Modernizing the Geopotential Datum: Replacing NAVD 88

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Outline

- **What is a vertical datum?**
- **Why isn't NAVD 88 good enough anymore?**
- **Possible ways to fix NAVD 88**
- **How will I access the new vertical datum?**
- **Additional Information**

What is a vertical datum?

- Many variations of the definition exist
- Strictly speaking, a vertical datum is:
  - A ***surface*** representing zero elevation
- Traditionally, a vertical datum has been thought of in a more broad sense:
  - A ***system*** for the determination of heights above a zero elevation surface

What is a vertical datum?

- A vertical datum always has two components:
  - Its ***definition***
    - Parameters and other descriptors
  - Its ***realization***
    - Its physical method of accessibility

What is a vertical datum?

- Example: North American Vertical Datum of 1988 (NAVD 88)

- ***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.

Vertical Control Network NAVD 88

Figure 3. Vertical control used in 1988 adjustment.

450,000 BM's over 1,001,500 km

Why isn't NAVD 88 good enough anymore?

- **NAVD 88 suffers from use of bench marks that:**
  - Are almost never re-checked for movement
  - Disappear by the thousands every year
  - Are not funded for replacement
  - Are not necessarily in convenient places
  - 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

Why isn't NAVD 88 good enough anymore?

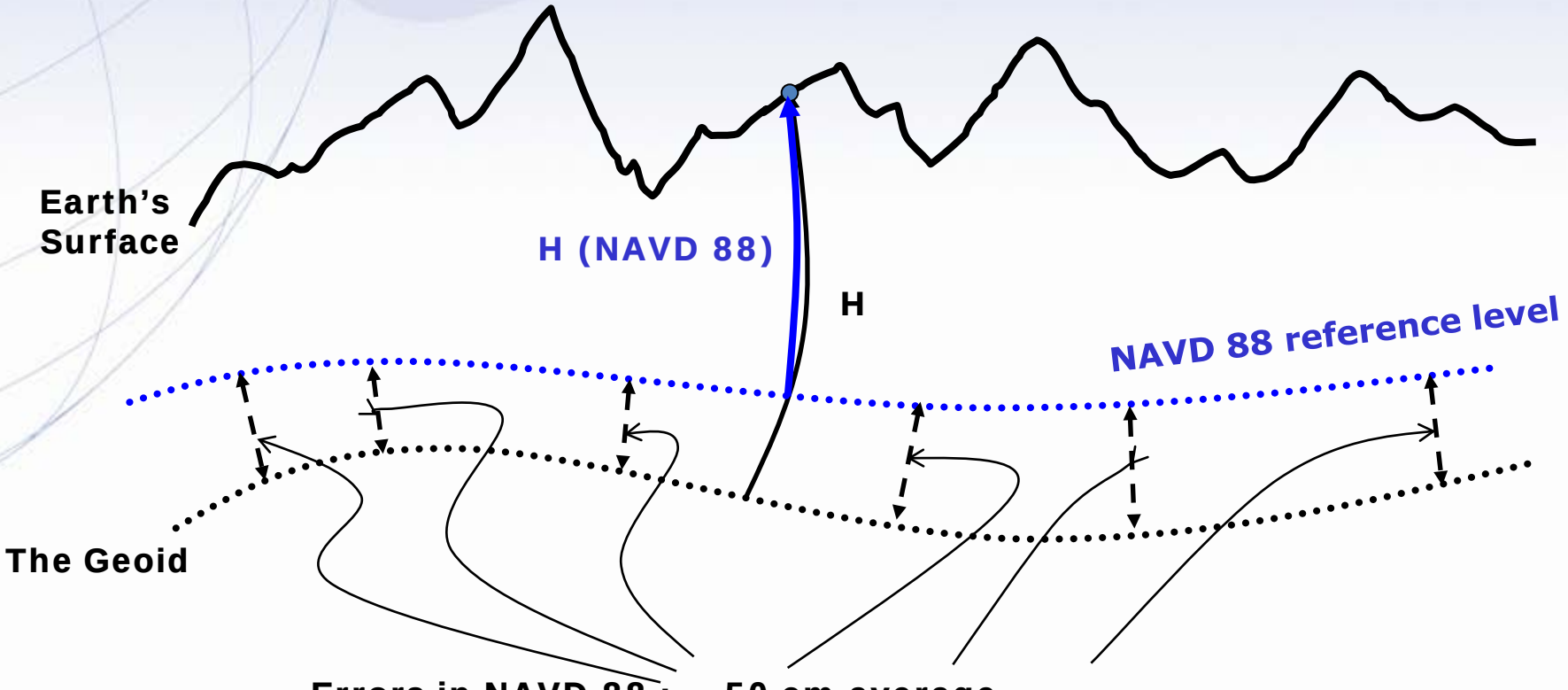
- **NAVD 88 suffers from:**

- A zero height surface that:

  - Has been proven to be ~50 cm biased from the latest, best geoid models (GRACE satellite)

  - Has been proven to be ~ 1 meter tilted across CONUS (again, based on the independently computed geoid from the GRACE satellite)

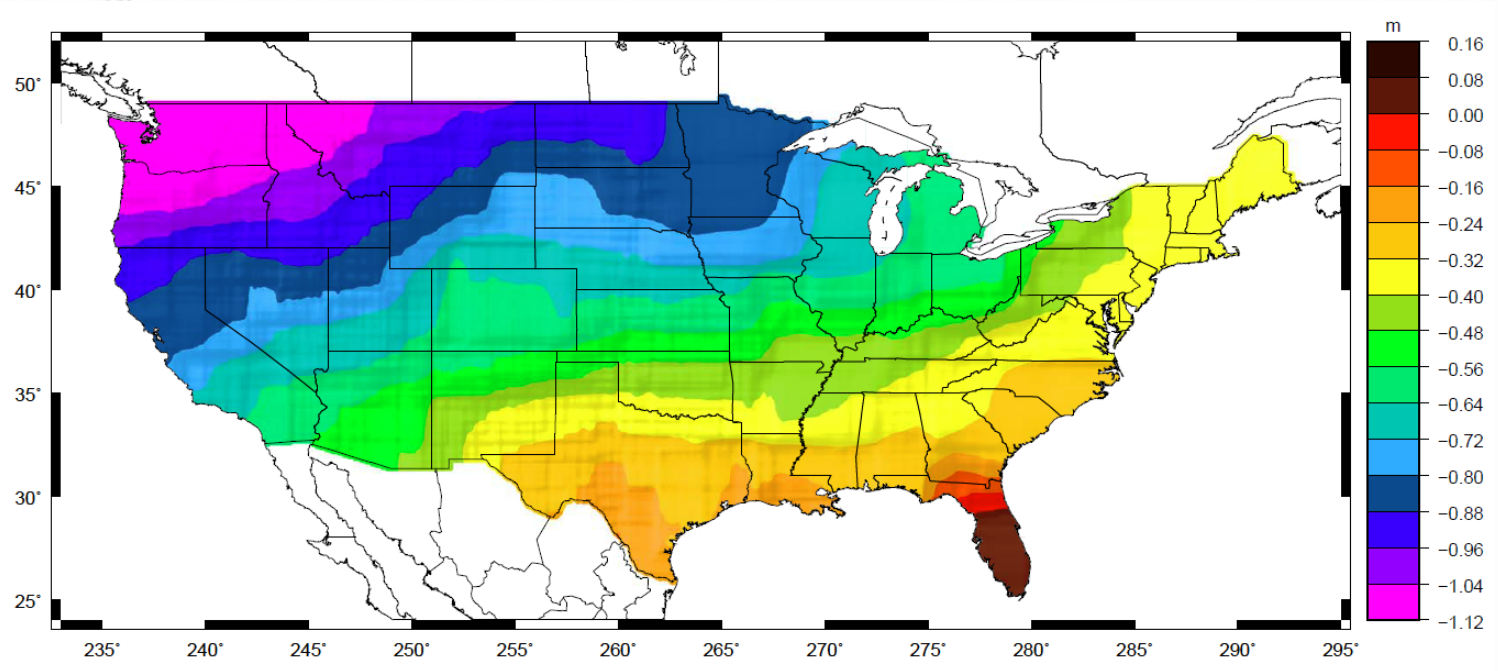
Why isn't NAVD 88 good enough anymore?



