Case study of USA

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NOAA's National Geodetic Survey

Here's were we are on the agenda …

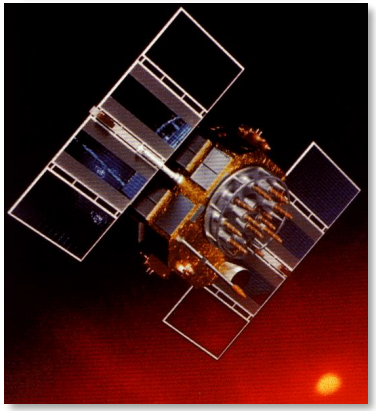
- **13:00 – 14:30 Session 3: Case Studies 1**
  - **Case Study of Vietnam**
    - ***Mr. Vu Thien Quang,*** *VGCR, Vietnam*
  - **Case Study of Japan**
    - ***Mr. Basara Miyahara***, GSI, MLIT, Japan
  - **Case study of USA**
    - ***Dr. Kevin Ahlgren,*** National Geodetic Survey, National Oceanic & Atmospheric Administration (NOAA)
- **14:30 – 15:00 Coffee Break**

Topics

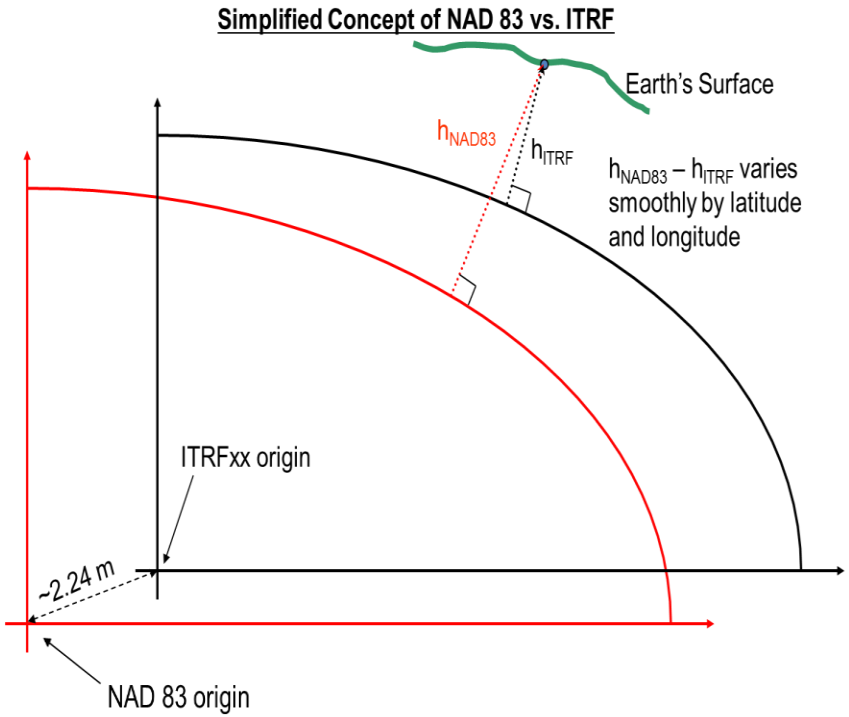
- *Current horizontal and vertical datums in USA*
  - *North American Datum of 1983 (NAD 83)*
  - *North American Vertical Datum of 1988 (NAVD 88)*
- *National Spatial Reference Frame of 2022*
  - *Replaces both NAD 83 and NAVD 88*
  - *Four Terrestrial Reference Frames based on ITRF14*
  - *Geopotential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

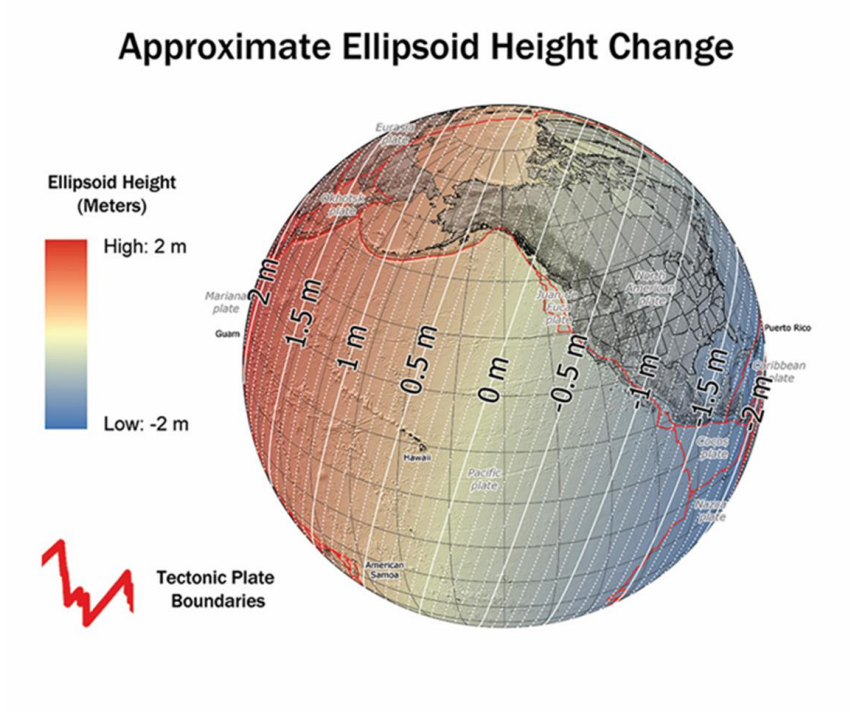
A brief history of NAD 83

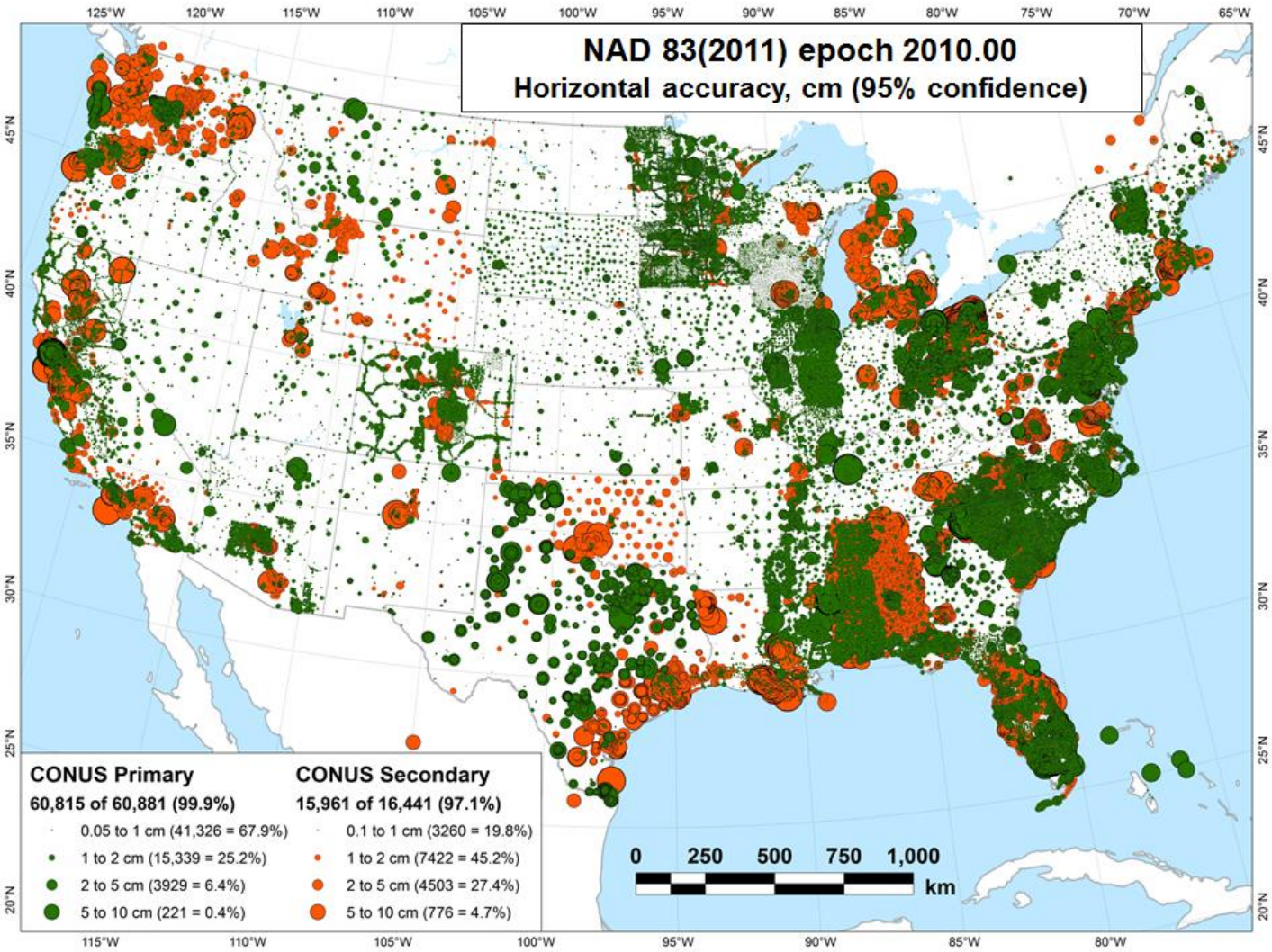
- Original realization completed in 1986
  - Consisted (almost) entirely of classical (optical) observations
- "High Precision Geodetic Network" (HPGN) and "High Accuracy Reference Network" (HARN) realizations
  - Most done in 1990s, essentially state-by-state
  - GNSS based, with classical obs. incl. 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***



