

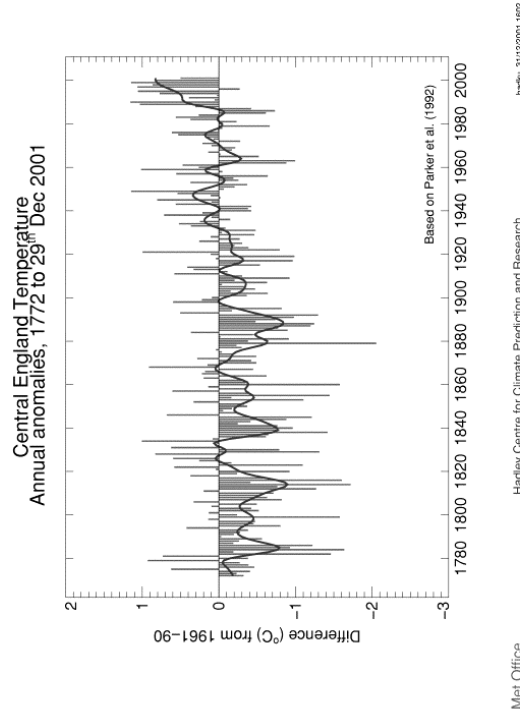
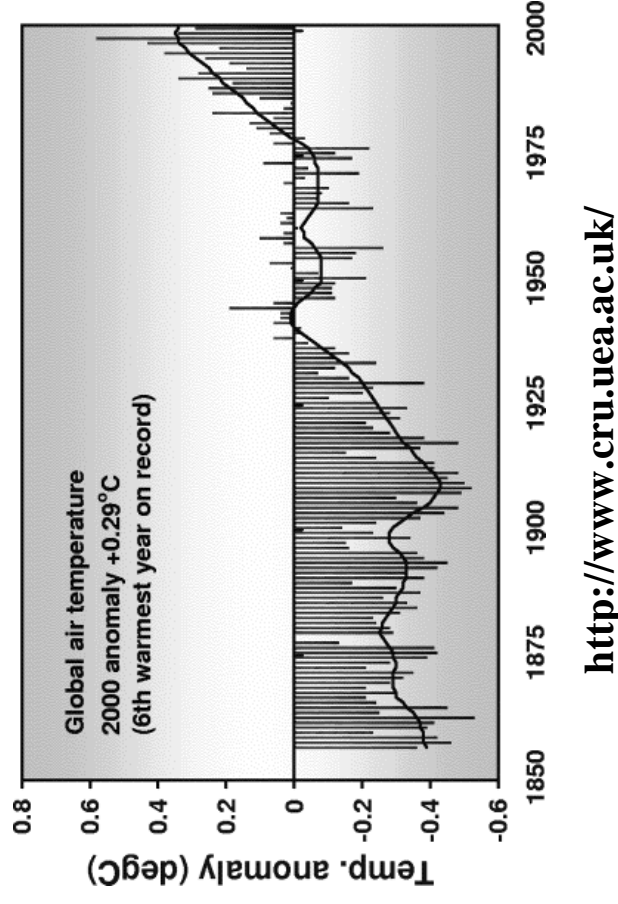
Exploration of trends in atmospheric temperatures

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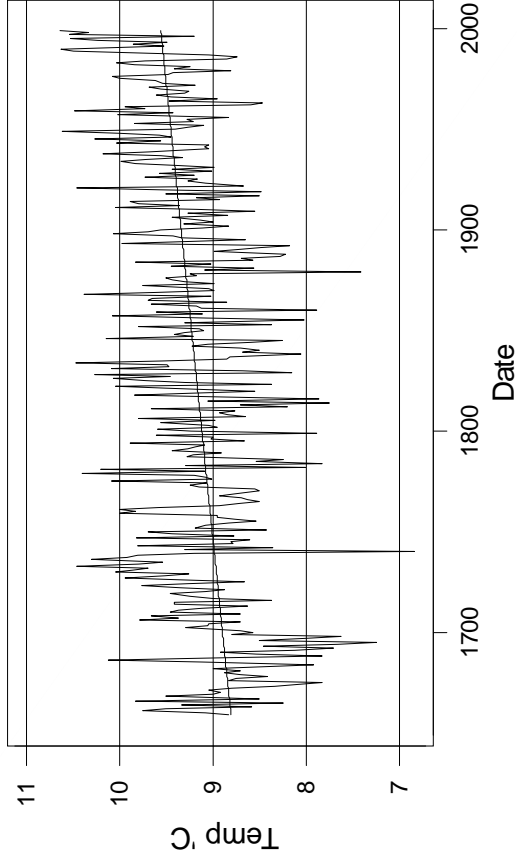
TIES, June 19, 2002

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
 - $(\max + \min)/2$
 - Since 1772
 - 230 years, 83276 observations



CET annual (mean)

