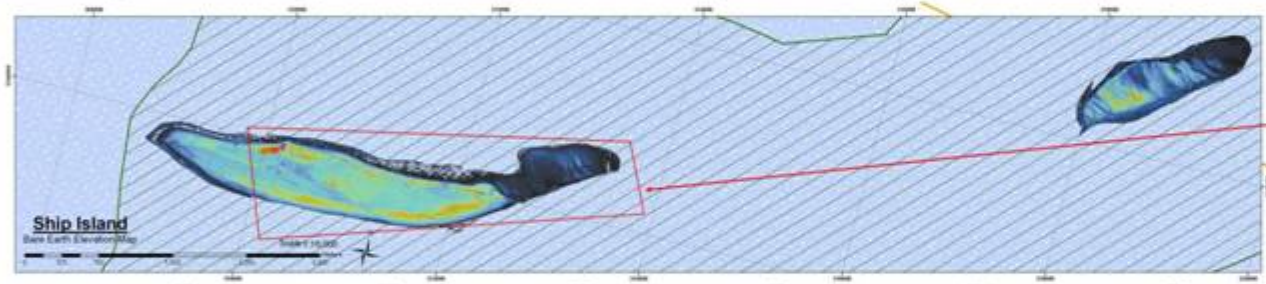
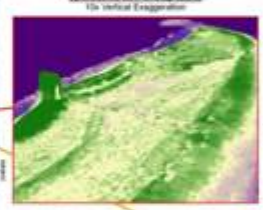
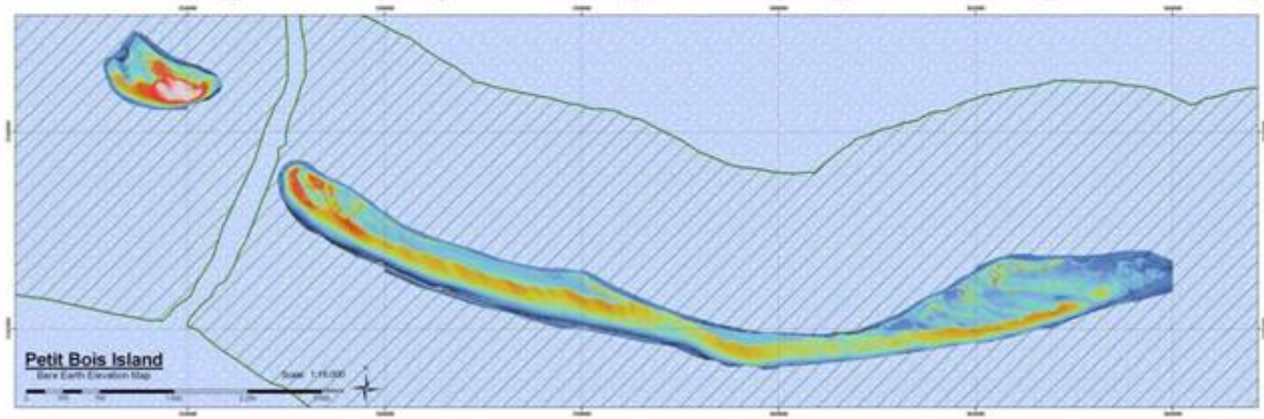
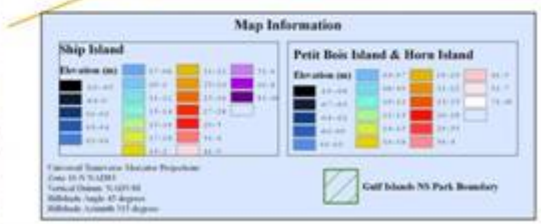
Gulf Islands NS - 2005 EAARL LiDAR Survey - Post Hurricane Katrina









