BABY STEPS TOWARDS A NEW FRAMEWORK FOR UNDERSTANDING COASTAL ELEVATION CHANGE

Scott Spurgeon and Charlene Sylvester
CIRP Technical Discussion
12 September 2024

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RESEARCH TEAM

Charlene Sylvester
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Research Civil Engineer

Sam Jackson
Research Forrester

Brooke Walker
Research Physical Scientist

ORISE Fellow
Post-Masters, Doctoral Student or Post-Doctoral Fellowship

Multi-disciplinary, cross-lab, experienced research team with room to grow!

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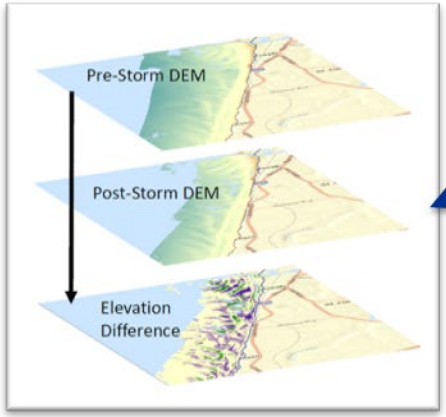
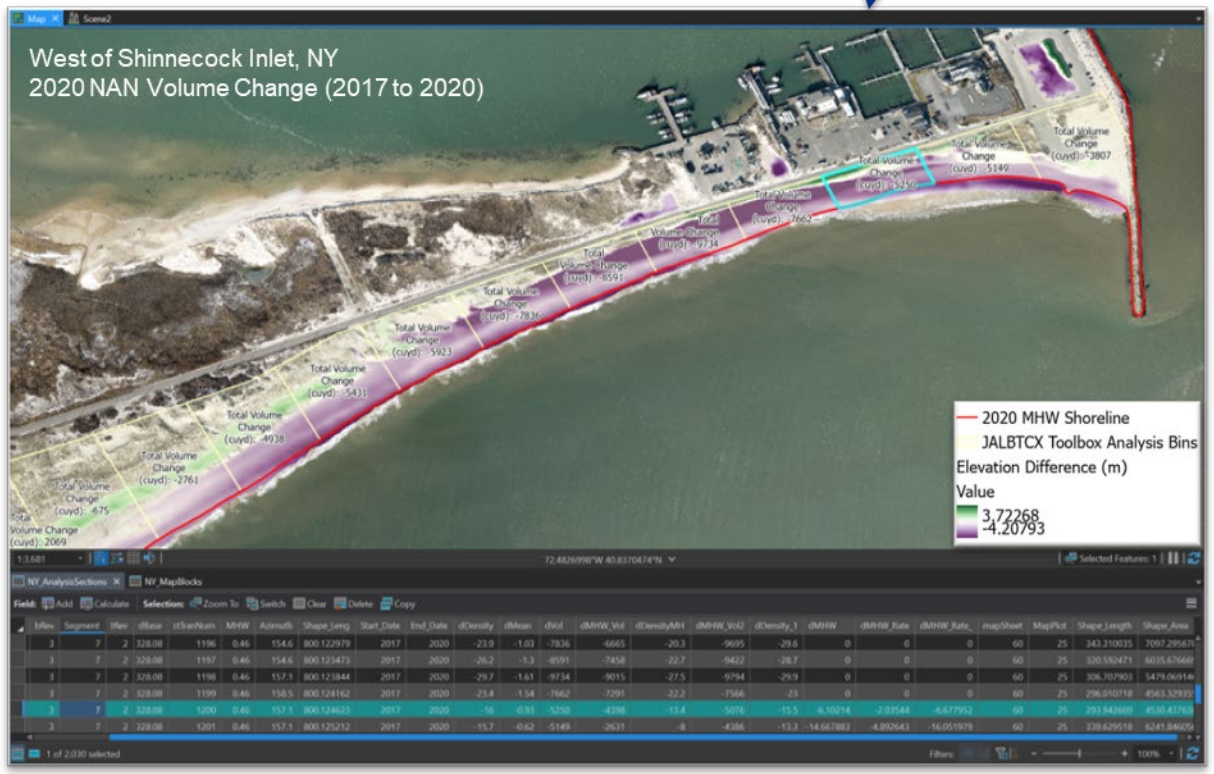
BACKGROUND AND MOTIVATION

- SoN 2024-N-1968: New volume-change tools to improve sediment management
  - USACE operations in Navigation, Flood Risk Management, and Environment **require advanced spatio-temporal sediment volume change analysis tools** to capture sediment transport during planning, construction, and monitoring phases of projects.
- SoN 2024-N-1969: Incorporating shoaling rates into sediment budget creation to improve sediment management
  - USACE operations in Navigation, Flood Risk Management, and Environment can **benefit in efficiency gains from volume change analysis tools to capture sediment transport** during planning, construction, and monitoring phases of projects.



Existing Framework:

DEMs of Difference
&
Transect Bins



LIMITATIONS OF CURRENT METHODS

- While the existing framework of DEMs of Difference (DoD) and Transect Bins can quantify volumetric change within the fixed in space volume “bins”, there are several limitations to this approach:

1. Following storm events, it is often necessary to modify the cross-shore extent of the transect bins. **The modification of the spatial extent of transect bins limits direct comparison to previous results.**
2. Bathymetric data coverage varies with water clarity and breaking waves at the time of data acquisition. Therefore, **the net volume quantities between time periods are not directly comparable where bathymetric data coverage varies**.
3. While the movement of sediment may be inferred from the DoD, **transport direction of sediment is not currently captured**.

PROJECT ROADMAP

FY24

- Lit Review
- ORISE Fellow
- Data Compilation
- **ERDC Special Report**
- **Data inventory geodatabase**
- Tech Transfer

FY25

- Volume Partitioning
- Hotspot Analysis
- Bias Assessments
- **Workflow for space-time cubes**
- **TPI-based products and vegetation metrics**
- Tech Transfer

FY26

- Methods Refinements
- Additional Pilot Sites
- Product Development
- **Enhanced land cover and planform mapping products**
- **Next-generation volume products**
- Tech Transfer

FY24 RESEARCH GOALS

- FY24 Research Goals
  - Literature Review
    - Review literature on the state-of-art of multi-temporal change detection, data requirements for robust change analysis, and tools for performing change detection analysis.
  - Pilot Site Data Compilation
    - Build dataset inventory for pilot sites identified through field feedback. Assess fitness-for-use and perform processing to ensure spatial alignment of datasets and fill small data voids.
  - Secure ORISE Team Member
    - Develop requirements and advertise ORISE Fellowship opportunity in collaboration with CIRP Hazardous Inlet Shoals project.
  - Tech Transfer (this presentation!)
    - Continued coordination and communication with team members, PDT members, and program management.

