GNSS-IR provides new insights into surface water dynamics

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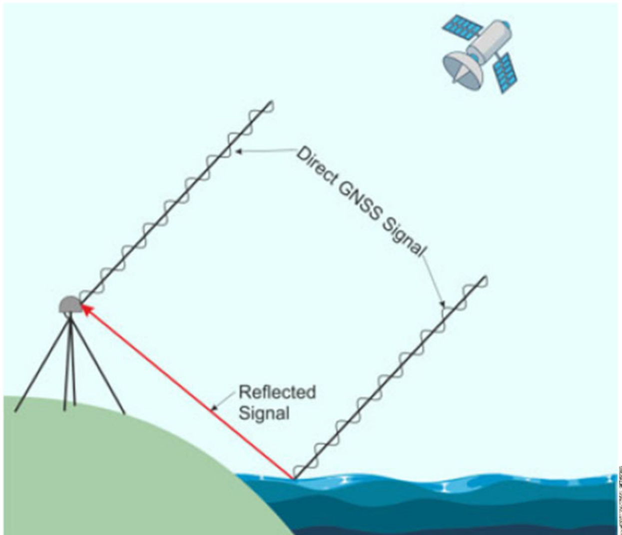
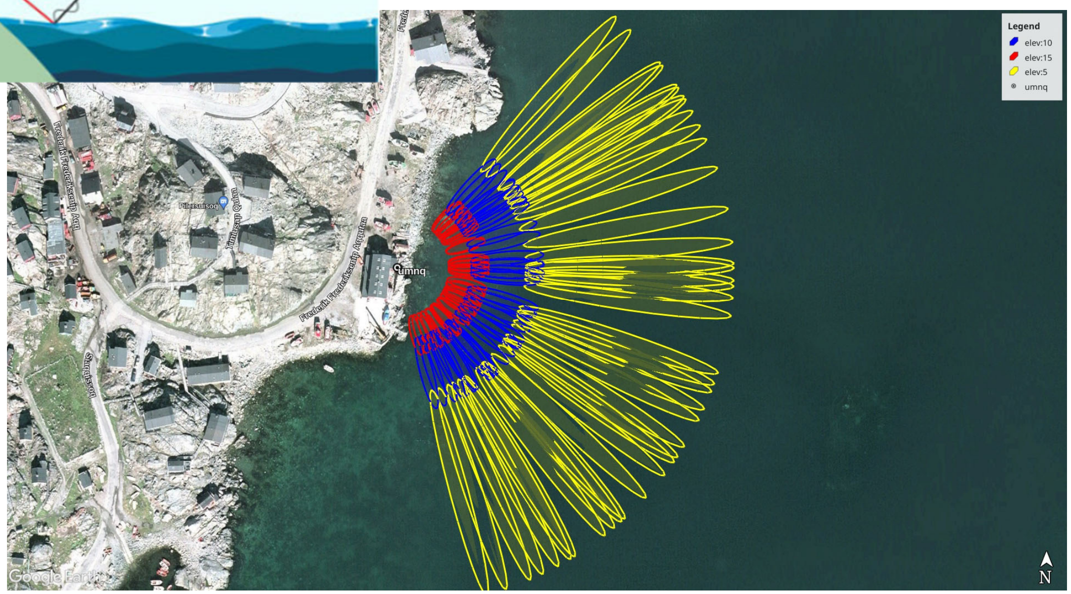
Outline

- GNSS-IR overview
- Applications
- Ongoing projects
- Future work

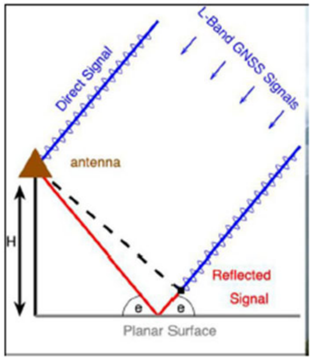
What is GNSS-IR?

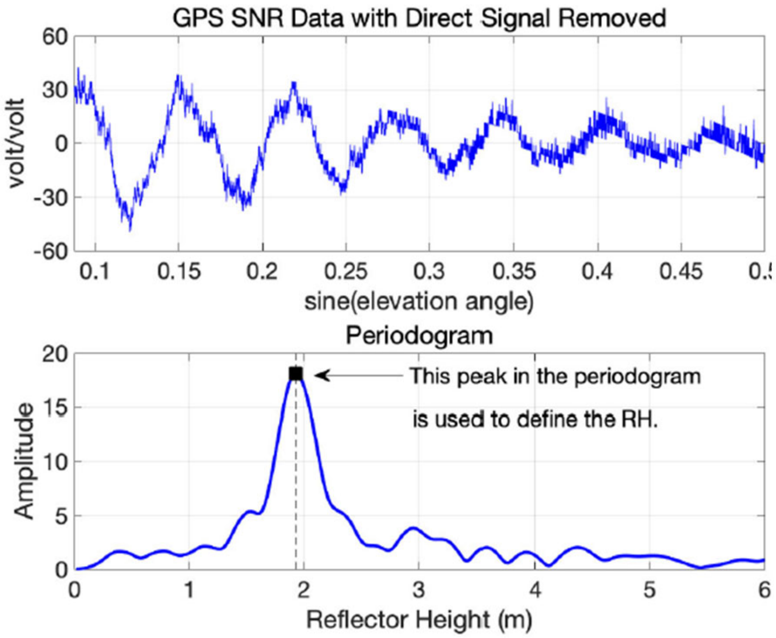


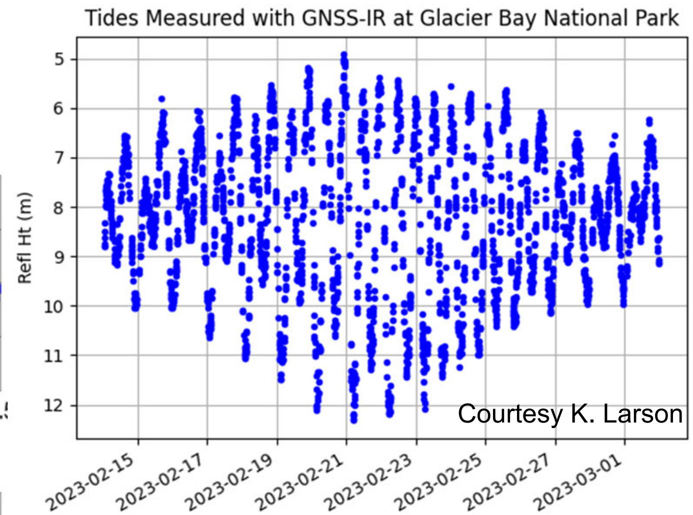


- GNSS interferometric reflectometry (GNSS-IR) is a techniques that uses the multipath noise to estimate the height of coherent surfaces below the antenna.
- This is done for each satellite visible to the receiver and can be done for any overhead constellation (GPS, GLONASS, Galileo, BeiDou).
- Generally, a single receiver height value is estimated for each rising and setting satellite arc.
- To use the method optimally, one must identify the GNSS satellite arc reflections (right).
- The method fails if the reflecting surface is very rough.

