SANDSNAP: DIGITAL GRAIN-SIZE IMAGERY ANALYSIS AND ENGAGING CITIZEN SCIENTISTS
INLET GEOMORPHOLOGY WORK UNIT

Brian McFall & David Young

Shelley Whitmeyer (JMU), Dan Buscombe (Marda Science), Jon Warrick (USGS)

Doug Krafft, Kelsey Fall, Brooke Walker (CHL)

District PDT Members

Lisa Winter (NAE), Monica Chasten (NAP), Kevin Hodgens (SAJ), Rod Moritz (NWP)

COASTAL INLETS RESEARCH PROGRAM
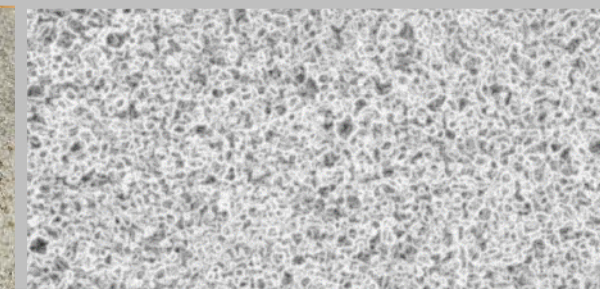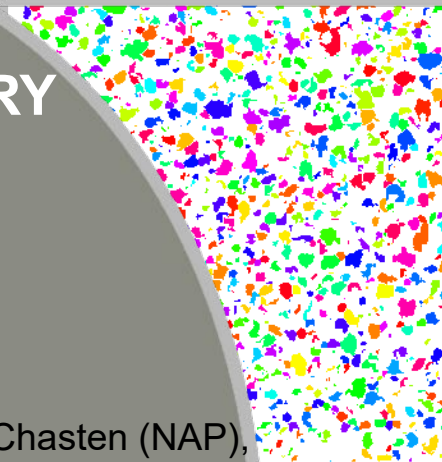
FY20 IN PROGRESS REVIEW

Mike Ott
HQ Navigation Business Line Manager

Eddie Wiggins
Technical Director

Katherine Brutsché
Associate Technical Director

CIRP — Mission Support / Technology Transfer / Research & Development

US Army Corps of Engineers®

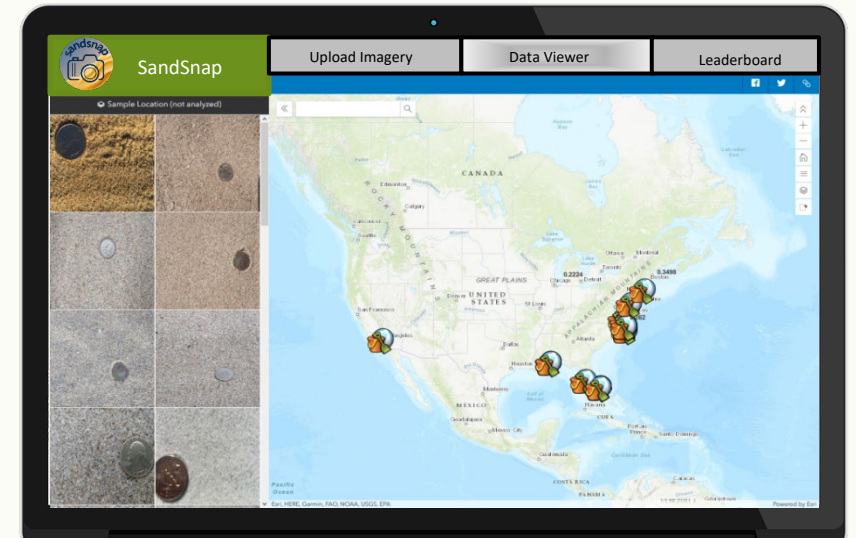CHL — COASTAL & HYDRAULICS LABORATORY

ERDC — ENGINEER RESEARCH & DEVELOPMENT CENTER

Problem Statement

- **The lack of a nationwide beach grain size database is a fundamental knowledge gap in the composition of our beaches and coastlines.**
  - **Grain size often has the largest uncertainty in sediment transport modeling (Soulsby, 1997)**
- **It is unfeasible to collect beach grain size data on a nationwide scale with traditional methods (e.g., sample collection and sieve analysis).**
- **This deficiency critically limits USACE morphology modeling capability.**

