Adjusting the inhomogeneity in daily temperature series using wavelet analysis

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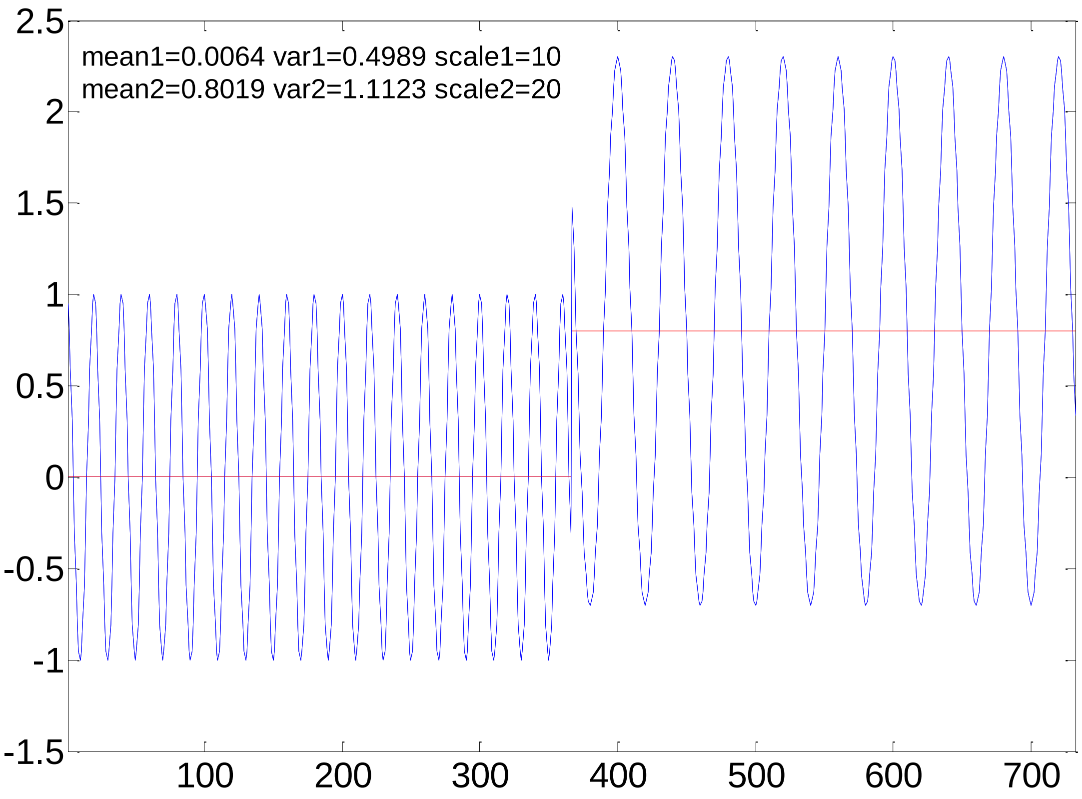
Outline

- Introduction
- Data and method
- Results
- Conclusion

Introduction

- A homogeneous climate series is essential for quantifying climate change;
- Inhomogeneity is almost unavoidable due to various non-natural changes such as those in the observing location, environs, protocols…



Inhomogeneity not only affects mean level, but also variability at different timescales.

A summary of current methods

MASH, TPR, SNHT → mean level

Higher-order moments (HOM)
SPLIDHOM, Percentiles

High-order + Autocorrelation
(HOMAD, Rhtest v3.0)

→ climate extremes in daily series

Why wavelet analysis ?

- Climate extremes / strong weather phenomena are mainly related to daily and weekly variability in observational series

  – Yan et al 2001

- There are inhomogeneities existing mainly for certain time-scale variability – Yan and Jones 2008

It is beneficial to develop a wavelet-analysis-based method to adjust inhomogeneities hidden in some particular time-scale fluctuations.

This talk is to demonstrate

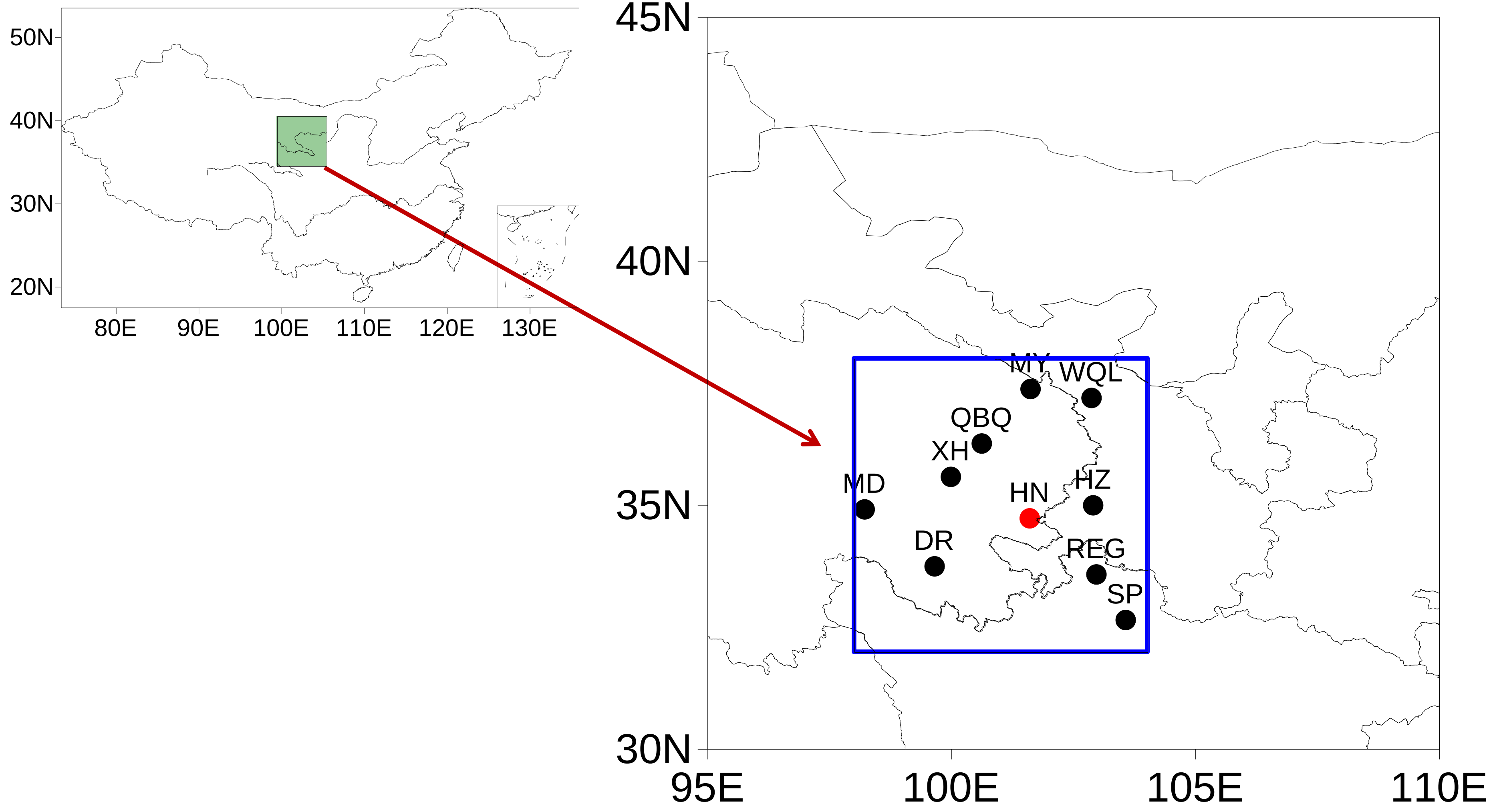
- Problems in current methods of homogenization of climate data;
- How the wavelet-based method works;
- Influence on estimates of climate change especially dealing with climate extremes.