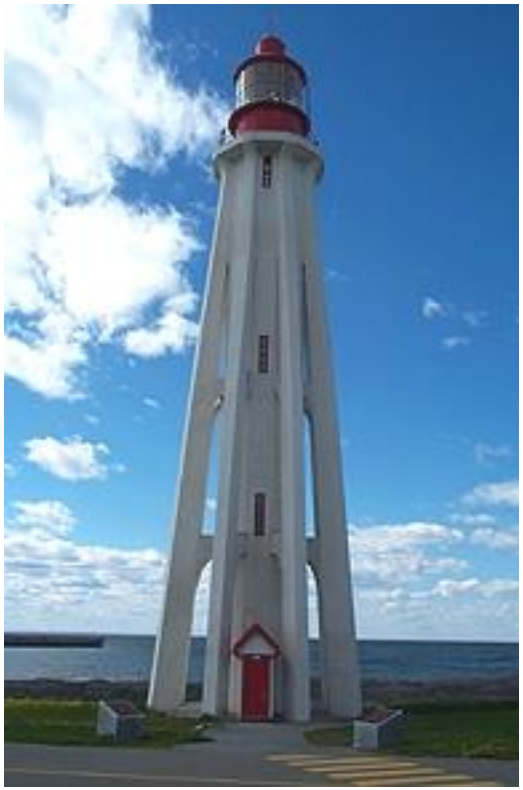
Datum Defect in NAD 83






NAD 83(2011) epoch 2010.00
Horizontal accuracy, cm (95% confidence)
CONUS Primary
60,815 of 60,881 (99.9%)
0.05 to 1 cm (41,326 = 67.9%)
1 to 2 cm (15,339 = 25.2%)
2 to 5 cm (3929 = 6.4%)
5 to 10 cm (221 = 0.4%)
CONUS Secondary
15,961 of 16,441 (97.1%)
0.1 to 1 cm (3260 = 19.8%)
1 to 2 cm (7422 = 45.2%)
2 to 5 cm (4503 = 27.4%)
5 to 10 cm (776 = 4.7%)
0 250 500 750 1,000
km

