Supplement S1. Validation of annual maxima daily discharge and storm surge

For this study we select the simulated discharge from JULES runoff routed with CaMa-Flood based on the performance tests presented in Beck et al. (2017) and Schellekens et al. (2017). Here, we complement these tests by looking at the rank correlation coefficient and the absolute average lag in the timing of the annual maxima in observations with a record length of at least 20 years. We also apply similar performance tests for the storm surge variable.

We use the Spearman's rank correlation, a nonparametric measure for monotonic relationships between two variables. The rank correlation coefficient is equivalent to the Pearson's product moment correlation, ρ, applied to the ranks of the annual maxima both observed (X_o) and simulated (X_s), such that:

$$r_{X_o,X_s} = \rho(X_o, X_s)$$

We also calculate a simple metric often used in flood forecasting studies, the Hit Rate, H, but applied to the date of the annual maximum. This corresponds to the probability of detection of the date of the annual maxima. We assume that the simulated date of the annual maximum D_S^i is correctly represented if it is within ± 3 days of the observed annual maximum D_O^i in the i-th year considered:

$$H = \frac{\sum_{i=1}^{N}(D_S^i \cap D_O^i)}{N}$$

S1.1 Annual maxima of daily discharge

We compare the performance of the modelled annual maxima of daily discharge with discharge observations from the Global Runoff Data Base (GRDB) from the Global Runoff Data Centre[1] . We follow a similar procedure as described in Zhao et al. (2017) to select stations in near-natural areas, and therefore minimise anthropogenic influence on the measured discharge. A catchment is selected if less than 2% of its upstream area is subject to irrigation, if the total reservoir capacity in the catchment is less than 10% of its long-term mean annual discharge, and if the record length is at least 20 years with a minimum completeness of 75% per year within the period 1980-2014. This leads to the selection of 1182 stations, shown in Figure S1 and S2. The timing of the simulated discharge annual maxima compared with observations varies greatly globally. We find a median hit rate of 0.21 (min:0, max:0.79, s.d.:0.18) and a median rank correlation coefficient is 0.56 (min: -0.35, max: 0.96, s.d.: 0.23).

[1] The Global Runoff Data Centre, 56068 Koblenz, Germany www.bafg.de/GRDC/EN/Home/homepage_node.html

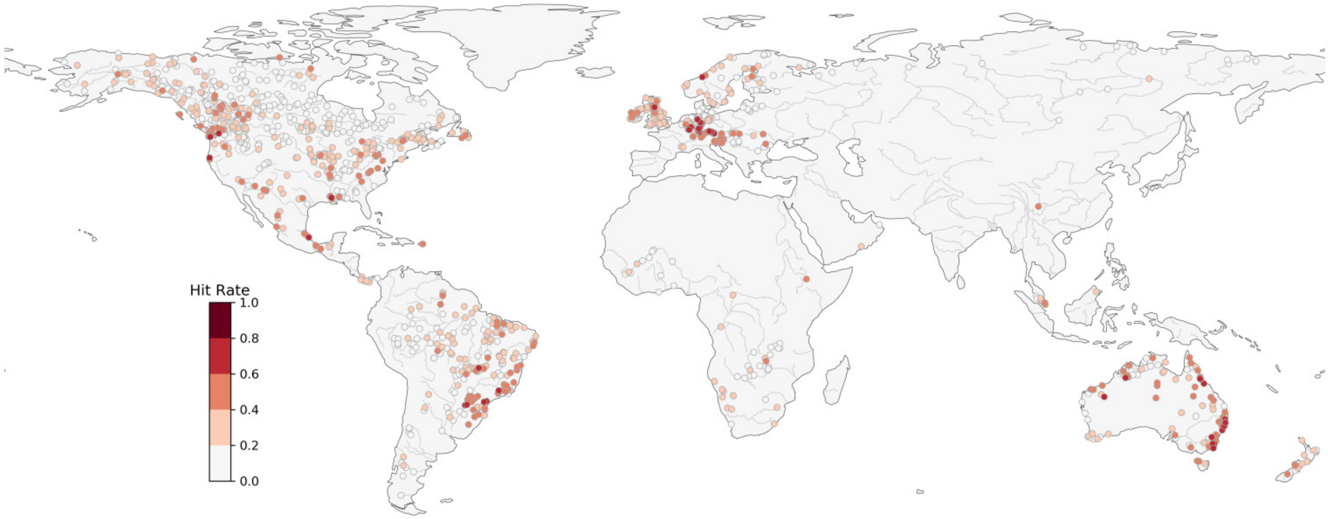

Figure S1: Probability of correctly detecting the date of the discharge annual maxima within ± 3 days.

