Supplement Table 1: Comparison of Load Love Numbers h_l, k_l, and l_l Between CitcomSVE and Semi-Analytical Solutions and the corresponding errors.

case	h(0)	k(0)	|l(0)|	h(40)	k(40)	|l(40)|	ε_{ha}	ε_{ka}	ε_{la}	ε_{hd}	ε_{kd}
Analytic_l1	-1.2543	-1.0000	0.8866	-1.4964	-1.0000	1.9090					
l1m0_R1	-1.2527	-1.0000	0.8869	-1.4943	-1.0000	1.9171	1.37E-03	2.00E-06	2.67E-03	3.99E-04	5.56E-05
l1m0_R2	-1.2548	-1.0000	0.8859	-1.4967	-1.0000	1.9115	2.29E-04	1.00E-06	8.68E-04	1.01E-04	1.50E-05
l1m0_R3	-1.2547	-1.0000	0.8846	-1.4968	-1.0000	1.9105	2.66E-04	0.00E+00	5.10E-04	4.39E-05	6.58E-06
l1m0_R4	-1.2546	-1.0000	0.8864	-1.4968	-1.0000	1.9101	2.91E-04	0.00E+00	4.00E-04	2.50E-05	3.94E-06
Analytic_l2	-0.9577	-0.3041	0.0200	-2.4066	-0.9396	0.8216					
l2m0_R1	-0.9549	-0.3037	0.0201	-2.4000	-0.9373	0.8305	2.43E-03	1.91E-03	7.19E-03	3.64E-04	4.13E-04
l2m0_R2	-0.9578	-0.3039	0.0202	-2.4060	-0.9388	0.8242	1.24E-04	4.98E-04	2.19E-03	9.54E-05	1.04E-04
l2m0_R3	-0.9585	-0.3042	0.0200	-2.4064	-0.9391	0.8232	1.79E-04	2.51E-04	1.38E-03	4.25E-05	4.61E-05
l2m0_R4	-0.9574	-0.3038	0.0203	-2.4066	-0.9392	0.8229	2.30E-04	1.85E-04	1.10E-03	2.30E-05	2.65E-05
Analytic_l2m1	-0.3058	1.0944	0.1118	0.6151	2.1973	0.1884					
l2m1_R1	-0.3094	1.0836	0.1103	0.5583	2.1294	0.1653	7.10E-02	2.08E-02	8.97E-02	8.10E-03	5.82E-04
l2m1_R2	-0.3063	1.0925	0.1116	0.6077	2.1885	0.1847	1.01E-02	2.89E-03	1.46E-02	1.07E-03	6.46E-05
l2m1_R3	-0.3100	1.0900	0.1111	0.6144	2.1964	0.1878	1.78E-03	4.93E-04	3.08E-03	8.14E-04	6.37E-05
l2m1_R4	-0.3056	1.0948	0.1118	0.6178	2.2003	0.1891	2.99E-03	7.52E-04	2.34E-03	4.99E-04	3.60E-05
Analytic_l4	-1.0251	-0.1342	0.0568	-4.4402	-0.9416	0.3411					
l4m0_R1	-1.0194	-0.1341	0.0565	-4.4105	-0.9339	0.3480	6.18E-03	7.58E-03	1.25E-02	3.70E-04	1.42E-03
l4m0_R2	-1.0254	-0.1343	0.0569	-4.4354	-0.9397	0.3432	9.21E-04	1.94E-03	3.60E-03	9.21E-05	3.58E-04
l4m0_R3	-1.0253	-0.1342	0.0569	-4.4384	-0.9407	0.3425	3.29E-04	9.63E-04	2.29E-03	4.22E-05	1.58E-04
l4m0_R4	-1.0247	-0.1341	0.0569	-4.4395	-0.9410	0.3423	1.25E-04	6.08E-04	1.89E-03	2.39E-05	9.24E-05
Analytic_l8	-1.2376	-0.0772	0.0302	-8.8405	-0.9605	0.0958					
l8m4_R1	-1.2172	-0.0767	0.0301	-8.5145	-0.9171	0.1048	3.09E-02	3.94E-02	3.54E-02	6.22E-04	4.94E-03
l8m4_R2	-1.2354	-0.0772	0.0302	-8.7607	-0.9492	0.0980	7.26E-03	1.01E-02	8.95E-03	1.60E-04	1.21E-03
l8m4_R3	-1.2359	-0.0771	0.0304	-8.7960	-0.9544	0.0977	3.85E-03	5.29E-03	8.55E-03	7.12E-05	5.91E-04
l8m4_R4	-1.2372	-0.0772	0.0303	-8.8084	-0.9563	0.0977	2.63E-03	3.56E-03	8.50E-03	4.21E-05	3.02E-04
Analytic_l16	-1.6868	-0.0574	0.0229	-17.8470	-0.9726	0.0479					
l16m8_R1	-1.5913	-0.0544	0.0225	-15.0636	-0.7883	0.0329	1.39E-01	1.74E-01	2.55E-01	1.00E-03	2.05E-02
l16m8_R2	-1.6660	-0.0568	0.0228	-17.0264	-0.9179	0.0418	3.88E-02	4.92E-02	9.26E-02	2.52E-04	4.86E-03
l16m8_R3	-1.6781	-0.0572	0.0228	-17.3994	-0.9437	0.0430	2.06E-02	2.54E-02	7.45E-02	1.12E-04	2.14E-03
l16m8_R4	-1.6825	-0.0573	0.0228	-17.5347	-0.9530	0.0435	1.40E-02	1.69E-02	6.71E-02	6.60E-05	1.20E-03
l16m8_R5	-1.6805	-0.0572	0.0228	-17.6230	-0.9579	0.0464	1.04E-02	1.31E-02	2.26E-02	6.50E-05	1.33E-03

