Modernization of the National Spatial Reference System

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

MSGIC Spring Mtg

Denton

April 23, 2014

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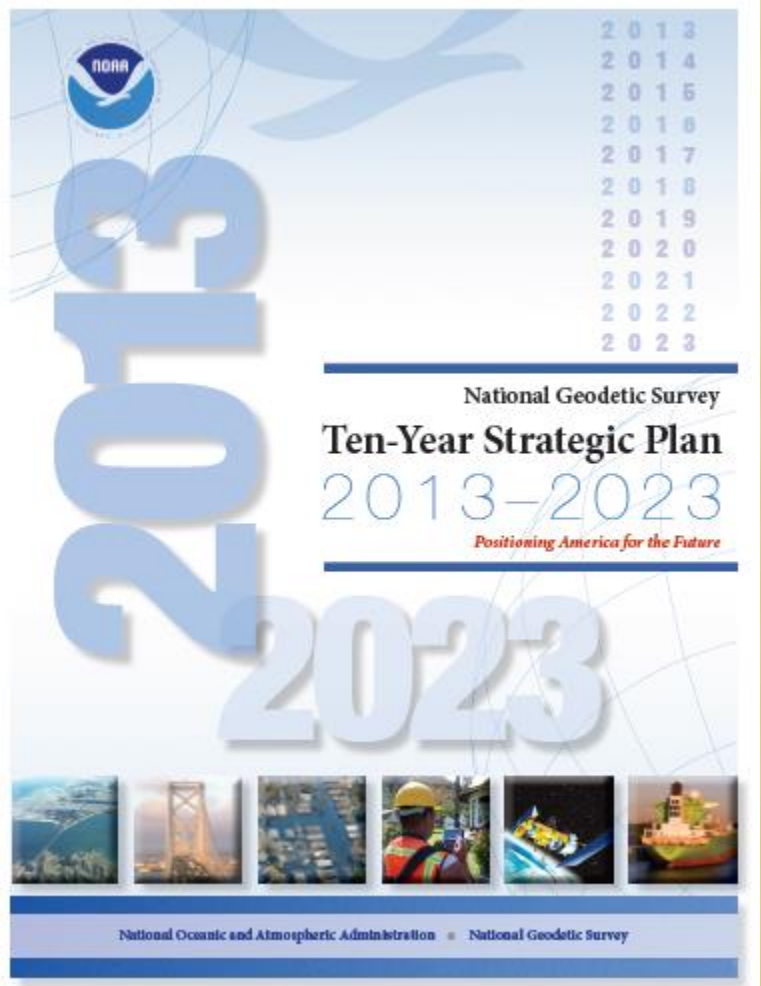
The National Geodetic Survey 10 year plan
Mission, Vision and Strategy
2013 – 2023

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



National Spatial Reference System (NSRS)

Consistent National Coordinate System

- Latitude/Northing (SPC or UTM)
- Longitude/Easting (SPC or UTM)
- Height
- Scale
- Gravity
- Orientation

and how these values change with time

File Edit View Go Bookmarks Tools Help

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

Go

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

Global Positioning System

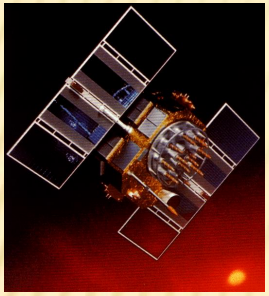
GPS Block I

GPS Block II

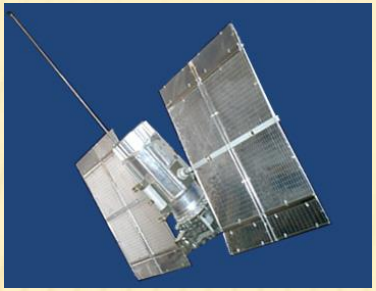
GPS Block III

- 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!

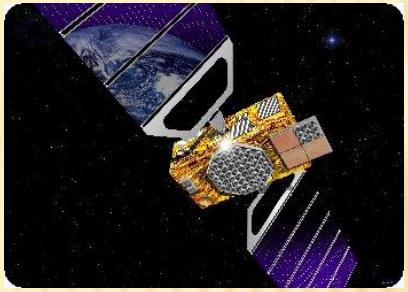
Global Navigation Satellite System



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, 24 by 2019)
- BEIDOU – China (30+ by 2020?)

GEODETIC DATUMS

HORIZONTAL

2-D (Latitude and Longitude)
U.S. Standard Datum, NAD 27, NAD 83 (1986)
Fixed and Stable - Coordinates seldom change

GEOMETRIC

3-D (Latitude, Longitude and Ellipsoid Height)
Fixed and Stable - Coordinates seldom change
NAD 83 (1991), NAD 83 (CORS96), NAD 83 (2007), NAD 83 (2011)

4-D (Latitude, Longitude, Ellipsoid Height, Velocities) Coordinates change with time (e.g. ITRF00, IGS08)

VERTICAL

1-D (Orthometric Height) (Leveling constrained to 1 or more long-term tide stations) (e.g. NGVD 29, NAVD 88)

GEOPOTENTIAL

1-D (Orthometric Height) (Realized by GNSS + High Accuracy Gravimetric Geoid Model – e.g. GRAV-D)

