



Case Study for United States

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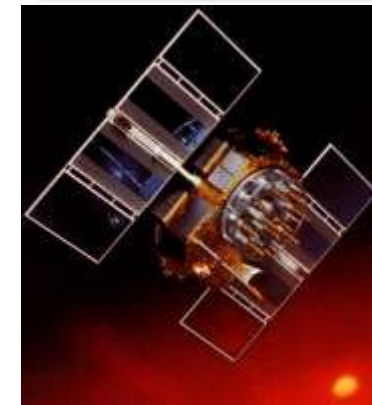


Topics

- *Current horizontal and vertical datums in USA*
 - *North American Datum of 1983 (NAD 83)*
 - *North American Vertical Datum of 1988 (NAVD 88)*
- *National Spatial Reference Frame of 2022*
 - *Replaces both NAD 83 and NAVD 88*
 - *Four Terrestrial Reference Frames based on ITRF14*
 - *Geopotential Datum based on EGM2020, aerogravity and surface gravity*
 - *GRAV-D project for a centimeter geoid provides aerogravity*
- *How will heights be determined in 2022₂*

A brief history of NAD 83

- Original realization completed in 1986
 - Consisted (almost) entirely of classical (optical) observations
- “High Precision Geodetic Network” (HPGN) and “High Accuracy Reference Network” (HARN) realizations
 - Most done in 1990s, essentially state-by-state
 - GNSS based, with classical obs. incl. in adjustments
 - Did NOT use CORS as constraints
- National Re-Adjustment of 2007
 - NAD 83(CORS96) and (NSRS2007)
 - Simultaneous nationwide adjustment (GNSS only)
- ***New realization: NAD 83(2011) epoch 2010.00***

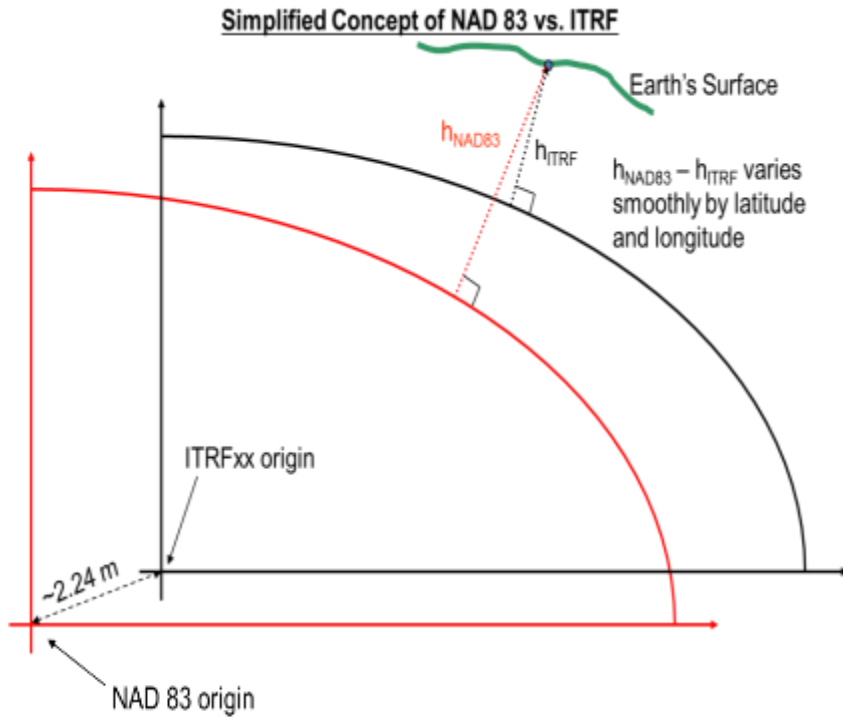


FIG/IGM-Chile Technical Seminar

Reference Frames in Practice



Datum Defect in NAD 83



Approximate Ellipsoid Height Change

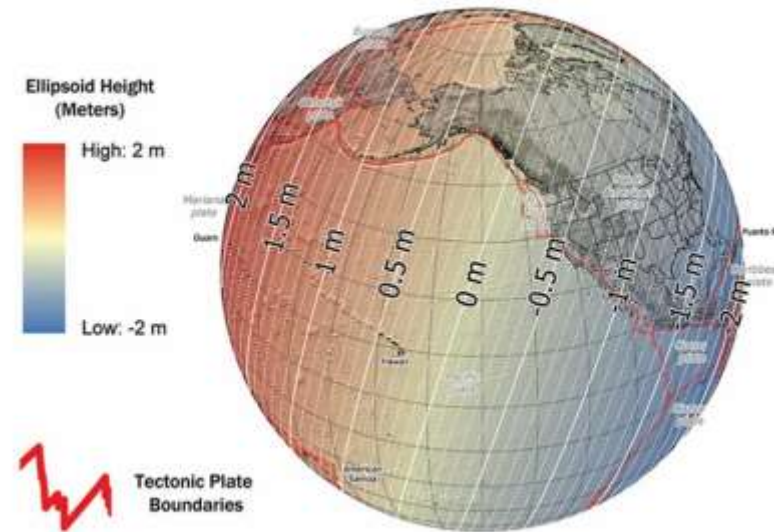
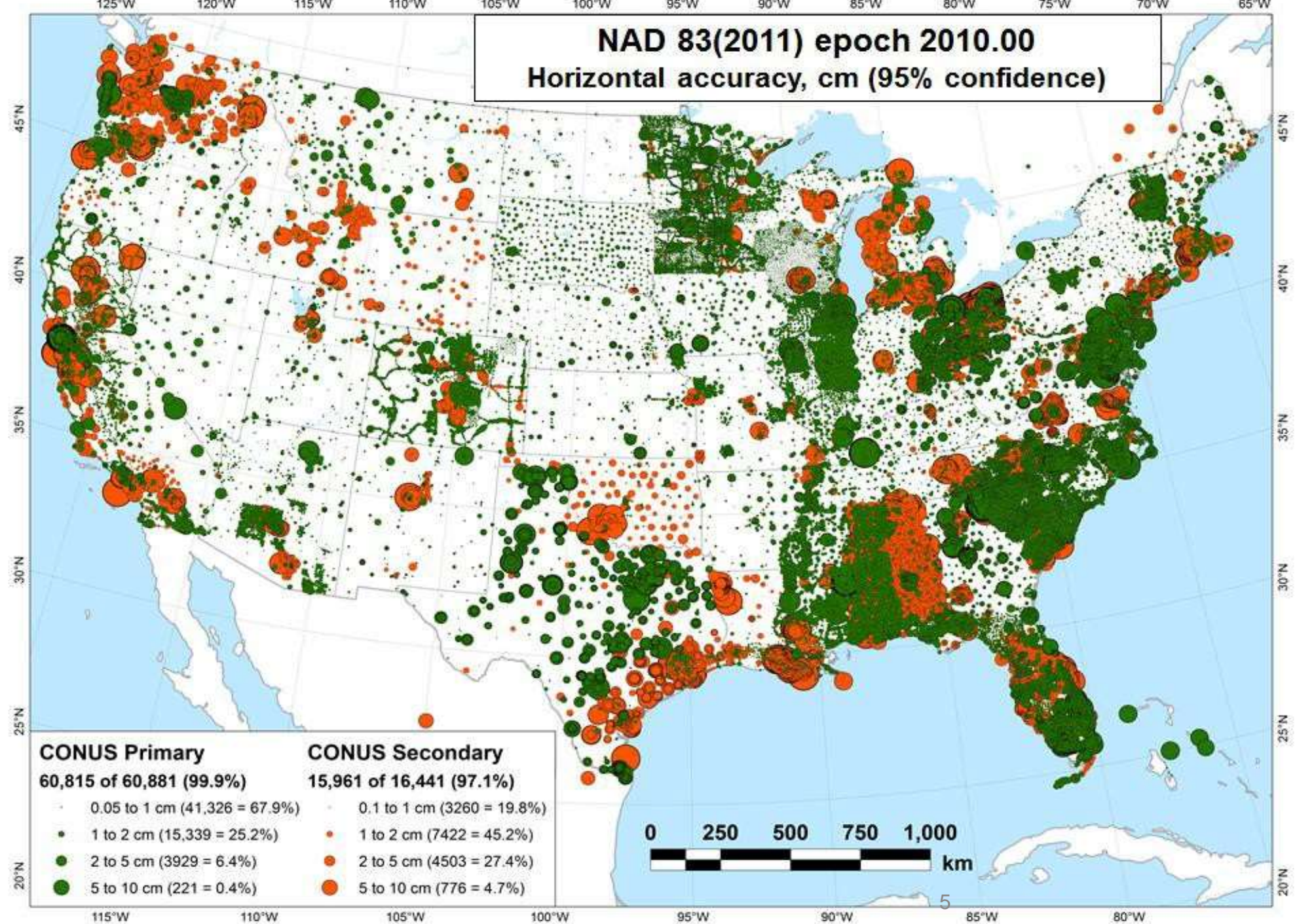


