National Geodetic Survey Update – Preparing for Tomorrow (*New Datums are Coming!*)

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NOAA's National Geodetic Survey
geodesy.noaa.gov

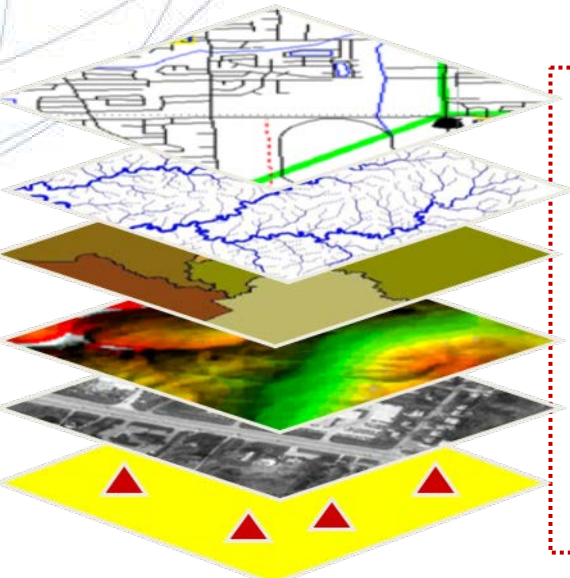
Arizona Professional Land Surveyors
Chartered 1979

May 18, 2017
Tucson

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Geodetic Survey

Mission: To define, maintain & provide access to the ***National Spatial Reference System (NSRS)*** to meet our Nation's economic, social & environmental needs

National Spatial Reference System



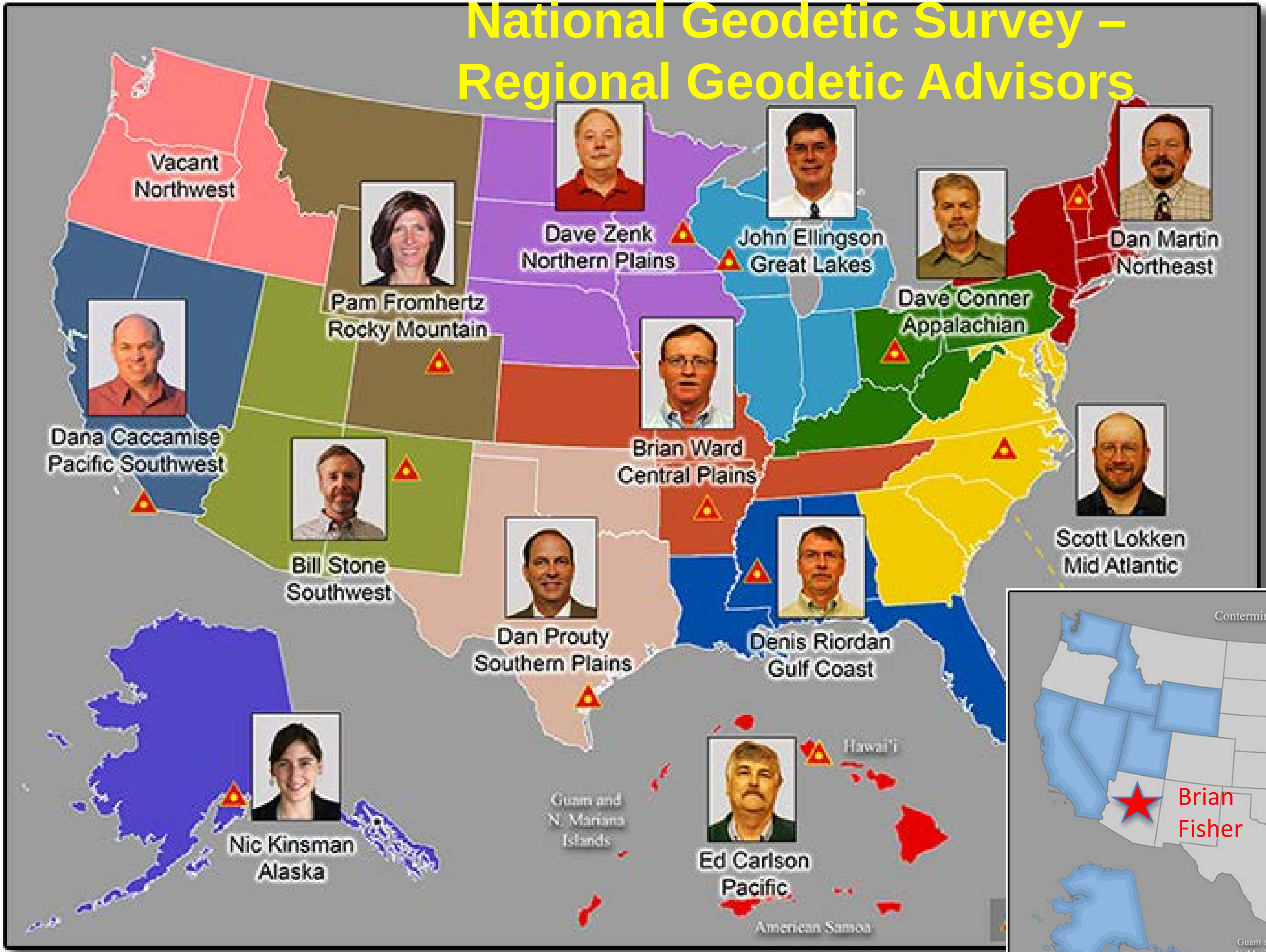
- **Latitude**
- **Longitude**
- **Height**
- Gravity
- Orientation
- Scale

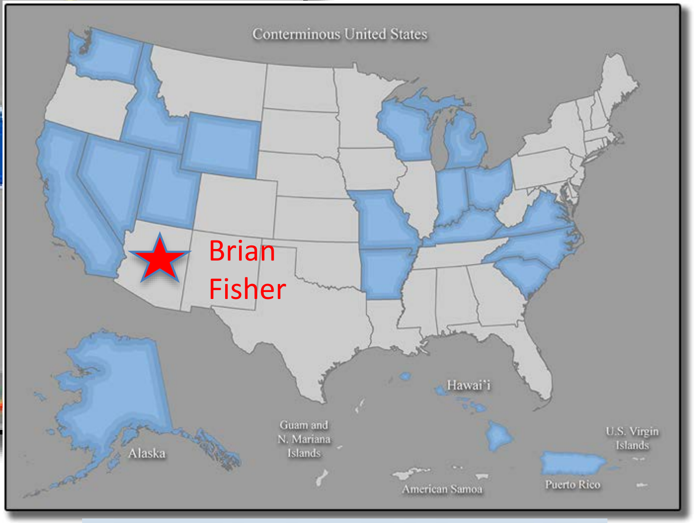
& their time variations

(& National Shoreline, etc.)

- North American Datum 1983 (NAD83)
- North American Vertical Datum 1988 (NAVD88)

National Geodetic Survey – Regional Geodetic Advisors

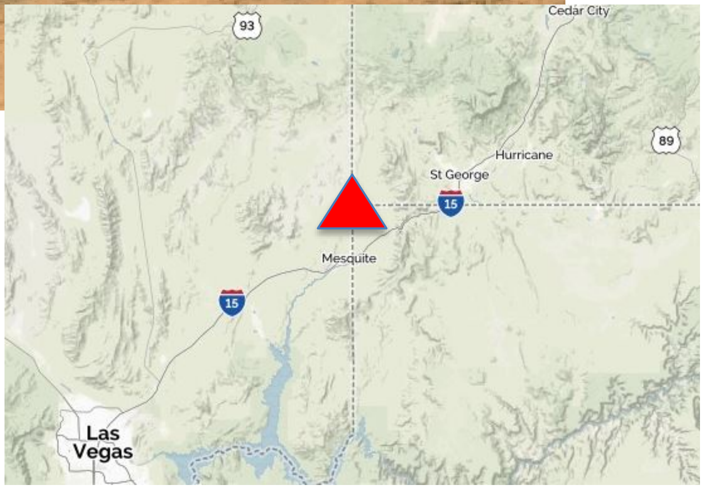




State Geodetic Coordinators

National Geodetic Survey


N
NEVADA
UTAH
UCLS
W
E
ARIZONA
Arizona - Nevada - Utah
Monument 2016
S


93
Cedar City
89
Hurricane
St George
15
Mesquite
15
Las Vegas

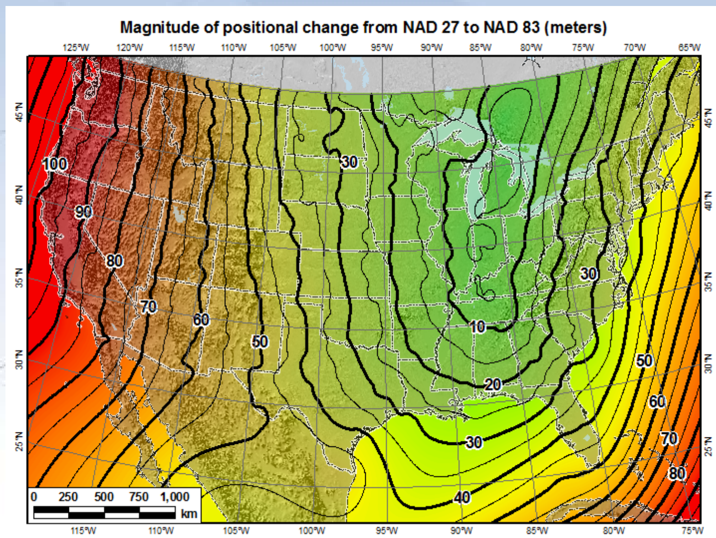
USER: william.stone@noaa.gov DATE: February 24, 2017
RINEX FILE: 3cor054u.17o TIME: 05:29:02 UTC

SOFTWARE: page5 1209.04 master52.pl 160321 START: 2017/02/23 20:52:00
EPHEMERIS: igu19374.eph [ultra-rapid] STOP: 2017/02/23 23:59:00
NAV FILE: brdc0540.17n OBS USED: 7658 / 8153 : 94%
ANT NAME: CHCX90D-OPUS NONE # FIXED AMB: 43 / 45 : 96%
ARP HEIGHT: 0.180 OVERALL RMS: 0.014(m)

REF FRAME:	NAD_83(2011)(EPOCH:2010.0000)		IGS08 (EPOCH:2017.1478)	
X:	-2078663.057(m)	0.010(m)	-2078663.936(m)	0.010(m)
Y:	-4657799.043(m)	0.014(m)	-4657797.727(m)	0.014(m)
Z:	3817863.470(m)	0.003(m)	3817863.352(m)	0.003(m)

LAT:	37 0 0.69689	0.005(m)	37 0 0.71029	0.005(m)
E LON:	245 56 59.81599	0.015(m)	245 56 59.76184	0.015(m)
W LON:	114 3 0.18401	0.015(m)	114 3 0.23816	0.015(m)
EL HGT:	752.973(m)	0.009(m)	752.229(m)	0.009(m)
ORTHO HGT:	778.810(m)	0.021(m)	[NAVD88 (Computed using GEOID12B)]	

A (very) Brief History of U.S. Horizontal / Geometric Datums



U.S. Standard Datum

NAD27

NAD83 (1986)

NAD83 (HARN / 199X)

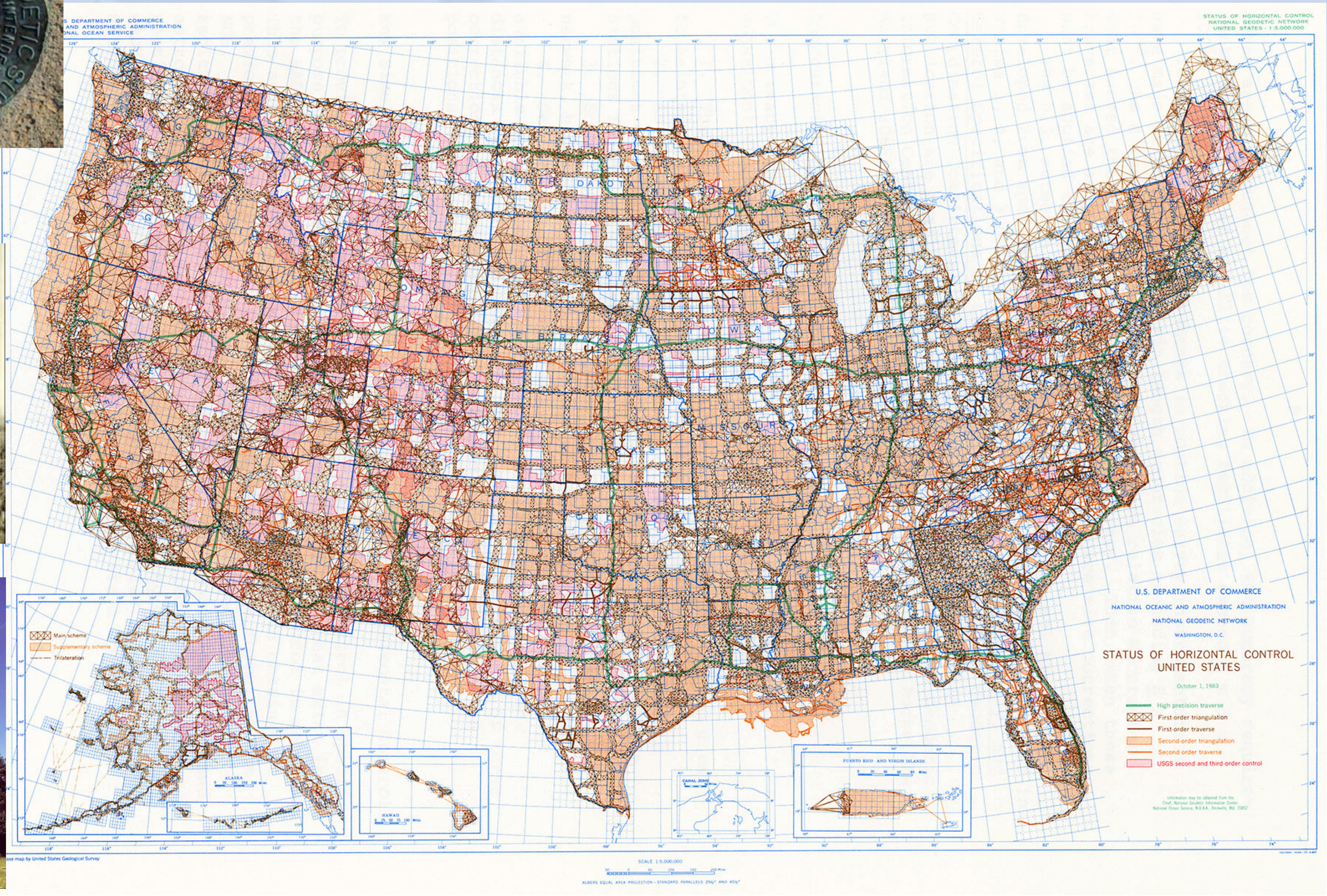
NAD83 (2007)

NAD83 (2011)

time

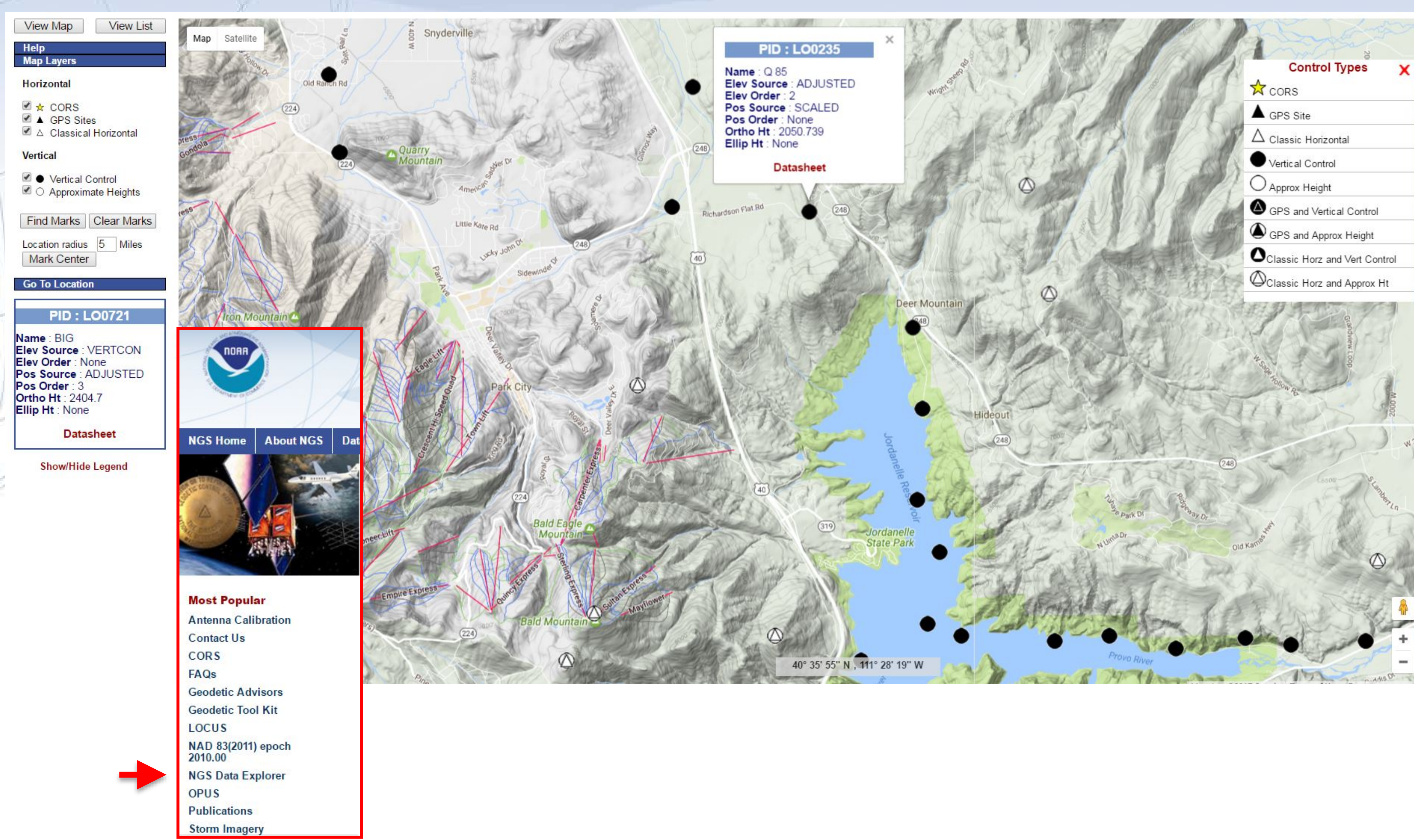
shift: < 10 m | tens of meters | few 0.1m | few 0.01m | few 0.01m

Status of Horizontal Control 1983



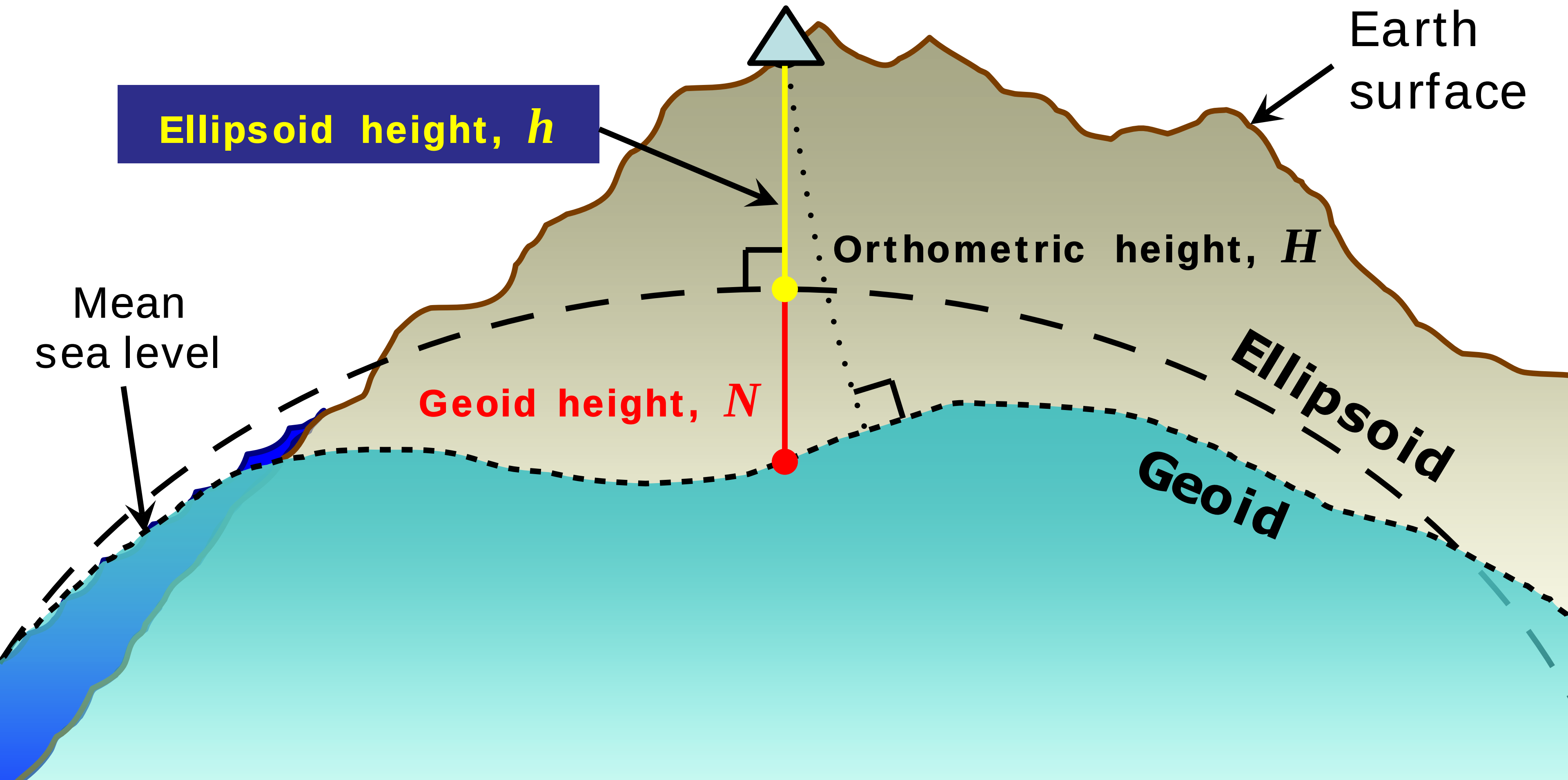
National Geodetic Survey Data Explorer

National Geodetic Survey



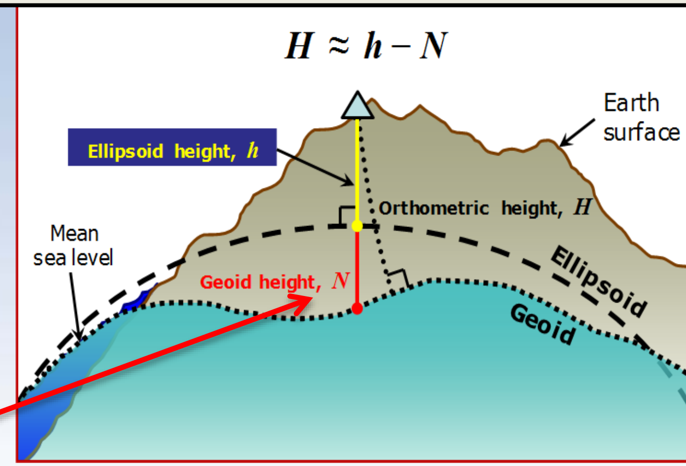
Heights 101

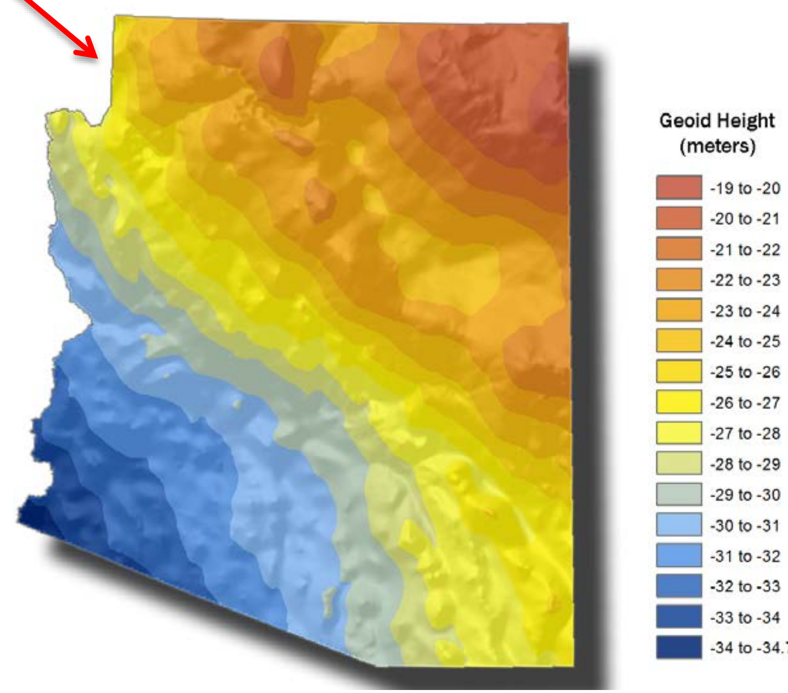
$$H \approx h - N$$



NAD 83(2011) epoch 2010.00

```
*****************************************************************************
 HT_MOD       -  This is a Height Modernization Survey Station.
 DESIGNATION -  MOUNTAIN DEW
 PID         -  AJ3970
 STATE/COUNTY-  AZ/MARICOPA
 COUNTRY     -  US
 USGS QUAD   -  LONE BUTTE (1973)

                         *CURRENT SURVEY CONTROL
 ______________________________________________________________________
 NAD 83(2011) POSITION- 33 19 53.32163(N) 112 03 39.06324(W)   ADJUSTED
 NAD 83(2011) ELLIP HT-   768.819 (meters)        (06/27/12)   ADJUSTED
 NAD 83(2011) EPOCH   -  2010.00
 NAVD 88 ORTHO HEIGHT -   798.62  (meters)      2620.1   (feet) GPS OBS
 ______________________________________________________________________
 NAVD 88 orthometric height was determined with geoid model    GEOID09
 GEOID HEIGHT    -          -29.79  (meters)                   GEOID09
 GEOID HEIGHT    -          -29.74  (meters)                   GEOID12B
 NAD 83(2011) X  - -2,003,780.483 (meters)                     COMP
 NAD 83(2011) Y  - -4,944,405.440 (meters)                     COMP
 NAD 83(2011) Z  -  3,485,155.376 (meters)                     COMP
 LAPLACE CORR    -           1.27  (seconds)                   DEFLEC12B

 Network accuracy estimates per FGDC Geospatial Positioning Accuracy
 Standards:
        FGDC (95% conf, cm)     Standard deviation (cm)     CorrNE
           Horiz  Ellip           SD_N   SD_E   SD_h       (unitless)
 -------------------------------------------------------------------
 NETWORK    0.94   1.27           0.41   0.36   0.65       0.04667664
 -------------------------------------------------------------------
 Click here for local accuracies and other accuracy information.


The horizontal coordinates were established by GPS observations
and adjusted by the National Geodetic Survey in June 2012.

NAD 83(2011) refers to NAD 83 coordinates where the reference
frame has been affixed to the stable North American tectonic plate. See
NA2011 for more information.

The horizontal coordinates are valid at the epoch date displayed above
which is a decimal equivalence of Year/Month/Day.

The orthometric height was determined by GPS observations and a
high-resolution geoid model using precise GPS observation and
processing techniques.
```





GEOID12B

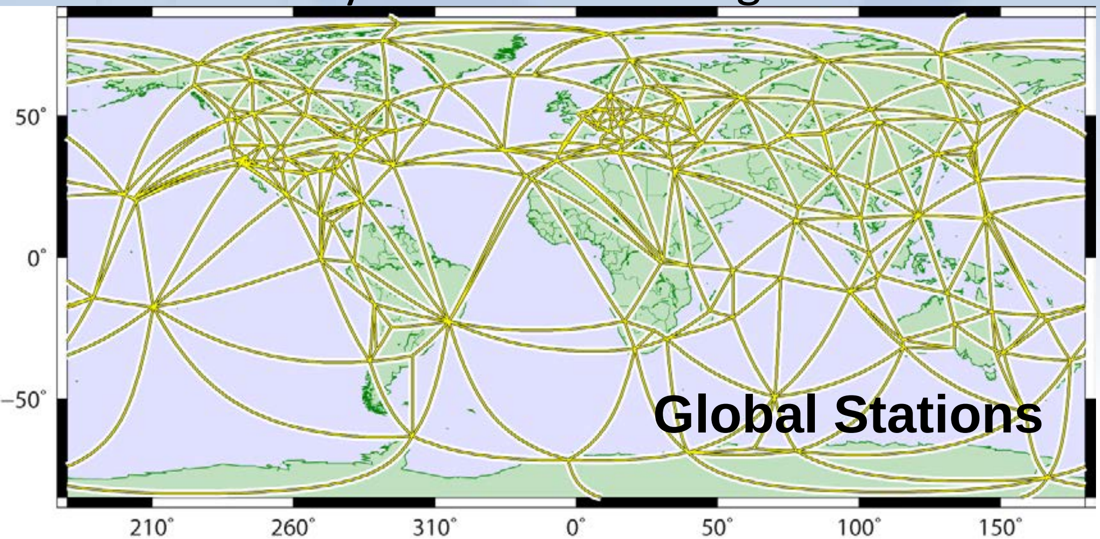
NAD 83(2011) epoch 2010.00

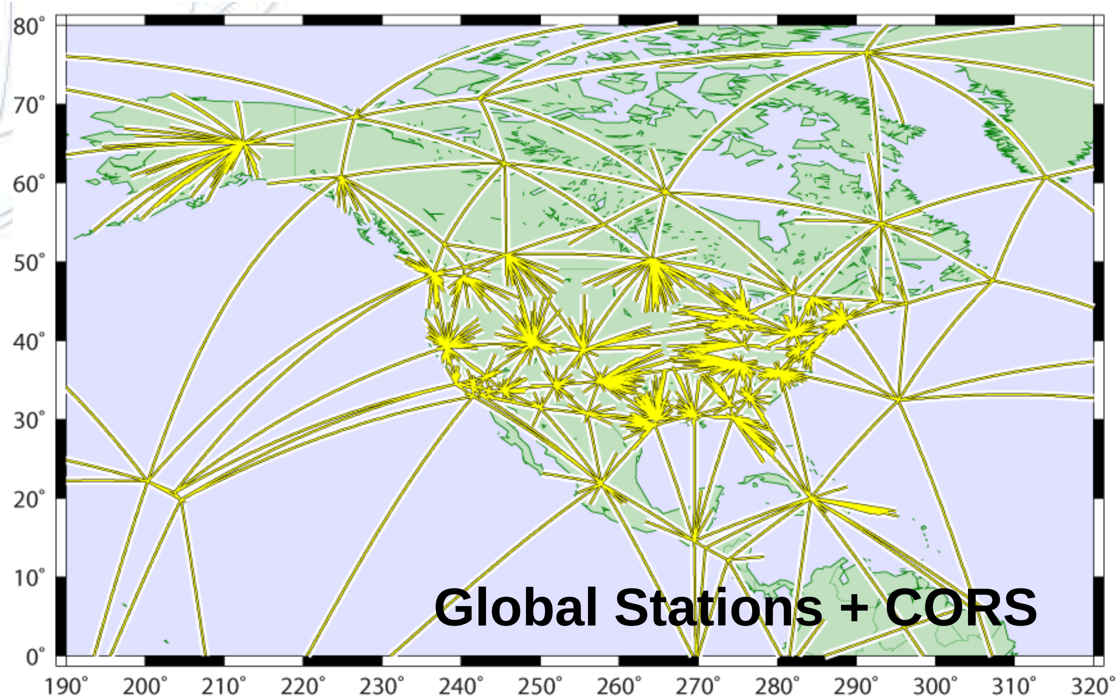
- **Multi-Year CORS Solution (MYCS)**
  - Reprocessed all CORS GPS data Jan 1994 - Apr 2011
  - 2264 CORS & global stations
  - NAD 83 computed by *transformation* from IGS08
  - Published September 2011

- **National Adjustment of 2011 (NA2011)**
  - New adjustment of GNSS passive control
  - GNSS vectors tied (and constrained) to CORS
  - 80,872 stations; 424,711 GNSS vectors
  - Median shifts: 1.9 cm H / 2.1 cm V
  - Published June 2012

Multi-Year CORS Solution: defining NAD83(2011) epoch 2010.00

5 years in the making >>> new CORS coordinates & velocities





- **global tracking network:**
  - **satellite orbits (15-min intervals)**
  - **terrestrial framework**
  - **Earth Orientation (EOPs)**
  - **global station positions (weekly averages)**
- **U.S. CORS tied to global framework via single baselines**
  - **minimizes frame distortions from local effects in dense regional networks**

✓ 1994-2010.5 tracking history

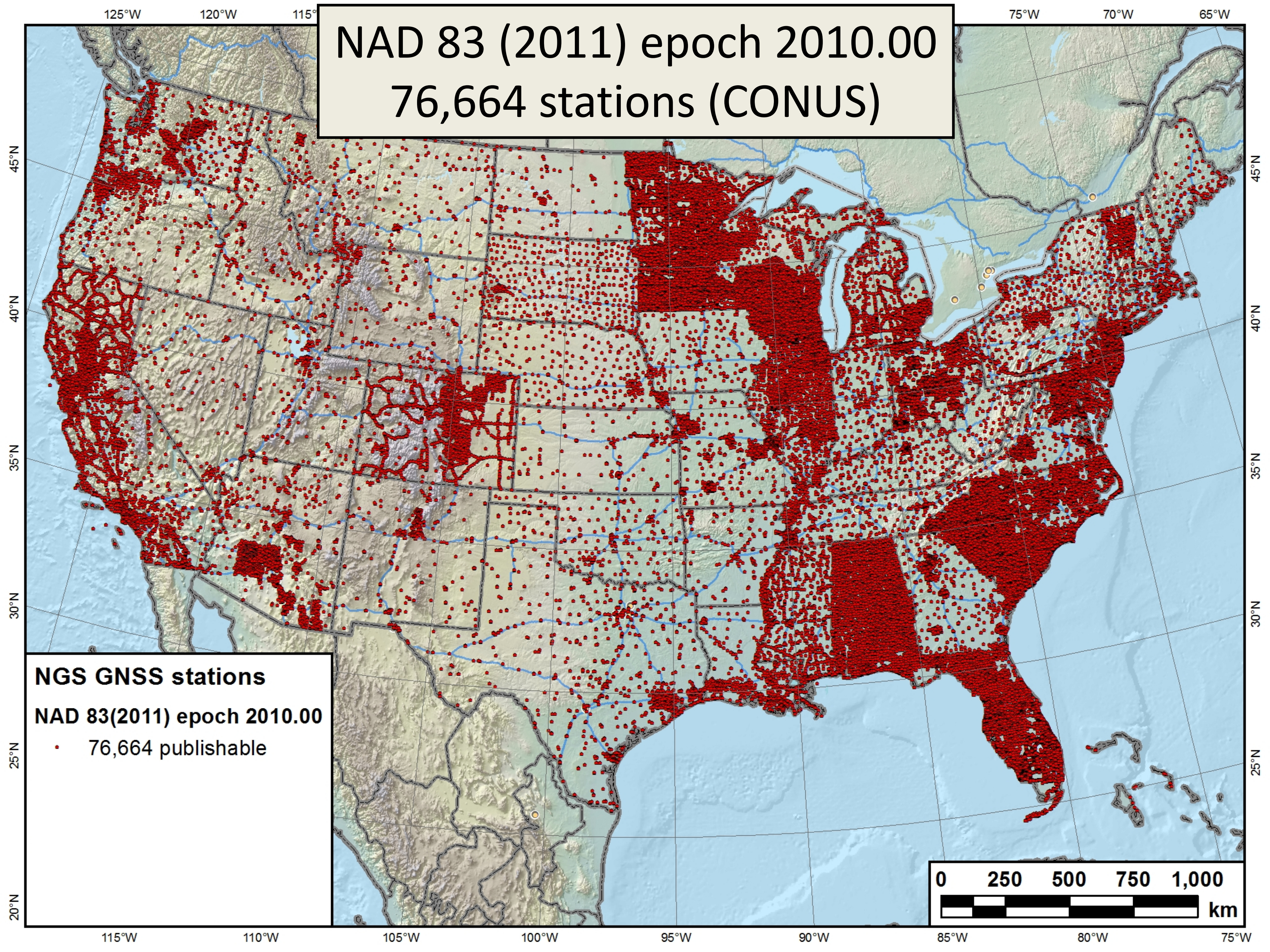
✓ 90 billion double-difference eqs.

✓ relative >>> absolute antenna cals.

