Establishing Project Control

A Few Challenges & Recommendations

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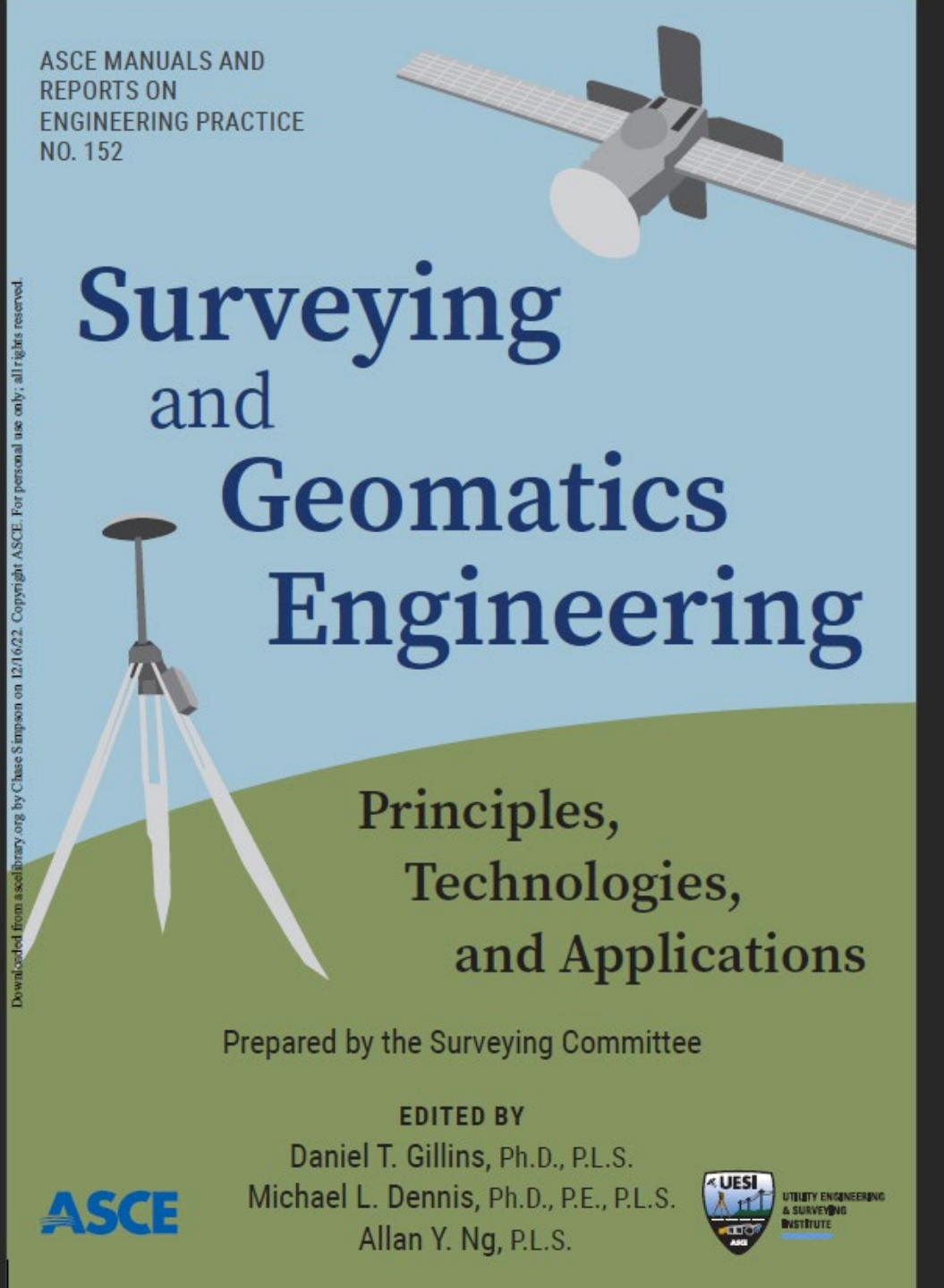
Acknowledgement

Most of the content I'm presenting is summarized from Chapters 3, 4, 7 and 11 of this reference manual.

I highly recommend this resource and believe it will be a powerful reference as we approach the transition to the modernized NSRS



Four things we should be thinking of when using geospatial data

1. Geodetic datum definitions & reference coordinates

   How are the data going to be connected to the Earth?

2. Grid coordinate systems and computations

   How are the data going to be displayed? How are the data used?

3. Vertical datums and height systems

   How high is it? How deep is it? Where will water go?

