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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

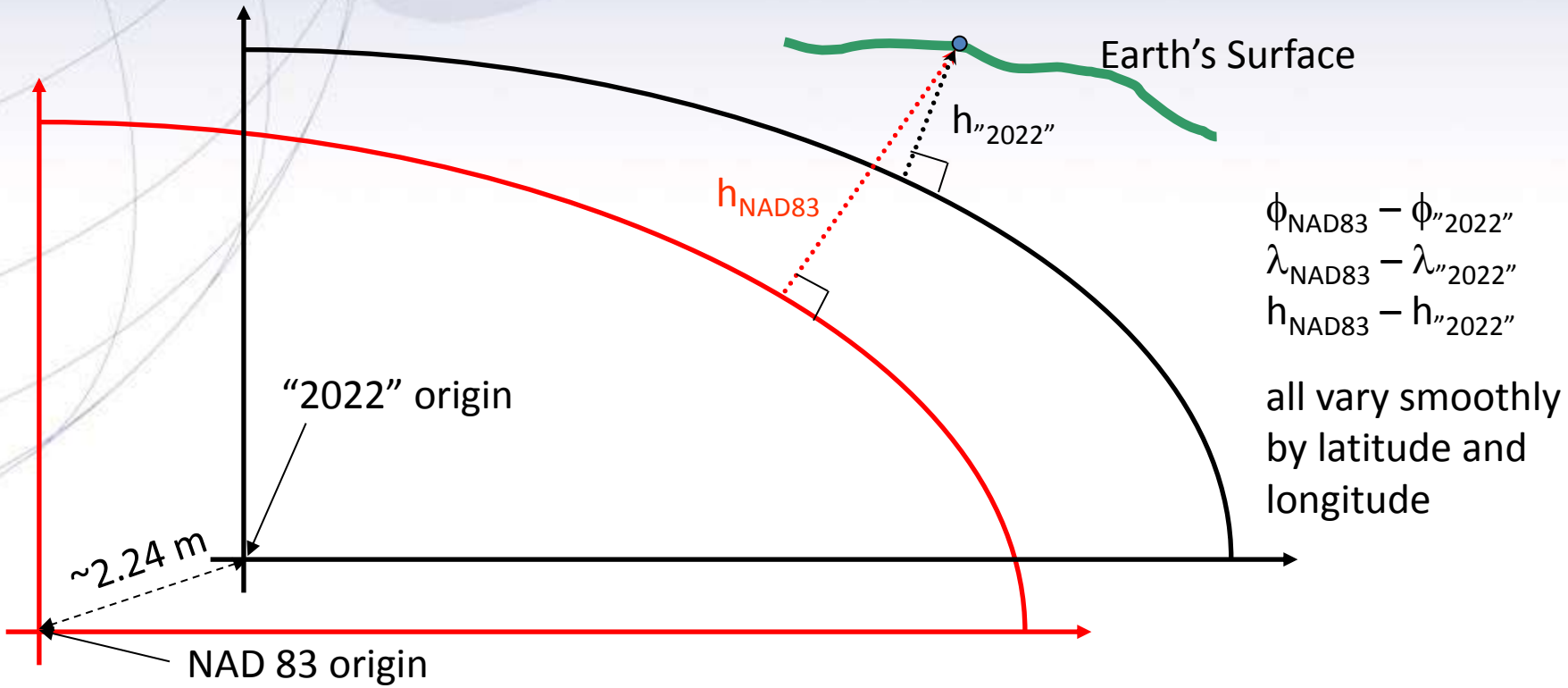
NGS Vision

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"

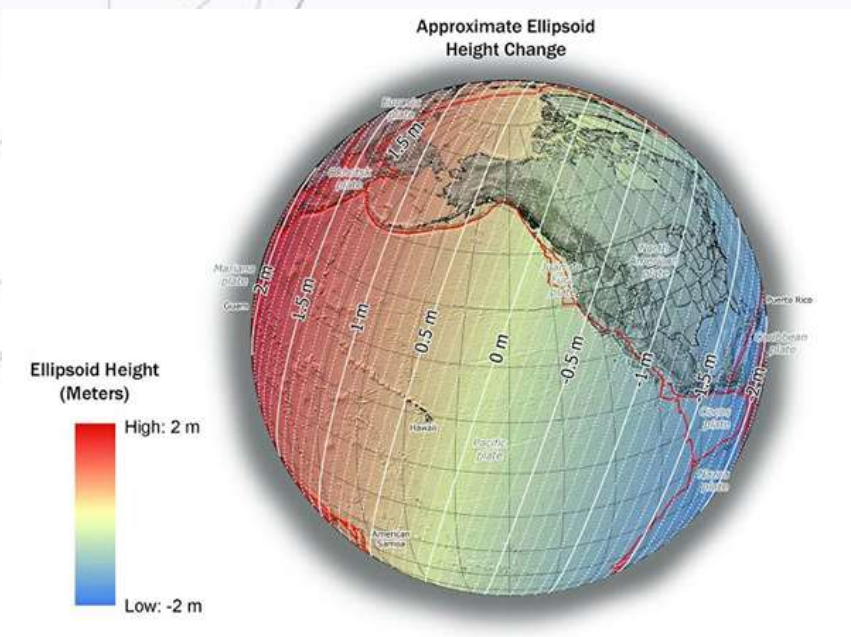


$\phi_{NAD83} - \phi_{"2022"}$
$\lambda_{NAD83} - \lambda_{"2022"}$
$h_{NAD83} - h_{"2022"}$