❑ ***NAD83 (2011) epoch 2010.00***

❑ ***IGS08 epoch 2005.0***

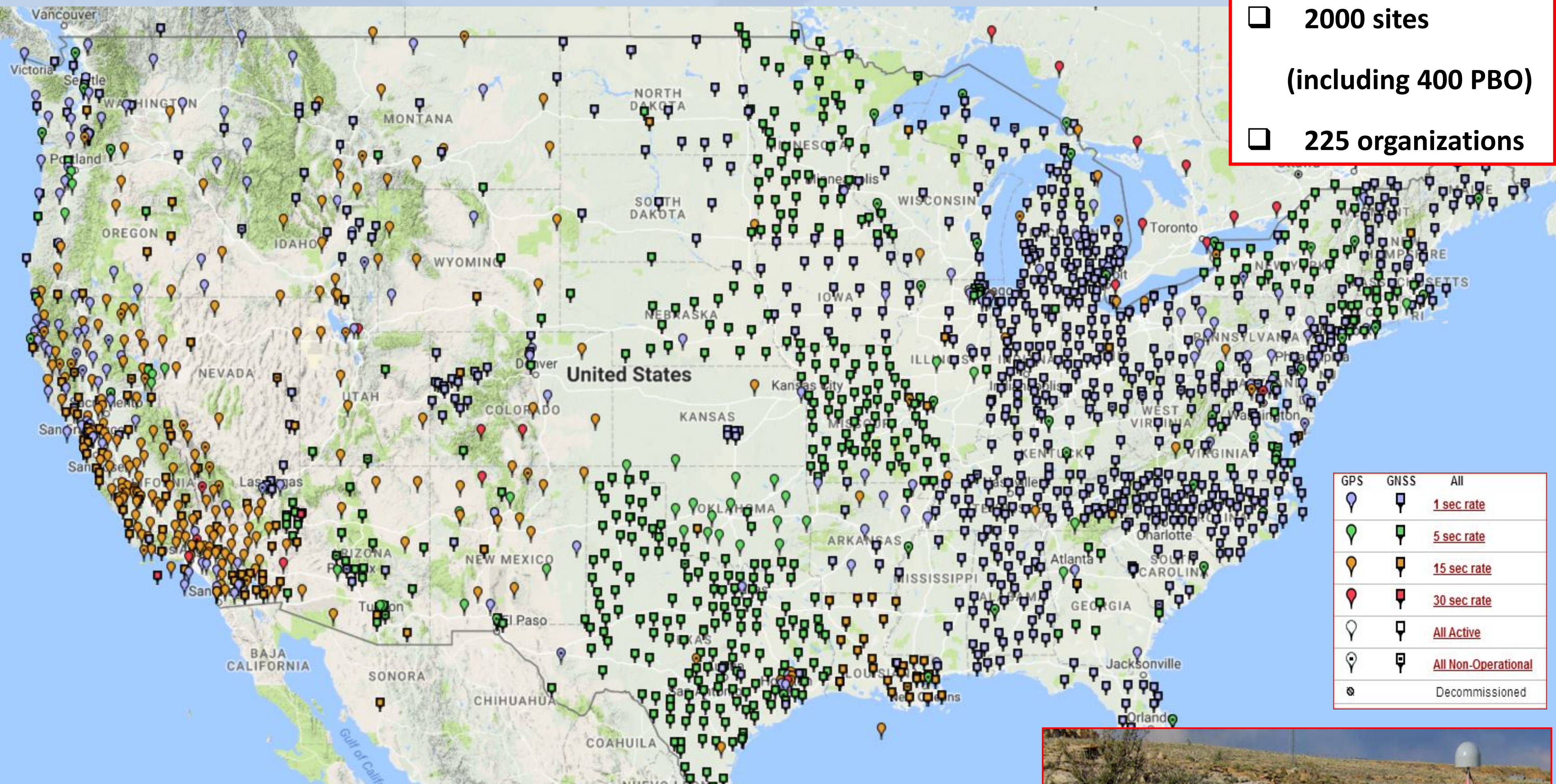
❑ ***"few cm" change from previous***

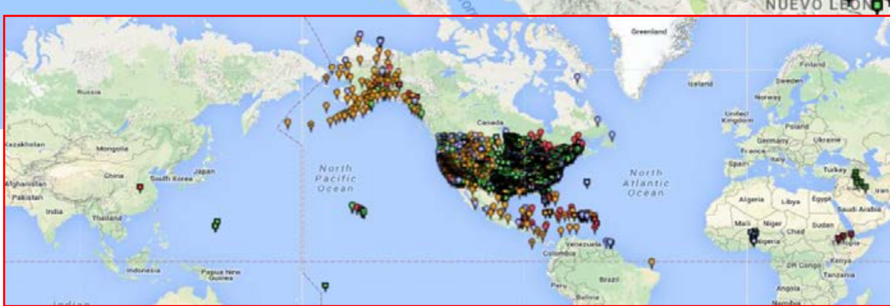


NAD 83 (2011) epoch 2010.00
76,664 stations (CONUS)
NGS GNSS stations
NAD 83(2011) epoch 2010.00
76,664 publishable
0 250 500 750 1,000
km
125°W
120°W
115°W
75°W
70°W
65°W
45°N
40°N
35°N
30°N
25°N
20°N
115°W
110°W
105°W
100°W
95°W
90°W
85°W
80°W
75°W

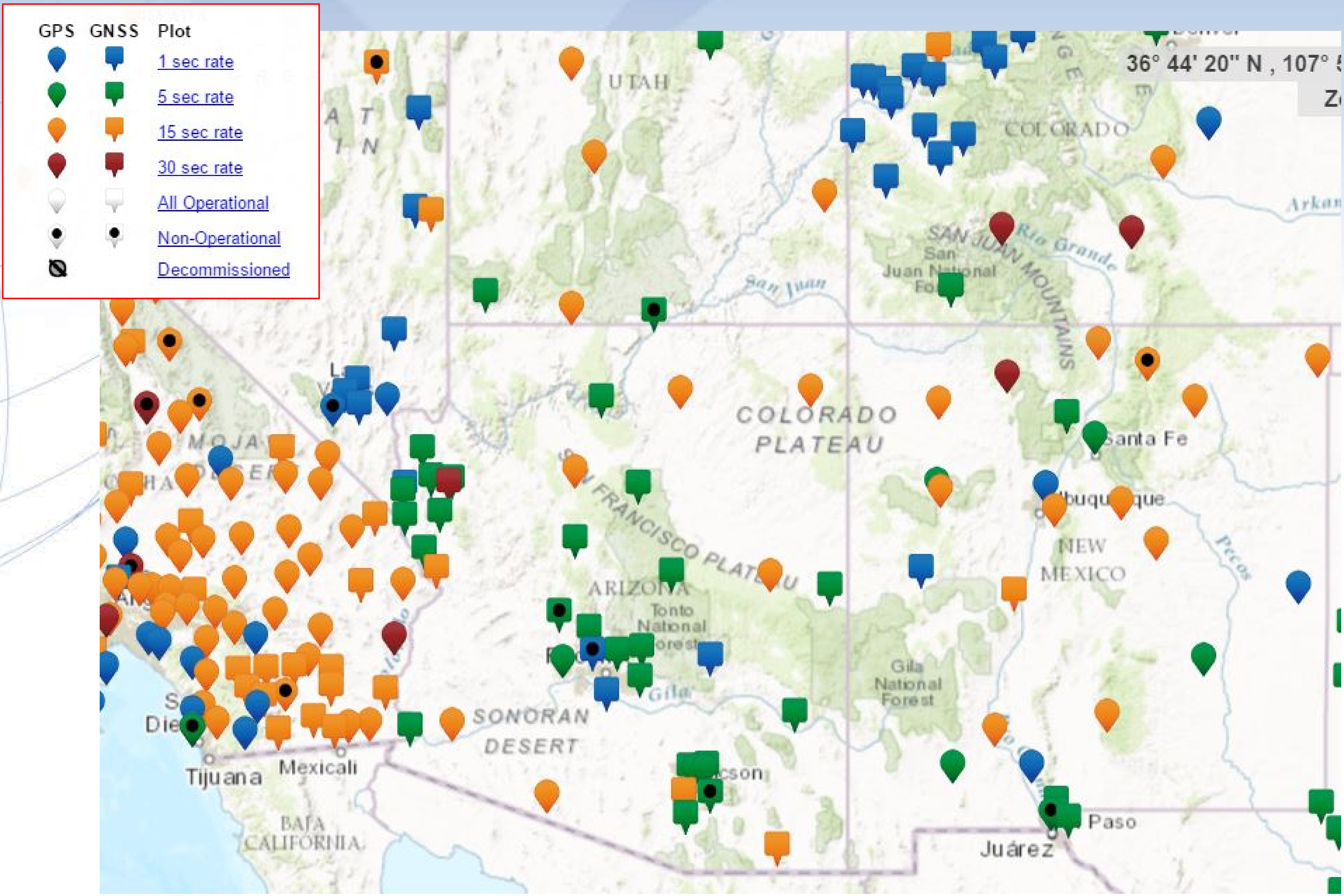
Continuously Operating Reference Station (CORS) Network

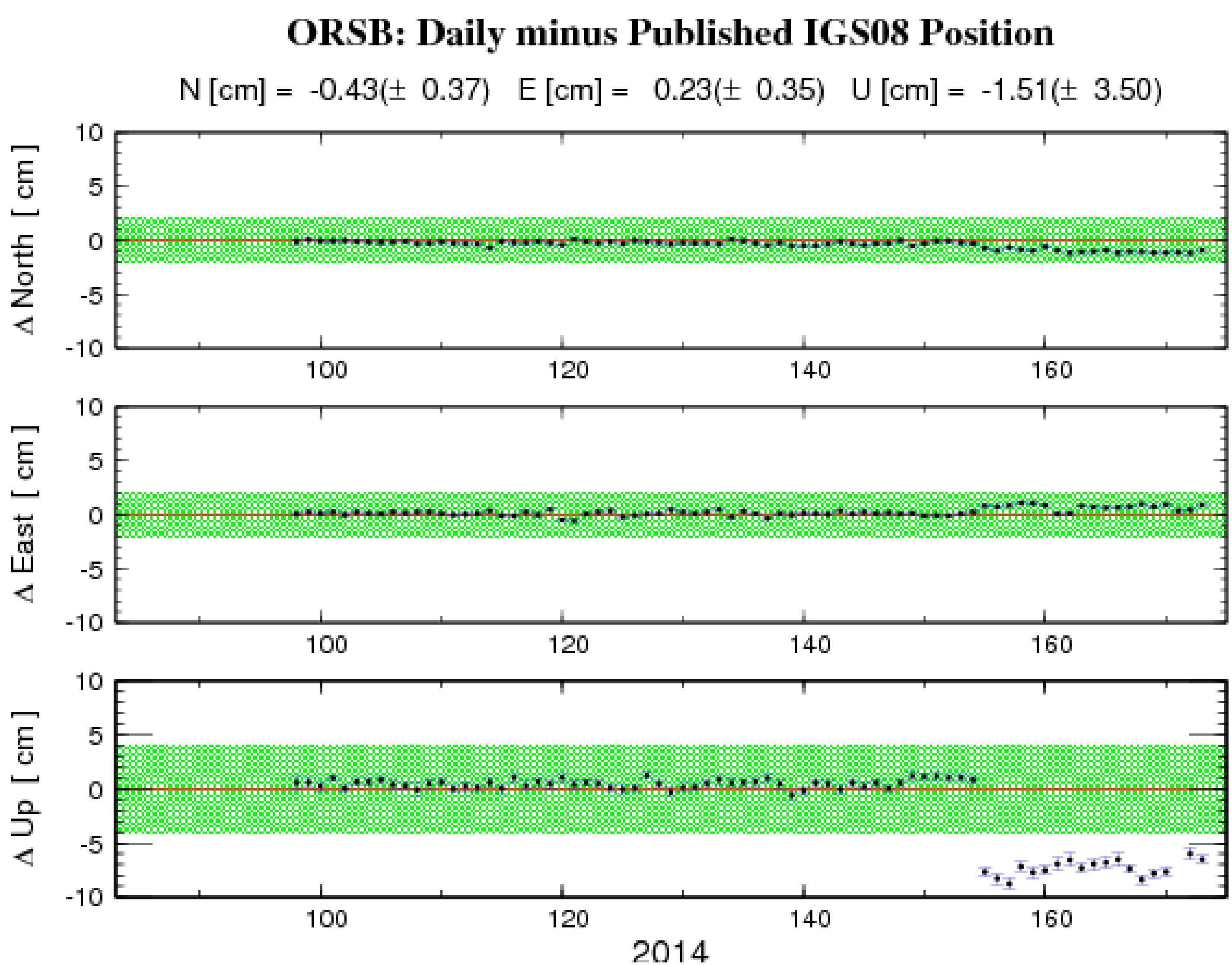
- 2000 sites (including 400 PBO)
- 225 organizations



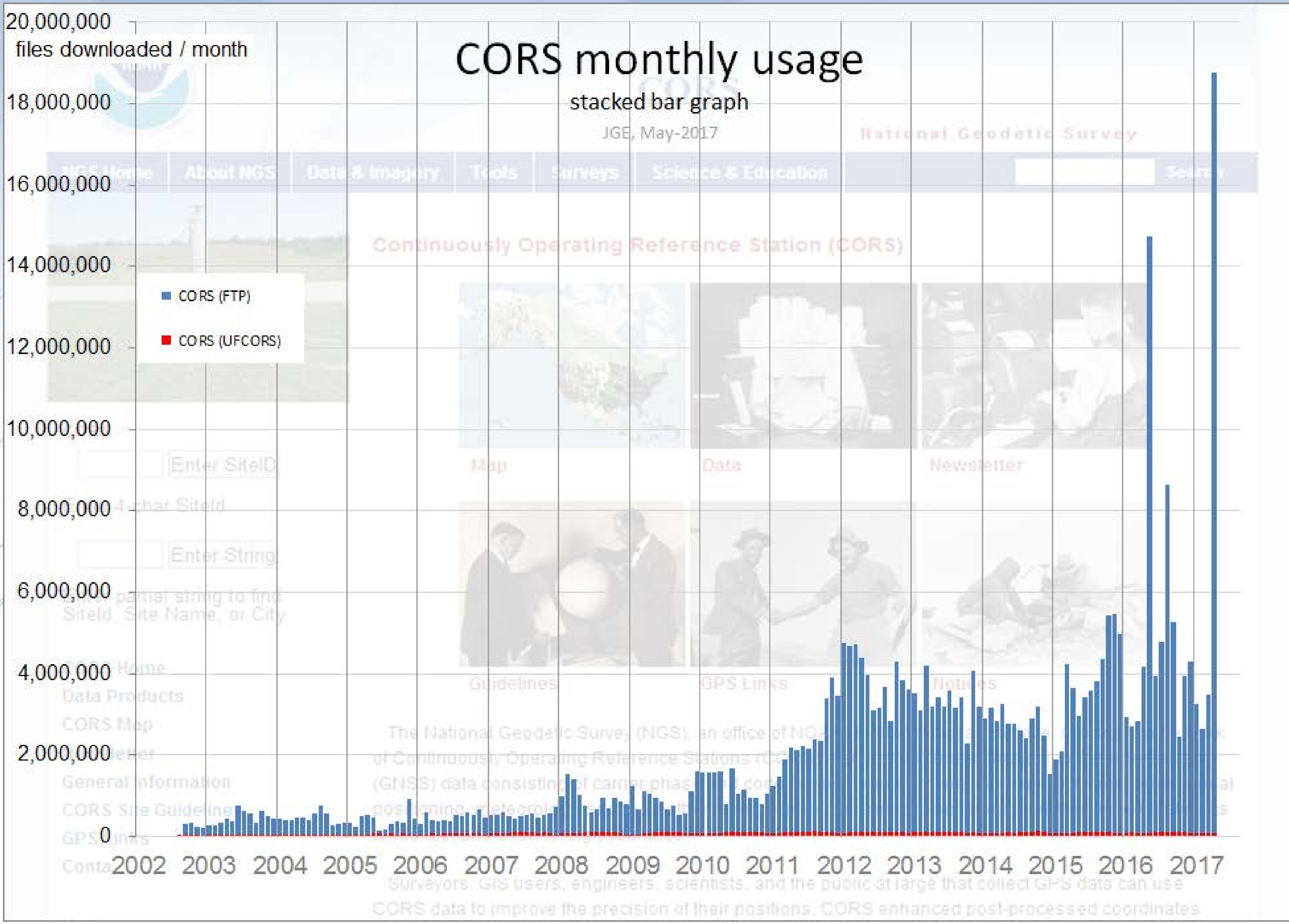


Continuously Operating Reference Station (CORS) Network




ORSB: Daily minus Published IGS08 Position
N [cm] = -0.43(± 0.37) E [cm] = 0.23(± 0.35) U [cm] = -1.51(± 3.50)
Δ North [cm]
Δ East [cm]
Δ Up [cm]
10
5
0
-5
-10
100
120
140
160
2014


Trimble
GNSS


CORS monthly usage
stacked bar graph
JGE, May-2017
files downloaded / month
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
CORS (FTP)
CORS (UFCORS)
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017

International Terrestrial Reference Frame (ITRF)

4 Global Independent Positioning Technologies

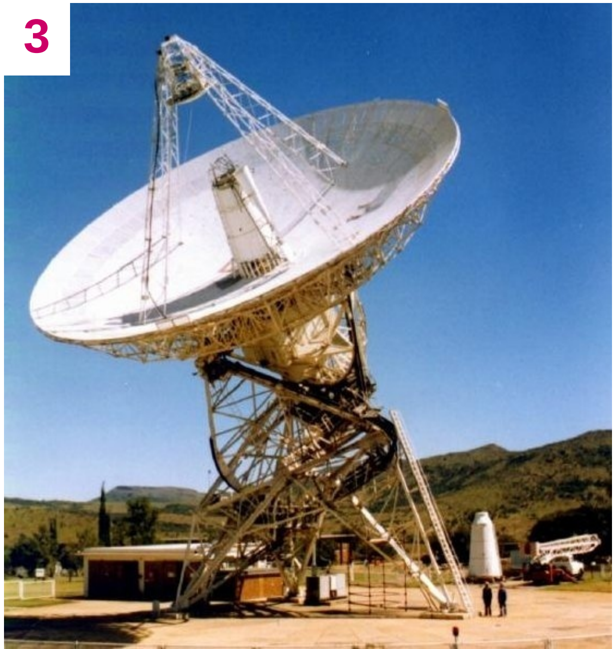
- 1. Global Navigation Satellite Systems (GNSS)
- 2. Satellite Laser Ranging (SLR)
- 3. Very Long Baseline Interferometry (VLBI)
- 4. Doppler Orbitography & Radiopositioning Integrated by Satellite (DORIS)

4

1

2

3



NOAA's National Geodetic Survey Positioning America for the Future

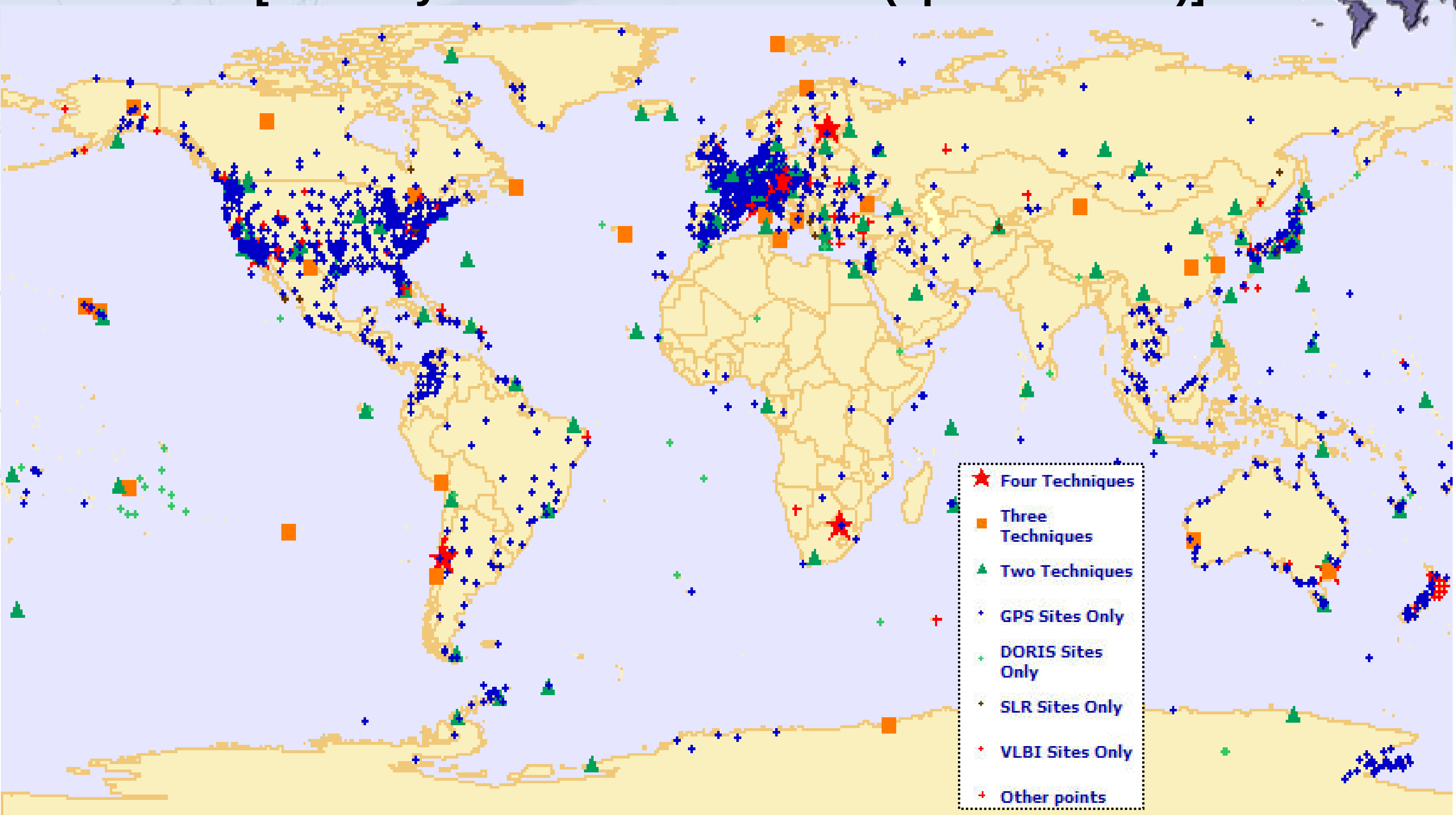
National Radio Astronomy Observatory
Enabling forefront research into the Universe at radio wavelengths

International Terrestrial Reference Frame (ITRF)

space-based techniques: VLBI, DORIS, SLR, GNSS

current version @ NGS: ITRF 2008 (epoch 2005.0)

[recently released: ITRF 2014 (epoch 2010.0)]



International Earth Rotation and Reference System Service (IERS)
(http://www.iers.org)

International GNSS Service

Formerly the International GPS Service

General GPS/GNSS questions?
Please visit resource links

The International GNSS Service (IGS), formerly the International GPS Service, is a voluntary federation of more than 200 worldwide agencies that pool resources and permanent GPS & GLONASS station data to generate precise GPS & GLONASS products. The IGS is committed to providing the highest quality data and products as the standard for Global Navigation Satellite Systems (GNSS) in support of Earth science research, multidisciplinary applications, and education. Currently the IGS includes two GNSS, GPS and the Russian GLONASS, and intends to incorporate future GNSS. You can think of the IGS as the highest-precision international civilian GPS community.

- GPS satellite ephemerides
- GLONASS satellite ephemerides
- Earth rotation parameters
- IGS tracking station coordinates and velocities
- GPS satellite and IGS tracking station clock information
- Zenith tropospheric path delay estimates
- Global ionospheric maps

IGS Product Availability

Three types of GPS ephemeris, clock and earth orientation solutions are computed.

Final
: The final combinations are available at 12 days latency.

Rapid
: The Rapid product is available with approximately 17 hours latency.

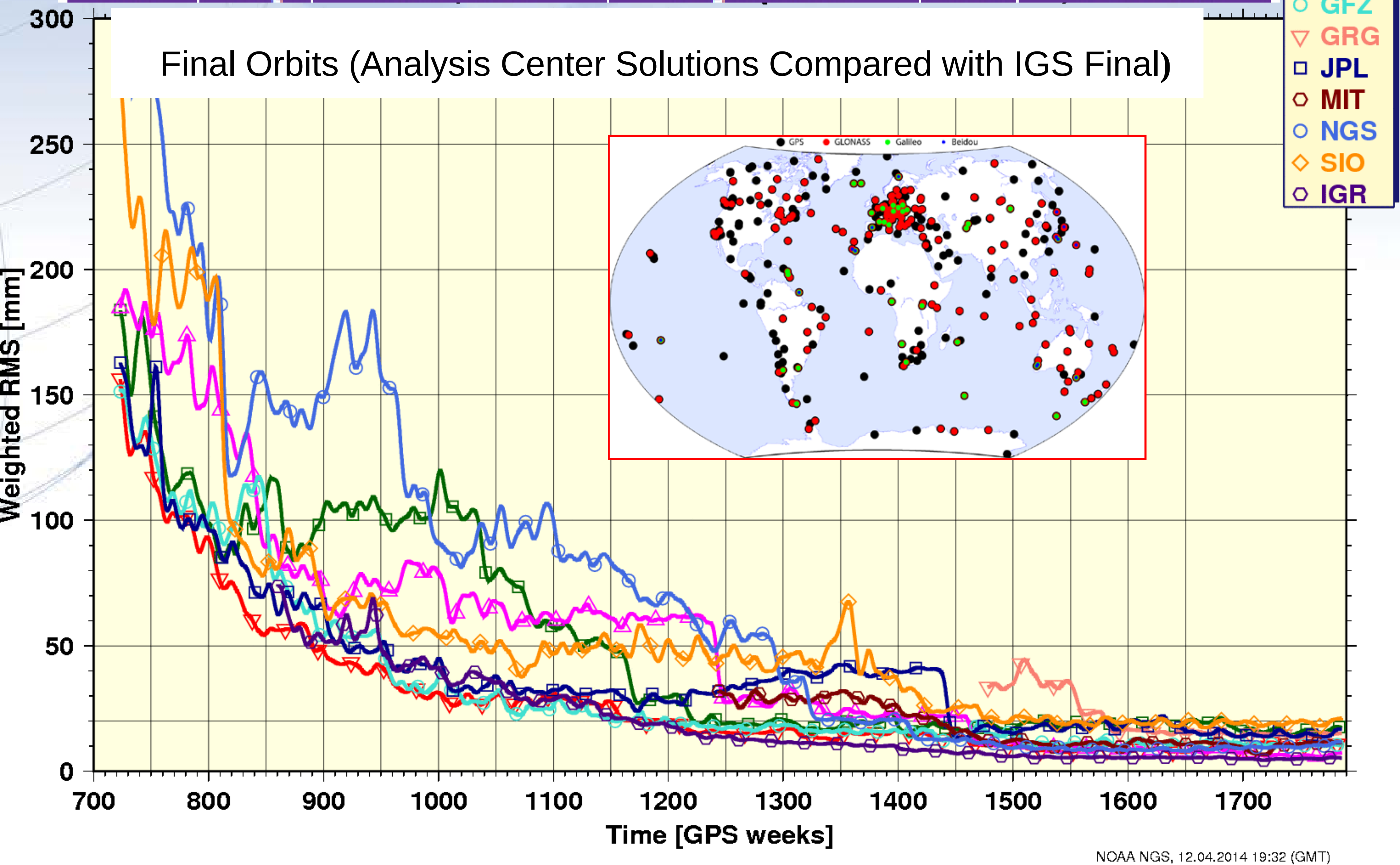
UltraRapid
: The UltraRapid combinations are released four times each day (at 0300, 0900, 1500, and 2100 UT) and contain 48 hours worth of orbits; the first half computed from observations and the second half predicted orbit. The files are named according to the midpoint time in the file: 00, 06, 12, and 18 UT.

International GNSS Service

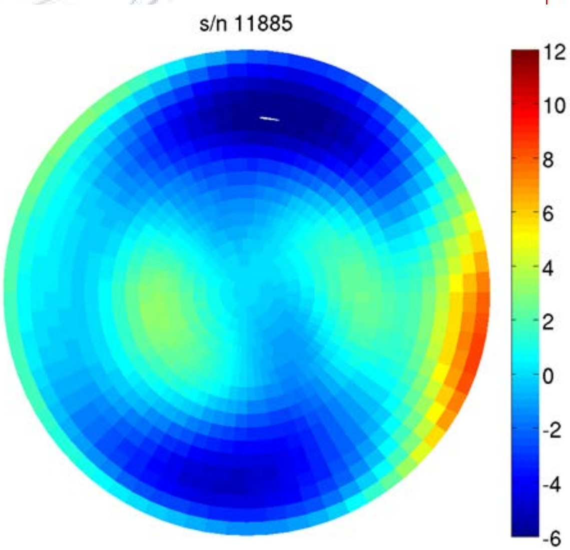
Formerly the International GPS Service

About IGS | Data & Products | Tracking Network | Pilot Projects & Working Groups | Calendar

MAIL | FAQ | Publications | Organization | FTP | Site Index



Absolute GNSS Antenna Calibrations



Antenna Calibrations

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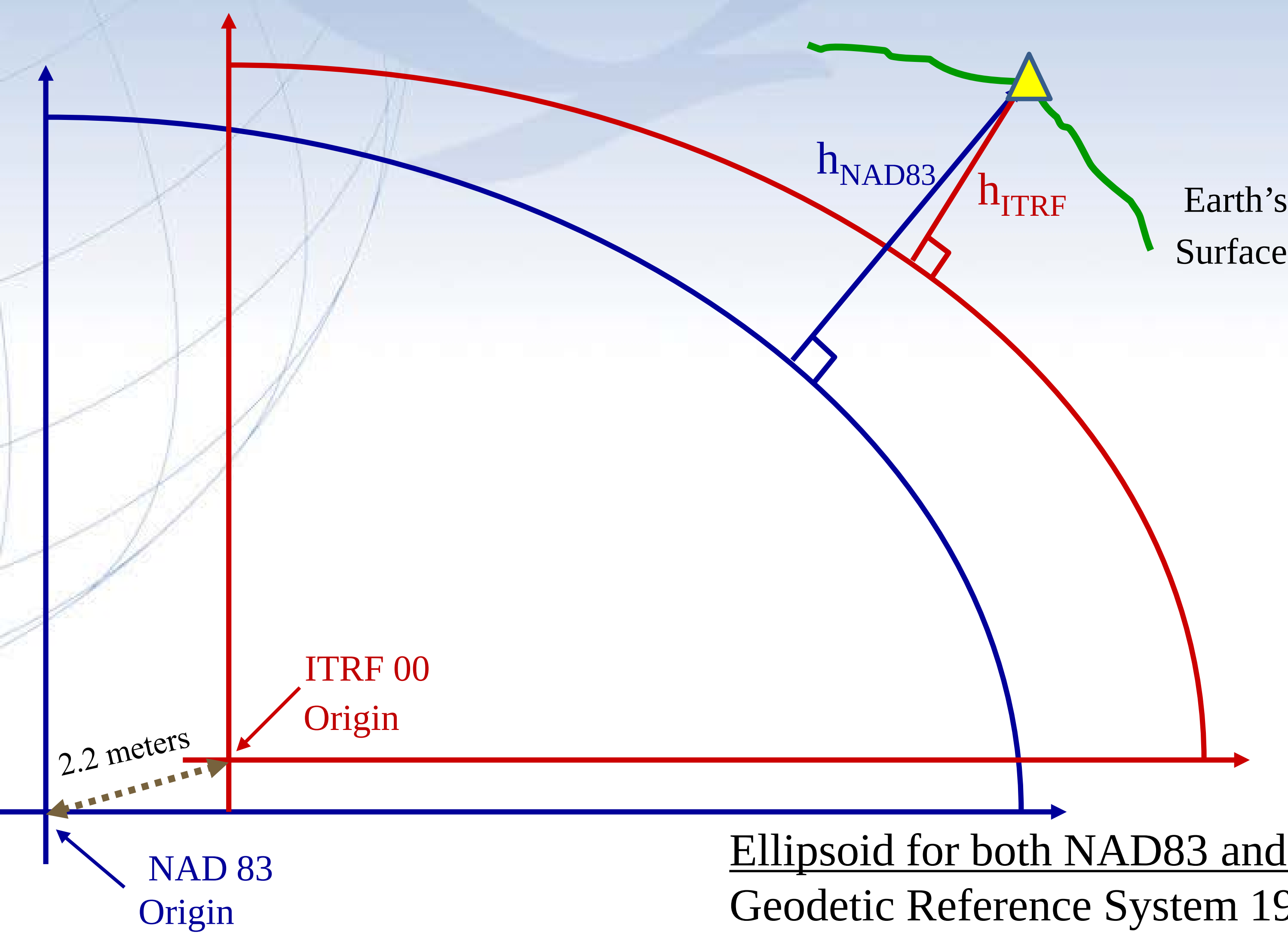
Antenna Model	Radome	Images	Calibrations	Description
TRM14177.00	NONE		ANTEX ANTINFO	4000ST L1 Geodetic, Model 14177.00
TRM14532.00	NONE	Drawing Side Top	ANTEX ANTINFO	4000ST L1/L2 Geodetic, Model 14532.00
TRM14532.10	NONE	Drawing Side Top	ANTEX ANTINFO	4000SSE Kin L1/L2, Model 14532.10
TRM22020.00+GP	NONE	Drawing Side Top	ANTEX ANTINFO	Geod. L1/L2 compact, with groundplane, Model 22020-00
TRM22020.00-GP	NONE	Drawing Side Top	ANTEX ANTINFO	Geod. L1/L2 compact; w/o groundplane, Model 22020-00
TRM22020.02	TCWD		ANTEX ANTINFO	L1/L2 w/rd and gp
TRM23903.00	NONE	Drawing Side Top	ANTEX ANTINFO	Permanent L1/L2, Model 23903.00, cast preamp housing
TRM27947.00+GP	NONE	Side Top	ANTEX ANTINFO	Rugged L1/L2 with groundplane, Model 27947.00
TRM27947.00-GP	NONE	Side Top	ANTEX ANTINFO	Rugged L1/L2 w/o groundplane, Model 27947.00
TRM29659.00	OLGA		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	SCIT		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	SNOW		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	TCWD		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	UNAV	Drawing Side Top	ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	SCIS		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	NONE	Drawing Side Top	ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2

Simplified Concept of NAD 83 vs. ITRF



<u>Ellipsoid for both NAD83 and ITRF:</u>

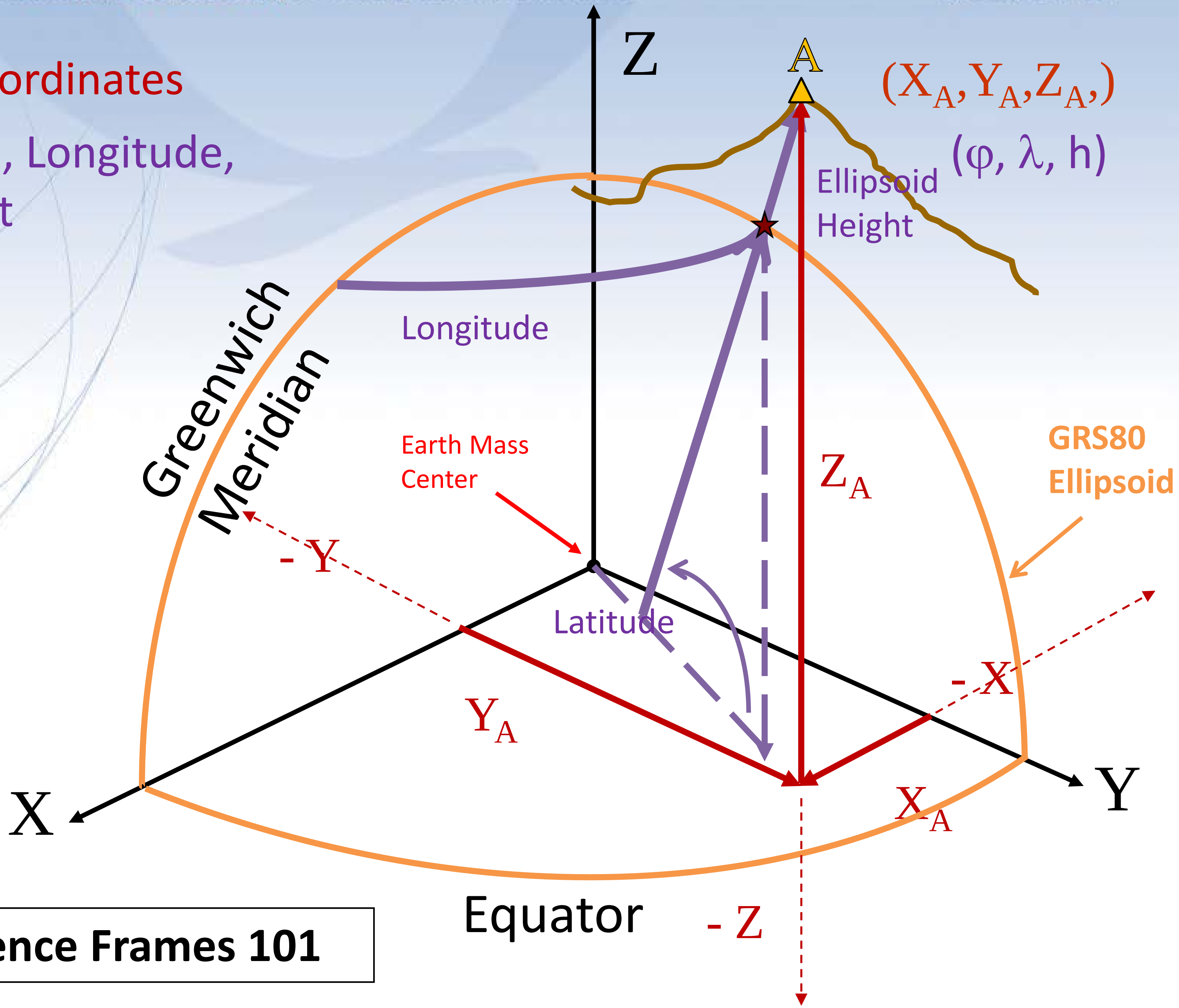
Geodetic Reference System 1980 (GRS80)

a = 6,378,137.000 meters (semi-major axis)

1/f = 298.25722210088 (flattening)

ECEF Coordinates

Latitude, Longitude, & Height



Reference Frames 101

CORS Coordinates

IGS08 = International GNSS Service 2008
(GPS-only realization of ITRF2008)

[replaces ITRF00 (epoch 1997.0)]

```
        Antenna Reference Point(ARP): SCOTTSDALE CORS ARP
        ---------------------------------------------------
                           PID = AH3759

IGS08 POSITION (EPOCH 2005.0)
Computed in Aug 2011 using data through gpswk 1631.
    X =  -1982826.934 m     latitude     =  33 34 07.39597 N
    Y =  -4936878.021 m     longitude    = 111 52 55.77821 W
    Z =   3506904.128 m     ellipsoid height =  391.322   m

IGS08 VELOCITY
Computed in Aug 2011 using data through gpswk 1631.
    VX =  -0.0128 m/yr      northward =  -0.0060 m/yr
    VY =   0.0023 m/yr      eastward  =  -0.0127 m/yr
    VZ =  -0.0055 m/yr      upward    =  -0.0008 m/yr

NAD_83 (2011) POSITION (EPOCH 2010.0)
Transformed from IGS08 (epoch 2005.0) position in Aug 2011.
    X =  -1982826.249 m     latitude     =  33 34 07.38024 N
    Y =  -4936879.362 m     longitude    = 111 52 55.73421 W
    Z =   3506904.203 m     ellipsoid height =  392.188   m

NAD_83 (2011) VELOCITY
Transformed from IGS08 velocity in Aug 2011.
    VX =   0.0023 m/yr      northward =   0.0033 m/yr
    VY =   0.0028 m/yr      eastward  =   0.0011 m/yr
    VZ =   0.0017 m/yr      upward    =  -0.0019 m/yr
________________________________________________________________

L1 Phase Center of the current GPS antenna: SCOTTSDALE CORS L1 PC C
```