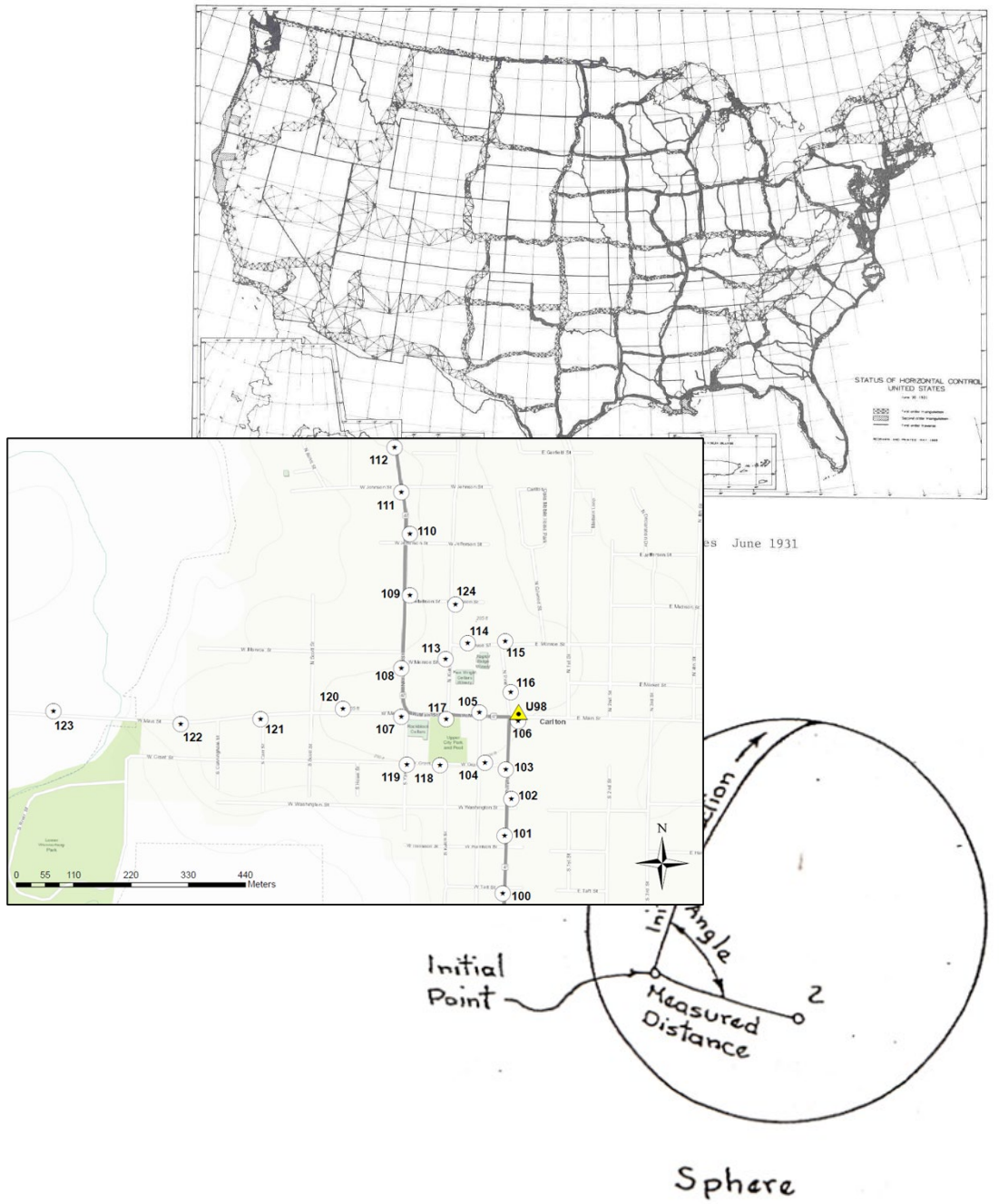
4. Accuracy estimation and reporting

   Is it in the right place? By how much? How do you know?

Defined during the **Control Survey**

What is the purpose of a "Control" survey?

- Establish precise horizontal/vertical positions of reference monuments
  - Typically "Geodetic Positions"
  - Sometimes "Local Positions"
- Primary reference for nearly all other surveys/construction processes
- Essential for GIS/LIS
- Account for shape of the earth
  - Ideally, Computations are performed on the ellipsoid



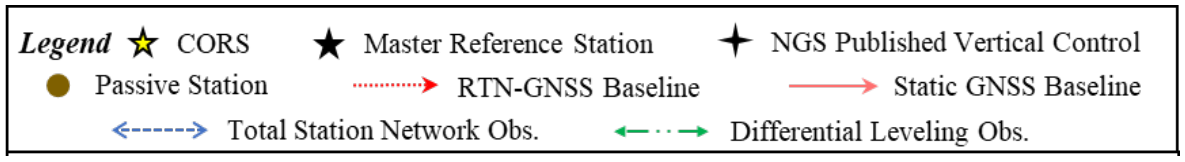
Surveying Methods

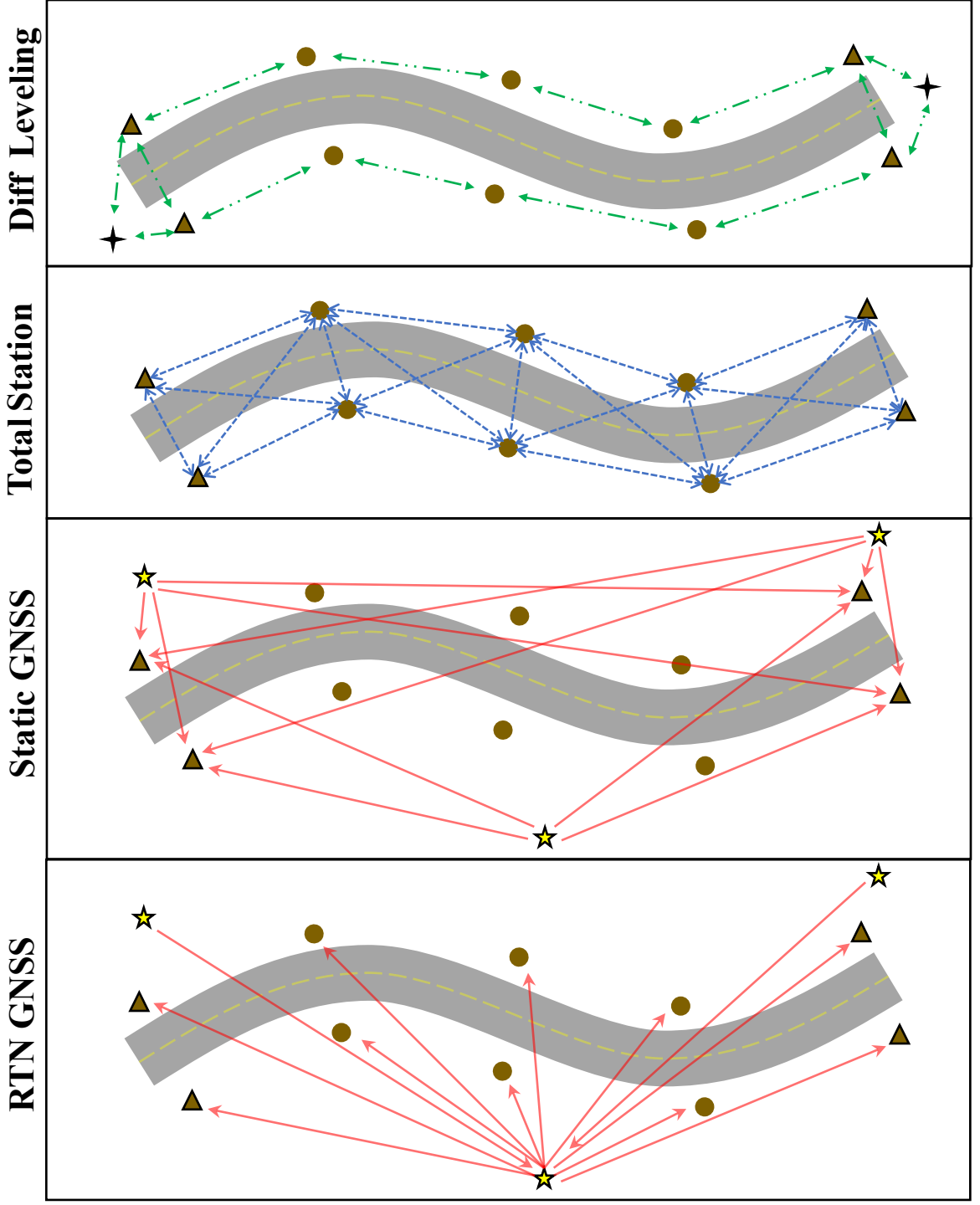
- Conventional (optical) Surveys
  - Trilateration, Triangulation, Traverse, Level Loops, etc.
  - Observations made on local tangent planes at each instrument setup

