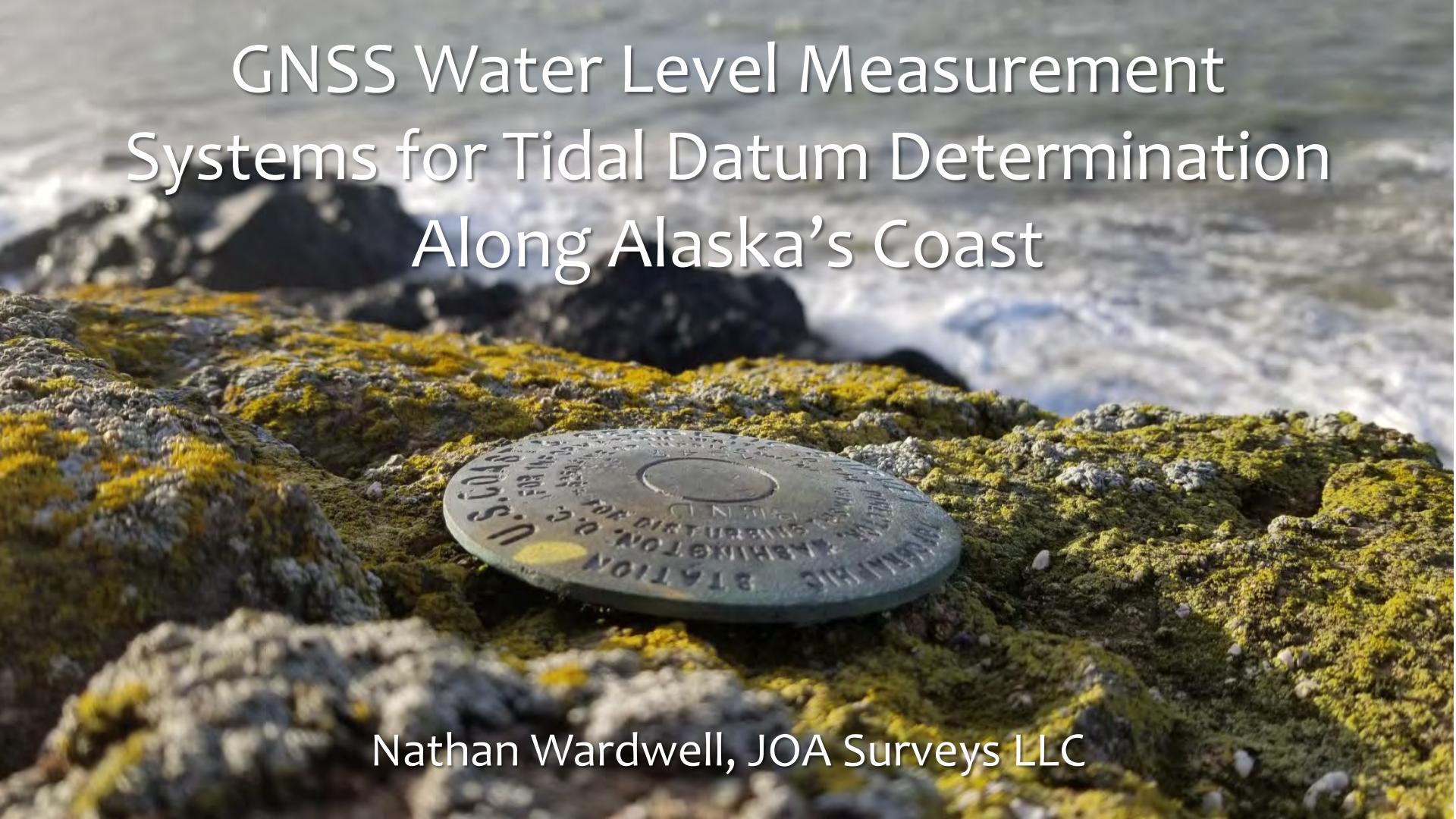
GNSS Water Level Measurement Systems for Tidal Datum Determination Along Alaska's Coast



Nathan Wardwell, JOA Surveys LLC

Presentation Overview

* Overview of JOA Surveys
* Comparison of traditional and GNSS water level measurement systems
* Examples from recent GNSS deployments

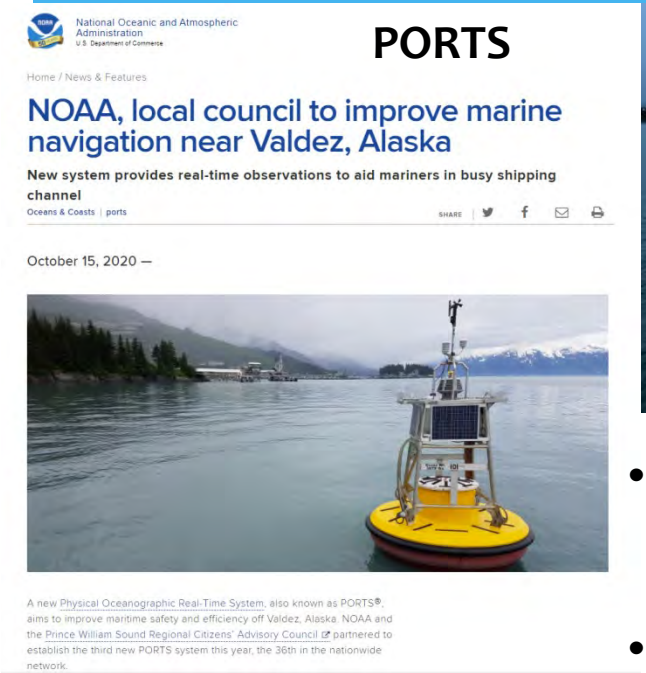
Company Overview

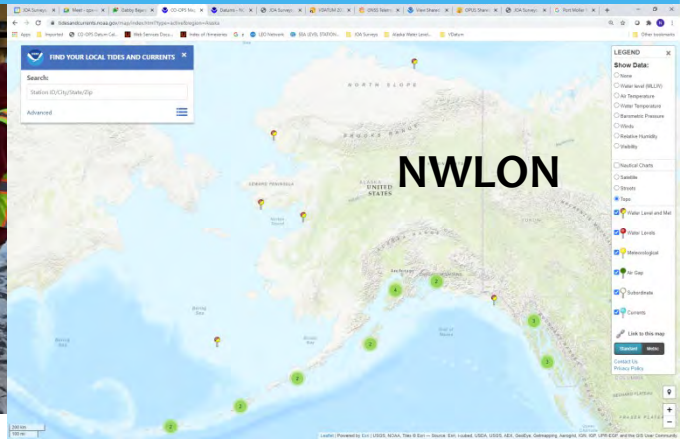
* Small Business located in Anchorage AK
* Owners (3)
* Full Time Employees (4)
* Part Time/Seasonal Employees (10)
* Land Surveyor Licensed in Alaska (3)
* International Hydrographic Organization Cat A Hydrographer (1)
* Geospatial Information Science Certificate (1)

