Improvements to the Geoid Models

Gerald L. Mader and Daniel R. Roman

Determining Elevations with GNSS

Lindy C Boggs International Conference Center
University of New Orleans

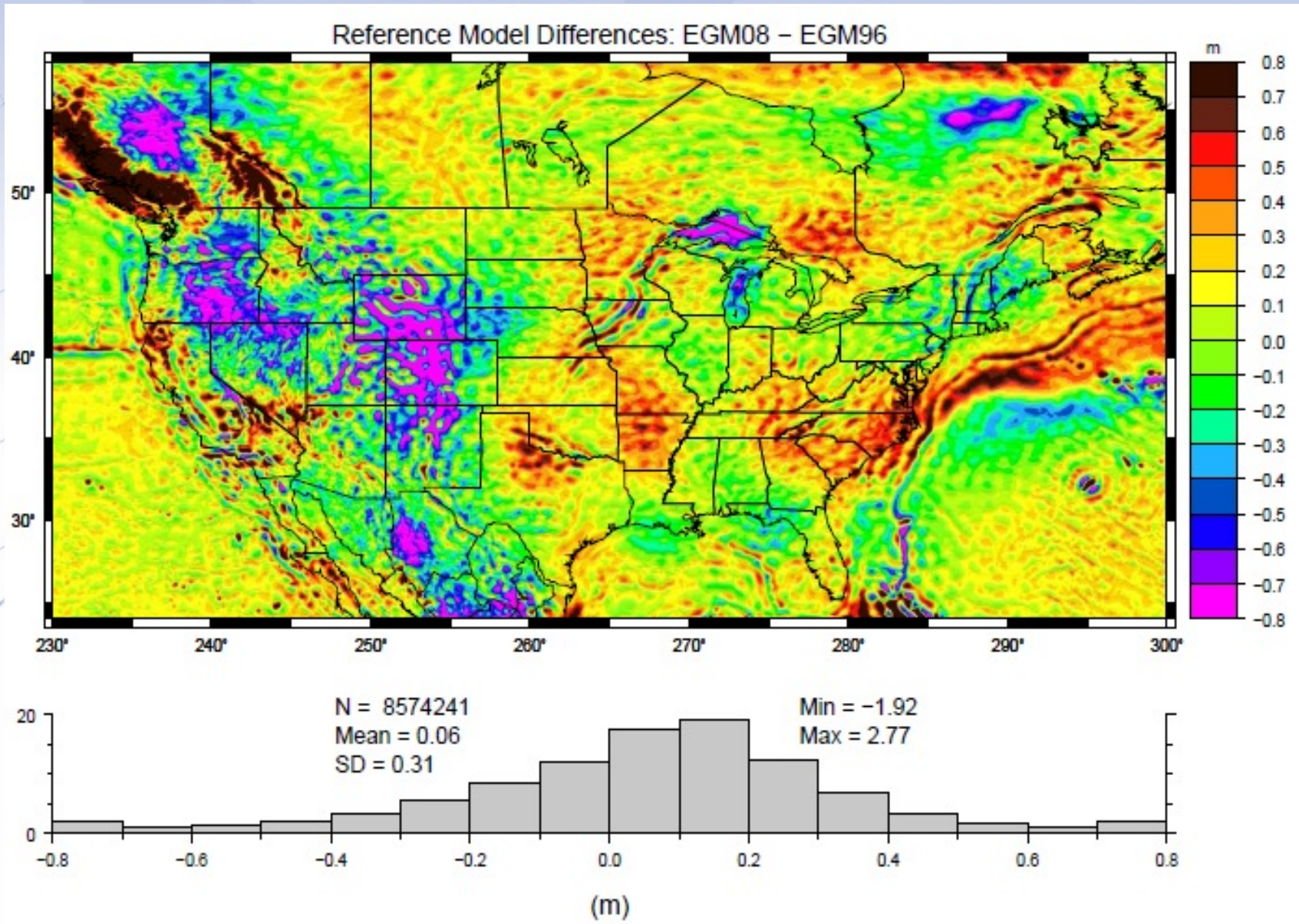
June 20-21, 2011

OUTLINE

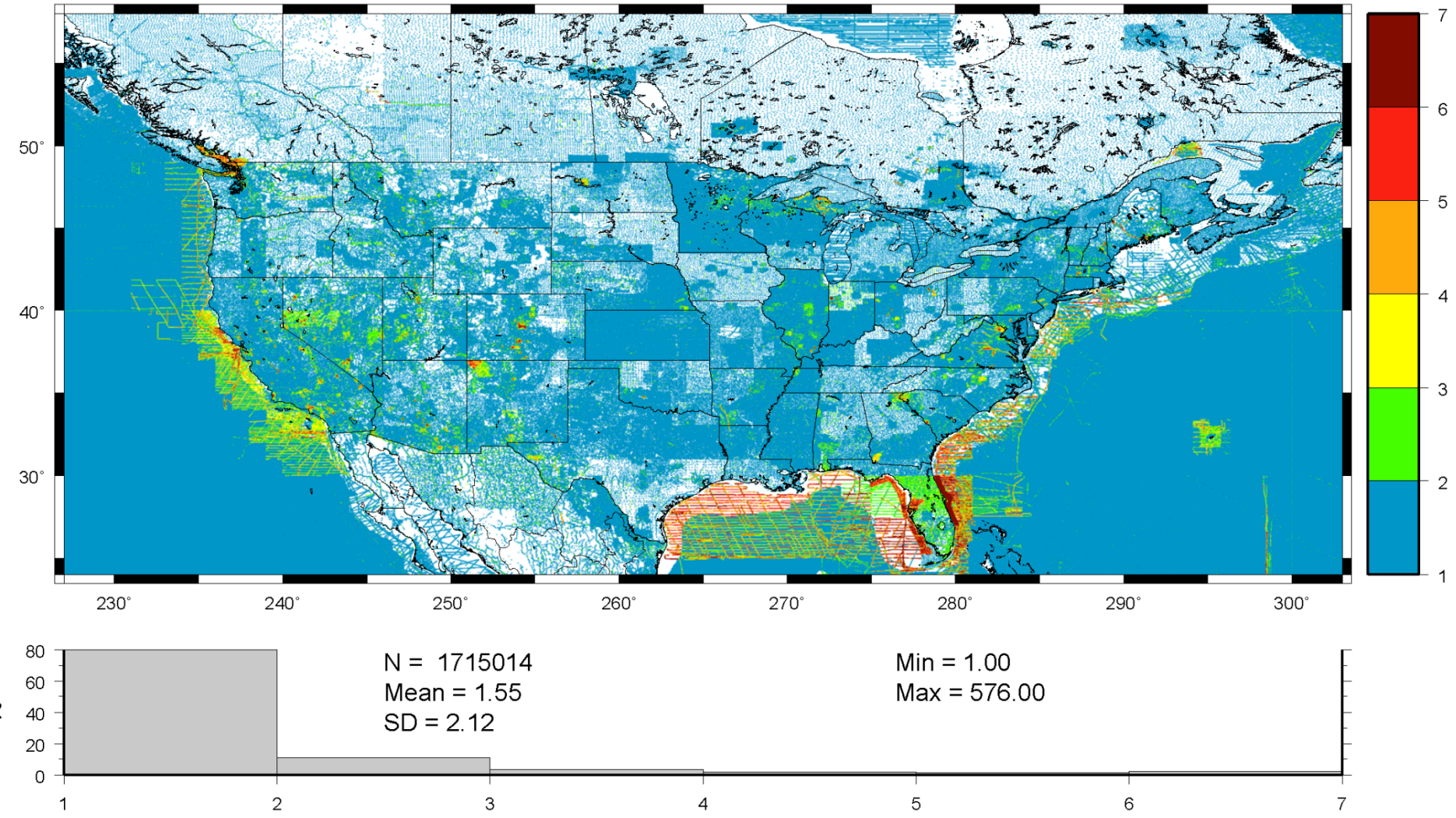
- GRACE and EGM2008
- USGG2009
- GPSBM2009
- GEOID09
- Upcoming
  - USGG2012/GOCE
  - GRAV-D
  - GEOID12/NA 2011/OPUS-DB

