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COLLEGE OF ENGINEERING | School of Civil and Construction Engineering

Overview and Discussion of Current and Pertinent GNSS Research

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Oregon GNSS Users Group Meeting

Friday, January 20, 2023

A Few Note Worthy Research Articles

- OSU
  - **Gillins et al (2017)** – Inclusion of Leveling with GNSS Observations in a Single, 3-D Geodetic Survey Network Adjustment
  - **Allahyari et al(2018)** – Tale of two RTNs
  - **Weaver et al (2018)** – Hybrid Survey Networks
  - **Jamieson et al (2018)** – Comparing multiple online Static GNSS processing services
  - **Simpson et al (2021)** – SPR304-821 ODOT UPDATED SURVEY STANDARDS AND CONTROL GUIDANCE FOR IMPROVED OPERATIONS

- NGS
  - **Gillins et al (2019)** – Accuracy of GNSS observations from three Real-time networks
  - **Gillins et al (2019)** – Evaluation of the Online Positioning User Service for Processing Static GPS Surveys: OPUS-Projects, OPUS-S, OPUS-Net, and OPUS-RS

Note, there are MANY other great and useful articles out there
These are just some I've chosen to highlight today

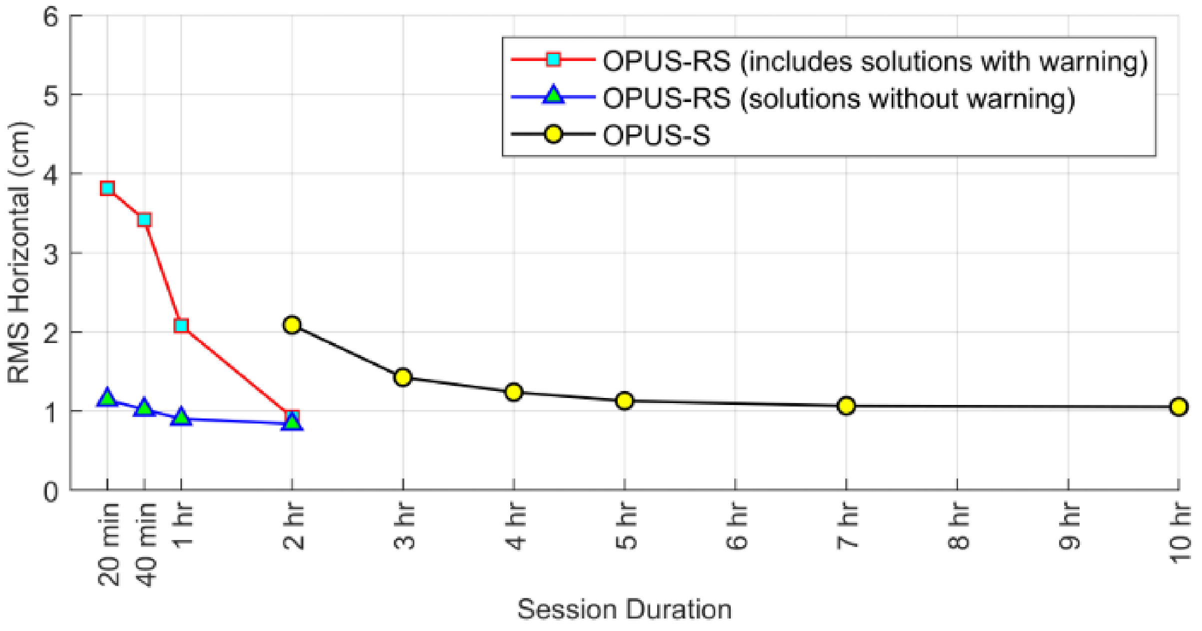
OPUS Accuracies in Oregon

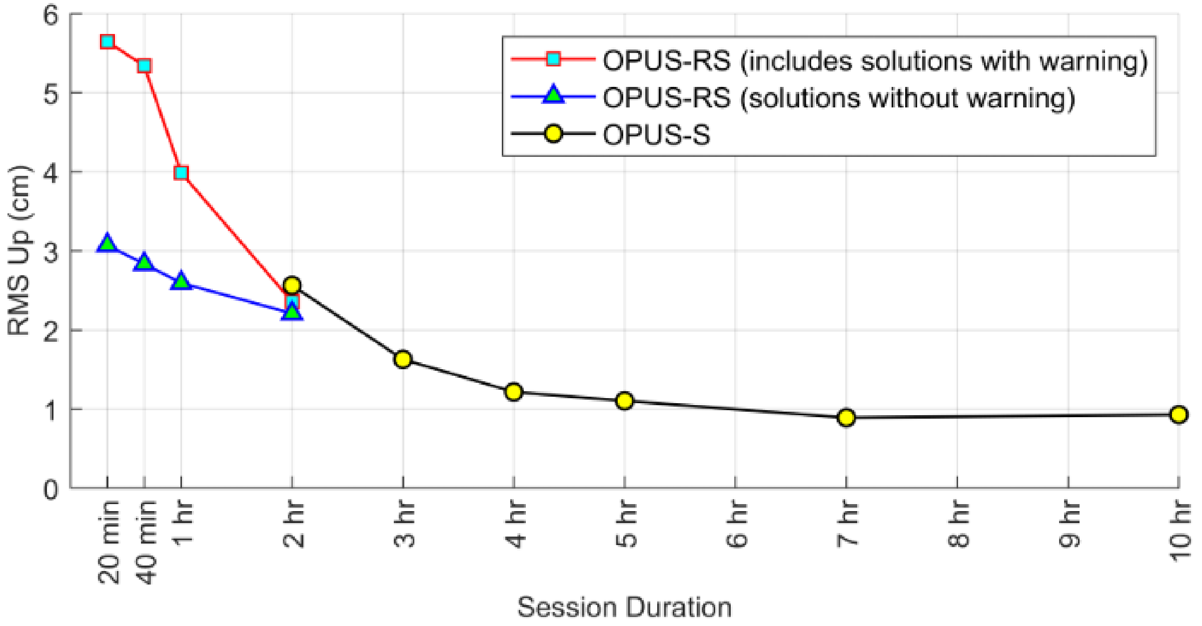
<u>**Gillins, D.T., Kerr, D., and Weaver, B. (2019)**</u>

  – Reported RMSE (~68% confidence level)

Some key findings:

- Longer observation times improve accuracy
- Longer sessions also reduced the likelihood of a failure or weak solution
- When using OPUS-S there was not much benefit beyond 4-5 hours
- At T=2 hours, OPUS-RS performed better than OPUS-S

