MODERNIZATION OF THE NATIONAL SPATIAL REFERENCE SYSTEM

Keeping Pace with Changes in Positioning Technology and User Expectations in a Dynamic World

American Society for Photogrammetry and Remote Sensing

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National Spatial Reference System (NSRS)

Consistent National Coordinate System

- Latitude / Northing (SPC, UTM)
- Longitude / Easting (SPC, UTM)
- Height (Orthometric /Ellipsoid)
- Scale
- Gravity
- Orientation

and how these values change with time

File Edit View Go Bookmarks Tools Help

http://www.ngs.noaa.gov/TOOLS/

NGS Geodetic Tool Kit

on-line interactive computation of geodetic values

See the text version of an article about the NGS Geodetic Toolkit that appeared in the *Professional Surveyor* magazine, May 2003 Volume 23, Number 4

(**See all the Professional Surveyor Articles about the NGS Geodetic Toolkit**)

To learn more about a particular online program, click on its link for a description:

DEFLEC99
DYNAMIC_HT
G99SSS
GEOID99
GEOID03
USGG2003
HTDP
IGLD85
Inverse/Forward/Invers3D/Forwrd3D

LVL_DH
Magnetic Declination
NADCON
NAVD 88 Modelled Gravity
Online Adjustment User Services
Online Adjustment Utilities User Services
OPUS
State Plane Coordinates

Surface Gravity Prediction
Tidal and Orthometric Elevations
U.S. National Grid
Universal Transverse Mercator Coordinates
VERTCON
XYZ Coordinate Conversion

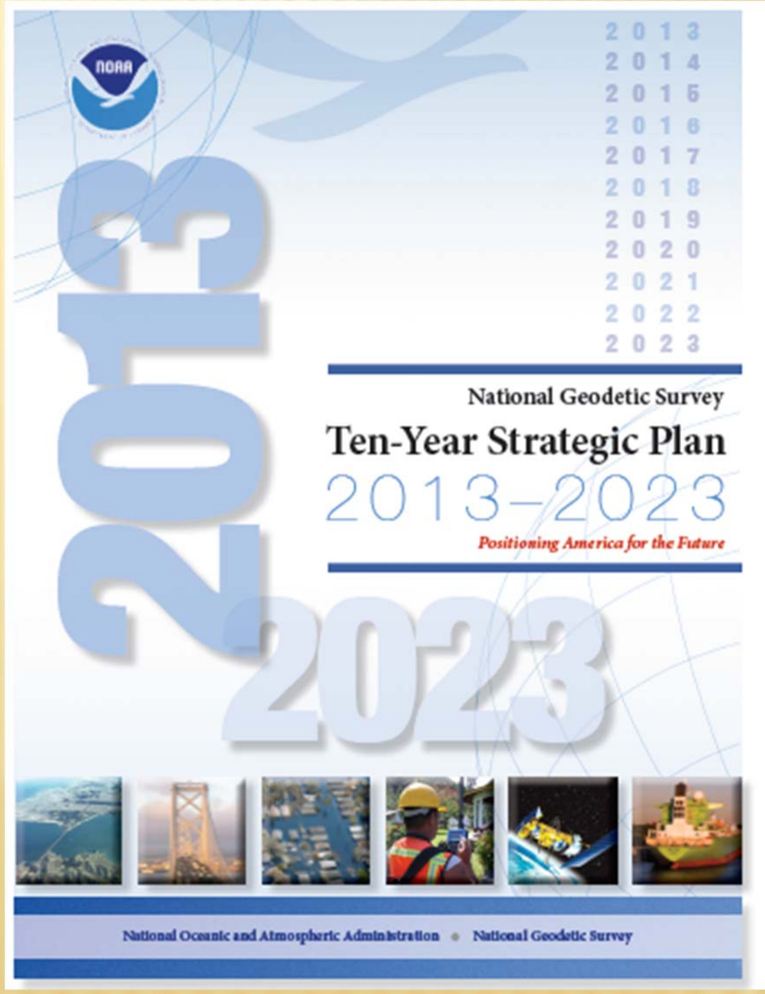
OR... Know what you want to do?
Select a function from this list:

SELECT A TOOLKIT SHORTCUT

The National Geodetic Survey 10 year plan Mission, Vision and Strategy 2013 – 2023

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

- Official NGS policy as of Jan 31, 2013
  - Updates 2008 plan
  - Modernized and Improve NSRS
  - Attention to accuracy
  - Attention to time-changes
  - Improved products and services
  - Fully vetted by NSPS/AAGS
- 2022 Targets:
  - Replace NAD 83 and NAVD 88
  - Cm-accuracy access to all coordinates



Problems with NAD 83 and NAVD 88

NAD 83 is not as geocentric as it could be (approx. 1.5 m for CONUS).
Surveyors don't see this – Yet

NAD 83 is not well defined with positional velocities

NAVD 88 is realized by passive control (bench marks) most of which have
Not been releveled in 30-40 years

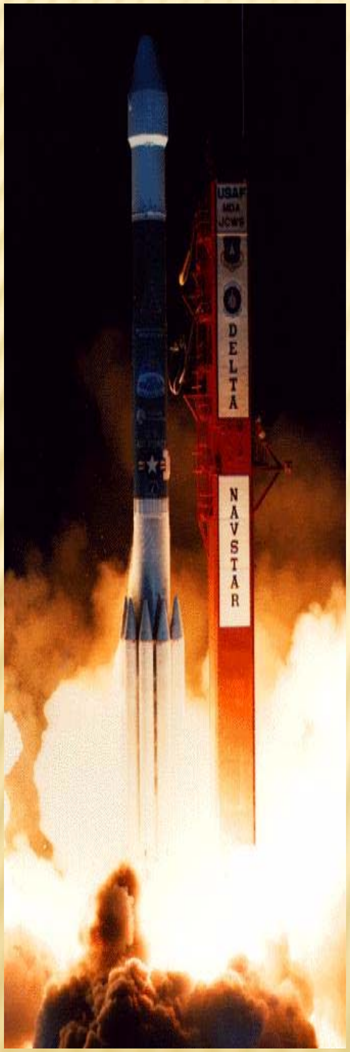
NAVD 88 does not easily account for local vertical velocities (subsidence / uplift)

- Post glacial isostatic readjustment
- Subsurface fluid/hydrocarbon extraction
- Sediment loading - Compaction
- Sea level rise

- NAVD 88 Leveled heights do not truly represent changes in gravity potential

- Current practice of computing hybrid geoid models will never result in a nation-wide system of 2 cm (or better) heights from GNSS

Global Positioning System



GPS Block I

GPS Block II

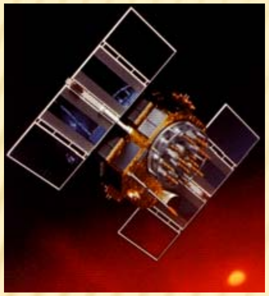
GPS Block III

- **February 22, 1978 - 1st NAVSTAR Satellite launched**
- **July 17, 1995 - System Fully Operational**
- **May 1, 2000 - Selective Availability turned off**
- **September 26, 2005 - L2C band added**
- **May 28, 2010 - First L5 Satellite added**
- **Mid 2015 – First Block III scheduled for launch**
- **2020? - 10-50 cm real-time accuracy!**

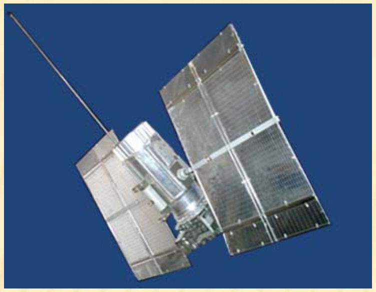
Macrometer V-1000 GPS Receiver
1982 ~ appox. $250,000 each

Where are we now??

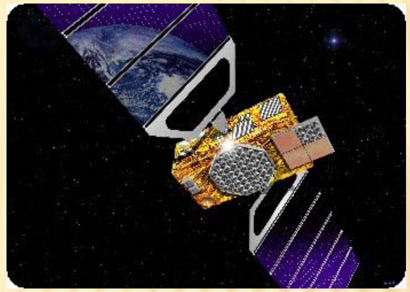
Global Navigation Satellite System



US - GPS



Russia - GLONASS



EU - Galileo

China – BeiDou

Four positioning and navigation systems

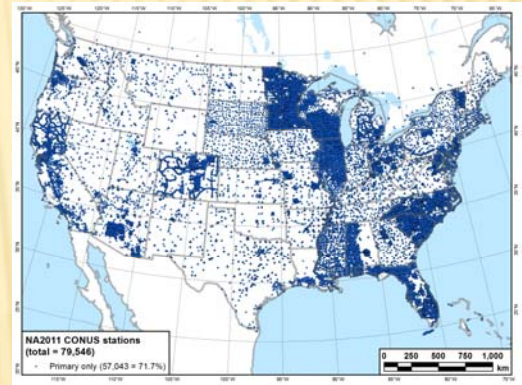
- NAVSTAR/GPS – US (Currently 31)
- GLONASS – Russia (Currently 24)
- GALILEO – EU (Currently 4, 30 by 2019)
- BEIDOU – China (30+ by 2020?)

