How to Transition to the United States 2022 National Coordinate System Without Getting Left Behind

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The National Geodetic Survey (NGS)

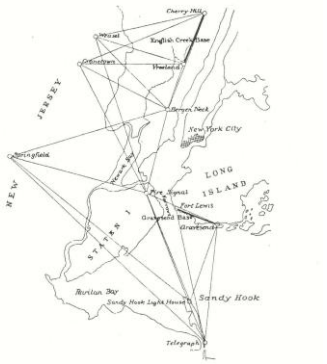
Our Nation's first science agency

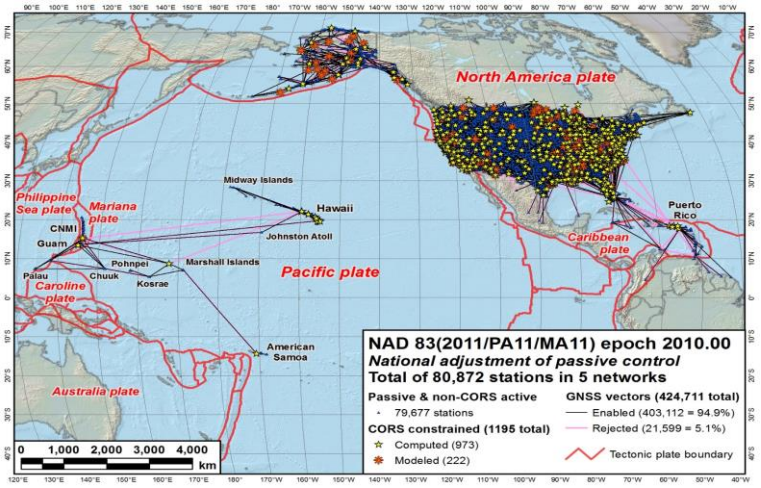
1807
Thomas Jefferson
Survey of the Coast

1807
Ferdinand R. Hassler
First Superintendent

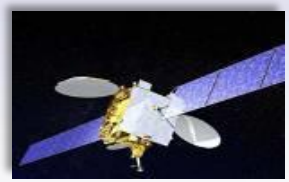
1878
U.S. Coast and Geodetic Survey

1970
NOAA is established





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



Satellite Operations

Personal Navigation

Survey Marks

NGS Programs

Modernizing the NSRS

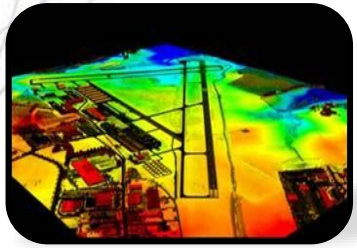
CORS

Height Modernization

GRAV-D

Ecosystem and Climate Operation

NGS Products and Services

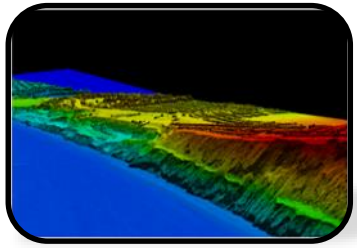


Airport Surveys

OPUS

VDatum

GPS Satellite Orbits



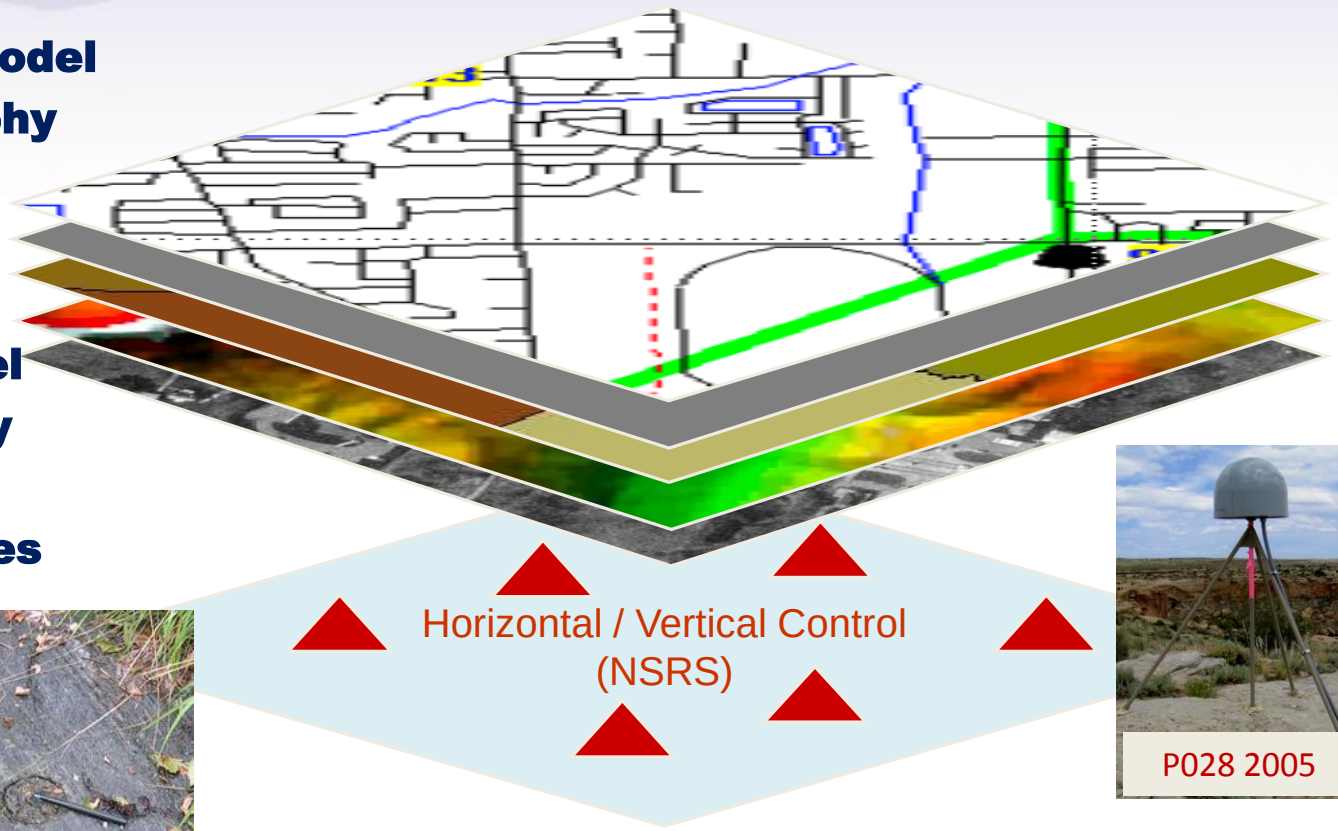
Coastal Mapping

Regional Advisor Program

Emergency Response Imagery

National Spatial Reference System
Ties It All Together

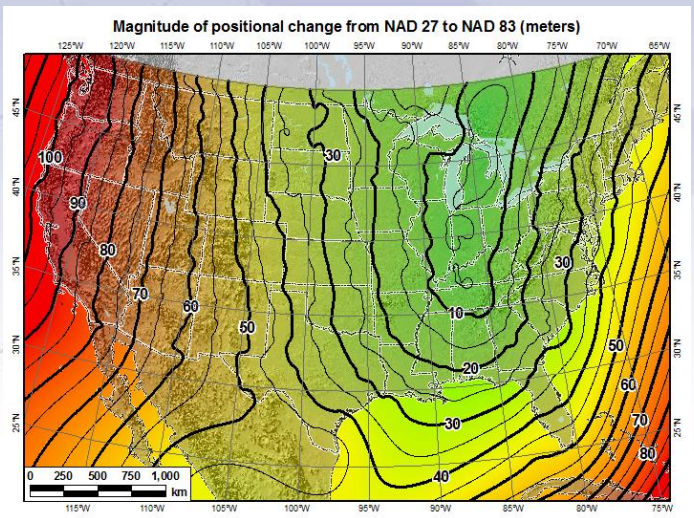
- LiDAR
- Digital Terrain Model
- Aerial Photography
- Cartography
- Parcels
- Engineering
- Laser Scan Model
- Satellite Imagery
- Hydrography
- Natural Resources




BUTTERMILK 1833

P028 2005

NSRS - Evolved Over Time



U.S. Standard Datum

NAD27

NAD83 (1986)

NAD83 (HARN /199X)

NAD83 (2007)

NAD83 (2011)

