

GST-1: A high-resolution Global Sediment Thickness model

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Supplementary Information

This Supplementary Information includes six sections of technical details that support methods and results reported in Bird and Mooney, “GST-1: A high-resolution Global Sediment Thickness model.”

Liang et al. (2020) compared SGG-UGM-2 with EGM2008 and reported that (p. 871), “... the large differences between SGG-UGM-2 and EGM2008 are located at areas where there are no gravity data or only sparse gravity data used for compiling EGM2008, such as the Tibetan Plateau, South America, central Africa, and Antarctica,” and, “... there are also large differences around coast lines, which might reflect differences in the marine gravity anomaly data ...”.

Based, in part, on these comments, we select three test areas for comparing gravity models and layer densities from two global crust models (Afonso et al., 2019; Liang et al., 2020; Mooney et al., 2023): 1) North America, 2) central Africa, and 3) central and south Asia (Figure SI-0). Results of these comparisons are summarized in Table SI-1.

The North America test area extends west and east, from coast-to-coast, and from north of contiguous United States to Mexico and the Gulf of Mexico in the south. This area includes the large geothermal region beneath the Great Basin, terrestrial basins such as the Anadarko, Williston, Michigan, Appalachian, and the deep marine east Atlantic coast passive margin and Gulf of Mexico Basins.

The central Africa test area also extends west to east, from coast-to-coast, and includes deep coastal Somali and Kwanza Basins as well as the Niger Delta basin. This area also includes the large terrestrial Congo Basin and several narrow rift basins in the East African rift zone.

The central and south Asia test area includes the Tibetan Plateau, India, large parts of Indochina, and northern Indian Ocean. This test area includes the most dramatic basement range possible, from the Himalayas to the deep basin beneath the Bengal Fan. In addition to the marine Bengal Basin, several terrestrial basins are located in this area including the Indus, Ganga, Tarim, and Sichuan Basins.

- SI-1) Global gravity models**, EGM2008 and SGG-UGM-2. These gravity models are compared for each of the three test areas. Then, using GST-1 workflow where EGM2008 is replaced by SGG-UGM-2, sediment thicknesses are modeled in the test areas and compared to GST-1 model.
- SI-2) GST-1 calculated anomaly wavelengths** from gravity inversions. Figures illustrate calculated gravity fields used to compute power spectra displayed in Methods section (Figure 3).
- SI-3) Example of GST-1 sediment thickness grid merges**. An example of regional model sediment thickness grid merges (Section 3.4 3D gravity inversions).
- SI-4) Sediment thickness calculations using densities from global crust models** ECM1 and LithoRef18. Variable densities from these global crust models are imported into the three 3D test area models and, following GST-1 workflow, sediment thicknesses are calculated and compared to GST-1 model.
- SI-5) Examinations of deep layer densities and density contrasts** in North America. Figures illustrate layer densities (crystalline crust and upper mantle) and density contrasts (basement and base of crust surfaces).
- SI-6) Comparisons of global crust and mantle densities**. World maps of four global model layer densities (crystalline crust and upper mantle).

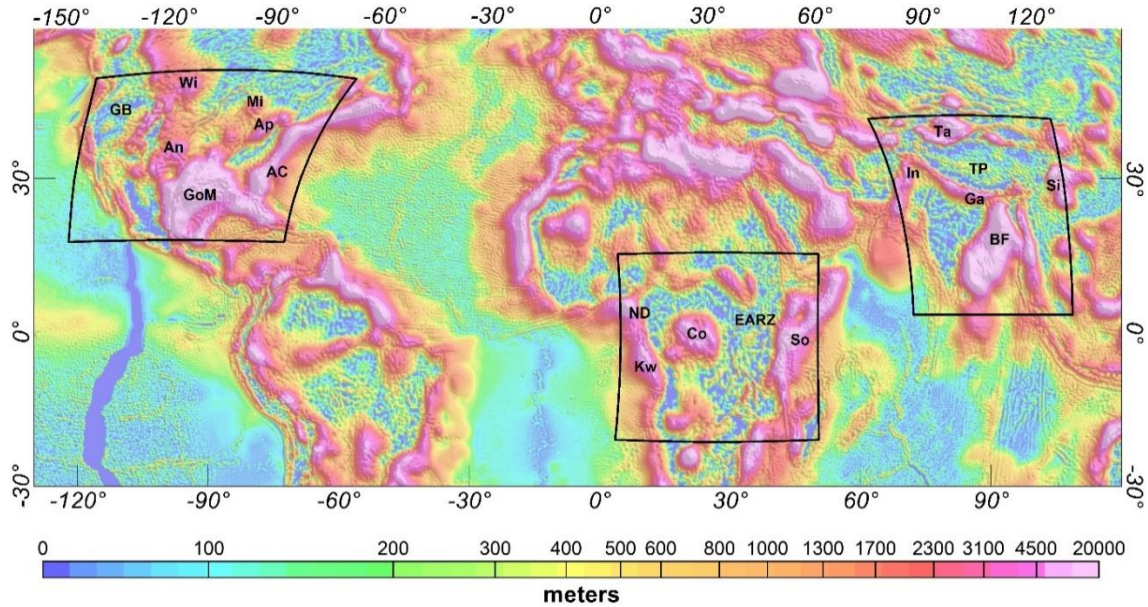


Figure SI-0. Three test areas over GST-1 sediment thickness model. Identified basins in the text, North America: Great Basin (GB), Williston (Wi), Michigan (Mi), Appalachian (Ap), Anadarko (An), Gulf of Mexico (GoM), and Atlantic coast passive margin (AC); Africa: Niger Deltaa (ND), Kwanza (Kw), Congo (Co), Somali (So), and the East African Rift Zone (EARZ); Asia: Tarim (Ta), Indus (In), Ganga (Ga), Sichuan (Si), and Bengal Fan (BF).

Figure	Page	Model type	Model name	Test areas	Mean ± std	Acc (%)	Loc500 (%) Mean ± std	Loc1k (%) Mean ± std
SI-1.1	4	Gravity	SGG-UGM-2	NOAM	0.097 ± 3.566 mGal	0.728	n/a	n/a
SI-1.2	5	Gravity	SGG-UGM-2	Africa	0.011 ± 4.993 mGal	1.261	n/a	n/a
SI-1.3	6	Gravity	SGG-UGM-2	Asia	0.649 ± 8.791 mGal	1.326	n/a	n/a
SI-1.4	7	Crust	SGG-UGM-2	NOAM	0.8 ± 73.6 m	0.56	-0.029 ± 2.985	-0.024 ± 1.828
SI-1.5	8	Crust	SGG-UGM-2	Africa	1.9 ± 66.1 m	0.66	0.047 ± 2.997	-0.014 ± 1.874
SI-1.6	9	Crust	SGG-UGM-2	Asia	9.6 ± 136.8 m	0.48	0.516 ± 6.831	0.363 ± 3.829
SI-4.1	12	Crust	ECM1	NOAM	2.5 ± 93.7 m	0.71	0.081 ± 4.551	-0.082 ± 2.725
SI-4.2	13	Crust	ECM1	Africa	30.3 ± 61.7 m	0.61	1.272 ± 2.814	0.999 ± 1.757
SI-4.3	14	Crust	ECM1	Asia	-87.4 ± 78.2 m	0.48	-2.915 ± 3.074	-2.071 ± 1.857
SI-4.4	15	Crust	LithoRef18	NOAM	41.1 ± 200.9 m	1.52	0.986 ± 6.283	0.739 ± 4.338
SI-4.5	16	Crust	LithoRef18	Africa	30.3 ± 61.7 m	0.61	-2.18 ± 12.009	-1.871 ± 10.909
SI-4.6	17	Crust	LithoRef18	Asia	-84.7 ± 78.2 m	0.48	2.129 ± 11.058	1.166 ± 8.725

Table SI-1. Comparisons of Global Models with GST-1 in three test areas. Global gravity model EGM2008 (Pavlis et al., 2012) is compared to the newer gravity model, SGG-UGM-2 (Liang et al., 2020). Accuracy (**Acc**) is the standard deviation percentage with respect to the model range. Local accuracies are calculated from a ratio of model differences for total sediment thickness >500 m (Loc500), and for total sediment thickness >1 km (Loc1k). Crust models: Earth Crust Model 1 (ECM1, Mooney et al., 2023), LithoRef18 (Afonso et al., 2019). NOAM = North America.

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Supplementary Information 1 (SI-1). Global gravity models

Gravity models SGG-UGM-2 (Liang et al., 2020) and EGM2008 (Pavlis et al., 2012) are compared. Then, using GST-1 workflow with SGG-UGM-2 replacing EGM2008, sediment thickness is modeled in the three test areas and compared with GST-1 results (Sections 2. Gravity data, and 5.1.1, Gravity model SGG-UGM-2).

