2021 Alaska Coastal & Ocean Mapping Summit

The Path Forward

December 1st 2021 | Virtual

Modern Airborne Photogrammetry from a Manned Aircraft and its Applications in Alaska Coastal Science

Matt Nolan, Fairbanks Fodar

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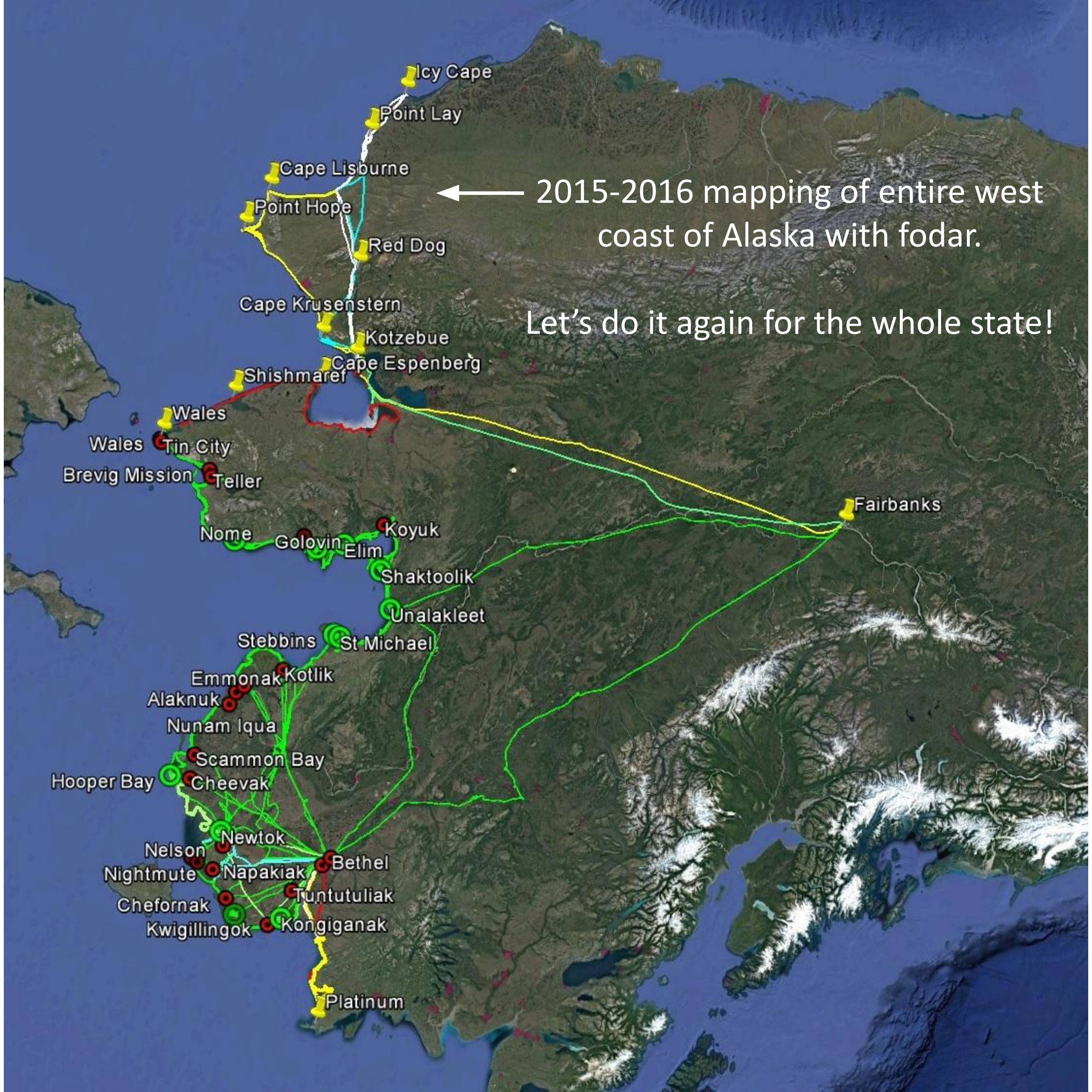
Modern Airborne Photogrammetry from a Manned Aircraft and its Applications in Alaskan Coastal Science

Dr Matt Nolan
Fairbanks Fodar
www.fairbanksfodar.com



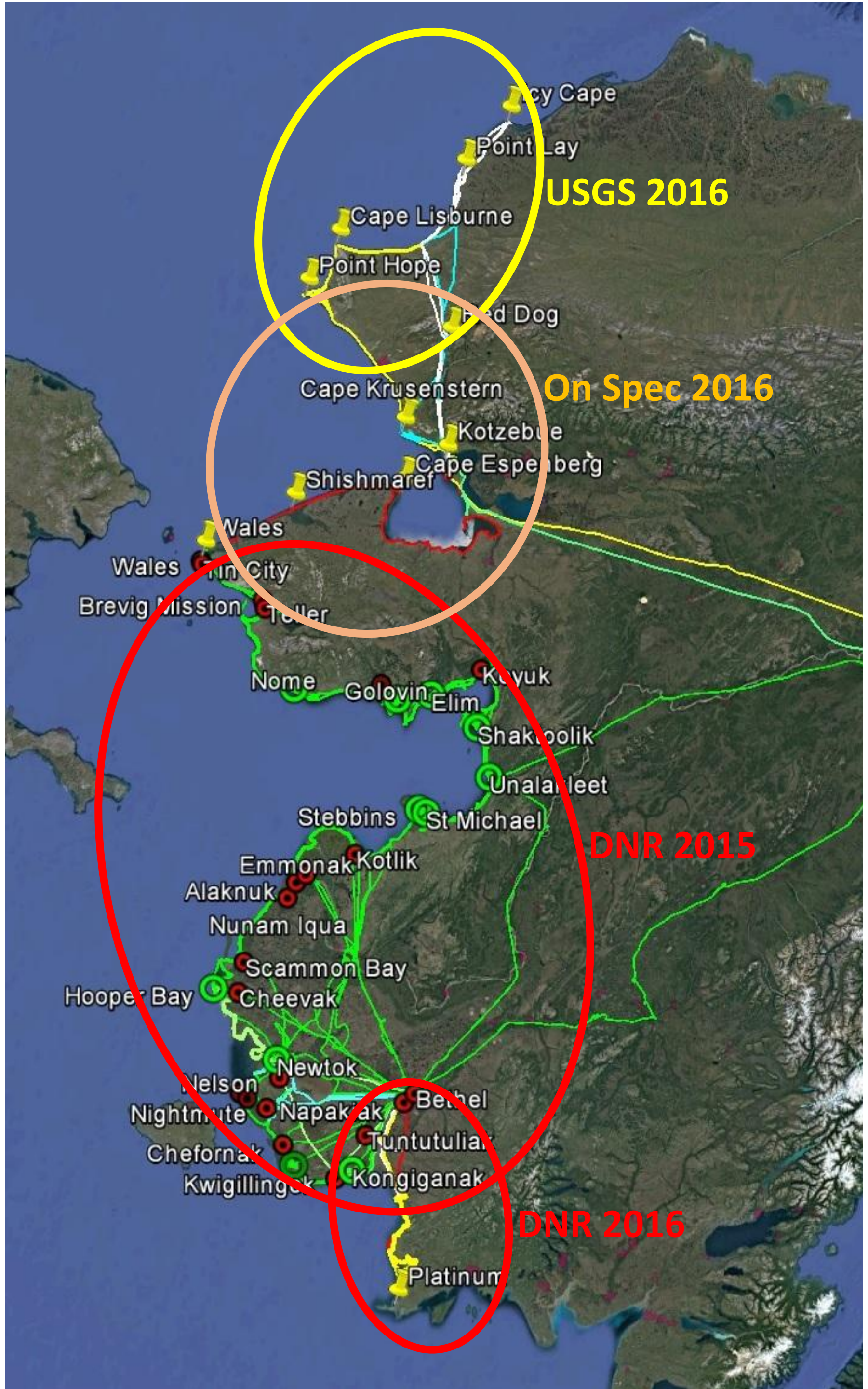
Fodar Mapping of West Coast

Coastline: About 2500 km long and 1500-3000m inland at 17 cm GSD at lowest tides
Villages: ~35 villages at 8-20 cm GSD

__DNR 2015__
Funded: 23 July 2015
Mapping began: 30 July 2015
Mapping ended: 11 September 2015 (**95%**)
Village data delivered: October- December
Final Delivery: July 2016
Initial fodar award: ~$300,000
(~100 Billion measurements)
Initial GCP surveying award: ~$300,000
(~125 GCPs and checkpoints)
Note: No GCPs were used in photogrammetric processing

Fodar precision: 8-25 cm @95%
Village checkpoints accuracy: <15 cm @95%
Coastal checkpoint accuracy: ~45 cm @95%
Best Accuracy Assessment: 8 - 15 cm

Download: https://elevation.alaska.gov/



To Learn More about Fodar: Peer-reviewed Papers and Blogs

Technology overview: https://fairbanksfodar.com/accuracy-and-precision-of-fodar-data Describes the technology and gives an overview on many of my precision/accuracy analyses with links to more info.

Mapping Snow Depth: https://tc.copernicus.org/articles/9/1445/2015/tc-9-1445-2015.pdf Best technology paper, includes assessment of precision and accuracy with comparisons to lidar and fodar and GCPs, development of snow depth mapping technique.

Coastal Studies Example: https://fairbanksfodar.com/science-in-the-1002-area See the 2018 barter island comparison to lidar in particular, ~10 cm std dev misfit and extraction of change details on the order of centimeters.

Coastal Studies Example: https://www.sciencedirect.com/science/article/pii/S0169555X19301278 Barter Island coastal erosion, aligning 4 of my maps to see centimeter-scale erosion, and comparison with 10,000 GCPs better than 20 cm at 95%.

Coastal Studies Example: https://fairbanksfodar.com/wp-content/uploads/2015/05/Kinsman_etal_2015.pdf Comparison of west coast fodar to tide gage, GCPs, and lidar measuring precision < 20 cm @95%.

Denali Mountain Topography: https://fairbanksfodar.com/the-first-fodar-map-of-denali-alaska Mapped the tallest peak in North America twice with 8 cm difference, comparisons to GCP, Ifsar, and USGS maps to validate use for high altitude glacier change.

Brooks Range Mountain Topography: https://tc.copernicus.org/articles/10/1245/2016/ Mapping 5 tallest peaks in the US Arctic 3-5 times, alignment to each other (up to +/- 4 cm) and to GPS better than 20 cm at 95% and better than lidar there overall, used as validation study for glacier volume change.

Tree Canopy Mapping: https://fairbanksfodar.com/first-results-from-2018-botswana-fodar-of-elephant-habitats We used the point cloud to study Elephant impacts on forests in Botswana through repeat mapping.

Fodar Backstory: https://fairbanksfodar.com/the-fairbanks-fodar-backstory Blogs here reveal the development history of fodar and the wide range of cryospheric targets I used for testing and validation.

Take home messages:

Fodar precision: +/- 5-30 cm @95% (smaller projects do better than larger)
Fodar Accuracy (w/o GCPs): < 0-1 m (better in mountains than flats)
Fodar Accuracy (w/ GCPs): Reduces to precision level
Change Detection: Repeat mapping can reveal changes at centimeter level in mountains or coasts.
Point Clouds: Fodar point clouds can be used to study or remove vegetation just like lidar, though more case dependent.

Just me in my 1952 Cessna 170B…

I flew about 25,000 miles and took ~200,000 photos in total

Services were few and far between…


Melting ice off the wings in fall (August)…

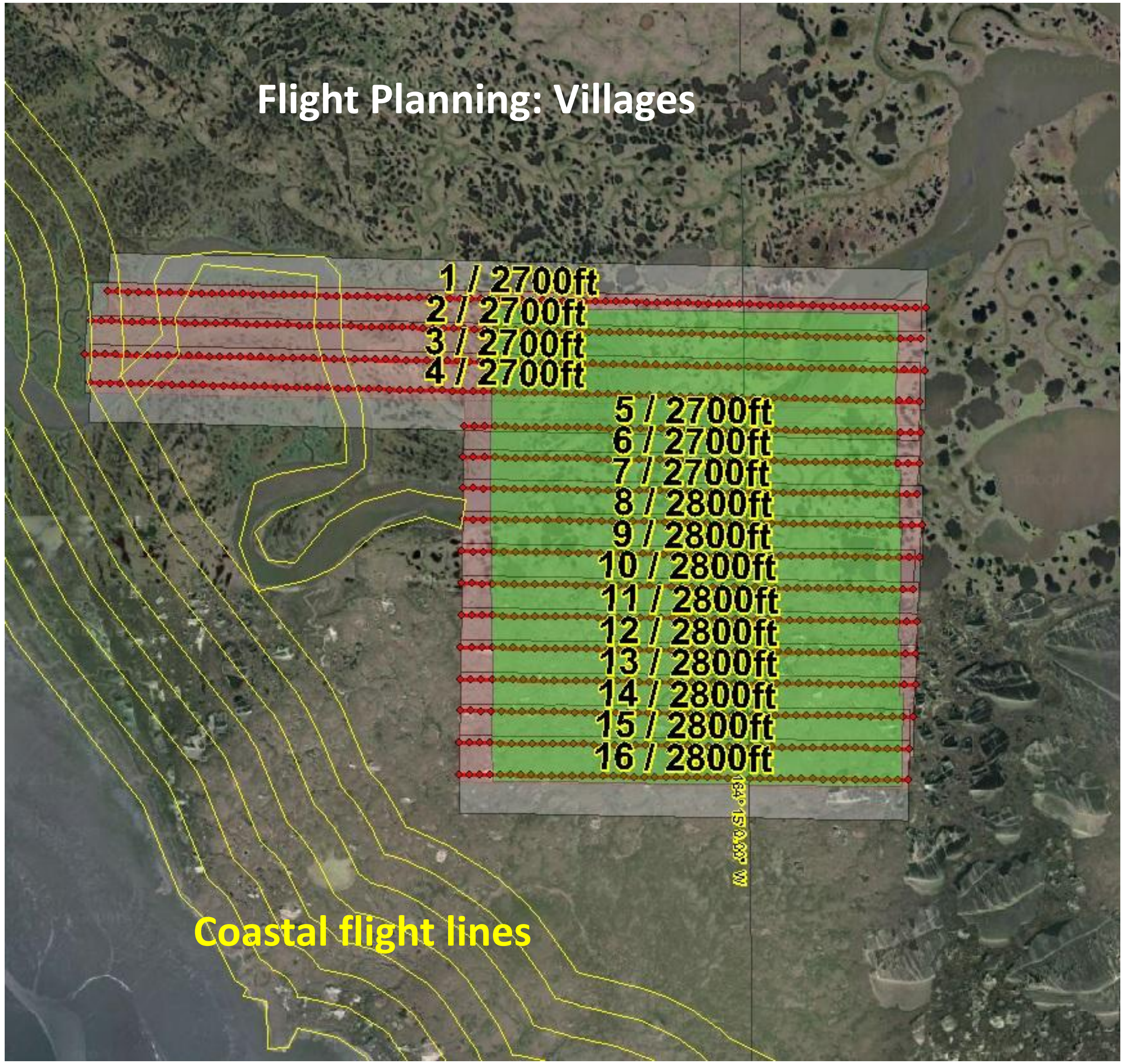

Weather was everything!


I got good at changing oil and cleaning spark plugs!

Flight Planning: Coastal Lines

I pre-planned flightlines following the coast by drawing an initial coastal vector in Google Earth and stepping back required sidelap distance 4-8 lines. Where reality deviated from Google Earth, I had to adjust by eye in the air. Following the coast rather than mapping in blocks allowed me to accomplish the project in 6 weeks rather than 6 months. Only a small, single engine plane like mine can be this maneuverable.

Flight Planning: Villages

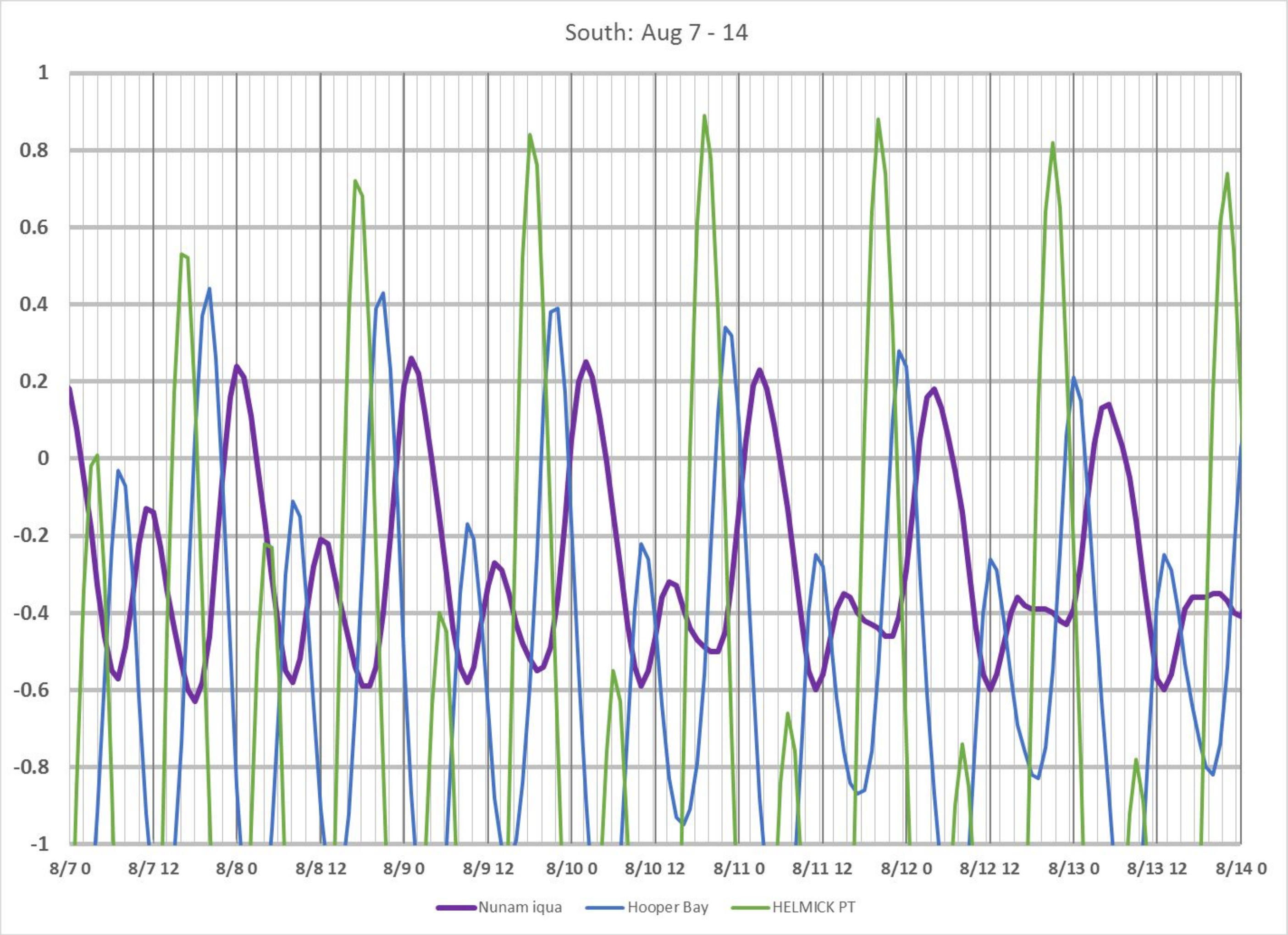


I flew the villages in regular blocks.

Here, Chefornak, is separated from the 8 coastal lines (3000 m swath), but often the villages overlapped with the coast.

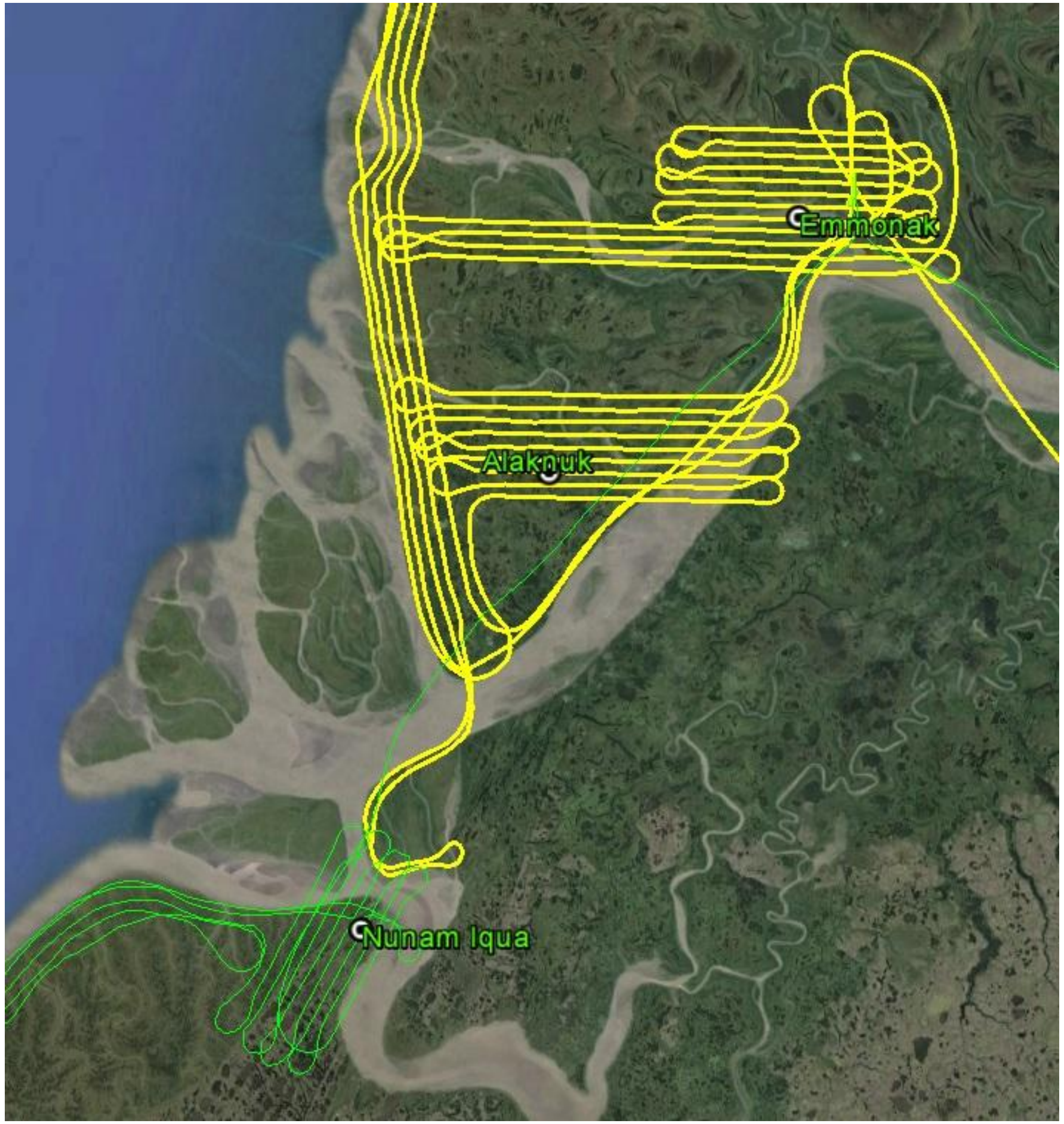
Since I flew the coast and villages separately, it allowed me to compare the two data sets for validation of precision.

Flight Planning: Tide Predictions



I used NOAA's Co-Ops to plot tide predictions along entire coast for 2 months and took hard copies like these into the field to ensure I was mapping at the lowest possible tides. The predictions worked great!

Examples of actual flight lines from two different days (yellow and green).



Whenever I was commuting past an area I had already mapped, I would add additional lines, just because I could.

This seemed like a good idea at the time, but I believe merging data from different days like this led some parts of the final product to have reduced accuracy and precision, as described later.

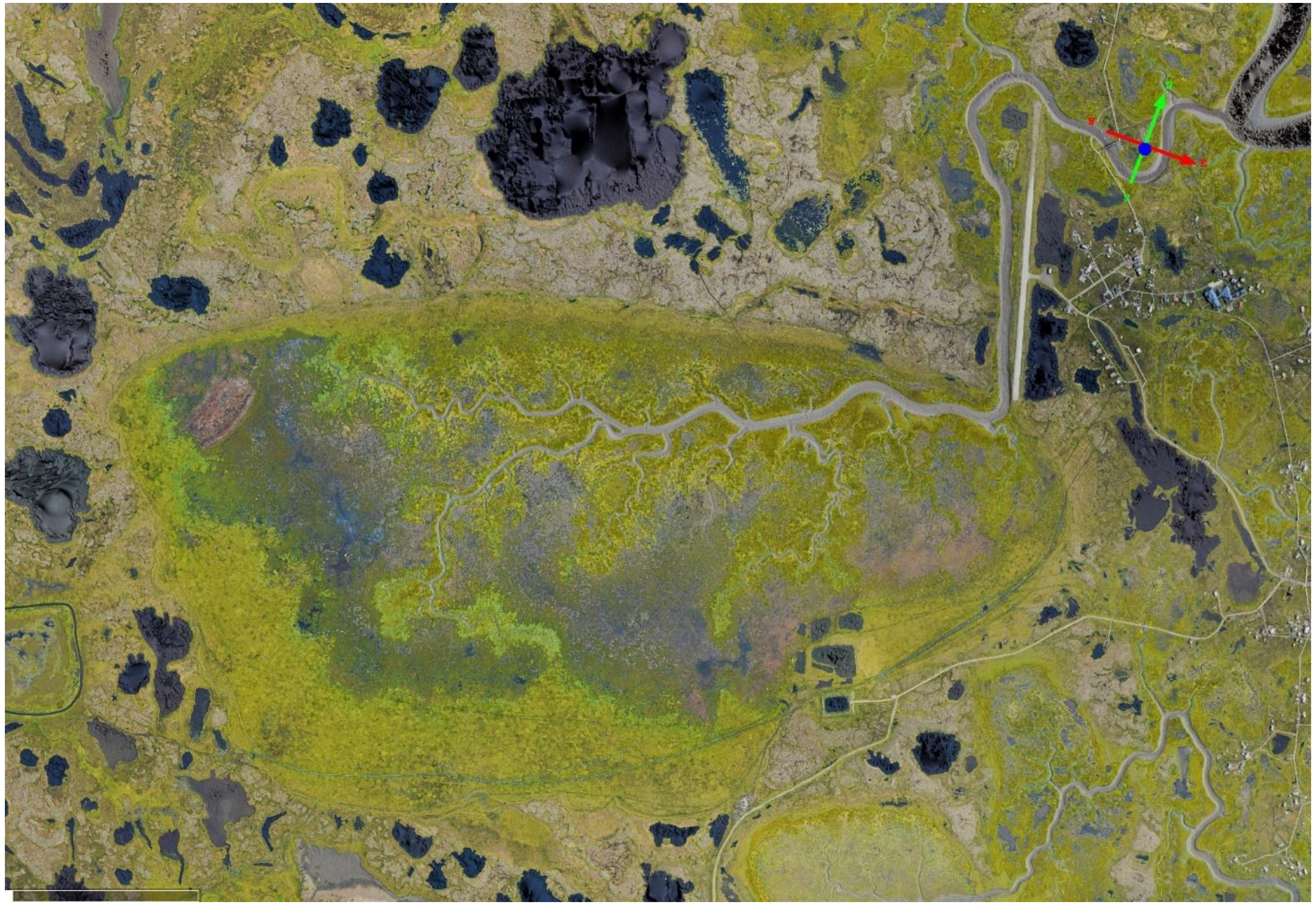
Fortunately these data can be reprocessed and new acquisitions will be unaffected.

West Side Story

I blogged continuously throughout the acquisitions..

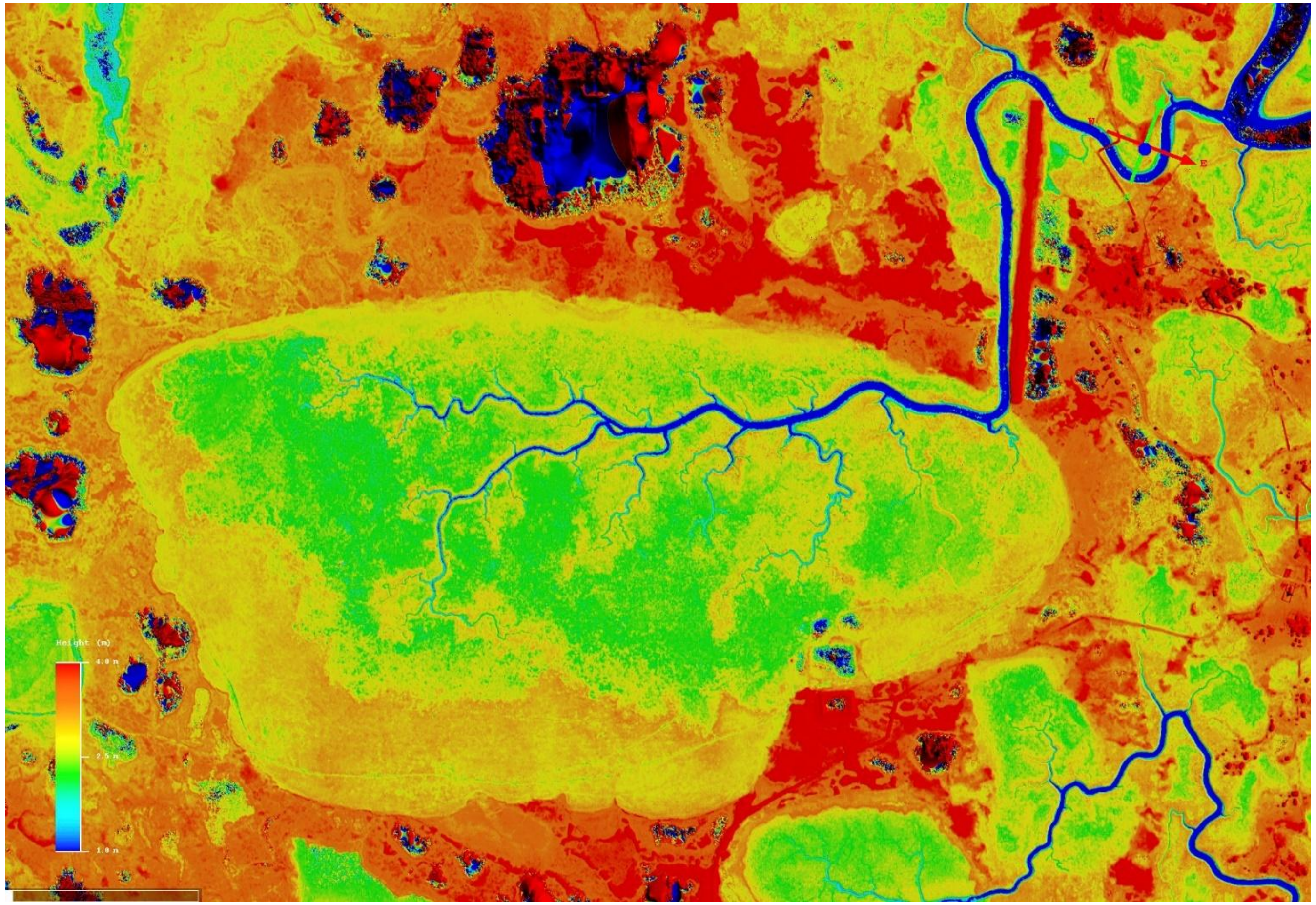
30-Jul-15	http://fairbanksfodar.com/success-in-unalakleet-again
5-Aug-15	http://fairbanksfodar.com/a-big-day-in-norton-sound
6-Aug-15	http://fairbanksfodar.com/coast-of-eastern-norton-sound-complete
12-Aug-15	http://fairbanksfodar.com/a-bit-better-weather-in-bethel
13-Aug-15	http://fairbanksfodar.com/a-happy-day-in-hooper-bay
14-Aug-15	http://fairbanksfodar.com/mapping-the-dash
19-Aug-15	http://fairbanksfodar.com/tiptoeing-over-tuntutuliak
21-Aug-15	http://fairbanksfodar.com/two-one-charlie-vs-the-toxic-avenger
23-Aug-15	http://fairbanksfodar.com/theres-no-place-like-nome
27-Aug-15	http://fairbanksfodar.com/wales-russians-and-snow-oh-my
28-Aug-15	http://fairbanksfodar.com/saving-the-wales
29-Aug-15	http://fairbanksfodar.com/the-bombs-of-st-marys
1-Sep-15	http://fairbanksfodar.com/mapping-the-golden-pixel
6-Sep-15	http://fairbanksfodar.com/west-coast-villages-complete
9-Sep-15	http://fairbanksfodar.com/a-mile-wide-and-a-micron-deep-mapping-the-coastline-from-wales-to-bethel
1-May-16	http://fairbanksfodar.com/eek
4-May-16	http://fairbanksfodar.com/goodnews-sort-of
5-May-16	http://fairbanksfodar.com/more-goodnews
7-May-16	http://fairbanksfodar.com/not-goodnews-great-news
15-Sep-16	https://fairbanksfodar.com/how-the-west-was-won

Sample Results: Orthoimage



This orthomosaic is cropped out of the entire coast and is probably composed of a few hundred photos, yet no seam lines or visual artifacts are apparent.

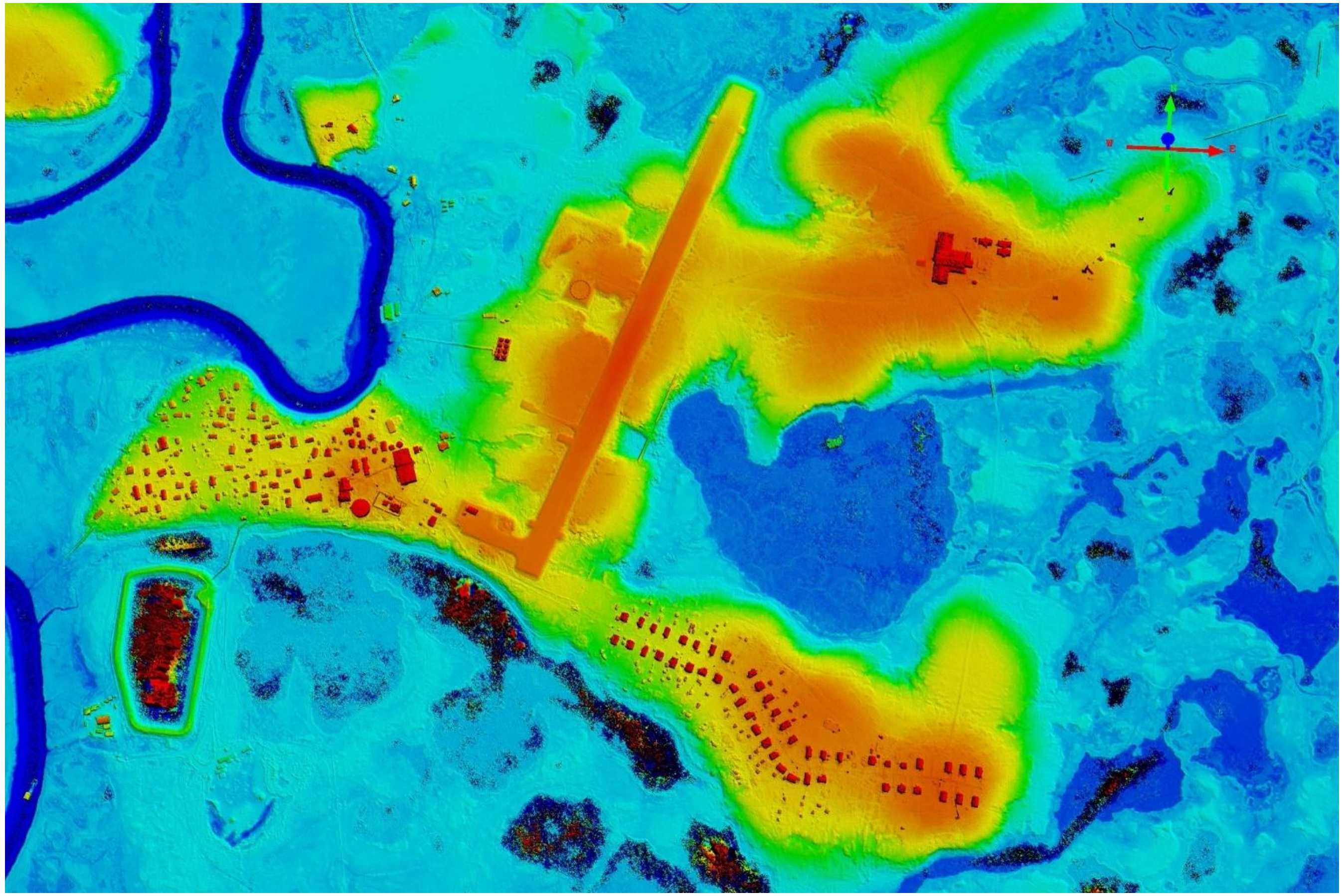
Sample Results: DEM



Colors represent topography; eg, green to yellow ~10 cm.
Note the absence of any visible artifacts even at the centimeter level and the plethora of subtle natural detail at that level.