via case studies

Data for case studies

Daily mean temperature series at

- ➢ Central England (CE)
- 1772-2003, homogenized by Parker et al (1992)
- ➢ Henan(HN, western-central China)
- original,1960-2008
- MASH-homogenized 1960-2008 (Li&Yan 2009, using 9 ref. stations)
- HOM-homogenized 1960-2008 (this work, using 9 ref. stations)
- Rhtest-homogenized 1960-2008 (this work, using 9 ref. stations)
- TPR-homogenized 1960-2004 (Li et al 2006, different ref. stations)



Geographical distribution of HN (red dot) and reference stations used by MASH, RHtest, and HOM method (black dots)

Method

- Morlet wavelet analysis - Yan et al 2001

Morlet wavelet function:

$$w(t) = s^{-\frac{1}{2}} g(t') \exp(i\pi t')$$

$$g(t) = \exp(-t^2/2)$$

Timescales 2S:

$S=2^{p+q/Q}$

$p=0,1,\ldots P$ $P=15$

$q=0,1,\ldots Q-1$ $Q=2$

2S=2, 2.8, 4, ..., 64,...days

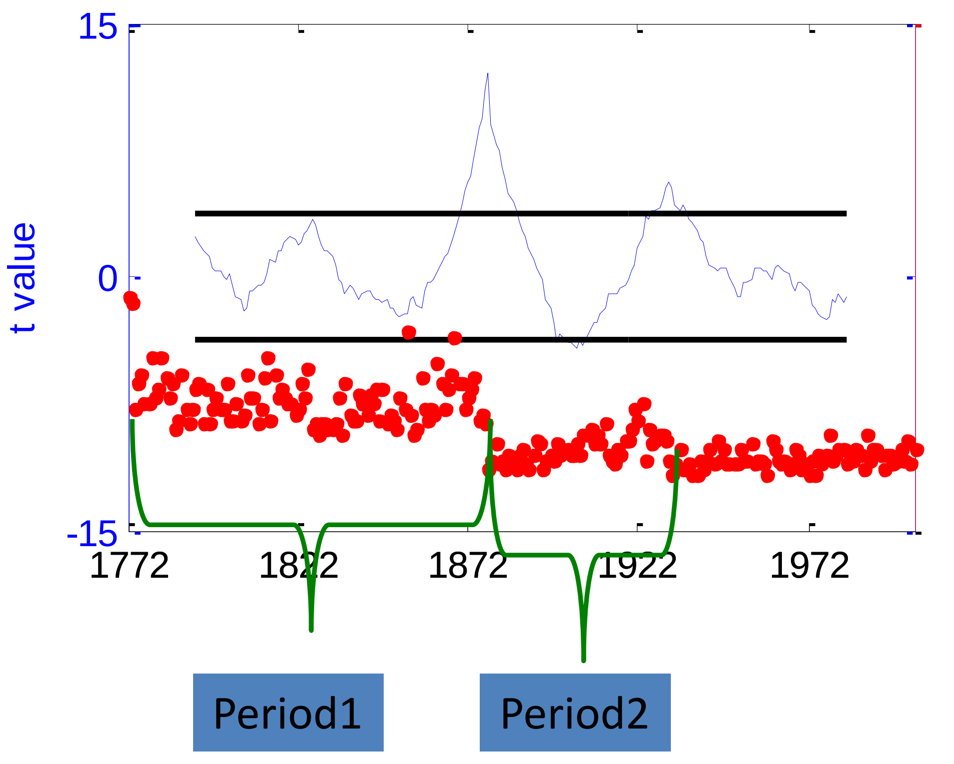
↓ ↓ ↓ ↓

band 1，band 2，band 3，...，band 11,...

