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# The U.S. National Spatial Reference System in 2022

**Daniel R. Roman, (Chief Geodesist)**

**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

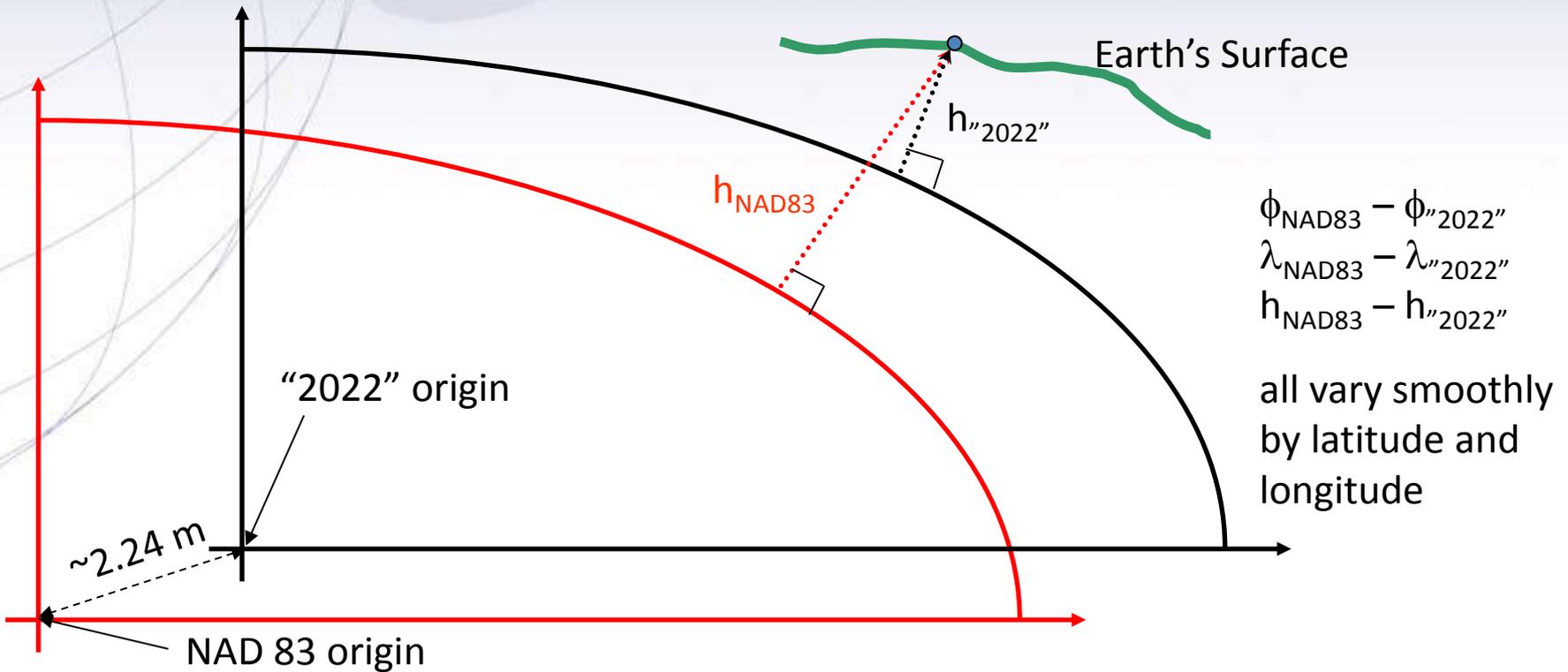
# NGS Vision

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

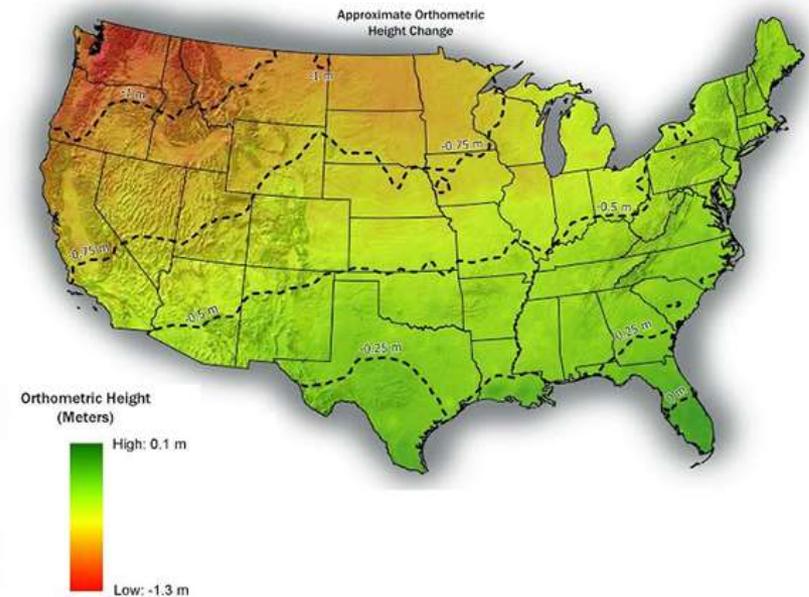
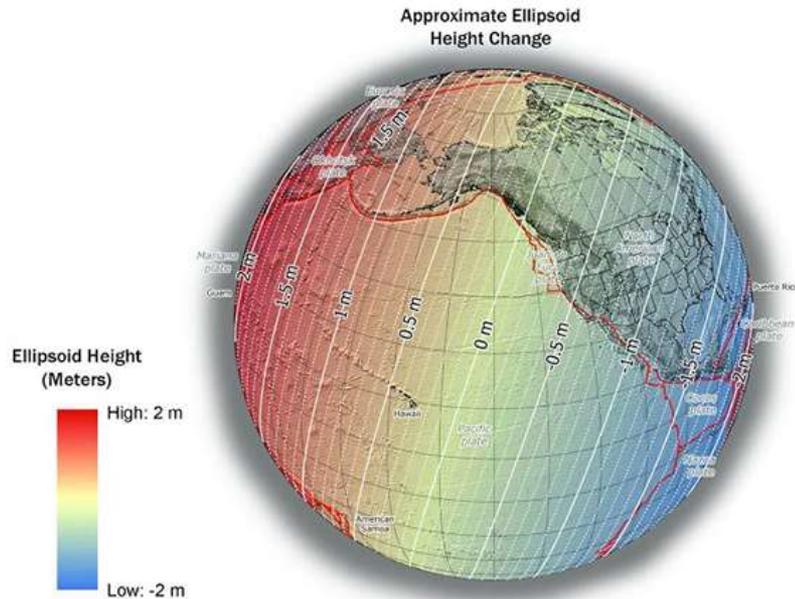
## Simplified concept of NAD 83 vs. "2022"