National Spatial Reference System is Evolving

1 Million Monuments
(Separate Horizontal and Vertical Systems)

→

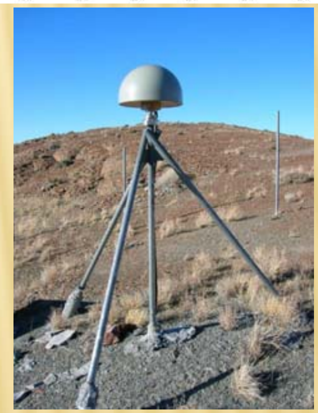
80,000 + Passive Marks
(3-Dimensional)
(HPGN/HARN)



Passive Marks
(Limited Knowledge of Stability)

→

2,000+ GPS CORS
(Time Dependent System Possible; 4-Dimensional)



GPS CORS → GNSS CORS

International Gold Standard

International Earth Rotation and Reference System Service (IERS)

Established 1987
Office in Paris, France

Produces the International Terrestrial Reference System
And
International Terrestrial Reference Frame
First ITRF – 1988
Latest ITRF - 2008

IERS Four Geodetic Services

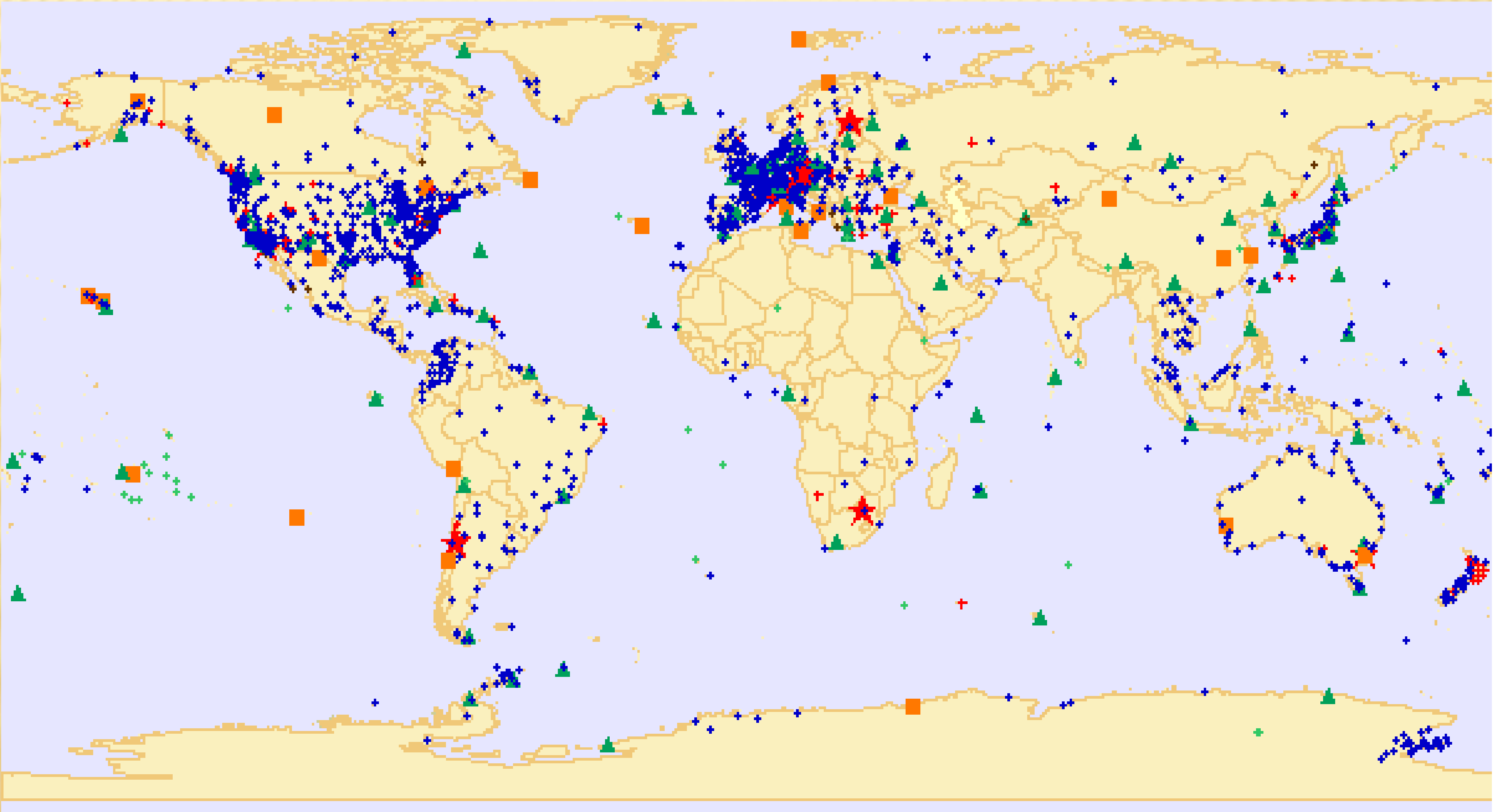
International GNSS Service

International VLBI Service

International Laser Ranging Service

International DORIS Service

IERS NETWORK



IGS08 is the GNSS component of the ITRF08
They can be considered to be equivalent