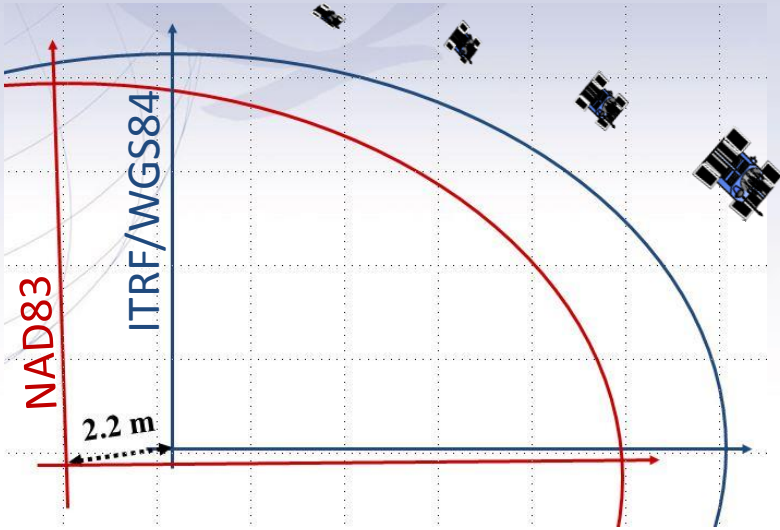
time

< 10m | ~ 10m | 1m | 0.1m | 0.01m | 0.01m

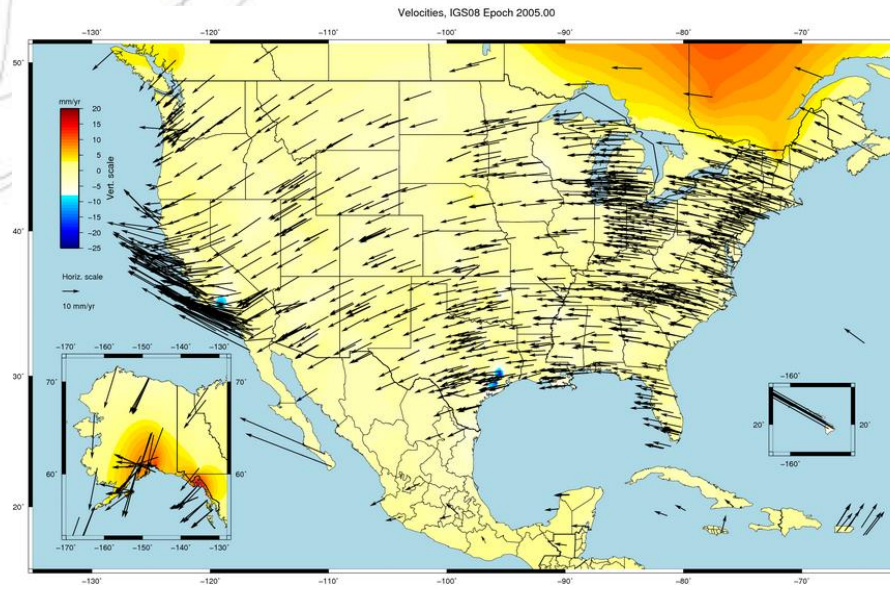
Network Accuracy

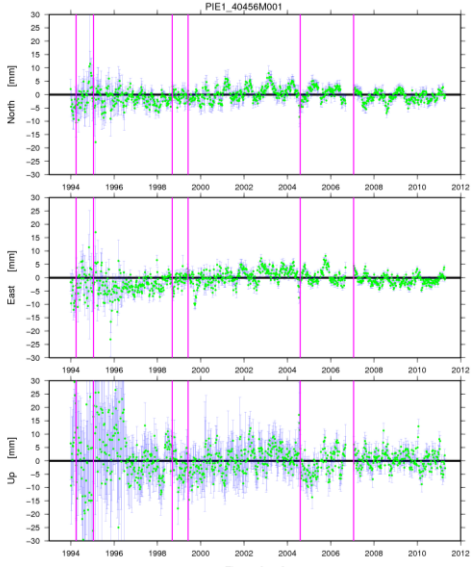
NAD83 Shortcomings

- 2.2 m offset – NAD83 vs.
- International Terrestrial Reference Frame (ITRF) [~ International GNSS Service (IGS)]
- World Geodetic System 1984 (WGS84)

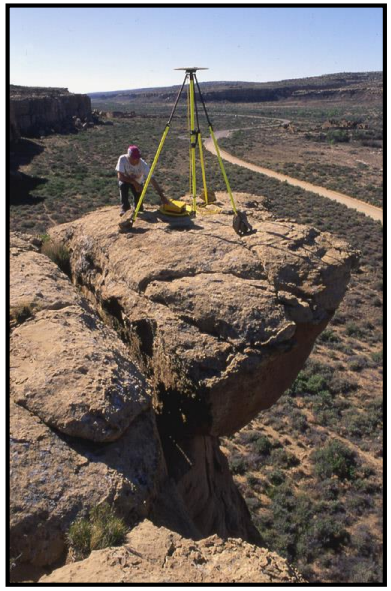


- CORS <> passive network "disconnect"





vs.



Why replace NAD 83 & Vertical Datums?

- **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")

The National Geodetic Survey Ten-Year Plan

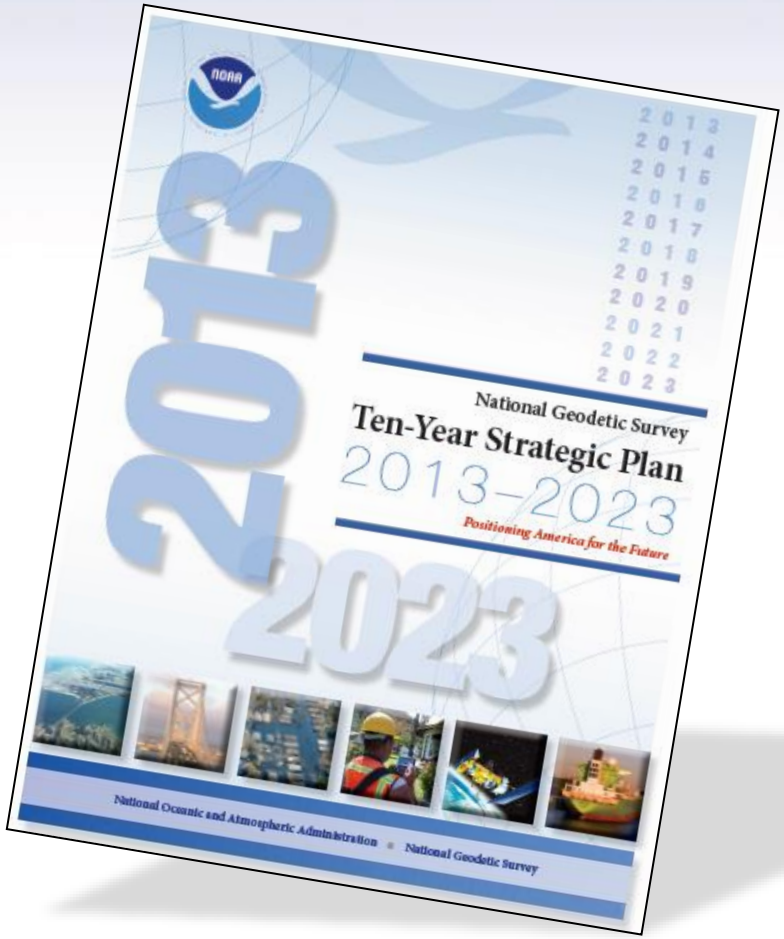
Support the users of the National Spatial Reference System.

Modernize and improve the National Spatial Reference System.
(i.e., Replace NAD83 & NAVD88)

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.

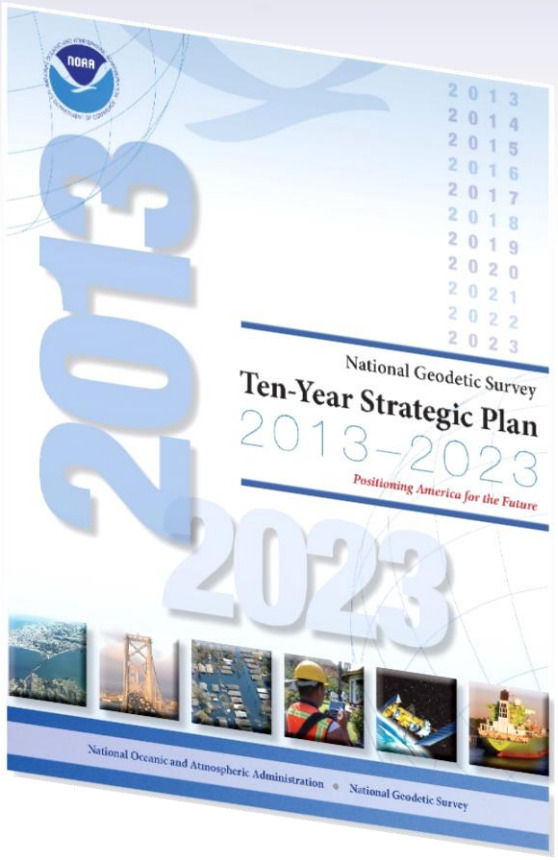


2022 Datums Goals

- **"Replace NAD83"** - By 2022, reduce all definitional & access-related errors in geometric reference frame to 1 cm when using ~30 min of GNSS data

