Presented at the FIG Working Week 2017,
May 29 - June 2, 2017 in Helsinki, Finland

Geoid Modeling at NOAA's National Geodetic Survey as 2022 Approaches (8815)

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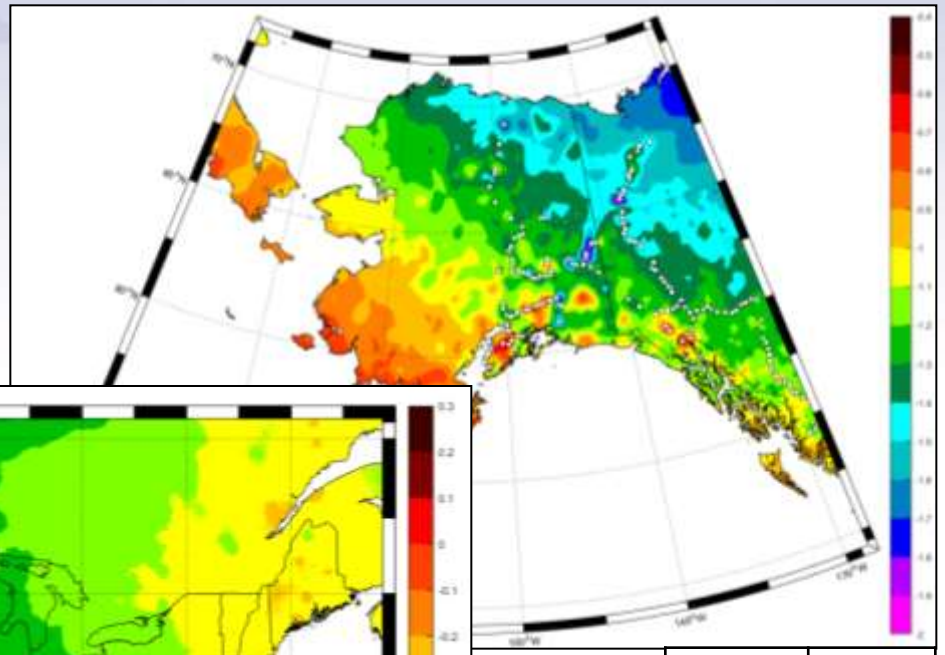
NSRS Modernization

	The Old:	The New:
Orthometric Heights	NAVD 88	The North American-Pacific Geopotential Datum of 2022 (NAPGD2022)
Normal Orthometric Heights	PRVD 02	– GEOID2022
	VIVD09	– DEFLEC2022
	ASVD02	– GRAV2022
	NMVD03	– Geopotential Model of 2022 (GM2022)
	GUVD04	
Dynamic Heights	IGLD 85	
Gravity	IGSN71	
Geoid Undulations	GEOID12B	
Deflections of the Vertical	DEFLEC12B	

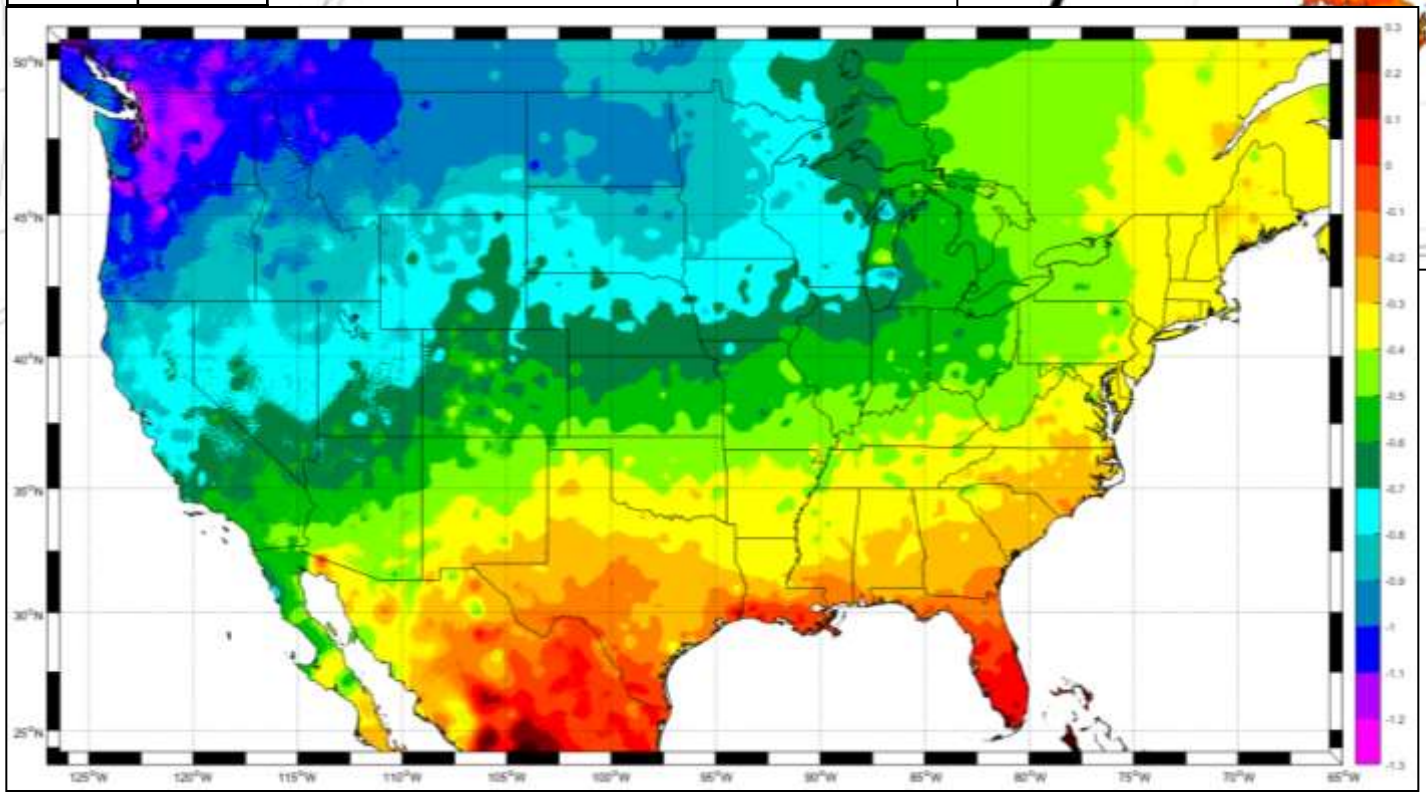
https://www.ngs.noaa.gov/datums/newdatums/