- **SON's:**
  - **2020-NAV-1528: Creating a Beach Sediment Database through "Citizen Scientist" Engagement**
  - **2020-FRM-1529: Creating a Beach Sediment Database through "Citizen Scientist" Engagement - Improve Beach-Fill CRSM Performance**
  - **2020-ENV-1528 Creating a Beach Sediment Database through "Citizen Scientist" Engagement**

US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory

Capability and Strategic Impact Statement

This project will create a nationwide beach grain size database from cell phone images collected by citizen scientists, saving the government up to $1M/year.

This database will improve regional-scale studies, and capture spatial and temporal gradation variations to improve nourishment life cycle analysis and uncertainty, and increase range of beach compatible sediment. Additionally, engaging citizens in the data collection will garner more public support for USACE coastal projects.

US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory

Sample Methodology

1.

2.

3.

US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory

Grain Size Estimation Approaches

- **Geometric Analysis:**
  - Isolate and separate sediment grains into discrete objects to analyze separately.
  - 34% d_{50} error from *in situ* test images.
- **Statistical Analysis:**
  - Characterize grain size using measures of image texture.
  - Many approaches: auto-correlation, semi-variance, fractals, wavelets.
  - Wavelet approach (pyDGS) in Buscombe (2013) – 36% d_{50} error from *in situ* test images.
- **Both approaches discarded:**
  - Larger overall error.
  - Work better when tailored to specific sediment types/sizes.

McFall et al. 2020

Buscombe 2013

US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory
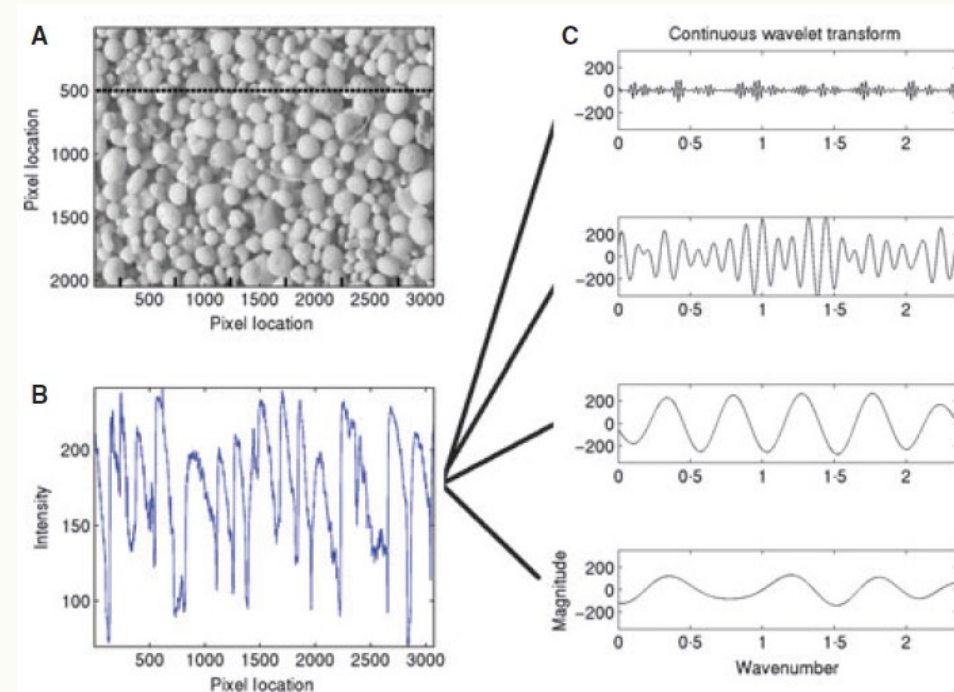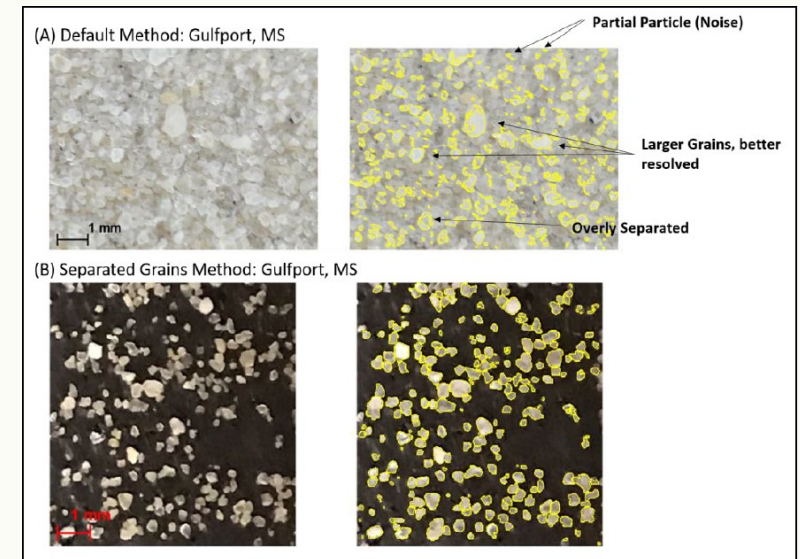
Machine Learning: SediNet

