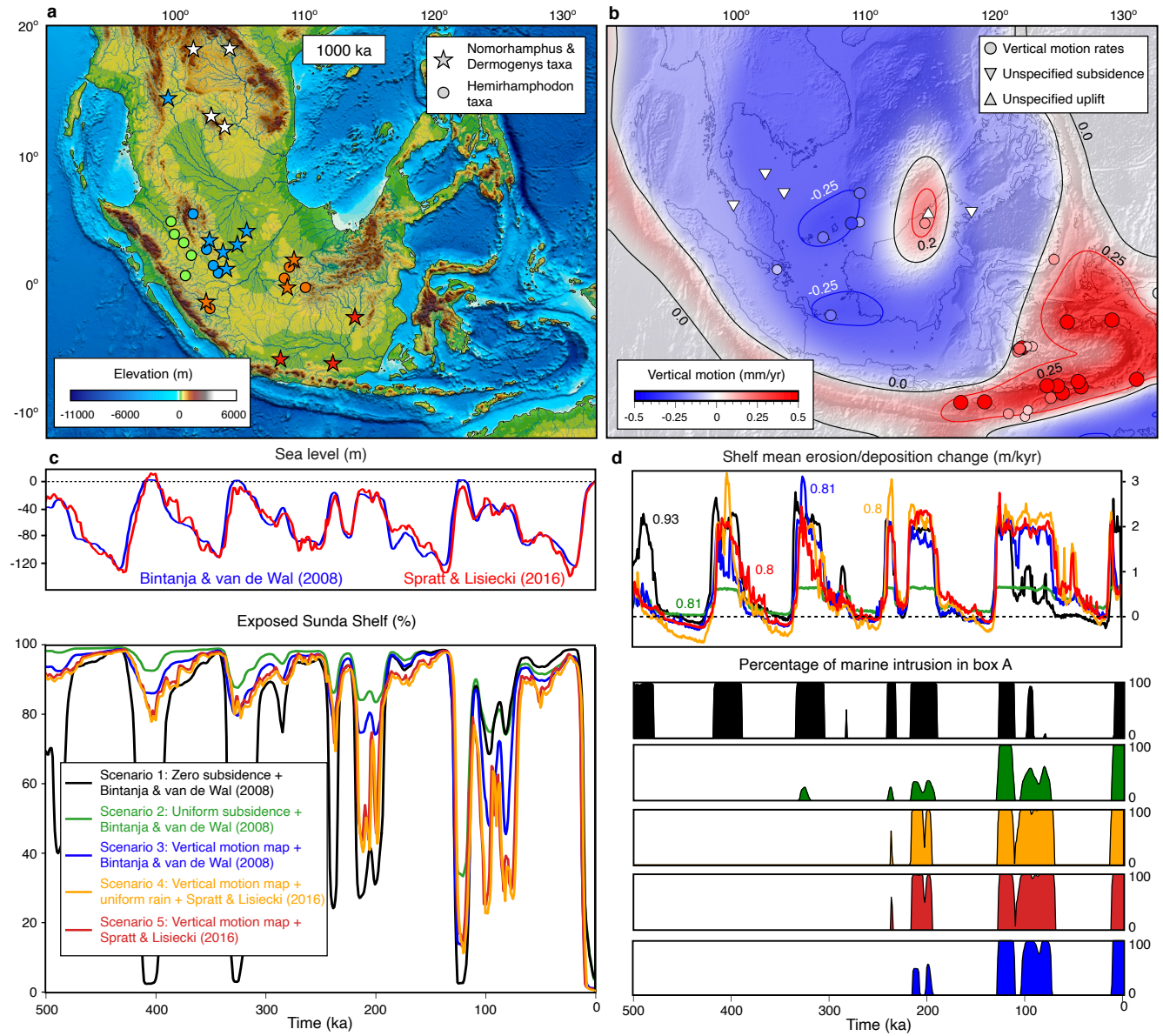