General Review of Modeling

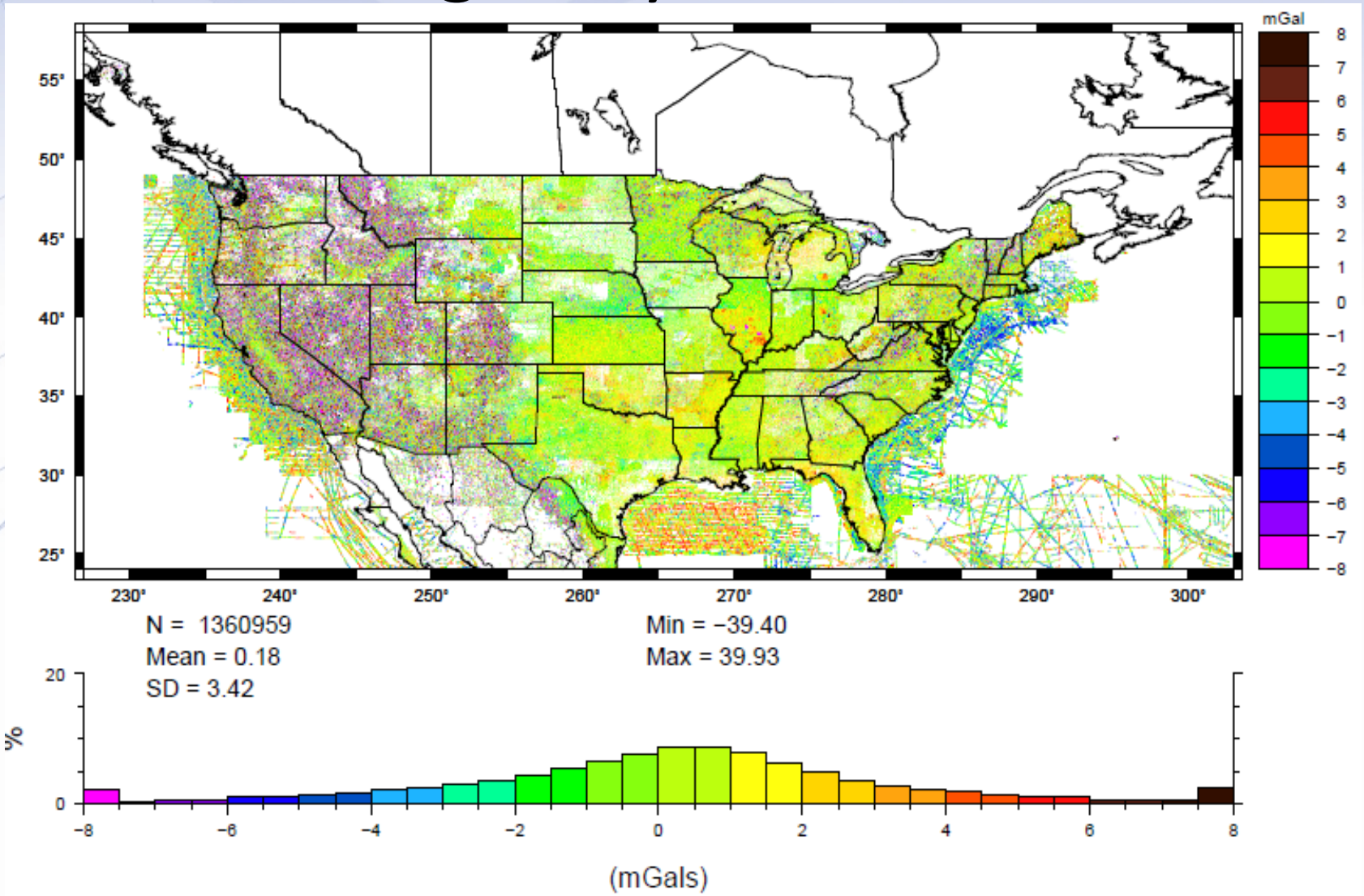
- Developing a Gravimetric Geoid
  - Reference model covers global aspects
    - In some ITRF version (i.e., USGG2009 is in ITRF00)
  - Point gravity data enhance to fill in finer detail
  - Elevation models account for shortest wavelengths
- Developing a Hybrid Geoid
  - Start from gravimetric geoid
  - Well distributed & accurate control data (GPSBM's)
  - Everything on the same datum (NAD 83)


Reference Model Differences: EGM08 − EGM96
m
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
50°
40°
30°
230°
240°
250°
260°
270°
280°
290°
300°
N = 8574241
Mean = 0.06
SD = 0.31
Min = −1.92
Max = 2.77
20
0
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
(m)

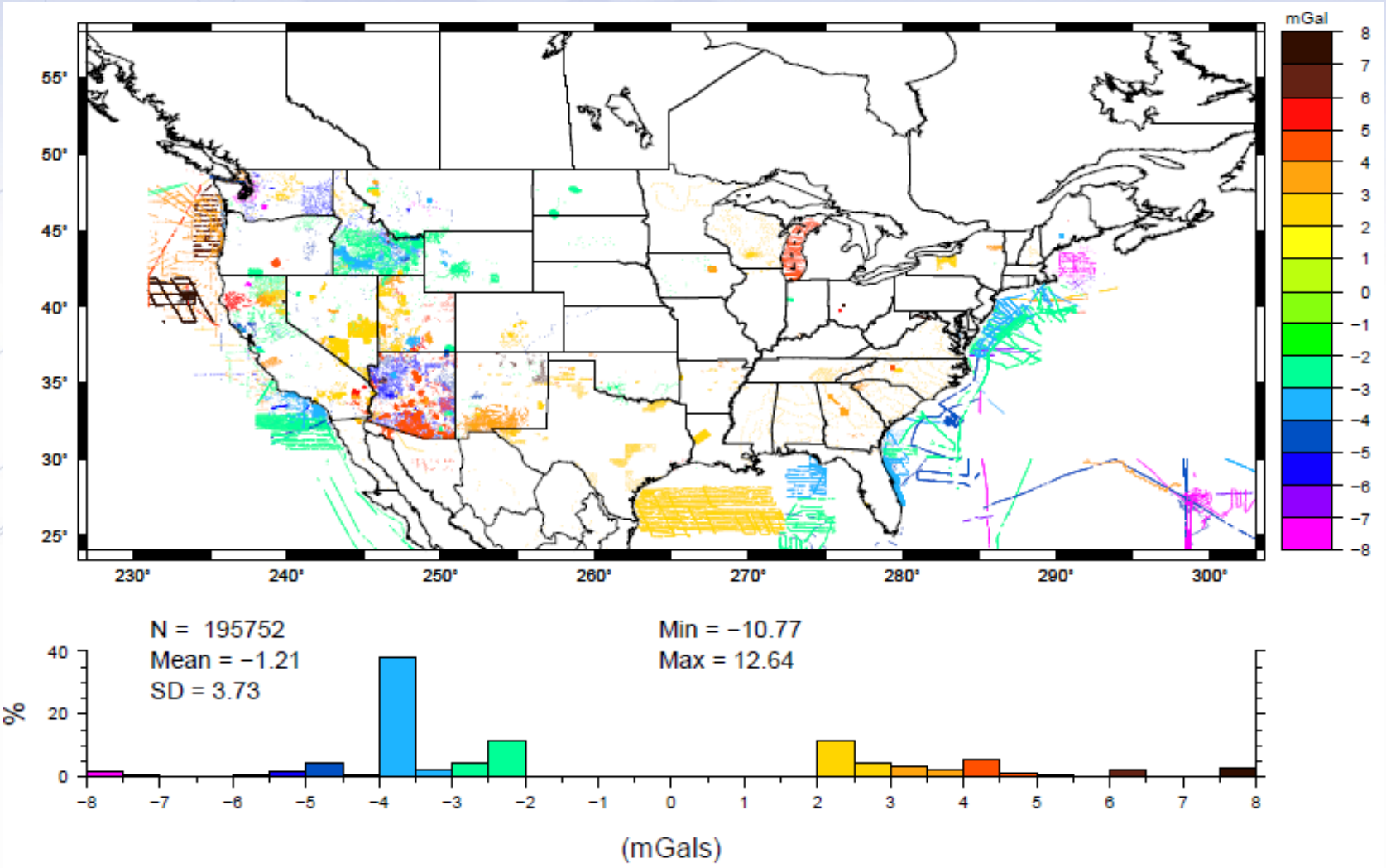
Number of Gravity Points Per 1x1 Minute cell