- GNSS Surveys
  - Static-GNSS, Real-Time Networks, PPP, etc.
  - Geometric Observations *(lat, long, h)*

So which of these approaches do we use to establish project control??

- It depends completely on our desired accuracy requirements and time
- Multiple methods typically necessary and combined via a least squares adjustment





Required Order of work	RECOMMENDED PROCEDURES LEVERAGING THE ORGN	
	Horizontal	*Vertical*
0.015 ft (0.005 m)	(4) independent 5 minute NRTK observations* on each control station OR Static-GNSS survey following NGS specifications -AND- Total Station Network Survey (reference ODOT SSPM for specific guidelines)	Differential Leveling using NGS first order standards or approved ODOT method, refer to ODOT SPPM for specific guidelines.
0.030 ft (0.010 m)	(2) independent 5 minute NRTK observations* on each control station OR Static-GNSS survey following NGS specifications -AND- Total Station Traverse Survey (reference ODOT SSPM for specific guidelines)	Digital Differential Leveling with bar code rod or approved ODOT alternate, refer to ODOT SPPM for specific guidelines -AND- (4) independent 5 minute NRTK observations* on a subset of the stations
0.050 ft (0.015 m)	(3) independent 5 minute NRTK observations* on each control station	Digital or Optical differential leveling with standard rod -AND- (3) independent 5 minute NRTK observations* on a subset of the stations
0.070 ft (0.020 m)	(2) independent 5 minute NRTK observations* on each control station	(4) independent 5 minute NRTK observations* on each control station -OR- Digital or Optical differential leveling with standard rod AND (2) independent 5 minute NRTK observations on a subset of stations
0.100 ft (0.030 m)	(2) independent 3 minute^ NRTK observations* on each control station	(2) independent 5 minute NRTK observations* on each control station
0.150 ft (0.040 m)	(2) independent 1 minute^ NRTK observations* on each control station	(2) independent 3 minute^ NRTK observations* on each control station
0.200 ft (0.050 m)	(2) independent 30 second^ NRTK observations* on each control station	(2) independent 1 minute^ NRTK observations* on each control station
0.300 ft (0.100 m)	(2) independent 5 second^ NRTK observations* on each control station	(2) independent 5 second^ NRTK observations* on each control station

Notes:
* NRTK Observations required to be included in a least squares adjustment using the Hybrid Survey Network methodology proposed by Weaver et. al, (2018).
^ Recommended NRTK occupation times based on findings outlined in Allahyari et. al, (2018).

Reference: SPR304-821: Updated Survey Standards and Control Guidance for Improved Operations, Mar. 2021

Combining Observations of different types

Need to perform computations on the same reference surface, ideally a geodetic reference surface

- Simplest mathematical reference surface is the ellipsoid
  - Conveniently, this is what our GNSS vectors arealready referenced to (e.g., ellipsoidal ECEF)
- Projected coordinate systems (e.g., SPCSs) are not really suitable
  - They're really only 2D systems that we attach a height to (which relative to a different reference surface)

After the adjustment is performed; simply project the resulting coordinates to your LDP or state plane coordinate system

