ASTRA

ATMOSPHERIC & SPACE TECHNOLOGY RESEARCH ASSOCIATES

SCIENCE + TECHNOLOGY + APPLICATIONS // *Bringing it all together*

Monitoring ocean water level in remote shoreline locations using GPS reflectometry

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May 22, 2018
Alaska Water Level Meeting, Anchorage AK

NOAA — NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION — U.S. DEPARTMENT OF COMMERCE

AOOS Alaska Ocean Observing System

Goals of Presentation

- Description of sensor
- Primary uses of sensor
- Infrastructure and system requirements for installation
- Test examples of collections in Alaska
- Possible new sites where sensor(s) could be installed

ASTRA Overview

❖Science
❖ Technology
❖ Applications

Bringing It All Together

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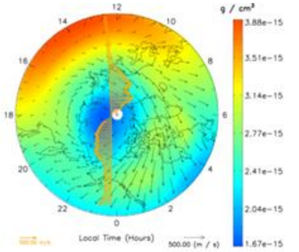
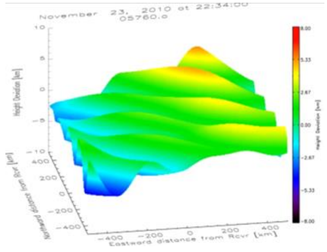
Modeling

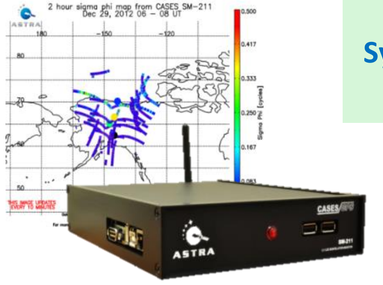
- Physics-Based Modeling (TIMEGCM)
- Real-Time Specification of Ionosphere/ Thermosphere





Data Assimilation

- High-latitude Electrodynamics
- Global Ionosphere
- Thermospheric Neutral Density
- Satellite Drag & Ballistic Coefficients



Data & Eng. Services

- Space Based Data (OPIR, etc.)
- Ground Based Data
- Forensic Space Weather Analysis
- Spacecraft Modeling
- Systems Engineering

Celebrating our 13th Anniversary

Ground-based Instrument Development

- GPS-based Space Weather Monitor
- E-fields and Magnetometers
- Low Power Ionospheric Sounder
- HF TID Mapper
- HF Systems
- Lidar Systems

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Space Systems

CubeSat Missions

- NSF: DICE & LAICE
- AF: DIME, SIPS & TSS
- NASA: SORTIE & MiRaTa

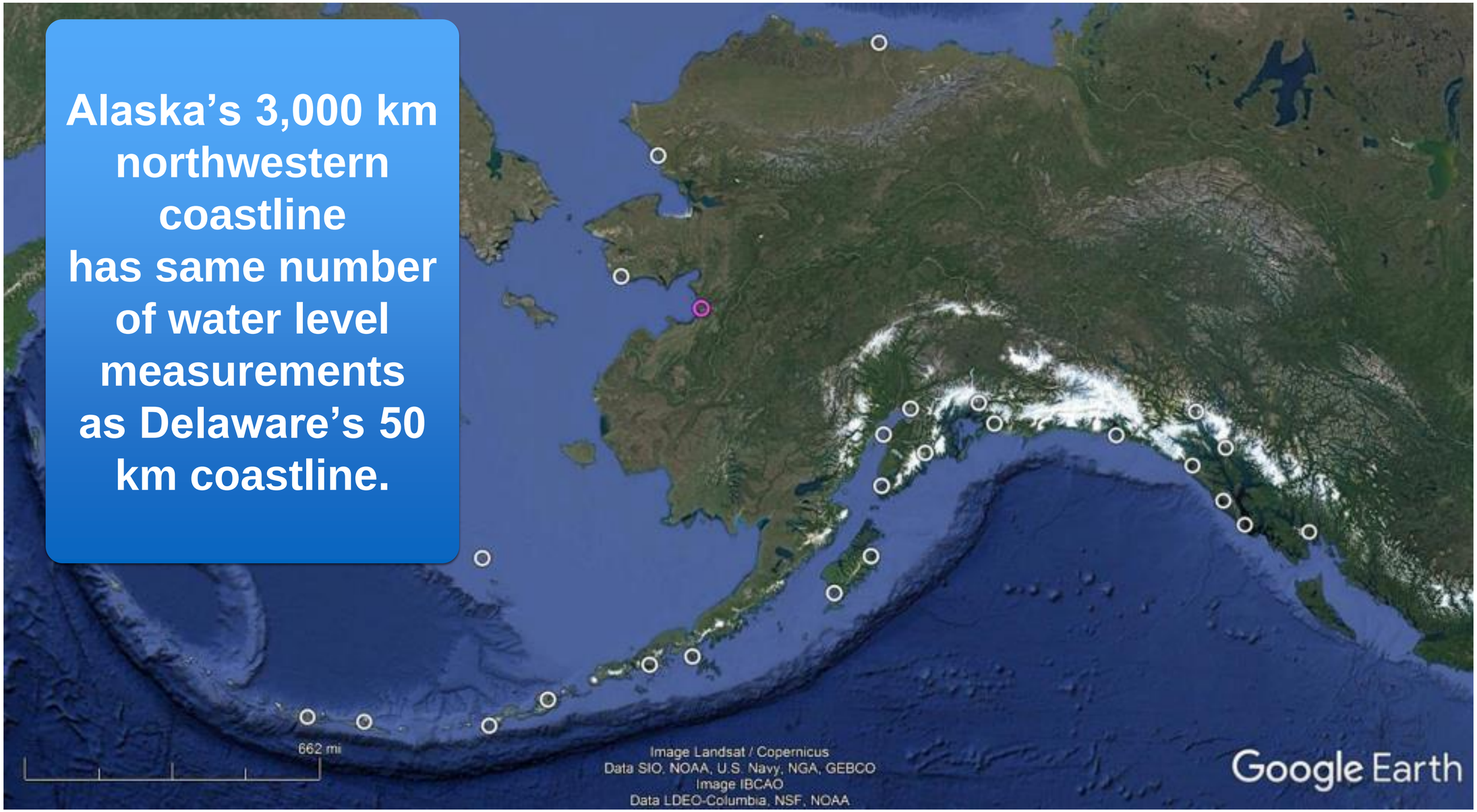
Plug-N-Play Avionics

CubeSat Instruments

- Scanning UV Photometer
- E-field Double Probe
- RF Waves & Sounder
- Wind Profiler
- GPS-based Space Weather Monitor
- Magnetometer & Langmuir Probe

Hosted Payloads

The Problem

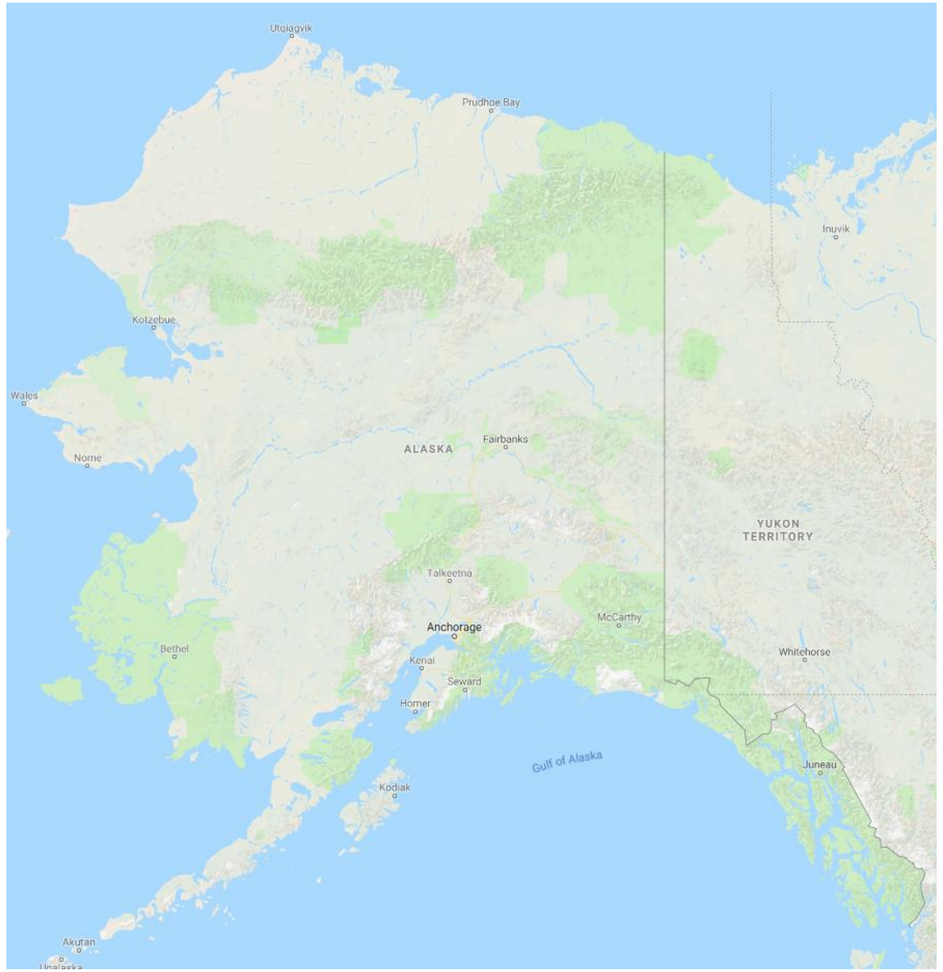


Alaska's 3,000 km northwestern coastline has same number of water level measurements as Delaware's 50 km coastline.