# 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

Orthometric Heights

Normal Orthometric Heights

Dynamic Heights

Gravity

Geoid Undulations

Deflections of the Vertical

# 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?

# Outline

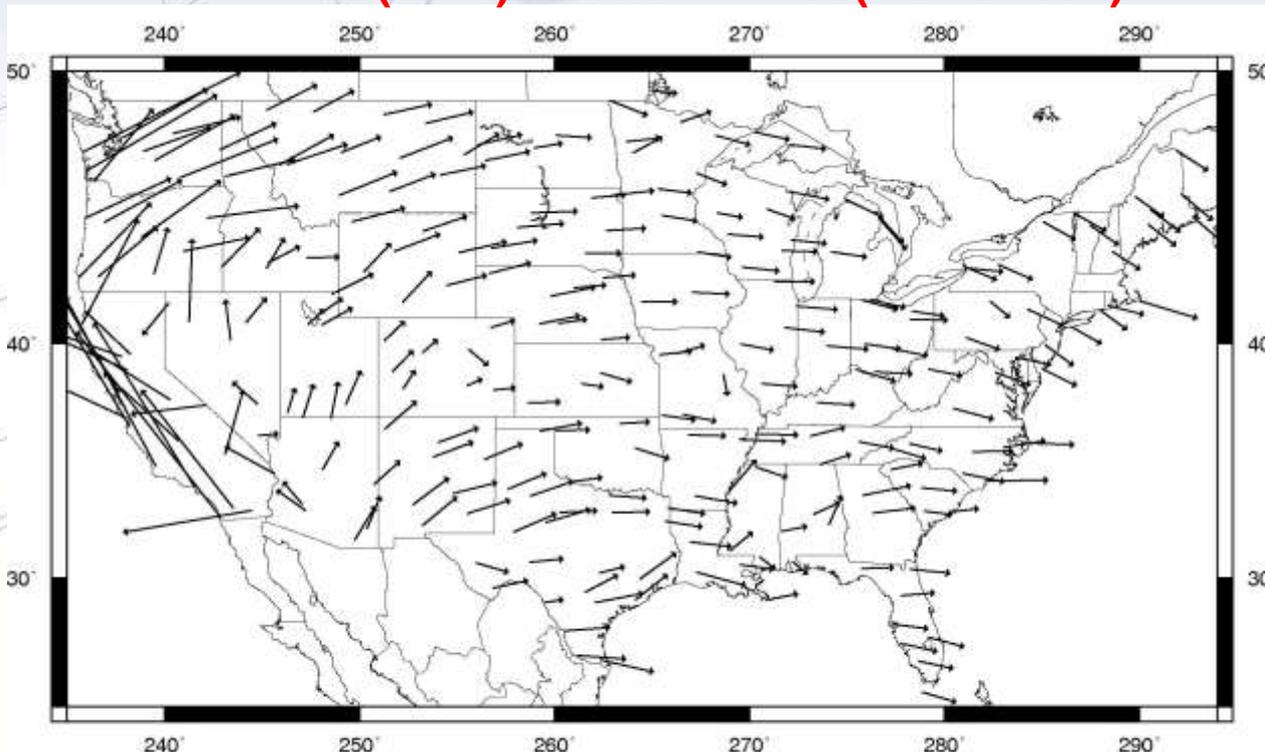
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# Replacing the NAD 83's

- 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)



→  
0.040 meters

(\*)=NA, CA, MA or PA

NAD 83(NSRS2007)

- Epoch **2002.0**

NAD 83(2011)