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              U.S. NAVAL OBSERV (USNO),  DISTRICT OF COLUMBIA
 ______________________________________________________________________________
|                                                                              |
|        Antenna Reference Point(ARP): U.S. NAVAL OBSERV CORS ARP              |
|        --------------------------------------------------------              |
|                           PID = AI7403                                       |
|                                                                              |
|                                                                              |
| IGS08 POSITION (EPOCH 2005.0)                                                |
| Published by the IGS in Nov 2010.                                            |
|     X =   1112189.773 m     latitude    =  38 55 08.26603 N                  |
|     Y =  -4842955.026 m     longitude   = 077 03 58.41015 W                  |
|     Z =   3985352.266 m     ellipsoid height =   48.869   m                  |
|                                                                              |
| IGS08 VELOCITY                                                               |
| Published by the IGS in Nov 2010.                                            |
|     VX =  -0.0150 m/yr      northward =   0.0040 m/yr                        |
|     VY =   0.0000 m/yr      eastward  =  -0.0146 m/yr                        |
|     VZ =   0.0024 m/yr      upward    =  -0.0011 m/yr                        |
|                                                                              |
|                                                                              |
| NAD_83 (2011) POSITION (EPOCH 2010.0)                                        |
| Transformed from IGS08 (epoch 2005.0) position in Aug 2011.                  |
|     X =   1112190.454 m     latitude    =  38 55 08.23647 N                  |
|     Y =  -4842956.480 m     longitude   = 077 03 58.39613 W                  |
|     Z =   3985352.362 m     ellipsoid height =   50.151   m                  |
|                                                                              |
| NAD_83 (2011) VELOCITY                                                       |
| Transformed from IGS08 velocity in Aug 2011.                                 |
|     VX =   0.0015 m/yr      northward =  -0.0008 m/yr                        |
|     VY =   0.0015 m/yr      eastward  =   0.0018 m/yr                        |
|     VZ =  -0.0019 m/yr      upward    =  -0.0021 m/yr                        |
|______________________________________________________________________________|
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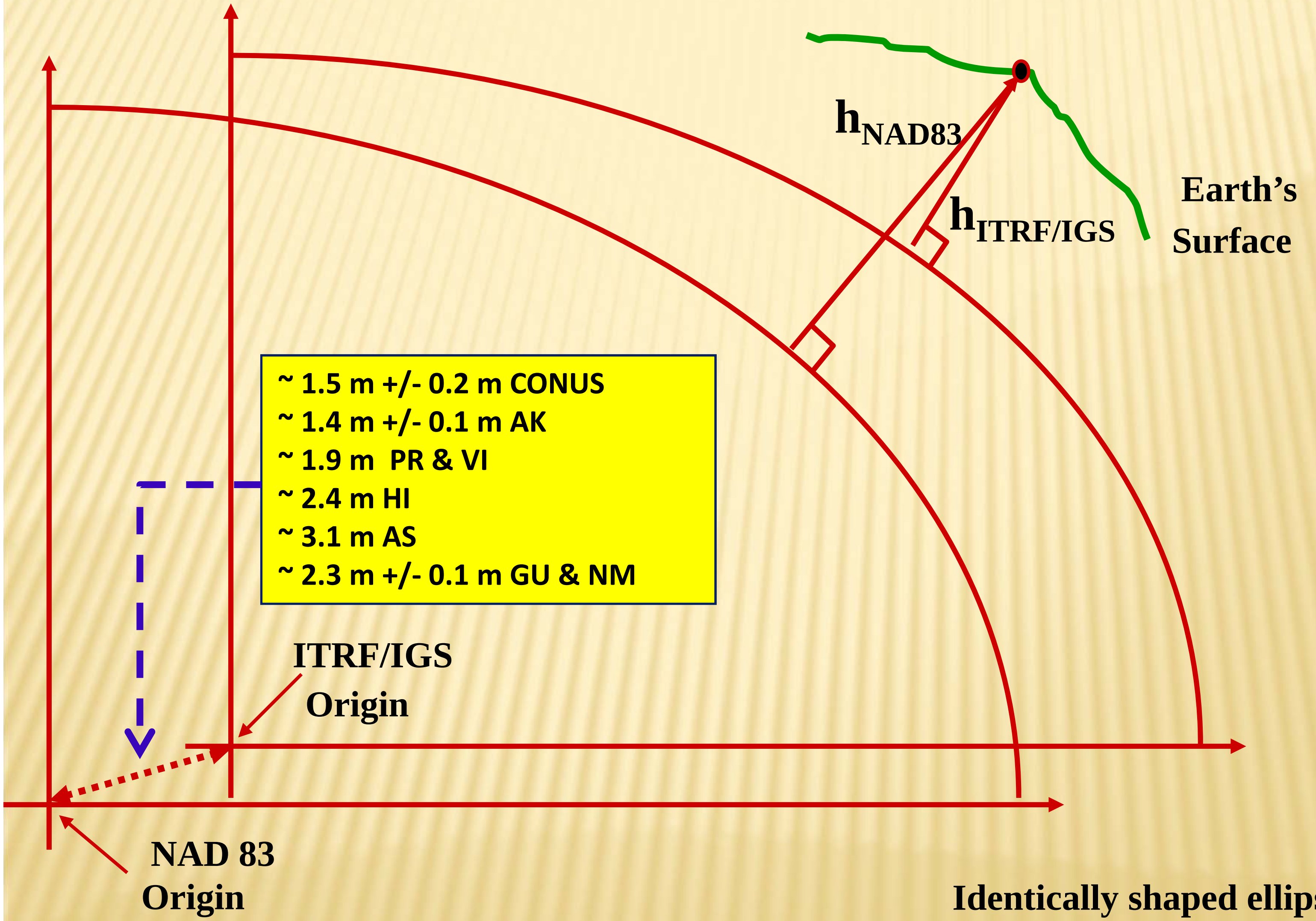
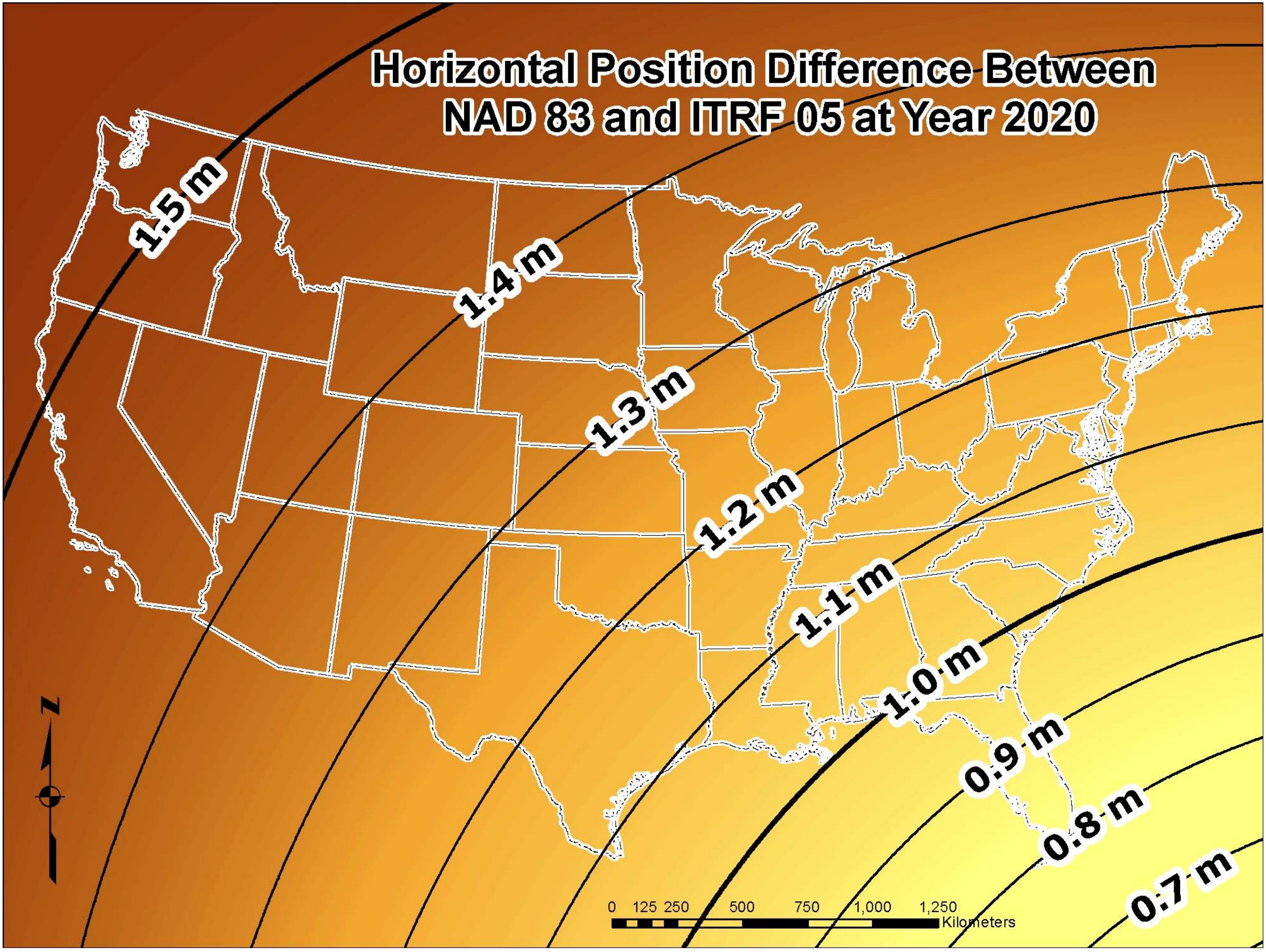
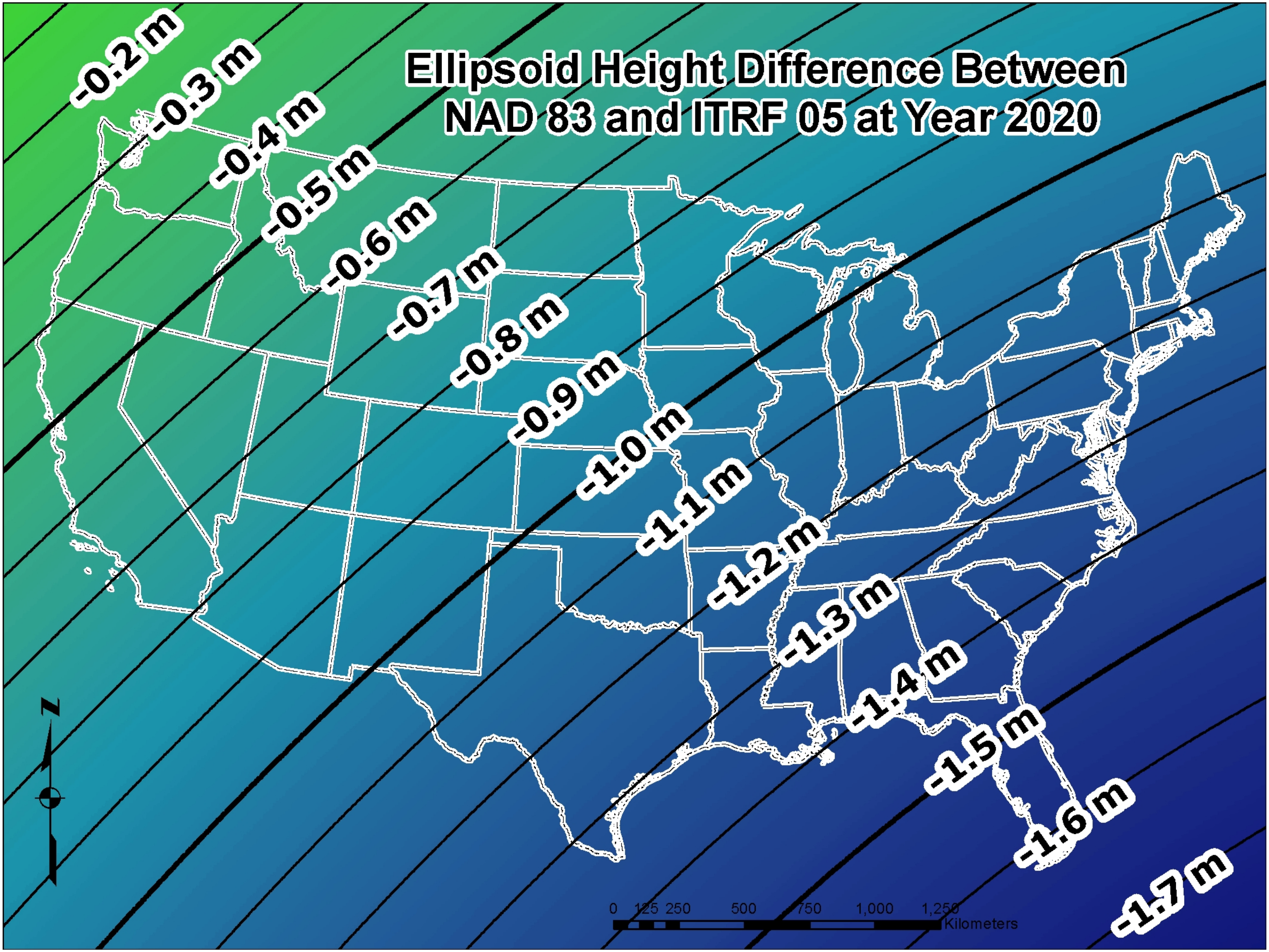
IGS08 – NAD 83(2011)
ΔHoriz = 0.972 m
ΔEHt = 1.282 m