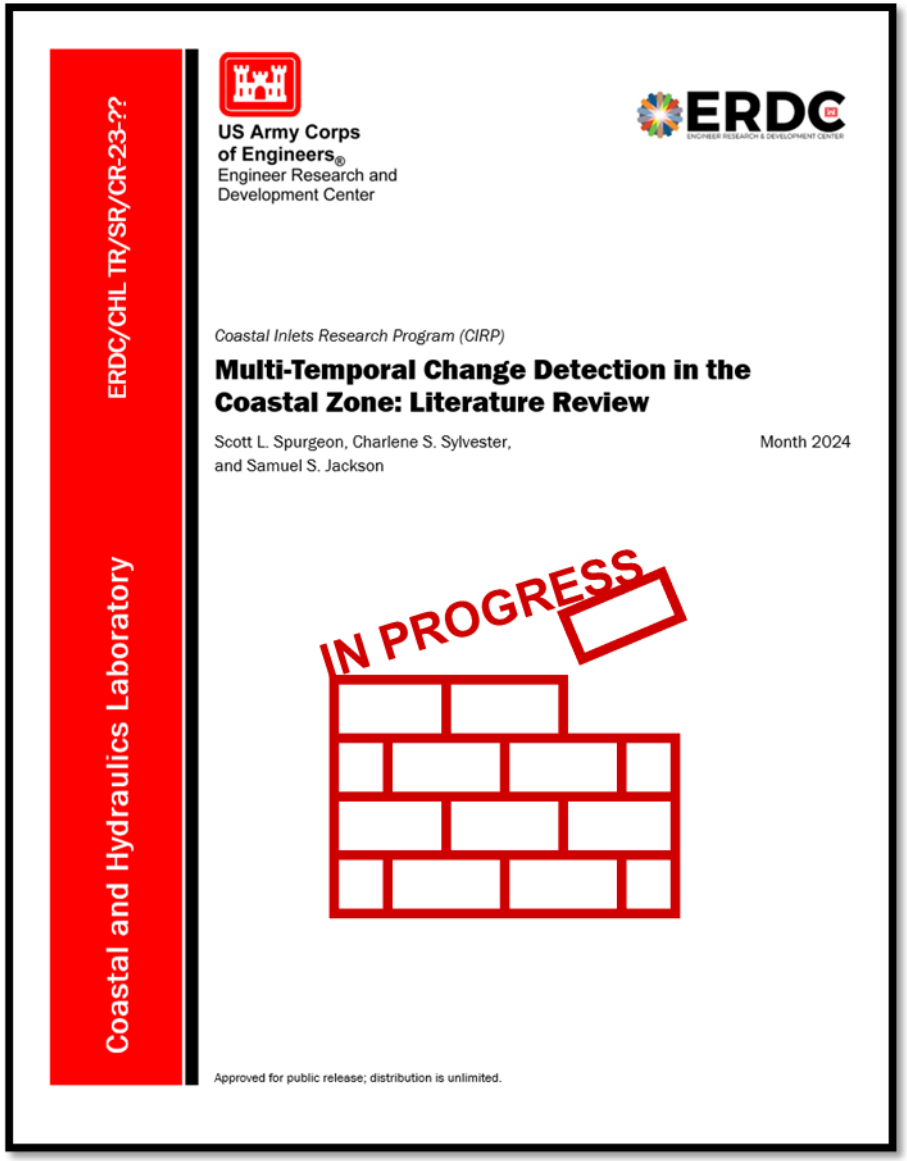
LITERATURE REVIEW - IN PROGRESS

Literature Review Purpose

- BLUF: To determine the current state-of-art related to multi-temporal change detection, identify temporal data requirements for robust change analysis, and identify existing tools for performing change detection analysis.
- 73 Refereed Pieces of Literature Sourced from 1993-2024

Topics Include:

- Geomorphology Change Detection Background
- 1-D Change Detection: Shoreline Position
- 1-D Change Detection: Beach Profiles
- 2.5-D Change Detection: DEM of Difference
- Space-Time Cube Analysis
- Errors and Uncertainties



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LITERATURE REVIEW

Literature Review Compilation

Literature of interest was downloaded, and metadata information was sourced into a tracking spreadsheet that can serve as a deliverable. Rows in the tracking spreadsheet were color-coded based on their inclusion in the Special Report.

Tracked fields included:

- Title
- Authors
- Publish Year
- Abstract
- Summary & Key Points
- Keywords
- Quotes with Page Number
- Search Category for Result
- Current Status

https://usace.dps.mil/:x:/s/TDL-CEERD-HNC-CIRP/EfAKcJbq9x9AqfwwXat001IBrIuluSM3MSlO-mb6oZWl3A?e=8jqFEe