- **"Replace NAVD88"** - By 2022, reduce all definitional & access-related errors in orthometric heights, relative to sea level, in geopotential datum to 2 cm when using ~30 min of GNSS data

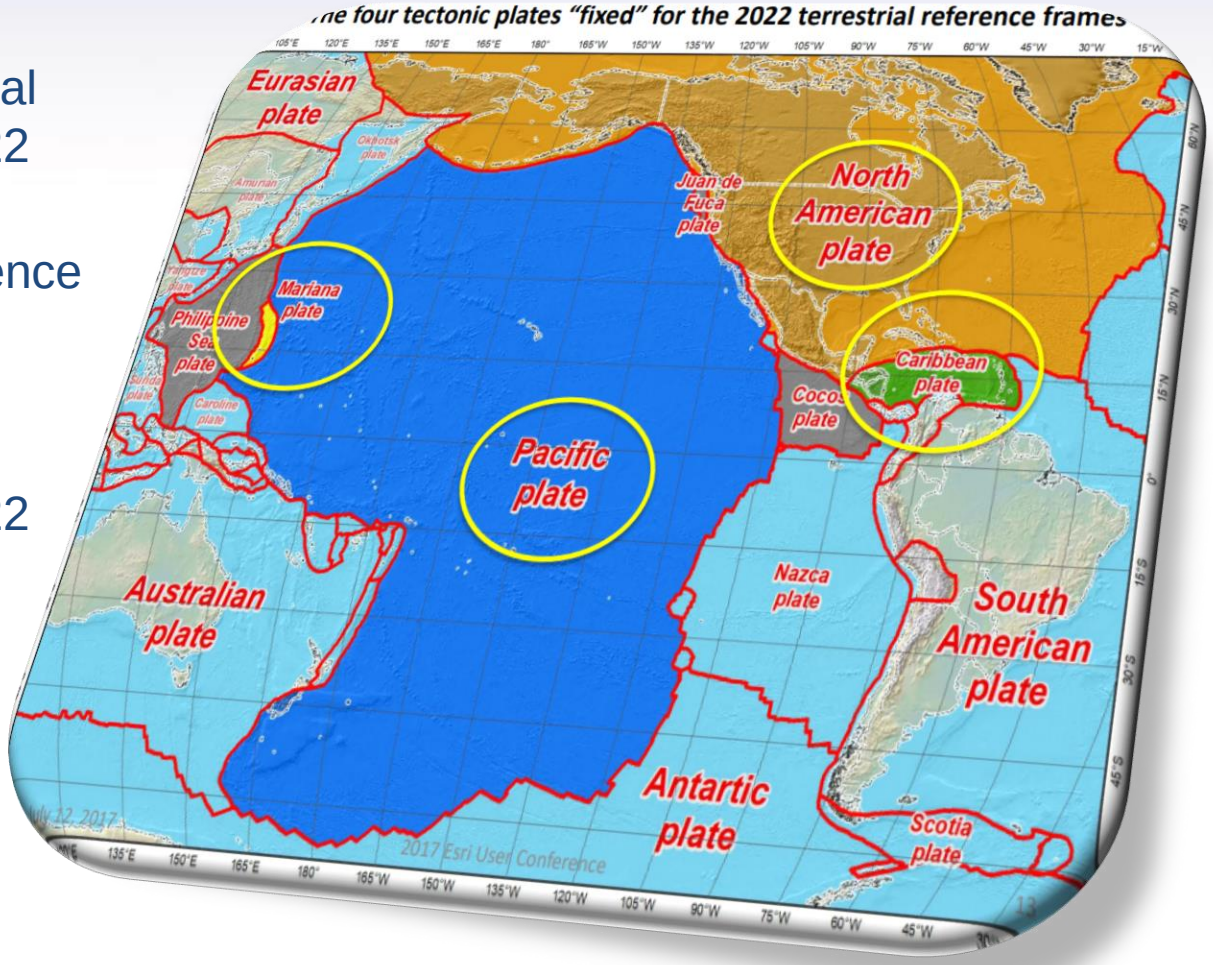
- Provide tools to easily transform between new old datums



Four Tectonic Plates NGS Monitors

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

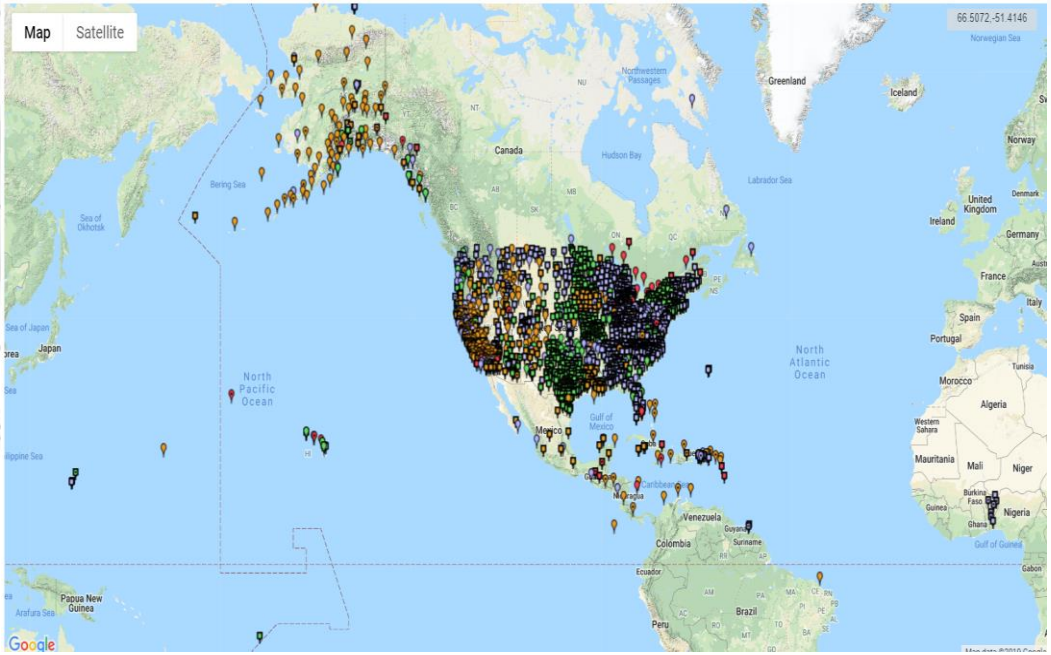
- ✓ North American Terrestrial Reference Frame of 2022 **(NATRF2022)**
- ✓ Pacific Terrestrial Reference Frame of 2022 **(PATRF2022)**
- ✓ Caribbean Terrestrial Reference Frame of 2022 **(CATRF2022)**
- ✓ Mariana Terrestrial Reference Frame of **(MATRF2022)**



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)



- ~2300 Continuously Operating Reference Stations
- Run by more than 200 organizations (various government, academic, and private organizations)
- Provide access to the U.S. National Spatial Reference System