IGS08 Position >>>

IGS08 Velocity >>>

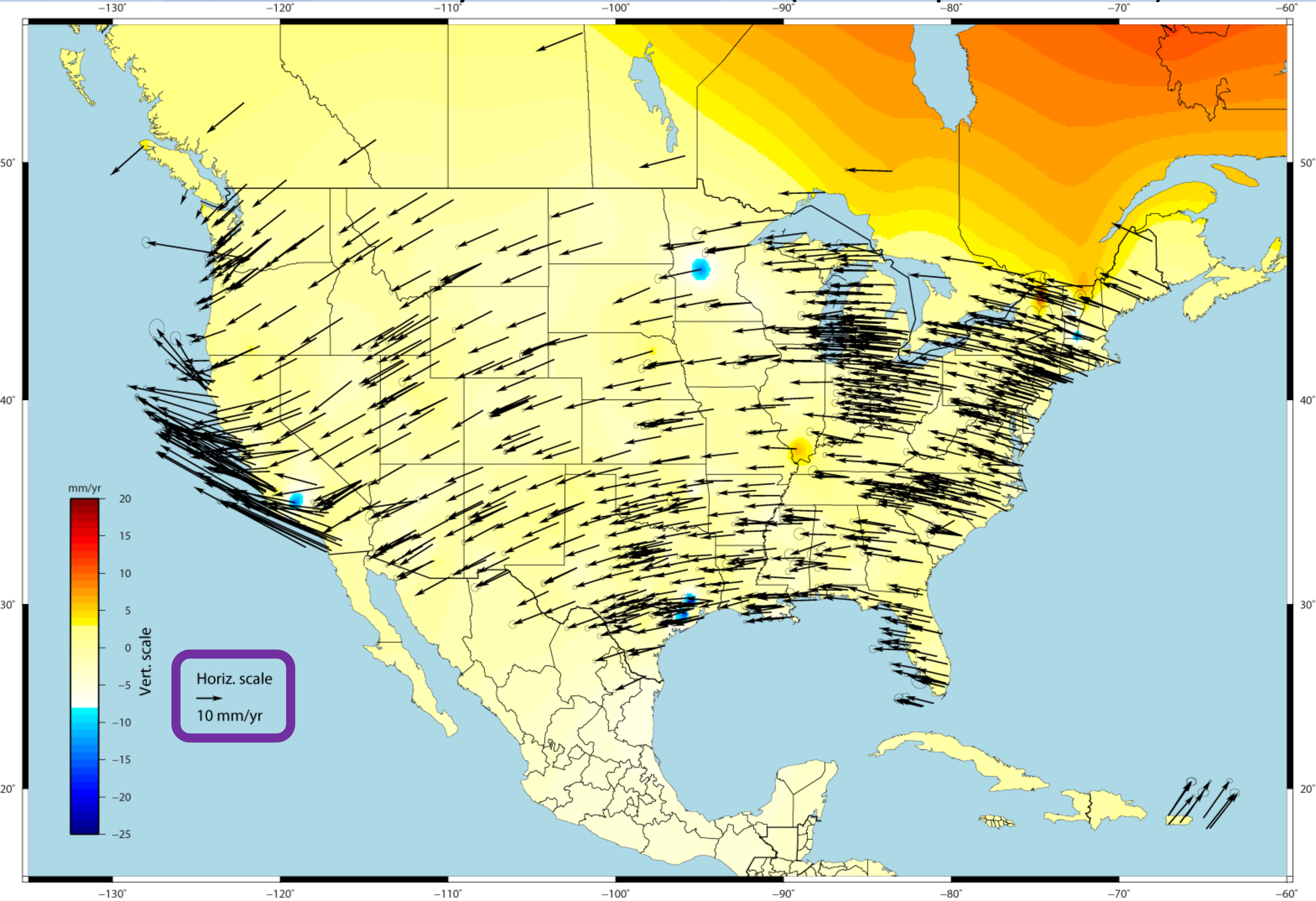
NAD83 Position >>>

NAD83 Velocity >>>

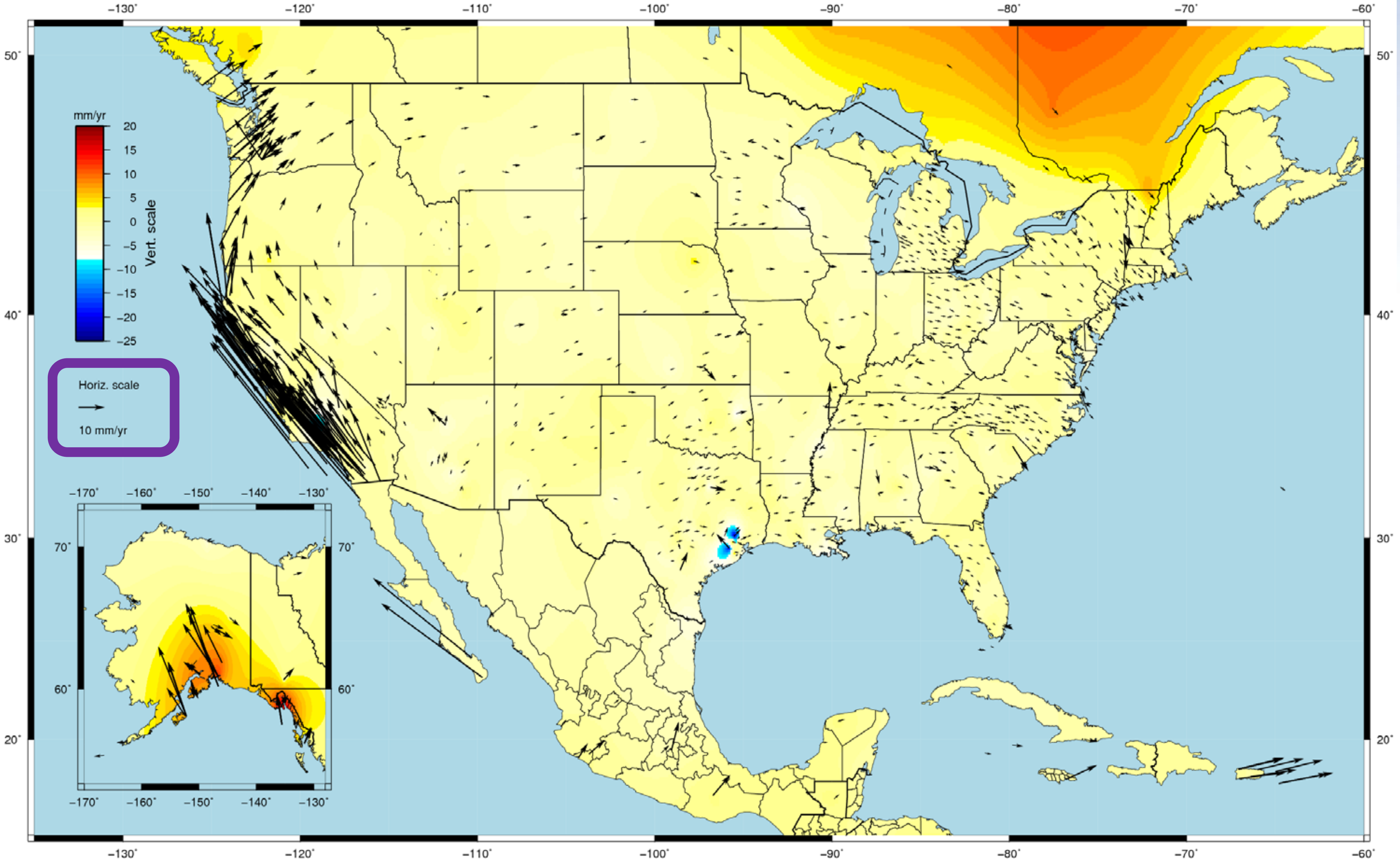
NAD83 (2011) epoch 2010.00 = North American Datum 1983
(2011 realization @ January 1, 2010)

[replaces NAD83(CORS96) (epoch 2002.0)]

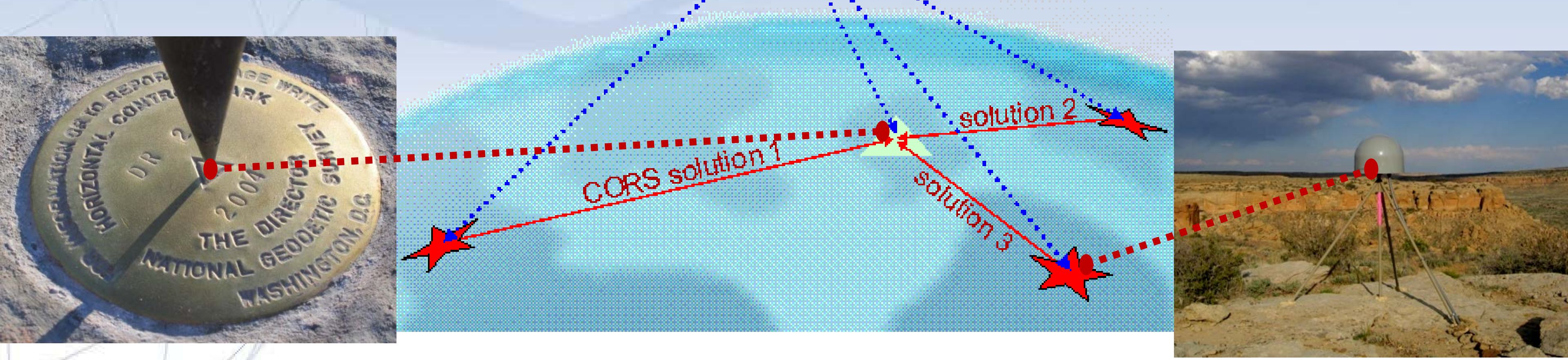
U.S. CORS Velocity Field – ITRF2008 (IGS08 epoch 2005.0)



U.S. CORS Velocity Field - NAD83(2011) epoch 2010.00



Online Positioning User Service (OPUS)



- upload L1/L2 GPS data >>> solution via email in minutes
  - ➢ OPUS-RS (Rapid Static) ----15 min to 2 hr (per CORS)
  - ➢ OPUS-S (Static) ---- 2 to 48 hr (anywhere)
  - ➢ OPUS-DB (Database) --- sharing of results
  - ➢ OPUS-Projects --- network of multi-stations/occupations

Fast, easy, consistent access to NSRS

Antenna Height Measurement

The height – in METERS – is measured vertically (NOT slant) from the mark to the ARP.

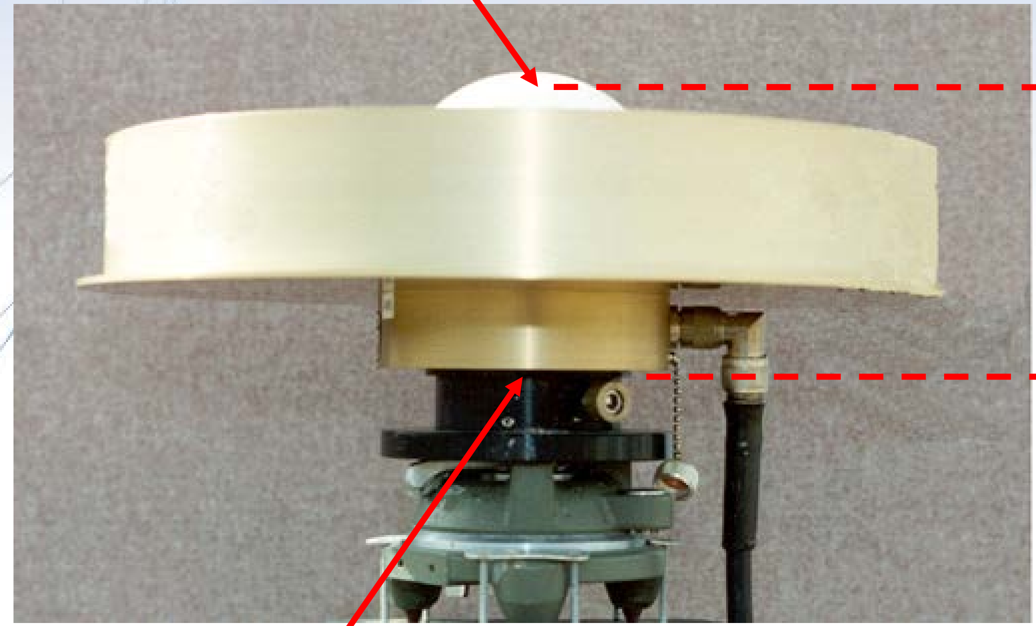
ARP is generally the center of the bottom-most, permanently attached, surface of the antenna.

See GPS Antenna Calibration Page for photos & diagrams that show ARP for most antennas.

If the default height of 0 is entered, OPUS will return the ARP position.

WHY DO I NEED THE ANTENNA TYPE?

The antenna phase centers are located somewhere around here.



phase ctr.

The antenna offsets are the distance between the phase centers and the ARP

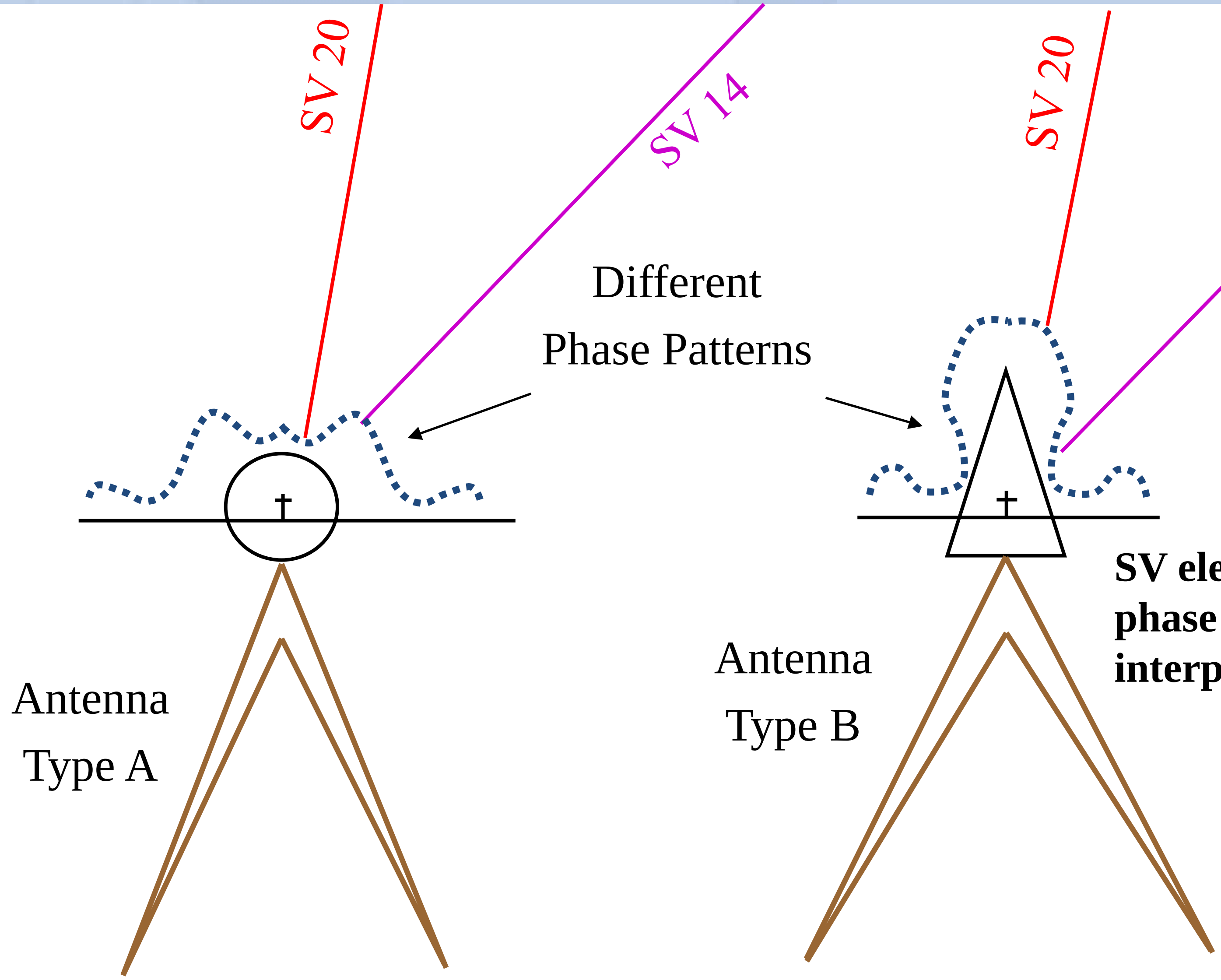
ARP

You do not need to know these offsets. They are passed to the processing software through the antenna type

The Antenna Reference Point (ARP) is almost always located in the center of the bottom surface of the antenna.

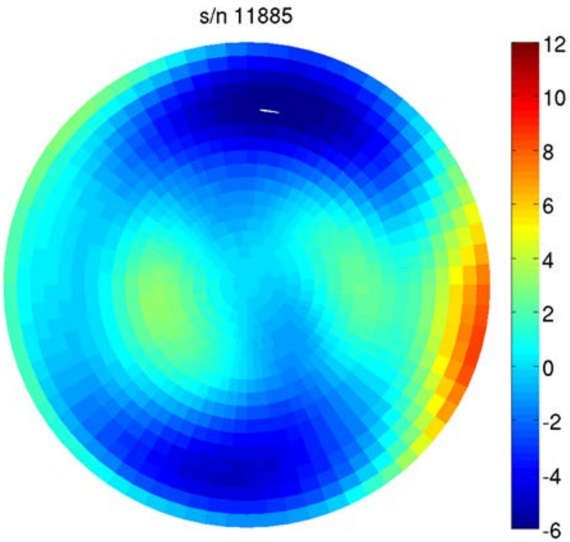
Incorrect or missing antenna type → big vertical errors

Antenna Phase Center Variation



SV elevation and varying phase patterns affect signal interpretation differently

NGS Absolute GNSS Antenna Calibrations



Antenna Calibrations

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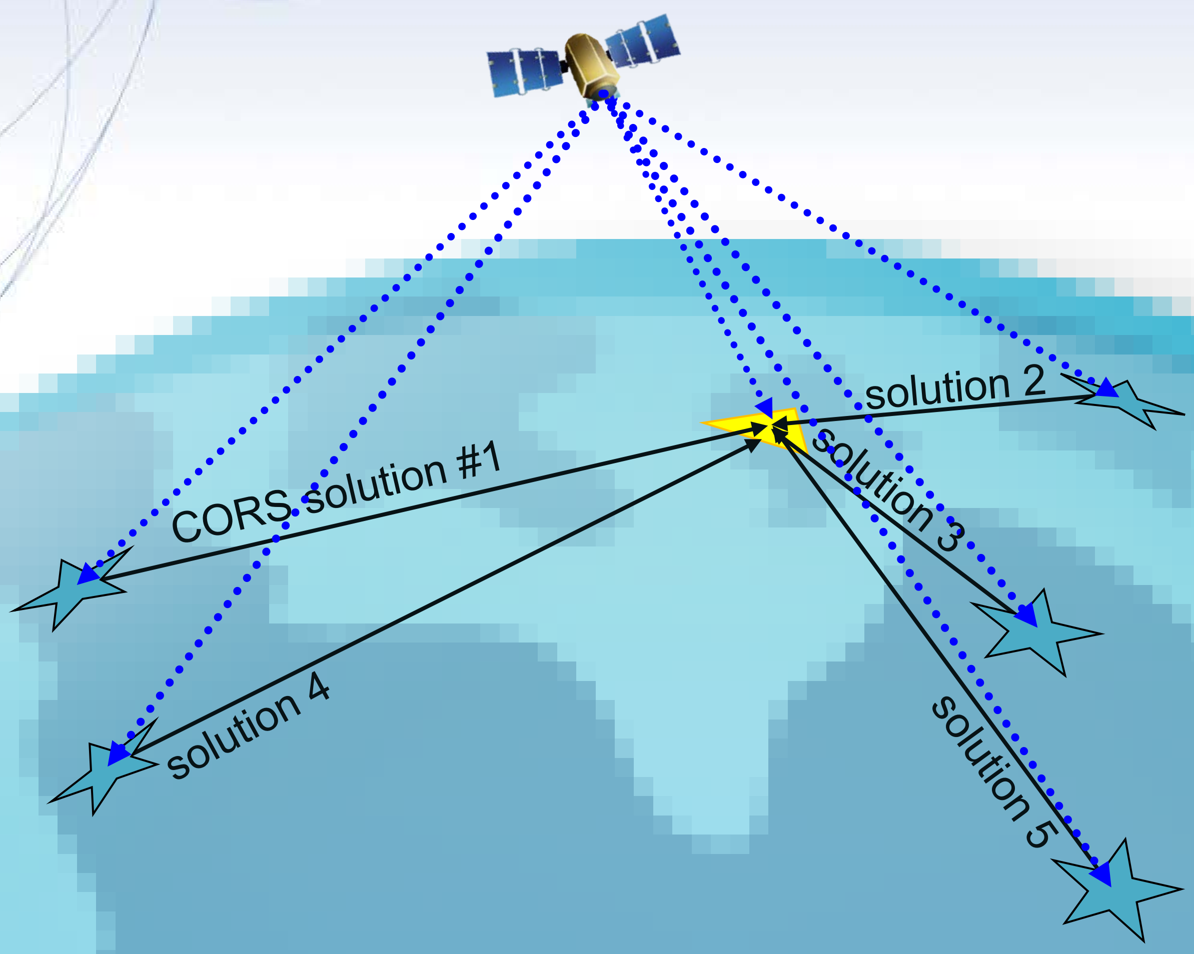
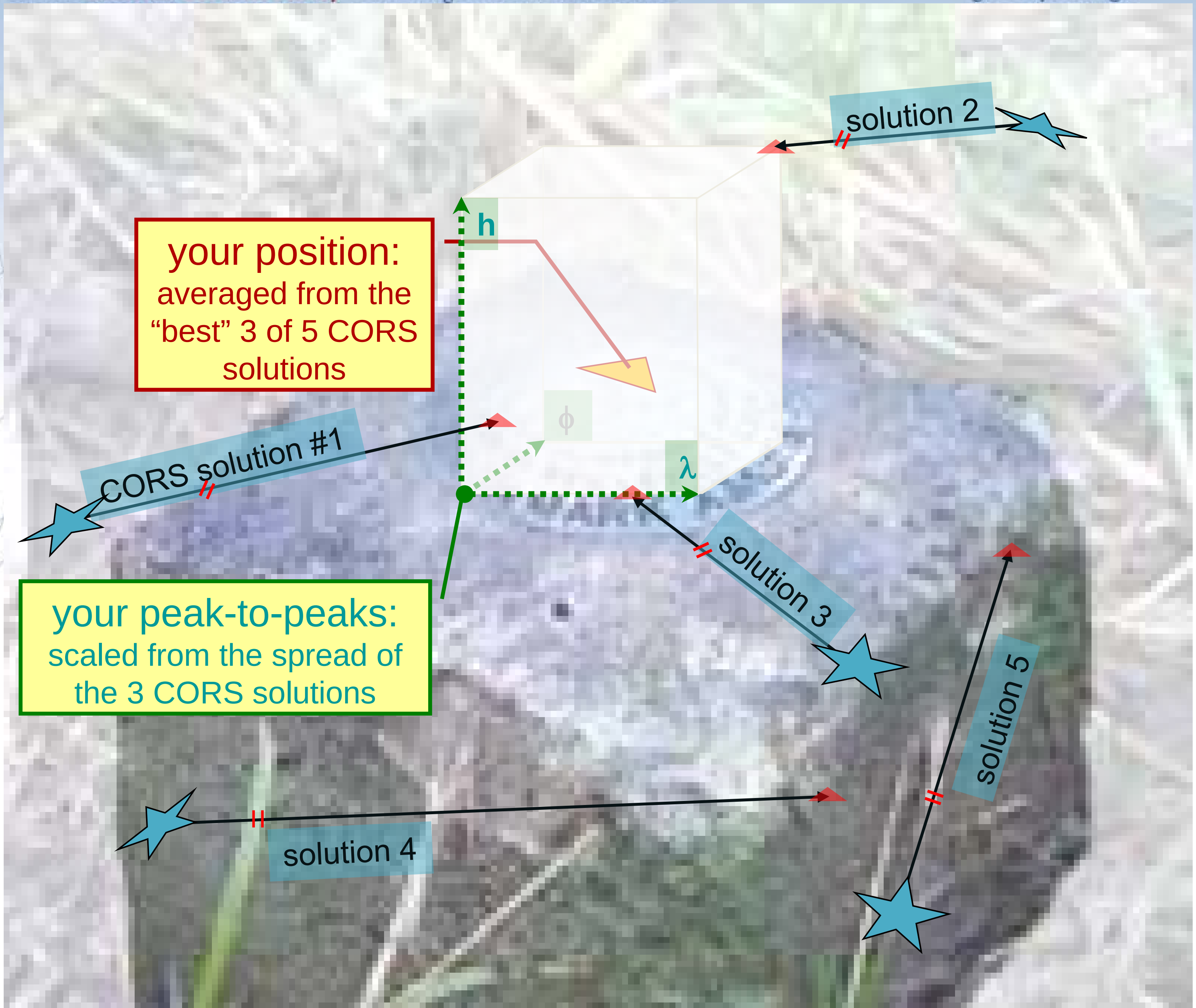
Trimble

Antenna Model	Radome	Images	Calibrations	Description
TRM14177.00	NONE		ANTEX ANTINFO	4000ST L1 Geodetic, Model 14177.00
TRM14532.00	NONE	Drawing Side Top	ANTEX ANTINFO	4000ST L1/L2 Geodetic, Model 14532.00
TRM14532.10	NONE	Drawing Side Top	ANTEX ANTINFO	4000SSE Kin L1/L2, Model 14532.10
TRM22020.00+GP	NONE	Drawing Side Top	ANTEX ANTINFO	Geod. L1/L2 compact, with groundplane, Model 22020-00
TRM22020.00-GP	NONE	Drawing Side Top	ANTEX ANTINFO	Geod. L1/L2 compact; w/o groundplane, Model 22020-00
TRM22020.02	TCWD		ANTEX ANTINFO	L1/L2 w/rd and gp
TRM23903.00	NONE	Drawing Side Top	ANTEX ANTINFO	Permanent L1/L2, Model 23903.00, cast preamp housing
TRM27947.00+GP	NONE	Side Top	ANTEX ANTINFO	Rugged L1/L2 with groundplane, Model 27947.00
TRM27947.00-GP	NONE	Side Top	ANTEX ANTINFO	Rugged L1/L2 w/o groundplane, Model 27947.00
TRM29659.00	OLGA		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	SCIT		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	SNOW		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	TCWD		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	UNAV	Drawing Side Top	ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	SCIS		ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2
TRM29659.00	NONE	Drawing Side Top	ANTEX ANTINFO	Trimble L1/L2 Dorne Margolin element with chokeringsModel 2

OPUS-Static: OPUS determines your position with a differential GPS static solution, using 2-48 hours of data.

This process is repeated 4x from other CORS.




solution 2
h
your position:
averaged from the
"best" 3 of 5 CORS
solutions
ϕ
λ
CORS solution #1
solution 3
your peak-to-peaks:
scaled from the spread of
the 3 CORS solutions
solution 5
solution 4

How Does OPUS-RS Work?

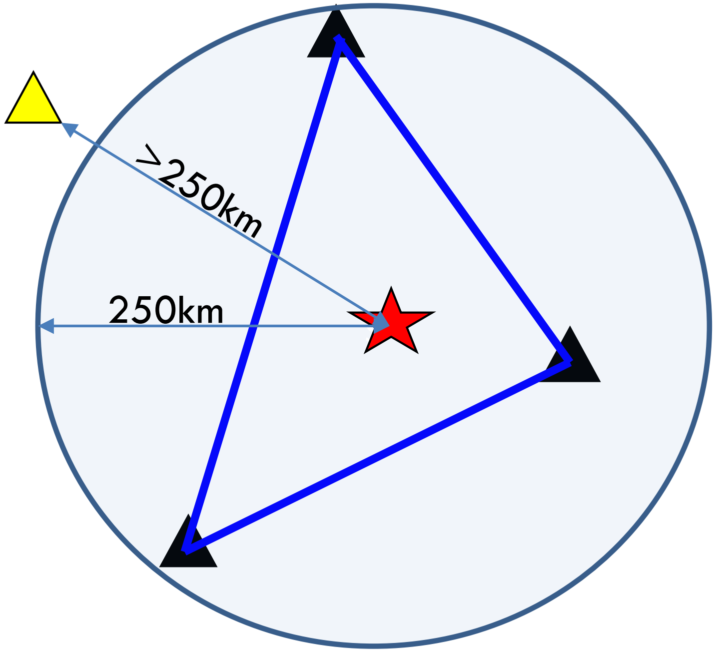
OPUS-RS selects three to nine "best" CORS based upon:

- Having common satellite visibility with the user data.
- Having distances from the user's site <250 km.

This is shown here graphically. The star represents the user's site. The triangles are CORS.

No CORS farther than 250 km from the user's site will be included.

The three CORS minimum is shown. No more than nine are used.



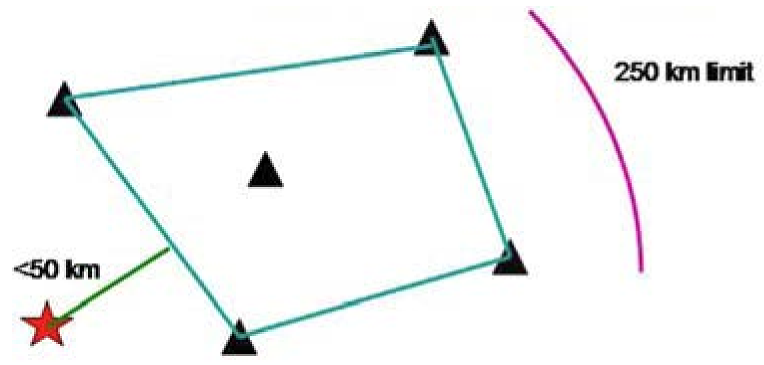
Choi, 2010, personal communication.

How Does OPUS-RS Work?

In addition, user's site must be no more than 50 km from the (convex) polygon created by the selected CORS.

Again in this figure, the star represents the user's site; the triangles are CORS. Five CORS and their resulting polygon are shown in this example.

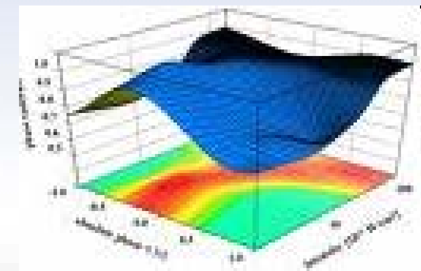
If the user's site, the star, is more than 50 km outside this polygon, alternate CORS will be considered. If none can be found, the processing will abort.

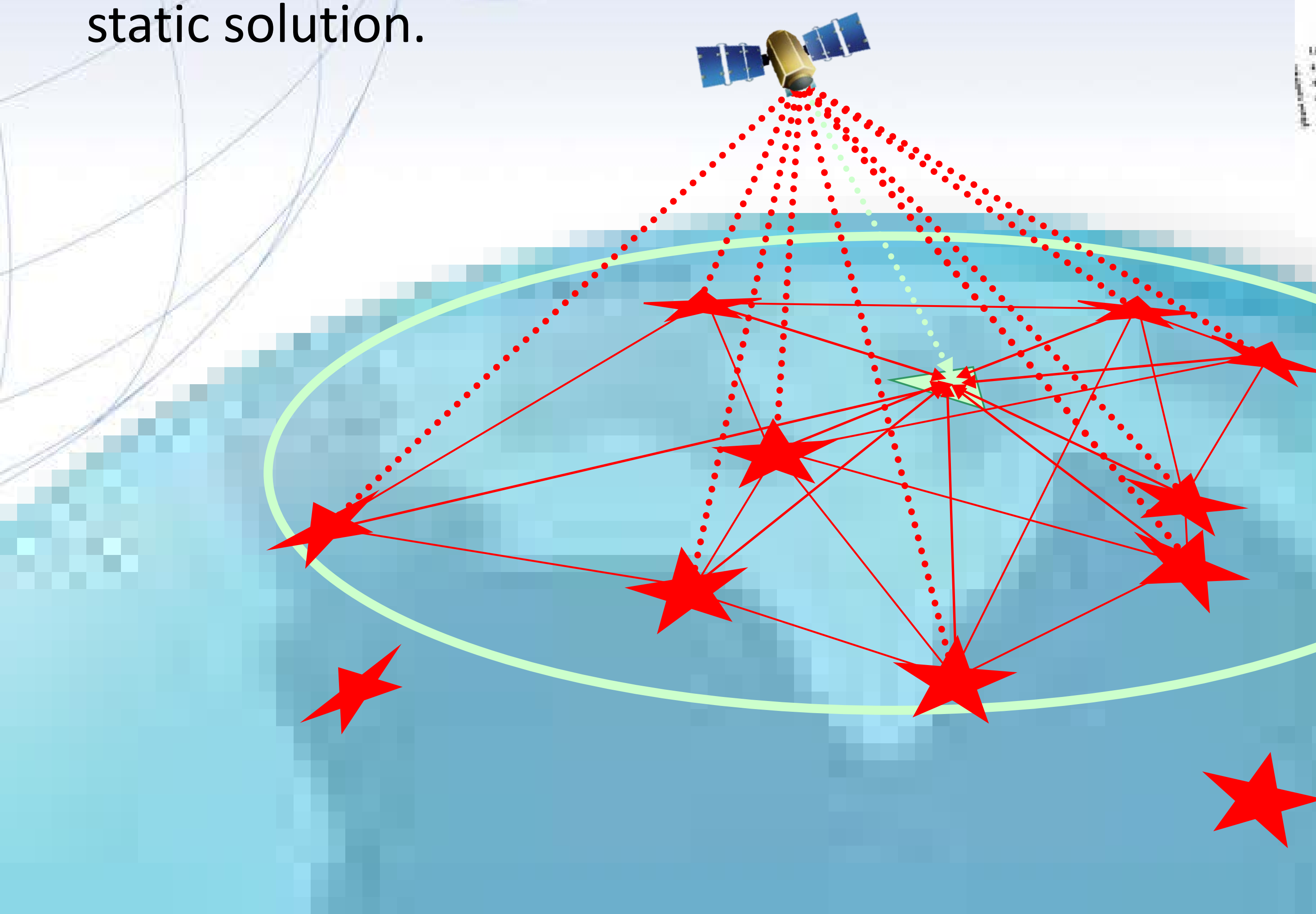


Schwarz et al., "Accuracy assessment of the National Geodetic Survey's OPUS-RS utility", 2009, *GPS Solutions*, 13(2), 119-132.

Rapid-static: OPUS first creates an atmospheric delay model from surrounding CORS data.

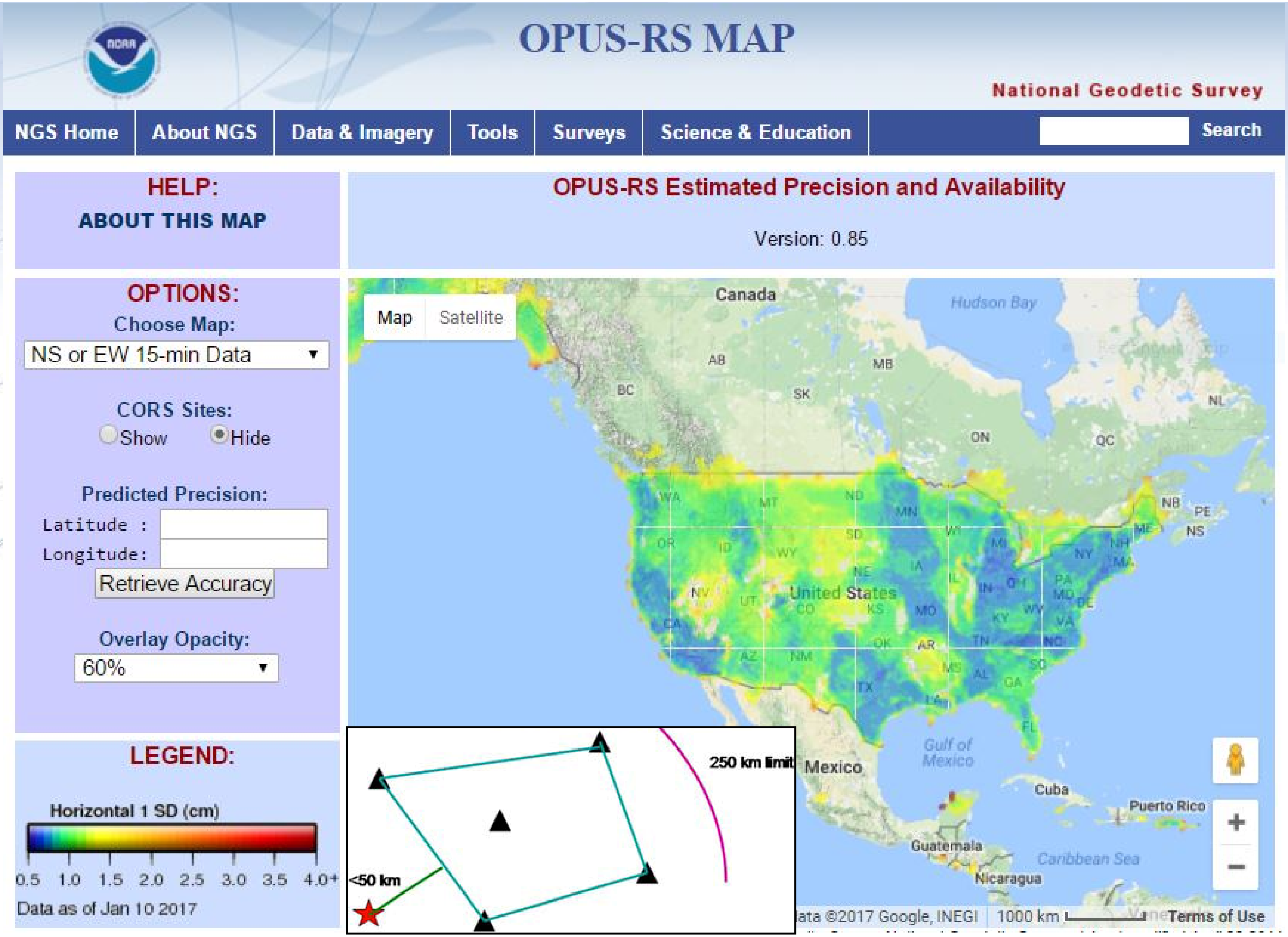
Your position is then quickly determined by differential GPS static solution.





