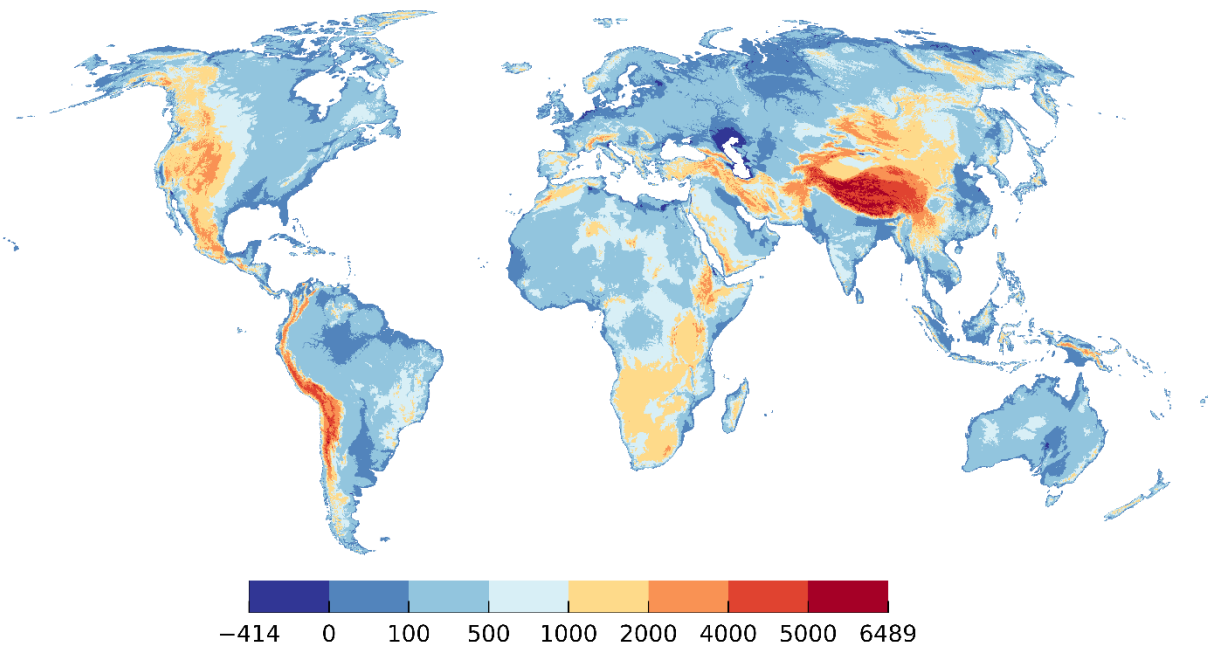**Figure S1** Difference [m] between mean elevation and P_{30} elevation. Maximum value 1365 m**.**

5   **Figure S2** Land surface elevation [m] used in G³M: 5' average of 30"land surface elevation used in Fan et al. (2013).
