Changes in the shape of summer temperature distributions and the probability of extremes

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Three sections of the talk

daily temperature data, non-normality, and quantile regression

changes in the shape of summer temperature distributions

comparison with the large ensemble
daily temperature data, non-normality, and quantile regression

changes in the shape of summer temperature distributions

comparison with the large ensemble
Data source: global historical climatology network

Daily Summaries Station Details

<table>
<thead>
<tr>
<th>STATION DETAILS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>BOULDER, CO US</td>
</tr>
<tr>
<td>Network:ID</td>
<td>GHCND:USC00050848</td>
</tr>
<tr>
<td>Latitude/Longitude</td>
<td>39.9919°, -105.2667°</td>
</tr>
<tr>
<td>Elevation</td>
<td>1671.5 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERIOD OF RECORD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Date¹</td>
<td>1893-10-01</td>
</tr>
<tr>
<td>End Date¹</td>
<td>2016-01-24</td>
</tr>
<tr>
<td>Data Coverage²</td>
<td>96%</td>
</tr>
</tbody>
</table>

Contains daily maximum and minimum temperatures from weather stations

Data quirks: changes in location, thermometers, time of observation
Example: Boulder summer temperature anomalies

![Probability density curve for TMAX anomaly (°C)]
Most non-coastal stations have negative skew
Most non-coastal stations have negative skew
In Europe, coastal influence on skewness extends inland.
Example: decreasing variance and skewness
Change in quantile function across percentiles
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comparison with the large ensemble
Analysis of NH extratropics (30-90N)

Location of stations that have sufficient data from 1980-2014
Dominant patterns of variability in quantile space

![Graph showing normalized amplitude vs. percentile]

- X-axis: Percentile
- Y-axis: Normalized amplitude
- Graph lines represent different patterns of variability in quantile space
Dominant patterns of variability in quantile space

![Graph showing normalized amplitude against percentile, with curves labeled as "Variance", "Skewness", and "Kurtosis". The graph illustrates how normalized amplitude changes with shifts in percentile.]
Dominant patterns of variability in quantile space

Mean shift explains 87% of variance globally for TMAX
Dominant patterns of variability in quantile space

Mean + three basis functions explain 98.7% of variance
Total change in 95th percentile of TMAX (1980-2014)
Change in 95th due to mean shift

\[ \Delta T \text{ (1980-2014) (°C)} \]
Change in 95th due to variance basis function

$\Delta T (1980-2014)$ (°C)
Change in 95th due to skewness basis function

ΔT (1980-2014) (°C)
Change in 95th due to kurtosis basis function

$\Delta T$ (1980-2014) (°C)
Residual change in the 95th percentile
Distinct spatial patterns for mean and variance.
Total change in 95th percentile of TMAX (1980-2014)
Change in 95th due to mean shift
Change in 95th due to variance basis function

ΔT (1980-2014) (°C)
Change in 95th due to skewness basis function

ΔT (1980-2014) (°C)
Change in 95th due to kurtosis basis function

$\Delta T (1980-2014)$ (°C)
Residual change in the 95th percentile
Variance acts to amplify 95th percentile in TMAX
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Summer: $\Delta T$ relatively flat across percentile space

Trends for continental US from 1979-2014

- TMIN
- TMAX

Figure from Andy Rhines
Observations generally within envelope of ensemble members

Trends for continental US from 1979-2014
Final thoughts

Daily temperature distributions are non-normal, and changes in their shape can be estimated using quantile regression.

Changes in summer temperature distributions can largely be explained by a ‘shift’, but changes in the variance, skewness, and kurtosis control amplify or damp extremes.

Quantile trends from the large ensemble are variable compared to the observations. Future work will compare ensemble members with different behaviors in quantile space.