OPUS – Best Practices

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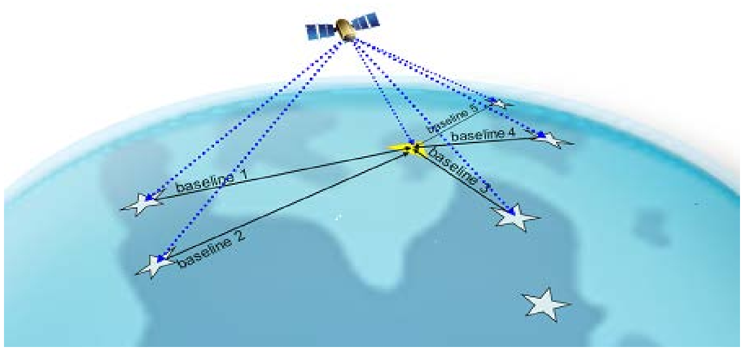
OPUS Introduction

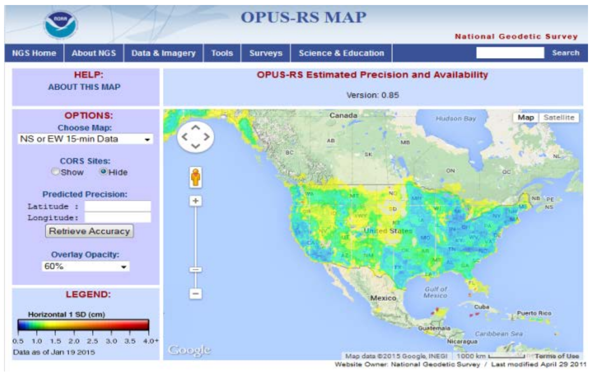
OPUS

- Static data: 2-48 hours of L1 & L2
- GPS-only (no GLONASS yet)
- PAGES software
- Option to Share to OPUS-DB (if data > 4 hours)
- Available globally

OPUS-RS

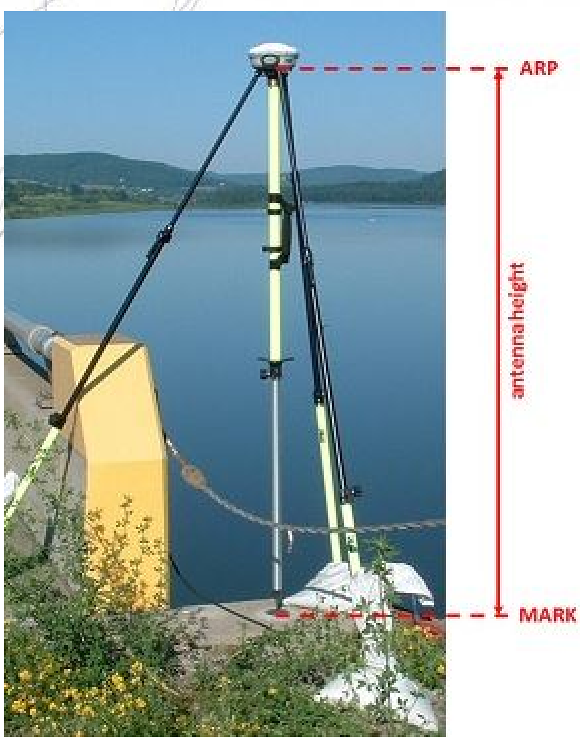
- Static data: >15 minutes to 2 hours of L1 & L2
- GPS-only (no GLONASS yet)
- Upgraded RSGPS software
- No option to Share to OPUS-DB
- Limited availability

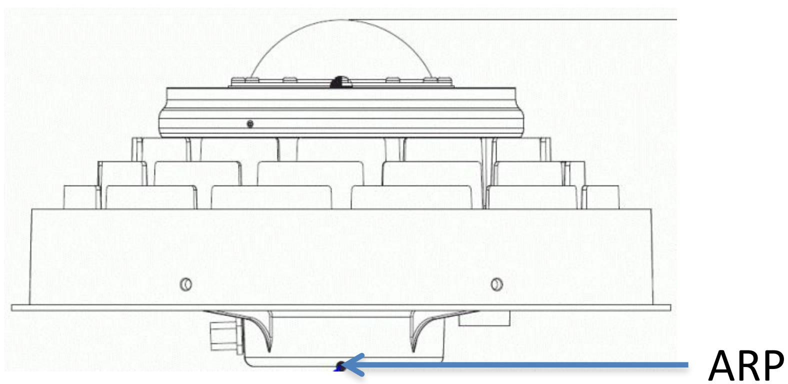




Antennas

- Use dual-frequency, geodetic quality antennas.
- Antenna height – vertical distance from monument to antenna reference point (ARP) in meters.





Antennas

- An antenna height of 0.0 m should be used if you want coordinates computed for the antenna reference point (ARP).
- Antenna calibration models exist for most GPS antennas. Calibration models account for antenna phase center offsets (PCO) and phase center variations (PCV). Vertical errors as large as 8 cm can result if the incorrect antenna is selected when processing GPS data.

Receivers

- Accurate results require the use of dual-frequency, geodetic quality receivers with at least 12 tracking channels.
- OPUS and Pages software currently process GPS data. Plans are underway to modify the tools and software to process GPS+GLONASS data simultaneously.
- Receiver sampling rate can be set to 1, 5, 10, 15 or 30 seconds.
- Receiver memory should be sufficient to collect several days worth of data.
- Program GPS receivers to collect L1, L2, P1, P2, CA. Doppler and signal strength data are not needed.