Description of sensor

- **New type of water level sensor**
  - Accurate real-time measurement of water levels and extraction of tidal constituents

- **Features:**
  - GPS-based
  - Low-cost
  - Non-contact with water
  - Low-profile
  - Remote-deployable (needs no infrastructure)
  - No maintenance



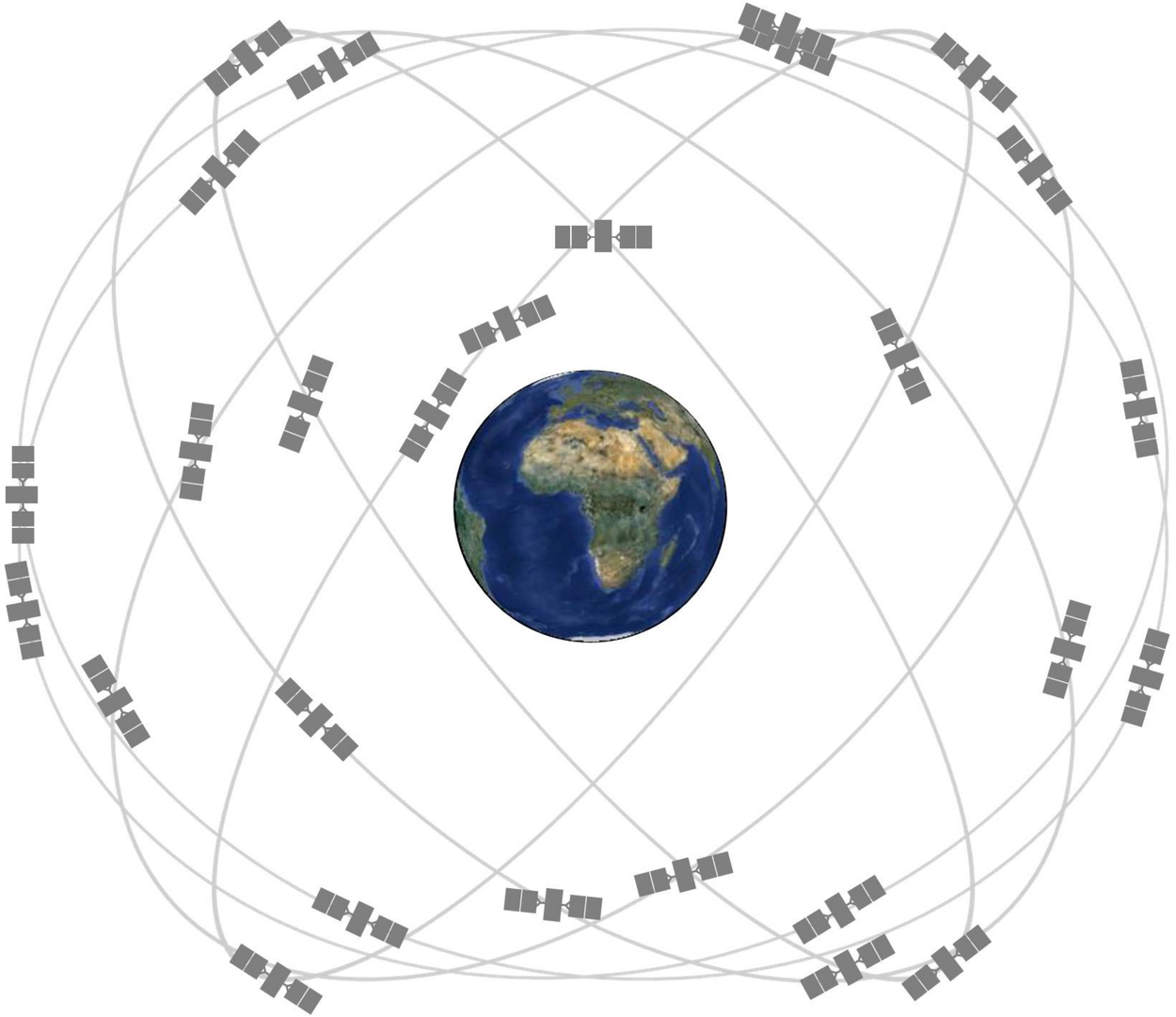
GPS - Introduction

- GPS Satellites transmit signals
- Receivers on earth receive and decode the signals
- GPS is primarily used for location
  - E.g. car navigation, smart phones

- GPS has lots of other uses:

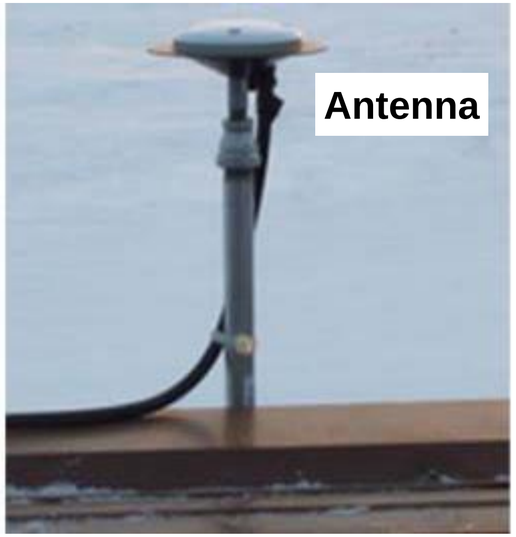
ASTRA builds GPS receivers for space weather monitoring

- ***Development funded by US Air Force SBIR program***



Installation Requirements

- **Equipment/Resources**
  1) ASTRA Receiver
  2) Dual frequency GPS antenna
  3) Power source
  4) Data Storage and/or Communication method



Installation Requirements

- **Equipment/Resources**
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  2) Dual frequency GPS antenna
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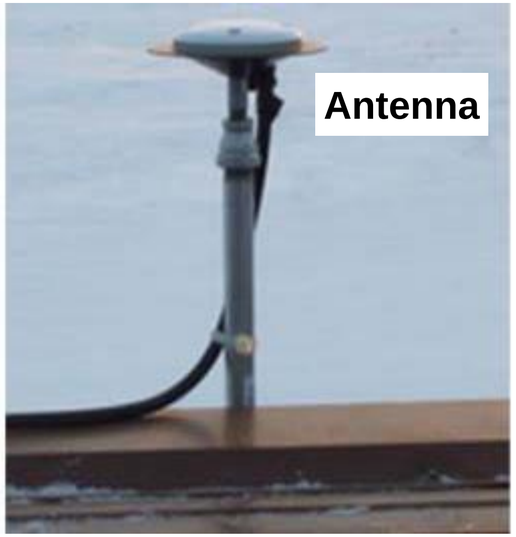
- **Two types of installations**
  - ***Land-powered*** installation
    - AC power & Cellular or Ethernet Comms
  - ***Stand-alone*** installation for remote locations
    - Solar panels & Battery & Iridium Comms

- **Specifications**
  - <2.5 Watts for GPS receiver
  - < 5 Watts total for GPS & comms & storage
  - Antenna is 5” diam x 2”
  - Total system size < 1 cubic foot (not incl. solar panels)
  - Total system weight < 10 lbs (not incl. solar panels)

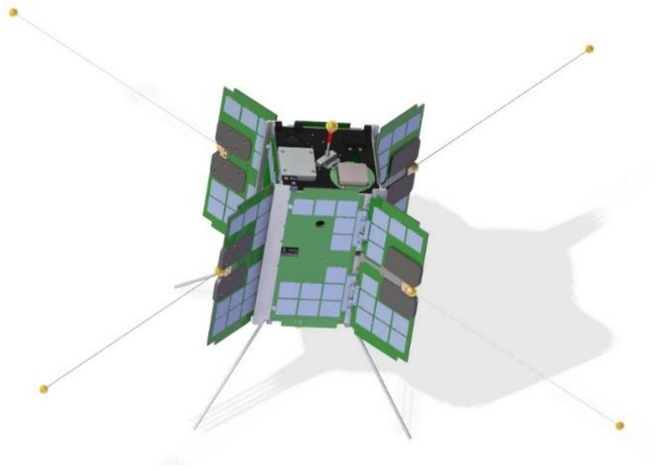
ASTRA Receiver


Antenna


Standalone Power Module

GPS Receiver Uses

- **ASTRA GPS receivers have been deployed:**
  - From the Arctic to the Antarctic
  - Aboard aircraft
  - On Cube-Sats (toaster-sized satellites)
  - On Liquid Robotics Wave Glider Buoy
  - August 2018 - two NOAA TAO buoys