Input image
(1024 x 1024 x 3 pixels)

SediNet model
for beach grain size

Convolution layers are filters that share weights spatially, sensitive to a hierarchy of repeating patterns

Feature extracting layers

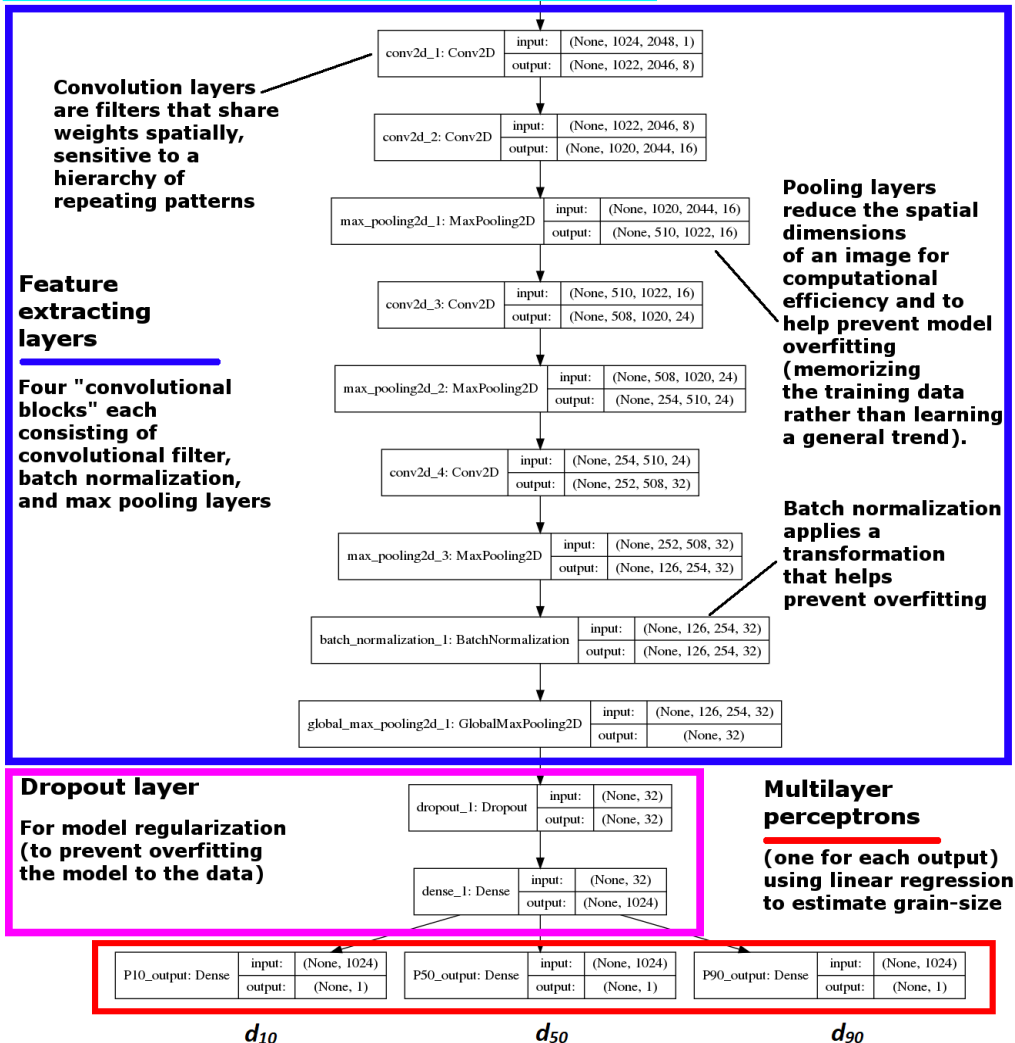**Four "convolutional blocks" each consisting of convolutional filter, batch normalization, and max pooling layers**

