Survey Data - topographic

Mobile Lidar

• Systems on both boat and ATV
• Regularly used for beach renourishment surveys
• No RGB- intensity and elevation only
• Data is usually processed in cross sections.
Data Availability

- **Ehydro** - sounding data from all USACE

- Raw data available to public via FOIA request

- Data used for government purposes usually provided without FOIA
Charleston District - Building Strong!

Questions?

www.sac.usace.army.mil
Habitat Maps through Predictive Modeling

NCCOS
Laura Kracker
Bryan Costa
Tim Battista
Will Sautter
Ayman Mabrouk
Rachel Husted
Kim Edwards
Chris Taylor
Erik Ebert

Partners
NOAA - NCCOS, OMAO, OCS, NMFS, CRCP
USGS, CFMC, USVI, DPNR, PR-DNER, UVI, UPR, UNCW

National Centers for Coastal Ocean Science
NCCOS….we’re all in the same boat

Improving seafloor mapping capabilities in the
Southeast US coast and outer continental shelf
April 18-19, 2018
Charleston, SC
What is a “Habitat Map”?

OBJECTIVES:

Establish common technical language
What do you want to see in a habitat map?
Minimum criteria / standards for baseline data to create a habitat map
“Habitat” Mapping

Focus

Coral reefs
Bathymetric features
Fisheries, spawning aggregations
Offshore energy
Sand resources
Archeological significance
Today’s Objective: Describe a predictive modeling approach for habitat mapping*

Project Objective: Develop a habitat map* (for USVI Insular Shelf south of St. Thomas and St. John) based on multibeam and optical data, as well as machine learning techniques

* What is habitat mapping?
## Habitat Maps through Predictive Modeling

Pixel-based, machine learning vs. classification, delineation of polygons

<table>
<thead>
<tr>
<th>Approach</th>
<th>Technique</th>
<th>Resolution (Grain Size)</th>
<th>Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel-based</td>
<td>Machine learning assigns a probability of</td>
<td>Based on the ‘best attainable’ resolution of the original data and the error associated</td>
<td>Pixel resolution up to any merged or</td>
</tr>
<tr>
<td>predictive</td>
<td>occurrence to each pixel</td>
<td>with position of GV (ROV, camera) data. (ie. 11x11m)</td>
<td>threshold-ed scale</td>
</tr>
<tr>
<td>modeling (BRTs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delineation</td>
<td>Classify the sonar response into like pixels</td>
<td>Minimum mapping unit (ie. 100 - 1000+ m²)</td>
<td>Static. Can only scale up / simplify</td>
</tr>
<tr>
<td>of features</td>
<td>(PCA), segment, and label polygons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(polygons)</td>
<td></td>
<td></td>
<td></td>
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</tbody>
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## Habitat Maps through Predictive Modeling

Pixel-based, machine learning vs. classification, delineation of polygons

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<th>Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pixel-based predictive modeling (BRTs)</strong></td>
<td>Machine learning assigns a probability of occurrence to each pixel</td>
<td>Based on the ‘best attainable’ resolution of the original data and the error associated with position of GV (ROV, camera) data. (ie. 11x11m)</td>
<td>Pixel resolution up to any merged or thresholded scale</td>
</tr>
<tr>
<td><strong>Delineation of features (polygons)</strong></td>
<td>Classify the sonar response into like pixels (PCA), segment, and label polygons</td>
<td>Minimum mapping unit (ie. 100 - 1000+ m²)</td>
<td>Static. Can only scale up / simplify</td>
</tr>
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</table>
Habitat Maps through Predictive Modeling

Moderate depth benthic habitats of St. John

East end of the Insular shelf study area south of St. John

Delineation of polygons
Costa et al. 2009

Pixel-based predictive modeling
Costa et al. 2017
...by developing many simple regression (tree) models that relate a response (i.e., habitat type) to environmental predictors by iteratively splitting the data into two homogenous groups. These models are built in a stage-wise fashion, where existing trees are left unchanged and the variance remaining from the last tree is used to fit the next one. These simple models are then combined linearly to produce one final combined model. (Friedman, 2002; Elith et al., 2006; Elith et al., 2008).
Multibeam surveys (2003-2011) with ROV tracks
Bathymetric derivatives
Ground Validation and Accuracy Assessment data collection sites
1. Take pictures of seafloor at GV and AA sites