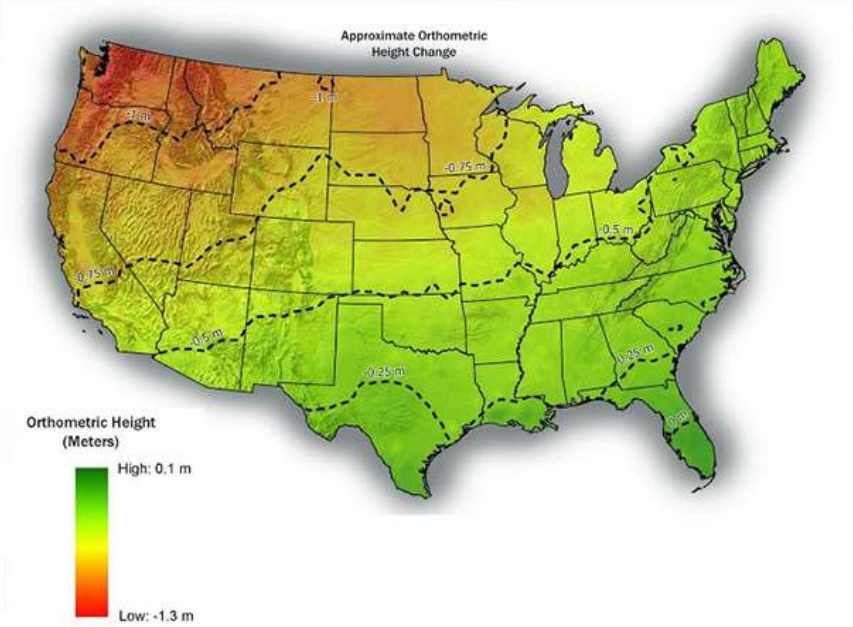
all vary smoothly by latitude and longitude

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

<u>The Old:</u>

Orthometric Heights
- NAVD 88

Normal Orthometric Heights
- PRVD 02
- VIVD09
- ASVD02
- NMVD03
- GUVD04

Dynamic Heights
- IGLD 85

Gravity
- IGSN71

Geoid Undulations
- GEOID12B

Deflections of the Vertical
- DEFLEC12B

<u>The New:</u>

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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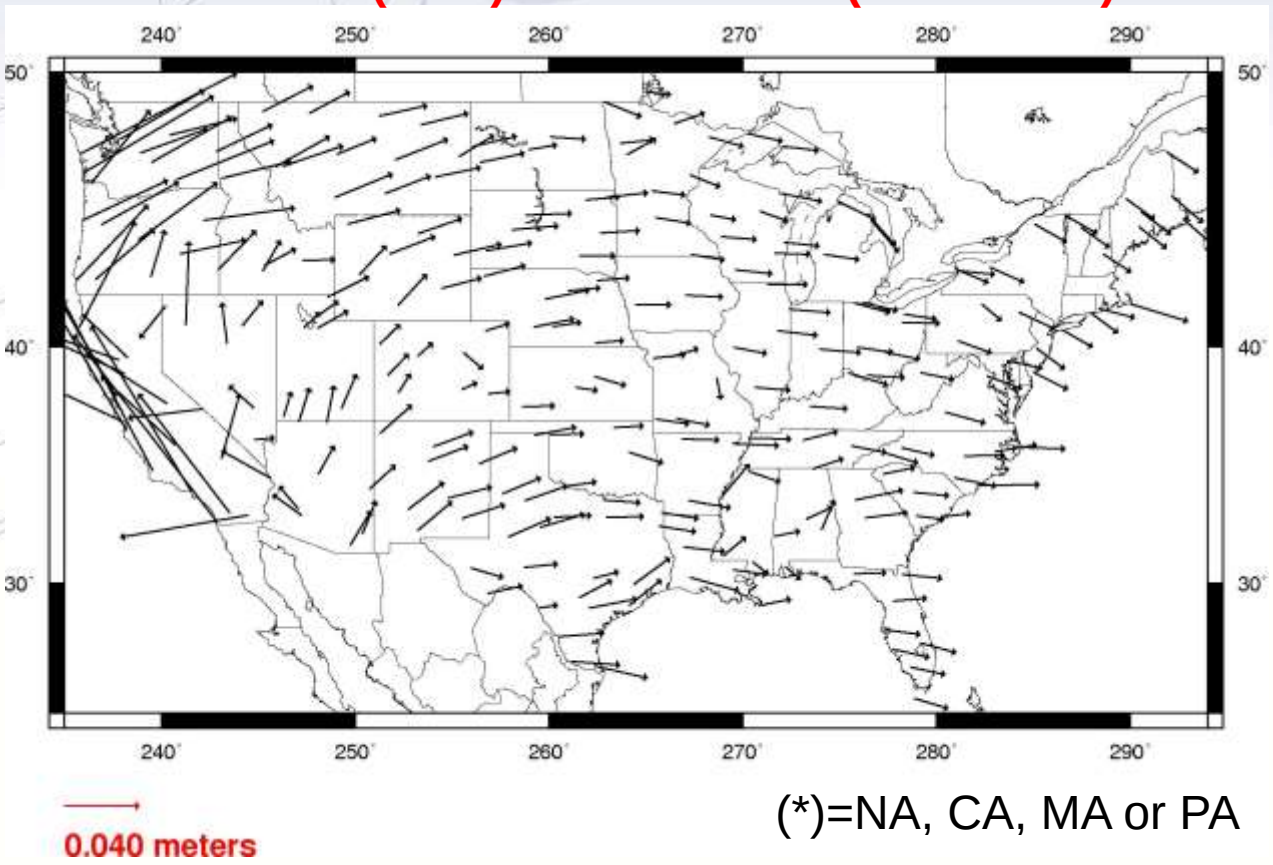
Replacing the NAD 83's