What is GNSS-IR?





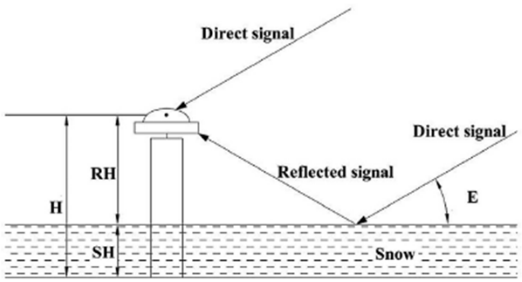


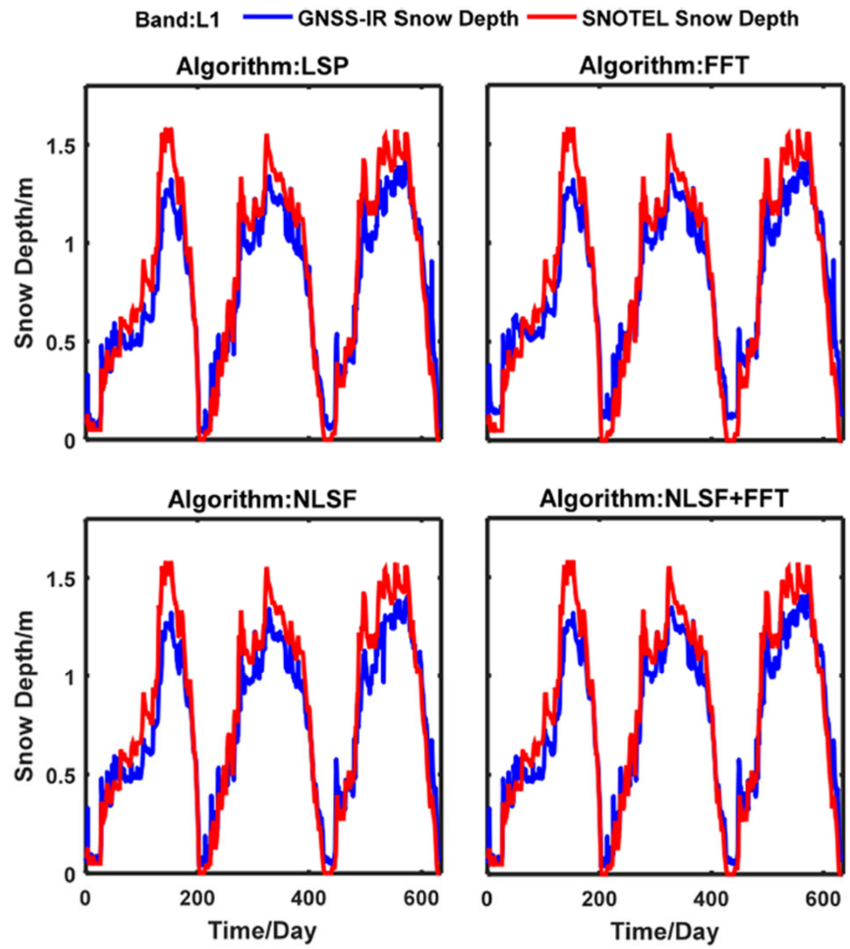
- GNSS-IR treats the GNSS system as a bistatic radar. The interference pattern created by the direct GNSS signal and the signal reflected from a planar surface the antenna has a distinctive frequency that is related to H (left).
- The estimate of H is derived from the dominant frequency in the GNSS Signal-to-Noise Ratio (SNR) data.

https://psmsl.org/data/gnssir/introduction.php
Larson et al., 2021

GNSS-IR: Snow depth

- GNSS-IR snow depth inversion experiment using observation data from P351 station (Plate Boundary Observatory), located in the Boise National Forest, Idaho, 2013-2016.
- Left: Comparison of P351 GNSS-IR and local SNOTEL station snow depth measurements for four different fitting algorithms.



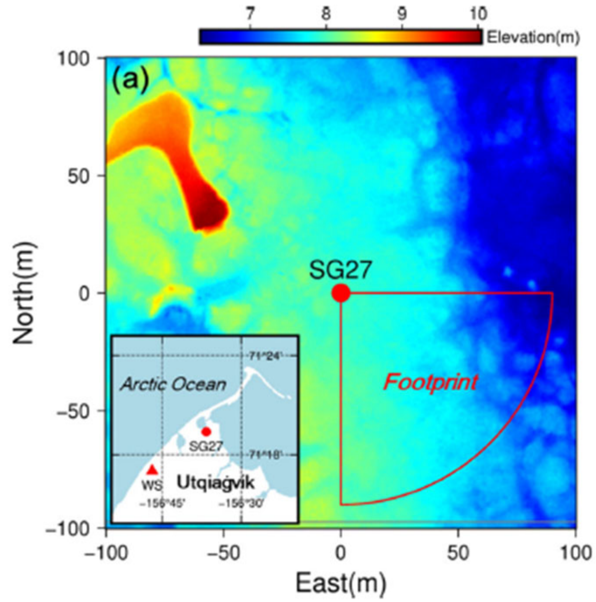


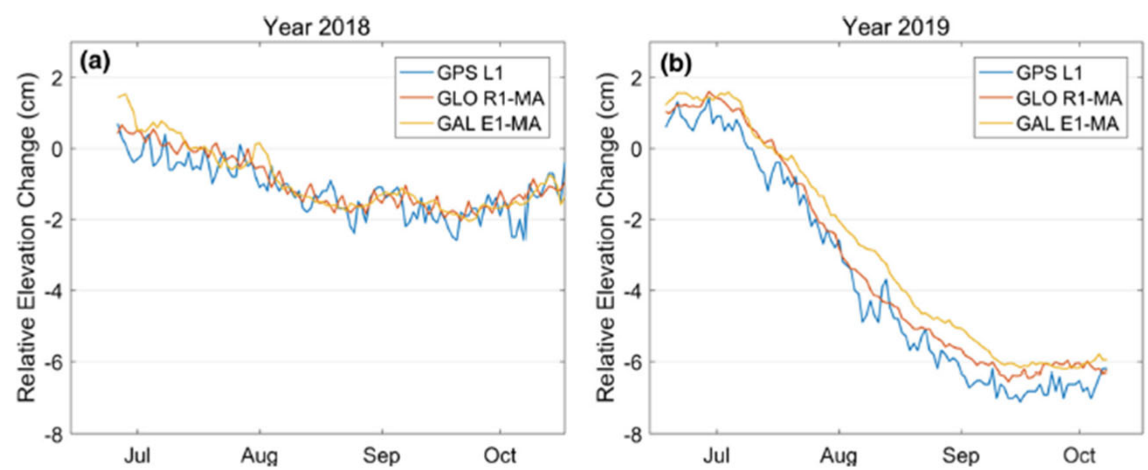
Li et al., 2020

GNSS-IR: Permafrost

SG27 is a continuous operating PBO reference station (71.3229°N,156.6103°W) with a geodetic GNSS receiver, located in Northern Utqiaġvik (formerly Barrow) Alaska (top).

