Supplementary material for Hydrology and Earth System Sciences (HESS) manuscript submission: A high-resolution perspective of extreme rainfall and river flow under extreme climate change in Southeast Asia

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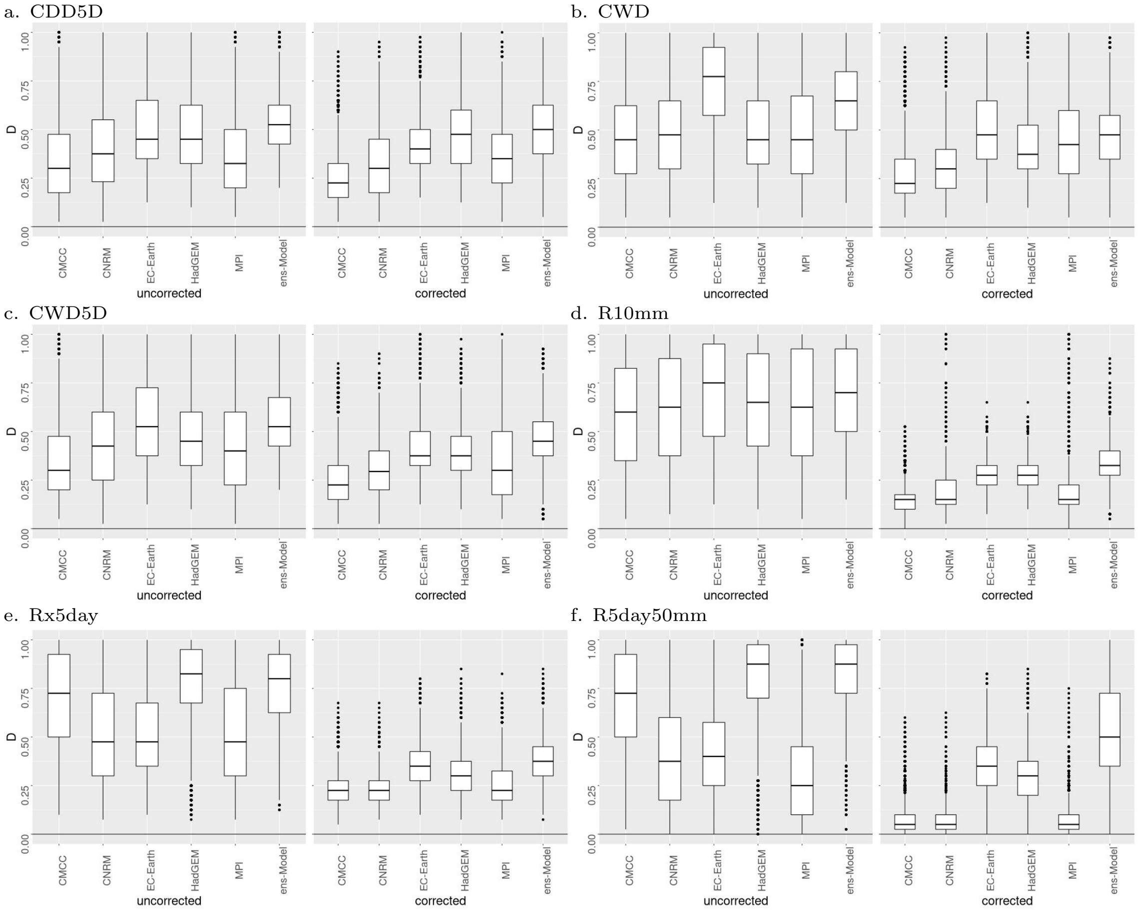
January 10, 2023

This supplementary material provides figures that are used to further illustrate the analyses and add additional detail.