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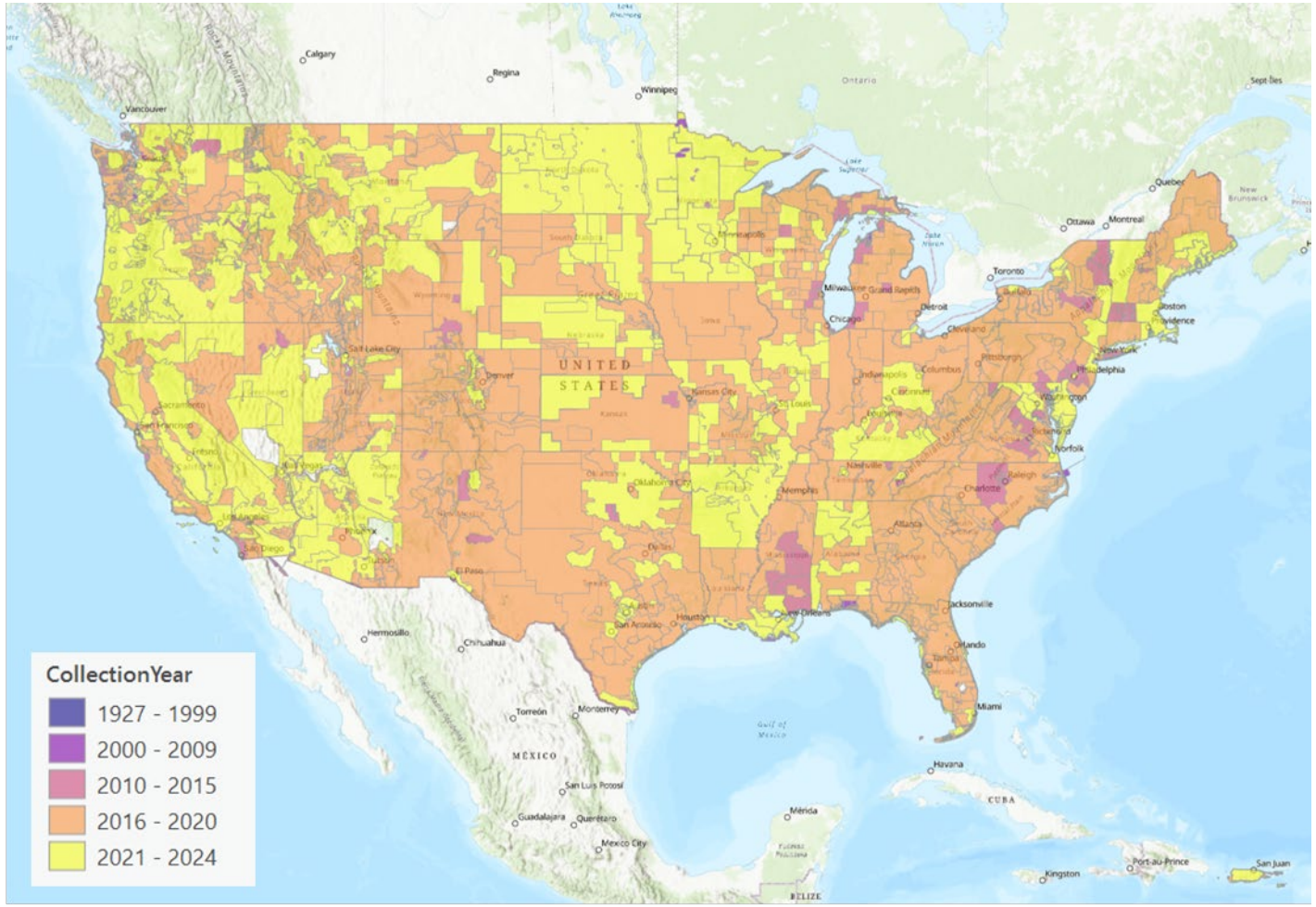
DATA INVENTORY

Purpose

- Identify coastal areas with data coverage that has sufficient spatial and temporal resolution to meet the objectives of this R&D.

Data Requirements:

- Spatial resolution supports 3-m DEM
- Datasets are available for at least 10 temporally-unique time periods
- Adequate geospatial metadata to support datum transformations



Source: US Interagency Elevation Inventory polygons, August 2024, NOAA Office of Coastal Management

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DATA INVENTORY – JOIN WITH TESSELLANTION GRID

Purpose

- Identify coastal areas with data coverage that has sufficient spatial and temporal resolution to meet the objectives of this R&D.

Data Requirements:

- Spatial resolution supports 3-m DEM
- Datasets are available for at least 10 temporally-unique time periods
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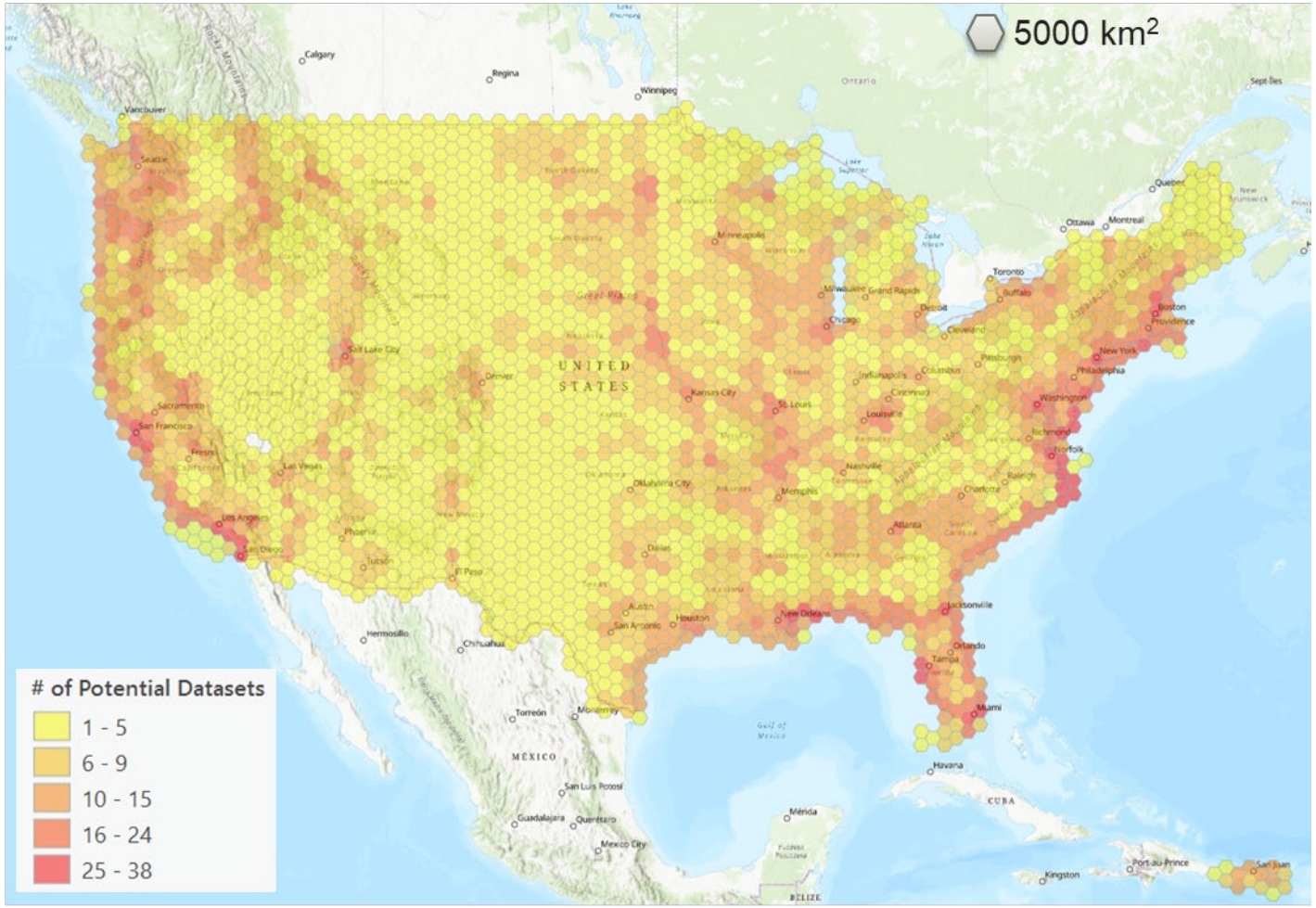
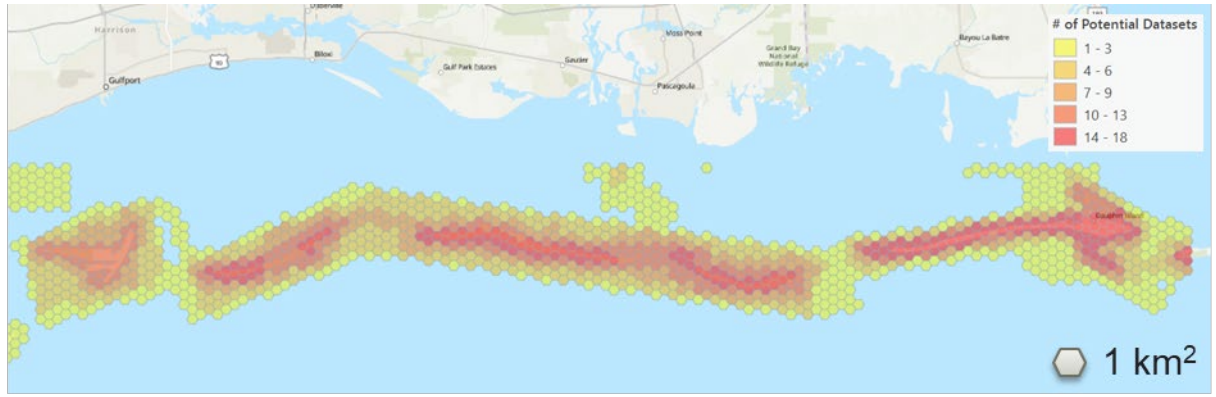


Source: Spatial join of tessellation grid and US Interagency Elevation Inventory Polygons

PILOT AREA: MS/AL BARRIER ISLANDS

- Part of MSCIP project
- Aligns with MS Sediment Budget update (SAM reimbursable project)
- Existing volume change products, advanced landcover and vegetation metrics