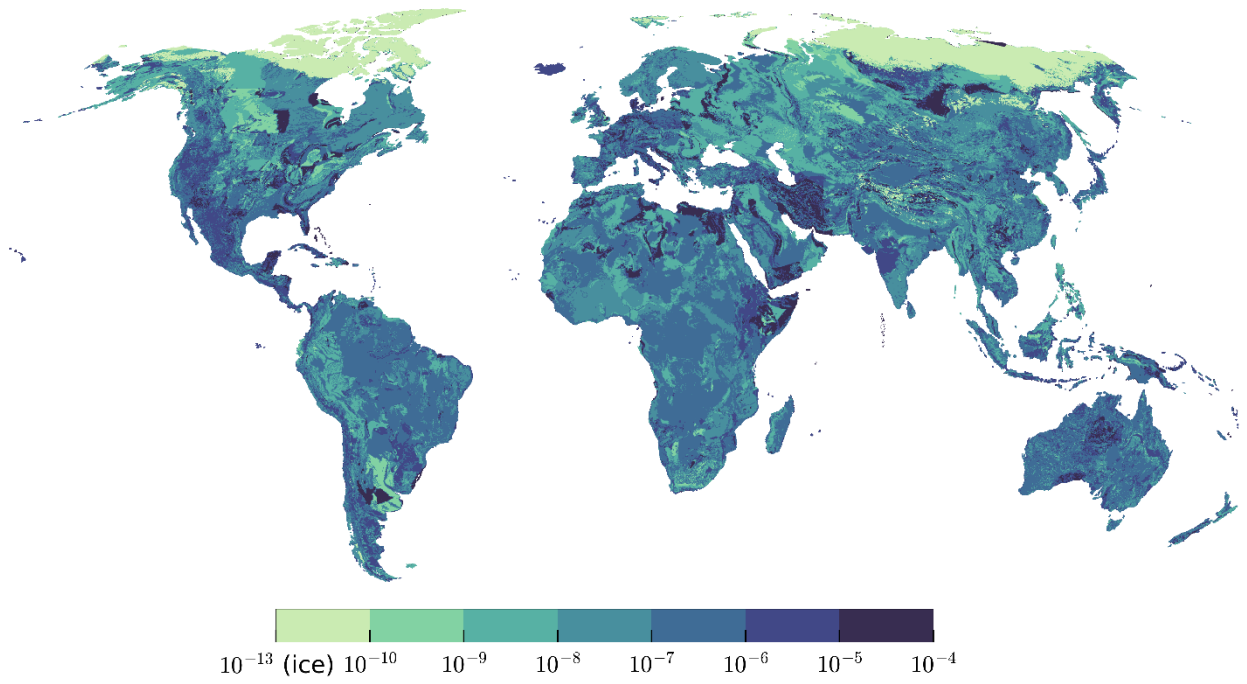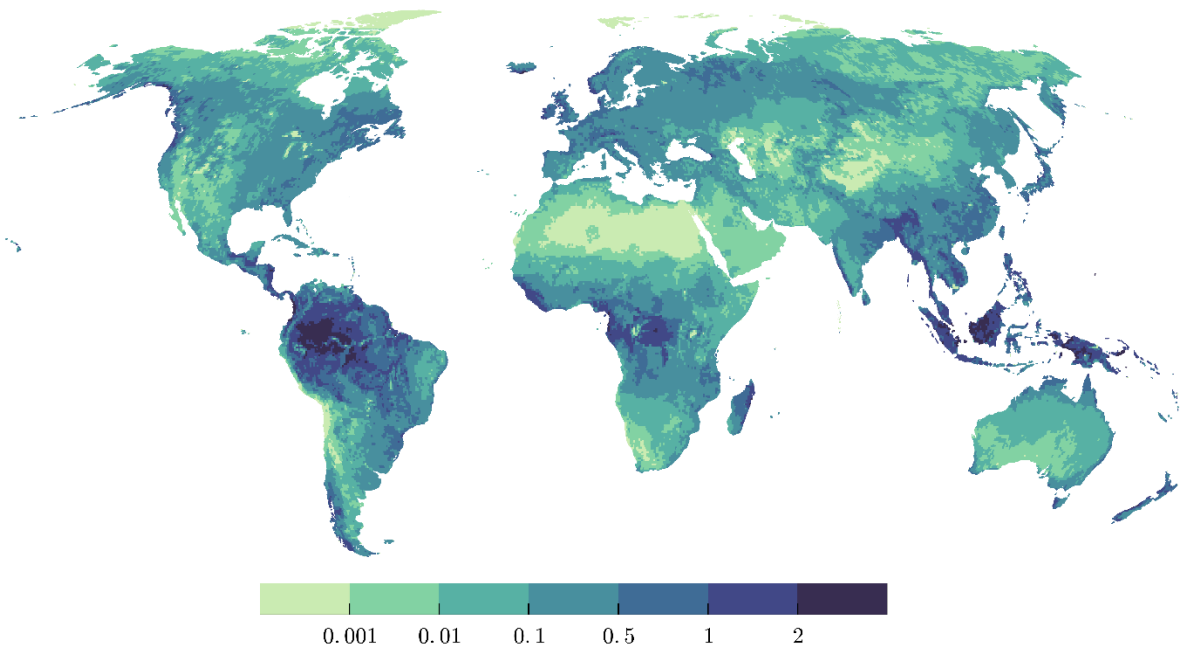
Figure S3 Hydraulic conductivity [ms^{-1}] derived from Gleeson et al., 2014) by scaling it with the geometric mean to 5'. Very low values in the northern hemisphere are due to permafrost conditions.

