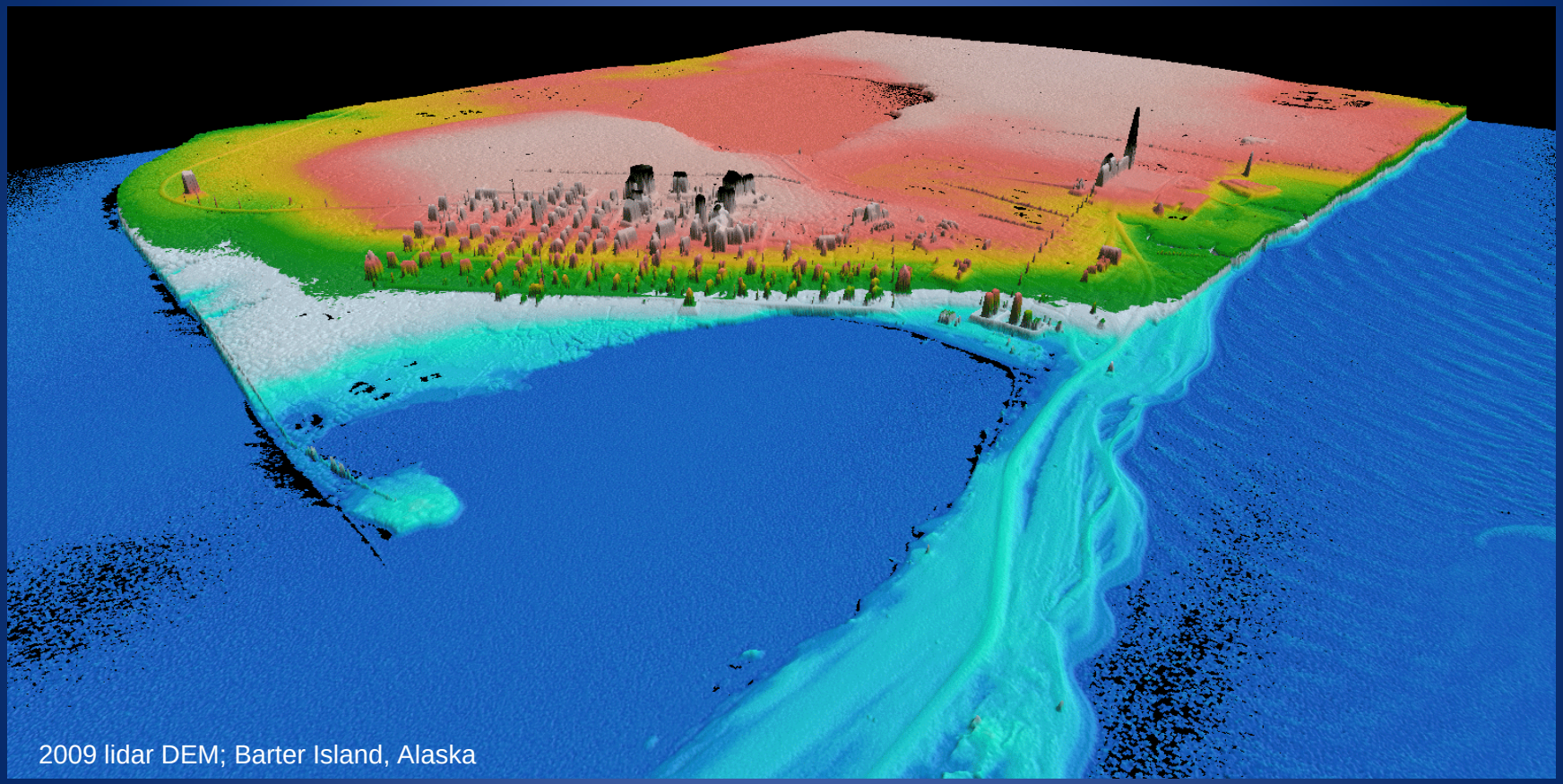
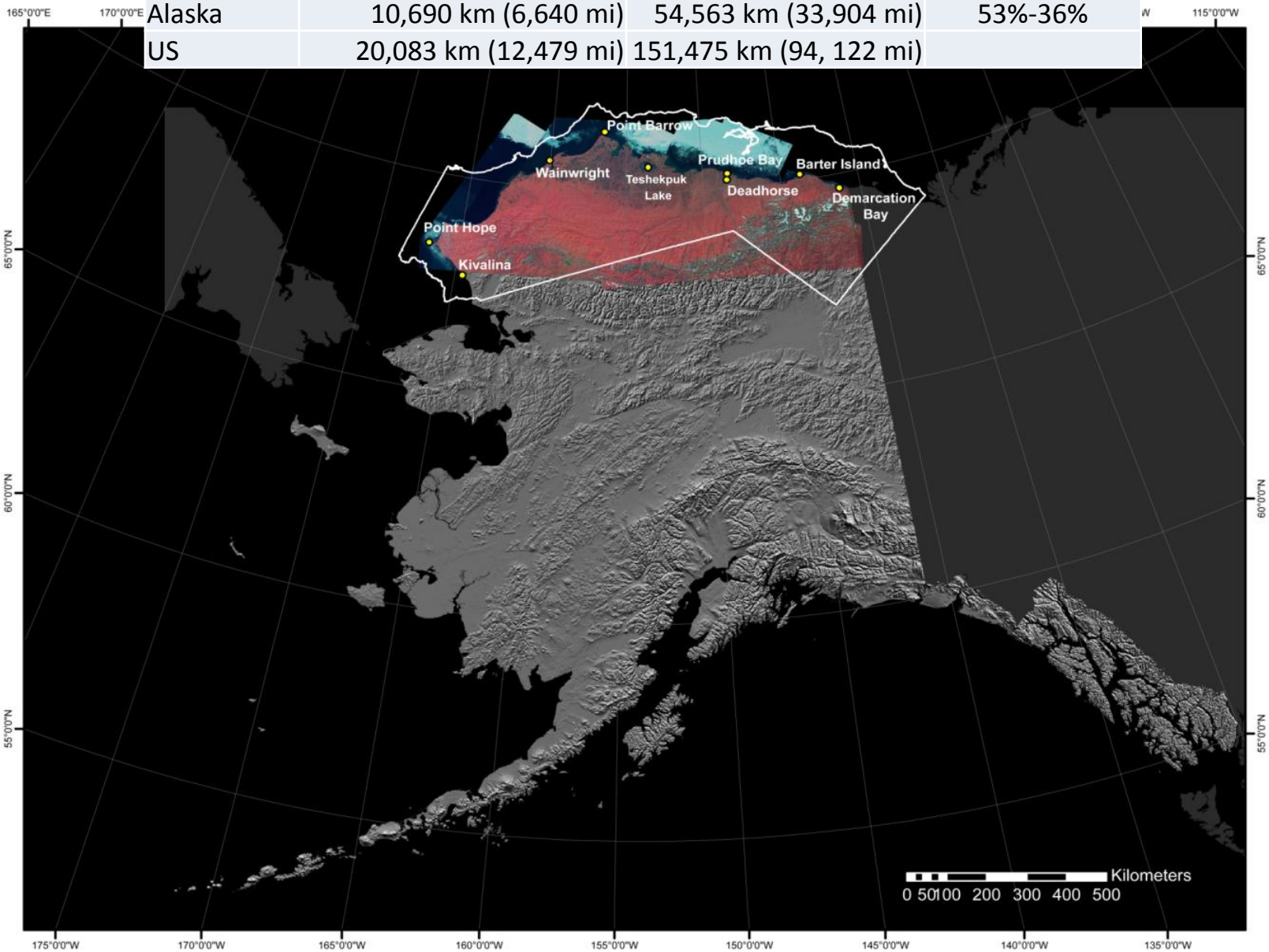
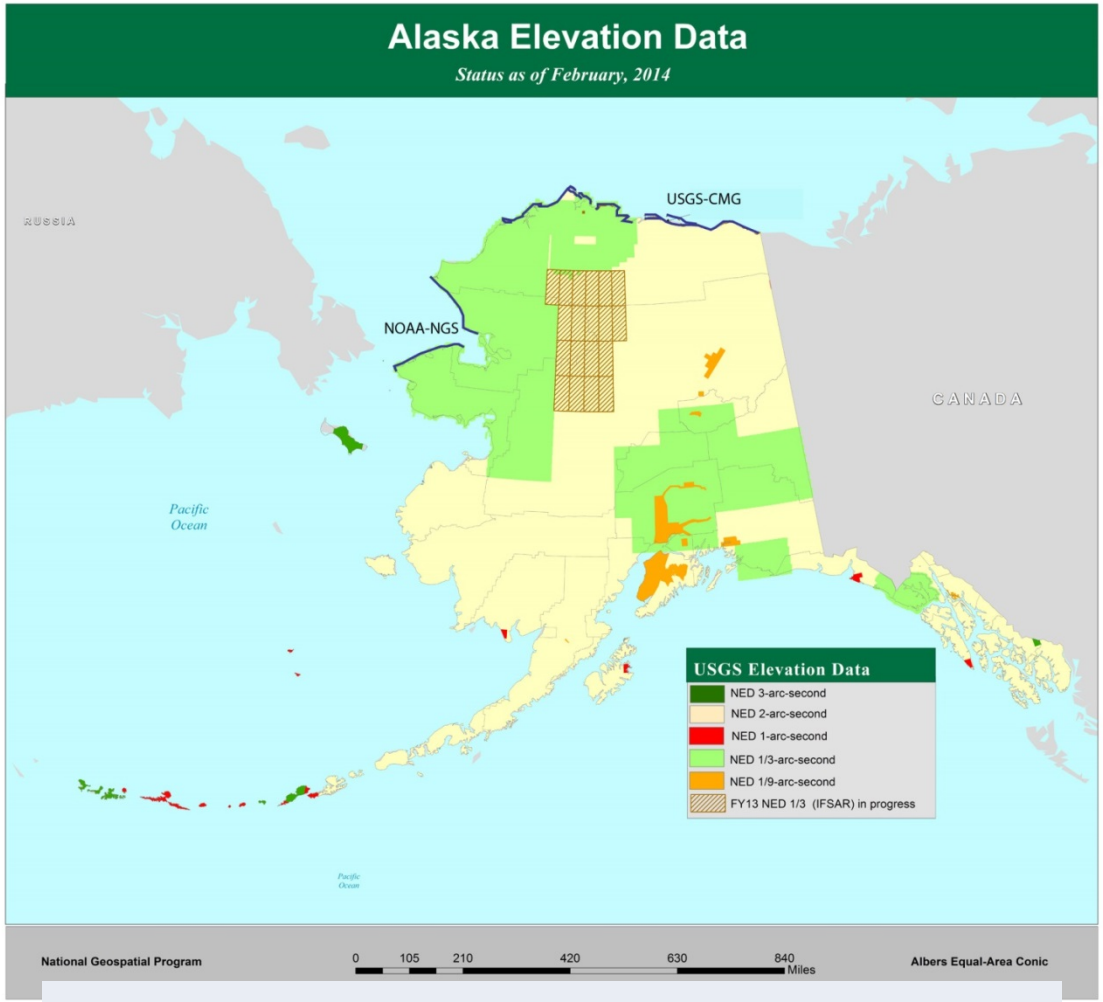
Coastal Lidar Acquisition in Alaska
Challenges and Opportunities

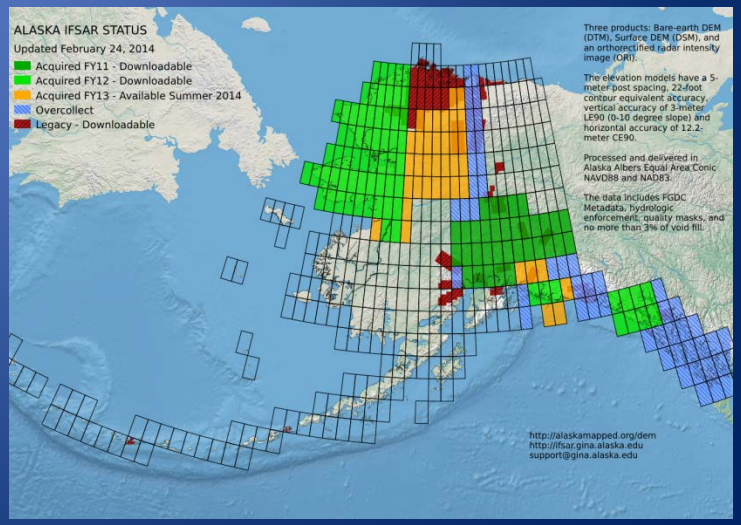

2009 lidar DEM; Barter Island, Alaska

Ann Gibbs (agibbs@usgs.gov)
USGS Pacific Coastal and Marine Science Center
Santa Cruz CA

Coastline Length (NOAA, +/- tidal areas)			
	Method 1	Method2	% of US coast
Alaska	10,690 km (6,640 mi)	54,563 km (33,904 mi)	53%-36%
US	20,083 km (12,479 mi)	151,475 km (94, 122 mi)	

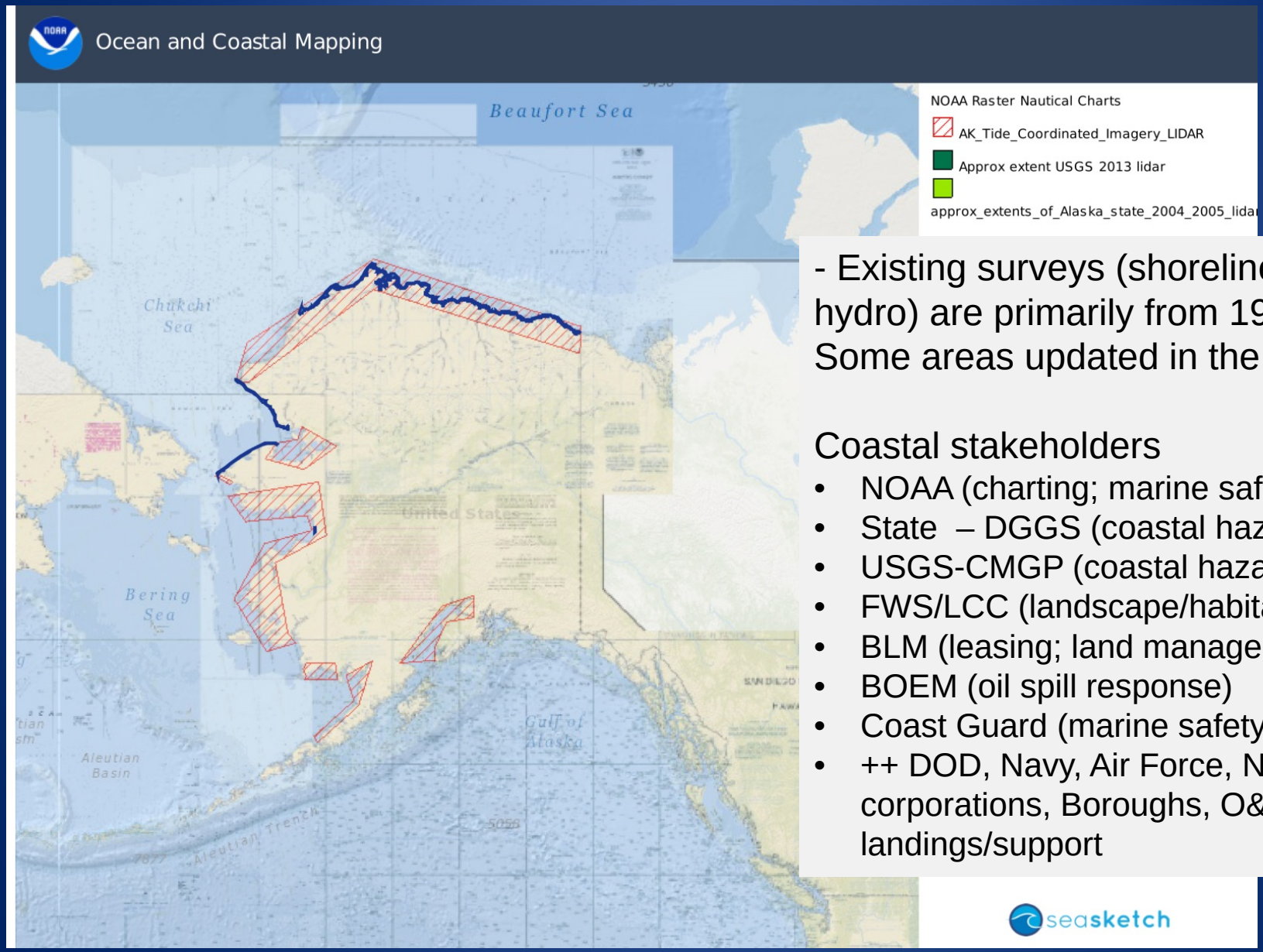






- Prior to ~ 2002 = 1-arc second (~30 x 60-m post spacing product from 1950s aerial photography)
- 2002+, IfSAR = 1/3 arc-second (QL5; 5 m posting, 12 m HA, ~ 3 m VA)
- 2004-2012+,Topo Lidar (= 1/9 arc-second (QL2.5; 1-2 m nominal point spacing; <25 cm V)

Increasing need for updated shoreline surveys and high-resolution coastal elevation data (hydro too)

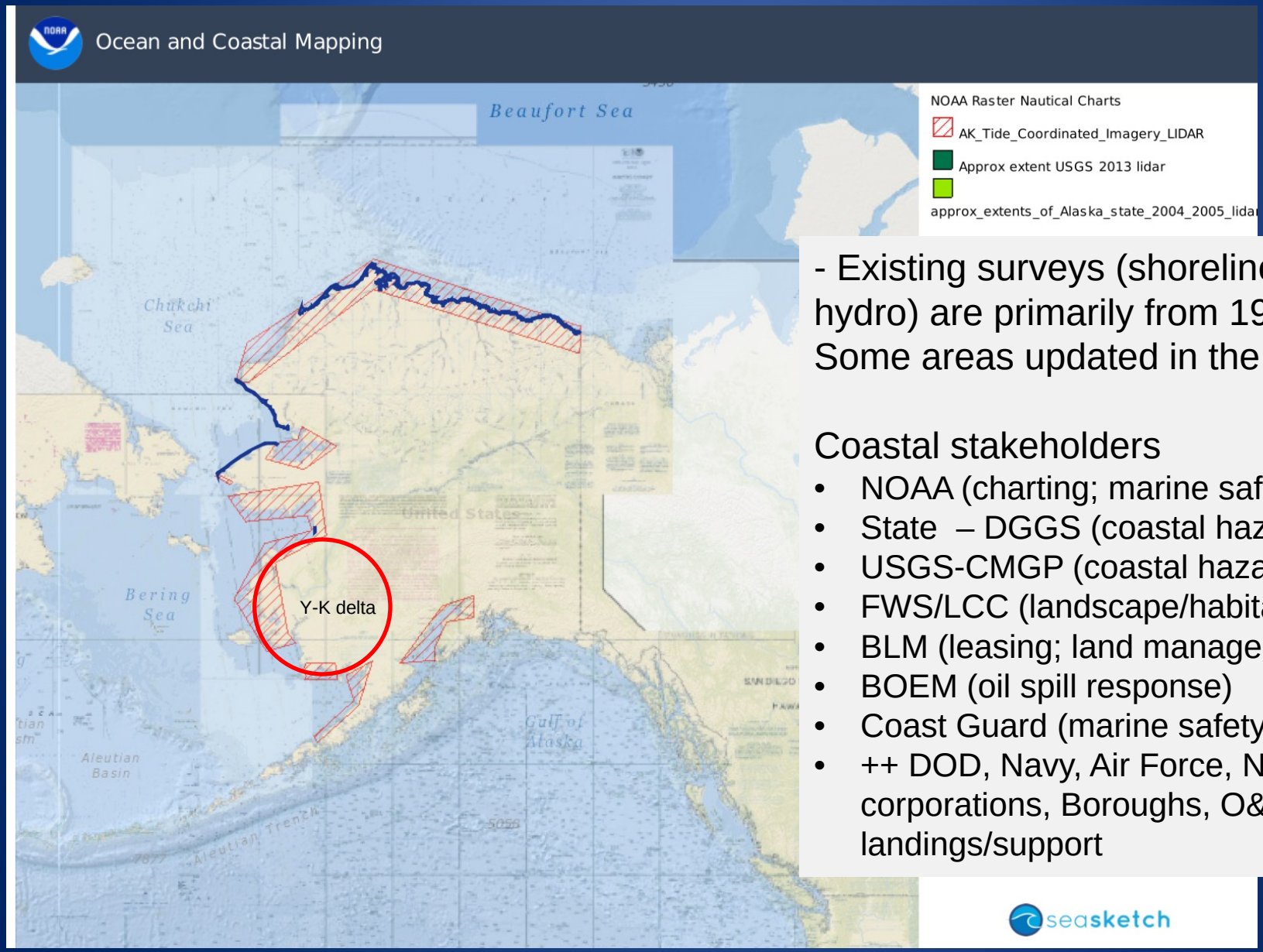


- Existing surveys (shoreline and hydro) are primarily from 1940s. Some areas updated in the 1980s.