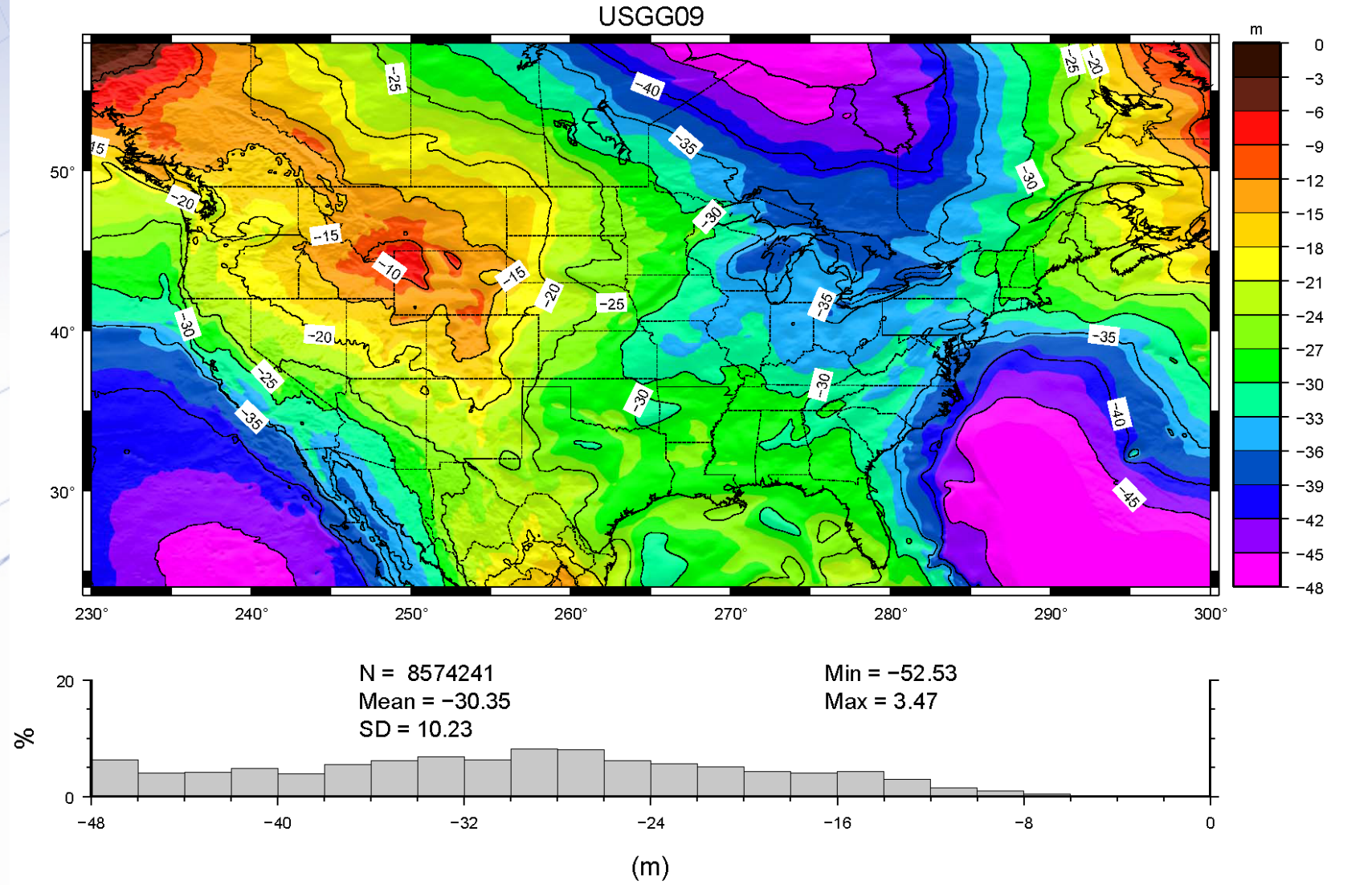


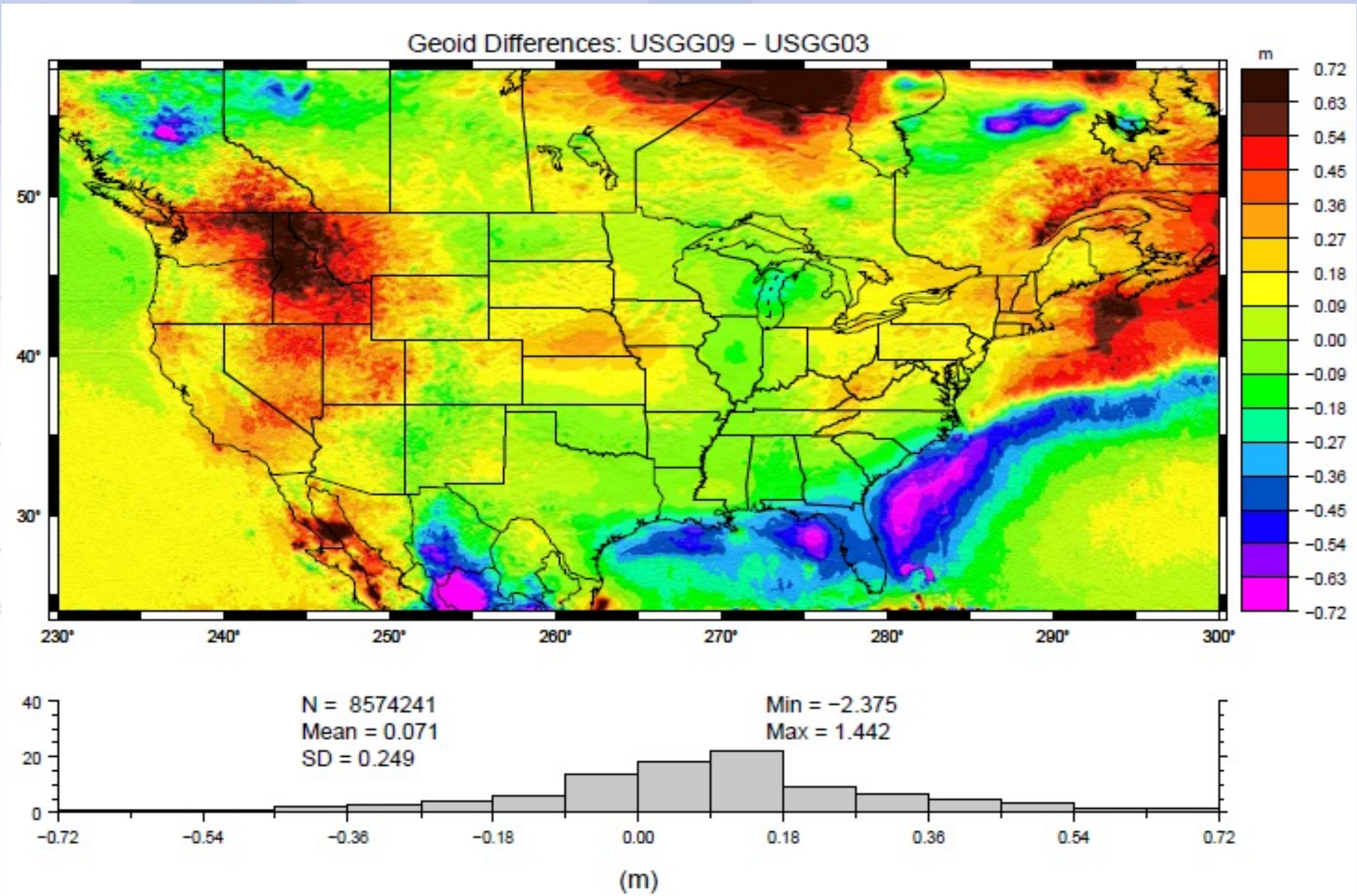
Residual gravity data for CONUS



244 Surveys with Significant Biases



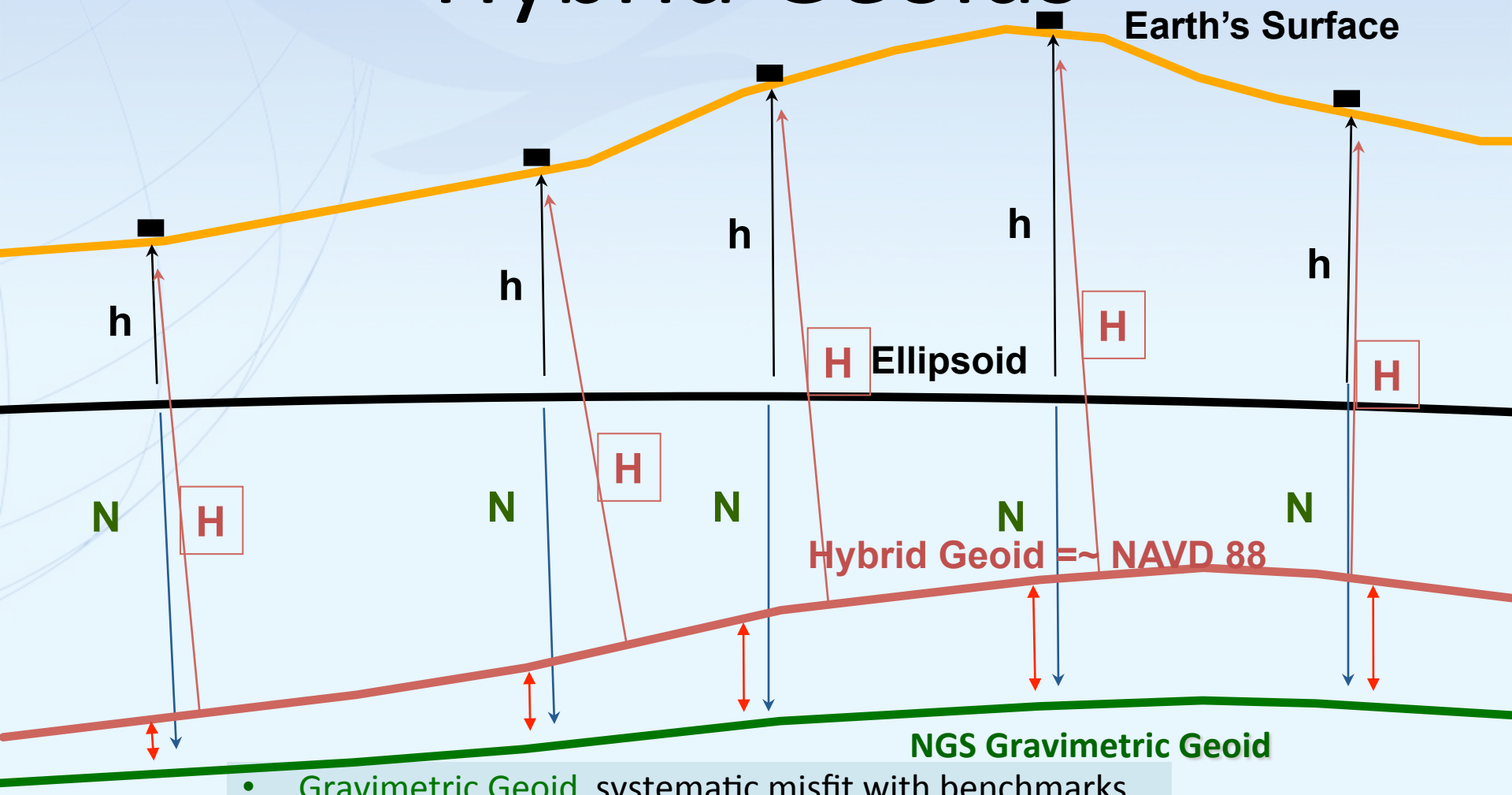

USGG09
m
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-36
-39
-42
-45
-48
50°
40°
30°
230°
240°
250°
260°
270°
280°
290°
300°
N = 8574241
Mean = −30.35
SD = 10.23
Min = −52.53
Max = 3.47
%
20
0
−48
−40
−32
−24
−16
−8
0
(m)


Geoid Differences: USGG09 – USGG03
m
0.72
0.63
0.54
0.45
0.36
0.27
0.18
0.09
0.00
−0.09
−0.18
−0.27
−0.36
−0.45
−0.54
−0.63