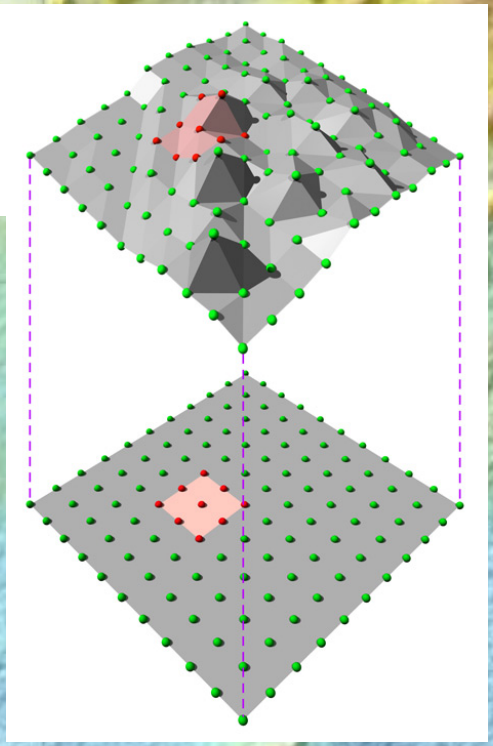


CORAL REEF APPLICATIONS

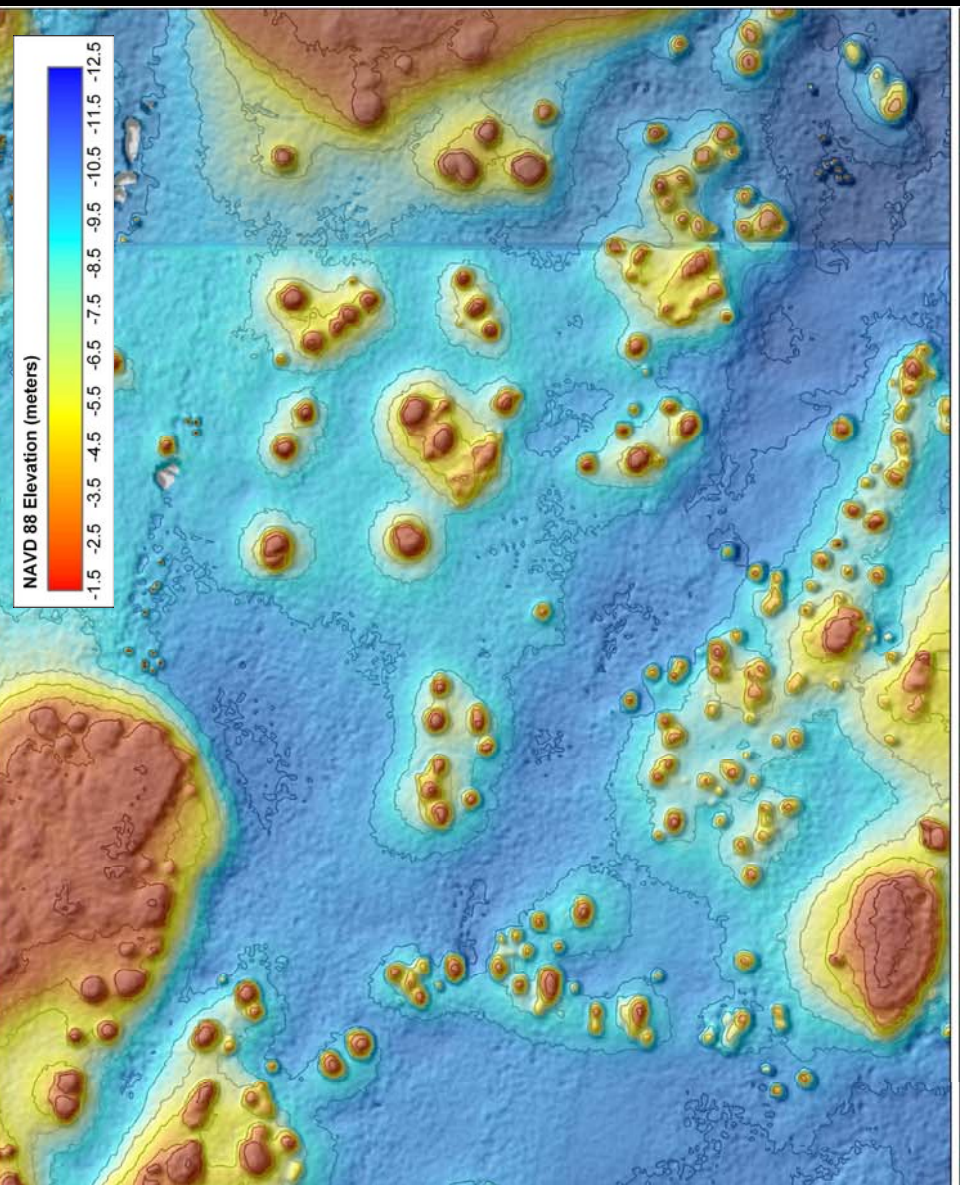
Image courtesy of NASA

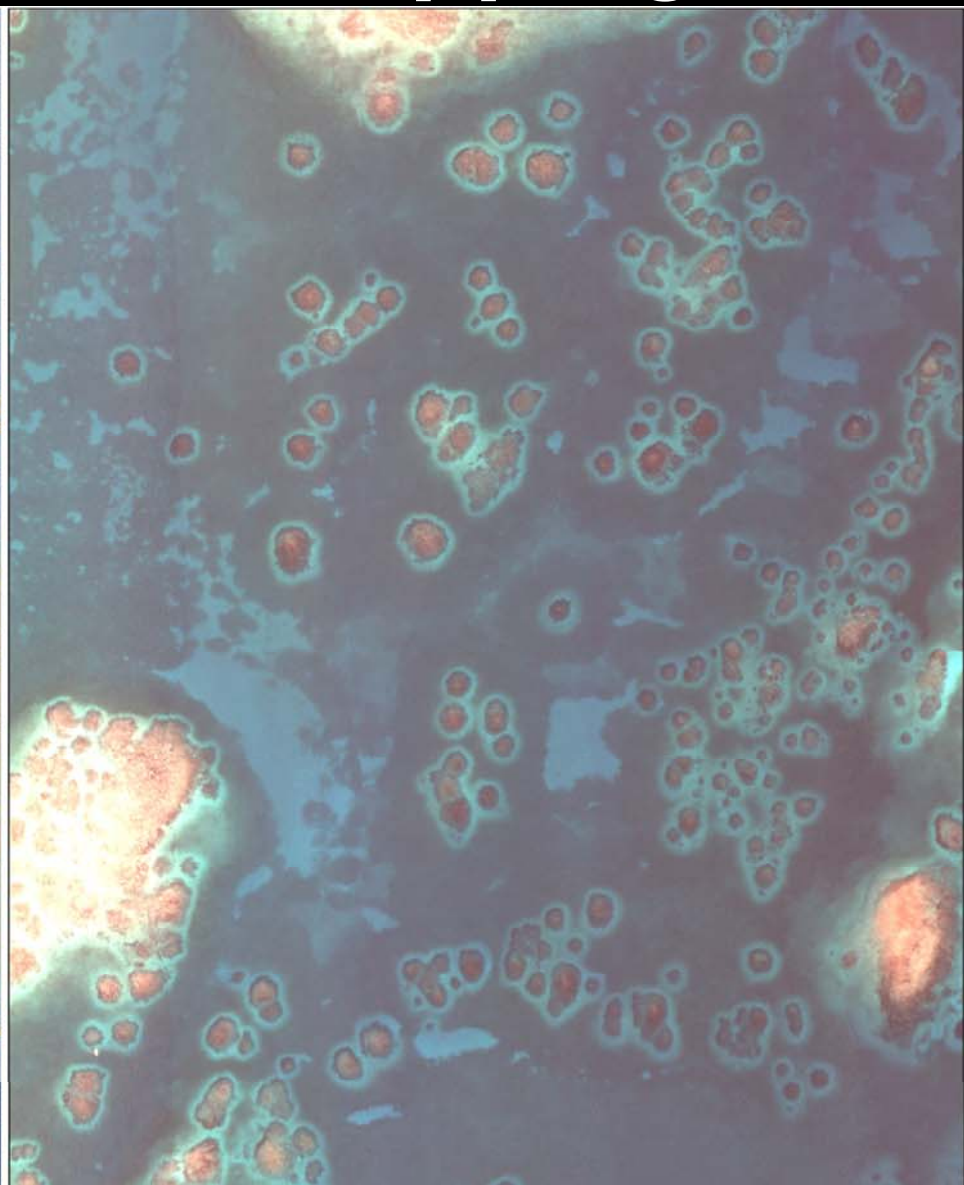
Reef Topography from Aircraft Lidar

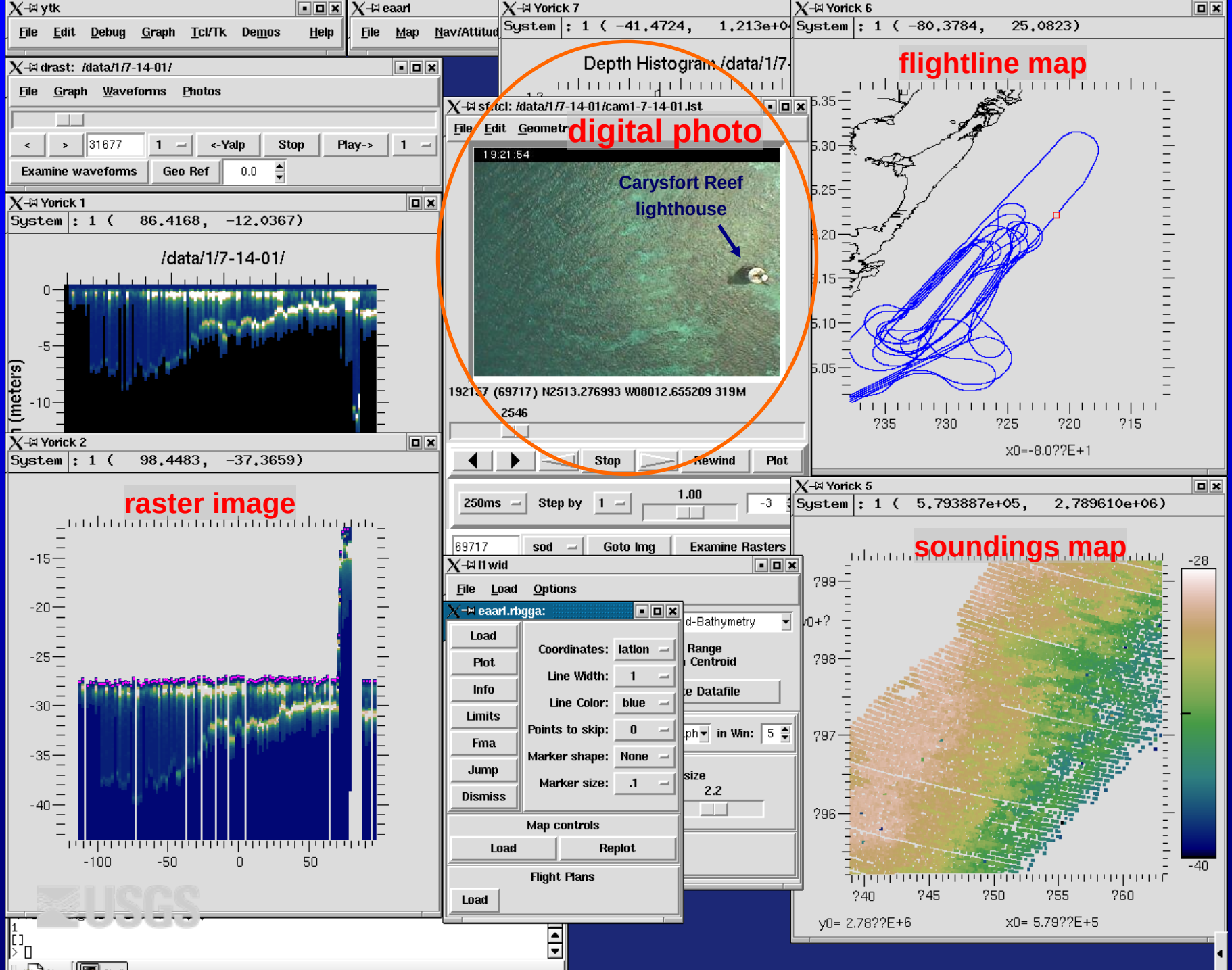
Creation of synoptic topographic complexity (rugosity) maps based on airborne lidar surveys