Sample Results: Orthomosaic

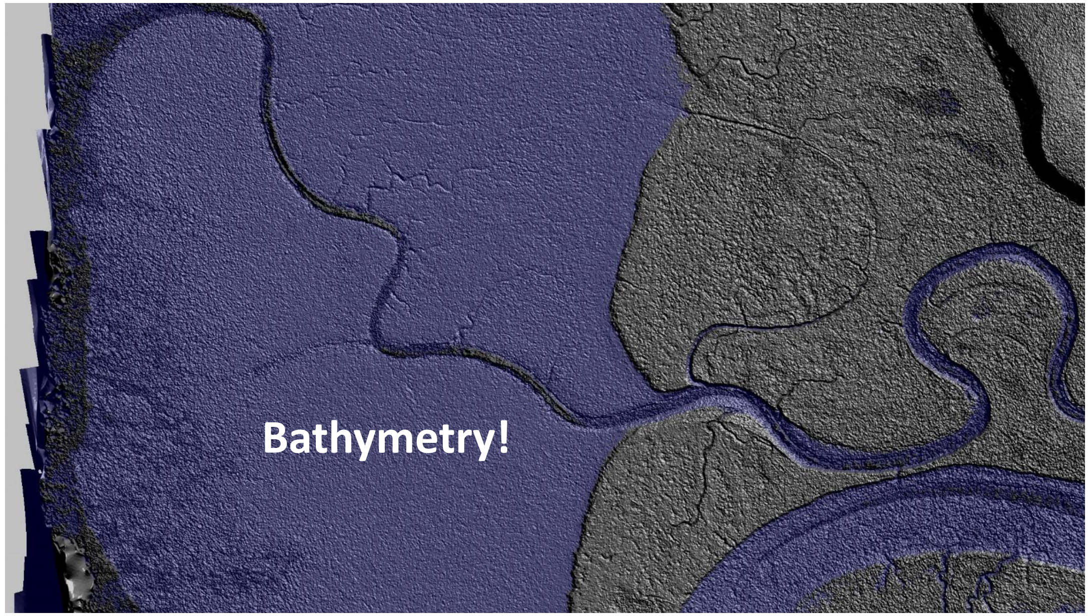
Sample Results: DEM

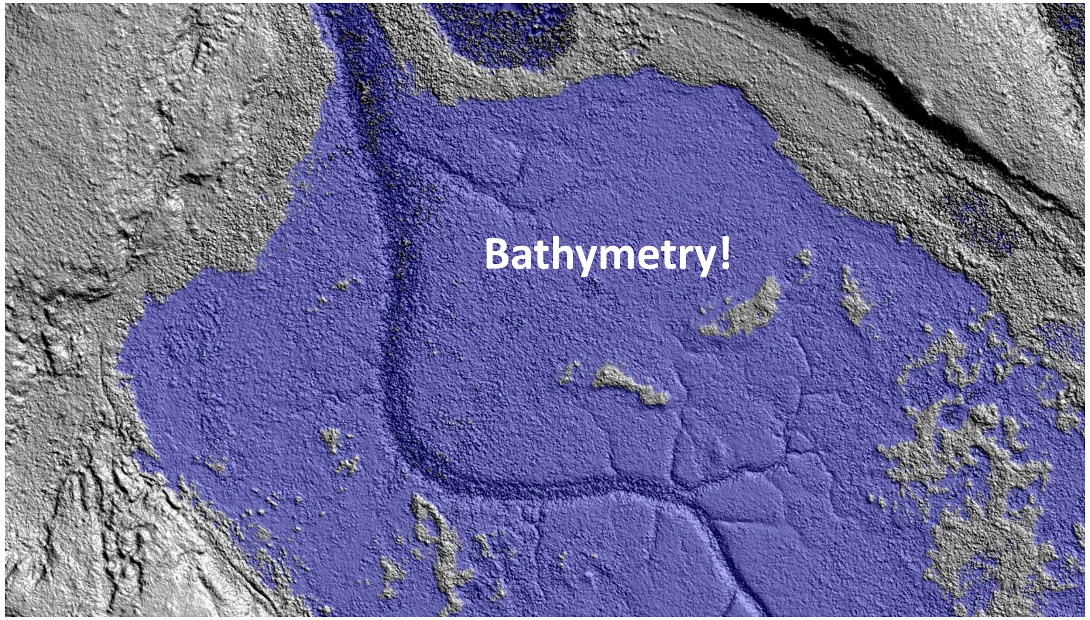


Notice there are no warps, cups, or tilts in the data, as seen in the subtle shades of blue in the flats. You won't find any such artifacts anywhere within these data.

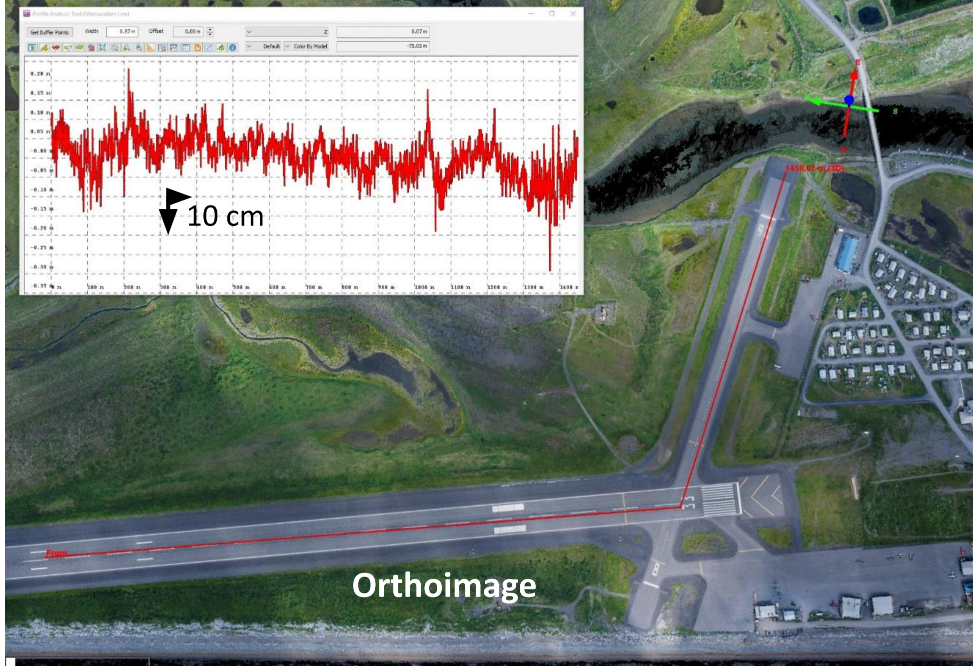
Sample Results: Low Tide Bathymetry of Mud Flats

Sample Results: Low Tide Bathymetry of Mud Flats





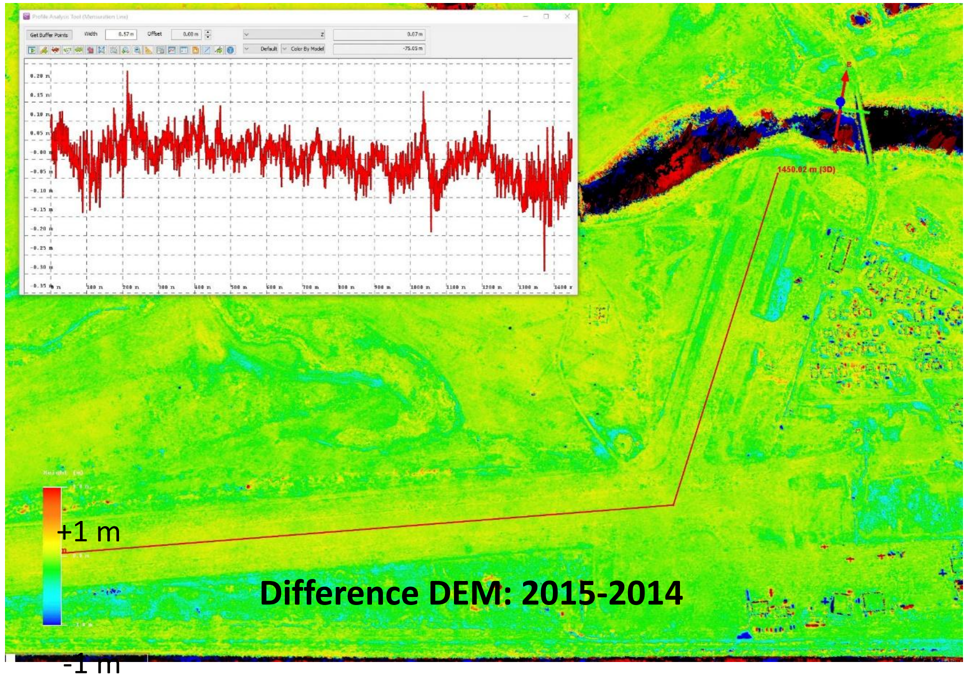
I believe that I can also measure bathymetry through water photogrammetrically, as long as the photos see the bottom, but this would take a development effort.



The Unalakleet airport: 2014 to 2015 comparison.

I mapped the village in 2014 as part of a pilot project, which led to the full project in 2015.

Top: Once I mapped it again in 2015, I compared them. Here the red line on the runway is the profile at left, which shows **95% of difference is within +/- 10 cm** (that is, standard deviation <5 cm).

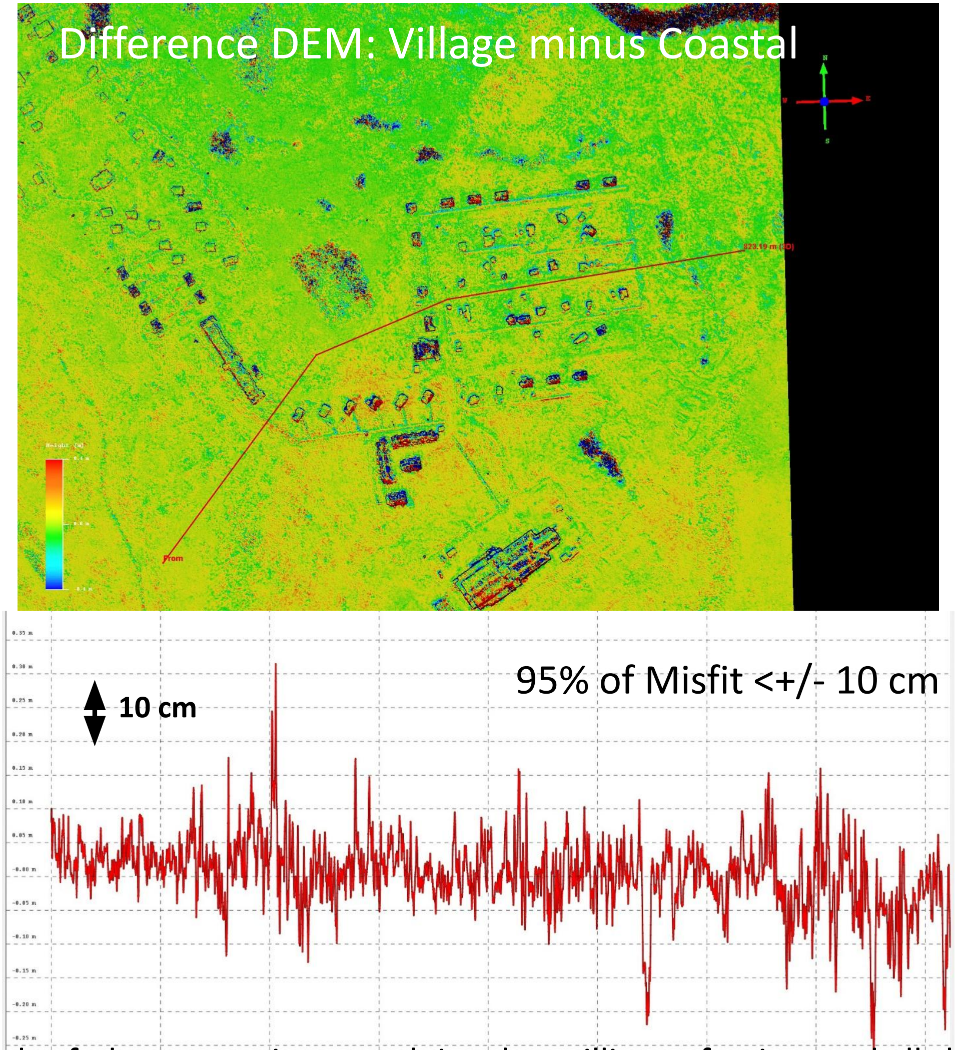


Bottom: A difference DEM, colorstretch +/- 1 m. **Here the green-yellow transition is no change, +/- 10cm**. The trend in runway slopes (~10 cm) and the variations within the runways (up to 15 cm) could be real (frost heave/consolidation) or spatially correlated noise. Examining the difference image in detail, at least some of the variations seem real and unlikely to be noise.

Conclusion: Fodar is capable of **amazing** precision.

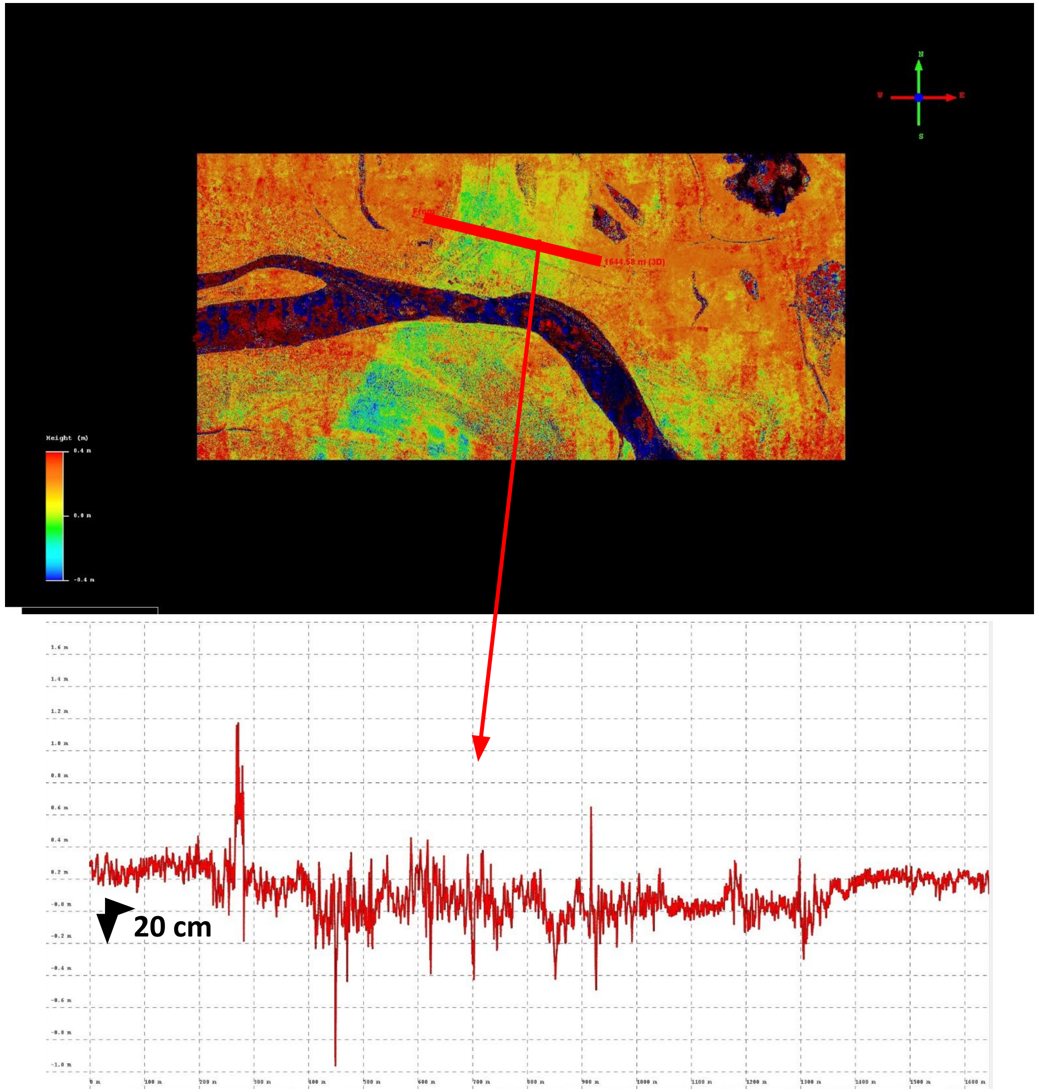
Example Precision Validation: Hooper Bay

(see lots more of the same in the final report)



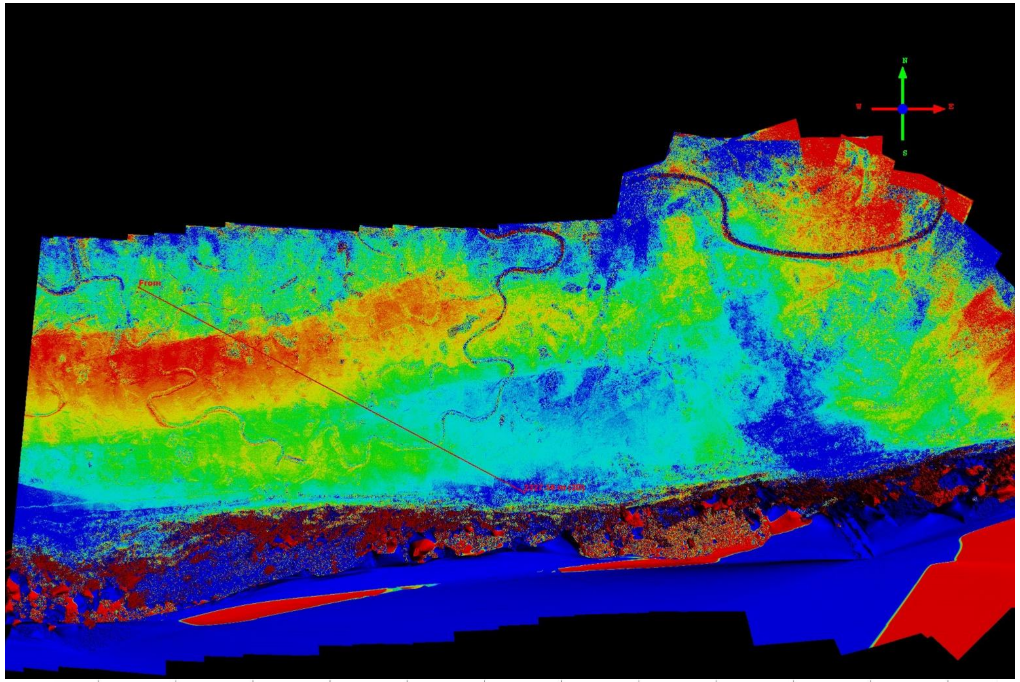
Note that these fodar-fodar comparisons each involve millions of points and all show basically the same thing.

Example Precision Validation: Emmonak



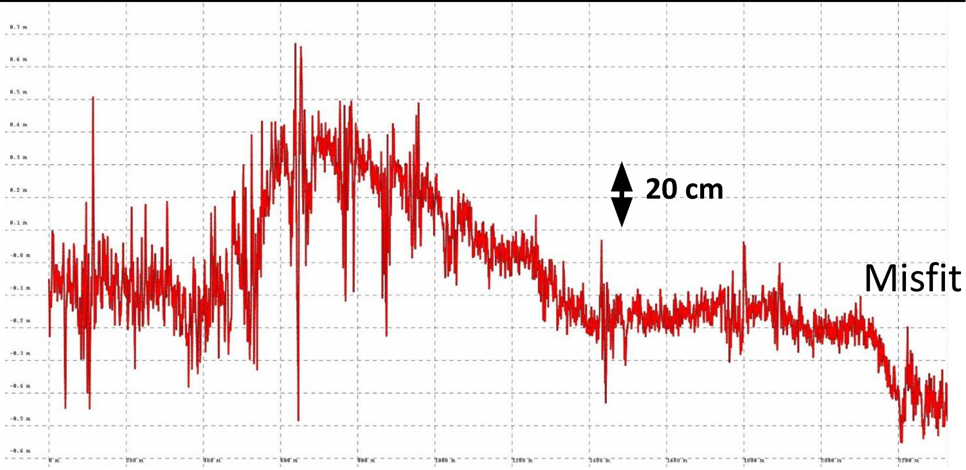
Example of a single flight line being slightly misplaced, leading to a 20 cm systematic error.

Example Precision Validation: Endlap of Coastal Blocks



A single flight line slightly misplaced at the endlap of two blocks showing +/-25 cm offset.

Most of this type of noise did not end up in the final delivery as the endlaps get cropped, but it's this type of noise that improved processing techniques would eliminate.



Misfit: +/- 5 cm at 95%

Example Horizontal Precision Validation: Toksook

Flicker with the next image to assess spatial offsets between the two mosaics.

The horizontal accuracy here is essentially perfect.

Example Horizontal Precision Validation: Toksook

Flicker with the next image to assess spatial offsets between the two mosaics.

Example Horizontal Precision Validation: Endlap Between Blocks

Flicker with the next image to assess spatial offsets between the two mosaics.

Example Horizontal Precision Validation: Endlap Between Blocks

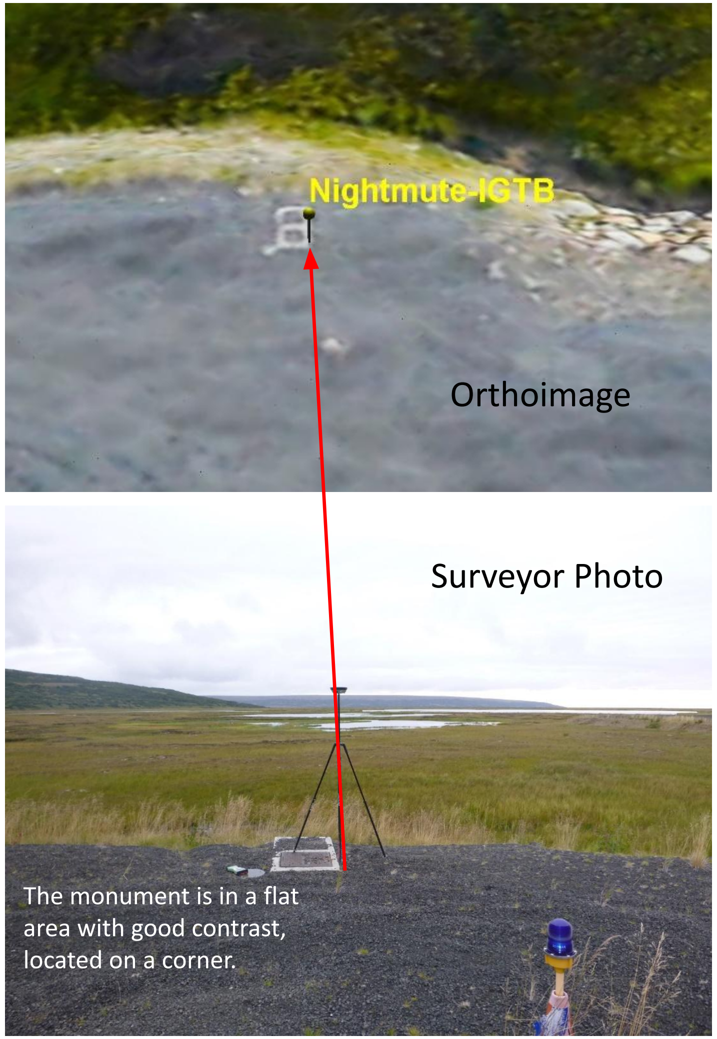
Flicker with the next image to assess spatial offsets between the two mosaics.

Example Checkpoint Accuracy Validation

These photo-identifiable checkpoints are fine, but probably less than half were this good.
You can find comparisons like this for every checkpoint in the final report.

Nightmute

Horizontal accuracy: < 1 pixel
Vertical misfit: 7 cm

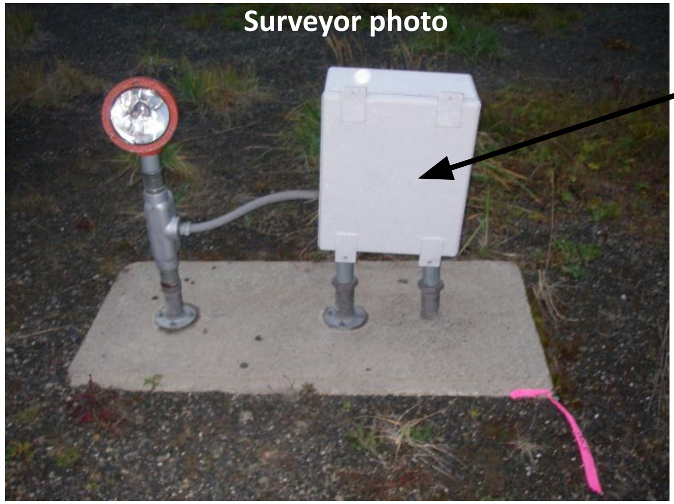


Toksook Bay

Horizontal accuracy: < 1 pixel
Vertical misfit: 13 cm

Example Checkpoint Accuracy Validation: Shaktoolik

These photo-identifiable checkpoints are mediocre at best and certainly skew the vertical accuracy assessment.
Maybe a quarter were like this.
Note these comparisons were made against the DEM, not the point cloud,
which I believe is a better metric for end-user accuracy even though the misfits are worse.



Utility box introduces noise to fodar elevation comparison with checkpoint.

Vertical misfit: -29 cm

Spatial biasing of checkpoint elevation caused by abrupt changes in topography

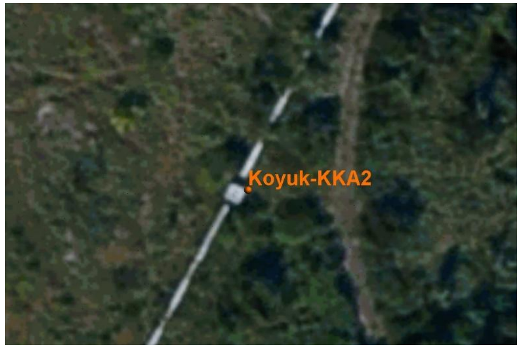
Platform is higher than surrounding terrain.

Vertical misfit: -12 cm

Example Checkpoint Accuracy Validation: Shaktoolik

These photo-identifiable checkpoints suck for vertical. A lot were like this.

Koyuk



Utilidor is 0.84 m above ground (!!!)

Vertical misfit: 80 cm

Kwigillingok

Point is at corner of boardwalk near sloping ground next to 30 cm high grass.

Vertical misfit: 0.420 m

My Favorite Accuracy Assessment:

Comparison of MHW Vectors Derived from Orthoimage and DEM

The mean high water line derived from fodar DEM was nearly identical to line manually digitized using orthoimage, but took a fraction of the time to produce.

Lateral distance between the lines was never more than 4 m, and often within 1 m. Vertical offsets between the two had a 14 cm standard deviation.

Both vectors were greatly superior to the line derived from USGS maps of 50 years ago.

Comparison to the published MHW tidal datum had only an 8 cm mean misfit (well within the noise of wave runup)!

To me, this is the only accuracy that matters for delineation of the MHW vector, which was what drove this project.

Kinsman, Nicole, ANN GIBBS, and Matt Nolan. "EVALUATION OF VECTOR COASTLINE FEATURES EXTRACTED FROM 'STRUCTURE FROM MOTION'-DERIVED ELEVATION DATA." *The Proceedings of the Coastal Sediments 2015*. 2015.

Note: I am not a Professional Land Surveyor and am not holding myself out as one: all data provided for use at your own risk for research purposes only!

Extra slides for discussion or if time permits

Summary of 2015 Validation Data

We evaluated precision and accuracy in several ways:

Comparisons of fodar to fodar (all n > 1 million (!!!))

- **Visual inspection:** Awesome!
- **2014-2015 data:** Random vert. noise <10 cm @ 95%, Spatially coherent noise <25 cm @ 95%
- **Village to Coastal DEMs:** Horizontal <1-3 pixels, random noise < 10 cm @95%
- **Endlaps between coastal swaths:** Random <10 cm @ 95%, Spatially coherent <25 cm @ 95%
- **Orthoimage to DEM comparisons:** < ~1m horizontally @95(?)%, max 4 m horizonal offset
- **MHW DEM-derived elevation vs MHW tidal datum**: 8 cm (!!!) accuracy with no GCPs used (!!!)

Comparisons of fodar to GCPs (all n<100 (!!!))

- **Villages**
  - **Horizontal:** Perfect!
  - **Vertical:** Precision <10 cm @ 95%, Accuracy <10 cm mean
- **Coastal**
  - **Horizontal:** 1-3 pixels
  - **Vertical:** Precision ~45 cm @95%, Accuracy 14 cm mean

Take home messages:

- Fodar precision (repeatability): random noise < 10 cm, spatially coherent noise <25 cm
- Fodar accuracy: No GCPs < 1 m, w/ GCPs ~same as precision
- Fodar-to-fodar or fodar-to-lidar comparisons always indicate that fodar is more precise than fodar-to-GCPs (and there are good reasons for this)

Mapping Coastal Erosion with Fodar

(and validating its accuracy)

Geomorphology 336 (2019) 152–164

Contents lists available at ScienceDirect

Geomorphology

ELSEVIER

journal homepage: www.elsevier.com/locate/geomorph

Assessing patterns of annual change to permafrost bluffs along the North Slope coast of Alaska using high-resolution imagery and elevation models

Ann E. Gibbs [a,*], Matt Nolan [b], Bruce M. Richmond [a], Alexander G. Snyder [a], Li H. Erikson [a]

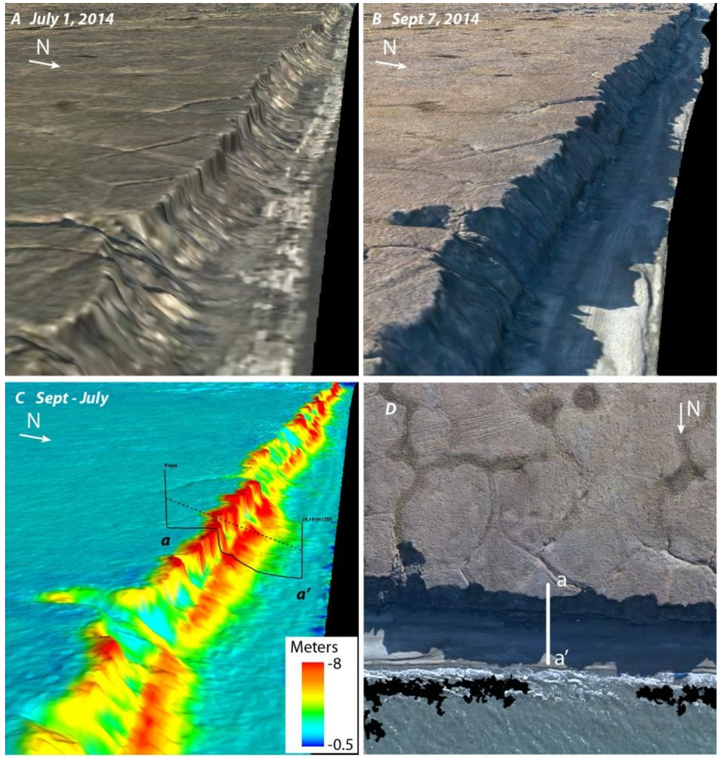
[a] U.S. Geological Survey, Pacific Coastal and Marine Science Center, 2885 Mission Street, Santa Cruz, CA 95060, USA
[b] Fairbanks Fodar, P.O. Box 82416, Fairbanks, AK 99708, USA

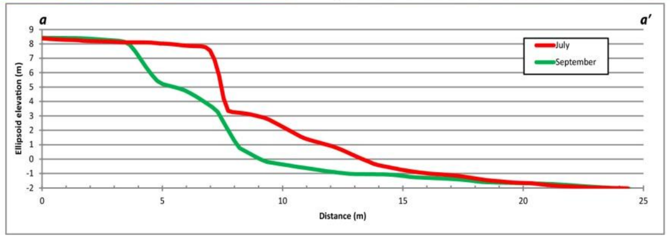
Table 2. Summary statistics for DSM versus GPS elevations for surveyed locations.