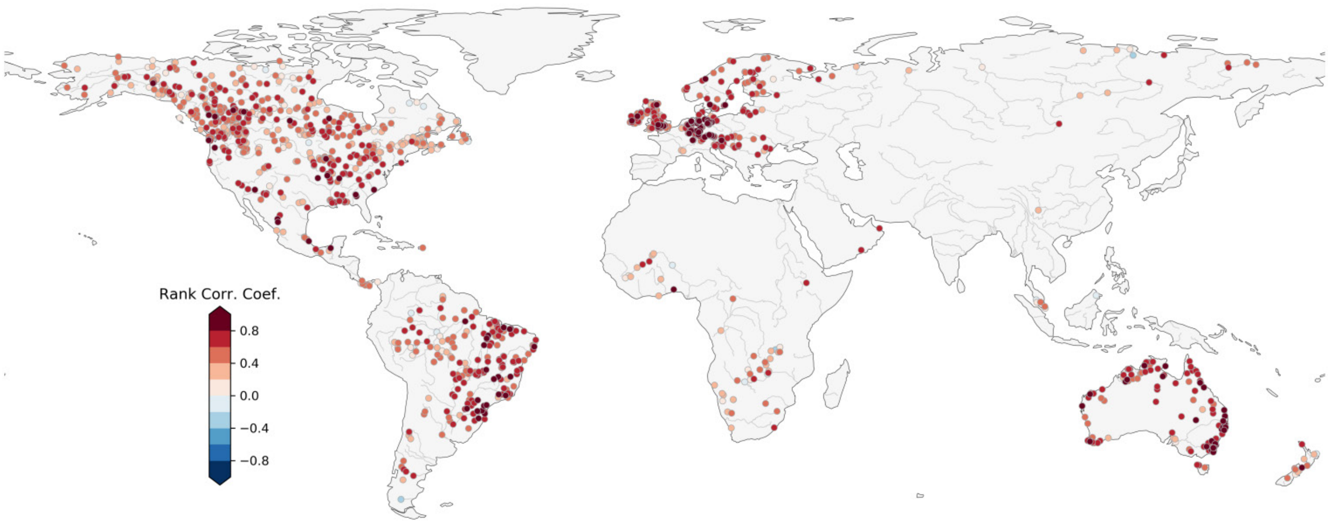

Figure S2: Spearman's rank correlation between the daily discharge annual maxima occurrence obtained from the model and from the observations.

S1.2 Annual maxima of storm surge

In order to compare the simulated storm surge variable with observations, we extract the equivalent of the storm surge from the sea levels observations of the Global Extreme Sea-level Analysis Version 2 database (GESLA-2) database (Woodworth et al., 2017). We select coastal stations if they have at least 20 years of data and a minimum completeness of 75% per year and compare it with the closest GTSM output location within a maximum radius of 20 km. The timing of the simulated storm surge annual maxima compared with observations varies greatly globally. We find a median hit rate of 0.32 (min: 0, max: 0.70, s.d.: 0.21) and a median rank correlation coefficient of 0.37 (min: -0.45, max: 0.81, s.d.:0.31).

Figure S3: Probability of correctly detecting the date of the storm surge annual maxima.

