Using CORS and OPUS for Positioning

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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.
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

- NSF (PBO)+Academic: 15%
- Foreign: 3%
- Commercial: 11%
- City Govt.: 2%
- County Govt.: 6%
- State Govt.: 34%
- NOAA (NOS+NWS): 8%
- USCG: 15%
- NASA+other Federal: 3%
- FAA: 2%
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 Geophyiscal Data Center
  Anonymous FTP  ftp://wwwwest.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

vertical RMS = \frac{3.7}{\sqrt{T}}

horizontal RMS = \frac{1.0}{\sqrt{T}}

RMS (cm)

Session Duration (T, hours)
Positioning Accuracy with Code Data

Observation Time = 1 minute

RMS error = 25 cm + 2 ppm
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)
Quick Link to OPUS from NGS Home Page
www.ngs.noaa.gov
1. Enter your email address

2. Enter your DATA file
   Now accepting RINEX and selected receiver formats.
   Data files may also be compressed (.ZIP, .zip, .gz)

3. SELECT NO ANTENNA TYPE
   no antenna selected - see FAQ #6

4. Enter the antenna height
   If desired, select from several options to modify the basic OPUS procedures.

5. Options

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.
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.

| REF FRAME: NAD_83(CORS96) (EPOCH: 2002.0000) | ITRF00 (EPOCH: 2005.1596) |
| X: -249423.165 (m) 0.018 (m) | -249423.872 (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 07.91054 0.002 (m) | 44 35 07.92698 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) | 130.010 (m) 0.043 (m) |

<table>
<thead>
<tr>
<th>UTM COORDINATES</th>
<th>STATE PLANE COORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northing (Y) [meters]</td>
<td>4936954.907</td>
</tr>
<tr>
<td>Easting (X) [meters]</td>
<td>475821.322</td>
</tr>
<tr>
<td>Convergence [degrees]</td>
<td>-0.21381402</td>
</tr>
<tr>
<td>Point Scale</td>
<td>0.99960719</td>
</tr>
<tr>
<td>Combined Factor</td>
<td>0.99959034</td>
</tr>
</tbody>
</table>

US NATIONAL GRID DESIGNATOR: 10TDQ7582136955 (NAD 83)

<table>
<thead>
<tr>
<th>BASE STATIONS USED</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID</td>
</tr>
<tr>
<td>AH2489 NEWP NEWPORT CORS ARP</td>
</tr>
<tr>
<td>AJ6959 CHZZ CAPE MEARS CORS ARP</td>
</tr>
<tr>
<td>DH4503 P376 EOLARESVR OR2004 CORS ARP</td>
</tr>
</tbody>
</table>

NEAREST NGS PUBLISHED CONTROL POINT

| PID | DESIGNATION | LATITUDE | LONGITUDE |
| 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
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

<table>
<thead>
<tr>
<th>Requirement</th>
<th>OPUS-S</th>
<th>OPUS-RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of GPS data from rover</td>
<td>2 – 48 hours</td>
<td>0.25 – 4.00 hours</td>
</tr>
<tr>
<td>Local CORS geometry</td>
<td>3 CORS, preferably located within 600 km of rover</td>
<td>3 to 9 CORS located within 250 km of rover, preferably with IDOP &lt; 0.8</td>
</tr>
</tbody>
</table>
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 = \( \frac{1}{\sqrt{N}} \)
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 = \[ \left( \frac{\sum d_i^2}{n} \right)^{0.5} \]

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

\[
\text{STDERR(north)} \approx \left[ (1.8 \text{cm}\cdot\text{IDOP})^2 + (0.05 \text{ppm}\cdot\text{RMSD})^2 \right]^{0.5} \\
\text{STDERR(east)} \approx \left[ (1.8 \text{cm}\cdot\text{IDOP})^2 + (0.05 \text{ppm}\cdot\text{RMSD})^2 \right]^{0.5} \\
\text{STDERR(up)} \approx \left[ (6.7 \text{cm}\cdot\text{IDOP})^2 + (0.15 \text{ppm}\cdot\text{RMSD})^2 \right]^{0.5}
\]
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

**RMSE vs RMSD for IDOP = 0.45**

- **RMSE (cm)**
- **RMSD (km)**

Lines represent:
- **Vert (15 min)**
- **Vert (4 hr)**
- **Horz (15 min)**
- **Horz (4 hr)**
<table>
<thead>
<tr>
<th>DEFAULT</th>
<th>OPTION</th>
<th>OPUS FLAVOR</th>
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</thead>
<tbody>
<tr>
<td>US only</td>
<td>global results</td>
<td>OPUS-global</td>
</tr>
<tr>
<td>hours of data</td>
<td>minutes of data</td>
<td>OPUS-RS</td>
</tr>
<tr>
<td>no archive</td>
<td>share results</td>
<td>OPUS-DB</td>
</tr>
<tr>
<td>one receiver</td>
<td>multiple receivers</td>
<td>OPUS-projects</td>
</tr>
<tr>
<td>no delimiters</td>
<td>delimited results</td>
<td>OPUS-XML</td>
</tr>
<tr>
<td>GPS only</td>
<td>GNSS signals</td>
<td>OPUS-GNSS</td>
</tr>
<tr>
<td>$$$$ receiver</td>
<td>$$$ receivers</td>
<td>OPUS-mapper</td>
</tr>
</tbody>
</table>
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.