ε_{ha}, ε_{ka}, and ε_{la} are amplitude errors for Love numbers h, k, and l, respectively. ε_{hd} and ε_{kd} are dispersion errors for Love numbers h and k, respectively.

Supplement Table 2: Maximum errors in modeled RSL from different cases compared to the reference case (K3) among an ensemble of semi-analytical calculations with a wide range of viscosity models

	North America[a]	Fennoscandia	Far Field
K1[c]	6.54% (22.8 m)[b]	4.81% (10.0 m)	4.69% (10.6 m)
AS1	4.53% (23.2 m)	4.89% (11.0 m)	2.97% (2.7 m)
AS2	0.49% (4.5 m)	0.32% (0.8 m)	0.19% (0.4 m)

a. "North America", "Fennoscandia", and "Far Field" are regions with groups of sites used in calculating RSL. The numbers of sites are 18, 12, and 36 for North America, Fennoscandia, and Far Field, respectively. The North American and Fennoscandian sites are from (Peltier et al., 2015). The far-field sites are from (Lambeck et al., 2014).

b. The relative error in modeled RSL for each site is defined as $\epsilon_i = \frac{\int_0^T |RSL_{x,i}(t) - RSL_{K3,i}(t)|dt}{\int_0^T |RSL_{K3,i}(t)|dt}$, where $RSL_{x,i}$ is modeled RSL at site i for case K1, AS1, or AS2, and $RSL_{K3,i}$ is for the reference case K3. The regionally averaged relative error is defined as the average error among all sites within each region, i.e.,$\Sigma\epsilon_i/N$, where ϵ_i is the error for each site i and N is the total number of sites within each region. The numbers out of parenthesis represent the maximum region-averaged relative error among the 806 calculations of varying mantle viscosity. The numbers inside parenthesis represent the maximum absolute error (i.e., $\max(|RSL_x(t) - RSL_{K3}(t)|)$ among all time periods t and all sites in each region from those 806 calculations of varying mantle viscosity. Those numbers measure the maximum possible error for each case among reasonable mantle viscosity structures.

c. The meaning of case K1, AS1, and AS2 can be found from the main text.