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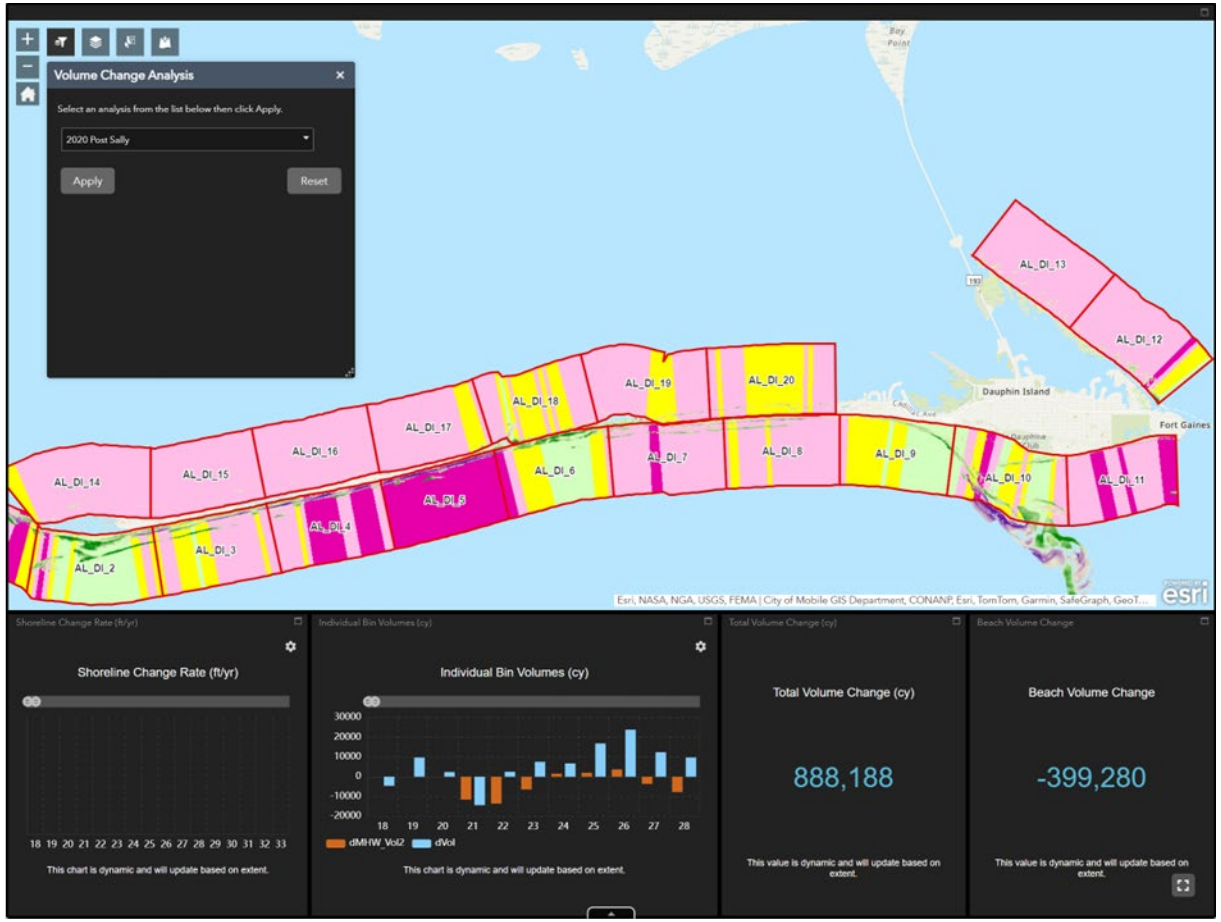
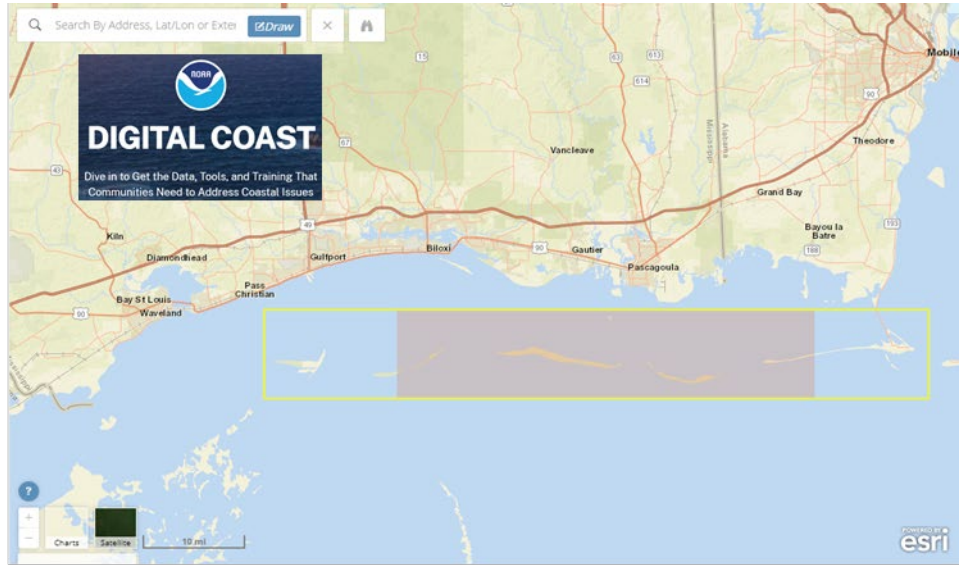
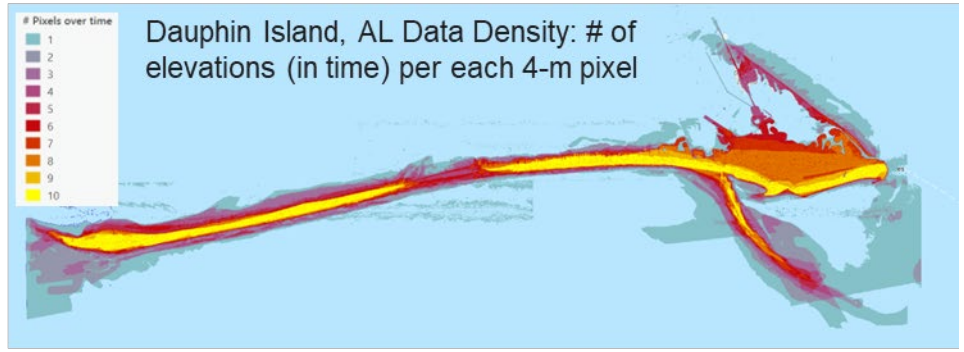


Source: JALBTCX Volume Change Web Application
Volume Change Analysis (arcgis.com)

PILOT AREA: MS/AL BARRIER ISLANDS, CONT.

YEAR	DATASET	BEG_DATE	END_DATE	SOURCE	COVERAGE	DATASET_URL	METADATA_URL	NOTES
1998	1998 Fall Gulf Coast NOAA/USGS/NASA Airborne LiDAR Assessment of Coastal Erosion (ALACE) Project for the US Coastline	10/29/1998	11/9/1998	NOAA/USGS/NASA	Topography	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=22	https://noaa-nos-coastal-lidar-pds.s3.amazonaws.com/laz/geoid18/22/1998_FallGC_metadata.html	Skinny strip of shoreilne coverage
2001	2001 USGS/NASA Airborne Topographic Mapper (ATM) Lidar: Coastal Alabama, Florida, Louisiana, Mississippi, Texas	9/9/2001	10/13/2001	USGS/NASA	Topography	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=525	https://www.fisheries.noaa.gov/inport/item/50098	MS data coverage from 9/9-9/10/2001. Skinny strip of shoreline coverage.
2004	2004 US Army Corps of Engineers (USACE) Topo/Bathy Lidar: Alabama, Florida, Mississippi and North Carolina	4/1/2004	9/25/2004	USACE	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=19	https://www.fisheries.noaa.gov/inport/item/50049	Ship Island, MS to Dauphin Island, AL - 20040421 to 20040505. Very limited bathymetric data.
2005	2005 US Army Corps of Engineers (USACE) Post-Hurricane Katrina Topo/Bathy Project for the Alabama, Florida, Louisiana and Mississippi	10/12/2005	12/11/2005	USACE	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=31	https://www.fisheries.noaa.gov/inport/item/50056	Post-storm survey. Very limited bathymetry.
2007	2007 USGS/NPS/NASA Experimental Advanced Airborne Research Lidar (EAARL): Northern Gulf of Mexico Barrier Islands	6/27/2007	6/30/2007	USGS/NPS/NASA	Topography	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=522	https://www.fisheries.noaa.gov/inport/item/50105	
2010	2010 USACE NCMP Topobathy Lidar: Alabama	5/27/2010	5/29/2010	USACE	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=8653	https://www.fisheries.noaa.gov/inport/item/55145	Coverage of Dauphin Island only in MSCIP AOI.
2011	2011 USACE NCMP Topobathy Lidar: Gulf Coast (AL, LA, MS)	5/31/2011	6/4/2011	USACE	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=9433/details/9433	https://www.fisheries.noaa.gov/inport/item/50017	Mostly if not all topography.
2014	2014 Mobile County, AL Lidar	1/12/2014	1/22/2014	City of Mobile, AL	Topography	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=4966	https://www.fisheries.noaa.gov/inport/item/48145	
2016	2016 USACE NCMP Topobathy Lidar: Gulf Coast (AL, FL, MS, TX)	7/23/2016	10/10/2016	USACE	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=6371	https://www.fisheries.noaa.gov/inport/item/49738	BEST bathymetric coverage
2018	2018 USGS Topobathy Lidar: Gulf Coast Islands (AL, FL, LA)	10/27/2018	11/3/2018	USGS	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=9117/details/9117	https://www.fisheries.noaa.gov/inport/item/64345	Coverage includes only Dauphin Island in MSCIP AOI
2018	2018 USACE NCMP Topobathy Lidar: Gulf Coast (AL, MS)	11/16/2018	11/18/2018	USACE	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=8668	https://www.fisheries.noaa.gov/inport/item/55844	Coverage excludes Dauphin Island in MSCIP AOI. Post-storm survey.
2019	2019 USACE NCMP Topobathy Lidar: Gulf Coast (MS)	11/5/2019	11/10/2019	USACE	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=9134/details/9134	https://www.fisheries.noaa.gov/inport/item/60214	Coverage excludes Dauphin Island in MSCIP AOI.
2020	2020 USACE NCMP Post Sally Topobathy Lidar: Gulf Coast (AL, FL, MS)	10/1/2020	10/13/2020	USACE	Topography and Bathymetry	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=9264/details/9264	https://www.fisheries.noaa.gov/inport/item/64384	Coverage excludes Cat Island. Decent bathymetric coverage. Post-storm dataset.
2022								
2023	2023 USGS Lidar: Southwest Central Alabama	1/9/2023	3/5/2023	USGS	Topography	https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=10144/details/10144	https://www.fisheries.noaa.gov/inport/item/72983	Coverage includes only Dauphin Island in MSCIP AOI.