Foundation CORS Requirements

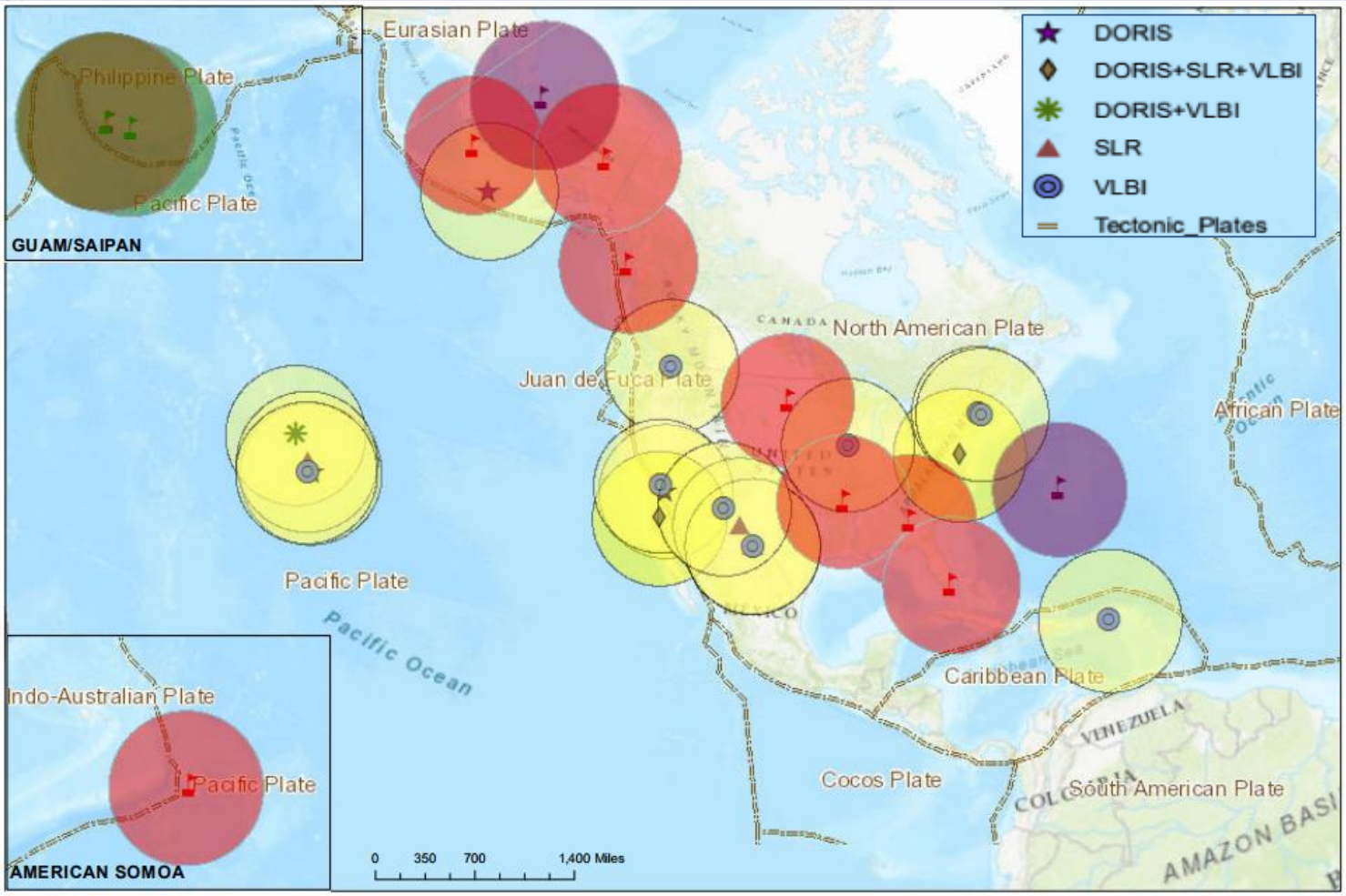
- **Baseline Foundation CORS Network:**
  - **COLLOCATE - All Sites** within the Foundation CORS target area of the United States, that have an existing space geodetic techniques **(SLR, VLBI or DORIS)** will have a collocated Foundation CORS

- **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.

Foundation CORS tentative target

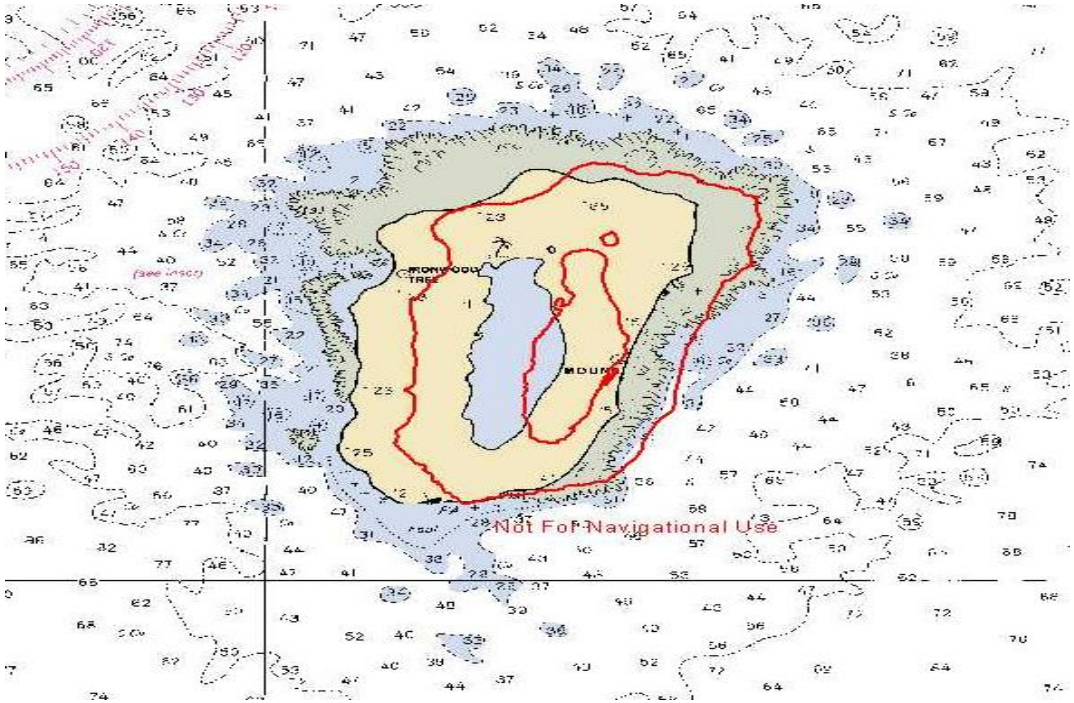
Criteria

1. Co-located with space-based technology
2. Density
3. Euler pole
4. Additional site (Bermuda)



Density Buffer 800km
Euler Buffer 800km
Additional Buffer 800km
SBT Buffer 800km
Tectonic_Plates

All coordinates & ellipsoid heights will change!

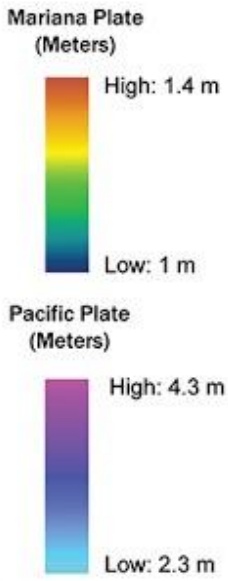


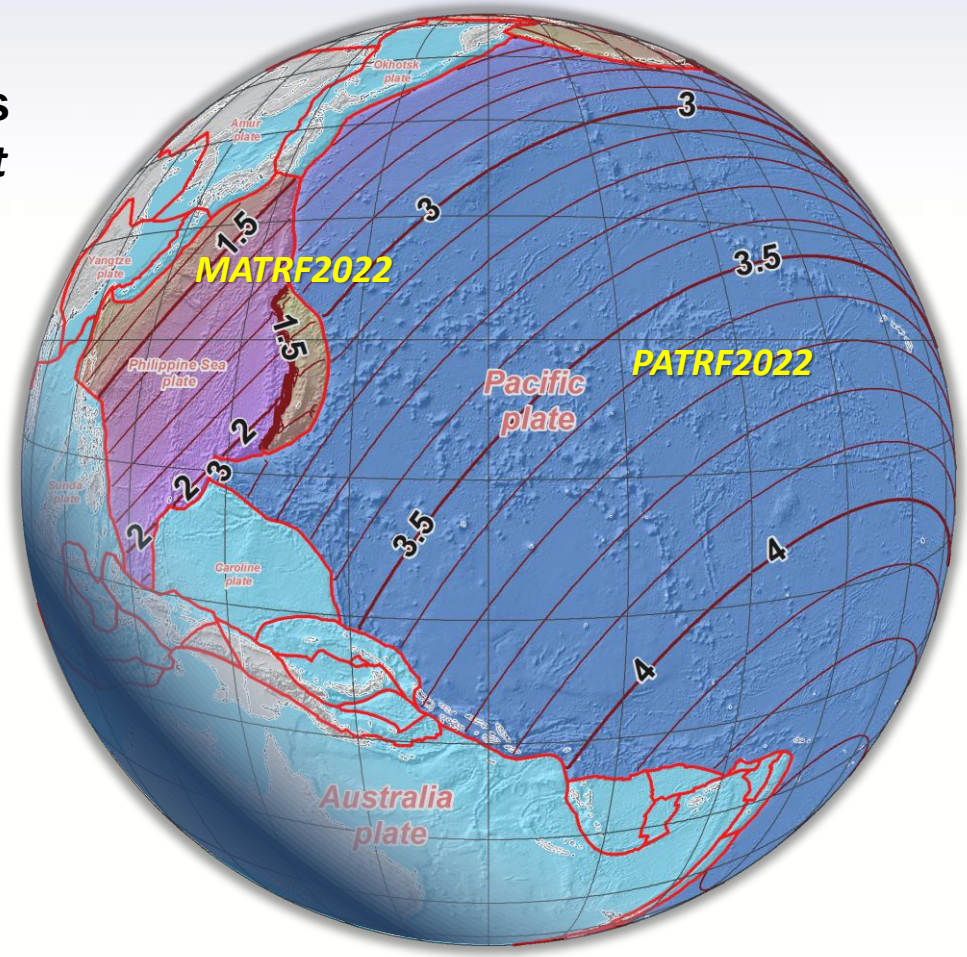
Approximate Horizontal Change

NAD 83 (2011/PA11/MA11) epoch 2010.00 → 2022 Terrestrial Reference Frames

Horizontal change at epoch 2022.00

(contours in meters)

