Using and Understanding OPUS

Vermont Society of Land Surveyors

September 17, 2021

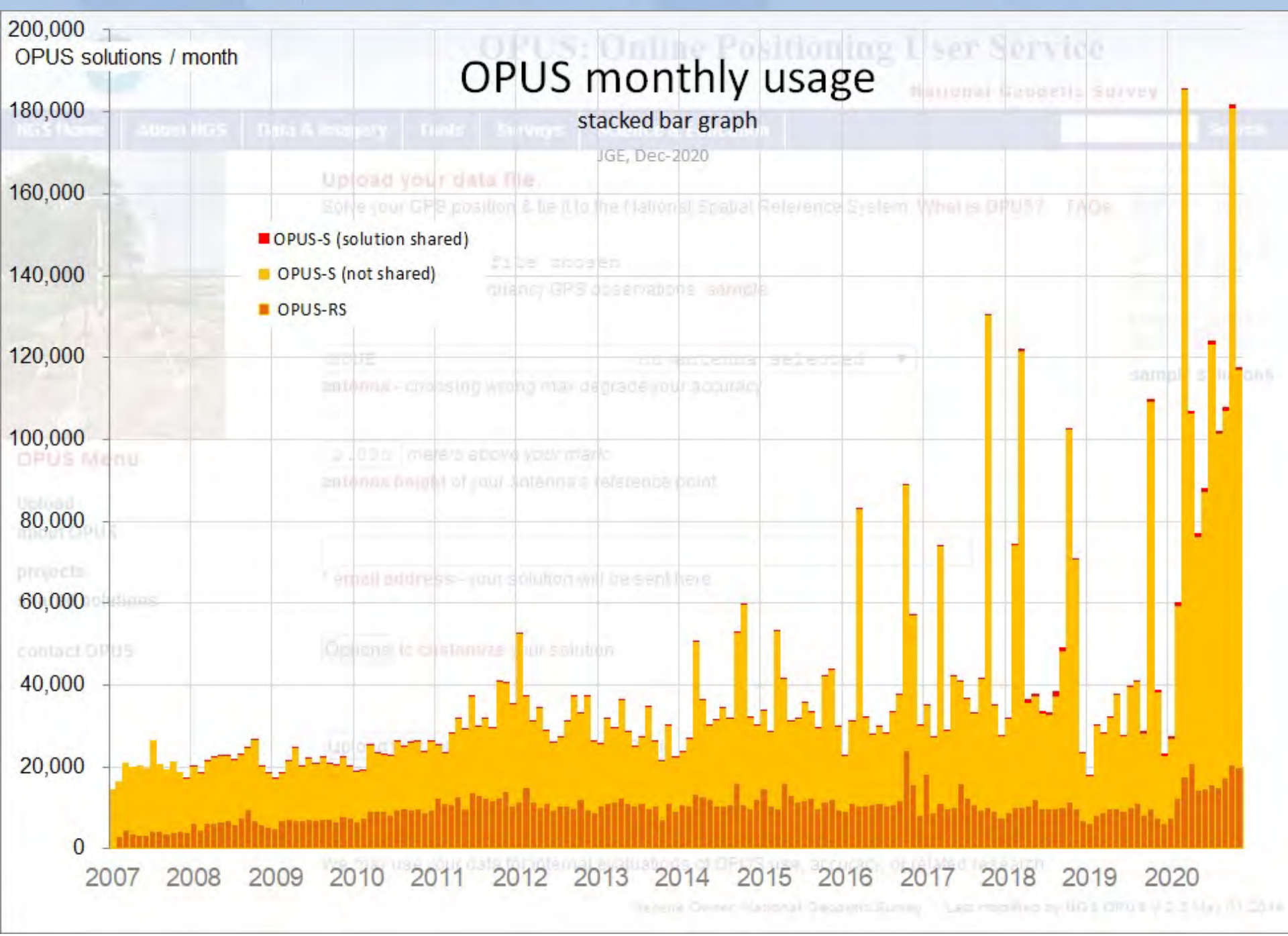
Dan Martin
Northeast Regional Geodetic Advisor
Dan.martin@noaa.gov
240-676-4762

What is OPUS?

- OPUS, the **On-line Positioning User Service**, is a growing set of applications offering web-based access to the tools and resources provided by the NGS.
- Currently, OPUS is composed of
  - OPUS-S……static processing
  - OPUS-RS……rapid-static processing
  - Sharing……database of solutions
  - OPUS Projects…..campaign survey processing

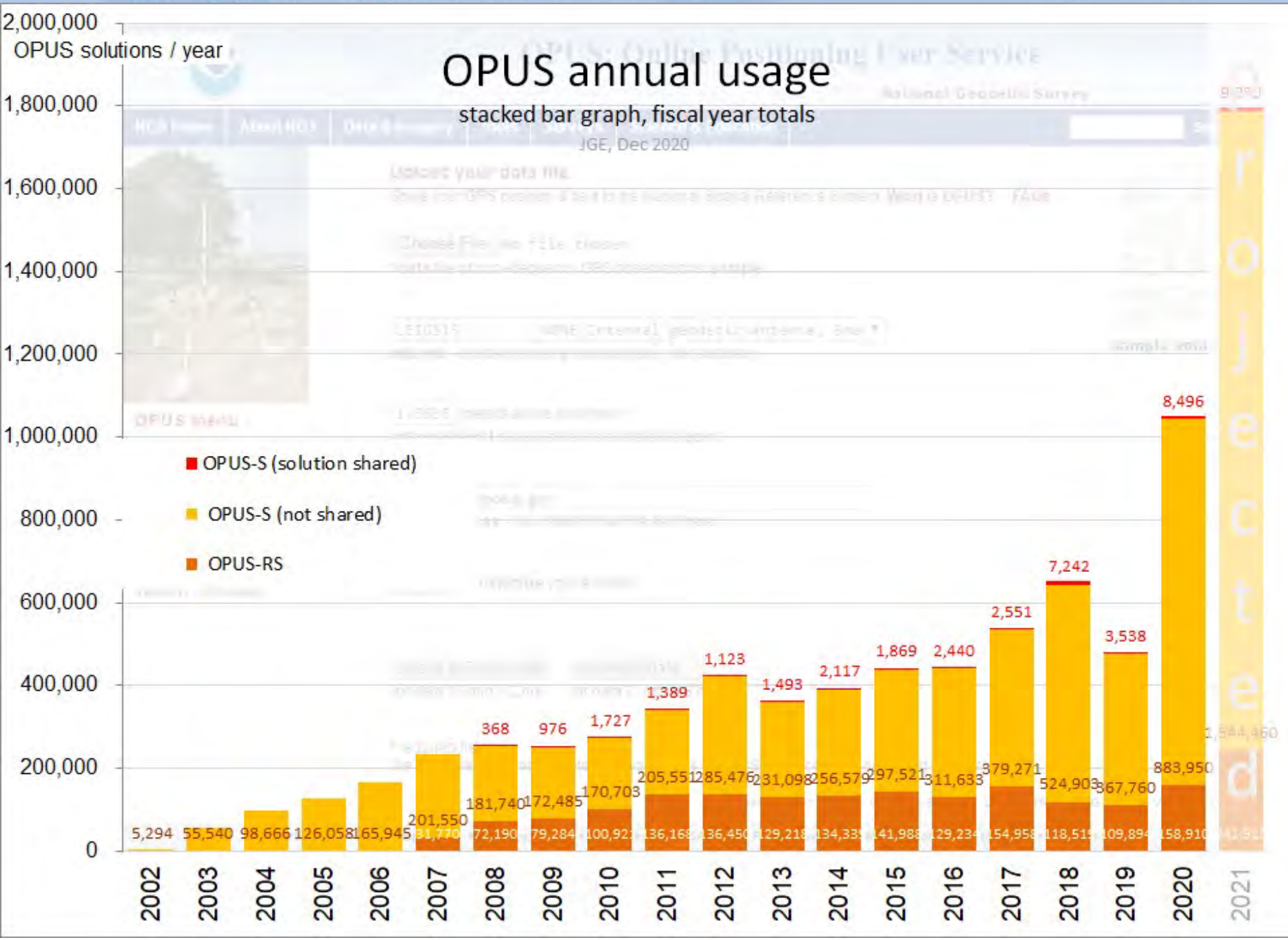
What is OPUS?

- On-line Positioning User Service
  - Submit dual frequency (GPS) Data
  - 15 min - 2 hours data OPUS_RS (Rapid Static)
  - 2 hours - 48 hours data OPUS_S (Static)
  - Processed by NGS computers relative to NCN
  - Results received in minutes via e-mail
  - Provides consistent access to NSRS


OPUS monthly usage
stacked bar graph
OPUS solutions / month
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
OPUS-S (solution shared)
OPUS-S (not shared)
OPUS-RS
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

OPUS annual usage

stacked bar graph, fiscal year totals



The OPUS-S Interface

Beautiful in its simplicity, the user need only provide:

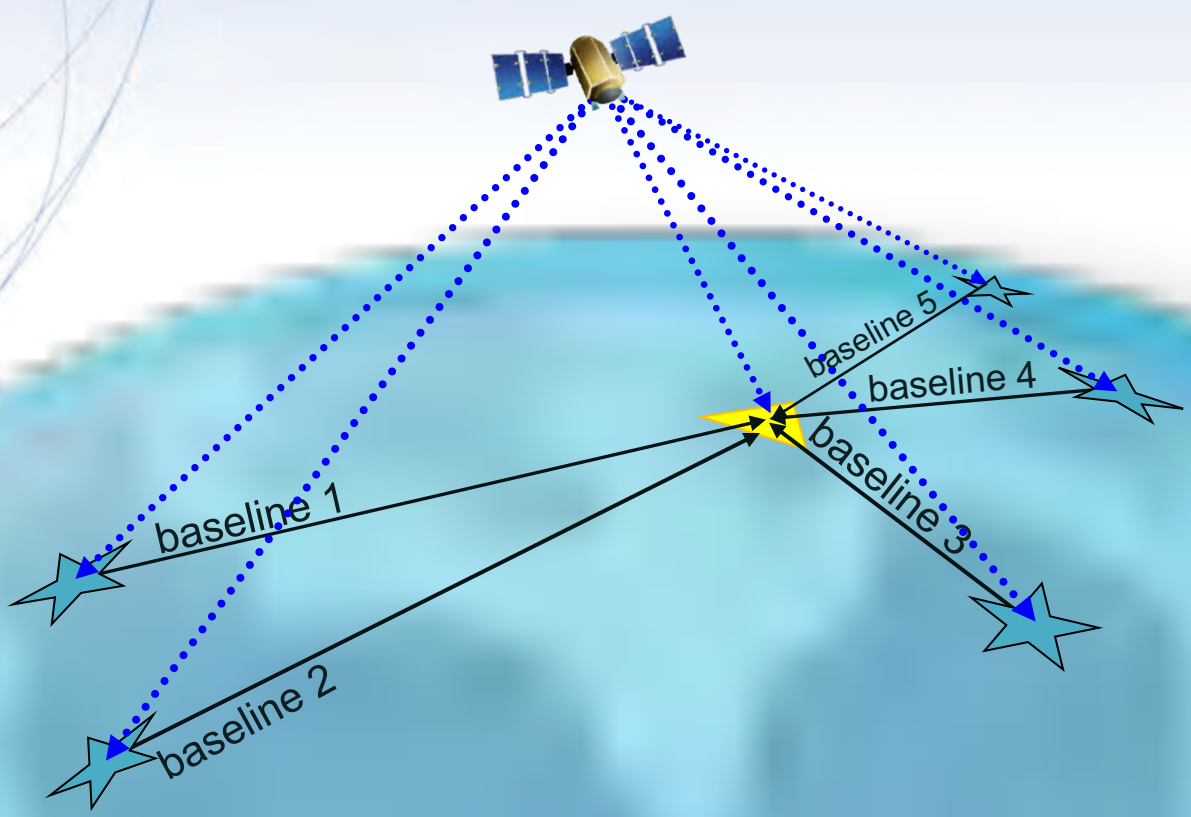
- Their email address.
- The antenna type.
- The offset to the **antenna reference point** (ARP).
- 2- to 48-hours of GPS L1 + L2 data.