- Daily Variability (DV): less than 3 days (bands 1-2) -local scale
- Weekly Variability (WV):4 days up to 2 months (bands 3-11) - large scale

Adjustment of wavelet power:

$$\propto = \frac{\Delta P_{\_period2}}{\Delta P_{\_period1}} = \frac{\frac{1}{n_1}\sum_{i=1}^{n1} \Delta P_2}{\frac{1}{n_2}\sum_{i=1}^{n2} \Delta P_1}$$



Adjust wavelet power of period 1 to period 2 for each band and season (if there is a jump beyond 0.001 significance threshold), relevant to a reference series

Other methods used in this study

- Multiple Analysis of Series for Homogenization(MASH)
- Higher-Order Moment (HOM)
- Relative Homogenization test (RHtest)
- Two Phase Regression F-test (TPR)

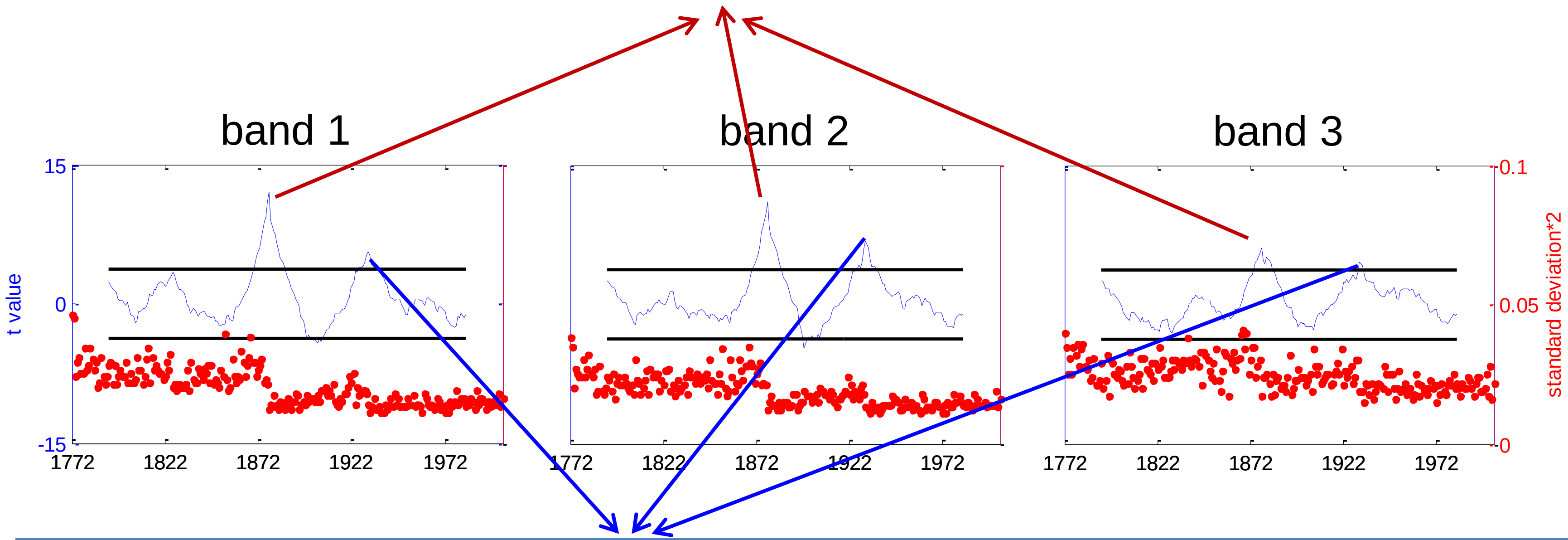
- Moving t-test (a=0.001) for detecting jumps in wavelet power

Results

Case 1: Central England Temperature (CET)

wavelet analysis of CET – for original series

From one station to three-station average on 1 January 1878 and Parker et al. (1992) adjusted the whole variance of earlier period 1772-1877.

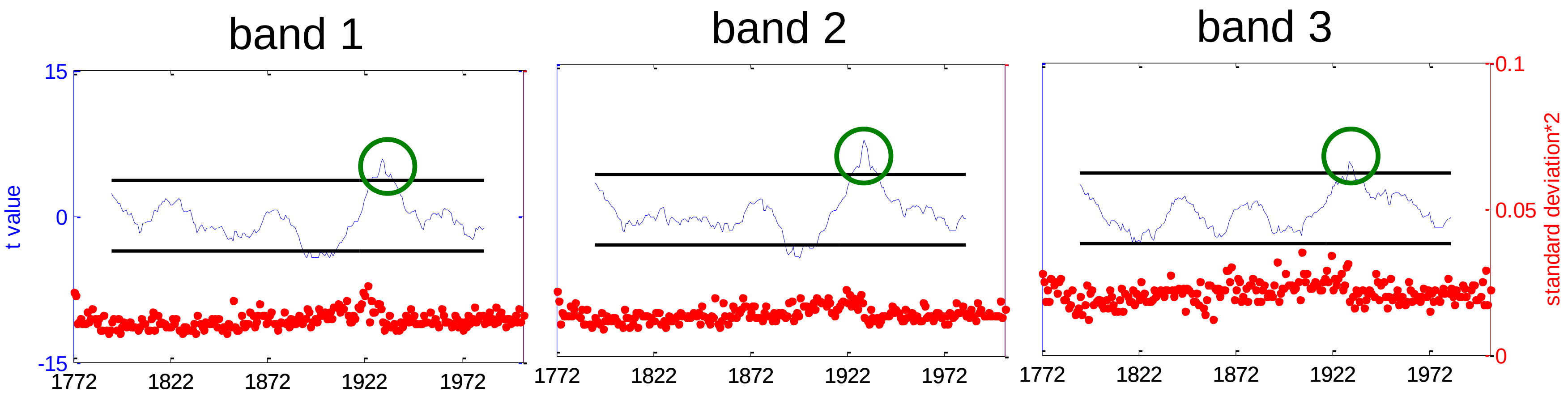


From three-station average to another three-station average on 1 January 1931 (Parker et al. 1992)

Annual wavelet power (red dots) of bands 1-3 in original CET 1772-2003, corresponding moving t-test (blue lines) and the 0.001 significance thresholds (black lines).