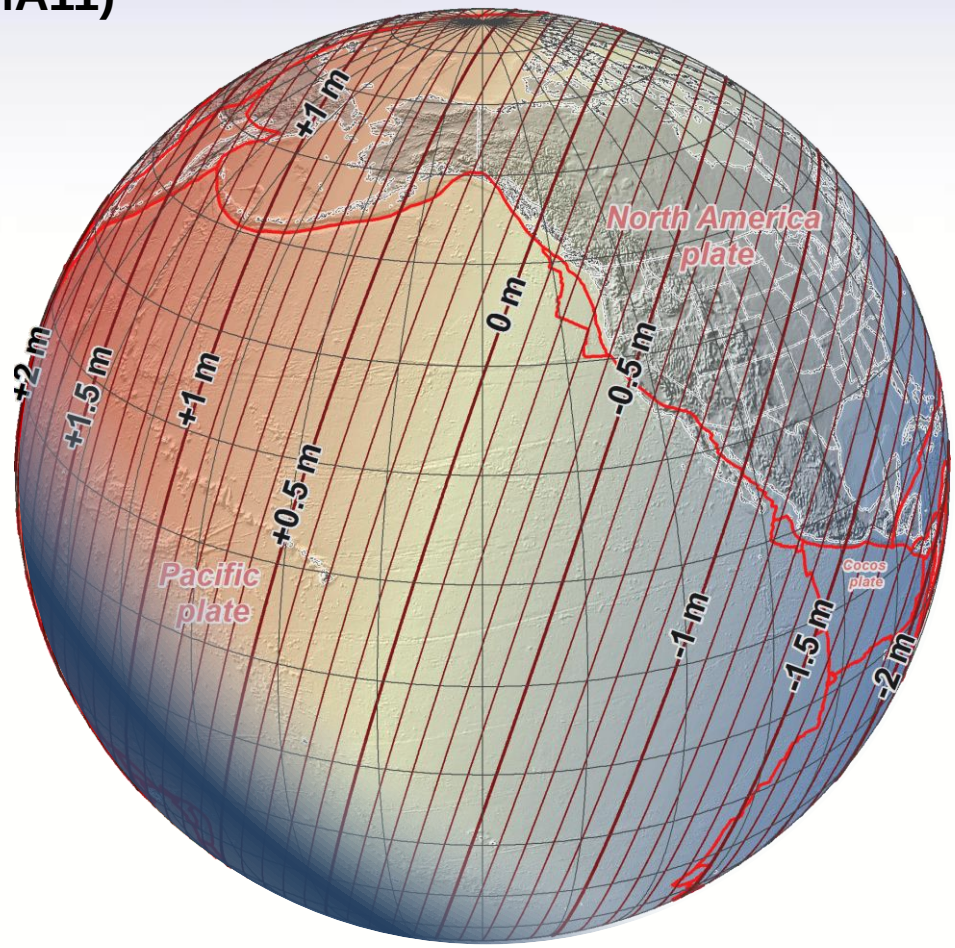


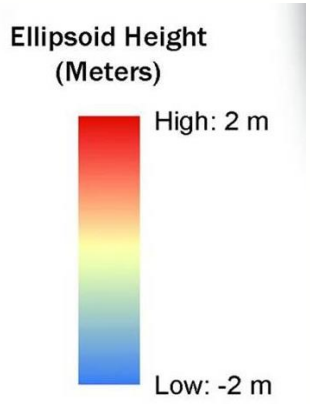


Approximate Ellipsoid Height Change

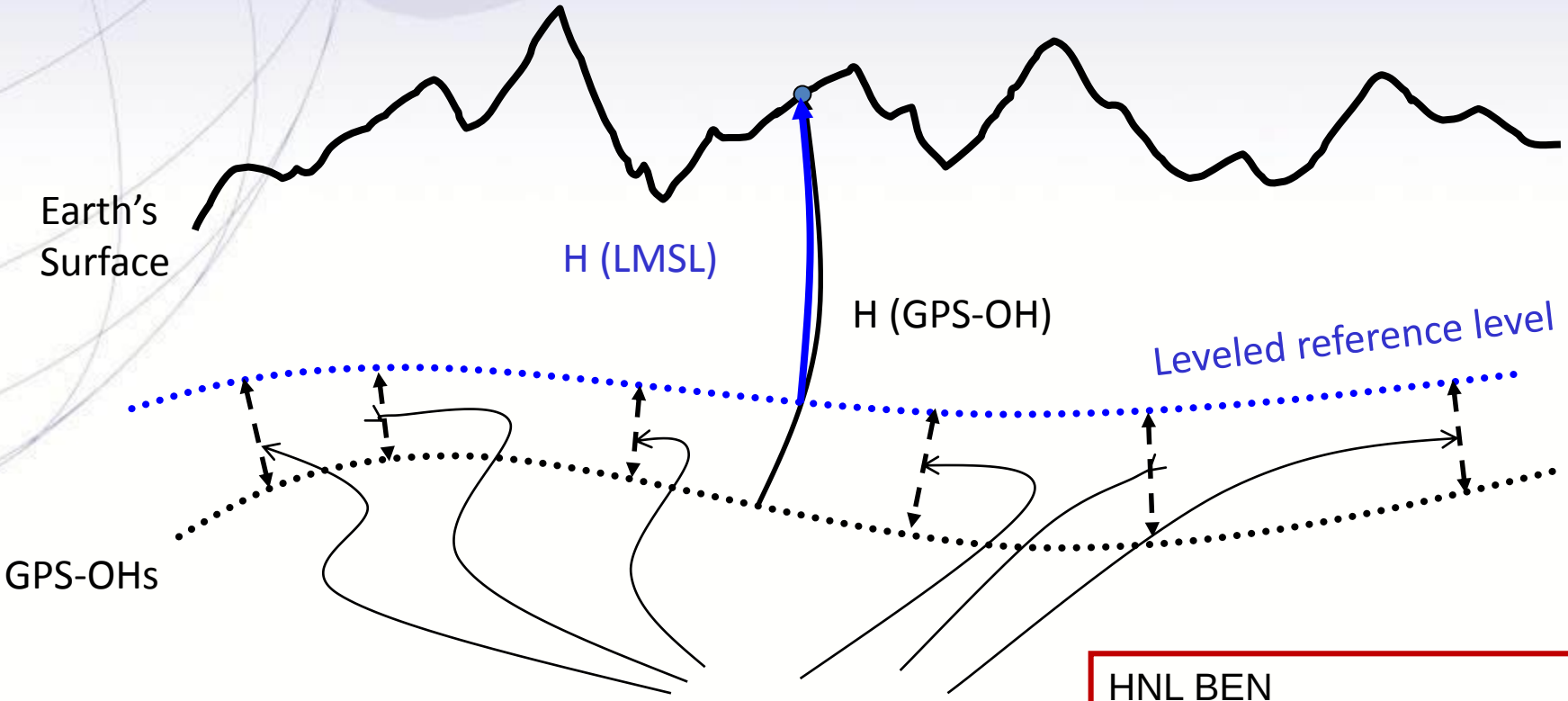
NAD 83 (2011/PA11/MA11) epoch 2010.00 → 2022 Terrestrial Reference Frames

Change in ellipsoid heights at epoch 2022.00
(contours in meters)





Problems in the Vertical with NSRS



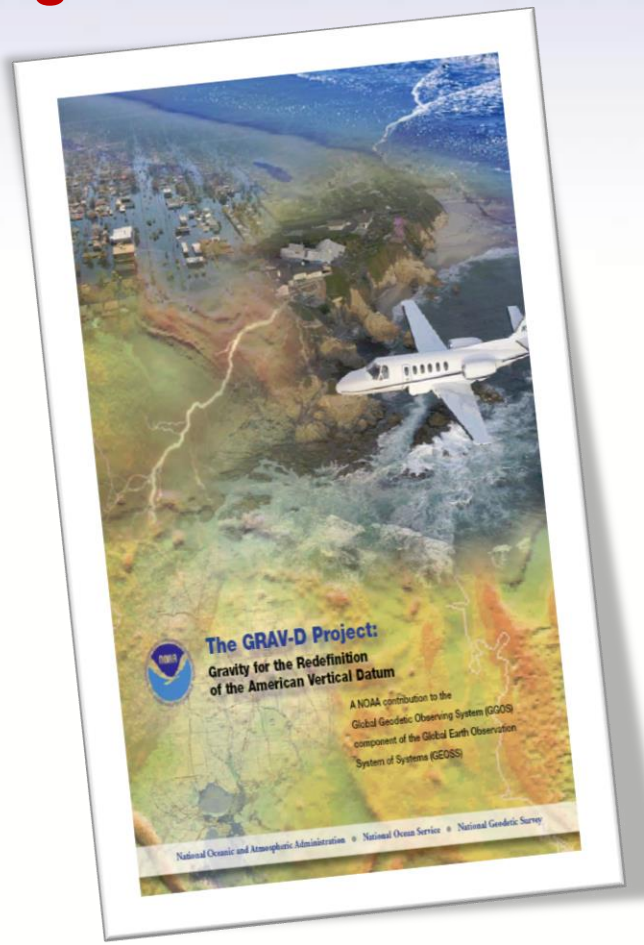
Errors : ~50 cm average,
100 cm CONUS tilt,
50/70 cm in Hawaii
1-2 meters average in Alaska