Image Date	n	RMSEz	Max offset (m)	Mean offset (m)	StDev
Photo-identifiable survey monuments					
Jul-14	7	0.11	−0.21	−0.08	0.09
Sep-14	7	0.09	0.15	0.07	0.06
Jul-15	7	0.11	−0.13	0.04	0.11
Stable ground features					
Jul-14	1182	0.04	−0.12	−0.02	0.03
Sep-14	1182	0.03	0.08	−0.02	0.02
Jul-15	1182	0.03	−0.08	−0.02	0.02
9 cross-bluff transects					
Jul-14	9818	0.09	0.27	0.00	0.09
Sep-14	9818	0.13	0.35	−0.08	0.10
Jul-15	9818	0.21	0.12	−0.19	0.09
All points					
Jul-14	11,007	0.08	0.27	0.00	0.08
Sep-14	11,007	0.12	0.35	−0.07	0.10
Jul-15	11,007	0.20	0.15	−0.17	0.10

Surveyed Monuments (in white X's) 3x worse

11,000 (!!!) Checkpoints



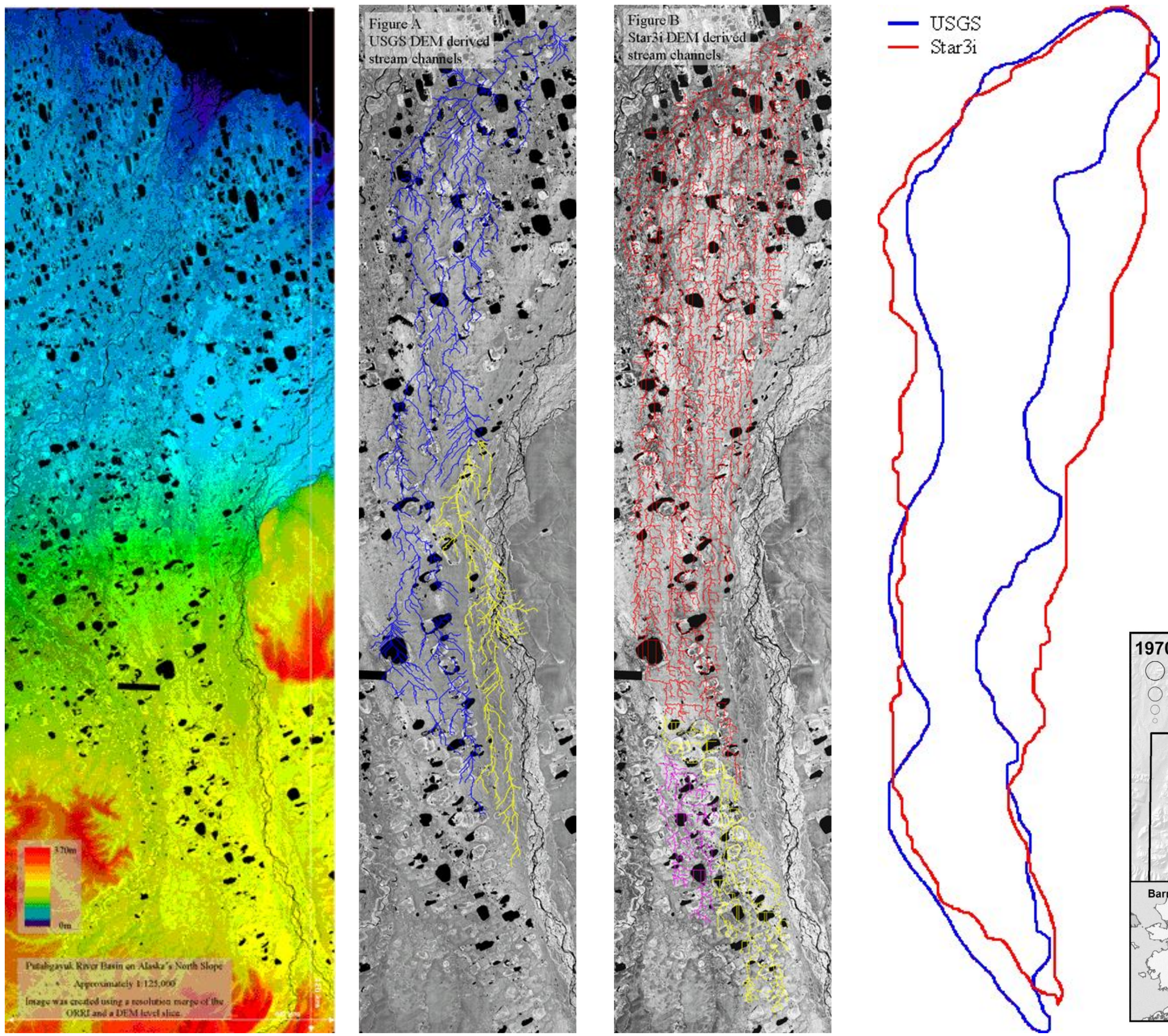


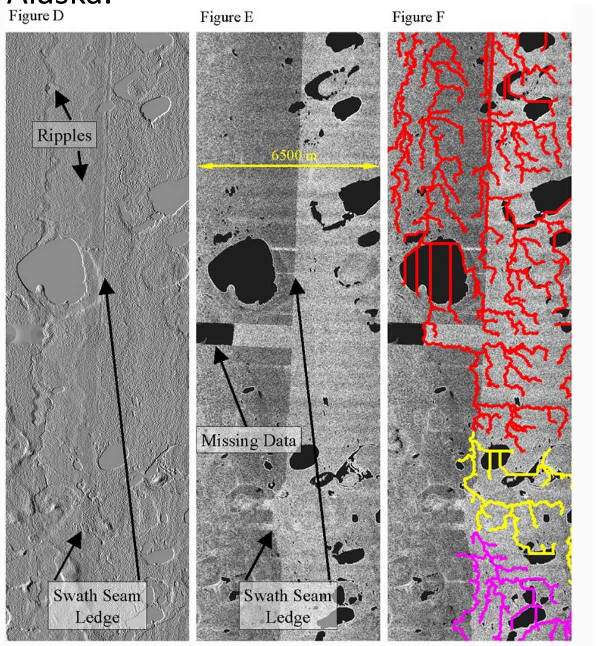
Take homes:

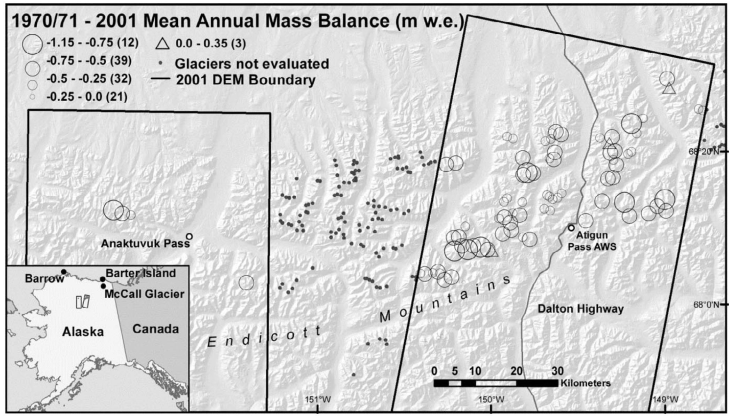
1) Just like we almost always find, comparison to GCP monuments is 2-3x worse than comparison to natural features
2) Repeat fodar can elucidate process mechanisms from the tiniest changes in topography, just like we always find.

Professional Background 1990s-2000s:
New Mapping Technique to Aid Hydrology and Glacier Studies

Exploring a new commercial topographic mapping technology (Intermap's Star3i insar) in studying permafrost hydrology and glaciers in Alaska.







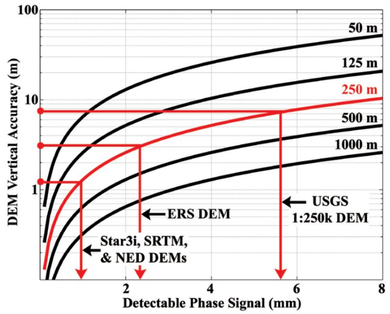
Nolan, M., and P. Prokein. "Evaluation of a new DEM of the Putuligayuk watershed for Arctic hydrological applications." *Permafrost: Proceedings of the 8th International Permafrost Conference*. 2003.

Geck, Jason, Regine Hock, and Matt Nolan. "Geodetic mass balance of glaciers in the Central Brooks Range, Alaska, USA, from 1970 to 2001." *Arctic, antarctic, and alpine research* 45.1 (2013): 29-38.

Professional Background 2000s:
New Topographic Maps Aid in Soil Moisture Measurement

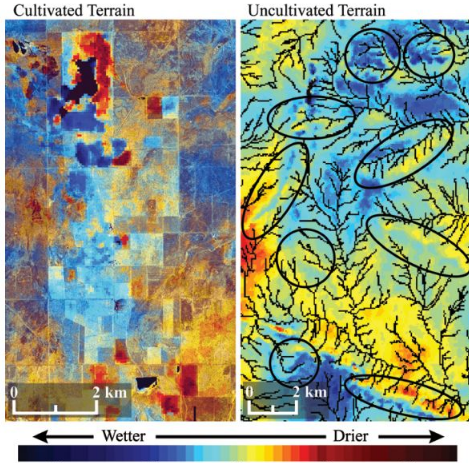
Developing a new method to measure soil moisture by combining Star3i DEMs with spaceborne insar

Theory



Nolan, Matt, and Dennis R. Fatland. "New DEMs may stimulate significant advancements in remote sensing of soil moisture." *Eos, Transactions American Geophysical Union* 84.25 (2003): 233-237.

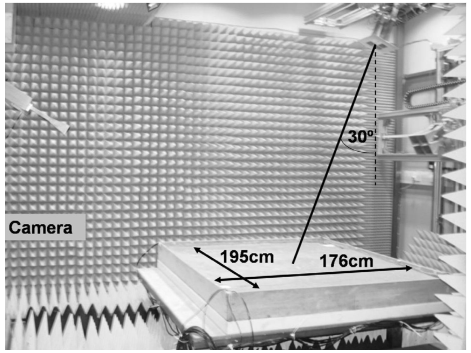
Satellite Measurements



Nolan, Matt, and Dennis R. Fatland. "Penetration depth as a DInSAR observable and proxy for soil moisture." *IEEE Transactions on Geoscience and Remote Sensing* 41.3 (2003): 532-537.

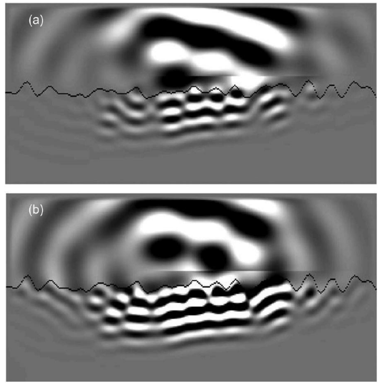
Nolan, Matt, Dennis R. Fatland, and Larry Hinzman. "DInSAR measurement of soil moisture." *IEEE transactions on geoscience and remote sensing* 41.12 (2003): 2802-2813..

Lab insar measurements of a sandbox



Morrison, Keith, et al. "Laboratory measurement of the DInSAR response to spatiotemporal variations in soil moisture." *IEEE transactions on geoscience and remote sensing* 49.10 (2011): 3815-3823.

Numerical Modeling



Rabus, Bernhard, Hans Wehn, and Matt Nolan. "The importance of soil moisture and soil structure for InSAR phase and backscatter, as determined by FDTD modeling." IEEE transactions on geoscience and remote sensing 48.5 (2010): 2421-2429.

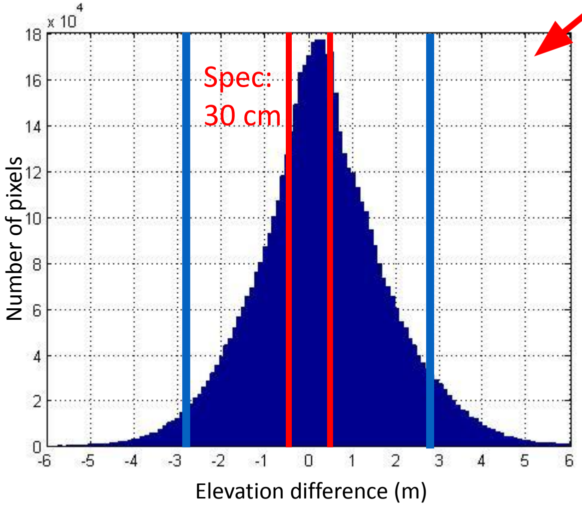
Now: Our own airborne insar mounted on small aircraft

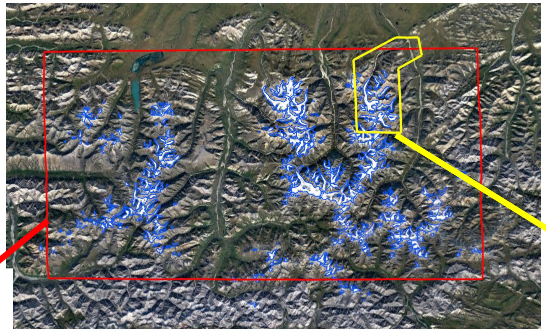
Uses for our airborne insar to map coastal wet/dry line? Soil type? Freeze/thaw?

Professional Background 2008:
Learning the Realities of Lidar

This commercial lidar acquisition of my glaciers was by far the biggest purchase ($400k) by NSF in Alaska and not likely to happen again for another 10 years.

Mediocre Precision:
+/- 270 cm @ 95%

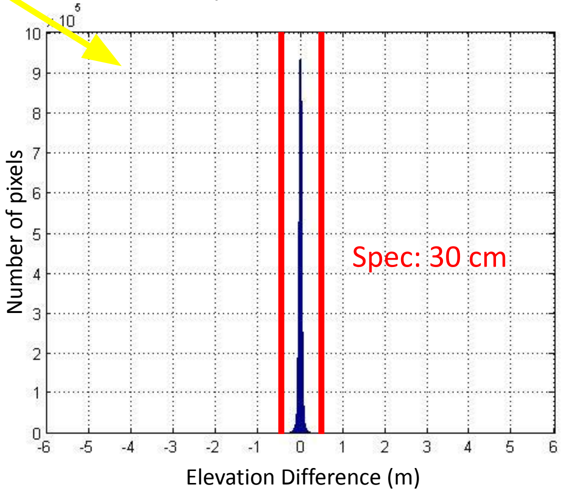




Same company, same lidar sensor, same location, same year, same project, and same deliverable specs yet wildly different quality in results.

All remote sensing is part art, part science, and part luck –
all technologies show a similar spread and all are constantly improving by learning from their mistakes.

Awesome Precision:
+/- 10 cm @ 95%



Take home messages:

1) It would be unfair to characterize all lidar data as having +/- 2.7 meter accuracy based on this single project, just like it would be unfair to characterize all photogrammetry by the worst photogrammetric result.

2) Commercial lidar is simply too expensive for academics on the repeat time-scales needed for climate-change science in Alaska – a new solution was needed.

End of Presentation

Thank you!

Alaska Coastal Mapping Pilot Project Recommendations

Dave Maune, Dewberry Engineers, Inc.

December 1st 2021 | Virtual

Alaska Coastal Mapping Technologies Whitepaper and Pilot Projects

David F. Maune, PhD, CP, CFM, PSM, PS, GS, SP

Alaska Coastal Mapping Summit: December 1, 2021

Presidential Memorandum of 2019

The Presidential Memorandum (11/2019) called for two strategies:

1. Development of a strategy for National Ocean Mapping, Exploration and Characterization (NOMEC)
2. Development of an Alaska Coastal Mapping Strategy (ACMS)

While addressing the AMEC Coastal Subcommittee's Implementation Plan 2020-2030, my whitepaper proposes the Navigable Area Limit Line (NALL)[1] as the dividing line between these two strategies. Although somewhat subjective, the NALL is the 3.5 meter depth contour below the chart datum (Mean Lower Low Water – MLLW)

[1] https://nauticalcharts.noaa.gov/publications/docs/standards-and-requireements/specs/HSSD_2021.pdf

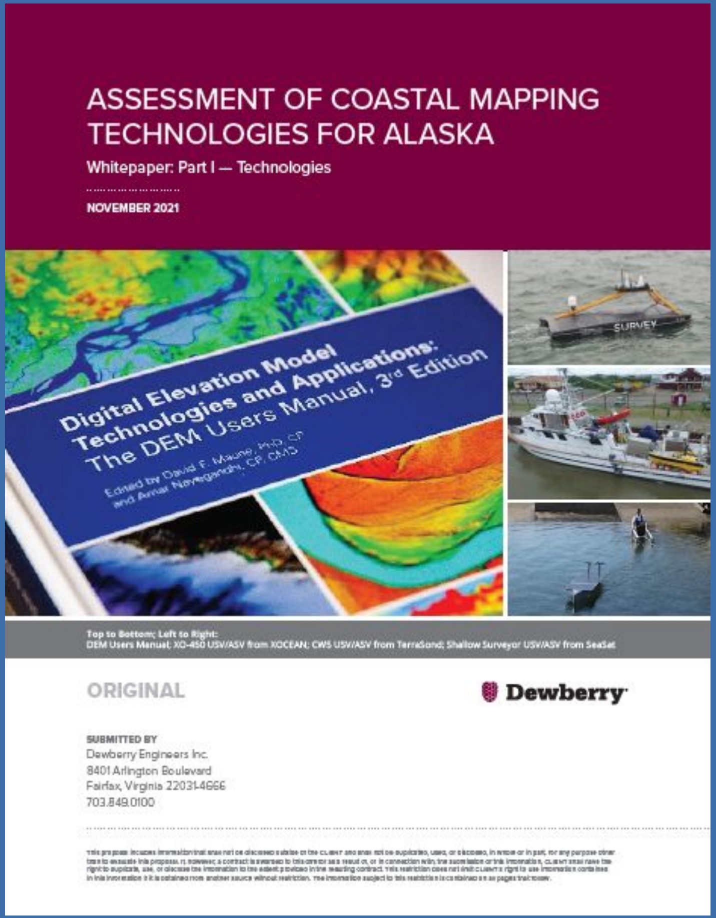
AMEC-CS ACMS Implementation Plan 2020-2030 Objective 3.2 Milestones

- **Milestone 3.2.1**. Compile and maintain list of existing and emerging science and technology requirements and testing opportunities from the Alaska mapping community (operations, research, industry) through published materials and relevant meetings/workshops (e.g., ASMC, Alaska Coastal Mapping Summit)
- **Milestone 3.2.2**. Identify technology demonstration pilot projects to test and evaluate new methods/platforms and related costs/ efficiencies for suitability in meeting Alaska mapping requirements

The Whitepaper has three major parts

- **Part I** provides a detailed overview of coastal mapping technologies: (1) tidal datum technologies, (2) technologies for mapping the intertidal zone, (3) technologies for mapping shallow water bathymetry, and (4) technologies for mapping the topographic surface.
- **Part II** proposes 13 pilot projects to be summarized today.
- The **Executive Summary** is Business Confidential because it included estimated costs for the pilot projects if conducted in Norton Sound; but many pilot project areas are changing to better satisfy AMEC-CS priorities, so costs will change for new areas.

Whitepaper Part I -- Technologies



- Introduction and References
- Technology Assessment Strategy
- Tidal Datum Technologies
- Technologies for Mapping the Intertidal Zone
  - Topobathy Lidar
  - Satellite Derived Bathymetry (SDB)
  - Sonar Technologies and Platforms
  - Topographic Lidar
  - Photogrammetry
  - IfSAR and DInSAR

This assessment of coastal mapping technologies for Alaska is based on five strategies

1. Determine which technologies are best for developing tidal datums and VDatum for the entire Alaska shoreline.
2. Collect high resolution, high accuracy topobathy lidar of as much of the Alaska coastline as can be cost-effectively collected -- out to the 3.5-meter Navigable Area Limit Line (NALL) -- with priority to coastal communities, the southeast Alaska panhandle when adjoining slopes are not too steep, and areas where high and low tides cannot be accurately predicted.
3. Where tides can be predicted, collect bathymetric data at high tide, for coastal communities only, out to the 3.5-meter NALL. Determine which sonar sensors are best for collecting shallow water bathymetry. Determine the effectiveness of Satellite Derived Bathymetry (SDB) for non-populated coastlines. Costs for topobathy lidar or sonar cannot be justified for mapping shallow water nearshore bathymetry for the vast, remote and unpopulated coastal areas of Alaska.

This assessment of coastal mapping technologies for Alaska is based on the following strategy (continued)

4. Where tides can be predicted, collect topographic data and imagery at low tide for the entire Alaska coastline. Determine which Alaska coastlines are best mapped with topographic lidar, photogrammetry, including Structure from Motion (SfM), and the new high resolution, high accuracy aerial IfSAR now available. Each of these technologies will have advantages along different portions of the Alaska coastline and none of them are dependent on water clarity. When collected at low tide, these topographic datasets can be used to map Alaska's official shoreline based on Mean High Water (MHW) when tidal datums are established.
5. For coastal communities, establish a seamless high-resolution grid of bathymetric and topographic elevation data from the NALL, through the intertidal zone, and onto the topographic surface to a distance of at least one kilometer from the shoreline.

Note: These is no "one size fits all" solution for the vast Alaska shoreline; these technologies complement each other for different portions of the shoreline

Priority 1: We must establish tidal datums and VDatum statewide for Alaska

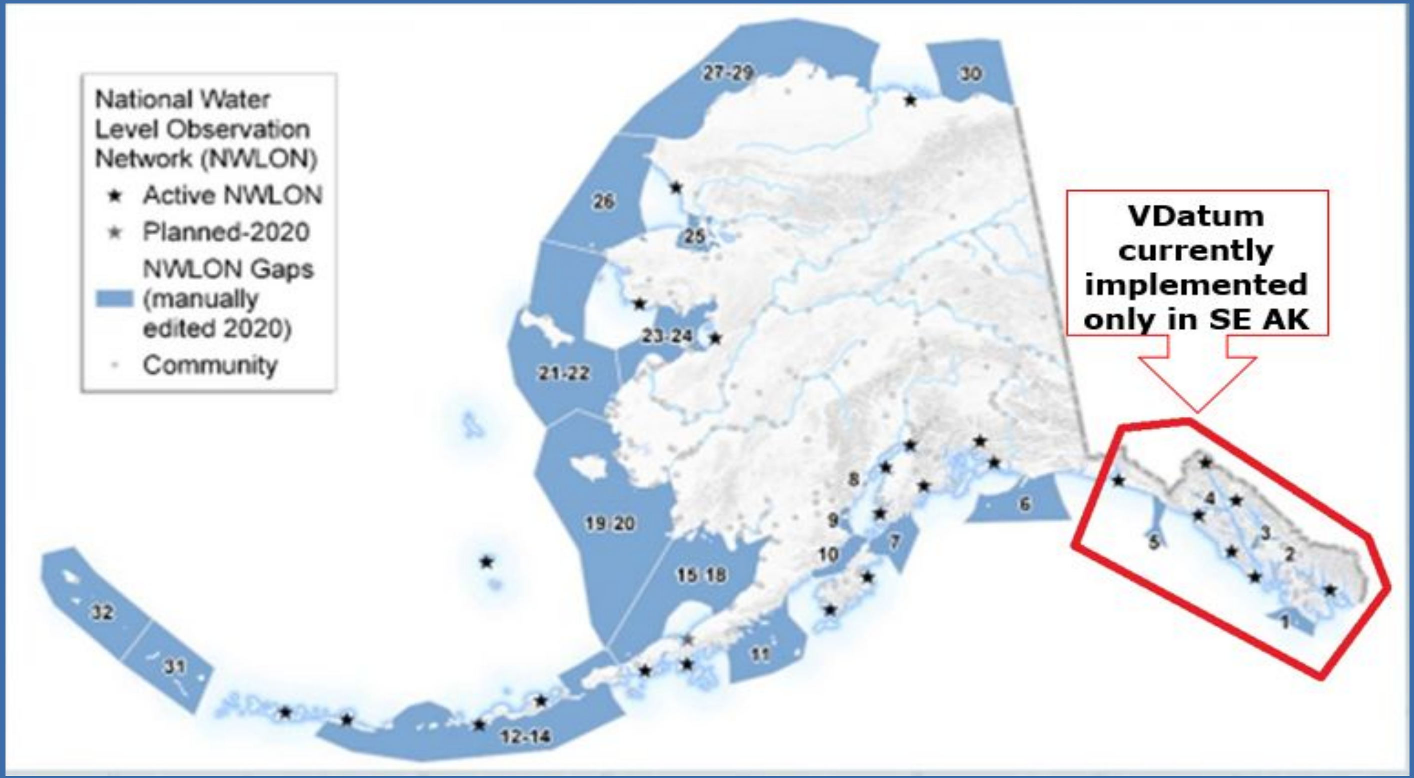


Image credit: Alaska Water Level Watch

- As shown in blue, there are 32 major gaps in the National Water Level Observation Network (NWLON) in Alaska and VDatum only works now in southeast Alaska

Vertical Datum Transformation Tool (VDatum)

VDatum converts elevation data from various sources into a common reference system

- Ellipsoid datum and Ellipsoid Heights
- Orthometric datums and Orthometric Heights (Elevations)
- Tidal datums and Bathymetric Depths

All GPS/GNSS observations give Ellipsoid Heights (h) above the mathematical reference ellipsoid

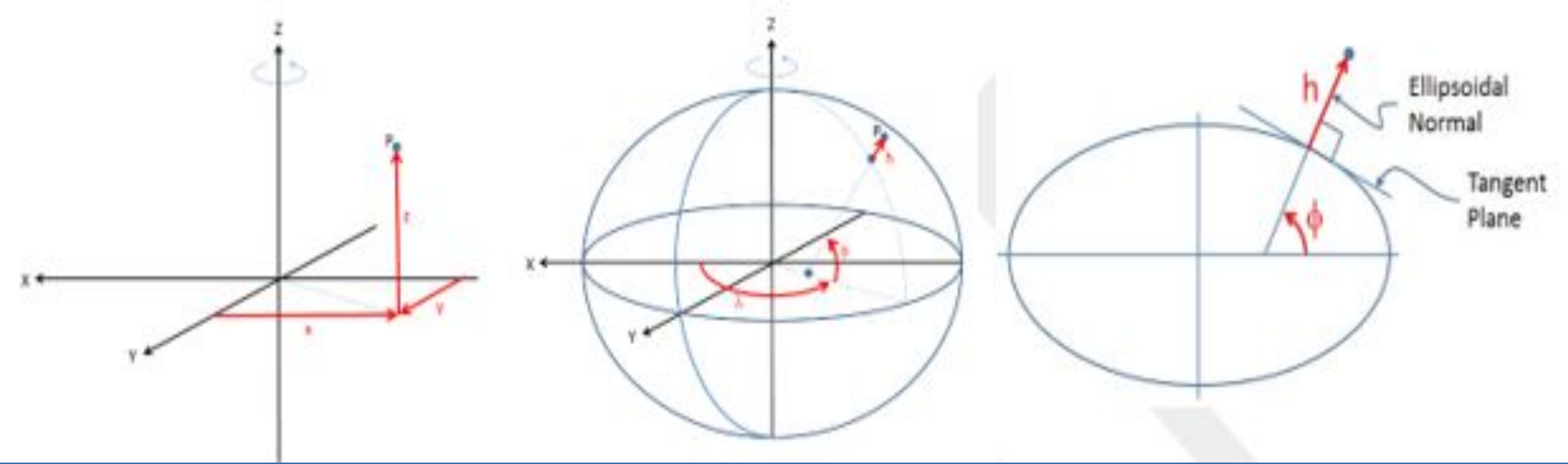
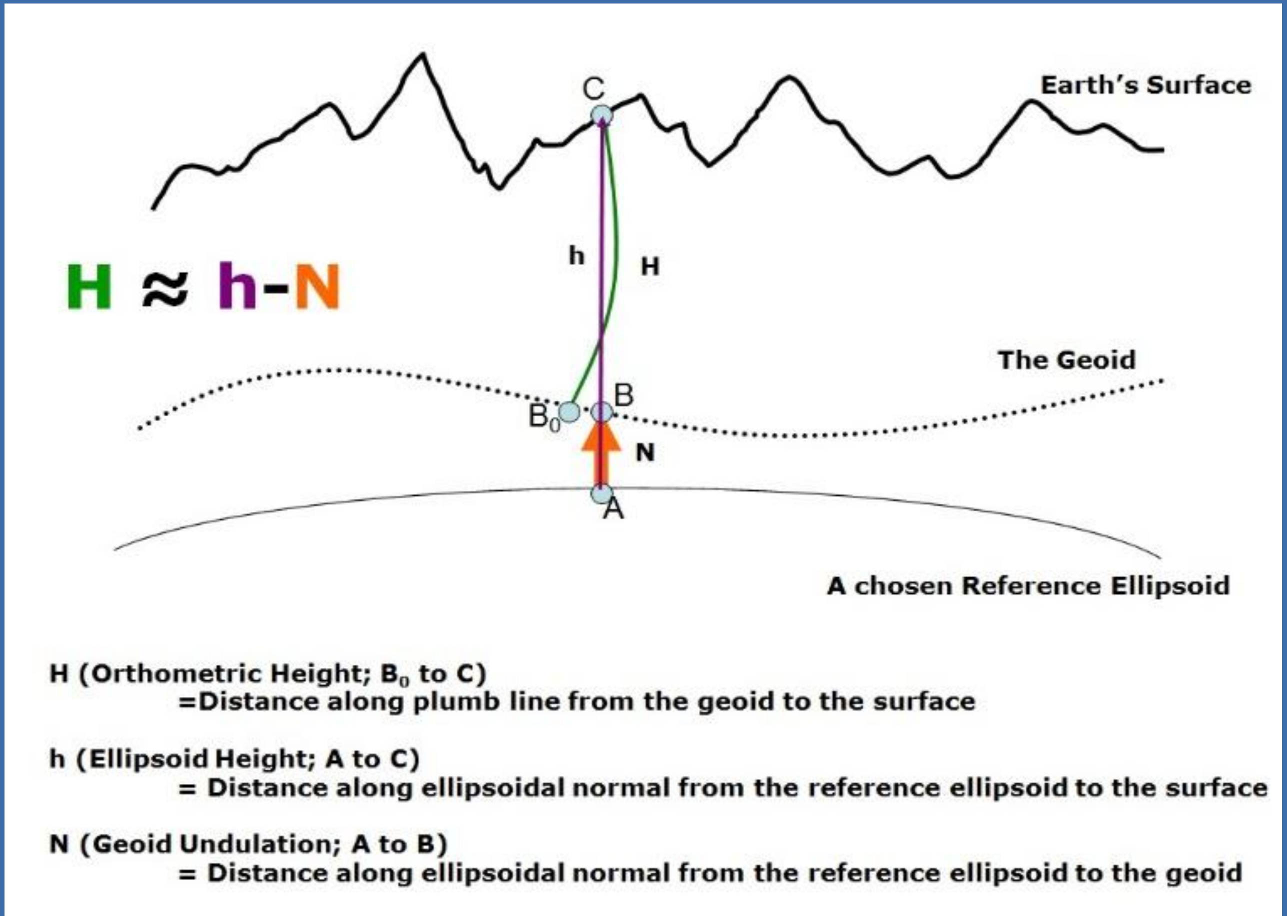


Image credit: NOAA

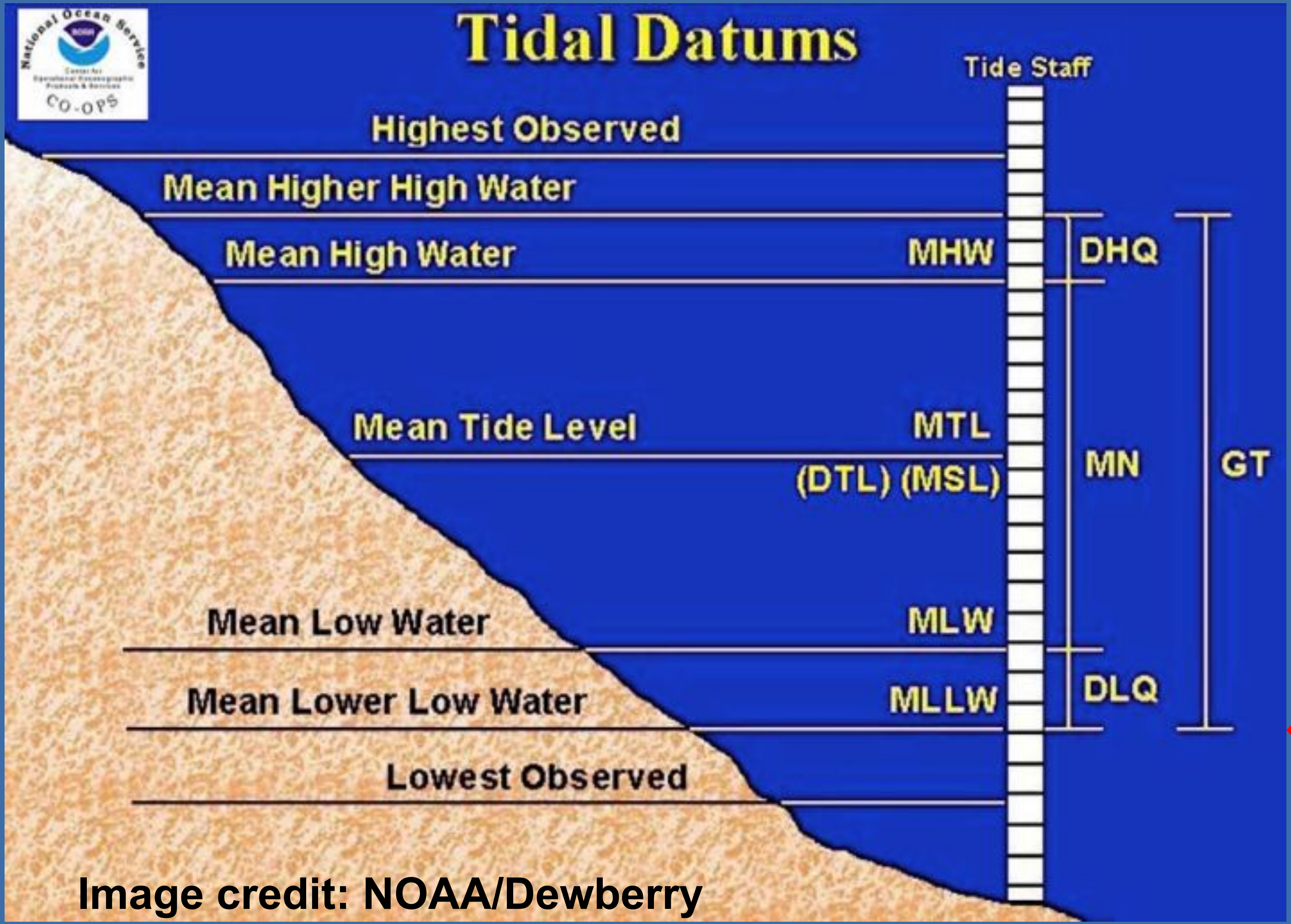
Orthometric heights (H) give elevations above the gravimetric geoid; note undulation (N)



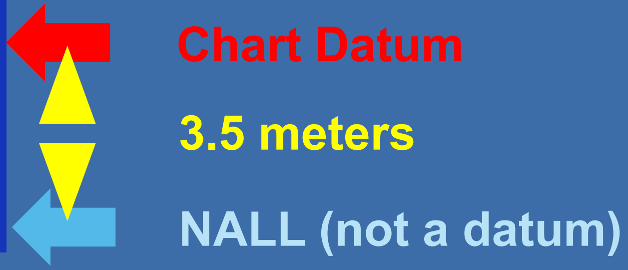
GRAV-D will change all elevations (H) when NAVD88 is replaced by the new NAPGD2022 in a few years with new values for N statewide

Image credit: NOAA

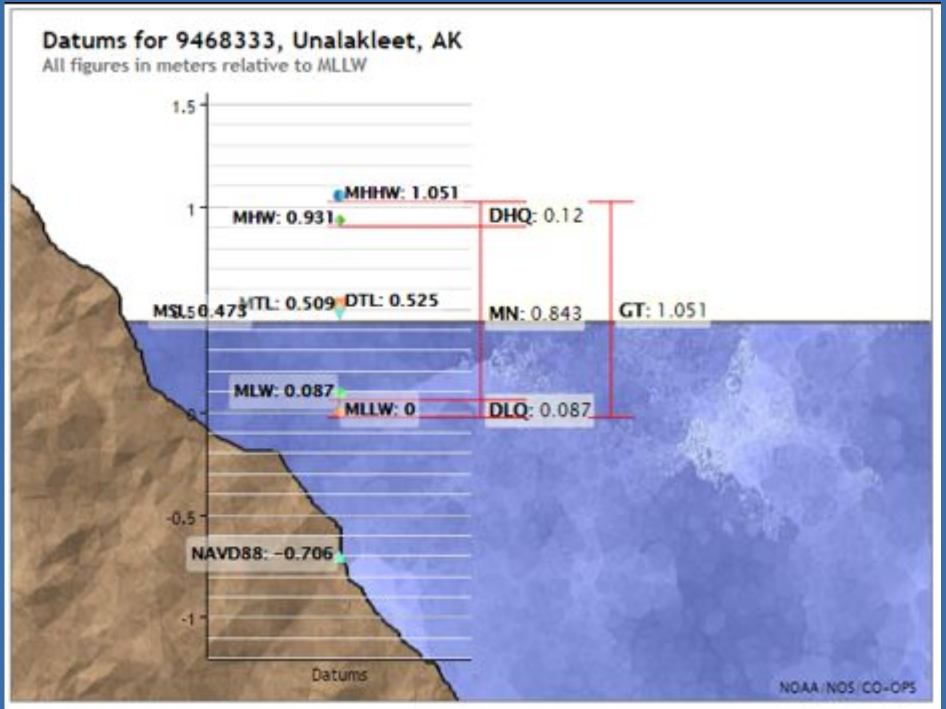
There are many tidal datums



- For safety of navigation, the chart datum is MLLW
- The NALL (blue arrow) is 3.5-meters below the MLLW (red arrow)

