OPUS History and Development

- **9:00am to 10:15am**

- **Joe.Evjen@noaa.gov**

OPUS HomePage - Microsoft Internet Explorer provided by National Geodetic Survey

Address http://www.ngs.noaa.gov/OPUS/ Go File Edit View Favorites

Online Positioning User Service

OPUS Upload | What is OPUS | Using OPUS | Recent Solutions | Faqs | OPUS Policies | Contact OPUS

What is OPUS

Using OPUS

Recent Solutions

FAQs

OPUS Policies

Contact OPUS

Recent Developments

[Nov 10, 2004] Format of the OPUS data sheet is changed to provide space for the

1. Ente

2. Ente

3. NON Sele

4. 0.0 Ente the basic OPUS

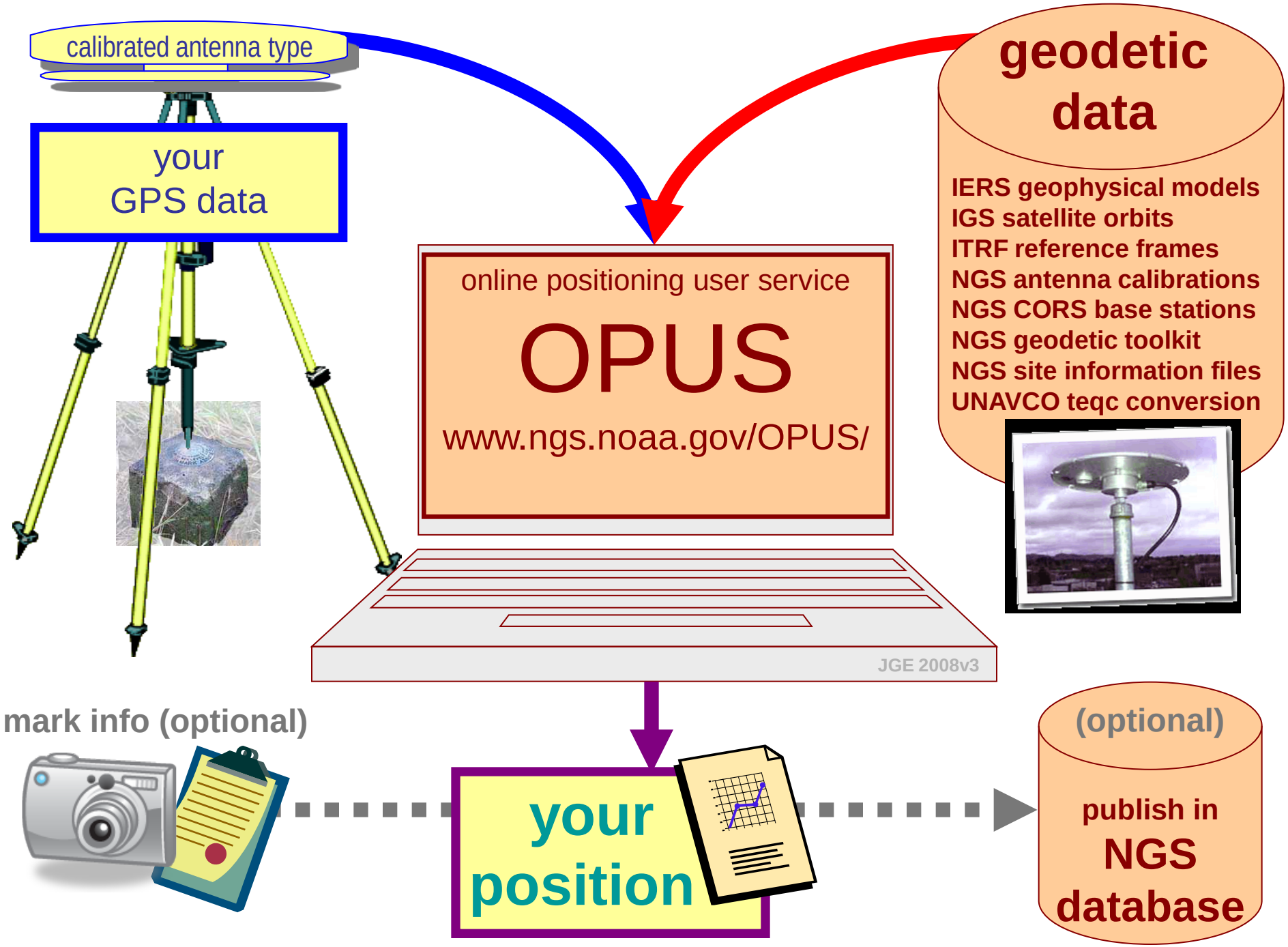
You've got mail!

OPUS solution report

latitude, longitude, height

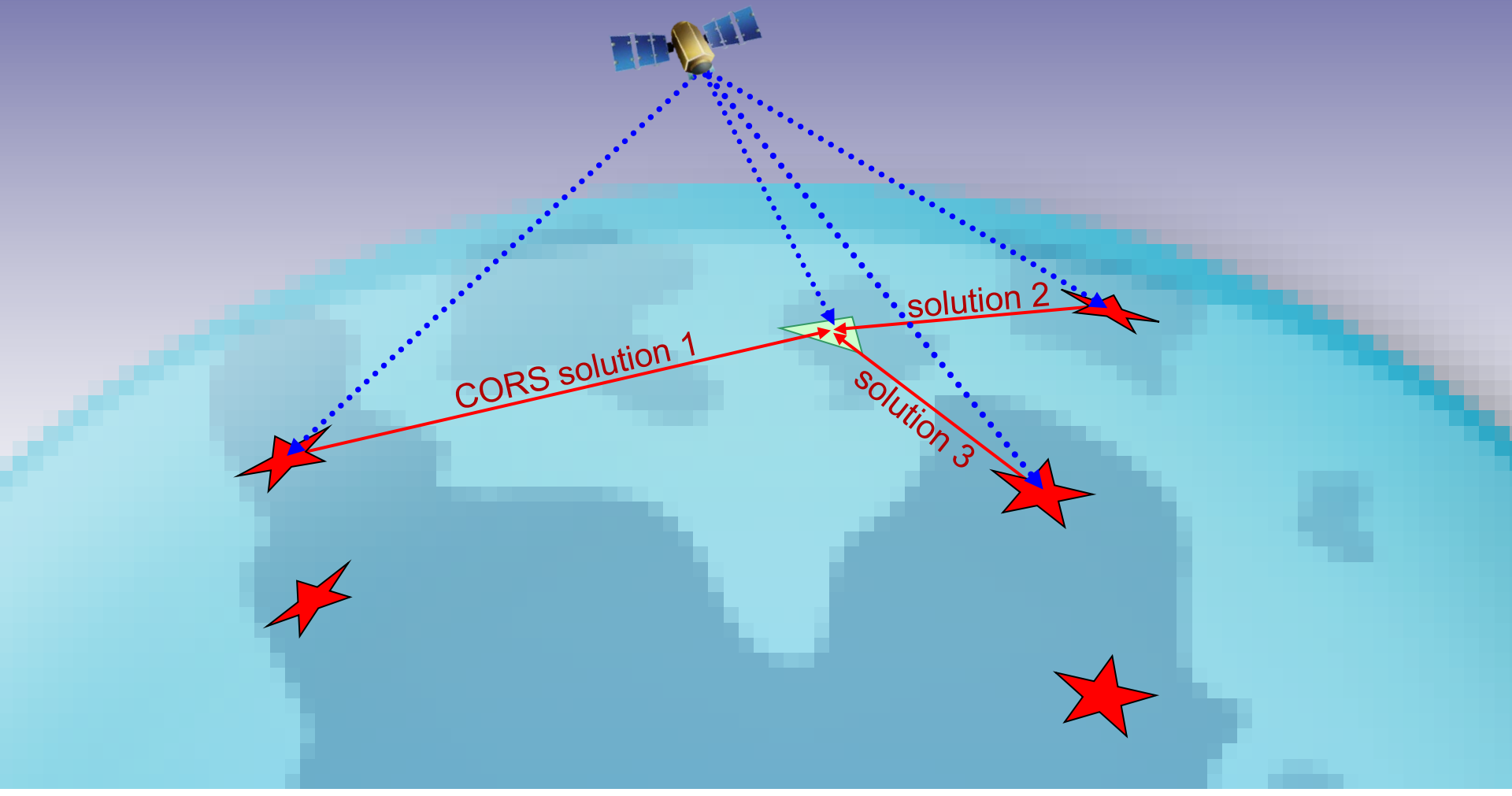
Upload File

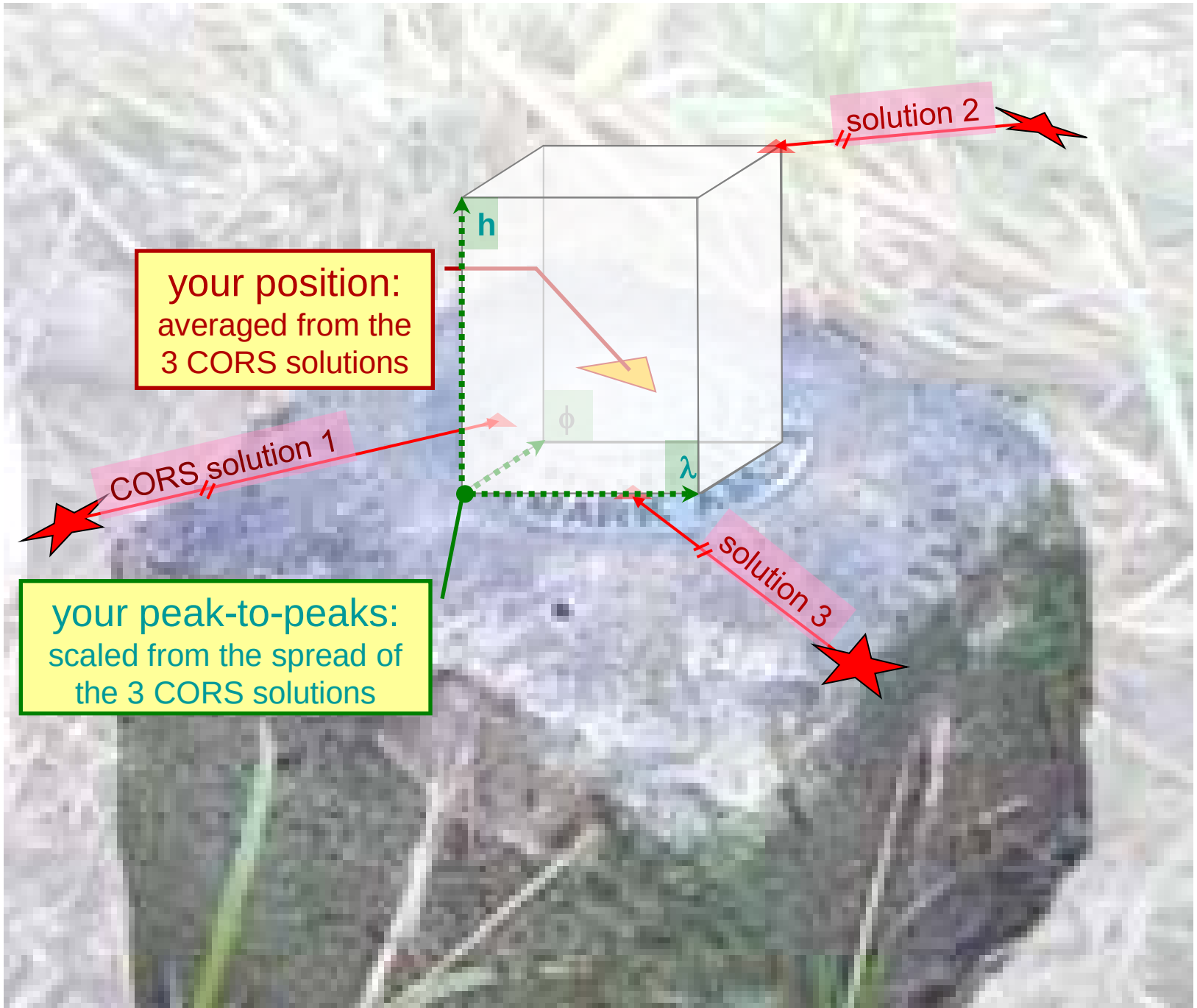
Your data must be dual frequency data (L1 and L2) and a minimum of 2 hours of observations is recommended.
Your collection rate must be 1,2,3,5,10,15 or 30 seconds.


calibrated antenna type
your GPS data
online positioning user service
OPUS
www.ngs.noaa.gov/OPUS/
geodetic data
IERS geophysical models
IGS satellite orbits
ITRF reference frames
NGS antenna calibrations
NGS CORS base stations
NGS geodetic toolkit
NGS site information files
UNAVCO teqc conversion
JGE 2008v3
mark info (optional)
your position
(optional)
publish in NGS database

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

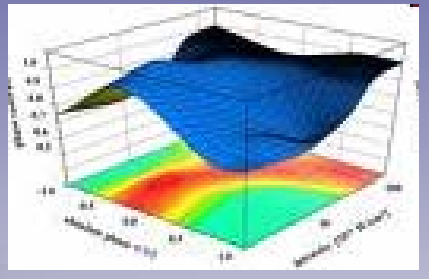
This process is repeated twice from other CORS.

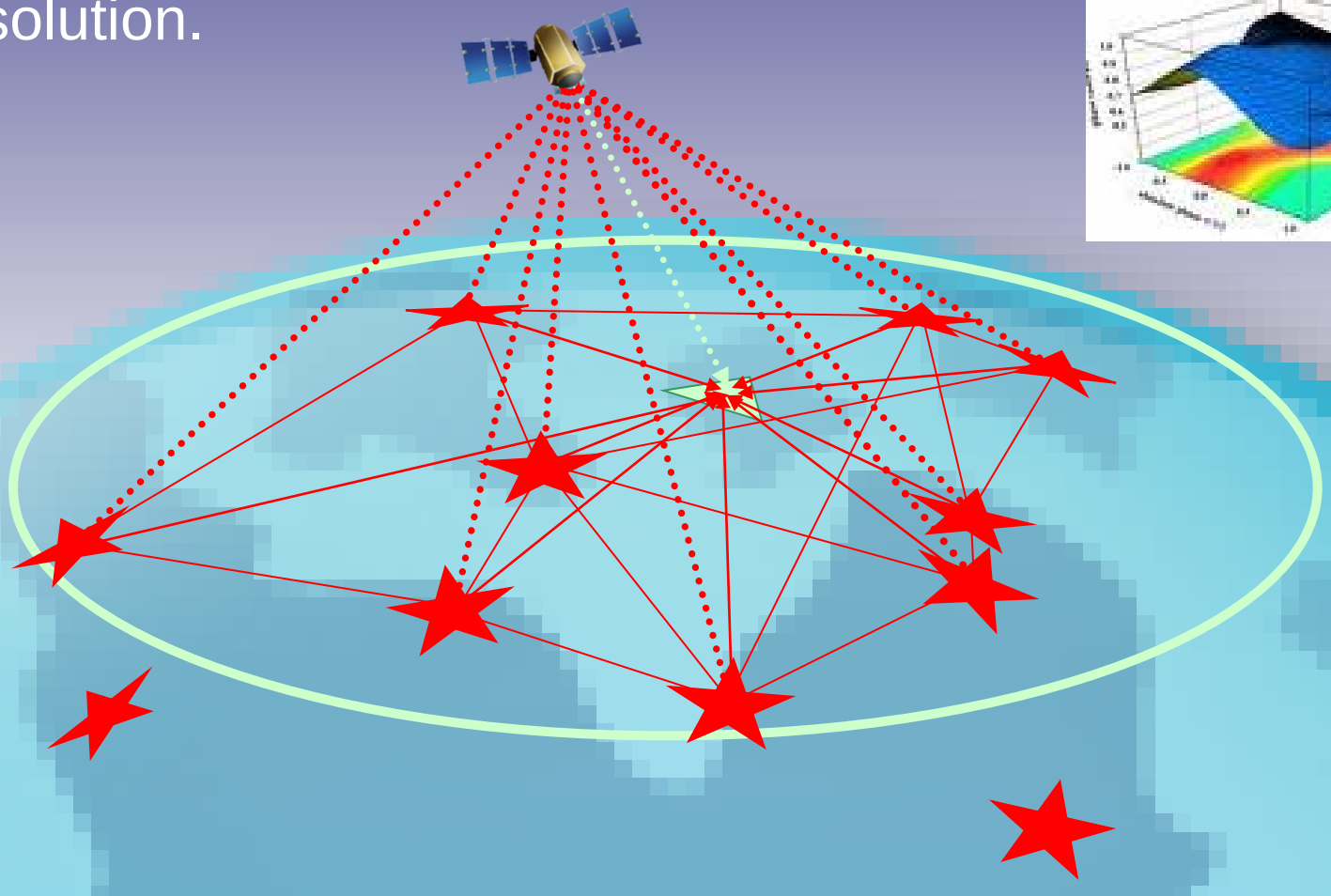



solution 2
h
your position:
averaged from the
3 CORS solutions
ϕ
λ
CORS solution 1
solution 3
your peak-to-peaks:
scaled from the spread of
the 3 CORS solutions

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

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



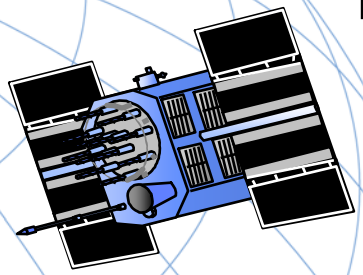


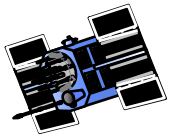
Question 1:

Why did NGS create OPUS and offer it to the public?

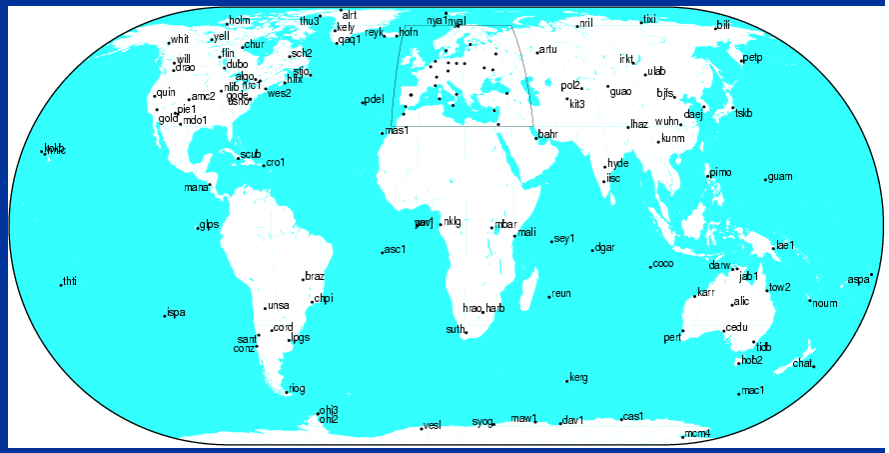
- PAGES: Program for the Adjustment of GPS Ephemerides
- Automated for generation of daily CORS positions
- A lab project
- Internal business (airport surveys, coast mapping)
- *"… define, maintain, and **provide access to** the National Spatial Reference System …"*
- ? In competition with PPP, AUSPOS, Auto-Gipsy, SCOUT, GrafNav, Bernese, TGO, etc?

NGS / IGS PRECISE ORBITS





- **Precise (Final)**
  - **14 days latency**
  - **1 cm accuracy**
  - **updated weekly**
- **Rapid**
  - **1 day latency**
  - **2 cm accuracy**
  - **updated daily**
- **UltraRapid**
  - **24 hrs observed / 24 hrs**
  - **5 cm / 10 cm accuracy**
  - **updated 4 times/day**

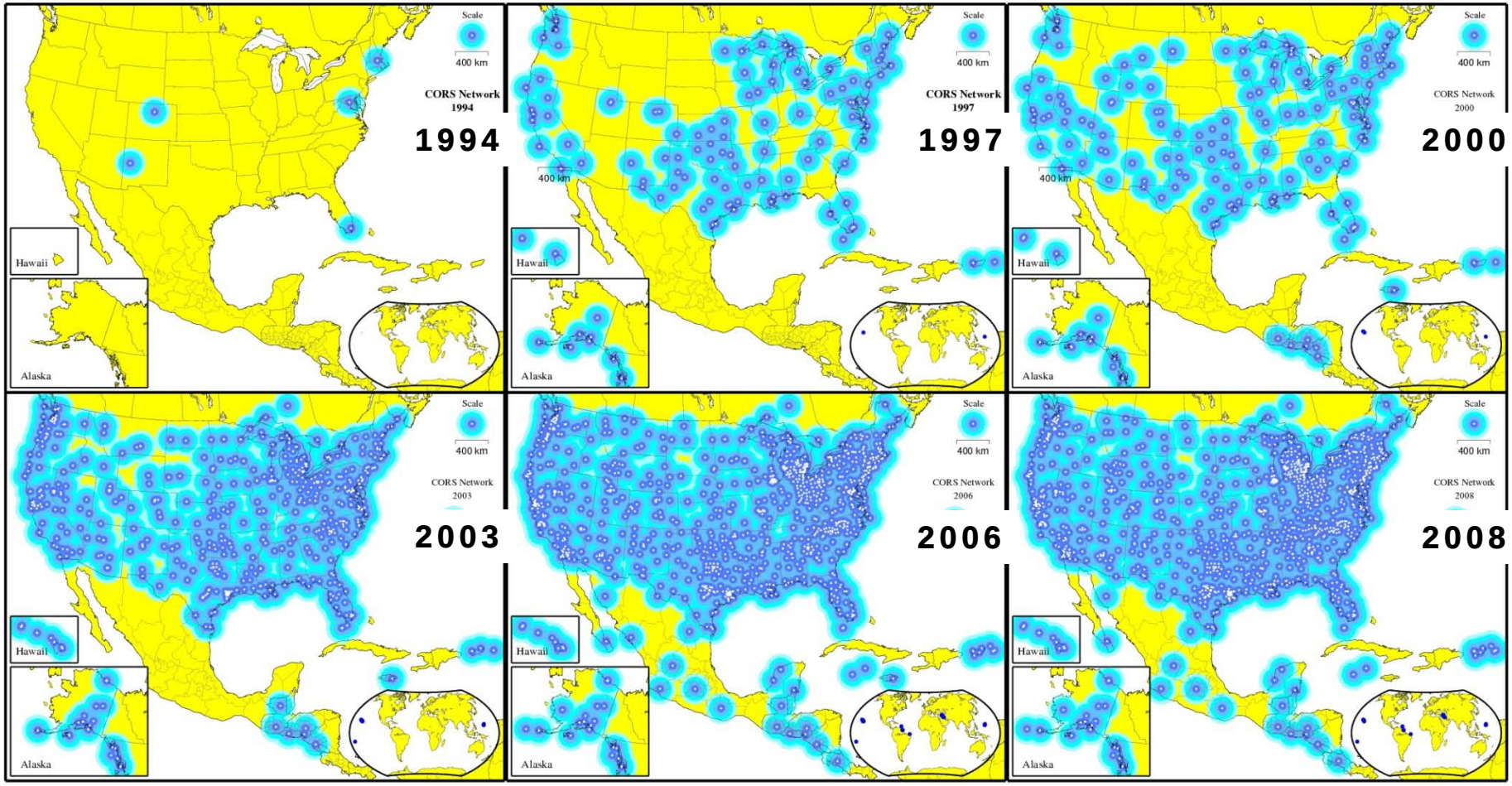


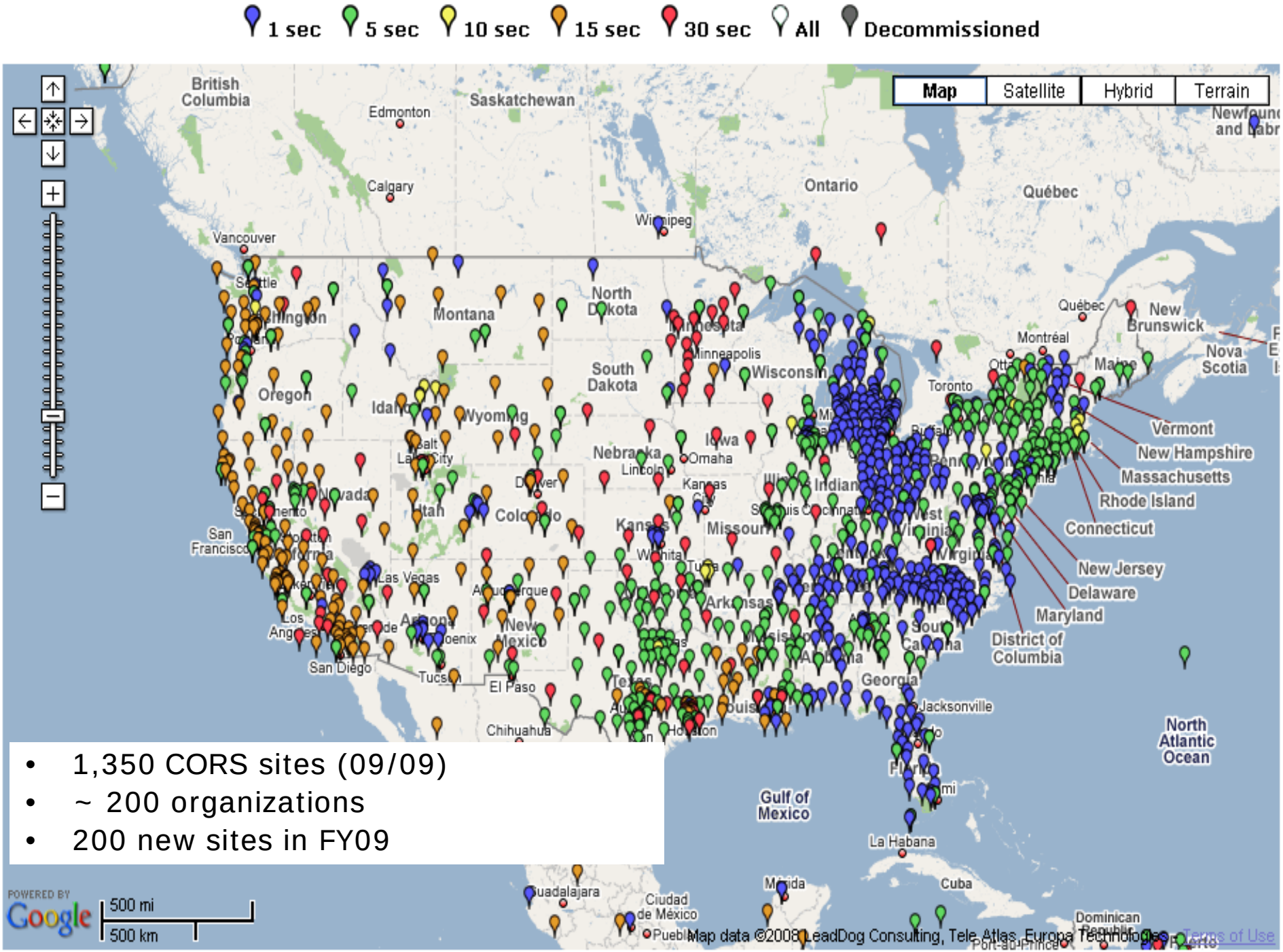
CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

1300+ Installed and Operated by various Federal-State-local Agencies

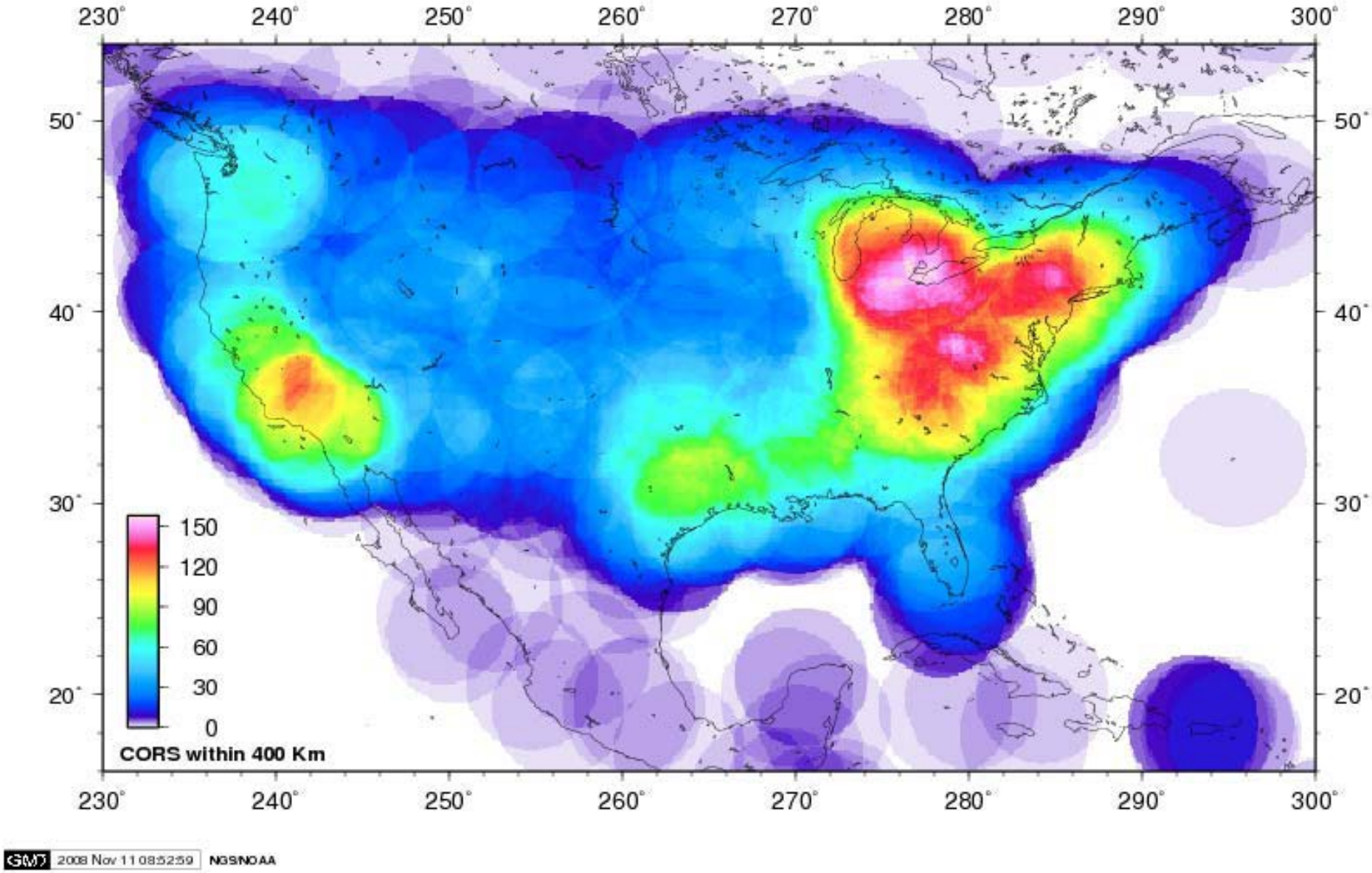
NOAA / National Geodetic Survey
NOAA / OAR Global Systems Division
U.S. Coast Guard - DGPS / NDGPS
Corps of Engineers - DGPS
FAA - WAAS / LAAS
State DOTs
County and City
Academia
Private Companies