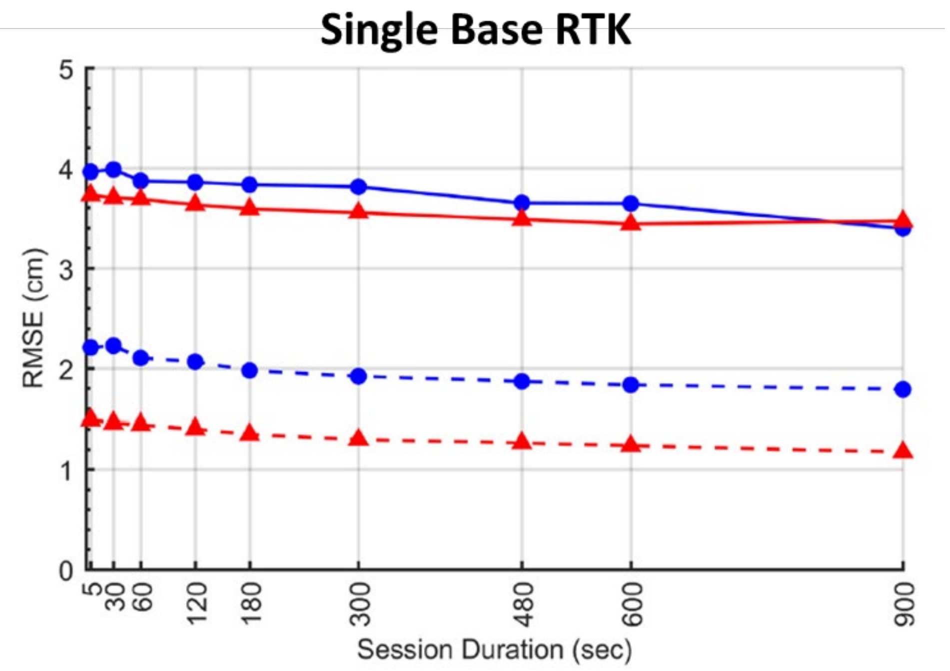


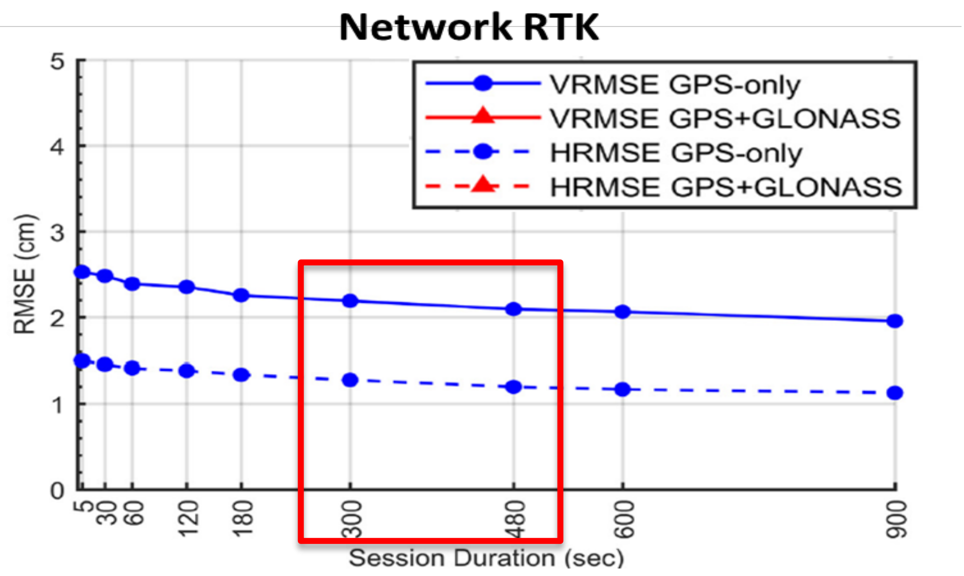


Real-Time Accuracies in Oregon

Single Base vs Network RTK

- **<u>Allahyari, M., Gillins, D.T., Olsen, M.J., and Dennis, M. (2018)</u>**
- Reported RMSE (68% confidence level)
- Data collected with the full network (nRTK) tended to be more accurate and precise than data collected using a single reference station (sRTK)
- GLONASS improved the accuracy of the observations and helped obtain more fixed solutions at longer baseline lengths.





Post-Processing Overview for RTN data

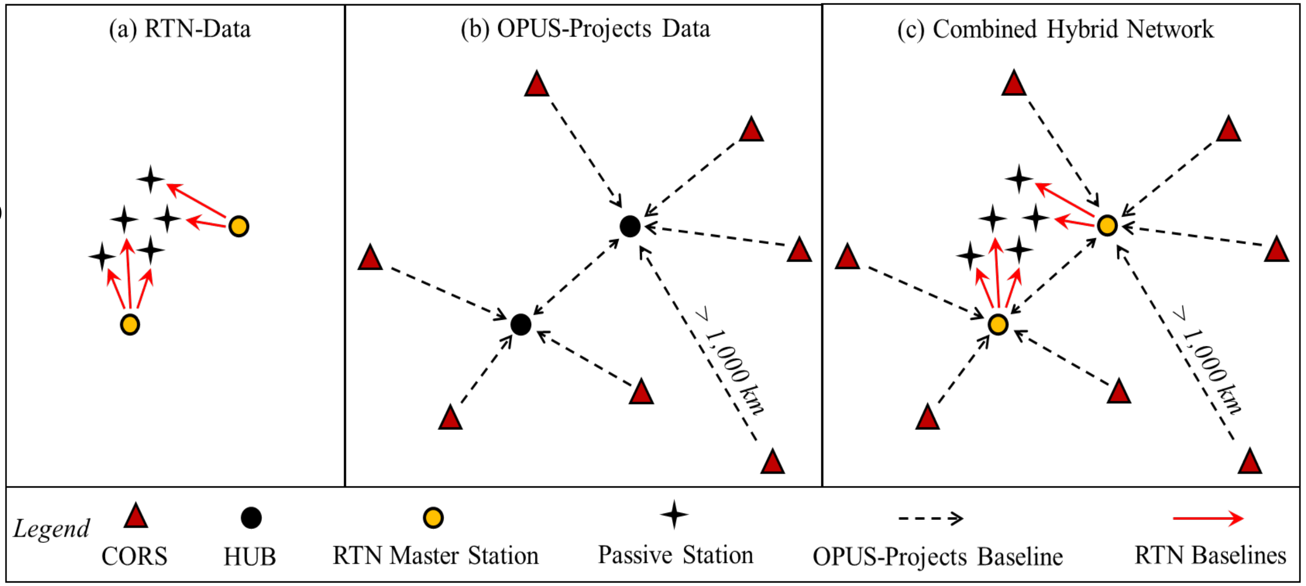
Hybrid GNSS Survey Network

1. Collect RTN Data
   - 5-minute observations per each independent observation
   - Need the baselines from the reference station to the passive marks

2. Align Master Station to NSRS via post-processing
   - Utilizes Static GNSS processing
   - Compute baselines from CORS to the real-time reference station

3. Create the "Hybrid Network"
   - Least squares adjustment
     - Static baselines from CORS to Master station
     - real-time network baselines from master station to survey marks

4. Done!
   - QA/QC the results, ensure everything was properly weights, no outliers, etc. etc.



<u>**See the following articles for more details:**</u>

- ***Weaver et al., 2018.*** *Combining real-time and static GNSS observations for optimizing height Modernization.*
- ***Gillins et al., 2019.*** *Accuracy of GNSS Observations from Three Real-Time Networks in Maryland.*