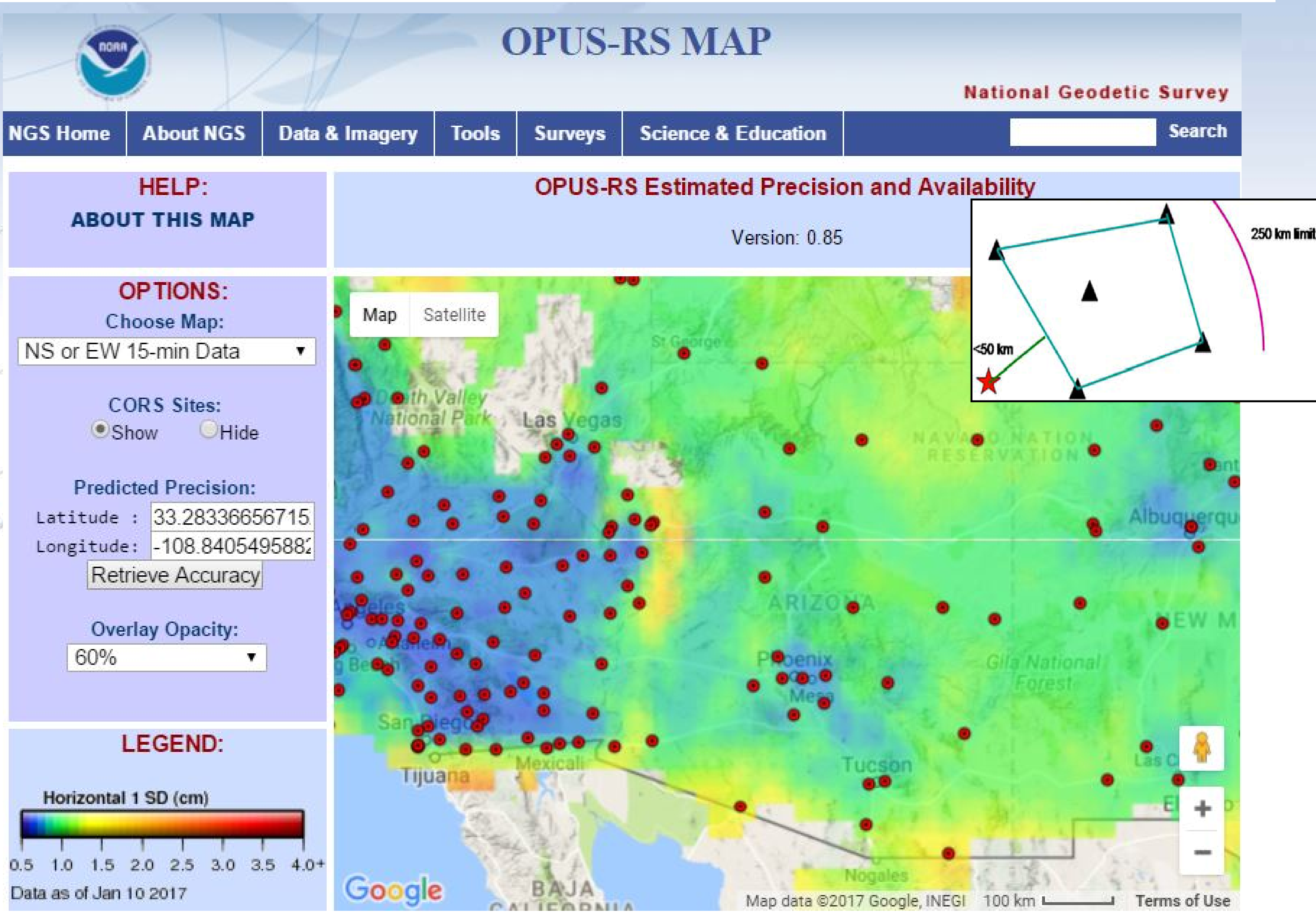
OPUS-RS Predicted Accuracy (1-sigma)

N-S or E-W coordinates with 15 minutes of data



OPUS-RS Predicted Accuracy (1-sigma)

N-S or E-W coordinates with 15 minutes of data



OPUS – Share (aka OPUS-DB)

❑ Sharing Criteria:

- NGS-calibrated antenna
- > 4 hour data span
- > 70 % observations used
- > 70 % fixed ambiguities
- < 0.04m H peak-to-peak
- < 0.08m V peak-to-peak

❑ Uses:

- GPS on BMs
- PLSS / GCDB
- Data archive
- Data sharing

Shared Solution

PID: GT0228
Designation: F 72
Stamping: F 72 1928
Stability: Most reliable; expected to hold position well
Setting: In rock outcrop or ledge
Mark Condition: G
Description: The station is located 6.2 miles along the Mount Whitney Trail from the trailhead at the Whitney Portal, west of Lone Pine. It is located at Trail Camp, about 250 feet south of the south shore of a lake and about 50 feet south of the trail, opposite a 10-feet-tall boulder that sits directly along the north side of the trail. The station is a USCGS bench mark disk set flush in the top of a granite outcrop measuring about 75 feet by 25 feet and standing about 10 feet above the level of the trail.
Observed: 2010-08-17T16:53:00Z   See Also 1928
Source: OPUS - page5 1209.04

Close-up View

REF_FRAME: NAD_83(2011)	EPOCH: 2010.0000	SOURCE: NAVD88 (Computed using GEOID12A)	UNITS: m	SET PROFILE	DETAILS

LAT:	36° 33' 46.36644"	± 0.006	m
LON:	-118° 16' 46.29502"	± 0.003	m
ELL HT:	3645.963	± 0.013	m
X:	-2431390.178	± 0.006	m
Y:	-4519449.679	± 0.013	m
Z:	3780713.238	± 0.002	m
ORTHO HT:	3671.261	± 0.031	m

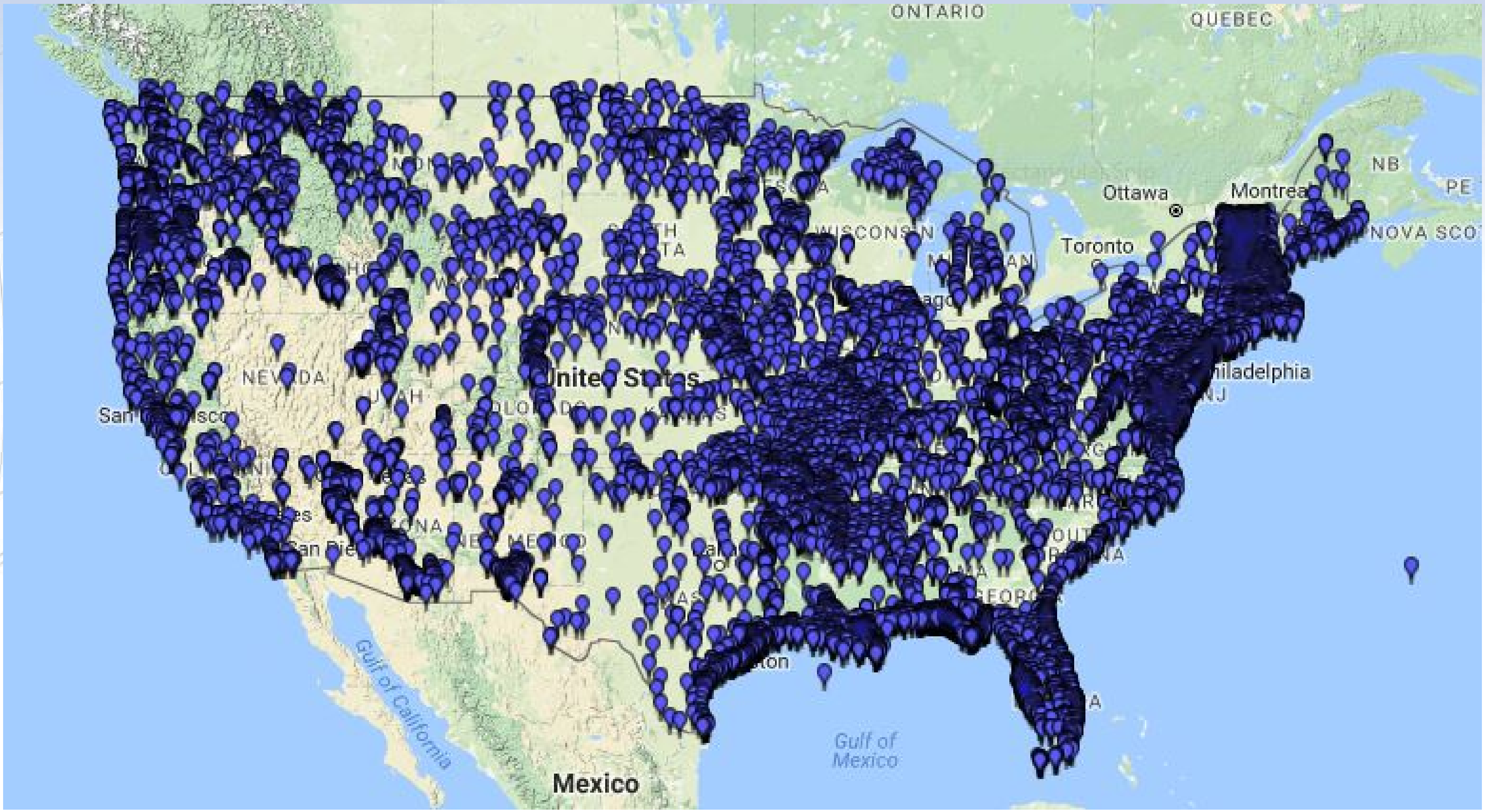
	UTM 11	SPC 404(CA 4)
NORTHING:	4047144.640m	636673.937m
EASTING:	385501.607m	2064491.407m
CONVERGENCE:	-0.76230261°	0.42982529°
POINT SCALE:	0.99976152	0.99994136
COMBINED FACTOR:	0.99918979	0.99936952

CONTRIBUTED BY

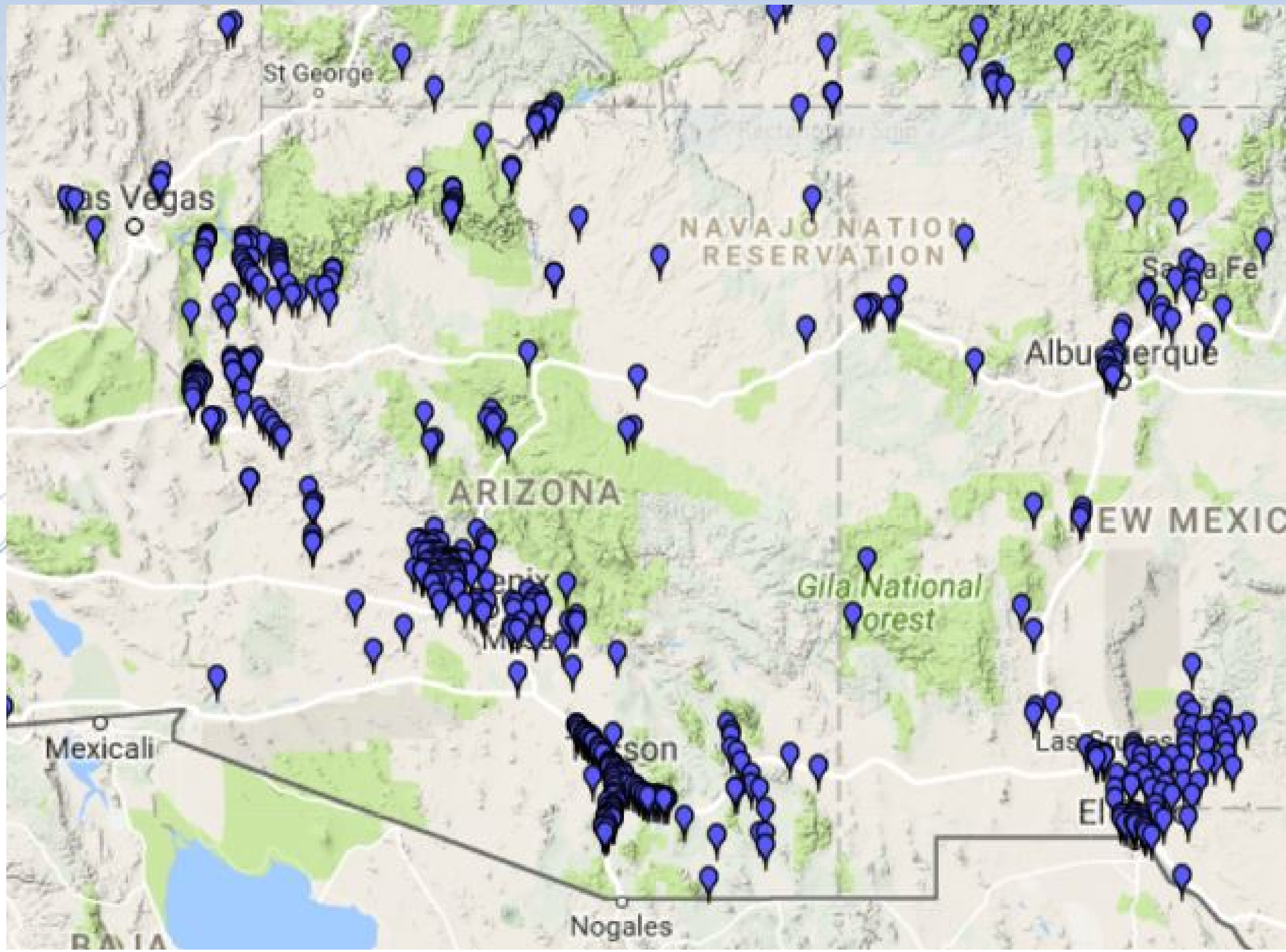
william.stone
National Geodetic Survey

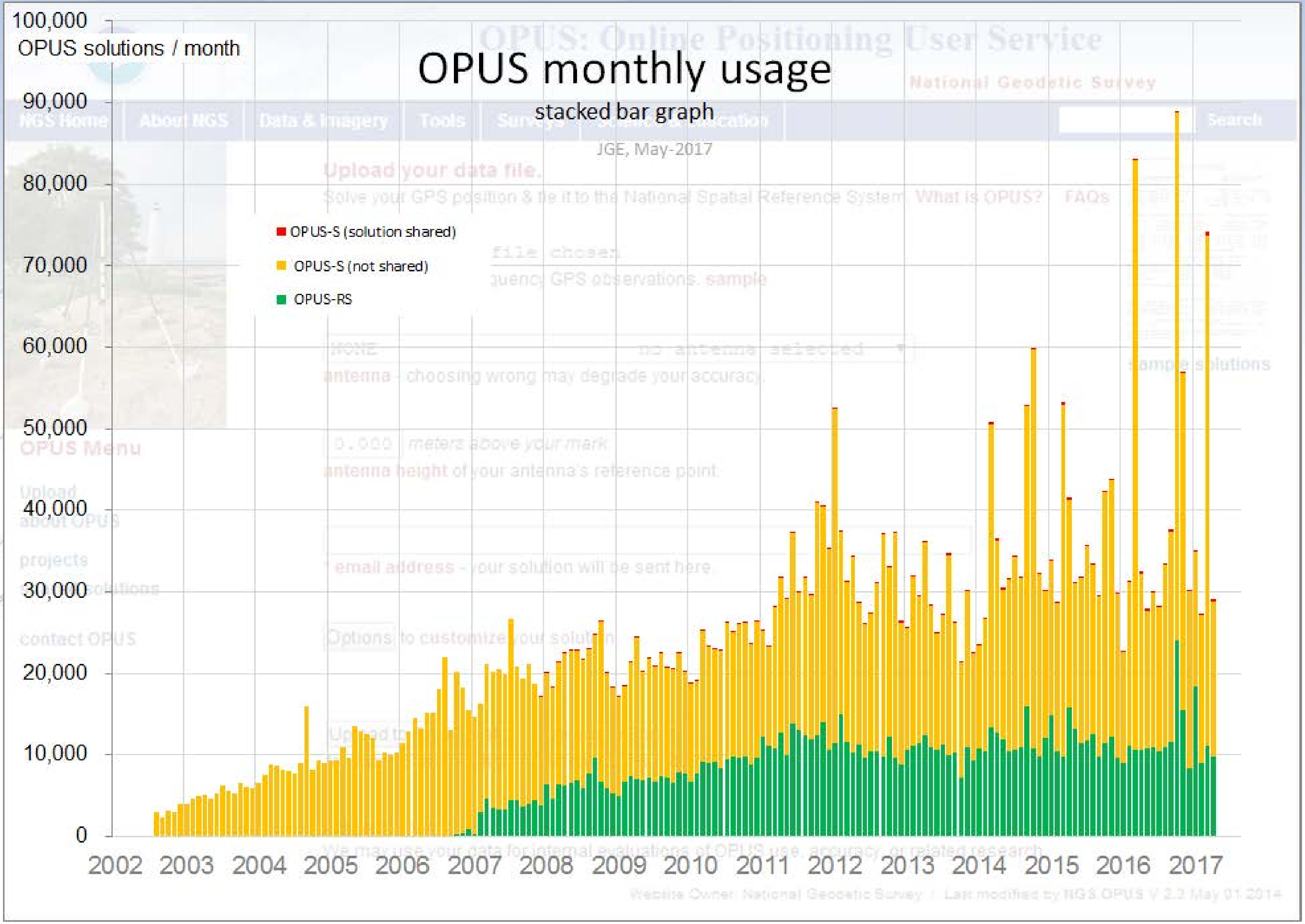
Horizon View

Shared OPUS Solutions



Shared OPUS Solutions




OPUS monthly usage
stacked bar graph
JGE, May-2017
OPUS solutions / month
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
OPUS-S (solution shared)
OPUS-S (not shared)
OPUS-RS
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

National Geodetic Survey ***Ten-Year Strategic Plan***

- By 2022, reduce all definitional & access-related errors in geometric reference frame to 1 cm when using 15 min of GNSS data

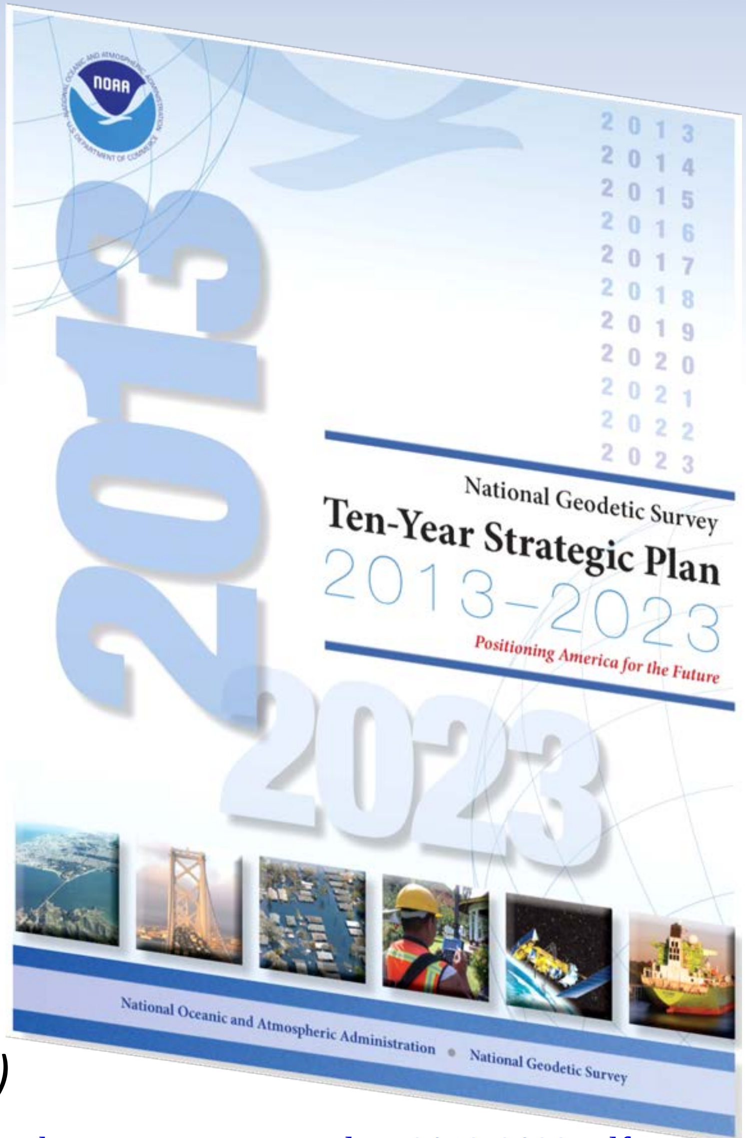
  “**Replace NAD83**”

(NAD83 = North American Datum 1983)

- By 2022, reduce all definitional & access-related errors in orthometric heights in geopotential reference frame to 2 cm when using 15 min of GNSS data

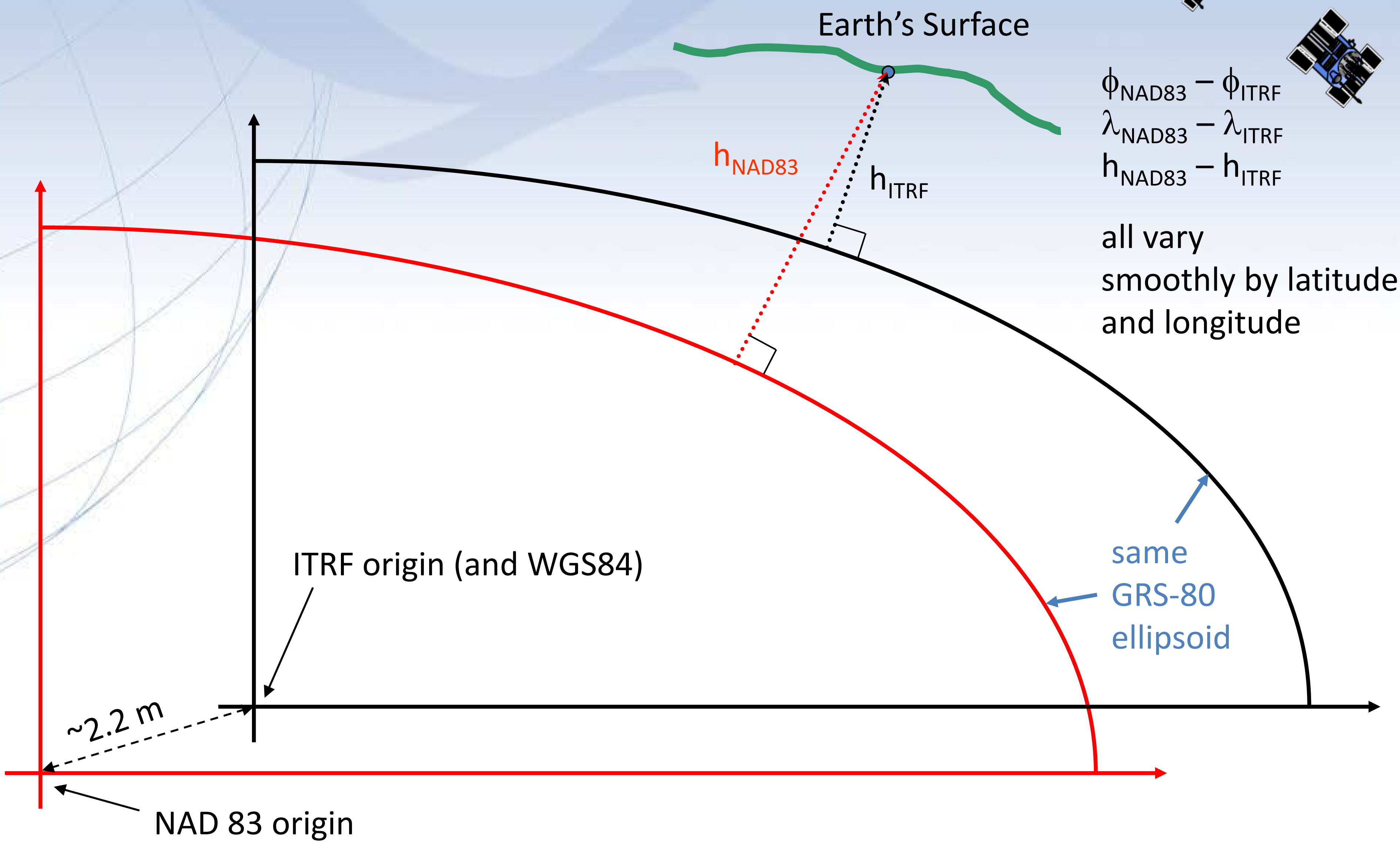
  “**Replace NAVD88**”

(NAVD88 = North American Vertical Datum 1988)



http://www.geodesy.noaa.gov/web/news/Ten_Year_Plan_2013-2023.pdf

NAD 83's non-geocentricity



Future Geometric (3-D) Reference Frame

- **replace NAD83 with new geometric reference frames – by 2022**
- **CORS-based, accessed via GNSS observations**
- **coordinates & velocities in ITRF & new US reference frame**
- **passive control tied to new reference frame (not a component)**
- **transformation tools to relate historical to new US reference frames**

  (HTDP / NADCON / GEOCON ...)

And it shall be called…

<u>North American Terrestrial Reference Frame of 2022</u>
(NATRF2022)

(& <u>Pacific</u>/<u>Mariana</u>/<u>Caribbean</u> Terrestrial Reference Frame of 2022)

- 4 (essentially) tectonic-plate-fixed reference frames
- identical to IGS*<u>XX</u>* reference frame at TBD epoch (2022.0?)
- over time, will relate to IGS frame via *<u>Euler Pole Rotation</u>*
- all CORS velocities deviating from rigid-plate (Euler) rotation will be captured in 3-D velocity model (a secondary product to transform to fixed epoch)

Four Frames/Plates in 2022

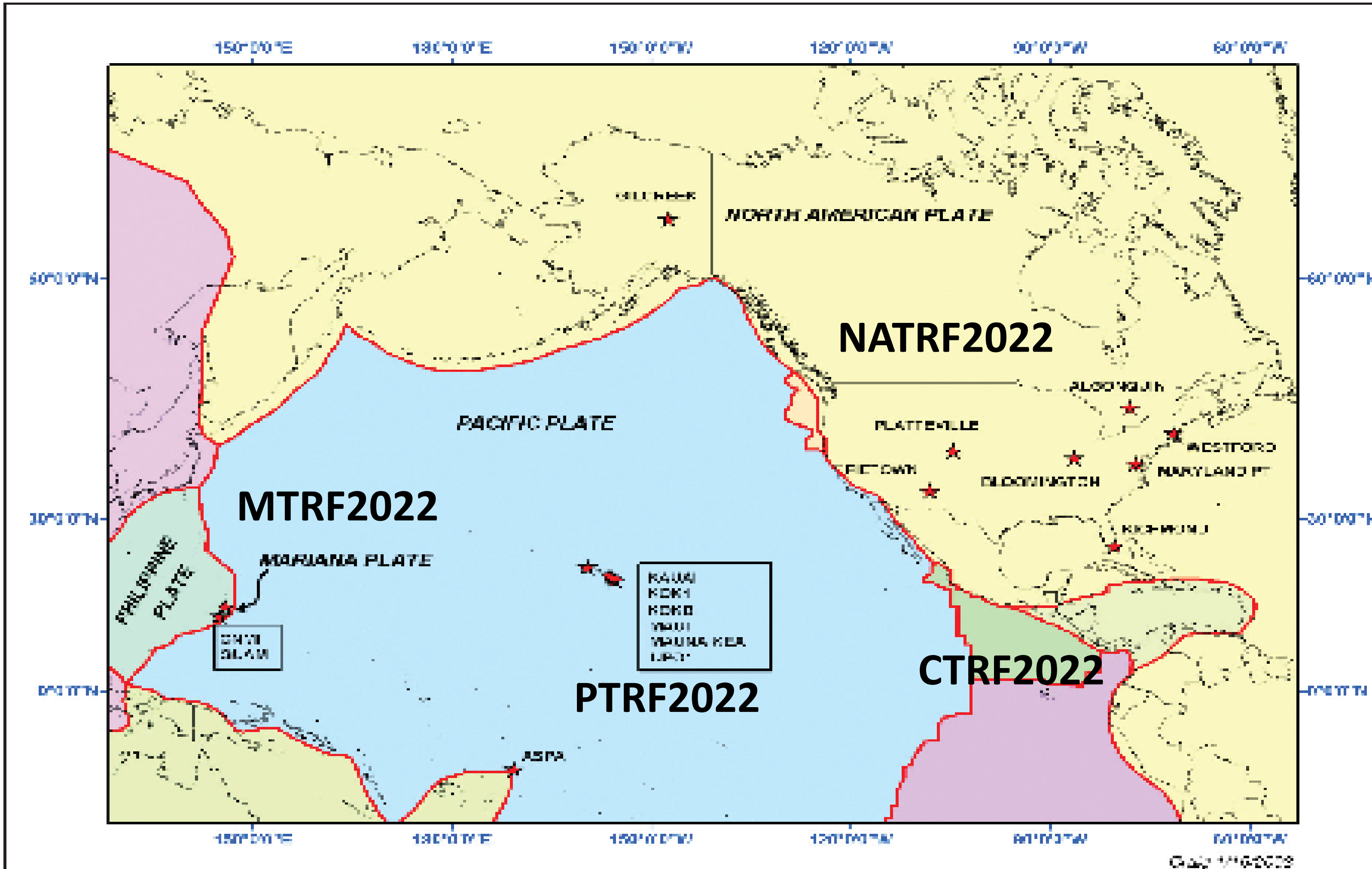
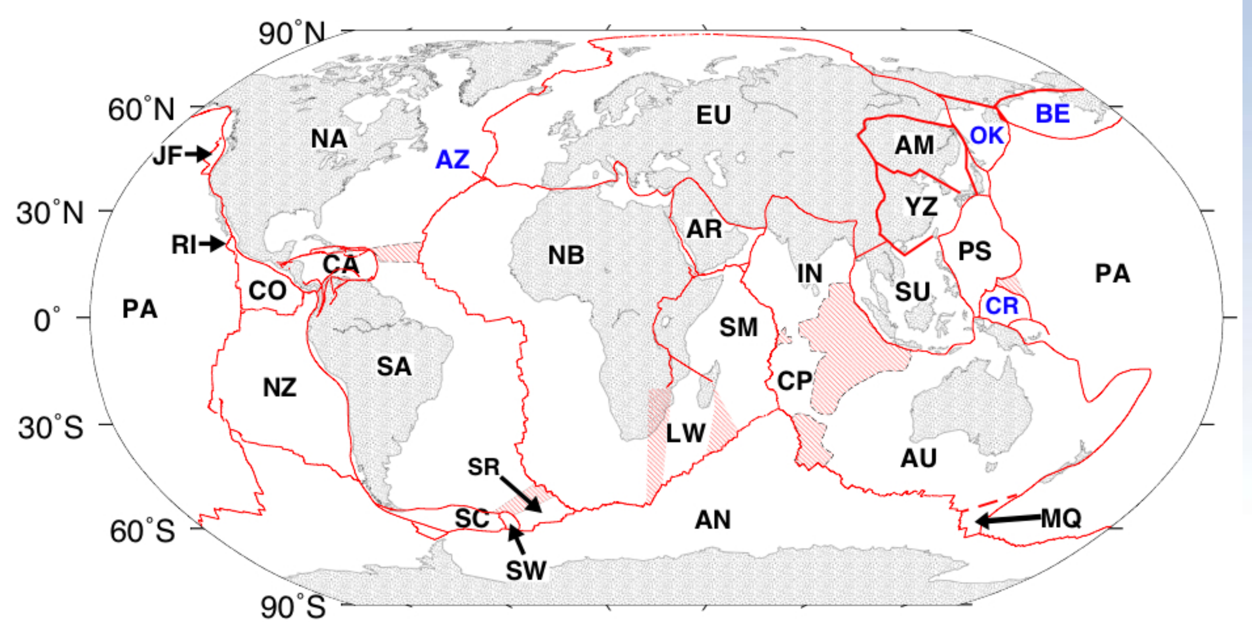


Image from Snay 2003

Euler Poles



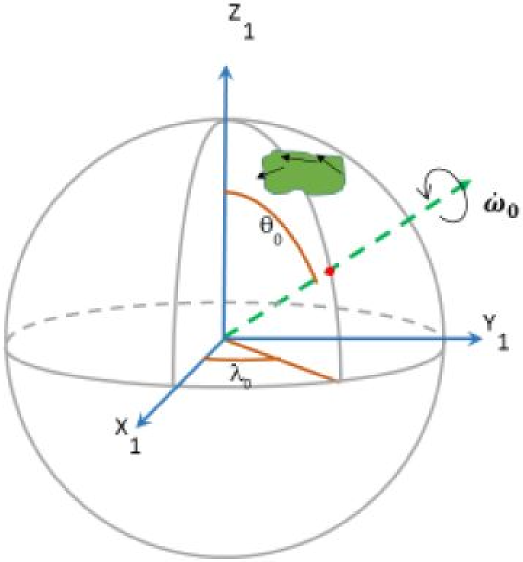


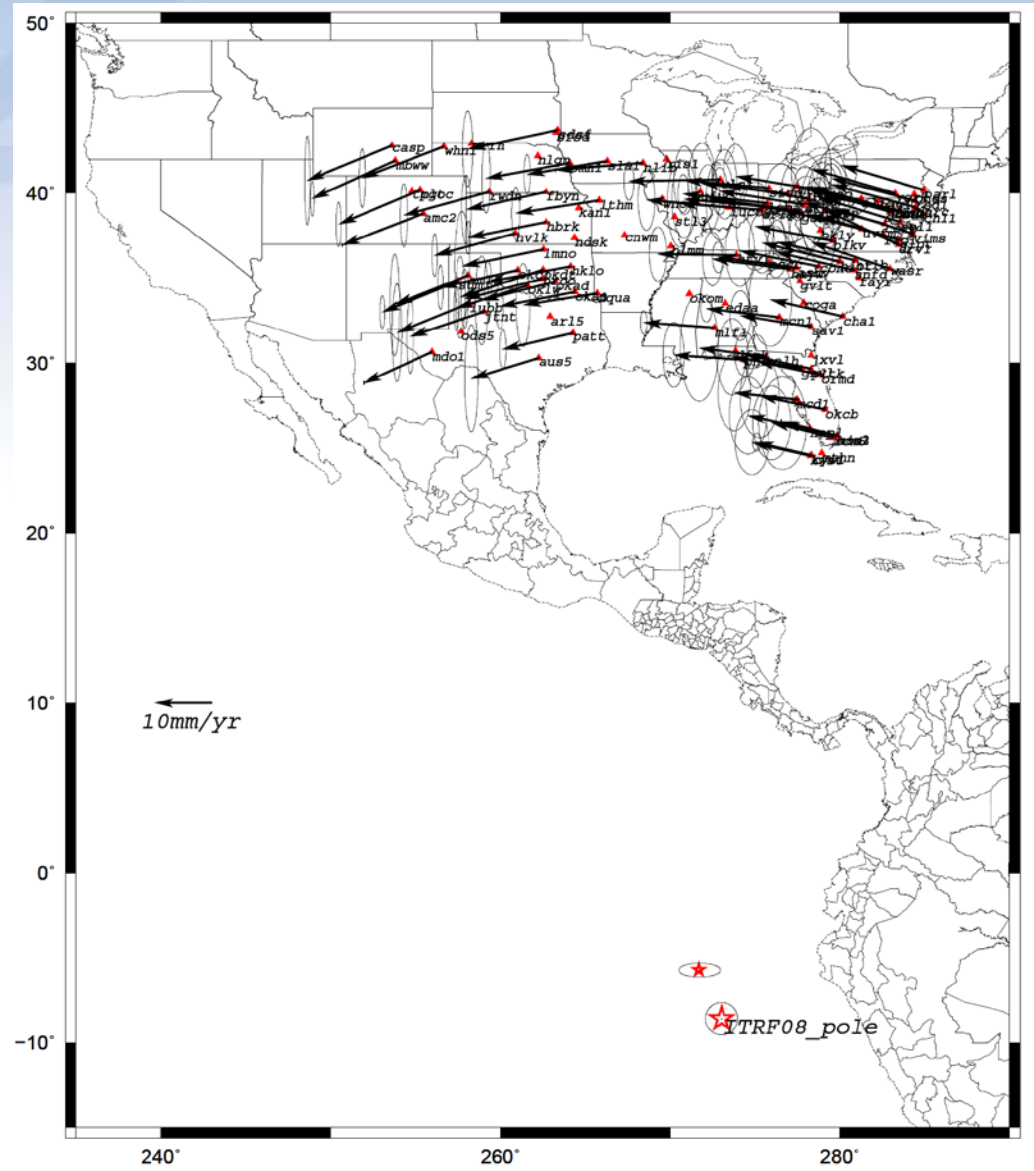
Figure 6: A rotating tectonic plate (green) and its Euler Pole (dashed green arrow and red dot).

Euler Pole

Each reference frame will get 3 parameters:

- Euler Pole Latitude
- Euler Pole Longitude
- Rotation rate (radians/year)

Used to compute time-dependent TRF2022 coordinates from time-dependent ITRF coordinates.



NOAA Technical Report NOS NGS 62

Blueprint for 2022, Part 1: Geometric Coordinates

$$[\widetilde{R_3^{\alpha}}]^{-1} = \begin{bmatrix} 1 & \alpha & 0 \\ -\alpha & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + \begin{bmatrix} 0 & \alpha & 0 \\ -\alpha & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} = (I + A) \qquad (39)$$

Where the tilde is used to indicate "approximation". The reason for splitting the matrix into *I* and *A* components will be obvious soon.

Applying equation 39 to 35:

$$\begin{aligned} \widetilde{M^{-1}} &= \left[R_1^{\lambda_0}\right]^{-1}\left[R_2^{\theta_0}\right]^{-1}[\widetilde{R_3^{\alpha}}]^{-1}R_2^{\theta_0}R_1^{\lambda_0} = \left[R_1^{\lambda_0}\right]^{-1}\left[R_2^{\theta_0}\right]^{-1}(I+A)R_2^{\theta_0}R_1^{\lambda_0} \\ &= \left[R_1^{\lambda_0}\right]^{-1}\left[R_2^{\theta_0}\right]^{-1}(I)R_2^{\theta_0}R_1^{\lambda_0} + \left[R_1^{\lambda_0}\right]^{-1}\left[R_2^{\theta_0}\right]^{-1}(A)R_2^{\theta_0}R_1^{\lambda_0} \\ &= I + \alpha(t)\begin{bmatrix} 0 & cos\theta_0 & -sin\lambda_0 sin\theta_0 \\ -cos\theta_0 & 0 & cos\lambda_0 sin\theta_0 \\ sin\lambda_0 sin\theta_0 & -cos\lambda_0 sin\theta_0 & 0 \end{bmatrix} \end{aligned} \qquad (40)$$

See now that by splitting into I and A, the *I* portion of the equation collapses into another I, while the *A* component collapses into a simple skew symmetric matrix.