wavelet analysis of CET

– after the 1878 inhomogeneity has been adjusted

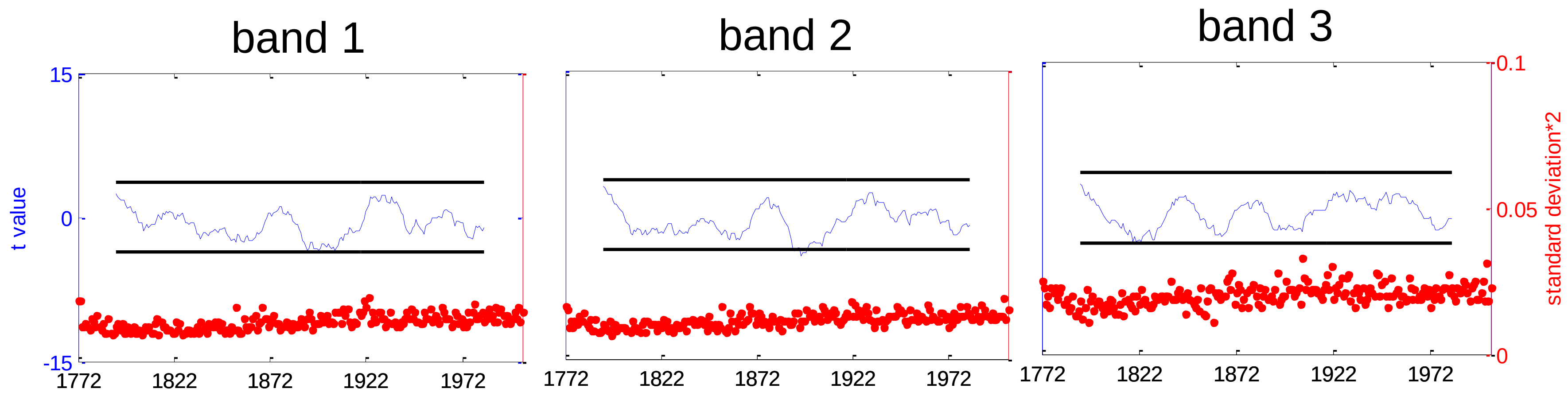


Annual wavelet power (red dots) of bands 1-3 in series after adjusting the 1878 inhomogeneity, corresponding moving t-test (blue lines) and the 0.001 significance thresholds (black lines).

Comparing Parker et al: we adjusted 'variance' for different timescales

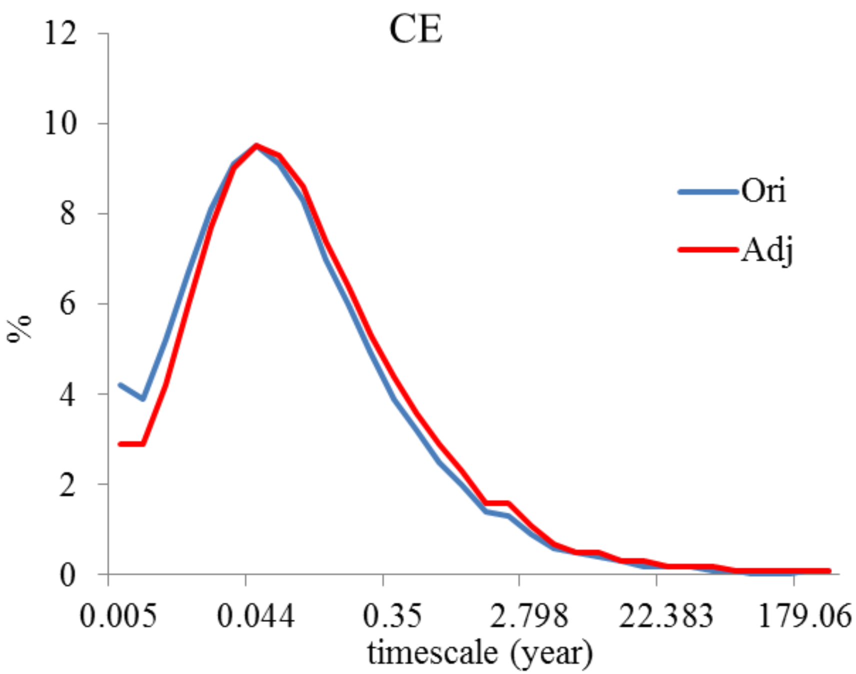
wavelet analysis of CET

– after the 1931 inhomogeneity has been adjusted

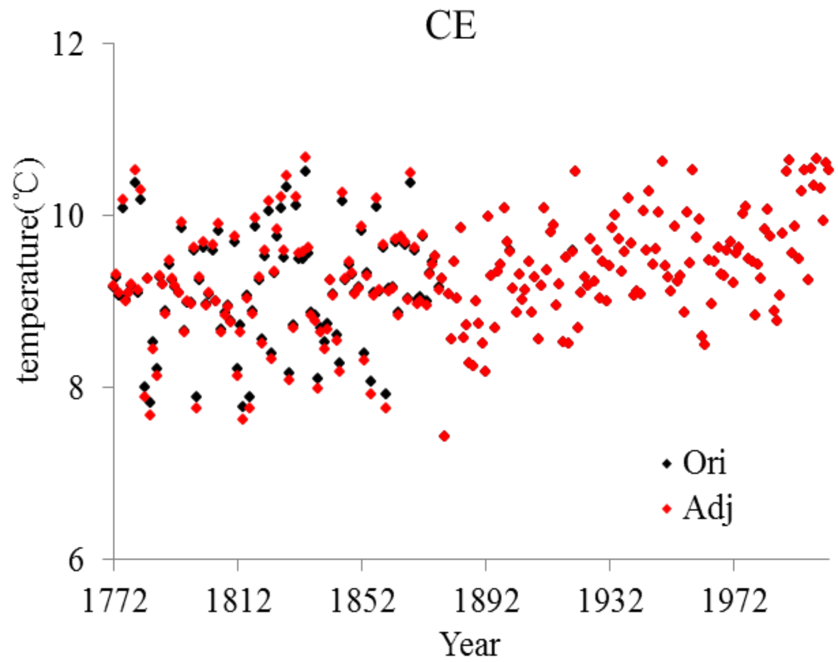


Annual wavelet power (red dots) of bands 1-3 adjusted series, and corresponding moving t-test and the 0.001 significance thresholds (blue lines).