RTN Accuracies from the ORGN

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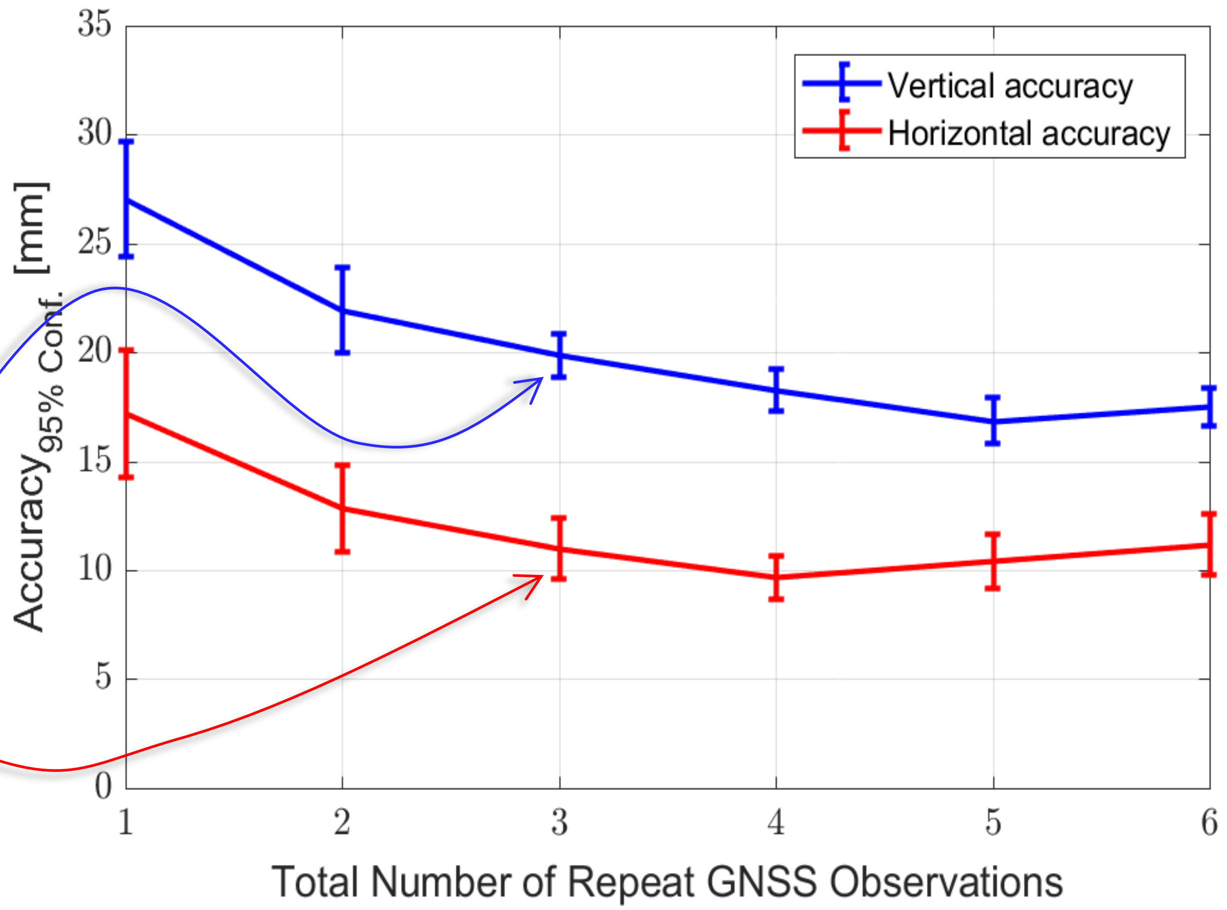
Quantitative Analysis

OSU Research Project

- Used GNSS hybrid methodology proposed by (Weaver et al, 2018)
- Varied Independent Repeat Observations from 2-6 per point

- Results
  - Achievable accuracies (95% CL):
    - Vertical: 2.0 ± 0.10 cm @ 3 obs.
    - Horizontal: 1.1 ± 0.14 cm @ 3 obs.

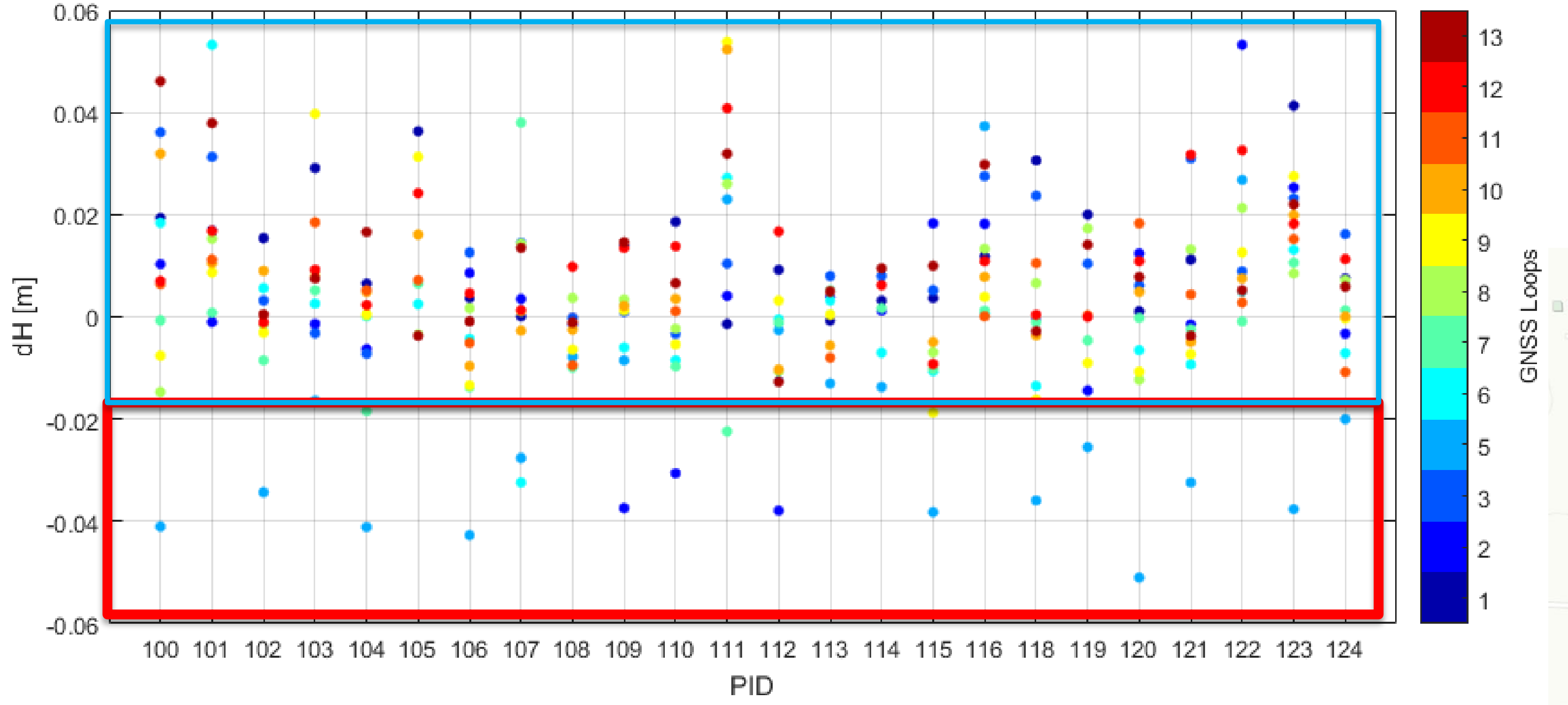
- High accuracies attainable when post-processing RTN Observations!