Occupation

- Use a fixed height pole and/or tripod to mount antenna.
- Avoid setting antenna near flat galvanized roofs, other reflective surfaces and high voltage power lines.
- If possible, collect 2 or more hours of data in the session.
- Have ample battery power for the duration of the occupation.
- Program receiver settings before session is scheduled to begin.

OPUS Processing

- www.ngs.noaa.gov/OPUS/
- Upload file in native receiver (binary) or RINEX format.
- If you upload in binary, conversion to RINEX will take place within OPUS using Teqc.
- OPUS currently uses RINEX version 2.x format.
- Let OPUS choose the CORS stations automatically to get a more robust selection of CORS stations.
- Let OPUS choose the local State Plane Coordinates (SPC). In boundary mapping regions you can force OPUS to select the appropriate SPC.
- Always select extended output which contains more detailed information and facilitates data screening.

CORS Reference Stations

- OPUS computes an initial set of coordinates from the submitted data to calculate approximate rover location.
- OPUS then identifies all the CORS within 1000 km of the rover and chooses the best five to use in the final OPUS solution.
- The five CORS that are chosen are not necessarily the closest. Numerous quality control tests are performed on the CORS archived data to select the best CORS.
- Some of the quality control tests look at 1) data availability, 2) common time blocks, 3) distance, 4) geometric distribution, 5) redundancy, and 6) multipath.

Solution Report

- Results are reported in meters and degrees, minutes and seconds.
- Coordinates referred to the geocentric IGSxx frame are reported at the average epoch of the observation span.
- NAD 83 coordinates are referred to a pre-specified epoch such as January 1st, 2010. All frames and epochs are clearly stated on the solution report.
- Peak to peak errors (ranges between maximum and minimum values) are reported for coordinates.
- Overall solution RMS is also reported.

Diagnostics

- Look at the overall solution RMS. Smaller value typically indicates a good solution (i.e. RMS = 0.011 m).
- Next look at the coordinate peak to peak values. If all values are relatively small, then there is greater confidence in the solution. If there is a large peak to peak value, the data for one or more CORS in the processing may be the problem. Try reprocessing by eliminating/replacing one CORS at a time until the solution improves.
- There is the possibility that the rover data could also be noisy or contain bad data which would also result in high peak to peak errors.

Diagnostics (cont.)

- To resolve this quandary, check the extended output. Look for the peak to peak of each individual baseline. If all of them are high, the problem may be the rover data.
- If a single baseline to any CORS shows large peak to peak errors, rerun OPUS replacing that CORS by a different CORS site.
- The main issue is to obtain the results inside certain tolerance. Generally, the ellipsoid height errors should be about three times larger than the horizontal errors.
- The relationship between peak to peak and RMS (1σ) is

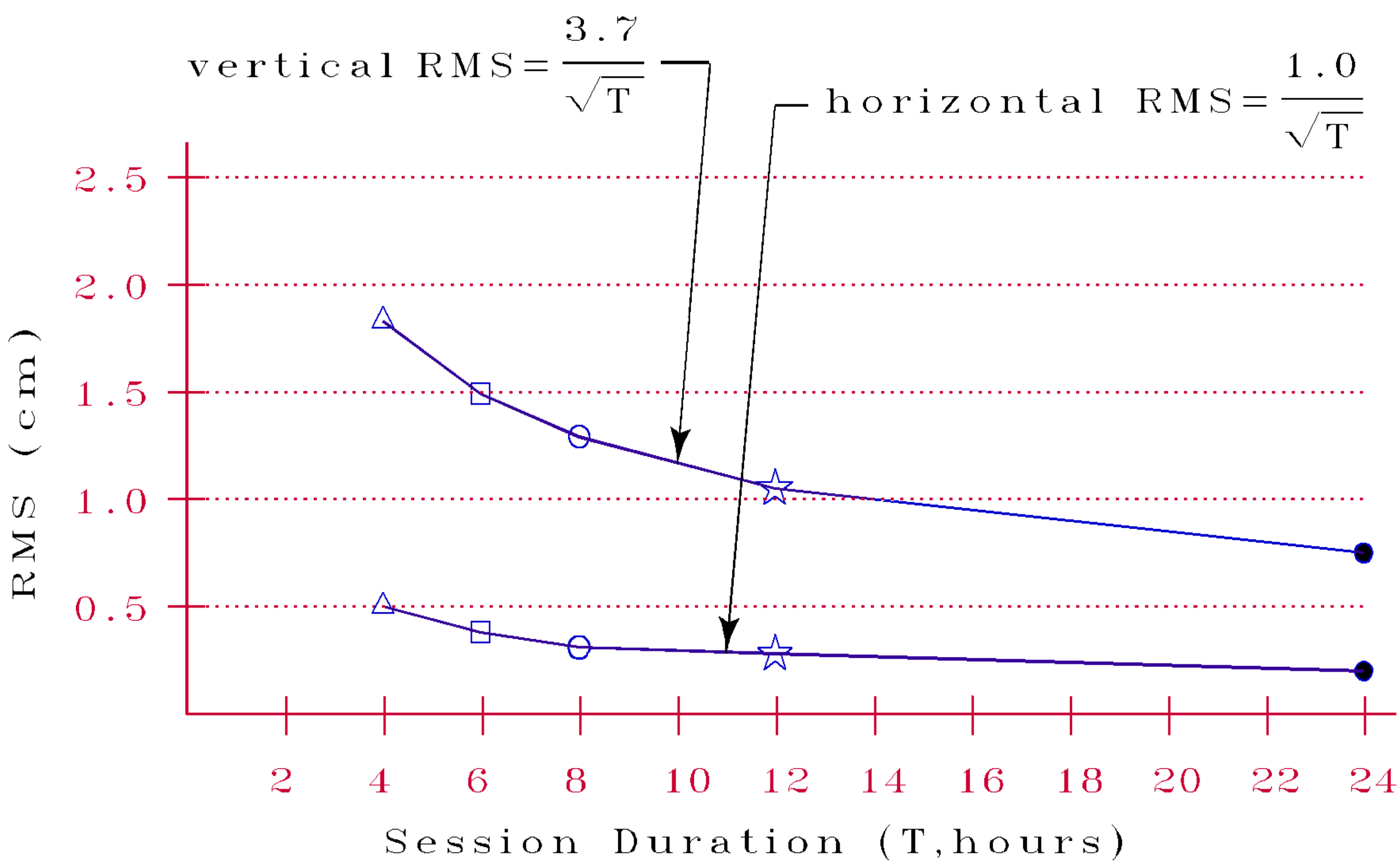
$$\text{peak-to-peak} = 1.6929 \times \sigma$$