Pooling layers reduce the spatial dimensions of an image for computational efficiency and to help prevent model overfitting (memorizing the training data rather than learning a general trend).

Batch normalization applies a transformation that helps prevent overfitting

Dropout layer

For model regularization (to prevent overfitting the model to the data)

Multilayer perceptrons

(one for each output) using linear regression to estimate grain-size

d_{10} d_{50} d_{90}

Buscombe 2019

- **SediNet (Buscombe 2019):**
  - **Deep Learning Model.**
  - **Convolutional Neural Network with multiple processing layers.**
  - **Estimates grain size information from imagery.**
  - **https://github.com/MARDAScience/SediNet**
  - **Can estimate up to 9 numeric grain size metrics.**
  - **Can also calculate categorical variables (grain shape, population, color).**
  - **Uses GPU for computations with tensorflow package in python.**
- **<12% d_{50} error from *in situ* test images.**
- **Can be trained on a wide range of sediments – applied more generally.**

US Army Corps of Engineers ● Engineer Research and Development Center ● Coastal and Hydraulics Laboratory

Retrained SediNet Model

Retrained w/ **High-Quality Images**

- **Images cropped to avoid coin.**
- **Sub-Images -1024x1024 pixels.**
- **Sub-Images Flipped Horizontally.**
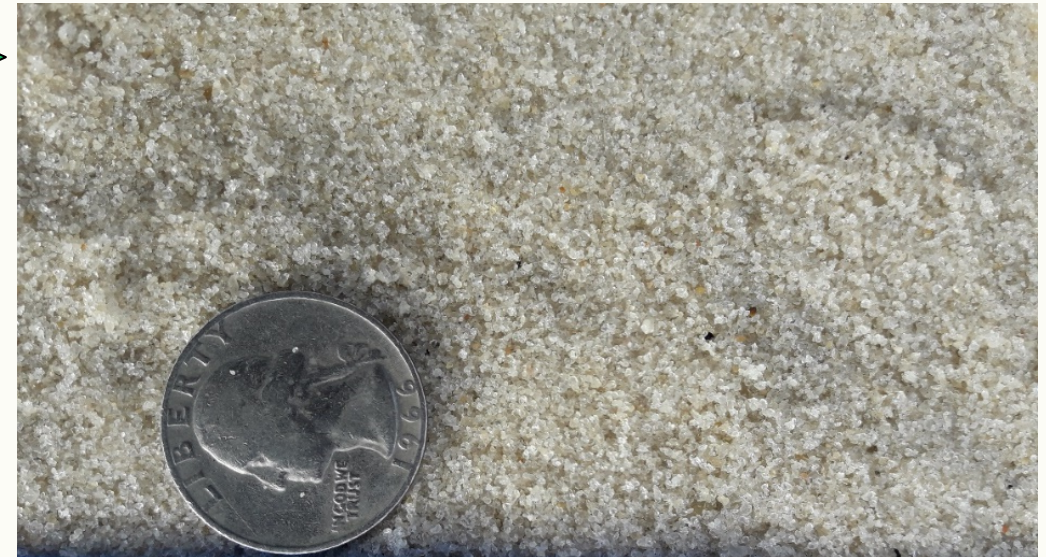- **50% for Training.**
- **50% for Testing.**