Here, GNSS-IR receiver heights were averaged over 8-day intervals to produce permafrost subsidence during the summers of 2018 and 2019.

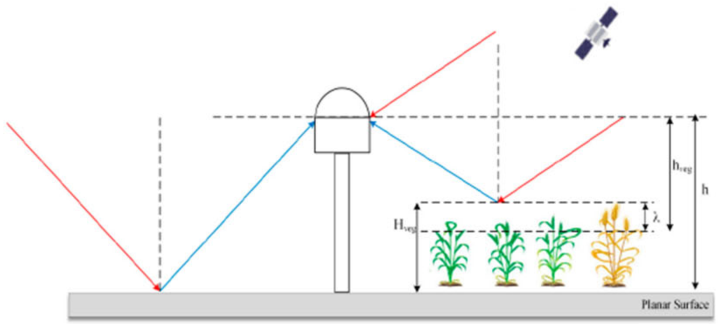


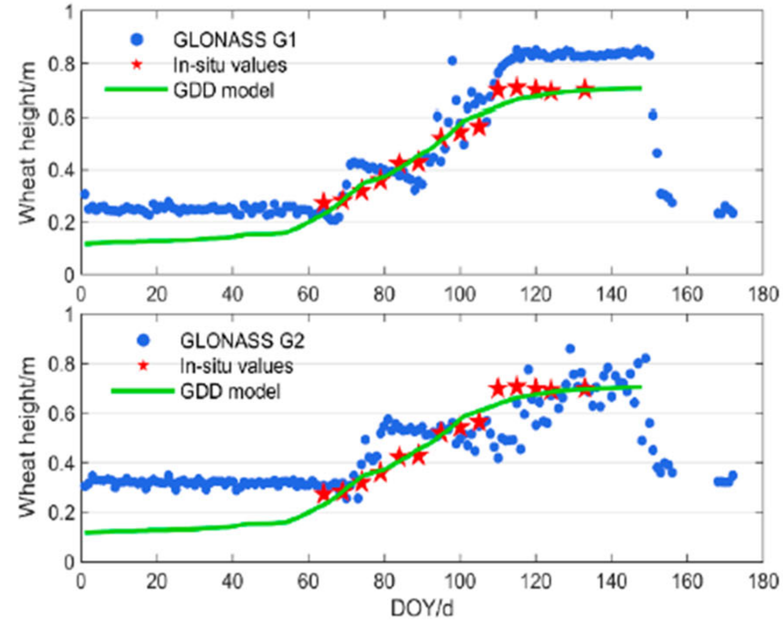


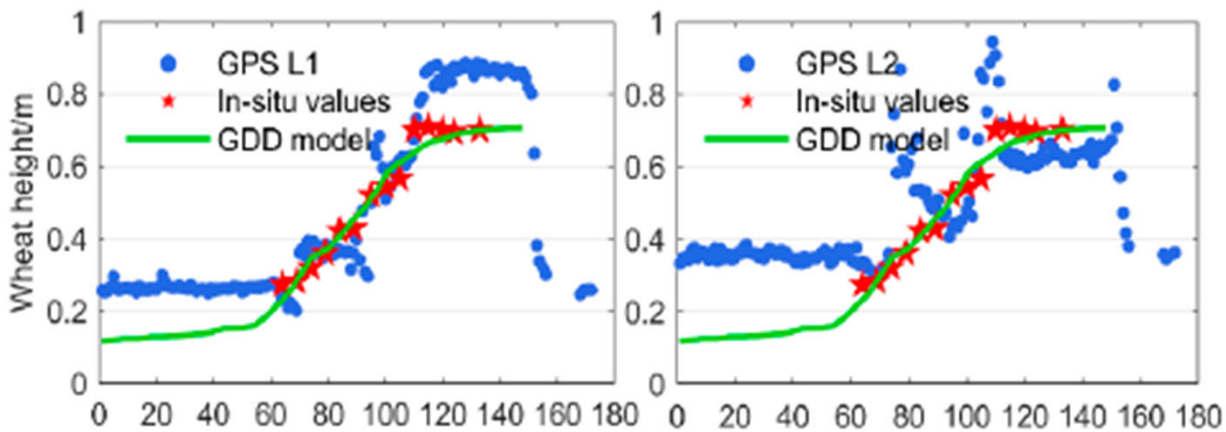
Hu et al., 2022

GNSS-IR: Vegetation Height

- GNSS-IR experiments in wheat fields in Fengqiu County, Henan Province, China.
- Schematic of wheat field measurements shown on left.
- Graphs compare in situ values for L1 and L2 frequencies, both GLONASS (right, top) and GPS (bottom).



