Report on the Comparisons of Refined Colorado Geoid Models

YM Wang, R Forsberg, L Sanchez, J Ågren, JL Huang and et al.

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Participation Commission and Working Groups:

1. IAG Working Group 2.2.2: 1-cm Geoid Experiment
2. GGOS Working Group 0.1.2
3. IAG Subcommission 2.2
4. Joint Study Group 0.15 and Joint Working Group 2.2.1

15 groups participated in this experiment.
9 groups updated their models (2nd iteration): Curtin, Minia, IAPG, DGFI, LM-KTH, ITU, CGS (height anomaly), NGS, and USP.

Models provided by 15 groups

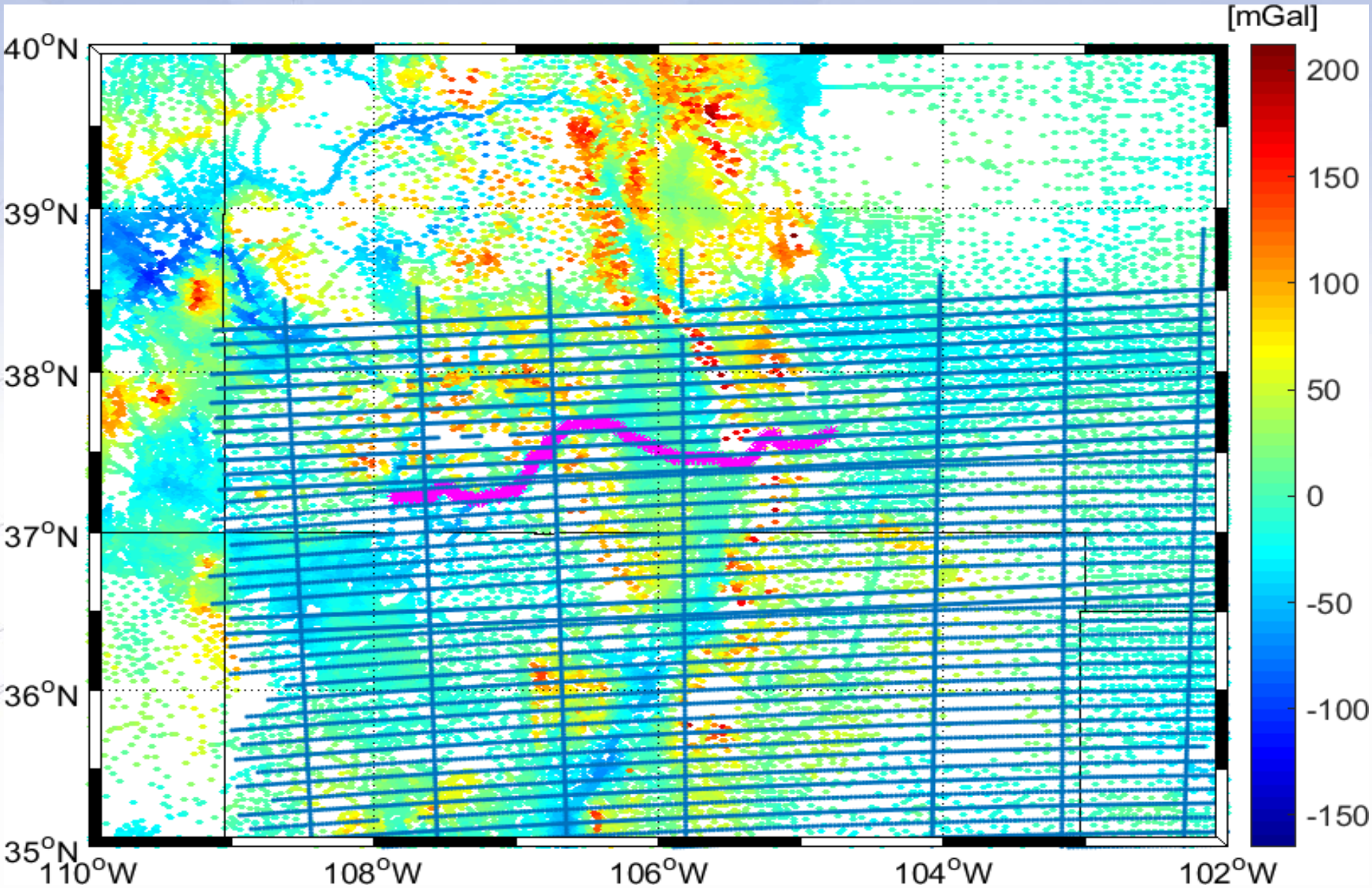
	AUTh	CASM	CGS	Curtin	DGFI	DTU	Minia	GSI	IAPG	ITU	LM-KTH	NGS	NTIS-GEOF	Polimi	USP
Geoid (GSVS17)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
H.A. (GSVS17)	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
W (GSVS17)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Geoid Grids	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
H.A. Grids	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
Ref. Model	XGM-16	EGM-2008	RefB	RefB	XGM-16	XGM-16	Eigen-6C4	XGM-16	XGM-16	XGM-16	RefB	RefB	XGM-16	XGM-16	GOC-O5S
Theory	M	M	H-S	M	M	M	M	H-S	M	M	M	M	M	M	H-S
Assigned No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