Optical methods

When camera is 1-2 m above seafloor
(start annotation) |----------------------| (end annotation)
Time 0 → 10 sec
2. Review video; annotate **substrate** and **cover** type

**RESPONSE:**

presence-absence for each **substrate** and **cover** type

- Coral Reef
- Pavement
- Sand
- Rhodoliths
- Live hard coral
- Live soft coral
3. Extract seafloor metrics, etc. at each GV site

**PREDICTORS:**
Bathymetric, oceanographic, geographic attributes
Bathymetric data as Predictors

**PREDICTORS**

Bathy/Seafloor characteristics at GV sites

Seafloor metrics (n=8)

- Depth
- Depth std dev.
- Curvature
- Curvature (plan)
- Curvature (profile)
- Rugosity
- Slope
- Slope rate of change
Oceanographic data as Predictors

**PREDICTORS**
Oceanographic characteristics at GV sites

Oceanographic variables (n=8)

- Euphotic depth
- Euphotic depth std error
- Turbidity @547nm
- Turbidity std error
- SST anomaly frequency
- SST Anomaly Frequency std error
- Thermal stress anomaly frequency
- Thermal Stress Anomaly Frequency std error
Geographic data as Predictors

**PREDICTORS**

Geographic characteristics at GV sites

Geographic variables (n=4)

- Distance to shelf edge
- Distance to shore
- Latitude
- Longitude
4. Run the BRT model many times and create:
   - predictive surface of probability of occurrence
   - coefficient of variation surface

Boosted regression trees (BRTs) model complex ecological relationships by developing many simple regression (tree) models that relate a response (ie. habitat type) to environmental predictors by iteratively splitting the data into two homogenous groups. These models are built in a stage-wise fashion, where existing trees are left unchanged and the variance remaining from the last tree is used to fit the next one. These simple models are then combined linearly to produce one final combined model (Friedman, 2002; Elith etal., 2006; Elith etal., 2008).
Results:

Prevalence in GV data
Model parameters and performance

Predicted surfaces showing
- Probability of occurrence
- Coefficient of variation
Results: Cover
- Probability of occurrence and coefficient of variation
Results: Substrate
- Probability of occurrence and coefficient of variation
Model runs for each substrate and cover type

**STEP 5.** Cluster the predicted surfaces of each *substrate* and *cover* type into commonly co-occurring habitat classes (BCTs).
Results: Composite benthic habitat map
Cluster substrate & cover types into five commonly co-occurring habitat classes

1. Coral reef colonized with live coral
2. Pavement colonized with live coral
3. Rhodoliths with macroalgae
4. Bare sand
5. Rhodoliths with macroalgae and bare sand
Results: Composite benthic habitat map
348 underwater videos used to evaluate map accuracy

OA = 85.6%  \( \tau = 0.82 \)

<table>
<thead>
<tr>
<th>Map (i)</th>
<th>Coral Reef Colonized with Live Coral</th>
<th>Pavement Colonized with Live Coral</th>
<th>Rhodoliths with Macroalgae and Bare Sand</th>
<th>Rhodoliths with Macroalgae</th>
<th>Bare Sand</th>
<th>( \eta )</th>
<th>User’s Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coral Reef Colonized with Live Coral</td>
<td>119</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>134</td>
<td>89%</td>
<td></td>
</tr>
<tr>
<td>Pavement Colonized with Live Coral</td>
<td>10</td>
<td></td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>91%</td>
<td></td>
</tr>
<tr>
<td>Rhodoliths with Macroalgae and Bare Sand</td>
<td>2</td>
<td>48</td>
<td>13</td>
<td>6</td>
<td>69</td>
<td>70%</td>
<td></td>
</tr>
<tr>
<td>Rhodoliths with Macroalgae</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>104</td>
<td>3</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td>Bare Sand</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>17</td>
<td>24</td>
<td>71%</td>
<td></td>
</tr>
<tr>
<td>( \eta )</td>
<td>120</td>
<td>23</td>
<td>52</td>
<td>122</td>
<td>31</td>
<td>348</td>
<td></td>
</tr>
<tr>
<td>Producet’s Accuracy (%)</td>
<td>99%</td>
<td>43%</td>
<td>92%</td>
<td>85%</td>
<td>55%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OA = 85.6%
\( \tau = 0.82 \)

