Anomalous Accretion Along Outer Cape Cod Shoreline

Possibly Linked with Aeolian Transport Associated with Parabolic Dune Field

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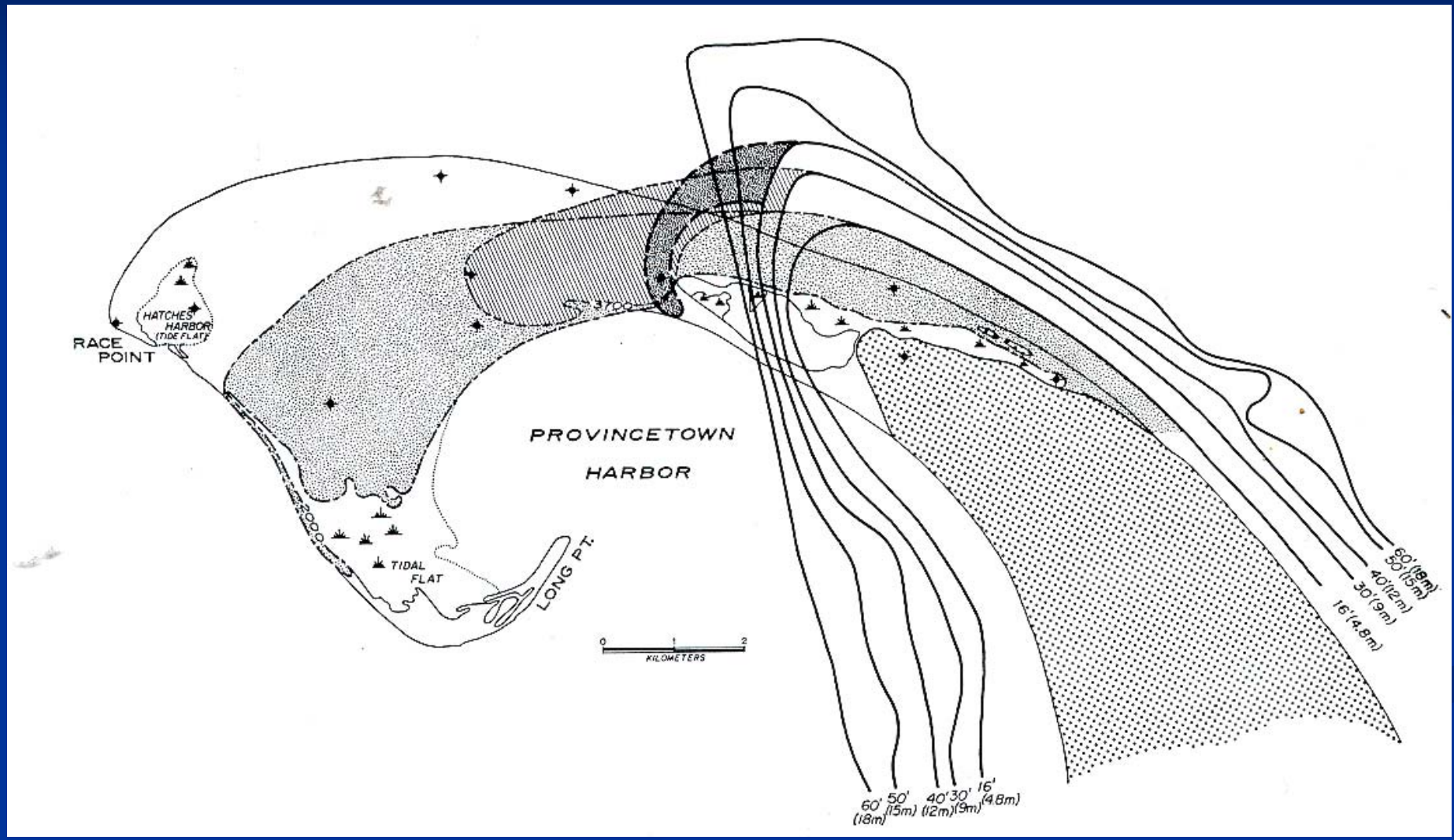
www.coastalstudies.org

Outer Cape Parabolic Dune Field

Photo Source: MassGIS, 2005

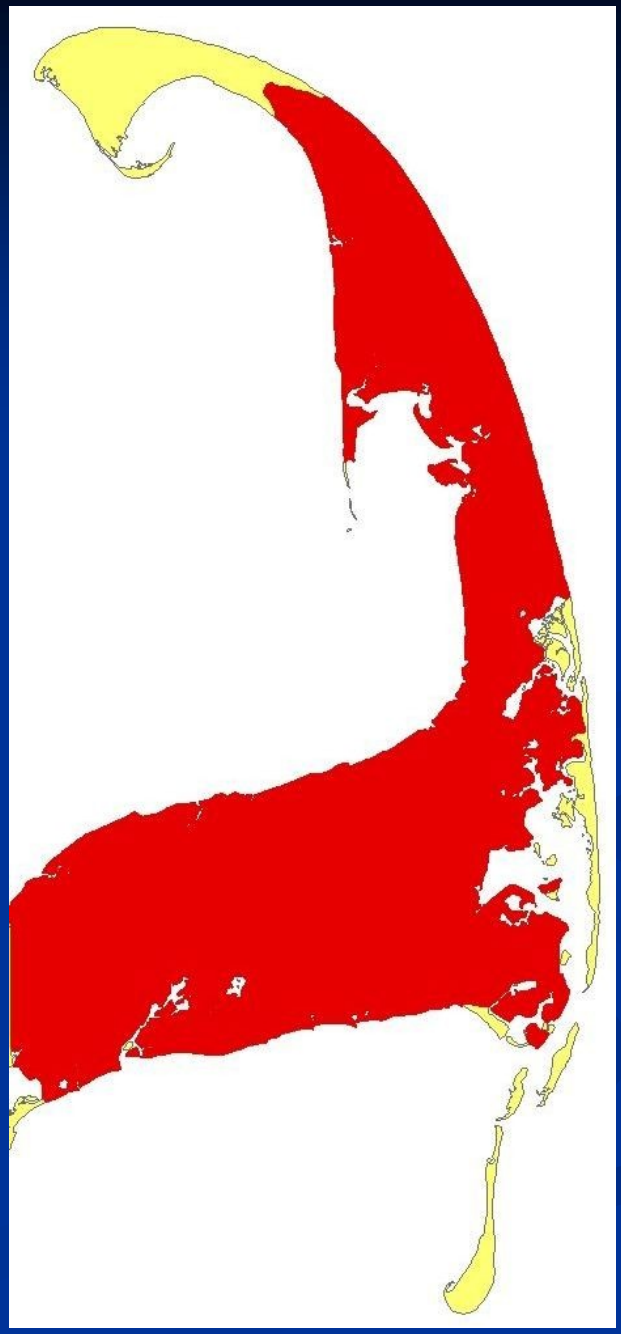
Formation of Provincetown Hook



Zeigler et al., 1965

Glacial sediment
Deposited before
15,000 years BP

Modern sediment
Deposited after
15,000 years BP



Giese et al., 2007

Dune Field Development

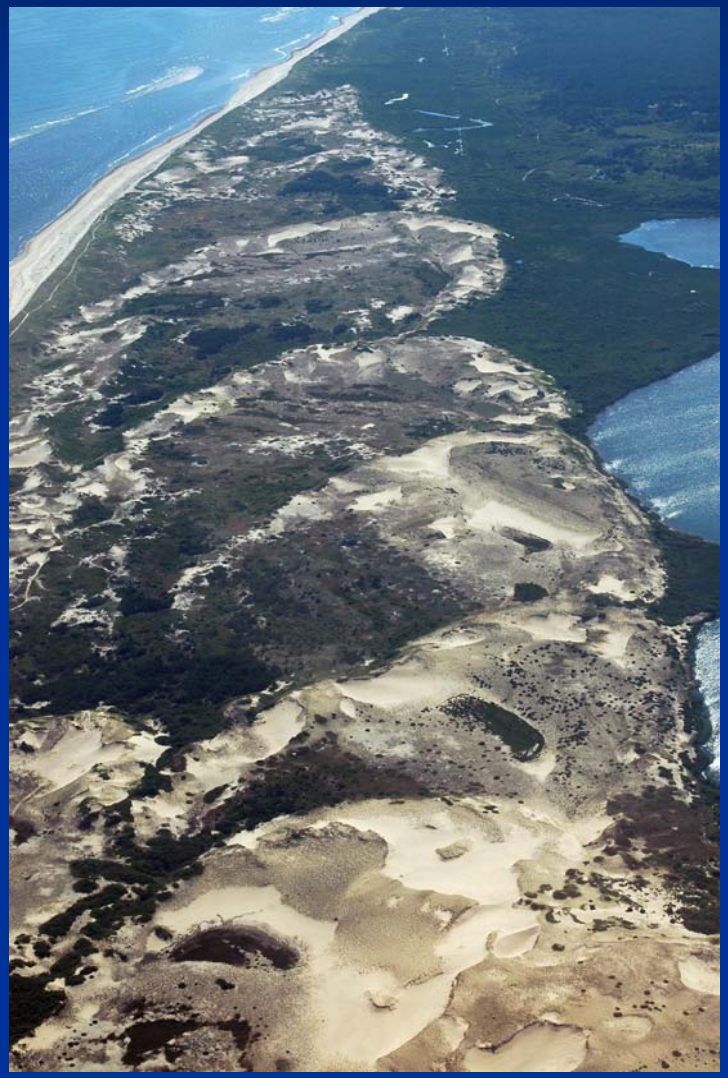
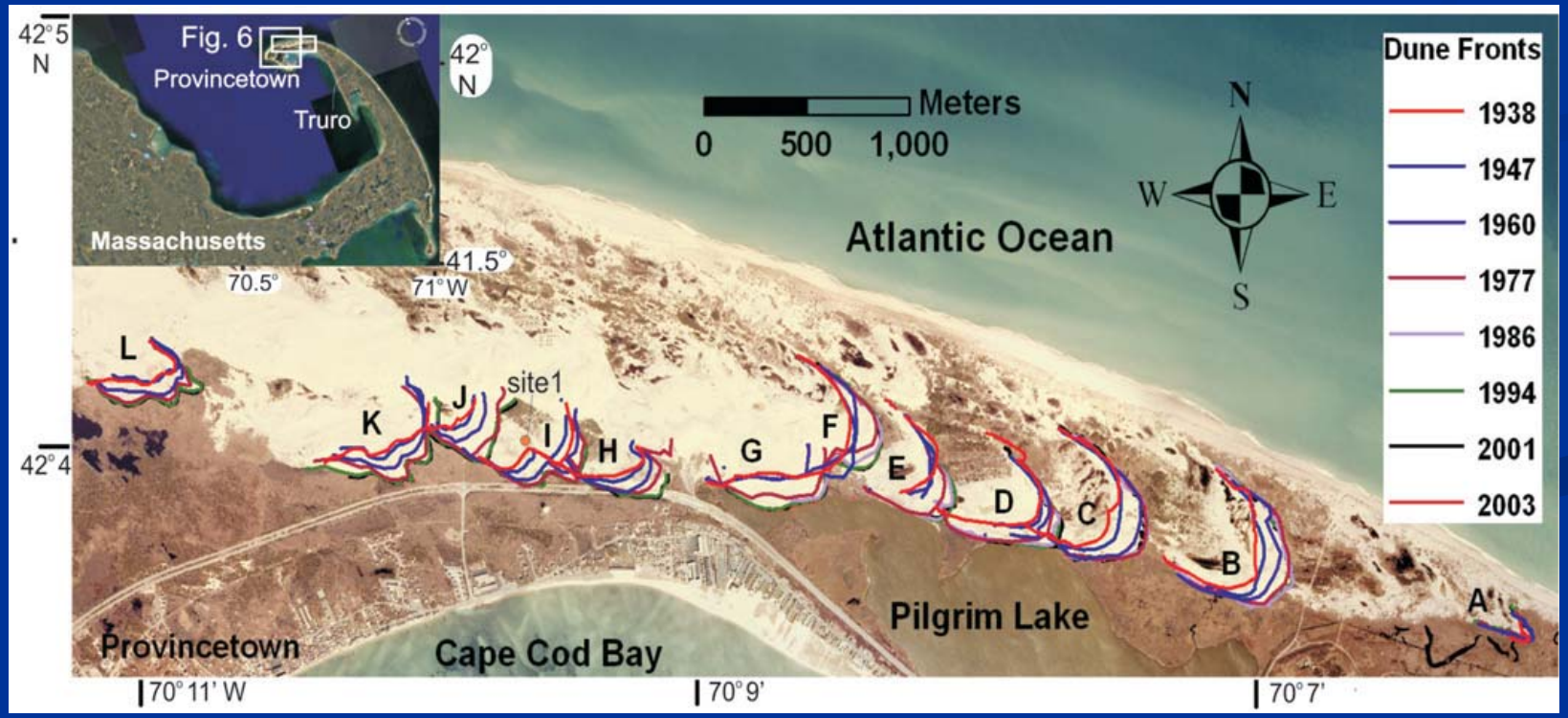


Photo Source: Peter Rosen

- Dune field formed at the end of the late 17th century due to human settlement and related land cover changes.
- Parabolic dunes: arms anchored by vegetation and the center portion advances based on wind and climate.
- The dunes appeared to broaden and migrate seaward over time.
- National Park effort to re-vegetate dunes 20-30 years ago.