Company Overview

* Active Coastal Projects
  * Alaska (OCS, CO-OPS, AOOS, NPS, USACE)
  * Caribbean (CO-OPS)
  * Great Lakes (CO-OPS)
  * America Samoa (USACE)

PORTS & NWLON Station Services

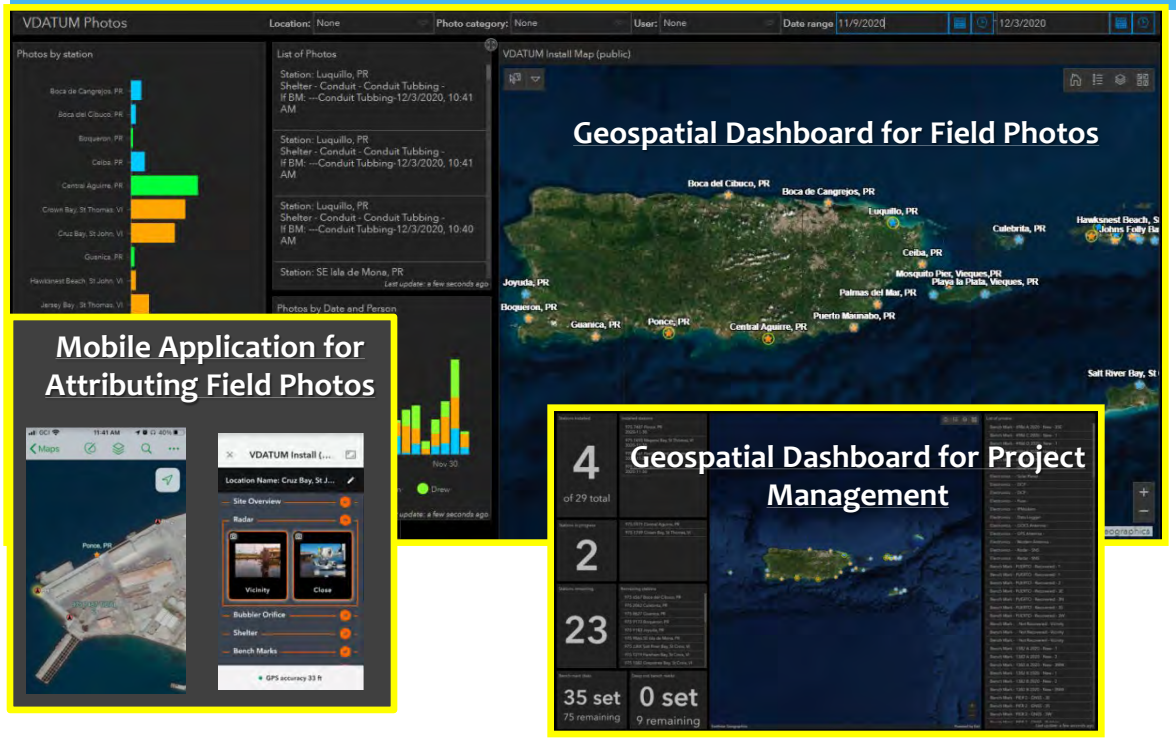




- Technical and maintenance support for the new Valdez Physical Oceanographic Real Time System (PORTS)
- Scheduled and unscheduled maintenance of National Water Level Observation Network (NWLON) stations in Alaska

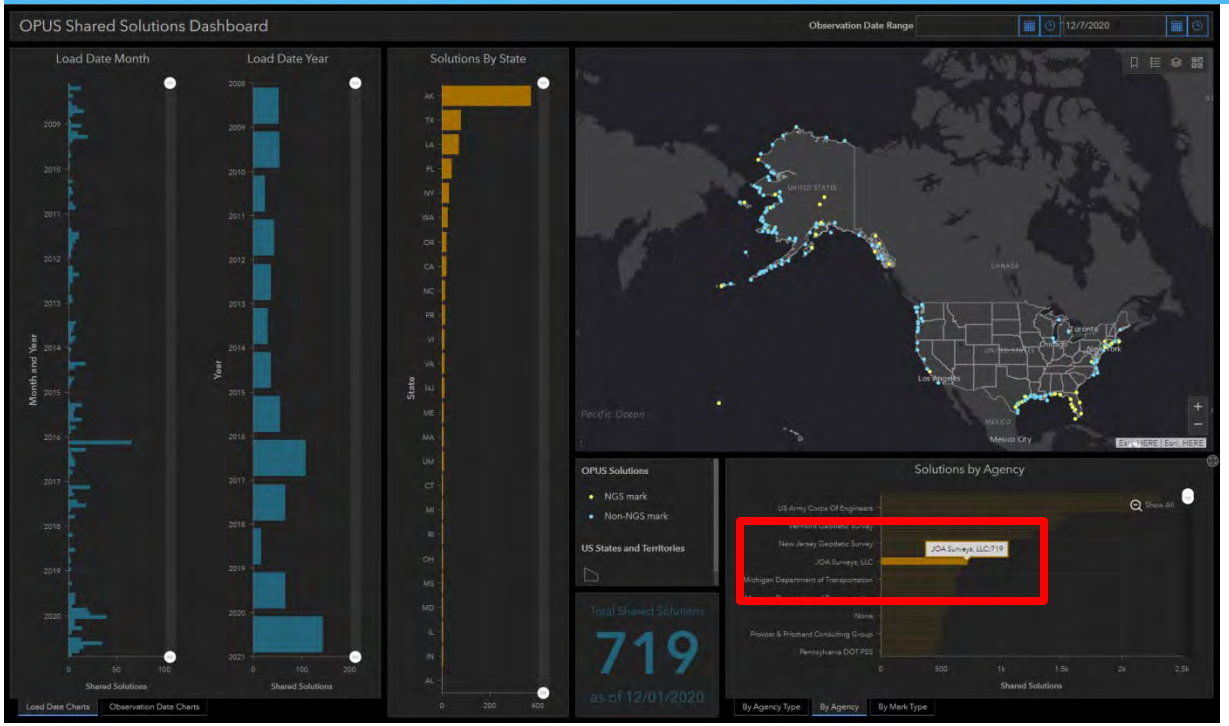
JOA Surveys, LLC
At the boundary between land and sea