Comparing wavelet power spectra and annual men temperature between original and adjusted CET



Average wavelet power for daily mean temperature anomaly series 1772-2003 at CE



The annual mean temperature in original and adjusted series 1772-2003 at CE

Potential for adjusting inter-annual and longer-term variability if reference series are available

Influences on trends of mean temperature and extremes in CET

		annual	winter	summer
Mean	Ori	**0.034***	**0.055***	**0.009**
	Adj	**0.034***	**0.056***	**0.008**
Hot day	Ori	**0.331***	**0.090***	**0.086***
	Adj	**0.348***	**0.119***	**0.070**
Cold day	Ori	**-0.873***	**-0.206***	**-0.101**
	Adj	**-0.883***	**-0.216***	**-0.109***
		annual	summer-half year	winter-half year
Heat wave	Ori	**0.053***	**0.031***	**0.023***
	Adj	**0.027***	**0.016***	**0.012**
Cold surge	Ori	**-0.105***	**-0.037***	**-0.069***
	Adj	**-0.142***	**-0.052***	**-0.092***

Linear trends in original and adjusted annual and seasonal mean temperature and extreme series 1772-2003 at Central England.

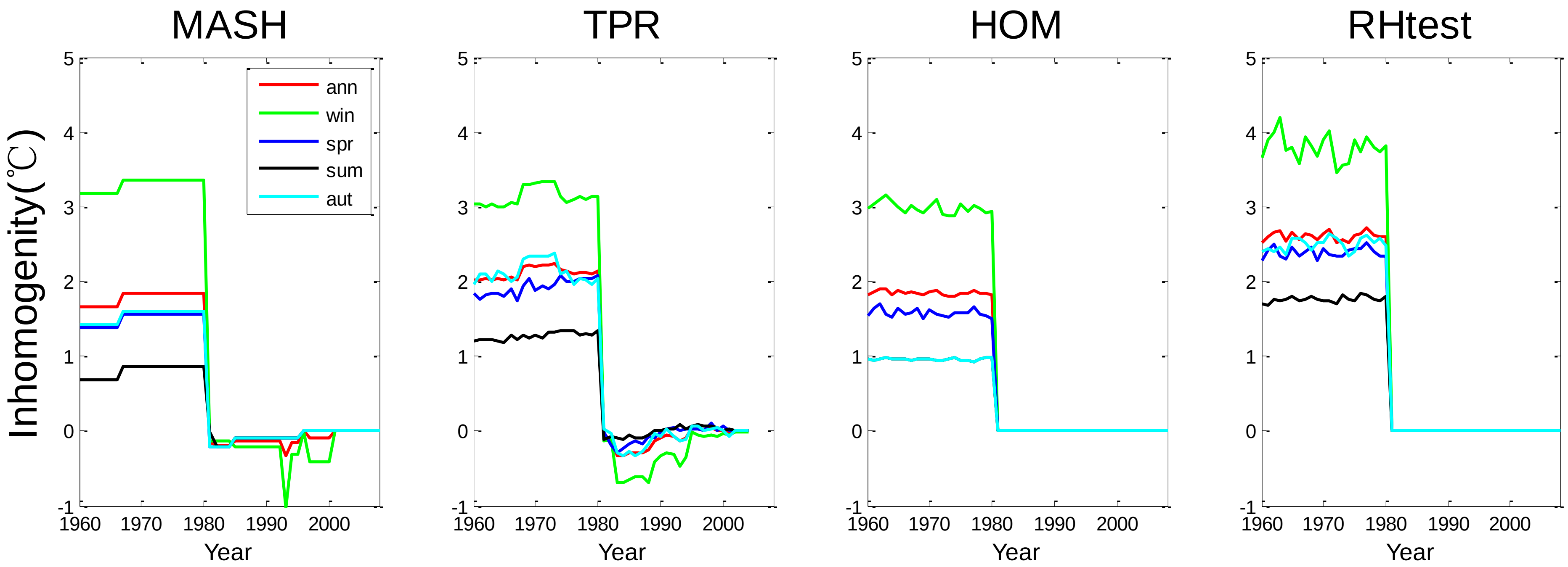
(* denotes the linear trends significant at $\alpha = 0.05$)

Results

Case 2: Henan (HN) station

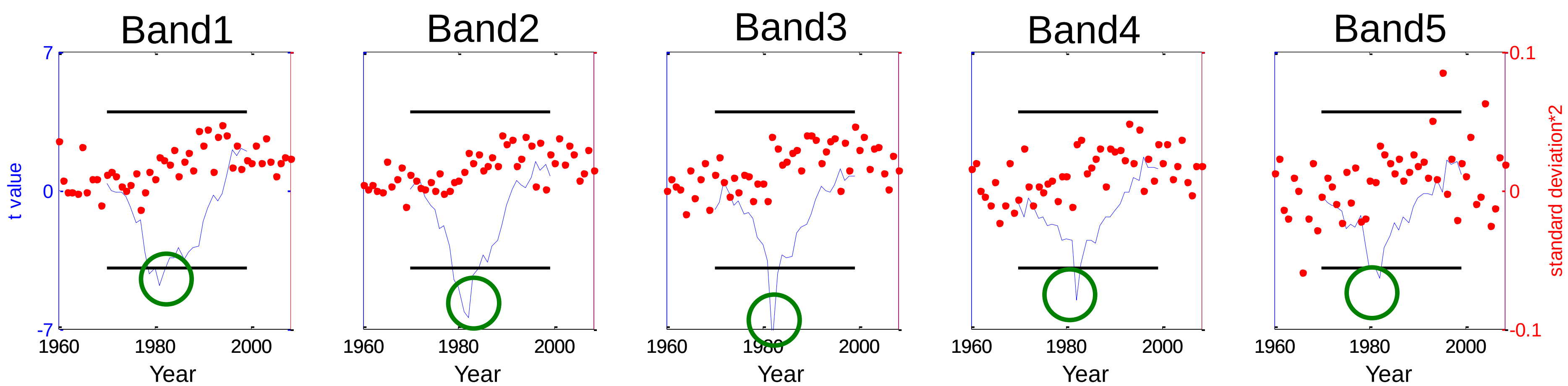
Inhomogeneities estimated by different methods

There is a relocation on 1 January 1981 with a change in elevation from 1974.4m to 3414.1m.



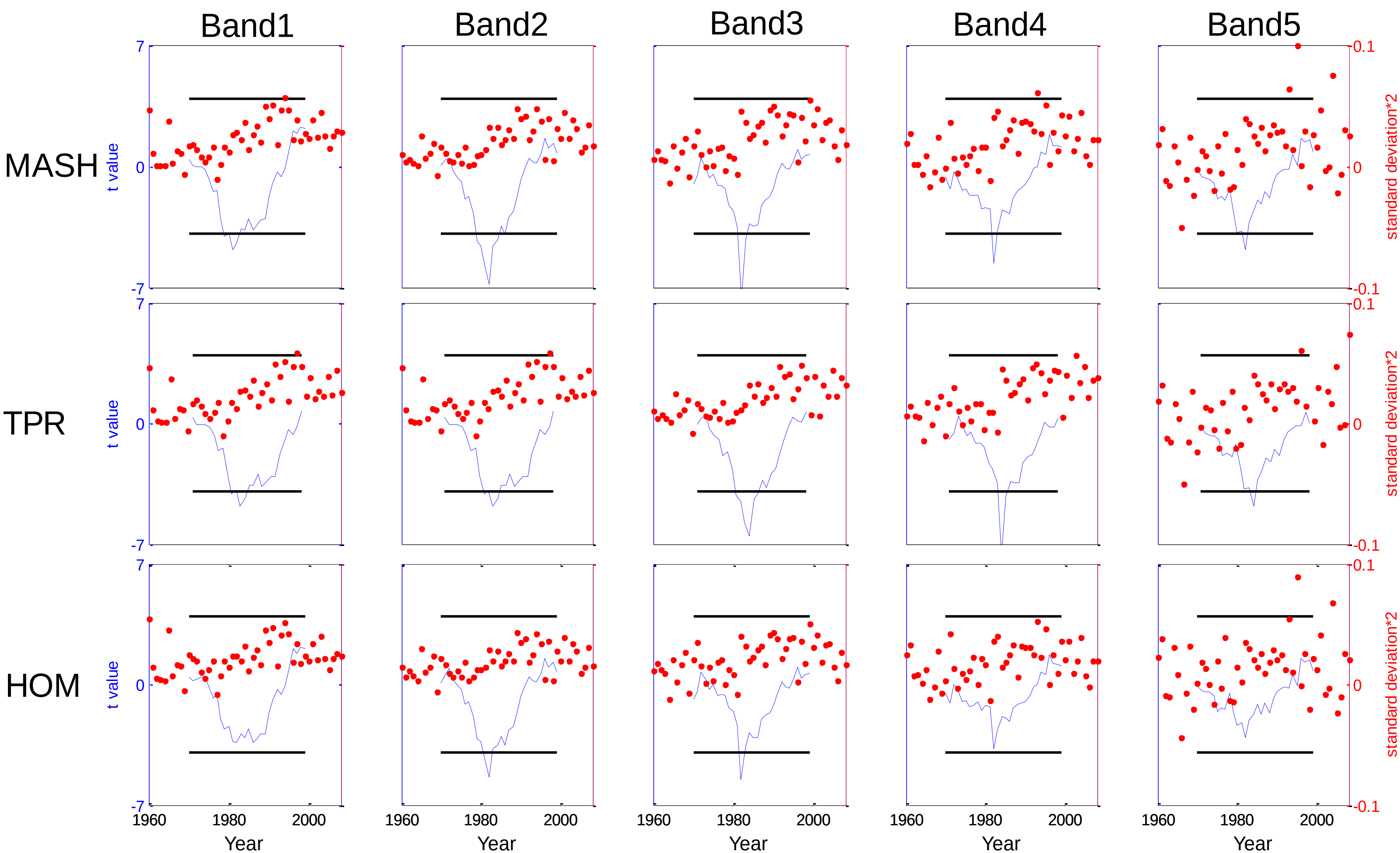
The annual and seasonal inhomogeneities estimated by MASH, TPR, HOM and RHtest at HN

