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Observed trends in precipitation extreme indices as inferred from a homogenized daily precipitation dataset for Canada

Xiaolan L. Wang *and Y. Feng*

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Environment and Climate Change Canada's 50th anniversary
50e anniversaire d'Environnement et Changement climatique Canada
Meteorological Service of Canada's 150th anniversary
150e anniversaire du Service météorologique du Canada

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Outline

Source datasets used

Data homogenization procedures

Observed trends in precipitation extreme indices and how these compare with the ERA5 counterparts

Concluding remarks

Source datasets

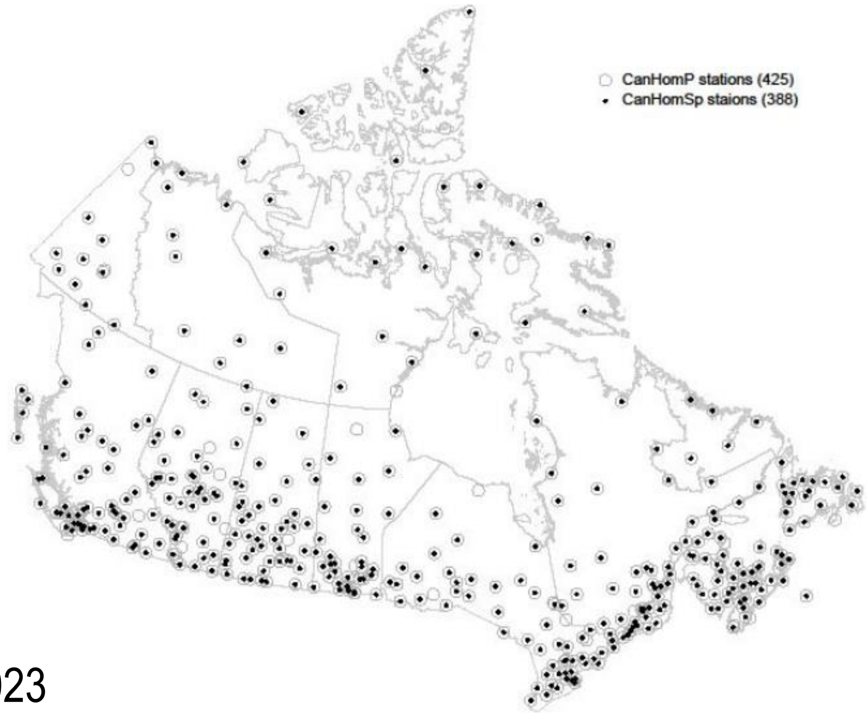
1) V2 of Canadian homogenized monthly precipitation (CanHomP) data for 425 stations for 1949-2023

(Wang et al. 2025, under review)

2) QC'd daily precipitation data observed at the 425 stations for 1949-2023, including adjusted daily rainfall and snowfall data (Wang et al. 2017)

3) Daily proxy snowfall data for 388 stations for 1949-2023, derived from homogenized daily precipitation and daily mean temperature data (Qian et al. 2025)

4) The ERA5 daily precipitation data for 1949-2023 (Hersbach et al. 2020; on 0.25° x 0.25° lat.-long. grid, ~31 km)



Changepoint detection (monthly data done by Wang, Feng, Zwiers, & Cheng, 2025 (under review))