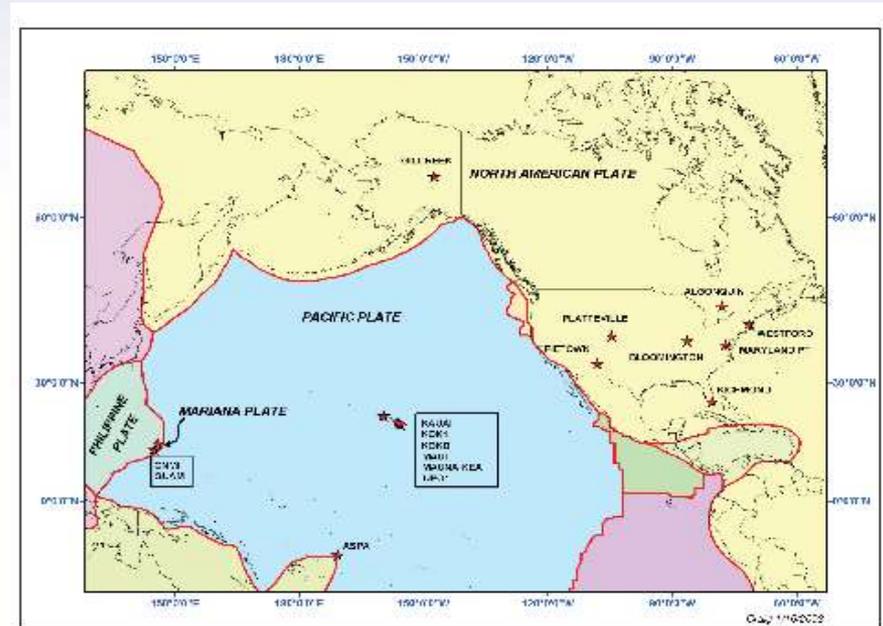
- Epoch **2010.0**

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

(\*)TRF2022 will determine a new Euler Pole rotation for each of 4 plates.

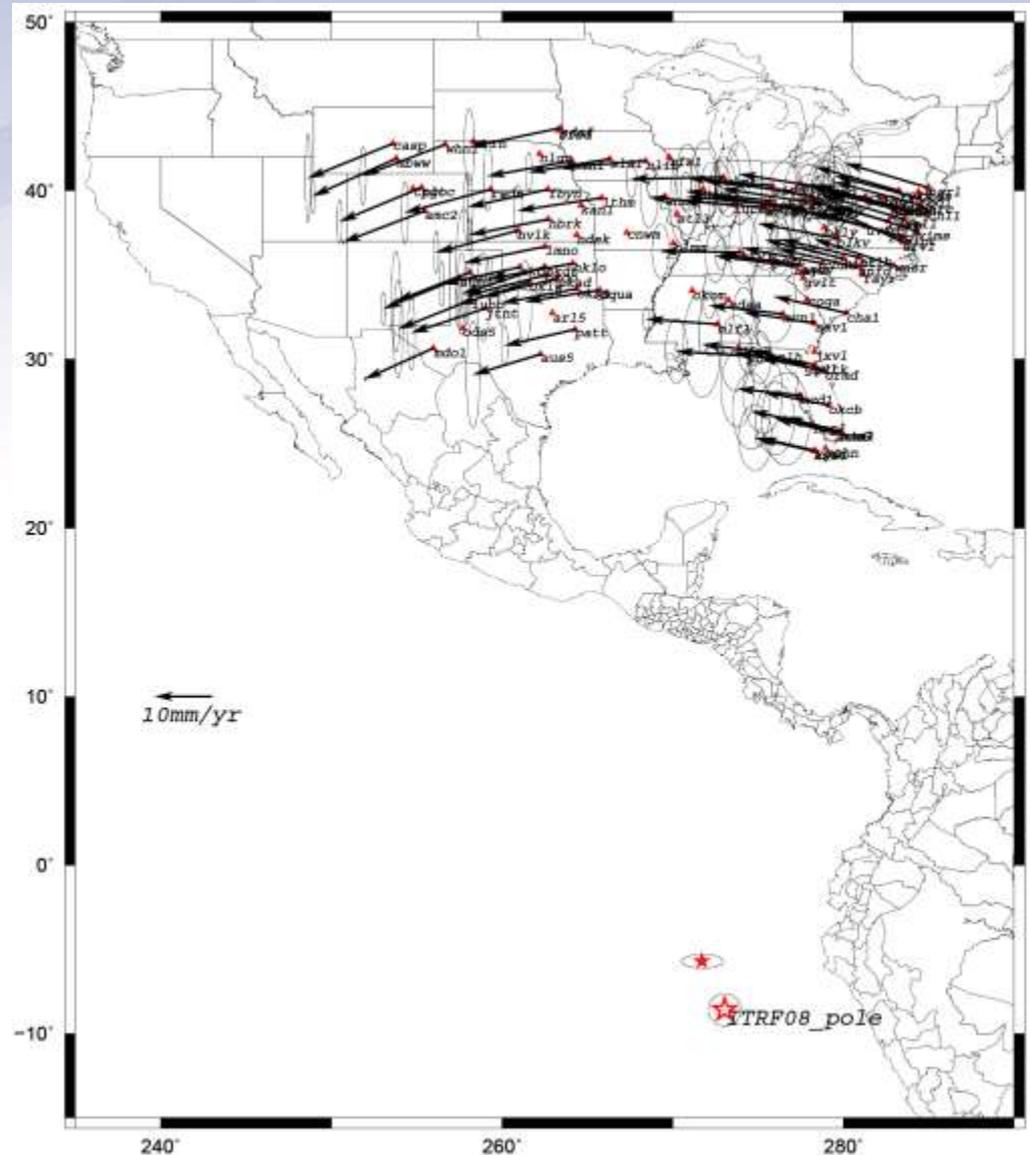
# Four Frames/Plates in 2022

- Previous NGS frames (Snay 2003)
  - North America
  - Pacific
  - Mariana
- Caribbean will be treated as 4<sup>th</sup> frame



