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Greater than averages: How metrics of extreme weather are trending differently than averages would suggest

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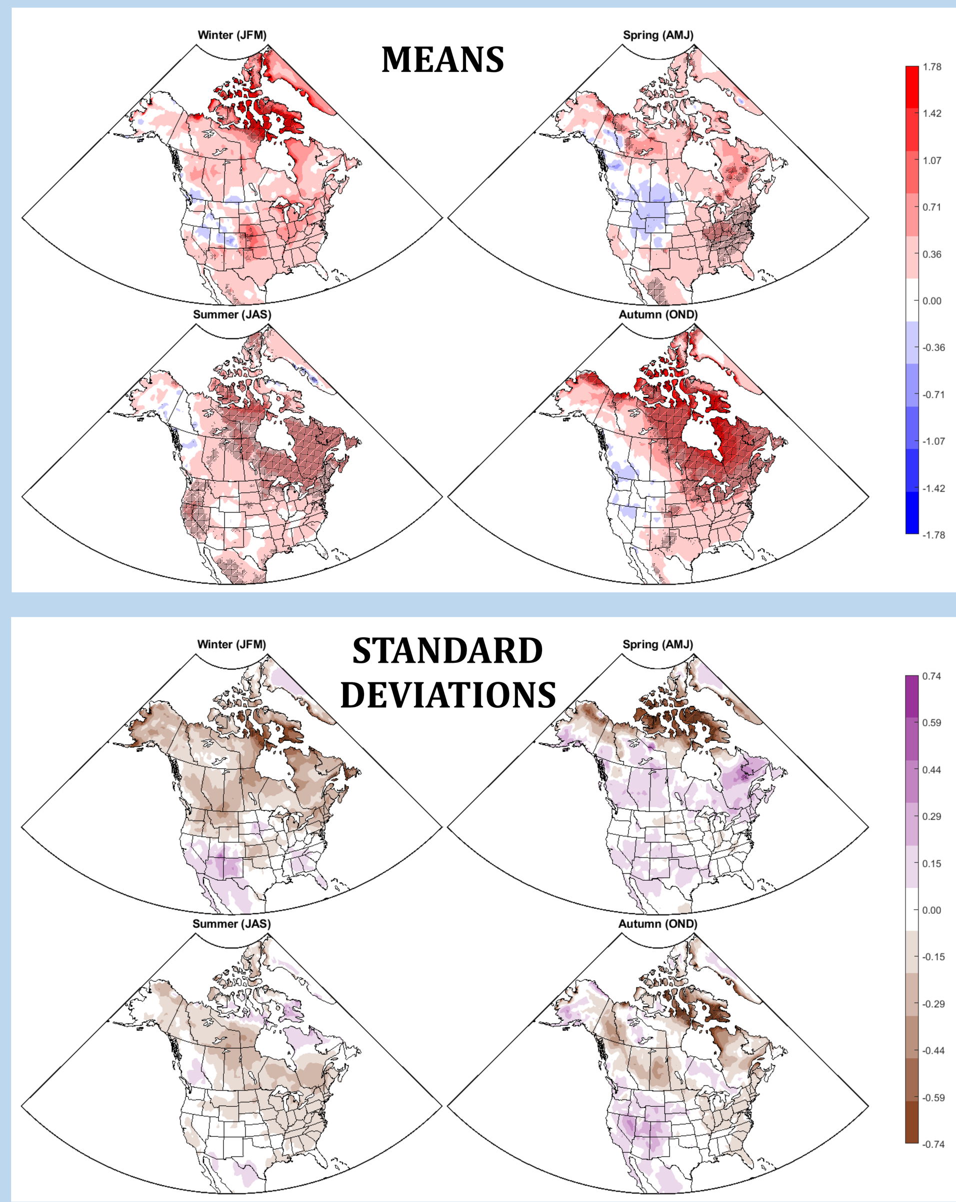
INTRODUCTION & IMPETUS

Upon the backdrop of steadily rising global average temperatures, it is the extreme weather events that are arguably more important and impactful than changing averages – especially on human health. This research examines trends in North America of three different parameters of extreme temperature events important to human thermal comfort and public health: their frequency, duration, and spatial extent. **Four extremes were considered: hot, cold, humid, and dry.**