CI \( (\pm) = 0.05 \)
Products

Benthic Habitat Maps for the Insular Shelf South of St. Thomas and St. John

https://maps.coastalscience.noaa.gov/biomapper/biomapper.html?id=insular

NOAA Tech Memo 241
Questions?
Ocean Exploration in the Southeast FY17 and FY18

Kasey Cantwell & Derek Sowers
NOAA Office of Ocean Exploration and Research
SECART 2018 Mapping Workshop
The only federal organization dedicated to exploring our unknown ocean

- Support innovations in exploration tools and capabilities
- Encourage the next generation of ocean explorers, scientists, and engineers
- Provide a foundation of publicly available data and information to give resource managers the information they need to make informed decisions
DEEP SEARCH: Deep Sea Exploration to Advance Research on Coral/Canyon/Cold seep Habitats

- 4.5 yr BOEM-USGS-NOAA study
- BOEM contractor: TDI-Brooks International; project manager: Erik Cordes (Temple U)
- USGS supporting 5 complementary science teams; lead: Amanda Demopoulos
- Y1 field work: NOAA Ship *Pisces*, AUV *Sentry*
- Y2 field work: NOAA Ship *Nancy Foster* (April); R/V *Atlantis*, HOV *Alvin* (August)
NOAA Ship *Okeanos Explorer*

America’s ship for ocean exploration

- 9 scientific sonars to map the seafloor and water column
- Custom-built, 6,000 m dual ROV system
- CTD with DO, LSS, and ORP
- Cutting edge telepresence technology
- Science team primarily based on shore
Mapping Sonars: Multibeam

- Kongsberg 30 kHz EM302 Multibeam
- Operating efficiency depths ~250m – 6500m

<table>
<thead>
<tr>
<th>Water Depth (meters)</th>
<th>Cell Size (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>300</td>
<td>3</td>
</tr>
<tr>
<td>500</td>
<td>4</td>
</tr>
<tr>
<td>1000</td>
<td>9</td>
</tr>
<tr>
<td>2000</td>
<td>17</td>
</tr>
<tr>
<td>3000</td>
<td>26</td>
</tr>
<tr>
<td>4000</td>
<td>35</td>
</tr>
<tr>
<td>5000</td>
<td>44</td>
</tr>
<tr>
<td>6000</td>
<td>52</td>
</tr>
</tbody>
</table>
Knudsen 3260 Subbottom Profiler

- Knudsen Subbottom Profiler
  - Sub-seabed structures
    - Sediment layers
    - Gas
    - Buried channels
- 3.5 kHz chirp
- Up to ~ 80 m penetration below seabed
Simrad EK 60 Split beam sonars:
18, 38, 70, 120, 200 kHz

BIOMASS

GAS PLUMES
Teledyne ADCPs 38, 300 kHz

Image: Jules Hummon UHDAS
Telepresence
Atlantic Deepwater Data

*Okeanos Explorer (EX)* and Extended Continental Shelf (ECS) mapping efforts

- Cumulative multibeam sonar coverage
- EX cruises
- ECS cruises (NOAA/UNH)
- 10-30m resolution on shelf
- 50-100m resolution canyons/abyss
Exploration Priority: “Stetson Mesa”
Region of the Blake Plateau
• Habitat Area of Particular Concern for Deep Water Corals
• Restricted Area for Contact Fishing
Searching for U-576
NOAA team discovers two vessels from WWII convoy battle off North Carolina

German U-boat 576 and freighter Bluefields found within 240 yards of one another

October 21, 2014

U-576 sonar image. Photo: NOAA

Bluefields sonar image. Photo: NOAA

The German U-576 departing Saint-Nazaire, France, circa 1940-1942. The submarine was sunk in 1942 by aircraft fire after attacking and sinking the Nicaraguan freighter Bluefields and two other ships off North Carolina. (Credit: With permission from Ed Caram)
2018 Planned Operations