Coastal stakeholders

- NOAA (charting; marine safety)
- State – DGGS (coastal hazards)
- USGS-CMGP (coastal hazards)
- FWS/LCC (landscape/habitat change)
- BLM (leasing; land management)
- BOEM (oil spill response)
- Coast Guard (marine safety)
- ++ DOD, Navy, Air Force, Native corporations, Boroughs, O&G landings/support

Increasing need for updated shoreline surveys and high-resolution coastal elevation data (hydro too)



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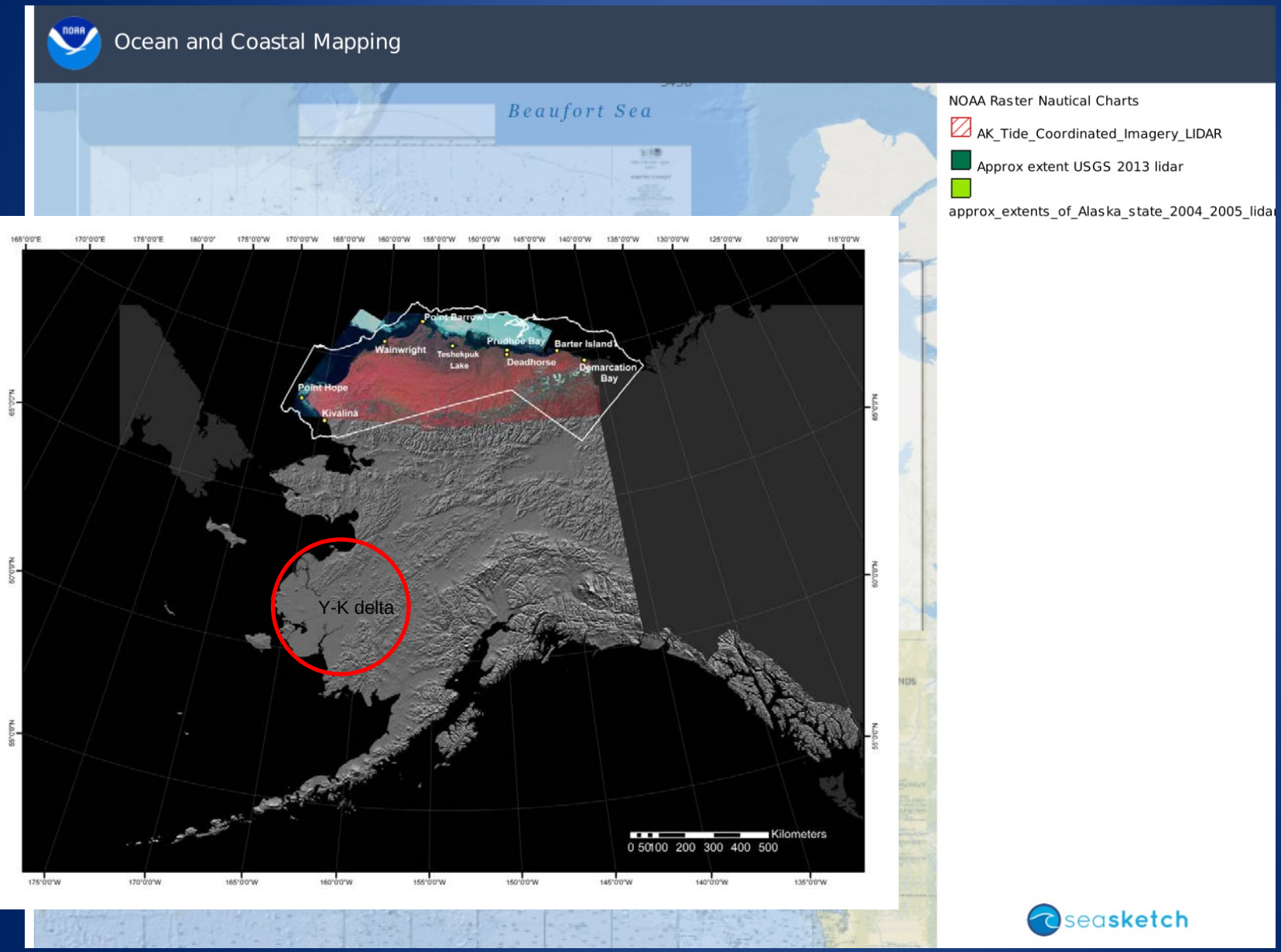
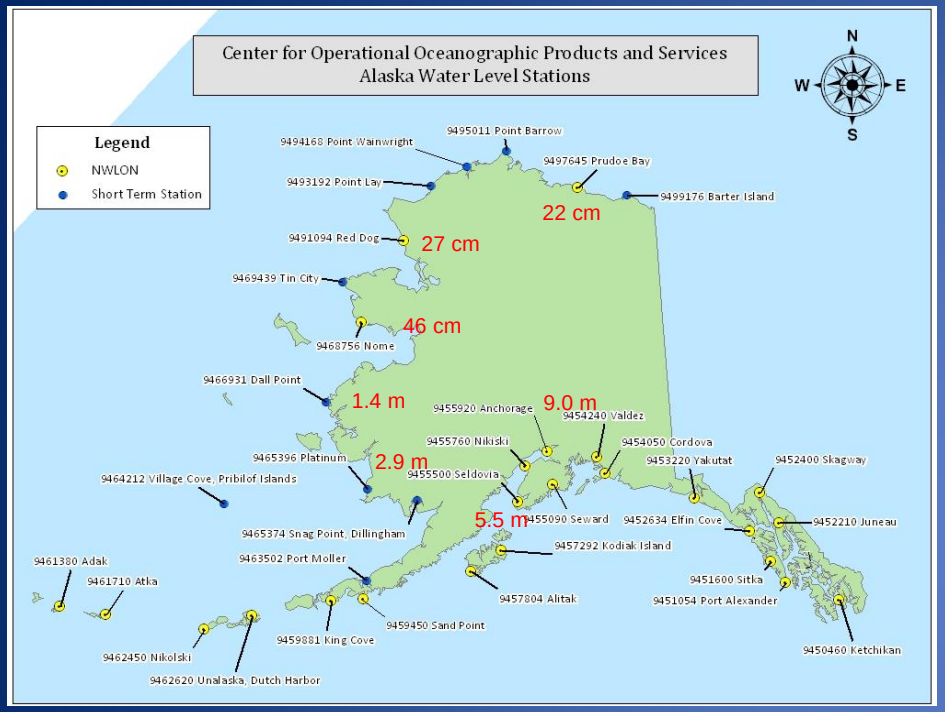


Coastal Surveying Challenges

- Wow! That's a lot of land!
- Remote, with minimal infrastructure
  - Few roads
  - Few airstrips (fuel, lodging, support, GPS control)
- Technically and logistically expensive
- ~ 3 month survey window (landfast ice, snow, fog, storms)
- Coincident with hurricane season (July-Sept)
- Permitting!
- Water level issues
- Geodetic issues

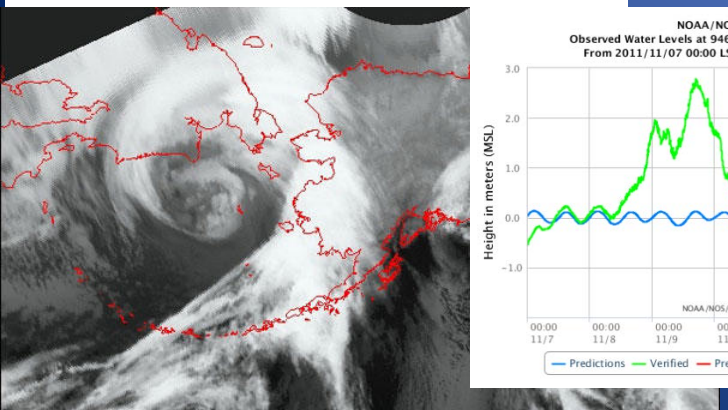
Coastal Surveying Challenges

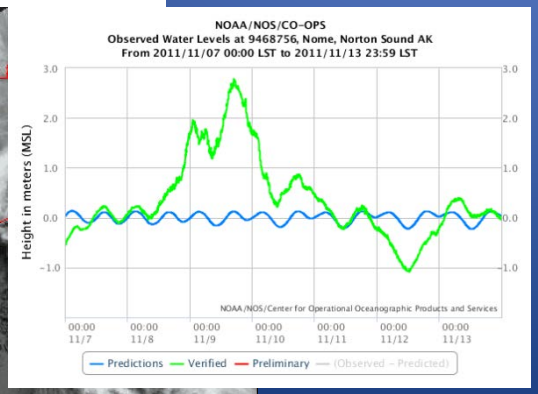
Water Levels

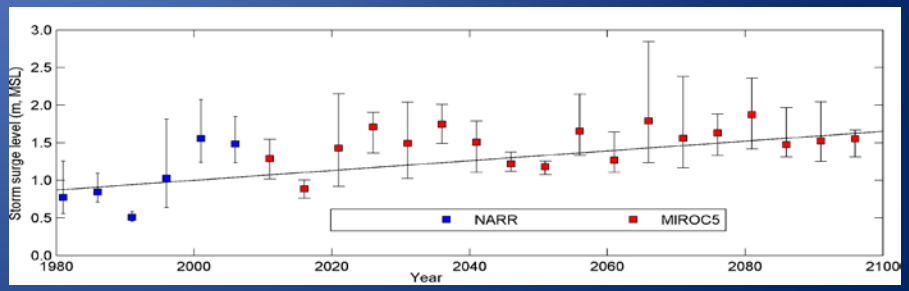


- Limited historic or current water level information
  - One continually recording tide gauge for entire north slope at Prudhoe Bay
  - Three permanent gauges north of Aleutian Islands
  - Arctic tidal ranges are small (diurnal range from 0.2 – 0.5 m)
  - Storm surge and local winds can elevate or decrease water levels by 2-4 m.

Nov. 2011 Bering Sea “Superstorm”



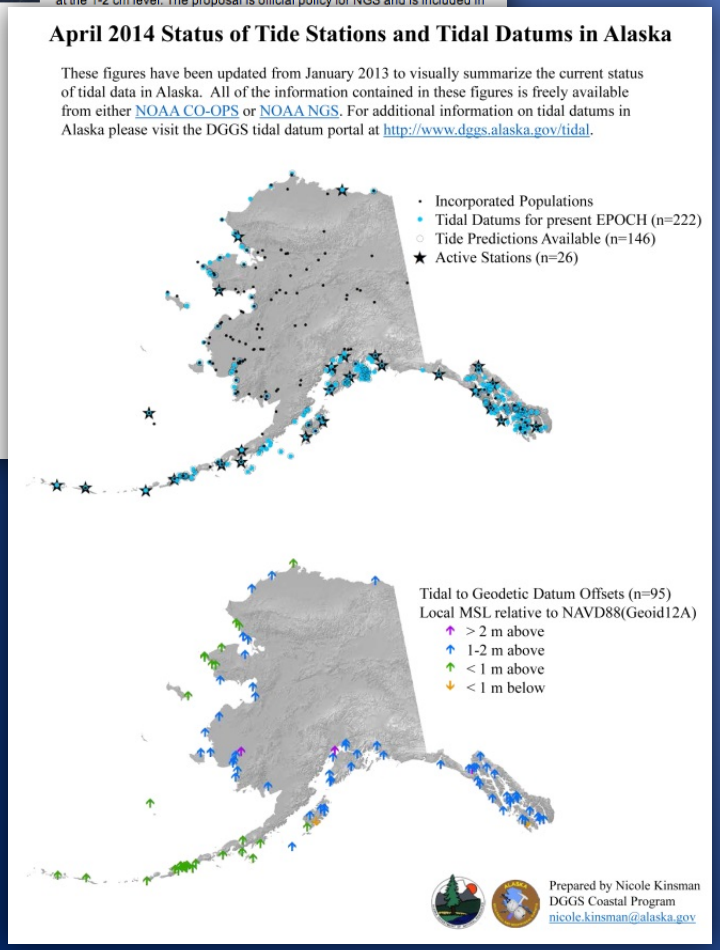




Extreme storm surge levels. Hindcast (NARR; 1981-2010) and projected (MIROC5; 2010-2100) total storm surge levels at Arey Lagoon in response to spatially and temporally varying wind and sea-level pressure fields.

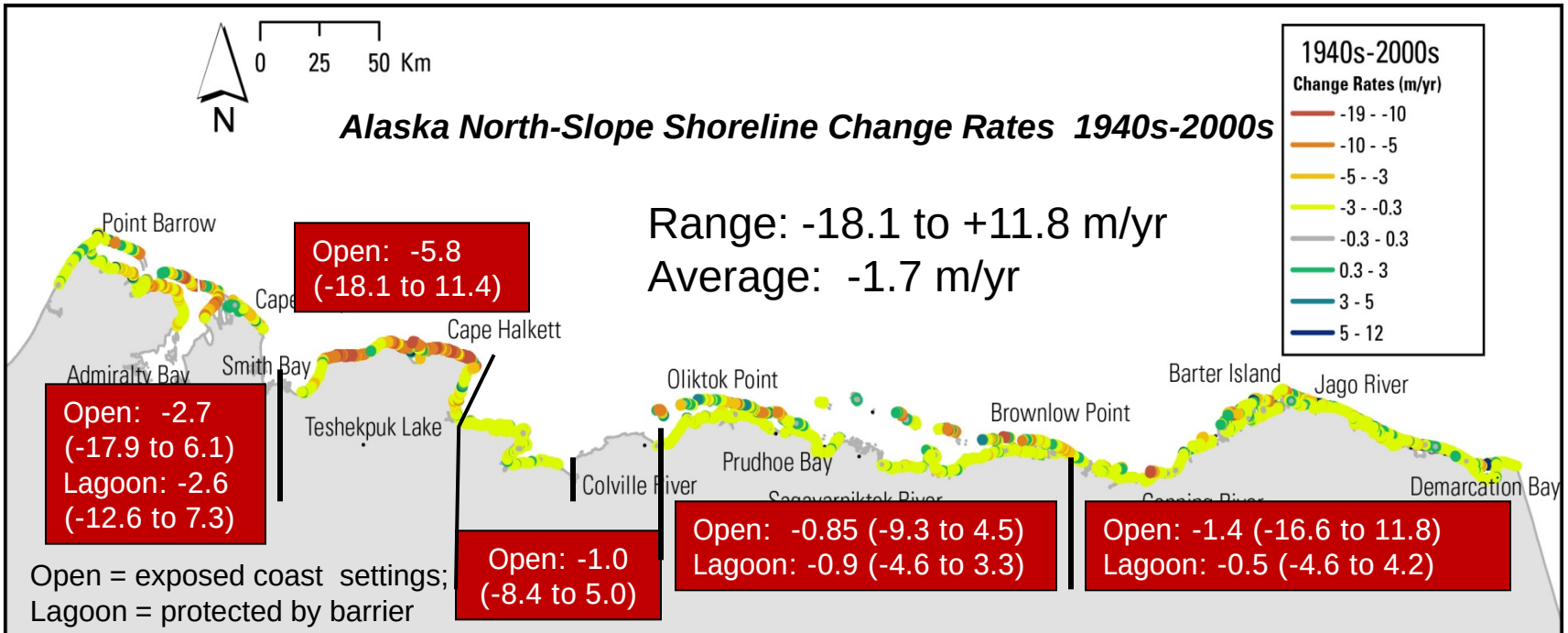
Coastal Surveying Challenges

Geodetic Issues



- Poor GEOID model statewide
  - Inhibits development and use of elevation data sets
  - NOAA/NGS currently working on improved GEOID via GRAV-D project (North Slope)
- Limited geodetic control, especially vertical, associated with tidal datums and lacking ties to ellipsoid elevations.
  - Inhibits determination of a tidally correlated shoreline positions, coastal inundation and hazard mapping.

Is coastal lidar acquisition worth it?



- Rapid changes to the coastal landscape (e.g. erosion, inundation extents, shifting habitats) are being observed along the Alaska coast and will likely increase with the effects of climate change (e.g. longer ice-free season, increased atmospheric, land, and water temperatures, more frequent and stronger storms).
- Despite the water level and geodetic issues that that exist in Alaska, higher resolution coast and nearshore elevation (bathy) data will greatly improve the ability to assess , model, and manage coastal hazard and ecosystem changes and also carbon contribution to the ocean and atmosphere.
- Uncertainty levels associated with models and assessments will decrease with improved baseline elevations, especially once the issues are resolved.