Change in Orthometric Height

Min	-1.352
Max	0.309
Mean	-0.577
StdDev	0.282



Min	-2.102
Max	-0.112
Mean	-1.230
StdDev	0.255



Evolution of Recent NGS Geoid Models

EGM08

2008

GRAV-D

2012

USGG2012

GEOID12A/B

GOCO

GOCO03s

GOCO05S

2014

2015

2016

xGeoid14B

xGeoid15B

xGeoid16B

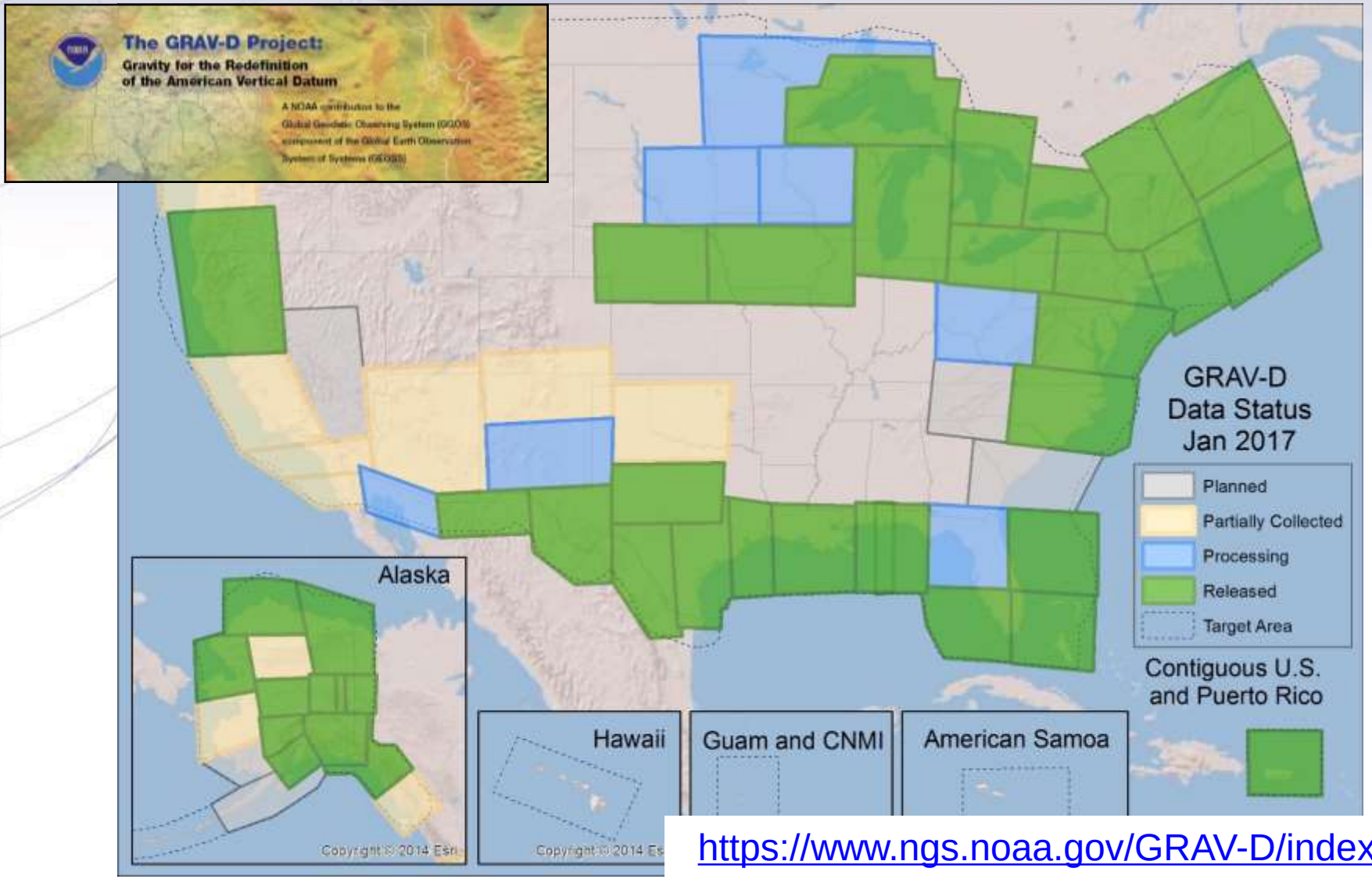
GRACE

NASA

+

GOCE

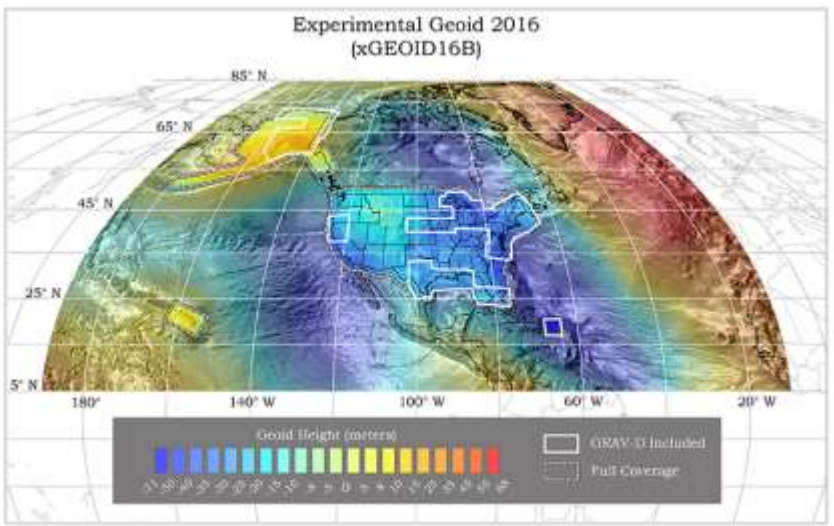
GRAV-D Status: 4/30/17 – 60.47%



https://www.ngs.noaa.gov/GRAV-D/index.shtml

Experimental Geoid Model (xGEOIDs)

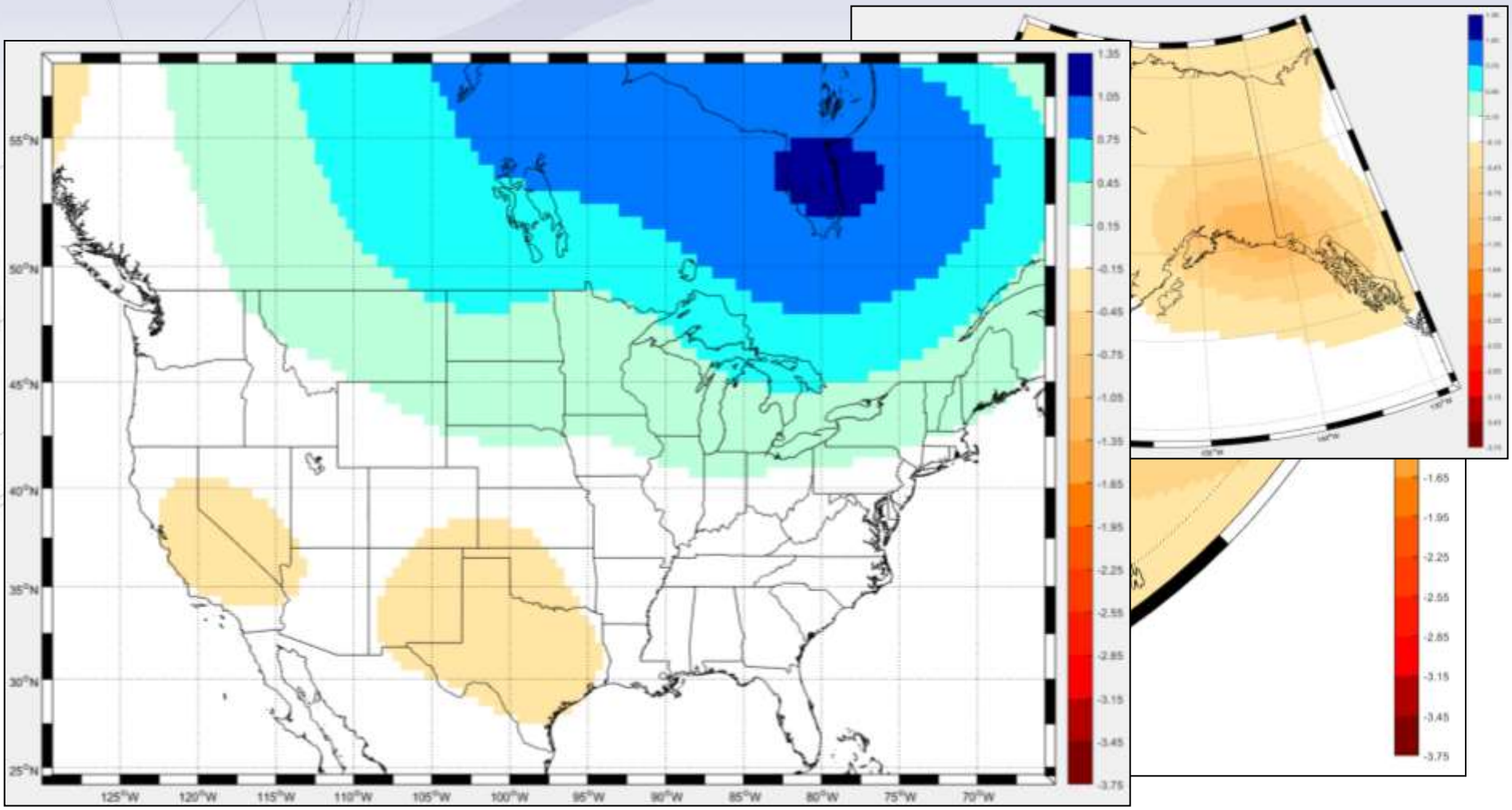
- Annual model series
- A (without GRAV-D) and B (with GRAV-D) models
- W_0 = 62,636,856.00 m^2/s^2 representing coastal mean sea-level based on tide gauges in the U.S. and Canada
- Grid Coverage:
  - 1' spatial resolution
  - Latitudes: 5° – 85°
  - Longitudes: 170° – 350°