In turn, the user receives:

- Coordinates accurate to a few centimeters.

Static: OPUS determines your position with a differential GPS static solution, using hours of data.

This process is repeated four more times from other CORSs.



How Does OPUS-S Work?

The primary steps of OPUS-S processing are:

1. Prepare and quality control the submitted data.
2. Estimate a crude point-position.
3. Compute distances to every available CORS.
4. Select the five "best" CORSs based upon:
   - Being closest to the user's site.
   - Having common satellite visibility with the user data.
   - Having more than 80% of the possible data available.
   - Having low multipath measures.
5. Complete the single-baseline processing using PAGES.
6. Check the solution quality and select the best three.
7. Generate and email the report to the user.

How Does OPUS-S Work?

OPUS-S uses PAGES (Program for Adjustment of GPS Ephemerides) for data processing.

PAGES is a state-of-the-art processing engine developed by the NGS.

Besides OPUS-S, PAGES is used for OPU-Projects session processing, orbit production, reference frame definition, network monitoring and many other GPS data processing tasks.

http://geodesy.noaa.gov/GRD/GPS/DOC/toc.html
http://igscb.jpl.nasa.gov/igscb/center/analysis/noaa.acn

How Does OPUS-S Work?

OPUS-S modeling highlights:

- Satellite coordinates from the **International GNSS Service** (IGS) precise ephemerides.
  http://igscb.jpl.nasa.gov/components/usage.html.
- CORS coordinates and hardware histories from the NGS site information data base.
- Receiver antenna phase center offsets and variations from the NGS absolute antenna model data base.
  http://geodesy.noaa.gov/ANTCAL/.
- **International Earth Rotation Service** (IERS) 2003 solid Earth tide model.
  http://www.iers.org/nn_11216/IERS/EN/Publications/TechnicalNotes/tn32.html.
- Surface met from a climatological model.
  Boehm et al., "Short Note: A global model of pressure and temperature for geodetic applications", J. Geod., 2007.

How Does OPUS-S Work?

OPUS-S processing highlights:

- Everything is "done" in the **IGS14 Reference Frame**.
- SV coordinates are held rigidly fixed.
- CORS coordinates are heavily constrained.
- Neutral atmosphere (tropo) dry component modeled.
- Neutral atmosphere (tropo) wet component estimated.
- Double-differenced, ion-free carrier phase observable.
- Carrier phase ambiguities are fixed to their integer values where possible; float ambiguities are estimated otherwise.
- Individual baselines are processed and the results combined generating mean coordinates and peak-to-peak uncertainties.

How Does OPUS-S Work?

Some thoughts on phase ambiguity integer fixing.

The ambiguities, (charged and neutral) atmosphere delays and station heights strongly alias into each other.

There are really only two ways to "break" this aliasing:

1. Introduce more data.
2. Introduce additional information.

How Does OPUS-S Work?

OPUS-S uses the former strategy.

Depending upon the circumstances, 1- to 2-hours of observations are sufficient to decorrelate the ambiguities, atmosphere and heights allowing reliable estimation of all. Thus the requirement for a minimum of 2-hours in OPUS-S.

As an aside, be aware that while simply having more data helps, it is actually the change in orientation of the satellites over the data span that forces the decorrelation.

NOAA's National Geodetic Survey Positioning America for the Future geodesy.noaa.gov

OPUS: Online Positioning User Service

National Geodetic Survey

NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education

Upload your data file.

Solve your GPS position & tie it to the National Spatial Reference System. What is OPUS? FAQs

Options to customize your solution.

extended solution

formats	standard		format details
base stations	Use: / Exclude:	Look up site IDs	type in 4-char site IDs, or select from map, any CORS you wish to explicitly include or exclude from your solution sample
			NOTE: the automated selection of base stations has recently improved; this option should now be used only sparingly
			in/exclude CORS
state plane	let OPUS choose		overrule your native SPCS zone **SPC zone**
project identifier			**project** enter the id provided by your project manager
my profile			**profile** customize OPUS defaults for future solutions
share my solution	No, don't share		**share** why share?

Upload to Rapid-Static for data 15 min. - 2 hrs.

Upload to Static for data 2 hrs. - 48 hrs.

OPUS-RS or OPUS-Static
(15 min-2 hr) (2-48 hr)

* required fields

We may use your data for internal evaluations of OPUS use, accuracy, or related research.

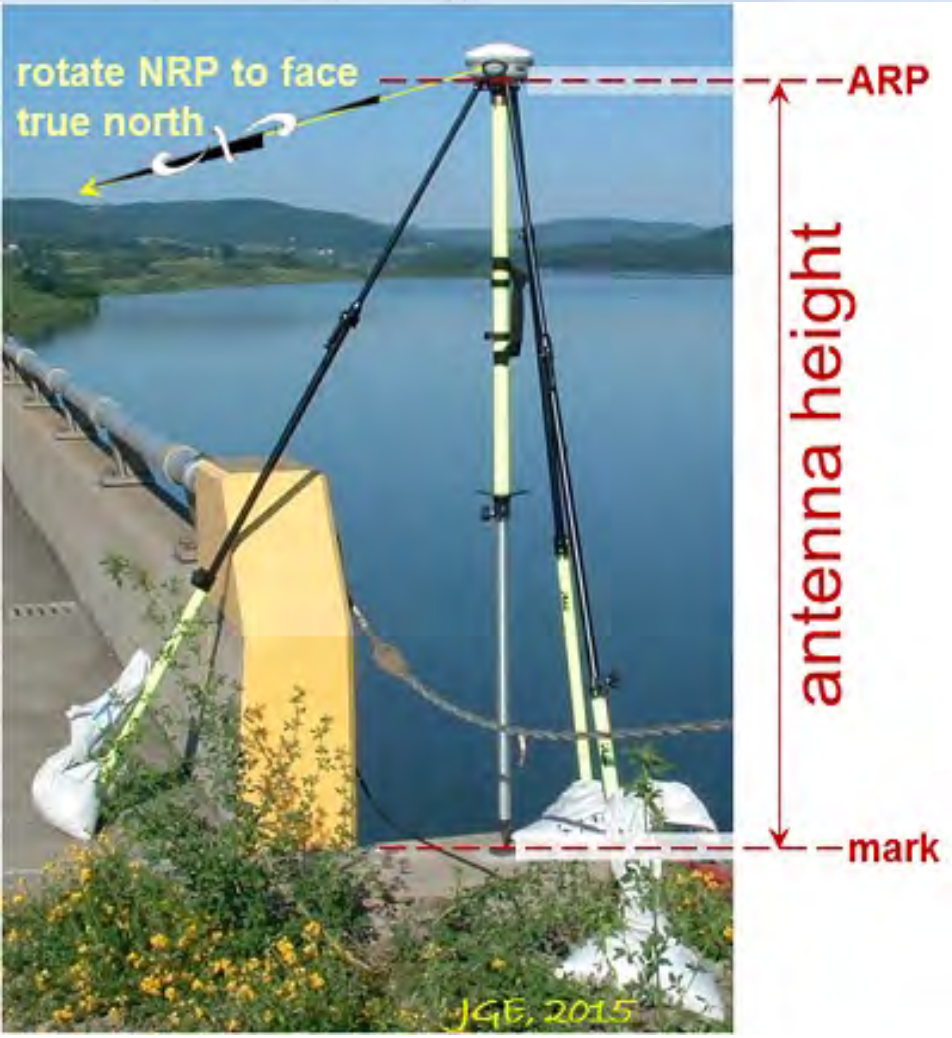
Website Owner: National Geodetic Survey / Last modified by NGS.OPUS V 2.3 Dec 11 2014

Antenna Type, height – easy, right?

- Type?
  - Verify by looking up in ANTCAL
  - Orient the North Reference Point to true north
  - Centered over the mark? (check plummet or bubble)

- Height?
  - Height to what? (antenna ARP, not L1-phase center)
  - Fixed-height tripods are easier than slip-legs.
  - Vertical, NOT slant-height.
  - Is your fixed-height tripod really fixed? (measure!)

HOW IS THE ANTENNA HEIGHT MEASURED?



The height is measured vertically (NOT the slant height) from the mark to the ARP of the antenna.
The height is measured in meters.

The ARP is almost always the center of the bottom-most, permanently attached, surface of the antenna.

See GPS Antenna Calibration for photo's and diagrams that show where the ARP is on most antennas:

http://geodesy.noaa.gov/ANTCAL/

If the default height of 0.0000 is entered, OPUS will return the position of the ARP.

GSVS Equipment Calibration

- Calibrated, fixed-height antennas, all identical models
- In Texas 2011:
  - 20 complete sets of equipment (2 parties, 10 sets each)
  - Each party observed 10 new stations each day
  - 20 hours of observation each day
  - Project processed with OPUS Projects

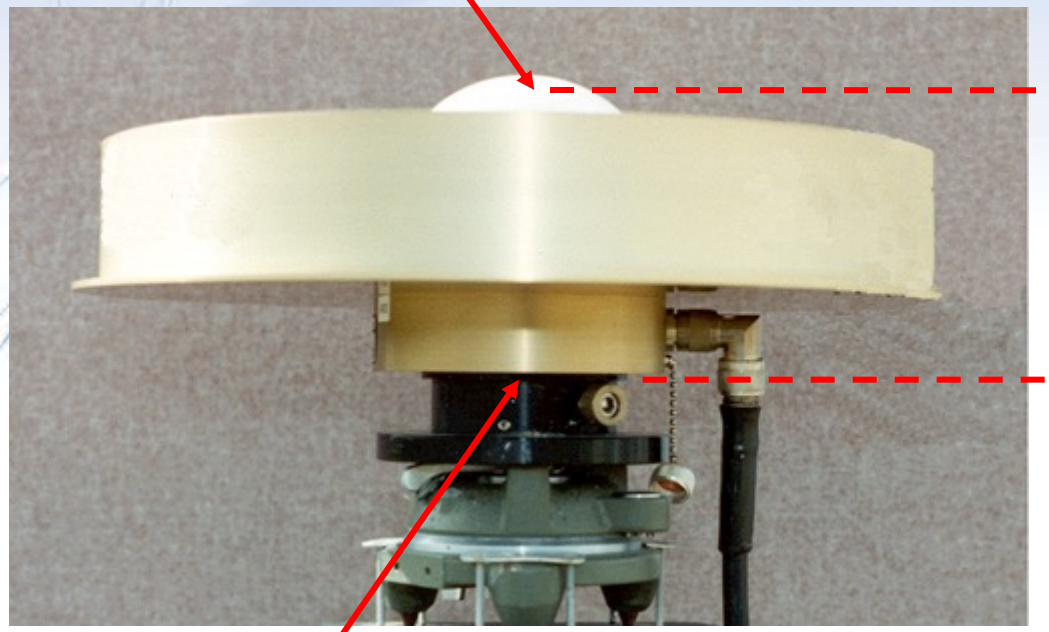
Two-meter fixed height pole???