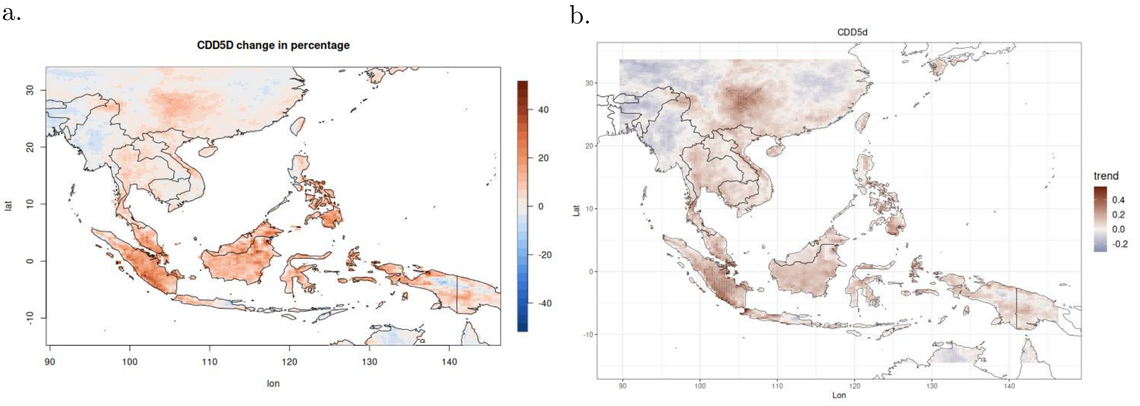
Supplementary 1

Supplementary Figure S01 shows the Kolmogorov–Smirnov statistic value between the original model dataset and the bias-corrected model dataset. The statistic value calculated for simulating a) CDD5D, b) CWD, c) CWD5D, d) R10mm, e) Rx5day and f) R5day50mm.



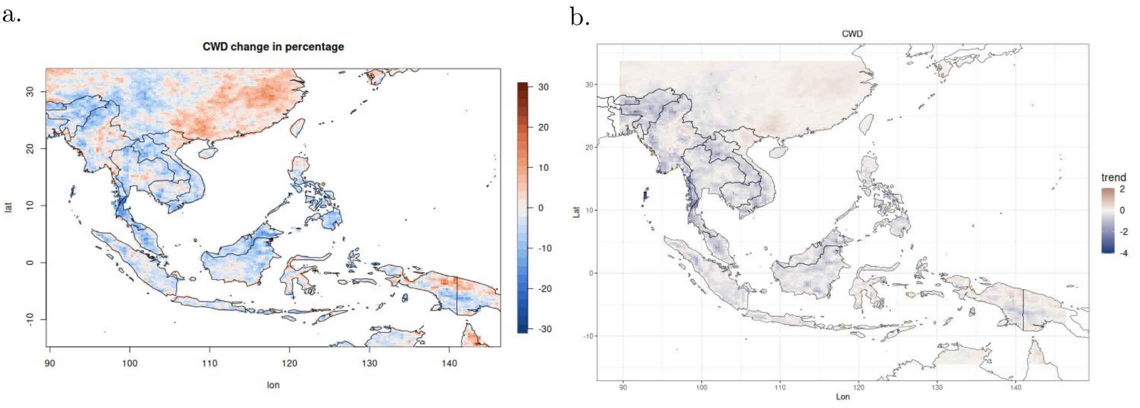
Supplementary 2

Supplementary Figure S02 shows annually a number of consecutive dry day periods with more than 5 days (CDD5D) change in percentage in the near future (2021-2050) compared to the historical period (1981-2010) (left), and the trend of CDD5D on the period 1971-2050 (right). The dashes in the trend map indicate model agreement in the trend significant at 60% level agreement. Slightly different from the CDD (Fig 3), increasing CDD5D is less in the Indochina region but more spread out over Sumatra and Borneo in the Indonesia region. The increasing CDD5D were found in the Malaysian peninsula and the Philippines. Based on the model agreement, a significant increasing trend of CDD5D is only found in the southern part of Sumatra and an area in the centre of China with a positive trend of CDD5D up to 0.4 per decade.



Supplementary 3

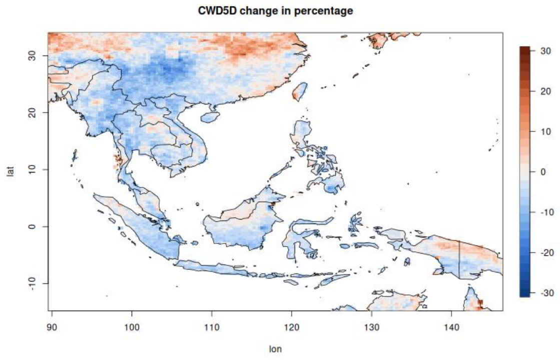
Supplementary Figure S03 shows annually a maximum number of consecutive wet day periods (CWD) change in percentage in the near future (2021-2050) compared to the historical period (1981-2010) (left), and the trend of CWD on the period 1971-2050 (right). The dashes in the trend map indicate model agreement in the trend significant at 60% level agreement. The annual maximum wet spell length (CWD) and the annual number of wet spells exceeding 5 days (CDD5D) increase up to 5% and 10% respectively appears over the east part of China, the north part of Myanmar and the north part of Papua(Fig. S2a and S3a). The largest part of the SEA region shows decreasing length and trends of wet spells, also when filtered to include wet spells of 5 days or longer, but the trend is not statistically significant (Fig. S2b and S3b).