Dune Migration Study

- Strong winter dry westerly-northwesterly wind drives the dunes movement and sediment source.
- Rate of dune movement affected by amount of moisture (Forman et al., 2008).



Cape Cod Outer Coast

Photo Source: Cape Cod National Seashore

Marconi Station, Wellfleet

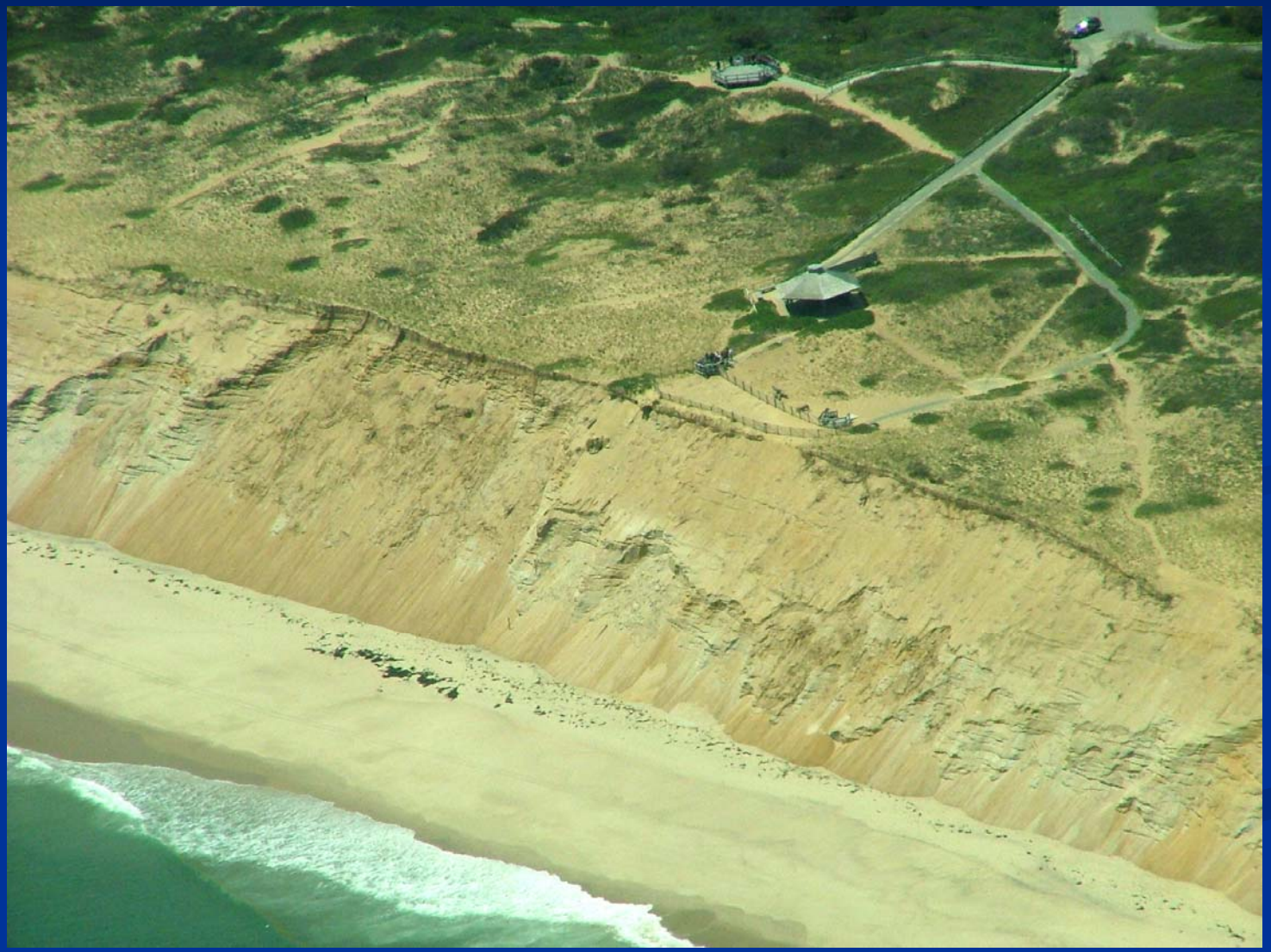


Photo Source: Cape Cod National Seashore

Cahoon Beach, Wellfleet

Photo Source: Cape Cod National Seashore

Historic Examples

Coast Guard Station
Moved from Chatham to
Race Point, Provincetown

Recent Examples

Highland Light Move, 1996

Truro, Massachusetts

Current Examples

Photo Source: Christopher Seufert Photography

North Beach, Chatham

Photo Sources: Cape Cod Times (January and March, 2008)

Ballston Beach, Truro

Photo Source: Cape Cod National Seashore

February 3, 2008

February 3, 2008

February 3, 2008

February 3, 2008

February 9, 2008

March 21, 2008

March 30, 2008

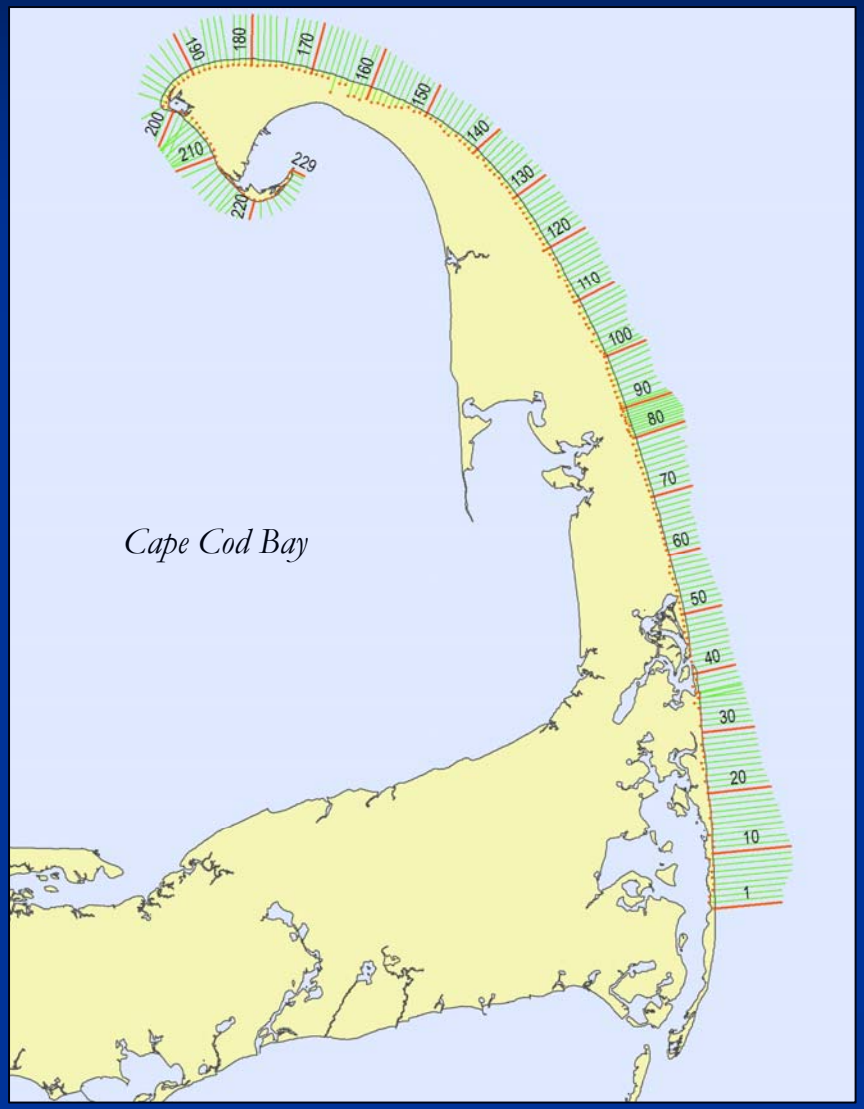
July 19, 2008

Prepared to Move

January 27, 2009

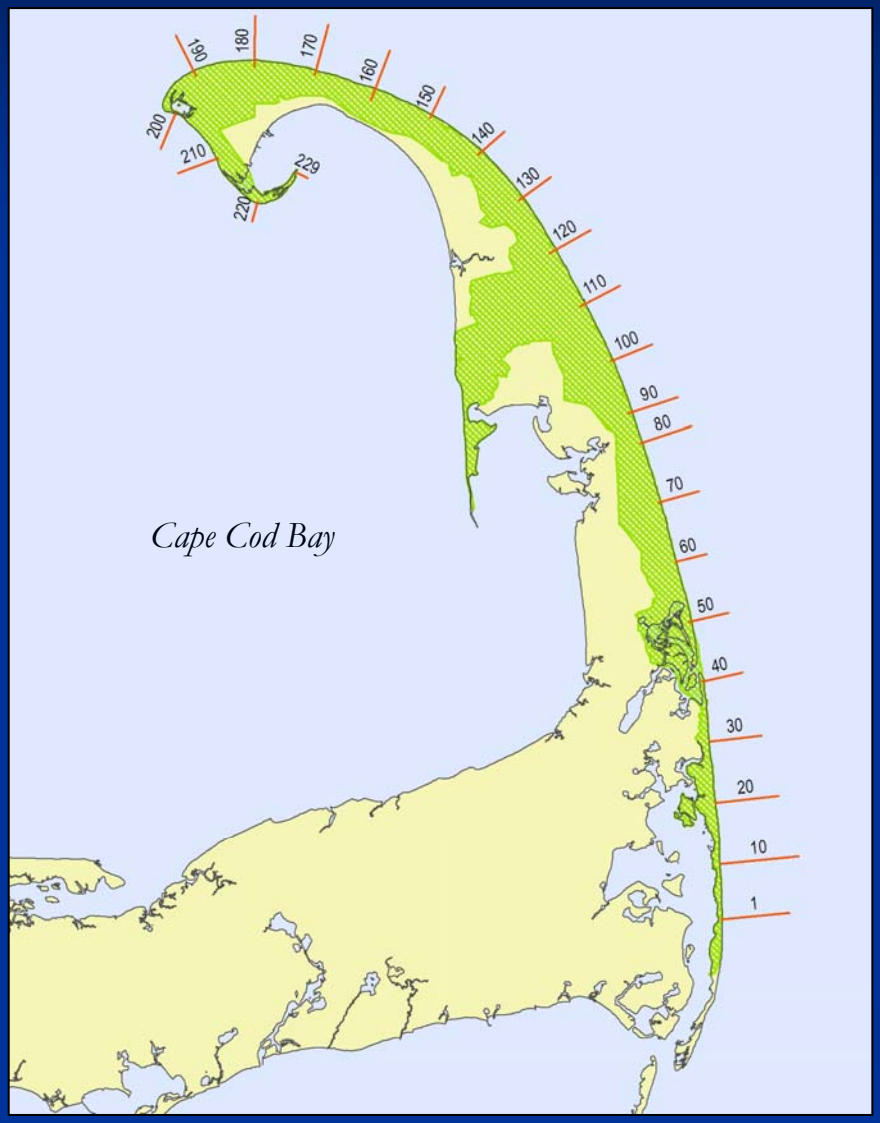
Photo Sources: Cape Cod Times (January 28, 2009)

Marindin Surveys



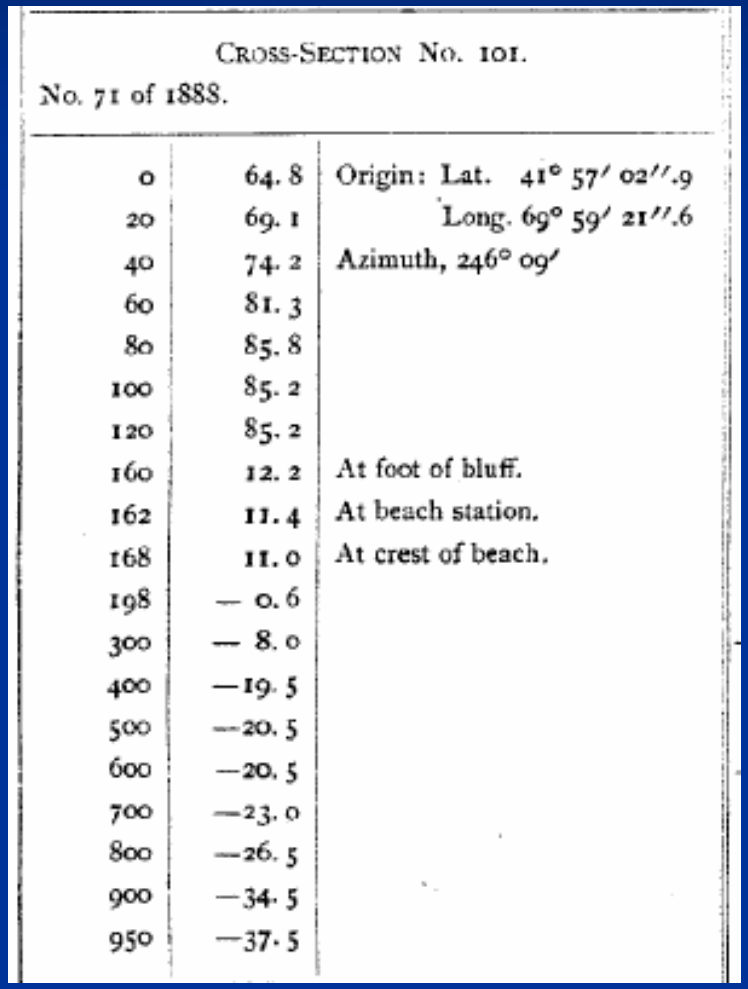
- Survey of Outer Cape Cod Coast from Chatham to Provincetown in late 1800s
- 229 on and offshore survey lines recorded in Coastal Geodetic Survey Annual Reports, 1889 and 1891.
- Locations reoccupied in 1950s by Zeigler et al.
- Average rate of erosion approximately 1 meter/year, varied over distance along shoreline.