HNL BEN
Geoid12A
5.894 = 21.090 – (+15.196)m
5.894 = 5.320m (LMSL)
Difference ~ 0.574m or 1.87ft

2022 Vertical Datum

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

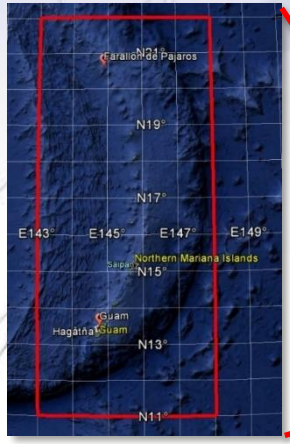
- Biggest requirement: An updated, accurate, nationwide gravity survey
  - Airborne
  - GRAV-D!
    - **G**ravity for the **R**edefinition of the **A**merican **V**ertical **D**atum



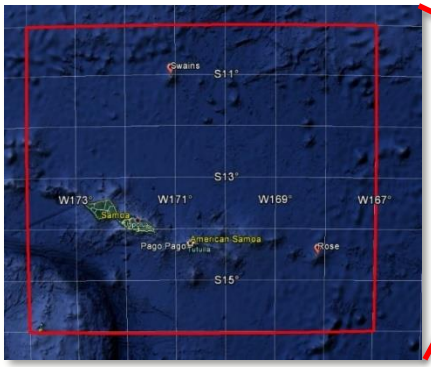
http://www.ngs.noaa.gov/GRAV-D/pubs/GRAV-D_v2007_12_19.pdf

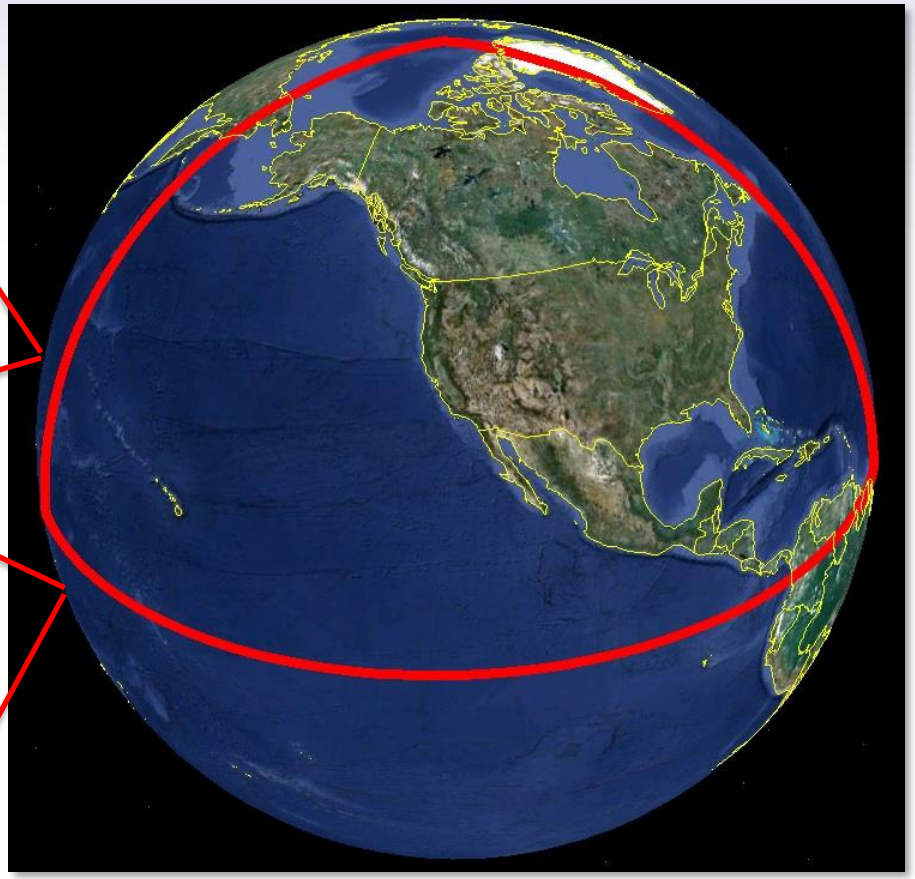
Extent of Gravimetric Geoid Model NAPGD2022

Guam and Northern Marianas Islands



American Samoa





International Coordination

- IAG (Comm. 1 & 2)
  - ITRF/IHRF
  - SIRGAS
  - APREF
- UN-GGIM
  - UN-GGRF
  - UN-GGIM-Americas
  - UN-GGIM- AP
- FIG et al.
- ISO – TC 211, TC 172
- GLCC – IGLD update