Supplementary 4

Supplementary Figure S04 shows annually a number of consecutive wet day periods with more than 5 days (CWD5D) change in percentage in the near future (2021-2050) compared to the historical period (1981-2010) (left), and the trend of CWD5D on the period 1971-2050 (right). The dashes in the trend map indicate model agreement in the trend significant at 60% level agreement.

a.



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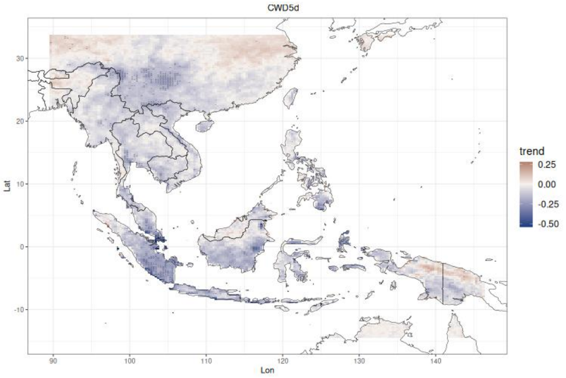
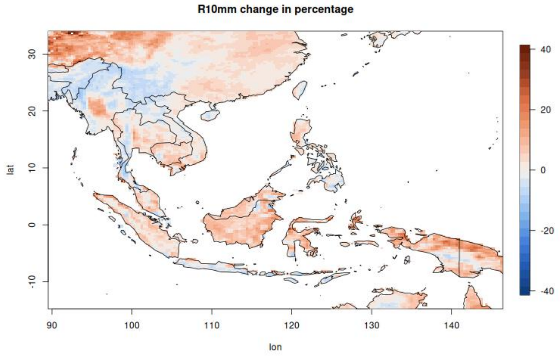


Supplementary 5

Supplementary Figure S05 shows annually a number of days with heavy rainfall (> 10mm) (R10mm) change in percentage in the near future (2021-2050) compared to the historical period (1981-2010) (left), and the trend of CWD5D on the period 1971-2050 (right). The dashes in the trend map indicate model agreement in the trend significant at 60% level agreement. A similar pattern of an increasing number of events that were shown by R20mm (Fig 4) is also found for R10mm (Fig. S4a), these are clearly seen over Borneo and mountainous areas in northern Papua.

a.



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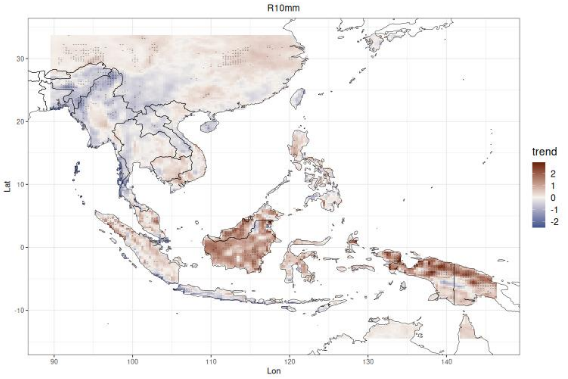
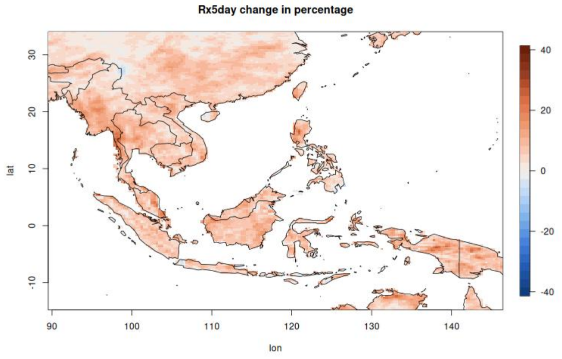


Supplementary 6

Supplementary Figure S06 shows annually a maximum 5-day rainfall (Rx5day) change in percentage in the near future (2021-2050) compared to the historical period (1981-2010) (left), and the trend of Rx5day on the period 1971-2050 (right). The dashes in the trend map indicate model agreement in the trend significant at 60% level agreement.

a.