CORAL REEFS
3D Benthic Habitat Mapping



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File Edit Debug Graph Tcl/Tk Demos Help
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System : 1 (-80.3784, 25.0823)
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Line Color: blue
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Marker shape: None
Marker size: .1
Map controls
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Replot
Flight Plans
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d-Bathymetry
Range
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in Win: 5
size
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Yorick 5
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-28
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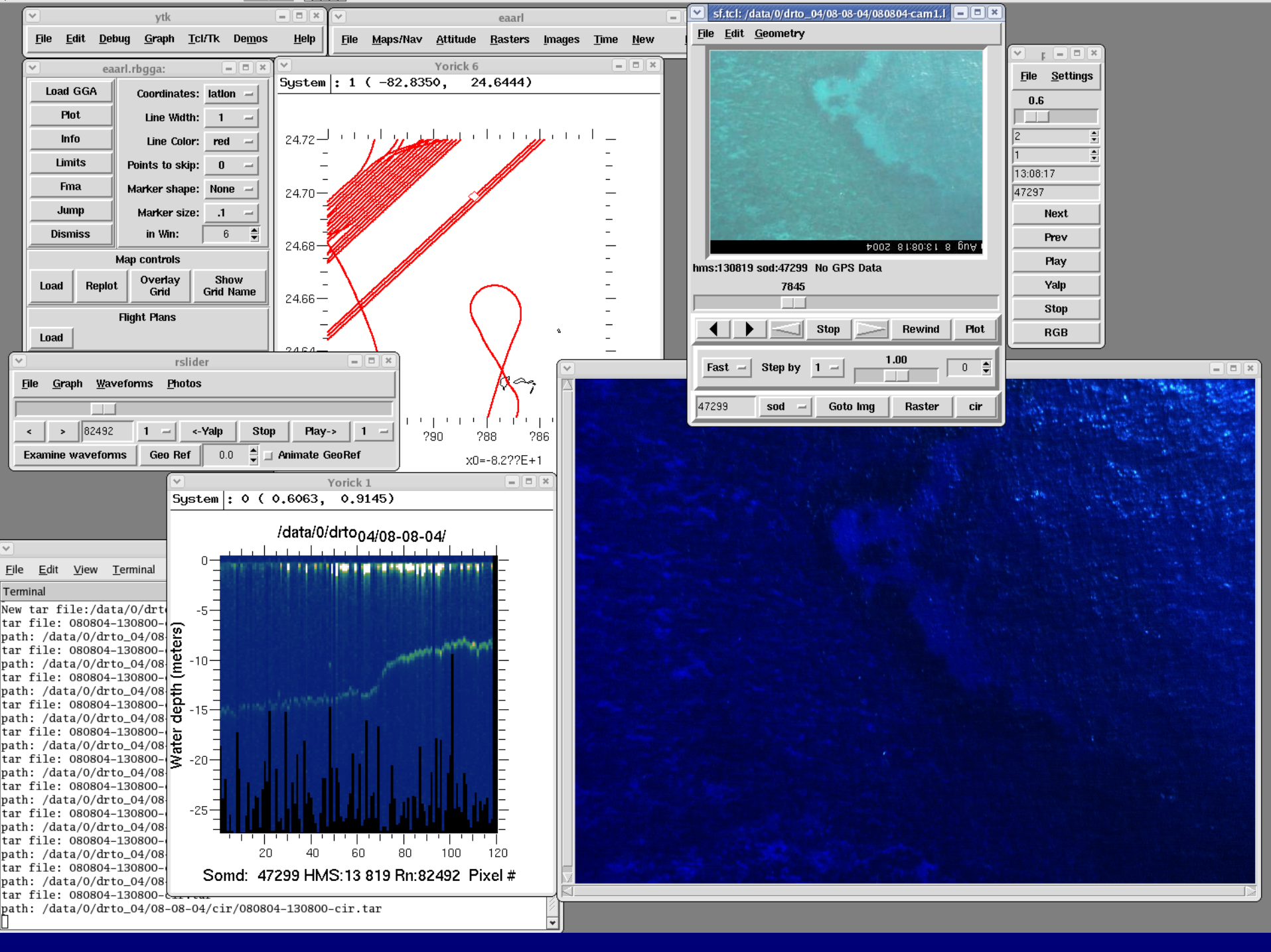
x0= 5.79??E+5
USGS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Yorick 6
System : 1 (-82.8350, 24.6444)
24.72
24.70
24.68
24.66
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x0=-8.2??E+1
rslider
File Graph Waveforms Photos
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Examine waveforms
Geo Ref
0.0
Animate GeoRef
Yorick 1
System : 0 (0.6063, 0.9145)
/data/0/drto04/08-08-04/
Water depth (meters)
0
-5
-10
-15
-20
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File Edit View Terminal
Terminal
New tar file:/data/0/drt
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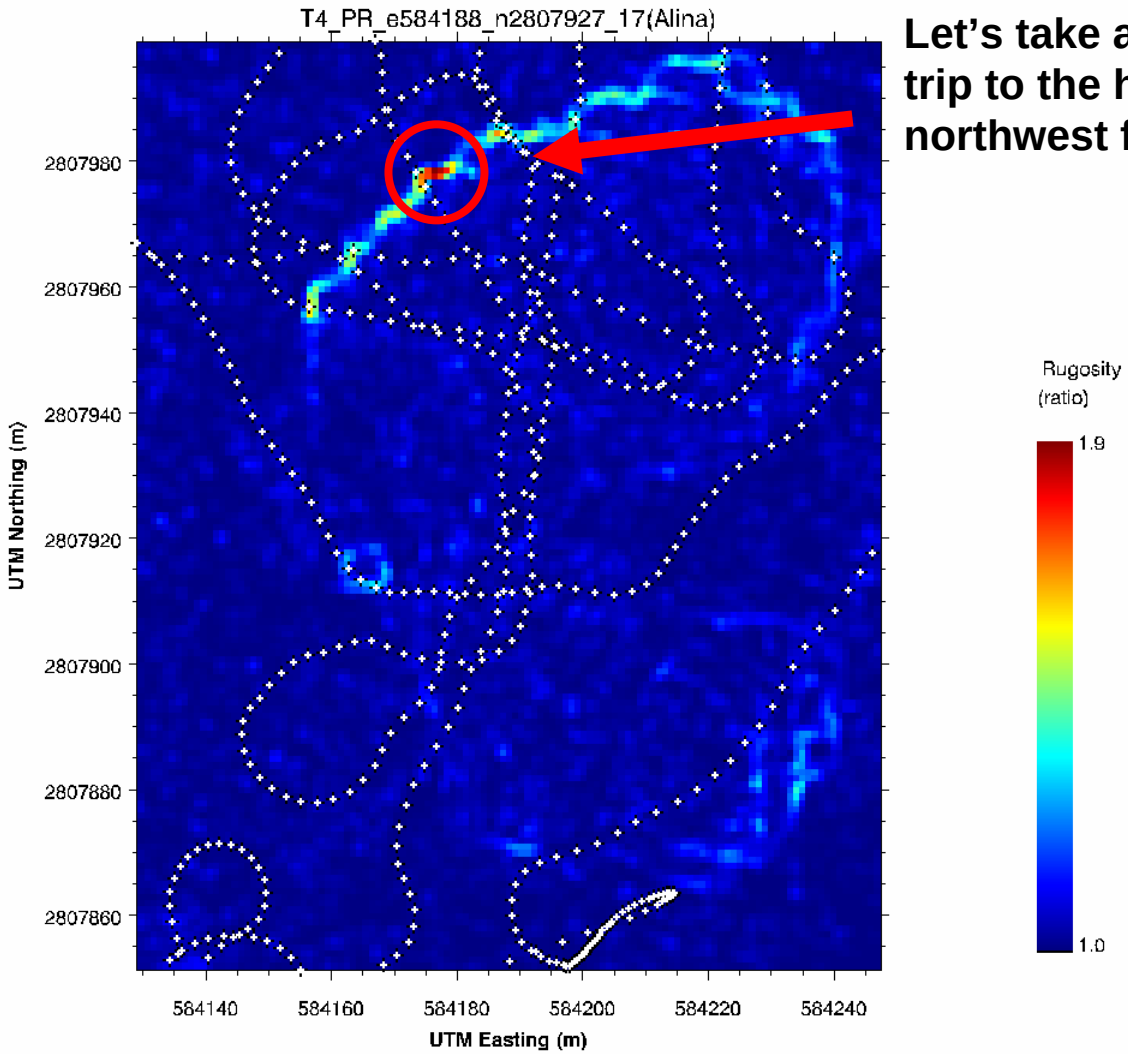
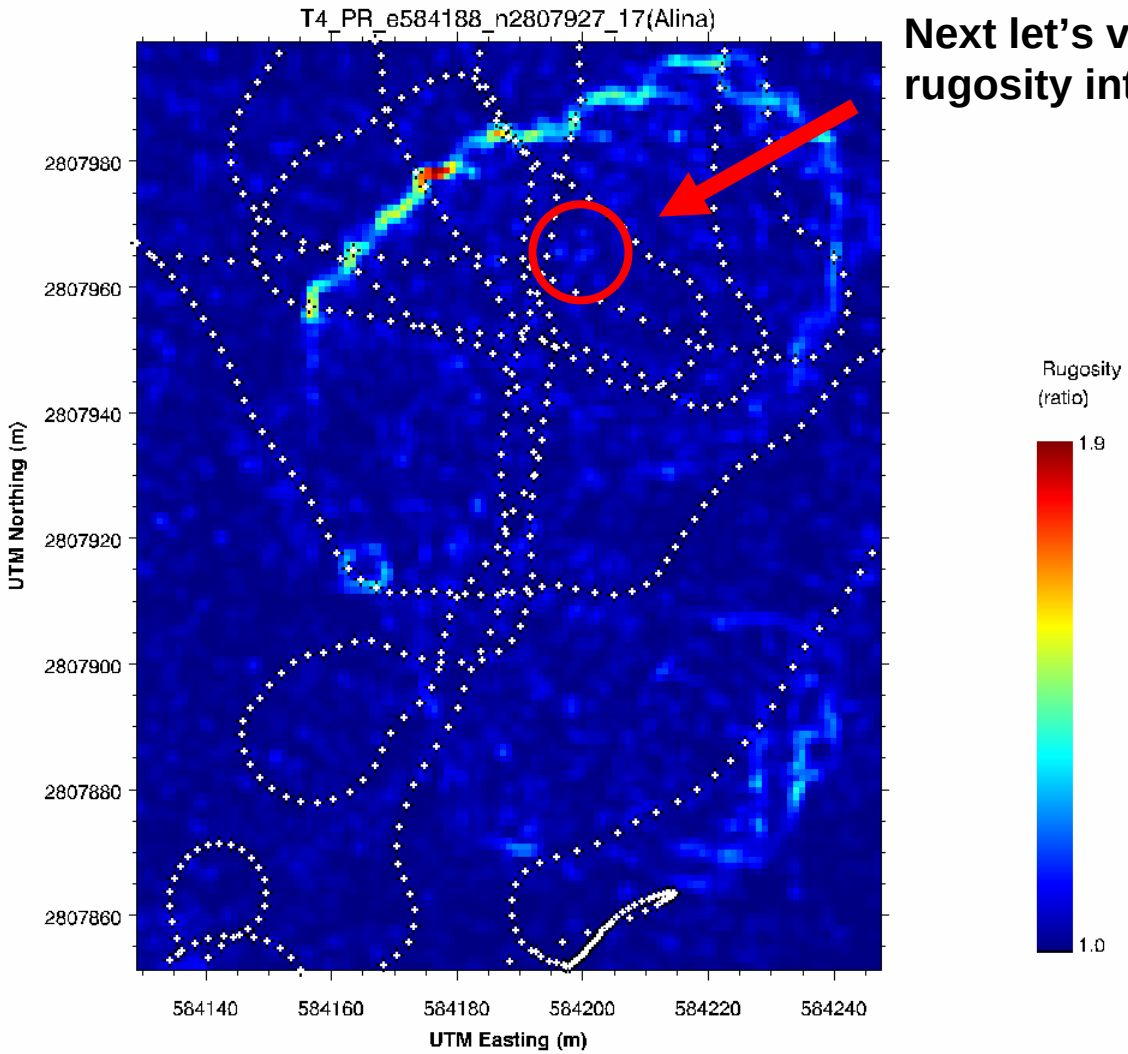
CORAL REEFS
Lidar Rugosity Mapping