- 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)



(*)=NA, CA, MA or PA

NAD 83(NSRS2007)
- Epoch **2002.0**

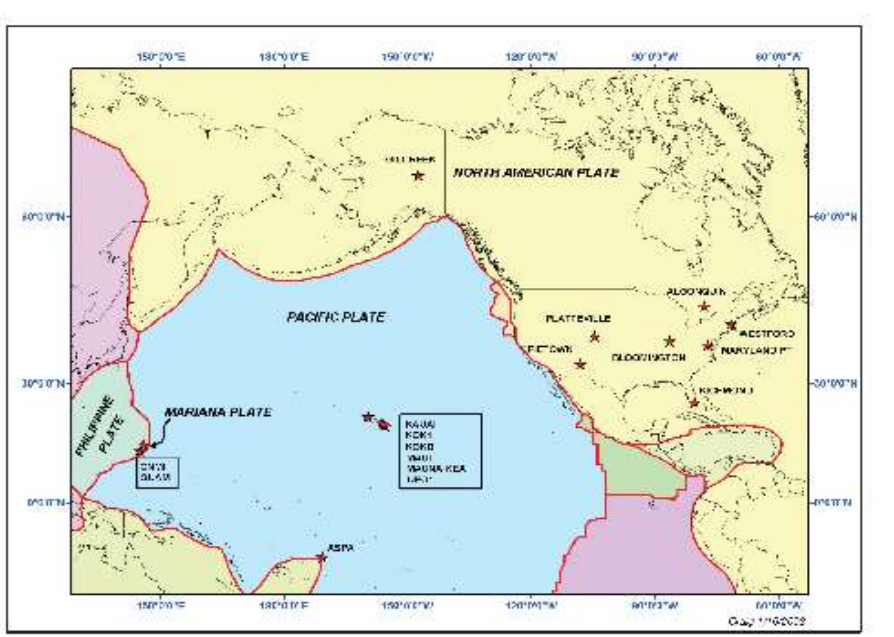
NAD 83(2011)
- Epoch **2010.0**

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.

