Positioning a nation for the future: Modernizing the United States National Spatial Reference System

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SIRGAS 25 Year Symposium
Aguascalientes, Mexico:
October 9-12, 2018

SIRGAS2018 GEOCENTRIC REFERENCE SYSTEM FOR THE AMERICAS
Aguascalientes, Mexico

NGS and the NSRS continue to evolve!

The National Geodetic Survey (NGS) has been around a long time!

Our Nation's first science agency (211 years)

1807
Thomas Jefferson
Survey of the Coast

1807
Ferdinand R. Hassler
First Superintendent

1878
U.S. Coast and
Geodetic Survey

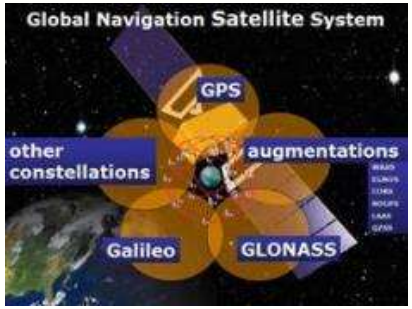
1970
NOAA is
established

The National Spatial Reference System continues to evolve with us.

Passive
Control
(Monuments)

GPS

Active
Control
(CORS)



GNSS

NGS Provides the Geospatial Infrastructure Critical to Our Economy through the NSRS

Satellite Operations

Personal Navigation

Survey Marks

The National Geodetic Survey Ten-Year Plan

Support the users of the National Spatial Reference System.

Modernize and improve the National Spatial Reference System.

Expand the National Spatial Reference System stakeholder base through partnerships, education, and outreach.

Develop and enable a workforce with a supportive environment.

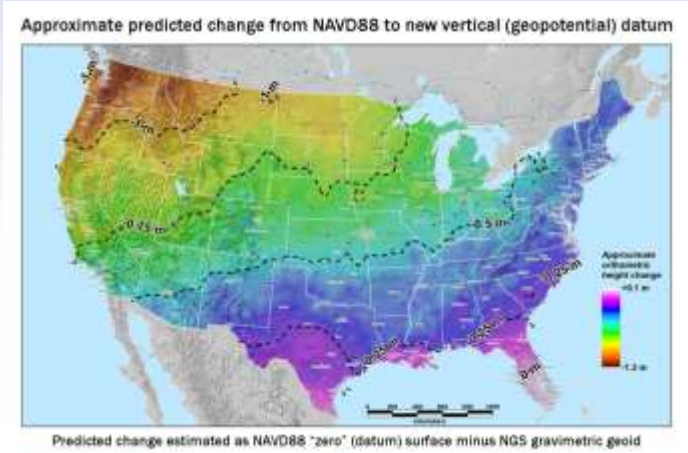
Improve organizational and administrative functionality.

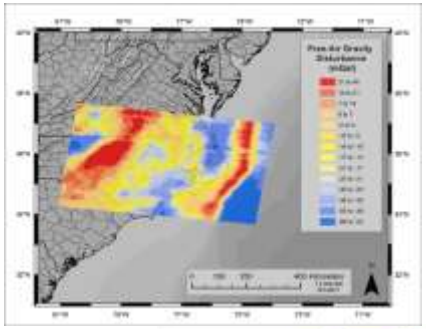
http://www.ngs.noaa.gov/web/news/Ten_Year_Plan_2013-2023.pdf

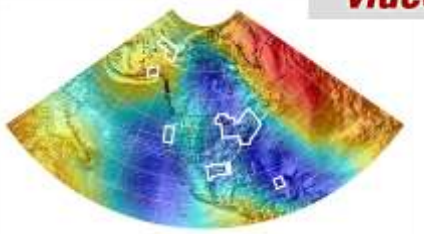
New Datums Are Coming in 2022!

- **NOAA's National Geodetic Survey** will release new **geometric** (horizontal) and **geopotential** (vertical) datums in **2022**
- The realization of the new datums will be through **GPS/GNSS receivers** and will replace the **current datums:**

  NAD 83(geometric) and NAVD 88 (geopotential)
- **Target:** 2-centimeter accuracy relative to sea level (orthometric heights) using GPS/GNSS and a geoid (gravity) model from NGS' GRAV-D project.
- **NGS will provide the tools** to easily transform between the new and old datums.







MORE INFO:

New Datums Webpage and Videos:

http://www.geodesy.noaa.gov/datums/newdatums/NewDatums.shtml

NGS Programs

Modernizing the NSRS

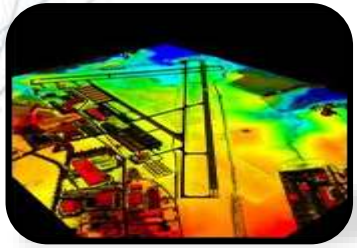
CORS

Height Modernization

GRAV-D

ECO

NGS Products and Services

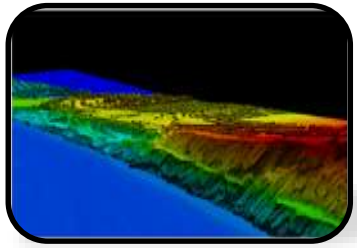


Airport Surveys

OPUS

VDatum

GPS Satellite Orbits



Coastal Mapping

Regional Advisor Program

Emergency Response Imagery

Phew... a lot going on at the NGS

2016 South Louisiana Control Update

* Combining Leveling with a GNSS/Geoid Based Vertical Datum

* Common Gravity Data Set

Comprehensive Toolkit Improvements

* Deriving a Valid Path for OPUS Projects GPS Projects to be Loaded to the NGS IDB

* Euler Pole Parameters

* Foundation CORS

* Geoid Monitoring Service

* Geoid Slope Validation Survey of 2017

* GNSS Derived Heights

* GPS Campaign for Transformations

Guam & CNMI Survey

* Hybrid Geoid 2018

IGLD Height Modernization Resurvey

IFVM Scoping

Industry Days and Convocation

JILA Atomic Clock Survey

NACAG 18

New GNSS Software (On-Hold)

* NSRS Database

* OPUS For Everything

*OPUS Projects for Leveling (On Hold)

OPUS Projects 4.0

OPUS RTK/GNSS

* Organize All Historic GPS Files - Scoping

RTK updates to NGS-58

RTN Validation Service

Solaris to Linux Migration

* State Plane Coordinate System

Strategic Human Resource Plan

* Ten Year Plan update

Transfer of Gravity Base Station Descriptors from NGA to NGS

VERTCON 3

Web Content Transformation

xGeoid 18

* *Projects Critical to 2022 NSRS Update*

NGS Geospatial Summit 2019

Next Geospatial Summit coming May 6-7, 2019 and you are invited!

Webinar videos and presentations are available

Debriefing the 2017 Geospatial Summit: NGS Webinar Series

September 14, 2017 - Webinar Information

https://geodesy.noaa.gov/geospatial-summit/

NGS Partners & Constituents

Federal

- Bureau of Land Management
- Forest Service
- National Park Service
- US Geological Survey
- Bureau of Reclamation
- Department of Energy
- US Army Corps of Engineers
- Int'l Boundary & Water Commission
- US Armed Forces
- National Guard
- National Laboratories
- National Science Foundation (NSF)
- National Aeronautical and Space Administration (NASA)
- National Geospatial-Intelligence Agency (NGA)

State

- Geological Surveys
- Water Authorities
- Geospatial Authority / Clearinghouse
- Departments of Transportation
- Environment / Land Management
- State Surveyor / Cartographer

Other

- State GIS Councils / Committees
- Cities & Counties
- Colleges, Universities
- Private Sector Firms / Contractors
- State Surveying Organizations
- Regional Government Councils
- Tribal Governments
- Railroads

2018 NSRS Modernization Industry Workshop

Goal

To discuss industry needs and concerns regarding the NSRS modernization scheduled for 2022.

External Attendees

Software developers
(surveying and GIS vendors)

Internal Attendees

NGS subject matter experts

Webinar videos and presentations are available at:

https://www.ngs.noaa.gov/web/science_edu/webinar_series/industry-engagement.shtml

Why replace NAD 83 and NAVD 88?

Main driver: Global Navigation Satellite System (GNSS)

- **ACCESS!**
  - GNSS equipment is fast, inexpensive, reliable (and improving)
  - Reduces reliance on finding survey control ("bench marks")
- **ACCURACY!**
  - Insensitive to distance-dependent errors; reliable
  - Immune to bench mark instability (referenced to CORS)
- **CONSISTENCY!**
  - Eliminates systematic errors in current datums
  - Aligned with global reference frames
  - Integrated system for both positions and heights ("elevations")

Replace North American Datum (NAD 83)

ACCESS AND DEFINITION

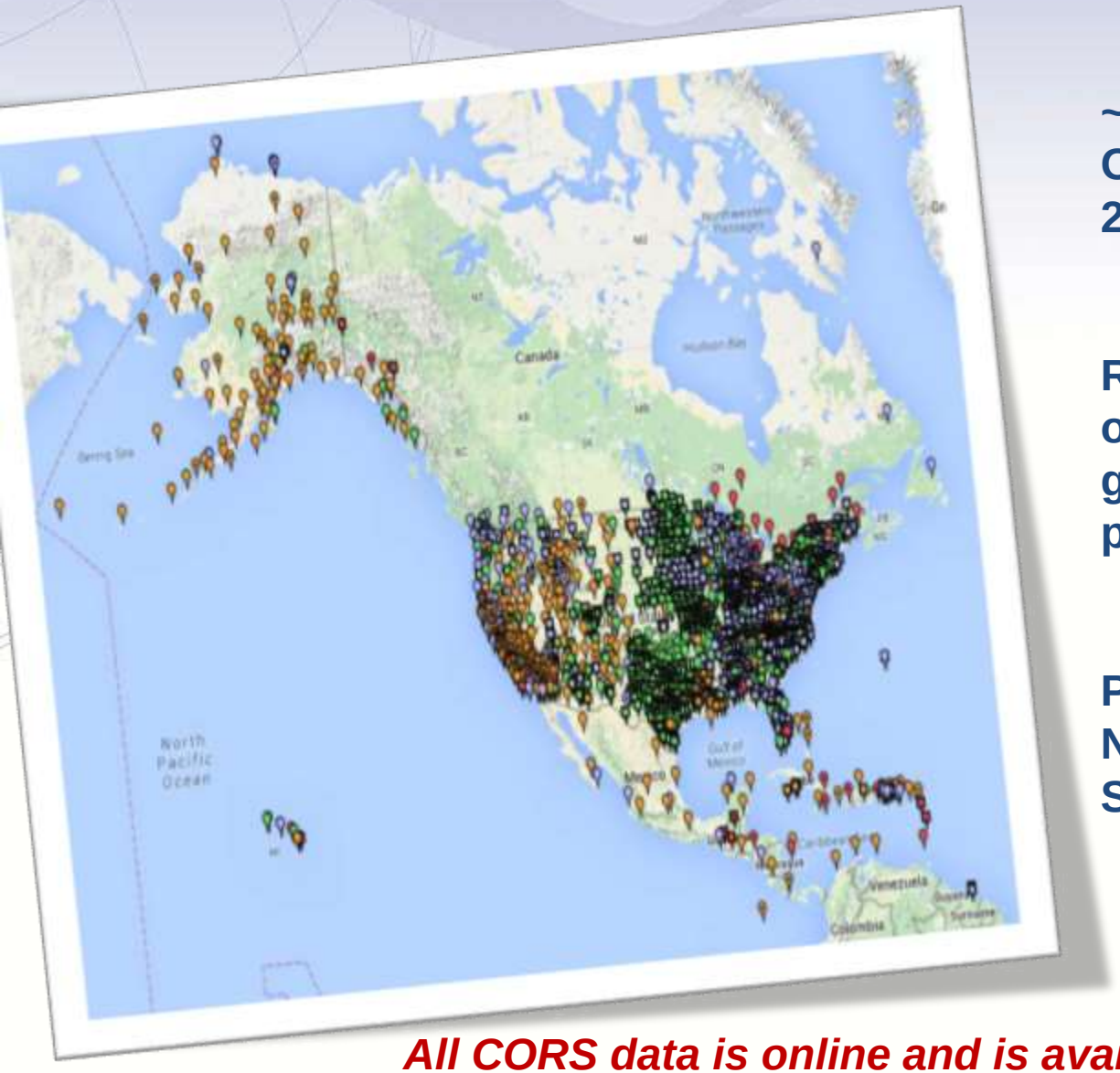
- **Primary: CORS**
  - Continuous monitoring
  - OPUS
  - IGS coordinates
    - Transformable to any national reference frame chosen for 2022
  - Static Surveys
  - RTK/RTN
    - Validation service

- **Secondary: Passive**
  - Time-tagged coordinates
  - Will reflect each occupation of the mark
  - Will *generally* not be accepted as "fixed control" in surveys turned into NGS

Guiding Principals

- By 2022, the National Spatial Reference System (NSRS) will be modernized with CORS becoming a more foundational component.
- The International Earth Rotation and Reference Systems Service (IERS) International Terrestrial Reference System (ITRF) will continue to be the worldwide standard reference system.
- NGS will continue to support the ITRF through International GNSS Service (IGS) reference sites.
- The NSRS will continue to be defined in relation to the ITRF.

