

# Assessment of observed increases in extreme warm exceedances in locations with short warm side tails

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## I. Introduction

Locations with **shorter-than-Gaussian warm side temperature distribution tails** would experience a **more rapid increase** in extreme warm temperature threshold exceedances under a simple uniform shift. Such locations occur in spatially coherent regions<sup>1</sup> and are projected by CMIP5 to experience more rapid-than-Gaussian increases in warm exceedances by the mid-21<sup>st</sup> century, resulting in several “hotspots” of future warming.<sup>2</sup>

### Scientific questions:

- Do **ground truth in situ weather station** data reproduce observed short tails from reanalysis?
- Can more rapid-than-Gaussian increases in warm exceedances be detected in observation records for locations with short warm tails?

## II. Data

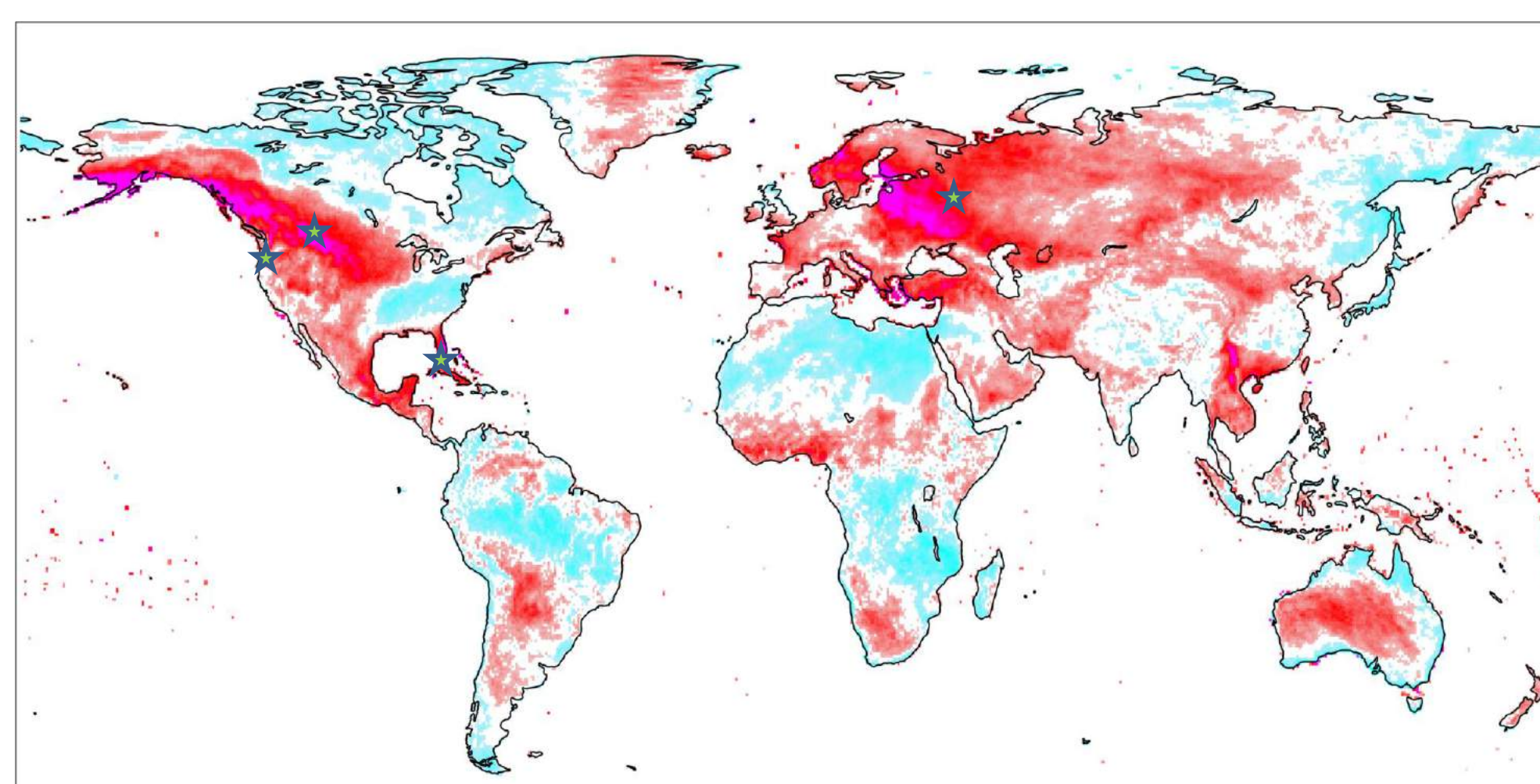
Station data from **GHCN-D<sup>3</sup>** were selected based on the following criteria:

- Region identified from reanalysis as having a **short warm tail**.
- Station has **60 years** of daily data or more.