Simplified Concept of NAD 83 vs. ITRF/IGS



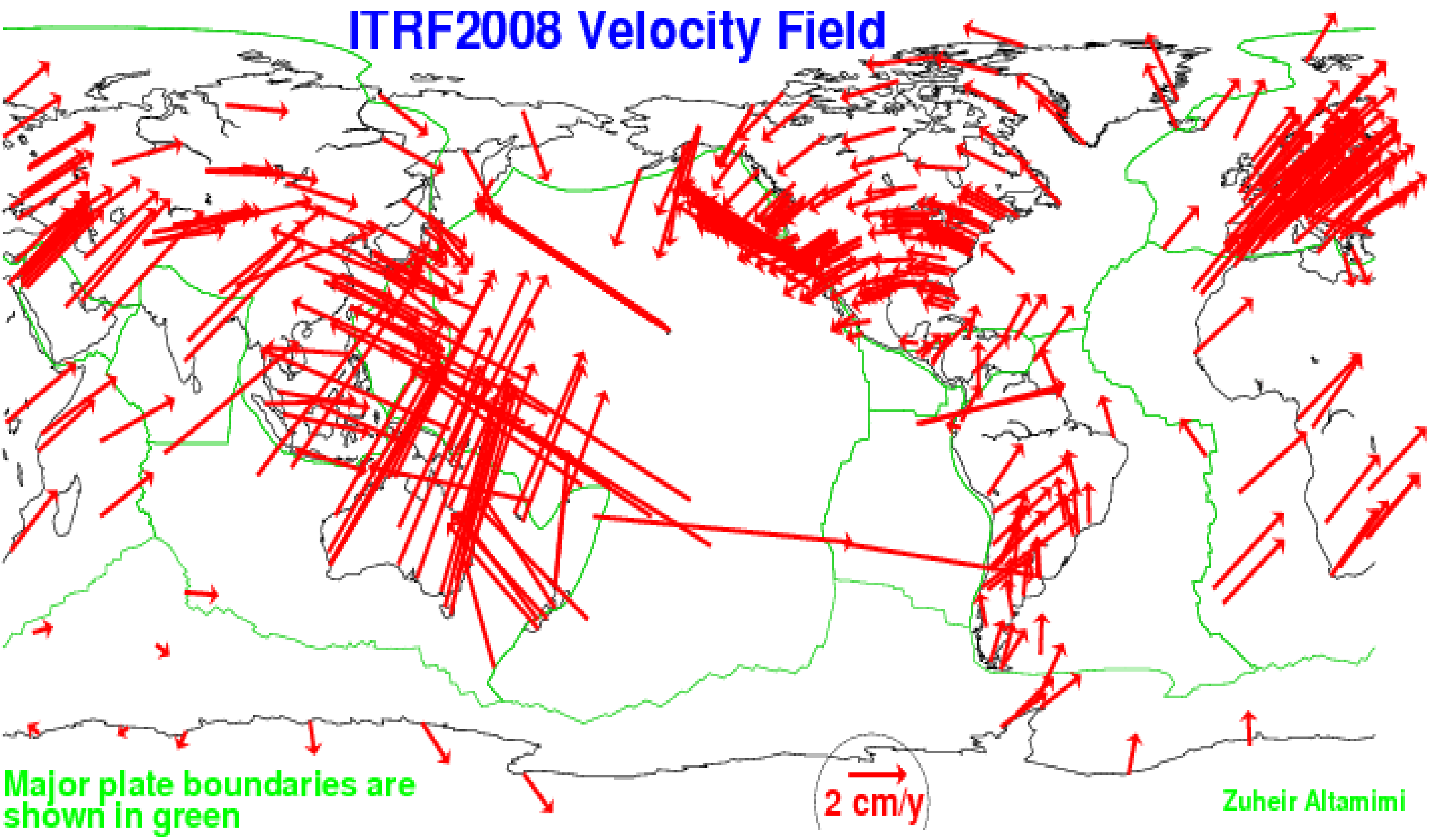
Identically shaped ellipsoids (GRS-80)
a = 6,378,137.000 meters (semi-major axis)
1/f = 298.25722210088 (flattening)


Horizontal Position Difference Between
NAD 83 and ITRF 05 at Year 2020
1.5 m
1.4 m
1.3 m
1.2 m
1.1 m
1.0 m
0.9 m
0.8 m
0.7 m
N
0 125 250 500 750 1,000 1,250
Kilometers



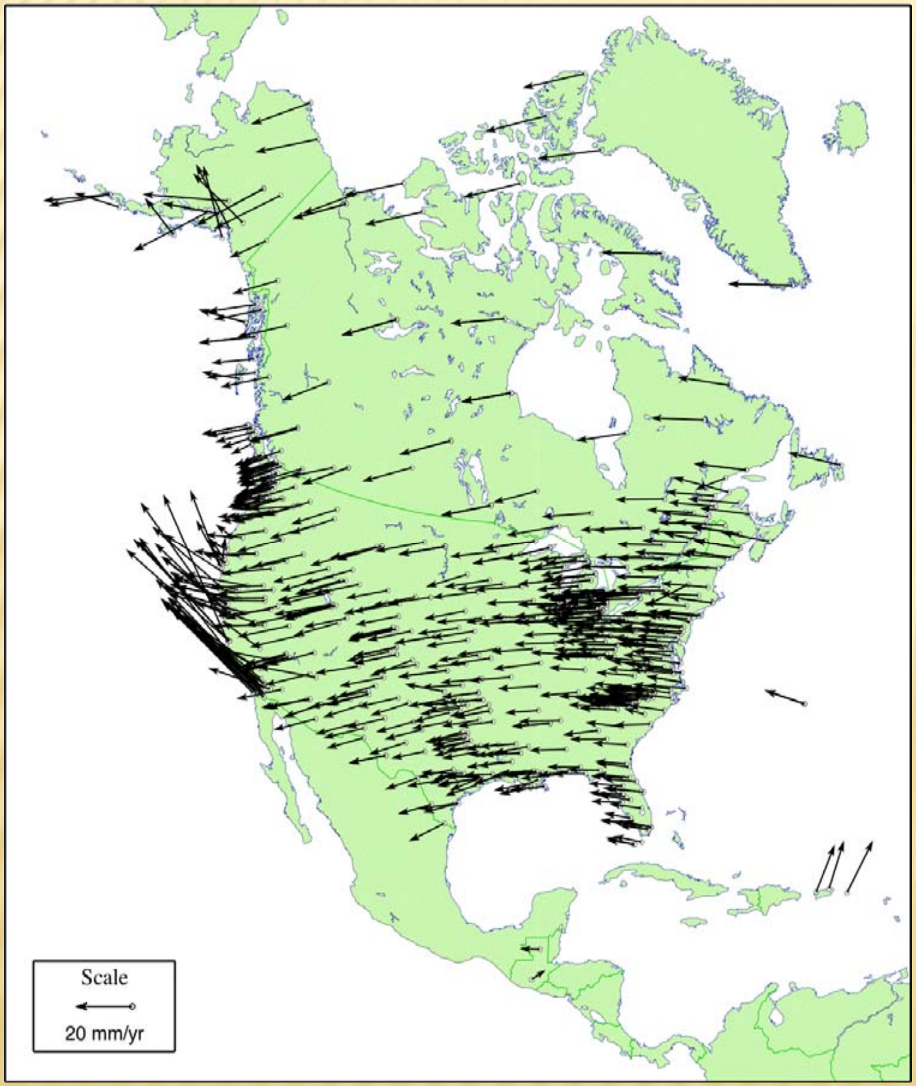
Ellipsoid Height Difference Between
NAD 83 and ITRF 05 at Year 2020
-0.2 m
-0.3 m
-0.4 m
-0.5 m
-0.6 m
-0.7 m
-0.8 m
-0.9 m
-1.0 m
-1.1 m
-1.2 m
-1.3 m
-1.4 m
-1.5 m
-1.6 m
-1.7 m
N
0 125 250 500 750 1,000 1,250
Kilometers