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

GEOID2022 = Static + Time-Dependent

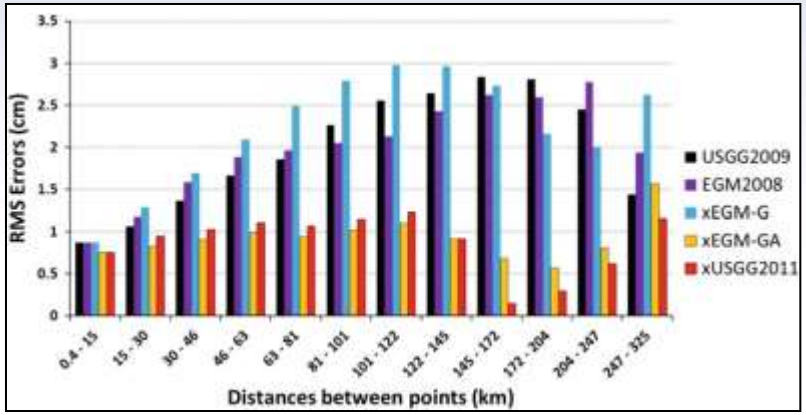
$$N(t) = N(t_0) + \dot{N}(t - t_0)$$



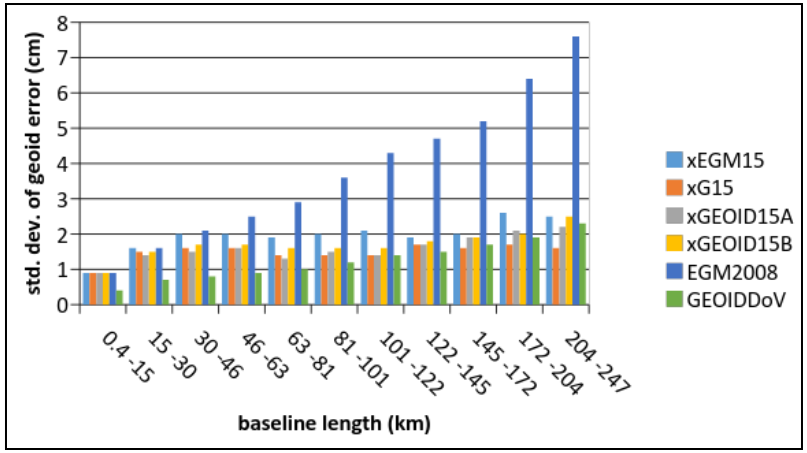
Geoid Rate from GRACE: mm / yr

Geoid Slope Validation Surveys (GSVS)

- GSVS11 – Texas
  - Close to the geoid and flat topography
  - Sub-cm geoid accuracy
  - (Smith, et al. 2013) →

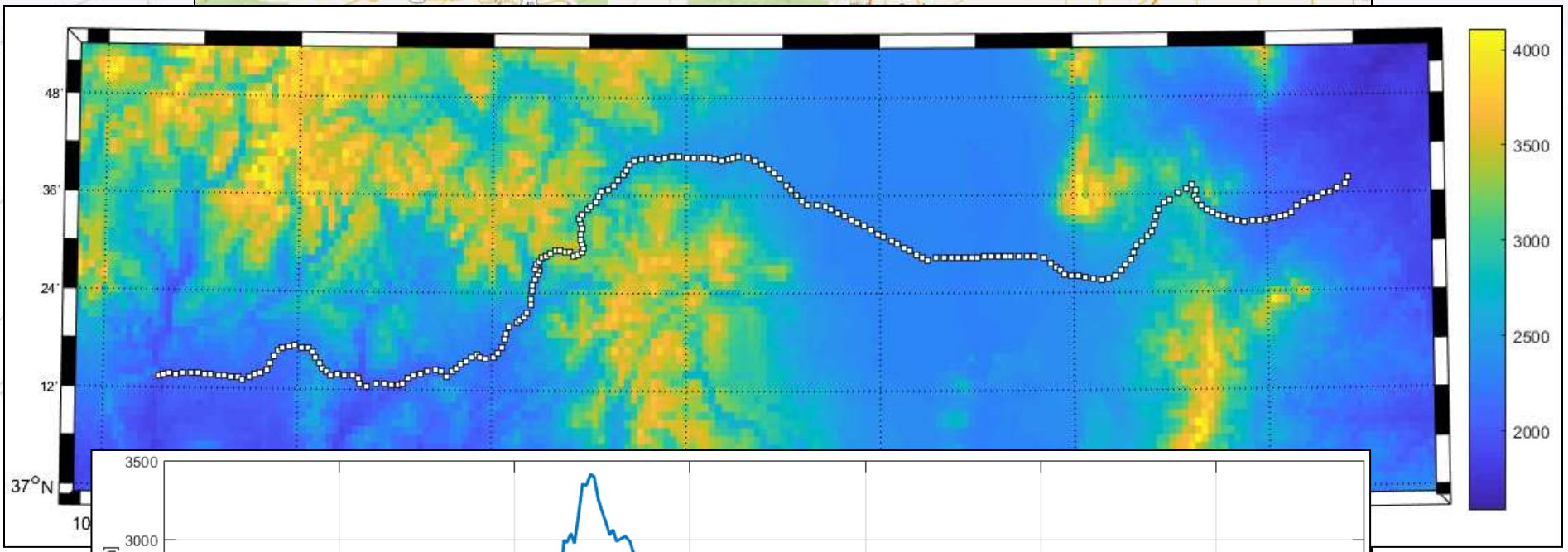


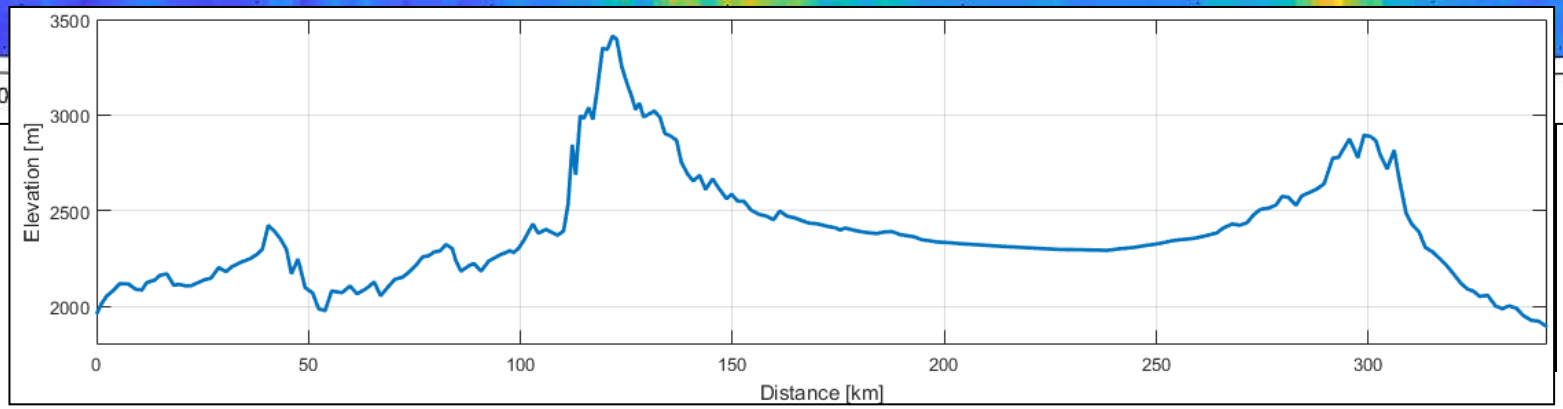
- GSVS14 – Iowa
  - Moderate topography, but large gravity signal
  - 2-cm geoid accuracy
  - (Wang, et al. 2017) →