FIG
Ref



Reference Frames in Practice Current Vertical Datum in the

USA

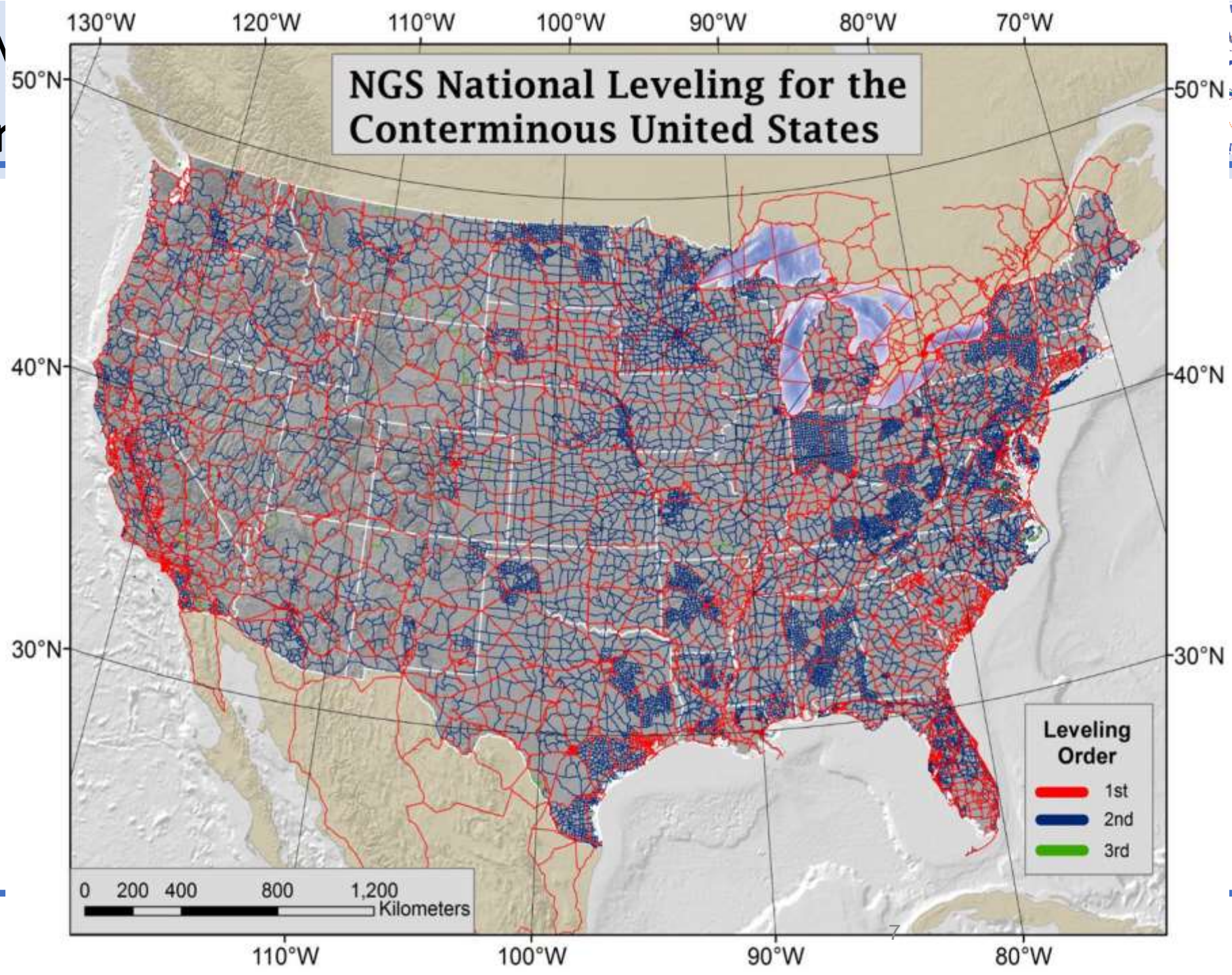


Father Point
Lighthouse, Quebec

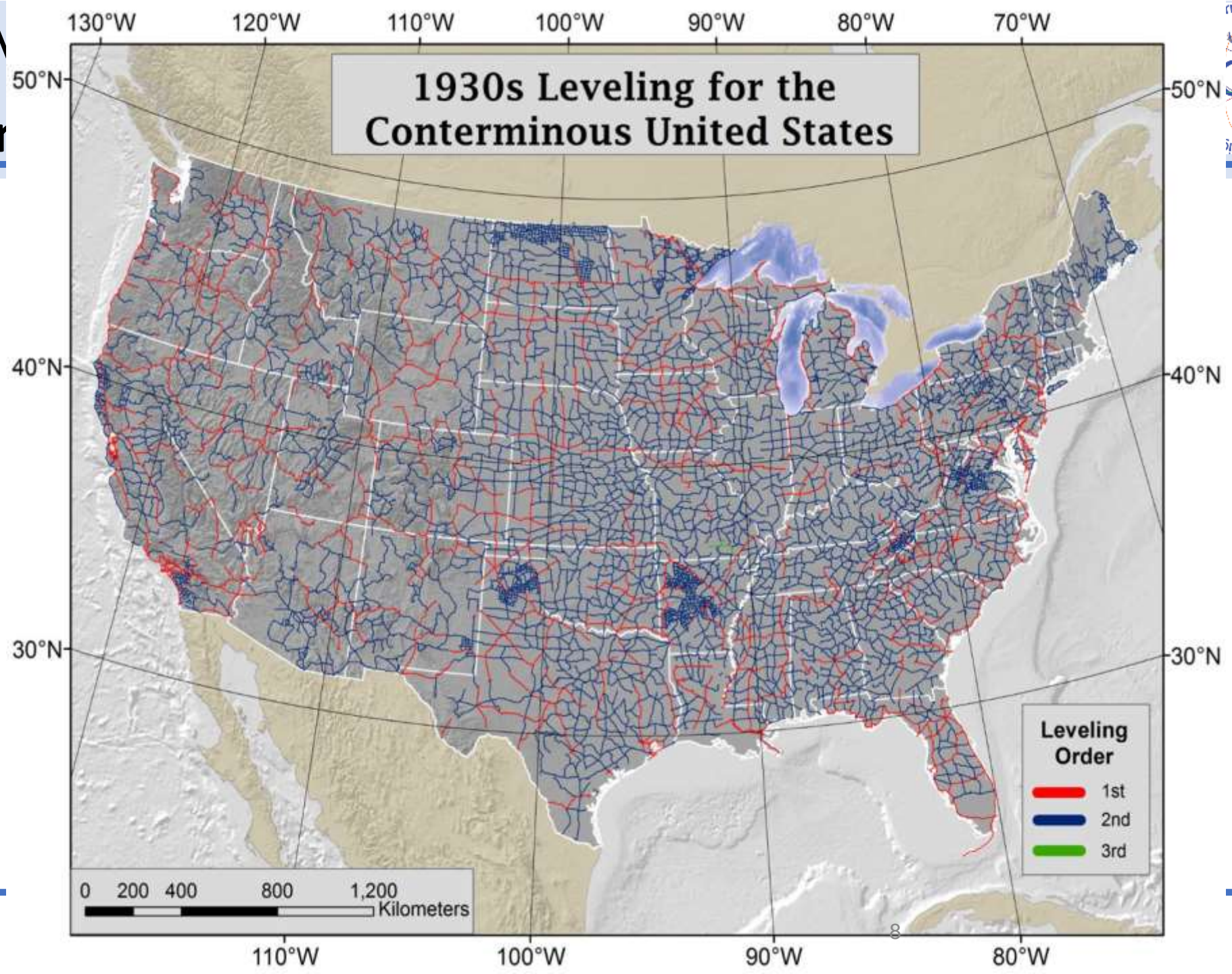
- **NAVD 88:** North American Vertical Datum of 1988
- **Definition:** The surface of equal gravity potential to which orthometric heights shall refer in North America*, and which is 6.271 meters (along the plumb line) below the geodetic mark at “Father Point/Rimouski” (NGSIDB PID TY5255).
- **Realization:** Over 500,000 geodetic marks across North America with published Helmert orthometric heights, most of which were originally computed from a minimally constrained adjustment of leveling and gravity data, holding the geopotential value at “Father Point/Rimouski” fixed.