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

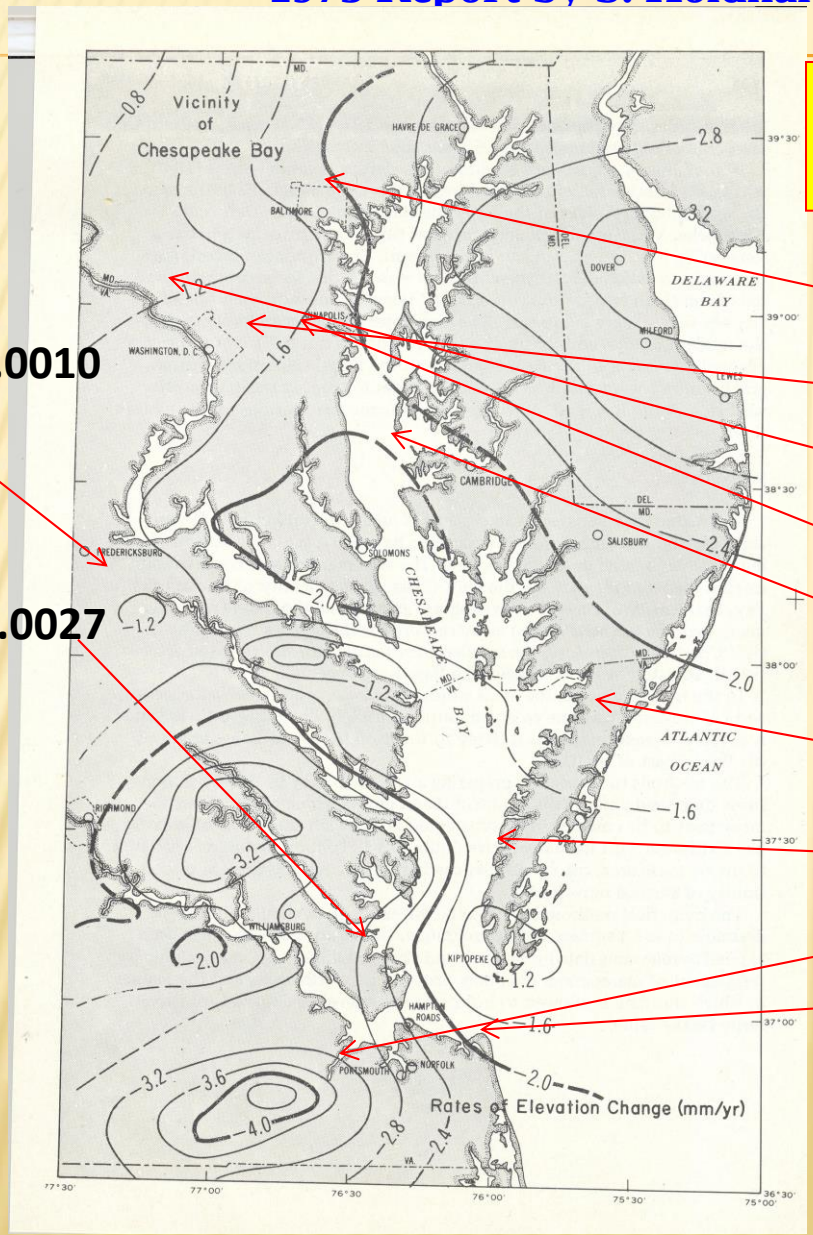
NAVD 88 does not easily account for local vertical velocities (subsidence / uplift)

- **Post glacial isostatic readjustment – Glacial forebulge collapse**
- **Subsurface fluid/hydrocarbon extraction**
- **Sediment loading - Compaction**
- **Sea level rise - Ocean City = + 5.5 mm/yr (1.6 ft in 100 years)**
  Baltimore = + 3.1 mm/yr (1.0 ft in 100 years)

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

Subsidence in the area of Chesapeake Bay

1973 Report by S. Holdhal and N. Morrison



IGS08
Vertical Velocity at Selected CORS

CORB = - 0.0010

VAGP = - 0.0027

BACO = - 0.0032

GODE = - 0.0011

GAIT = - 0.0004

ANP6 = - 0.0016

HNPT = - 0.0024

VAWI = - 0.0043

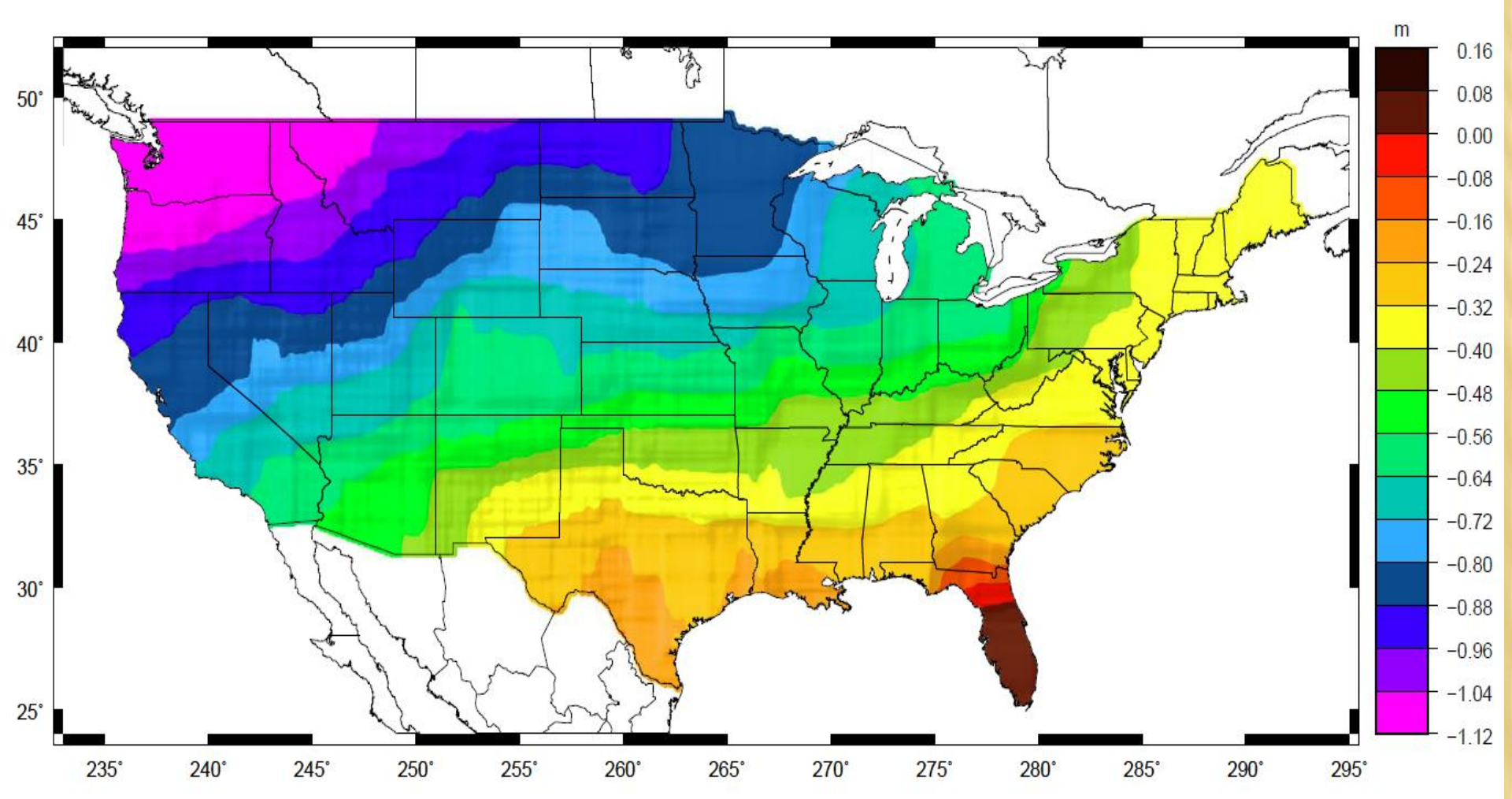
VIMS = - 0.0034

DRV6 = - 0.0033

COVX = - 0.0016

Why isn't NAVD 88 good enough anymore?

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

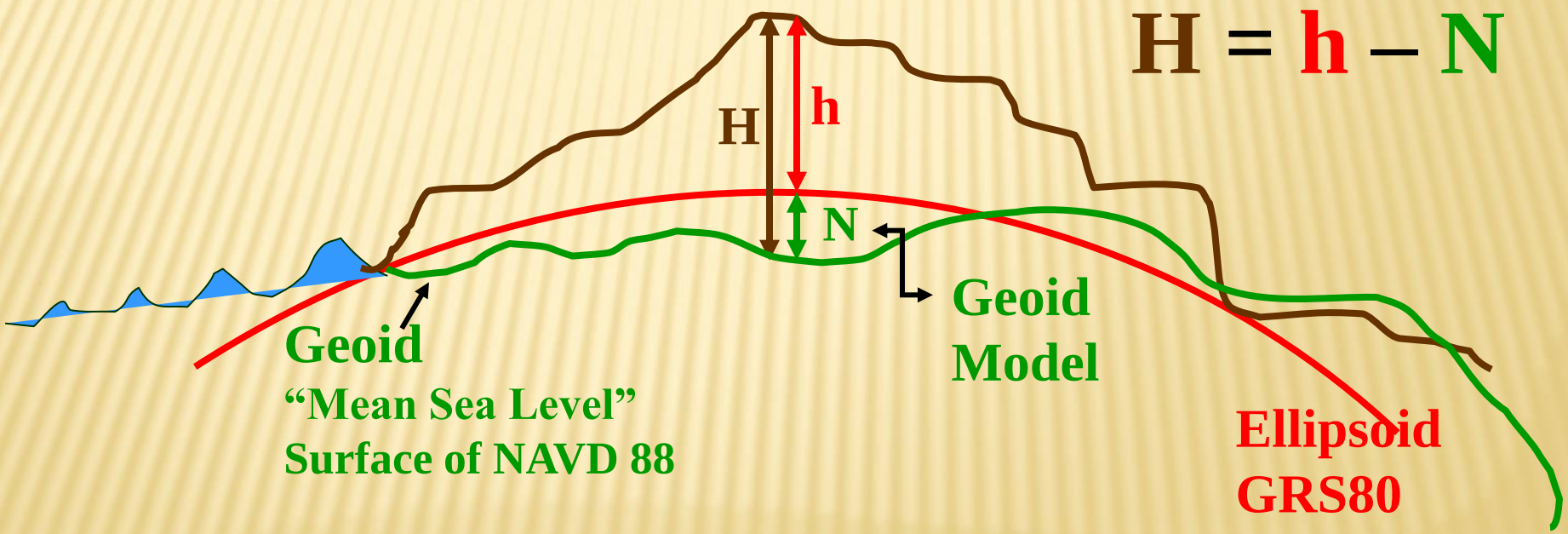


ELLIPSOID – GEOID RELATIONSHIP

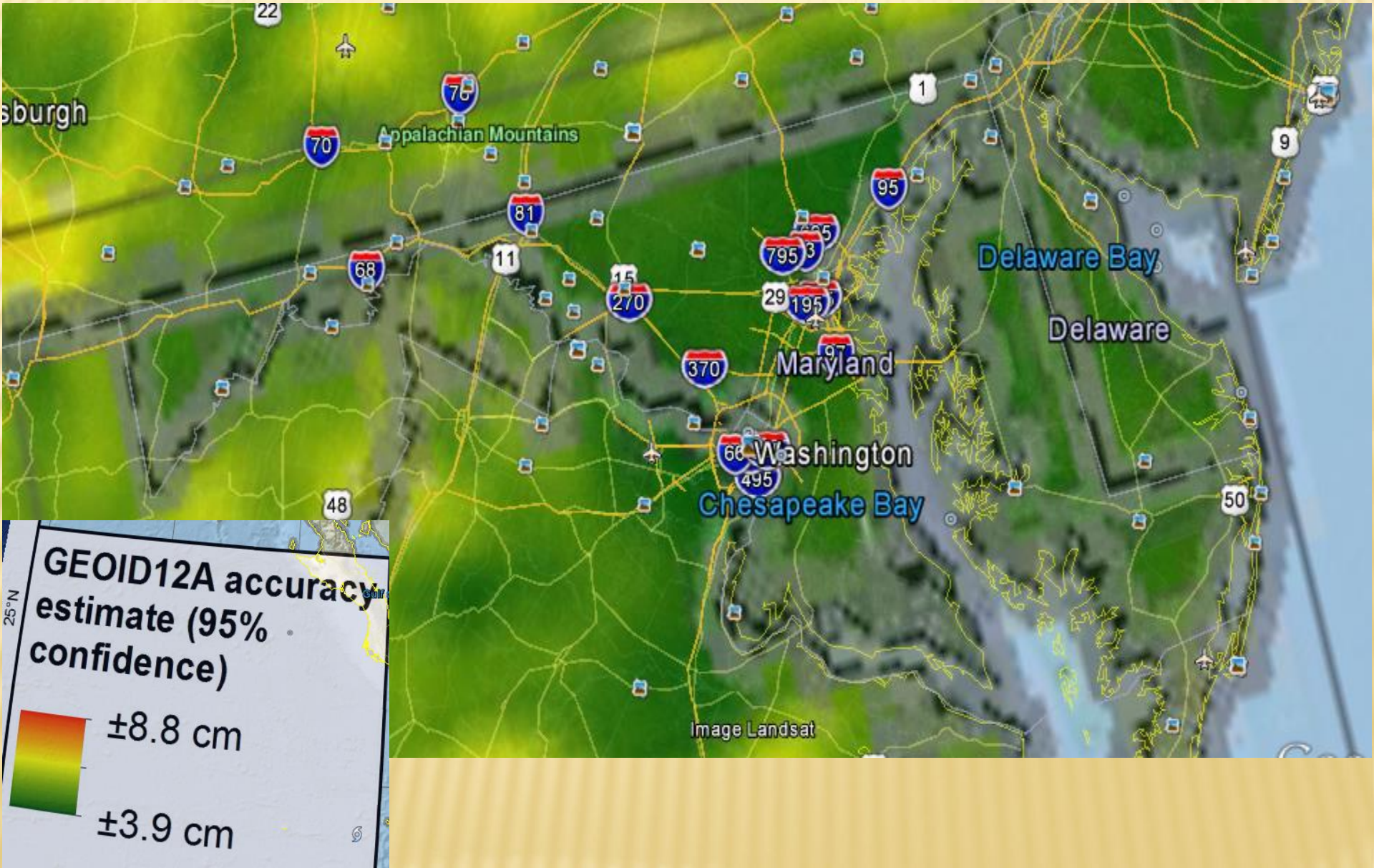
H = Orthometric Height (NAVD 88)

h = Ellipsoid Height (NAD 83 (2011))

N = Geoid Height (GEOID12A)



GEOID 12A ACCURACY IN MARYLAND



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

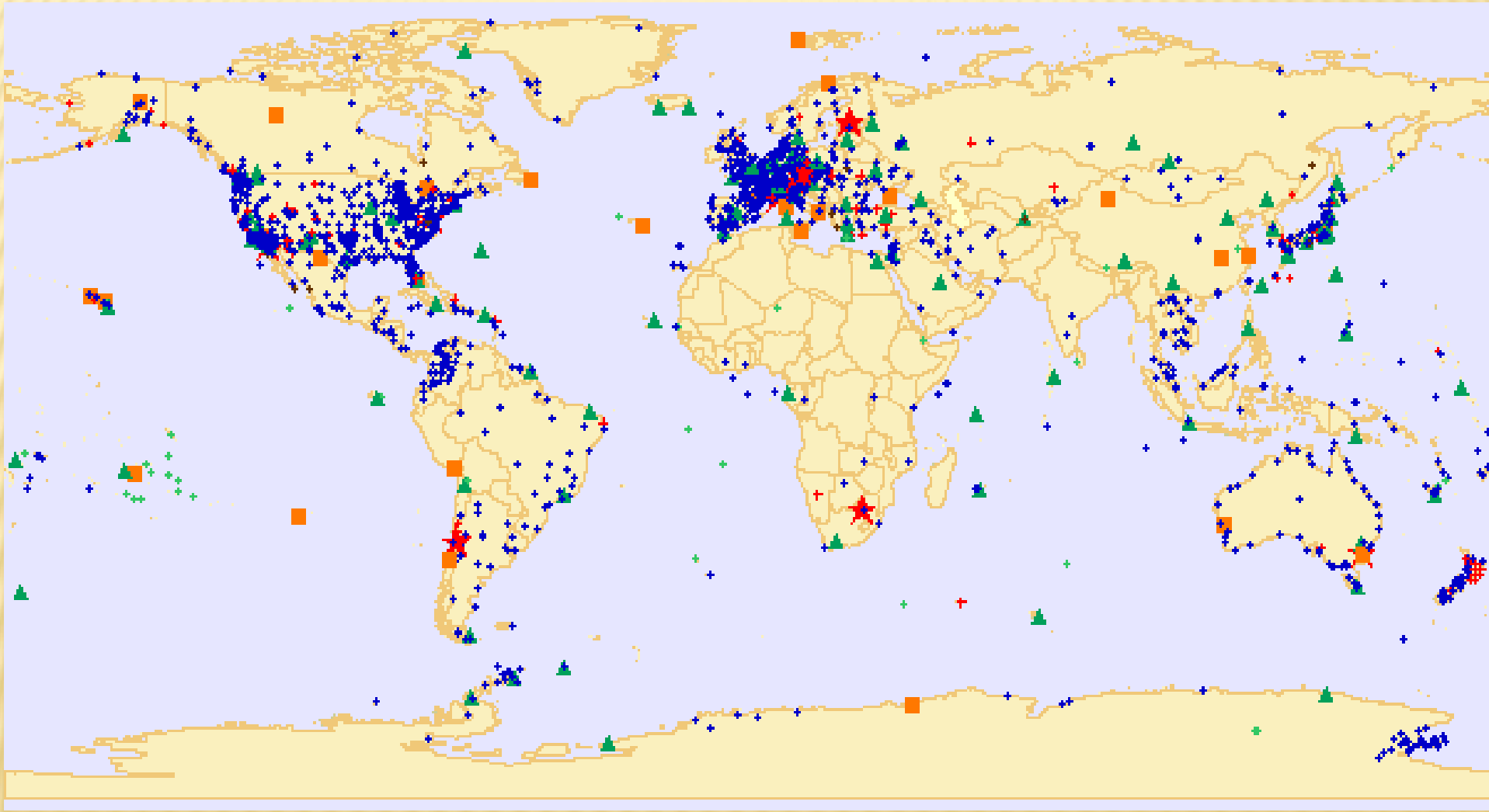
International GNSS Service

International VLBI Service

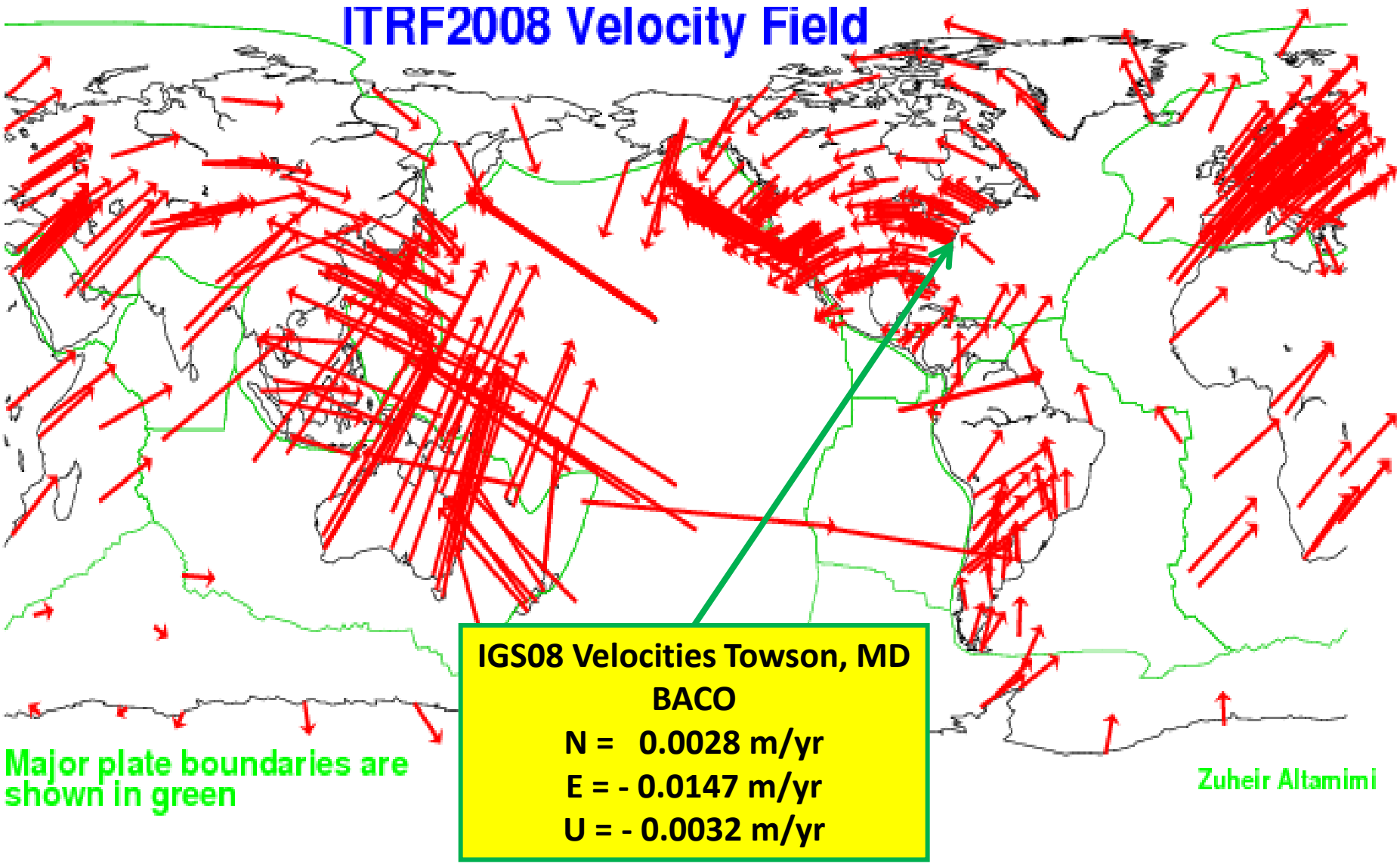
International Laser Ranging Service

International DORIS Service

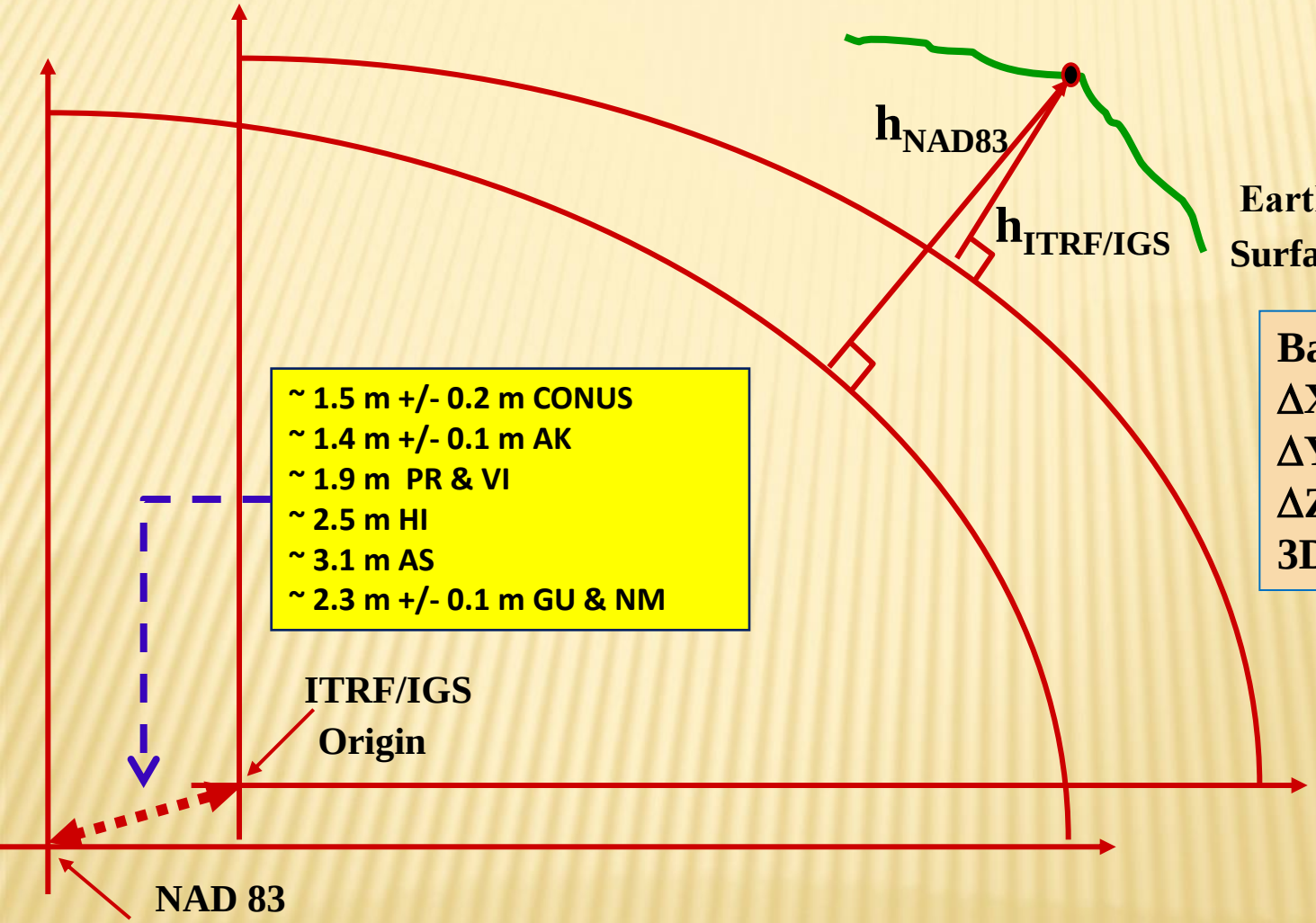