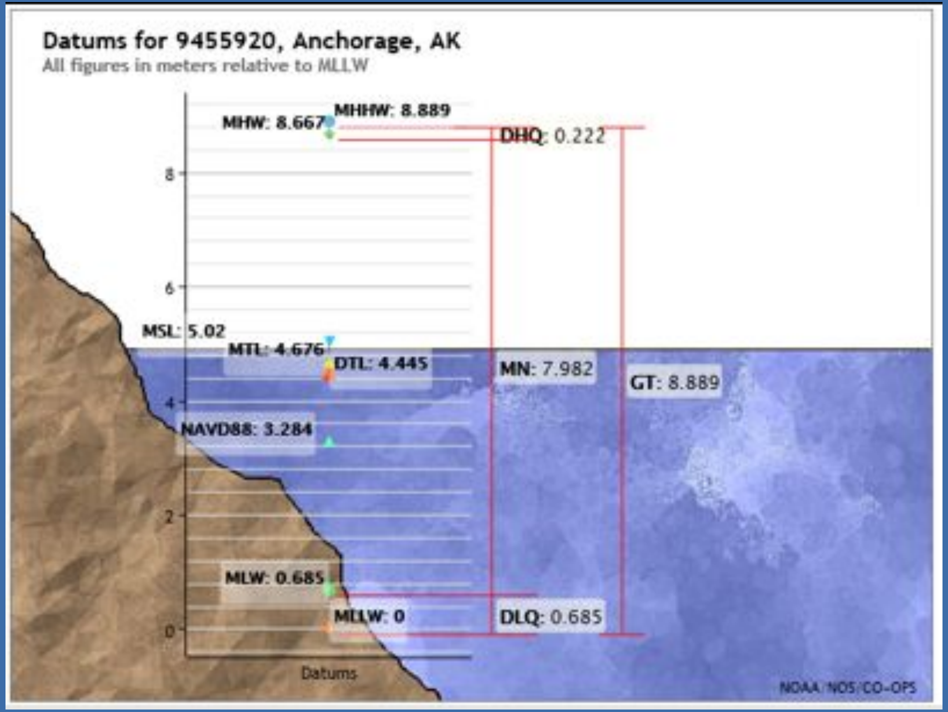


Note that NAVD88 can be significantly above or below MLLW in different parts of Alaska



In Unalakleet, NAVD 88 is .706 meters below MLLW and the NALL is 2.8m below NAVD 88

Image credits: NOAA



In Anchorage, NAVD 88 is 3.284 meters above MLLW and the NALL is 6.8m below NAVD 88

Lack of tidal datums affect maritime safety and cause administrative boundary challenges

Alternatives to Tier A NWLON Stations

Image credit: JOA Surveys

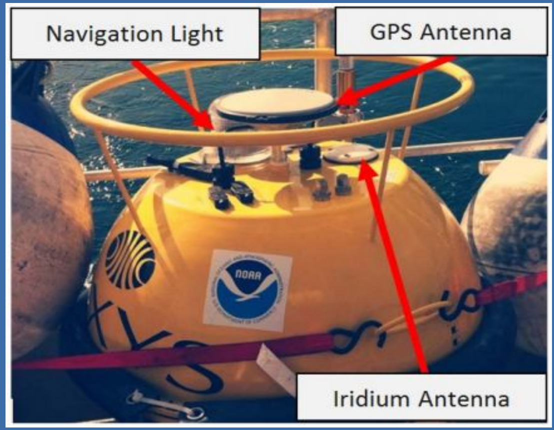


Image credit: NOAA

Image credit: AOOS

Image credit: CIDCO

Image credit: AXYS Technologies

Image credit: JOA Surveys

Priority 2: We must map AK's coastal communities seamlessly from the water onto land

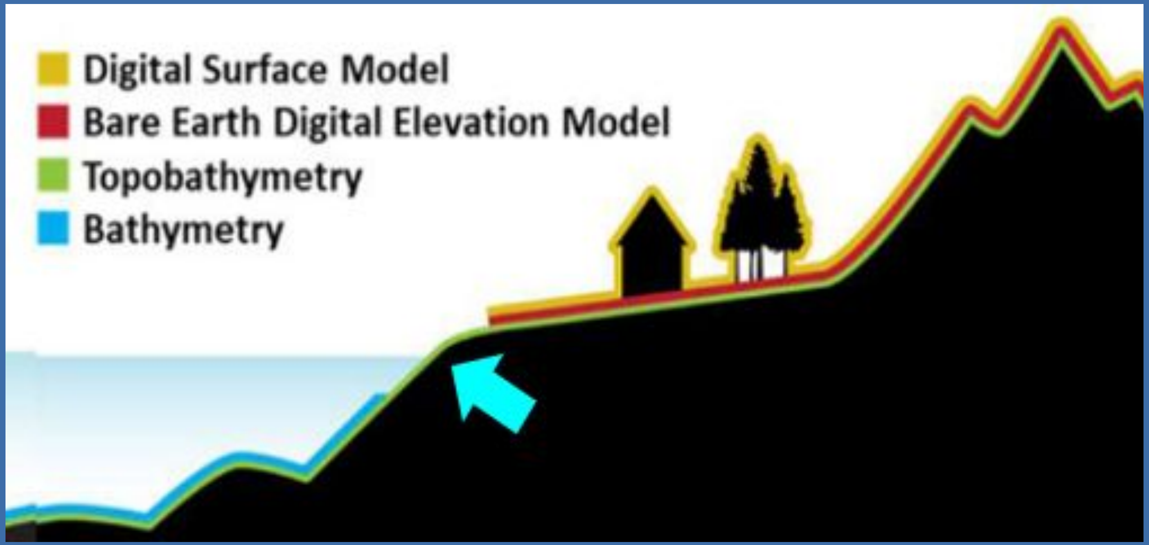


Image credit: Alaska Coastal Mapping Strategy

- Topobathy lidar technologies
- Sonar technologies
- Topographic lidar technologies
- Photogrammetric technologies
- Radar technologies
- Data merge techniques

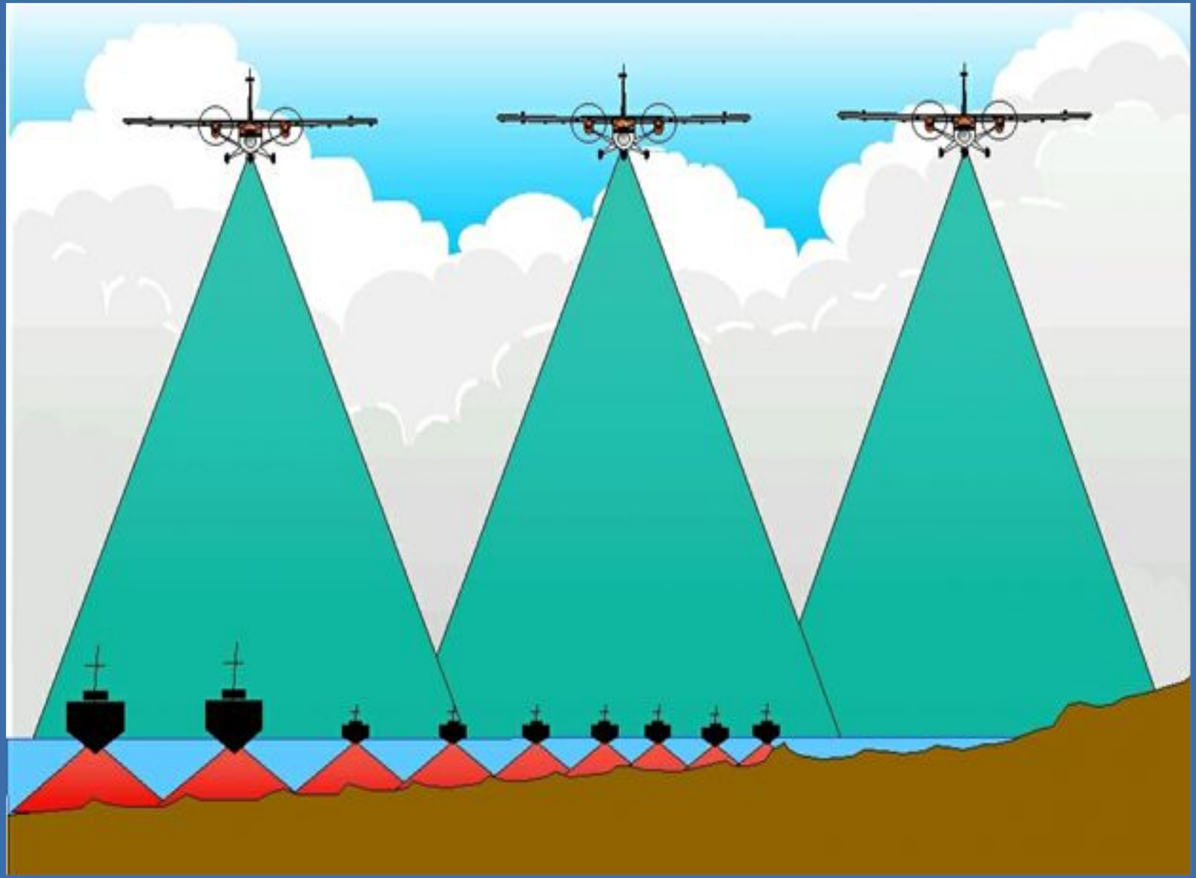
Pros and Cons of Bathymetric Technologies

Technology	Advantages	Disadvantages
Topobathy Lidar	Maps the full intertidal zone including topo and bathy surfaces	Bathymetric mapping success depends on water clarity
Satellite Derived Bathymetry (SDB)	Possibly the least expensive way to map nearshore bathymetry	Lower resolution bathymetry. Needs clear water
Single Beam Echo Sounder (SBES)	Not dependent on water clarity; maps shallow water bathymetry	Single tracks do not provide full bottom sonar coverage
Multi Beam Echo Sounder (MBES)	Not dependent on water clarity; ideal for deep water bathymetry	Generally does not map shallower than 3.5m NALL
Side Scan Sonar	Not dependent on water clarity; images seabed features	Provides qualitative information but not quantitative bathymetry
Interferometric Sonar	Not dependent on water clarity; maps shallow depths for swaths up to 10X water depth	Less accurate than depths from SBES and MBES

Pros and Cons of Bathy Mapping Platforms

Platform	Advantages	Disadvantages
Aircraft	Topobathy lidar can map the entire intertidal zone	Water penetration depends on water clarity
Satellites	SDB can be most cost effective	Imagery must be acquired when waters are clear
Crewed hydro survey vessel	MBES surveys, simultaneously serving as mother ship for USVs	Can have high mobilization costs to AOI
C-Worker 5 by L3-Harris	Popular USV for nearshore bathy with different sonar sensors	Requires mothership, preferably surveying MBES in deeper water
Shallow Surveyor by SeaSat	Fly in on small aircraft. Manual launch. Least expensive	Designed for SBES, not MBES
X-450 by XOCEAN	"Over the horizon" remote operations, 24/7 from Ireland	Requires expensive launch & recovery support vessel
Saildrone ASV	Operates autonomously 24/7 monitored by Mission Control	Maps deeper waters only, not shallower than the NALL

Topobathy Lidar



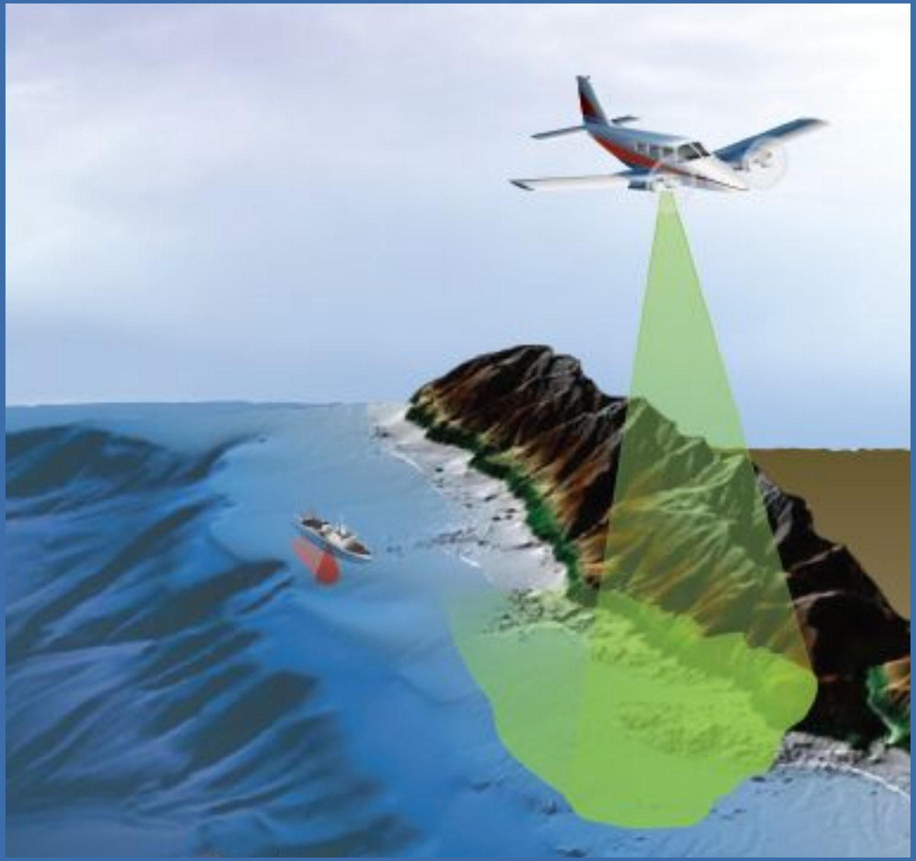


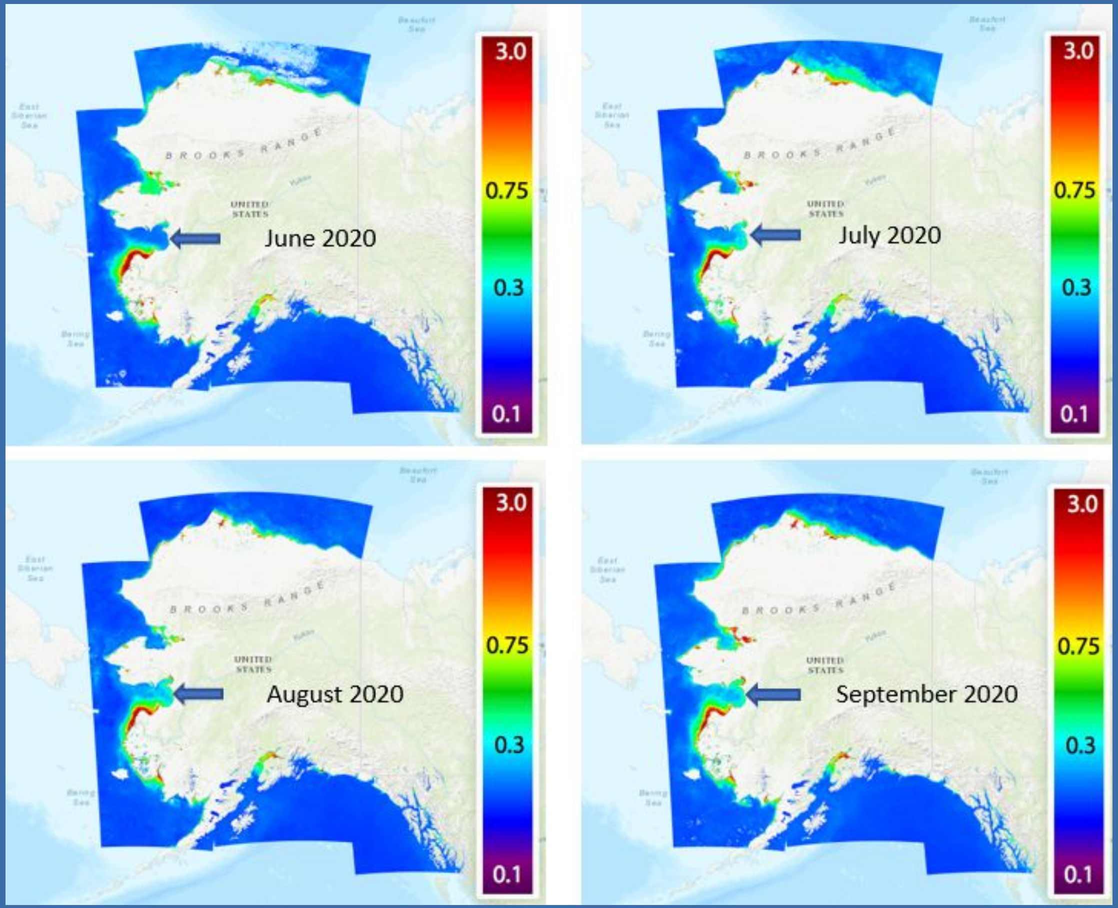
Image credits: JALBTCX, Dewberry

Topobathy Lidar System Capabilities

Sensor	Shallow Water	Deep Water	Max Depth
Optech CZMIL Supernova	X	X	4.4/Kd (deep) 3.0/Kd (shallow)
Leica Chiroptera 4X	X		2.7/Kd
Leica Hawkeye 4X		X	4/Kd
Riegl VQ-880-G II	X		1.5 Secchi depth
Riegl VQ-840-G (UAV)	X		1.7-2.5 Secchi depth
Fugro RAMMS	X	X	3/Kd

Kd = Diffuse attenuation coefficient at wavelength of 532nm (measure of depth performance)

NOAA's Water Clarity Climatology Tool for Alaska – June, July, August & September 2020



- Kd is a measure of how light dissipates with depth in water.
- The Kd color bar is shown here.
- The dark blue represents ideal conditions nearshore while dark red represents substandard conditions.

Image credits: NOAA

Turbidity and Topobathy Lidar Data Voids

Alaska

Image credit: ShoreZone

Puerto Rico

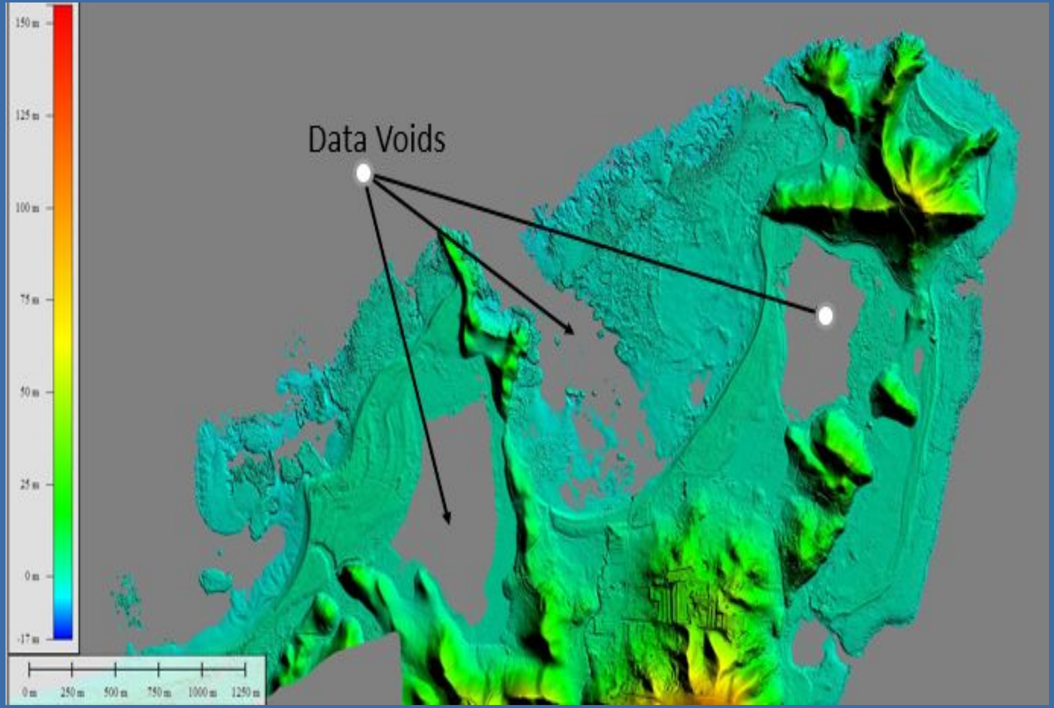


Image credit: Dewberry

Dewberry

JALBTCX Topobathy projects in AK

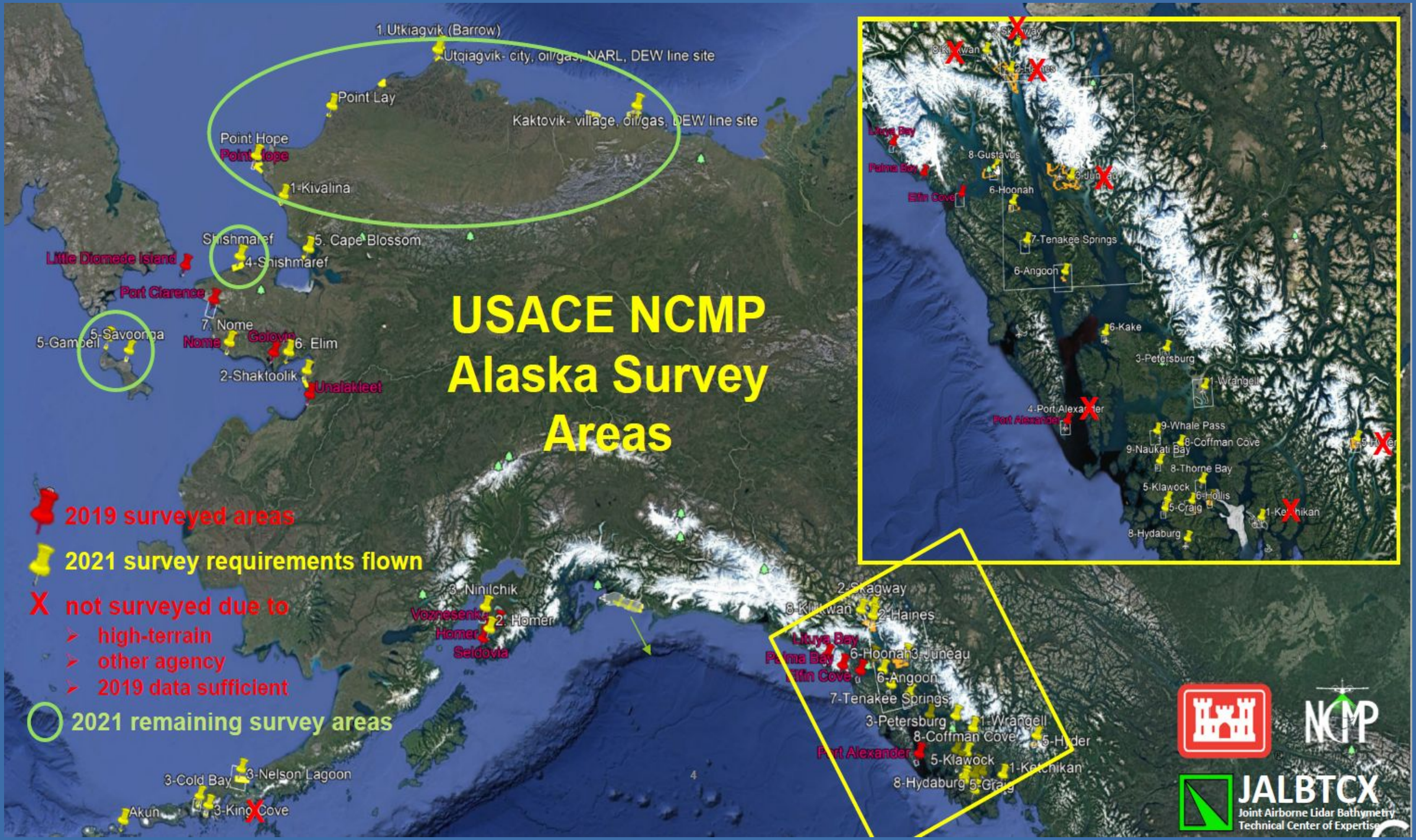


Image credit: JALBTCX

Pros and Cons of Satellite Derived Bathymetry (SDB)

Advantages	Disadvantages
Can be done completely remotely	Coarse resolution compared to MBES or lidar (2m vs. cm)
No environmental impacts or risks to personnel and equipment	Not Safety of Life at Sea (SOLAS) compliant; can’t be used for official safety of navigation
No permitting or mobilization required	Not suitable for regions with persistent turbidity
Cost effective and time efficient	No official International Hydrographic Organization (IHO) standards exist yet for SDB
Useful for change detection	

Types of Sonar Sensors

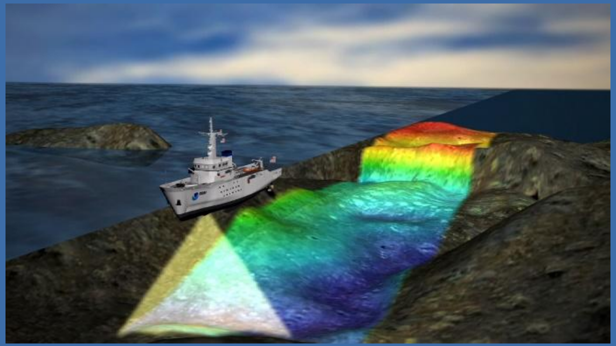


Image credit: NOAA

Image credit: Teledyne Marine

Image credit: EdgeTech

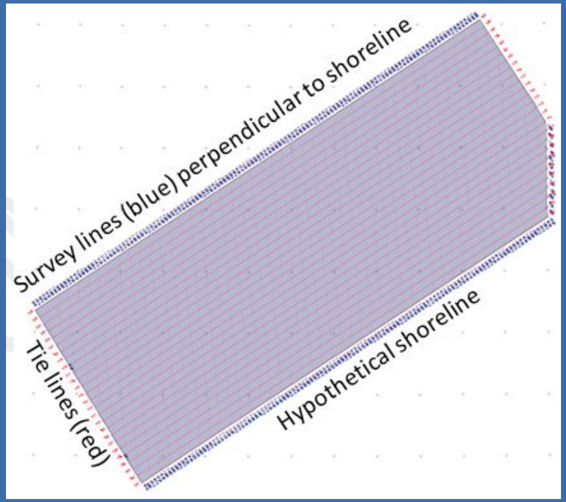


Image credit: Dewberry

Image credit: Norbit

Image credit: EdgeTech

Sonar Mapping Platforms

Image credit: TerraSond

Image credit: X-Ocean

Image credit: SeaSat

Image credit: X-Ocean

Pros and Cons of Topographic Technologies

Technology	Advantages	Disadvantages
Topobathy Lidar	Maps entire intertidal zone	Relatively expensive
Single Photon or Geiger-Mode Lidar	High altitude; high density lidar	Broad area topo only; expensive
Linear Mode Lidar	Well established standards/specs	Better for large AOIs rather than irregular coastlines
Stereo Photogrammetry	Well established standards/specs	Requires extensive Ground Control Points (GCPs)
SfM Photogrammetry	Inexpensive; easy to use, minimal GCPs	Accuracy TBD
Satellite Photogrammetry	Large provider pool	Less accurate than airborne
Aerial IFSAR	Maps through clouds/fog; now available with higher resolution and accuracy	Costs >$1M to mobilize; small pool of providers
Satellite Differential SAR	Best for mapping post glacial rebound and subsidence with free Sentinel-1	Commercial SAR has higher resolution; but often not archived

Stereo and Structure from Motion (SfM) Photogrammetry

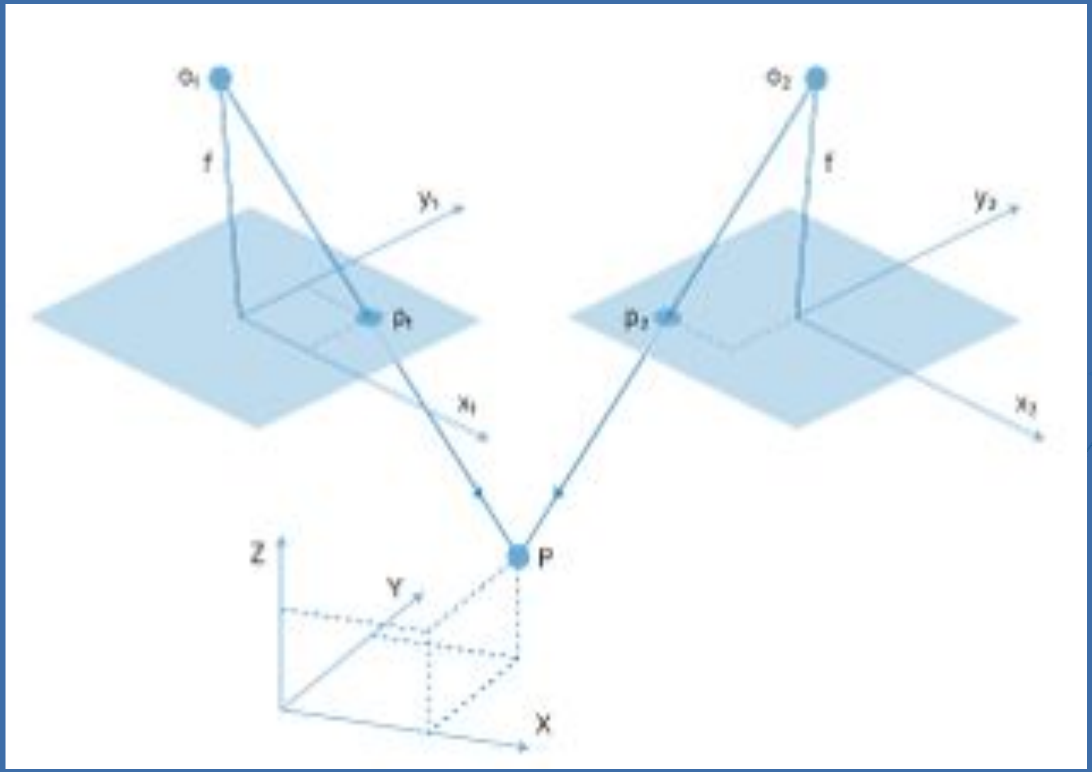


Image credit: Dewberry

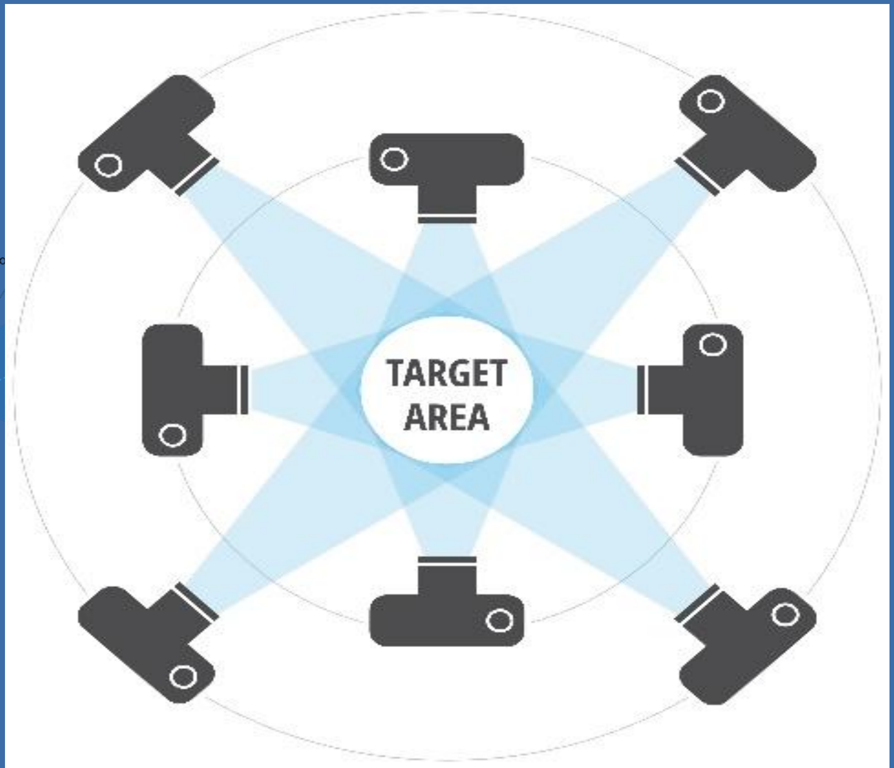


Image credit: Dewberry

Fairbanks Fodar's SfM Acquisitions

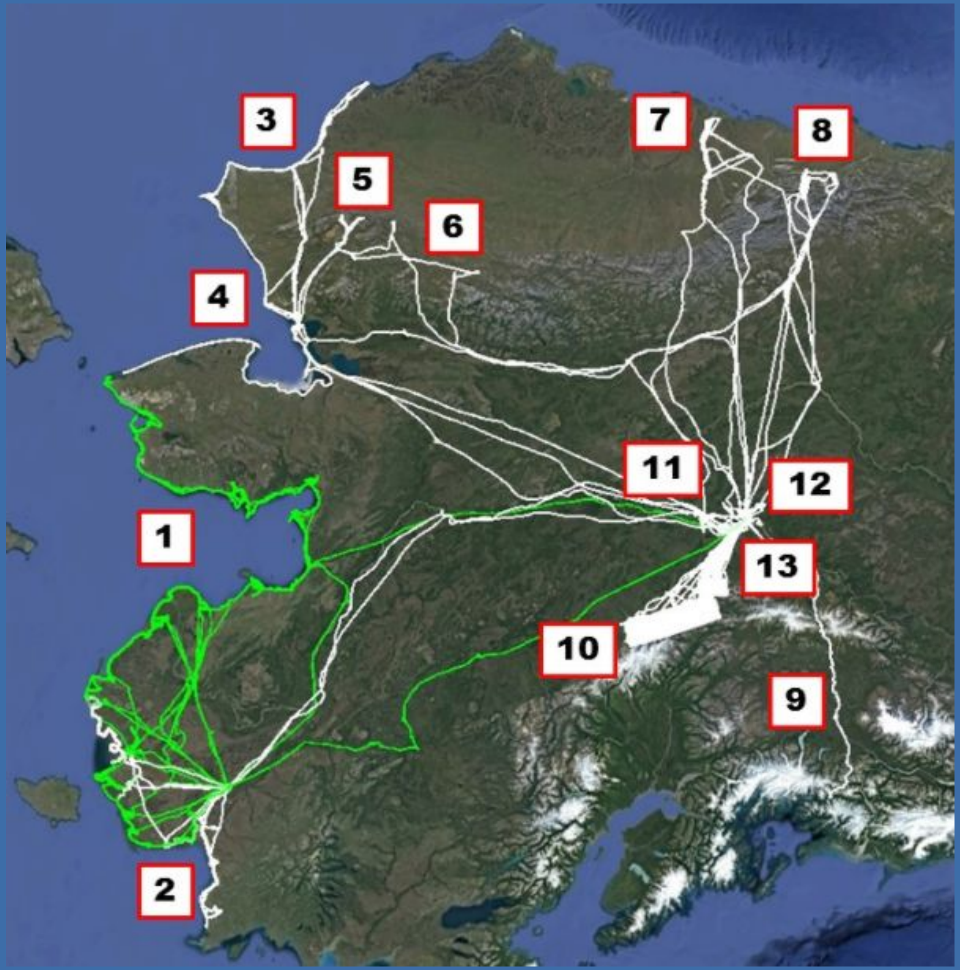


Image credit: Fairbanks Fodar

- Fairbanks Fodar does not normally use GCPs in the aerial triangulation process, so the accuracy and precision should be tested.
- Fortunately, lidar point clouds can offer us an opportunity to determine whether this is a problem <u>or not</u> compared with SfM point clouds and client requirements for SfM.
- Regardless, SfM is a low-cost solution, not expected to be as accurate as higher-cost lidar