- GSVS17 – Colorado
  - Rugged/High topography
  - Survey in progress

GSVS17 - Colorado





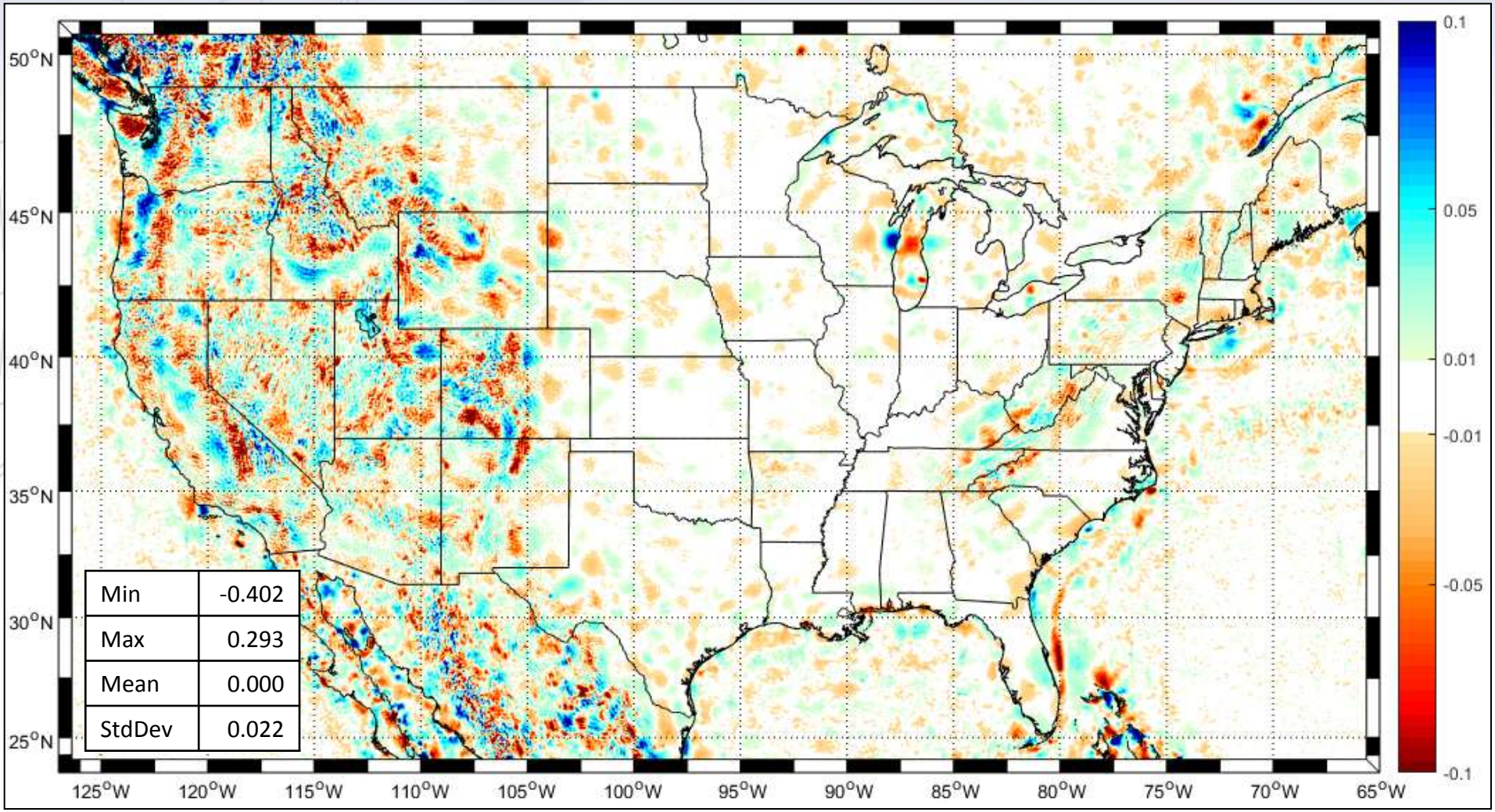
xGEOID17

What's new?

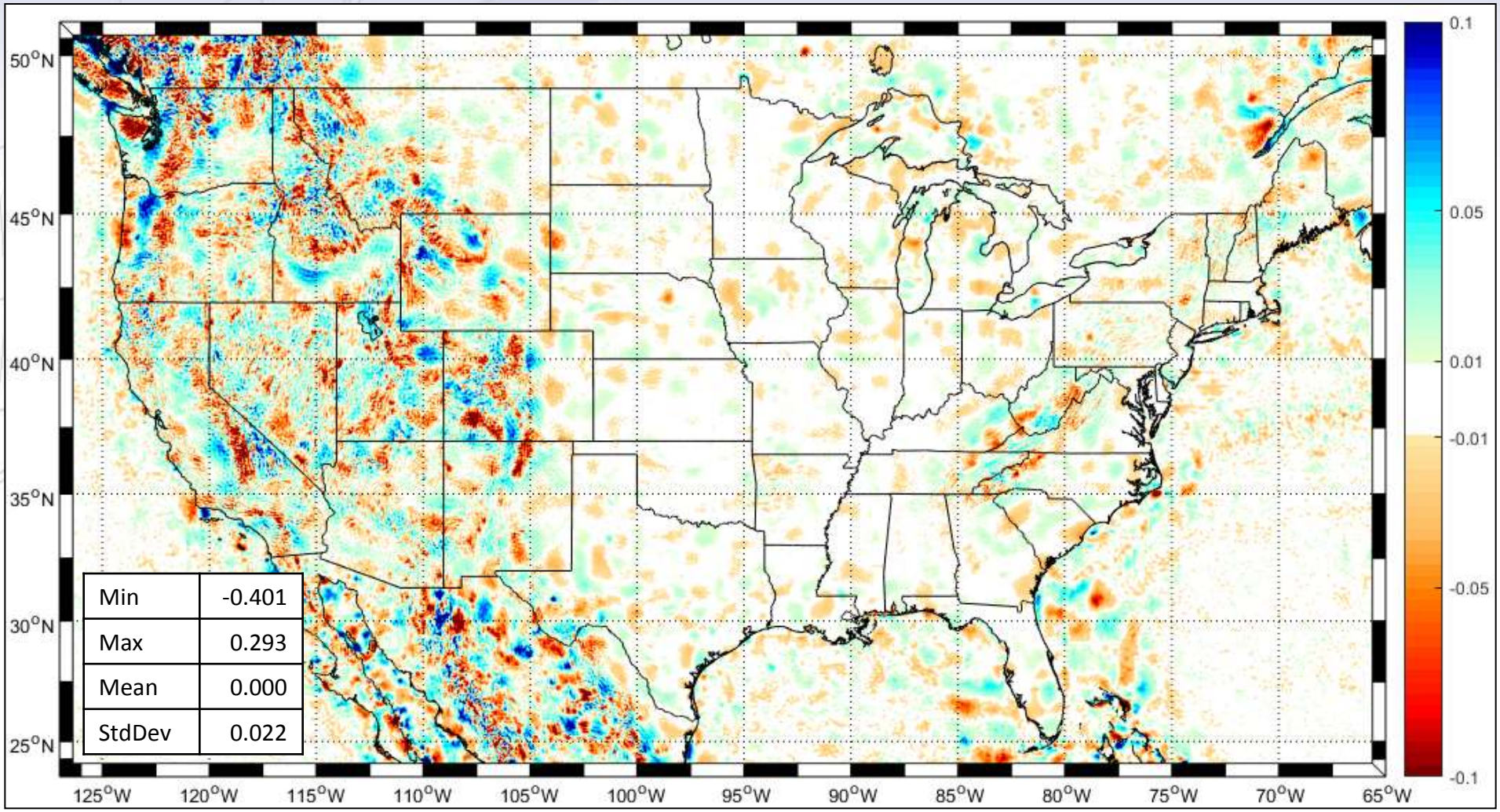
- GRAVD data – 2 blocks in Alaska and 1 block in Florida
- Altimetry data – DTU13
- Surface Gravity data – incorporation of a largely new dataset
- Reference model (moved away from using EGM2008 as the reference)
- Modeling of the surface gravity data:
  - Bias corrected using GOCO05s