**Not adopted in Canada*

FIG/IGN Referer

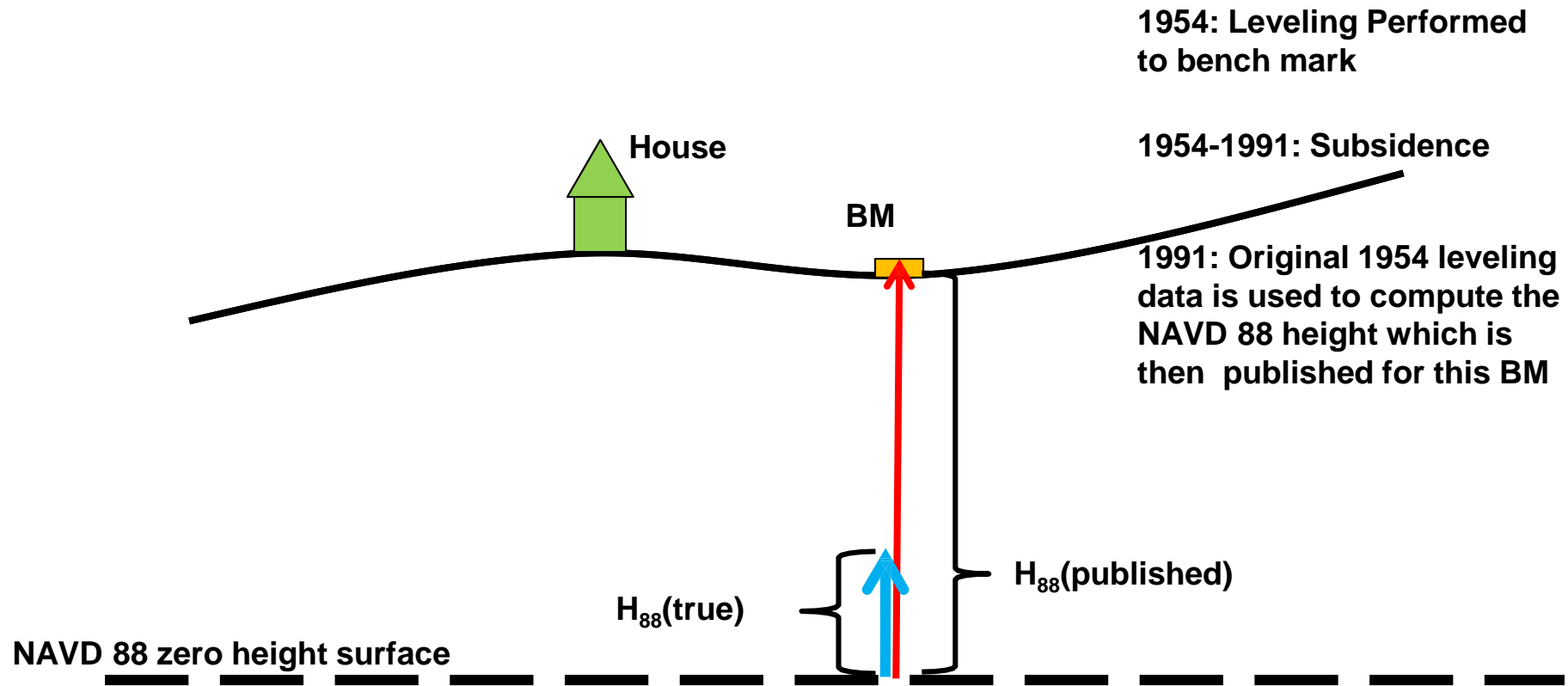


FIG/IGN Referer





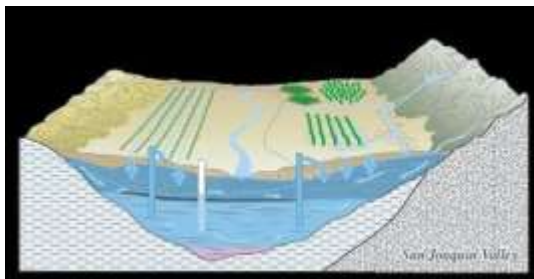
Subsidence and Bench Mark Height



Obviously the true height relative to the NAVD 88 zero surface is not the published NAVD 88 height



Bench marks

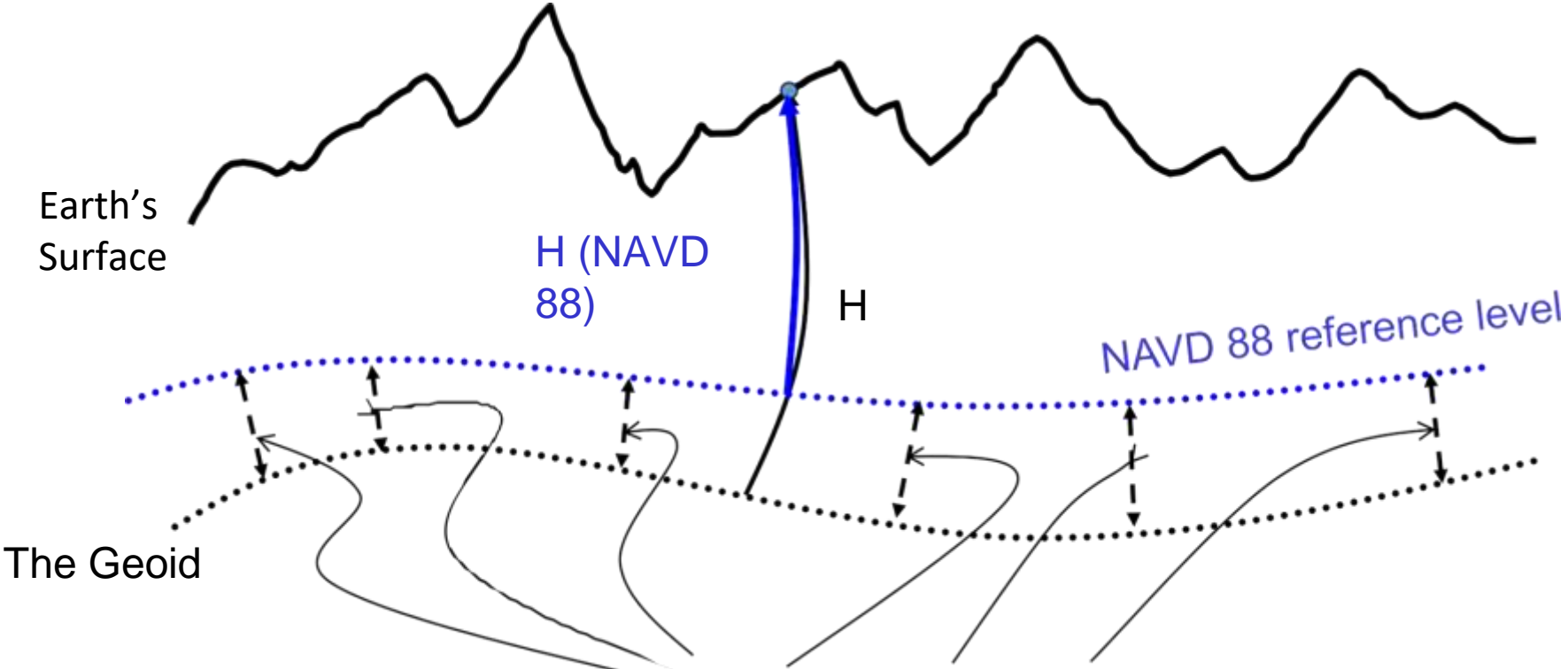


- **NAVD 88 uses bench marks that:**
 - Are rarely re-checked for movement
 - Disappear by the thousands every year
 - Are not funded for replacement
 - Are not necessarily in convenient places, particularly for GPS measurements
 - Don't exist in most of Alaska
 - Weren't adopted in Canada
 - Were determined by leveling from a single point, allowing cross-country error build up



