Using CORS and OPUS for Positioning

Richard Snay
NOAA's National Geodetic Survey

Civil GPS Service Interface Committee
USSLGS Regional Meeting
Honolulu, Hawaii
June 24, 2009

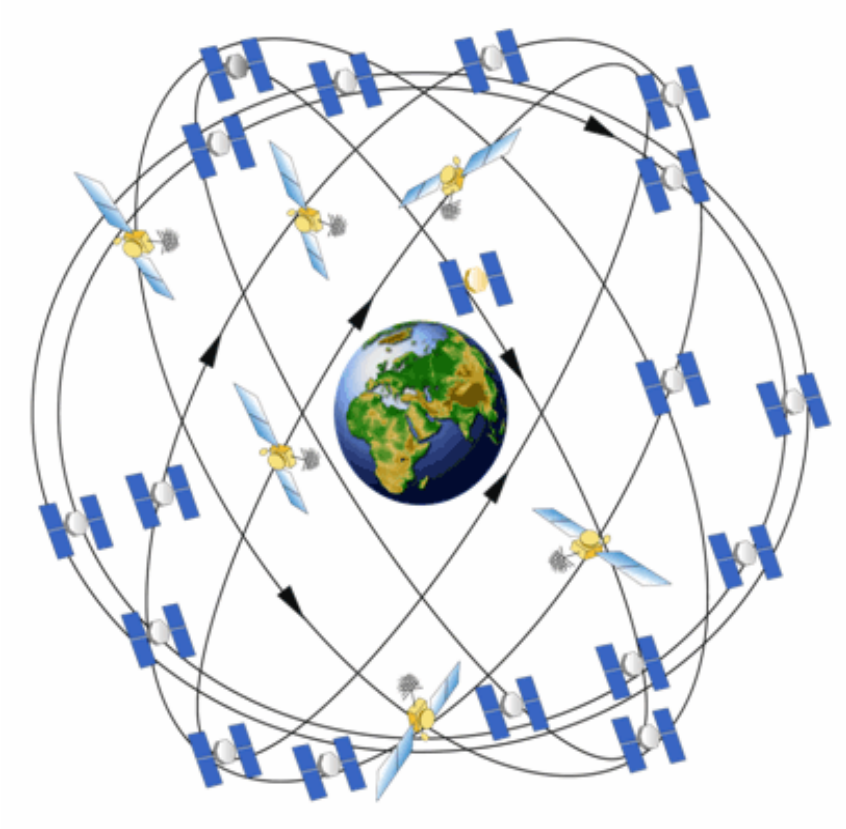
NOAA's National Geodetic Survey

Everyone is able to know where they are and

where other things are anytime, anyplace!

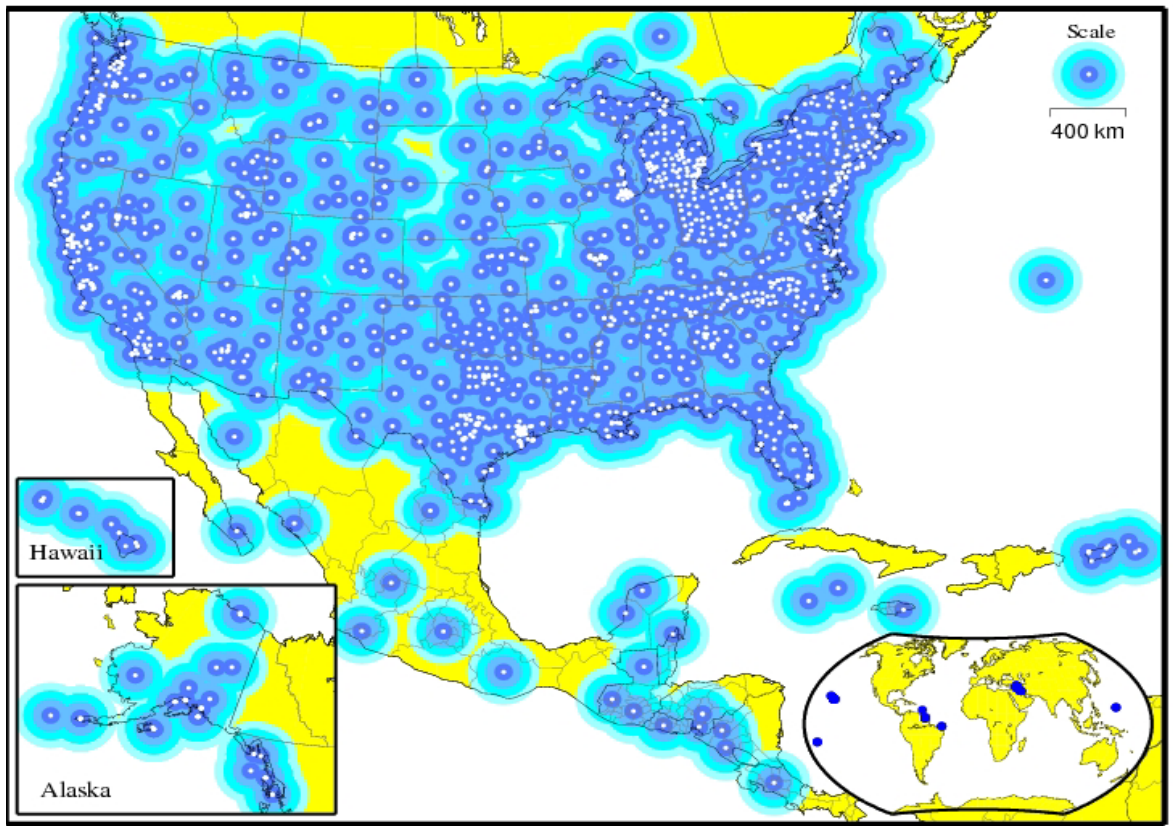
The Global Positioning System (GPS)

Unaugmented GPS enables positioning with accuracies ranging from 1 to 10 meters.