wavelet analysis at HN – for original series



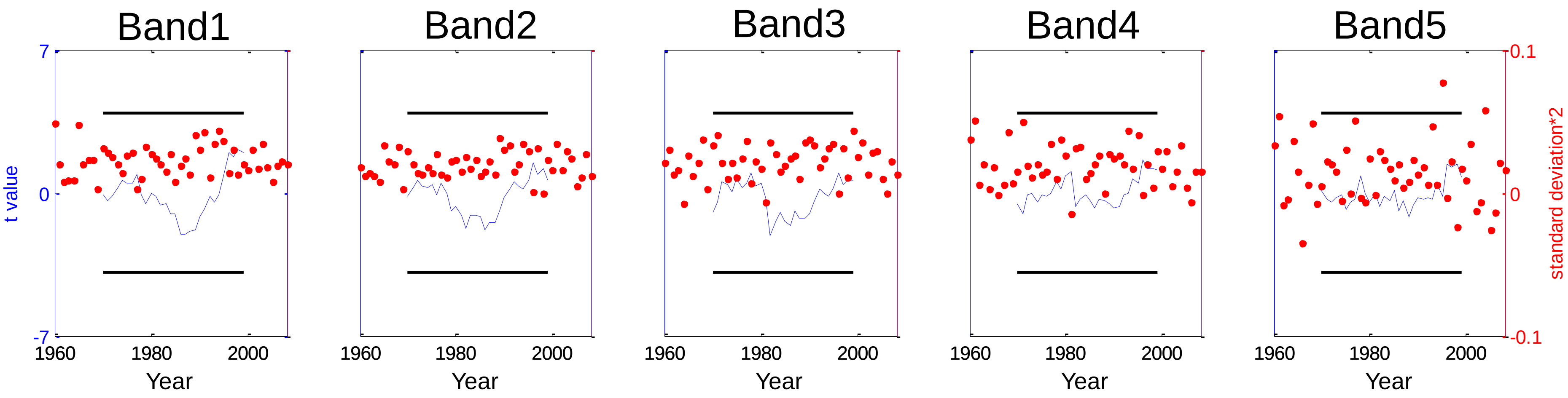
The difference of winter mean wavelet power (bands 1-5) (red dots) between HN and HJL and corresponding moving-t test with the 0.001 significance thresholds (blue line).

wavelet analysis at HN – For conventionally adjusted series



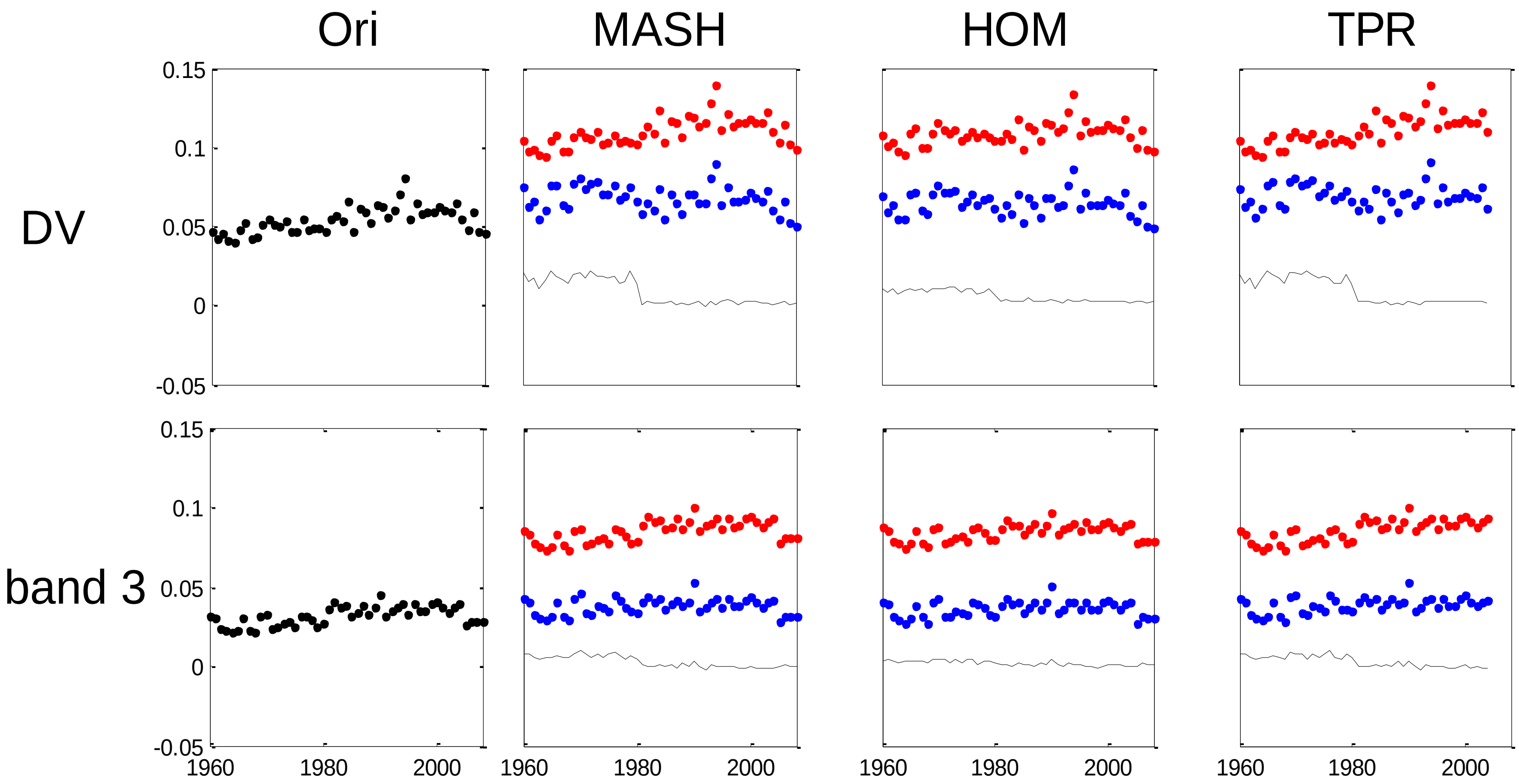
The inhomogeneities in 1981 are still obvious, especially for the homogenized series based on MASH and TPR.