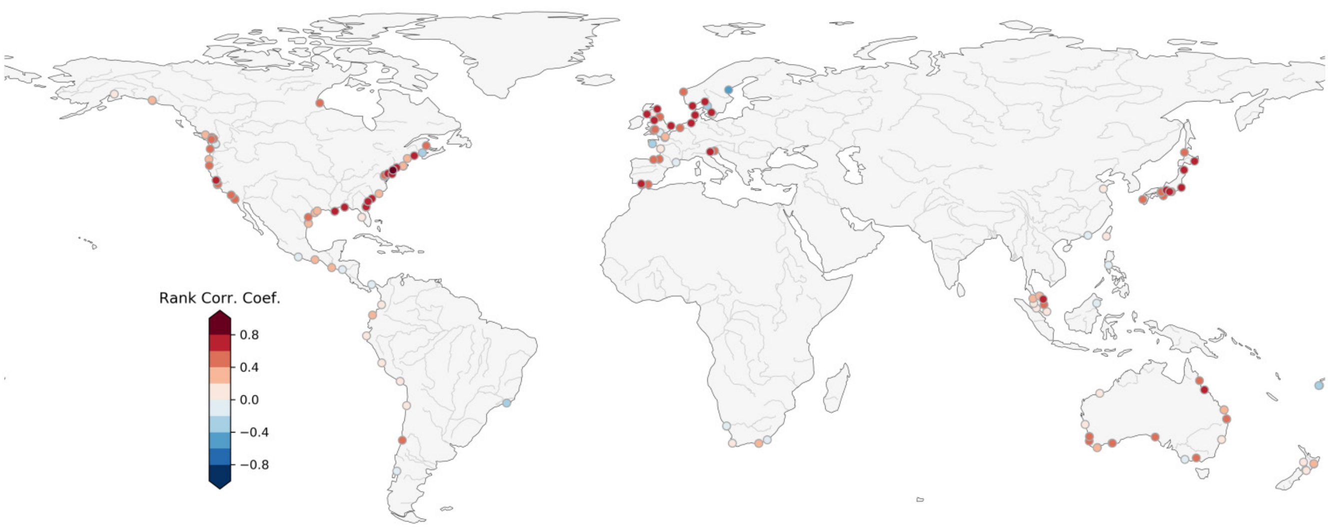

Figure S4: Spearman's rank correlation between the storm surge annual maxima occurrence obtained from the model and from the observations.