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

Why isn't NAVD 88 good enough anymore?

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



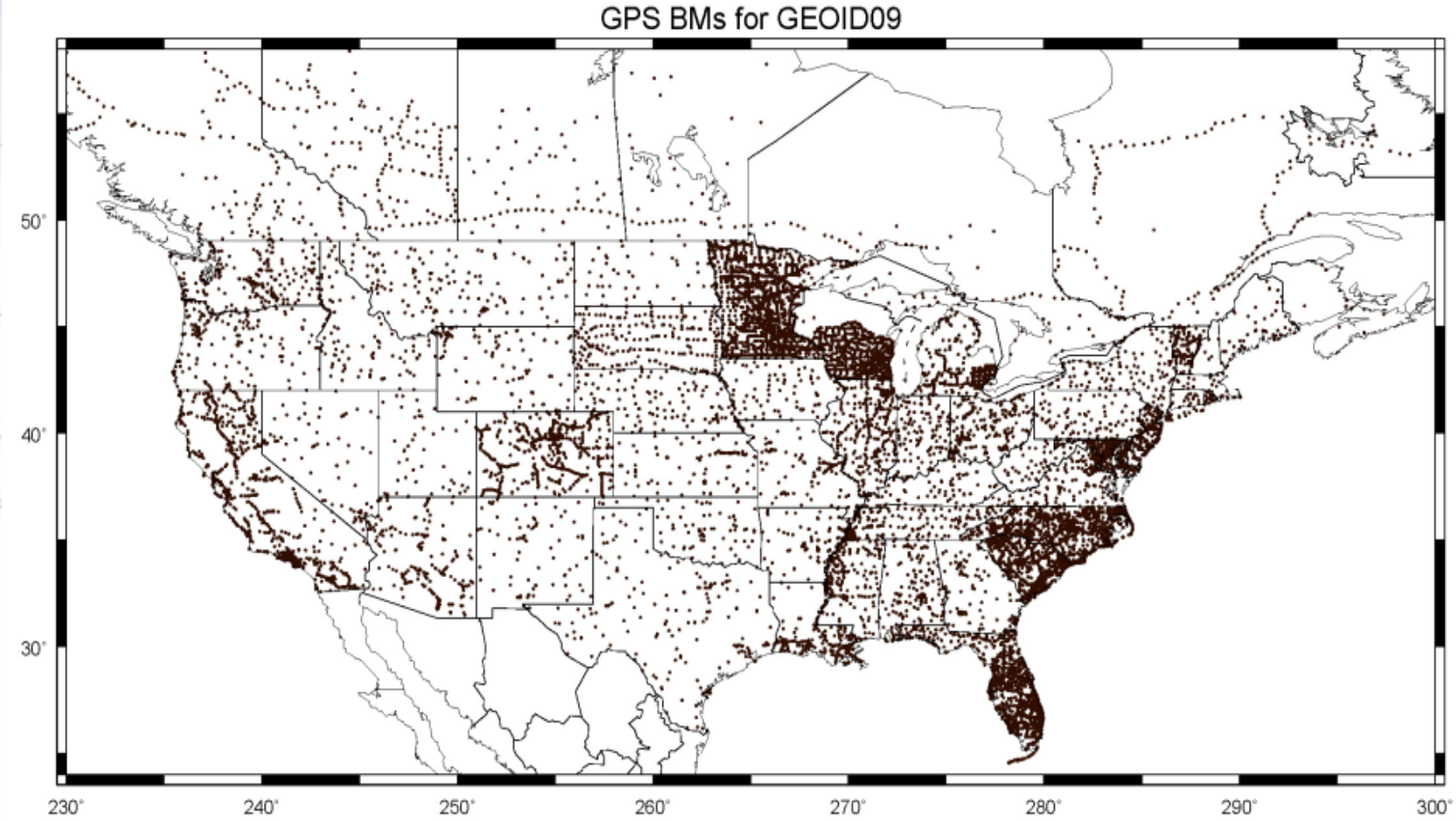
Possible ways to fix NAVD 88

- **Short term fixes**:
  - Provide fast methods of expanding NAVD 88 in areas where it is needed
- **Long term fixes**:
  - Re-level some / all of NAVD 88
  - Replace NAVD 88 bench marks

Possible ways to fix NAVD 88

- Short term fix: **Height Modernization GPS surveys**
  - Have provided a fast way to disseminate NAVD 88 bench mark heights to new marks through the use GPS and a constrained least squares adjustment
  - NOAA TM NOS NGS 58 and 59 guidelines
  - Keeps NAVD 88 useful and accessible, but does not address the majority of problems of NAVD 88 itself

GPSBM2009 (GEOID09 Control Data)



20446 total less 1003 rejected leaves 18,867 (CONUS) plus 576 (Canada)

Possible ways to fix NAVD 88

- Long term fix: **Re-level some/all of NAVD 88**
- Re-leveling NAVD 88 would cost between ***$200 Million*** and ***$2 Billion***
- This wouldn't fix all of the problems associated with the use of bench marks though

Possible ways to fix NAVD 88

- Long term fix: **Replace NAVD 88**
- Find a method of defining a vertical datum that seeks to fix all of the known issues with NAVD 88
- Best option: Define the datum as a given geoid model and realize it through GNSS technology
  - GRAV-D