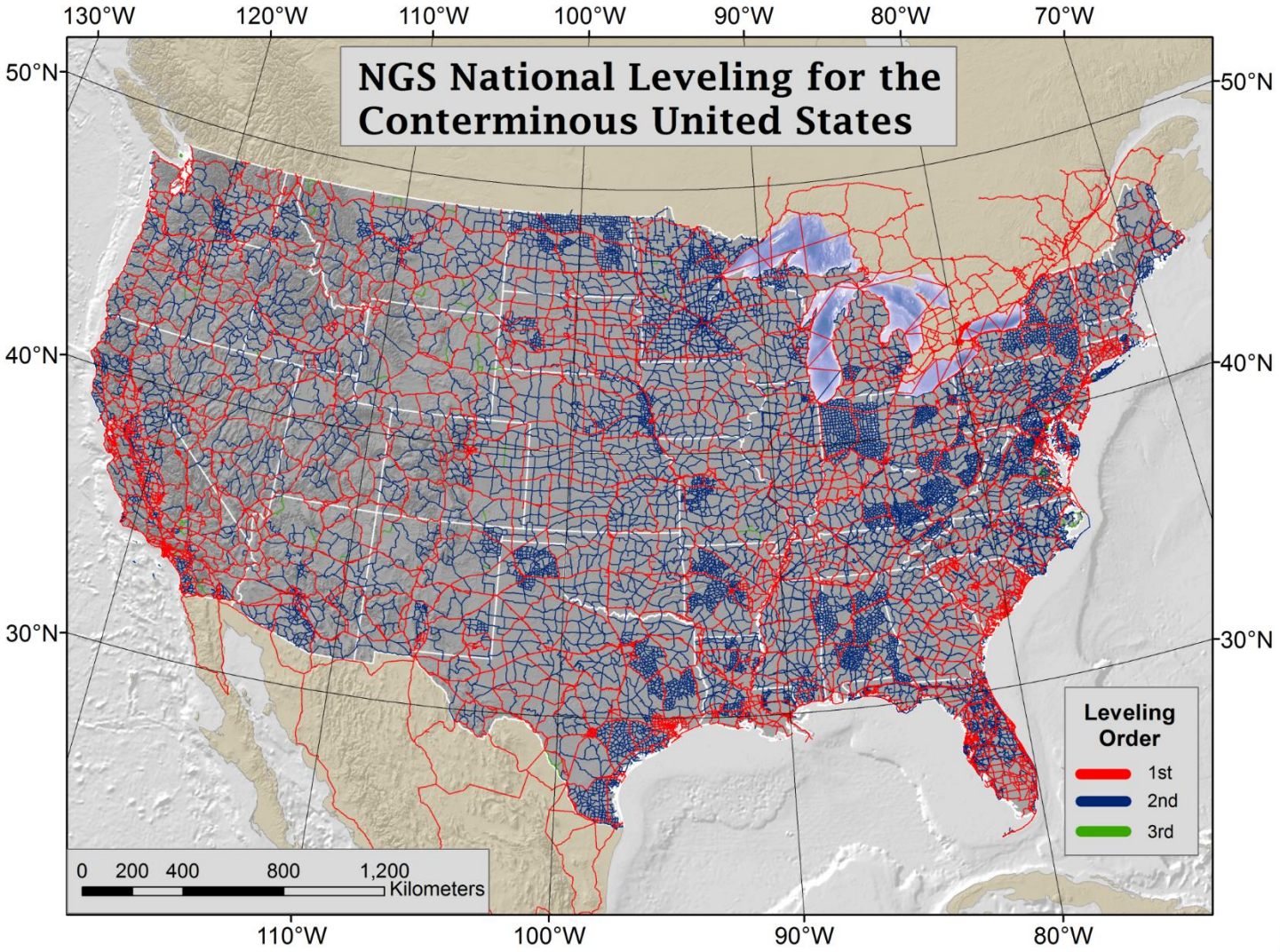
Current Vertical Datum in the USA

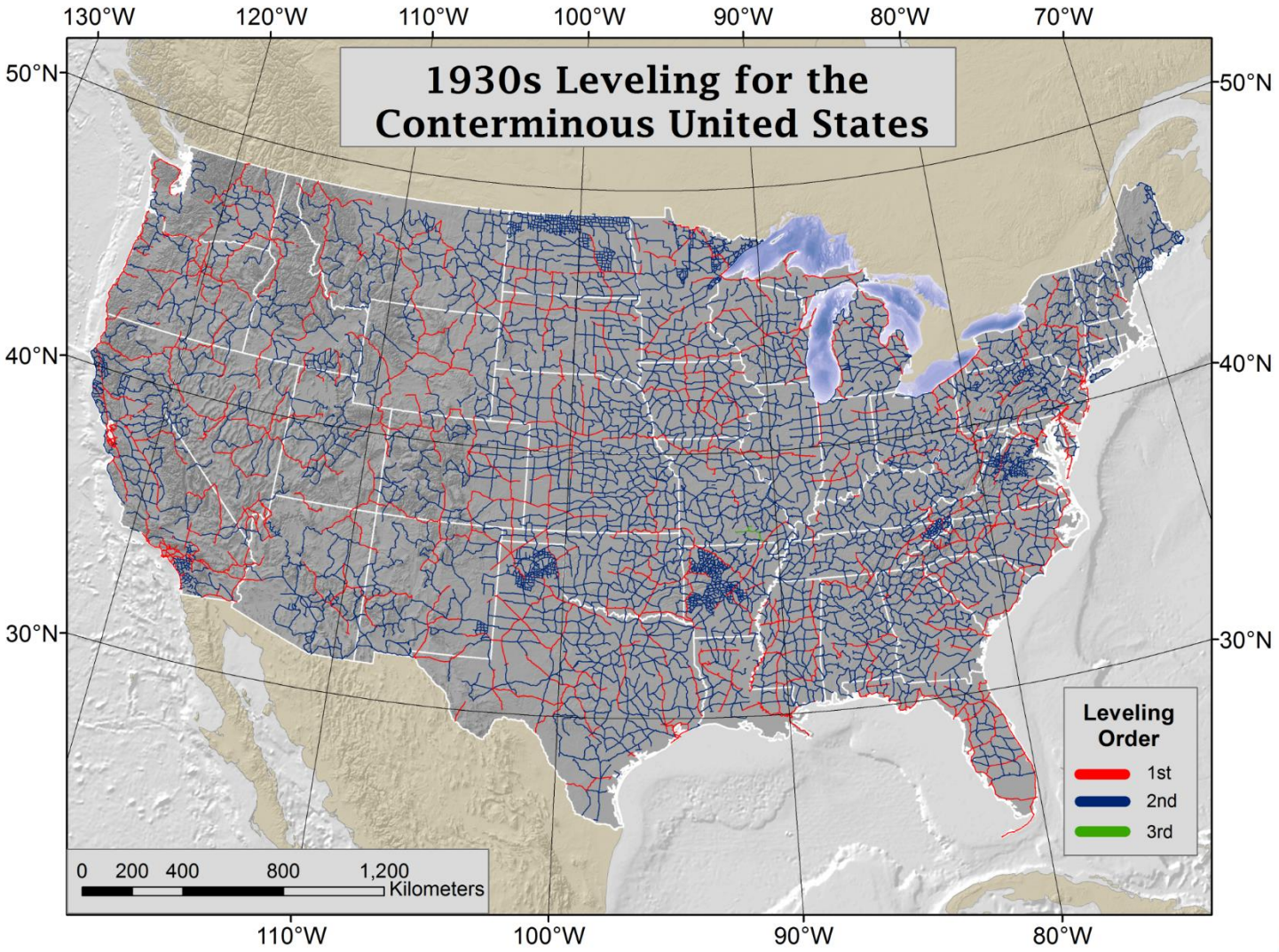


Father Point
Lighthouse, Quebec

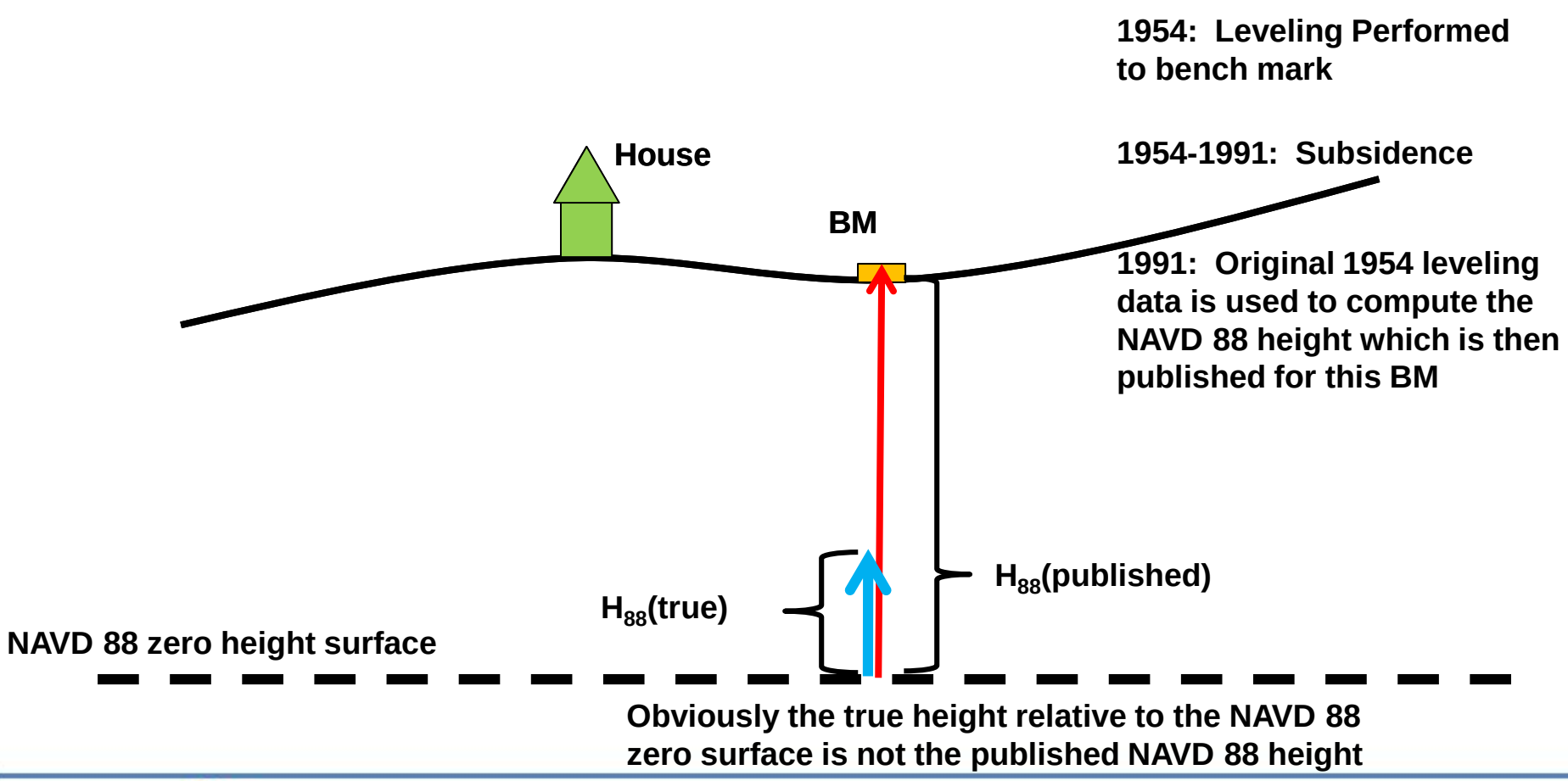
- **NAVD 88**: North American Vertical Datum of 1988
- ***Definition:*** The surface of equal gravity potential to which orthometric heights shall refer in North America*, and which is 6.271 meters (along the plumb line) below the geodetic mark at “Father Point/Rimouski” (NGSIDB PID TY5255).
- ***Realization:*** 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*

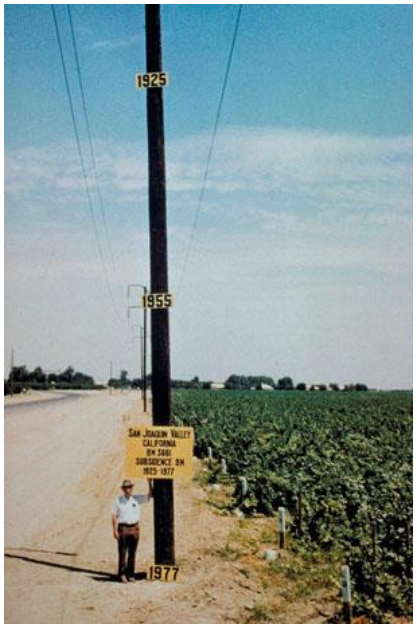

NGS National Leveling for the Conterminous United States
130°W
120°W
110°W
100°W
90°W
80°W
70°W
50°N
40°N
30°N
Leveling Order
1st
2nd
3rd
0 200 400 800 1,200
Kilometers


1930s Leveling for the Conterminous United States
130°W
120°W
110°W
100°W
90°W
80°W
70°W
50°N
40°N
30°N
Leveling Order
1st
2nd
3rd
0 200 400 800 1,200
Kilometers

