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Trends in temperatures: exploration and estimation

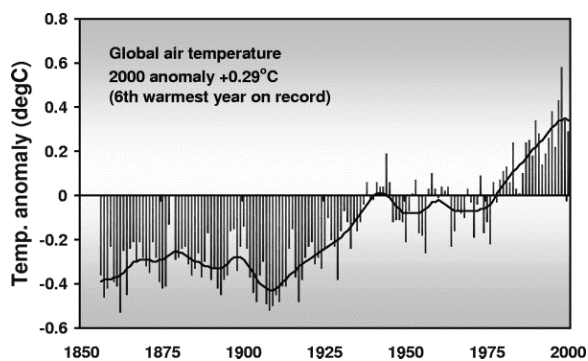
Howard Grubb

School of Applied Statistics

The University of Reading

<http://www.rdg.ac.uk/~snsgrubb>

ESSG, March 14, 2002



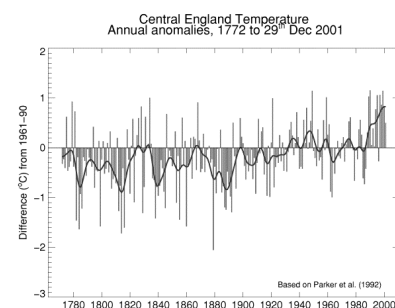
<http://www.cru.uea.ac.uk/>

Outline

1. Central England Temperature
 - Long series – data meeting
 - Monthly patterns
 - Aggregation
 - Shorter series
2. CET daily
 - Annual extremes
 - Other functionals (timing)
 - Monthly extremes
 - Shorter series

1. Central England Temperature

- Average of several sites in “Central England”
 - Bristol, Manchester, London
 - data meeting
- Average monthly temperature
 - 341 years
 - 4092 observations

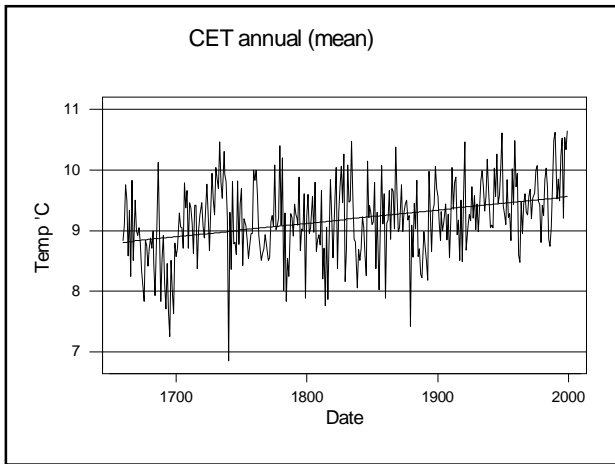
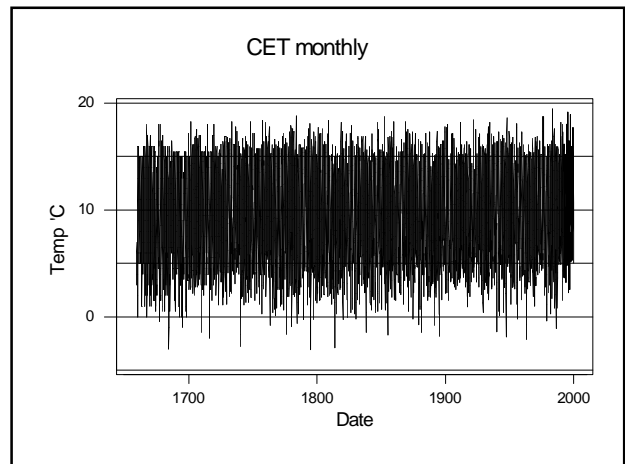
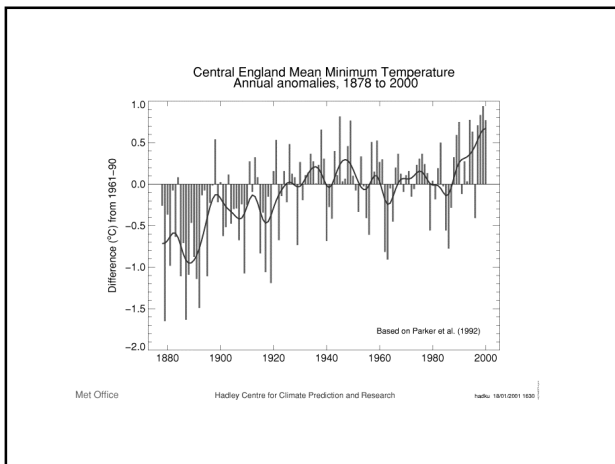


Met Office

Hadley Centre for Climate Prediction and Research

hadu_31/12/2001_1023

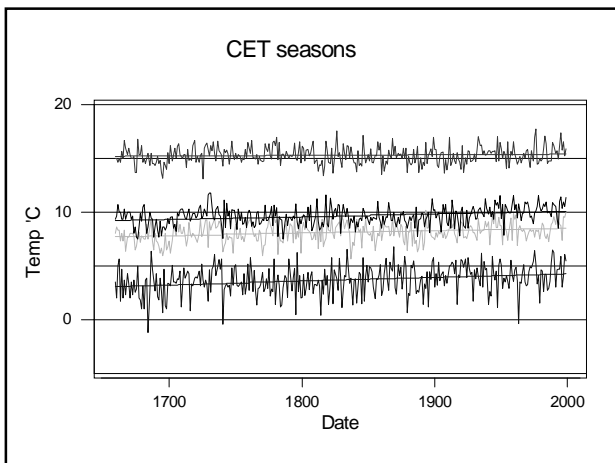
<http://www.met-office.gov.uk/research/hadleycentre/obsdata/CET.html>



1.1 Annual – linear trend

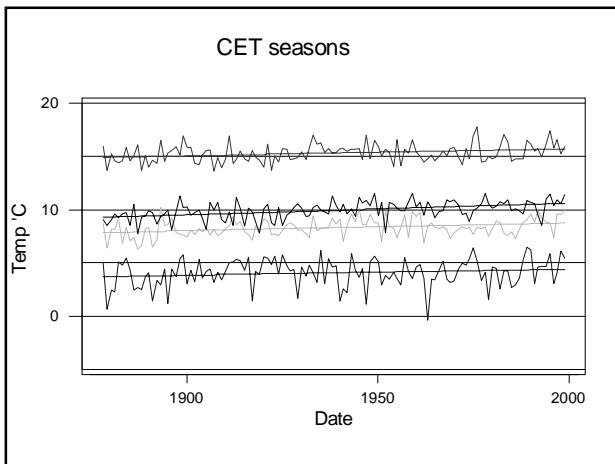
	Rise °C/100Y	p	rho1
Annual Mean	0.226	0.000	0.22
With AR(1)	0.227	0.000	
1878–	0.773	0.000	0.17

- rho1 > 0.11, reduces significance



1.2 Seasons – linear trend

Season	Rise °C /100Y	p	rho1
DJF	0.35	0.000	-0.01
MAM	0.23	0.000	0.19
JJA	0.06	0.179	0.10
SON	0.25	0.000	0.20

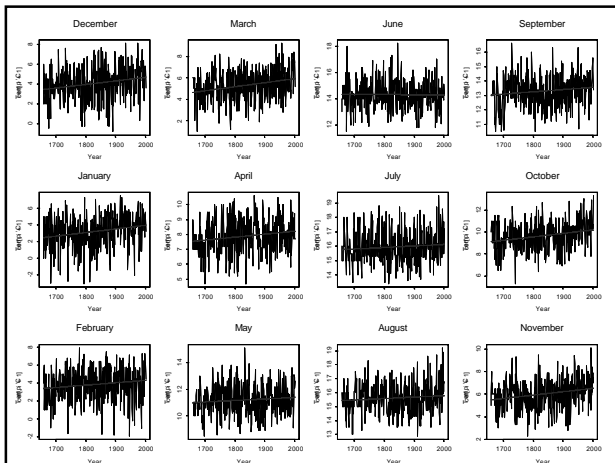
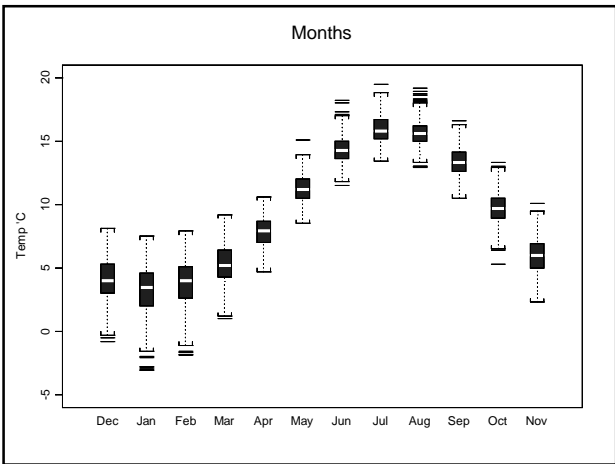


1.3 Seasons – shorter series

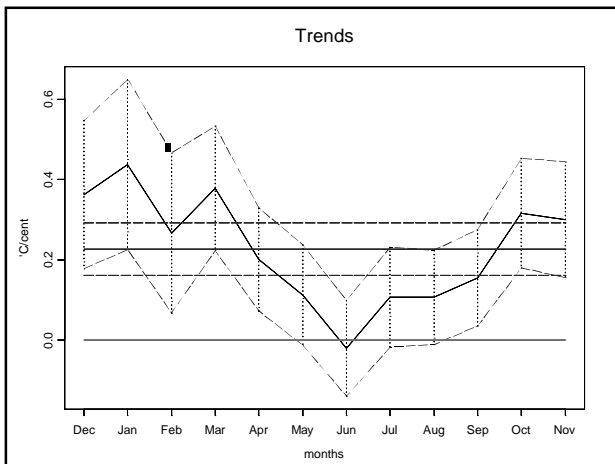
Season	all	1878-	p	rho1
DJF	0.35	0.55	0.101	0.10
MAM	0.23	0.74	0.000	0.13
JJA	0.06	0.64	0.003	-0.01
SON	0.25	1.09	0.000	0.00

1.4 Months

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



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

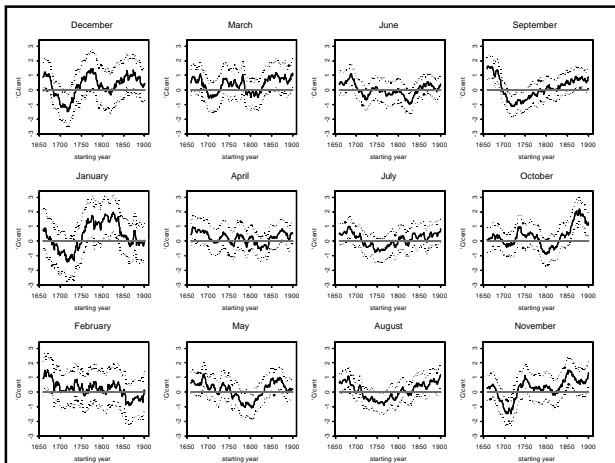
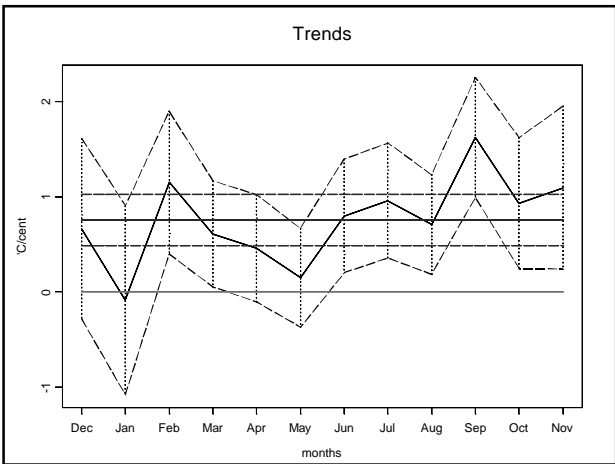


1.4a Monthly vs annual?

- Trade-off is variance: annual confidence intervals are $1/\sqrt{12}=0.29$ of monthly
- But averaging obviously different trends brings estimate towards zero
- Should model structure

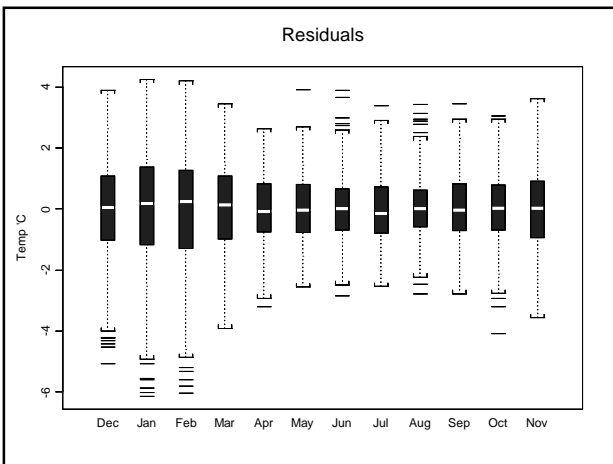
1.5 Months – shorter series

- 1878– only
- Trade-off – shorter length reduces precision, but trends may be larger
- Can also consider short series at various points
 - sensitivity of 100Y trend



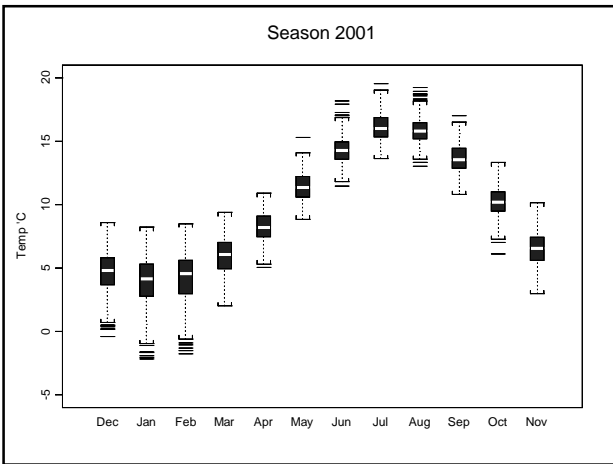
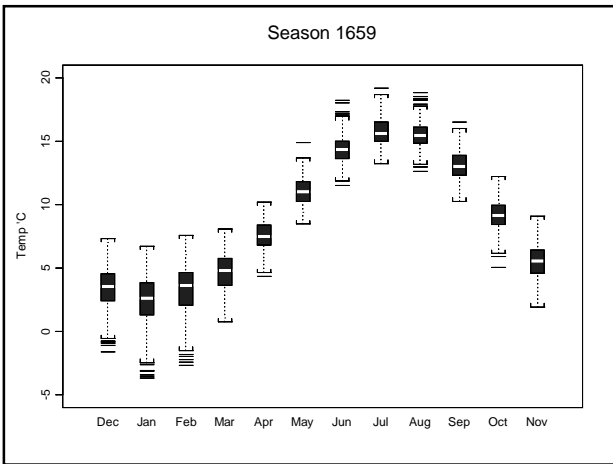
1.6 One model? Heterogeneity

- Could put all months together
 - if variances are homogeneous
- Slight summer/winter heterogeneity
- One model saves 11 variance d-o-f
- For large samples, relatively little benefit



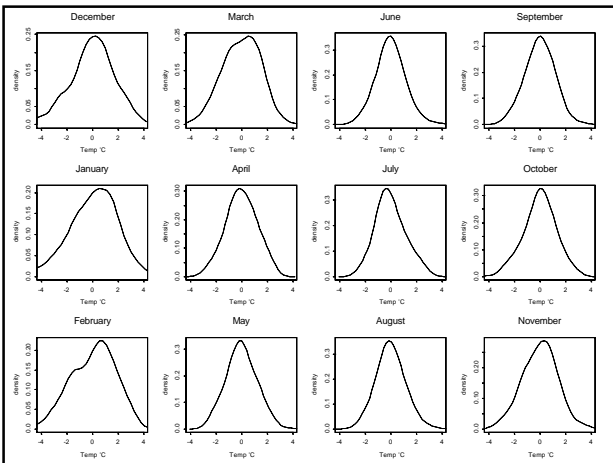
1.7 Changing seasons

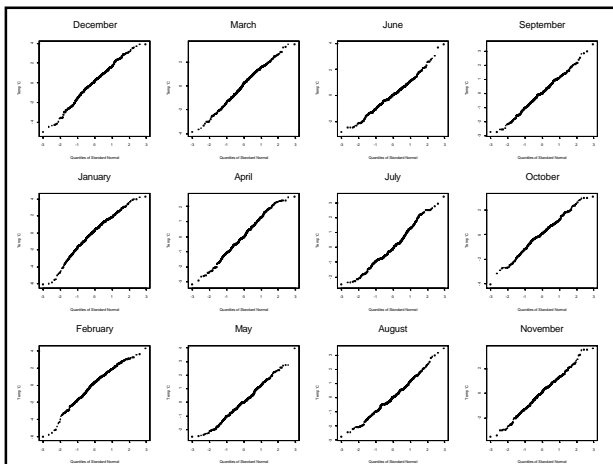
- Different trends in different months
 - changing seasonal pattern
- Seasonal cycle has become (slightly) compressed



1.8 Linear modelling assumptions?

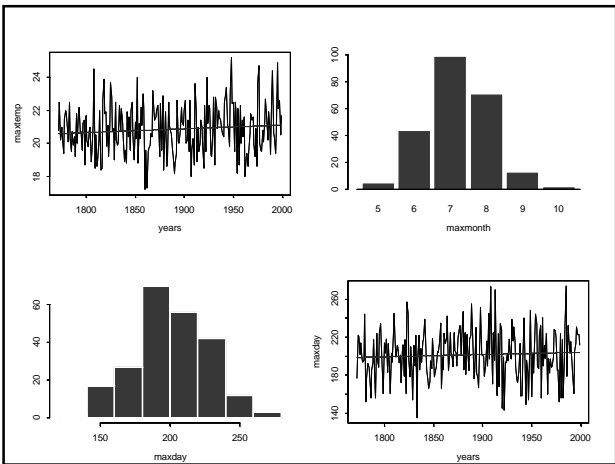
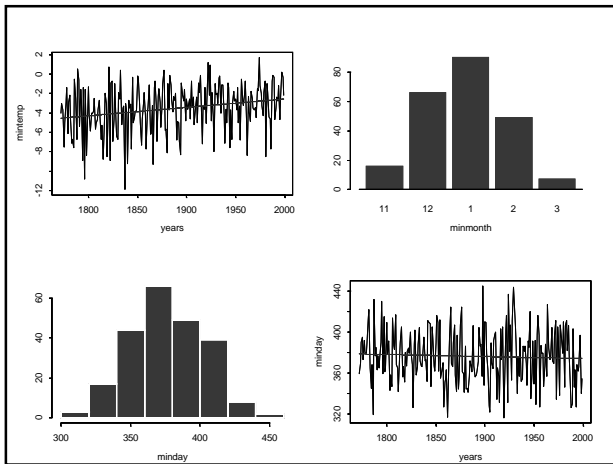
- Normal
 - symmetry for estimation
 - full Normality for significance
 - data are averages
- Independence
 - autocorrelation – okay for season/month lags





2. Daily series

- 1772–
- Can now look at other characteristics
- 227 annual extremes (each of 365+ values)
- As well as actual value, consider **timing**:
 - min is usually in January
 - and max is usually in July
- Other functionals – degree days



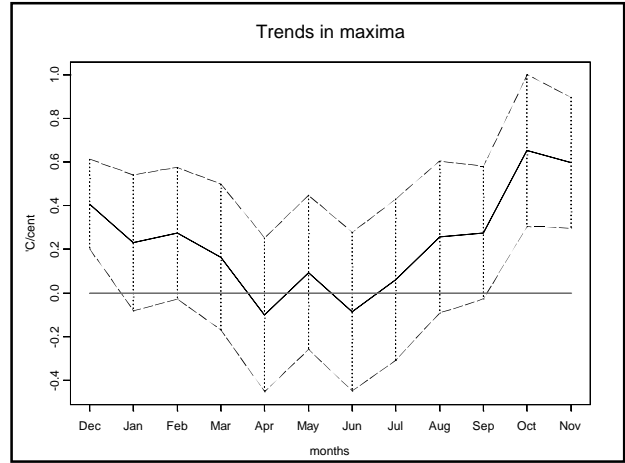
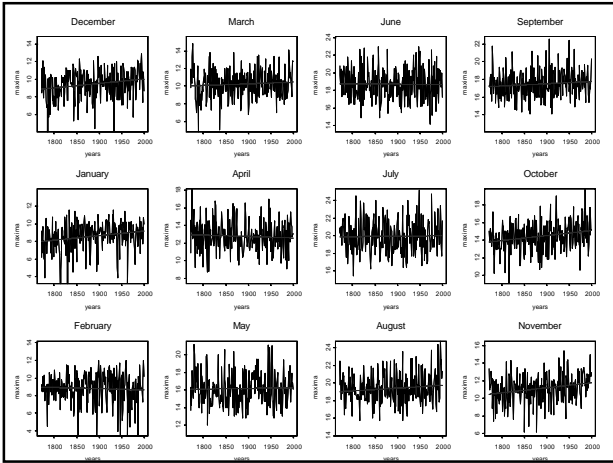
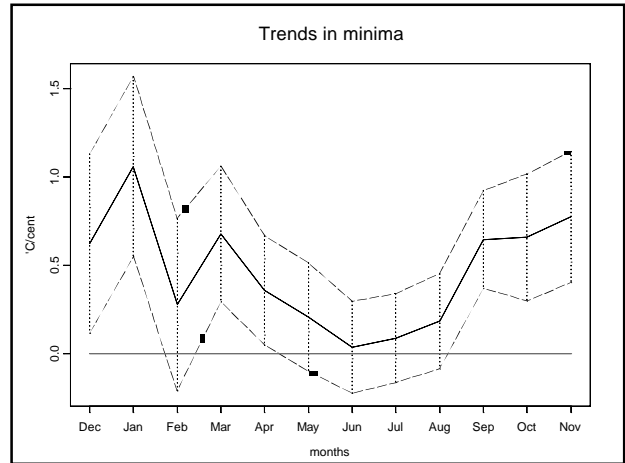
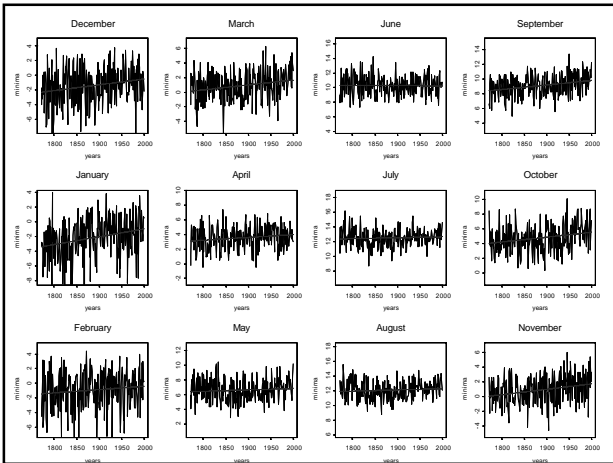
2.1 Trends in (annual) extremes

- Summer maxima
 - no trend ($p=0.13$)
- Winter (overlapping Dec) minima

	Trend °C/C	s.e.
Linear	0.87	0.24
GEV	0.67	0.22

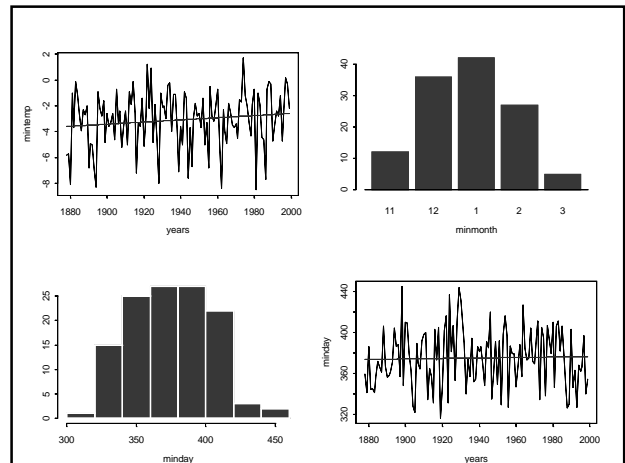
2.2 Monthly extremes

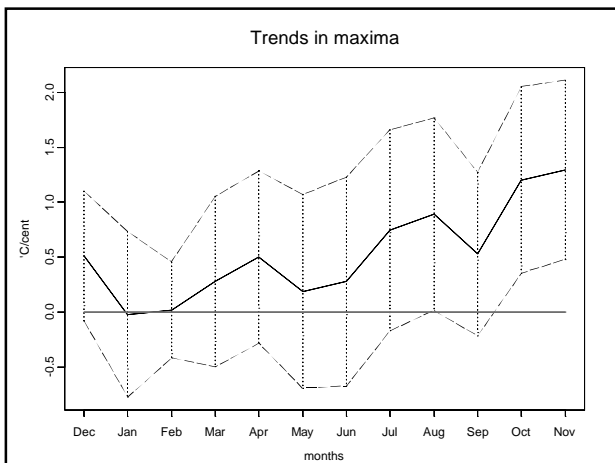
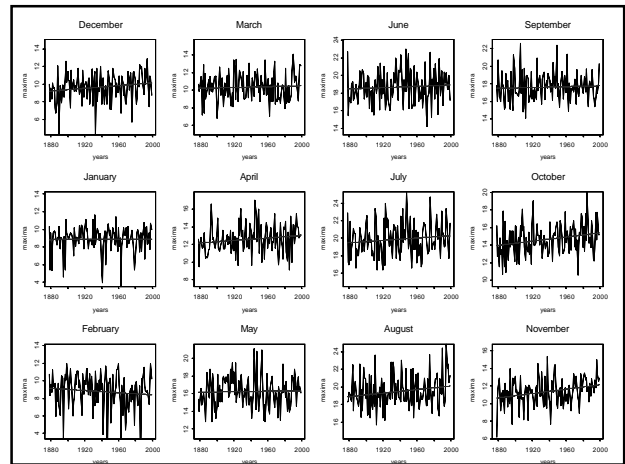
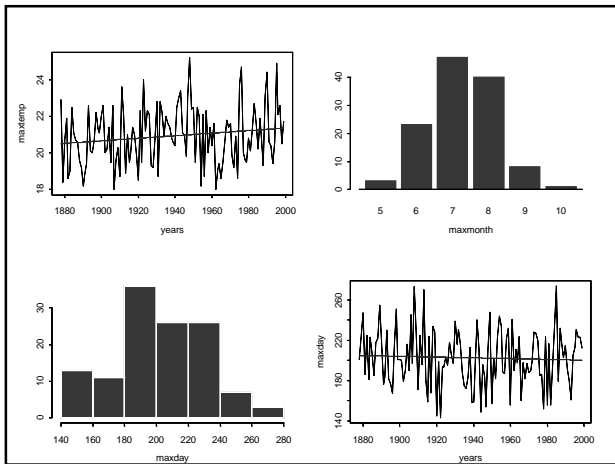
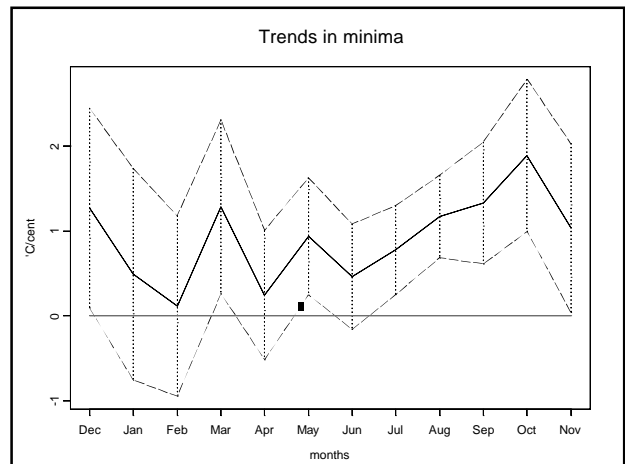
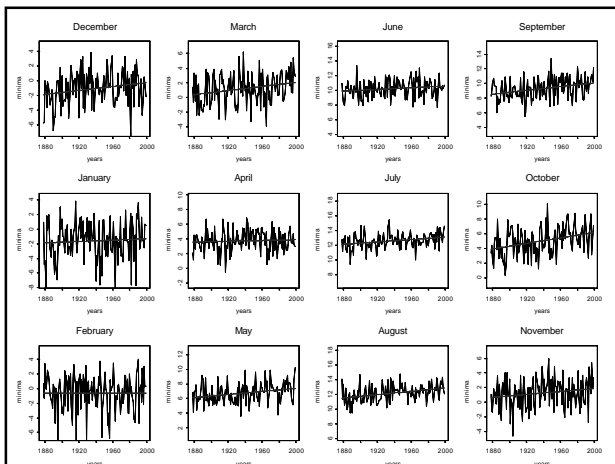
- 30(ish) values
 - 30 daily temperatures – extremes
- Monthly minima
- Monthly maxima



2.3 Shorter data series

- As before, consider 1878–
- Trends/changes somewhat stronger





3. Remarks

- Linear trends are useful **exploratory** tools
- Take account of:
 - structure – seasons
 - heterogeneity – may not put everything in one model
 - autocorrelation? May be small effect at seasonal lag
 - data length – trade-off strength and consistency vs significance
 - other forms of pooling (sites)
- Look at patterns/trends in **functionals** of interest (timing, cumulative)