Project Objectives



- Develop a current model of sediment erosion, transportation and deposition of outer Cape Cod coastline.
- Understand and predict the formation and destruction of coastal landforms on Cape Cod.
- Provide valuable information for future management and planning strategies.

Data Sources



CROSS-SECTION No. 101.

No. 71 of 1888.

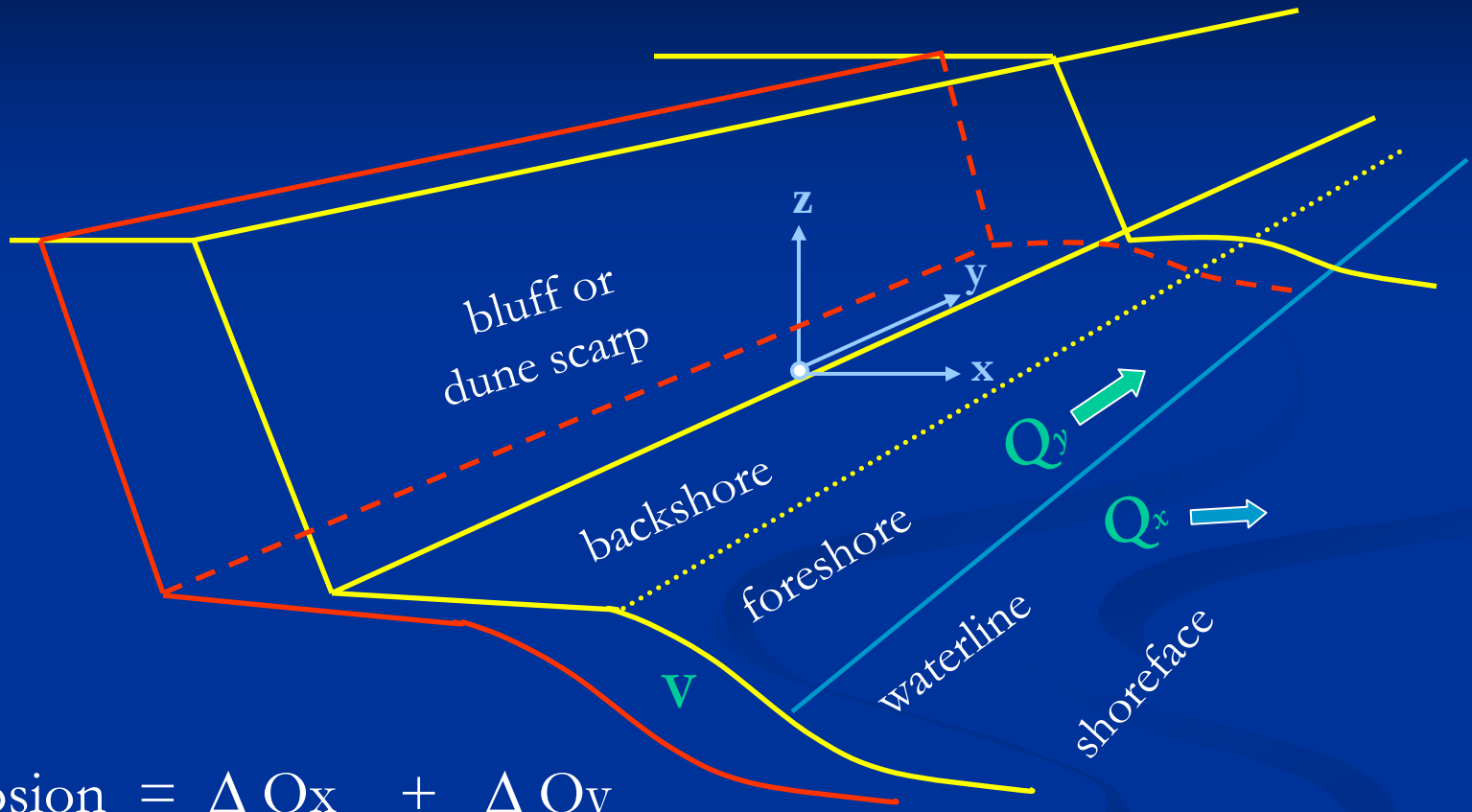
0	64. 8	Origin: Lat. 41° 57′ 02″.9
20	69. 1	Long. 69° 59′ 21″.6
40	74. 2	Azimuth, 246° 09′
60	81. 3	
80	85. 8	
100	85. 2	
120	85. 2	
160	12. 2	At foot of bluff.
162	11. 4	At beach station.
168	11. 0	At crest of beach.
198	— 0. 6	
300	— 8. 0	
400	—19. 5	
500	—20. 5	
600	—20. 5	
700	—23. 0	
800	—26. 5	
900	—34. 5	
950	—37. 5	

- Marindin's late 1800's origins, elevations and depths.
- Lidar data from 2005.
- GPS Surveys 2008-9 of marine/terrestrial boundary.
- Offshore bathymetric data collected 2008-9.

Study Methods

- Create GIS data layer of Marindin's origins and transects in ArcView 9.3.
- GPS field work to gather the current marine/terrestrial boundary.
- Lidar data (airborne laser mapping technology) data for onshore portion.
- Offshore boat fieldwork to gather bathymetric data.
- Plot data in Matlab and compare current to late 1800s.
- Calculate the volume change and flux rate over time.

Flux Along and Across Shore



Rate of Erosion = Δ Qx + Δ Qy

Q_y : Net alongshore sediment flux in +y direction

Q_x : Net cross-shore sediment flux in +x direction

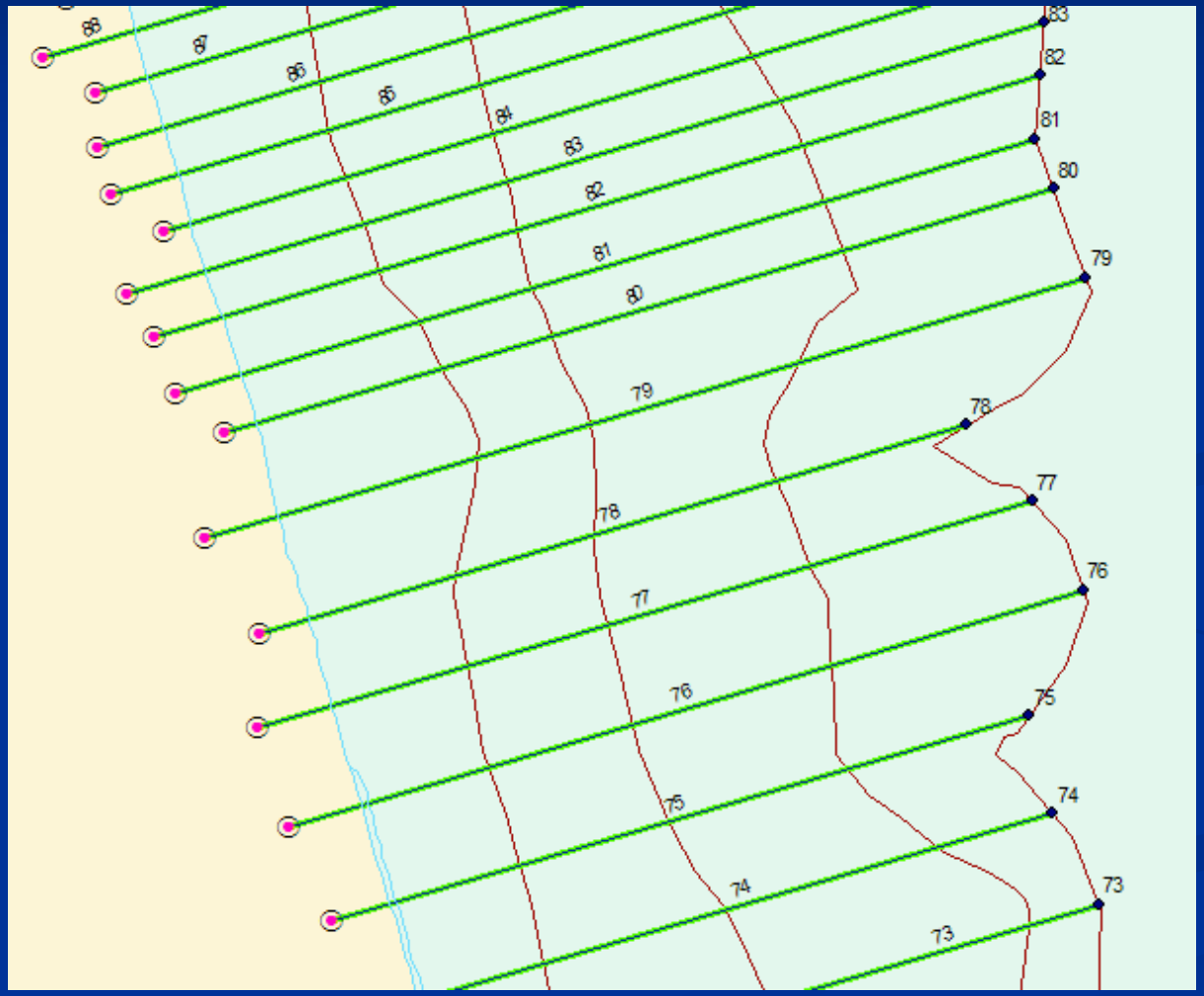
V : Volume between (e.g.) 1888 & 2008 surveys

Convert Origins and Azimuths

Transect	STN_ID	LAT_ORIGINAL	LONG_ORIGINAL	LAT_27	LONG_27	LAT_27DD	LONG_27DD	LAT_83DD	LONG_83DD	UTM_X	UTM_Y
1	1.0	41° 42' 16.3"	69° 55' 44.5"	41 42 15.7	69 55 44.5	41.70436111	-69.92902778	41.70447262	-69.9284872	422749.7399	4617381.447
2	2.0	41° 42' 25.6"	69° 55' 54.4"	41 42 25.0	69 55 54.4	41.70694444	-69.93177778	41.70705588	-69.93123728	422524.0328	4617670.723
3	3.0	41° 42' 35.3"	69° 55' 52.6"	41 42 34.7	69 55 52.6	41.70963889	-69.93127778	41.70975026	-69.93073729	422568.8637	4617969.417
4	4.0	41° 42' 45.3"	69° 55' 45.6"	41 42 44.7	69 55 45.6	41.71241667	-69.92933333	41.71252798	-69.92879284	422733.9572	4618276.066
5	5.0	41° 42' 55.1"	69° 55' 43.8"	41 42 54.5	69 55 43.8	41.71513889	-69.92883333	41.71525013	-69.92829286	422778.8096	4618577.845
6	6.0	41° 43' 05.0"	69° 55' 46.3"	41 43 04.4	69 55 46.3	41.71788889	-69.92952778	41.71800006	-69.92898734	422724.3323	4618883.779
7	7.0	41° 43' 14.6"	69° 55' 47.2"	41 43 14.0	69 55 47.2	41.72055556	-69.92977778	41.72066666	-69.92923737	422706.7296	4619180.063
8	8.0	41° 43' 24.4"	69° 55' 43.3"	41 43 23.8	69 55 43.3	41.72327778	-69.92869444	41.72338882	-69.92815404	422800.0993	4619481.319
9	9.0	41° 43' 33.8"	69° 55' 51.5"	41 43 33.2	69 55 51.5	41.72588889	-69.93097222	41.72599986	-69.93043188	422613.7697	4619773.256
10	10.0	41° 43' 43.8"	69° 55' 44.2"	41 43 43.2	69 55 44.2	41.72866667	-69.92894444	41.72877758	-69.9284041	422785.7535	4620079.831
11	11.0	41° 43' 53.6"	69° 55' 42.5"	41 43 53.0	69 55 42.5	41.73138889	-69.92847222	41.73149974	-69.92793189	422828.2849	4620381.636
12	12.0	41° 44' 03.3"	69° 55' 03.6"	41 44 02.7	69 55 43.6	41.73408333	-69.928778	41.73419411	-69.92823748	422806.097	4620681.054
13	13.0	41° 44' 12.4"	69° 55' 50.2"	41 44 11.8	69 55 50.2	41.73661111	-69.93061111	41.73672182	-69.93007087	422656.6602	4620963.34
14	14.0	41° 44' 22.7"	69° 55' 43.5"	41 44 22.1	69 55 43.5	41.73947222	-69.92875	41.73958287	-69.92820975	422814.8557	4621279.319
15	15.0	41° 44' 32.3"	69° 55' 44.6"	41 44 31.7	69 55 44.6	41.74213889	-69.92905556	41.74224947	-69.92851534	422792.6388	4621575.653
16	16.0	41° 44' 41.7"	69° 55' 48.3"	41 44 41.1	69 55 48.3	41.74475	-69.93008333	41.74486051	-69.92954316	422710.3049	4621866.468
17	17.0	41° 44' 50.9"	69° 55' 46.6"	41 44 50.3	69 55 46.6	41.74730556	-69.92961111	41.747416	-69.92907095	422752.6319	4622149.77
18	18.0	41° 45' 00.9"	69° 55' 47.8"	41 45 00.3	69 55 47.8	41.75008333	-69.92994444	41.75019371	-69.92940432	422728.2454	4622458.466
19	19.0	41° 45' 10.6"	69° 55' 50.6"	41 45 10.0	69 55 50.6	41.75277778	-69.93072222	41.75288809	-69.93018217	422666.8072	4622758.31
20	20.0	41° 45' 20.4"	69° 55' 51.8"	41 45 19.8	69 55 51.8	41.7555	-69.93105556	41.75561024	-69.93051558	422642.3572	4623060.838
21	21.0	41° 45' 30.1"	69° 55' 51.1"	41 45 29.5	69 55 51.1	41.75819444	-69.93086111	41.75830462	-69.9303212	422661.7524	4623359.809
22	22.0	41° 45' 39.2"	69° 55' 58.0"	41 45 38.6	69 55 58.0	41.76072222	-69.93277778	41.76083232	-69.93223795	422505.4508	4623642.175
23	23.0	41° 45' 49.0"	69° 55' 54.9"	41 45 48.4	69 55 54.9	41.76344444	-69.93191667	41.76355448	-69.9313769	422580.3016	4623943.63
24	24.0	41° 45' 58.5"	69° 55' 03.5"	41 45 57.9	69 56 03.5	41.76608333	-69.9343056	41.76619329	-69.93376593	422429.885	4624250.49
25	25.0	41° 46' 08.3"	69° 55' 04.3"	41 46 07.7	69 56 04.3	41.76880556	-69.9345278	41.76891545	-69.9339882	422369.701	4624541.19
26	26.0	41° 46' 18.5"	69° 55' 59.3"	41 46 17.9	69 55 59.3	41.77163889	-69.93313889	41.77174872	-69.93259934	422488.5514	4624854.504