Supplement S2. Co-occurrences of joint annual maxima at selected locations

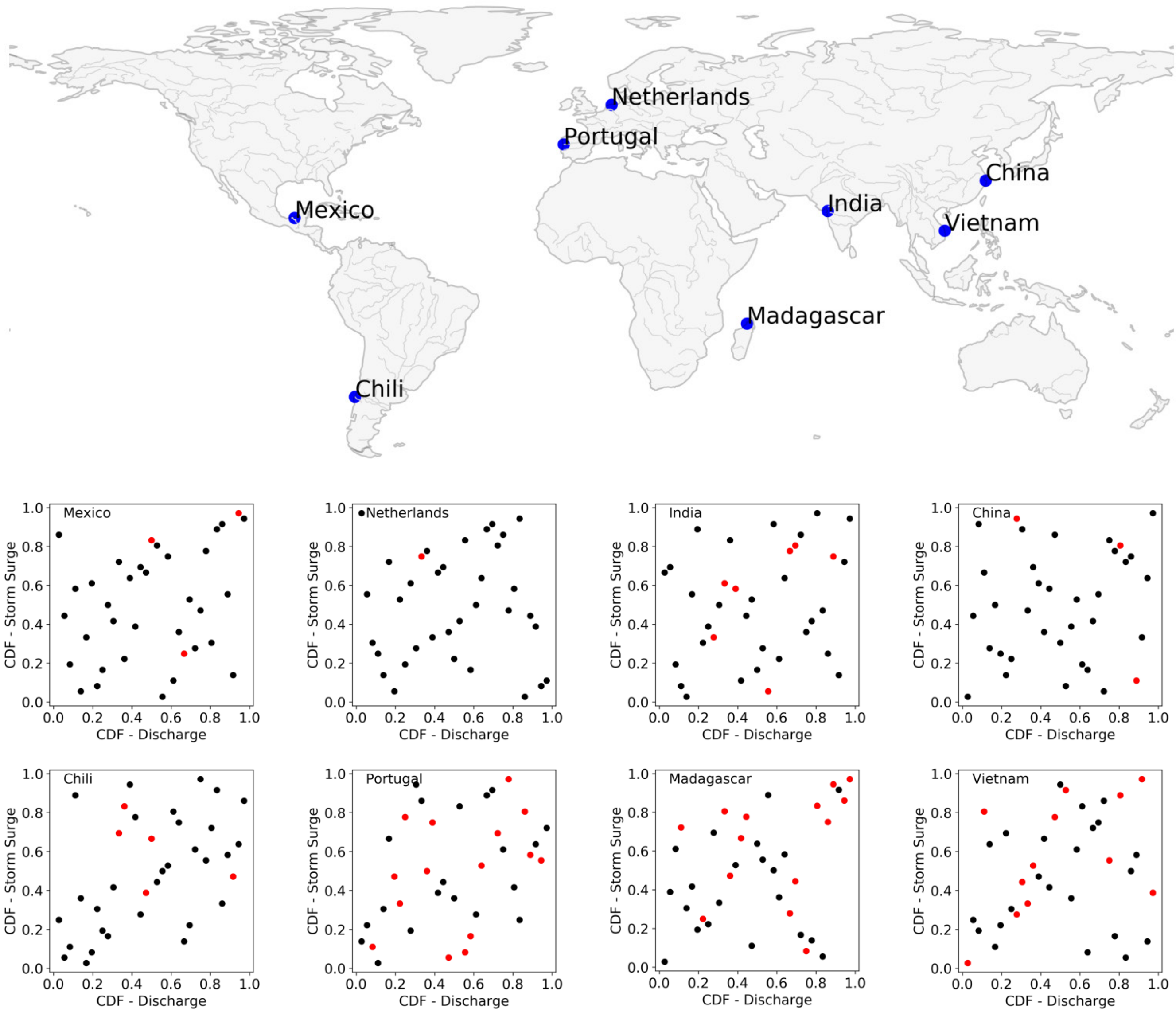

Figure S5: Examples of pseudo-observations from simulated annual maxima of discharge Q and storm surge S at selected locations. Red dots indicate a co-occurrence of Q and S, (Q^*, S^*), within a time lag of 3 days.

Supplement S3. Sensitivity of time window on Spearman's r_s correlation coefficient

Time window Δ	Storm surge conditional on discharge annual maxima (Q_n, s_n)		Discharge conditional on storm surge annual maxima (S_n, q_n)	
	α = 0.05	α = 0.10	α = 0.05	α = 0.10
0	0.11	0.17	0.18	0.24
1	0.14	0.19	0.19	0.24
2	0.14	0.20	0.19	0.24
3	0.14	0.21	0.19	0.25
4	0.15	0.21	0.18	0.24
5	0.15	0.21	0.18	0.24
6	0.15	0.21	0.19	0.24
7	0.16	0.22	0.18	0.24

Table S1: Fraction of paired locations with a positive and statistically significant Spearman's rank correlation coefficient both for $(\mathbf{Q_n}, \mathbf{s_n})$ and $(\mathbf{S_n}, \mathbf{q_n})$ pairs and significance levels of α = 0.05 and α = 0.10.