Positioning With 2022 Datum

Four Frames/Plates in 2022

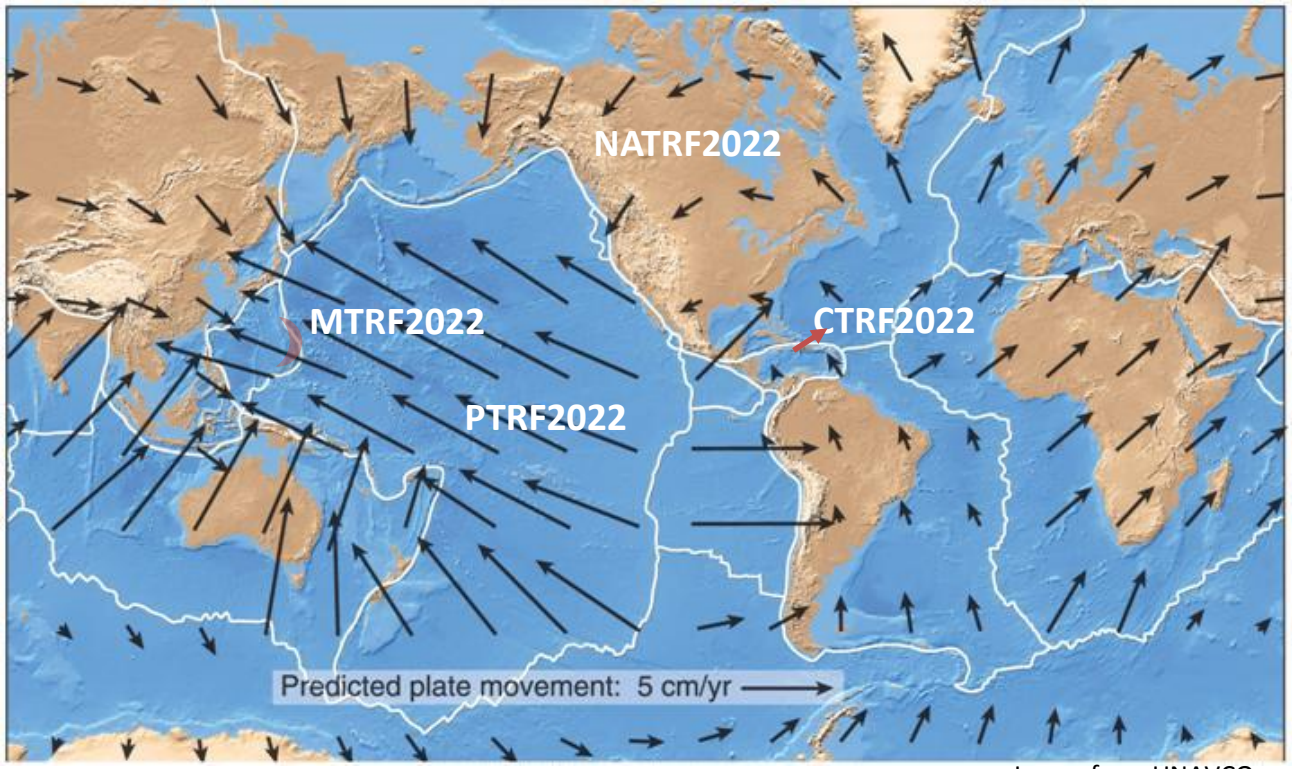


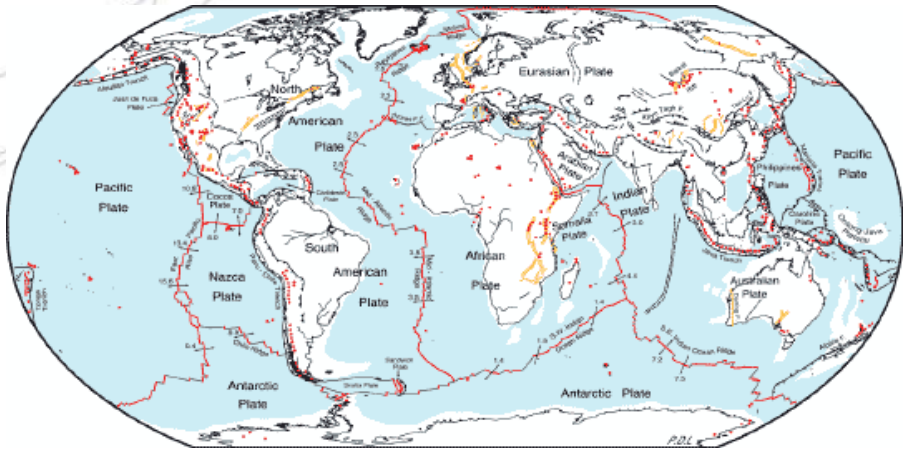
Image from UNAVCO

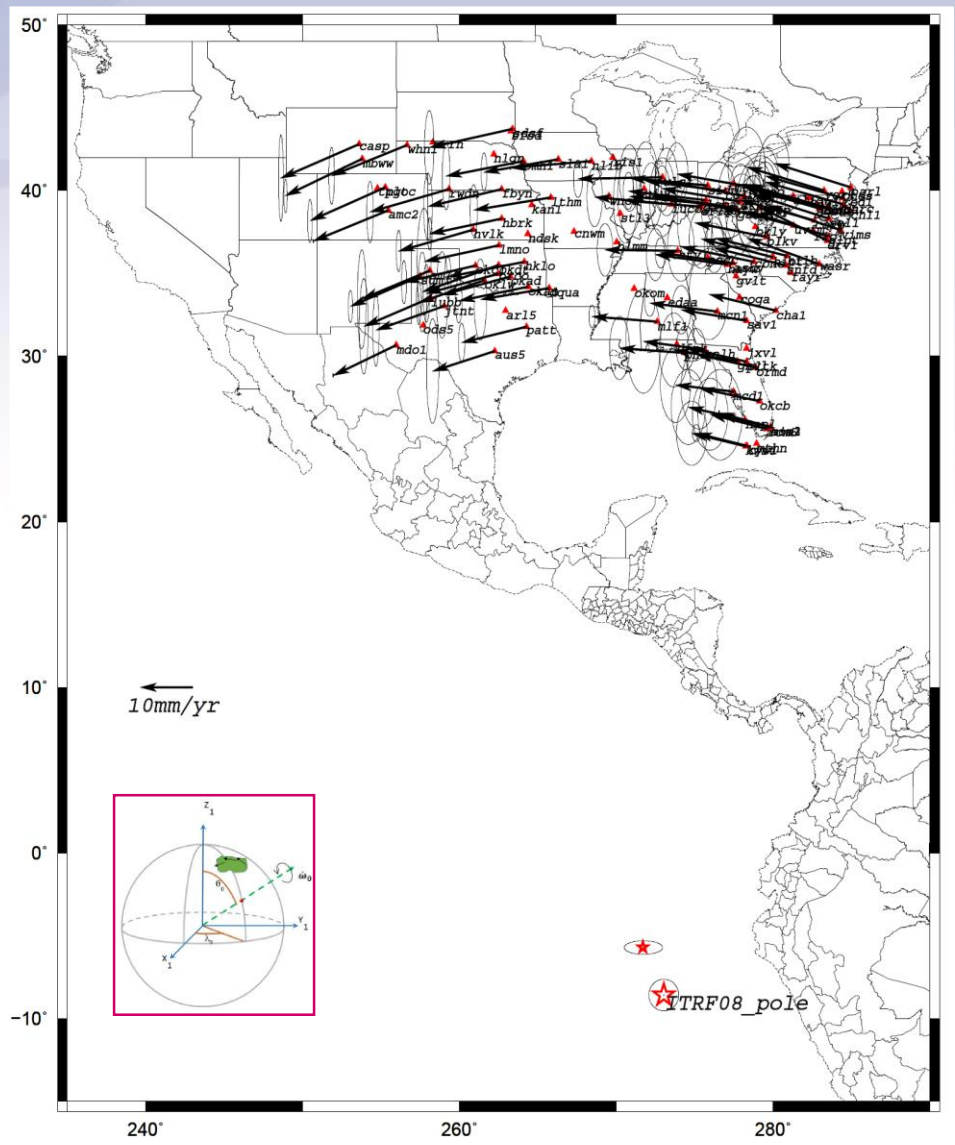
Euler Pole

Each reference frame will get:

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

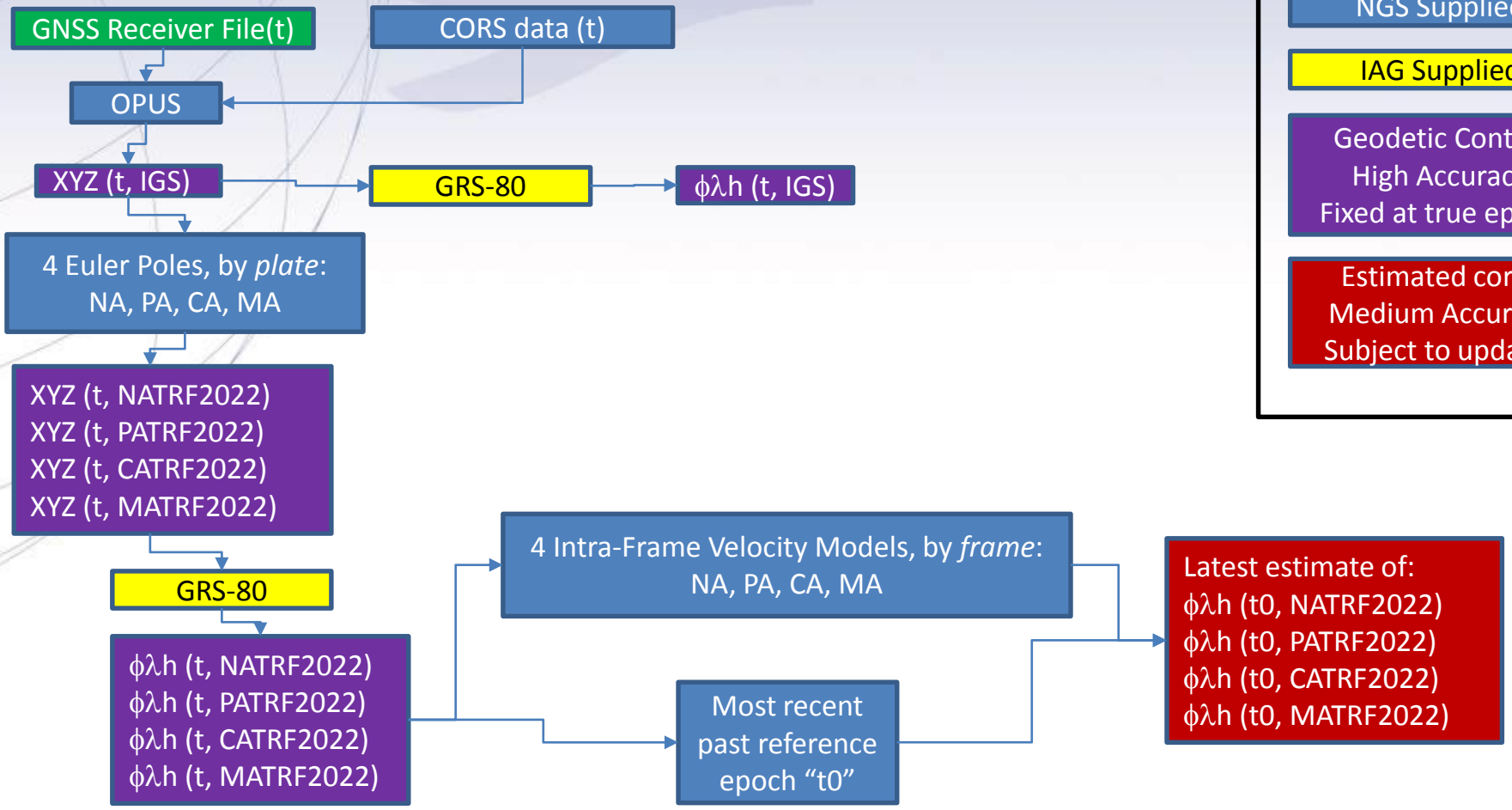
Used to compute time-dependent TRF2022 coordinates from time-dependent global (IGS) coordinates