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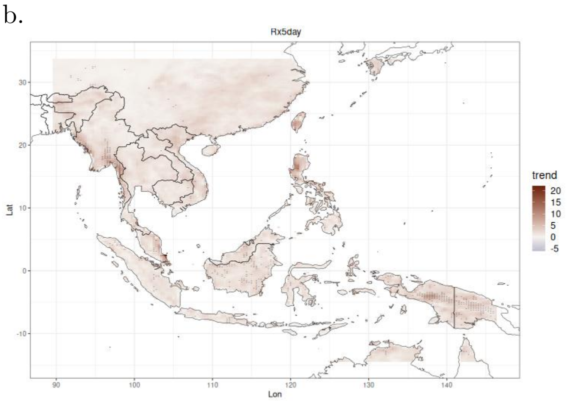
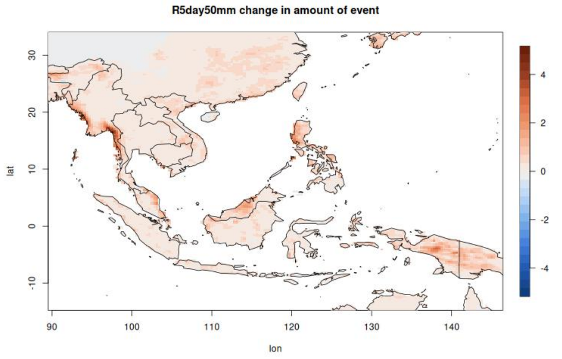


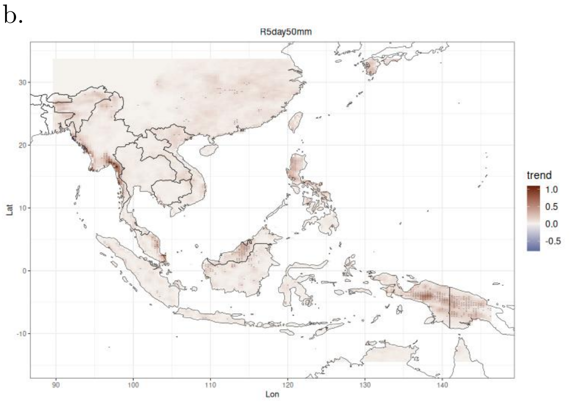
Supplementary 7

Supplementary Figure S07 shows annually a number of the 5-day period with cumulative rainfall >50mm (R5day50mm) change in a number of events in the near future (2021-2050) compared to the historical period (1981-2010) (left), and the trend of R5day50mm on the period 1971-2050 (right). The dashes in the trend map indicate model agreement in the trend significant at 60% level agreement. In terms of the number of 5 days with precipitation exceeding 50 mm (Rx5day50mm), the result shows increasing numbers of events in the near future over the East coast of the Malaysian peninsula, northern Borneo, and Papua (Fig. S6a). Moreover, the increase is high over (>4 events) in some areas on the west coast of Myanmar. For the trend of Rx5day50mm, it can be seen from the result that the trend is similar to Rx1day and Rx5day. A significant increasing trend is also found over the Papua and west coast of Myanmar (Fig. S6b).

a.



b.



Supplementary 8

Recession analysis is one of the methods for analysing the daily time series discharge to produce information about the low flow regime of a river.

Rivers with a slow recession rate are typically groundwater or lake dominated, whereas a fast rate is characteristic of flashy rivers draining impermeable catchments with limited storage. The recession curve is modelled by fitting an analytical expression to the outflow function Q_t where Q is the rate of flow and t time. The time interval Δt is normally in the order of days. If Q_t is modelled as the outflow from a first-order linear storage with no inflow, the recession rate will follow the simple exponential equation:

$$Q_t = Q_0 \exp\left(-t/C\right)$$

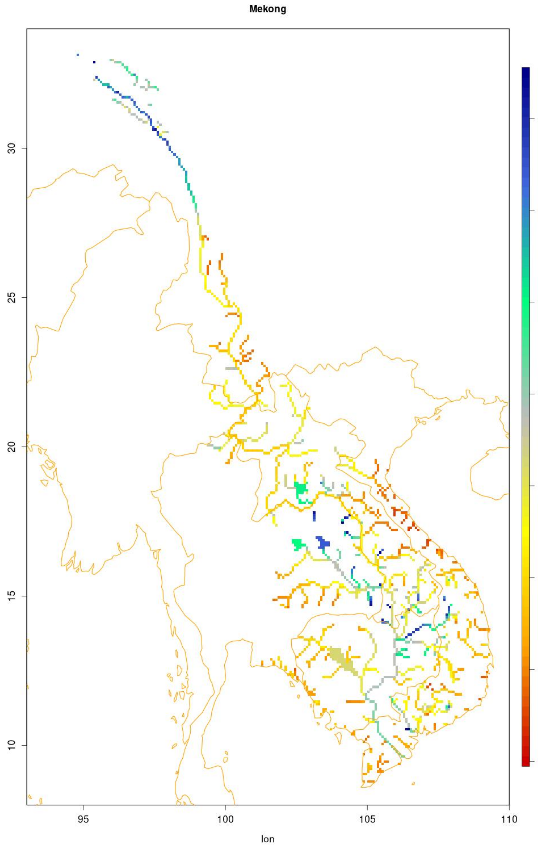
where Q_t is the flow at time t; Q_0 is the flow at the start of the modelled recession period (t = 0); and C is the recession constant (dimension time).

We used recession analysis to calculate the recession constant (C). The C value is the overall recession rate in days. The calculation is used lfstat (https://rdrr.io/cran/lfstat/man/recession.html) r package which is based on World Meteorological Organization (WMO) manual on low-flow estimation and prediction (Gustard and Demuth, 2009).

The individual recession segments (IRS) method with threshold level Q90 was used in the recession analysis. In the IRS method, the variability in individual recession segments is explicitly accounted for by fitting a recession model to each segment. Sample statistics of the model parameters, for example, the mean and variance of the recession constant, can subsequently be determined to characterize the overall recession behaviour of the catchment.

Figure a,b,c and d are the C value for rivers in the Mekong, the Sumatera-Malaysian peninsula, Java and Borneo regions. The black boxes over Sumatera (Fig S07b) show the location of the Kampar (top) and Batang Hari (bottom) Rivers. While the black box over Java (Fig S07c) shows the location of part of the Bengawan Solo River.

a.


Mekong
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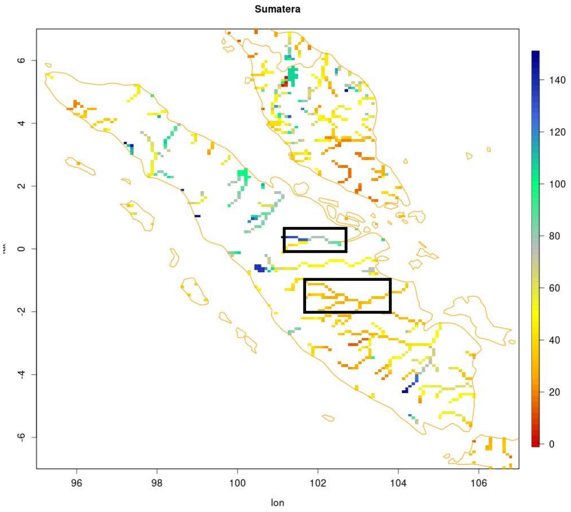
b.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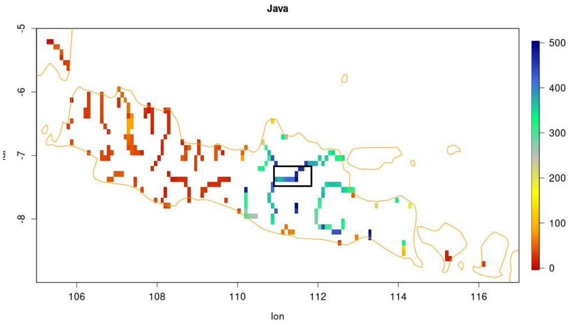
c.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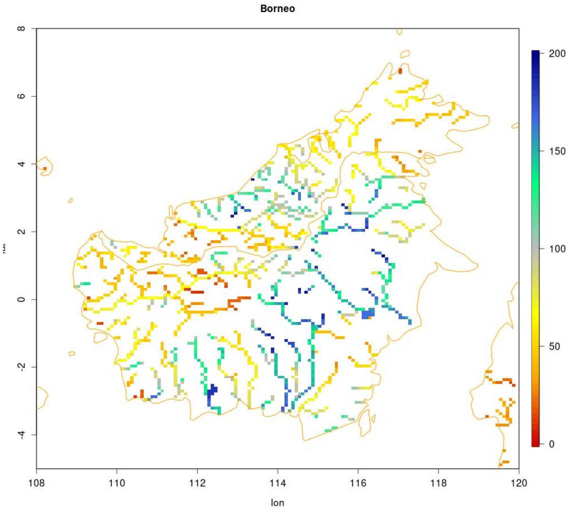
d.