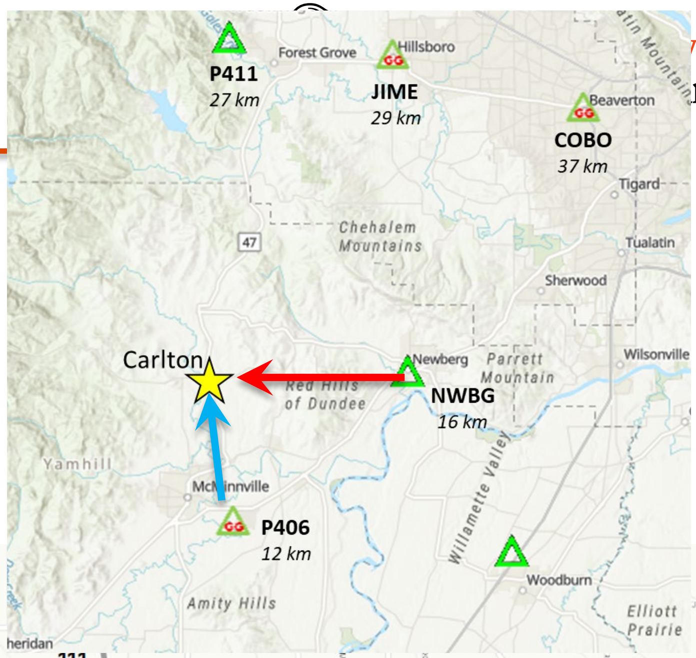


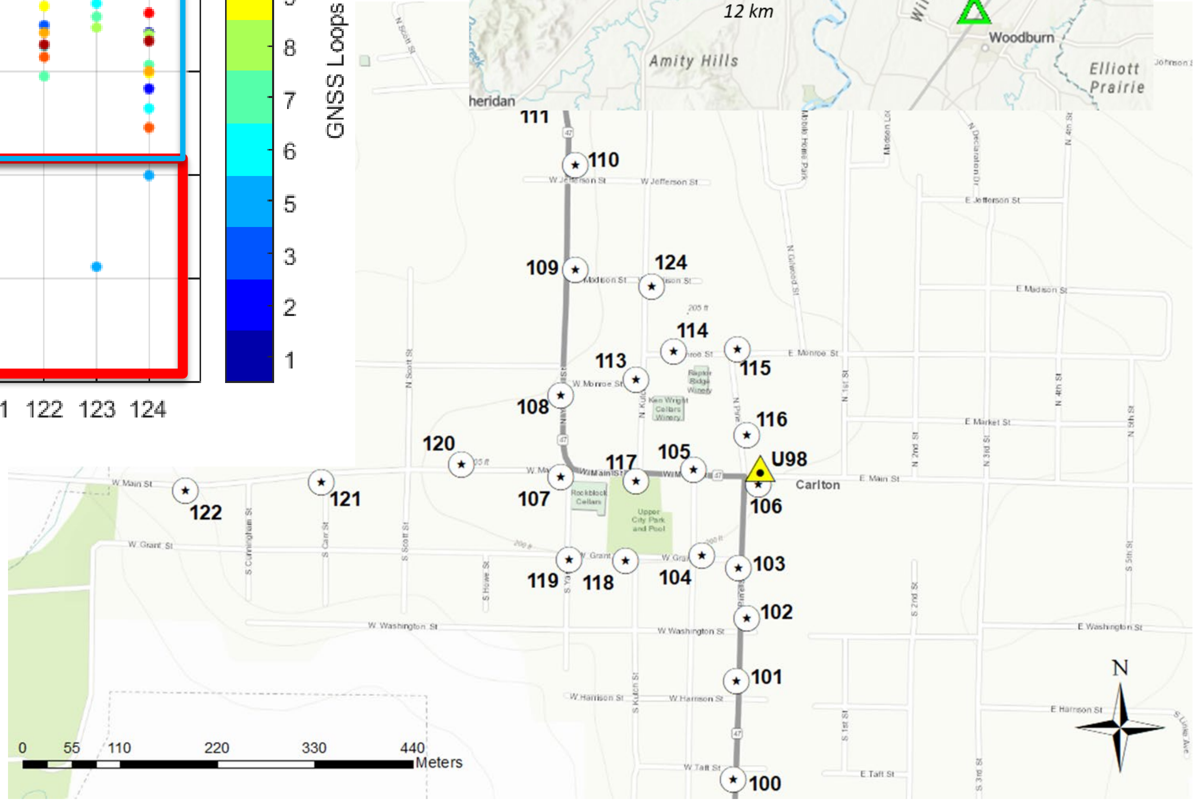
Simpson et al., 2021. *SPR304-821 ODOT Updated Survey Standards and Control Guidance for Improved Operations*

Why RTN's Should be monitored

GNSS Elevation for each point compared to "truth"







NGS Recommendation Table

GNSS Specifications coming to a town near you!

NGS GNSS Control Recommendations:

– Table is a draft from new specifications coming soon

Vertical Accuracy Standard (cm)	Required Total Static GPS Observation Time (hours)	Recommended Static GPS Session	Requirements for SRTK Instead of Static GPS	Requirements for NRTK Instead of Static GPS
4.0			(4) 5-min., GPS or GNSS	
3.5			(5) 5-min., GPS or GNSS	(2) 5-min., GPS or GNSS
3.0	4	(2) 2-h sessions	Not Recommended	(3) 5-min., GPS or GNSS
2.5	8	(3) 3-h sessions or (2) 4-h sessions	Not Recommended	(4) 5-min., GPS-only or (3) 5-min., GNSS
2.0	20	(4) 5-h sessions or (3) 7-h sessions or (2) 10-h sessions	Not Recommended	(6) 5-min., GPS-only or (5) 5-min., GNSS
1.7	48	(6) 8-h sessions or (4) 12-h sessions or (2) 24-h sessions	Not Recommended	Not Recommended

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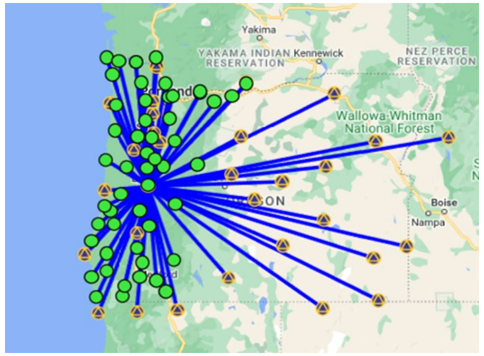
Develop a network processing and adjustment workflow

How should we combine and adjust CORS data?

- We Implemented NGS recommendation
- Utilized OPUS-Projects and Included **5 days** of **24-hour** data files
- Constructed multiple network configurations:
  - Held NGS CORS fixed in all networks

Network Design ID	Description
A	Constrain a single hub in each session. Choose the best most centralized hub and use it for all 5 sessions.
B	Constrain 4-6 hubs for entire state (2-3 in west; 2-3 in east) and use for all 5 sessions.
C	Constrain 1 hub for each RTN cluster for each session. Choose the best most centralized hub and use it for all 5 sessions.
D	Constrain 1 hub for each cluster for each session. Choose a different hub for each session (when possible) to form GNSS loops
E	Constrain 2-3 hubs for each RTN cluster (16-24 total for entire state)
F	Constrain all acceptable NGS CORS that satisfy our QC thresholds

A



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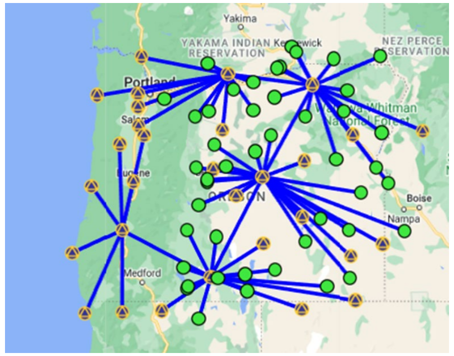

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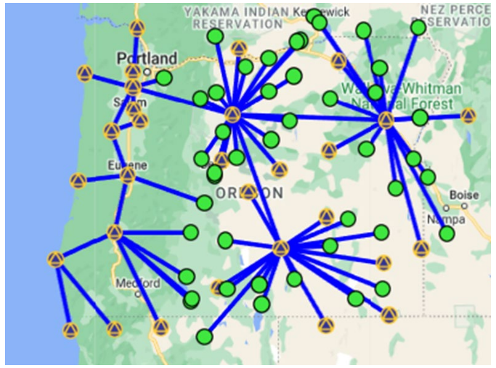

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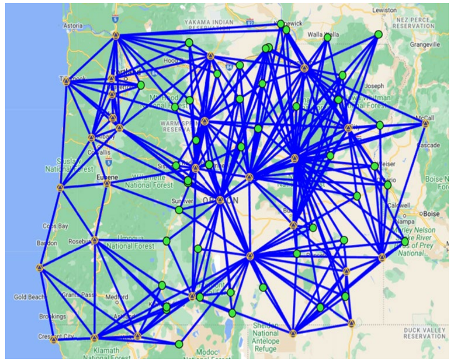

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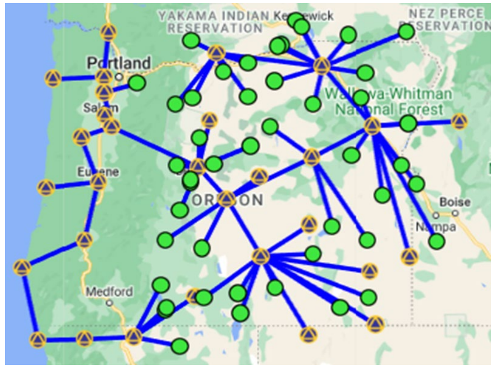