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Reference Frames in Practice



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

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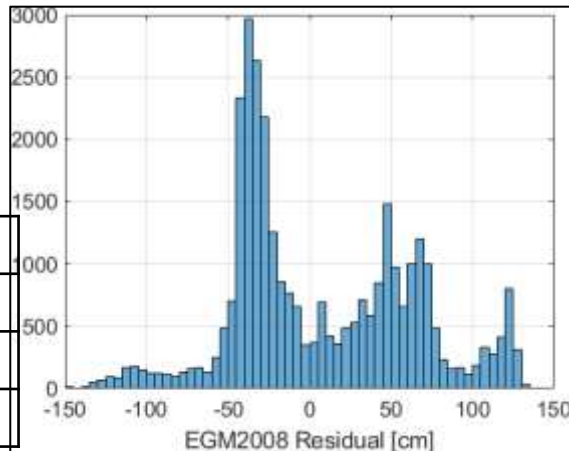
Reference Frames in Practice



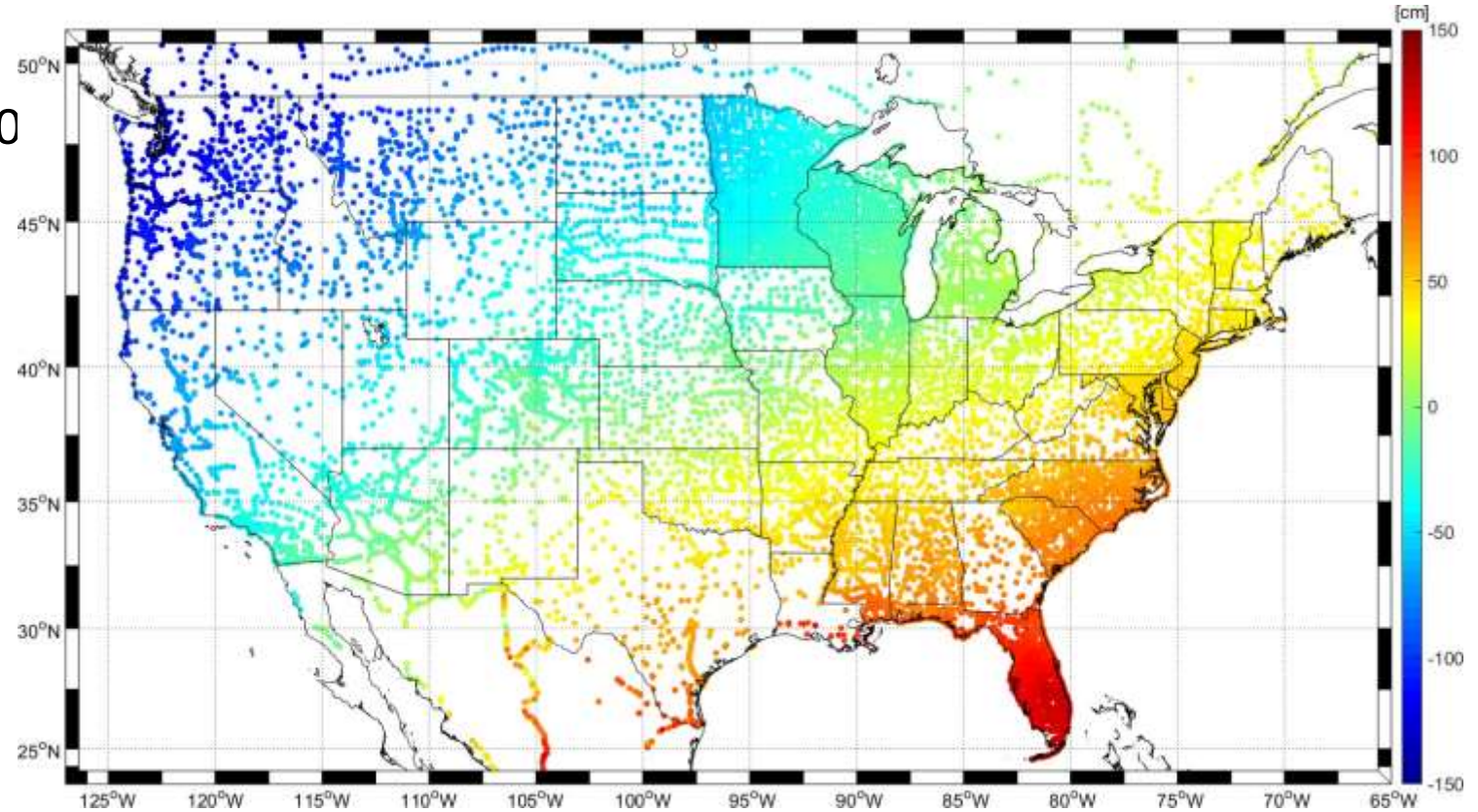
GPS on Bench marks

$$r = h_{\text{NAD83}} - H_{\text{NAVD 88}} - N_{\text{EGM200}}$$

[cm]