H-S: Helmert-Stokes scheme 3 groups

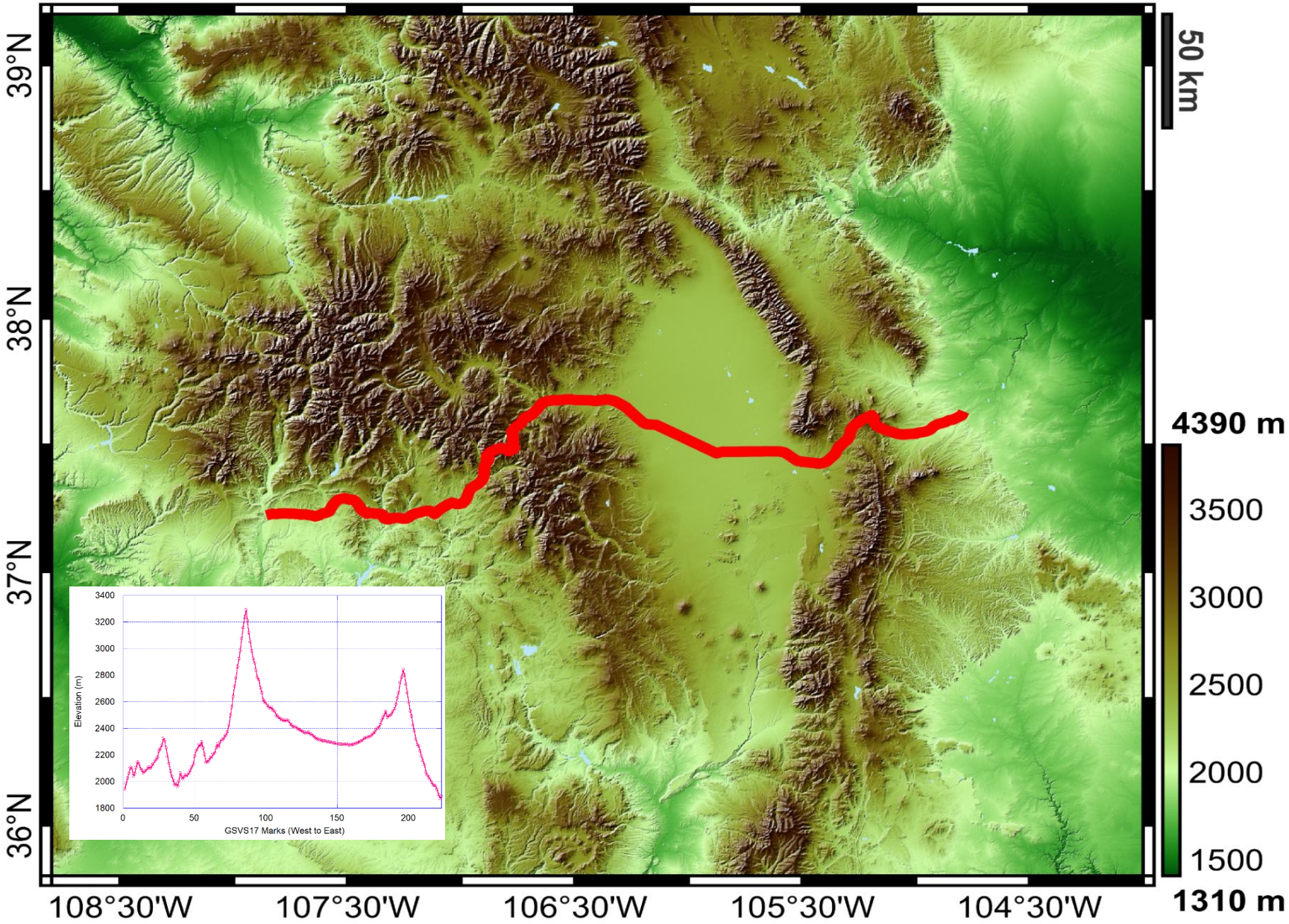
M: Molodensky height anomaly 12 groups

Reference model used:

RefB 4, xGM16 8, EGM2008 1, GOCO05S 1, Eigen-6C4 1

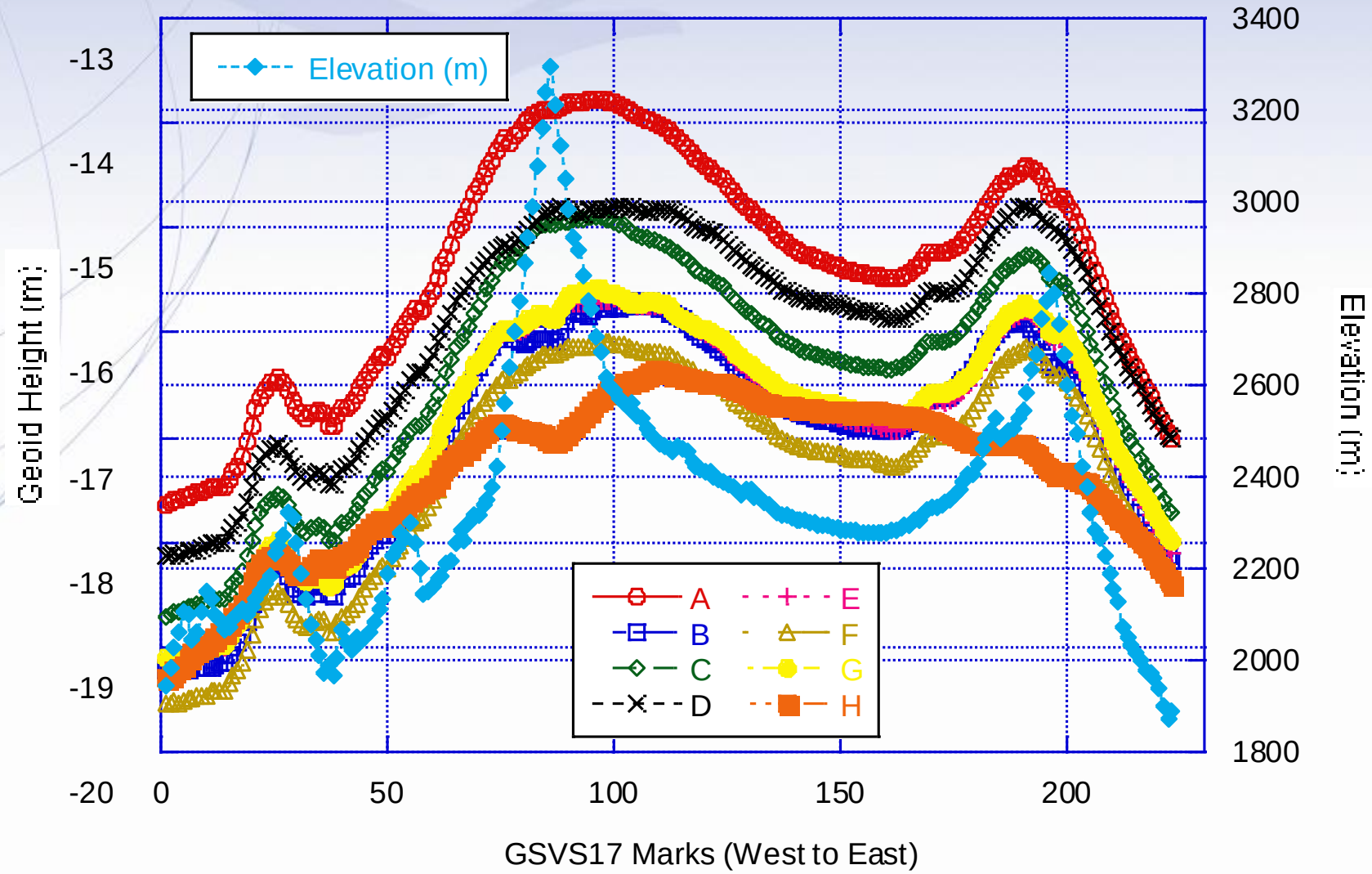


Distribution of surface and airborne gravity data (GRAV-D MS05). The pink line is the location of GSVS17 benchmarks.