North Slope of Alaska Coastal Lidar Survey

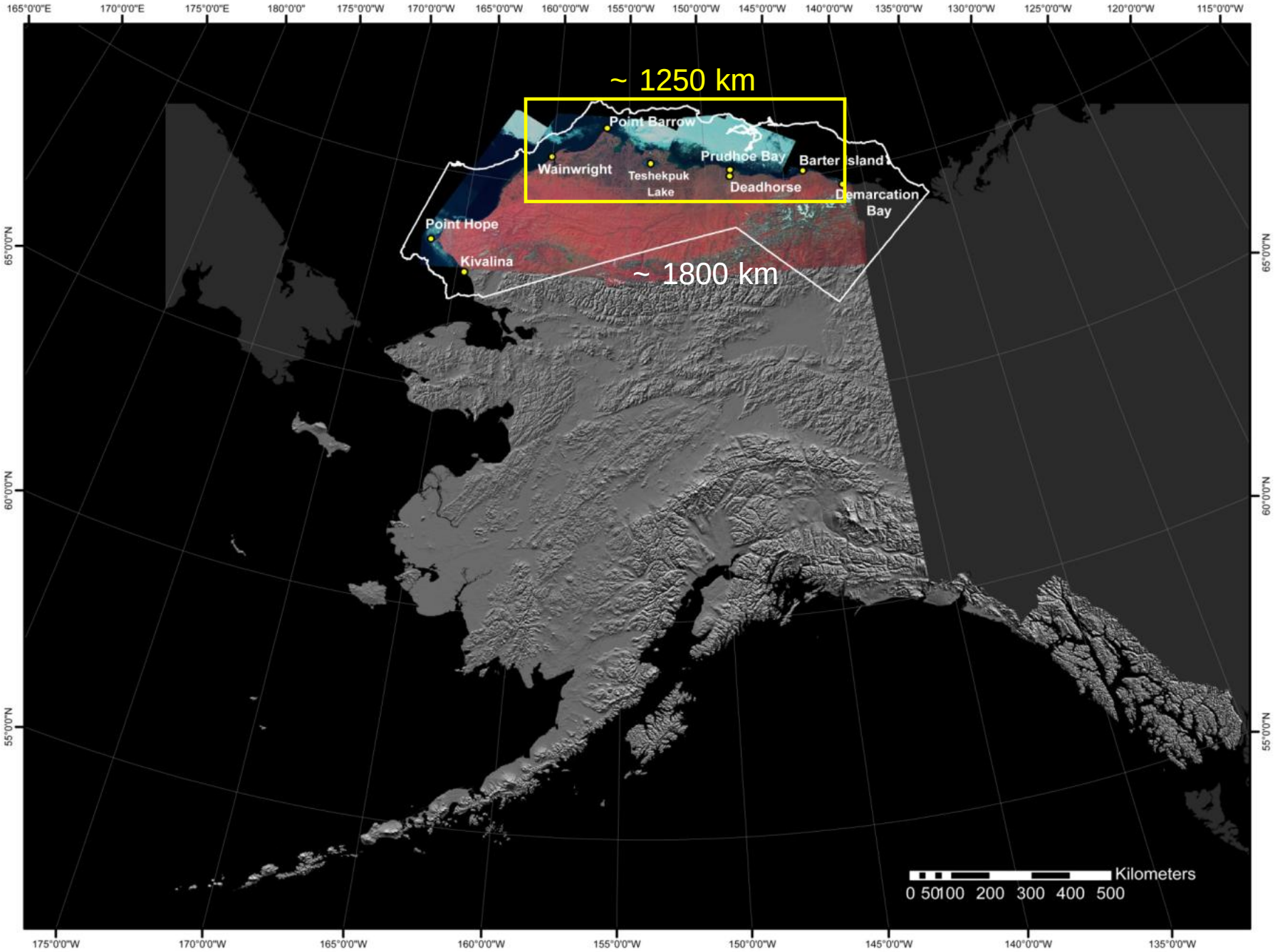
Initially acquired in support of the USGS/CMGP National Assessment of Shoreline Change project

Precisely document the current state of the north coast of Alaska (Icy Cape to the Canadian border) by collecting a benchmark high-resolution elevation / image data set and creating a derivative coastal Digital Elevation Model (DEM).

Produce quantitative maps upon which future change can be measured accurately on a regional scale.

Model future shoreline change and coastal inundation of a barrier island/lagoon system in response to climate change.

Evaluate the relationship between geomorphology and rates and patterns of coastal change along a permafrost coast


~ 1250 km
~ 1800 km
Point Barrow
Wainwright
Teshekpuk Lake
Prudhoe Bay
Barter Island
Deadhorse
Demarcation Bay
Point Hope
Kivalina
Kilometers
0 50 100 200 300 400 500
165°0'0"E
170°0'0"E
175°0'0"E
180°0'0"
175°0'0"W
170°0'0"W
165°0'0"W
160°0'0"W
155°0'0"W
150°0'0"W
145°0'0"W
140°0'0"W
135°0'0"W
130°0'0"W
125°0'0"W
120°0'0"W
115°0'0"W
65°0'0"N
60°0'0"N
55°0'0"N

Low-lying marsh, wet sedge, inundated tundra

Low-lying beach/barrier – no bluffs

High-bluffs – variable beach width

Overhanging tundra/peat (visoring)

Gary Clow photo (USGS)

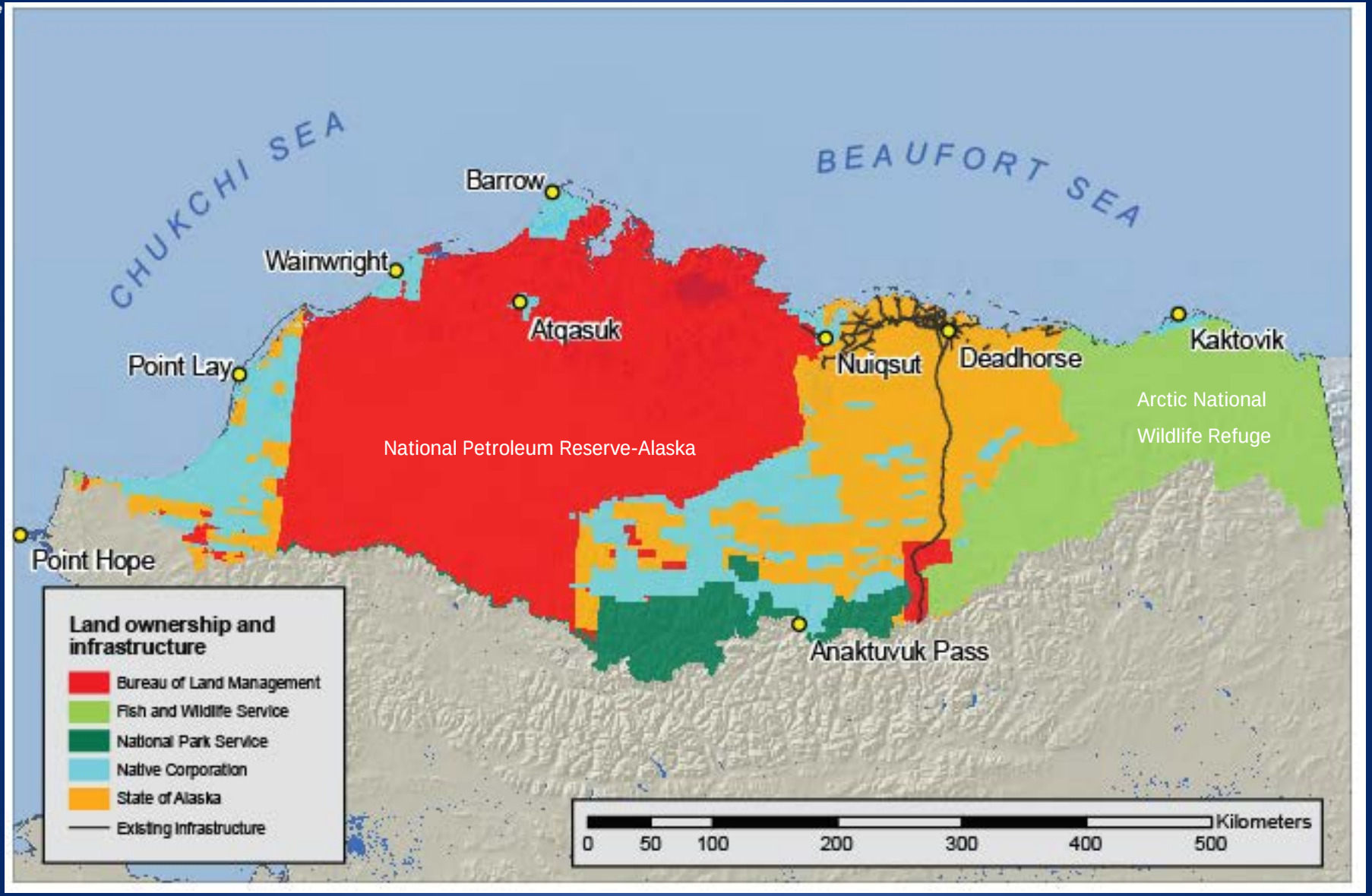
USGS
science for a changing world

Low bluff – variable beach width ice wedge polygons

Low barrier islands; dynamic, little vegetation

High barrier islands; stable, vegetated core

Large Federal Land and Resource Holdings



57 million acres in the Arctic are under DOI jurisdiction

Threatened habitat and villages

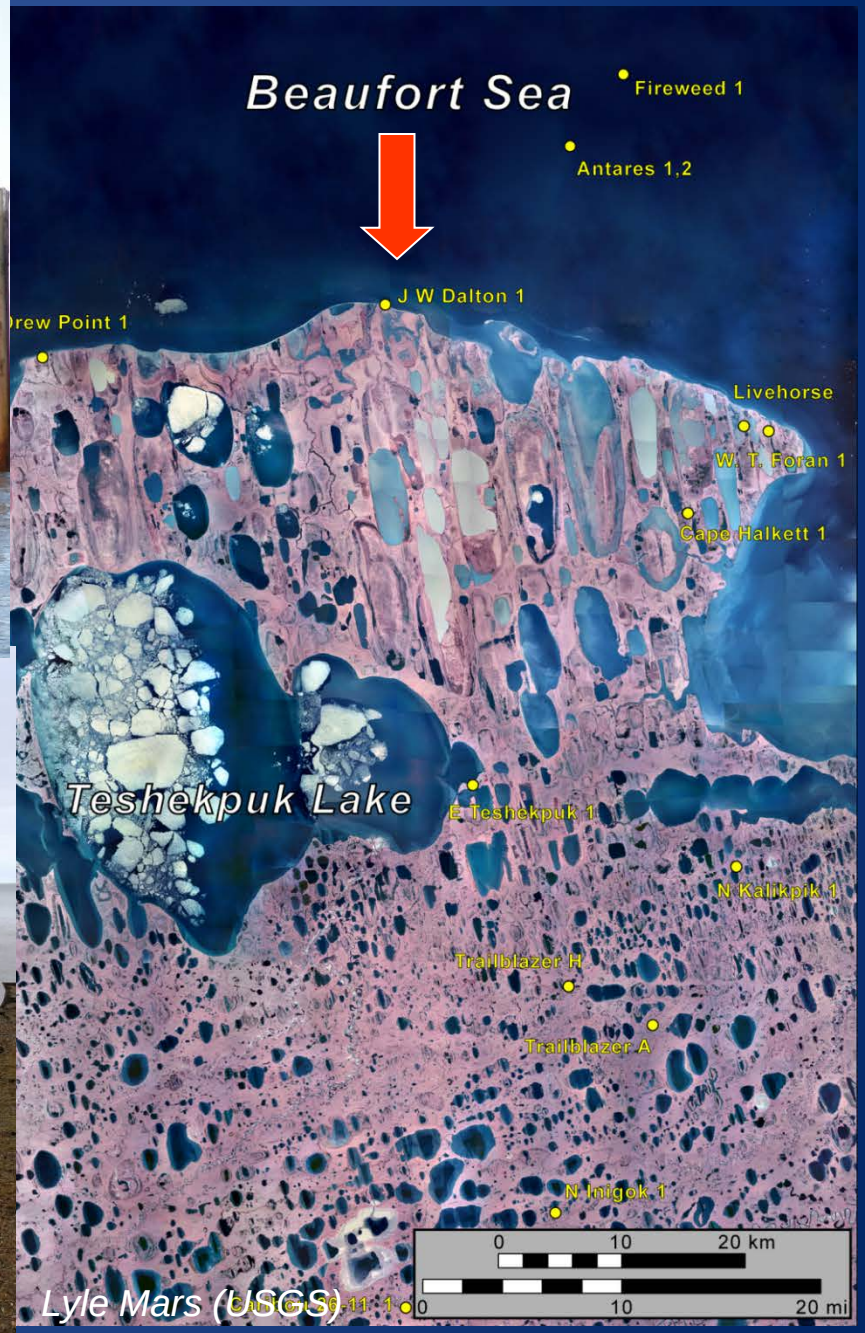
Threatened O&G infrastructure

J.W. Dalton well head and pilings
September 2004

Stan Porhola photo (BLM)

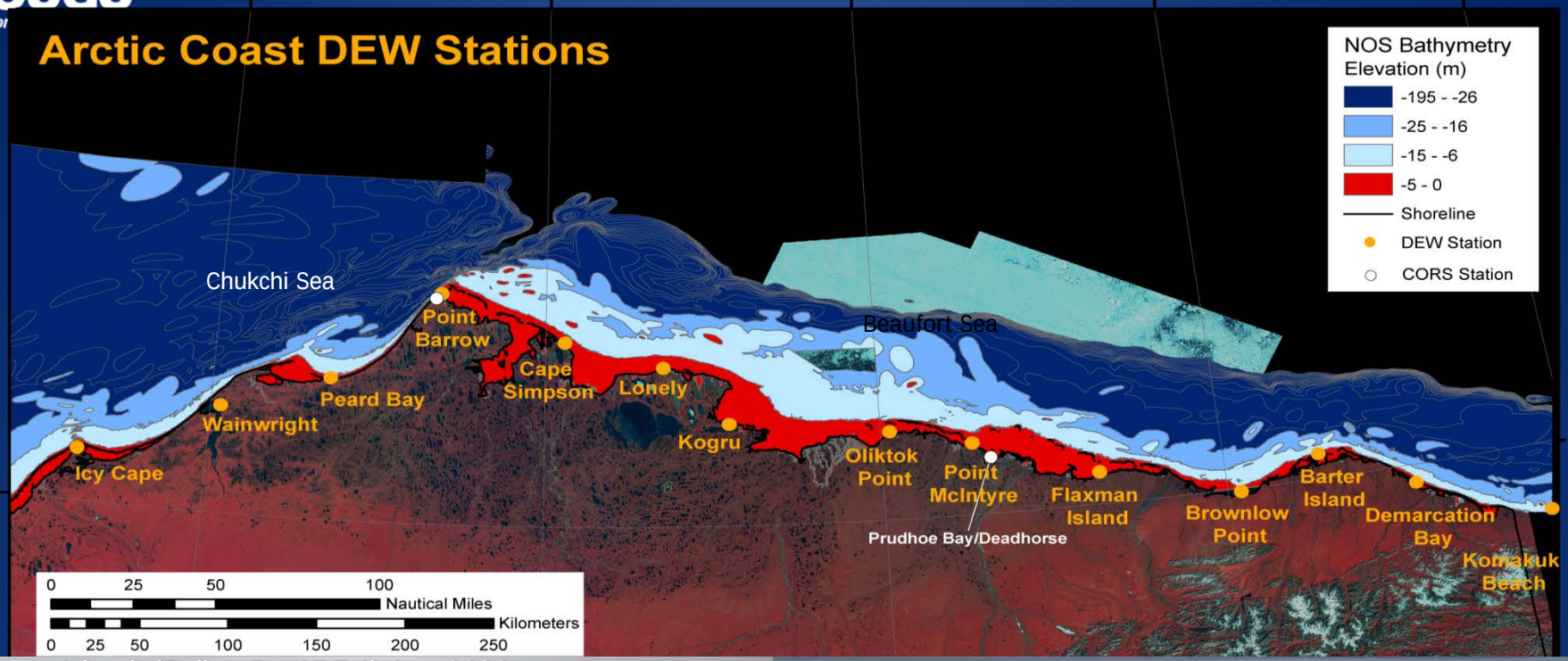
Post P & A - J.W. Dalton pilings
September 2005

Susan Flores photo (BLM)



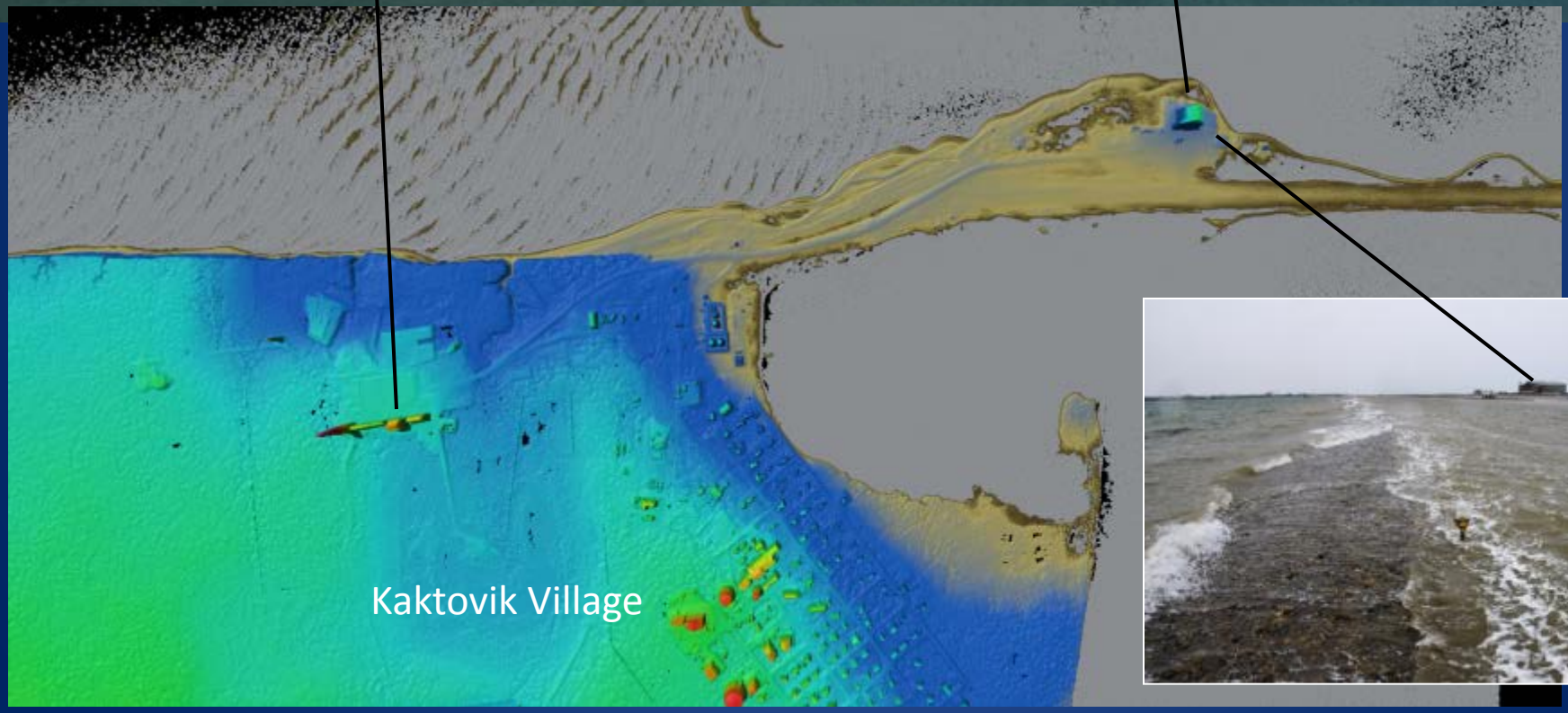
Lyle Mars (USGS)