Possible ways to fix NAVD 88

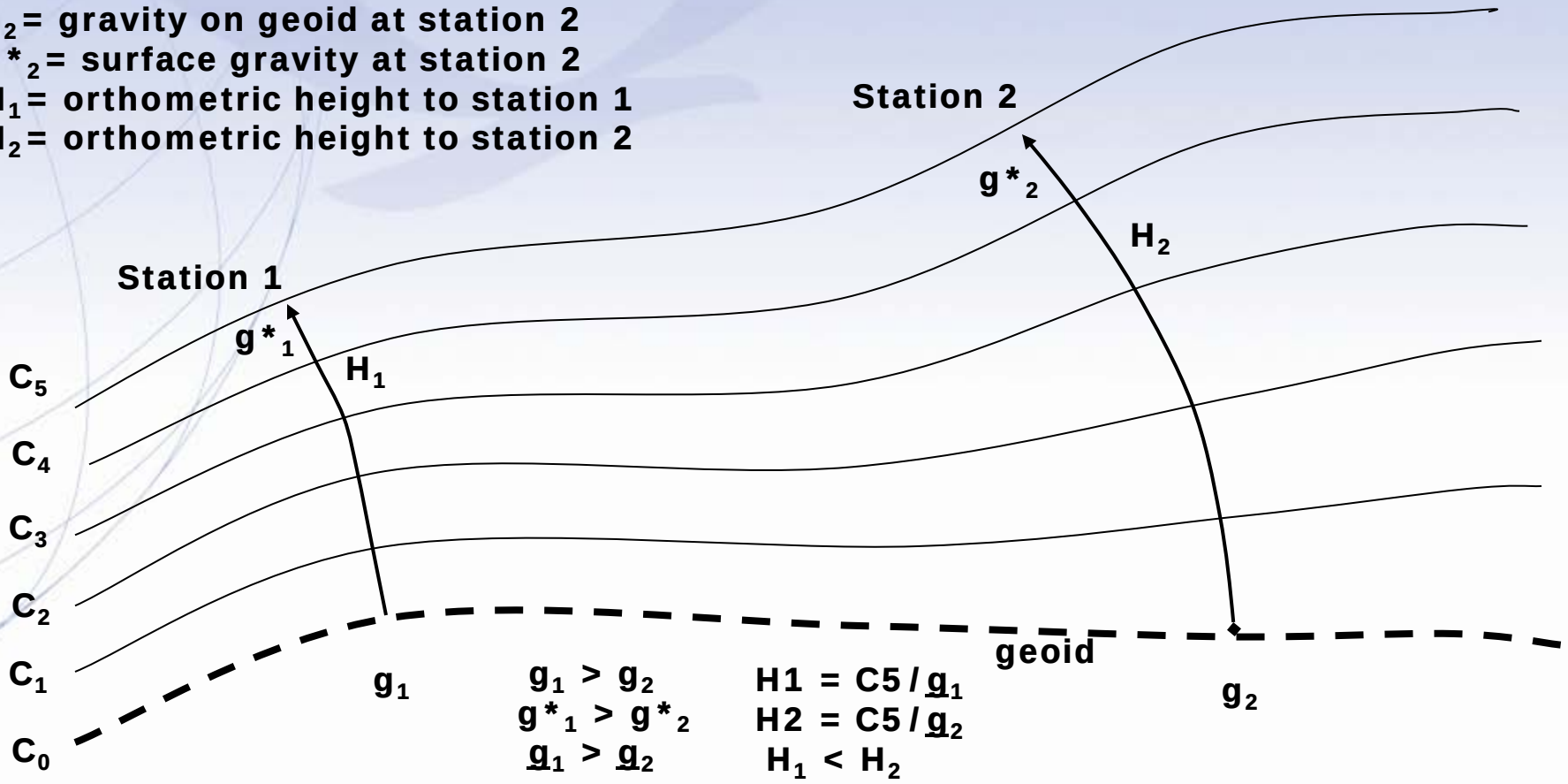
- Long term fix: **Replace NAVD 88 (continued)**

- **GRAV-D Trade-offs:** Datum is only realizable to 2 cm at best at any given point (GNSS error + geoid error)
  - However, this is an improvement over NAVD 88 realization error
  - The datum could then be disseminated locally through very precise geodetic leveling

Relationship between Gravity and Heights

g_1 = gravity on geoid at station 1
g^*_1 = surface gravity at station 1
g_2 = gravity on geoid at station 2
g^*_2 = surface gravity at station 2
H_1 = orthometric height to station 1
H_2 = orthometric height to station 2

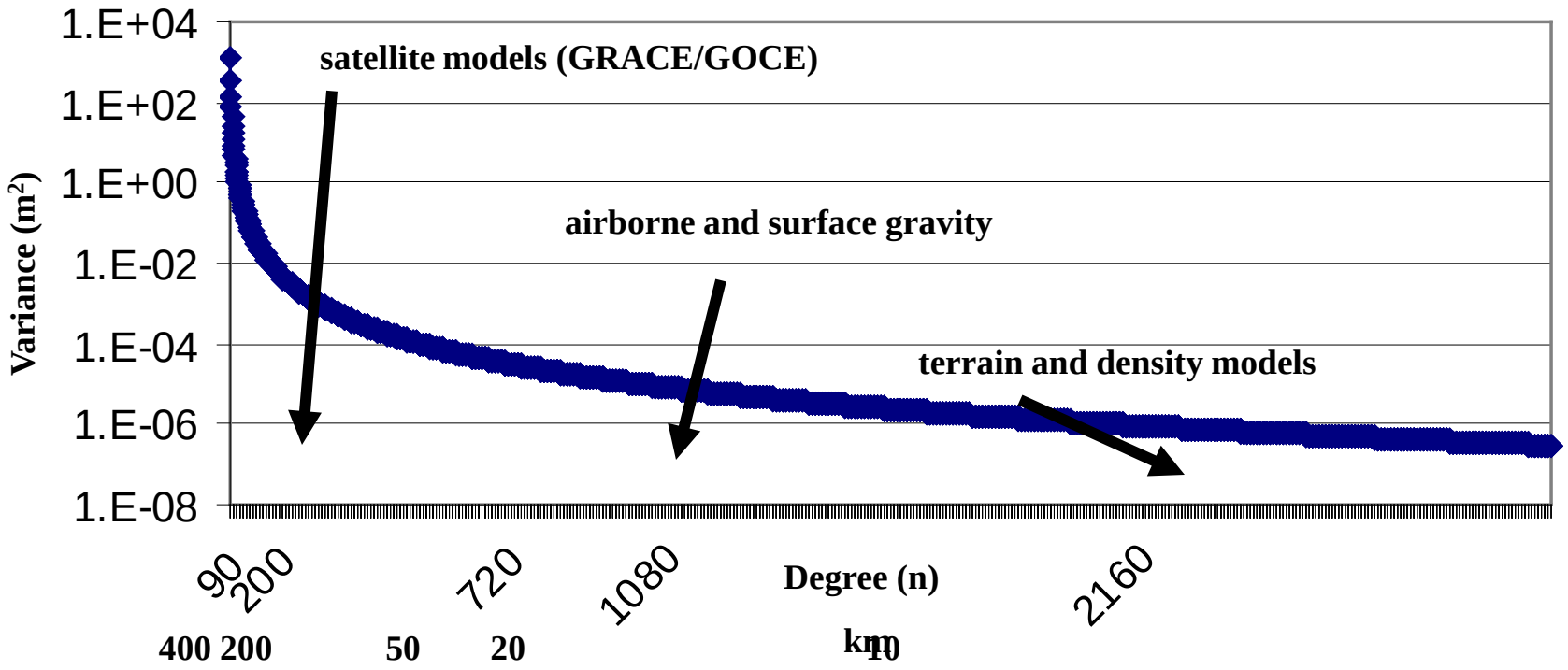
$\underline{g}_1$ = average gravity from g_1 to g^*_1
$\underline{g}_2$ = average gravity from g_2 to g^*_2



