A comparison of intra-annual and long-term trend scaling of extreme precipitation with temperature in a large-ensemble regional climate simulation

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Motivation

- Long term changes in extreme daily and sub-daily precipitation simulated by climate models are often compared with corresponding temperature changes to estimate the sensitivity of extreme precipitation to warming.
- Such “trend scaling” rates are difficult to estimate from observations, however, due to limited data availability and high background variability.
- Intra-annual temperature scaling (binning scaling), which relates extreme precipitation to temperature at or near the time of occurrence, has been suggested as a possible trend scaling substitute.
- While previous studies have discussed the difference between binning scaling and trend scaling from a statistical perspective, they did not have sufficient data to produce statistically robust trend scaling estimates.
- The availability of a large ensemble simulation provides an opportunity to answer the question: whether intra-annual scaling is reliable to predict future changes in precipitation extremes?

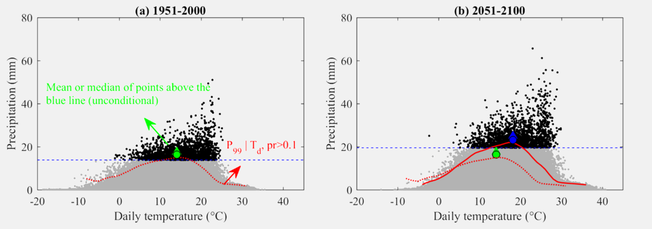

Fig. 1. Schematic diagram for the statistical interpretation of binning and trend scaling approaches. The dashed and solid red lines indicate the binning curves derived from data for the whole year for the 99th percentile of wet event precipitation amounts (3-hourly precipitation > 0.1 mm) conditional on daily air temperature for the 1950-2000 and 2051-2100 periods, respectively. The black dots in (a) and (b) indicate daily maxima of 3-hourly amounts above the 99.7th percentile level of all zero and non-zero values (corresponding approximately to the annual maximum of all zero and non-zero values. Data are from the simulation by CanRCM4 at the location (84.3°W, 35.2°N).

Data

A large ensemble of 35 regional climate simulations for North America using the Canadian Regional Climate Model (CanRCM4);

Hourly precipitation, daily mean near surface air temperature, and daily mean dewpoint temperature from those simulations;

Hourly precipitation for each grid cell is aggregated into 3-hour and 24-hour accumulations.

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Binning scaling curves and binning scaling estimation

- Let Pd_{hh} (hh=01, 03 and 24 respectively) be the daily maxima of precipitation for different durations.
- Pd_{hh} values are binned according to daily mean air temperature or dewpoint temperature for each duration separately, using a bin width of 2.0°C and allowing a 1°C overlap between bins.
- Find the 99th percentile of wet (>0.1 mm) Pd_{hh} values ($P99_{hh}$), which are estimated only for bins with sample sizes larger than 100 (50 for summer and winter) and are smoothed across bins using a 3-bin moving-window average, producing a binning curve.
- Exponential scaling rates for 1 °C temperature increments T_d to T_d + 1 °C are calculated for temperatures T_d beginning with first bin with positive scaling and continuing until $T_d = T_{peak}$ -1 °C; the average of these scaling rates is taken as the binning rate.

Trend scaling estimation

- Trend scaling rates are estimated for each accumulation period are given by

$$\gamma = \left(e^{\frac{\ln P_b - \ln P_a}{T_b - T_a}} - 1\right) \times 100\%$$

where P_a and P_b are the median of annual, summer, winter maximum precipitation amounts for the period 1951–2000 and the period 2051-2100 respectively. T_a and T_b are the average of annual, summer, and winter mean temperatures or dewpoint temperatures for the two periods, separately.