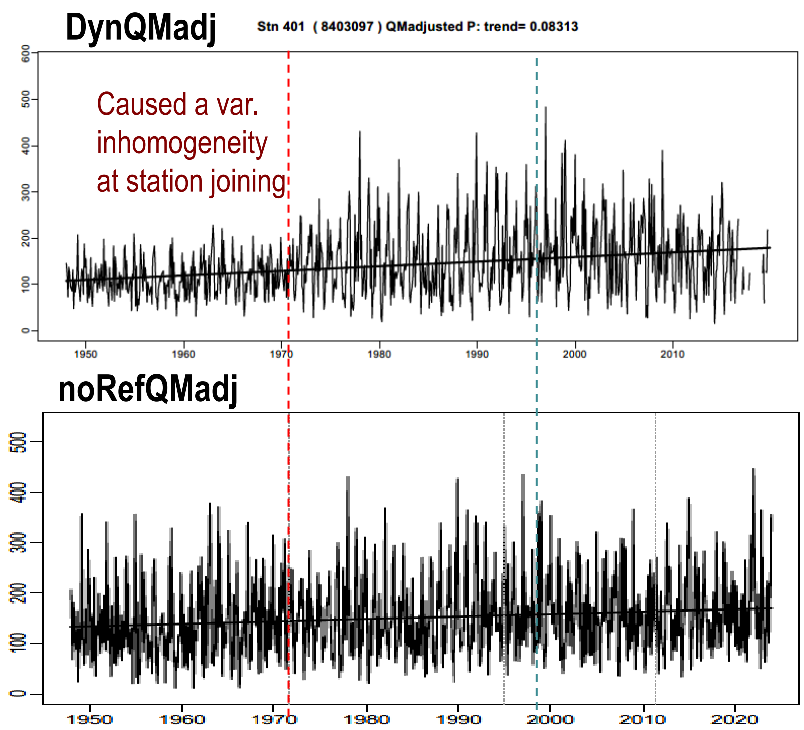
- **Used** the suite of tests in the RHtests package to detect changepoints in monthly precipitation (P) series
- **Conducted** tests with **and** without using a Ref, and **accounted for** both type-0 and type-1 changepoints

  Type-1: the cause is unknown, statistically significant even without metadata support   Type-0: the cause is known/documented
- **Used** up to 6 Ref series, including:
  - up to 4 best significantly-correlated neighbour stations
  - The ANUSPLIN estimates of monthly P for the Base station.
  - 20CRv3 ensemble-mean monthly P at the nearest gridpoint (20CRv3est).
- **Investigated** metadata to find all potential type-0 changepoints, including start- and end-points of data gaps.
- **Used** automated procedures that first "screen-in all potential changepoints" and then screen-out insignificant ones, one-by-one, giving priority to keep changepoints due to station joining or relocation (reliable causes).
- **Manually investigated**, station by station, the results obtained above to finalize the lists of changepoints.
- **Relied** on homogenized monthly P series and the changepoints identified therein to homogenize the corresponding daily P series. Specifically,
  - **Used** the RHtests_dlyPrcp package to find the most likely day of change in the month that was found to have a significant changepoint in the corresponding monthly P data series.
  - **Used** the RHtests_dlyPrcp to estimate daily proportions of adjustments needed to homogenize daily data series, so that the adjusted daily values sum up to the corresponding adjusted monthly P values.
  - Missing daily P vales were infilled with ANUSPLIN andvanced spatial interpolation of a much larger dataset

Used Quantile Matching (QM) adjustments to diminish inhomogeneities

- Conducted QM adjustment **without** using a Reference (noRefQMadj), because quality reference series are not available for this precipitation observing network of low station density. Our comparison found that, for this network, the use of best-correlated homogeneous reference segments (DynQMadj) did not improve the quality of adjusted data (Wang et al., 2023)
  Note that this conclusion might not be applicable for other variables or other precipitation network of higher station density.

An example showing that the use of poor Ref series could introduce a new problem into the adjusted series →



An example of data inhomogeneity (Wang et al. 2025, under review)