- **ASTRA GPS receivers used for:**
  - Measuring Ionosphere Activity (scintillation, TEC)
  - Soil Moisture
  - Snow Depth
  - Water level & tides

GPS Monitoring of Space Weather in the Ionosphere

❖Science
❖ Technology
❖ Applications
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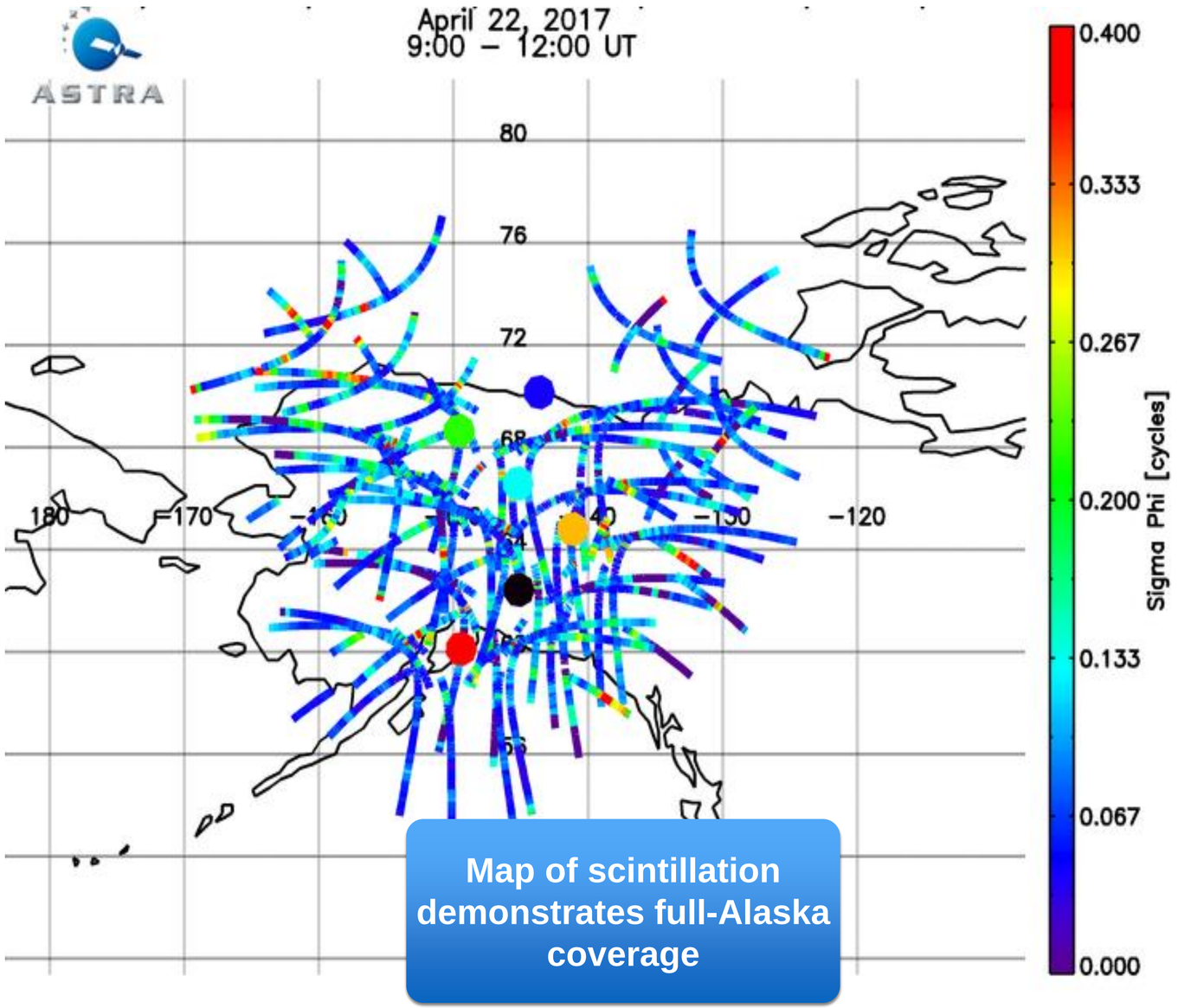
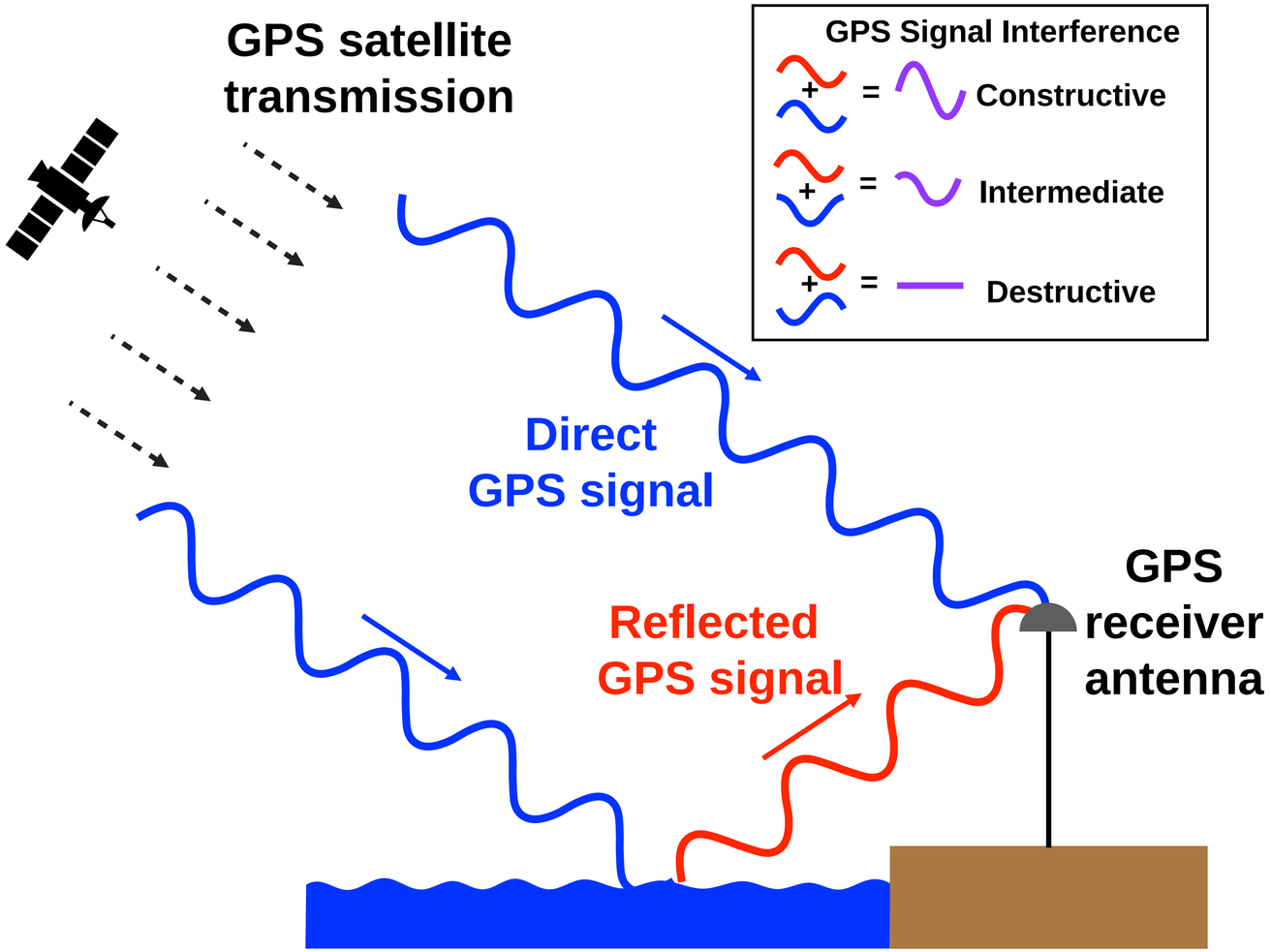
- **ASTRA deployed an array of GPS receivers in Alaska for measuring ionospheric activity**
- **5+ year continuous operation across Alaska**



Map of scintillation demonstrates full-Alaska coverage

GPS Reflectometry: Using "Noise" as a new "Signal"



- GPS Multipath (reflections) add noise to typical measurements
- Multipath causes interference
- Resulting signal amplitude depends on relative phase of the two contributing signals
- As GPS satellites rise and set, varying signal amplitude contains information about antenna height above reflecting surface