- Convert origin latitude/longitude to North American Datum 1927 by subtracting -0.6 from latitude (Giese and Adams, 2007).
- Convert NAD27 latitude/longitude to NAD83.
- Convert latitude/longitude NAD83 to UTM, meters Zone 19N.

Create Azimuth Lines for Navigation

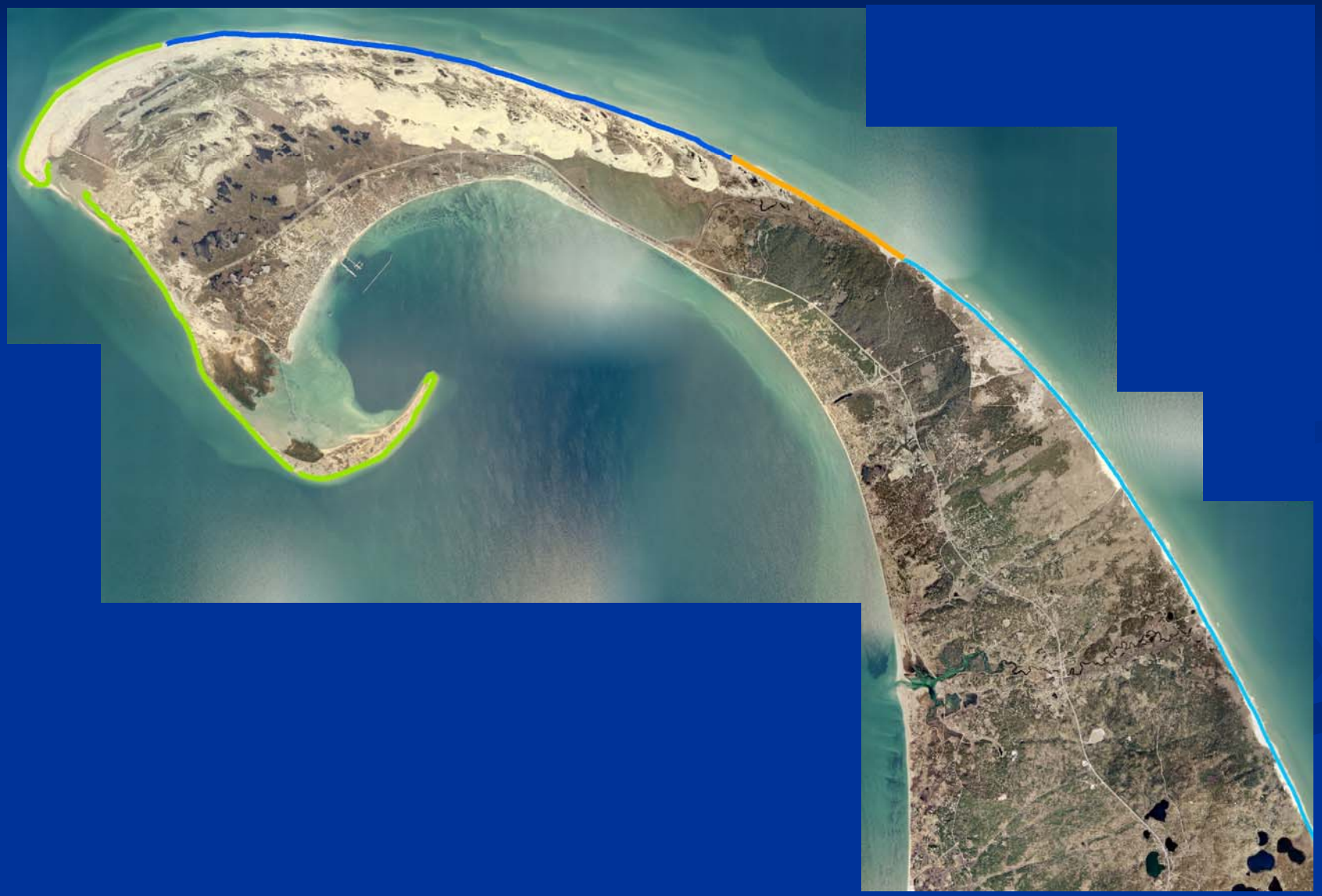


- Extend Marindin's lines along same azimuth to 20 m depth.
- Data lines from NOAA charts available from MassGIS.

GPS and Boat Survey Fieldwork

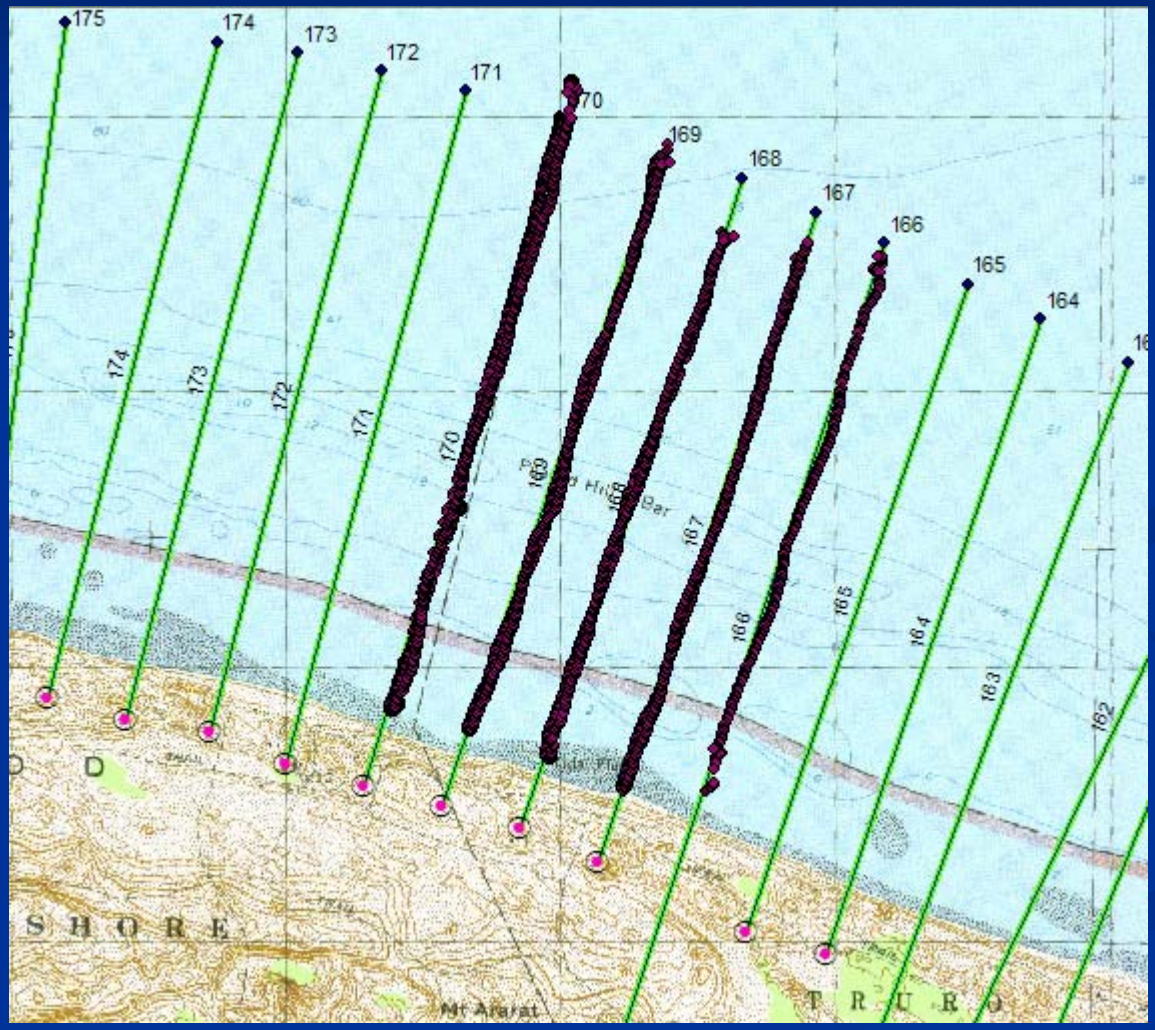
- Terrestrial/Marine boundary location.
- Bathymetric data.