thus, the peak-to-peak statistic is more pessimistic than σ

Diagnostics (cont.)

- Another fact that must be emphasized is that, generally speaking, under standard observational conditions, vertical GPS results are about 3.7 times larger than the horizontal results.
- This could be attributed to the difficulty of modelling the atmospheric corrections (ionospheric and tropospheric effects).
- The following graphs show the results obtained from an experiment using OPUS-S, 12 baselines disseminated around the country, and 10 days of GPS data observed in 1998 and processed using observing sessions of 4, 6, 8, 12 and 24 hours.

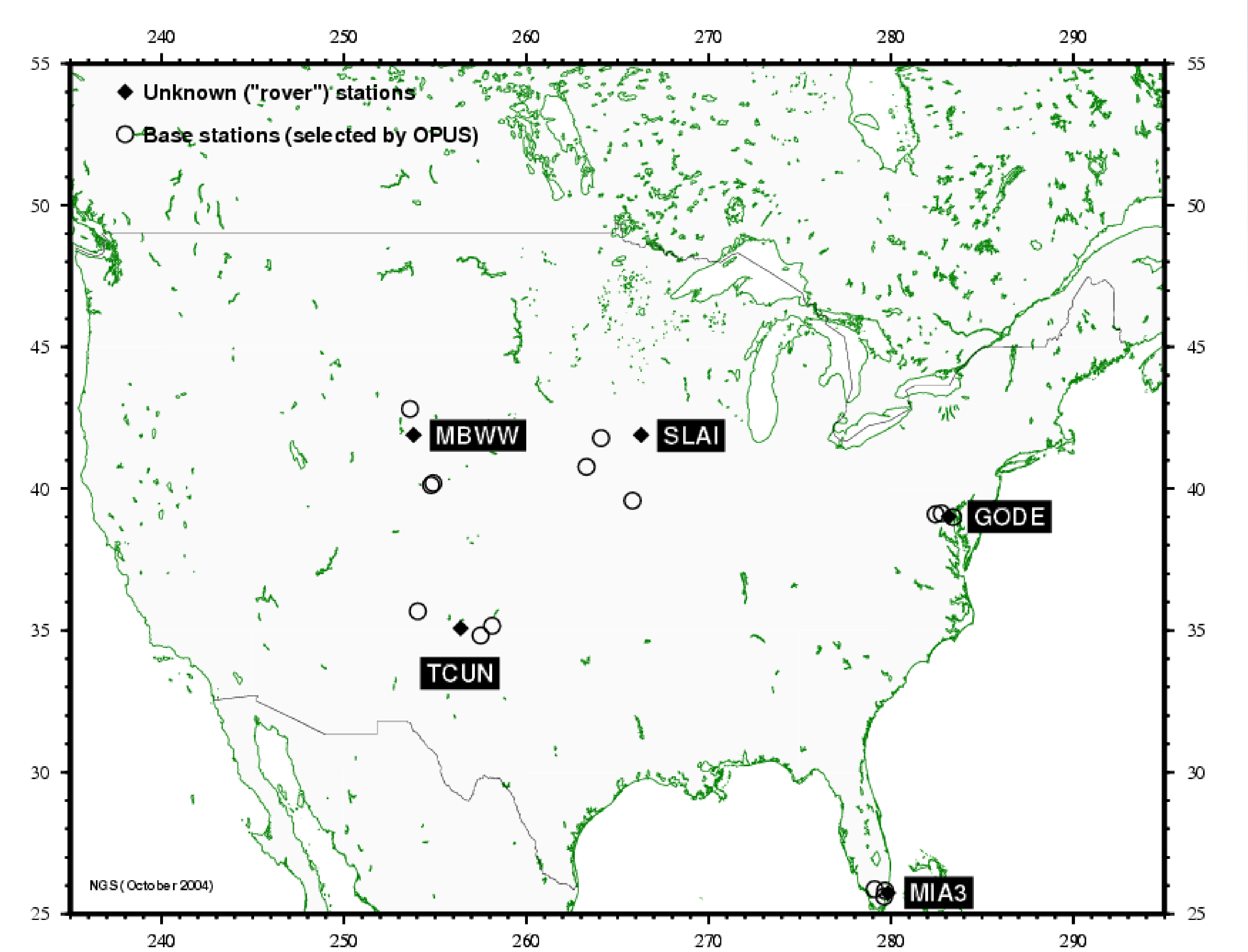
Time of observation vs. RMS (OPUS-S)



