Supplementary Material 1 – HYPE model construction and validation results for this study

The Hydrological Predictions for the Environment (HYPE) semi-distributed hydrological model (Lindström et al., 2010), is a subcontinent-scale catchment model that has been established for the Greater Mekong Region (GMR) within Southeast Asia, this version being known as GM-HYPE (Du et al., 2022). The GMR encompasses 13 river basins, six of which are international river basins, collectively accounting for 90% of the total model domain. These basins traverse the entire territories of Vietnam, Laos, and Cambodia, and parts of China, Thailand, and Myanmar.

The GM-HYPE model has been calibrated and validated using regionalization, satellite altimetry-based water levels, and satellite-based reservoir operation data for both "naturalized" and regulated stream flows across the study domain (Du et al., 2020 and 2022; Ali et al., 2023). The version used here, GM-HYPE v1.4, covers a 1.2 million km^2 study area, subdivided into 1,230 sub-catchments and includes all operating reservoirs and dams constructed up to the year 2020. Validation of GM-HYPE involved the use of diverse metrics across ~30 river gauging stations, yielding an overall Kling-Gupta Efficiency (KGE) of 0.72 and a Pearson's correlation coefficient (CC) of 0.84 for the pre-dam period (1991-2001). For the post-dam period (2016-2019), the model achieved metrics of 0.60 for KGE and 0.78 for the CC.

GM-HYPE's aptitude in simulating river outputs for our analysis, using ERA5 input climate data, was also tested against 20 gauged observations internal to the GMR model domain (Table S1.1). Goodness of fit ranges between 0.79 and 0.98 for CC, and between 0.47 to 0.82 for KGE. Specific modelled river stage and stream flow data at Khong Chiam, located at the river border between Laos and Thailand, are compared against the gauged record, for the period 2002-2007 in Fig. S1.1. It shows that scores of 0.97 CC and 0.82 KGE, provide good model accuracy – particularly with the rising annual flood, but a slight tendency to underestimate stream flow peaks and the receding limb of the hydrograph.

Table S1.1 – GM-HYPE model A fit against observed data scores, at 20 stations across the GMR, over the period 2002-2007. Model outputs for Khong Chiam (shaded) are compared against gauged data in Fig. S1.1.

River Gauge	Country	Lat	Long	CC	KGE
Dao Duc	Vietnam	22.592	104.945	0.81	0.75
Lao Cai	Vietnam	22.282	104.222	0.81	0.70
Lai Chau	Vietnam	22.155	103.379	0.84	0.61
Yen Bai	Vietnam	21.328	105.193	0.82	0.56
Vu Quang	Vietnam	21.287	105.428	0.83	0.78
Hoa Binh	Vietnam	21.260	105.353	0.79	0.58
Ta Bu	Vietnam	21.218	104.327	0.86	0.59
Son Tay	Vietnam	21.002	105.886	0.90	0.82
Xa La	Vietnam	20.913	103.976	0.81	0.64
Vientiane	Laos	17.940	102.613	0.93	0.57
Chiang Khan	Thailand	17.901	101.662	0.96	0.47
Nong Khai	Thailand	17.880	102.714	0.94	0.49
Thakhek	Laos	17.382	104.800	0.97	0.73
Mukdakhan	Thailand	16.534	104.742	0.96	0.81
Khong Chiam	Thailand	15.325	105.495	0.97	0.82
Pakse	Laos	15.110	105.789	0.96	0.80
StungTreng	Cambodia	13.539	105.955	0.95	0.70
Kratie	Cambodia	12.519	105.993	0.95	0.65
KamPong Cham	Cambodia	12.006	105.471	0.98	0.58
Chroy Chang Var	Cambodia	11.625	104.939	0.92	0.72