GIS Applications



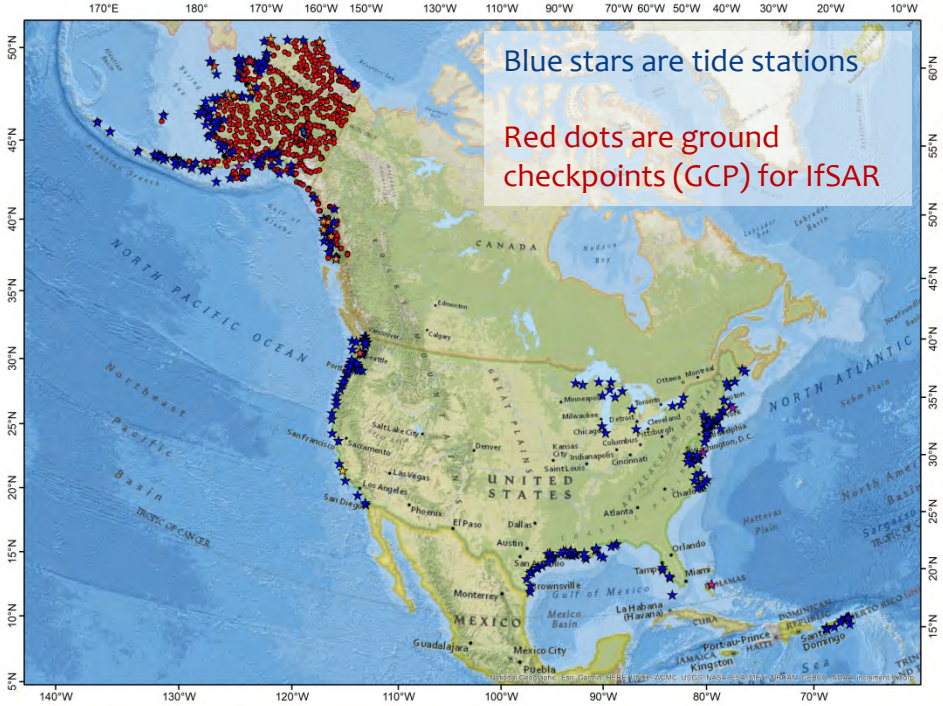
- Awarded task order in 2019 to install **69 temporary tide stations** along coasts of TX, LA, FL, PR, and VI
- COVID-19 travel restrictions pushed us to **develop mobile applications and online dashboards** to:
  - Attribute photos
  - View photos
  - Track progress and share info with client.

Contributions to OPUS Shared



- Of the top ten agencies using OPUS Shared JOA is the only private agency
- First dataset submitted in March of 2008
- 719 solutions published
- Solutions span 25 states, territories and islands

Tides, Tides, Tides… and GCP



- Started installing tide stations for NOS Mapping and Charting Program in 2003
- 10 year term contract to provide Environmental Field Services nationwide to CO-OPS
- Installed more than 300 temporary tide stations for NOS
- Built 9 NWLON stations in Alaska
- Surveyed more than 900 IfSAR ground check points throughout Alaska

www.tidaldatumtool.com

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Anchorage, AK 99507
Phone: (907) 561-0136

Online Tidal Datum Computations

Registration Page

Convert your data to information. Upload water level measurements and get tidal datums referenced to the National Tidal Datum Epoch within minutes.

First Name:	Enter First Name
Last Name:	Enter Last Name
Organization:	Organization
Phone:	Phone Number
Email:	nathan@joasurveys.com
Password:	••••••••
Confirm:	Confirm Password

I'm not a robot

reCAPTCHA

Get Started

Already registered? ***Sign In here***

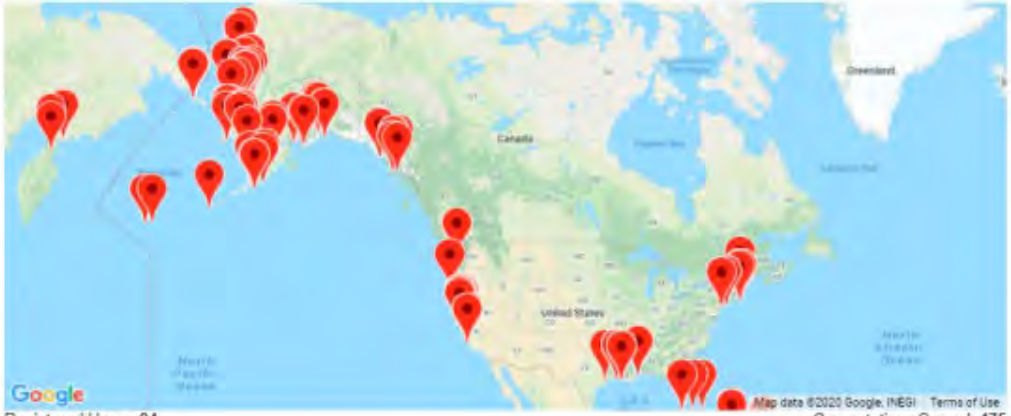
Explanation

JOA Surveys has completely automated the tidal datum computation process. Water level enthusiasts no longer need to immerse themselves in tidal datum computation methodology. Instead this tool allows a user to focus their effort on data interpretation.

The only required inputs are a comma delimited file and the users email address. The input water level data can be sampled at any interval from 1 second to 60 minutes. The data must span at least 24 hours. The resulting tidal datums are referenced to the current National Tidal Datum Epoch, when applicable.

All of the computations are based on the methodology developed by the United States' water level and tidal datum authority NOAA's Center for Oceanographic Operational Products and Services. The tool does not derive prediction based datums such as Lowest Astronomical Tide.