SI-1.1 North America – gravity models

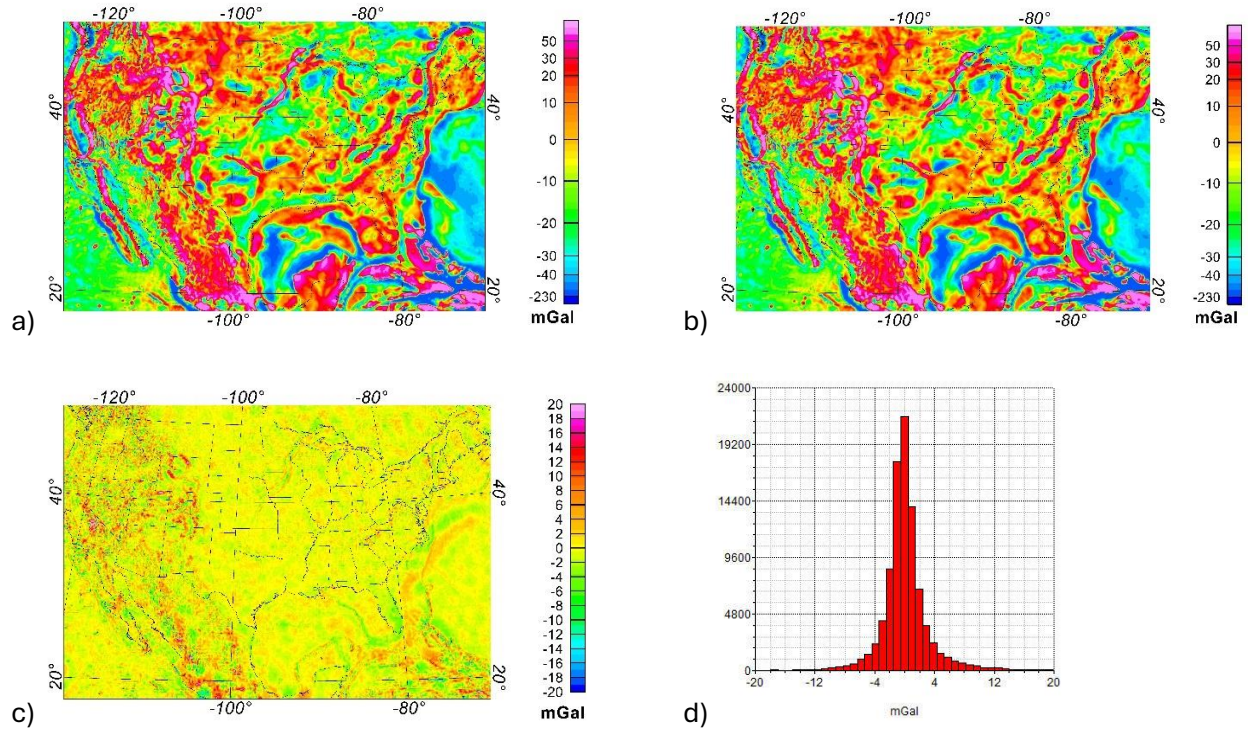


Figure SI-1.1. Comparison of gravity models, North America test area. Free air gravity anomalies, a) SGG-UGM-2, and b) EGM2008, c) Difference between SGG-UGM-2 and EGM2008, and d) Histogram of difference. Respective mean and standard deviation are 0.097 and 3.566 mGal, or 0.728% of the total range of SGG-UGM-2 over North America (490 mGal).

SI-1.2 Central Africa – gravity models

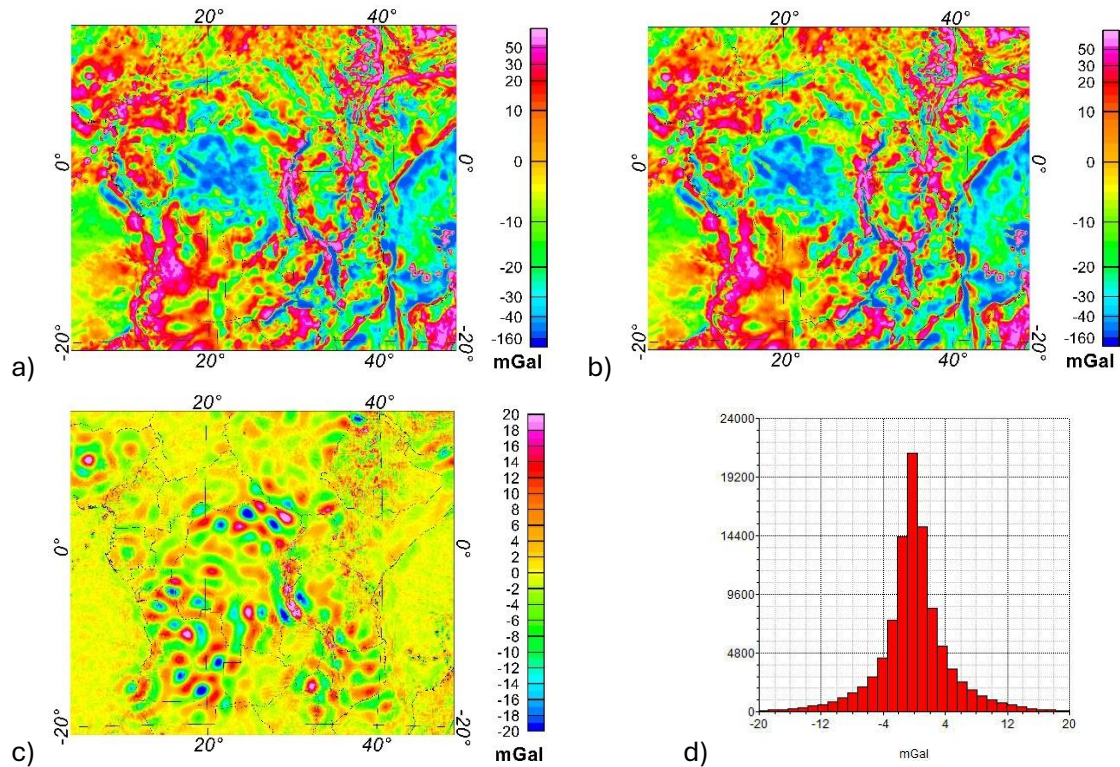


Figure SI-1.2. Comparison of gravity models, central Africa test area. Free air gravity anomalies, a) SGG-UGM-2, and b) EGM2008, c) Difference between SGG-UGM-2 and EGM2008, and d) Histogram of difference. Respective mean and standard deviation are 0.011 and 4.993 mGal, or 1.261% of the total range of SGG-UGM-2 over central Africa (396 mGal).

SI-1.3 Central and south Asia – gravity models

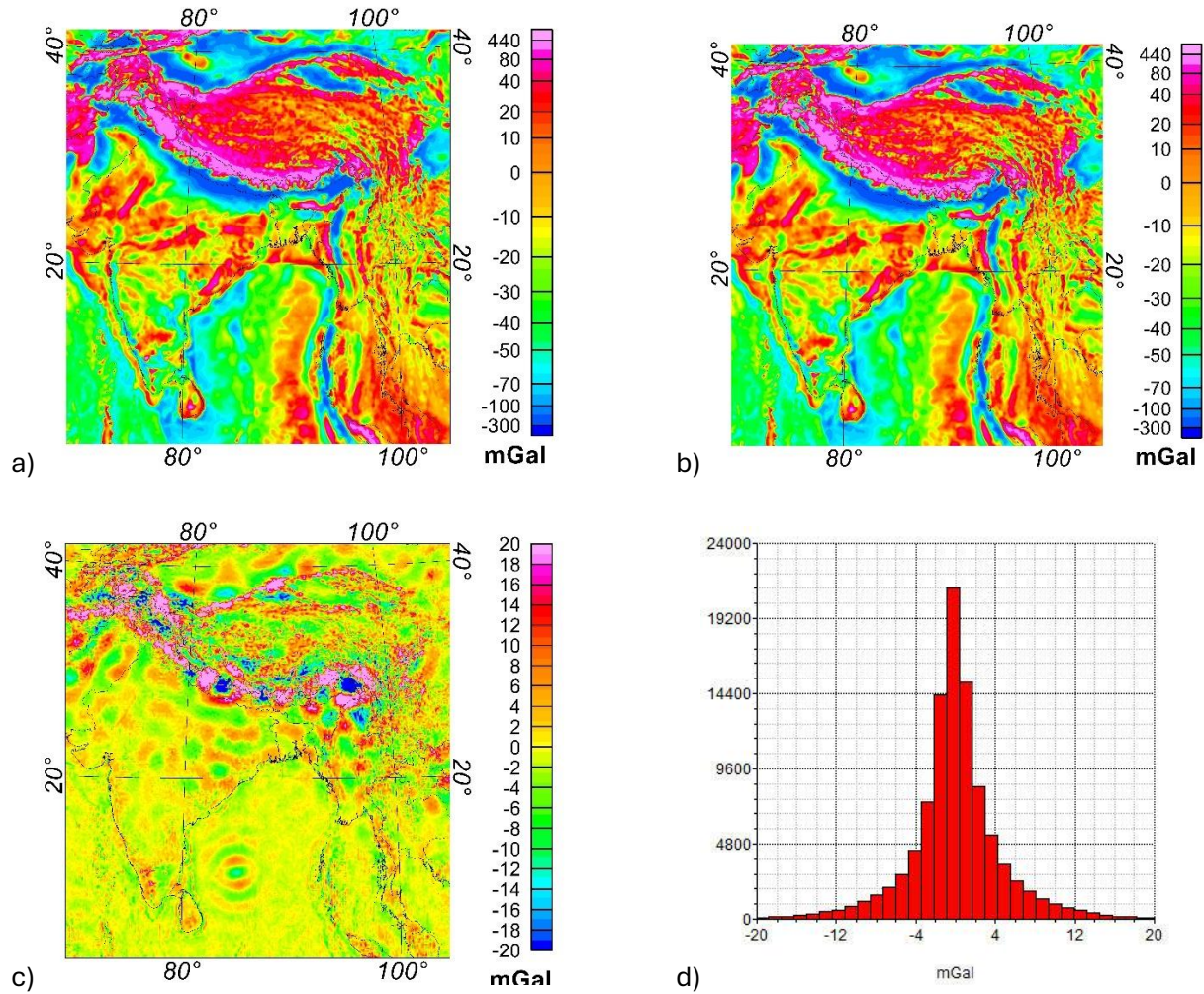


Figure SI-1.3. Comparison of gravity models, central and south Asia test area. Free air gravity anomalies, a) SGG-UGM-2, and b) EGM2008, c) Difference between SGG-UGM-2 and EGM2008, and d) Histogram of difference. Respective mean and standard deviation are 0.649 and 8.793 mGal, or 1.326% of the total range of SGG-UGM-2 over central and south Asia (663 mGal).