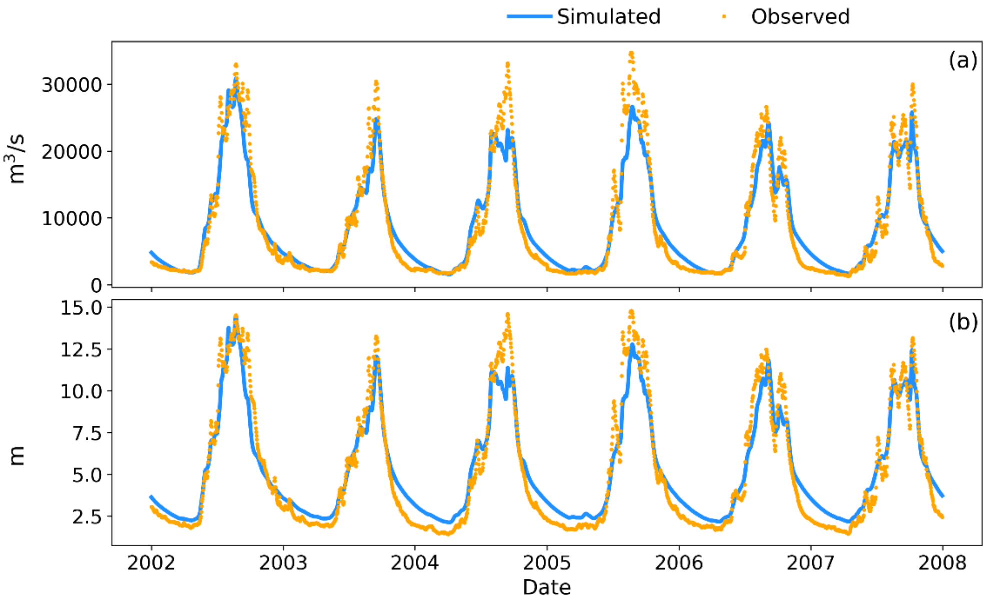

Figure S1.1 - Validation of river flows (a) and water surface elevation (b) at Khong Chaim, with HYPE outputs in blue, and observed data in orange (2002-2007)

We created two distinct models using GM-HYPE, utilising 1970-2019 ERA 5 reanalysis precipitation data from the Copernicus climate data store (https://cds.climate.copernicus.eu/) (Hersbach et al., 2020): (1) Model A is the baseline model driven with ERA5 precipitation data for the GMR. ERA5 data characterises all rainfall types (monsoon, TC-linked etc) in this region; and (2) Model B is this baseline Model A, but with TC-induced precipitation removed.

The precipitation data files for model A were created by clipping a timeseries of 0.5° × 0.5° latitude/longitude grids of ERA5 total daily precipitation reanalysis data to the GMR domain. We then duplicated this precipitation file for model B, cutting out the precipitation data within a 500 km radius of TC epicentres. TC-epicentres were located by cross referencing IBTrACS data with the strong differences in counterpart ERA5 wind and pressure data (also downloaded from the Copernicus climate data store), in an approach similar to the methodology described in Rodgers et al., (2000), Englehart et al. (2001), and Darby et al., (2016), albeit here we did not back-fill precipitation voids with background precipitation data.

Supplementary Material 2 – ERA5 forced HYPE model sub-catchment outputs: mean, and 95th percentile, streamflows

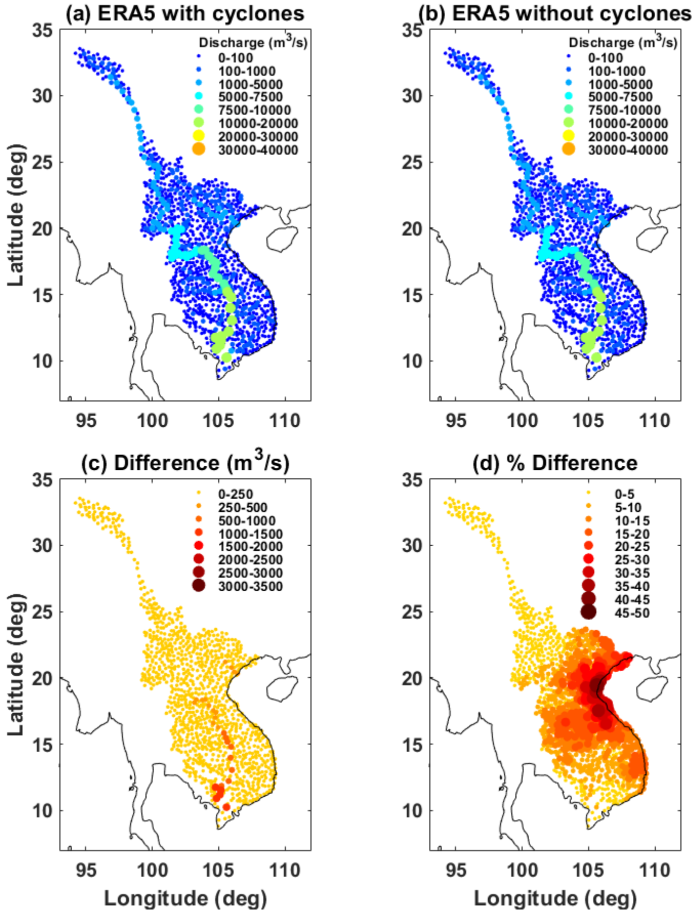

Figure S2. 1 - The mean flows from model simulations. (a) from scenario A: ERA5 precipitation including TCs; (b) scenario B: ERA5 precipitation without TCs; (c) the discharge difference between (a) and (b) (m^3s^{-1}); and (d) the percentage difference between (a) and (b).

