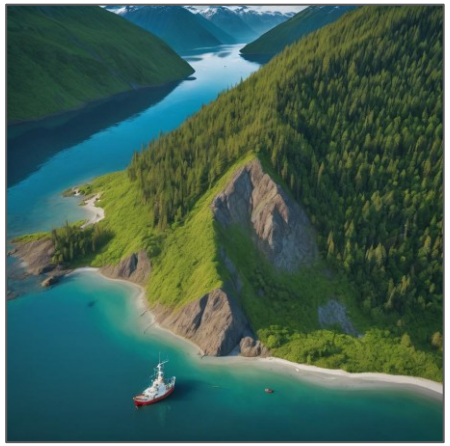
Alaska Coastal Mapping: A Deep Dive from Space



TCARTA

ALASKA GEOSUMMIT 2025 Anchorage, Alaska APRIL 9-11

Ross Smith, ***Senior Geospatial Scientist***
ross@tcarta.com

DOI: 10 April, 2025

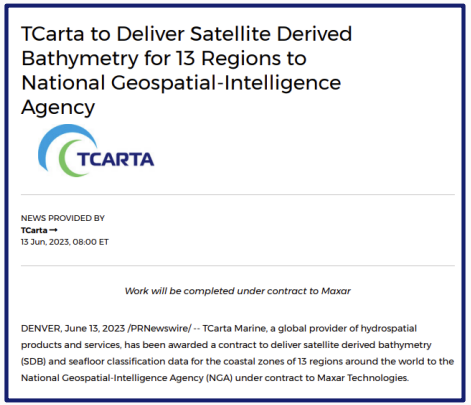
Introduction: TCarta Background

- **TCarta** is a **Hydrospatial** & Marine **Remote Sensing** company, located in Denver, CO, USA, specializing in space-based hydrography and coastal mapping technologies.

SBA WOSB Woman Owned Small Business

SBA U.S. Small Business Administration

COLORADO CO USA COMPANY



TCarta to Deliver Satellite Derived Bathymetry for 13 Regions to National Geospatial-Intelligence Agency

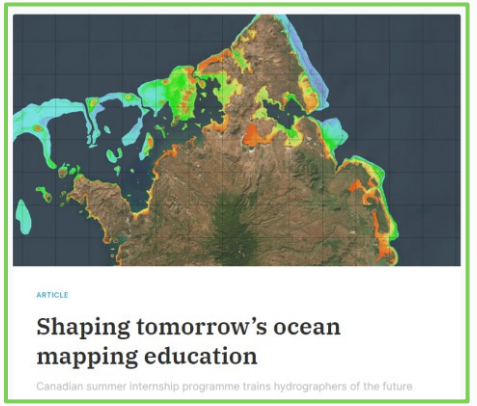
TCARTA

NEWS PROVIDED BY
TCarta →
13 Jun, 2023, 08:00 ET

Work will be completed under contract to Maxar

DENVER, June 13, 2023 /PRNewswire/ -- TCarta Marine, a global provider of hydrospatial products and services, has been awarded a contract to deliver satellite derived bathymetry (SDB) and seafloor classification data for the coastal zones of 13 regions around the world to the National Geospatial-Intelligence Agency (NGA) under contract to Maxar Technologies.

CISION PR News Wire- June 2023



ARTICLE

Shaping tomorrow's ocean mapping education

Canadian summer internship programme trains hydrographers of the future

Hydro International- June 2024

NASA

ICESat-2 Early Adopter/Applied Users Program (2019-Present)

NSF

SBIR Phase 1 & 2 (2018-2022)

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

SBIR Phase 1 & 2 (2018-2022)

SBIR Phase 1 (2024 - 2025)

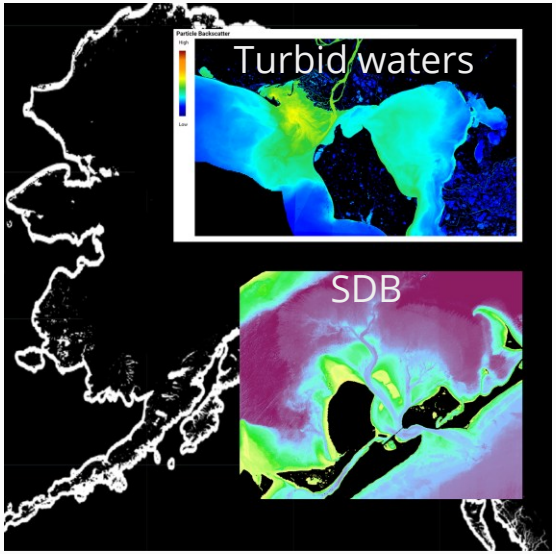
National Geospatial-Intelligence Agency United States of America

Tech Accelerator Cohort 3 (2022)

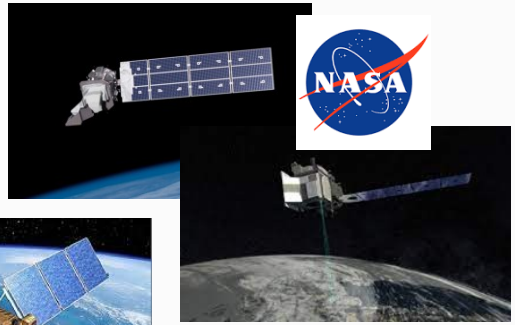
NOAA SBIR Grant: Multi-Sensor SDB in Alaska and Arctic Waters

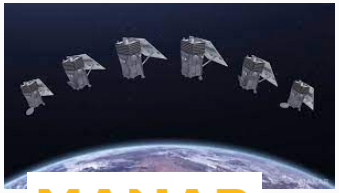
Multi-Platform Integration | Sub-Daily Imaging | Customized Collection for Arctic Conditions | Space, Aerial, Marine Survey Interoperability

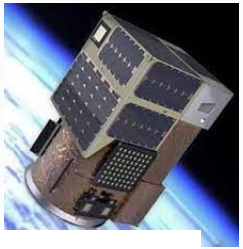
TCarta completed Phase 2 of a Small Business Innovation Research (SBIR) grant focused on multisensor integration, custom sensor tasking parameterization for marine imaging, and adaptation of Satellite Derived Bathymetry techniques to Alaska and Arctic waters.

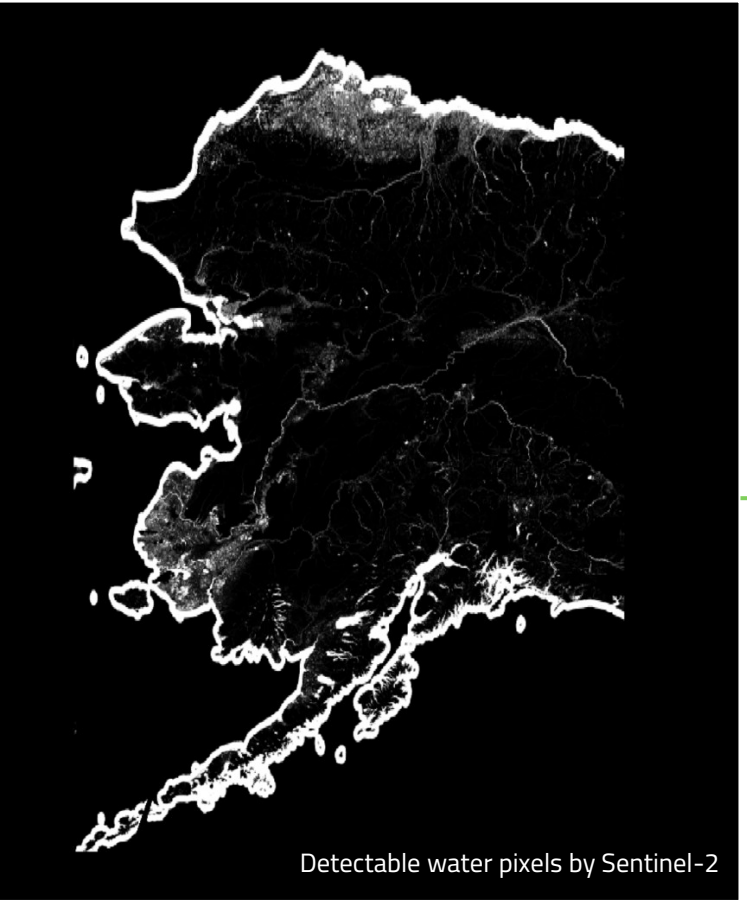


Multispectral | Hyperspectral | Space-Based LiDAR | Synthetic Aperture Radar (SAR)









Detectable water pixels by Sentinel-2

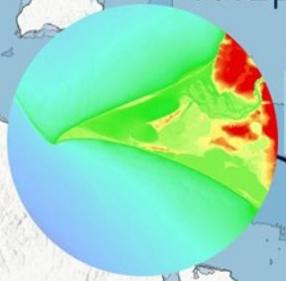
PRESIDENTIAL MEMORANDA

Memorandum on Ocean Mapping of the United States Exclusive Economic Zone and the Shoreline and Nearshore of Alaska

ENERGY & ENVIRONMENT | Issued on: November 19, 2019

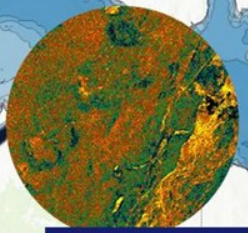
★ ★ ★

Mapping Alaska Using American Satellites



Point Hope

Seamless Topobathy Digital Elevation Model



Sagavanirktok River, Deadhorse

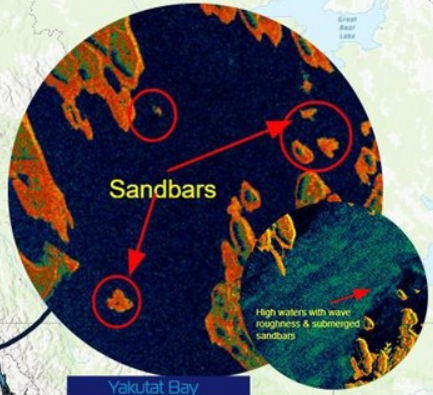
Permafrost Identification

Port Of Nome

Shoreline Extraction

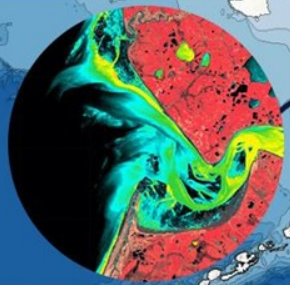
Kachemack Bay

Satellite Derived Bathymetry



Yakutat Bay

High & Low Tide Analysis



Egegik, Bristol Bay

Daily to Sub-daily Water Quality Monitoring

MAXAR TECHNOLOGIES

planet.

Capella Space

US Based Commercial Satellite Imaging Providers

MAXAR

planet.

Capella Space

pixxel *

SATELLOGIC *

TCARTA

*Not originally US based, but moving towards larger NA base/presence

MAXAR

Based in Westminster, Colorado

- 125-plus petabyte imagery archive
- More coverage: 60% of Earth's surface monthly
- Daily collection: More than 3.8 million sq km per day
- Most spectral diversity commercially available
- Fastest 50 cm revisit times—intraday revisits
- High geolocational accuracy

Worldview-1

50 cm resolution
<5.0 m CE90

Worldview-3

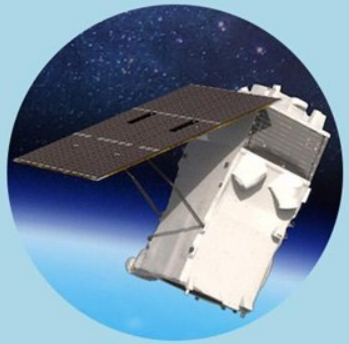
31 cm resolution
<5.0 m CE90

Worldview-2

46 cm resolution
<5.0 m CE90

Geoeye-1

41 cm resolution
<5.0 m CE90



*Four Worldview Legion

34 cm resolution
<5.0 m CE90

MAXAR TECHNOLOGIES

*6 total, 4 in epipolar orbit

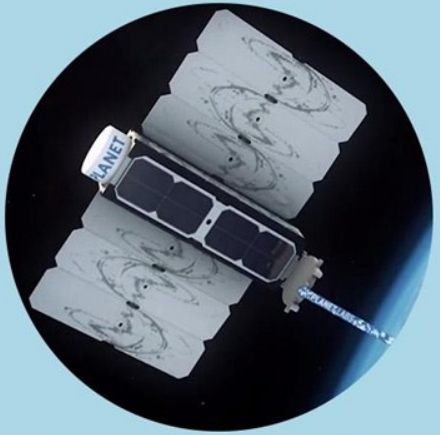
Multispectral Satellites

PLANET LABS

Based in San Francisco, California

- 10+ billion sq km of imagery
- Proprietary datasets back to 2009 and public datasets back to 1972
- Rapid Revisit Platform can capture up to 12 images per day
- Polar orbit occuring every 90 min, capturing the earths entire landmass daily
- A fleet of over 200 satellites called 'Doves'

planet.