SI-1.4 North America – sediment thickness calculated using SGG-UGM-2 gravity model

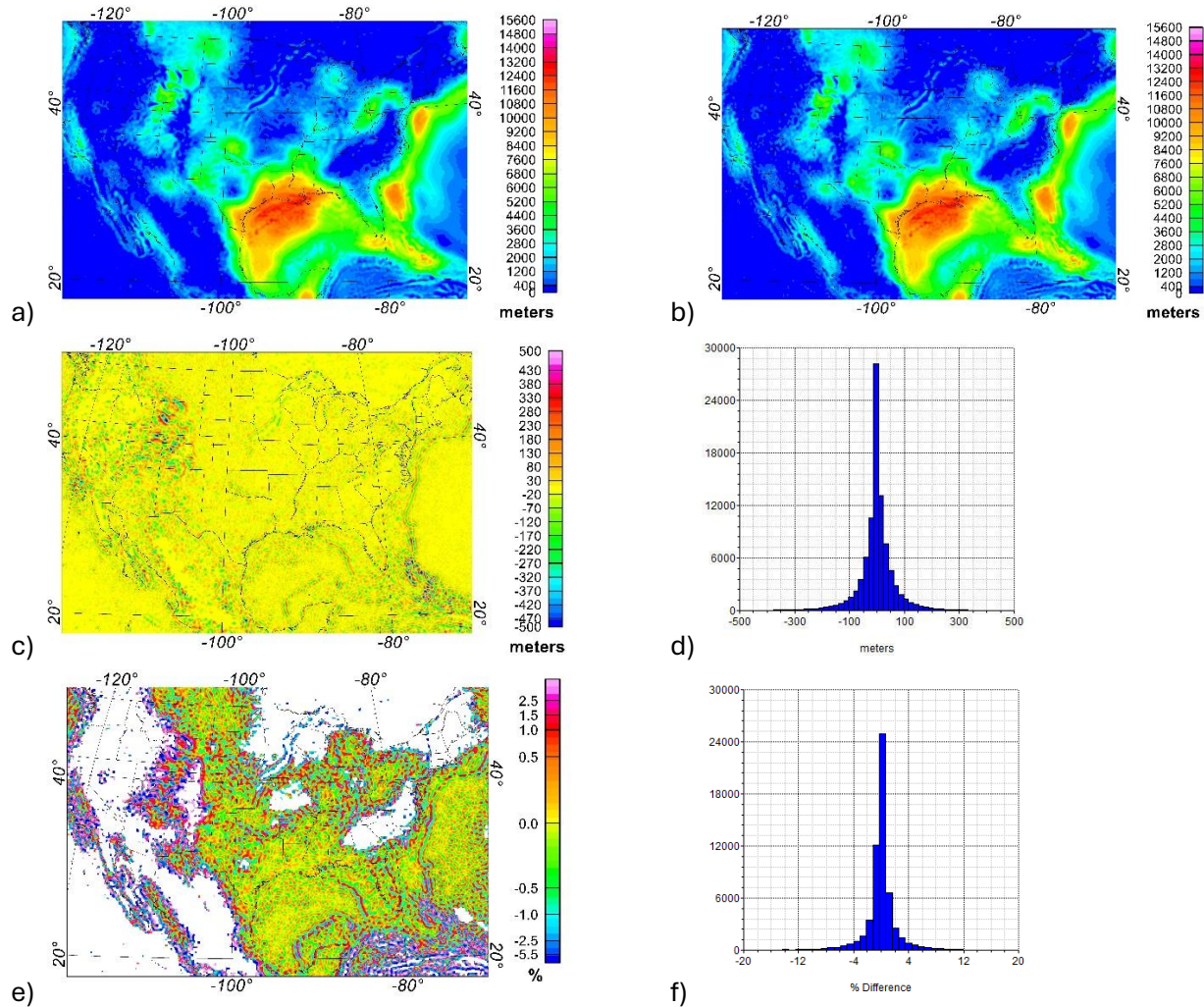


Figure SI-1.4. Comparison of sediment thickness using SGG-UGM-2 gravity model with GST-1 model, a) GST-1, b) Using SGG-UGM-2 gravity model, c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are -0.8 and 73.6 m, which is a difference of 0.56%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m (= difference / total thickness), f) Histogram of the local difference percentage. Respective mean and standard deviation are -0.029% and 2.985%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are -0.024% and 1.828% (not displayed).

SI-1.5 Central Africa – sediment thickness calculated using SGG-UGM-2 gravity model

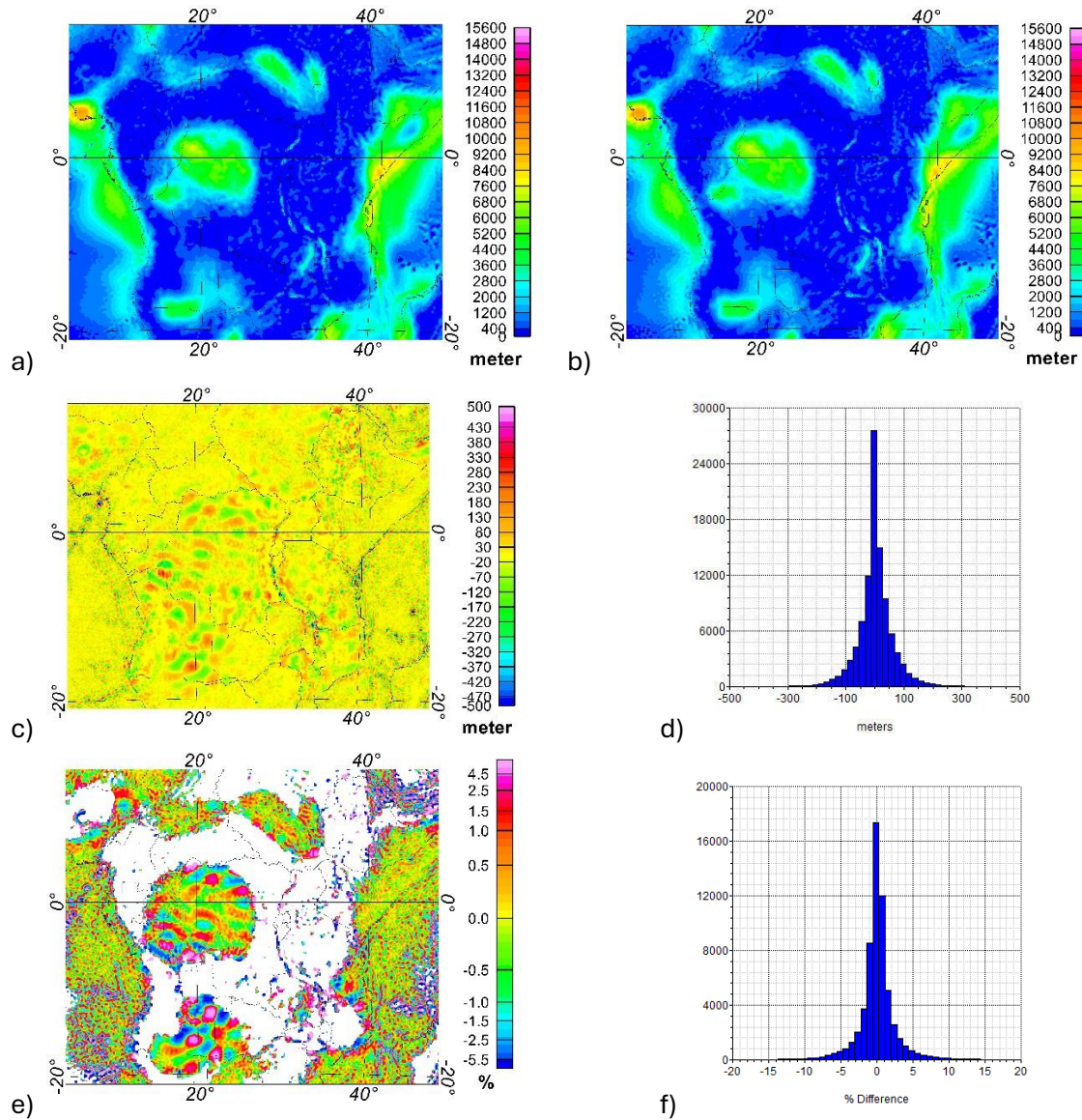


Figure SI-1.5. Comparison of sediment thickness using SGG-UGM-2 gravity model with GST-1 model, a) GST-1, b) Using SGG-UGM-2 gravity model, c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are 1.9 and 66.1 m, which is a difference of 0.66%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m (= difference / total thickness), f) Histogram of the local difference percentage. Respective mean and standard deviation are 0.047% and 2.977%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are -0.014% and 1.874% (not displayed).

SI-1.6 Central and south Asia – sediment thickness calculated using SGG-UGM-2 gravity model