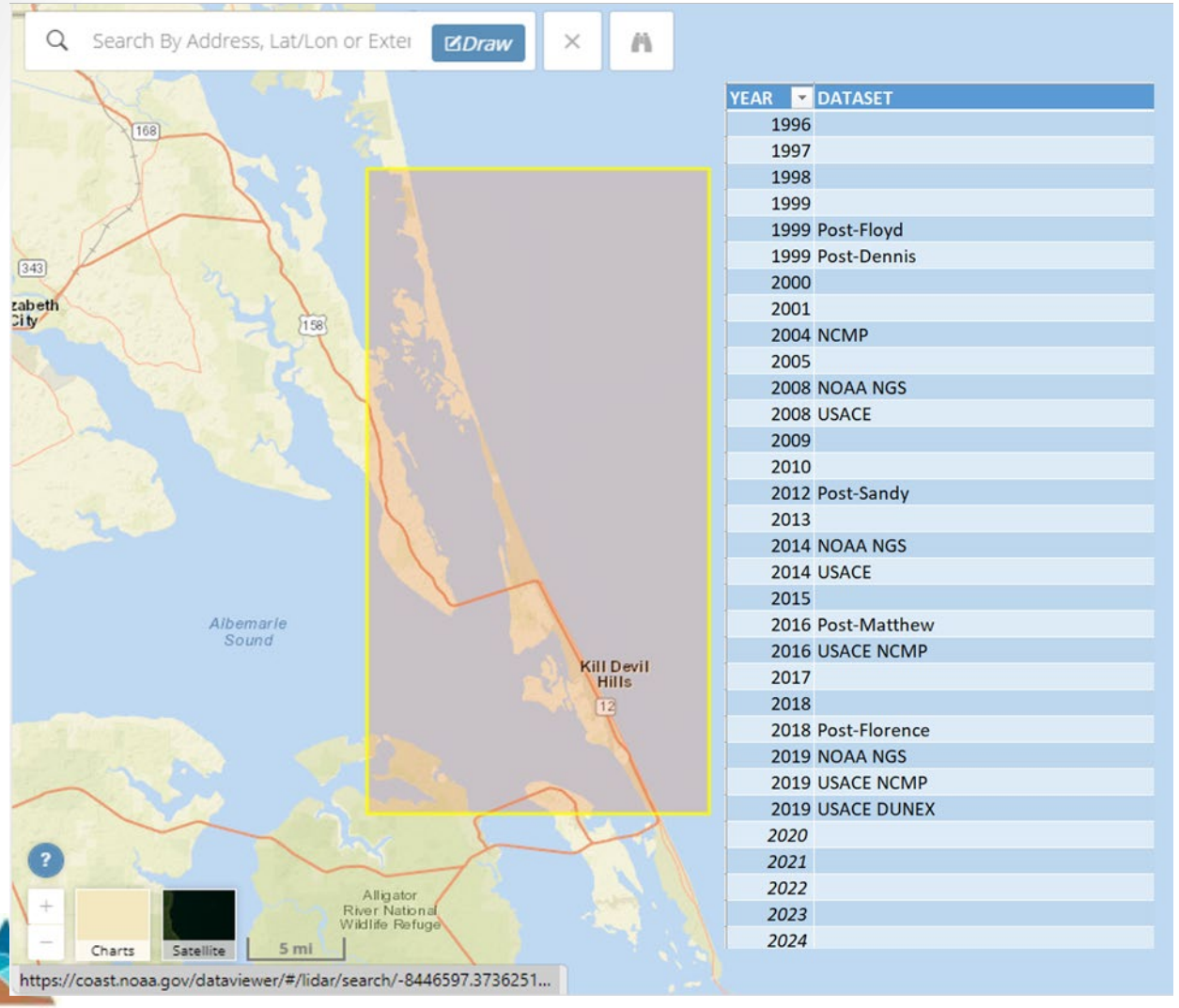




- Data coverage, spatial and temporal
- Fitness for use
- Data processing
- Assessment of relative bias
- Lead – Brooke Walker