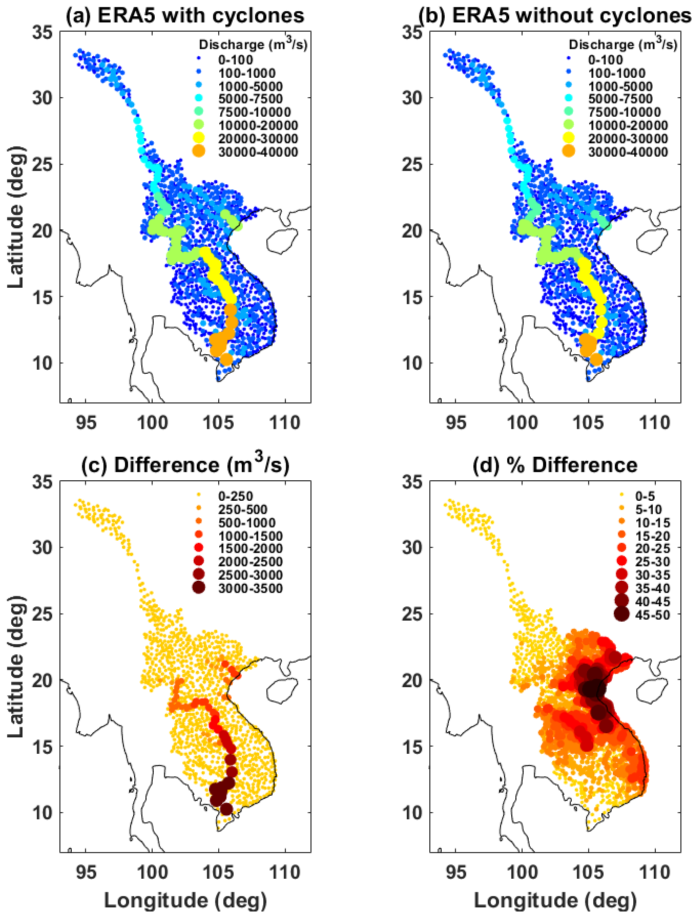

Figure S2. 2 - 95th percentile flows from model simulations. (a) from scenario A: ERA5 precipitation including TCs; (b) scenario B: ERA5 precipitation without TCs; (c) the discharge difference between (a) and (b) (m^3s^{-1}); and (d) the percentage difference between (a) and (b).

Supplementary Material 3 – HYPE model sub-catchment outputs, using ERA5 input data (1970-2019): mean and 95th percentile precipitation

Figure S3. 1 - The percentage difference between mean model output stream flows (ERA5 precipitation with and without TCs). Black lines indicate historic TCs and tropical storms or depressions during that year. TC track data obtained from the IBTRACS database (Knapp et al., 2010).