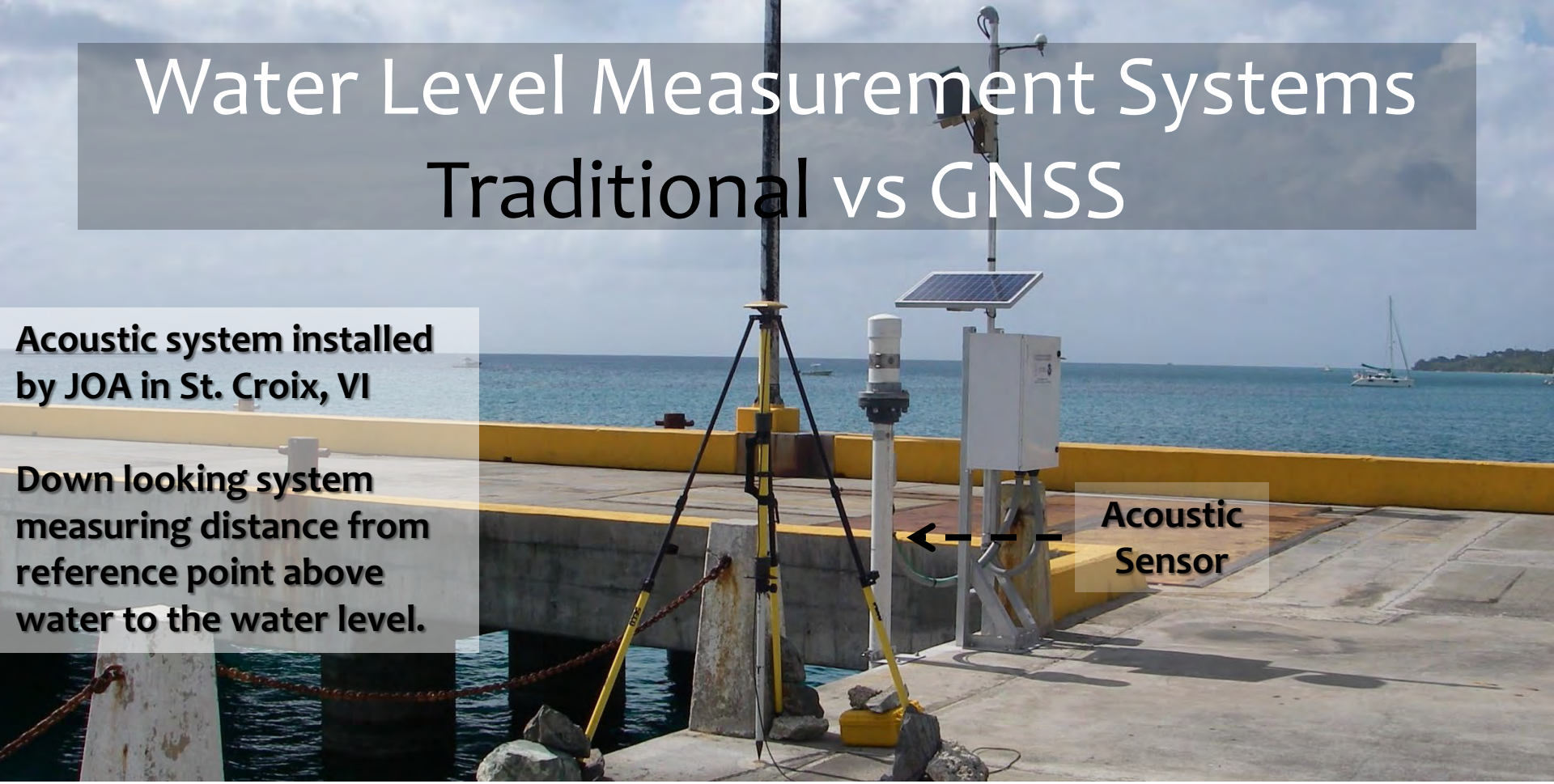
The results are dependent on the quality of the data being submitted, duration, and the applicability of the controlling station selected (if chosen).



Registered Users: **84**

Computations Served: **475**

Water Level Measurement Systems
Traditional vs GNSS



Acoustic system installed by JOA in St. Croix, VI

Down looking system measuring distance from reference point above water to the water level.

Water Level Measurement Systems
Traditional vs GNSS

<u>Radar</u> system installed by JOA along Lake Michigan for IGLD update

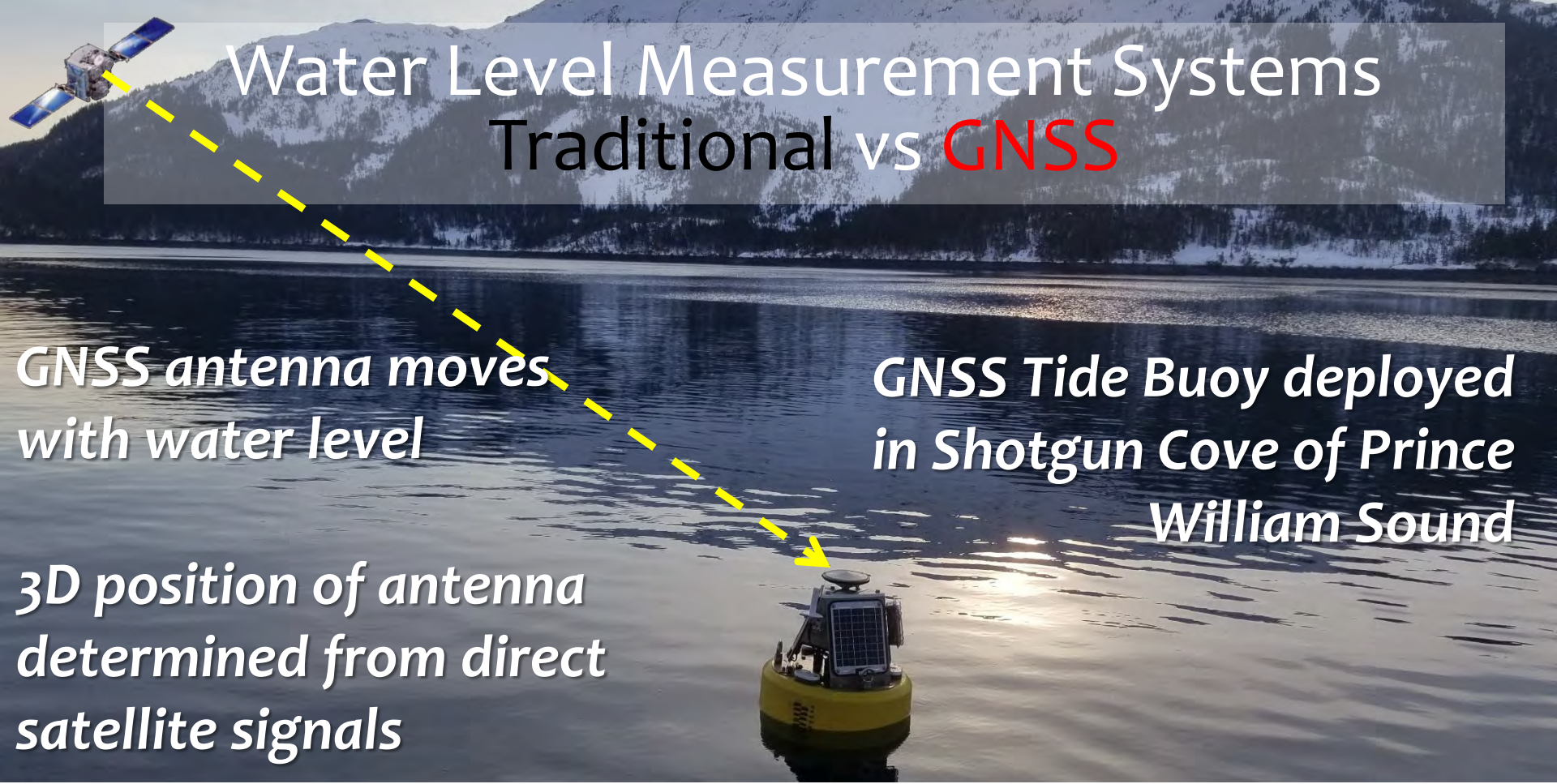
Down looking system measuring distance from reference point above water to the water level.