Acknowledging that the effect of the total rotation, $\alpha(t)$ must be split into rotations among the three axes of the ideal frame, and since $\alpha(t)$ is "small", it can be concluded that the axial rotations must also be small. Thus, matrix R_{ZYX} reduces to:

$$\widetilde{R_{ZYX}} = \begin{bmatrix} 1 & \omega_Z & -\omega_Y \\ -\omega_Z & 1 & \omega_X \\ \omega_Y & -\omega_X & 1 \end{bmatrix} \qquad (41)$$

Now equate the approximations of M^{-1} and R_{ZYX} to one another (applying equations 39 and 40 to equation 34):

$$I + \alpha(t)\begin{bmatrix} 0 & cos\theta_0 & -sin\lambda_0 sin\theta_0 \\ -cos\theta_0 & 0 & cos\lambda_0 sin\theta_0 \\ sin\lambda_0 sin\theta_0 & -cos\lambda_0 sin\theta_0 & 0 \end{bmatrix} = \begin{bmatrix} 1 & \omega_Z & -\omega_Y \\ -\omega_Z & 1 & \omega_X \\ \omega_Y & -\omega_X & 1 \end{bmatrix} \qquad (42)$$

Equation 42 allows for an easy solution to the three axial rotations in terms of the Euler Pole's location and angular velocity:

$$\omega_X = \alpha(t)cos\lambda_0 sin\theta_0 \qquad (43)$$

$$\omega_Y = \alpha(t)sin\lambda_0 sin\theta_0 \qquad (44)$$

$$\omega_Z = \alpha(t)cos\theta_0 \qquad (45)$$

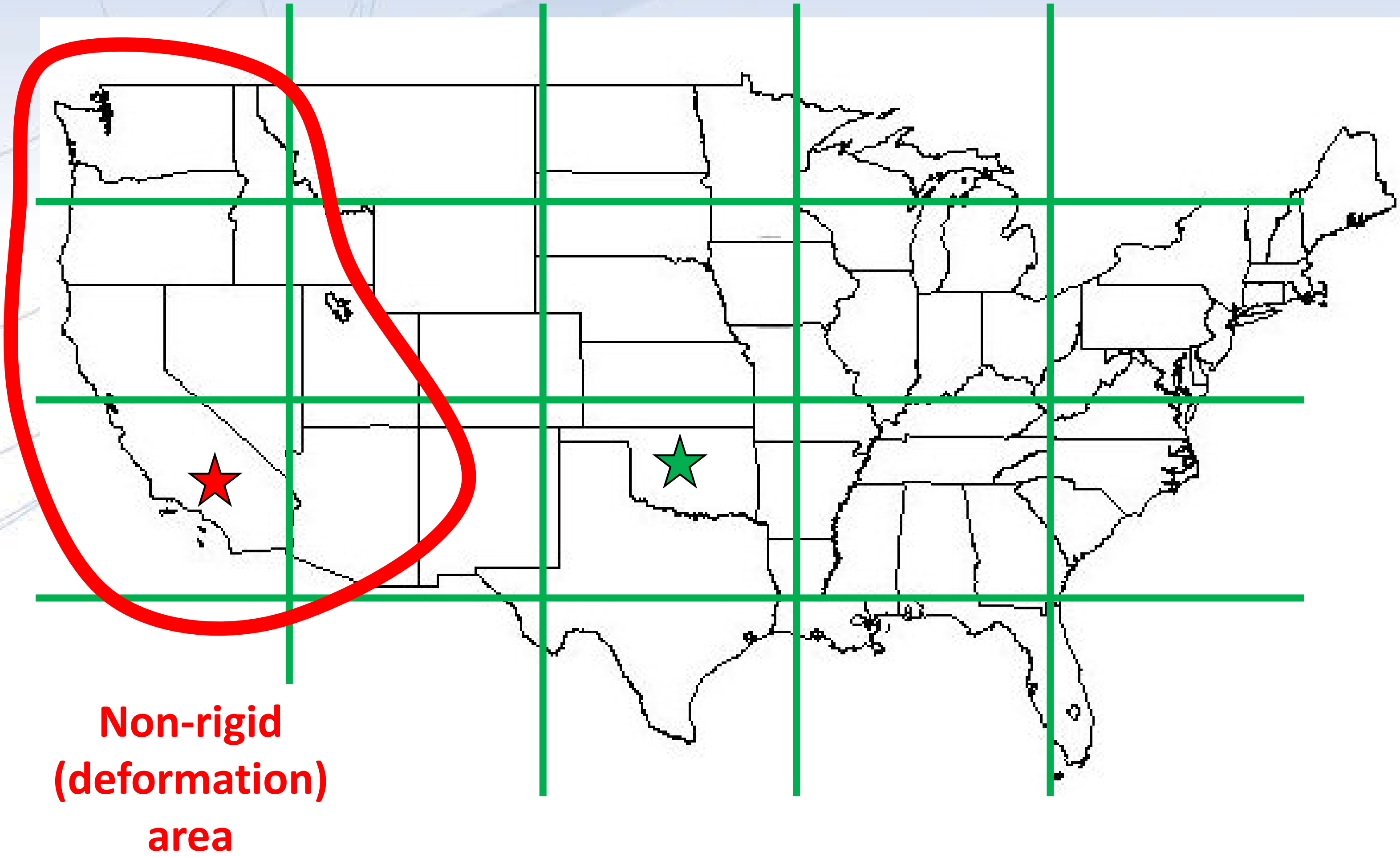
Recall, however, that the ω_X, ω_Y and ω_Z values are time-dependent (see equation 27). Applying equation 27 and also applying the expansion of $\alpha(t)$ into its components, yields:

$$\omega_X(t_0) + (\Delta t)\dot{\omega}_X = [\dot{\omega}_0\Delta t]cos\lambda_0 sin\theta_0 \qquad (46)$$

$$\omega_Y(t_0) + (\Delta t)\dot{\omega}_Y = [\dot{\omega}_0\Delta t]sin\lambda_0 sin\theta_0 \qquad (47)$$

$$\omega_Z(t_0) + (\Delta t)\dot{\omega}_Z = [\dot{\omega}_0\Delta t]cos\theta_0 \qquad (48)$$

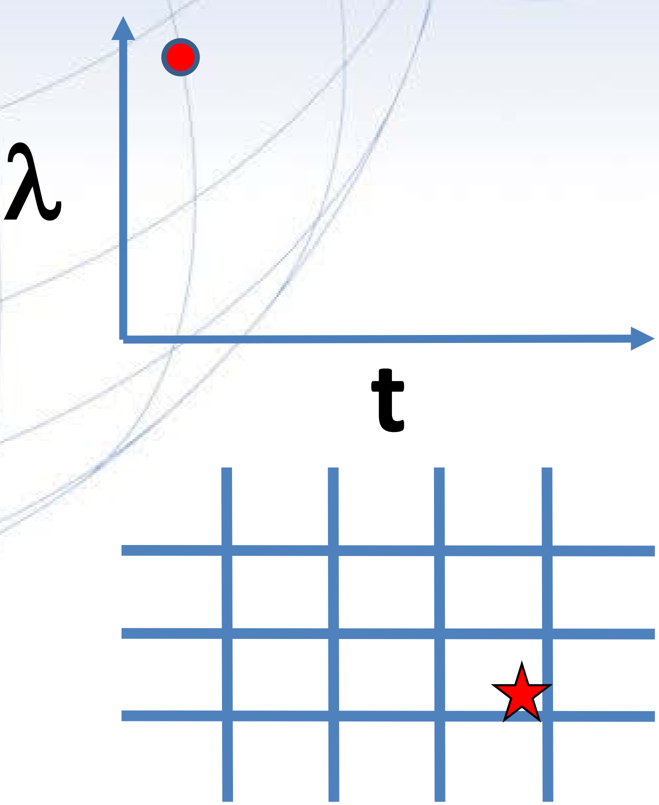
Frame is rigid and fixed to rigid part of plate



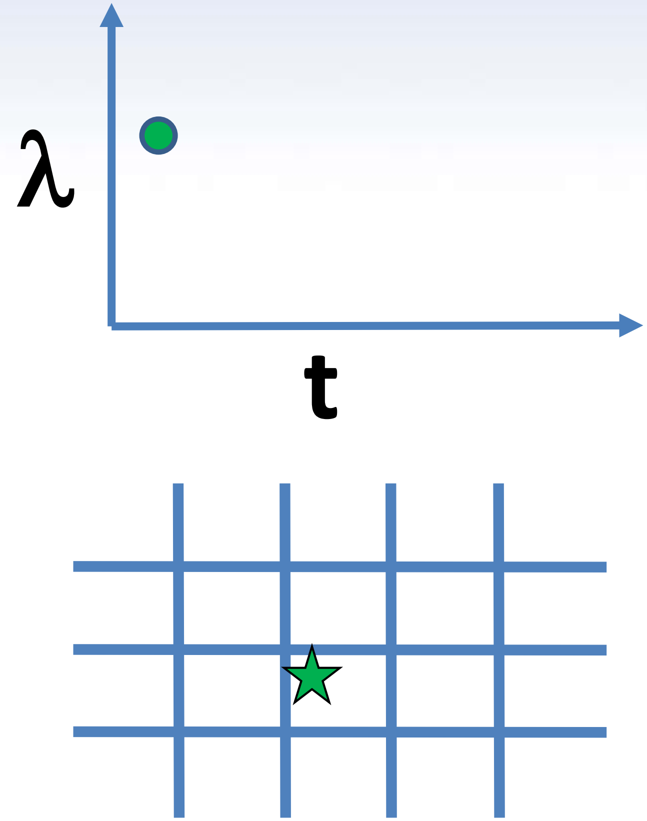
NATRF2022 coordinates over time

(Remember: The NATRF2022 *frame* is rigid)

★ Point on deforming part of plate



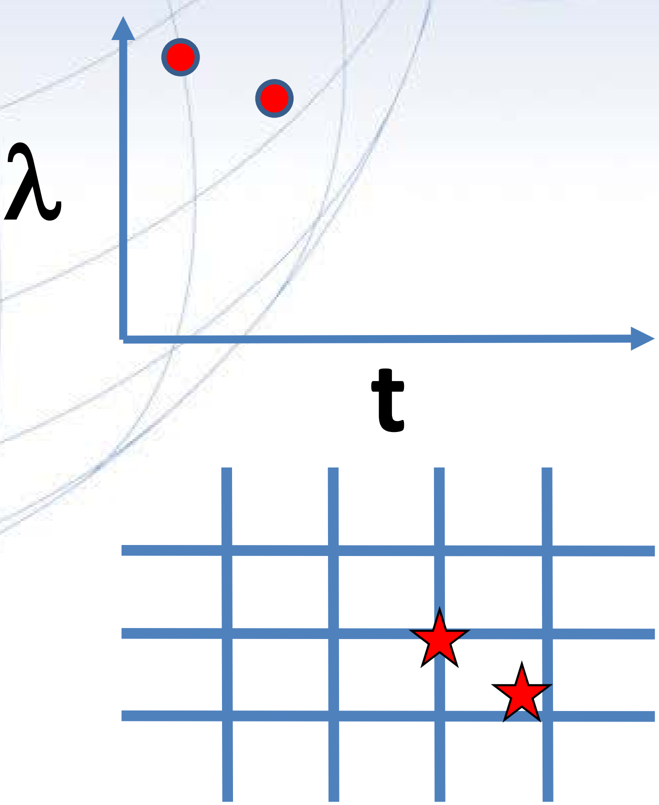
★ Point on rigid part of plate



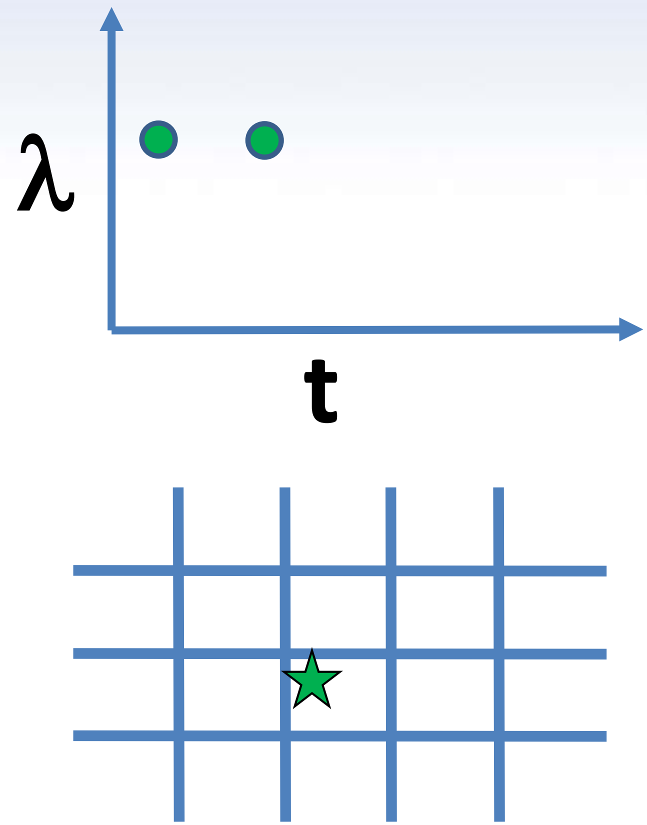
NATRF2022 coordinates over time

(Remember: The NATRF2022 *frame* is rigid)

Point on <u>deforming</u> part of plate



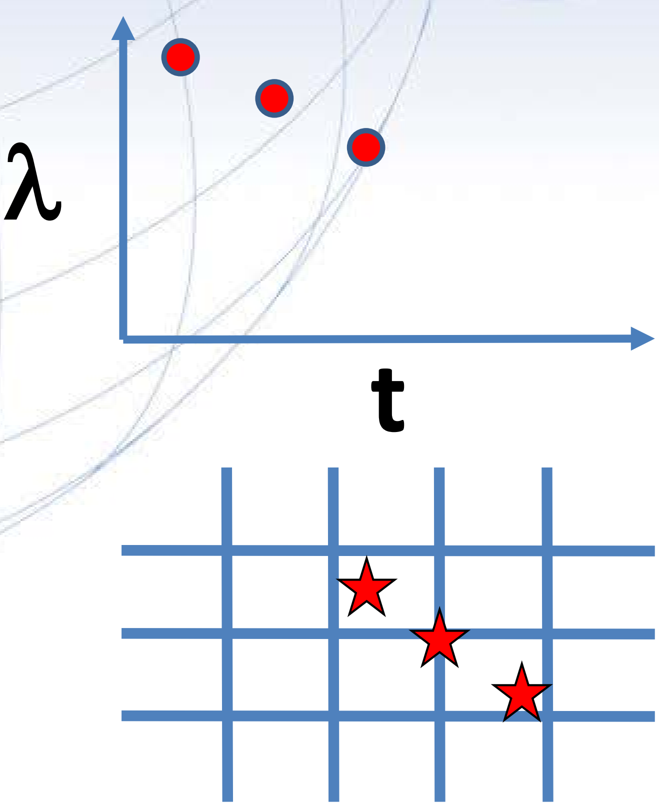
Point on <u>rigid</u> part of plate



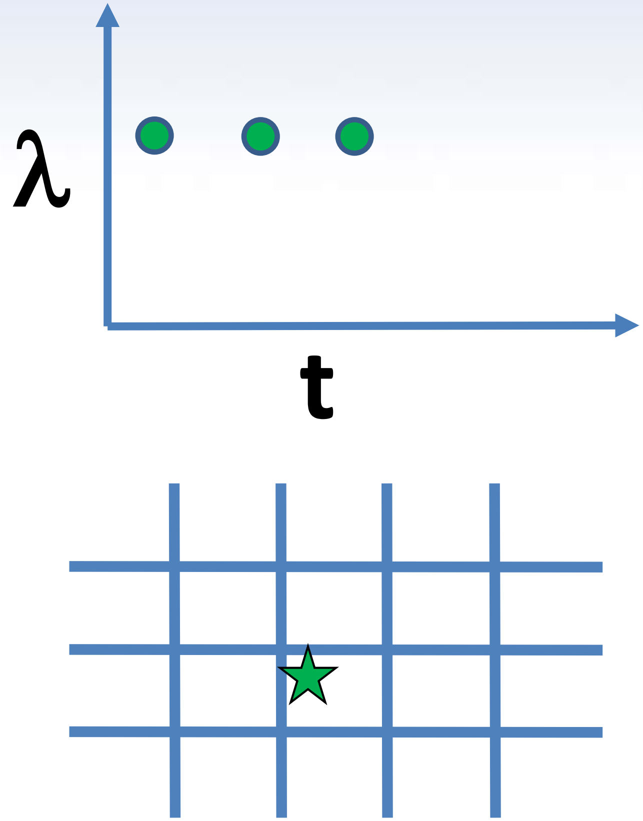
NATRF2022 coordinates over time

(Remember: The NATRF2022 *frame* is rigid)

Point on deforming part of plate



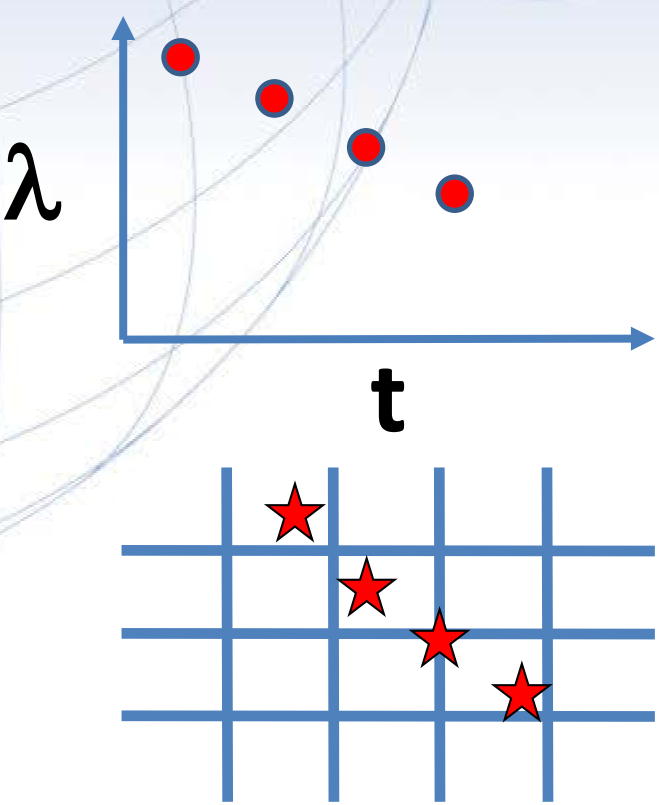
Point on rigid part of plate



NATRF2022 coordinates over time

(Remember: The NATRF2022 *frame* is rigid)

★ Point on deforming part of plate



★ Point on rigid part of plate

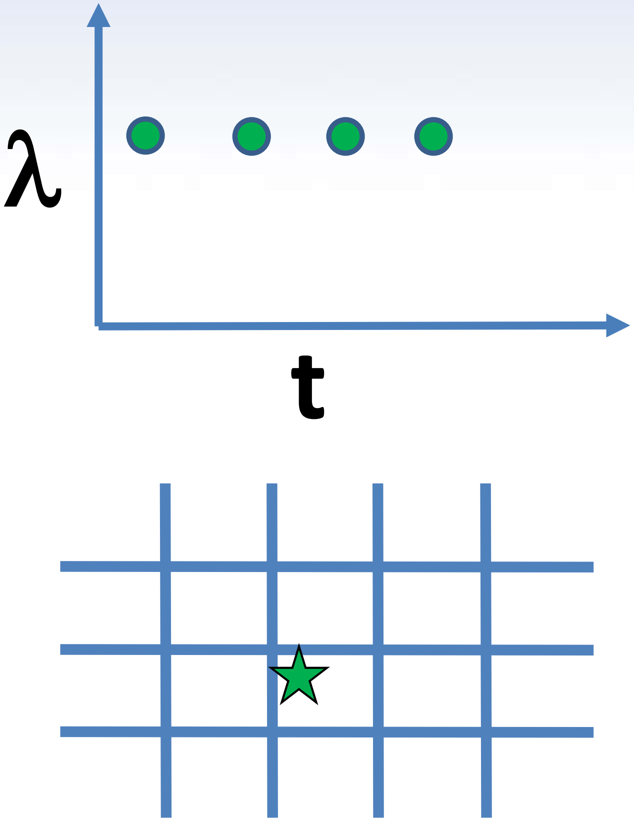
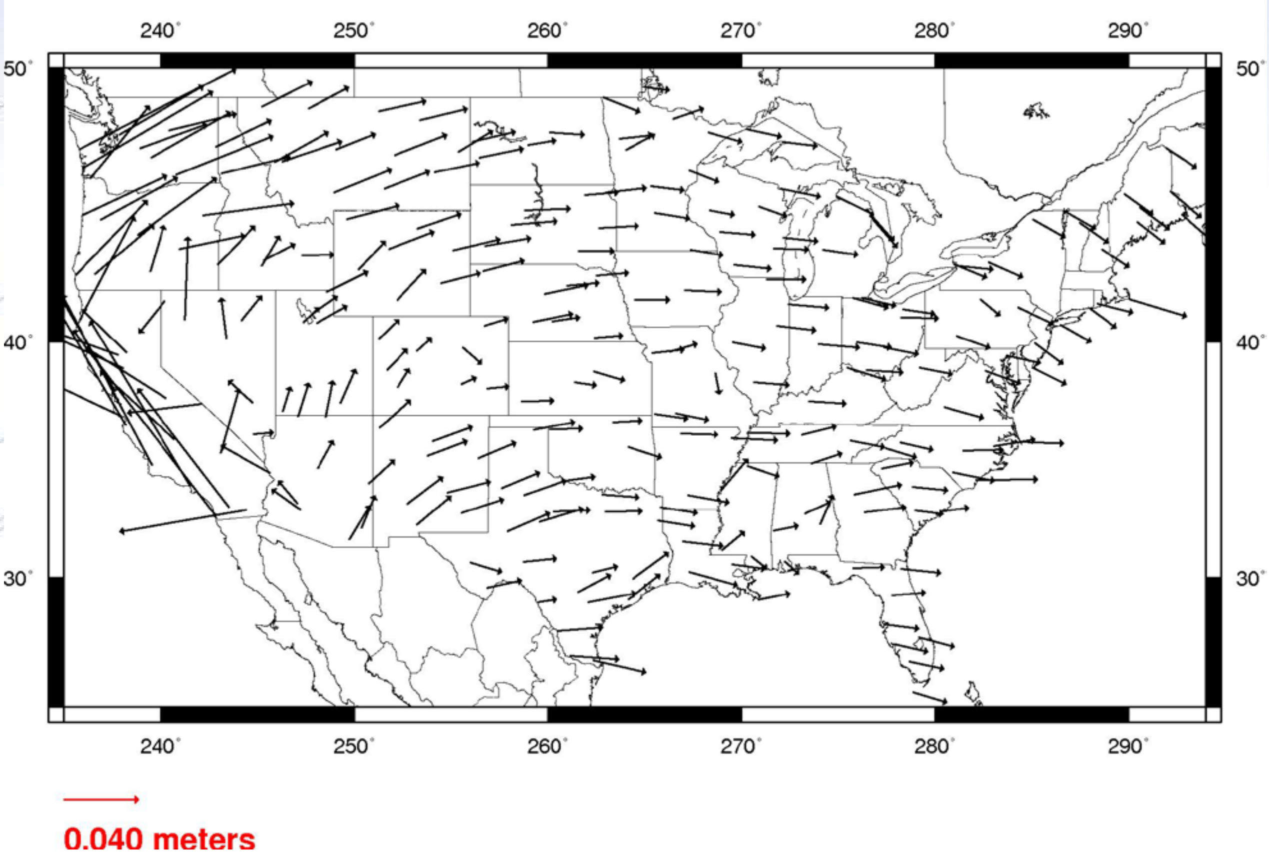


Plate-(pseudo)fixed frames

NAD 83(2011) minus NAD 83(NSRS2007)



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

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

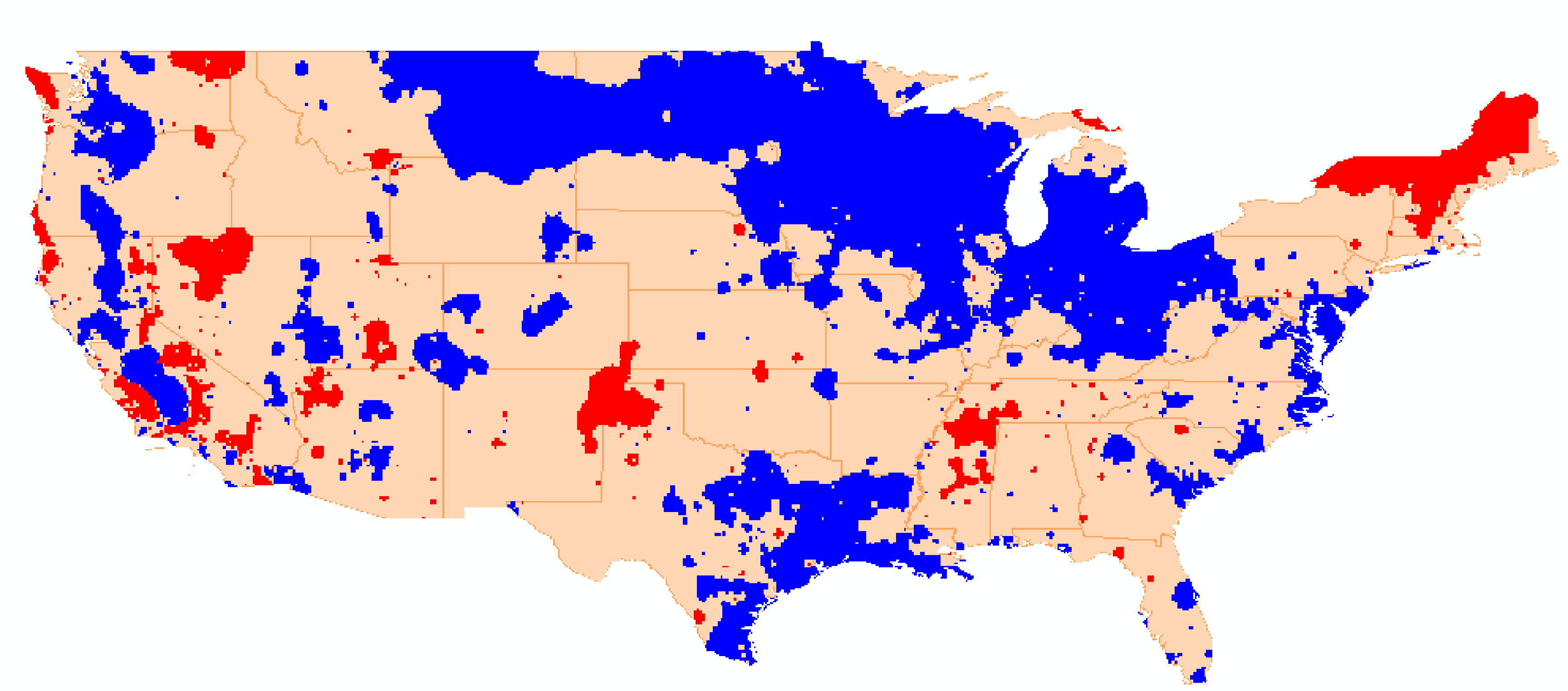
If NAD 83 were truly "plate fixed" then an 8 year epoch change would not yield the systematic plate rotation seen here.

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

(*)=NA, C, T or P

CONUS with 1+ mm/yr

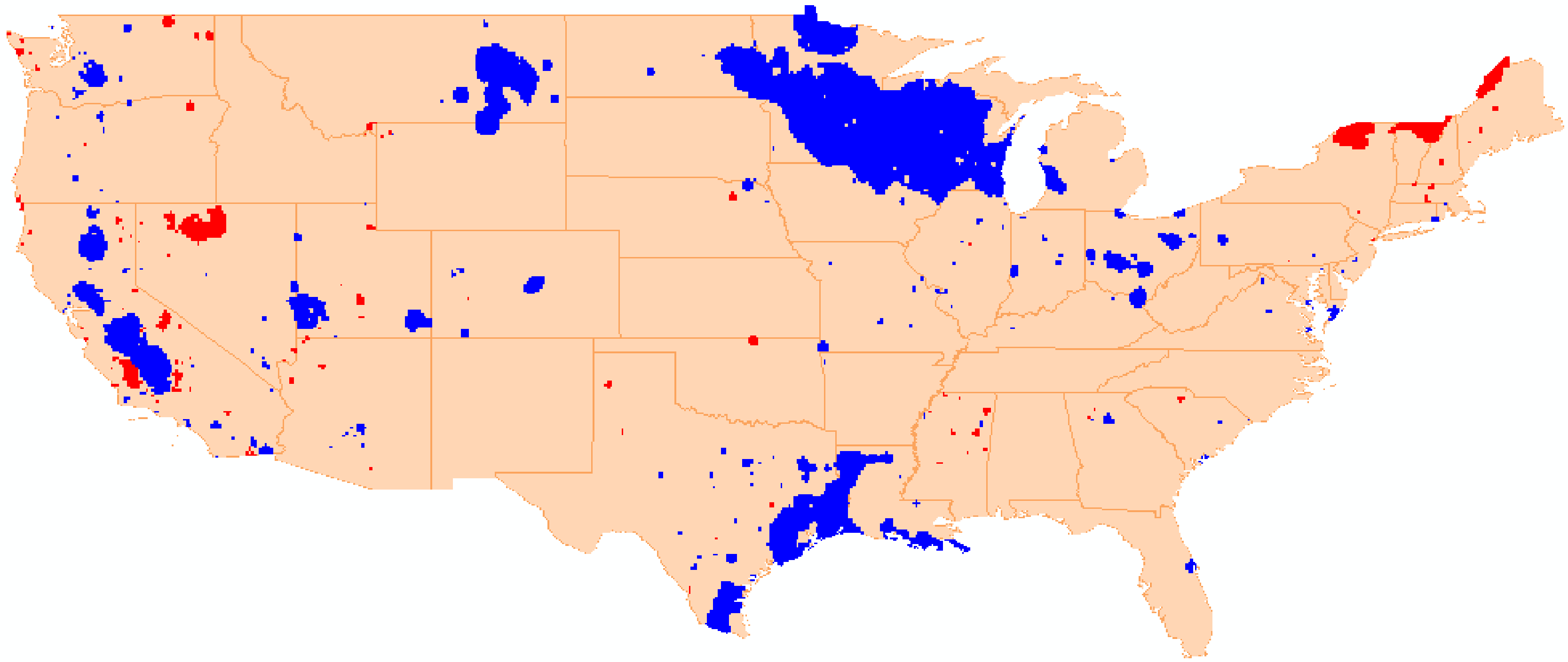
Red is uplift, Blue is subsidence



Courtesy Galen Scott

CONUS with 2+ mm/yr

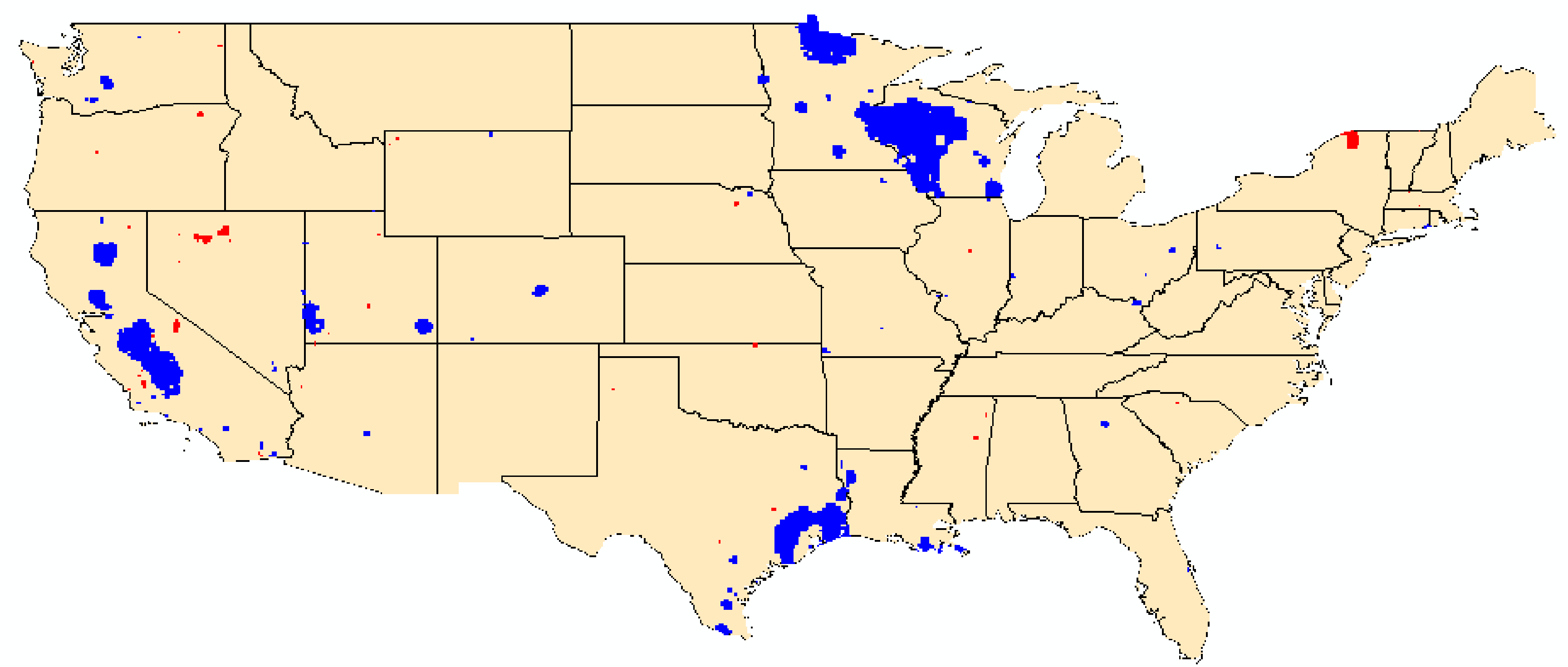
Red is uplift, Blue is subsidence



Courtesy Galen Scott

CONUS with 3+ mm/yr

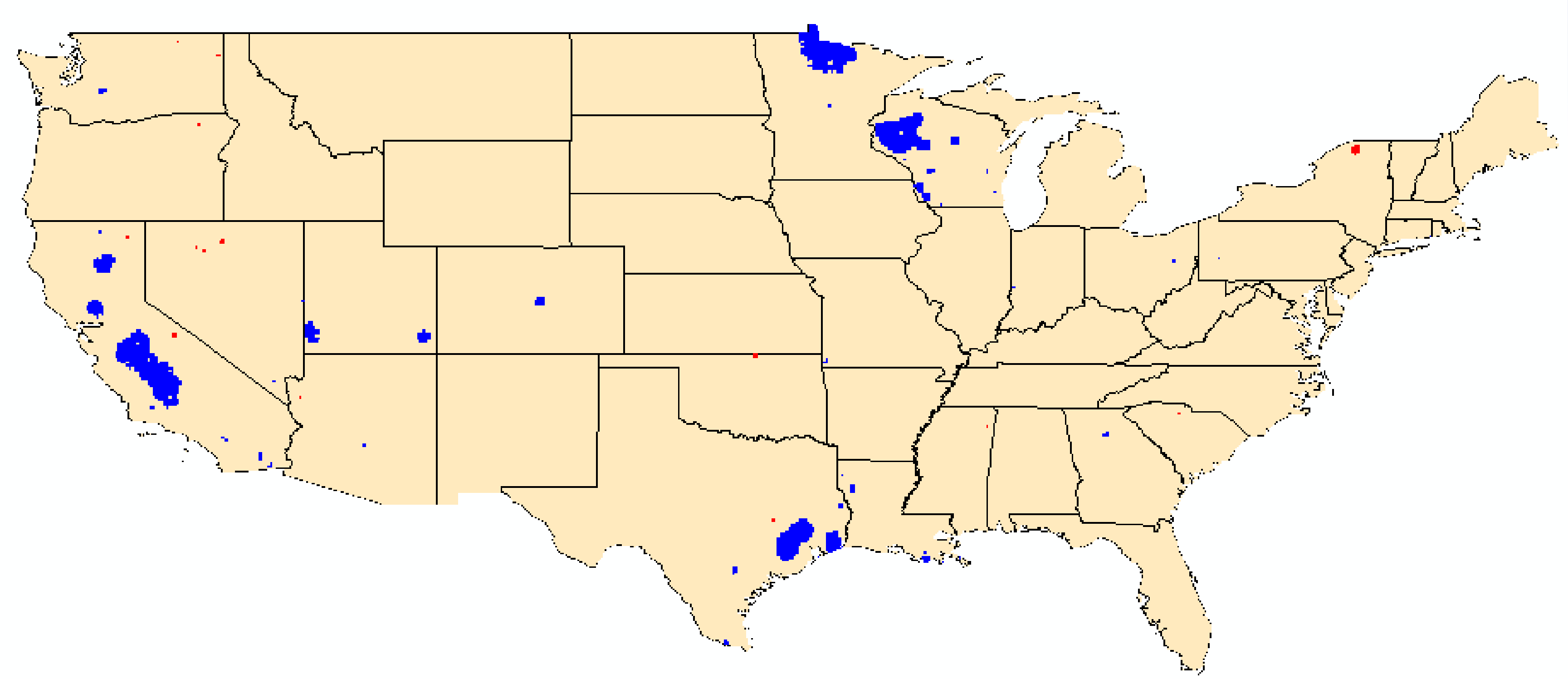
Red is uplift, Blue is subsidence



Courtesy Galen Scott

CONUS with 4+ mm/yr

Red is uplift, Blue is subsidence



Courtesy Galen Scott

Approximate Horizontal Change North American Plate

North American Plate (Meters)

High: 2 m

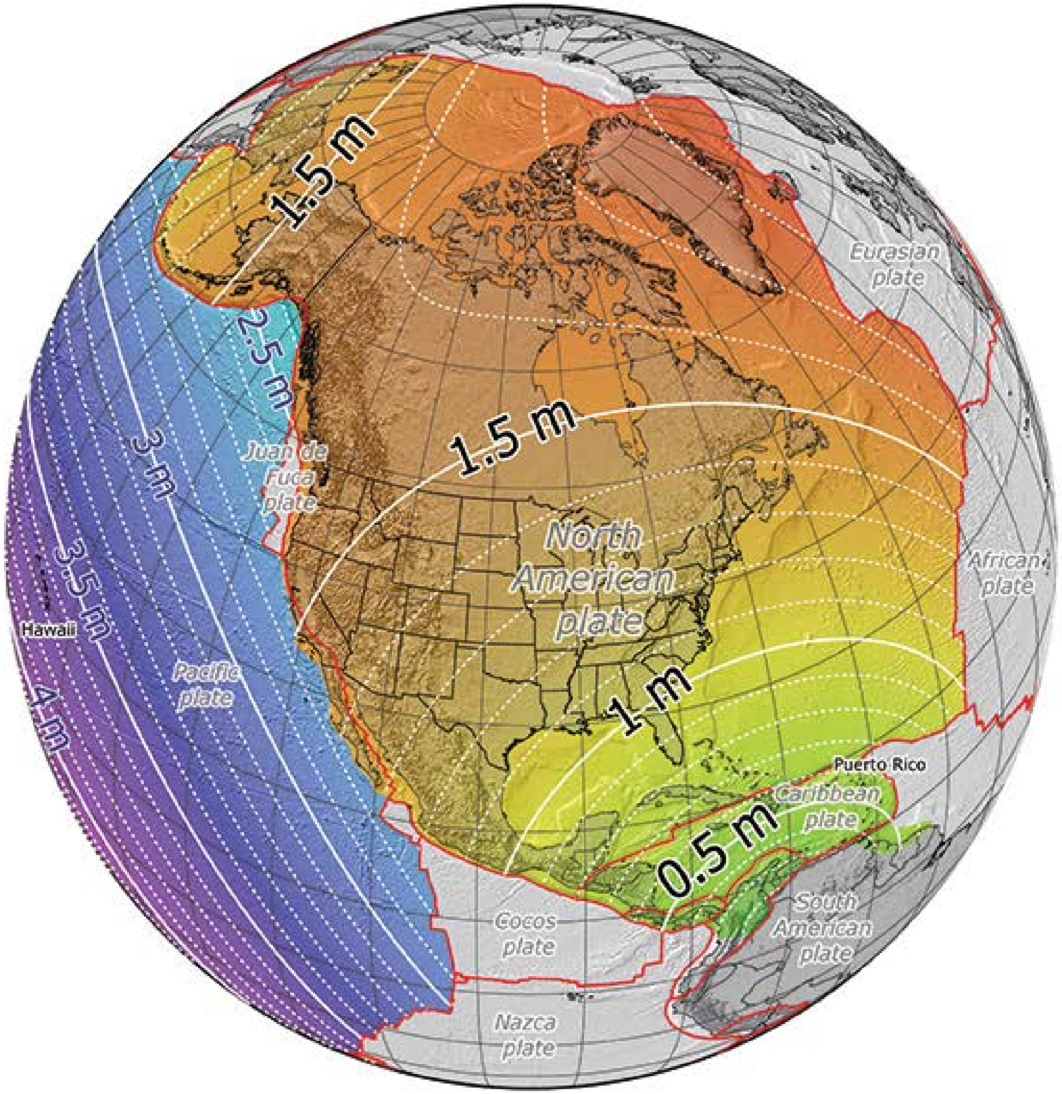
Low: 0 m

Pacific Plate (Meters)

