

Supplementary information, figures, and tables

”High-resolution Neogene and Quaternary estimates of Nubia-Eurasia-North America plate motion”

by C. DeMets, G. Iaffaldano, and S. Merkouriev

Contents

The supplementary documents include two figures and four formatted tables within this PDF file and fourteen separate text files with information that complements the material in the primary manuscript. Text files with all of the magnetic reversal, fracture zone, and transform fault crossings that were inverted by Merkouriev & DeMets (2014*ab*) to determine best-fitting Eurasia-North America and Nubia-North America finite rotations are included, as are text files with all of the noise-reduced finite and stage rotations that were derived and used for the analysis. Each text file has header information to explain the file contents.

List of text file contents

1. *EuNa_RvrslXings.txt*: Crossings of 21 magnetic reversals that were used by Merkouriev & DeMets (2014*a*) to estimate Eurasia-North America finite rotations. More information is given in the file header.
2. *EuNa_FZ_Xings.txt*: Crossings of fracture zones that were used by Merkouriev & DeMets (2014*a*) to estimate Eurasia-North America finite rotations. More information is given in the file header.
3. *EuNa_TF_Xings.txt*: Crossings of transform faults that were used by Merkouriev & DeMets (2014*a*) to estimate Eurasia-North America finite rotations. More information is given in the file header.
4. *NbNa_RvrslXings.txt*: Crossings of 21 magnetic reversals used by Merkouriev & DeMets (2014*b*) to estimate Nubia-North America finite rotations. More information is given in the file header.
5. *NbNa_FZ_Xings.txt*: Crossings of fracture zones that were used by Merkouriev & DeMets (2014*b*) to estimate Nubia-North America finite rotations. More information is given in the file header.
6. *NbNa_TF_Xings.txt*: Crossings of transform faults that were used by Merkouriev & DeMets (2014*b*) to estimate Nubia-North America finite rotations. More information is given in the file header.
7. *table_1_Eu_Na_frt.txt*: Eurasia-North America finite rotations and covariances from the RED-BACK analysis of the original best-fitting rotation sequence from Merkouriev & DeMets (2014*a*). Table 1 in this supplementary document lists the same rotations and their covariances along with additional necessary information about the rotation sequence.

8. *table_2_Eu_Na_sav.txt*: Eurasia-North America stage angular velocities and covariances output from the REDBACK analysis of the original best-fitting rotation sequence from Merkuriev & DeMets (2014a). Table 2 in this supplementary document lists the same rotations and their covariances along with additional necessary information about the rotation sequence.
9. *table_3_Nb_Na_frt.txt*: Nubia-North America finite rotations and covariances from the REDBACK analysis of the original best-fitting rotation sequence from Merkuriev & DeMets (2014b). Table 3 in this supplementary document lists the same rotations and their covariances along with additional necessary information about the rotation sequence.
10. *table_4_Nb_Na_sav.txt*: Nubia-North America stage angular velocities and covariances output from the REDBACK analysis of the original best-fitting rotation sequence from Merkuriev & DeMets (2014b). Table 4 in this supplementary document lists the same rotations and their covariances along with additional necessary information about the rotation sequence.
11. *table_5_Nb_Eu_frt.txt*: Nubia-Eurasia finite rotations and covariances as described and given in Table 1 of the primary document.
12. *table_6_Nb_Eu_sav.txt*: Nubia-Eurasia stage angular velocities and covariances as described and given in Table 2 of the primary document.
13. *EuNa_RDB_input_parameters.txt*: This file lists the input parameters to REDBACK that were used to determine the Eurasia-North America rotations in Tables 1 and 2 of this document.
14. *NbNa_RDB_input_parameters.txt*: This file lists the input parameters to REDBACK that were used to determine the Nubia-North America rotations in Tables 3 and 4 of this document.

REDBACK analysis graphics

Figures S1 and S2 show the primary outcomes from our REDBACK analyses of the best-fitting Eurasia-North America and Nubia-North America finite rotations. from Table 2 of Merkuriev & DeMets (2014ab). The REDBACK input parameters that created these results are found in the supplementary files named "EuNa_RDB_input_parameters.txt" and "NbNa_RDB_input_parameters.txt". Descriptions of the diagnostics shown in both figures and interpretations thereof are provided in the extensive documentation provided with the REDBACK software. Interested readers are referred to Iaffaldano *et al.* (2014), to "www.earth.org.au/codes/REDBACK", and to G. Iaffaldano for further information.

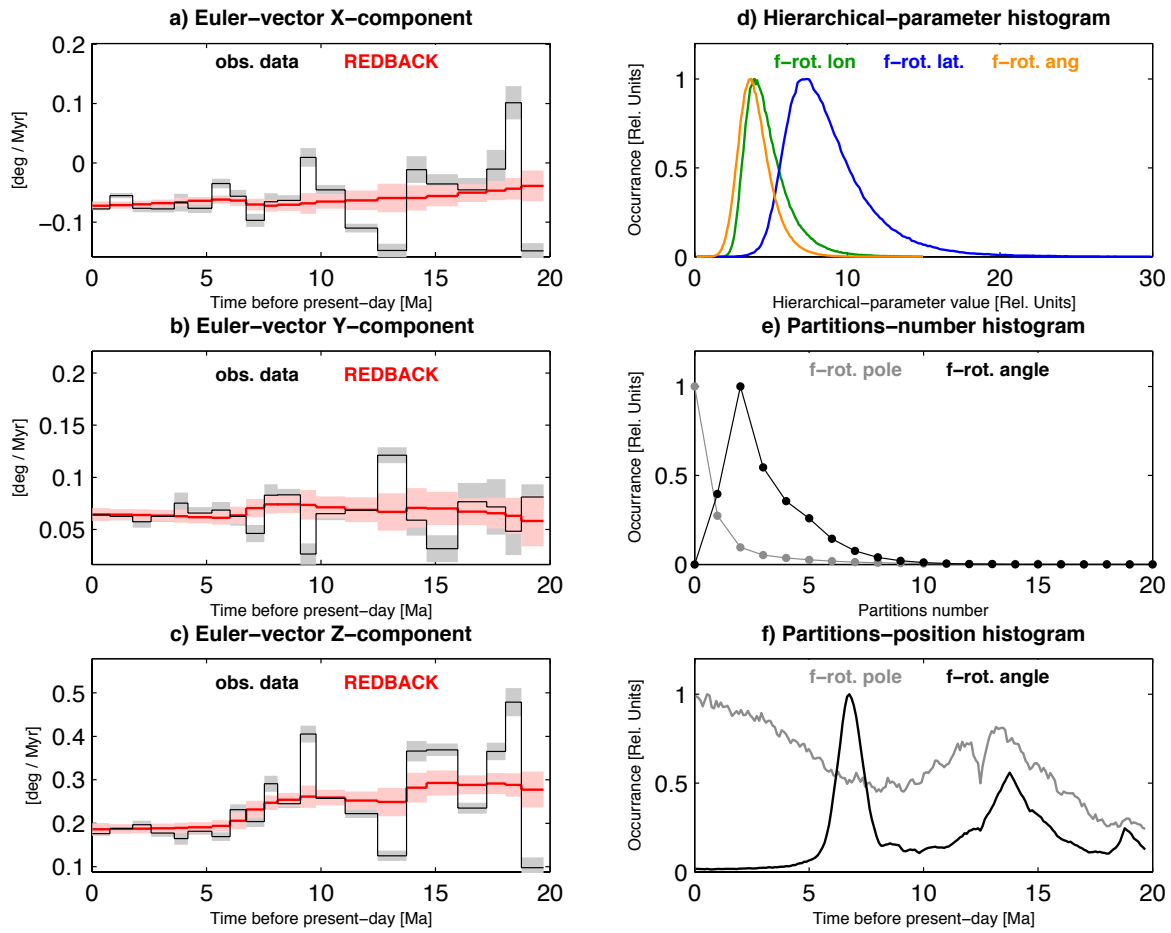


Fig. S1. REDBACK diagnostic output for Eurasia-North America finite rotations from Table 2 in Merkuriev & DeMets (2014a). REDBACK input parameters are provided in the supplemental file "EuNa_RDB_input_parameters.txt".