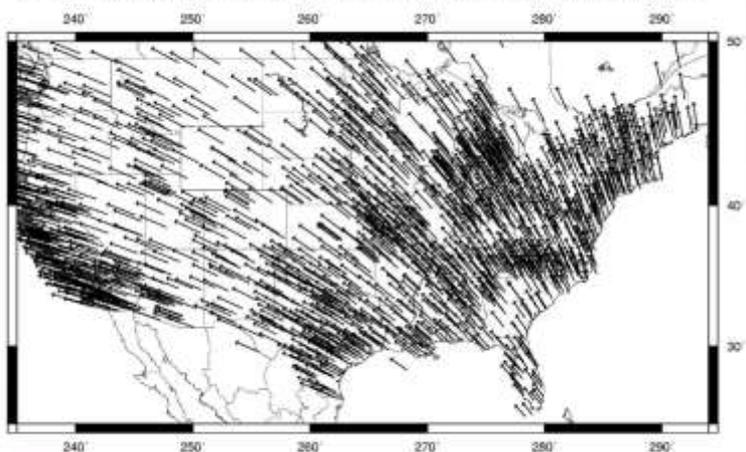
- Each frame will get 3 parameters
- Euler Pole Latitude
  - Euler Pole Longitude
  - Rotation rate (radians / year)

This will be used to compute time-dependent TRF2022 coordinates from time-dependent IGS coordinates.

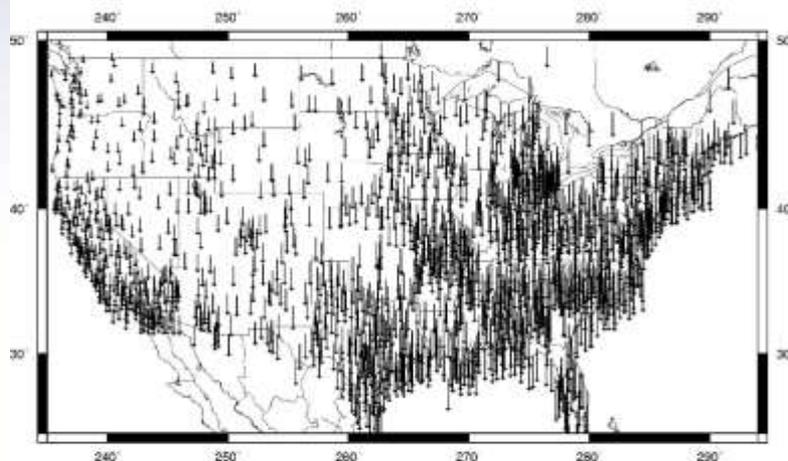


# Fixed-Epoch Transformation NAD 83 to “2022”

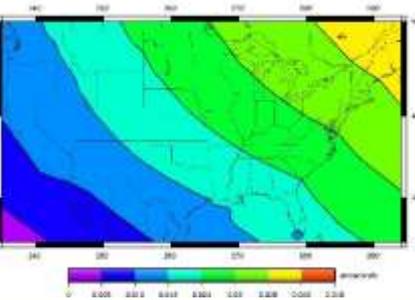
NADCON v5.0 IGS08 minus nad83\_2011 HOR-thin(900 sec) conus-entire mtd



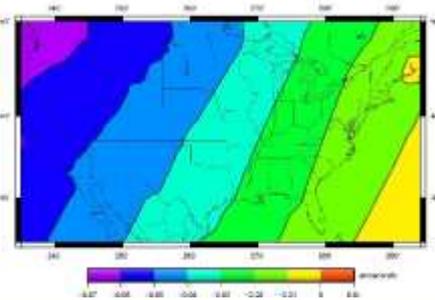
NADCON v5.0 IGS08 minus nad83\_2011 EHT-thin(900 sec) conus-entire mtd



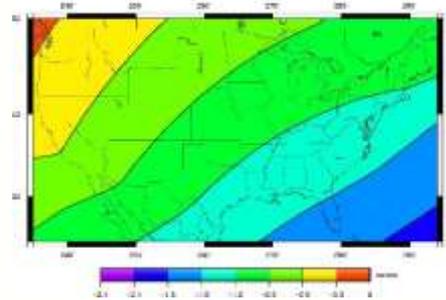
NADCON v5.0 IGS08 minus nad83\_2011 LAT(900 sec) conus-entire mtd