−0.72
50°
40°
30°
230°
240°
250°
260°
270°
280°
290°
300°
N = 8574241
Mean = 0.071
SD = 0.249
Min = −2.375
Max = 1.442
40
20
0
−0.72
−0.54
−0.36
−0.18
0.00
0.18
0.36
0.54
0.72
(m)

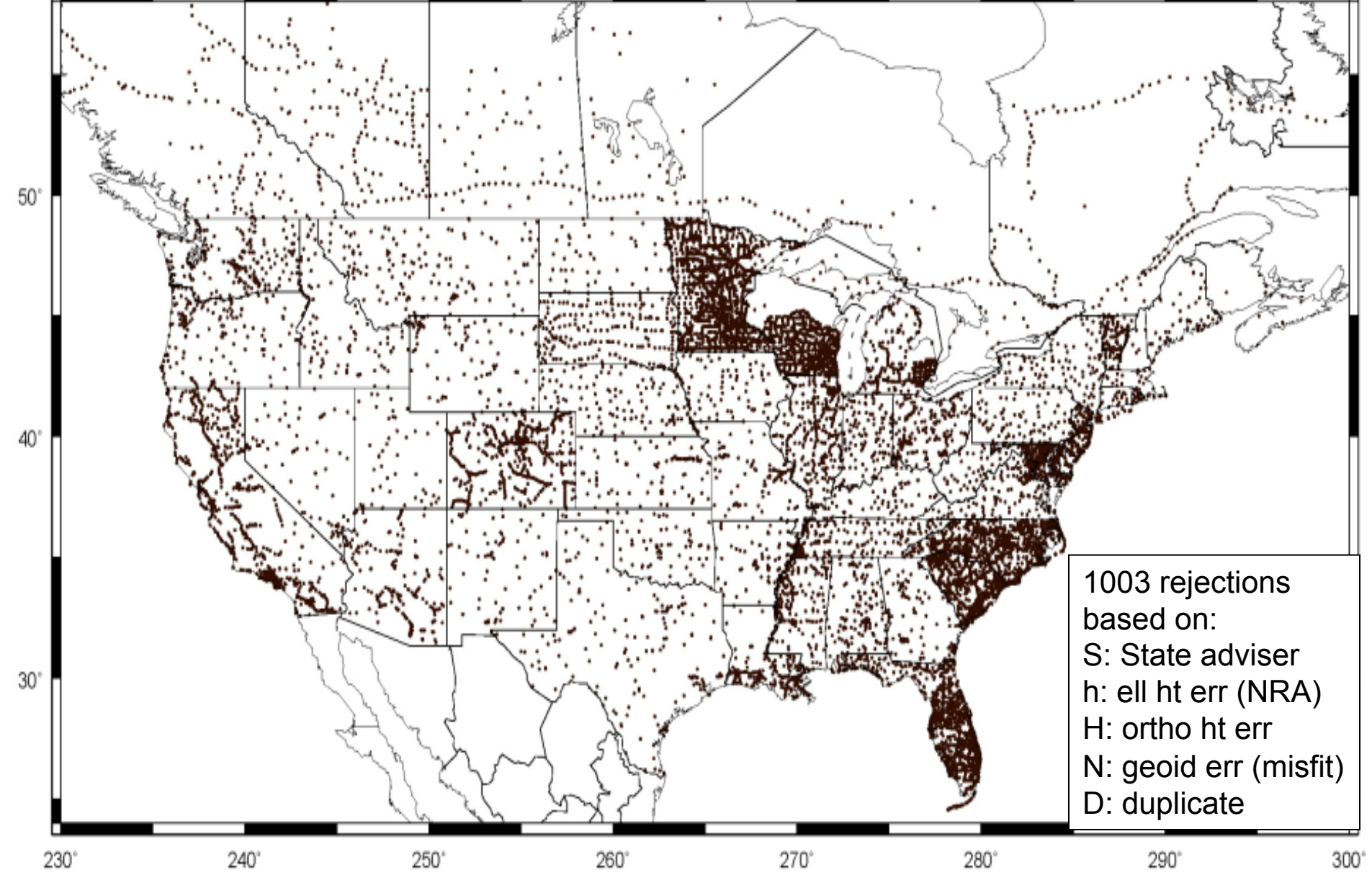
USGG2009 Summary

- Based in ITRF 00
  - Converts from ITRF 00 to selected geoid surface
  - Does **not** convert between NAD 83 and NAVD 88
- Best for scientific applications
  - It's geocentric and has data offshore
  - Tied to universally accepted global model (GRACE)
- Significant changes from USGG2003
  - Multi-dm to meter level