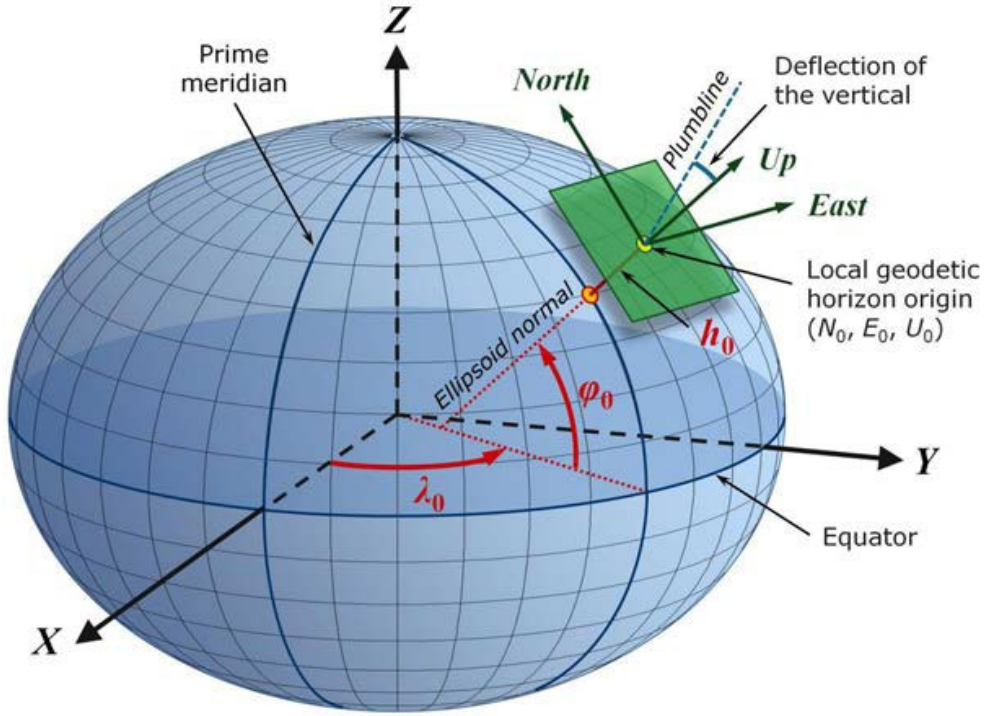


Image Credit: ASCE Surveying Manual

All geospatial LSQ software should be capable of doing this… but you should check the documentation

Geoidal to Ellipsoidal

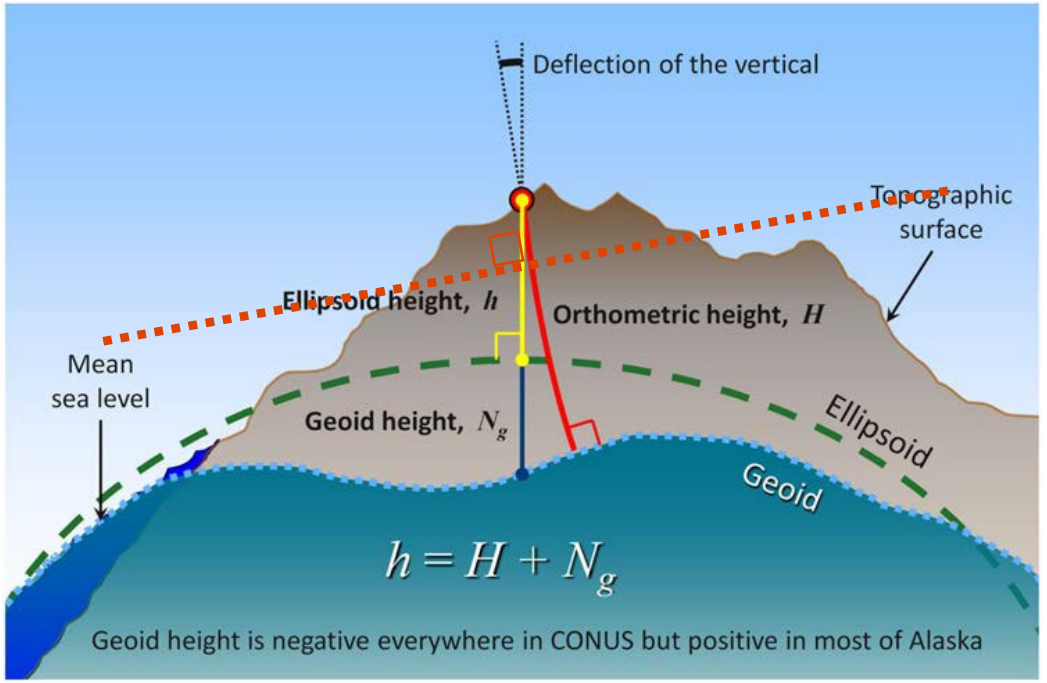
(Necessary if combining TS with GNSS)

Need to correct the total stations observations from geoidal to ellipsoidal using the deflection of the vertical

- *Angle between the plumbline & ellipsoid Normal*
- *Less than one arcminute for the entire US*
  Average ~ 6 arcseconds
- *Varies from place to place due to variations in gravity (e.g., geoid undulations)*
- *Reported as two components:*
  - *deflection in the meridian (north-south), xi*
  - *Deflection in the prime vertical (east-west), eta*

Provided by NGS as a supplement to their Geoid models (GEOID18 → DEFLEC18)

- *Our Location:*
  xi = -4 arcseconds; eta = 6.65 arcseconds



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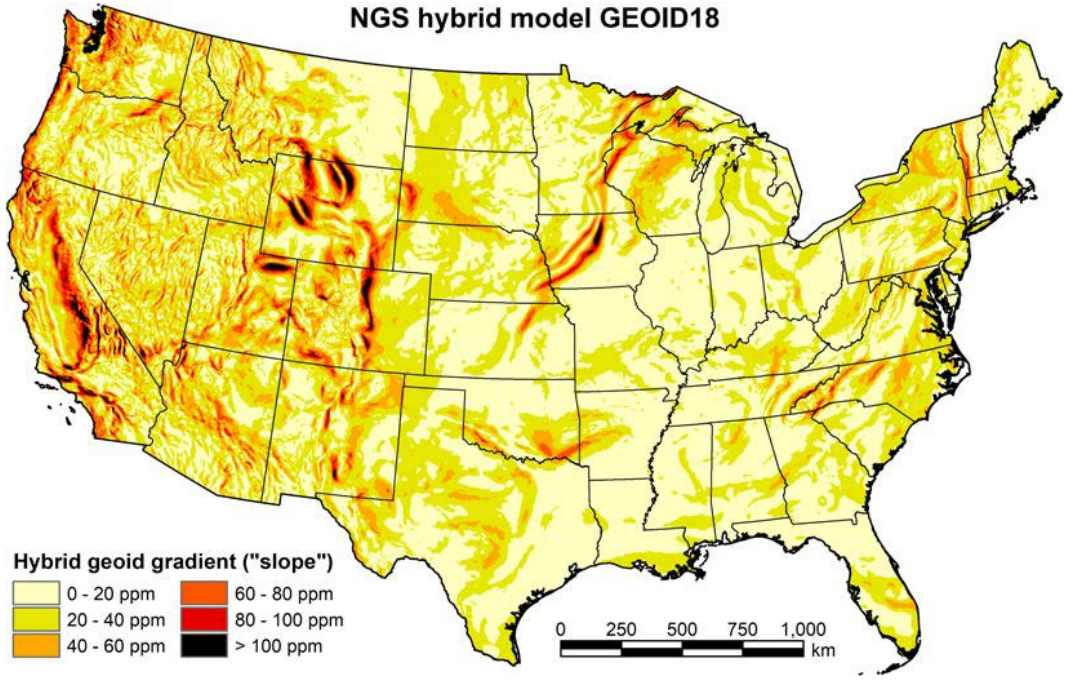
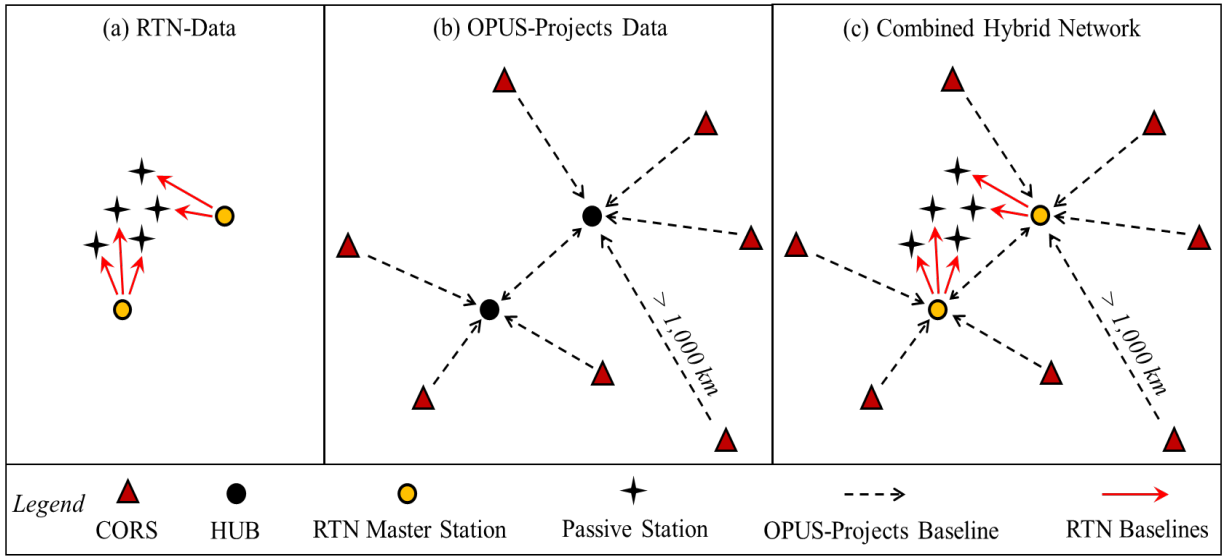


Recommend Post-Processing ORGN vectors

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.

