

GNSS-R

Drew Lindow
Jim Mitchell
Nathan Wardwell

GNSS-R History

- * **1988: Georgiadou and Kleusberg** “On carrier signal multipath effects in relative GPS positioning”
- * “extreme multipath interference can render useless GPS observations for precise positioning applications”

GNSS-R *Interference patterns from a planar surface below an antenna had a **distinct frequency** related to the height of the antenna above the surface.*

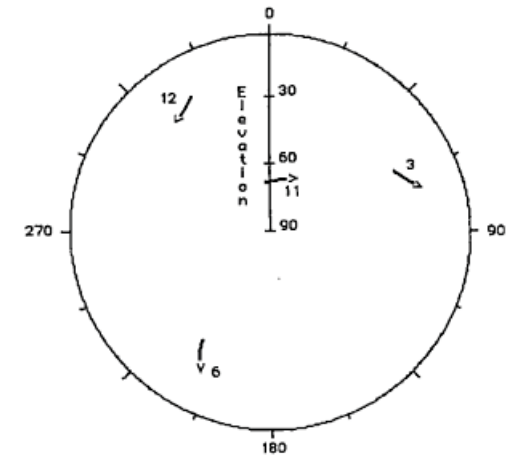


Figure 2: Satellite polar plot, Dec. 14, 1986, 13:30–13:40 UT

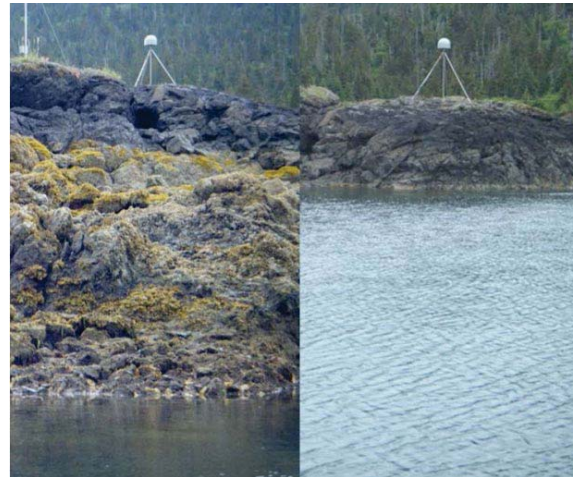
GNSS-R History

- * **2013: Larson et al. First demonstration of water levels GPS-IR SNR measurements**

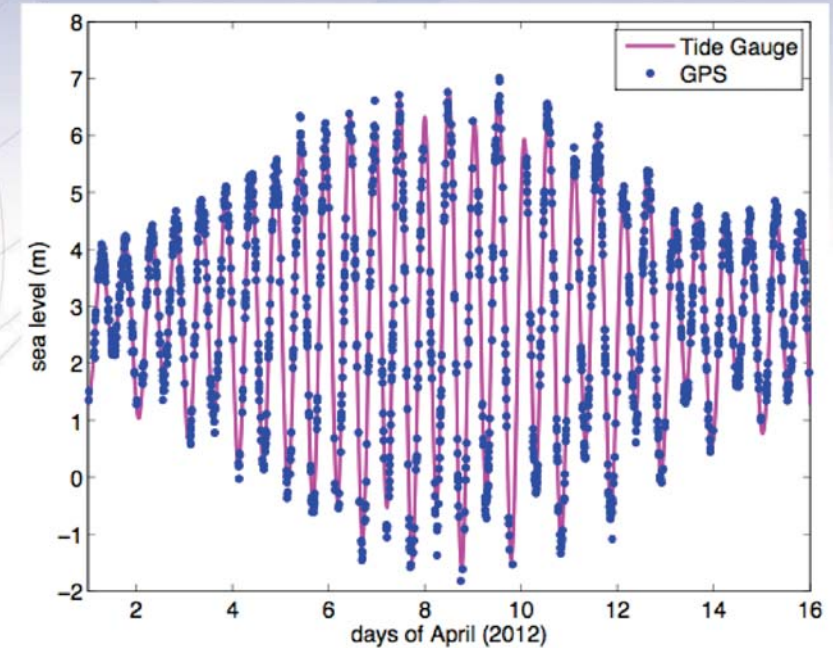
Onsala, Sweden



- * Petersen Bay, AK



Comparison between GPS and Seldovia NWLON Record



GNSS-R History

- * 2017: Larson et al. 10-year comparison at Friday Harbor, Washington, between a GPS-IR analysis and collocated tide gauge (350 m SE) **showed daily averages** to be in agreement at the 2-cm level



SC02 (Friday Harbor) GPS

GNSS-R at JOA

- * AT01 & PBAY GNSS-R @ JOASurveys.com
- * 2020 Whittier Deployed Pressure Gauge, GNSS Buoy, GNSS-R
- * 2021 Wainwright Egegik

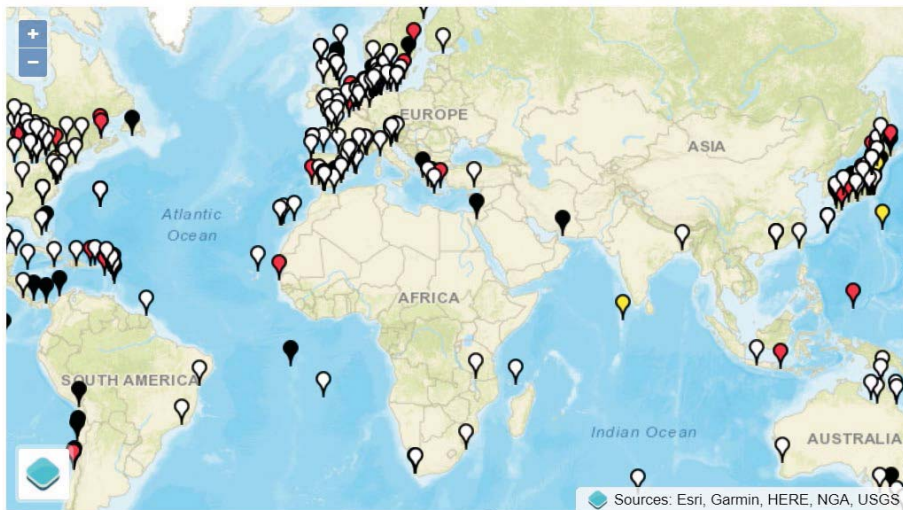


Permanent Service for Mean Sea Level

<https://psmsl.org>

* 275 Sites around the world

GNSS-IR Site Map



- Good site - reflectometry works well and data is available
- Decommissioned - reflectometry works well, data is available, but site is no longer operating
- Questionable - reflectometry works sometimes or the signal is very weak probably due to location
- Bad - no data available at the site, either due to positioning of the sensor, lack of signal to noise ratio data, or data sampling is inadequate for the height of the sensor

GNSS-IR Portal

- Portal homepage
- Site map
- Site list
- Site page example (Newlyn)
- Other useful files

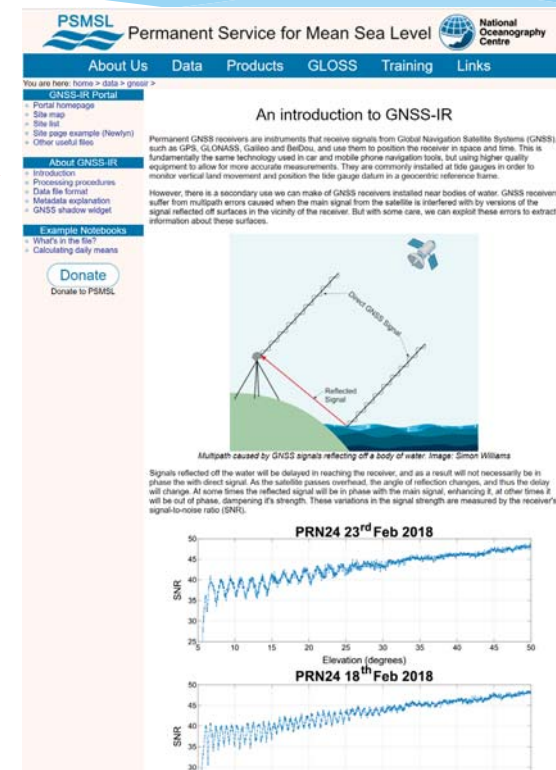
About GNSS-IR

- Introduction
- Processing procedures
- Data file format
- Metadata explanation
- GNSS shadow widget

Example Notebooks

- What's in the file?
- Calculating daily means

Excellent Introduction





https://psmsl.org

* 10 sites in Alaska

CODE	Site	GNSS Data
ELDC	Eldred Rock	1/5/2022
AB43	Cape Spencer	current
AC43	Seal Rocks	9/10/2021
PBAY*	Peterson Bay	current
AC59	Ursus Head	current
AV02	Augustine Volcano	1/16/2023
UGAI	Ugaiushak Island	6/21/2022
AC12	Chernabura	1/21/2023
AV09	Unalaska	current
AT01	St. Michael	current

* GPS Only

 **PSMSL** Permanent Service for Mean Sea Level  **National Oceanography Centre**

About Us Data Products GLOSS Training Links

You are here: home > data > gnssir >

GNSS-IR Portal

- Portal homepage
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- Other useful files

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- GNSS shadow widget

Example Notebooks





- What's in the file?
- Calculating daily means

[Donate](#)
Donate to PSMSL

GNSS-IR Site Map



Sources: Esri, Garmin, HERE, NGA, USGS


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-  Decommissioned - reflectometry works well, data is available, but site is no longer operating
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<https://gnss-reflections.org/>