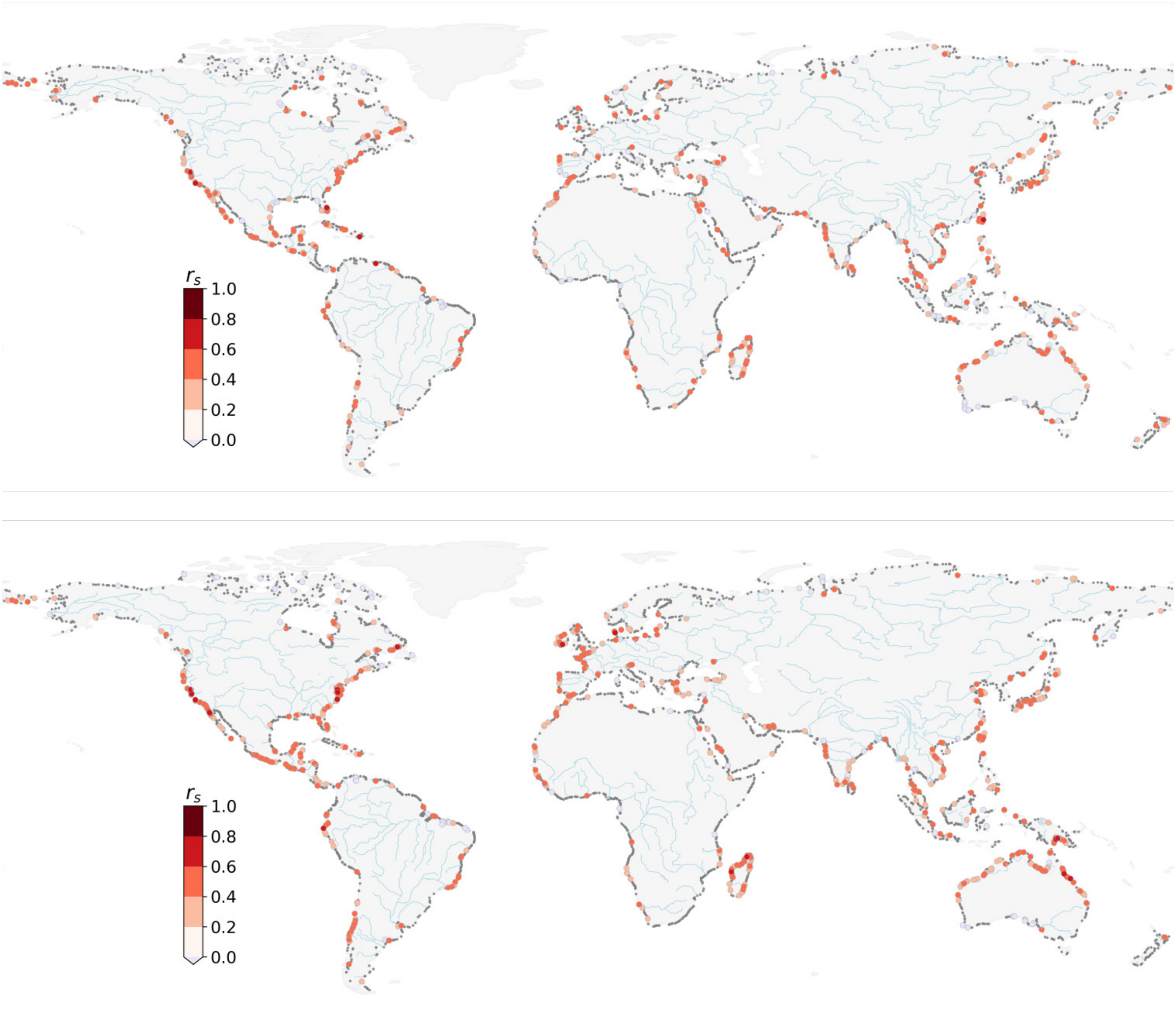

Figure S6: Spearman's r_s correlation coefficient between storm surge conditional on discharge annual maxima (Q_n, s_n) for a time window of Δ = 0 days (top) and Δ = 7 days (bottom). Black dots denote locations with no significant dependence (α = 0.05).