Note that surface location of station 1 is closer to the geoid than station 2.
A steep gradient of geops indicates higher gravity – less steep indicates lower gravity.
The geops being farther apart beneath station 2 to reflect lower local mass and gravity.
Hence, H1 should be less than H2 – even though both have the same geopotential.

Geoid Power and Potential Sources

Work with many groups to obtain other data sets as well as what we observe



- **Spectrally merge the data sources to obtain a seamless gravity field**
- **Work with neighbors to incorporate regional data (North American Geoid / IAG CP 2.2)**
- **Use rigorous geodetic theory and / or forward modeling to make a geoid height model**

Possible ways to fix NAVD 88

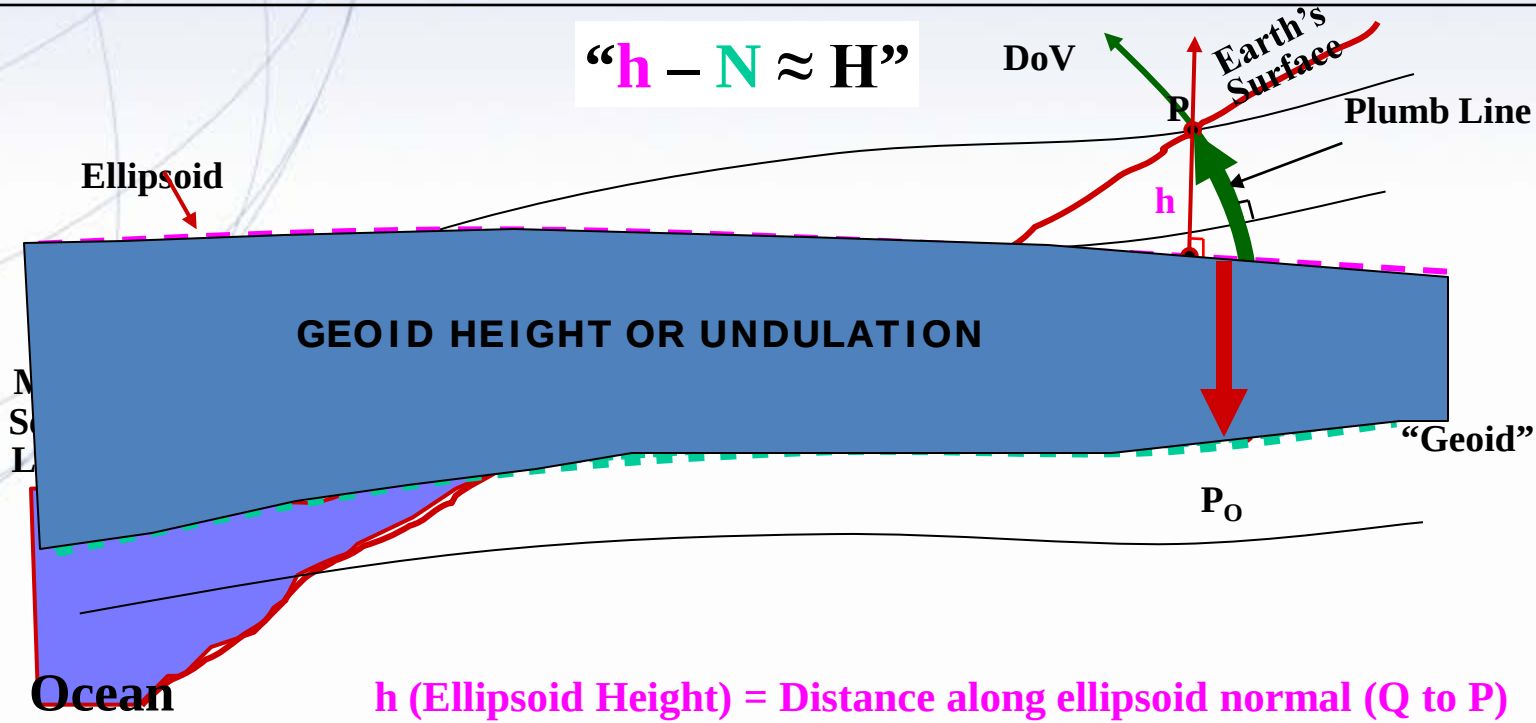
- Long term fix: **Replace NAVD 88 (continued)**

- **GRAV-D International Issues**
  - Canada has agreed to move to a geoid based vertical datum
    - Negotiations with USA underway
  - Mexico has discussed this with USA, but have not chosen to move to a geoid based datum yet
  - Central American, Caribbean: No policy to switch, but the datum will be freely available to them

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 removed to provide orthometric heights in the new datum
  - No passive marks needed
  - But, could be used to position a passive mark

Relationship between ellipsoid, geoid and orthometric heights.



h (Ellipsoid Height) = Distance along ellipsoid normal (Q to P)

N (Geoid Height) = Distance along ellipsoid normal (Q to P_O)