• First year of new campaign — Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE)

• 32 DAS
  – 5/23-6/1: Mapping cruise (Mayport, FL to Charleston)
  – 6/6-6/27: ROV/Mapping cruise (Charleston, SC to Norfolk, VA)

• Deep sea corals, shipwrecks, canyons, Blake Plateau and Ridge, seeps, and geohazards
The Opportunity/ How to get involved

FY18
- Participate and share expedition within your network
- Engage with the ship via outreach opportunities

FY19+
- Submit high level priorities
- Identify regional data gaps
Timeline

January/February:
- Refine operating areas

February- April:
- Call for mapping and dive targets
- Regular planning calls begin (week of 5/1)

May-June:
- Participate!
- Real-time data available
- Outreach opportunities

July: Initial summary materials

July- September: Data and samples to archives

2019-2020: Continue Southeast work and potentially expand to Caribbean pending regional input and support
Questions?

Follow up with Kasey Cantwell (Kasey.Cantwell@noaa.gov) and Derek Sowers (Derek.sowers@noaa.gov)

OceanExplorer.NOAA.gov
Marine Minerals Information System (MMIS)

Lora Turner (BOEM Project Lead)
Brian Zweibel (DOI PM)
Alexa Ramirez (QSI PM)
Dave Stein (NOAA COR)

Charleston, SC
April 18, 2018
• Background
• Data
• Coastal and Marine Ecological Classification Standard (CMECS) Implementation
• Access
• MMIS Demo
• Mapping Plans
Why?

Data Steward
- Maintain marine minerals data

Physical Scientist / Analyst
- Characterize the subsurface to support leasing and environmental decisions

Planner
- Consume authoritative marine mineral datasets to identify conflicts with other OCS activities / regional planning

Manager
- To manage the resource, we need to know what we have

Leadership
- Oversee the development of marine mineral resources on the OCS

Pre-dredge Survey
Post-dredge Survey

SC Folly Lease OCS-A-0504

NJ LBI Lease OCS-A-0505

Background
Collaboration with our Partners

- Analyzed Geotechnical / Geophysical Source Data
- Digital data from physical core samples
- Digital derived data from external drives, CD's, paper sources
- Cooperative Agreements
- Leasing data
- Dredge data
- Environmental Studies Data

Background

A tool to support the National OCS Sand Inventory for Coastal Restoration Projects

Discover

Analysis

Id Gaps
• Data are being used to understand seafloor/subsurface composition as well as habitat
  – Interferometric Sidescan Sonar, Multibeam, Sub-bottom Seismic, Sidescan Sonar, Magnetometer, grab and core samples…

• *Importance of Mapping*
  – OCS energy and mineral resource assessment
  – Locations of sensitive benthic habitats, submerged cultural resources, undersea cables, etc. for environmental analysis, reviews and post monitoring
  – Track Federal leases and resource utilization
  – Pre- and post-dredge bathymetric surveys
Fig. 5: Spatial comparison of sand resource assessment offshore Duck, NC.
Mapping offshore resources with our partners

Reconnaissance Offshore Sand Search Inventory (OSSI)

OSSI registered with DATA.GOV

Sediment Thickness
• MMIS crosswalk completed
• Incorporated CMECS attributes into MMIS schema
• QSI development towards a CMECS completion tool
Access

MMIS Demo

Planned for the Public
• **Collection** - currently no new acquisition plans
  – (ASAP Phase 2 / GSAP - tbd)
• **Evaluate existing offshore data** – ongoing
  – Geophysical data: multi-beam, chirp sub-bottom profiling, swath bathymetry, sidescan sonar and magnetometer
  – Geotechnical data: sediment samples (vibracores and surface grab samples) analyzed for texture (grain size) and composition (organic, mineral and shell content, color and sand percentage)
• **Identify data gaps / priority areas** - ongoing
• **Assess future sand / sediment needs** - ongoing
• **Identify potential sources** – ongoing
• **Facilitate public accessibility of data** – in progress

