D00193

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

DESCRIPTIVE REPORT

Type of Survey:	Reconnaissance
Registry Number:	D00193

LOCALITY

State(s):	North Carolina
General Locality:	Beaufort Inlet
Sub-locality:	Entrance to Beaufort Inlet

2015

CHIEF OF PARTY
Dave Bernstein

LIBRARY & ARCHIVES

Date:

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTRY NUMBER:

HYDROGRAPHIC TITLE SHEET

D00193

INSTRUCTIONS: The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

State(s):	**North Carolina**
General Locality:	**Beaufort Inlet**
Sub-Locality:	**Entrance to Beaufort Inlet**
Scale:	**30000**
Dates of Survey:	**04/13/2015 to 04/14/2015**
Instructions Dated:	**N/A**
Project Number:	**S-F344-KR-15**
Field Unit:	**Geodynamics LLC**
Chief of Party:	**Dave Bernstein**
Soundings by:	**Kongsberg Maritime EM 3002 (MBES)**
Imagery by:	**Kongsberg Maritime EM 3002 (MBAB)**
Verification by:	**Atlantic Hydrographic Branch (AHB) meters**
Soundings Acquired in:	**at Mean Lower Low Water**

Remarks:

Any revisions to the Descriptive Report (DR) applied during office processing are shown in red italic text. The DR is maintained as a field unit product, therefore all information and recommendations within this report are considered preliminary unless otherwise noted. The final disposition of survey data is represented in the NOAA nautical chart products. All pertinent records for this survey are archived at the National Centers for Environmental Information (NCEI) and can be retrieved via https://www.ncei.noaa.gov/.

Products created during office processing were generated in NAD83 UTM 18N, MLLW. All references to other horizontal or vertical datums in this report are applicable to the processed hydrographic data provided by the field unit.

DESCRIPTIVE REPORT MEMO

May 26, 2015

MEMORANDUM FOR: Atlantic Hydrographic Branch

FROM: Dave Bernsetin
Chief Hydrographer, Geodynamics LLC

SUBJECT: Submission of Survey D00193

Survey S-F344-KR-15 was conducted by Geodynamics LLC to provide a ground truth survey for the SBIR Phase 2 project, NOAA Contract No: WC-133R-14-CN-0119 "An Advanced Algorithm for Radar Derived Bathymetry". The depth range of the radar-derived bathymetry is 3 - 20 meters, with a spatial resolution of 100 meters. The project area encompasses Beaufort Inlet and surrounding waters south of the entrance.

There were no products created for this survey.

All soundings were reduced to Mean Lower Low Water using VDatum. The horizontal datum for this project is North American Datum of 1983 (NAD 83). The projection used for this project is Universal Transverse Mercator (UTM) Zone 18.

Two datasets were delivered for this project. One dataset was reduced to MLLW with tides and zoning while the second dataset was reduced to MLLW from a datum separation model integrated with the ellipsoidally-based GPS tide records. The zoned dataset was corrected for tides using a combination of verified tides from station 8656483 and preliminary tides from station 8658163 zoned with the NOAA provided "F901NRT22010CORP.zdf" file. The ERS survey utilized corrections from a semi-permanent RTK-GPS basestation located at the University of North Carolina's Institute for Marine Science .

All survey systems and methods utilized during this survey were as described in the survey proposal issued to OCS. Multibeam sonar data was collected within the project area on set line spacing. Geodynamics' survey vessel, the RV 4 Points, was outfitted with a Kongsberg Dual-Head EM3002 sonar system (20 degree mount) combined with a POS MV v5 and AML Oceanographic sound speed instrumentation (MicroSV-X and Smart SV&P-X) to collect sounding data. A precise vessel dimensional control (dimcon) survey was performed on the RV-4Points and integrated sensors on April 9, 2015. Following the dimcon survey, patch tests and a performance test were performed in and around the Morehead City State Port and Beaufort Inlet. Sounding data was corrected in real-time for position and ellipsoidally-referenced water levels from a semipermanent RTK-GPS basestation located at the University of North Carolina Institute for Marine Science. The RTK-

GPS basestation was comprised of a Trimble R7 receiver, Zephyr Geodetic antenna and Trimble TDL450 UHF Radio on frequency 461.1000.

All data were reviewed for DTONs and none were identified in this survey.*

Chart comparison was not required as per project instructions. However, for general quality assurance, chart comparisons were made with Survey H12266 and Chart 11547_1. It was expected that many portions of the survey area show small to more significant changes in chart comparisons due to the ephemeral nature of this tidal inlet and the time span between surveys. In areas where little change was expected (nearshore Atlantic Beach and deep portions of the shipping channel), chart comparisons agree well.

This survey does not meet charting specifications and is not adequate to supersede prior data. Survey data should be archived at NCEI and the DR memo forwarded to HSD.**

Sixteen (16) soundings were selected during the survey review that represented the shoal seaward migration. he D00193 shoal soundings selected reflect the change in depth within the common charted areas. The submitted soundings are located within depth areas that are shoaler than the current charted depth range.

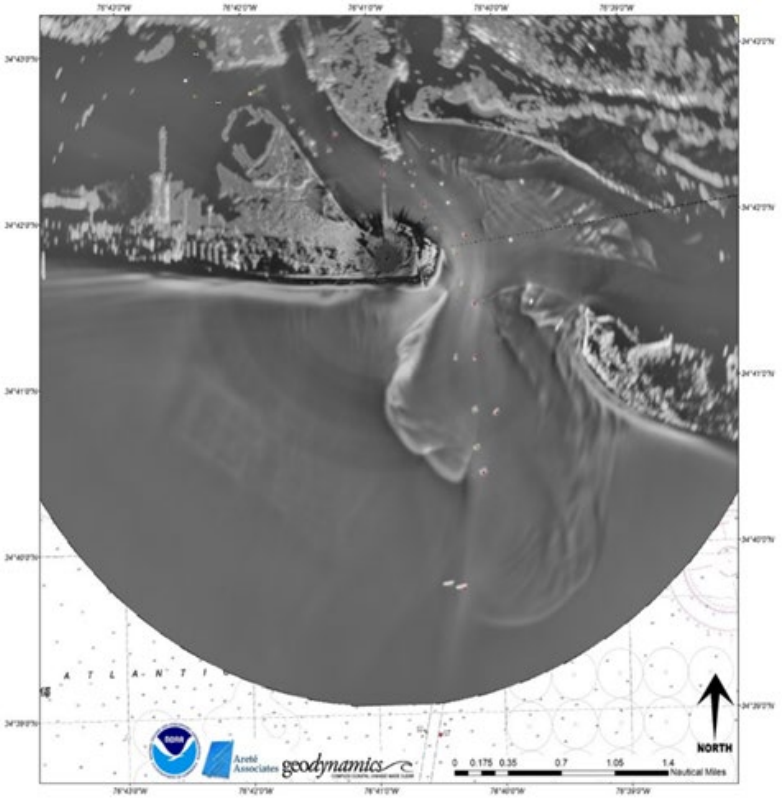
****Upon further review by AHB, it was determined that this survey does meet charting specifications and is adequate to supersede prior data.***

Areté Associates

Bathymetric X-Band Radar at Beaufort Inlet, NC:
Rapid Detection of Navigational Shoaling, Shoreline Change & Nearshore Bathymetry

Kenneth Vierra, Steven Anderson, Seth Zuckerman (Areté Associates)
Chris Freeman (Geodynamics)

U.S. 2017 Hydro Conference (March 20-23, 2017)



NOAA SBIR Bathy Radar Objectives:

Near-Term Goals:

- Remotely measure shallow water bathy in real-time
  - A low-cost tool to precisely target & quantify rapid shoaling zones that pose a hazard to navigation
- Produce robust algorithms and data products to promote safe navigation
  - Serve real-time data over the web to various stakeholders & NOAA Navigational Response Teams

Long-Term Goals:

- Transition the capability to NOAA Office of Coast Survey, USACE, and other stakeholders
  - Fill current void in updating charts at rapidly changing tidal inlets

Just some of THE BENEFITS!