Threatened DOD infrastructure



Photos: Gibbs and Richmond, 2009 (http://pubs.usgs.gov/ds/436/)

Coastal Inundation



USGS
science for a changing world

USGS
science for a changing world

National Assessment of Shoreline Change: Historical Shoreline Changes Along Alaska's North Coast: U.S.-Canadian Border to Icy Cape

Ann E. Gibbs, Bruce M. Richmond

USGS Lat: 70.553639 Lon: -149.441698 UTC: 18:09:02 09 Aug 2006 IMG_9154.JPG

Open-File Report 2014-XXXX

U.S. DEPARTMENT OF THE INTERIOR

Activities in 2009 that led to commercial data collection …

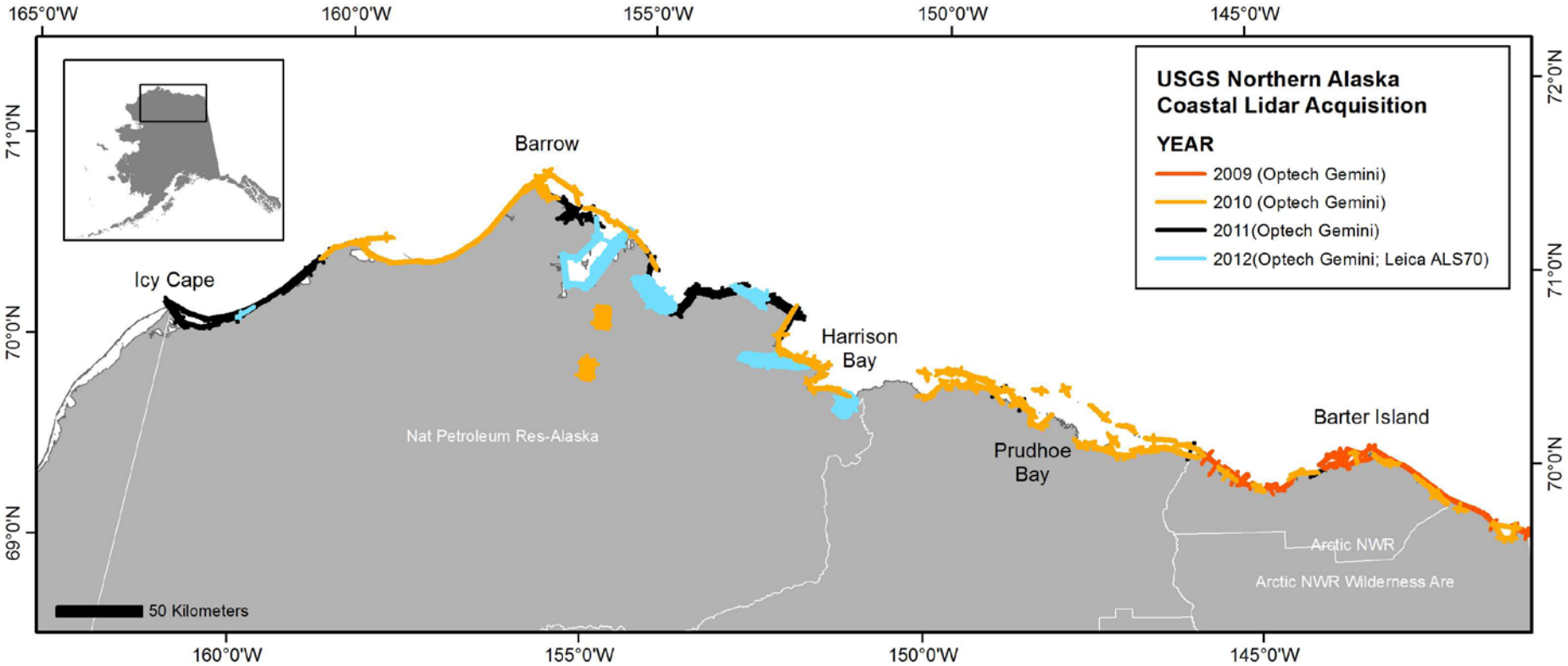
- Original plan was to acquire lidar data using the USGS topo-bathy lidar system (EAARL)
- The current EAARL platform (Pilatus) was deemed unsuitable for surveying in NS Alaska by the DOI Aviation Management Division.
- A commercial collect was coordinated with USGS NGTOC Commercial Partnership Team
- Aerometric-AK (Quantum Spatial) was selected as the vendor

Commercial lidar planning

- Survey to be conducted during snow and ice-free conditions (summer months July – Oct)
- Long GPS base lines (~100 km) accepted
- Vertical accuracy requirement = 25 cm
- Only minimal processing of data required by vendor. All returns required in deliverable
- Coastline coverage along “polyline” extending to ~1500 m inland; 2 passes
- No coincident photography (video 2010)
- LAS 1.2; unclassified (Cloud/1st/last); xyz, intensity
- (ANC based contractor)

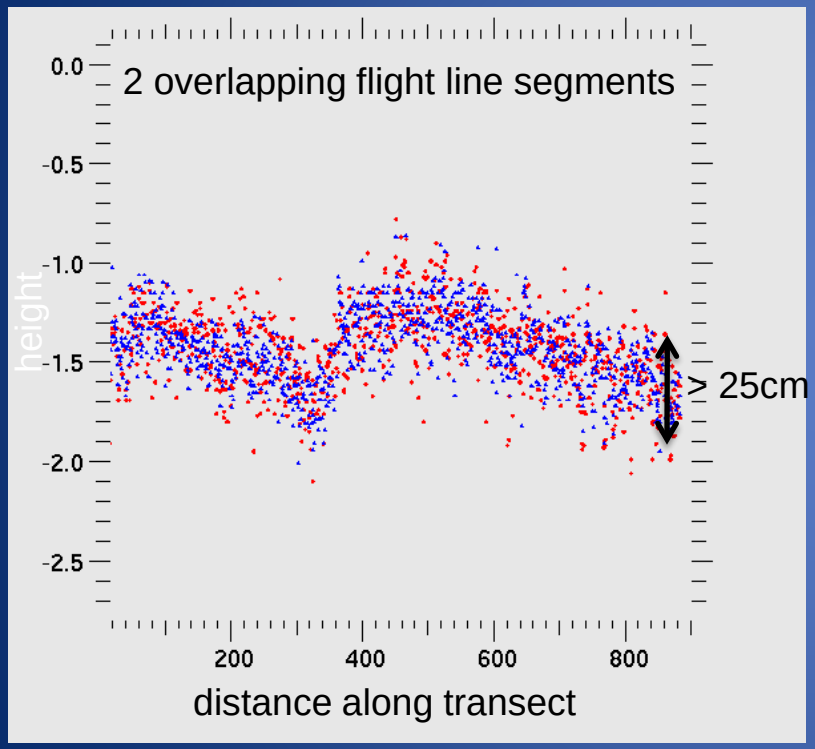
Northern Alaska Coastal Lidar Survey

- 7,119 line-km (~ 11 K km^2) acquired between 2009 and 2012
- Icy Cape to the US-Canadian Border
- Mainland coast and barrier islands (limited delta and estuary)
- Waterline to approximately 1.5 km inland; 2-4 overlapping passes
- ~ 1m point spacing/30 cm vertical accuracy (0.14 RMSE)
- *NAD83; Ellipsoidal elevation*

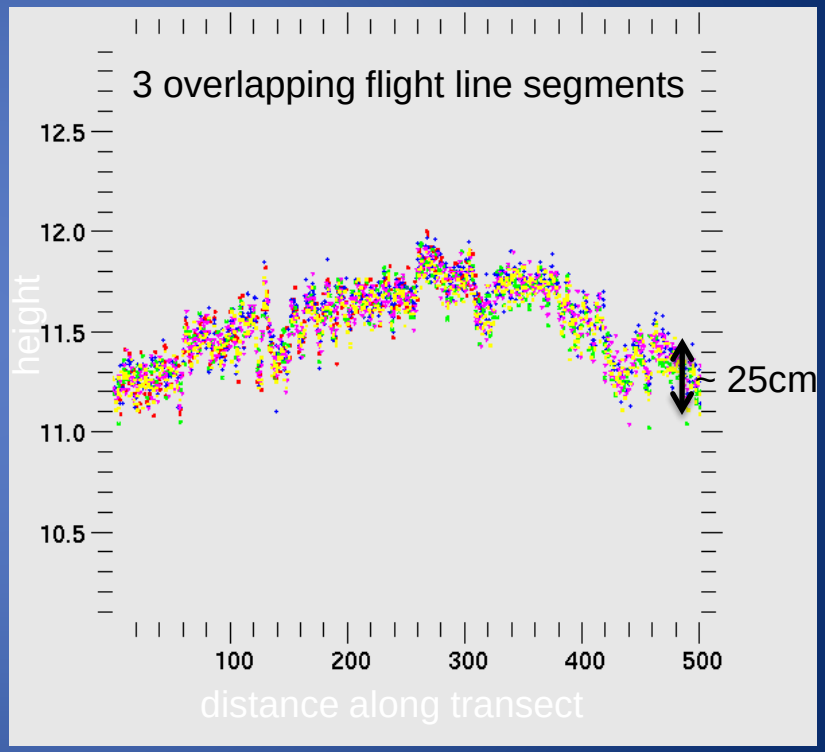


Quality Check

Region 1



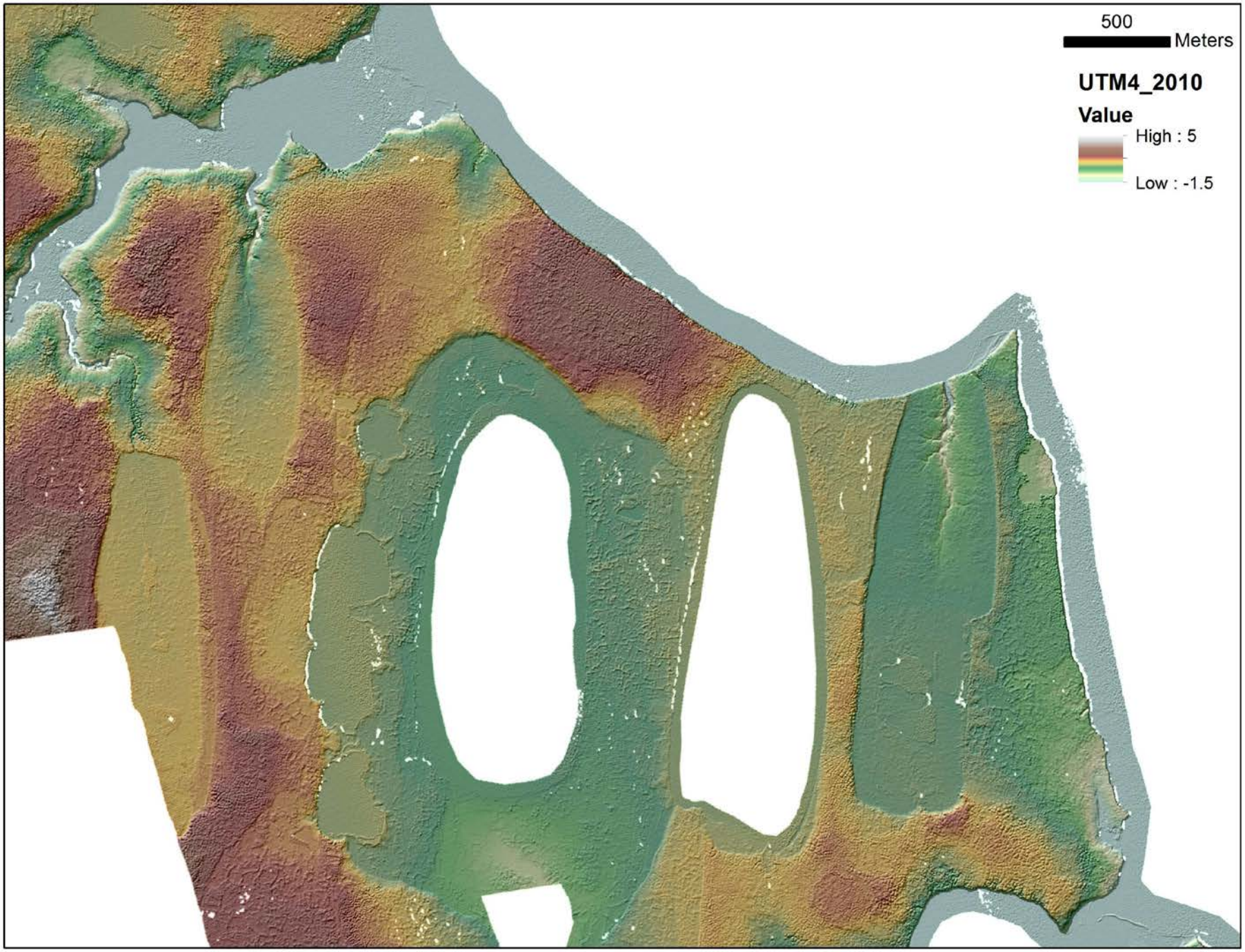
Region 2

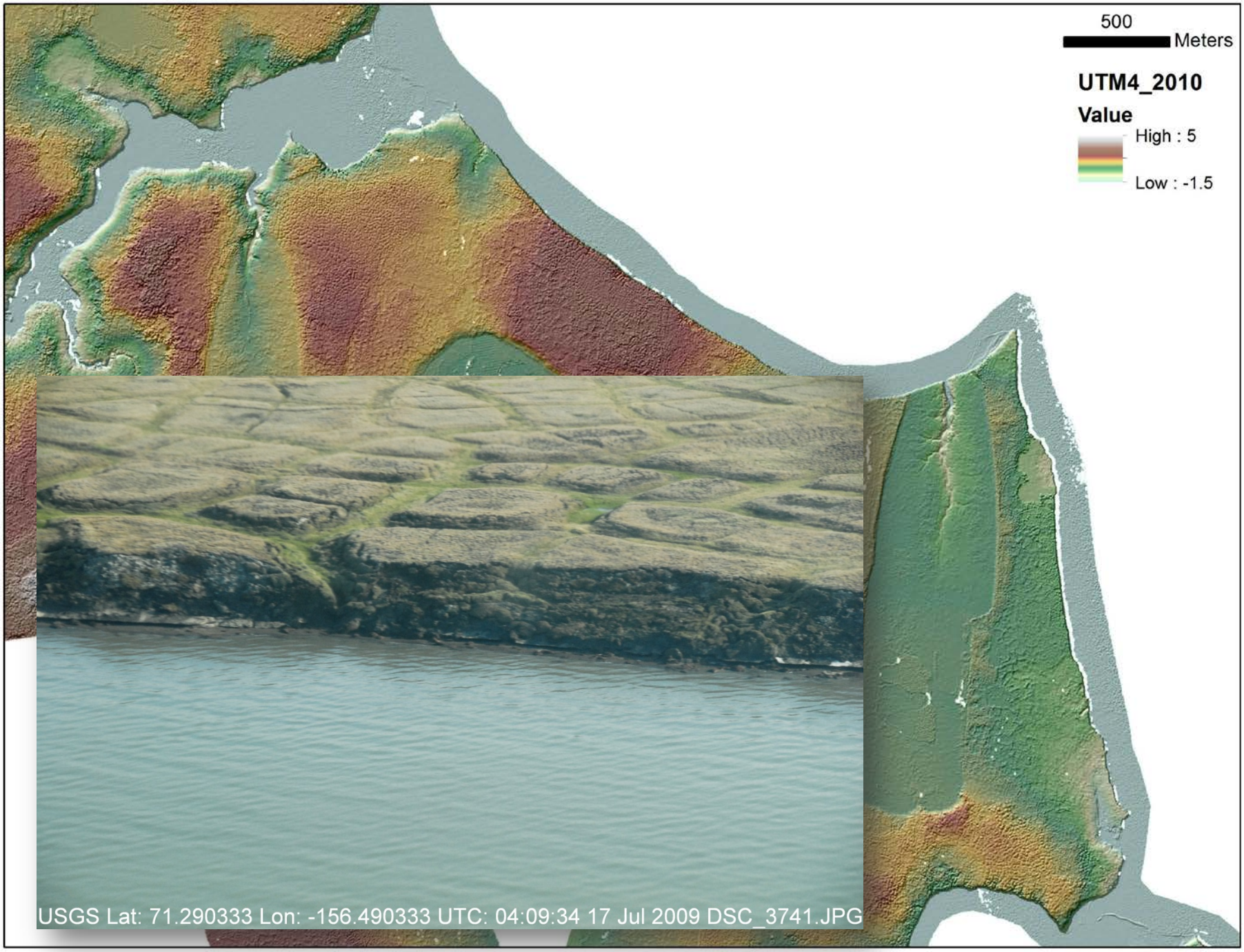


Data Gaps

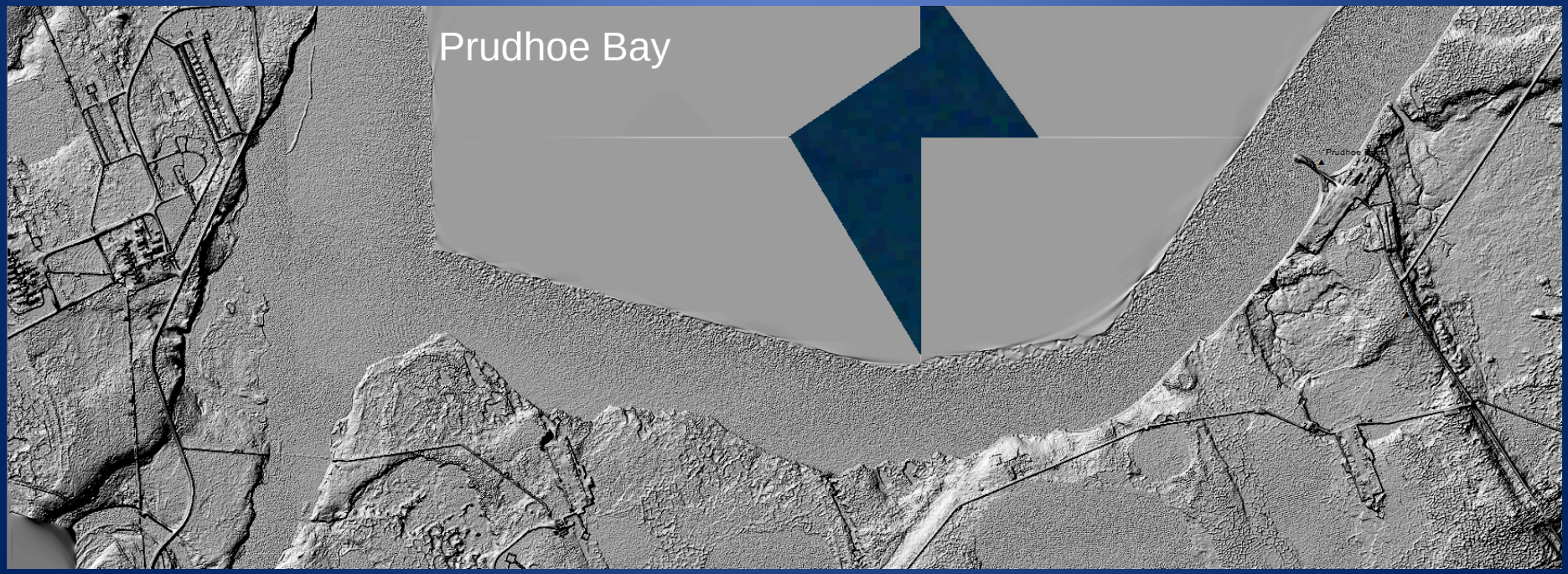
Data gaps where the near infrared laser did not reflect off the "dark" water surface