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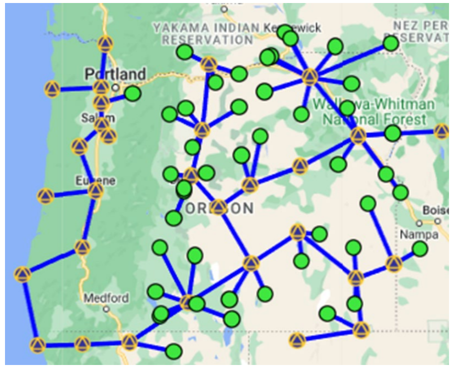

Results

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PUBLISHED ORGN CORS COMPARED TO OPUS COORDINATES (n=75)							
TEST	DESC	EAST					
		RMSE					
		GPSCOM		ADJUST		Difference	
		ΔH	ΔUP	ΔH	ΔUP	ΔH	ΔUP
A	SINGLE HUB	0.0105	0.0109	0.0105	0.0107	0.000	0.000
B	4-5 HUBS	0.0110	0.0119	0.0099	0.0100	0.001	0.002
C	1 HUB PER CLUSTER	0.0128	0.0116	0.0085	0.0105	0.004	0.001
D	1 HUB PER CLUSTER(LOOP)	0.0130	0.0123	0.0091	0.0105	0.004	0.002
E	2-3 HUBS PER CLUSTER	0.0132	0.0120	0.0087	0.0120	0.004	0.000
F	ALL HUBS	0.0129	0.0121	0.0091	0.0108	0.004	0.001

PUBLISHED ORGN CORS COMPARED TO OPUS COORDINATES n = 81							
TEST	DESC	WEST					
		RMSE					
		GPSCOM		ADJUST		Difference	
		ΔH	ΔUP	ΔH	ΔUP	ΔH	ΔUP
A	SINGLE HUB	0.0184	0.0122	0.0123	0.0122	0.006	0.000
B	4-5 HUBS	0.0135	0.0122	0.0125	0.0116	0.001	0.001
C	1 HUB PER CLUSTER	0.0058	0.0122	0.0112	0.0116	-0.005	0.001
D	1 HUB PER CLUSTER(LOOP)	0.0058	0.0219	0.0136	0.0114	-0.008	0.010
E	2-3 HUBS PER CLUSTER	0.0155	0.0130	0.0132	0.0128	0.002	0.000
F	ALL HUBS	0.0152	0.0133	0.0124	0.0117	0.003	0.002

RMSE @95% confidence level

Automated Workflow for Monitoring RTN Stations

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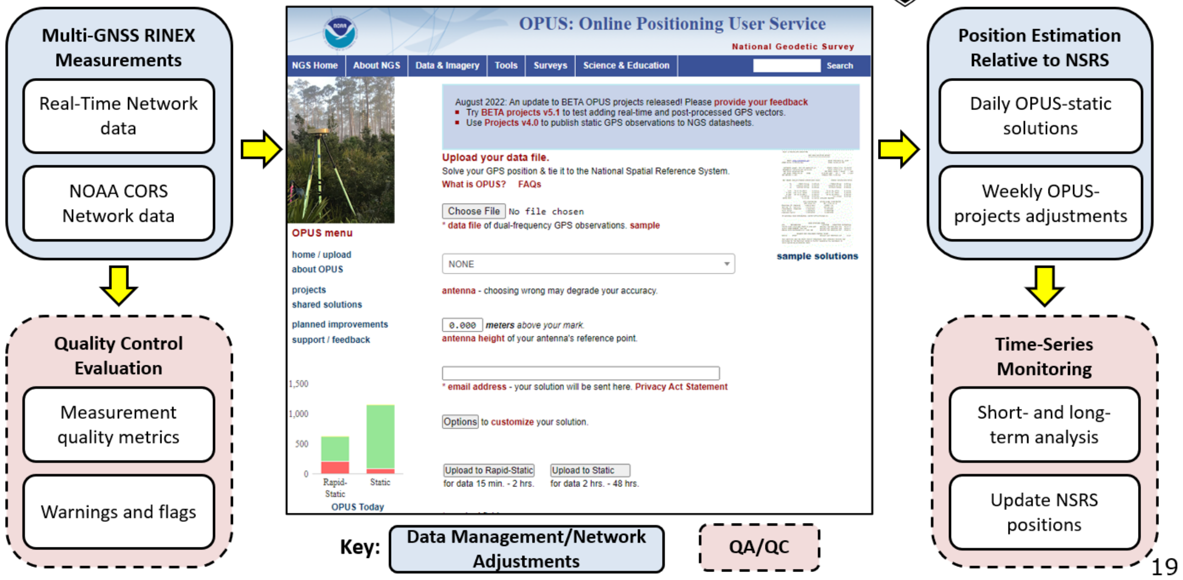
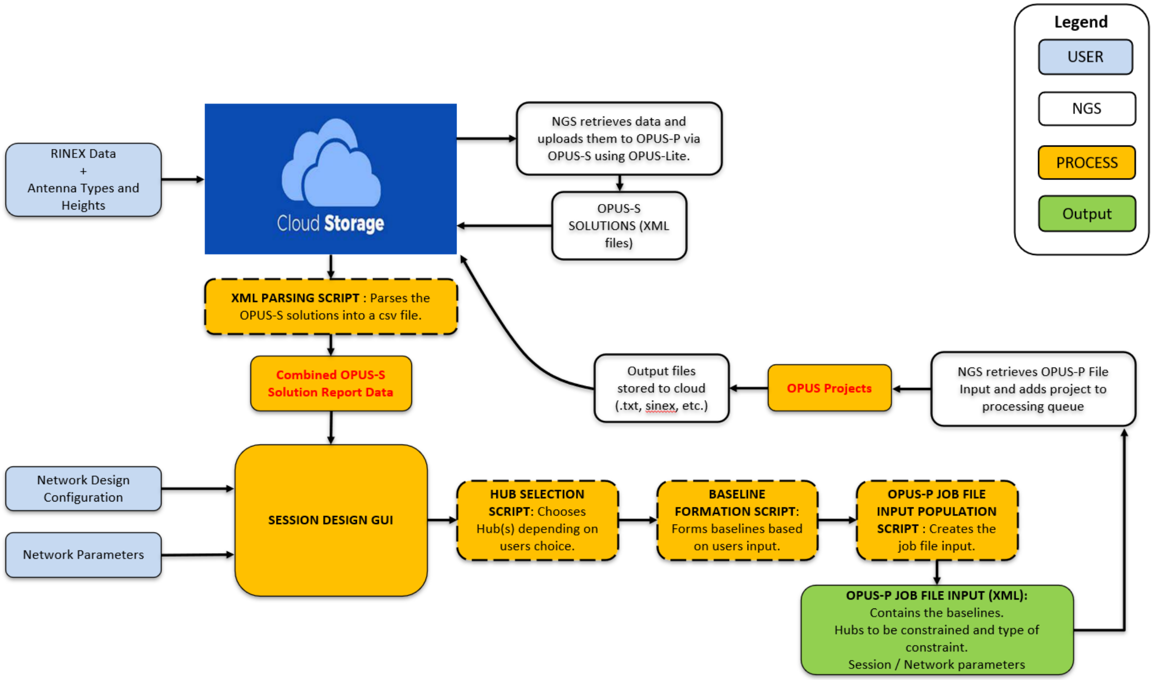
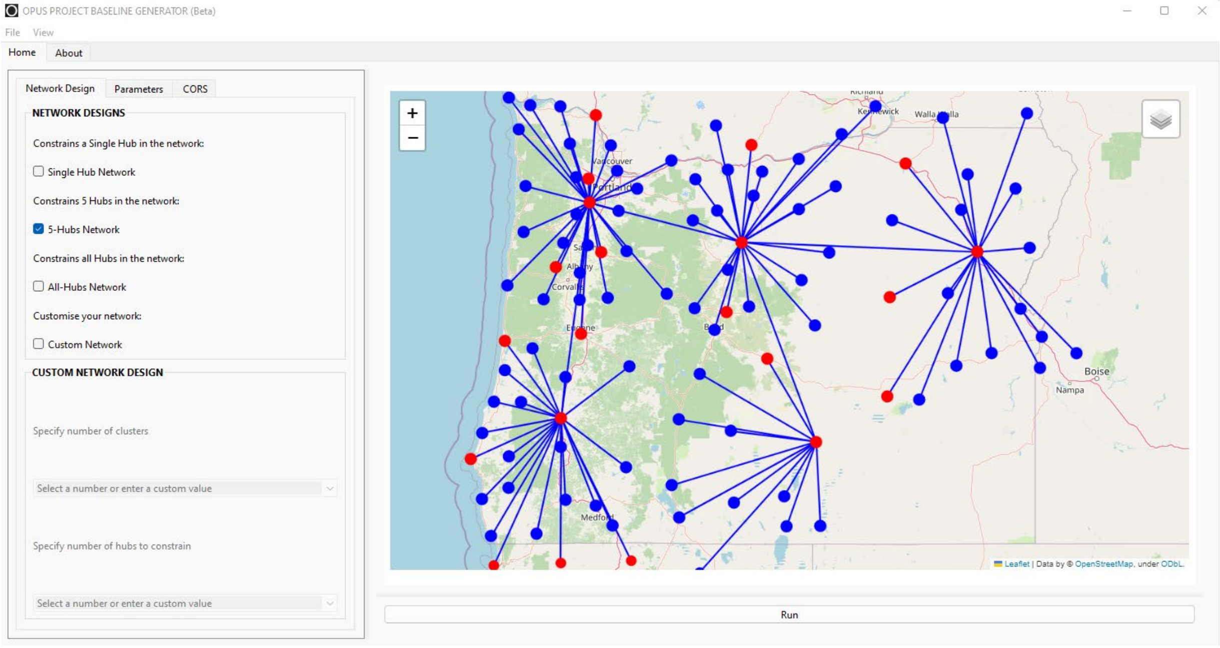