Hybrid Geoids



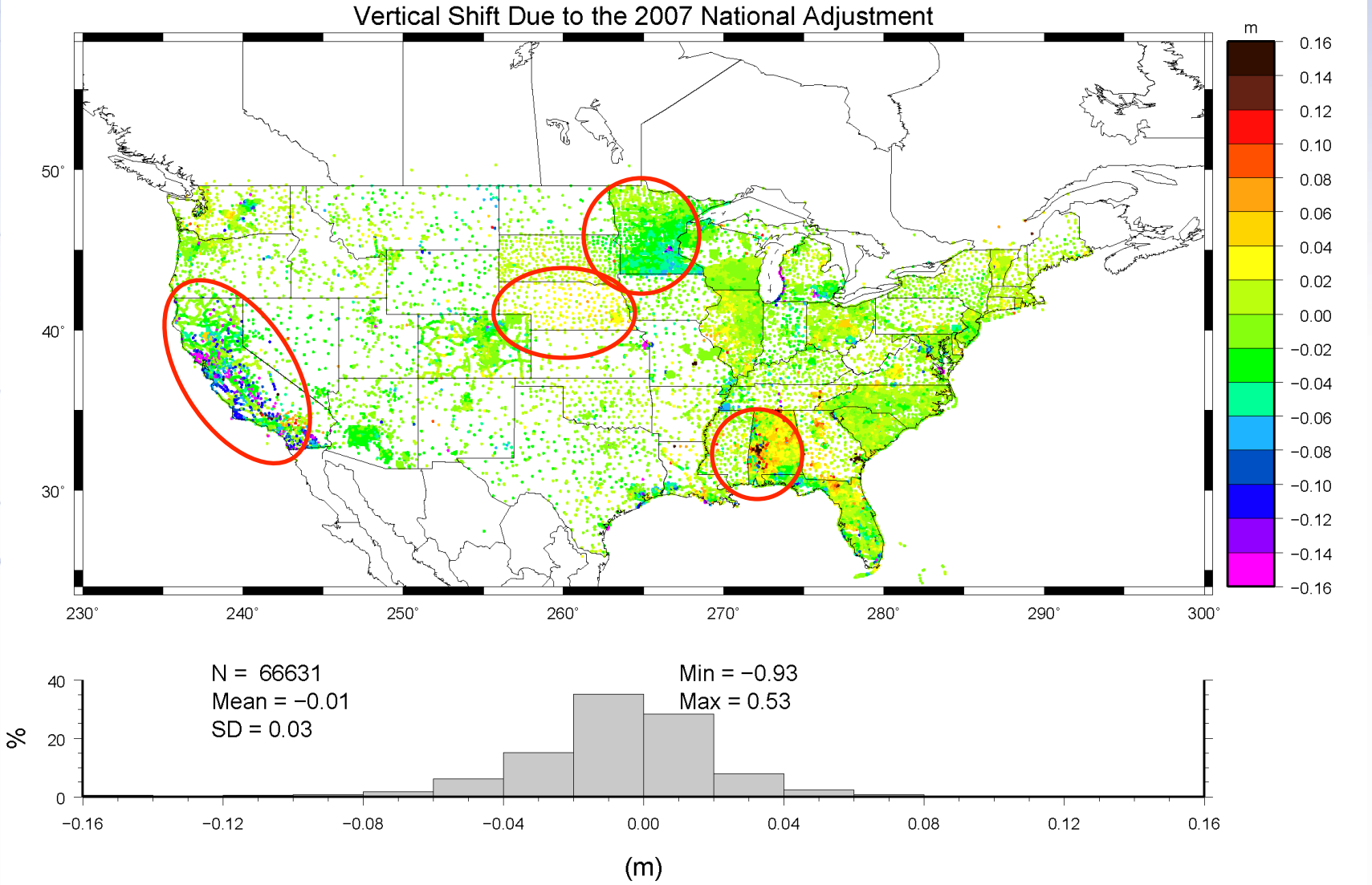
- Gravimetric Geoid systematic misfit with benchmarks
- Hybrid Geoid biased to fit local benchmarks
- e = h – H - N