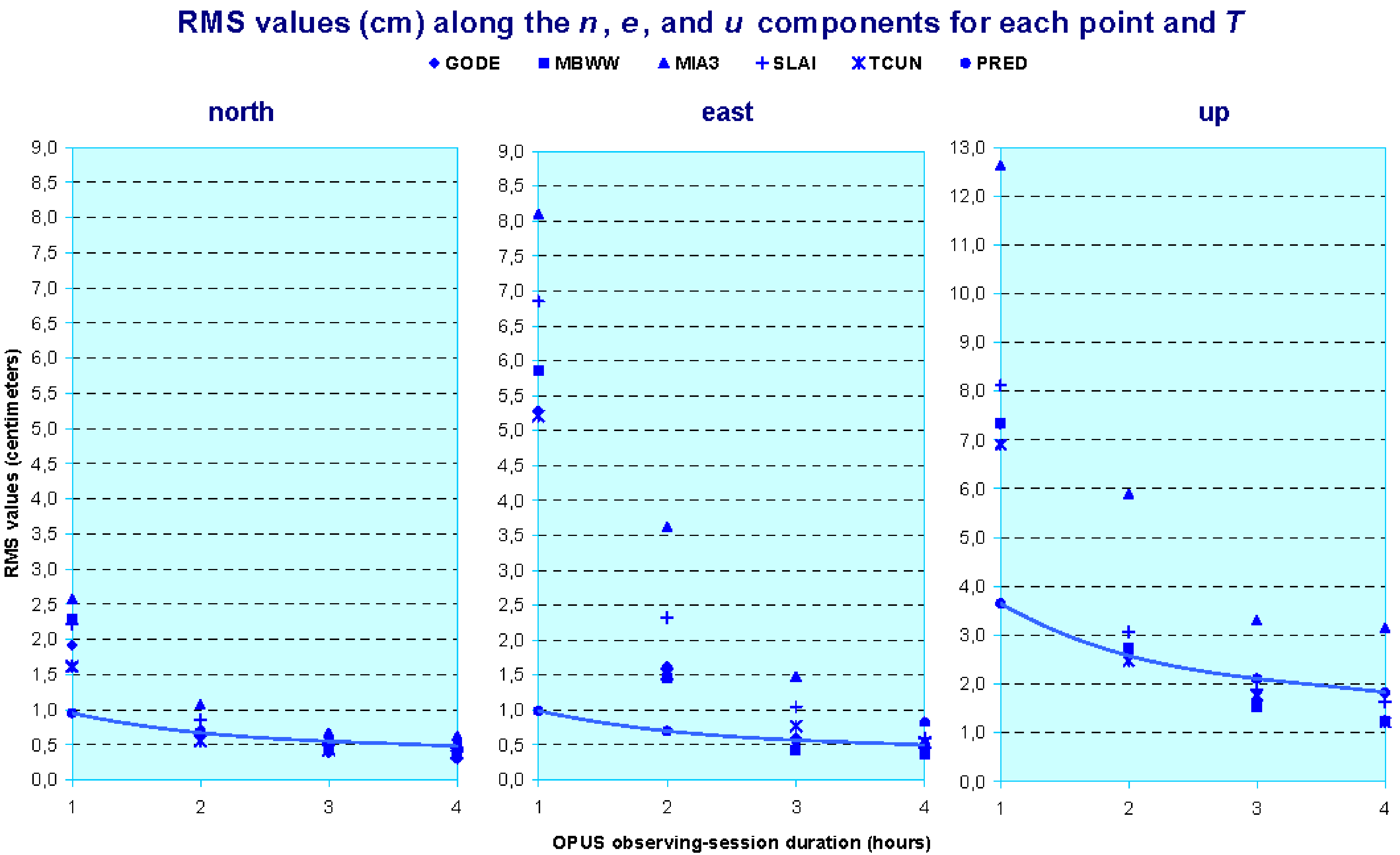
Diagnostics (cont.)

- A second experiment was devised to quantify the degradation of the RMS value when observing less than 4 hours (30 days of data, June 2004, 6 CORS).
- The major errors affecting short observation spans are:
  1) The difficulty in fixing integers
  2) Correcting for tropospheric effects that are very much affected by the water content in the atmosphere (humidity, rain, storm fronts, etc.)
- The results of the next plots show that when observing less than 2 hours the OPUS-S software does not agree well with the predicted RMS curve shown before.

1 to 4 hours sessions vs. RMS (OPUS-S)



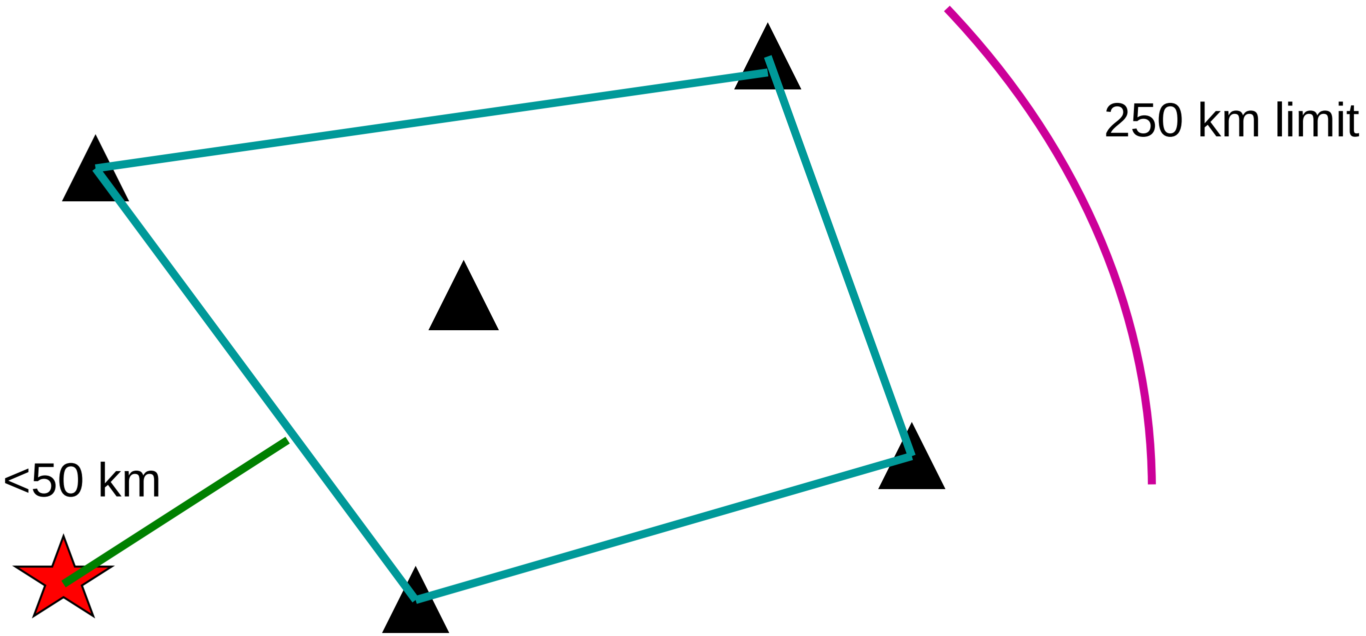
1 to 4 hours sessions vs. RMS (OPUS-S)