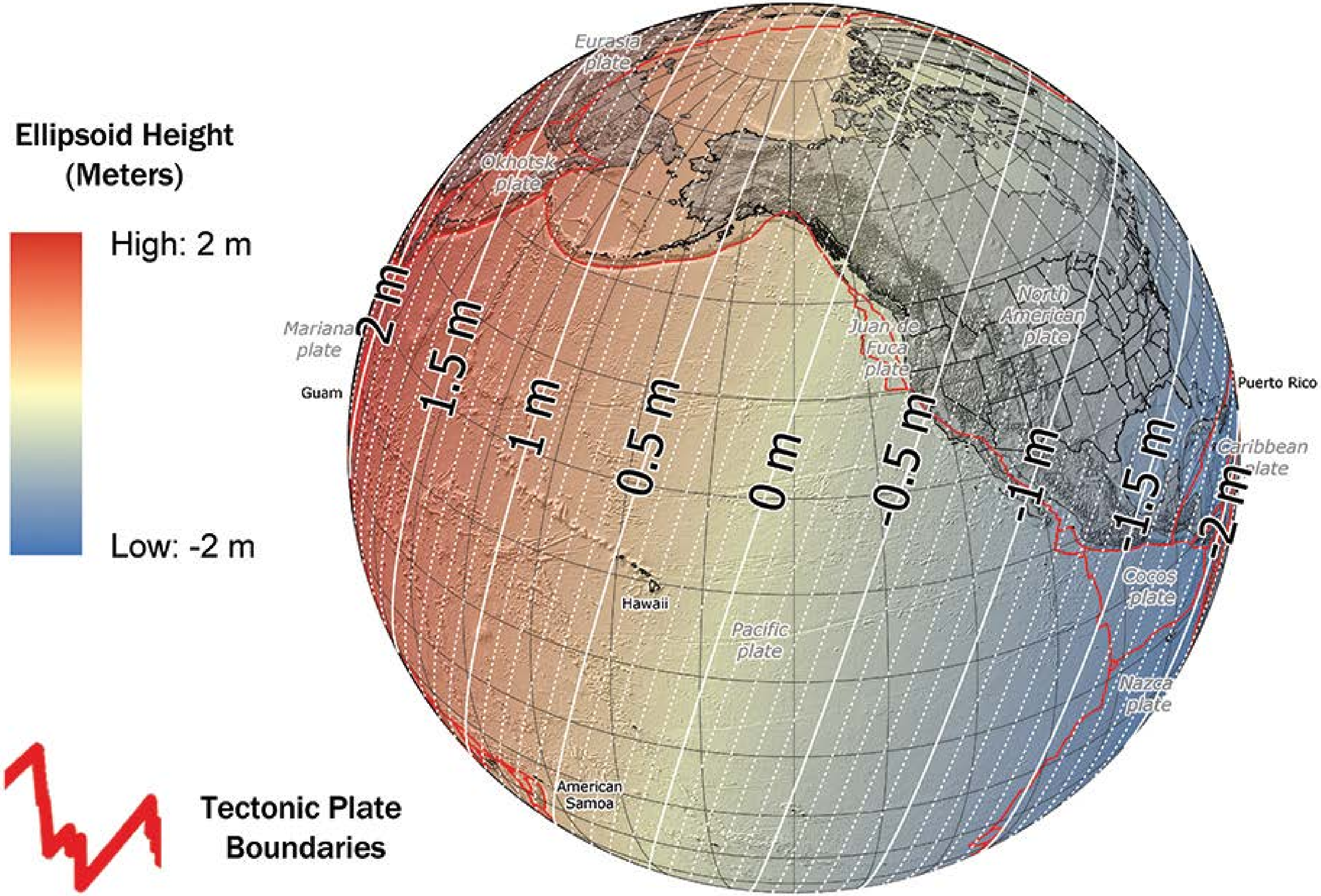
High: 4.3 m

Low: 2.3 m

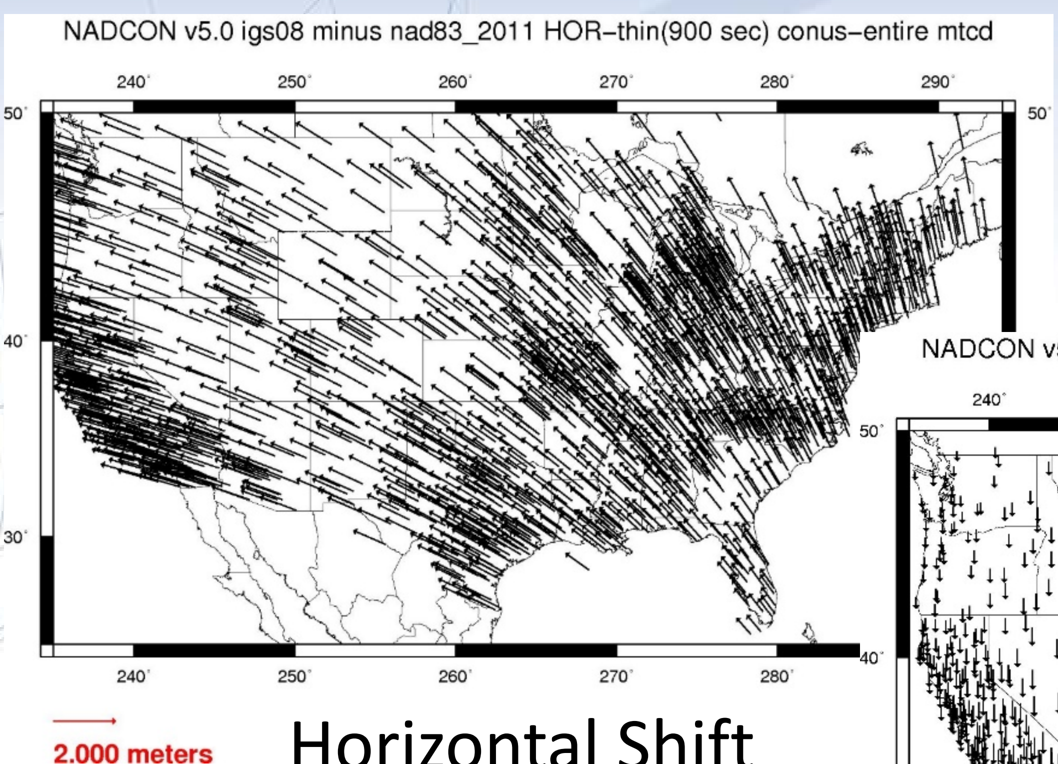
Tectonic Plate Boundaries



Approximate Ellipsoid Height Change

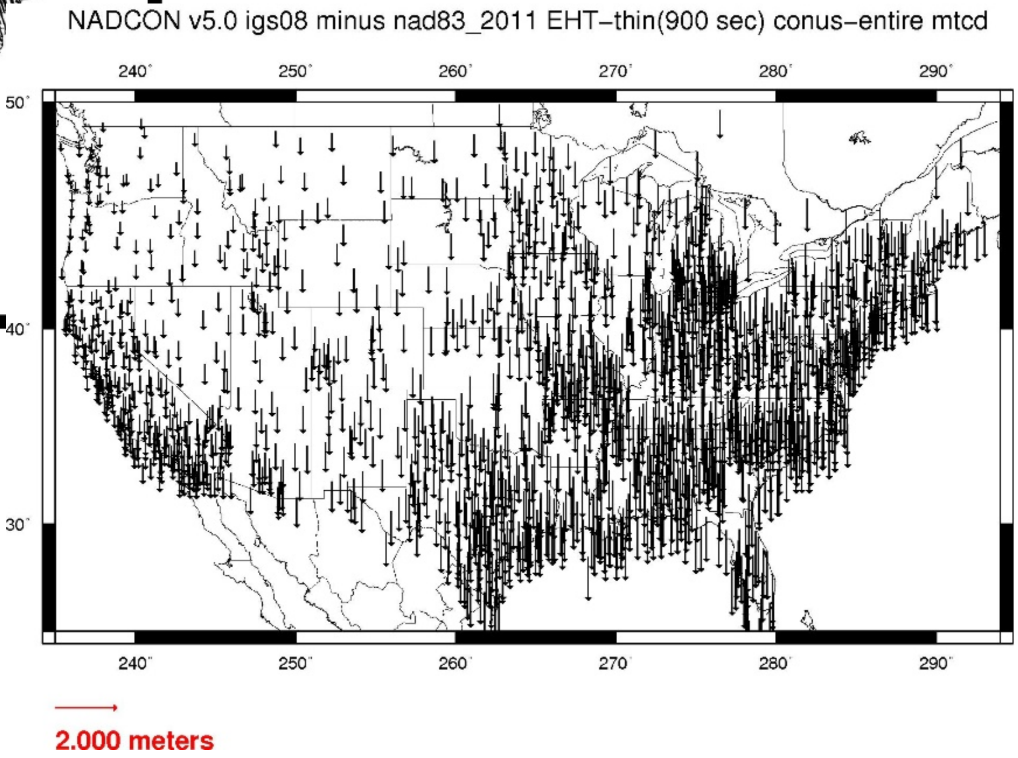


Fixed-Epoch Transformation NAD 83 to NATRF2022

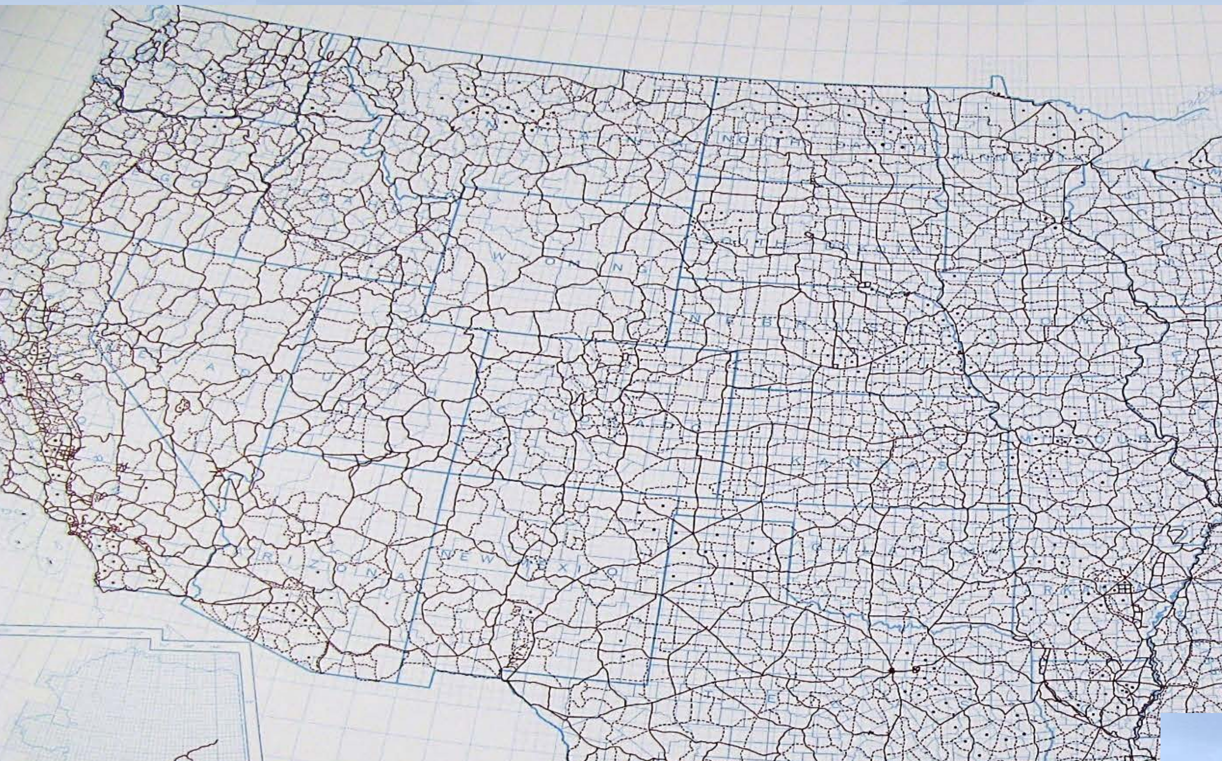


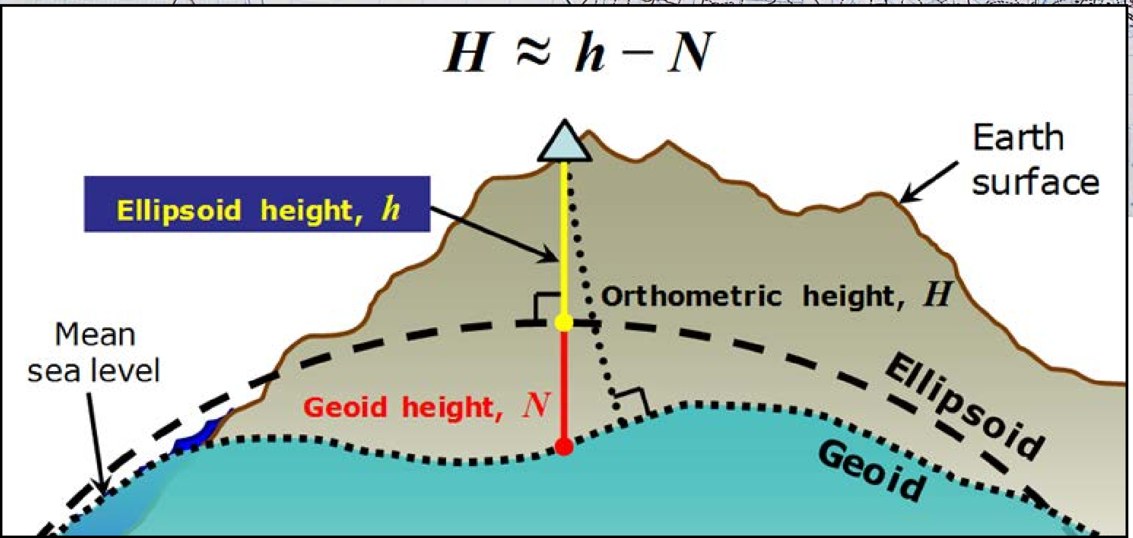
Horizontal Shift

Ellipsoid Height Shift

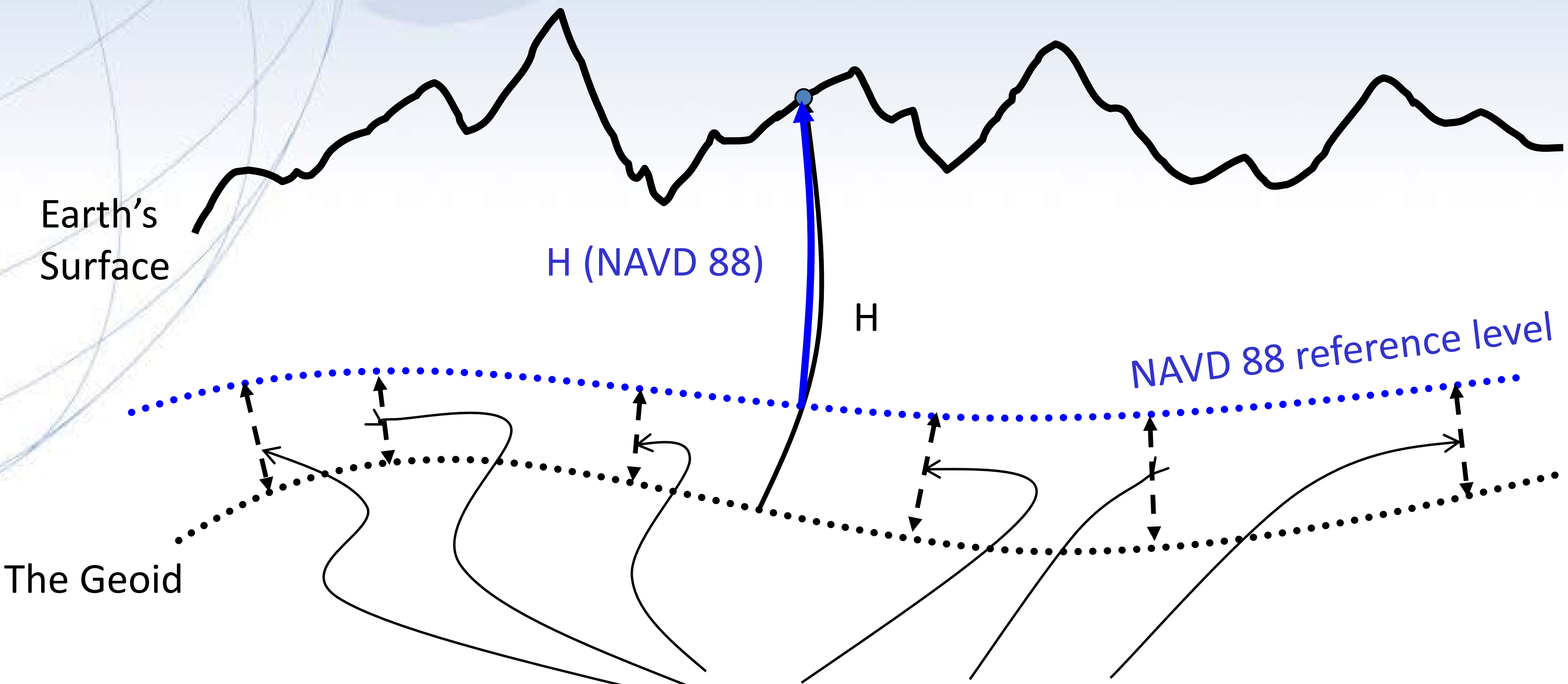


NORTH AMERICAL VERTICAL DATUM 1988 (NAVD88)





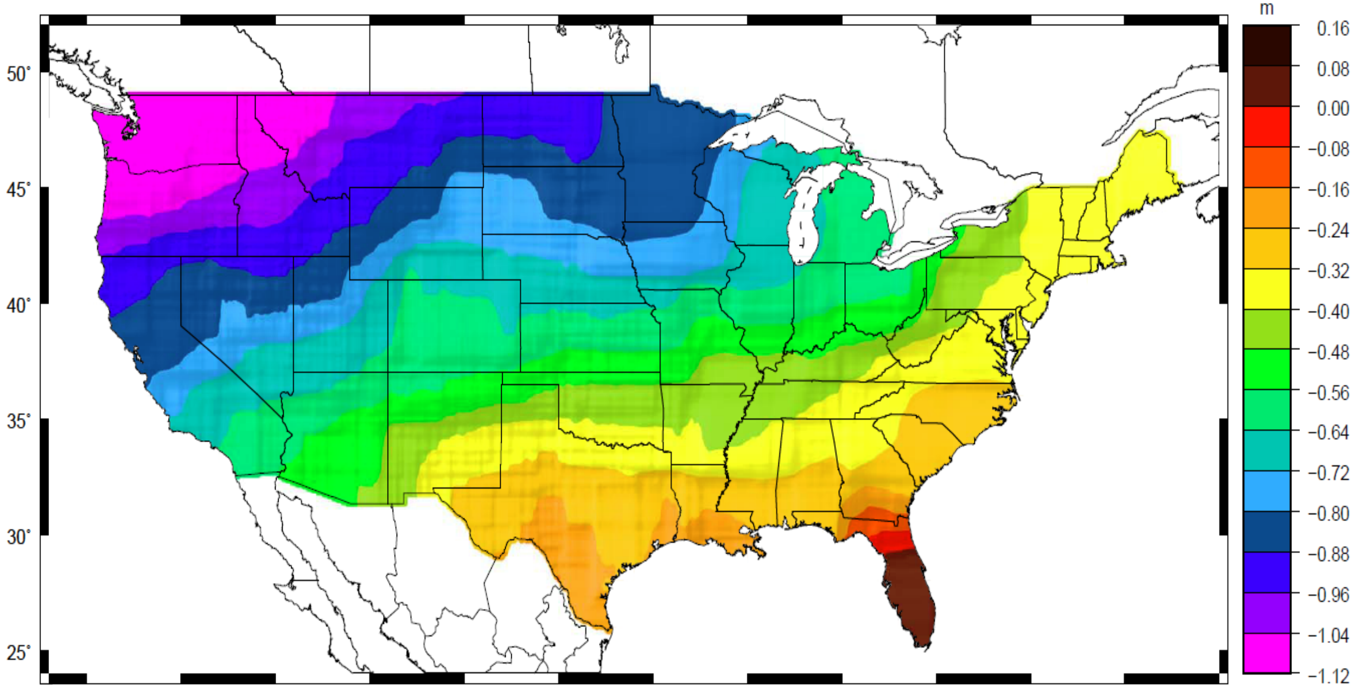
Why isn't NAVD 88 good enough anymore?



Errors in NAVD 88 : ~50 cm average,
100 cm CONUS tilt,
1-2 meters average in Alaska
NO tracking

North American Vertical Datum 1988 (NAVD88) Shortcomings

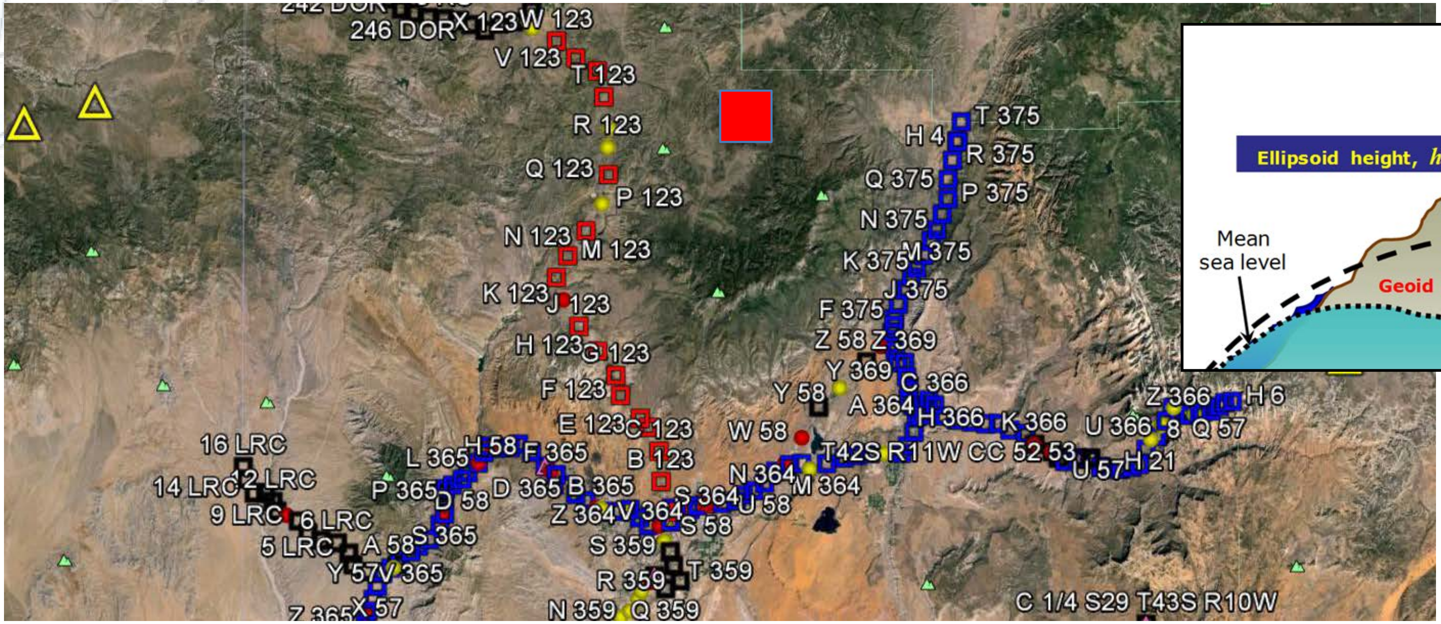
- **Cross-country errors (1-m tilt)**
- **0.5 m bias in reference surface vs. global mean sea level**
- **Subsidence, uplift, freeze/thaw invalidate BM elevations**
- **LIMITED AVAILABILITY / ACCESS**

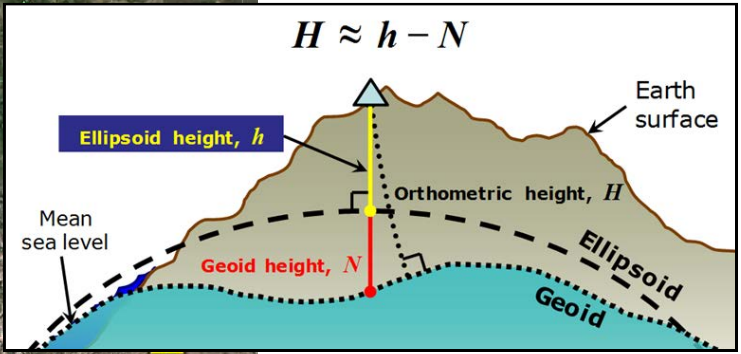


Approximate Geoid Mismatch in the NAVD88 H=0 surface

Future Geopotential (Vertical) Datum

- **replace NAVD88 – by 2022**
- **accessed by GNSS & gravimetric geoid**
- **monitor time-varying nature of gravity field**
- **most accurate continental gravimetric geoid model ever built: 1 cm**





And they shall be called…

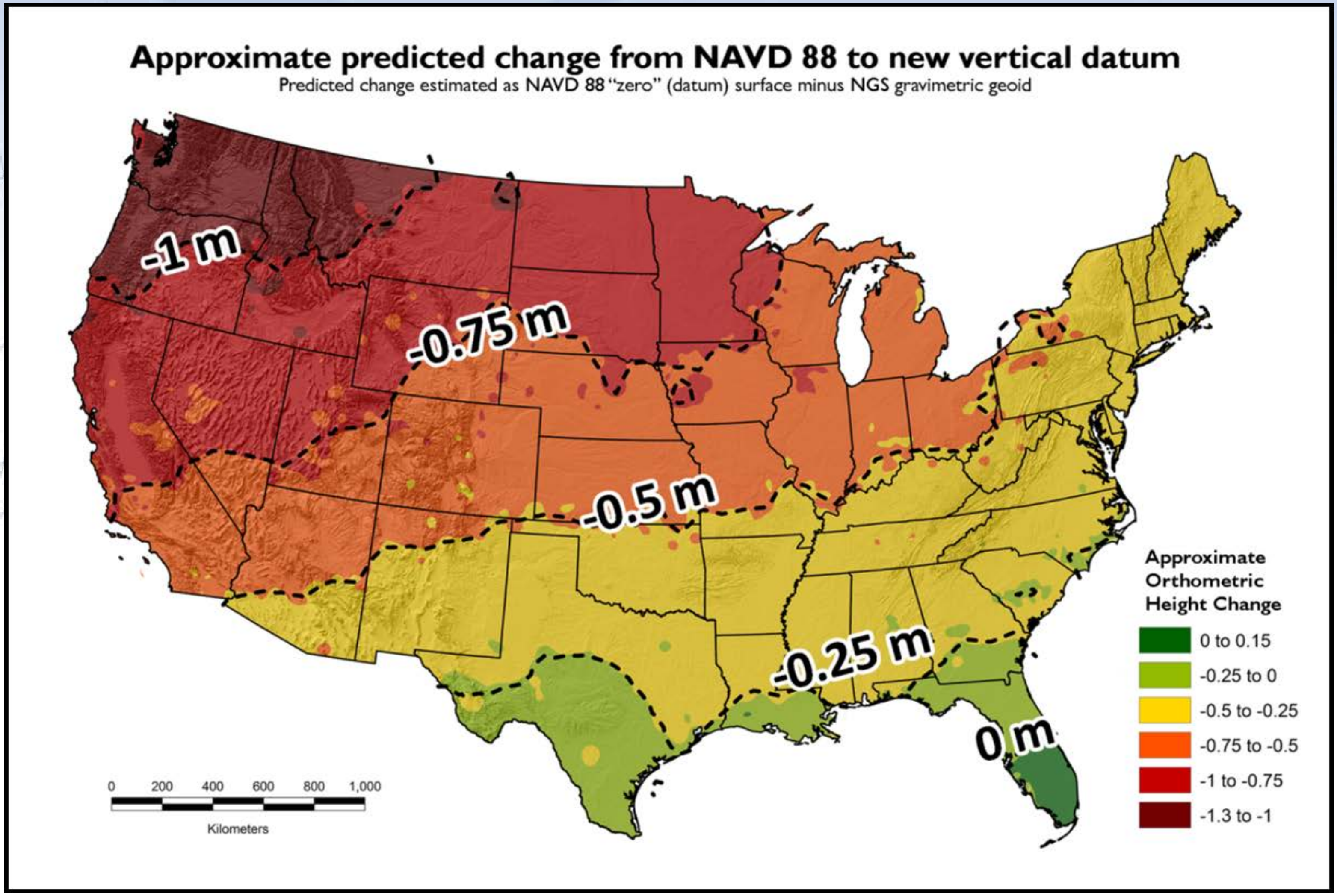
North American-Pacific Geopotential Datum of 2022
(NAPGD2022)

&

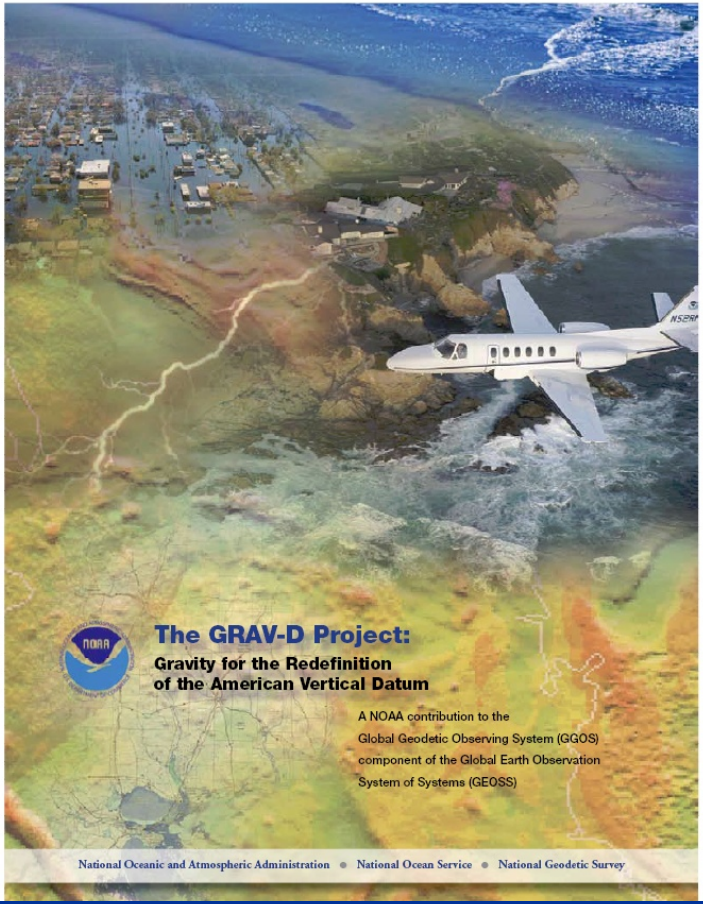
GEOID2022

- NAPGD2022 will contain information for:
  - Orthometric heights
  - Geoid undulations
  - Gravity anomalies
  - Deflections of the vertical
  - & other gravity field information
- GEOID2022 will be time-dependent

Future Geopotential (Vertical) Datum



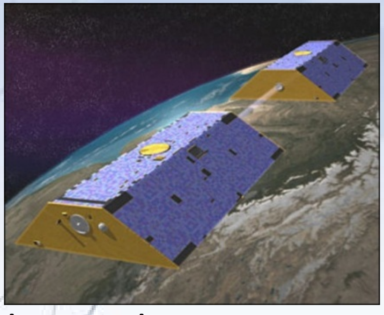
Gravity for the Redefinition of the American Vertical Datum (GRAV-D)



Gravity *and* ***Heights*** *are inseparably connected*

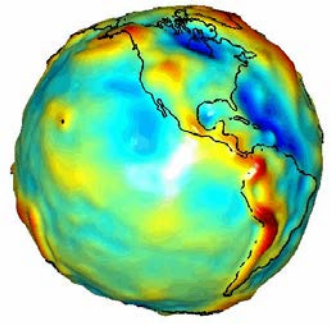
- Replace the national vertical datum (NAVD88) by 2022 with a ***1 cm accurate gravimetric geoid***
- Orthometric heights accessed via GNSS ***accurate to 2 cm***
- Thrusts of project:
  - Airborne gravity survey of entire country and its holdings
  - Long-term geoid change monitoring
  - Partnership surveys

Building a Gravity Field

GRACE/GOCE/Satellite Altimetry

Long Wavelengths
(≥ 250 km)



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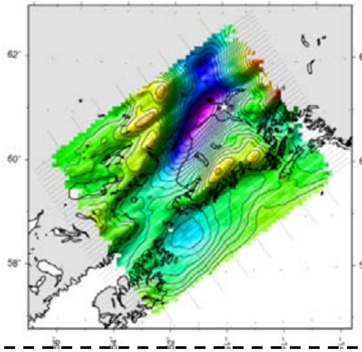
Airborne Measurement

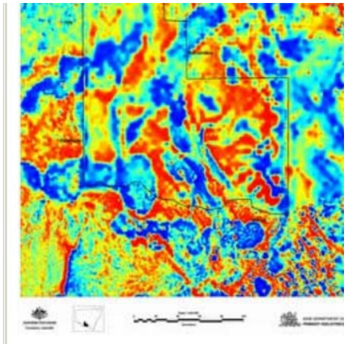
Intermediate Wavelengths
(300 km to 20 km)



+

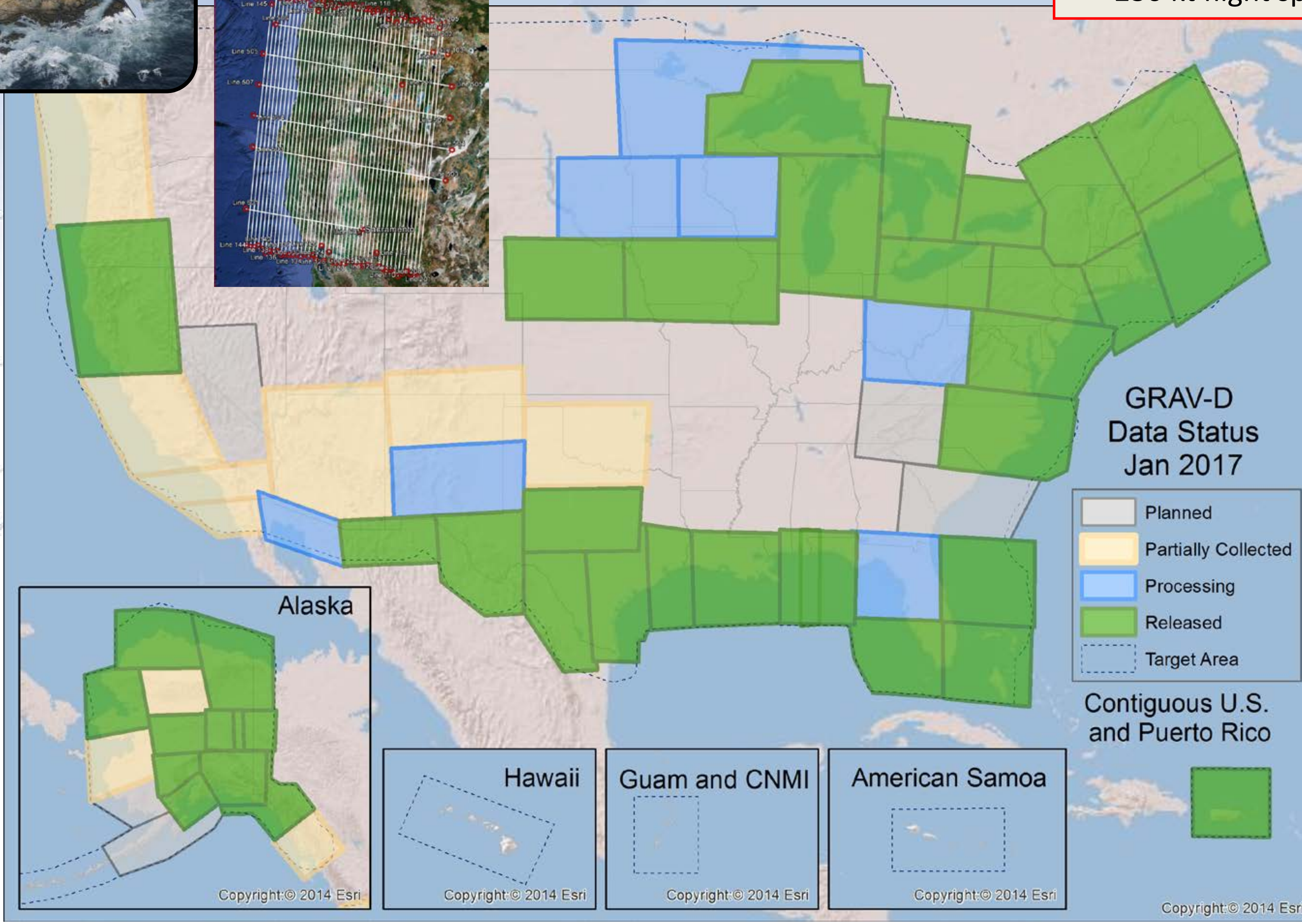

Surface Measurement and
Predicted Gravity from Topography

Short Wavelengths
(< 100 km)



GRAV-D Status (58%)

- 10 km data lines
- 70 km cross lines
- 20,000 ft altitude
- 230 kt flight speed

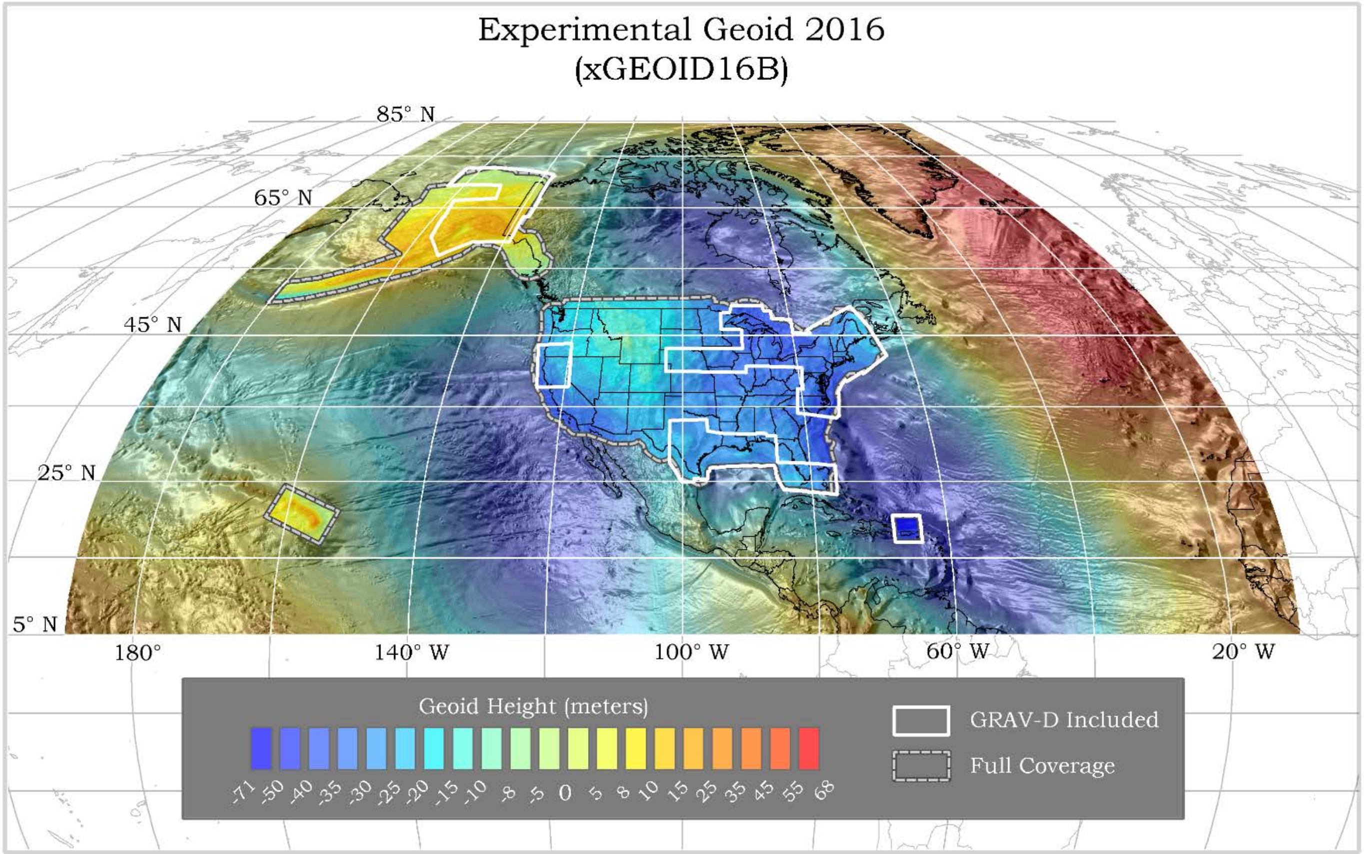


GRAV-D Data Collection Scope

- Entire U.S. and territories
  - Area: 15.6 million sq km
  - Initial target area for 2022
  - ~200 km buffer around territory or shelf break