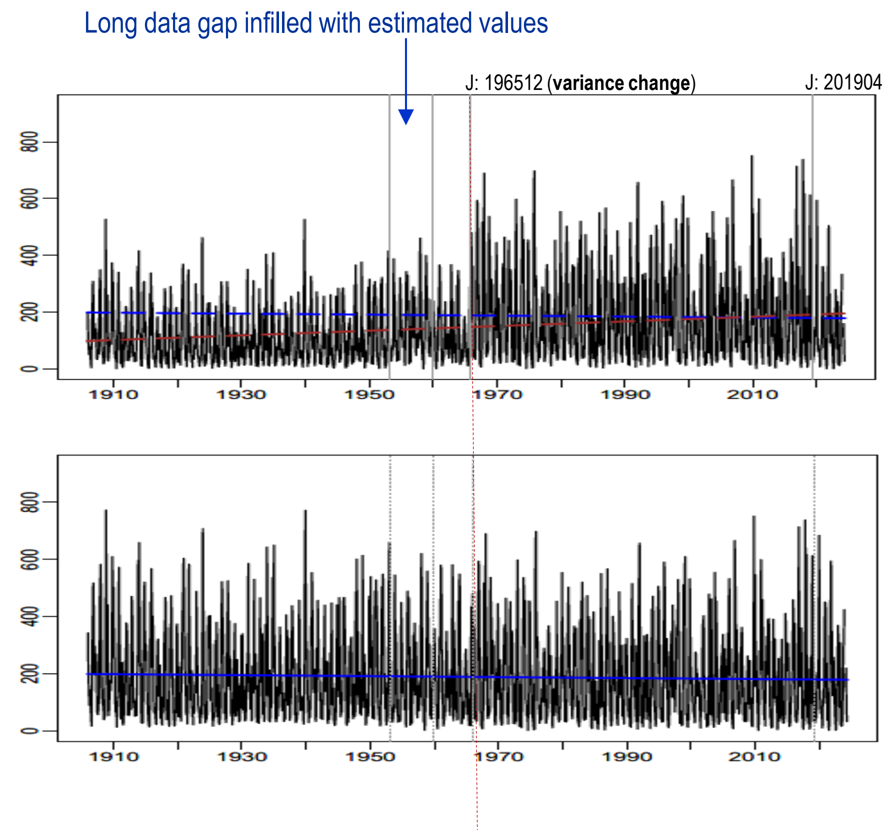
J = Station joining

Monthly precipitation for Port Alberni, BC (1057050): 2 Cs due station joining (J) + 2 Cs due to a gap infilled with estimated values

Unhomogenized monthly series:
(trend = 8.2 mm/decade ⬆)

Homogenized series:
(trend = -1.7 mm/decade ⬇)

The trend was biased from a small ⬇ to a large ⬆

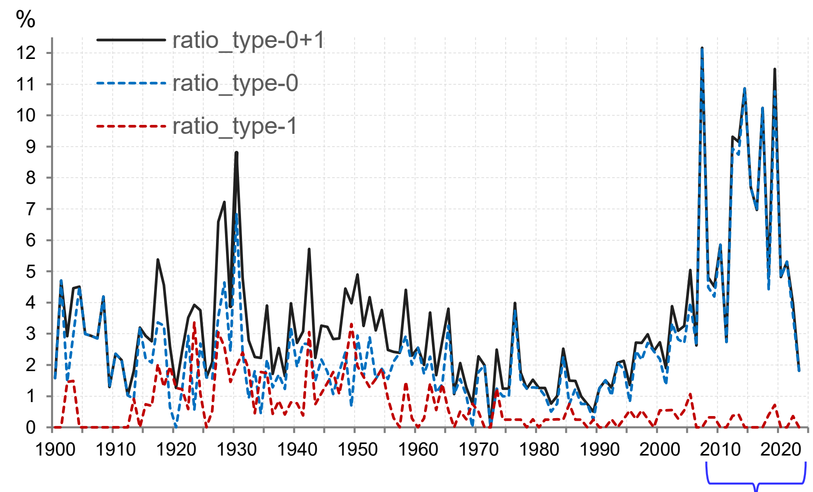


This also shows that the QM adjustments can diminish variance change at an identified changepoint (due to station joining in this case).

V2 changepoints (Cs) statistics (Wang, Feng, Zwiers, & Cheng, 2025 (under review))

No. of Cs	0	1	2	3	4	5	>5
No. of stns	65	75	91	68	54	25	47

360 of the 425 data series were found to be inhomogeneous, containing 1125 chpts (891 type-0, 234 type-1)