wavelet analysis at HN – For adjusted series by RHtest



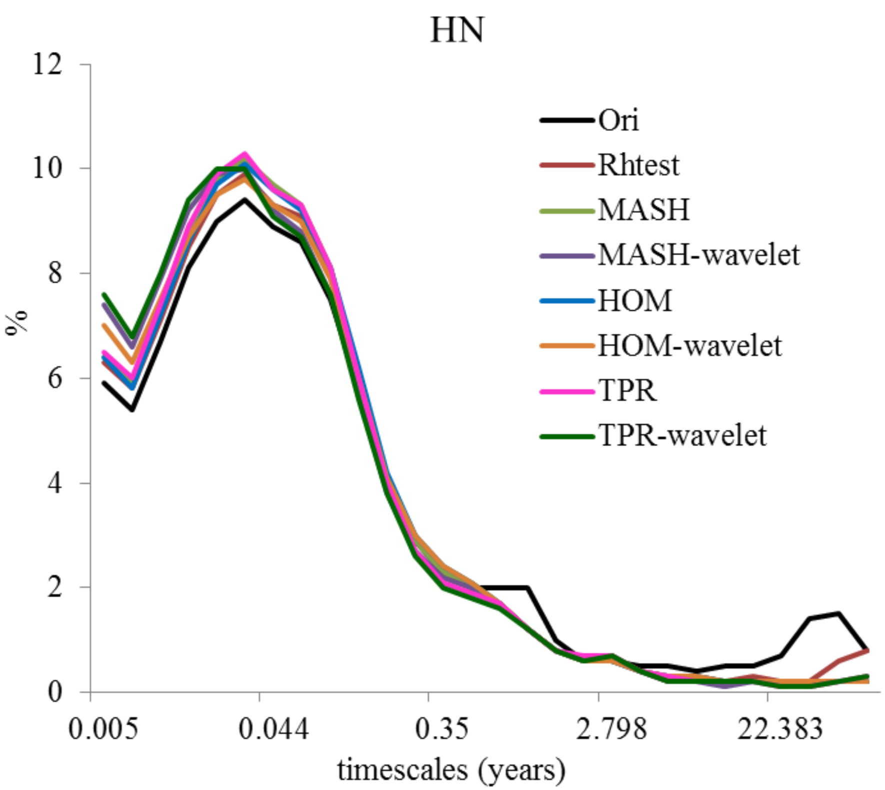
Rhtest tends to have improved the wavelet power spectra regarding inhomogeneity hidden in DV and WV (bands 1-5).

Comparing annual wavelet power of DV and band3 for the original and various homogenized series

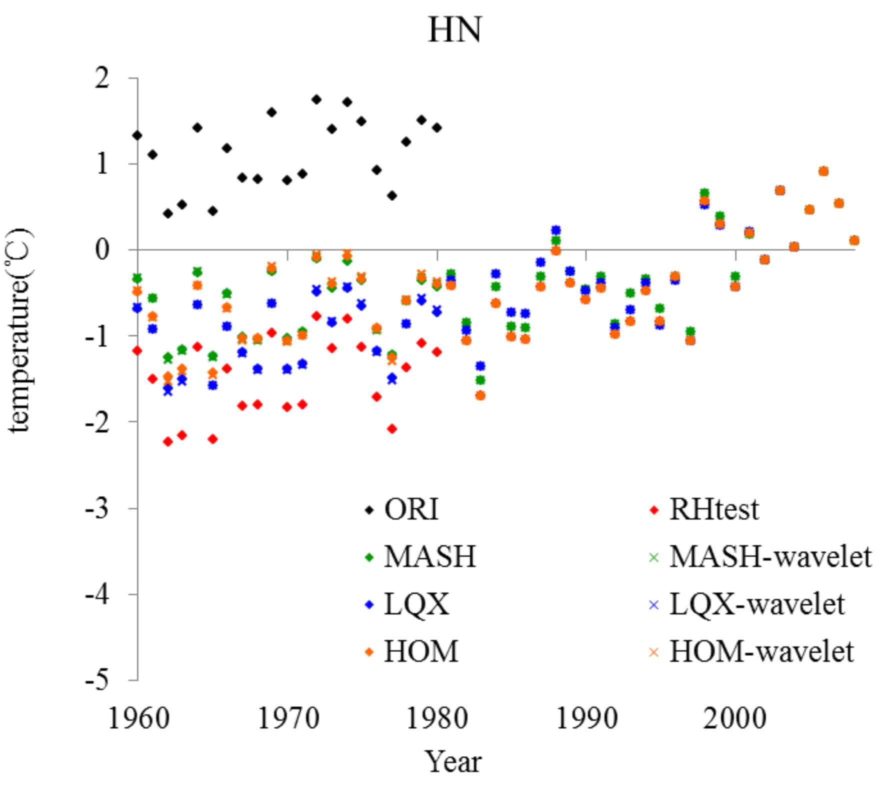


Original: black dots; Previously homogenized: red dots;
Present adjusted: blue dots;
differences between the present and previously homogenized series: black line).

Comparing wavelet power spectra and annual men temperature between the original and various homogenized at HN



Average wavelet power for the daily mean temperature anomaly series 1960-2008(1960-2004 for TPR) at HN



The annual mean temperature in original and various homogenized series 1960-2008 (1960-2004 for TPR) at HN

Influences on trends of mean temperature and extremes at HN

	Mean	Hot day	Cold day	Heat wave	Cold surge
Original	**-0.273***	**-4.73***	**2.92***	**-0.76***	**0.23**
MASH	**0.240***	**3.44***	**-1.19**	**0.26***	**-0.25**
MASH-wavelet	**0.241***	**3.25***	**-1.41**	**0.30***	**-0.23**
TPR	**0.289***	**3.70***	**-2.13***	**0.33***	**-0.39***
TPR-wavelet	**0.290***	**3.36***	**-2.13***	**0.35***	**-0.32**
HOM	**0.251***	**3.33***	**-1.90***	**0.28***	**-0.31***
HOM-wavelet	**0.252***	**3.17***	**-2.02***	**0.32***	**-0.28***
RHtest	**0.476***	**4.21***	**-8.67***	**0.45***	**-1.12***

Linear trends in original and various homogenized annual mean temperature and climate extreme series since 1960 at HN.

(* denotes the linear trends significant at α = 0.05)

Conclusion

- Most of current methods adjust inhomogeneities mainly regarding the mean levels, but hardly identify those hidden in variability of different timescales.

- The wavelet-analysis-based method by this study adjusts those inhomogeneities unsolved with conventional approaches.

- The wavelet adjustments do not influence on estimating trends in mean temperature; but do on estimating climate extremes and changes.