500
Meters

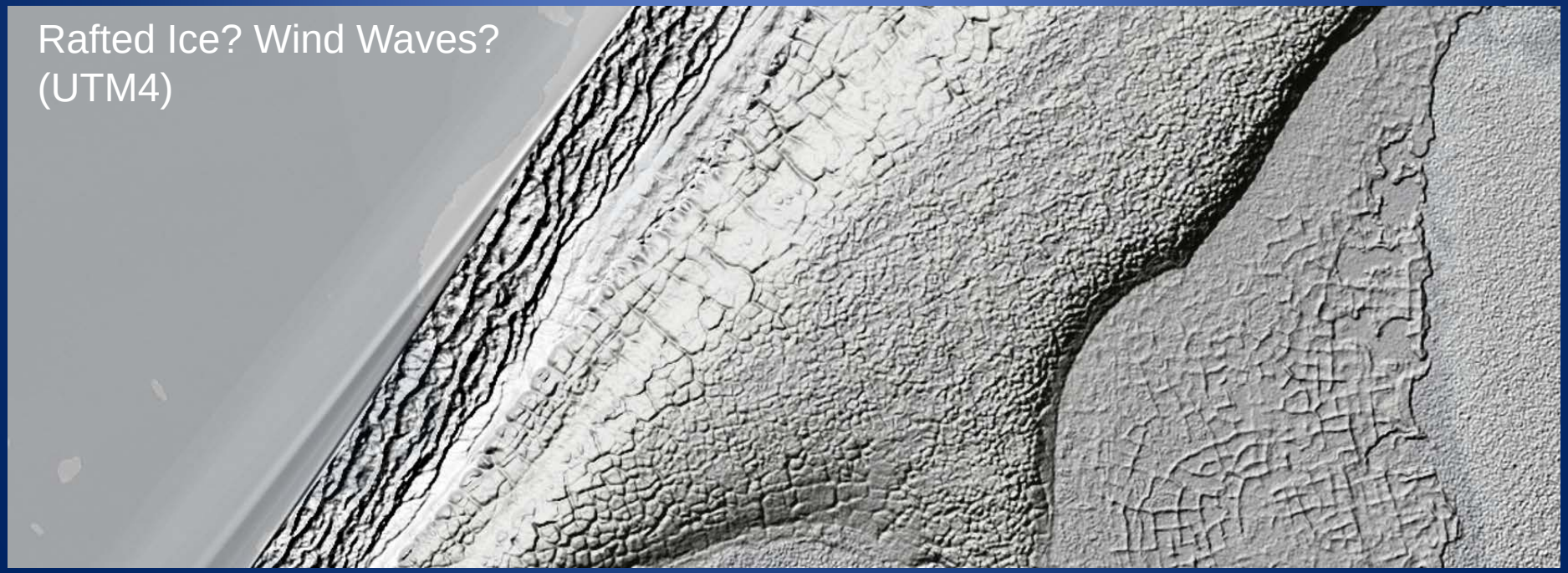

500
Meters
UTM4_2010
Value
High : 5
Low : -1.5


500
Meters
UTM4_2010
Value
High : 5
Low : -1.5
USGS Lat: 71.290333 Lon: -156.490333 UTC: 04:09:34 17 Jul 2009 DSC_3741.JPG

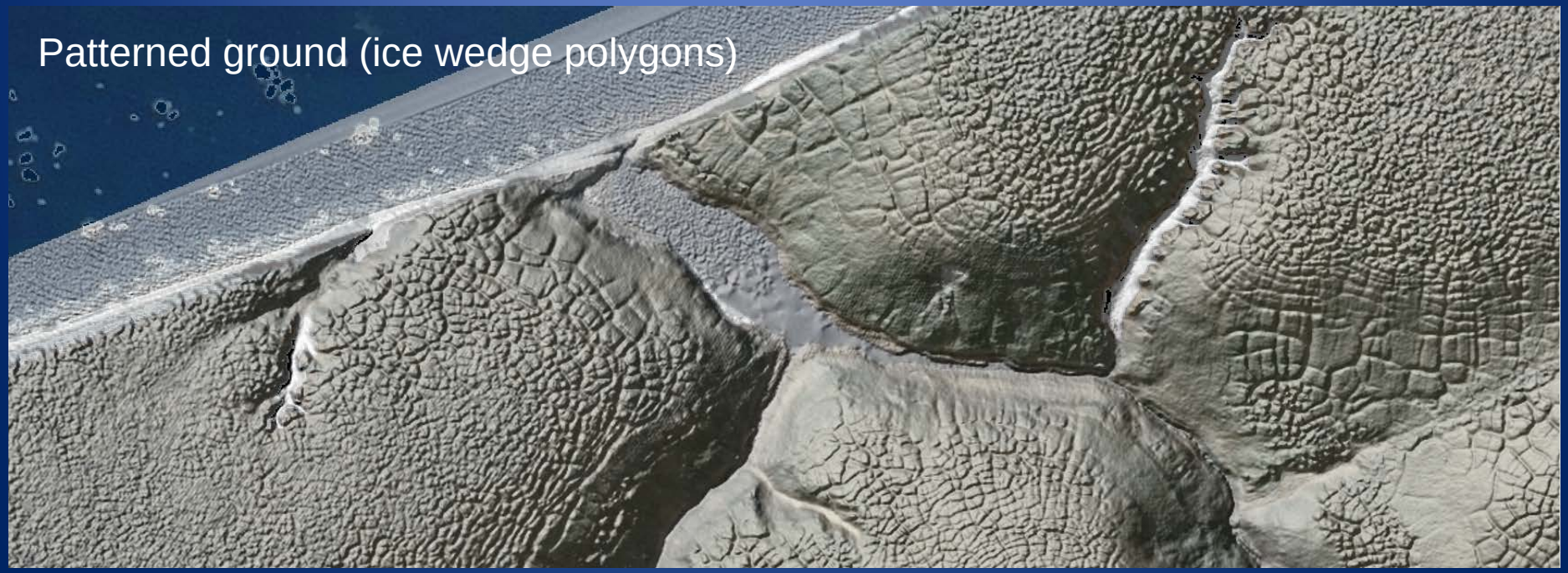
Wiley Post Regional
Airport (Barrow)
Post/Rogers Memorial Field


Prudhoe Bay

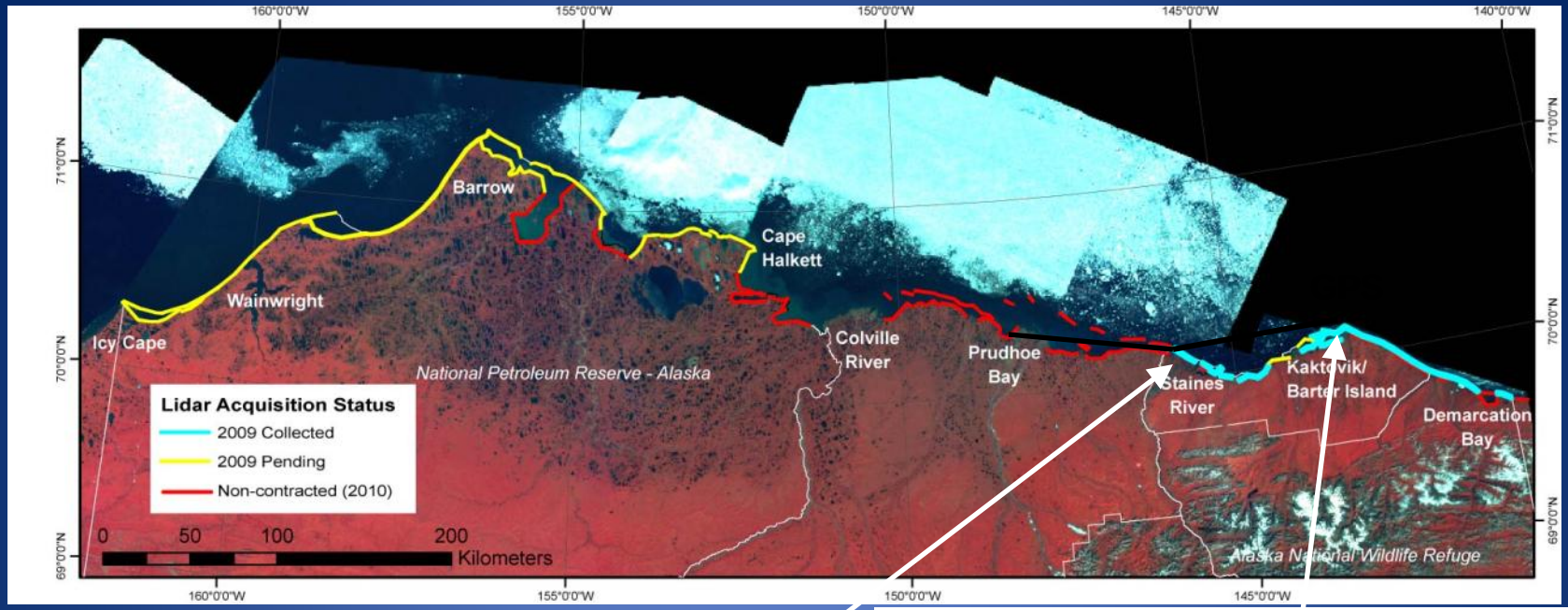
Waves in LiDAR (UTM4)

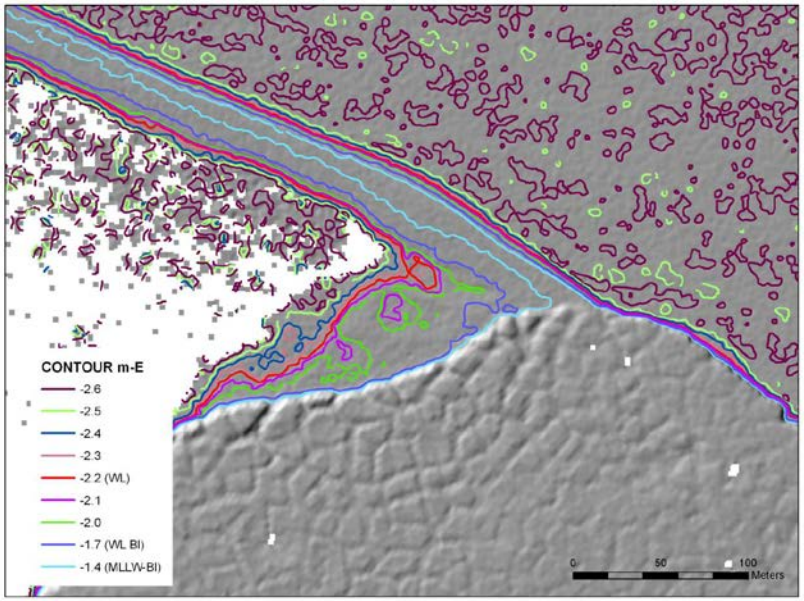

Rafted Ice? Wind Waves?
(UTM4)

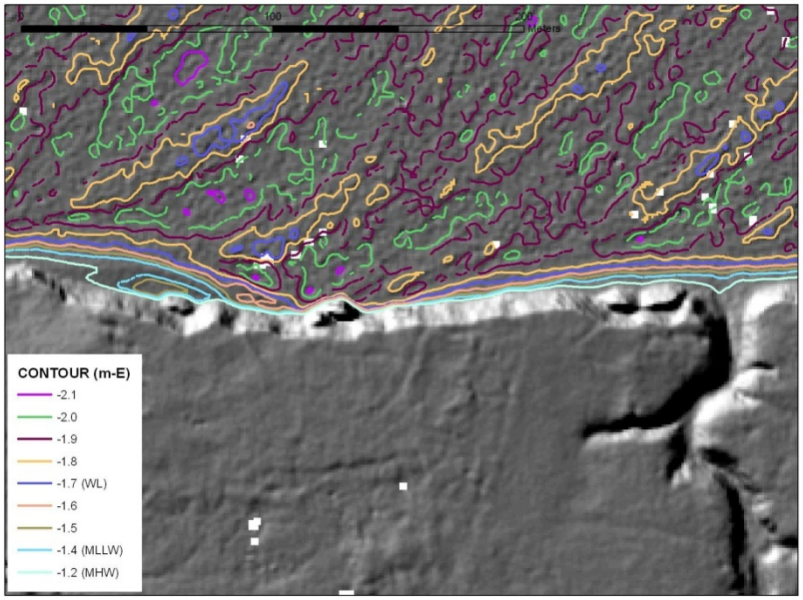
Katakturuk River


Patterned ground (ice wedge polygons)

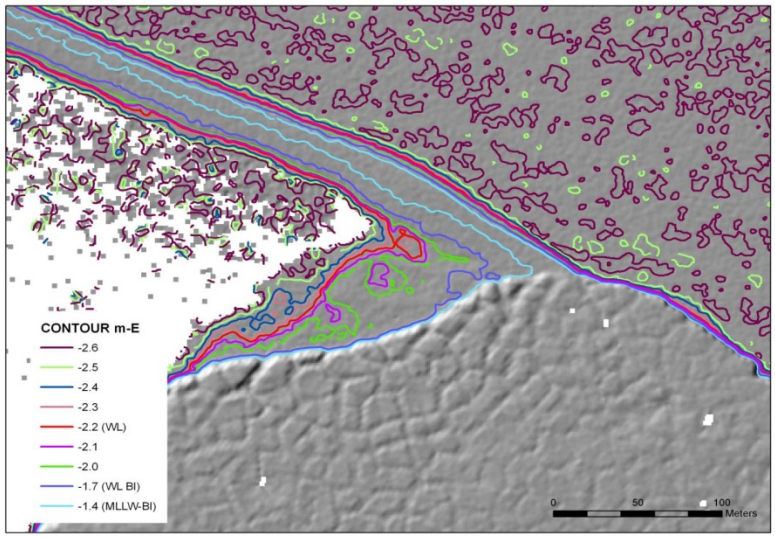
Shoreline extraction



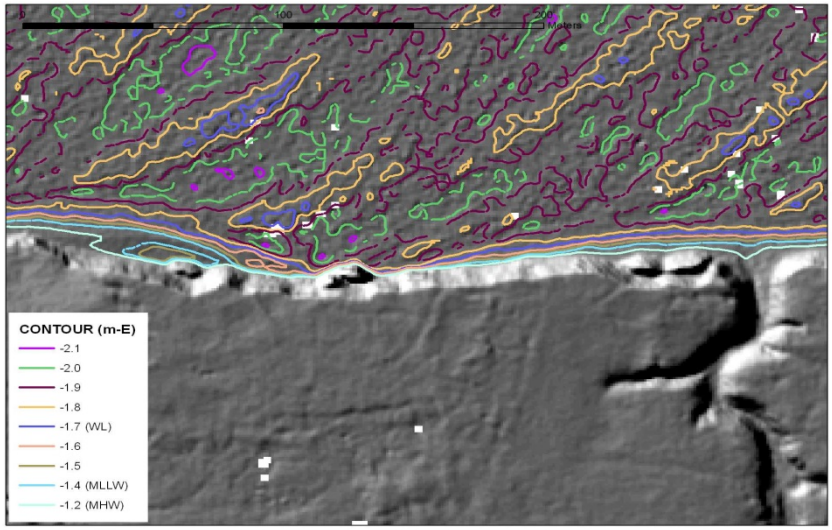




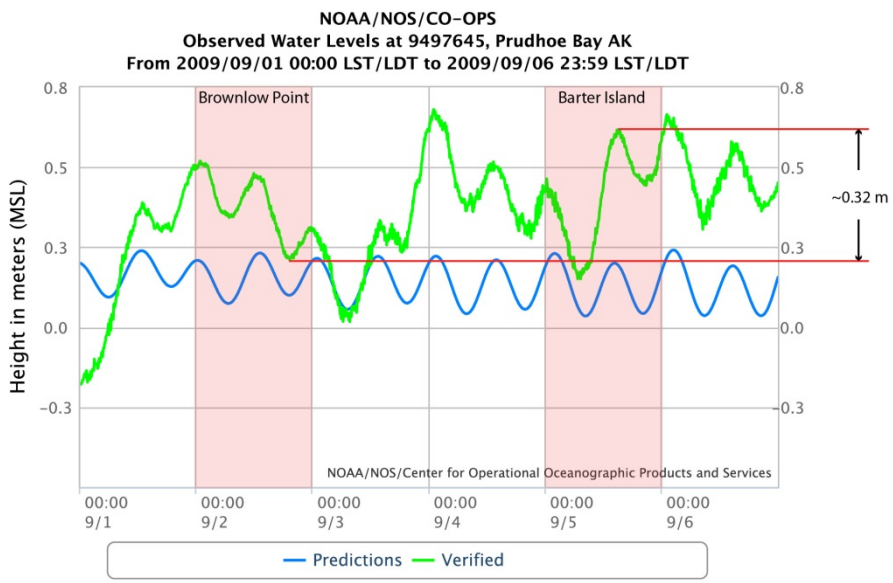
Water level at Brownlow Point is ~0.5 m lower than at Barter Island