PLANETSCOPE

3 m resolution
350M+ km2/day

RAPIDEYE

5 m resolution
Archive back to 2009

SKYSAT

50 cm resolution
400K km2/day

Multispectral Satellites

Capella Space

Based in San Francisco, CA

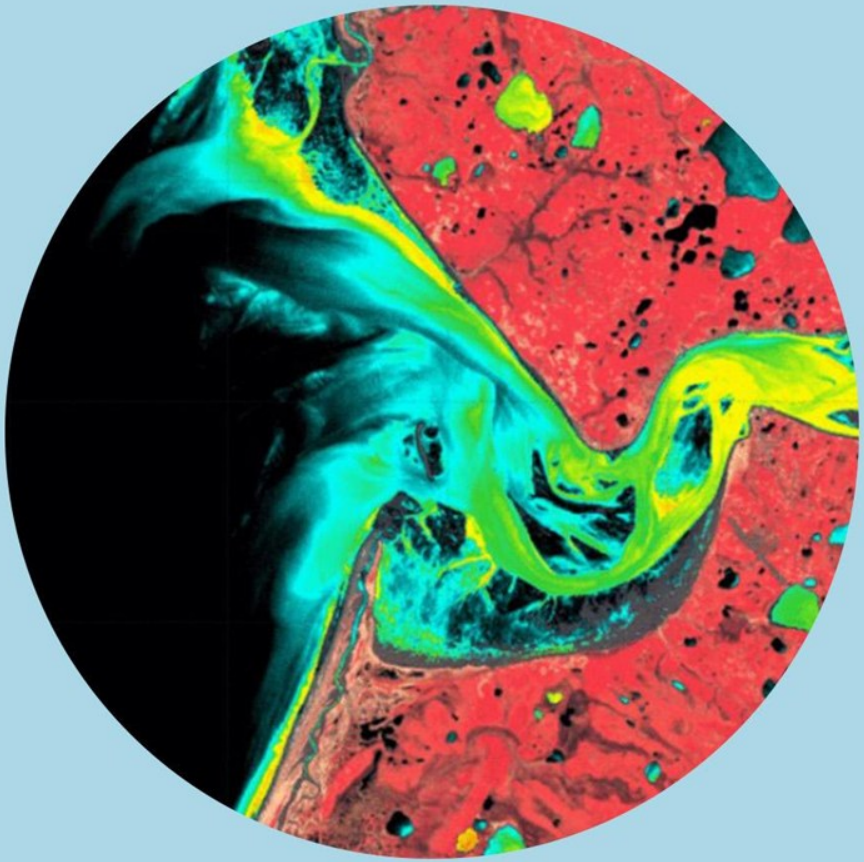
- *Founded in 2016*
  - *First US commercial Synthetic Aperture Radar*
- *Four satellites currently in orbit - 3rd gen*
- *3 Collection modes: spotlight, site or strip*
- *Up to 0.5m resolution depending on mode*
- *Day or night / all weather collection*

Acadia/Whitney Constellation
25cm- 3.5m resolution
3x per day capture

Capella Space

Egegik, Bristol Bay

PlanetScope imagery enables daily to sub-daily monitoring of water clarity at 3-meter resolution, providing valuable insights into aquatic environments. These images can generate indices such as turbidity, surface temperature, suspended sediments, and other water quality metrics, allowing for detailed tracking of changes in water quality. This capability is essential for managing water resources, detecting pollution, and supporting ecosystem health assessments.



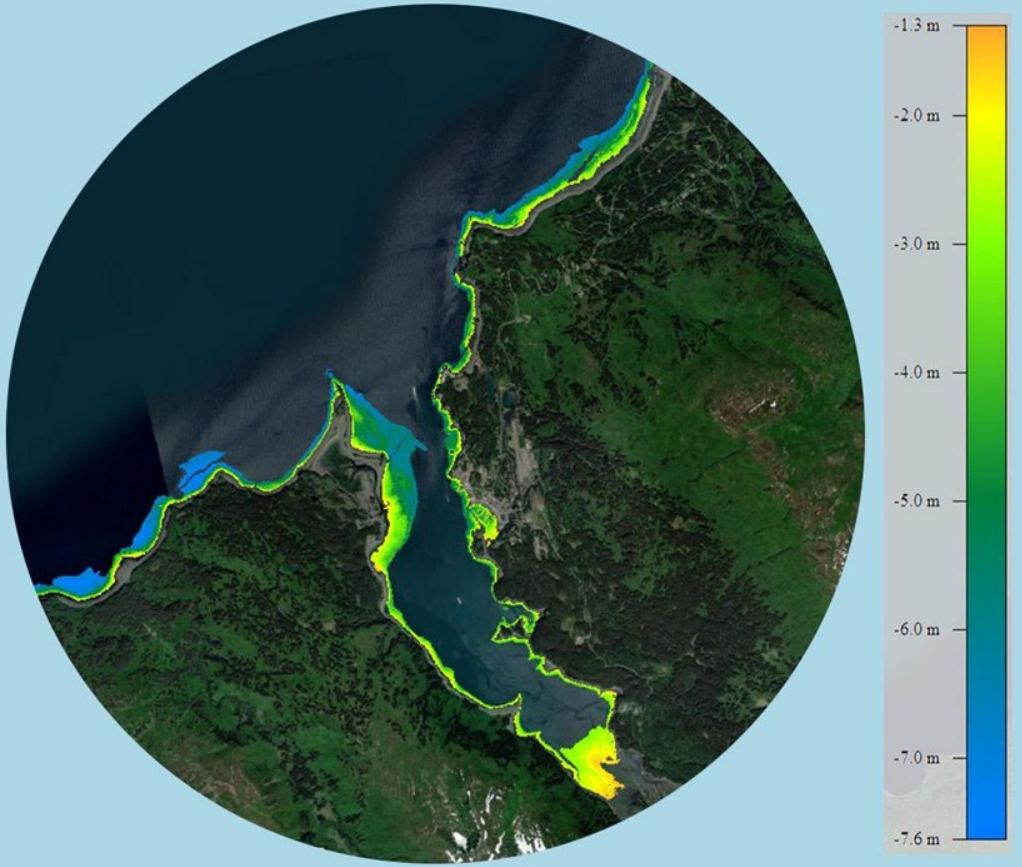
Daily to Sub-daily Water Quality Monitoring

TCARTA Denver, Colorado

planet.

Kachemak Bay

Satellite-derived bathymetry (SDB) uses satellite imagery to determine water depths in coastal waters, offering a cost-effective and rapid alternative to traditional survey methods, especially in difficult to reach areas. By analyzing light penetration and reflection from the seafloor, SDB provides critical data for coastal mapping, navigation, and habitat assessment. Its applications are particularly valuable for continuous monitoring of dynamic coastal zones, supporting disaster preparedness, and aiding in marine spatial planning.



Satellite Derived Bathymetry And Benthic Classification

TCARTA Denver, Colorado
MAXAR TECHNOLOGIES
planet.

Port of Nome

Synthetic Aperture Radar (SAR) is highly effective for shoreline extraction, leveraging differences in radar backscatter to accurately distinguish between land and water surfaces. This method enables precise delineation of shorelines, even in challenging conditions such as cloudy weather or at night. SAR's high-resolution capabilities make it an essential tool for monitoring coastal changes and managing dynamic shoreline environments.

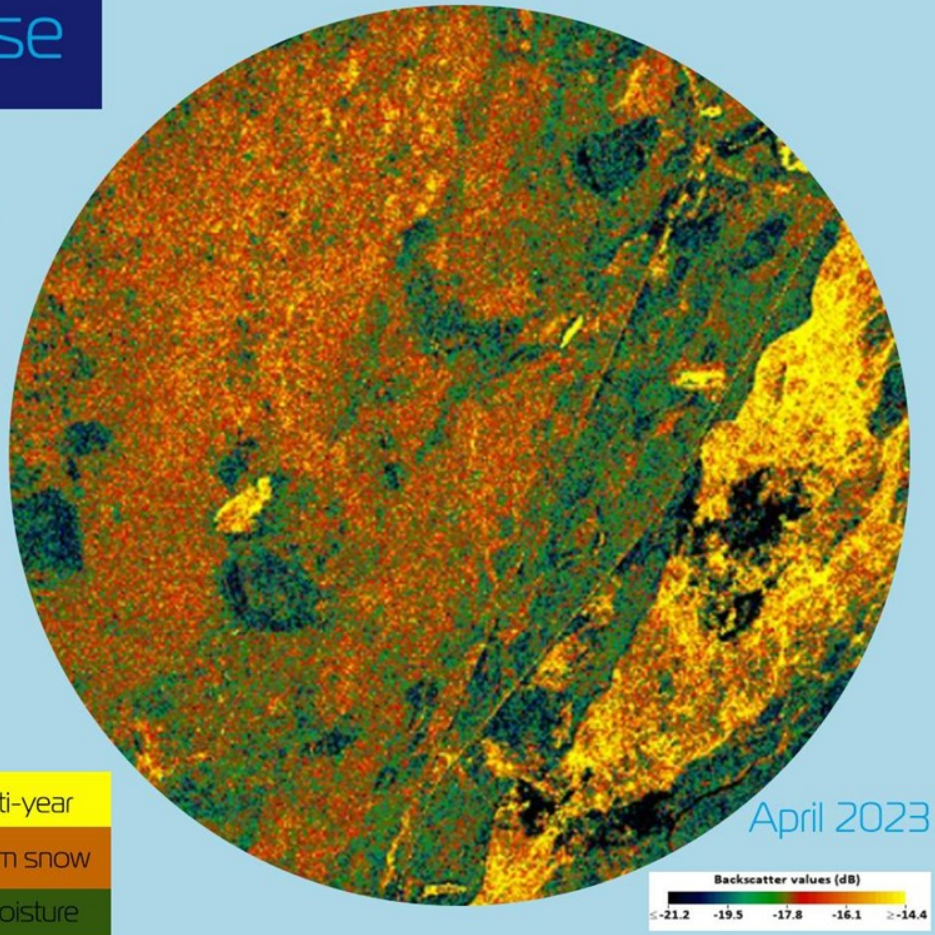
Shoreline Extraction

TCARTA Denver, Colorado

Capella Space

Sagavanirktok River, Deadhorse

Synthetic Aperture Radar (SAR) is a valuable tool for identifying permafrost by detecting surface deformations caused by freeze-thaw cycles and monitoring changes in soil moisture. SAR's ability to penetrate through vegetation and provide high-resolution data in all weather conditions makes it ideal for mapping permafrost extent and assessing its stability. This information is critical for understanding climate change impacts and managing infrastructure in permafrost regions.



April 2023

- Frozen - potentially multi-year
- Frozen - roughness from snow
- Thawing ground and moisture
- Fresh Smooth Ice

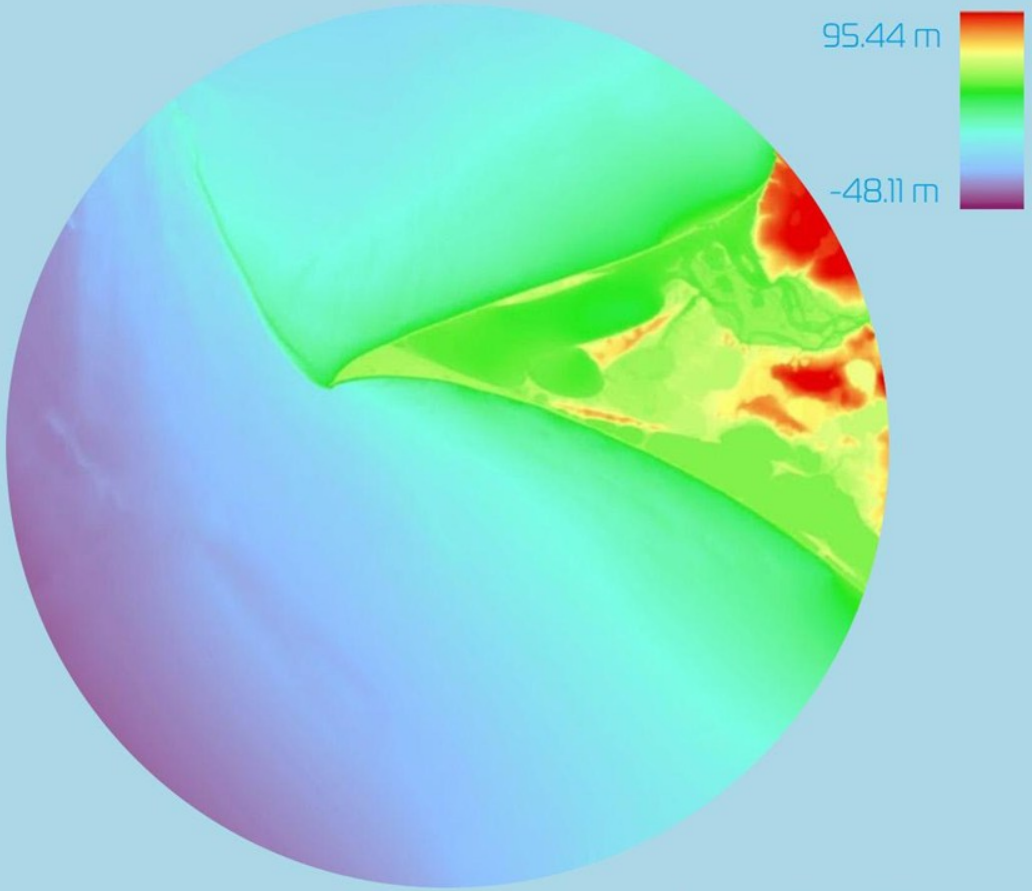
TCARTA
Denver, Colorado

Capella Space

Permafrost Identification

Point Hope

Seamless Topobathymetric Digital Elevation Models (DEMs) are advanced geospatial data products that integrate topographic (land-based) and bathymetric (underwater) elevation data into a single, continuous surface. By combining existing datasets and satellite data products, a comprehensive model of a coastal region can be derived. These models are essential for applications such as coastal management, navigation, and disaster planning.