- Full antenna recalibration check before survey
- Each fixed height tripod height measured before and after
- 20 complete sets of equipment - 2 parties (10 sets each)
- Each party observe 5 new and 5 repeat stations each day
- 30 observation days
- Project processed with OP

ID	before	after	a - b	avg.
A	2.0028	2.0029	0.0001	2.0029
B	2.0019	2.0018	-0.0001	2.0018
C	2.0005	2.0002	-0.0003	2.0004
D	2.0079	2.0079	0.0000	2.0079
E	2.0011	2.0010	-0.0001	2.0010
F	1.9999	1.9998	-0.0001	1.9998
G	2.0006	2.0009	0.0003	2.0008
H	2.0016	2.0017	0.0001	2.0017
I	2.0020	2.0020	0.0000	2.0020
J	2.0041	2.0041	0.0000	2.0041
K	2.0003	2.0004	0.0001	2.0003
L	2.0010	2.0007	-0.0003	2.0008
M	2.0000	2.0002	0.0002	2.0001
N	1.9964	1.9963	-0.0001	1.9963
O	2.0005	2.0005	0.0000	2.0005
P	2.0003	2.0002	-0.0001	2.0002
Q	2.0024	2.0029	0.0005	2.0027
R	1.9999	1.9999	0.0000	1.9999
S	2.0052	2.0052	0.0000	2.0052
T	2.0026	2.0023	-0.0003	2.0024
U	2.0031	2.0031	0.0000	2.0031
V	1.9995	1.9995	0.0000	1.9995
W	2.0002	2.0003	0.0001	2.0003
X	2.0020	2.0022	0.0002	2.0021
Y	2.0053	2.0053	0.0000	2.0053
Z	2.0016	2.0014	-0.0002	2.0015

WHY DO I NEED THE ANTENNA TYPE?

The antenna phase centers are located somewhere around here.



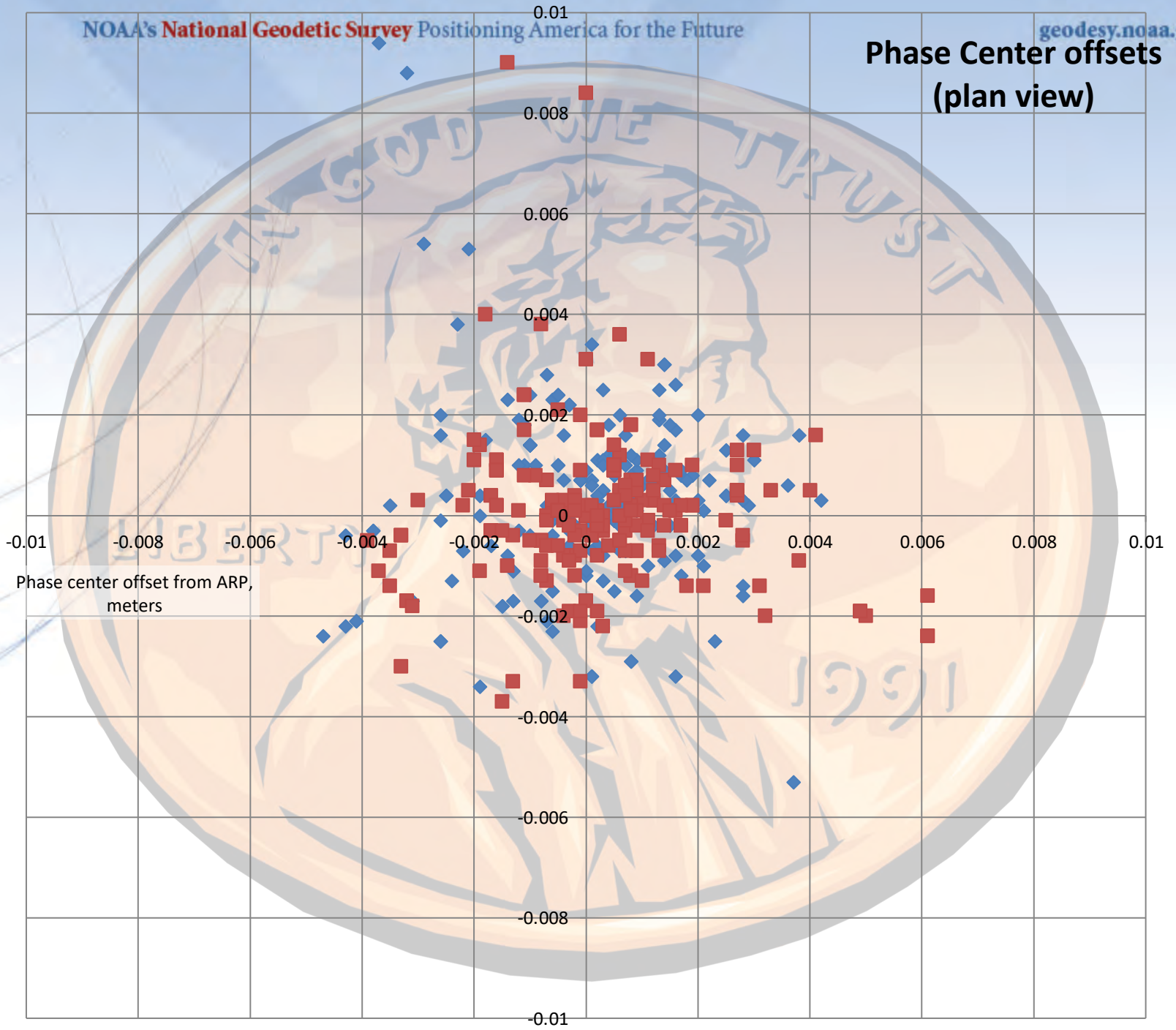
The antenna offsets are the distance between the phase centers and the ARP

You do not need to know these offsets. They are passed to the processing software through the antenna type

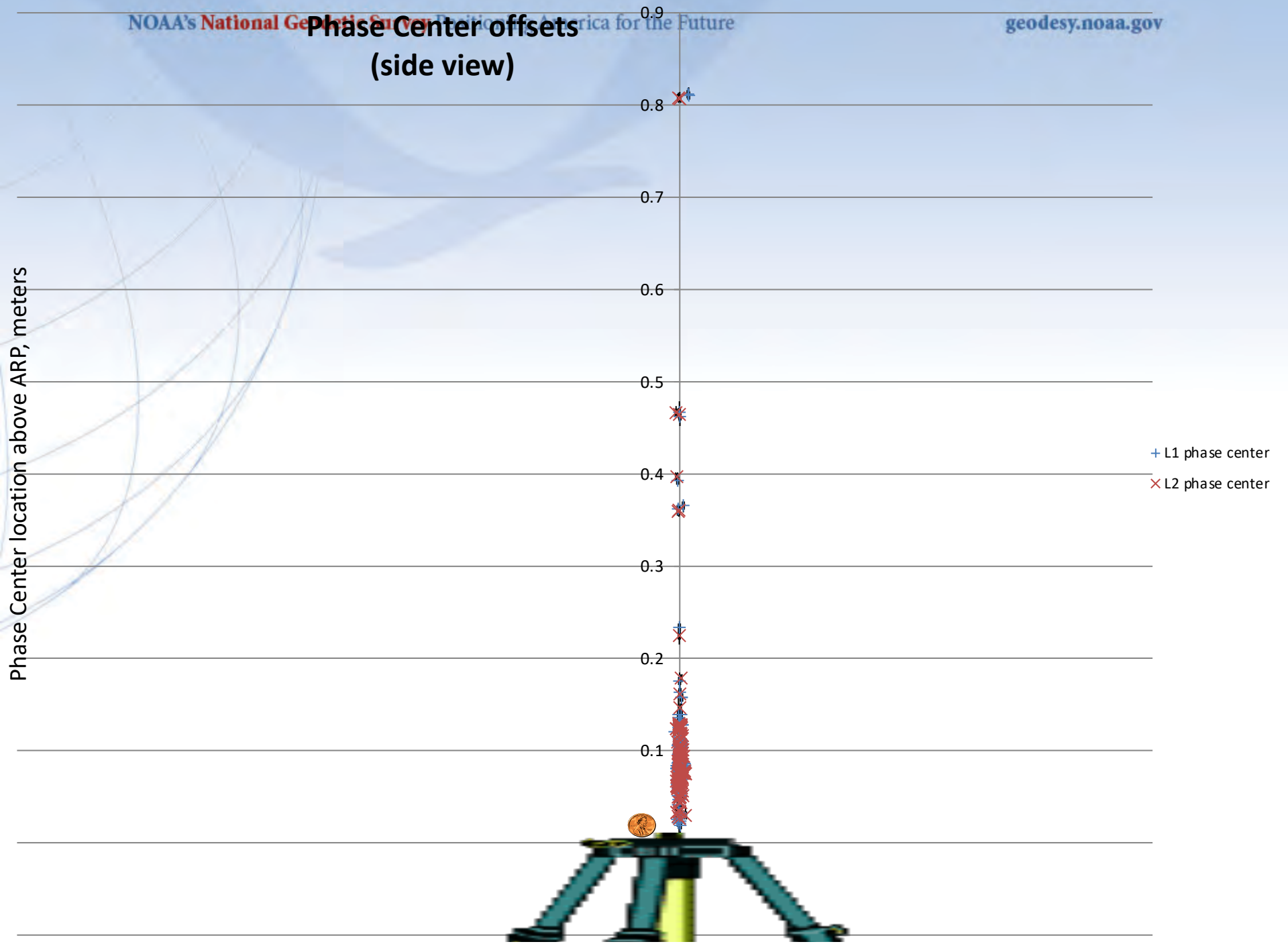
The Antenna Reference Point (ARP) is almost always located in the center of the bottom surface of the antenna.

Incorrect or missing antenna type → big vertical errors

Phase Center offsets (plan view)



Phase Center offsets (side view)



L2 Phase Center Variation

as satellite passes overhead

NOAA's National Geodetic Survey

geodesy.noaa.gov

Variation from L2 Phase center offset, meters

0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0

satellite elevation above horizon, degrees

What else can go wrong?

- Site
  - instability, multi-path
  - mark ID (search database, check stamping)
- Weather
  - wild, local troposphere issues?
  - space weather: ionospheric issues?
- "Truth" (orbits, CORS, etc.)
  - Rapid (next-day) orbits required for publishing, Final Precise (≈ 14 days) recommended.

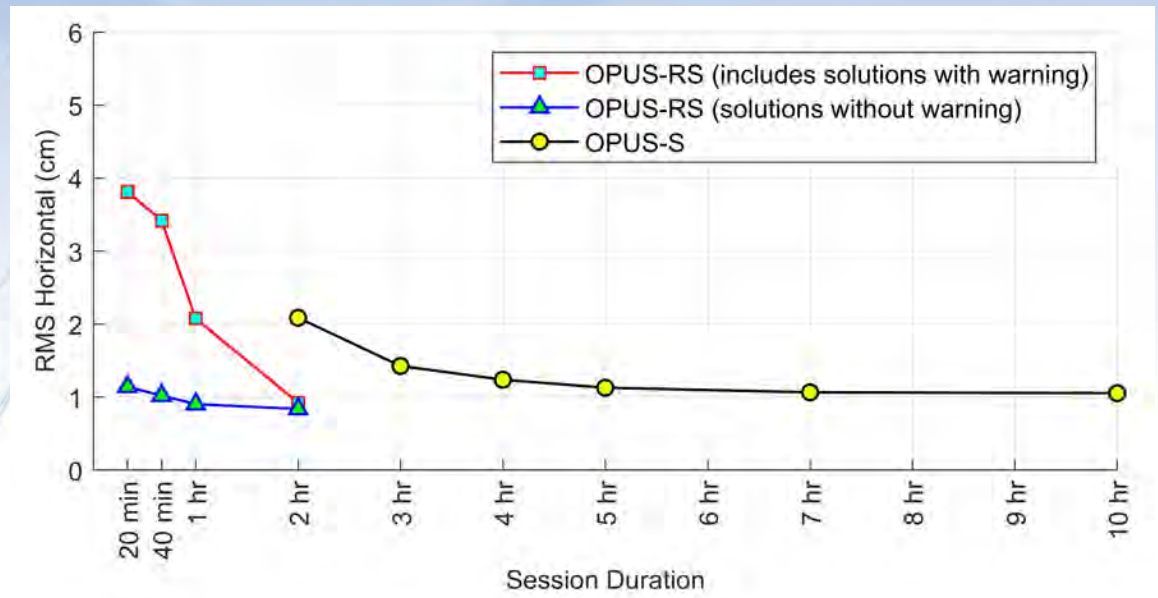
How Good Can I Do With OPUS-S?

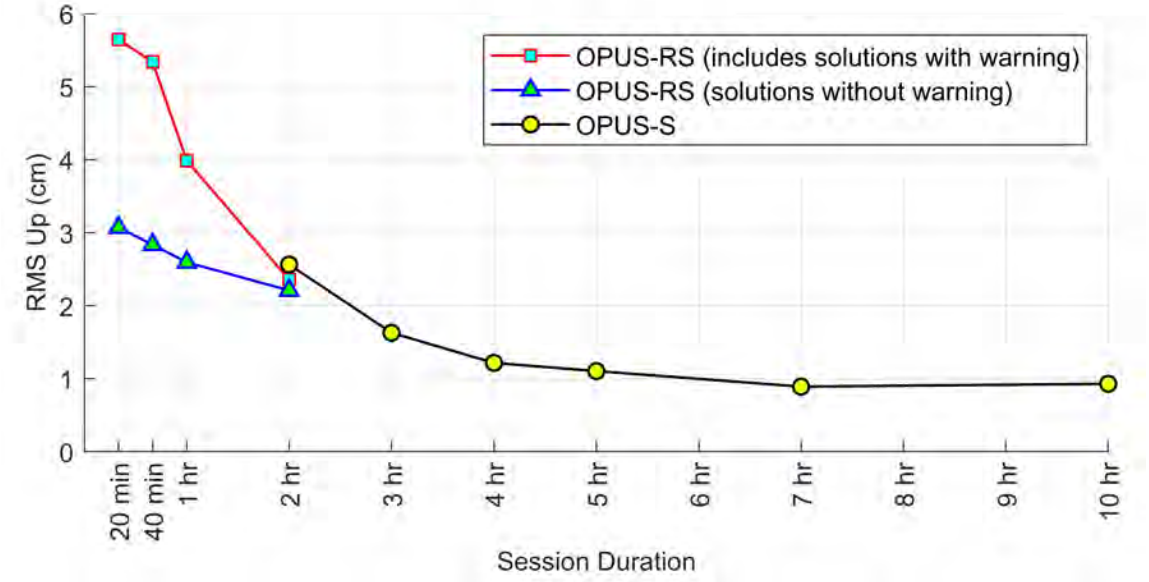
OPUS-S reliably addresses the more historically conventional requirements for GPS data processing. It typically yields accuracies of:

1 – 2 cm horizontally
2 – 4 cm vertically

However, there is no guarantee that this stated accuracy will result from any given data set. Confirming the quality of the OPUS solution remains the user's responsibility. That's the "price" for automated processing.

How Good Can I Do With OPUS-S?





A Quick Example

```
 USER: dan.martin@noaa.gov                    DATE: December 17, 2020
RINEX FILE: llcz124m.18o                          TIME: 15:14:13 UTC


  SOFTWARE: page5  2008.25 master70.pl 160321      START: 2018/05/04  12:21:00
 EPHEMERIS: igs19995.eph [precise]                 STOP: 2018/05/04  17:12:00
  NAV FILE: brdc1240.18n                       OBS USED: 10773 / 11522   :  93%
  ANT NAME: TRM41249.00     NONE             # FIXED AMB:    72 /    72   : 100%
ARP HEIGHT: 1.9991                          OVERALL RMS: 0.014(m)


 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)              ITRF2014 (EPOCH:2018.3387)

         X:      1375953.713(m)   0.004(m)            1375952.797(m)   0.004(m)
         Y:     -4377647.163(m)   0.007(m)           -4377645.766(m)   0.007(m)
         Z:      4415360.116(m)   0.006(m)            4415360.117(m)   0.006(m)

       LAT:   44  5 19.75355      0.003(m)         44  5 19.78984      0.003(m)
     E LON:  287 26 55.09907      0.002(m)        287 26 55.07862      0.002(m)
     W LON:   72 33  4.90093      0.002(m)         72 33  4.92138      0.002(m)
    EL HGT:          250.906(m)   0.010(m)                249.752(m)   0.010(m)
 ORTHO HGT:          278.358(m)   0.049(m) [NAVD88 (Computed using GEOID18)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 18)         SPC (4400   VT)
Northing (Y) [meters]     4884653.345           176510.512
Easting (X)  [meters]      696026.306           495886.797
Convergence  [degrees]     1.70423611          -0.03573611
Point Scale                1.00007262           0.99996449
Combined Factor            1.00003328           0.99992515

US NATIONAL GRID DESIGNATOR: 18TXP9602684653(NAD 83)


                              BASE STATIONS USED
PID       DESIGNATION                          LATITUDE    LONGITUDE DISTANCE(m)
AF9563 VCAP VERMONT CAPITAL CORS ARP       N441543.106 W0723456.554   19400.1
DN8745 VTRI RICHMOND CORS ARP              N442447.726 W0725941.373   50539.4
DL2744 VTMI MIDDLEBURY CORS ARP            N435955.025 W0730909.380   49220.7
```

Here is part of the report for this submission.

FYI, these results differ by 8 mm N, 3 mm E, & 8 mm Up from the accepted position.

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Again, I'm assuming familiarity with the report, but …

… at the risk of stating the obvious, there are a few items I want to draw attention to.

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I apologize for stating the obvious, but …

When reviewing your OPUS solution, double check that the information you provided is correct.

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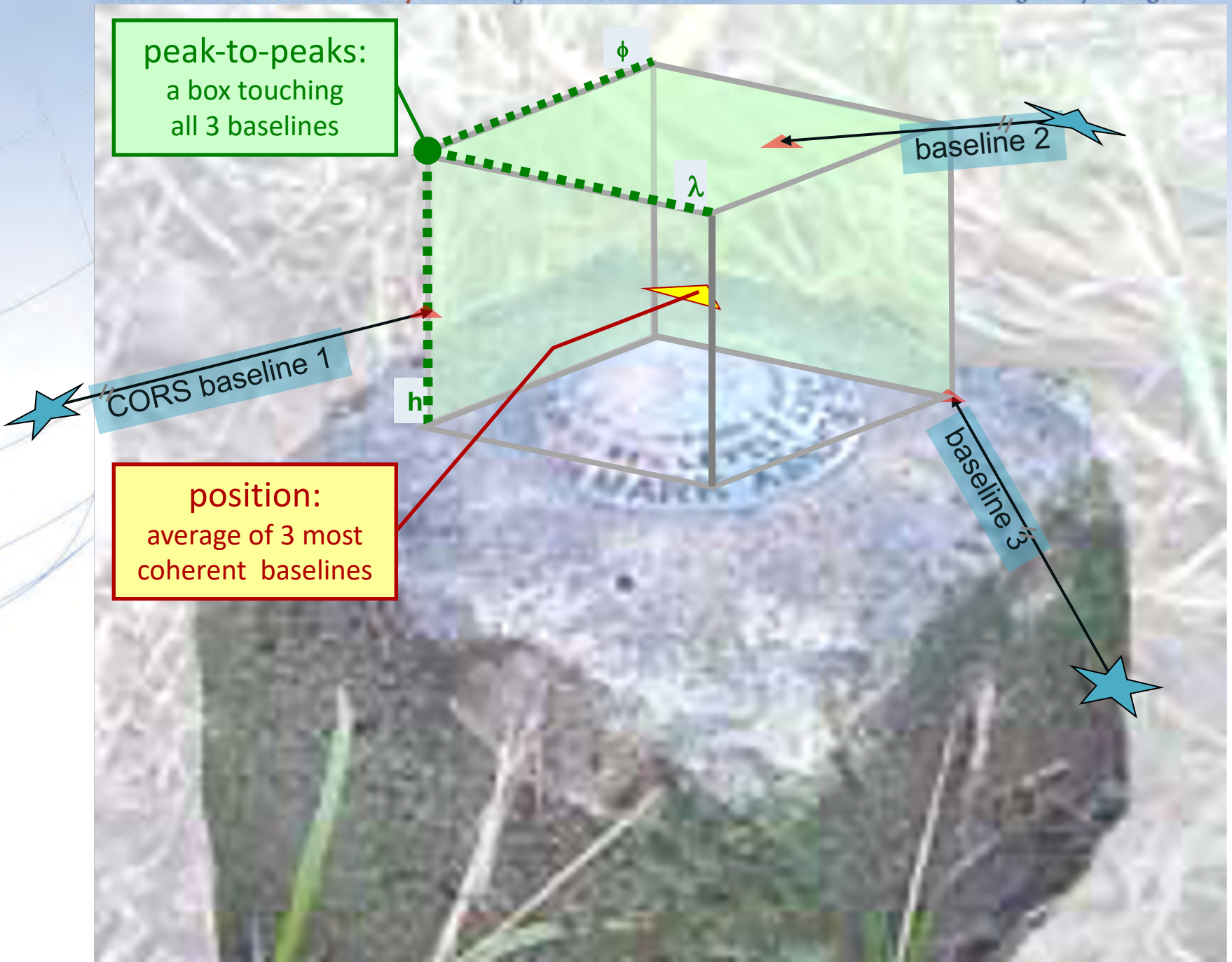
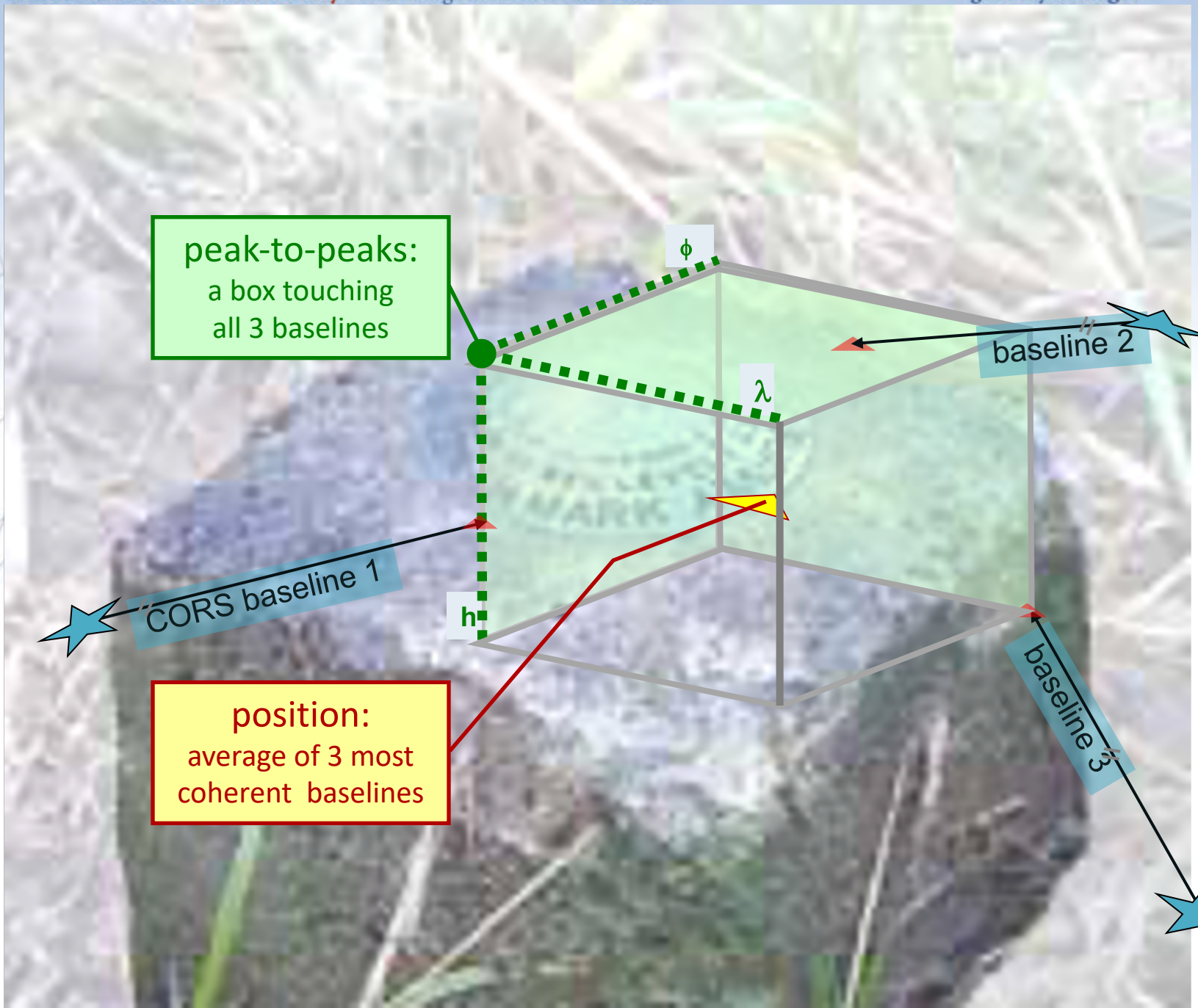
```

I apologize for stating the obvious, but …

Check the quality control measures provided:

OBS USED > 90%
 # FIXED AMB > 50%
OVERALL RMS < 3 cm
peak-to-peak < 5 cm


peak-to-peaks:
a box touching
all 3 baselines
ϕ
λ
h
baseline 2
CORS baseline 1
baseline 3
position:
average of 3 most
coherent baselines


peak-to-peaks:
a box touching
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ϕ
λ
h
baseline 2
CORS baseline 1
baseline 3
position:
average of 3 most
coherent baselines

The Extended Report

```
                        BASE STATION INFORMATION

STATION NAME: p376  a    2 (EOLARESVR_OR2004; Salem, OR  United States)
 MONUMENT: NO DOMES NUMBER
XYZ  -2469806.7634  -3788348.6049   4482853.4377  MON @ 1997.0000 (M)
XYZ        -0.0141         0.0030        -0.0043  VEL (M/YR)
NEU        -0.0000         0.0000         0.0083  MON TO ARP (M)
NEU         0.0009         0.0009         0.1068  ARP TO L1 PHASE CENTER (M)
NEU         0.0002         0.0017         0.1251  ARP TO L2 PHASE CENTER (M)
XYZ        -0.1715         0.0365        -0.0523  VEL TIMES 12.1597 YRS
XYZ        -0.0032        -0.0049         0.0059  MON TO ARP
XYZ        -0.0402        -0.0633         0.0761  ARP TO L1 PHASE CENTER
XYZ  -2469806.9782  -3788348.6366   4482853.4674  L1 PHS CEN @ 2009.1596
XYZ         0.0000         0.0000         0.0000  + XYZ ADJUSTMENTS
XYZ  -2469806.9782  -3788348.6366   4482853.4674  NEW L1 PHS CEN @ 2009.1596
XYZ  -2469806.9381  -3788348.5733   4482853.3913  NEW ARP @ 2009.1596
XYZ  -2469806.9348  -3788348.5684   4482853.3855  NEW MON @ 2009.1596
LLH  44 56 28.32921  236 53 51.83975    180.9607  NEW L1 PHS CEN @ 2009.1596
LLH  44 56 28.32918  236 53 51.83971    180.8539  NEW ARP @ 2009.1596
LLH  44 56 28.32918  236 53 51.83971    180.8456  NEW MON @ 2009.1596

STATION NAME: mcso  a    1 (MARION CNTY COOP; Salem, Oregon, U.S.A.)
 MONUMENT: NO DOMES NUMBER
XYZ  -2458668.9460  -3792427.4770   4485327.2930  MON @ 1997.0000 (M)
XYZ        -0.0131         0.0018        -0.0047  VEL (M/YR)
NEU         0.0000         0.0000         0.0000  MON TO ARP (M)
NEU         0.0025         0.0013         0.1065  ARP TO L1 PHASE CENTER (M)
NEU        -0.0007         0.0013         0.1254  ARP TO L2 PHASE CENTER (M)
XYZ        -0.1593         0.0219        -0.0572  VEL TIMES 12.1597 YRS
XYZ         0.0000         0.0000         0.0000  MON TO ARP
XYZ        -0.0389        -0.0624         0.0770  ARP TO L1 PHASE CENTER
XYZ  -2458669.1442  -3792427.5176   4485327.3129  L1 PHS CEN @ 2009.1596
XYZ        -0.0000        -0.0000        -0.0000  + XYZ ADJUSTMENTS
XYZ  -2458669.1442  -3792427.5176   4485327.3129  NEW L1 PHS CEN @ 2009.1596
XYZ  -2458669.1053  -3792427.4551   4485327.2358  NEW ARP @ 2009.1596
XYZ  -2458669.1053  -3792427.4551   4485327.2358  NEW MON @ 2009.1596
LLH  44 58 25.71729  237  2 39.30118     52.9227  NEW L1 PHS CEN @ 2009.1596
LLH  44 58 25.71721  237  2 39.30112     52.8162  NEW ARP @ 2009.1596
LLH  44 58 25.71721  237  2 39.30112     52.8162  NEW MON @ 2009.1596
```

If the extended report option was selected, next you'll see the BASE STATION section.

Here, the components contributing to the base stations' coordinates are shown in detail. These and the following information are expressed in the ITRF currently in use.

The Extended Report

The state plane coordinates expressed using the international foot or US Survey foot (depending on state legislation) rather than meters …

```
 STATE PLANE COORDINATES - U.S. Survey Foot
         SPC (4400      VT)
Northing (Y) [feet]          579101.571
Easting  (X) [feet]         1626921.933
Convergence  [degrees]      -0.03573611
Point Scale                  0.99996449
Combined Factor              0.99992515
```

The Extended Report

```
********** New Reference Frame Preview **********

We are replacing the nation's NAD 83 and NAVD 88 datums,
to improve access and accuracy of
the National Spatial Reference System. More at
https://geodesy.noaa.gov/datums/newdatums/

Below are approximate coordinates for this solution in the
new frames:

APPROX ORTHO HGT:    277.974 (m) [PROTOTYPE (Computed
using xGeoid19B,GRS80,ITRF2014)]
```

A Little OPUS-RS History

Although successful, OPUS obviously does not satisfy the needs of all users. Discussions with the user community about future development began almost immediately after OPUS was made public.

These early discussions clearly indicated that the most desired enhancement would be a tool capable of producing a similar quality result from a shorter data span.

RSGPS

- Based (conceptually) on OSU MPGPS program
- Similar to Wide Area Rapid Static and Virtual Reference Station (VRS) computations
- 96 subroutines (21 in LAMBDA)
  - Least squares Ambiguity De-correlation Adjustment
- 9739 lines of code (1336 from LAMBDA)

OPUS-RS

- Uses RSGPS program instead of PAGES (based on OSU MPGPS program)
- Uses P1 and P2 as well as L1 and L2 obs
- Resolves all ambiguities with LAMBDA
- Geometry free linear combination used to determine DD ionospheric delays

The OPUS-RS Interface

With OPUS-RS, the beautiful simplicity remained. In fact the entry form is the same as for OPUS-S. The user provides:

- Their email address.
- An antenna type.
- The vertical offset to the ARP.
- 15-minutes to 2-hours of GPS L1 + L2 data.

The user receives:

- Coordinates accurate to a few centimeters.

The OPUS-RS Interface

http://geodesy.noaa.gov/OPUS/

The same interface is used except one clicks the "Upload to RAPID-STATIC" button instead.

How Does OPUS-RS Work?

OPUS-RS uses the RSGPS program which was developed specifically for this purpose.

Like OPUS-S, OPUS-RS uses state-of-the-art models, but the strategy to fix phase ambiguities to their integer values differs.

To fix integers, OPUS-RS introduces more information:

- Pseudorange and carrier phase.
- More reference stations if possible.

How Does OPUS-RS Work?

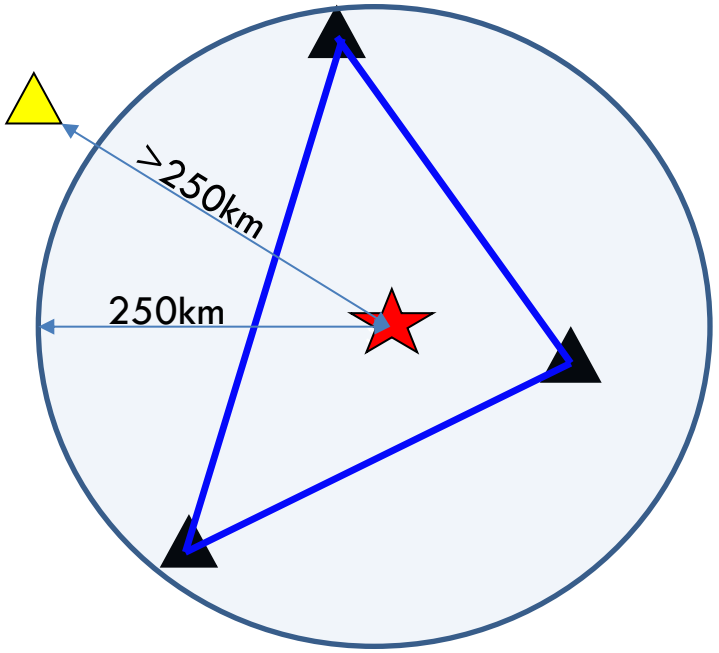
OPUS-RS selects three to nine "best" CORS based upon:

- Having common satellite visibility with the user data.
- Having distances from the user's site <250 km.

This is shown here graphically. The star represents the user's site. The triangles are CORS.

No CORS farther than 250 km from the user's site will be included.

The three CORS minimum is shown. No more than nine are used.



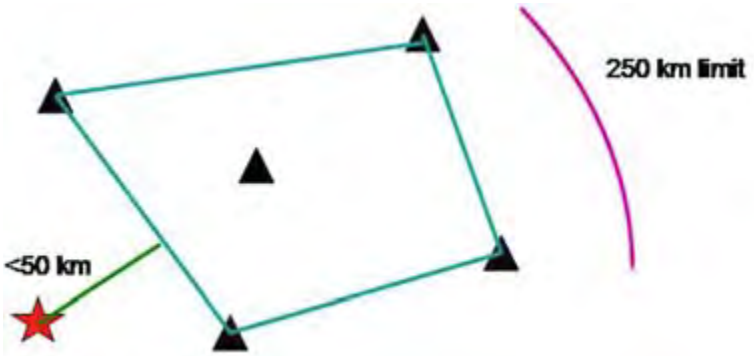
Choi, 2010, personal communication.

How Does OPUS-RS Work?

In addition, user's site must be no more than 50 km from the (convex) polygon created by the selected CORS.

Again in this figure, the star represents the user's site; the triangles are CORS. Five CORS and their resulting polygon are shown in this example.

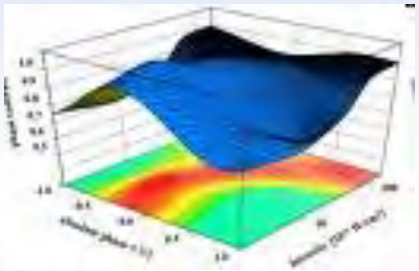
If the user's site, the star, is more than 50 km outside this polygon, alternate CORS will be considered. If none can be found, the processing will abort.



Schwarz et al., "Accuracy assessment of the National Geodetic Survey's OPUS-RS utility", 2009, *GPS Solutions*, 13(2), 119-132.

Rapid-static: OPUS first creates an atmospheric delay model from surrounding CORS data.

Your position is then quickly determined by differential GPS static solution.



How Does OPUS-RS Work?

OPUS-RS uses no less than 1-hour of CORS data and no more than the submitted data's span plus 15-minutes before and after.

The CORS data are used to estimate the atmospheric delays at each CORS and predict them at the user's site.

OPUS-RS then processes each baseline to the user's site individually to produce an improved a priori position.

Switching modes, the previously determined values and all data are used in an "integer-fixed" solution for the user's site.

Schwarz et al., "Accuracy assessment of the National Geodetic Survey's OPUS-RS utility", 2009, *GPS Solutions*, 13(2), 119-132.

A Quick Example

```
      USER: mark.schenewerk@noaa.gov                DATE: April 01, 2010
RINEX FILE: corv059f.09o                            TIME: 16:17:51 UTC


  SOFTWARE: rsgps  1.35 RS11.prl 1.57             START: 2009/02/28 05:00:00
 EPHEMERIS: igs15206.eph [precise]                 STOP: 2009/02/28 06:59:30
  NAV FILE: brdc0590.09n                       OBS USED:  5652 / 11169    :  51%
  ANT NAME: ASH700936C_M                     QUALITY IND.  48.23/108.85
ARP HEIGHT: 1.521                          NORMALIZED RMS:        0.280


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2009.15959)

         X:     -2498422.589(m)   0.015(m)          -2498423.330(m)   0.015(m)
         Y:     -3802821.147(m)   0.012(m)          -3802819.929(m)   0.012(m)
         Z:      4454736.644(m)   0.021(m)           4454736.717(m)   0.021(m)

       LAT:   44 35  7.91061      0.004(m)        44 35  7.92619      0.004(m)
    E LON:  236 41 43.48069      0.011(m)       236 41 43.42230      0.011(m)
    W LON:  123 18 16.51931      0.011(m)       123 18 16.57770      0.011(m)
    EL HGT:          105.986(m)   0.026(m)               105.602(m)   0.026(m)
 ORTHO HGT:          128.517(m)   0.030(m) [NAVD88 (Computed using GEOID09)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (3601 OR N)
Northing (Y) [meters]     4936954.909           105971.559
Easting (X)  [meters]      475821.309          2277335.372
Convergence  [degrees]    -0.21381414          -1.98897509
Point Scale                0.99960719           0.99994603
Combined Factor            0.99959058           0.99992942

US NATIONAL GRID DESIGNATOR: 10TDQ7582136954(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DH4503 P376 EOLARESVR_OR2004 CORS ARP      N445628.313 W1230608.100   42648.2
DG5352 STAY STAYTON COOP CORS ARP          N444950.530 W1224915.036   47030.9
DE6258 MCSO MARION CNTY COOP CORS ARP      N445825.701 W1225720.639   51226.8
DI7529 P367 NEWPRTAIR_OR2007 CORS ARP      N443506.870 W1240341.598   60113.5
                                    ⋮
```

Shown here is part of the OPUS-RS report for the same CORV data discussed earlier.

The results differ by 2.4 cm horizontally and 0.2 cm vertically from the accepted position projected to the epoch of the data.

A Quick Example

```
      USER: mark.schenewerk@noaa.gov                DATE: April 01, 2010
RINEX FILE: corv059f.09o                            TIME: 16:17:51 UTC


  SOFTWARE: rsgps  1.35 RS11.prl 1.57           START: 2009/02/28 05:00:00
 EPHEMERIS: igs15206.eph [precise]              STOP: 2009/02/28 06:59:30
  NAV FILE: brdc0590.09n                    OBS USED:  5652 / 11169   :  51%
  ANT NAME: ASH700936C_M                  QUALITY IND.  48.23/108.85
ARP HEIGHT: 1.521                       NORMALIZED RMS:       0.280


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2009.15959)

         X:     -2498422.589(m)    0.015(m)          -2498423.330(m)    0.015(m)
         Y:     -3802821.147(m)    0.012(m)          -3802819.929(m)    0.012(m)
         Z:      4454736.644(m)    0.021(m)           4454736.717(m)    0.021(m)

       LAT:   44 35  7.91061      0.004(m)        44 35  7.92619      0.004(m)
     E LON:  236 41 43.48069      0.011(m)       236 41 43.42230      0.011(m)
     W LON:  123 18 16.51931      0.011(m)       123 18 16.57770      0.011(m)
    EL HGT:          105.986(m)    0.026(m)               105.602(m)    0.026(m)
 ORTHO HGT:          128.517(m)    0.030(m) [NAVD88 (Computed using GEOID09)]

                      UTM COORDINATES    STATE PLANE COORDINATES
                       UTM (Zone 10)         SPC (3601 OR N)
Northing (Y) [meters]     4936954.909          105971.559
Easting (X)  [meters]      475821.309         2277335.372
Convergence  [degrees]    -0.21381414         -1.98897509
Point Scale                0.99960719          0.99994603
Combined Factor            0.99959058          0.99992942

US NATIONAL GRID DESIGNATOR: 10TDQ7582136954(NAD 83)



                            BASE STATIONS USED
PID       DESIGNATION                        LATITUDE     LONGITUDE DISTANCE(m)
DH4503 P376 EOLARESVR_OR2004 CORS ARP      N445628.313 W1230608.100   42648.2
DG5352 STAY STAYTON COOP CORS ARP          N444950.530 W1224915.036   47030.9
DE6258 MCSO MARION CNTY COOP CORS ARP      N445825.701 W1225720.639   51226.8
DI7529 P367 NEWPRTAIR_OR2007 CORS ARP      N443506.870 W1240341.598   60113.5
```

Note that the solution quality measures are slightly different.

OBS USED > 50%
QUALITY IND. > 3
NORM. RMS ≈ 1
Uncertainties < 5 cm

The uncertainties are standard deviations from the solution, not the peak-to-peak values reported by OPUS-S.

A Quick Example

```
      USER: mark.schenewerk@noaa.gov                DATE: April 01, 2010
RINEX FILE: corv059f.09o                            TIME: 16:17:51 UTC


  SOFTWARE: rsgps  1.35 RS11.prl 1.57             START: 2009/02/28 05:00:00
 EPHEMERIS: igs15206.eph [precise]                 STOP: 2009/02/28 06:59:30
  NAV FILE: brdc0590.09n                       OBS USED:  5652 / 11169   :  51%
  ANT NAME: ASH700936C_M                    QUALITY IND.  48.23/108.85
ARP HEIGHT: 1.521                         NORMALIZED RMS:        0.280


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2009.15959)

         X:     -2498422.589(m)    0.015(m)          -2498423.330(m)    0.015(m)
         Y:     -3802821.147(m)    0.012(m)          -3802819.929(m)    0.012(m)
         Z:      4454736.644(m)    0.021(m)           4454736.717(m)    0.021(m)

       LAT:   44 35  7.91061      0.004(m)        44 35  7.92619      0.004(m)
     E LON:  236 41 43.48069      0.011(m)       236 41 43.42230      0.011(m)
     W LON:  123 18 16.51931      0.011(m)       123 18 16.57770      0.011(m)
    EL HGT:          105.986(m)    0.026(m)               105.602(m)    0.026(m)
 ORTHO HGT:          128.517(m)    0.030(m) [NAVD88 (Computed using GEOID09)]

                       UTM COORDINATES    STATE PLANE COORDINATES
                        UTM (Zone 10)         SPC (3601 OR N)
Northing (Y) [meters]     4936954.909          105971.559
Easting (X)  [meters]      475821.309         2277335.372
Convergence  [degrees]    -0.21381414         -1.98897509
Point Scale                0.99960719          0.99994603
Combined Factor            0.99959058          0.99992942

US NATIONAL GRID DESIGNATOR: 10TDQ7582136954(NAD 83)