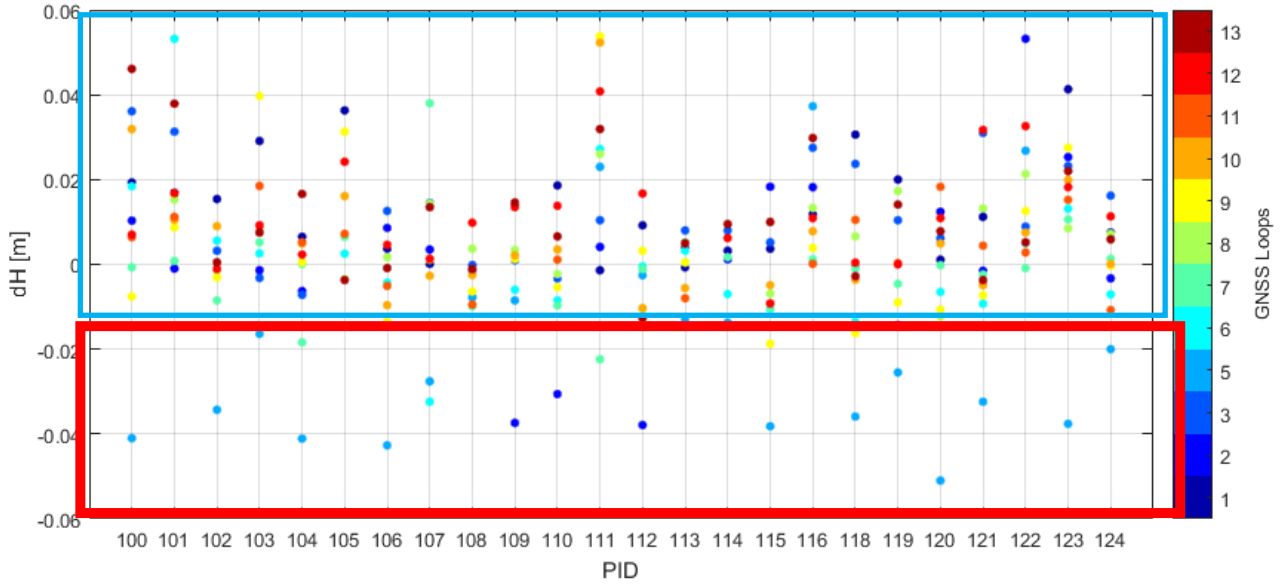


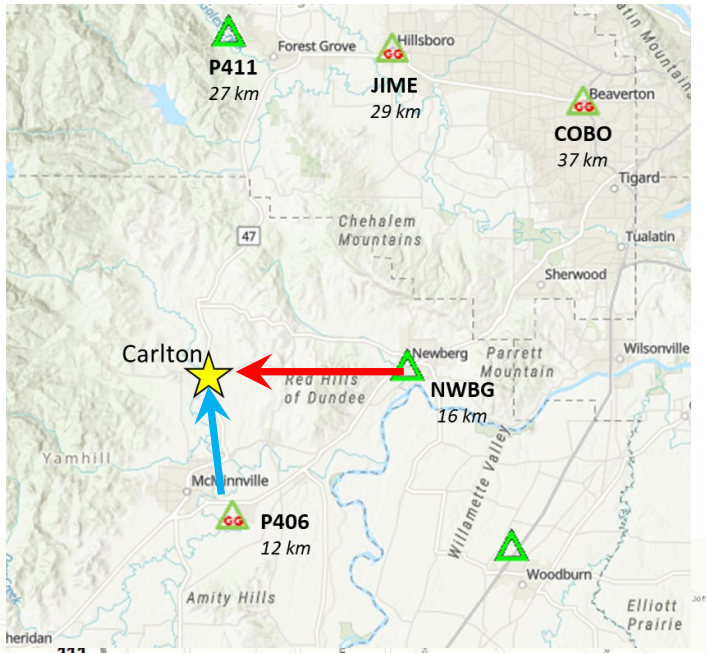
See the following articles for more details:

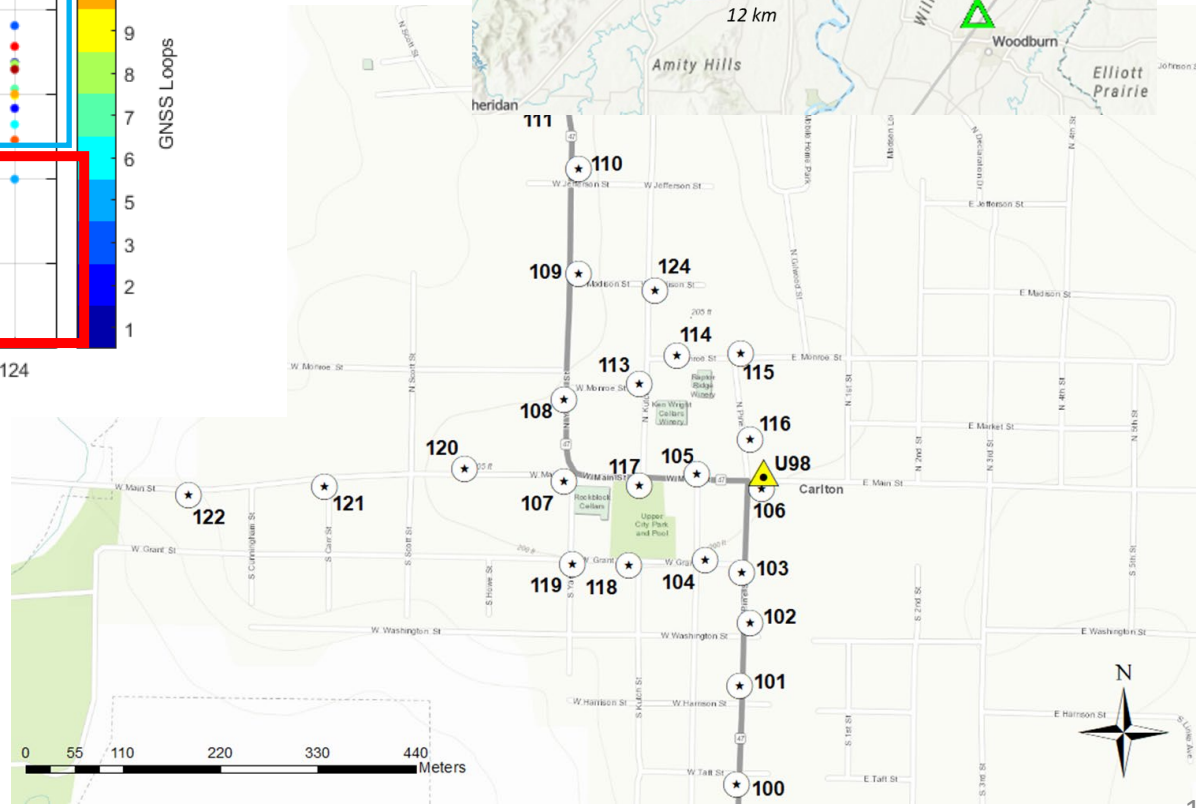
- ***Weaver et al., 2018****. Combining real-time and static GNSS observations for optimizing height Modernization.*
- ***Gillins et al., 2019.*** *Accuracy of GNSS Observations from Three Real-Time Networks in Maryland.*

RTN Base Stations can have errors

GNSS Elevation for each point compared to “truth”