AOOS Ocean Tide Pilot Program

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❖ Technology
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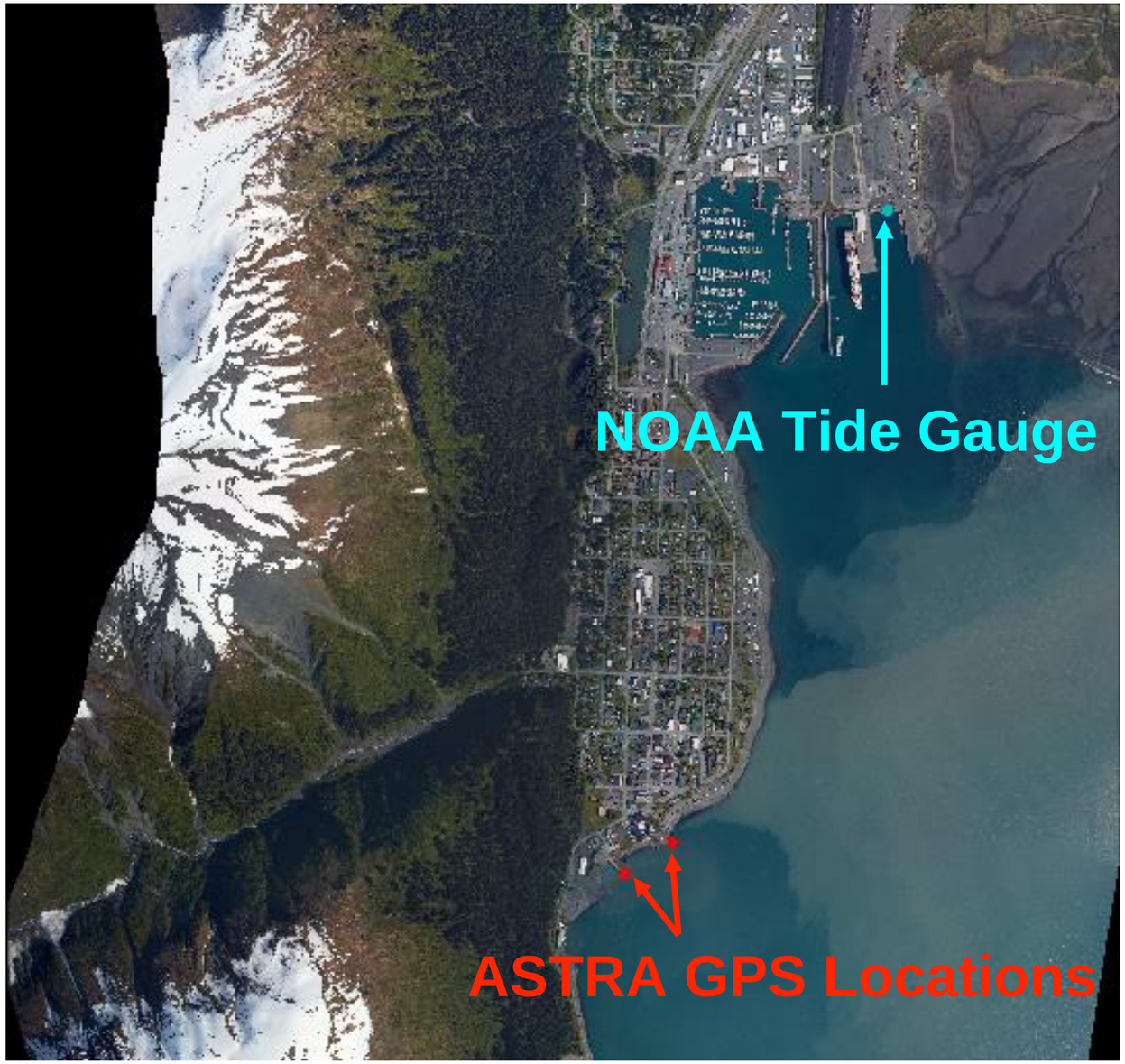
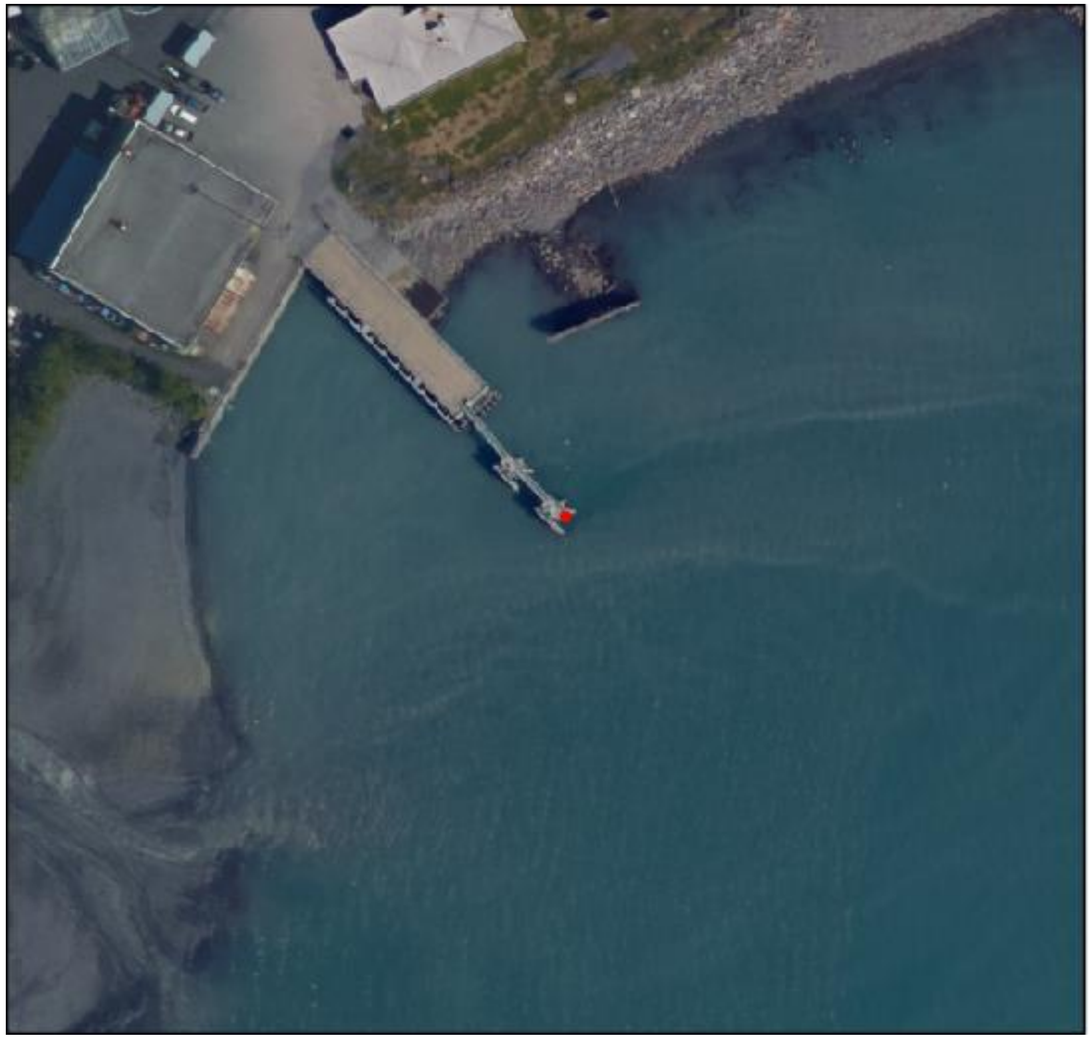
Seward Pilot Installation