Tectonic Plate Velocities

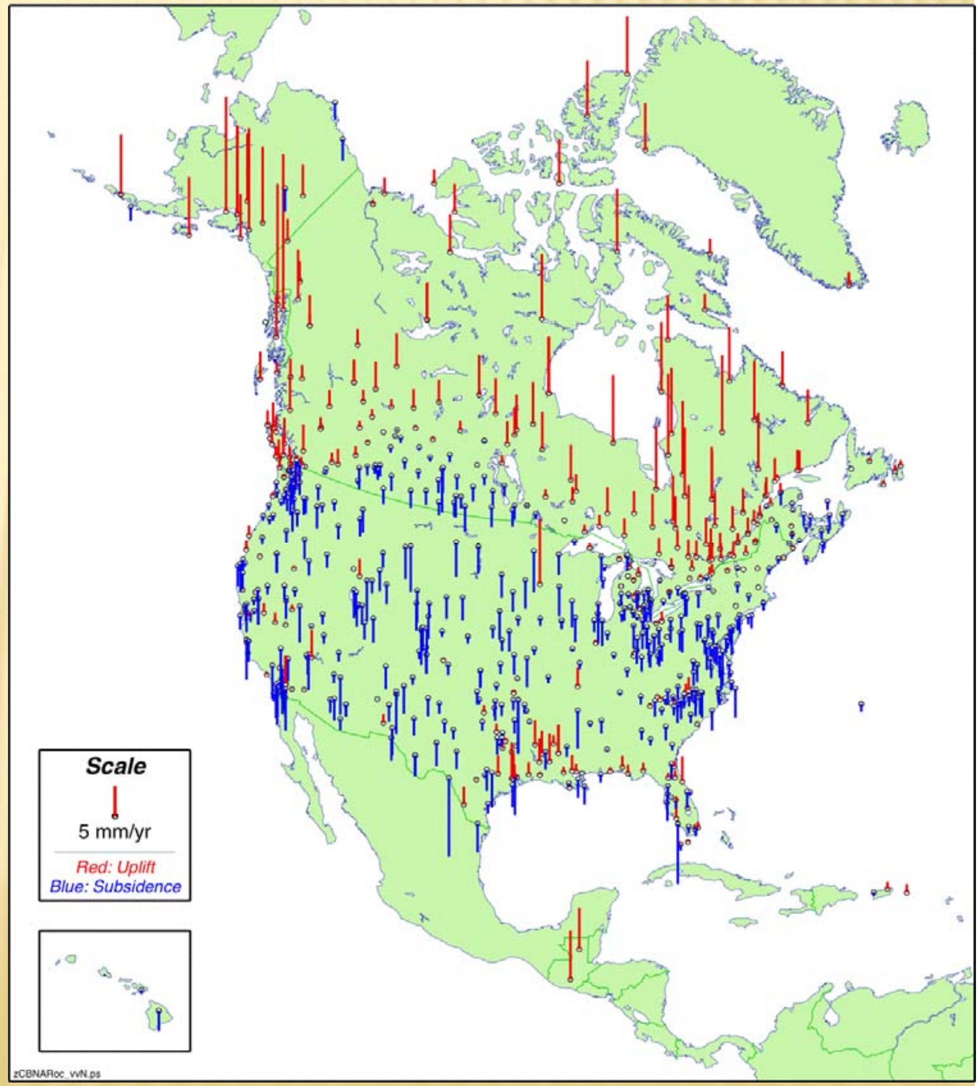


Tectonic Plate Velocities

Horizontal

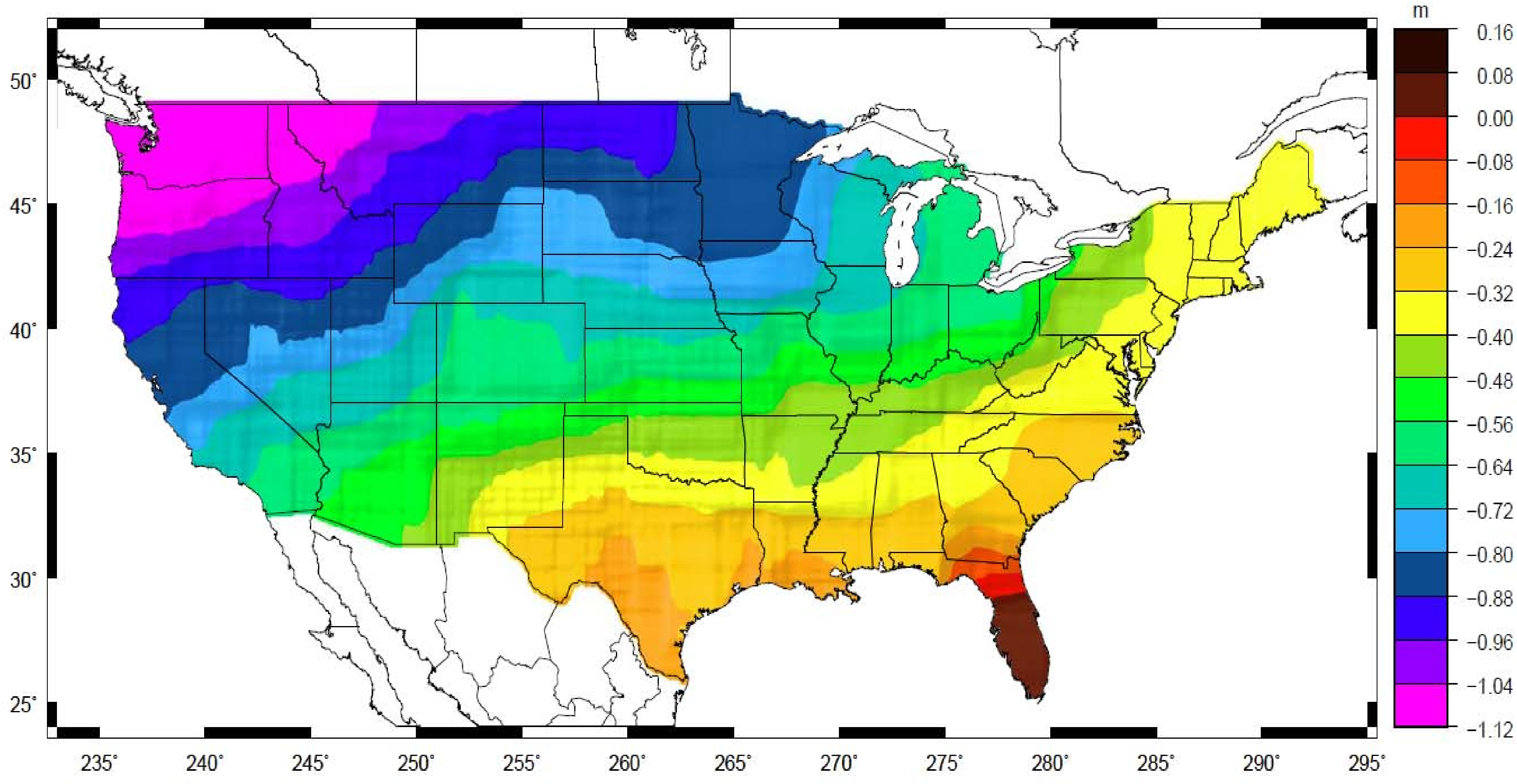


Vertical

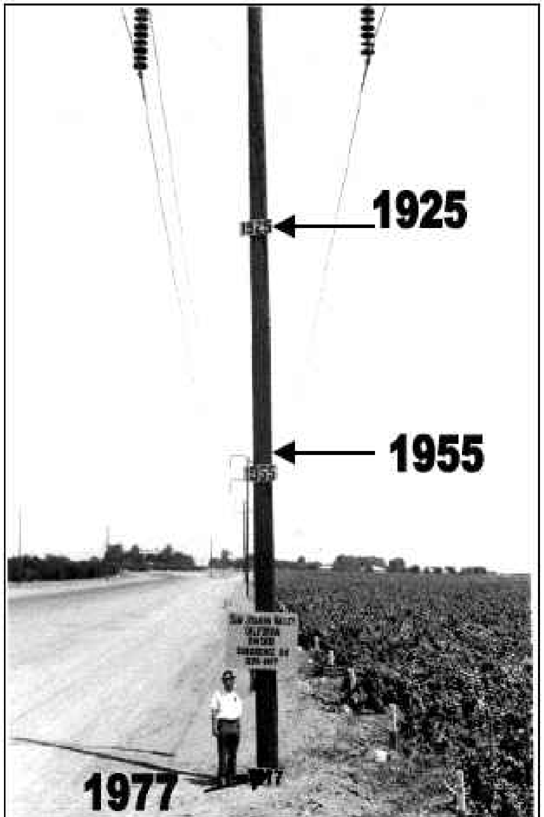


Why isn't NAVD 88 good enough anymore?

Approximate level of global geoid mismatch known to exist in the NAVD 88 zero surface:



NAVD 88 is Defined by Bench Marks That:



Approximate levels of subsidence. The signs show the position of land surface in 1925, 1955, and 1977. Although the rate of subsidence has decreased, the continued pumping of ground water has resulted in additional subsidence in the past 20 years.

Figure 6 Subsidence in California's Central Valley

-- Are rarely re-leveled for movement