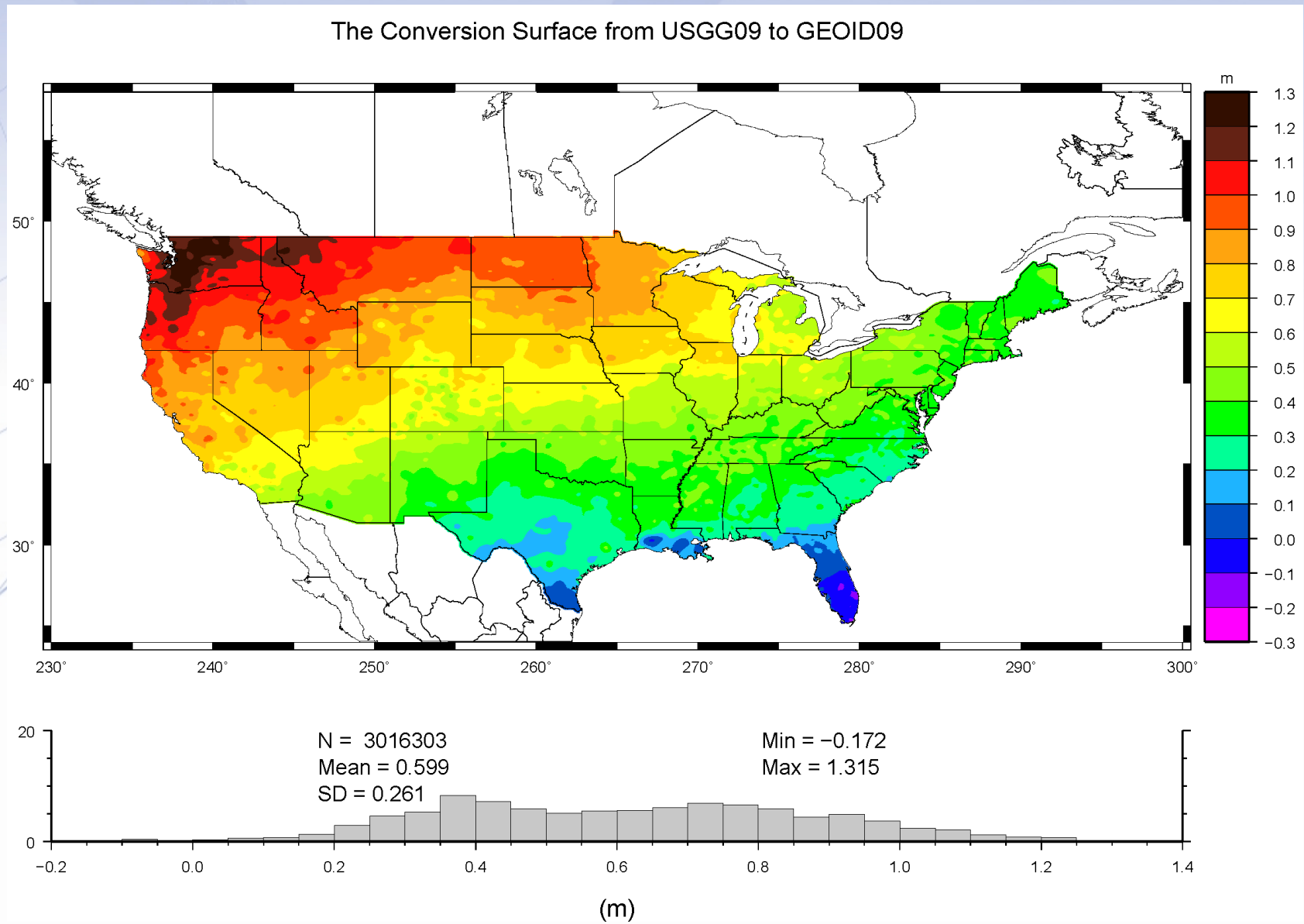


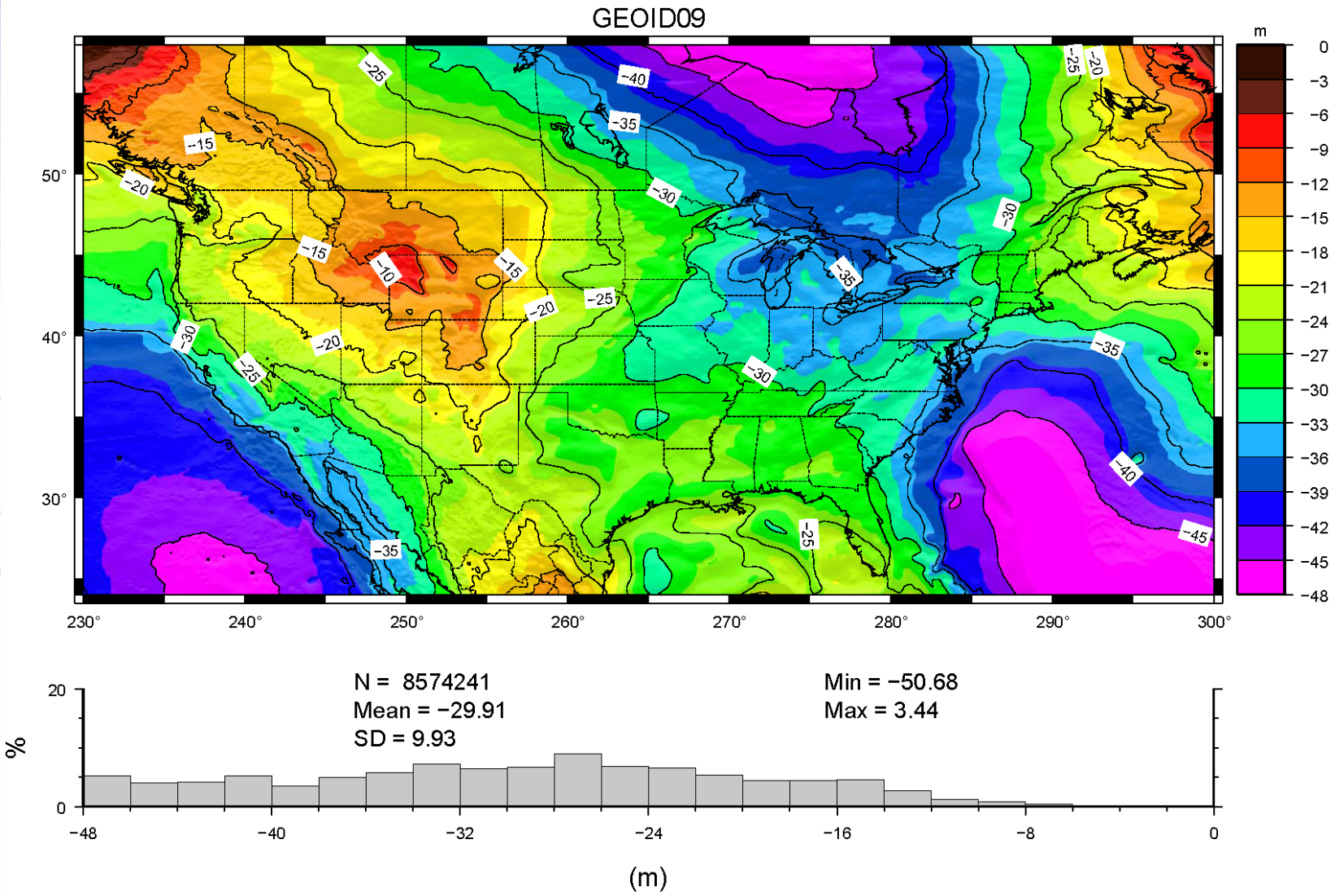
GPSBM1999: 6,169 total 0 Canada STDEV 9.2 cm (2σ)

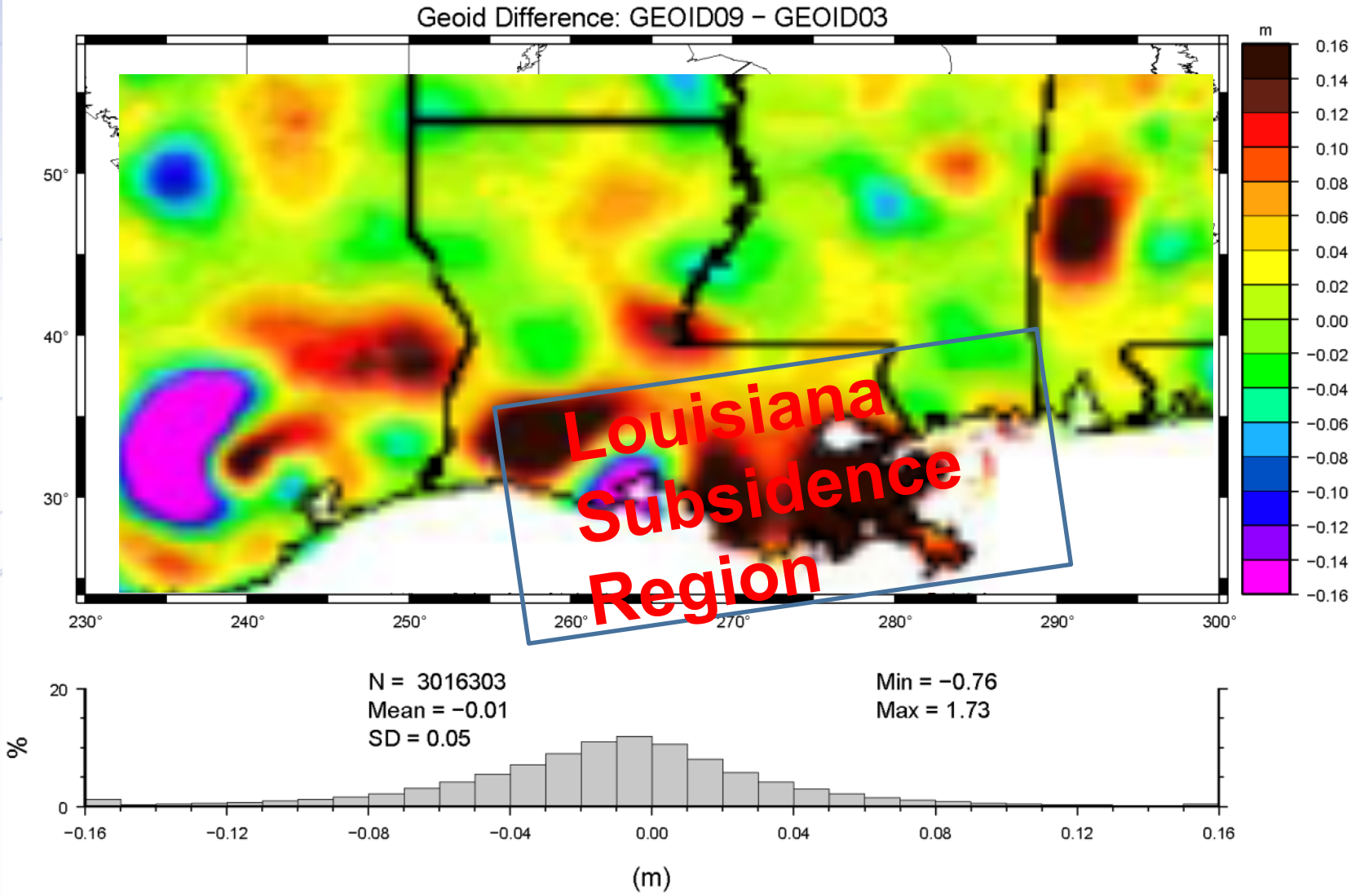
GPSBM2003: 14,185 total 579 Canada STDEV 4.8 cm (2 σ)

GPSBM2009: 18,867 total 576 Canada STDEV 3.0 cm (2 σ)


Vertical Shift Due to the 2007 National Adjustment
m
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
−0.14
−0.16
50°
40°
30°
230°
240°
250°
260°
270°
280°
290°
300°
N = 66631
Mean = −0.01
SD = 0.03
Min = −0.93
Max = 0.53
%
40
20
0
−0.16
−0.12
−0.08
−0.04
0.00
0.04
0.08
0.12
0.16
(m)

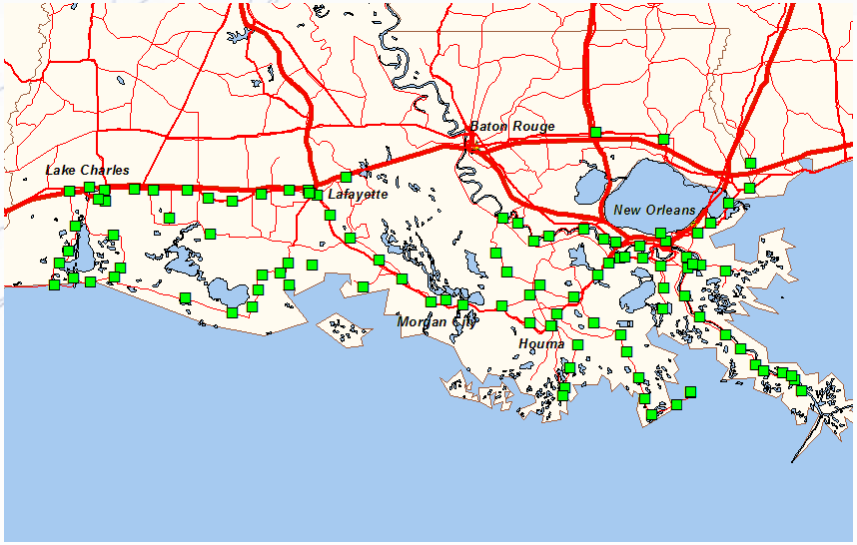

The Conversion Surface from USGG09 to GEOID09
m
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
50°
40°
30°
230°
240°
250°
260°
270°
280°
290°
300°
N = 3016303
Mean = 0.599
SD = 0.261
Min = −0.172
Max = 1.315
20
0
−0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
(m)