- ASTRA receivers 200m apart
  - Alaska SeaLife Center
  - Seward Marine Center

- NOAA Tide Gauge is 2400m from ASTRA receivers

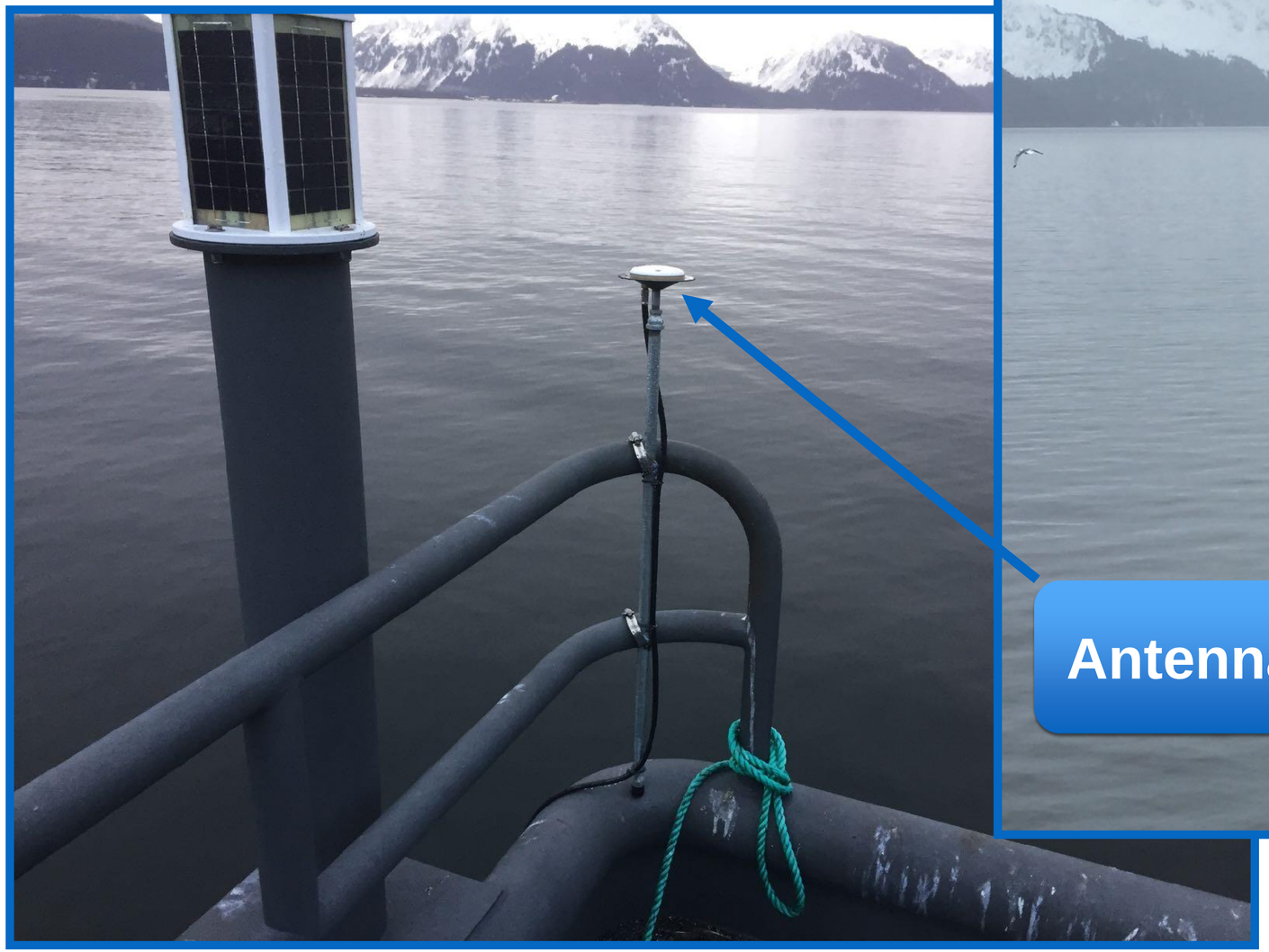


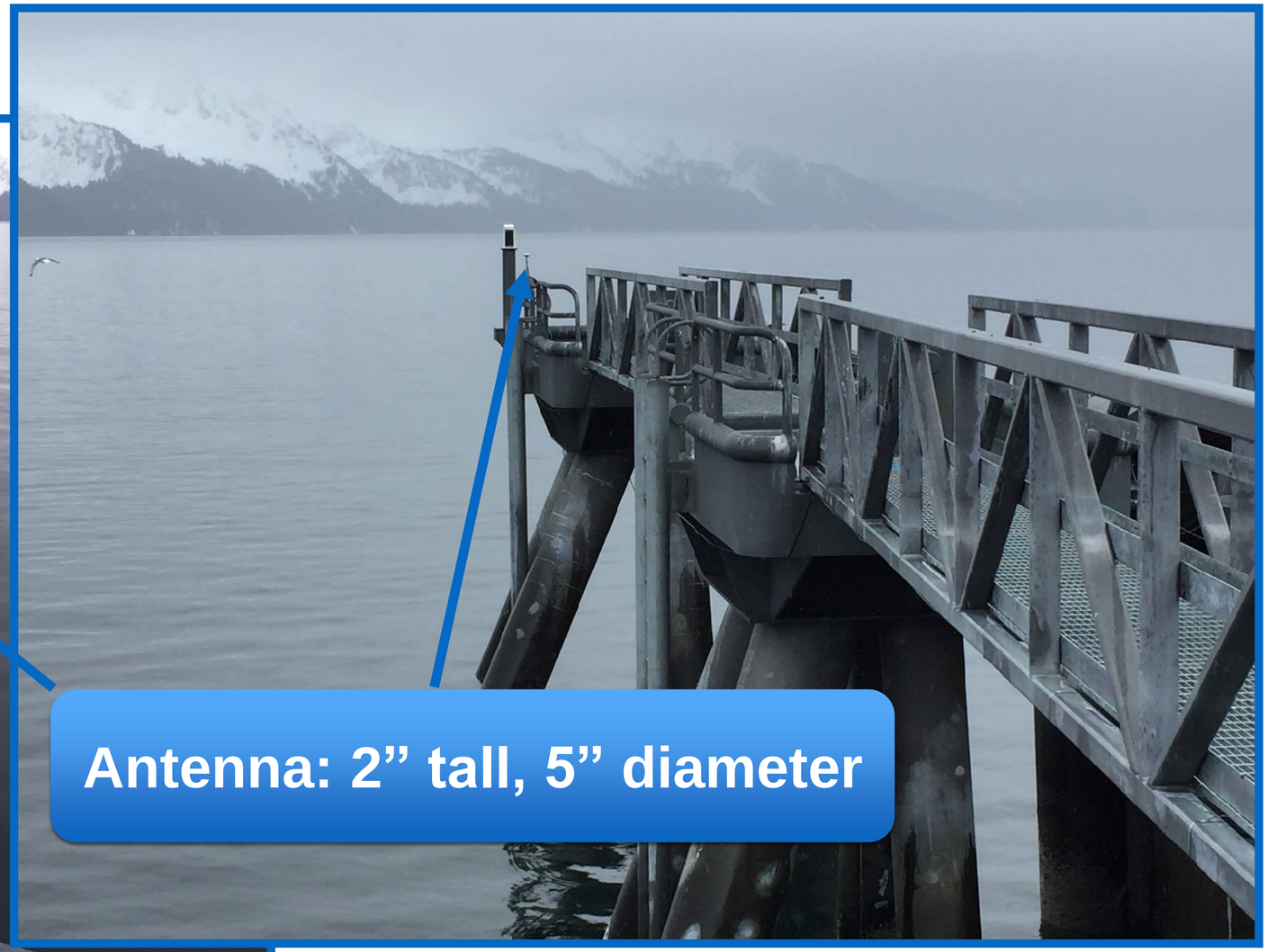
GPS Antenna Location



- Antennas need a good view of the water
- In the Northern Hemisphere, it helps to have a clear view to the south

GPS Antenna Location

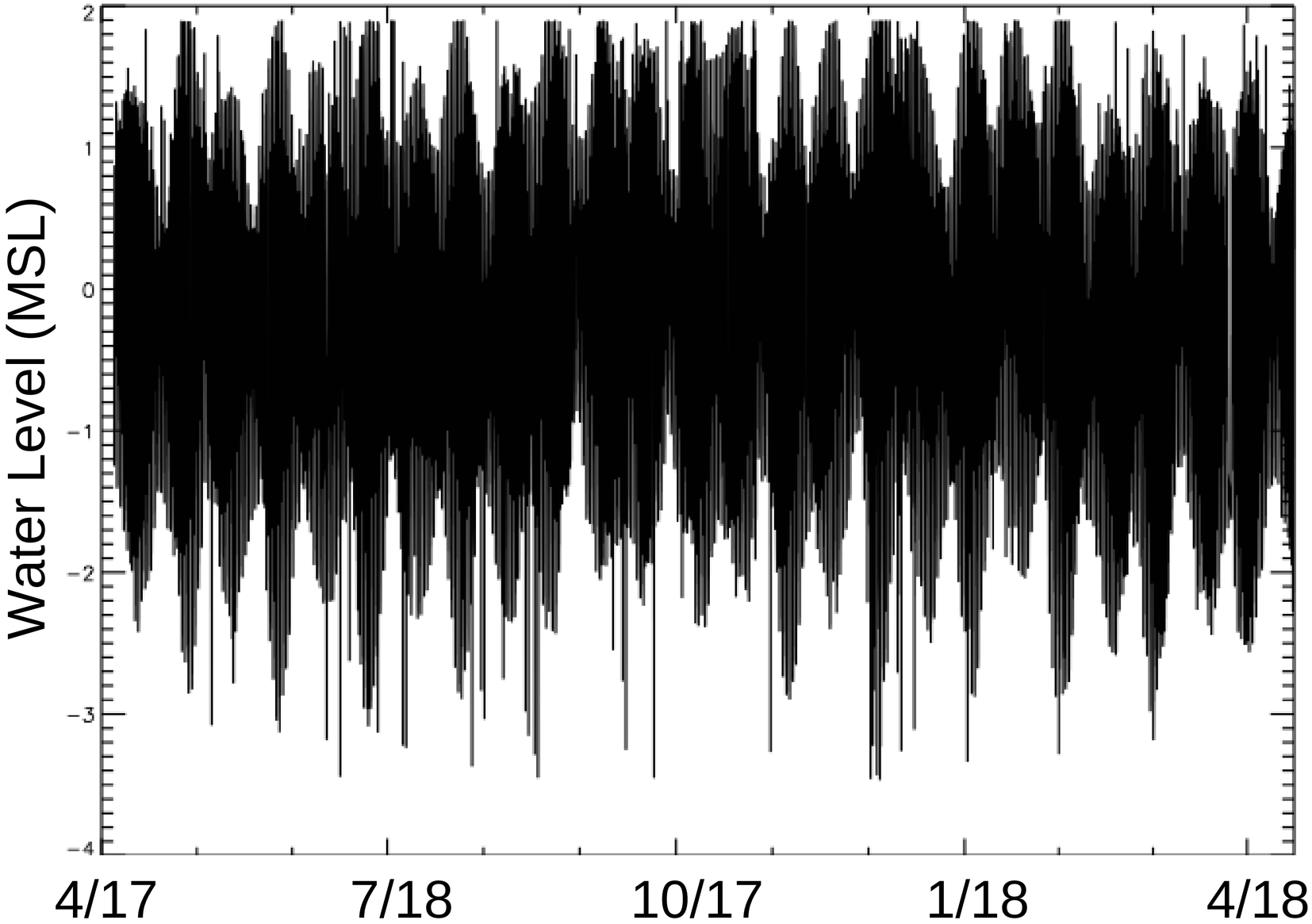




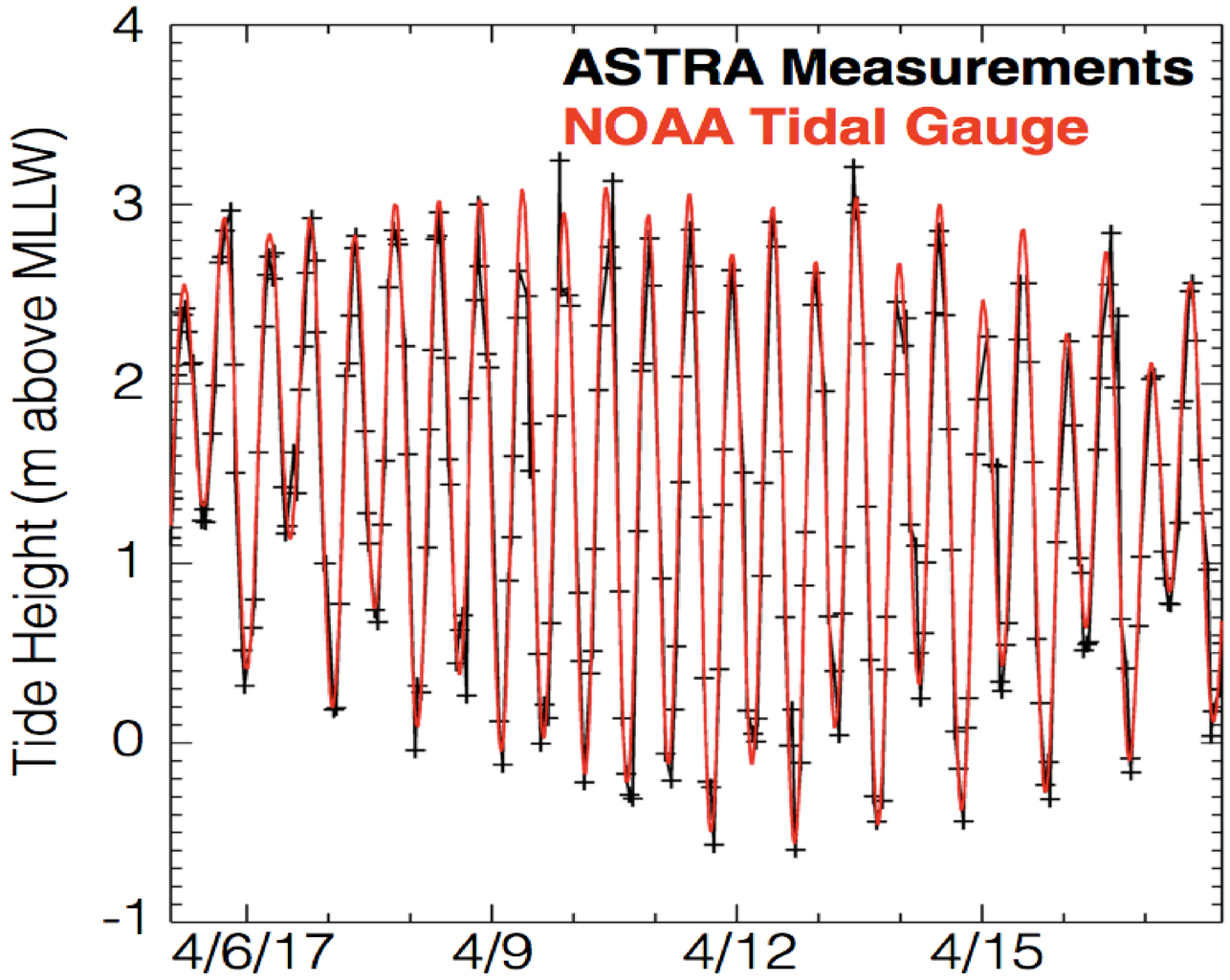
Antenna: 2” tall, 5” diameter

Year-Long Data Series

- Over 1 year of continuous water level data
- 5 meter tidal swings

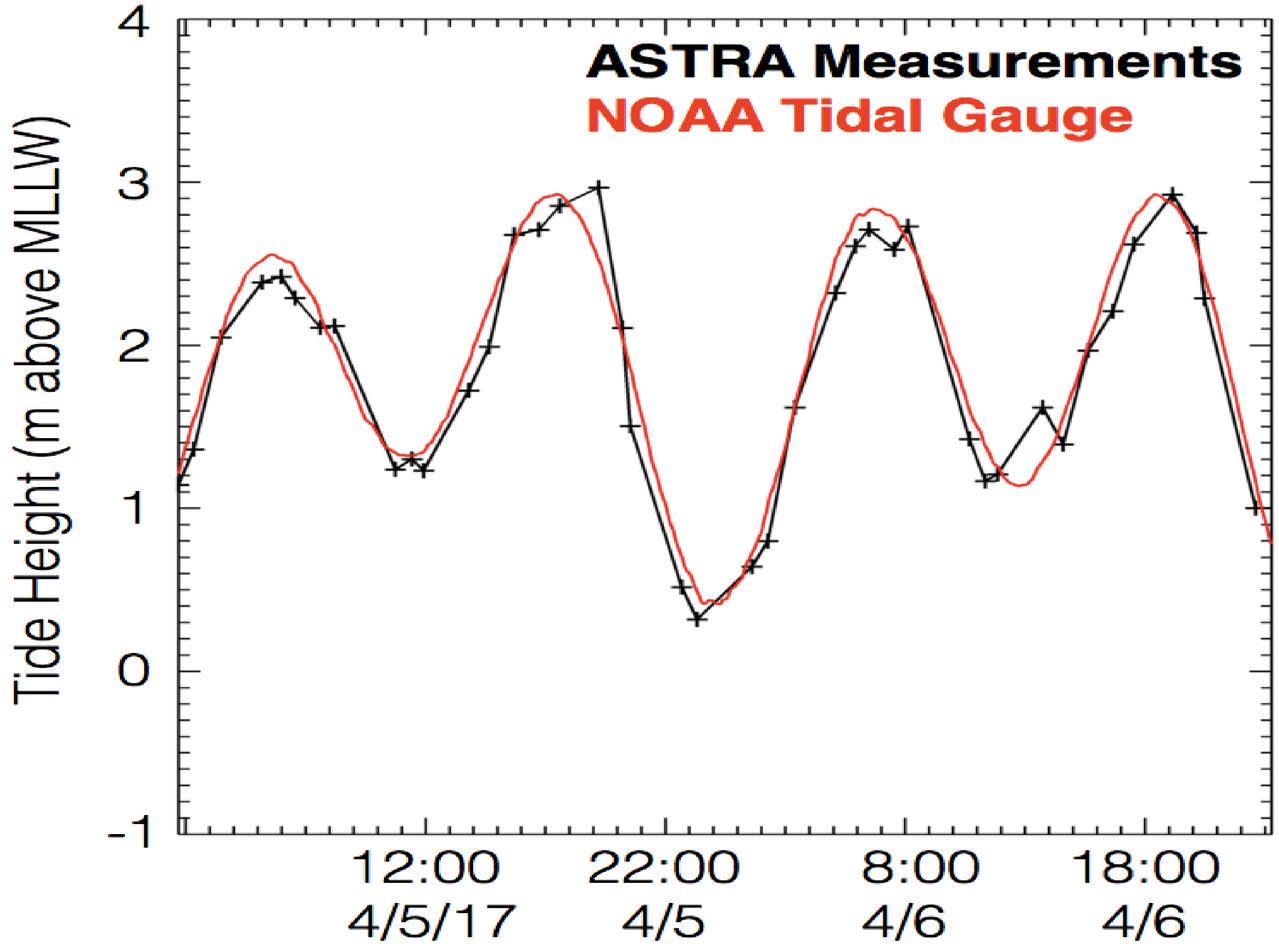


Validated against NWLON data



- Accurate measurements
- Low cost system
- Easy to deploy

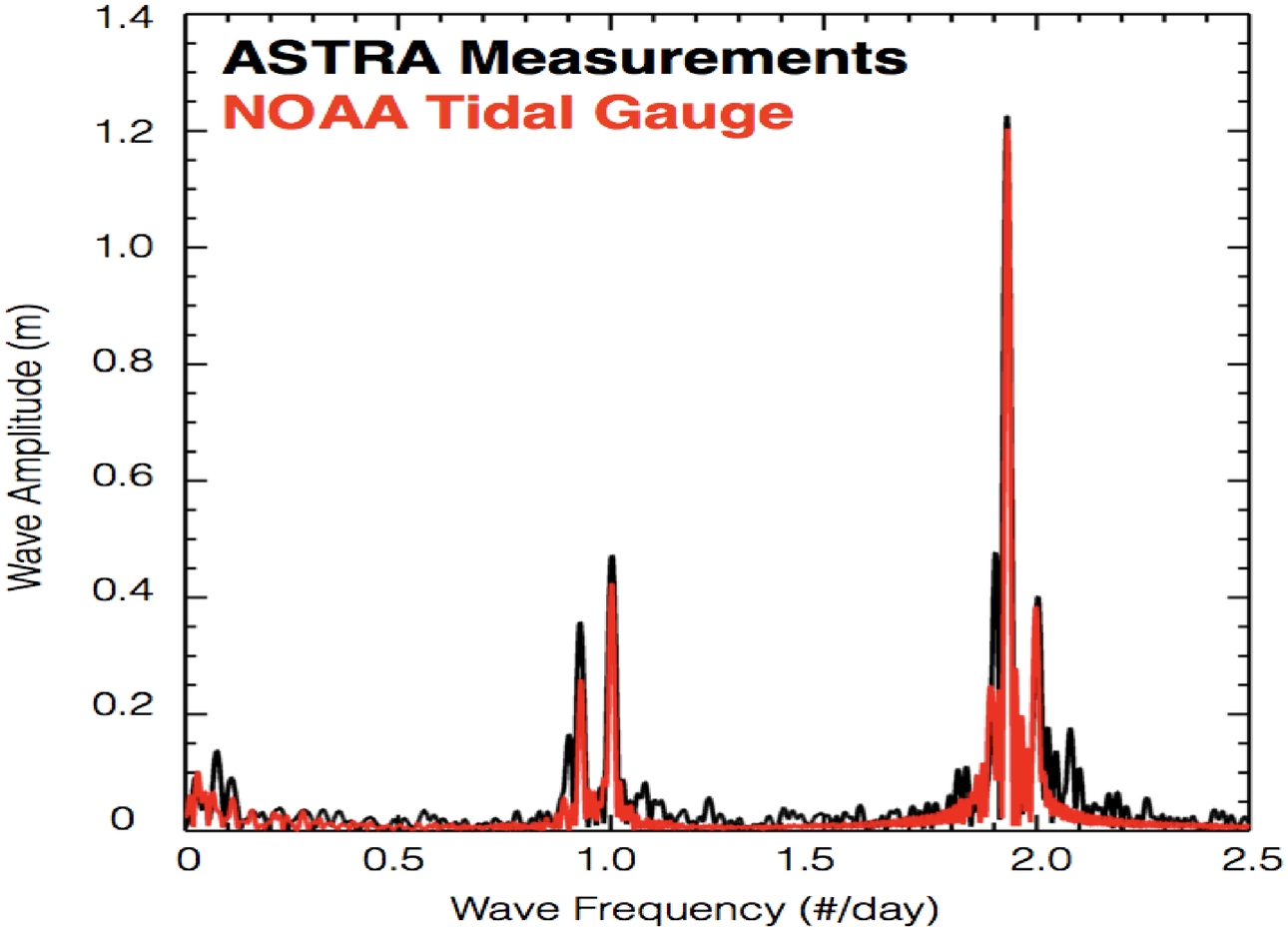
Accurate Measurements



- Accurate measurements
- Low cost system
- Easy to deploy

Frequency Analysis

- Frequency analysis shows tidal harmonic constituents
- ASTRA Receivers reproduce diurnal and semi-diurnal tidal motions



