Supplementary Material

How accurate are estimates of glacier ice thickness? Results from the ITMIX, the Ice Thickness Models Intercomparison eXperiment

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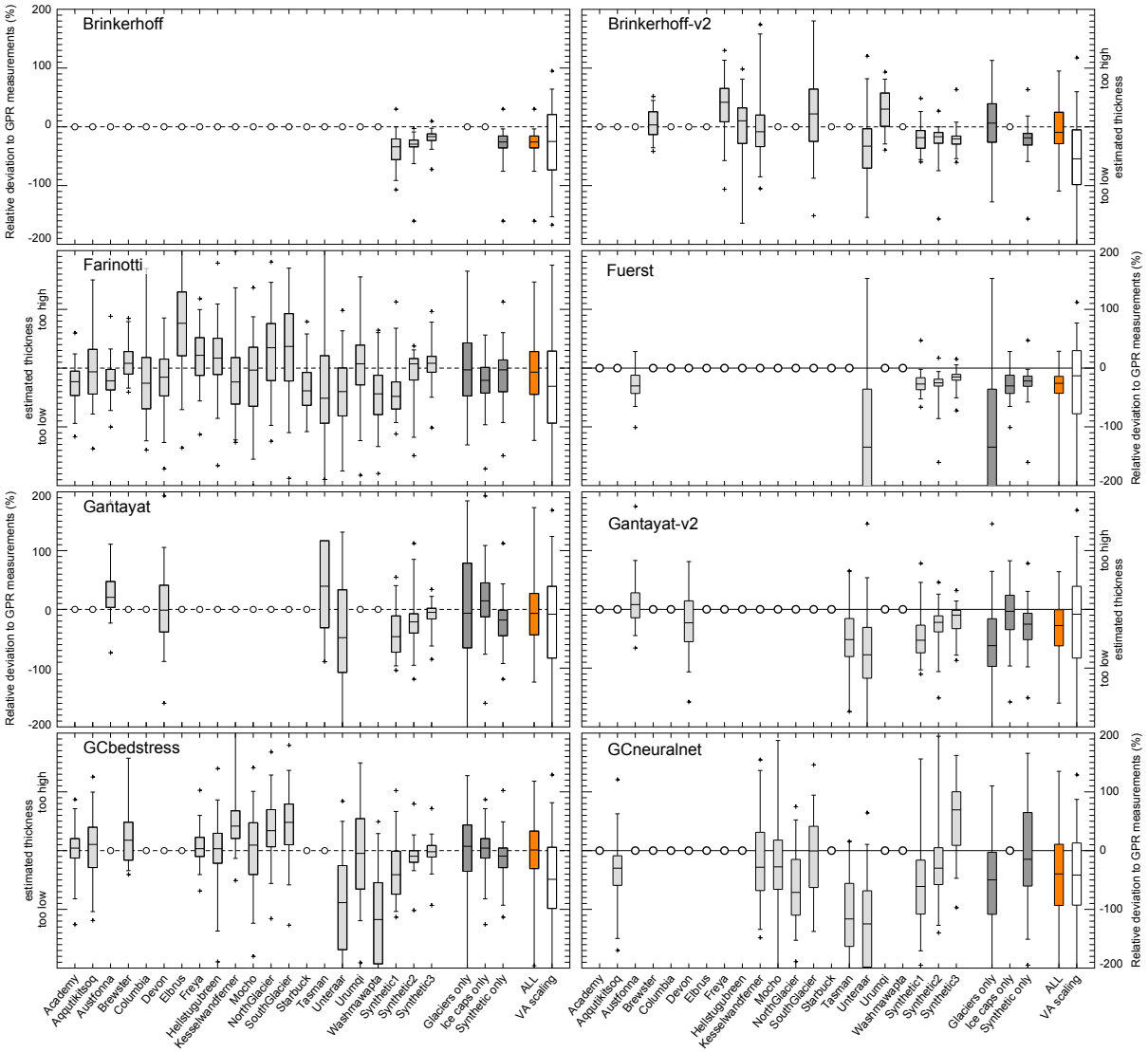

Figure S1: Differences between estimated and measured ice thickness for all test cases. Models are shown in alphabetical order (models not displayed in the figure are found in Fig. S2 on the next page). Boxplots show minimum and maximum values (crosses), the 95 % confidence interval (whiskers), the interquartile range (box) and the median (lines within box).