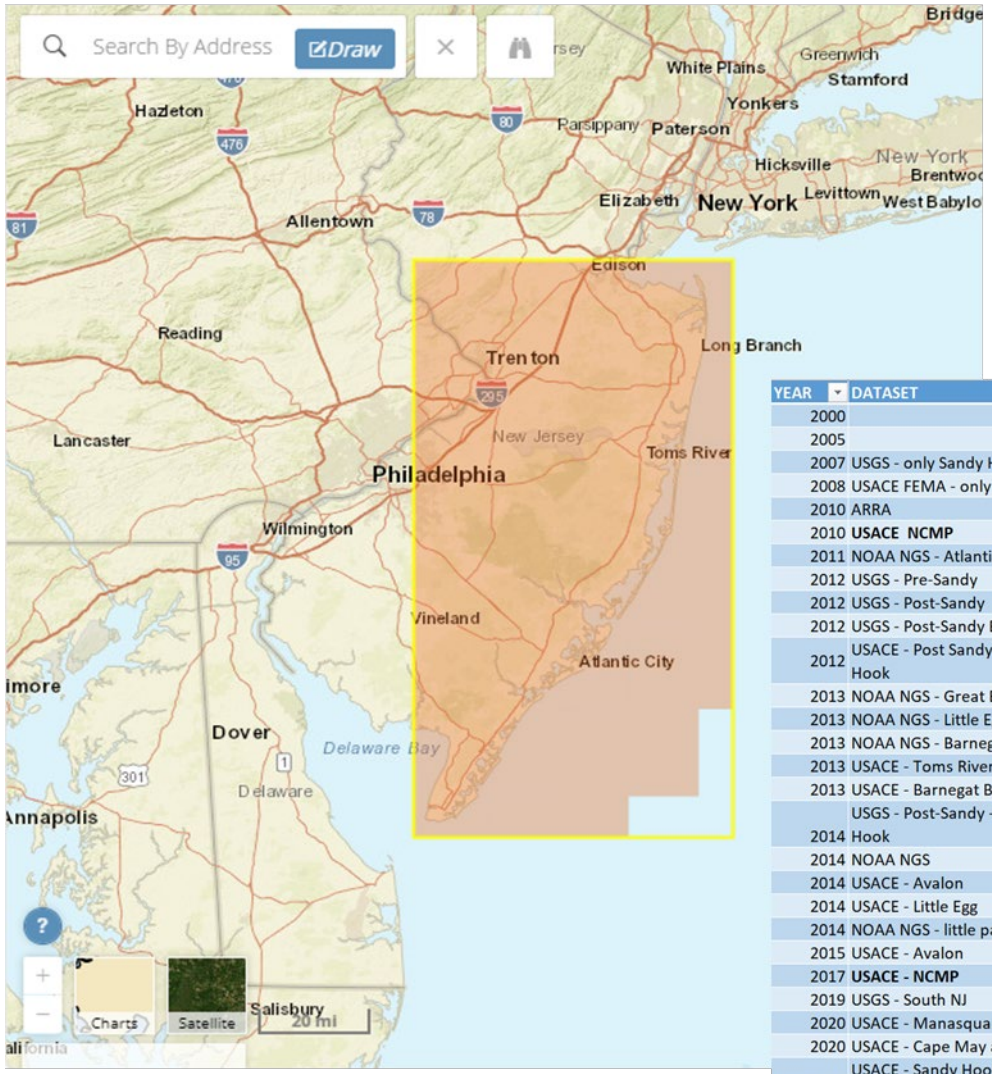
ADDITIONAL PILOT AREAS

North Carolina



YEAR	DATASET
1996	
1997	
1998	
1999	
1999	Post-Floyd
1999	Post-Dennis
2000	
2001	
2004	NCMP
2005	
2008	NOAA NGS
2008	USACE
2009	
2010	
2012	Post-Sandy
2013	
2014	NOAA NGS
2014	USACE
2015	
2016	Post-Matthew
2016	USACE NCMP
2017	
2018	
2018	Post-Florence
2019	NOAA NGS
2019	USACE NCMP
2019	USACE DUNEX
2020	
2021	
2022	
2023	
2024	

New Jersey



YEAR	DATASET
2000	
2005	
2007	USGS - only Sandy Hook
2008	USACE FEMA - only Cape May
2010	ARRA
2010	**USACE NCMP**
2011	NOAA NGS - Atlantic City to Cape May
2012	USGS - Pre-Sandy
2012	USGS - Post-Sandy
2012	USGS - Post-Sandy Barnegat Bay
2012	USACE - Post Sandy - Toms River to Sandy Hook
2013	NOAA NGS - Great Egg
2013	NOAA NGS - Little Egg
2013	NOAA NGS - Barnegat Bay
2013	USACE - Toms River to Atlantic City
2013	USACE - Barnegat Bay and Seaside
2014	USGS - Post-Sandy - Manasquan to Sandy Hook
2014	NOAA NGS
2014	USACE - Avalon
2014	USACE - Little Egg
2014	NOAA NGS - little patches everywhere
2015	USACE - Avalon
2017	**USACE - NCMP**
2019	USGS - South NJ
2020	USACE - Manasquan to Sandy Hook
2020	USACE - Cape May and Atlantic City
2022	USACE - Sandy Hook, Atlantic City, and Avalon

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PATH FORWARD

FY24

- Lit Review
- ORISE Fellow
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- **ERDC Special Report**
- **Data inventory geodatabase**
- Tech Transfer

FY25

- Volume Partitioning
- Hotspot Analysis
- Bias Assessments
- **Workflow for space-time cubes**
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FY26

- Methods Refinements
- Additional Pilot Sites
- Product Development
- **Enhanced land cover and planform mapping products**
- **Next-generation volume products**
- Tech Transfer

ANTICIPATED MILESTONES AND PRODUCTS

FY24

- **Special Report: Multitemporal Change Detection in the Coastal Zone: Literature Review**
- Pilot Site Data Inventory & Geodatabase

FY25

- Volume Partitioning
  - Relative Relief, Geomorphons, and Vegetation Metrics for Pilot Sites
  - Segmented DEMs and Volumes for Pilot Sites
  - **TN: DEM Segmentation Using Regional Datasets**
- Hot Spot Analysis
  - ArcGIS Pro Workflow and Space-Time Cube Products for Pilot Sites
  - **TN: Workflows for Creating Space Time Cubes from DEM Datasets**
- Investigate Methods to Address Bias
  - Calculation of Bias Metrics and Anomaly Surfaces for Pilot Sites

FY26

- Refinement of Volume Partitioning
  - Enhanced Landcover Derivative Products for Pilot Sites
  - Proof-of-Concept Demonstration of Using Enhanced Landcover Derivative Products in SBAS
  - **TN: Use of Segmented Volumes in SBAS: A Case Study**
- Refinement of Hot Spot Analysis
  - **TN/JA: Parameter evaluation for Hot Spot Analysis using ArcGIS Pro**
  - Planform Mapping Products for Pilot Sites
- Refinement of Methods to Address Bias
  - **ERDC Publication or Journal Article on Developing Uncertainty Estimates for Volumes**

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FEEDBACK – HOW DO VOLUMES INFORM DECISIONS?