---

**Lease Borrow Areas**

- **USACE Pre Dredge Surveys**
  – Martin – Jan 2018
  – Longboat Key - tbd
  – Patrick AFB - tbd
  – Collier – tbd

- **USACE Post Dredge Surveys**
  – Brevard – tbd
  – Myrtle Beach –tbd

---

**Agreements / Partnerships**

- Cooperative Agreements (2014-2018) (processing)
- USACE MOA (2017) (collaboration)
- AASG MOA (2015-2020) (collaboration)
- IA with NOAA OCM (2017-2022) (acquisition)
Thank you

Lora Turner

https://www.boem.gov/Marine-Minerals-Program/

marineminerals@boem.gov
Investigations Into South Carolina’s Outer Continental Shelf (OCS) Sand Resources: Data Inventory, Resource Assessment, and Recent Data Collection and Analysis Efforts

Andrew Tweel¹, Katherine Luciano², Denise Sanger¹, Scott Howard²

¹ Marine Resources Research Institute, Marine Resources Division – South Carolina Department of Natural Resources
² South Carolina Geological Survey, Land, Water and Conservation Division – South Carolina Department of Natural Resources
Increase in Offshore Borrow Cost Over Time

![Graph showing the increase in offshore borrow cost over time. The x-axis represents the years from 1950 to 2020, and the y-axis represents the cost per CY ($/CY). There is a general upward trend indicating an increase in cost over time.]
Goals for the BOEM SC State Cooperative Project I (2014 – 2016):
1. Identify existing geophysical/geotechnical data and acquire data, where possible
2. Assess South Carolina’s coastal communities’ sand needs in relation to identified data gaps
3. Compile data and provide to BOEM with FGDC-compliant metadata and in a compatible format

Goals for the BOEM SC State Cooperative Project II (2016 – 2018):
1. Continue integrating historical datasets into database through sub-projects with the College of Charleston and the University of South Carolina
2. Process and analyze all data collected offshore of South Carolina by CB&I in 2015
3. Integrate historical data and ASAP data, along with high-resolution bathymetry, to identify potential areas of beach-compatible sand material in the 3-8 nautical mile Outer Continental Shelf
Geophysical Data Coverage: Pre- and Post-Project
Geotechnical Data Coverage: Pre- and Post-Project
Understanding Where Data Gaps Exist: Data Coverage by Type
Understanding Where Data Gaps Exist: Geophysical Data Density
Understanding Where Data Gaps Exist: Geotechnical Data Density

(points/km²)
Identified Data Gaps
Needs for South Carolina’s Nourished Beaches:
Needs for South Carolina’s Nourished Beaches: Past Sand Usage

Time-average sand usage by beach community

Average time span between nourishment events
Addressing Known Data Gaps: Recommendations for ASAP Data Collection

- BOEM contractor CB&I, North Carolina and Georgia state cooperative partners, and representatives from the Charleston and Wilmington district USACE met in early 2015 to discuss data acquisition

- Based on known data distribution, age and quality of the available data, and past need for nourishment quality sand resources, several areas were recommended

- South Carolina was allocated 475 km of trackline and 30 geologic samples (19 vibracores, 11 grab samples)
Processed ASAP Data: Chirp Subbottom Profiler

- Water column
- Seafloor
- Paleochannel

8 meters
15 meters
23 meters
BOEM ASAP Data – Chirp Subbottom + Vibracore

- Data obtained from ASAP project includes information on grain size, mineralogy, shell content.
- Additional analyses are currently being conducted to learn more about the sedimentology, mineralogy, and relative ages of the surficial and sub-surface materials.
2014 Folly borrow area
~ 4 miles
~ 1.5 million cubic yards
Bottom vibracore sample

Sand thickness > 5 ft

Bottom grab sample
Potential sand resources

Thicker / thinner
Estimated sand deposit*

11 mcy
5 to 12 ft thick
~ 5 miles

23 mcy
5 to 12 ft thick
~ 8 miles

4 mcy
5 to 10 ft thick
~ 10 miles

Previous Folly nourishment:
1.5 million yd³ (mcy)

*Very preliminary data, subject to change
Thank You!