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Figure S4 Mean annual groundwater recharge [$mm\ day^{-1}$] between 1901-2013, from WaterGAP 2.2c.
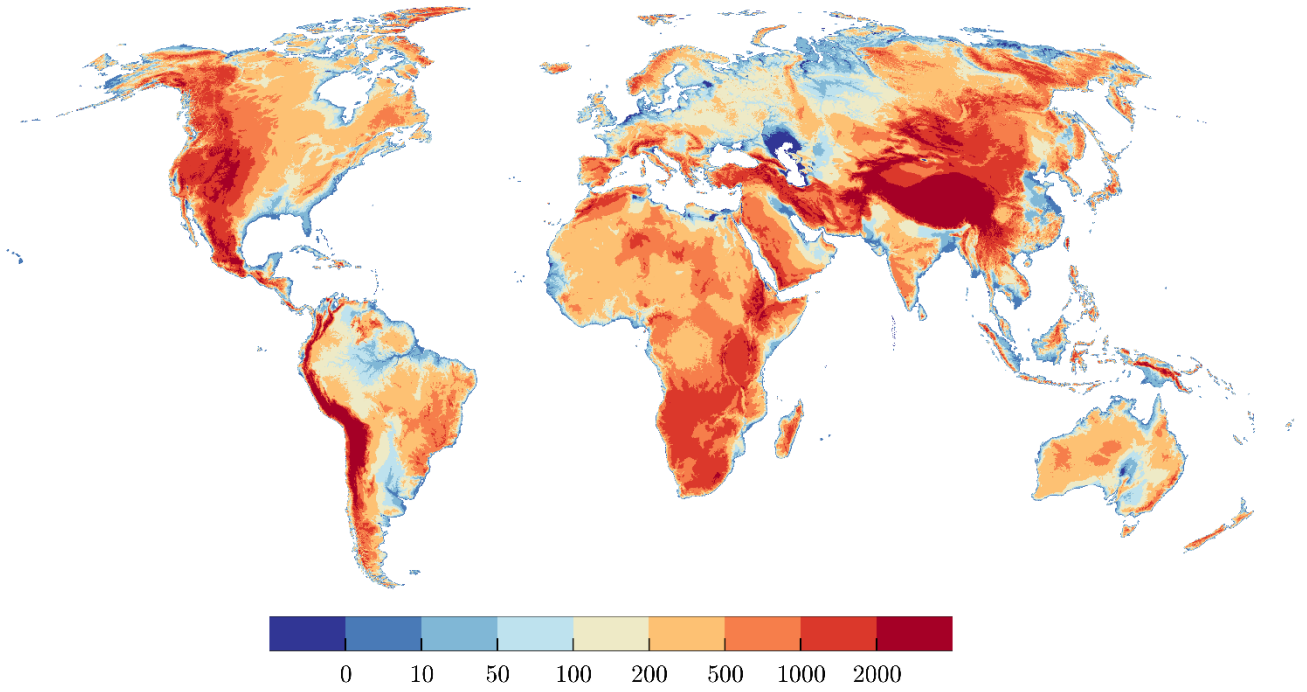
Figure S5 Hydraulic head [*m*] as calculated by G³M for steady-state conditions. Max: 6375 m, Min: -414 m
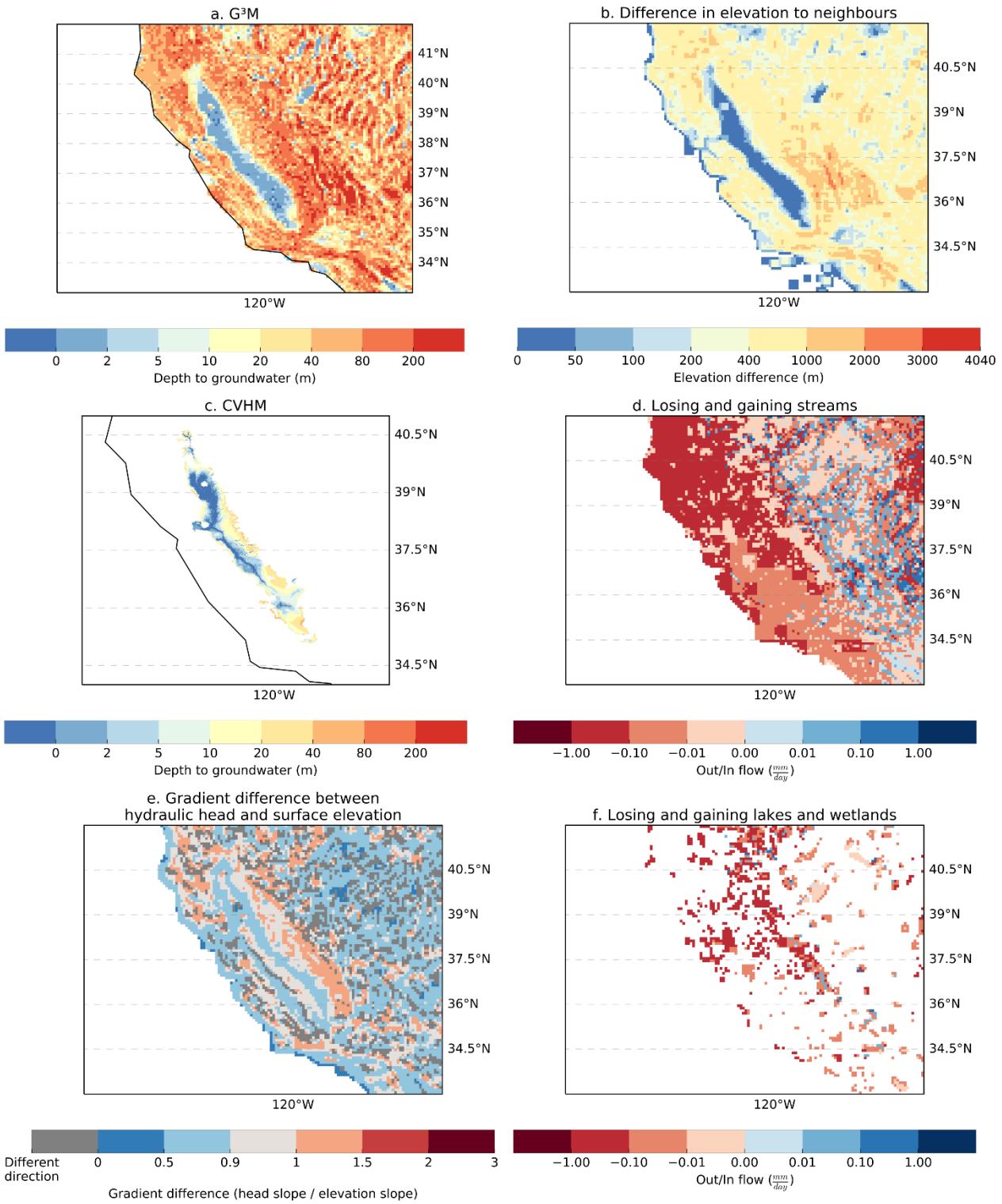
Figure S6 Plots of depth to GW as calculated by G³M (a), difference in surface elevation to neighbouring cells (b), depth to GW as used by the CVHM as the natural state and starting condition (Faunt, 2009) (c), losing and gaining streams as calculated by G³M (d), difference in gradient of hydraulic head and surface elevation (e), losing and gaining lakes and wetlands as calculated by G³M for the Central Valley and the Great Basin.