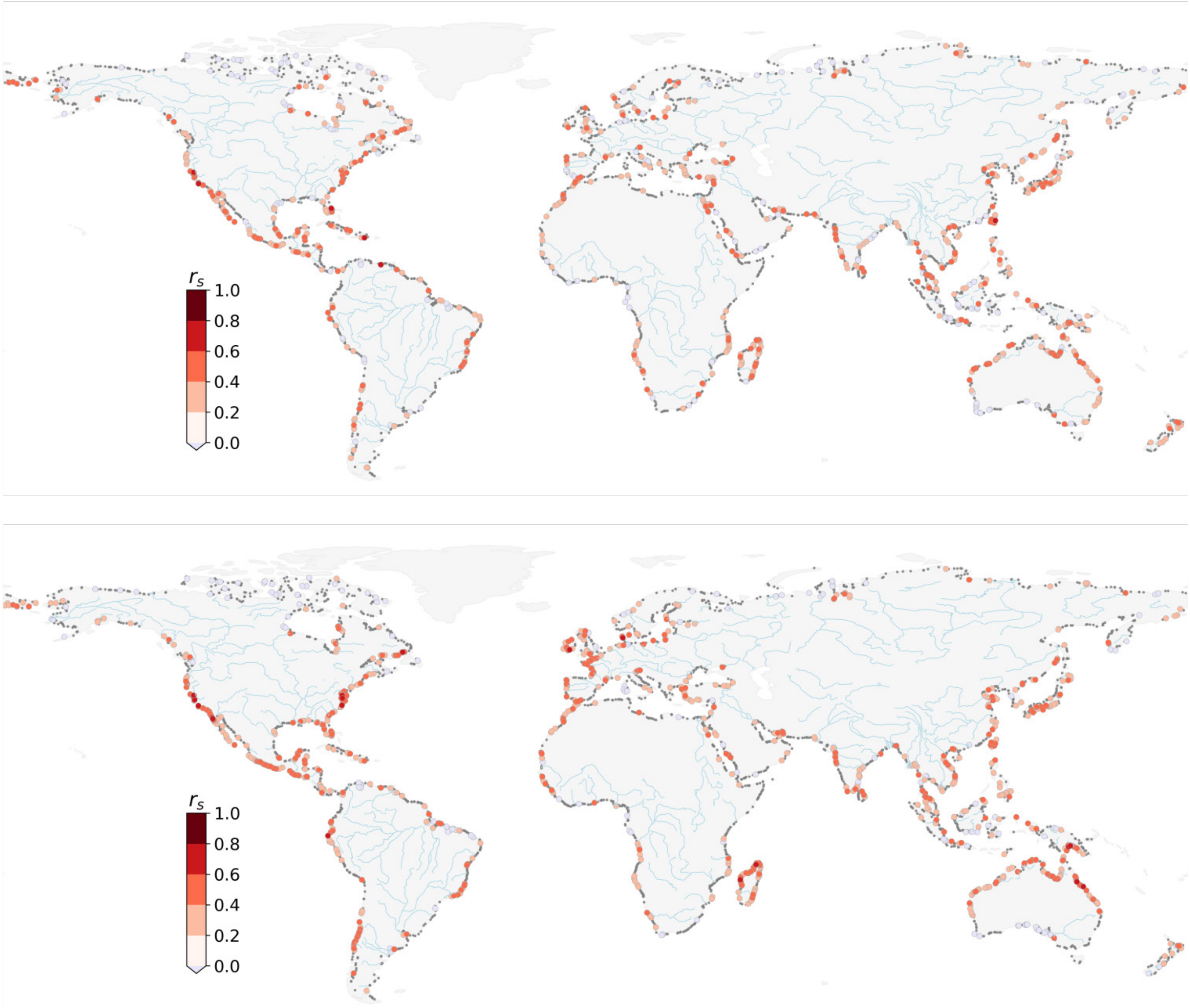

Figure S7: Spearman's r_s correlation coefficient between storm surge conditional on discharge annual maxima (Q_n, s_n) for a time window of Δ = 0 days (top) and Δ = 7 days (bottom). Black dots denote locations with no significant dependence (α = 0.10).