Current Continuously Operating Reference Stations (CORS)



~ 2000 Continuously Operating Reference Stations
20+ years of data

Run by more than 200 organizations (various government, academic, and private organizations)

Provides access to the U.S. National Spatial Reference System

All CORS data is online and is available for use (i.e., SIRGAS)

Four Tectonic Plates NGS Monitors

In 2022, the entire National Spatial Reference System (NSRS) will be modernized and will contain four new reference frames:

- ✓ North American Terrestrial Reference Frame of 2022 **(NATRF2022)**
- ✓ Pacific Terrestrial Reference Frame of 2022 **(PATRF2022)**
- ✓ Caribbean Terrestrial Reference Frame of 2022 **(CATRF2022)**
- ✓ Mariana Terrestrial Reference Frame of **(MATRF2022)**

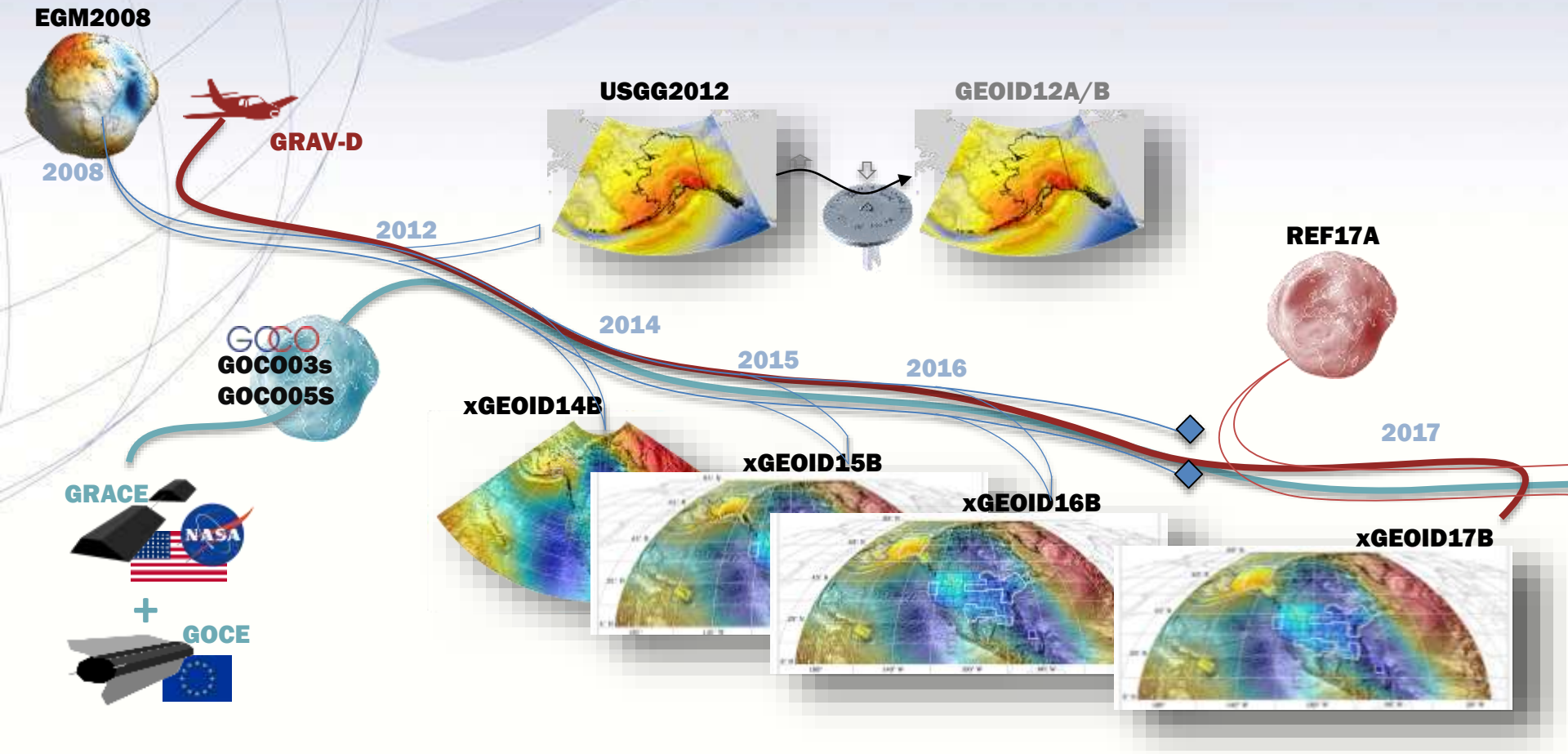
Replace NAVD 88

- Changing from a ***leveling-based*** to a **geoid/GNSS-based** vertical datum

- Biggest requirement: An updated, accurate, nationwide gravity survey
  - Airborne
  - GRAV-D!
    - **G**ravity for the **R**edefinition of the **A**merican **V**ertical **D**atum

http://www.ngs.noaa.gov/GRAV-D/pubs/GRAV-D_v2007_12_19.pdf

Evolution of Recent NGS Geoid Models

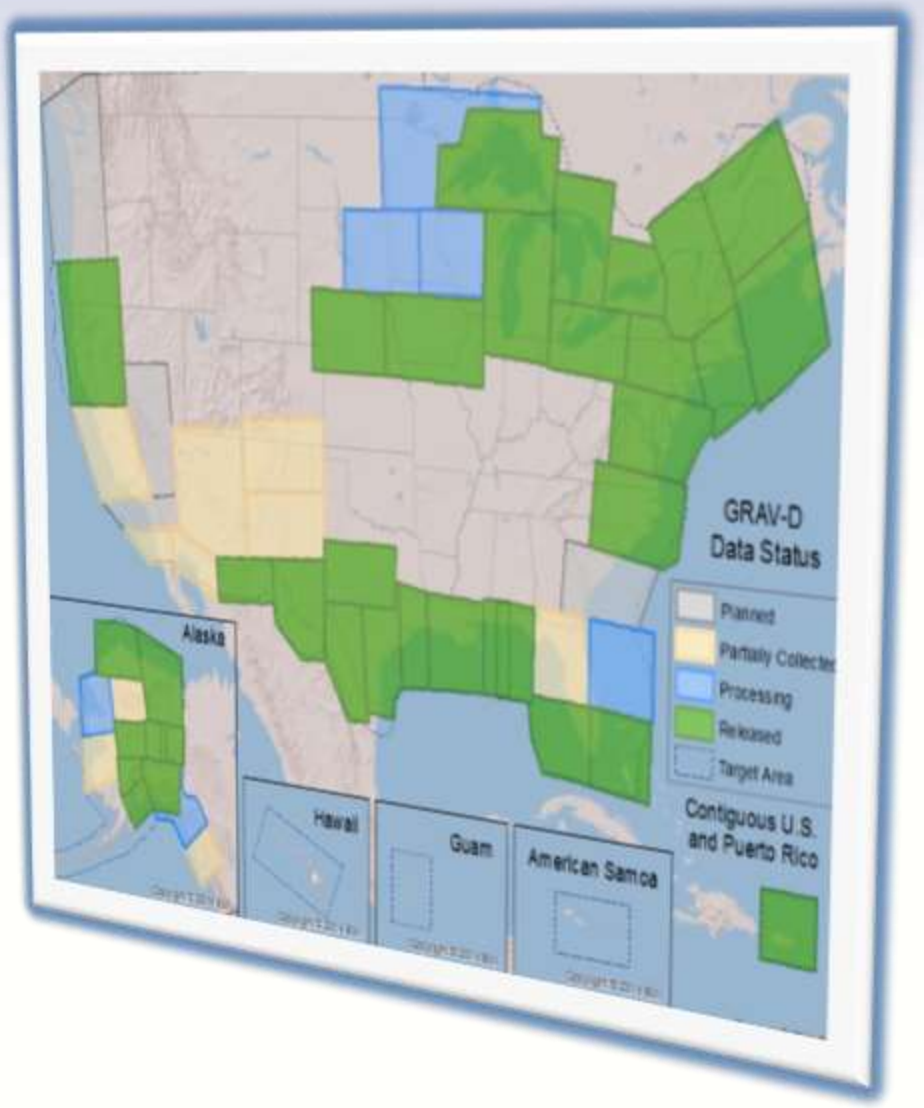


https://beta.ngs.noaa.gov/GEOID/xGEOID17/

GRAV-D Status

100% BY 2022

- 50% mark hit in FY2016
  - **Q4 2018: 72% flown**
  - **Q4 2018: 68% complete**
- Two aircrafts at a time
  - Occasionally three
- Mix of **Government and Private** Industry Flights
- Experiments with G4
  - If successful, begin using G4 to collect Pacific states and territories as early as next year



International Coordination

- IAG (Comm. 1 & 2)
  - ITRF/IHRF
- UN-GGIM
  - UN-GGRF
  - UN-GGIM-Americas
  - SIRGAS
- FIG et al.
- ISO – TC 211
- GLCC – IGLD update

NGS Video Library

Educational Videos about New Datums and more

http://www.ngs.noaa.gov/corbin/class_description/NGS_Video_Library.shtml

NGS Homepage:

geodesy.noaa.gov

National Geodetic Survey

Positioning America for the Future

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

Quick Links

- OPUS
- CORS
- Survey Mark Datasheets
- NGS Data Explorer
- OPUS Projects
- Geodetic Tool Kit
- State Plane Coordinates
- Antenna Calibration
- UFCORS
- GEOID
- GPS on Bench Marks
- Geodetic Advisors
- Storm Imagery
- Publications
- 2017 Geospatial Summit
- FAQs
- Contact Us
- Subscribe for email notifications

Coming in 2022: New Datums! Learn more...

NOAA's National Geodetic Survey (NGS) provides the framework for all positioning activities in the Nation. The foundational elements of latitude, longitude, elevation, shoreline information impact a wide range of important activities.

Learn more about:

- Data and tools we provide
- Activities in your area
- Applications of geodesy

GNSS & GPS Data

Get coordinate information and the tools you need to work independently.

Learn More

Remote Sensing

Download data and critical information into nautical charts.

Learn More

Land Surveying

View guidelines and get tools to support land surveyors.

Learn More

Geodesy

NGS works closely with the global researchers advancing geodetic science.

Learn More

Training & Education

Classes and educational resources on scientific topics relating to geodesy.

Learn More

Datums & Transformations

NGS defines datums to help align data and tools to transform coordinates.

Learn More

Looking for Bench Marks?

Emergency Response

Post Hurricance Aerial Imagery:
Hurricane Nate

Hurricane Maria

Hurricane Irma

Hurricane Harvey

Previous Storms

Notices

Live Release:
NADCON 5

Beta Release:
CORS & OPUS Share Maps

Previous Notices

In the News

11/17/2017 - U.S. and Canada Collaborate on Great Lakes Data Collection

11/09/2017 - NGS and NASA Discuss Organizational Mission Requirements

NGS Public News Subscription Service

Click here to subscribe or unsubscribe.