Accurate Tidal Constituents

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Tidal Constituent	ASTRA 85.6%	NOAA NWLON 96.9%	NOAA Predicted Constituents
M2	1.146 ± 0.039	1.195 ± 0.018	1.198
S2	0.420 ± 0.041	0.458 ± 0.017	0.411
N2	0.199	0.206	0.245
K1	0.323	0.362	0.463
O1	0.270	0.285	0.289

ASTRA Constituents within 5 cm (!) of NOAA at 10% of cost

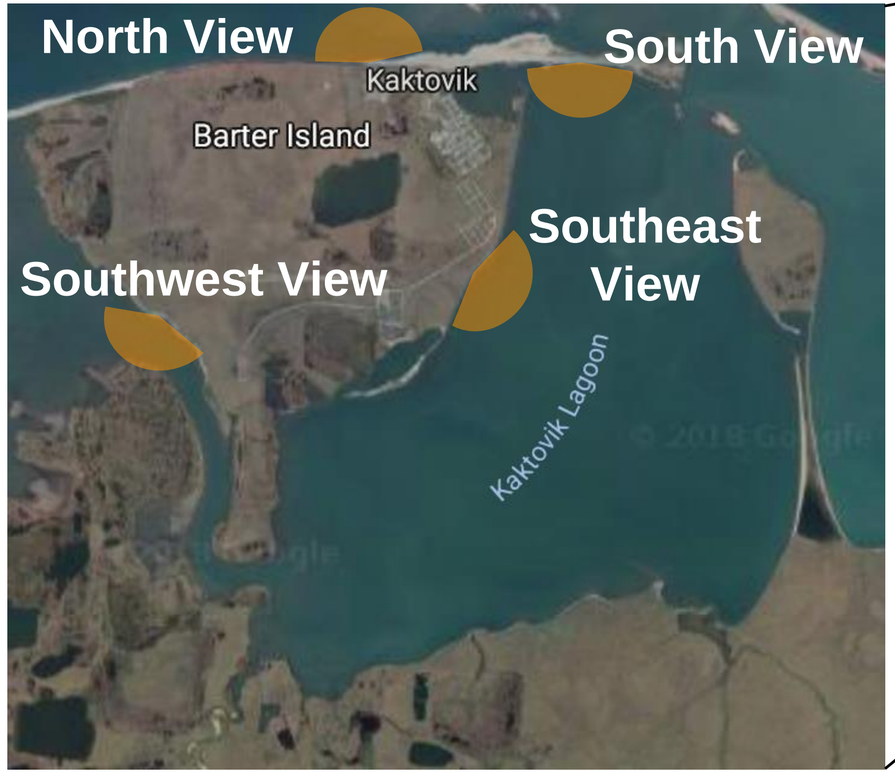
Install Locations

- These receivers could be installed anywhere along the coast
  - Preferably with a southern view of the water, but we can use GPS satellites that are setting over the northern horizon
- We are planning additional installations in Anchorage and Homer