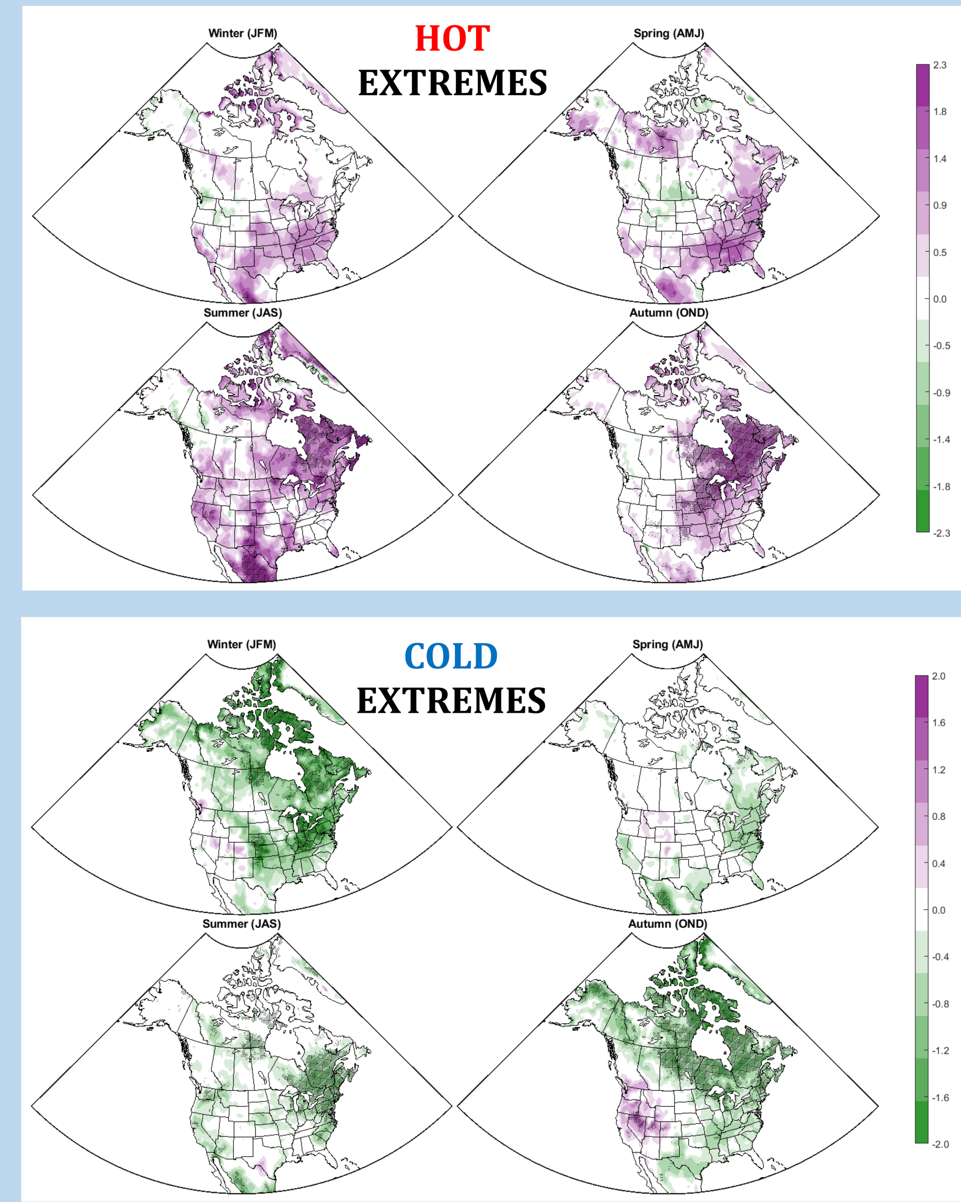
DATA & METHODS

Daily mean 2-meter temperature and 2-meter dew points were retrieved from the North American Regional Reanalysis (NARR), for 1979-2016, for 18,661 land-based gridcells in the domain. The NARR dataset was validated to see how well reanalysis model extremes matched station-based extremes. **Seasonally-relative 5th and 95th percentile** curves were used to define seasonal extreme event thresholds. Duration was calculated using a day-in-sequence approach that simply creates a daily-scale time series which counts consecutive occurrences of each event type at each location. Daily domain-wide percent areal extent was calculated by determining the spatial set of gridcells that met their own local percentile threshold for each of the four extreme events (corrected for latitude). Trends for each parameter (frequency, duration, or extent) were calculated using **Theil-Sen slope estimates** on annual-level statistics, or where results are partitioned into seasons, then seasonal-annual level statistics (e.g. Winter 1979, Winter 1980, etc.), where n=38 years for all trend estimates. Statistical significance was determined using the non-parametric **Mann-Kendall test** for trend. Then, for all mapping, an individual gridcell's significance was determined by **controlling for the false detection ratio**, effectively requiring each local test to meet a stricter significance threshold (lower p-value) to achieve field significance, considering the 18,661 local tests being computed.