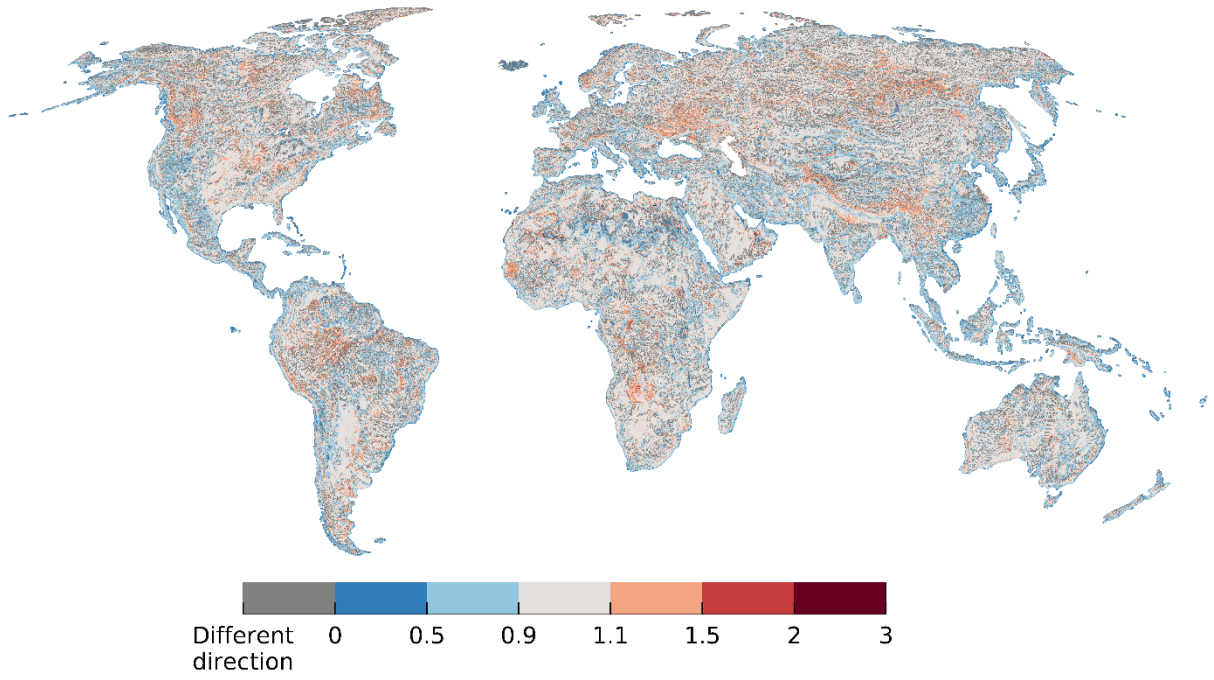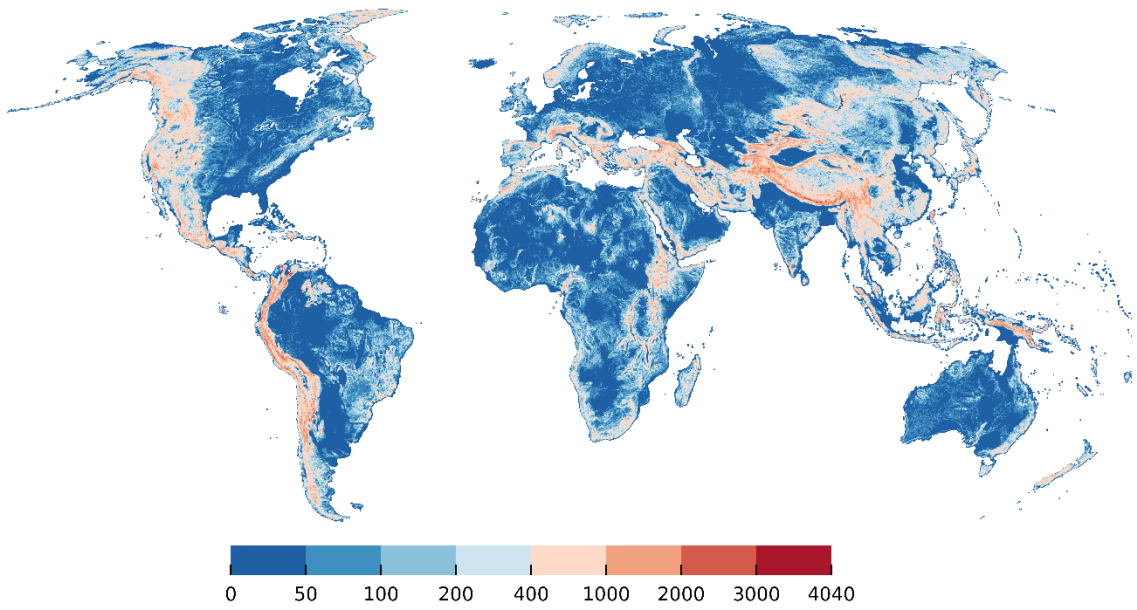
Figure S7 Ratio of hydraulic head gradient to 5' mean surface elevation gradient, only computed if the difference in direction of the gradient was smaller than 45°.

