

Increasing Weather Risk: Fact or Fiction?

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Outline

Motivation

Research questions and objectives

Methods

Empirical application

Data

Results

Conclusions

Motivation I

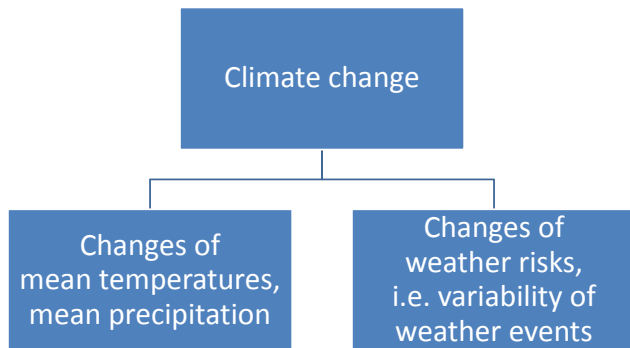


Figure: Climate change

Motivation II

- ▶ Undisputed statement among meteorologists and insurance companies: Weather risk / weather extremes increased due to climate change (e.g. IPCC (2007), Alexander et al.(2006), Munich Re (2011))
- ▶ Differentiation required with regard to:
 - ▶ weather event (temperature, rainfall, basic weather variables, weather indices)
 - ▶ region
 - ▶ time (continuous change, jumps, unidirectional)

Motivation III

Standard procedure for testing a change of weather risk in meteorology

1. Definition of a weather index that measures an "“extreme”" (e.g. min / max temperature, length of dry spells, amount of rainfall within a certain period)
2. Determination of an observation period
3. Slope test (e.g. Mann-Kendall-Test) for the mean of the specific extreme weather index)

Alternatives

- ▶ Looking at quantiles of weather variables
- ▶ Local tests
- ▶ Change point tests
- ▶ Extreme value theory

Research questions and objectives

- ▶ Does weather risk increase for temperature related events as well as for precipitation related events?
- ▶ Is weather risk increasing everywhere?
- ▶ Does increasing weather risk of basic weather variables translate into increasing risk of (economically relevant) weather indices?
- ▶ Refinement of statistical testing procedure (local tests, change pool tests, quantile regression)

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Tests

- ▶ t- test: the significance of the slope parameter
- ▶ change point test: whether there is a significant difference between the means in two sub intervals
- ▶ Mann Kendall test: a nonparametric test for trend or change point detection
- ▶ detect slope or change point

t test

$$m(t) = \alpha + \beta t \quad (1)$$

a significant slope parameter β ?

The estimation of parameter:

$$\operatorname{argmin}_{\alpha, \beta} \sum_t (T_t - \alpha - \beta t)^2 \quad (2)$$

The null hypothesis : $\beta = 0$, and the alternative: $\beta \neq 0$.

Change point test

Two windows L_1 (n_1) and L_2 (n_2) . Sample mean:

$$\mu_j = \sum_t^{n_j} T_t, j \in 1, 2, t \in L_j \quad (3)$$

The null hypothesis $\mu_1 = \mu_2$; the alternative $\mu_1 \neq \mu_2$. The test statistics:

$$V = \frac{n_1 n_2}{n_1 + n_2} \frac{(\hat{\mu}_1 - \hat{\mu}_2)^2}{\tilde{\sigma}^2} \xrightarrow{\mathcal{L}} \chi^2(1),$$

where $\tilde{\sigma}$ is from:

$$\begin{aligned} \tilde{r}_t &= T_t - \hat{m}_h(t) \\ \hat{m}_h(t) &= \frac{\sum_s K\{(s-t)/h\} T_s}{\sum_s K\{(s-t)/h\}} \end{aligned}$$

Mann Kendall test

Test statistics:

$$S = \sum_{t=2}^n \sum_{s=1}^{t-1} \text{sign}(T_t - T_s)$$

For $n \rightarrow \infty$, S asymptotically normal:

$$S^* = \frac{S}{\sqrt{n(n-1)(2n+5)/18}} \xrightarrow{\mathcal{L}} \mathbf{N}(0, 1).$$

Local Trend Tests

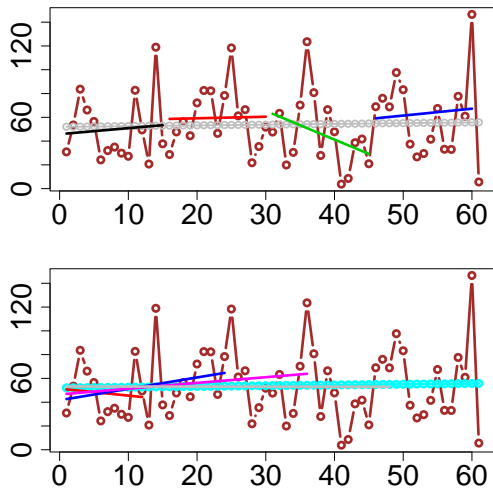


Figure: Demonstration

Local Trend Tests

- ▶ Apply test in a rolling window
- ▶ Consecutive significant signals
- ▶ τ (the minimum number of subsequent P-values that is eligible to create a summation measure)
- ▶ κ (the maximum number of insignificant P-values to drop everything to 0)