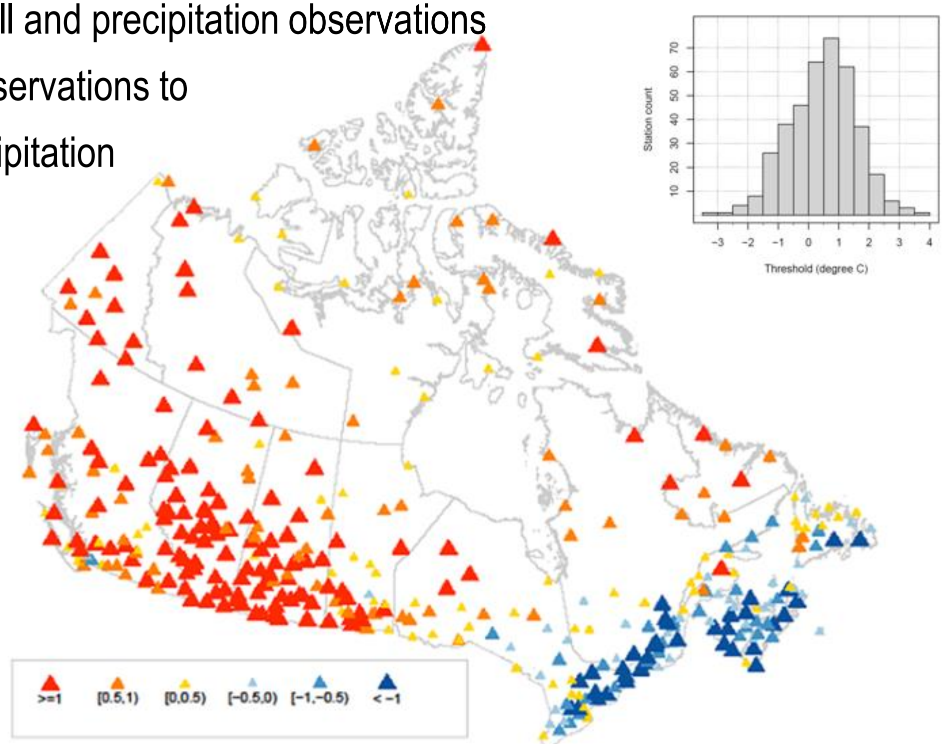
The percentage of stations with at least one changepoint is higher before late 1960s and since 2005. The latter is due to

- station joining (~28%),
- gauge or observing frequency changes (~17%),
- other changes associated with a data gap (~ 55%); automated stations have lots of missing data.

Daily proxy snowfall data (Qian, Wang, Feng, & Zwiers, 2025, in press)

- **Current automated** all-weather precipitation gauges do not report snowfall → no snowfall observations for the recent decades
- **For each station**, used available daily snowfall and precipitation observations and co-located daily mean temperature (T) observations to calibrate a T threshold, below which daily precipitation can be taken as snowfall

  (also tried to use Tmax or Tmin, but not as good)



- **Used** the station-specific threshold and

  homogenized daily P &

  homogenized daily mean T

  to produce proxy daily snowfall & rainfall data

- **Used** the homogenized daily P, and proxy daily snowfall and rainfall data to derive annual extreme indices

Annual extreme indices (ETCCDI indices as in Zhang et al. 2011, calculated using RClimDex software)

PrX1day: annual maximum 1-day precipitation amounts

PrX5day: annual maximum 5-day precipitation amounts

Pr10mm: annual number of heavy precipitation days (Pr ≥ 10 mm)

SnX1day: annual maximum 1-day snowfall amounts

Sn10mm: annual number of heavy precipitation days (Sn ≥ 10 mm)

RaX1day: annual maximum 1-day rainfall amounts

RaX5day: annual maximum 5-day rainfall amounts

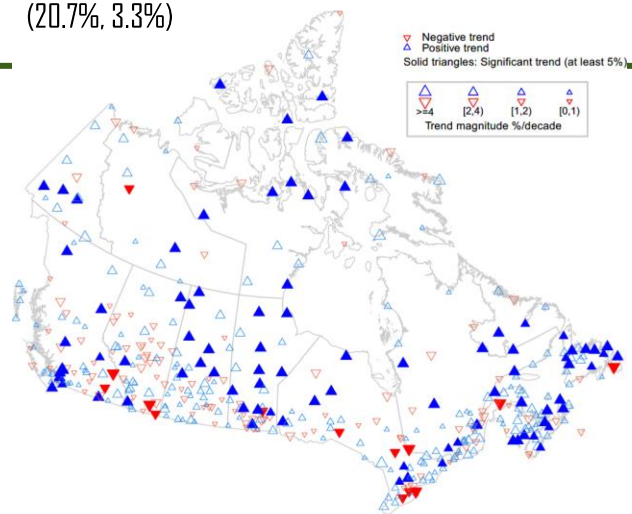
Ra10mm: annual number of heavy rainfall days (Ra ≥ 10 mm)

