An analysis of recent anomalously warm seasons in Europe

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• Observations
• Trends
• Climate model trends
• 2006/2007 weather
• Climate model extremes
• What is going on?
Temperatures at De Bilt 1706-2007
Temperatures in Europe relative to 1961-1990

<table>
<thead>
<tr>
<th>Season</th>
<th>Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>JJA 2006</td>
<td>![Map of JJA 2006 temperatures in Europe]</td>
</tr>
<tr>
<td>SON 2006</td>
<td>![Map of SON 2006 temperatures in Europe]</td>
</tr>
<tr>
<td>DJF 2006/2007</td>
<td>![Map of DJF 2006/2007 temperatures in Europe]</td>
</tr>
<tr>
<td>MAM 2007</td>
<td>![Map of MAM 2007 temperatures in Europe]</td>
</tr>
</tbody>
</table>
Return times

- Fit tail of cumulative distribution to function $F(x)$, excluding year to be studied $i$
- Compute $T_i = 1/(1 - F(x_i))$

Consider two forms for $F(x)$:

1. Normal distribution; in Europe works well in spring and autumn but not in summer (positively skewed) or winter (negatively skewed).

2. Peak-over-Threshold method: Generalised Pareto Distribution fitted to the tail above a threshold:

$$H(z) = 1 - \left(1 + \frac{z\xi}{\sigma}\right)^{-1/\xi} \quad (1)$$

We take the threshold at 80% (fit to 10-20 points).
Hypothesis I: only interannual variability

Assume no other variability than interannual (autocorrelation zero from year to year).
Hypothesis I: only interannual variability

Without long-term variability the return times of autumn 2006 would be $O(10^4)$ years in large parts of Europe.
Hypothesis II: PDF shifts only

Assume most long-term climate variability is global:

\[ T'(x, y, t) = A(x, y)T'_{\text{global}}(t) + \epsilon(x, y, t) \]  \hspace{1cm} (2)

The effects are largest in the tails of the distribution.
Local vs global warming: $A(x, y)$

HadCRUT3 observations

regr Jan–Dec averaged HadCRUT3 global temperature index with Jan–Dec averaged HadCRUT3 SST/T2m anom 1948:2006

Main features are very similar, how about the details?

ESSENCE, 17 runs with ECHAM5/MPI-OM

Dec averaged Essence (ECHAM5/MPI-OM) t2m 0–360E –90–90N ensemble with Jan–Dec averaged Essence (ECHAM5/MPI-OM) t2m 1950:2007
Local vs global warming: $A(x, y)$

HadCRUT3 observations

GFDL CM 2.1

Main features are very similar, how about the details?
Observed trends, 2,3,4,5σ contours ECHAM5 1950-2006
Trends: $A(x, y)$

- West-central Europe has warmed almost a factor 2 faster than the global mean
- Climate models simulate a factor 1
- The difference is very unlikely due to natural variability
- We are investigating which biases in the models contribute
Weather at De Bilt $\epsilon(5^\circ E, 52^\circ N, t)$

Autocorrelation is zero now
Weather at De Bilt $\epsilon(5^\circ E, 52^\circ N, t)$

SON: $T_{2006} = 650 \text{ yr}$, 95\% CI: 125-10000 yr (normal distr.)
Weather at De Bilt $\epsilon(5^\circ E, 52^\circ N, t)$

![Graphs showing temperature data for different seasons and return periods.](graphs)

- **JJA T2m De Bilt - A Tglobal 1901:2005**
- **SON T2m De Bilt - A Tglobal 1901:2005**
- **DJF T2m De Bilt - A Tglobal 1901:2005**
- **MAM T2m De Bilt - A Tglobal 1901:2006**

**Gauss fit** and **GPD fit** are shown for each season. The return periods range from 1 year to 10,000 years.
De Bilt: return times of $\epsilon(5^\circ\text{E}, 52^\circ\text{N}, 2006/2007)$

Given the distribution of the previous seasons

<table>
<thead>
<tr>
<th>season</th>
<th>fit</th>
<th>central</th>
<th>2.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>summer 2006</td>
<td>GPD</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>autumn 2006</td>
<td>Normal</td>
<td>650</td>
<td>125</td>
</tr>
<tr>
<td>winter 2007</td>
<td>GPD</td>
<td>220</td>
<td>55</td>
</tr>
<tr>
<td>spring 2007</td>
<td>Normal</td>
<td>250</td>
<td>75</td>
</tr>
<tr>
<td>product</td>
<td></td>
<td>$4 \times 10^8$</td>
<td>$2 \times 10^6$</td>
</tr>
</tbody>
</table>

After subtracting the linear effect of global warming
Europe: return times of $\epsilon(x, y, 2006/2007)$

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<th>JJA 2006</th>
<th>SON 2006</th>
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<tr>
<td>$t_{2006}$ Jun-Aug averaged GHCN/CAMS t2m $-$ HadCRUT3 global temperature 1948:2005</td>
<td>$r_{2006}$ Sep-Nov averaged GHCN/CAMS t2m $-$ HadCRUT3 global temperature 1948:2005</td>
</tr>
<tr>
<td>DJF 2006/2007</td>
<td>MAM 2007</td>
</tr>
</tbody>
</table>
Hypothesis III: change in PDF as well as shift

Not enough data in observations to determine changes in the width, look at climate models.
Change in PDF?

ESSENCE, summer temperatures
Change in PDF in summer

Change in PDF?

ESSENCE, autumn temperatures
No change in PDF in autumn

No change in PDF in autumn

GFDL CM2.1  UKMO HadGEM1  CCCMA CGCM3.1
ESSENCE, winter temperatures
Change in PDF?

ESSENCE, spring temperatures
No change in high tail PDF in spring until 2095

Weather $\epsilon(x, y, 2006/2007)$

- Highly improbable sequence of temperature anomalies after subtracting trend (and persistence)

- Climate models do not simulate a change in PDF, only a shift, except in summer
Conclusions and questions

- The warming trend in west-central Europe is two times faster than the climate models simulate.
- This is very unlikely due to natural variability.
- On top of this trend, a series of unlikely temperature extremes occurred over the last year.
- Climate models only simulate a change in PDF other than a shift in summer.
- Missing non-linear physics in the climate models?
Circulation

July 2006

August 2006
Circulation

September 2006

October 2006
Circulation

November 2006  December 2006
Circulation

January 2007

February 2007
Circulation

March 2007  April 2007