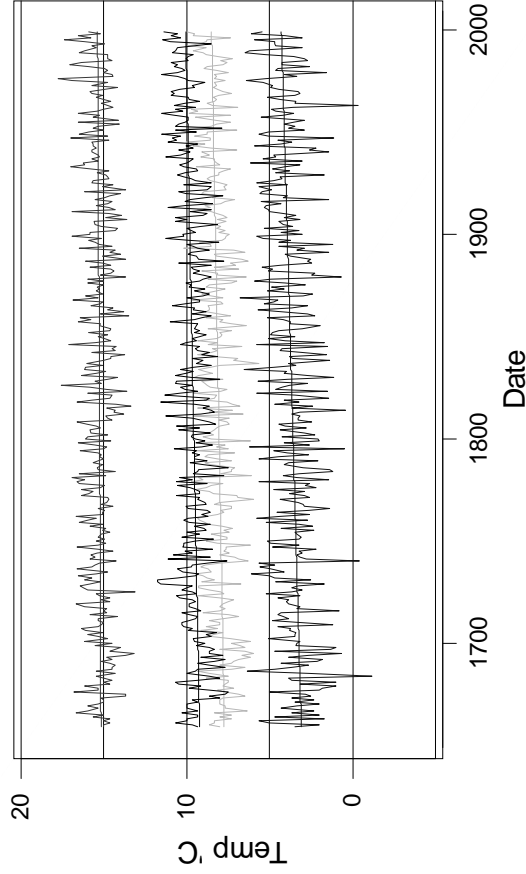


1.1 Annual – linear trend

	Rise ‘C/100Y	p	rho1
Annual Mean	0.226	0.000	0.22
With AR(1)	0.227	0.000	
1878–	0.773	0.000	0.17

- rho1>0.11, reduces significance

CET seasons

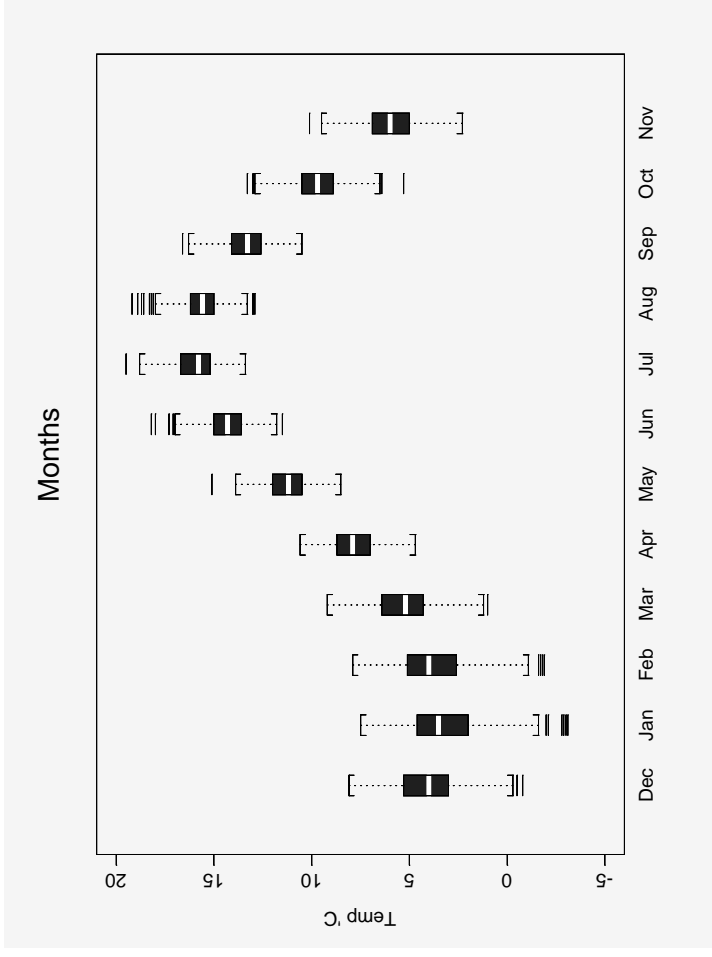
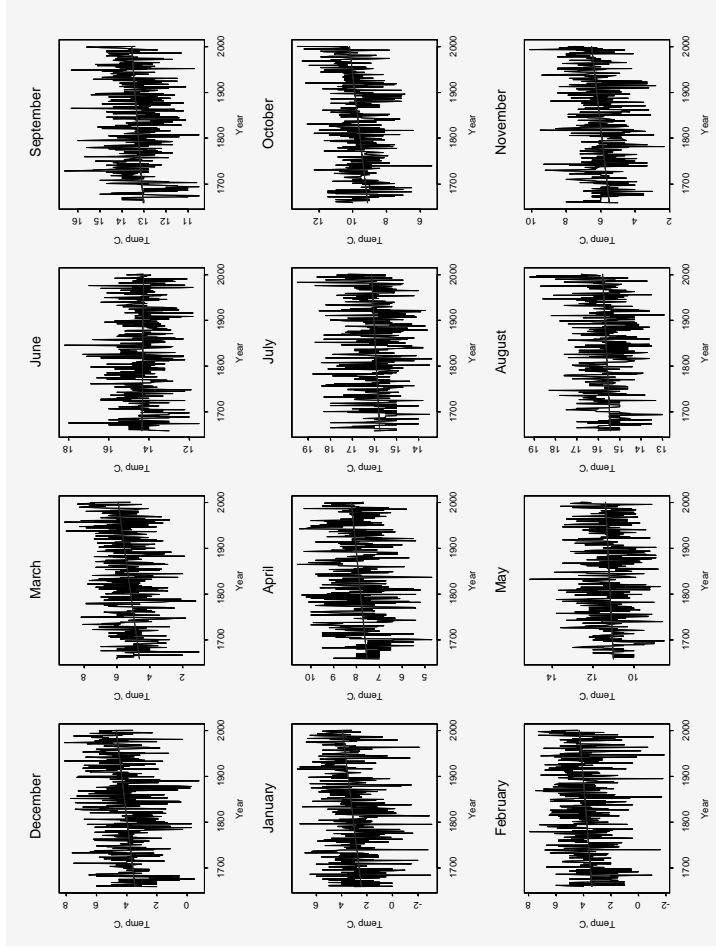