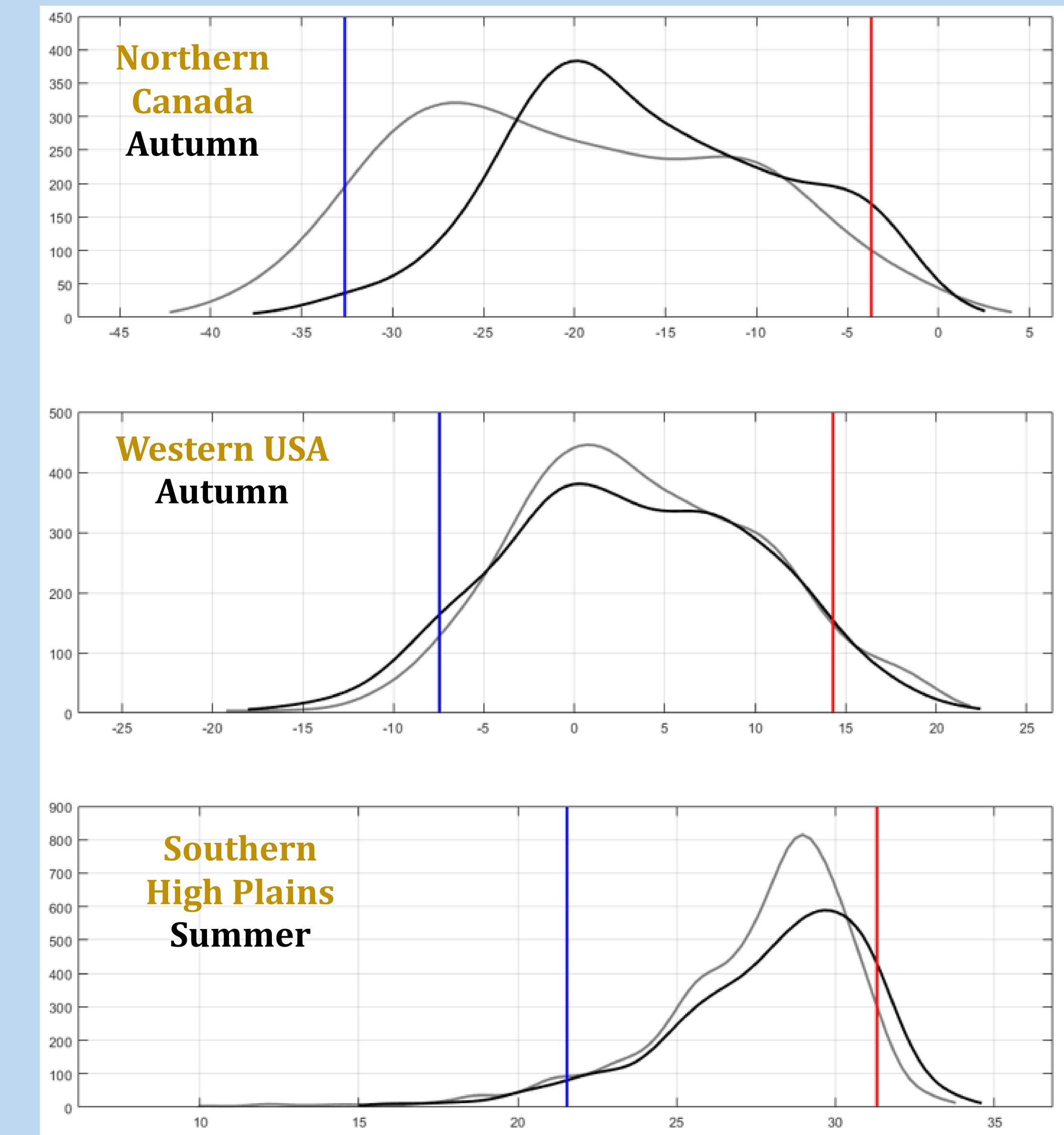
SEASONAL RESULTS AND MEANS vs. EXTREMES



Decadal changes in 2-m temperature means (top 4) and standard deviations (bottom 4), by season. Units are in Δ°C/decade. Statistically significant (p<0.05) values are shown with stippling.



Decadal changes in extreme 2m warm event frequencies (top) and extreme 2m cold event frequencies (bottom), by season. Units are Δ event-days per season, per decade. Statistically significant (p<0.05) values are shown with stippling. Note the different scale for the two types of events.