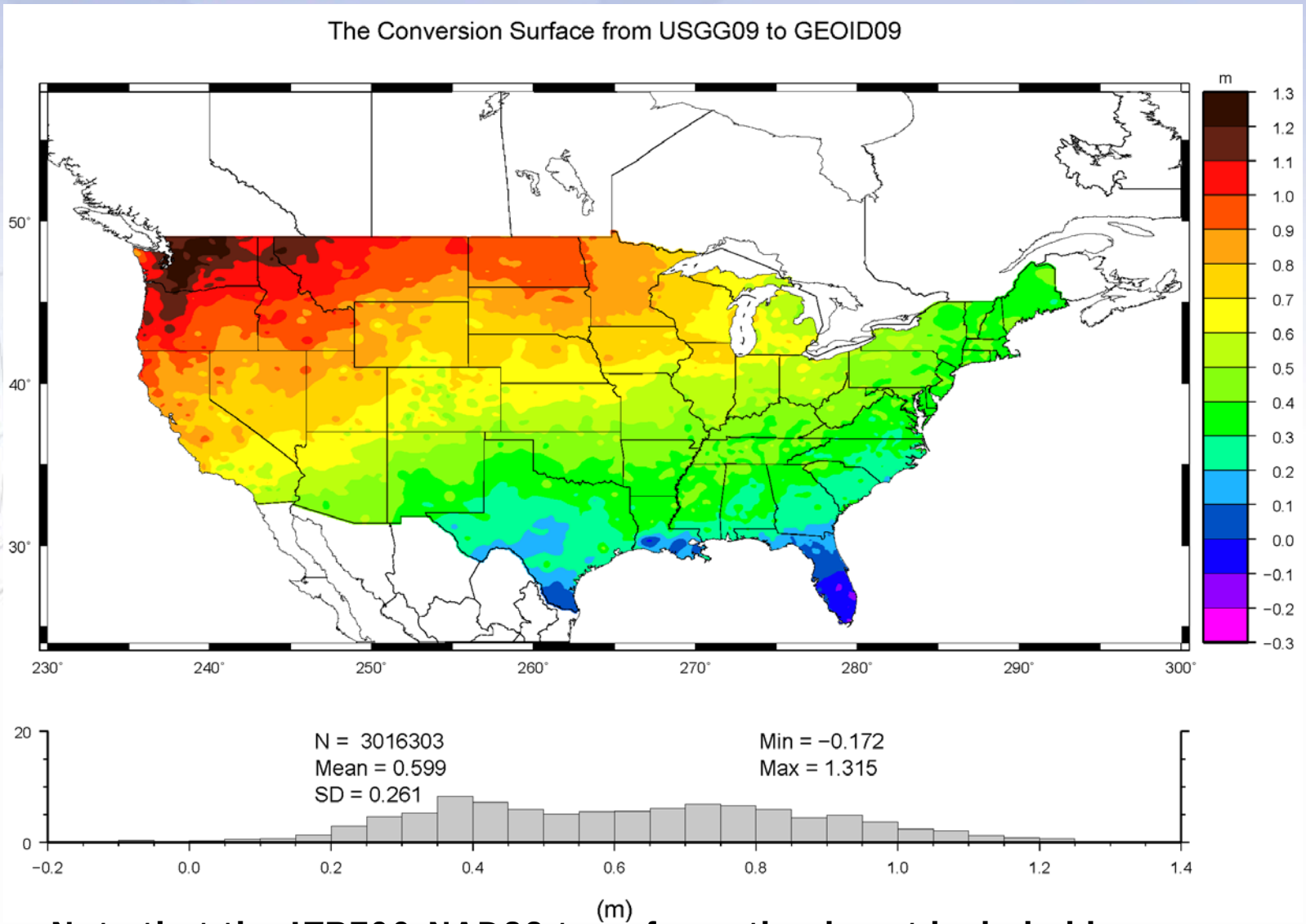
H (Orthometric Height) = Distance along plumb line (P_O to P)

How will I access the new vertical datum?

- **Secondary access** (Use at your own risk)
  - Passive marks that have been tied to the new vertical datum
  - NGS will provide a "data sharing" service for these points, but their accuracy (due to either the quality of the survey or the age of the data) will not be a responsibility of NGS

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
    - Only where recent GNSS ellipsoid heights exist to provide modern heights in the new datum



Note that the ITRF00-NAD83 transformation is not included here
This was neglected to highlight the significant systematic features

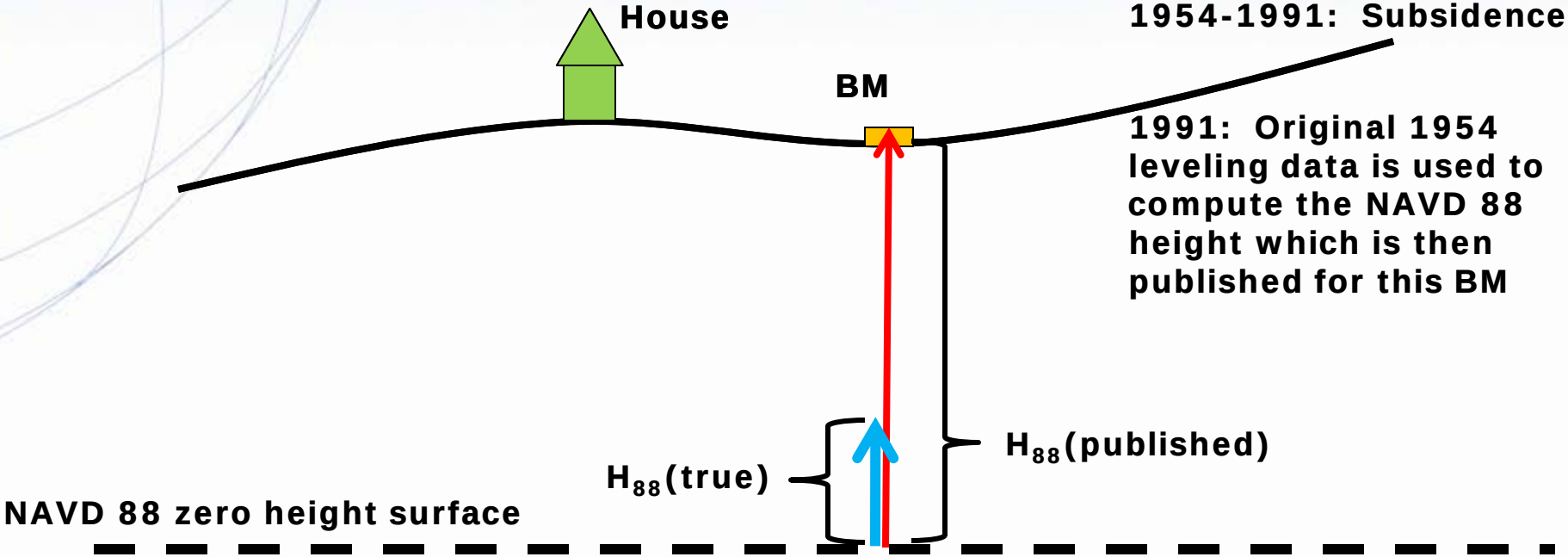
How will I access the new vertical datum?

Example 1: Flood insurance survey

1954: Leveling Performed to bench mark

1954-1991: Subsidence

1991: Original 1954 leveling data is used to compute the NAVD 88 height which is then published for this BM



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

How will I access the new vertical datum?