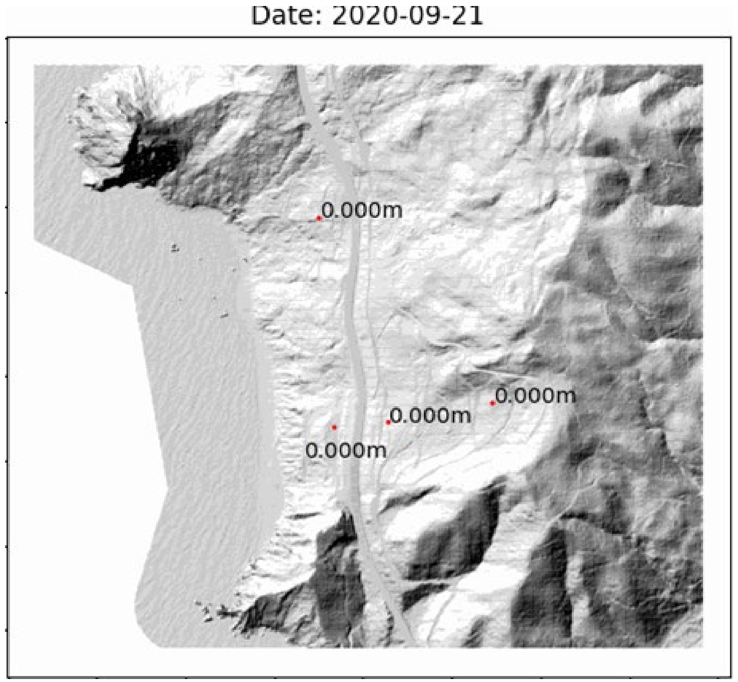


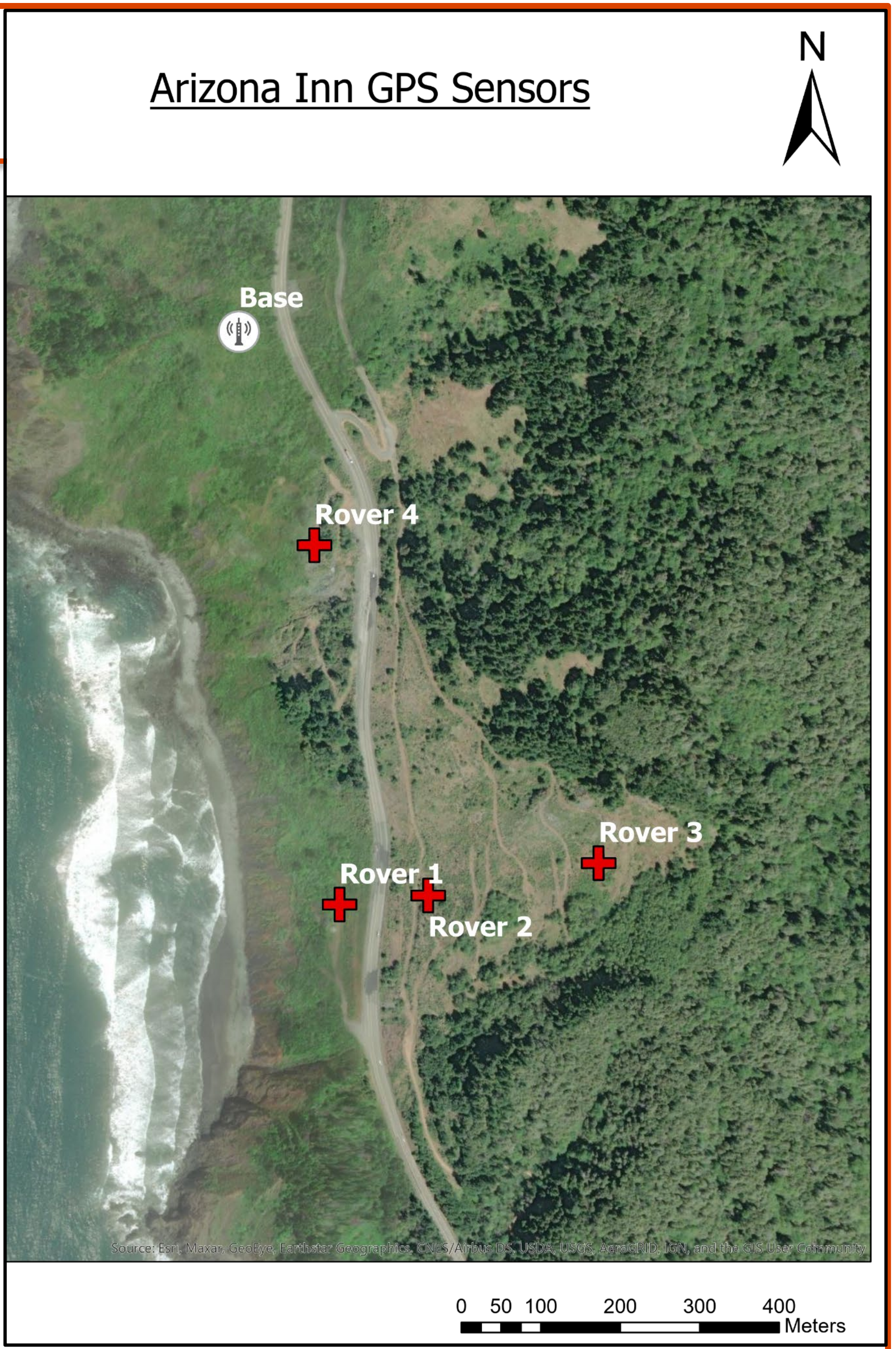


IMPLEMENTATION OF REAL-TIME SURFACE MONITORING FOR ACTIVE LANDSLIDES

ODOT Funded Research:

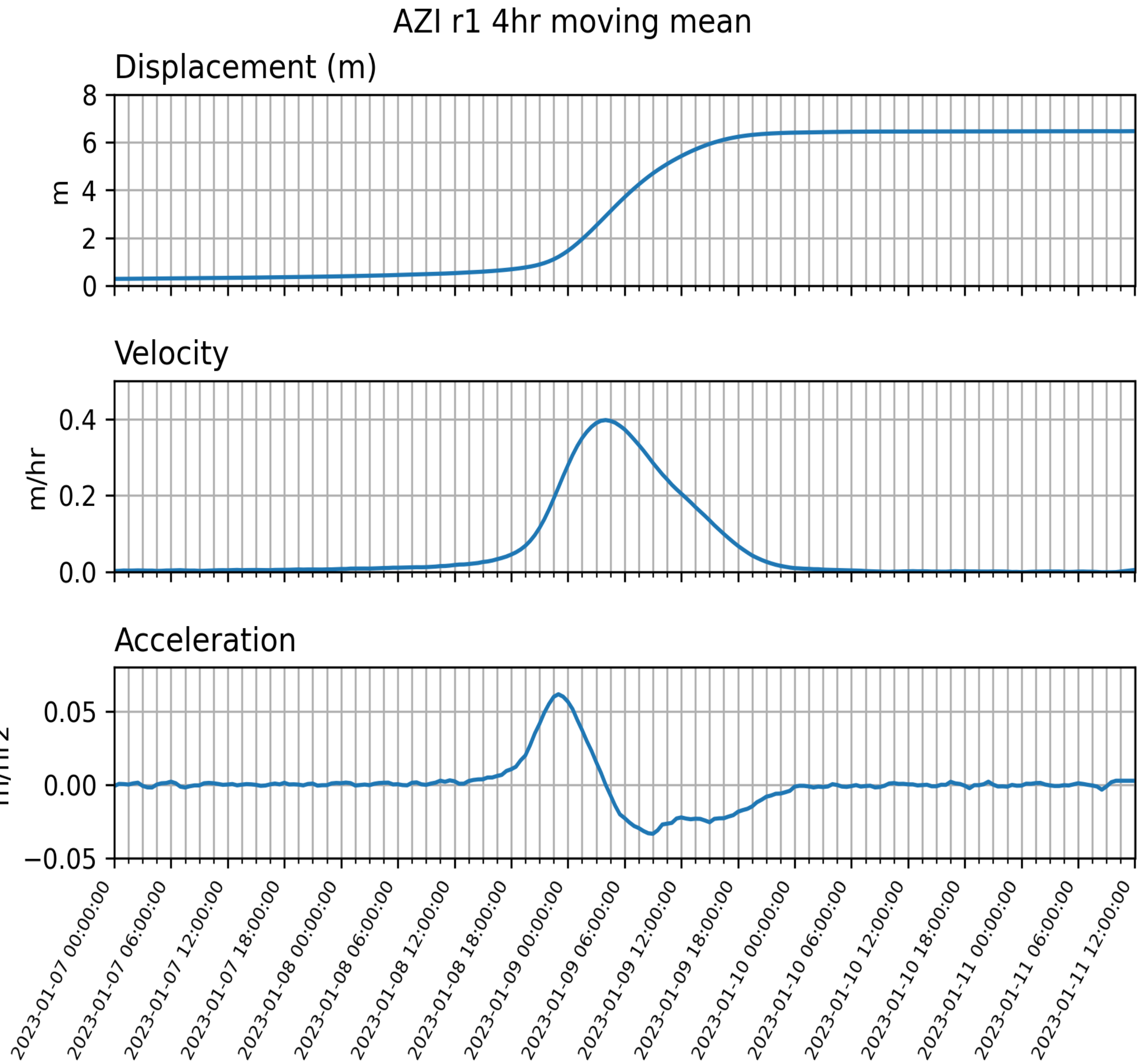
- Michael Olsen, Ben Leshchinsky, **Andrew Senogles**
- Helping engineers better monitor, characterize and track landslides





Arizona Inn Landslide

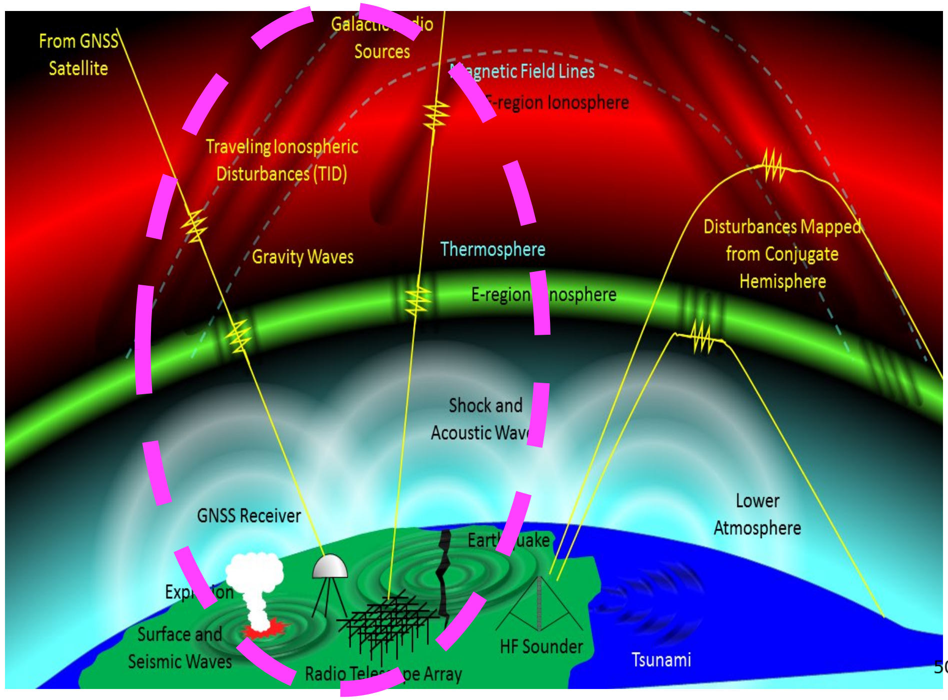
HWY 101 – Near Port Orford



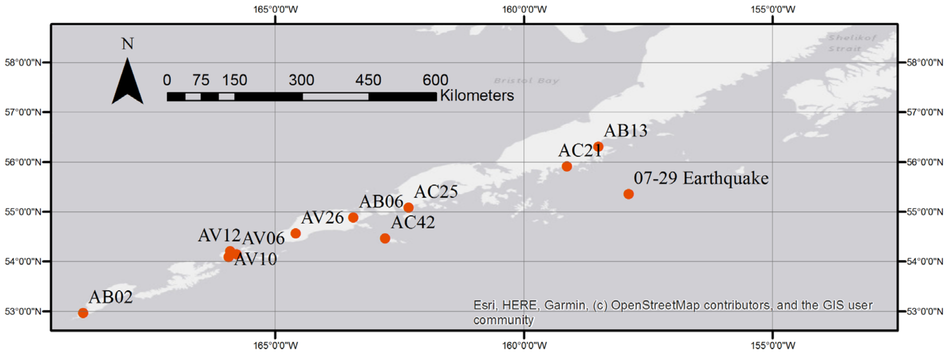
- Slide Event June 8th 2023
- Closed highway 101
- Research was used to inform ODOT Engineering/Maintenance decisions