Observed trends in amounts (1949-2023)

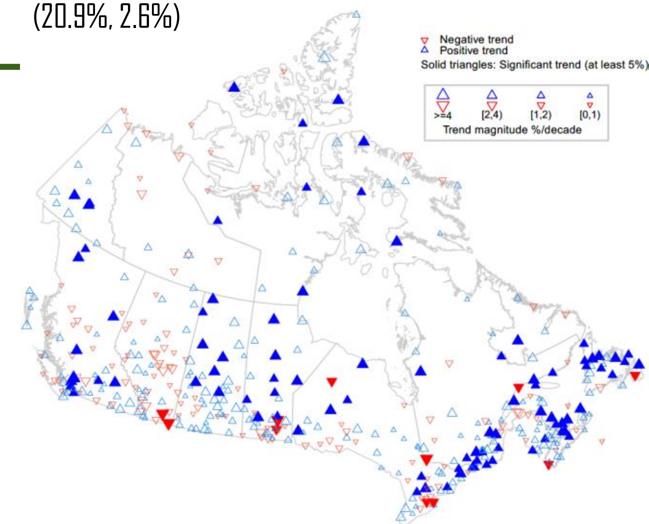
Percentages (a, b) indicate field significance of the (positive, negative) trend (10.6% or higher = significant at least at the 5% level)

Annual max 1-day & 5-day precipitation amounts have increased significantly across Canada

Annual max 1-day precipitation (20.7%, 3.3%)

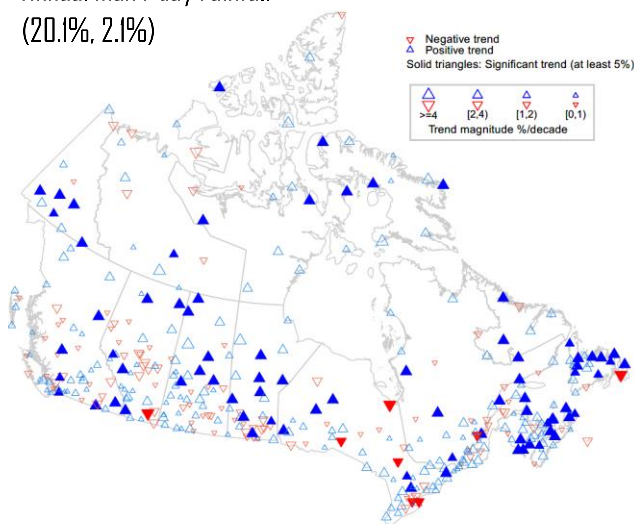


Annual max 5-day precipitation (20.9%, 2.6%)

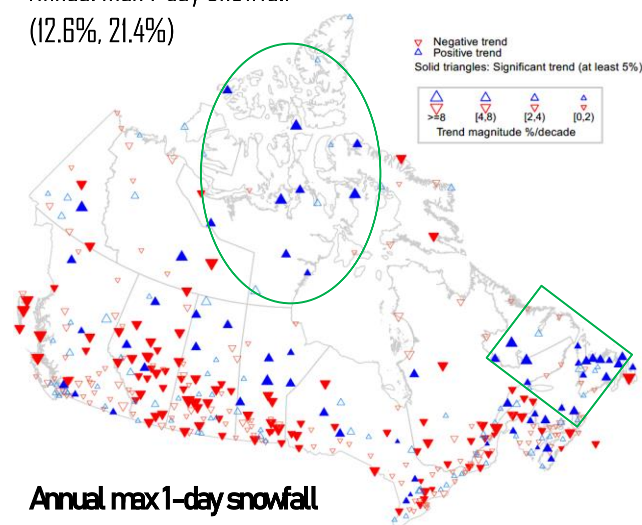


Similar trend patterns for annual max 1-day (& 5-day) rainfall

Annual max 1-day rainfall (20.1%, 2.1%)



Annual max 1-day snowfall (12.6%, 21.4%)