Dewberry

IFSAR now flies lower and delivers higher resolution and accuracy

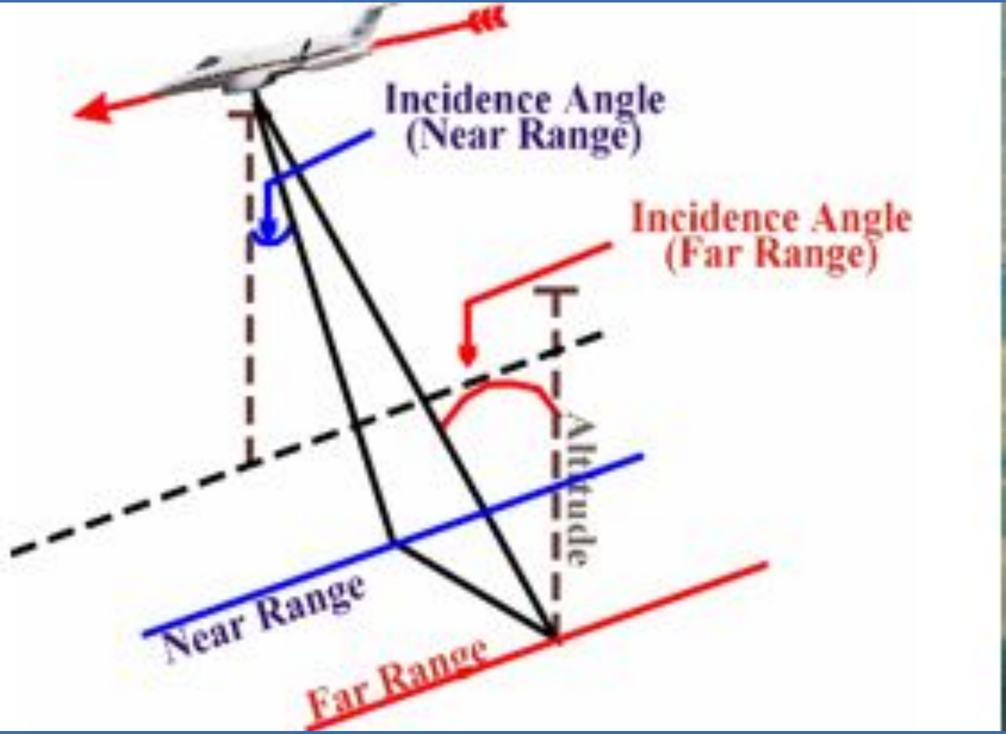


Image credits: Intermap Technologies

Whitepaper Part II – Pilot Projects

1. Tide Buoy/GNSS-R Pilot
2. VDatum Plan of Action
3. Topobathy Lidar
4. CW-5 USV w/ different sonar options
5. XO-450 USV controlled from Ireland
6. SeaSat Shallow Surveyor with SBES
7. Multi Sensor SDB
8. GCPs and QA/QC checkpoints
9. Topographic Lidar
10. SfM Pilot & Research
11. Type-1 2m IFSAR
12. DInSAR coastal mapping, post glacial rebound & subsidence
13. Topo/bathy data merge for meeting intertidal zone objectives

Norton Sound originally proposed for bathymetric and topographic pilot projects

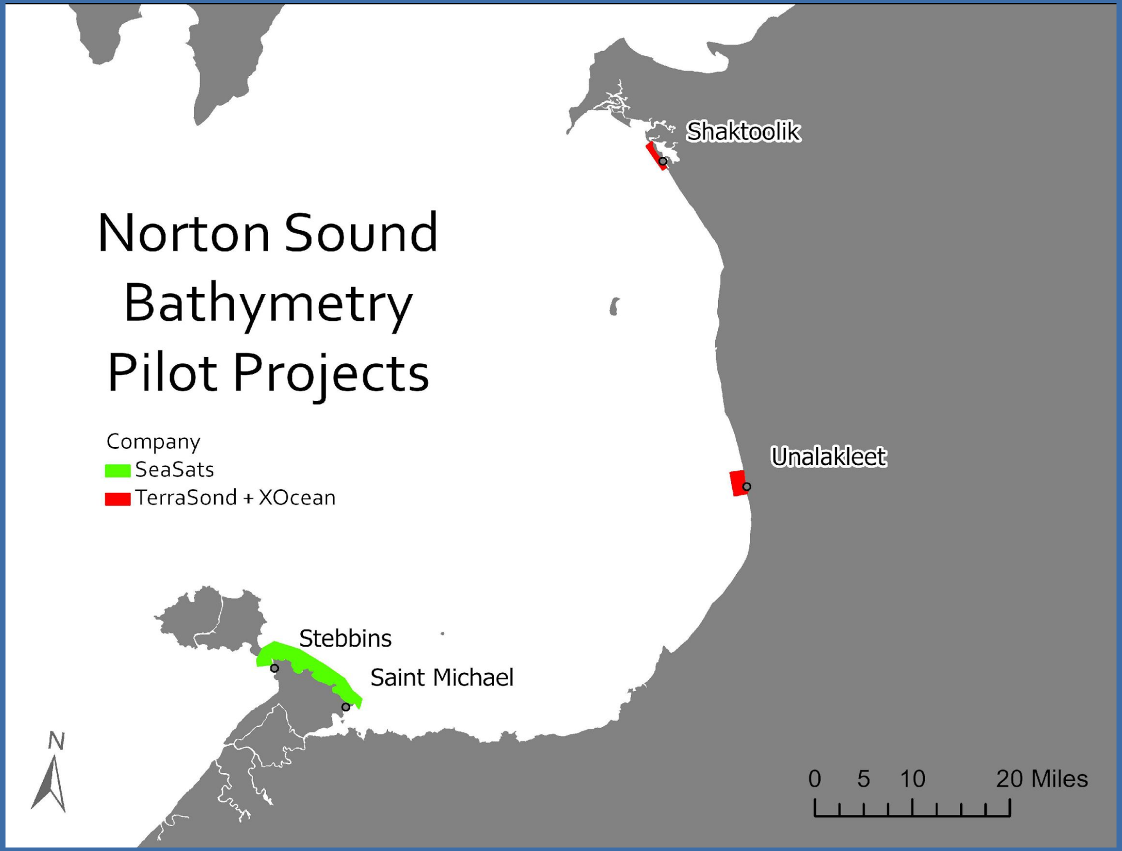


Image credits: Dewberry

Pilot #1: AXYS Tide Buoy/GNSS-R

Image credit: AOOS

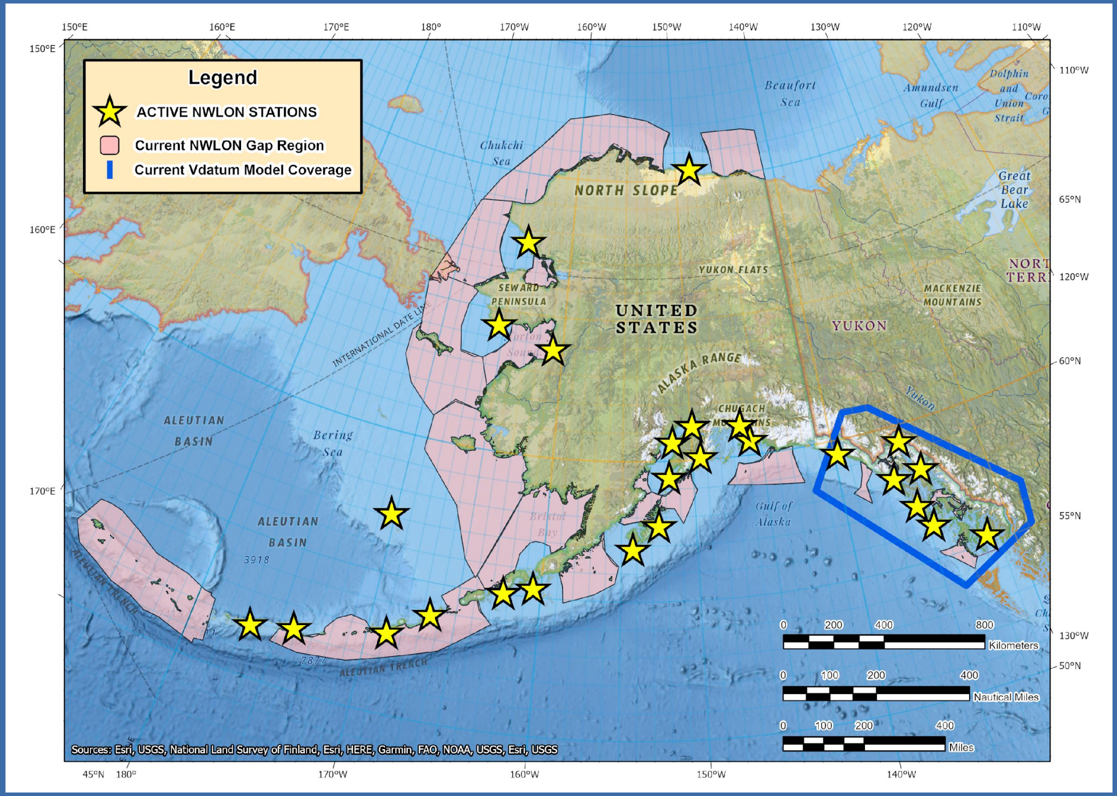
Image credit: JOA Surveys

Image credit: AXYS Technologies

Can the solar-powered AXYS Hydrolevel Buoy observe tides simultaneously with GNSS-R stations for 90 days so that GNSS-R sites can be established as Tier B stations?

Pilot #2: VDatum Plan of Action

Can lessons learned from Pilot #1 help NOAA develop a VDatum Plan of Action to expand VDatum statewide?



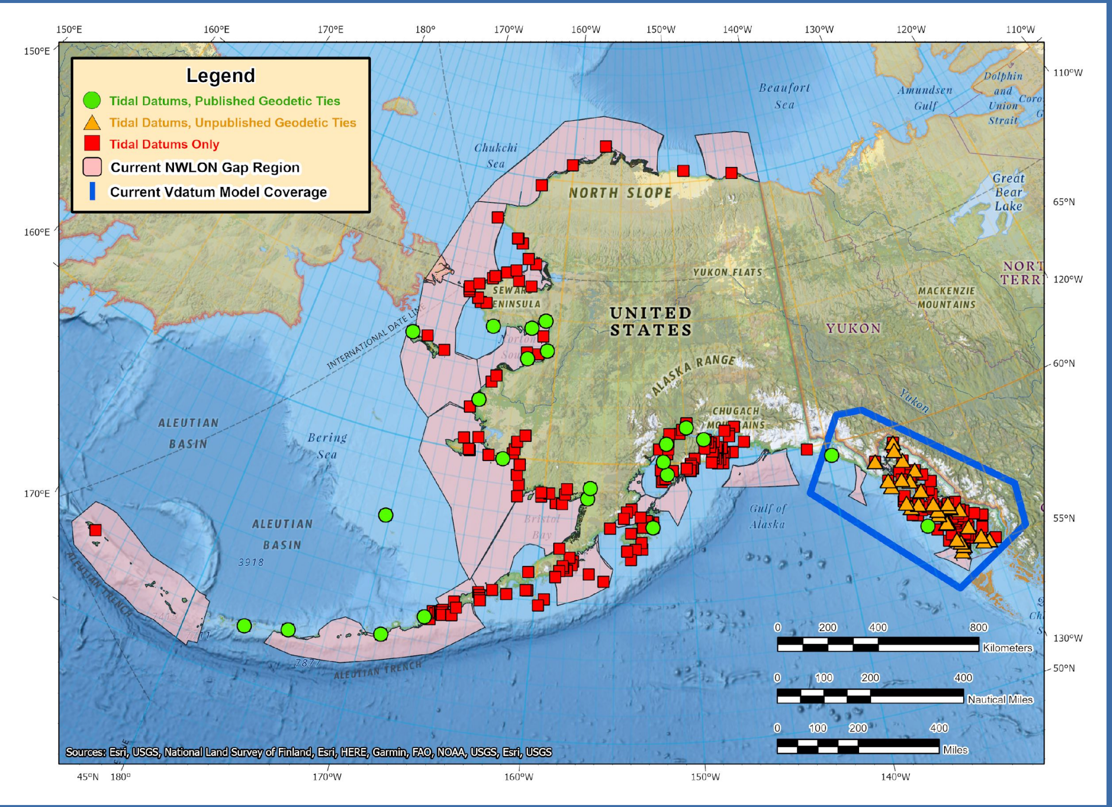


Image credits: NOAA

Pilot #3: Topobathy Lidar

Can we acquire topobathy lidar of all coastal communities in Alaska, and can we determine how to best fill the missing gaps when topobathy lidar does not capture nearshore bathymetry to the desired depths?

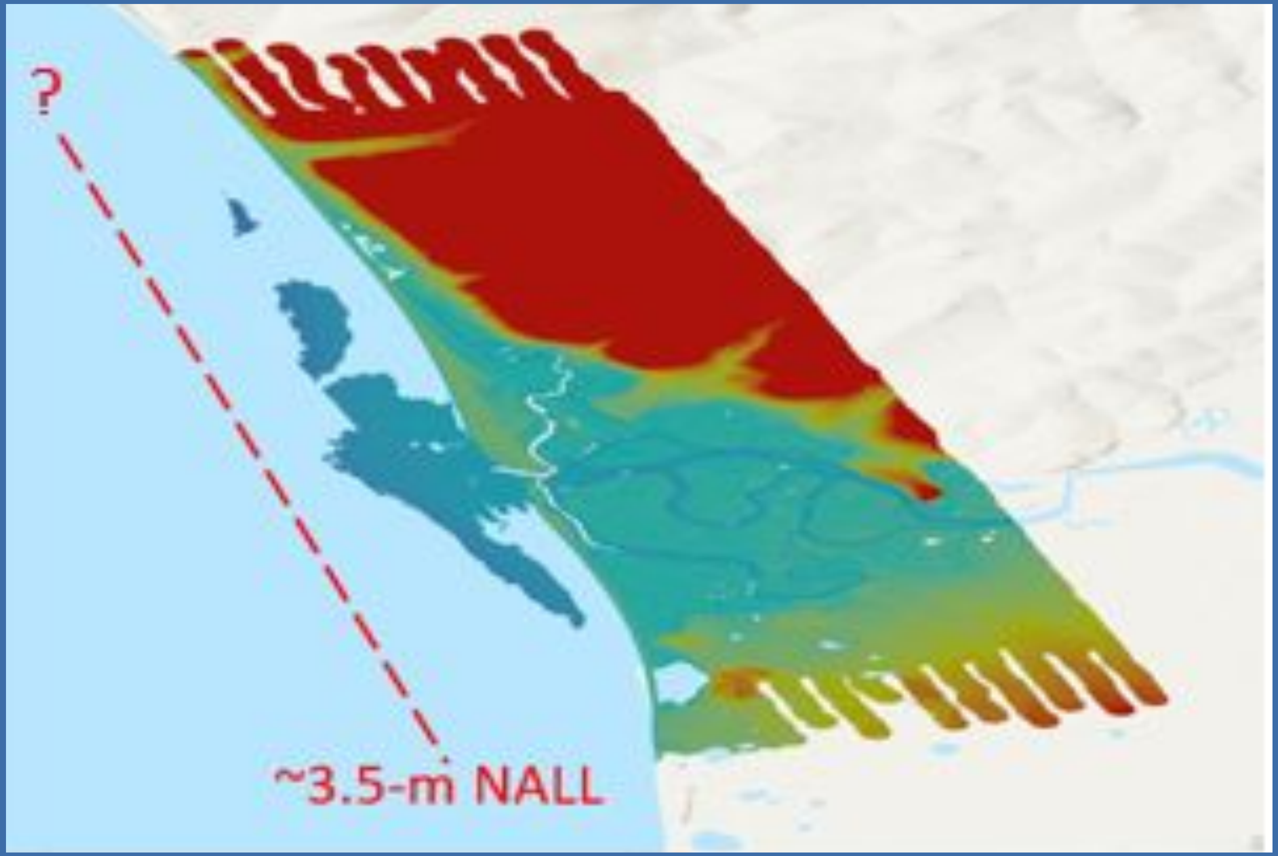


Image credit: JALBTCX

Alaska Prioritization Survey for Bathymetry (2019)

High Priority	Topobathy Lidar		Medium Priority	Topobathy Lidar
Deering			Utqiagvik	Yes
Nome	Yes		Kivalina	Yes
Shaktoolik	Yes		Shishmaref	Yes
Unalakleet	Yes		Wales	
			Golovin	Yes
			Hooper Bay	
			Togiak	
			St. Paul; St. George	
			Nelson Lagoon	Yes

Locations of sonar pilot projects will depend on turbidity issues with topobathy lidar in above project areas, or areas not suitable for topobathy lidar

Pilot #4: USV Sonar Sensor Options

Can Uncrewed Surface Vessels (USVs) cost-effectively map shallower waters at high tide, between zero and the 3.5-m depth contour, using: (a) dual-head MBES, (b) side scan sonar, or (c) interferometric sonar?

Image credit: TerraSond

Image credit: Teledyne Marine

Image credits: EdgeTech

Pilot #5: XOCEAN Over-the Horizon USV/ASV

We know that remote-controlled USVs/ASVs such as the XOCEAN's XO-450 can map portions of the Great Lakes with a curved head MBES; but can it do so safely and cost-effectively to map Alaska's <u>shallow</u> shoreline bathymetry at high tide while controlled from thousands of miles away in Ireland?

Image credit: X-Ocean

Pilot #6: SeaSat Shallow Surveyor USV/ASV

Can the Shallow Surveyor cost-effectively fly into remote Alaska airfields and acquire high density but narrowly spaced SBES tracks at high tide for 0-3.5m depth bathymetry that may be unsafe for MBES?

Image credit: SeaSat

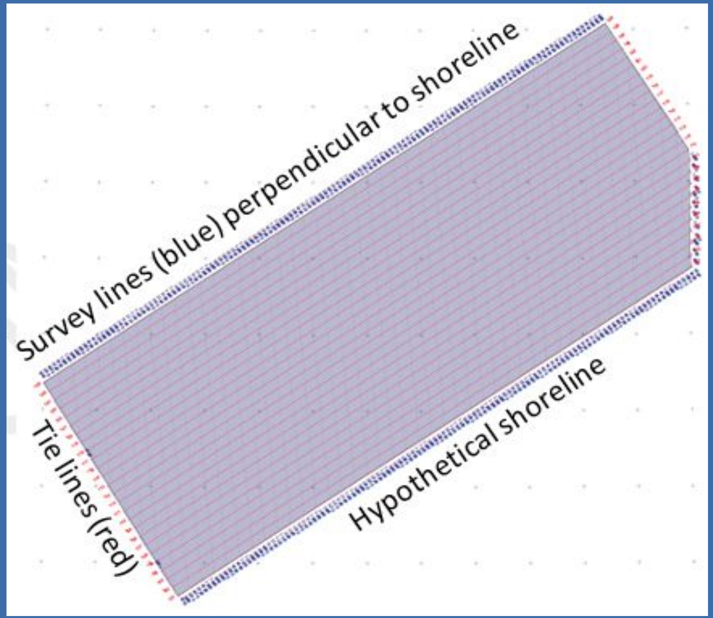


Image credit: Dewberry

Pilot #7: Satellite Derived Bathymetry (SDB)

We know that Satellite Derived Bathymetry (SDB) works in areas where waters are clear; but can it cost-effectively and reliably provide near-shore bathymetry out to the 3.5-meter NALL and beyond?

SDB could be best for unpopulated coastlines.

Image credit: Maxar

Pilot #8: GCPs & Checkpoints

For multiple topographic and bathymetric pilot projects, can surveyors cost effectively survey photo identifiable GCPs and wet and dry QA/QC checkpoints simultaneously usable for control and accuracy testing of SfM photogrammetry, lidar and IfSAR on land, as well as sonar in the intertidal zone?

Image credits: JOA Surveys

Pilot #9: Topographic Lidar

Recognizing that some coastlines are too dangerous for lower-flying SfM or topobathy lidar, can topographic lidar be cost effectively collected from higher altitudes for mapping narrow coastal corridors that might be crenulated with sharp turns?

For selecting the pilot area, wait for update to the prioritization survey.

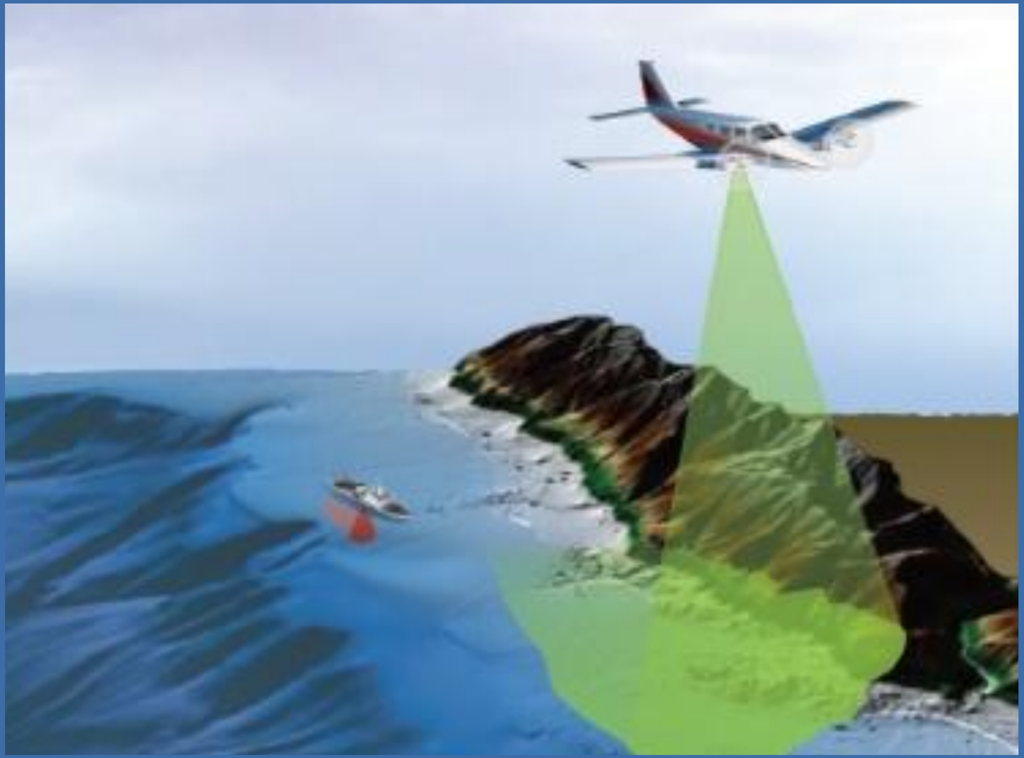


Image credit: Dewberry

Pilot #10: SfM Photogrammetry/Lidar Research

With high-accuracy, high-cost lidar point clouds available of the same area where Fairbanks Fodar has delivered low-cost Structure from Motion (SfM) photogrammetric elevations, can we compare elevation differences and determine if SfM accuracy can be improved?

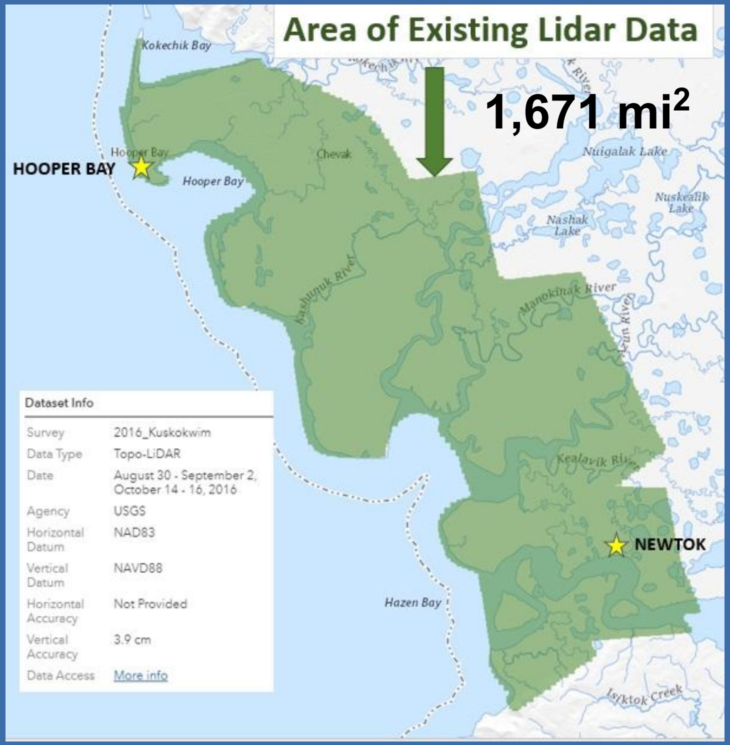


Image credit: Dewberry

Image credit: Fairbanks Fodar

Accuracy and Precision

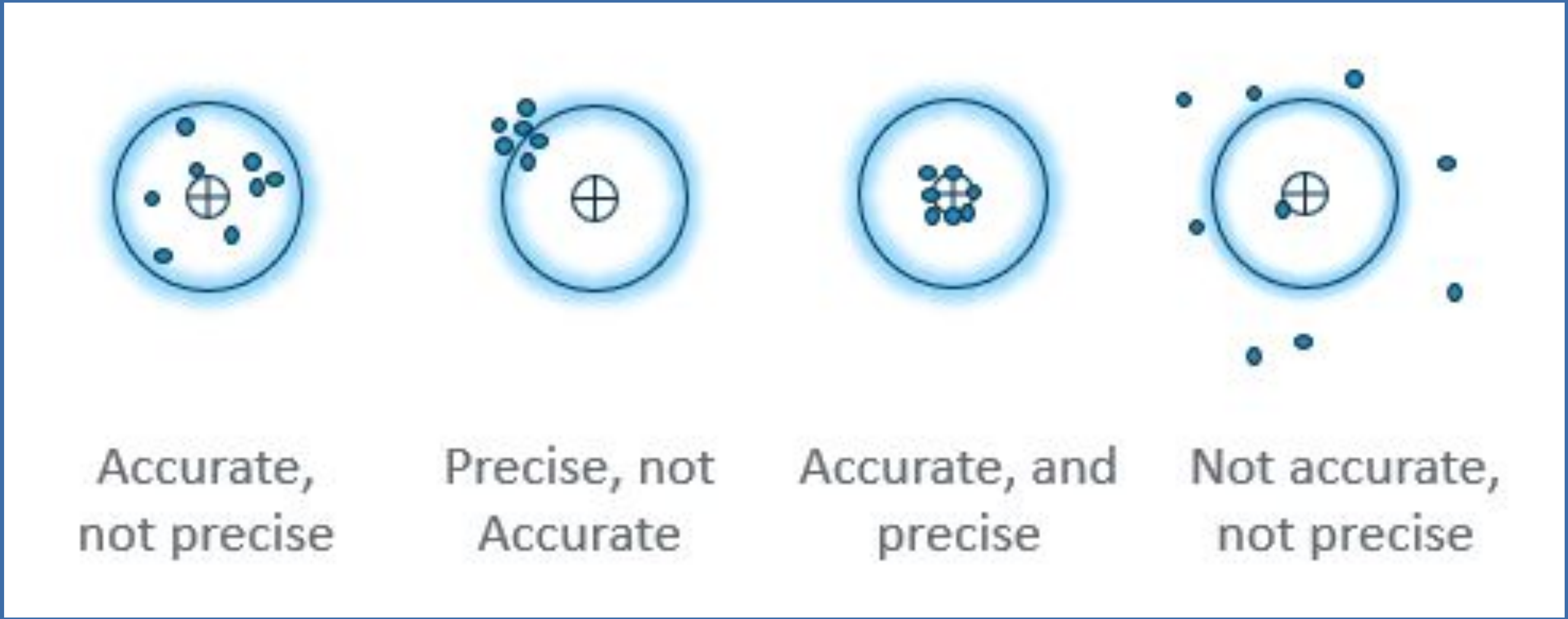


Image credit: Woolpert

Pilot #11: Type-I IfSAR 2m DSM/DTM

To improve upon the existing 5m DSMs and DTMs, can Intermap cost effectively collect lower-altitude (18,000 ft.) IfSAR and deliver Type-I 2m DSMs/DTMs with 50cm RMSEz and 25cm ORIs for mapping Alaska's coastlines in selected AOIs, especially the Western Aleutians where lidar or SfM are impractical?

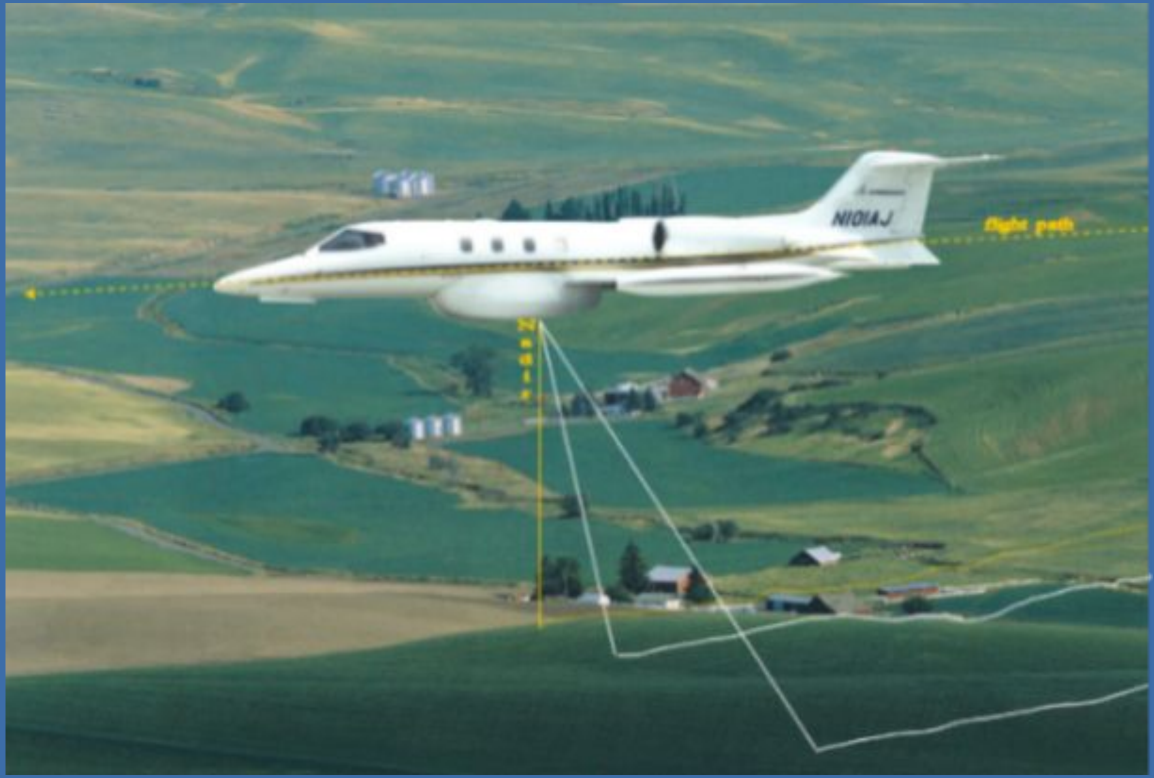


Image credit: Intermap Technologies

Pilot #12: Coastal DInSAR

We know that portions of Alaska are uplifting at rates between 10 and 25 mm/year while other areas are subsiding from permafrost thaw or other reasons, and we know that Differential Interferometric Synthetic Aperture Radar (DInSAR) technology can be used to map annual rates of subsidence at the cm and mm level; but can DInSAR be cost-effectively used to map "hot spots" and annual rates of isostatic rebound and subsidence along a coastal strip, 10 km wide, for the 10,000 km Alaska coastline?

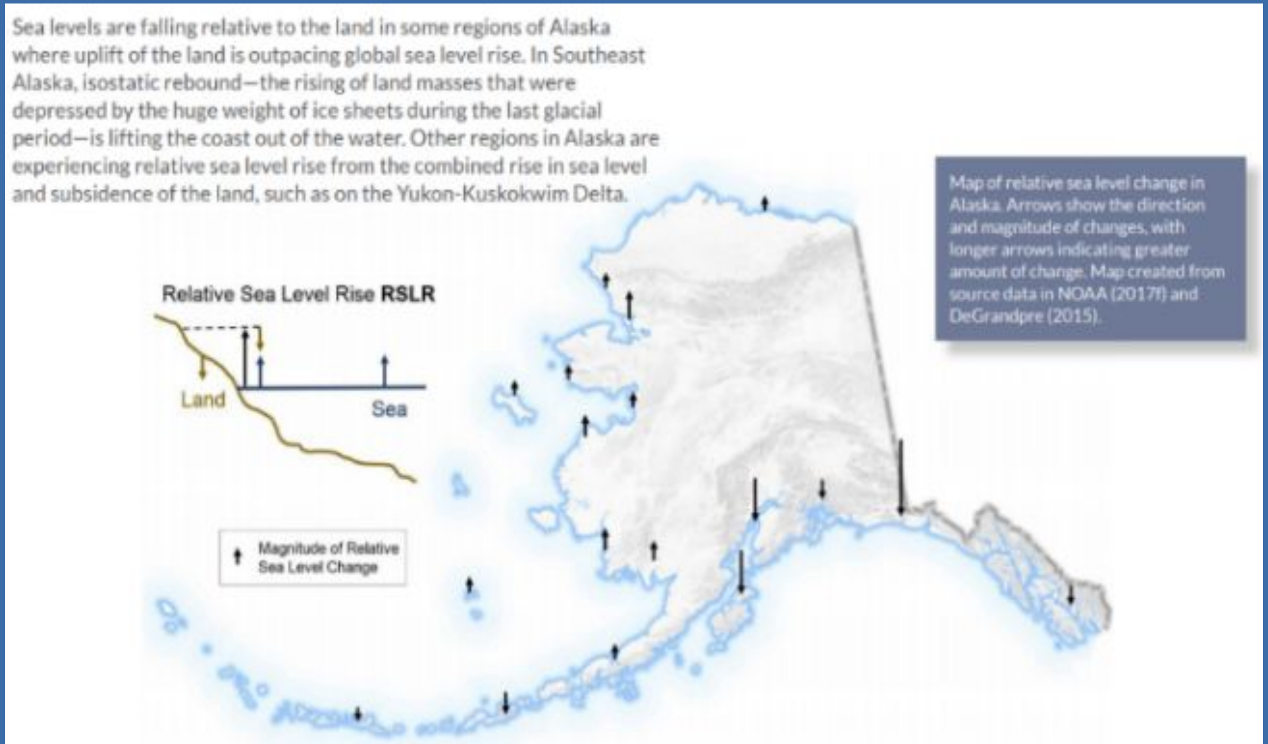


Image credit: AK DGGS Circular 72:
Alaska Coastal Mapping Gaps and Priorities

Dewberry

Pilot #13: Topo/Bathy Data Merges

Can we successfully merge topographic lidar, topobathy lidar, and sonar of Wainwright, AK, collected to different datums to create a seamless surface from water onto land?