Min	-166.3
Max	136.5
Mean	6.4
StdDev	56.4



Based on 32,149 GPS on Bench marks used in GEOID18



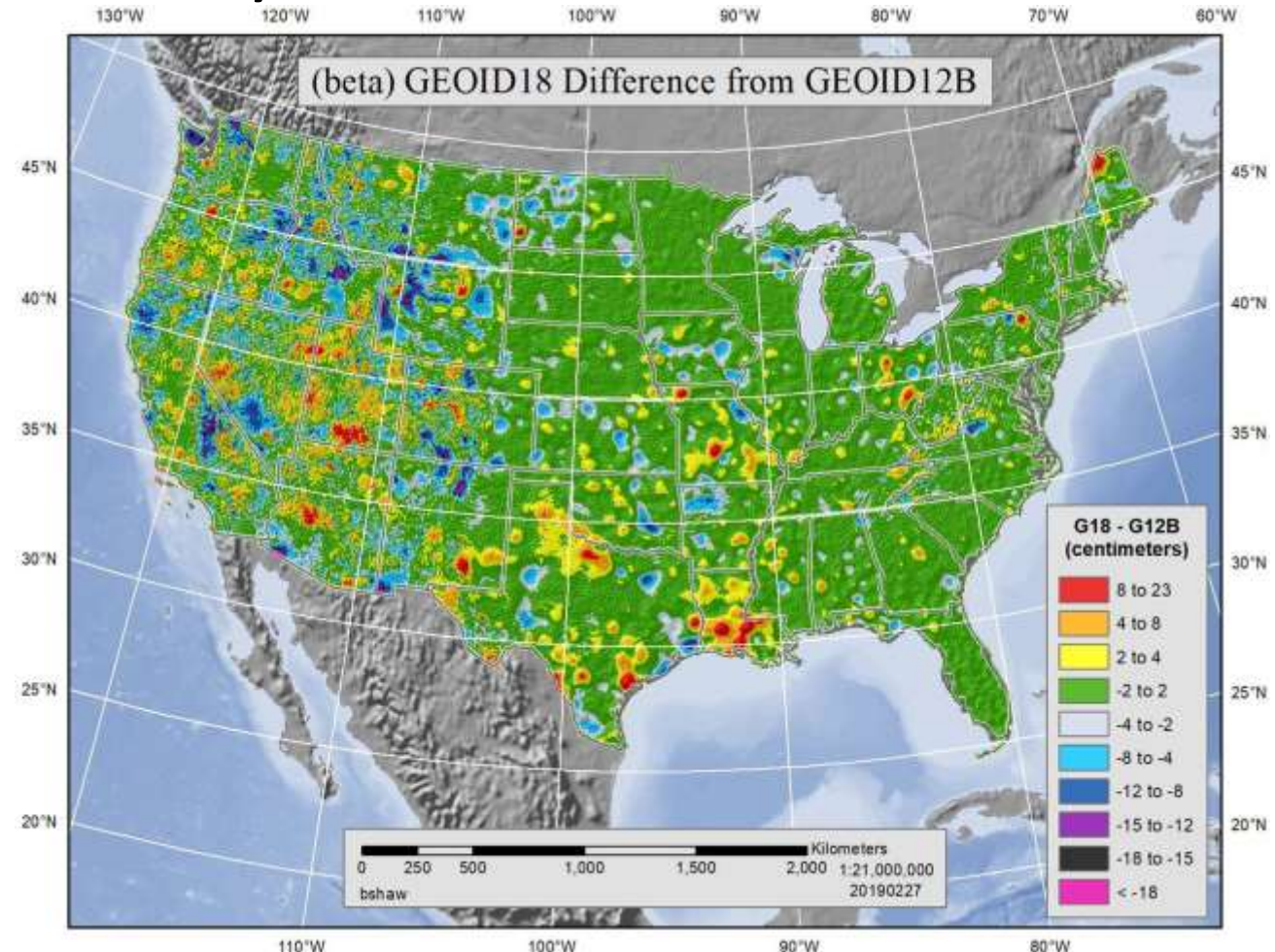
Access NAVD 88 with Hybrid Geoid Model

GPS on Bench marks used to constrain gravimetric geoid

Current Production Model:
GEOID12B

Future Model:
BETA **GEOID18**

- Valid in CONUS and Puerto Rico/ U.S. Virgin Islands
- 32,149 GPS on Bench marks
- Paper Presentation (TS03E – Tuesday at 11:00)





NSRS Modernization: Four New Frames

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)

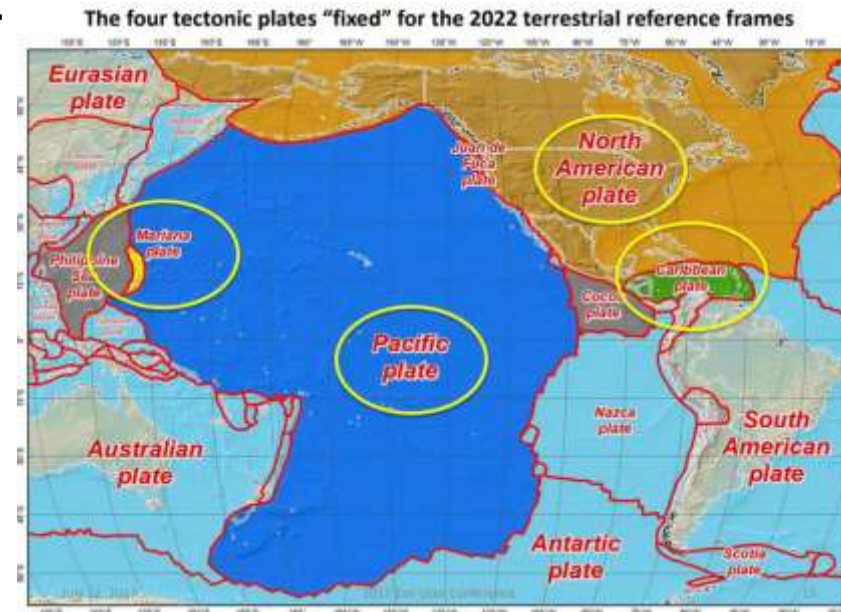
The Pacific Terrestrial Reference Frame of 2022
(PATRF2022)

The Mariana Terrestrial Reference Frame of 2022
(MATRF2022)



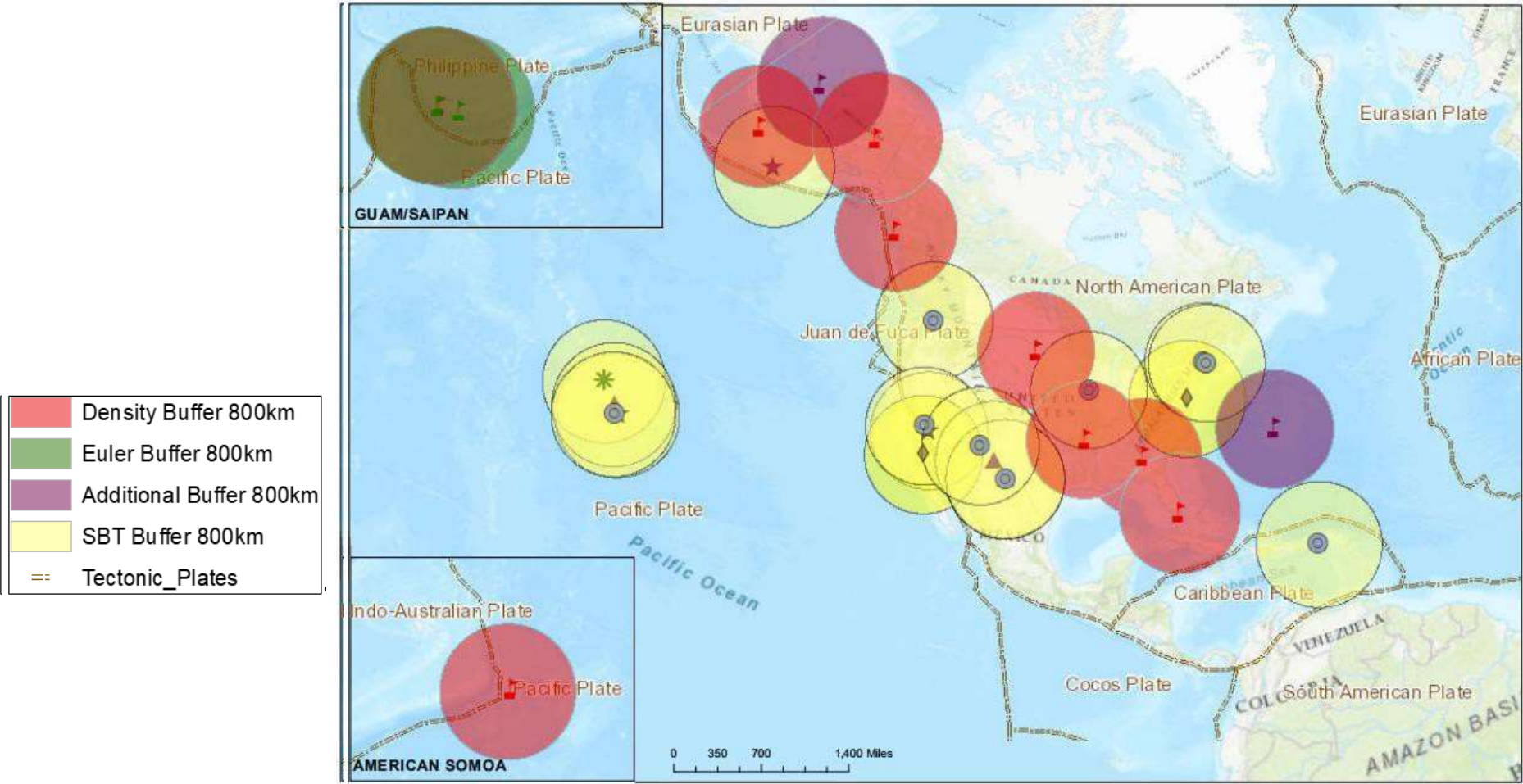
NSRS Modernization

- Densified ITRF model
- Control stations
 - FCORS/IGS sites \Leftrightarrow ITRF
- Subset chosen for EPP
- Four Frames after EPP
 - CATRF (w/SIRGAS)
 - MATRF (~ w/GGIM-AP)
 - NATRF (IAG 1.3c)
 - PATRF (w/GGIM-AP)
- Intra-Frame Velocity Models





Foundation CORS (IGS sites)