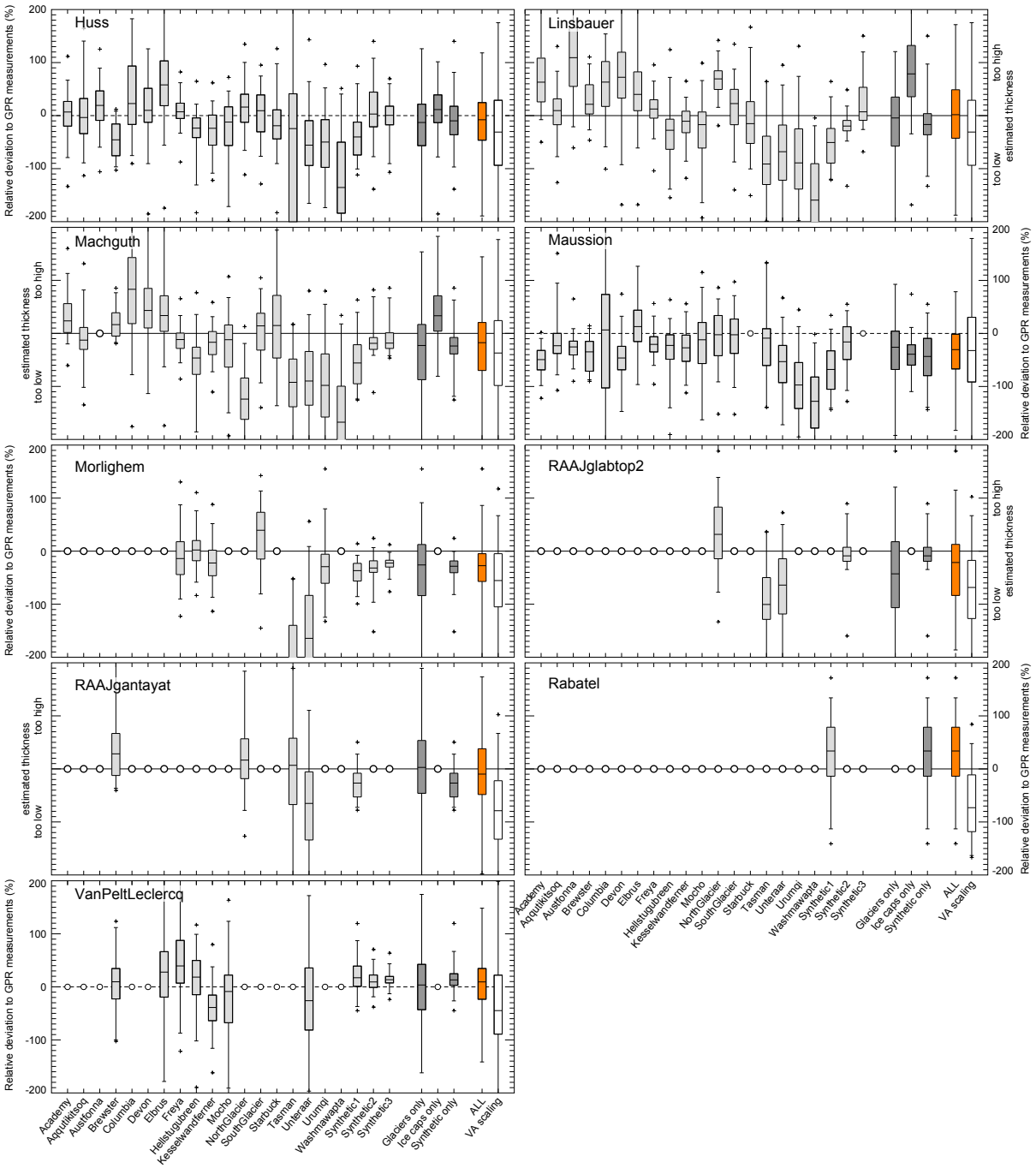

Figure S2: Differences between estimated and measured ice thickness for all test cases. Models are shown in alphabetical order (models not displayed in the figure are found in Fig. S1 on the previous page). Boxplots show minimum and maximum values (crosses), the 95 % confidence interval (whiskers), the interquartile range (box) and the median (lines within box).

Table S1: Years the input data used during the experiment are referring to. OL: Glacier outline, DEM: digital elevation model of the glacier surface, SMB: surface mass balance, Vel.: ice flow velocity at the surface, DHDT: rate of ice thickness change, H: ice thickness measurements. References for data sources are given in Table 1 of the main article.

Test case	OL	DEM	SMB	Vel.	DHDT	H
Academy	1997	1997	-	-	-	1997
Aqqutikitsoq	2014	2014	-	-	-	2014
Austfonna	2008	2007	2004-2013	1995-1996	2003-2009	1983
Brewster	1997	1997	2004-2008	2004-2008	-	1997
Columbia	2007	2007	-	-	-	2010
Devon	1999	2000	-	2007-2008	-	2000
Elbrus	1997	1997	1984-2010	-	1957-1997	2005-2007,2013,2014
Freya	2013	2013	2008-2014	-	-	2013
Hellstugubreen	2003	2009	1997-2010	2011-2013	1997-2009	2011
Kesselwandferner	1997	1997	1988-1997	-	-	1995
Mocho	2000	2013	2006-2014	-	-	2013
NorthGlacier	2007	2007	-	2006-2012	-	2008,2009,2011
SouthGlacier	2007	2007	2007-2012	2006-2014	-	2008,2009,2011
Starbuck	2003	2003	-	-	-	2013
Tasman	1986	1986	2000-2010	2000-2011	-	1971-1973
Unteraar	2003	2003	1997-2003	1997	1997-2003	1997,1998,2000
Urumqi	2012	2012	2011-2014	-	-	2012
Washmawapta	2007	2007	-	-	-	2006

Table S2: Case-by-case model performance. For each test case and every paticipating model, the average (avg), median (med), interquartile range (IQR), and 95 % confidence interval (95 %) of the deviations from ice thickness measurements are given (indicators). Values are percentual deviations from the mean ice thickness. The numbers in parentesis are the rank of every indicator (first three ranks are highlighted). The average rank of the four indicators is given in the last column (AVG).

