The changing shape of summer temperature distributions

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with Andy Rhines, Martin Tingley, Peter Huybers, and Clara Deser

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The Hot Summer of 2010: Redrawing the Temperature Record

Map of Europe

David Barriopedro, Erich M. Fischer, Jürg Luterbacher, Ricardo M. Trigo, Ricardo García-Herrera

European summer temperature

Prior work: has summer temperature variance increased?
Two sections of the talk

- a proposed method for quantifying changes in daily temperature distributions
- comparison between observations and the CESM large ensemble
Two sections of the talk

a proposed method for quantifying changes in daily temperature distributions

comparison between observations and the CESM large ensemble
Quantile regression: trends in different percentiles

Roosevelt, AZ
Heterogeneous trends across space and percentile

trends from 1980-2015

nb: analysis for full NH in paper under review in JGR-Atmospheres
Four basis functions explain 98.8% variance

b) PCA on $T_x$
Results from PCA ~ trends from changing moments

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Value of basis function</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Moments</td>
<td>b) PCA on Tx</td>
</tr>
<tr>
<td></td>
<td>c) PCA on Tn</td>
</tr>
<tr>
<td></td>
<td>d) Legendre</td>
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</tbody>
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![Graph showing Moments](image)
‘Quick and not-so-dirty’ PCA approx: Legendre polynomials

Gibson et al (1992), *Physica D: Nonlinear Phenomena*
Most of variance explained by mean shift

87%
Mixed spatial pattern of sign of variance changes

87%

a) shift

73%

b) var
Skewness locally, not globally, important

- a) shift
- b) var
- c) skew
- d) kurt

87% in a) shift
73% in b) var
13% in c) skew
Kurtosis locally, not globally, important

- a) shift
- b) var
- c) skew
- d) kurt

87%
73%
13%
4%
Two sections of the talk

a proposed method for quantifying changes in daily temperature distributions

comparison between observations and the CESM large ensemble
Can models help us understand which of these changes are ‘forced’?
Comparison: observed and modeled shift

obs
Comparison: observed and modeled shift

obs

ensemble mean
Comparison: observed and modeled shift

- **observational data (obs)**
- **ensemble mean**
- **ensemble standard deviation (ensemble σ)**

The maps illustrate the spatial distribution of observed and modeled temperature shifts across the United States, with a gradient color scale indicating the magnitude of the shifts in °C per decade.
Comparison: observed and modeled shift

- **obs**
- **ensemble mean**
- **ensemble member**
- **ensemble σ**

The diagrams show the comparison between observed and modeled shift, with different maps representing different measures such as shift, variance, skew, and kurtosis.
Smaller spatial scales of change in mean than obs
Closely related to trends in sensible heat flux
Most models show greater sensitivity to SHFLX than circulation.
**Summary**

Quantile regression can be used to quantify changes in the shape of temperature distributions. The percentile trends can be summarized using Legendre polynomials, which can be interpreted (approximately) as changes in the first four statistical moments. A large majority of the observed changes in summer temperature distributions can be explained by a positive shift. There is not a hemispherically-consistent signal for changes in shape. Members of the large ensemble exhibit a wide range of trends in the mean. The spatial scales tend to be smaller than observations, perhaps due to the large influence of sensible heat fluxes.

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Extras
Prior work: has summer temperature variance increased?

Perception of climate change

James Hansen\textsuperscript{a,1}, Makiko Sato\textsuperscript{a}, and Reto Ruedy\textsuperscript{b}
Shape changes have a large impact on tails

- **a)** Western US Tx
  - + mean
  - - var

- **b)** Eastern Europe Tx
  - + mean
  - + var

- **c)** Northeastern US Tn
  - + skew

Temperature anomaly (°C)
Recent high-impact summer heat waves in the NH

2003
http://www.history.com/

2012
https://www.blue-point-trading.com/

2010
http://i.telegraph.co.uk/
Many studies on changes in interannual variability suggest that seasonal and hemispheric variations in these distributions, when using the algorithm leading to Fig. 1a, naturally decrease in magnitude from the 1950s to the 1990s, but then increase recently, indicating major changes in climate variability. Some features of this pattern are consistent with the global increase in temperature variability since 1980 suggested by many studies. However, we find little or no indication of an overall increase in temperature variability despite the perception of increased variability in many regions.

No increase in global temperature variability despite changing regional patterns

Chris Huntingford¹, Philip D. Jones²,³, Valerie N. Livina⁴,⁵, Timothy M. Lenton⁶ & Peter M. Cox⁷
Data source: global historical climatology network

Fraction of days with data

a) TMAX
Daily temperature is usually non-normal

Boulder, CO

- standard dev: 3.6
- skewness: -0.66
- excess kurtosis: 0.87
Globally, most stations have neg skewed TMAX
Quantile regression: trends at different percentiles

Ordinary least squares (mean)

Quantile regression (median)

Quantile regression (other percentiles)
Comparison: observed and modeled variance change

data

obs
Comparison: observed and modeled variance change

obs

ensemble mean
Comparison: observed and modeled variance change

- **obs**
- **ensemble mean**
- **ensemble σ**
Comparison: observed and modeled variance change

- (a) shift
- (b) var
- (c) skew
- (d) kurt
Regions of greatest uncertainty are most variable

... consistent with Thompson et al (2015), *J Clim*
But model variability displaced from observed
In general, more shape changes in CESM than obs