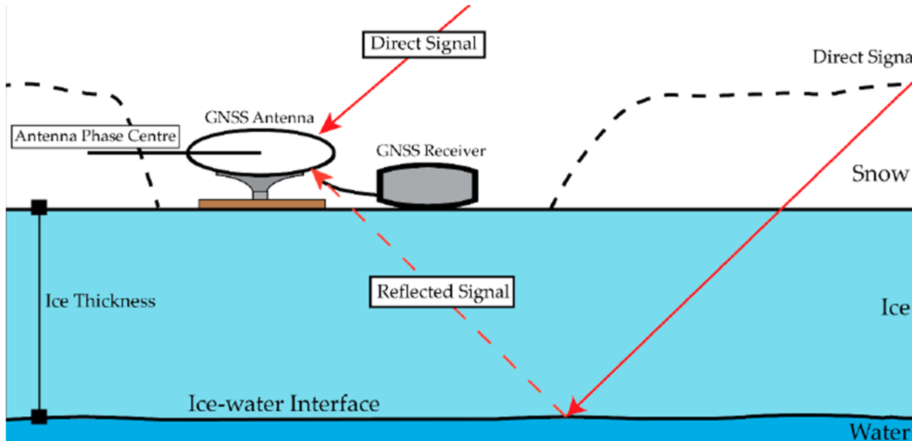


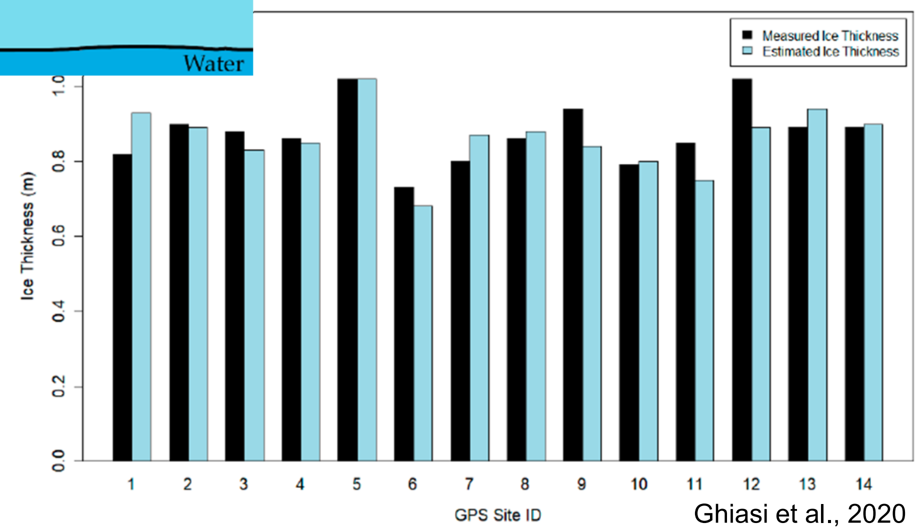


Sui et al., 2022

GNSS-IR: Lake Ice Thickness

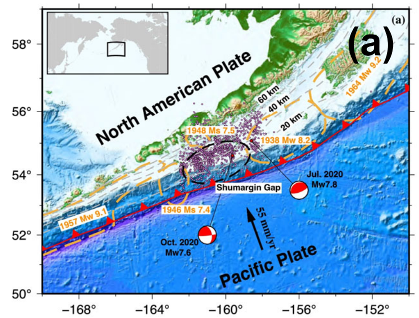
- Top right: Lake site locations, 14 GNSS-IR experiments carried out on L1 band data acquired from 8-22 March, 2017-2019, Northwest Territories, Canada.
- Top left: Schematic of GNSS-IR signal recovery.
- Bottom left: GNSS receiver setup.
- Bottom right: Comparison of GNSS-IR ice thickness estimates and in situ measurements.