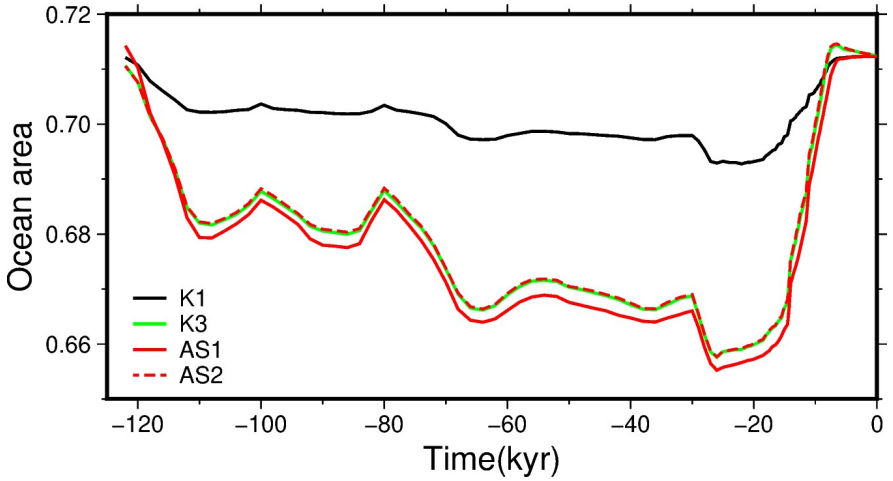

Figure S1. Normalized ocean areas determined from the ocean functions from four different semi-analytical calculations: K1, K3, AS1, and AS2.). Calculation K3, the reference case, represents the convergent solutions after the third outer iteration based on the algorithm from Kendall et al., (2005), while K1 is that after the first outer iteration. AS1 represents the first outer iteration based on the pre-calculated ocean functions determined assuming rigid Earth, and AS2 is the second outer iteration with updated ocean functions and initial topography following AS1.