OPUS-RS

- In order to provide NGS constituency with accurate results for observation spans between 15 minutes and 2 hours, NGS embarked in the development of a new version of OPUS named OPUS-RS (Rapid Static).
- The basic software used by OPUS-RS, named RSGPS (Rapid Static GPS) was developed at OSU partially supported by NGS that later expanded it to serve the demand of many OPUS users for short span sessions.
- 1) OPUS-RS uses P-code range observations as well as phase observations on both L1 and L2 frequencies. The difficulty in fixing integers

OPUS-RS search algorithm



- Sort stations in CORS network by distance from rover. Select up to nine CORS that are less than 250 km from rover and that have suitable data.
- No solution is attempted if fewer than three CORS selected.
- No solution attempted if distance from rover to polygon enclosing selected CORS is greater than 50 km.

OPUS-RS (cont.)

- OPUS-RS uses the well-known LAMBDA algorithm to find the integer values.
- It has two processing modes: network and rover.
- The network mode adjust the observations from a set of reference stations and produces:

1) Reference stations coordinates and their covariance.
2) Tropospheric refraction parameters and their covariance matrix at reference stations.
3) Integer valued double difference ambiguities on baseline between reference stations.
4) Double difference delays and their v-c matrix at each epoch.

OPUS-RS (cont.)

- The rover mode uses the previous parameters determined in the network solution with integer fixed ambiguities to apply constraints (predicted tropospheric refraction and ionospheric delays) to the solution containing one or more rover stations.
- The network solution typically uses 1-2 h of data from the reference stations. The rover solution uses only the reference station data that matches the time span of the rover data set, typically 15 min.
- The rover data must be carefully conditioned to ensure that is free of cycle slips, data spans less than 15 min., and excessive multipath effects.

OPUS-RS (cont.)

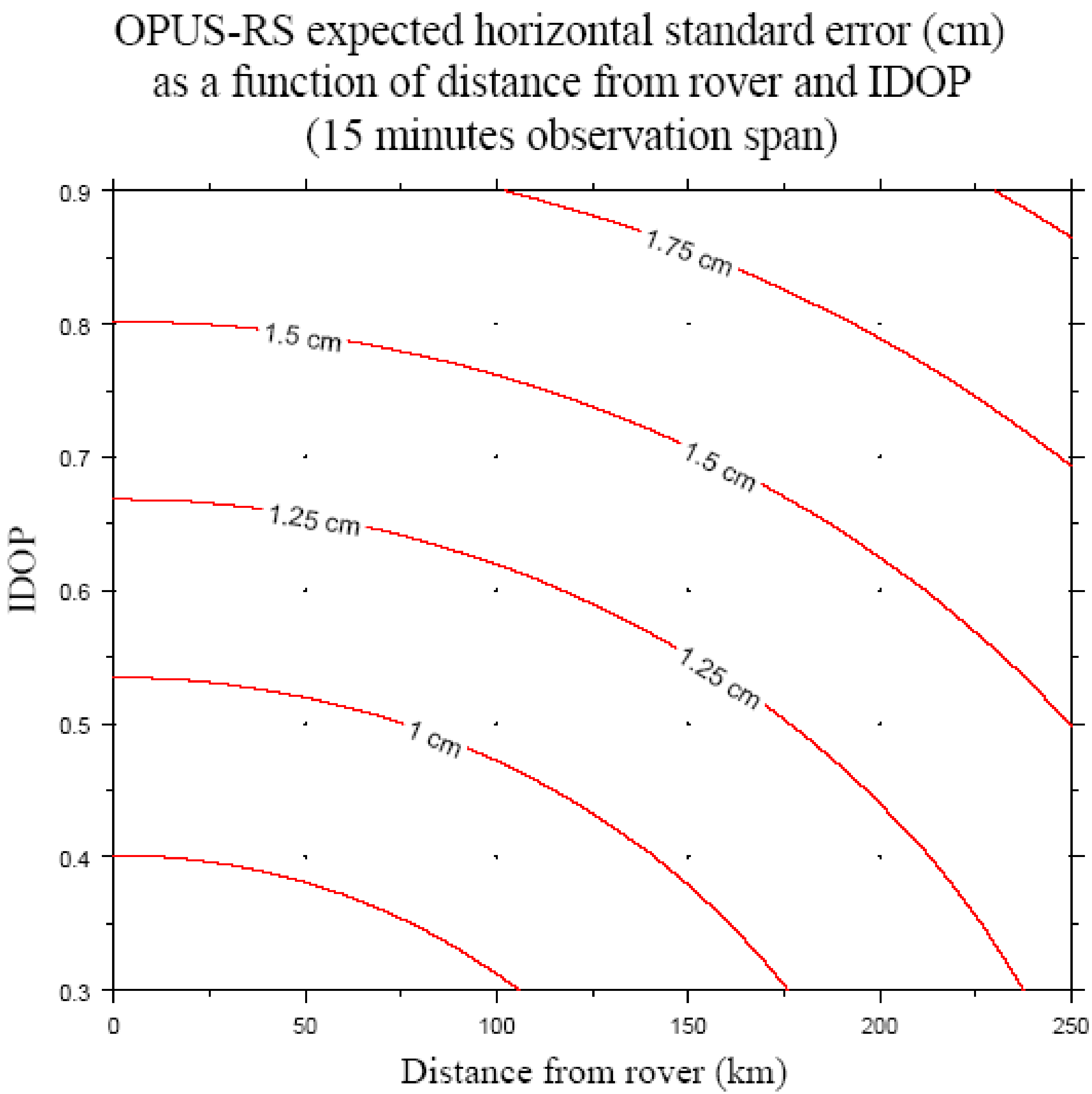
- Because of the interpolation scheme used that predicts atmospheric delays at the rover from the network results at several CORS (within 250 km from the rover), the final coordinates depend highly on the local geometry of the CORS network and the distance between rover and local CORS.
- Consequently, two parameters are introduced to determine the accuracy of the OPUS-RS solutions:
- 1) Interpolative Dilution of Precision (IDP).
- 2) Root Means Square Distance (RMSD) between the rover and the individual CORS involved in the OPUS-RS computations.