-- Disappear by the hundreds every year

-- Are not funded for replacement

-- Are not often readily located for GPS observations

-- Don't exist in most of Alaska

-- Determined by leveling from a single point allowing cross-country error build up.

"THE" GEOID

An equipotential surface to which gravity is normal and most closely approximates Mean Sea Level over the entire Earth.

So What Do We have in the U.S.??

Types of Geoid Height Models

Gravimetric (or Gravity) Geoid Height Models

(e.g. USGG2012, USGG2009)

Defined by gravity data crossing the geoid

Refined by terrain models (DEM's)

Scientific and engineering applications

Composite (or Hybrid) Geoid Height Models

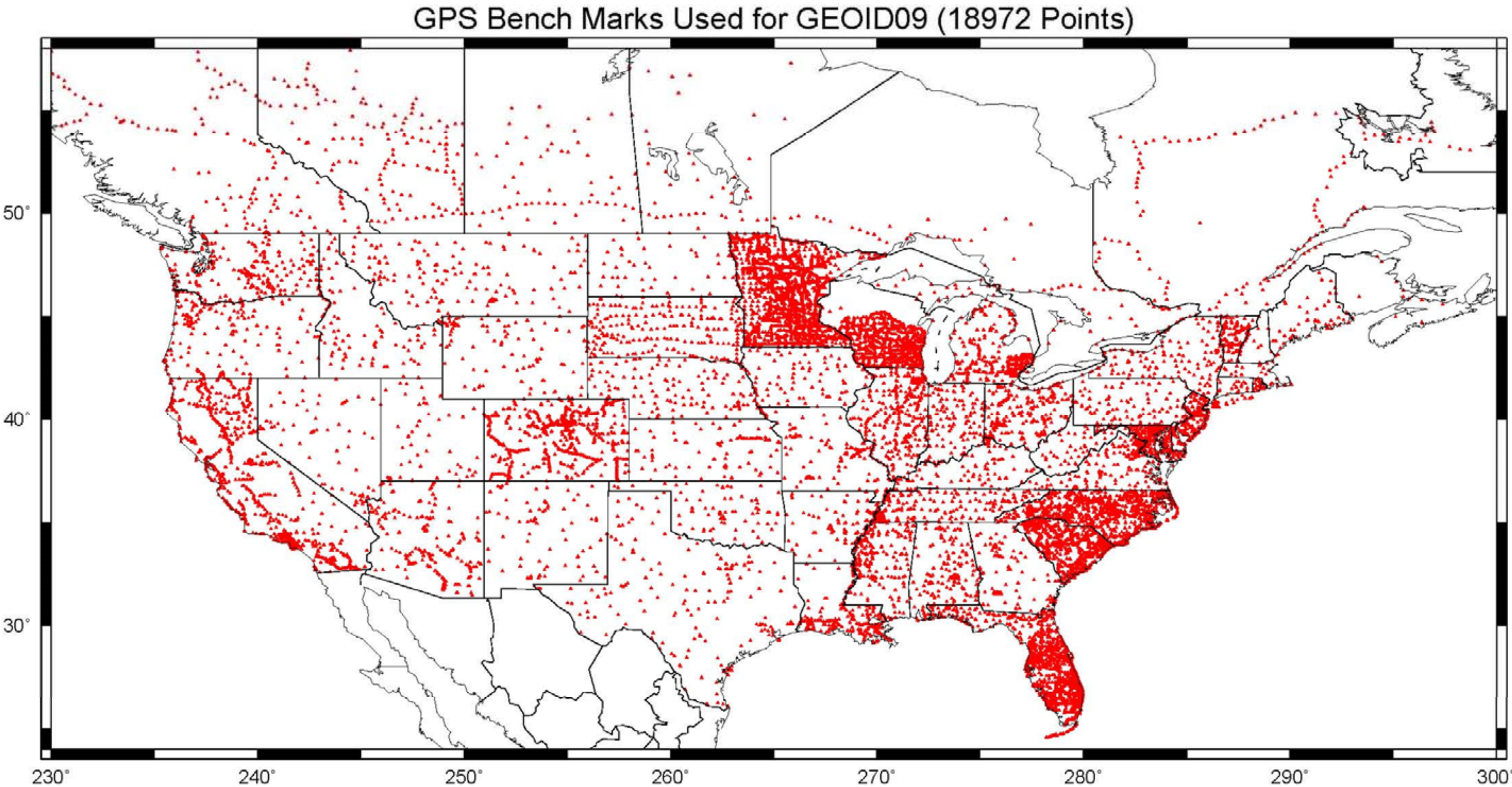
(e.g. GEOID12A, GEOID09)