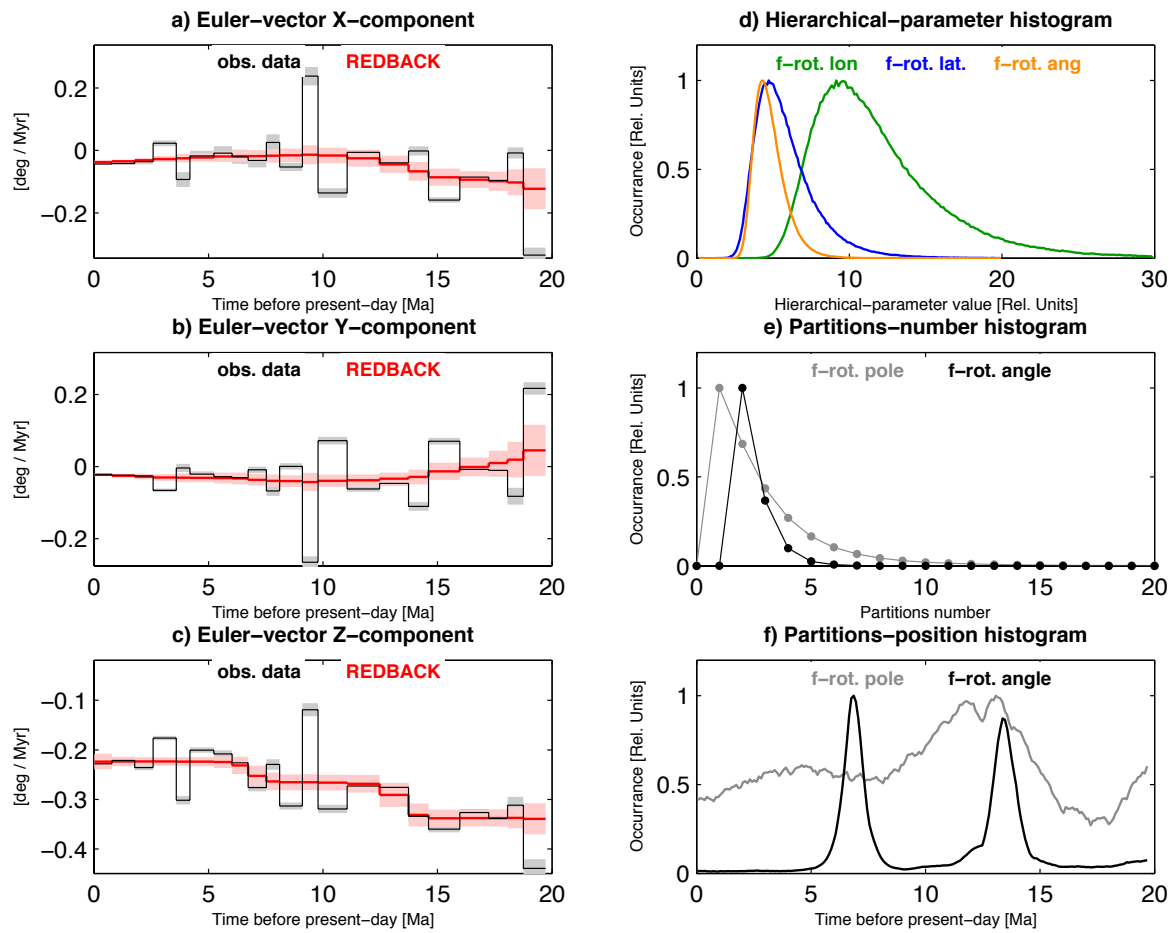


Fig. S2. REDBACK diagnostic output for Nubia-North America finite rotations from Table 2 in Merkuriev & DeMets (2014b). REDBACK input parameters are provided in the supplemental file "NbNa_RDB_input_parameters.txt".

References

- Iaffaldano, G., Hawkins, R., Bodin, T., & Sambridge, M., 2014. REDBACK: Open-source software for efficient noise-reduction in plate kinematic reconstructions, *Geochm. Geophys. Geosys.*, **15**, 1663–1670, doi: 10.1002/2014GC005309.
- Merkouriev, S. & DeMets, C., 2014a. High-resolution Quaternary and Neogene reconstructions of Eurasia-North America plate motion, *Geophys. J. Int.*, **198**, 366–384, doi: 10.1093/gji/ggu142.
- Merkouriev, S., & DeMets, C., 2014b. High-resolution estimates of Nubia-North America plate motion: 20 Ma to present, *Geophys. J. Int.*, **196**, 1281–1298, doi: 10.1093/gji/ggt463.