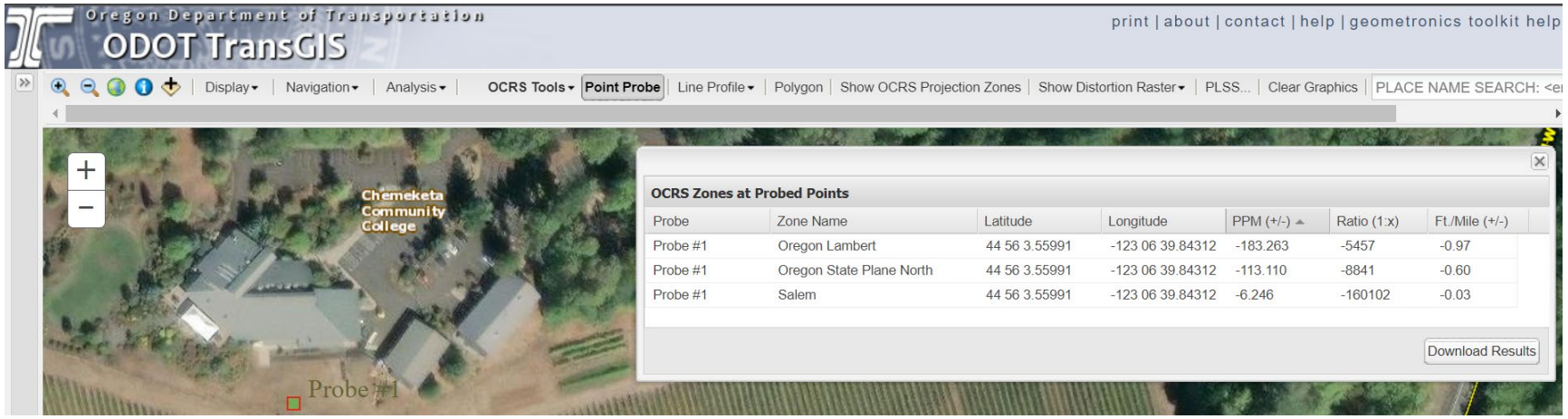






General Recommendations for Project Control

1. If establishing new control, start with a well defined coordinate system
   - SPCS, Low distortion (e.g., OCRS), etc.
   - ODOT's Geometronics Toolkit Probe utility can help you determine the most appropriate zone



2. Only Localize/perform site calibrations when absolutely necessary
3. Ensure that your control network design and methodology is appropriate for the application(s)
   - Survey methods
   - Quantity/Spacing of Control Stations
   - Relative/Absolute Accuracy requirements

Disadvantages of performing Localizations

1. Increased complexity of coordinate system definition without improving performance
   - They are easy to do, but not technically correct, and often not needed.

2. Significant decrease in data transferability
   - Makes it extremely difficult, sometimes impossible, to get final data products into GIS

3. Difficult to separate errors due to coordinates vs GNSS observations
   - All errors are bundled together and minimized as a single source to best fit the control coordinates. But what if the coordinates for one control point are erroneous?

4. Many users emphasize inspecting residuals of the localization to determine quality
   - scale of the horizontal localization?
   - slope of a multi-point vertical calibration?

When to use Horizontal Calibration/Localizations

1. When matching coordinates for undefined (or poorly defined) systems
   - *Example: Matching point coordinates on an engineering plan set with no coordinate system defined.*

2. When aligning real-time GNSS surveys with different datum realizations
   - *Example: Using the ORGN, which provides coordinates relative to NAD83 (2011) epoch 2010.00 when the existing control coordinates are relative to NAD83 (2007 - OR any previous realization)*

3. As a tool for searching for points in the field using real-time GNSS
   - *Example: localizing to a boundary survey using computed coordinate geometry from the plat.*

If you need to localize in the horizontal….

… try to define a georeferenced coordinate system that best matches you the target coordinates

Results in small translation & rotation parameters & Ensures the scale is close to 1

What about Vertical Calibration/Localizations?

Vertical localizations much more common and necessary

- Ellipsoid Heights combined with a hybrid Geoid model rarely match published NAVD88 Orthometric Heights
- Won't be an issue with NAPGD2022 and GEOID2022, a purely gravimetric GEOID model

To correct for the inconsistencies a localization is performed:

1. Single points, or average vertical shift
   - Most common method used when combined with a hybrid GEOID model
2. Multi-point vertical calibrations
   - Can be used to approximate a planar geoidal surface
   - Should be avoided for large areas (>20km)
   - Recommended to use a minimum of 4 points but more is better

Feel free to reach out

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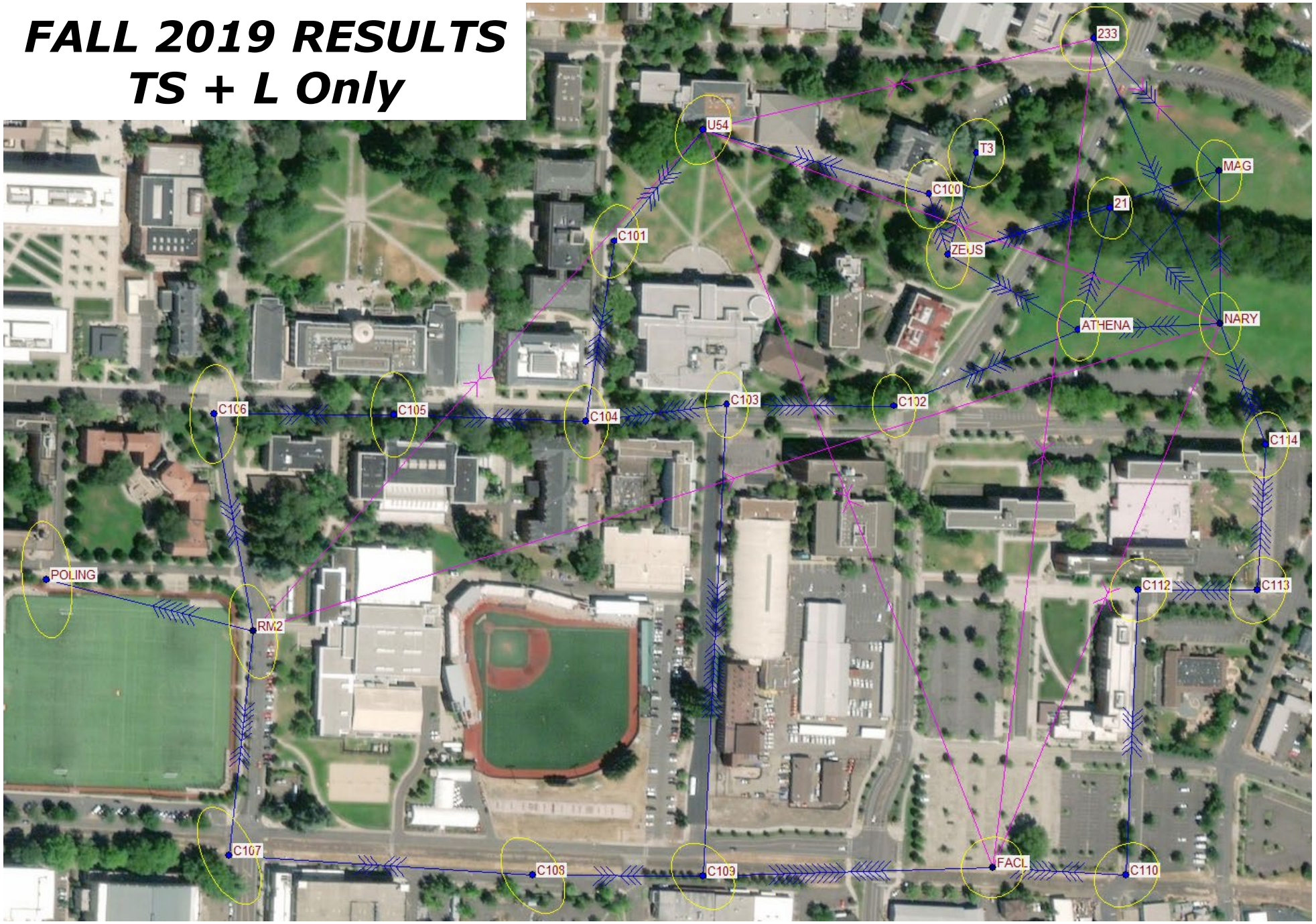
FALL 2019 RESULTS
TS + L Only