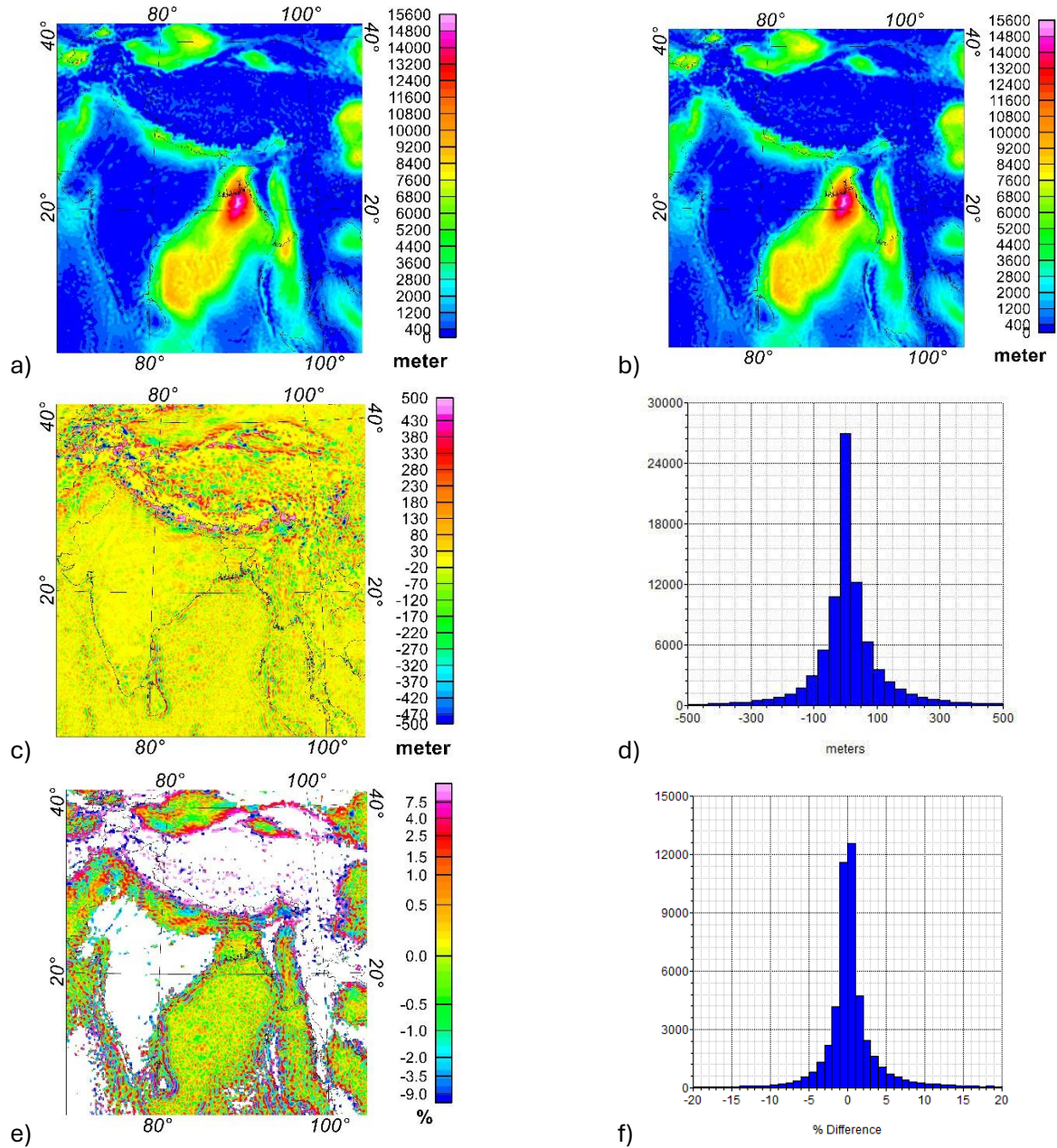


Figure SI-1.6. Comparison of sediment thickness using SGG-UGM-2 gravity model with GST-1 model, a) GST-1, b) Using SGG-UGM-2 gravity model, c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are 9.6 and 136.8 m, which is a difference of 0.48%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m (= difference / total thickness), f) Histogram of the local difference percentage. Respective mean and standard deviation are 0.516% and 6.831%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are 0.363% and 3.829% (not displayed).

Supplementary Information 2 (SI-2), GST-1 inversion calculated anomalies

Power spectra of calculated gravity field differences, Initial and base crust inversion and base crust and basement inversions (Section 3. Methods).

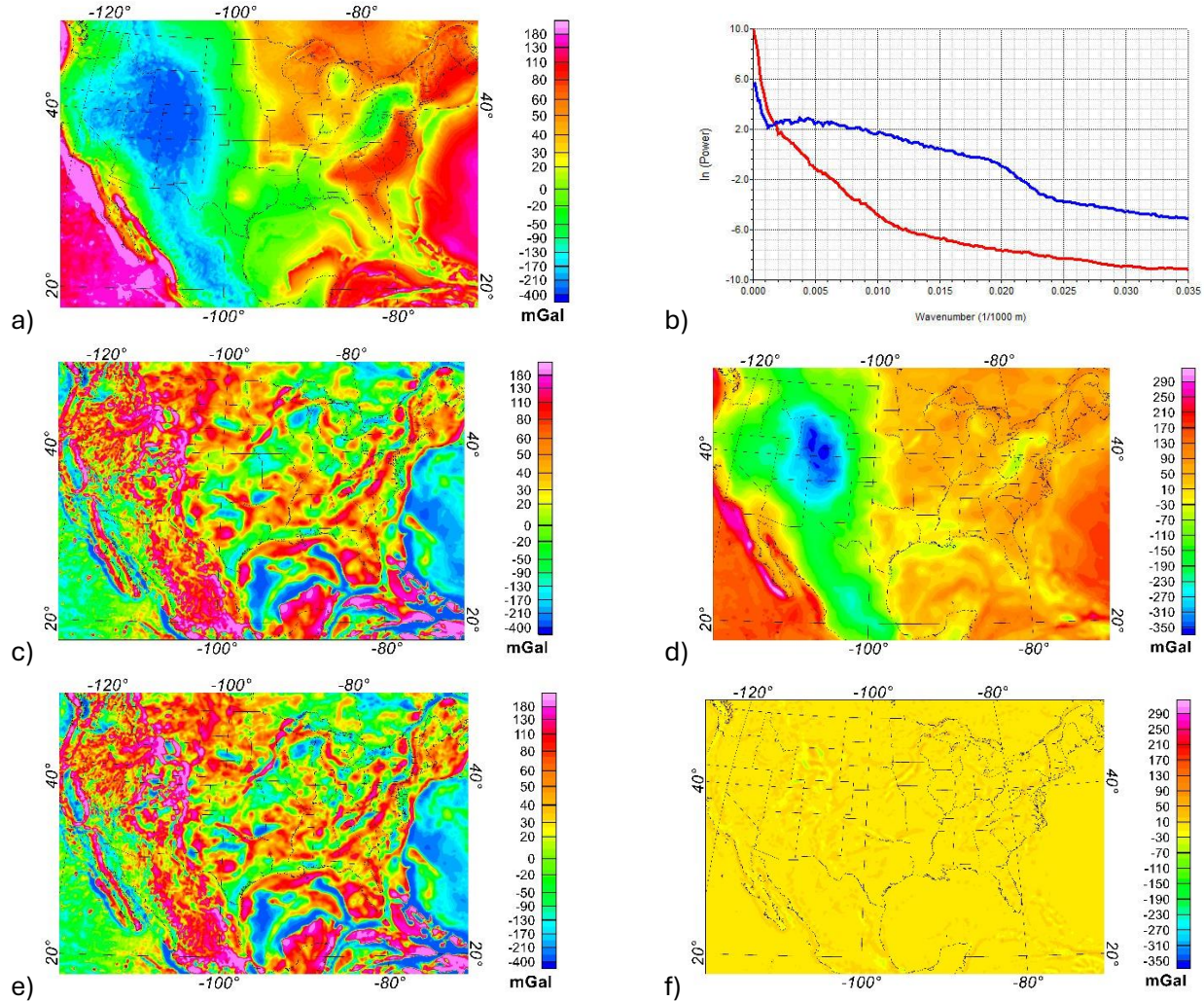


Figure SI-2. 3D model calculated gravity over North America illustrate anomaly wavelengths that control gravity inversions, a, c, e) Initial, base crust inversion, and basement inversion calculated gravity anomalies, d) Difference of calculated gravity anomalies, base crust inversion from initial, f) Difference of calculated gravity anomalies, base crust from basement inversions, and b) Power spectra profiles of calculated differences: base crust (red profile), and basement (blue profile).

Supplementary Information 3 (SI-3), 3D model sedimentary thickness grid merges

Section 3.4, 3D gravity inversions, introduces the ten regional 3D gravity models that are constructed to compute sediment thicknesses which are then merged into the global GST-1 model. Each model area extends 10° beyond the boundaries displayed in Figure 2a on all sides. Below, the north-south overlapping zone between Maps NWW and NW, along longitude -90° from the equator to 60°N is examined (Figure SI-3). Merged sedimentary thickness differences between the two models are 0.69% and 0.70%, respectively (Figure SI-3b and SI-3c).

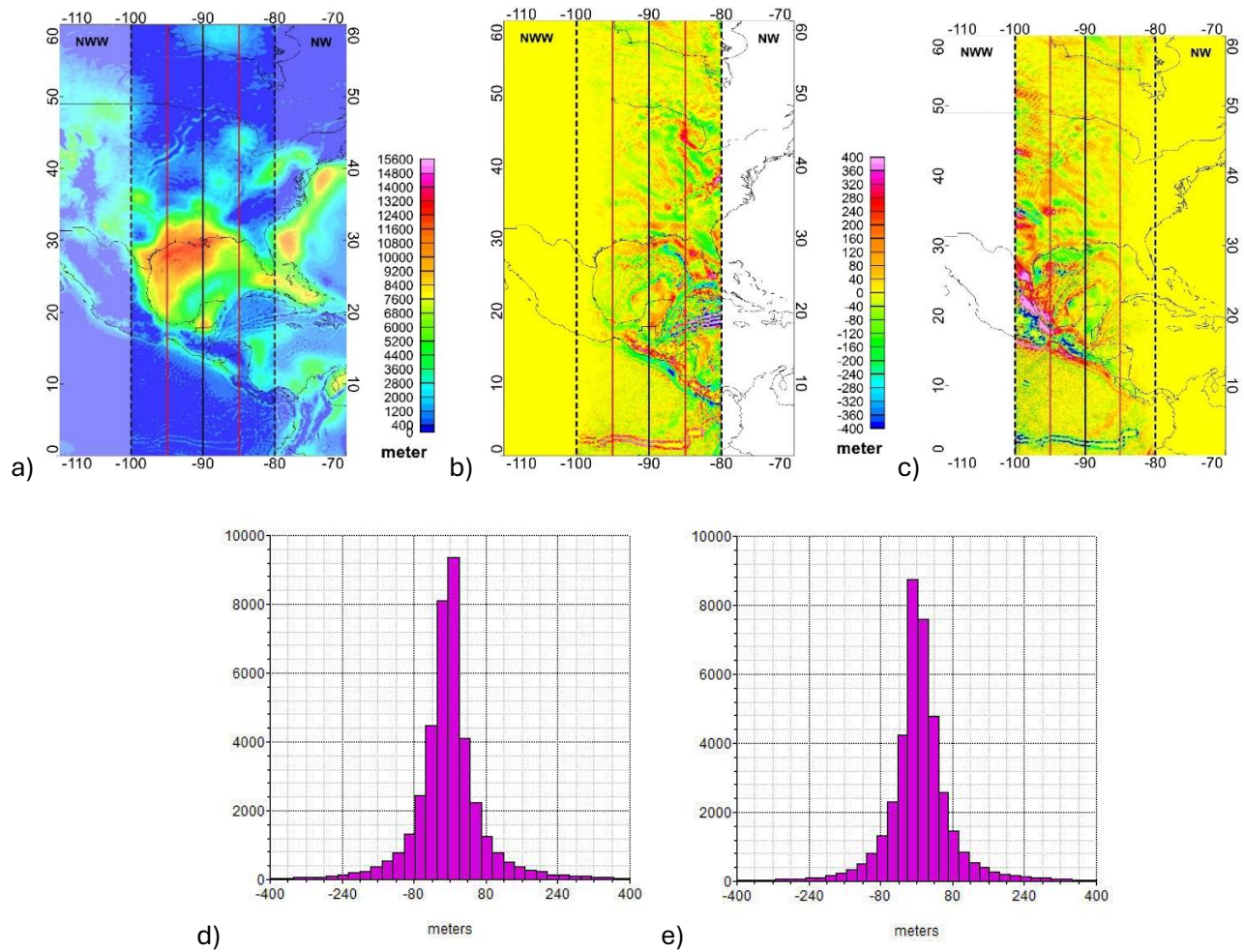


Figure SI-3. Overlapping sediment thickness models NWW and NW is an example of quantitative effects encountered when merging the ten regional modeled sediment thickness grids that make GST-1, a) Merge seam (-90°), total overlap zone (-100° to -80°), and within the 10° overlap (red lines). Maps b) and c) are sediment thickness differences between the final merge and each model (same color bar). The respective mean and standard deviations of differences between the final merged sediment thickness and sediment thicknesses from regional models NWW and NW are -1.850 and 90.757 m, and 3.588 and 91.424 m, which are d) 0.698% and e) 0.703% of the total thickness range (12997 m) in the seam zone (-95° to -85°), respectively.