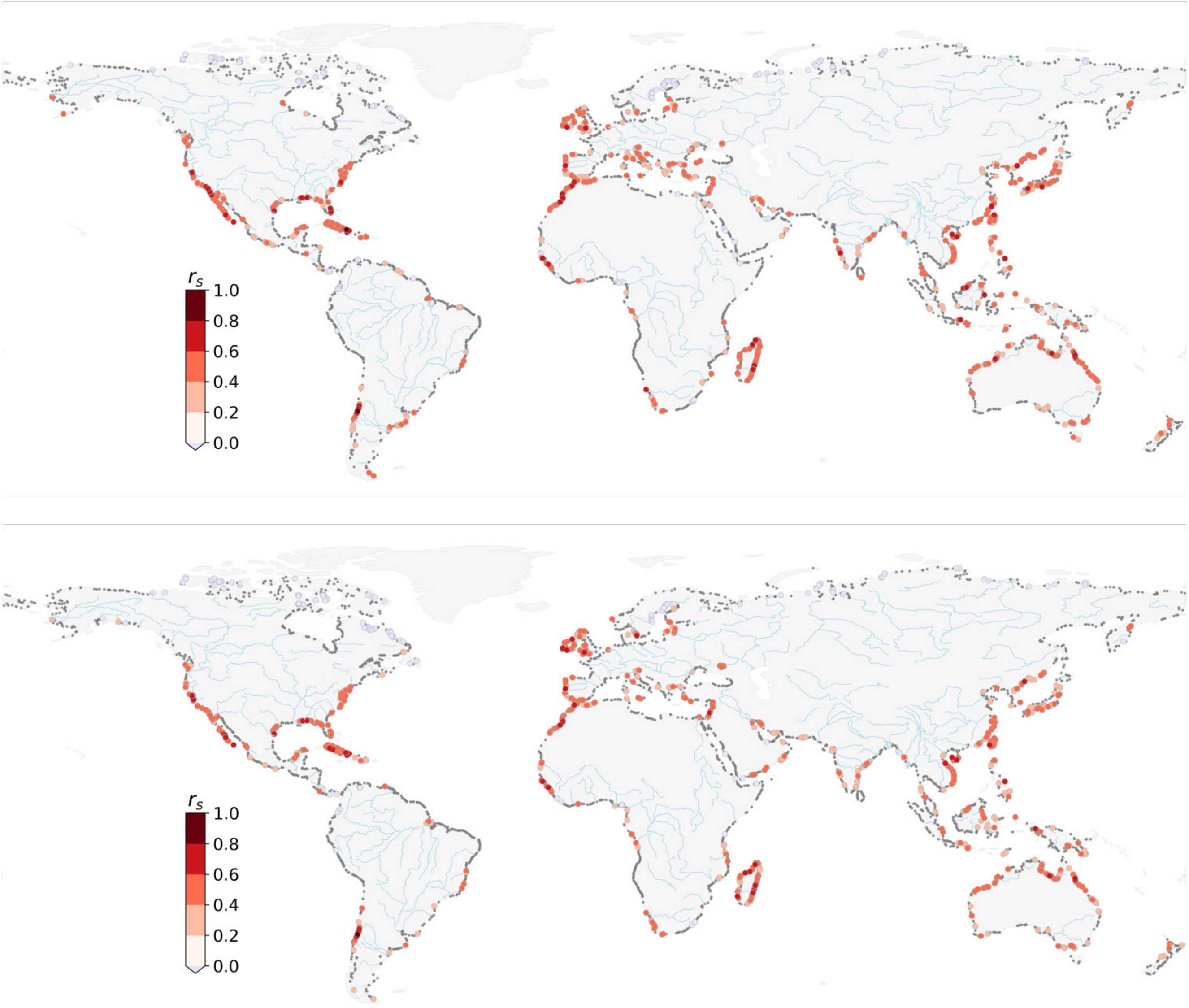

Figure S8: Spearman's r_s correlation coefficient between discharge conditional on storm surge annual maxima (S_n, q_n) for a time window of Δ = 0 days (top) and Δ = 7 days (bottom). Black dots denote locations with no significant dependence (α = 0.05).

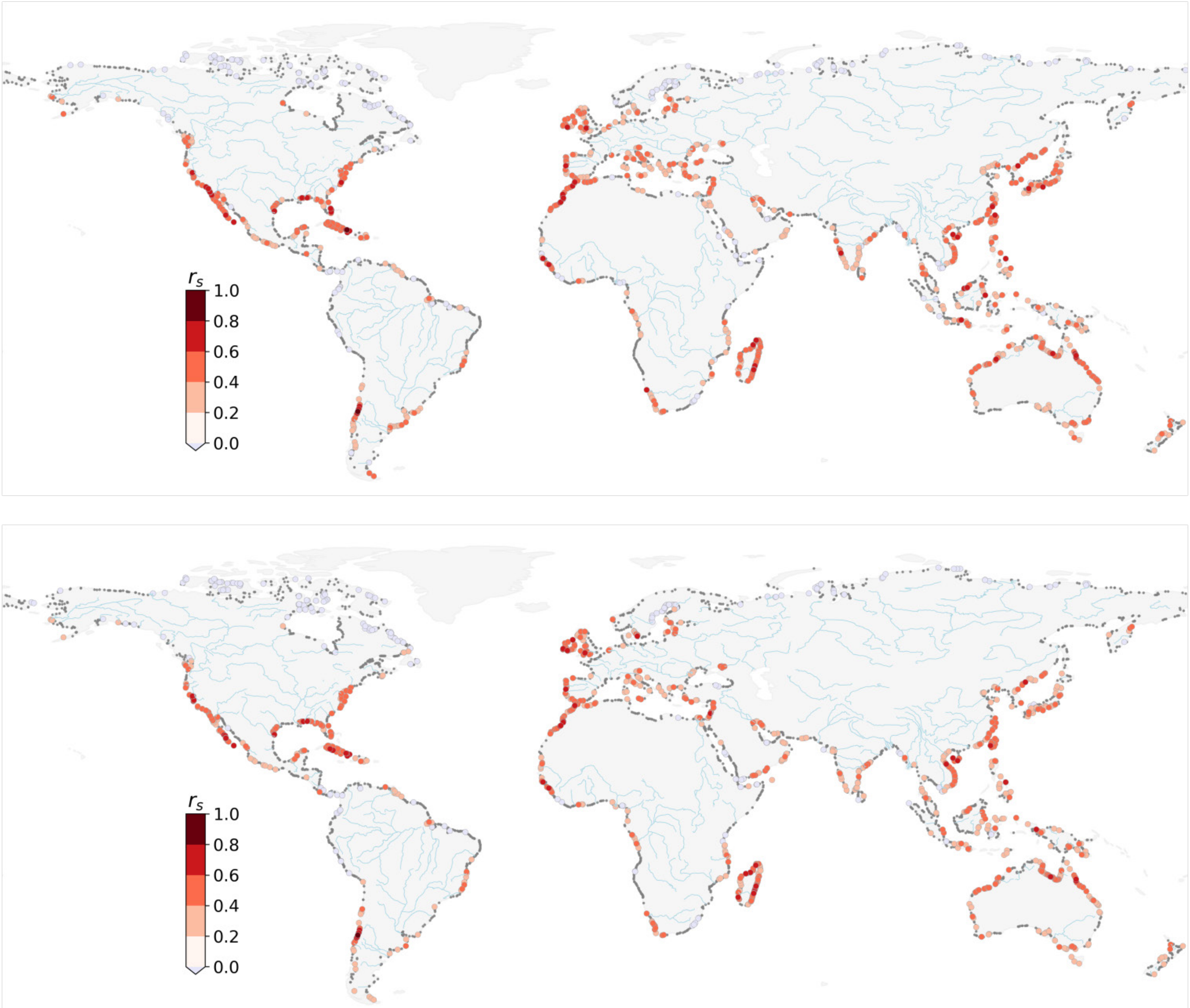

Figure S9: Spearman's r_s correlation coefficient between discharge conditional on storm surge annual maxima (S_n, q_n) for a time window of Δ = 0 days (top) and Δ = 7 days (bottom). Black dots denote locations with no significant dependence (α = 0.10).