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Figure S8 Land surface elevation difference [**m**] to mean elevation of neighboring cells on 5' resolution.
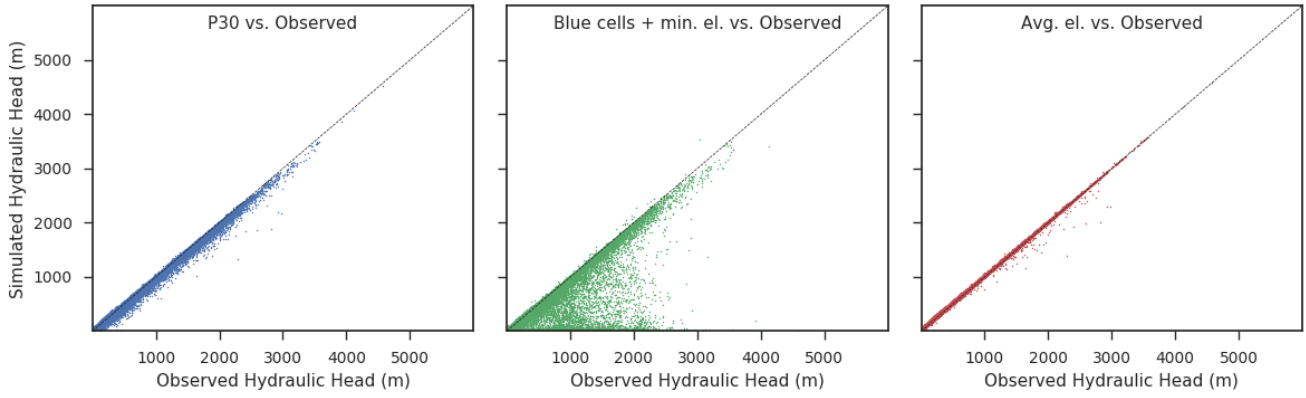
Figure S9 Comparison between three alternatives for setting h_{swb}. Left to right: Fit of simulated hydraulic heads observations if h_{swb} is set (1) to the 30th percentile of the 30" land surface elevations (standard model) , (2) alternatively to the average elevation of all "blue" cells of the 30" water table results of Fan et al., (2013) or (3) is set to the average of the 30" land surface elevations. A blue cell has a depth to GW of less than 0.25 m and indicates GW discharge to the surface. If no "blue" cell exists in the 5' cell, the minimum elevation of the 30" land surface elevation values within the cell was used.
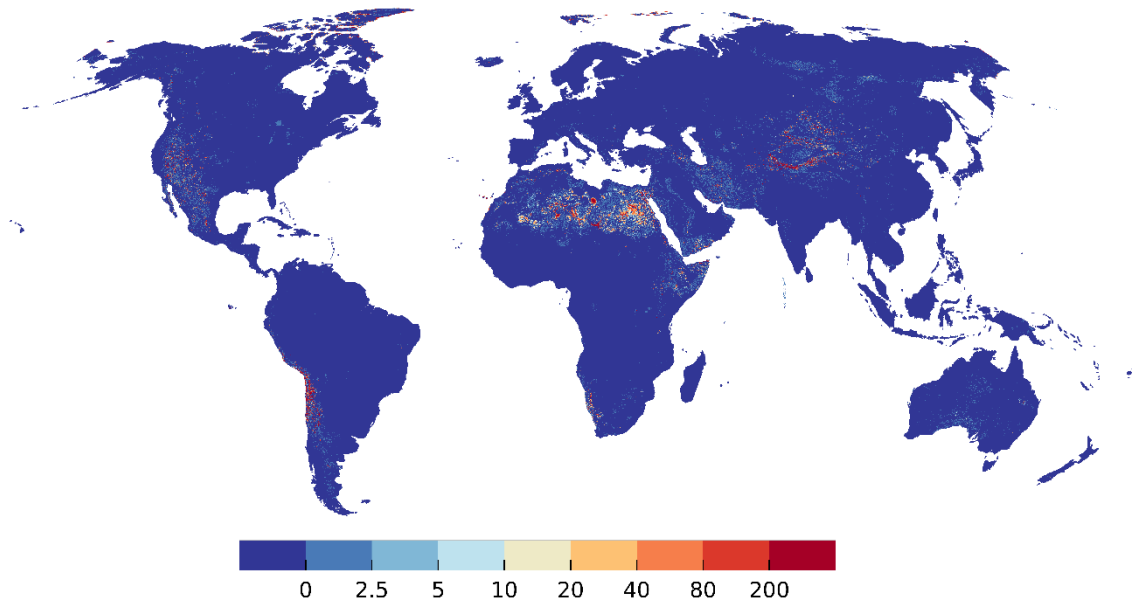

Fig. S10 Depth to groundwater [m] for SW body elevation at average of 30" land surface elevations.