NGS Training/Online Learning Email Notifications

If you would like to receive an email informing you of upcoming training/learning opportunities presented by NOAA's National Geodetic Survey, please fill in the information below.

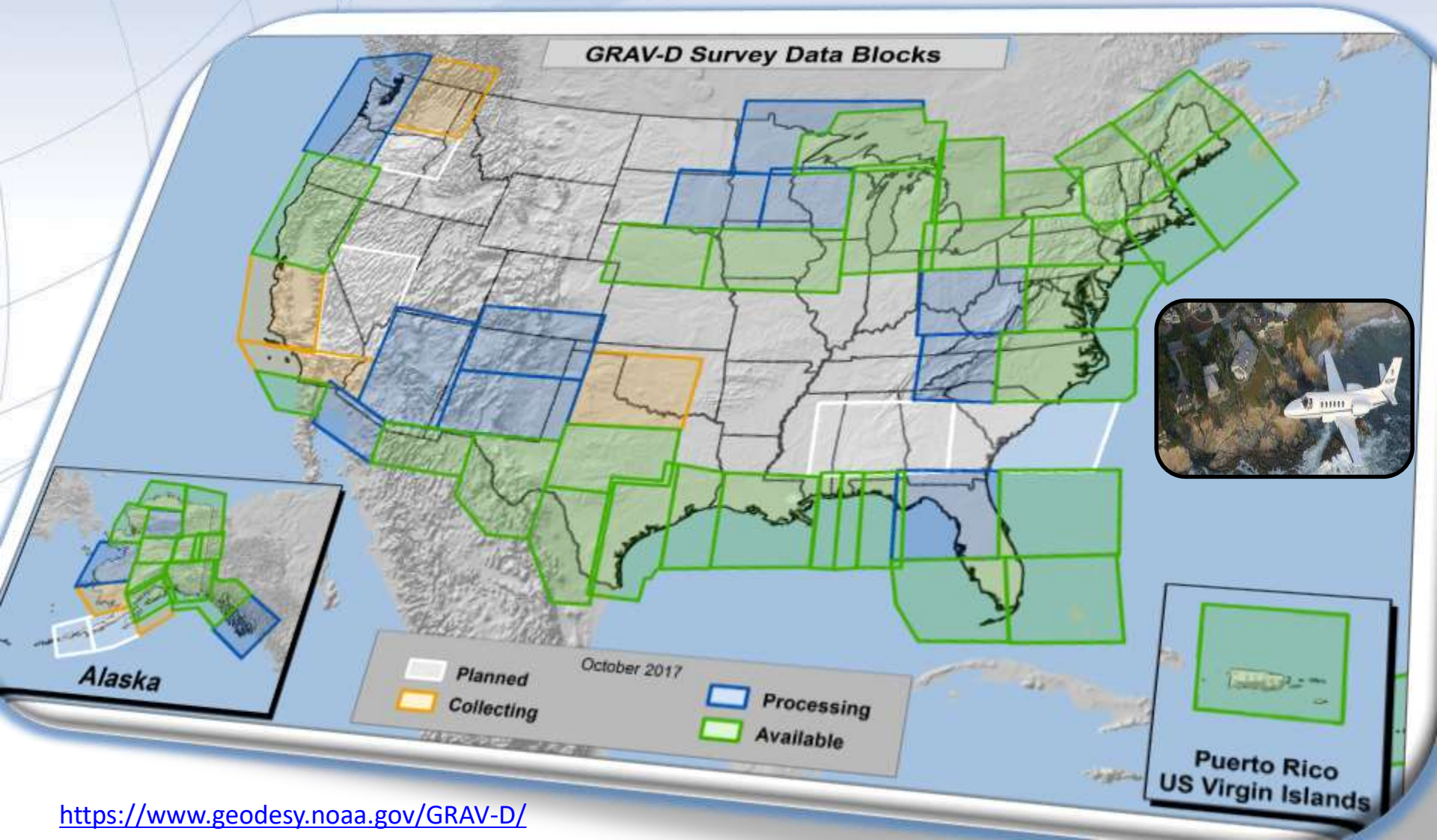
* Required

Your email address *

Thank You !

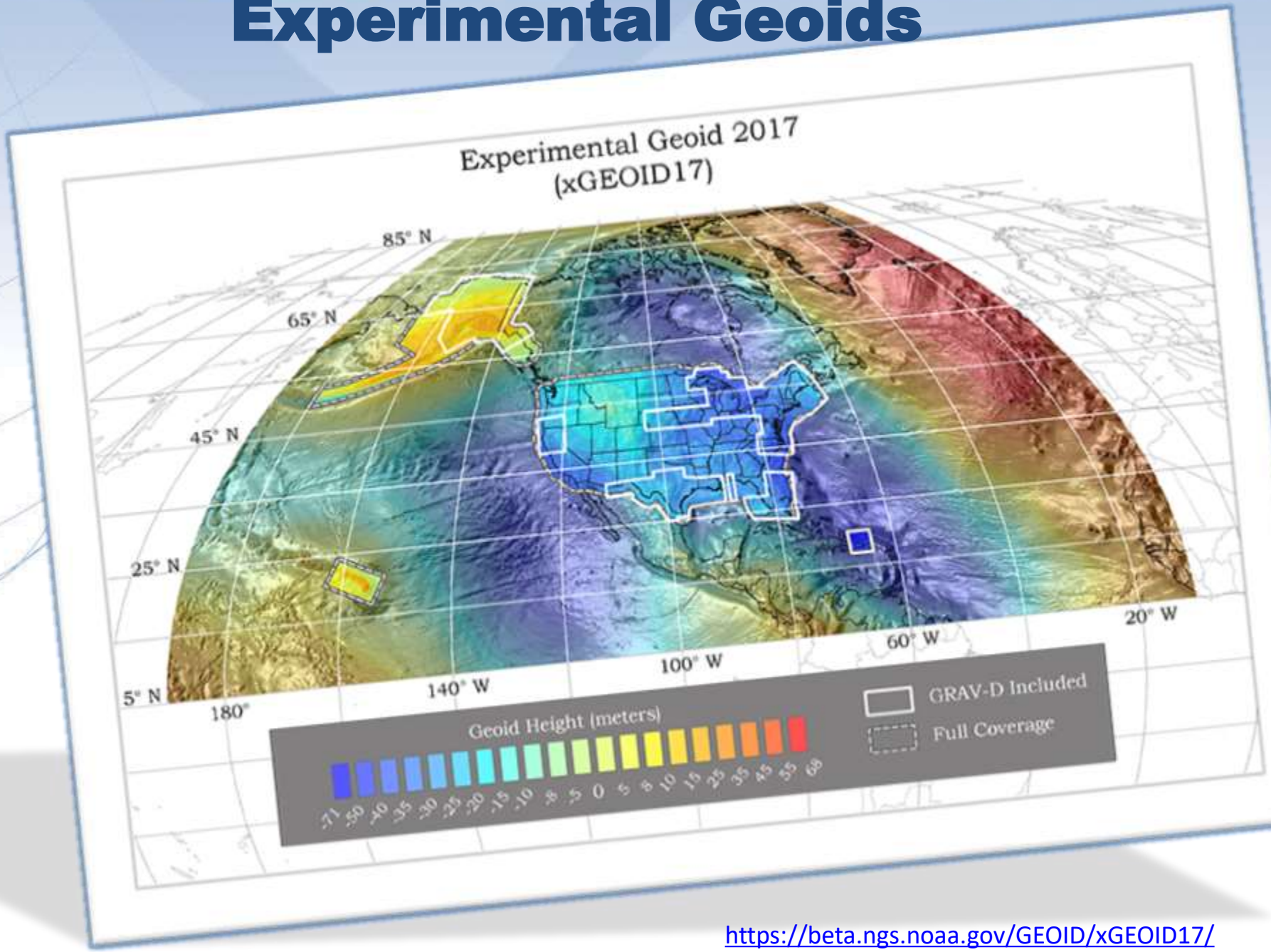
QUESTIONS?

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



https://www.geodesy.noaa.gov/GRAV-D/

Experimental Geoids



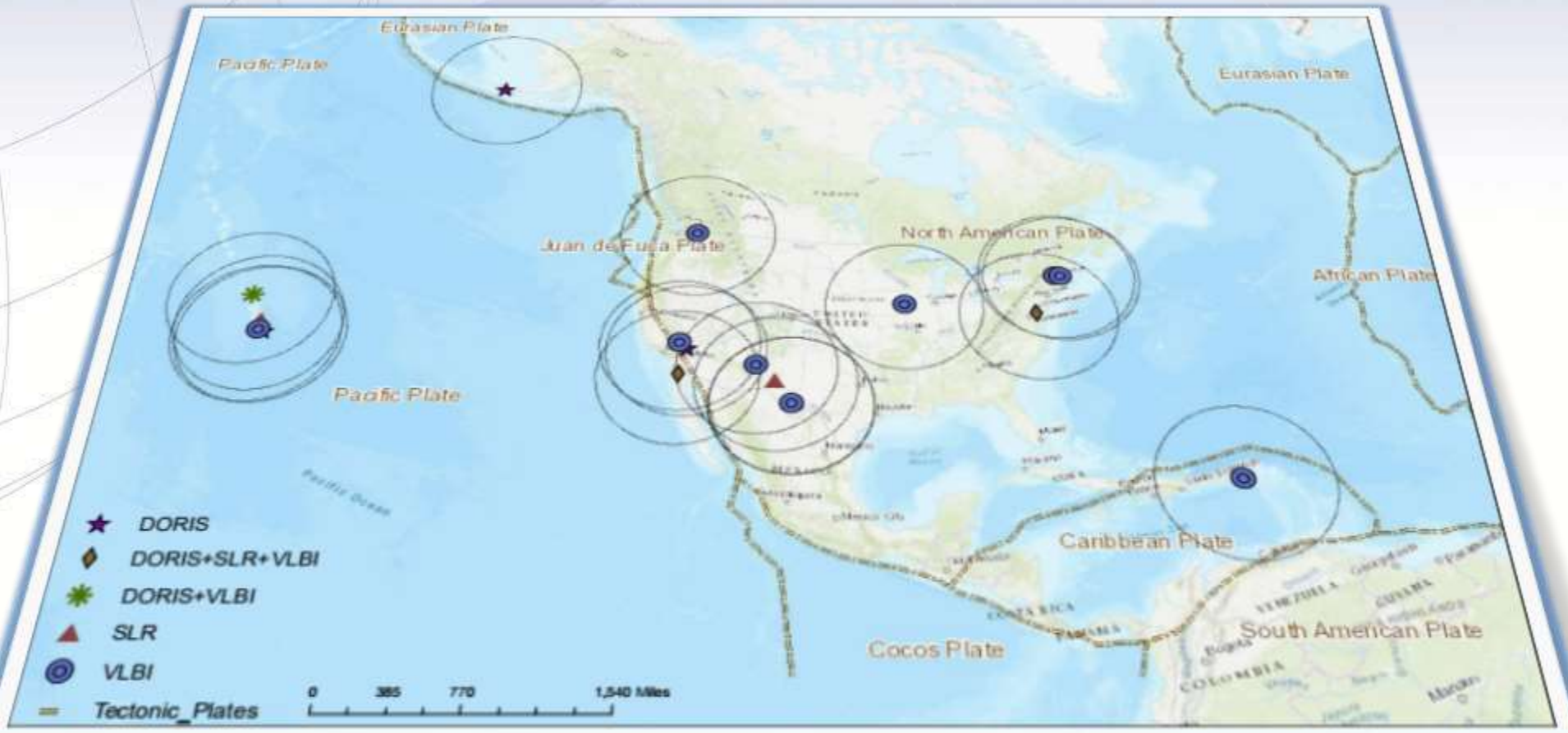
https://beta.ngs.noaa.gov/GEOID/xGEOID17/

Foundation CORS Requirements

- **Baseline Foundation CORS Network:**
  - **COLLOCATE - All Sites** within the Foundation CORS target area of the United States, that have an existing space geodetic techniques **(SLR, VLBI or DORIS)** will have a collocated Foundation CORS

- **Additional Desired Foundation CORS Network Requirements:**
  - **DENSITY** – Install or adopt new stations within the Foundation CORS target area of the United States, to fulfill the spacing criteria of 800 km within the Foundation CORS target area, after the above criteria are met.
  - **EULER** – Install or adopt new stations within the Foundation CORS target area of the United States to raise the minimum number of Foundation CORS to 3 on each of the 4 plates of interest, once the above criteria are met.
  - **ADDITIONAL (Gap Filling)** – Install or adopt new stations, on a case-by-case basis, once the above criteria is met.