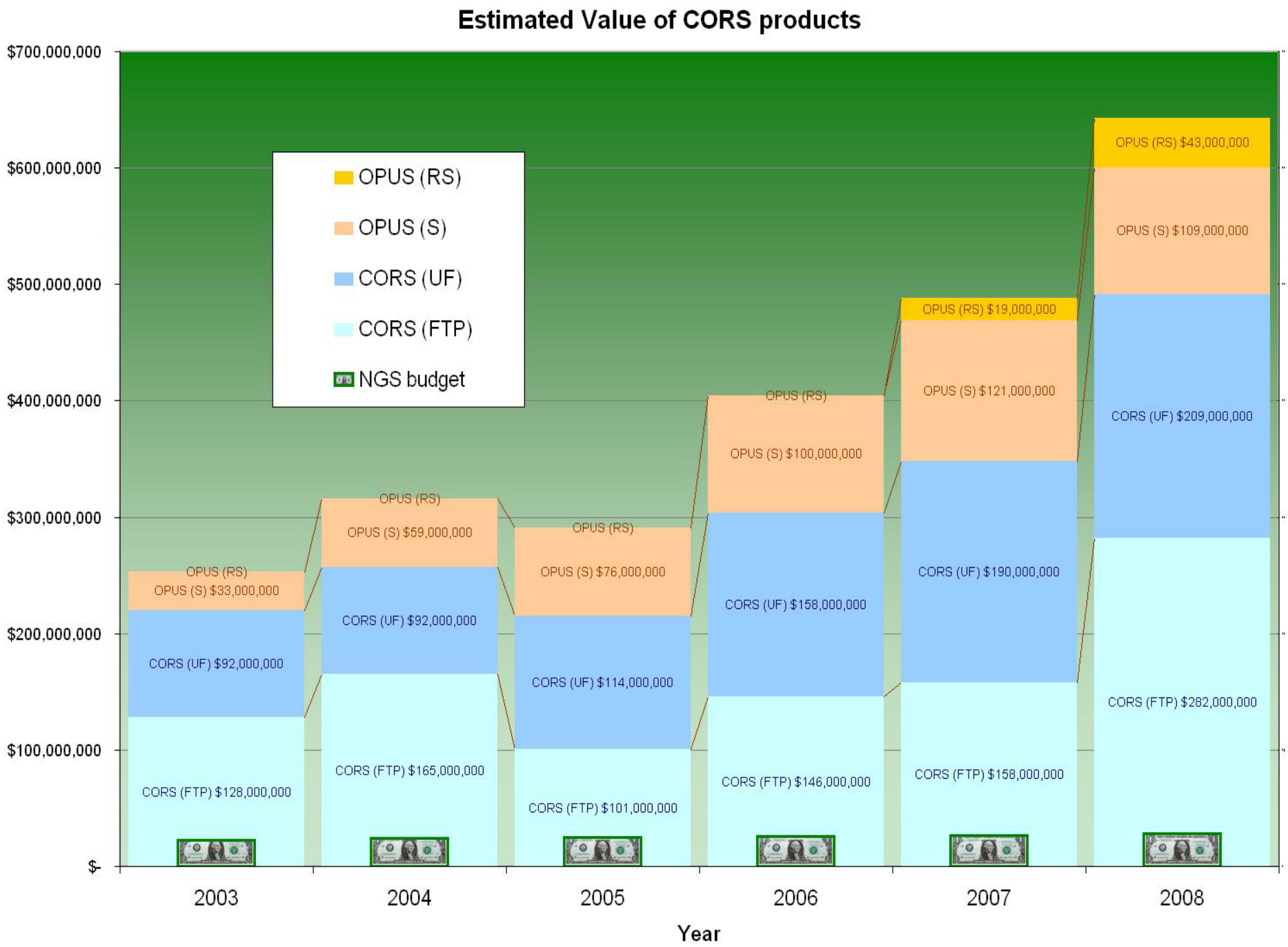
CORS Network Evolution
1994 - 2008





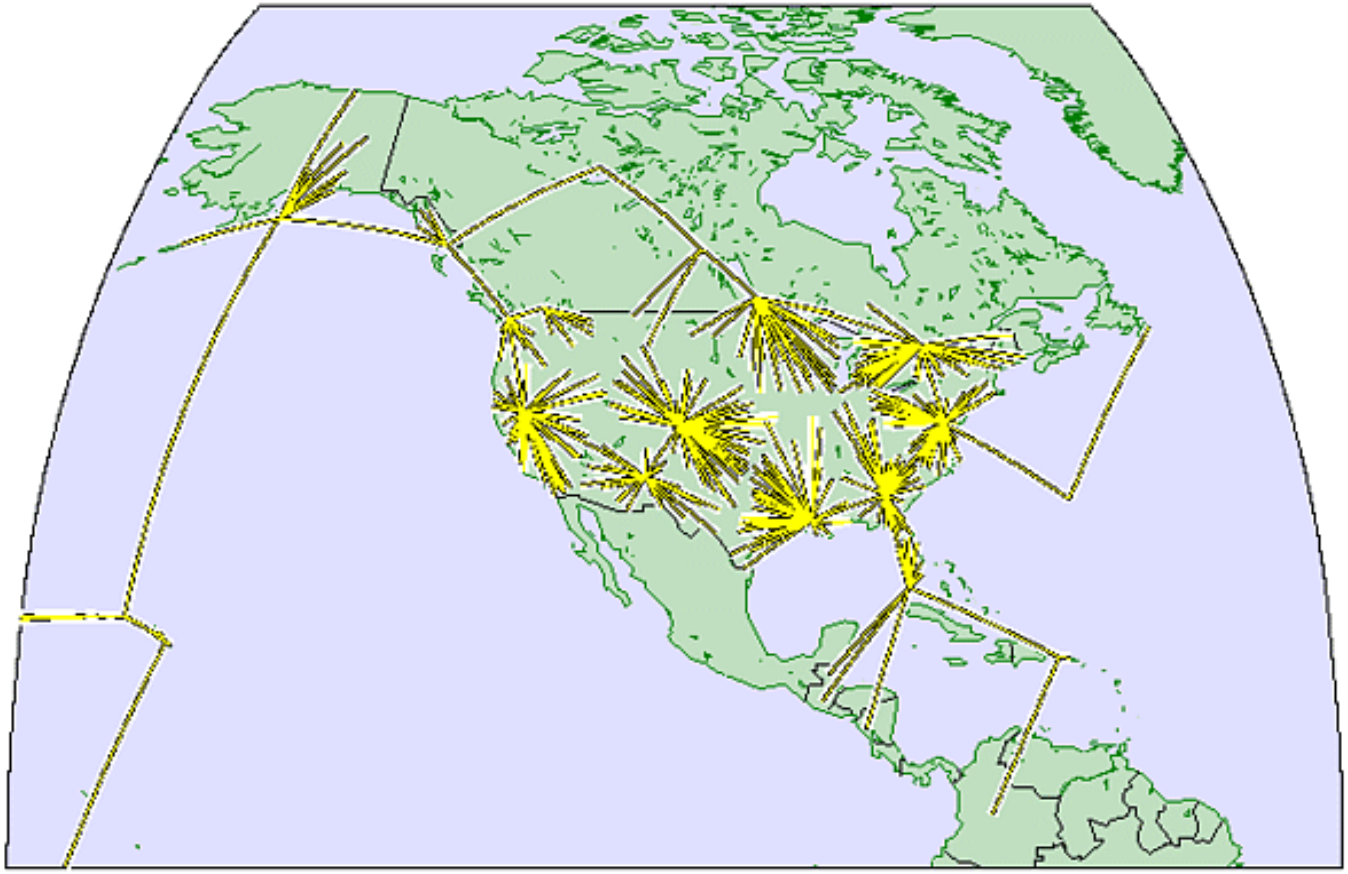
- 1,350 CORS sites (09/09)
- ~ 200 organizations
- 200 new sites in FY09


230°
240°
250°
260°
270°
280°
290°
300°
50°
40°
30°
20°
150
120
90
60
30
0
CORS within 400 Km
GMT 2008 Nov 11 08:52:59
NGS/NOAA


Estimated Value of CORS products
$700,000,000
$600,000,000
$500,000,000
$400,000,000
$300,000,000
$200,000,000
$100,000,000
$-
OPUS (RS)
OPUS (S)
CORS (UF)
CORS (FTP)
NGS budget
OPUS (RS)
OPUS (S) $33,000,000
CORS (UF) $92,000,000
CORS (FTP) $128,000,000
OPUS (RS)
OPUS (S) $59,000,000
CORS (UF) $92,000,000
CORS (FTP) $165,000,000
OPUS (RS)
OPUS (S) $76,000,000
CORS (UF) $114,000,000
CORS (FTP) $101,000,000
OPUS (RS)
OPUS (S) $100,000,000
CORS (UF) $158,000,000
CORS (FTP) $146,000,000
OPUS (RS) $19,000,000
OPUS (S) $121,000,000
CORS (UF) $190,000,000
CORS (FTP) $158,000,000
OPUS (RS) $43,000,000
OPUS (S) $109,000,000
CORS (UF) $209,000,000
CORS (FTP) $282,000,000
2003
2004
2005
2006
2007
2008
Year

Baseline Plot National

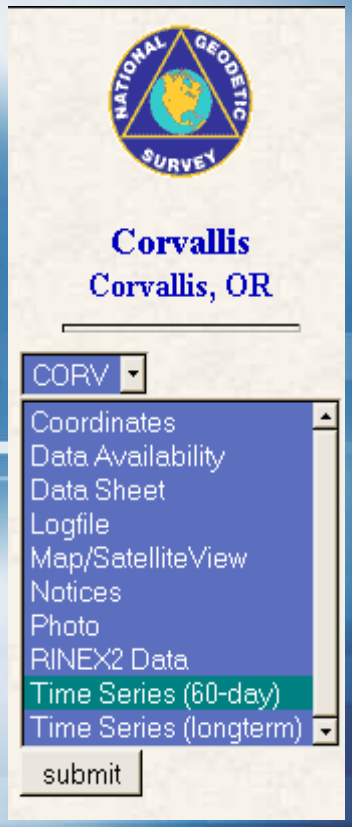
05072 CORS



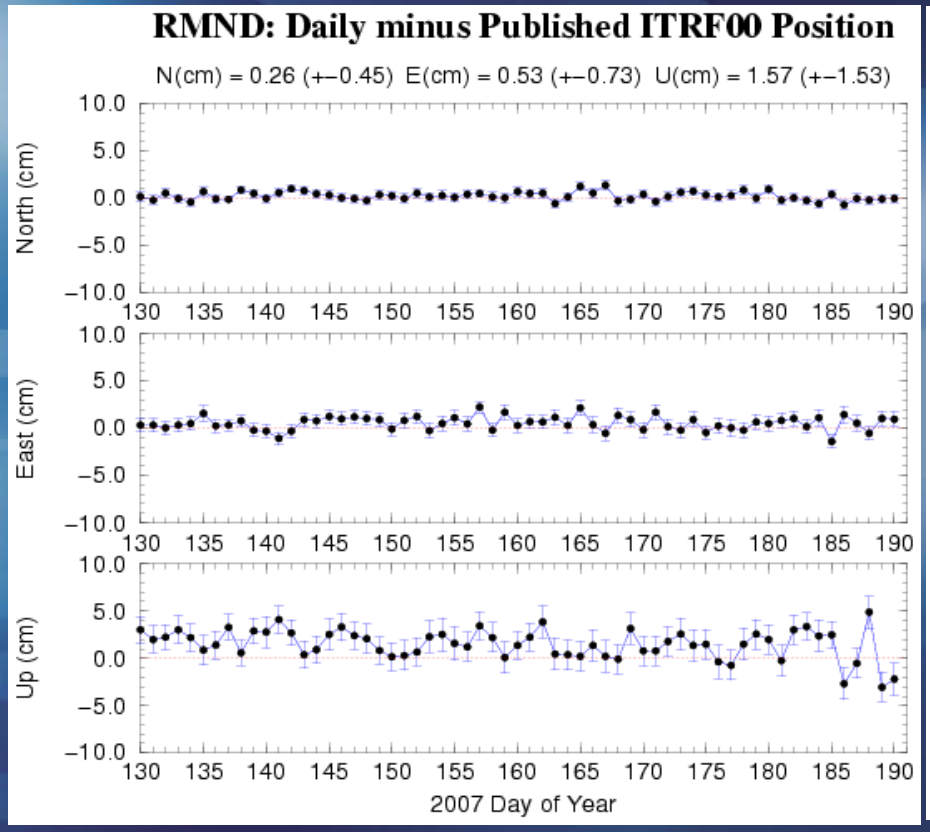
Time-series plots, 60-day and long-term

NATIONAL GEODETIC SURVEY

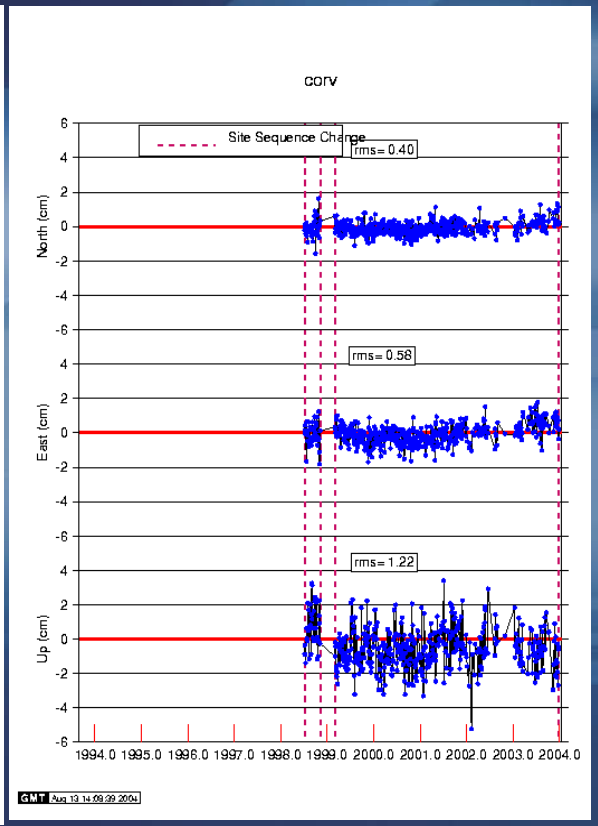
web page



60-day time series



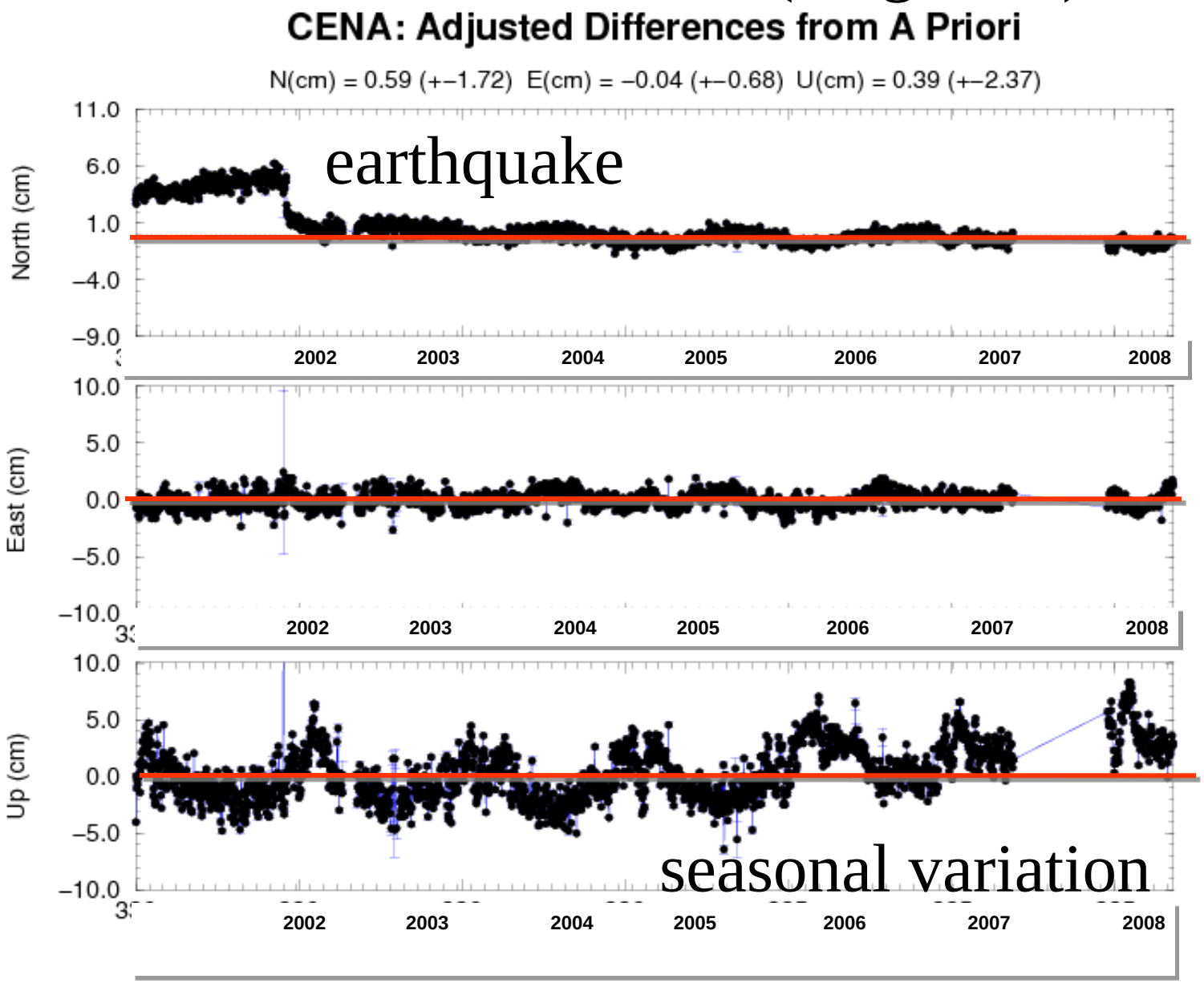
Long-term time series



The time series plots provide a means of evaluating the small changes in position of a CORS.

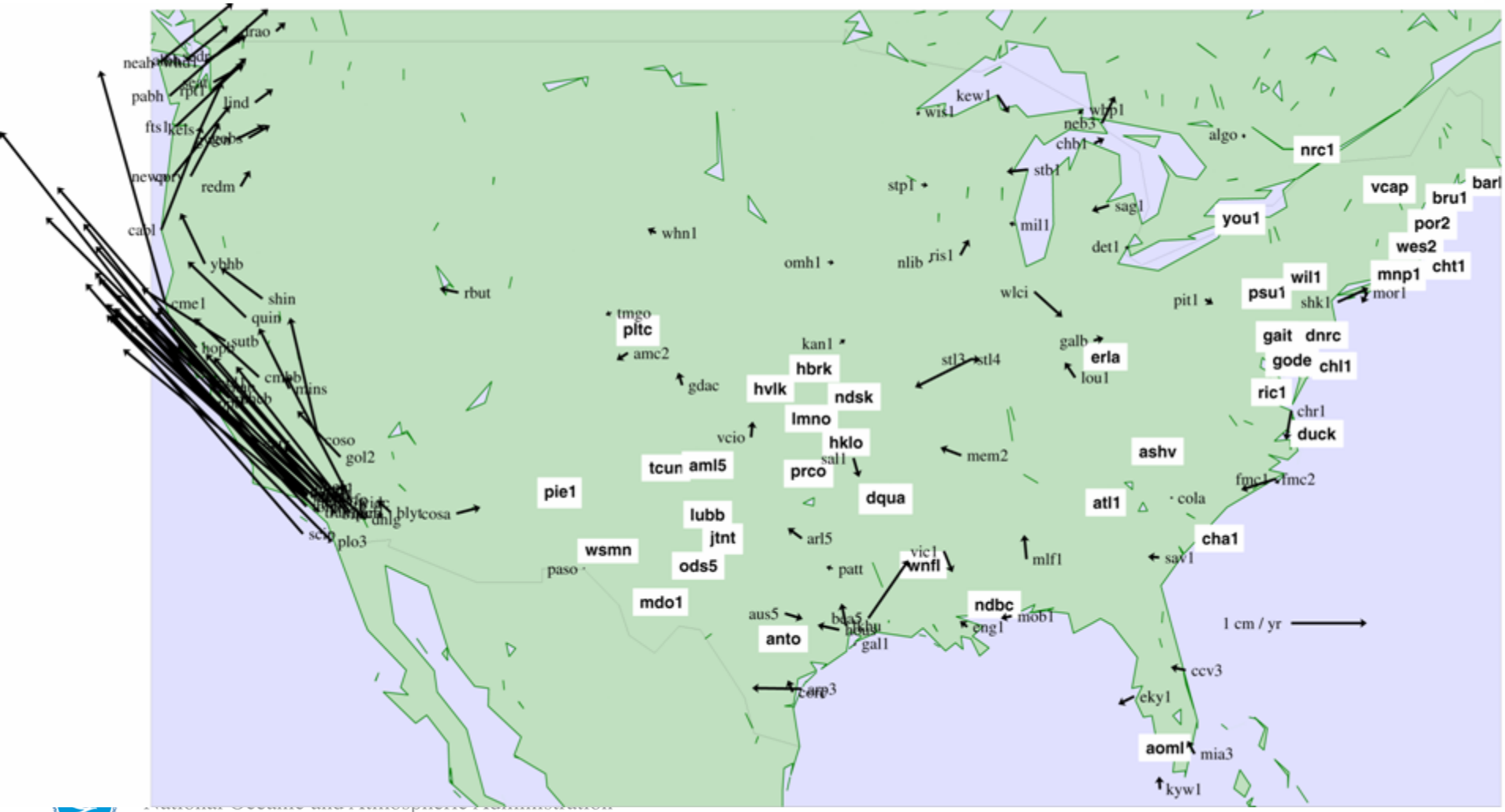
National Oceanic and Atmospheric Administration

Position Time Series (long-term)

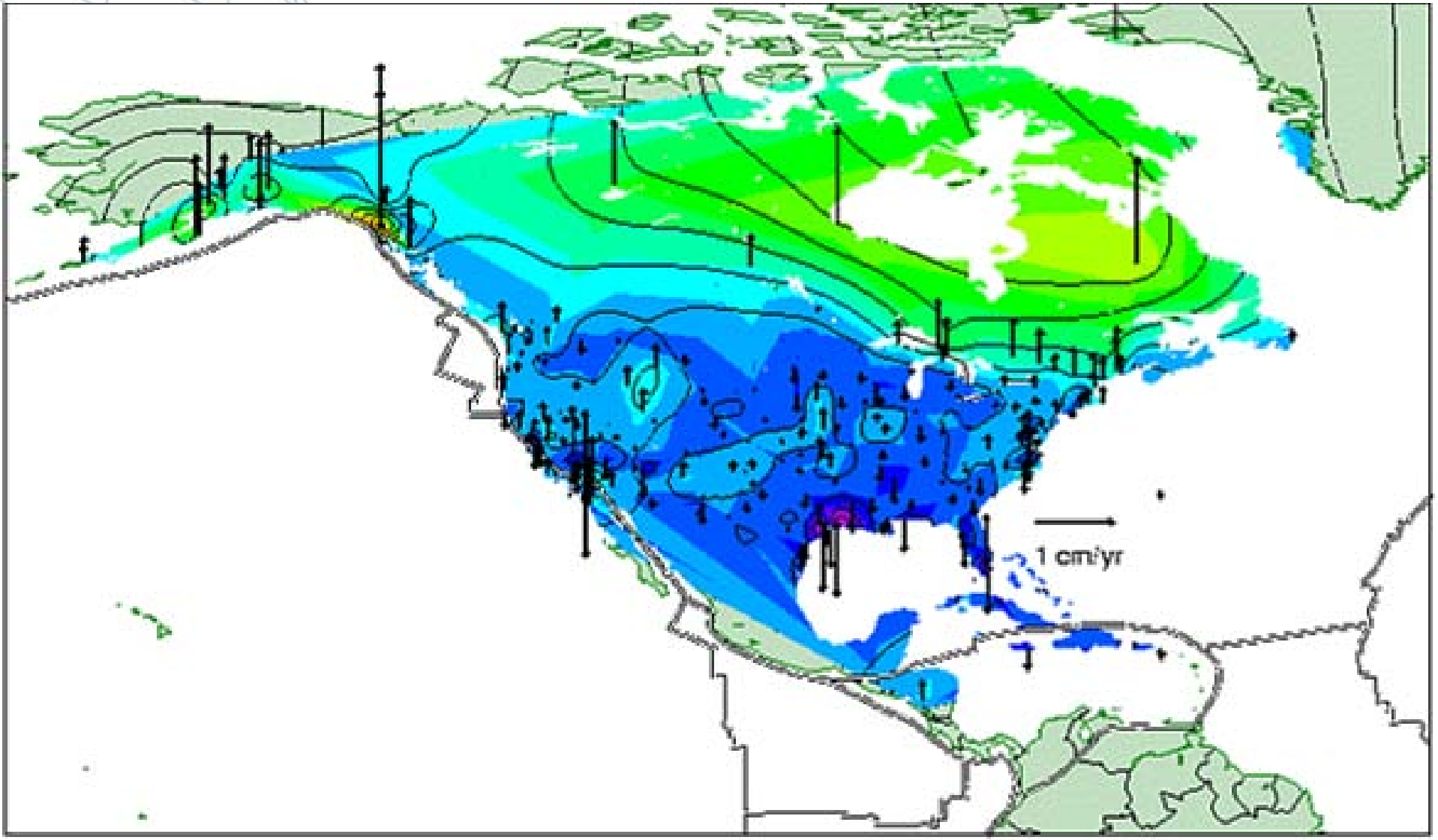


Horizontal velocities relative to “stable” sites

Points with more than 3 yrs of data



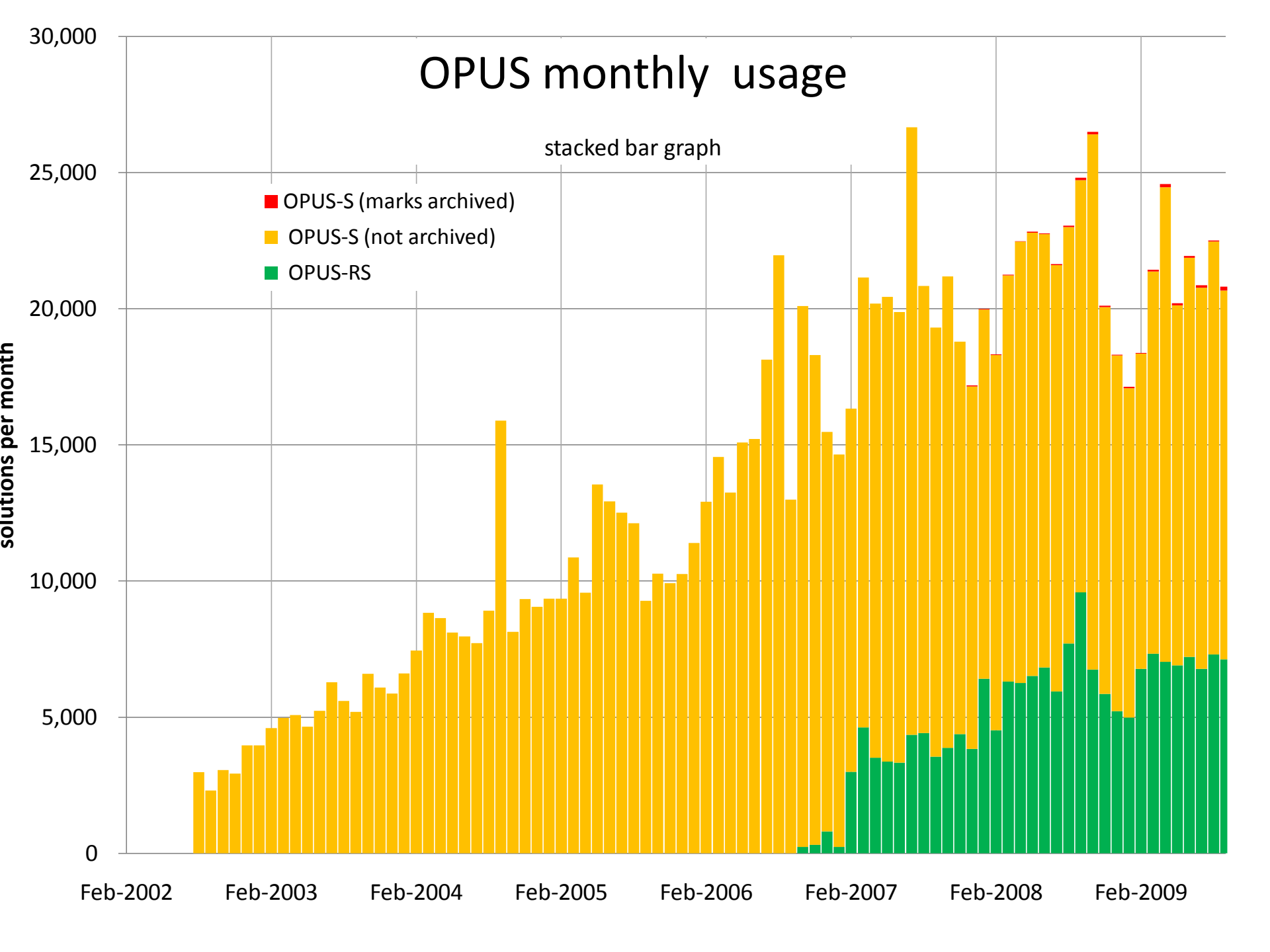
Land Movement Velocities Measured by GPS CORS



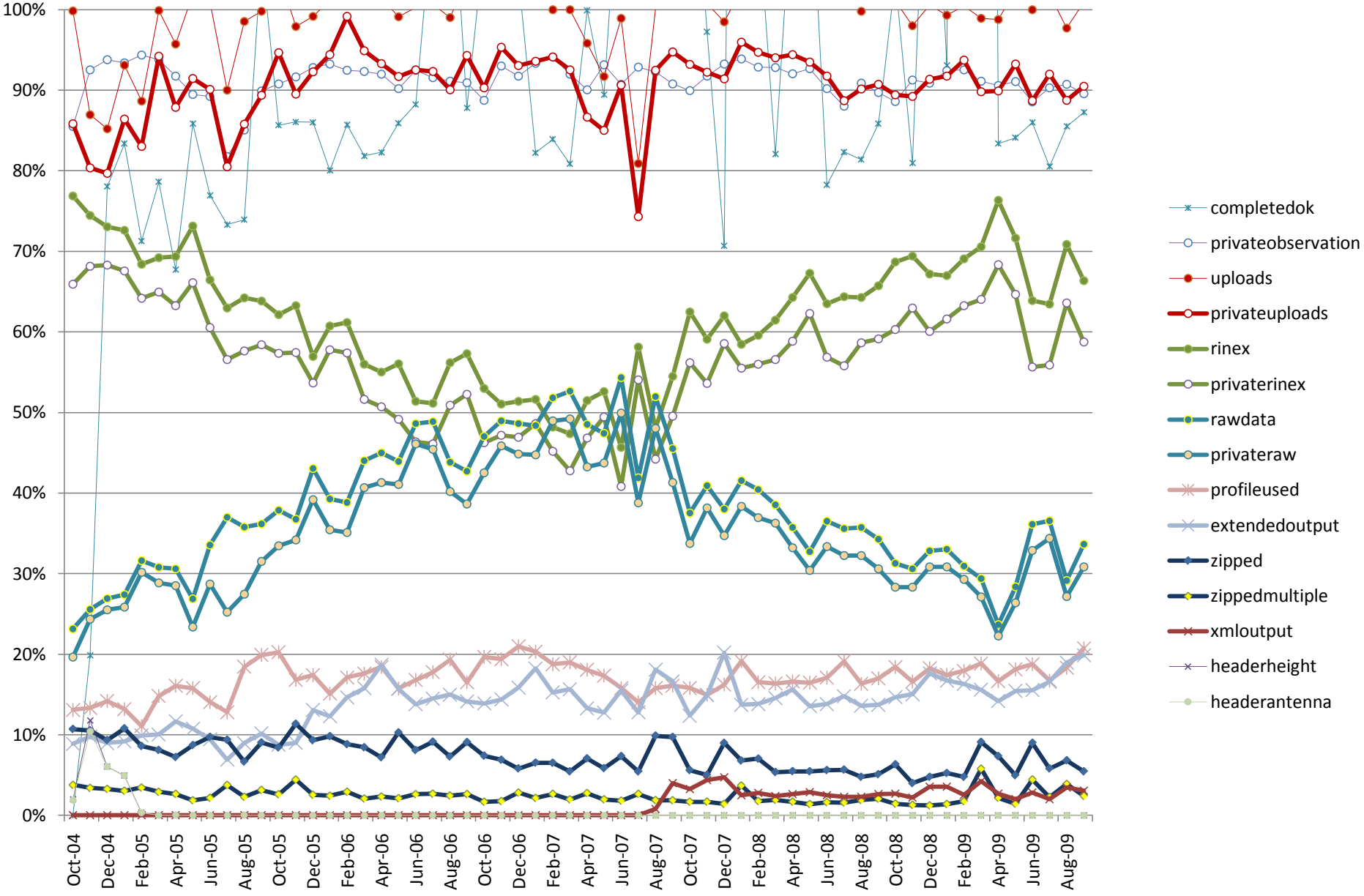
Question 2:

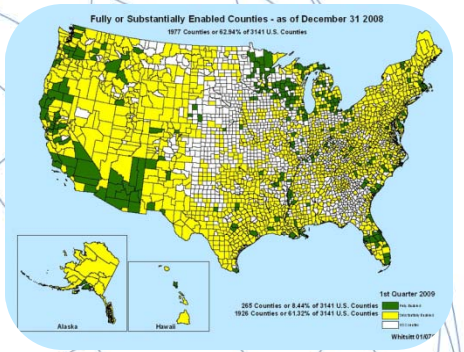
Is OPUS being fully used as intended?