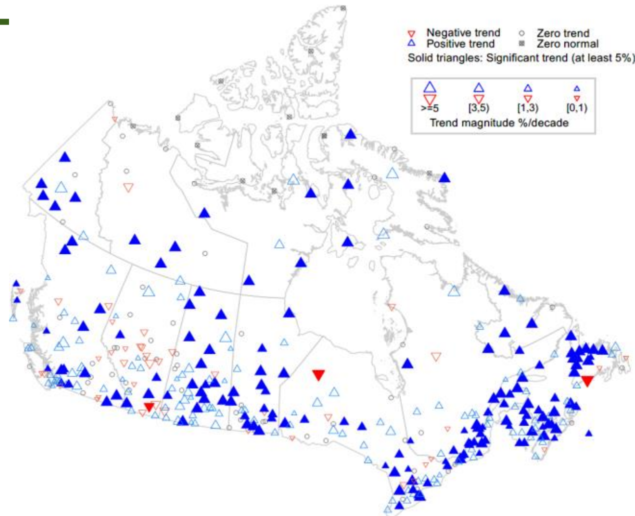


Annual max 1-day snowfall has decreased at most stations in southern Canada, but increased in the central North and Newfoundland

Observed trends in frequency (1949-2023)

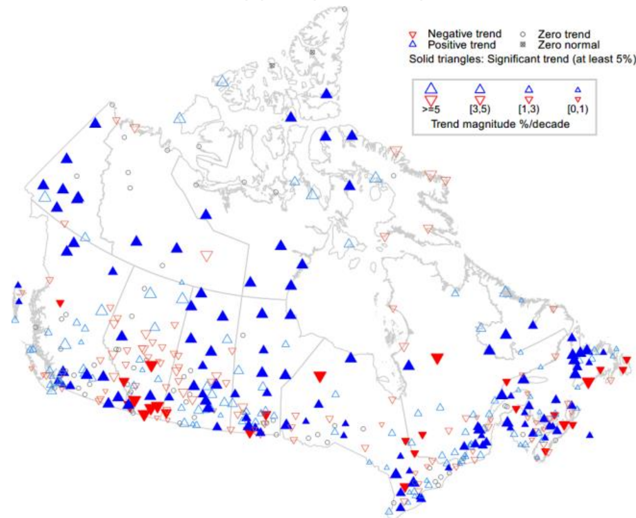
Percentages (a, b) indicate field significance of the (positive, negative) trend (10.6% or higher = significant at least at the 5% level)

Annual number of heavy rainfall days (38.7%, 0.8%)

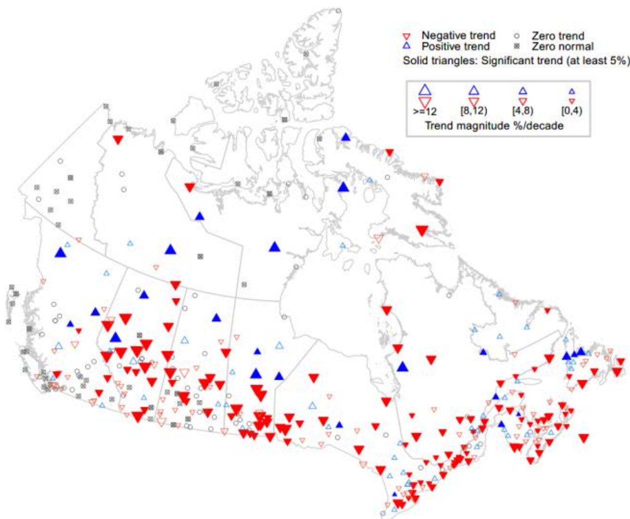


Heavy rainfall events have become significantly more frequent across Canada

Annual number of heavy precipitation days (26.6%, 6.4%)



Annual number of heavy snowfall days (5.2%, 29.1%)