Water Level Measurement Systems
Traditional vs GNSS

NWLON station with a vented pressure system installed by JOA in Alaska.

Provides measurement of water pressure above submerged reference point.

Water Level Measurement Systems
Traditional vs GNSS

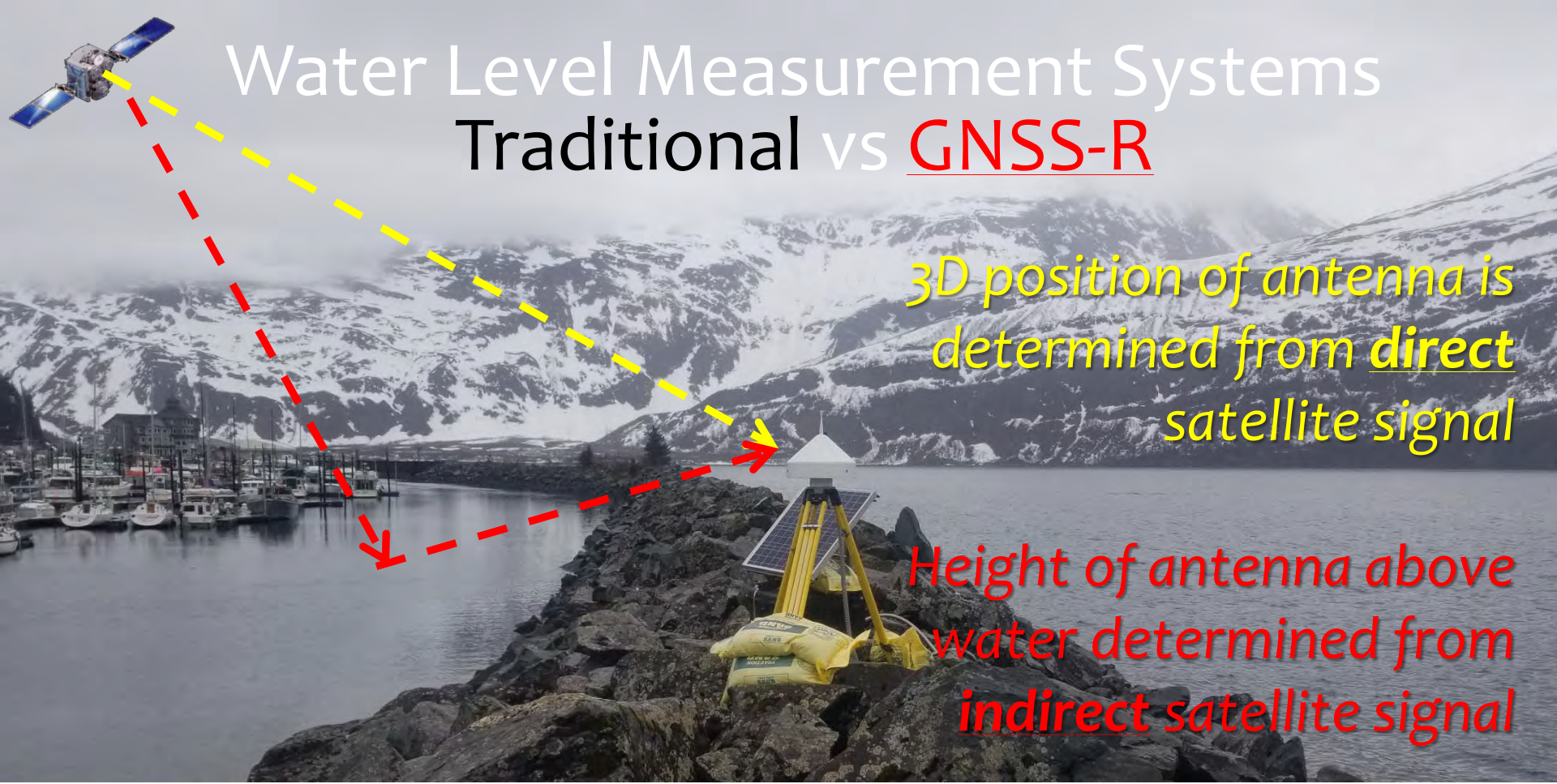


GNSS antenna moves with water level

GNSS Tide Buoy deployed in Shotgun Cove of Prince William Sound

3D position of antenna determined from direct satellite signals

Water Level Measurement Systems
Traditional vs GNSS-R



Water Level Measurement Systems
Traditional vs GNSS

Traditional

* Arbitrary **local** datum
* **Cannot** relate tidal datum planes at one location to another

GNSS

* **Global** Reference Frame
* **Can** relate tidal datum planes at one location to another
* Measure of Sea Surface Topography
  * i.e. LMSL vs GEOID

Water Level Measurement Systems
Traditional vs GNSS

Traditional	GNSS
* Install sensor * Install tidal benchmarks * Differential level tie btw sensor and marks * Static GNSS session on mark	

Water Level Measurement Systems
Traditional vs GNSS

Traditional

* Install sensor
* Install tidal benchmarks
* Differential level tie btw sensor and marks
* Static GNSS session on mark

GNSS

* Install sensor (that is it!)