Quantile Regression

$\{t, Y_t\}_{t=1}^T$, Y_t s independent.

$$Y_t = l(t) + \varepsilon_t, \quad (4)$$

where $\mathbb{P}(\varepsilon_t > 0) = \tau$.

$$\begin{aligned} \hat{l}(s) = & \operatorname{argmin}_{\theta} (1 - \tau) \sum_{t=1} (\theta - Y_t) \mathbf{I}(\theta > Y_t) w_t \\ & - \tau \sum_{t=1} (Y_t - \theta) \mathbf{I}(\theta \leq Y_t) w_t, \end{aligned}$$

where $w_t = K\{(t - s)/h\}$, and $K(\cdot)$ a kernel function

Cumulative Indices

- ▶ Growing Degree Days (GDD) (Temperature)

$$GDD = \sum_{j=\tau BS}^{\tau ES} \max\{(T_{\max,j} + T_{\min,j})/2 - T_{\text{base},j}, 0\},$$

where BS and ES are the beginning and the end of a vegetation period.

- ▶ Cumulative Rainfall Index (CRI) (Rainfall):

$$CRI = \sum_{j=\tau BS}^{\tau ES} R_j. \quad (5)$$

Extreme Indices

- ▶ Frost Days Index (FDI)(Temperature):

$$FDI = \sum_{j=\tau B}^{\tau E} \mathbf{I}(T_j < T_{\min,j}),$$

where B and E are the beginning and the end of a cumulation period.

- ▶ Potential Flood Indicator (PFI) (Rainfall):

$$PFI = \max_{\tau \in \{1, \dots, 365-s+1\}} \left(\sum_{j=\tau}^{s+\tau-1} R_j \right), \quad (6)$$

which estimates the wettest s-day period in the year, e.g. five days.

Empirical application: Data

- ▶ Berlin Tempelhof: Jan, 1st, 1948- Mar, 22nd, 2011
- ▶ Taipei: Jan, 1st, 1910- Dec, 31st, 2008.
- ▶ Iowa: Jan, 1st, 1905- April, 6th, 2011

Illustration of Quantiles

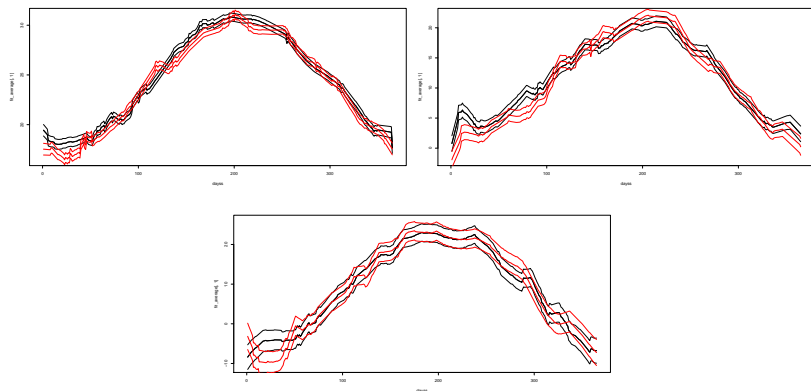


Figure: %90 quantile and the band the temperature from 1989 – 1998 averaged over a five year interval for city Taiwan, Berlin and Iowa, chronological order: black, red

Illustration of Quantiles

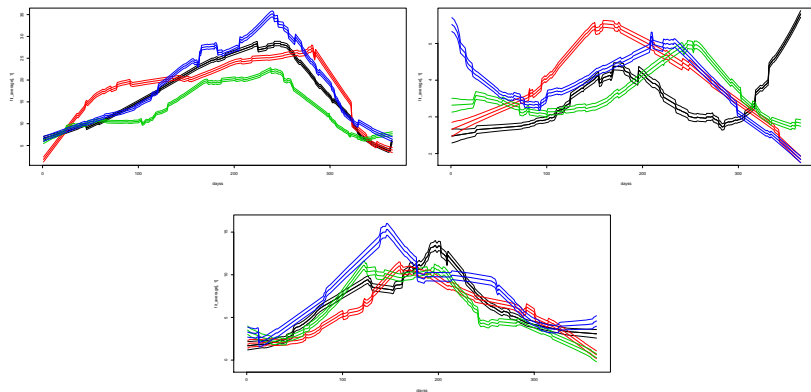


Figure: %90 quantile and the band the rainfall from 1989 – 2010 averaged over a five year interval for city Taiwan, Berlin and Iowa, chronological order: black, red, green, blue