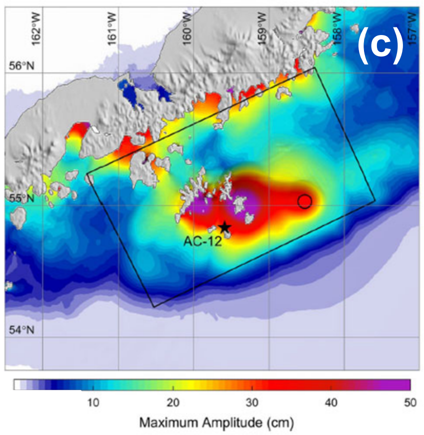


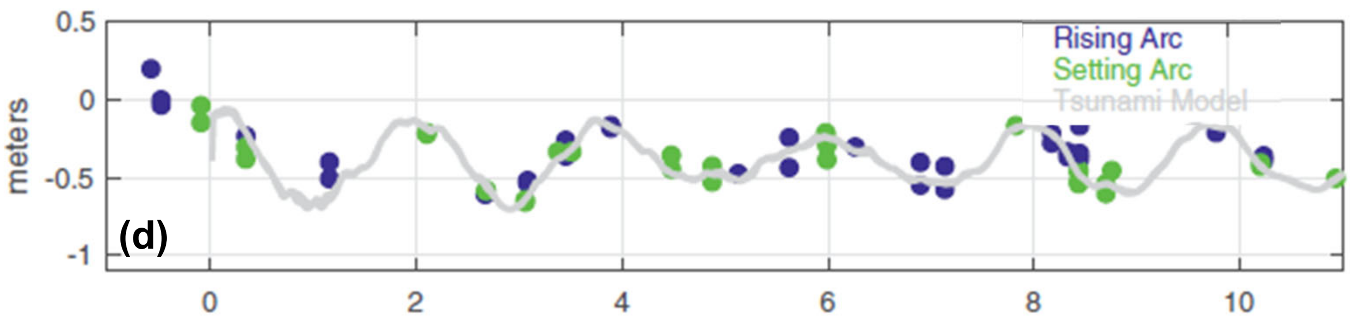


Ghiasi et al., 2020

GNSS-IR: Tsunami



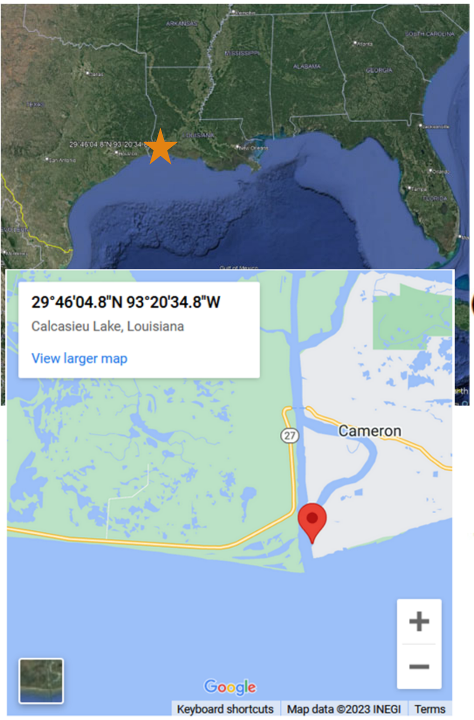


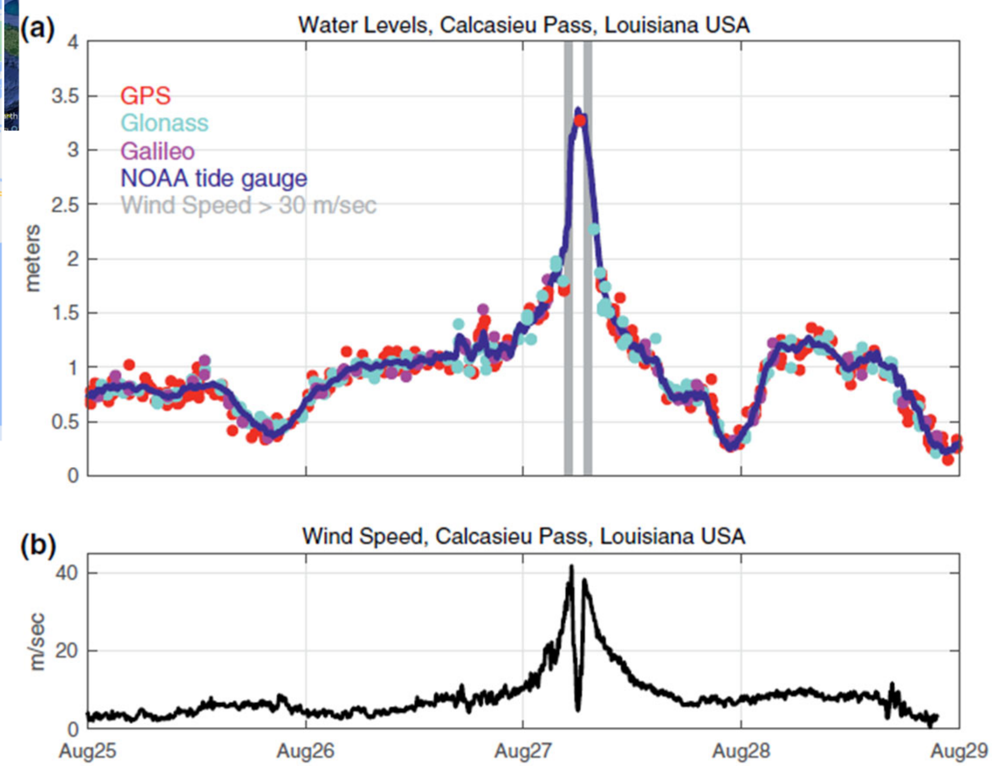


(a) July 22, 2020, Shumagin Gap earthquake.
(b) GNSS receiver AC-12 on Chernabura Island, Alaska (Photo credit: UNAVCO) and reflection zones used for AC-12 water level measurements.
(c) Maximum computed tsunami amplitude for the Shumagin Islands earthquake; circle indicates the epicenter. Location of GNSS station AC-12 is indicated with the star.
(d) Sea level estimates based on de-tided GNSS-IR relative sea level measurements for rising (blue) and setting (green) satellites and the tsunami model (gray).

Larson et al., 2021
Xiao et al., 2021
Maps courtesy of Google Earth.

GNSS-IR: Storm Surge



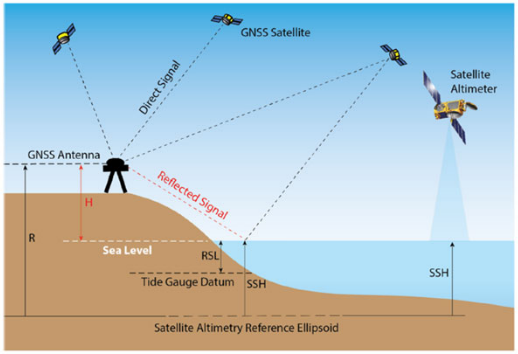


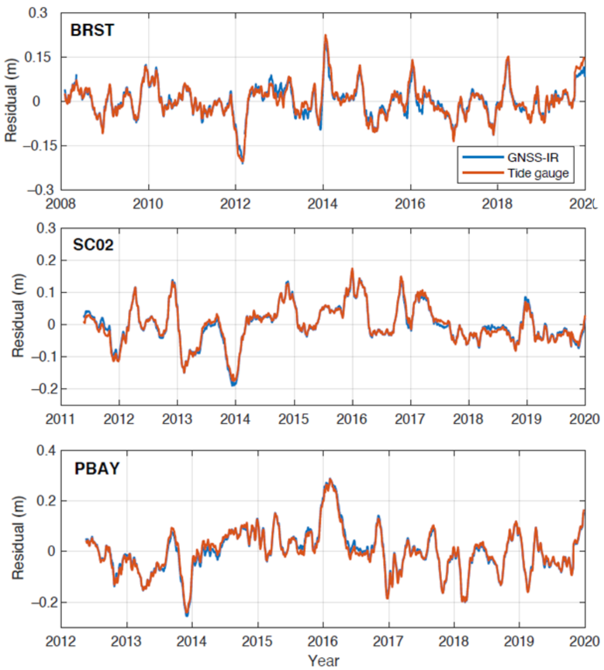
Hurricane Laura struck the Gulf Coast of the United States in late August 2020.

GNSS-IR was able to accurately track the storm surge throughout the landfall of the event.

GNSS-IR measurements from GPS, GLONASS and Galileo satellites during Hurricane Laura, and acoustic tide gauge and wind speed at the same location, left.

