Applications for GNSS Reflectometry in Alaska

A Case Study in Shared Infrastructure

57th Meeting of the Civil GPS Service Interface Committee
Surveying, Mapping, and Geosciences Subcommittee
September 25, 2017

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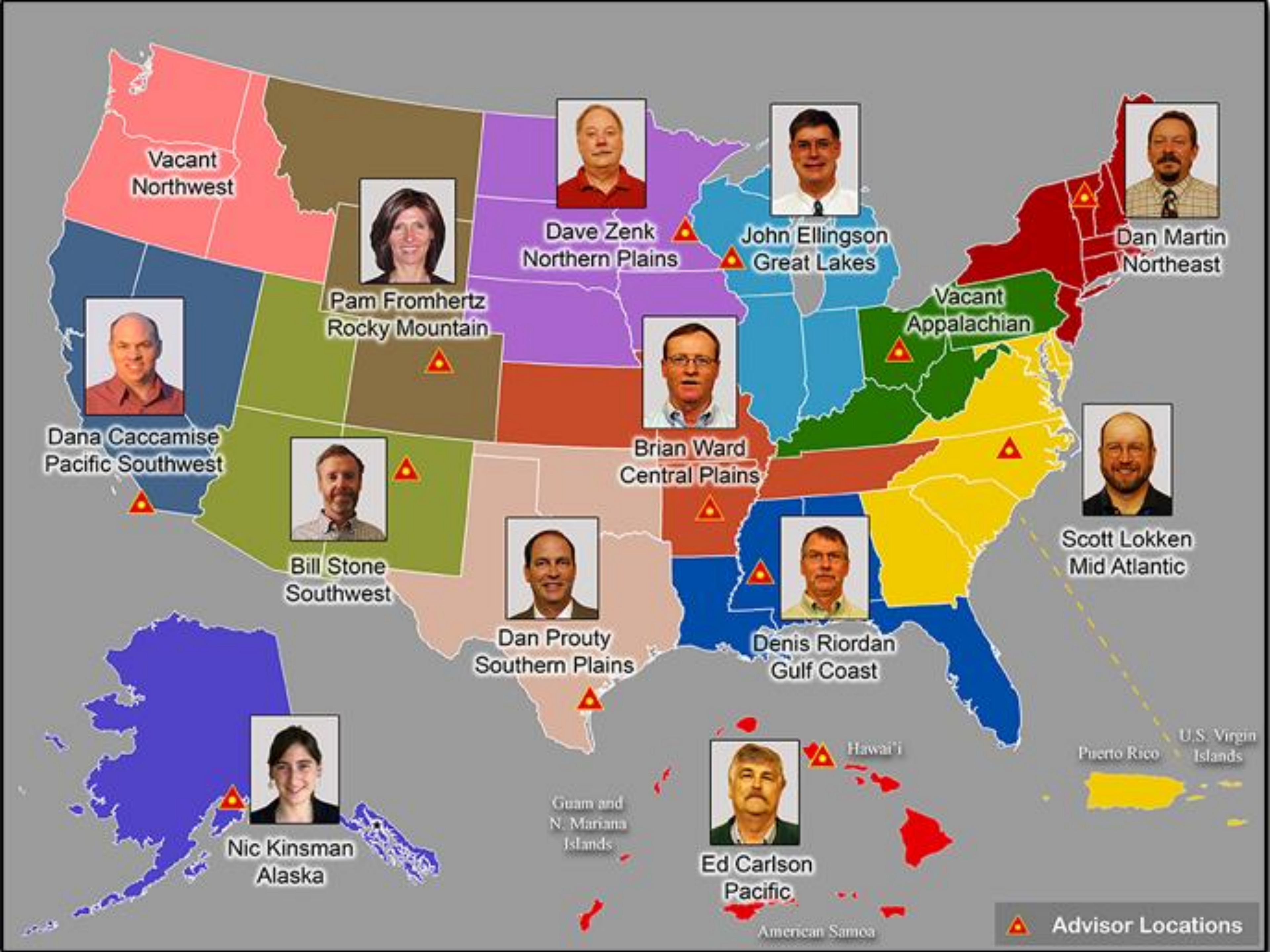
ASTRA, LLC



Vacant
Northwest
Pam Fromhertz
Rocky Mountain
Dave Zenk
Northern Plains
John Ellingson
Great Lakes
Dan Martin
Northeast
Vacant
Appalachian
Dana Caccamise
Pacific Southwest
Brian Ward
Central Plains
Scott Lokken
Mid Atlantic
Bill Stone
Southwest
Dan Prouty
Southern Plains
Denis Riordan
Gulf Coast
Nic Kinsman
Alaska
Guam and
N. Mariana
Islands
Ed Carlson
Pacific
Hawai'i
American Samoa
Puerto Rico
U.S. Virgin
Islands
Advisor Locations

An Introduction to

ACTIVE GEODETIC CONTROL IN ALASKA

Alaska Geospatial Council

AGC Geodetic Technical Working Group


Alaska Geospatial Council
Approval of the Alaska Geospatial
Geodetic Technical Working Group Charter

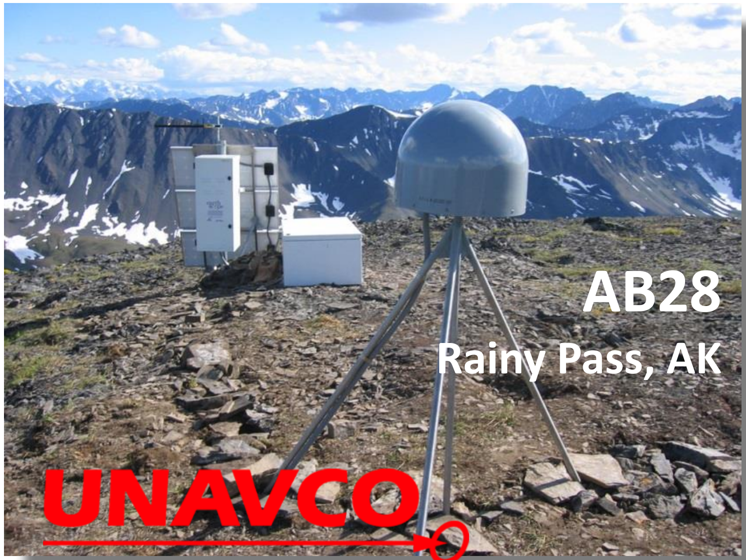
ED FOGELS, Chair
Dep. Commissioner
Department of Natural Resources

Date: 12/22/16

To unify the geodetic priorities of diverse stakeholders within Alaska; to preserve, densify, and enhance Alaska's geodetic control networks for the maximum benefit of a broad user base, and to support statewide precise positioning and mapping activities through the identification and recommendation of consistent practices appropriate for different applications, geodetic product/tool development, and educational outreach.

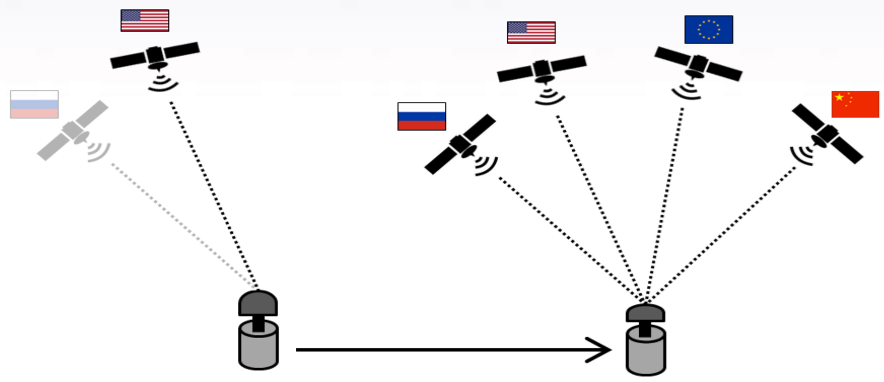
CORS Challenges

- Limited access (few roads, autonomous power, **telecommunications**)
- Harsh weather (high winds, extreme cold temperatures)
- Wild animals (cable/radio damages)
- Tectonically active sites
- **<u>Higher cost</u>** for installation and maintenance

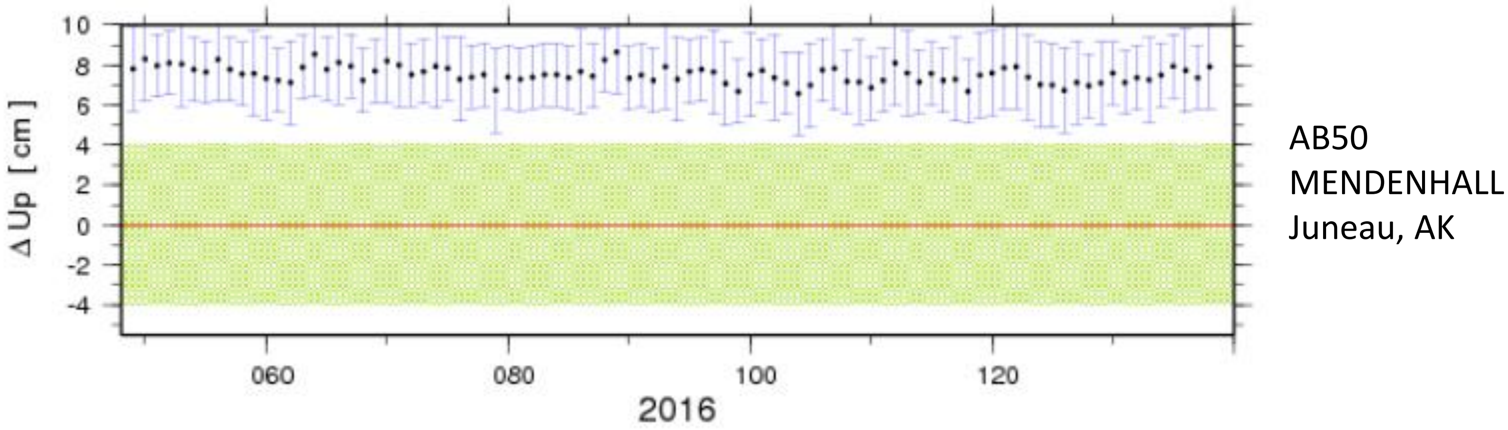


CORS Challenges in Alaska

- Communication outages; **~10%** of stations are 'non-operational'
- **<15%** of stations are full-GNSS