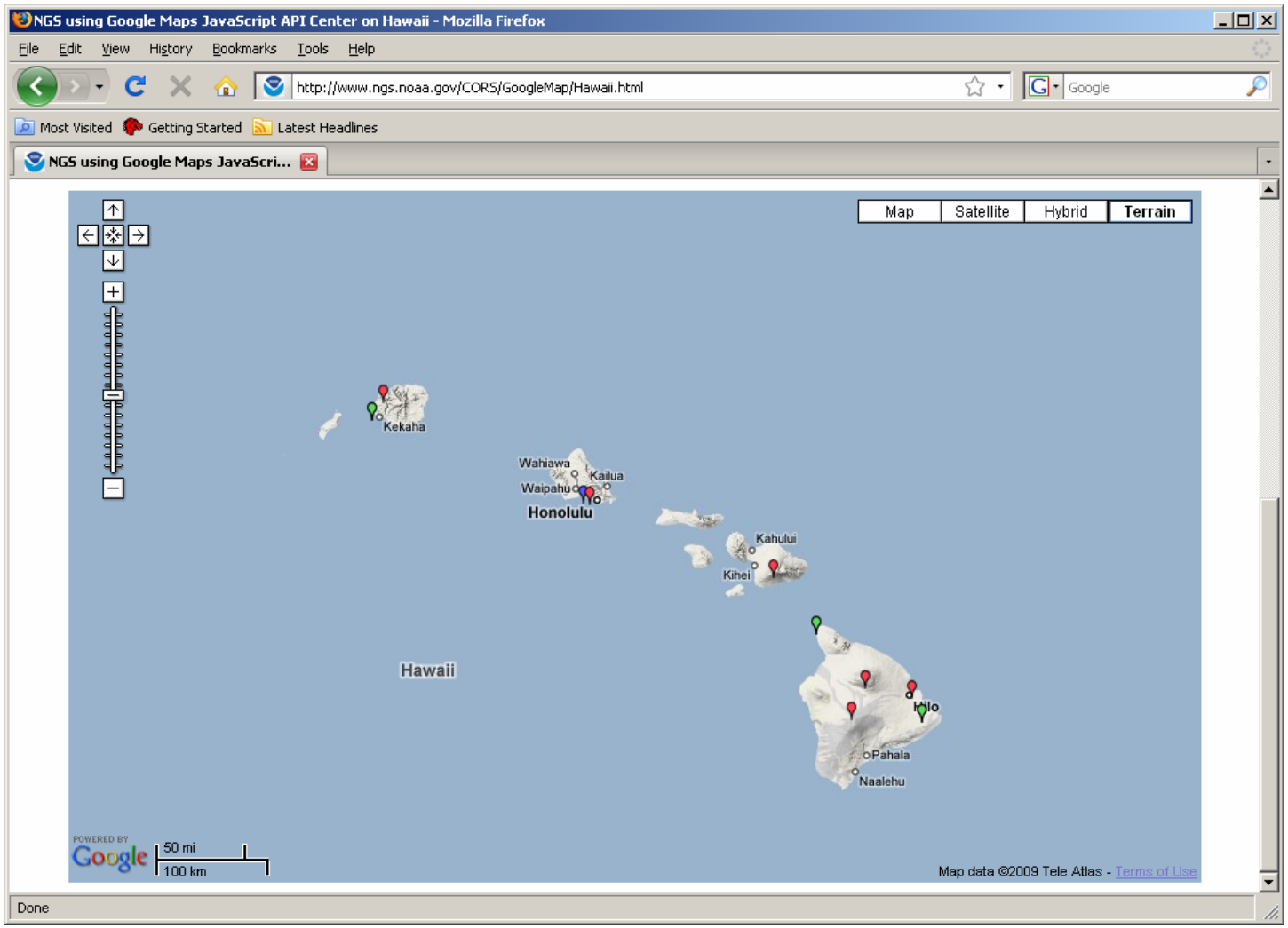


Continuously Operating Reference Stations (CORS)

The CORS network enables differential GPS positioning with accuracies from 1 to 10 centimeters, or better.



Hawaiian CORS

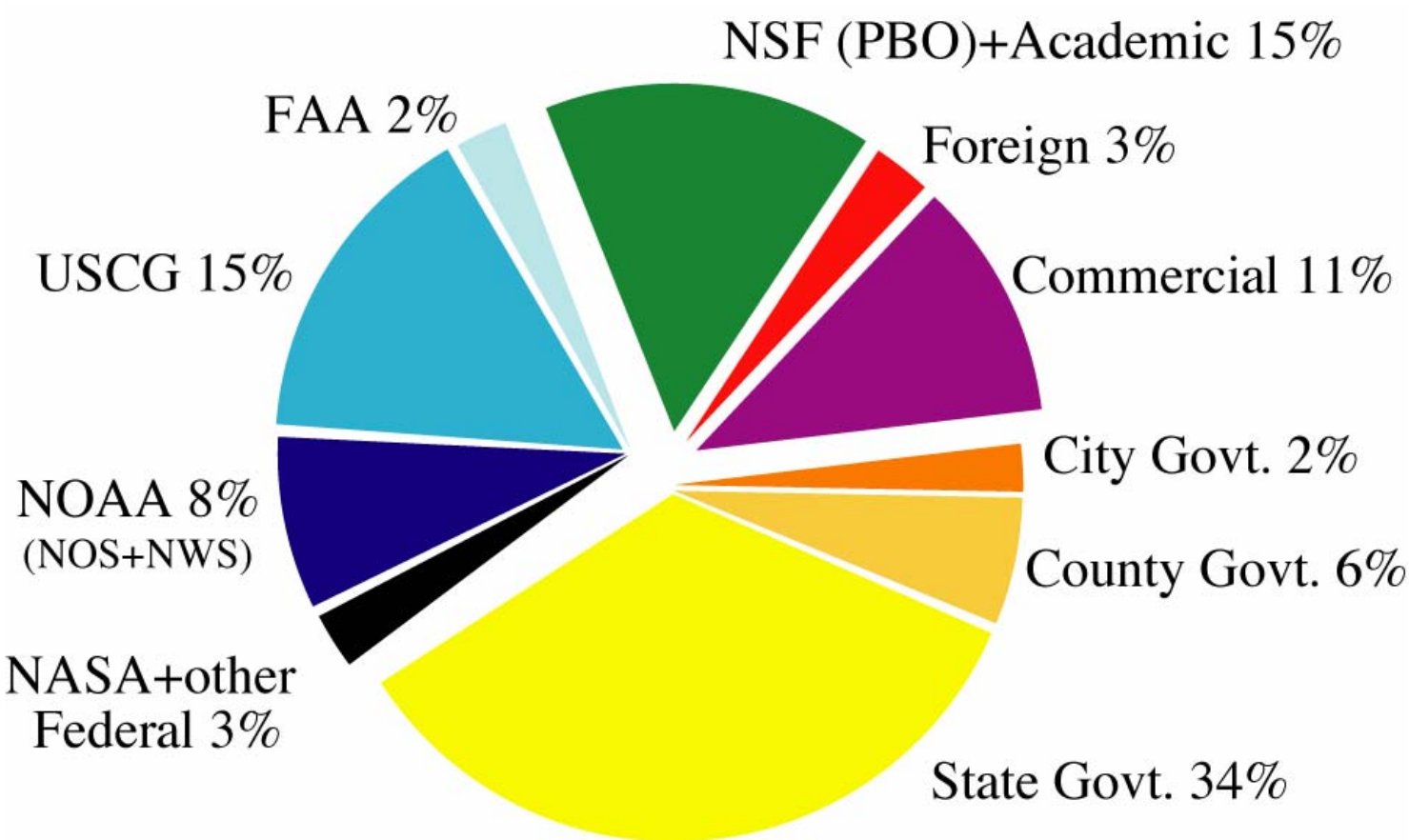


Sample CORS Sites

CORS Information

- CORS network contains over 1,300 stations as of June 2009.
- Growing at rate of about 200 stations per year.
- Each station collects GPS signals, and NOAA makes these data freely available to the public via the Internet for post-processing applications.
- Over 200 organizations participate in the CORS program by sponsoring and operating one or more stations.