Seamless Topobathy Digital Elevation Model

TCARTA Denver, Colorado
MAXAR TECHNOLOGIES
planet.

2023 Project

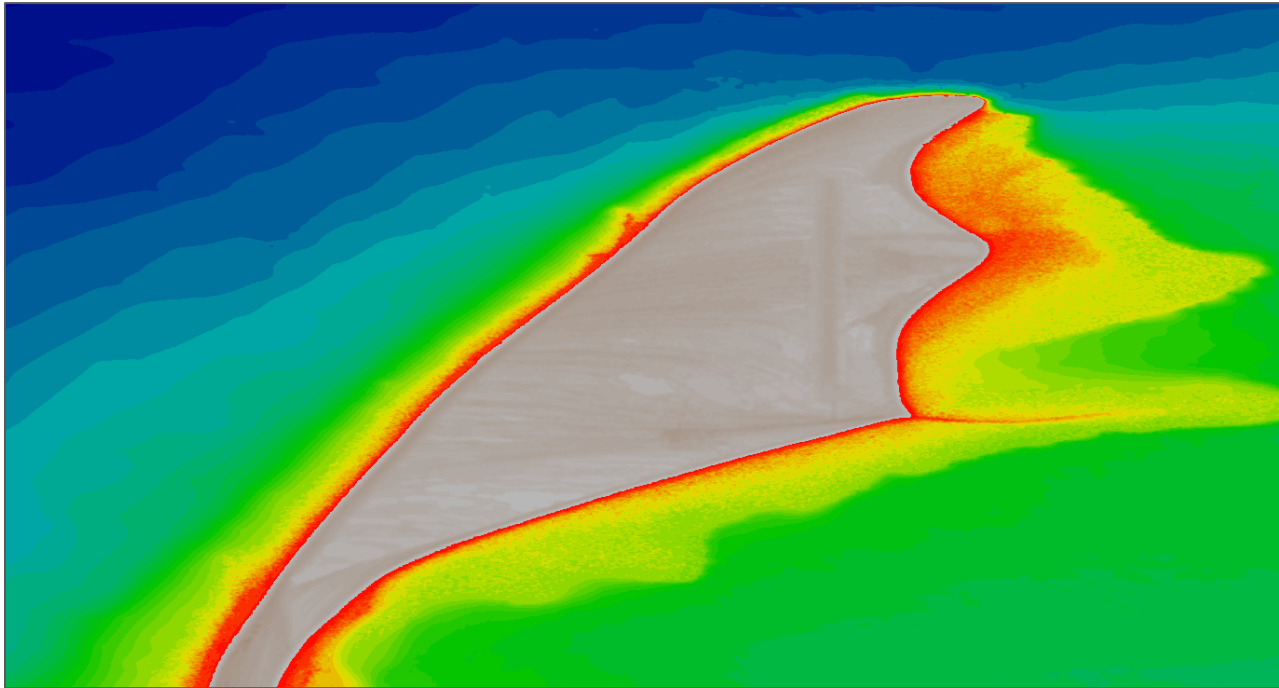
1305M223FNCNP0283 – The Generation of a Seamless Topo-Bathy DEM NOAA

OFFICE FOR COASTAL MANAGEMENT

Axim GEOSPATIAL AN NV5 COMPANY

TCARTA

"This project has the goal of filling gaps in bathymetric data according to the Alaska Mapping Executive Committee (AMEC) Alaska Coastal Mapping Strategy."

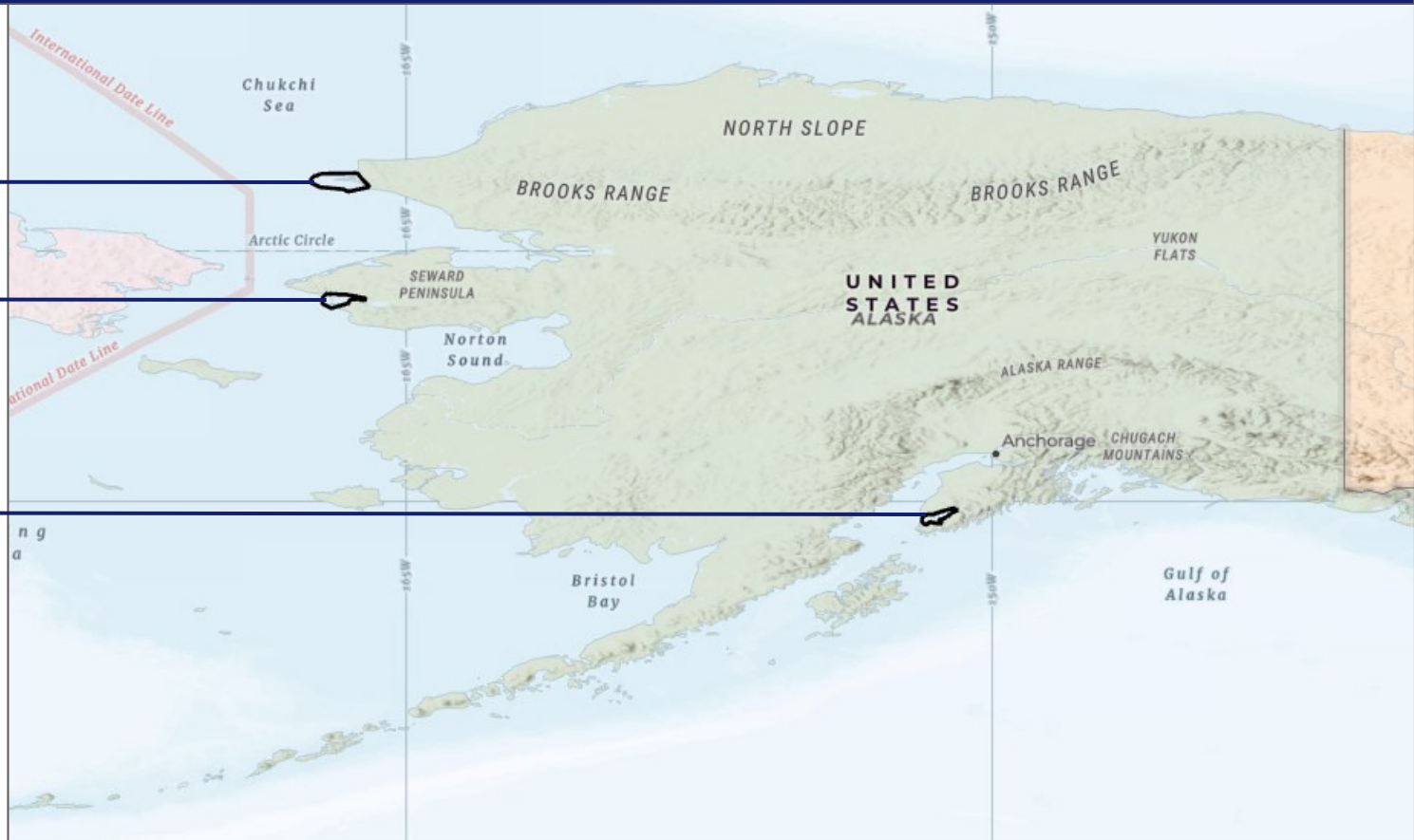


Project Locations

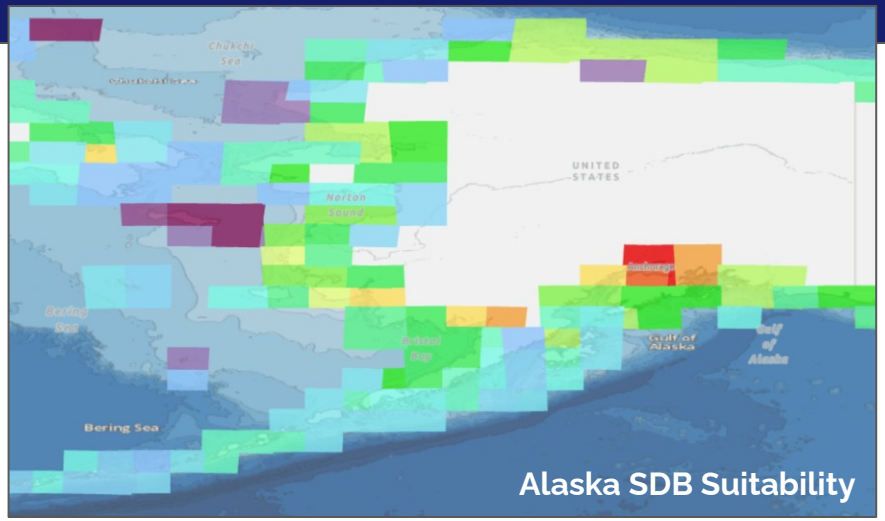
Point Hope - 68.4° N

Teller - 65.3° N

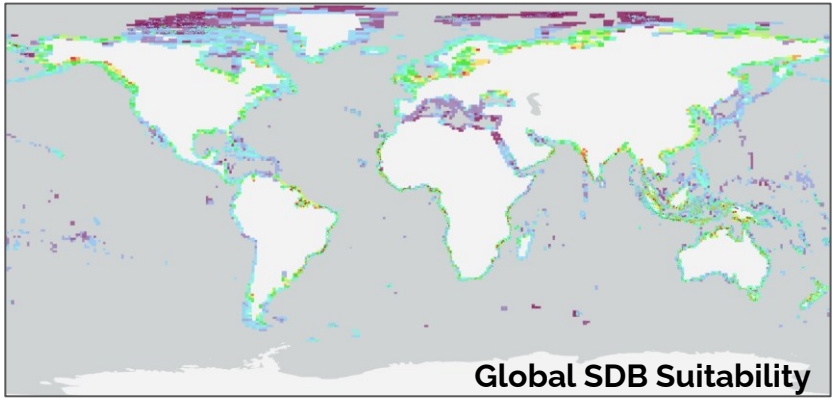
Kachemak Bay - 59.6° N

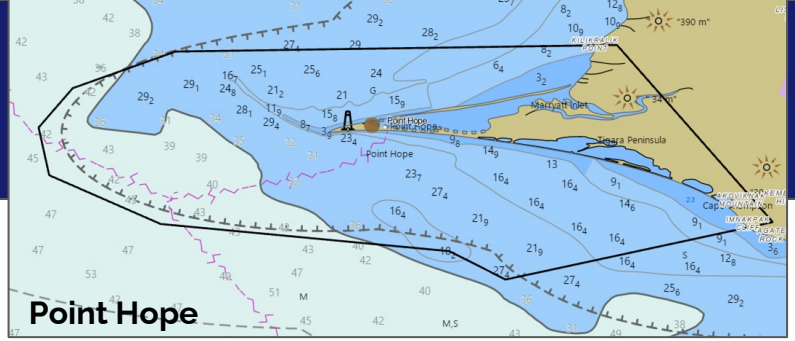


Project Locations

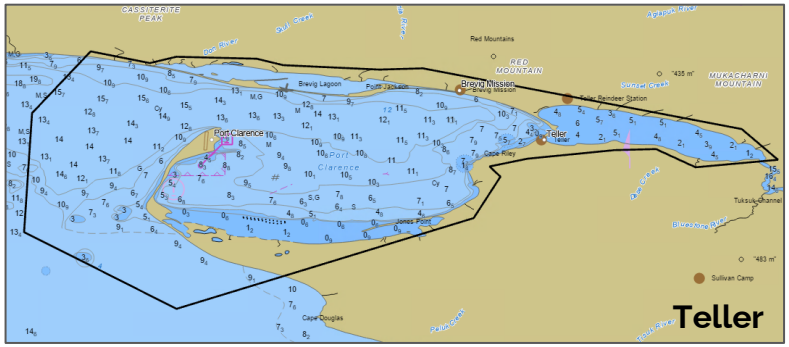


Alaska SDB Suitability

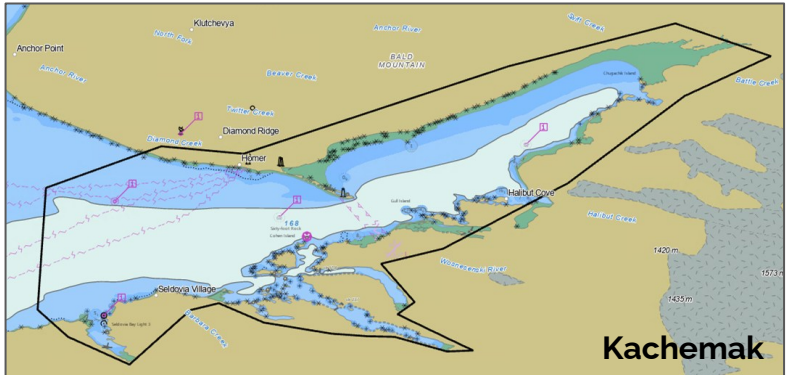

Global SDB Suitability



Point Hope



Teller



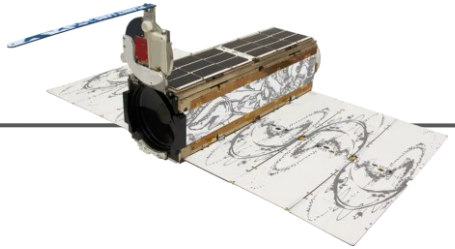
Kachemak

Satellite Imagery Sources

Maxar - WorldView 2&3

8 band MSI
Best radiometric & positional accuracy

Planet - PlanetScope



New flocks are 8 band MSI
Daily imaging at 3m GSD
Pushing the limits of satellites for SDB