Collocated Spaced Based Technology (SBT)



Nomenclature

- A chance to increase accuracy in *naming*!
  - "North American"?
    - Ignores Guam, Hawaii, American Samoa, Northern Mariana Islands
  - Datum vs Reference Frame?
  - Plate-specific?
  - Vertical vs Geopotential?

- 6/8/2016: NGS and the Canadian Geodetic Survey negotiated a naming proposal
  - Approved by NGS ESC
  - Approved by the CGS leadership (with minor reservations)
  - *Awaiting final word from INEGI as of 10/26/2016….*

The current naming proposal

- Geometric Reference Frames (XYZ, $\phi\lambda h$):

Plate	Name	Acronym
North American	North American Terrestrial Reference Frame of 2022	NATRF2022
Pacific	Pacific Terrestrial Reference Frame of 2022	PATRF2022
Caribbean	Caribbean Terrestrial Reference Frame of 2022	CATRF2022
Marianas	Marianas Terrestrial Reference Frame of 2022	MATRF2022

- Geoid Models (N):

Grid Area	Name
North America (pole to equator; Aleutians to Greenland)	GEOID2022-NA
American Samoa	GEOID2022-AS
Guam and CNMI	GEOID2022-GC

- Geopotential Datum (H, H_{dyn}, g, Δg, ξ, η, etc)

Area	Name	Acronym
All	North American-Pacific Geopotential Datum of 2022	NAPGD2022

Replacing the NAD 83's

The Old:

NAD 83(2011)

NAD 83(PA11)

NAD 83(MA11)

The New:

The North American Terrestrial Reference Frame of 2022 (NATRF2022)

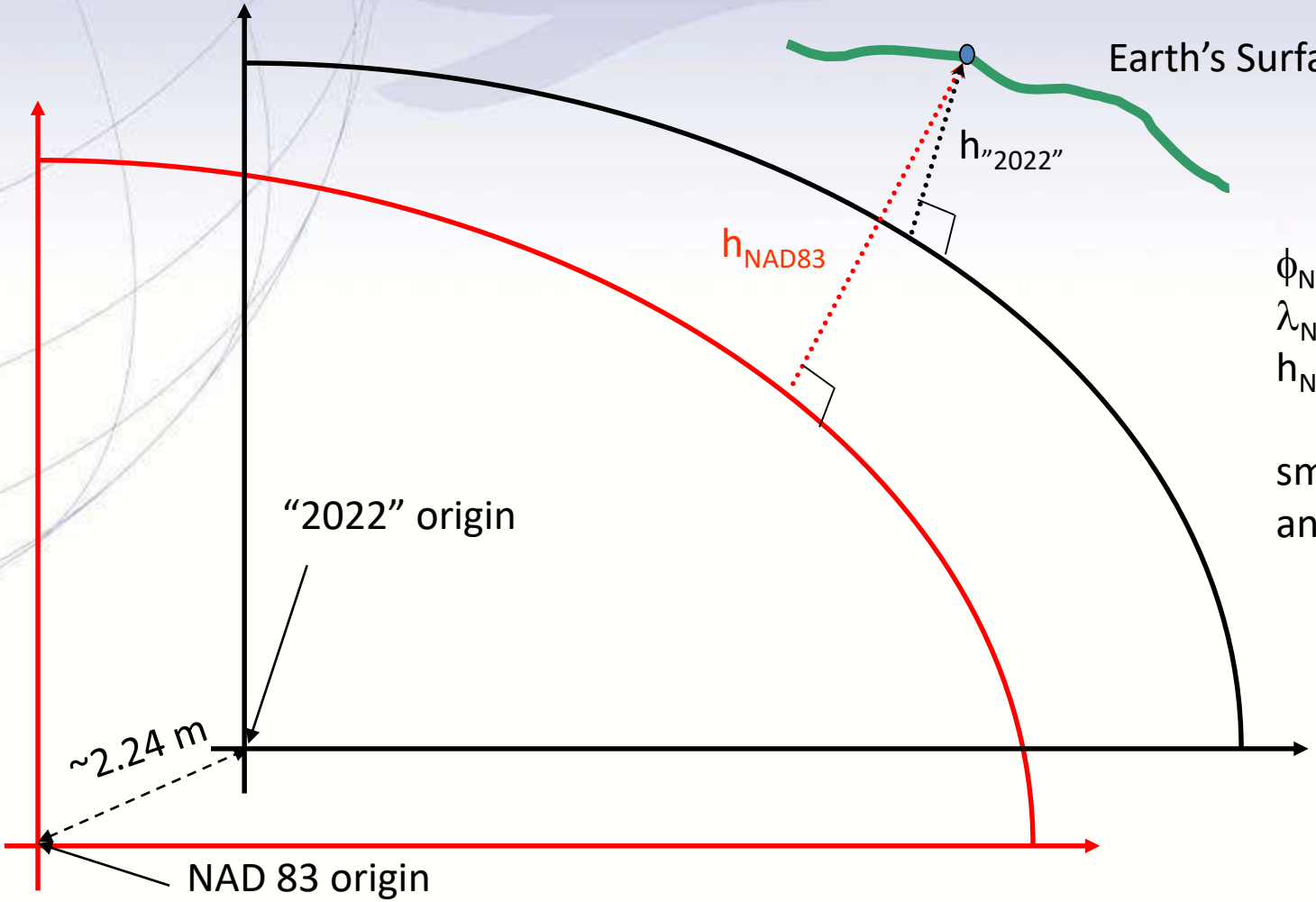
The Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)

The Pacific Terrestrial Reference Frame of 2022 (PATRF2022)

The Mariana Terrestrial Reference Frame of 2022 (MATRF2022)

Replace NAD 83

Simplified Concept of NAD 83 vs. "2022"



$\phi_{NAD83} - \phi_{"2022"}$
$\lambda_{NAD83} - \lambda_{"2022"}$
$h_{NAD83} - h_{"2022"}$
all vary smoothly by latitude and longitude

Replacing the NAD 83's

- Three plate-(*pseudo*)fixed frames will be replaced with four *plate-fixed* reference frames
  - N.Amer., Pacific, Mariana, Caribbean(new!)
- Remove long-standing non-geocentricity of NAD 83 frames
- All four : identical to IGSxx at a TBD epoch
  - 2020.00?
- All four : differ from IGSxx by plate rotation only
  - Updated Euler Pole determination for rigid plate only

The TRFs

- All are global frames (no "boundary")
  - This was true for the NAD 83's also, BTW
  - But each frame will rotate with one tectonic plate
    - Put another way: "***The frame rotates so your coordinates don't have to***"
- All will have an Intra-Frame Velocity Model
  - To capture any motions outside of tectonic rotation
    - *Residual* horizontal motions
    - *All* vertical (ellipsoid height) motions

What's Being Replaced

- What's being replaced:

Horizontal

- ~~NAD 83(2011)~~
- NAD 83(PA11)
- NAD 83(MA11)

Latitude
Longitude
Ellipsoid Height
State Plane Coordinates

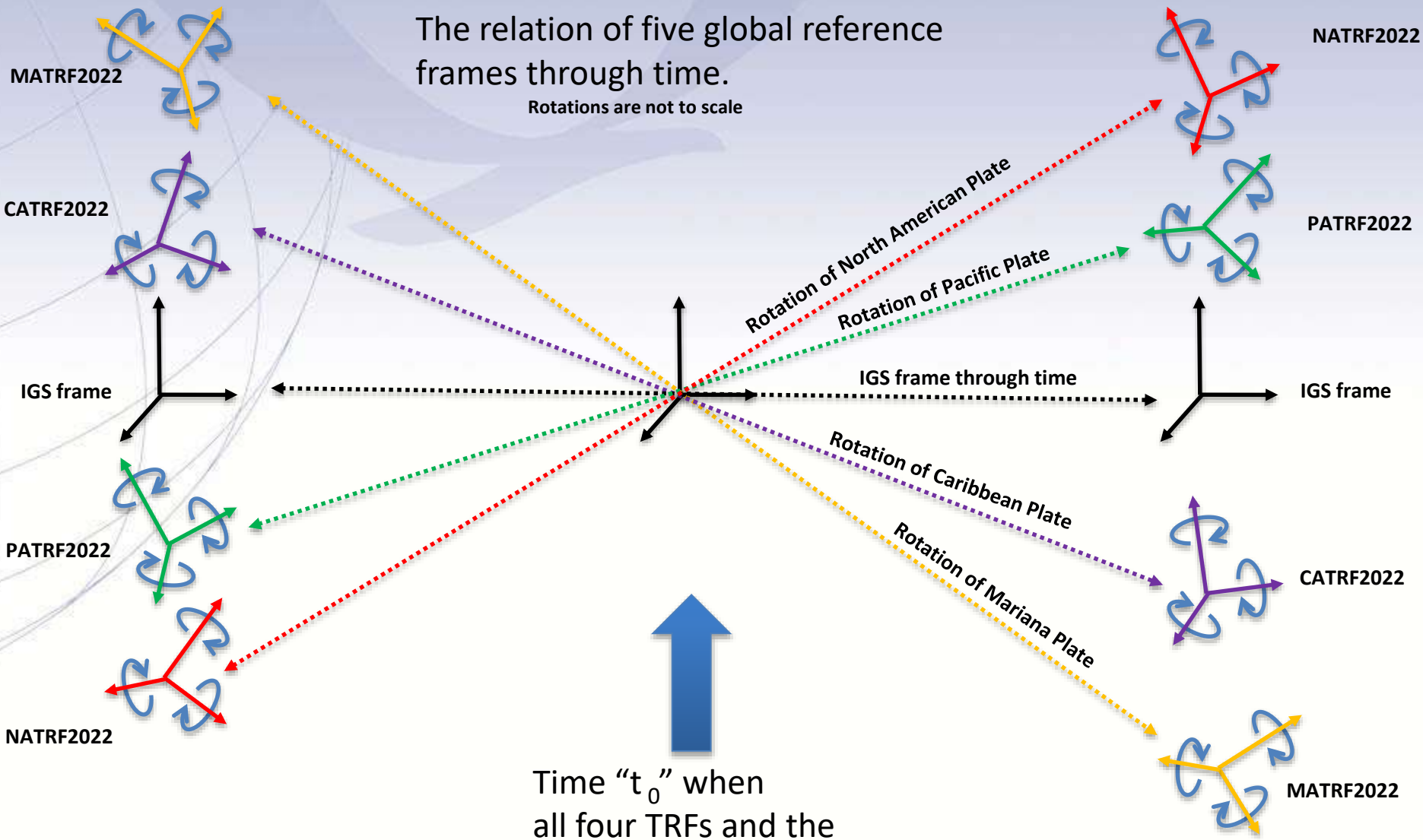
Vertical

- NAVD 88
- PRVD 02
- VIVD09
- ASVD02
- NMVD03
- GUVD04
- IGLD 85

Heights

The relation of five global reference frames through time.