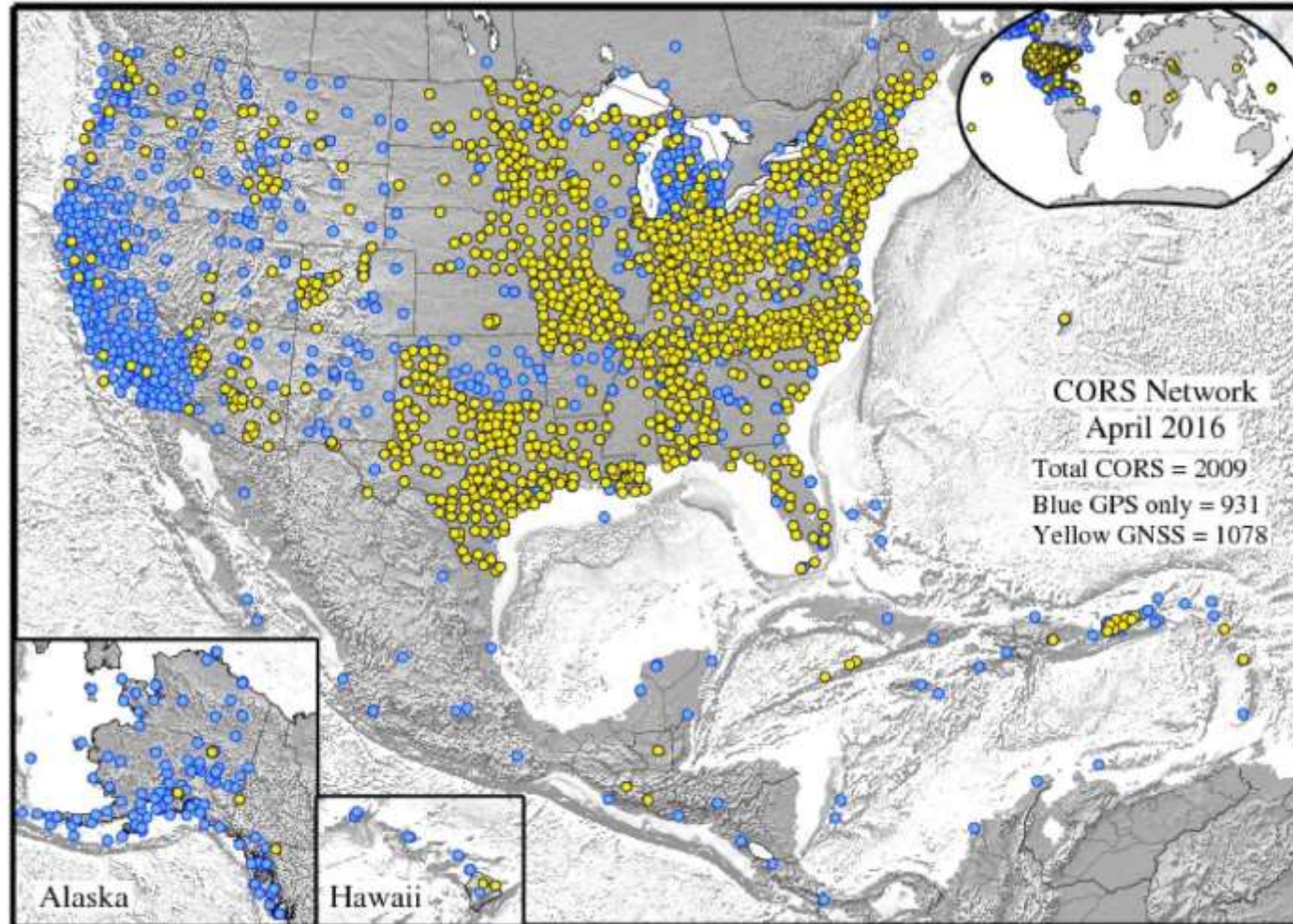


FIG/IGM-Chile Technical Seminar

Reference Frames in Practice



CORS Network





NSRS Modernization: NAPGD2022

The Old:

Orthometric
Heights

NAVD 88

Normal
Orthometric
Heights

PRVD 02

VIVD09

ASVD02

NMVD03

GUVD04

Dynamic
Heights

IGLD 85

Gravity

IGSN71

Geoid
Undulations

GEOID12B

Deflections of
the Vertical

DEFLEC12B

The New:

The North American-Pacific
Geopotential Datum of 2022
(NAPGD2022)

- Will include GEOID2022

DEFLEC2022

GRAV2022

DEM2022

IGLD 2020

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Reference Frames in Practice



xGEOID18

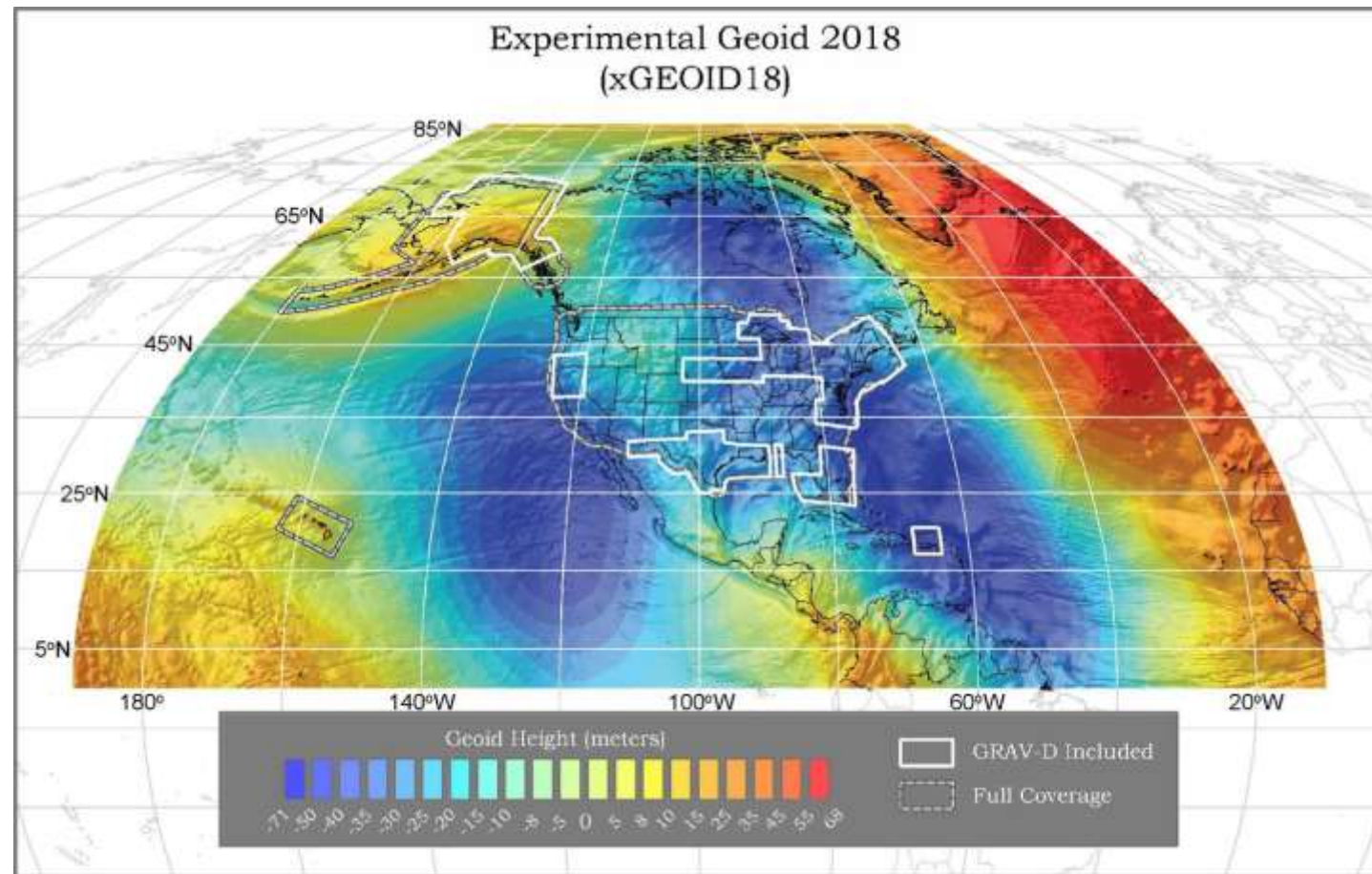
xGEOID models will culminate in GEOID2022