Sourcing Satellite Imagery

Approach	Provider	Pros	Cons
1. Archive Imagery	Maxar	Low risk imagery Selection of suitable imagery	Archive is not deep; imagery may be 3-5 yrs old, getting older
2. Precision, high quality tasked imagery	Maxar	New imagery from the best sensors for the task	High Risk; Challenging water conditions, difficult to predict clear-water collection opportunities; <10% chance of success in AK
3. Daily Imaging from small-sats	Planet	Best chance to capture imagery with clear water; new 8-band flocks	Lower radiometric quality; S/N

Task 1:

Acquire new bathymetric data processed using satellite derived bathymetry techniques (SDB)

- Typical SDB Capabilities and Specifications - Out the window

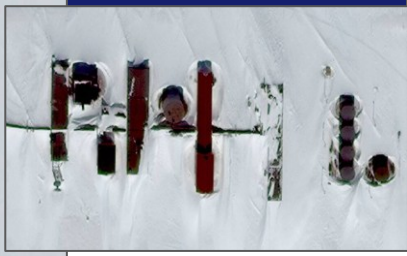
- All-of-the-above approach for SDB

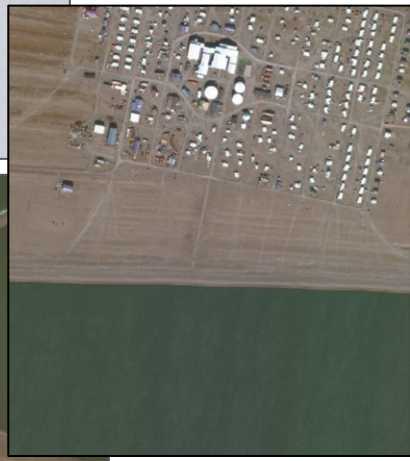
3 SDB Algorithms

Radiative Transfer | Machine Learning | Band Ratio

Corrections & Considerations:

- Atmospheric correction
- Glint/specular reflection mitigation
- BRDF artifact mitigation
- Tide datum adjustment
- Automated Mitigation of land, whitewash, and anthropogenic features
- 3D Point Cloud Editing - spurious points removal
- Reflective signal extinction depth delineation, removal of optically deep areas

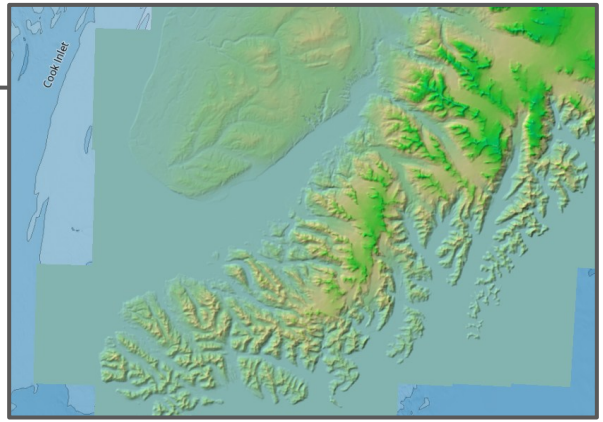




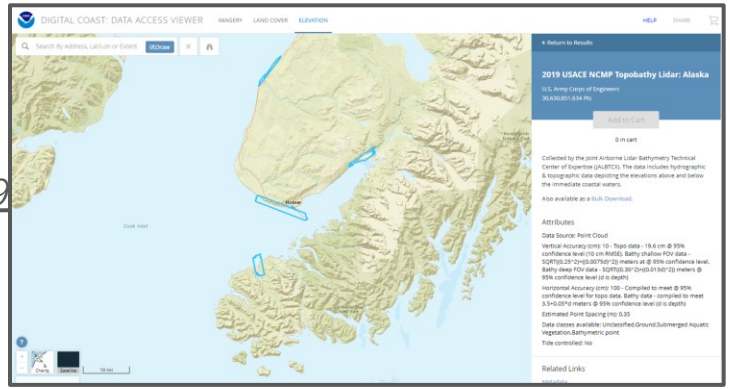
Task 2:

"Create a seamless topobathymetric DEM using existing topobathymetric lidar, sonar derived bathymetry, terrestrial lidar, iFSAR and the SDB produced from this project."

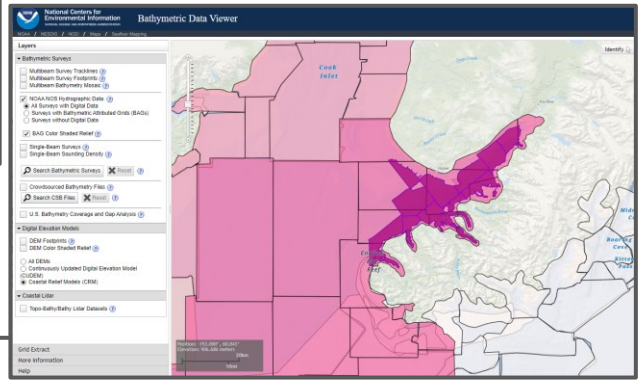
IFSAR DEM - 2016 -2019



Topo-Bathy LiDAR - *2016-2019*



SBES & MBES Bathymetric Surveys - *1950's-2010's*



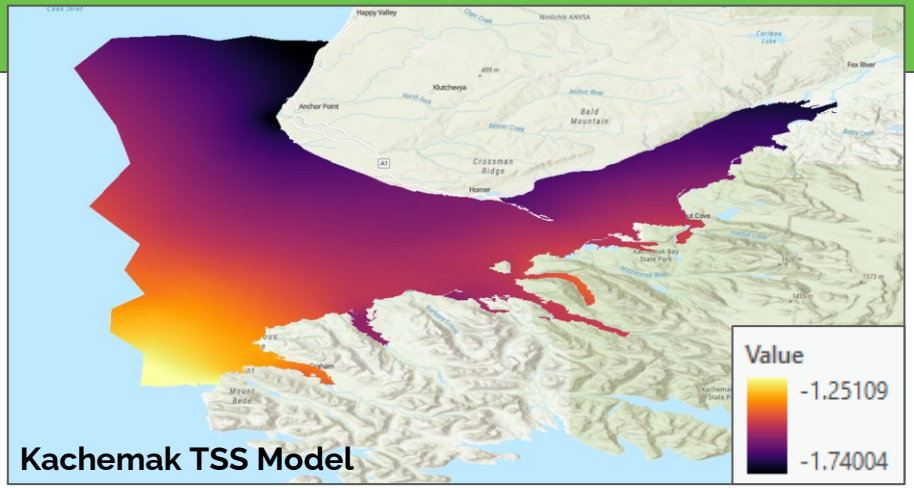
Accounting for Vertical Datums

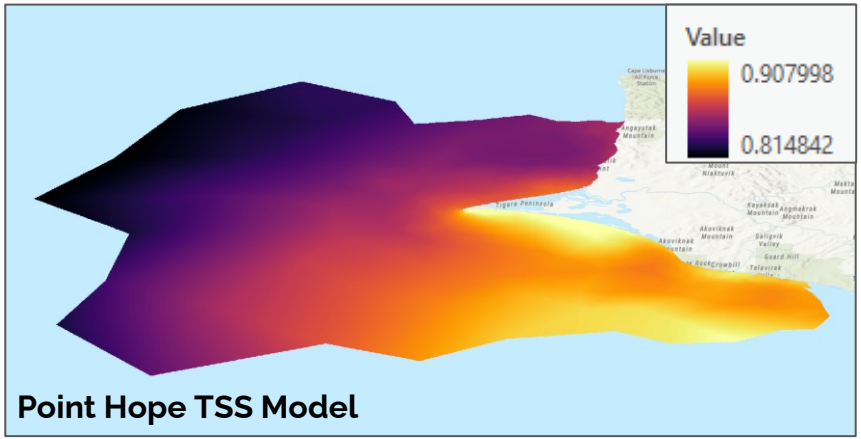
- VDatum transformation from MLLW to NAVD88 (GEOID12)

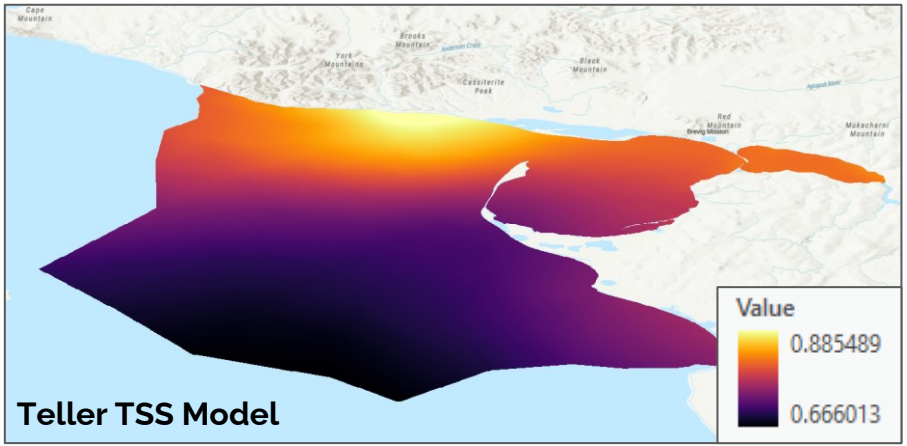
- Ellipsoidal-Referenced Tide Datum Model (ERTDM) - based on *Riley et al,* 2016

- A MLLW to NAVD88 (GEOID 12) triangulated mesh covering all the Alaskan tidal benchmarks acquired from Coast Survey Development Lab

- For each in situ point, the coincident MLLW to NAVD88 TSS correction was applied in order to convert the vertical datum to the project standard.





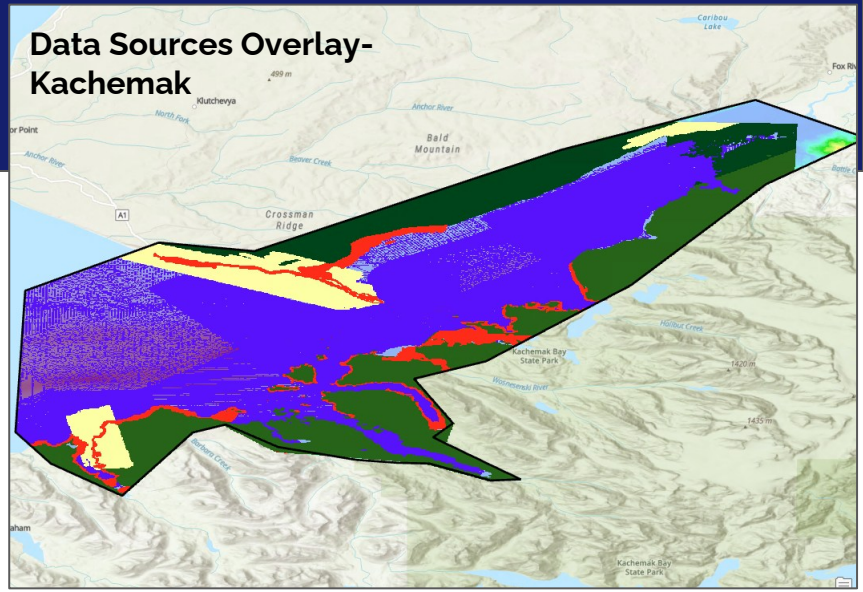


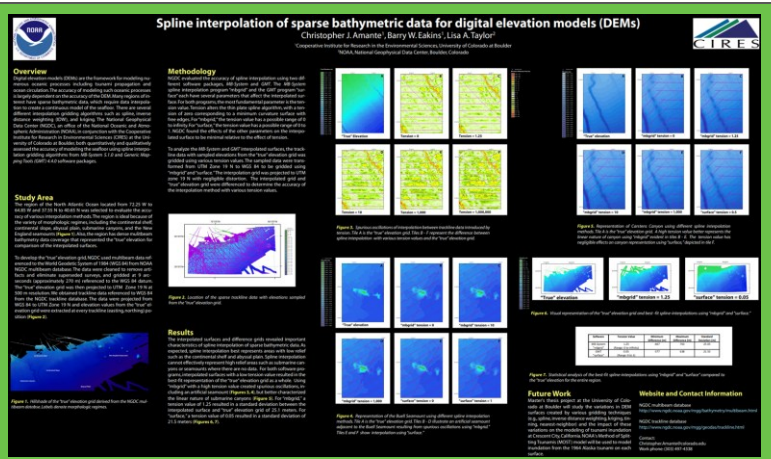
Data Weighting and Interpolation

- Each data source assigned unique weight based on sensor/collection type, date of collection, and data provenance.