Water Level Measurement Systems
Traditional vs GNSS

Installing vented pressure sensor

Water Level Measurement Systems

Traditional vs GNSS

Installing tidal benchmarks

Differential level tie btw sensor and benchmarks

Water Level Measurement Systems
Traditional vs GNSS

Water Level Measurement Systems

Traditional vs GNSS

Benchmark set in 2015 and recovered in 2019

Water Level Measurement Systems

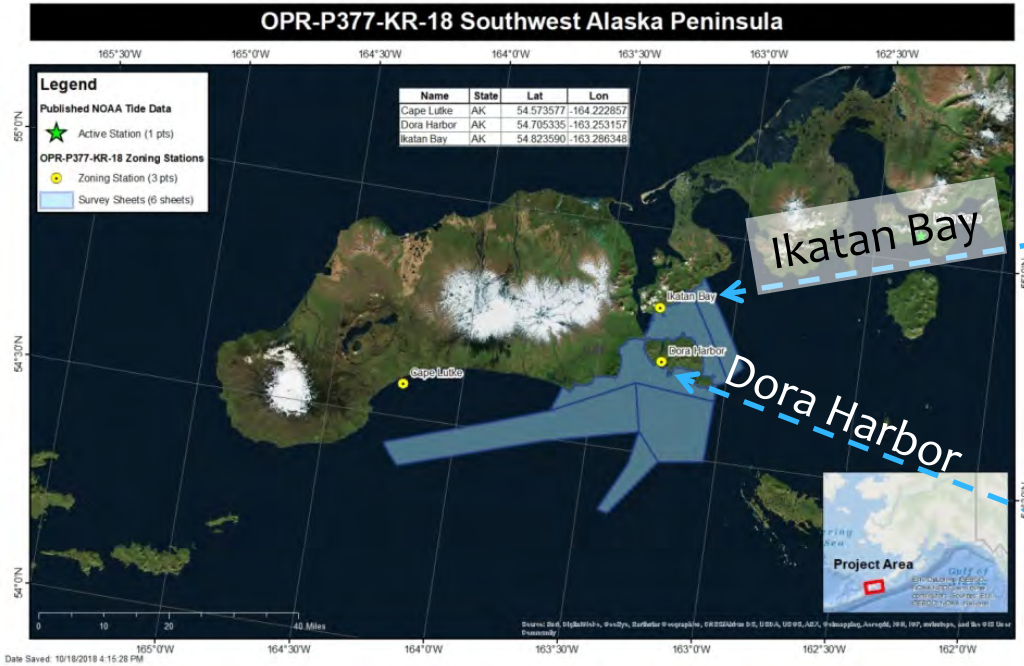
Traditional vs GNSS

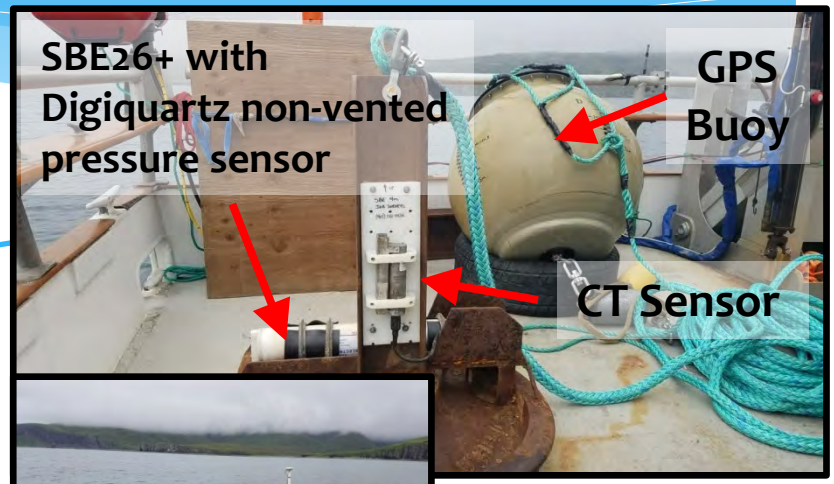
Water Level Measurement Systems

Traditional vs GNSS

Scotch Cap, Unimak Island, Alaska

Water Level Measurement Systems
Traditional vs GNSS





Co-located traditional and GNSS systems

Water Level Measurement Systems

Traditional vs GNSS

Ikatan Bay

	Traditional*	GNSS**	Deltas
MHW	18.448	18.448	0.000
MSL	17.717	17.715	0.002
MLLW	16.594	16.592	0.002
GT	2.057	2.061	-0.004
MN	1.433	1.435	-0.002
DHQ	0.203	0.205	-0.002
DLQ	0.421	0.421	0.000
		RMS	**0.002**
		STD	**0.002**

All values in meters

Based on 30 days of data

Dora Harbor

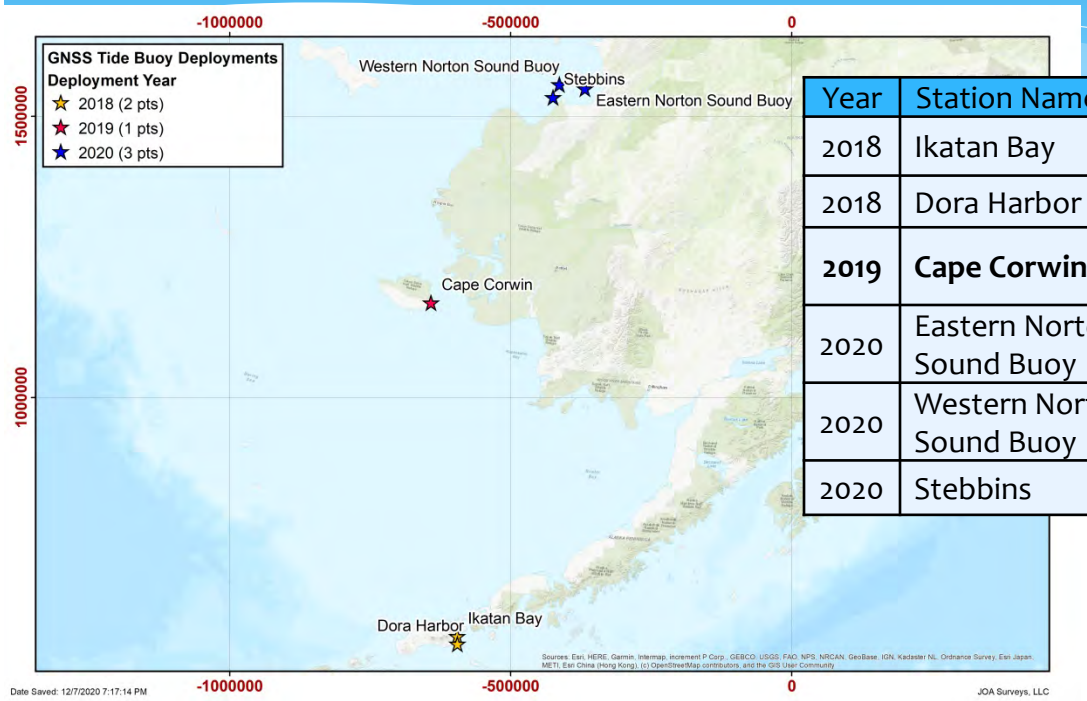
	Traditional*	GNSS**	Deltas
MHW	18.715	18.714	0.001
MSL	18.016	18.015	0.001
MLLW	16.922	16.921	0.001
GT	1.989	1.991	-0.002
MN	1.366	1.364	0.002
DHQ	0.195	0.199	-0.004
DLQ	0.427	0.428	-0.001
		RMS	**0.002**
		STD	**0.002**

* The traditional gauge was a non-vented system with a Digiquartz pressure sensor