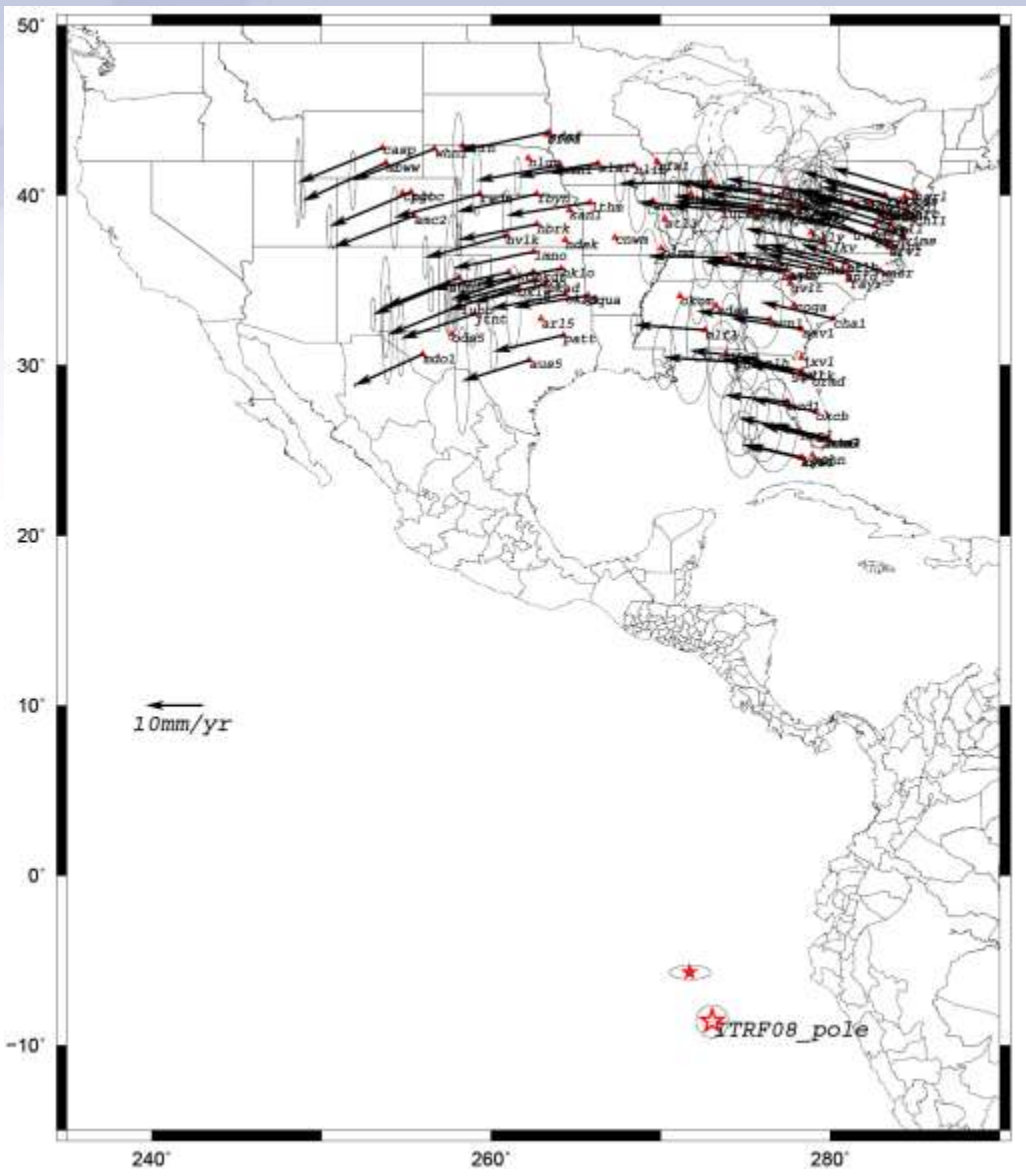
Four Frames/Plates in 2022

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

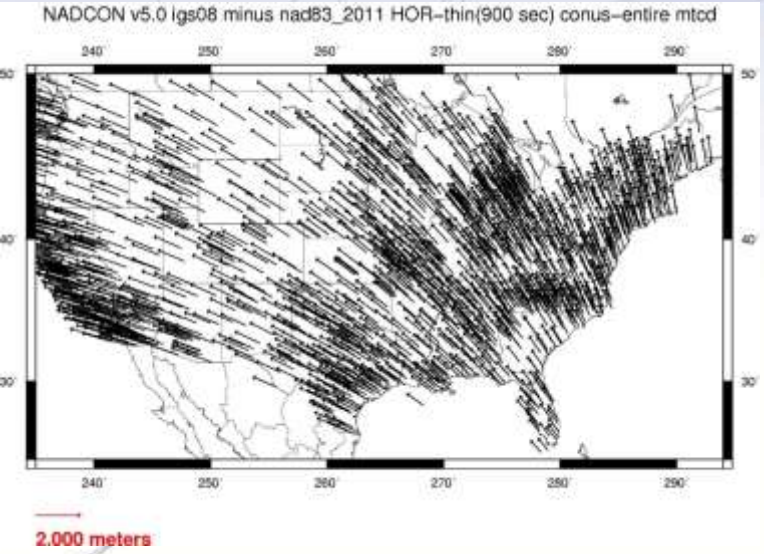


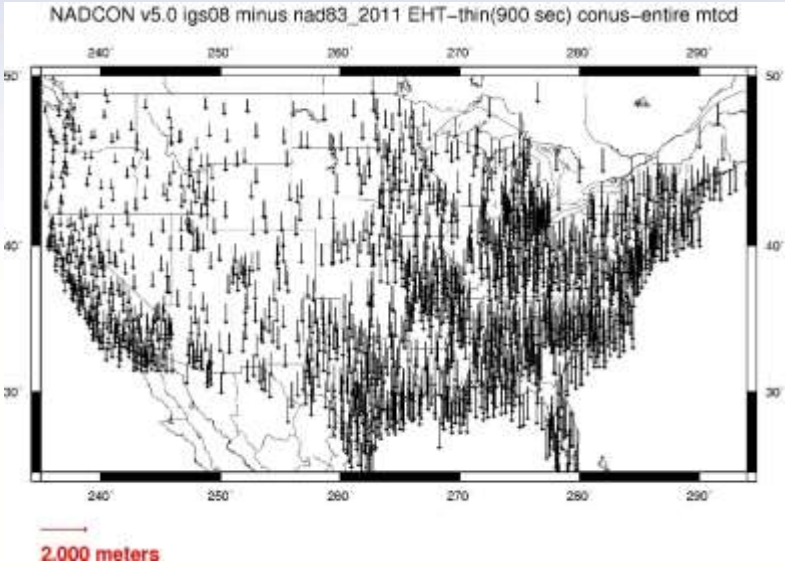
Each frame will get 3 parameters
- Euler Pole Latitude
- Euler Pole Longitude
- Rotation rate (radians / year)

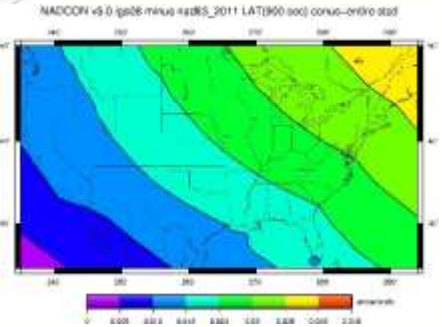
This will be used to compute time-dependent TRF2022 coordinates from time-dependent IGS coordinates.