- For each grid cell with multiple contributing/coincident sources, a weighted average value is calculated.

- Grid cells without one or more direct measurements are modelled using a continuous curvature spline-in-tension interpolation




Spline interpolation of sparse bathymetric data for digital elevation models (DEMs)

Christopher J. Amante', Barry W. Eakins', Lisa A. Taylor²

'Cooperative Institute for Research in the Environmental Sciences, University of Colorado at Boulder

²NOAA, National Geophysical Data Center, Boulder, Colorado

CIRES

Overview

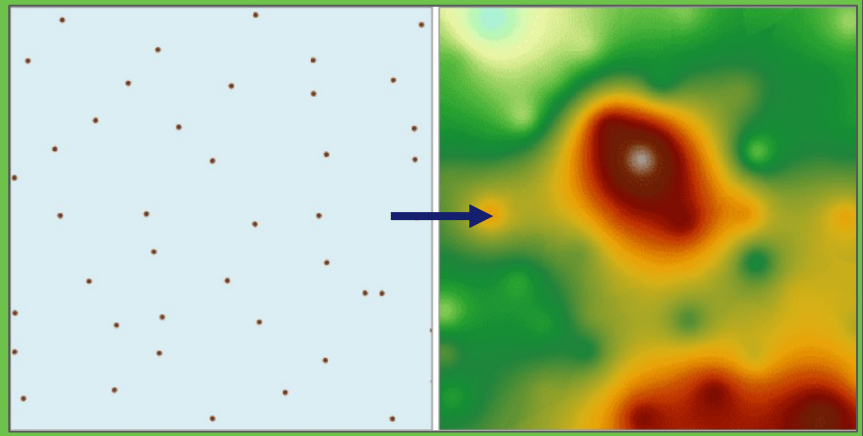
Methodology

Study Area

Results

Future Work

Website and Contact Information

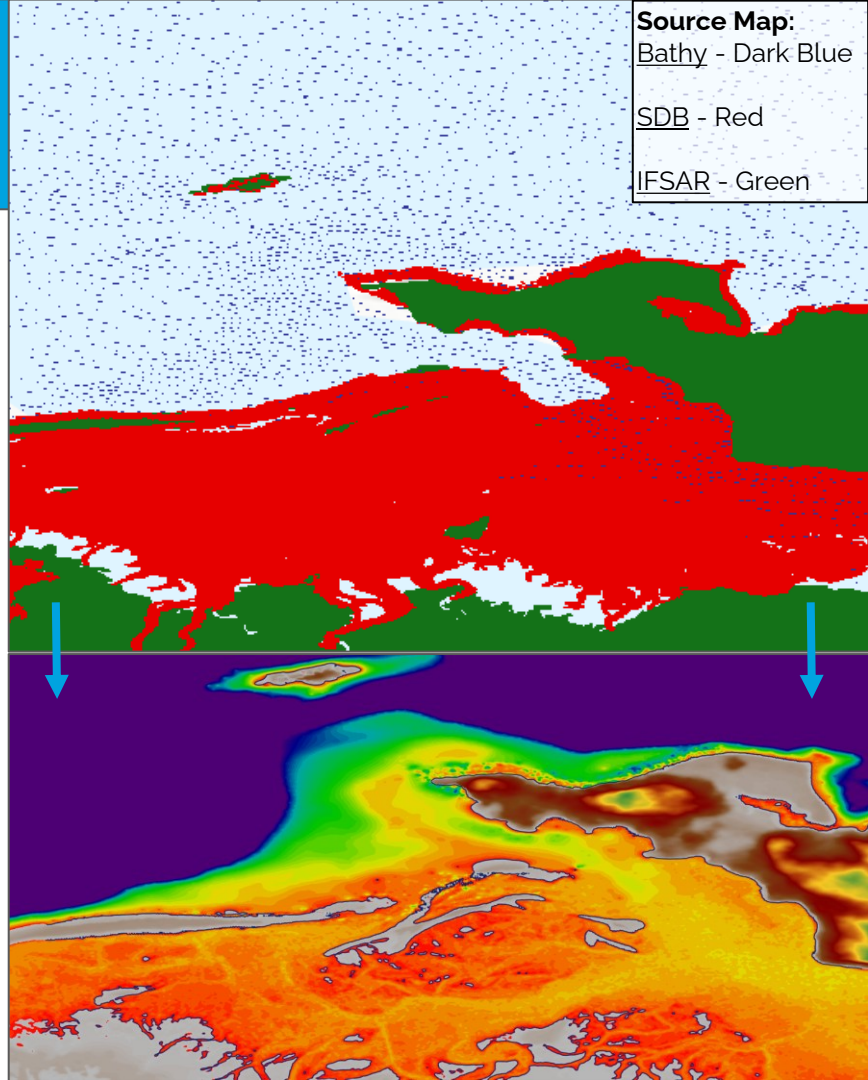


Multi Source Data
Gridding & Interpolation

	Kachemak Bay	Teller	Point Hope
WorldView Images	9	8	5
Planet Images	9	2	2

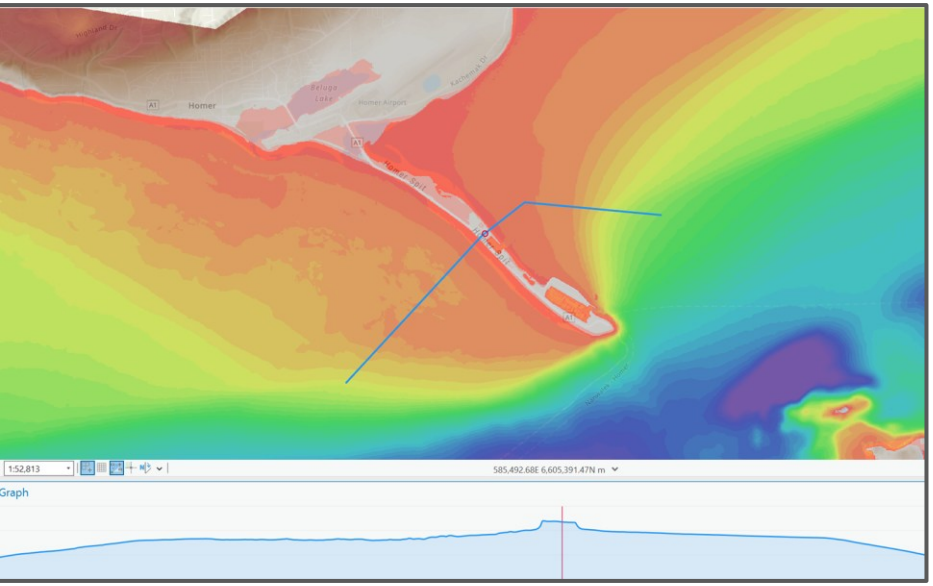
SDB: 'the glue' used to infill gaps between sparse sources

Data Type	Unique Areal Contribution (km^2)			
	Kachemak	**Teller**	**Point Hope**	**Total**
SDB	9.68	131.55	1.51	142.74
Sonar (Single- & Multibeam)	0.91	60.21	73.18	134.3
Topobathymetric LiDAR	42.11	36.63	1.94	80.68
Terrestrial LiDAR	93.15	N/A	66.13	159.28
iFSAR	41.47	39.05	56.36	136.88
Interpolation	825.42	893.25	2093.16	3811.83
Total Coverage	1012.74	1160.69	2292.28	4465.71