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

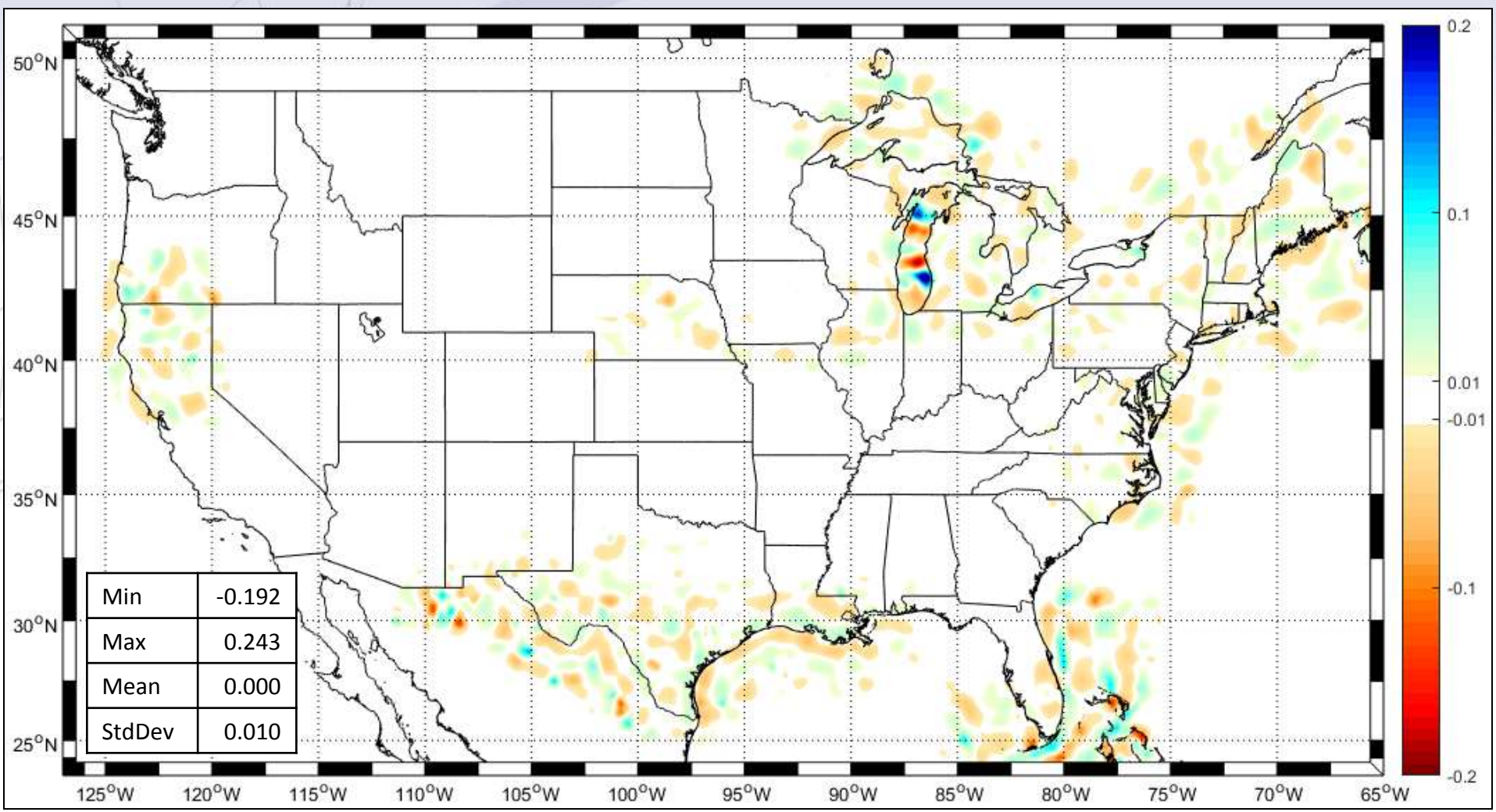
xGEOID Models: 16A vs. 17A (m)



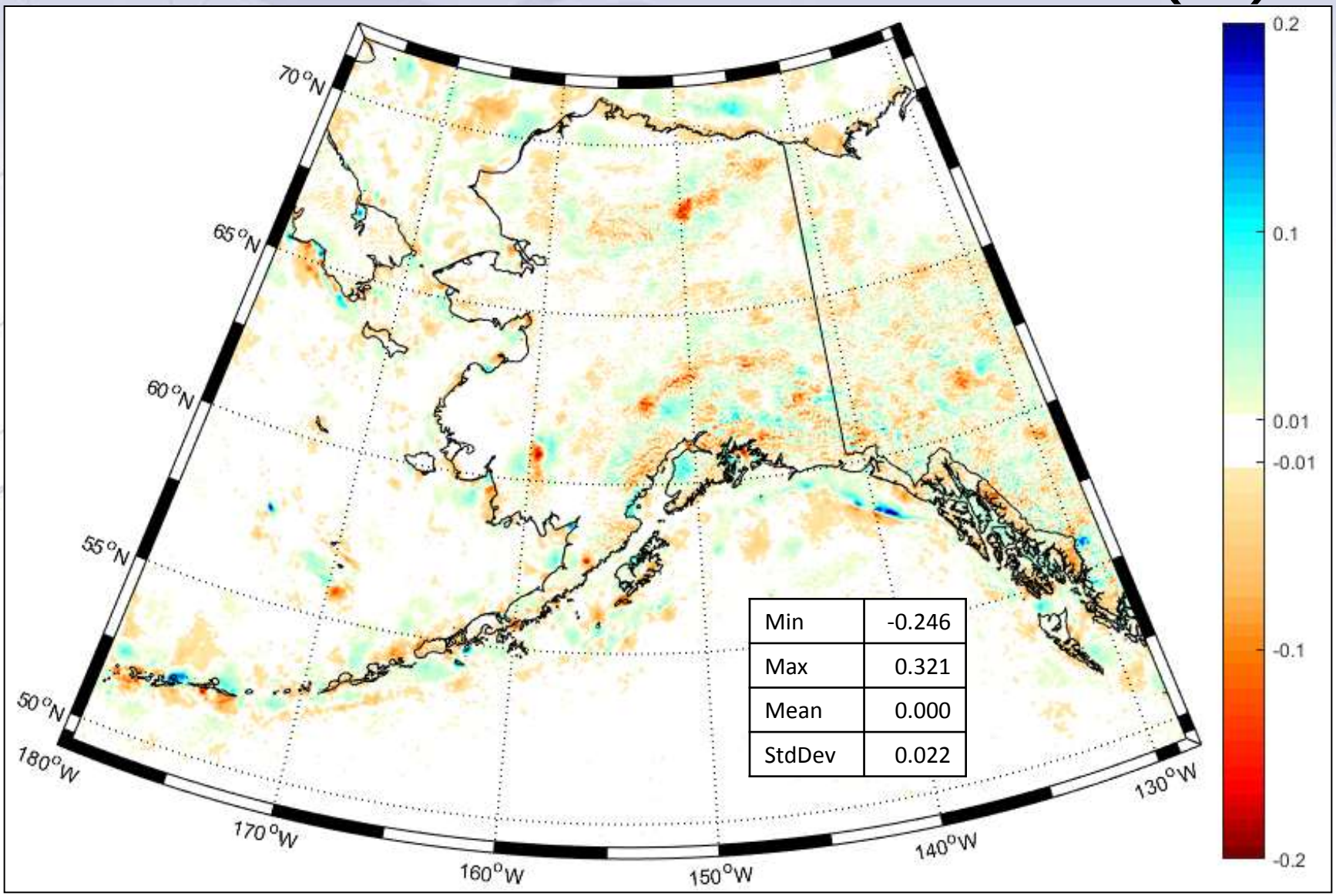
xGEOID Models: 16B vs. 17B (m)