                            BASE STATIONS USED
PID       DESIGNATION                        LATITUDE     LONGITUDE DISTANCE(m)
DH4503 P376 EOLARESVR_OR2004 CORS ARP      N445628.313 W1230608.100   42648.2
DG5352 STAY STAYTON COOP CORS ARP          N444950.530 W1224915.036   47030.9
DE6258 MCSO MARION CNTY COOP CORS ARP      N445825.701 W1225720.639   51226.8
DI7529 P367 NEWPRTAIR_OR2007 CORS ARP      N443506.870 W1240341.598   60113.5
```

Although the quality indices, normalized RMS and uncertainties are OK, the percentage of observations used gives this solution a 

The Extended Report

Of necessity, the OPUS-RS extended report is larger than the corresponding OPUS-S solution. Too large to be conveniently shown here. But while seemingly intimidating, the OPUS-RS extended report sections are basically the same as those in the OPUS-S extended report.

Some additional sections include:

- A covariance matrix for the reference-station-only solution.
- A correlation as well as a covariance matrix.
- Various Dilutions Of Precision (DOPs).

How Good Can I Do With OPUS-RS?

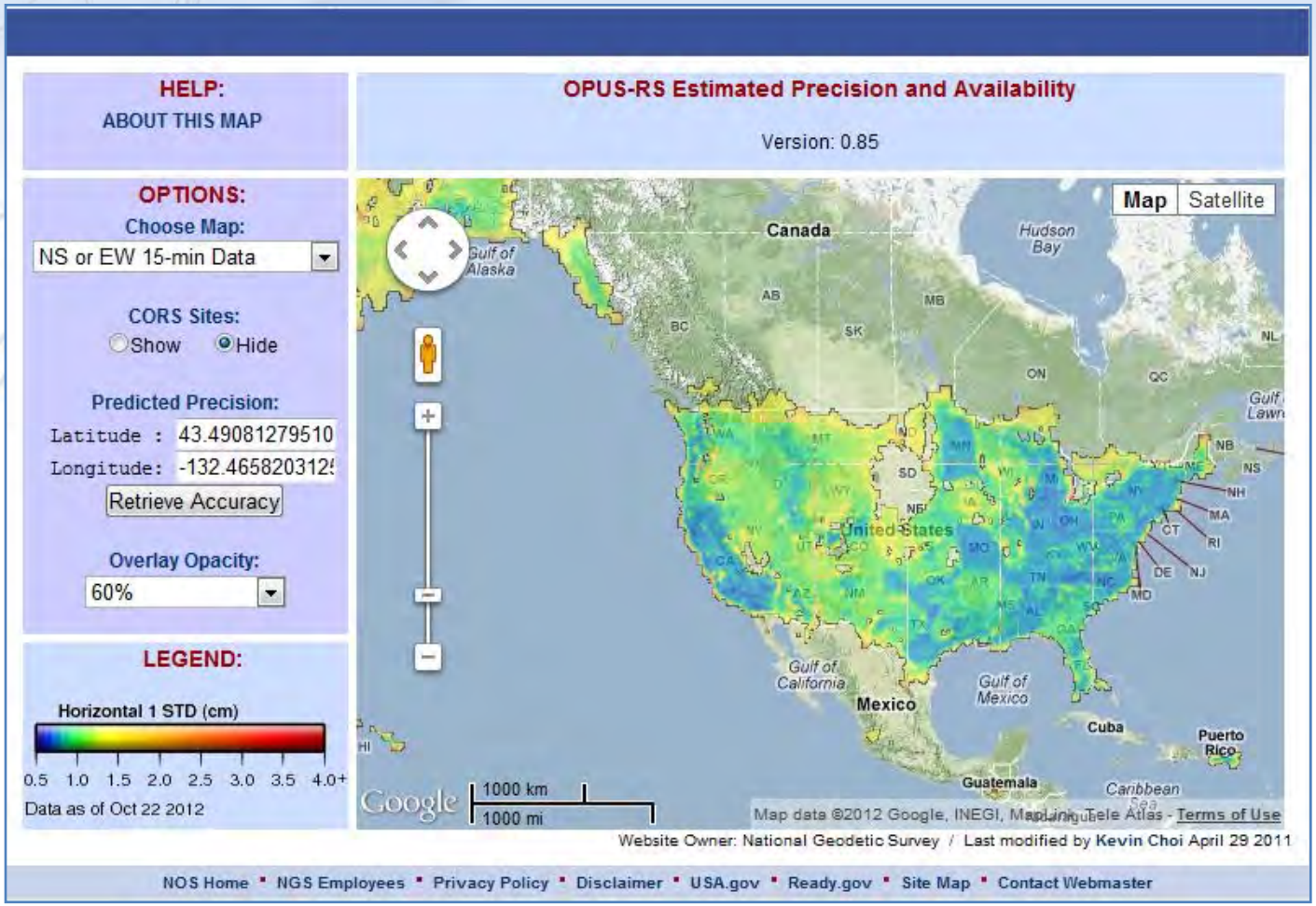
OPUS-RS can produce quality results from more challenging "short" data sets, but it is slightly more restrictive in the data sets allowed. NGS has made available the "OPUS-RS Accuracy and Availability" tool (Choi, NGS).
https://www.ngs.noaa.gov/OPUSI/Plots/Gmap/OPUSRS_sigmap.shtml

Typical estimated and empirical accuracies within the continental U.S. are comparable to OPUS-S.

Remember that the estimated accuracies suggested by this tool are just that - estimates. Confirming the quality of the OPUS solution remains the user's responsibility.

How Good Can I Do With OPUS-RS?

The OPUS-RS Accuracy and Availability Tool.



http://www.ngs.noaa.gov/OPUSI/Plots/Gmap/OPUSRS_sigmap.shtml

OPTIONS:

Choose Map: NS or EW 15-min Data

CORS Sites: Show / Hide

Predicted Precision:

Latitude :

Longitude:

Retrieve Accuracy

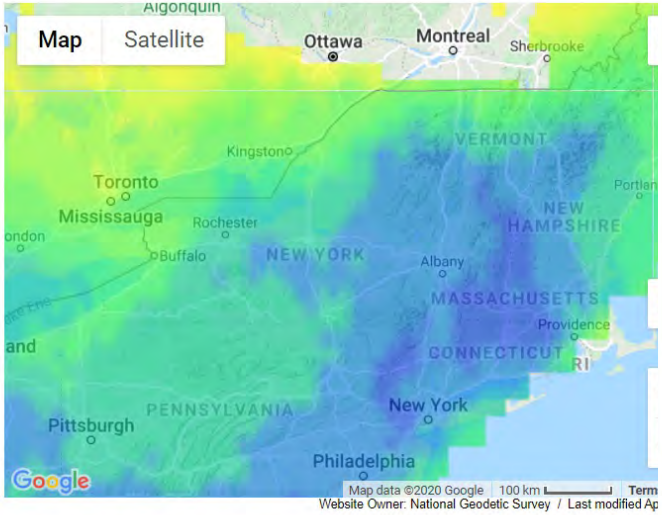
Overlay Opacity: 60%

LEGEND:

Horizontal 1 SD (cm)

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0+

Data as of Jan 16 2020



Website Owner: National Geodetic Survey / Last modified Ap

OPTIONS:

Choose Map: NS or EW 1-hour Data

CORS Sites: Show / Hide

Predicted Precision:

Latitude :

Longitude:

Retrieve Accuracy

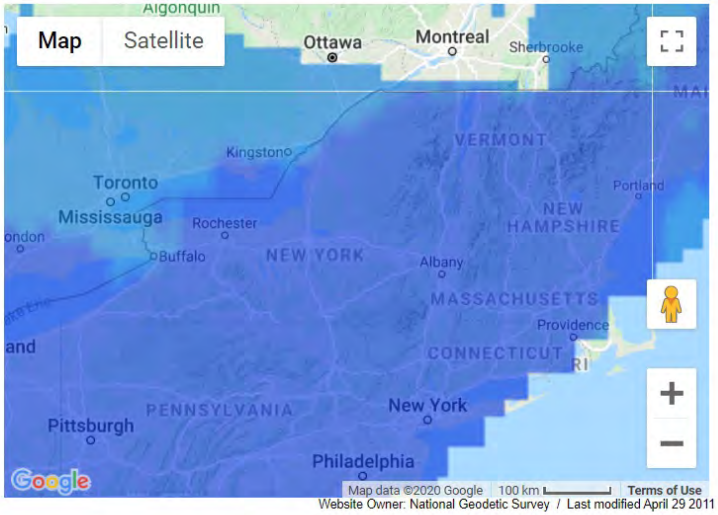
Overlay Opacity: 60%

LEGEND:

Horizontal 1 SD (cm)

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0+

Data as of Jan 16 2020



Website Owner: National Geodetic Survey / Last modified April 29 2011

OPTIONS:

Choose Map: Ellipsoid Height 15-min Data

CORS Sites: Show / Hide

Predicted Precision:

Latitude :

Longitude:

Retrieve Accuracy

Overlay Opacity: 60%

LEGEND:

Ellipsoid Height 1 SD (cm)

1 2 3 4 5 6 7 8+

Data as of Jan 16 2020

Website Owner: National Geodetic Survey / Last modified A

OPTIONS:

Choose Map: Ellipsoid Height 1-hour Data

CORS Sites: Show / Hide

Predicted Precision:

Latitude :

Longitude:

Retrieve Accuracy

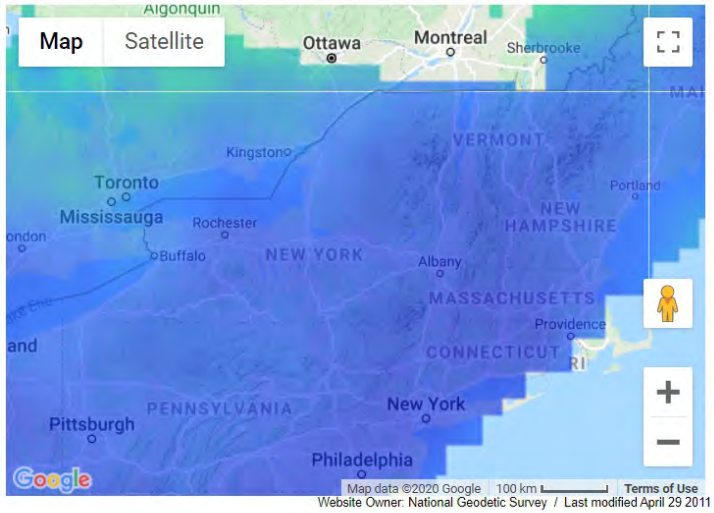
Overlay Opacity: 60%

LEGEND:

Ellipsoid Height 1 SD (cm)

1 2 3 4 5 6 7 8+

Data as of Jan 16 2020



Website Owner: National Geodetic Survey / Last modified April 29 2011

OPUS static vs. rapid static

	static	rapid static
input (dual-frequency GPS)	**2-48 hours**	**15 minutes-2 hours**