- USGS 3DEP lidar collected in 2019
- Tidal datum established in 2020
- JALBTCX topobathy lidar in 2021
- Alaska DGGS collected single beam sonar in 2021

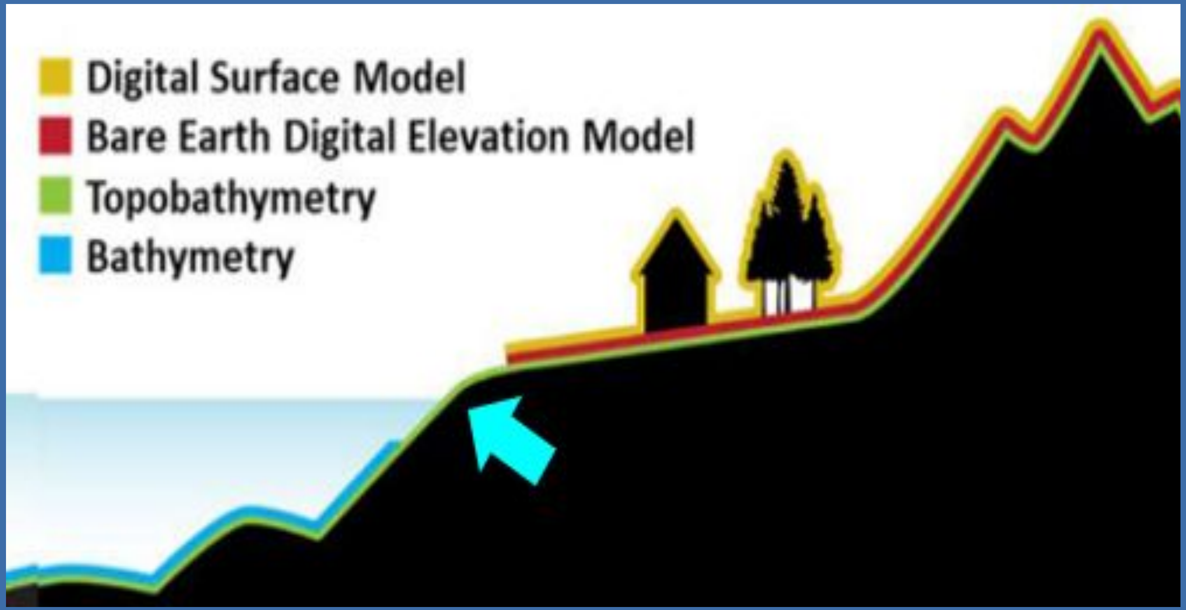
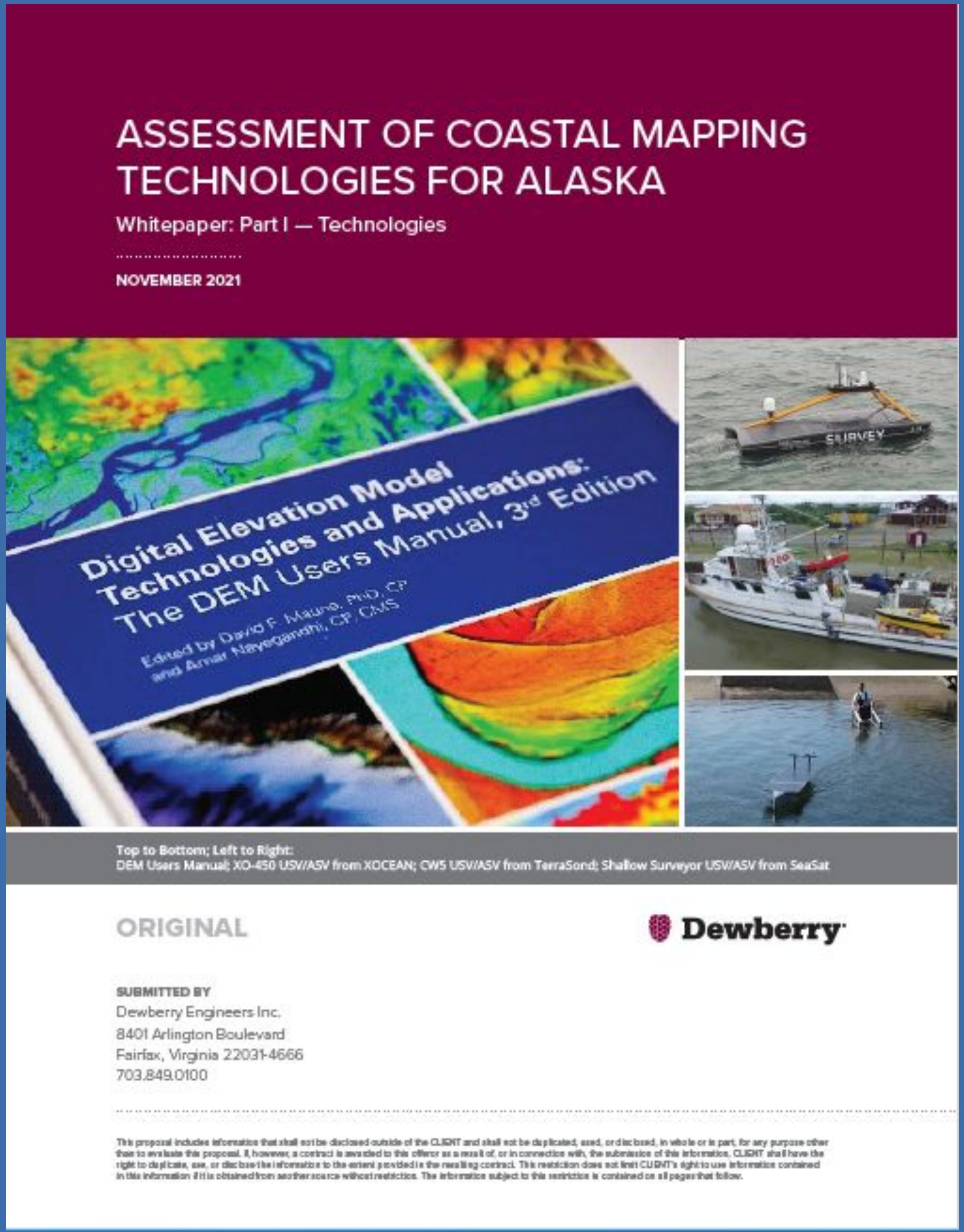


Image credit: Alaska Coastal Mapping Strategy

Pilot Project Menu

1. AXYS Tide Buoy/GNSS-R
2. VDatum Plan of Action
3. Topobathy Lidar
4. USV Sonar Sensor Options
5. XOCEAN over-the-horizon
6. Shallow Surveyor w/SBES
7. Satellite Derived Bathymetry
8. GCPs and Checkpoints
9. Topographic Lidar
10. SfM Photogrammetry Research
11. Type-I IfSAR 2m DSM/DTM
12. Coastal DInSAR
13. Topo/Bathy Data Merges



ASSESSMENT OF COASTAL MAPPING TECHNOLOGIES FOR ALASKA

Whitepaper: Part I — Technologies

NOVEMBER 2021

Digital Elevation Model Technologies and Applications: The DEM Users Manual, 3rd Edition

Edited by David F. Maune, PhD, CP and Amar Nayegandhi, CP, CMS

SURVEY

Top to Bottom; Left to Right:
DEM Users Manual; XO-450 USV/ASV from XOCEAN; CW5 USV/ASV from TerraSond; Shallow Surveyor USV/ASV from SeaSat

ORIGINAL

Dewberry

SUBMITTED BY
Dewberry Engineers Inc.
8401 Arlington Boulevard
Fairfax, Virginia 22031-4666
703.849.0100

End of Presentation

Thank you!

Tidal Datums and Positional Control

Nathan Wardwell, JOA Surveys

December 1st 2021 | Virtual

Tidal Datums and Positional Control

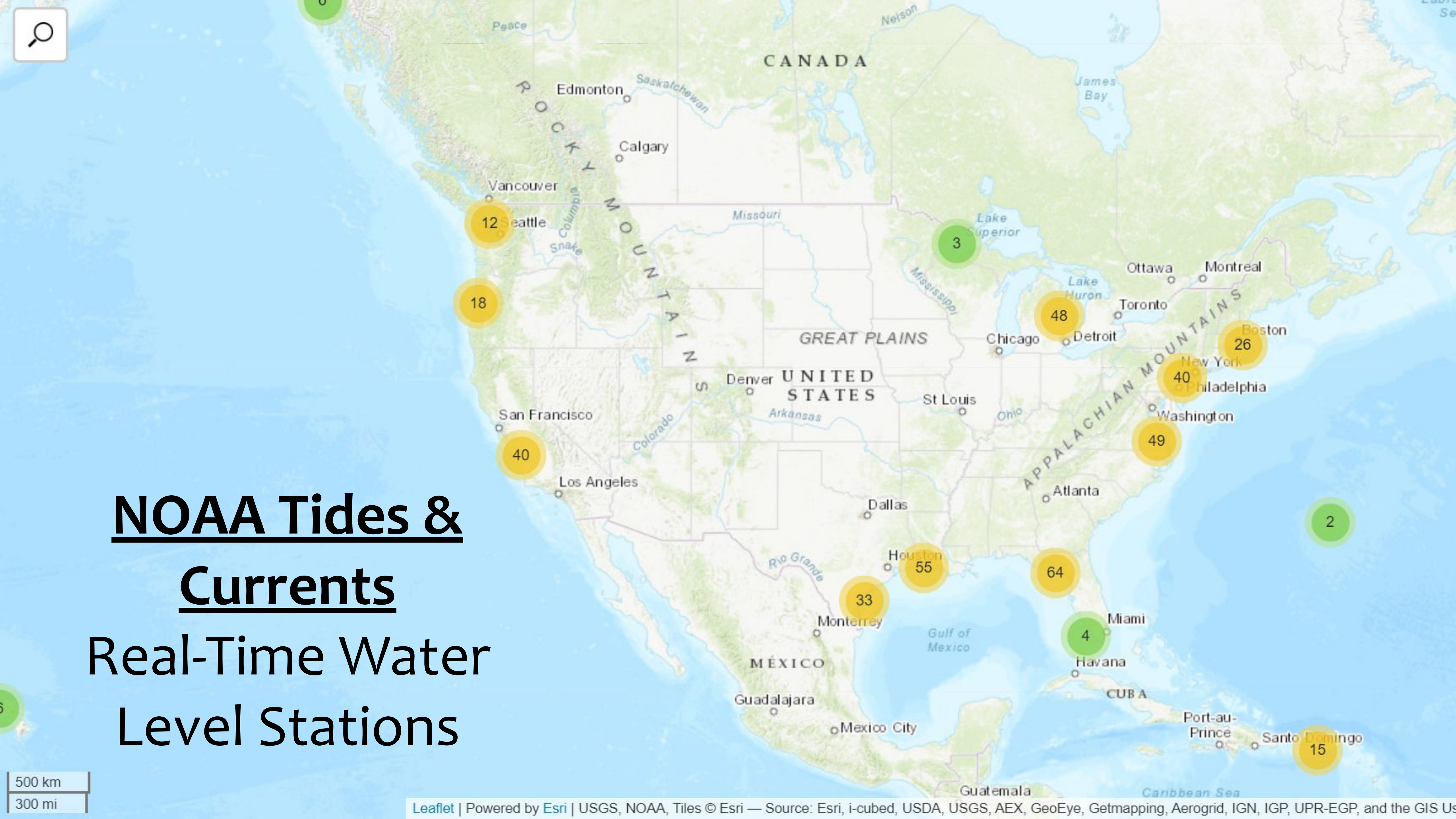
Nathan Wardwell, JOA Surveys LLC

Overview

* Real-Time Water Level Network
* Spatial Distribution of Published Tidal Datums
* Challenges
* Considerations for The Path Forward

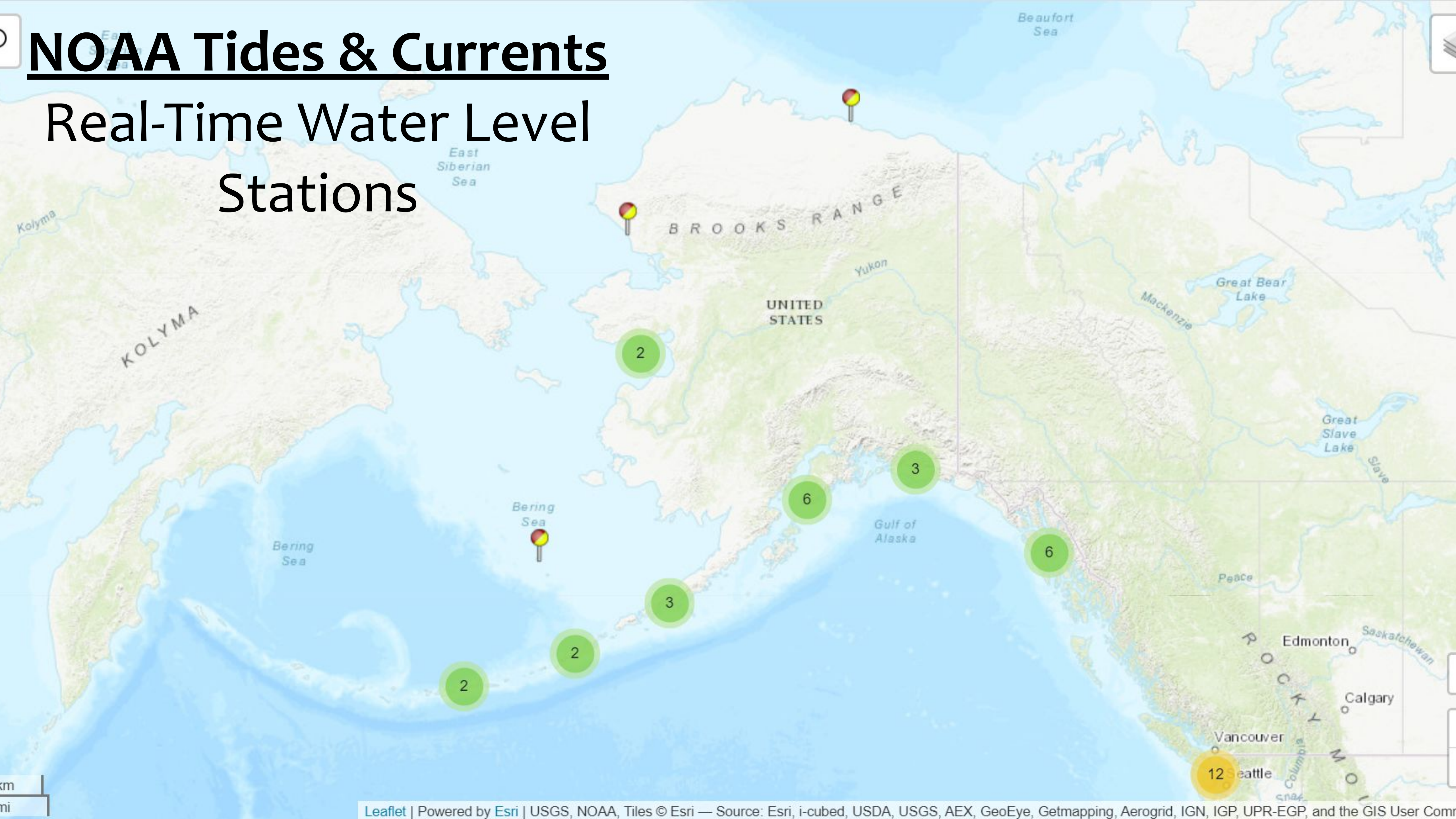
NOAA Tides & Currents

Real-Time Water Level Stations

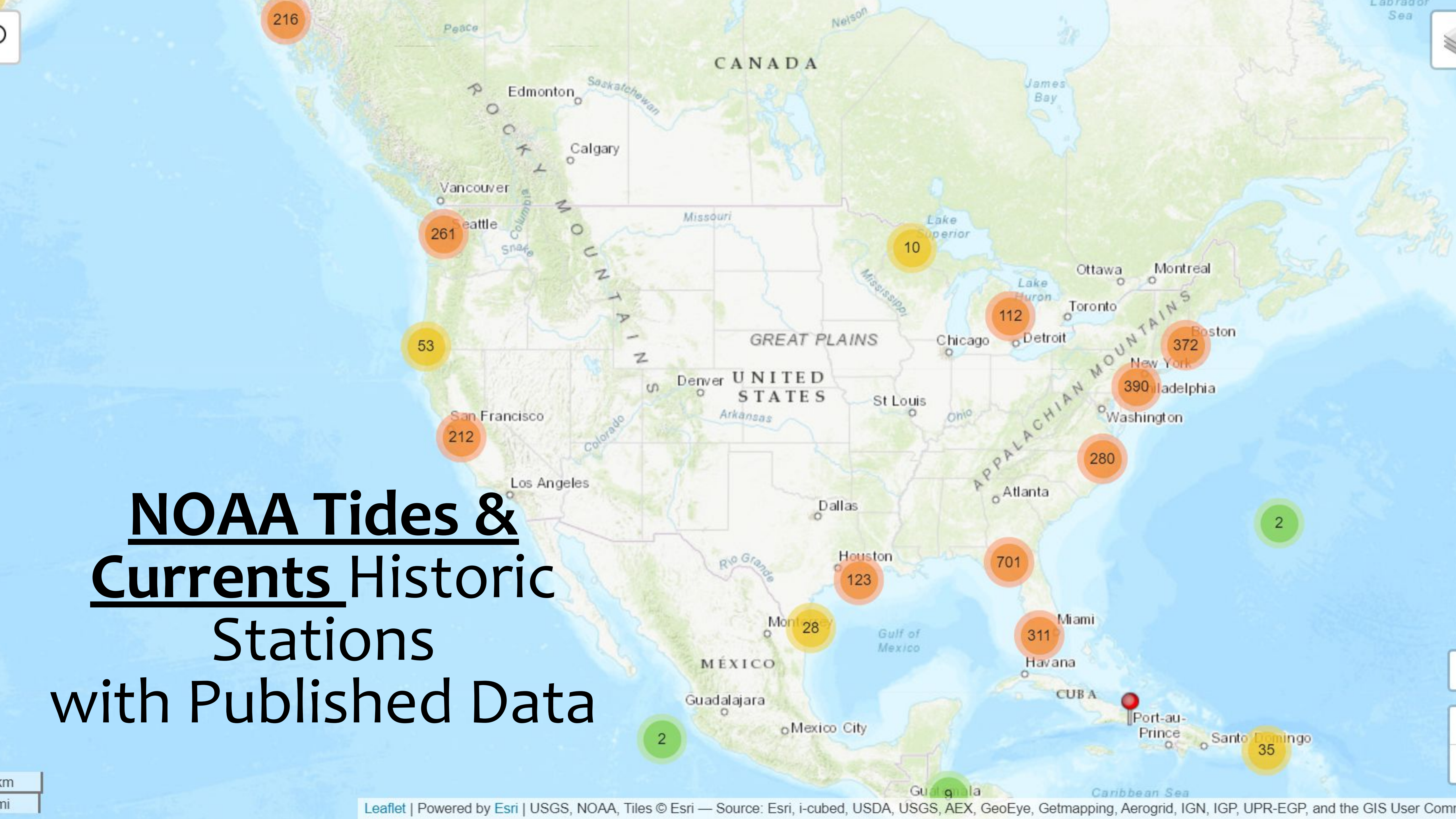


NOAA Tides & Currents

Real-Time Water Level Stations



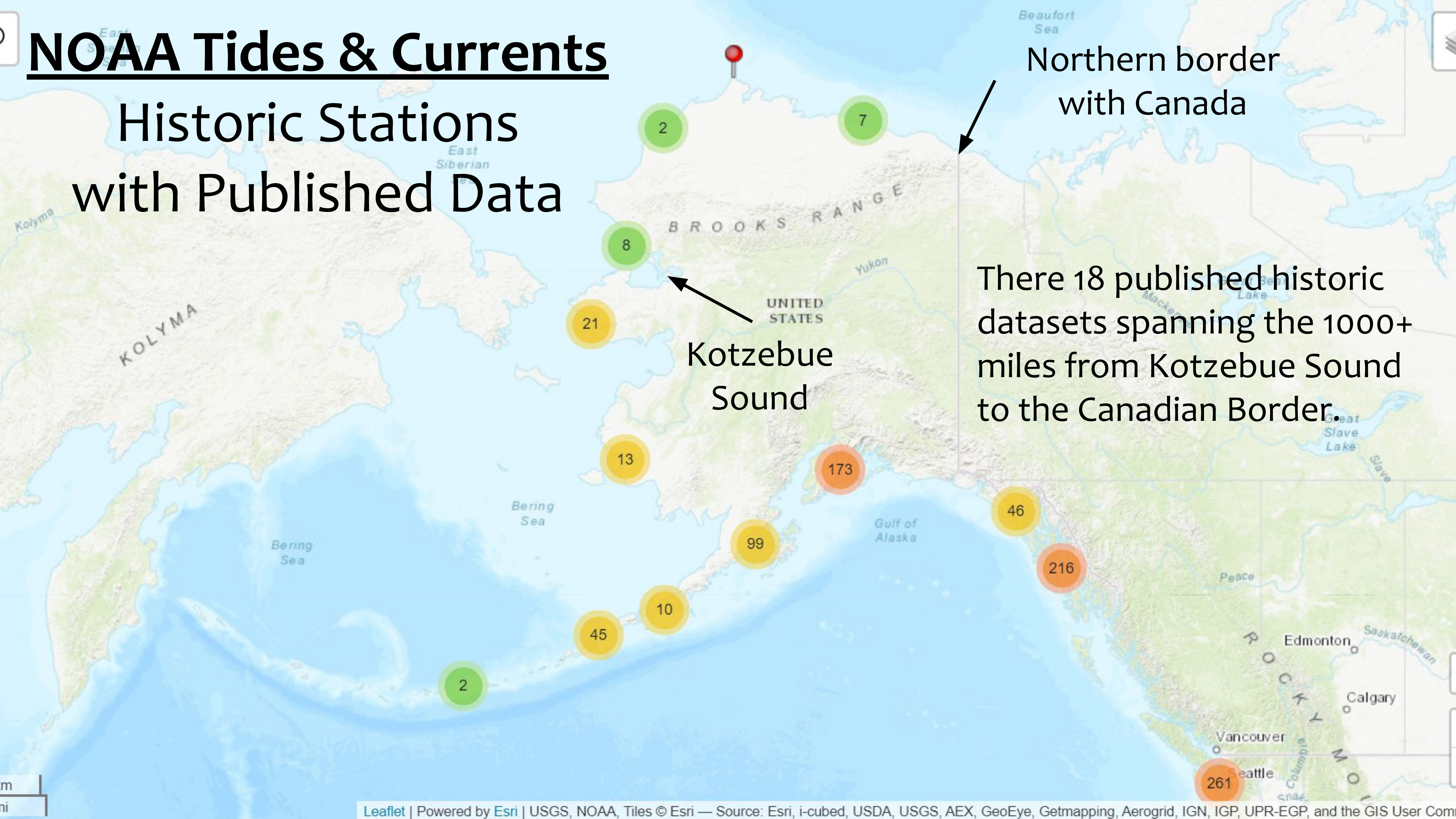
NOAA Tides & Currents Historic Stations with Published Data



NOAA Tides & Currents

Historic Stations with Published Data

There 18 published historic datasets spanning the 1000+ miles from Kotzebue Sound to the Canadian Border.



Weather

November ice extent in Chukchi Sea is well above average of past 30 years

By Davis Hovey, KNOM
Updated: November 19, 2021
Published: November 19, 2021

Sea ice and open water north of Unalakleet in March 2018. (Loren Holmes / ADN)

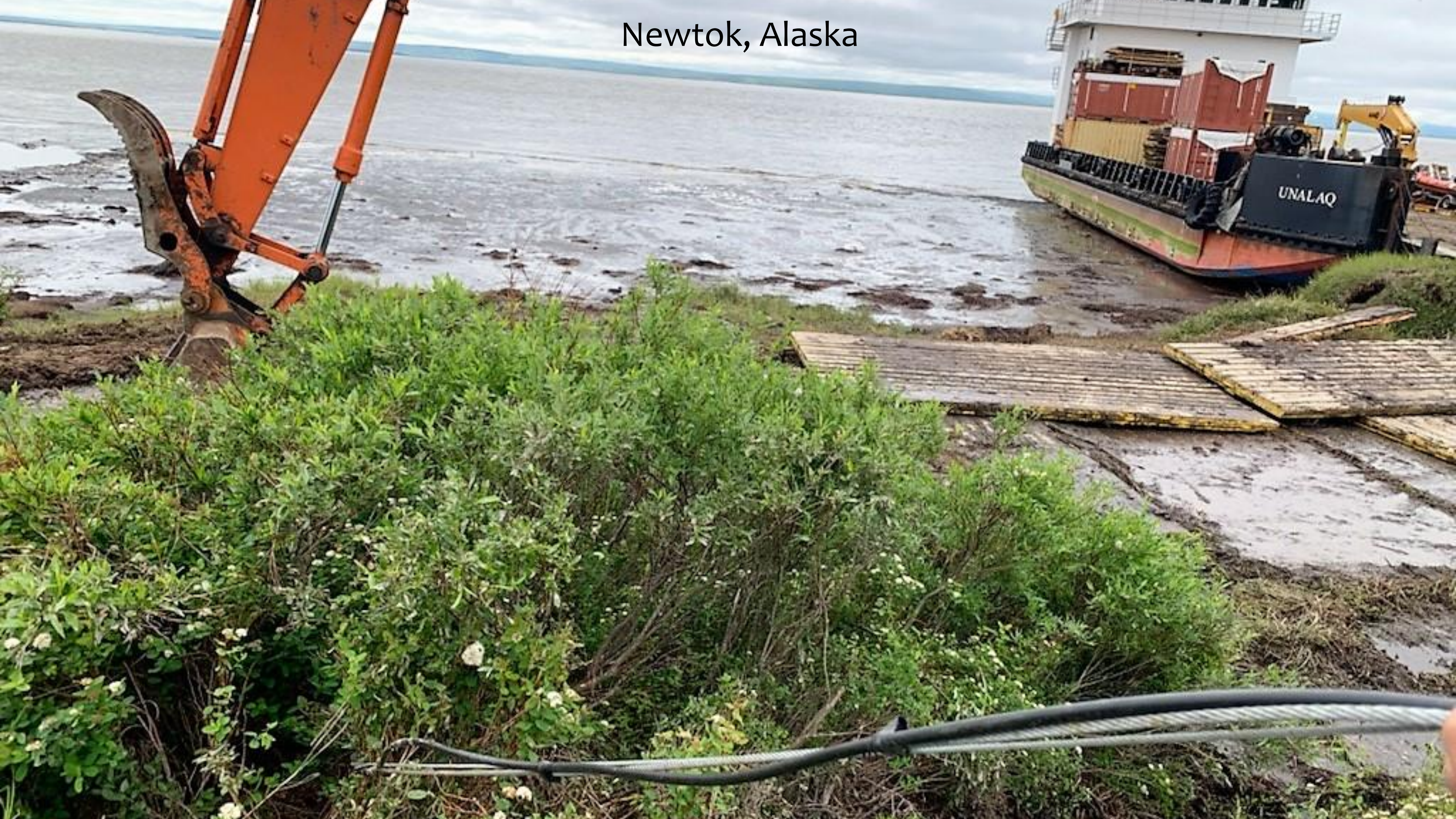
This article originally appeared at KNOM.org and is republished here with permission.

Through the weekend of Nov. 13, ice extent in the Chukchi Sea was well above the month's average of the last 30 years.


Newtok, Alaska


Newtok, Alaska

Newtok, Alaska



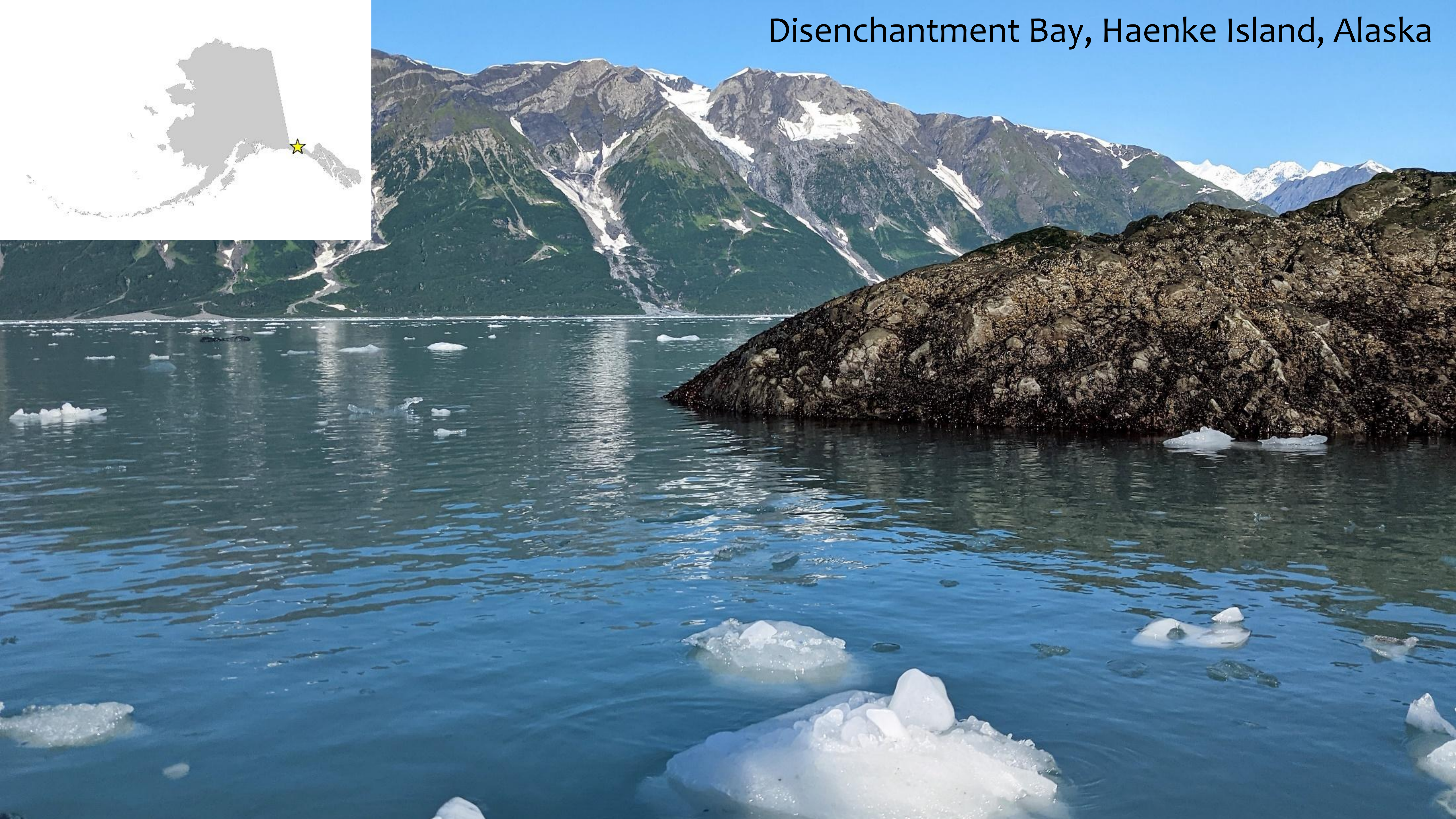

Utqiagvik, Alaska

Egegik, Alaska


Egegik, Alaska


Egegik, Alaska

Disenchantment Bay, Haenke Island, Alaska



Hurricane Reinforced Gulf Coast Water Level Station

Great Lakes Water Level Station

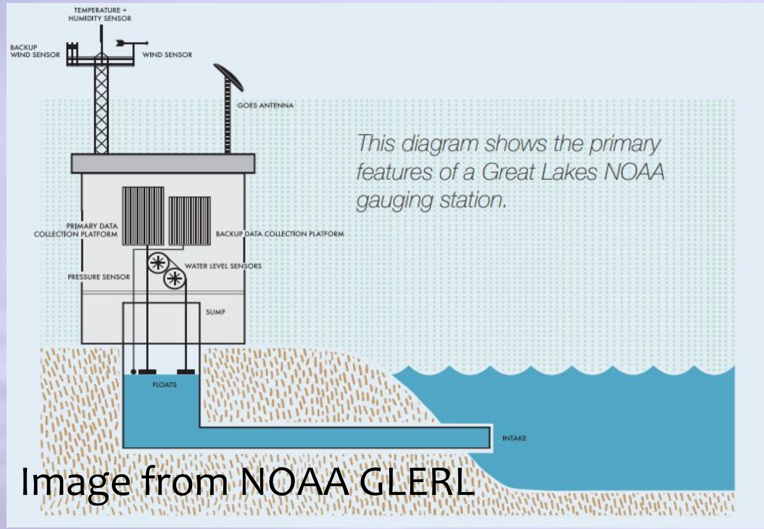
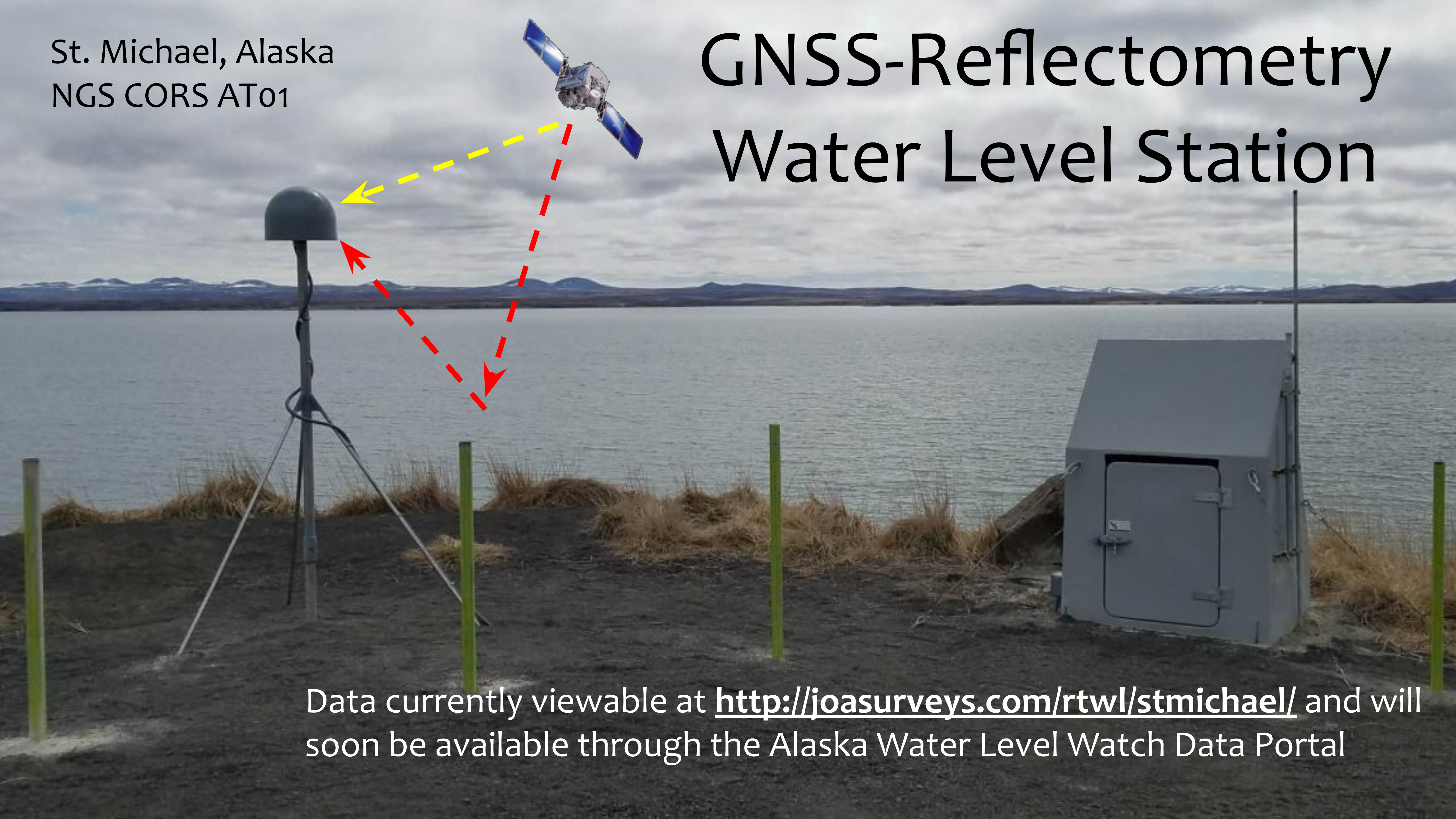