CORS Partners



Access to CORS Data

In Silver Spring, Maryland (CORS-East)

- Anonymous File Transfer Protocol (FTP)
  ftp://cors.ngs.noaa.gov
- UFCORS - User Friendly CORS
  http://www.ngs.noaa.gov/UFCORS

In Boulder Colorado (CORS-West)

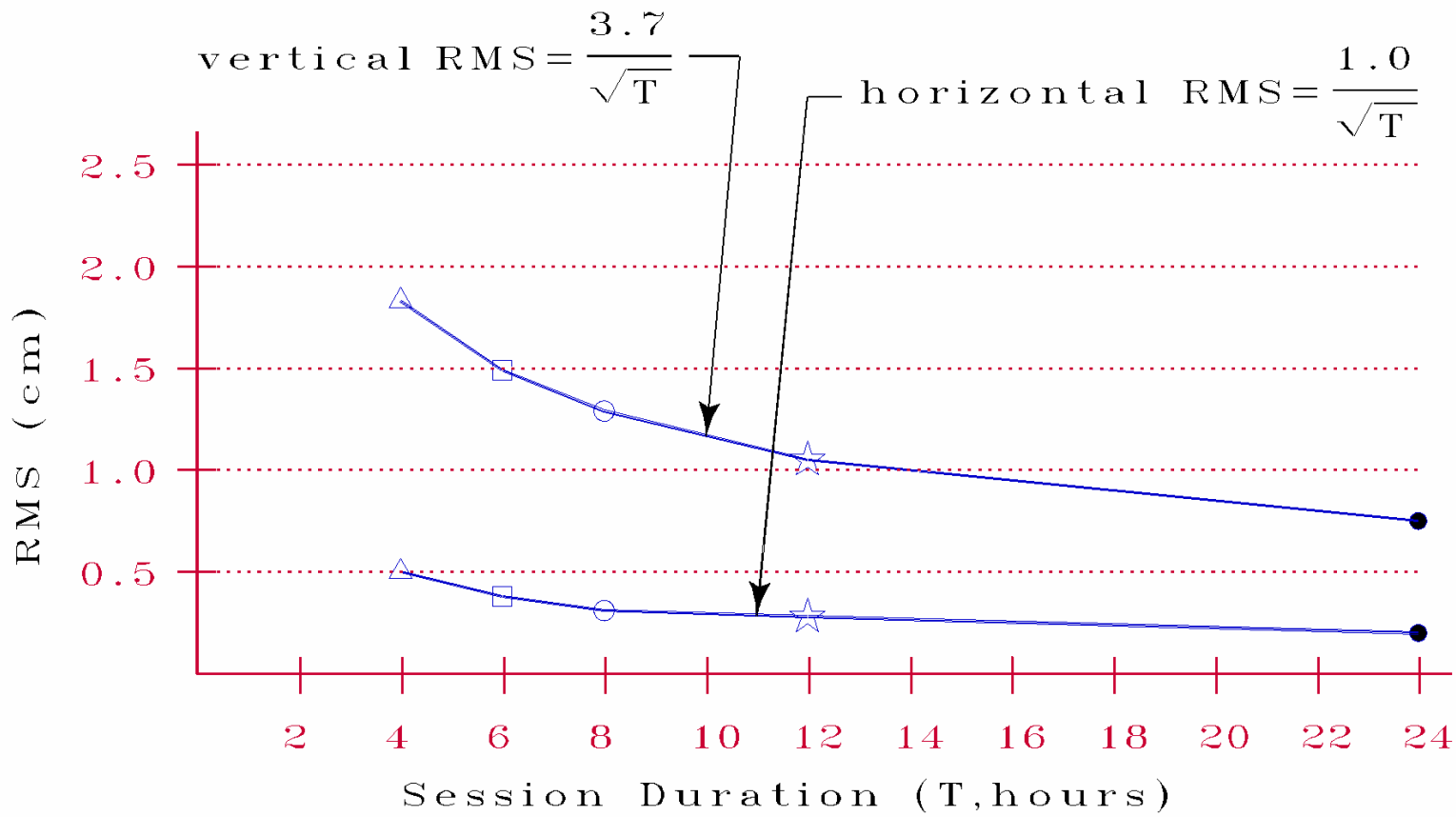
- Parallel and independent data collection and on-line storage at NOAA's National Geophysical Data Center
  Anonymous FTP ftp://wwwest.ngs.noaa.gov

