The U.S. National Spatial Reference System in 2022

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NOAA’s National Geodetic Survey
Outline

• Why change?
• Naming conventions of NSRS 2022
• Geometric component
  – Regional Terrestrial Reference Frames
  – Intra Frame Velocity Models
• Geopotential component
  – Static
  – Time-varying
• Future Plans and Summary
NGS Vision

Everyone *accurately* knows where they are and where other things are anytime, anyplace.

**NGS 10 Year and Strategic Plans** provide a more detailed description of NGS and the vision for the future looking ten years out.
Replace NAD 83

Simplified concept of NAD 83 vs. “2022”

- All vary smoothly by latitude and longitude

- \( \phi_{\text{NAD83}} - \phi_{\text{"2022"}} \)
- \( \lambda_{\text{NAD83}} - \lambda_{\text{"2022"}} \)
- \( h_{\text{NAD83}} - h_{\text{"2022"}} \)

NAD 83 origin

“2022” origin

\(~2.24\text{ m}\)

Earth’s Surface
Vertical Shifts

Ellipsoidal

Orthometric
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NSRS Modernization

The Old:
- NAD 83(2011)
- NAD 83(PA11)
- NAD 83(MA11)

The New:
- The North American Terrestrial Reference Frame of 2022 (NATRF2022)
- The Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)
- The Pacific Terrestrial Reference Frame of 2022 (PATRF2022)
- The Mariana Terrestrial Reference Frame of 2022 (MATRF2022)
NSRS Modernization

The Old:
- NAVD 88
- PRVD 02
- VIVD09
- ASVD02
- NMVD03
- GUVD04
- IGLD 85
- IGSN71
- GEOID12B
- DEFLEC12B

The New:
- The North American-Pacific Geopotential Datum of 2022 (NAPGD2022)
- Will include GEOID2022
NSRS Modernization

The Old:
Bluebooking
(PAGES, ADJUST, B files, G files, FORTRAN)

The New:
OPUS-Projects for Everything
GPS/GNSS
Leveling
Traverse
Gravity
RTK/RTN
More?
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Replacing the NAD 83’s

• Three plate-(pseudo)fixed frames will be replaced with four plate-fixed reference frames
  – North America, Pacific, Mariana, Caribbean

• Remove long-standing non-geocentricity of NAD 83 frames

• All four : identical to IGSxx at a TBD epoch
  – 2020.00?

• All four : differ from IGSxx by plate rotation only
  – Updated Euler Pole determination for rigid plate only
Plate-(pseudo)fixed frames

NAD 83(2011) minus NAD 83(NSRS2007)

NAD 83(NSRS2007)
• Epoch 2002.0

NAD 83(2011)
• Epoch 2010.0

If NAD 83 were truly “plate fixed” then an 8 year epoch change would not yield the systematic plate rotation seen here.

(*)=NA, CA, MA or PA

(*)TRF2022 will determine a new Euler Pole rotation for each of 4 plates.
Four Frames/Plates in 2022

• Previous NGS frames (Snay 2003)
  – North America
  – Pacific
  – Mariana
• Caribbean will be treated as 4th frame
Each frame will get 3 parameters:
- Euler Pole Latitude
- Euler Pole Longitude
- Rotation rate (radians / year)

This will be used to compute time-dependent TRF2022 coordinates from time-dependent IGS coordinates.
Fixed-Epoch Transformation
NAD 83 to “2022”
NATRF2022 frame is rigid and fixed to rigid part of the N.A. plate

Non-rigid part of the N.A. plate (deformation) area
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So if not HTDP, then what?

- NATRF2022 would account for most horizontal velocity over time
- Remaining signal typically modeled by HTDP (now)
- In future, a TBD velocity model would be applied to account for that and vertical
- The simplest solution is gridded CORS velocities
Horizontal velocities after Repro1

Note scale difference between West (10 mm/yr) and east (2 mm/yr)
CORS Implied Vertical Velocities - Control

Courtesy Galen Scott

31 May 2017, 1600         TS05C
Reference Systems and Frames

FIG Working Week 2017
Helsinki, Finland
CORS Implied Vertical Velocities – Heat Map

Legend (mm/yr)
cns_clean_idw
Value
High: 6.60007
Low: -232.25

This map was created using the MDA5 velocities available on the University of Nevada Reno's Nevada Geodetic Laboratory's website: http://geodesy.unr.edu/index.php

Citation:

Courtesy Galen Scott
31 May 2017, 1600
Reference Systems and Frames
FIG Working Week 2017
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What if this isn’t enough?

• Will investigate sufficiency of gridded CORS
• Concern is dynamic areas: horizontal & vertical
• Will look at other models to evaluate
  – GIA models
  – INSAR
• Cost versus benefit
  – What we can easily do in-house and support
  – increased complexity from outside models
• Alternatively, users can model their own ...
How to use this information?