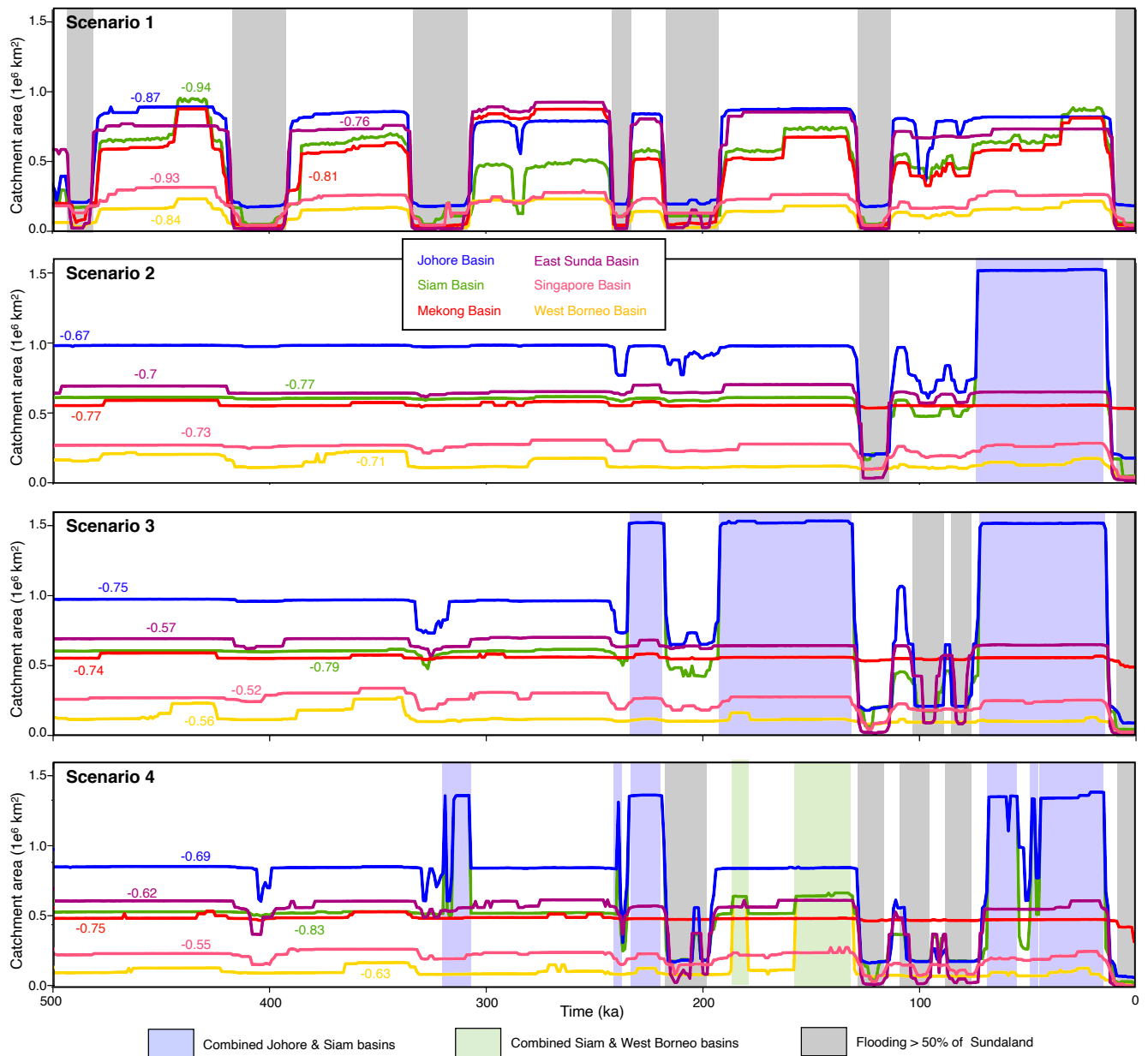