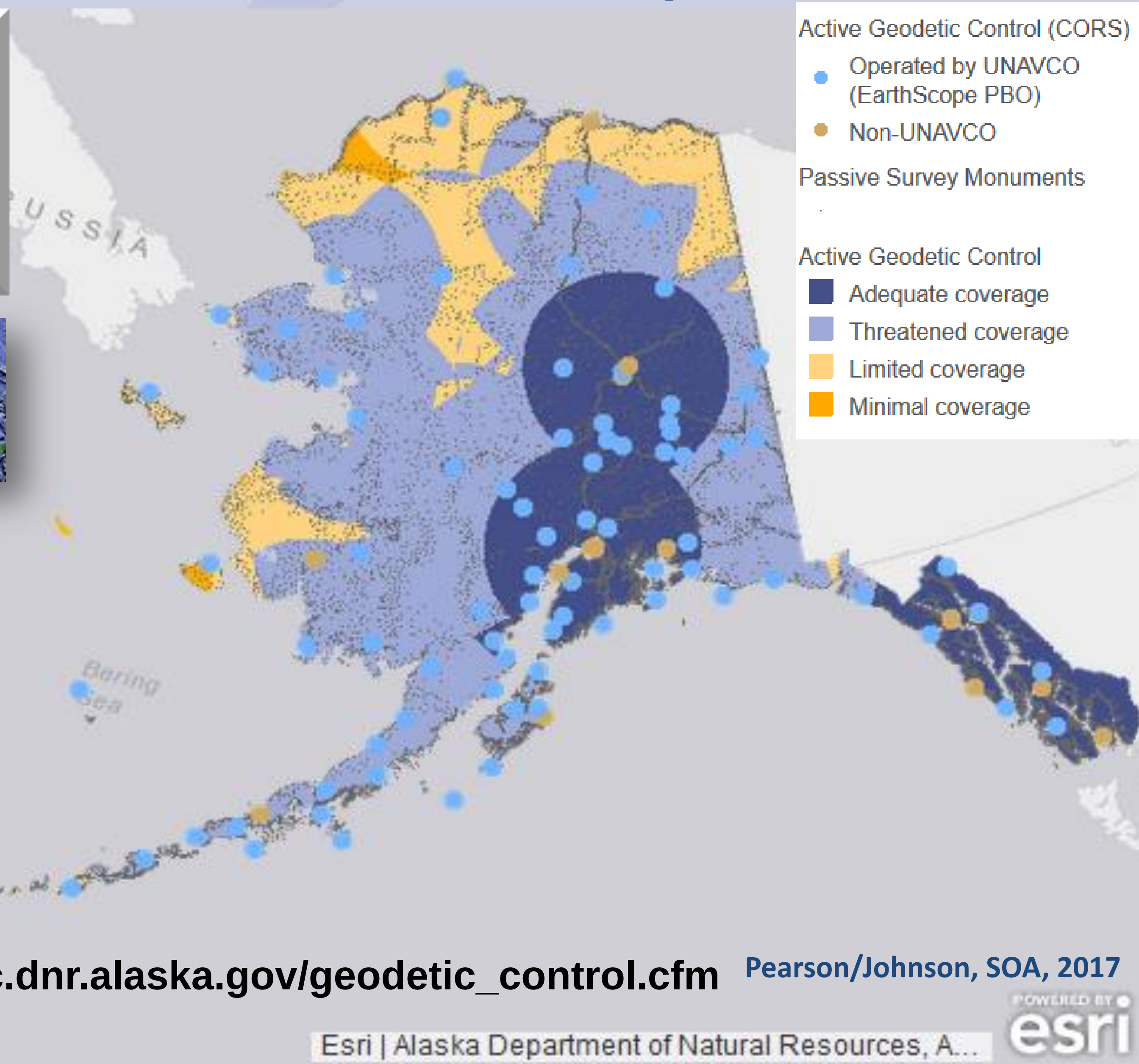
- **45%** of published positions are out of tolerance (2 cm ⇔, 4 cm ⇕)



CORS Network Gaps

Guidance:

CORS spacing of approximately 250 km is typically adequate to meet the minimum requirements of most common users (OPUS)



http://agc.dnr.alaska.gov/geodetic_control.cfm

Pearson/Johnson, SOA, 2017

Applications of GNSS

Tectonic Processes

- Long-term tectonic motions
- Fault strain accumulation
- Characterizing deformation
- Earthquake studies
- Transients

Deeper Earth Processes

- Thickness of elastic lithosphere and asthenosphere
- Viscosity of asthenosphere and upper mantle

Hydrosphere/Cryosphere

- Seasonal snow and water loading
- Longer term hydrologic change
- Glacial Isostatic Adjustment
- Sea level studies

Atmosphere

- Water Vapor in lower atmosphere
- Ionosphere: Total Electron Content, electron density, scintillation

Industry, Construction, Surveying, Agriculture

- Base station for differential surveys
- Real-time corrections
- Soil moisture estimates
- Vegetation growth estimates

Hazards

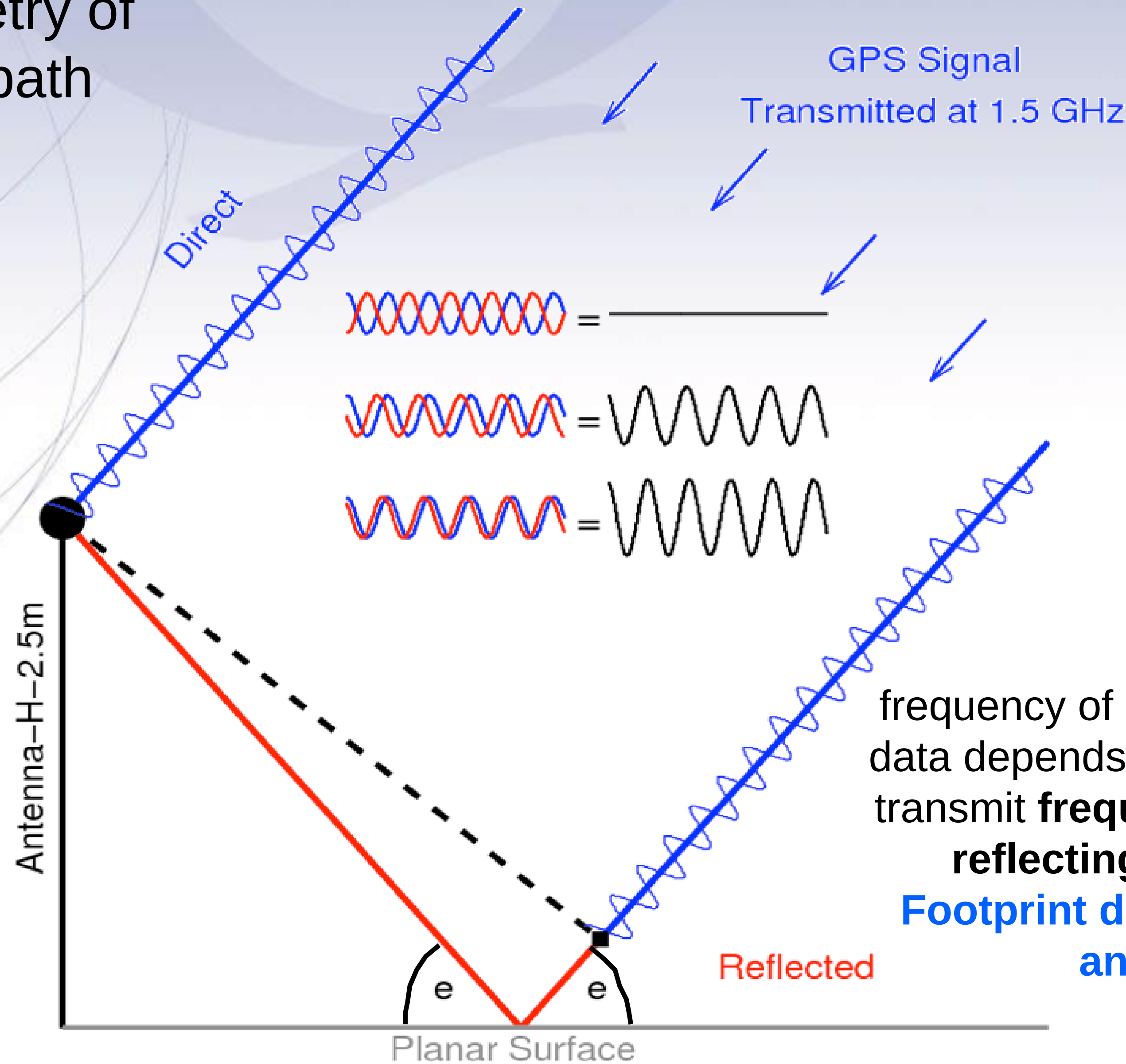
- Volcano monitoring
- Volcanic ash detection
- Earthquake early warning
- Rapid fault slip and magnitude estimates
- Tsunami early warning

from Julie Elliot, Purdue University, AGU 2015

An overview of

GNSS REFLECTOMETRY

Geometry of Multipath



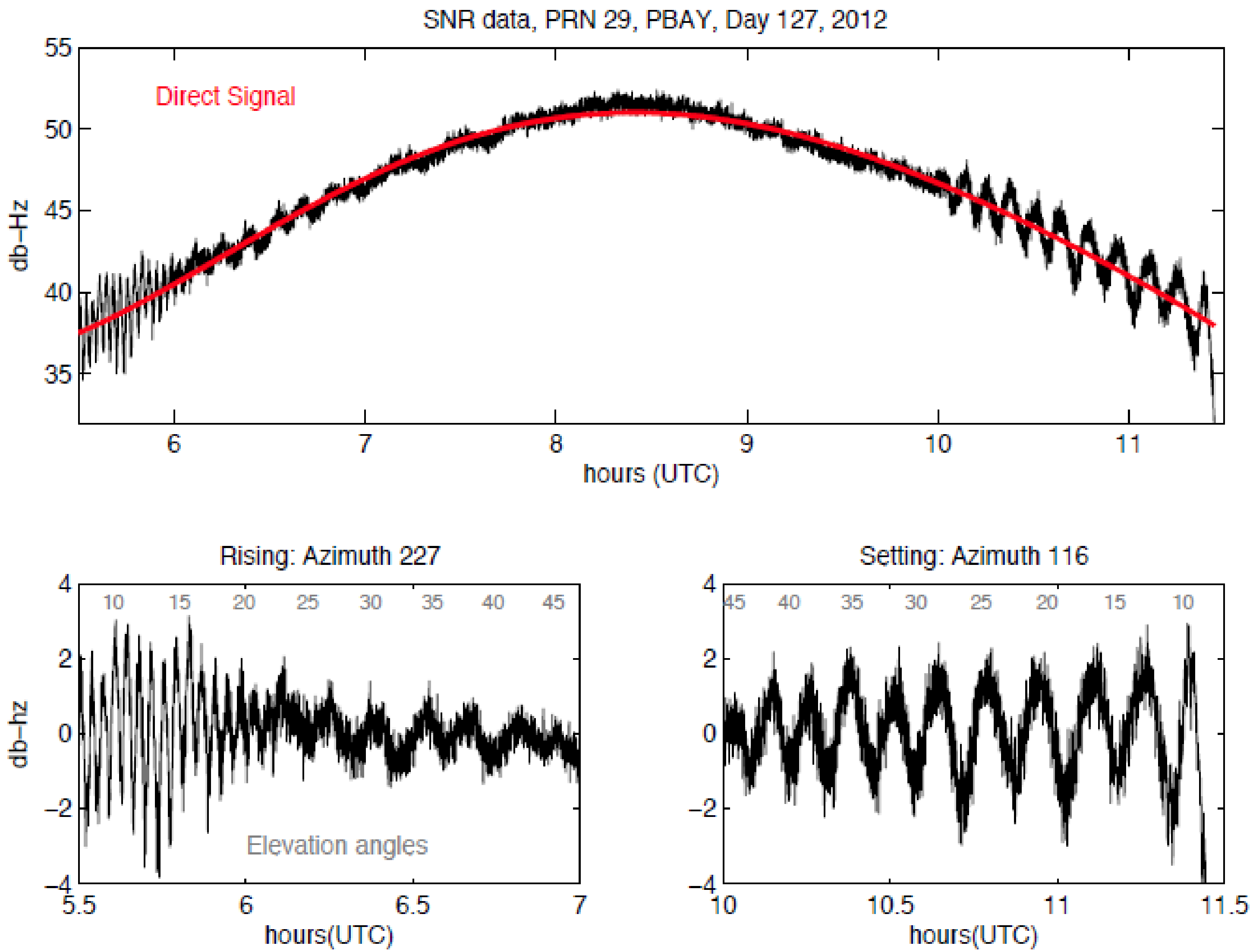
frequency of signal strength data depends on **H**, the GPS transmit **frequency**, and the **reflecting medium.**

Footprint depends on H and e.

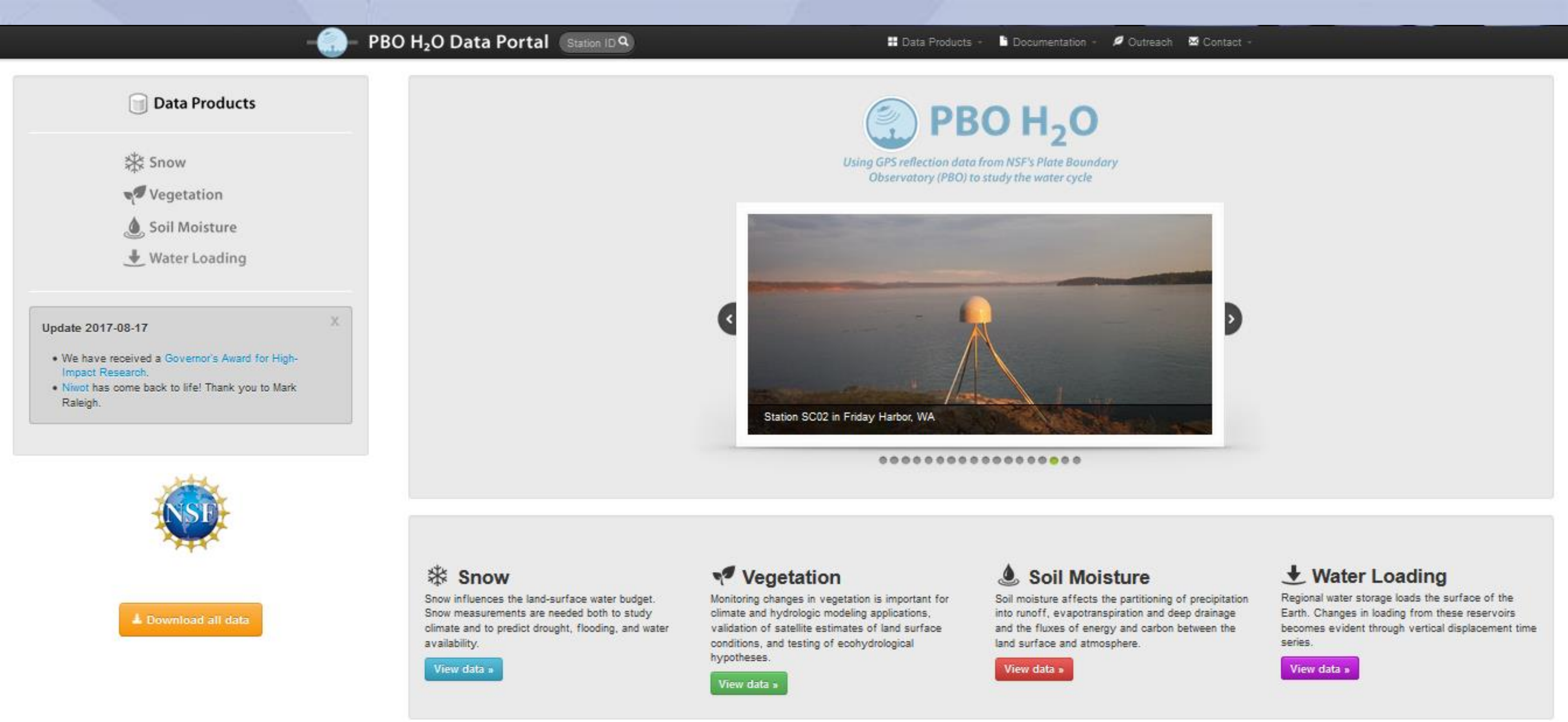
GPS site becomes an interferometer

from K. Larson

GPS SNR Data



http://xenon.colorado.edu/spotlight/index.php?product=spotlight&station=PBAY



PBO H_2O http://xenon.colorado.edu/portal

Liu, L. and K.M. Larson, **Decadal changes of surface elevation over permafrost area estimated using reflected GPS signals**, *The Cryosphere*, doi 10.5194/tc-2017-139, 2017 [in Review]

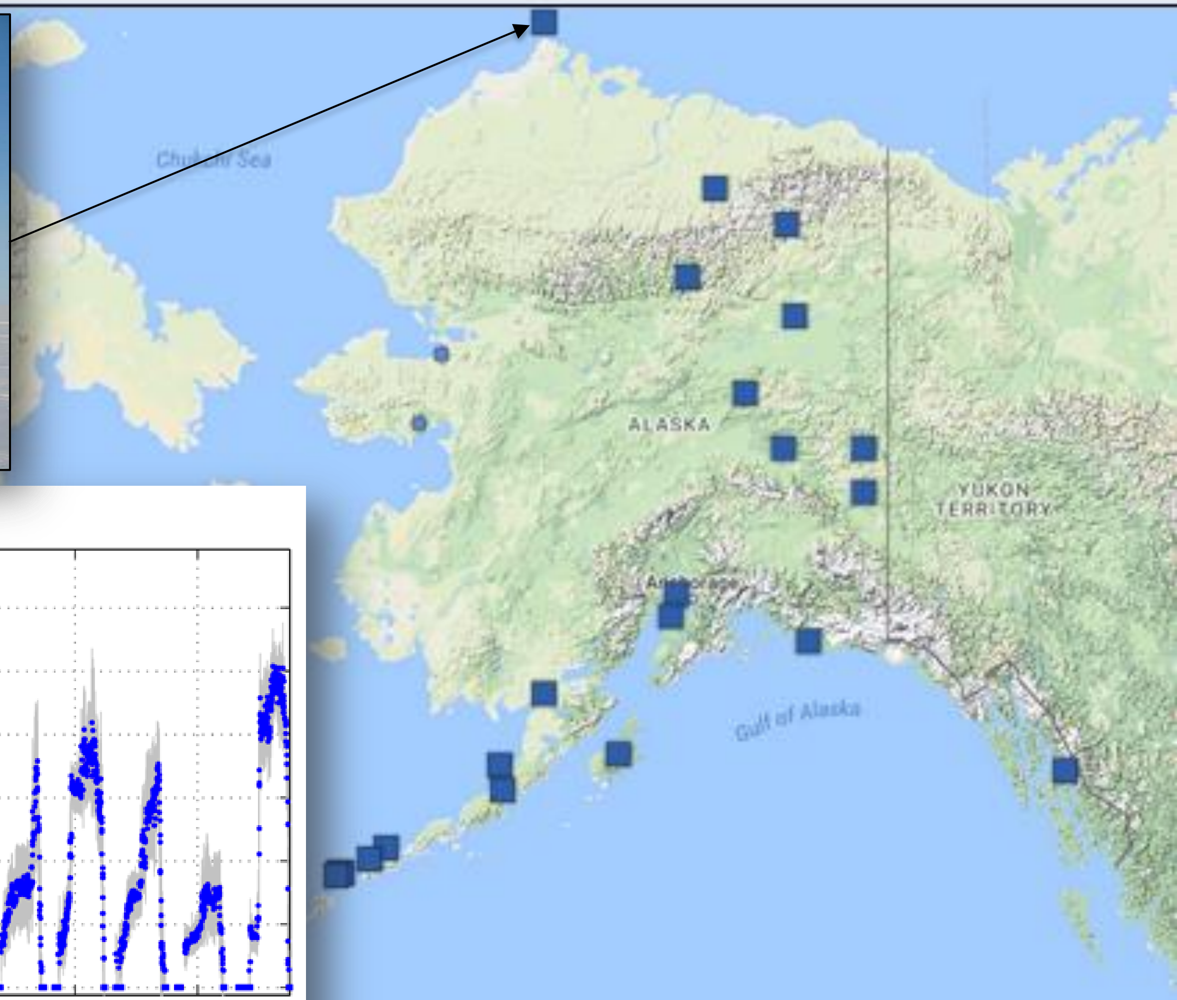
Larson, K.M., R.D. Ray, and S.P. Williams, **A ten year comparison of water levels measured with a geodetic GPS receiver versus a conventional tide gauge**, *J. Atmos. Ocean Tech, Vol. 34(2),* 295-307, doi: 10.1175/JTECH-D-16-0101.1, 2017.