Test case / Model	avg	med	IQR	95%	AVG
Academy					
1 GCbedstress	3 (**2**)	4 (**1**)	±17 (**1**)	±77 (5)	2.2
2 Farinotti	−27 (**3**)	−23 (**3**)	±21 (**3**)	±59 (**2**)	2.8
3 Huss	2 (**1**)	7 (**2**)	±23 (4)	±73 (4)	2.8
4 Maussion	−51 (5)	−49 (5)	±18 (**2**)	±44 (**1**)	3.2
5 Machguth	32 (4)	24 (4)	±27 (5)	±66 (**3**)	4.0
6 Linsbauer	77 (6)	63 (6)	±41 (6)	±128 (6)	6.0
Aqqutikitsoq					
1 Linsbauer	7 (4)	9 (**3**)	±24 (**3**)	±81 (**1**)	2.8
2 Huss	2 (**2**)	−4 (**1**)	±33 (5)	±115 (7)	3.8
3 Machguth	−11 (5)	−13 (5)	±21 (**2**)	±92 (**3**)	3.8
4 Maussion	−16 (6)	−23 (6)	±19 (**1**)	±86 (**2**)	3.8
5 Farinotti	1 (**1**)	−6 (**2**)	±38 (7)	±114 (6)	4.0
6 GCbedstress	6 (**3**)	11 (4)	±34 (6)	±102 (4)	4.2
7 GCneuralnet	−34 (7)	−30 (7)	±25 (4)	±106 (5)	5.8
Austfonna					
1 Gantayat-v2	9 (**1**)	8 (**1**)	±21 (4)	±64 (4)	2.5
2 Maussion	−27 (5)	−26 (5)	±13 (**1**)	±38 (**1**)	3.0
3 Farinotti	−20 (**3**)	−22 (4)	±17 (**3**)	±52 (**3**)	3.2
4 Fuerst	−26 (4)	−30 (6)	±16 (**2**)	±47 (**2**)	3.5
5 Huss	18 (**2**)	19 (**2**)	±28 (6)	±74 (6)	4.0
6 Gantayat	28 (6)	21 (**3**)	±22 (5)	±67 (5)	4.8
7 Linsbauer	118 (7)	109 (7)	±55 (7)	±166 (7)	7.0
Brewster					
1 Brinkerhoff-v2	5 (**2**)	3 (**1**)	±19 (**2**)	±40 (**1**)	1.5
2 Farinotti	13 (**3**)	8 (**2**)	±19 (**1**)	±57 (5)	2.8
3 Machguth	20 (4)	17 (4)	±22 (**3**)	±47 (**2**)	3.2
4 VanPeltLeclercq	4 (**1**)	10 (**3**)	±29 (6)	±106 (8)	4.5
5 Linsbauer	29 (6)	21 (6)	±28 (4)	±62 (6)	5.5
6 Maussion	−40 (7)	−35 (8)	±28 (5)	±48 (**3**)	5.8
7 GCbedstress	27 (5)	18 (5)	±32 (8)	±96 (7)	6.2
8 Huss	−46 (9)	−46 (9)	±30 (7)	±53 (4)	7.2
9 RAAJgantayat	41 (8)	28 (7)	±40 (9)	±121 (9)	8.2
Columbia					
1 Farinotti	−14 (**1**)	−26 (**3**)	±44 (**2**)	±147 (**3**)	2.2
2 Huss	38 (**3**)	23 (**2**)	±55 (**3**)	±129 (**2**)	2.5
3 Linsbauer	58 (4)	63 (4)	±42 (**1**)	±106 (**1**)	2.5
4 Maussion	−18 (**2**)	6 (**1**)	±88 (5)	±238 (5)	3.2
5 Machguth	87 (5)	83 (5)	±62 (4)	±184 (4)	4.5
Devon					
1 Farinotti	−15 (**2**)	−16 (**3**)	±31 (**2**)	±106 (4)	2.8
2 Gantayat	3 (**1**)	−1 (**1**)	±40 (6)	±97 (**3**)	2.8
3 Huss	17 (**3**)	10 (**2**)	±32 (**3**)	±108 (5)	3.2
4 Gantayat-v2	−20 (4)	−23 (4)	±35 (4)	±94 (**2**)	3.5
5 Maussion	−49 (6)	−46 (6)	±22 (**1**)	±90 (**1**)	3.5
6 Machguth	47 (5)	43 (5)	±37 (5)	±166 (6)	5.2
7 Linsbauer	78 (7)	72 (7)	±43 (7)	±177 (7)	7.0

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Table S2: Continued from previous page.