IERS NETWORK



Tectonic Plate Velocities

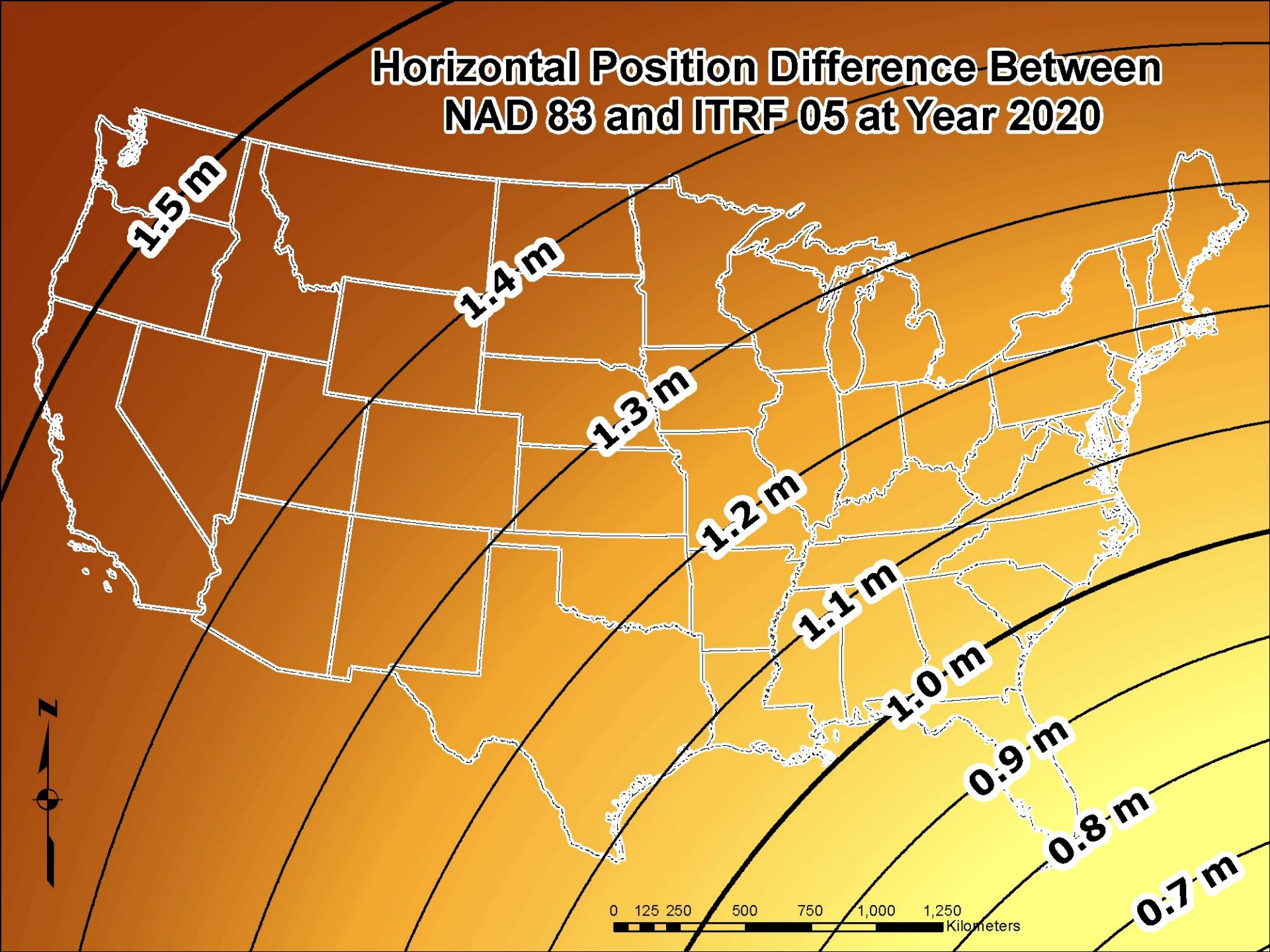


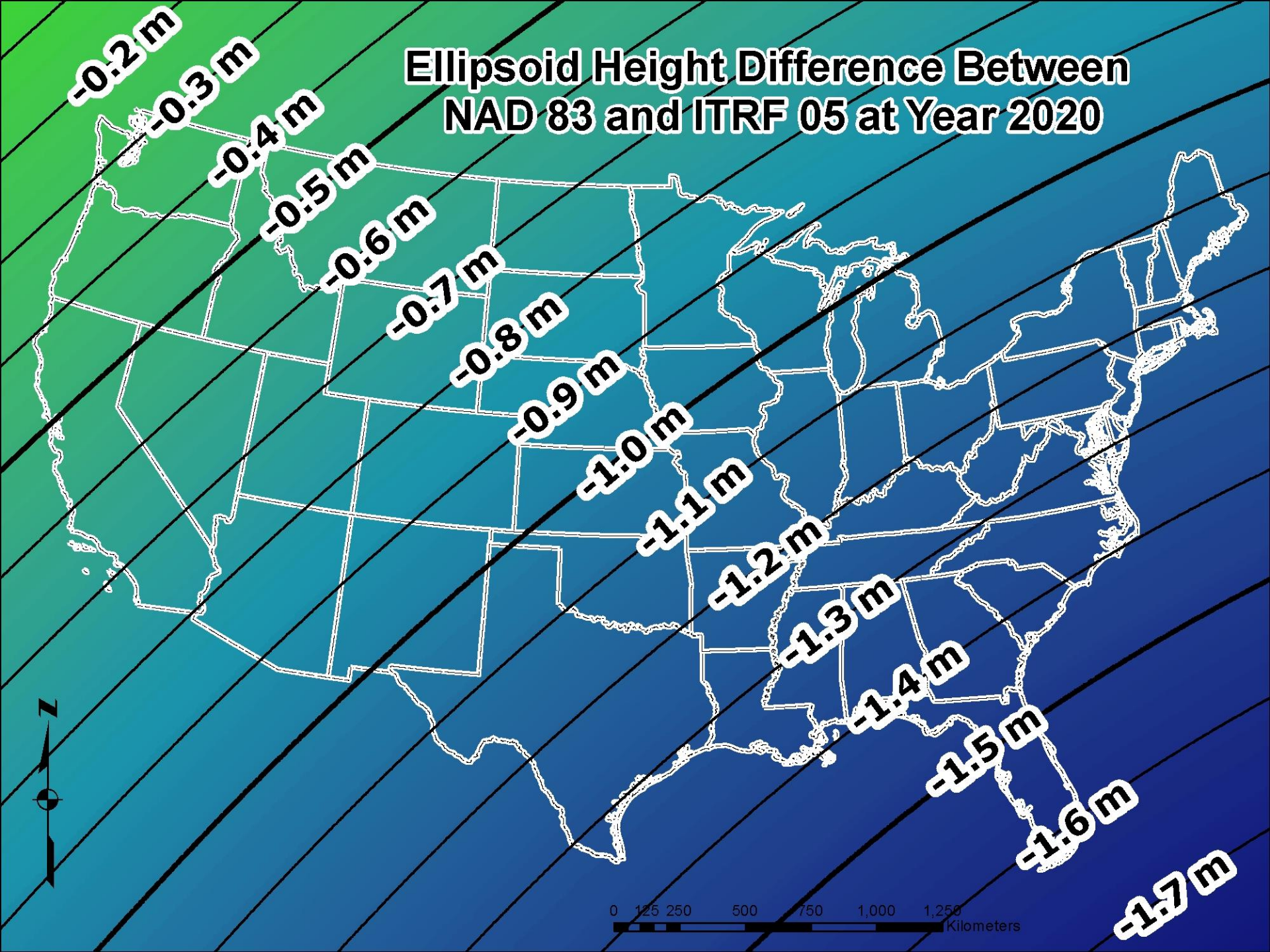
Simplified Concept of NAD 83 vs. ITRF/IGS