GPS of Terrestrial/Marine Line



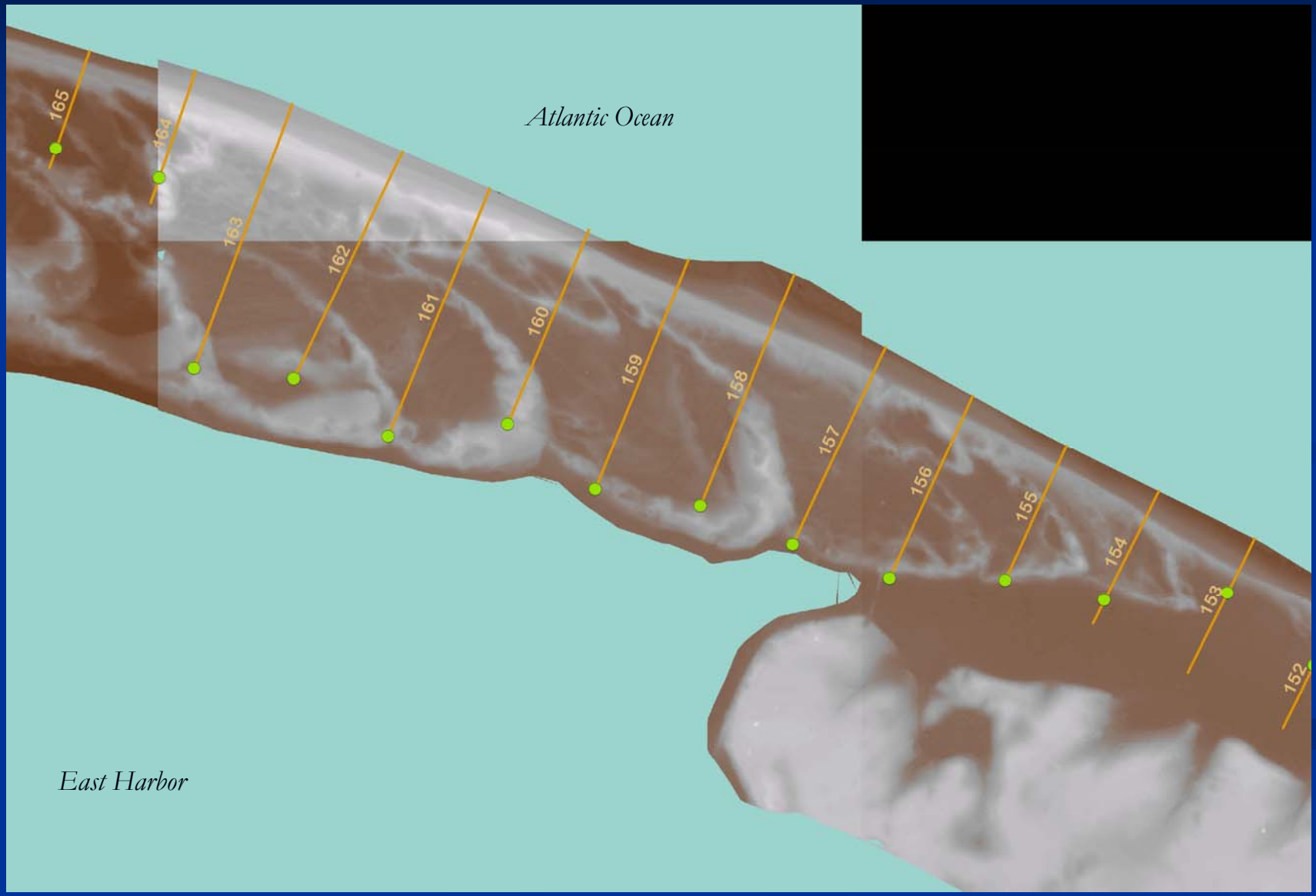
GPS of Terrestrial/Marine Line

Raw Depth Data Collected 2008

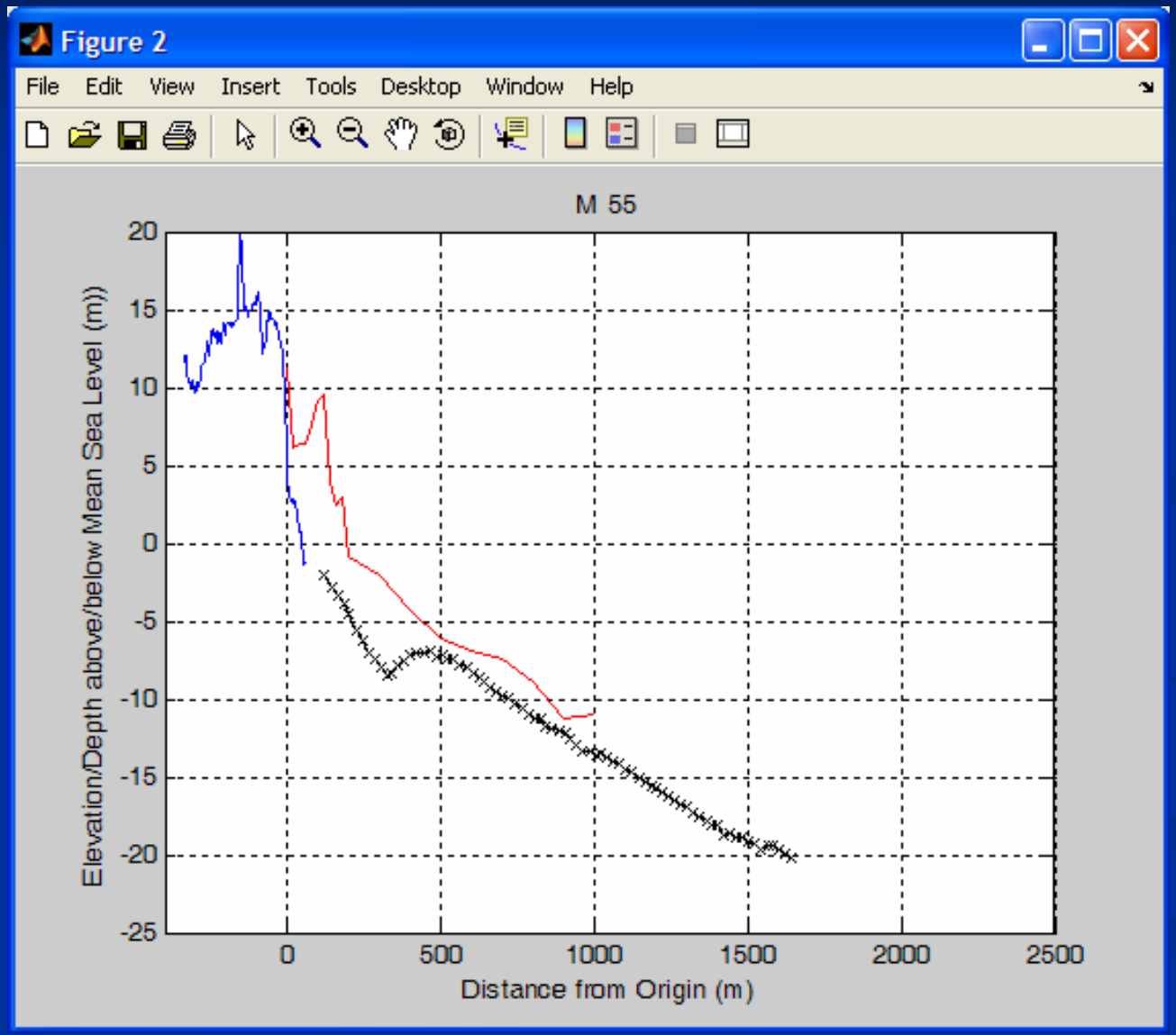


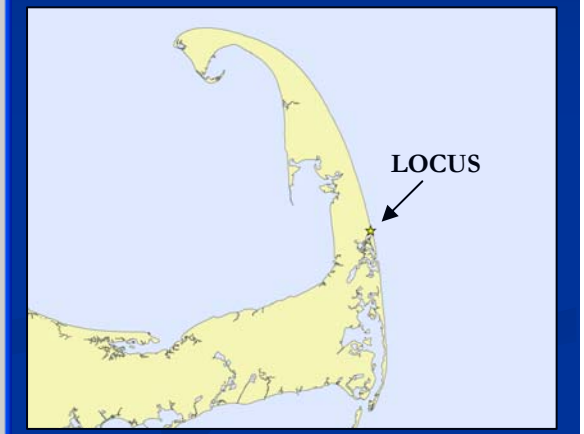
- Offshore data snapped to nearest azimuth line.
- Corrected for tides and sea level (in progress).