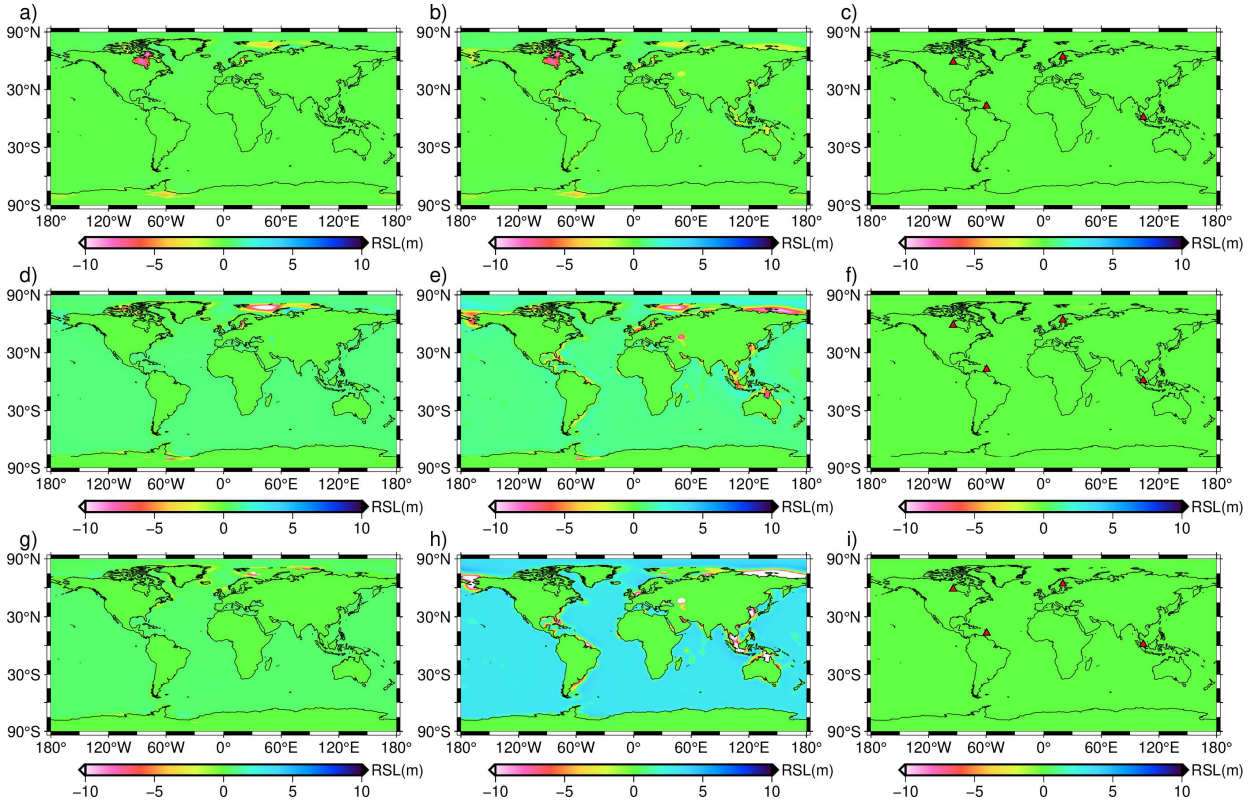

Figure S2. Comparison of modeled relative sea level (RSL) at 5 kybp (the top row), 10 kybp (the middle row), and 15 kybp (the bottom row) among four different semi-analytic calculations: K1, K3, AS1 and AS2. Shown here are the differences (or the errors) in RSL to reference case K3 from AS1 (the left column, a, d, and g), K1 (the middle column, b, e and h), and AS2 (the right column, c, f, and i), respectively. The difference (or error) at a given time is defined as $(RSL_x - RSL_{\mathrm{K3}}) \cdot O_x$, where x is AS1, K1, or AS2, O_x is the ocean function. Note that RSL is only meaningful for ocean regions (including coastlines), since RSL records at one site can exist only if this site is ocean for that time period. The red triangles in the last column represent sites in Figure S3. Note the ice model and viscosity model used are ICE6G and VM5a.