Baltimore Co. - BACO
ΔX = - 0.682 m
ΔY = + 1.448 m
ΔZ = + 0.079 m
3D = 1.603 m

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

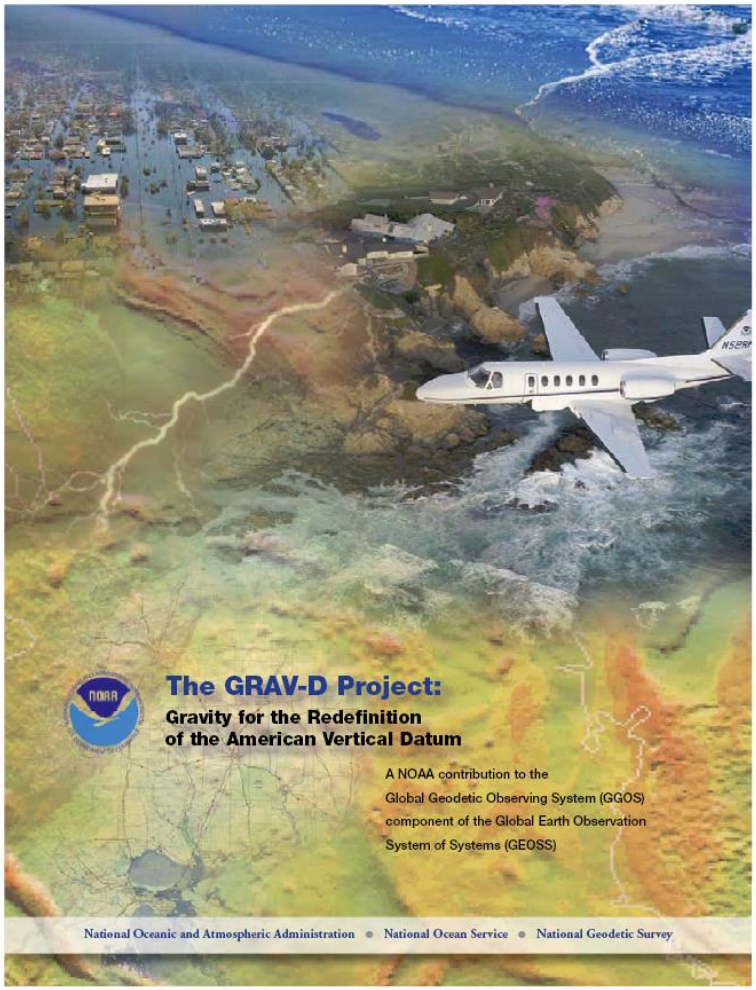

Horizontal Position Difference Between
NAD 83 and ITRF 05 at Year 2020
1.5 m
1.4 m
1.3 m
1.2 m
1.1 m
1.0 m
0.9 m
0.8 m
0.7 m
N
0 125 250 500 750 1,000 1,250
Kilometers


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

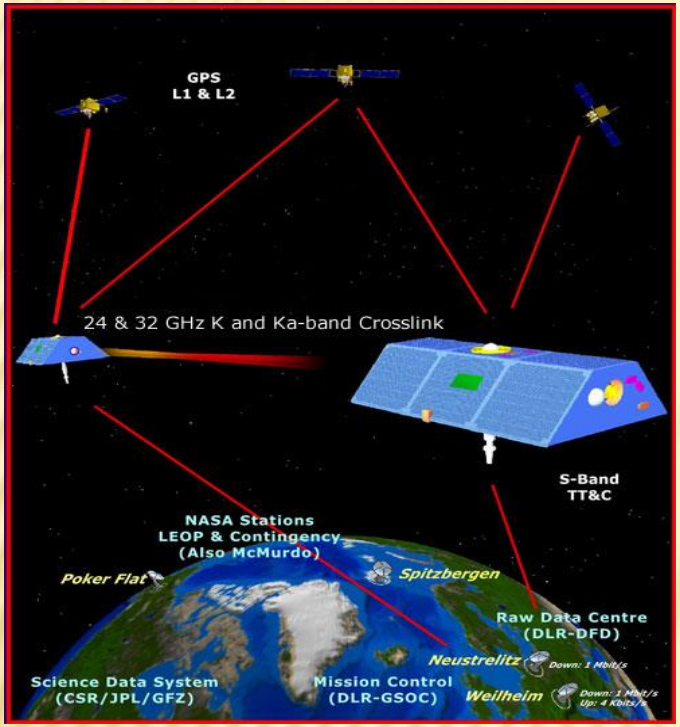
Transition to the Future – GRAV-D

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 34% Complete



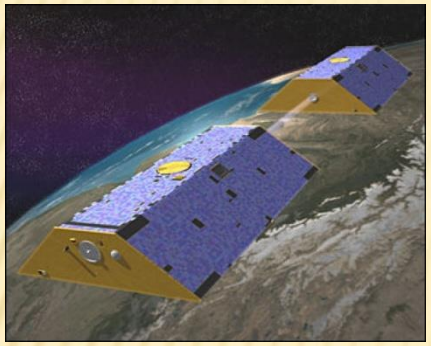
Space-Base Gravity Observations



Gravity Recovery And Climate Experiment (GRACE) Launched - 2002

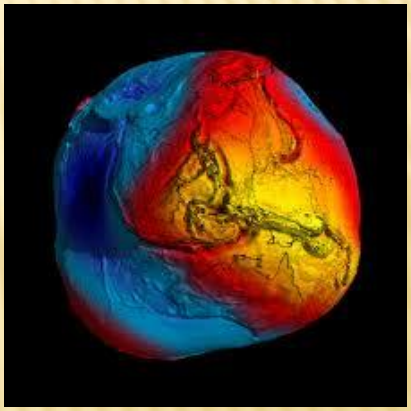
Gravity field and steady state Ocean Circulation Explorer (GOCE) Launched – 2009 Re-entered - 2013

Building a model of the Earths Gravity Field



GRACE & GOCE Satellites

Long Wavelengths:
(≥ 400 km)



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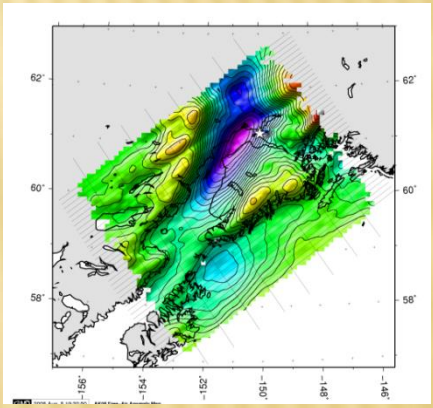
Airborne Measurement

Intermediate Wavelengths
(500 km to 20 km)