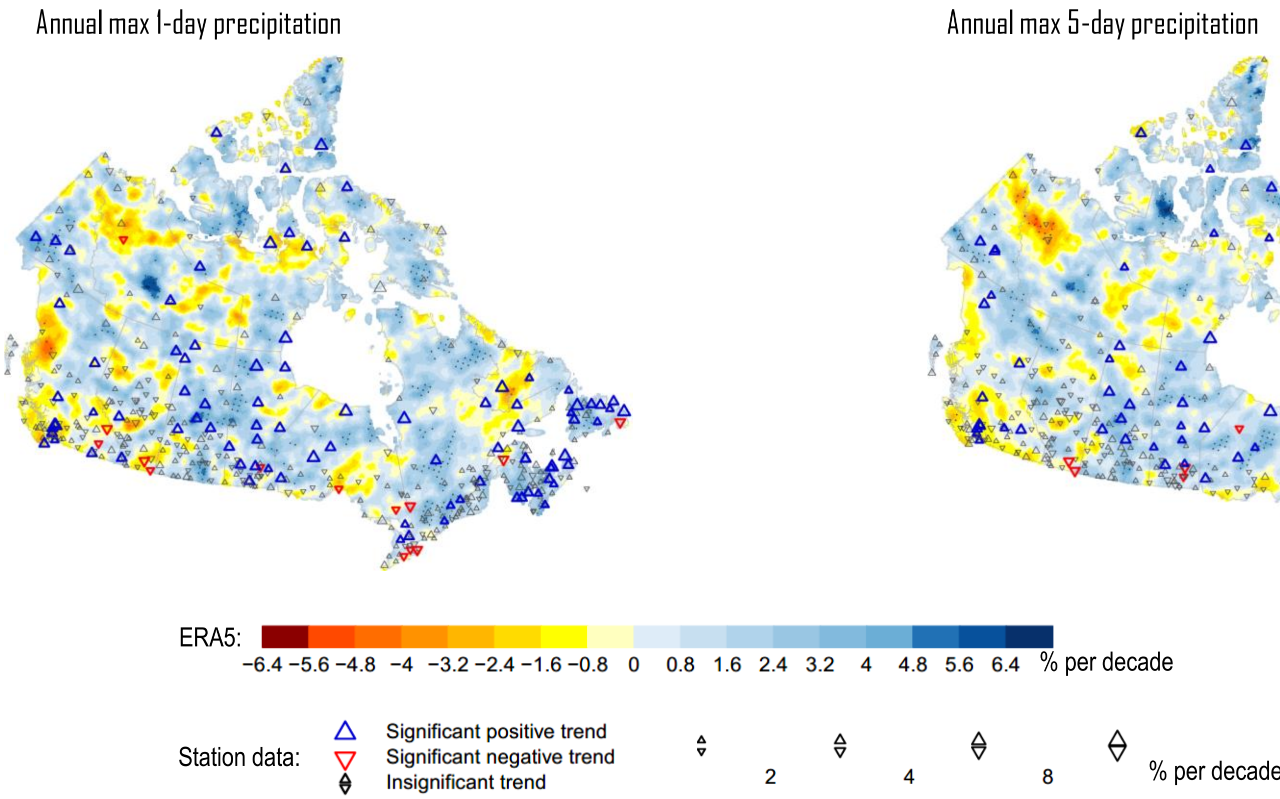


Heavy snowfall events have become significantly less frequent across southern Canada

In terms of the total precipitation, heavy precipitation events have become significantly more frequent across northern Canada and at many stations in the South, with a significant decrease seen at some stations in southern Alberta and southeastern Canada

Comparison of trends in station data and ERA5

Good consistency of trend between station data and ERA5



Concluding remarks

- It is difficult to homogenize precipitation data, even for monthly data, especially for stations in a sparsely observed region

- It is even more difficult to homogenize daily precipitation data, which are non-negative values and have lots of zero values. One needs to ensure that the adjusted values do not have negative values.

- One shall directly homogenize (untransformed) precipitation data series to obtain homogenized precipitation (HP); shall not homogenize the log(P) data series and then back-transformed HlogP to obtain the homogenized data (i.e., HP_fromHlogP).