Test case / Model		avg		med		IQR		95%		AVG
Elbrus										
1	Maussion	15	(**1**)	13	(**1**)	±30	(**1**)	±112	(**1**)	1.0
2	Machguth	49	(**3**)	34	(**3**)	±34	(**2**)	±167	(4)	3.0
3	Linsbauer	54	(4)	40	(4)	±37	(**3**)	±166	(**3**)	3.5
4	VanPeltLeclercq	23	(**2**)	28	(**2**)	±43	(5)	±194	(6)	3.8
5	Huss	66	(5)	58	(5)	±42	(4)	±142	(**2**)	4.0
6	Farinotti	79	(6)	76	(6)	±54	(6)	±171	(5)	5.8
Freya										
1	GCbedstress	6	(**1**)	3	(**1**)	±16	(4)	±50	(4)	2.5
2	Huss	10	(**3**)	7	(**2**)	±14	(**3**)	±48	(**3**)	2.8
3	Machguth	−13	(5)	−12	(**3**)	±14	(**2**)	±45	(**1**)	2.8
4	Maussion	−20	(6)	−21	(6)	±14	(**1**)	±46	(**2**)	3.8
5	Linsbauer	12	(4)	12	(4)	±17	(5)	±54	(5)	4.5
6	Morlighem	−10	(**2**)	−14	(5)	±31	(7)	±89	(8)	5.5
7	Farinotti	22	(7)	22	(7)	±32	(8)	±78	(6)	7.0
8	Brinkerhoff-v2	37	(8)	42	(9)	±28	(6)	±85	(7)	7.5
9	VanPeltLeclercq	57	(9)	39	(8)	±40	(9)	±168	(9)	8.8
Hellstugubreen										
1	Morlighem	2	(**2**)	2	(**1**)	±19	(**2**)	±67	(**1**)	1.5
2	GCbedstress	−2	(**1**)	3	(**2**)	±25	(4)	±112	(8)	3.8
3	Huss	−27	(6)	−24	(7)	±19	(**1**)	±76	(**2**)	4.0
4	Maussion	−29	(7)	−23	(6)	±23	(**3**)	±84	(**3**)	4.8
5	Farinotti	19	(5)	17	(4)	±31	(8)	±97	(4)	5.2
6	Brinkerhoff-v2	−3	(**3**)	10	(**3**)	±30	(7)	±123	(9)	5.5
7	VanPeltLeclercq	14	(4)	18	(5)	±32	(9)	±101	(5)	5.8
8	Linsbauer	−33	(8)	−28	(8)	±28	(6)	±105	(6)	7.0
9	Machguth	−54	(9)	−46	(9)	±26	(5)	±111	(7)	7.5
Kesselwandferner										
1	Linsbauer	−14	(**2**)	−11	(**2**)	±20	(**1**)	±60	(**2**)	1.8
2	Machguth	−17	(4)	−17	(**3**)	±22	(**2**)	±52	(**1**)	2.5
3	Brinkerhoff-v2	−4	(**1**)	−8	(**1**)	±27	(7)	±122	(8)	4.2
4	Morlighem	−20	(6)	−22	(4)	±24	(4)	±69	(5)	4.8
5	Maussion	−28	(7)	−27	(7)	±25	(6)	±69	(4)	6.0
6	Huss	−30	(8)	−24	(6)	±28	(8)	±68	(**3**)	6.2
7	Farinotti	−20	(5)	−24	(5)	±40	(9)	±129	(9)	7.0
8	VanPeltLeclercq	−41	(9)	−39	(9)	±24	(5)	±77	(6)	7.2
9	GCbedstress	52	(10)	42	(10)	±24	(**3**)	±111	(7)	7.5
10	GCneuralnet	−15	(**3**)	−28	(8)	±50	(10)	±135	(10)	7.8
Mocho										
1	GCbedstress	1	(**1**)	9	(**3**)	±44	(6)	±112	(**3**)	3.2
2	Machguth	−27	(6)	−12	(4)	±40	(4)	±109	(**1**)	3.8
3	Farinotti	−17	(**2**)	−3	(**1**)	±50	(8)	±121	(5)	4.0
4	Huss	−28	(7)	−12	(6)	±36	(**2**)	±109	(**2**)	4.2
5	Maussion	−23	(4)	−12	(5)	±39	(**3**)	±125	(6)	4.5
6	VanPeltLeclercq	−21	(**3**)	−9	(**2**)	±45	(7)	±157	(7)	4.8
7	Linsbauer	−33	(8)	−17	(7)	±34	(**1**)	±115	(4)	5.0
8	GCneuralnet	−23	(5)	−28	(8)	±42	(5)	±216	(8)	6.5

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Table S2: Continued from previous page.