Rotations are not to scale

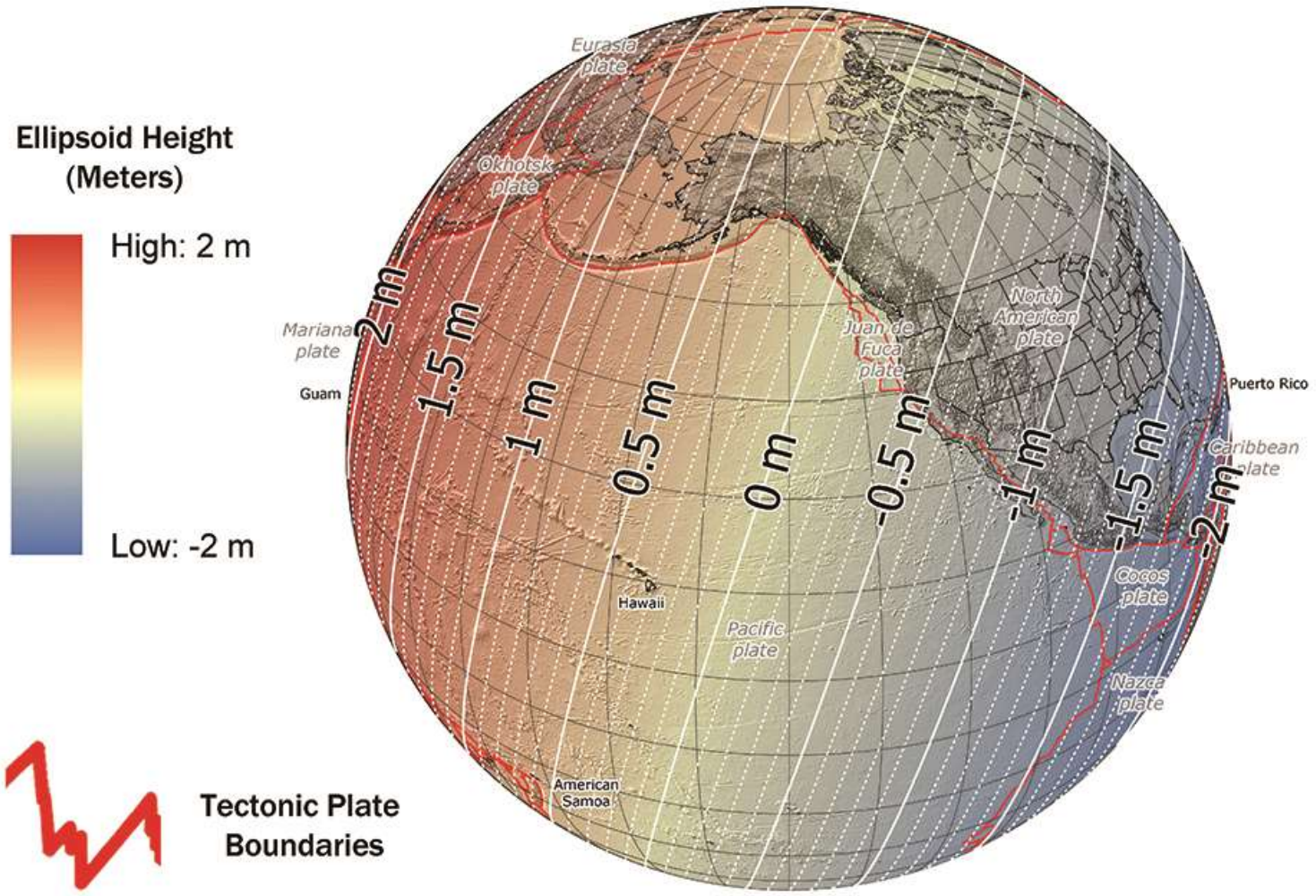


$t=t_0 - \Delta t$
("the past")

Time "t_0" when all four TRFs and the IGS are identical. (maybe 2020.0?)

$t=t_0 + \Delta t$
("the future")

Approximate Ellipsoid Height Change



Approximate Horizontal Change North American Plate

North American Plate
(Meters)

High: 2 m

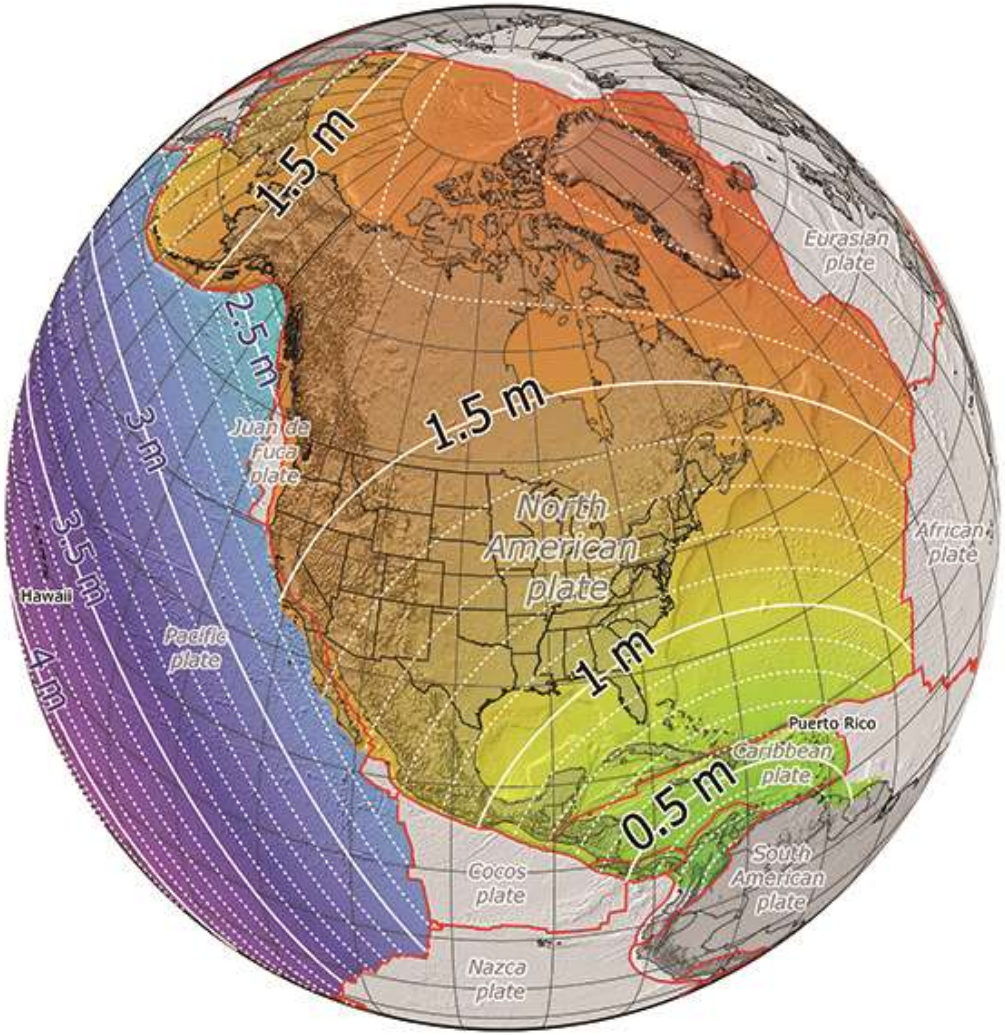
Low: 0 m

Pacific Plate
(Meters)

High: 4.3 m

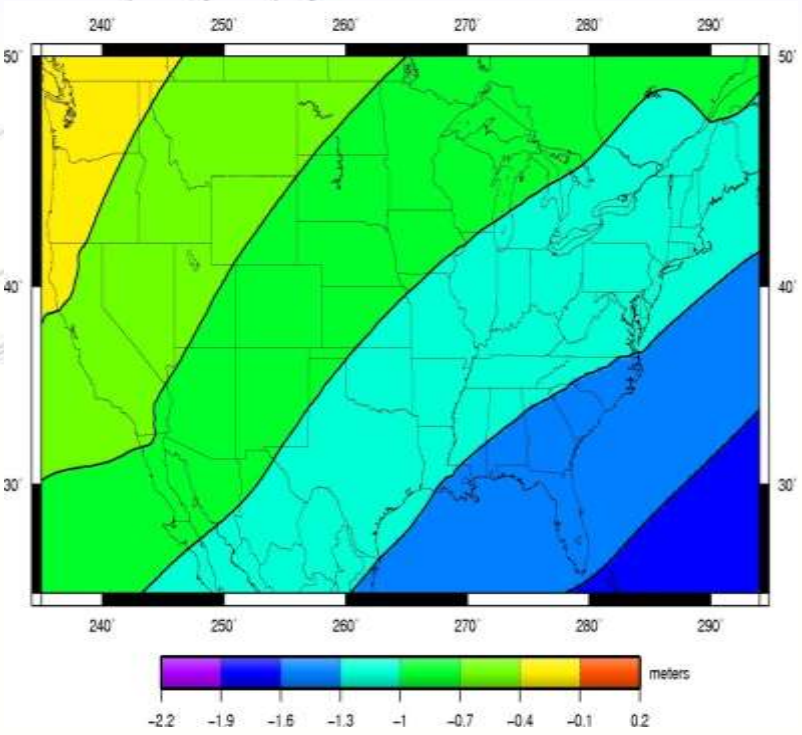
Low: 2.3 m

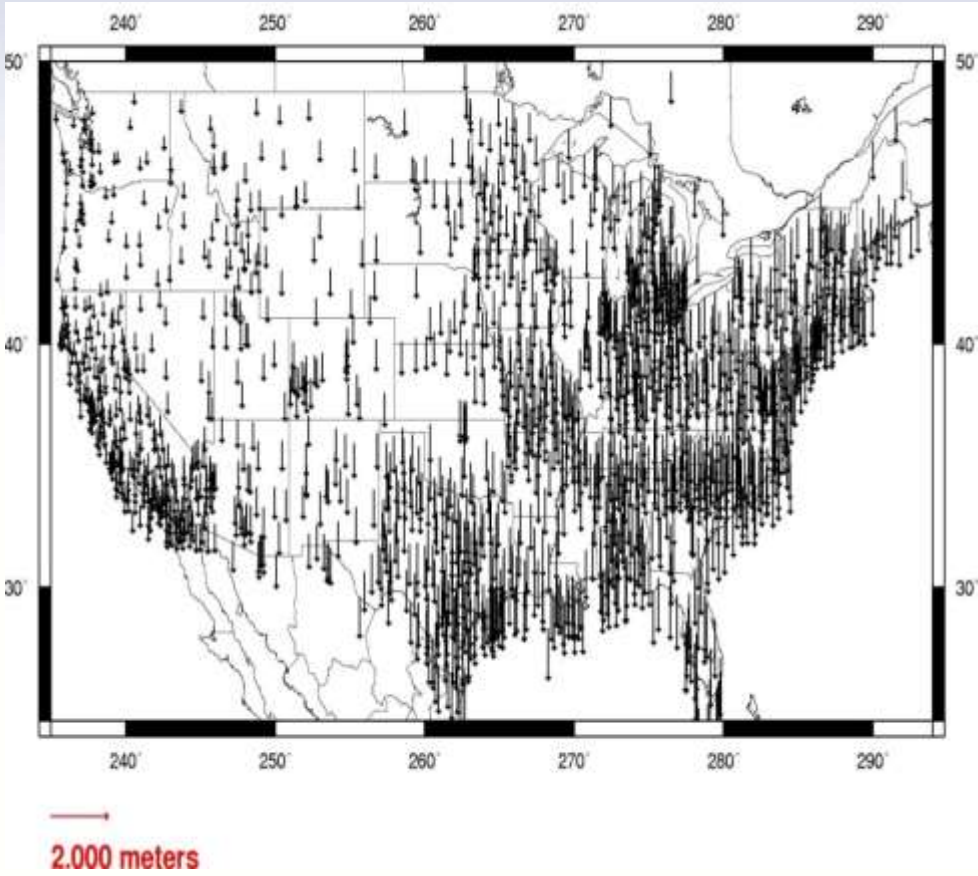
Tectonic Plate Boundaries



Ellipsoid Height Shifts

- Approximate
  - IGS08(GRS-80) minus NAD 83(2011)