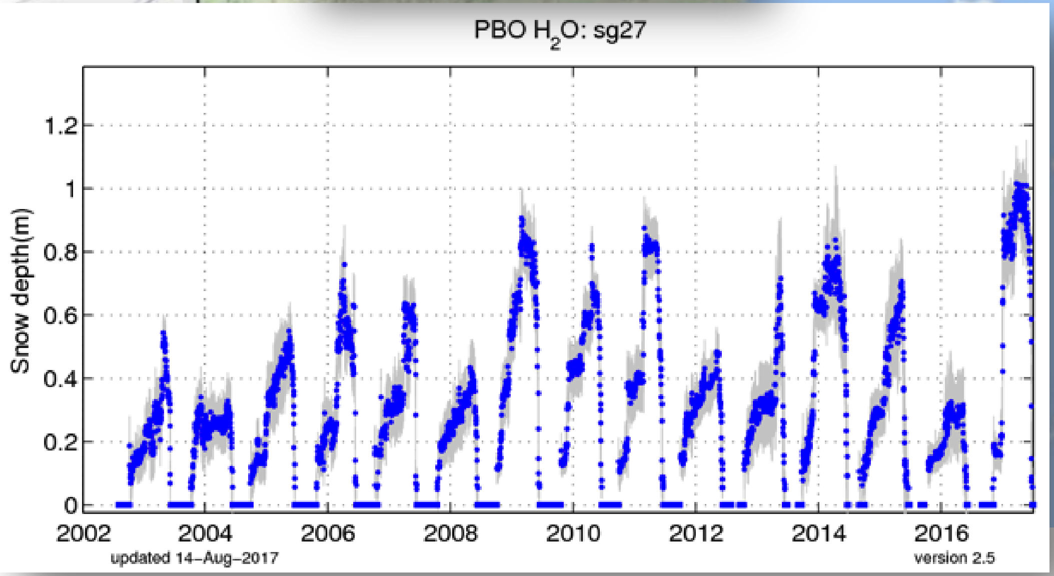
Larson, K.M., R. Ray, F. Nievinski, and J. Freymueller, **The Accidental Tide Gauge: A Case Study of GPS Reflections from Kachemak Bay, Alaska**, *IEEE GRSL*, Vol 10(5), 1200-1205, doi:10.1109/LGRS.2012.2236075, 2013

Snow Depth Sites in Alaska

PBO H2O

Snow

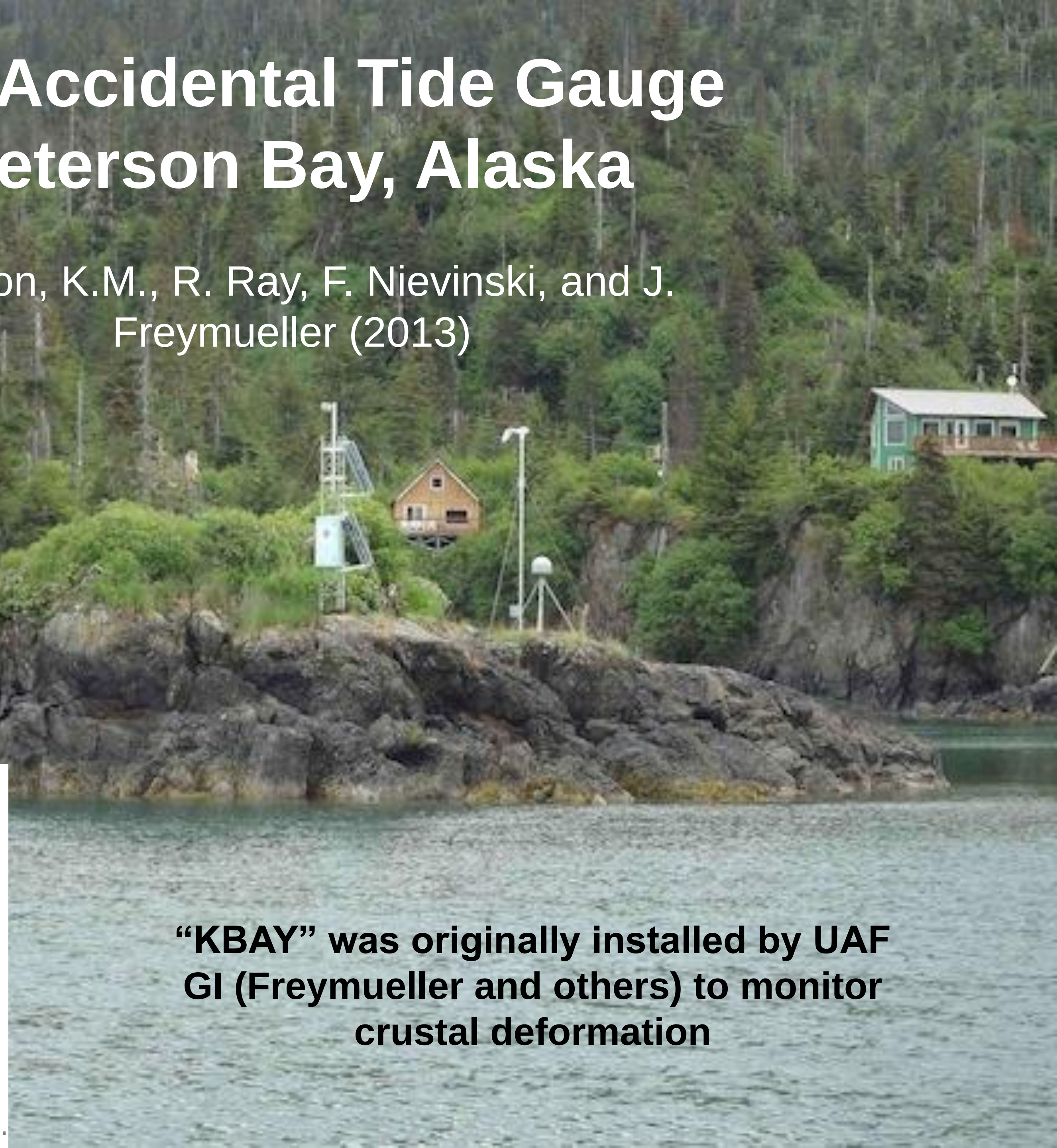


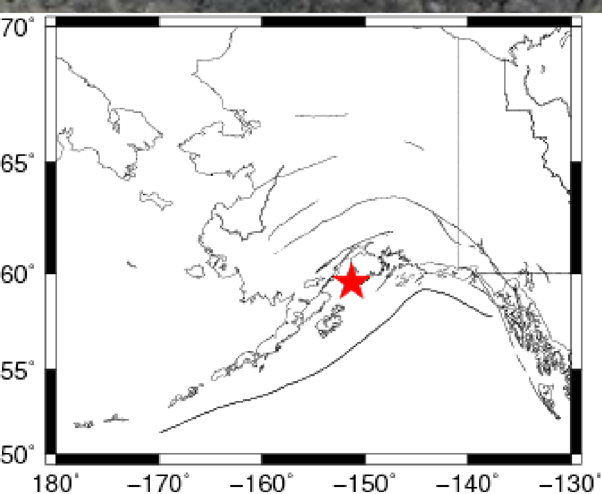


Data also available at the NSIDC

The Accidental Tide Gauge
Peterson Bay, Alaska

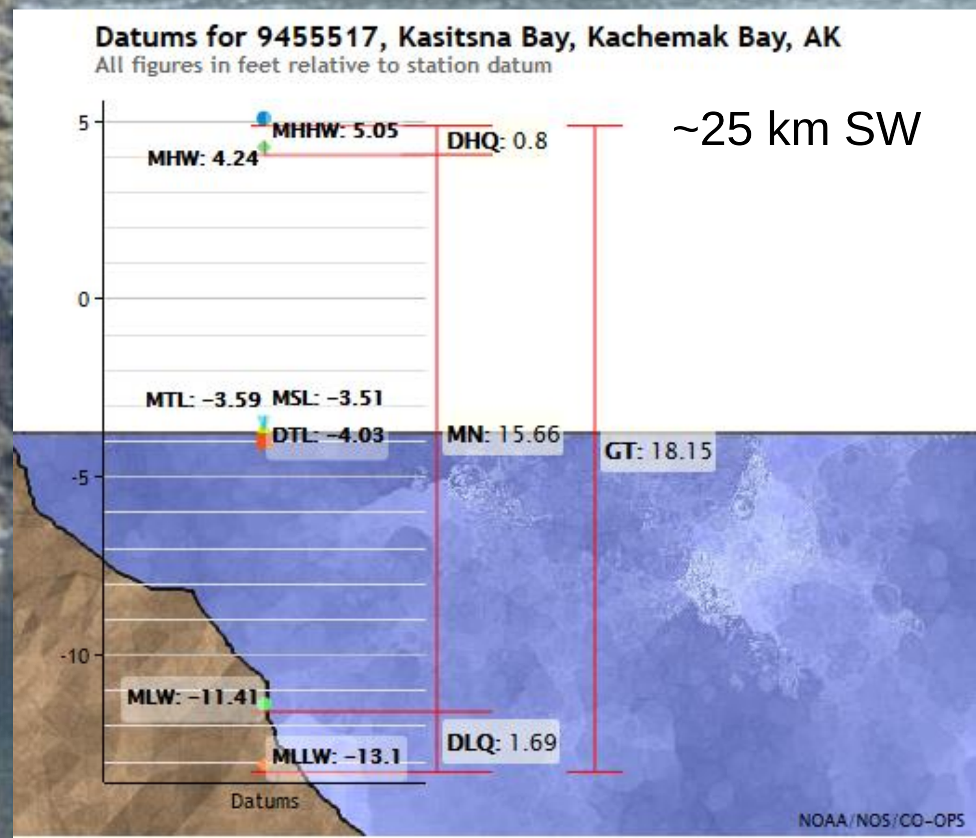
Larson, K.M., R. Ray, F. Nievinski, and J. Freymueller (2013)