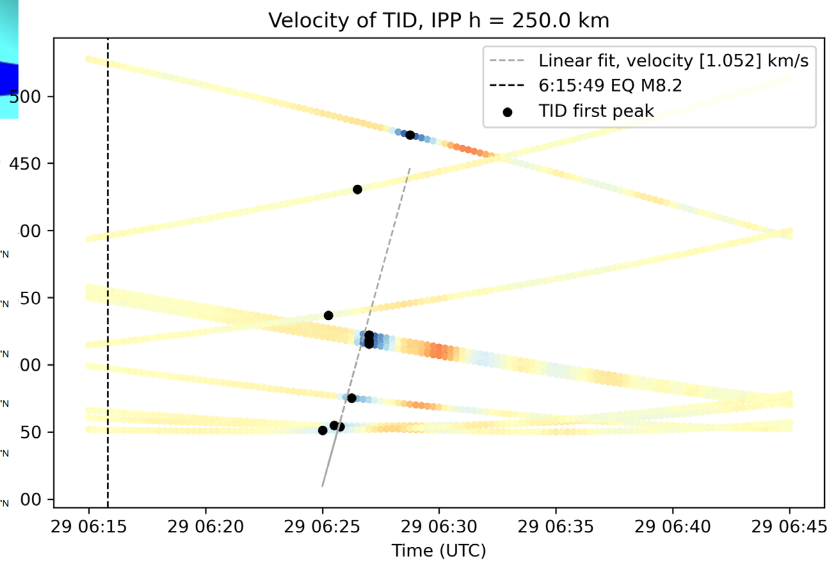
Atmospheric Disturbance Classification and Estimation Using Novel Sensors and Sensor Data Fusion

Funded by DARPA AtmoSense Program (Feb 2021 – April 2023)



- GNSS has been widely used to monitor electron distribution in the ionosphere
- Various geophysical events induce gravity, acoustic-gravity, and acoustic waves that propagate upward and disturb the ionosphere --> TID
- Ground-based GNSS station networks can be utilized to observe the ionospheric variation over the region





- Case study:
  - TID occurred by an earthquake in Alaska 2018
  - Data from 10 GNSS stations were processed
  - TIDs were detected using Machine learning technique
- Continue work for differentiating multiple source events (tsunamis, volcanic eruptions, etc.)

Adapting GNSS-Reflectometry (GNSS-R) as an operational framework for coastal monitoring

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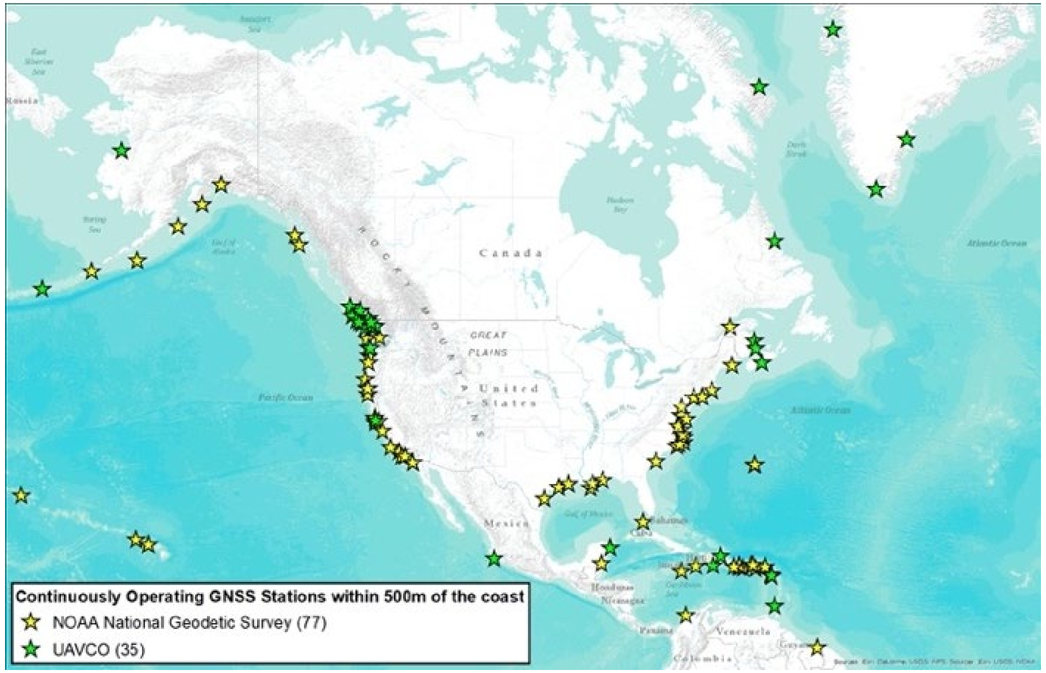
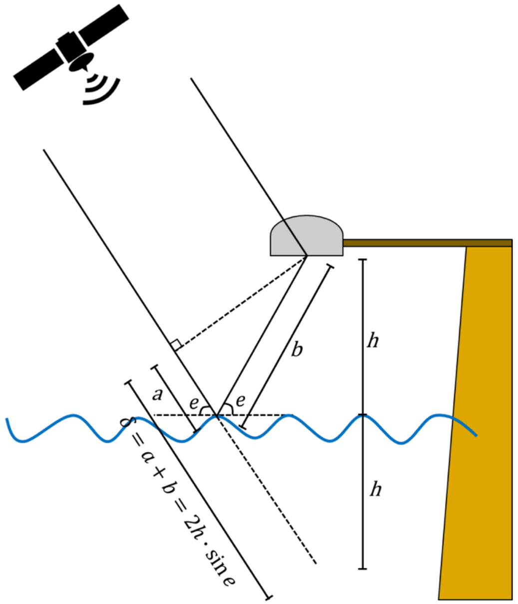
Funded by NOAA IOOS OTT Program (Oct 2021 – Sept 2024)

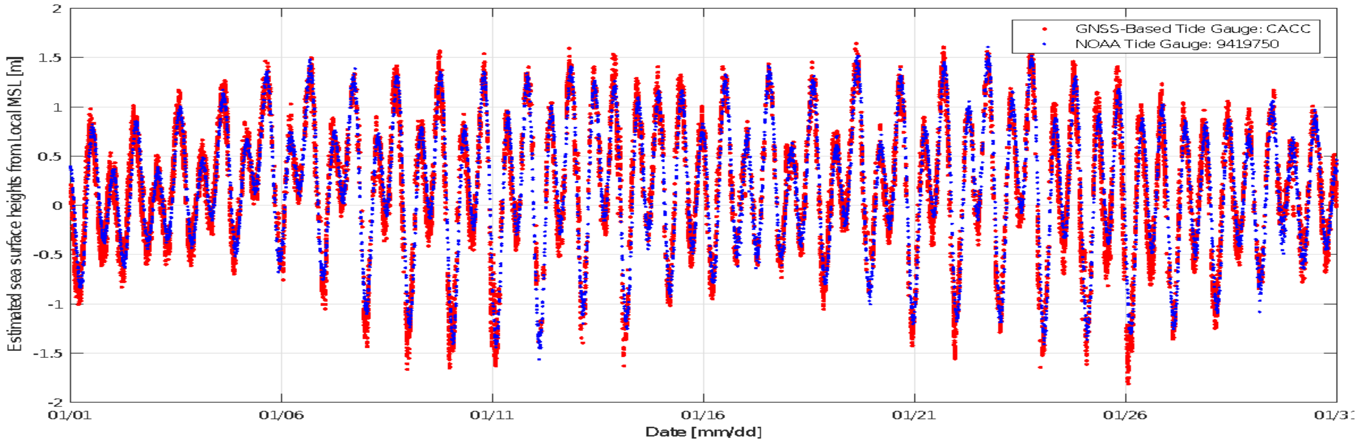
GNSS-Reflectomety (GNSS-R)

- Utilizes multipath signals
- Analyzing various near ground environments
- Can observe water level variations, snow accumulations, soil moisture, vegetation growth, sea ice, ocean wind, etc.



The *overarching goal* is to adapt Global Navigation Satellite System (GNSS) as a *new operational water level measurement facility*, referred to as the **GNSS Water level Observation System (GWOS)**, which will *improve existing coastal monitoring capabilities* of water level.





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Questions??

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