1. Decrease survey costs by precisely locating the problems areas first
2. Markedly increase safety at shallow approaches through real-time monitoring
3. Increase management efficiency and decrease costs in maintenance
4. Promote synergy between the USCG, the USACE, NOAA & Port Facilities

Areté Associates

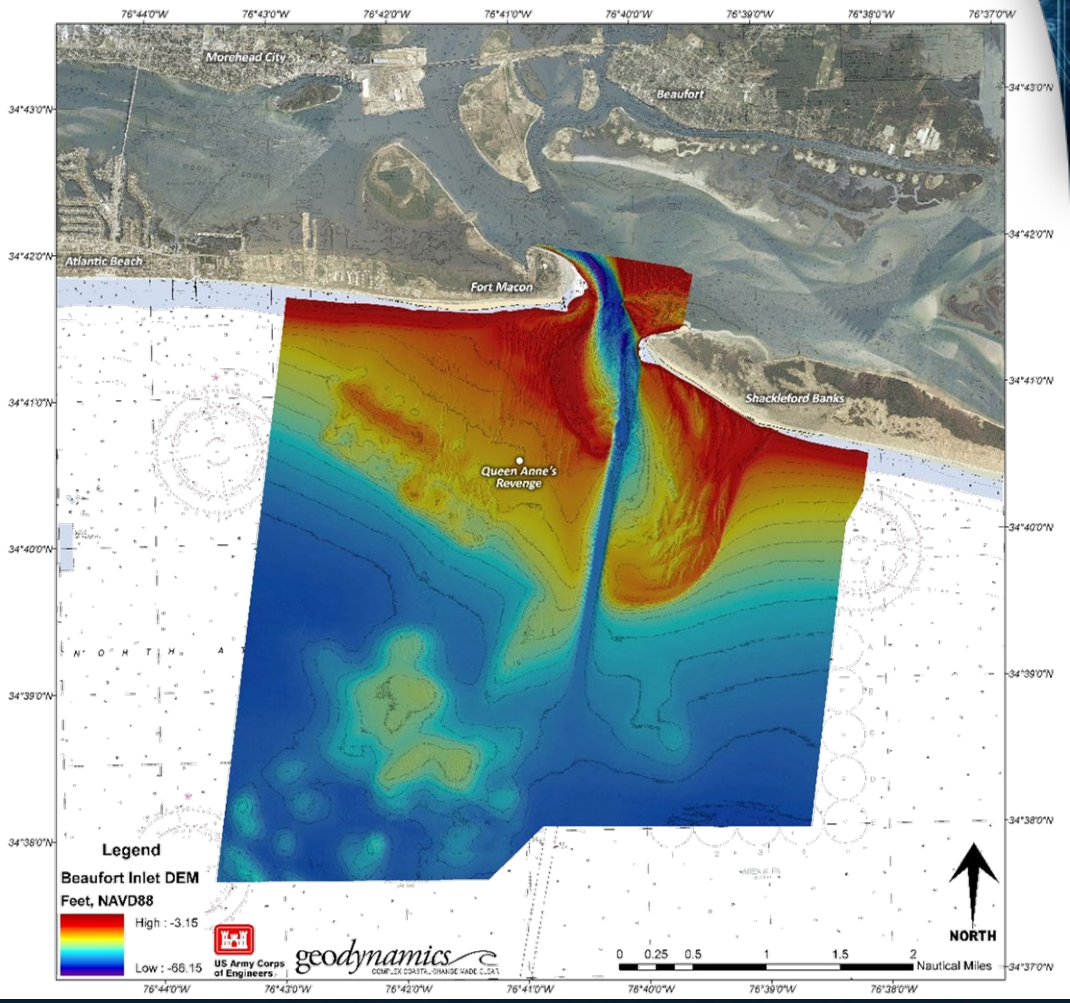
Capability Demonstration:

Beaufort Inlet, NC / Approaches to Port of Morehead City

The Highlights:

- Setup & Calibration at Beaufort Inlet (BI) USCG Station Ft. Macon
- 10 weeks of X-Band Radar data collected April 2 – June 15, 2015
- Simultaneous MBES survey of approach
- Shoreline monitoring data quantifying the shoaling source
- Validation of Phased-based Celerity (PC) algorithm
  - variant of cBathy from Holman et al (2013)

Exploits observation of shoaling waves to derive bathymetry



Setup & Calibration:

USCG, Sector North Carolina Fort Macon

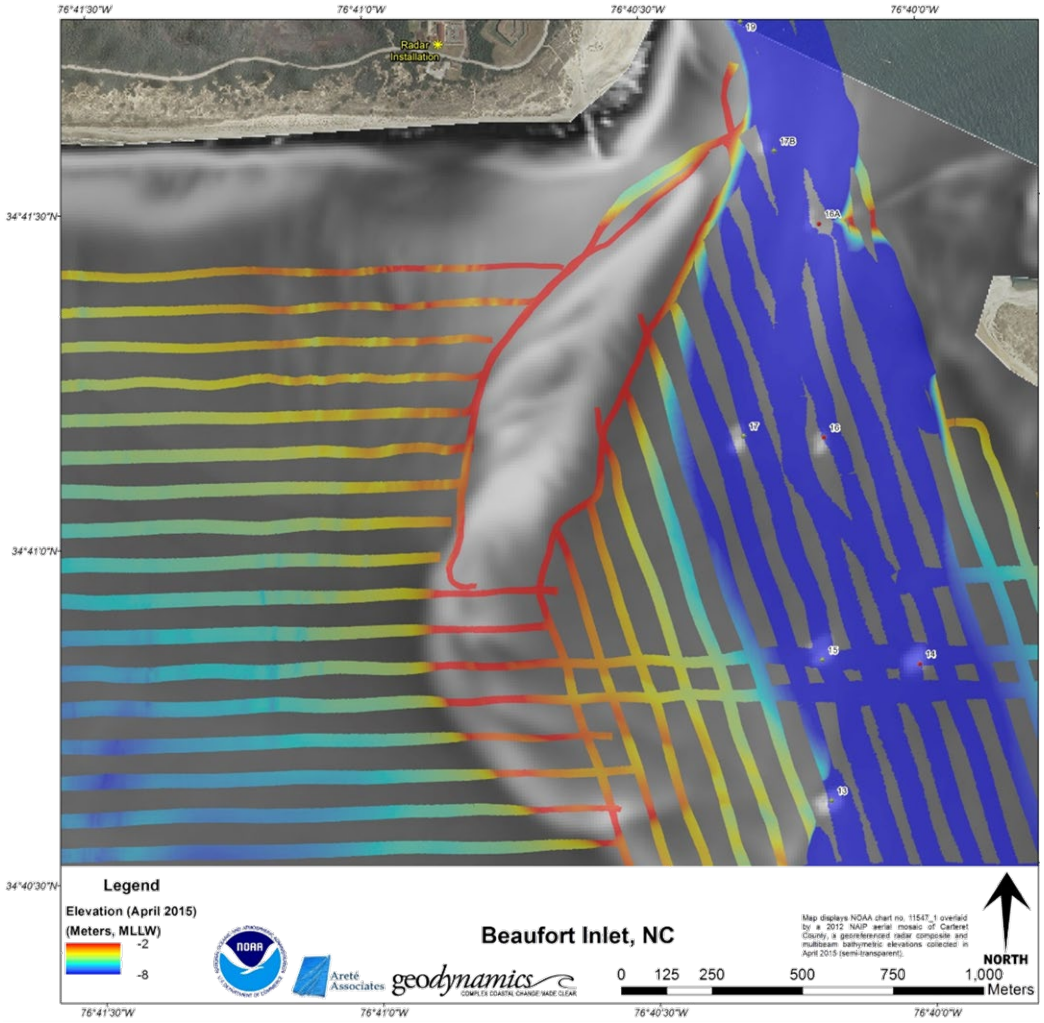
System Fully Functional and Collecting Radar Data April 2 – June 15, 2015