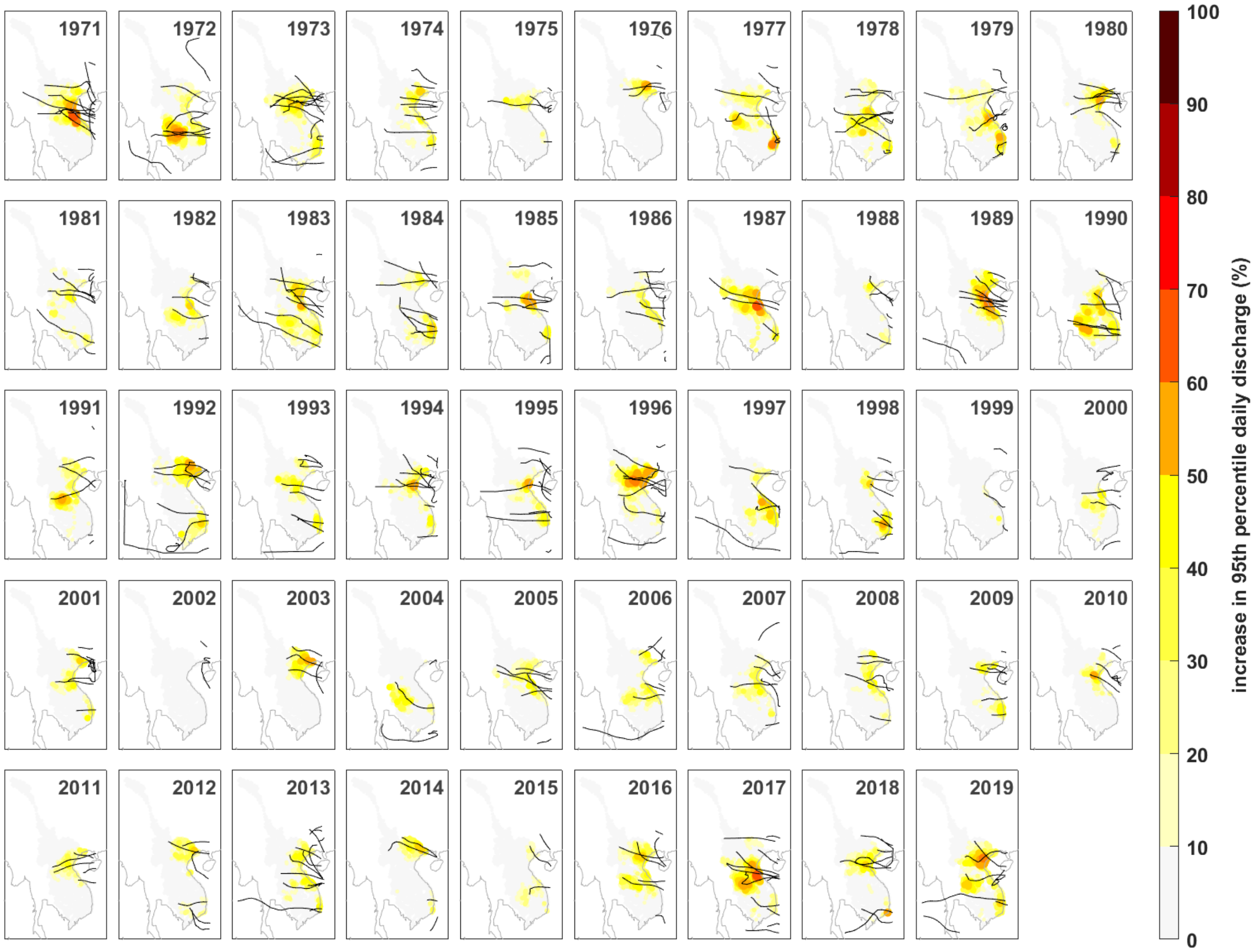

Figure S3. 2 - The percentage difference between 95th percentile model output stream flows (ERA5 precipitation with and without TCs). Black lines indicate historic TCs and tropical storms or depressions during that year. TC track data obtained from the IBTRACS database (Knapp et al., 2010).

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Supplementary Material 4 – Mann-Kendall statistic 'S' for mean and 95th percentile flows, to highlight trends in the GMR (1970-2019 data).

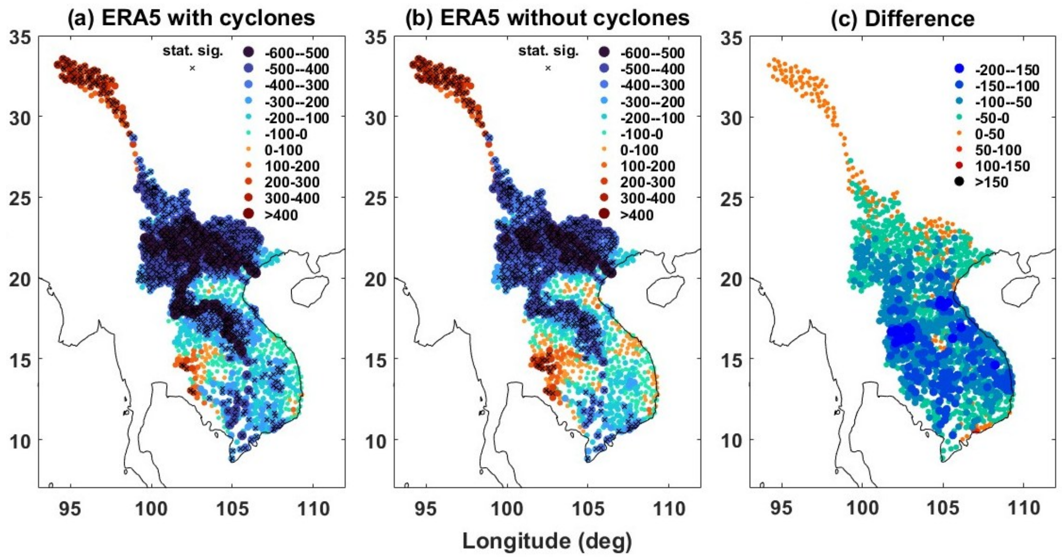


Figure S4. 1 – Mann Kendall 'S' (Sen slope) statistic, showing magnitude or strength of trend - calculated on mean sub-catchment river flows. Sub-catchments with an 'x' have statistical significance, with certainty of α=0.05. Comparing model scenario A: ERA5 precipitation including TCs (a); with model scenario B: ERA5 precipitation without TCs (b). The direction of the trend (c).