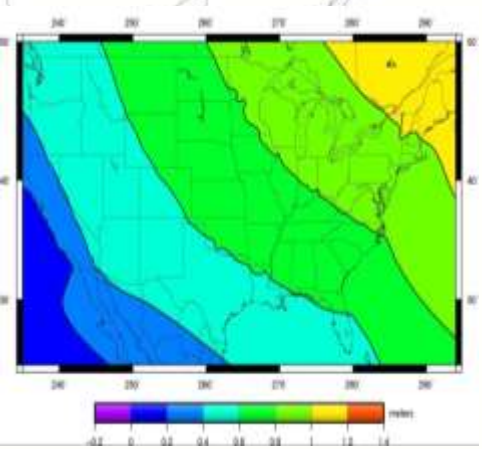




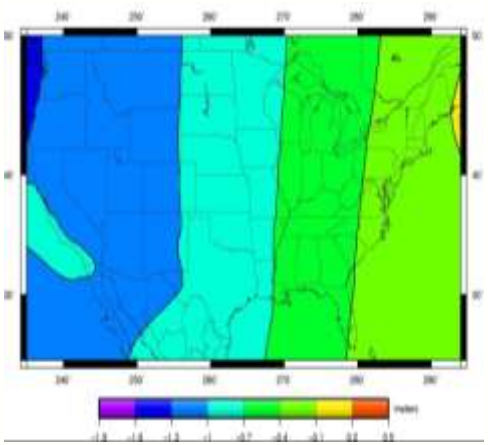
Horizontal Shifts

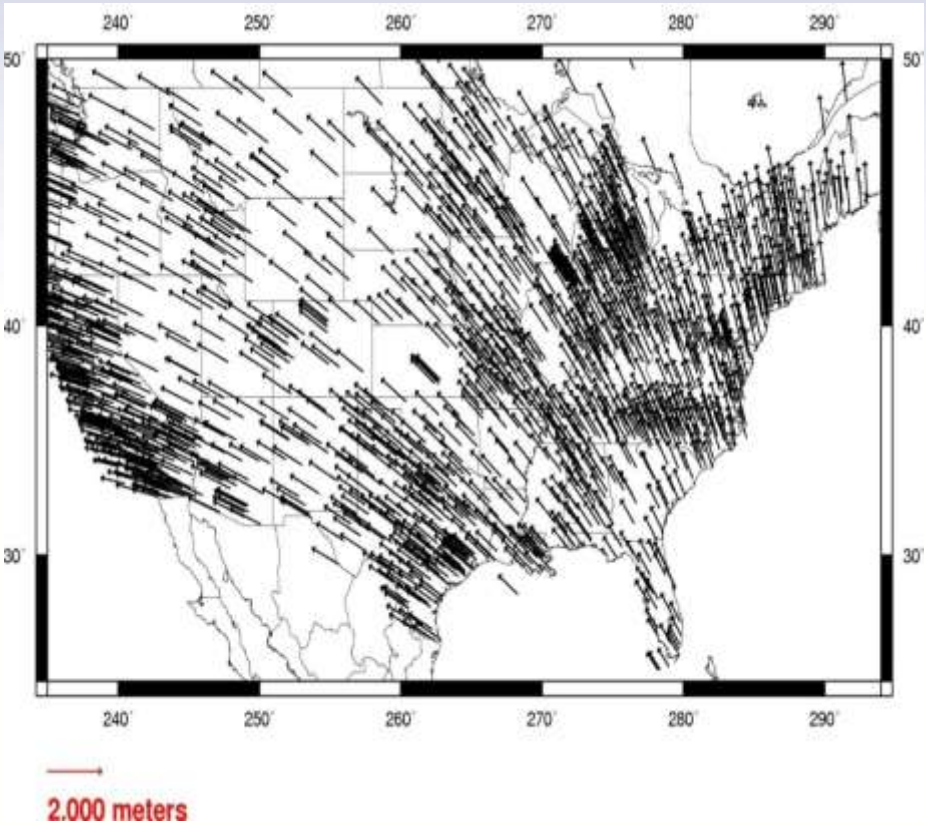
- Approximate
  - IGS08(GRS-80) minus NAD 83(2011)

Lat:

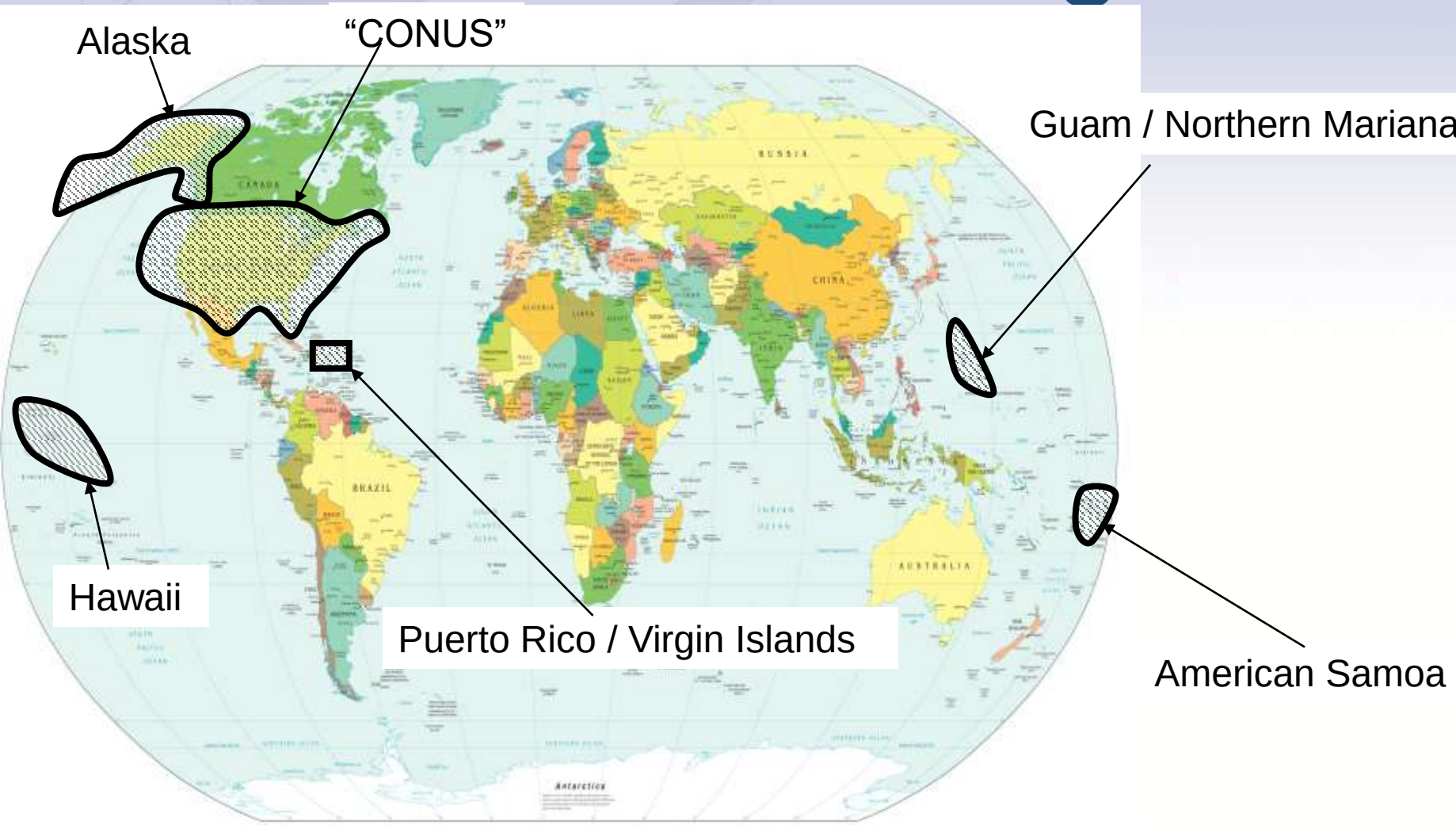


Lon:

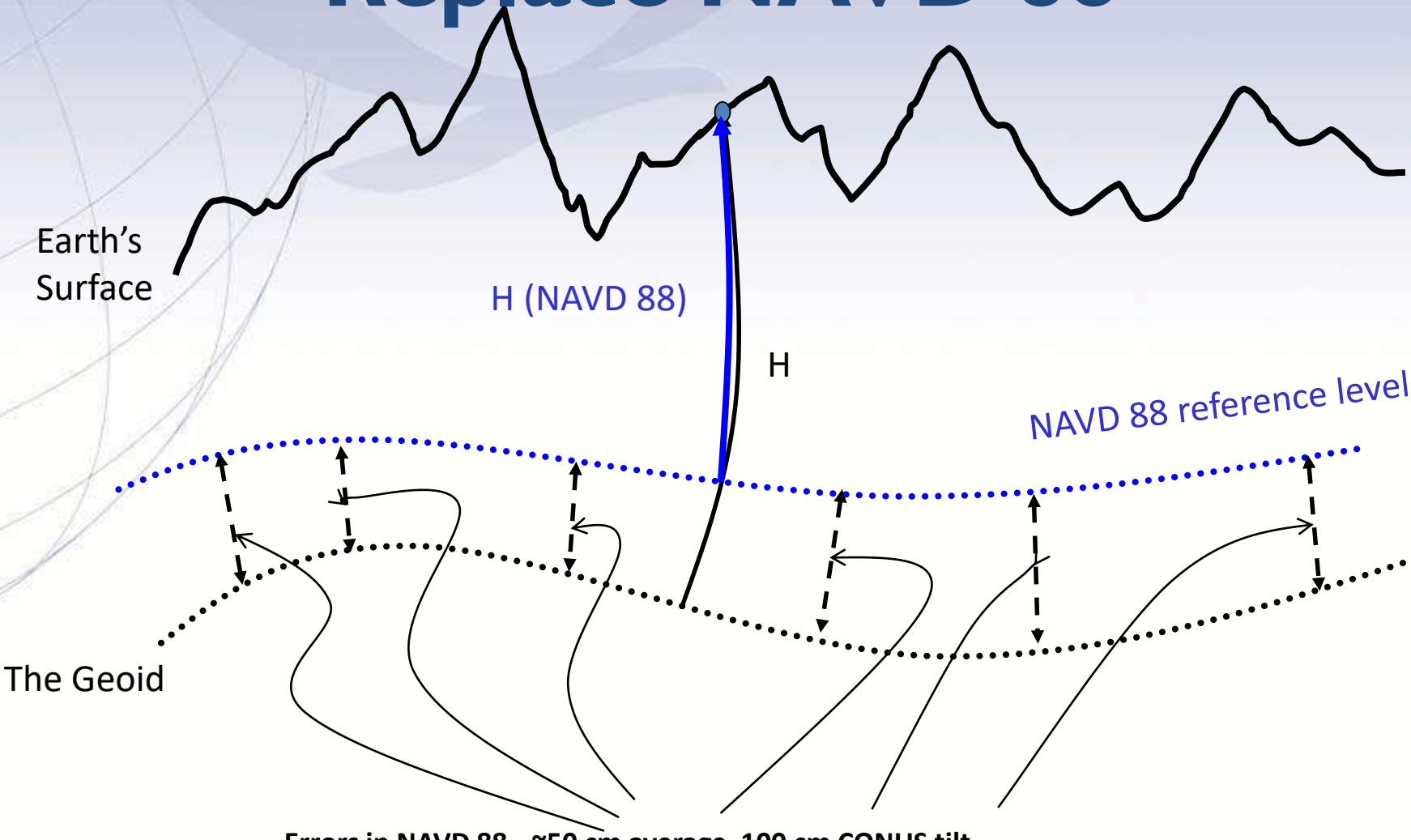




GRAV-D Coverage



Replace NAVD 88

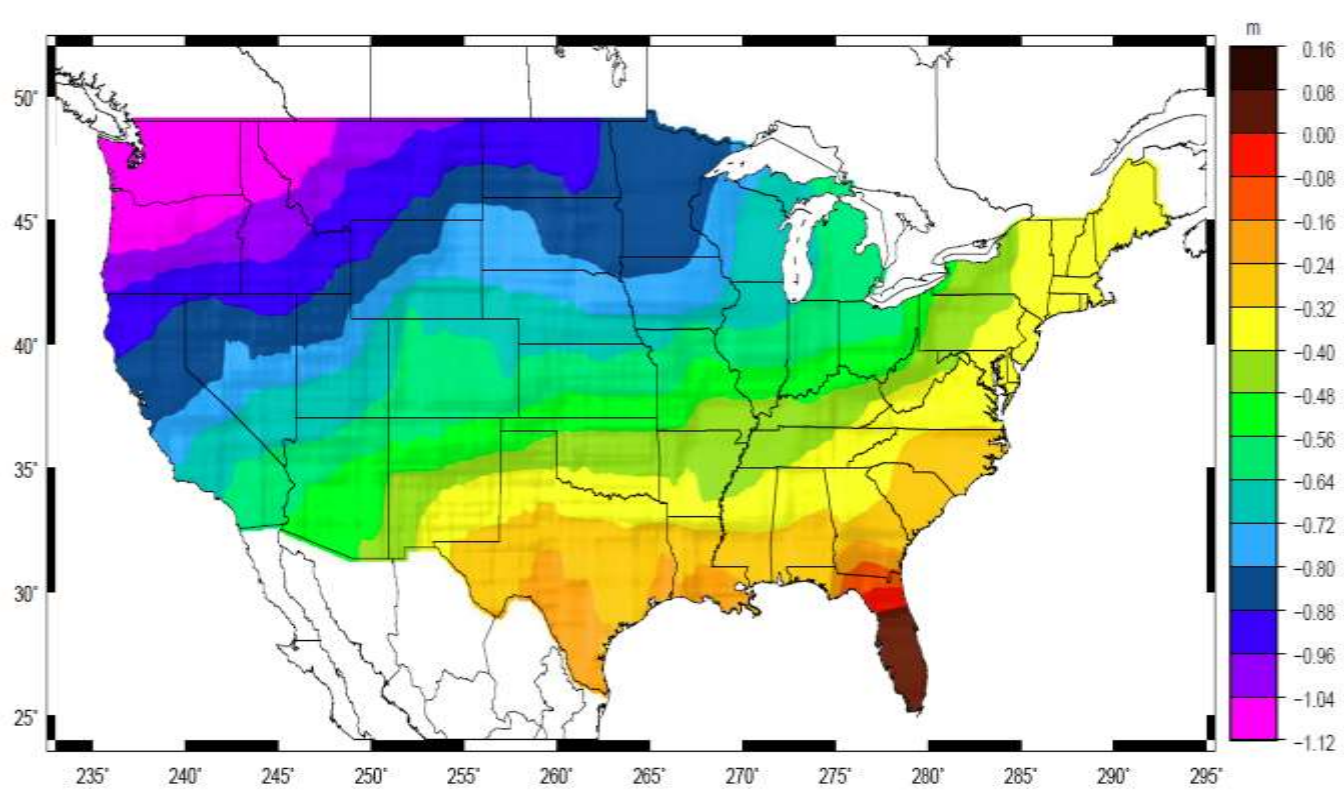


Errors in NAVD 88 : ~50 cm average, 100 cm CONUS tilt, 1-2 meters average in Alaska, NO tracking

Orthometric Heights

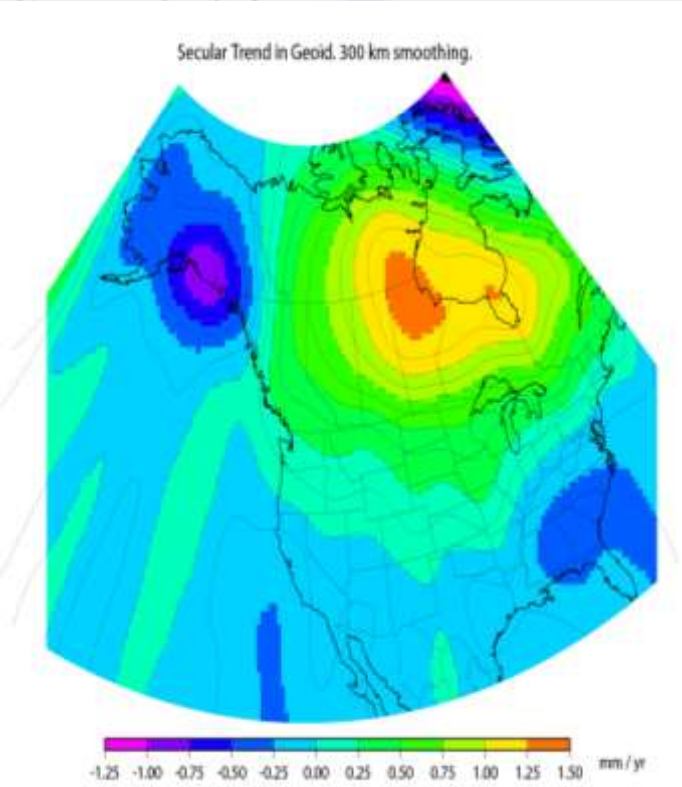
APPROXIMATE EXPECTED SHIFTS

- **Approximate level of geoid mismatch known to exist in the NAVD 88 zero surface:**
  - **Does not include local subsidence issues**



Time Dependencies

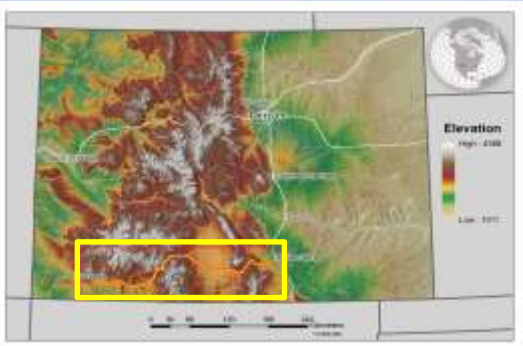
GEOID CHANGES CAUSE HEIGHT CHANGES



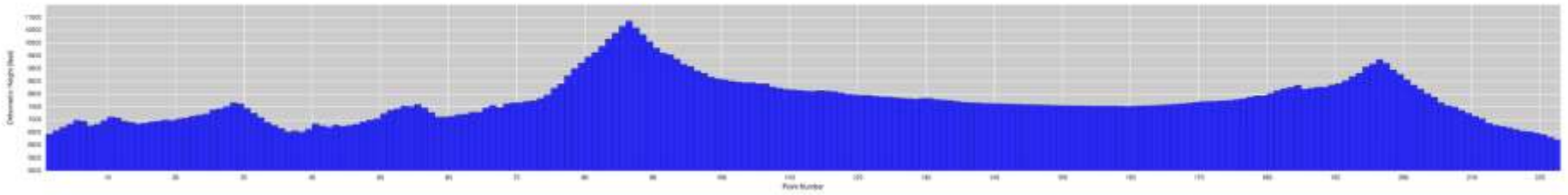
- The zero elevation surface will change with time
- Heights will be time tagged to respect:
  - Geoid change
  - Subsidence
- Possibly start a Geoid monitoring service?

Geoid Slope Validation Survey (GSVS17)

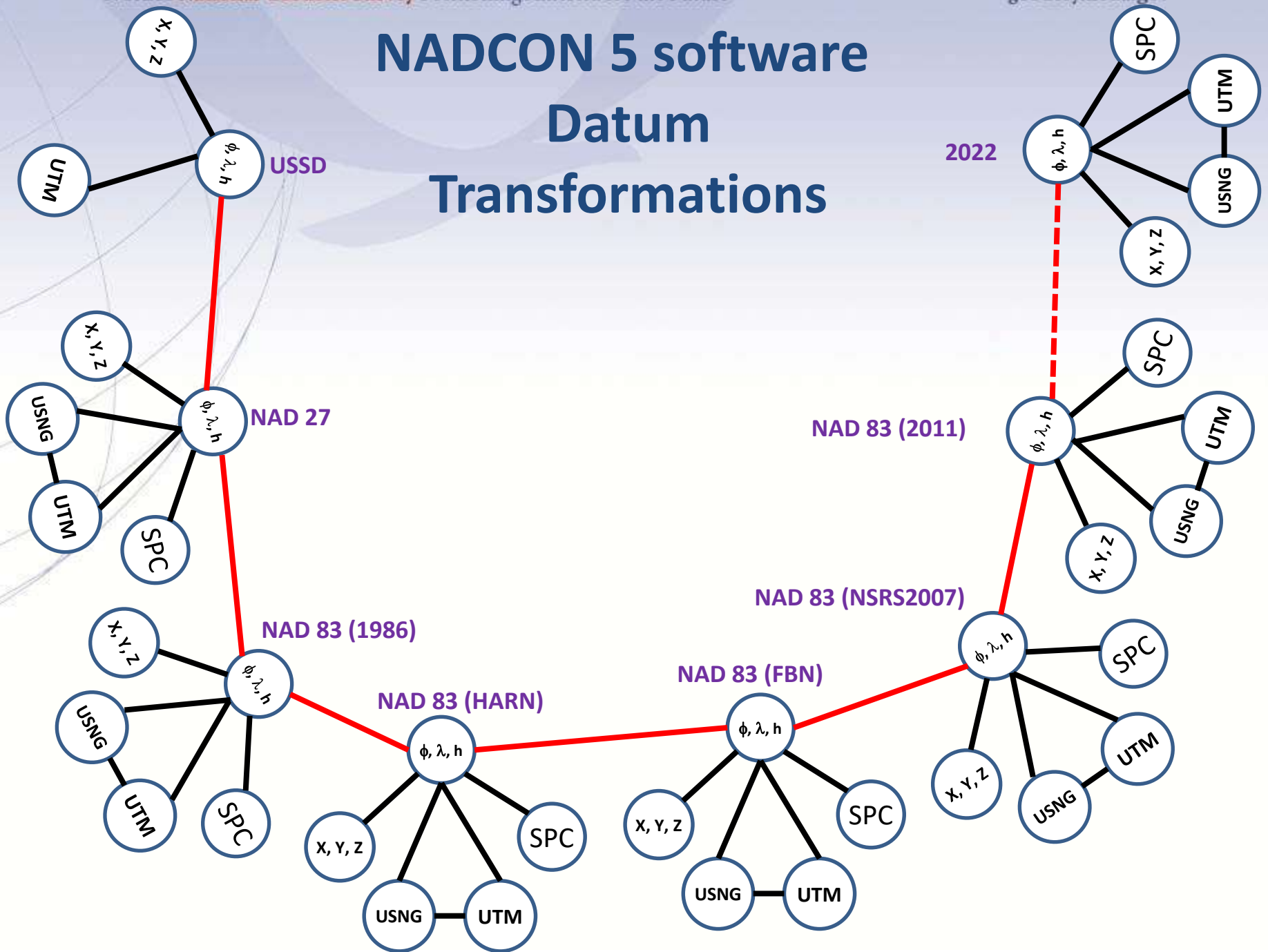
Colorado along Hwy 160
Durango to Walsenburg
>1250m (~4100 ft) elevation change
221 new monuments, 221 miles of hwy