- * Kristine Larson
Git Hub –
<https://github.com/kristinemlarson>
- * YouTube Videos Webinars ...
- * Short Course May 2- May 5, 2023

GNSS-IR Reflections ??? Geoid ReflZones People API RINEX3 Pubs

The New GNSS-IR API



Examples

Antarctica:
☒ long ☐ phnx ☐ uthw ☐ lthw

Greenland:
☐ gls1 ☐ gls2 ☐ gls3 ☐ smm3

Soil Moisture/Snow:
☐ p360 ☐ p038 ☐ p041 ☐ p037

Water Levels:
☐ at01 ☐ sc02 ☐ mchn

Output file
txt

Submit

Upload RINEX File

Choose File No file chosen

Freq	MinRH	MaxRH
L1	0.4	8.0
MinElAng	MaxElAng	ReqAmp
5.0	25.0	6
PkNoise	Output file	MinAzim
3.0	txt	0
MaxAzim	Rinex	Submit
360	2.11	

10 MByte file size limit and strict filename rules. Upload must take less than 30 sec or the api will timeout.

Analyze RINEX data from archives

Station	Year	DOY
p038	2019	200
Freq	MinRH	MaxRH
L1	0.4	8.0
MinElAng	MaxElAng	ReqAmp
5.0	25.0	6
Pk2Noise	Output file	MinAzim
3.0	txt	0
MaxAzim	Submit	
360		

Archive
all

Submit

RINEX 2.11: UNAVCO, SOPAC, or SONEL
RINEX 3: the file must be at CDDIS

<https://gnss-reflections.org/>



Kristine M. Larson

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Measuring Water Levels with GPS



Posted

November 8, 2015

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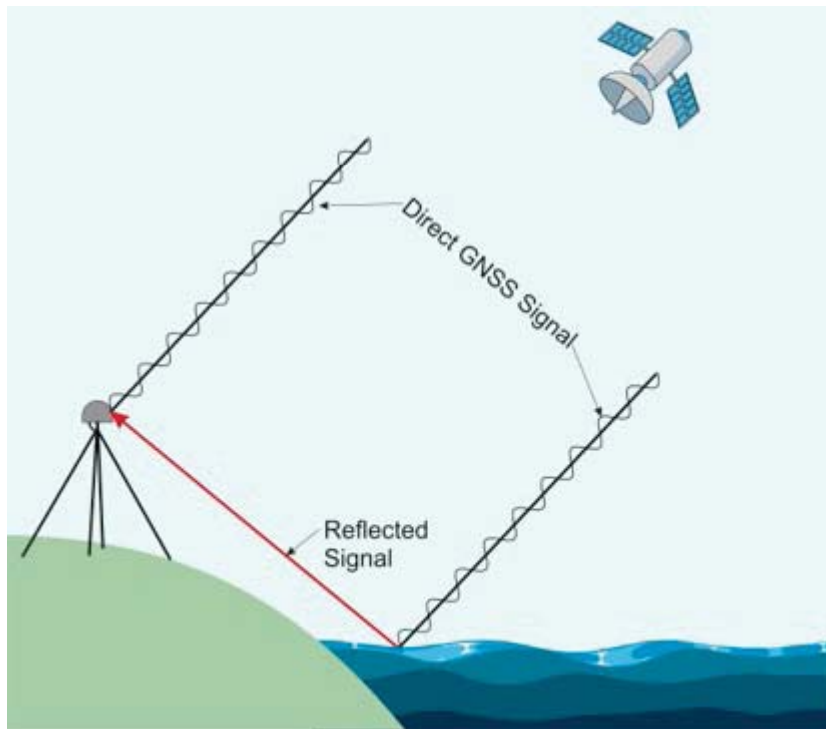


GNSS signals reflect off water surfaces. Unlike for soil moisture and snow depth, which varies most dynamically only on the day that it rains or snows, water levels vary throughout the day. This adds a bit of complexity for using the GPS/GNSS Interferometric Reflectometry (GPS-IR or GNSS-IR) technique to measure tidal variations for example. The advantage of using GNSS-IR with a standard geodetic receiver is that you can simultaneously measure the three-dimensional position of the GNSS antenna in the International Terrestrial Reference Frame.