Starts with gravimetric geoid

Warped to fit available GPSBM control data

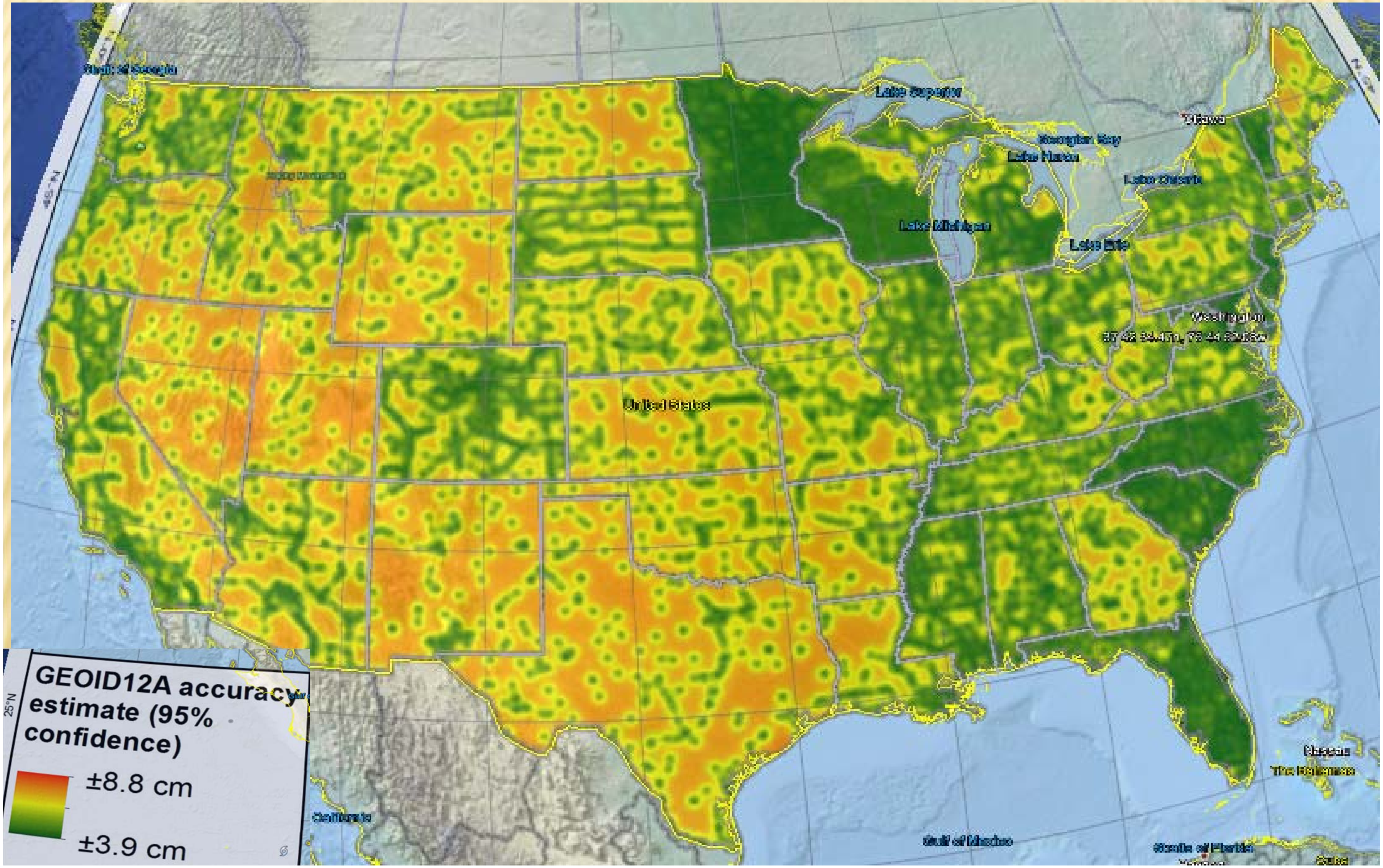
Defined by legislated ellipsoid (NAD 83) and local vertical datum (NAVD 88, PRVD02, etc.)

May be statutory for some surveying & mapping applications



GPSBM1999: 6,169 total 0 Canada STDEV 9.2 cm (2σ)
GPSBM2003: 14,185 total 579 Canada STDEV 4.8 cm (2σ)
GPSBM2009: 18,291 total 576 Canada STDEV 2.8 cm (2σ)

CONUS GEOID 12A ACCURACY
Available only in DSWorld
http://www.ngs.noaa.gov/PC_PROD/PARTNERS/index.shtml



Transition to the Future – GRAV-D

Gravity for the Redefinition of the American Vertical Datum

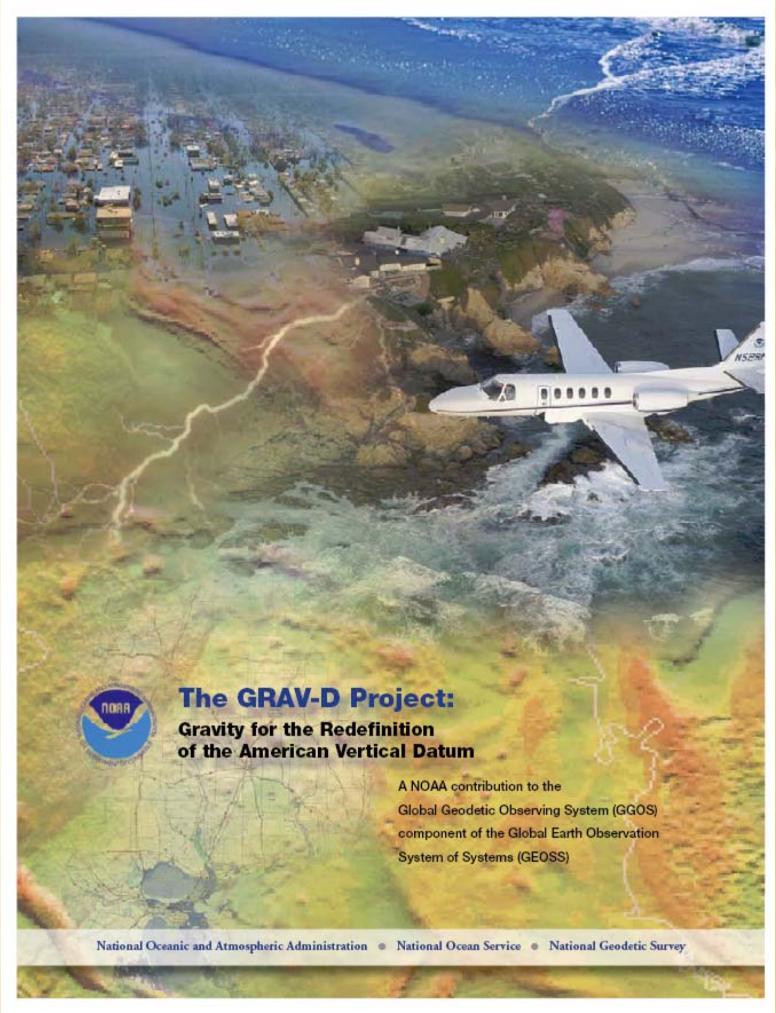
Official NGS policy as of Nov 14, 2007
$38.5M over 10 years

Airborne Gravity Snapshot

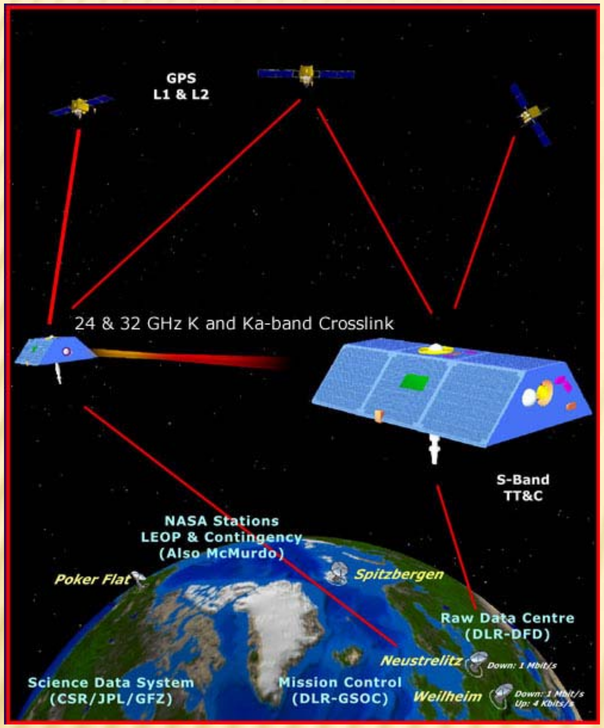
Absolute Gravity Tracking

Re-define the Vertical Datum of the USA by 2022

Approximately 35% Complete



Space-Base Gravity Observations



Gravity Recovery And Climate Experiment (GRACE)

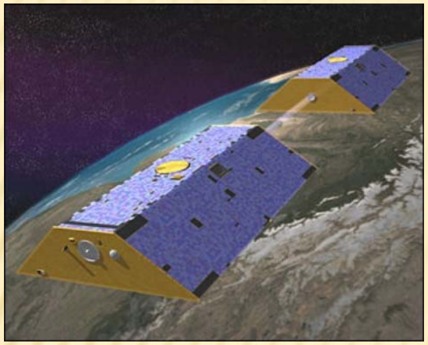
Launched - 2002

Gravity field and steady state Ocean Circulation Explorer (GOCE)

Launched – 2009

Reentered November 2013

Building a model of the Earths Gravity Field

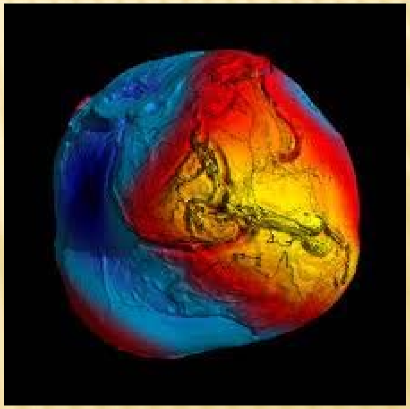


GRACE & GOCE Satellites

Airborne Measurement

Surface Measurement

Long Wavelengths:
(≥ 400 km)



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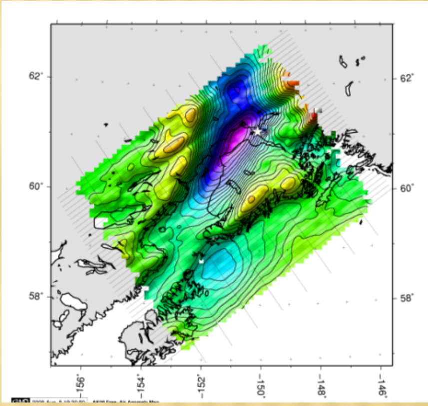
Intermediate Wavelengths
(500 km to 20 km)



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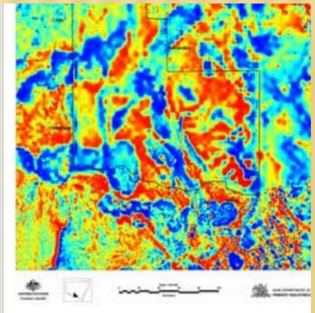
Short Wavelengths
(< 200 km)



Why GRAV-D?