"Volumes play a critical role in the navigation and beach nourishment projects from all project phases from feasibility to O&M. Without volumes, it is impossible to design projects or maintain them. Volumes are used during design, development of plans and specs, and during emergency post-storm evaluations."

"Sediment budget analysis of tidal inlets and coastal barrier islands. Planning Beneficial Use and DMMPs for coastal Nav projects."

"The [volumes] are critical. Sediment budgets are critical for decision making. Understanding the rates of change (erosion/accretion) and stability of regions is critical for the understanding of the best alternative to apply. for example, shoaling rates (for nav) -- what are the infilling rates of channels, shoaling regions? for FRM -- what is the longevity of beaches to protect from coastal storms, for ecosystem restoration -- which marsh areas are eroding? accreting? we need high-resolution dems and profiles to do / justify anything . . ."

"For navigation, capacities for placing channel sediments; understanding sediment budgets.
For CSRM, renourishment quantities and locations; tracking hot spot causes and dynamics; sediment budgets
For Emergency Management, post-storm calculations that help inform response for emergency supplemental repairs."

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FEEDBACK – WHAT'S MISSING IN EXISTING TOOLS?

"There is a variety of tools being employed in our district and no consistency. A set of tools that are easy to use and to replicate the results would be ideal. This was when projects shift, or staff retire new engineers can recreate the old analysis."

"The main limitation of the tools that are being developed is that they are geared towards LIDAR or other dense datasets. Most of the surveys that we work with are topo/bathy surveys with 500-1000 ft spacing and these surveys do not work well with the existing toolboxes during limited testing. It would be helpful to have tools that are more suited for working with this type of data. One example is that we still use RMAP to develop unit volumes and then use the average end-area method to find the volume change between adjacent survey points. RMAP is nice but it is clunky and slow to use. Having an updated version of the tool would help us process surveys quicker when using average end-area."

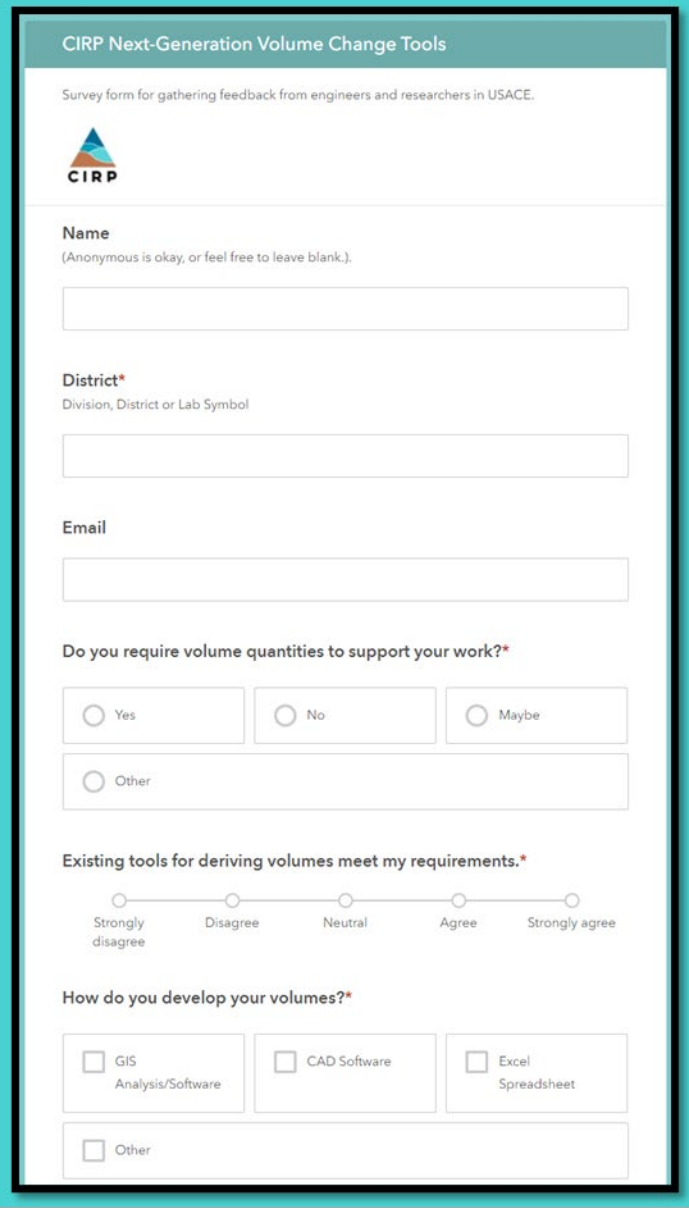
"Ability to compare baseline conditions as both rates and raw volume changes while also being able to include storm impacts, management changes and actions. So, to include them in my analysis but separate them."

HAVE FEEDBACK? KNOW SOMEONE WHO CAN HELP?

Have thoughts?
Challenges?
Uses?
Requirements?
Tools?

- Feedback form
- Public data collection
- No login required

https://arcg.is/Tr5v50


CIRP Next-Generation Volume Change Tools

Survey form for gathering feedback from engineers and researchers in USACE.

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Name
(Anonymous is okay, or feel free to leave blank.).

District*
Division, District or Lab Symbol

Email

Do you require volume quantities to support your work?*
Yes | No | Maybe | Other

Existing tools for deriving volumes meet my requirements.*
Strongly disagree | Disagree | Neutral | Agree | Strongly agree

How do you develop your volumes?*
GIS Analysis/Software | CAD Software | Excel Spreadsheet | Other

ORISE Research Fellowship

- Post-doctoral, post-masters, or current doctoral student
- ½ time with Hazardous Inlet Shoals Team

https://www.zintellect.com/Opportunity/Details/ERDC-CHL-2024-0010

ORISE

QUESTIONS?

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