1.2 Seasons – linear trend

Season	1659-			1878-		
	Rise ‘C /100Y	p	rho1	Rise ‘C /100Y	p	rho1
DJF	0.35	0.000	-0.01	0.55	0.101	0.10
MAM	0.23	0.000	0.19	0.74	0.000	0.13
JJA	0.06	0.179	0.10	0.64	0.003	-0.01
SON	0.25	0.000	0.20	1.09	0.000	0.00

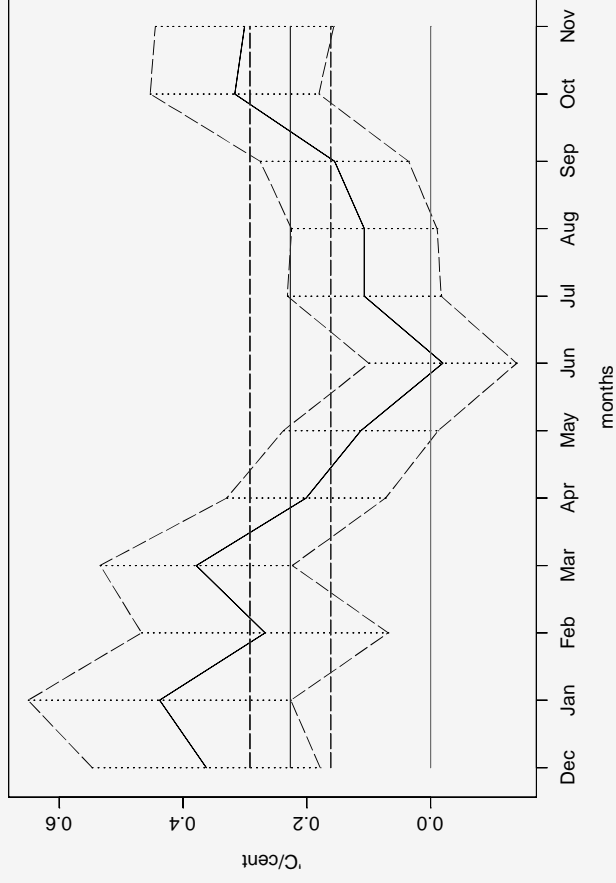
1.3 Months

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

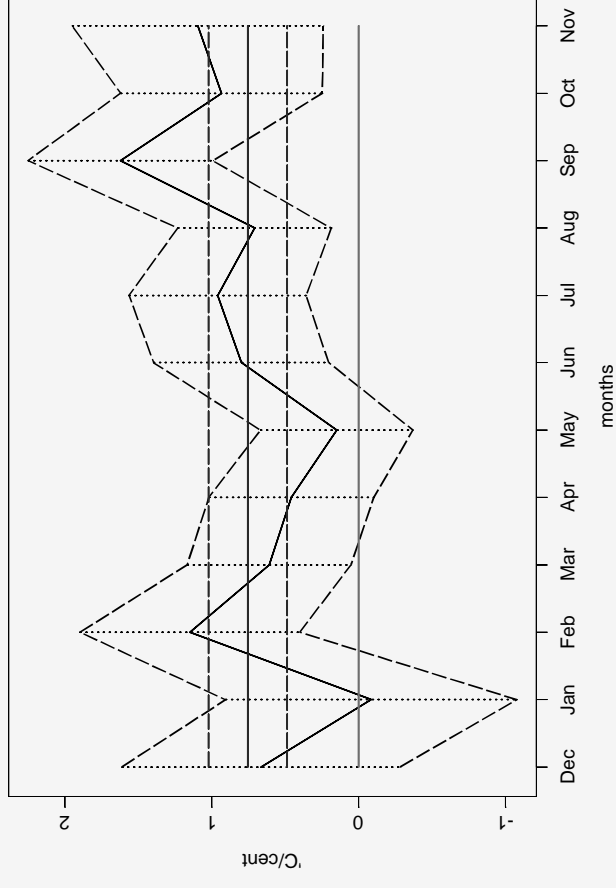


Month	Trend 'C/100Y	p	rho1
December	0.36	0.000	0.02
January	0.44	0.000	0.01
February	0.27	0.008	-0.05
March	0.38	0.000	0.07
April	0.20	0.002	0.12
May	0.11	0.072	0.15
June	-0.02	0.736	-0.06
July	0.11	0.086	0.04
August	0.11	0.070	0.15
September	0.15	0.010	0.15
October	0.32	0.000	0.09
November	0.30	0.000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