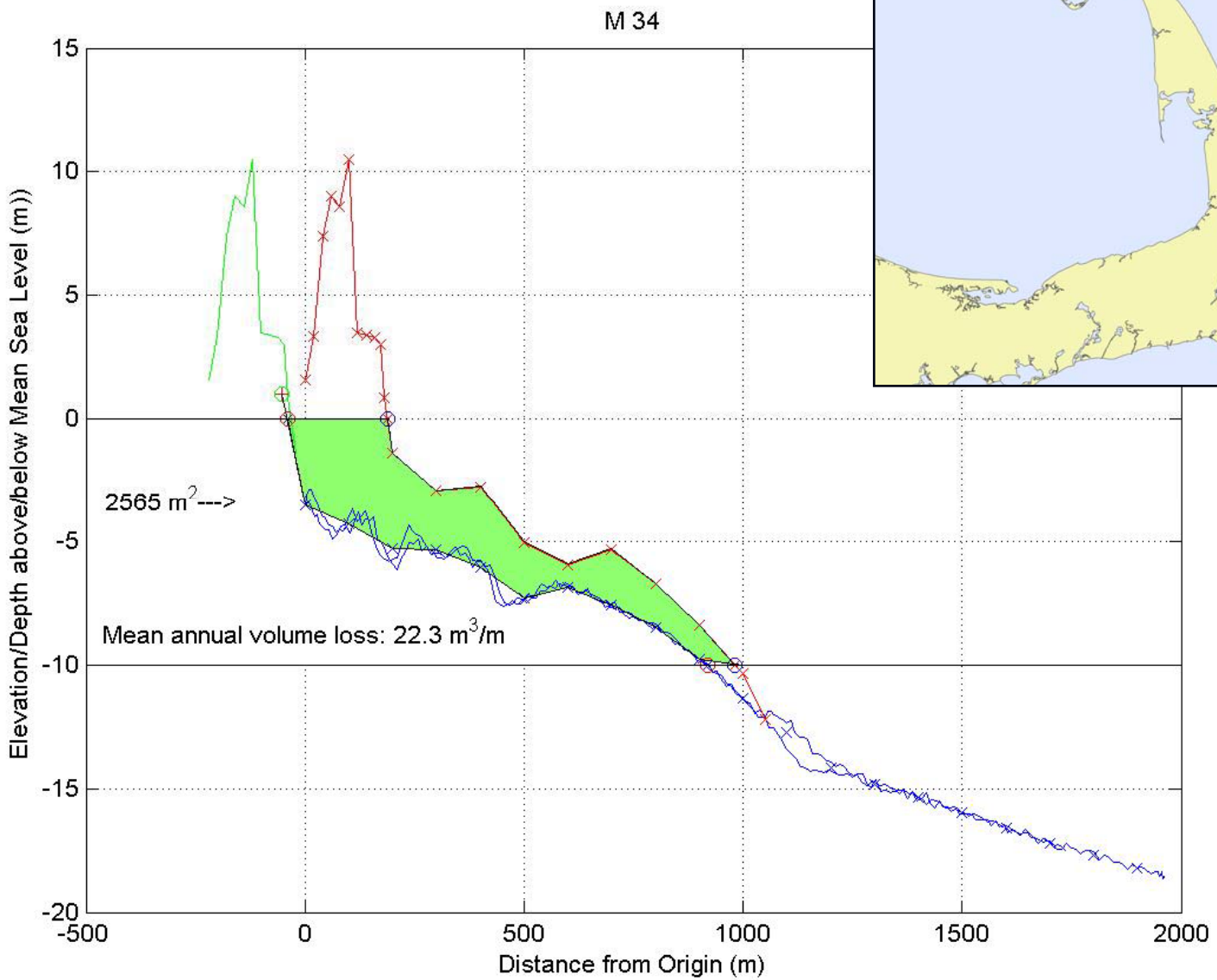
EAARL Lidar Data from 2005



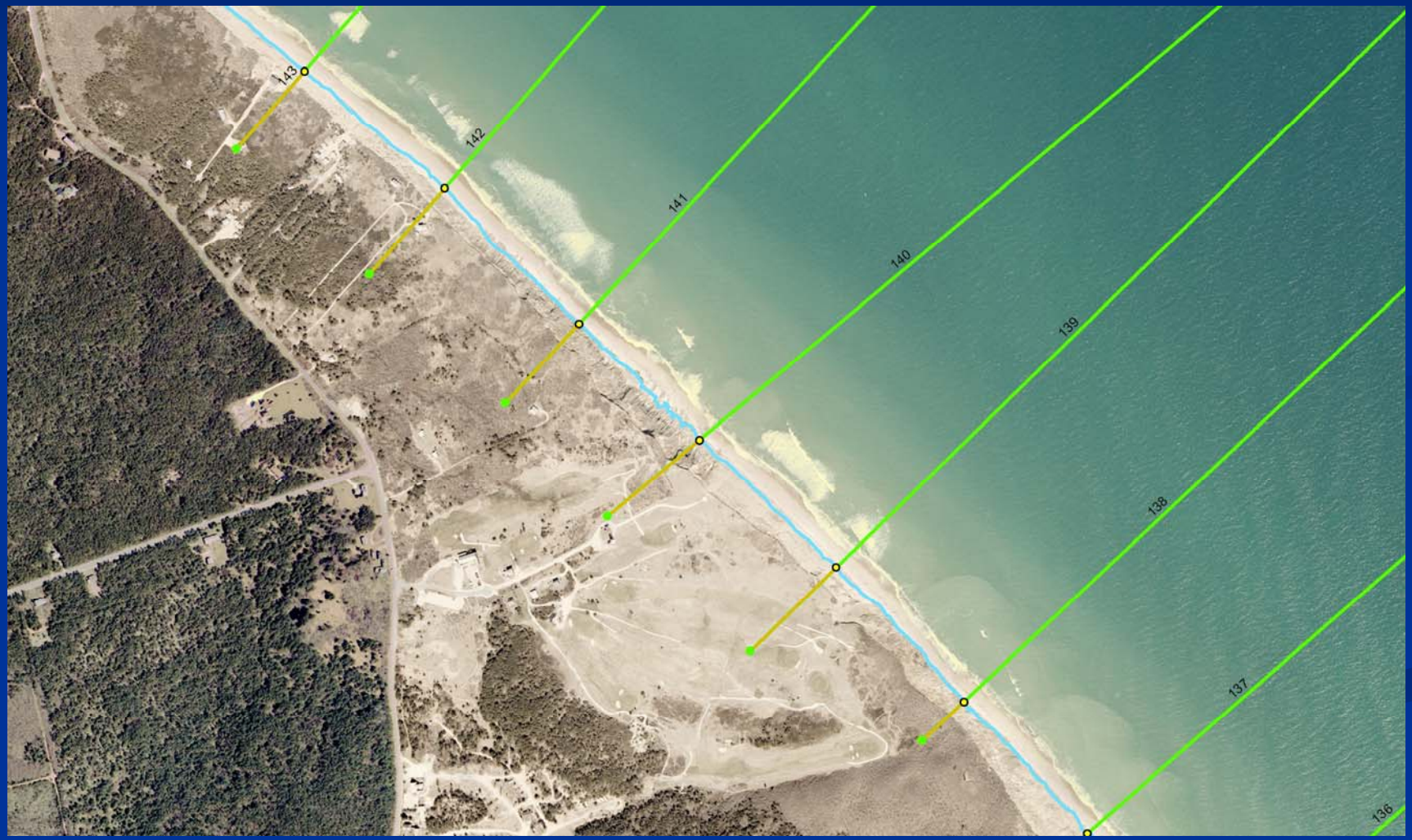
Results of Raw Data





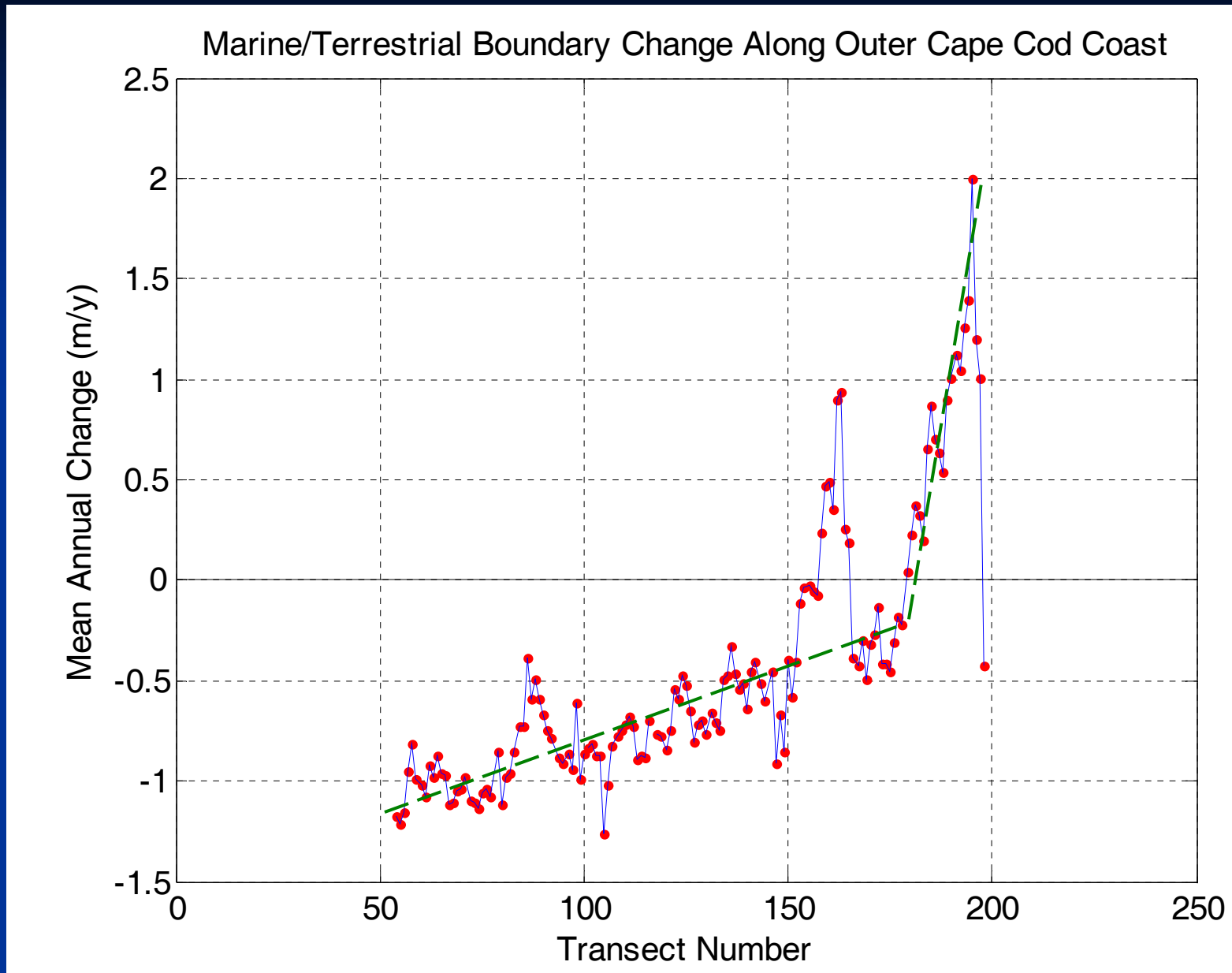

M 34
LOCUS
2565 m2--->
Mean annual volume loss: 22.3 m3/m
Elevation/Depth above/below Mean Sea Level (m))
Distance from Origin (m)
15
10
5
0
-5
-10
-15
-20
-500
0
500
1000
1500
2000

Intersect Marindin's Lines with GPS



Comparison of Landform Location

STN_ID	Est_Bluff_Toe (m)	Bluff_Toe (m)	GIS_BluffDune_Length	Difference 1890-2008
54	140		0.06	139.94
55	140		-4.02	144.02