• Assuming CORS spacing is sufficient – grid
  – Yields horizontal plus vertical signal (IFVM & GIA)

• Vertical important for orthometric heights:
  \[ H^t = (h^{t_0} + (t-t_0)\times dh/dt) - (N^{t_0} + (t-t_0)\times dN/dt) \]
  • Where \( H^t \) is orthometric height at desired time
  • \( h^{t_0} \) is ellipsoidal height at epoch (maybe 2020.0)
  • \( N^{t_0} \) is geoid height at epoch
  • \( dh/dt \) is change in ellipsoid height over time
  • \( dN/dt \) is change in geoid height over time
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NAPGD2022

- Begins with a 3-D global geopotential model

- Then, derivative products are built
  - GEOID2022
  - DEFLEC2022*
  - NGRAV2022*

* Names not yet finalized
GEOID2022 (et al.) over the North America/Pacific/Caribbean/Central America/Greenland region will range from 0 to 90 latitude and from 170 to 350 longitude.

GEOID2022 (et al) over American Samoa: -16 to -10, 186-193

GEOID2022 (et al) over Guam/CNMI: 11-22, 143-148
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NAPGD2022: Pre-decisional items

- Three types of geoid change will be tracked
  - Size, Shape, Change to W0
- Time/Space span evaluated for cost/benefit ratio
- Examples:

<table>
<thead>
<tr>
<th>Issue</th>
<th>Type of Change</th>
<th>Temporal Period</th>
<th>Temporal Duration of Geoid Change</th>
<th>Spatial Impact</th>
<th>Magnitude of geoid change</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accretion of Space Dust</td>
<td>Size</td>
<td>Secular</td>
<td>Permanent</td>
<td>Global</td>
<td>4x10^{-7} mm / y</td>
<td>Ignore</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>Shape</td>
<td>Episodic</td>
<td>Permanent-ish</td>
<td>Local</td>
<td>Can be as large as a few cm</td>
<td>Study further</td>
</tr>
<tr>
<td>GMSL rise</td>
<td>W0 value</td>
<td>Secular</td>
<td>Permanent</td>
<td>Global</td>
<td>1.7 mm / y</td>
<td>Provide as optional correction</td>
</tr>
</tbody>
</table>
Time-Varying Geoid

GRACE/GFO

Figure 3 from Tregoning et al. (2009)

Non-Stationary GRACE Signals

GeMS

- Geoid Monitoring Service
- Part of GRAV-D
- Theresa Damiani, Ph.D. lead
- SG and other meters to monitor select gravity BM’s
- Supplements and validates satellite-derived models
- GIA signals over Hudson Bay, Greenland, and Alaska
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Future Plans and Summary

• IGS Stations => Foundation CORS (FCORS)
  – Sites collocated with other techniques (IERS)
  – Adopt some/build others/cover all plates
• Foundation CORS => Regional CORS/Repro’s
  – Constrain Euler solutions/CORS positions to FCORS
  – Standing up IAG NA WG on Euler Pole
  – Forms four separate Frames
Future Plans and Summary

• Models of Intraplate velocities (hor. & ver.)
  – Could be simply modeled from existing CORS
    • Density and quality of CORS impacts
    • GIA signal must be taken into account (hor. & ver. vel.)
  – Could be as complicated as Trans4D or equivalent
    • How to maintain?
    • Earthquakes? Re-surveys?

• Orthometric heights in 2022: \( H(t) = h(t) - N(t) \)
  \( h(t) = \) survey epoch  \( N(t) = N(t_0) + \dot{N} (t - t_0) \)
To Learn More
Visit the New Datums web page

gerodesy.noaa.gov/datums/newdatums/index.shtml
To Learn More
Attend the Geospatial Summit

2017 Geospatial Summit

Save the Date

On April 24-25, 2017 we will host the 2017 Geospatial Summit in Silver Spring, Maryland.

The 2017 Geospatial Summit will provide updated information about the planned modernization of the National Spatial Reference System (NSRS). Specifically, NGS plans to replace the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD 88) in 2022.

The Summit will provide an opportunity for NGS to share updates and discuss the progress of projects related to NSRS Modernization. NGS also looks forward to hearing feedback and collecting requirements from its stakeholders across the federal, public and private sectors. This event will also help continue discussions from previous Geospatial Summits held in 2010 and 2015.

Additional information about the 2017 Geospatial Summit will be posted online. In the coming months, NGS will update the web-page with information about the agenda, registration options, logistics and frequently asked questions. If you have questions or comments, contact us.

geodesy.noaa.gov/geospatial-summit/index.shtml

• Silver Spring, MD
• April 24-25, 2017
• FREE
Questions?