Andrew Tweel – tweela@dnr.sc.gov
Katie Luciano – lucianok@dnr.sc.gov
Offshore mapping and student research
College of Charleston and Partners

M. SCOTT HARRIS, PH.D., P.G. (AND LOTS OF COLLEAGUES)

DEPARTMENT OF GEOLOGY AND ENVIRONMENTAL GEO SCIENCES
DIRECTOR OF ARCH AEOLOGY
MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES PROGRAM
OCCASIONALLY, MARINE BIOLOGY PROGRAM
Elevations
Data

- BOEM/CCU/NOAA
- Inshore USGS

Figure 4. OCU-NOAA survey lines contributed in July 2015 to the SC BOEM initiative. The purple tracklines represent multibeam, chirp, side scan and split beam fish sonar data intended to test NOAA’s thematic habitat mapper over a regional scale following a series of paleovalleys across the shelf to shelf break as well as an area of paleo-iceberg keel marks on the upper shelf near Georgetown Hole published in Geology (Hill et al., and Nature Geoscience, Hill et al.). Two areas of detail multibeam, chirp, side scan and fish sonar data are shown in red. The inshore area had complete complete side scan and chirp data along with multibeam and fish sonar. The offshore site was predominately multibeam, fish sonar and more limited chirp data. In the detailed study areas NOAA completed numerous camera drops to verify habitat / fishery data.
Source Rocks (Fall Zone)

Photo Credit: M. Scott Harris
Barrier systems and need

Photo Credit: M. Scott Harris

Photo Credit: M. Scott Harris
History of Continental Shelf Geology

Harris et al., 2009
The Stats: Since 2007...

- **142 students** have completed the CofC BEAMS Program as of Spring 2017.

- **68 of the 124 students who have graduated (55%) are currently in the marine geospatial workforce**
  - in private, government or academic positions
  - **32 of these students (47%) are women.**
Where have they gone?

BEAMS Program Students and Alums (2007-2017)
History of Continental Shelf Geology

Harris et al., 2013
Ice Ages (last 600 ka)

Last Interglacial to Present

Harris et al., 2013

USGS Fay 1976 minisparker data
Recent Sea Level Rise

Harris et al., 2013
Recent Years and Sea Level Rise

8665530 Charleston, South Carolina

3.21 +/- 0.22 mm/yr

https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8665530
Targeting ancient heritage and former coasts (Paleogeography)

- Where were the shorelines?
- Apply glacial isostatic adjustments to compensate for rebound effect of ice melting since LGM
Findings:
Shorelines Through Time
26,000 years ago

Estimated shoreline with adjustments for glacial isostatic adjustment
Positions on shelf likely +/- 10 km

Harris, 2018
Transitions

Modem Coast
6,000 ya

Photo Credit: M. Scott Harris
Where do we go from here?

- We are continuing our offshore paleolandscape work with BOEM ASAP and BOEM Wind partners.
- Attempting to more efficiently map the OCS—maybe bathy LiDAR - excellent visibility offshore!!!
- Setting up a program bridging between CP and CS using alternate geophysical techniques.
- Finishing up the CP and CS map to establish working areas for cadre of students over the next decade.
Acknowledgements

(too many to count!)

- **Funding:**
  BOEM, SC Sea Grant, USGS, College of Charleston Faculty R&D, SSM Dean, GEOL, NPS, Fulbright

- **Historic Cooperatives:**
  All the above, plus NSF, TNC, SouthWings, USACE, Charleston Parks and Recreation, Every SC Coastal Jurisdiction

- **Software and hardware partners:**
  QPS, SonarWiz, Hypack, Caris, ESRI, Edgetech, Klein, Mala Geosystems, Seafloor Systems, USM, R2Sonic,

- **People:**
  Colleagues at CofC, USC, UNC, ECU, UGA, SKIO, W&M, Clemson, CCU, SC-DNR, Sea-Grant, BOEM, NOAA, USACE, USGS

- **Topography:** USGS; Bathmetry: NOAA and TNC