Furuno X-Band FAR-2127-BB Series Radar System

- Pulsewidth: 0.07μs (range resolution 10.5m)
- PRR: 3000 Hz
- Rotation: 42 rpm
- Beamwidth (H): 0.95°
- Beamwidth (V): 20°
- Acquisition sampling range: 3m
- Acquisition total range: 5000m

Ground Truth:

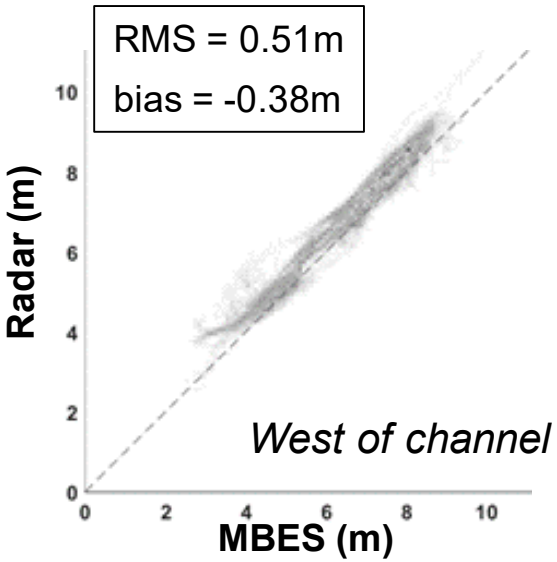
Multibeam Survey of the Approach & Nearshore Shoals

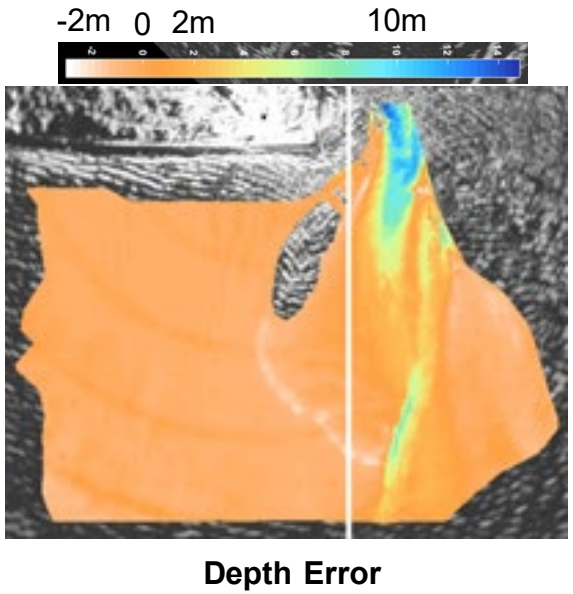


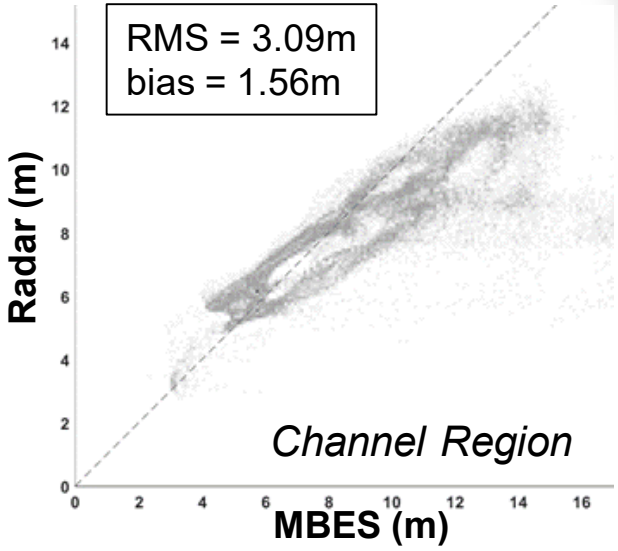
- MBES validation surveys performed April 27-28, 2015
- EM3002 Dual Head
- Ellipsoidally Referenced Survey (ERS)

PC Algorithm Validation:

Phased-based Celerity (PC) Algorithm Depths versus MBES Depths







The Highlights:

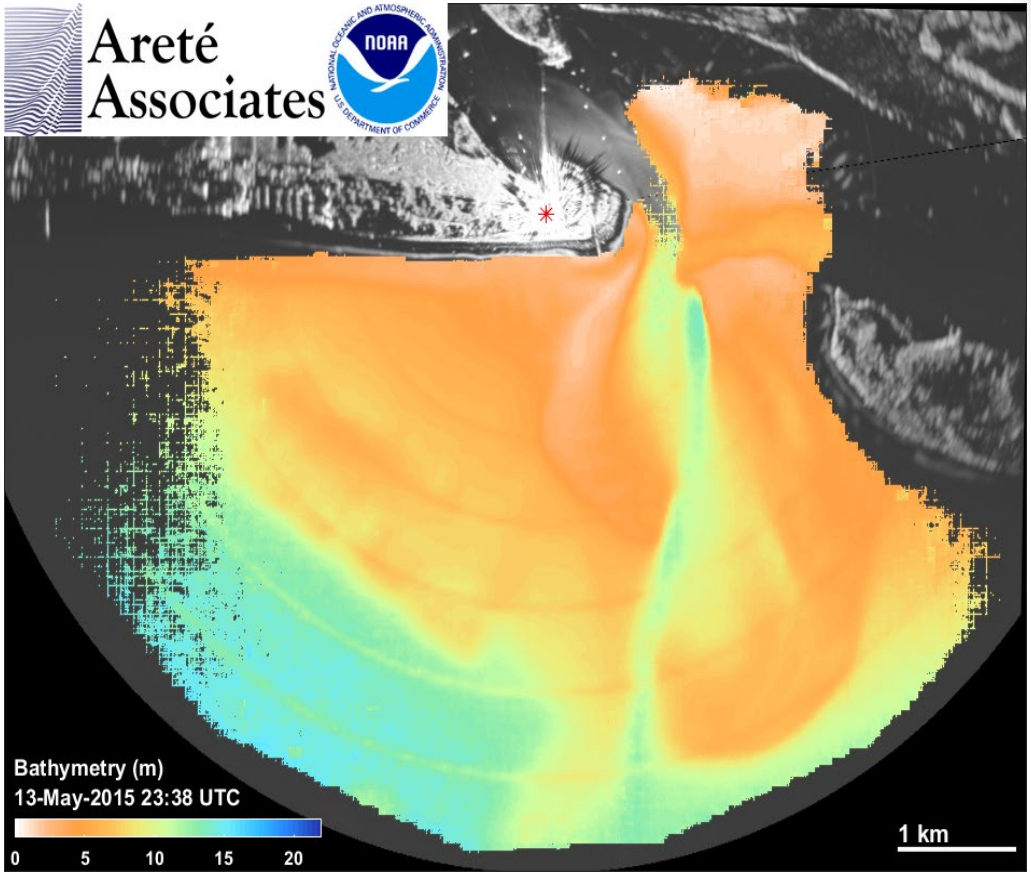
- Single radar pixel at 9m resolution w/ MBES gridded also at 9m resolution
- One week of data collection
- Good performance west of the channel
- Radar derived bathymetry struggles to capture deep channel depths