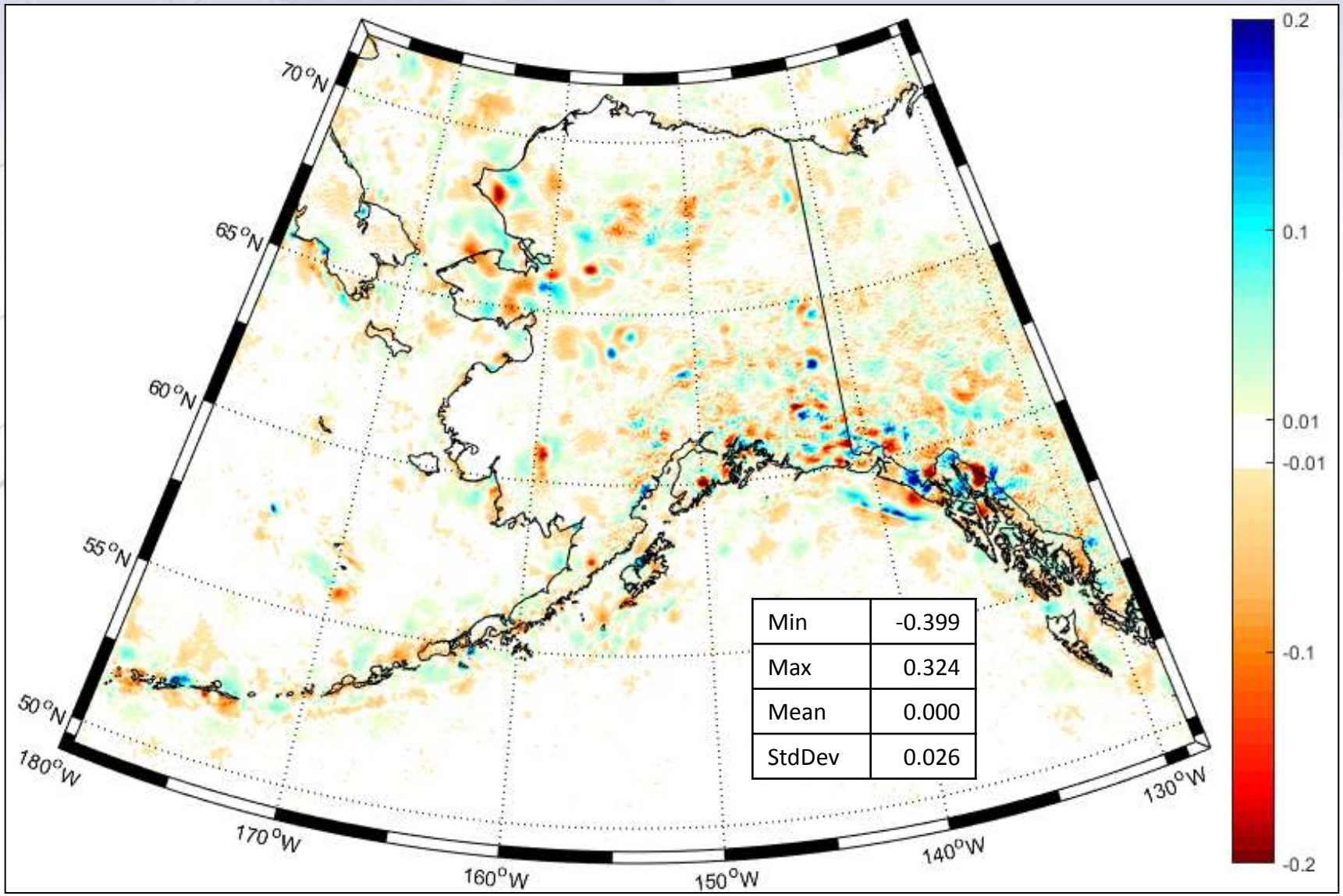
xGEOID Models: 17A vs. 17B (m)



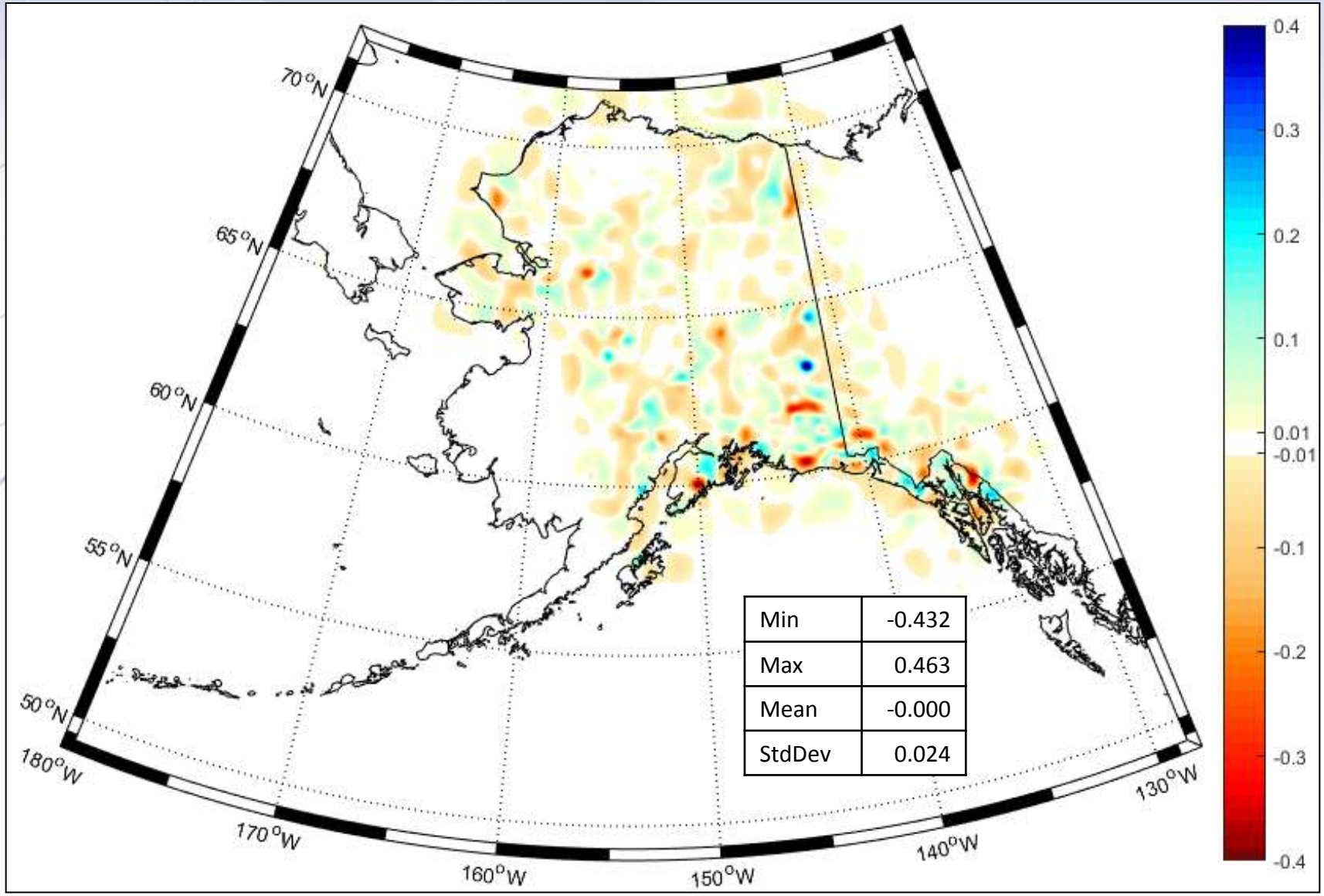
xGEOID Models: 16A vs. 17A (m)