Supplementary Information 4 (SI-4), Sediment thickness modeling with densities from global models ECM1 & LithoRef18

Crust and mantle layer densities from two global models, ECM1 and LithoRef18 (Afonso et al., 2019; Mooney et al., 2023), are incorporated into the three test 3D models and the GST-1 workflow is followed to calculate sediment thickness (Section 5.1.2, Crust and lithospheric models: ECM1 and LithoRef18).

SI-4.1 North America – sediment thickness calculated using ECM1 crystalline crust and upper mantle densities

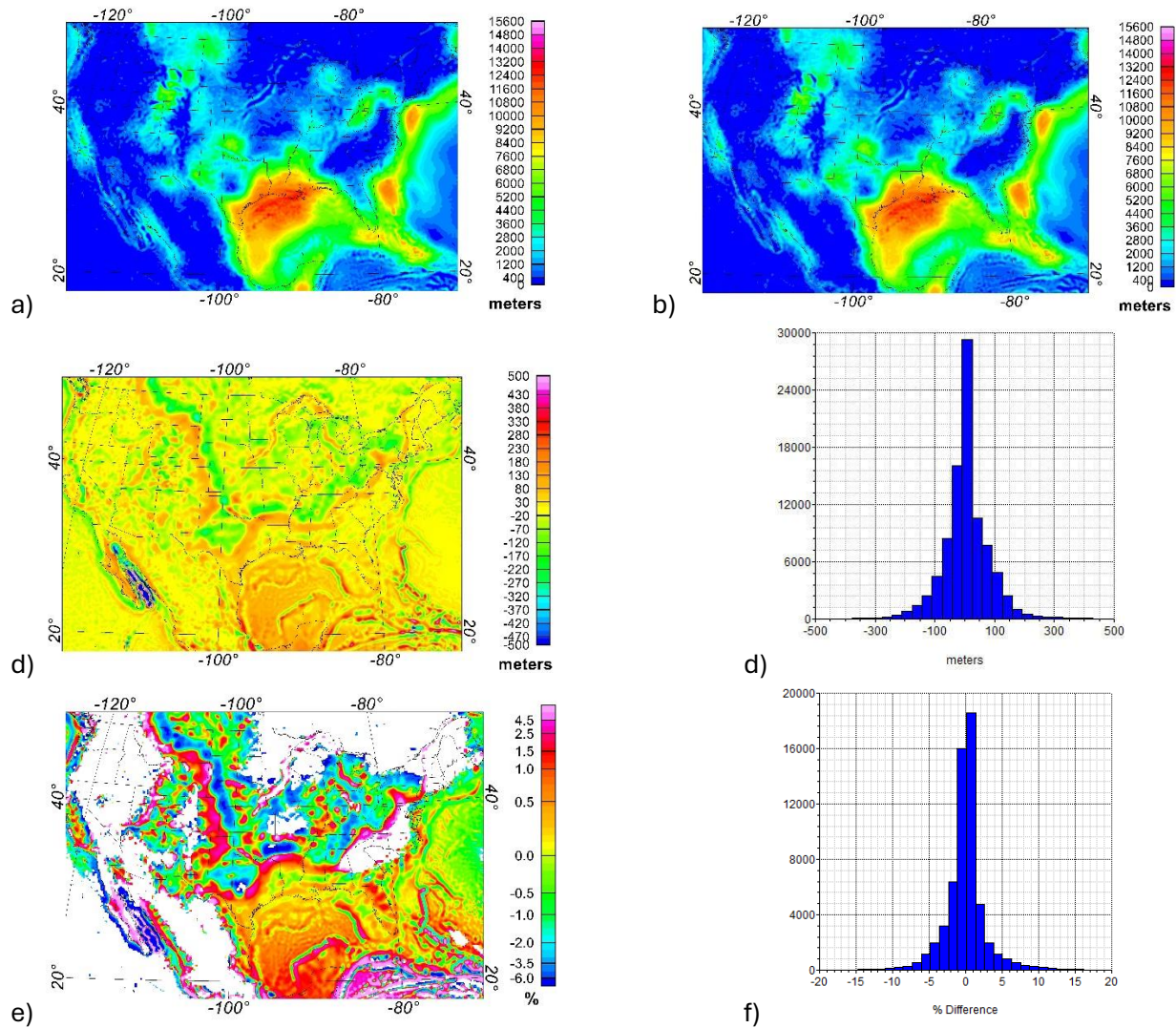


Figure SI-4.1. Comparison of sediment thickness from ECM1 model with GST-1 model, a) GST-1, b) Modeled with ECM1 crystalline crust and upper mantle densities c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are 2.5 and 93.7 m, which is a difference of 0.71%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m ($= \text{difference} / \text{total thickness}$), f) Histogram of the local difference percentage. Respective mean and standard deviation are -0.081% and 4.551%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are -0.082% and 2.725% (not displayed).

SI-4.2 Central Africa – sediment thickness calculated using ECM1 crystalline crust and upper mantle densities

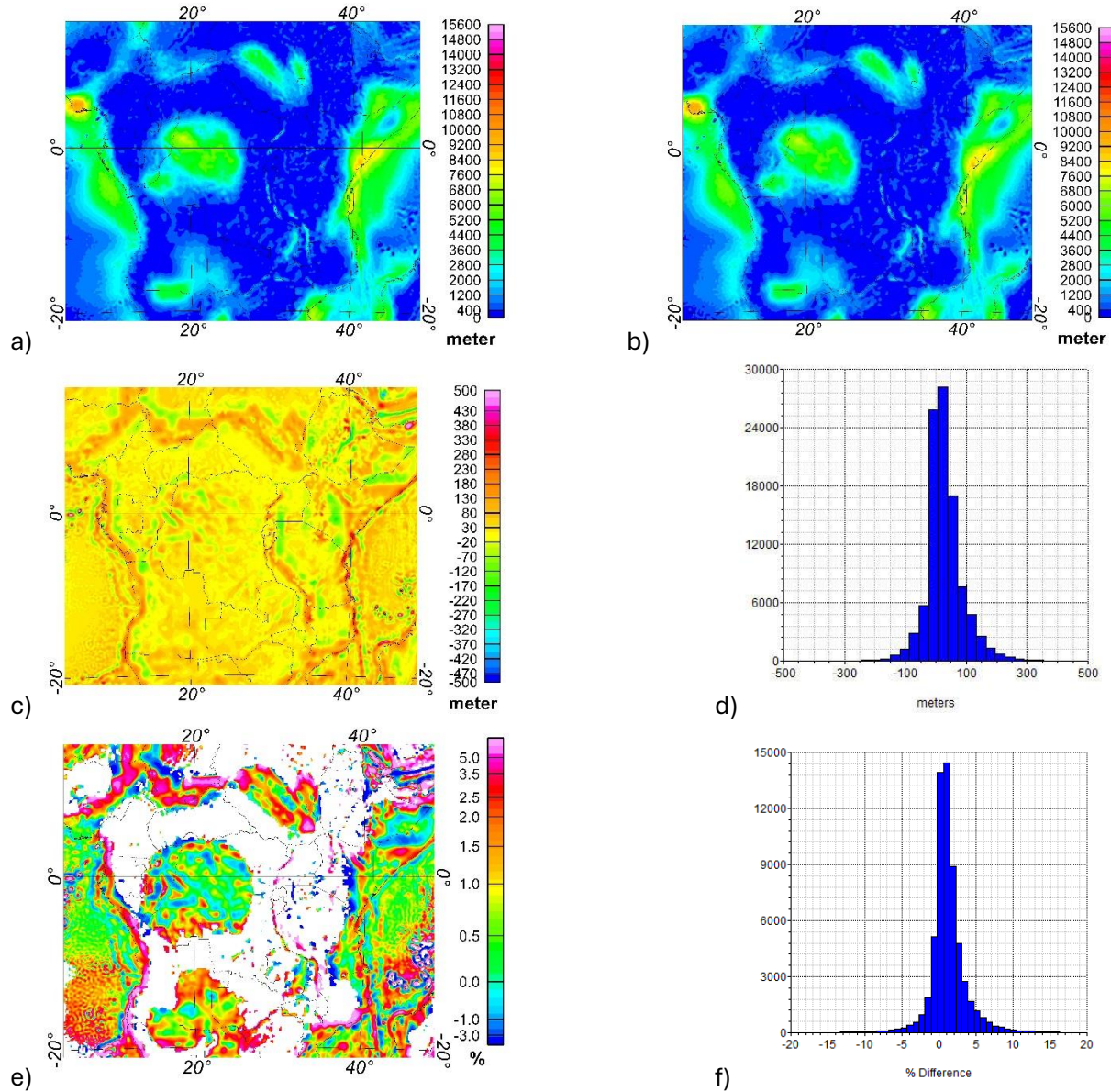


Figure SI-4.2. Comparison of sediment thickness from ECM1 model with GST-1 model, a) GST-1, b) Modeled with ECM1 crystalline crust and upper mantle densities c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are 30.3 and 61.7 m, which is a difference of 0.61%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m ($= \text{difference} / \text{total thickness}$), f) Histogram of the local difference percentage. Respective mean and standard deviation are 1.272% and 2.814%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are 0.999% and 1.757% (not displayed).