- Who knows?
  - Many solution report details unanalyzed (privacy)
  - No adverse use cases are known to NGS.
- Much use for shorter duration sessions
- Confusion about antenna type, height


OPUS monthly usage
stacked bar graph
OPUS-S (marks archived)
OPUS-S (not archived)
OPUS-RS
solutions per month
30,000
25,000
20,000
15,000
10,000
5,000
0
Feb-2002
Feb-2003
Feb-2004
Feb-2005
Feb-2006
Feb-2007
Feb-2008
Feb-2009

OPUS metrics, as % of observation files

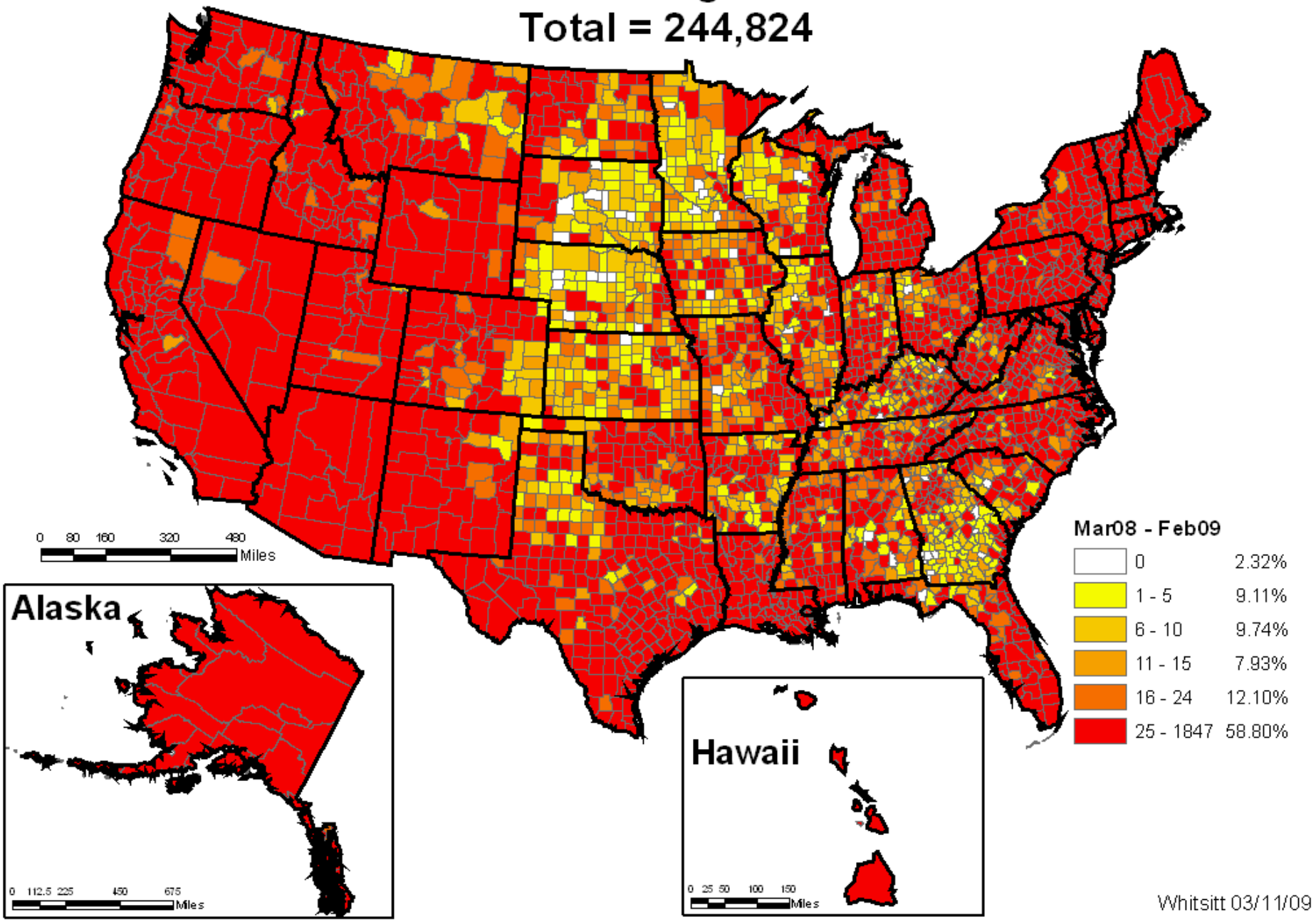




Feedback from Customers

- NOAA has a relatively new performance metric that assesses how well we are doing at “enabling” local capacity for accurate positioning. This metric:
  - Makes use of NOAA’s Online Positioning User Service (OPUS) as a proxy to assess the local use of NOAA positioning tools and services. Was developed over the past several years in partnership with National Association of County Surveyors (NACS).
  - Involves the use of a web-based county scorecard of 23 survey questions specifically focusing on infrastructure, NGS models and tools, NGS capacity building and outreach, and overall satisfaction.

OPUS and OPUS-RS Usage Mar2008 - Feb2009
Total = 244,824



Whitsitt 03/11/09

```
                    NGS OPUS SOLUTION REPORT
                    ========================

      USER: dave.doyle@noaa.gov                    DATE: September 12, 2005
RINEX FILE: mlf1254p.05o                           TIME: 17:42:32 UTC


  SOFTWARE: page5  0411.19 master19.pl            START: 2005/09/11  15:00:00
 EPHEMERIS: igr13400.eph [rapid]                   STOP: 2005/09/11  17:00:00
  NAV FILE: brdc2540.05n                       OBS USED:  3389 /  3557   :  95%
  ANT NAME: ASH700829.3     SNOW             # FIXED AMB:    19 /    21   :  90%
ARP HEIGHT: 0.0                              OVERALL RMS: 0.016(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2005.6950)

         X:       246130.025(m)   0.018(m)            246129.362(m)   0.018(m)
         Y:     -5403153.828(m)   0.087(m)          -5403152.345(m)   0.087(m)
         Z:      3368920.205(m)   0.040(m)           3368920.028(m)   0.040(m)

       LAT:   32  5 24.91739      0.013(m)        32  5 24.93859      0.013(m)
     E LON:  272 36 29.49572      0.017(m)       272 36 29.47304      0.017(m)
     W LON:   87 23 30.50428      0.017(m)        87 23 30.52696      0.017(m)
    EL HGT:           10.478(m)   0.096(m)                 9.103(m)   0.096(m)
 ORTHO HGT:           38.371(m)   0.099(m) [Geoid03 NAVD88]


Northing (Y) [meters]
Easting (X)  [meters]
Convergence  [degrees
Point Scale
Combined Factor

US NATIONAL GRID DESI



PID       DESIGNATION
AI4943 OKOM OKOLONA CORS ARP              N340524.926 W0885144.900  260842.3
AF9559 MOB1 MOBILE POINT 1 CORS ARP       N301339.046 W0880126.752  215133.5
DF5876 HAC1 HACKELBURG 1 CORS ARP         N341649.966 W0875121.382  246735.2
```

HOW GOOD ARE OPUS ORTHOMETRIC HEIGHTS?

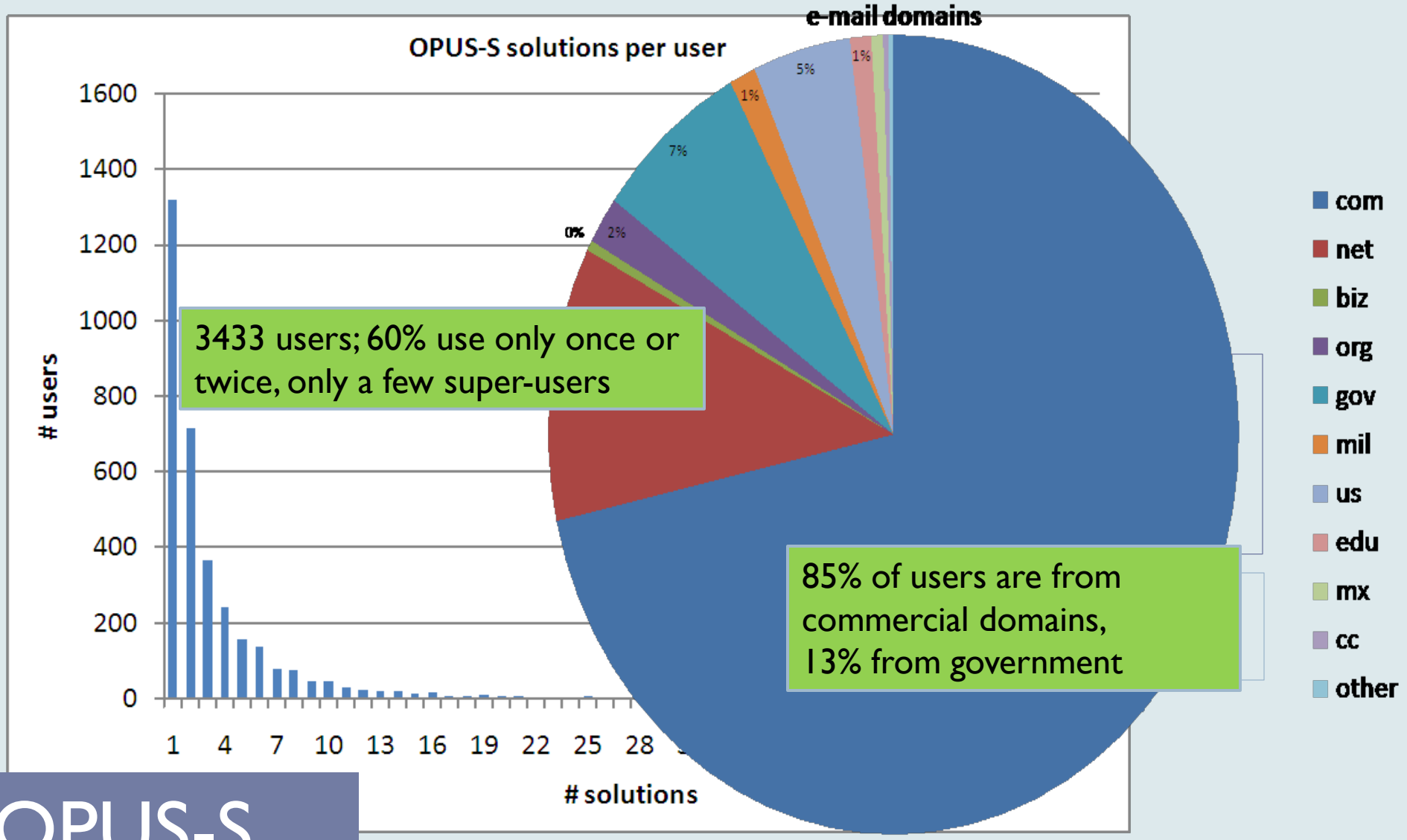
IT DEPENDS!

ORTHOMETRIC HEIGHT ~ 0.02 – 0.04 m
GEOID03 ~ 0.048 m (2 sigma – 95% confidence)
Error ~ 0.03 + 0.05
~ 0.08 m

OPUS-S and OPUS-RS usage patterns

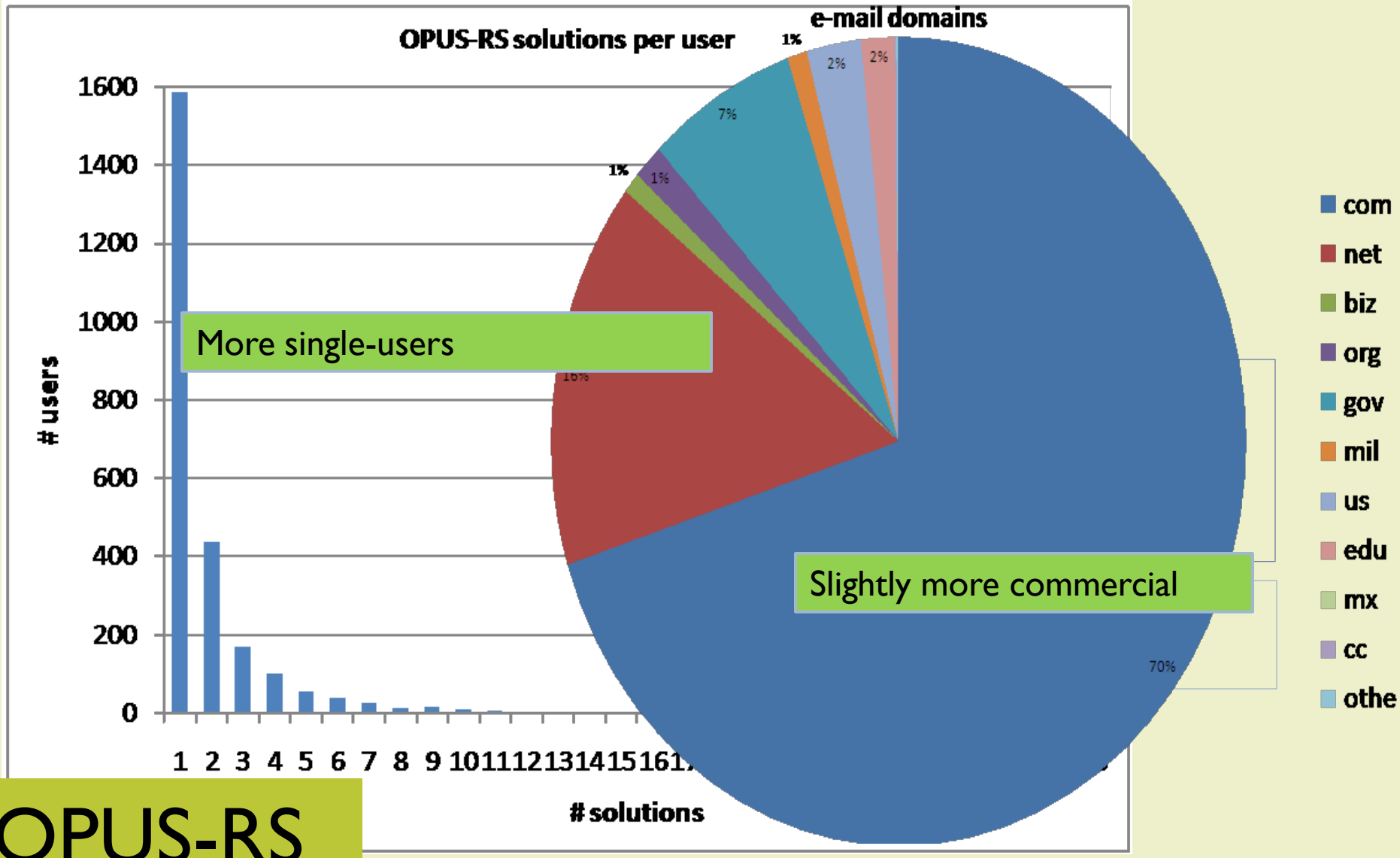
Distribution of values from OPUS solution reports, November – December 2008

13,818 OPUS-S runs, Nov-Dec 2008
99 runs per work hour

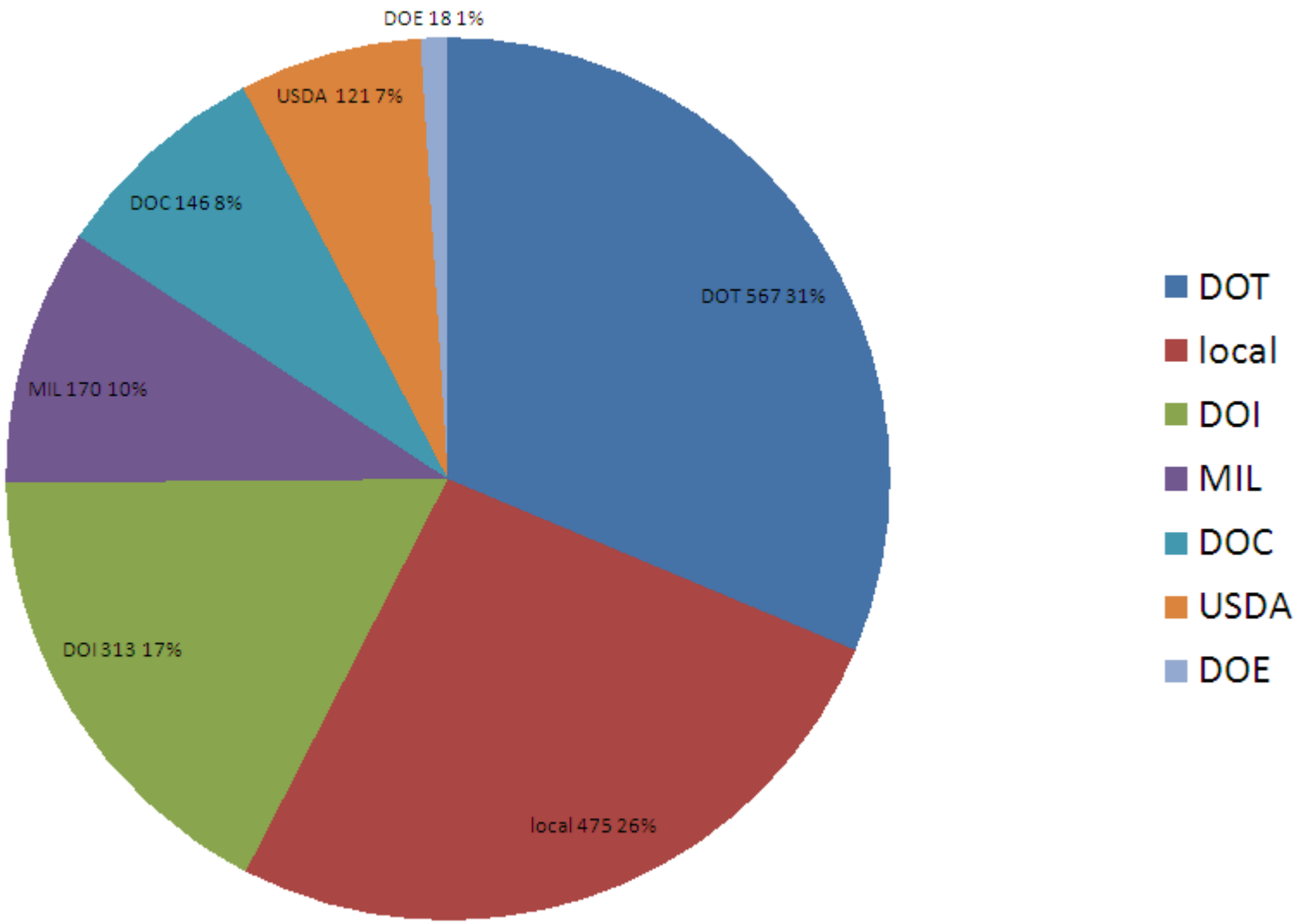


OPUS-S

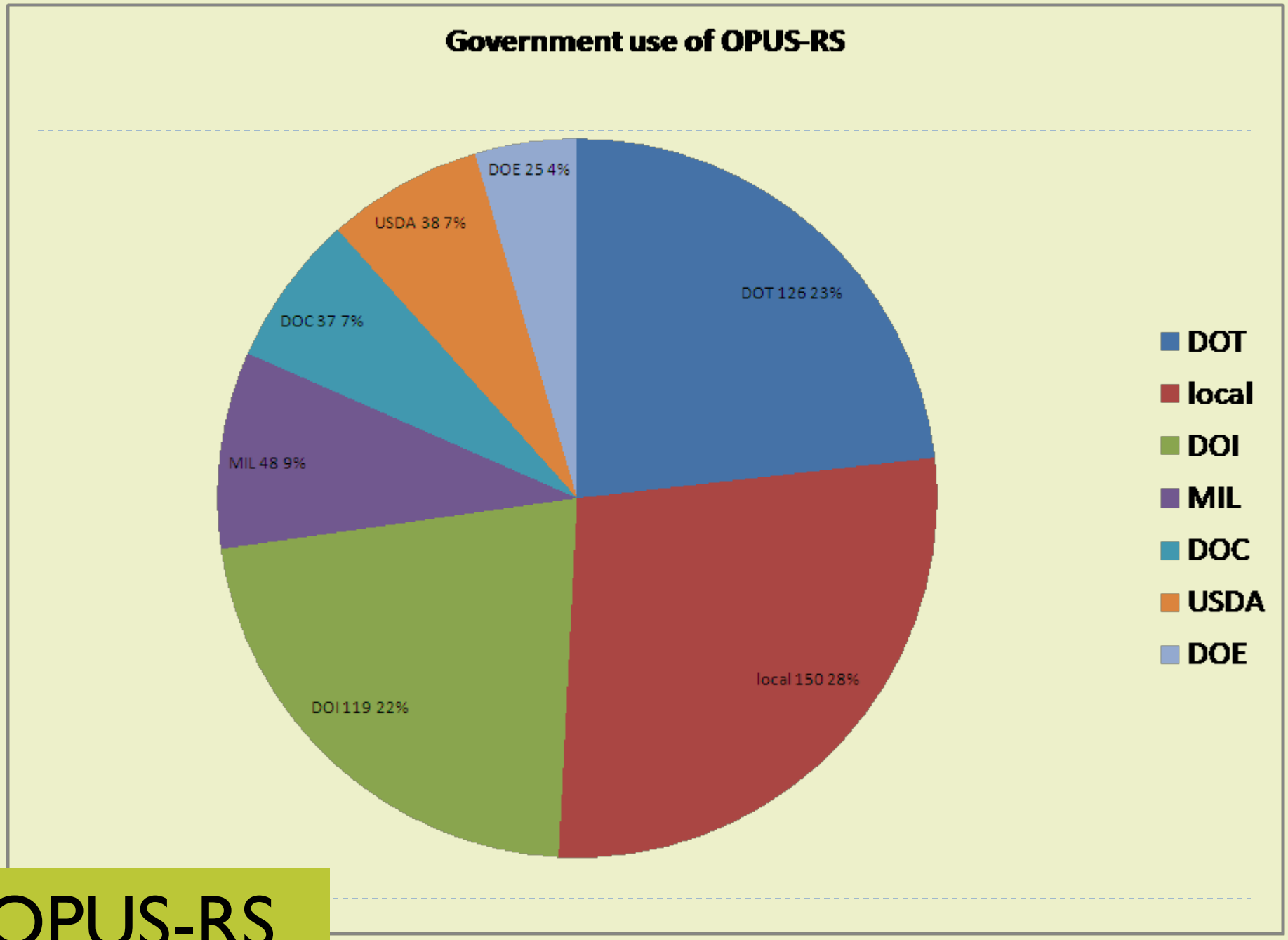
5,227 OPUS-RS runs, Nov-Dec 2008
58 runs per work hour



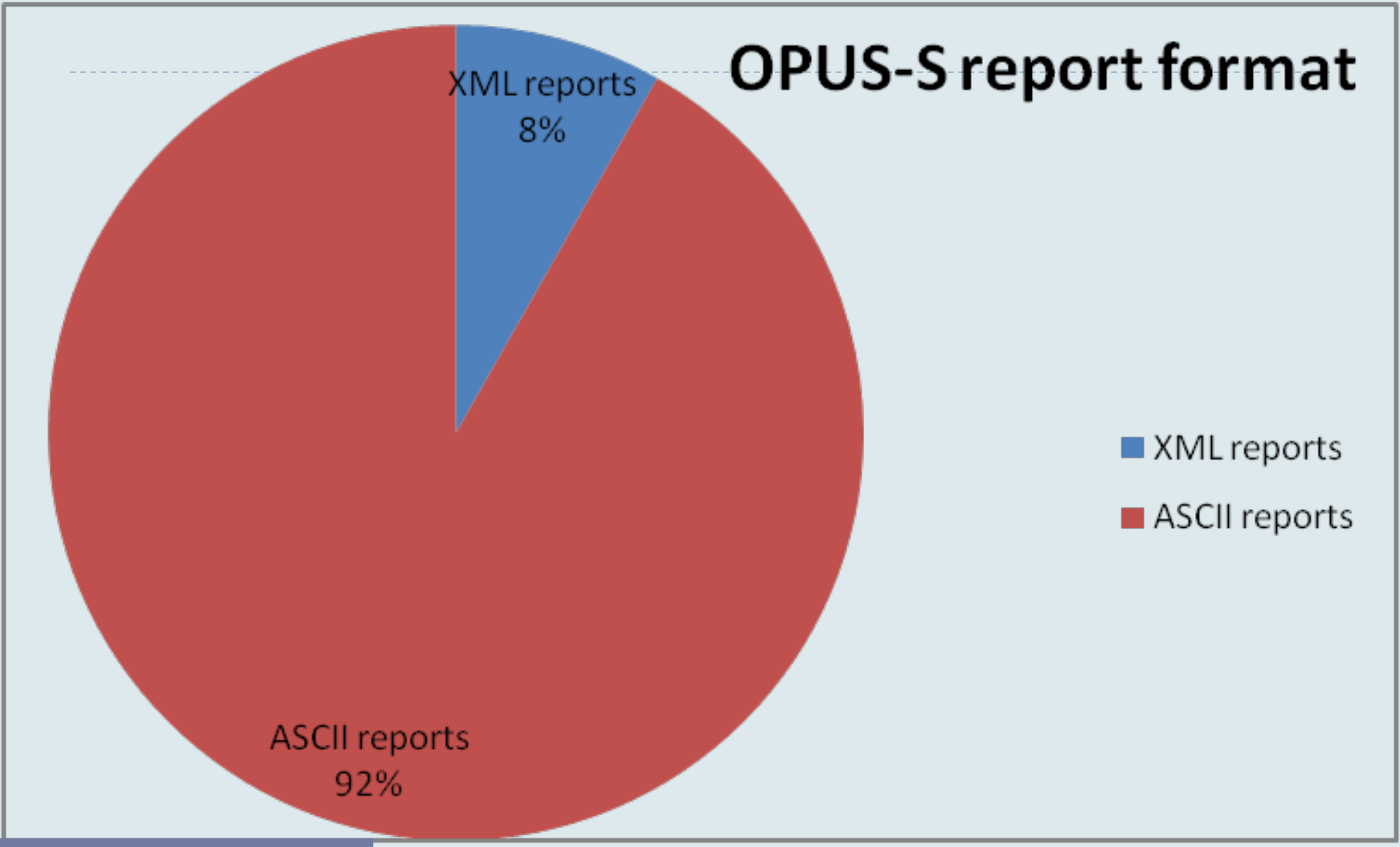
OPUS-RS


Government use of OPUS
DOE 18 1%
USDA 121 7%
DOC 146 8%
MIL 170 10%
DOI 313 17%
local 475 26%
DOT 567 31%
DOT
local
DOI
MIL
DOC
USDA
DOE

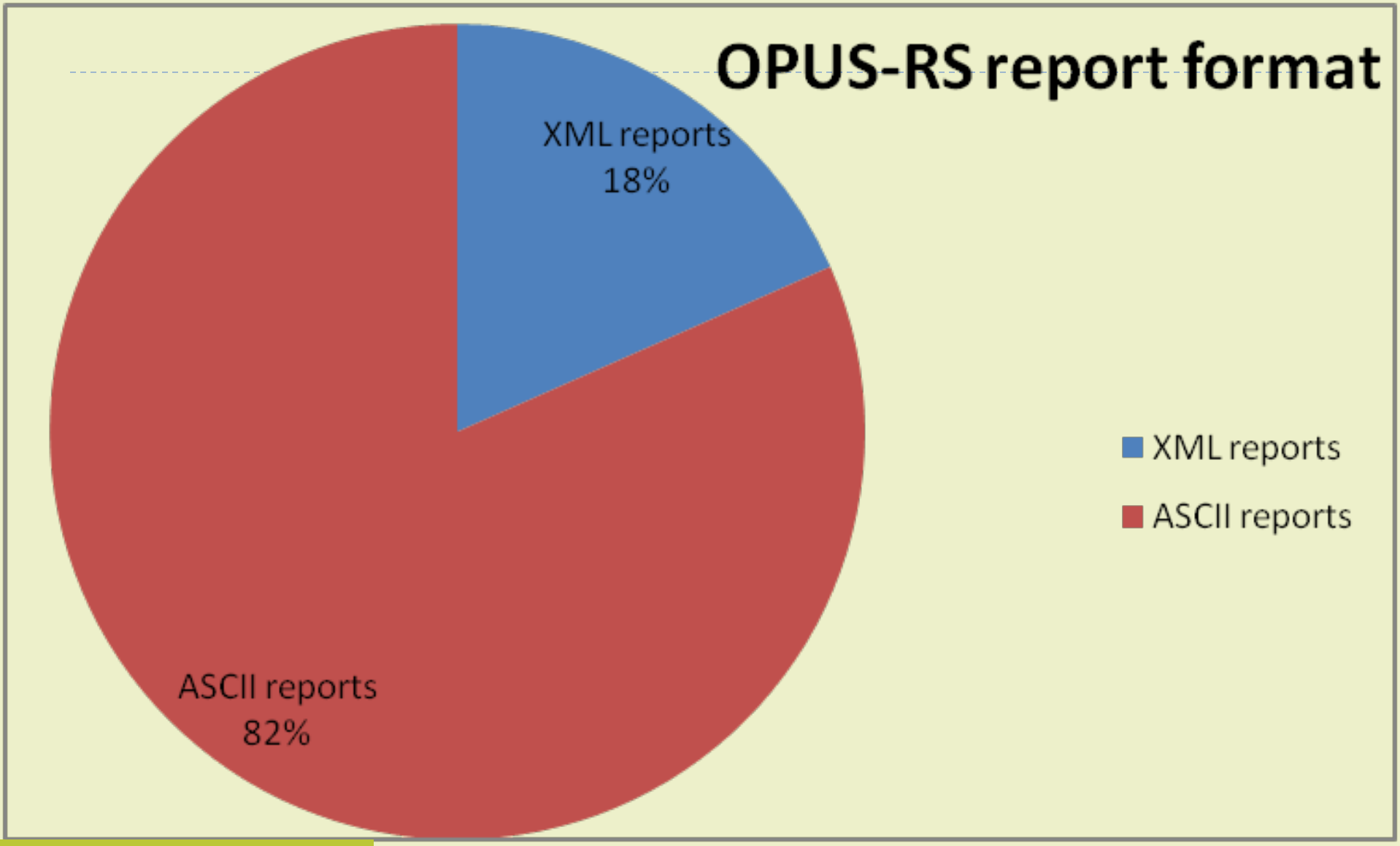
OPUS-S


Government use of OPUS-RS
DOE 25 4%
USDA 38 7%
DOC 37 7%
MIL 48 9%
DOI 119 22%
local 150 28%
DOT 126 23%
DOT
local
DOI
MIL
DOC
USDA
DOE

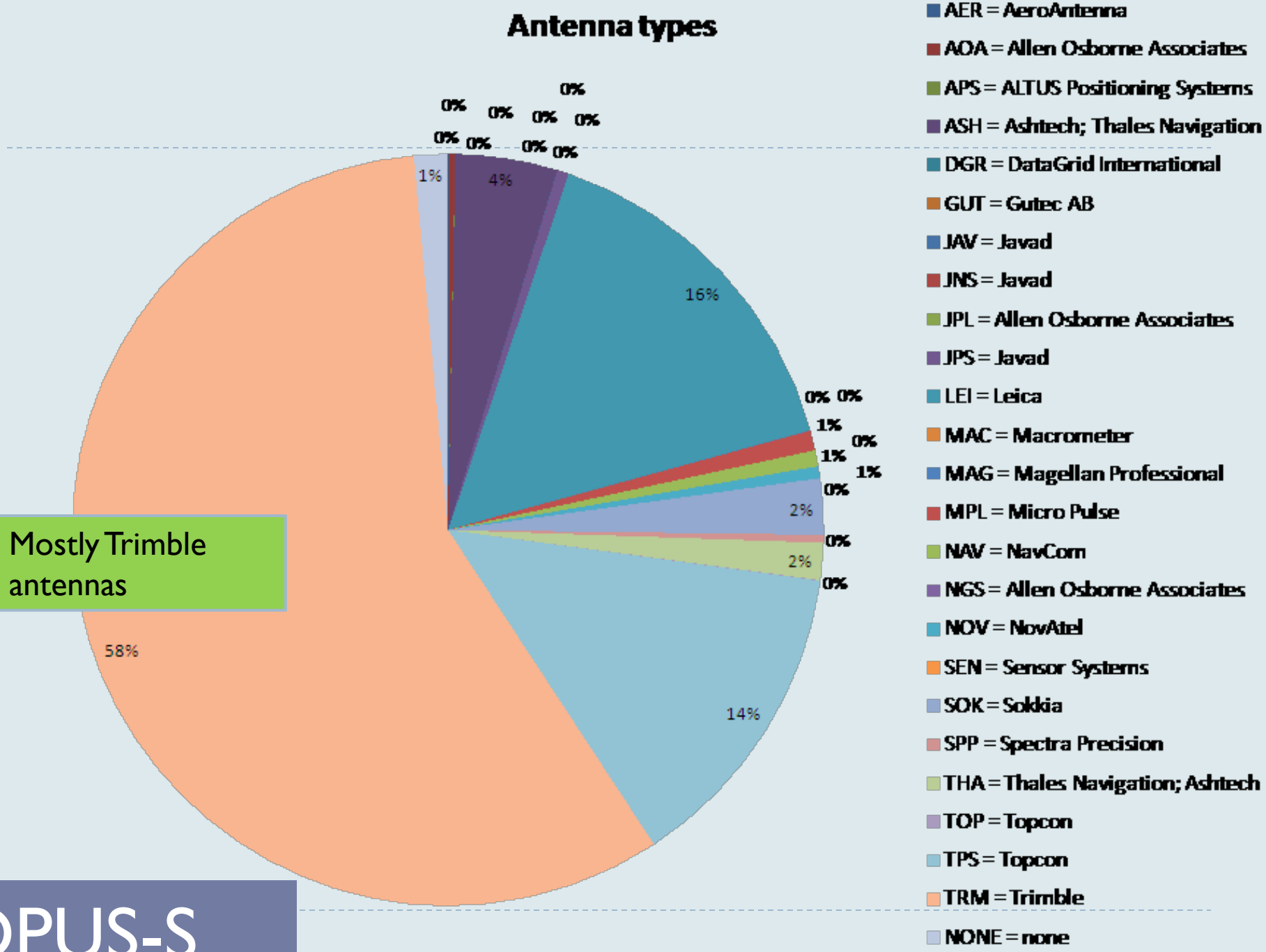
OPUS-RS


OPUS-S report format
XML reports
8%
ASCII reports
92%
XML reports
ASCII reports

OPUS-S

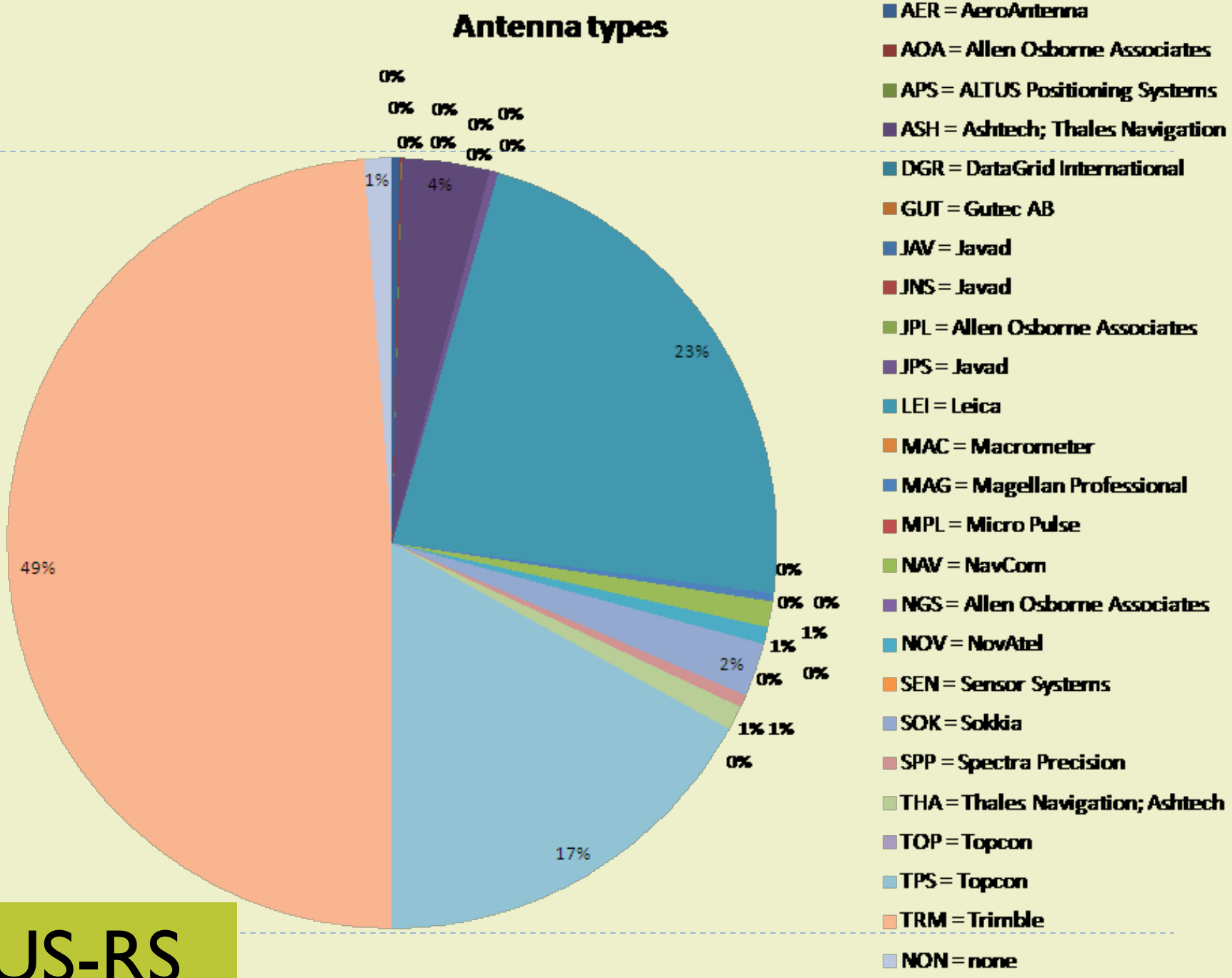

OPUS-RS report format
XML reports
18%
ASCII reports
82%
XML reports
ASCII reports

OPUS-RS



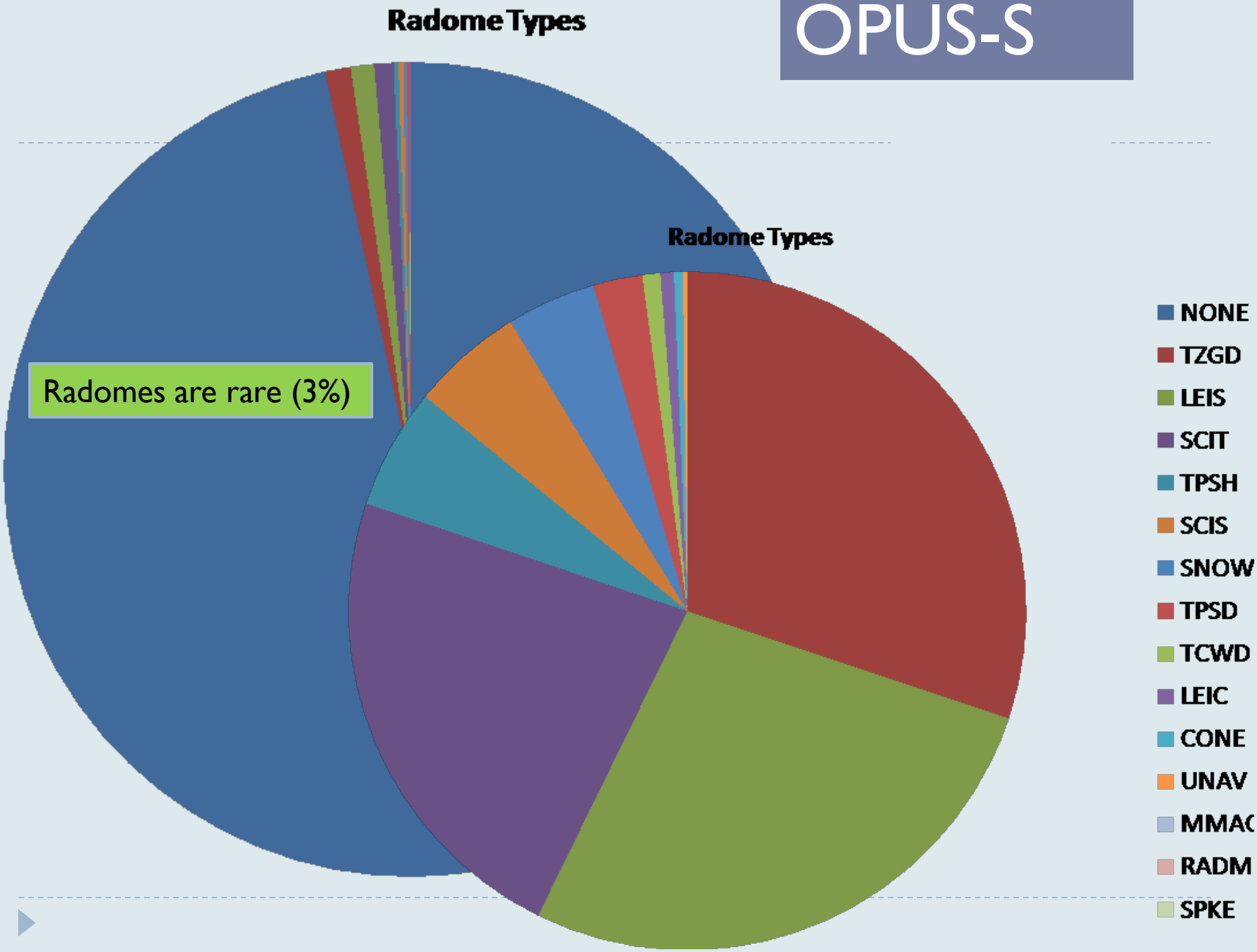
Mostly Trimble antennas

OPUS-S

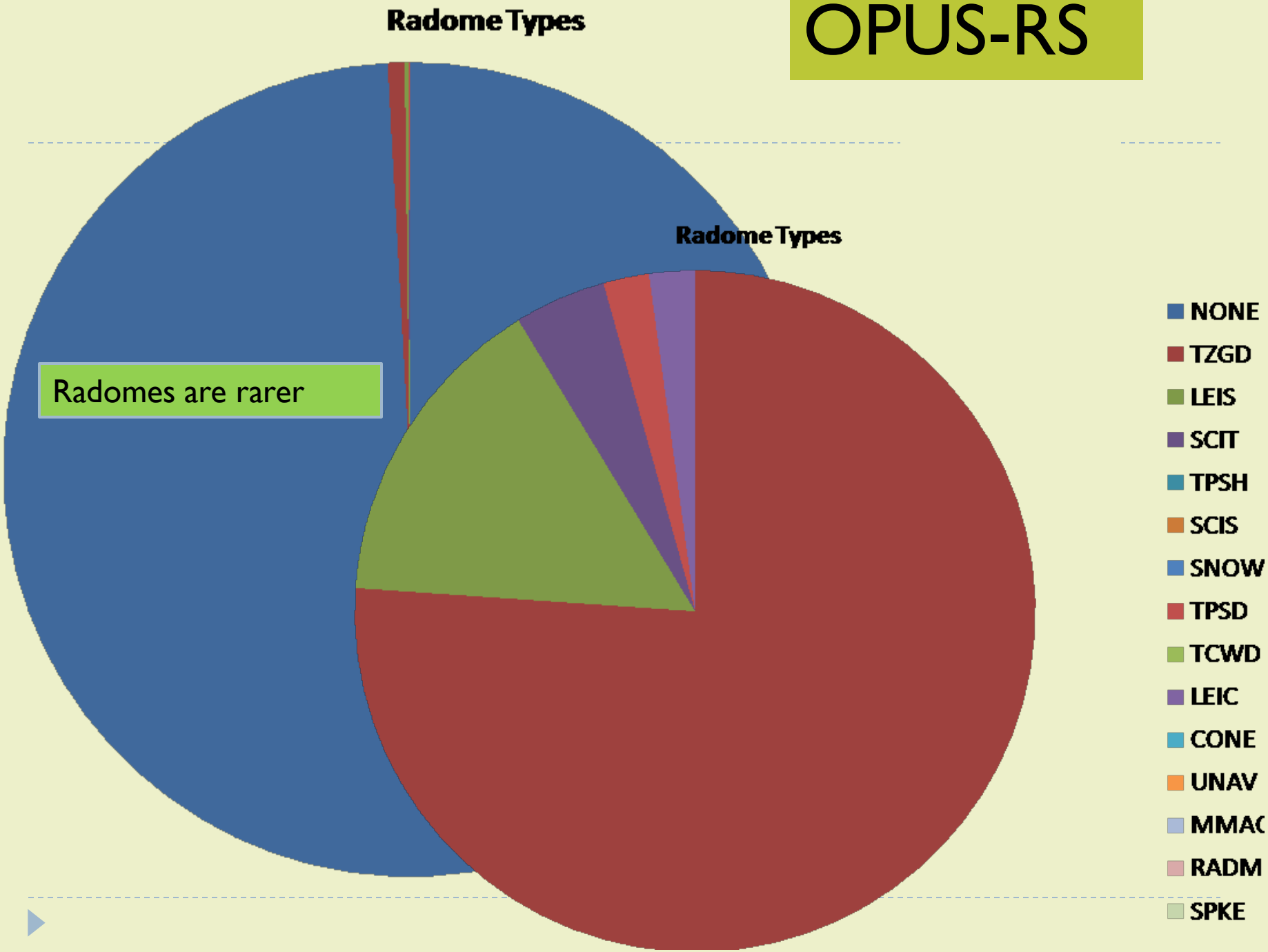

Antenna types
0%
0%
0%
0%
0%
0%
0%
0%
1%
4%
23%
0%
0%
0%
1%
1%
2%
0%
0%
1%
1%
0%
17%
49%
AER = AeroAntenna
AOA = Allen Osborne Associates
APS = ALTUS Positioning Systems
ASH = Ashtech; Thales Navigation
DGR = DataGrid International
GUT = Gutec AB
JAV = Javad
JNS = Javad
JPL = Allen Osborne Associates
JPS = Javad
LEI = Leica
MAC = Macrometer
MAG = Magellan Professional
MPL = Micro Pulse
NAV = NavCom
NGS = Allen Osborne Associates
NOV = NovAtel
SEN = Sensor Systems
SOK = Soldkia
SPP = Spectra Precision
THA = Thales Navigation; Ashtech
TOP = Topcon
TPS = Topcon
TRM = Trimble
NON = none

OPUS-RS

OPUS-S

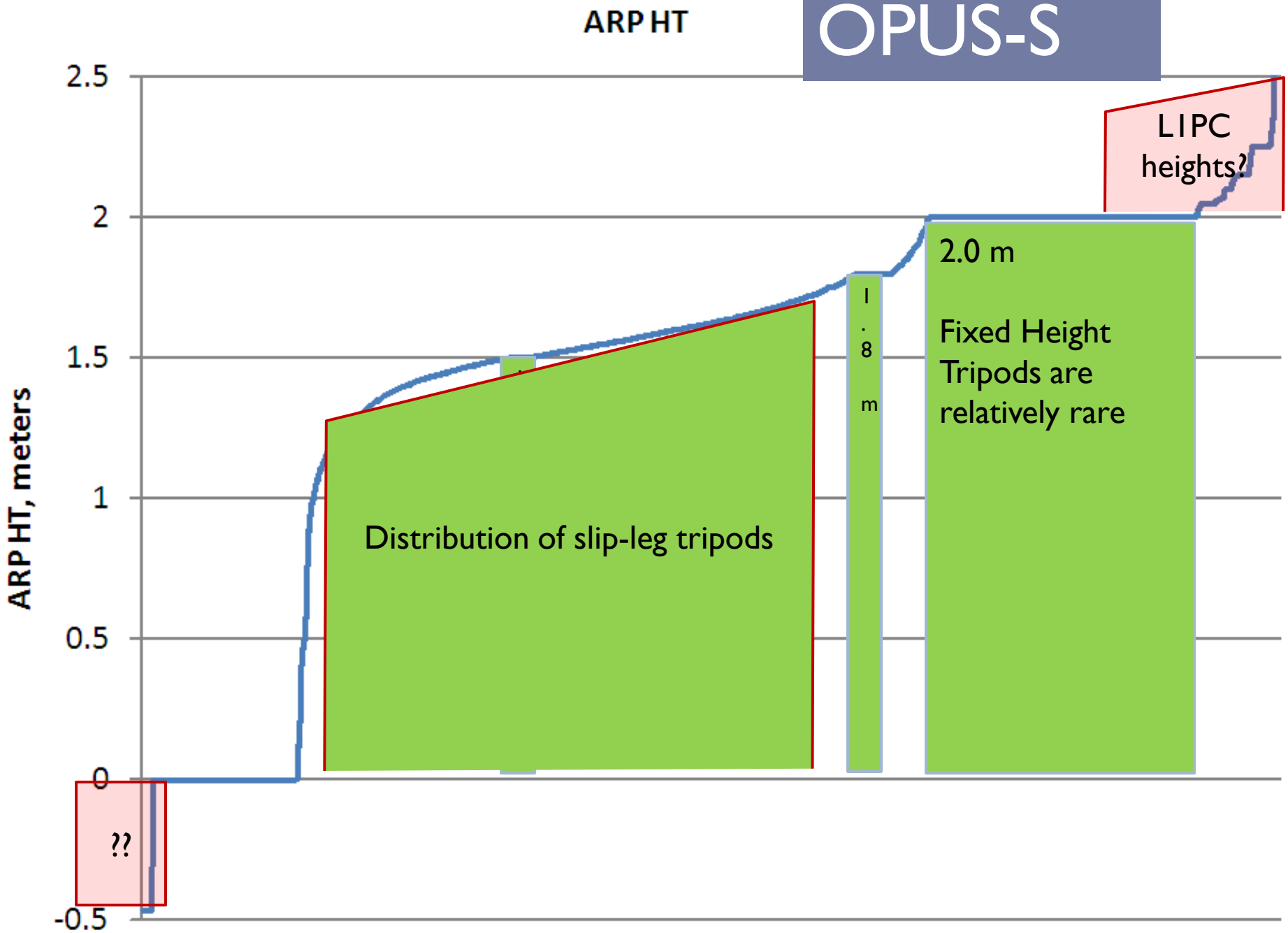

Radome Types
Radomes are rare (3%)
Radome Types
NONE
TZGD
LEIS
SCIT
TPSH
SCIS
SNOW
TPSD
TCWD
LEIC
CONE
UNAV
MMAC
RADM
SPKE

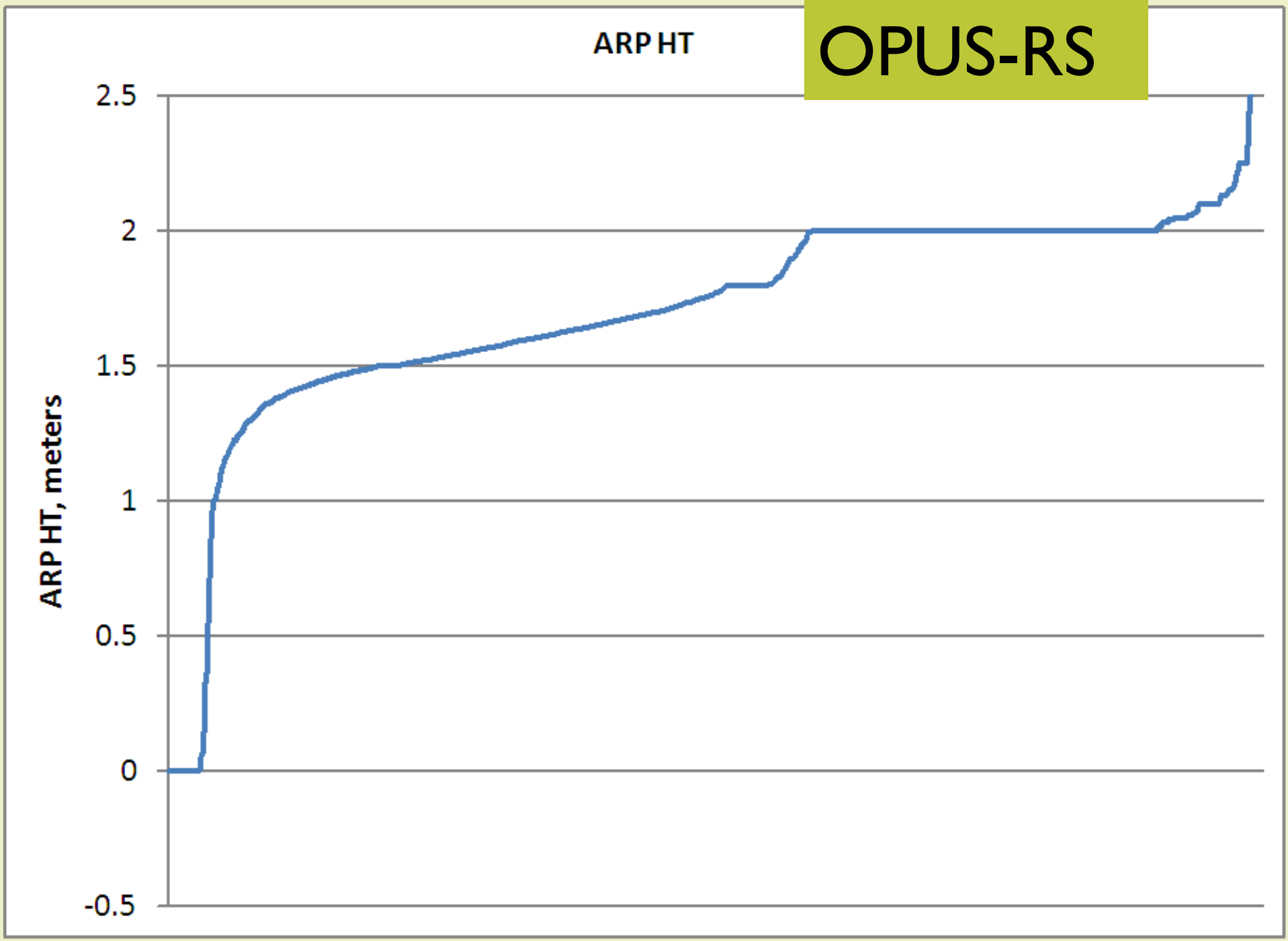
OPUS-RS



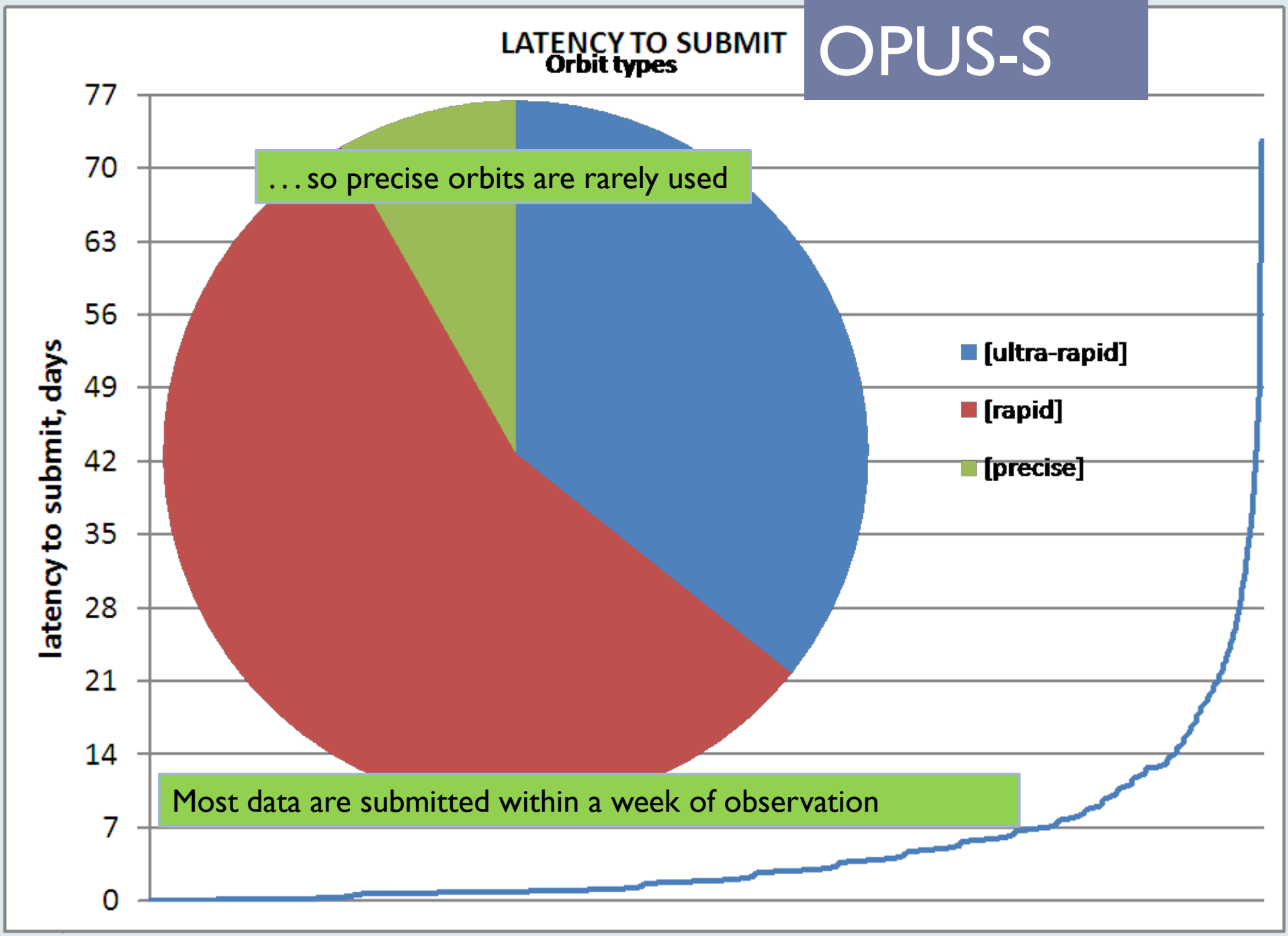
Radomes are rarer

OPUS-S

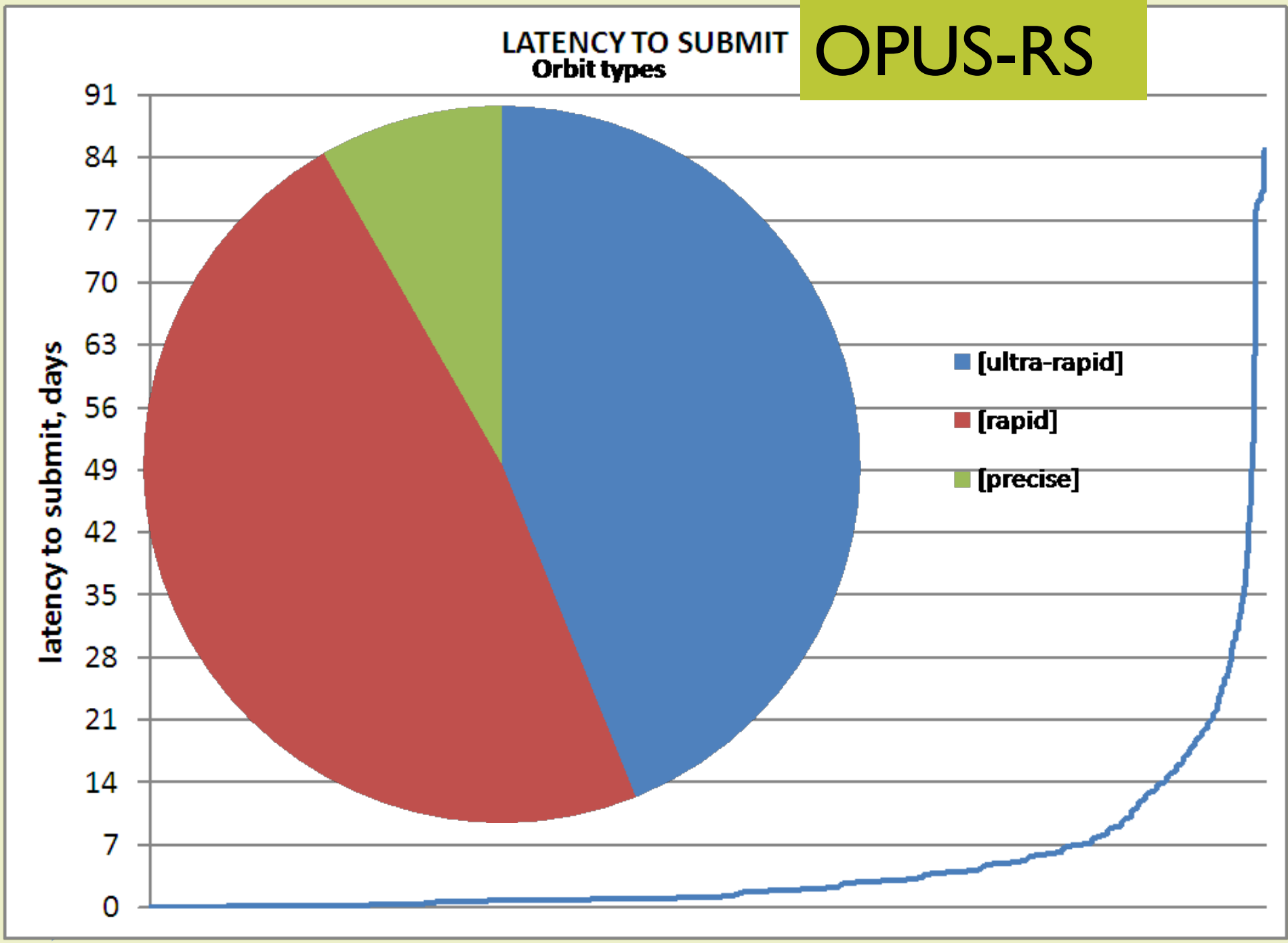

ARP HT
ARP HT, meters
2.5
2
1.5
1
0.5
0
-0.5
LIPC heights?
2.0 m
Fixed Height Tripods are relatively rare
1.8 m
Distribution of slip-leg tripods
??