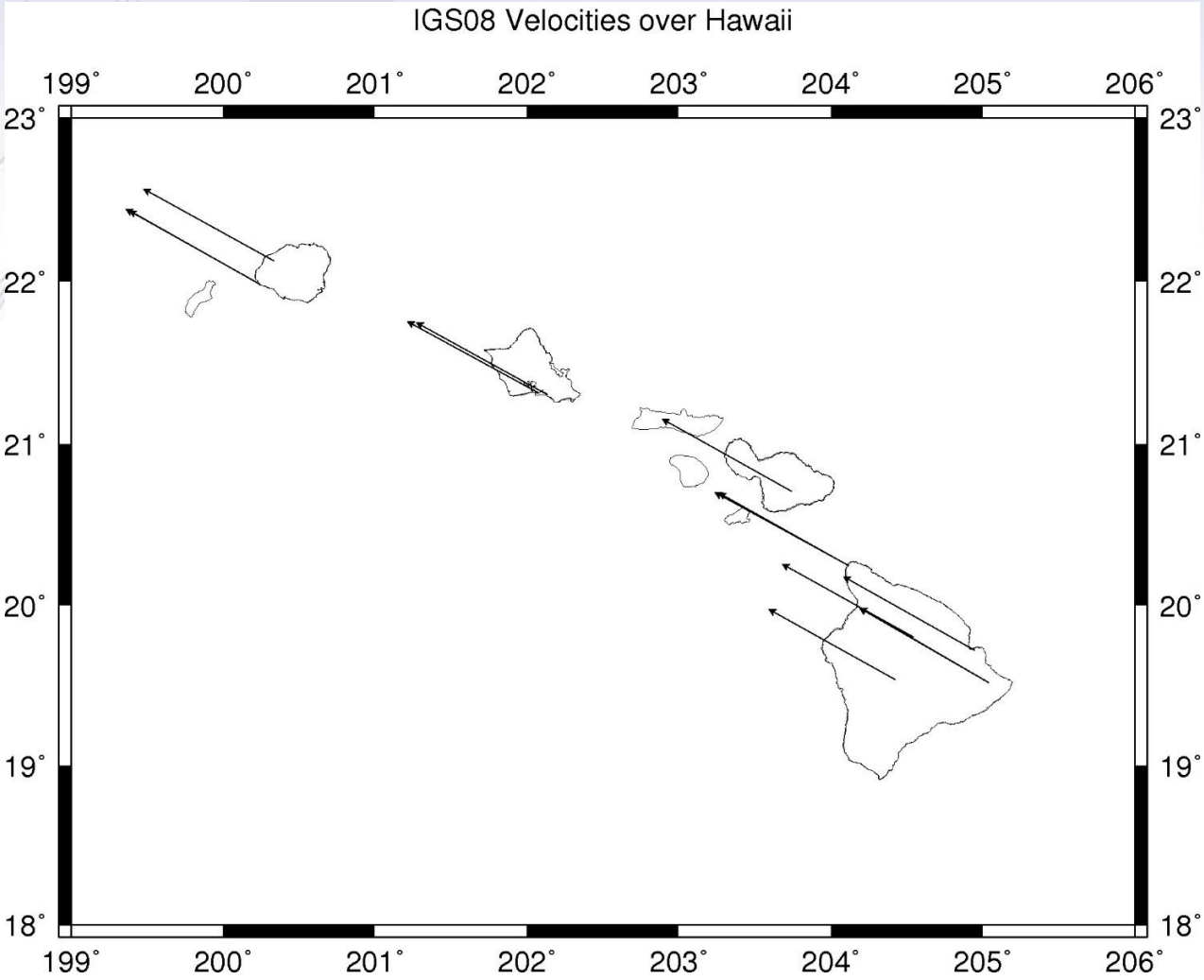
Euler's fixed point theorem states: any motion of a rigid body on the surface of a sphere may be represented as a rotation about an appropriately chosen rotation pole ("Euler Pole")

Using the TRFs

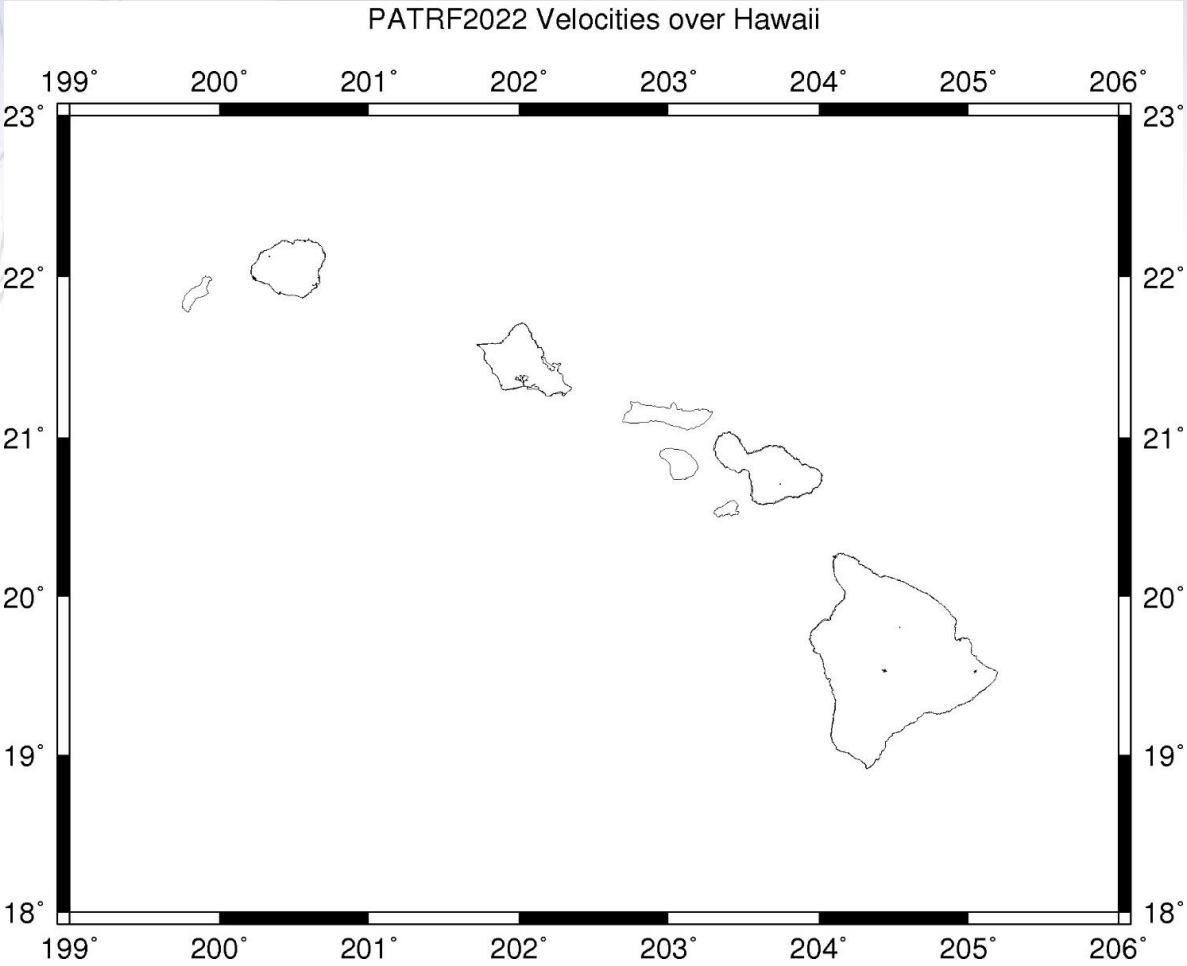


Blueprint for 2022, Part 1: Geometric Coordinates

CORS Velocities Hawaii IGS08



CORS Velocities Hawaii PATRF2022



After Euler Pole Correction and IFVM applied for Pacific Terrestrial Reference

Benefits of the 2022 Datum

USGS

Improved 3DEP and other topographical products

More accurate representation of the physical world in our elevation (and other georeferenced) products

FEMA

More accurate horizontal and vertical coordinates for NFIP

NFIP requires thousands of precise horizontal and vertical measurements of buildings to know where water will flow during floods

USACE

Consistency of vertical datums across the country

Improved accuracy of GPS derived elevations and a better relationship between geodetic and hydrologic datums to manage levies and waterways

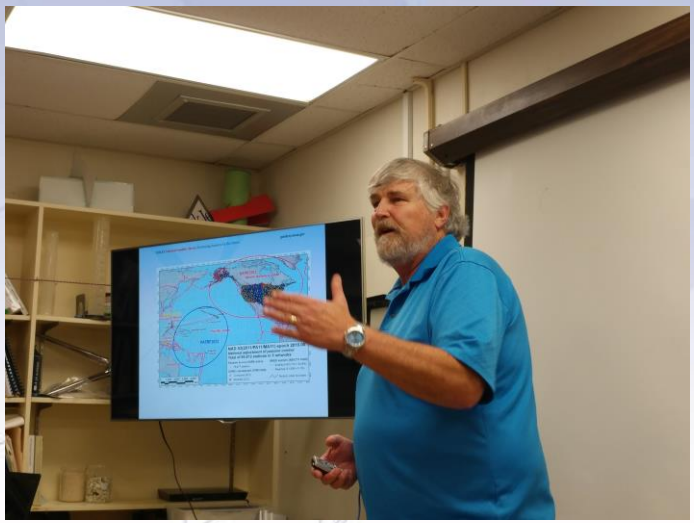
FAA

More closely aligns US NAS to global system (WGS 84)

Improved horizontal and vertical coordinates for airport obstacles

NGA

More closely aligned with WGS 84 and ITRF



Mahalo
Questions ????

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