output	normal, extended, XML **datasheet, project**	normal, extended, XML
accuracy (95%confidence)	1-2 cm horizontal **2-4 cm** ellipsoidal height	1-2 cm horizontal **4-6 cm** ellipsoidal height
network geometry	3 CORS, preferably within **1000 km** of rover	3-9 CORS, surrounding & within **250 km** of rover
availability	**global**	**> 90% of CONUS** (subject to CORS configuration)

G.I.G.O.

We still need surveyors. We hope OPUS can help, but it can't do your job for you.

- Follow your project's specifications.
- Use best practices and careful field procedures.
- Select permanent marks of public interest.
- Good coordinates come from good data.

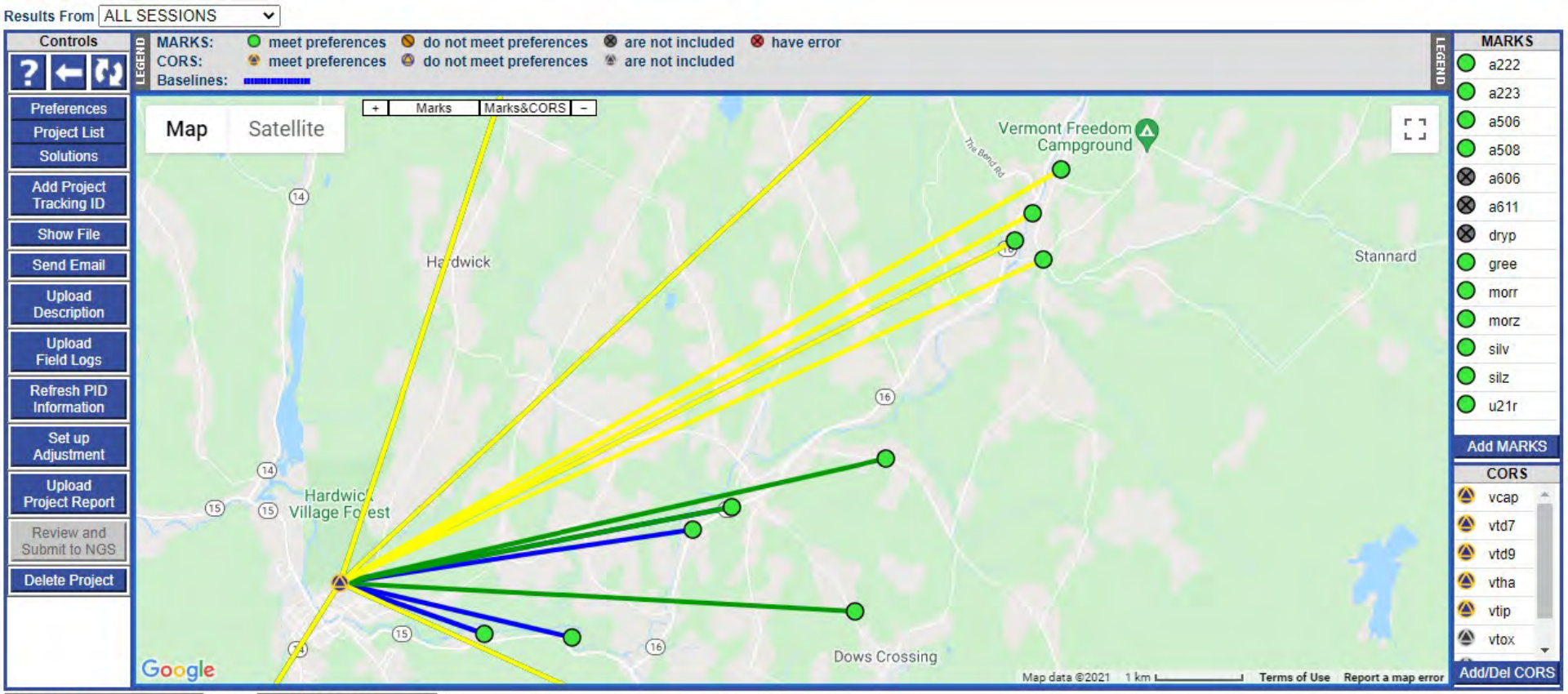
http://gis.larc.nasa.gov/

What's New with OPUS??

- OPUS Projects 4.0 (production)
- OPUS Projects 5.0 (Beta) beta.ngs.noaa.gov
- M-PAGES (Alpha) (internal only)

OP 4.0

- Full Support for Submission to NGS (Bluebook)
- Full manual developed with context sensitive help in app.
- Creating training modules (OP101, OP102)



Occupation From ALL SESSIONS

MARKS	Sessions 2013-273 A	2013-273 B	2013-273 C	2013-274 A	MARKS
a222	●				a222
a223	●				a223
a506		●			a506
a508		●			a508
a606				⊗	a606
a611				⊗	a611
dryp				⊗	dryp
gree			●		gree
morr	●				morr
morz	●	●			morz
silv			●	⊗	silv
silz		●	●		silz
u21r			●		u21r
vcap	▲	▲	▲	▲	vcap
vtd7	▲	▲	▲	▲	vtd7
vtd9	▲	▲	▲	▲	vtd9
vtha	▲	▲	▲	▲	vtha
vtip	▲	▲	▲		vtip
vtox				▲	vtox
vtsa				▲	vtsa

- Visualize processing by session
- Processing statistics available through dropdown
- Access to station information through station hyperlink

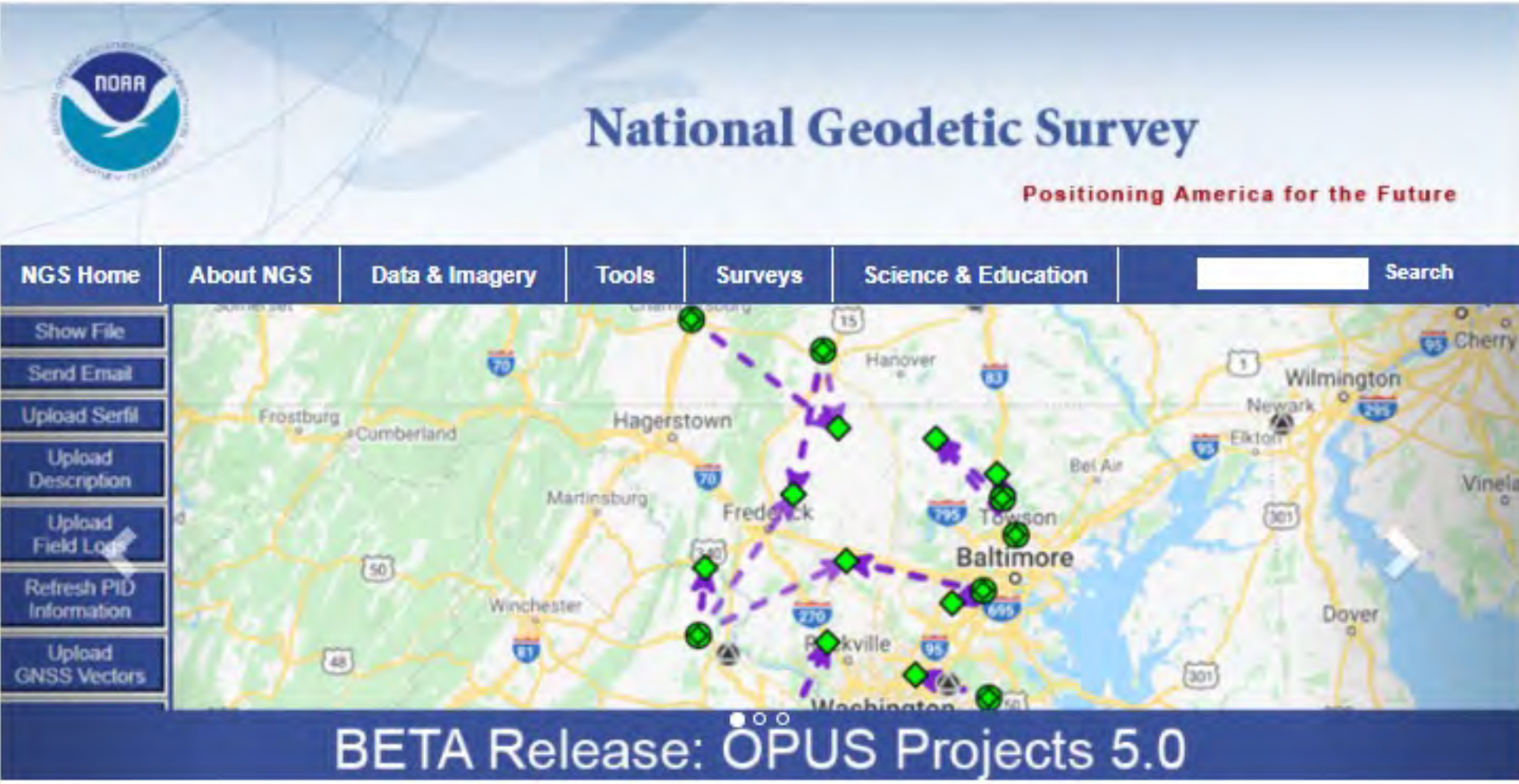
What is OP

OP 5.0

- Went to BETA ***YESTERDAY*** 9/16/21
- Ability to include RTK/RTN vectors (any vector for that matter)
  - Has sample data to try
  - Contact your vendor about converting to gvx format

National Geodetic Survey

Positioning America for the Future



M-PAGES = Multi-GNSS PAGES

- Meets the current IGS (i.e. repro3 = ITRF2020) requirements.
- Capable of ingesting all GNSS observables currently supported by the global infrastructure.
- Capable of using more than two frequencies.
- Capable of ingesting RINEX 2 or 3.
- Capable of using pseudorange and phase.
- Capable of multi-GNSS processing.
- Uses a single-difference processing strategy.

- M-PAGES can support NGS strategic objectives.

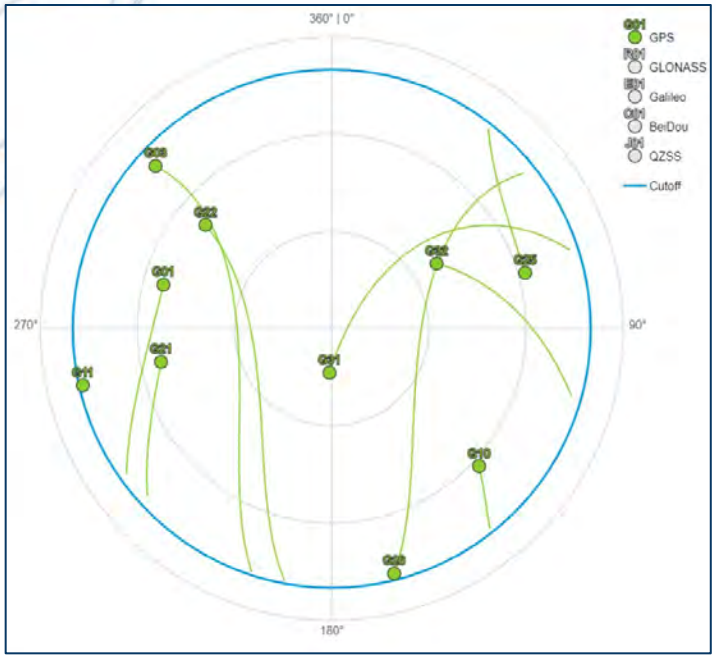
M-PAGES

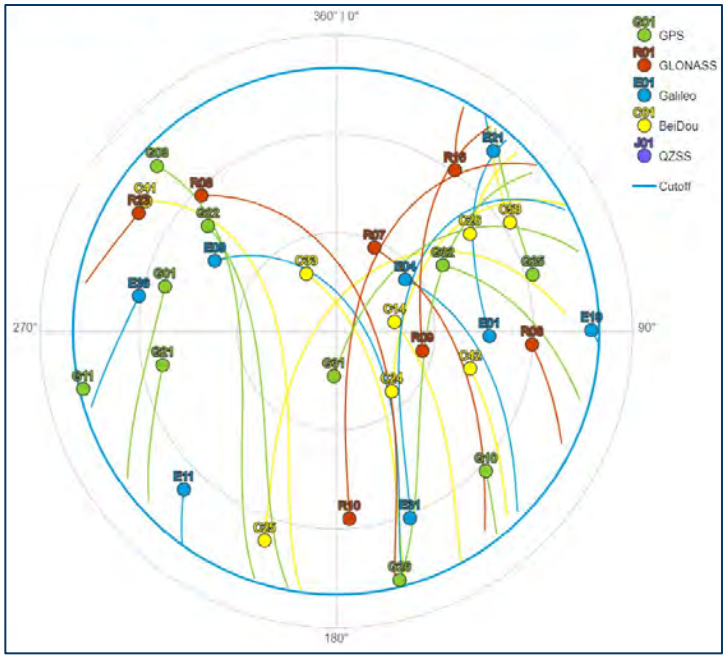
- GPS : Global Positioning System
- GLONASS: Globalnaya Navigatsionnaya Sputnikovaya Sistema
- Galileo :
- BeiDou : BeiDou Navigation Satellite System
  BDS, BeiDou-2, COMPASS
- IRNSS : Indian Regional Navigation Satellite System
  NavIC
- QZSS : Quasi-Zenith Satellite System
  Michibiki
- SBAS : Satellite-based Augmentation Systems

https://en.wikipedia.org/

Why All the Fuss?

- The distribution of and changes in the relative positions of the satellites with respect to the receiving antenna are the most important data characteristics for high accuracy positioning.
- GPS (left) is good. Multi-GNSS (right) is better.

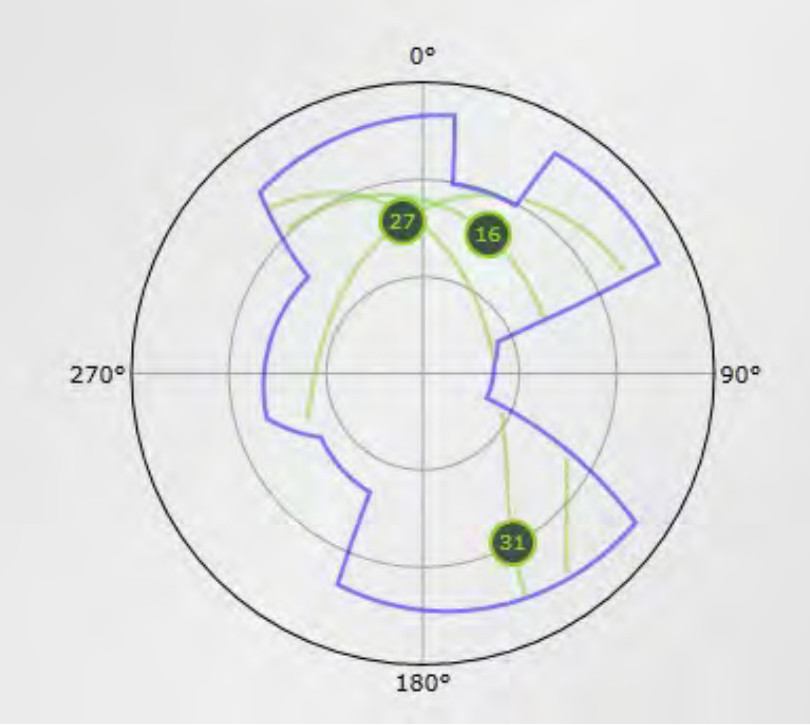


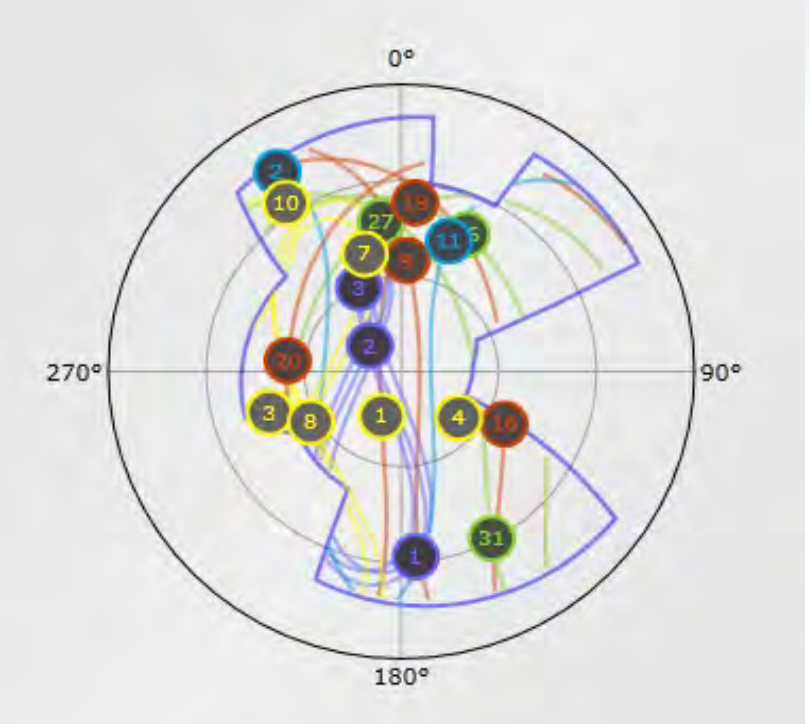


https://www.gnssplanning.com/#/settings

Obstructed View

- Simulated sky coverage in urban or natural canyon.
- GPS-only (left) isn't viable. Multi-GNSS (right) is.





http://www.gnssplanningonline.com