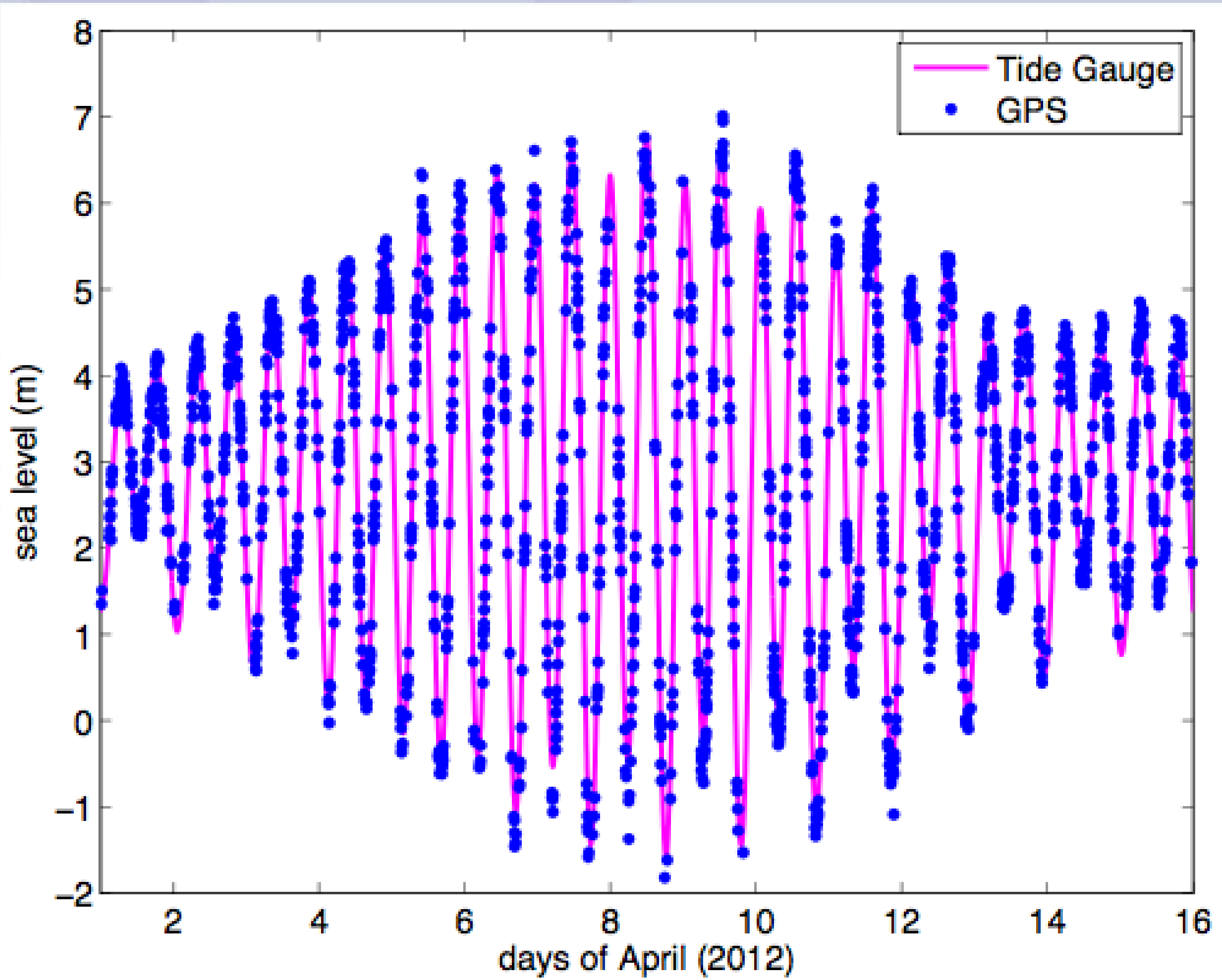


“KBAY” was originally installed by UAF GI (Freymueller and others) to monitor crustal deformation

Water Levels

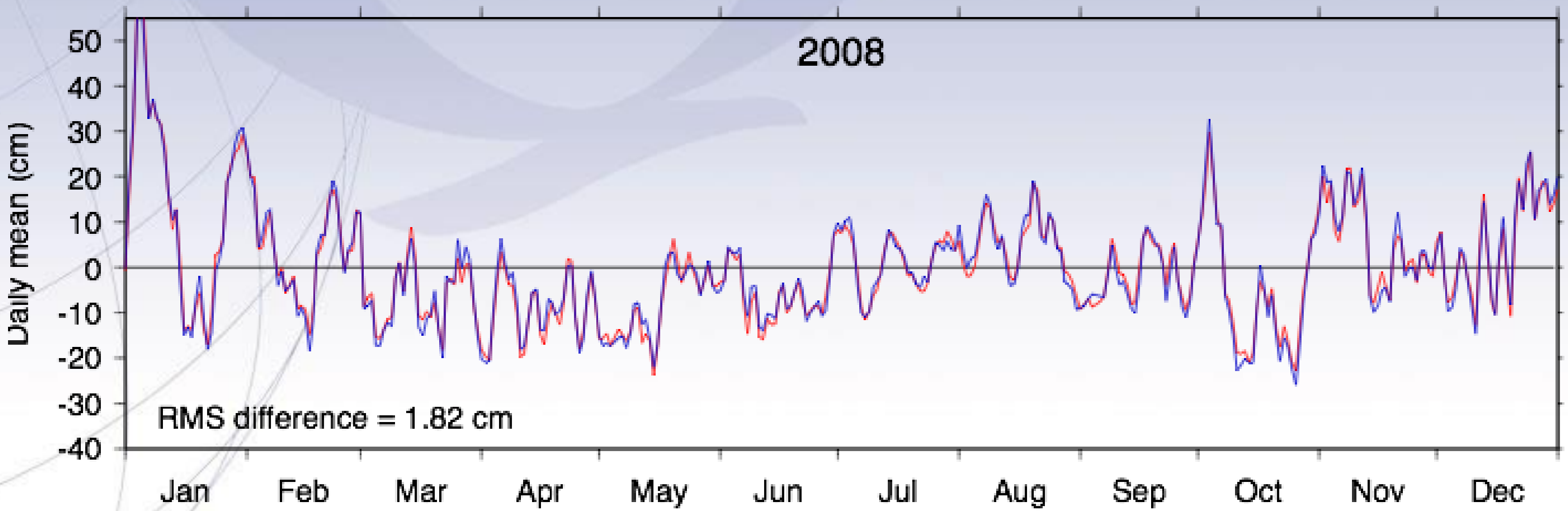


Comparison between GPS and Seldovia NWLON Record



Larson et al., The Accidental Tide Gauge, IEEE GRSL, 2013

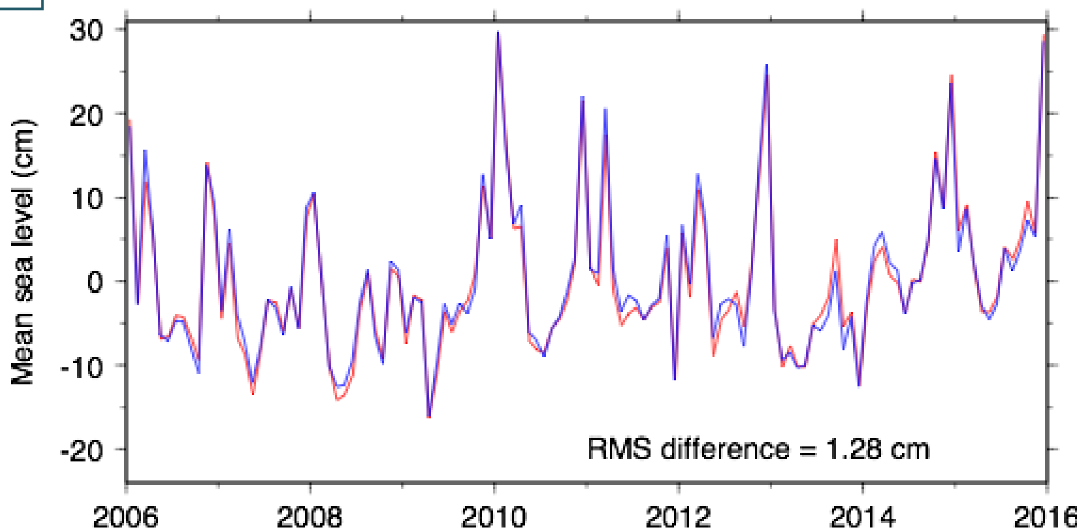
Daily Comparison with NOAA tide gauge



Friday Harbor, Washington

The amplitudes of estimated tidal coefficients agree with the "real" tide gauge at the 2-5 mm level.