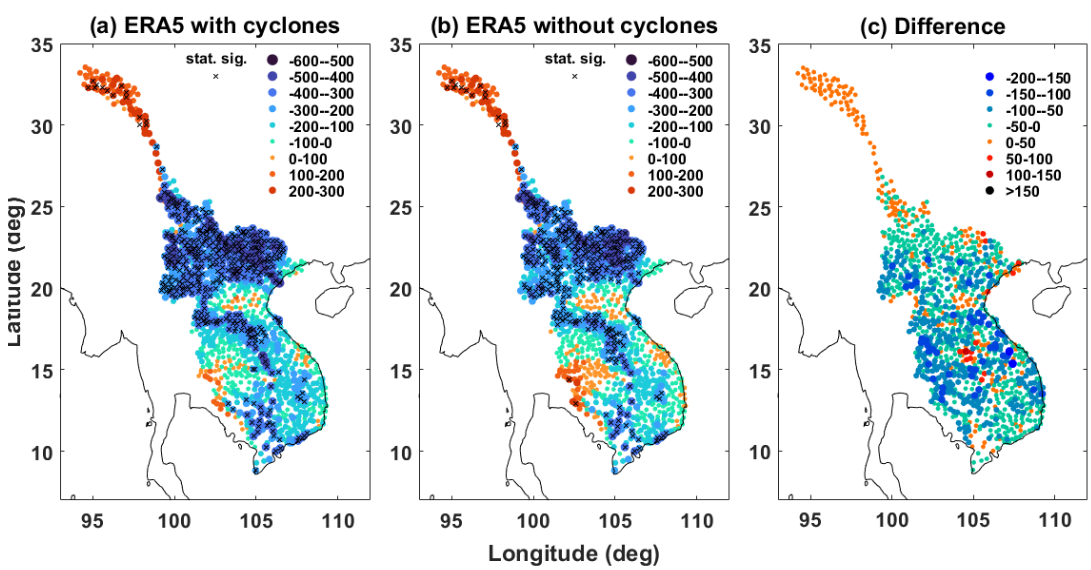


Figure S4. 2 – Mann Kendall 'S' (Sen slope) statistic, showing magnitude or strength of trend - calculated on 95th percentile sub-catchment river flows. Sub-catchments with an 'x' have statistical significance, with certainty of α=0.05. Comparing model scenario A: ERA5 precipitation including TCs (a); with model scenario B: ERA5 precipitation without TCs (b). The direction of the trend (c).

Supplementary Material 5 – Analysis of relationships between modelled outputs

An OLS regression analysis of model outputs was performed to determine relationships between excess extreme stream flows (**ExStream**), as the modelled response, and catchment excess precipitation (**ExPrecip**), catchment excess soil moisture (**ExMoist**), and mean catchment slope (**Slope**). Data were log10 transformed to correct a moderate to heavy right skew (Figure S6.1). Then a log-linearized power law model was fit to the transformed data, where excess soil moisture was shown to be the only significant term in the model. Diagnostics were good overall but a couple of points (169 and 730) had marginal influence/leverage (Figure S6.2), which were both on the extreme low end (~10-10). These points were dropped, and the regression reran to reveal not much difference between models with or without points, so we went with the original model. Predicted (i.e. conditional mean) vs observed model in arithmetic space are shown in Figure S6.3 and in log space in Figure S6.4.