Sep. 02, 2009



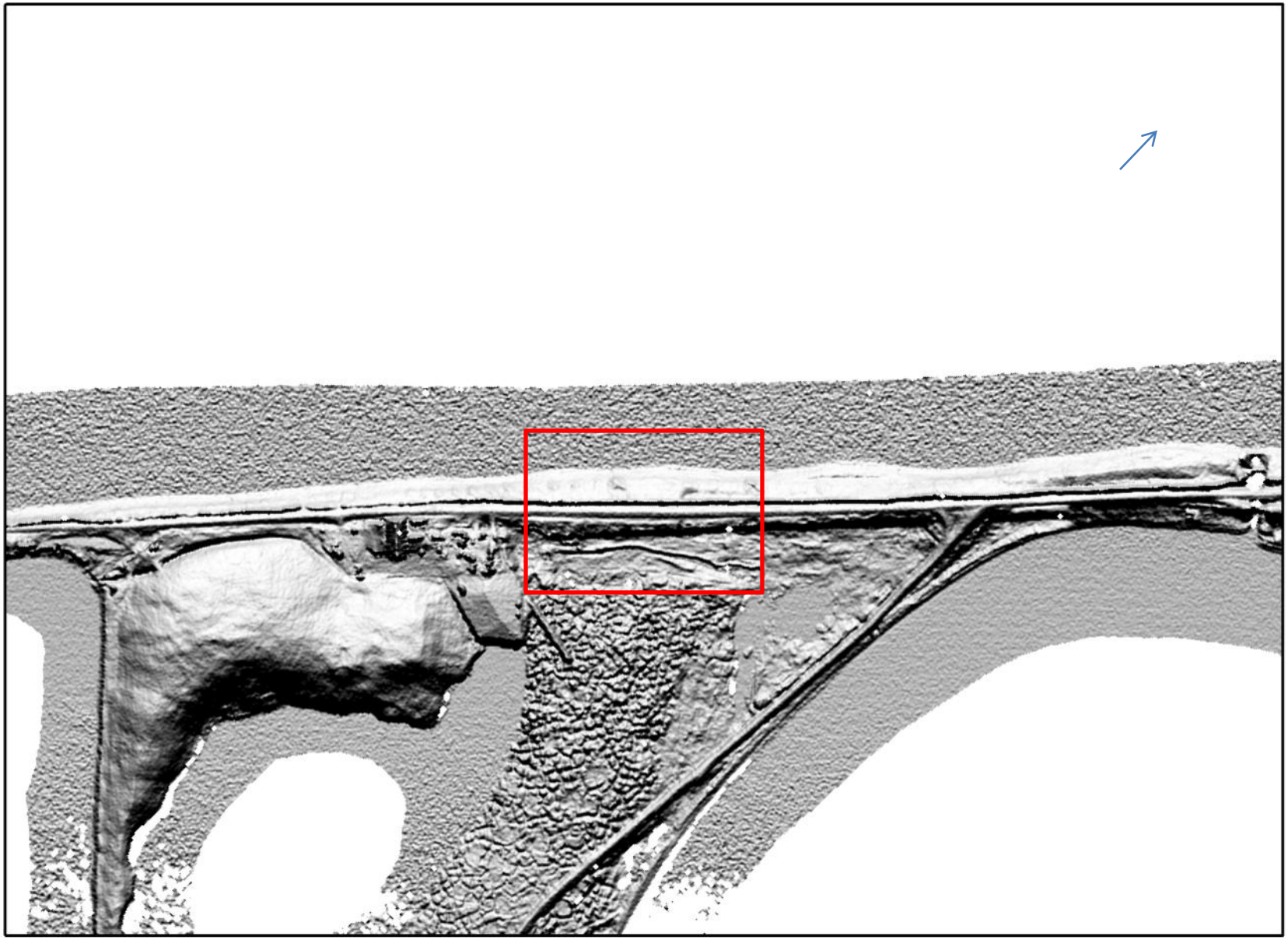
Sep. 09, 2009



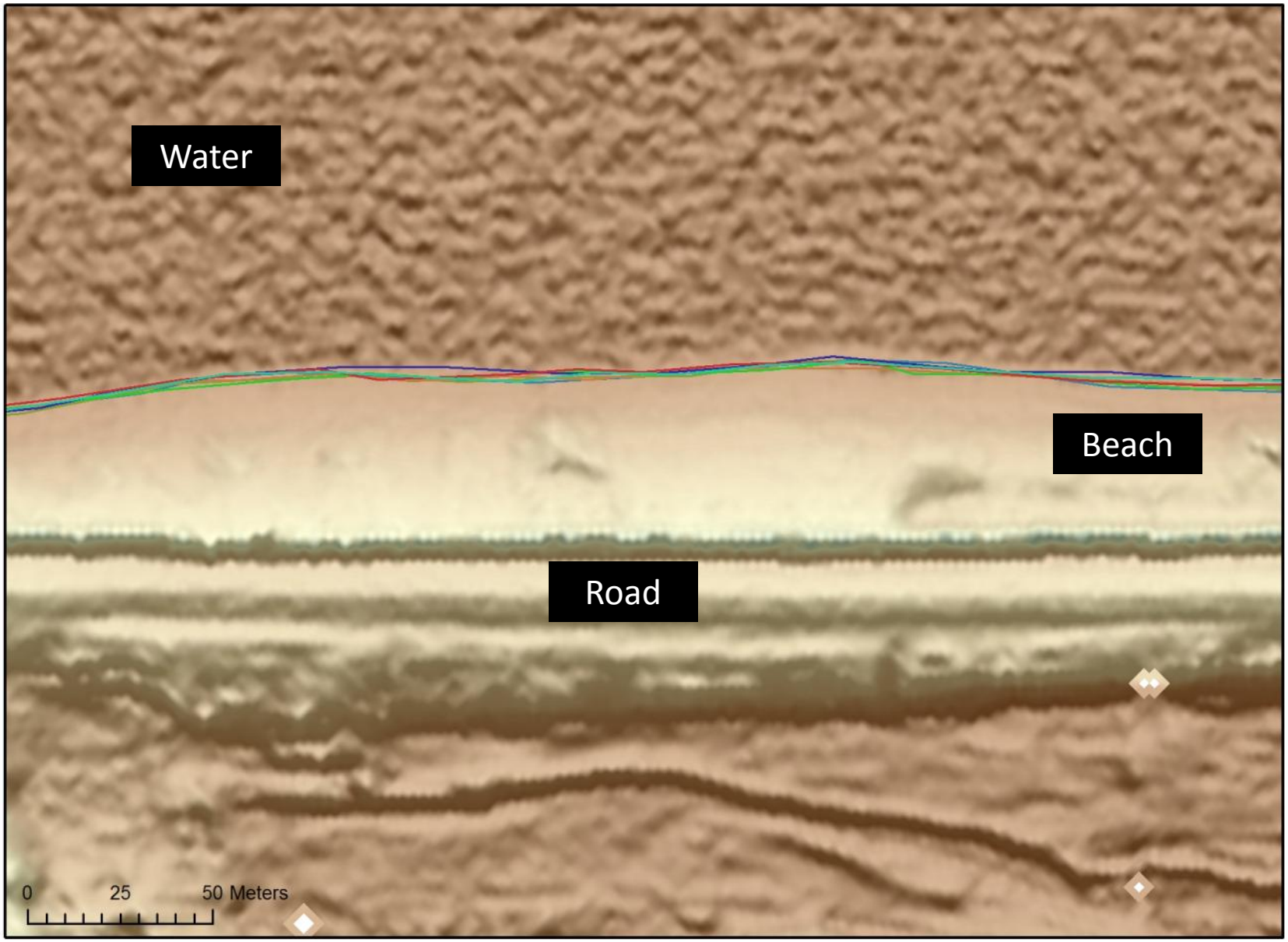
Water level variation on different survey days?

Ellipsoid variation?

Lidar bias/error?



NAD83; UTM Zone 4



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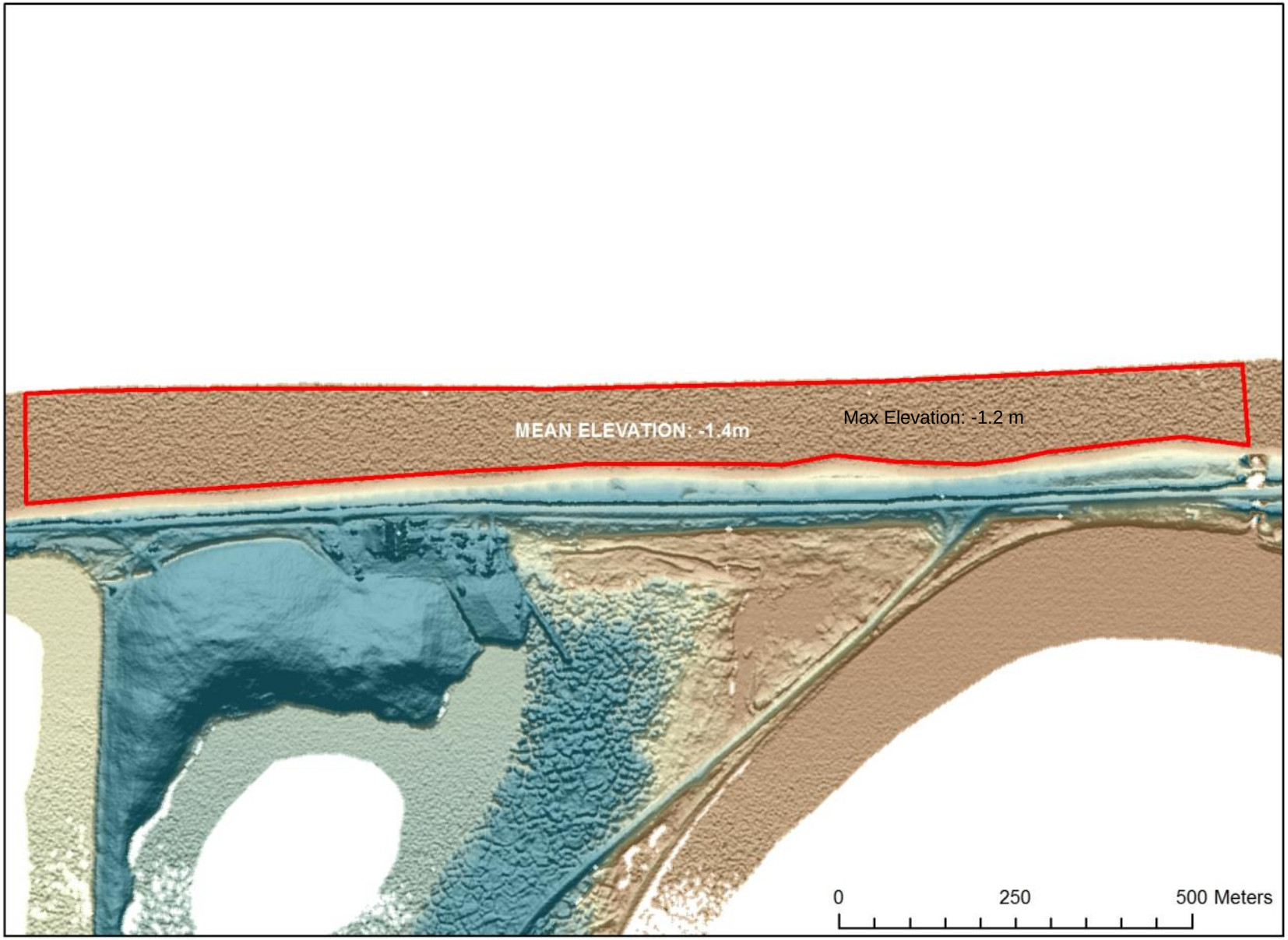
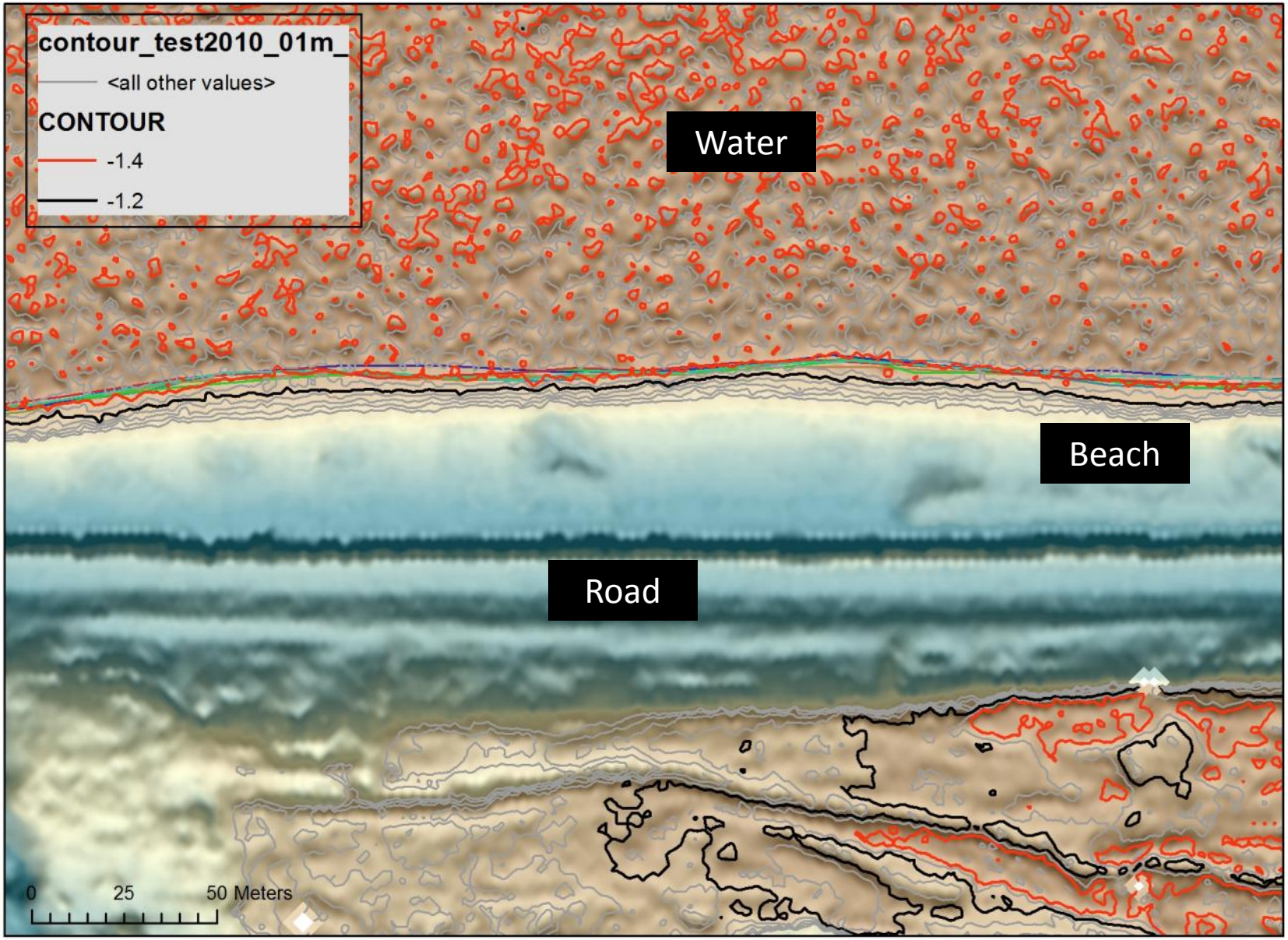
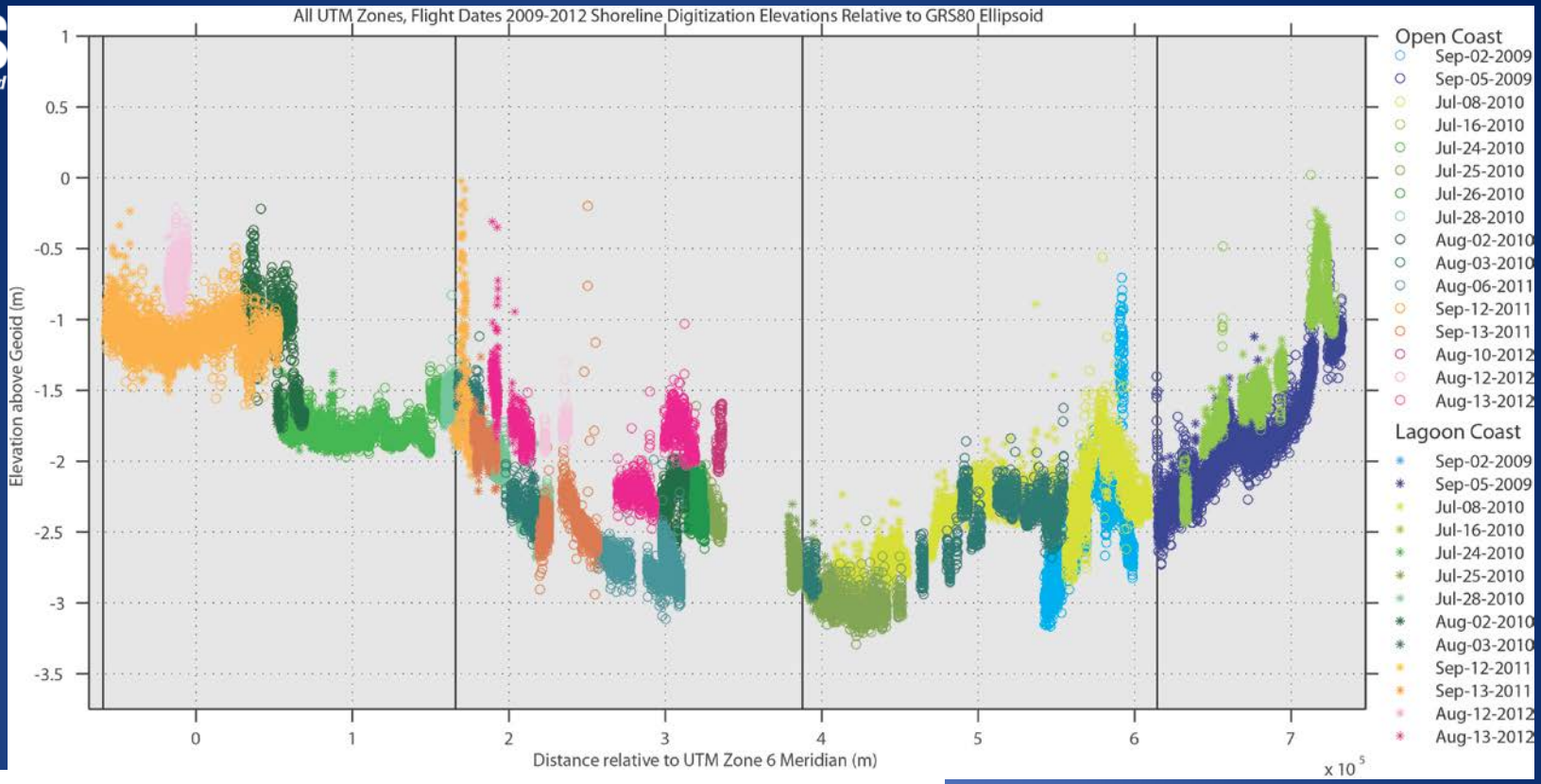
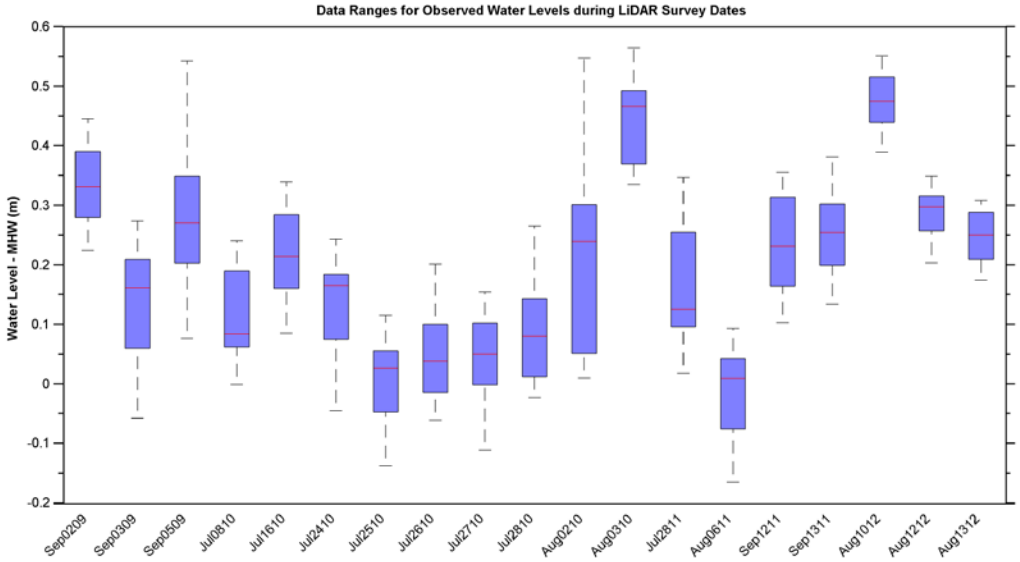