Install Locations

Many “North” facing coastlines have multiple options for installation

E.g. Kaktovik



Summary-1

❖Science
❖ Technology
❖ Applications
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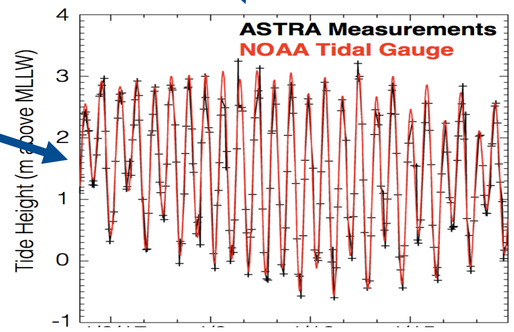
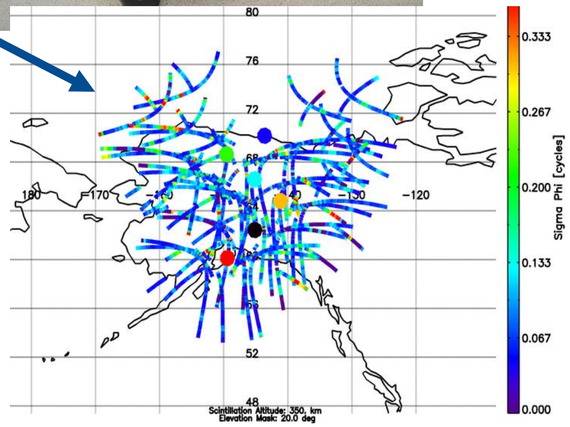
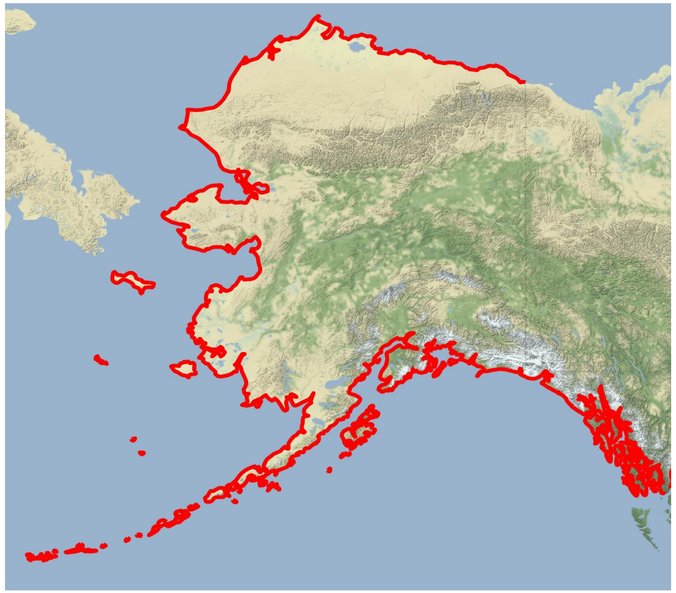
Sensor description	**ASTRA GPS Receiver**
Primary use(s)	**Ionospheric space weather** **Water level, tides** **Snow depth** **Soil moisture**
Test examples in Alaska	

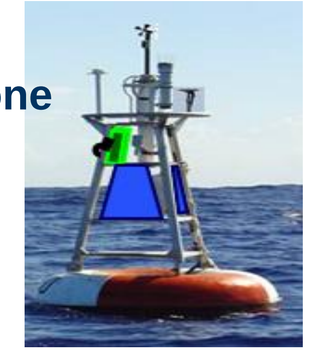




Possible New Sites



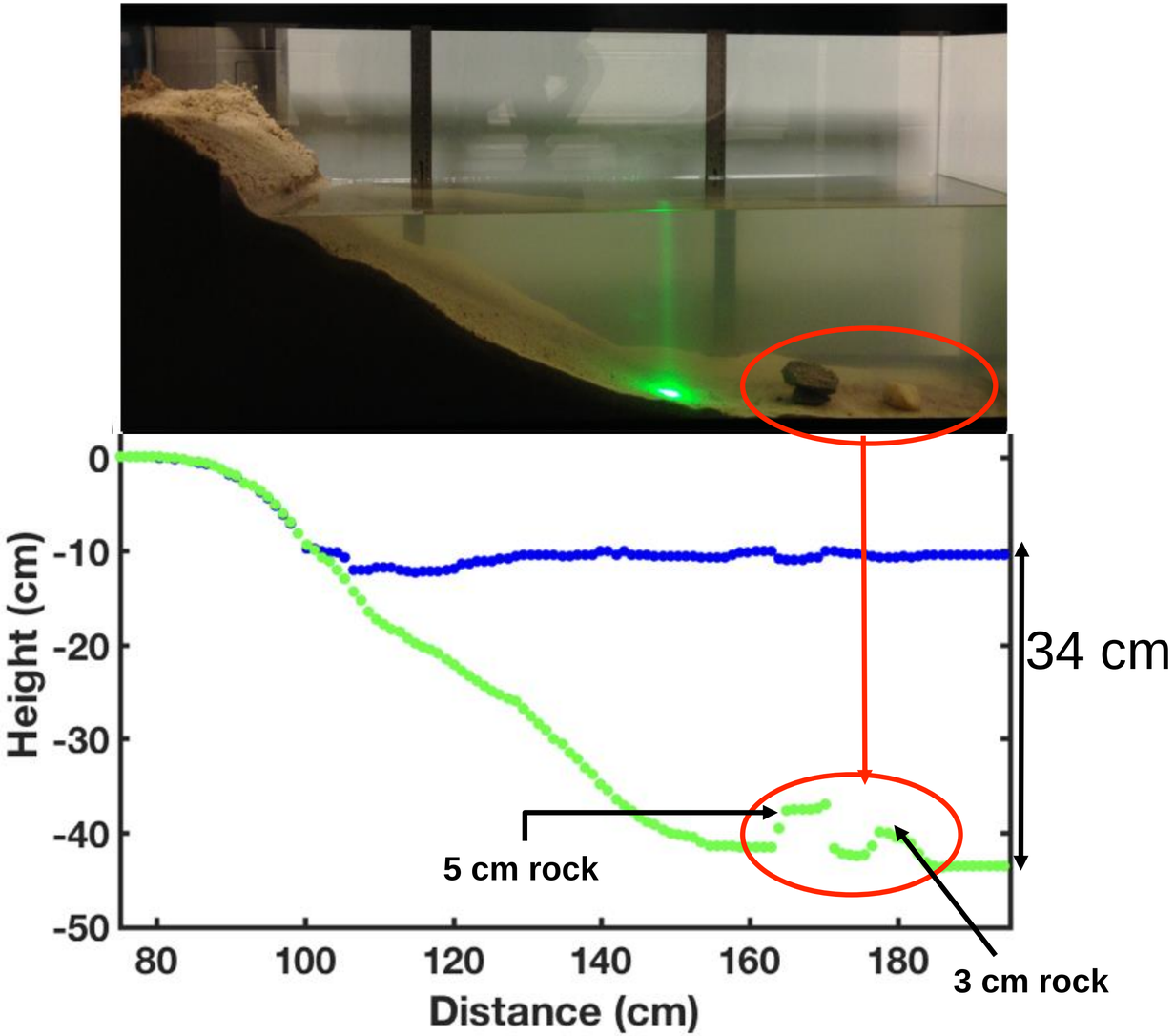
Infrastructure requirements: Benign to Extreme Environments



Summary-2

- Accurate water level measurements
  - < 5 cm tidal constituents
- Installations possible in remote locations
- Low cost versus legacy NWLON sensors
- Low-cost means we could deploy multiple locations
- Sole-source is OK because this is an SBIR product

Novel Lidar for Water Measurement



Laboratory demonstration

These data highlight several milestones:

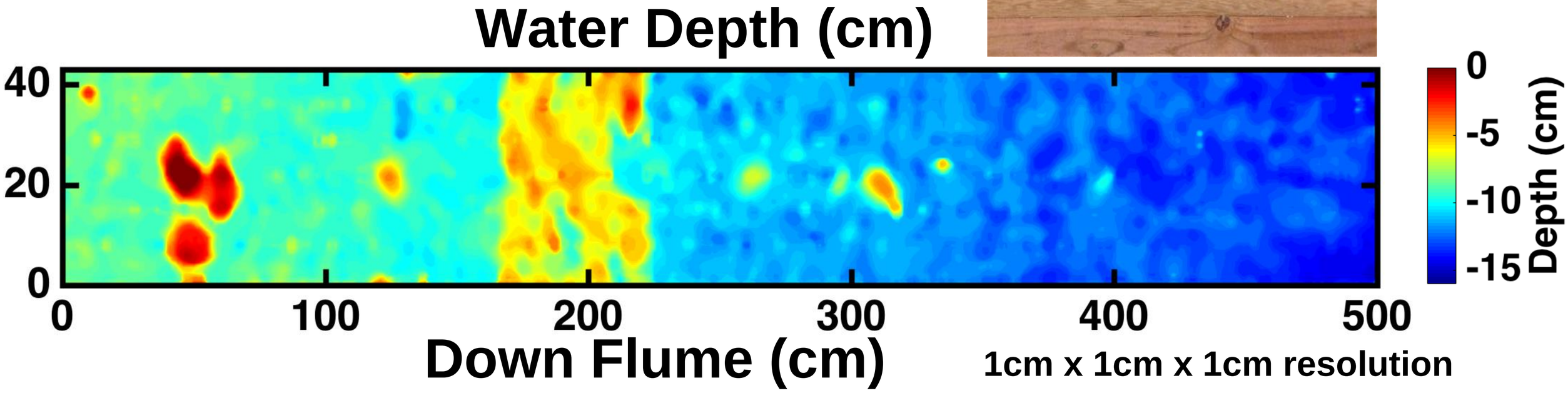
1) seamless land-to-water transition

2) <1 cm depth resolution

3) high precision subsurface mapping clearly identifying the two small rocks

Water Depth mapping

- Flowing water
- Depth Ranging from ~15cm to 1cm
- Centimeter Precision
- Bathymetry (Rock Garden)
- Notable depth change due to sloped flume



1cm x 1cm x 1cm resolution