OPUS-RS (cont.)

- The estimated standard errors of the OPUS-RS determined coordinates can be computed using the equation:

$$\sigma(IDOP,RMSD)=\sqrt{(\alpha\cdot IDOP)^2+(\beta\cdot RMSD)^2+\gamma^2}$$

- The equations to compute the values of IDOP (as a function of the geometry) and RMSD (as a function of the distances) were cited in the references given at the end of the presentation.
- Knowing the values of IDOP and RMSD for each case, the constants α, β, and γ where determined using a least-squares procedure.

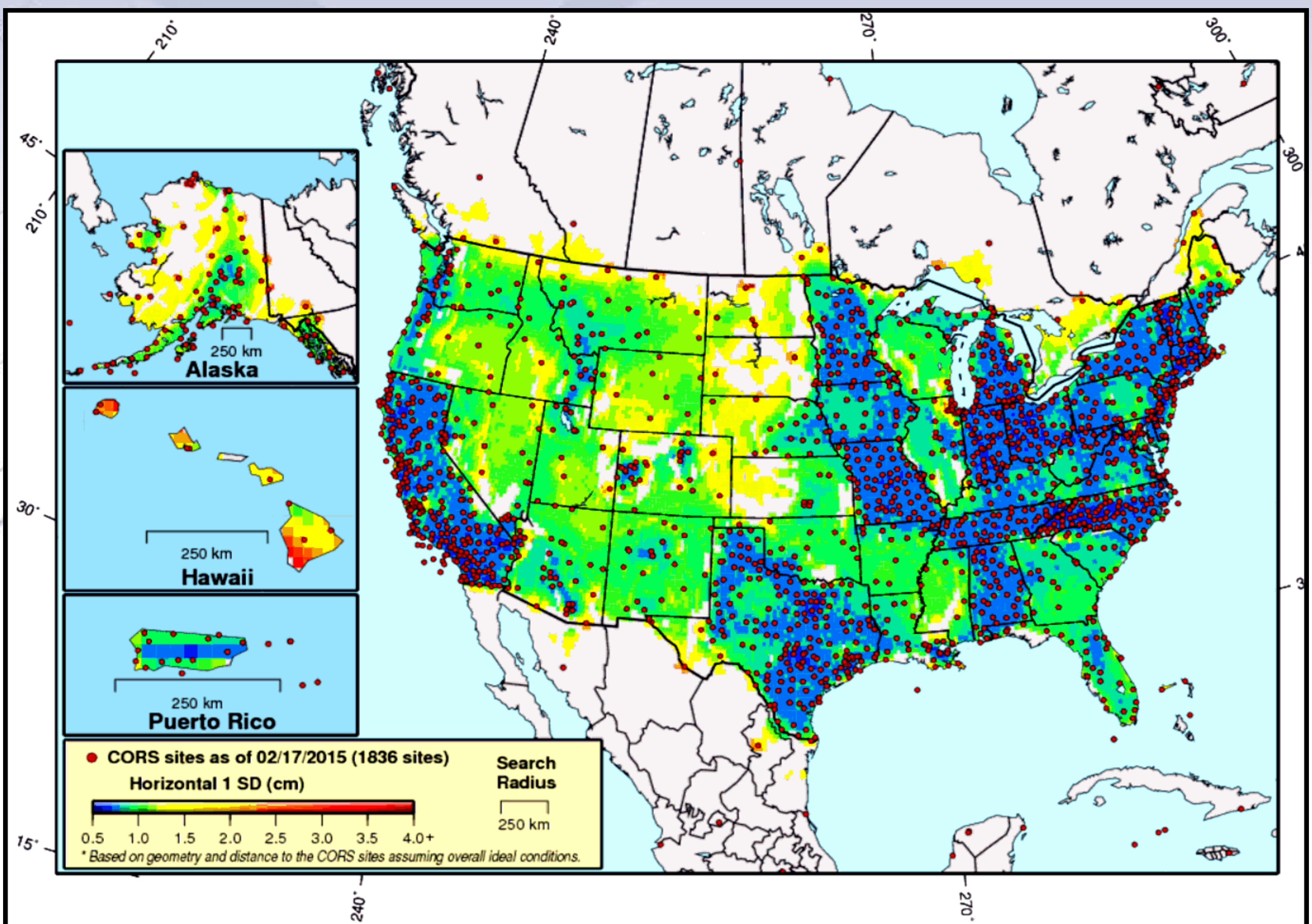


OPUS-RS expected horizontal standard error (cm)
as a function of distance from rover and IDOP
(15 minutes observation span)
IDOP
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
50
100
150
200
250
Distance from rover (km)
1.75 cm
1.5 cm
1.5 cm
1.25 cm
1.25 cm
1 cm

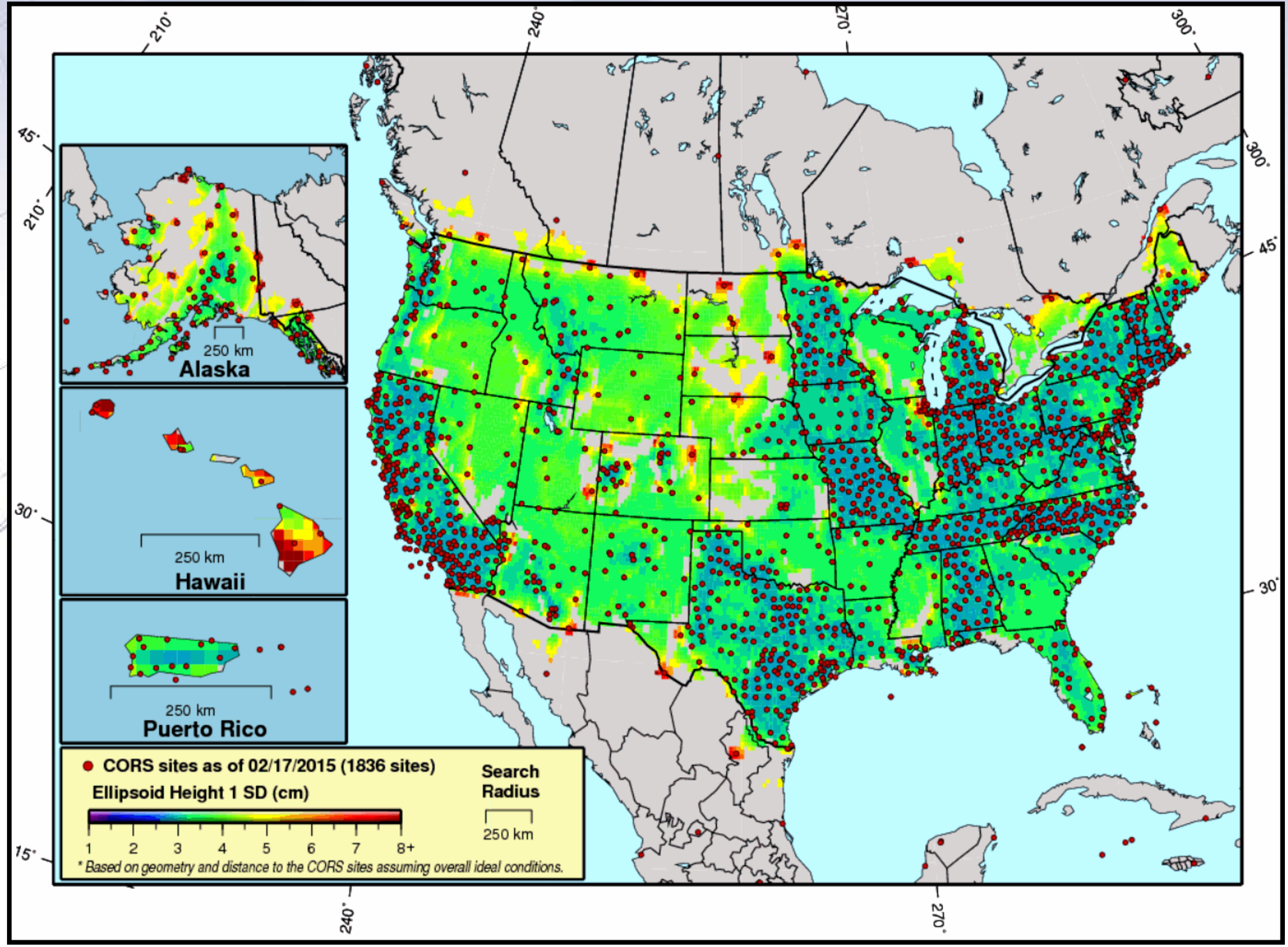
OPUS-RS (cont.)

- This concept was applied to the particular distribution of CORS stations around the US and its territories.
- The expected accuracies of the OPUS-RS along the horizontal and vertical components, depending of the location of the rover and the time of observation were graphically visualized in a map.
- Standard deviations for GPS-observations using time spans of 15 minutes and 1 hour were estimated.
- These maps are constantly updated because new CORS are installed and old ones decommissioned. Thus, the geometry of the network changes.

OPUS-RS (cont.)

