Electronic Supplementary Material

Regional contrasts in extreme precipitation intensity and wet-day occurrence across Northeast China during 1990-2022

Theoretical and Applied Climatology

Online Resource 1: Extended index definitions and statistical interpretation

This file accompanies the corresponding manuscript submitted to *Theoretical and Applied Climatology*.

This online resource expands the methodological definitions used in the main manuscript. It does not introduce additional results or causal attribution.

S1. Study design and aggregation

Daily precipitation observations from 252 meteorological stations were evaluated for 1990-2022. The study domain was divided into Liaoning, Jilin, Heilongjiang, and the five eastern leagues and cities of Inner Mongolia (Hulunbuir, Hinggan, Tongliao, Chifeng, and Xilingol). Annual indices were used for temporal-trend analysis, while annual and meteorological-season summaries were used to describe spatial patterns.

Meteorological seasons were defined as spring (March-May), summer (June-August), autumn (September-November), and winter (December-February). Regional means were used to compare broad subregional behaviour, whereas the station-level maps retained local trend direction and significance.

S2. Extreme precipitation indices

Let $P(s,d)$ denote daily precipitation at station s on day d. Let $I(.)$ be an indicator equal to 1 when its condition is true and 0 otherwise. For each station-year, the four indices were defined as follows.

$Rx1day(s,y) = \max P(s,d)$, *for all days d in year y.*

$Rx5day(s,y) = \max \Sigma_{j=0}^{4} P(s,d+j)$, *for all valid 5-day windows in year y.*

$R99p(s,y) = \Sigma\, P(s,d)\, I[P(s,d) > Q99(s)]$, *where $Q99(s)$ is the station-specific 99th-percentile wet-day threshold used in the analysis.*

$RD(s,y) = \Sigma\, I[P(s,d) \geq 1\ mm]$, *for all days d in year y.*

Table S1. Definitions and interpretation of the four precipitation indices.

Index	Definition	Unit	Interpretation
Rx1day	Annual maximum 1-day precipitation	mm	Largest single-day event magnitude
Rx5day	Annual maximum consecutive 5-day precipitation	mm	Largest multi-day accumulation
R99p	Annual total above the station-specific 99th-percentile wet-day threshold	mm	Contribution from very wet days
RD	Annual number of days with precipitation ≥ 1 mm	day	Wet-day occurrence

S3. Linear trend scaling

For an annual index $x(y)$, the linear model $x(y) = \alpha + \beta y + \varepsilon(y)$ was fitted against calendar year. The coefficient β has units per year. Figure 2 reports the scaled coefficient $k = 10\beta$, expressed as millimetres per decade for Rx1day, Rx5day, and R99p and days per decade for RD. The fitted line summarizes average change over 1990-2022 and does not by itself establish statistical significance.

S4. Mann-Kendall trend test

The Mann-Kendall statistic was calculated as $S = \Sigma_{i=1}^{n-1} \Sigma_{j=i+1}^{n} \mathrm{sgn}[x(j) - x(i)]$, where sgn is -1, 0, or 1 according to the sign of the difference. Under the null hypothesis of no monotonic trend, S has expectation zero.

With tied groups of size t_p, $\mathrm{Var}(S) = \{n(n-1)(2n+5) - \Sigma_p\, t_p(t_p-1)(2t_p+5)\} / 18$. The standardized statistic is $Z = (S-1)/\mathrm{sqrt}[\mathrm{Var}(S)]$ when $S > 0$, $Z = 0$ when $S = 0$, and $Z = (S+1)/\mathrm{sqrt}[\mathrm{Var}(S)]$ when $S < 0$.

A two-sided significance level of $\alpha = 0.05$ was used. Positive Z indicates an upward monotonic tendency and negative Z indicates a downward tendency. Statistical significance describes evidence against the no-trend null hypothesis; it does not measure the magnitude or practical importance of change.

Table S2. Station-level trend classes used in the spatial significance maps.

Class	Criterion	Map colour	Interpretation
Positive significant	$Z > 1.96$	Blue	Statistically significant increase
Positive non-significant	$0 < Z \leq 1.96$	Yellow	Upward tendency without significance
Negative non-significant	$-1.96 \leq Z < 0$	Green	Downward tendency without significance
Negative significant	$Z < -1.96$	Red	Statistically significant decrease

S5. Interpretation of spatial patterns

Regional series and station-level maps answer different questions. Regional series summarize broad interannual behaviour but can conceal opposite trends at individual stations. Station maps retain spatial

heterogeneity, but isolated significant stations should not be interpreted as region-wide change. The main manuscript therefore treats regional averages, station-level trend magnitude, and Mann-Kendall significance as complementary evidence.

The spatial maps describe observed covariation in the station network. They do not independently identify thermodynamic, circulation, topographic, urban, or land-cover causes. Mechanistic attribution would require additional moisture, circulation, and exposure analyses that are outside the evidence used for the main conclusions.

S6. Abbreviations

Abbreviation	Meaning
HLJ	Heilongjiang Province
JL	Jilin Province
LN	Liaoning Province
IM	Five eastern leagues and cities of Inner Mongolia
M-K	Mann-Kendall
ESM	Electronic Supplementary Material

References cited in this online resource are provided in the reference list of the main manuscript.