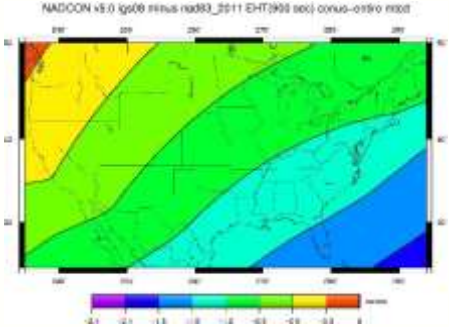


Fixed-Epoch Transformation NAD 83 to "2022"

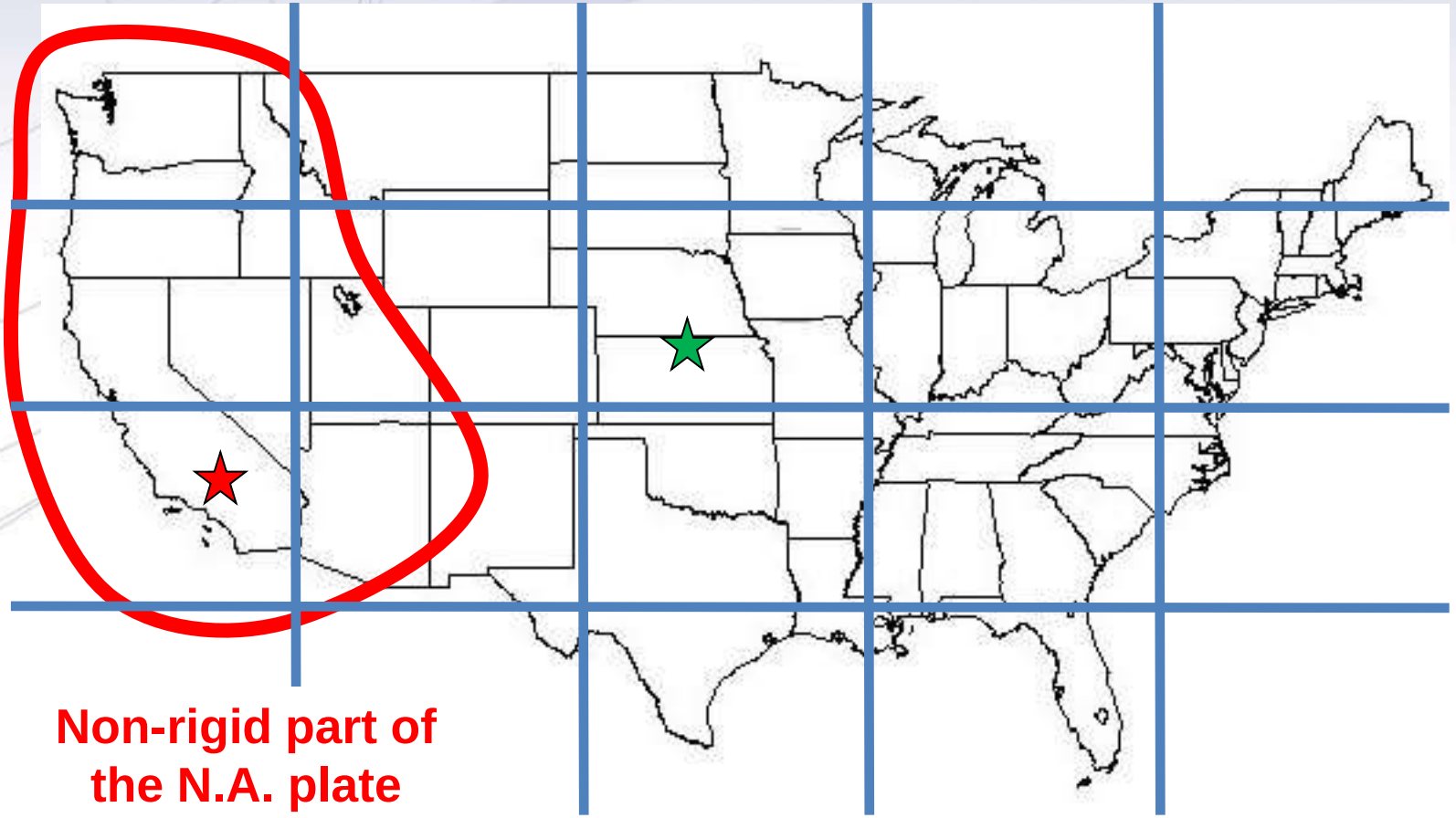








NATRF2022 frame is rigid and fixed to rigid part of the N.A. plate



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

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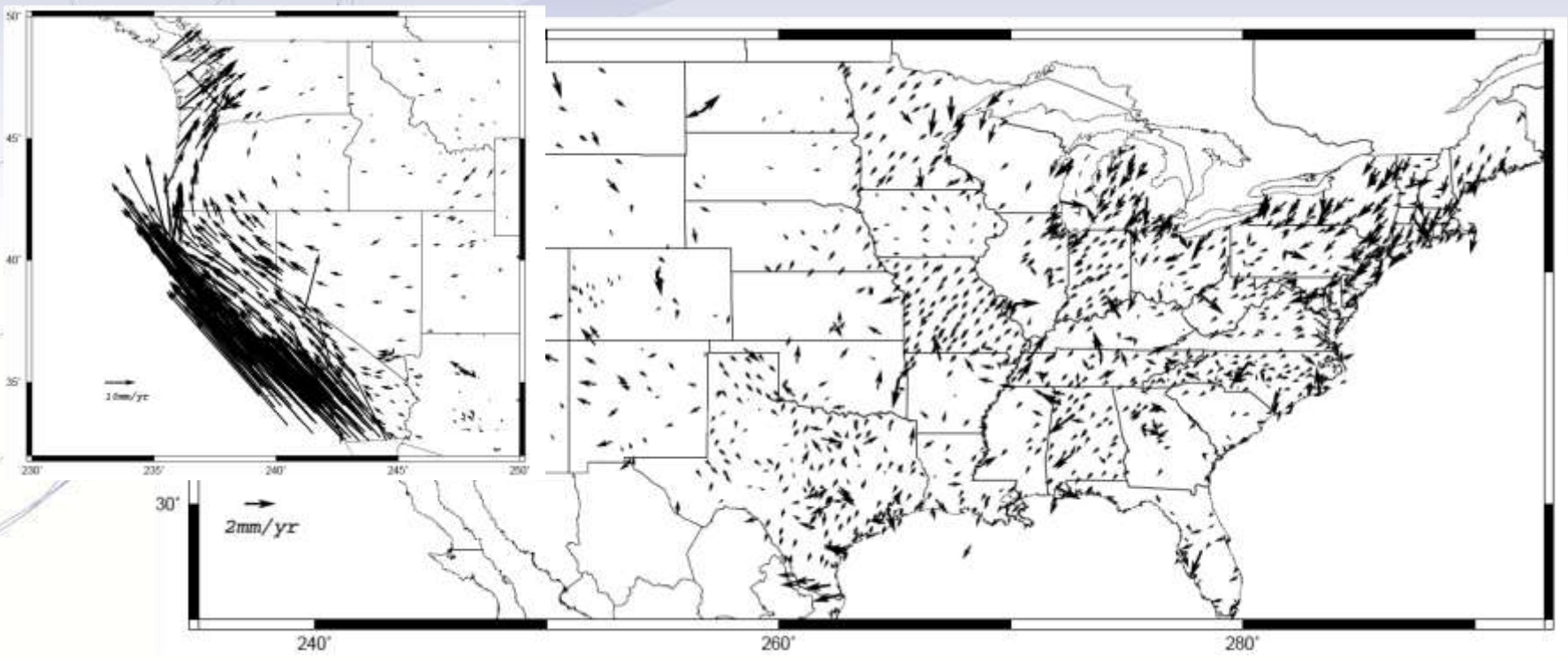