** The GNSS system was a GNSS Tide Buoy. **No tilt sensor on buoy.**

Water Level Measurement Systems

Traditional vs GNSS

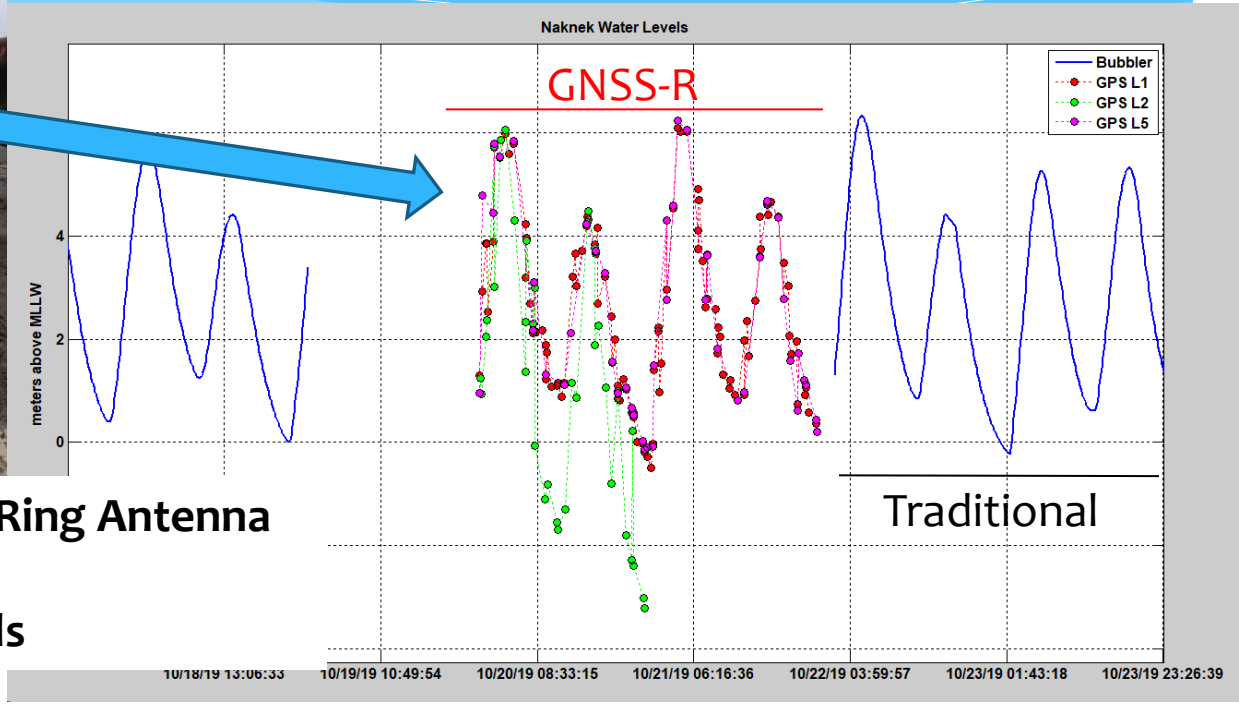


		MLLW above NAD83			
Year	Station Name	Obs	Model	Deltas	Note
2018	Ikatan Bay	16.592	16.754	-0.162	30 days of data
2018	Dora Harbor	16.921	17.028	-0.107	30 days of data
2019	**Cape Corwin**	**10.254**	**10.088**	**0.166**	**One month of data, Published**
2020	Eastern Norton Sound Buoy	8.200	8.261	-0.061	30 days of data
2020	Western Norton Sound Buoy	7.255	7.187	0.068	30 days of data
2020	Stebbins	7.845	7.738	0.107	One month of data

RMS	**0.168**
Max	**0.166**
Min	**-0.162**

All values in meters

Water Level Measurement Systems
Traditional vs GNSS-R



Septentrio PolaRx5 with Choke Ring Antenna

GNSS-Reflectometry water levels

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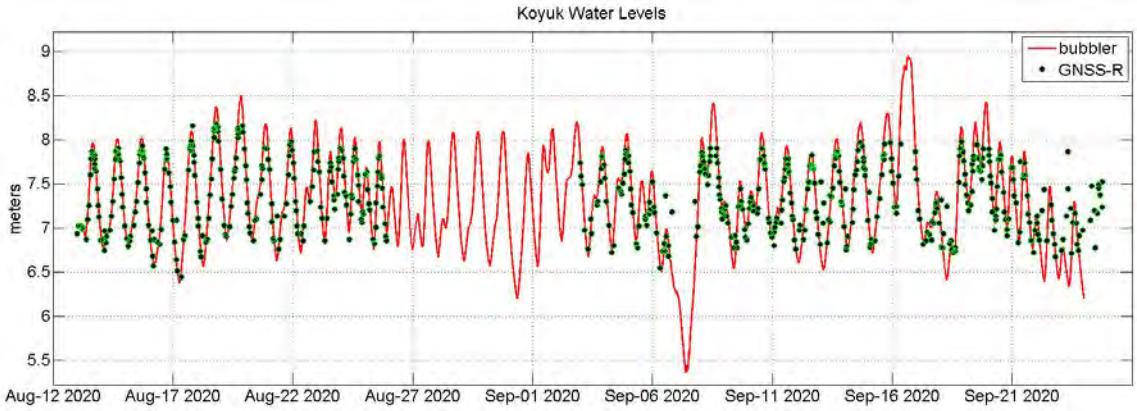
Water Level Measurement Systems
Traditional vs GNSS-R



	MLLW	MHW
Traditional – Bubbler	6.638 m	7.541 m
GNSS-R	6.795 m	7.475 m
Delta	**-0.157 m**	**0.066 m**

- Gap in data record due to vandalism. Did not measure extreme low and high. End of data series is noise.
- Preliminary datums computed using 13 days of data for bubbler and GNSS-R systems.