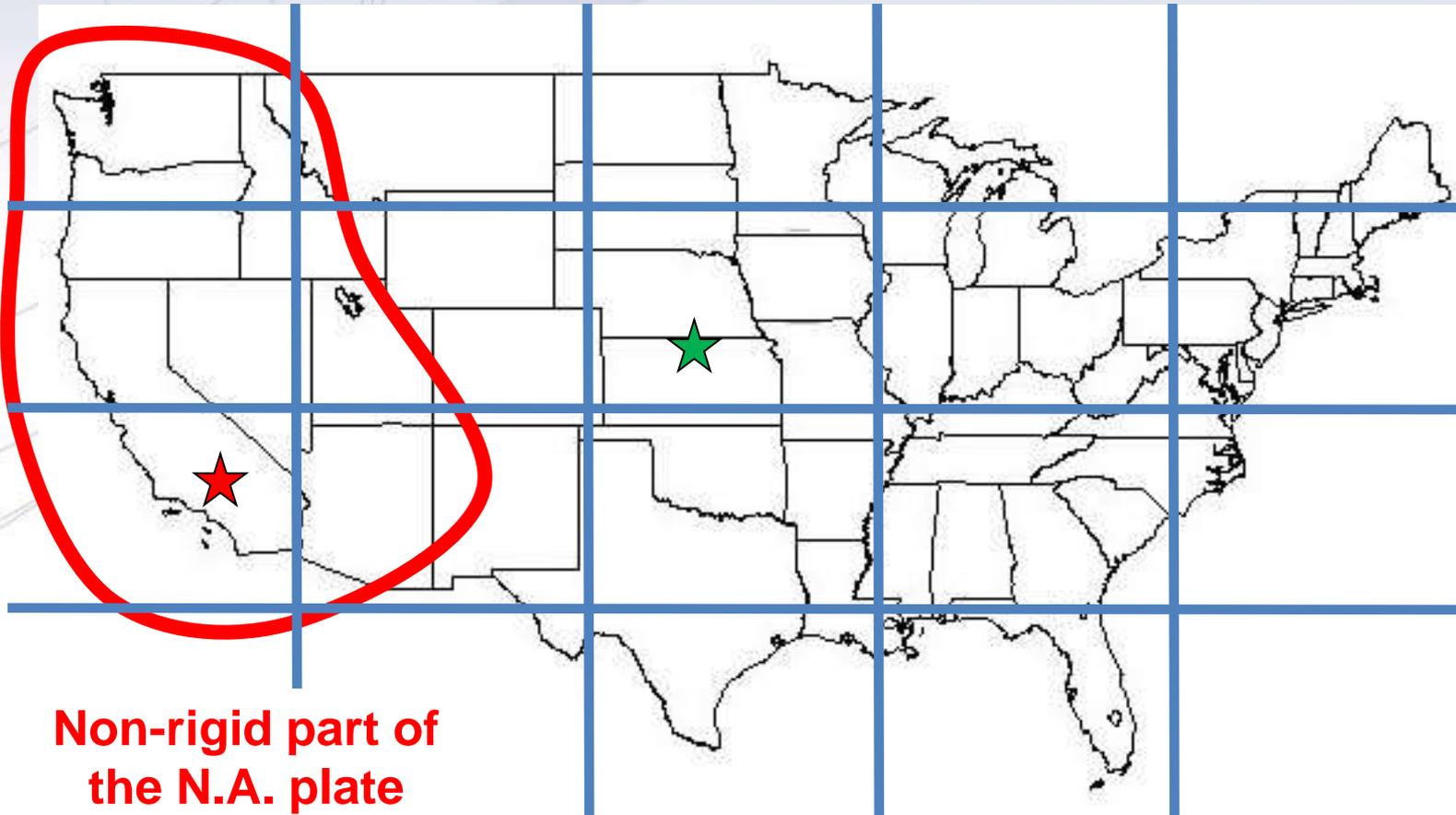
NADCON v5.0 IGS08 minus nad83\_2011 LON(900 sec) conus-entire mtd