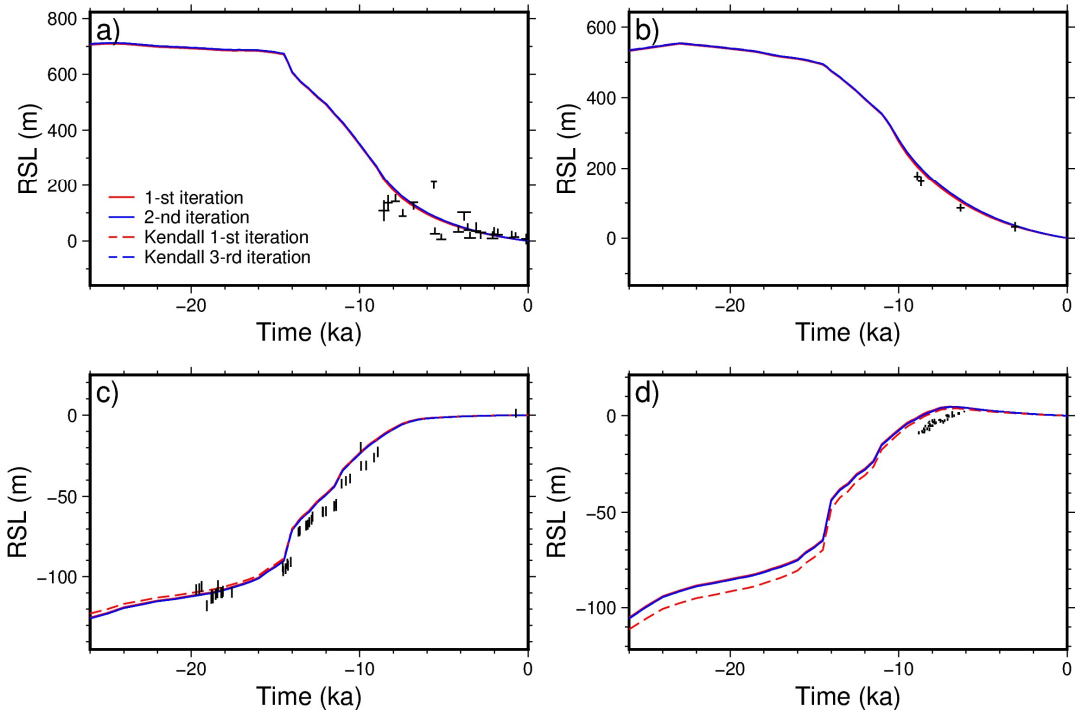

Figure S3. Comparison of modeled RSL curves at four sites from four semi-analytic calculations (AS1, K1, AS2, and K3 as in Figure S1): Churchill (Hudson Bay) (a), Vasterbotten (b), Barbados (c), and Geylang (d) (i.e., same sites as in Figure 6 where their longitudes and latitudes are given). The locations of those four sites are also shown in Figure S2. Case AS1 is represented by the red solid lines (labeled as "1-st iteration"), case K1 is the red dash lines ("Kendall 1-st iteration"), case AS2 is the blue solid line ("2-nd iteration"), and the standard case K3 is the blue dash line ("Kendall 3-rd iteration"). The symbols represent the observed RSL changes.