Table 1: Eurasia-North America noise-reduced finite rotations

Magnetic reversal	Age (Ma)	Lat. (°N)	Long. (°E)	Ω (degrees)	Covariances					
					a	b	c	d	e	f
1n	0.781	62.51	138.27	-0.164	3.5	-3.2	4.2	2.8	-3.8	5.1
2n	1.778	62.69	138.05	-0.374	6.4	-5.7	7.7	5.1	-6.9	9.3
2An.1	2.581	62.87	137.87	-0.542	10.1	-9.1	12.3	8.2	-11.1	15.0
2An.3	3.596	63.13	137.63	-0.756	16.6	-15.1	20.4	13.7	-18.6	25.2
3n.1	4.187	63.31	137.47	-0.880	21.2	-19.4	26.4	17.8	-24.2	32.8
3n.4	5.235	63.65	137.18	-1.101	31.1	-28.7	39.2	26.6	-36.3	49.4
3An.1	6.033	63.94	136.96	-1.270	39.3	-36.6	50.1	34.1	-46.7	63.9
3An.2	6.733	64.22	136.76	-1.427	44.2	-41.5	57.0	39.0	-53.6	73.5
4n.1	7.528	64.54	136.55	-1.627	44.0	-41.5	57.2	39.3	-54.2	74.7
4n.2	8.108	64.78	136.38	-1.783	40.8	-38.7	53.4	36.9	-51.0	70.4
4A	9.105	65.21	136.06	-2.055	34.0	-32.5	45.0	31.3	-43.5	60.5
5n.1	9.786	65.53	135.84	-2.245	30.2	-29.0	40.3	28.2	-39.3	54.9
5n.2	11.056	66.08	135.46	-2.595	26.7	-25.7	35.7	25.3	-35.5	50.1
5An.2	12.474	66.55	135.14	-2.977	25.2	-24.3	33.7	24.1	-34.0	48.4
5AC	13.739	66.94	134.85	-3.311	35.2	-34.0	47.2	34.1	-48.4	69.3
5AD	14.609	67.31	134.58	-3.568	27.2	-25.7	35.4	26.1	-37.2	53.9
5Cn.1	15.974	67.91	134.13	-3.983	16.2	-14.1	18.5	14.5	-20.8	31.1
5D	17.235	68.44	133.70	-4.359	12.3	-9.8	12.0	10.1	-14.6	22.7
5E	18.056	68.78	133.42	-4.605	12.2	-9.3	11.0	9.7	-14.0	22.2
6ny	18.748	69.06	133.18	-4.810	14.1	-10.7	12.5	11.2	-16.2	25.9
6no	19.722	69.45	132.87	-5.087	17.2	-12.6	14.0	13.2	-19.1	31.2

These finite rotations reconstruct movement of the Eurasia plate relative to the North America plate and include location-dependent corrections for outward displacement described by Merkouriev & DeMets (2014a). Reversal ages are adopted from the GTS12 time scale of Ogg (2012). Rotation angles Ω are positive anticlockwise. These noise-reduced rotations were determined from a Bayesian analysis of the best-fitting rotations from Table 2 of Merkouriev & DeMets (2014a), as described in the text. The Cartesian rotation covariances are calculated in a Eurasia-fixed reference frame and have units of 10^{-8} radians². Elements a , d , and f are the variances of the (0°N, 0°E), (0°N, 90°E), and 90°N components of the rotation. The covariance matrices are reconstructed as follows:

$$\begin{pmatrix} a & b & c \\ b & d & e \\ c & e & f \end{pmatrix}$$

Table 2: Eurasia-North America noise-reduced stage angular velocities

Age(o)	Age(y)	Lat.	Long.	$\dot{\omega}$	Covariances					
(Ma)	(Ma)	(°N)	(°E)	(deg. Myr ⁻¹)	a	b	c	d	e	f
0.781	0.000	62.51	138.27	0.210	1.73	-1.32	-2.21	1.24	2.02	6.94
1.778	0.781	62.84	137.87	0.210	1.08	-0.81	-1.24	0.83	1.14	4.13
2.581	1.778	63.25	137.48	0.210	1.12	-0.84	-1.05	0.88	0.99	3.91
3.596	2.581	63.79	136.97	0.210	1.16	-0.87	-0.95	0.91	0.93	3.89
4.187	3.596	64.38	136.46	0.210	1.52	-1.10	-0.82	1.20	0.83	4.29
5.235	4.187	65.03	135.94	0.211	1.29	-0.97	-0.97	1.06	0.97	4.42
6.033	5.235	65.82	135.31	0.212	1.56	-1.12	-1.30	1.29	1.31	5.68
6.733	6.033	66.40	134.96	0.224	2.53	-1.93	-3.15	2.06	3.07	11.35
7.528	6.733	66.78	134.76	0.252	2.88	-2.12	-3.51	2.31	3.43	12.63
8.108	7.528	67.27	134.29	0.268	3.08	-2.11	-1.83	2.37	1.87	9.00
9.105	8.108	68.03	133.59	0.274	3.05	-1.98	-1.08	2.09	1.25	7.08
9.786	9.105	68.92	132.88	0.280	8.52	-5.74	-2.43	5.34	3.16	19.08
11.056	9.786	69.51	132.39	0.276	4.20	-3.00	-0.97	3.26	1.17	8.97
12.474	11.056	69.74	132.36	0.269	8.17	-4.31	-0.41	4.16	1.59	12.96
13.739	12.474	70.36	131.44	0.265	16.57	-10.13	-1.76	9.18	4.17	32.08
14.609	13.739	71.96	129.77	0.296	13.24	-8.69	-4.40	9.90	5.55	35.03
15.974	14.609	72.92	128.47	0.305	8.49	-5.77	-3.51	6.54	4.24	24.69
17.235	15.974	73.81	126.82	0.300	5.63	-3.43	-1.73	4.59	2.17	14.38
18.056	17.235	74.53	125.59	0.302	7.08	-4.43	-2.03	5.96	2.62	18.24
18.748	18.056	75.11	124.72	0.298	9.77	-6.64	-1.60	8.42	2.34	22.36
19.722	18.748	75.95	123.63	0.286	19.86	-14.15	-5.07	17.76	6.57	52.49

These angular velocities specify Eurasia plate motion relative to the North America plate during the time period given in the first two columns, as determined from the REDBACK noise-reduction software (Iaffaldano *et al.* 2014). They include corrections for outward displacement described by Merkouriev & DeMets (2014a). The angular rotation rates $\dot{\omega}$ are positive anticlockwise for the old to the young limit of each time interval. The Cartesian angular velocity covariances are calculated in a Eurasia-fixed reference frame and have units of 10^{-8} radians² Myr⁻². Further information about the rotation covariances can be found in the footnotes for Supplemental Table 1.

Table 3: Nubia-North America noise-reduced finite rotations

Chron	Lat.	Long.	Ω	Covariances					
				a	b	c	d	e	f
	(°N)	(°E)	(degrees)						
1n	78.98	30.83	-0.178	6.0	3.4	-4.0	2.1	-2.4	2.9
2n	79.08	33.75	-0.405	6.7	4.2	-5.0	2.8	-3.4	4.2
2An.1	79.18	36.04	-0.587	7.6	5.0	-6.1	3.6	-4.6	5.9
2An.3	79.34	39.09	-0.817	8.8	6.4	-8.0	5.0	-6.6	9.0
3n.1	79.44	40.65	-0.952	10.0	7.3	-9.1	6.1	-8.2	11.6
3n.4	79.64	43.15	-1.189	11.8	9.3	-12.1	8.4	-11.8	17.2
3An.1	79.80	44.95	-1.371	13.2	10.8	-14.4	10.4	-15.0	22.7
3An.2	79.94	46.53	-1.535	14.2	11.4	-15.0	11.6	-17.1	27.1
4n.1	80.08	48.36	-1.738	15.0	10.2	-11.6	11.0	-16.6	28.8
4n.2	80.17	49.71	-1.893	18.8	9.4	-6.5	10.6	-15.6	30.9
4A	80.29	51.91	-2.160	28.6	10.1	1.4	11.5	-15.7	39.0
5n.1	80.35	53.43	-2.343	41.9	12.7	8.9	14.2	-17.4	51.7
5n.2	80.45	55.10	-2.685	65.5	18.6	17.2	21.0	-26.0	82.6
5An.2	80.44	55.21	-3.071	93.2	24.5	22.2	30.2	-42.9	125.1
5AC	80.33	53.00	-3.445	134.3	29.0	39.5	38.3	-53.5	155.0
5AD	80.21	50.15	-3.739	176.9	22.7	76.3	36.9	-48.4	157.7
5Cn.1	80.00	44.01	-4.209	190.0	-6.3	106.6	29.2	-48.0	141.2
5D	79.78	38.35	-4.644	170.5	-28.3	110.8	27.6	-50.8	125.0
5E	79.64	34.69	-4.928	161.6	-38.5	112.7	29.8	-54.8	121.8
6ny	79.51	31.58	-5.166	186.1	-54.2	137.8	38.3	-69.0	145.0
6no	79.24	26.05	-5.507	224.7	-101.9	184.3	83.8	-130.2	214.1