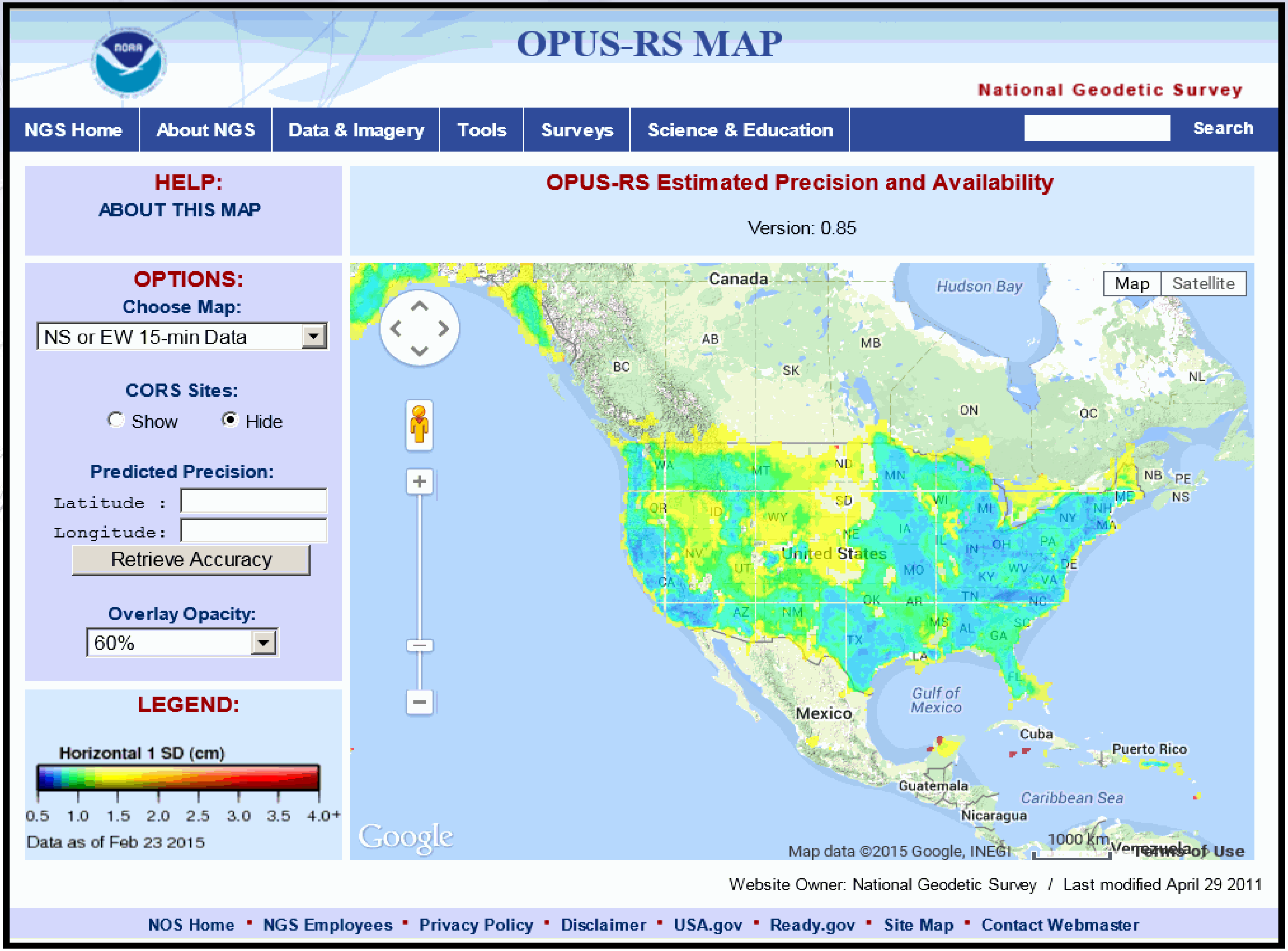

250 km
Alaska
250 km
Hawaii
250 km
Puerto Rico
CORS sites as of 02/17/2015 (1836 sites)
Horizontal 1 SD (cm)
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0+
* Based on geometry and distance to the CORS sites assuming overall ideal conditions.
Search Radius
250 km
210°
240°
270°
300°
45°
30°
15°

OPUS-RS (cont.)



250 km
Alaska
250 km
Hawaii
250 km
Puerto Rico
CORS sites as of 02/17/2015 (1836 sites)
Ellipsoid Height 1 SD (cm)
1 2 3 4 5 6 7 8+
* Based on geometry and distance to the CORS sites assuming overall ideal conditions.
Search Radius
250 km
210°
240°
270°
300°
45°
30°
15°

OPUS-RS (cont.)


OPUS-RS MAP
National Geodetic Survey
NGS Home
About NGS
Data & Imagery
Tools
Surveys
Science & Education
Search
HELP:
ABOUT THIS MAP
OPUS-RS Estimated Precision and Availability
Version: 0.85
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 Feb 23 2015
Map
Satellite
Canada
Hudson Bay
United States
Gulf of Mexico
Mexico
Cuba
Puerto Rico
Guatemala
Caribbean Sea
Nicaragua
Map data ©2015 Google, INEGI
1000 km
Terms of Use
Website Owner: National Geodetic Survey / Last modified April 29 2011
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OPUS-RS (cont.)

- Notice that OPUS-RS cannot be used when the distribution of CORS sites is not dense. That is the case, for example in North and South Dakota.
- The maps are available at the NGS Web site: http://geodesy.noaa.gov/OPUSI/Plots/OPUSRSall-h.15-min.png
- An interactive web-based version is also available at:

  http://geodesy.noaa.gov/OPUSI/Plots/Gmap/OPUSRS_sigmap.shtml
- These maps come handy for planning GPS surveys that later are going to be processed using OPUS-RS. Before going to the field it is possible to predict (in normal conditions) the (horizontal & vertical) standard deviations obtainable using the OPUS-RS software.

References

- NGS Main:
  - http://www.ngs.noaa.gov/
- OPUS Main:
  - http://www.ngs.noaa.gov/OPUS/
- During the years scientists at NGS have published scientific and tutorial papers describing the principal characteristics and how to properly use OPUS-S and OPUS-RS.
- The majority of these papers are available at the CORS/OPUS portal:
  http://www.ngs.noaa.gov/CORS/Articles/

Thank You

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