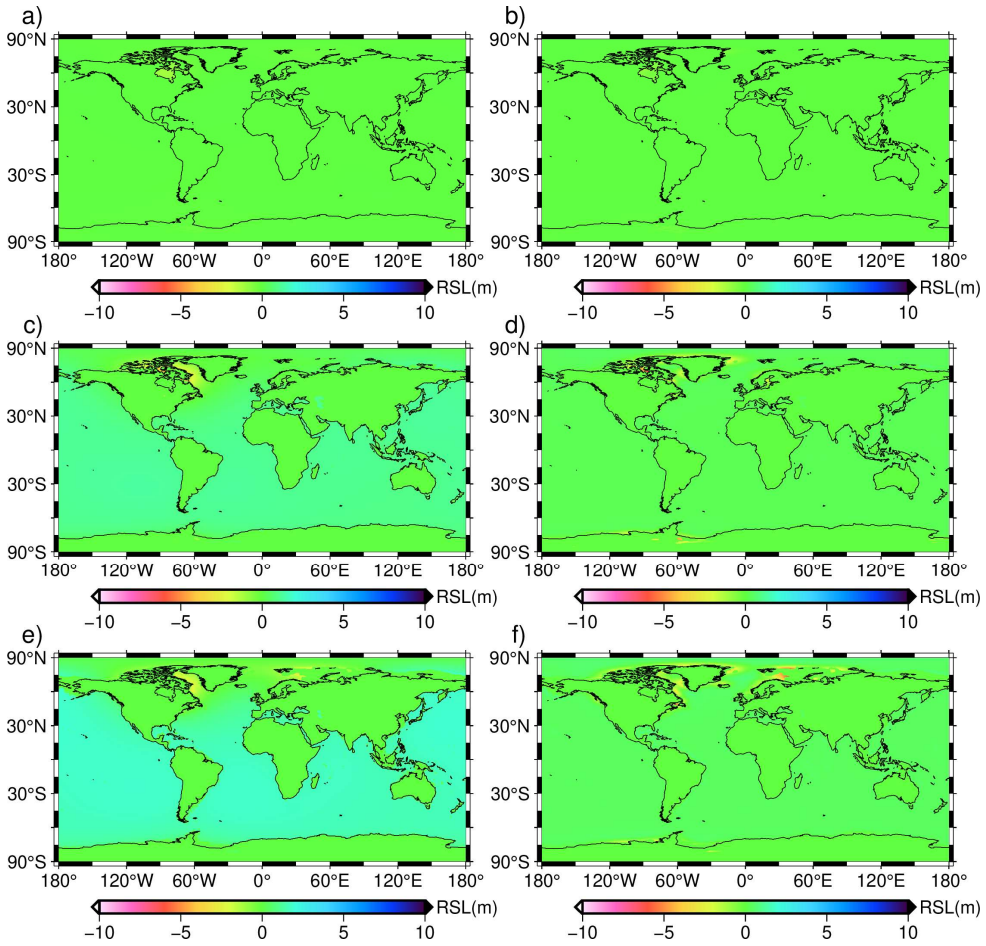

Figure S4. The RSL differences to calculation K3 from calculation AS1, or $(RSL_{AS1} - RSL_{\mathrm{K3}}) \cdot O_{AS1}$, for the case with an extremely strong mantle (the left column, a, c, and e for 5 kybp, 10 kybp and 15 kybp, respectively), and the case with an extremely weak mantle (the right column, b, d, and f for 5 kybp, 10 kybp and 15 kybp, respectively). Note that the pre-calculated ocean functions for both cases are constructed assuming a “rigid Earth”.