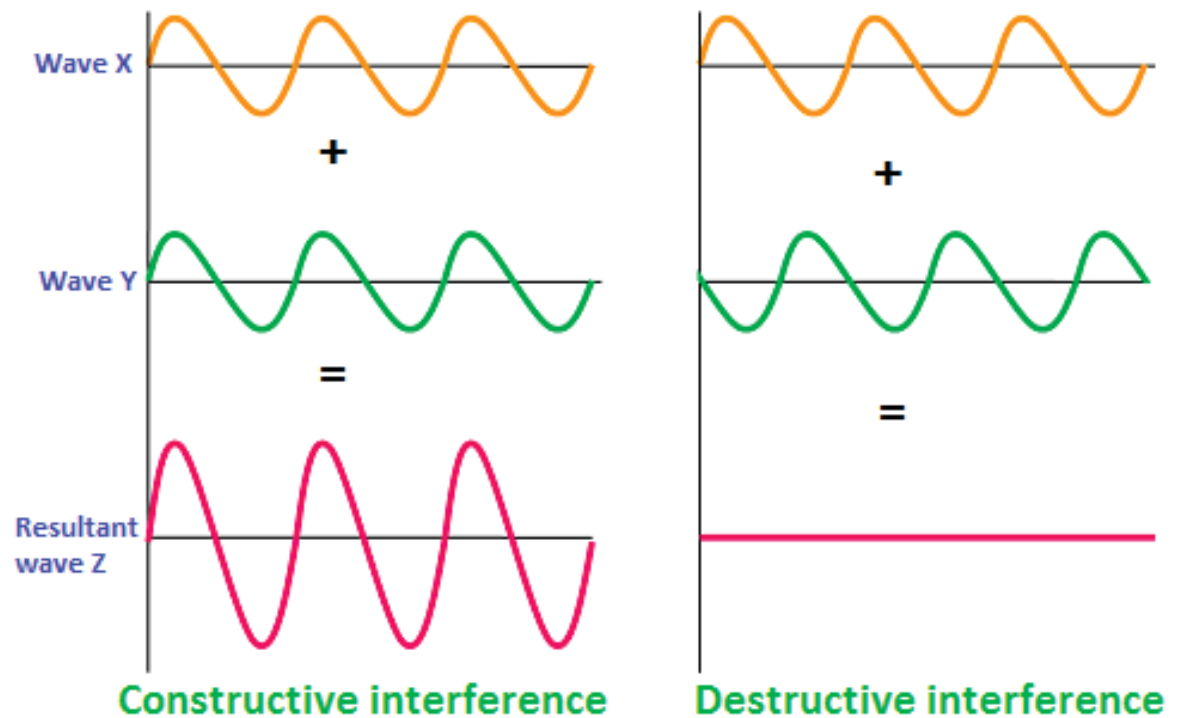


JOA Surveys, LLC
At the boundary between land and sea

Reflected Signal Interference



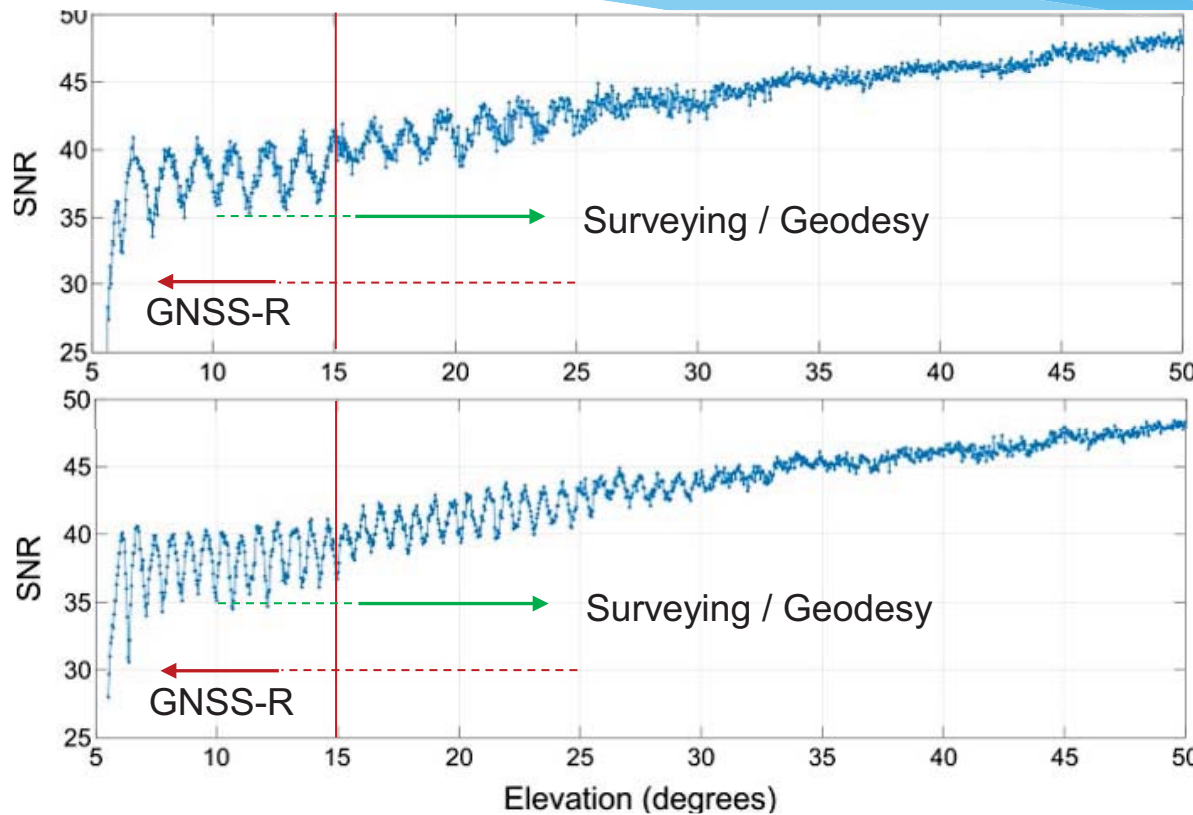
Wave Interference



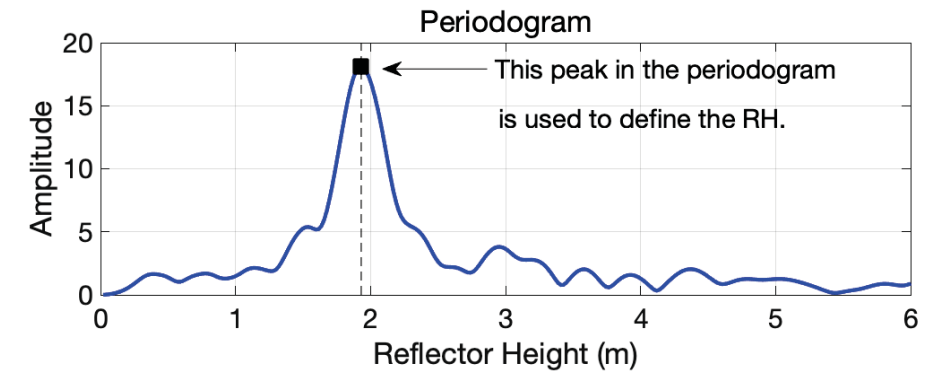
JOA Surveys, LLC
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SNR Oscillation Frequency

High Tide




















Low Tide



My Start with GNSS-R Shelter Cove, CA RECON December 1-4, 2022



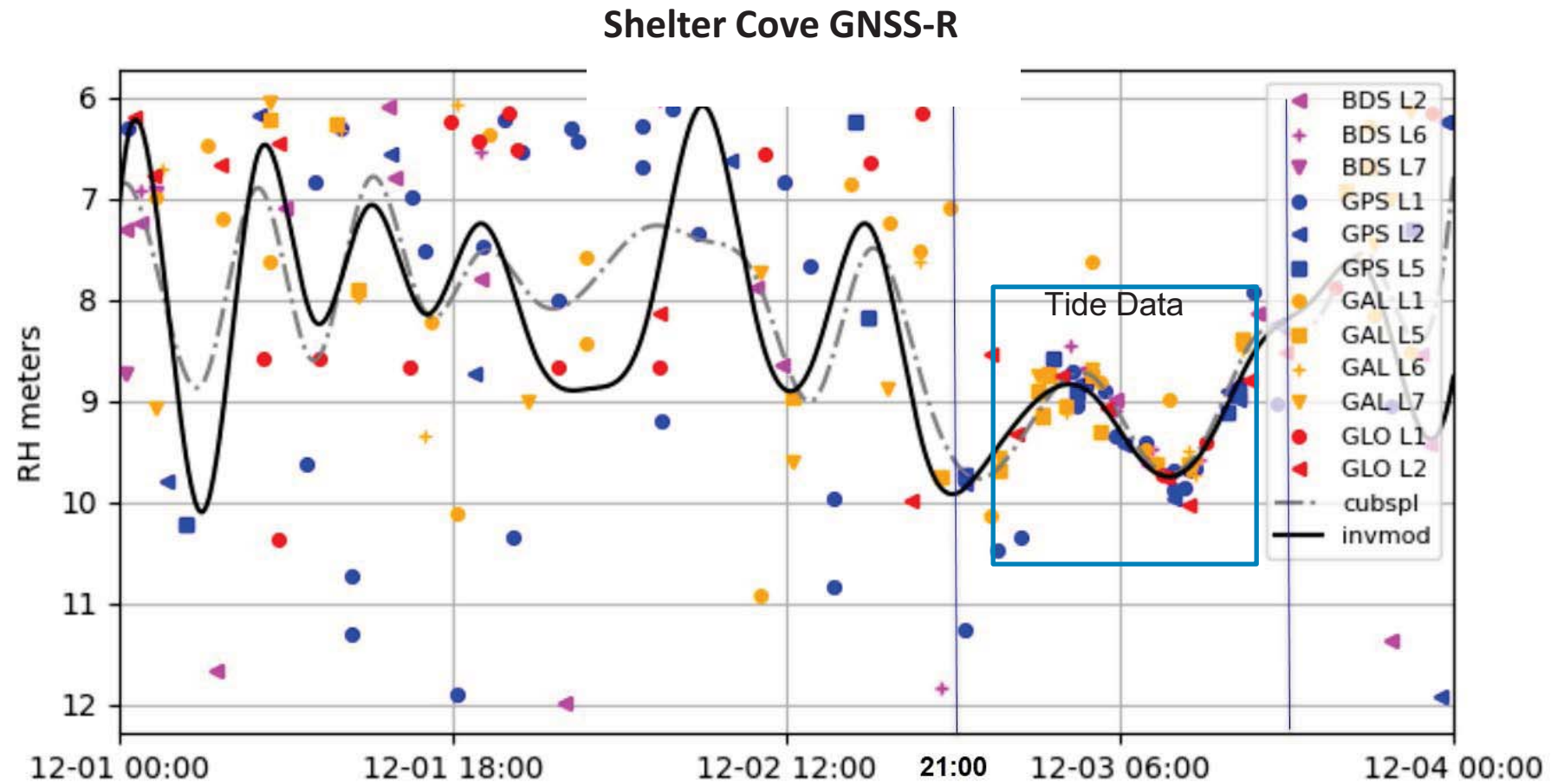
Shelter Cove, CA

 BACK336a00.22_.gz	3,841,784	GZip File	12/1/2022 3:15:39 PM
 BACK336a15.22_.gz	4,147,418	GZip File	12/1/2022 3:30:25 PM
 BACK336a30.22_.gz	4,239,622	GZip File	12/1/2022 3:45:49 PM
 BACK336a45.22_.gz	4,424,211	GZip File	12/1/2022 4:00:32 PM
 BACK336b00.22_.gz	4,260,002	GZip File	12/1/2022 4:16:36 PM
 BACK336b15.22_.gz	4,124,577	GZip File	12/1/2022 4:30:24 PM
 BACK336b30.22_.gz	3,918,243	GZip File	12/1/2022 4:46:06 PM
 BACK336b45.22_.gz	3,834,197	GZip File	12/1/2022 5:01:29 PM
 BACK336c00.22_.gz	3,789,097	GZip File	12/1/2022 5:15:47 PM
 BACK336c15.22_.gz	3,864,674	GZip File	12/1/2022 5:30:28 PM
 BACK336c30.22_.gz	3,837,553	GZip File	12/1/2022 5:45:38 PM
 BACK336c45.22_.gz	4,106,515	GZip File	12/1/2022 6:00:34 PM
 BACK336d00.22_.gz	4,129,858	GZip File	12/1/2022 6:15:38 PM
 BACK336d15.22_.gz	3,887,867	GZip File	12/1/2022 6:30:16 PM
 BACK336d30.22_.gz	3,433,531	GZip File	12/1/2022 6:45:50 PM
 BACK336d45.22_.gz	3,594,523	GZip File	12/1/2022 7:00:25 PM
 BACK336e00.22_.gz	3,436,760	GZip File	12/1/2022 7:15:22 PM



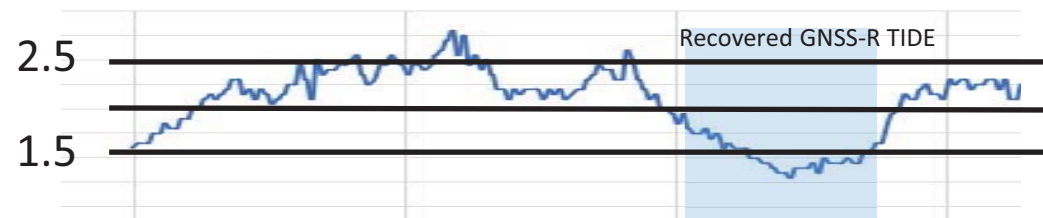
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Shelter Cove GNSS-R Data

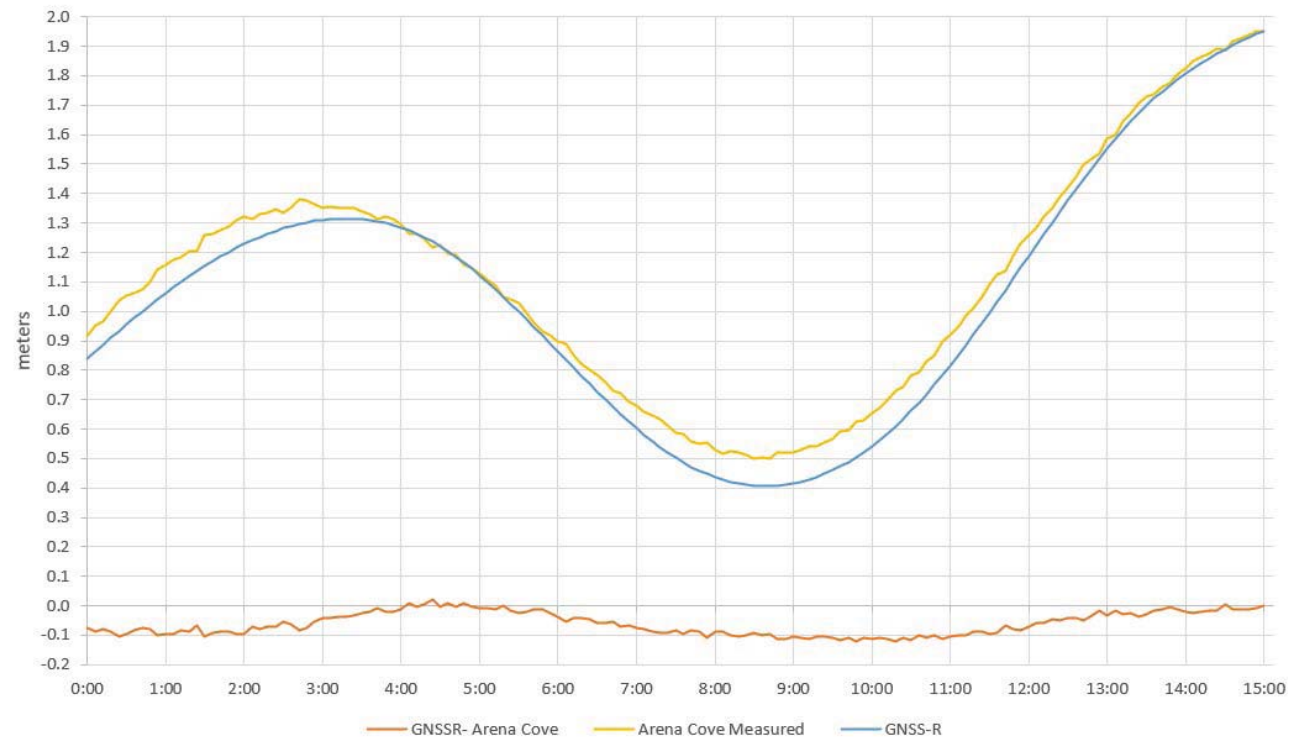


Shelter Cove GNSS-R Comparison with Arena Cove NWLON

Wave Height at Buoy 46014 near Shelter Cove



Shelter Cove, CA
GNSS-R 12/03 0:00 to 15:00



<https://gnss-reflections.org/>



Kristine M. Larson

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Measuring Water Levels with GPS



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If the surface isn't too rough, GNSS signals reflect off water surfaces. Unlike for soil moisture and snow depth, which varies most dynamically only on the day that it rains or snows, water levels vary throughout the day. This adds a bit of complexity for using the GPS/GNSS Interferometric Reflectometry (GPS-IR or GNSS-IR) technique to measure tidal variations for example. The advantage of using GNSS-IR with a standard geodetic receiver is that you can simultaneously measure the three-dimensional position of the GNSS antenna in the International Terrestrial Reference Frame.



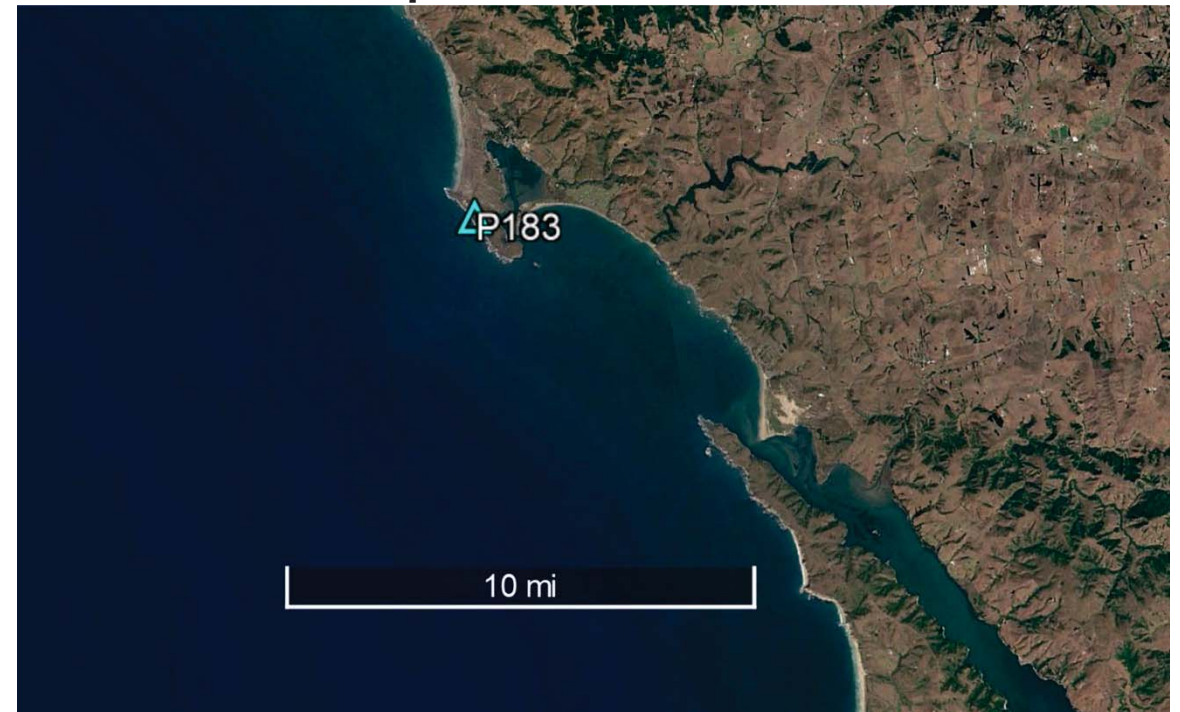
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GNSS-R Where Does it Work?

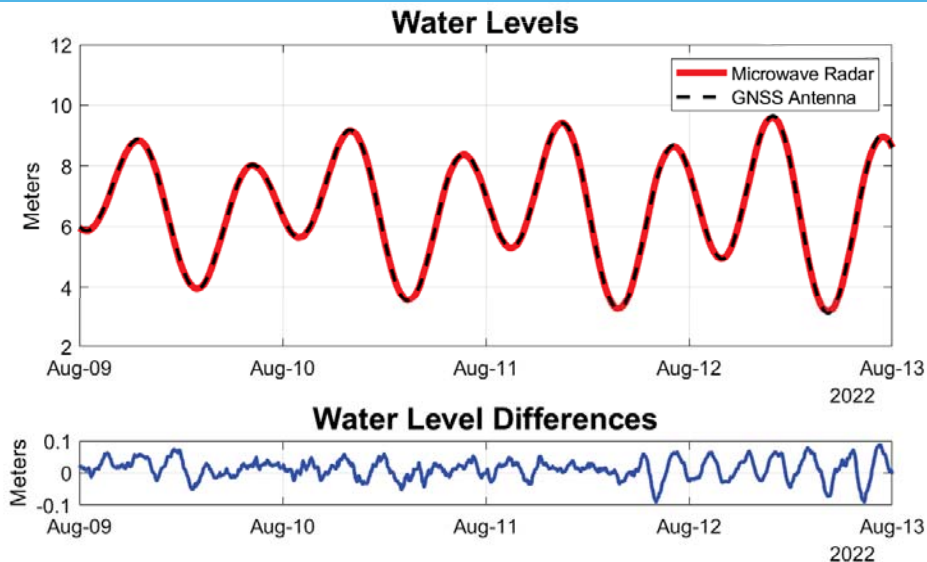
Bartlett Cove, Alaska – Protected Waters



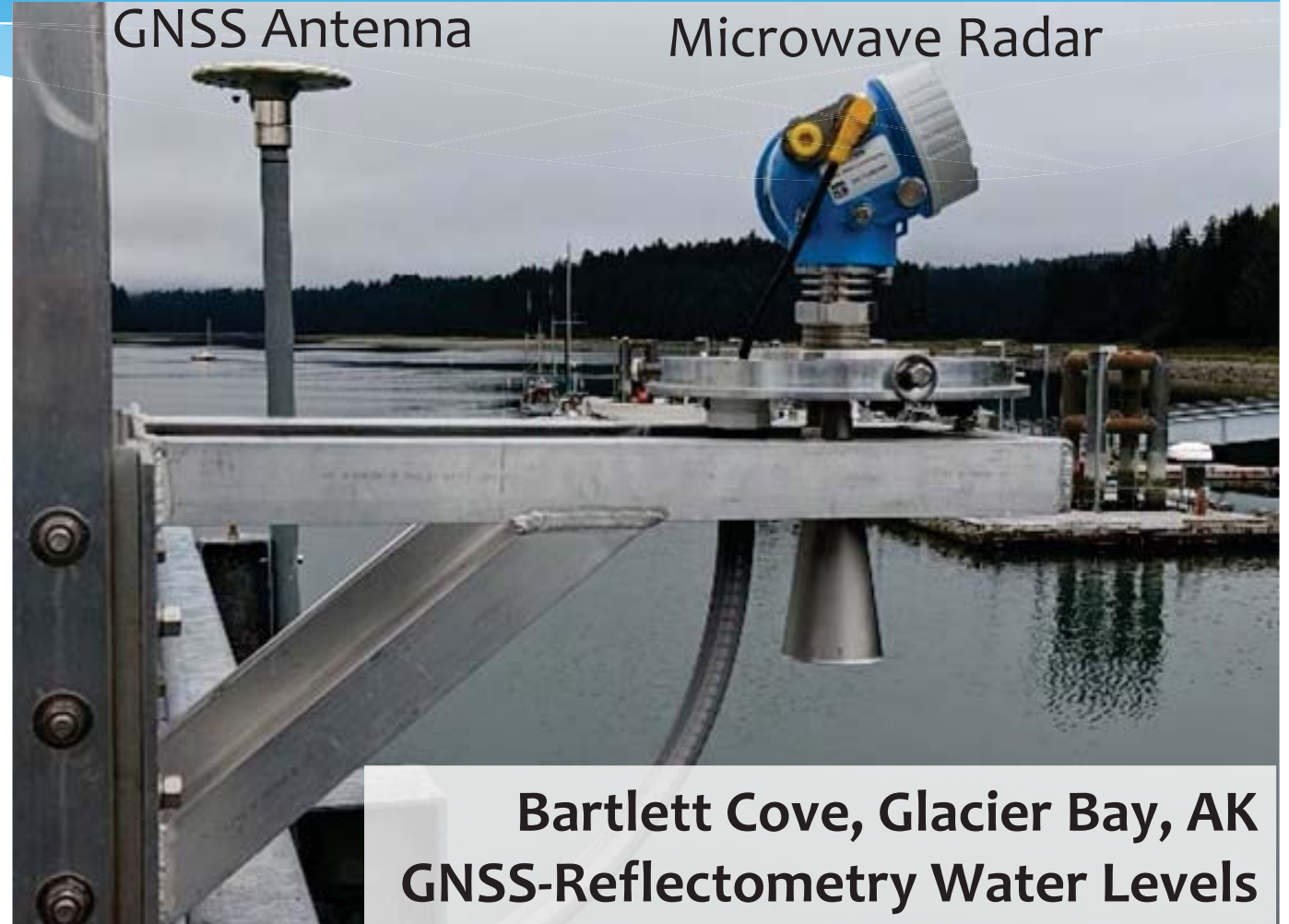
P183 Pacific Coast at Bodega Bay, California
Open Ocean



Bartlett Cove - GLBX



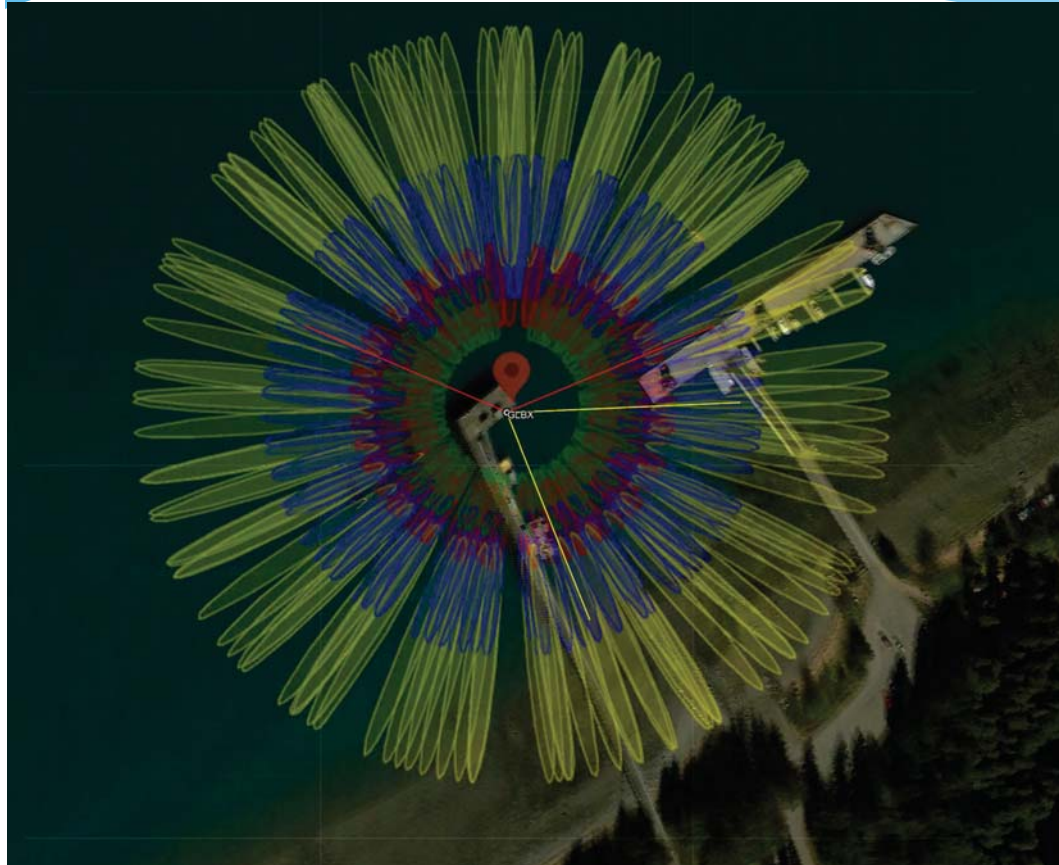
The GNSS antenna is next to a radar sensor. Both are in a protected area.



Bartlett Cove, Glacier Bay, AK
GNSS-Reflectometry Water Levels

Processed using: github.com/kristinemlarson

Bartlett Cove - GLBX



Current Processing Parameters

Azimuth 293 to 068 (red line)

Elev. Angle 5 (yellow) ,7 (blue), 10 (red) , 12 (green)

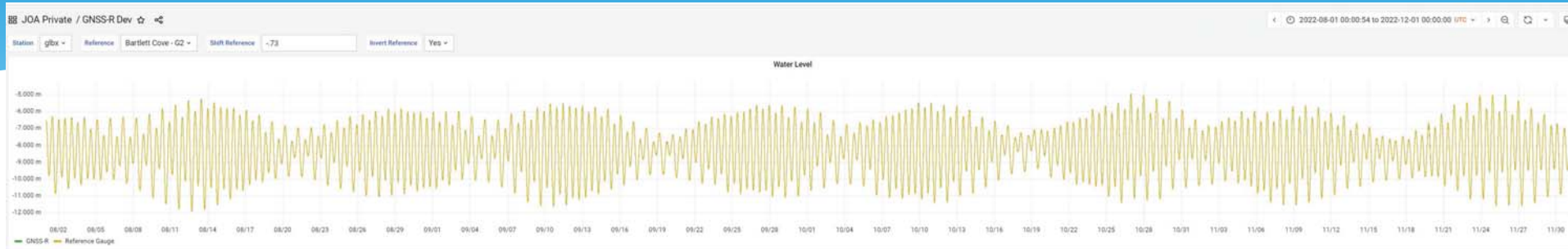
Reflector Height 3-17 meters

To Do

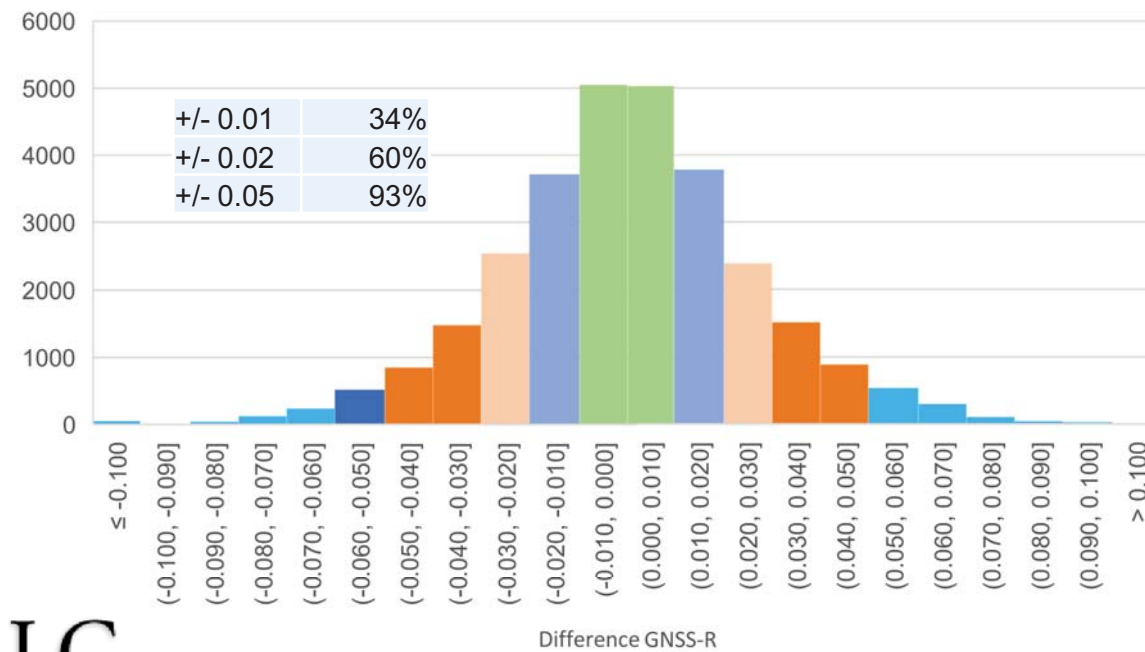
1) AZ 88 – 158 Elev. Angle 8 -12 (5 - 7 go dry)

2) AZ 180 - 293 Elev. Angle 5 -9 (9 – 12 hit dock)

Bartlett Cove - GLBX

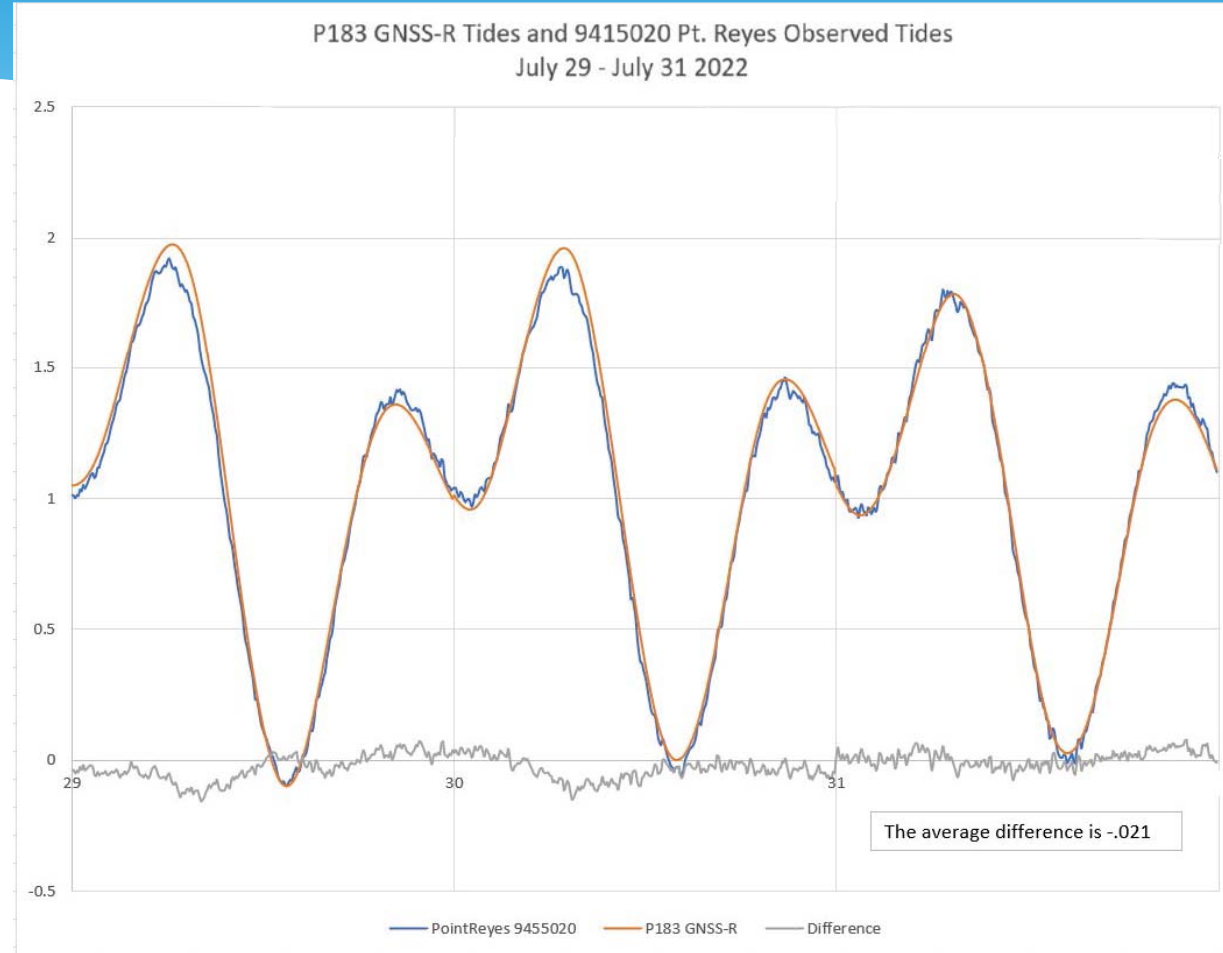


GLBX 08/01 -> 11/30 2022
GNSS-MWWL

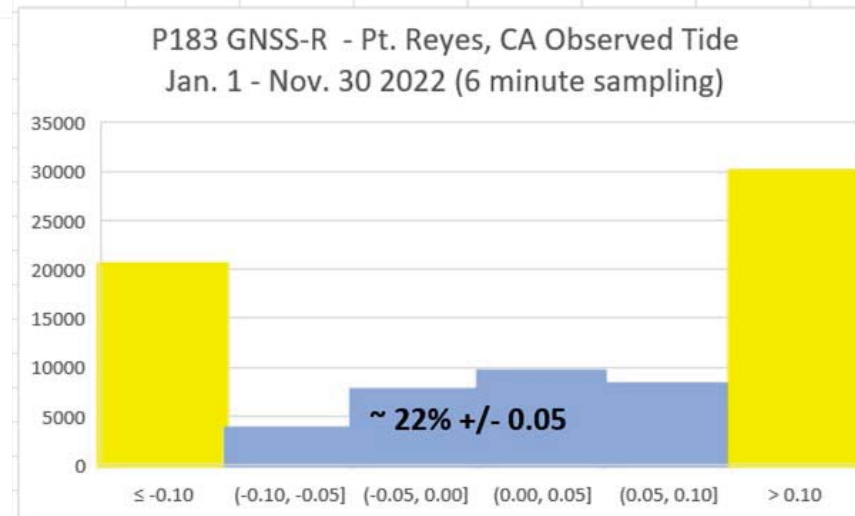
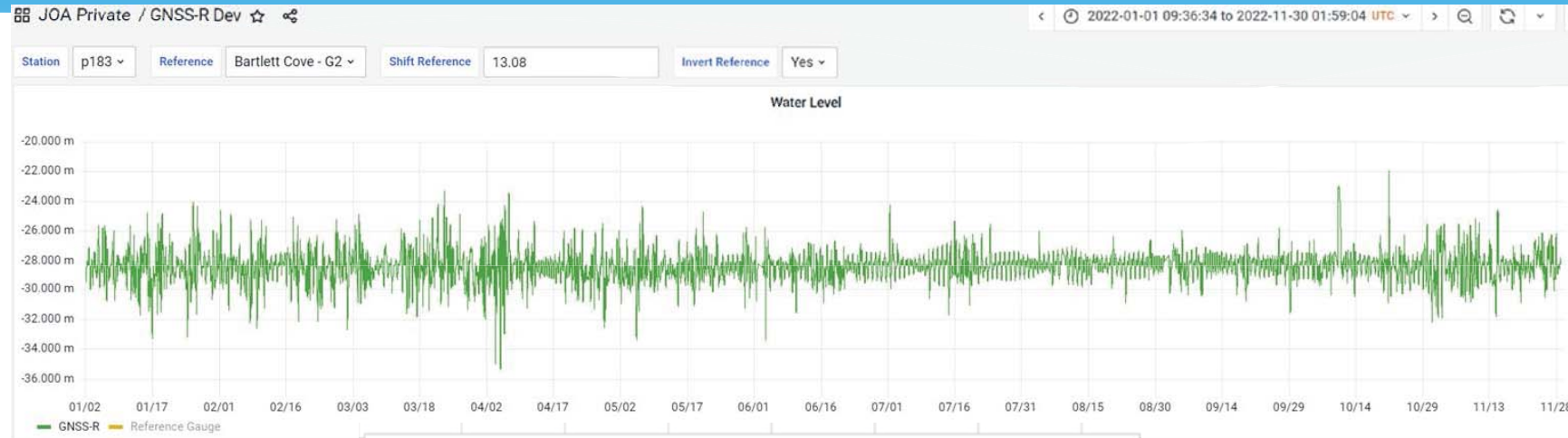


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P183



P183



Site Analysis for Processing Parameters

GNSS-IR Reflection Zone Mapping

Station Location
Input 4 character station name: (uses Nevada Reno database)
OR
Input coordinates: Lat. (deg) Lon. (deg) EllipseHt (m)

Reflection Height (meters)
☒ Use Mean Sea Level ☐ Set Reflector Ht. Value

Frequency
☒ L1 ☐ L2 ☐ L5

Compute Nyquist (this takes a few seconds)
☐ no ☒ yes rcvr sample rate (sec)

Elevation Angles (degrees)
☐ 5,10,15 ☒ 5,10,15,20,25 ☐ 5,7,10,12 ☐ 5,6,7 ☐ 10,15,20 ☐ 5,7,10

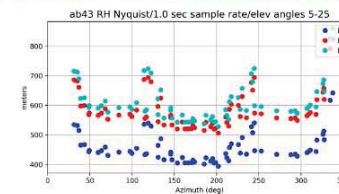
Azimuth Angles (degrees)
Start (deg) End (deg)

Constellation
☒ GPS ☐ Galileo ☐ Glonass ☐ Beidou(MEO)



GNSS-IR Reflection Zone Mapping

Station: ab43
Latitude: 58.19884215
Longitude: -136.6408077
Ellipsoidal Height(m): 26.925
Reflection Ht. (m) : 22.605
Elevation Angles (deg) : 5,10,15,20,25
Azimuth Angles (deg) : 0 to 360
Constellation : GPS
Frequency: L1

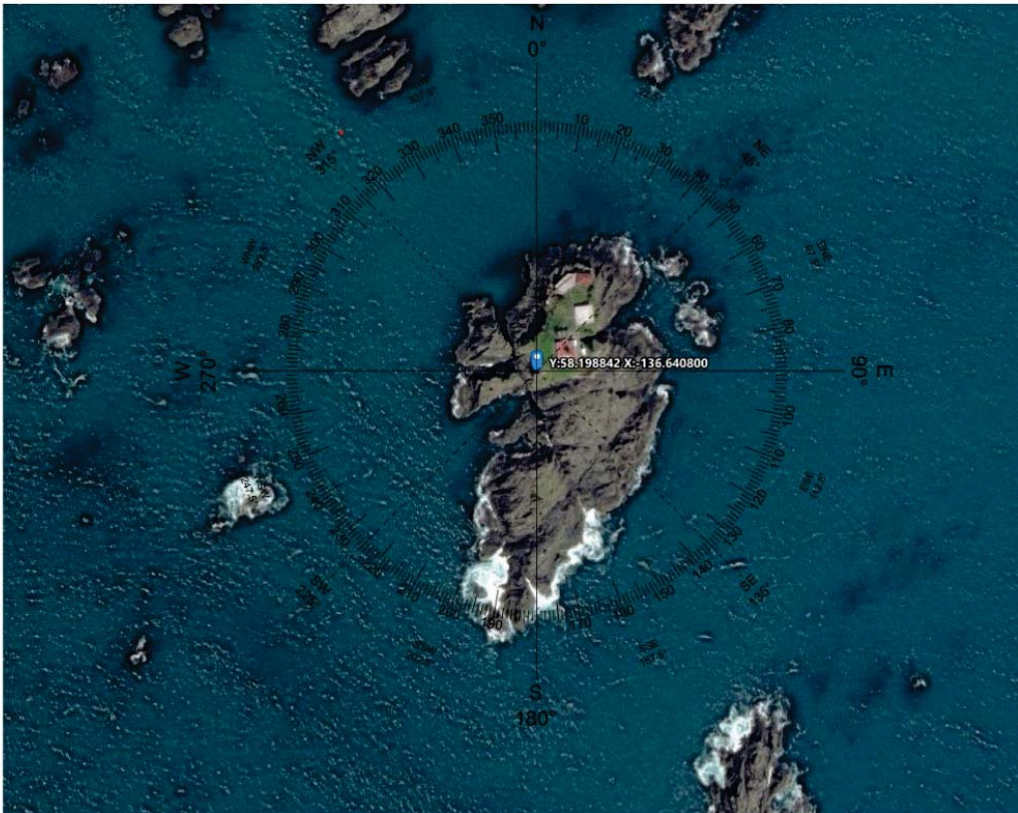


[Return to the Reflection Zone API](#)