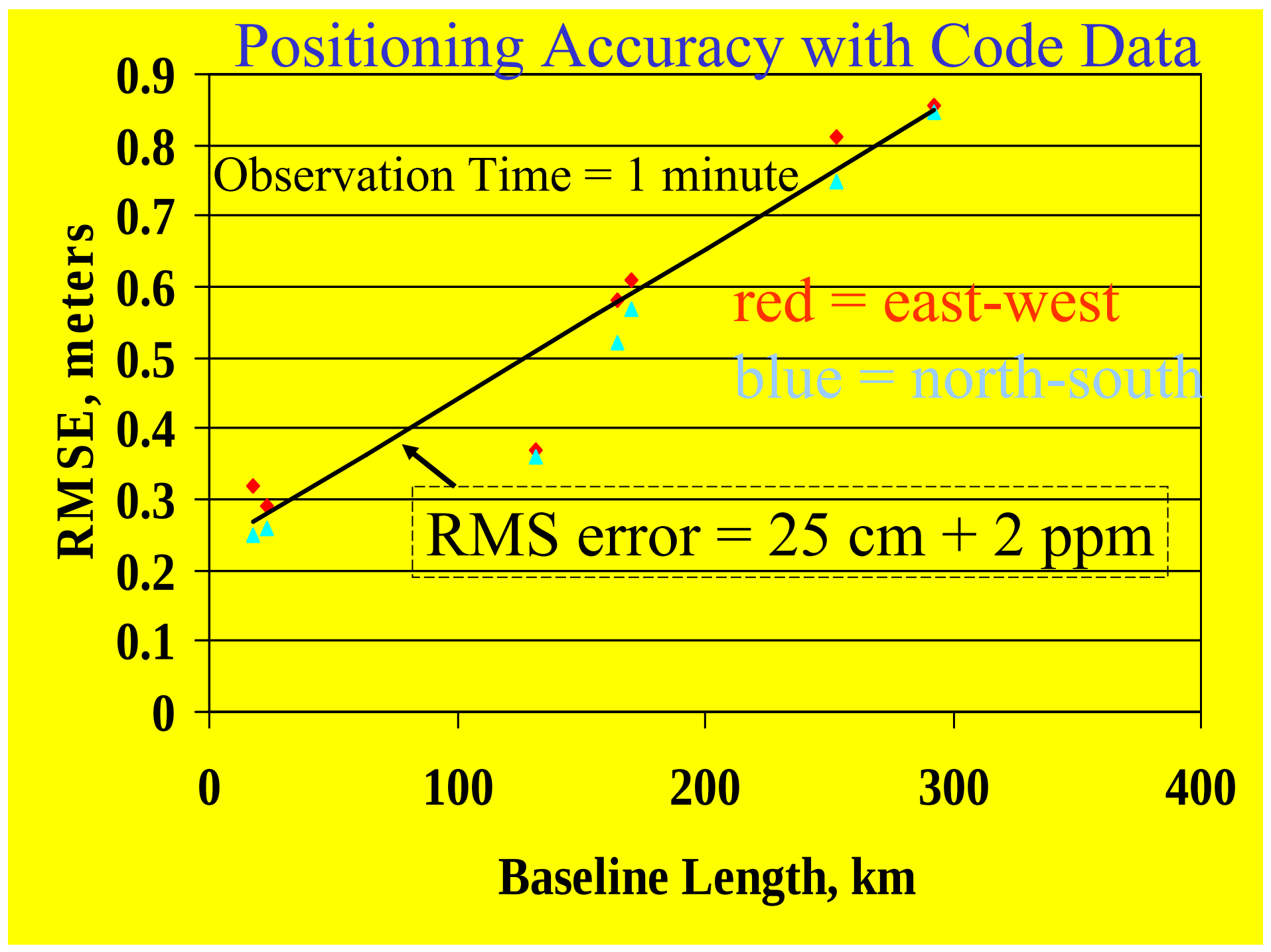
CORS Supports Precise Positioning

Before CORS: Accurate differential GPS positioning with multi-person field crew.

After CORS: Accurate differential GPS positioning with one-person field crew.

Positioning Error vs. Duration of the Observing Session




Positioning Accuracy with Code Data
RMSE, meters
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Observation Time = 1 minute
red = east-west
blue = north-south
RMS error = 25 cm + 2 ppm
0
100
200
300
400
Baseline Length, km

Online Positioning User Service (OPUS)

- Collect at least 15 minutes of dual-frequency GPS data
- Submit data to www.ngs.noaa.gov/OPUS/
- Data are processed automatically using NOAA computers & software
- Corresponding positional coordinates computed with respect to at least 3 suitable CORS or IGS sites
- Computed coordinates returned via email (usually in minutes)

U.S. DoC / NOAA / NOS / National Geodetic Survey - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media

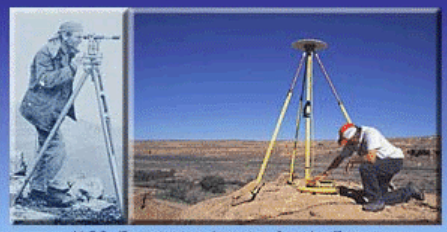
Address http://www.ngs.noaa.gov/

Go Links

MySearch Google AltaVista Ask Jeeves AlltheWeb LookSmart Customize this toolbar Highlight

mywebsearch Search Smiley Central My Info Fun Tools Games Customize My Button 1 Highlight

National Geodetic Survey



U.S. Department of Commerce

National Oceanic and Atmospheric Administration

National Ocean Service

NGS, Positioning America for the Future

aeronautical data | CORS / OPUS GPS data | datasheets Find/Update a point | geodetic tool kit | PC software

Search for

Go

Site Map
What We Do
What's New
Products & Services
State Advisors
Contracting Opportunities
Our History
FAQ

Project & Division pages

Geoid
Geosciences Research (GRD)
Remote Sensing
FGCS/GIAC

Monday, March 15, 2004

• Upcoming Events • NGS In The News •
• *The Observer* Newsletter •

Check these out...

NGS Dedicates Commemorative Marker at U.S. Mint in Philadelphia: On March 12, NOAA dedicated a survey marker at the U.S. Mint in Philadelphia that commemorates Lewis and Clark's expedition across America two hundred years ago. ...*more info* ...Denver Mint dedication is March 15.

Cooperative CORS Providers/Users Group Meeting: The 2nd Annual Cooperative CORS Providers/Users Group Meeting will be held at the ACSM conference in Nashville. ...*more info*

New Options added to OPUS: This new version of OPUS optionally allows users control over which CORS sites are used for a solution, to receive their output in an extended format, and have their solution computed in State Plane coordinates. See Option #5 on the OPUS main page.

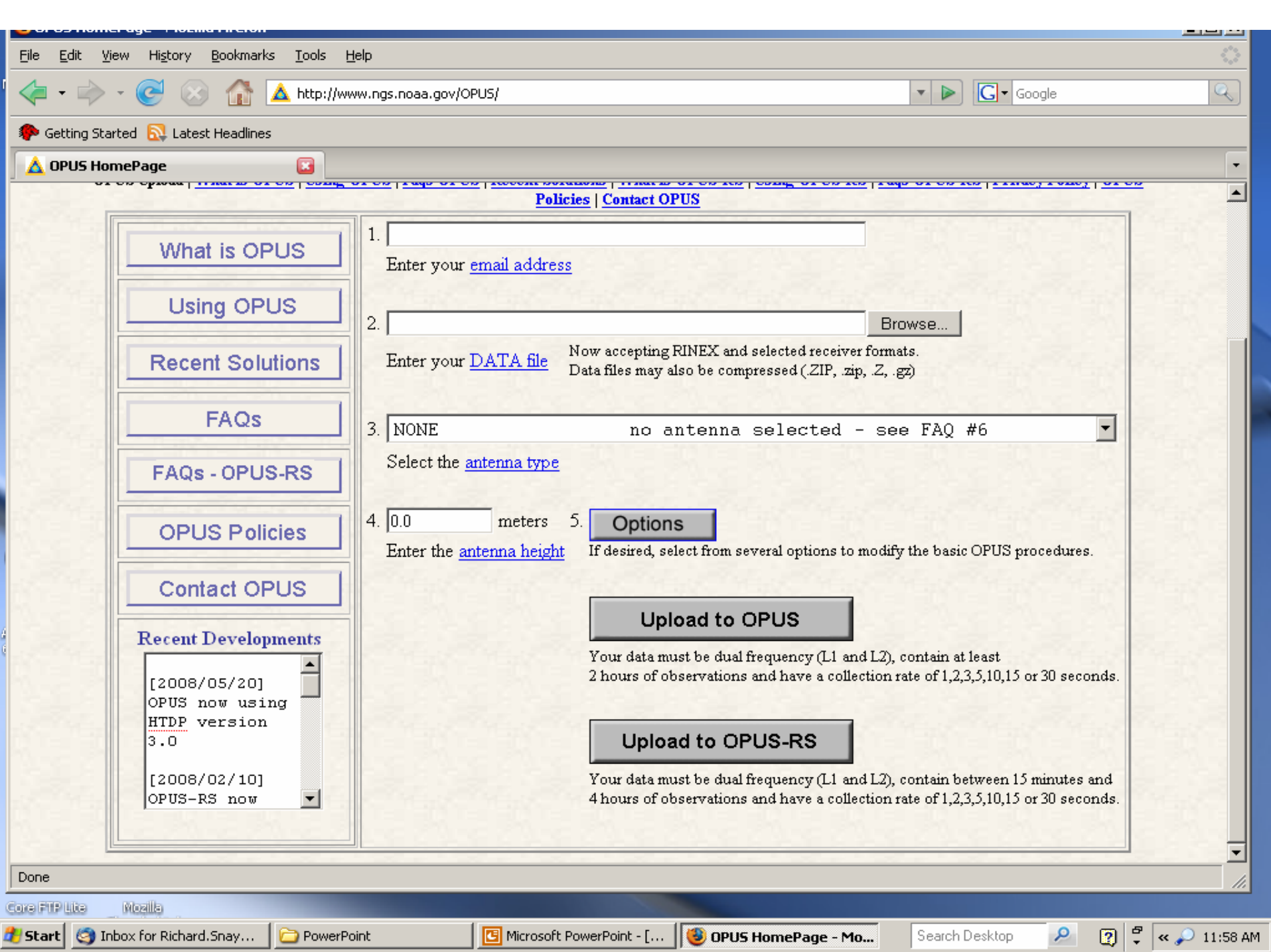
Lewis And Clark Bicentennial: To honor Lewis and Clark's contributions to mapping, NGS is installing a series of commemorative markers along the route that Lewis and Clark traveled.