GEOID09
m
0
−3
−6
−9
−12
−15
−18
−21
−24
−27
−30
−33
−36
−39
−42
−45
−48
50°
40°
30°
230°
240°
250°
260°
270°
280°
290°
300°
N = 8574241
Mean = −29.91
SD = 9.93
Min = −50.68
Max = 3.44
%
20
0
−48
−40
−32
−24
−16
−8
0
(m)

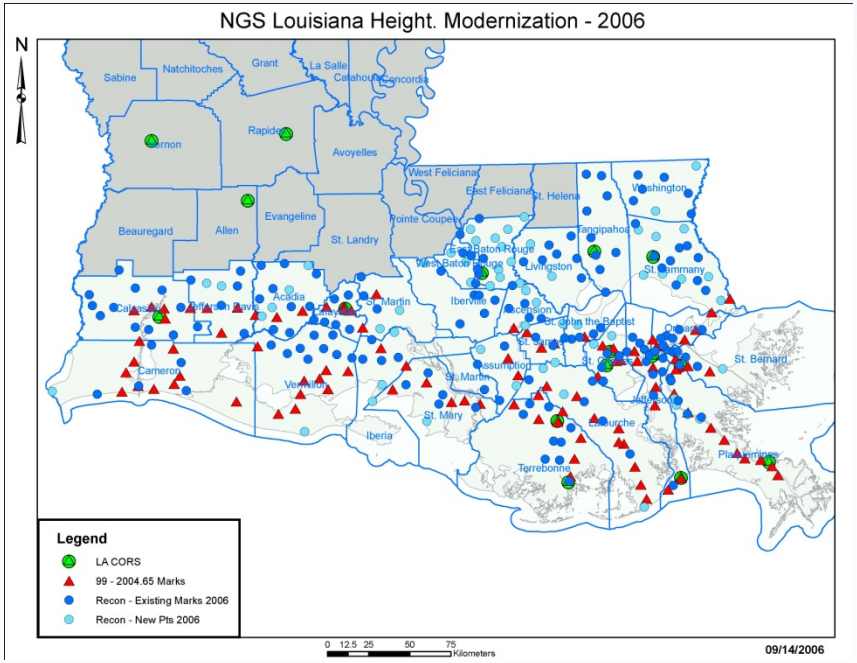

Geoid Difference: GEOID09 − GEOID03
m
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
−0.14
−0.16
50°
40°
30°
230°
240°
250°
260°
270°
280°
290°
300°
Louisiana Subsidence Region
N = 3016303
Mean = −0.01
SD = 0.05
Min = −0.76
Max = 1.73
%
20
0
−0.16
−0.12
−0.08
−0.04
0.00
0.04
0.08
0.12
0.16
(m)

LA differences result from use of GPS-derived orthometric heights

HT MOD 2004 => GEOID03 *



HT MOD 2006 => GEOID09



Current Work

- GOCE
- Cleaning up the surface gravity data
- GRAV-D plans
- NA2011
- OPUS-DB

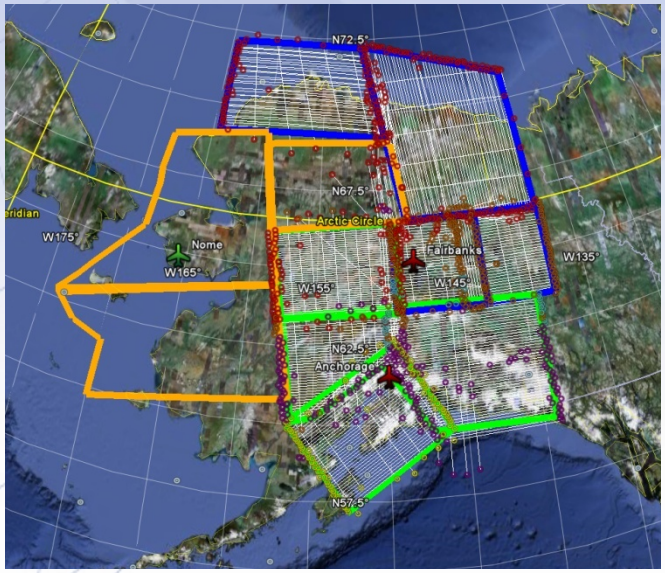
GRAV-D Processing Update

- Alabama ('08) and 2008 Alaska survey already delivered to Geoid team (Newton v1.1)
- Next major version of aerogravity processing software is complete by week's end (Newton 1.2)
- Newton 1.2 data for Alabama and Louisiana will be delivered to geoid team by month's end; other surveys will quickly follow
- LA/AL airborne gravity data will release publicly in next month via a web page designed to share data
- Still partnering for flights; seeking a dedicated plane

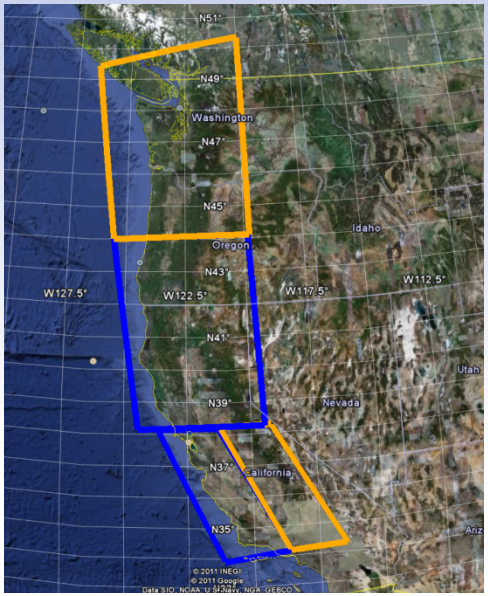
GRAV-D Survey Plans

- FY 2011:
  - Alaska
  - California/Oregon coastline
  - Eastern Great Lakes Region
  - As of June 1, 13.45% of total area has been surveyed
- FY2012:
  - Great Lakes region
  - Washington State
  - California
- FY2013:
  - Finish Great Lakes
  - TBD

Alaska FY11

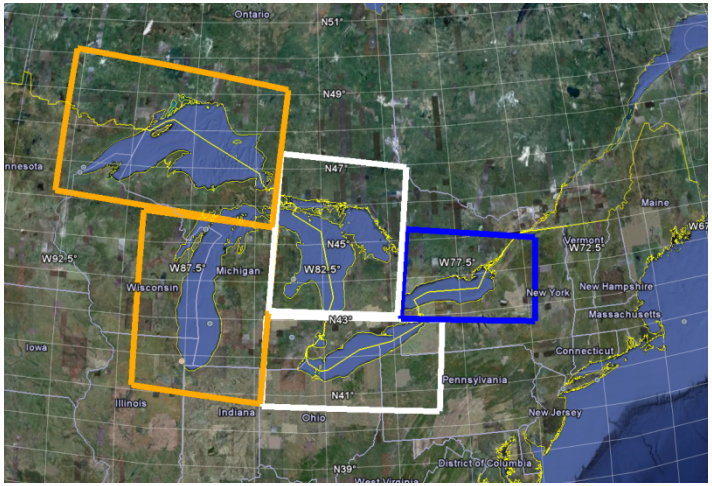


West Coast FY11-12



(FY11 Already Flown)

FY11-13 Great Lakes Plan



FY10 = Green
FY11 = Blue
FY12 = Orange
FY13 = White

Discussion about NA2011

- This adjustment use same vectors as NA 2007
- However, they'll be tied to CORS coordinates
- Hence, the NA 2011 values should be consistent with CORS and OPUS-DB solutions
- Michael Dennis is lead and Jarir Saleh is technical lead
- The aim is to deliver NA 2011 by the end of CY
- Look for GEOID12 shortly after NA 2011 release