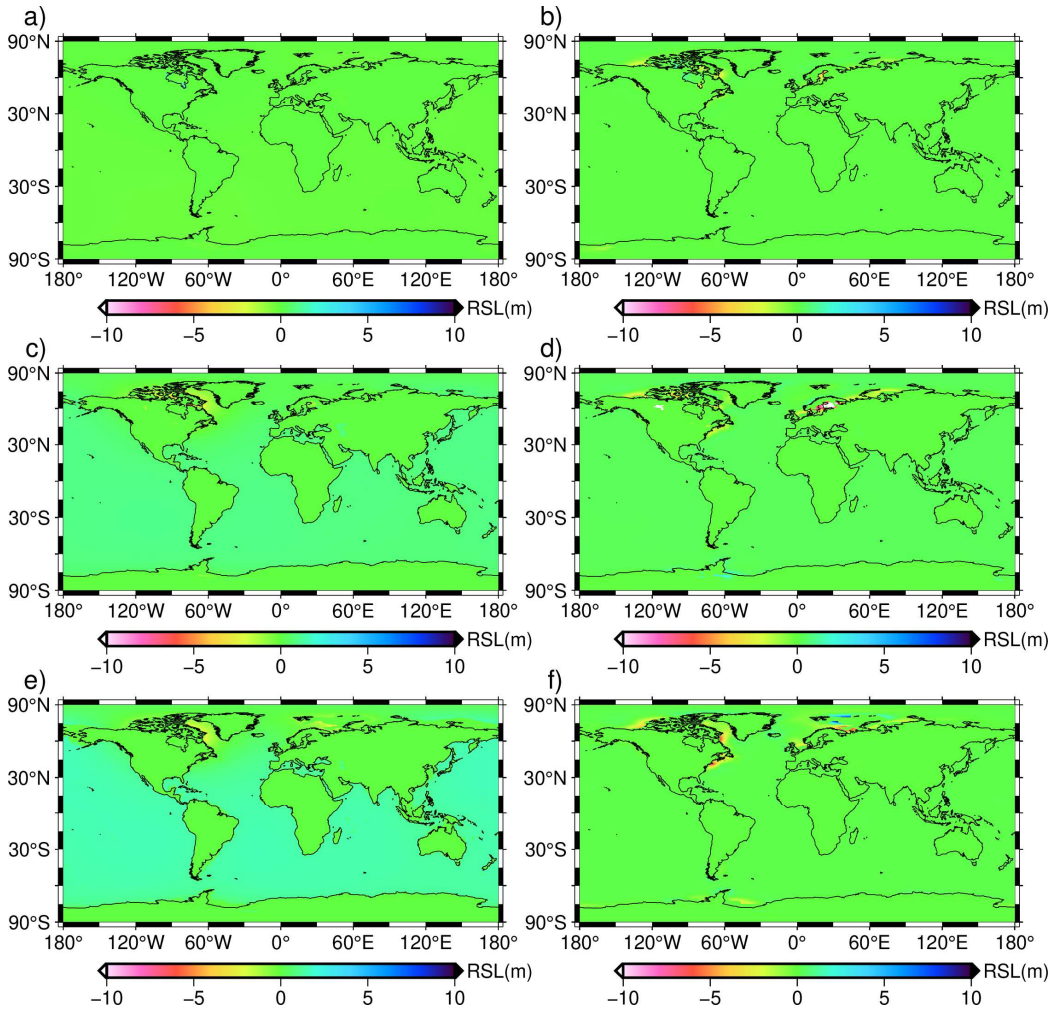

Figure S5. The same as in Figure S4, except for using different pre-calculated ocean functions. The RSL differences to calculation K3 from calculation AS1, or $(RSL_{AS1} - RSL_{\mathrm{K3}}) \cdot O_{AS1}$, for the case with an extremely strong mantle (the left column, a, c, and e for 5 kybp, 10 kybp and 15 kybp, respectively), and the case with an extremely weak mantle (the right column, b, d, and f for 5 kybp, 10 kybp and 15 kybp, respectively). The pre-calculated ocean functions for both cases are constructed from the convergent solutions (i.e., with three outer iterations) using Kendall et al., (2005) for a reference viscosity model (i.e., 100-km thick lithosphere overlying the mantle with uniform viscosity of 10^{21} Pas). Note that the reference viscosity model is only used for constructing the pre-calculated ocean functions.

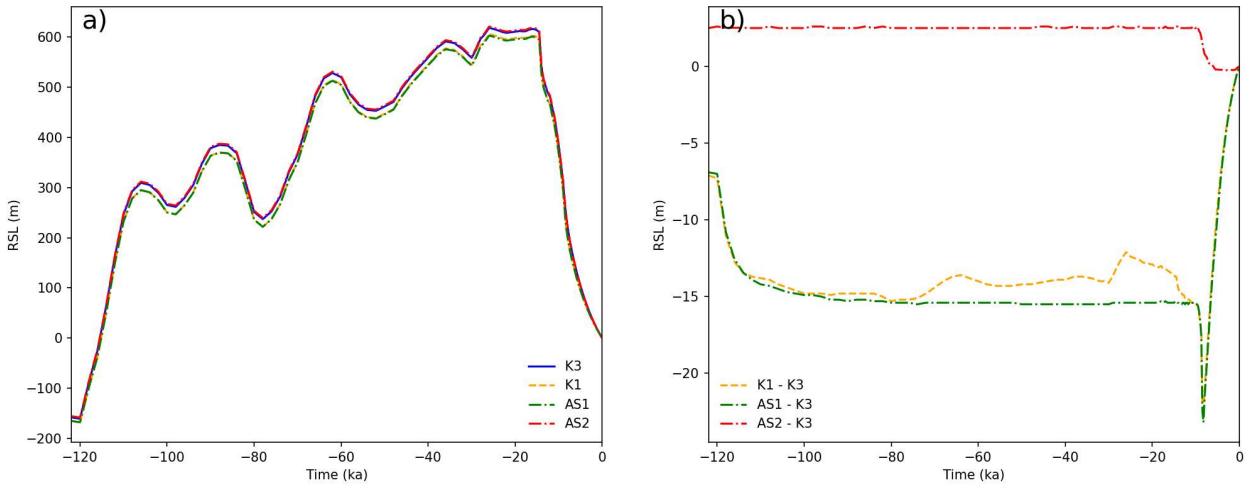

Figure S6. The modeled RSL (a) for calculations for the site and the viscosity model that yields the maximum absolute error presented in Supplement Table 2 (i.e. 23.20 m, the maximum absolute error for AS1 in North America). (b) shows the differences in RSL between K1, AS1, and AS2 to the reference case K3 for that site and viscosity model. The site is Churchill, and the mantle viscosities are 1.26×10^{20} Pas and 1.26×10^{23} Pas for upper and lower mantle, respectively.