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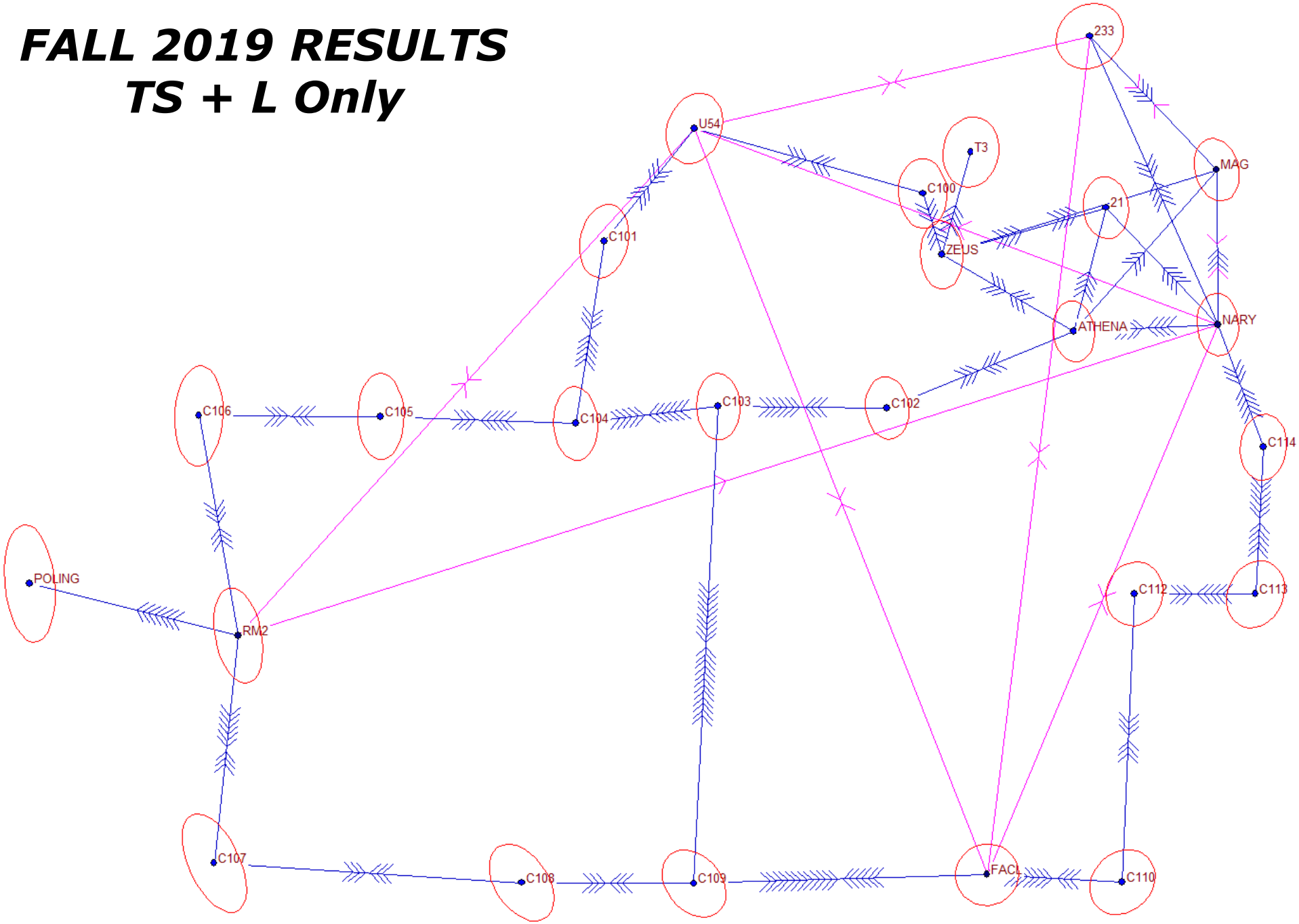

FALL 2019 RESULTS W/ GNSS BASELINES