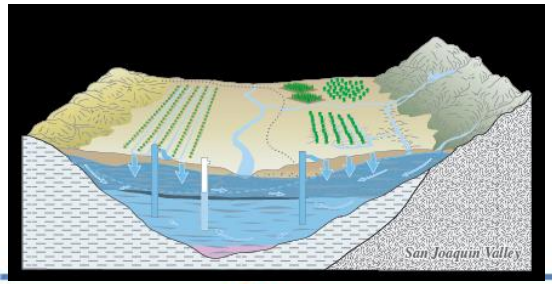
Subsidence and Bench Mark Height

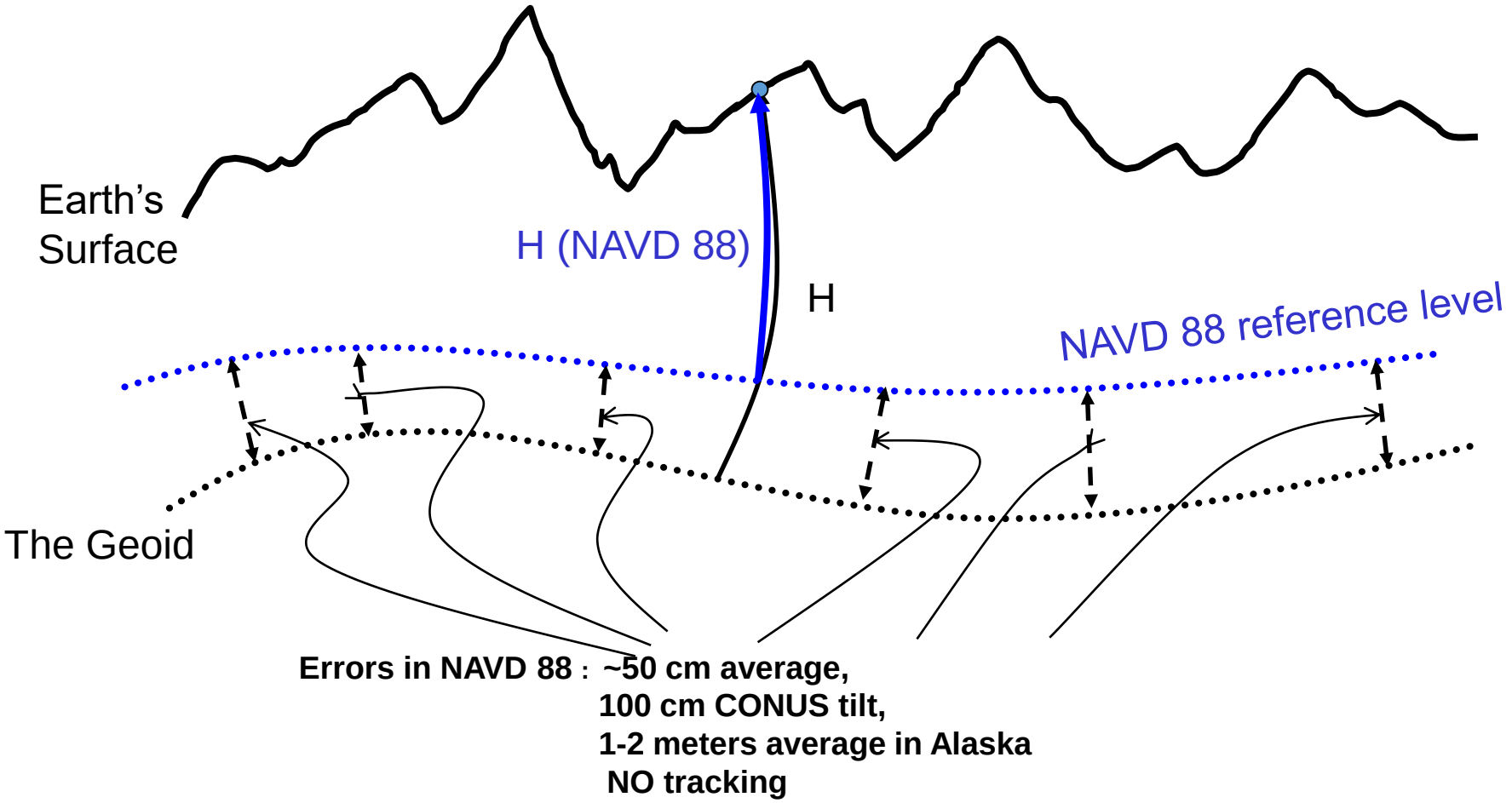


Bench marks



- **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





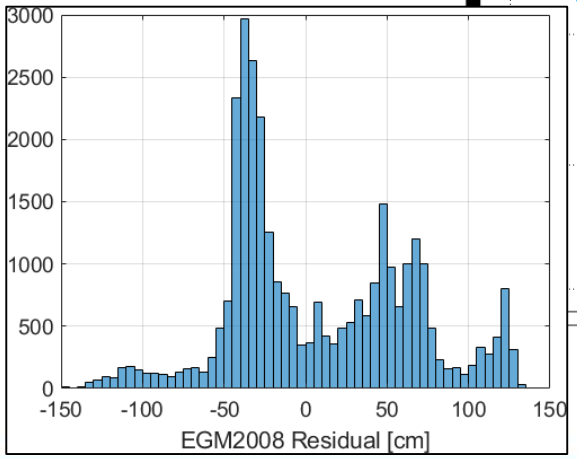
Errors in NAVD 88 : ~50 cm average,
100 cm CONUS tilt,
1-2 meters average in Alaska
NO tracking

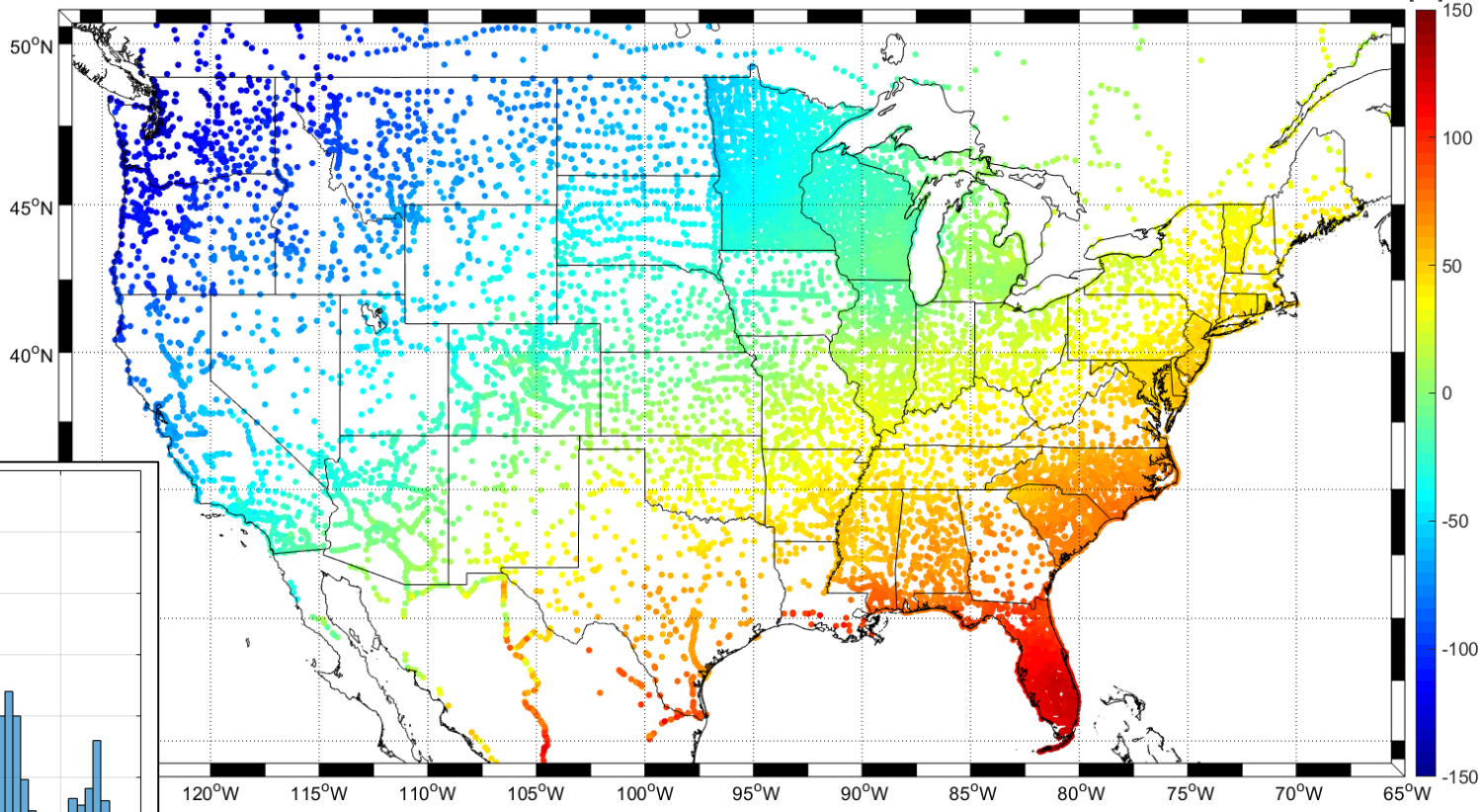
GPS on Bench marks

$r = h_{NAD83} - H_{NAVD\ 88} - N_{EGM2008}$

[cm]

Min	-166.3
Max	136.5
Mean	6.4
StdDev	56.4





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

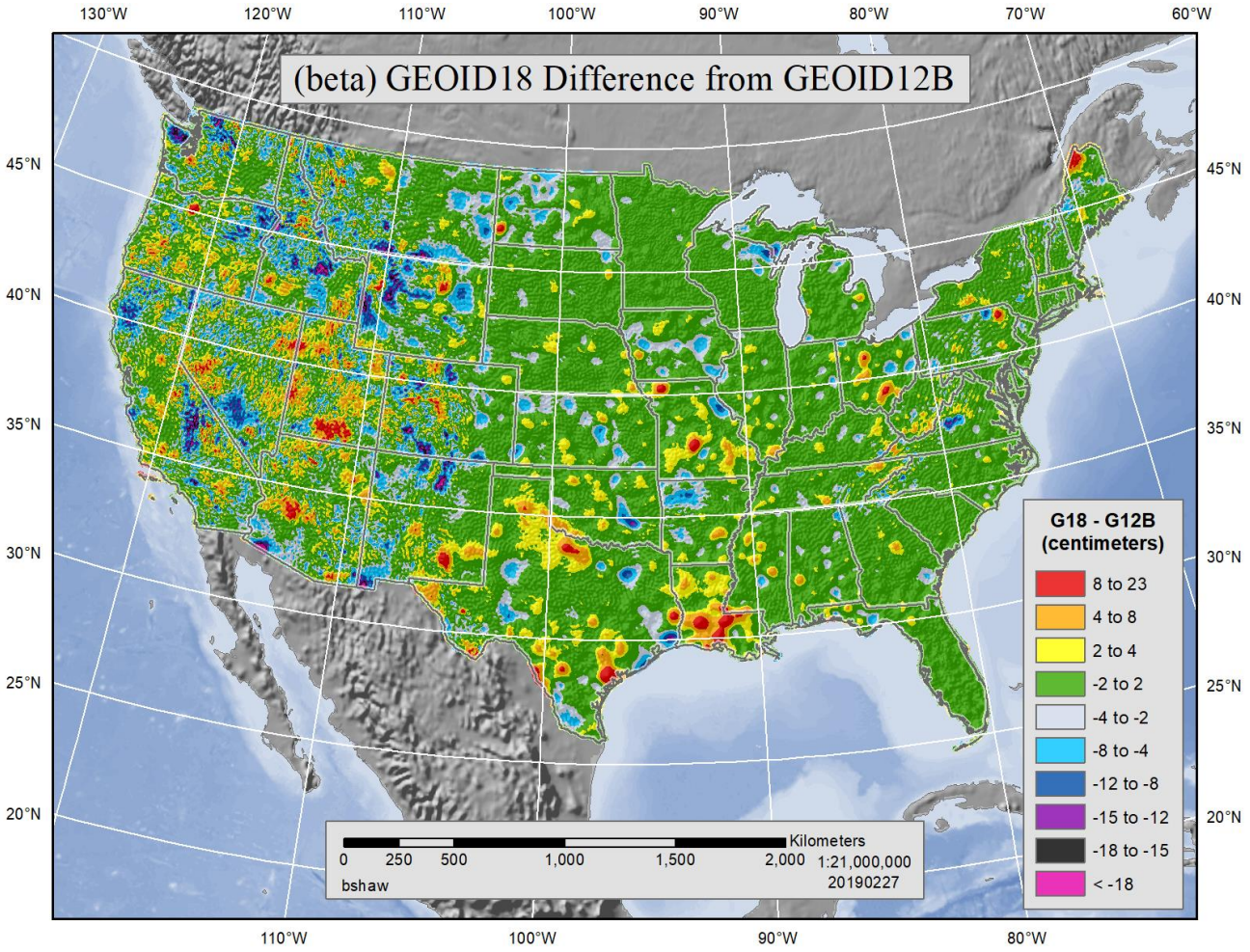
Access NAVD 88 with Hybrid Geoid Model

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

<u>The Old:</u>

NAD 83(2011)

NAD 83(PA11)

NAD 83(MA11)

<u>The New:</u>

The North American Terrestrial Reference Frame of 2022 (NATRF2022)

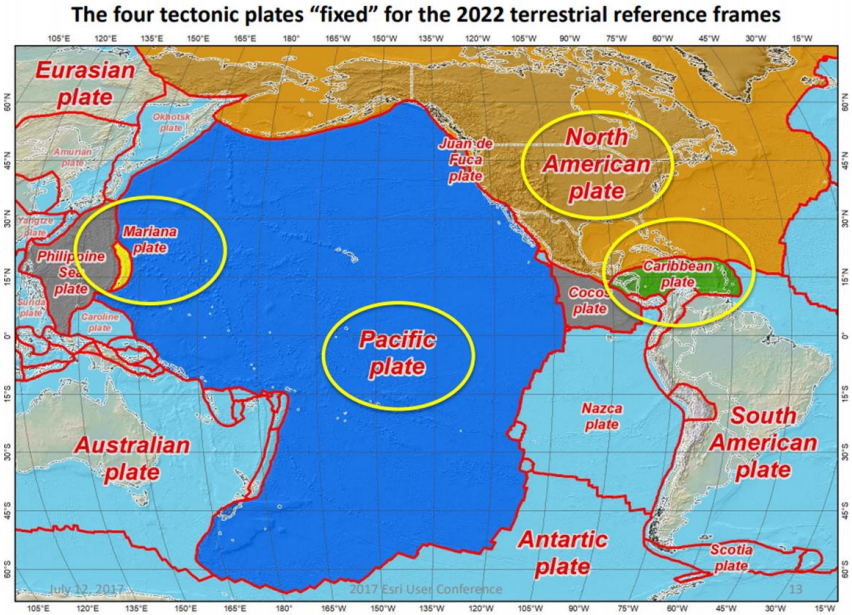
The Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)

The Pacific Terrestrial Reference Frame of 2022 (PATRF2022)

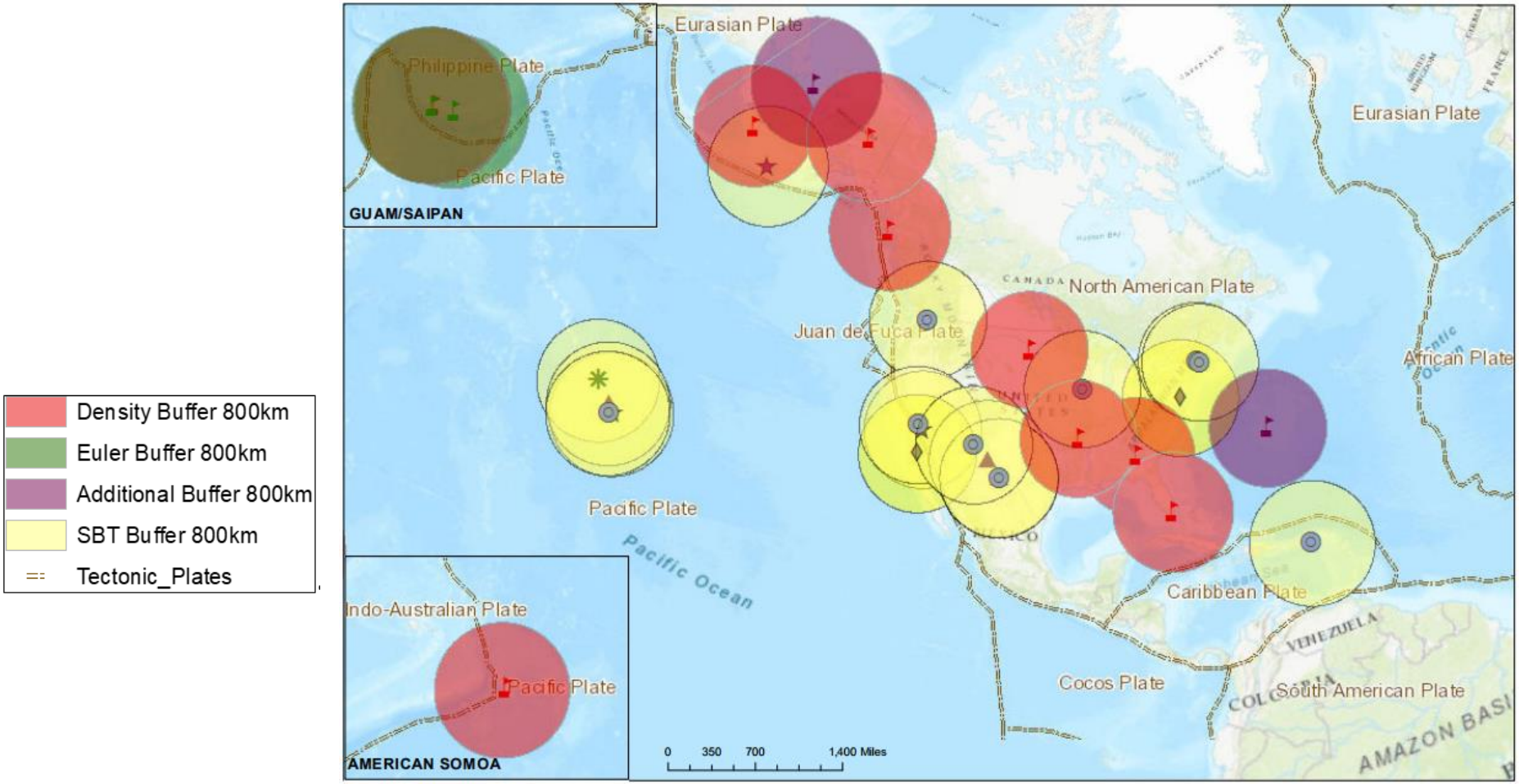
The Mariana Terrestrial Reference Frame of 2022 (MATRF2022)