The National Readjustment

Quick Link to OPUS from NGS Home Page

www.ngs.noaa.gov

Done Internet


File Edit View History Bookmarks Tools Help
http://www.ngs.noaa.gov/OPUS/
Google
Getting Started
Latest Headlines
OPUS HomePage
Policies | Contact OPUS
What is OPUS
Using OPUS
Recent Solutions
FAQs
FAQs - OPUS-RS
OPUS Policies
Contact OPUS
Recent Developments
[2008/05/20]
OPUS now using
HTDP version
3.0
[2008/02/10]
OPUS-RS now
1.
Enter your email address
2.
Browse...
Enter your DATA file
Now accepting RINEX and selected receiver formats.
Data files may also be compressed (.ZIP, .zip, .Z, .gz)
3.
NONE no antenna selected - see FAQ #6
Select the antenna type
4.
0.0
meters
Enter the antenna height
5.
Options
If desired, select from several options to modify the basic OPUS procedures.
Upload to OPUS
Your data must be dual frequency (L1 and L2), contain at least
2 hours of observations and have a collection rate of 1,2,3,5,10,15 or 30 seconds.
Upload to OPUS-RS
Your data must be dual frequency (L1 and L2), contain between 15 minutes and
4 hours of observations and have a collection rate of 1,2,3,5,10,15 or 30 seconds.
Done
Core FTP Lite
Mozilla
Start
Inbox for Richard.Snay...
PowerPoint
Microsoft PowerPoint - [...
OPUS HomePage - Mo...
Search Desktop
11:58 AM

OPUS Output

NAD 83 coordinates (3D)

ITRF coordinates (3D)

NAVD 88 height

State Plane coordinates

UTM coordinates

US National Grid

A more comprehensive output is also available upon request.

```
FILE: corv0590.05o 000416827

 1008   NOTE:  Antenna offsets supplied by the user were zero.  Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008

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

     USER: jeff.olsen@noaa.gov                    DATE: January 13, 2006
RINEX FILE: corv059f.05o                          TIME: 19:08:14 UTC


  SOFTWARE: page5  0601.10 master3.pl            START: 2005/02/28  05:00:00
 EPHEMERIS: igs13121.eph [precise]                STOP: 2005/02/28  06:59:30
  NAV FILE: brdc0590.05n                      OBS USED:  4228 /  4314   :  98%
  ANT NAME: ASH700936B_M    NONE            # FIXED AMB:    25 /    29   :  86%
ARP HEIGHT: 0.0                             OVERALL RMS: 0.013(m)
```

```
 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2005.1596)

         X:     -2498423.165(m)   0.018(m)          -2498423.872(m)   0.018(m)
         Y:     -3802822.048(m)   0.021(m)          -3802820.836(m)   0.021(m)
         Z:      4454737.695(m)   0.024(m)           4454737.792(m)   0.024(m)

       LAT:   44 35  7.91054      0.002(m)        44 35  7.92698      0.002(m)
     E LON:  236 41 43.48129      0.014(m)       236 41 43.42434      0.014(m)
     W LON:  123 18 16.51871      0.014(m)       123 18 16.57566      0.014(m)
    EL HGT:          107.485(m)   0.034(m)               107.108(m)   0.034(m)
 ORTHO HGT:          130.010(m)   0.043(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (3601 OR N)
Northing (Y) [meters]     4936954.907          105971.557
Easting (X)  [meters]      475821.322         2277335.385
Convergence  [degrees]    -0.21381402          -1.98897497
Point Scale                0.99960719           0.99994603
Combined Factor            0.99959034           0.99992918

US NATIONAL GRID DESIGNATOR: 10TDQ7582136955(NAD 83)
```

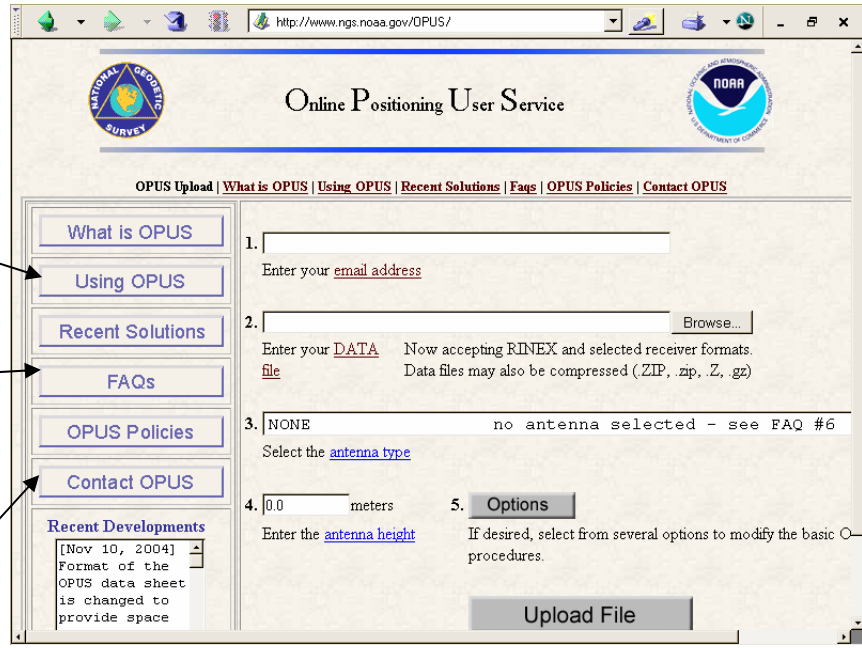
```
                                BASE STATIONS USED
PID       DESIGNATION                       LATITUDE    LONGITUDE DISTANCE(m)
AH2489 NEWP NEWPORT CORS ARP              N443506.072 W1240342.736   60138.7
AJ6959 CHZZ CAPE MEARS CORS ARP           N452911.437 W1235841.187  113322.4
DH4503 P376 EOLARESVR_OR2004 CORS ARP     N445628.313 W1230608.100   42648.2

                     NEAREST NGS PUBLISHED CONTROL POINT
AH2486      CORVALLIS CORS ARP            N443507.910 W1231816.519       0.0
```