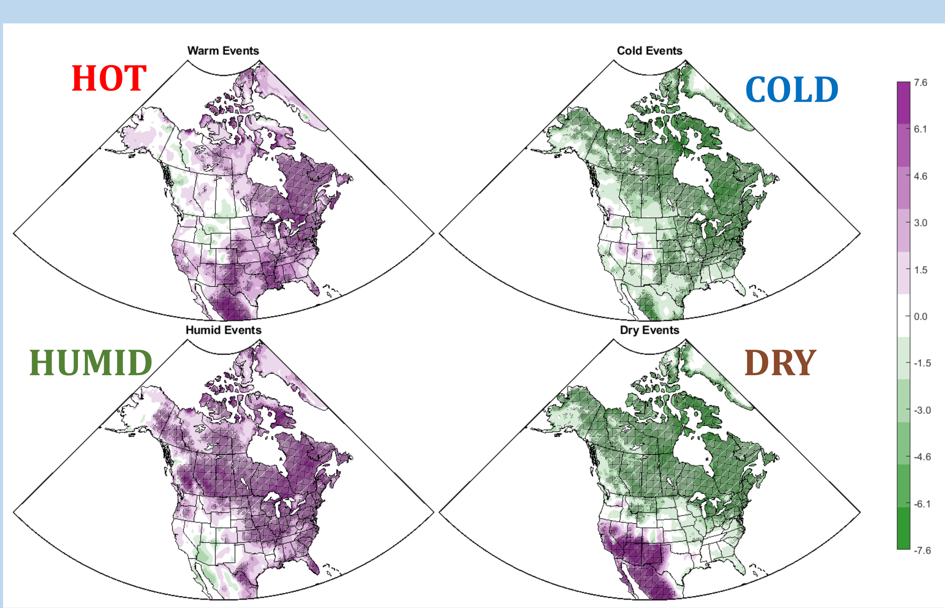
Changes in 2-meter temperature distributions between the first half (1979-1997; gray lines) and last half (1998-2016; black lines) of the study period. Blue and red vertical lines denote thresholds for extreme temperature events (at the 5th and 95th percentiles).

Large increase in mean temperatures, but no significant increase in extreme heat events… instead, large decrease in cold events, due to decreased variability

No significant trends in mean temperatures, but significant increase in cold events, due to increased variability