Example 1: Flood insurance survey

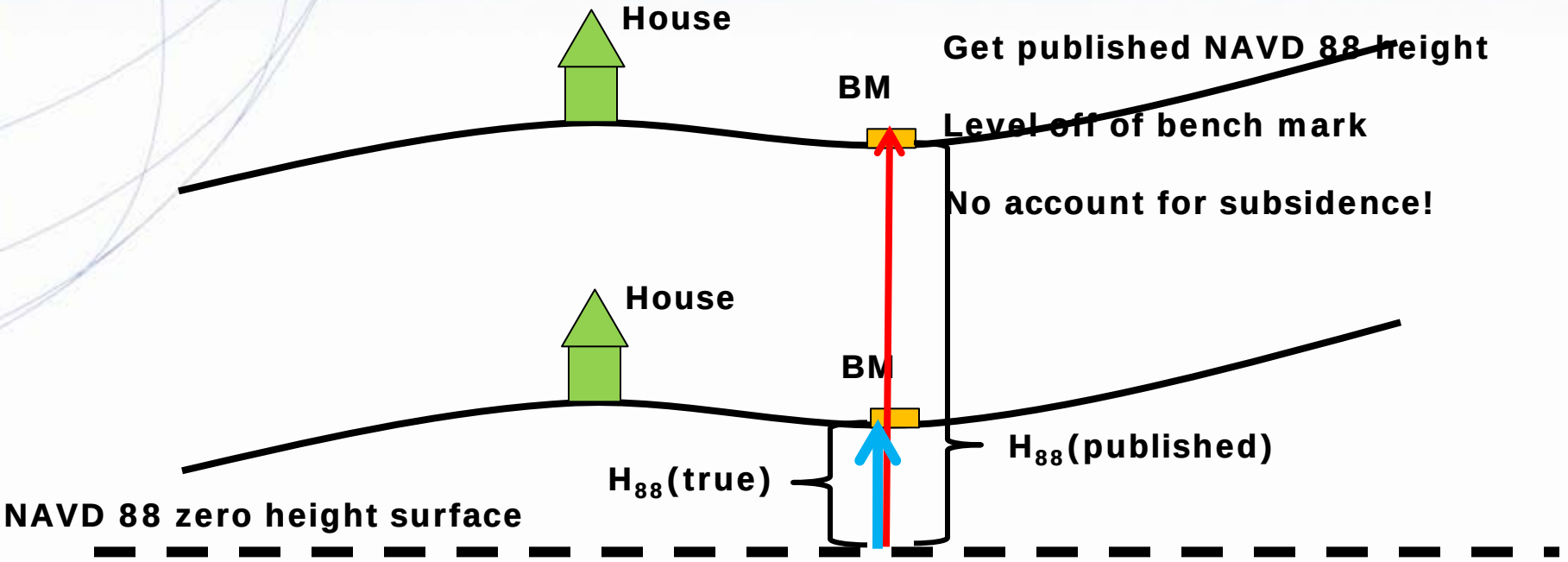
Using Existing Techniques:

Find bench mark (if you can)

Get published NAVD 88 height

Level off of bench mark

No account for subsidence!



How will I access the new vertical datum?

Example 1: Flood insurance survey

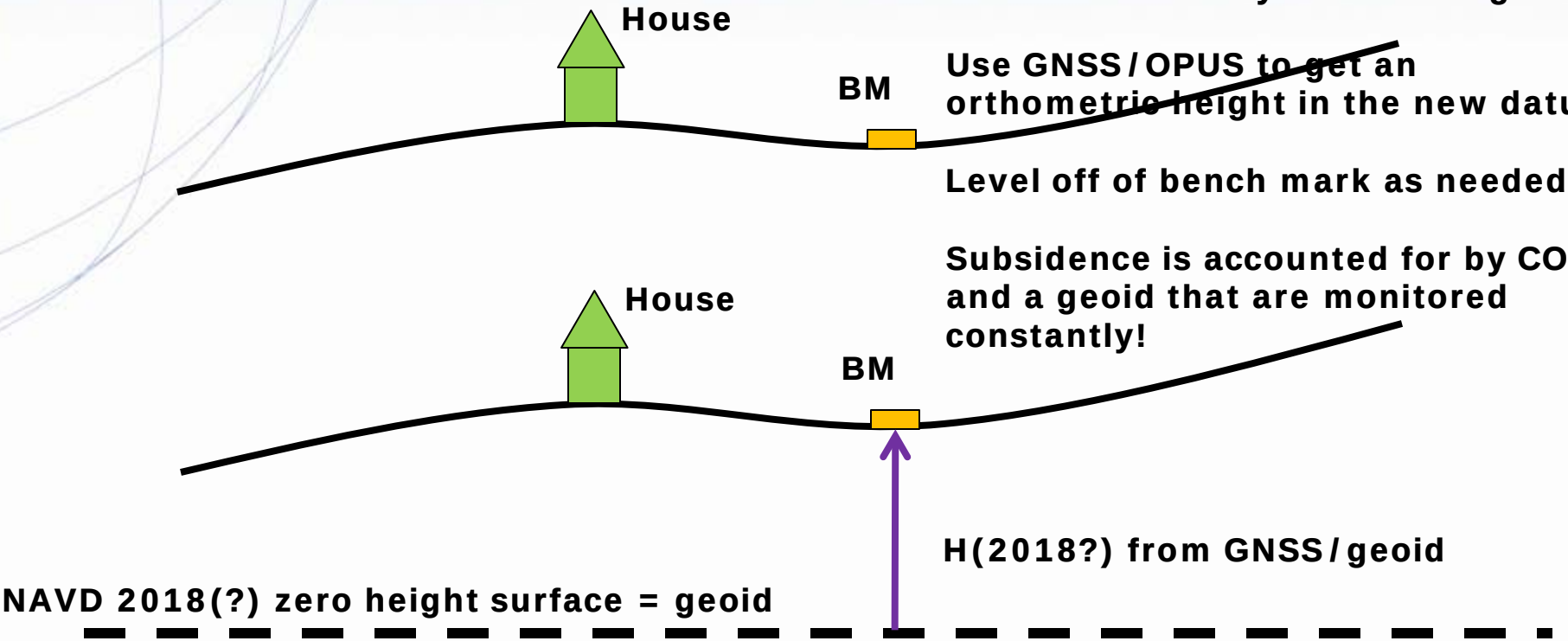
Using Future Techniques:

Find bench mark if you wish, or set a new one of your choosing

Use GNSS/OPUS to get an orthometric height in the new datum

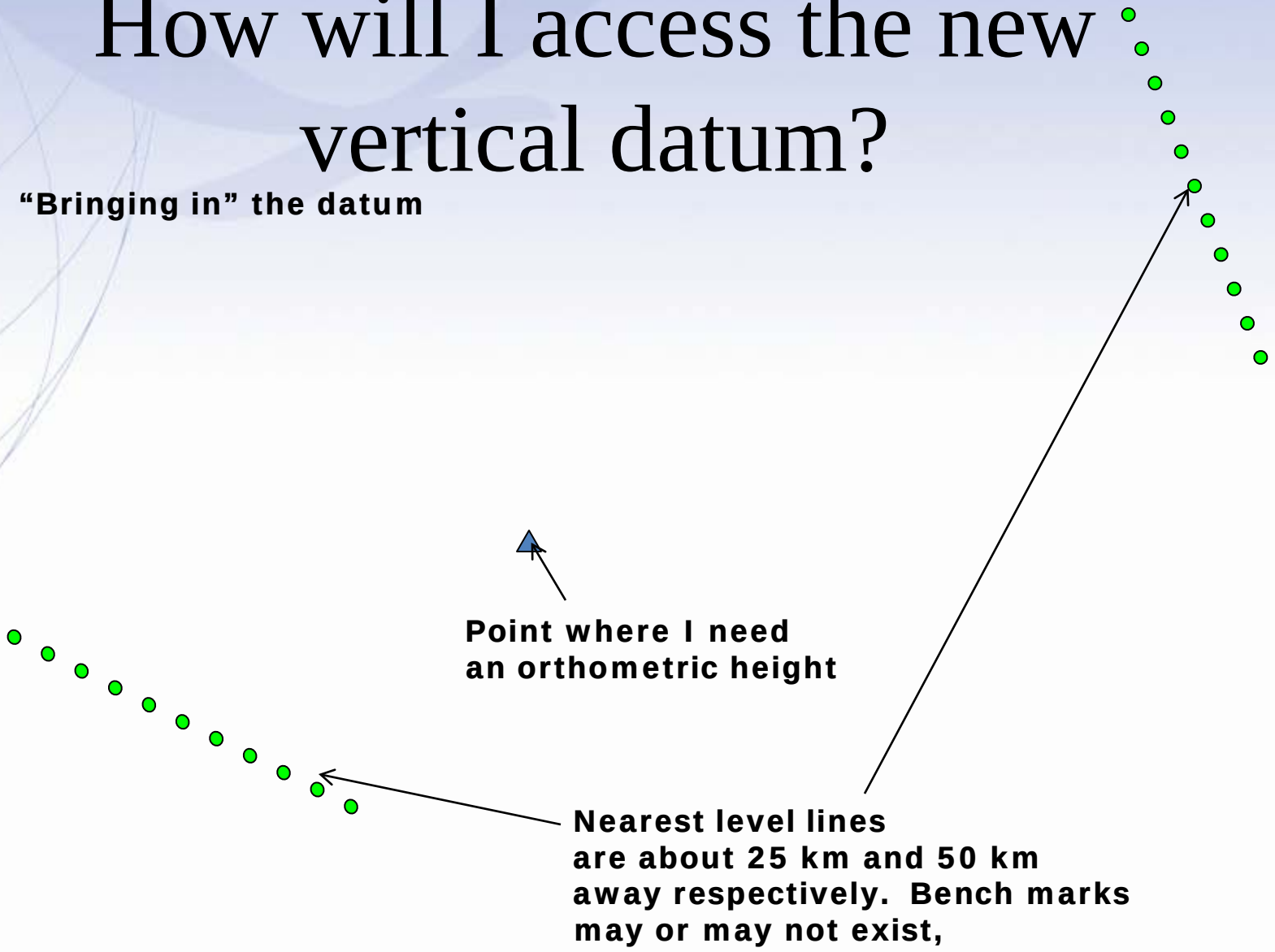
Level off of bench mark as needed

Subsidence is accounted for by CORS and a geoid that are monitored constantly!



How will I access the new vertical datum?

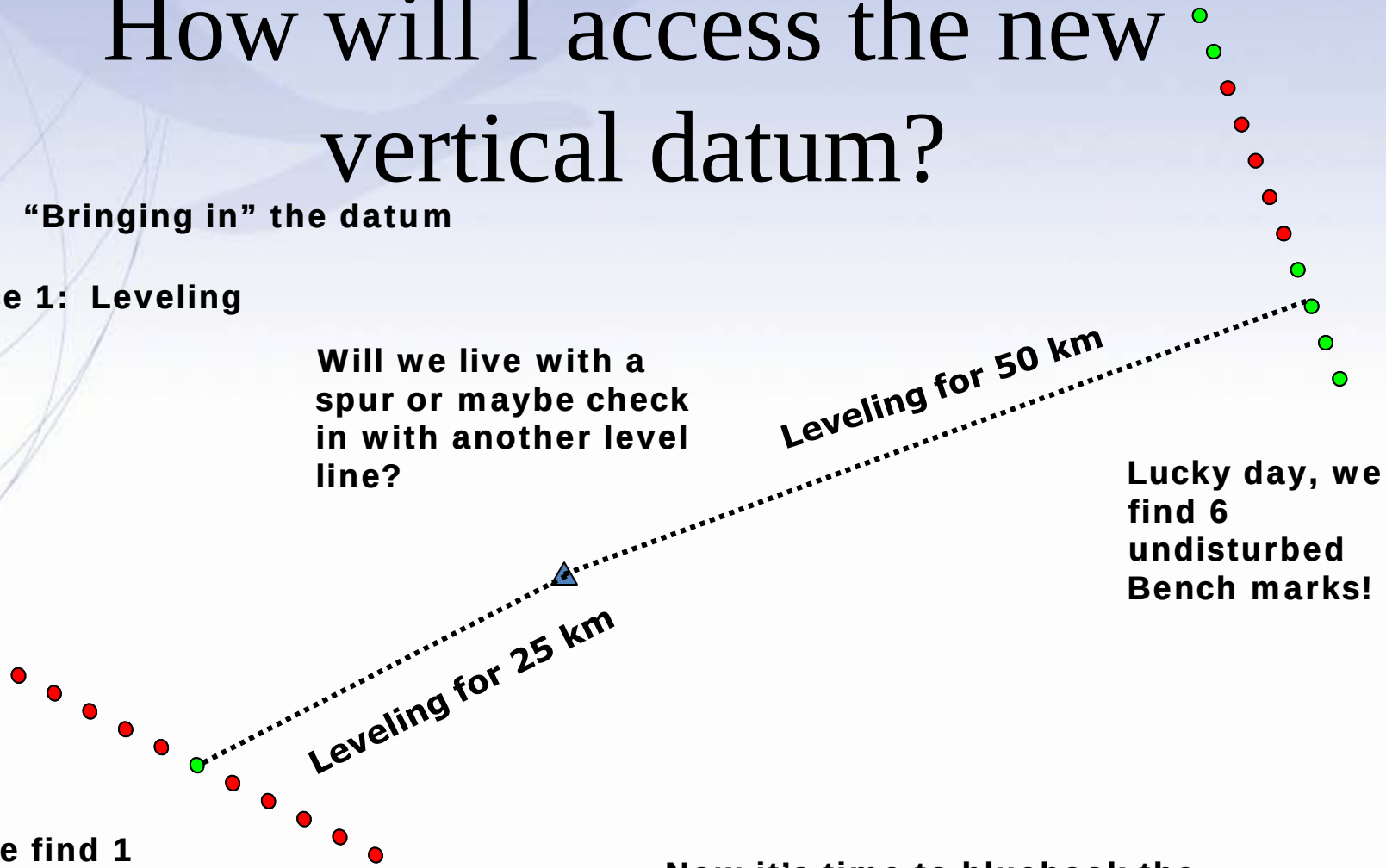
Example 2: "Bringing in" the datum



How will I access the new vertical datum?