SI-4.3 Central and south Asia – sediment thickness calculated using ECM1 crystalline crust and upper mantle densities

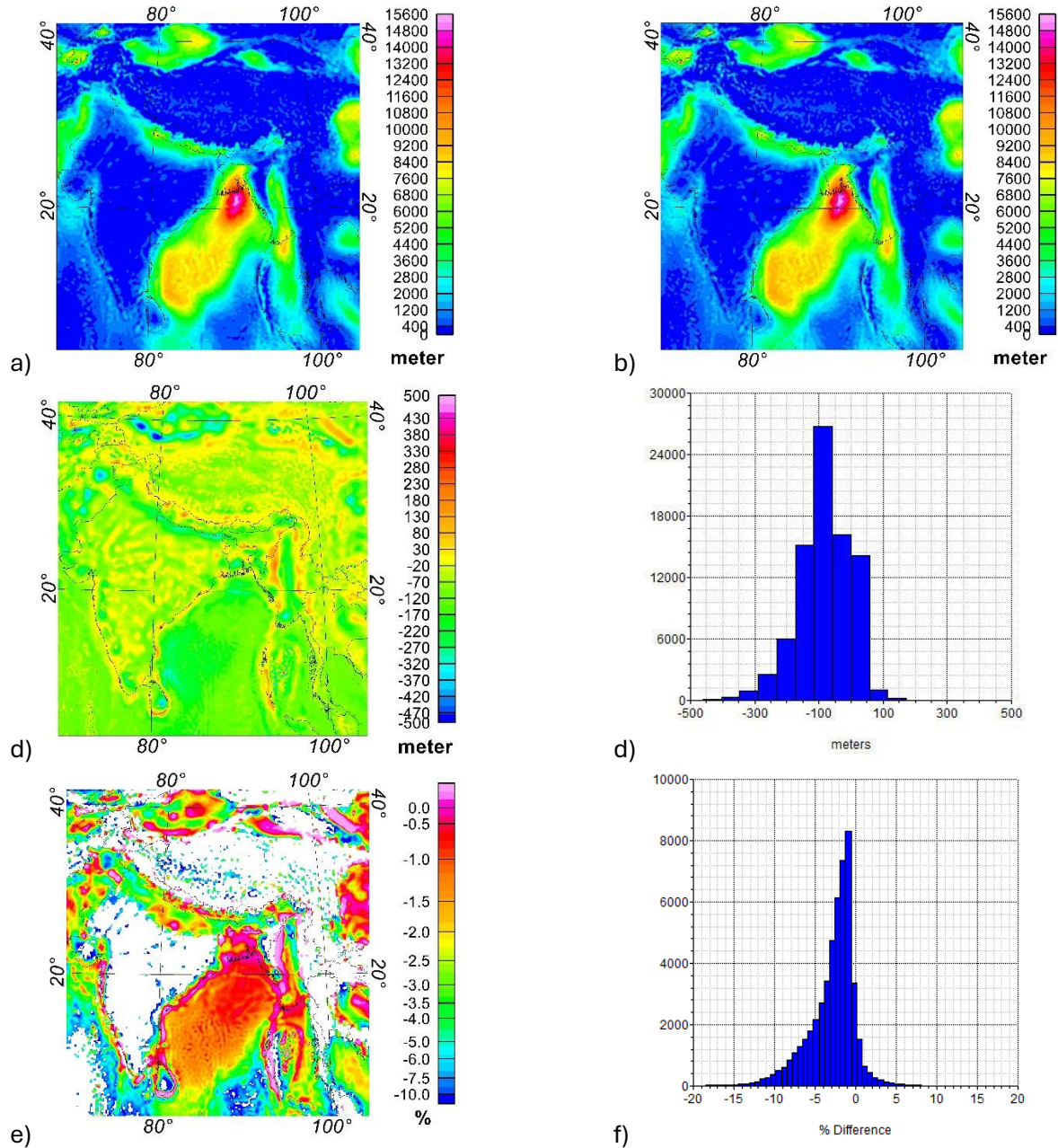


Figure SI-4.3. Comparison of sediment thickness from ECM1 model with GST-1 model, a) GST-1, b) Modeled with ECM1 crystalline crust and upper mantle densities c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are -84.7 and 78.2 m, which is a difference of 0.48%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m (= difference / total thickness), f) Histogram of the local difference percentage. Respective mean and standard deviation are -2.915% and 3.074%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are -2.071% and 1.857% (not displayed).

SI-4.4 North America – sediment thickness calculated using LithoRef18 crystalline crust and upper mantle densities

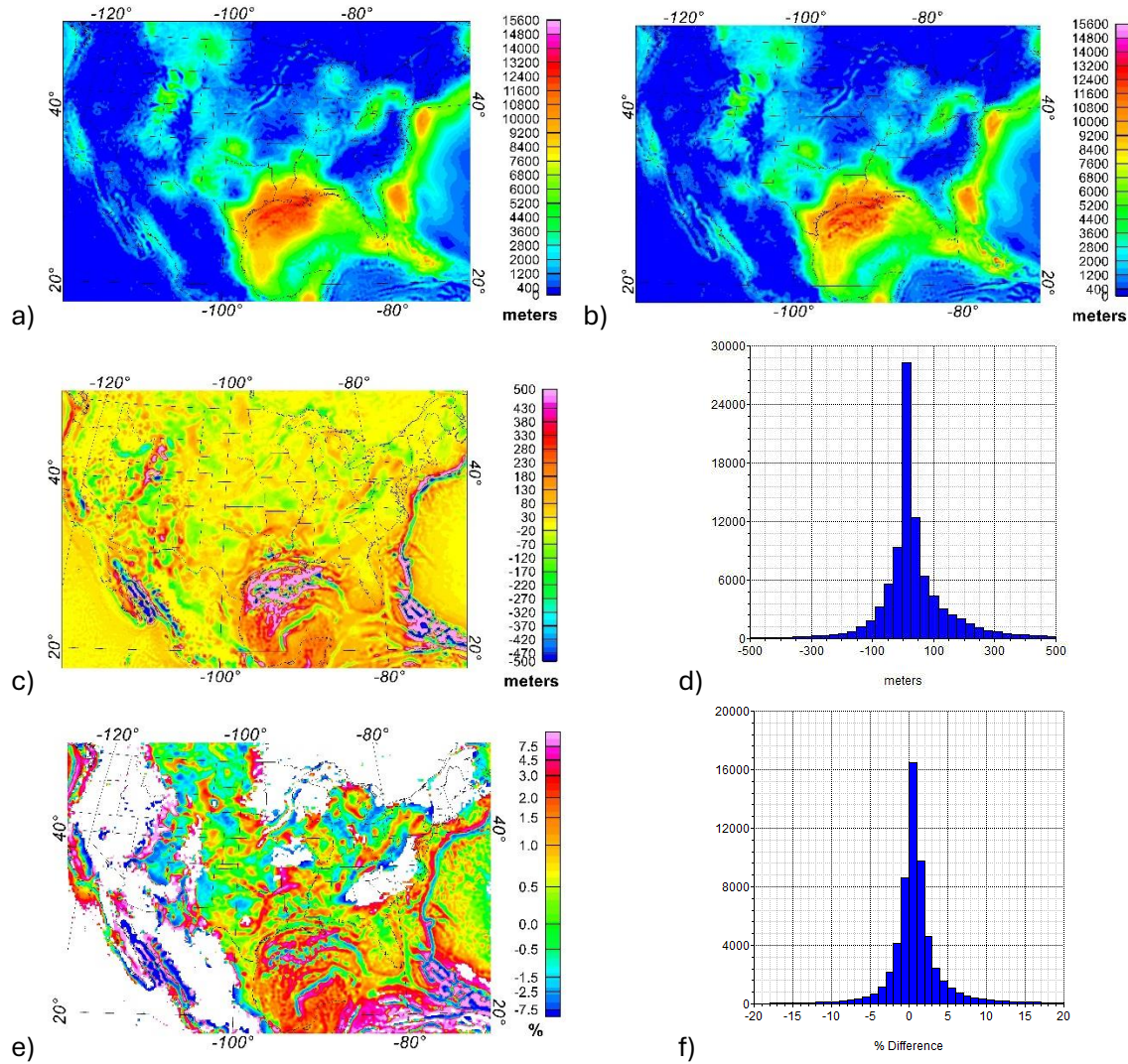


Figure SI-4.4. Comparison of sediment thickness from LithoRef18 model with GST-1 model, a) GST-1, b) Modeled with LithoRef18 crystalline crust and upper mantle densities c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are 41.1 and 200.9 m, which is a difference of 1.52%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m (= difference / total thickness), f) Histogram of the local difference percentage. Respective mean and standard deviation are 0.986% and 6.283%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are 0.739% and 4.338% (not displayed).

SI-4.5 Central Africa – sediment thickness calculated using LithoRef18 crystalline crust and upper mantle densities