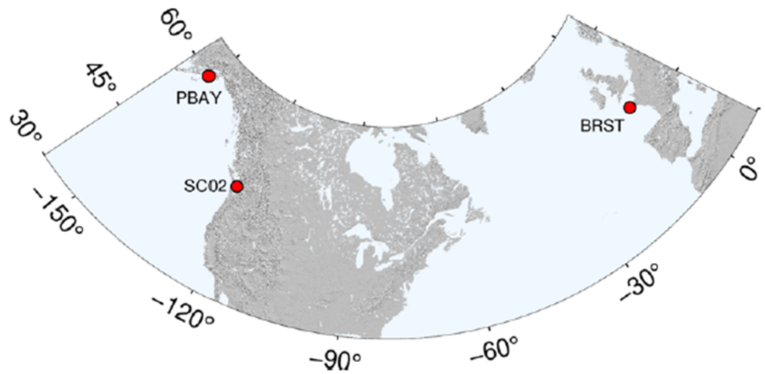
Larson et al., 2021

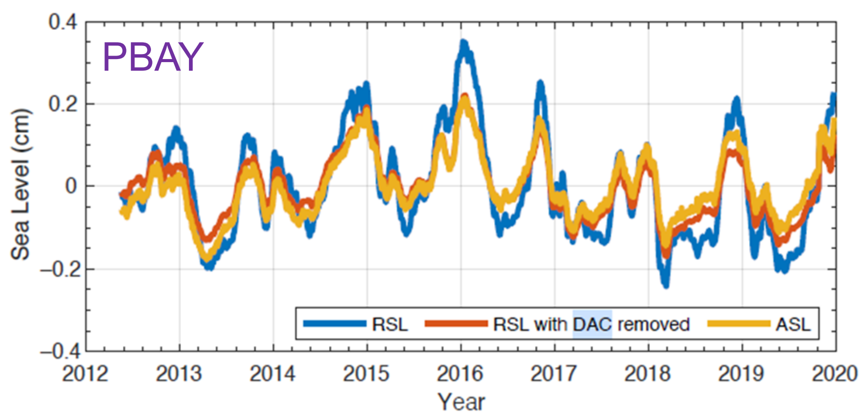




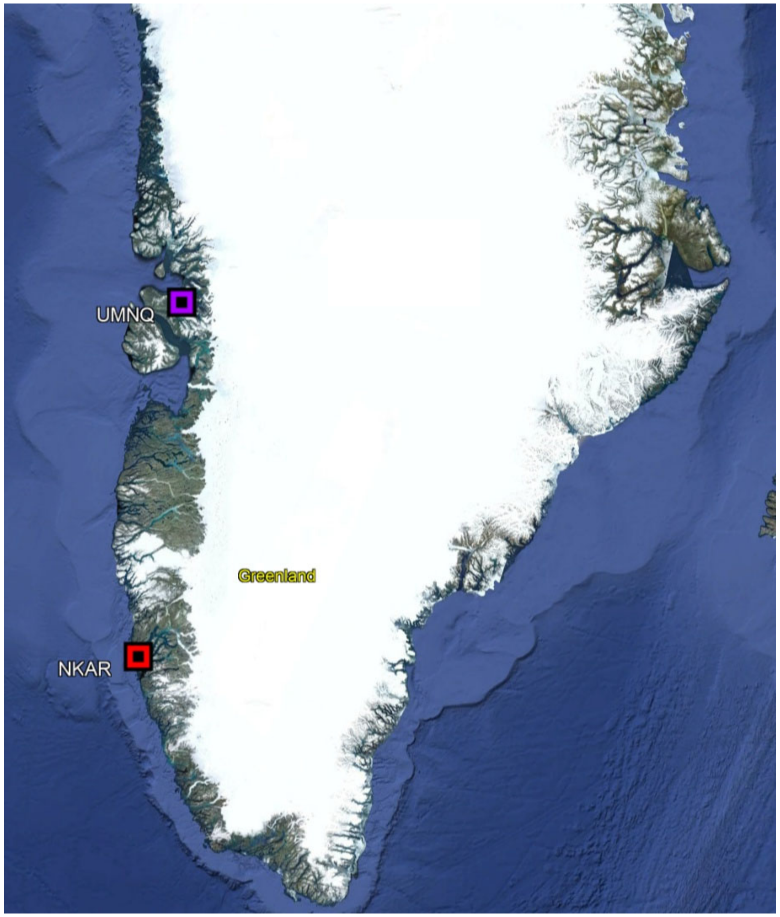
Peng et al., 2021

GNSS-IR: Sea level change





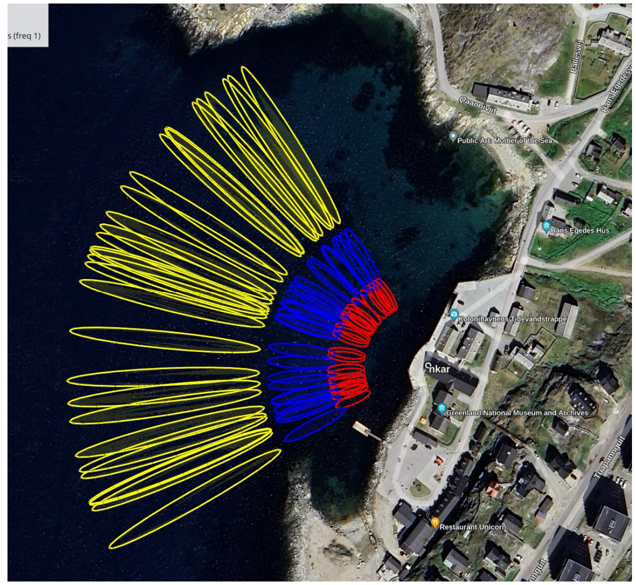
- Here, GNSS-IR was used to measure coastal absolute sea-level changes using three coastal GNSS stations from different regions (center).
- Comparison of deseasoned GNSS-IR sea level heights at the three stations show (bottom left).
- Relative and absolute sea level at PBAY, below.



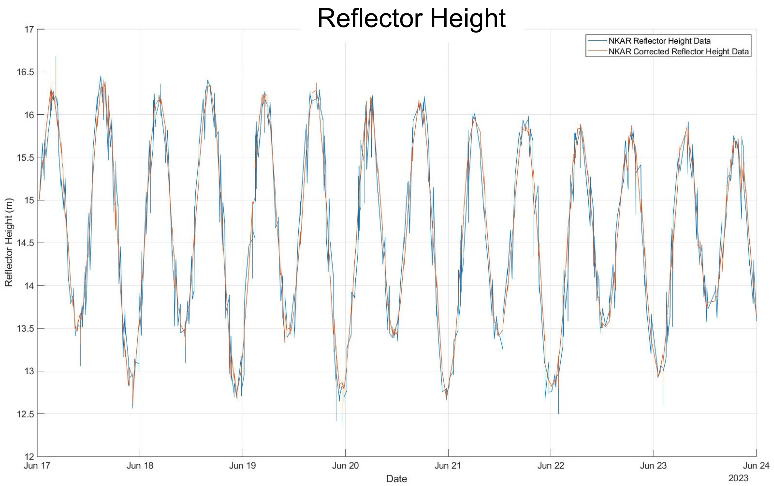
Greenland Hazards Project

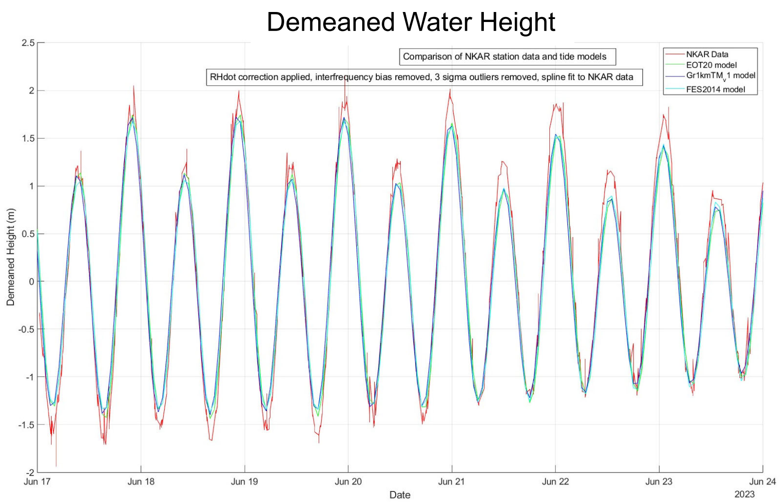
- Under an NSF Navigating the New Arctic project, we installed two GNSS stations in coastal towns to obtain GNSS-IR time series of changing water height.
- We hope to characterize storm surge, sea level rise and large waves caused by ice calving, landslides.
- The project includes both data analysis and modeling, and characterization of the background wave signal in each harbor.