Comparison of binning and trend scaling rate

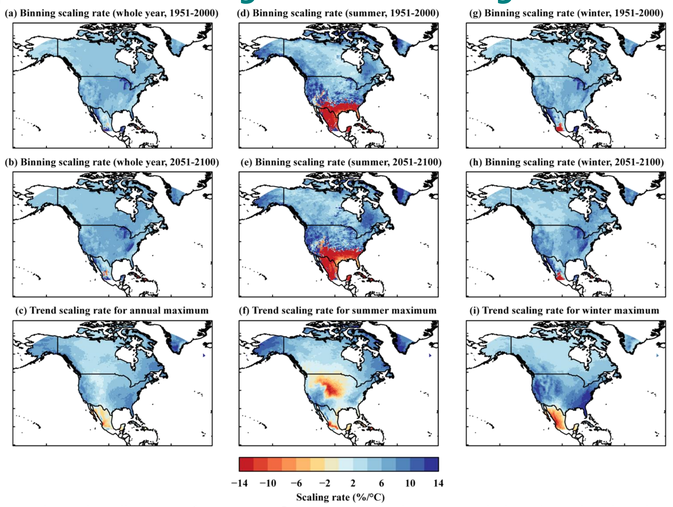

Fig. 2. Binning and trend scaling rates for extreme 3-hour precipitation accumulations based on hourly precipitation from a 35-member ensemble of CanRCM4 simulations. Binning scaling raters are based on the variation of $P99_{03}$ with daily near surface air temperature during the 1951–2000 and 2051–2100 periods. Trend scaling rates are based on changes in the median of annual/seasonal maximum 3-hourly precipitation during the two periods. (a–c) for the whole year; (d–f) for summer; (g–i) for winter.

Shifts in binning curves with warming

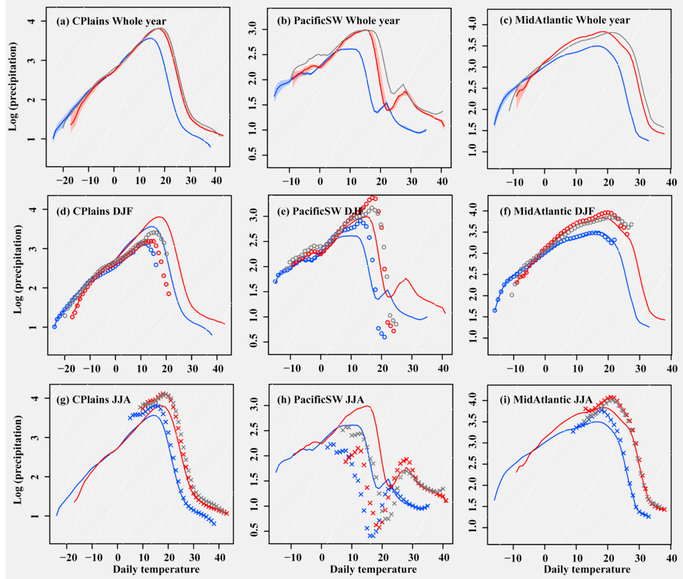

Fig. 3. Binning curves with daily air temperature for the CPlains, PacificSW, and MidAtlantic Bukovsky regions. (a–i) Binning curves for the whole year, DJF, and JJA 3-hour precipitation extremes during 1951–2000 (blue) and 2051–2100 (red) together with a version of the curve for 1951-2000 that has been shifted by 7% per ℃ of projected warming between the two periods (gray). Thick lines, circles, and crosses indicate binning curves based on data for the full year, DJF, and JJA, respectively. Shaded areas show the 5 to 95 percentile spread determined via bootstrapping.

Results using dewpoint temperature as the binning scaling variable

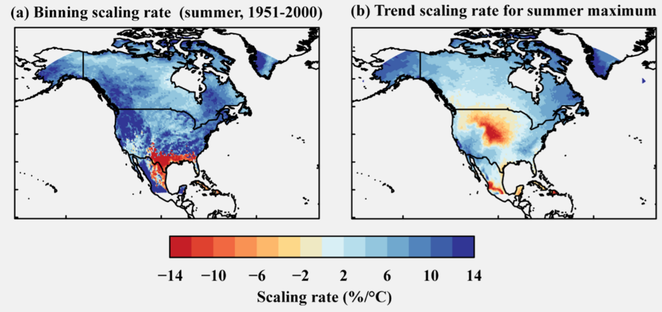

Fig. 4. Binning scaling rate for $P99_{03}$ with daily dewpoint temperature during the 1951–2000, and trend scaling rate for maximum precipitation of 3-hour duration precipitation with dewpoint temperature change for summer.

Conclusion

- Binning curves reflect seasonal changes in the relationship between temperature and extreme precipitation.
- The magnitude and spatial pattern of binning and trend scaling rates are quantitatively different, regardless of precipitation duration or choice of temperature variable.
- Binning scaling with temperature is not a reliable predictor for future changes in precipitation extremes in the climate simulated by CanRCM4.