NADCON v5.0 IGS08 minus nad83\_2011 EHT(900 sec) conus-entire mtd



# NATRF2022 frame is rigid and fixed to rigid part of the N.A. plate



**Non-rigid part of  
the N.A. plate  
(deformation)  
area**

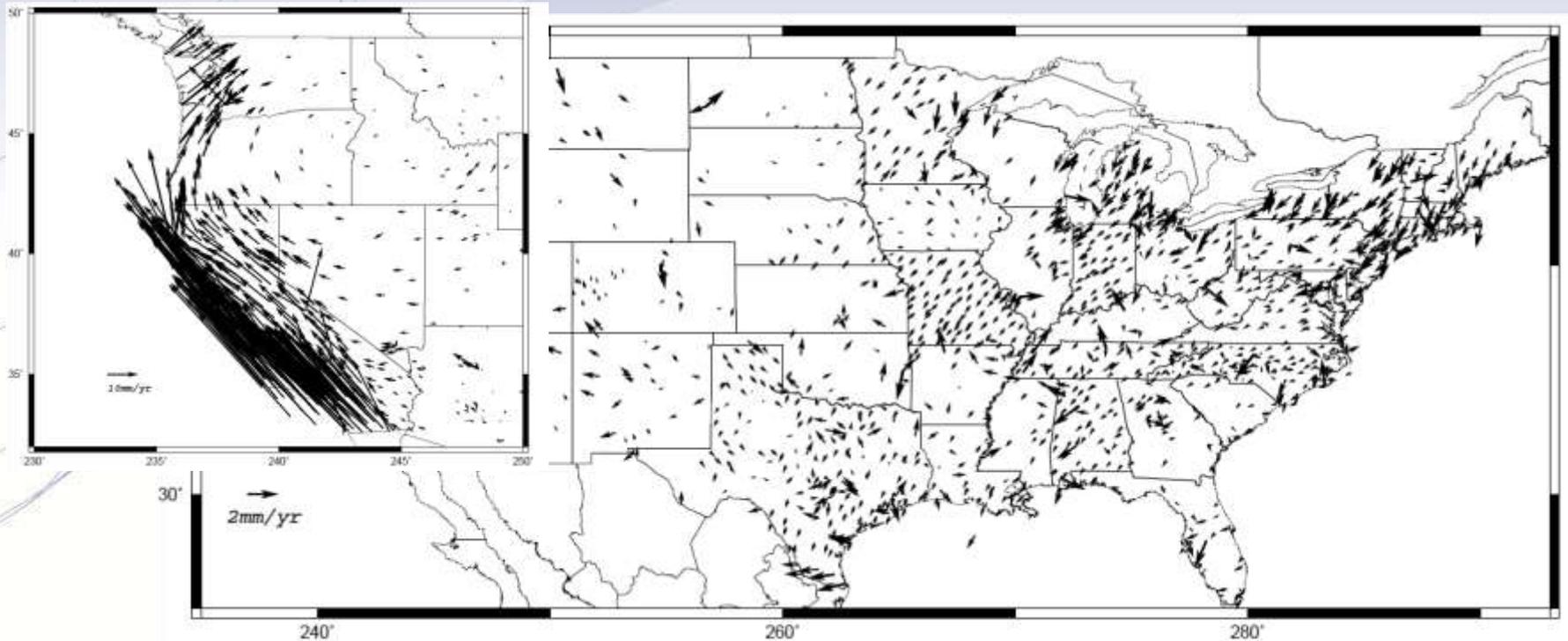
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# So if not HTDP, then what?

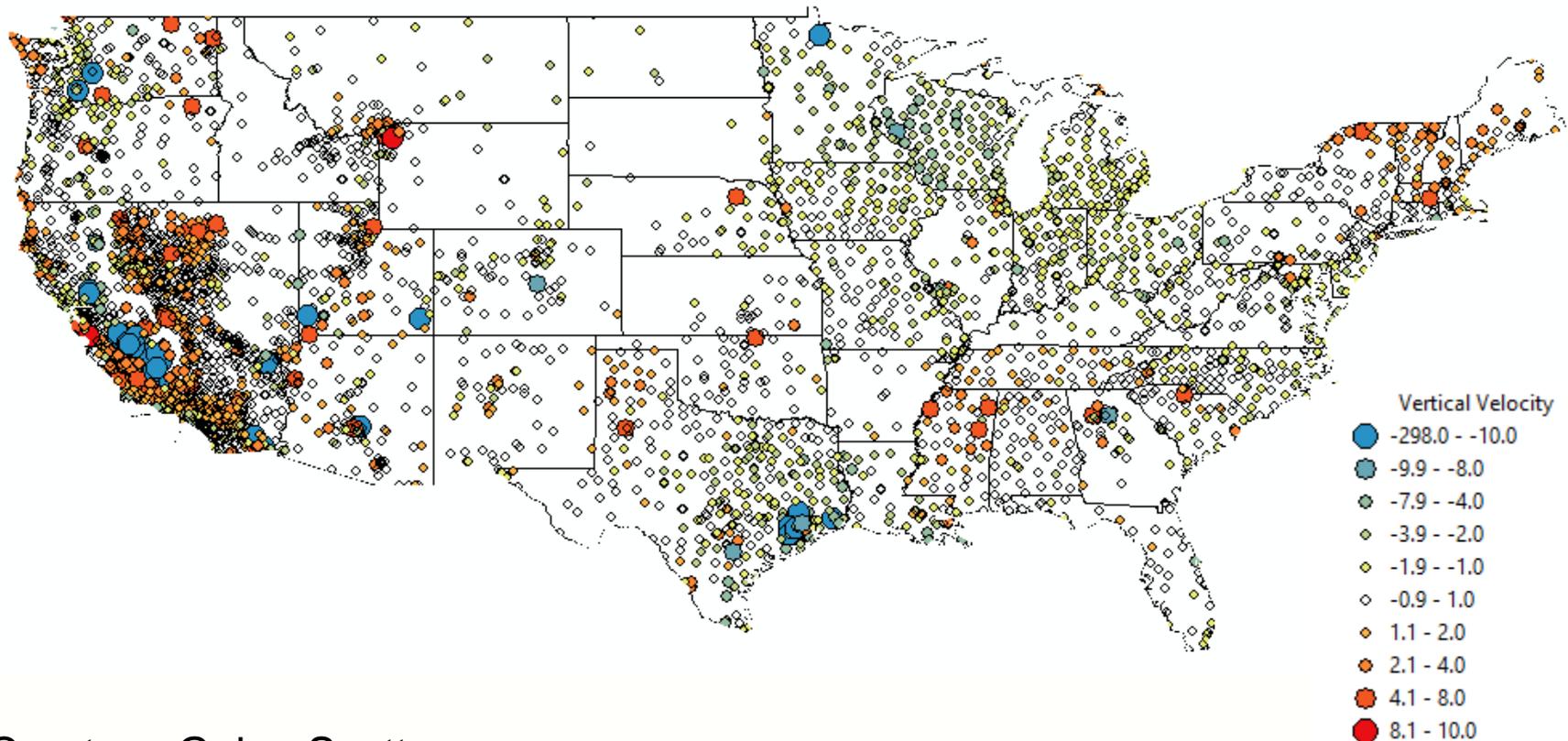
- NATRF2022 would account for most horizontal velocity over time
- Remaining signal typically modeled by HTDP (now)
- In future, a TBD velocity model would be applied to account for that and vertical
- The simplest solution is gridded CORS velocities