Monthly Comparison



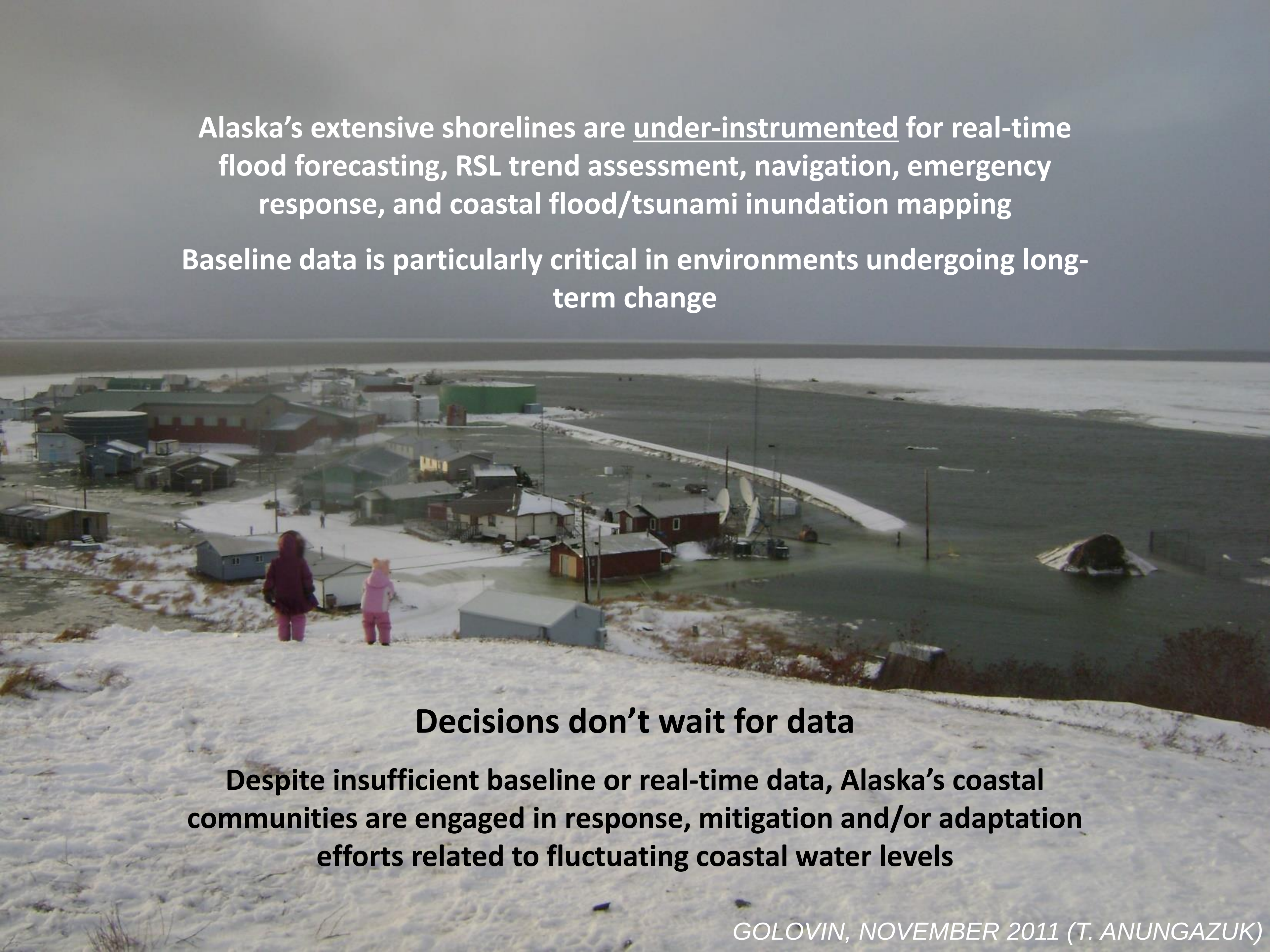
K.M. Larson, Richard Ray, and Simon Williams, J. Ocean Atmos. Tech., 2017

Why

GNSS TIDE GAUGES?

Alaska's extensive shorelines are under-instrumented for real-time flood forecasting, RSL trend assessment, navigation, emergency response, and coastal flood/tsunami inundation mapping

Baseline data is particularly critical in environments undergoing long-term change



Decisions don't wait for data

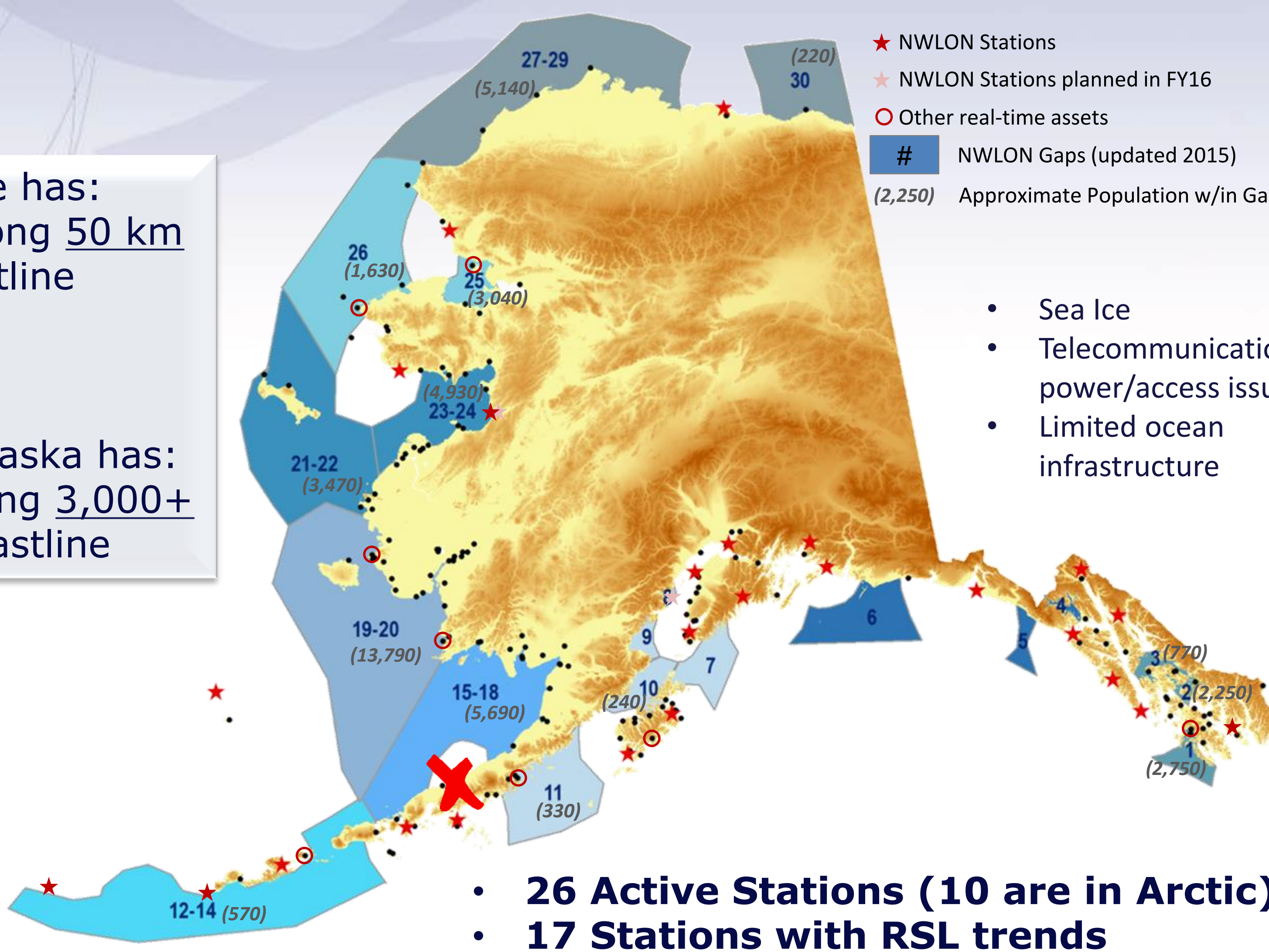
Despite insufficient baseline or real-time data, Alaska's coastal communities are engaged in response, mitigation and/or adaptation efforts related to fluctuating coastal water levels

GOLOVIN, NOVEMBER 2011 (T. ANUNGAZUK)

ALASKA IS DATA LIMITED: Real Time Water Levels

Delaware has:
4 gauges along 50 km of coastline

Northwest Alaska has:
4 gauges along 3,000+ km of coastline

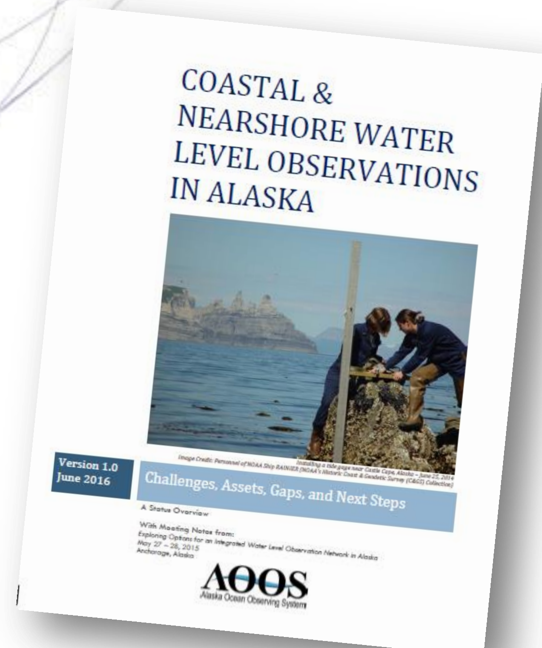


- Sea Ice
- Telecommunications/ power/access issues
- Limited ocean infrastructure

- **26 Active Stations (10 are in Arctic)**
- **17 Stations with RSL trends**
- **~5 stations with cGPS w/in 1 km**
- **Modified 5-year Procedure for datums**