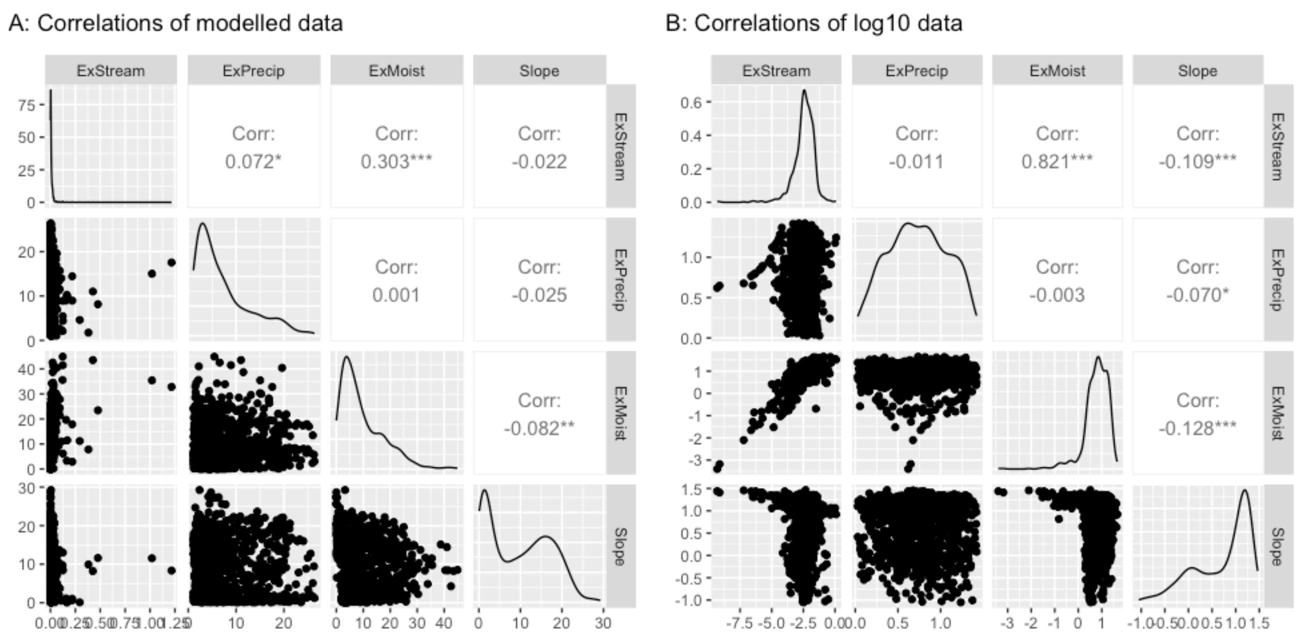


Figure S5.1 – Scatterplot matrices before (left) and after (right) log10 transformation of all variables.

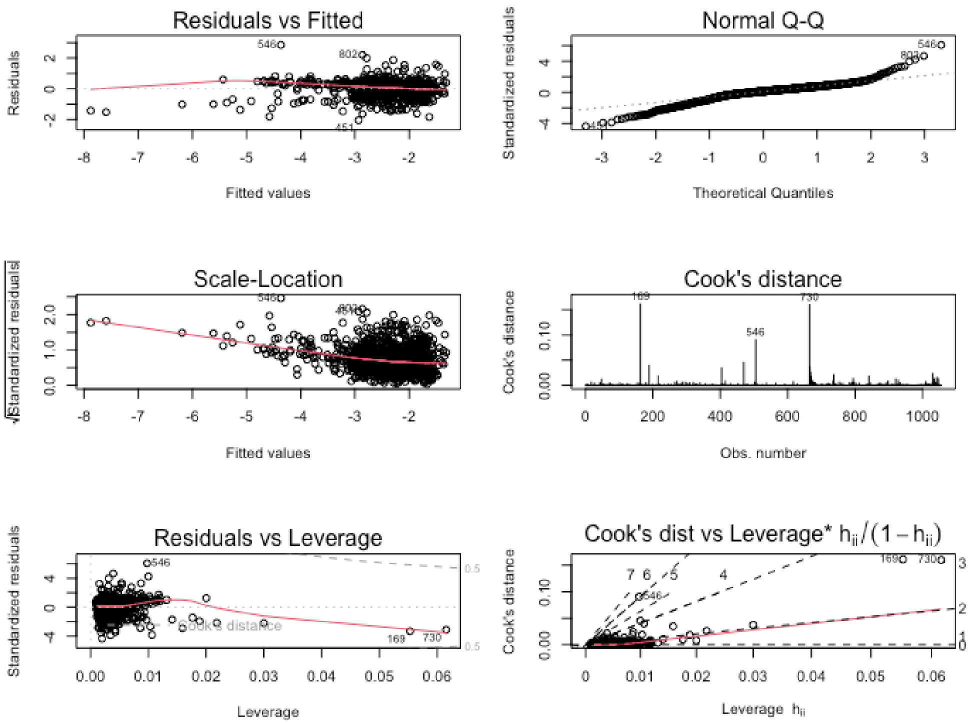


Figure S5.2 – Diagnostic plots of final model indicating mild leverage/influence and well fit data.