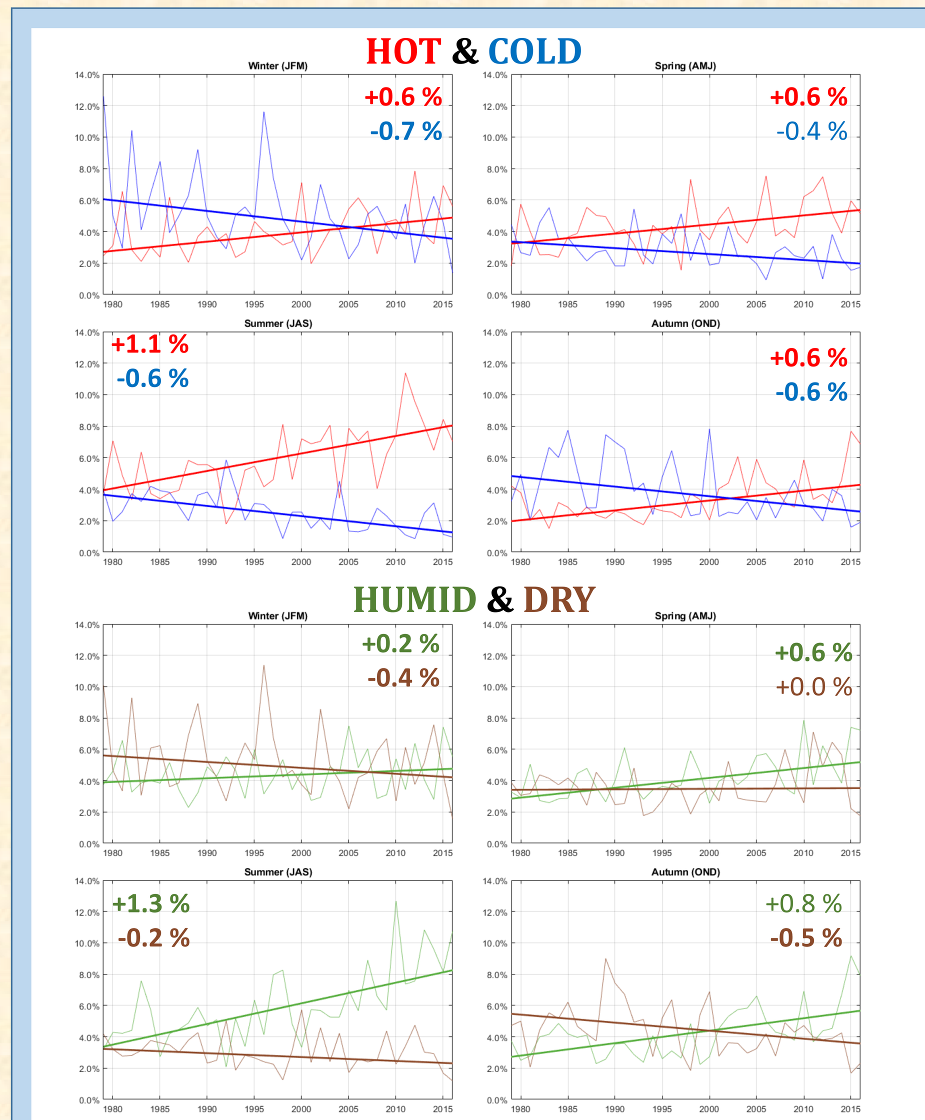
Little change in mean temperatures, but large increase in extreme heat events, due to large and significant changes in skew (increased) and kurtosis (decreased).

TRENDS IN ANNUAL EXTREME EVENT FREQUENCY



Decadal change in annual event frequencies. Units are change in event-days per year, per decade. Stippling indicates statistical significance (p<0.05).

EXTREME EVENT SPATIAL EXTENTS



Domain-wide time series (thin lines) & linear trend lines (thick lines) for extreme event spatial extent, by season. Percentage-point change in areal extent per decade is noted in the corner of each graph. Statistically significant trends are bolded.

Y-axis units are latitude-corrected percentage of area (within the domain) covered by events.

SUMMARY RESULTS IN BRIEF…

- Most trends are in the 'expected' direction…
  - Extreme warm and/or humid events are up; cold and/or dry events are down
- Trends in extreme event **duration** are not nearly as widespread as changes in event frequency and spatial extent
- Changes in events vary by season…
  - Seasonally-relative extremes (non-summer heat events & non-winter cold events) are changing significantly
  - Annual-only results can offset important seasonal trends; must partition results by season
- While overall extreme humid and extreme warm events are increasing, this does NOT mean that extreme cold and extreme dry events are decreasing at similar rates
- Trends in higher order statistical moments shed new light on the changing *distributions* of climate variables, including extreme events…
  - Even with no change in averages, significant changes in extreme events are still occurring due to **changes in variability, skew, and/or kurtosis**

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DATA: