Work Towards a Geometric and Vertical Reference Frame by 2022

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55th Meeting of the Civil GPS Service Interface Committee
Tampa Convention Center    14-15 September 2015
Outline

• NGS Personnel Changes
• SRSD Personnel Changes
• 2022 Reference Frames
  – Reference Frames≈Datums
  – Geometric
    • CORS Updates
    • OPUS Updates
  – Vertical (Geopotential)
    • GSVS 11/14/16
    • GRAV-D
    • xGEOID14/15
• Outreach Efforts
• Summary and Outlook

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NGS Personnel Changes

• HQ
  – Dru Smith now NSRS Implementation Manager (e.g., 2022 datums)
  – Neil Weston is now Chief Geodesist
  – Brett Howe is serving as acting Deputy Director

• Other Divisions
  – Vicki Childers is now the Chief, OAD
  – Gerry Mader has retired as Chief, GRD
  – Steve Hilla is filling in as acting Chief, GRD
  – Ross Mackay is filling in as acting Chief, GSD
Personnel Changes in SRSD

• GSA Branch
  – Bang Le is new RTN Liaison
  – Dave Hatcher and Weibing Wang are OPUS Analysts
  – They replace Cindy Craig and Bob Siclari

• CORS Branch
  – Kevin Choi is Branch Chief and will soon divest ACC duties
  – Sungpil Yoon and Jarir Saleh are Orbiteers
  – Fran Coloma and Lijuan Sun are CORS Analysts
2022 Geometric Reference Frame

- Will be fit from global to local
- Foundation CORS will be the U.S. subset of IGS global sites
- These will adjust the CORS Sites
  - Collected/archived at ~ 2000 sites
  - Even when a site is dropped, it must be maintained in the list
- CORS Sites can then adjust RTN’s
- Akin to Helmert Blocking scheme
2022 Geometric Reference Frame

- The archived CORS data are used in OPUS tools
  - Currently, OPUS output is only Shared (e.g., OPUS Database)
  - Official coordinates remain those in the NGSIDB
- RTN Validator tool in DEV
  - Difference between OPUS solution and reported coordinates
  - Expedited upload – as frequent as wanted

QA test of OPUS-S with 2-hour data sets at 200 CORS: Compare output to CORS coord.

Mean: <0.1 cm
N-S RMS: 0.8 cm
E-W RMS: 1.4 cm
Validate RTNs with a modified OPUS process

- Major steps in OPUS are shown in left column
- Some steps can be skipped for RTN case
- Site is well established
- Operator would have an ID and appropriate header info
- Expedited upload avoids most QC checks

Diagram:
- Upload to webpage
- OPUS Solution
- Describe/OPUS ID
- Verify
- Approve
- Review
- OPUS-DB
- RTN appends RINEX header (OPUS ID)
- FTP Site
- Display on RTN Validator
RTN Validator Tool for Base Station

• On a periodic (e.g., daily) basis, data are FTP’d and processed
• Top section has similar elements as in OPUS-DB
• Middle section shows available solutions
• Bottom shows a time series for X-Y-Z or lat-lon-ht
• Offset and trends are clear
RTN Validation for Users

• To evaluate the base station, the RTN operator would make that sheet available and/or publish to OPUS-DB

• Additionally, occupy established GPS bench marks listed in either the NGSIDB or OPUS-DB
  – Any systematic features observed between the established solutions and those from roving on the RTN would indicate a potential bias/offset
  – Should be located within 20 km intervals
CORS Updates

• Repro2 – better late than never
  – Reprocessing 1 (or repro1) happened as a part of IGS08/MYCS
  – After Kevin Choi turns over his IGS ACC duties (December)
  – Will reprocess all CORS data (cleaning, stacking, etc.)
  – Will bring in newer CORS sites (since 2008) and update velocities
  – Will define transformation to IGS2014
  – For CORS site coordinates, orbits, and derived positions
  – There will not be a new Realization of NAD 83
    • Since IGS2014 is expected to nearly equal IGS2008
CORS Updates (continued)

• Reference Frame definition
  – Likely adopting most recent IGS model (e.g. 2014 if nothing newer)
  – Examining plate fixed vs. semi-dynamic vs. dynamic
  – Velocities could be as simple as Euler pole rotation to use of HTDP

• GNSS data collection
  – 40% of CORS sites have GNSS receivers (GLONASS)
  – Started archiving this data in January of this year
  – Not using the GNSS data in OPUSS yet but will eventually (2022 goal)
OPUS

• NOS/NGS 58/59 updates
  – HT MOD surveys still are being bluebooked
  – Goal it so have OPUS Projects (OP) replace this
  – Two separate studies: OSU vs. OSU (Ohio State U. vs. Oregon State U.)
  – Possibly reduction in collection times
  – Still aiming for Fall of 2016

• OPUS Projects
  – Multiple observations on multiple sites on multiple days
  – Uses hub and spoke design to get local control plus national ties
Simple Hub & Spoke Network Design Strategy

Consider a single hub site when that mark has more than 4 hrs of data:

- Include and tightly constrain CORS, loosely constrain the hub.
- Connection to CORS creates a strong connection to the ITRF.
- Provides a consistent reference for each project mark.
What’s in it for me?