# Horizontal velocities after Repro I



Note scale difference between West (10 mm/yr) and east (2 mm/yr)

# CORS Implied Vertical Velocities - Control

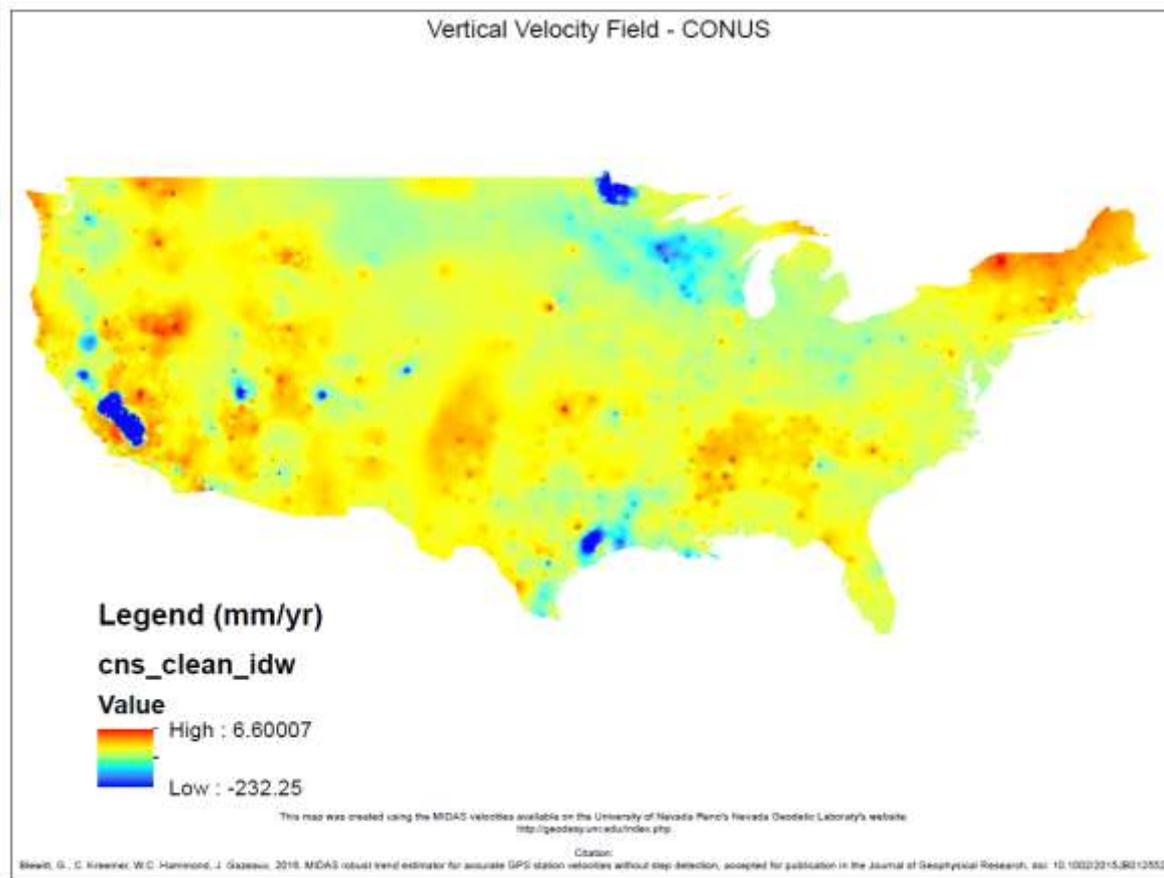


Courtesy Galen Scott

31 May 2017, 1600 TS05C  
Reference Systems and Frames

FIG Working Week 2017  
Helsinki, Finland

# CORS Implied Vertical Velocities – Heat Map



Courtesy Galen Scott

31 May 2017, 1600 TS05C  
Reference Systems and Frames

FIG Working Week 2017  
Helsinki, Finland

# 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:

$$H^t = (h^{t_0} + (t-t_0)*dh/dt) - (N^{t_0} + (t-t_0)*dN/dt)$$

- 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\*

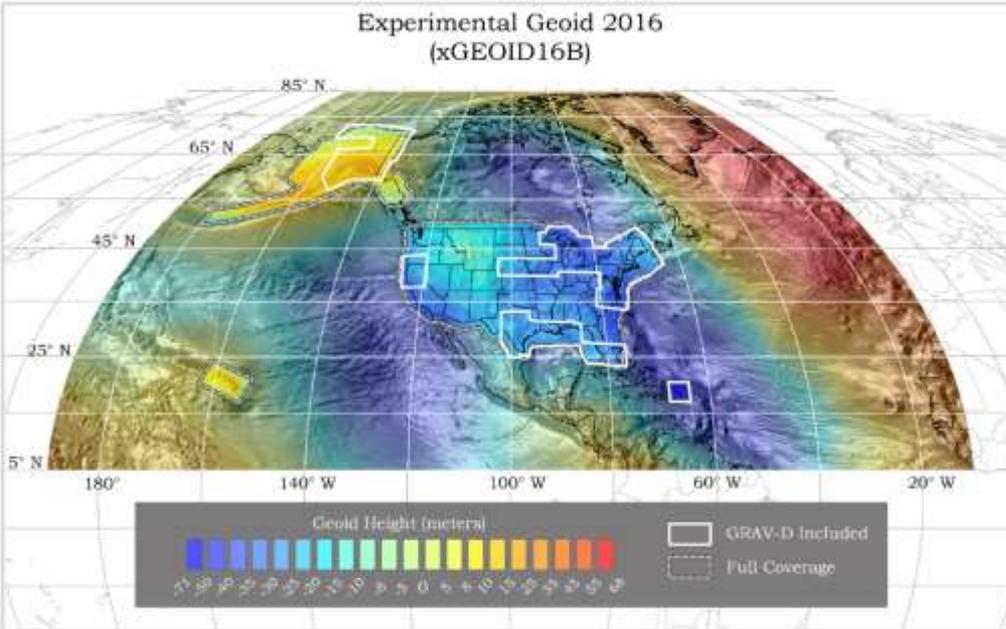
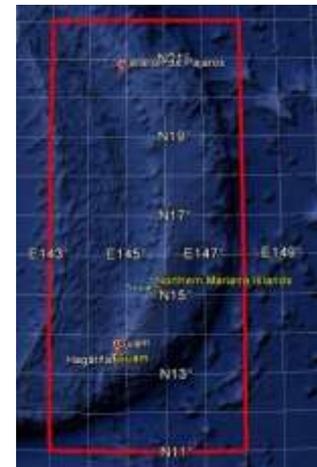
\* Names not yet finalized

# NAPGD2022

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



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



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.

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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:

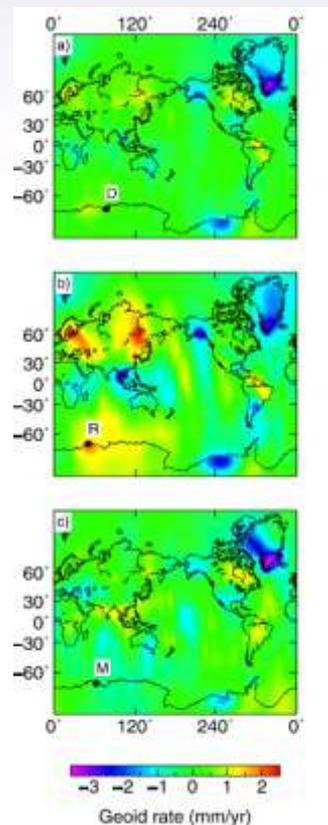
Issue	Type of Change	Temporal Period	Temporal Duration of Geoid Change	Spatial Impact	Magnitude of geoid change	Decision
Accretion of Space Dust	Size	Secular	Permanent	Global	$4 \times 10^{-7}$ mm / y	Ignore
Earthquakes	Shape	Episodic	Permanent-ish	Local	Can be as large as a few cm	Study further
GMSL rise	W0 value	Secular	Permanent	Global	1.7 mm / y	Provide as optional correction

# 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:  $H(t) = h(t) - N(t)$   
 $h(t) = \text{survey epoch}$     $N(t) = N(t_0) + \dot{N} (t - t_0)$