## III. Methods

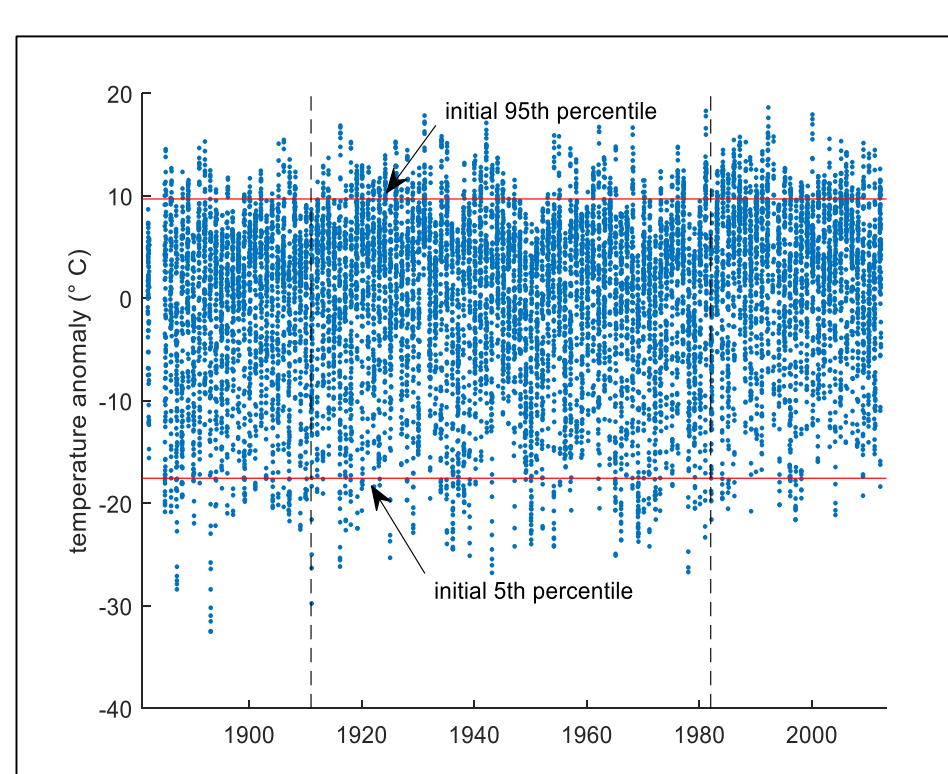
- **Temperature anomaly** is obtained from daily temperature maximum for DJF.
  - Moving mean with a 5-day window is calculated and used to calculate the mean daily climatology over the entire data series.
  - Temperature anomaly distributions are obtained for the first and last 30 years of the time series.
- **Extreme warm threshold** is defined as the 95<sup>th</sup> percentile of the temperature anomaly distribution.
  - **Short tails** are defined by shifting the initial distribution by  $0.5\sigma$ .
    - If the % of days exceeding the 95<sup>th</sup> percentile of the initial distribution is significantly greater than would be expected from shifting a Gaussian, a short warm tail is defined.
    - **Shift ratio** is calculated by dividing % of days exceeding the 95<sup>th</sup> percentile after shifting the distribution by  $0.5\sigma$  by that from shifting a Gaussian by  $0.5\sigma$ .
- The % of days in the later distribution exceeding the initial 95<sup>th</sup> percentile is calculated and determined to be significantly different from a shifted Gaussian or not.
  - **Actual shift ratio** is calculated by dividing % of days exceeding the 95<sup>th</sup> percentile after shifting the distribution by the corresponding percent for a Gaussian distribution shifted by the actual warming as a fraction of the standard deviation,  $\sigma$ .
- **Statistical significance** is determined by randomly sampling and shifting a Gaussian by  $0.5\sigma$  10,000 times. If the % of days exceeding the pre-shifted 95<sup>th</sup> percentile of the temperature distribution is greater than the 95<sup>th</sup> percentile of the Gaussian shift distribution, the warm tail is significantly shorter than Gaussian.