How do I get help?

- Study the Guidelines under “Using OPUS”

- Study the answers under “FAQs”

- Submit specific questions, comments or suggestions using “Contact OPUS” link



OPUS-S vs. OPUS-RS

What are the fundamental differences between OPUS-Static (OPUS-S) and OPUS-Rapid Static (OPUS-RS)?

OPUS-S vs. OPUS-RS

OPUS-S requires at least two hours of GPS data from the rover, together with the same amount of data from 3 CORS (preferably located within 600 km of the rover), to solve for

* the rover's coordinates,

* atmospheric refraction parameters at both the rover and the 3 CORS, and

* integer ambiguities (in the doubly differenced phase observations).

OPUS-S vs. OPUS-RS

OPUS-RS involves a 3-step process:

* Use at least one hour of GPS data from 3 to 9 CORS (located within 250 km of the rover) to solve for atmospheric refraction parameters at these CORS.
* Interpolate (or extrapolate) these refraction parameters to predict corresponding refraction parameters at the rover.
* Use at least 15 minutes of GPS data at the rover, together with the same amount of data at the nearby CORS to solve for:
  - the rover's coordinates and
  - integer ambiguities.

OPUS-S vs. OPUS-RS

Requirement	OPUS-S	OPUS-RS
Amount of GPS data from rover	2 – 48 hours	0.25 – 4.00 hours
Local CORS geometry	3 CORS, preferably located within 600 km of rover	3 to 9 CORS located within 250 km of rover, preferably with IDOP < 0.8

What is IDOP?

The interpolative dilution of precision (IDOP) is a unitless number that quantifies the local geometric strength of the CORS network relative to the rover's location in terms of how well atmospheric conditions at nearby CORS can be interpolated (or extrapolated) to predict corresponding atmospheric conditions at the rover.

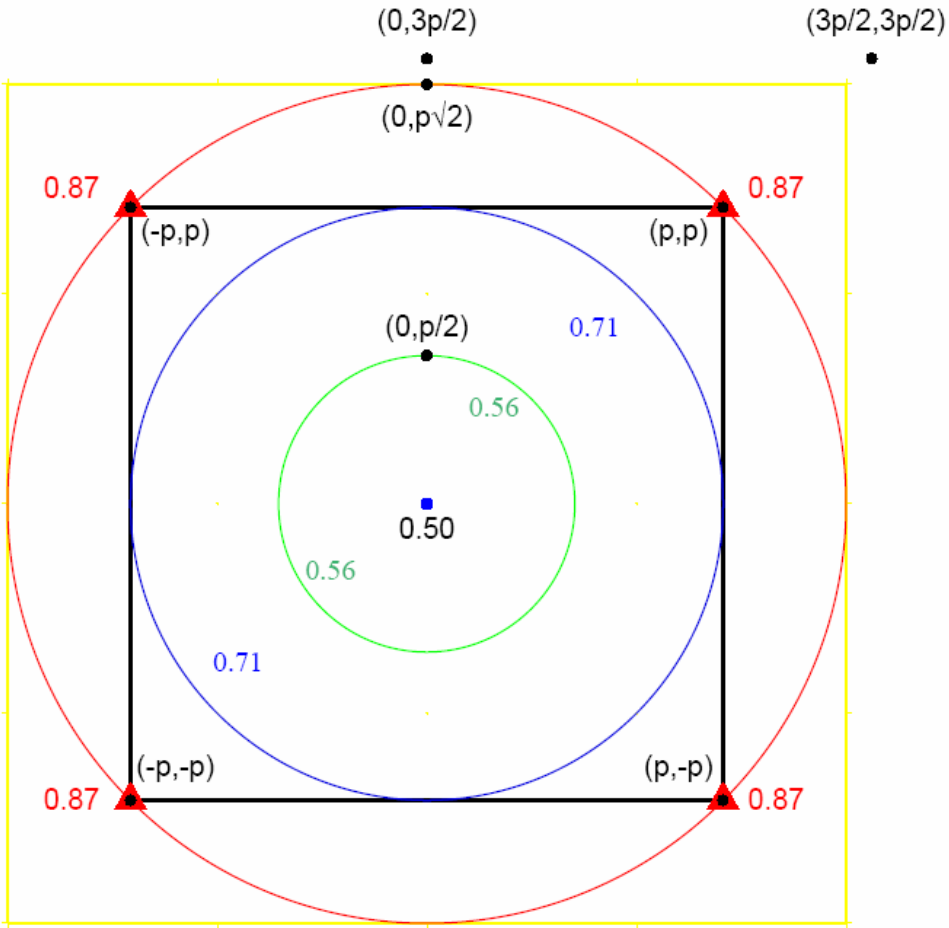
The smaller the value of IDOP the better.

IDOP VALUES AS A FUNCTION OF LOCATION
EXAMPLE FOR THE CASE OF 4 CORS LOCATED AT THE CORNERS OF A SQUARE

Best IDOP = $1/\sqrt{N}$ where N denotes the number of CORS. Best IDOP occurs at the centroid of the CORS.

With these 4 CORS, the best IDOP = 0.5 and IDOP increases as the distance from the centroid increases.

With 9 CORS, IDOP would equal 0.33 at the centroid of the CORS.