Trends



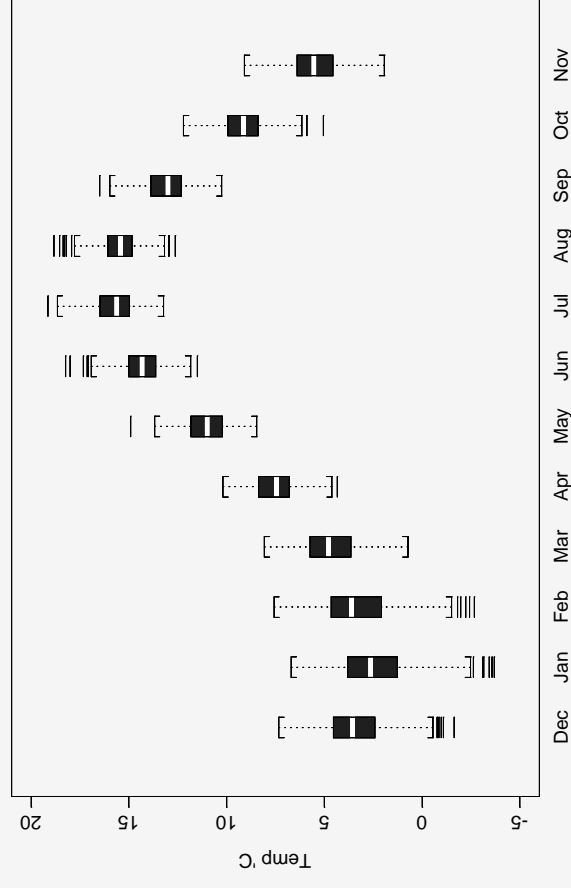
Trends



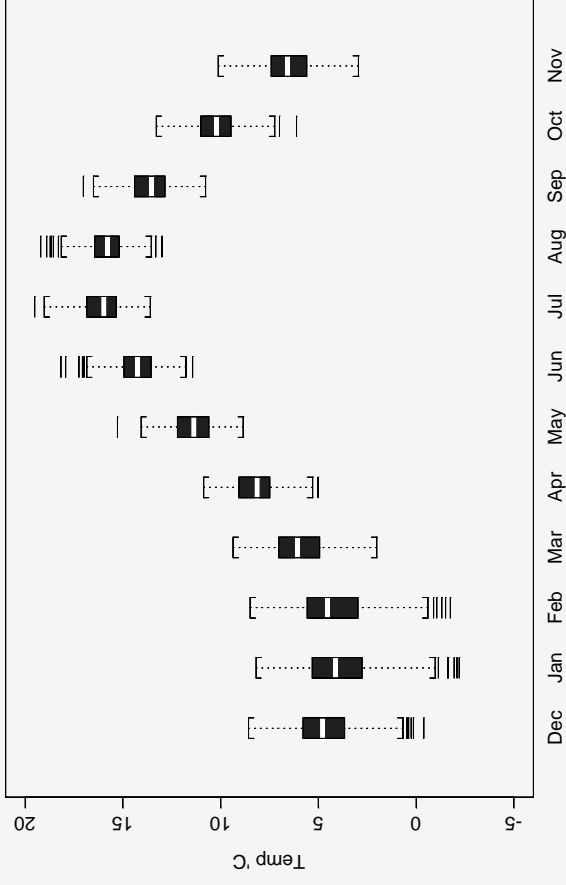
1.4 Changing seasons

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

Season 1659



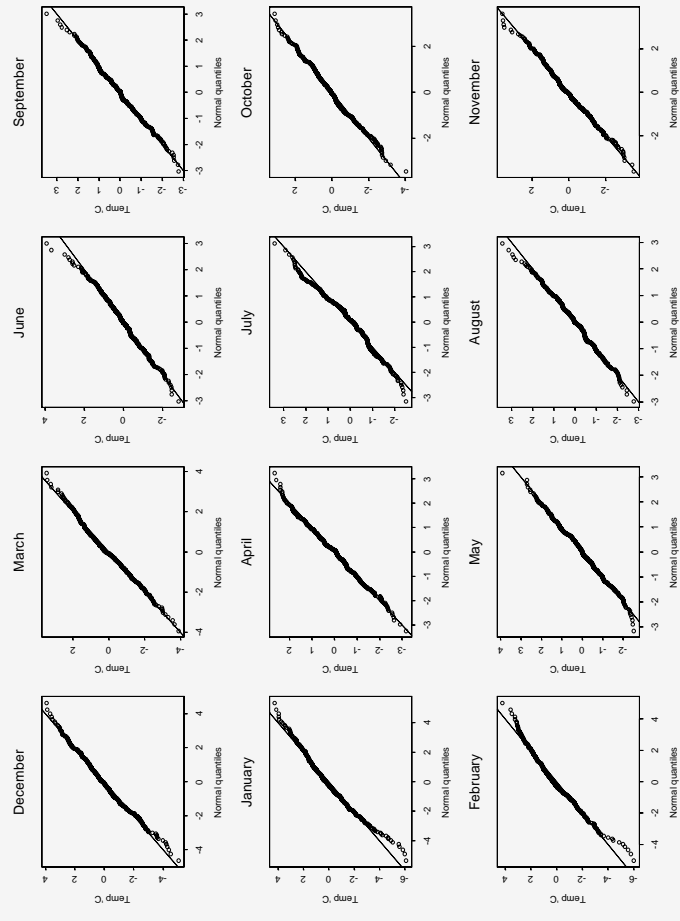
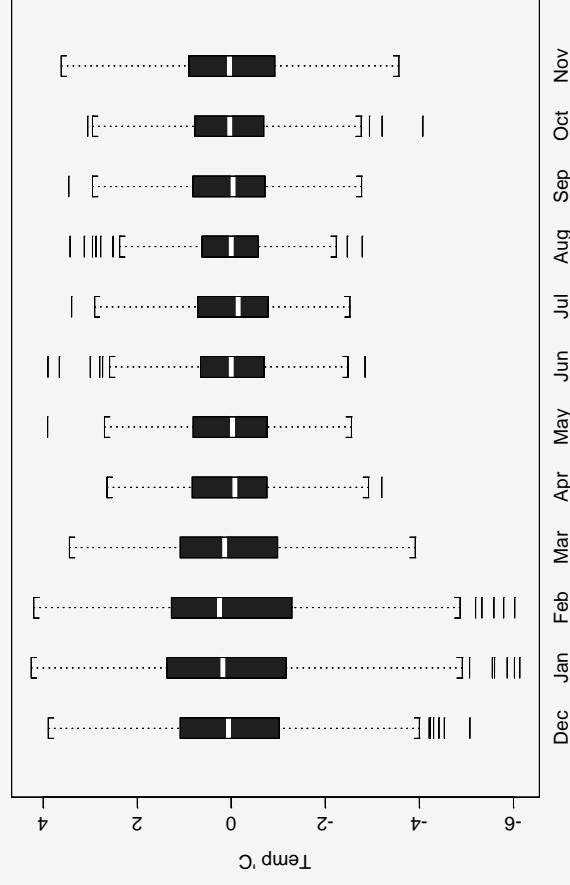
Season 2001



1.5 Assumptions/heterogeneity

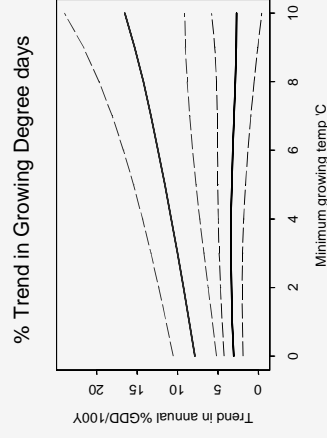
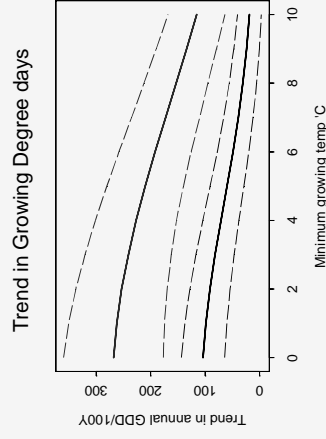
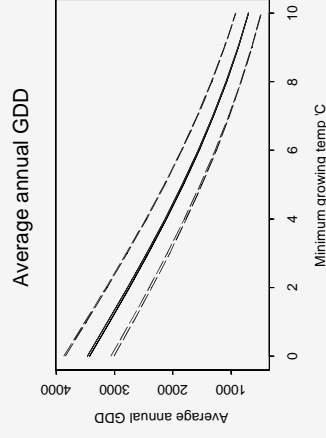
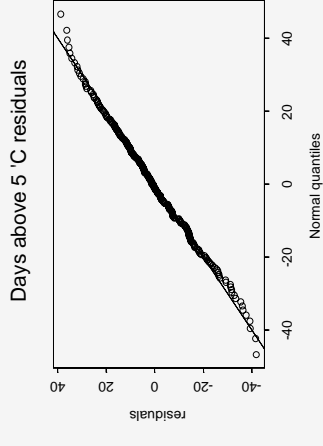
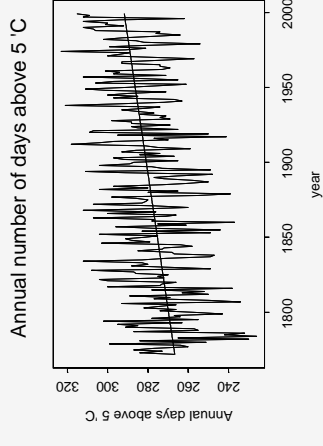
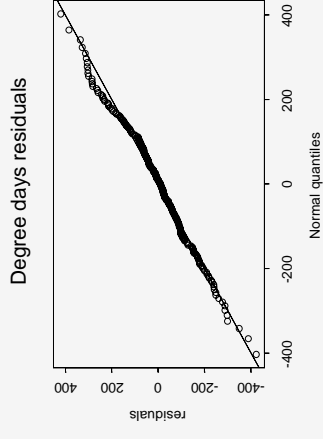
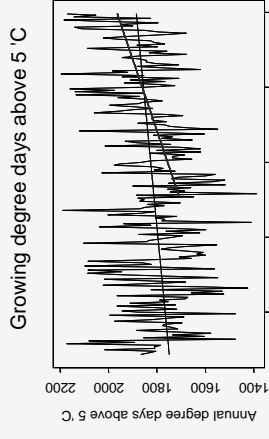
- Could put all months together
 - if variances are homogeneous
- Summer/winter heterogeneity?
- Autocorrelation (monthly)
- Normality?

Residuals



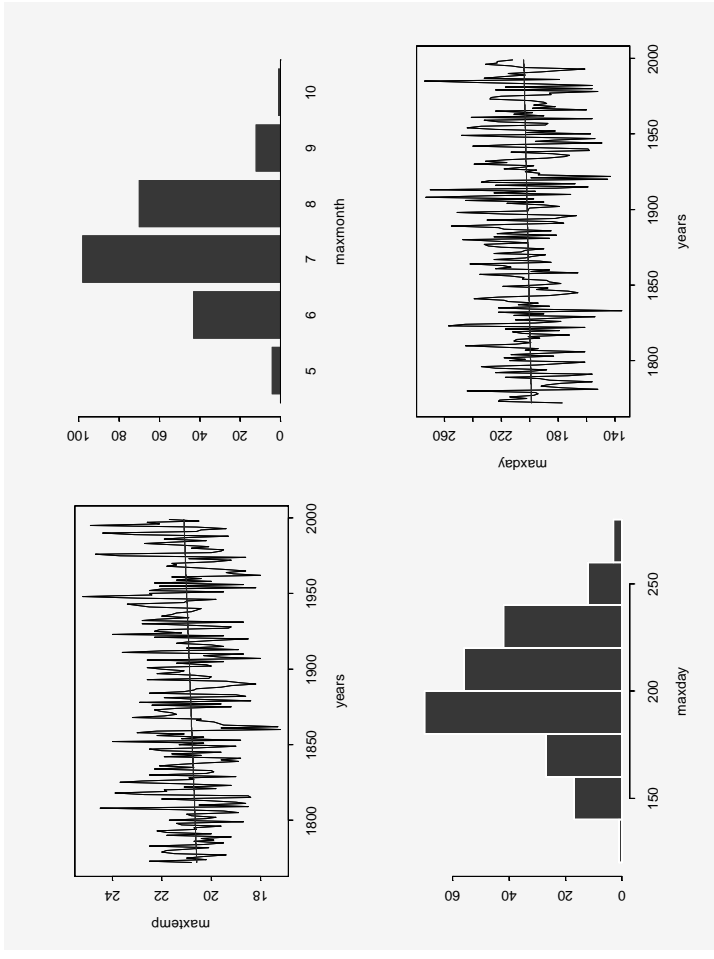
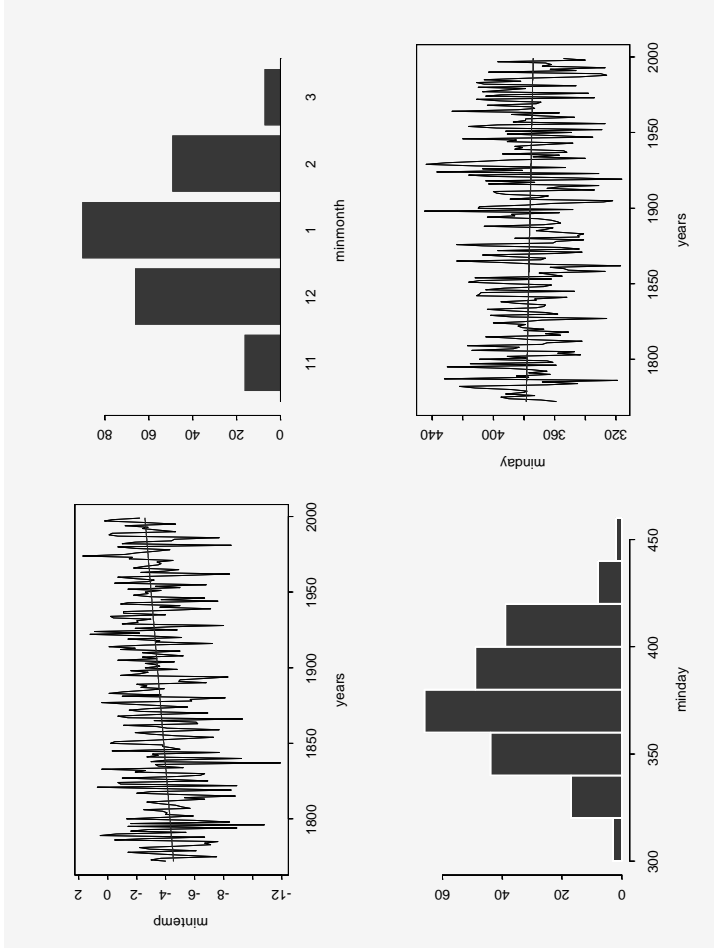
2. Daily series

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



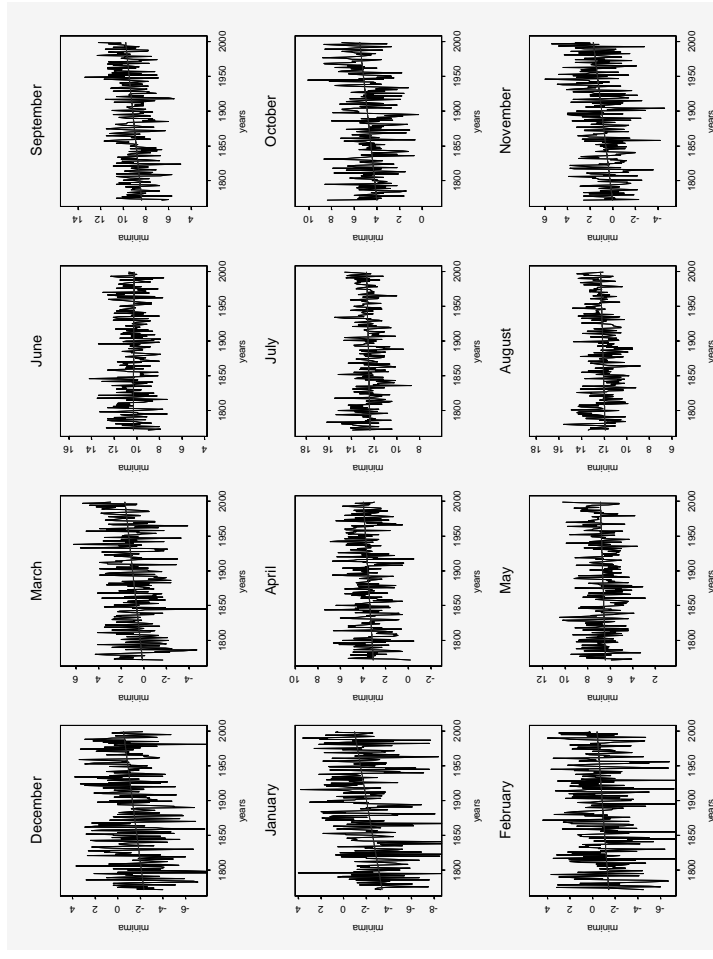
2.1 Extremes

- 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

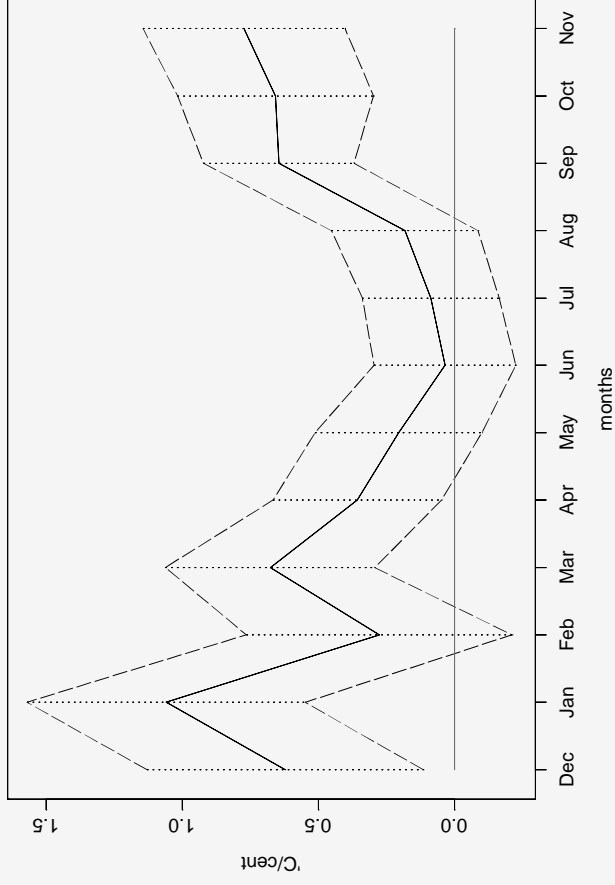


2.2 Trend estimates

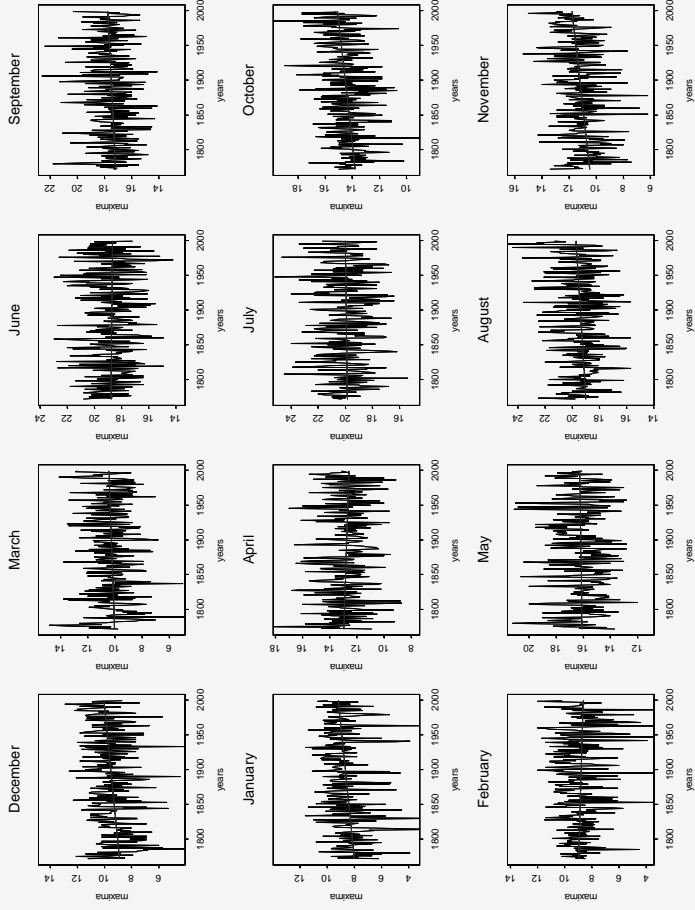
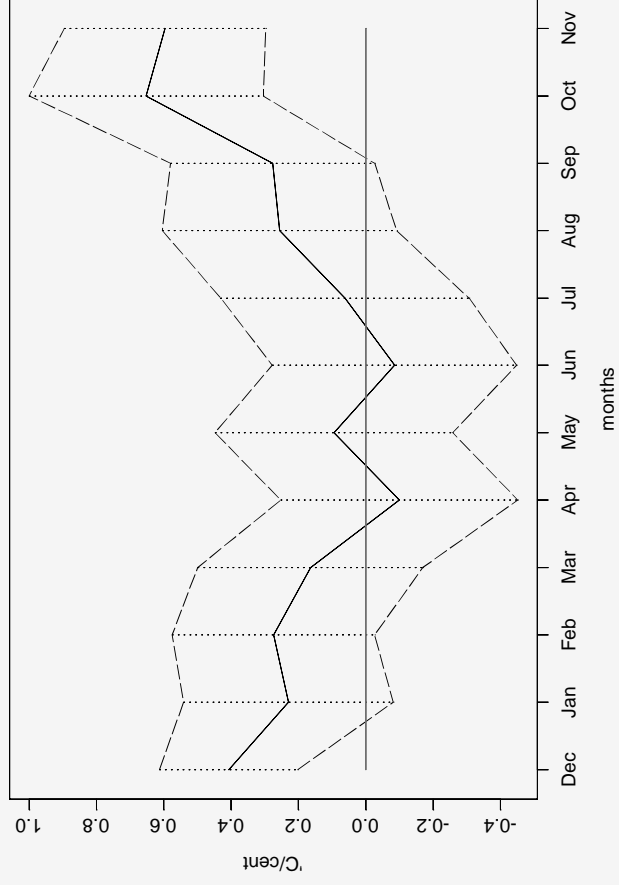
- Summer maxima
 - no trend ($p=0.13$)
- Winter (Dec-Jan-Feb) minima
 - $0.67^\circ\text{C}/100\text{Y}$ (s.e.0.22)
 - (estimated as GEV)



Trends in minima



Trends in maxima



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)