Borneo
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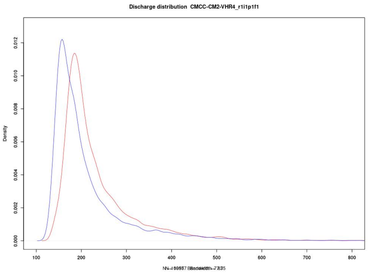
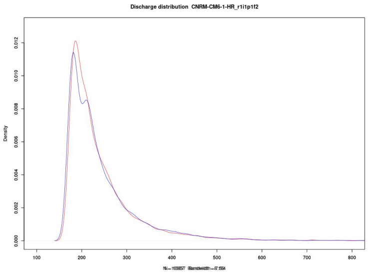
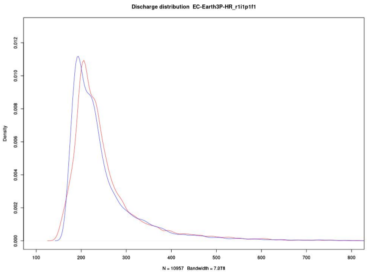
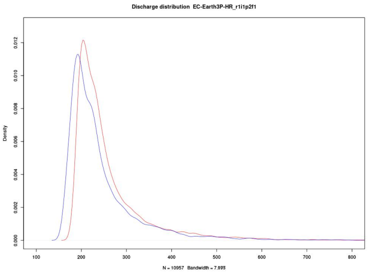
Supplementary 9

Discharge distribution of Bengawan Solo river (relatively high C value)


Discharge distribution CMCC-CM2-VHR4_r1i1p1f1


Discharge distribution CNRM-CM6-1-HR_r1i1p1f2


Discharge distribution EC-Earth3P-HR_r1i1p1f1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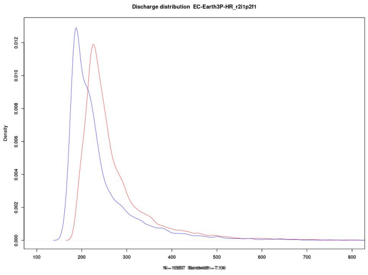
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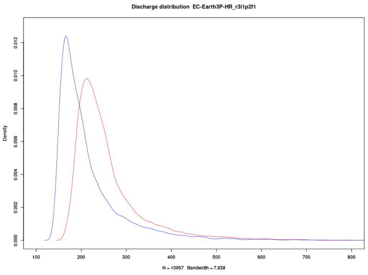
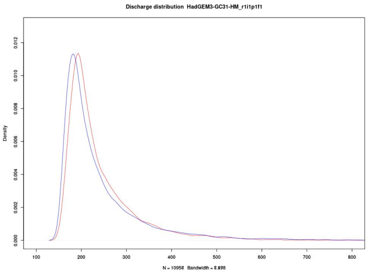
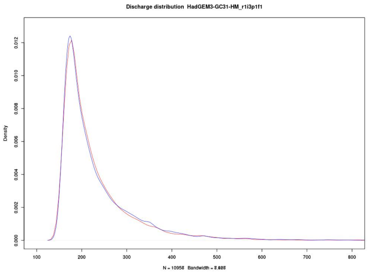
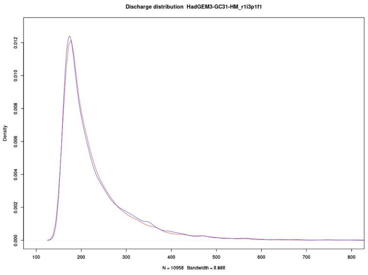
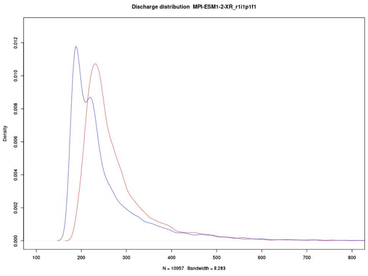