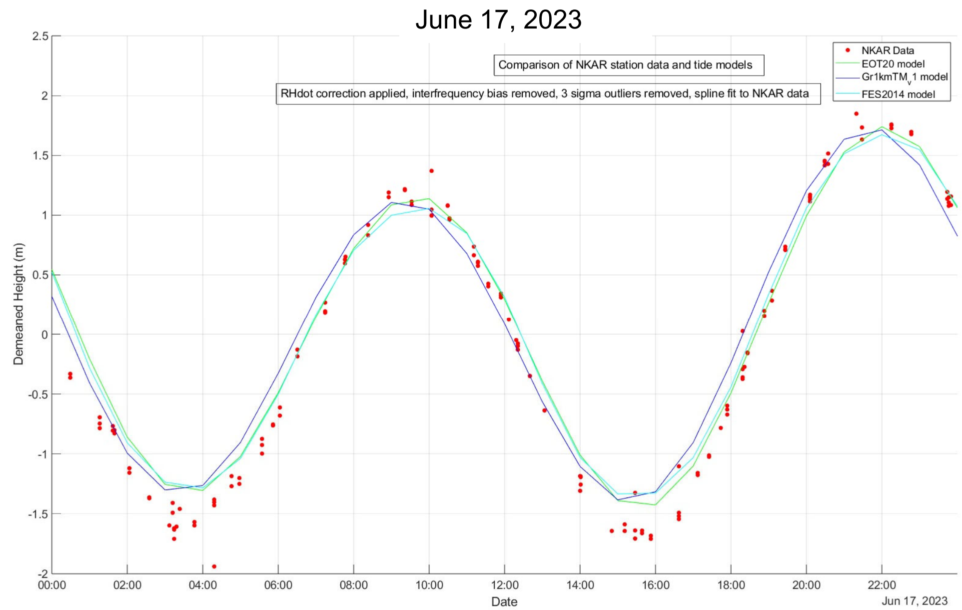
Greenland: NKAR



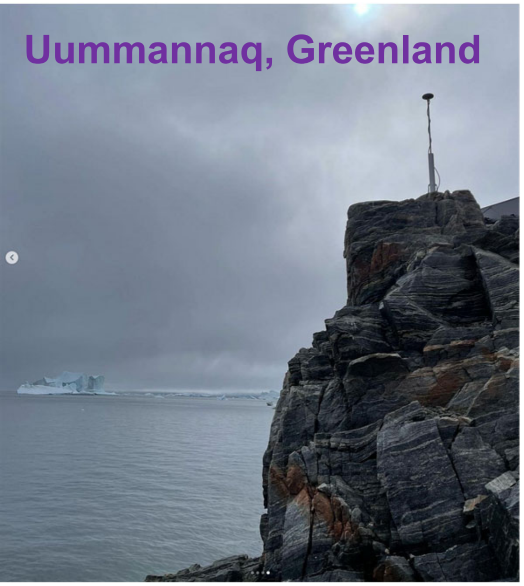
Greenland: NKAR

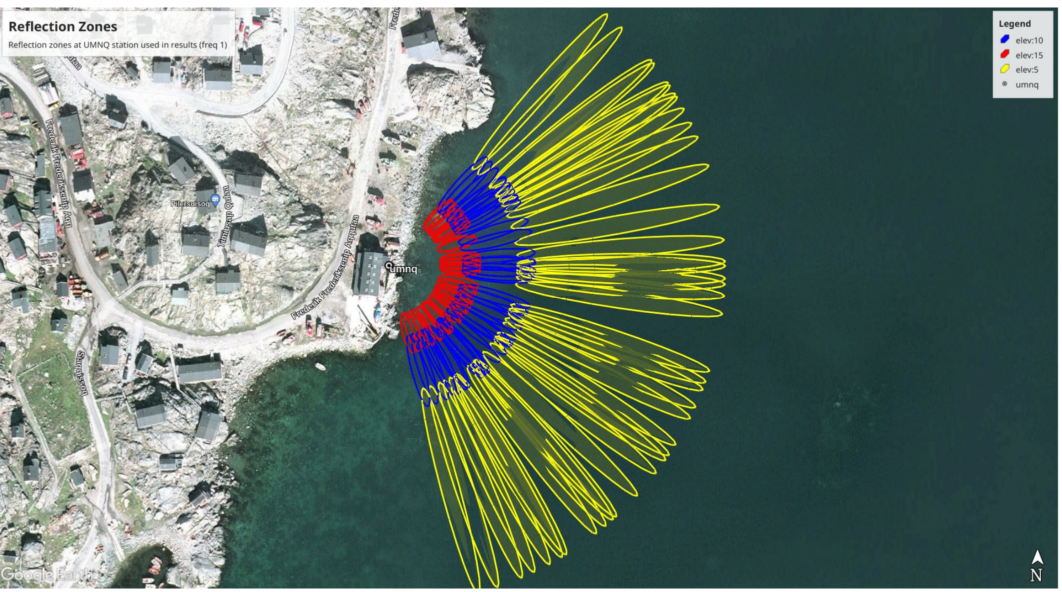


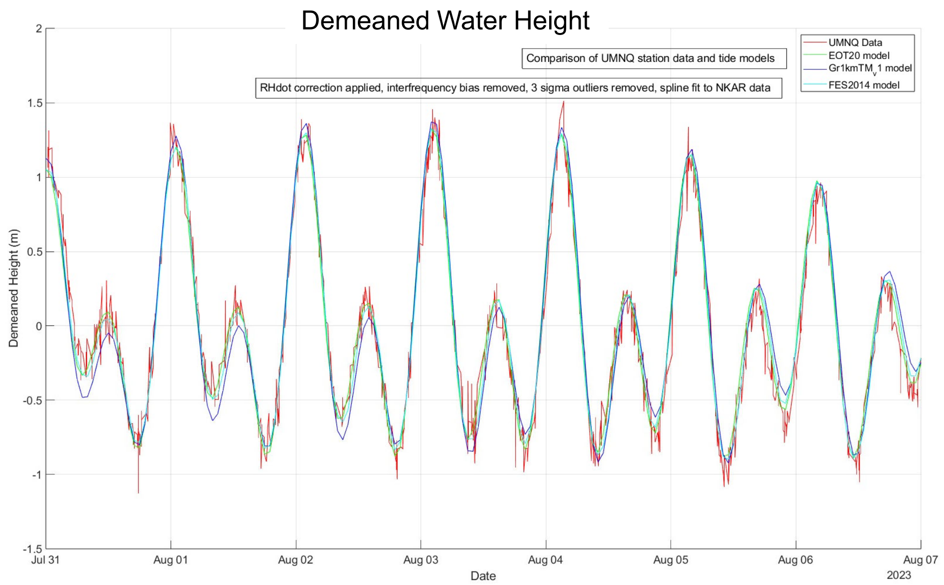


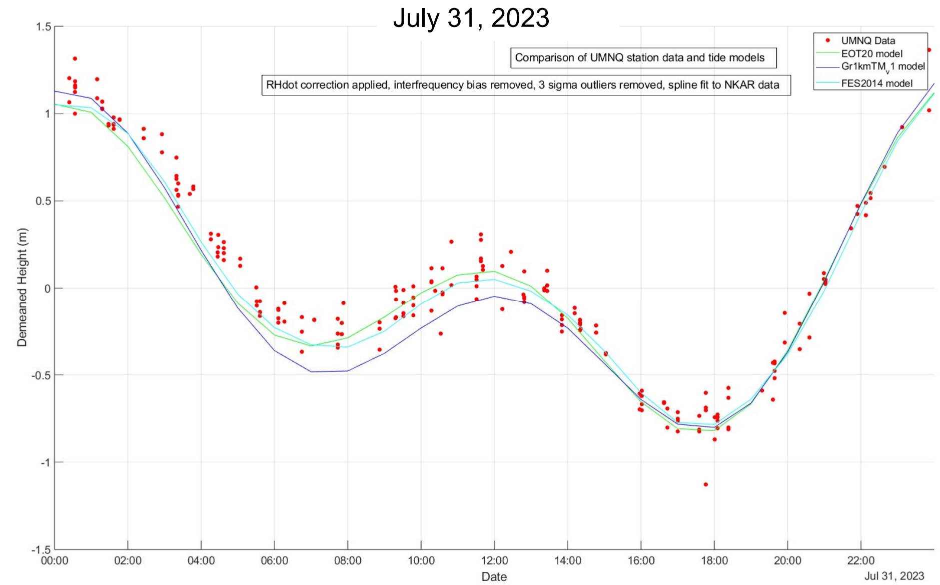


Greenland: UMNQ









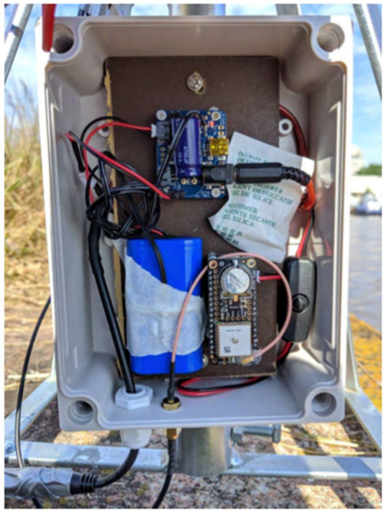
Greenland: UMNQ

On-Demand GNSS-IR Network

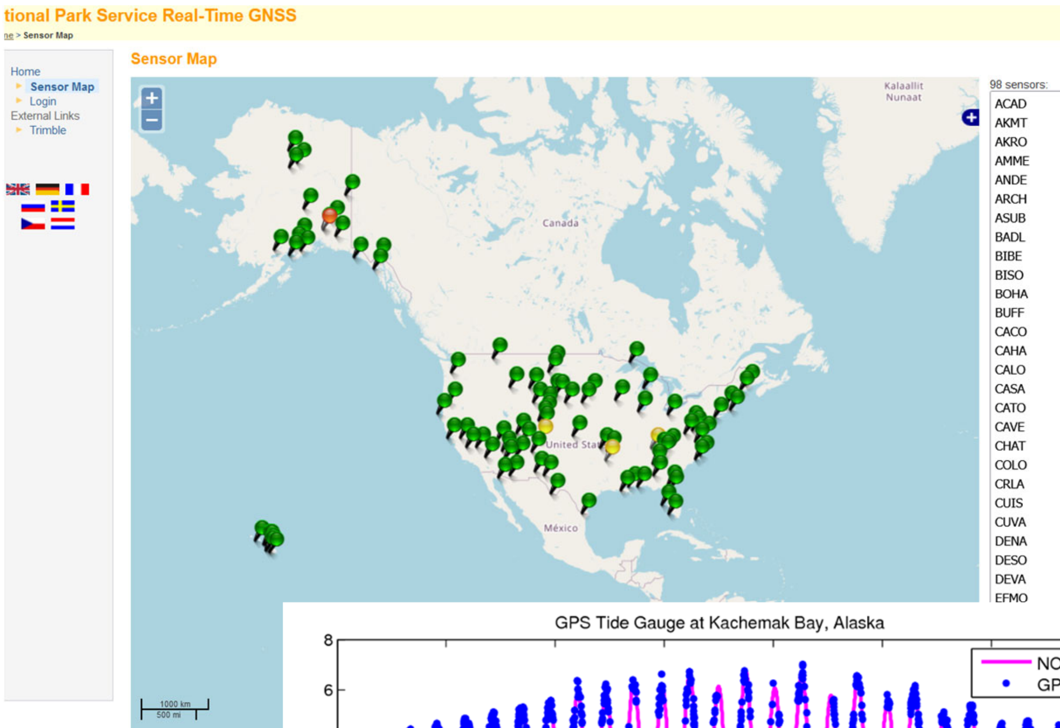
- We are purchasing an ad hoc network of GNSS-IR instruments that can be deployed to study dynamic or remote phenomena.
- 10-15 stations, both pre-assembled SparkFun kits and custom-built stations.
- SparkFun units are pre-assembled, but with a greater power draw and higher cost.
- The custom built units are cheaper and with a lower power draw.