The latter approach could introduce artificial variance inhomogeneity in the adjusted data series…

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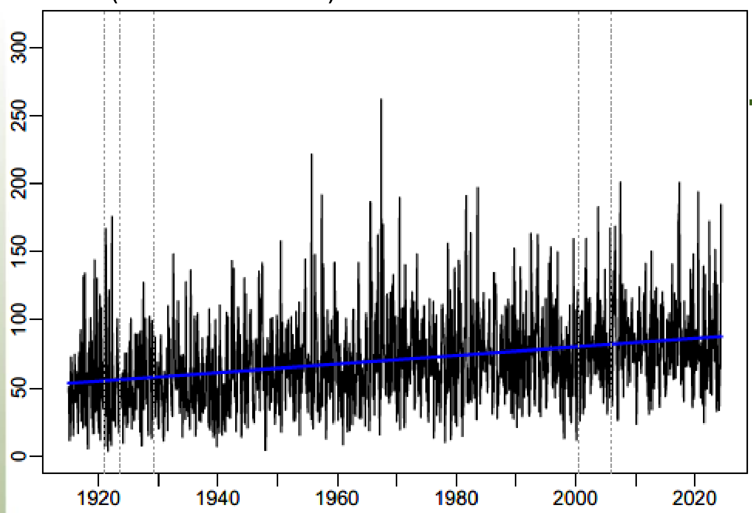
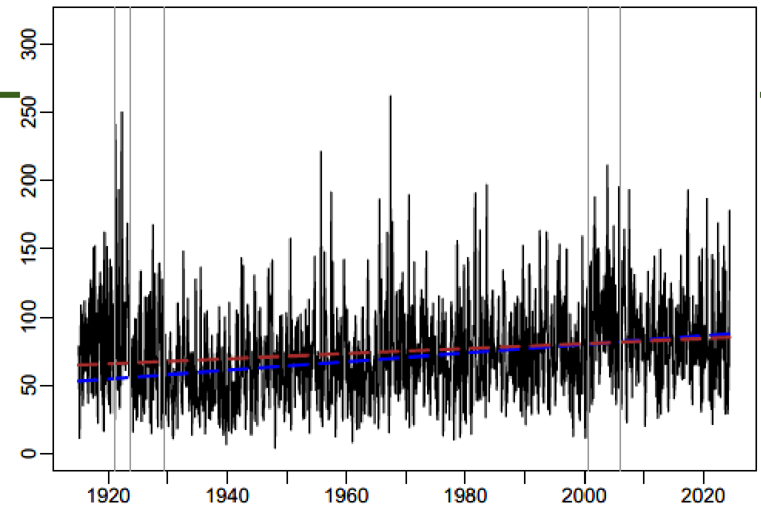
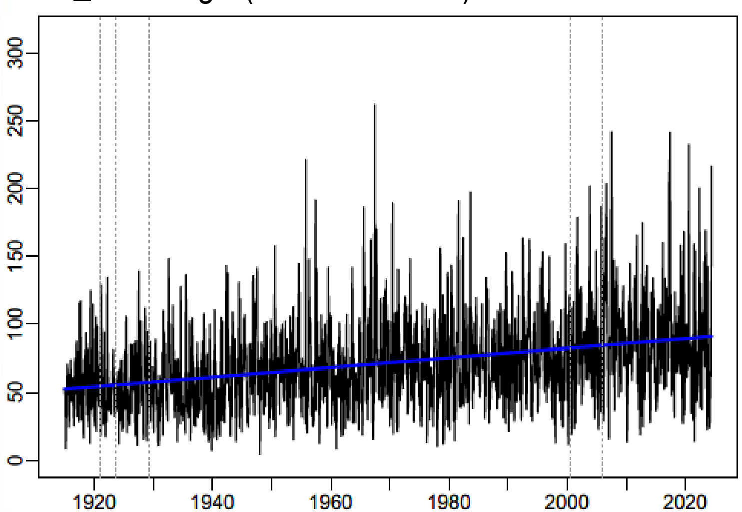
HP (trend = -0.0186)



Raw/unhomogenized P (blue line is the HP trend)



HP_fromHlogP (trend = -0.0296): the variance increases over time, which is not seen in the raw data series



Note that homogenizing log-transformed ratios is equivalent to homogenizing P through homogenizing logP (i.e., HP_fromHlogP) using a reference series:

$$\log(B_t/R_t) = \log(B_t) - \log(R_t)$$

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Thank you very much for your kind attention!

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