Three total grids

The first will cover as shown to the right

The second will cover Guam & CNMI

The third will cover American Samoa



<https://beta.ngs.noaa.gov/GEOID/xGEOID18/>

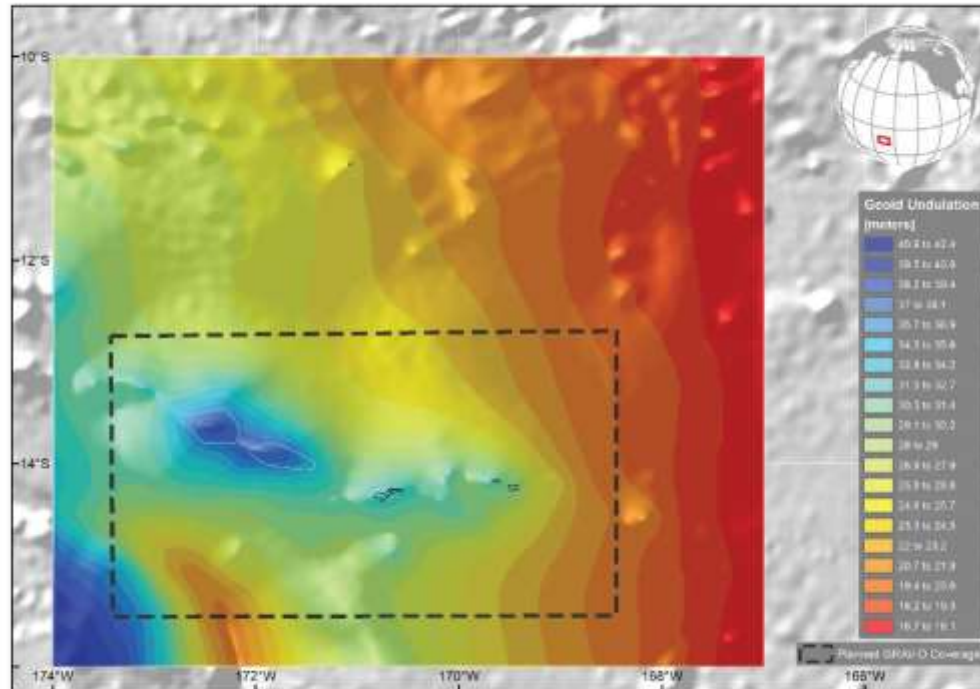
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Reference Frames in Practice



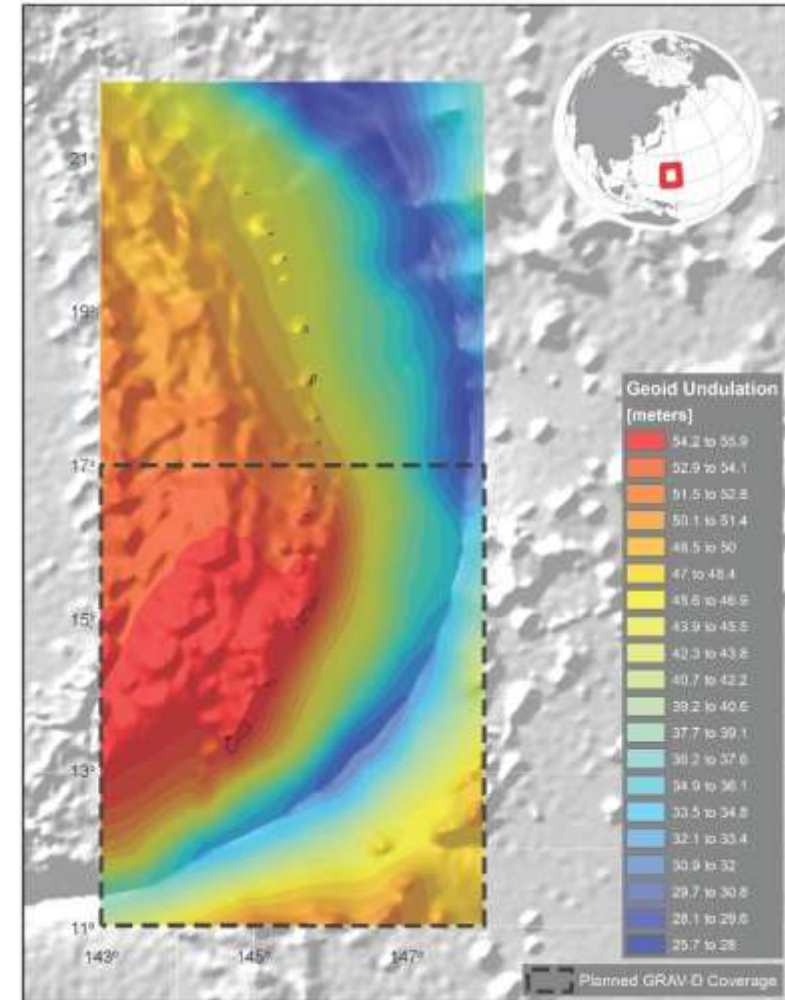
xGEOID18

xGEOID18 - American Samoa



<https://beta.ngs.noaa.gov/GEOID/xGEOID18/>

xGEOID18: Guam / Central Northern Marianas Islands

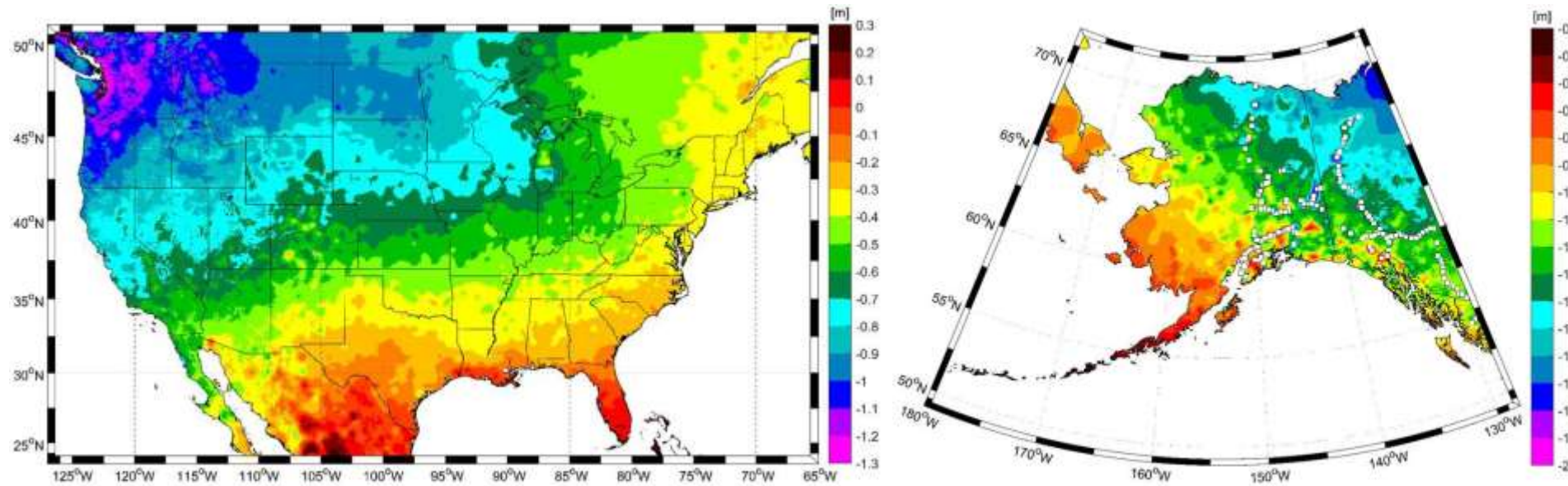


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Reference Frames in Practice



Expected changes to orthometric heights





The Future of Leveling

- To develop absolute heights, known heights on passive control must be used. Currently this means a mark of unknown quality
- In NAPGD2022, “known” heights for a leveling survey:
 - Primary: Perform your own GPS survey
 - Yields starting orthometric heights using GEOID2022
 - RTK may be perfectly acceptable!
 - Secondary: Find a “not stale” passive mark
 - “Staleness” depends on the mark



Definitional Relationship

$$H_{NAPGD2022}(t) \equiv h_{*?ATRF2022}(t) - N_{GEOID2022}(t)$$

* N C M P

Time-dependencies of ellipsoid heights come from OPUS, where time-dependent CORS coordinates serve as control for your time-dependent GNSS survey.