Empirical application: Local test for FDI and PFI

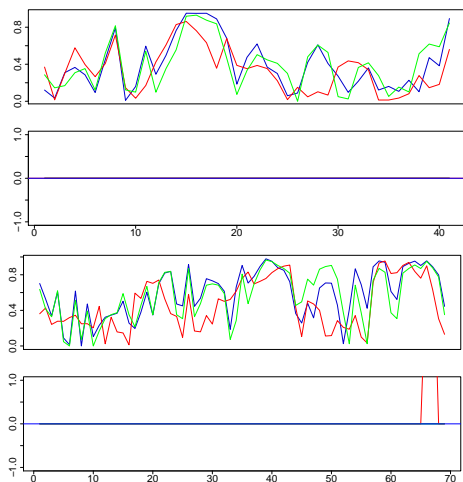


Figure: Local test results for temperatures four cities, FDI, t test (blue), change point test (red), Mann Kendall test (green)

Empirical application: Local test for FDI and PFI

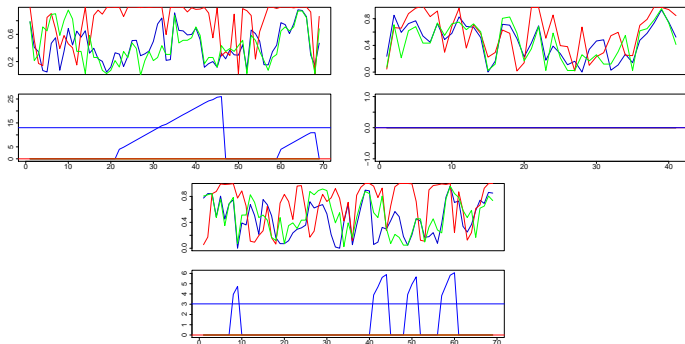


Figure: Local test results for rainfall four cities, PFI, t test (blue), change point test (red), Mann Kendall test (green), Taipei, Berlin, Iowa

Empirical application: Quantile for GDD

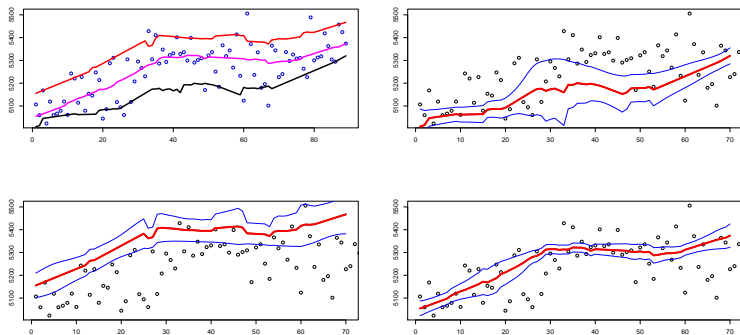


Figure: Plot quantile GDD Taiwan, left upper panel: %75, %50, %25 quantile curve, right upper panel: %25 quantile curve and its band, left lower panel: %75 quantile curve and its band, right lower panel: %50 quantile curve and its band

Empirical application: Quantile for CRI

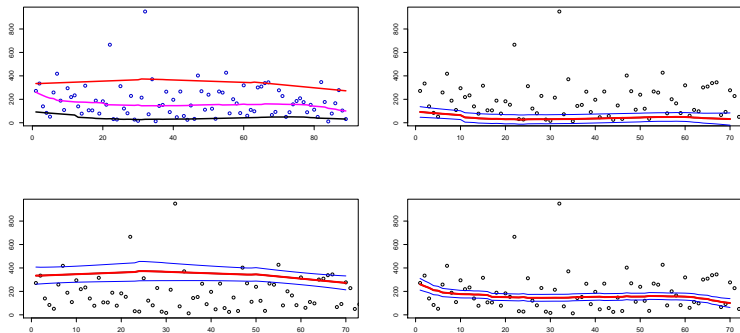


Figure: Plot quantile CRI Taiwan, left upper panel: %75, %50, %25 quantile curve, right upper panel: %25 quantile curve and its band, left lower panel: %75 quantile curve and its band, right lower panel: %50 quantile curve and its band