Test case / Model	avg	med	IQR	95%	AVG
NorthGlacier					
1 Huss	14 (**2**)	16 (**2**)	±26 (**2**)	±83 (**3**)	2.2
2 Maussion	−6 (**1**)	−3 (**1**)	±38 (5)	±78 (**2**)	2.2
3 Linsbauer	68 (8)	69 (7)	±18 (**1**)	±53 (**1**)	4.2
4 GCbedstress	37 (6)	34 (5)	±32 (**3**)	±92 (4)	4.5
5 RAAJgantayat	24 (**3**)	17 (**3**)	±38 (4)	±131 (9)	4.8
6 RAAJglabtop2	34 (5)	32 (4)	±49 (9)	±108 (7)	6.2
7 Farinotti	27 (4)	35 (6)	±49 (8)	±122 (8)	6.5
8 GCneuralnet	−60 (7)	−71 (8)	±47 (7)	±102 (6)	7.0
9 Machguth	−122 (9)	−124 (9)	±39 (6)	±92 (5)	7.2
SouthGlacier					
1 Maussion	−6 (**3**)	−3 (**2**)	±32 (**1**)	±87 (**2**)	2.0
2 Huss	4 (**1**)	9 (**3**)	±35 (5)	±76 (**1**)	2.5
3 Machguth	5 (**2**)	14 (4)	±35 (4)	±89 (4)	3.5
4 Linsbauer	14 (5)	23 (6)	±33 (**2**)	±87 (**3**)	4.0
5 GCneuralnet	−10 (4)	−1 (**1**)	±52 (8)	±116 (7)	5.0
6 Brinkerhoff-v2	24 (6)	22 (5)	±45 (7)	±134 (8)	6.5
7 Morlighem	29 (7)	39 (8)	±44 (6)	±97 (5)	6.5
8 GCbedstress	45 (9)	48 (9)	±35 (**3**)	±97 (6)	6.8
9 Farinotti	35 (8)	37 (7)	±57 (9)	±140 (9)	8.2
Starbuck					
1 Huss	−14 (**2**)	−19 (**3**)	±27 (**1**)	±94 (**2**)	2.0
2 Linsbauer	−7 (**1**)	−15 (**2**)	±39 (**3**)	±114 (**3**)	2.2
3 Farinotti	−34 (4)	−39 (4)	±28 (**2**)	±83 (**1**)	2.8
4 Machguth	15 (**3**)	15 (**1**)	±59 (4)	±166 (4)	3.0
Tasman					
1 Maussion	−19 (**2**)	−9 (**2**)	±35 (**2**)	±136 (6)	3.0
2 Gantayat-v2	−45 (4)	−51 (6)	±32 (**1**)	±120 (**3**)	3.5
3 RAAJgantayat	−10 (**1**)	7 (**1**)	±63 (8)	±225 (9)	4.8
4 Machguth	−94 (9)	−92 (8)	±45 (4)	±117 (**2**)	5.8
5 Linsbauer	−84 (7)	−91 (7)	±46 (5)	±132 (5)	6.0
6 RAAJglabtop2	−91 (8)	−100 (9)	±39 (**3**)	±120 (4)	6.0
7 Farinotti	−19 (**3**)	−51 (5)	±57 (7)	±225 (10)	6.2
8 Gantayat	52 (5)	39 (4)	±74 (9)	±169 (7)	6.2
9 GCneuralnet	−106 (10)	−116 (10)	±54 (6)	±111 (**1**)	6.8
10 Huss	−73 (6)	−24 (**3**)	±125 (11)	±271 (11)	7.8
11 Morlighem	−237 (11)	−214 (11)	±102 (10)	±196 (8)	10.0
Unteraar					
1 Brinkerhoff-v2	−39 (**2**)	−33 (**2**)	±33 (**1**)	±118 (**3**)	2.0
2 Farinotti	−43 (4)	−40 (**3**)	±41 (**3**)	±119 (4)	3.5
3 Maussion	−58 (6)	−53 (5)	±35 (**2**)	±101 (**1**)	3.5
4 Huss	−52 (5)	−56 (6)	±42 (4)	±115 (**2**)	4.2
5 VanPeltLeclercq	−24 (**1**)	−26 (**1**)	±59 (9)	±184 (14)	6.2
6 RAAJglabtop2	−69 (8)	−64 (7)	±52 (8)	±142 (8)	7.8
7 Linsbauer	−70 (9)	−68 (9)	±52 (7)	±135 (7)	8.0
8 Gantayat	−43 (**3**)	−48 (4)	±70 (13)	±184 (13)	8.2
9 Gantayat-v2	−78 (10)	−77 (10)	±43 (5)	±145 (10)	8.8
10 Machguth	−88 (11)	−90 (12)	±51 (6)	±131 (6)	8.8
11 RAAJgantayat	−67 (7)	−65 (8)	±64 (10)	±171 (12)	9.2
12 GCbedstress	−94 (12)	−89 (11)	±72 (14)	±144 (9)	11.5
13 Morlighem	−146 (15)	−164 (15)	±66 (12)	±129 (5)	11.8
14 GCneuralnet	−137 (14)	−125 (13)	±65 (11)	±171 (11)	12.2
15 Fuerst	−113 (13)	−135 (14)	±86 (15)	±228 (15)	14.2