Results:

Radar Derived Bathymetry

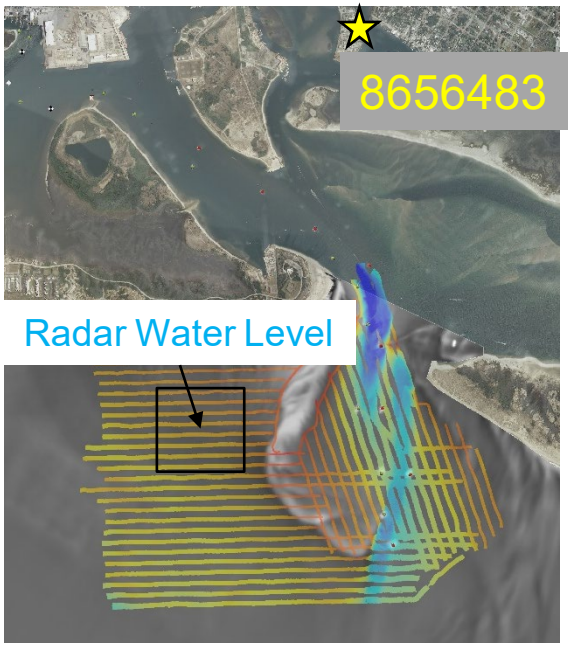
The Highlights:

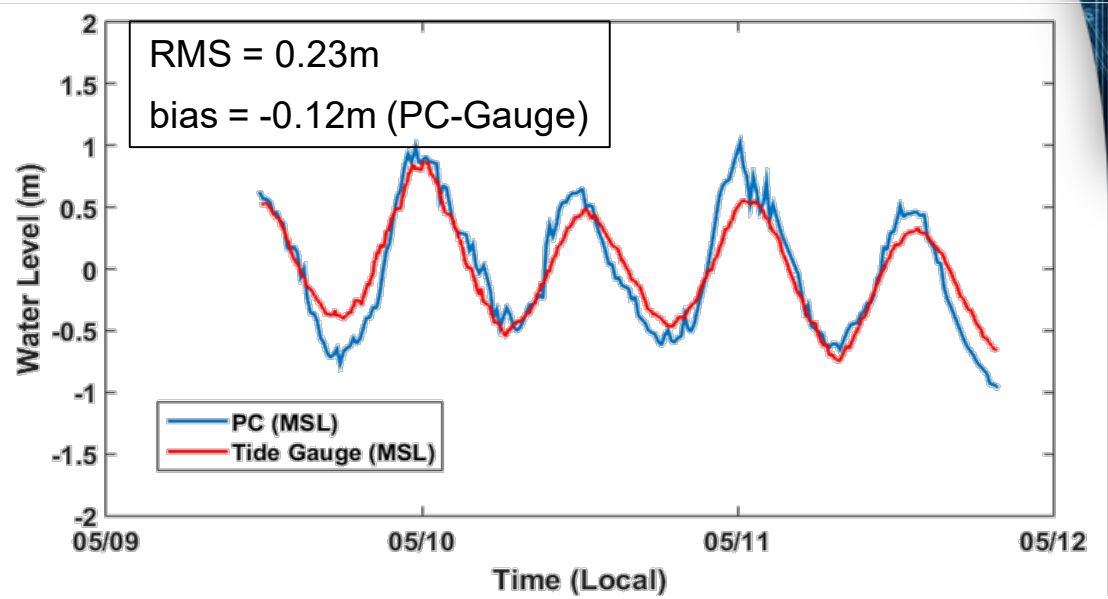
- Areté has successfully demonstrated radar bathy with PC algorithm
- Depth estimate at each pixel on 9m resolution grid
- Measured depths out to 5km (the max range of the radar) with values as shown ranging from ~2m to ~20m
- Bathy data products updated every 60 min



PC Algorithm Validation:

Radar-derived Water Level vs. CO-OPS Station 8656483 (Beaufort)





- Relative water levels: Radar retrievals (blue) and Gauge 8656483 (red).
- Radar water levels are derived by averaging a subsection of depth retrievals at each time step and subtracting the mean offset from all time steps
- Ground data was adjusted use zone tide information (ZDF)

Port of Morehead City, NC:

Shoaling and Navigation Issues

Areté Associates

The FACTS:

- Beaufort Inlet / MHC Port is the second largest deep draft port between Norfolk and Charleston
- The Port is one of the east coasts most accessible; located only 3nm from open ocean
- The Port is critical to NC Military Defense Logistics and serves the Sealift Command & troop deployments from Camp Lejeune, Fort Bragg and Cherry Point

The "Solution" 2011-2017:

- Since Irene (2011) the USACE has awarded 5 contracts totaling approx. $60m to remove over 4.5 million cubic yards of material
- Last 3 dredging contracts have been emergency related w/ an unknown inflation factor.

A Real-World Example of the Problem:

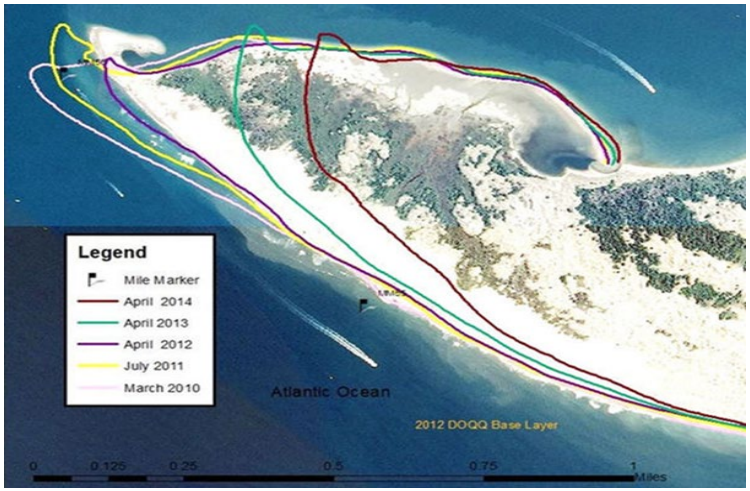
- Pola Palekh ran aground Nov 17, 2016 at "Cutoff" Range shoal at **16A**
- Carrying 35,800 metric tons of fertilizer and 27,000 gal of fuel (no spill)
- Channel temp closed to deep draft commercial traffic

A long-term radar deployment would allow for 24-7 monitoring & analysis of the SEVERE & COSTLY shoaling at this approach