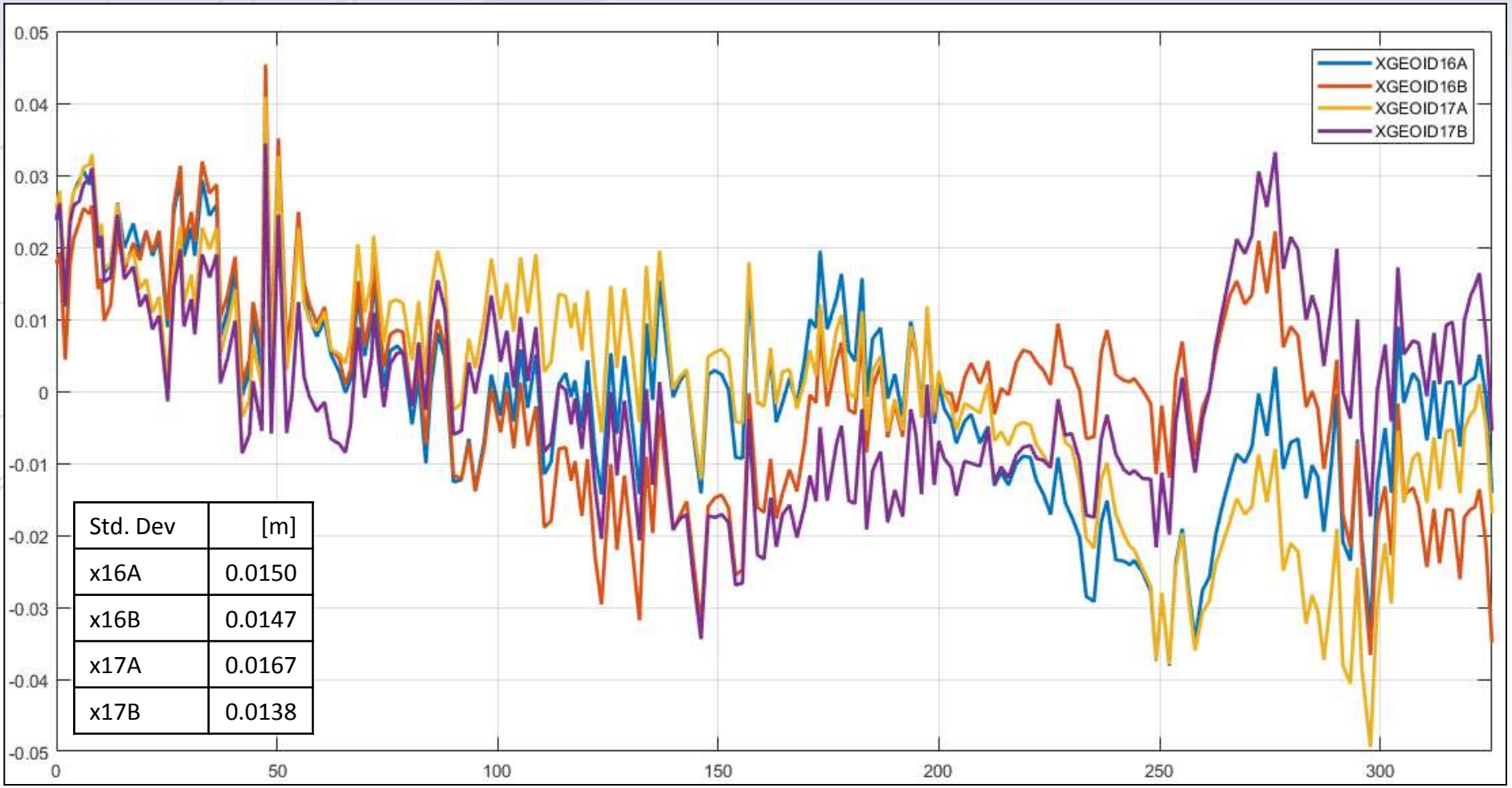
xGEOID Models: 16B vs. 17B (m)



xGEOID Models: 17A vs. 17B (m)



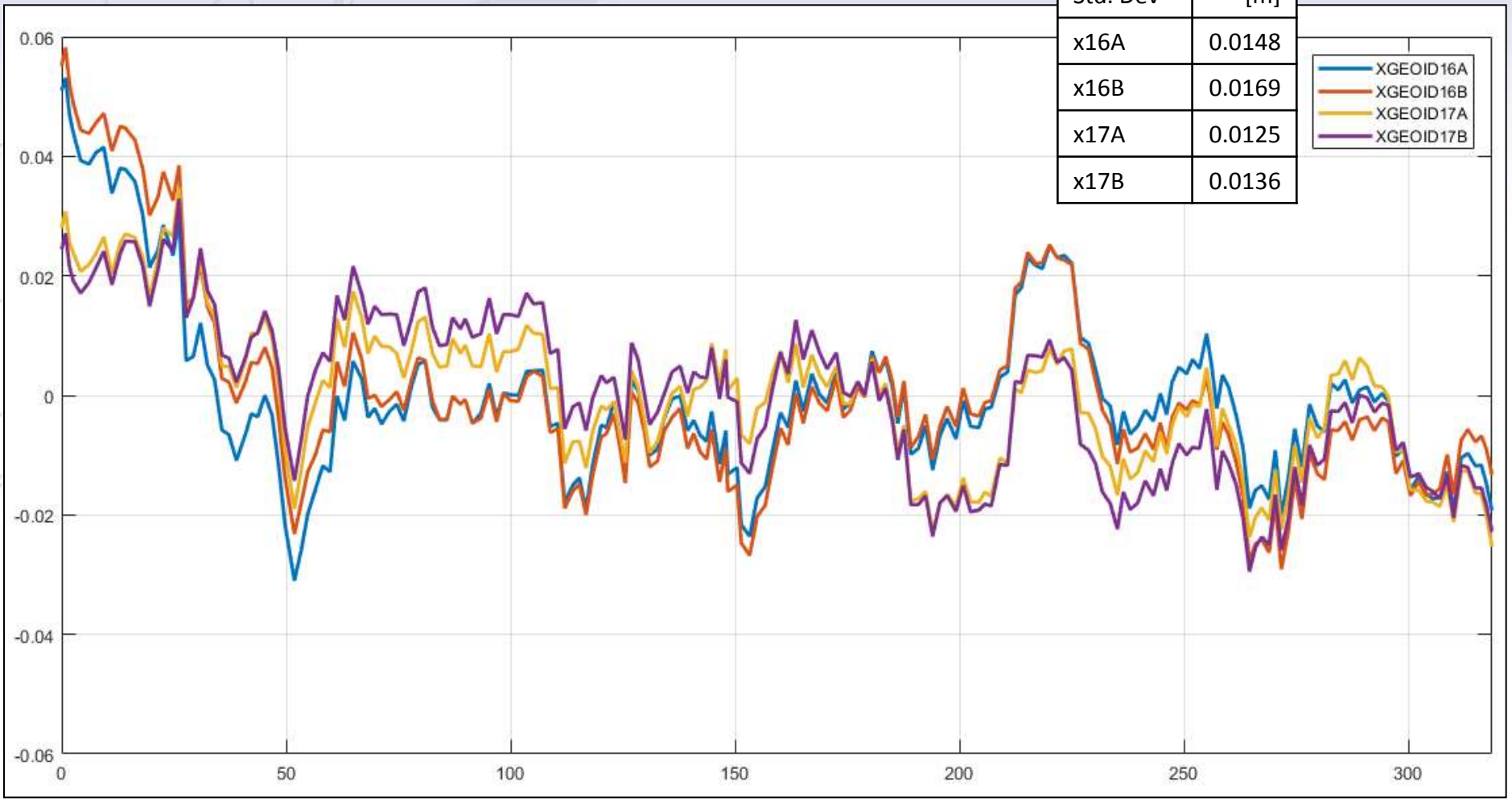
Validation with GSVS11: Texas



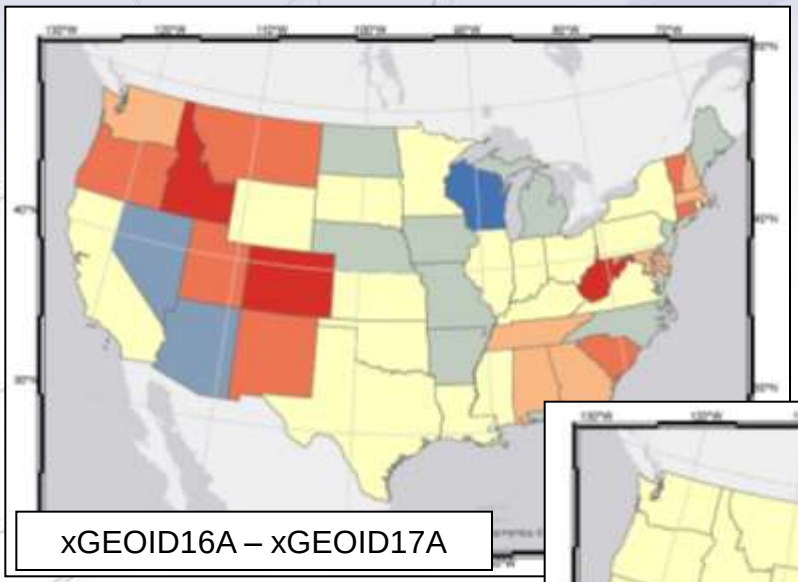
Std. Dev	[m]
x16A	0.0150
x16B	0.0147
x17A	0.0167
x17B	0.0138