Exploring Options for Integrated Water Level Observation in Alaska

- May 2015
- 2-day Workshop
- Organized and hosted AOOS Alaska Ocean Observing System
- Presentations:
  - Existing Technologies
  - Databases
  - Existing Assets/Resources


COASTAL & NEARSHORE WATER LEVEL OBSERVATIONS IN ALASKA

Version 1.0
June 2016

Challenges, Assets, Gaps, and Next Steps

A Status Overview

With Meeting Notes from:
Exploring Options for an Integrated Water Level Observation Network in Alaska
May 27 – 28, 2015
Anchorage, Alaska

AOOS
Alaska Ocean Observing System

Division of Homeland Security & Emergency Management, State of Alaska

Department of Commerce, Community, and Economic Development, State of Alaska

National Tsunami Warning Center (NTWC)

Arctic Landscape Conservation Cooperative

National Ocean Service, NOAA, Center for Operational Oceanographic Products & Services, CO-OPS

USGS science for a changing world

U.S. Fish & Wildlife Service, Department of the Interior

Transportation & Public Facilities, State of Alaska

NOAA Office of Coast Survey 1807

JOA Surveys, LLC — At the boundary between land and sea

ACCAP Alaska Center for Climate Assessment and Policy — A NOAA RISA Team

US Army Corps of Engineers®

Alaska Geological and Geophysical Surveys

National Weather Service

National Park Service

Western Alaska LCC

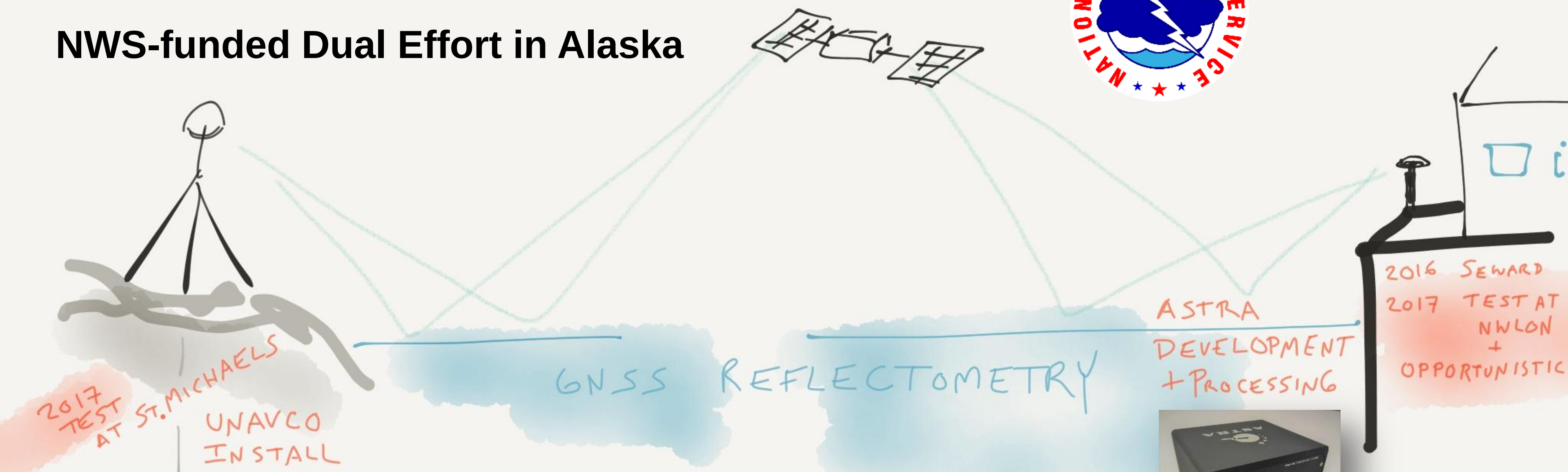
Alaska Native Tribal Health Consortium

Alaska’s New

GNSS TIDE GAUGE PROJECTS

IOOS | Integrated Ocean Observing System

NWS-funded Dual Effort in Alaska



UNAVCO

- Science
- Technology
- Applications

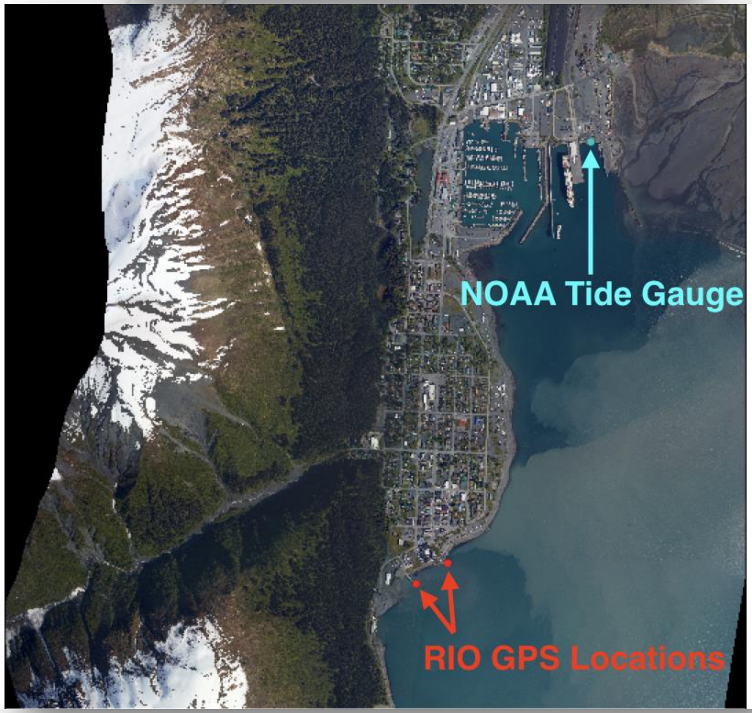
Bringing It All Together

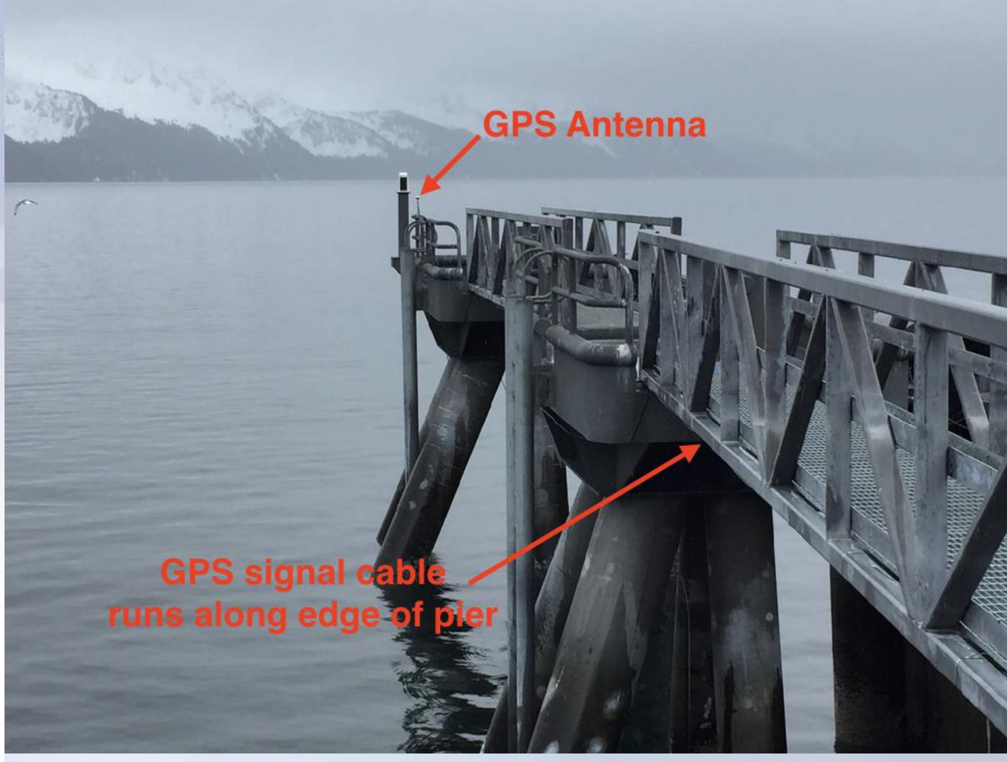
ASTRA

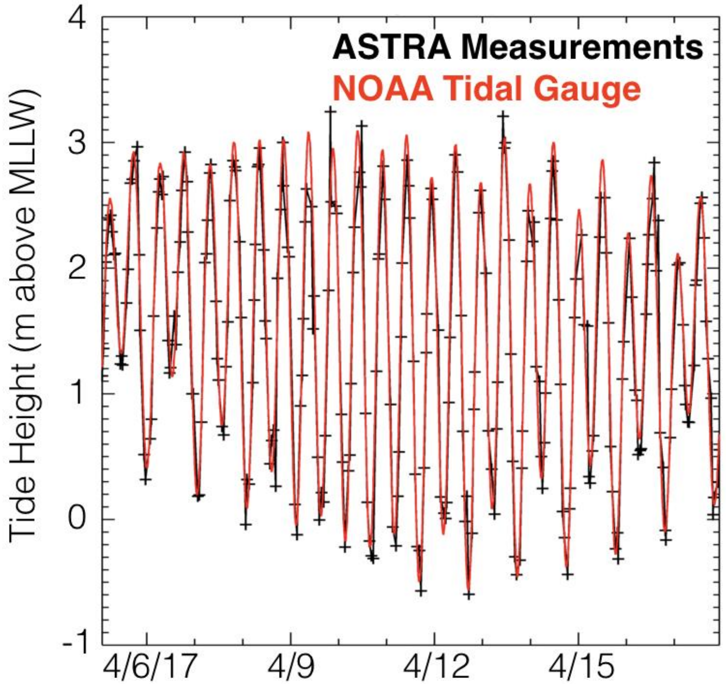
- New PBO-type station in Western AK
- Multi-user data gap