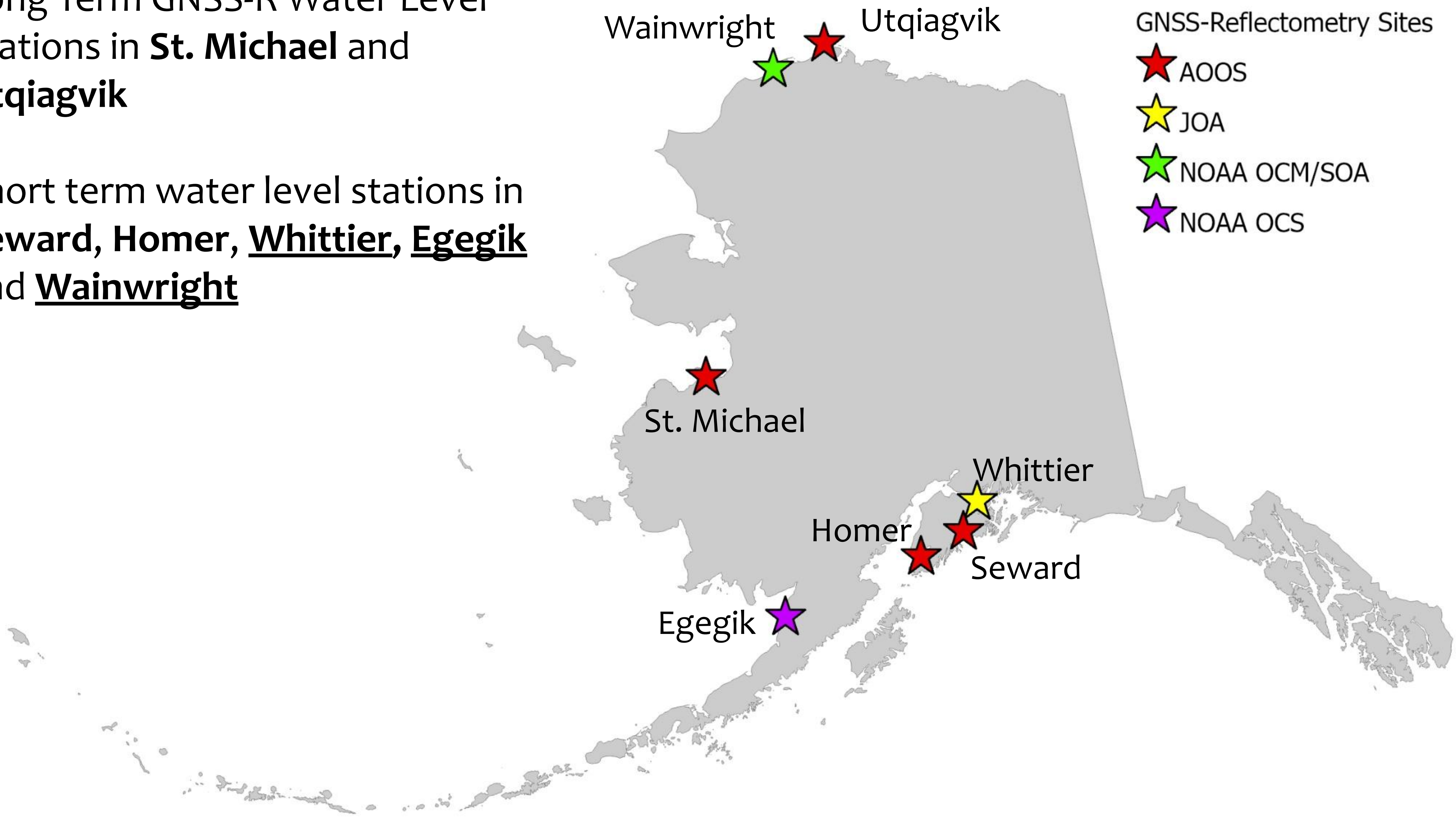
Image from NOAA GLERL

Holland, MI

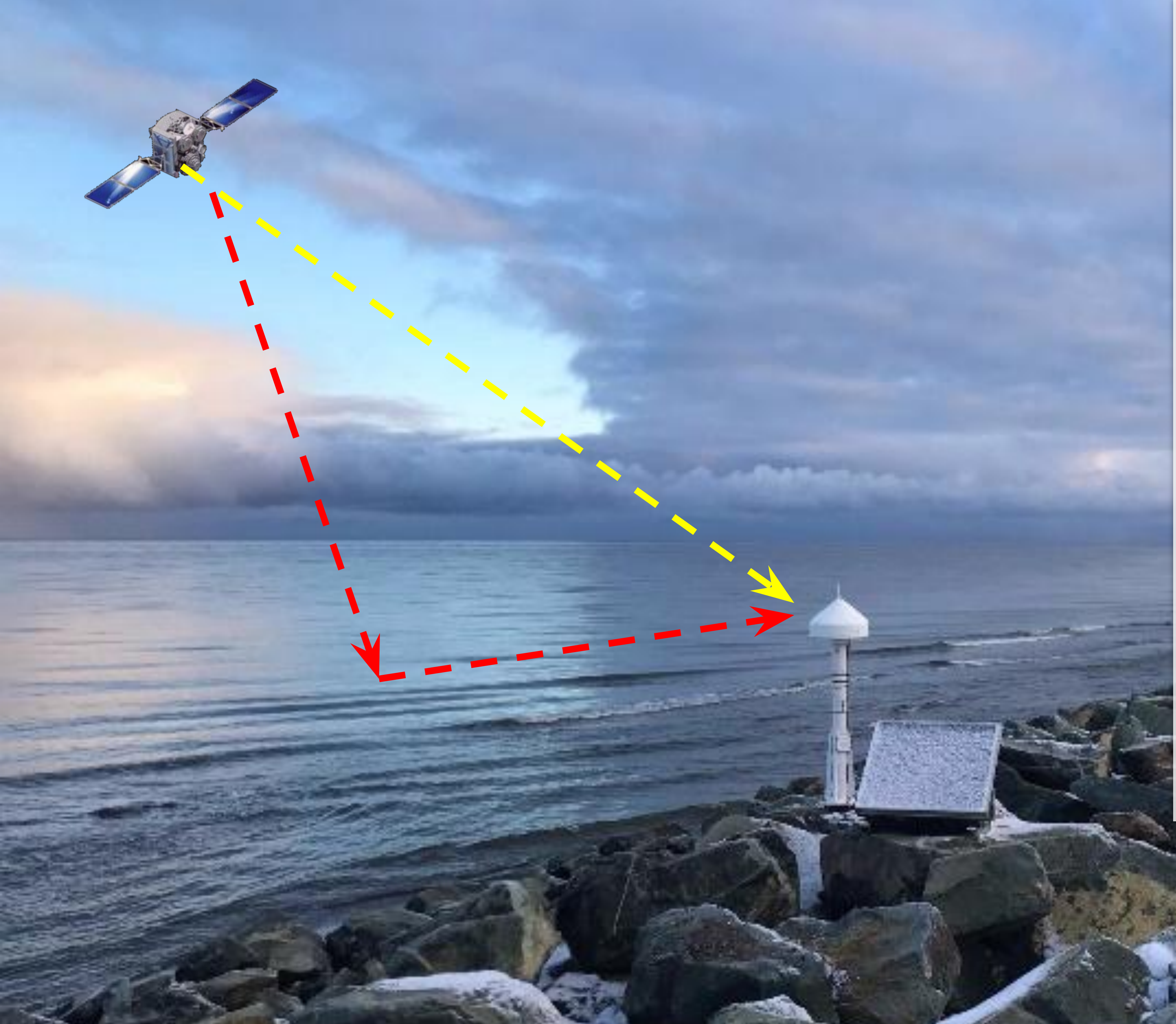

St. Michael, Alaska
NGS CORS AT01
GNSS-Reflectometry
Water Level Station
Data currently viewable at http://joasurveys.com/rtwl/stmichael/ and will
soon be available through the Alaska Water Level Watch Data Portal

Long Term GNSS-R Water Level Stations in **St. Michael** and **Utqiagvik**

Short term water level stations in **Seward**, **Homer**, **<u>Whittier</u>**, **<u>Egegik</u>** and **<u>Wainwright</u>**




Wainwright, Alaska
1.7 km from GNSS-R system to Mooring 1
Mooring 1
Mooring 2
GNSS-R
Google Earth
Image © 2021 Maxar Technologies

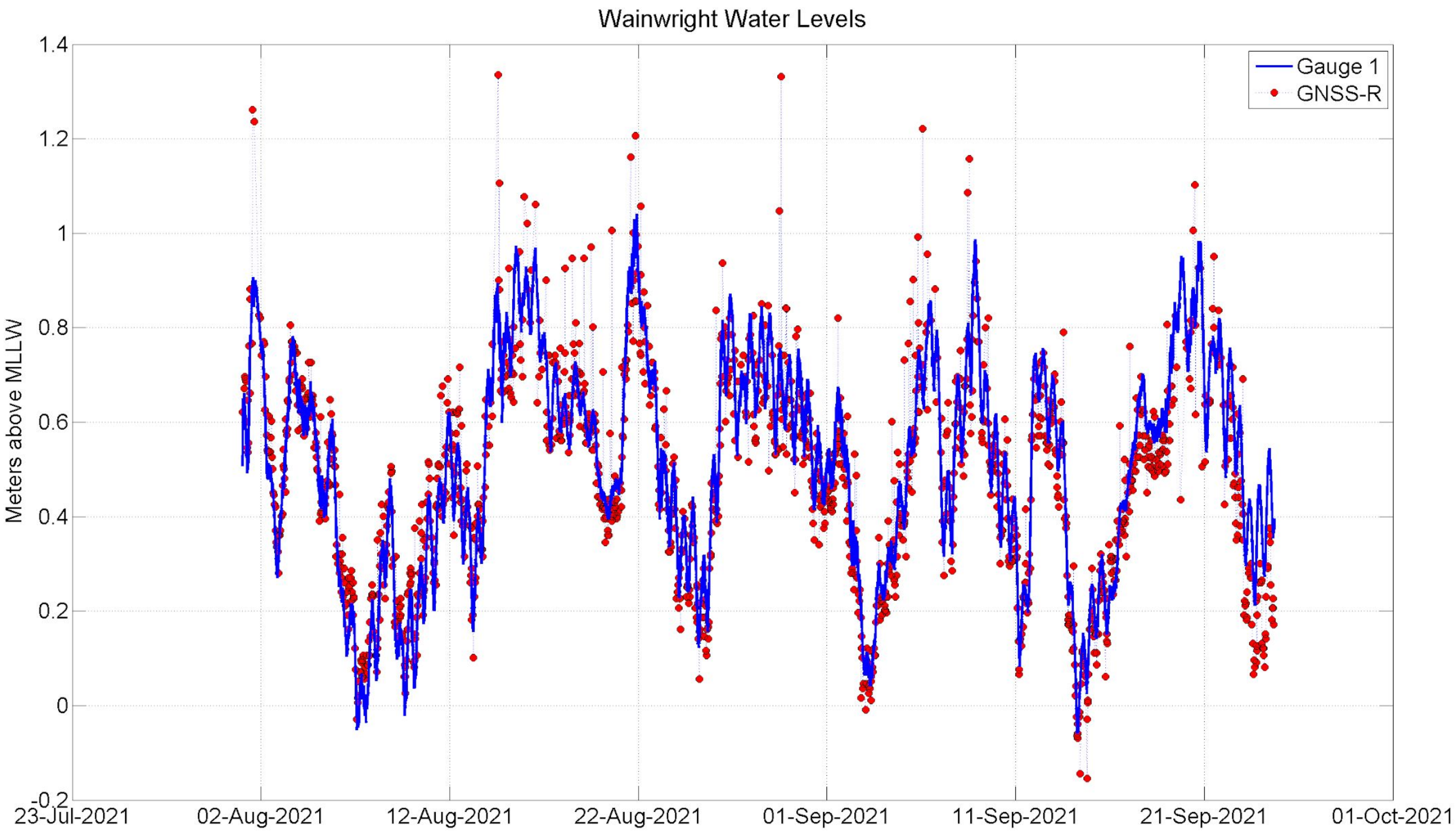


GNSS-Reflectometry Water Level System

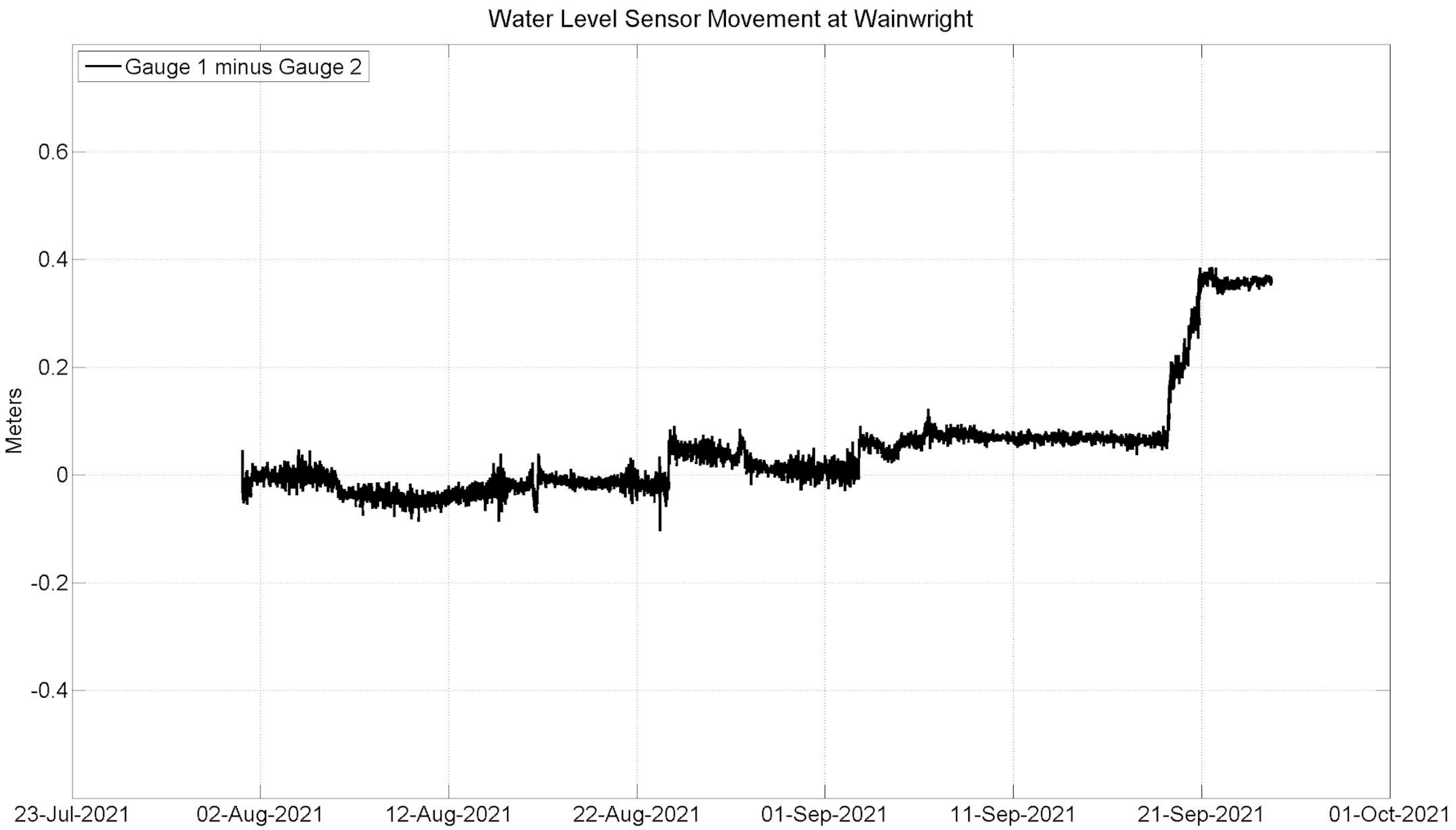
*3D position of antenna is determined from **direct** satellite signal*

*Height of antenna above water determined from **indirect** satellite signal*

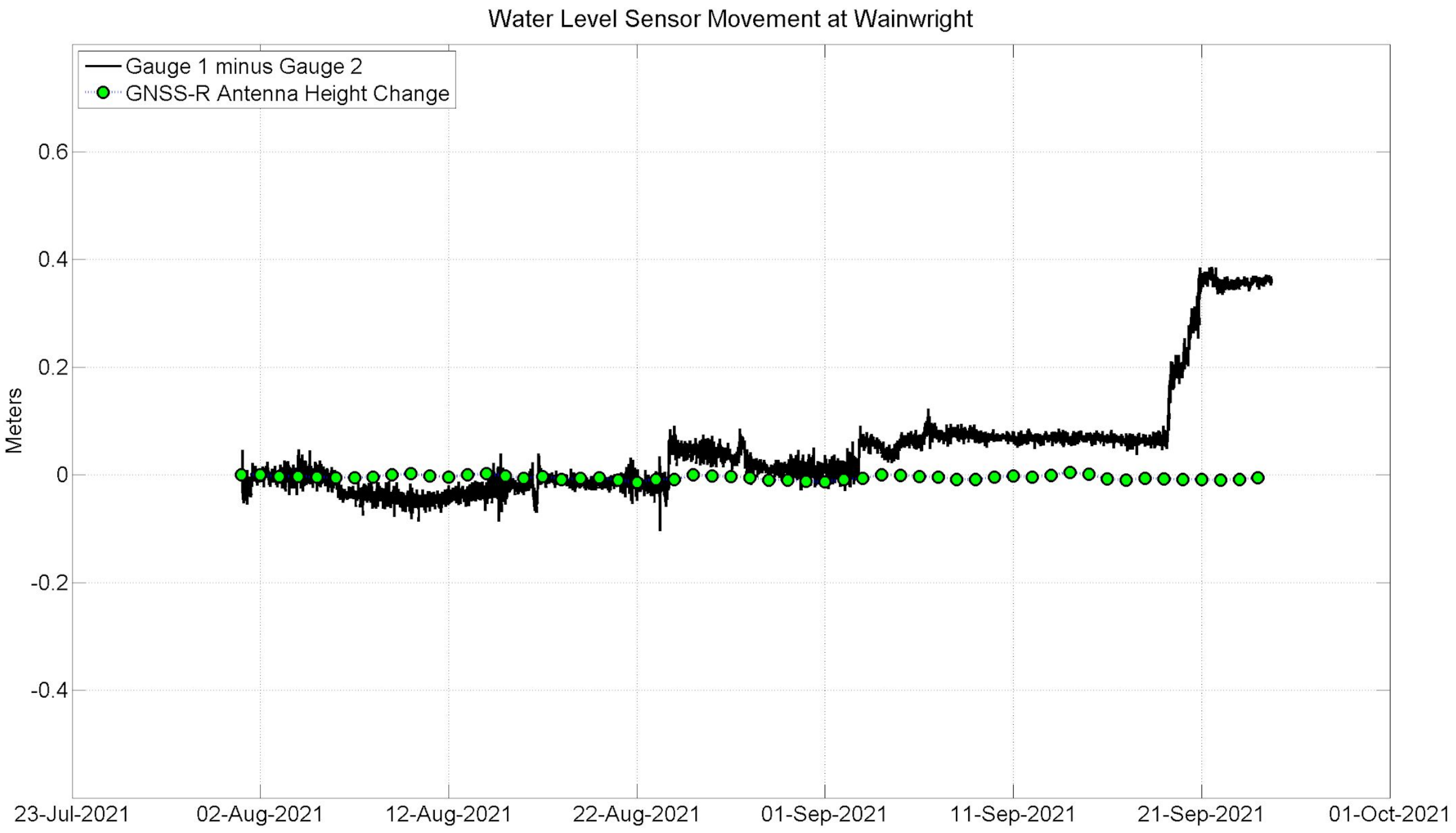
Installation did not require a boat, benchmarks or leveling



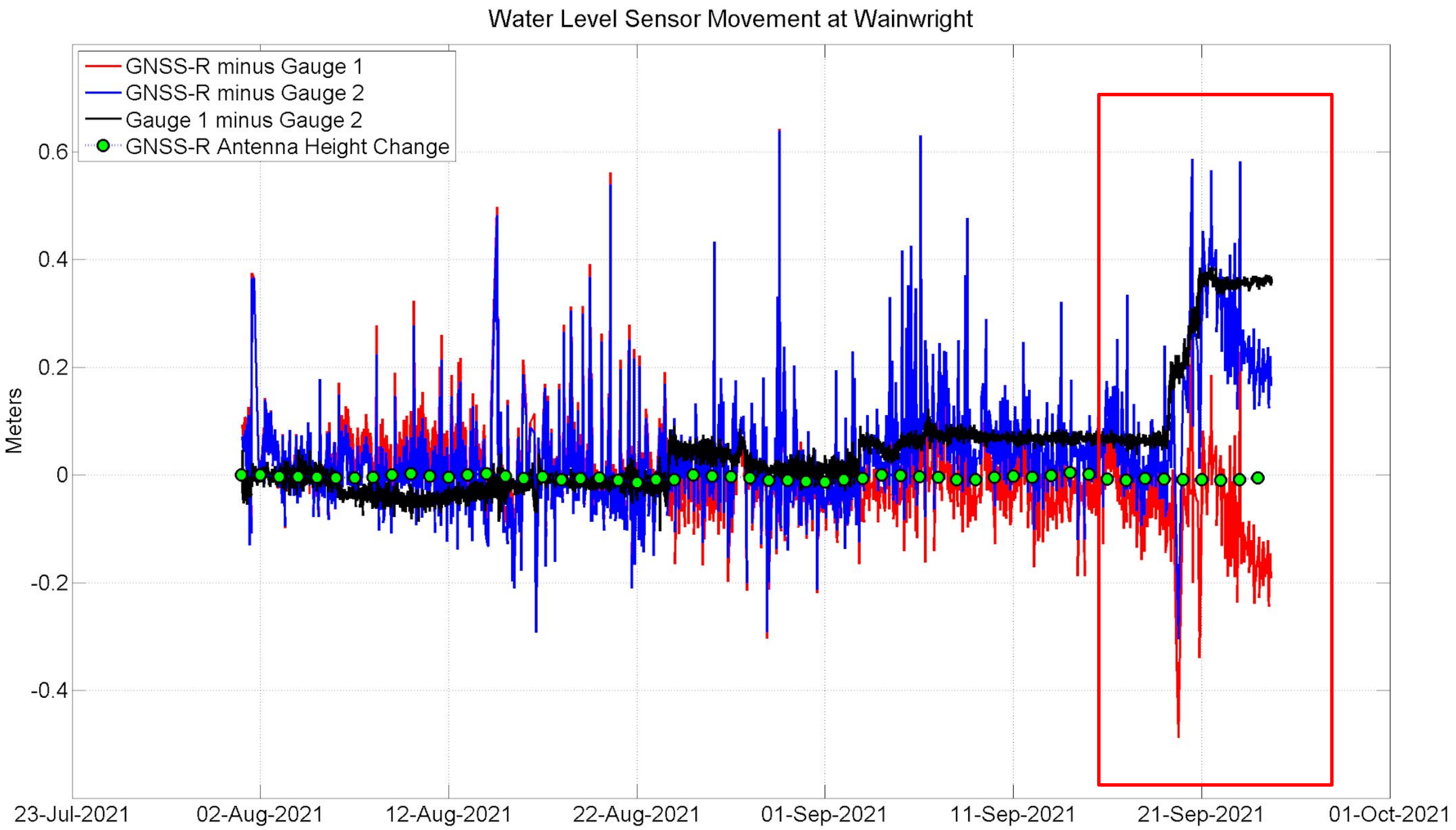
Wainwright Water Levels
Meters above MLLW
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
23-Jul-2021
02-Aug-2021
12-Aug-2021
22-Aug-2021
01-Sep-2021
11-Sep-2021
21-Sep-2021
01-Oct-2021
Gauge 1
GNSS-R



Water Level Sensor Movement at Wainwright
Gauge 1 minus Gauge 2
Meters
0.6
0.4
0.2
0
-0.2
-0.4
23-Jul-2021
02-Aug-2021
12-Aug-2021
22-Aug-2021
01-Sep-2021
11-Sep-2021
21-Sep-2021
01-Oct-2021



Water Level Sensor Movement at Wainwright
Gauge 1 minus Gauge 2
GNSS-R Antenna Height Change
Meters
0.6
0.4
0.2
0
-0.2
-0.4
23-Jul-2021
02-Aug-2021
12-Aug-2021
22-Aug-2021
01-Sep-2021
11-Sep-2021
21-Sep-2021
01-Oct-2021



Water Level Sensor Movement at Wainwright
GNSS-R minus Gauge 1
GNSS-R minus Gauge 2
Gauge 1 minus Gauge 2
GNSS-R Antenna Height Change
Meters
0.6
0.4
0.2
0
-0.2
-0.4
23-Jul-2021
02-Aug-2021
12-Aug-2021
22-Aug-2021
01-Sep-2021
11-Sep-2021
21-Sep-2021
01-Oct-2021

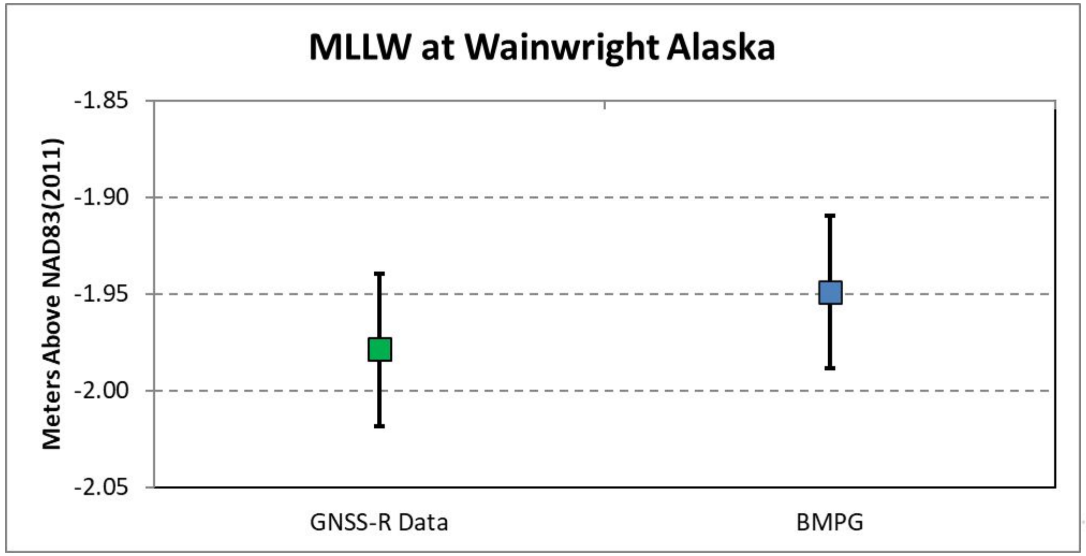
Offshore Wainwright, Arctic Ocean, Alaska

