Exploration of trends in atmospheric temperatures

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TIES, June 19, 2002

1. Central England Temperature

- Average of several sites in “Central England”
  - London (SE), Manchester (NW) and Bristol (SW)
- Average monthly temperature
  - since 1659 – longest continuous series
  - 340 years, 4092 observations
- Average daily temperature
  - \((\text{max} + \text{min})/2\)
  - Since 1772
  - 230 years, 83276 observations

http://www.met-office.gov.uk/research/hadleycentre/obsdata/CET.html
1.1 Annual – linear trend

<table>
<thead>
<tr>
<th></th>
<th>Rise ‘C/100Y</th>
<th>p</th>
<th>rho1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Mean</td>
<td>0.226</td>
<td>0.000</td>
<td>0.22</td>
</tr>
<tr>
<td>With AR(1)</td>
<td>0.227</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>1878–</td>
<td>0.773</td>
<td>0.000</td>
<td>0.17</td>
</tr>
</tbody>
</table>

- rho1 > 0.11, reduces significance

1.2 Seasons – linear trend

<table>
<thead>
<tr>
<th>Season</th>
<th>1659-</th>
<th>1878-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rise ‘C/100Y</td>
<td>p</td>
</tr>
<tr>
<td>DJF</td>
<td>0.35</td>
<td>0.000</td>
</tr>
<tr>
<td>MAM</td>
<td>0.23</td>
<td>0.000</td>
</tr>
<tr>
<td>JJA</td>
<td>0.06</td>
<td>0.179</td>
</tr>
<tr>
<td>SON</td>
<td>0.25</td>
<td>0.000</td>
</tr>
</tbody>
</table>

- rho1 > 0.11, reduces significance
1.3 Months

- Smooth variation through year
- Are trends better-defined by not aggregating (heterogeneity)?

<table>
<thead>
<tr>
<th>Month</th>
<th>Trend 'C/100Y</th>
<th>p</th>
<th>rho1</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>0.36</td>
<td>0.000</td>
<td>0.02</td>
</tr>
<tr>
<td>January</td>
<td>0.44</td>
<td>0.000</td>
<td>0.01</td>
</tr>
<tr>
<td>February</td>
<td>0.27</td>
<td>0.008</td>
<td>-0.05</td>
</tr>
<tr>
<td>March</td>
<td>0.38</td>
<td>0.000</td>
<td>0.07</td>
</tr>
<tr>
<td>April</td>
<td>0.20</td>
<td>0.002</td>
<td>0.12</td>
</tr>
<tr>
<td>May</td>
<td>0.11</td>
<td>0.072</td>
<td>0.15</td>
</tr>
<tr>
<td>June</td>
<td>-0.02</td>
<td>0.736</td>
<td>-0.06</td>
</tr>
<tr>
<td>July</td>
<td>0.11</td>
<td>0.086</td>
<td>0.04</td>
</tr>
<tr>
<td>August</td>
<td>0.11</td>
<td>0.070</td>
<td>0.15</td>
</tr>
<tr>
<td>September</td>
<td>0.15</td>
<td>0.010</td>
<td>0.15</td>
</tr>
<tr>
<td>October</td>
<td>0.32</td>
<td>0.000</td>
<td>0.09</td>
</tr>
<tr>
<td>November</td>
<td>0.30</td>
<td>0.000</td>
<td>0.07</td>
</tr>
</tbody>
</table>
1.4 Changing seasons

- Different trends in different months
  - changing seasonal pattern
- Seasonal cycle has become (slightly) compressed
1.5 Assumptions/heterogeneity

- Could put all months together
  - if variances are homogeneous
- Summer/winter heterogeneity?
- Autocorrelation (monthly)
- Normality?
2. Daily series

- 1772–
- Can now look at other characteristics
- Trends in **functionals**
  - degree days above 5°C (growing)
  - extremes

2.1 Extremes

- 227 annual extremes
  - each of 365+ daily values
  - seasons – around 90 values
  - GEV
- As well as actual value, consider **timing**:
  - min is usually in January
  - and max is usually in July
2.2 Trend estimates

- Summer maxima
  - no trend (p=0.13)

- Winter (Dec-Jan-Feb) minima
  - 0.67°C/100Y (s.e.0.22)
  - (estimated as GEV)
3. Remarks

- Linear trends are useful exploratory tools
  - trend parameterised as change per unit time
- Take account of
  - structure – seasons
  - heterogeneity – may not put everything in one model
  - changing pattern through time – shorter series
  - trade-off strength and consistency of trend against amount of data (significance)
  - Autocorrelation (weak at seasonal lags of residuals)
- Other functionals (extremes, timing, GDD)