NGSIDB Versus OPUS-DB

NGSIDB

- Passive control
- Episodically refined (NA2011)
- Traditional surveying
- A lot of (important!) numbers and text

OPUS-DB

- Actively determined from CORS
- Constantly refined
- GPS Surveying
- A lot of numbers/text and some useful graphics/images

The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

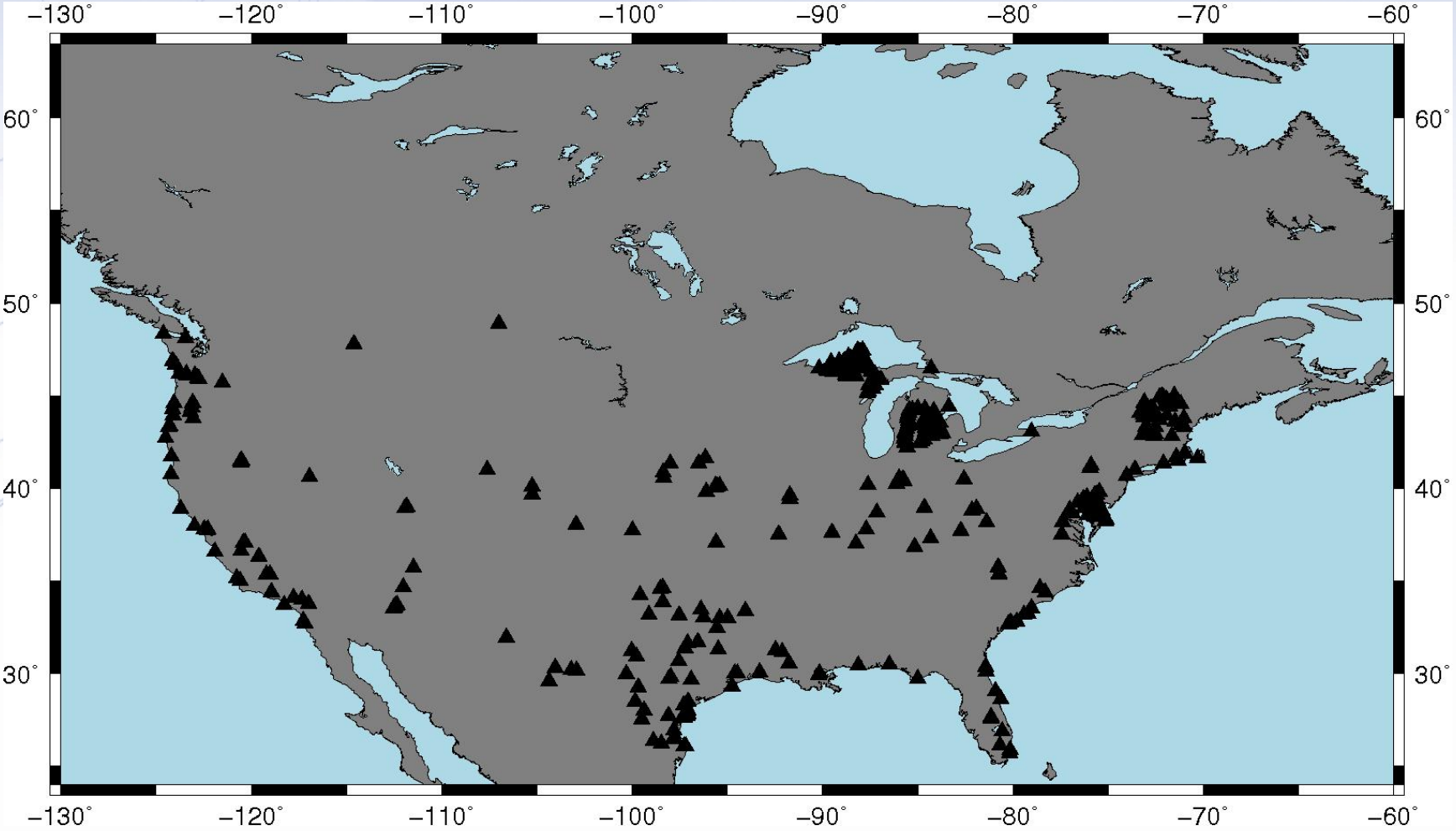
```
DATABASE =  ,PROGRAM = datasheet, VERSION = 7.86
1       National Geodetic Survey,   Retrieval Date = APRIL 20, 2011
 DO0454 ***********************************************************************
 DO0454  DESIGNATION -  C 281
 DO0454  PID         -  DO0454
 DO0454  STATE/COUNTY-  TX/THROCKMORTON
 DO0454  USGS QUAD   -  THROCKMORTON NE (1965)
 DO0454
 DO0454                        *CURRENT SURVEY CONTROL
 DO0454  ______________________________________________________________________
 DO0454* NAD 83(2007)-  33 11 10.75472(N)     099 06 11.86433(W)      NO CHECK
 DO0454* NAVD 88     -       383.465  (meters)    1258.08   (feet)   ADJUSTED
 DO0454  ______________________________________________________________________
 DO0454  EPOCH DATE  -         2002.00
 DO0454  X           -     -845,419.278 (meters)                      COMP
 DO0454  Y           -  -5,276,185.563 (meters)                      COMP
 DO0454  Z           -   3,471,464.429 (meters)                      COMP
 DO0454  LAPLACE CORR-            0.24  (seconds)                    DEFLEC09
 DO0454  ELLIP HEIGHT-          353.943 (meters)          (02/10/07) NO CHECK
 DO0454  GEOID HEIGHT-          -28.98  (meters)                     GEOID09
 DO0454  DYNAMIC HT  -          383.004 (meters)    1256.57  (feet)  COMP
 DO0454
 DO0454  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 DO0454  Type    PID    Designation                      North   East   Ellip
 DO0454  ----------------------------------------------------------------------
 DO0454  NETWORK DO0454 C 281                             1.10   1.47   2.14
 DO0454  ----------------------------------------------------------------------
 DO0454  MODELED GRAV-      979,426.2    (mgal)                      NAVD 88
 DO0454
 DO0454  VERT ORDER  -  SECOND    CLASS 0
 DO0454
```

SURVEY DATASHEET (Version 1.0) http://www.ngs.noaa.gov/CORS-Proxy/OPUS_old/getDatasheet.jsp?PI...

SURVEY DATASHEET (Version 1.0)

The numerical values for this position solution have satisfied the quality control criteria of the National Geodetic Survey. The contributor has verified that the information submitted is accurate and complete.

Leveled Bench Marks Occupied by GPS and stored in OPUS-DB



Statistics of the 422 OPUS-DB Points

		A		B		C	
Groups of the 422 points pulled from OPUS-DB	**No. Pts**	**NGSIDB Res.**		**OPUS-DB Res.**		**OPUS-DB–NGSIDB**	
		Ave	**SD**	**Ave.**	**SD**	**Ave**	**SD**
(1.a) All Common Points that were used in GEOID09	80	-0.009	0.065	0.004	0.036	0.013	0.060
(1.b) Common Points less the 9 rejects	71	-0.004	0.015	0.003	0.031	0.006	0.028
(2) Common Points but *not* used to make GEOID09	57	0.001	0.043	0.007	0.037	0.006	0.044
(3.a) Points Not Previously Observed with GPS	285	n/a	n/a	-0.011	0.112	n/a	n/a
(3.b) Points Not Previously Observed less the 11 rejects	274	n/a	n/a	-0.008	0.047	n/a	n/a

Conclusions

- Big changes from USGG2003 to USGG2009
  - Mostly due to changes in reference field
  - Also due to rejection criteria (northern Rockies)
  - Rejections will significantly drop in USGG2012 by incorporating 3"-5' RTM
- More changes from GEOID03 to GEOID09
  - Mostly from NA 2007 (changes in ellipsoid height)
  - Changes in Louisiana are from HT MOD survey changes to GPS-derived orthometric heights

Conclusions (cont.)

- OPUS-DB shows great promise for filling gaps
- BM's can be targeted by State Advisers based on coverage maps of NGSIDB to supplement
- However, this will not help in Louisiana
  - OPUS-DB puts GPS on previously unoccupied leveling
  - It cannot help make GPS-derived leveling better
  - Use better VTDP models or adopt a gravimetric geoid
- Improvements to gravimetric geoids are coming