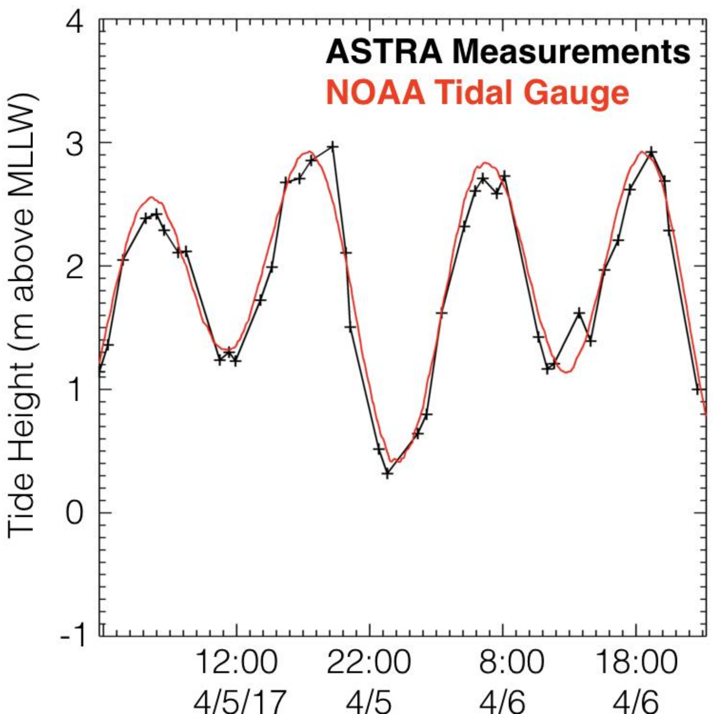
- Small Business Innovation Research Program
- "Grab-and-go" Receiver System

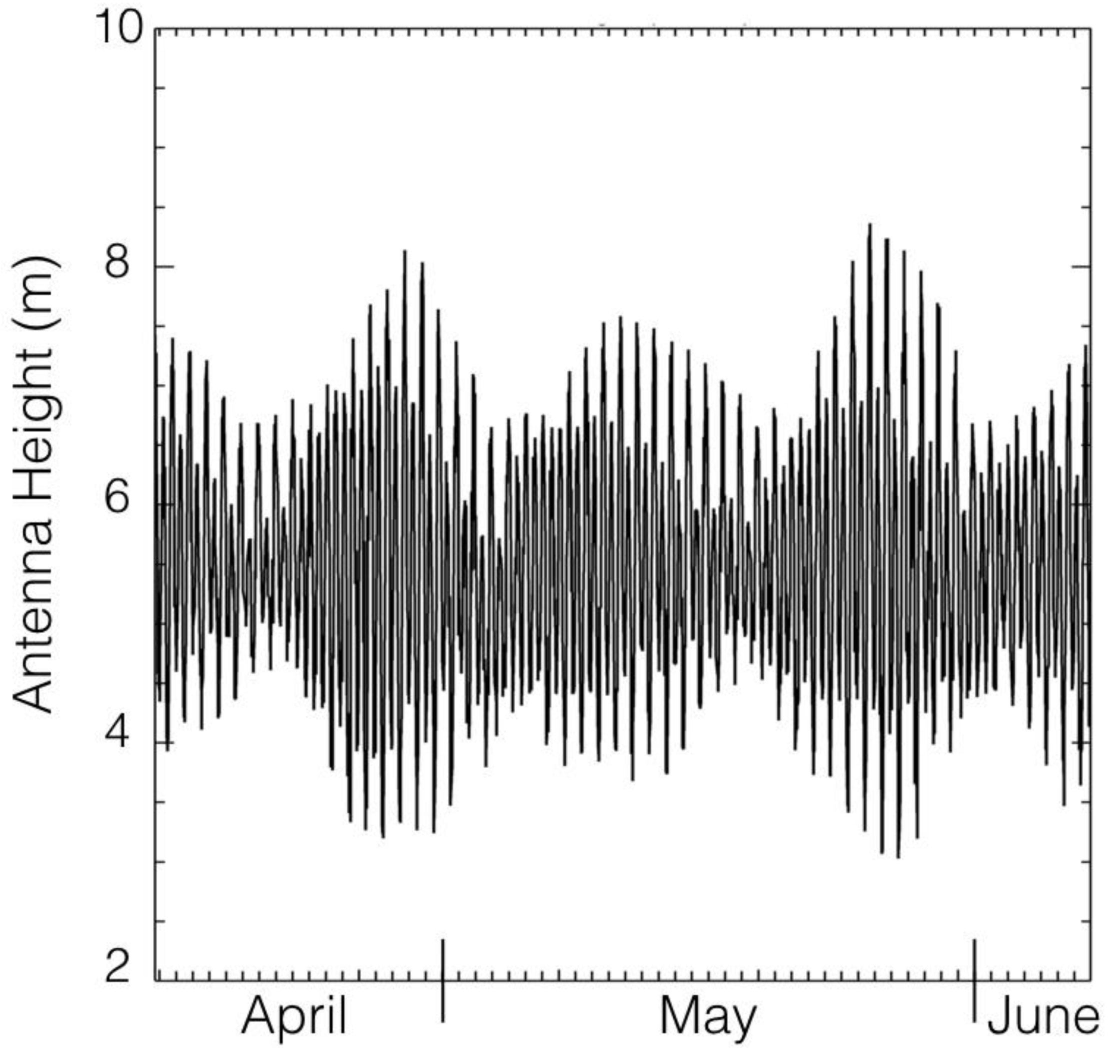
ASTRA Pilot Project (2016-17)







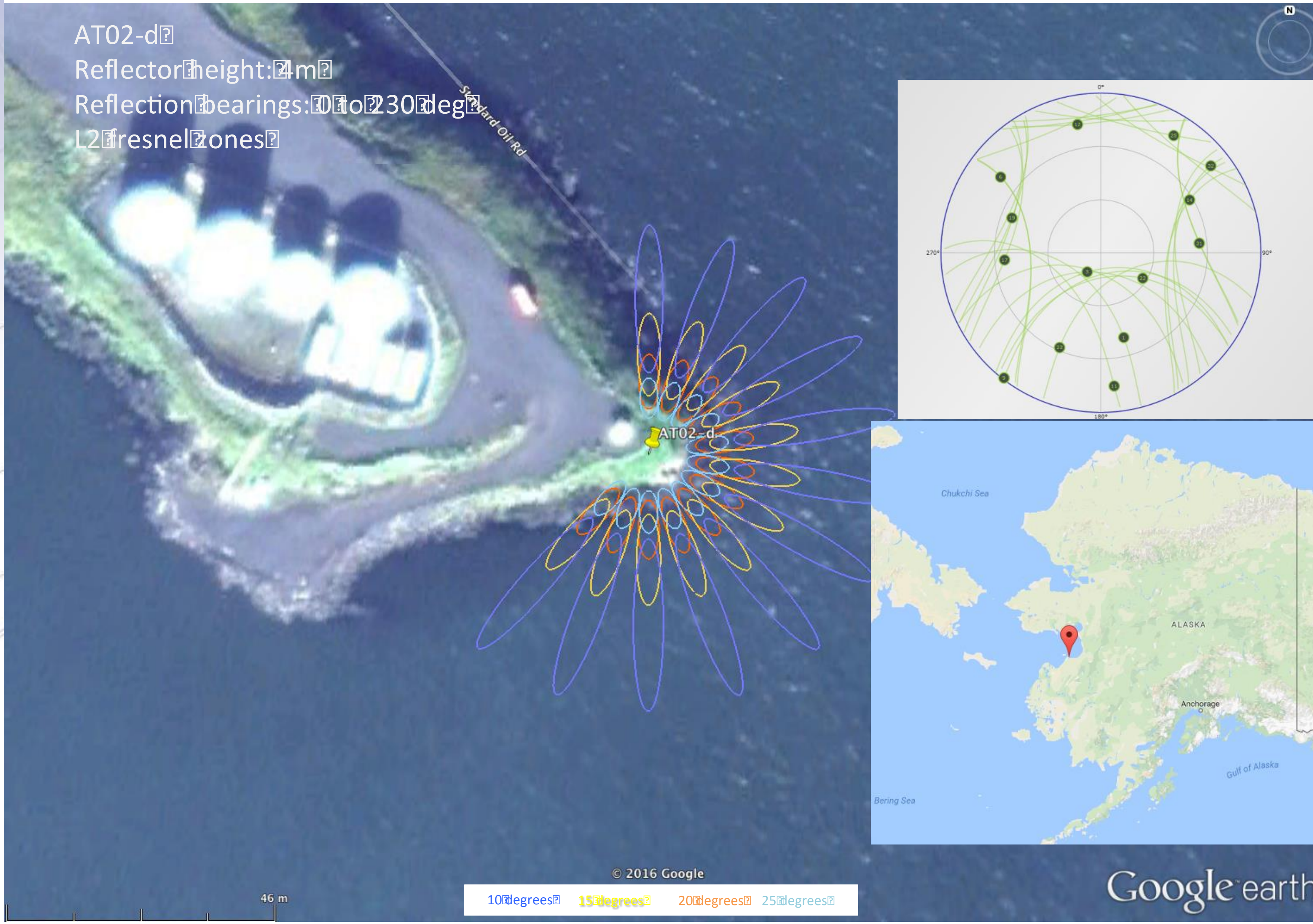




ASTRA Pilot Project

- March – September 2017
- Compared to NWLON <2km away

New NWS Project Location(s) in 2017-18



2017-18 Install: St. Michael, Alaska

Why use GPS to measure water levels?

- A GPS tide gauge is inherently defined in a terrestrial reference frame, so you can correct for glacial isostatic adjustment, subsidence, effects of earthquakes, etc.
- No part of a GPS receiver is in salt water.
- It's *relatively* cheap, and simple to operate and maintain.
- Since the reflection zone is based on the height of the GPS antenna above the surface, the system can be set relatively far from the coast.

Consider:

1. Archive S1/S2/S5 in RINEX files
2. Remove elevation angle masks
3. Track (and archive) modern signals
4. Add opportunistic met. packages (+other systems)

from K. Larson

Thank You