Discharge distribution EC-Earth3P-HR_r3i1p2f1

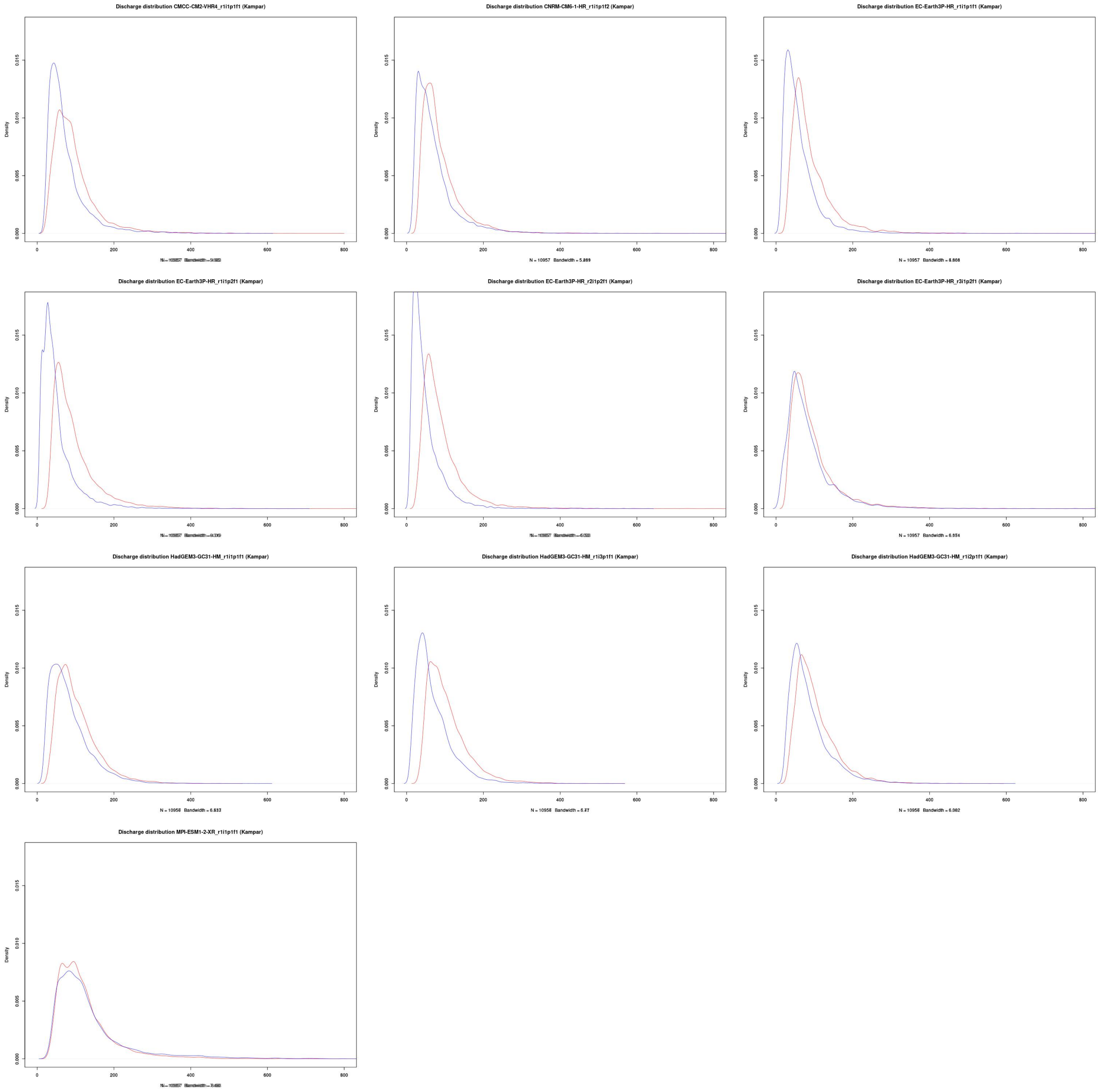

Discharge distribution HadGEM3-GC31-HM_r1i1p1f1


Discharge distribution HadGEM3-GC31-HM_r1i3p1f1


Discharge distribution HadGEM3-GC31-HM_r1i3p1f1

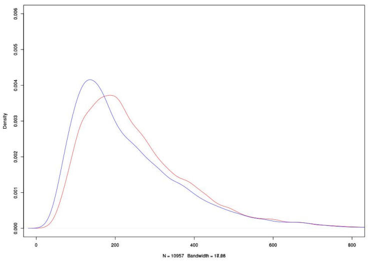

Discharge distribution MPI-ESM1-2-XR_r1i1p1f1

Discharge distribution of Kampar river (relatively high C value)