NAD83; UTM Zone 4



NAD83; UTM Zone 4

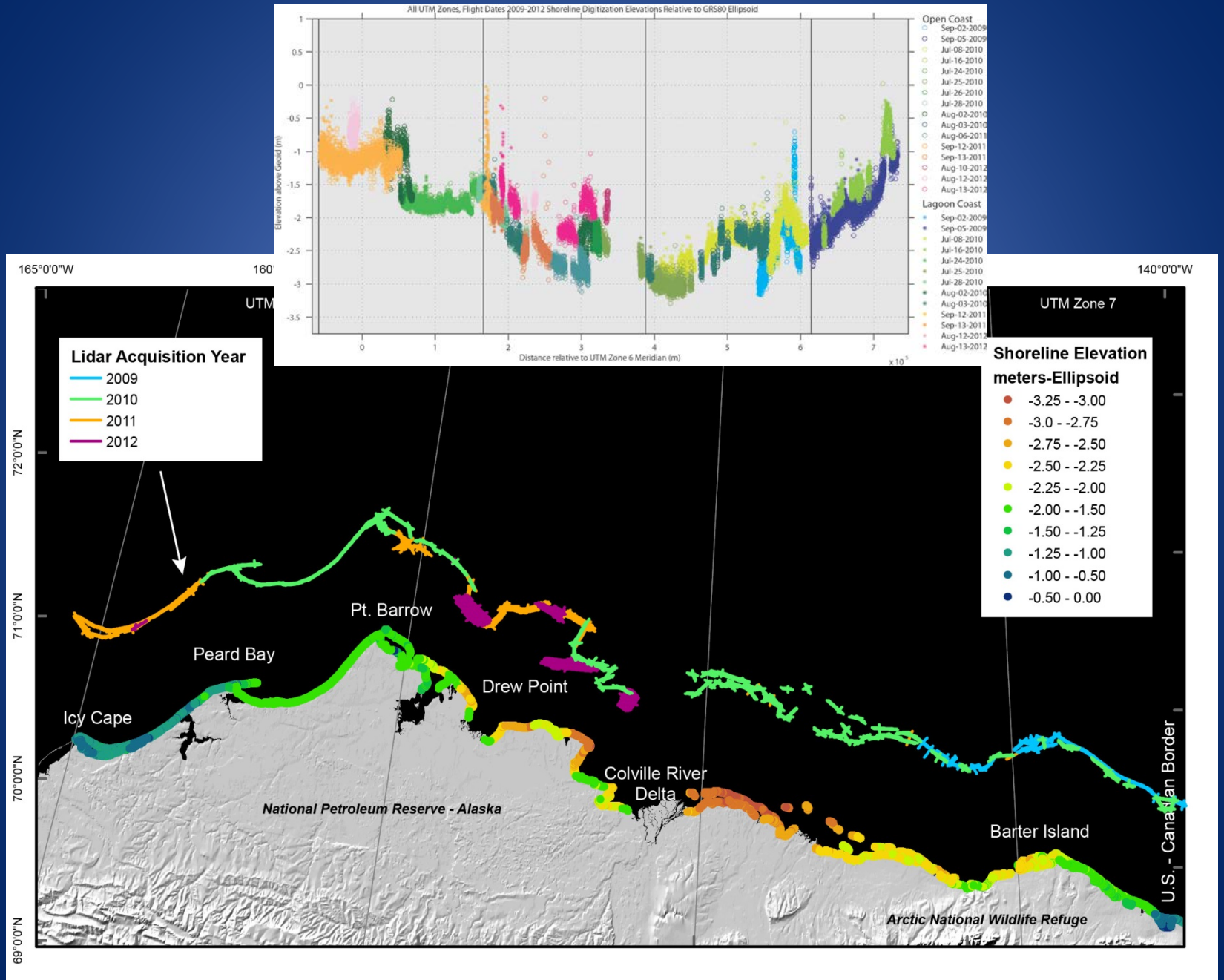




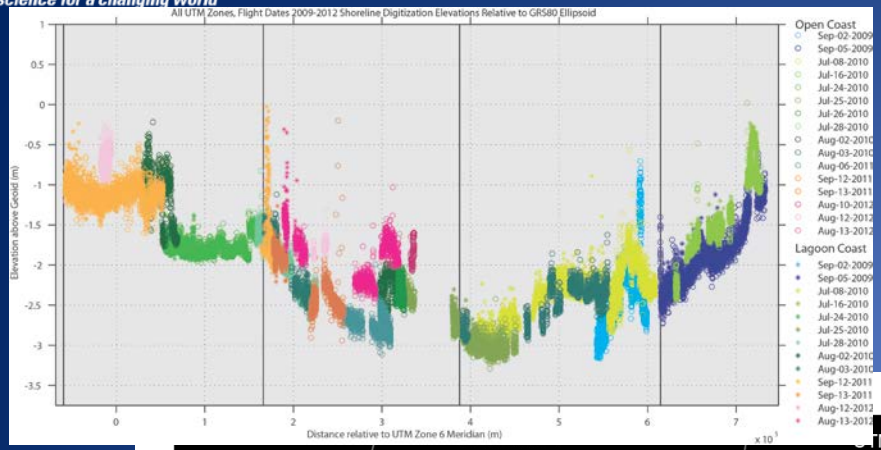
Change in 'shoreline elevation' varies by ~ 3 m across study area (4 years, numerous days)

Verified water levels at Prudhoe Bay vary by < 0.8 m during lidar acquisiton.

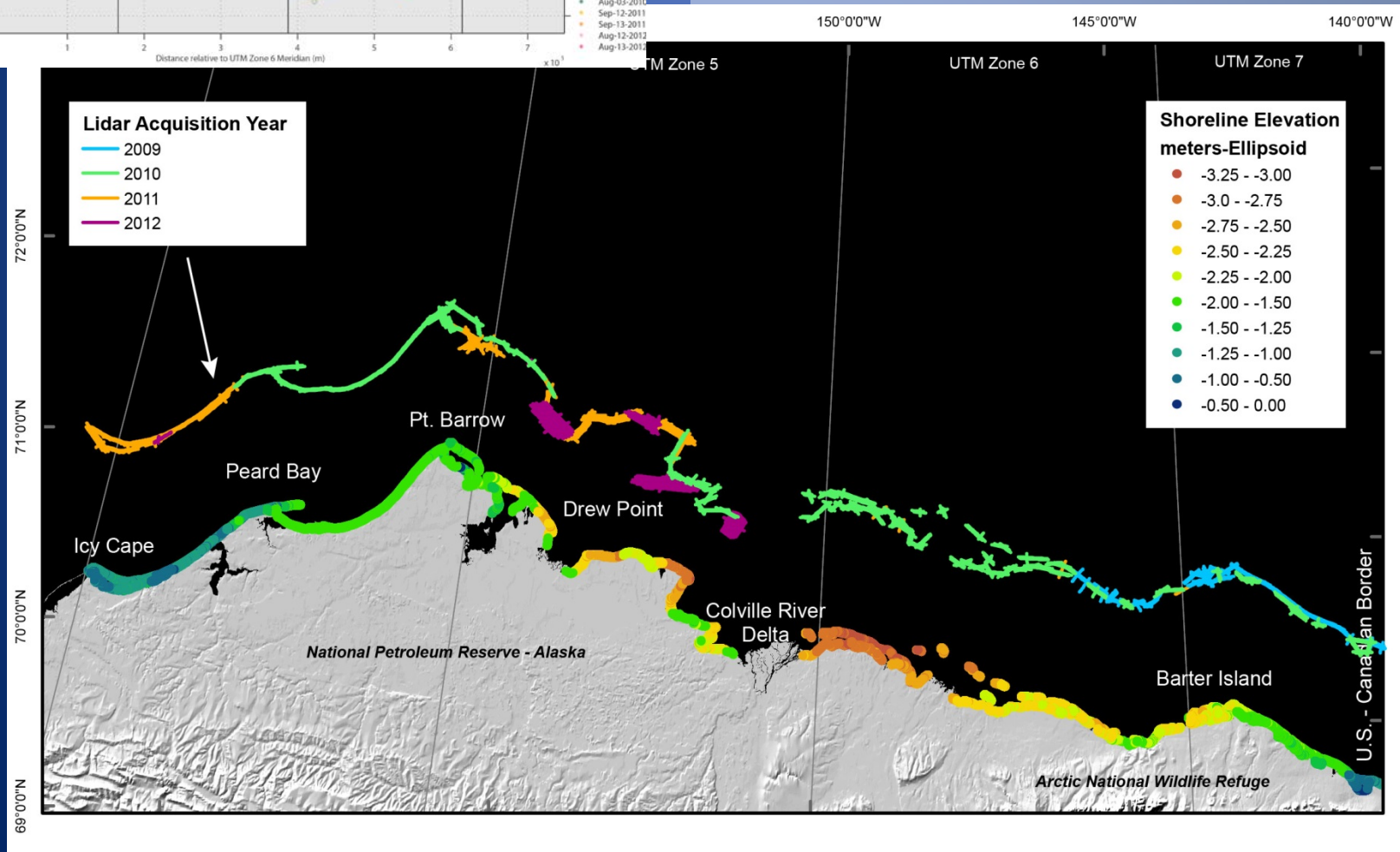
Shoreline elevation difference across study area



Shoreline elevation difference across study area



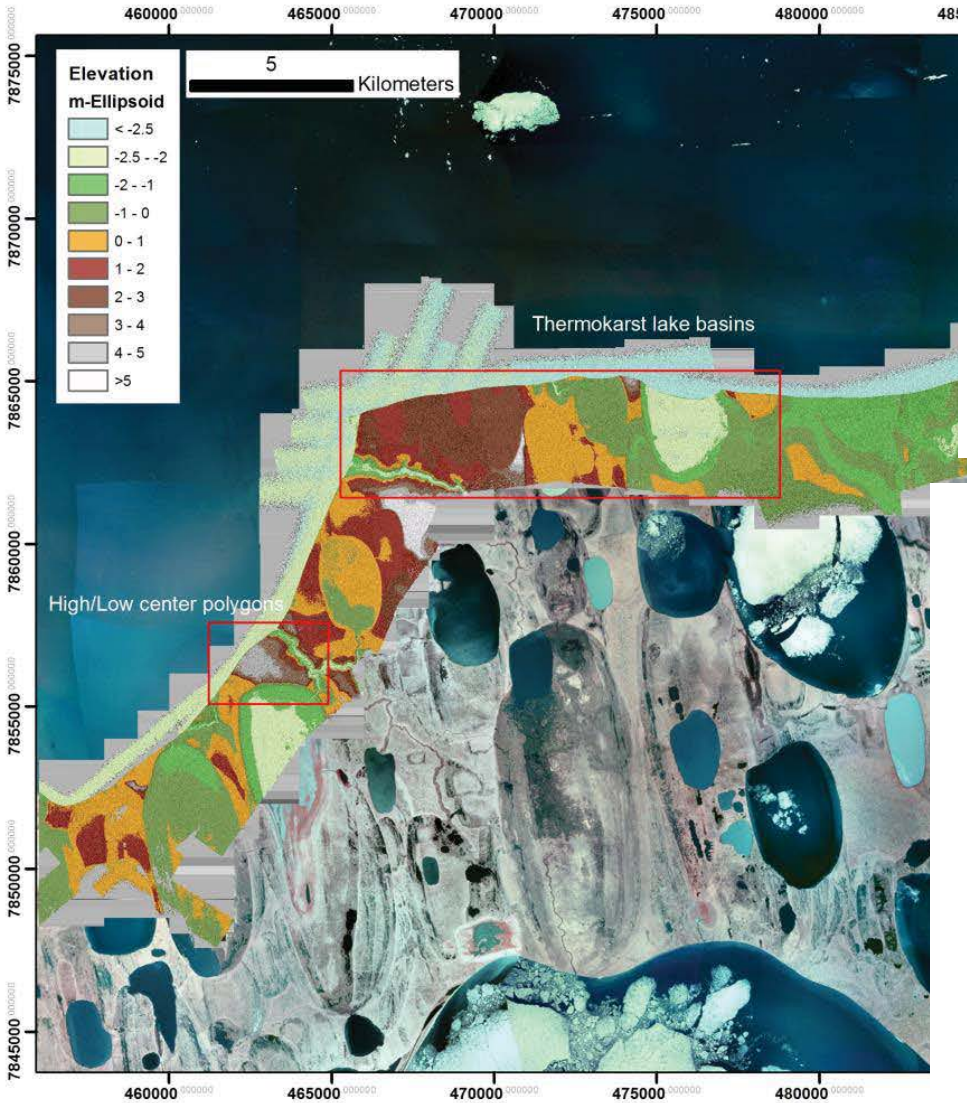
Digitization problem?
Ellipsoid?
Local water surface set up/set down?
Nearshore ice?
Will a better GEOID improve this?
E <-> SL can be established locally, but…



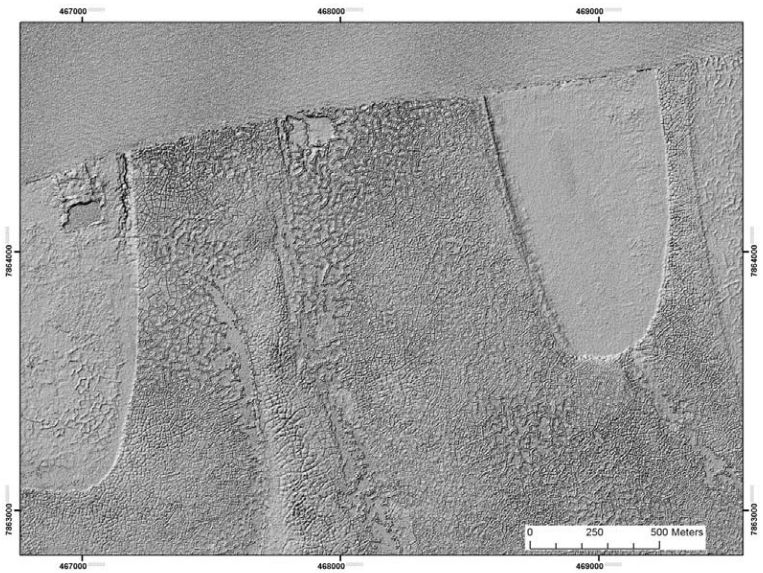
Thanks!