Site	# Images	# Sub-Images for Training/Testing		Mean d_{50} Error
Assateague, MD	~~12~~	~~116~~		~~62.3 %~~
False Cape, VA	~~12~~	~~106~~		~~47.8 %~~
Calvert Cliffs, MD	4	32	11.5%	~~17.1 %~~
Biloxi, MS	7	74	11.2%	~~14.5 %~~
Gulfport, MS	9	88	8.1%	~~19.05 %~~
Ocean Springs, MS	7	68	15.2%	~~19.2 %~~
in situ Test Total:	**27** ~~51~~	**262** ~~484~~	**11.2%**	~~**33.5 %**~~

Assateague, MD Image

Gulfport, MS Image

- **Retrained model:**
  - **16 new sites.**
  - **+ 56 images.**
- **17% error for all sites.**

US Army Corps of Engineers ● Engineer Research and Development Center ● Coastal and Hydraulics Laboratory

Cloud & High Performance Computing

- **Microsoft Azure Environment**
  - **Mobile District Geospatial Data Branch.**
  - **App sends images to cloud.**
  - **Images scanned and passed to trained machine learning model.**
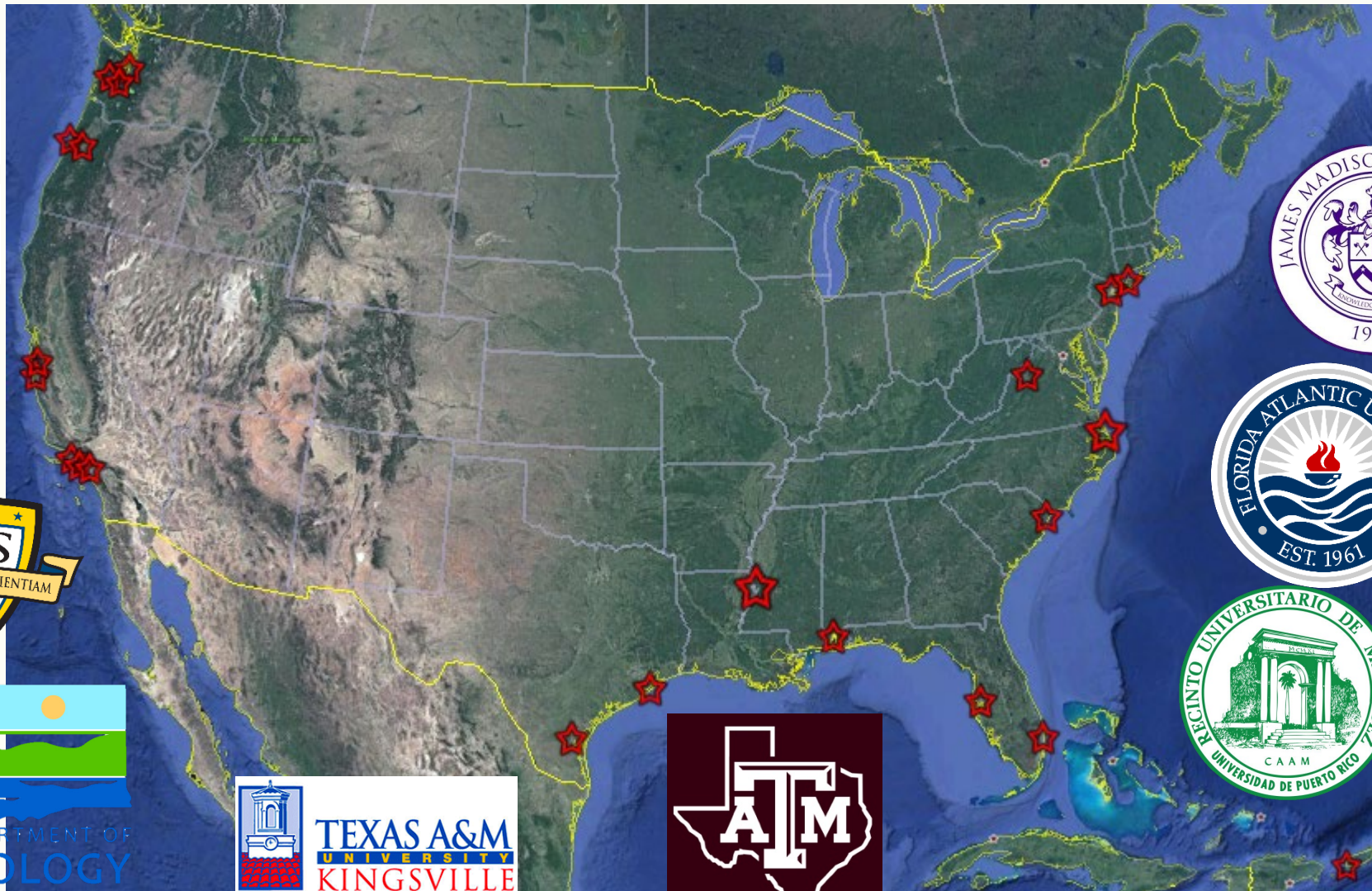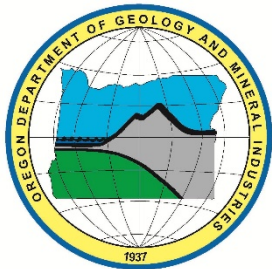 - **Output to cloud-stored grain size database.**
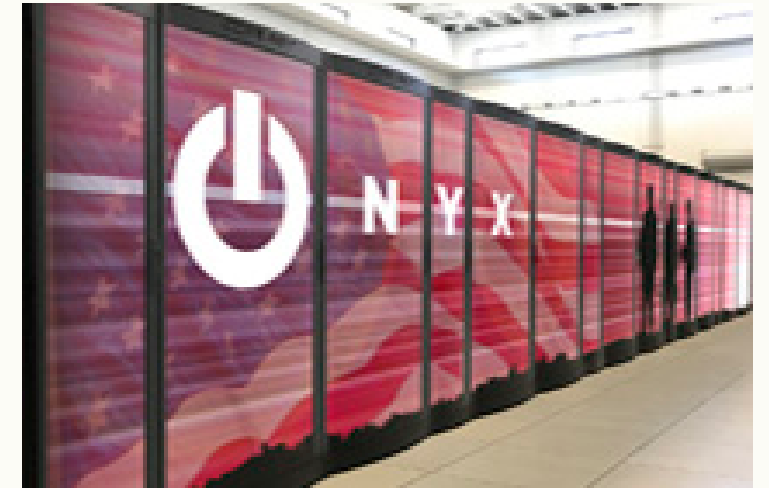
- **In FY21 explore training model on USACE HPC resources (Onyx).**
  - **Graphics Card limits model training speed.**
  - **Will become an issue as model training database ↑.**
  - **Work with ITL to migrate model training from desktop to HPC.**
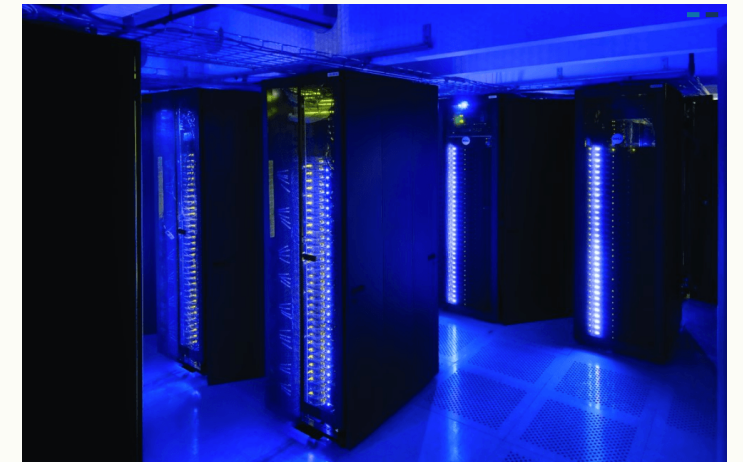
US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory

Collaborations

US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory

Outreach

Girl Scouts
**"Think Like a Citizen Scientist Journey"**
Scheduled: May 3, 2020
Cedar Beach, NY

Image Credit: Girls Scouts of America

US Army Corps of Engineers ● Engineer Research and Development Center ● Coastal and Hydraulics Laboratory

Outreach – With Social Distancing

Library STEM Activity Bags
"Beach Kits"

Petri Dish

Hand Lens

STEM Activities:

- "Sorting It Out" (Sieve & Sand Castle)
- "That Settles It" (Settling Tube)
- "Digging In Deeper" (Petri Dish & Hand Lens)
- SandSnap

Settling Tube After Several Hours

Settling Tube After One Day
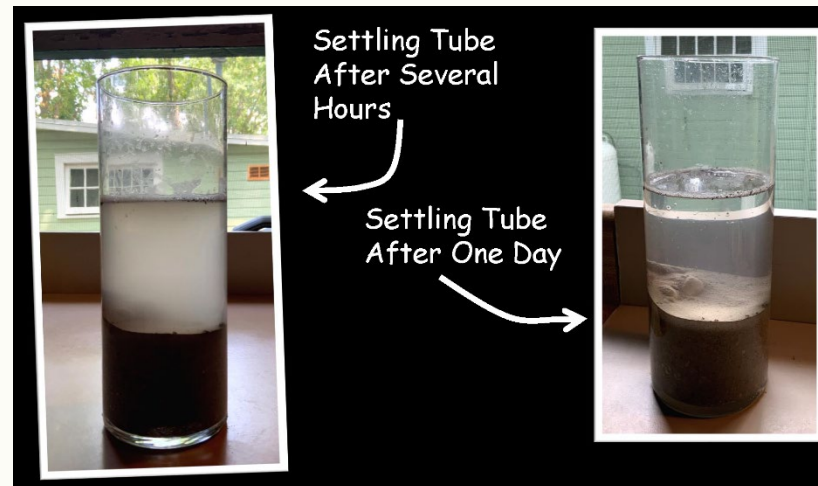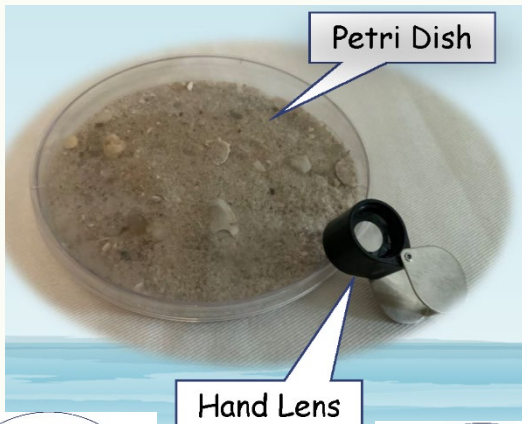
TEST LOCATIONS:

- John Jermain Memorial Library in Sag Harbor, NY
- Nature Center at Jones Beach State Park in Jones Beach, NY
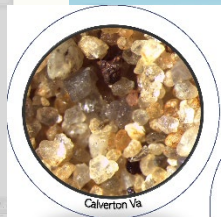
US Army C...   ...neers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory

Ways to Keep Citizen Scientists Engaged

IMMEDIATE
- **Immediate Response**
- **Fun Facts**
- **Leaderboard**

STRATEGIC
- **Water Bottle Stickers**
- **Library STEM Activity Bags**
- **CoastSnap Collaboration**
- **Class Lesson Plans**
- **Science Fair Projects**
- **Girl Scout Journey/Citizen Science Badge**
- **Boy Scout Oceanography Merit Badge**
- **Promote with Nature-centric Groups**
  - **Master Naturalist Association**
  - **Audubon Society**
  - **Coastal State Parks**

Beach Location	Fun Fact	Re-written Fact	Fact Info	d50	Grouping
South Beach, Edgartown, MA, USA	The movie *JAWS* was filmed here in 1975.	Your medium sand is similar to the sand in South Beach, Edgartown, MA, USA. The movie JAWS was filmed here in 1975.	Link	0.230	medium
Paradise Island, Bahamas	The *James Bond* film *Casino Royale* was filmed at The Ocean Club here.	Your fine sand is similar to the sand in Paradise Island, Bahamas. The James Bond film Casino Royale was filmed at The Ocean Club here.	Link	0.165	fine
Cape Hatteras Point, NC, USA	This is the location of the Cape Hatteras Lighthouse, a lighthouse that was picked up by the local town and moved a distance of 2900 ft in 1999.	This is the location of the Cape Hatteras Lighthouse, a lighthouse that was picked up by the local town and moved a distance of 2900 ft in 1999.	Link	0.181	fine
Panama City Beach, FL, USA	concentrations of wild bottle-nose dolphins in the world.	Panama City Beach has one of the highest concentrations of wild bottle-nose dolphins in the world.	Link	0.200	fine
Point Barrow, AK, USA	Barrow, Alaska is the northernmost city in the United States!	Your fine sand is similar to the sand in Point Barrow, AK, USA. Barrow, Alaska is the northernmost city in the United States!	Link	0.165	fine

US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory

Summary

FY20 Major Advances in Capability

- **Feasibility Study Completed**
- **Developed a Sample Methodology**
- **Trained Deep-Learning Model (multiple times)**
- **Printed 1,000 Water Bottle Stickers with QR code**
- **Collected More Images and Physical Samples**
- **Assembled 75 Fun Beach Facts**
- **Created 4 STEM Activity Bags**
- **Began Model Migration to the Cloud**

FY20 Major Products & Collaborations

- **TN: Technical Feasibility of Creating a Beach Grain Size Database with Citizen Scientists**
- **6 Webinars (CWG, RSM, CHL Research Forum, Kiwanis Club, ASBPA Science & Tech. Committee, ERDC Data Science Workshop)**
- **1 CIRP TD**
- **Collaborations:**
  - ► **Key Collaborators: James Madison University, Marda Science, LLC., USGS**
  - ► **Imagery & Samples: 18 Universities and Gov't Agencies**
  - ► **STEM Bags: Library Sag Harbor, NY; Nature Center in Jones Beach, NY**
- **FY21 – RSM & CIRP Proposals**

FY21 Products/Advances

- **Complete Interactive Web Application**
- **Conference Presentation**
- **Retrain Deep-Learning Model (Quarterly)**
- **Public Outreach (Girl Scouts/Library Bags)**

US Army Corps of Engineers • Engineer Research and Development Center • Coastal and Hydraulics Laboratory