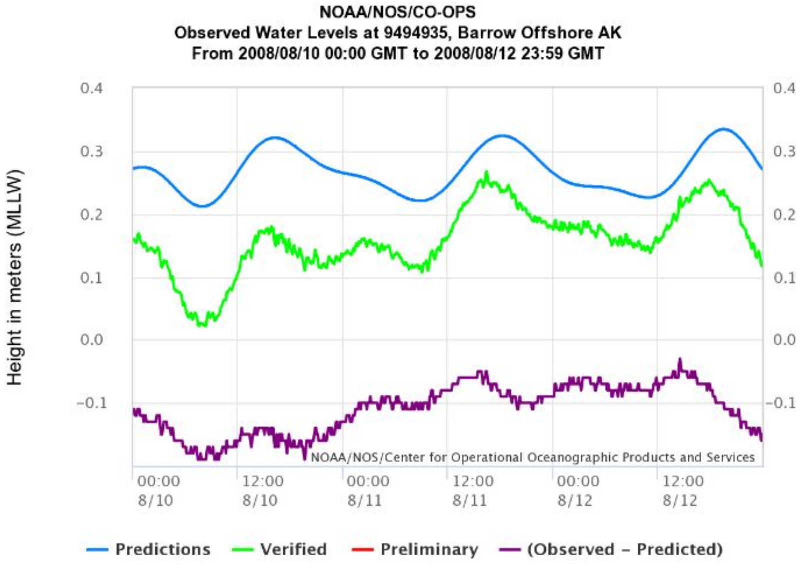
Tide Type: Mixed Semidiurnal

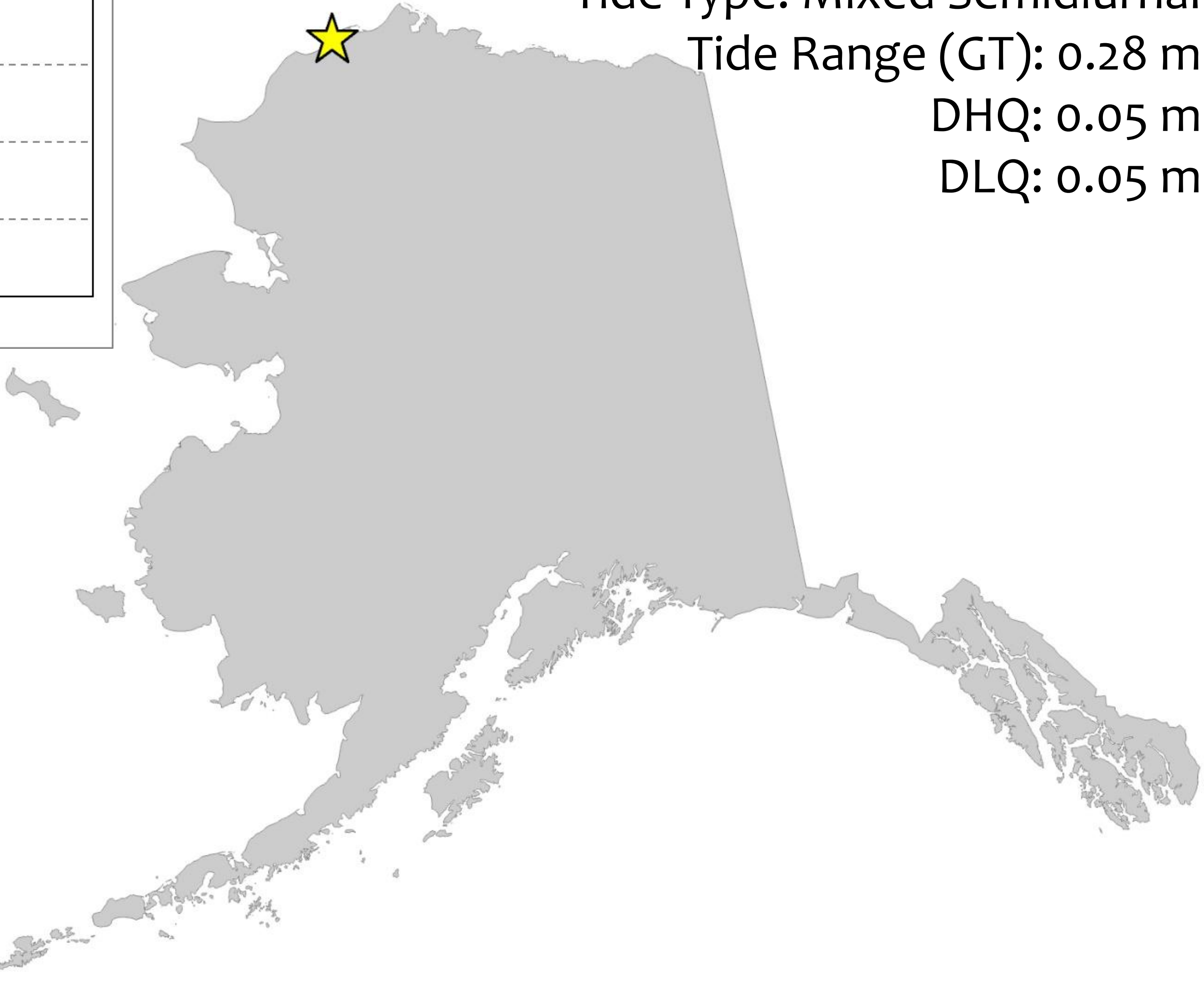
Tide Range (GT): 0.28 m

DHQ: 0.05 m

DLQ: 0.05 m







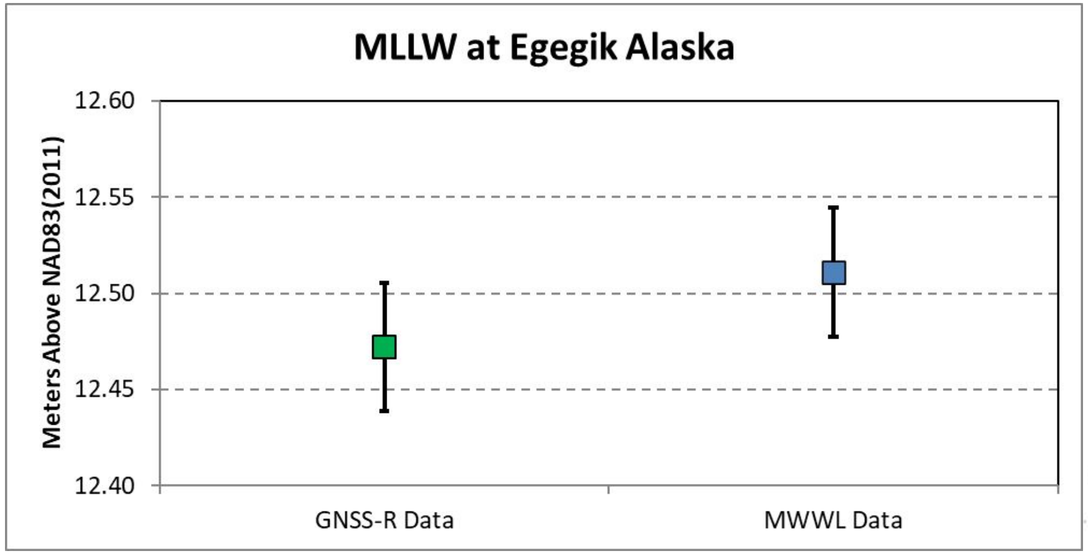
Egegik, Bristol Bay, Alaska

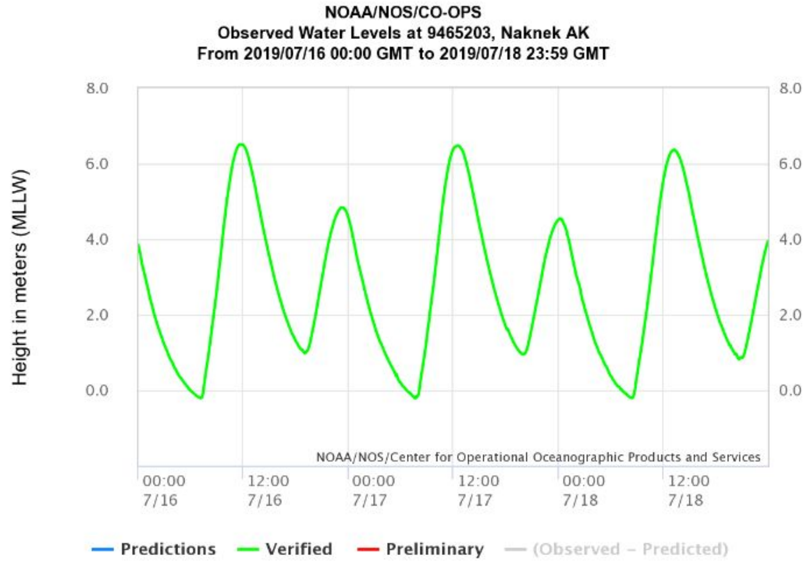
Tide Type: Mixed Semidiurnal

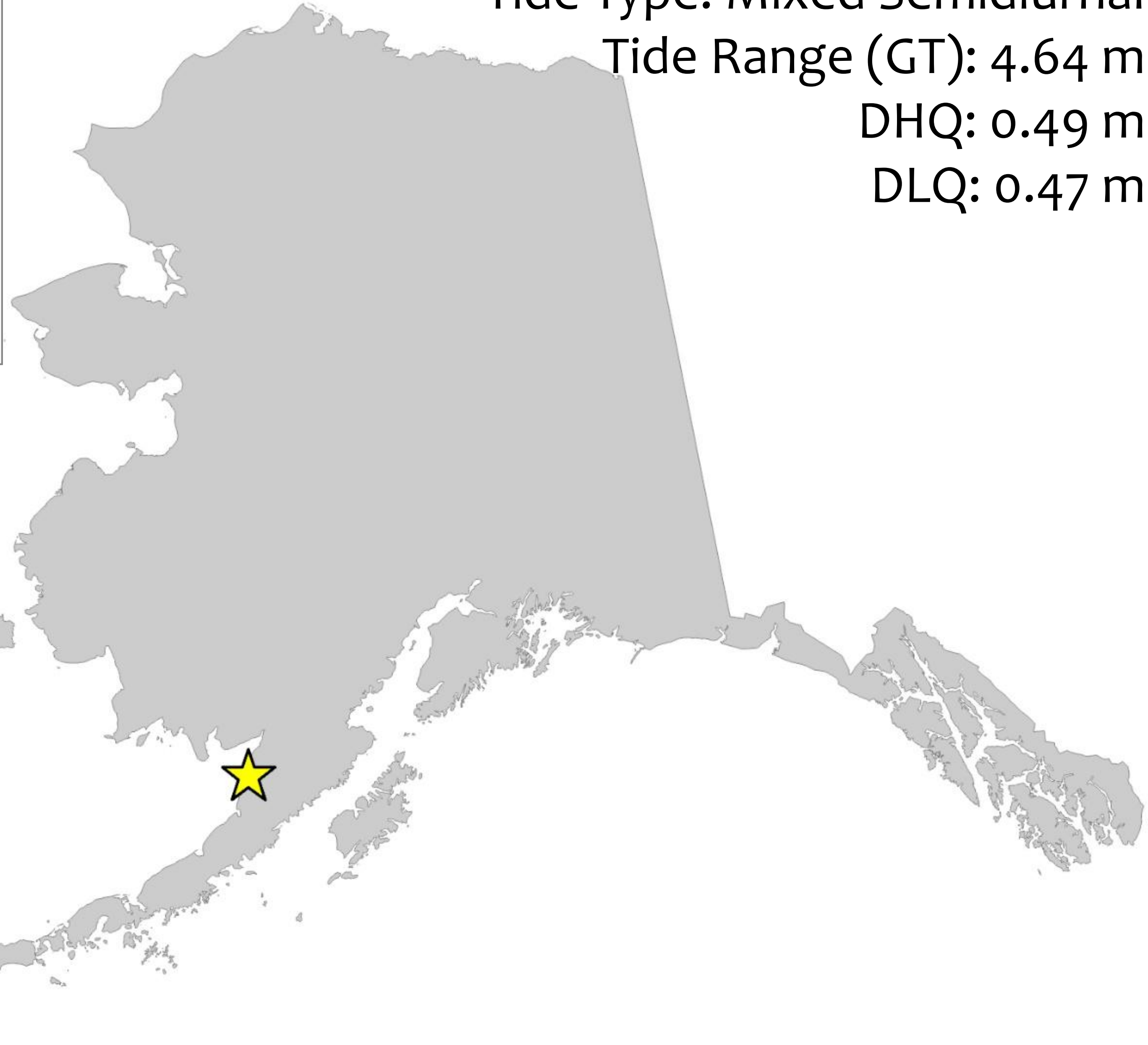
Tide Range (GT): 4.64 m

DHQ: 0.49 m

DLQ: 0.47 m







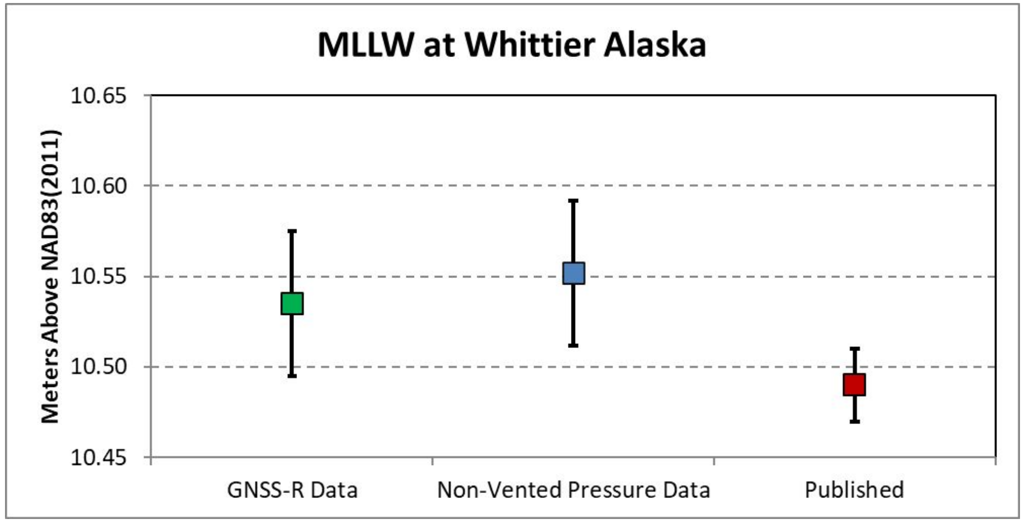
Whittier, Prince William Sound, Alaska

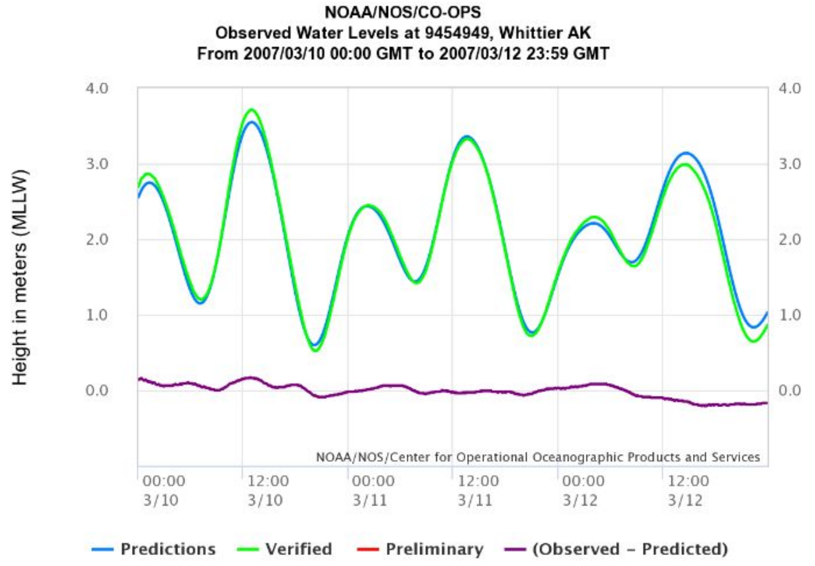
Tide Type: Mixed Semidiurnal

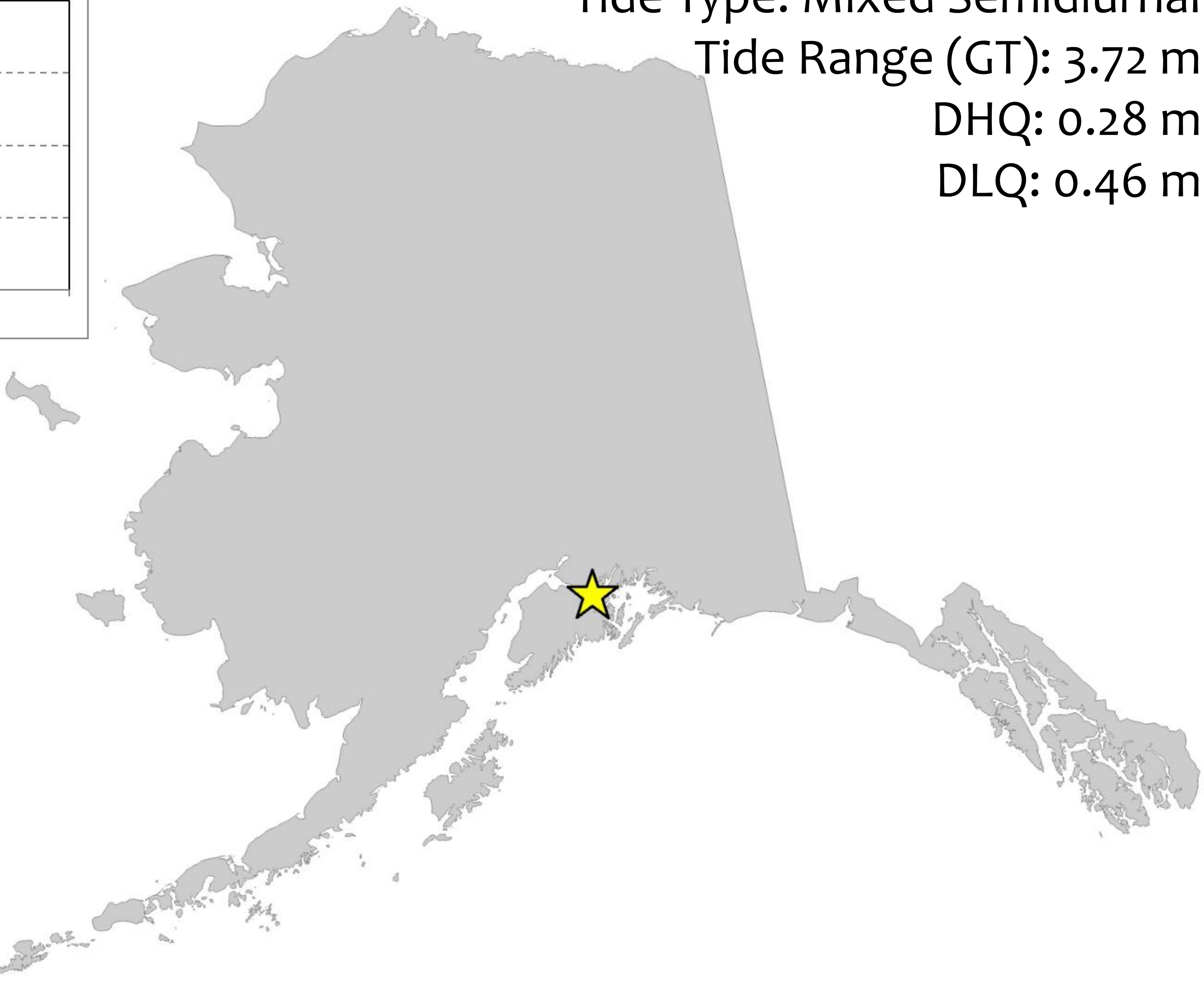
Tide Range (GT): 3.72 m

DHQ: 0.28 m

DLQ: 0.46 m







The Path Forward?

The Path Forward?

The Path Forward!

End of Presentation

Thank you!

NOAA Foundation CORS Program

Will Freeman, NOAA

December 1st 2021 | Virtual

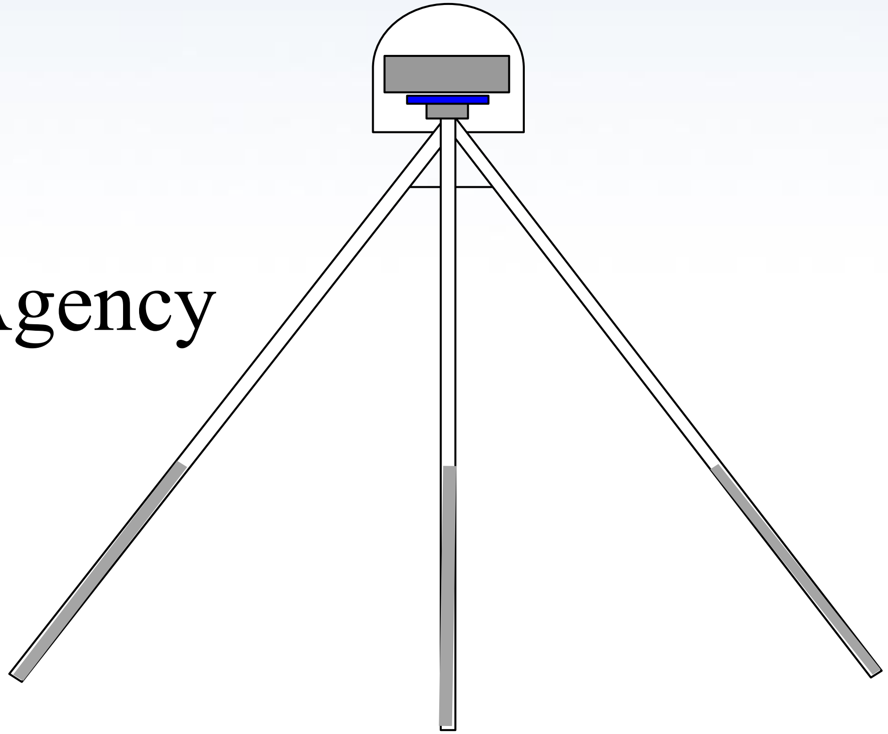
The NOAA Foundation CORS Network

Will Freeman
CORS Program Manager
NOAA/NGS/Spatial Reference System Division

December 01, 2021 2021 Alaska Coastal and Ocean Mapping Summit

Outline

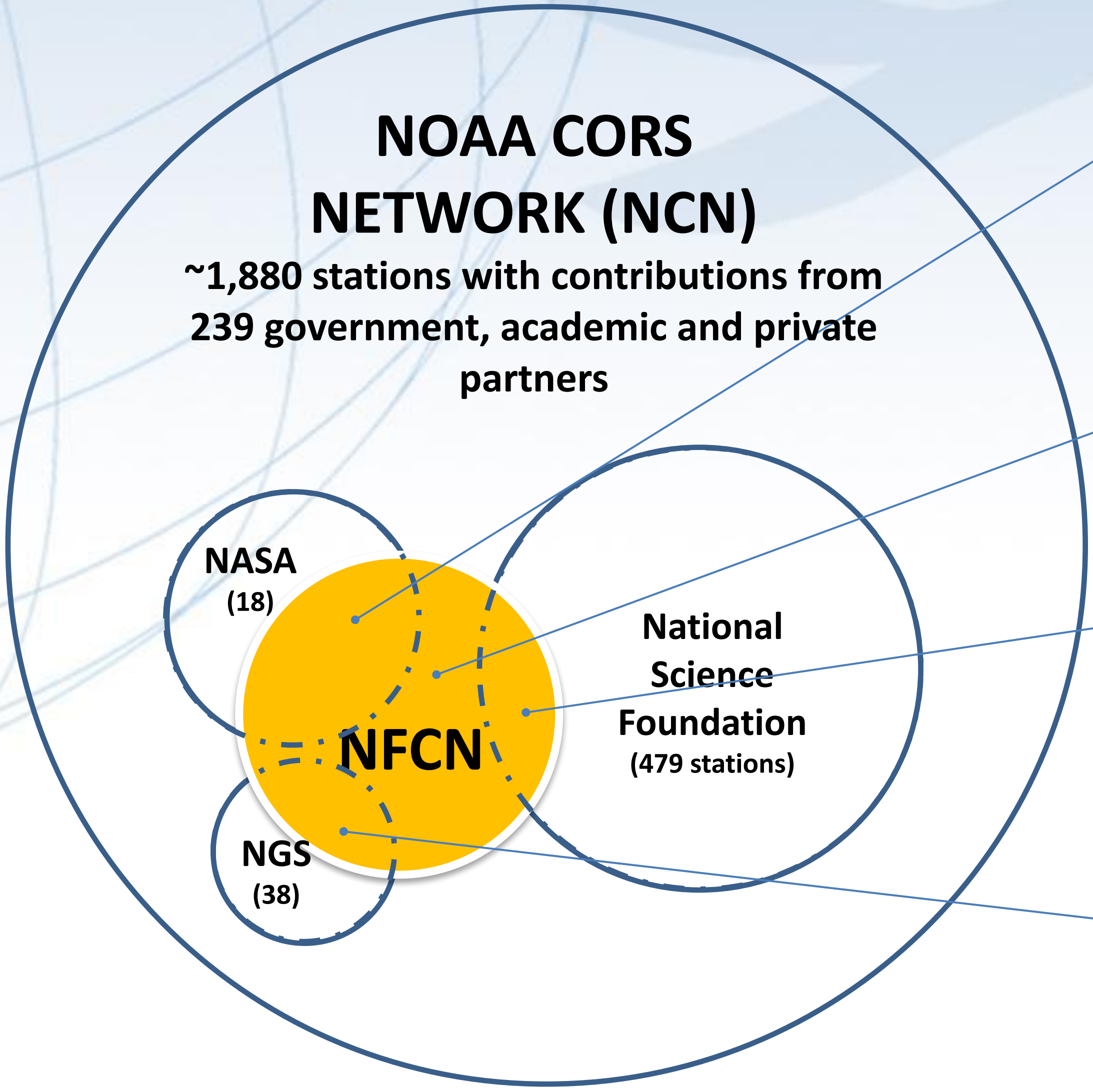
- What are the Foundation CORS
- How are they different from other CORS
- Why do we need them
- Challenges managing FCORS stations
- NGS/National Geospatial-Intelligence Agency (NGA) – FCORS Partnership
- Final Program Updates



What are the Foundation CORS (FCORS)

- A Multi-Agency Partnership between NOAA, NSF, NASA and DoD
- FCORS stations are similar in configuration to some of the existing ~1,880 partner CORS stations that make up NOAA CORS Network (NCN), but with some important differences *(as described in the following slides)*
- NGS has identified a set of **36 stations** across the U.S. and its territories that meets this criteria and provides consistent national access to the NSRS.
- This subnetwork of the NCN is known as the **NOAA Foundation CORS Network, or NFCN.**

NOAA Foundation CORS Network (NFCN)



NASA

12 FCORS (18 total NCN stations)

NFCN 36 stations

NSF

6 FCORS (479 total NCN stations)

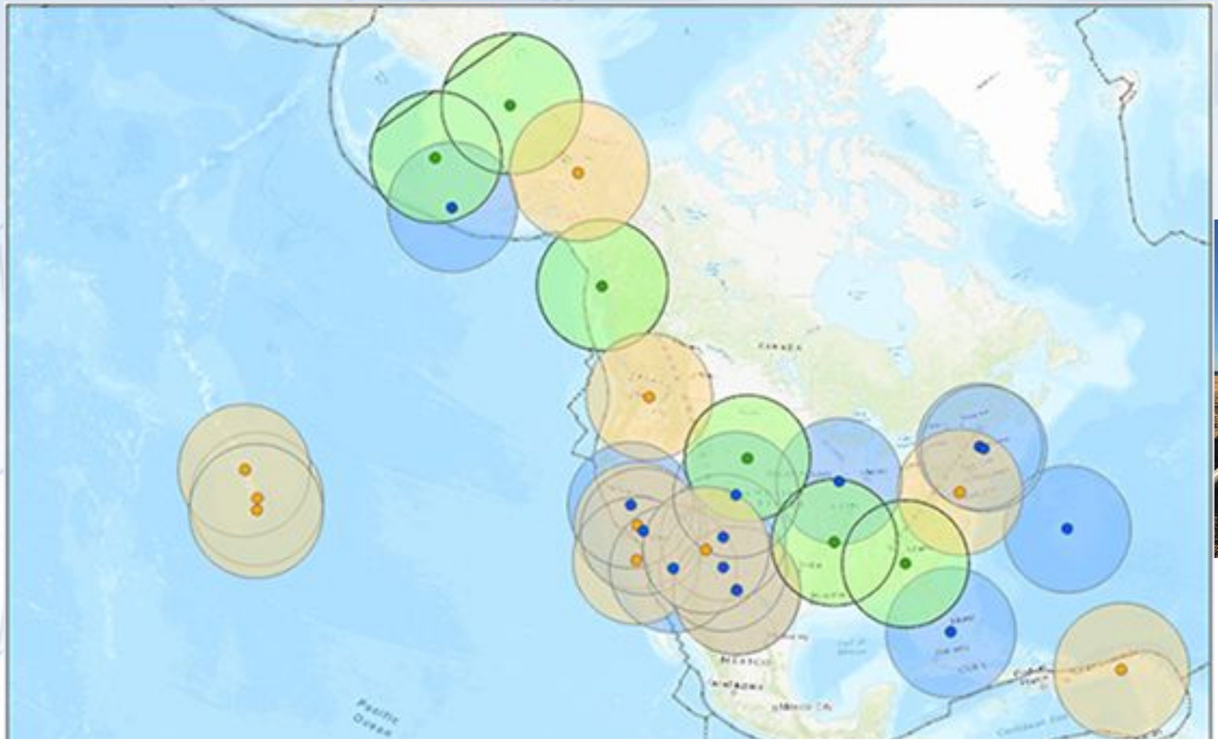
NGS

7 existing FCORS stations

11 new CORS stations (FY22–FY25)

(38 total NCN stations)

FCORS Station Locations



Federal Partners	Site ID	Location
National Science Foundation (NSF) **Existing Sites** Program: EarthScope Plate Boundary Observatory (PBO)	AB09	Wales, AK
	P777	Dennard, AR
	P804	Georgia
	AB51	Petersburg, AK
	ATQK	Atqasuk, AK
	P043	Wyoming
National Aeronautics and Space Administration (NASA) **Existing Sites** Program: Global GNSS Network (GGN), operated by Jet Propulsion Laboratory	CRO1	Saint Croix, VI*
	BREW	Brewster, WA*
	FAIR	Fairbanks, AK
	GODE	Greenbelt, MD*
	GOL2?	Goldstone, CA*
	MDO1	McDonald Observatory, Texas*
	MONP	Mount Laguna, CA*
	PIE1	Pie Town, NM*
	GUAM	GUAM
	KOKB	Kauai, HI*
	MKEA	Mauna Kea, HI*
	HAL1	Haleakala, HI*
NOAA- National Geodetic Survey (NGS) **Existing and New Sites** Program: Continuously Operating Reference Stations (CORS)	ASPA	American Samoa
	CNMR	Saipan, TQ
	GUUG	GUAM*
	BRSG	Bermuda
	FLF1	Richmond, FL*
	WES2	Westford, MA*
	TMG2	Boulder, CO
	NEW	Apache Point, NM*
	NEW	Fort Davis, TX*
	NEW	Fort Irwin, CA*
	NEW	Hancock, NH*
	NEW	Los Alamos, NM*
	NEW	Kitt Peak, AZ*
	NEW	Owens Valley, CA*
	NEW	Cold Bay, AK*
	NEW	North Liberty, IA*
TBD	TBD	Existing location in Caribbean
	TBD	Existing location in Caribbean

A set of federally-operated, ultra-high-quality, high-reliability stations with the longevity to guarantee citizens access to official NSRS positions and support international positioning consistency efforts.

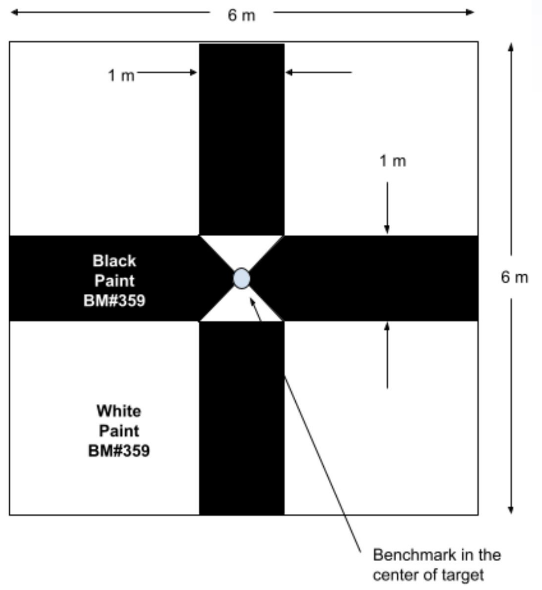
26 in North America, 4 in the Pacific, 3 in the Caribbean, and 3 in the Marianas.

How are they different from other CORS?

- Federally-owned and operated "backbone" to the NSRS
- Stations chosen for location, longevity, and high quality
- Located on Federally owned land with long term agreements – monumentation service life goal of 100+ years
- Operational Goals:
  - Non-operational time minimized for each station
  - 90% of NOAA Foundation CORS Network available at any time (no more than 4 stations non-operational)
- All stations are critical to some function of the new NSRS
- 22 out of 36 stations are (currently or will be) co-located with other space geodetic stations supporting the IGS/ITRF
- NGS conducts Local tie surveys ("IERS site survey") will link together all geodetic instruments/marks at the site every 5 years.

NGS FCORS Stretch Goals

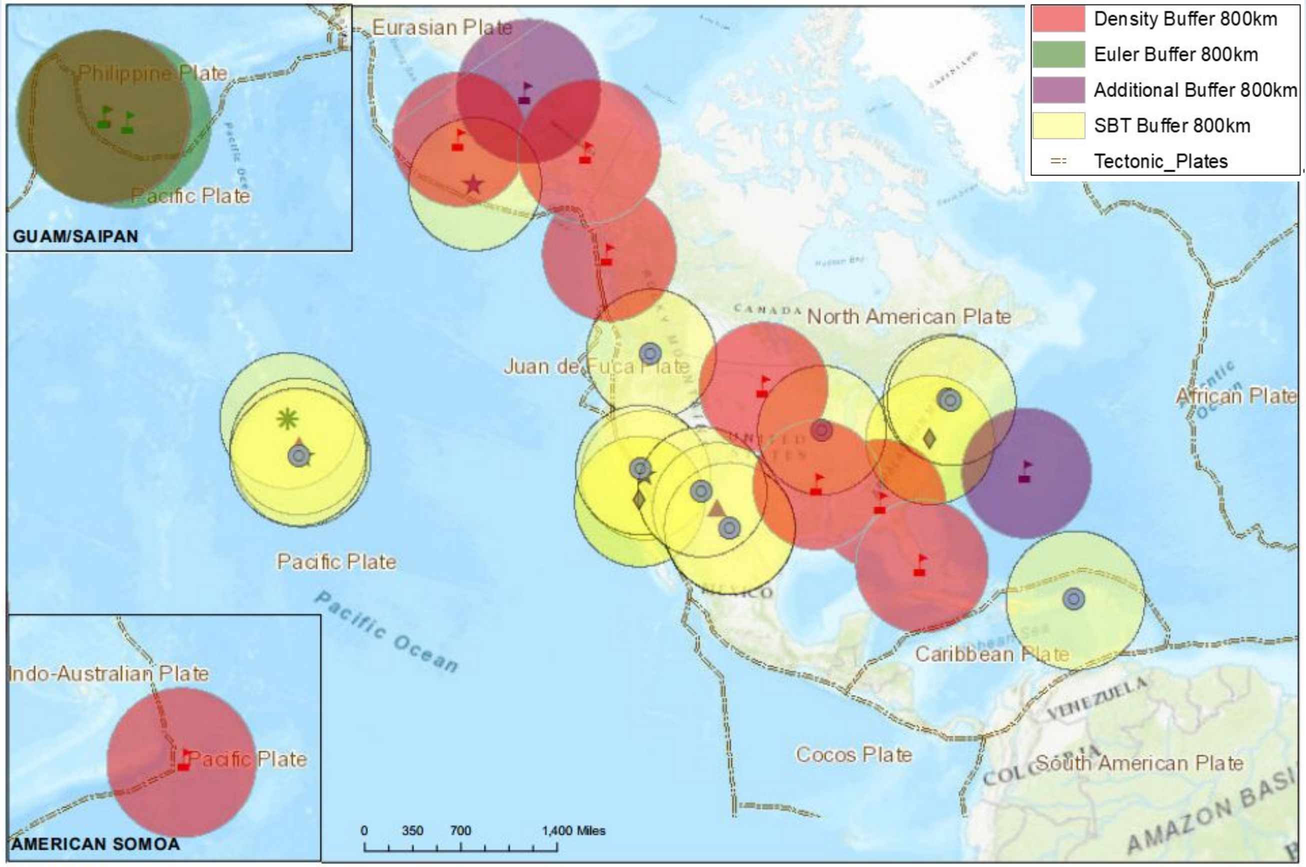
- FCORS station, installation of:
  - **Synthetic Aperture Radar (SAR) passive corner reflectors** (ascending and descending at each FCORS station)
    - Potential joint NGS / NASA project (NASA funded, NGS executed)
    - These efforts will directly support calibrating and validating (cal/val) Sentinel-1 and NISAR vertical velocity data for surface deformation processes
  - **Optical targets**
    - Support remote sensing and LIDAR applications
    - Example of a 6 m x 6 m target for VLBA Fort Davis



Why do we need Foundation CORS?

The Foundation CORS targeted locations provide:

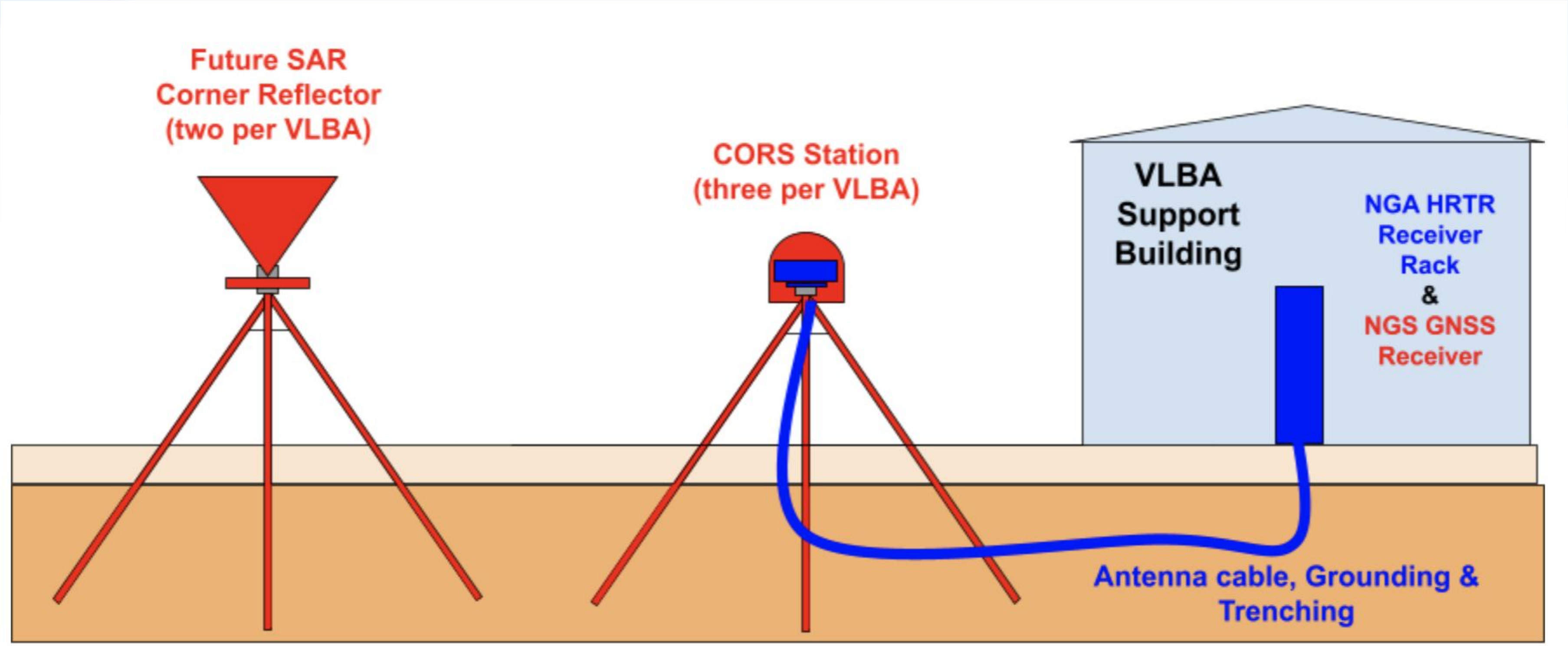
1. A geographic distribution no greater than 800 km to provide 1.5 cm accuracy ellipsoidal height results through NGS' OPUS tools anywhere in the U.S.
2. Support for the ITRF by co-locating at existing space-based geodetic sites.
3. Favorable geometry to monitor tectonic plate (Euler Pole) rotation.
4. Gap Filling in international areas where foundational stations are needed to support the U.S. NSRS, e.g. Caribbean



Challenges Managing FCOR/CORS Stations

- **Communications**
  - Cell modems (ex: RV50) are ideal, but don't work in remote or poor coverage areas
  - Local networks, a delicate balance NOAA IT requirements and the host IT security requirements
- **Lightning Strikes** - Endless battle of fried equipment, *even with surge protection*
- **Power Quality** – receivers are sensitive to voltage fluctuations
- **Poor Grounding** –
  - Potential source of a lot of station performance issues (true for any sensitive electronics)
  - Soil resistance not tested prior to station design/configuration, nor tested annually
- **No dedicated Lightning Protection System**
  - NGS plans to test lightning protection systems at the NGS Corbin, VA Testing & Training Center
- **Station Equipment Configuration Management**
  - Wide array of different equipment configurations create challenges for remote troubleshooting
- **Travel** –
  - remote locations are expensive to visit to make repairs or station upgrades

NGS/National Geospatial-Intelligence Agency (NGA) – FCORS Partnership



NGS/National Geospatial-Intelligence Agency (NGA) – FCORS Partnership

Location	Space	Site Recon	Design Status	Installation Status
NEW - NGS / NGA Partner NFCN Stations - NGS provides monumentation; NGA provides equipment				
Saint Croix, VI	VLBA			
Hancock, NH	VLBA	10/27/2021	0%	
North Liberty, IA	VLBA			
Fort Davis, TX	VLBA	5/25/2021	100%	~ Spring 2022
Los Alamos, NM	VLBA			
Pie Town, NM	VLBA	5/25/2021	100%	~ Spring 2022
Kitt Peak, AZ	VLBA			
Owens Valley, CA	VLBA			
Brewster, WA	VLBA			
Mauna Kea, HI	VLBA			
NEW - Other FCORS Stations - NGS Installation (NGS provides monumentation & all equipment)				
Apache Point, NM	SLR	5/26/2021		
Cold Bay, AK	DORIS			
Potentially additional FCORS stations*....stay tuned*	DORIS, other			

Final Program Updates

- NGS is currently in the process of developing a CORS Comprehensive Plan (CCP)
  - Comprehensive 5-year plan to evaluate current operations and evaluating way to improve, expand and streamline services
  - Includes coordination and feedback from our stakeholders and partners
- Funding – potential new program funding from:
  - NASA for SAR corner reflector design & deployment
  - Infrastructure Investment and Jobs Act
- Evaluating the need for redundant FORS stations
- Support Service Contract –
  - NOAA award of new 5-year CORS support contract in FY22

Foundation CORS at NGS' Table Mountain Geophysical Observatory in Boulder, CO (ID: TMG2)

Thank You

Will.freeman@noaa.gov

NGS Foundation Website

Session Q&A

Ask questions of our presenters by typing them into the question box, found in the menu bar to the right. Click the triangle next to “Questions” to expand.

Poll Question:

What do you see as the path forward for coastal mapping in Alaska?

Please type your thoughts into the questions box found in the menu bar to the right. Click the triangle next to “Questions” to expand.