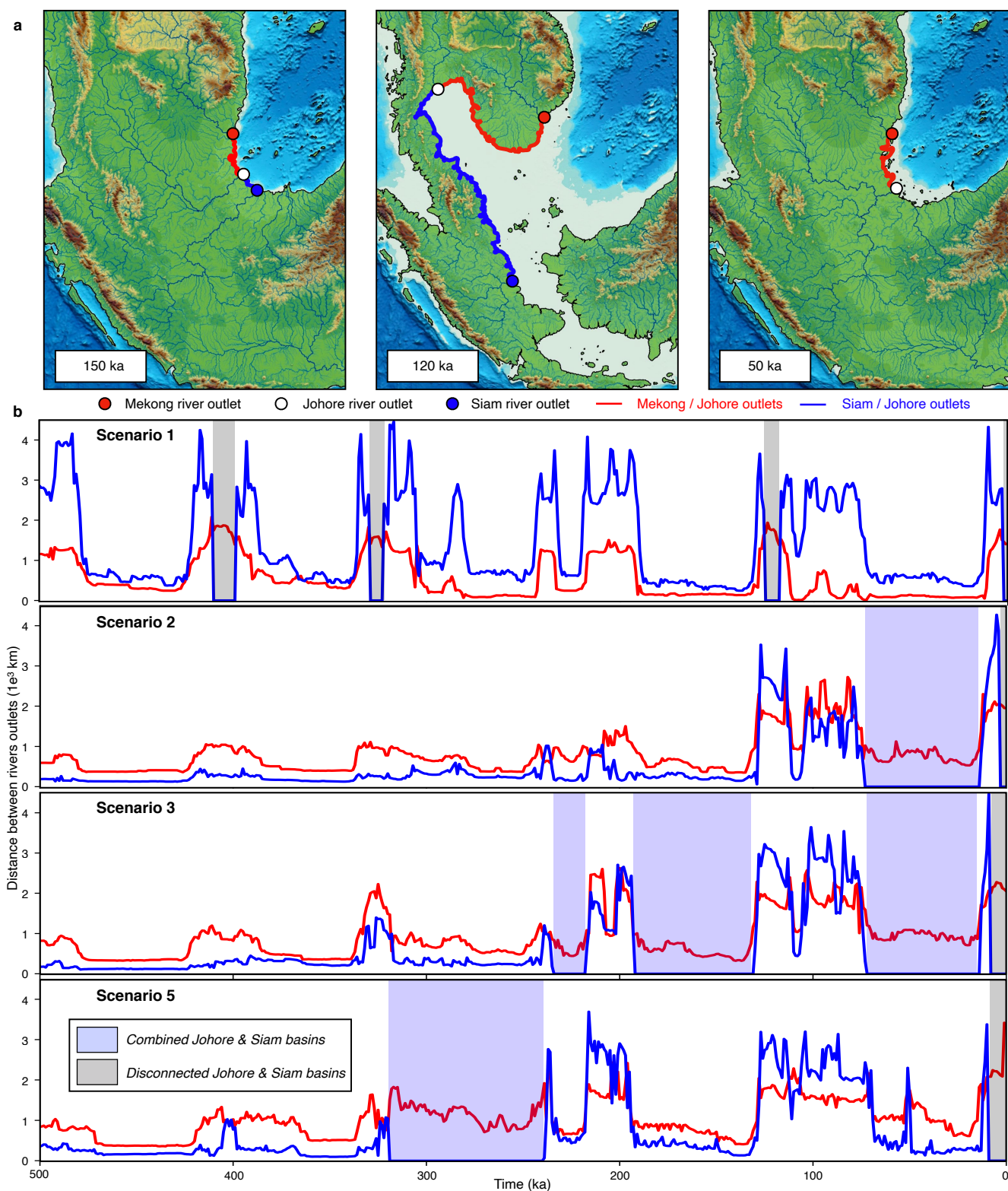
Supplementary Figures and Tables



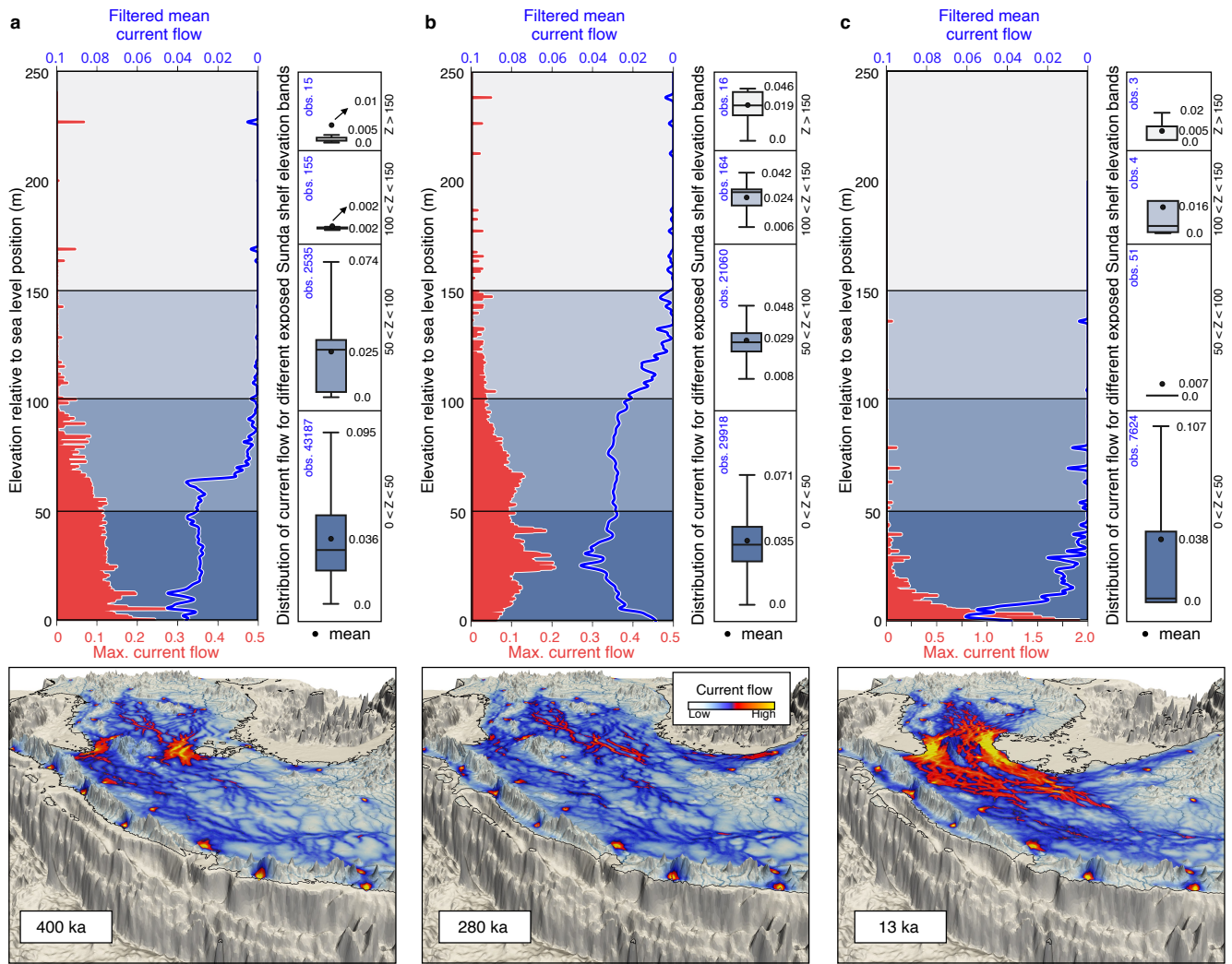
Supplementary Figure 1. Landscape evolution calibration process. **a.** Initial paleogeography of the region one million years before present with location of freshwater halfbeak fishes used to constrain the main catchment basins¹ (Supplementary Tab. 4). **b.** Tectonic map (uplift and subsidence rates) constrained with tectonic studies (Supplementary Tab. 1) and interpolated over time. **c.** Sea-level curves (top) used in the simulations and calculated percentage of exposed shelf (bottom) for four different runs. The first run has no vertical land motion and the sea-level curve from². The four others are forced with tectonic regime (uniform subsidence of 0.25 mm/yr³ and tectonic map defined in **b** for the last two) and sea-level curves^{2,4}. **d.** The top graph shows the calculated shelf erosion/deposition changes over 1,000 years time-steps for the different scenarios (in **c**) and associated Pearson's correlation coefficients with imposed sea-level curves. The bottom four panels show the number of marine intrusion events in box A (Fig. 1b) for the different simulations.