OPUS-RS Accuracy Depends on IDOP and RMSD

RMSD = Root mean square distance = $[(\sum d_i^2) / n]^{0.5}$

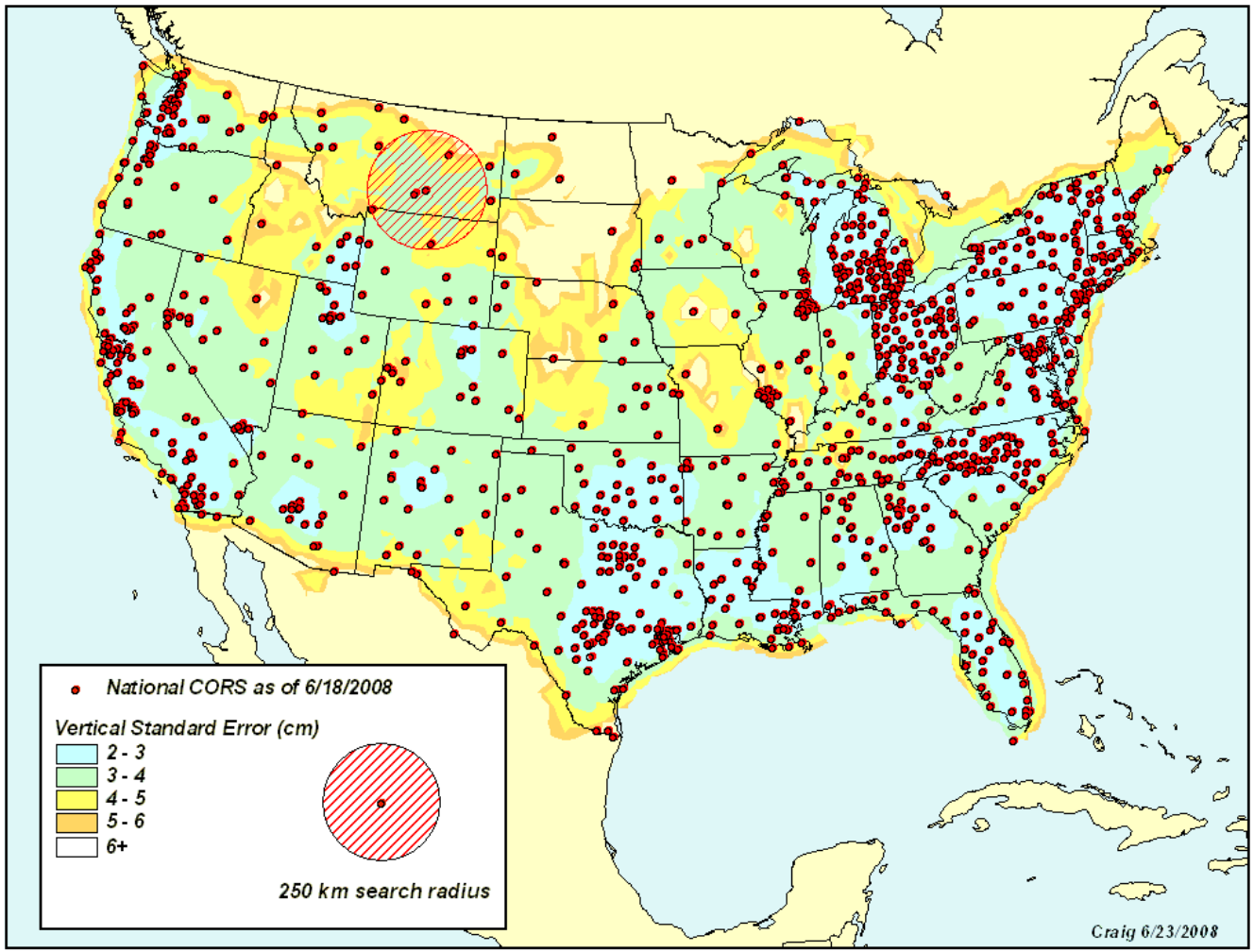
where d_i is the distance between the rover
and the i-th CORS,
and n equals the number of CORS being used.

$$STDERR(north) \approx [(1.8cm \bullet IDOP)^2 + (0.05ppm \bullet RMSD)^2]^{0.5}$$

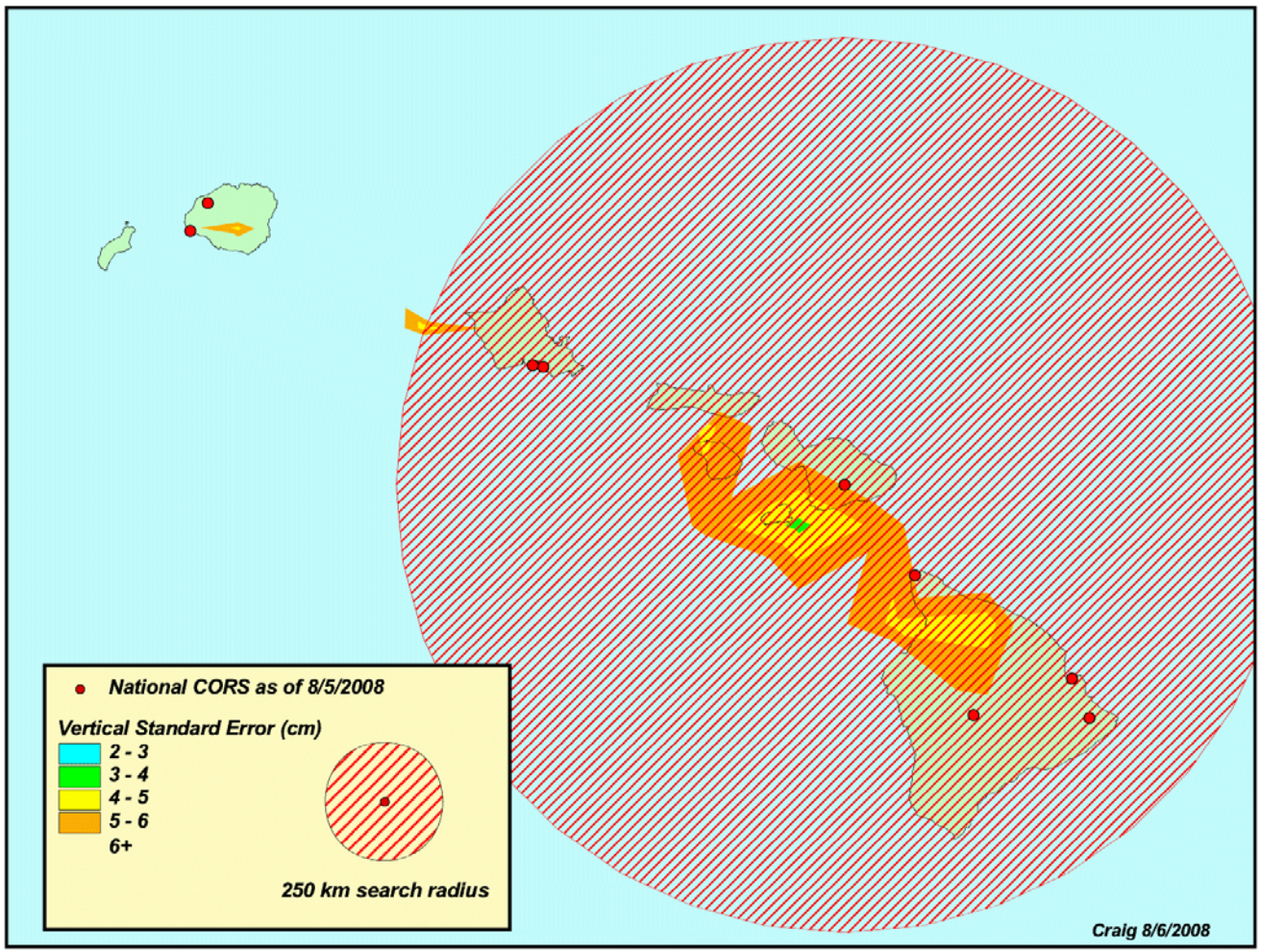
$$STDERR(east) \approx [(1.8cm \bullet IDOP)^2 + (0.05ppm \bullet RMSD)^2]^{0.5}$$