Time-dependencies of geoid undulations are captured in the dynamic component of GEOID2022 (“DGEOID2022”), which will come from the geoid monitoring service, or GeMS.



Tools in Development

- Several tools under development as variants of OPUS Projects
- Control level marks created via GNSS survey and NAPGD2022
- Leveling between these control would be adjusted separately
- A unified adjustment software is being developed to replace GPSCOM, ADJUST, etc.
- Submissions will be entirely online and streamlined
- Replaces Bluebooking/submission process entirely

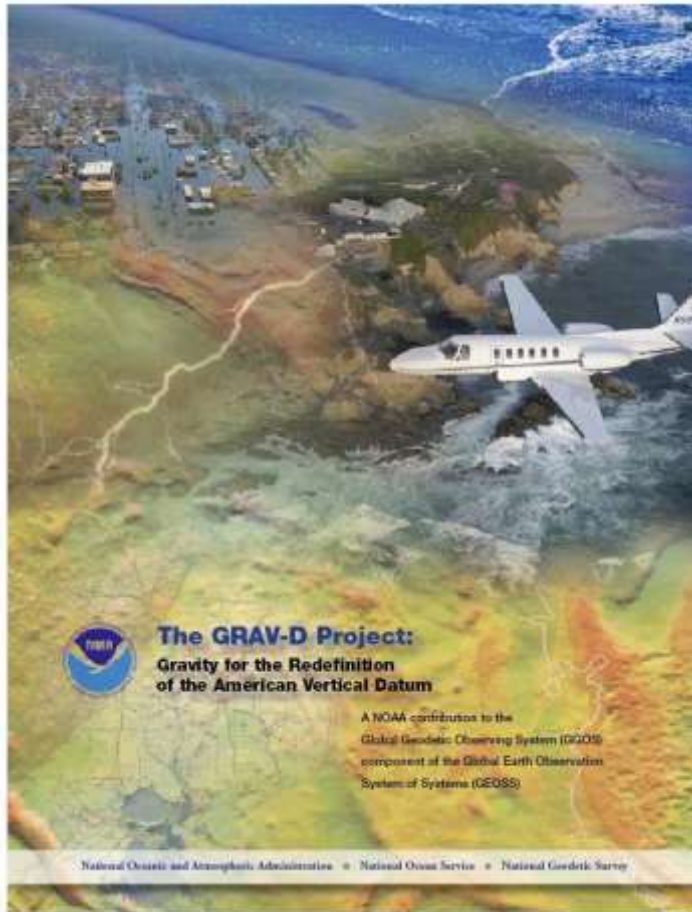


Implementation

- Foundation CORS tied to IGS solutions
- Reprocessing yields consistent CORS coordinates and velocities
- Bench Marks are then adjusted to fit CORS control
- GNSS/OPUS coordinates supersede bench mark values
- Velocities applied to revert back to datum epoch (2022.0)
- Effectively provides “fixed” plate & state plane coordinates
- Permits use for RTK positioning at current epoch



GRAV-D Project Overview



- **Overall Target:** orthometric heights accurate to 2 cm from GNSS and a geoid model
- **GRAV-D Objective:** Create gravimetric geoid accurate to 1 cm where possible using airborne gravity data
- **GRAV-D:** two phases
 - Airborne gravity survey of entire country and its holdings
 - Long-term monitoring of geoid change

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Reference Frames in Practice

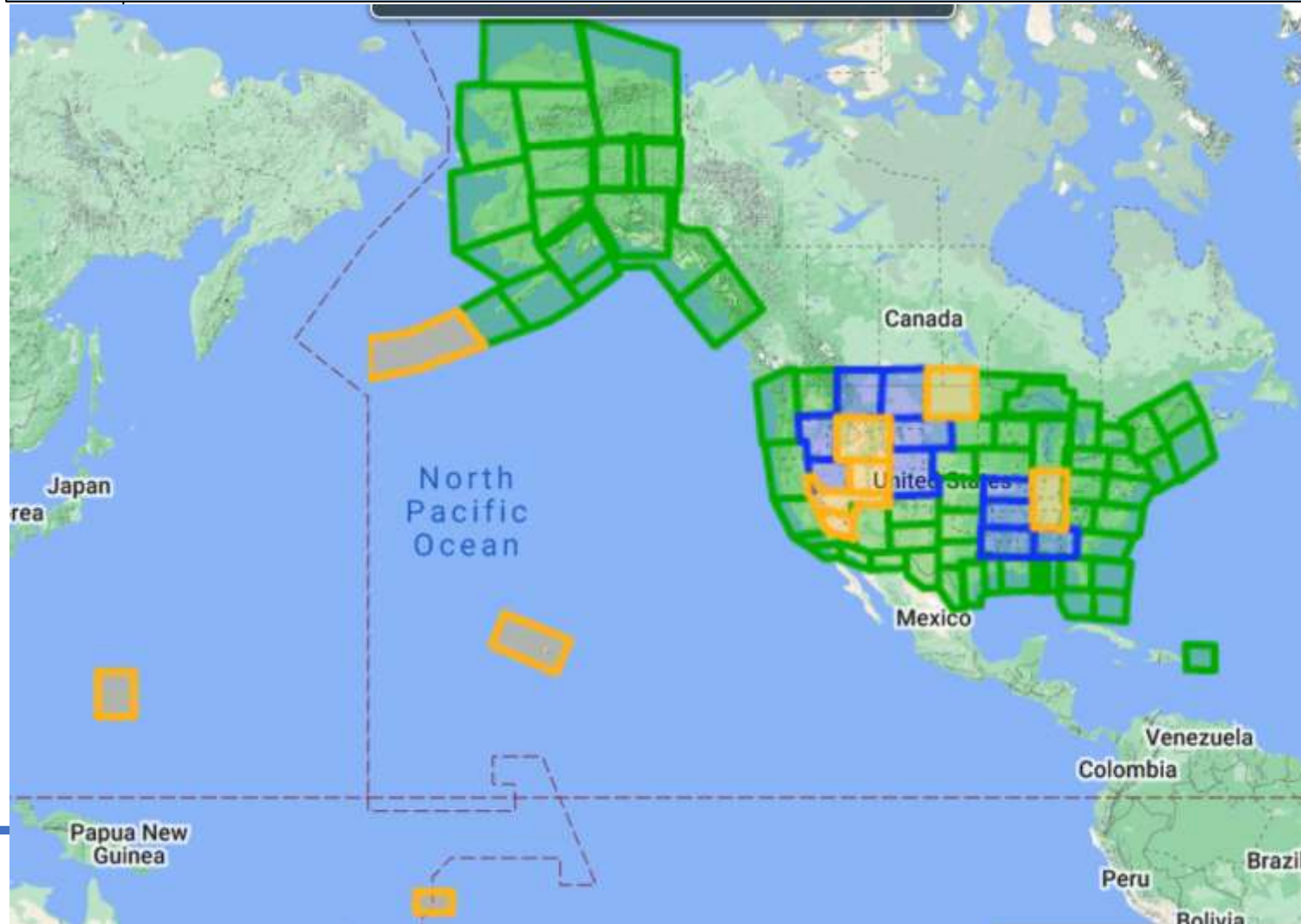


GRAV-D Status 10-1-22: 97%

Complete

Processing

Collection





Summary

- Existing datums have meter level errors and must be replaced
- Four new TRF's: NATRF, CATRF, PATRF, MATRF
- NAPGD2022 will cover three areas in each of the frames
- Time dependent orthometric heights will be developed
- Bench mark control (passive) will be replaced by GNSS access
- GRAV-D derived aerogravity will ensure NAPGD 2022 continuity and time varying component



Questions?

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