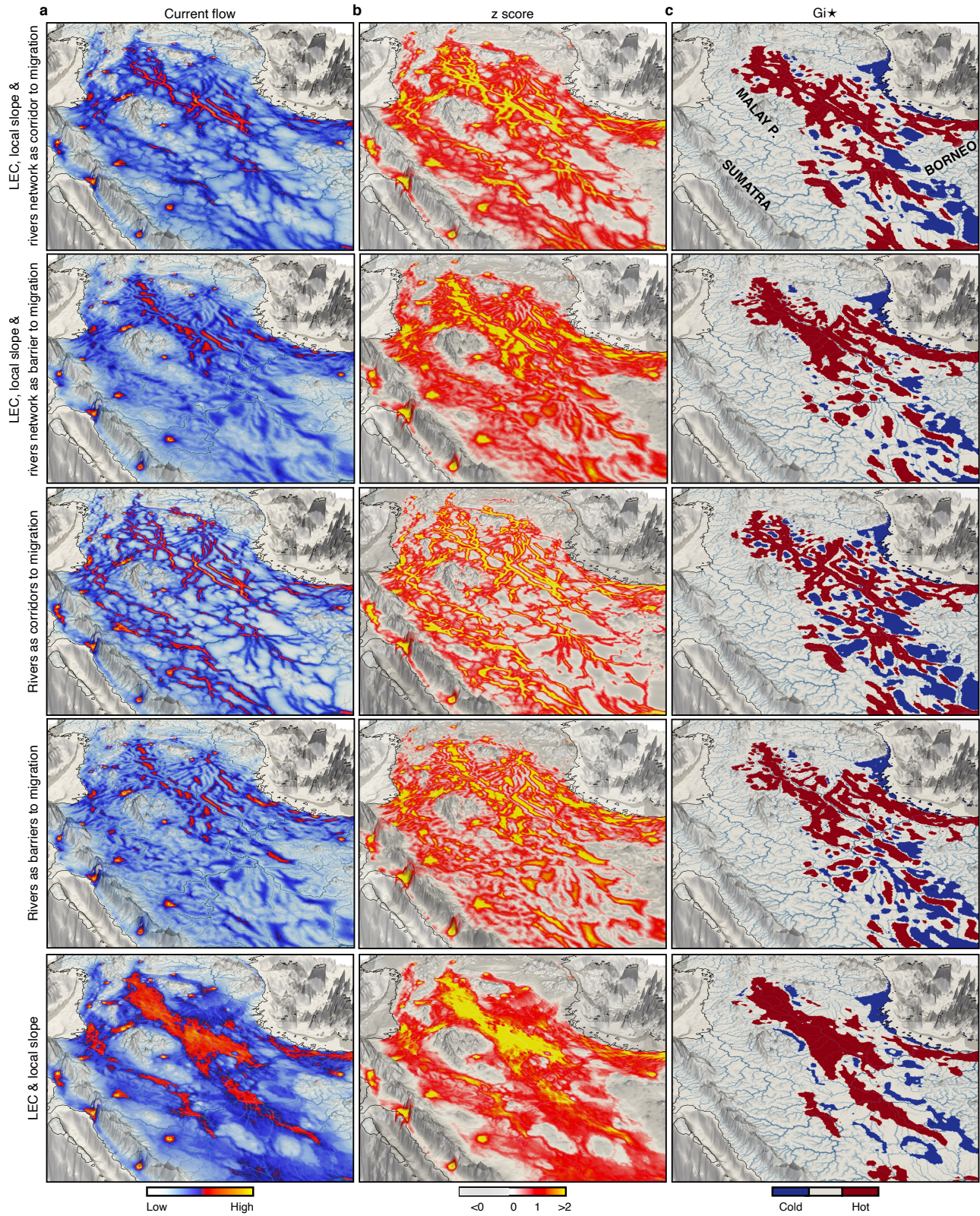
Supplementary Figure 2. Sundaland main basins physiography analysis for 3 simulations. Evolution of the drainage basins (Johore, Siam, Mekong, East Sunda, Singapore and West Borneo basins; defined in Fig. 3a) under four forcing conditions (Supplementary Fig. 1c). Pearson's coefficients indicate negative correlations between catchment physiography and sea-level height. Main flooding events (grey) and combined basins periods (blue and green) show how tectonics and sea-level fluctuations affect drainage reorganisations. Maximum number of flooding episodes and no major catchment combination are visible for the no tectonics case while maximum reorganisations (between Johore, Siam and West Borneo basins) happened with tectonics, uniform rainfall and sea-level variations⁴ (scenario 4 - second panel).