Validation with GSVS14: Iowa

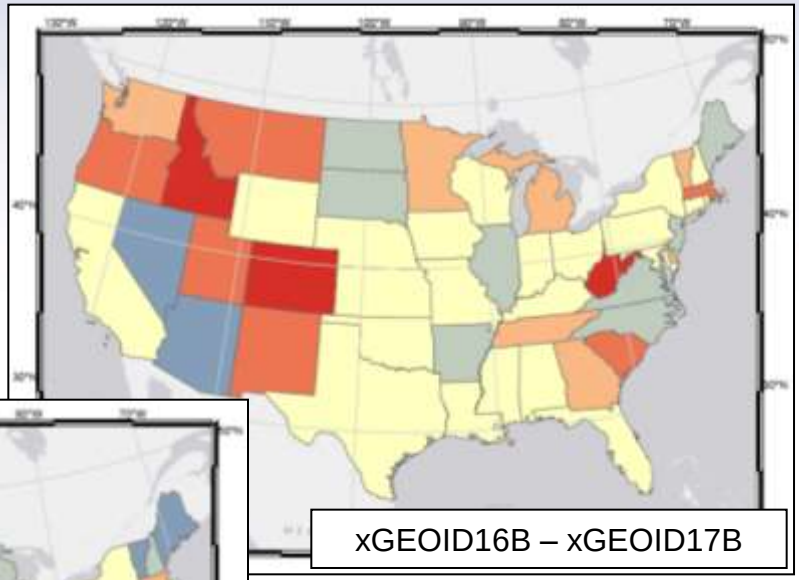
Std. Dev	[m]
x16A	0.0148
x16B	0.0169
x17A	0.0125
x17B	0.0136



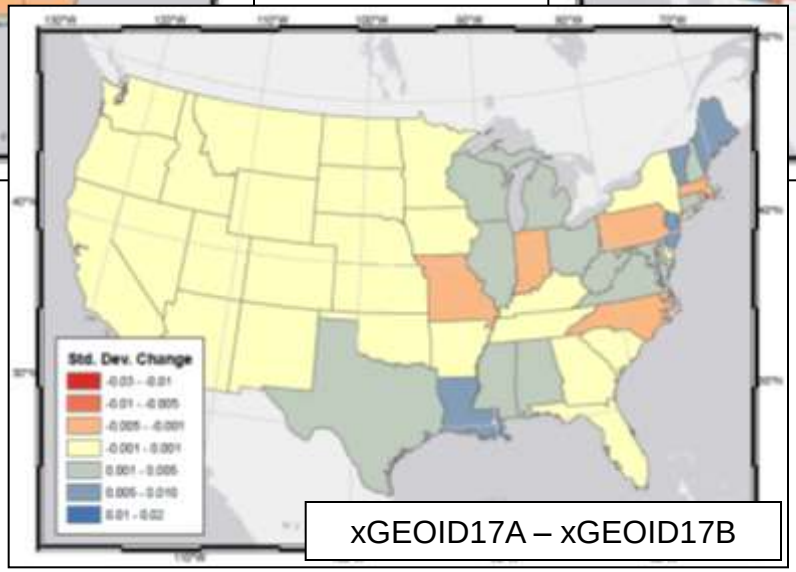
Validation with Historical GPS/Leveling



xGEOID16A – xGEOID17A



xGEOID16B – xGEOID17B



xGEOID17A – xGEOID17B

Change in Std. Dev. State by State: (+ / blue is an improvement in (i.e. lower) std. dev.)

GPS/Leveling Results with xGEOIDs

Overall Std. Dev.	n = 21,596
x16A	0.303
x16B	0.303
x17A	0.304
x17B	0.304

State	Number	xGEOID16A	xGEOID16B	xGEOID17A	xGEOID17B
AL	390	0.0573	0.0587	0.0610	0.0591
AR	144	0.0371	0.0371	0.0351	0.0352
AZ	337	0.1004	0.1004	0.0935	0.0932
CA	793	0.1275	0.1274	0.1274	0.1273
CD	575	0.3191	0.3190	0.3153	0.3153
CO	602	0.0726	0.0727	0.1010	0.1008
CT	24	0.0275	0.0292	0.0342	0.0298
DC	17	0.0261	0.0262	0.0273	0.0271
DE	69	0.0331	0.0326	0.0368	0.0369
FL	2523	0.0811	0.0790	0.0789	0.0795
GA	150	0.0707	0.0707	0.0730	0.0740
IA	103	0.0588	0.0544	0.0560	0.0551
ID	137	0.0842	0.0842	0.0958	0.0958
IL	420	0.0812	0.0814	0.0821	0.0804
IN	133	0.0492	0.0504	0.0495	0.0514
KS	117	0.0584	0.0579	0.0576	0.0574
KY	184	0.0351	0.0351	0.0344	0.0349
LA	151	0.1524	0.1434	0.1521	0.1427
MA	43	0.0257	0.0230	0.0278	0.0294
MD	557	0.0298	0.0307	0.0316	0.0302
ME	69	0.0440	0.0340	0.0394	0.0314
MI	807	0.0504	0.0452	0.0491	0.0462
MN	7086	0.0444	0.0446	0.0448	0.0456
MO	193	0.0735	0.0747	0.0723	0.0745
MS	466	0.0955	0.0927	0.0963	0.0928
MT	225	0.0892	0.0892	0.0963	0.0967
MX	177	0.2151	0.2151	0.2143	0.2129
NC	1987	0.0479	0.0476	0.0444	0.0466
ND	63	0.0419	0.0419	0.0395	0.0395
NE	158	0.0386	0.0361	0.0362	0.0365
NH	24	0.0225	0.0222	0.0260	0.0215
NJ	383	0.0286	0.0263	0.0275	0.0213
NM	130	0.0979	0.0979	0.1032	0.1033
NV	72	0.0793	0.0795	0.0734	0.0740
NY	252	0.0571	0.0570	0.0572	0.0577
OH	312	0.0447	0.0433	0.0455	0.0434
OK	82	0.0569	0.0570	0.0572	0.0571
ON	5	0.1420	0.1428	0.1369	0.1362
OR	244	0.0833	0.0831	0.0898	0.0904
PA	121	0.0460	0.0463	0.0451	0.0465
PQ	1	0.0000	0.0000	0.0000	0.0000
RI	33	0.0279	0.0285	0.0271	0.0291
SC	1536	0.0535	0.0536	0.0617	0.0620
SD	250	0.0589	0.0593	0.0580	0.0580
TN	313	0.0343	0.0343	0.0354	0.0357
TX	261	0.1004	0.0977	0.1004	0.0983
UT	58	0.0763	0.0763	0.0852	0.0854
VA	478	0.0365	0.0364	0.0372	0.0346
VT	449	0.0254	0.0236	0.0341	0.0277
WA	324	0.0840	0.0840	0.0884	0.0875
WI	992	0.0459	0.0300	0.0346	0.0309
WV	61	0.0387	0.0382	0.0506	0.0491
WY	115	0.0903	0.0903	0.0894	0.0895

State by State: GPS/Leveling Std. Devs. (m)

Outlook

- GSVS17 Survey In-Progress. Estimate on worst-case scenario for geoid modeling.
- Methodology: Error modeling, Spectral Weighting, Radial Basis Functions, Ellipsoidal Harmonics, Higher Degree (n_{max} = 10,800).
- Input Data: Data Cleaning (Air, Surface, Shiptrack).
- Expanding the model:
  - 0 – 90^{o} & 170 - 350^{o}
  - American Territories: American Samoa, Guam/Central Marianas
- Dynamic Model (DGEOID2022) with GeMS Project
- Other: DOV's, Interpolation Tools, Software

Conclusions

- **NAPGD2022**: basis for all physical quantities
  - GM2022, GEOID2022 (SGEOID2022 + DGEOID2022), DEFLEC2022, GRAV2022
- **Experimental Geoid (xGEOID) Series**
  - Models with and without GRAV-D
  - Progression toward SGEOID2022
- **xGEOID17 Models** – Arriving Soon!
  - New reference model independent from EGM2008
  - Different terrestrial gravity data (entirely new dataset and modeling)
  - Validation with GSVS lines is improved at 1-3 mm (std. dev.)

Questions?

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NOAA's National Geodetic Survey

Modernizing the National Spatial Reference System (NSRS)

- Replacing NAD 83
- **Replacing NAVD 88**
- Re-inventing Bluebooking
- Improving the Geodetic Toolkit
- Better Surveying Methodologies

https://www.ngs.noaa.gov/datums/newdatums/

NAVD88 – Current Vertical Datum

Father Point Lighthouse
Quebec, Canada

North American Vertical Datum 1988:

- Local mean-sea level derived surface for determining orthometric heights used in the United States

How Defined:

- 1980s survey campaign with leveling and gravity at >500,000 benchmarks
- Minimally constrained adjustment with one fixed point - "Father Point/Rimouski"

Realization:

- NAVD 88 is only defined at these benchmarks.