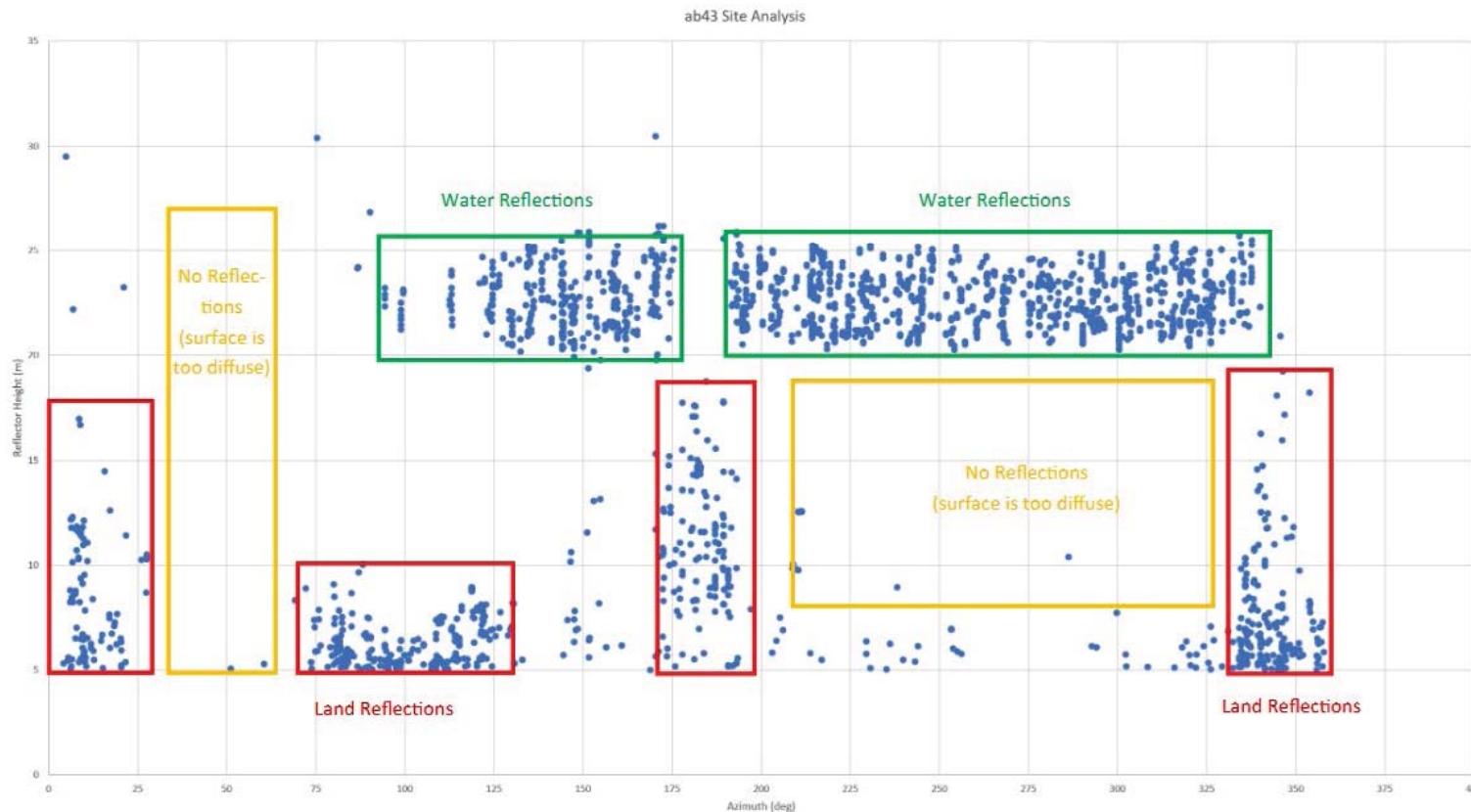
Site Analysis for Processing Parameters

ab43



CORS station AB43 is located on a island near the Gulf of Alaska. The antenna is ~23m above the water.

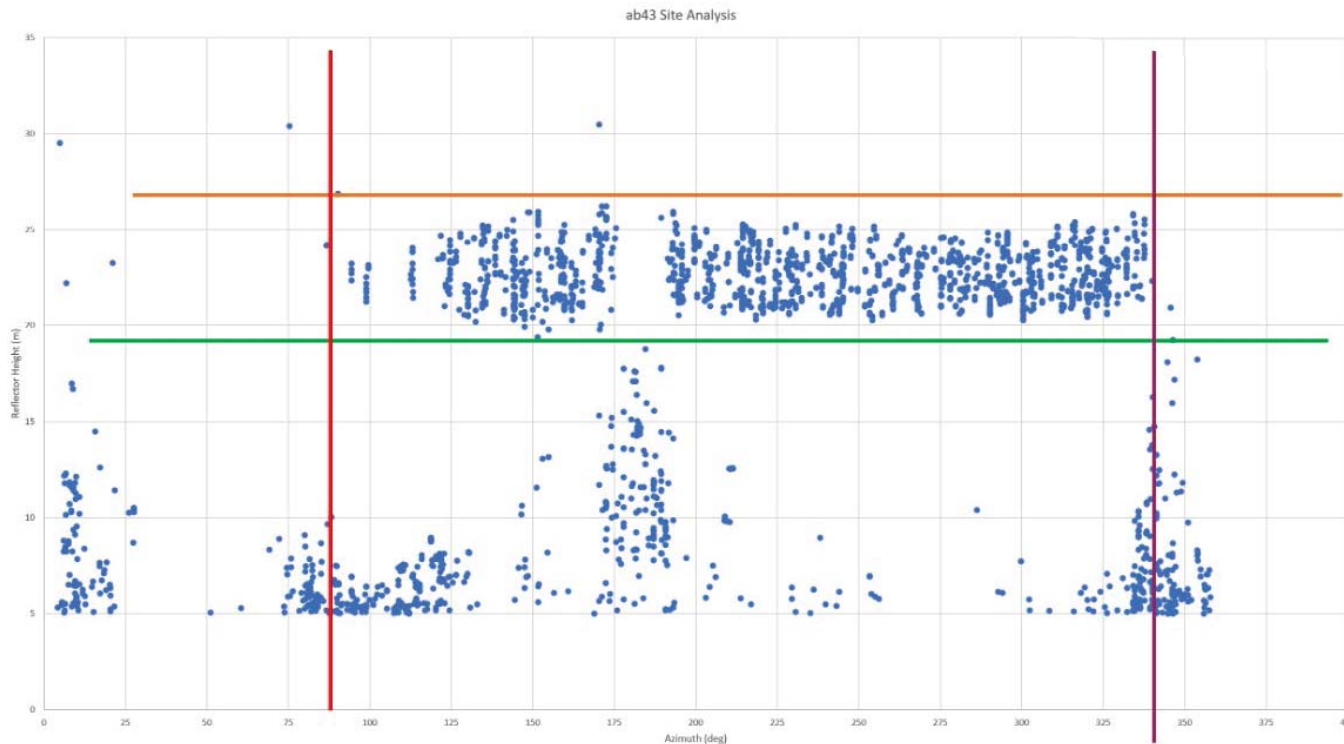
Site Analysis for Processing Parameters



GNSS-R analysis of data from CORS AB43 using full 360 degree azimuth span.

Azimuths for isolating water returns as outlined in green.