Conclusions

- ▶ There are spatial variabilities and time variabilities
- ▶ For GDD, normally the lower quantiles are more volatile.
- ▶ For CRI, Berlin: decreasing, Iowa: slightly increasing, Taipei: No change
- ▶ The quantile curves at different levels behave differently
- ▶ t-test, change point test have more power
- ▶ For FDI, there is no trend detected for both Berlin and Iowa.
- ▶ For PFI, Iowa and Taipei exhibit trends

Appendix

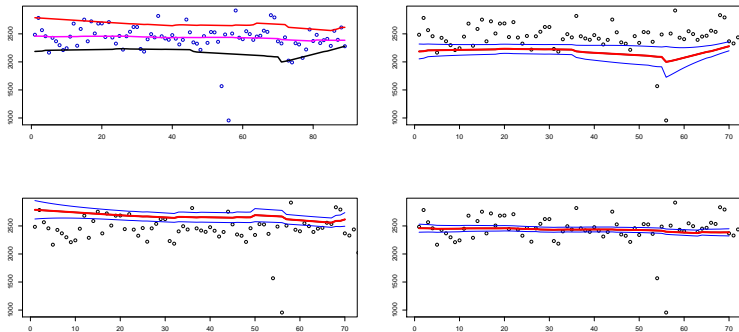


Figure: Plot quantile GDD lowa (temperature)

Appendix

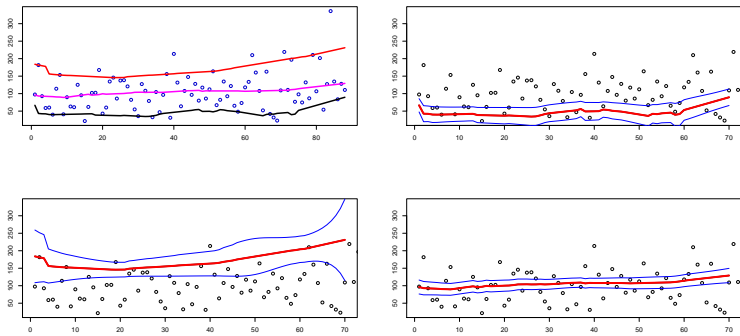


Figure: Plot quantile CRI May Iowa

Appendix

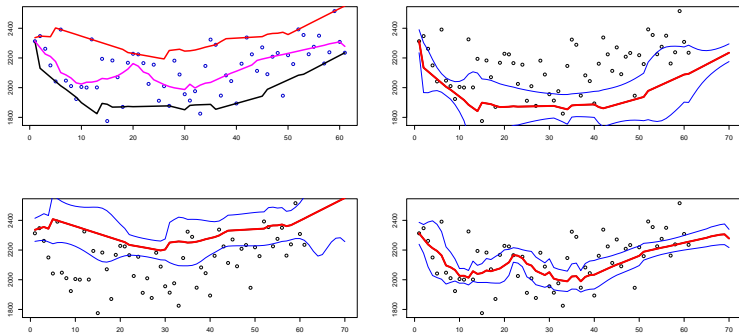


Figure: Plot quantile GDD Berlin

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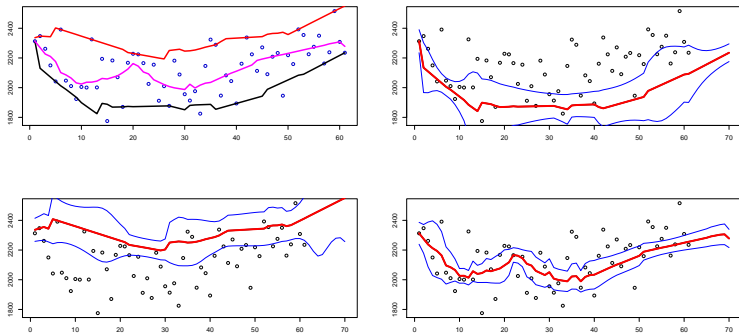


Figure: Plot quantile GDD Berlin

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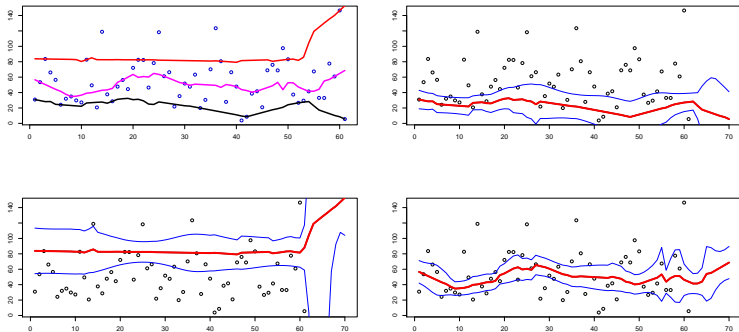


Figure: Plot quantile CRI Berlin (Rainfall)

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