Example 2: "Bringing in" the datum

Choice 1: Leveling



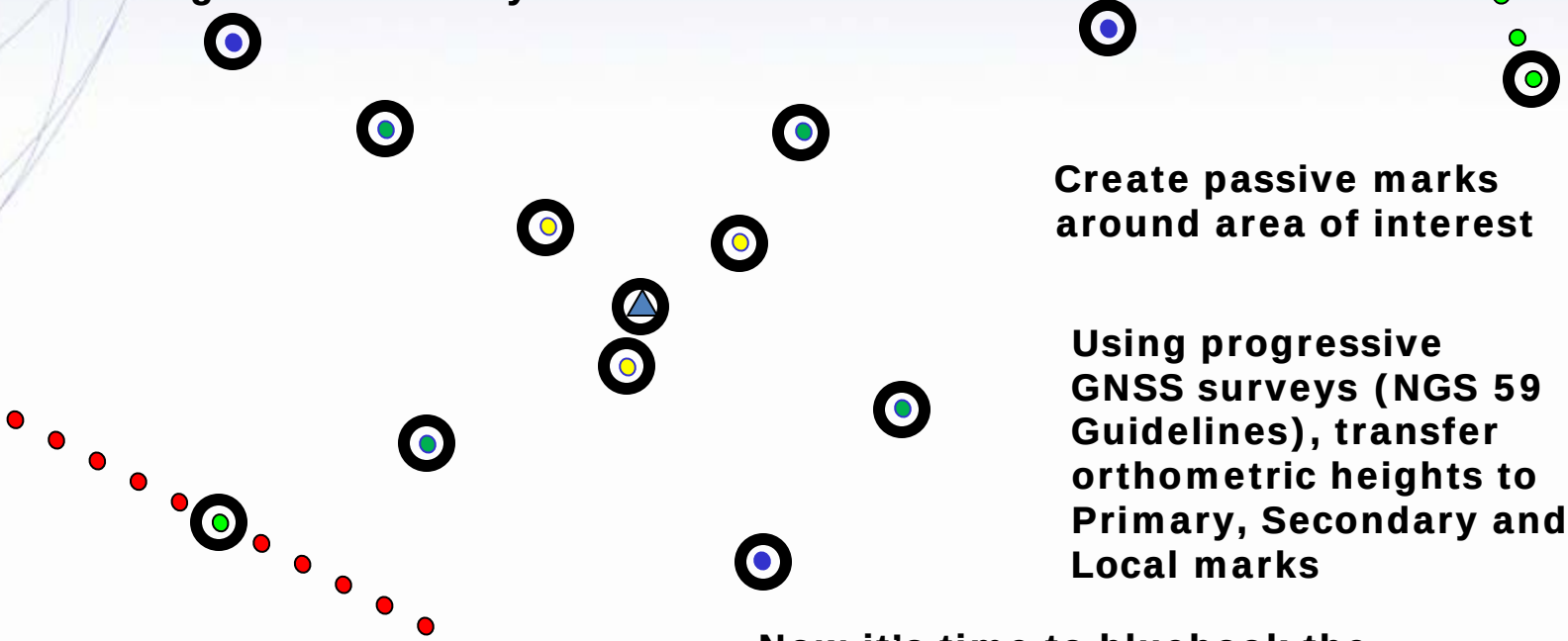
Now it's time to bluebook the data, submit to NGS, wait for the backlog to clear….

And all this assumes the published heights are correct to begin with…

How will I access the new vertical datum?

Example 2: "Bringing in" the datum

Choice 2: "Height Mod" survey



Create passive marks around area of interest

Using progressive GNSS surveys (NGS 59 Guidelines), transfer orthometric heights to Primary, Secondary and Local marks

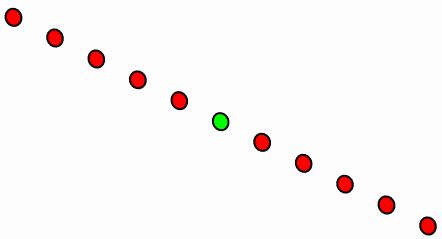
Now it's time to bluebook the data, submit to NGS, wait for it to be loaded into the IDB….

And all this assumes the published heights are correct to begin with…

How will I access the new vertical datum?

Example 2: "Bringing in" the datum

Choice 3: Once GRAV-D is complete

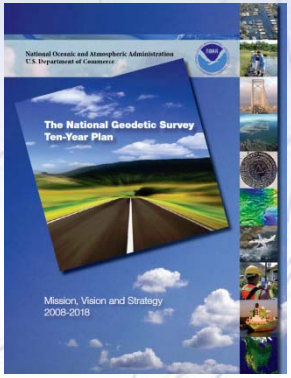


Set up GNSS receiver over mark

Submit data to OPUS and receive orthometric height

Feeling generous? Share your results with others using the NGS online database (no bluebooking involved). If not, take your height and walk away.

Additional Information

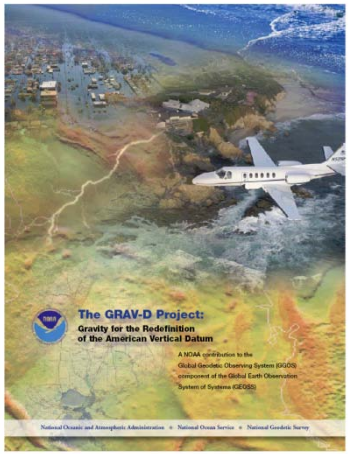


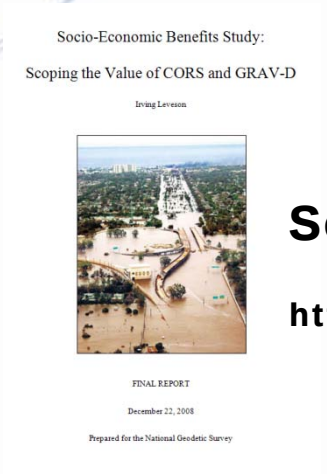
The NGS 10 year plan (2008-2018)

http://www.ngs.noaa.gov/INFO/NGS10yearplan.pdf

The GRAV-D Project

http://www.ngs.noaa.gov/GRAV-D




Socio-Economic Benefits Study:

Scoping the Value of CORS and GRAV-D

Irving Leveson

FINAL REPORT

December 22, 2008

Prepared for the National Geodetic Survey

Socio-Economic Benefits of CORS and GRAV-D

http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf

Questions?

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