So if not HTDP, then what?

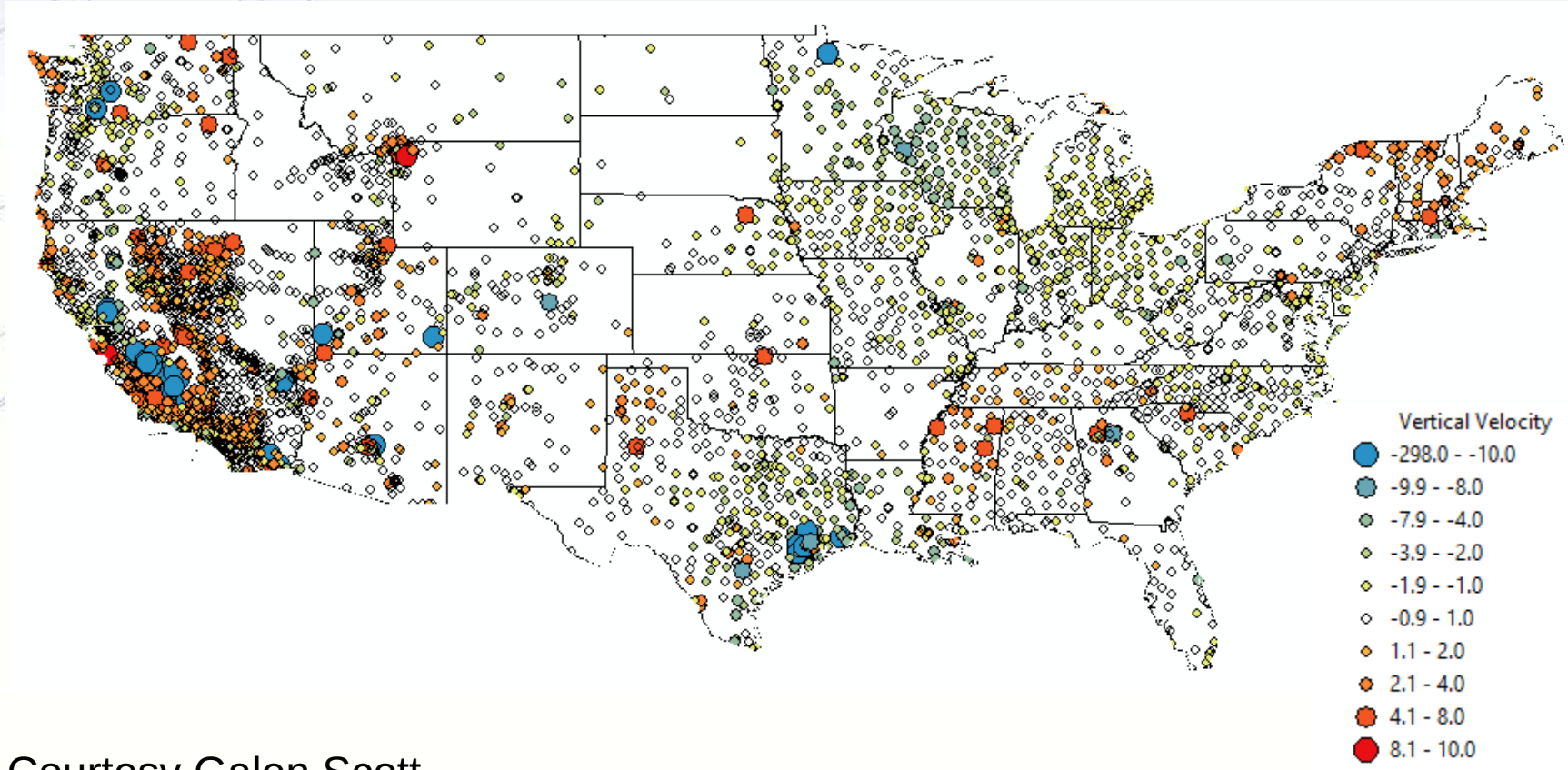
- NATRF2022 would account for most horizontal velocity over time
- Remaining signal typically modeled by HTDP (now)
- In future, a TBD velocity model would be applied to account for that and vertical
- The simplest solution is gridded CORS velocities