- **OPUS solutions** = pretty good, but each treated as independent and assumes “perfect” CORS.

- **Sessions** = simultaneously-observed marks processed together in sessions increases consistency.

- **Adjustments** = interlinking sessions through network adjustments increases accuracy.
A Possible Strategy for Use of RTN’s

• Use the RTN Validator Tool to keep RTN coordinates consistent
• During a survey, use RTN stations as supplemental control
• OP permits you to weight the various observations
• Upweight the RTN and CORS and downweight the GNSS sites
• Adjusts the observations locally based on all sites plus RTN’s
• Keeps regional and international control from CORS and ITRF
OPUS (continued)

• Currently, OP outputs only to the Project
• OP output to OPUS Database
  – A project is underway to Share into OPUSDB
• OP output to NGSIDB
  – Must resolve Bluebook vs. OP results
  – Can then use OP to process and then load into NGSIDB
• OP output to NSRS DB
  – With a NSRS DB defined, OP would feed it directly (2022 goal)
2022 Vertical Reference Frame

- Defined through a geopotential model (this is a broad term)
- Current models use LSC to fill in between control points
  - Doesn’t resolve underlying datum defects (1.2 m trend in NAVD 88)
  - These “hybrid” geoid models are datum conversion tools only
  - Only as reliable as the accuracy and distribution of the control points
- Previous studies show data grid > 1’ yields significant omission
- Could use a Gravimetric Geoid model (practical method)
  - Geoid model is one arc-minute resolution
  - Converts ellipsoid height to orthometric height ($H = h - N$)
  - Conversion to other heights/functions of the gravity is difficult
2022 Vertical Reference Frame (continued)

• Use a Geopotential model (desired method)
  – Geopotential yield any function of gravity field
  – Current models limited to degree 2160 => 5’
  – For 1’ resolution, require a degree 10,800 model
  – Likely ellipsoid harmonics vs. spherical harmonics

• Geoid Slope Validation Studies (GSVS)
  – GSVS 11 – completed (presented at EGU/elsewhere)
  – GSVS 14 – completed but still being processed
  – GSVS 16 – being planned (recon IP in Colorado)
  – Will be used to check geoid models for vertical RF
Geoid differences from GSVS 11 observations

- Data collected along the lines:
  - GPS on leveling marks (GPSL)
  - Astrogeodetic DoV’s
  - Relative & absolute gravity data
- Gravity data => xUSGG11 geoid
- GPSL => pointwise geoid heights
- DoV => pointwise geoid heights
• Desire is to compare vs. geoids
• Combine the DoV and GPSL
  – Long wavelength => GPSL
  – Short wavelength => DoV
• Now compare against geoids
  – xUSGG11 fits closest to zero line
  – Other models have large trends

(geoid model – Comb.) along the line
Geoid comparison (model – Comb.)

<table>
<thead>
<tr>
<th></th>
<th>GPSL (mm)</th>
<th>USGG09 (mm)</th>
<th>EGM08 (mm)</th>
<th>xUSGG11 (mm)</th>
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<td>-0.4</td>
<td>0.1</td>
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<tr>
<td>STD</td>
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<td>16.9</td>
<td>17.2</td>
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<tr>
<td>RMS</td>
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<tr>
<td>Max.</td>
<td>33.0</td>
<td>26.7</td>
<td>35.1</td>
<td>8.7</td>
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</tbody>
</table>
2022 Vertical Reference Frame (continued)

- GRAV-D to help define vertical RF
- Bridges spectral band between satellite and surface gravity data
- Satellite controls long wavelength (global to 500 km scales)
- Aerogravity controls intermediate wavelength (40-500 km)
- Terrestrial data and terrain models control short wavelength

Map Key - Airborne Gravity Data
Green: Available data and metadata
Orange: Data collection underway
Blue: Data being processed
White: Planned for data collection
xGEOID14 & xGEOID15

- These use available aerogravity
- Also use same techniques as USGG models but updated data
- xGEOID14A has no aerogravity
- xGEOID14B has data available from last year
- xGEOID15B is developed but still on Test/DEV website
- Will release to Beta in September

beta.ngs.noaa.gov/GEOID/xGEOID14/
OUTREACH

• Will continue at future Geospatial Summits and other national and international meetings.
• Continued collaboration with IAG, FIG, and the UN-GGIM
• Continued collaboration with Canada, Mexico, and nations in Caribbean and Central America
• Will work with state surveying groups through NSPS and others to hone message for States to implement new laws
Summary and Outlook

• OPUS Projects (OP) or some derivative thereof will serve as means of determining geometric coordinates in the 2022 Geometric Reference Frame

• GNSS data will be used – not just GPS

• These coordinates will be used in some type of geopotential model to derive orthometric and other heights

• The models will be consistent with other global models and reference systems
Questions?

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