NSRS Modernization

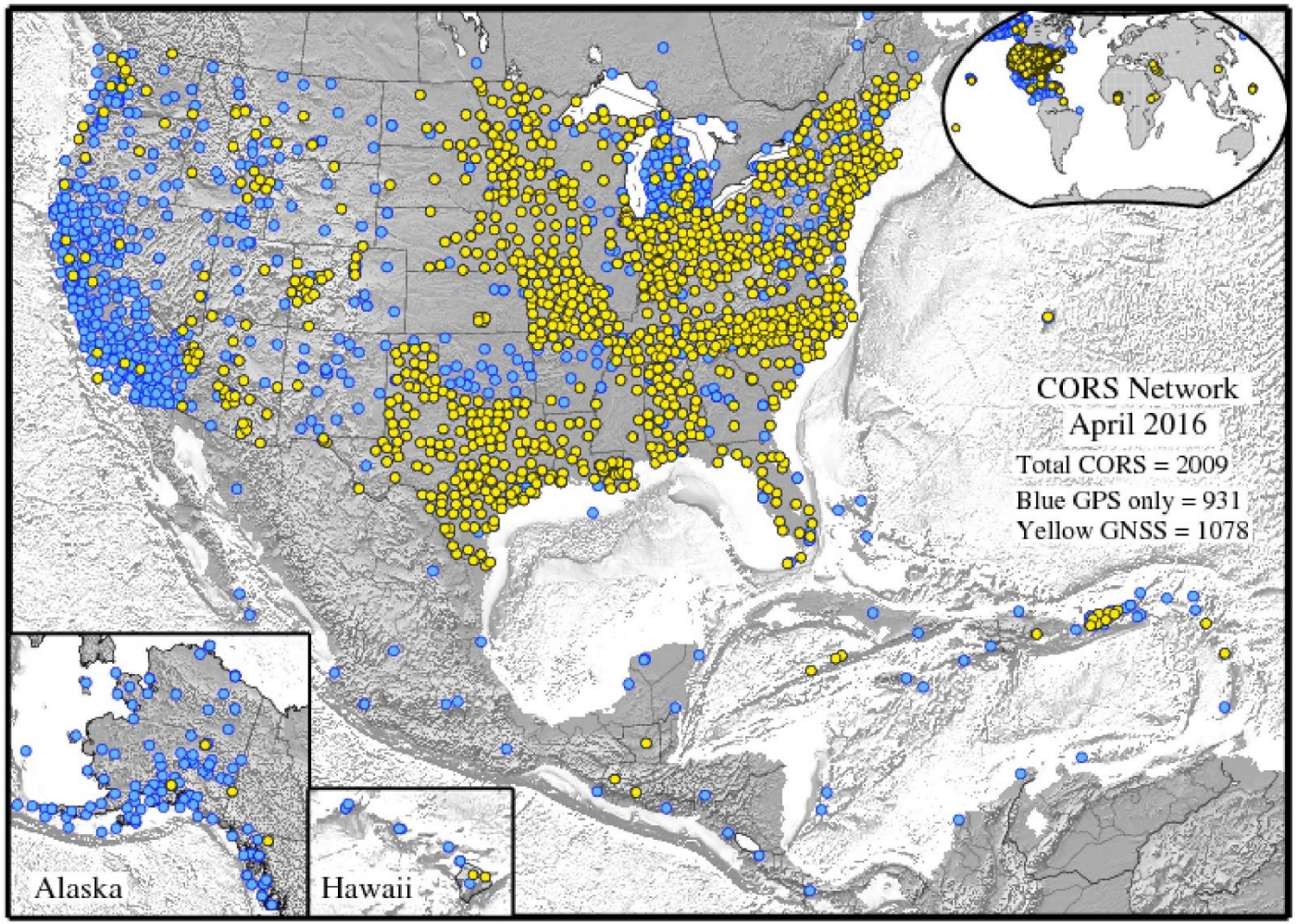
- Densified ITRF model
- Control stations
  - FCORS/IGS sites <=> ITRF
  - Subset chosen for EPP
- Four Frames after EPP
  - CATRF (w/SIRGAS)
  - MATRF (~ w/GGIM-AP)
  - NATRF (IAG 1.3c)
  - PATRF (w/GGIM-AP)
- Intra-Frame Velocity Models



Foundation CORS (IGS sites)



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

xGEOID18

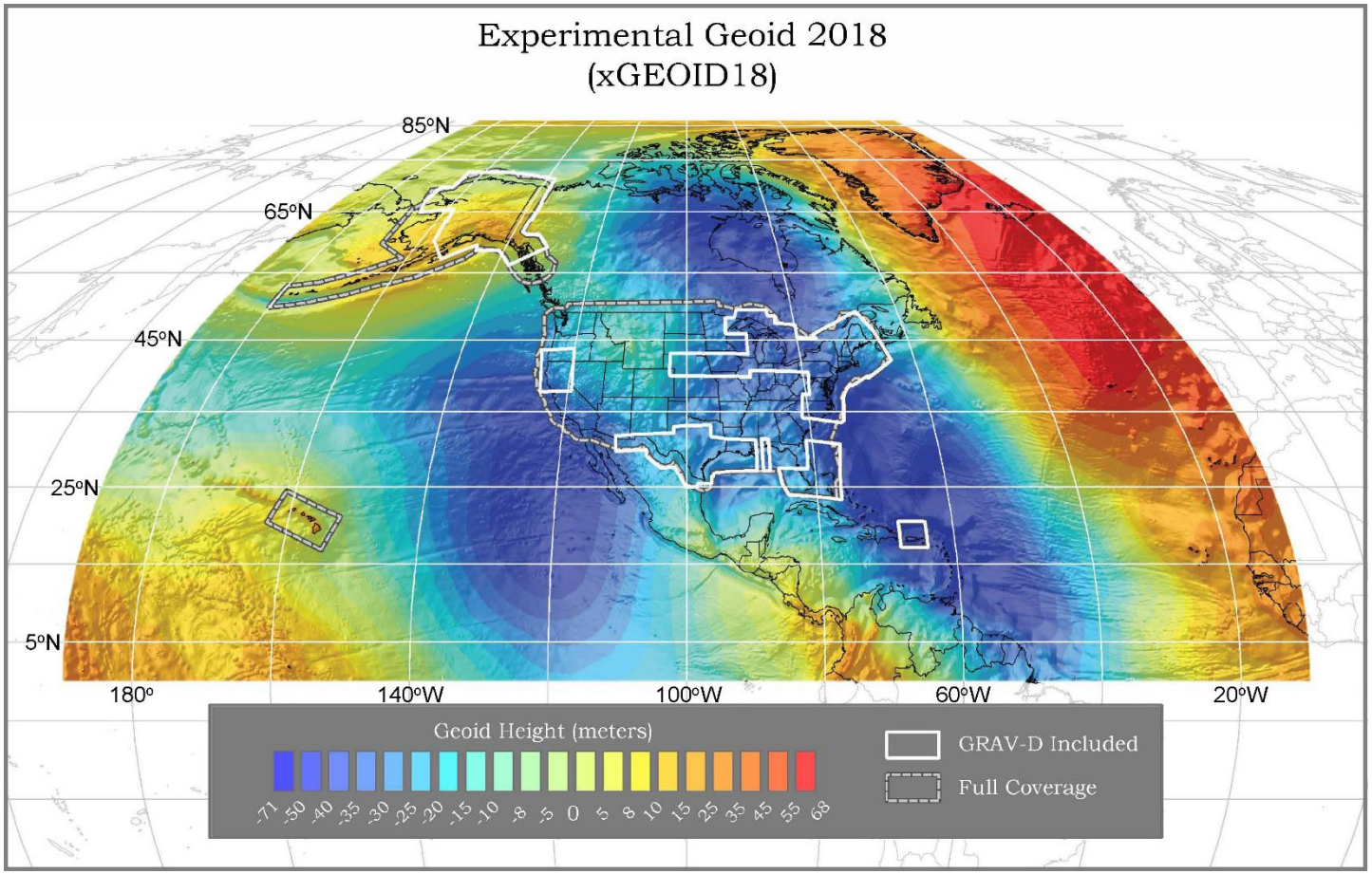
xGEOID models will culminate in GEOID2022