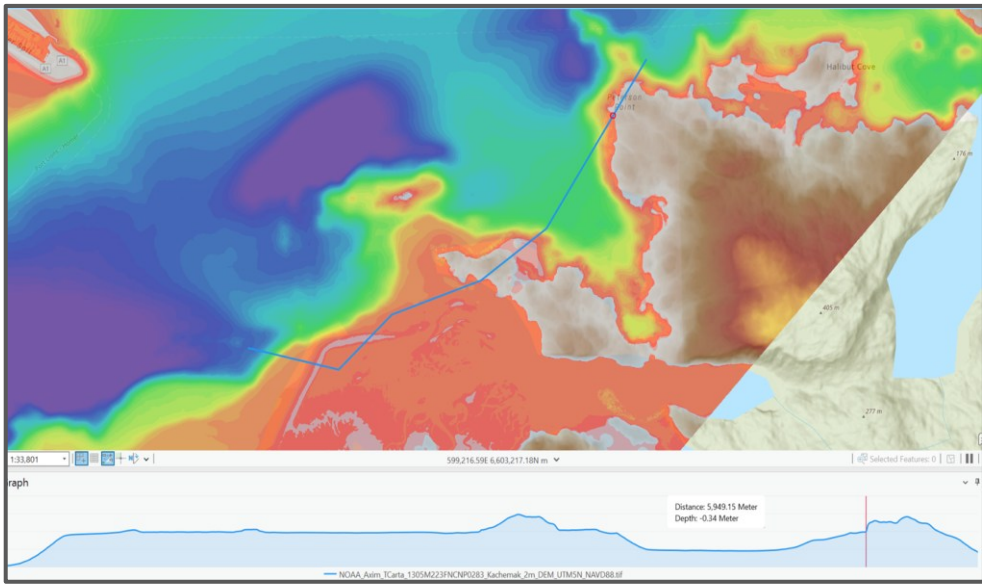


Seamless Topobathymetric DEM- Kachemak Bay

Homer

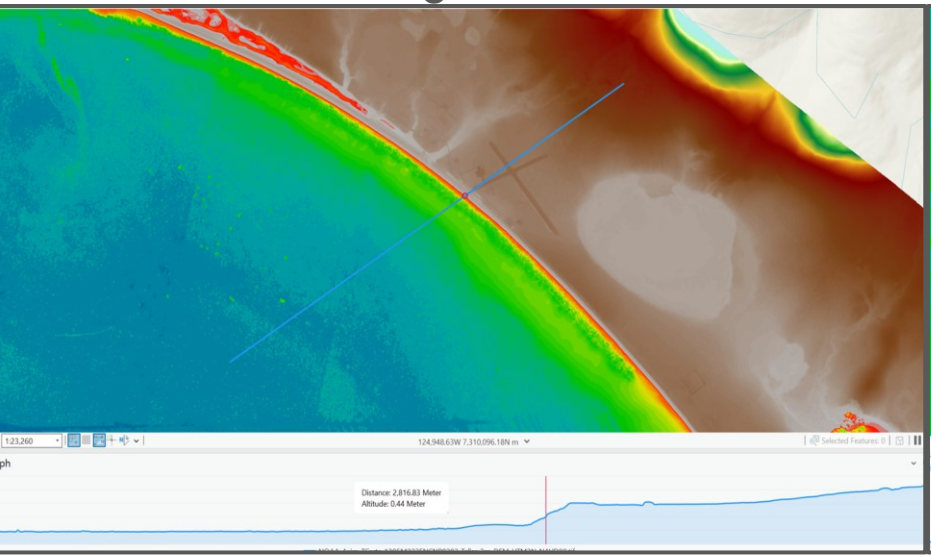


Peterson Point

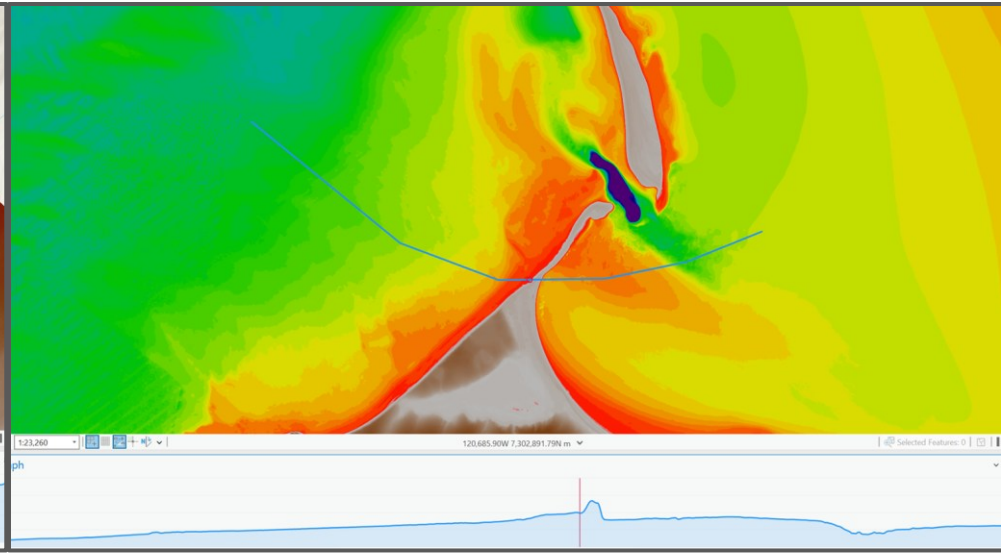


Seamless Topobathymetric DEM- Port Clarence/Teller

Brevig Mission

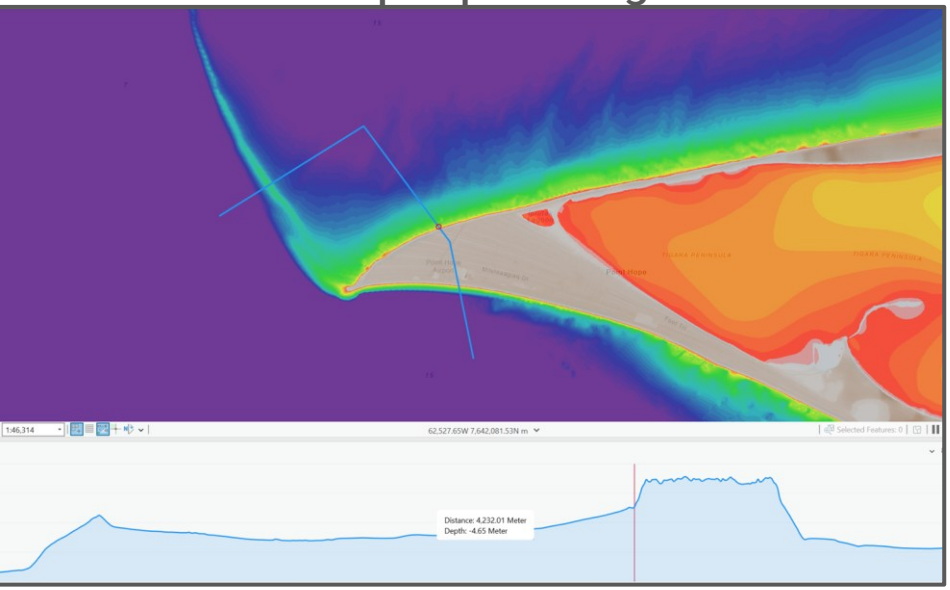


Teller

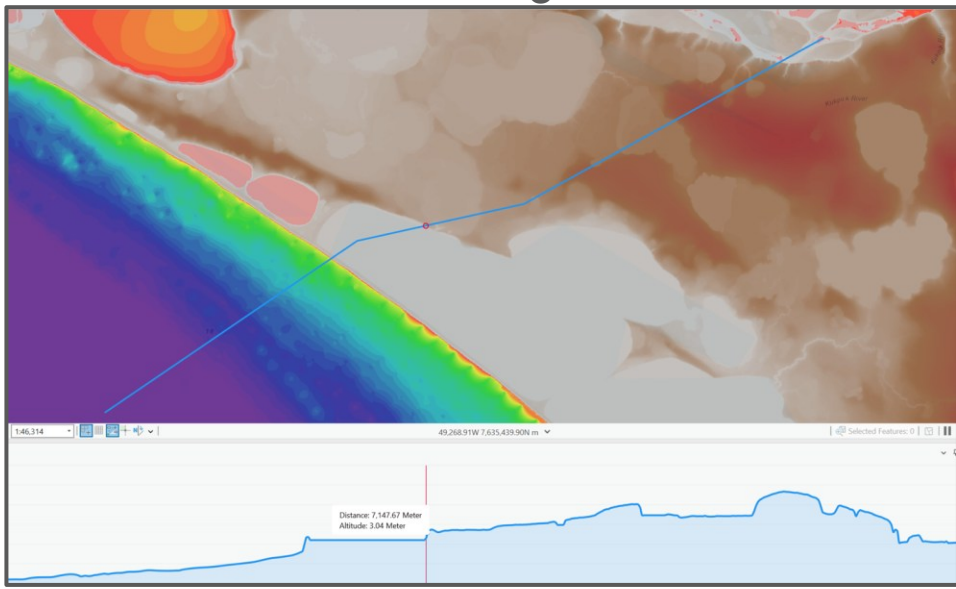


Seamless Topobathymetric DEM- Point Hope

Point Hope/Ipiutak Lagoon



Aiautak Lagoon



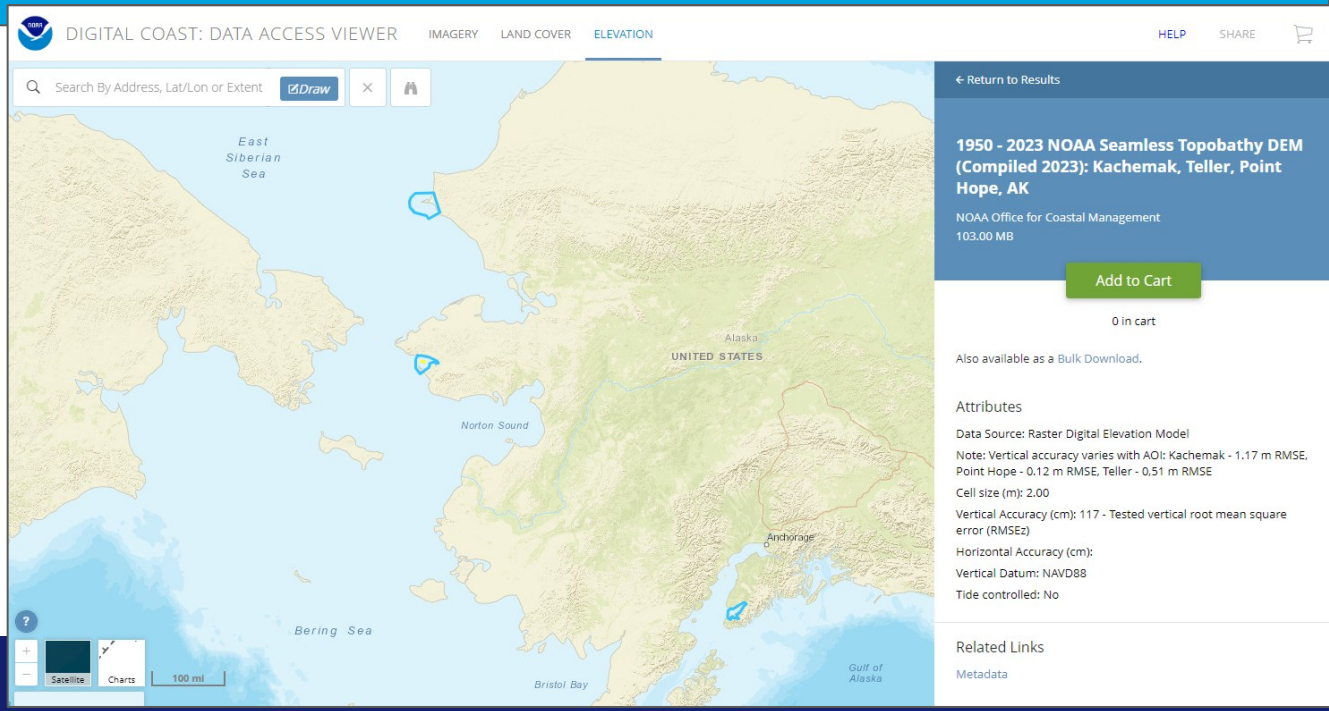
Data Made Available on NOAA Digital Coast

"these priorities that can be immediately used to support Alaska coastal mapping priorities and data users"

- Data made available for public use <1 month from delivery

- Multi-Source to Multi-Use

- Multi disciplinary team - SDB, hydro, geospatial, development



Topobathy Model Put to Use

USGS
science for a changing world

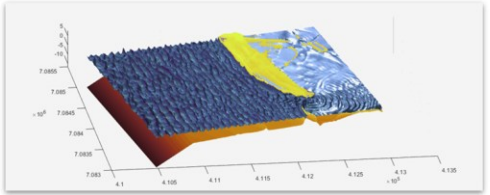
Coordinate – Collaborate – Innovate – Share

USGS

Quantifying flood hazards

Dynamic flood models

- Community-specific
- Represent relevant physics of a coastal storm
  - tides, waves, surge
- Predict likelihood of flooding due to sea-level rise and changing storminess



simulation at Unalakleet, AK

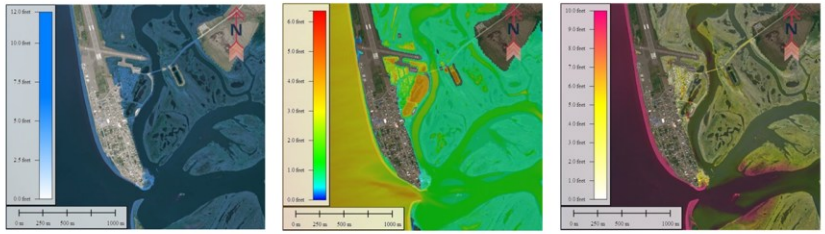
Coordinate – Collaborate – Innovate – Share

USGS

Quantifying flood hazards

Dynamic flood models

flood extents/depths | max velocities | max wave heights



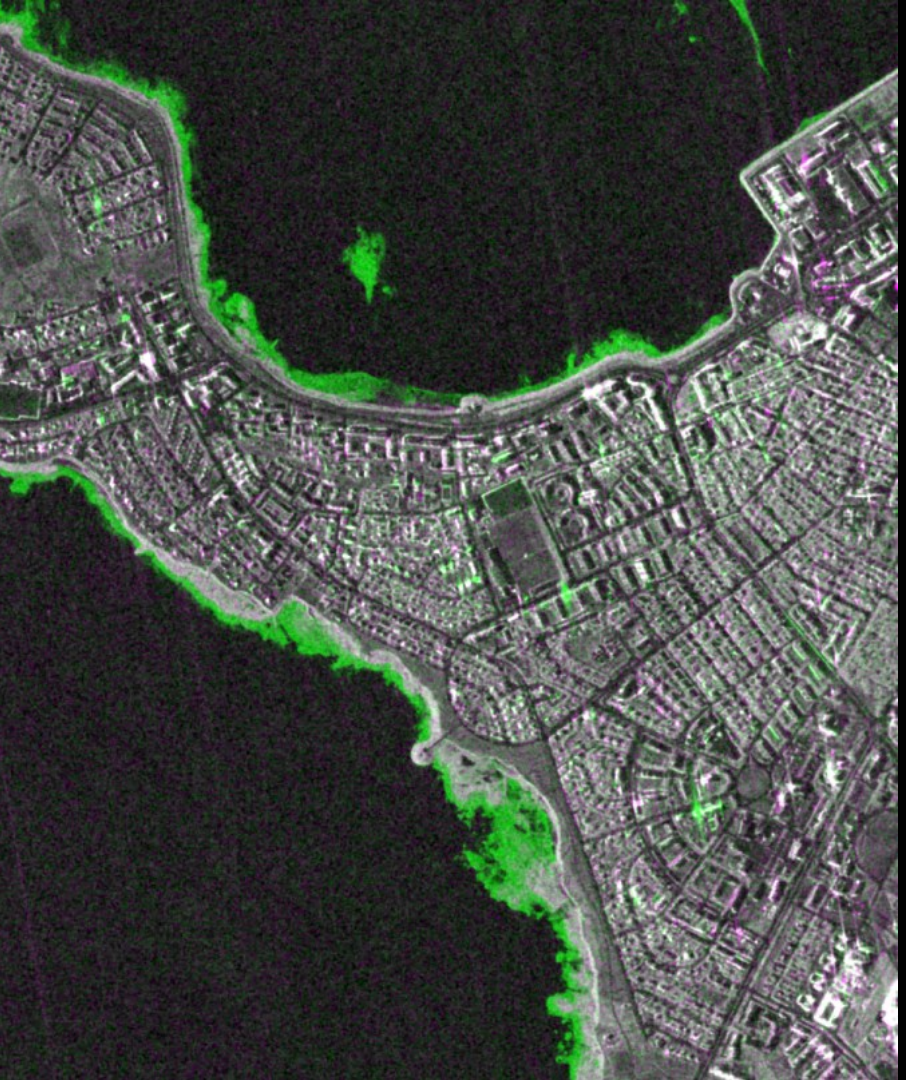
No Storm	Annual	10-Year	20-Year	50-Year	100-Year

Coastal storm (frequency)

None	50	100	150	200	300

Sea level rise, cm

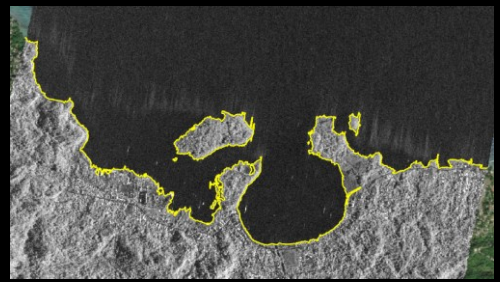
"in brief, the USGS is working to characterize coastal flooding and erosion in 20+ communities in NW Alaska by running a series of dynamic coastal inundation models. These numerical models capture the relevant physics of coastal storms and output flood extents, depths, water velocity, and wave heights, among other variables, for a wide range of modeled coastal storm intensities and sea level rise scenarios. The models rely critically on time series of weather forcings AND hi-resolution topobathymetric elevation models, which is where the TCARTA data come in for us."