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Table S2: Continued from previous page.

Test case / Model		avg		med		IQR		95%		AVG
Urumqi										
1	Brinkerhoff-v2	29	(**3**)	30	(4)	±28	(**2**)	±55	(**1**)	2.5
2	Morlighem	−31	(4)	−29	(**3**)	±27	(**1**)	±102	(**2**)	2.5
3	Farinotti	7	(**2**)	7	(**2**)	±34	(**3**)	±139	(8)	3.8
4	GCbedstress	−1	(**1**)	−5	(**1**)	±60	(8)	±134	(6)	4.0
5	Huss	−54	(5)	−50	(5)	±45	(5)	±113	(4)	4.8
6	Maussion	−97	(8)	−97	(7)	±43	(4)	±104	(**3**)	5.5
7	Linsbauer	−78	(6)	−89	(6)	±57	(6)	±136	(7)	6.2
8	Machguth	−92	(7)	−98	(8)	±60	(7)	±129	(5)	6.8
Washmawapta										
1	Farinotti	−44	(**1**)	−44	(**1**)	±33	(**1**)	±97	(**1**)	1.0
2	GCbedstress	−121	(**2**)	−117	(**2**)	±69	(4)	±141	(**3**)	2.8
3	Maussion	−128	(4)	−128	(**3**)	±48	(**2**)	±106	(**2**)	2.8
4	Huss	−122	(**3**)	−136	(4)	±67	(**3**)	±155	(5)	3.8
5	Linsbauer	−165	(5)	−159	(5)	±70	(5)	±154	(4)	4.8
6	Machguth	−172	(6)	−167	(6)	±74	(6)	±177	(6)	6.0
Synthetic1										
1	Brinkerhoff-v2	−20	(**2**)	−19	(**2**)	±15	(**2**)	±41	(**3**)	2.2
2	Fuerst	−27	(**3**)	−27	(4)	±10	(**1**)	±25	(**1**)	2.2
3	VanPeltLeclercq	19	(**1**)	17	(**1**)	±19	(5)	±62	(6)	3.2
4	RAAJgantayat	−28	(4)	−27	(**3**)	±22	(6)	±50	(5)	4.5
5	Brinkerhoff	−38	(7)	−34	(6)	±18	(4)	±46	(4)	5.2
6	Morlighem	−39	(9)	−37	(7)	±17	(**3**)	±39	(**2**)	5.2
7	Gantayat	−39	(10)	−46	(10)	±31	(9)	±68	(7)	9.0
8	Huss	−38	(8)	−40	(8)	±31	(10)	±80	(12)	9.5
9	Farinotti	−41	(11)	−48	(11)	±23	(7)	±80	(11)	10.0
10	Gantayat-v2	−45	(12)	−53	(13)	±23	(8)	±74	(8)	10.2
11	Rabatel	29	(5)	34	(5)	±46	(16)	±123	(15)	10.2
12	GCbedstress	−34	(6)	−41	(9)	±37	(13)	±85	(14)	10.5
13	Linsbauer	−54	(14)	−51	(12)	±33	(11)	±78	(10)	11.8
14	Maussion	−69	(16)	−68	(16)	±36	(12)	±74	(9)	13.2
15	Machguth	−57	(15)	−56	(14)	±37	(14)	±82	(13)	14.0
16	GCneuralnet	−50	(13)	−61	(15)	±46	(15)	±163	(16)	14.8
Synthetic2										
1	GCbedstress	−9	(4)	−10	(5)	±10	(5)	±30	(**2**)	4.0
2	RAAJglabtop2	−2	(**1**)	−9	(**3**)	±13	(9)	±53	(8)	5.2
3	VanPeltLeclercq	11	(6)	9	(4)	±12	(8)	±35	(4)	5.5
4	Linsbauer	−18	(8)	−20	(9)	±10	(4)	±33	(**3**)	6.0
5	Brinkerhoff-v2	−22	(11)	−17	(7)	±9	(**3**)	±37	(5)	6.5
6	Farinotti	−5	(**2**)	7	(**2**)	±18	(12)	±74	(11)	6.8
7	Brinkerhoff	−30	(14)	−30	(13)	±6	(**1**)	±27	(**1**)	7.2
8	Machguth	−13	(7)	−19	(8)	±11	(7)	±55	(9)	7.8
9	Fuerst	−28	(13)	−25	(12)	±6	(**2**)	±40	(6)	8.2
10	Huss	11	(5)	3	(**1**)	±33	(15)	±93	(14)	8.8
11	Maussion	−21	(10)	−16	(6)	±31	(13)	±75	(12)	10.2
12	Gantayat	−19	(9)	−21	(10)	±16	(11)	±90	(13)	10.8
13	Gantayat-v2	−26	(12)	−22	(11)	±14	(10)	±66	(10)	10.8
14	Morlighem	−32	(15)	−32	(15)	±11	(6)	±52	(7)	10.8
15	GCneuralnet	−7	(**3**)	−30	(14)	±31	(14)	±161	(15)	11.5