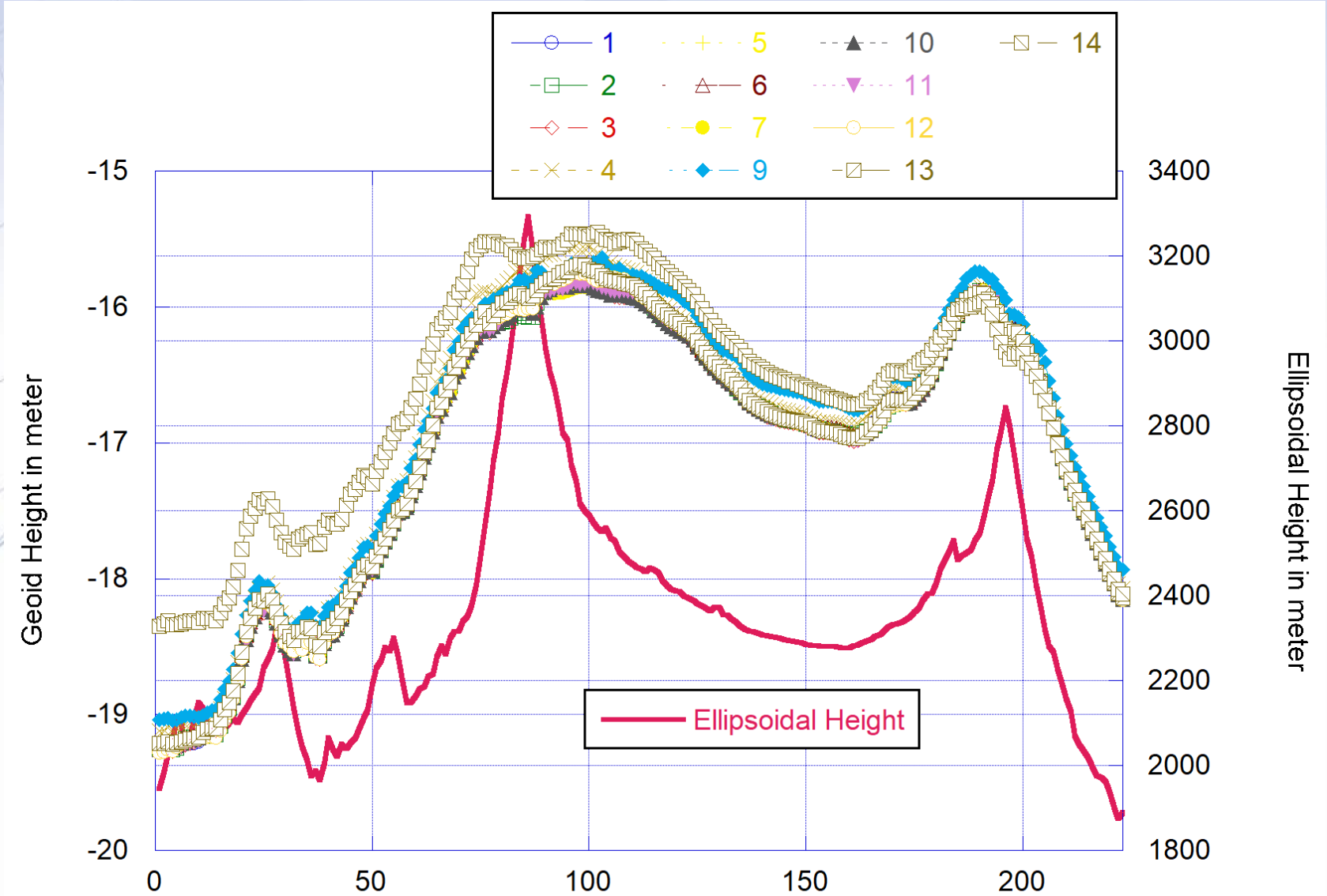


Topography and location of 223 GSVS17 benchmarks

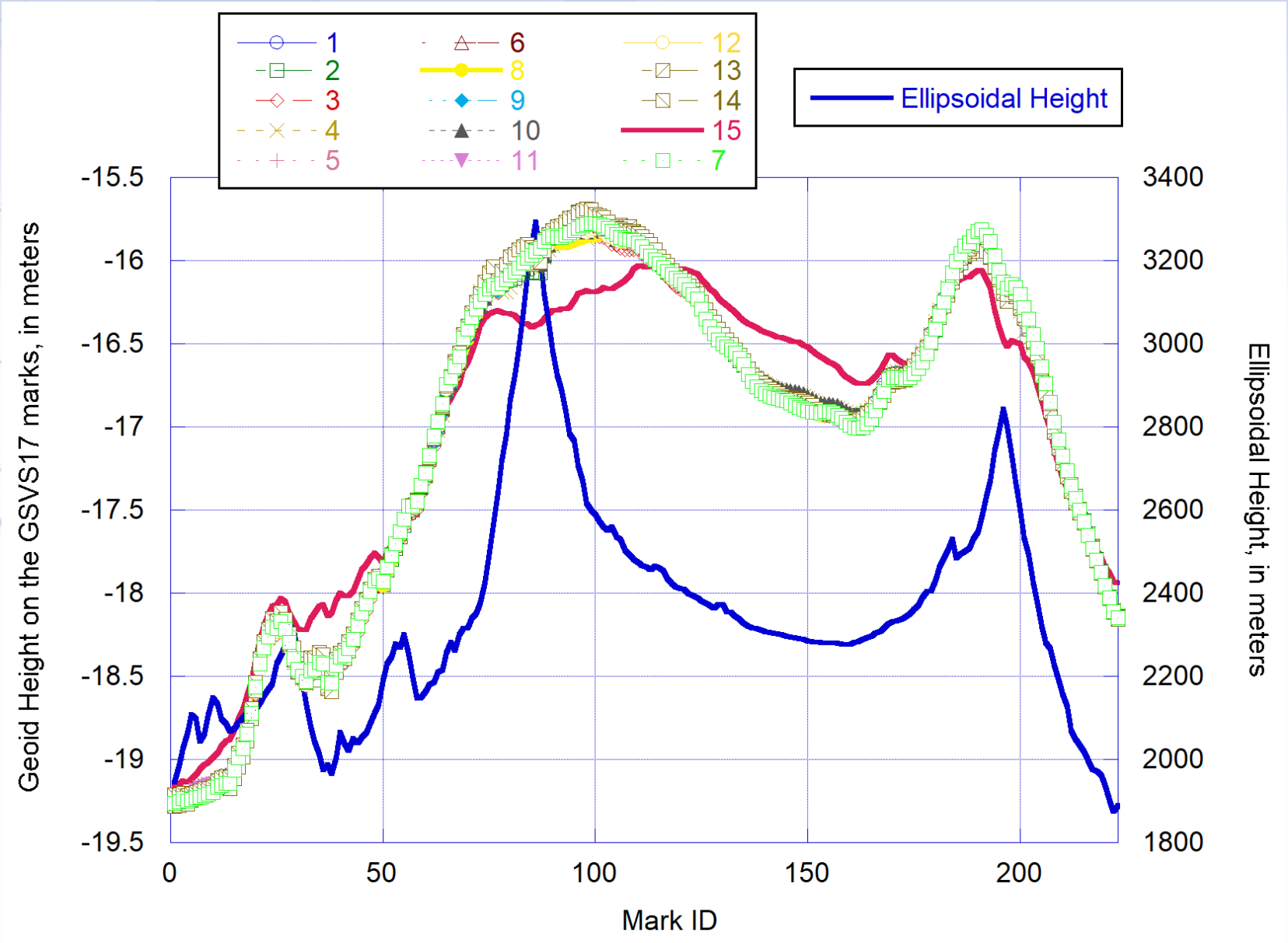
Geoid height on the GSVS17 marks (initial runs)

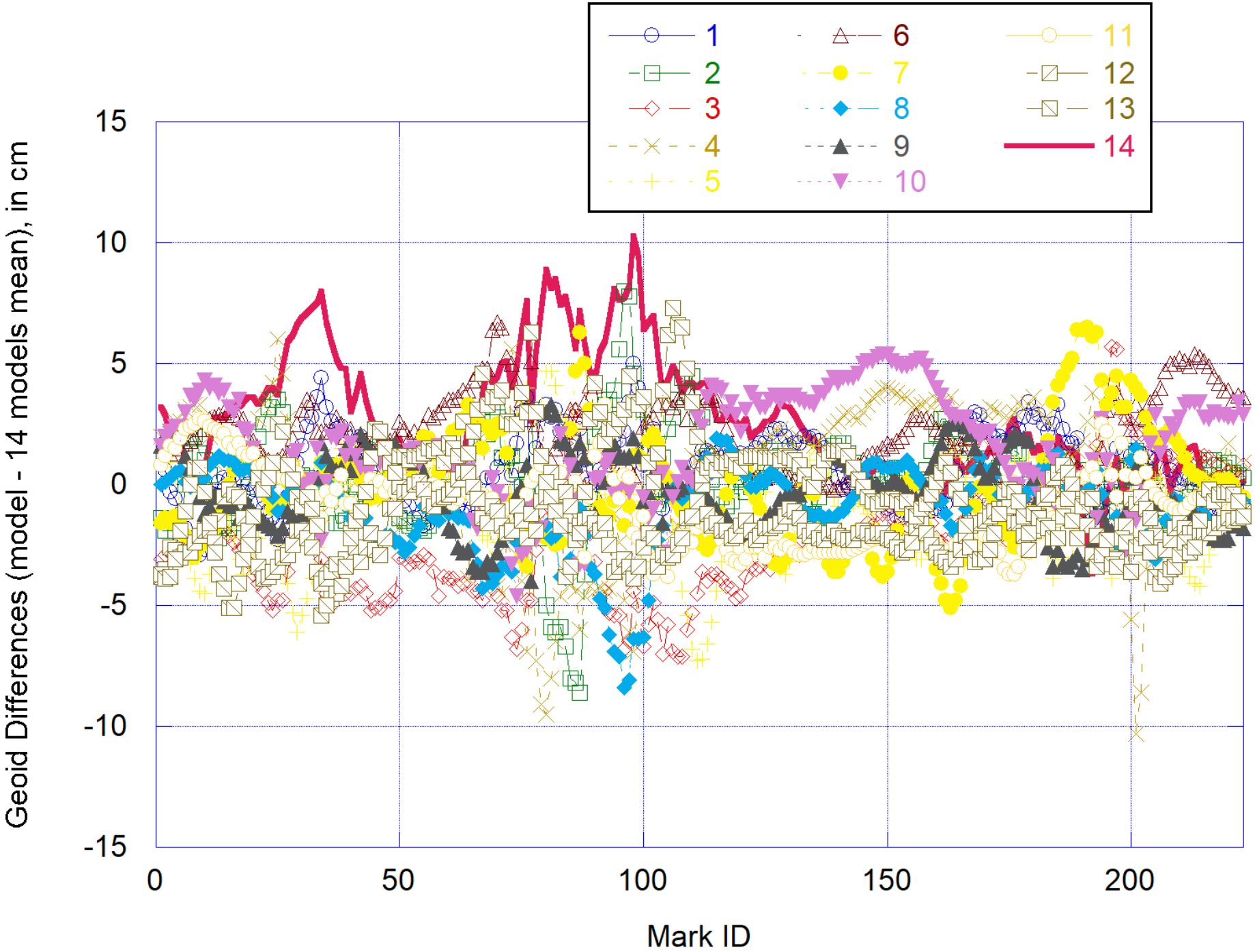


Geoid height on the GSVS17 marks (1st iteration)



Geoid height on the GSVS17 marks (2nd iteration)

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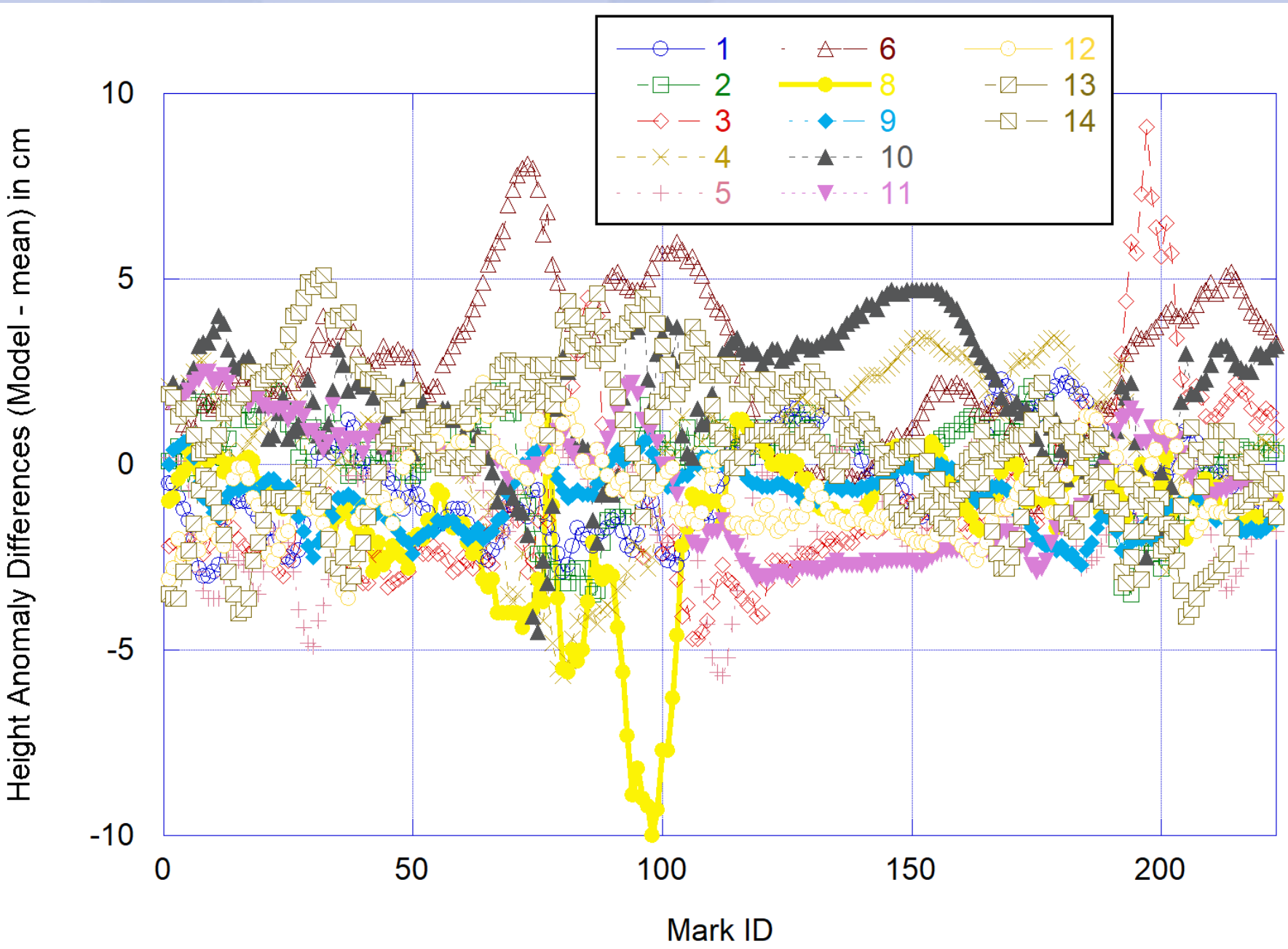
50
100
150
200
Geoid Differences (model - 14 models mean), in cm
Mark ID

Geoid height difference (model – mean*) on 223 GSVS17 benchmarks, Unit in cm

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mean	0.5	0.1	-2.4	0.3	0.0	2.1	0.1**	-1.1	-0.3	1.5	-1.0	-1.9	-0.2	2.5	2.3
STD	1.5	2.2	2.4	2.9	1.3	1.5	2.4	1.8	1.6	2.1	1.6	1.1	2.4	2.6	23.6
RMS	1.6	2.2	3.4	2.9	2.4	2.6	2.4	2.1	1.6	2.5	1.9	2.2	2.4	3.6	23.7
Min	-3.2	-8.7	-7.3	-10.3	-3.4	-1.4	-5.1	-8.5	-3.8	-4.5	-3.7	-4.7	-5.5	-3.6	-45.8
Max	4.9	7.9	5.6	6.0	3.4	6.5	6.6	1.7	3.3	5.2	3.2	0.7	7.3	10.2	43.1
Range	8.1	16.6	12.9	16.3	6.8	7.9	11.7	10.2	7.1	9.7	6.9	5.4	12.8	13.8	88.9

*14 model average, model 15 is excluded in the mean.
** 82 cm is added to model 8.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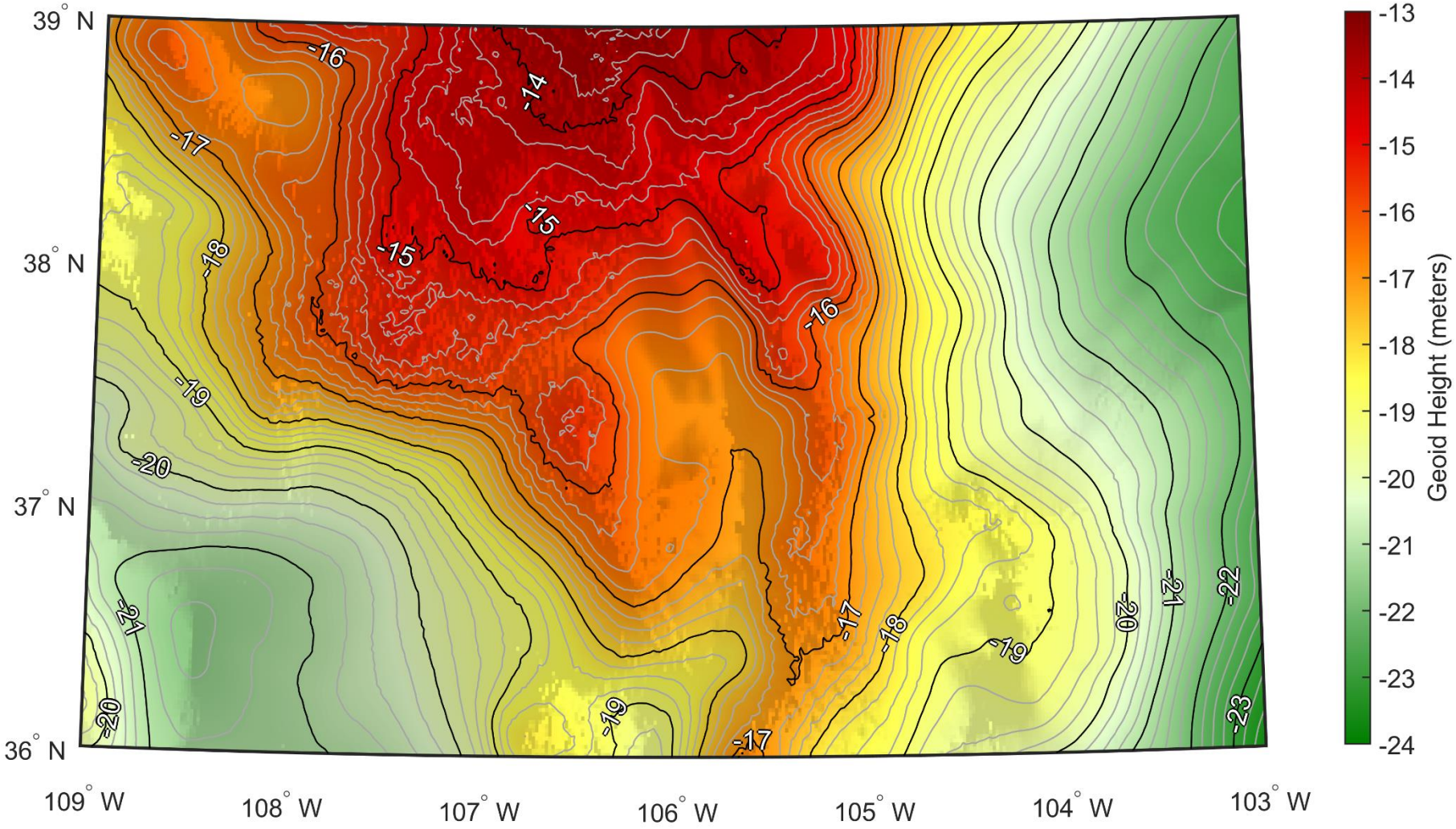
50
100
150
200
Height Anomaly Differences (Model - mean) in cm
Mark ID

Height anomaly difference (model – mean*) on 223 GSVS17 benchmarks, Unit in cm

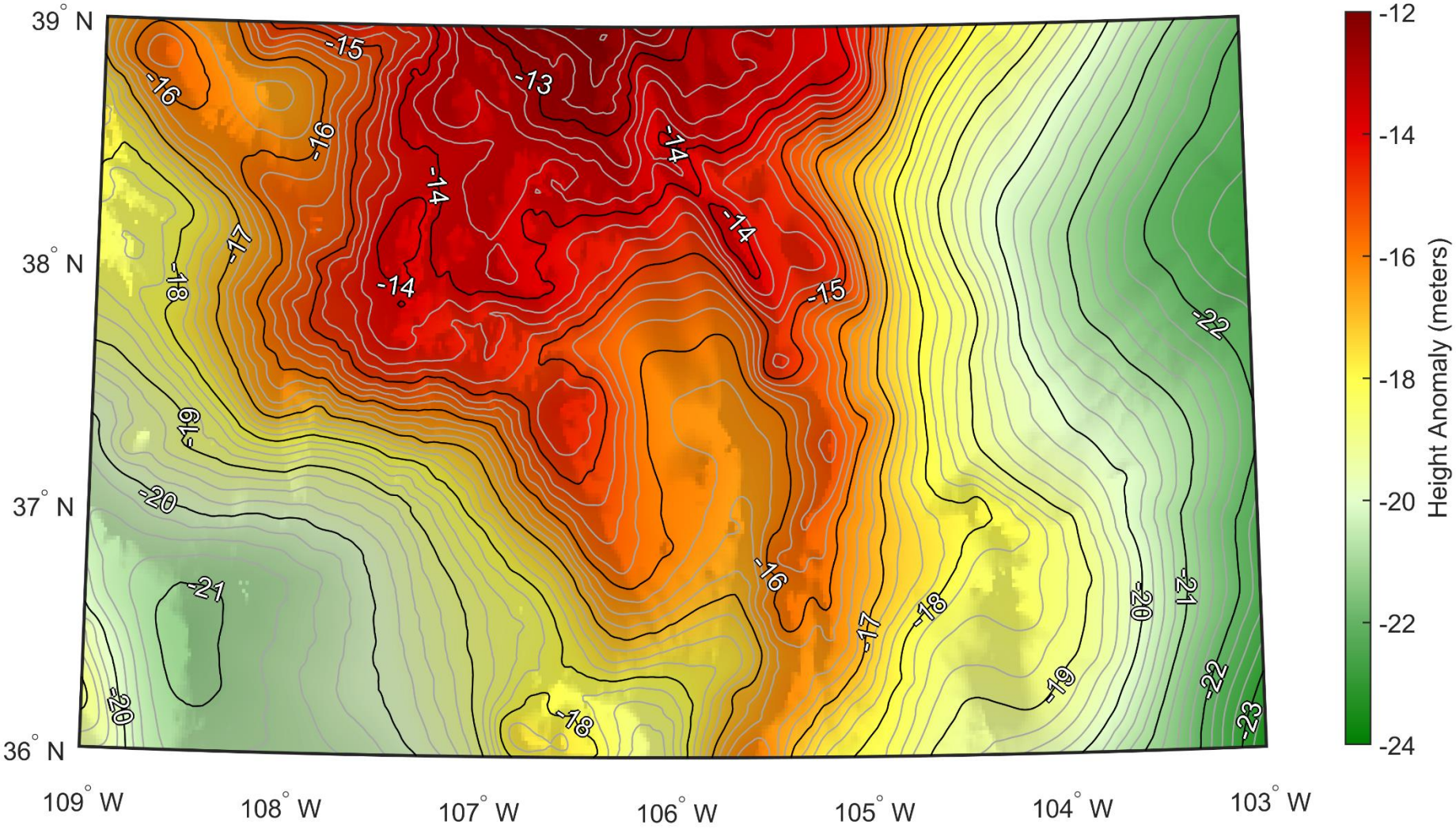
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mean	-0.6	0.1	-0.9	0.4	-0.5	2.7		-1.6	-1.0	1.8	-0.5	-0.9	-0.3	1.3	
STD	1.3	1.2	2.4	2.0	0.9	2.0		2.0	0.7	1.7	1.6	1.1	1.9	1.6	
RMS	1.5	1.2	2.6	2.1	1.0	3.4		2.6	1.2	2.5	1.7	1.4	1.9	2.1	
Min	-3.3	-3.5	-4.9	-5.7	-3.1	-1.1		-10.1	-2.8	-4.4	-3.1	-3.5	-4.1	-3.2	
Max	2.4	2.2	9.0	3.5	1.2	8.1		1.9	0.6	4.5	2.2	2.3	4.5	5.0	
Range	5.7	5.7	13.9	9.2	4.3	9.2		12.0	3.4	8.9	5.3	5.8	8.6	8.2	

*13 model average. All models are included.

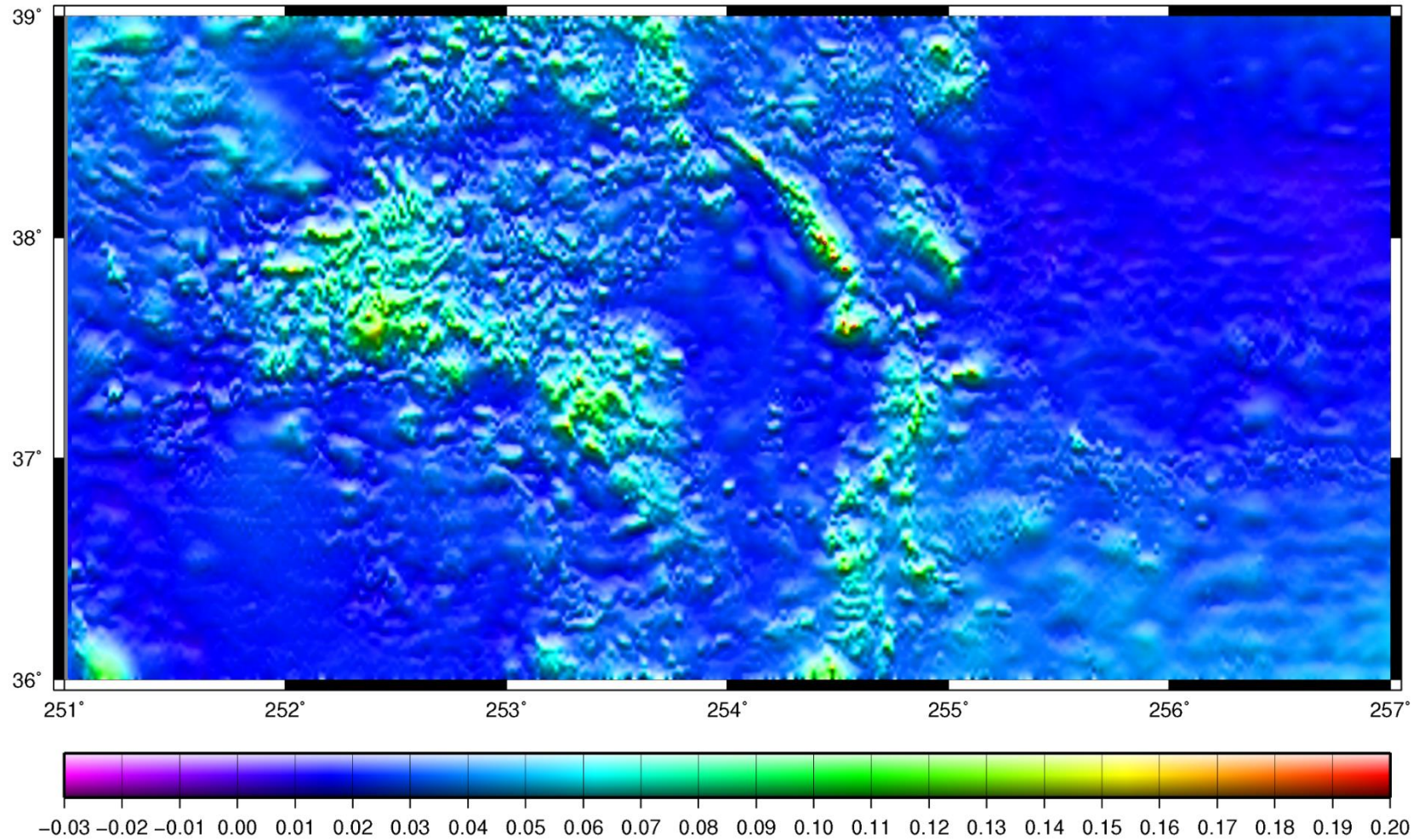
Mean geoid of 14 models



Mean Height Anomaly of 13 models

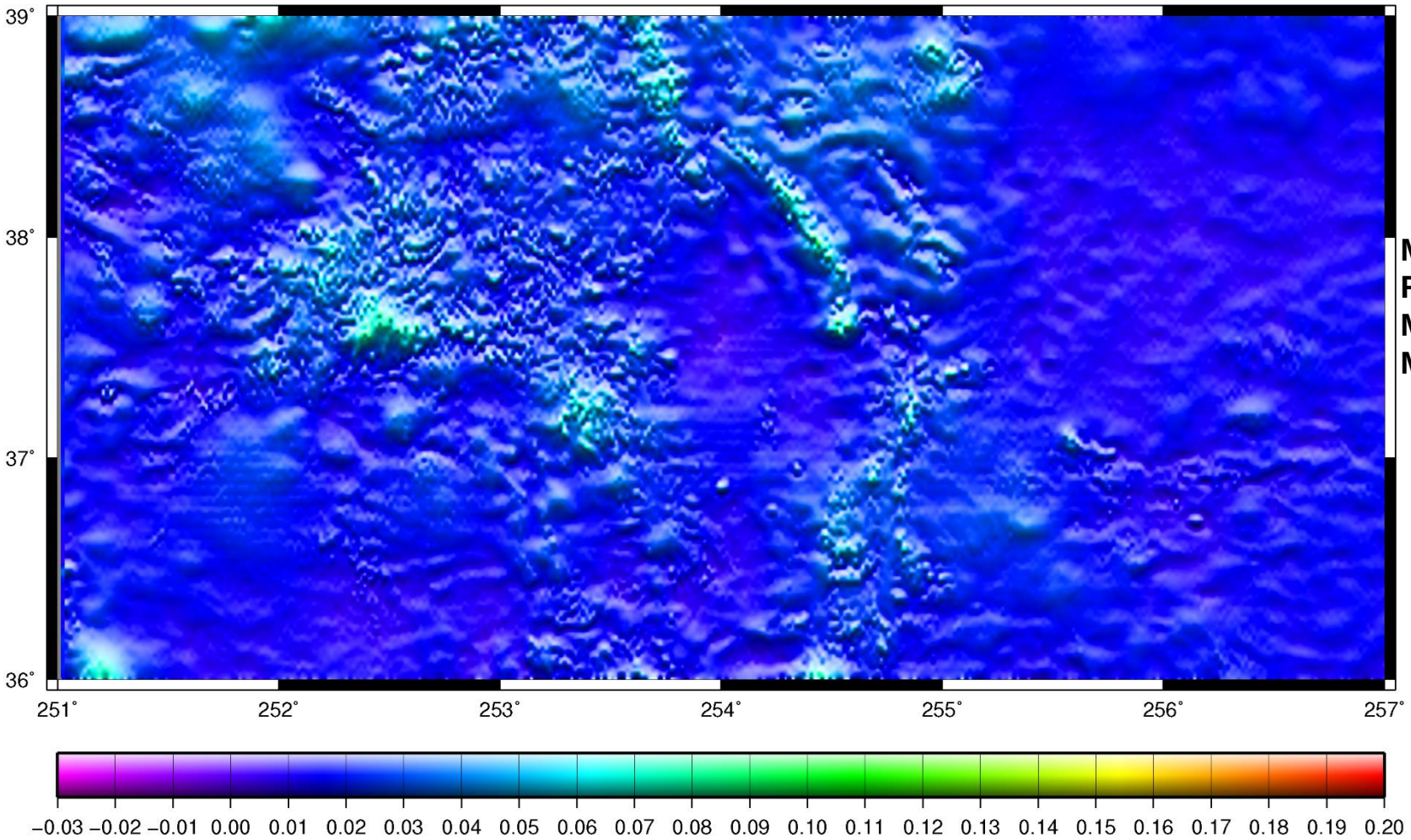


STD of geoid height of 14 models, unit in cm



Mean = 3.2
RMS= 3.6
Min= 0.6
Max = 21.8

STD of height anomaly of 13 models, unit in cm



Mean = 2.4
RMS= 2.7
Min= 0.6
Max = 15.2

GPS/leveling comparisons (h-H-model) on 177 benchmarks, 85 cm is subtracted from models.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mean	-0.6	-1.0	1.2	-1.1	1.2	-1.9	84.3	-0.4	0.3	-0.3	2.1	-1.2	2.1	-1.9	
STD	5.605	5.319	4.861	6.423	5.128	4.997	4.883	5.451	4.977	5.559	4.893	4.855	5.508	5.490	
RMS	5.6	5.4	5.0	6.5	5.3	5.4	84.4	5.5	5.2	5.6	4.9	5.0	5.9	5.8	
Min	-18.5	-18.8	-15.7	-23.6	-14.6	-19.0	70.0	-16.1	-15.0	-16.1	-14.2	-17.4	-16.2	-22.2	
Max	22.3	14.1	15.7	32.7	21.4	12.9	100.8	21.6	18.4	25.9	16.0	15.0	20.9	14.8	
Range	41.8	32.9	31.4	56.3	36.0	31.9	30.8	37.7	33.4	42.0	30.2	32.4	37.1	37.0	

Unit is in Cm. Comparison is made in the area: latitude: 36.1 to 38.9 degree; longitude: 251.1 to 256.9 degree

N / ζ (GSVS17) Comparisons!!!
87 cm is added to the models.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mean	-0.97/ 0.08	-0.52/ -0.64	1.99/ 0.39	-0.76/ -0.97	0.61/ 0.81	-2.54/ -3.18	81.67 /---	0.66/ 1.10	-0.11/ 0.46	-1.89/ -2.36	0.59/ 0.01	1.49/ 0.36	-0.20/ -0.25	-2.91/ -1.85	-2.80/ ---
STD	2.51/ 2.48	3.53/ 3.09	1.99/ 1.83	4.10/ 3.17	2.97/ 3.48	2.72/ 3.05	2.29 /---	2.90/ 2.92	3.06/ 2.93	3.67/ 3.44	2.69/ 2.79	2.33/ 2.32	3.92/ 3.55	3.90/ 3.58	24.85 /---
Min	-5.8/ -5.1	-9.2/ -4.5	-3.3/ -6.3	-9.4/ -6.3	-5.3/ -4.1	-8.3/ -10.6	76.7	-3.5/ -3.6	-5.0/ -3.3	-7.9/ -7.7	-5.7/ -5.3	-3.2/ -4.3	-9.7/ -6.0	-9.4/ -7.4	-45.5
Max	8.3/ 8.0	9.9/ 10.0	6.9/ 4.4	15.7/ 7.9	8.5/ 7.5	6.3/ 4.1	86.7	8.5/ 9.1	9.0/ 9.0	8.8/ 6.7	8.2/ 5.6	9.7/ 7.3	10.8/ 9.0	10.5/ 9.7	44.4
Range	13.6/ 13.1	19.1/ 14.5	10.2/ 10.7	25.1/ 14.2	13.8/ 11.6	14.6/ 14.7	10.0 /---	12.0/ 12.7	14.0/ 12.3	16.7/ 14.4	13.9/ 10.9	12.9/ 11.6	20.5/ 15.0	19.9/ 17.1	89.9 /---

Unit in cm.

Observations (1)

GSVS17 Profile Comparisons:

- All geoid models agree with each other around ± 2 - 3 cm, except one outlier.
- Geoid models agree with OLD GSPL data around ± 5 cm, because of bad quality of GPSL data.
- 14 models agree with GSV17 data ± 2 - 4 cm. Some models perform better than others noticeably.
- The best model (H-S) agrees with GVS17 data at ±1.99 cm.
- Height anomaly models agrees better with GSVS17 data. Canada's model agree the best with GSVS17 data at ±1.83 cm.

Observations (2)

Area comparisons

- Models differ more in areas where topography is rougher.
- The average of STD values over the area is ± 3.2 cm, with minimum 0.6 cm and maximum 21.8 cm.
- The average of STD values of height anomaly differences is ± 2.4 cm, smaller than the geoid differences. This implies that the geoid - quasigeoid separation has a difference of ±2.1 cm. Is this acceptable?

Observations/Conclusions

- Is the geoid or height anomaly rougher? Mean geoid has more high frequency features than the mean height anomaly. Why?
- Results show computation methods/parameterization can cause geoid differences of 10 cm or more, Indicating the importance of stability of computation method (e.g., downward continuation etc.) and topographic and gravity reductions in high mountains.
- Zero-degree geoid must be treated carefully, another reminder of parameters selection in computing the reference field.
- Colorado experiment is a good opportunity to calibrate the geoid computation methods/software!