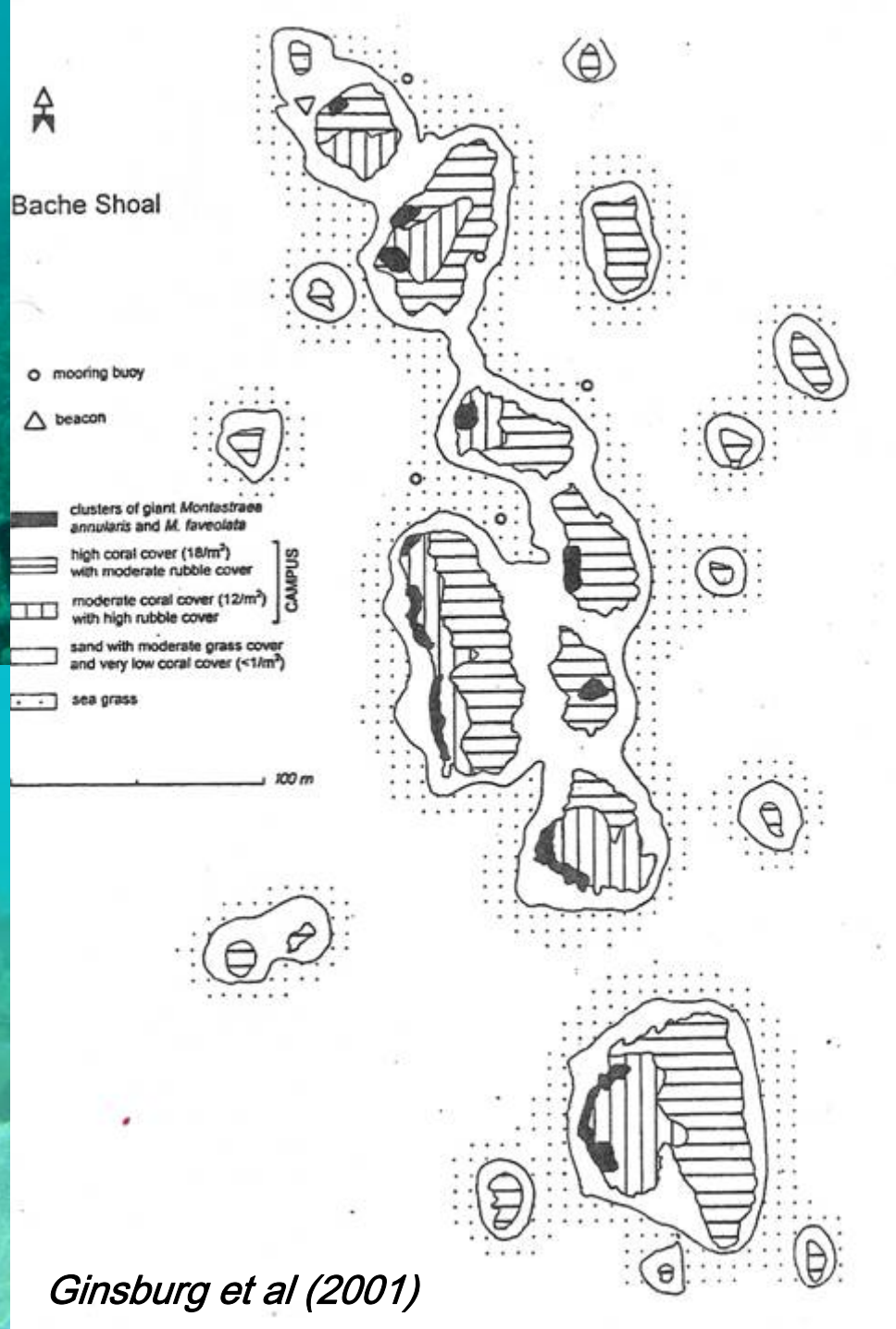


Let's take a virtual field trip to the high rugosity northwest fringe of this reef

CORAL REEFS
Lidar Rugosity Mapping

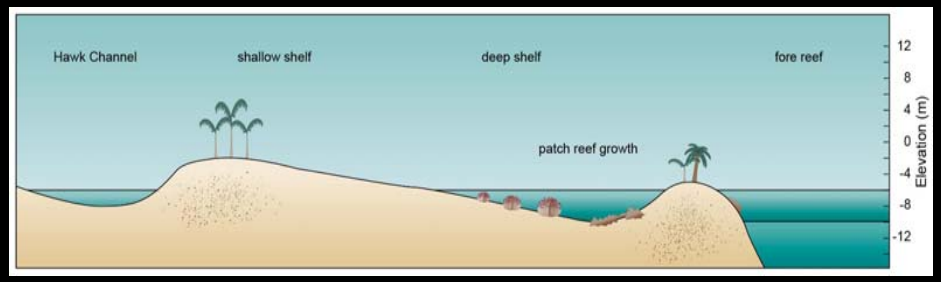


Next let's visit the low rugosity interior of the reef



Ginsburg et al (2001)

Patch Reef Morphological Development – Processes and Link to Sea Level

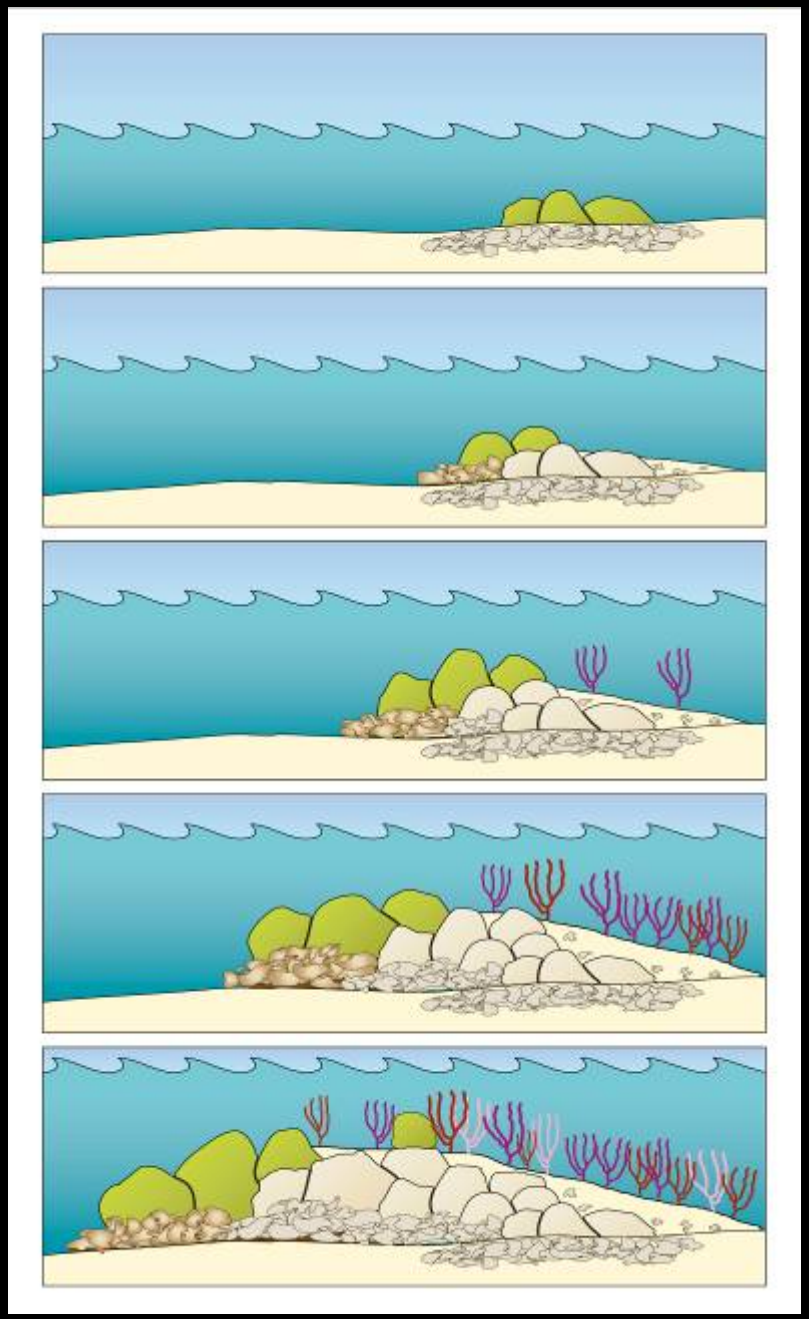


Processes:

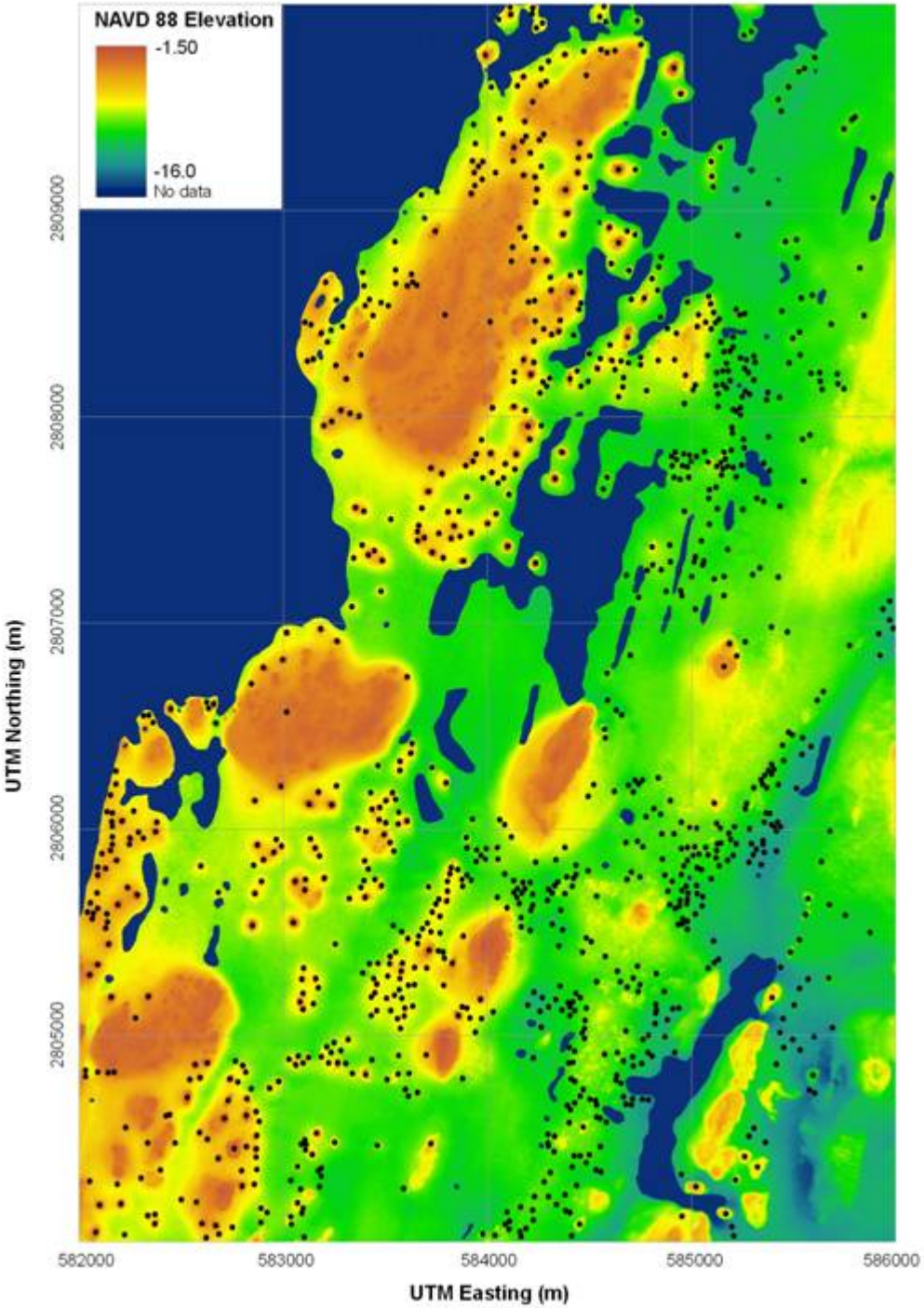
- Nucleation on favorable sites
- Vertical growth
- Rubble “calving” (colony destruction)
- Lateral growth by rim colonies
- Interior senescence and campus formation

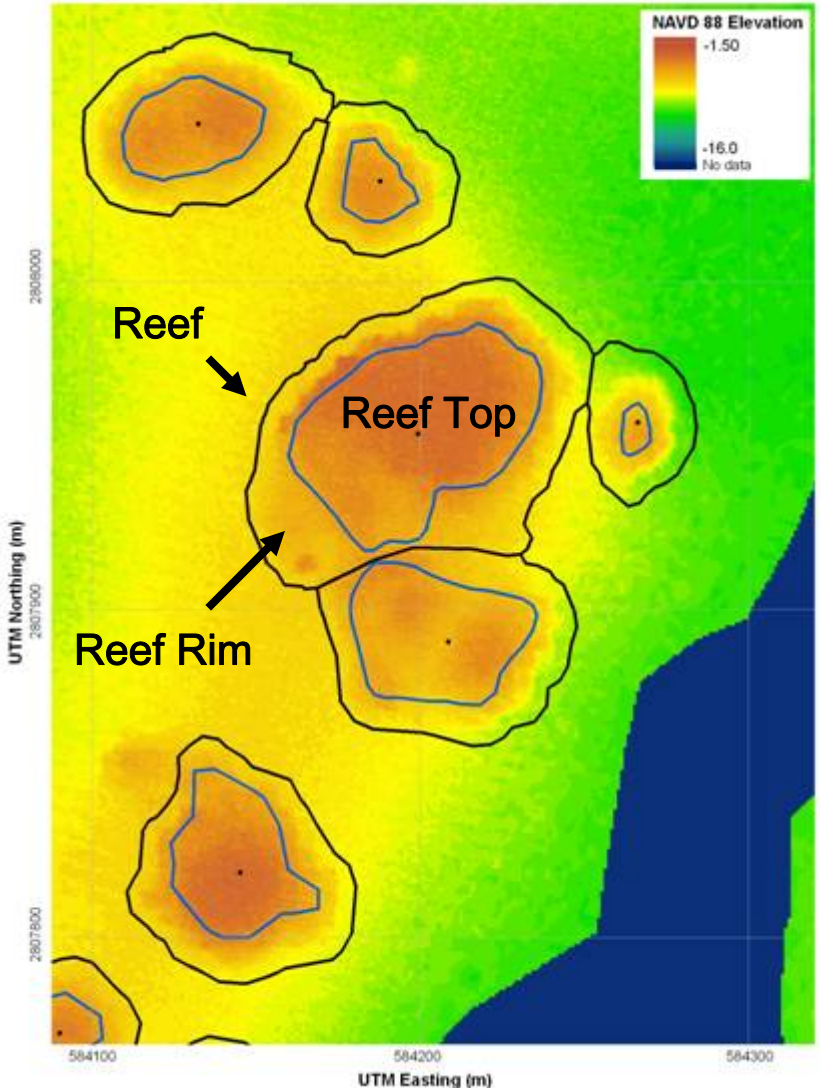
Sea Level Linkage:

- Wave action and/or subaerial erosion creates accommodation space for lateral growth.



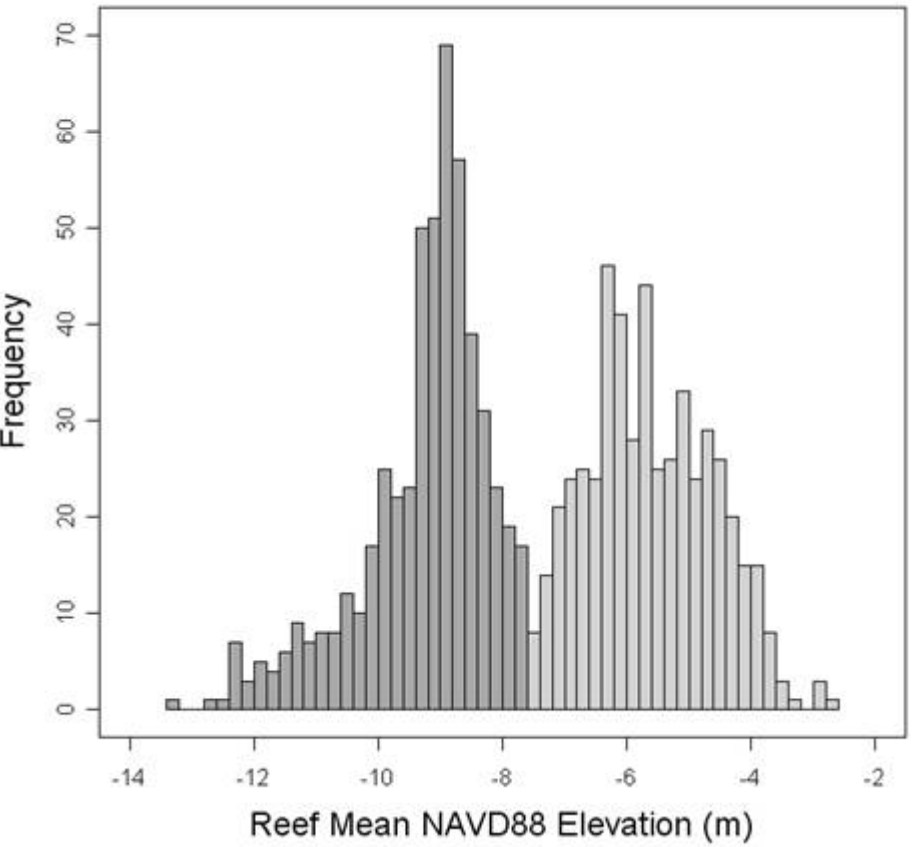
NFRT Patch Reef Topographic Analysis:
1034 reefs analyzed