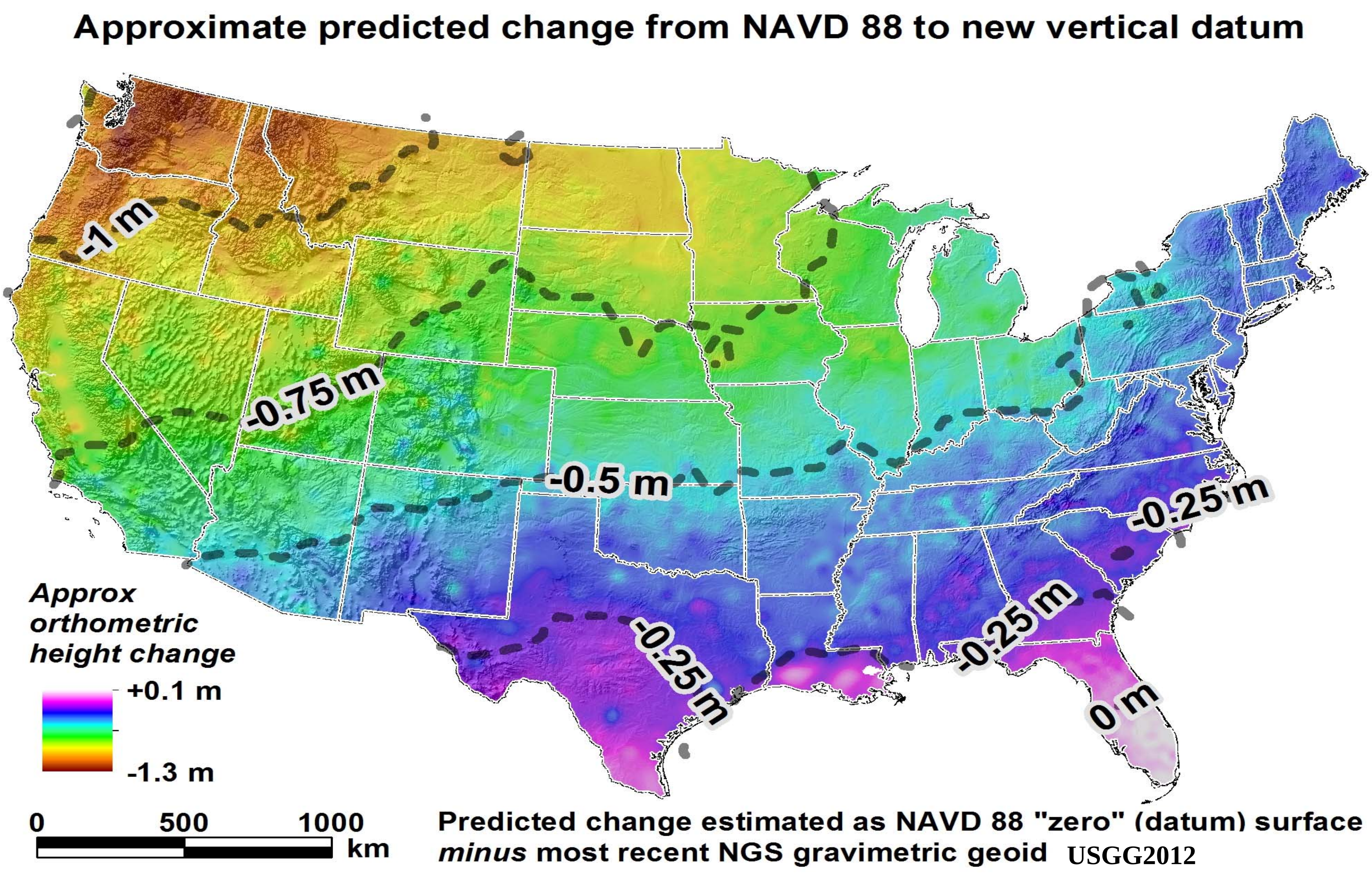
- A relatively small workforce can update the geoid as compared to the large workforce needed to re-level bench marks
- As the H=0 surface, the geoid will be tracked over time to keep the datum up to date
- A 2 cm target accuracy anywhere that GNSS receivers can be used, kept up to date through monitoring CORS and the geoid, is better than the accuracy and accessibility of NAVD 88 today
- It is far cheaper than leveling
- The geoid can't be bulldozed out of usefulness
- The effect of subsidence upon the realization will be known (and accounted for) by monitoring CORS and monitoring the geoid

How will you access the new vertical datum?

Primary access (NGS mission)

- **Users with geodetic quality GNSS receivers will continue to use RTNs, RTK and OPUS suite of tools**
- **Ellipsoid heights computed, and then a gravimetric geoid height applied to provide orthometric heights in the new datum**
- **No passive marks needed**
- **But, could be used to position a passive mark**

Geopotential Datum Changes



USGG2012

Predicated Positional Changes in 2022 in Washington D.C.
Computed for JEFFERSON PIER (UA0024)

HORIZONTAL = 1.14 m (3.7 ft)
ELLIPSOID HEIGHT = - 1.29 m (- 4.2 ft)
Computed with HTDP

ORTHOMETRIC HEIGHT = - 0.41 m (- 1.3 ft)
Computed with USGG2012

Can be easily computed from OPUS Extended Output

1: INVERSE NAD 83 (2011) and IGS08 Lat/Long
2: Subtract NAD 83 (2011) Eht from IGS08 Eht
3: Extended output gives estimated 2022 Orthometric Height

Predicated Positional Changes in 2022 near Seattle, WA

Computed for HAFF (SY5646)

HORIZONTAL = 1.49 m (4.9 ft)

ELLIPSOID HEIGHT = - 0.34 m (- 1.1 ft)

Predicted with HTDP

ORTHOMETRIC HEIGHT = - 1.23 m (- 4.0 ft)

Predicted with USGG2012

Can be easily computed from OPUS Extended Output

1: INVERSE NAD 83 (2011) and IGS08 Lat/Long
2: Subtract NAD 83 (2011) Eht from IGS08 Eht
3: Extended output gives estimated 2022 Orthometric Height

Predicated Positional Changes in 2022
Hawaii, Puerto Rico, Virgin Island

HAWAII

HORIZONTAL = 2.44 m (8.0 ft)
ELLIPSOID HEIGHT = 0.28 m (0.9 ft)
ORTHOMETRIC HEIGHT = - 0.74 m (- 2.4 ft)

PUERTO RICO

HORIZONTAL = 0.63 m (2.1 ft)
ELLIPSOID HEIGHT = - 1.87 m (- 6.1 ft)
ORTHOMETRIC HEIGHT = 0.35 m (1.2 ft)

U.S. VIRGIN ISLANDS

HORIZONTAL = 0.65 m (2.1 ft)
ELLIPSOID HEIGHT = - 1.88 m (- 6.2 ft)
ORTHOMETRIC HEIGHT = 0.39 m (1.3 ft)

What can you do to get ready for 2022??

Understand the impact of changing positions and heights for your community, company or agency

Consider legislative changes to federal regulations, state legislation and codes

Should NGS continue to publish State Plane Coordinates?
If yes:
Retain or change NAD 83 geometric parameters?

Communicate your issues directly to NGS
Joe Evjen – joe.evjen@noaa.gov
Mark Eckl – mark.eckl@noaa.gov

GOOD COORDINATION BEGINS WITH GOOD COORDINATES

GEOGRAPHY WITHOUT GEODESY IS A FELONY