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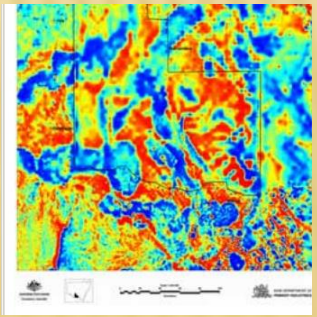
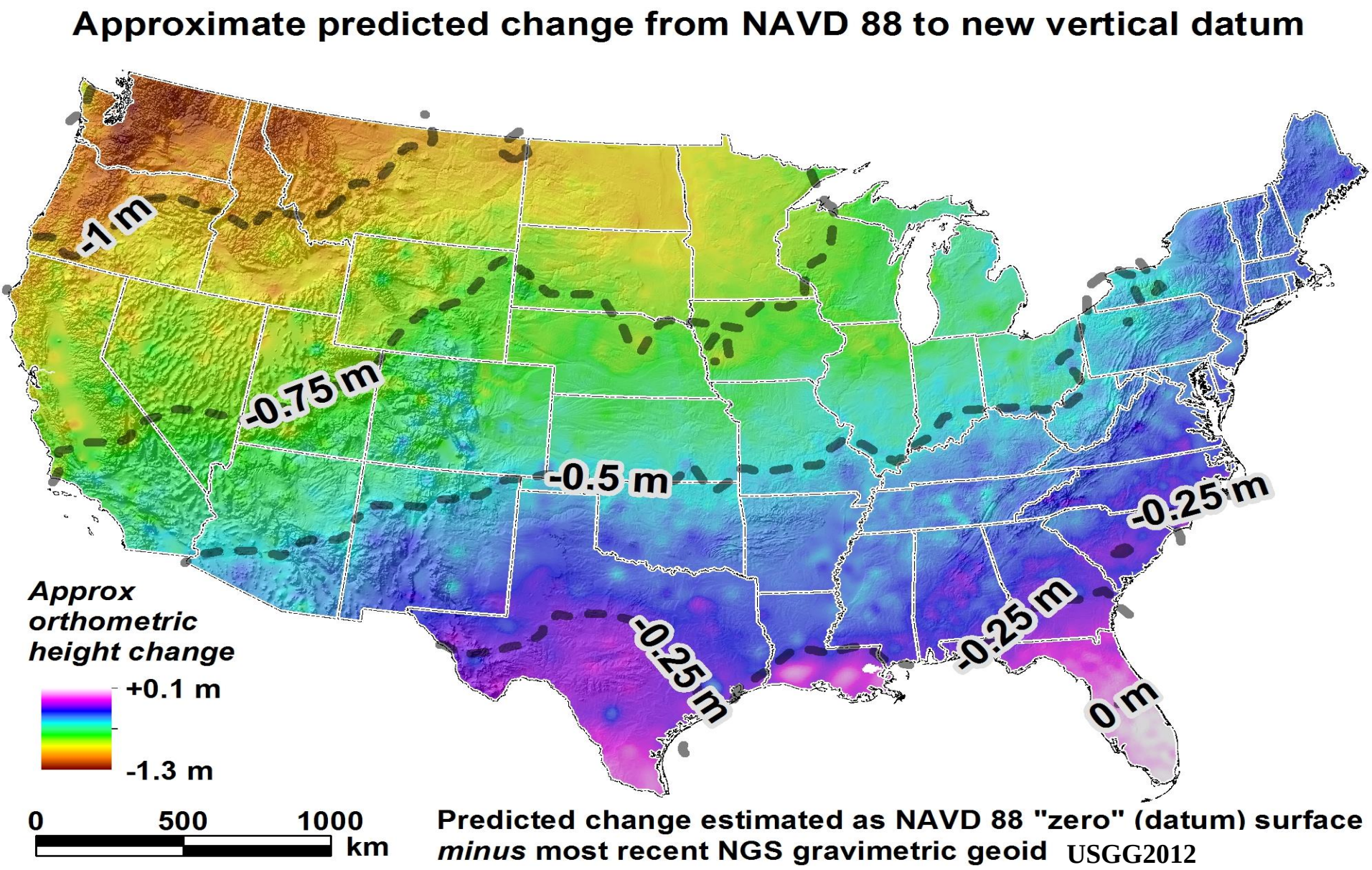
Surface Measurement

Short Wavelengths
(< 200 km)



Geopotential Datum Changes



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

Why GRAV-D?

NGS HAS CONCLUED:

- **Tradition vertical datum observed by classical leveling w/passive marks**
- **Limited number of control points delivering mm precision**
- **Seldom where needed**
- **Continuously being disturbed or destroyed**
- **Can only be validated or replaced by repeat leveling programs**
- **Substantial personnel resources**
- **Outrageously expensive (Billion +)**

- **Or**

- **A 2 cm target accuracy anywhere that GNSS receivers can be used**
- **Far cheaper than leveling**
- **Small support staff**
- **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 I access the new vertical datum?

Primary access (NGS mission)

- **Users with geodetic quality GNSS receivers will continue to use OPUS suite of tools**
- **Ellipsoid heights computed, and then a gravimetric geoid applied to provide orthometric heights in the new datum. The datum is the geoid model in a data collector**
- **No passive marks needed**

How will I access the new vertical datum?

NAVD 88 conversion to new datum

- A conversion will be provided between NAVD 88 and the new datum
- Accurate and reliable only where recent GNSS ellipsoid heights exist to provide modern heights in the new datum

Predicated Positional Changes in 2022 near Denton, MD Computed for BYPASS (HU2580)

HORIZONTAL = 1.13 m (3.7 ft)
ELLIPSOID HEIGHT = - 1.30 m (- 4.3 ft)
Computed with HTDP

ORTHOMETRIC HEIGHT = - 0.38 m (- 1.2 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**

METADATA

DATUMS and REALIZATIONS

NAD 27, NAD 83(1986), NAD83 (199X),
NAD 83 (2007), NAD 83 (2011),
NGVD29, NAVD88

UNITS

Meters, U.S. Survey Feet, International Feet

ACCURACY

A-Order, B-Order, 1st, 2nd, 3rd, 3cm, .1 ft, Scaled etc.

THE NUMBER OF DIGITS TO THE RIGHT OF THE DECIMAL POINT HAVE NOTHING TO DO WITH THE ACCURACY OF THE POSITON/HEIGHT

What can you do to get ready for 2022??

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

Watch for upcoming NGS status reports/webinars
www.ngs.noaa.gov/corbin/calendar.shtml

Consider legislative changes to
Maryland Real Property Code, Title 14, Miscellaneous Rules, Subtitle 4

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

Communicate issues directly to NGS
Joe Evjen – joe.evjen@noaa.gov – Geometric Datum Manager
Mark Eckl – mark.eckl@noaa.gov – Geopotential Datum Manager

GOOD COORDINATION BEGINS WITH GOOD COORDINATES

GEOGRAPHY WITHOUT GEODESY IS A FELONY