TCARTA

Capella Space
PARTNER
ANALYTICS PARTNER PROGRAM

Intertidal Zone Mapping: High/Low water lines, classification, object detection, change detection



Capella SAR Based Shoreline VS NOAA Continuously Updated Shoreline (CUSP)

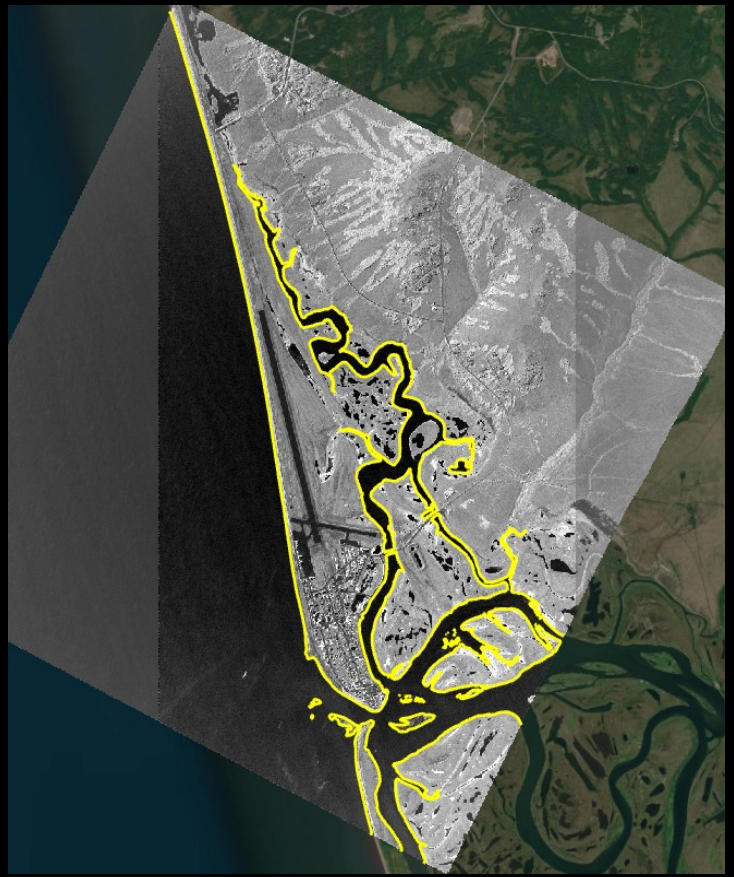
Study Area:
Unalakleet, Alaska

Date and Time of Image acquisition:

25 June 2022; 6:30 pm local time

Capella Image specifics:
HH polarization, Spotlight mode, 0.6m ground range spatial resolution

Tidal info: Low Tide Collection

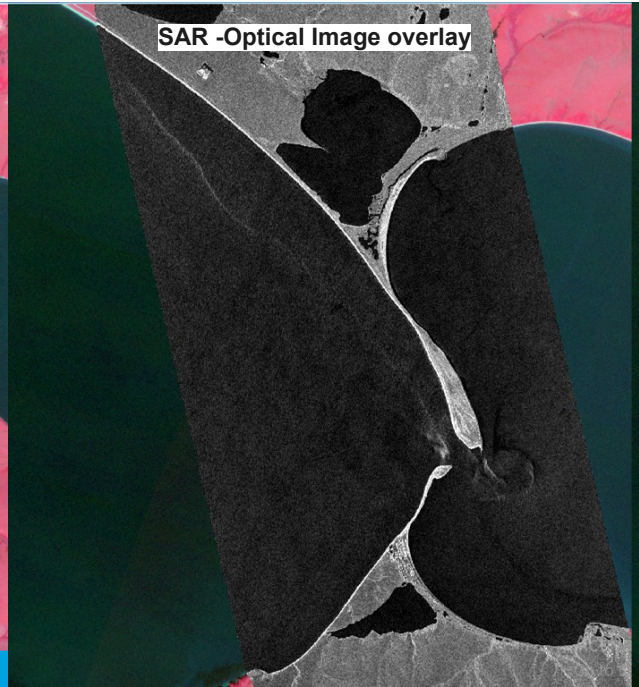


SAR - Optical Image overlay/fusion for Coastal feature Enhancement

SAR Sensor: Capella SAR (1m) ; Optical sensor: Planetscope MSI (3m)

Optical Image Acquisition date and time	23nd August 2022 (8:40 am)
SAR Image Acquisition date and time	23rd July 2022 (6:33 am)
Corresponding Tidal information	HT- 1:27 am; 3:39pm/ LT - 8:41am; 8:32pm

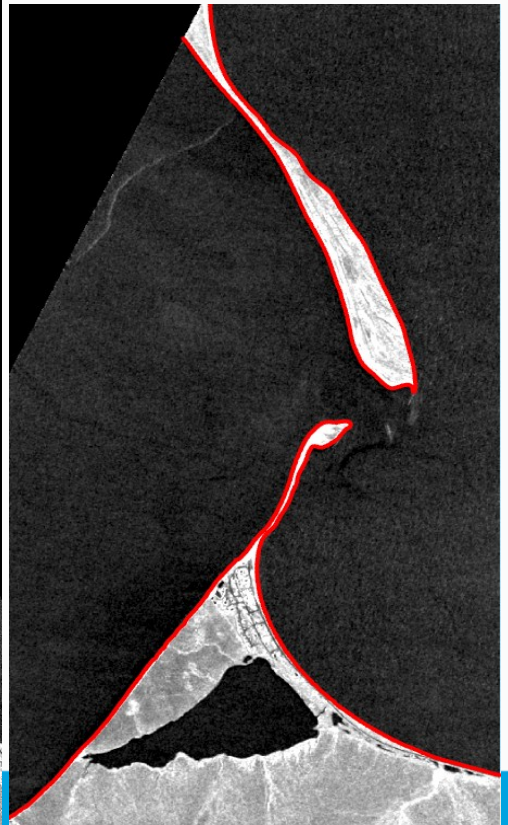
STUDY AREA:
TELLER, ALASKA



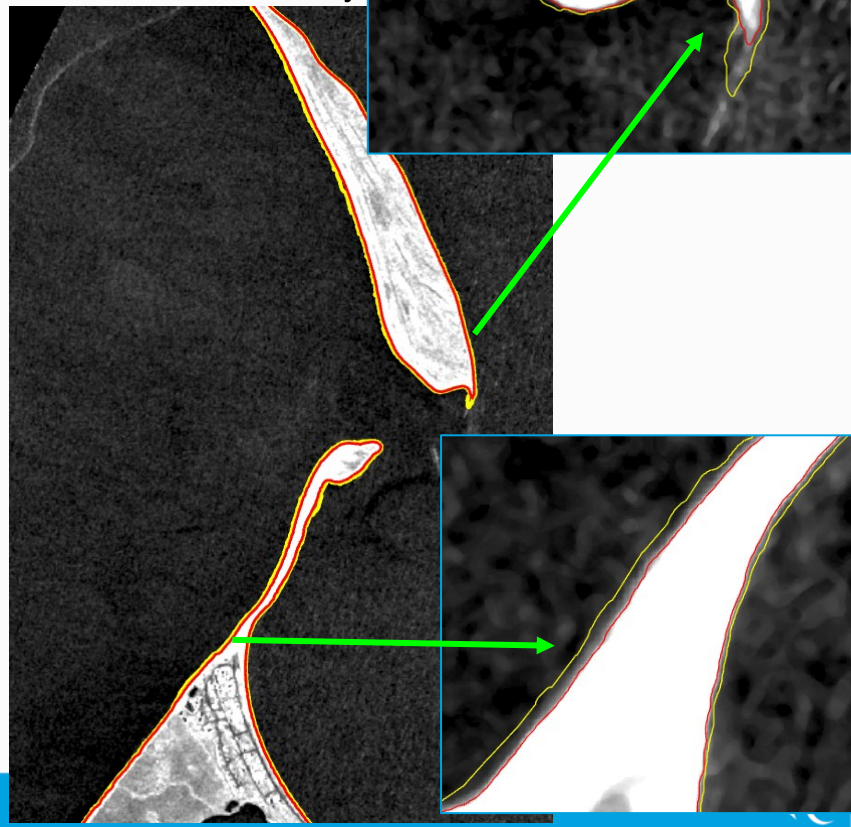
3. Teller, Alaska: *Shoreline (HTL & LTL) extraction*

Single Mean Low Tide Line
(computed from 2 LT images)

Single Mean High Tide Line
(computed from 4 HT images)

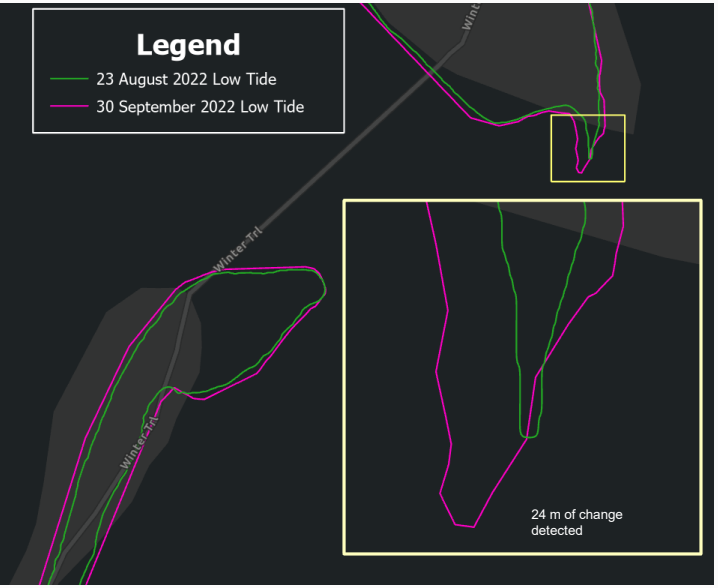


Mean LTL & HTL Overlay

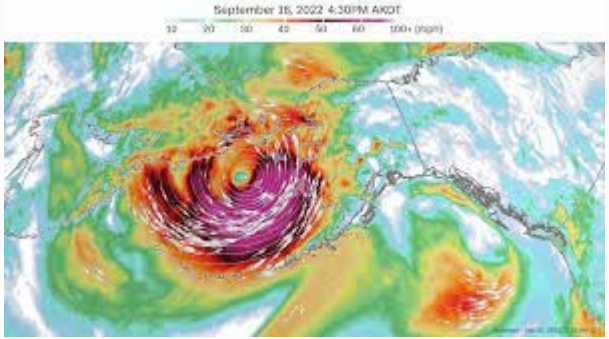


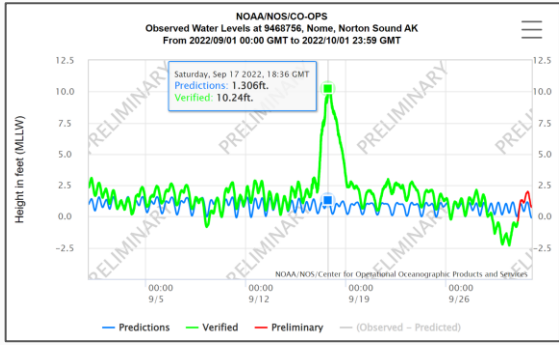
Shoreline change Pre and Post Typhoon Merbok

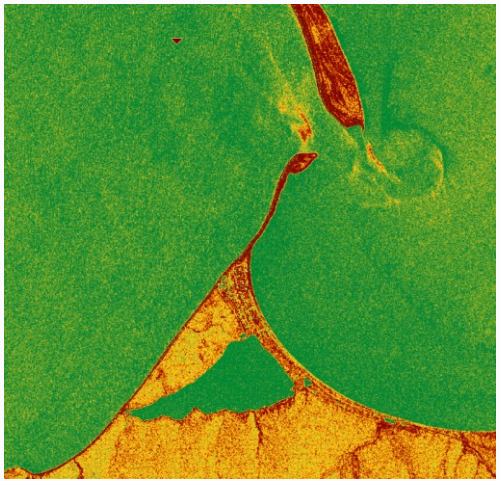
Capella SAR
- 1.5 m to 1.6 m resolution
- Accuracy of +/- 5 m