56	180		42.24	137.76
57	240		126.64	113.36
58	140		43.27	96.73
59	65		-52.85	117.85
60		73	-47.63	120.63
61		94	-34.57	128.57
62		91	-18.49	109.49
63		102	-13.99	115.99
64		92	-12.11	104.11
65		117	2.49	114.51


Marine/Terrestrial Boundary Change Along Outer Cape Cod Coast
Mean Annual Change (m/y)
Transect Number
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
200
250

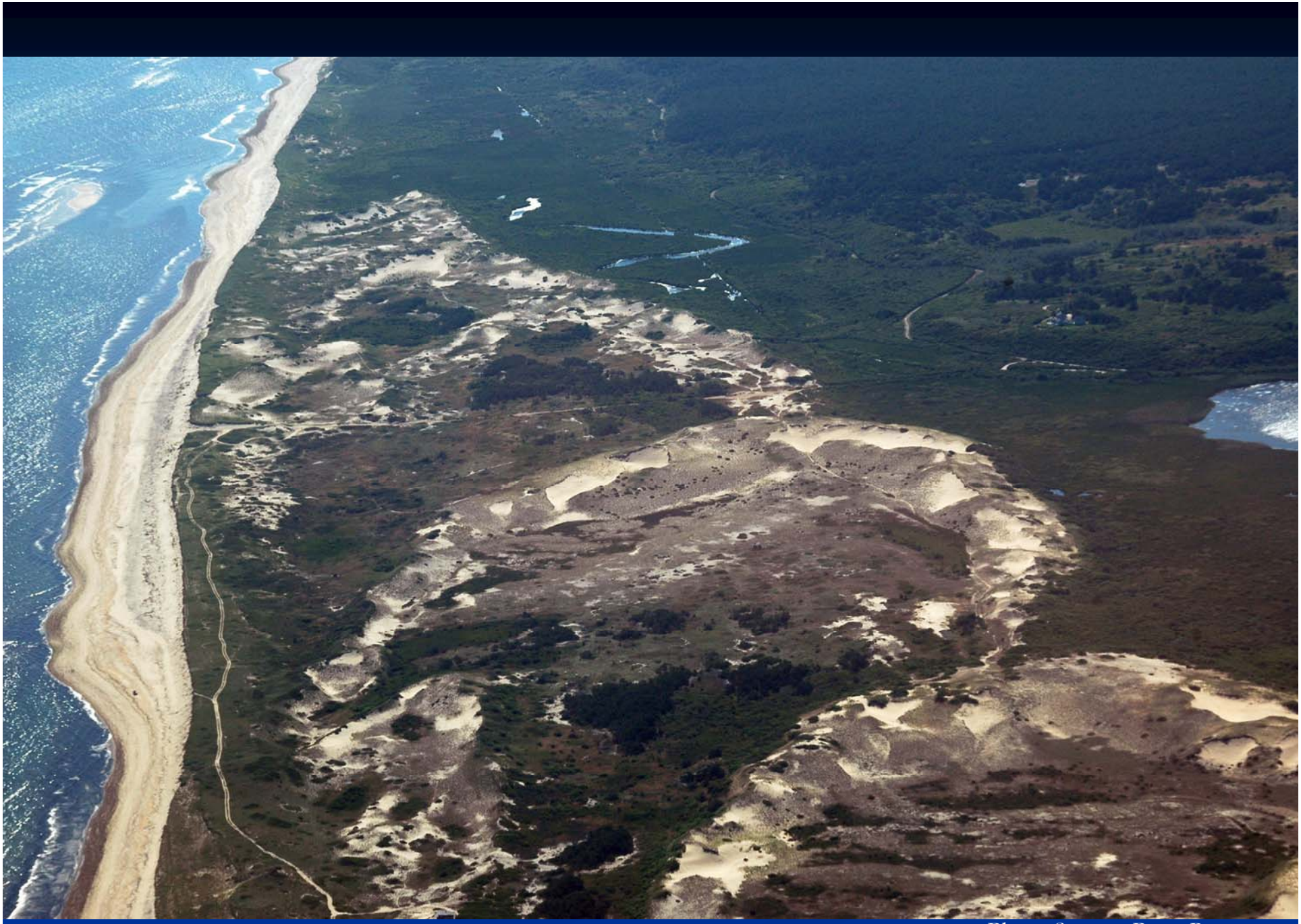
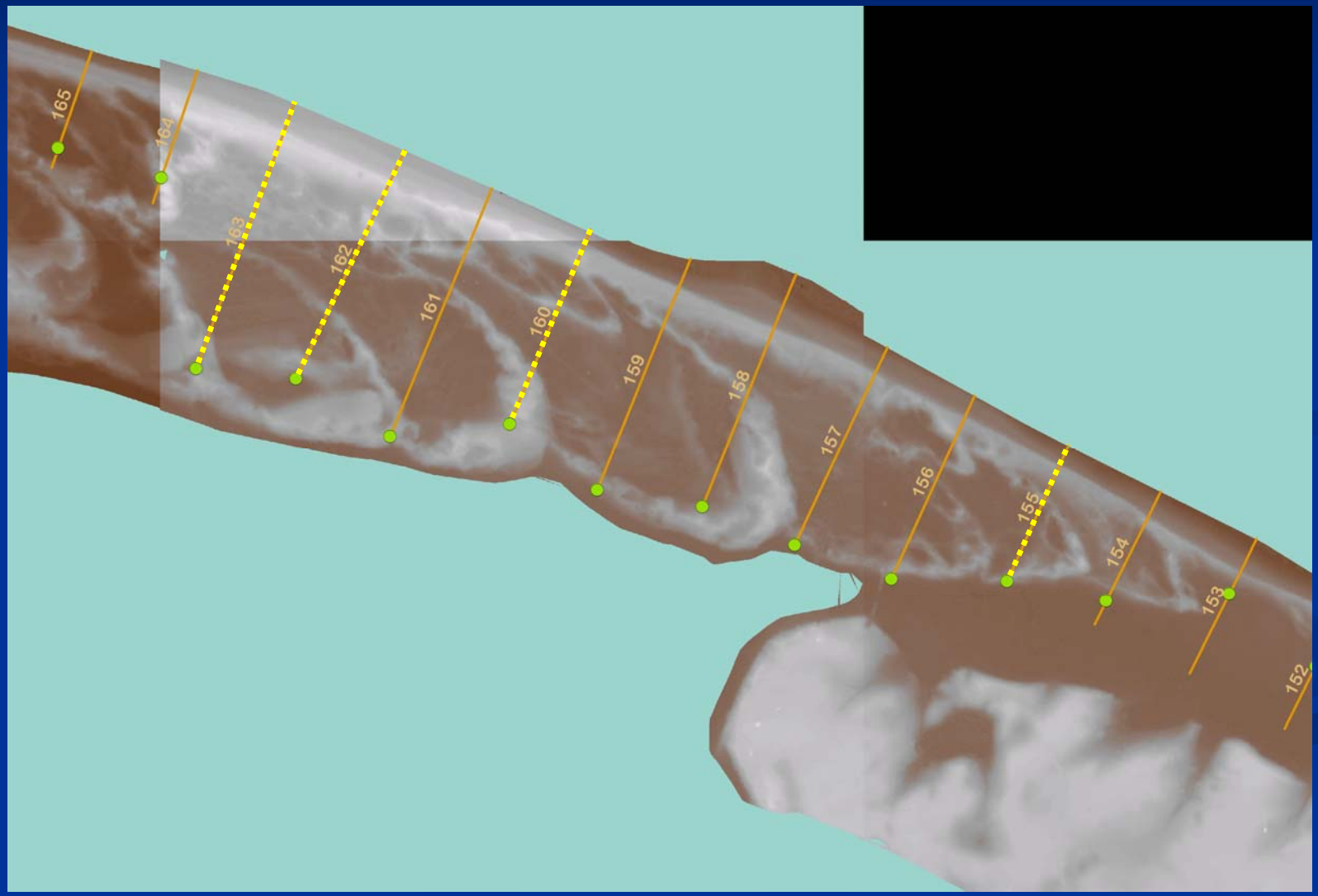
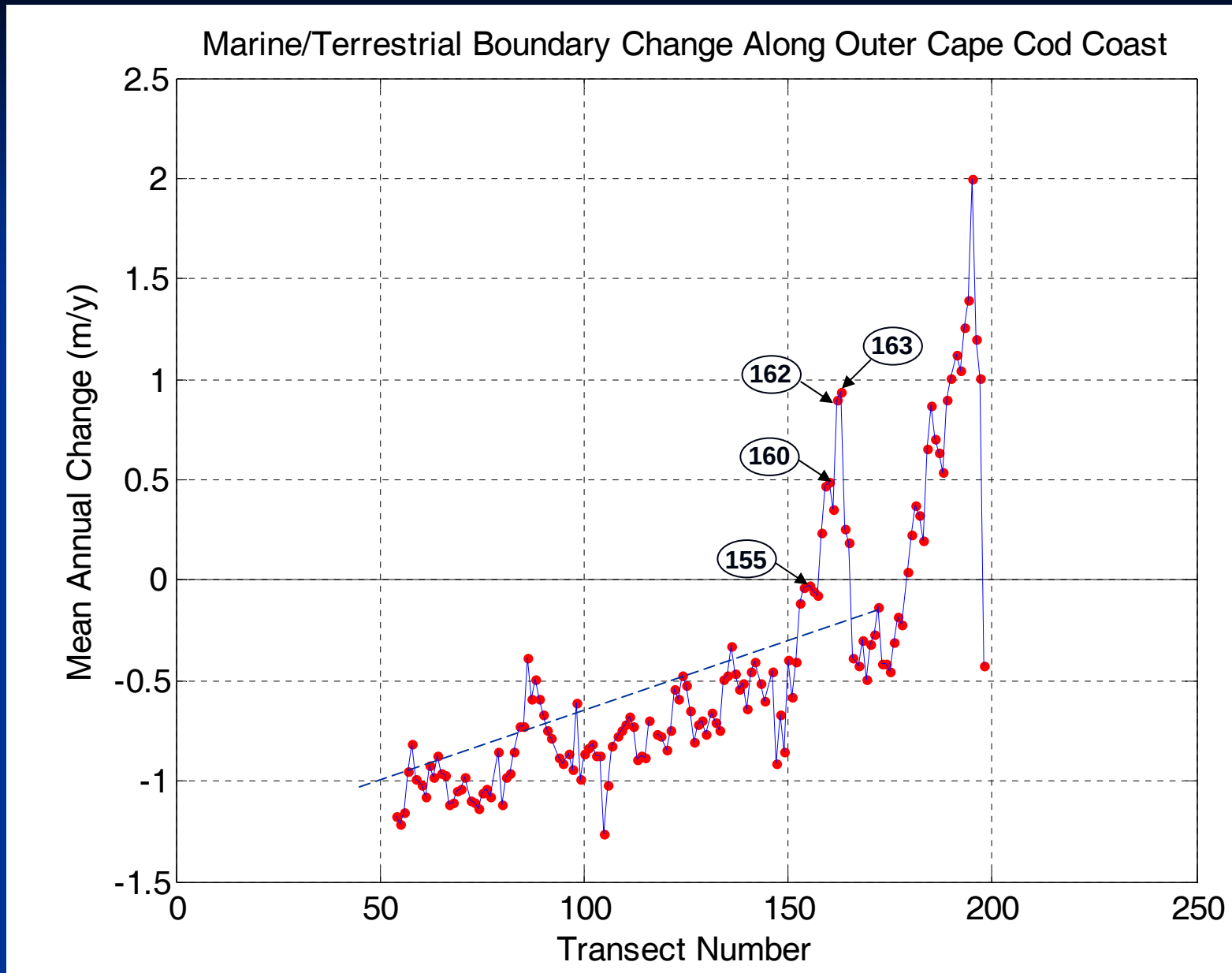
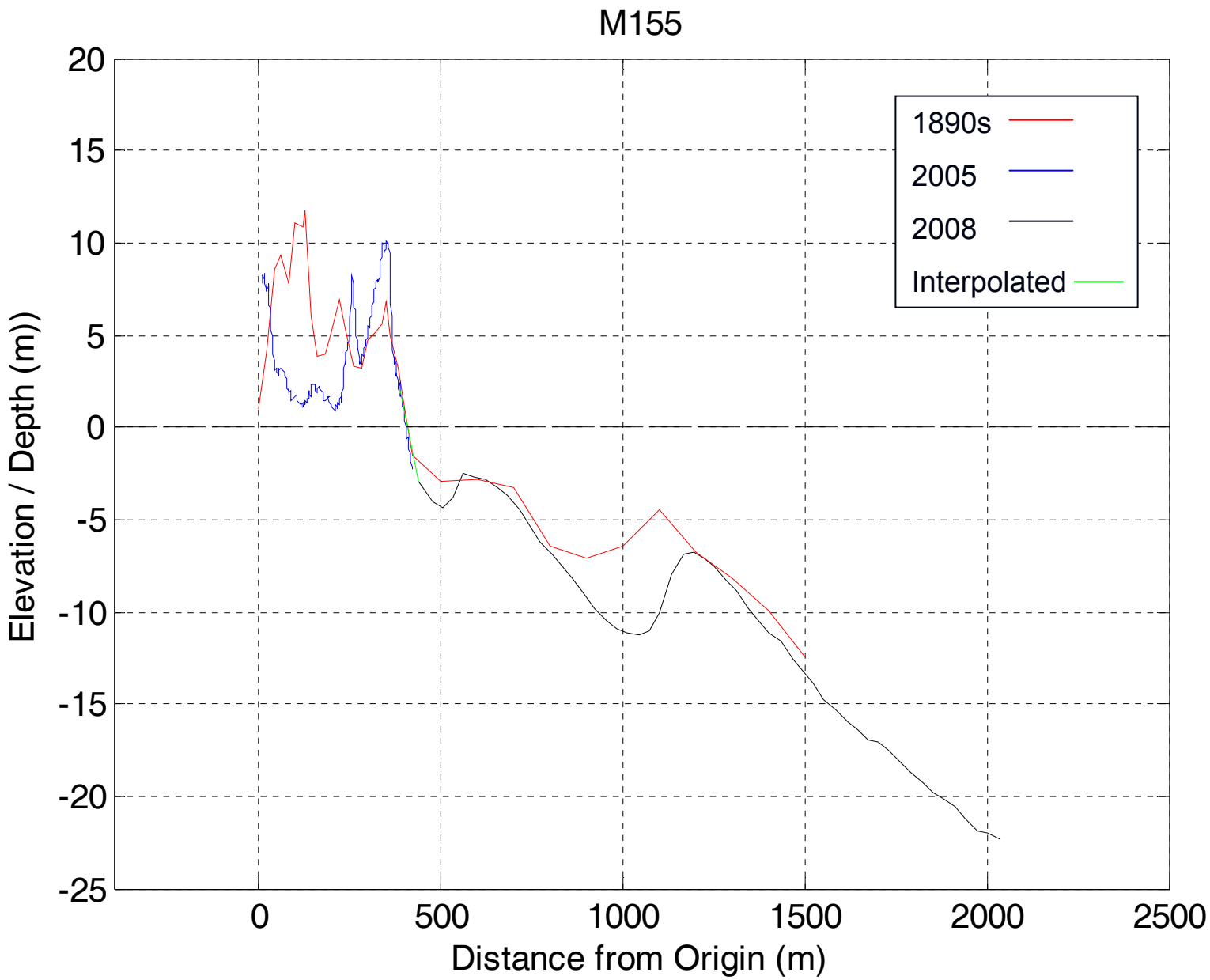