Site Analysis for Processing Parameters



Setting for this station:

reflector height min = 19 m

reflector height max = 27 m

azimuth min = 85°

azimuth max = 340°

Processing parameters for AB43

AB43 Processing



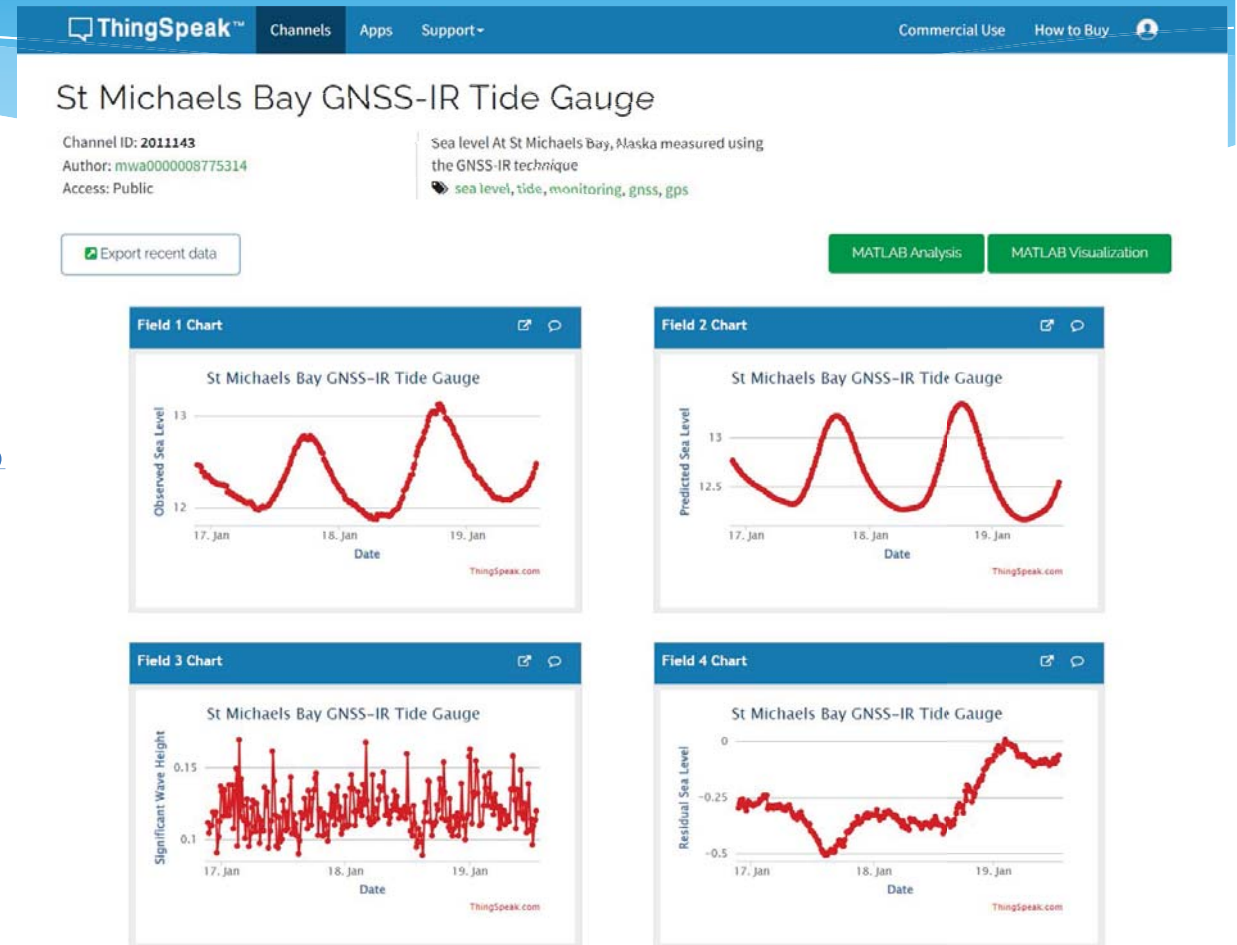
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Ideal Receiver Setup

- * GPS GLONASS Galileo BeiDou (LEO)
- * 1 Hz
- * SNR (Hi res)
- * 0 degree mask
- * Raw Binary or RINEX 3

Near Real Time: AT01

- * AT01 Near Real Time (15 minute)
Simon Williams
<https://thingspeak.com/channels/2011143>



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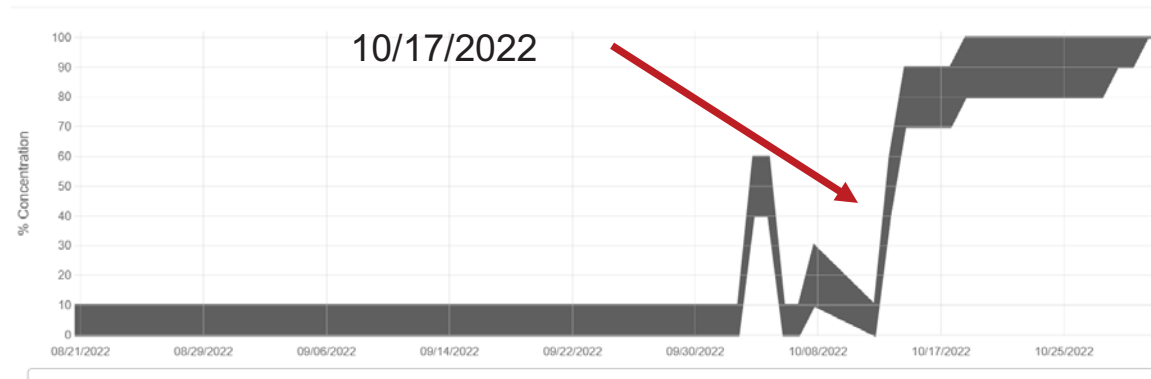
STP1 Prudhoe Bay



- * Early season ice growth

- * STP1 - Data provided by Hilcorp, with thanks to Karl Kyzer

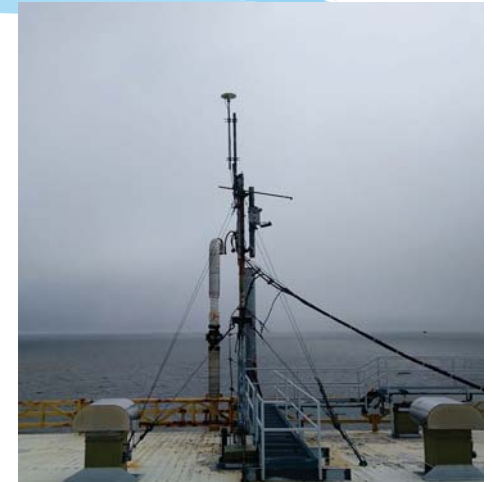
Sea Ice (NOAA)
70.422, -148.536



STP1



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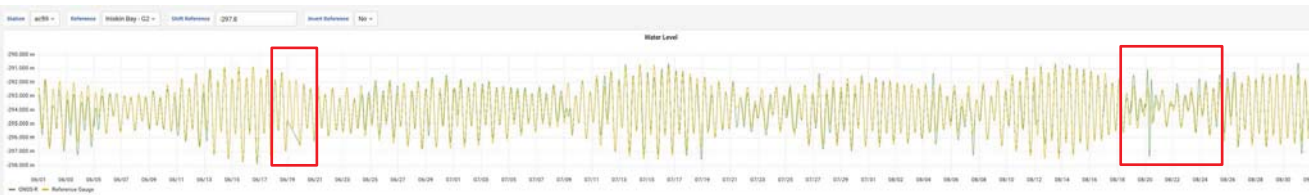
Accidental VDATUM Tide Gauge AC59

Events:

6/01-9/01 945 6525 Iniskin Bay VDATUM Gauge

6/19 Receiver Swap

8/20 – 8/22 High Winds



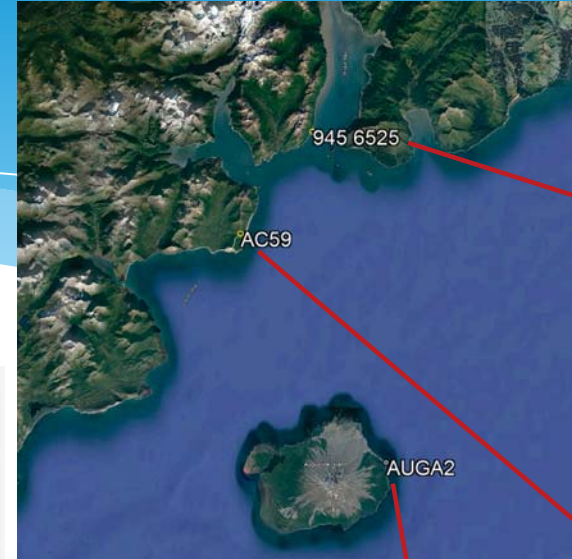
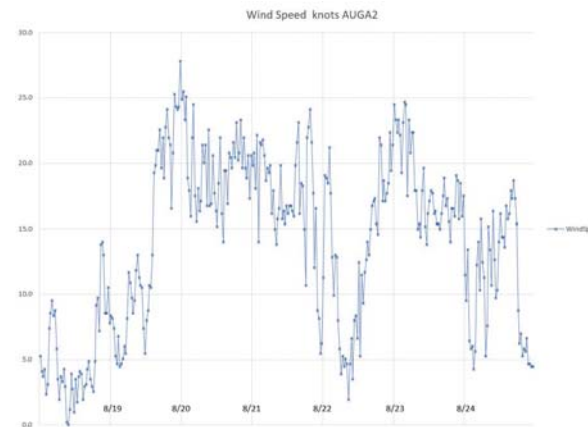
AC59 UNAVCO PBO GNSS Data

~ 290 m. above Cook Inlet

~ 7.5 sq. mi. refl. zone

~ 500 m. inshore

1 Hz data rate required



Results

- * GLBX – Full GNSS Large Window 500 arcs/day
- * ATO1 – 946 8333 missing low tides

GLBX – Data provided by National Parks Service, with thanks to Joel Cusick

STP1 - Data provided by Hilcorp, with thanks to Karl Kyzer

ATO1 & AC59 – Data provided by UNAVCO

Going Forward

- * Algorithm Development – (Strandberg) 1.0 ready latency 12 hours
 - * 2.0 Kalman Filter latency 15 min.
 - * Quality Control / Quality Assurance (or is it stormy)
- * Low Power setup with real-time communication
- * Automated near real-time processing with data access (AOOS?)
- * Address NWLON Gaps

Questions