Shoreline change of 0-24 m across the low tide line



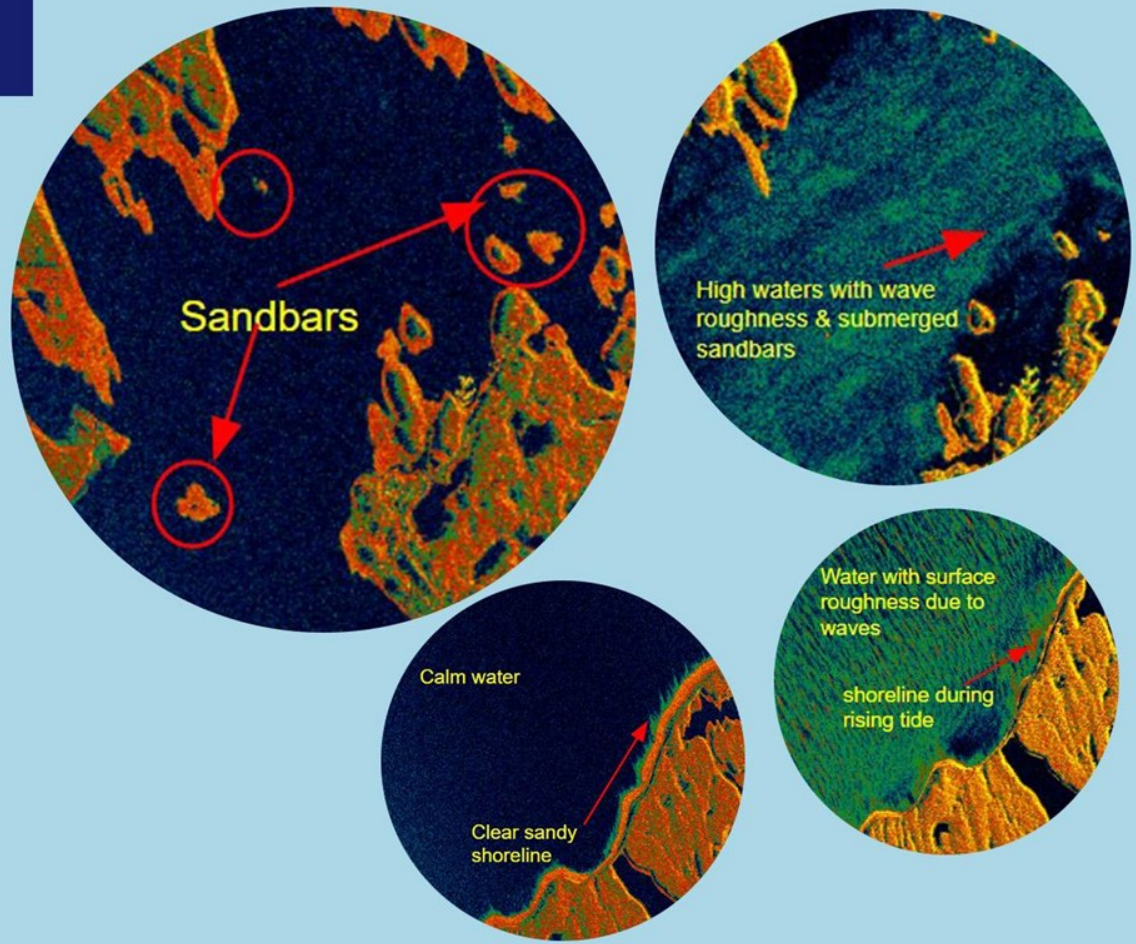




Dark brown to yellow colors depict land areas and surface roughness (high backscatter), while **tones of green** represent water, increase moisture laden areas or low backscatter regions).

Yakutat Bay

Synthetic Aperture Radar (SAR) is a powerful tool for analyzing tidal patterns due to its ability to capture high-resolution imagery regardless of weather or lighting conditions. By acquiring SAR data at different tidal stages, variations in water extent and surface roughness can be observed, allowing for the identification of high and low tide events. This capability is particularly useful in coastal zone management, habitat mapping, and flood risk assessment.

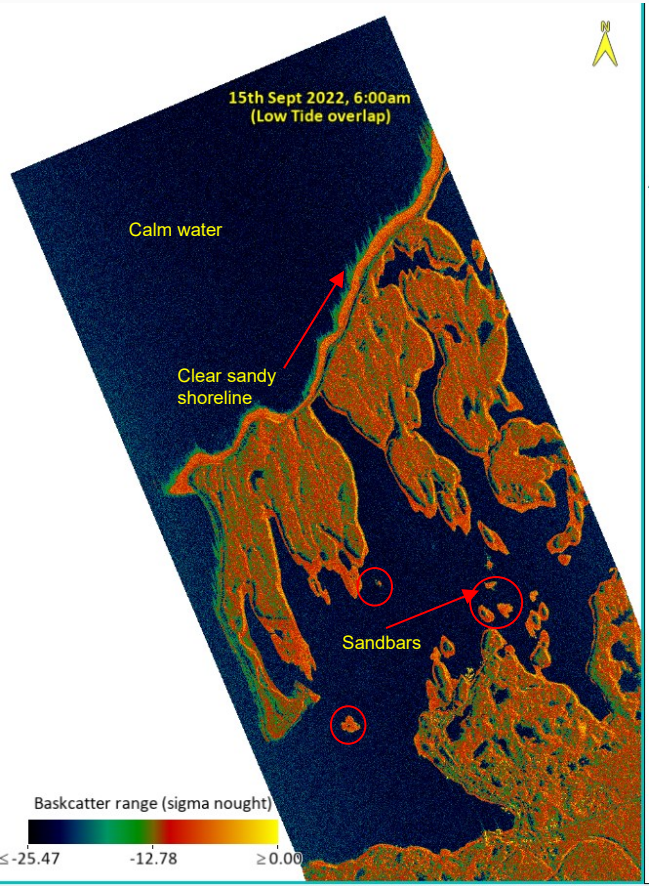


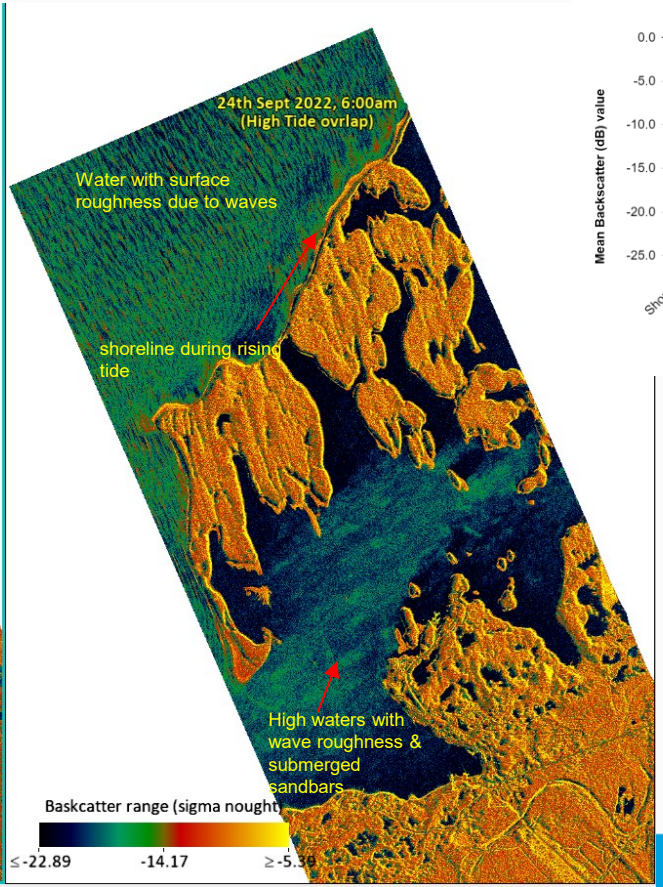
High & Low Tide Analysis

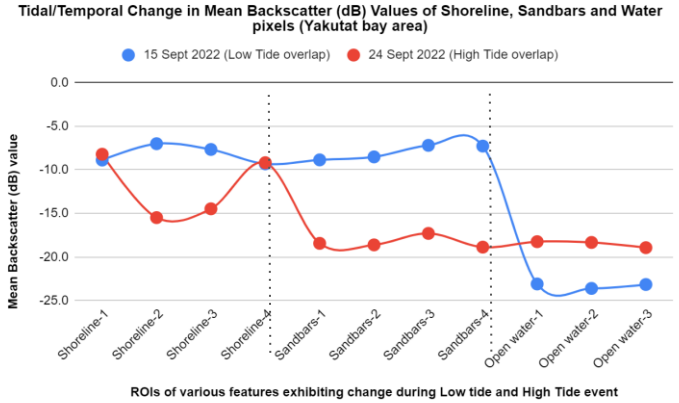
Evaluation of X-band SAR for Coastal feature identification and extraction

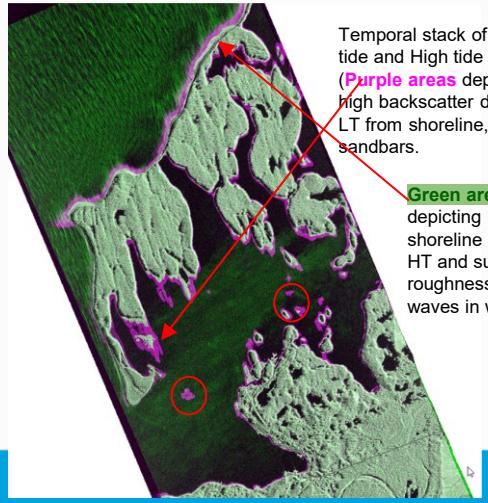
Sensor - Capella SAR ; Wavelength/Frequency- X band; Polarization- HH pol (single polarization); Imaging mode- Stripmap; Ground Spatial Resolution- 1m

STUDY AREA: YAKUTAT BAY, ALASKA





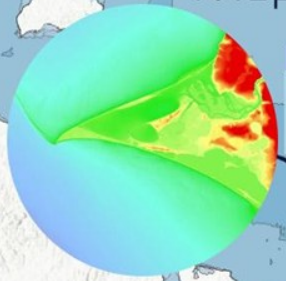




Temporal stack of Low tide and High tide image (**Purple areas** depict high backscatter during LT from shoreline, and sandbars.

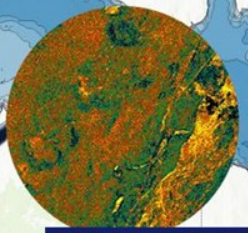
Green areas depicting shoreline during HT and surface roughness due to waves in water)

Mapping Alaska Using American Satellites



Point Hope

Seamless Topobathy Digital Elevation Model



Sagavanirktok River, Deadhorse

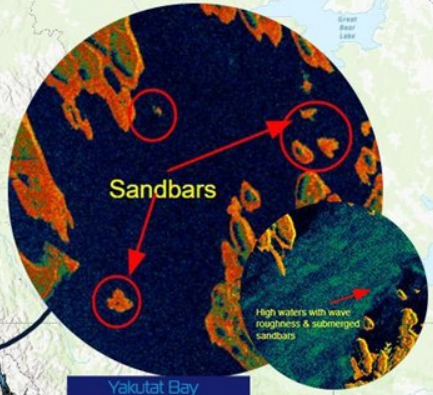
Permafrost Identification

Port Of Nome

Shoreline Extraction

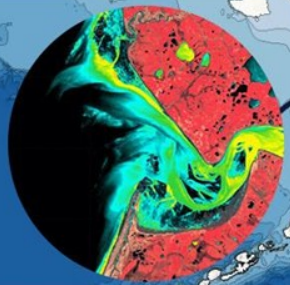
Kachemack Bay

Satellite Derived Bathymetry



Yakutat Bay

High & Low Tide Analysis



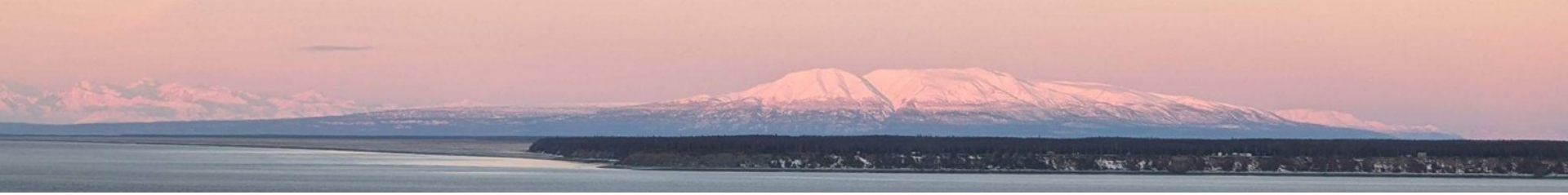
Egegik, Bristol Bay

Daily to Sub-daily Water Quality Monitoring

MAXAR TECHNOLOGIES

planet.

Capella Space



Alaska: Satellite Derived Bathymetry for the Last Frontier

ALASKA GEOSUMMIT 2025
Anchorage, Alaska
APRIL 9-11

TCARTA