- Both include solar power, battery backup, and microSD storage.

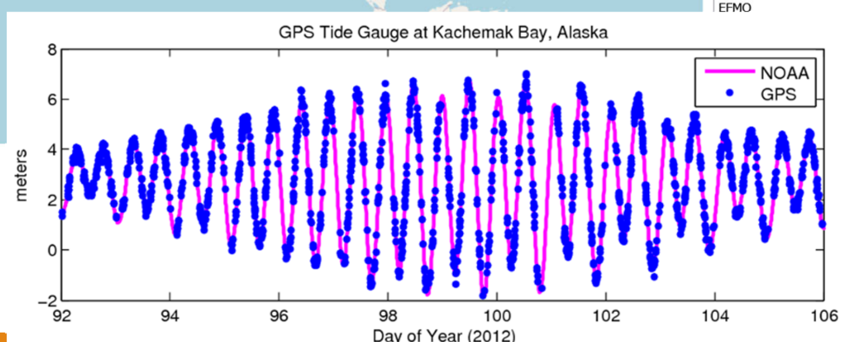
SparkFun RTK Express

Custom Build



https://github.com/fgnievinski/mphw





What’s next?

- With NPS, we are developing improved GNSS-IR time series of local water level height at selected stations and a near real-time processing algorithm.
- We will investigate potential error sources and corrections and provide guidance on appropriate siting criteria for new stations in efforts to reduce any error.
- Coupled with our work in Greenland and ad hoc network installations, the longer-term goal is better characterization of the complete surface water signal in various settings, including ice, boats, storm surge, and large waves.

Thank you!