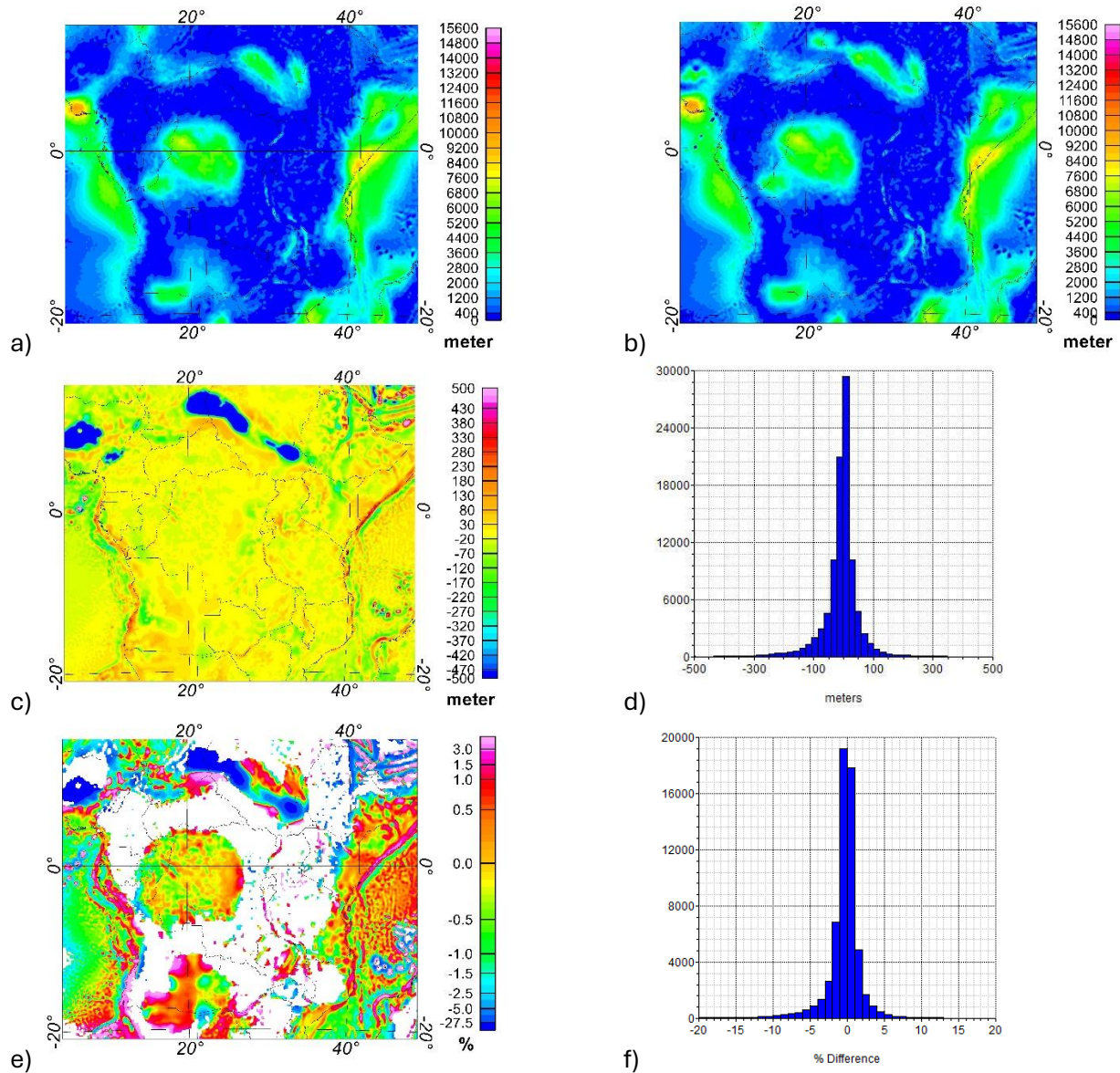


Figure SI-4.5. Comparison of sediment thickness from LithoRef18 model with GST-1 model, a) GST-1, b) Modeled with LithoRef18 crystalline crust and upper mantle densities c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are 30.3 and 61.7 m, which is a difference of 0.61%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m (= difference / total thickness), f) Histogram of the local difference percentage. Respective mean and standard deviation are -2.180% and 12.009%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are -1.871% and 10.909% (not displayed).

SI-4.6 Central and south Asia – sediment thickness calculated using LithoRef18 crystalline crust and upper mantle densities

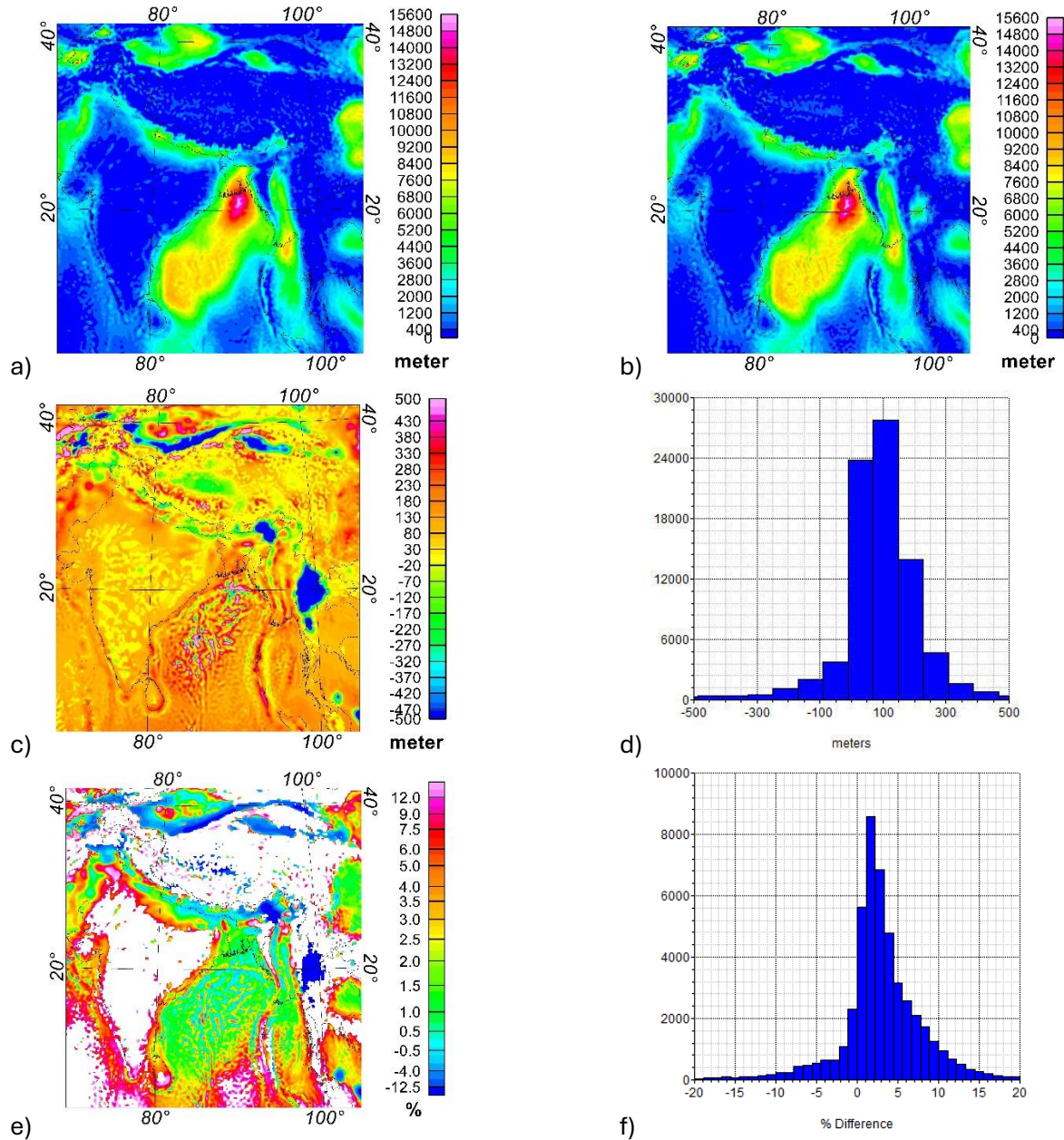


Figure SI-4.6. Comparison of sediment thickness from LithoRef18 model with GST-1 model, a) GST-1, b) Modeled with LithoRef18 crystalline crust and upper mantle densities c) Difference between the two models, and d) Histogram of the difference. Respective mean and standard deviation are -84.7 and 78.2 m, which is a difference of 0.48%, e) Local difference between the two models for an average sediment thickness (both models) greater than 500 m ($= \text{difference} / \text{total thickness}$), f) Histogram of the local difference percentage. Respective mean and standard deviation are 2.129% and 11.058%. For an average sediment thickness greater than 1000 m, the respective mean and standard deviation are 1.166% and 8.725% (not displayed).

Supplementary Information 5 (SI-5), Examinations of deep layer densities and density contrasts in North America

Layer densities in the model vary smoothly over the North American test area, exhibiting average lateral gradients 0.07 and 0.06 g/cm³, respectively for crystalline crust and upper mantle layers. Density contrasts at layer boundaries, basement and base of crust, are larger and effectively drive GST-1 gravity inversions (Section 5.1.3, Density layers and density contrasts).

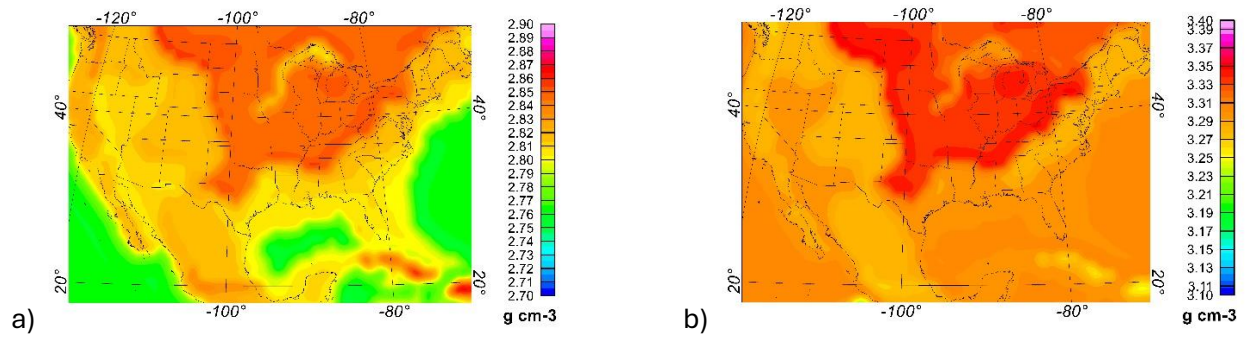


Figure SI-5.1. ECM1 layer densities, a) average crystalline crust, b) upper mantle.

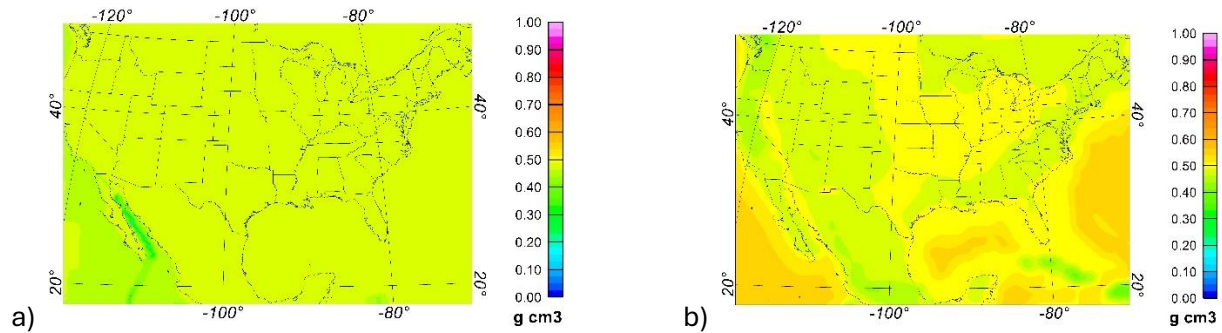


Figure SI-5.2. Base of crystalline crust density contrasts, a) GST-1, b) ECM1.

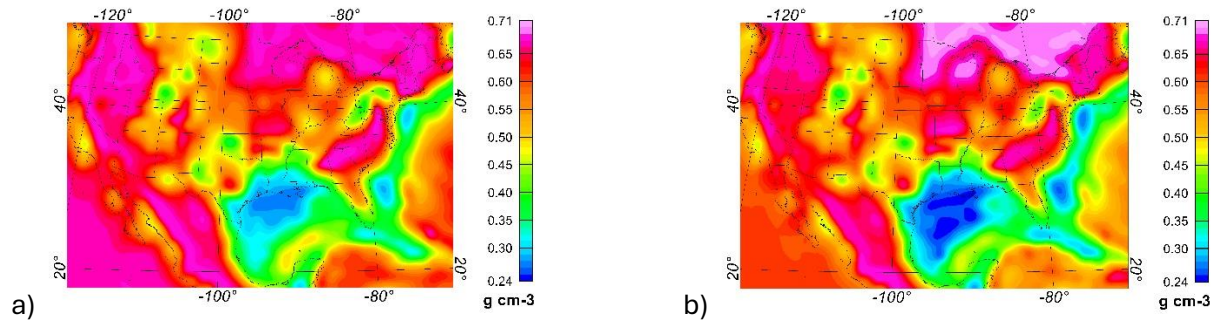
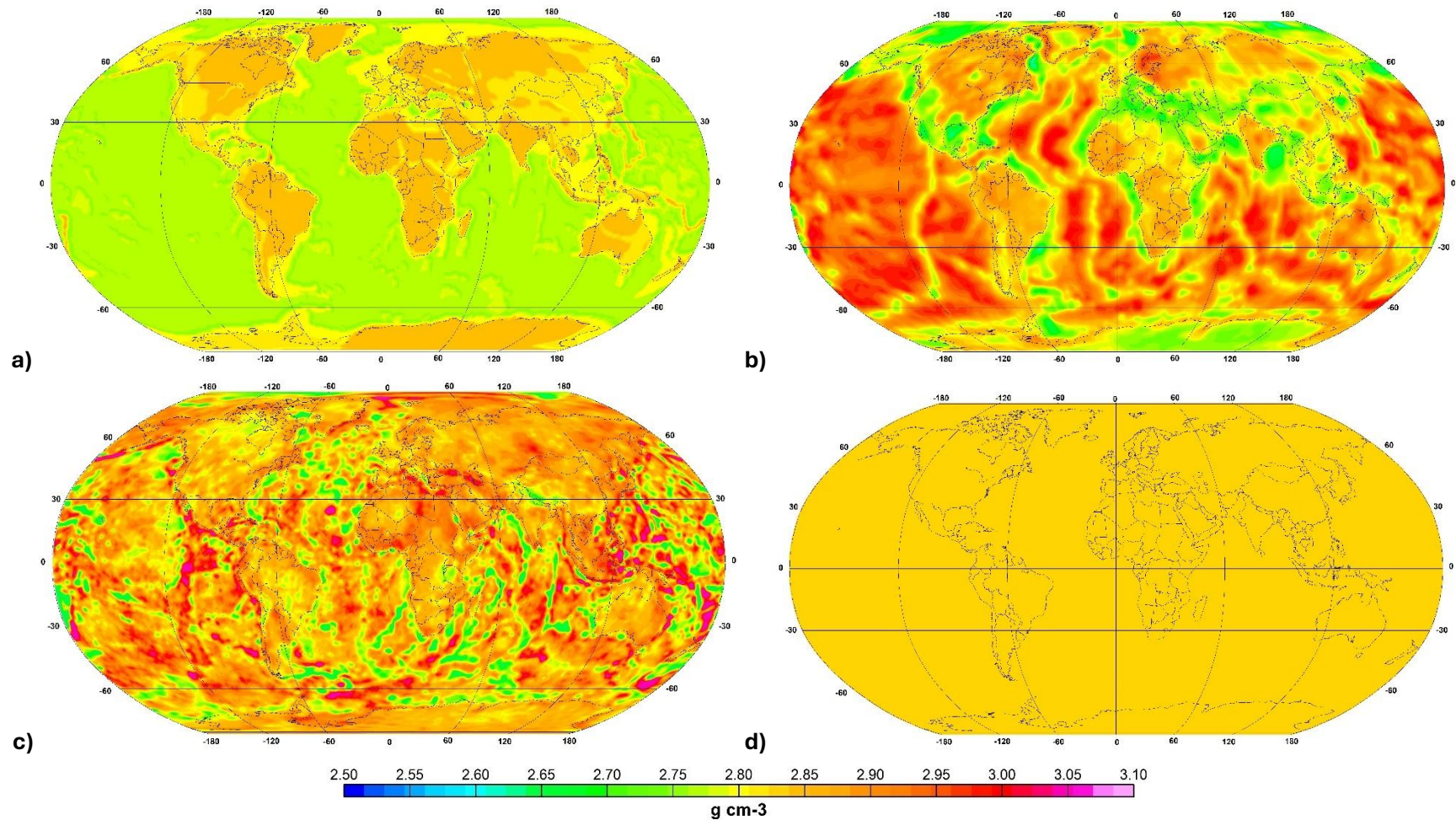


Figure SI-5.3. Basement density contrasts, a) GST-1, b) ECM1.

Supplementary Information 6 (SI-6), Comparisons of global crust and mantle densities

Crystalline crust and upper mantle densities have been proposed by different researchers (Afonso et al., 2019; Fullea et al., 2021; Mooney et al., 2023). These models are important in the effort to understand deep earth processes; however, in light of our results to refined relatively shallow basement geometries, integrating these into our workflow doesn't matter (Section 5.1.3, Density layers and density contrasts).



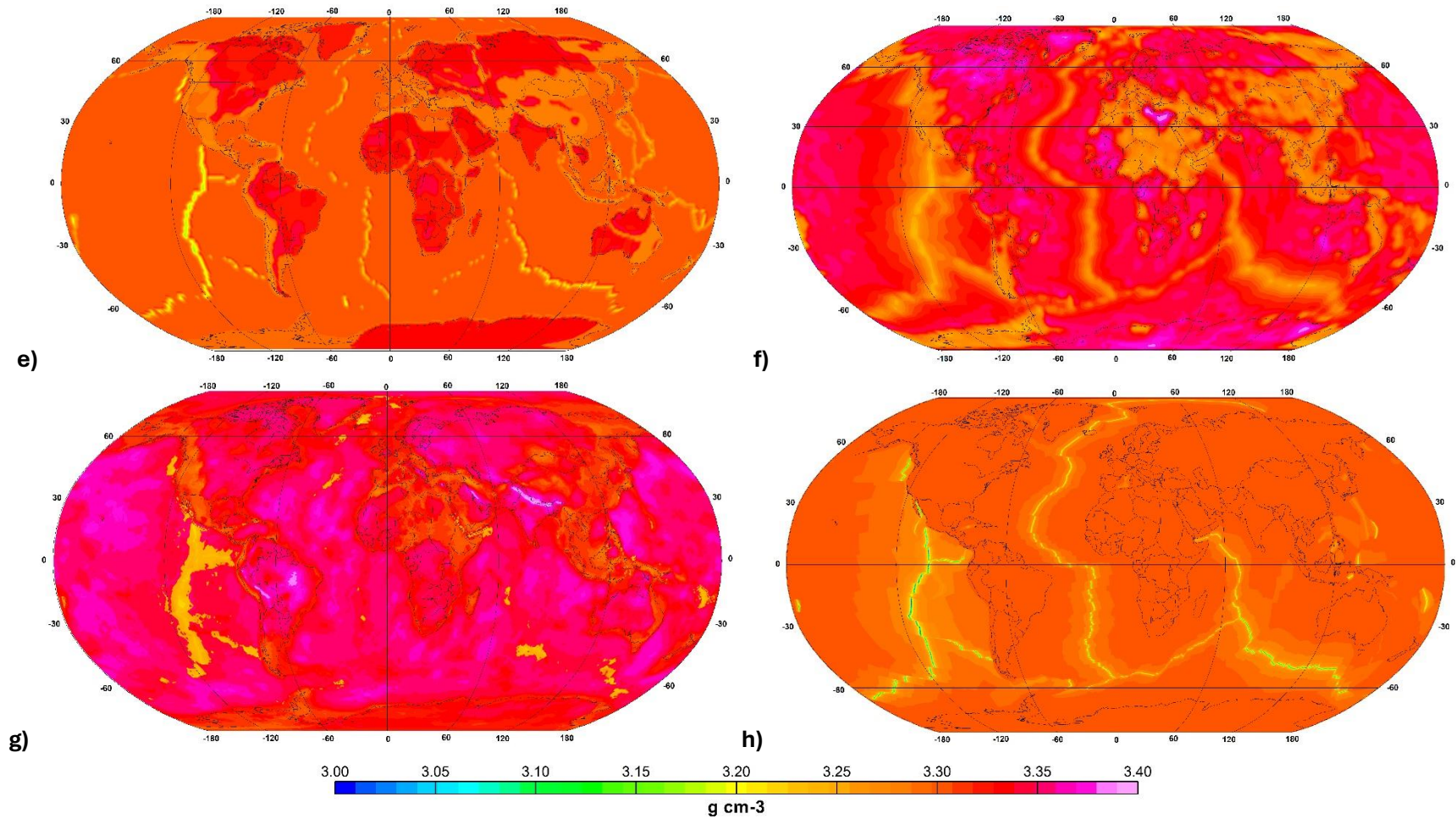


Figure SI-6. Global crust and mantle densities. Crust density models, a) ECM1, b) LithoRef18, c) WINTERC-G, and d) GST-1; upper mantle density models, e) ECM1, f) LithoRef18, g) WINTERC-G, and h) GST-1. Two color bars show the range of density for crust and mantle layers.