## IV. Results

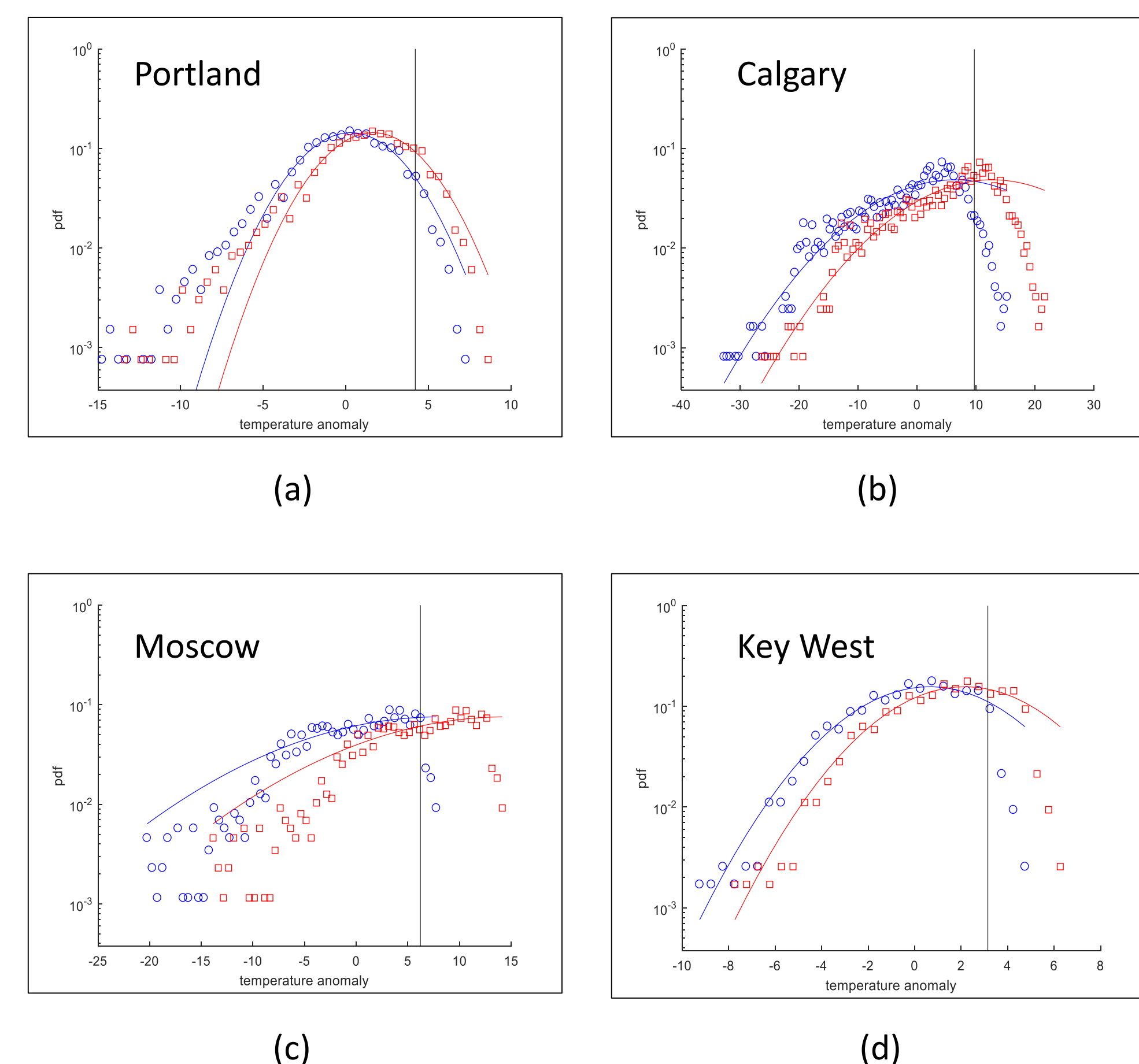


Long tail 0.5 1 1.5 Short tail

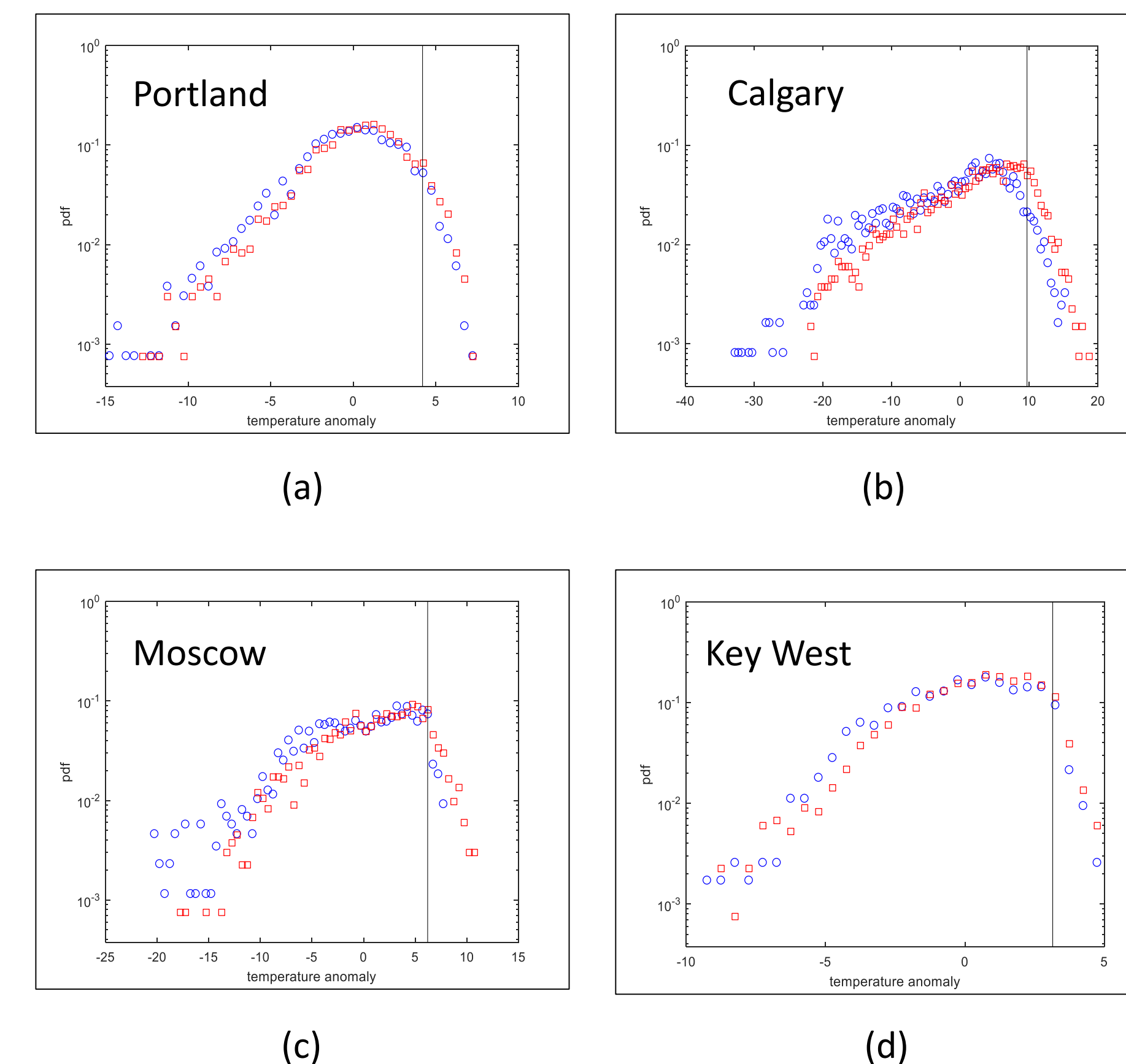
**Figure 1.** Shift ratio using a  $0.5\sigma$  warm shift in MERRA-CRU reanalysis<sup>4</sup>. Red cells indicate significant short warm tails. Locations used for this case study are marked with green stars.



**Figure 2.** Time series of DJF daily maximum temperature anomaly for Calgary, Alberta. The first and last 30 years are used to construct the histograms used in the analysis.



**Figure 3.** Histogram of temperature anomalies for first 30 years, along with the same distribution under a  $0.5\sigma$  warm shift and Gaussian fits for each distribution, at (a) Portland, OR; (b) Calgary, Alberta; (c) Moscow, Russia; (d) Key West, Florida. The black line shows the 95<sup>th</sup> percentile of the original distribution.



**Figure 4.** Histogram of temperature anomalies for first and last 30 years at (a) Portland, OR; (b) Calgary, Alberta; (c) Moscow, Russia; (d) Key West, Florida. The black line shows the 95<sup>th</sup> percentile of the initial period.

Location	Mean warming (°C); ( $\sigma$ )	Shift ratio	
		Uniform shift ( $0.5\sigma$ )	Actual
Portland, Oregon	0.49; (0.16)	<b>1.15</b>	1.04
Calgary, Alberta	3.3; (0.39)	<b>1.63</b>	<b>1.31</b>
Moscow, Russia	1.7; (0.31)	<b>1.81</b>	<b>1.14</b>
Key West, Florida	0.45; (0.19)	<b>1.41</b>	0.93

**Table 1.** Locations analyzed along with local mean warming in degrees Celsius and as a fraction of the standard deviation, and shift ratio for the uniformly shifted original distribution and the actual change. Bold signifies the quantity is statistically significant.

## V. Conclusions and Future Direction

- 4 stations with short warm tails are assessed for greater-than-Gaussian increases in warm extremes in the observed record.
- 2 stations show greater-than-Gaussian increases while 2 do not and show a shortening of the warm tail.
- Future work will analyze more stations and investigate mechanisms for deviations from expectations of a short tail

## References

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