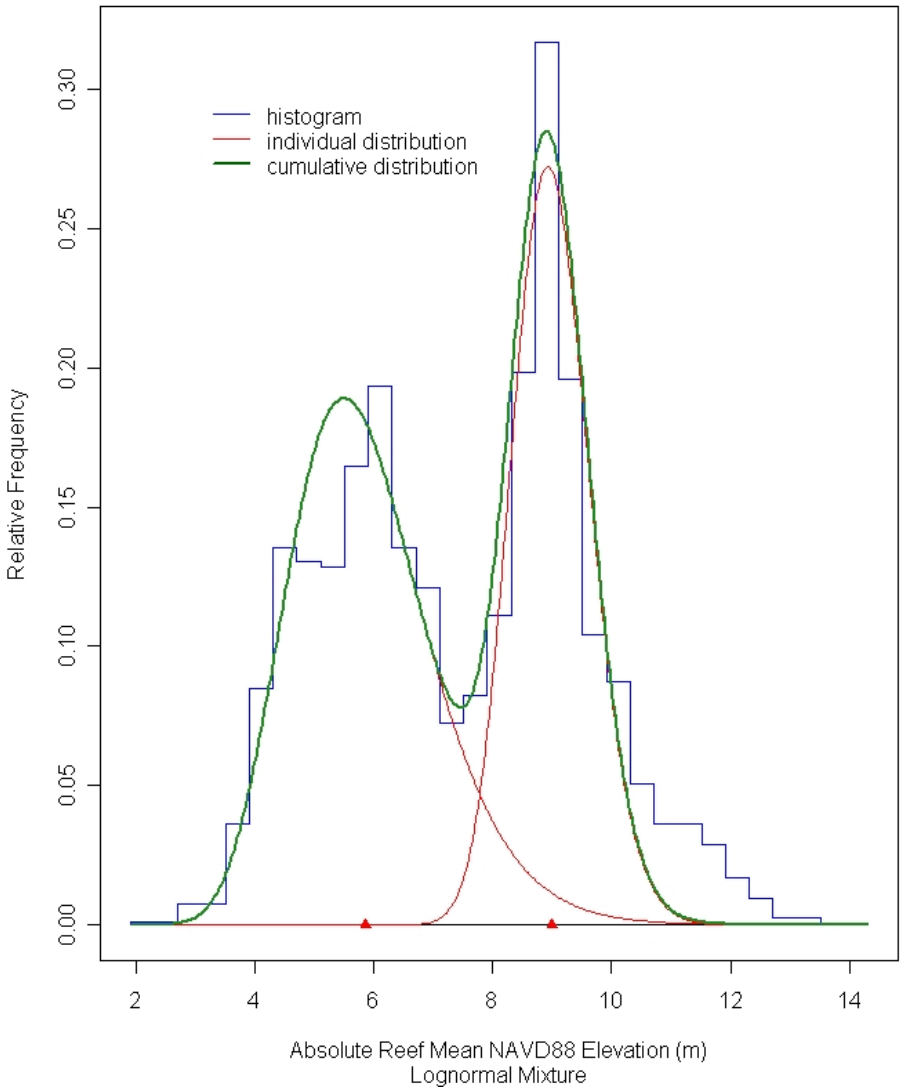




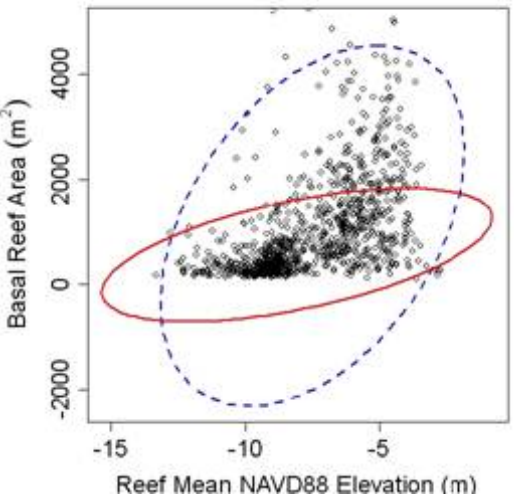
Reef Frequency vs. Depth

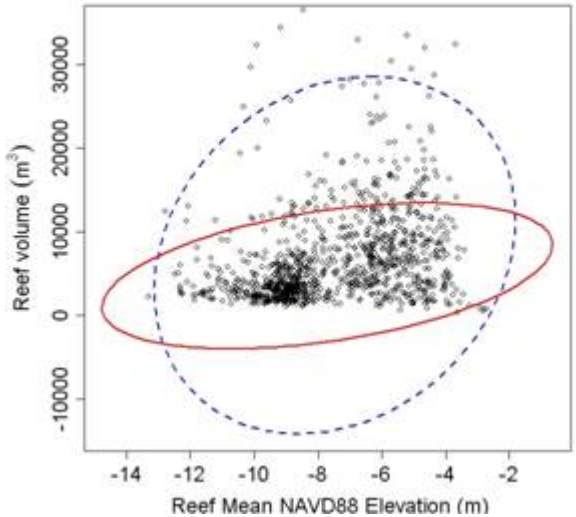
2 distinct reef populations are observed:
Deep population: -7.7 to -13 m
Shallow population: -7.7 to 2 m

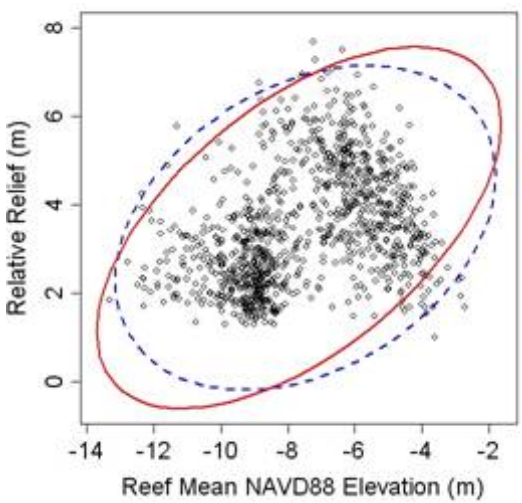


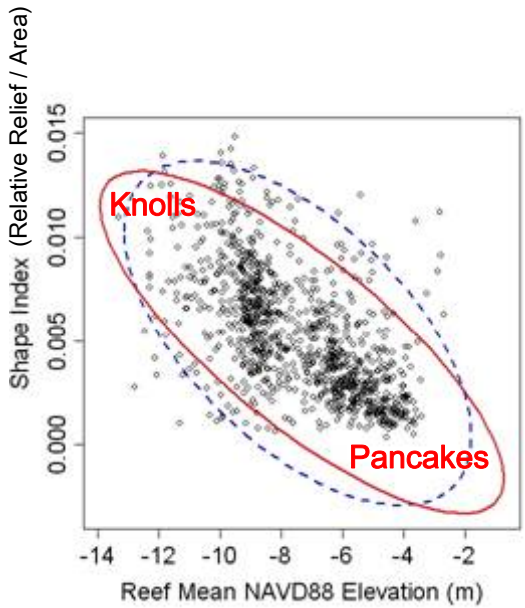


Morphometric – Depth Trends for All Patch Reefs:







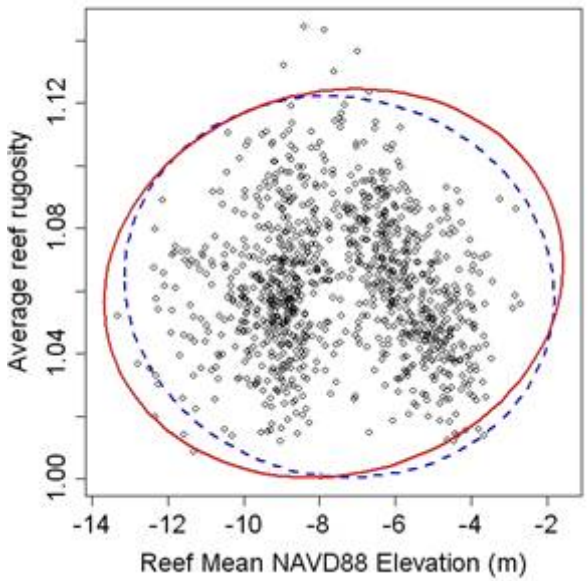


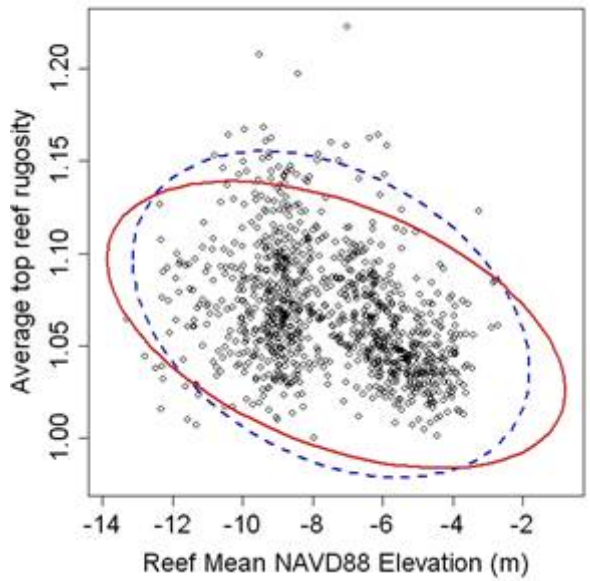
Robust Correlation Coefficients

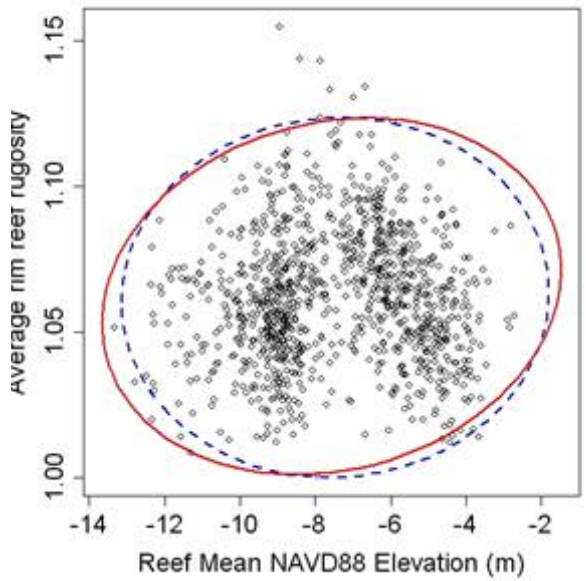
	Basal Area	Volume	Relative Relief	Shape Factor (height / area)
All Reefs	0.56	0.43	0.58	-0.80