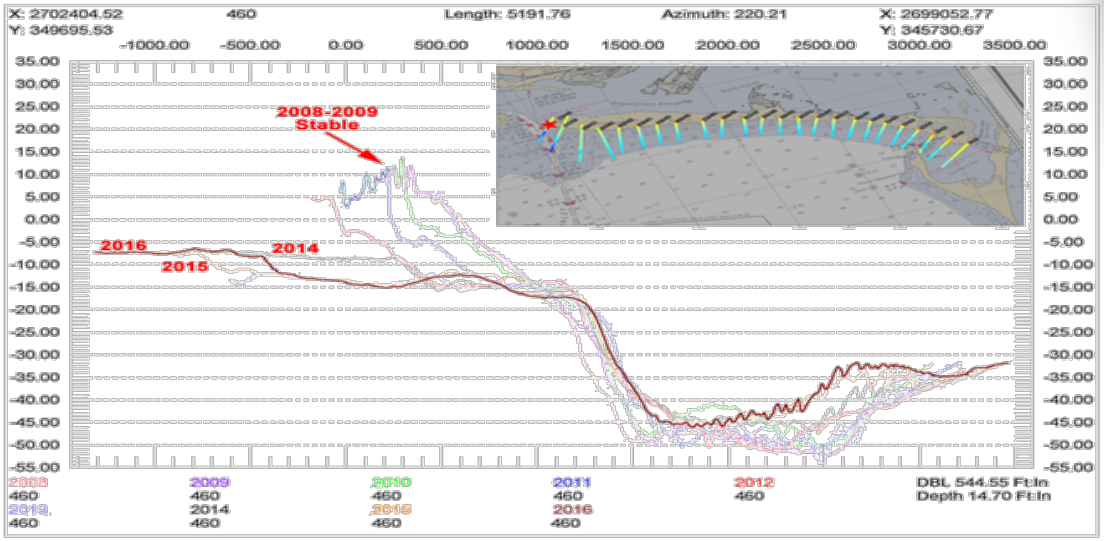
Cause of the Recent Shoaling Issue:

Accelerated Shoreline Erosion Adjacent to Navigation Channel

NPS Shoreline Data 2010 to 2014



Geodynamics Monitoring Profiles 2008 to 2016

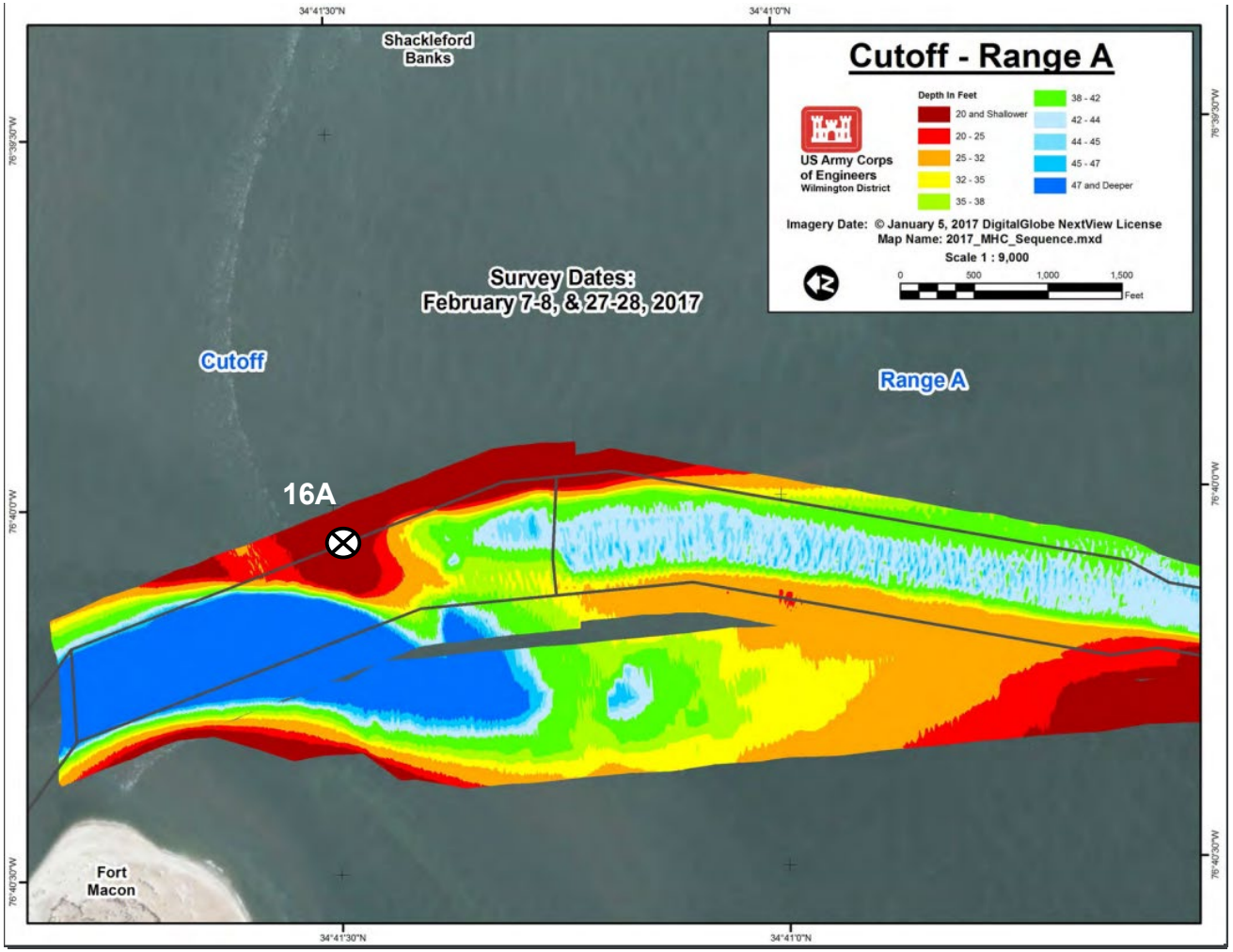


The Highlights:

- Rapid erosion of Shackleford Banks to the east following Hurricanes Irene (2011) and Sandy (2012) Sandy
- From 2010 to 2014 ~0.5 linear mi of beach eroded and input into E-W littoral system
- The 1st three monitoring transects adjacent to Beaufort Inlet (0.75 linear mi) thus far eroded
- Estimates from these transects, 5yrs after Irene & Sandy, show over 4m cu/yd of material input into the active zone of sediment transport

The Shoaling Issue:

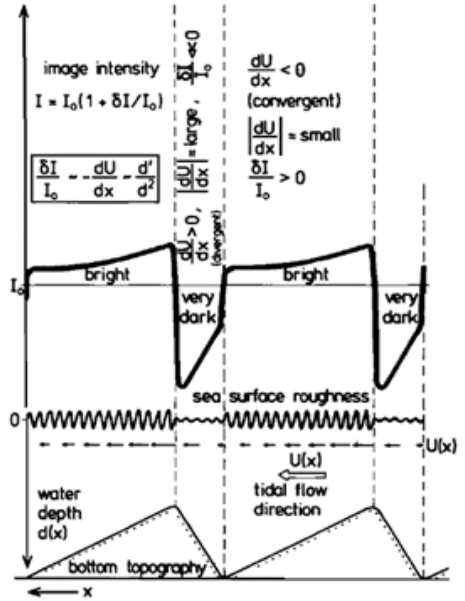
Sand Transport from Shackleford Banks into the "Cutoff" Range (2014-2017)



The Highlights:

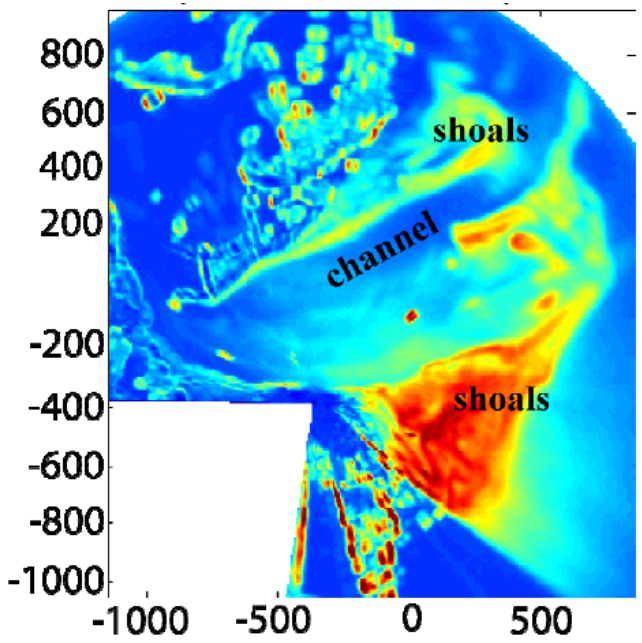
- Sand from Shackleford moving west into the "Cutoff" Range
- Even after two major dredging events the sediment is still pushing into navigation channel
- As of Feb 28, 2017 the channel is now blocked again

Radar Backscatter and Bathymetry:



Schematic plot of the relationship between an asymmetric sand wave profile and associated variations in tidal current velocity, short-scale surface roughness

From Alpers and Henning 1984

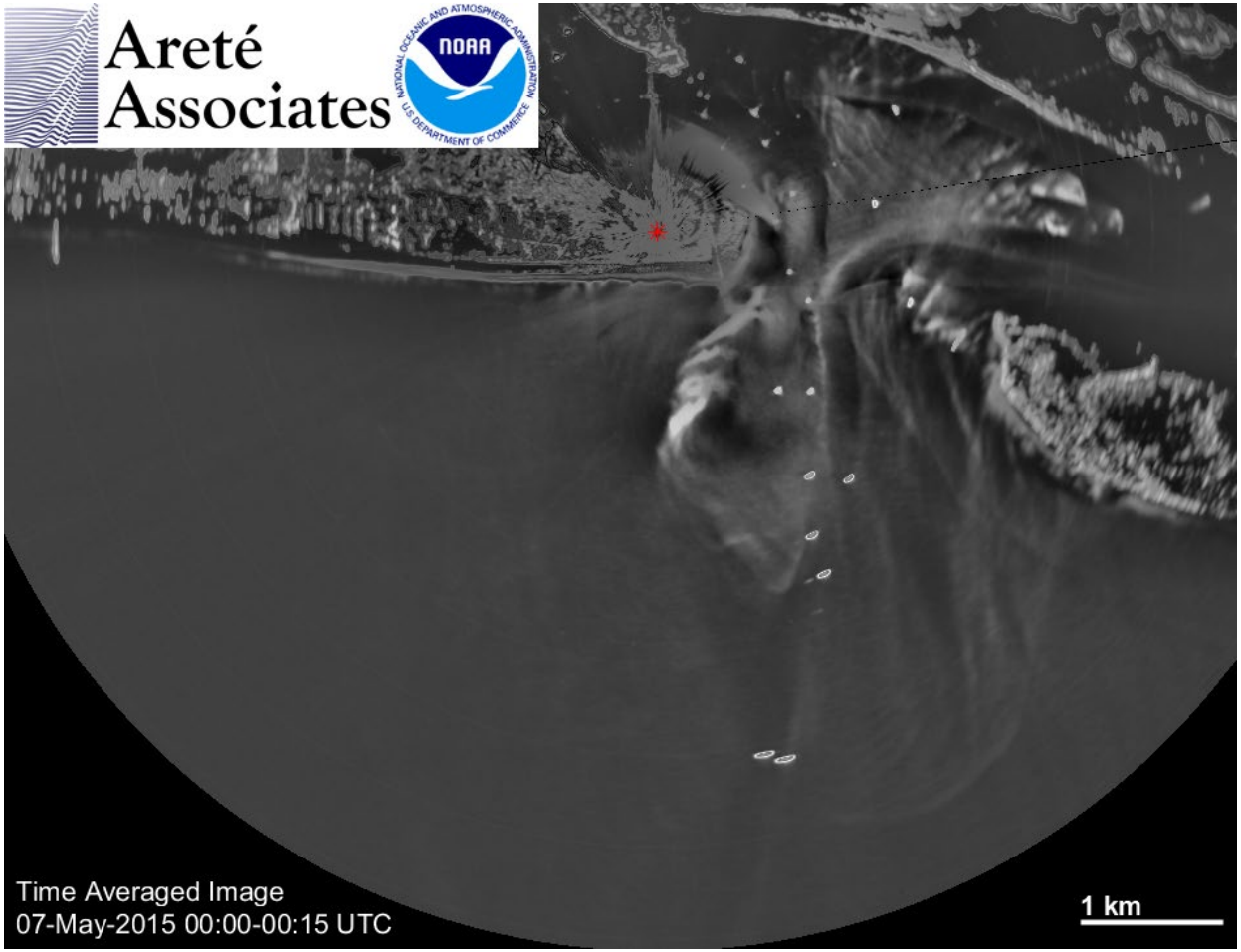


Mean X-band radar backscatter

From McNinch et al 2012

Bottom topography modulates the surface currents which in turn modulates surface roughness and radar backscatter intensity

X-Band Radar Coverage at Beaufort Inlet :



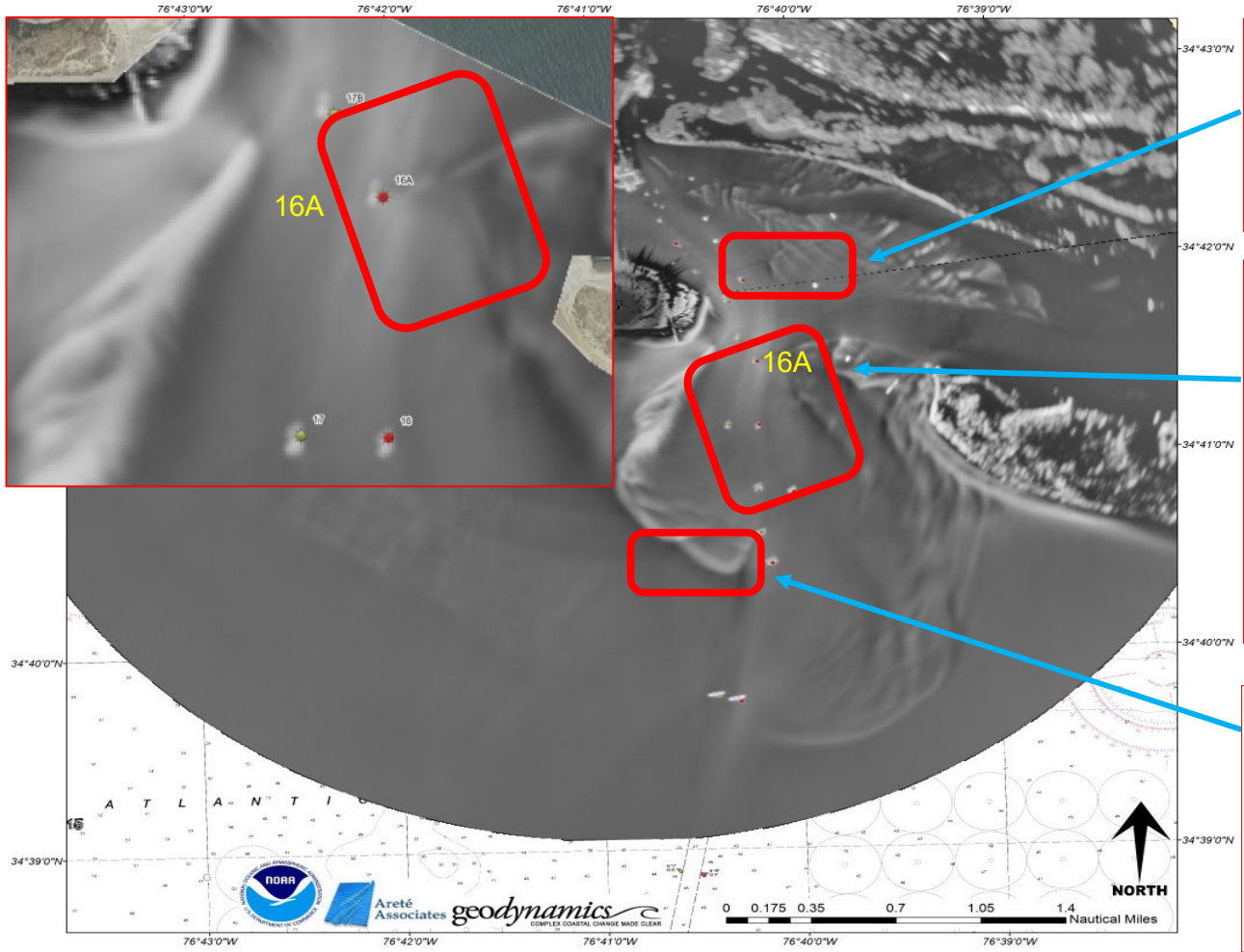
- X-Band radars can see signatures of subsurface morphology when radar images are averaged in time to remove surface wave signatures