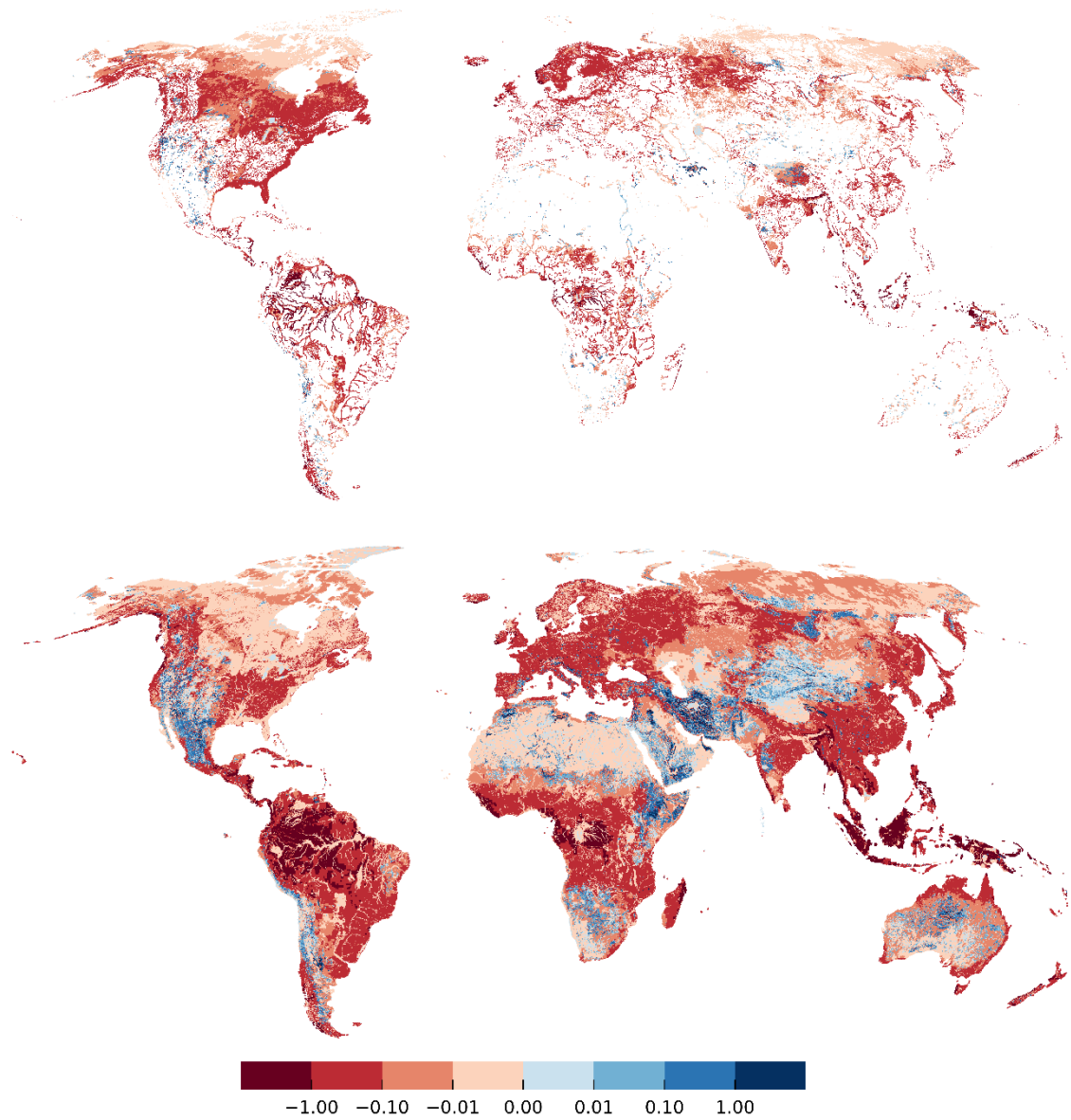
Figure S11 Gaining and losing rivers (lower panel) and wetlands and lakes (upper panel) as flow into/out the GW [$mm\,day^{-1}$] if h_{swb} is set to average elevation of all "blue" cells of the 30" water table results of Fan et al., 2013) (right). A blue cell is defined as a depth to groundwater of less than 0.25 m. If no "blue" cell exist in the 5' cell, the minimum elevation of the 30" land surface elevation values is used. Red denotes gaining SW bodies.