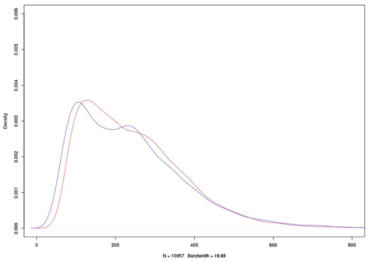


Discharge distribution of Batang Hari river (relatively low C value)

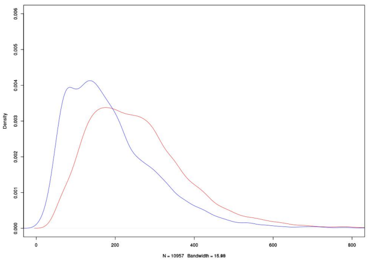
Discharge distribution CMCC-CM2-VHR4_r1i1p1f1 (Batang Hari)



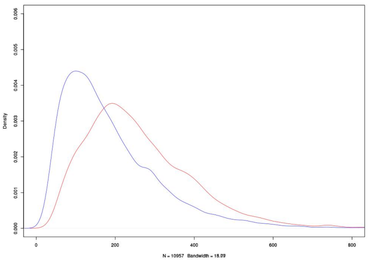
Discharge distribution CNRM-CM6-1-HR_r1i1p1f2 (Batang Hari)



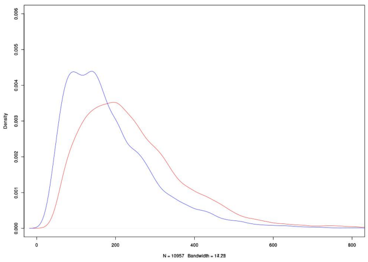
Discharge distribution EC-Earth3P-HR_r1i1p1f1 (Batang Hari)



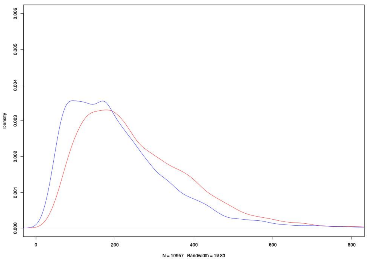
Discharge distribution EC-Earth3P-HR_r1i1p2f1 (Batang Hari)



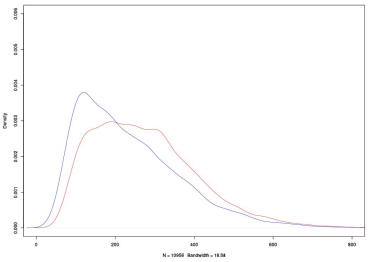
Discharge distribution EC-Earth3P-HR_r2i1p2f1 (Batang Hari)



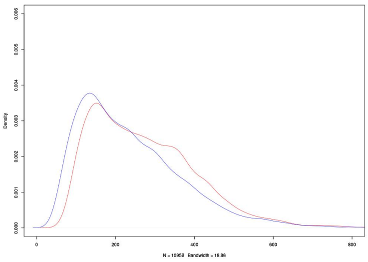
Discharge distribution EC-Earth3P-HR_r3i1p2f1 (Batang Hari)



Discharge distribution HadGEM3-GC31-HM_r1i1p1f1 (Batang Hari)



Discharge distribution HadGEM3-GC31-HM_r1i2p1f1 (Batang Hari)



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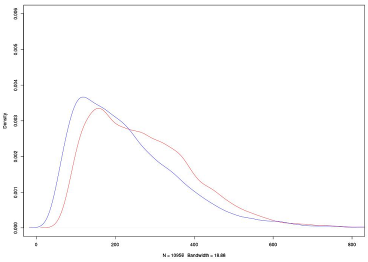
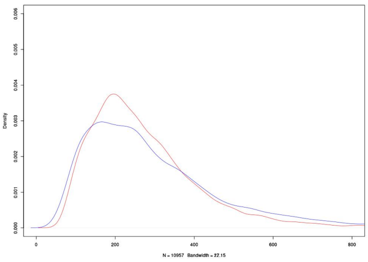


Discharge distribution MPI-ESM1-2-XR_r1i1p1f1 (Batang Hari)



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