Supplementary Figure 3. Evolution of the distance between the main rivers (Mekong, Johore and Siam rivers) under variable tectonic, climatic and sea-level conditions. a. Changes in outlet distances over the past 500 kyr for the case with uniform subsidence and sea-level fluctuations² (scenario 2). **b.** Rivers are rerouted over time by sea-level, tectonics and erosion-deposition with distance increasing between rivers outlets during extensive flooding periods. The Johore and Siam basins reorganise into a single large basin on several occasions (blue-shaded area - last three panels corresponding to scenario 2 to 4). Except for scenario 1, the Siam and Johore outlets are only disconnected during the last marine transgression (grey area).



Supplementary Figure 4. Cost surfaces across the Sunda Shelf for different eustatic sea-level amplitudes when considering rivers network as corridor to migration. Current flow field for **a.** partially flooded, **b.** exposed, and **c.** nearly fully submerged time intervals.



Supplementary Figure 5. Current flow fields for different cost surfaces and statistical indicators of preferential migration pathways. **a.** Current flow fields at 280 ka considering 5 different cost surfaces for the model with laterally variable tectonic and sea-level fluctuations⁴. **b.** Related plots of current flow z-scores with hot colour (red to yellow) representing important connectivity cells ($z_{sc} > 0$), and grey colours representing negligible connectivity cells ($z_{sc} < 0$). **c.** Hotspot analysis using Getis-Ord indicator (Gi^*) based on spatial clustering of the current flow values defined in **a**.

Lon.	Lat.	Tectonic rate (mm/yr)	Reference
6.65	104.24	<i>subsidence</i>	Alqahtani et al. (2015)
0.6	103.75	-0.125	Bird et al. (2006)
-8.26	125.58	0.475	Chappell & Veeh (1978)
-14.18	121.86	-0.45	Collins et al. (2011)
-13.89	121.85	-0.29	Collins et al. (2011)
-14.07	121.86	-0.04	Collins & Testa (2010)
-3.39	126.19	0.75	De Smet et al. (1989)
-3.18	129.51	2.5	De Smet et al. (1989)
-7.52	131.48	0.5	De Smet et al. (1989)
-8.8	125.96	10.0	De Smet et al. (1989)
-5.44	122.77	0.75	Fortuin et al. (1990)
3.14	107.31	-0.25	Hanebuth et al. (2011)
4.24	109.52	-0.95	Hanebuth et al. (2011)
-8.29	124.77	1.1	Hantoro et al. (1994)
-8.27	127.36	0.5	Harris et al. (2009)
-10.55	121.87	0.2	Harris et al. (2009)
-9.76	118.12	0.5	Harris et al. (2009)
-7.87	127.13	0.55	Major et al. (2013)
-10.73	123.17	0.1	Merritts et al. (1999) - Holocene
-10.23	123.36	0.1	Merritts et al. (1999) - Holocene
-10.24	123.64	<i>uplift</i>	Merritts et al. (1999) - Holocene
-9.19	125.09	0.3	Merritts et al. (1999) - Holocene
8.13	102.75	<i>subsidence</i>	Morley & Westaway (2006)
5.63	100.34	<i>subsidence</i>	Parham et al. (2014)
5.17	118.88	<i>subsidence</i>	Parham et al. (2014)
-5.31	123.57	0.14	Pedoja et al. (2018)
-5.31	123.16	0.12	Pedoja et al. (2018)
-5.64	122.65	0.16	Pedoja et al. (2018)
-5.31	123.16	0.12	Pedoja et al. (2018)
-5.54	122.73	0.14	Pedoja et al. (2018)
-5.53	122.5	0.29	Pedoja et al. (2018)
-5.72	122.47	0.25	Pedoja et al. (2018)
-5.5	122.6	0.3	Pedoja et al. (2018)
-9.67	119.98	0.49	Pirazzoli et al. (1993)
-2.99	107.9	-0.25	Sarr et al. (2019)
1.36	125.16	0.18	Sumosusastro et al. (1989)
-0.75	111.31	0.3	Wong et al. (2003)
6.61	110.17	-0.27	Wong et al. (2003)
4.33	110.15	-0.17	Wong et al. (2003)

Supplementary Table 1. Tectonic dataset. Discrete measurement of uplift and subsidence rates that are interpolated and applied to landscape evolution simulations.