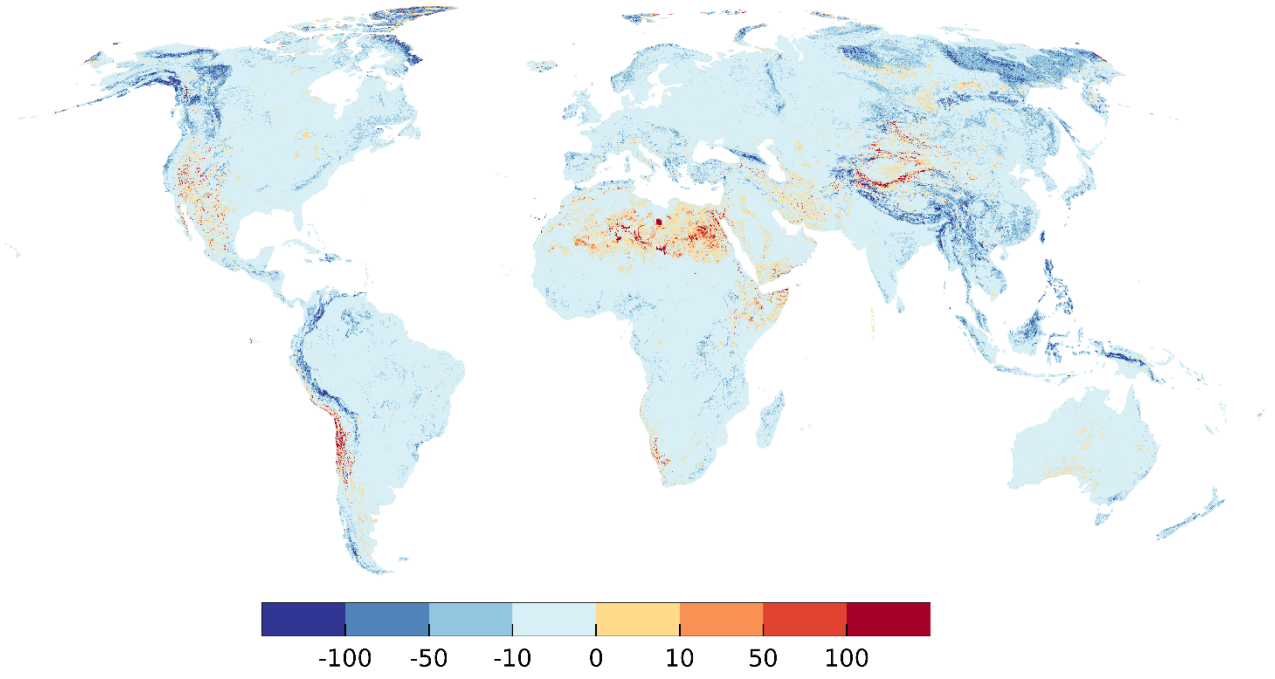
Fig. S12 Difference [m] between P_{30} elevation and hydraulic head.