Continued on next page.

Table S2: Continued from previous page.

Test case / Model		avg		med		IQR		95%		AVG
Synthetic3										
1	GCbedstress	−3	(**2**)	−2	(**2**)	±10	(7)	±34	(6)	4.2
2	Fuerst	−17	(7)	−15	(8)	±5	(**1**)	±28	(**3**)	4.8
3	Brinkerhoff	−18	(8)	−17	(9)	±6	(**2**)	±18	(**1**)	5.0
4	VanPeltLeclercq	14	(6)	14	(7)	±6	(**3**)	±28	(4)	5.0
5	Gantayat	−9	(5)	−5	(**3**)	±9	(6)	±42	(7)	5.2
6	Huss	−1	(**1**)	0	(**1**)	±18	(11)	±75	(12)	6.2
7	Farinotti	7	(**3**)	8	(5)	±14	(8)	±64	(10)	6.5
8	Morlighem	−24	(12)	−22	(12)	±6	(4)	±25	(**2**)	7.5
9	Brinkerhoff-v2	−23	(10)	−20	(11)	±7	(5)	±31	(5)	7.8
10	Machguth	−8	(4)	−18	(10)	±15	(9)	±54	(9)	8.0
11	Gantayat-v2	−18	(9)	−10	(6)	±16	(10)	±46	(8)	8.2
12	Linsbauer	23	(11)	7	(4)	±31	(12)	±73	(11)	9.5
13	GCneuralnet	58	(13)	69	(13)	±46	(13)	±105	(13)	13.0