Scenario	Sea-level	Tectonics	Rainfall	ε in $e^{-8} \text{ yr}^{-1}$	Marine intrusions
1	Bintanja & van de Wal (2008)	no tectonic	PaleoClim dataset	2.5	9
2	Bintanja & van de Wal (2008)	uniform subsidence	PaleoClim dataset	7.5	6
3	Bintanja & van de Wal (2008)	vertical motion map	PaleoClim dataset	5.0	5
4	Spratt & Lisiecki (2016)	vertical motion map	Uniform rainfall	7.5	5
5	Spratt & Lisiecki (2016)	vertical motion map	PaleoClim dataset	5.0	5

Supplementary Table 2. Tested scenarios forcing mechanisms, landscape evolution erodibility and local marine intrusions. ε is the erodibility coefficient defined in Eq. 1 which has been tested at $2.5e^{-8}$ increments from $1.e^{-8}$ to $1.e^{-7} \text{ yr}^{-1}$, the number of marine intrusions simulated in box A (Fig. 1b) where a total of 5 marine intrusion episodes were recorded based on borehole data and 3D seismic sections analysis⁵.

Deposits	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
30 - 100	50 - 105	15 - 68	10 - 65	21 - 70	14 - 84
~ 75	~ 63	~ 34	~ 44	~ 70	~ 81
40 - 80	75 - 108	31 - 55	30 - 58	28 - 65	38 - 73
~ 300	~ 271	~ 335	~ 320	~ 294	~ 305

Supplementary Table 3. Comparisons between sediment thickness dataset and simulated values across the shelf. The first column corresponds to deposits thickness in metres from 4 different sources. First row is from 3D seismic and borehole dataset from⁵. Second row has been estimated based on a 3D seismic survey offshore Indonesia and corresponds to the estimated deposition over the last 1.3 Myr⁶. Third row thickness range has been compiled based on seismic time-slice for the Malay basin and for the Pleistocene⁷. The last row is derived from 2D seismic for the shelf over the last 600 kyr⁸. The position of the surveys are defined by the coloured triangles in Fig. 1b. Simulated thicknesses for each scenario are given in the following columns.

Basin name	Lat.	Lon.	Genera
Mekong	18.92	101.72	Dermogenys
Mekong	18.69	104.70	Dermogenys
Mekong	13.26	103.24	Dermogenys
Mekong	12.34	104.11	Dermogenys
Johore	14.87	99.99	Dermogenys
Johore	3.18	103.02	Dermogenys
Johore	2.41	104.28	Dermogenys
Johore	2.89	105.55	Dermogenys
Johore	3.86	106.27	Dermogenys
Johore	0.79	104.46	Dermogenys
Johore	6.03	102.26	Hemirhamphodon
Johore	2.98	103.31	Hemirhamphodon
Johore	1.86	103.85	Hemirhamphodon
Johore	1.23	104.16	Hemirhamphodon
Siam	-1.81	103.07	Dermogenys
Siam	-0.10	109.21	Dermogenys
Siam	1.09	109.23	Dermogenys
Siam	-1.53	103.36	Hemirhamphodon
Siam	0.74	109.16	Hemirhamphodon
Siam	0.15	110.83	Hemirhamphodon
Siam	1.79	109.53	Hemirhamphodon
East Sunda	-6.56	106.69	Dermogenys
East Sunda	-7.34	112.32	Dermogenys
East Sunda	-3.08	114.04	Dermogenys
Singapore	0.99	101.65	Hemirhamphodon
Singapore	2.67	102.05	Hemirhamphodon
Singapore	3.73	101.49	Hemirhamphodon
Singapore	4.35	100.61	Hemirhamphodon
Singapore	5.53	100.37	Hemirhamphodon

Supplementary Table 4. Genera for freshwater halfbeak fishes and corresponding paleo-drainage basins. Sampling locations of freshwater halfbeak fishes, associated paleo-basin drainage and corresponding genera based on multigene phylogeny study¹.

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