  Alpers and Hennings 1994, Yu et al 2016, McNinch et al 2012]

- Time averaged radar images from Beaufort Inlet clearly show shoals in shallow areas
- Radar data is georeferenced to 9m spatial grid

X-Band at Beaufort Inlet:

Spatial Coverage Showing Current Shoal Problem Areas



- Another shoal moving into navigation channel
- This area currently not scheduled for dredging

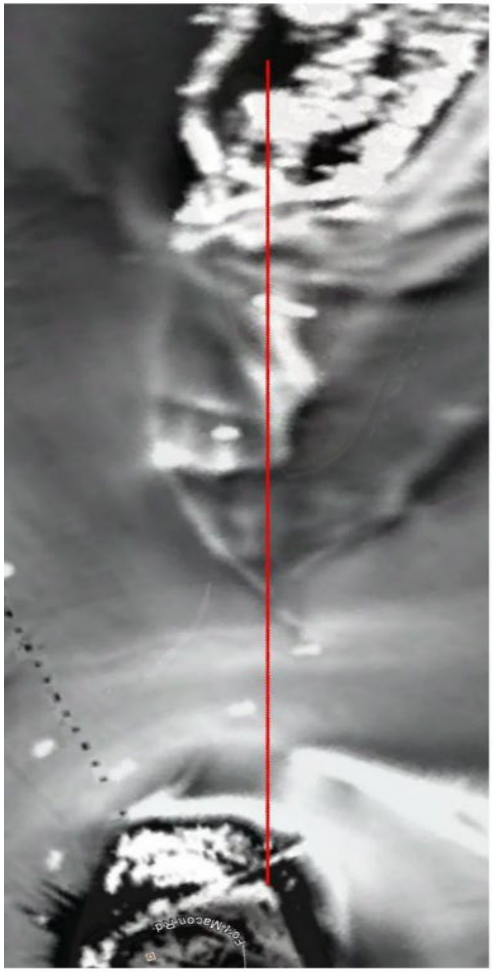
- Sub-aqueous remnants of western Shackleford Banks captured in the Phase II deployment
- East to west sediment transport being captured entering the navigation
- Location of Pola Palekh grounding

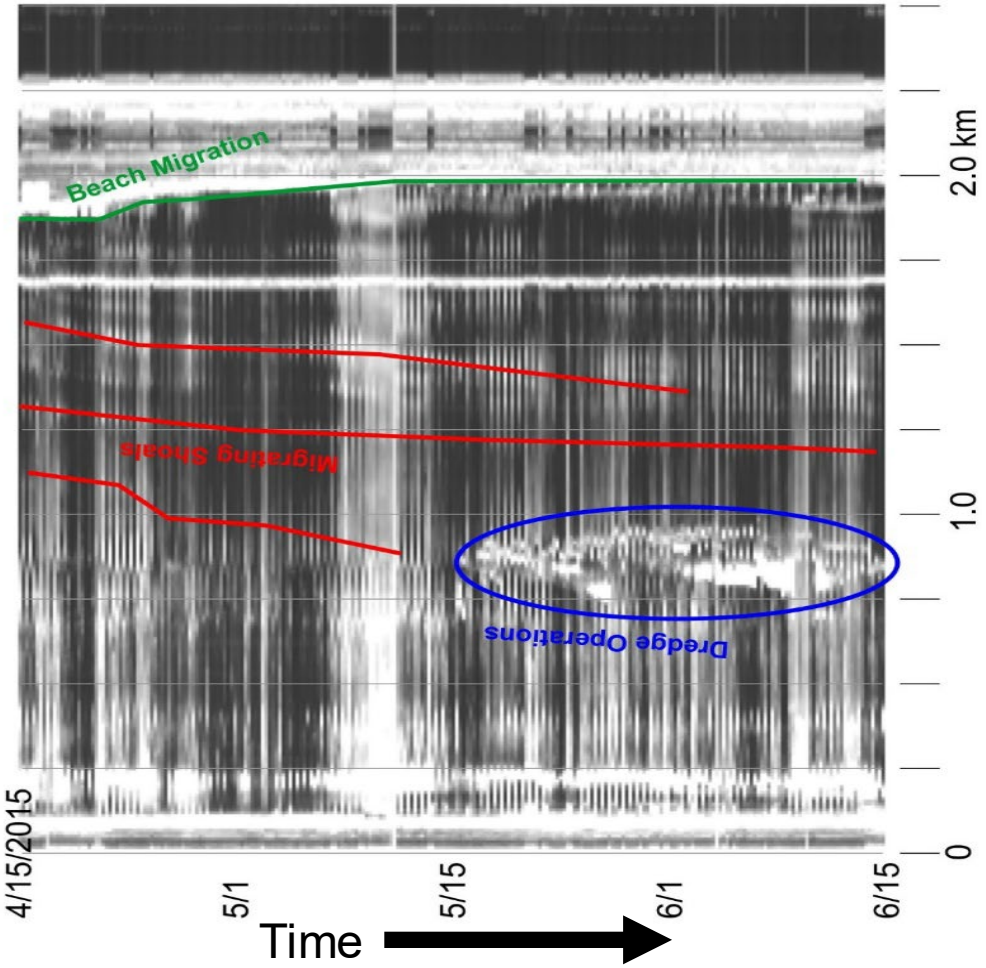
- Another shoal area beginning to move into the navigation channel.
- This area currently not scheduled for dredging (i.e. potentially another emergency dredge situation)

Areté Associates

X-Band at Beaufort Inlet:

Basic Analysis of the "Cutoff" and Areas around 16A



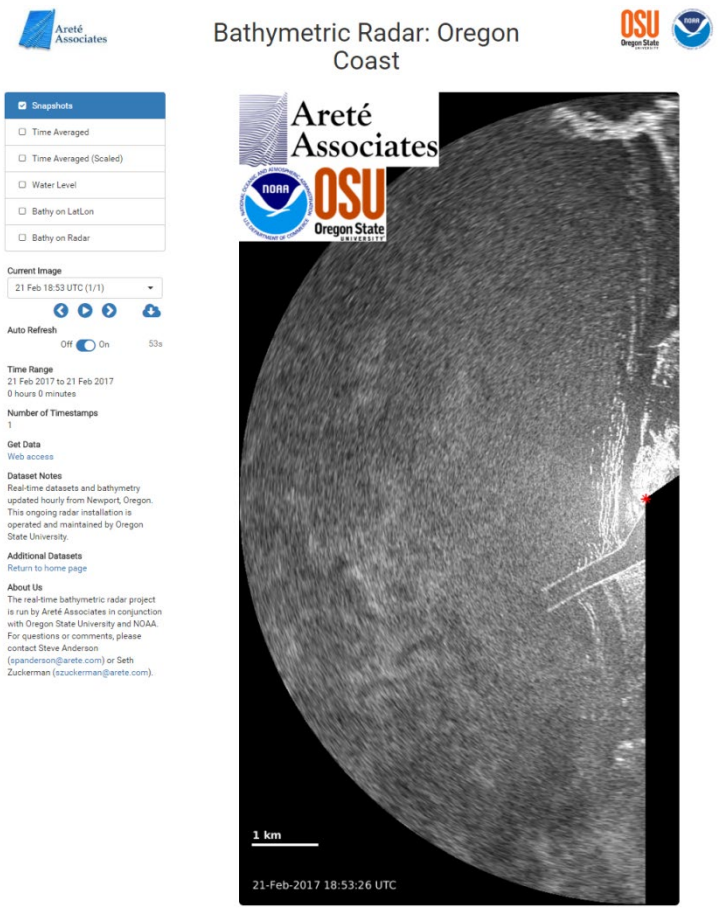


Ongoing & Future Work:

Operational Proto-Type Demo & Cloud Computing Web Interface

- Areté executing NOAA SBIR Phase III
- Installed OSU Koden radar for a long-term deployment atop the USCG Station Yaquina Bay tower
- Creating cloud based processing and web interface using Amazon Web Services to serve **real-time** data products
  1. 15-min average radar images
  2. Updated bathymetry hourly
  3. Updated bathymetry w/ error in BAG format hourly
- *Live demonstration to occur in early April*

Screen capture of operational website



Summary of X-Band Radar Demonstration:

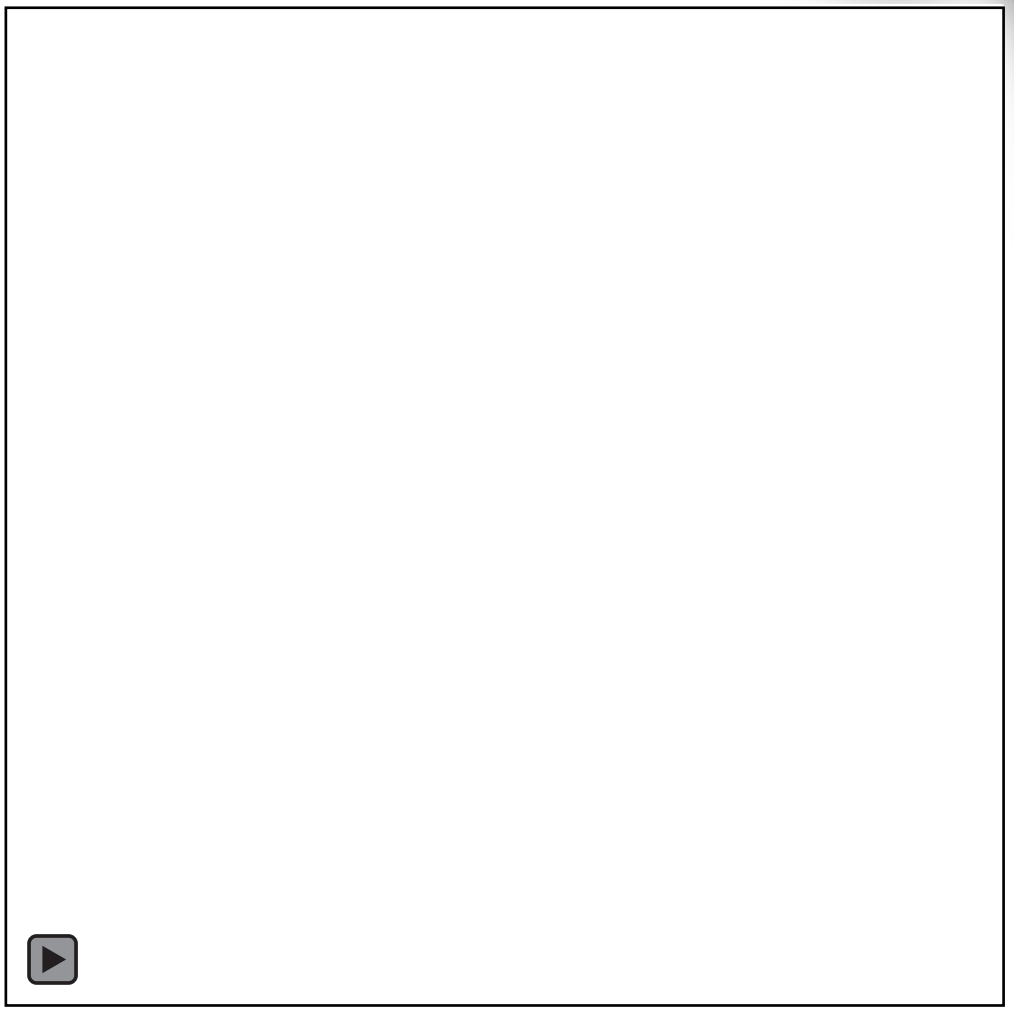
- Beaufort Inlet, NC has a long history of shoaling and significant complications to safe navigation
- We acquired 10 weeks of continuous X-band radar data from Beaufort Inlet
- Phased-Based Celerity (PC) algorithm proved robust for observing shallow water bathymetry
  - Derived bathymetry does not meet IHO Standards but useful for providing real-time monitoring in key areas
- Time-averaged images are capable of tracking shoaling and sand migration over time

Demonstration at Beaufort Illustrated:

1. X-band radar data products compliment existing survey technologies by providing real-time shoaling assessments on both long-term (background) and short-term (storms) timescales
2. Radar data products will allow those managing the navigation channels to understand when and where surveys are needed most
3. Radar data can provide ancillary data products that are important for safe navigation (e.g. surface currents, precise location of breaking waves, other hazards to navigation)
4. If deployed as a permanent asset, the system can provide a cost effective means for navigation situational awareness of other vessels

Acknowledgements & Thanks!

- The NOAA SBIR Program & the Korean Hydrographic and Oceanographic Agency for Development Funding
- The USCG Sector Ft. Macon for their assistance & installation site
- Oregon State University for use of their Radar system in development of the Operational Proto-Type Demo
- Geodynamics for ongoing support of this work



APPROVAL PAGE

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Data meet or exceed current specifications as certified by the OCS survey acceptance review process. Descriptive Report and survey data except where noted are adequate to supersede prior surveys and nautical charts in the common area.

The following products will be sent to NCEI for archive

- Descriptive Report
- Collection of Bathymetric Attributed Grids (BAGs)
- Processed survey data and records
- Geospatial PDF of survey products
- Backscatter mosaic

The survey evaluation and verification has been conducted according to current OCS Specifications, and the survey has been approved for dissemination and usage of updating NOAA's suite of nautical charts.

Approved: MCGOVERN.MEGHAN.ELIZABETH.1284020495 Digitally signed by MCGOVERN.MEGHAN.ELIZABETH.1284020495 Date: 2020.03.13 12:33:47 -04'00'

Commander Meghan McGovern, NOAA
Chief, Atlantic Hydrographic Branch