Extent of 2022 gravimetric geoid model used for new geopotential reference frame

Experimental Geoid 2016 xGEOID16B



https://beta.ngs.noaa.gov/GEOID/xGEOID16/

OPUS – Extended Report

********** New Reference Frame Preview **********

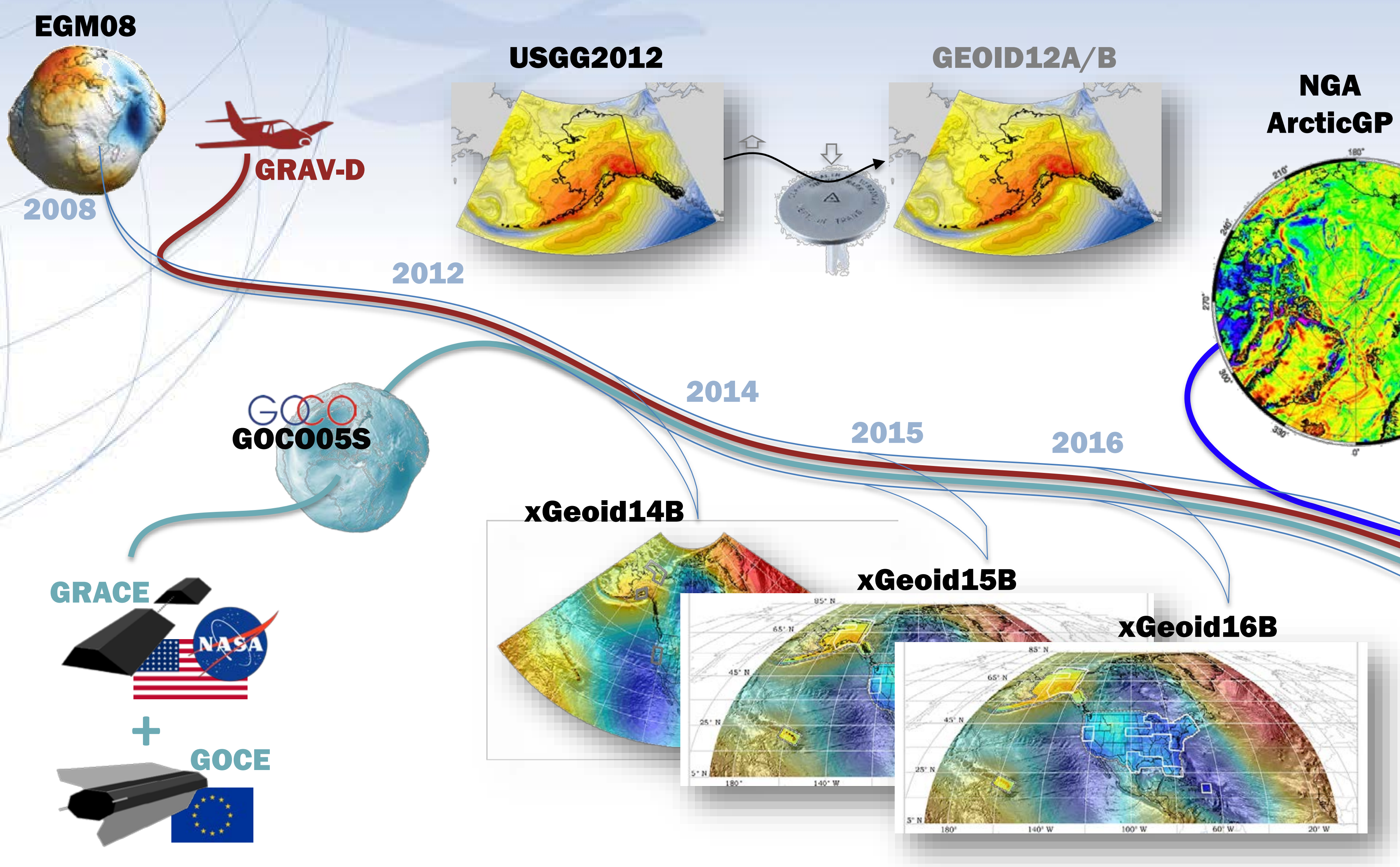
We are replacing the nation's NAD 83 and NAVD 88 datums, to improve access and accuracy of the National Spatial Reference System. More at https://geodesy.noaa.gov/datums/newdatums/

Below are approximate coordinates for this solution in the new frames:

APPROX ORTHO HGT: 778.126 (m) [PROTOTYPE (Computed using xGeoid16B,GRS80,IGS08)]

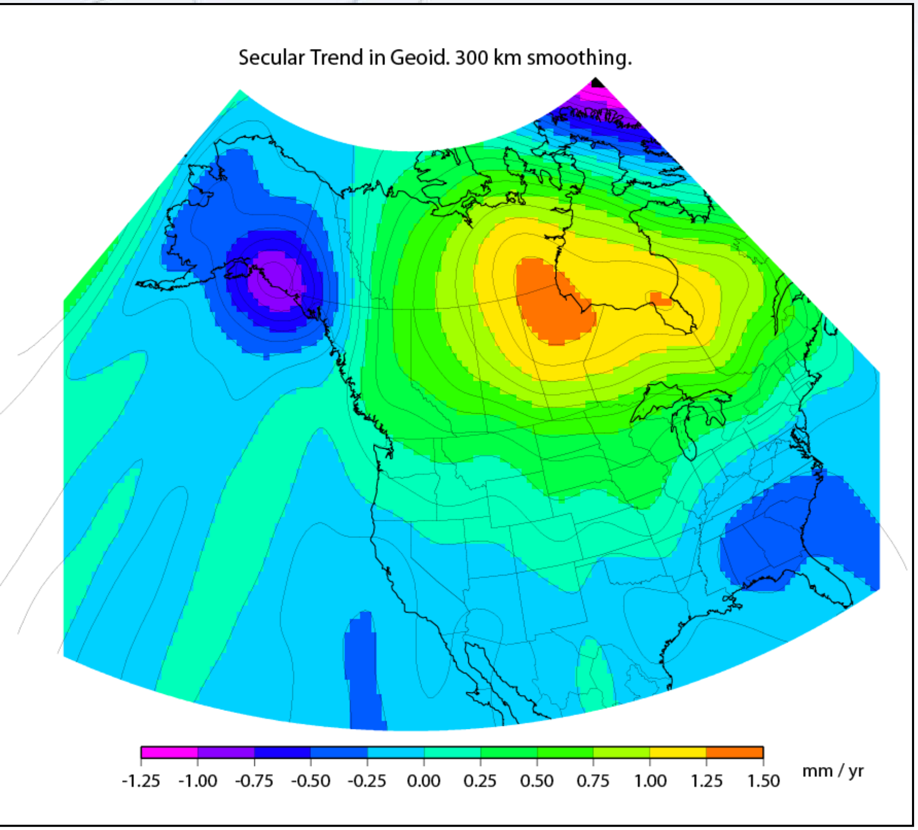
[for comparison, NAVD88 = 778.806 (m)]

Evolution of the Gravimetric Geoid



Time Dependencies

Geoid changes cause height changes



- The zero elevation surface will change with time
- Heights will be time tagged to respect:
  - Geoid change
  - Subsidence

Geoid Slope Validation Survey: 3 phases to validate accuracy of the gravimetric geoid model

Phase 1- GSVS11

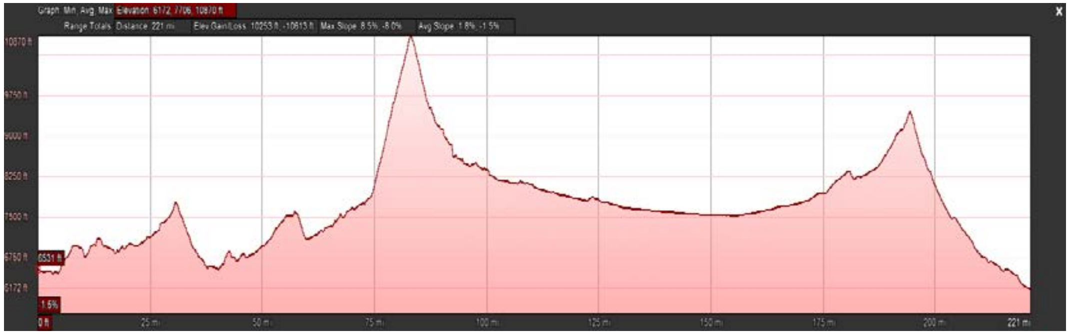
- 2011; Low/Flat/Simple: **Texas**

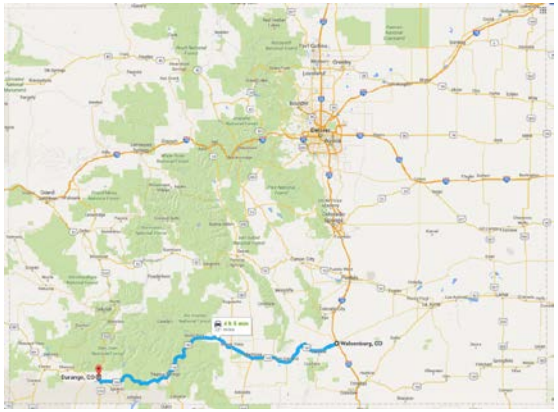
Phase 2- GSVS14

- 2014; High/Flat/Complicated: **Iowa**

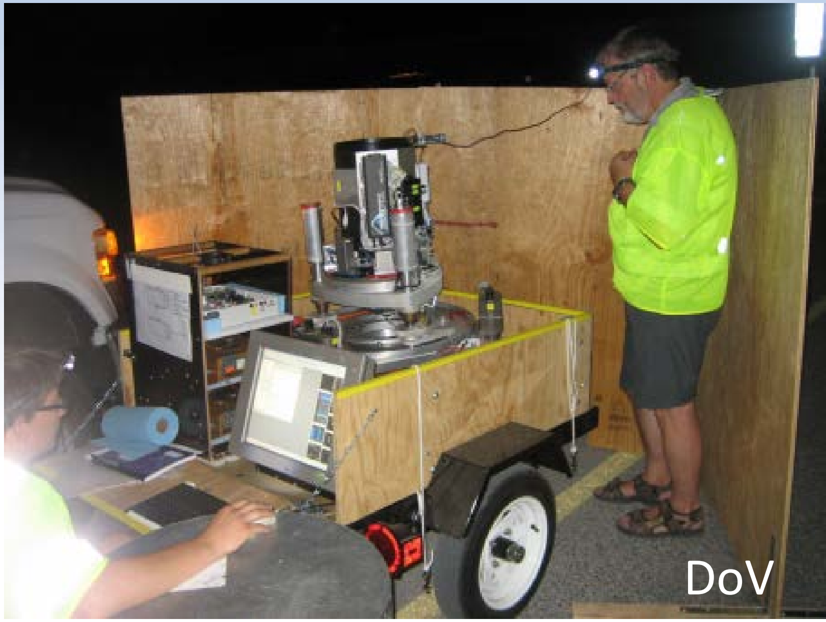
Phase 3 – GSVS17

- 2017; High/Rugged: **Colorado** (10,860ft)





Geoid Slope Validation Surveys – 2011 & 2014

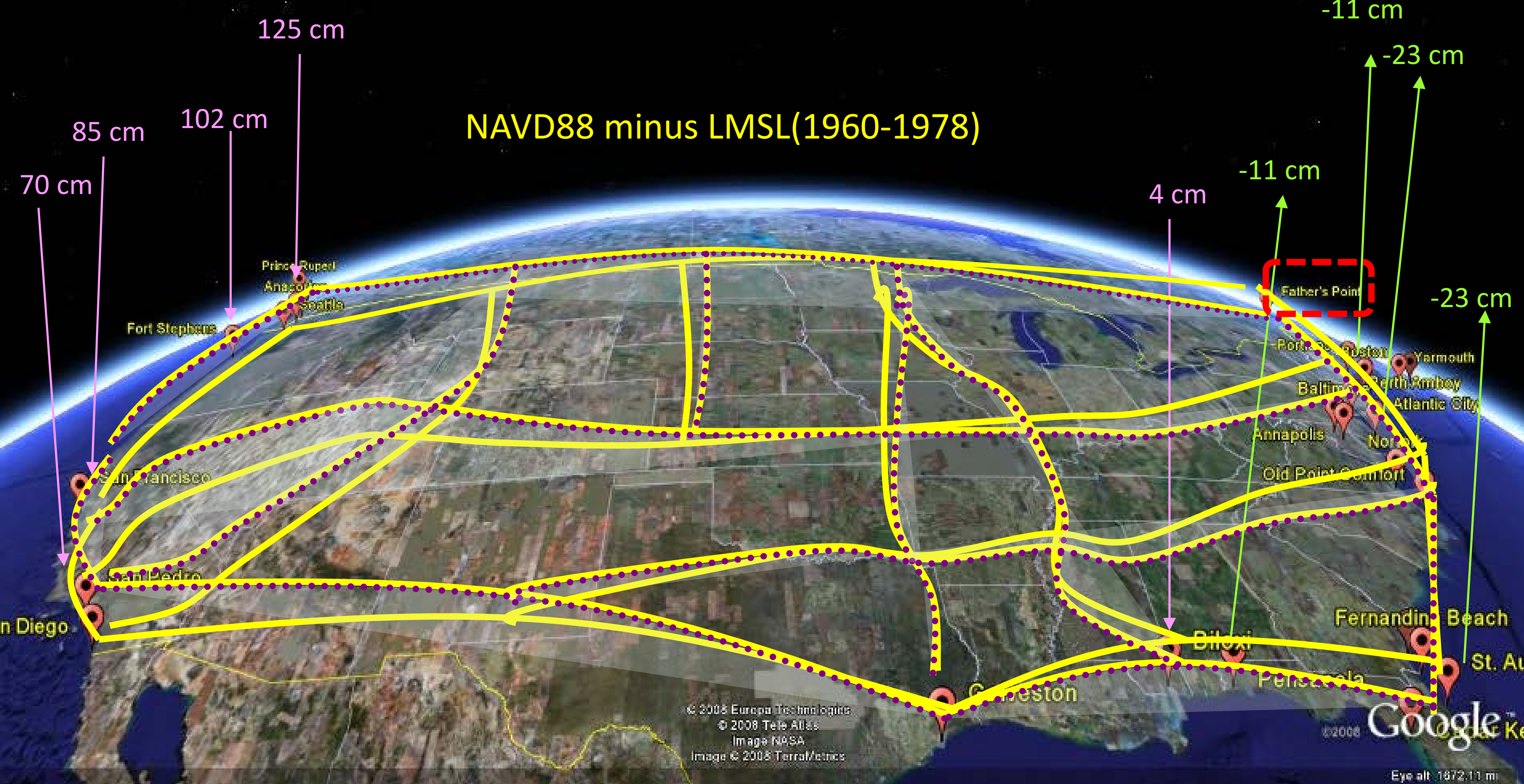


NGVD 29
NAVD 88

Referenced to 26 Tide Gauges

Referenced to 1 Tide Gauge

(Father's Point)



Agreement with Canada on W_0 Value for New Vertical Datum

Agreement: The U.S. National Geodetic Survey and The Canadian Geodetic Survey

March 14, 2012

The U.S. National Geodetic Survey and Natural Resources Canada's Geodetic Survey Division, via conference call held 2012/02/17, **agree**:

- To ***define*** the common (a unique) vertical datum for the United States of America (USA) and Canada (CA) through use of an equipotential surface, realized through one commonly (jointly) computed geoid model, corresponding to the mean coastal sea level for North America by 2022. Adoption is subject to National decisions;
- To ***compute*** the potential W_0 of this equipotential surface using Global Positioning System (GPS) data on tidal benchmarks, by April 1, 2012 and to ***use*** this value, for the realization of geoid models in the USA and CA until 2022;
- To ***maintain*** this equipotential surface as one option to adopt as the vertical datum even if this surface diverges (departs) from the true mean coastal sea level for (around) North America over time;
- To ***monitor*** differences between the above-mentioned equipotential surface and the mean sea level via Global Navigation Satellite Systems (GNSS) on tidal benchmarks, altimetry or other means as required;
- To ***provide*** to the public, deformational velocities (*N-dot*) of the equipotential surface W_0;
- To ***collaborate*** in the realization of geoid models, through the sharing of data and related information:
- To ***compute*** updated geoid models and geoid deformation models with improved realizations as needed;
- To ***inform*** each other when large discrepancies (outside 95% confidence region) are found in overlapping regions; and
- To ***choose*** a threshold value (in alignment with both stakeholder needs and scientific integrity) in 2022, between predicted (modeled) geoid change and true geoid change (including deformation and sea level change) which will warrant new realization of the vertical datum.

Denis Hains
Director
Geodetic Survey Division
Canada Centre for Remote Sensing
Natural Resources Canada / Ressources naturelles Canada
Canada

Juliana P. Blackwell
Director
National Geodetic Survey

Entente: National Geodetic Survey des États-Unis et les Levés géodésiques du Canada

14 mars, 2012

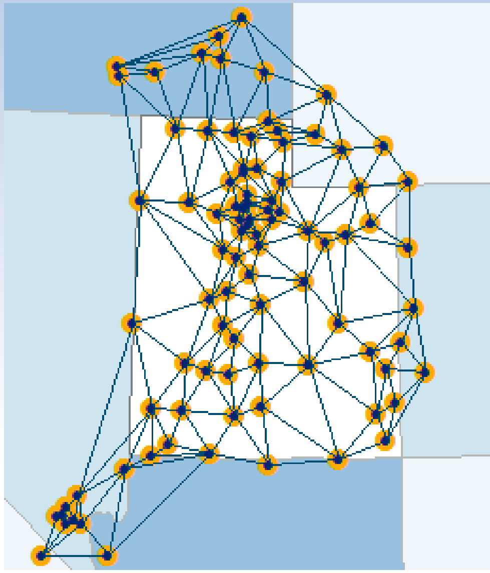
Le National Geodetic Survey des États-Unis et la Division des levés géodésiques du ministère des Ressources naturelles du Canada, par un appel conférence tenu le 2012/02/17, se sont **entendus** :

- À ***définir*** un datum vertical commun (unique) pour les États-Unis d'Amérique (USA) et le Canada (CA) par l'entremise d'une surface équipotentielle réalisée par un modèle du géoïde calculé en commun (ensemble), correspondant au niveau moyen des mers le long des côtes de l'Amérique du Nord par 2022. L'adoption est sujette aux décisions nationales;
- À ***calculer*** le potentiel W_0 de cette surface équipotentielle par mesures du Système de positionnement mondial (GPS) à des marégraphes avant le 1er avril 2012 et à ***utiliser*** cette valeur pour la réalisation des modèles du géoïde des USA et du CA jusqu'en 2022;
- À ***maintenir*** cette surface équipotentielle comme une option pour l'adoption d'un datum vertical même si cette surface diverge (s'écarte), avec le temps, du véritable niveau moyen des mers de (entourant) l'Amérique du Nord.
- À ***surveiller*** la différence entre la surface équipotentielle mentionnée ci-haut et le niveau moyen des mers par mesures des Systèmes mondiaux de navigation par satellites (GNSS) à des marégraphes, par altimétrie et par autres moyens requis;
- À ***fournir*** au public des vélocités (N-dot) de déformation de la surface équipotentielle W_0;
- À ***collaborer*** à la réalisation des modèles du géoïde en partageant des données et l'information reliée;
- À ***calculer*** des mises-à-jour des modèles du géoïde et de déformation au besoin;
- À ***s'informer*** mutuellement des écarts importants (à l'extérieur d'une marge de confiance de 95%) retrouvés en régions chevauchantes;
- À ***choisir*** une valeur seuil (cadrant avec les besoins des utilisateurs et scientifiquement rigoureuse) en 2022 entre les changements prédits et réels du géoïde (incluant sa déformation et le changement du niveau moyen des mers) qui justifieront une nouvelle réalisation du datum vertical.

Denis Hains
Directeur
Division des levés géodésiques
Centre canadien de télédétection
Ressources naturelles Canada / Natural Resources Canada
Canada

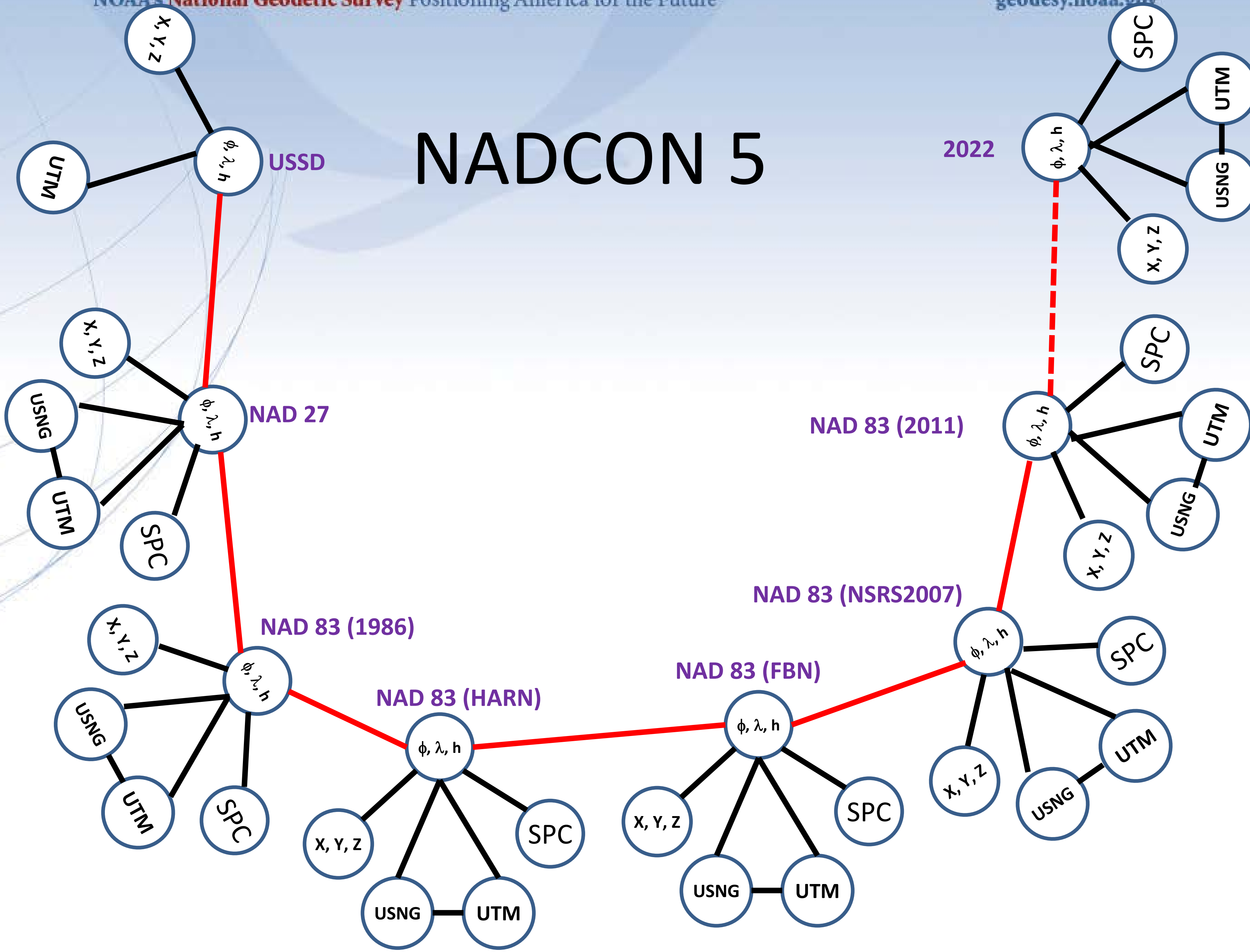
Juliana P. Blackwell
Directrice
National Geodetic Survey

How to Plan for 2022



- **<u>Move to NAD 83(2011) epoch 2010.00</u>**
  - via surveys (or *<u>possibly</u>* via NADCON/GEOCON)
- **<u>Move to NAVD 88</u>**
  - via surveys (or *<u>possibly</u>* via VERTCON)
- **<u>Move from reliance on passive marks to GNSS infrastructure</u>**
  - utilize CORS, OPUS, real-time networks (eg TURN), etc.
- **<u>Use OPUS-Share/Database for GPSBMs & NAD83(2011) ties</u>**
  - improve next geoid model & relationship with new datum
- **<u>METADATA!!!!</u>**

NADCON 5


USSD
NAD 27
NAD 83 (1986)
NAD 83 (HARN)
NAD 83 (FBN)
NAD 83 (NSRS2007)
NAD 83 (2011)
2022
ϕ, λ, h
X, Y, Z
UTM
USNG
SPC

Legislation

- When NAD 83 replaced NAD 27, Federal NSRS users were required to switch to NAD 83
- Through the 1980s and 1990s NGS worked with *states* to update their laws
  - To encourage use of the new system beyond Feds
- 48 states now have laws that refer to NAD 83
  - A name which will be *retired* in 2022

Legislation

- In 2016, NSPS, AAGS, and NGS formed a committee to address this issue
  - The NSPS/AAGS/NGS Advisory Committee on National Spatial Reference System Legislation
- New Legislative Template completed June 2016
  - Generic terminology: "NSRS or its successor," etc.
  - NSPS will work with states to adopt new template
    - 2017 - 2022

NSPS Draft NSRS Legislation

Template Draft NSRS Legislation

How to use this template:

1) Whenever the word "state" is used below, it should be taken to mean "state or territory"
2) The intent of this template is to augment, not fully replace, existing state laws dealing with a state-specific coordinate system and its relationship to existing or prior datums of the National Spatial Reference System (NSRS).
3) The National Geodetic Survey (NGS) intends to release a new State Plane Coordinate System (SPCS) as part of the release of any new geometric datum, including that planned for release in 2022. As such, it is imperative that each state do the following:
   a. Ensure that any changes from the 1983 SPCS which the majority of geospatial professionals in the state wish to make, be agreed at the state level and communicated to NGS, prior to 2022 and
   b. Ensure that any law naming the state-specific coordinate system contains a definition of how that state-specific coordinate system relates to the SPCS.
      i. For example, if Michigan wishes to legislate that the "Michigan Plane Coordinate System" be used in the state of Michigan, then the law should specify that the "Michigan Plane Coordinate System" is identical to (or in some other way, defined in the law, related to) the "Michigan portion of the State Plane Coordinate System as defined by the National Geodetic Survey".
4) Related to #2 above, language should *connect* the state-desired coordinate system to the federally-defined SPCS, while leaving state and federal responsibilities independent.
   a. For example, both NGS and the California Spatial Reference Center (CSRC) cannot be *jointly* responsible for the California Plane Coordinate System (if that is the name chosen by California). If the CSRC is going to define the California Plane Coordinate System, they should solely define it, and have the law reflect how it relates to the federal (NGS-specified) SPCS.
5) Reference to specific years or datum names within the NSRS should be avoided, as the intent of the template is to provide legislation that will be accurate and relevant both today (under NAD 83), through the new datum (in 2022) and beyond to whatever datums come after 2022.
6) Wherever the phrase "<state>" is used in the template below, insert the name of your specific state or territory.
7) Sections which are considered optional are set aside (in parentheses and in red)
8) Sections which are explanatory and not to be copied into the law are in ***bold and italic***.
9) Parts of the law where a choice of options must be made are set <in brackets and highlighted>
10) While most states legislate the use of a *planar* coordinate system, this template addresses both *planar* and *geodetic* coordinates, to provide the greatest flexibility across all states.

I. Acronyms

The following acronyms will be used throughout this law in order to increase conciseness.

NSRS = The National Spatial Reference System or its successors
NGS = The National Geodetic Survey or its successors
SPCS = State Plane Coordinate System or its successors
*PCS = <state> Plane Coordinate System ***(where * is the first letter of the state)***

(If a state feels clarity about the above terms is necessary, then insert a possible hierarchical section here, outlining that the NSRS is the overarching system, and that below that are various datums. Below the datums are projected coordinates within the datums, including the SPCS)

II. The <state> Plane Coordinate System

The most recent system of plane coordinates which has been established by NGS, based on the NSRS, and known as the SPCS, for defining and stating the positions or locations of points on the surface of the earth within the State of <state> shall be known as the "<state> Plane Coordinate System." ***This paragraph should serve, provided states do not wish to deviate from the SPCS. If they do, see the third parenthetical below.***

(Details how such a system should be used within your state)

(Keep existing 27/83 definitions in place)

(Any state or territory wishing to define other projections besides those found in NGS's SPCS should do so here. If the state-specific Plane Coordinate System will include anything like this, which is outside the scope of the SPCS, make sure not to attribute any aspects of it to NGS nor to the SPCS, but only to whatever state agency is going to define this exo-SPCS component of the state-specific Plane Coordinate System)

The plane coordinates of a point on the earth's surface, to be used in expressing the position or location of the point in the appropriate zone of the *PCS, shall consist of two distances, expressed in feet and decimals of a foot or meters and decimals of a meter. When the values are expressed in feet, the <define which foot to be used. Either "U.S. Survey foot," (one U.S. Survey foot = 1200/3937 meters) or "International foot," (one International foot = 0.3048 meters)> shall be used as the standard foot for *PCS. One of these distances, to be known as the "East x-coordinate," shall give the distance east of the Y axis; the other, to be known as the "North y-coordinate," shall give the distance north of the X axis. The Y axis of any zone shall be parallel with the central meridian of that zone. The X axis of any zone shall be at right angles to the central meridian of that zone.

(insert text about accuracy and use of points in the system)

III. Geodetic Coordinates

This section would only be inserted for those states specifically wishing to legislate the use of geodetic coordinates.

Your NAD 83-Based State Plane-Legislated Coordinates *Will Not* Be Maintained after 2022!

NSPS

AAGS

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

What will you and your fellow professionals do?
Panic? Ignore the Issue? *or Act?*
Please let us know!

What is changing?

The North American Datum of 1983 (**NAD 83**) will be replaced in 2022.
The new datum will have a different name.

The North American Vertical Datum of 1988 (**NAVD 88**) will also be replaced in 2022.
Its replacement will also have a new name.

Expected horizontal shifts from NAD 83 to the new datum are in the 1-2 meter range. The National Geodetic Survey will provide a coarse, map-grade transformation tool (such as NADCON and GEOCON) to connect NAD 83 with the new datum.

Who will be affected?

All states and territories will be transitioned to the new datums.
Forty-eight states have a state-specific coordinate system law tied to NAD 83.
Your state law will not reflect the National Spatial Reference System after 2022.

Who can help?

The National Geodetic Survey (**NGS**), **the National Society of Professional Surveyors** (**NSPS**) **and the American Association for Geodetic Surveying** (**AAGS**) are here to help your state make these changes in legislation!

You can help by understanding your own state's laws and how these changes will impact you.

Should you change or modify your state law?

NGS, NSPS and AAGS believe it would benefit state surveyors and mapping professionals for laws or regulations to reflect the latest federal geodetic infrastructure, namely **the National Spatial Reference System.**

Why should you change or modify your state law?

1. Federal agencies will adopt the new datum, so national products like **Federal Emergency Management Agency** (**FEMA**) **flood insurance rate maps** will no longer reference NAD 83, nor NAVD 88. Using the current (most updated) datum will avoid confusion and increase consistency with federal engineering or constructions projects.

3. More geospatial data is being collected and shared every day. A consistent and regularly updated NSRS will provide greater efficiency across surveying and mapping sectors.

What do you think?

We welcome your feedback! Please provide any feedback you like to one of our committee members, below.

NSPS/AAGS/NGS Advisory Committee on National Spatial Reference System Legislation

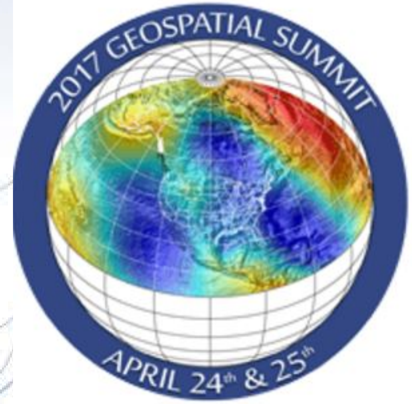
J.B. Byrd NSPS jbyrd@jmpa.us
Dave Doyle NSPS base9geodesy@gmail.com

NGS 2017 Geospatial Summit

National Geodetic Survey

Positioning America for the Future

NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education | Search



2017 Summit Home
Summit Documents
FAQs

Related Links

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

2017 Geospatial Summit

On April 24-25, 2017 NGS hosted the 2017 Geospatial Summit at the Silver Spring Civic Building at 1 Veterans Pl, Silver Spring, MD 20910.

The 2017 Geospatial Summit provided 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.

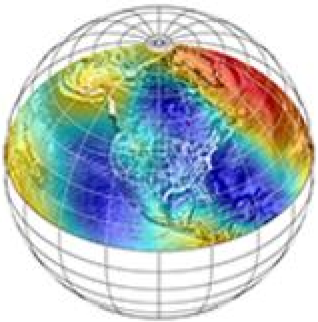
The Summit provided an opportunity for NGS to share updates and discuss the progress of projects related to NSRS Modernization. NGS also heard feedback and collected requirements from its stakeholders across the federal, public and private sectors. This event continued discussions from previous Geospatial Summits held in 2010 and 2015.

Additional information about the 2017 Geospatial Summit will be posted online. If you have questions or comments, contact us.

Website Owner: National Geodetic Survey / Last modified by NGS Infocenter May 02 2017

New Datums

National Geodetic Survey



September 20, 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

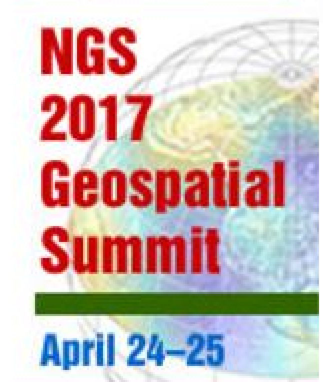
Watch Our Videos | Learn More

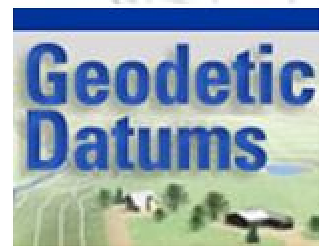
Why is NGS replacing NAD 83 and NAVD 88?

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.

New Datums Quick Links

- Home
- What to expect
- Get prepared
- Track our progress
- Related projects
- Watch videos
- Learn more
- New Datums FAQ
- Contact Us
- Sign up for list-serve





Issue 6, January 2017

NSRS Modernization News

For all issues of **NSRS Modernization News**, visit:
geodesy.noaa.gov/datums/newdatums/TrackOurProgress.shtml

Decision Points

The National Geodetic Survey (NGS), through a series of both internal debates and external discussions with the Canadian Geodetic Survey, has finalized certain key decisions in the replacement of the three NAD 83 reference frames, and in the replacement of the various vertical datums of the NSRS. These decisions cover both the science and nomenclature of the changes coming in 2022.

Four Terrestrial Reference Frames

Replacing the three existing NAD 83 reference frames will be four plate-fixed ***terrestrial reference frames.*** The tectonic plate for each frame may be inferred from their names, which are:

North American Terrestrial Reference Frame of 2022 (NATRF2022)

Pacific Terrestrial Reference Frame of 2022 (PTRF2022)

Mariana Terrestrial Reference Frame of 2022 (MTRF2022)

Caribbean Terrestrial Reference Frame of 2022 (CTRF2022)

Relationship to the IGS Frame

Each of the above four frames will be identical to the latest IGS reference frame (as available in 2022) at an epoch to be determined. Away from that epoch, the four frames will relate to the IGS frame through the definition of an Euler Pole rotation specific to that plate. All Continuously Operating Reference Stations (CORS) velocities which deviate from the rotation of a rigid plate will be captured in a residual 3-D velocity model.

Heights and Other Physical Coordinates

A ***geopotential datum*** will be created which will contain all of the necessary information to provide mutually consistent orthometric heights, geoid undulations, gravity anomalies, deflections of the vertical, and all other geodetic coordinates related to the gravity field. This geopotential datum will be called:

North American-Pacific Geopotential Datum of 2022 (NAPGD2022)

Geoid Model

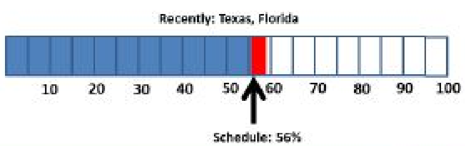
Within NAPGD2022, a variety of products will exist. The most prominent of these products will be a ***time-dependent model of the geoid,*** provided in three regions (the first covering the entirety of North and Central America, Hawaii, Alaska, Greenland, and the Caribbean; the second covering American Samoa; and the third covering Guam and the Commonwealth of the Mariana Islands). The name of this model will be:

GEOID2022

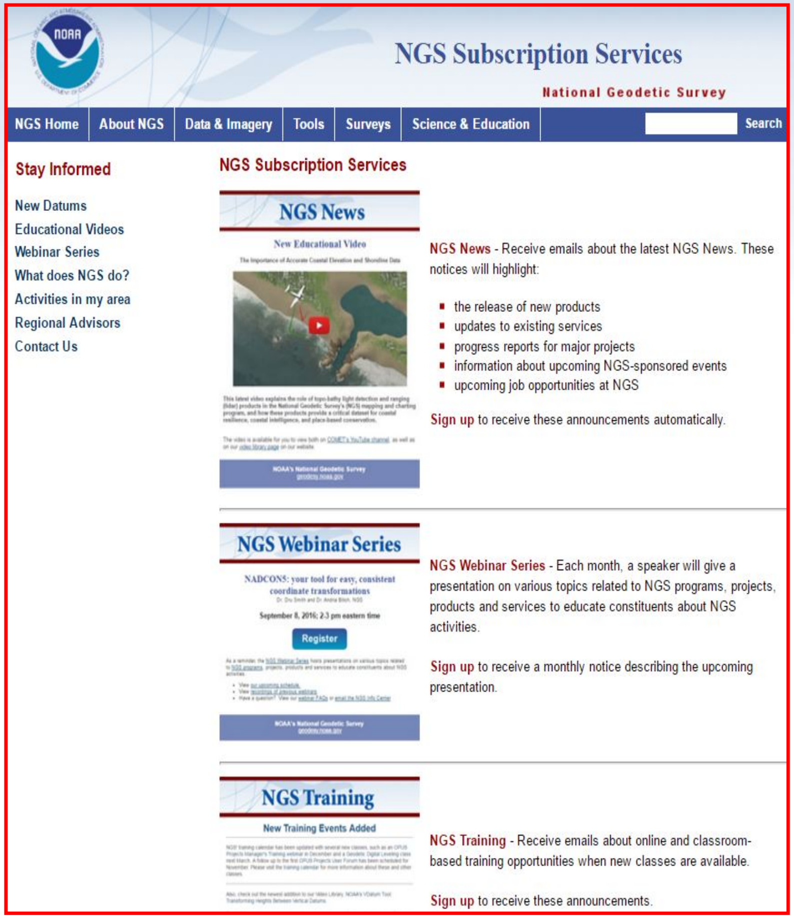
Further Information

A comprehensive white paper, outlining the technical details of the above decisions, is currently being drafted in NGS and we plan for it to be ready by the upcoming 2017 Geospatial Summit. In addition, details may be released on the NGS website and through our email listserv.

GRAV-D progress last quarter: up 3.0% to 58.4%
Ahead of Schedule!



geodesy.noaa.gov

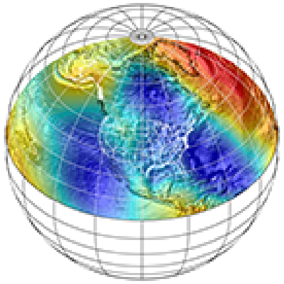


Attend a Monthly Webinar

NGS Webinar Series

National Geodetic Survey

NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education



Webinar Series Quick Links

- Overview
- Upcoming Webinars
- Recorded Webinars
- Frequently Asked Questions (FAQ)

Contact information

- Email us
- Sign-up for webinar announcements
- Sign-up for list-serve

Overview

Each month, a speaker will give a presentation on various topics related to NGS programs, projects, products and services to educate constituents about NGS activities.