These finite rotations reconstruct movement of the Nubia plate relative to the North America plate and include location-dependent corrections for outward displacement described by Merkouriev & DeMets (2014b). Rotation angles Ω are positive anticlockwise. The rotations are determined from a Bayesian analysis of the best-fitting rotations from Table 2 of Merkouriev & DeMets (2014b), as described in the text. The Cartesian rotation covariances are calculated in a Nubia-fixed reference frame and have units of 10^{-8} radians². Further information about the rotation covariances can be found in the footnotes for Supplemental Table 1.

Table 4: Nubia-North America noise-reduced stage angular velocities

Age(o)	Age(y)	Lat.	Long.	$\dot{\omega}$	Covariances					
(Ma)	(Ma)	(°N)	(°E)	(deg. Myr ¹)	a	b	c	d	e	f
0.781	0.000	78.99	30.86	0.228	0.53	-0.12	0.99	0.54	0.58	6.11
1.778	0.781	79.13	36.07	0.227	0.72	-0.51	0.35	0.88	0.24	2.38
2.581	1.778	79.32	41.26	0.227	1.39	-1.13	0.27	1.57	0.20	2.02
3.596	2.581	79.60	47.19	0.227	2.50	-1.98	0.24	2.32	0.22	2.07
4.187	3.596	79.89	50.77	0.227	5.08	-3.73	0.17	4.13	0.20	2.09
5.235	4.187	80.21	54.03	0.227	5.21	-3.79	0.16	4.16	0.23	2.24
6.033	5.235	80.53	58.02	0.228	7.73	-5.44	0.22	6.09	0.31	3.26
6.733	6.033	80.72	61.25	0.234	9.88	-6.65	0.76	7.45	0.86	7.85
7.528	6.733	80.76	63.68	0.256	10.51	-6.59	1.08	7.03	1.35	11.08
8.108	7.528	80.71	66.20	0.267	13.38	-8.39	0.83	8.34	1.17	9.57
9.105	8.108	80.70	68.72	0.269	13.44	-7.94	0.53	7.24	0.95	7.51
9.786	9.105	80.43	71.95	0.269	24.74	-15.28	0.48	15.81	0.46	7.57
11.056	9.786	80.84	67.31	0.269	18.21	-9.52	0.29	8.14	0.89	7.35
12.474	11.056	80.38	55.98	0.272	20.72	-10.26	0.39	7.88	1.24	9.04
13.739	12.474	79.07	36.77	0.296	22.74	-11.24	1.36	8.95	2.33	17.71
14.609	13.739	77.52	23.17	0.339	25.91	-13.76	1.09	12.47	1.80	15.16
15.974	14.609	75.56	8.70	0.349	21.90	-14.72	0.59	16.14	0.83	8.71
17.235	15.974	74.47	0.39	0.351	20.44	-14.93	0.31	18.65	0.82	7.95
18.056	17.235	73.57	354.11	0.352	27.05	-22.79	0.10	33.05	0.68	8.72
18.748	18.056	72.84	349.28	0.353	50.21	-45.85	0.00	70.55	0.67	13.89
19.722	18.748	68.94	339.74	0.364	127.94	-95.54	-5.74	152.35	2.90	29.83

These angular velocities specify Nubia plate motion relative to the North America plate during the time period given in the first two columns, as determined from the REDBACK noise-reduction software (Iaffaldano *et al.* 2014). They include corrections for 1 km of outward displacement (Merkouriev & DeMets 2014b). The angular rotation rates $\dot{\omega}$ are positive anticlockwise for the old to the young limit of each time interval. The Cartesian angular velocity covariances are calculated in a North America-fixed reference frame and have units of 10^{-8} radians² Myr⁻². Further information about the rotation covariances can be found in the footnotes for Supplemental Table 1.