# To Learn More

## Visit the New Datums web page

**New Datums**  
National Geodetic Survey

September 28, 2016

**Replacing NAVD 88 and NAD 83**  
NAD 83 and NAVD 88 will be replaced in 2022, and there are many related projects to make sure the transition goes smoothly. Read the **NGS Ten-Year Plan** to learn more and continue to visit this web-page for more information.

**What to Expect**      **Get Prepared**

**Related Projects**      **Track Our Progress**

**Watch Our Videos**      **Learn More**

**Why is NGS replacing NAD 83 and NAVD 88?**  
NAD 83 and NAVD 88, although still the official horizontal and vertical datums of the National Spatial Reference System (NSRS), have been identified as having shortcomings that are best addressed through defining new horizontal and vertical datums.

Specifically, NAD 83 is non-geocentric by about 2.2 meters. Secondly, NAVD 88 is both biased (by about one-half meter) and tilted (about 1 meter coast

**New Datums Quick Links**  
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What to expect  
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**NGS 2017 Geospatial Summit**  
April 24-25

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See our videos!

[geodesy.noaa.gov/datums/newdatums/index.shtml](http://geodesy.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**.

**2017 Summit Home**  
 Logistics  
 FAQs

**Related Links**  
 NGS 10-year plan  
 2015 Summit Proceedings  
 2010 Summit Proceedings  
 New Datums Web page

- Silver Spring, MD
- April 24-25, 2017
- FREE

[geodesy.noaa.gov/geospatial-summit/index.shtml](http://geodesy.noaa.gov/geospatial-summit/index.shtml)

# Questions?