Webinars are held on the second Thursday of every month, from 2:00-3:00 p.m. East Coast time. You can register for any presentation on the "Upcoming Webinars" page, and you can sign-up to receive a monthly notice describing the upcoming presentation.

This webinar series is a continuation of monthly presentations sponsored by the National Height Modernization Program, and you can download previous presentations from the Program's online meeting archive.

Many additional NGS resources are available online, including:

- Continuously Operating Reference Station (CORS) weekly newsletter archive
- Ecosystem and Climate Operations newsletter archive
- Educational videos
- Height Modernization monthly meeting archive
- Online Learning Resources (e.g. recorded webinars and online training modules)
- Presentation library

NGS Video Library

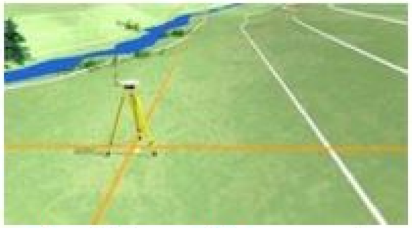
National Geodetic Survey

What are Geodetic Datums?

How Were Geodetic Datums Established?

What Is the Status of Today's Geodetic Datums?

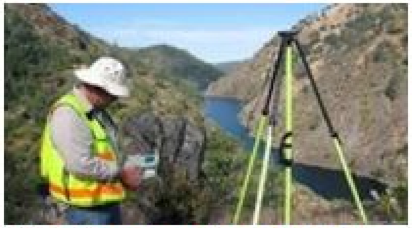
What's Next for Geodetic Datums?



Precision and Accuracy in Geodetic Surveying

Two Right Feet? U.S. Survey Feet vs. International Survey Feet

Geospatial Infrastructure for Coastal Communities: Informing Adaptation to Sea Level Rise



Best Practices for Minimizing Errors during GNSS Data Collection

The Importance of Accurate Coastal Elevation and Shoreline Data

Educational Videos Quick Links

Corbin Training Center

Online Lessons

Geospatial COMET MetED Resources

National Ocean Service Lesson Plan Libary

Other Videos +

Stay in Touch … Get More Email!

NGS Training

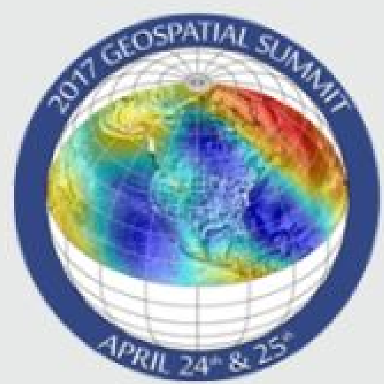
New Training Opportunities Posted

New training opportunities are available on the NGS Training Calendar.

OPUS Projects Manager's Training (webinar) - 5/16/17

OPUS Projects User Forum (webinar) - 6/7/17

Registration Open for 2017 Geospatial Summit April 24-25, Silver Spring, MD



You're Invited!

NGS plans to replace the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD 88) in 2022.

We will share updates and discuss the progress of related modernization projects. Stakeholders across the federal, public, and private sectors will also be providing feedback on these efforts.

National Geodetic Survey Positioning America for the Future geodesy.noaa.gov

GPS on Bench Marks Campaign

What is it?

NOAA's National Geodetic Survey encourages anyone with survey-grade Global Positioning System (GPS) receivers to join the **2016 GPS on Bench Marks Campaign**, a **National Surveyors Week (March 20–26, 2016)** event to raise awareness about professional surveying while improving the **National Spatial Reference System** (NSRS).

Why Participate?

The nation's height system, the **North American Datum of 1988** (NAVD 88), is founded on historic geodetic leveling surveys that use thousands of bench marks, many of which have not been positioned with GPS. Adding GPS coordinates to these marks allows them to be used in NGS' modern height reference-surface modeling. For instance, NGS' latest hybrid geoid model, GEOID12B, includes "GPS on bench mark" observations, but would greatly benefit from additional GPS data collection in many areas.

How to do it? It's 1-2-3:

Find

Collect

Share

1. **Find local bench marks.** Visit our website at Geodesy. noaa.gov for a priority listing of marks to occupy and maps to help you find them. Contact your NGS geodetic advisor for more details, or email us at ngs.GPSonBM@noaa.gov.

2. **Collect GPS** on your selected bench mark following careful field procedures.
   - If time permits, complete reconnaissance at your selected mark to ensure its usability and/or to identify alternative marks.
   - Collect a 4+ hour GPS data file.
   - Verify antenna type, height, and plumb.
   - Use a fixed-height tripod (recommended), and brace the legs with sandbags or chain.
   - Take two photos of the mark, and note any changes to the existing mark description. (Optional: use observer field log with this step.)

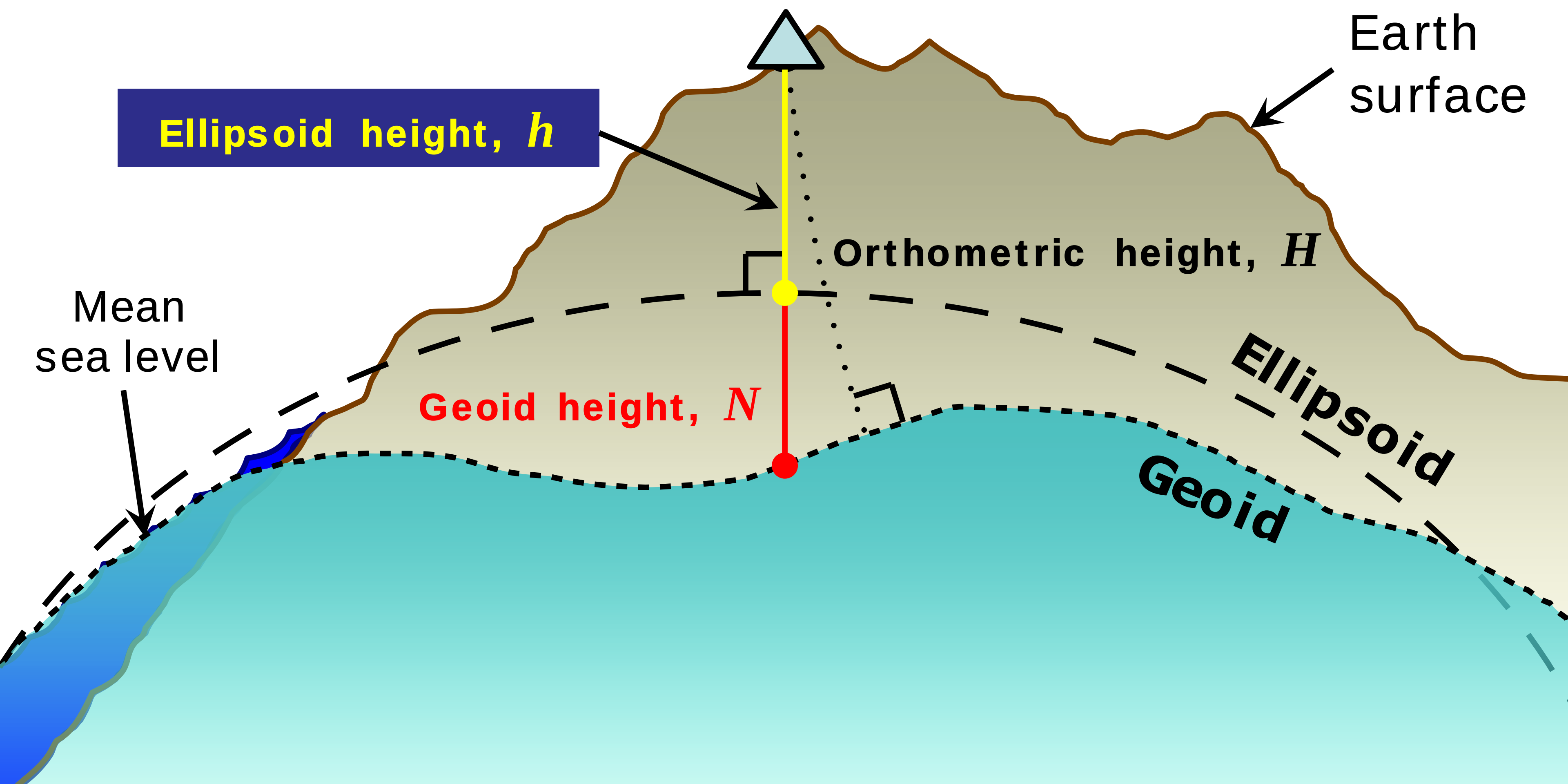
3. **Share your data** by uploading to our Online Positioning User Service (OPUS) on the NGS website Geodesy.noaa.gov.

Contribute!

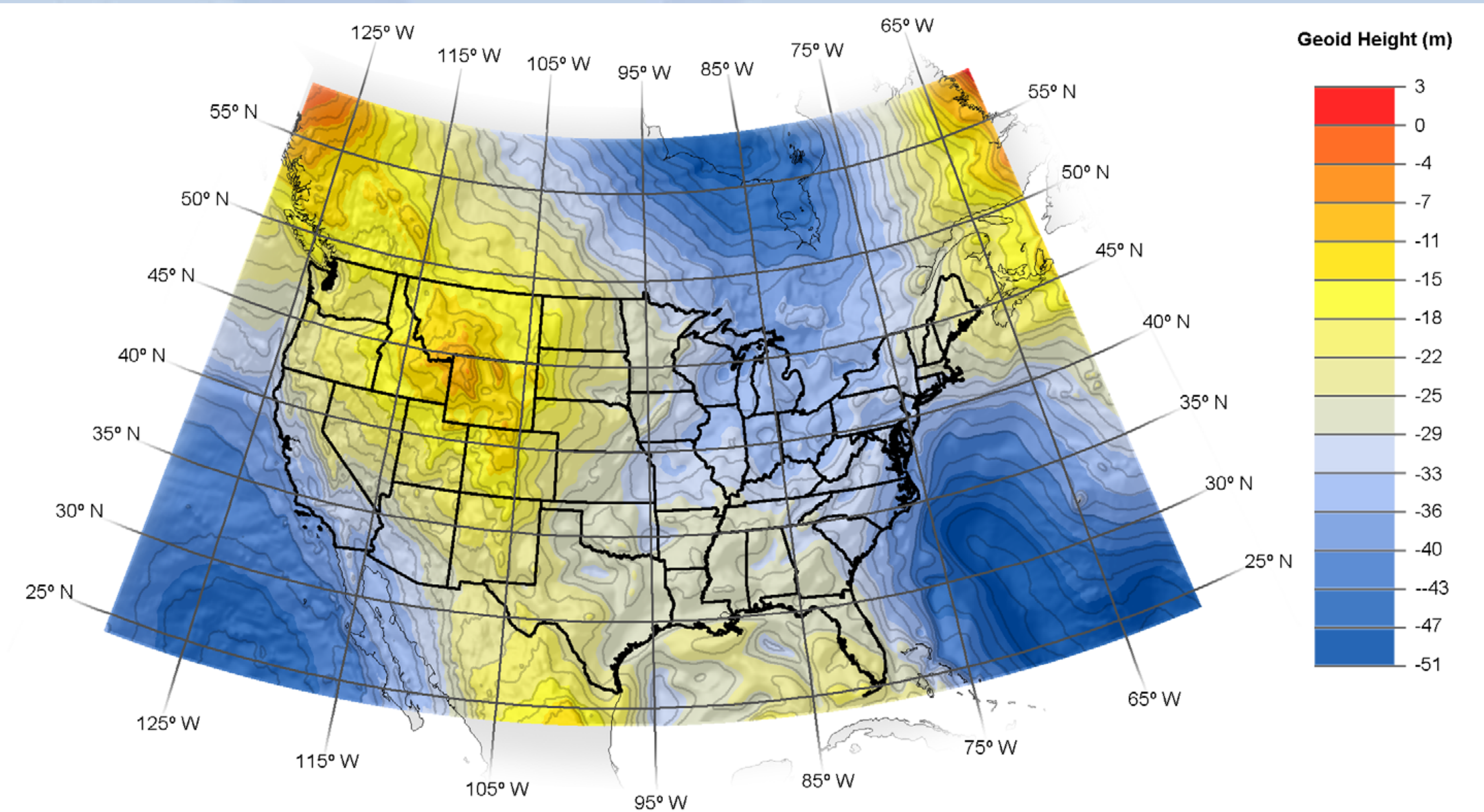
NGS will use data collected during this campaign to improve the next hybrid geoid model, increasing access to NAVD 88 and enabling conversions to the **new vertical datum in 2022.**

The Relationship of Heights

$$H \approx h - N$$

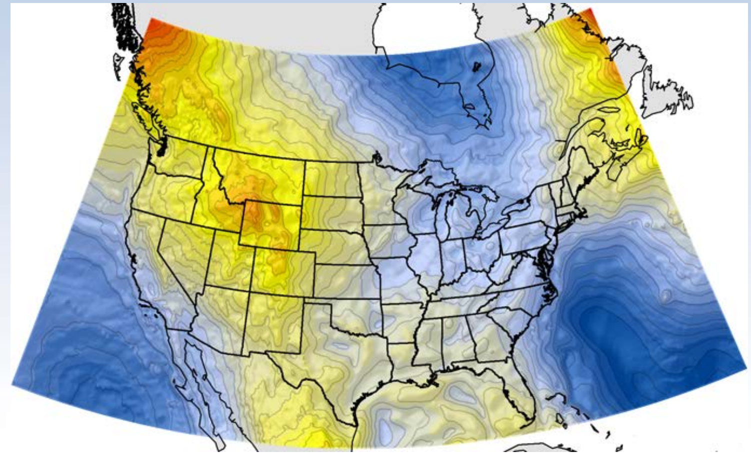


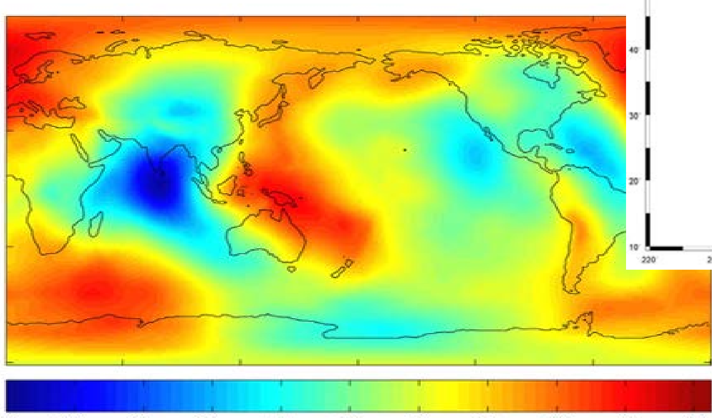
GEOID12B (Hybrid Geoid Model)

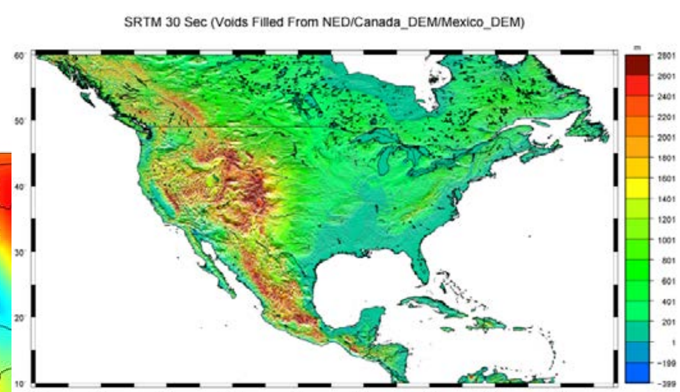


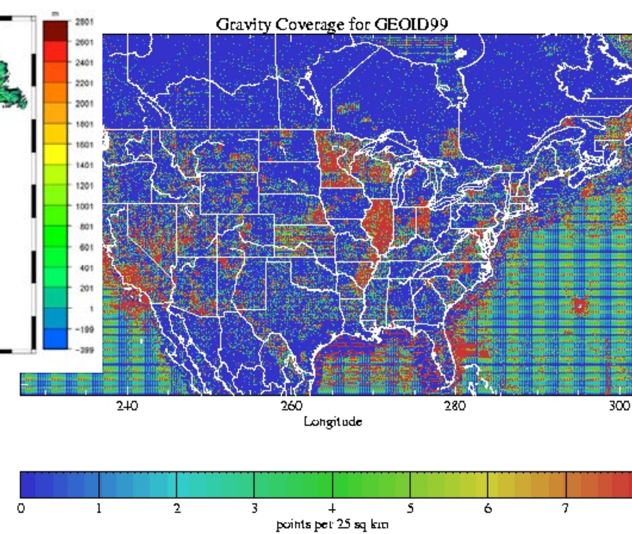
USGG2012 (Gravimetric Geoid)

- Satellite Gravity Models + EGM08
- 2.6 million terrestrial, ship-borne,
  altimetric gravity measurements
- 30 arc second Digital Elevation Data
- Computed on 1 x 1 arc minute grid spacing
- GRS-80 ellipsoid

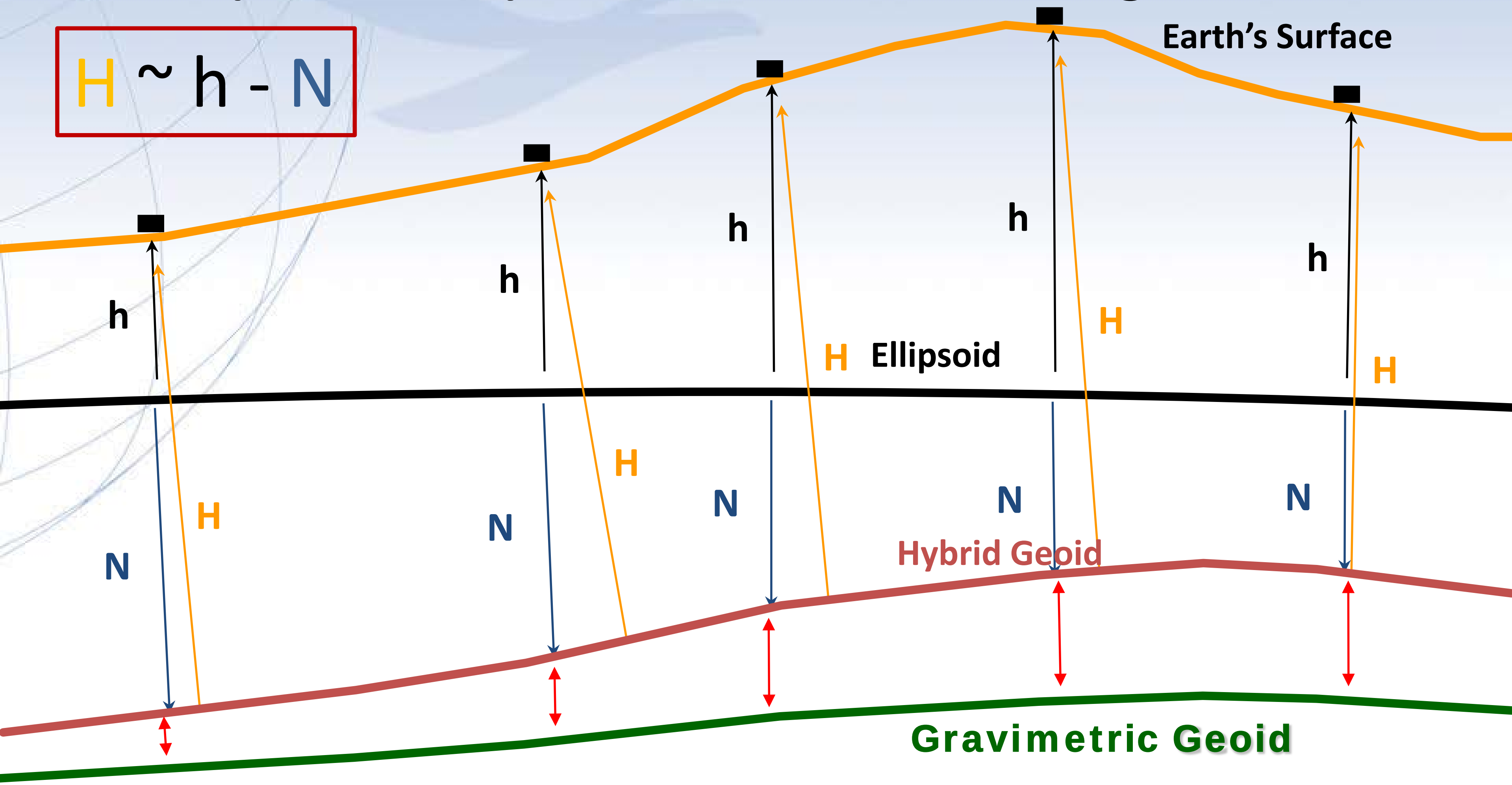






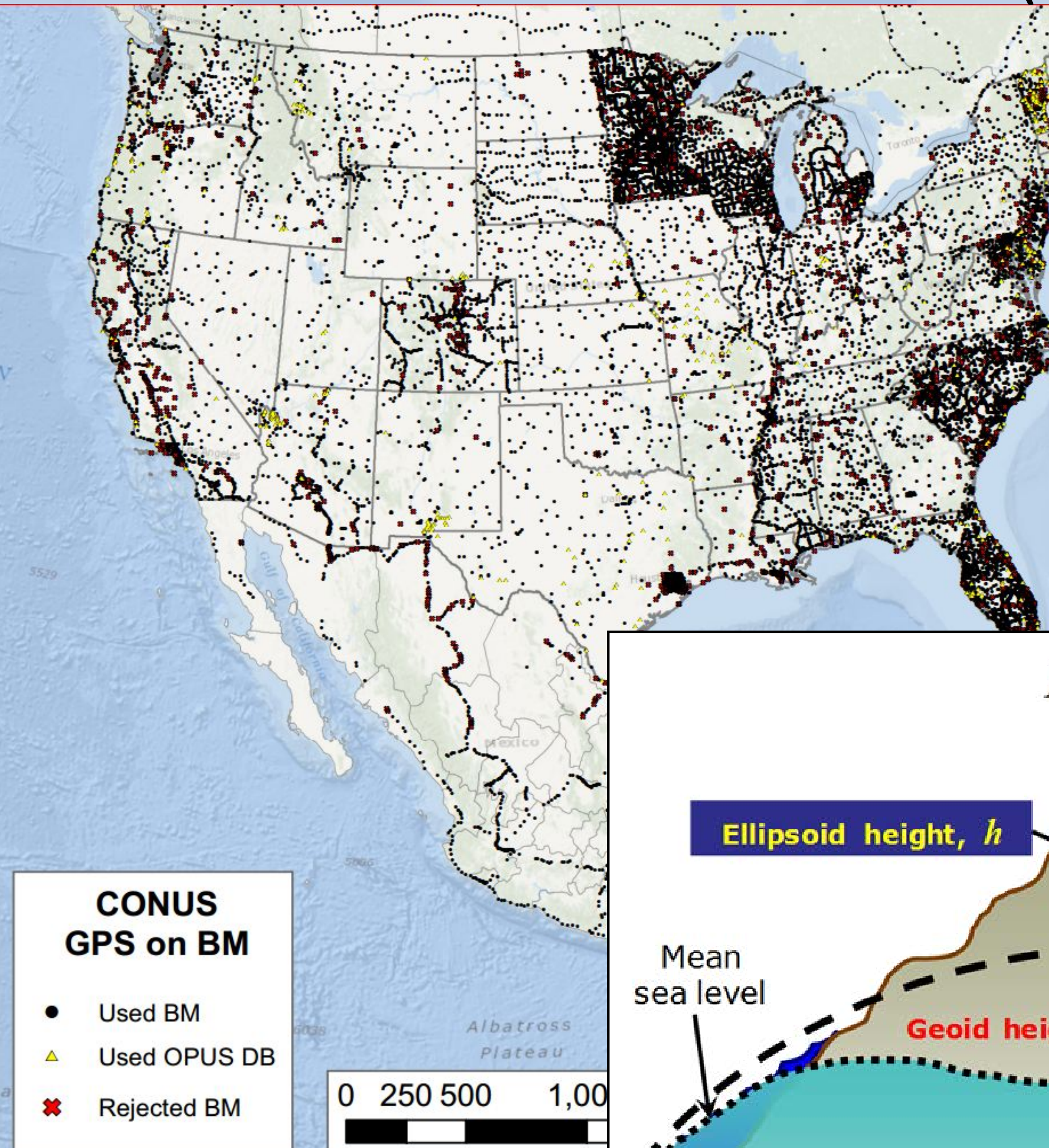


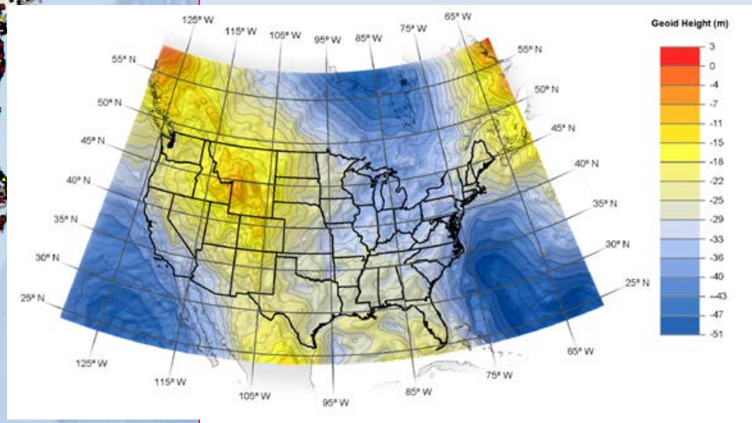
Hybrid Geoid Model (GEOID12B) & Gravimetric Geoid Model (USGG2012) Conversion Surface using GPSBM data

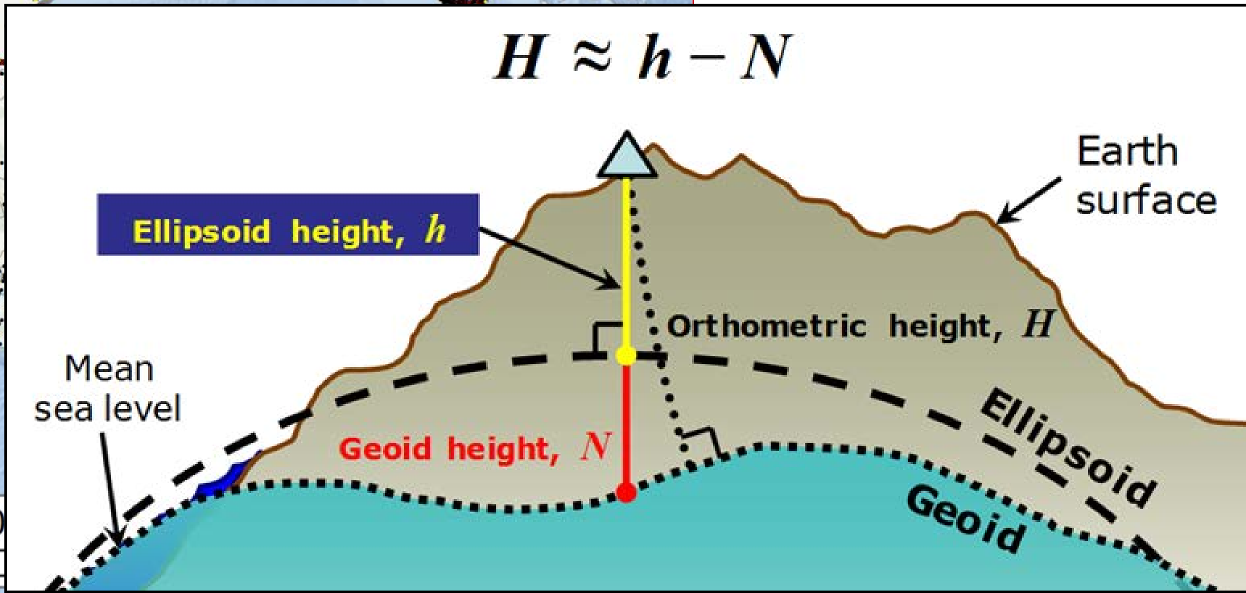


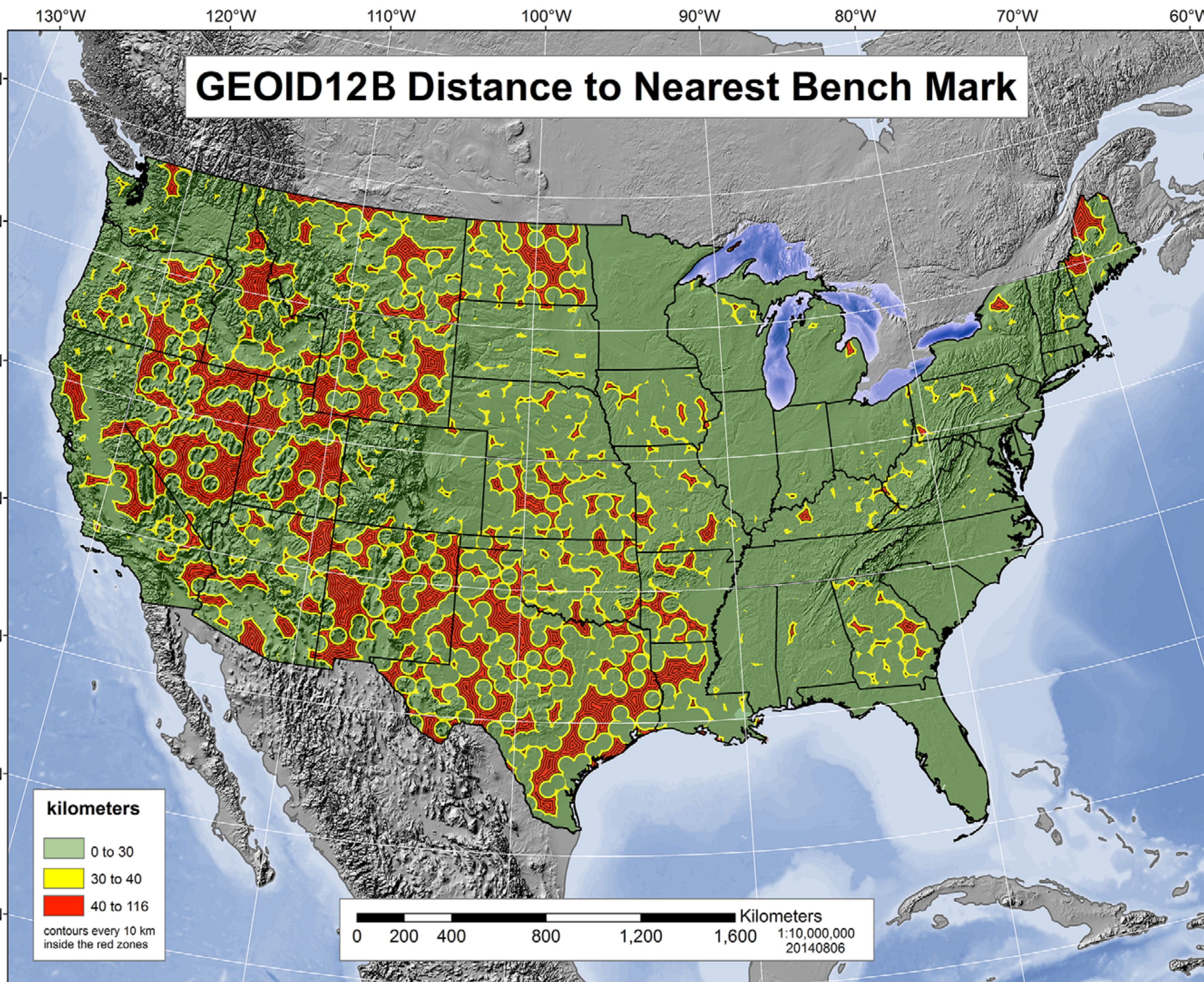
- Gravimetric Geoid systematic misfit to BMs but best fits "true" heights
- Hybrid Geoid "converted" to fit local BMs, so best fits NAVD 88 heights
- Conversion Surface model of systematic misfit derived from BMs in database

GEOID12B GPSBMs (~24,000)

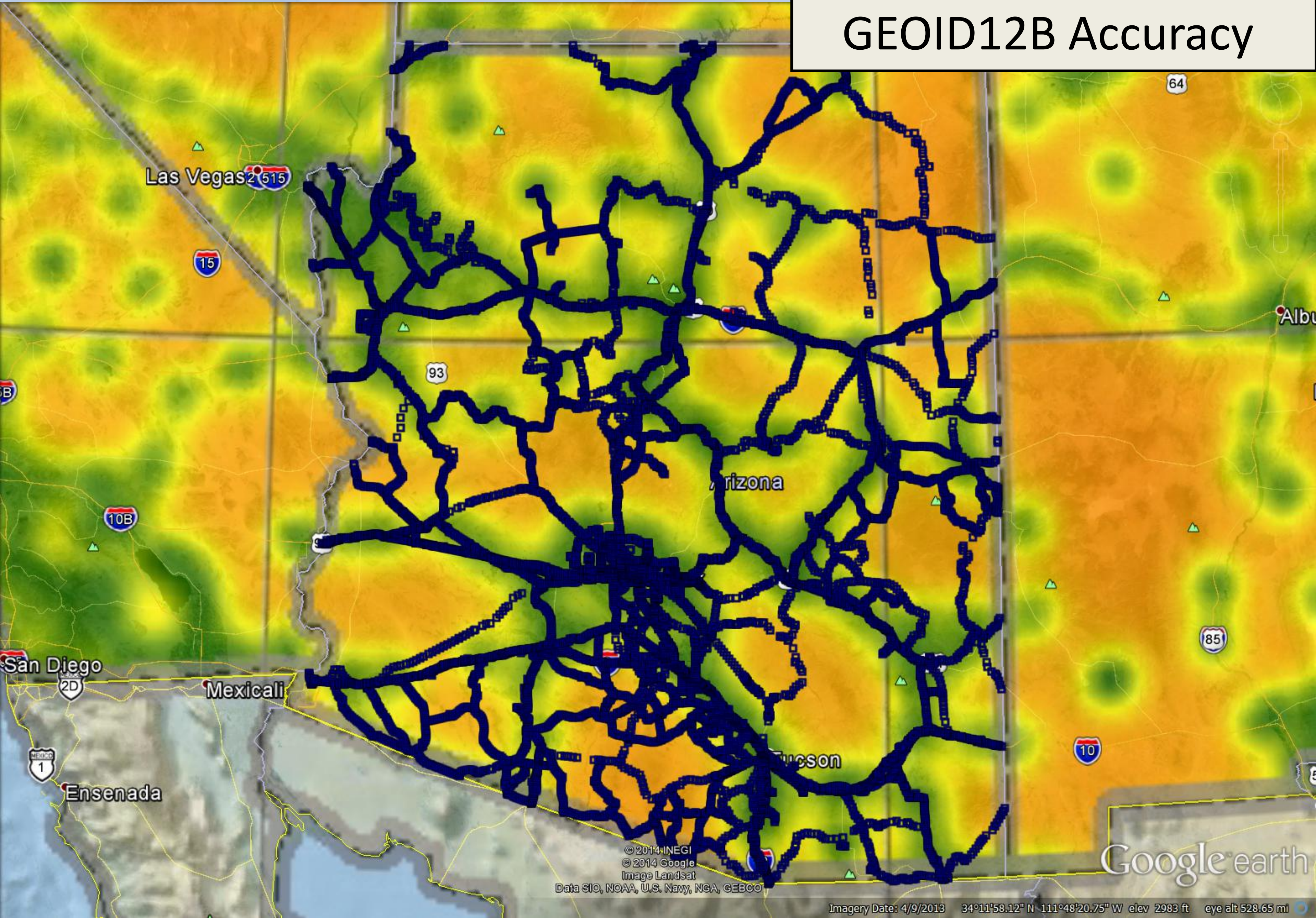




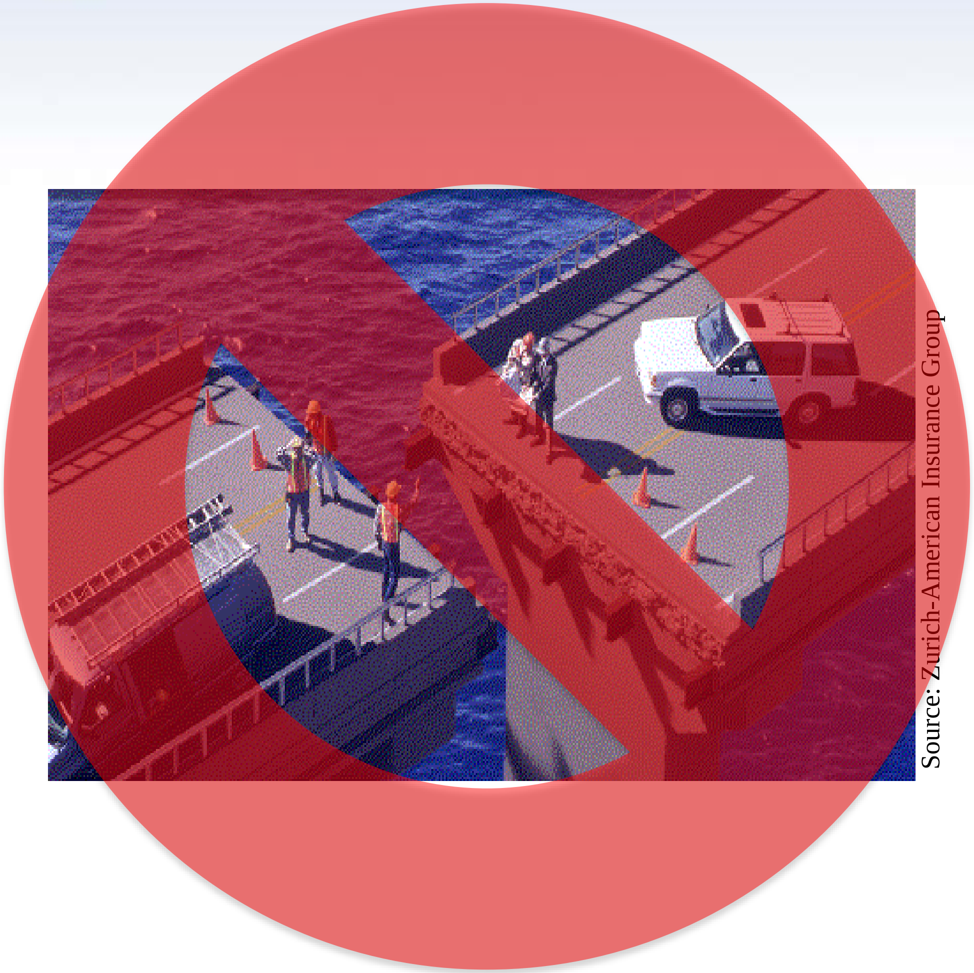



GEOID12B Distance to Nearest Bench Mark
130°W
120°W
110°W
100°W
90°W
80°W
70°W
60°W
50°N
45°N
40°N
35°N
30°N
25°N
20°N
kilometers
0 to 30
30 to 40
40 to 116
contours every 10 km inside the red zones
Kilometers
0
200
400
800
1,200
1,600
1:10,000,000
20140806

Existing NAVD88 BMs & GEOID12B Accuracy



Accurate positioning begins with *accurate* coordinates



Source: Zurich-American Insurance Group