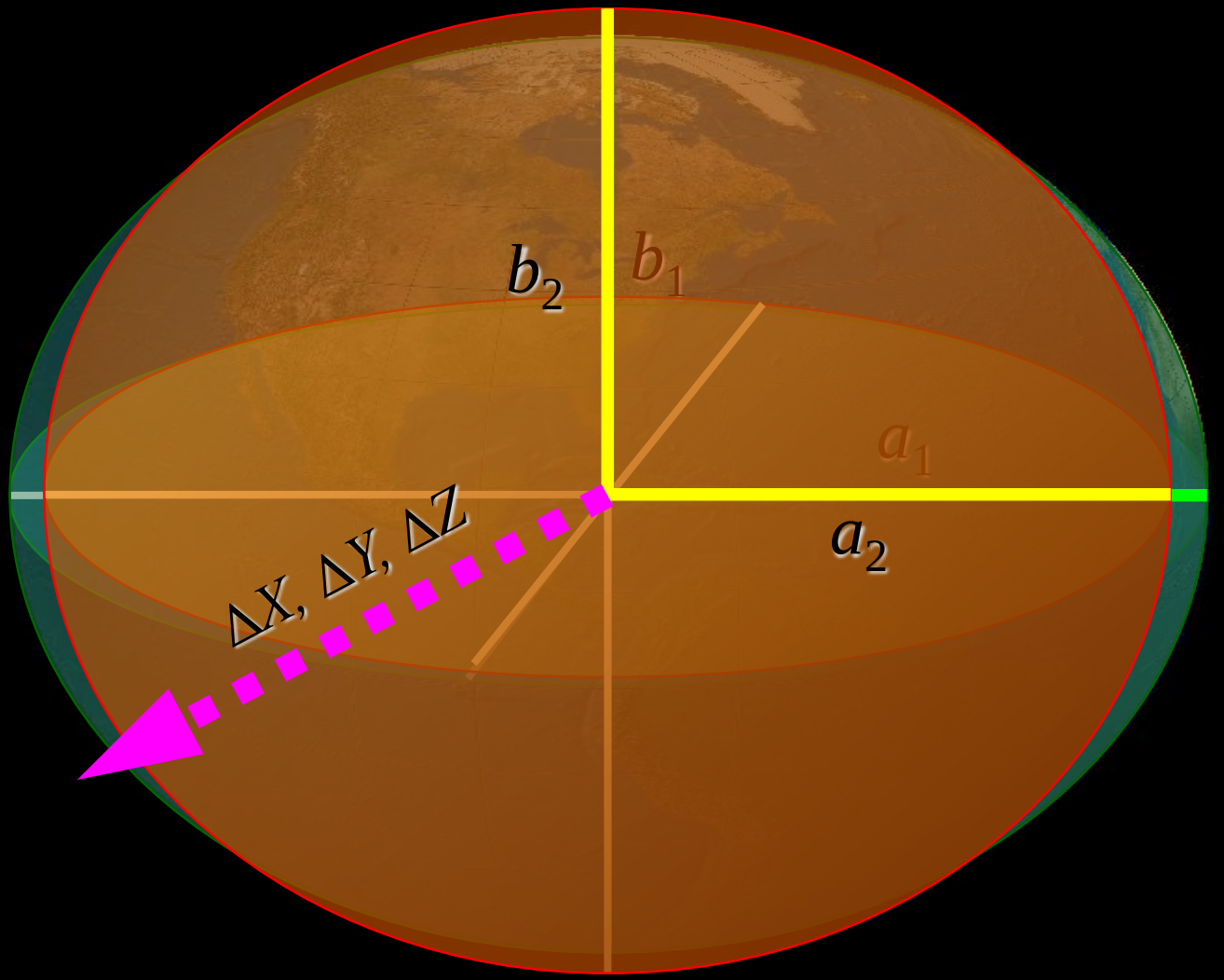
GSVS17 Elevation Profile



NADCON 5 software Datum Transformations

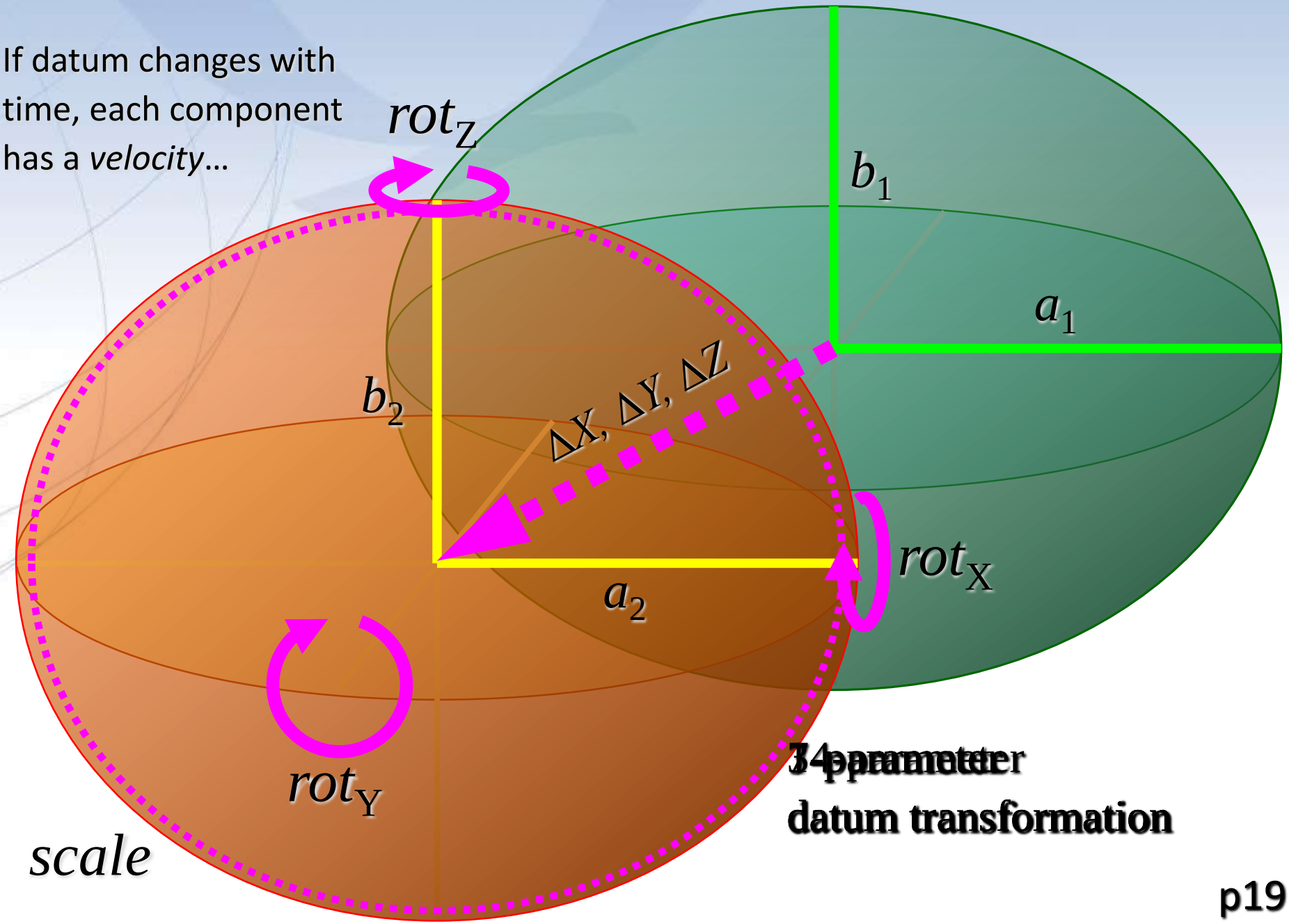


Geometric datum transformations



Geometric datum transformations

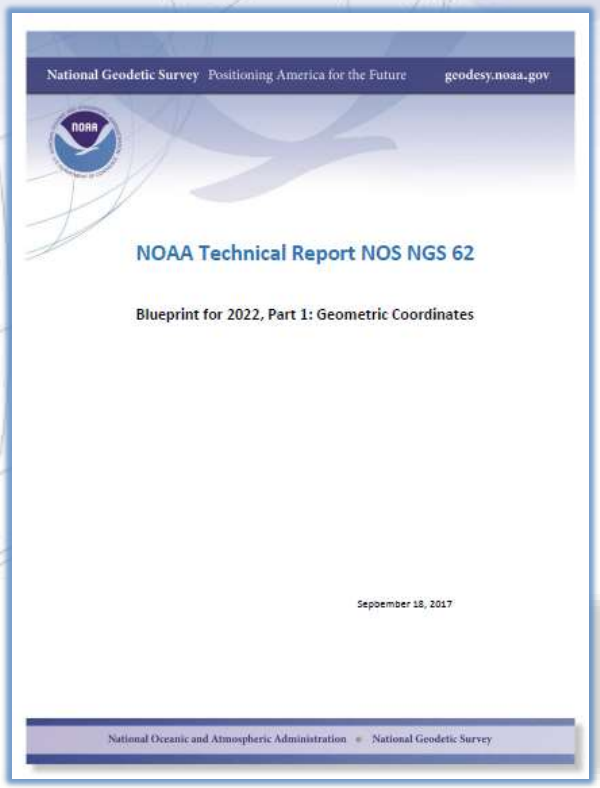
If datum changes with time, each component has a *velocity*…



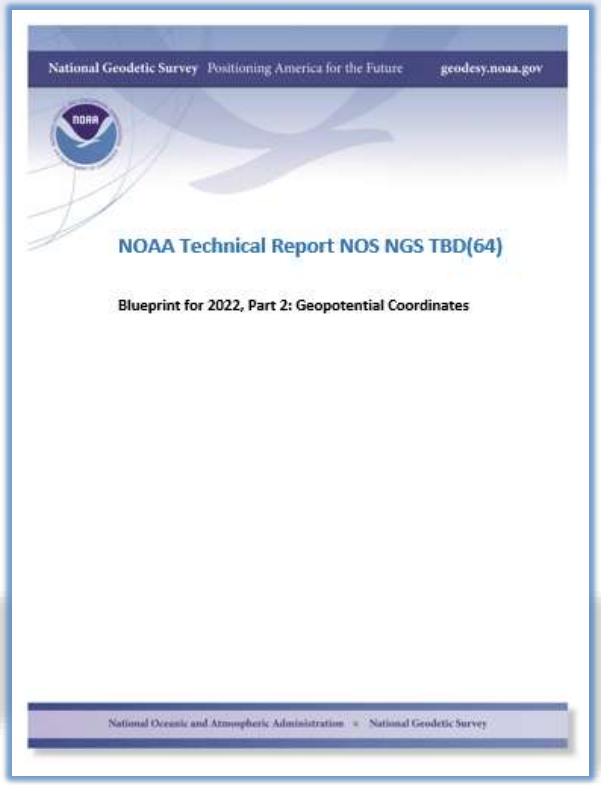
7-parameter datum transformation

Modernizing the NSRS

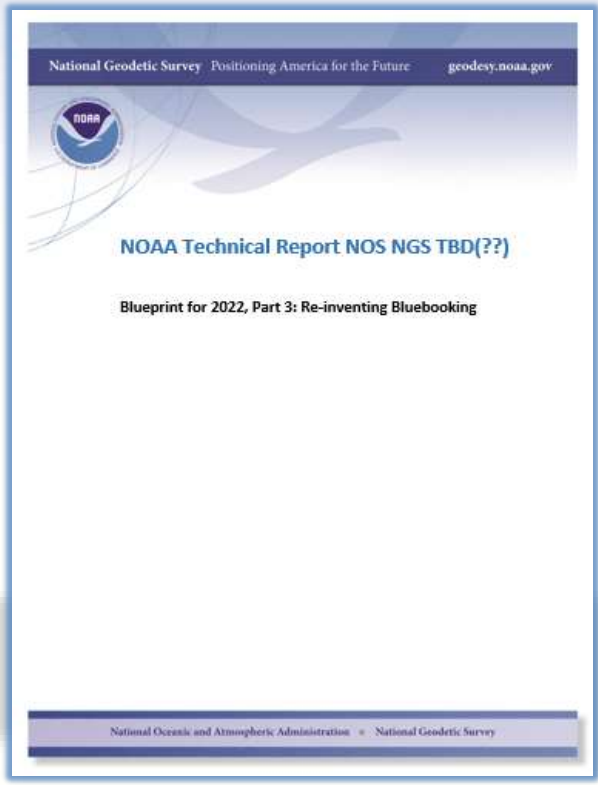
The "blueprint" documents: Your **best** source for **information**



Geometric:
May 2017
(minor update Sep. 2017)



Geopotential:
Oct. 2017



Bluebooking:
Spring 2018