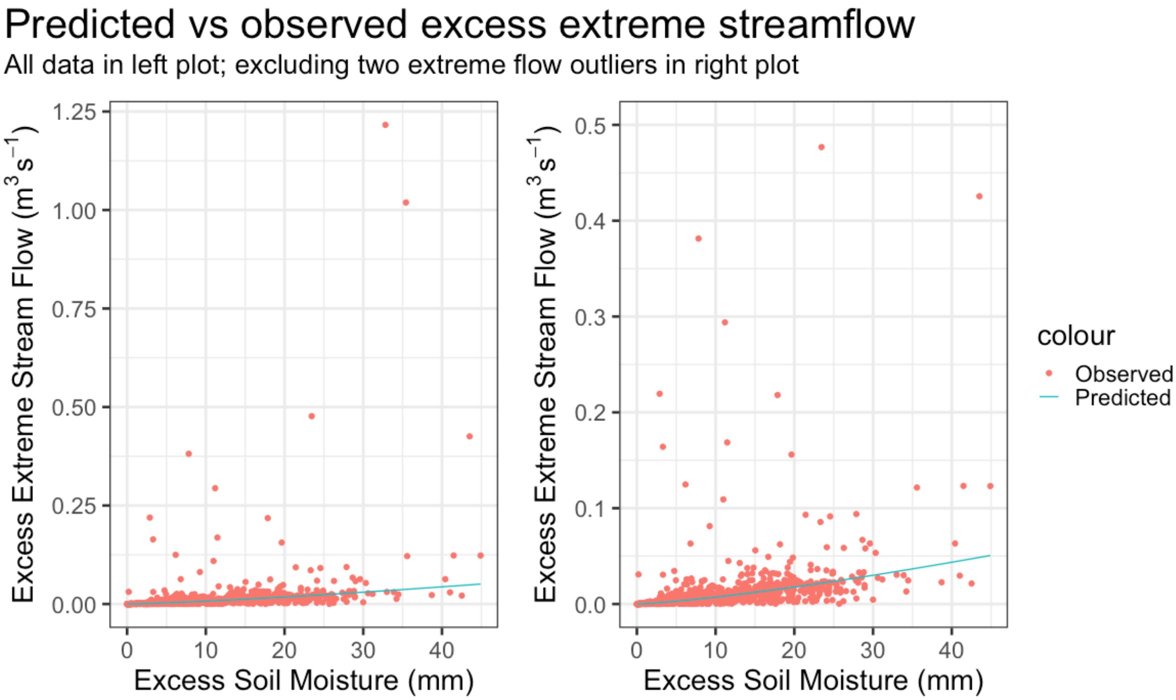


Figure S5.3 – Predicted (blue line) vs observed (red points) data showing slow geometric growth rate.