2 distinct reef populations are also observed in these morphometric – depth trends

Rugosity – Depth Trends for All Patch Reefs:







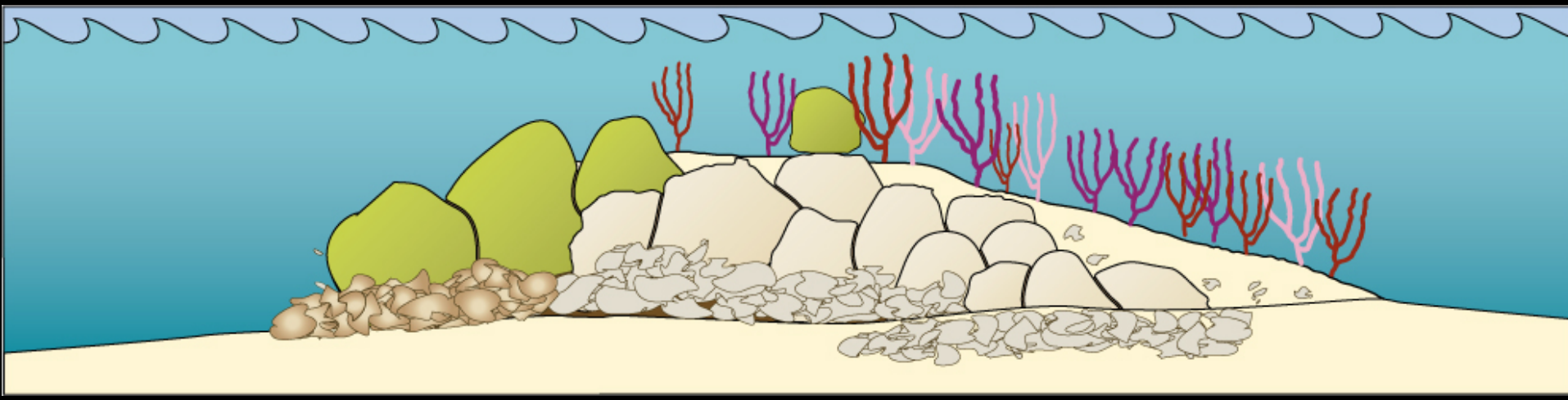
All Reefs		mean	max	min	stdev
Whole Reef	Perimeter (m)	117.63	500.38	36.50	62.13
	Area (m2)	1111.33	13678.65	92.65	1266.51
	Volume (m3)	7177.91	118429.03	333.49	7870.42
	Elevation (m)	-7.470077	-2.71	-13.31	2.085629
	Relative relief (m)	3.48	11.17	1.00	1.35
	Rugosity	1.06	1.14	1.00	0.02
Reef Tops	Perimeter (m)	51.22	395.41	8.84	46.94
	Area (m2)	274.03	8492.28	3.54	583.89
	Volume (m3)	1291.76	39834.48	10.87	2837.84
	Elevation (m)	-6.197957	-2.03	-12.69	2.242999
	Relative relief (m)	1.291636	5.17	0.07	0.653932
	Rugosity	1.066886	1.222759	1	0.032559
Rim reefs	Perimeter (m)	168.9057	895.85	57.14	107.1216
	Area (m2)	837.2438	7695.15	60.96	748.4888
	Volume (m3)	5886.147	78594.84	220.45	5414.678
	Elevation (m)	-7.698635	-2.74	-13.34	1.986695
	Relative relief (m)	3.228103	10.96	0.95	1.307643
	Rugosity	1.061906	1.154708	1.000736	0.022728

Robust Correlation Coefficients

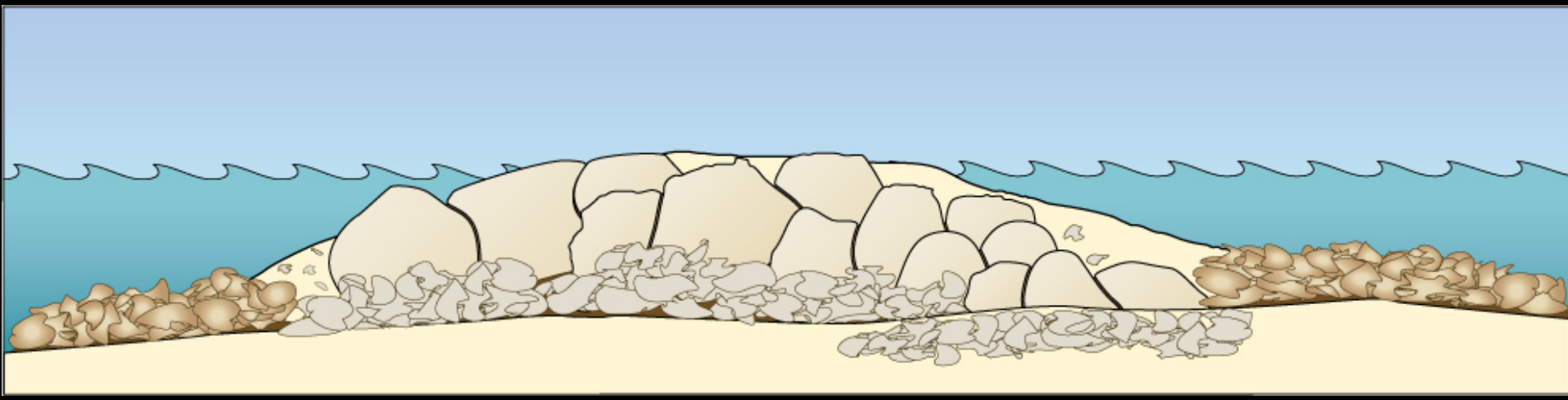
	Mean Whole Reef Rugosity	Mean Reef Top Rugosity	Mean Reef Rim Rugosity
All Reefs	0.10	-0.46	0.15

2 distinct reef populations are also observed in the patch reef rugosity – depth trends

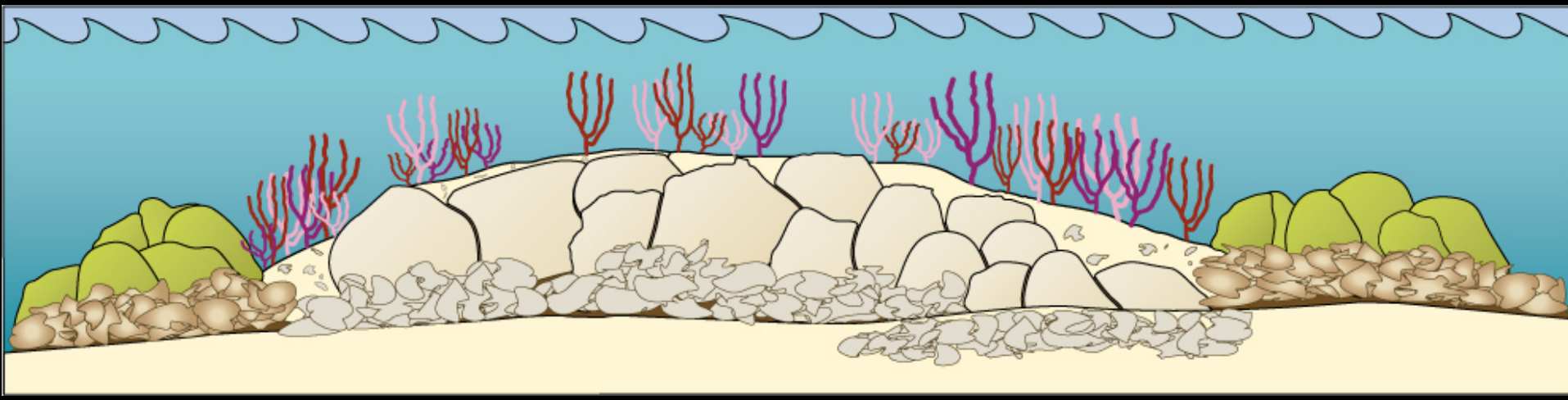
Patch Reef Growth Model – Effect of Sea Level Oscillation