$$STDERR(up) \approx [(6.7cm \bullet IDOP)^2 + (0.15ppm \bullet RMSD)^2]^{0.5}$$

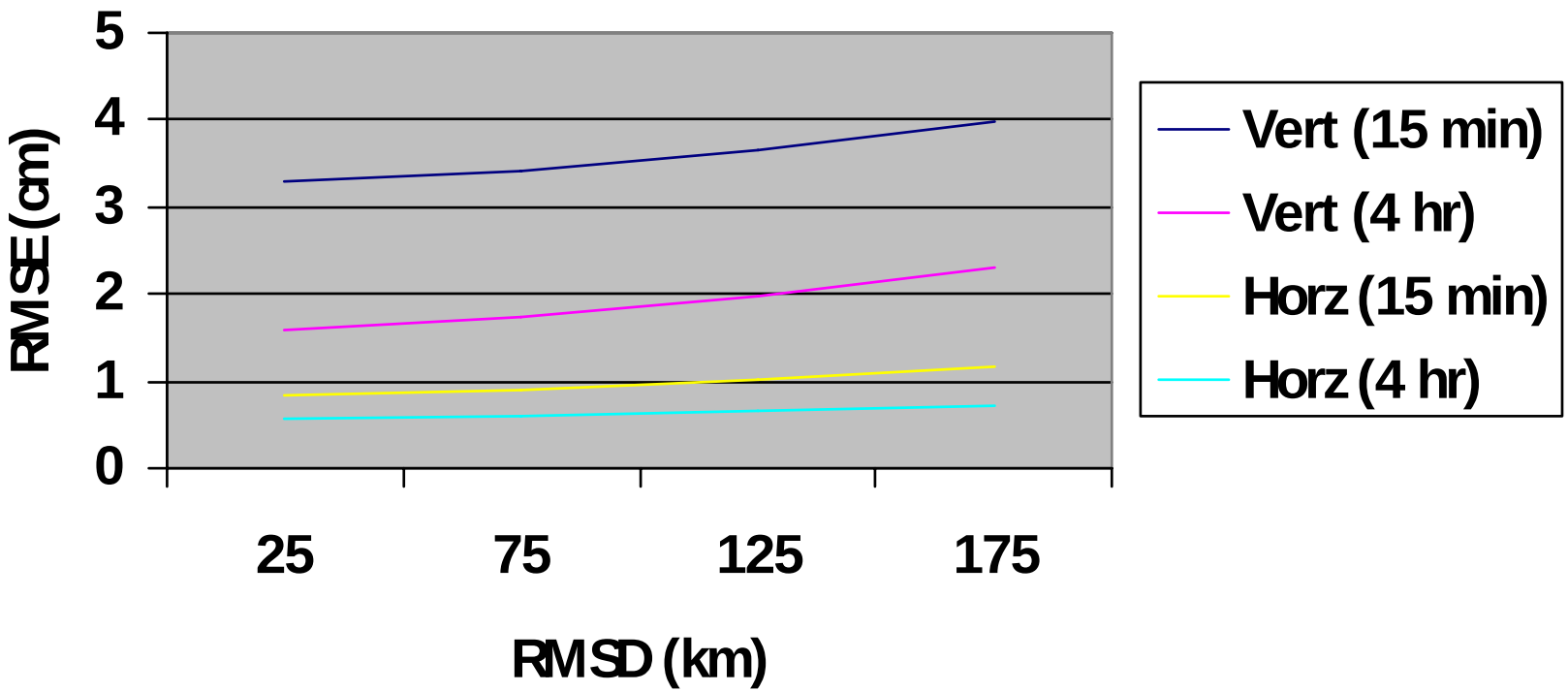
Vertical standard error achievable when a user submits 15 minutes of GPS data to OPUS-RS



Vertical standard error achievable when a user submits 15 minutes of GPS data to OPUS-RS



Comparing OPUS-RS Results for 15 – Minute Data Sets with Those for 4 – Hour Data Sets



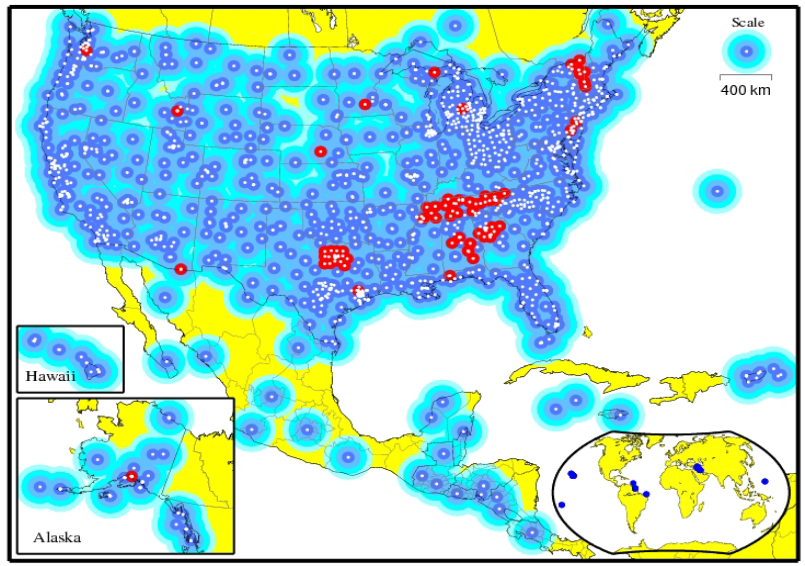
OPUS add-ons

DEFAULT	OPTION	OPUS FLAVOR
US only	global results	OPUS-global
hours of data	minutes of data	OPUS-RS
no archive	share results	OPUS-DB
one receiver	multiple receivers	OPUS-projects
no delimiters	delimited results	OPUS-XML
GPS only	GNSS signals	OPUS-GNSS
$$$ receiver	¢¢ receivers	OPUS-mapper

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.