Three total grids

The first will cover as shown to the right

The second will cover Guam & CNMI

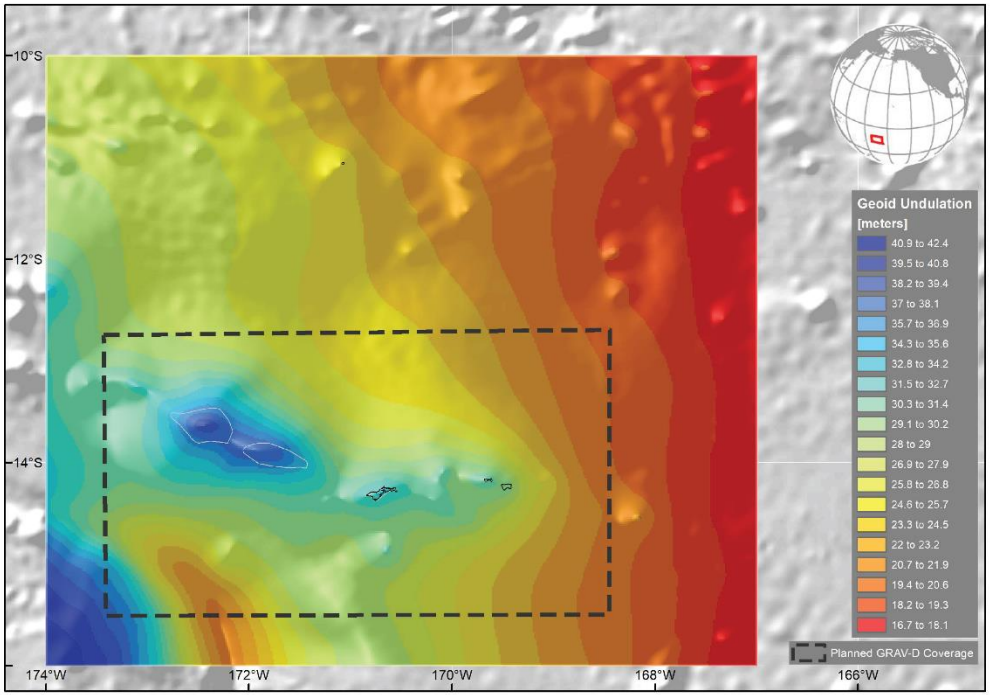
The third will cover American Samoa



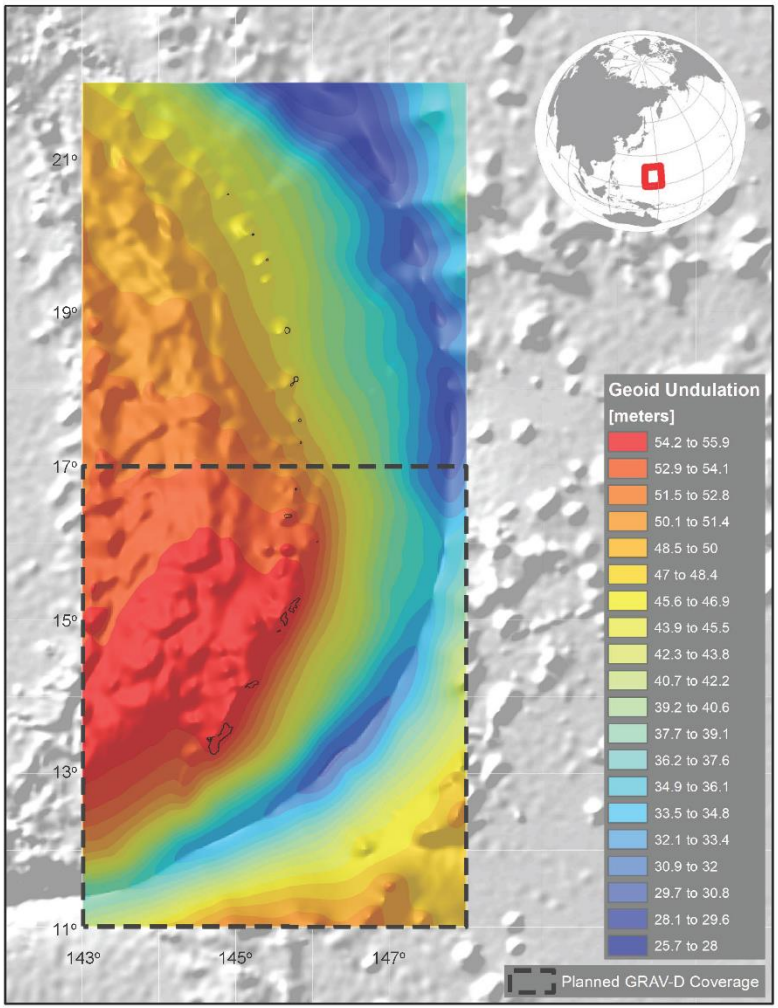
https://beta.ngs.noaa.gov/GEOID/xGEOID18/

xGEOID18

xGEOID18 - American Samoa

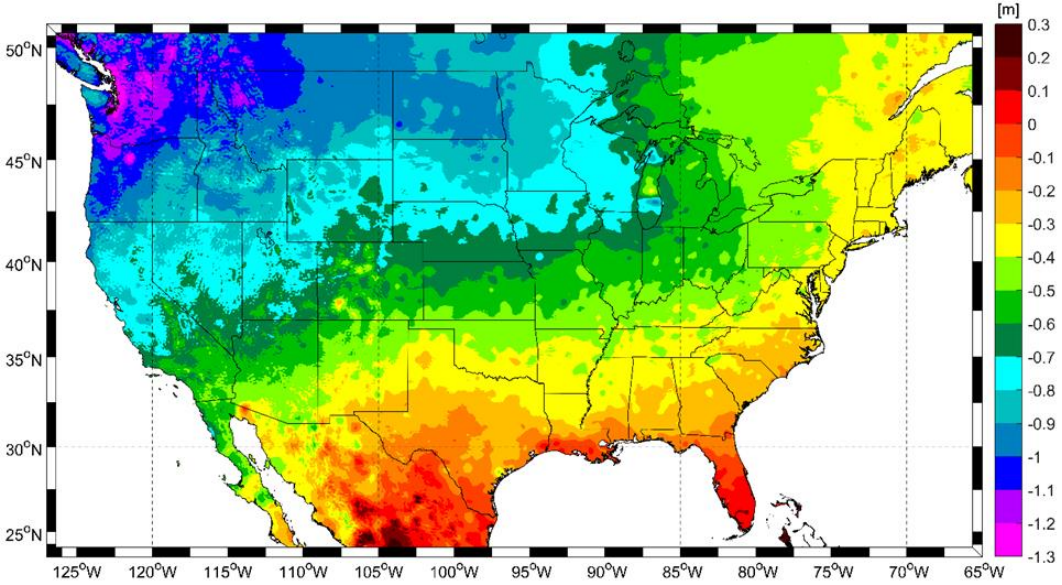


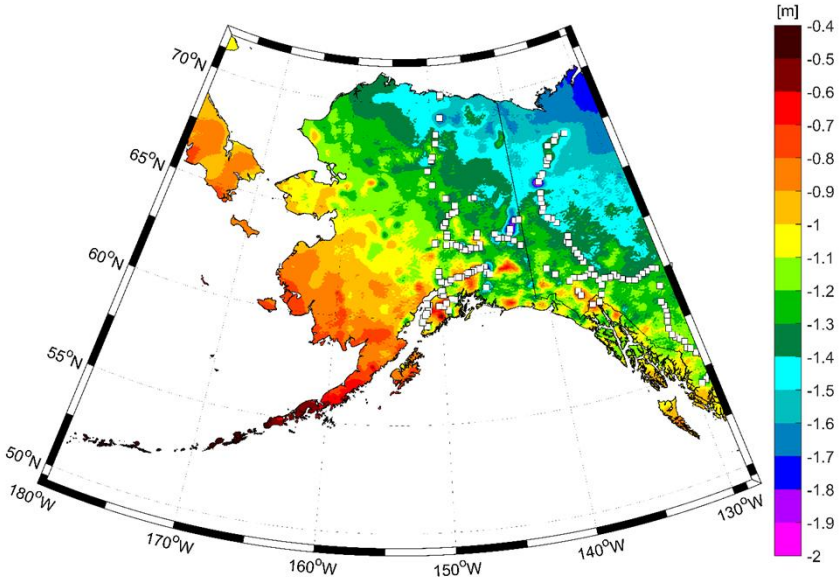
xGEOID18: Guam / Central Northern Marianas Islands



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

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

$$H_{NAPGD2022}(t) \equiv h_{*TRF2022}(t) - N_{GEOID2022}(t)$$

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.