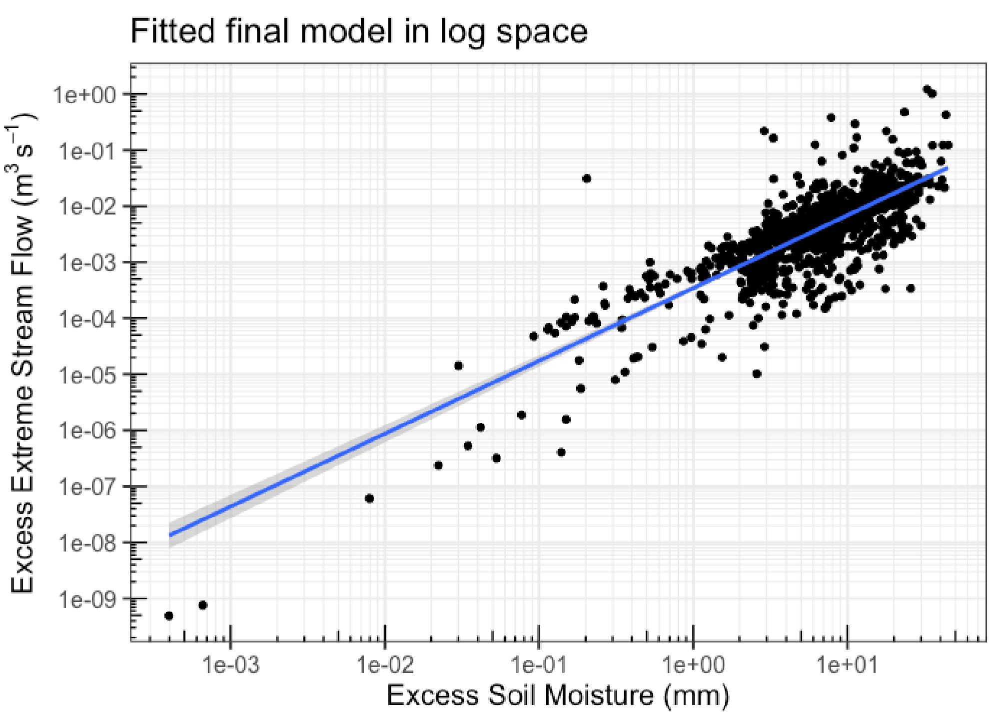
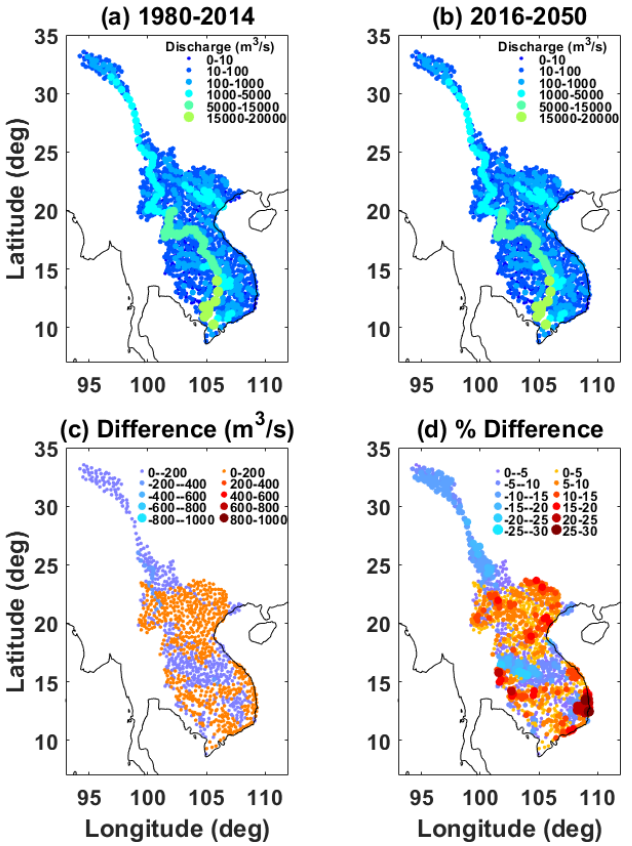


Figure S5.4 – Excess extreme streamflow vs excess soil moisture in log space.

Supplementary Material 6 – GCM forced HYPE model sub-catchment outputs: mean, and 95th percentile, streamflows



435 **Figure S6.1 - Mean flows from global climate model forced HYPE simulations: for a) global climate model 1980-2014; b) global climate model 2016-2050 ; c) the discharge difference between them; and d) the % difference between them.**

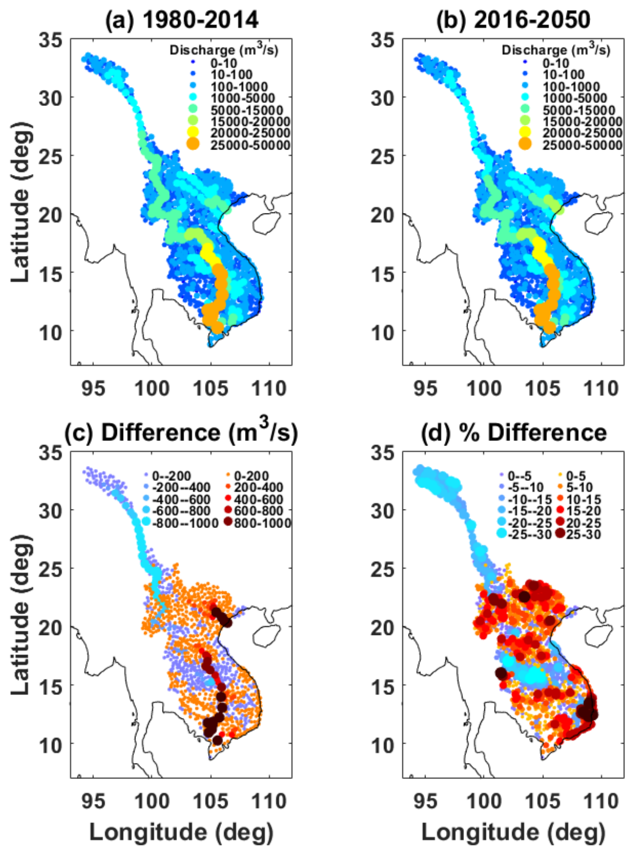


Figure S6.2 – 95th percentile flows from global climate model forced HYPE simulations: for a) global climate model 1980-2014; b) global climate model 2016-2050 ; c) the discharge difference between them; and d) the % difference between them.