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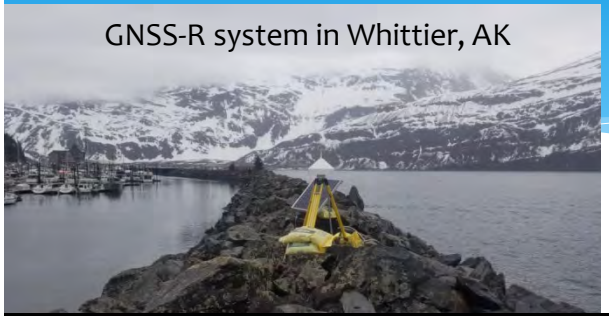
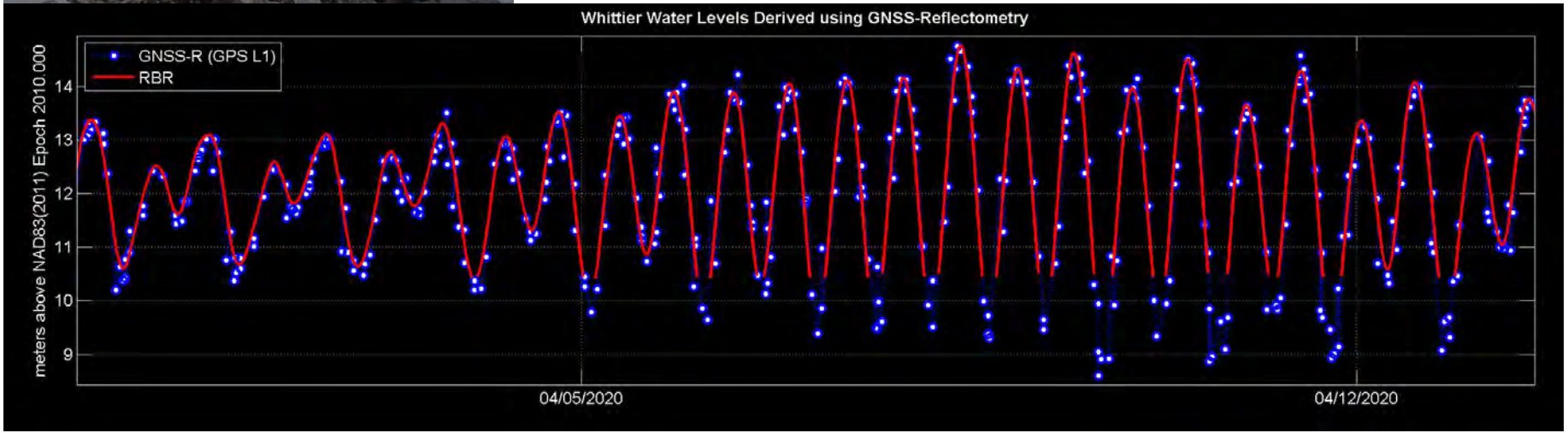
Water Level Measurement Systems



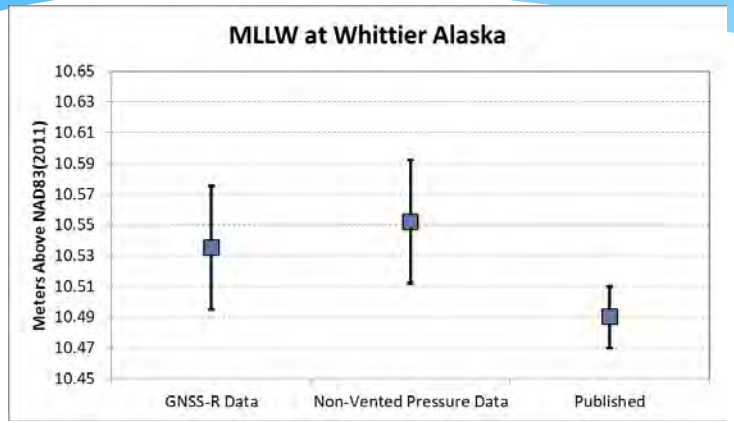
Traditional vs GNSS-R

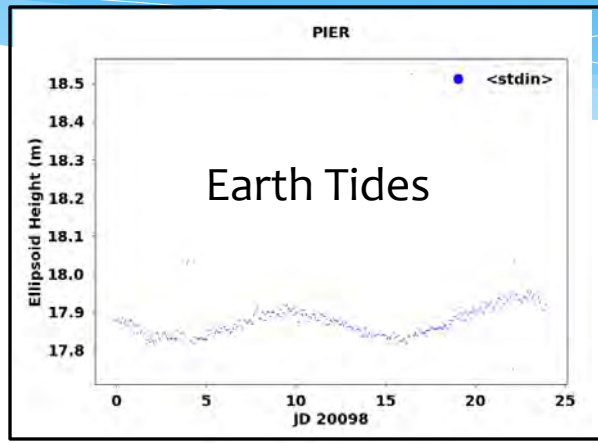
Note: The RBR (non-vented pressure sensor) went dry during spring low tides, whereas the GNSS-R system provided measurements during those tides.



Water Level Measurement Systems

Traditional vs GNSS- R



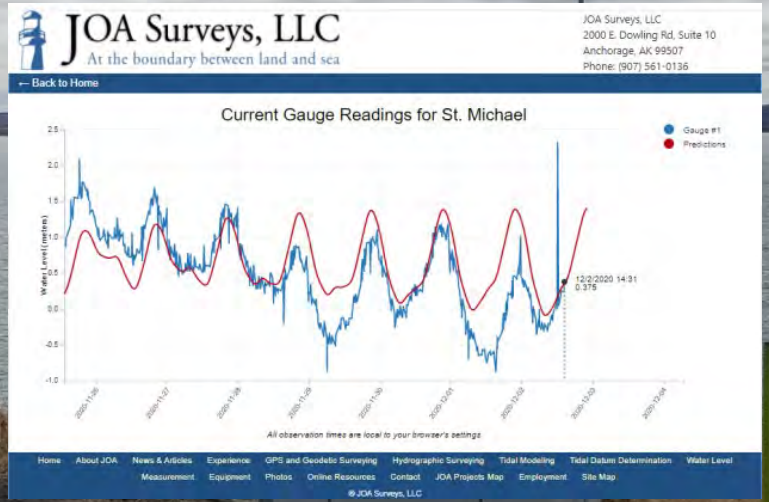


Earth tides were computed using data from the GNSS-R system.

Plot shows MLLW above NAD83(2011) determined using three approaches. The vertical error bars are based on the length of the data series used to compute MLLW. The MLLW value published for Whittier is based on 10 months of data. The MLLW value for GNSS-R Data and Non-Vented Pressure Data are based on 30 days of data.

Water Level Measurement Systems

Traditional vs GNSS- R



- Automated processing of water levels using data from NGS CORS in St. Michael (AT01)
- Updates every time file is written to UNAVCO server
- Datums and tide predictions generated from GNSS-R values
- Data viewable at **http://joasurveys.com/rtwl/stmichael/**

GNSS System Health Dashboard

- Interactive dashboard for viewing health of GNSS Tide Buoy and GNSS-R systems.
- Data transmitted via Iridium:
  - Power
  - Number of satellites
  - Relative Humidity
  - Disk Usage
  - Autonomous position
- Example for buoy deployed in **Norton Sound** for **71 days**
- Buoy was moved to new location halfway through deployment
- Buoy was retrieved on September 13

Water Level Measurement Systems
Traditional vs GNSS

Summary

- There is **not** one system that works everywhere
- GNSS water level measurement systems expand our capability of establishing tidal datums for:
  - Offshore validation
  - Areas with no infrastructure
- **Typically need a boat to deploy and retrieve a GNSS Tide Buoy**
- No boat required for a GNSS-R system
- Log SNR data at your GNSS base stations!
- Sea Ice!

Thanks