OPUS-RS
ARP HT
ARP HT, meters
2.5
2
1.5
1
0.5
0
-0.5

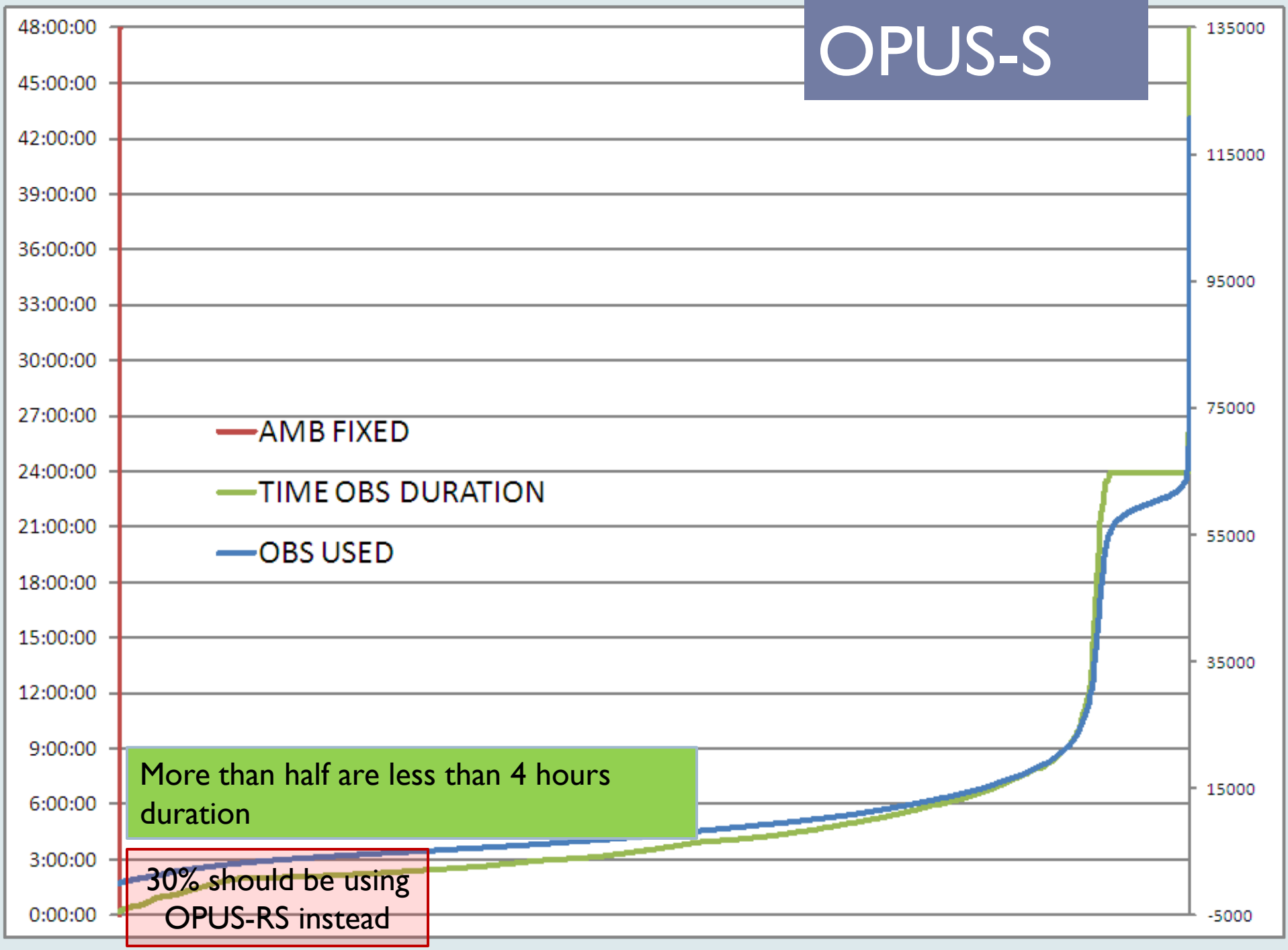
OPUS-S


LATENCY TO SUBMIT
Orbit types
latency to submit, days
77
70
63
56
49
42
35
28
21
14
7
0
[ultra-rapid]
[rapid]
[precise]
. . . so precise orbits are rarely used
Most data are submitted within a week of observation

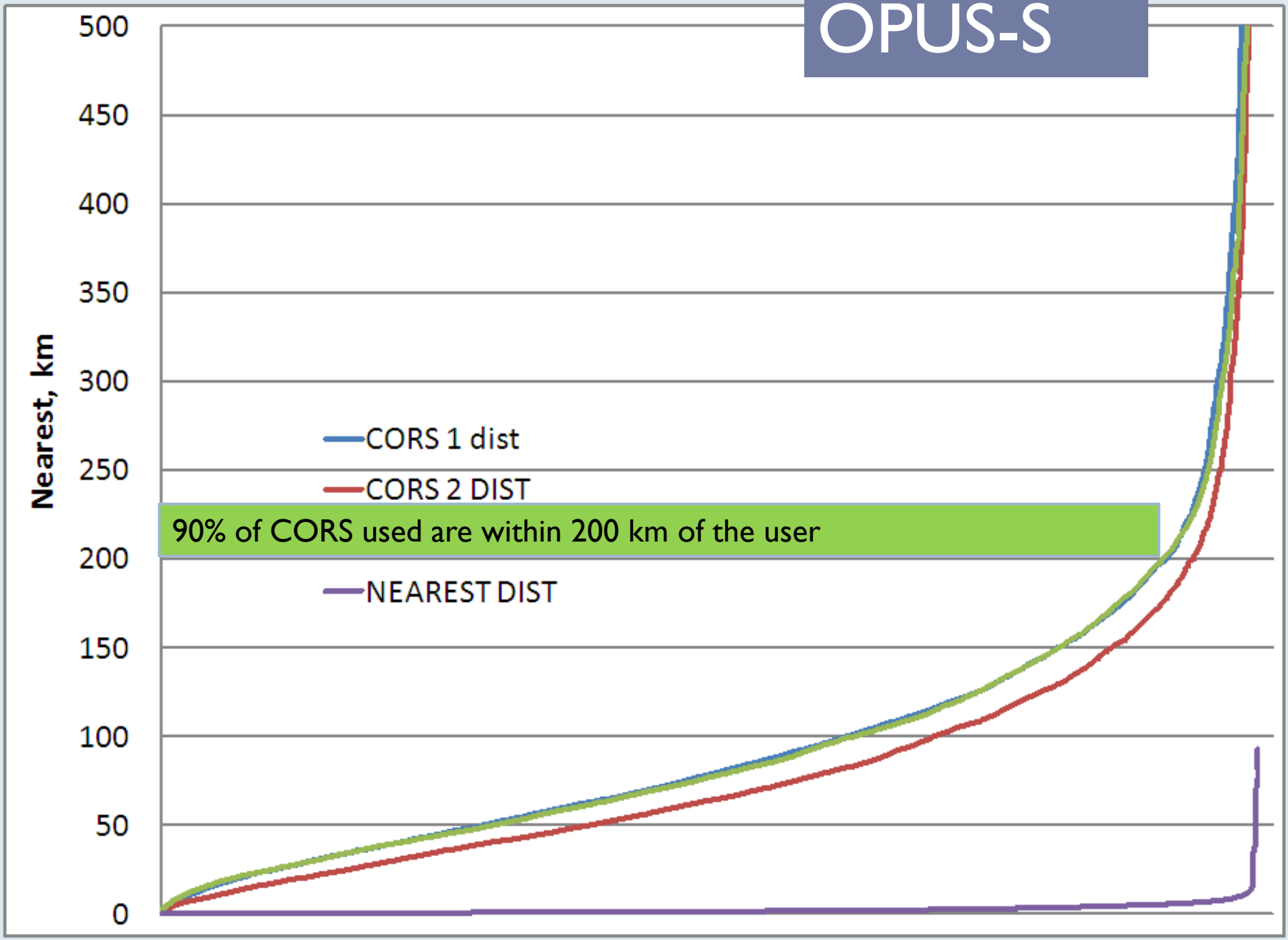
OPUS-RS


LATENCY TO SUBMIT
Orbit types
latency to submit, days
91
84
77
70
63
56
49
42
35
28
21
14
7
0
[ultra-rapid]
[rapid]
[precise]

OPUS-S

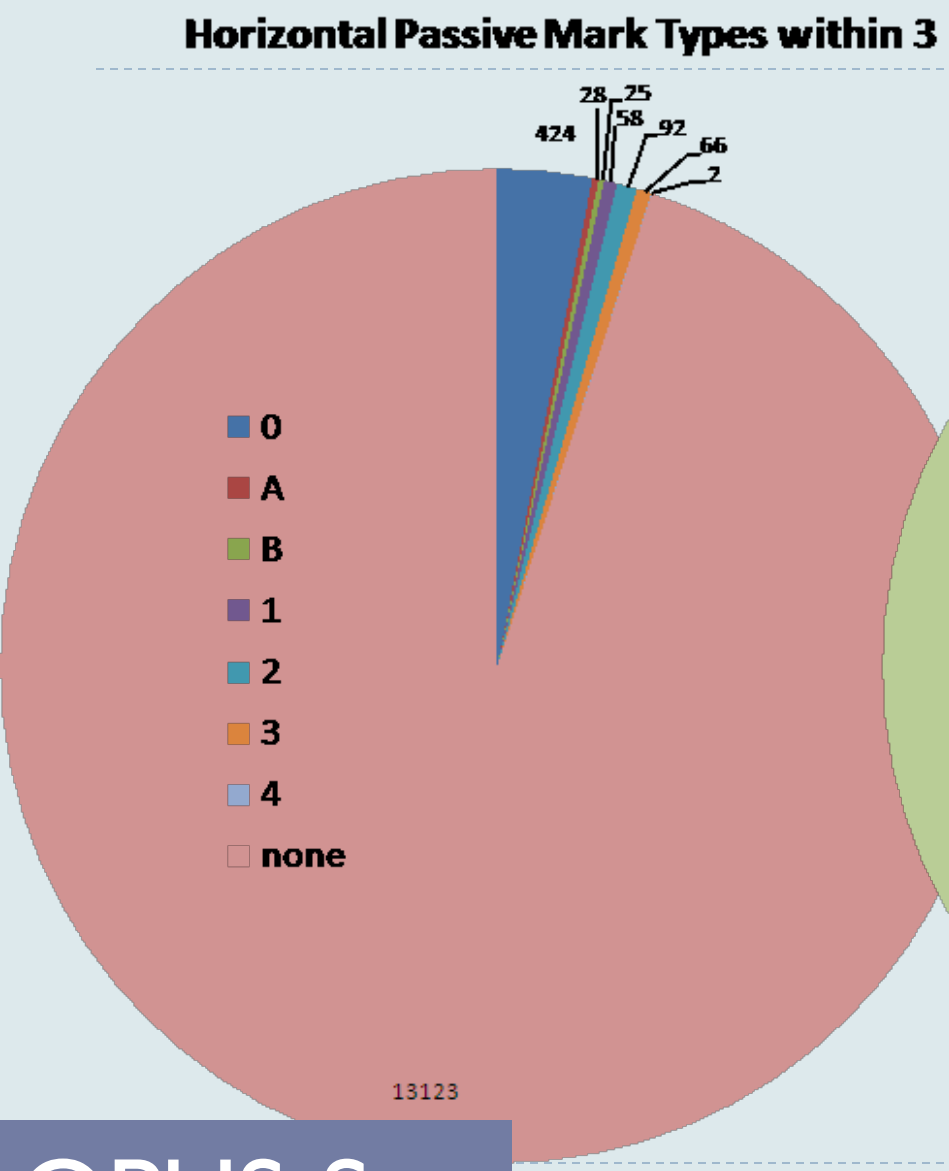

48:00:00
45:00:00
42:00:00
39:00:00
36:00:00
33:00:00
30:00:00
27:00:00
24:00:00
21:00:00
18:00:00
15:00:00
12:00:00
9:00:00
6:00:00
3:00:00
0:00:00
135000
115000
95000
75000
55000
35000
15000
-5000
AMB FIXED
TIME OBS DURATION
OBS USED
More than half are less than 4 hours duration
30% should be using OPUS-RS instead

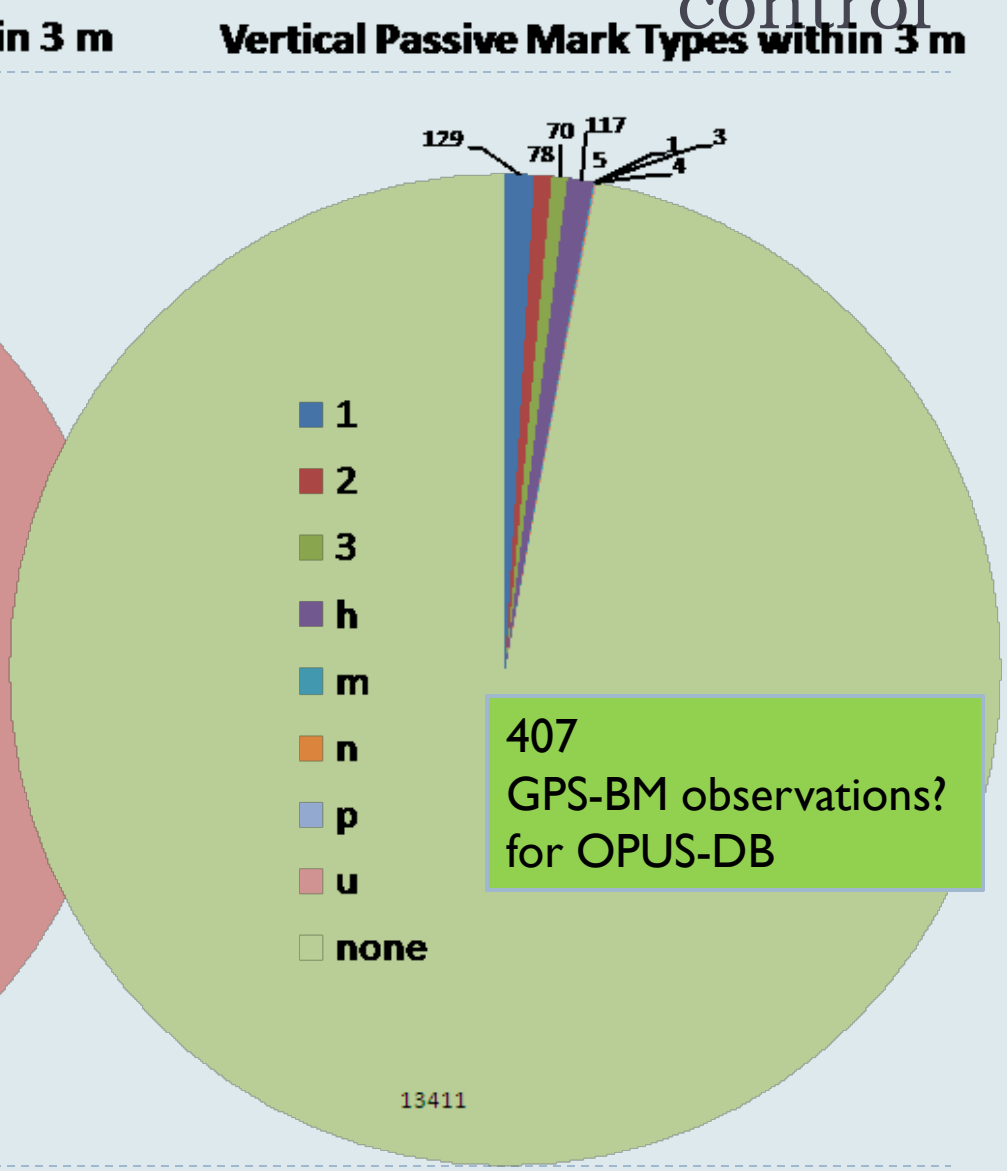
OPUS-S



90% of CORS used are within 200 km of the user

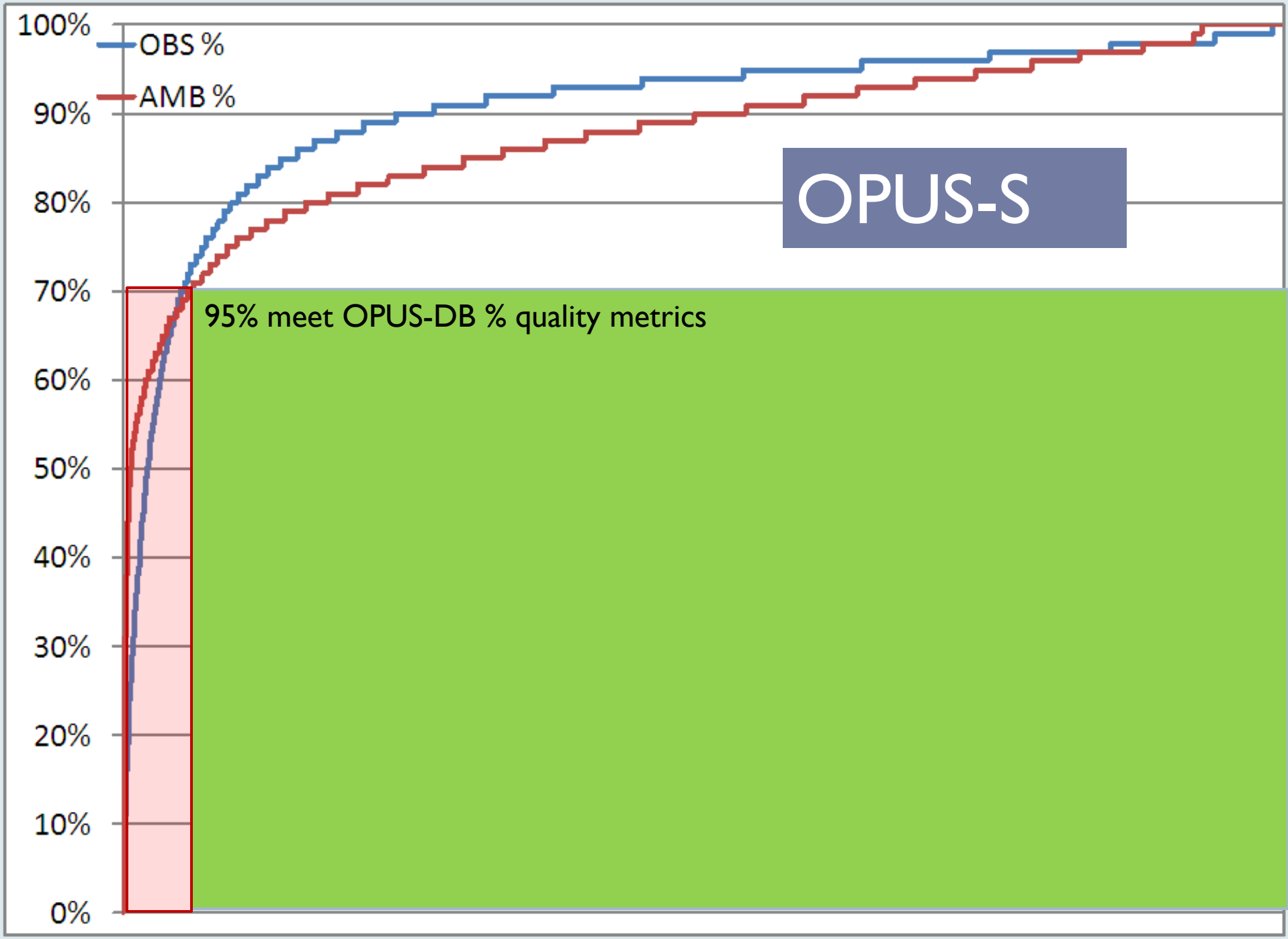
Many users occupy existing NGSIDB passive control

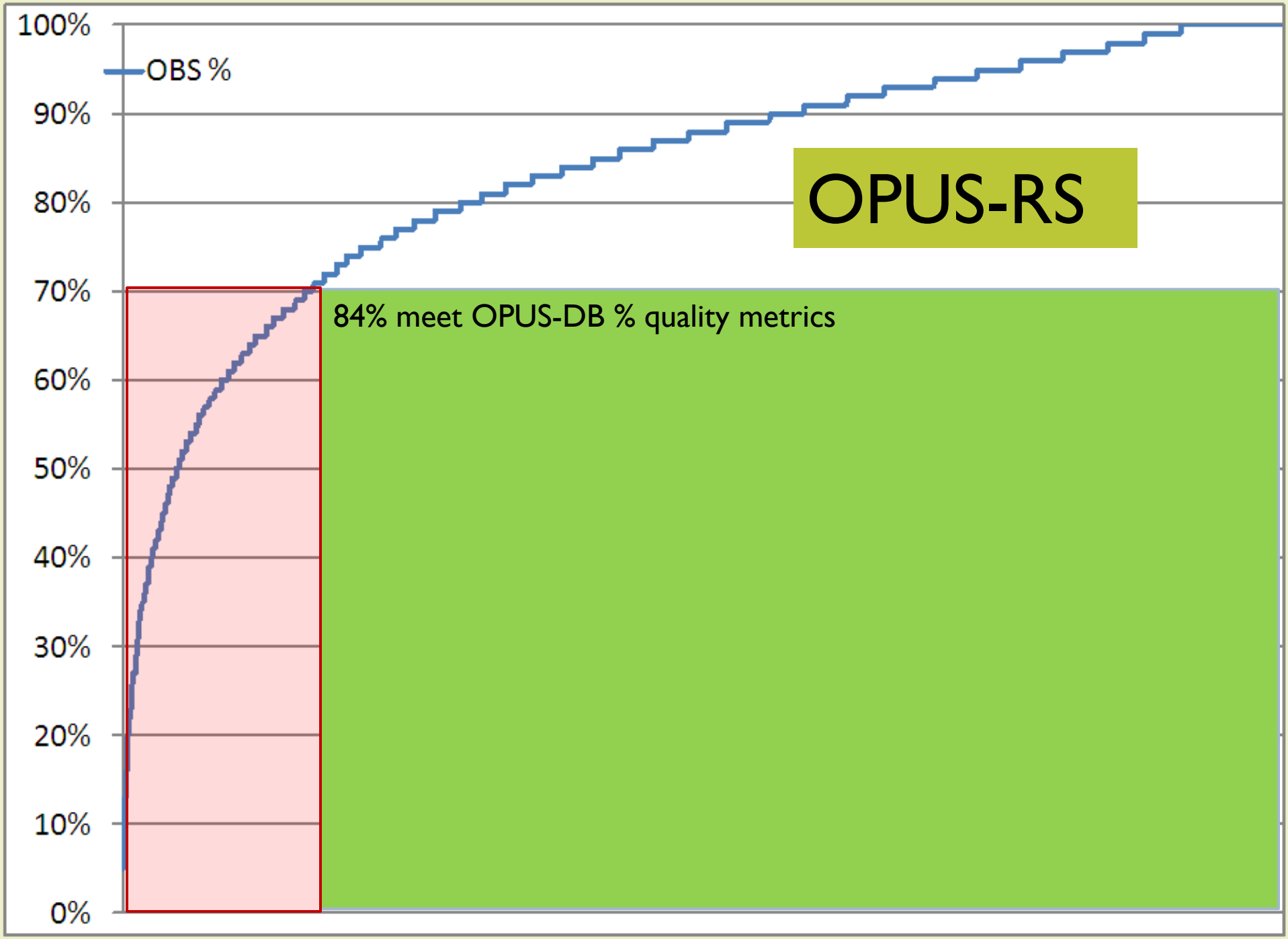


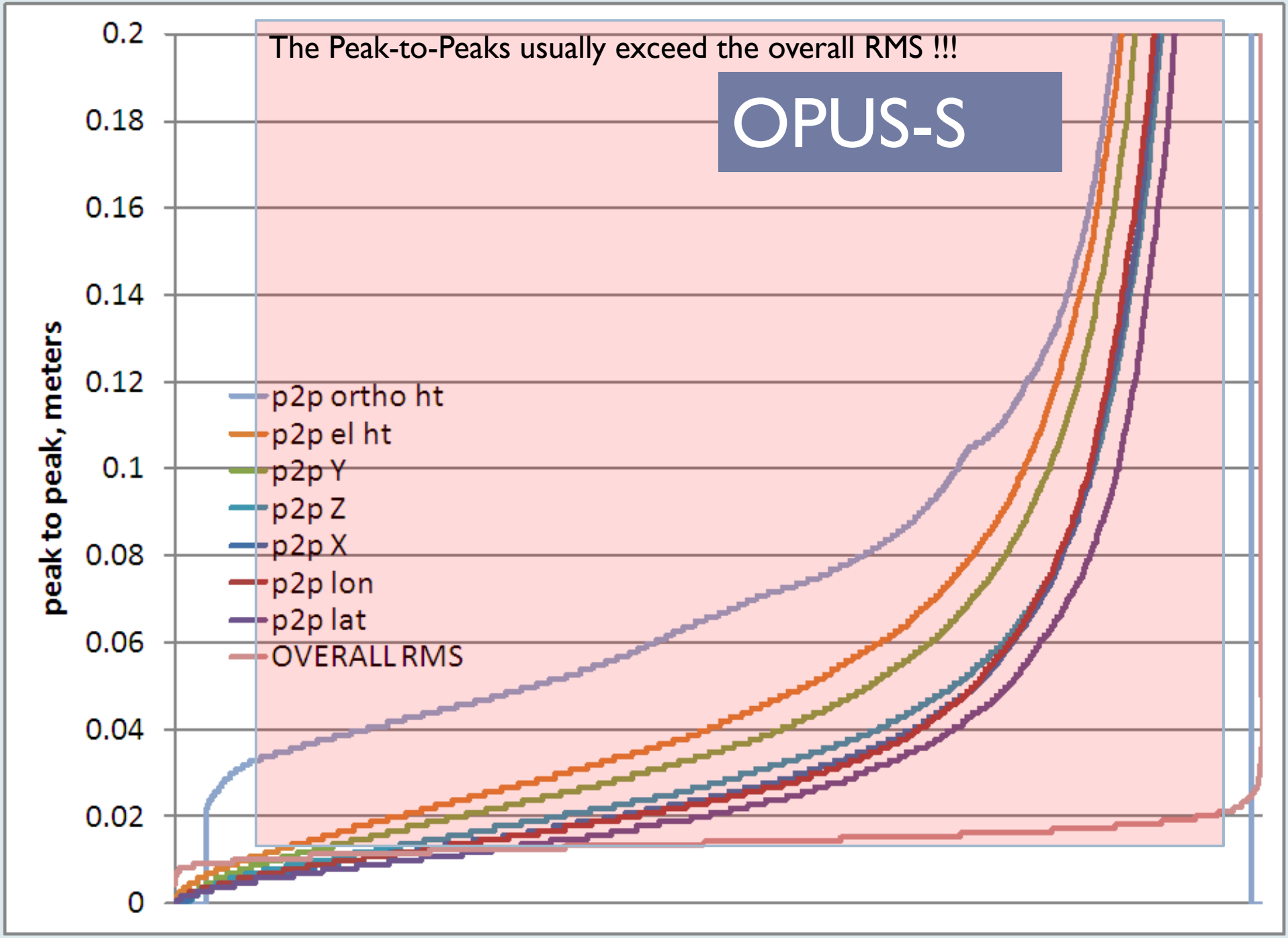


407
GPS-BM observations?
for OPUS-DB

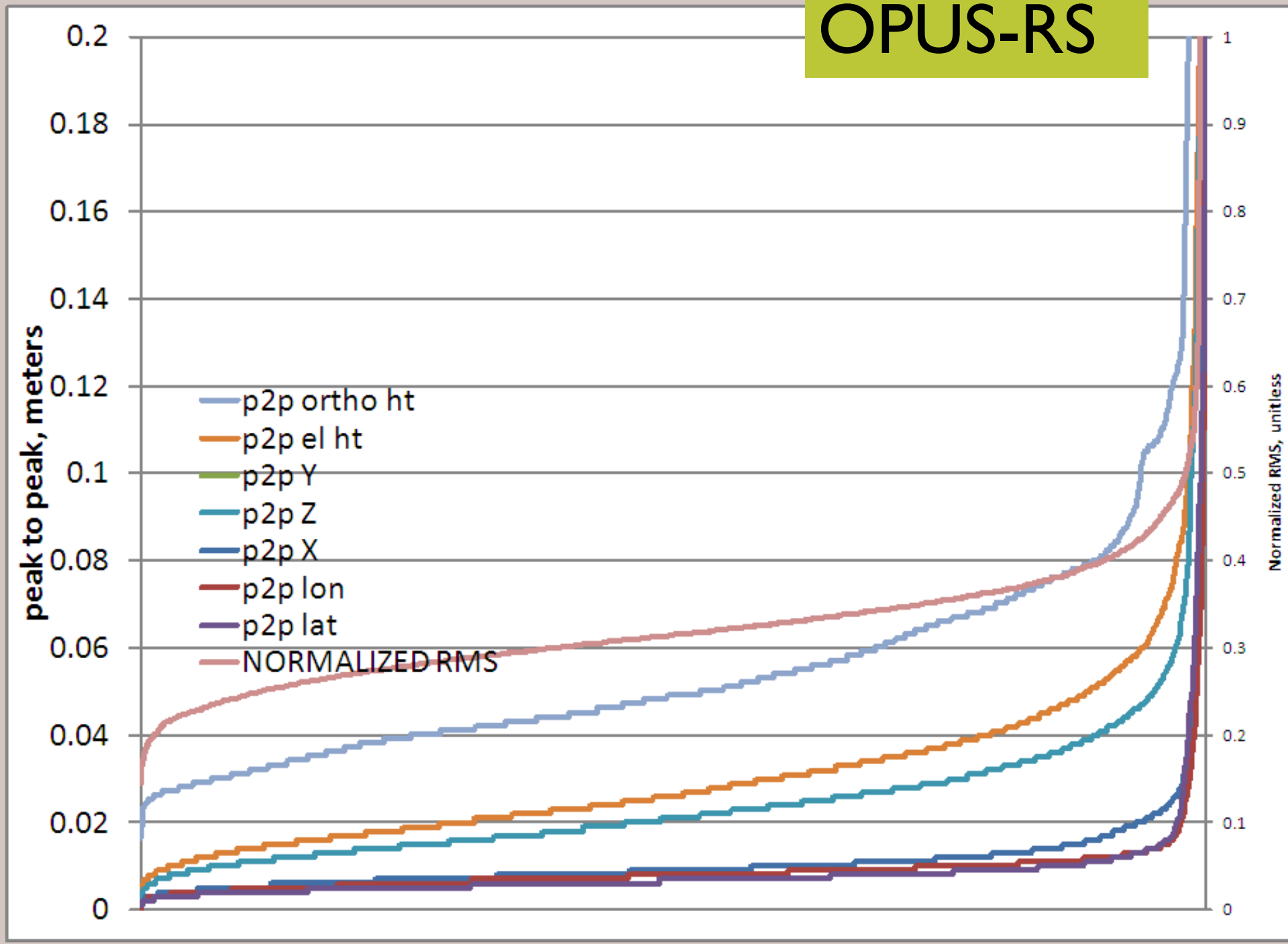
OPUS-S


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
OBS %
AMB %
OPUS-S
95% meet OPUS-DB % quality metrics


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
OBS %
OPUS-RS
84% meet OPUS-DB % quality metrics

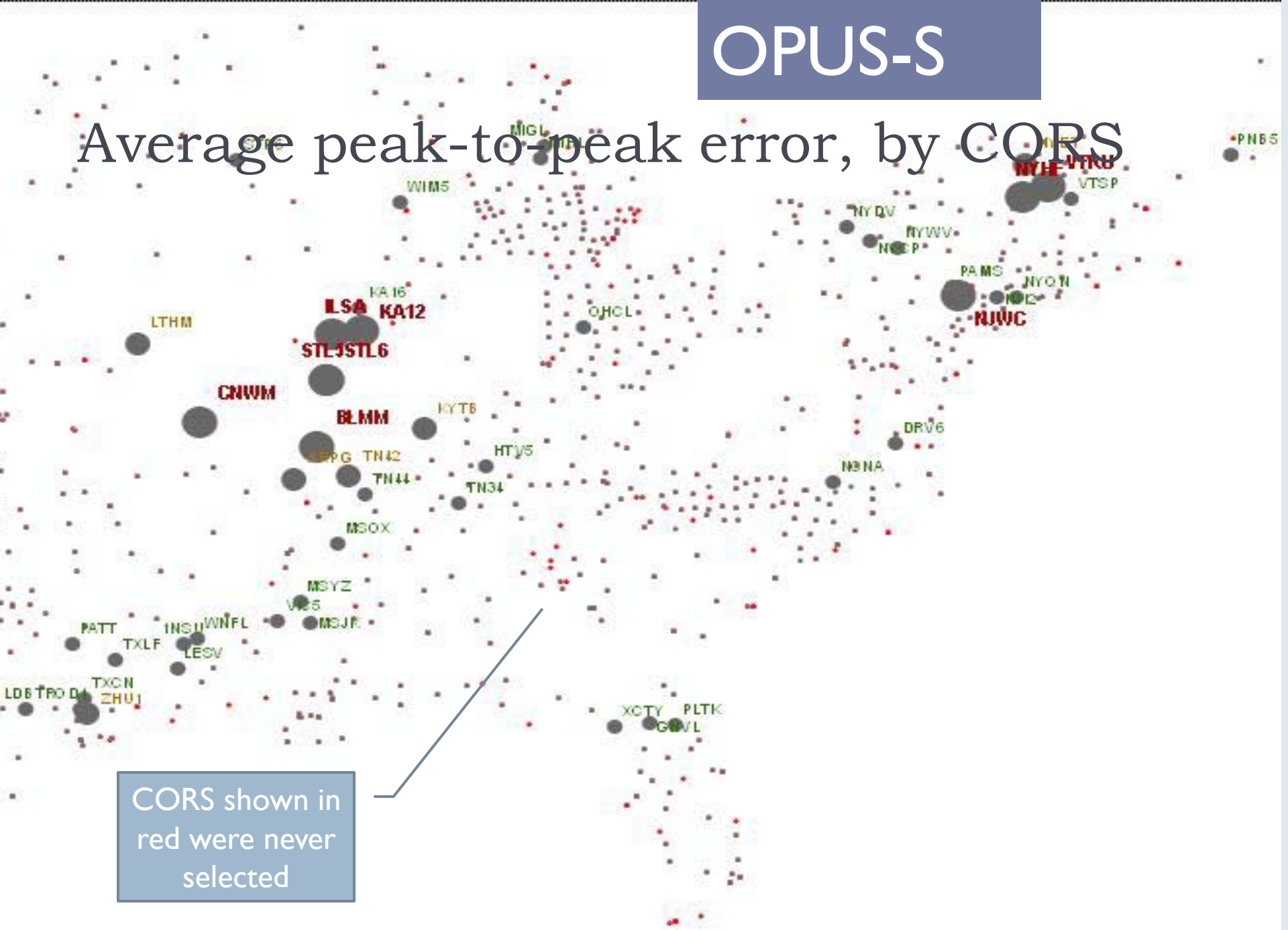

The Peak-to-Peaks usually exceed the overall RMS !!!
OPUS-S
peak to peak, meters
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
p2p ortho ht
p2p el ht
p2p Y
p2p Z
p2p X
p2p lon
p2p lat
OVERALL RMS

OPUS-RS


peak to peak, meters
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Normalized RMS, unitless
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
p2p ortho ht
p2p el ht
p2p Y
p2p Z
p2p X
p2p lon
p2p lat
NORMALIZED RMS

OPUS-S

Average peak-to-peak error, by CORS



CORS shown in red were never selected

Question 3:

What are some pitfalls using OPUS to control small projects? How should QA checking be performed.

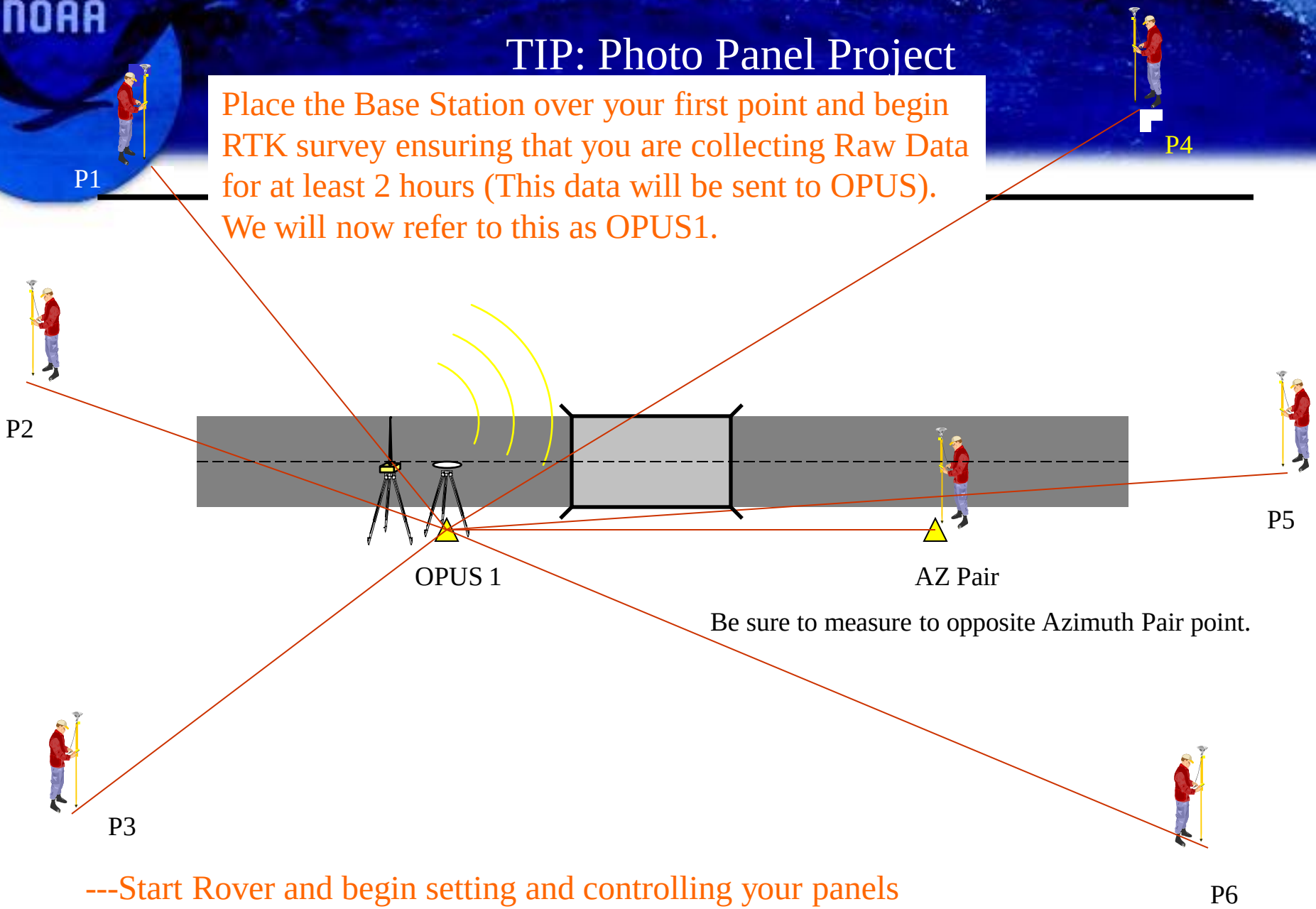
- OPUS guidelines are not available.
- Use cases are not well understood.
- Don’t ignore quality metrics
- North Carolina DOT bridge project

NC DOT example

- Using OPUS and RTK to control a bridge photo project

TIP: Photo Panel Project

Place the Base Station over your first point and begin RTK survey ensuring that you are collecting Raw Data for at least 2 hours (This data will be sent to OPUS). We will now refer to this as OPUS1.

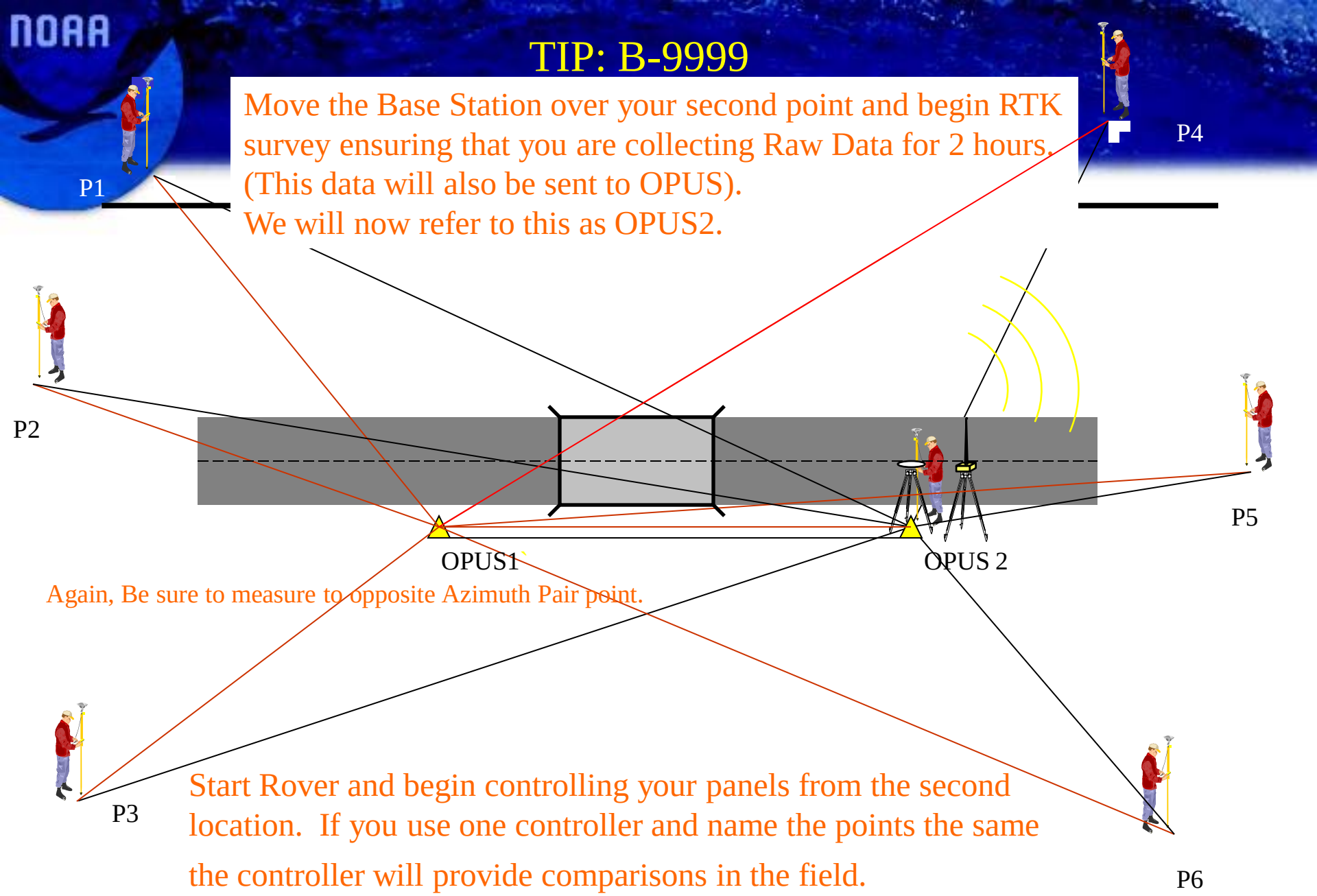


Be sure to measure to opposite Azimuth Pair point.

---Start Rover and begin setting and controlling your panels

TIP: B-9999

Move the Base Station over your second point and begin RTK survey ensuring that you are collecting Raw Data for 2 hours. (This data will also be sent to OPUS).
We will now refer to this as OPUS2.



Again, Be sure to measure to opposite Azimuth Pair point.

Start Rover and begin controlling your panels from the second location. If you use one controller and name the points the same the controller will provide comparisons in the field.

Field Work is now complete.

The following steps need to be taken to finish the process:

Office Process

- Download the Raw Data and RTK files
- Upload the 2 hr+ base files to:
- http://www.ngs.noaa.gov/OPUS/
- Receive the results from OPUS via email in minutes

Continued…

- Update the First base position with the coordinates provided by OPUS1
- Recompute your RTK data.
  After recomputing, everything in the rover file is corrected relative to the first base location (OPUS1)

Continued …

- Compare the OPUS2 position to what was derived from OPUS1/RTK session. This serves as another check.
- Coordinates can now be utilized as needed

Other Uses

- Test data viability
- Use as a check of your own processing
- Supplement the Field Log: if a data file name was entered incorrectly by an observer—Use OPUS to obtain particulars of the data set, start/end times, where and when data was collected.

Question 4:

When should OPUS-S or RS not be used or avoided?

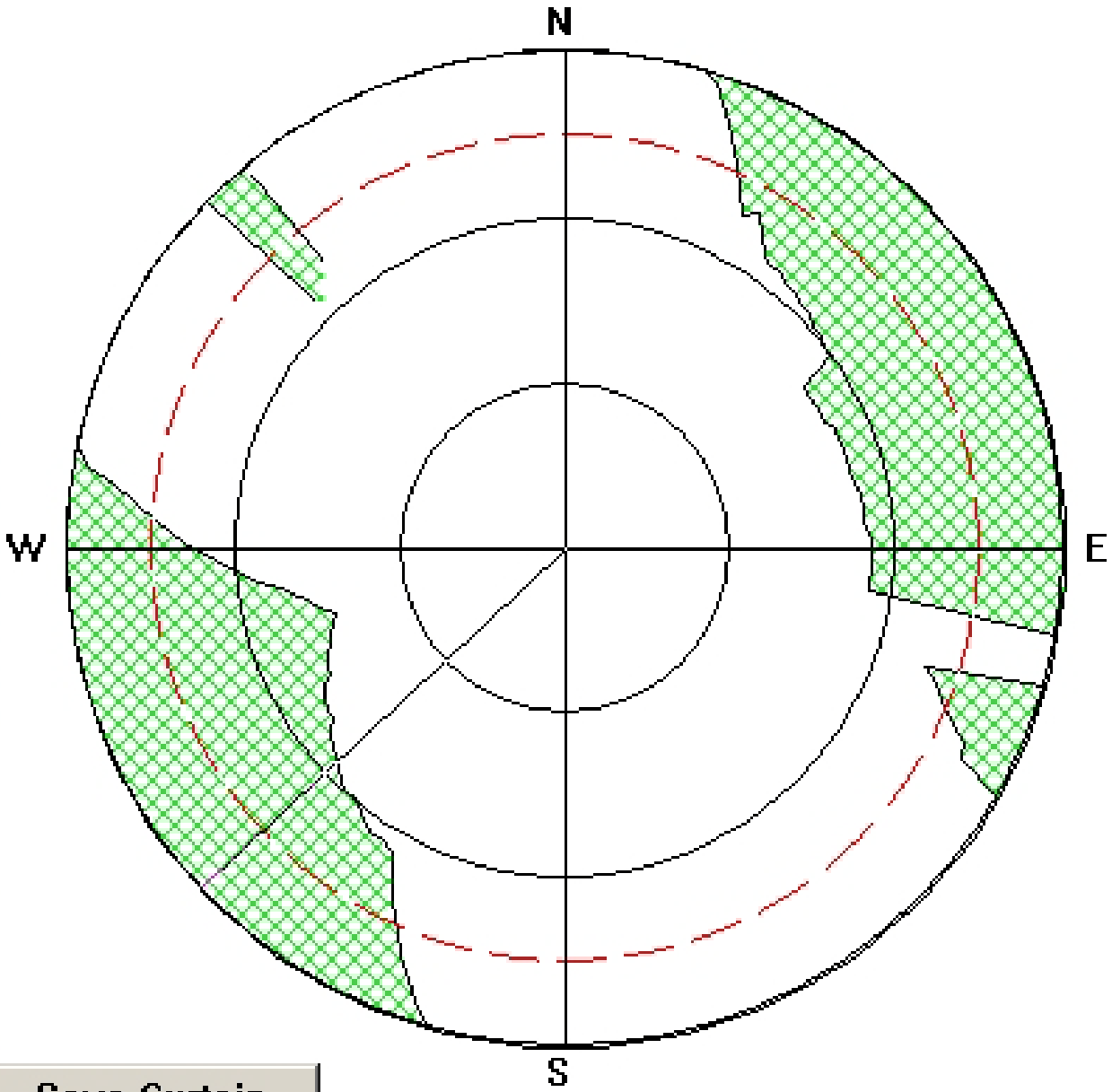
- See disclaimer: *The numerical values for this position solution have satisfied the quality control criteria of the National Geodetic Survey. The contributor has verified that the information submitted is accurate and complete.*
- Connect to CORS vs. adjacent passive network
- In remote areas use longer observations, better orbits
- Independent observations: Avoid repeating under same conditions (equipment, wx, time)

To improve accuracy and reliability:

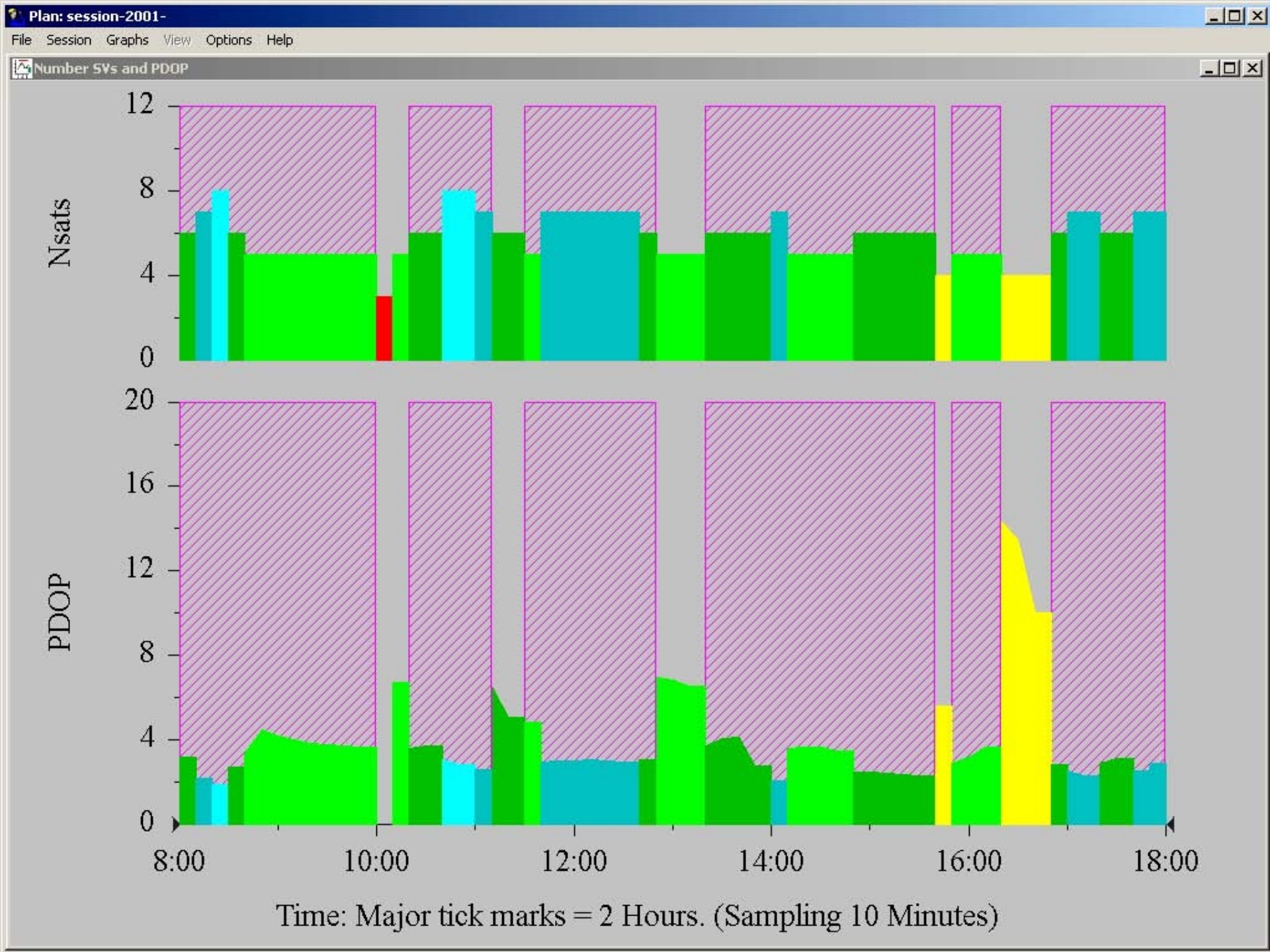
- Collect observations for more than 15 minutes
- Perform multiple observing sessions
- Avoid conditions that perturb the GPS signal—unsettled weather, solar flares, multipath (nearby reflective surfaces)
- Pre-plan your occupations!

Curtain editor - Raleigh Dur

File Edit Options Help



Save Curtain


Plan: session-2001-
File Session Graphs View Options Help
Number SVs and PDOP
Nsats
12
8
4
0
PDOP
20
16
12
8
4
0
8:00
10:00
12:00
14:00
16:00
18:00
Time: Major tick marks = 2 Hours. (Sampling 10 Minutes)

NOAA Technical Memorandum NOS NGS-58

GUIDELINES FOR ESTABLISHING GPS-DERIVED ELLIPSOID HEIGHTS
(STANDARDS: 2 CM AND 5 CM)
VERSION 4.3

David B. Zilkoski
Joseph D. D'Onofrio
Stephen J. Frakes

Silver Spring, MD

November 1997

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Ocean Service / National Geodetic Survey

Available "On-Line" at the NGS Web Site:

www.ngs.noaa.gov

Comparison of 30 Minute Solutions - Precise Orbit; Hopfield (0); IONOFREE
(30 Minute solutions computed on the hour and the half hour)

MOLA to RV22 10.8 Km

Day 264	dh (m)	Hours Diff.	Day 265	dh (m)	Day 264 minus Day 265 (cm)	* diff >2 cm	Mean dh (m)	Mean dh minus "Truth" (cm)	* diff >2 cm
14:00-14:30	-10.281	27hrs	17:00-17:30	-10.279	-0.2		-10.280	-0.5	
14:30-15:00	-10.278	27hrs	17:30-18:00	-10.270	-0.8		-10.274	0.2	
15:00-15:30	-10.281	27hrs	18:00-18:30	-10.278	-0.3		-10.280	-0.4	
15:30-16:00	-10.291	27hrs	18:30-19:00	-10.274	-1.7		-10.283	-0.7	
16:00-16:30	-10.274	27hrs	19:00-19:30	-10.274	0.0		-10.274	0.2	
16:30-17:00	-10.287	27hrs	19:30-20:00	-10.276	-1.1		-10.282	-0.6	
17:00-17:30	-10.279	27hrs	20:00-20:30	-10.261	-1.8		-10.270	0.6	
17:30-18:00	-10.270	27hrs	20:30-21:00	-10.251	-1.9		-10.261	1.5	
18:00-18:30	-10.277	21hrs	15:00-15:30	-10.270	-0.7		-10.274	0.2	
18:30-19:00	-10.271	21hrs	15:30-16:00	-10.276	0.5		-10.274	0.2	
19:00-19:30	-10.277	21hrs	16:00-16:30	-10.278	0.1		-10.278	-0.2	
19:30-20:00	-10.271	21hrs	16:30-17:00	-10.286	1.5		-10.279	-0.3	
20:00-20:30	-10.259	18hrs	14:00-14:30	-10.278	1.9		-10.269	0.7	
20:30-21:00	-10.254	18hrs	14:30-15:00	-10.295	4.1	*	-10.275	0.1	
							"Truth"		
14:00-21:00	-10.275		14:00-21:00	-10.276	0.1		-10.276		

Two Days/Same Time

-10.254
-10.251 > -10.253

Difference = 0.3 cm

"Truth" = -10.276

Difference = 2.3 cm

Two Days/ Different Times

-10.254
-10.295 > -10.275

Difference = 4.1 cm

"Truth" = -10.276

Difference = 0.1 cm

Question 5:

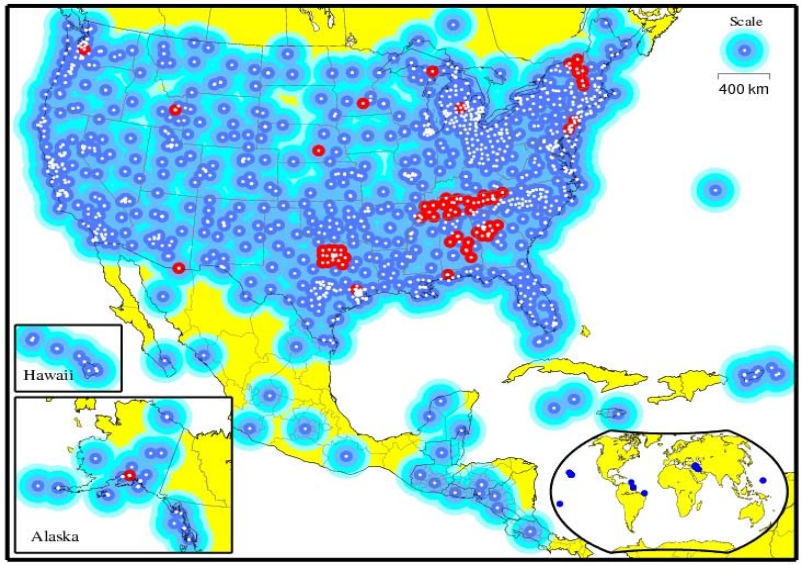
Will OPUS incorporate GNSS (non GPS) satellites into future solutions?

- Yes. GLONASS upgrade underway (non-trivial)

Just Around the Corner

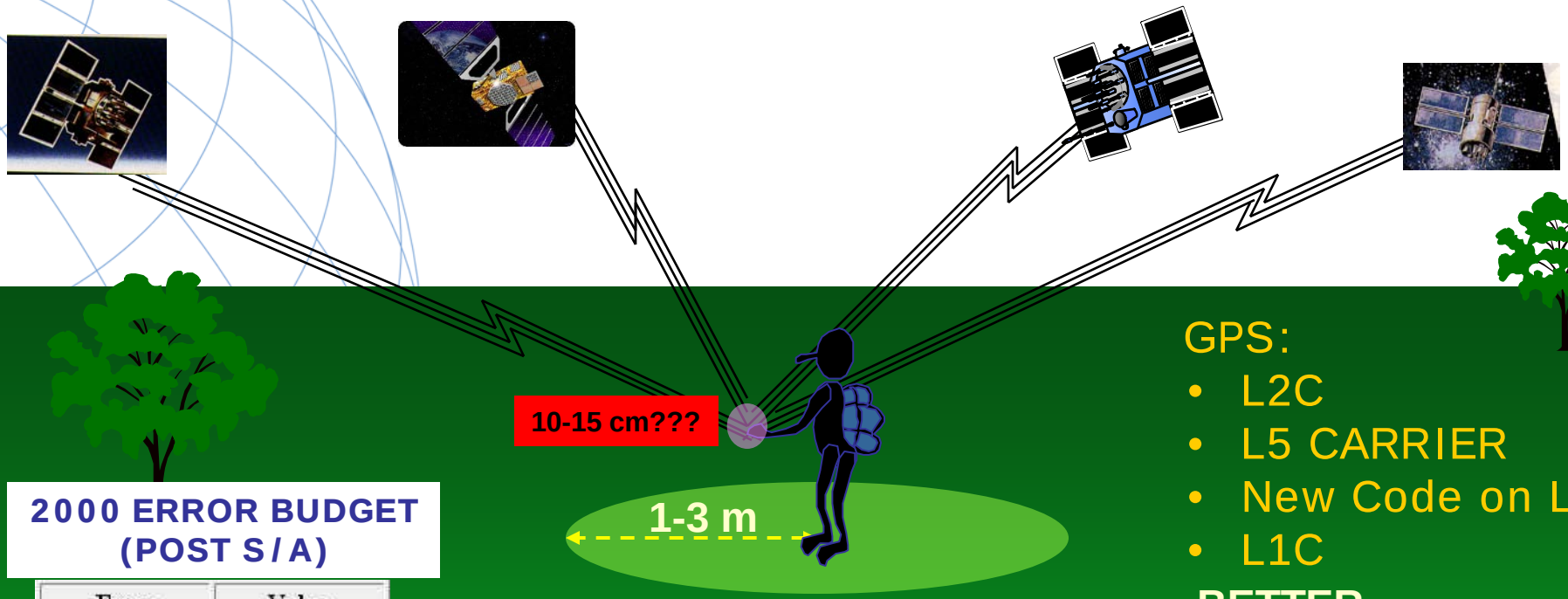
Within the next 12 months, the CORS system will:

- Provide GPS L2C data
- Provide GLONASS data
- Broadcast GNSS data via the Internet in real-time (on an experimental basis). (For selected sites only.)



Red dots identify locations of CORS sites that collect both GPS and GLONASS data.

STANDALONE POSITIONING: BY 2017?



2000 ERROR BUDGET (POST S/A)

Error	Value
Ionosphere	4.0 meters
Clock	2.1 meters
Ephemeris	2.1 meters
Troposphere	0.7 meters
Receiver	0.5 meters
Multipath	1.0 meter
Total	**10.4 meters**

GLONASS ENHANCEMENTS
EUROPEAN UNION - GALILEO
CHINA – COMPASS/BEIDOU

= 115 SATELLITES?

GPS:

- L2C
- L5 CARRIER
- New Code on L5
- L1C

BETTER RESISTANCE TO INTERFERENCE

FASTER AMBIGUITY RESOLUTION

AUGMENTED CODE APPLICATIONS

Question 6 (part 1):

Review recent changes and any proposed changes to OPUS processing rules.

- OPUS evolves regularly (lab project)
- Public change log is not maintained.
- OPUS moving into configuration management
- OPUS-S duration limit imposed (> 2 hours)
- OPUS datasheet quality metrics relaxed

- New features launch at beta.ngs.noaa.gov
- GEOID09 + geoid selection option
- OPUS best 3-of-5 CORS used

Question 6 (part 2):

Review measuring antenna heights to the ARP and relative and absolute calibrations.

- Antenna type and height, the weak link

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

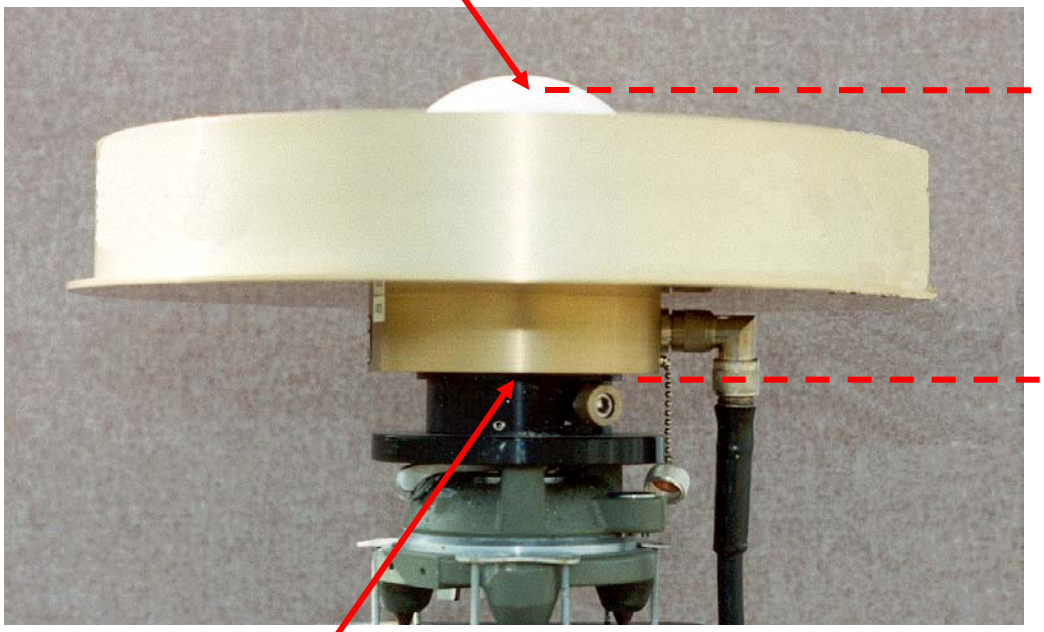
The ARP is almost always the center of the bottom-most, permanently attached, surface of the antenna.

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

http://www.ngs.noaa.gov/ANTCAL/

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

The antenna phase centers are located somewhere around here.



phase ctr.

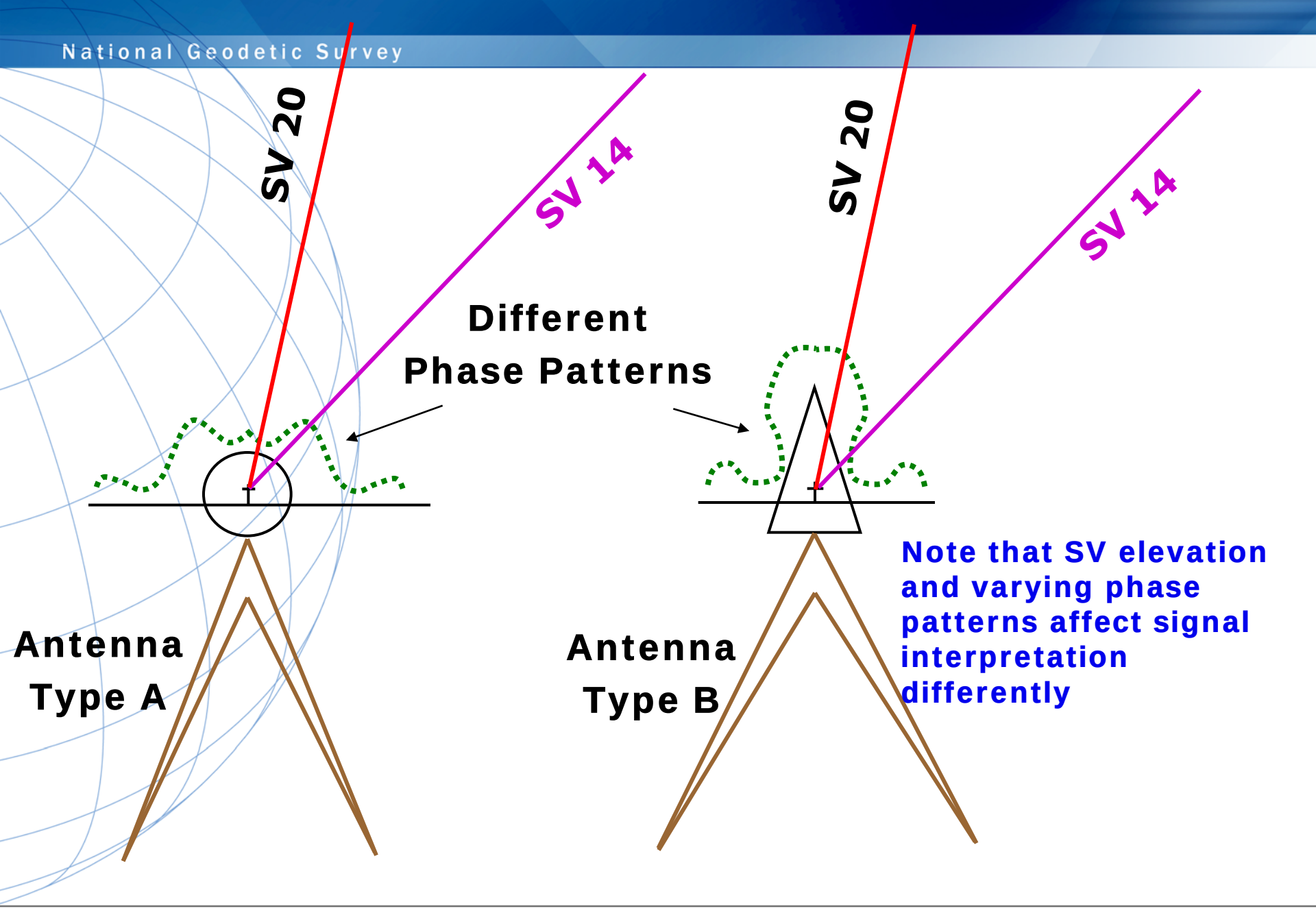
The antenna offsets are the distance between the phase centers and the ARP

ARP

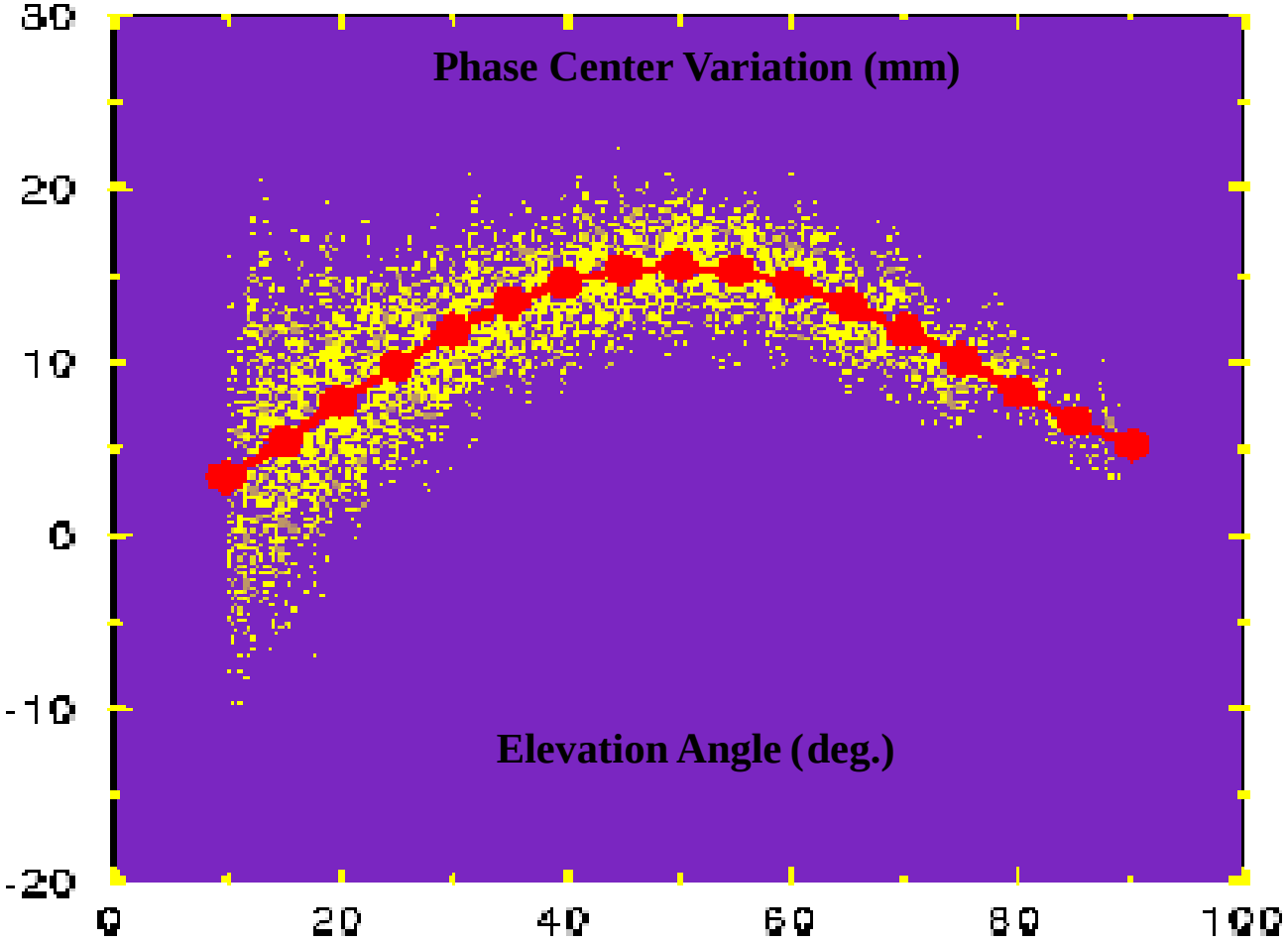
You do not need to know these offsets. They are passed to the processing software through the antenna type

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!


SV 20
SV 14
Different
Phase Patterns
Antenna
Type A
SV 20
SV 14
Antenna
Type B
Note that SV elevation and varying phase patterns affect signal interpretation differently

ELECTRONIC PHASE CENTER

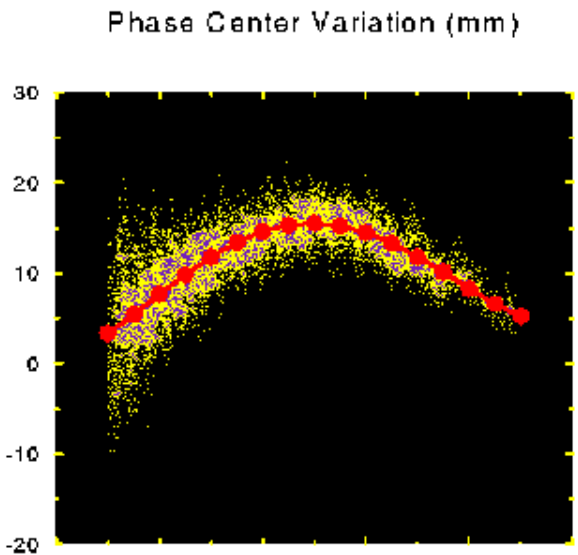


GPS Antenna Calibration

Calibrated Antennas:

- AeroAntenna
- Allen Osborne Associates
- Ashtech
- Javad
- Leica
- Macrometer
- Micro Pulse
- NavCom
- NovAtel
- Sensor Systems
- Sokkia
- Spectra Precision
- Thales Navigation
- Topcon
- Trimble
- GPS Block II A Satellite

Antenna testing facility in Corbin, VA



Antenna Calibration Resources

- Calibration Format Information
- *GPS Antenna Calibration at the National Geodetic Survey* [PDF Version] *by Gerald L. Mader*

- *Complete Relative Antenna Calibration Results*
- *Complete Absolute Antenna Calibration Results*

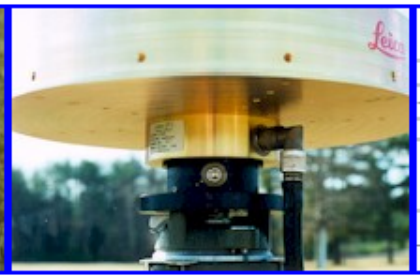
- *Leica SR399 Modification History*

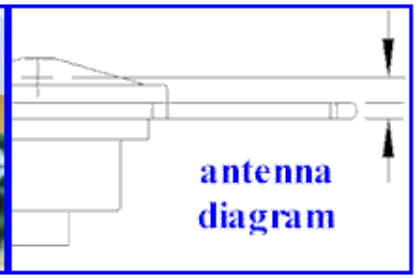
Leica Antennas

This page is maintained by NGS Software Requests

updated:03/10/05.07:27:03

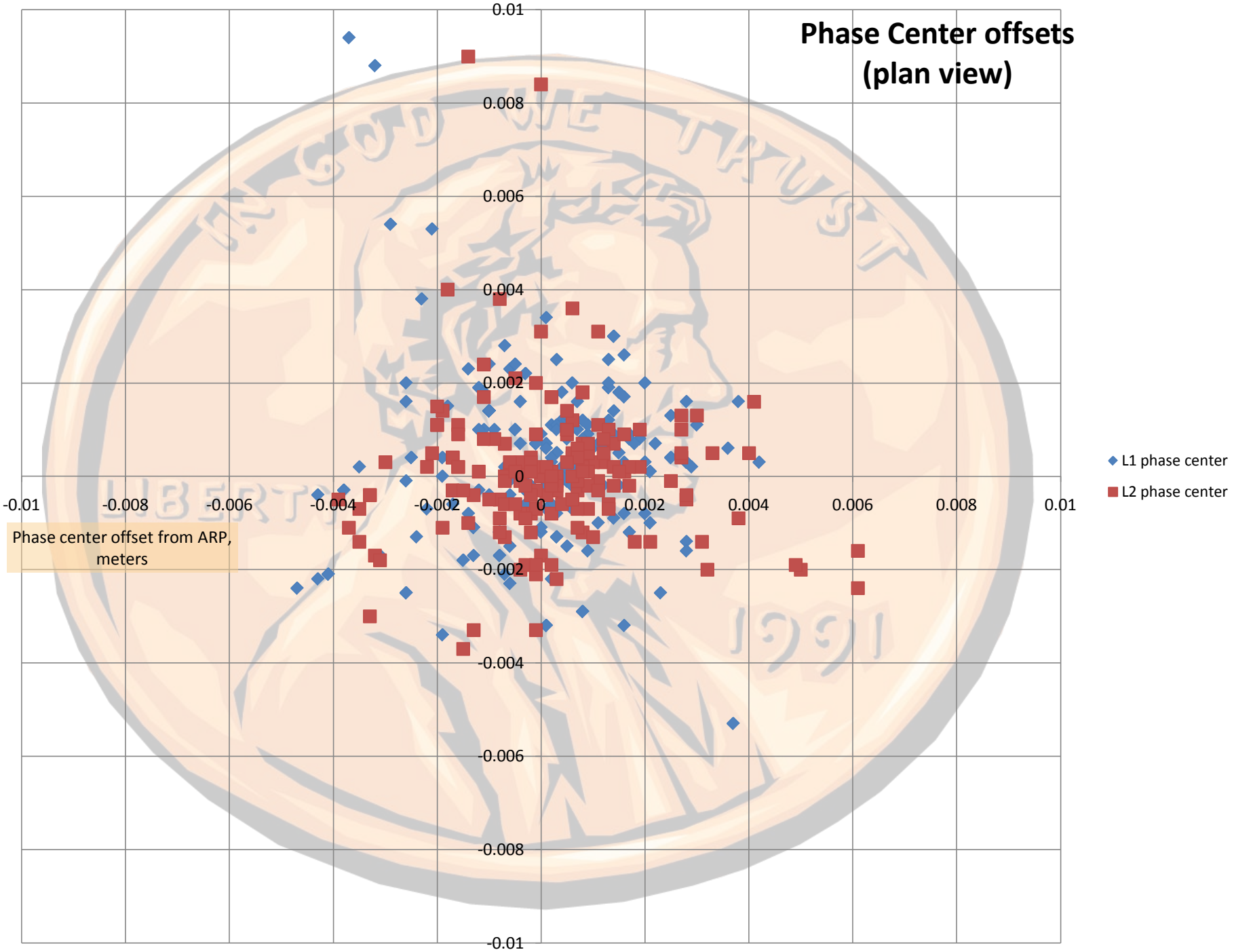
```
LEIAT504              D/M element, chokerings, -radome          NGS (  2) 99/02/05
        .3        -.3      109.3
    .0    .0   -.1   -.1    .0    .0    .0    .1    .1    .1
    .1    .2    .2    .3    .4    .5    .6    .0    .0
       1.1        1.1      128.2
    .0   -.1   -.1   -.1    .0    .0    .0    .0    .0   -.1
   -.2   -.2   -.3   -.3   -.2   -.1    .3    .0    .0
RMS MM (1 SIGMA)  2  MEASUREMENTS
        .6         .2         .6
    .0    .0    .1    .1    .1    .1    .1    .2    .2    .2
    .1    .1    .1    .1    .1    .1    .1    .0    .0
        .1        1.0         .5
    .0    .0    .0    .1    .0    .0    .0    .0    .0    .0
    .1    .0    .1    .1    .1    .1    .2    .0    .0
```

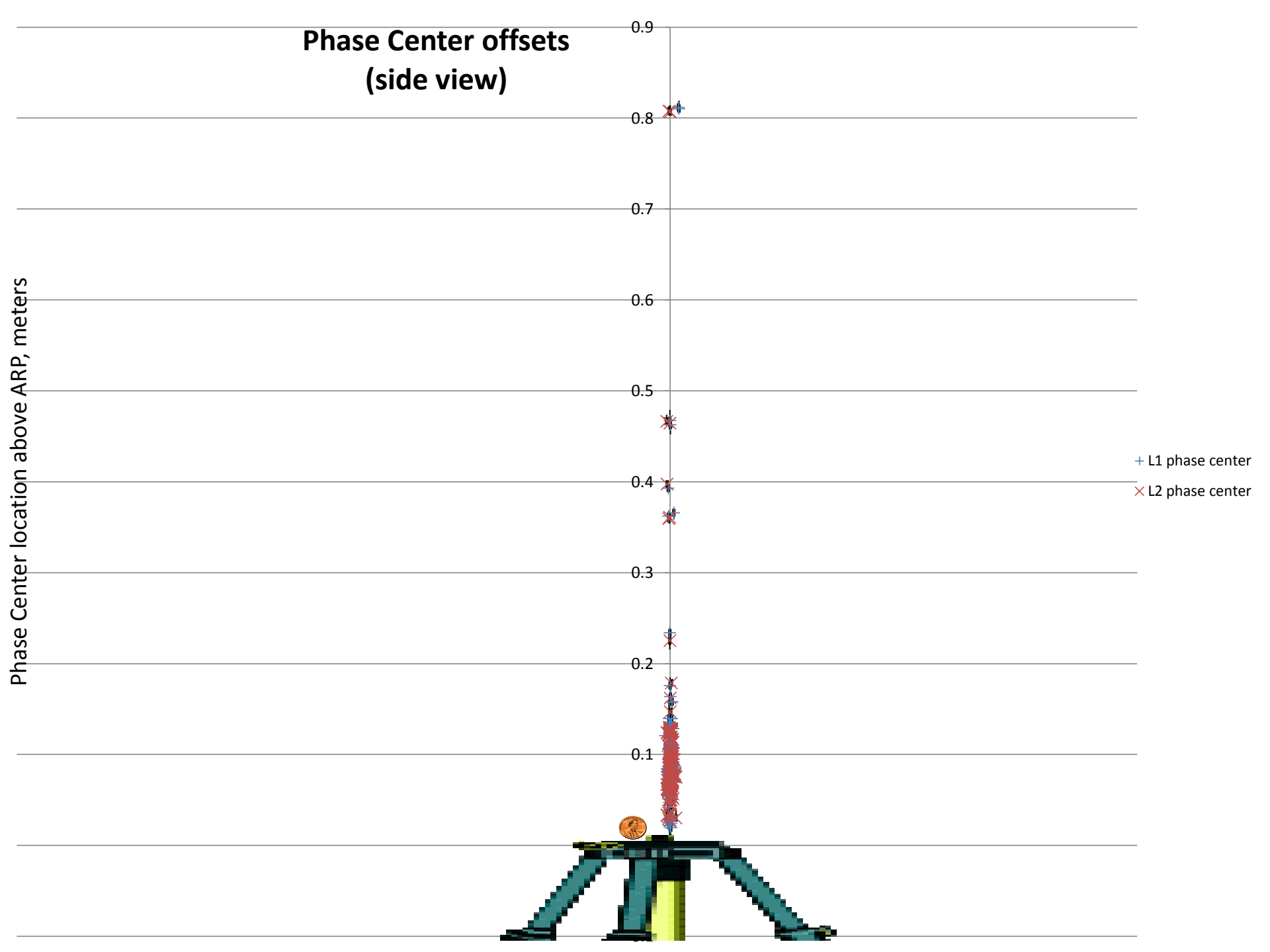


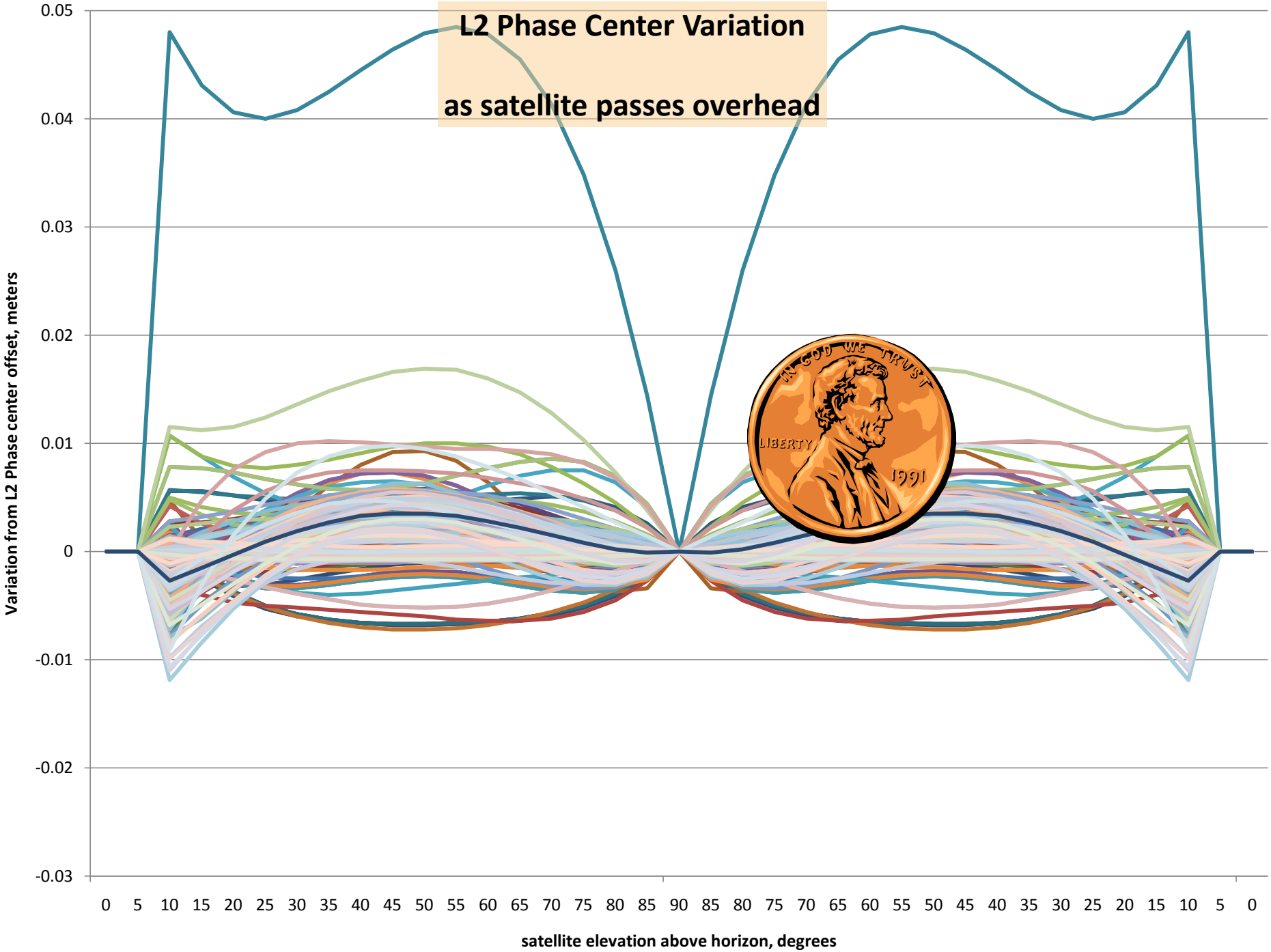


Leica

Description	Antenna Type
Leica External micropulse L1/L2 -groundplane	LEIAT202-GP.....
Leica External micropulse L1/L2 -groundplane	LEIAT302-GP.....
Leica Micropulse chokering antenna -radome	LEIAT303.....
Leica Micropulse chokering antenna +radome	LEIAT303.....LEIC


Phase Center offsets
(plan view)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.01
-0.008
-0.006
-0.004
-0.002
0
0.002
0.004
0.006
0.008
0.01
Phase center offset from ARP, meters
L1 phase center
L2 phase center


Phase Center offsets
(side view)
Phase Center location above ARP, meters
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
L1 phase center
L2 phase center


L2 Phase Center Variation
as satellite passes overhead
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
IN GOD WE TRUST
LIBERTY
1991

GNSS Absolute Antenna Calibration-

This will make a difference for very long baselines (1000 Km)

NGS Antenna Calibration facility in Corbin, VA, is available for private sector & government use

Question 7:

Review current datum, adjustments, and epochs including ITRF, latest WGS84 updates, and NAD83 adjustments up through NSRS 2007.

NAD 83(86) NETWORK PROBLEMS

Not “GPSABLE”

POOR STATION ACCESSIBILITY

IRREGULARLY SPACED

POSITIONAL ACCURACY

HARN

NATIONAL GEODETIC SURVEY

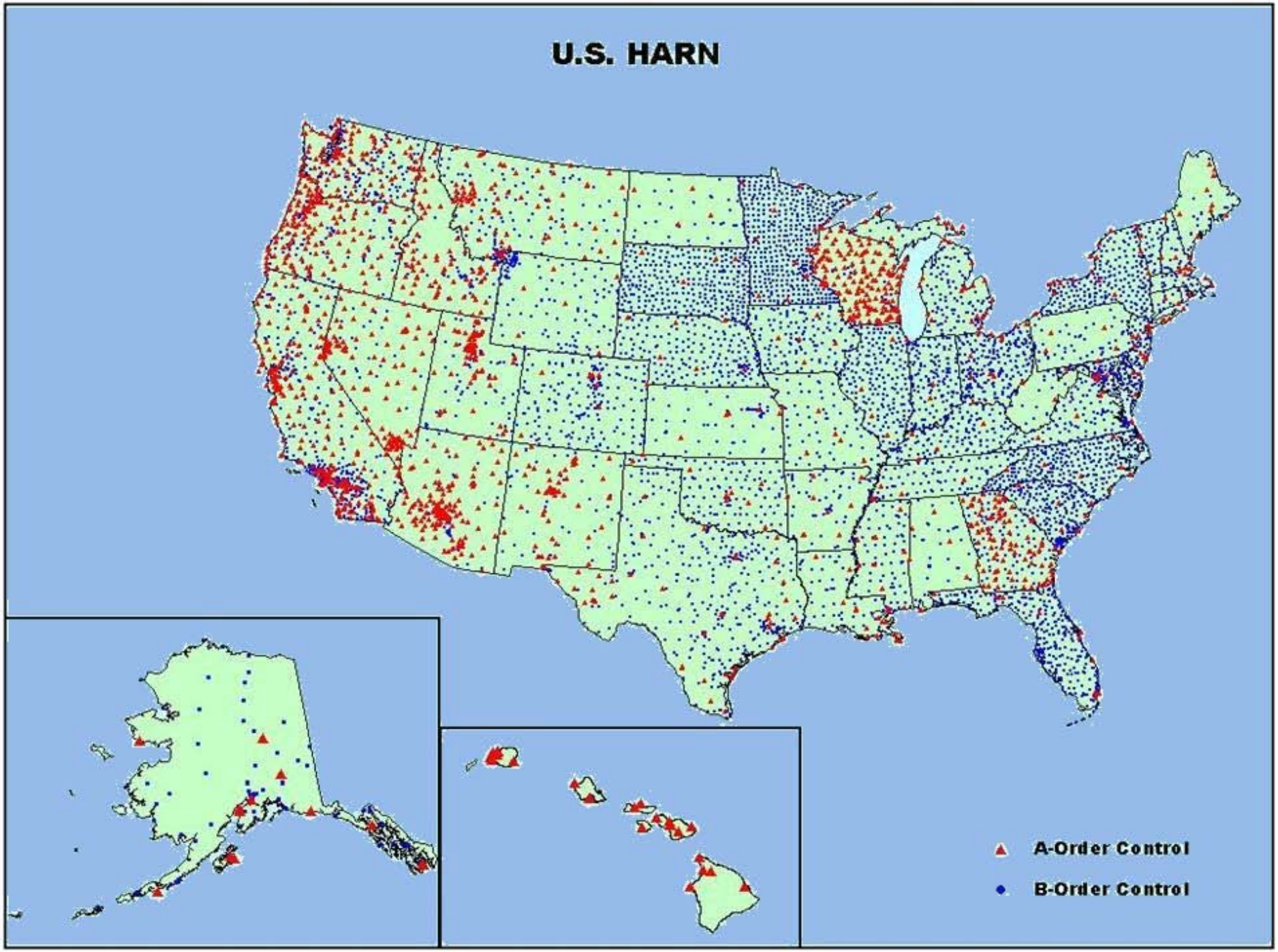
HIGH ACCURACY REFERENCE NETWORKS

"GPSABLE"
Clear Horizons for Satellite Signal Acquisition

EASY ACCESSIBILITY
Few Special Vehicle or Property Entrance Requirements

REGULARLY SPACED
Always within 20-100 Km

HIGH HORIZONTAL ACCURACY
A-Order (5 mm + 1:10,000,000)
B-Order (8mm + 1:1,000,000)


U.S. HARN
A-Order Control
B-Order Control

HARN ADJUSTMENT

A-Order Adjusted to VLBI-Existing FBN-CORS

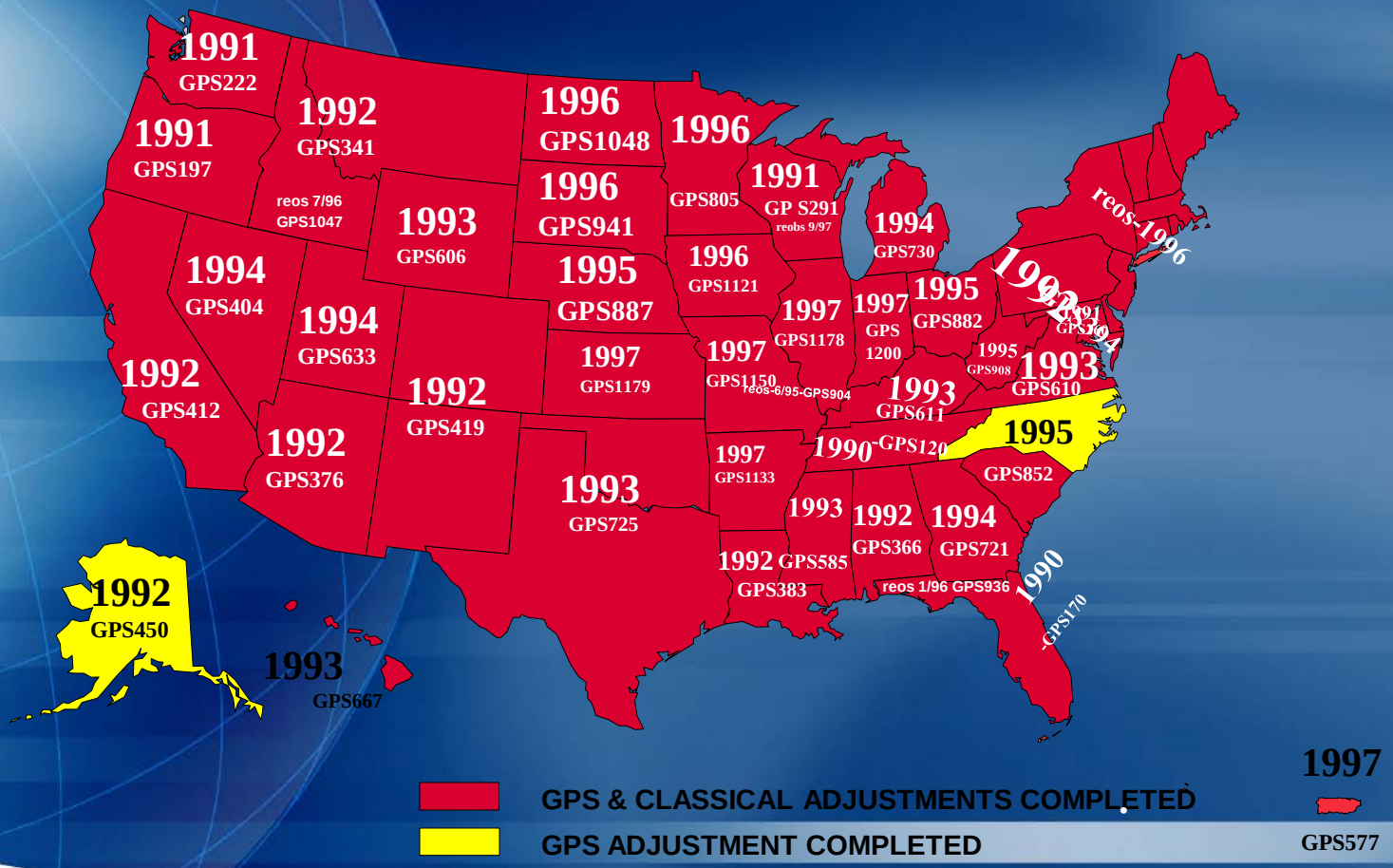
B-Order Adjusted to A-Order

Existing Horizontal (Conventional & GPS) Readjusted to A/B-Order

New Adjustment Date Tag e.g. NAD83(1995)

HARN & STATEWIDE NETWORK STATUS

NATIONAL GEODETIC SURVEY



National Oceanic and Atmospheric Administration

FEDERAL BASE NETWORK (FBN)

Reobserve the FBN to better connect the HARNs to the CORS

-MINIMUM 100 KM STATION SPACING

-2cm local horizontal accuracy

-2cm ellipsoid heights

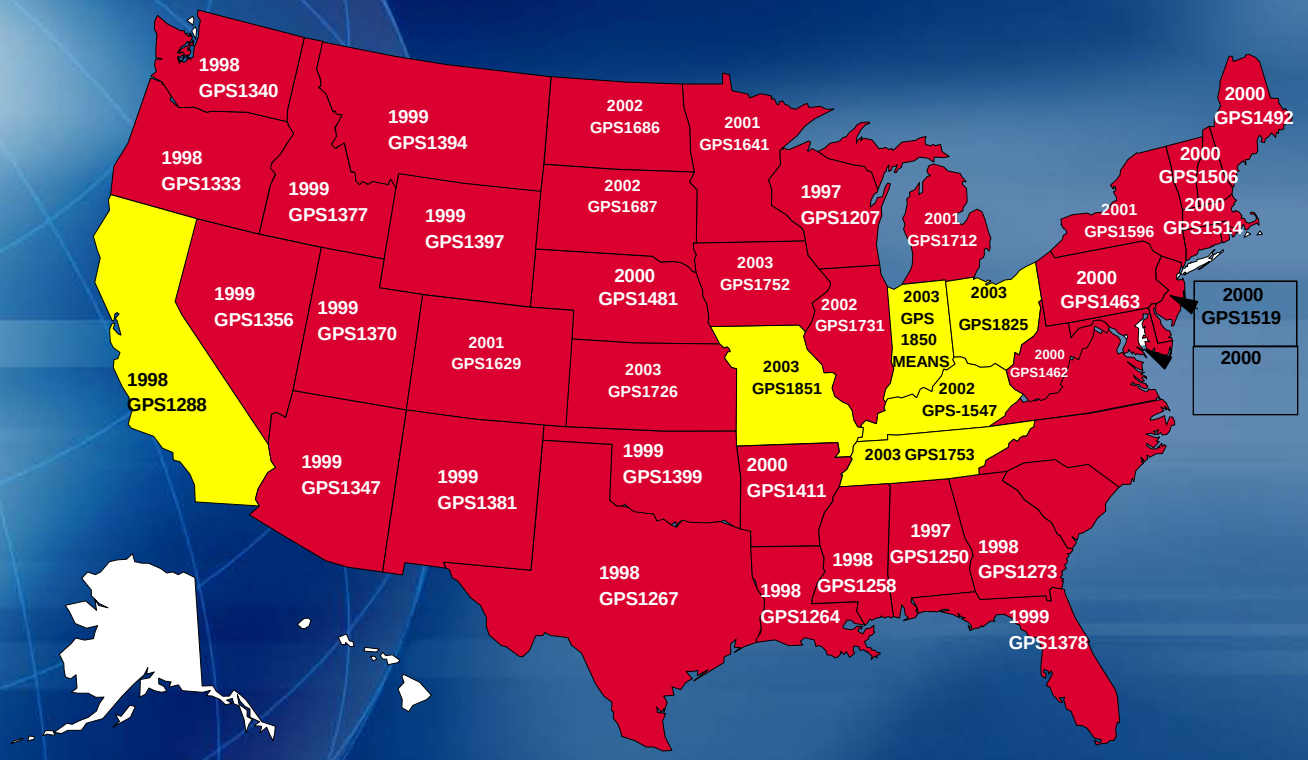
Also: observed concurrently

-CBN Cooperative Base Network

-User Densification Network

FBN/CBN SURVEYS

NATIONAL GEODETIC SURVEY



National Oceanic and Atmospheric Administration

Reasons for NEW Readjustment

- Multiple epoch dates
- Inconsistencies between states
- Need to be Consistent with CORS
- Compute Network and Local accuracies

September 24, 2003 NGS Executive Steering Committee approved a plan for the readjustment of the horizontal positions and ellipsoid heights for GPS stations in the contiguous United States.

NGS Adjustment Team (2005)

NATIONAL GEODETIC SURVEY

NAD 83 READJUSTMENT

ONLY GPS DATA WAS USED

CONTINUOUSLY OPERATING REFERENCE STATIONS

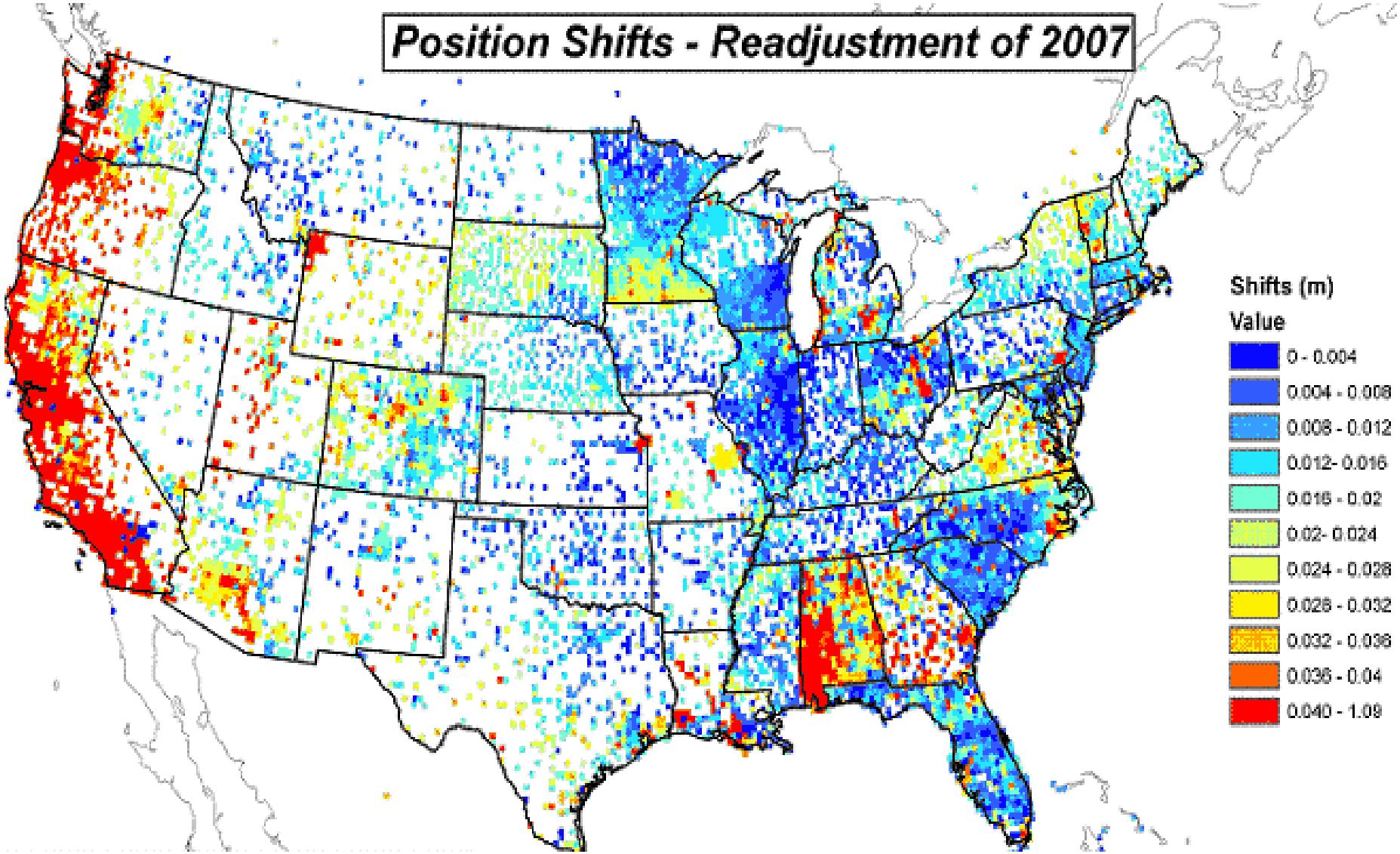
FEDERAL BASE NETWORK

COOPERATIVE BASE NETWORK

USER DENSIFICATION NETWORK

AIRPORT SURVEYS

Readjustment: What changed?



International Earth Rotation and Reference System Service (IERS)

(http://www.iers.org)

The International Terrestrial Reference System **(ITRS)** constitutes a set of prescriptions and conventions together with the modeling required to define origin, scale, orientation and time evolution

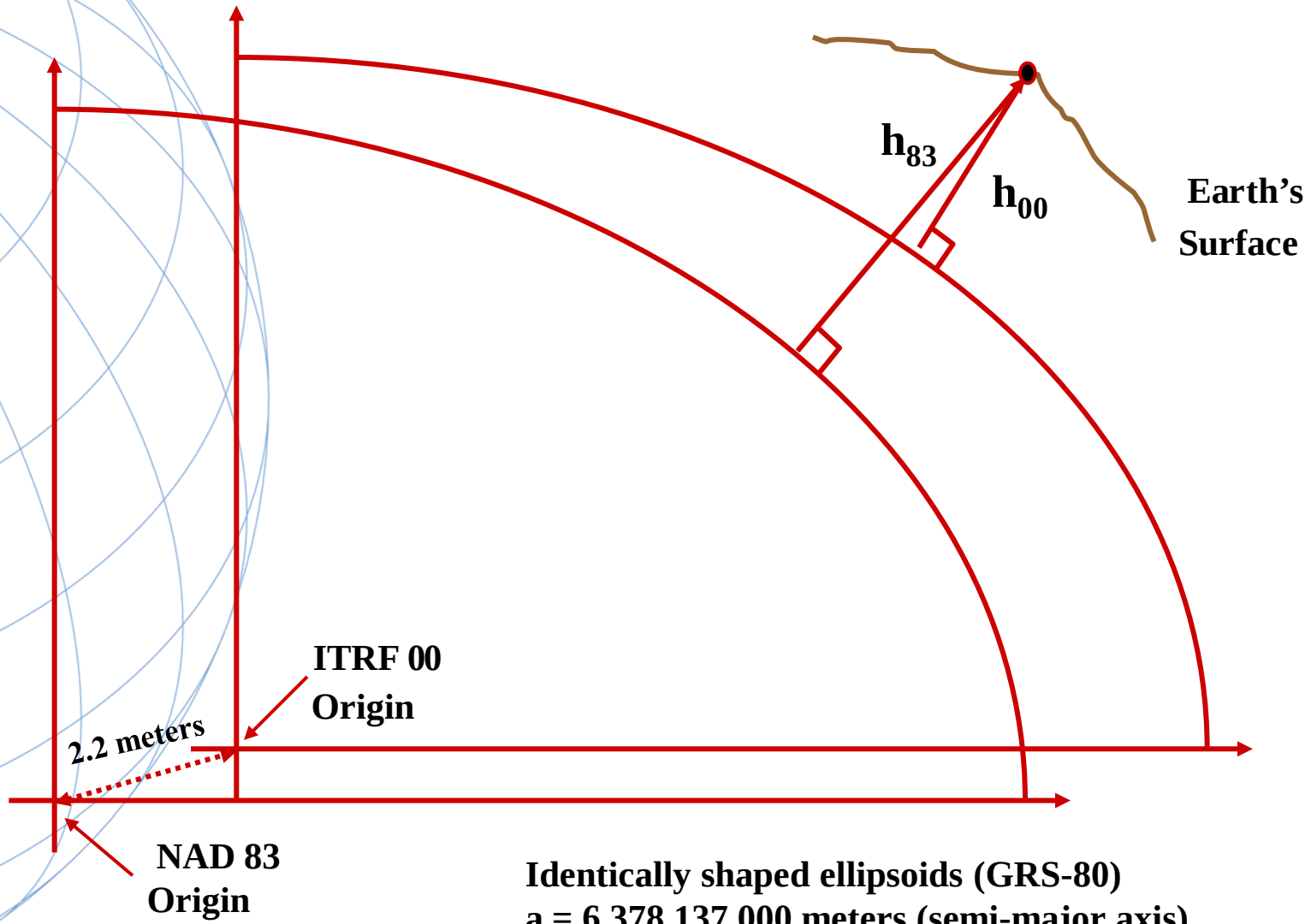
ITRS is realized by the International Terrestrial Reference Frame (**ITRF**) based upon estimated coordinates and velocities of a set of stations observed by Very Long Baseline Interferometry (**VLBI**), Satellite Laser Ranging (**SLR**), Global Positioning System and GLONASS (**GNSS**), and Doppler Orbitography and Radio- positioning Integrated by Satellite (**DORIS**).

ITRF89, ITRF90, ITRF91, ITRF92, ITRF93, ITRF94, ITRF95, ITRF96, ITRF97, ITRF2000, ITRF2005, ITRF2008 (soon)

International Terrestrial Reference Frame

4 Global Independent Positioning Technologies

Simplified Concept of ITRF 00 vs. NAD 83



Identically shaped ellipsoids (GRS-80)
a = 6,378,137.000 meters (semi-major axis)
1/f = 298.25722210088 (flattening)

Question 8:

Explain how ionospheric and tropospheric distortions affect OPUS solutions and how are they accounted for in processing through PAGES and RSGPS.

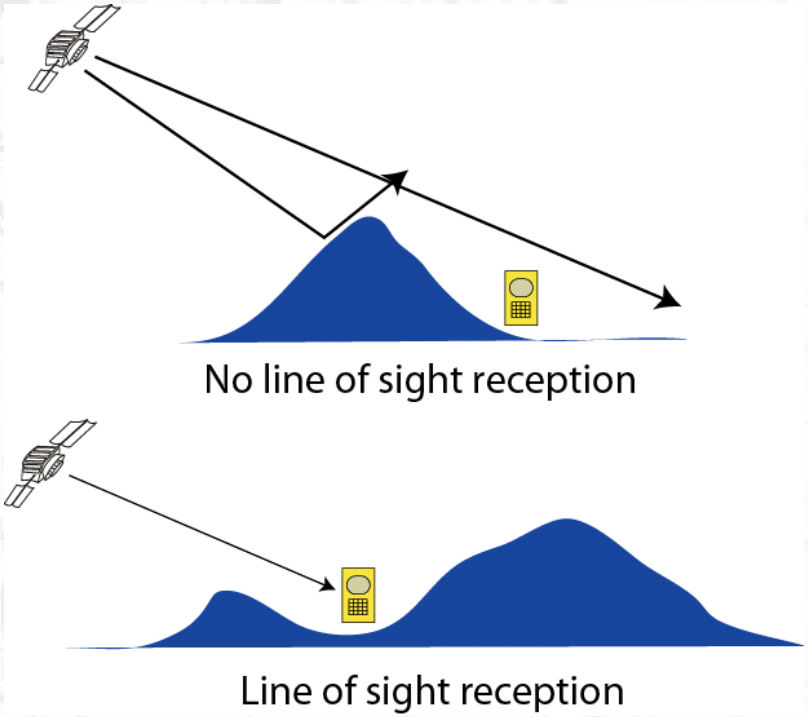
GPS Errors & Biases

GPS errors include:
Signal Propagation errors

- Ionospheric effects
- Dry troposphere delay
- Wet troposphere delay
- multipath

Line of Sight Transmissions

Line of sight is the ability to draw a straight line between two objects without any other objects getting in the way. GPS transmission are line-of-sight transmissions.



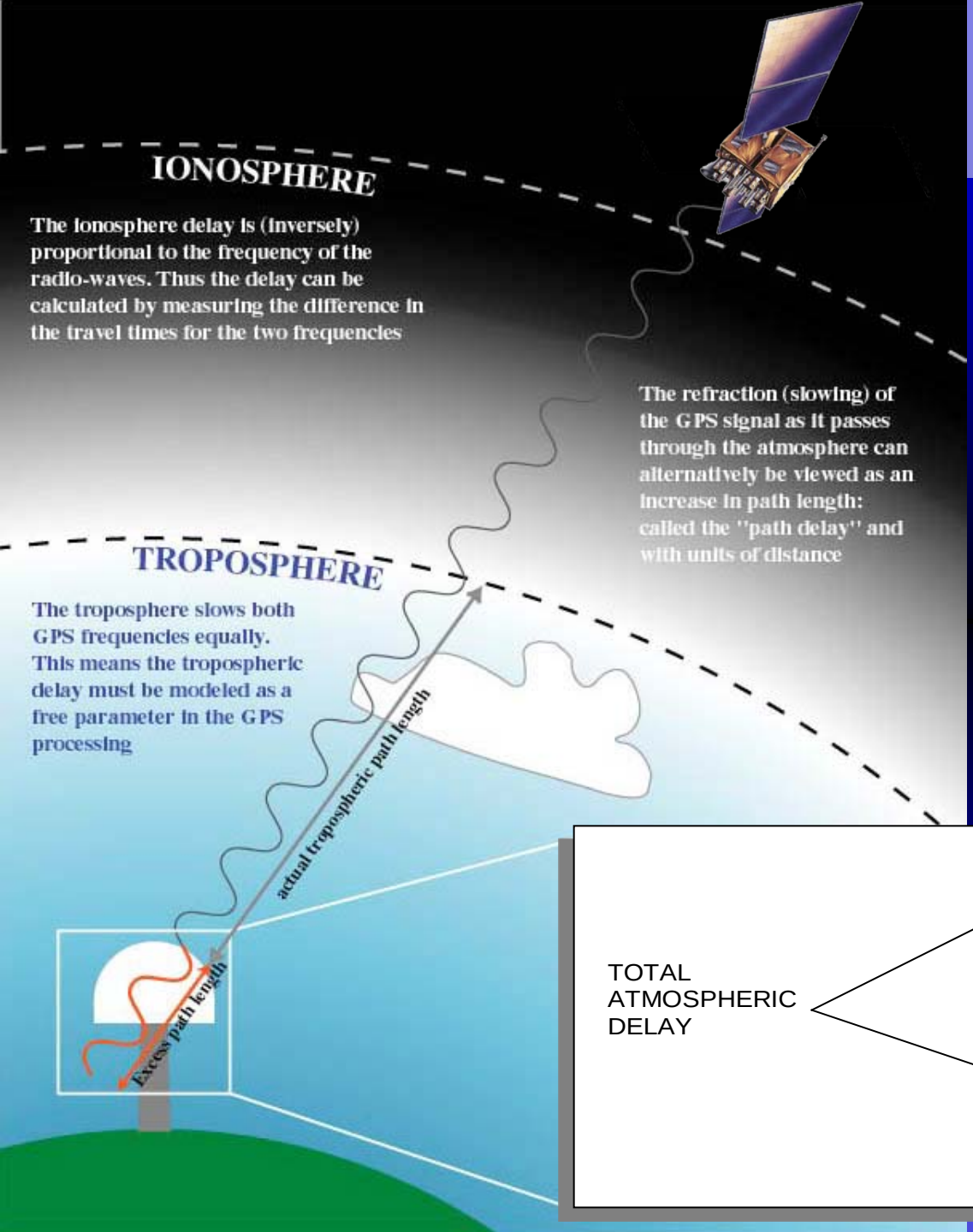
Obstructions such as trees, buildings, or natural formations may prevent clear line of sight.

Light Refraction

Sometimes the GPS signal from the satellite doesn't follow a straight line.

Refraction is the bending of light as it travels through one media to another.

GPS Signal Delays Caused by the Atmosphere



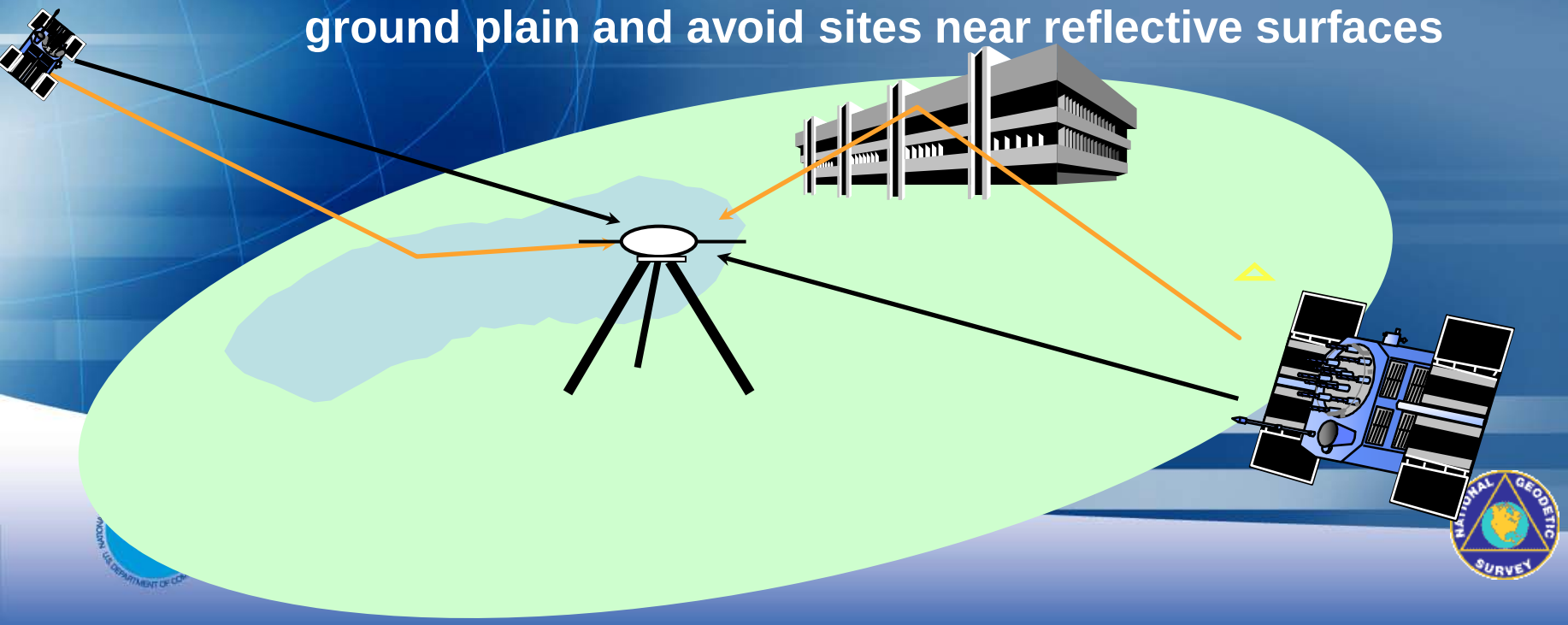
- TOTAL ATMOSPHERIC DELAY
  - IONOSPHERIC DELAY → TEC
  - TROPOSPHERIC DELAY
    - HYDROSTATIC DELAY
    - WET DELAY → IPWV

Atmospheric Error Sources

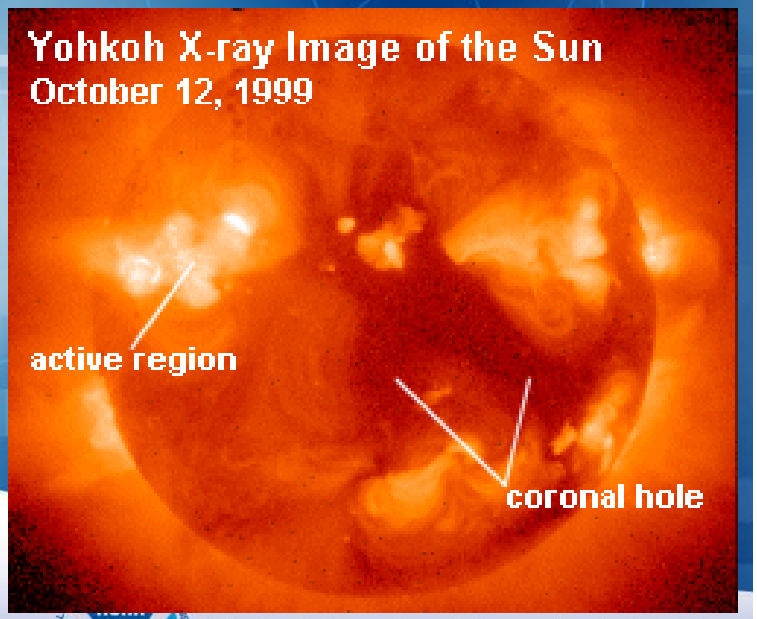
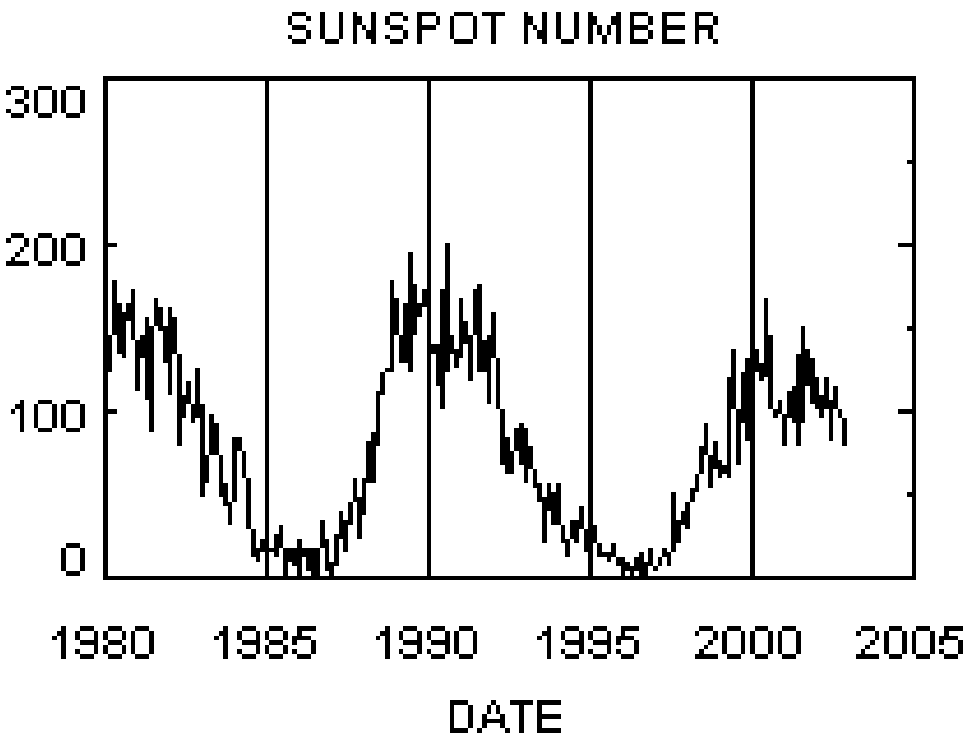
- Ionosphere
  - Greatest at 1400 (local time)
  - Typical 5 to 15 m at zenith
  - Extreme 0.15 to 50 m at zenith
  - Higher frequencies have less effect
  - Error correction by dual frequency
- "Wet" Troposphere
  - 10% of total effect
  - Model accuracy only 10 to 50%
  - Need humidity along path
  - About 20 cm at zenith
- Hydrostatic ("Dry") Troposphere
  - 90% of total effect
  - Model accuracy only 2 to 5%
  - Need surface atmospheric pressure and temperatures
  - Accurate pressure is ***critical***
  - About 2.2 m at zenith

Multipath

- Multiple signal paths between the satellite and receiver
- caused by reflected signals within the receiver environment
  - chain link fences
  - vehicles
  - road signs
- To reduce the errors associated with multipathing use a ground plain and avoid sites near reflective surfaces



Sunspot cycle

- Sunspots follow a regular 11 year cycle
- We are just past the peak of the current cycle
- Sunspots increase the radiation hitting the earth's upper atmosphere and produce an active and unstable ionosphere

http://www.spaceweather.com/