Horizontal velocities after Repro1



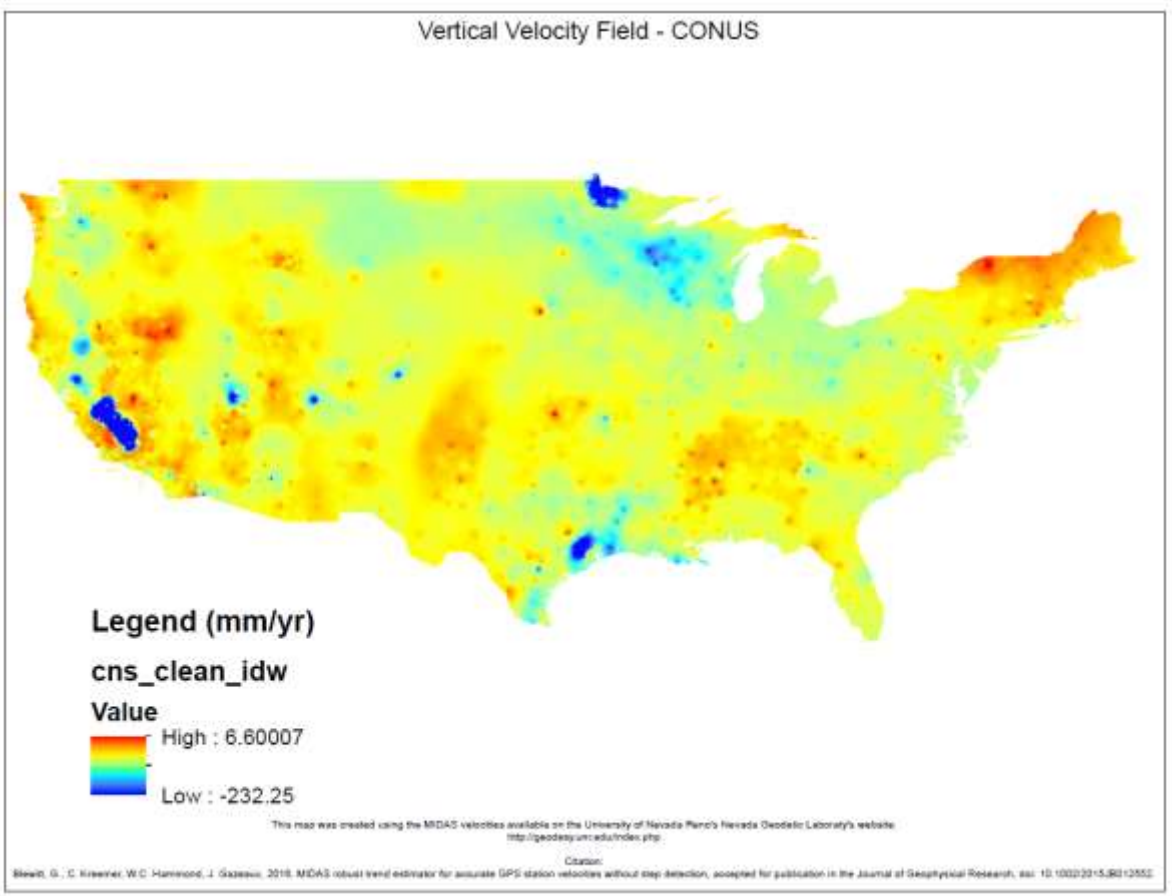
Note scale difference between West (10 mm/yr) and east (2 mm/yr)

CORS Implied Vertical Velocities - Control



Courtesy Galen Scott

CORS Implied Vertical Velocities – Heat Map



Courtesy Galen Scott

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:

$$H^t = (h^{t0} + (t-t_0)*dh/dt) - (N^{t0} + (t-t_0)*dN/dt)$$

  - Where H^t is orthometric height at desired time
  - h^{t0} is ellipsoidal height at epoch (maybe 2020.0)
  - N^{t0} 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