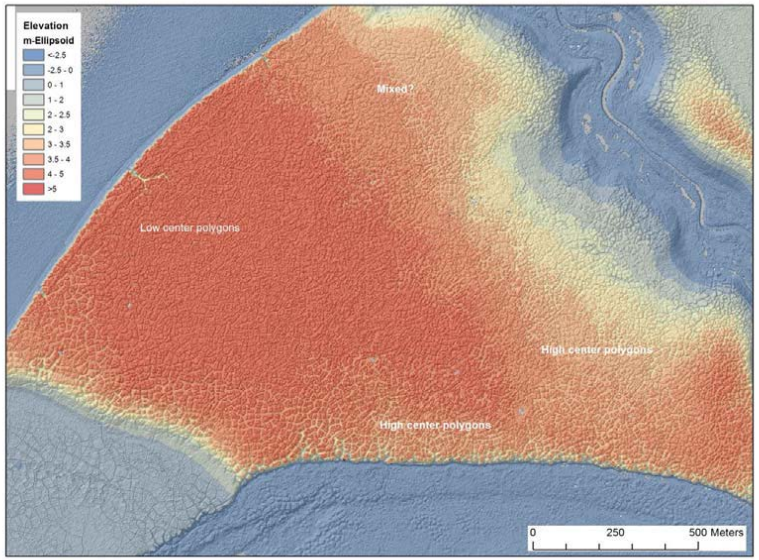
Ann Gibbs (agibbs@usgs.gov; 831-460-7540)

Morphometric Analysis
Surface complexity

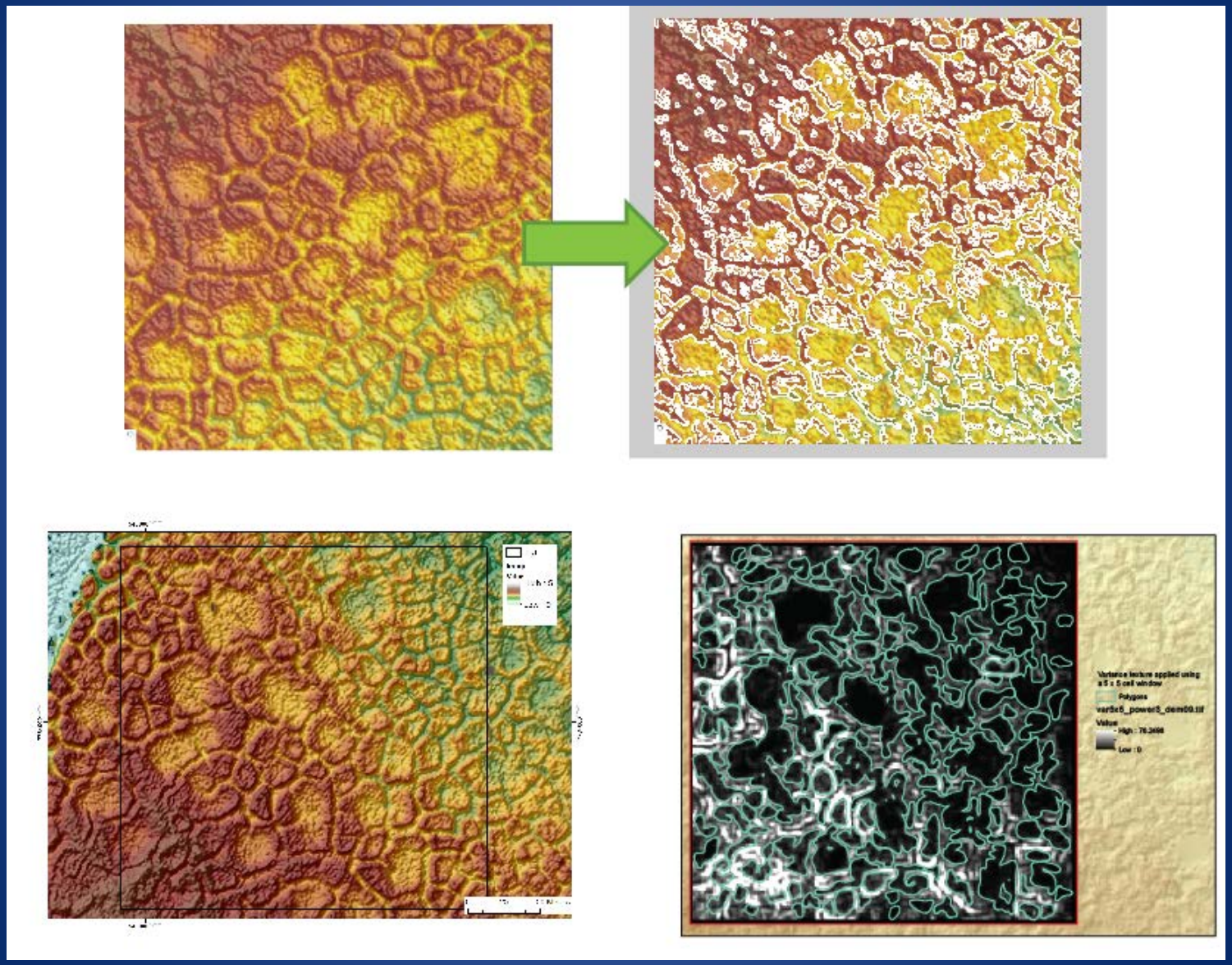


Background imagery: 2002 USGS DOQQ; Teshekpuk D1, D2 Quads; available from EarthExplore

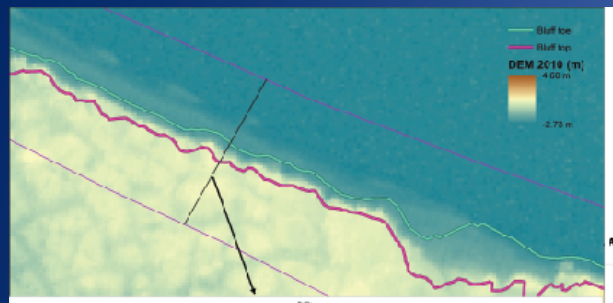




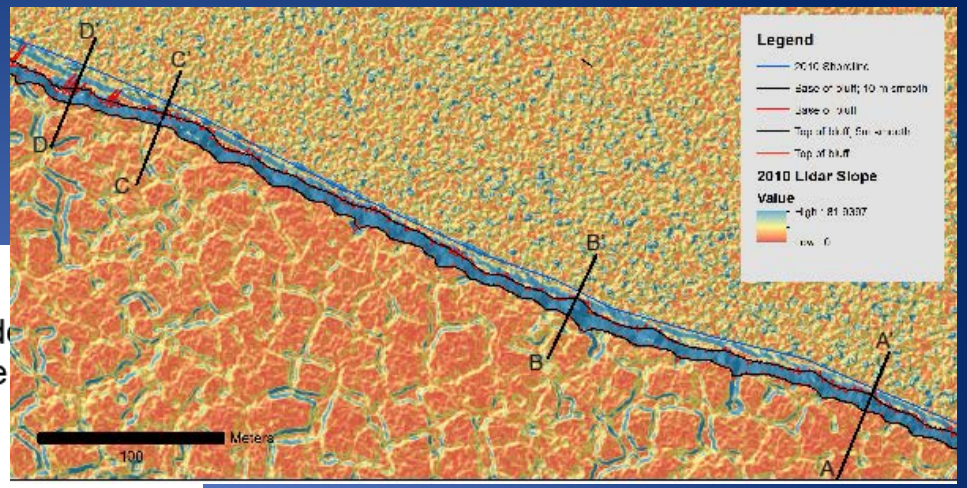
Morphometrics: Geometry of thermokarst polygons

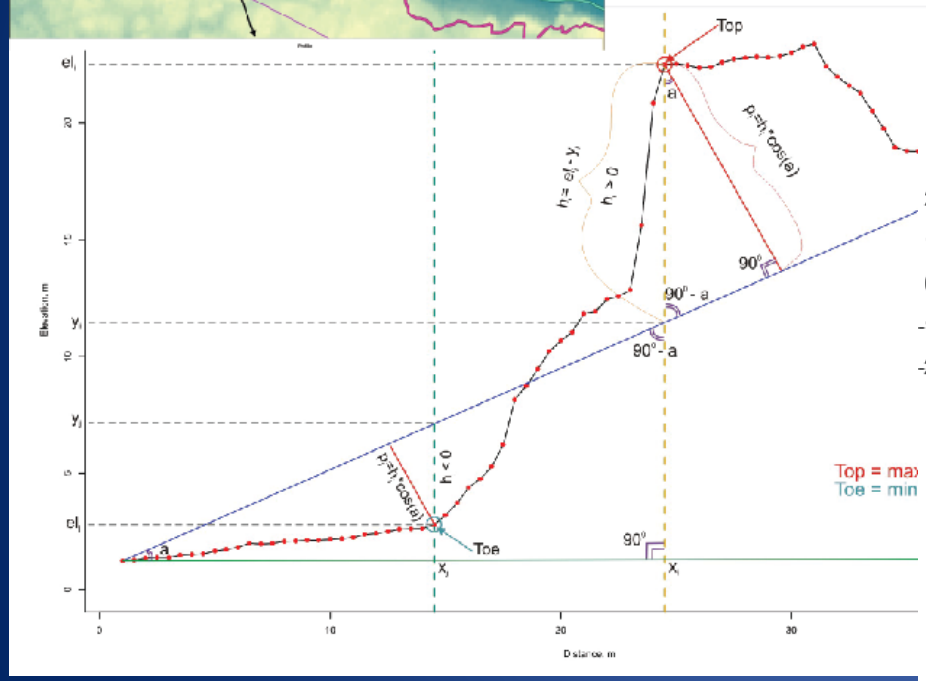


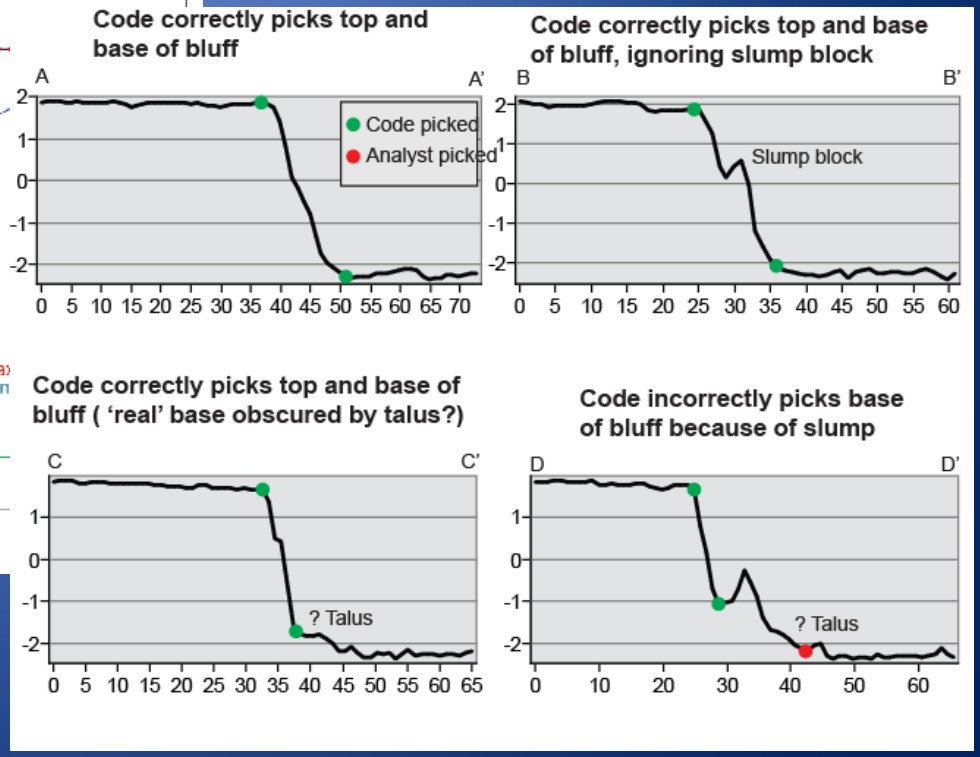
Morphometric Analysis
Top/toe, convexity of bluffs

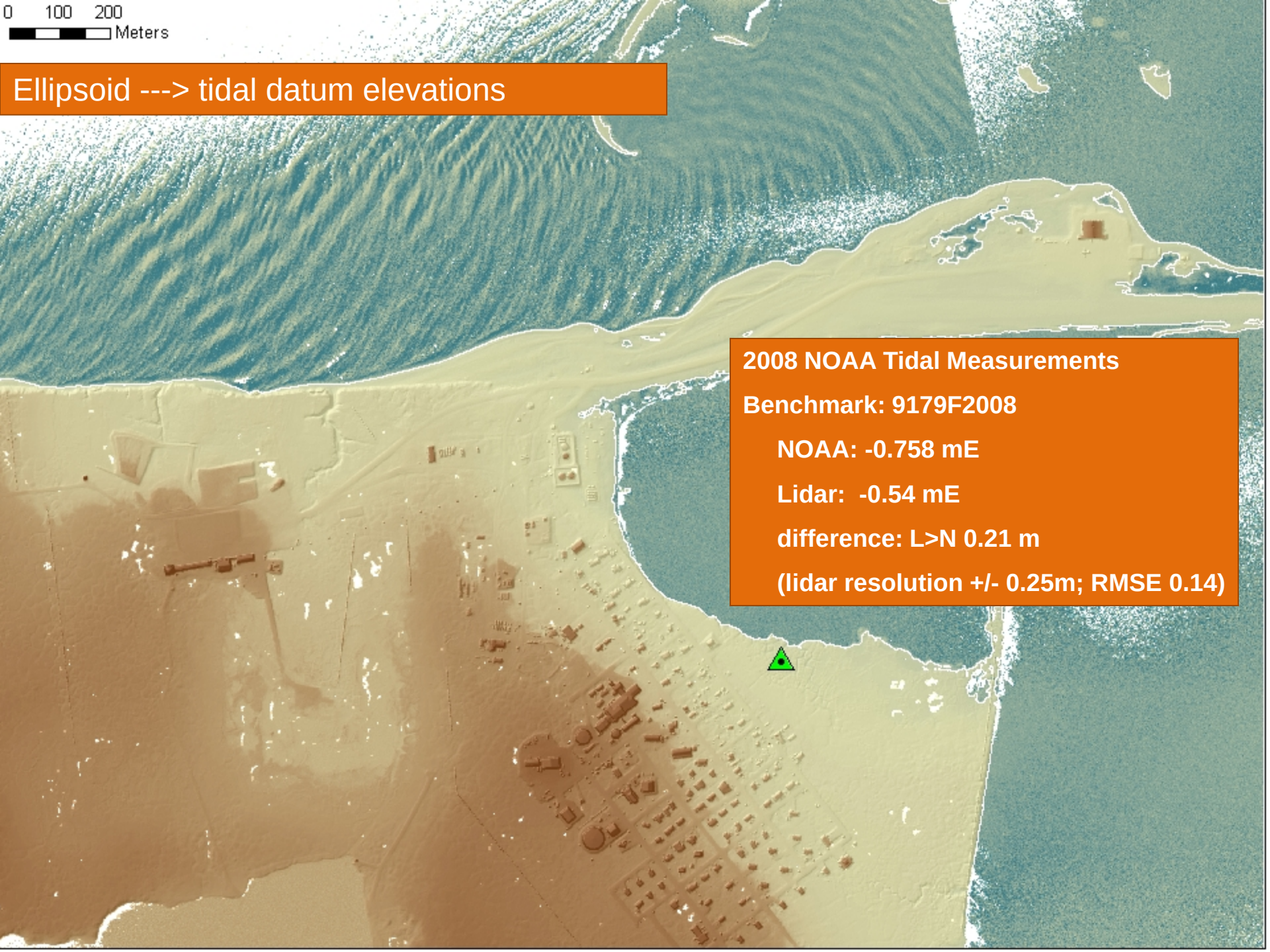


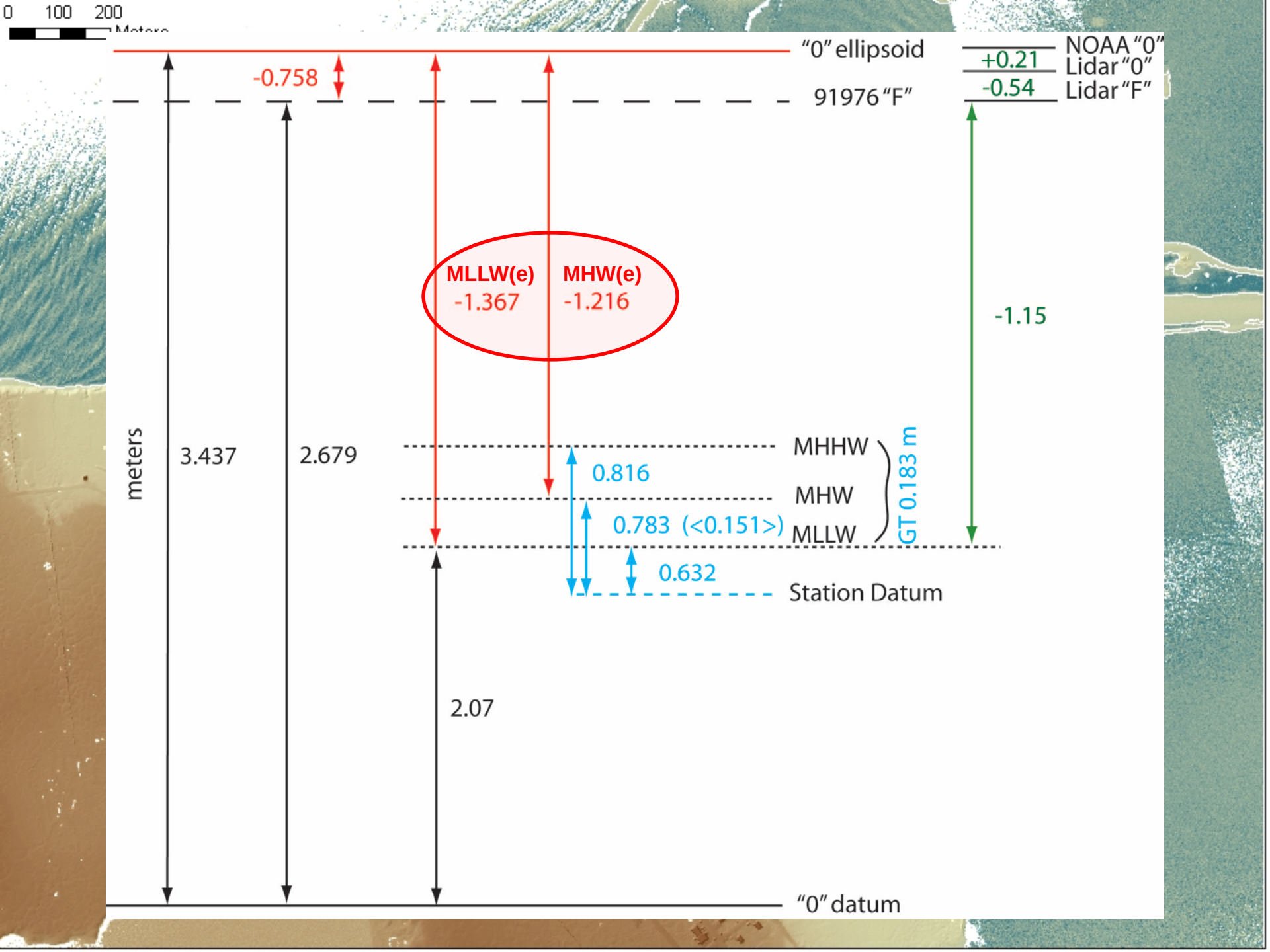
Initial code method identify top and toe








0 100 200
Meters
Ellipsoid ---> tidal datum elevations
2008 NOAA Tidal Measurements
Benchmark: 9179F2008
NOAA: -0.758 mE
Lidar: -0.54 mE
difference: L>N 0.21 m
(lidar resolution +/- 0.25m; RMSE 0.14)


0 100 200
"0" ellipsoid
NOAA "0"
+0.21
Lidar "0"
-0.54
Lidar "F"
-0.758
91976 "F"
MLLW(e)
-1.367
MHW(e)
-1.216
-1.15
meters
3.437
2.679
MHHW
0.816
MHW
0.783 (<0.151>)
MLLW
GT 0.183 m
0.632
Station Datum
2.07
"0" datum