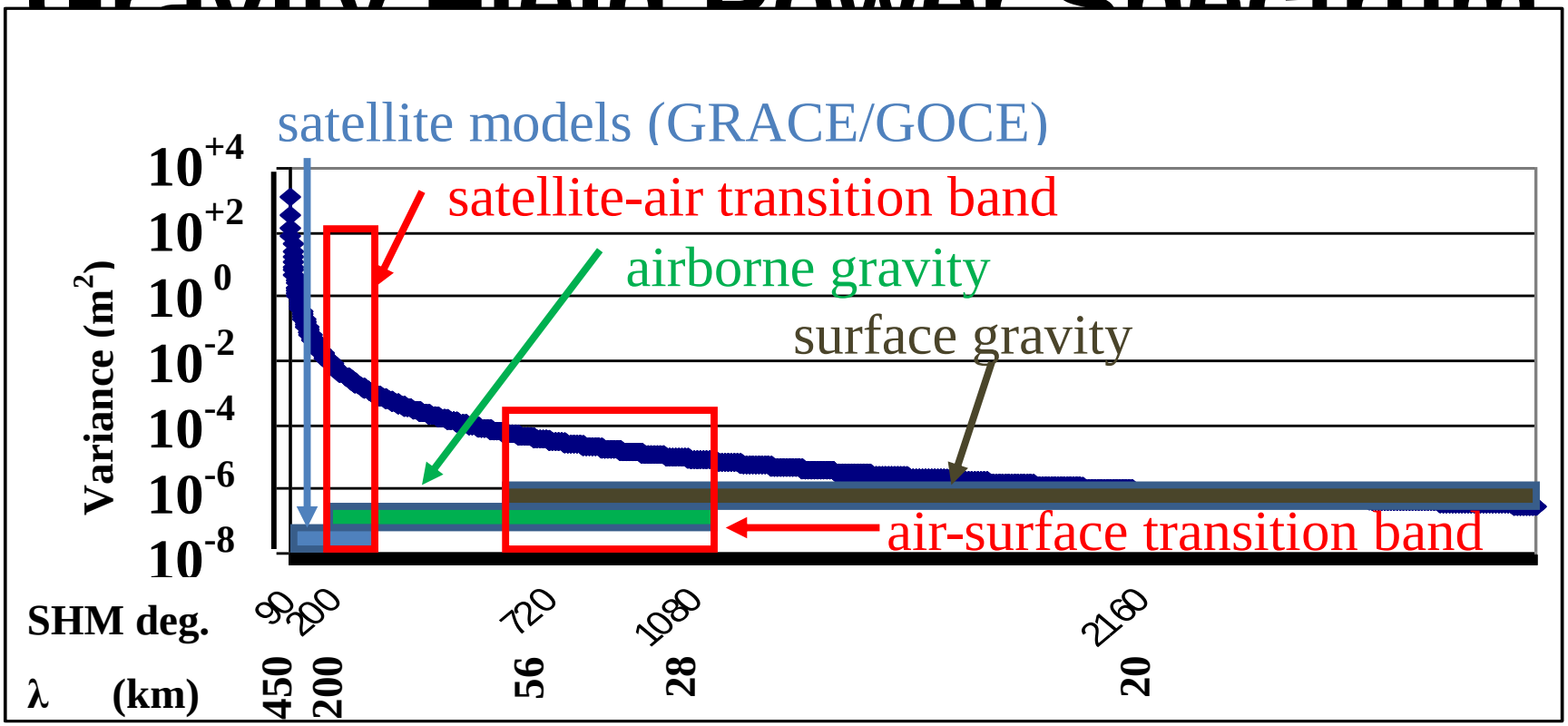
Tools in Development

- 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

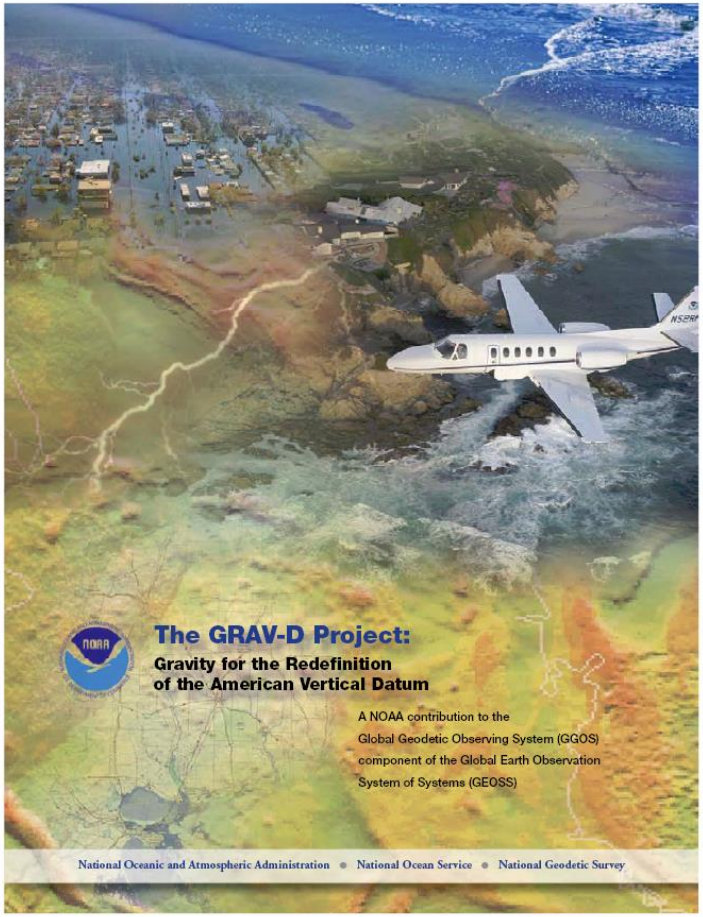
- Foundation CORS tied to IGS solutions
- Reprocessing yields consistent CORS coordinates and velocities
- Bench Marks are then adjusted to fit CORS control
- GNSS/OPUS coordinates supersede bench mark values
- Velocities applied to revert back to datum epoch (2022.0)
- Effectively provides “fixed” plate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

Gravity Field Power Spectrum



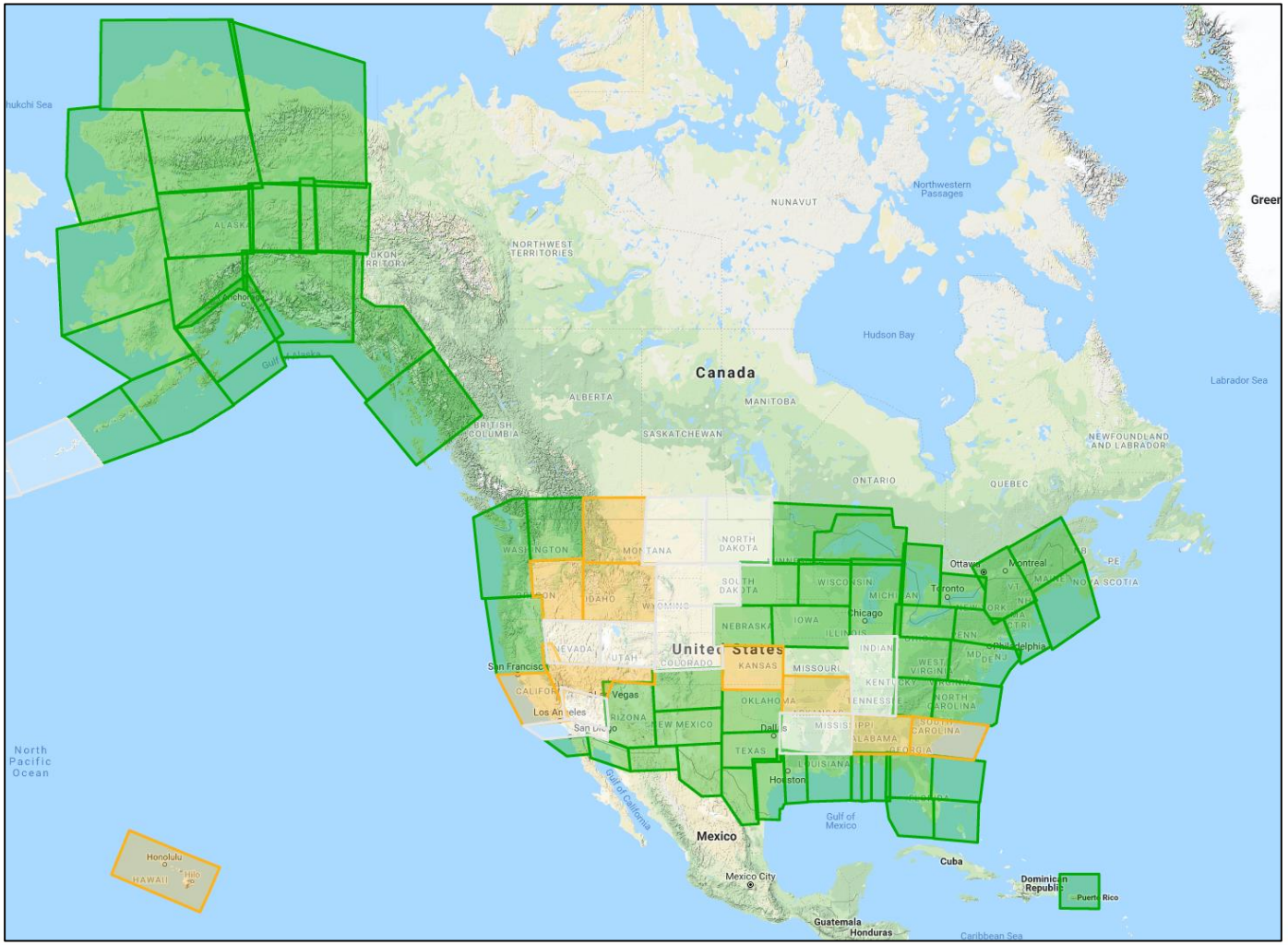
Power Spectrum plot of gravity field (blue line). Most power is at longest wavelengths (λ) at left on the lowest degree harmonics, where satellite (light blue bar) data dominate. Surface data (brown bar) contain the shortest to the right. Aerogravity (green bar) overlaps both parts of spectrum (red boxes).

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

GRAV-D Status 4-2-19: 75%



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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