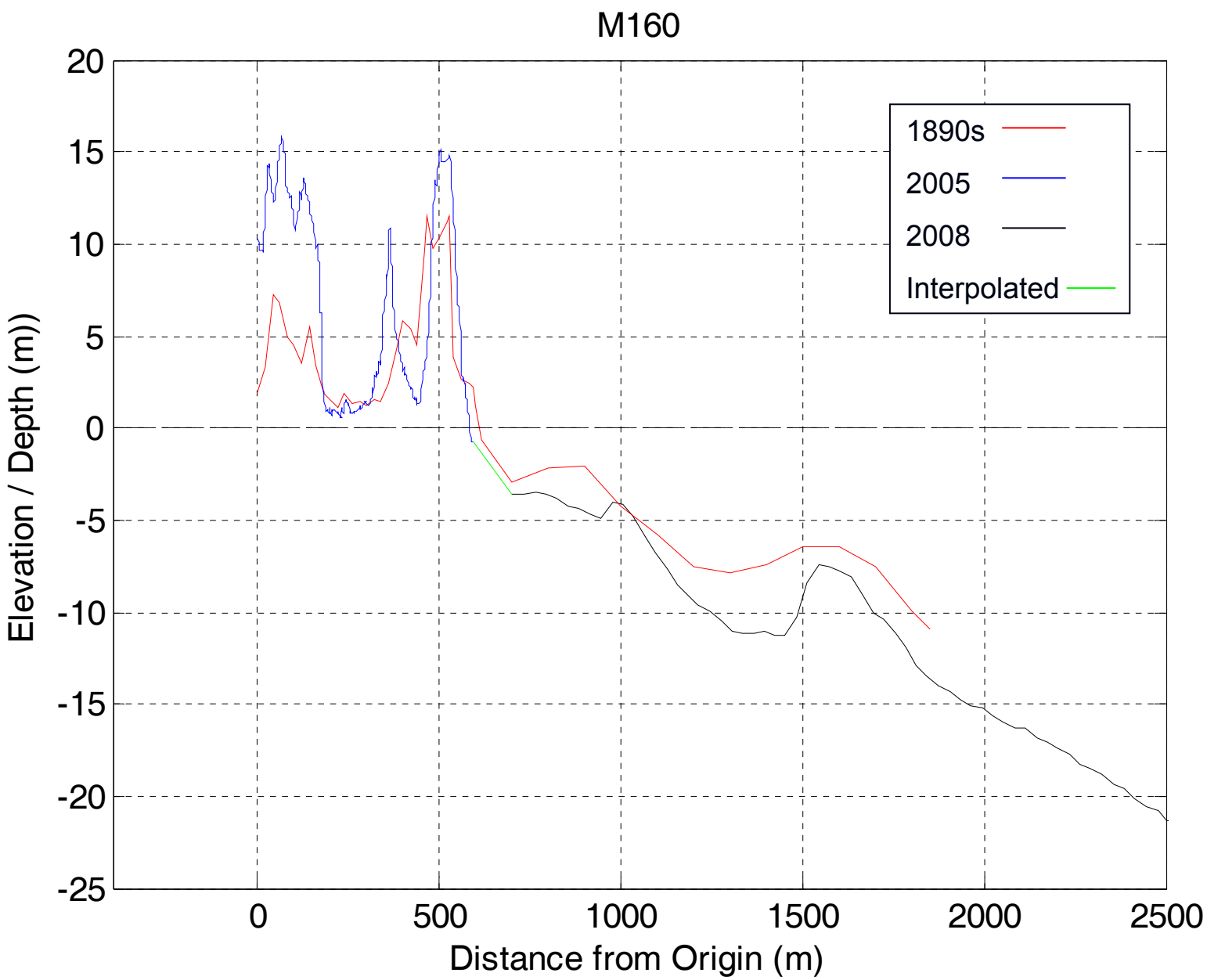
Photo Source: Peter Rosen

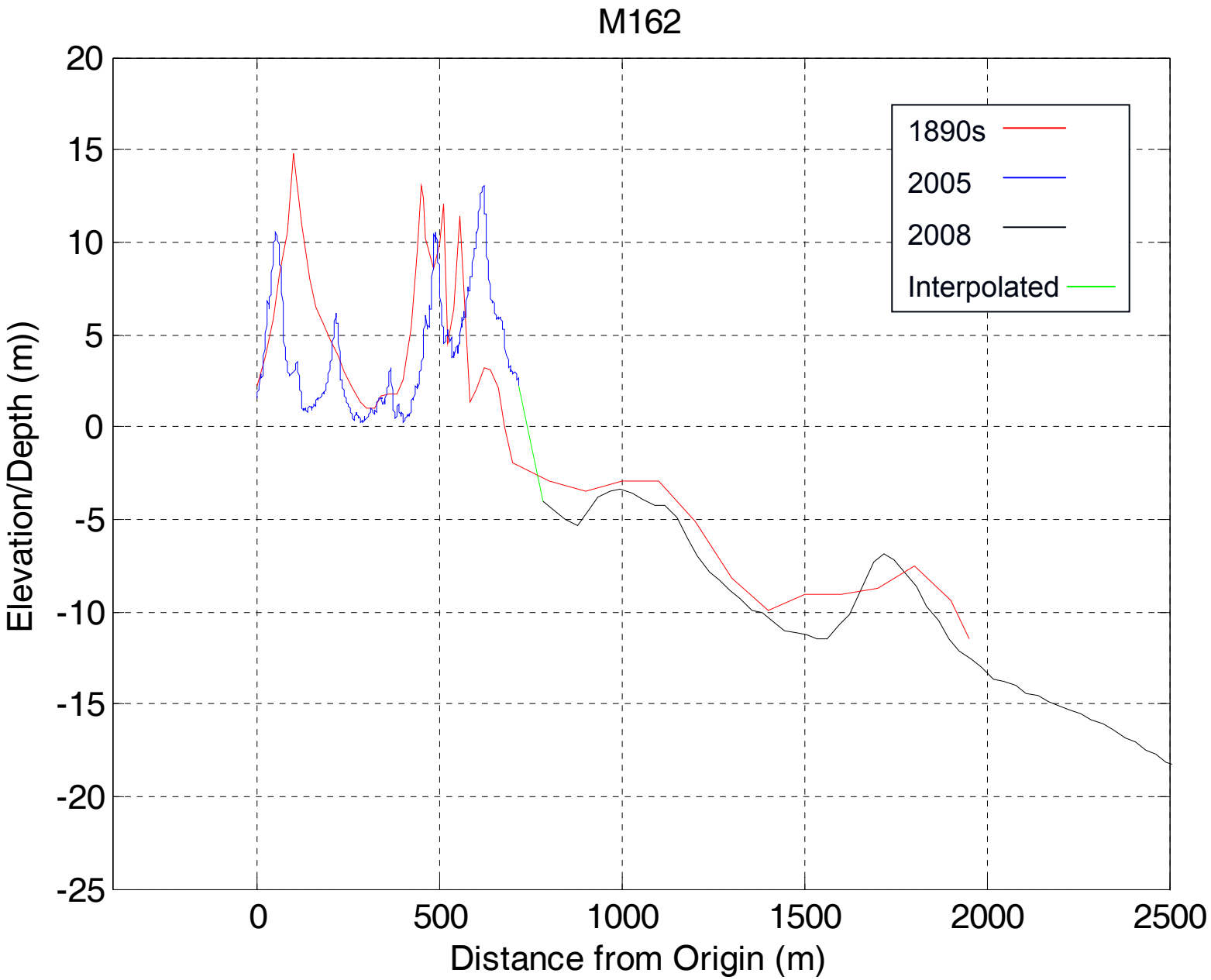
Lidar Coverage of Dune Field

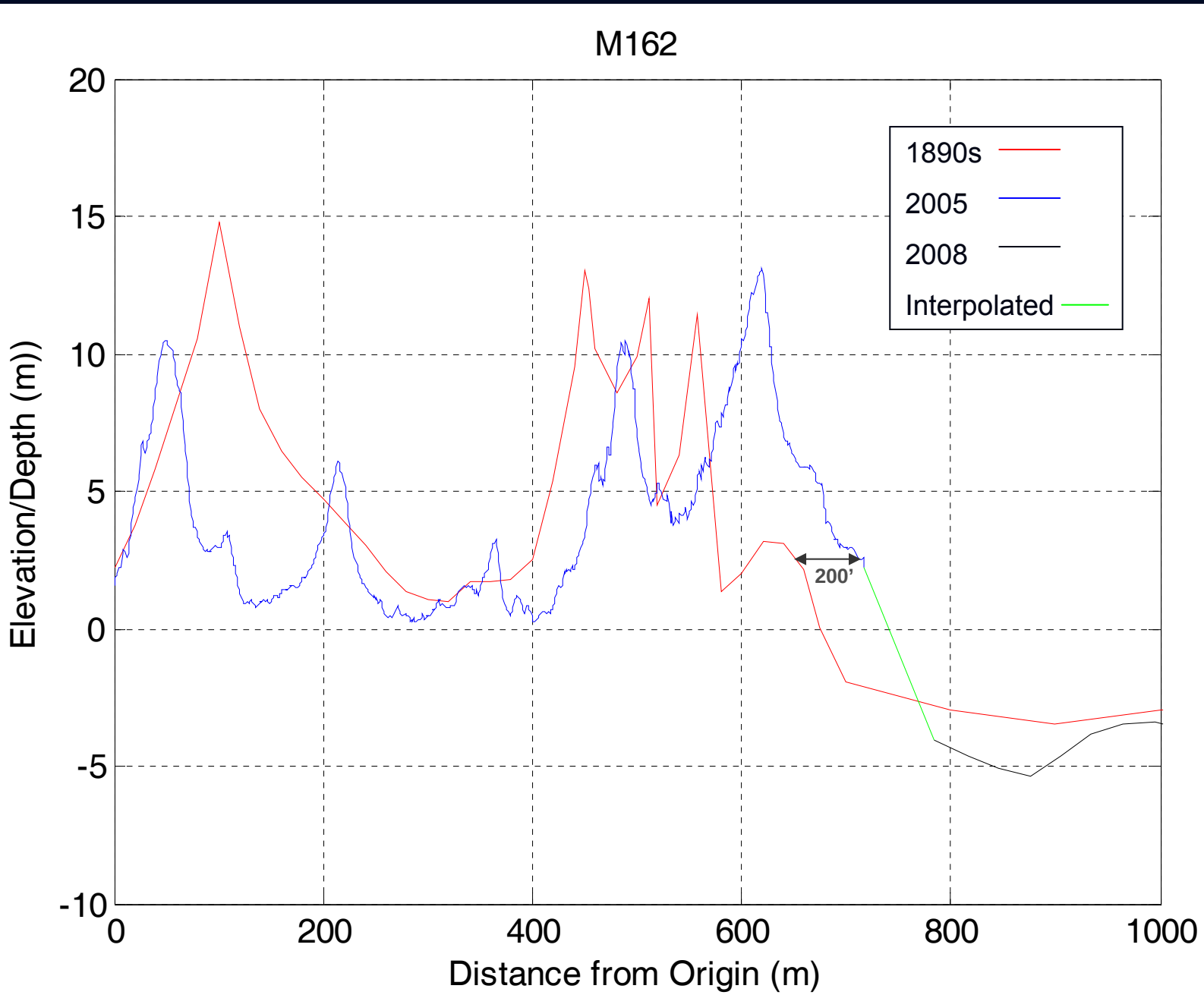


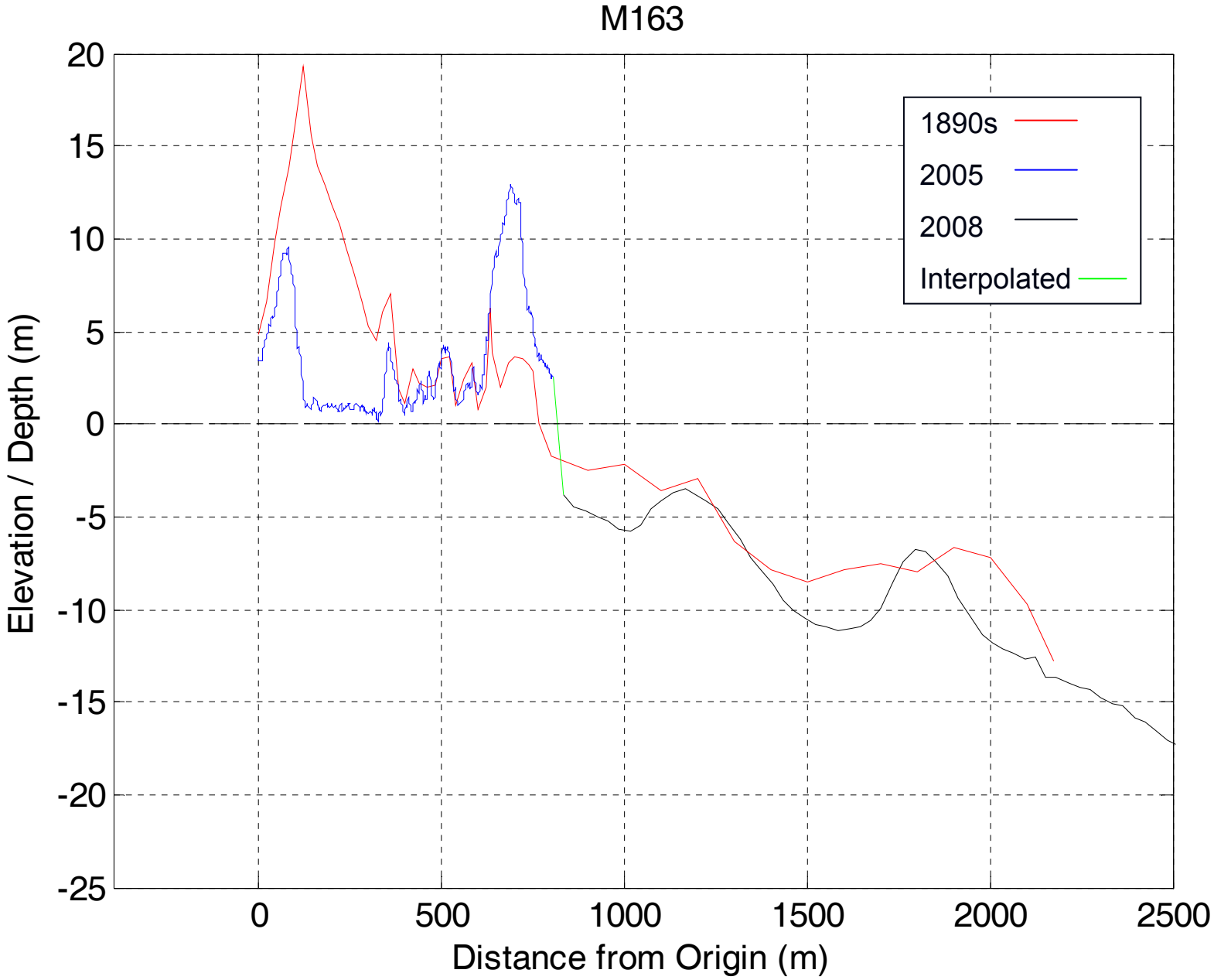

Marine/Terrestrial Boundary Change Along Outer Cape Cod Coast
Mean Annual Change (m/y)
Transect Number
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
200
250
163
162
160
155


M155
1890s
2005
2008
Interpolated
Elevation / Depth (m))
Distance from Origin (m)
20
15
10
5
0
-5
-10
-15
-20
-25
0
500
1000
1500
2000
2500


M160
1890s
2005
2008
Interpolated
Elevation / Depth (m))
Distance from Origin (m)
20
15
10
5
0
-5
-10
-15
-20
-25
0
500
1000
1500
2000
2500


M162
1890s
2005
2008
Interpolated
Elevation/Depth (m))
Distance from Origin (m)
20
15
10
5
0
-5
-10
-15
-20
-25
0
500
1000
1500
2000
2500

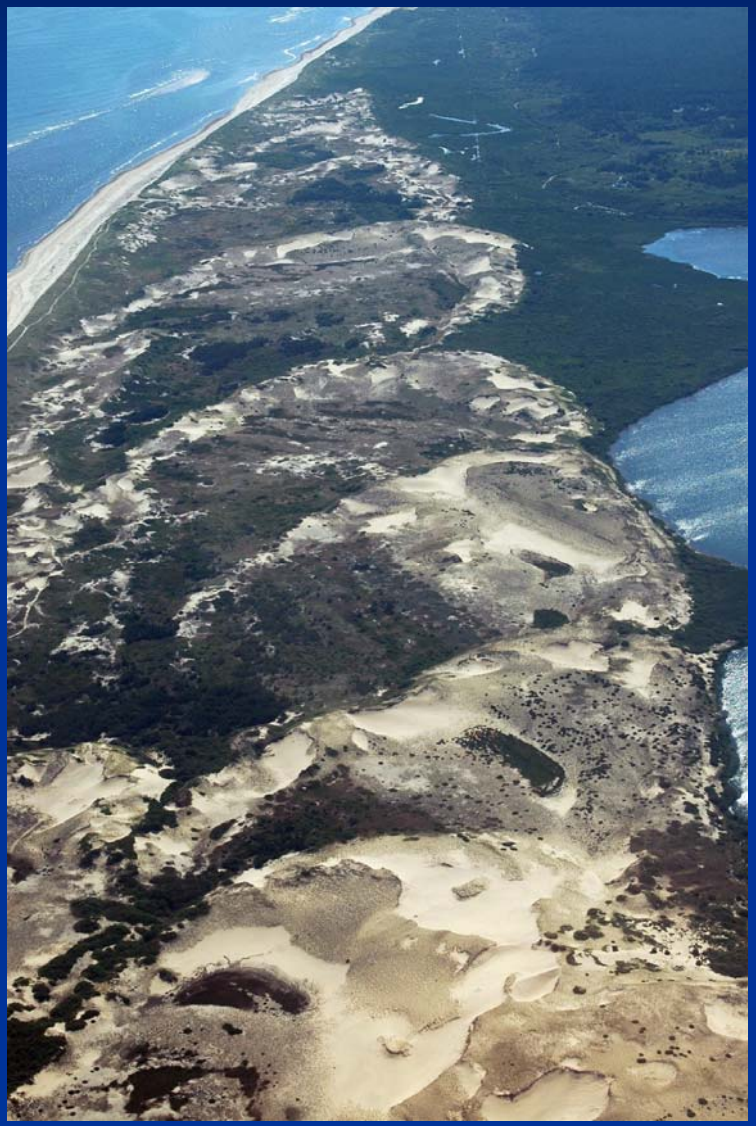

M162
1890s
2005
2008
Interpolated
200'
Elevation/Depth (m))
Distance from Origin (m)
20
15
10
5
0
-5
-10
0
200
400
600
800
1000


M163
1890s
2005
2008
Interpolated
Elevation / Depth (m)
Distance from Origin (m)
20
15
10
5
0
-5
-10
-15
-20
-25
0
500
1000
1500
2000
2500

Conclusions

- An apparent anomalous zone of shoreline growth was located off the outer Cape Cod coast.
- This growth was linked with the location of the parabolic dune field.
- The dune sand is thought to be a sediment source for the shoreline in this area.
- The contribution of the dunes to the overall system is a cross-shore element to consider in the development of a sediment model for the outer Cape Cod shoreline.

Acknowledgments



- Cape Cod National Seashore
- Provincetown Center for Coastal Studies
- Volunteers
- Cape Cod Five Cent Bank