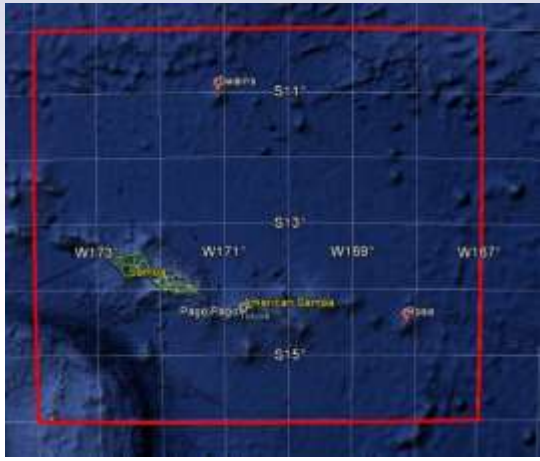
- Begins with a 3-D global geopotential model

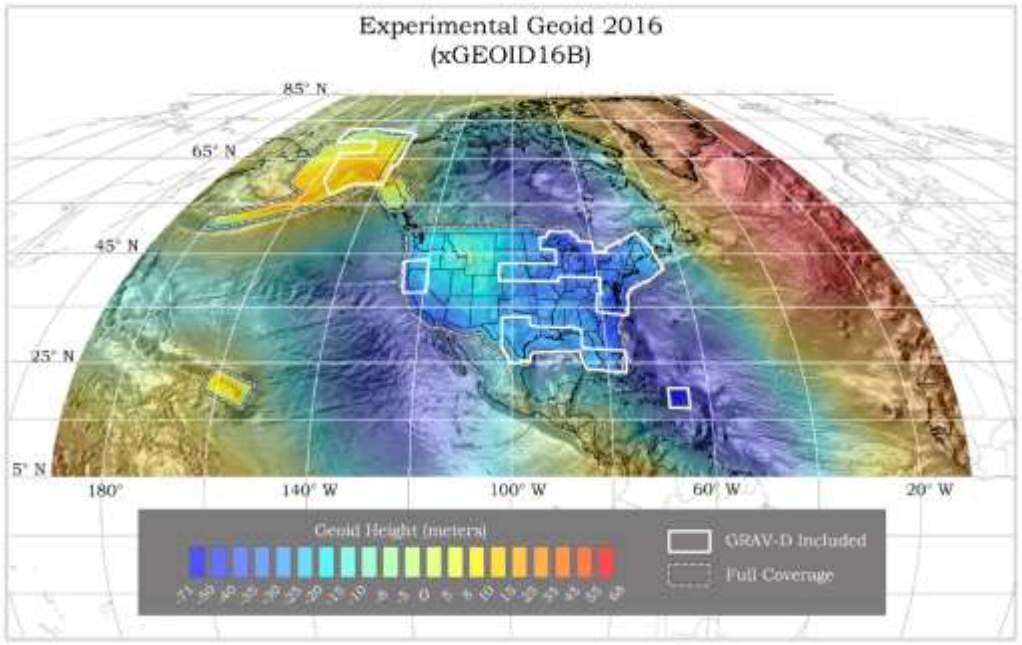
- Then, derivative products are built
  - GEOID2022
  - DEFLEC2022*
  - NGRAV2022*

* Names not yet finalized

NAPGD2022

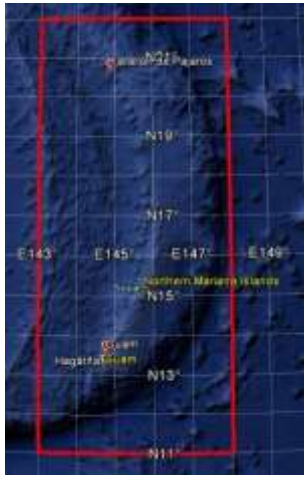
GEOID2022 (et al) over American Samoa: -16 to -10, 186-193





GEOID2022 (et al.) over 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 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:

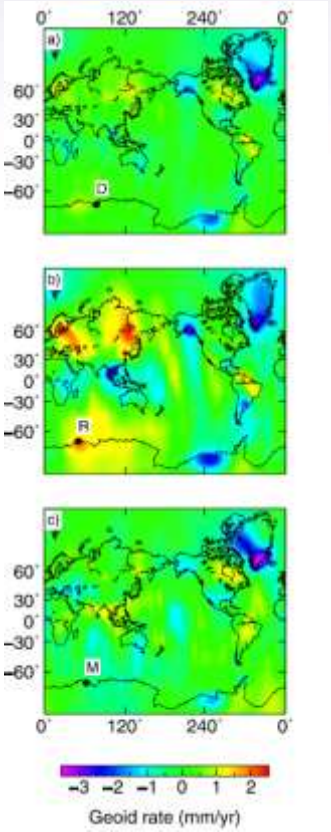
Issue	Type of Change	Temporal Period	Temporal Duration of Geoid Change	Spatial Impact	Magnitude of geoid change	Decision
Accretion of Space Dust	**Size**	**Secular**	**Permanent**	**Global**	**$4x10^{-7}$ mm / y**	**Ignore**
Earthquakes	**Shape**	**Episodic**	**Permanent-ish**	**Local**	**Can be as large 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: $H(t) = h(t) - N(t)$
  $h(t)$ = survey epoch $N(t) = N(t_0) + \dot{N}\,(t - t_0)$

To Learn More

Visit the New Datums web page

geodesy.noaa.gov/datums/newdatums/index.shtml

To Learn More

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Questions?