Supplement S4. Influence of the time window on number of co-occurring annual maxima

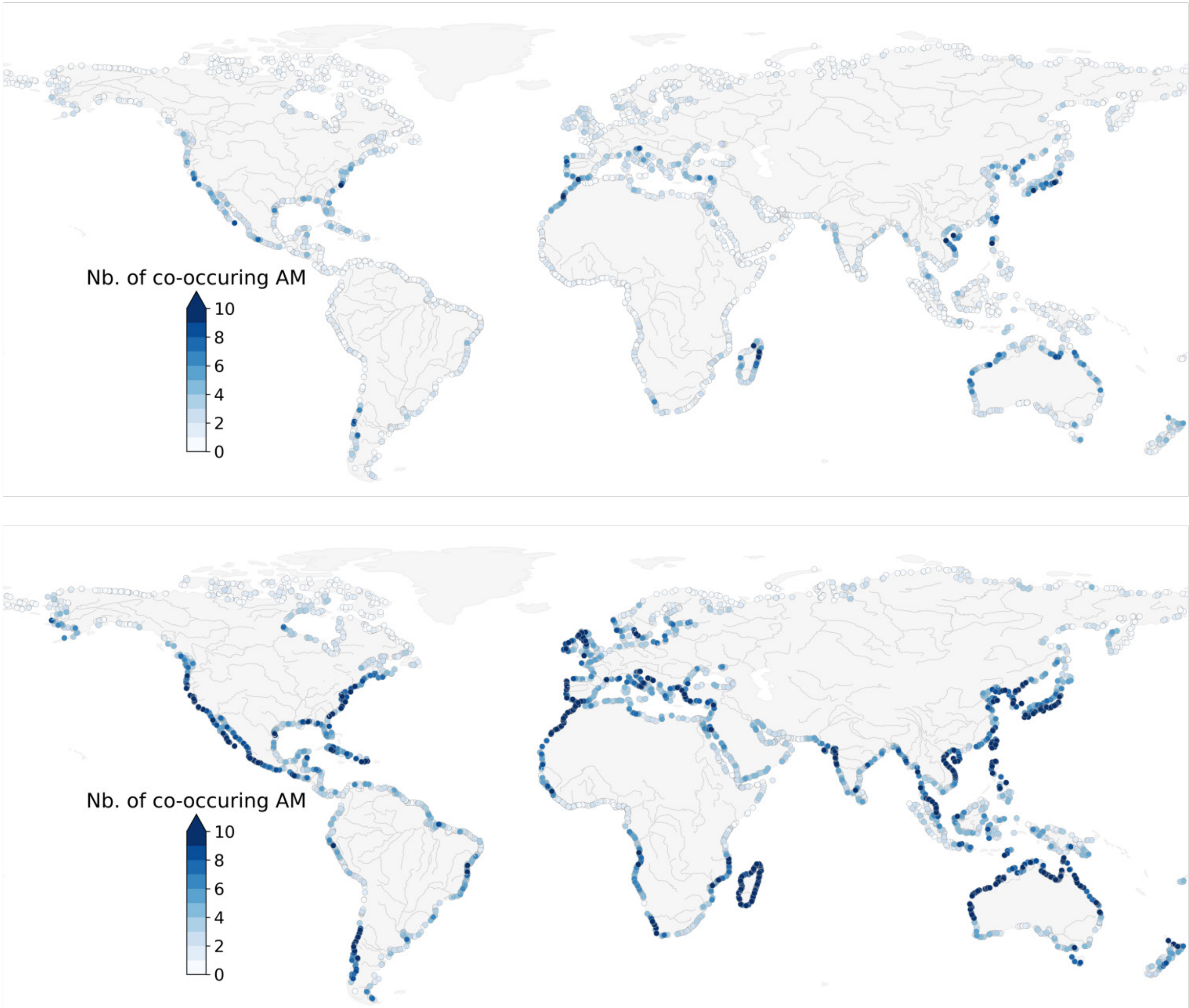

Figure S10: Number of co-occurring yearly maxima of storm surge and discharge obtained between 1980-2014 using a time window of Δ = 0 days (top) and Δ = 7 days (bottom).

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