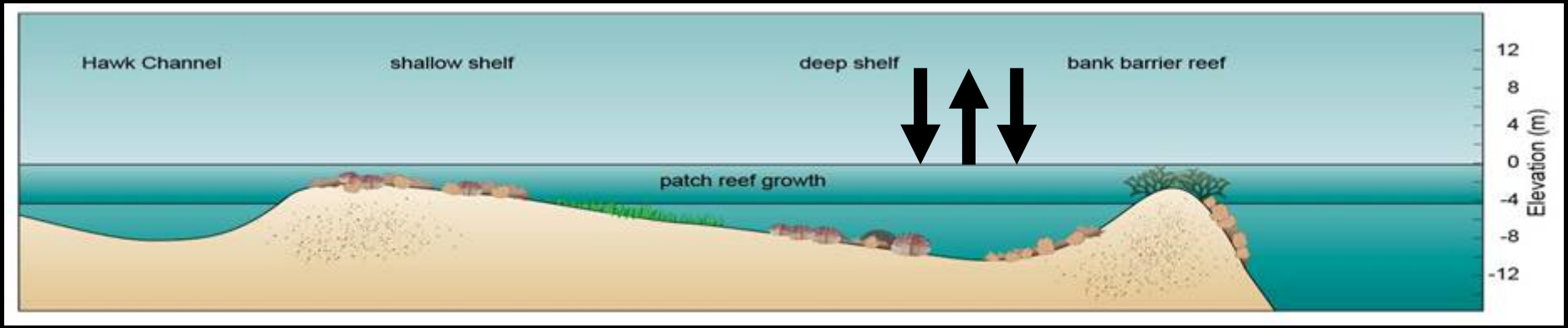
Patch Reef Growth Model – Effect of Sea Level Oscillation



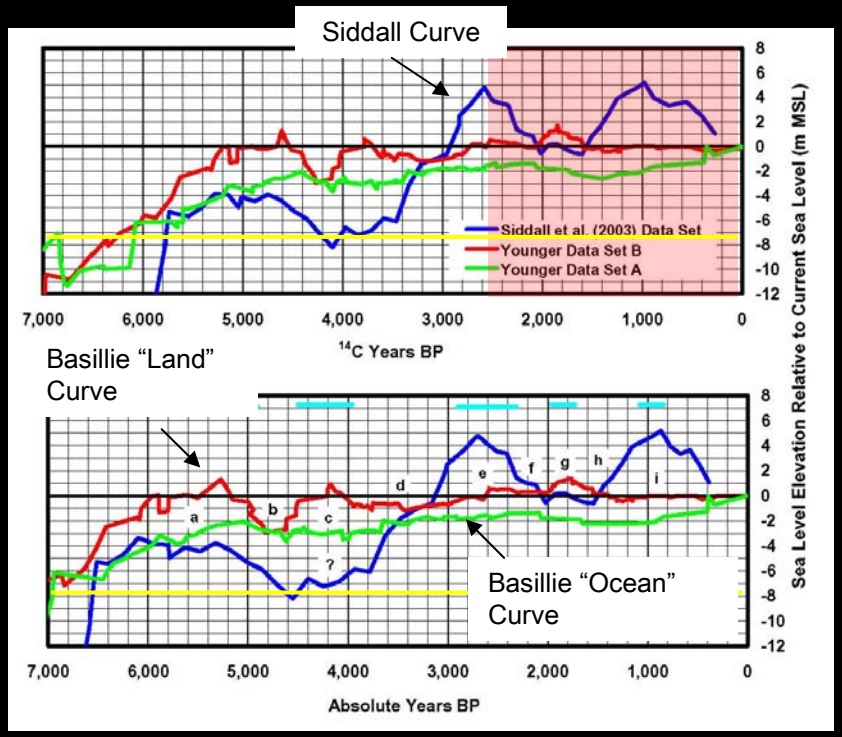
Patch Reef Growth Model – Effect of Sea Level Oscillation

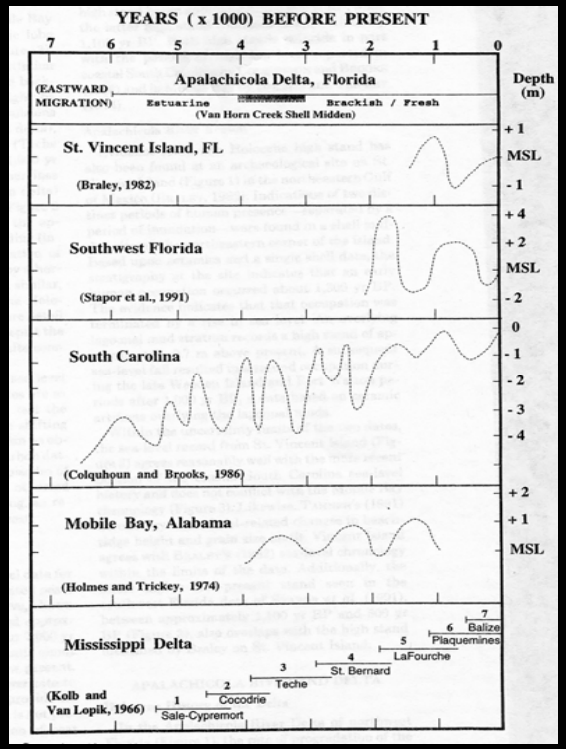


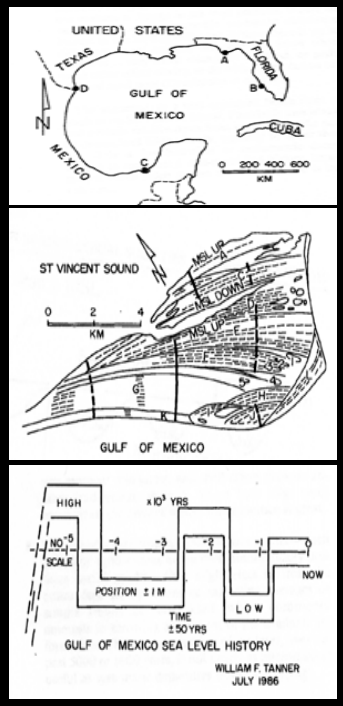
Sea Level Regime for the Shallow Reef Population: Jump to a highstand followed by sea level oscillation



Beach Ridge Evidence for Late Holocene Sea Level Highstands:

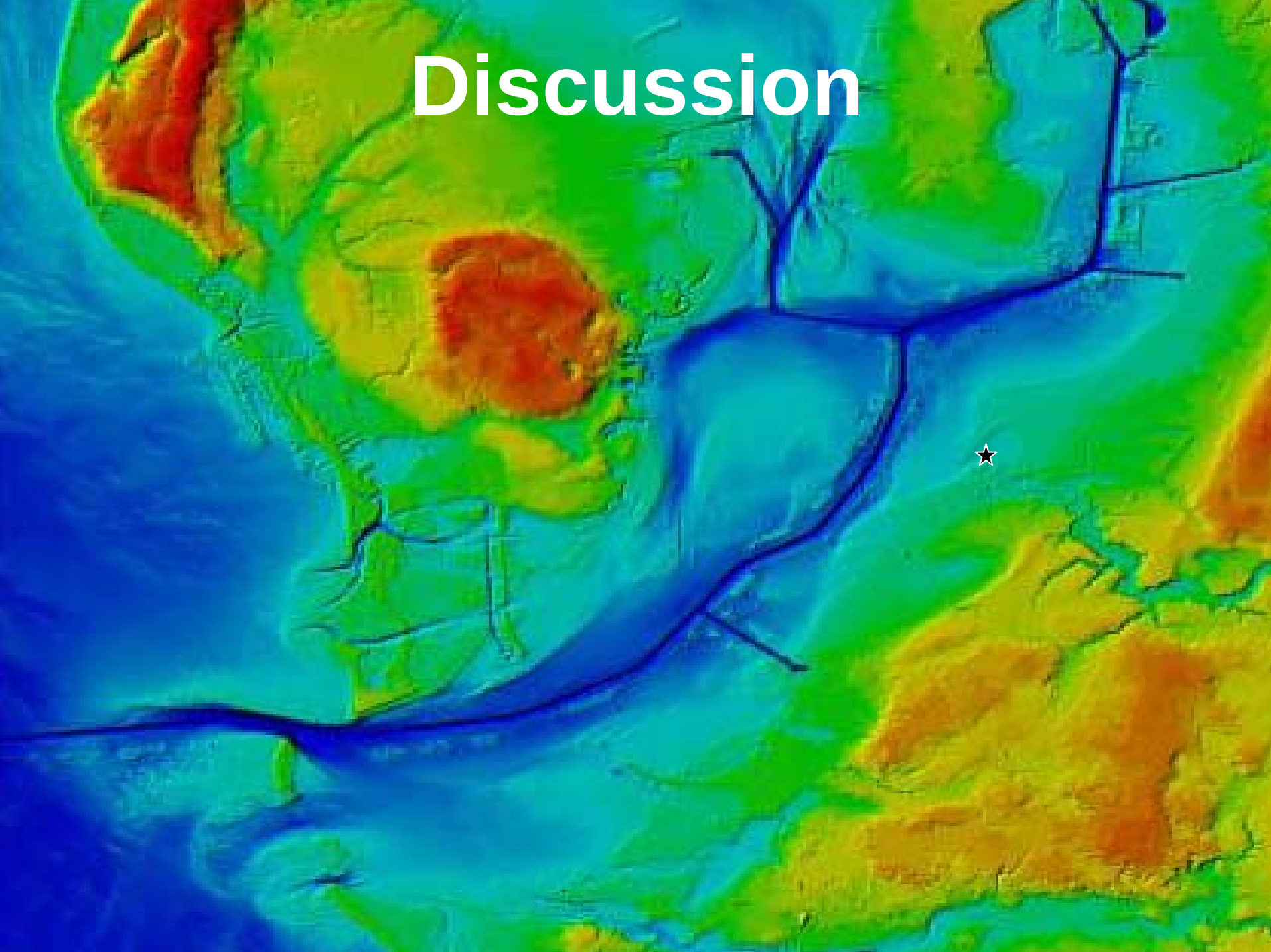






Siddall et al (2003); Balsillie and Donoghue (2004)

Donoghue and White (1995)

Tanner et al (1989)

Discussion