

Supplementary Material

Annual Relationships Between Hydroclimatic Extremes and Extreme Runoff in Houston, Texas

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Pseudocode for Data Processing and Statistical Analysis

START

SET study years to 1980 through 2023

CREATE empty storage for all daily values of:

- 2-m air temperature
- precipitation
- top-layer soil moisture
- total runoff

FOR each study year:

- LOAD** that year's Houston WLDAS daily data file

- ADD** that year's daily temperature values to the full temperature record

- ADD** that year's daily precipitation values to the full precipitation record

- ADD** that year's daily soil moisture values to the full soil moisture record

- ADD** that year's daily runoff values to the full runoff record

END FOR

CHECK the full temperature record for invalid fill values (none were found)

CALCULATE the 95th-percentile threshold for temperature
using all valid daily temperature values

CALCULATE the 95th-percentile threshold for soil moisture
using all daily soil moisture values

REMOVE zero-value days from the full precipitation record

CALCULATE the 95th-percentile threshold for precipitation
using only positive daily precipitation values

REMOVE zero-value days from the full runoff record

CALCULATE the 95th-percentile threshold for runoff
using only positive daily runoff values

CREATE annual arrays for:

- extreme heat frequency
- extreme heat severity
- extreme precipitation frequency
- extreme precipitation severity
- extreme soil moisture frequency
- extreme soil moisture severity
- extreme runoff frequency
- extreme runoff severity

FOR each study year:

- LOAD** that year's Houston WLDAS daily data file
- FIND** all days when temperature is greater than or equal to the temperature 95th-percentile threshold
- COUNT** those days
- STORE** the count as annual extreme heat frequency
- IF** at least one extreme heat day occurred:
 - CALCULATE** the mean temperature across those extreme heat days
 - STORE** the mean as annual extreme heat severity
- OTHERWISE:**
 - SET** extreme heat severity = NaN
- FIND** all days when precipitation is greater than or equal to the precipitation 95th-percentile threshold
- COUNT** those days
- STORE** the count as annual extreme precipitation frequency
- IF** at least one extreme precipitation day occurred:
 - CALCULATE** the mean precipitation across those extreme precipitation days
 - STORE** the mean as annual extreme precipitation severity
- OTHERWISE:**
 - SET** extreme precipitation severity = NaN
- FIND** all days when soil moisture is greater than or equal to the soil moisture 95th-percentile threshold
- COUNT** those days
- STORE** the count as annual extreme soil moisture frequency
- IF** at least one extreme soil moisture day occurred:
 - CALCULATE** the mean soil moisture across those extreme soil moisture days
 - STORE** the mean as annual extreme soil moisture severity
- OTHERWISE:**
 - SET** extreme soil moisture severity = NaN
- FIND** all days when total runoff is greater than or equal to the runoff 95th-percentile threshold
- COUNT** those days
- STORE** the count as annual extreme runoff frequency
- IF** at least one extreme runoff day occurred:
 - CALCULATE** the mean runoff across those extreme runoff days
 - STORE** the mean as annual extreme runoff severity
- OTHERWISE:**
 - SET** extreme runoff severity = NaN

END FOR

CREATE a list of 12 hydroclimatic–runoff variable pairs:

- extreme heat frequency with extreme runoff frequency
- extreme heat frequency with extreme runoff severity

extreme heat severity with extreme runoff frequency
 extreme heat severity with extreme runoff severity
 extreme precipitation frequency with extreme runoff frequency
 extreme precipitation frequency with extreme runoff severity
 extreme precipitation severity with extreme runoff frequency
 extreme precipitation severity with extreme runoff severity
 extreme soil moisture frequency with extreme runoff frequency
 extreme soil moisture frequency with extreme runoff severity
 extreme soil moisture severity with extreme runoff frequency
 extreme soil moisture severity with extreme runoff severity

FOR each hydroclimatic–runoff variable pair:

REMOVE any year where either variable is NaN

COUNT the remaining paired annual observations

STORE this as nominal sample size, N

CALCULATE the Pearson correlation coefficient, r

CALCULATE the Spearman rank correlation coefficient, rho

CALCULATE lag-1 autocorrelation for the hydroclimatic variable
using the remaining valid years

CALCULATE lag-1 autocorrelation for the runoff variable
using the remaining valid years

CALCULATE Dawdy-Matalas effective sample size:

$$\text{Neff} = N \times (1 - r_{1,x} \times r_{1,y}) / (1 + r_{1,x} \times r_{1,y})$$

where $r_{1,x}$ is the hydroclimatic variable's lag-1 autocorrelation
and $r_{1,y}$ is the runoff variable's lag-1 autocorrelation

IF Neff is greater than N:

SET Neff equal to N

USE Neff to calculate the two-tailed p-value
for the Pearson correlation coefficient

USE Neff to calculate the two-tailed p-value
for the Spearman rank correlation coefficient

SAVE the correlation coefficients, p-values, lag-1 autocorrelations,
nominal N, and Neff

END FOR

APPLY the Benjamini-Hochberg false discovery rate adjustment
to all 12 Pearson correlation p-values

APPLY the Benjamini-Hochberg false discovery rate adjustment
separately to all 12 Spearman correlation p-values

FOR each hydroclimatic–runoff variable pair:

IF both adjusted p-values are less than 0.05:

LABEL the relationship as significant in both tests

ELSE IF only the adjusted Pearson p-value is less than 0.05:

LABEL the relationship as significant in Pearson analysis only
ELSE IF only the adjusted Spearman p-value is less than 0.05:
LABEL the relationship as significant in Spearman analysis only
OTHERWISE:
LABEL the relationship as not statistically significant

END FOR

CREATE Table 1 using:

hydroclimatic variable
 runoff variable
 Pearson correlation coefficient
 adjusted Pearson p-value
 Spearman rank correlation coefficient
 adjusted Spearman p-value
 significance classification
 nominal sample size

CREATE Table 2 using:

hydroclimatic variable
 runoff variable
 hydroclimatic-variable lag-1 autocorrelation
 runoff-variable lag-1 autocorrelation
 nominal sample size
 Dawdy-Matalas effective sample size

CREATE a dataset containing the six annual hydroclimatic variables:

extreme heat frequency
 extreme heat severity
 extreme precipitation frequency
 extreme precipitation severity
 extreme soil moisture frequency
 extreme soil moisture severity

CALCULATE a Pearson correlation matrix for all six annual hydroclimatic variables,
 excluding NaN years on a pair-by-pair basis

CREATE Table 3 using the Pearson correlation matrix

CREATE a list of eight annual variables:

extreme runoff frequency
 extreme runoff severity
 extreme heat frequency
 extreme heat severity
 extreme precipitation frequency
 extreme precipitation severity
 extreme soil moisture frequency
 extreme soil moisture severity

FOR each annual variable:
 REMOVE years where the annual variable is NaN
 CALCULATE the Pearson correlation coefficient
 between study year and the annual variable
 STORE the correlation coefficient, unadjusted p-value,
 and nominal sample size
END FOR
APPLY the Benjamini-Hochberg false discovery rate adjustment
 to the eight secular-trend p-values
FOR each annual variable:
 IF adjusted p-value is less than 0.05:
 LABEL the secular trend as statistically significant
 OTHERWISE:
 LABEL the secular trend as not statistically significant
END FOR
CREATE Table 4 using:
 annual variable
 Pearson correlation coefficient with time
 Benjamini-Hochberg-adjusted p-value
 trend-significance label
 nominal sample size
END